# **Event Generator Physics**

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# **Event Generator Physics**

- 1. Basic principles
- 2. Parton showers
- 3. Hadronization
- 4. Survey of Event Generators
- 5. Matching

# **Event Generators**

## • PYTHIA

➡ Virtuality/k<sub>T</sub>-ordered shower, string hadronization

➡ v6 Fortran; v8 C++

HERWIG

Angular-ordered shower, cluster hadronization

➡ v6 Fortran; Herwig++

## SHERPA

Virtuality-ordered shower, string/cluster hadronization

### → C++

## Monte Carlo Programs in Practice

- 1. HERWIG 6
  - Status and Structure
  - Example input, control parameters
  - Example output
  - Physics examples
- 2. PYTHIA 6
  - Status and Structure
  - Example input, control parameters
  - Example output
  - Physics examples
- 3. Object Oriented Event Generators
  - PYTHIA 8
  - HERWIG++
  - SHERPA

Thanks to Mike Seymour, Torbjörn Sjöstrand, Stefan Gieseke, Frank Krauss and Peter Richardson

**Event Generator Physics 4** 

## **HERWIG 6**

- Current status:
- Version 6.510 released on October 31st 2005
  - http://hepwww.rl.ac.uk/theory/seymour/herwig/
  - ~ 64,000 lines of FORTRAN, 11 authors (5 currently active)
- 6.51\* will be the last FORTRAN version
- Some features:
  - Many built-in SM and MSSM processes
  - Les Houches Accord interface for arbitrary hard processes
  - Spin correlation algorithm  $\rightarrow$  see later
  - Interface to MC@NLO program (Frixione & Webber)  $\rightarrow$  see later
  - Interface to JIMMY multiple interaction underlying event model

## Structure



# **Example Main Program**



### **Processes Available**

IPRDC	
	Process
100	$\ell^+\ell^- \rightarrow q\bar{q}(q)$ (all q flavours)
100+ID	$\ell^+\ell^- \rightarrow q\bar{q}(q)$ (10 = 1.2.3.4.5.6 for $q = d. a. s. c. b.t$ )
107	$\ell^+\ell^- \rightarrow aa(a)$ (flotiticus process)
110	state and state (all Benceme)
110.10	$e^+e^- \rightarrow qqg$ (an maxima)
110+10	$e^+e^- \rightarrow qqg (1q as above)$
120	$\epsilon^+ \epsilon^- \rightarrow q q$ (all havours, no hard gluon correction)
120+IQ	$\ell^+\ell^- \rightarrow q\bar{q}$ (10 as above, no hard gluon correction)
127	$\ell^+\ell^- \rightarrow gg$ (fictitious process, no hard gluon correction)
150+IL	$\ell^+\ell^- \rightarrow \ell^-\ell^-$ (II. = 1, 2, 3 for $\ell^- = \epsilon, \mu, \tau, N.B.$ $\ell \neq \ell^-$ )
200	$\ell^+\ell^- \rightarrow W^+W^-$ (see sect. 4.3.2 cm control of $W/Z$ decays)
250	$\ell^+\ell^- \rightarrow Z^0Z^0$ (see sect. 4.3.2 on control of $W/Z$ decays)
300	$\ell^+\ell^- \rightarrow Z^0 H_{SM}^0 \rightarrow Z^0 q\bar{q}$ (all flavours)
300+IQ	$\ell^+\ell^- \rightarrow Z^0 H^0_{SM} \rightarrow Z^0 q\bar{q} (IQ \text{ as above})$
306+IL	$\ell^+\ell^- \rightarrow Z^0 H^0_{SM} \rightarrow Z^0 \ell \bar{\ell}$ (II. as above)
310, 311	$\ell^+\ell^- \rightarrow Z^0H^0_{SM} \rightarrow Z^0W^+W^-, Z^0Z^0Z^0$
IPRDC	Process
312	$\ell^+\ell^- \rightarrow Z^0 H_{SM}^0 \rightarrow Z^0 \gamma \gamma$
399	$\ell^+\ell^- \rightarrow Z^0 H_{SM}^0 \rightarrow Z^0$ anything
400+ID	$\ell^+\ell^- \rightarrow \nu \overline{\nu} H^0_{SM} + \ell^+\ell^- H^0_{SM}$ (ID as in IPROC = $300 \pm 10$ )
500+ID	$\ell^+\ell^- \rightarrow \ell^+\ell^-\gamma\gamma \rightarrow \ell^+\ell^- q\bar{q}/\ell\bar{\ell}/W^+W^-$
	(ID=0-10  as in IPRDC = 300 + ID)
550+ID	$\ell^+\ell^- \rightarrow \ell \nu \gamma W \rightarrow \ell \nu \eta \eta \ell / \ell^2$ (ID=0-9 as in IPROC = 300 + ID)
800	PP alles all d' (all a florente)
608±10	$P^+P^- \rightarrow a\bar{a}aa a\bar{a}a'\bar{a}' (D as above)$
000414	After reparation (1999) is submaness (see sort 4.2.5)
988.00	Mining Supersystem Standard Model (MSSM) processes
100-00	at initial supersylimetric standard filosi (MSSM) processes
100	$\epsilon^+\epsilon^- \rightarrow 2$ -sparticle processes (sum or 710, 730, 740 and 760)
710	$\varepsilon^* \varepsilon^- \rightarrow \text{feutraino pars (all neutralinos)}$
705+4191+182	$\epsilon^{+}\epsilon^{-} \rightarrow \chi_{IN1}^{-}\chi_{IN2}^{-}$ (IN1, 2-neutralino mass eigenstate)
Tau	$e^+e^- \rightarrow \text{chargino pairs (all charginos)}$
728+21C1+IC2	$\ell^+\ell^- \rightarrow \chi^{K1}\chi^{K2}$ (IC1, 2=chargmo mass eigenstate)
74D	$\ell^+\ell^- \rightarrow \text{slepton pairs (all flavours)}$
736+51L	$\ell^+ \ell^- \rightarrow \ell_{L,R} \ell^*_{L,R}$ (IL = 1, 2, 3 for $\ell = \tilde{e}, \tilde{\mu}, \tilde{\tau}$ )
737+51L	$\ell^+\ell^- \rightarrow \bar{\ell}_L \bar{\ell}_L^*$ (IL as above)
738+5IL	$\ell^+ \ell^- \rightarrow \overline{\ell}_L \overline{\ell}_R^*$ (II. as above)
739+51L	$\ell^+\ell^- \rightarrow \overline{\ell}_R \overline{\ell}_R^*$ (IL as above)
740+51L	$\ell^+ \ell^- \rightarrow \overline{\nu}_L \overline{\nu}_L^+$ (IL = 1, 2, 3 for $\overline{\nu}_e, \overline{\nu}_a, \overline{\nu}_r$ )
76D	$\ell^+\ell^- \rightarrow$ squark pairs (all flavours)
757+4ID	$\ell^+\ell^- \rightarrow \bar{q}_{\ell,0} q_{\ell,0}^2$ , $q_{\ell,0} (10 = 1, 2, 3, 4, 5, 6 \text{ for } \bar{q} = d, \bar{u}, \bar{s}, \bar{c}, \bar{b}, \bar{t})$
758+4ID	$\ell^+\ell^- \rightarrow \overline{\alpha}, \overline{\alpha}^*$ (III as above)
759±410	$\ell^+\ell^- \rightarrow \overline{m}  \overline{m}_{c}  (ID \text{ as above})$
76D+41D	$\ell^+\ell^- \rightarrow \bar{q}_*\bar{q}_*^*$ (10 as above)
888.99	R-parity violating supersymmetric processes
800-99	R-parity violating supersymmetric processes Single sporticle production sum of 810-840
800-99 800 810	R-parity violating supersymmetric processes Single sparticle production, sum of 810–840 $\ell^+\ell^- \rightarrow \bar{\gamma}^0 \mu$ , (all perturbations)
800-99 800 810	R-parity violating supersymmetric processes Single sparticle production, sum of 810–840 $\ell^+\ell^- \rightarrow \chi^0 v_i$ , (all neutralines) $\ell^+\ell^- \rightarrow \chi^0 v_i$ , (the production mass state)
800-99 800 810 810+IN 840	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \chi^0 \nu_{\ell_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \chi^0_{\ell_1} \nu_{\ell_1}$ (all neutralino mass state) $\ell^+\ell^- \rightarrow \chi^0_{\ell_1} \nu_{\ell_1}$ (all neutralino mass state)
800-99 800 810 810+IN 820 820	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \overline{\chi}^0_{P_0}$ , (all neutralinos) $\ell^+\ell^- \rightarrow \overline{\chi}^0_{P_0}$ , (III–neutralino mass state) $\ell^+\ell^- \rightarrow \overline{\chi}^0_{P_0}$ , (iII–neutralino mass state) $\ell^+\ell^- \rightarrow \overline{\chi}^0_{P_0}$ , (III–neutralino mass state)
800-99 800 810 810+IN 820 820+IC 820	R-parity violating supersymmetric processes Single sparticle production, sum of 810–840 $\ell^+\ell^- \rightarrow \bar{\chi}^0_{P_{\ell_1}}$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{P_{\ell_1}}$ (all neutralino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{P_{\ell_1}}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{P_{\ell_1}}$ (all chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{P_{\ell_1}}$
800-99 800 810 810+IN 820 820+IC 830 840	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all neutralino mass state) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all charginos) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all charginos) $\ell^+\ell^- \rightarrow \overline{\nu}_0 v_{\ell_1}^0$ and $\ell^+\ell^- \rightarrow \overline{\ell}_0^0 W^-$
800-99 800 810+IN 820 820+IC 830 840	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \tilde{\chi}^2 u_{\ell_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (all charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (b) $\ell^+\ell^- \rightarrow \tilde{\chi}^2 e_{\ell_1}^*$ (c) $\ell^+\ell^- \rightarrow \tilde{\ell}^2 e_{\ell_1}^*$ (c)
800-99 800 810 820 820 820+IC 830 840 850 850	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \bar{\chi}^0_{M_{\ell_1}}$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{M_{\ell_1}}$ (all neutralino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{L_1}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{L_1}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{L_1}$ and $\ell^+\ell^- \rightarrow \bar{\ell}^+_{L_1}$ $\ell^+\ell^- \rightarrow \bar{\mu}^0_{L_1}$ Mod $\ell^+\ell^- \rightarrow \bar{\ell}^+_{L_1}$ $\ell^+\ell^- \rightarrow \bar{\mu}^0_{L_1}$ $\ell^+\ell^- \rightarrow \bar{\mu}^0_{L_1}$
800.99 800 810 810+IN 820 820+IC 830 840 850 860 850	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all neutralino) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}$ (all neutralino mass state) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}^*$ (all charginos) $\ell^+\ell^- \rightarrow \overline{\chi}^0 v_{\ell_1}^*$ (1C—chargino mass state) $\ell^+\ell^- \rightarrow \overline{\nu}_{\ell_1} \delta^0$ and $\ell^+\ell^- \rightarrow \overline{\ell}_{\ell_1}^* H^-$ $\ell^+\ell^- = \overline{\nu}_{\ell_1} \delta^0 / H^0 / A^0$ and $\ell^+\ell^- \rightarrow \overline{\ell}_{\ell_1}^* H^-$ $\ell^+\ell^- = \overline{\nu}_{\ell_1} \delta^0$ Sum of S70 and S80 state = definition of S70 and S80
800-99 800 810 810+IN 820 820+IC 830 840 850 860 870	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 x_0$ , (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 x_0^-$ , (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 x_0^-$ , (c)-chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0 x_0^-$ , (c)-chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \lambda^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\mu}^0 \lambda^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\mu}^0 \lambda^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \bar{\lambda}^0 \lambda^0 \lambda^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 M^-$
800.99 800 810 810+18 820+1C 830 840 850 860 870 867+311.1+112	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{M_{\ell_1}}$ (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{M_{\ell_2}}$ ( $\Pi$ -neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{M_{\ell_2}}$ ( $\Pi$ -chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\mu}^0_{\ell_2}$ and $\ell^+\ell^- \rightarrow \tilde{\ell}^+_{\ell_1}H^-$ $\ell^+\ell^- \rightarrow \tilde{\mu}^0_{\ell_1}M^0/A^0$ and $\ell^+\ell^- \rightarrow \tilde{\ell}^+_{\ell_1}H^-$ $\ell^+\ell^- \rightarrow \tilde{\ell}^0_{\ell_1}M^0/A^0$ and $\ell^+\ell^- \rightarrow \tilde{\ell}^+_{\ell_1}H^-$ $\ell^+\ell^- \rightarrow \tilde{\ell}^{\ell_1}\chi^0_{\ell_1}$ Sum of 8°0 and 880 $\ell^+\ell^- \rightarrow \ell^{\ell_1}\chi^0_{\ell_{12}}$ (111,2–1,2,3 for $e_2\mu, \tau$ )
800-99 810 810+11 820 820+1C 830 840 850 850 850 870 860 870 1867+311+112	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \tilde{\chi}^0 u_{\alpha}$ (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 u_{\alpha}$ (iII-neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} e_1^*$ (all charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} e_1^*$ (all charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} e_1^*$ ( $-\tilde{\chi}^0_{\alpha} W^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} W^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} W^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} W^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0_{\alpha} W^-$ Sum of S10 and S80 $\ell^+\ell^- \rightarrow \ell^+_{1\alpha} \ell_{1\alpha}$ (III 2–1,2,3 for $e_2\mu, \tau$ ) Process
800-99 800 810+IN 820 820+IC 830 840 850 860 870 870 867+3114+IL2 7999	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \bar{\chi}^0_{M_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^{M_2}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^{M_2}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^{M_2}$ (all chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^{M_2}$ and $\ell^+\ell^- \rightarrow \bar{\ell}^+_{M_1}$ $\ell^+\ell^- \rightarrow \bar{\ell}^{M_2}$ ( $\ell^+_{M_2}$ ) $\ell^+\ell^- \rightarrow \bar{\ell}^+_{M_2}$ ( $\ell^+_{M_2}$ ) $\ell^+\ell^- \rightarrow \bar{\ell}^+_{M_2}$ ( $\ell^+_{M_2}$ ) Sum of S10 and S80 $\ell^+\ell^- \rightarrow \ell^+_{M_1}$ (111, 2–1, 2,3 for $e_{\pm}\mu, \tau$ ) Process ownerated by HERBM package
800-99 800 810 810+11 820 820+1C 830 840 850 850 850 850 87+3114+112 1PRDC 7999 8000	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \vec{\chi}^0 \nu_{\theta_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \vec{\chi}^- e_1^-$ (all charginos) $\ell^+\ell^- \rightarrow \vec{\chi}^- e_1^-$ $\ell^+\ell^- \rightarrow \vec{\chi}^- e_1^-$ Sum of S70 and S80 $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^- \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^-$ , via LLE only $\ell^+\ell^-$ , via LLE only $\ell^+\ell^-$ , via LLE only $\ell^+\ell^-$ , via LLE only $\ell^-$ , via LLE only $\ell^+\ell^-$ , via LLE only $\ell^-$ , via LLE only
800-99 800 810 810+1H 820 820+1C 830 840 850 867 870 867+3114+1L2 1PRDC 7999 8000	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_{\ell_1}$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^- (\bar{\chi}^0_{\ell_1}$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^{\ell_2} \bar{\chi}^0_{\ell_1}$ (10-chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^{\ell_2} \bar{\chi}^0_{\ell_1}$ (10-chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^{\ell_2} \bar{\chi}^0_{\ell_1}$ (10-chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0_{\ell_1} \bar{\chi}^0_{\ell_1}$ and $\ell^+\ell^- \rightarrow \bar{\ell}^+_{\ell_1} \bar{H}^-$ $\ell^+\ell^- \rightarrow \bar{\chi}^0_{\ell_1} \bar{\chi}^0_{\ell_1}$ (11.1 $\gtrsim$ -1,2,3 for $\epsilon_{\pm}\mu, \tau$ ) Process generated by HERBVI package Minimum bias soft hadron-hadron event Deep instate (parton package)
800-99 800 810 +11 820 +12 820 +12 830 840 850 850 850 850 857 + 3114 +112 1PRDC 9999 8000 9000 +10	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{0}(a)$ Insutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{0}(a)$ Insutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{-1}(a)$ Charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{-1}(a)$ Charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{-1}(a)$ Chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{-1}(a)$ Chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}_{2k}^{-1}(a)$ Charginos) $\ell^+\ell^- \rightarrow \tilde{\ell}_{2k}^{-1}(a)$ Sum of S70 and $\ell^+\ell^- \rightarrow \tilde{\ell}_{k}^{-1}H^-$ $\ell^+\ell^- \rightarrow \tilde{\ell}_{2k}^{-1}(a)$ Sum of S70 and S80 $\ell^+\ell^- \rightarrow \ell^-\tilde{\ell}_{1k}$ (III. 2–1,2,3 for $e_{\pm}\mu, \tau$ ) Process generated by HERBV package Minimum Eas soft hadron-hadron event Deep inslastic lepton scattering (AII Desurt lournent) Deep inslastic lepton scattering (AII Desurt lournent)
800.99 800 810 + II 820 820 + IC 820 + IC 820 + IC 820 + IC 820 + IC 850 870 867 + 3111 + IL2 1FRDC 7999 800 9000 + IQ 9010	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (iII-neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , (iII-chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , (iII-chargino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^-$ , $\ell^0 \kappa^ \tilde{\chi}^0 \kappa^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa^0$ and $\ell^+\ell^- \rightarrow \tilde{\xi}^0 \pi^-$ $\ell^+\ell^- \rightarrow \tilde{\kappa}^0 \kappa^0$ and S80 $\ell^+\ell^- \rightarrow \ell^+ \kappa^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \kappa_0^-$ , $\chi^0 = 1.2E$ only $\ell^+\ell^- \rightarrow \ell^+ \kappa_0^-$ , $\chi^0 = 1.2E$ , $\eta = 1.2$ ,
800-99 800 810 810+11 820 820+1C 830 840 850 850 850 850 850 850 850 9999 82000 9000+10 9000+10 9000+10	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu^0$ , $(1-e-hargino mass state)$ $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu^0$ , $\ell^0/\mu^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^+ \mu^-$ $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu^0$ , $\ell^0/\mu^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^+ \mu^-$ $\ell^+\ell^- \rightarrow \bar{\ell}^+ \mu^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^- \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^-$ , vi
800.99 800 810 810+IN 820 820+IC 820+IC 820+IC 820-IC 840 840 840 840 850 867+31L1+IL2 1PRDC 7999 8000+IQ 9000+IQ 9010	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (all-neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^2$ , (all-charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^2$ , (all-charginos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^2$ , $\ell^0 \kappa_0^- \kappa_0^2 \kappa_0^-$ $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^2$ , $\ell^0 \kappa_0^- \kappa_0^2 \kappa_0^-$ $\ell^+\ell^- \rightarrow \tilde{\kappa}^0 \kappa_0^2$ , $\ell^0 \kappa_0^- \kappa_0^2 \kappa_0^-$ $\ell^+\ell^- \rightarrow \tilde{\kappa}^0 \kappa_0^2$ , $\ell^0 \kappa_0^- \kappa_0^- \kappa_0^-$ , $\ell^0 \kappa_0^-$ $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \kappa_0^-$ , $\ell^0 \kappa_0^- \kappa_0^- \kappa_0^-$ , $\ell^- \kappa_0^-$
800.99 800 810 810+11 820 820+112 830 840 850 860 860 867+3111+112 7999 8000 9000+113 9000+113 9100+113 9100	R-parity violating supersymmetric processes Single sparticle production, sum of SIO-S40 $\ell^+\ell^- \rightarrow \vec{\chi}^0 u_i$ , (all neutralinos) $\ell^+\ell^- \rightarrow \vec{\chi}^0 e_i^-$ , (ill-neutralino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_i^+$ , ( $\ell^-$ -chargino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_i^+$ , ( $\ell^-$ -chargino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_i^+$ , ( $\ell^-$ -chargino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_i^-$ , $\ell^- e_i^- W^-$ $\ell^+\ell^- \rightarrow \vec{\chi}_{13} e_i^-$ , $\ell^- e_i^- W^-$ $\ell^+\ell^- \rightarrow \vec{\ell}_{14} e_{12}$ , $\ell^- e_i^- W^-$ $\ell^+\ell^- \rightarrow \ell^+ e_i^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ e_{12}^-$ , $\vec{\chi}_{12}$ , $(III, 2-1, 2, 3)$ for $e_2\mu, \tau$ ) Process generated by HERBM package Minimum bias soft hadron-hadron event Deep industic lepton scattering (all costral current) Deep industic lepton scattering (all charged current) Deep industic lepton scattering (Cor of flavour 1Q) Bosen industic lepton scattering (Cor of flavour 1Q) Bosen pluon fusion in neutral current DIS (all flavours) Bosen, fluon fusion in neutral current DIS (all flavours)
800-99 800 810 810+11 820 820+1C 830 840 840 850 850 870 867+3111+112 1PRDC 9000 9000+10 9000+10 9100+10 9100	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \vec{\chi}^0 \nu_{\mu}$ (all neutralinos) $\ell^+\ell^- \rightarrow \vec{\chi}^0 \nu_{\mu}$ (all charginos) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_{\ell}^2$ (all charginos) $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_{\ell}^2$ , $(10-\text{charginos})$ $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_{\ell}^2$ , $(10-\text{charginos})$ $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_{\ell}^2$ $\ell^+\ell^- \rightarrow \vec{\chi}_{12} e_{\ell}^2$ Sum of \$70 and \$80 $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\mu^-$ , via LLE only Begin charter lepton scattering (all neutral eurent) Deep indastic lepton scattering (all neutral eurent) Beson-gluon fusion in neutral current DIS (all as above) $\ell^+\ell^-$ before the proces future neutral eurent) Deep indastic lepton scattering (all neutral eure
800.99 800 810 +11 820 820 +11 820 +11 820 +12 820 +12 820 +12 820 +12 820 +11 1280 -2 999 -2 800 +12 9100 +12 910 -12 910 -12 910 -2 910 -2	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{R}(\alpha, (\text{III-neutralinos})$ $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{R}(\alpha, (\text{III-neutralino}) \text{mass state})$ $\ell^+\ell^- \rightarrow \ell^+\alpha, \text{ via LLE only}$ $\ell^+\ell^- \rightarrow \ell^+\alpha, \text{ via LLE only}$ Deep induct lepton scattering (all characterino) Deep induct lepton scattering (all characterino) De
800-99 800 810 810+11 820 820+1C 830 840 850 867+3114+112 1780C 17999 8000 9000+10 9010+10 9100 9100+10 9110 9110 9110	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_1$ (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_2$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_2$ (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu^0 / A^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 H^-$ $\ell^+\ell^- \rightarrow \bar{\mu}^0 \mu^0 / A^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 H^-$ $\ell^+\ell^- \rightarrow \bar{\ell}^0 \mu^0 / A^0$ and $\ell^+\ell^- \rightarrow \bar{\ell}^0 H^-$ $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^-$ , vi
800.99 800 810 810+11 820 820+11 820 820 840 850 867+3114+112 1880 1867+3114+112 1880 9000+10 9010-10 9010-10 9100+10 9100+10 9100+10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 9100-10 910-10 9	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{R}(a)$ (III-neutralinos) $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{R}(a)$ (III-neutralino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{R}(a)$ (III. 2-1, $\ell^{2n}_{R}$ for $\ell^{2n}_{R}$ , $\tau$ ) Process generated by HERBV package Minimum bias soft hadron-hadron event Deep industic lepton scattering (all floatural current) Deep industic lepton scattering (CC on flavour IQ) Deep
800-99 800 810 +11 820 820 +12 820 +12 820 +12 820 +12 820 -12 820 -12 820 -12 820 -12 840 -11 850 -12 867 +311 +11.2 900 +12 900 +12 910 -12 910 -	$ \begin{array}{llllllllllllllllllllllllllllllllllll$
800.99         800           810         810           810         810           810         810           820         820           820         820           840         840           850         867+3111+112           7999         9000+10           9000         90000+10           9100         9100           9100         9100           9100         9100           9110         9110           9140+1P         9140+1P	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (all neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0$ , (all-neutralinos) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , (II-neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , (II-neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , (II-neutralino mass state) $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , $\ell^0 \kappa_0^+ \kappa_0^+$ , $\ell^+\ell^- \rightarrow \tilde{\chi}^0 \kappa_0^+$ , $\ell^0 \kappa_0^+ \kappa_0^+$ , $\ell^+\ell^- \rightarrow \tilde{\kappa}^0 \kappa_0^+$ , $\ell^0 \kappa_0^+ \kappa_0^-$ , $\ell^+\ell^- \rightarrow \tilde{\kappa}^0 \kappa_0^+$ , $\ell^0 \kappa_0^+$ , $\ell^0 \kappa_0^+$ , $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$
800.99 800.99 810 810+11 820 820+1C 830 840 850 860 860 867+3111+112 1999 8000 9000+10 9010-10 9010-10 9100-10	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}\mu_{0}$ , (all neutralinos) $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}\mu_{0}$ , (ill-neutralino mass state) $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , (ill-chargino) $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , (ill-chargino) $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , (ill-chargino) $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , $\ell^-\ell^+\mu^-$ $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , $\ell^-\ell^+\mu^-$ $\ell^+\ell^- \rightarrow \vec{\chi}_{0}e_{1}^{*}$ , $\ell^-\ell^+\mu^-$ $\ell^+\ell^- \rightarrow \vec{\ell}_{1n}e_{1n}^{*}$ , $\ell^-\ell^-\ell^+\mu^-$ $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\mu^-$ , via LLE only $\ell^-\ell^-$ , via LLE only $\ell^-\ell$
800.99 800 810 810+11 820 820+1C 830 840 850 867+3114+112 1PRDC 1PRDC 9000+10 9000+10 9000+10 9100+10 9100+10 9100+10 9140+1P 9130 9140+1P	R-parity violating supersymmetric processes Single sparticle production, sum of S10–S40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , (all chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , (all chargino mass state) $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , ( $\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\chi}^0 \mu_t$ , ( $\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\ell}^0 \mu_t$ , ( $\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\ell}^0 \mu_t$ , ( $\ell^- \rightarrow \bar{\ell}^0 W^-$ $\ell^+\ell^- \rightarrow \ell^+ \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^- \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^-\ell^- \rightarrow \ell^-$ , via LLE only $\ell^-\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^-$ , via LLE only $\ell^-\ell^- \rightarrow \ell^-$ , via LLE only $\ell^-\ell^-$
800.99 800.99 810 810+11 820 820+1C 820 840 850 867+3114+112 1880 1867+3114+112 1880 900+110 9100+10 9500+10 9500	$ \begin{array}{l} & \text{R-parity violating supersymmetric processes} \\ & \text{Single sparticle production, sum of $10-$40$ \\ \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\text{R}}(n, (\text{III-neutralinos)} \\ \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\text{R}}(n, (\text{III-neutralinos)} \\ \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\text{R}}(\vec{\pi}, (\text{III-neutralino}) \\ \ell^+\ell^- \rightarrow \ell^+\ell^-, \text{ via LLE only} \\ \ell^+\ell^- \rightarrow \ell^+_{\text{III-neutralino}}(\text{III-neutralino}) \\ \ell^+\ell^- \rightarrow \ell^+_{\text{III-neutralino}}(\vec{\pi}, (\text{III-neutralino}) \\ \text{III-neutralino} \\ \ell^+\ell^- \rightarrow \ell^+_{\text{III-neutralino}}(\vec{\pi}, (\text{III-neutralino}) \\ \ell^+\ell^- \rightarrow \ell^{\text{III-neutralino}}(\vec{\pi}, (\text{III-neutralino}) \\ \ell^+\ell^- \rightarrow \ell^+_{\text{III-neutralino}}(\vec{\pi}, (\text{III-neutralino}) \\ \ell^+\ell^- \rightarrow \ell^+_{\text{III-neutralino}}(\vec{\pi}, (III-neutralino$
800-99 800-99 810 +11 820 820 +12 820 +12 820 +12 820 -12 820 -12 820 -12 820 -12 840 -11 850 -12 999 -12 867 +311 +11.2 999 -12 900 +12 910 -12 910 -12 91	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i$ , (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i$ , (all neutralinos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i$ , (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i^+$ , (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i^+$ , (all charginos) $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i^+$ , $\ell^ \bar{\ell}_i^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\chi}^0 u_i^+$ , $\ell^ \bar{\ell}_i^0 W^-$ $\ell^+\ell^- \rightarrow \bar{\ell}_{14}^+$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ u_i^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+ u_i^-$ , (ii. LLE only $\ell^+\ell^- \rightarrow \ell^+ u_i^-$ , (ii. LLE only $\ell^+\ell^- \rightarrow \ell^+ u_i^-$ , (iii. LLE only Deep inductic lepton scattering (All contrast true) Deep inductic lepton scattering (Caron flavour 1Q) Deep inductic lepton scattering (Caron flavour 1Q) Deep inductic lepton scattering (Caron flavour 1Q) Deep induction true true current DIS (all flavours) Deep induction true by Disson-gluon fusion $J(\phi + gluon production by Disson-gluon fusion (CD Compton process in to CD IS (1tri-1-12 for d - t, d - t)All \ell(a_0) NC processes (i.e. 9100+910)Haavy quark production by charged-current boson-gluon fusionIF: 1 = a_{\ell} = - a_{\ell} = a_{\ell} + d + d + (+ t, cni).)W^+W^- Z^0Z^0 \rightarrow H^0_{R_0} in DIS (Di as in 1PRO = 300+1D)as TFRDC - 1P but with a dot underlying event(soft remnant fragmentation in lepton-hadron) suppressed$
800.99 800.99 810 810+III 820 820+IC 820 840 840 850 867+31L1+IL2 1PRDC 7999 8400 9000+IQ 9000+IQ 9100+IQ 9100 9100+IQ 9100 9100+IQ 9100 9100+IQ 9100 9100+IQ 9100 9100+IP	$ \begin{array}{l} & \text{R-parity violating supersymmetric processes} \\ & \text{Single sparticle production, sum of $10-$40$ \\ \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}(, \text{all neutralinos}) \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}(, \text{all neutralinos}) \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}e^+_{\nu}(\text{all charginos}) \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}e^+_{\nu}(, \text{cle-chargino mass state}) \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}e^+_{\nu}(, \text{cle-chargino mass state}) \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}e^+_{\nu} \\ & \ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{\mu}e^+_{\nu}e^+_{\mu$
800.99 800.99 810 810+11 820 820+10 820 840 850 860 860 867+3114+112 7999 8000 9000+10 9010+10 9100+10 9100+10 9100+10 9100+11 9100 9100	R-parity violating supersymmetric processes Single sparticle production, sum of \$10-\$40 $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{eff}$ , (all-charginos) $\ell^+\ell^- \rightarrow \vec{\chi}^{2n}_{eff}$ , (all-charginos) $\ell^+\ell^- \rightarrow \vec{\chi}_{eff}$ , (all-charginos) $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\ell^-$ , via LLE only $\ell^+\ell^- \rightarrow \ell^+\pi_{find}$ (III, 2–1,2,3 for $e_{\pm}\mu, \tau$ ) Process generated by HERBM package Minimum base soft hadron-hadron event Deep indextic lepton scattering (All costital current) Deep indextic lepton scattering (All costital current) Deep indextic lepton scattering (All charged current) Deep indextic lepton scattering (CC on flavour IQ) Deep indextic lepton scattering (CC on flavour) QCD Compton process in nor DIS (III as above) $J/\psi^+$ gluon preduction by boson-gluon fusion QCD Compton process in NC DIS (IQ as above) $J/\psi^+ W^-/\xi^0 Z^0 \rightarrow B_{ind}^+$ in DIS (DI as in IPR0C = 300 + ID) us IFRDC = H biu with abus durkfying overt (scft remnant fragmentation in lepton-hadron) suppressed

TPHDC	Ptocess
880	$\ell^+\ell^- \rightarrow dd$ , via LLE and LQD
877+31q1+1q2	$\ell^+\ell^- \rightarrow d_{n,1}d_{n,2}$ (IQ1,2=1,2,3 for d, s,b)
910	$\ell^+\ell^- \rightarrow \nu_e p_e h^0 + e^+e^-h^0$
920	$\ell^+\ell^- \rightarrow \nu_e \rho_e H^0 + e^+e^- H^0$
980	$\ell^+\ell^- \rightarrow Z^0 h^0$
970	$\ell^+\ell^- \rightarrow Z^0H^0$
966	$\ell^+\ell^- \rightarrow H^+H^-$
965	$\ell^+\ell^- \rightarrow A^0h^0$
965	$\ell^+\ell^- \rightarrow A^0H^0$
1000+ID	$\ell^+\ell^- \rightarrow t t H_{SM}^0$ (ID as in IPROC=300+ID)
1110+10	$\ell^+ \ell^- \rightarrow q \bar{q} h^0$ (IQ as m IPRDC=100+IQ)
1116+IL	$\ell^+ \ell^- \rightarrow \ell^+ \ell^- n^- (IL=1,2,3 \text{ for } \ell, \mu, \tau)$
1120+10	$\ell^+ \ell^- \rightarrow q \bar{q} H'$ (IQ as in IPROC=100+1Q)
1126+1L	$\varepsilon \cdot \varepsilon \longrightarrow \varepsilon \cdot \varepsilon H^{-}$ (11=1,2,3 for $\varepsilon, \mu, \tau$ )
1130+10	$e^+e^- \rightarrow q\bar{q}A^-$ (1q as in 1PRDC=100+1q) $e^+e^- \rightarrow e^+e^-A^0$ (17 = 1.0.2 for a scale)
1140	$e^+e^- \rightarrow e^-e^- s + (11-1,2,5 \text{ tot} e, \mu, \tau)$ $e^+e^- \rightarrow de H^+ + sh^- consi$
11.41	$\ell^+\ell^- \rightarrow a \bar{a} \bar{a} \bar{a} \bar{a} + ch. conj.$
11.49	$\ell^+\ell^- \rightarrow b\bar{z}H^+ + ch$ comi
11.43	$\ell^+\ell^- \rightarrow eB_c H^+ + ch$ comi
1144	$\ell^+\ell^- \rightarrow \mu P_0 H^+ + ch.$ conj.
11.45	$\ell^+\ell^- \rightarrow \tau \rho_{\tau} H^+ + ch comi$
1200-99	Reserved for other $l^+l^-$ processes
1200	$a\bar{a} \rightarrow Z^0/\gamma \rightarrow \sigma'\bar{a}'$ (all flavours)
1300+ID	$q\bar{q} \rightarrow Z^0/\gamma \rightarrow q'\bar{q}'$ (10 = 1, 2, 3, 4, 5, 6 for $q = d, u, s, c, b, t$ )
135D	$a\bar{a} \rightarrow Z^0/\gamma \rightarrow \ell\bar{\ell}$ (all lanton spacies)
1350+IL	$q\bar{q} \rightarrow Z^0/\gamma \rightarrow \ell\bar{\ell}$ (IL = 1 - 6 for $\ell = e. \nu \mu. \nu \text{ etc.}$ )
1399	$q\bar{q} \rightarrow Z^0/\gamma \rightarrow anything$
1400	$q\bar{q} \rightarrow W^{\pm} \rightarrow q'\bar{q}^{\mu}$ (all flavours)
1400+IQ	$q\bar{q} \rightarrow W^{\pm} \rightarrow q^{i}\bar{q}^{\mu} (q^{i} \text{ or } q^{\pi} \text{ as above})$
145D	$q\bar{q} \rightarrow W^{\pm} \rightarrow \ell \nu_k$ (all lepton species)
1450+IL	$q\bar{q} \rightarrow W^{\pm} \rightarrow \ell \nu_{\ell} (IL = 1, 2, 3 \text{ for } \ell = e, \mu, \tau)$
1499	$q\bar{q} \rightarrow W^{\pm} \rightarrow anything$
1500	QCD 2 $\rightarrow$ 2 hard parton scattering
	After generation, IMPRO is subprocess (see sect. 4.6.2)
1600+ID	$gg/q\bar{q} \rightarrow H_{SM}^0$ (ID as in IPROC = $300 \pm ID$ )
1700+IQ	QCD heavy quark production (10 as above)
	After generation, IMPRO is subprocess (see sect. 4.6.2)
1800	QCD direct photon + iet production
IPRDC	Process
1000	After generation, IHPRO is subprocess (see sect. 4.6.5)
1900+ID	$q\bar{q} \rightarrow q\bar{q}'W^+W^-/Z^0Z^0 \rightarrow q\bar{q}'H_{SM}^{0}$ (II) as in IPROC = 30.0 + 10) 4 conduction of 100 conduction of 2003 (2008)
2010	t production via W – exchange (sum of 2001-2008)
2001 4	A T A W A T A W A
2001-4	$ab \rightarrow a\overline{a}, ab \rightarrow v\overline{i}, \overline{ab} \rightarrow \overline{a}\overline{i}, vb \rightarrow at$
2001-4 2005-8 2100	$ab \rightarrow d\bar{t}$ , $db \rightarrow v\bar{t}$ , $d\bar{b} \rightarrow d\bar{t}$ , $vb \rightarrow d\bar{t}$ $ab \rightarrow d\bar{t}$ , $sb \rightarrow c\bar{t}$ , $sb \rightarrow d\bar{s}$ , $cb \rightarrow s\bar{t}$ $W^{\pm} \pm i\bar{t}$ resolution
2001-4 2005-8 2100 2110	$ab \rightarrow d\bar{t}$ , $db \rightarrow v\bar{t}$ , $d\bar{b} \rightarrow \bar{u}\bar{t}$ , $v\bar{b} \rightarrow d\bar{t}$ $c\bar{b} \rightarrow d\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $c\bar{b} \rightarrow s\bar{t}$ $W^{b+}$ ; jut production $W^{b+}$ ; jut production $W^{b+}$ ; jut production
2001-4 2005-8 2100 2110 2120	$ab \rightarrow d\bar{e}$ , $d\bar{e} \rightarrow v\bar{e}$ , $d\bar{e} \rightarrow v\bar{e}$ , $v\bar{e} \rightarrow d\bar{e}$ , $ab \rightarrow d\bar{e}$ , $s\bar{b} \rightarrow e\bar{e}$ , $s\bar{b} \rightarrow e\bar{e}$ , $ab \rightarrow s\bar{e}$ $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ ) $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ ) $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ )
2001-4 2005-8 2100 2110 2120 2150	$ab \rightarrow d\bar{t}$ , $db \rightarrow u\bar{t}$ , $d\bar{b} \rightarrow a\bar{t}$ , $ub \rightarrow dt$ $ab \rightarrow s\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $c\bar{d} \rightarrow s\bar{t}$ $W^{2+} + jat production W^{4+} + jat production (Compton only: gq \rightarrow Wq)W^{4+} + jat production (annihilation only: qq \rightarrow Wg)Z^{0+} jat production$
2001-4 2005-8 2100 2110 2120 2150 2160	$ab \rightarrow d\bar{t}$ , $db \rightarrow v\bar{t}$ , $d\bar{b} \rightarrow a\bar{t}$ , $vb \rightarrow dt$ $ab \rightarrow d\bar{x}$ , $s\bar{b} \rightarrow c\bar{t}$ , $bb \rightarrow c\bar{c}$ , $c\bar{b} \rightarrow s\bar{t}$ $W^{4} + jet production (Compton only: gq \rightarrow Wq)W^{4} + jet production (Compton only: gq \rightarrow Wq)W^{5} + jet production (Compton only: qq \rightarrow Wg)Z^{0} + jet production (Compton only: qq \rightarrow Zq)$
2001-4 2006-8 2110 2110 2120 2150 2160 2170	$ab \rightarrow d\overline{c}$ , $db \rightarrow v\overline{c}$ , $d\overline{b} \rightarrow a\overline{c}$ , $vb \rightarrow dt$ $ab \rightarrow s\overline{c}$ , $s\overline{b} \rightarrow c\overline{c}$ , $sb \rightarrow c\overline{c}$ , $ab \rightarrow s\overline{c}$ $W^{+} + jet production (Compton only: gq \rightarrow Wq)W^{+} + jet production (Compton only: gq \rightarrow Wq)Z^{0} + jet production (Compton only: gq \rightarrow Zq)Z^{0} + jet production (Compton only: gq \rightarrow Zq)Z^{0} + jet production (Compton only: gq \rightarrow Zq)$
2001-4 2006-8 2110 2110 2120 2150 2160 2170 2200	$ab \rightarrow d\overline{t}$ , $db \rightarrow u\overline{t}$ , $d\overline{b} \rightarrow a\overline{t}$ , $ub \rightarrow dt$ $ab \rightarrow s\overline{t}$ , $b\overline{b} \rightarrow c\overline{t}$ , $b\overline{c} \rightarrow c\overline{t}$ , $c\overline{b} \rightarrow s\overline{t}$ $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ ) $W^{4+}$ jet production (annihilation only: $q\overline{q} \rightarrow Wg$ ) $Z^{0+}$ jet production $Z^{0+}$ jet production $Z^{0+}$ jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0+}$ jet production (Compton only: $gq \rightarrow Zq$ ) CCD direct holoton pair troubletion
2001-4 2005-8 2100 2110 2120 2150 2160 2170 2200	$ab \rightarrow d\bar{e}$ , $d\bar{e} \rightarrow u\bar{e}$ , $d\bar{b} \rightarrow u\bar{e}$ , $u\bar{b} \rightarrow d\bar{e}$ $bb \rightarrow d\bar{e}$ , $s\bar{b} \rightarrow c\bar{e}$ , $d\bar{b} \rightarrow s\bar{e}$ $W^{2} + jet production W^{2} + jet production (Compten culy: gq \rightarrow Wq)W^{2} + jet production (annihilation culy: qq \rightarrow Wg)Z^{0} + jet production (Z^{0} + jet production Z^{0} + jet production (compten culy: qq \rightarrow Zq)Z^{0} + jet production (annihilation culy: qq \rightarrow Zq)Z^{0} + jet production (annihilation culy: qq \rightarrow Zq)Z^{0}$
2001-4 2005-8 2100 2110 2120 2150 2150 2160 2170 2200	$ab \rightarrow d\bar{r}$ , $db \rightarrow v\bar{r}$ , $d\bar{b} \rightarrow a\bar{d}$ , $vb \rightarrow dt$ $ab \rightarrow s\bar{r}$ , $s\bar{b} \rightarrow c\bar{r}$ , $sb \rightarrow c\bar{r}$ , $ab \rightarrow s\bar{t}$ $W^{+}$ + jet production $W^{+}$ + jet production (Compten only: $q\bar{q} \rightarrow W\bar{q}$ ) $W^{+}$ + jet production (Compten only: $q\bar{q} \rightarrow Wg$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Z\bar{q}$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Z\bar{q}$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Z\bar{q}$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Z\bar{q}$ ) QCD direct photon pair production After generation, LIPRO is subprocess (see sect. 4.6.5.) QCD SM Hires + jet production (TD as in PHRC-3064-1D)
2001-4 2006-8 2100 2110 2120 2150 2150 2160 2170 2200 2300+1D	$ab \rightarrow d\overline{t}$ , $db \rightarrow u\overline{t}$ , $d\overline{b} \rightarrow a\overline{d}$ , $ub \rightarrow dt$ $ab \rightarrow d\overline{s}$ , $b\overline{b} \rightarrow d\overline{t}$ , $bb \rightarrow d\overline{s}$ , $bb \rightarrow d\overline{t}$ $W^{+} + jet production (Compton only: gq \rightarrow Wq)W^{+} + jet production (Compton only: gq \rightarrow Wg)Z^{0} + jet production (Compton only: gq \rightarrow Zq)Z^{0} + jet production (Compton only: qq \rightarrow Zq)Z^{0} + jet production (Compton only: qq \rightarrow Zq)QCD direct photon pair productionAfter generation, HPR0 is subprocess (see sect. 4.6.5)QCD SM Higgs + jet production (ID as in IPRO-300+1D)After generation, HPR0 is subprocess (see sect. 4.6.10)$
2001-4 2006-8 2100 2110 2120 2150 2160 2160 2160 2160 2170 2200 2300+1D	$ab \rightarrow a\overline{k}$ , $ab \rightarrow u\overline{i}$ , $\overline{ab} \rightarrow a\overline{i}$ , $ub \rightarrow dt$ $ab \rightarrow d\overline{i}$ , $ab \rightarrow d\overline{i}$ , $bb \rightarrow d\overline{i}$ , $ub \rightarrow dt$ $W^{+} + jet production$ $W^{+} + jet production (Compten only: gq \rightarrow Wq)W^{+} + jet production (annihilation only: q\overline{q} \rightarrow Wg)Z^{0} + jet production (Compten only: gq \rightarrow Zg)Z^{0} + jet production (Compten only: gq \rightarrow Zg)Z^{0} + jet production (Inhihilation colly: q\overline{q} \rightarrow Zg)QCD direct photon pair productionAfter generation, LHFRO is subprocess (see sect. 4.6.5.)QCD SM Higgs + jet production (1D as in IPRDC-380+1D)After generation, LHFRO is subprocess (see sect. 4.6.10)Mudlar-Tang colour single teachange$
2001-4 2006-8 2100 2110 2120 2150 2150 2150 2170 2200 2300+1D 2400 2450	$ab \rightarrow d\bar{r}, \ db \rightarrow v\bar{r}, \ d\bar{b} \rightarrow d\bar{x}', \ vb \rightarrow dt$ $ab \rightarrow K, \ ab \rightarrow c\bar{r}, \ bb \rightarrow d\bar{x}, \ bb \rightarrow dt$ $W^{+} + jet production$ (Compton only: $qq \rightarrow Wq$ ) $W^{+} + jet production$ (Compton only: $qq \rightarrow Wq$ ) $W^{+} + jet production$ (Compton only: $qq \rightarrow Wq$ ) $Z^{0} + jet production$ (Compton only: $qq \rightarrow Zq$ ) $Z^{0} + jet production$ (Compton only: $qq \rightarrow Zq$ ) QCD direct photon pair production After generation, LHPRO is subprocess (see sect. 4.6.5.) QCD SM Higgs + jet production (To as in HPRO-3004+D) After generation, LHPRO is subprocess (see sect. 4.6.10) Mudler-Tang colour singlet exchange Quark scattering via photon exchange
2001-4 2006-8 2110 2120 2150 2150 2150 2150 2170 2200 2300+1D 2450 2450 2450 2450	$ab \rightarrow a\bar{t}$ , $ab \rightarrow u\bar{t}$ , $ab \rightarrow a\bar{t}$ , $ub \rightarrow d\bar{t}$ $ab \rightarrow a\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $a\bar{b} \rightarrow c\bar{t}$ , $c\bar{b} \rightarrow s\bar{t}$ $W^{+} + jet production W^{+} + jet production (Compten culy: gq \rightarrow Wq)W^{+} + jet production (Compten culy: qq \rightarrow Wq)Z^{0} + jet production Z^{0} + jet production (Compten culy: qq \rightarrow Zq)Z^{0} + jet production (annihilation culy: qq \rightarrow Zq)ZC^{0} Higgs + jet production (gq \rightarrow Zq)ZC^{0} Higgs + jet production (D as in IPHOC-300.4 D)After generation, IBPRO is subprocess (see sect. 4.6.5)Mrel dramatical cultor is the process (see sect. 4.6.10)Muddar-Lang colour singlet exchangeQq qq \rightarrow (THRO-300.4 D)$
2001-4 2006-8 21D0 2110 2120 2150 2160 2170 2160 2170 2200 2300+1D 2400 2450 2500+1D 2500+1D	$ab \rightarrow a\overline{k}$ , $db \rightarrow v\overline{i}$ , $d\overline{b} \rightarrow a\overline{k}$ , $vb \rightarrow dt$ $bb \rightarrow k\overline{i}$ , $s\overline{b} \rightarrow d\overline{i}$ , $s\overline{b} \rightarrow d\overline{i}$ , $vb \rightarrow dt$ $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ ) $W^{2+}$ jet production (Compton only: $gq \rightarrow Wq$ ) $Z^{0+}$ jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0+}$ jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0-}$ Differse photon pair production (D as in IPRO-300+1D) After generation, HPRO is subprocess (see sect. 4.6.5.) QCD SM Higgs + jet production (D as in IPRO-300+1D) After generation, HPRO is subprocess (see sect. 4.6.10) Mudlar-Tang colour singlet exchange Quark scattering via photon exchange $gg/q\overline{q} \rightarrow UHR_{Bat}^{0}$ (D as in IPRO-300+1D) $q\overline{q} \rightarrow W=HR_{Bat}^{0}$ (D as in IPRO-300+1D)
2001-4 2006-8 21100 2120 2130 2150 2150 2150 2150 2160 2170 2200 2300+1D 2450 2450 2450 2450 2450 2450 2450 2450	$ab \rightarrow d\bar{r}$ , $db \rightarrow v\bar{r}$ , $d\bar{b} \rightarrow a\bar{d}$ , $vb \rightarrow dt$ $ab \rightarrow s\bar{t}$ , $s\bar{b} \rightarrow c\bar{t}$ , $sb \rightarrow t\bar{t}$ , $vb \rightarrow dt$ $W^{+}$ + jet production $W^{+}$ + jet production (Compten only: $q\bar{q} \rightarrow Wq$ ) $W^{+}$ + jet production (Compten only: $q\bar{q} \rightarrow Wq$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Zq$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Zq$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Zq$ ) $Z^{0}$ + jet production (Compten only: $q\bar{q} \rightarrow Zq$ ) QCD direct photon pair production After generation, LIPRO is subprocess (see sect. 4.6.5.) QCD SM Higgs + jet production (TD as in IPRO-300+1D) After generation, UPRO is subprocess (see sect. 4.6.10) Mudler-Tang colour singlet exchange Quark scattering via photon exchange $2g/q^{-1} \leftarrow tH^{0}_{2M}$ (ID as in IPRO-300+1D) $q^{q} \rightarrow Z^{0+H}_{2M}$ (ID as in IPRO-300+1D) $q^{q} \rightarrow Z^{0+H}_{2M}$ (ID as in IPRO-300+1D)
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2001-4 2005-8 2100 2110 2120 2150 2150 2150 2170 2200 2300+1D 2400 2450 2450 2450 2450 2450 2450 2450	$\begin{array}{llllllllllllllllllllllllllllllllllll$
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2001-4 2006-8 2100 2110 2120 2150 2150 2150 2150 2170 2200 2300+1D 2450 2450 2500+1D 2500+1D 2500+1D 2500+1D 2500+1D 2500+1D 2500+1D 2500+1D 2500+1 2500+1 2500+1 2500-2500-2500-2500-2500-2500-2500-2500	$\begin{array}{llllllllllllllllllllllllllllllllllll$
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2001-4 2006-8 2100 2110 2150 2150 2150 2170 2200 2300+1D 2400 2450 2450 2500+1D 2500+1D 2500+1D 2500 2810 2810 2810 2815 2820 2850 2850 2850 2850	$ab \rightarrow a\overline{t}$ , $ab \rightarrow a\overline{t}$ , $ab \rightarrow a\overline{t}$ , $ab \rightarrow d\overline{t}$ $bb \rightarrow s\overline{t}$ , $s\overline{b} \rightarrow d\overline{t}$ , $s\overline{b} \rightarrow d\overline{t}$ , $ab \rightarrow s\overline{t}$ $W^{+} + jet production (Compten culy: gq \rightarrow Wq)W^{+} + jet production (Compten culy: gq \rightarrow Wq)Z^{0} + jet production (Compten culy: gq \rightarrow Zq)Z^{0} + jet production (Compten culy: q\overline{q} \rightarrow Zq)Z^{0} + jet production (Compten culy: q\overline{q} \rightarrow Zq)Z^{0} + jet production (antihilation culy: q\overline{q} \rightarrow Zq)Z^{0} + jet production (Compten culy: q\overline{q} \rightarrow Zq)Z^{0} - jet production (Compten culy: q\overline{q} \rightarrow Zq)QCD Glinest photon pair productionAfter generation, LHRO is subprocess (see sect. 4.6.5.)QCD SM Higgs + jet production (ID as in IPHOC-300+ID)After generation, LHRO is subprocess (see sect. 4.6.10)Mudler-Tang (colour singlet exchangeguqA scattering via photon exchangeguqA^{0} \rightarrow W^{+}H_{Bd}^{0} (ID as in IPHOC-300+ID)q\overline{q} \rightarrow Z^{0}H_{Bd}^{0} (ID as in IPHOC-300+ID)q\overline{q} \rightarrow Z^{0}H_{Bd}^{0} (ID as in IPHOC-300+ID)W^{+}X^{0} production in hadron-hadron collisions (Z^{0} only)W^{+}Z^{0} production in hadron-hadron collisions (Z^{0} only)W^{+}Z^{0} production in hadron-hadron collisions (Z^{0} only)hadron-hadron -W^{+}Z^{0}X using MC@NLOhadron-hadron -W^{+}Z^{0}X using MC@NLOhadron-hadron -W^{+}Z^{0}X using MC@NLOhadron-hadron -W^{+}Z^{0}X using MC@NLO$
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2001-4 2005-8 2110 2110 2120 2150 2150 2150 2150 2170 2200 2300+1D 2400 2450 2450 2450 2450 2450 2450 2450	$\begin{array}{llllllllllllllllllllllllllllllllllll$
2001-4 2006-8 2100 2110 2150 2150 2150 2150 2170 2200 2300+1D 2400 2450 2500+1D 2500+1D 2500+1D 2500+1D 2500+1D 2810 2810 2810 2815 2825 2850 2850 2850 2850 2850 2850 285	$\begin{array}{llllllllllllllllllllllllllllllllllll$
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2001-4 2006-8 2110 2110 2150 2150 2150 2150 2170 2200 2300+1D 2400 2450 2450 2500+1D 2500+1D 2500+1D 2810 2810 2810 2810 2810 2810 2810 2810	$ab \rightarrow a\bar{k}$ , $ab \rightarrow a\bar{k}$ , $ab \rightarrow a\bar{k}$ , $ab \rightarrow d\bar{k}$ $bb \rightarrow \bar{k}\bar{k}$ , $ab \rightarrow a\bar{k}$ , $ab \rightarrow d\bar{k}$ , $ab \rightarrow a\bar{k}$ $W^{+}$ + jet production $W^{+}$ + jet production (Compton only: $gq \rightarrow Wq$ ) $W^{+}$ + jet production (Compton only: $gq \rightarrow Wq$ ) $Z^{0}$ + jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0}$ + jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0}$ + jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0}$ + jet production (Compton only: $gq \rightarrow Zq$ ) $Z^{0}$ - jet production (Compton only: $gq \rightarrow Zq$ ) QCD direct photon pair production After generation, LHR0 is subprocess (see sect. 4.6.5.) QCD SM Higgs + jet production (1D as in IPROC-308+1D) After generation, LHR0 is subprocess (see sect. 4.6.10) Mudlar-Tang (colour singlet exchange $gq \rightarrow W^{+}H_{Bd}^{0}$ (1D as in IPROC-308+1D) $qq \rightarrow Z^{0}H_{Md}^{0}$ (1D as in IPROC-308+1D) $dq \rightarrow Z^{0}P$ production in hadron-hadron collisions ( $Z^{0}$ only) hadron-hadron $-W^{+}W^{-}X^{0}$ wing MCONLO hadron-hadron $-W^{-}Z^{0}X^{0}$ wing MCONLO hadron -hadron $W^{-}Z^{0}X^{0}$ wing MCONLO hadron -hadron $W^{0}X^{0}X^{0}$ wing MCONLO hadron -hadron $W^{$

IPROC	Procuss
3310.3315	$ad' \rightarrow W^{\pm}h^0, H^{\pm}h^0$ (all $q, q'$ flavours – gauge bosons mediated only)
3320.3325	$qq' \rightarrow W^{\pm}H^{0}, H^{\pm}H^{0}$ [")
3335	$q\bar{q}' \rightarrow H^{\pm}A^{0}(")$
3350	$q\bar{q} \rightarrow W^{\pm}H^{\mp}$ (Higgstrahlung and Higgs mediated)
3355	$q\bar{q} \rightarrow H^{\pm}H^{\mp}$ (all q flavours — gauge boson mediated only)
3360.3365	$a\vec{v} \rightarrow Z^0 h^0, A^0 h^0$ (")
3370.3375	$a\vec{v} \rightarrow Z^0 H^0, A^0 H^0$ (*)
2410	$h_{2} \rightarrow b h_{2} + ch comi$
3420	$ba \rightarrow b H^0 + ch. conj.$
3430	$bq \rightarrow b A^0 + ch. coni.$
3450	$h_2 \rightarrow t H^- + ch.$ sori
2500	$ha \rightarrow ha^{\mu}H^{\pm} + ch$ comi
2610	$a_1^{(1)} \rightarrow b_1^{(0)} + ch(ch)$
3620	$q\bar{q}/q\bar{q} \rightarrow H^0$ (beavy scalar Hires)
2620	$a^{\overline{a}}/an \rightarrow A^0$ (rescalar Higgs)
2010	$q_{1/3y} \rightarrow q_{2} q_{2} q_{2} q_{2} q_{2} q_{3} q_{3} q_{4} q_{5} q_{5}$
3720	$q\bar{q} \rightarrow q\bar{q}W^+W^-/Z^0Z^0 \rightarrow q\bar{q}H^0$
2818⊥TD	$a_1 \rightarrow a_2 \rightarrow OOb^0$ (all a flavours in scharmel 10 as usual for O flavour).
2898±TD	$gg + qq \rightarrow q\bar{q}q$ (and income in scattering) $q$ as used to $q$ income).
3830±10	$gg + gg \rightarrow OOA^{0}$
2820	$a_2 + a_3 \rightarrow b_1^2 H^+ + ch$ comin (all a flavours in schonnal)
3840±10	$gg \rightarrow Q\bar{Q}h\rho$ (10 as above)
2858±TD	$aa \rightarrow (10^{10} R^{0})^{(2)}$
3868±10	99
3869	$gg \rightarrow bH^+ + ch$ , conig.
3878±10	$a\bar{a} \rightarrow OOh^0$ (all a flavours in s-channel T0 as above)
3880+ID	$q\bar{q} \rightarrow Q\bar{Q}H^0$ (")
3890±TD	$a\bar{a} \rightarrow O\bar{O}A^0$ (*)
2899	$a\bar{a} \rightarrow b\bar{b}H^+ \pm ch.$ conir. (all a flavours in scharmel)
2900-99	Reserved for other hadron-hadron MSSM processes
4000-99	R-parity violating supersymmetric processes via LQD
4000	single sparticle production, sum of 4010-4050
4010	$\bar{u}_{i}d_{k} \rightarrow \bar{\chi}^{0}l_{t}^{-}, \bar{d}_{i}d_{k} \rightarrow \bar{\chi}^{0}\nu_{t}$ (all neutralinos)
4018+IN	$a_{i}d_{k} \rightarrow \chi^{0}_{II}l_{i}^{-}, d_{i}d_{k} \rightarrow \chi^{0}_{IN}\nu_{t}$ (IH-neutralino mass state)
4020	$a_{i}d_{k} \rightarrow \overline{\chi}^{-}\nu_{i}, \overline{d}_{1}d_{k} \rightarrow \overline{\chi}^{-}e_{i}^{+}$ (all charginos)
4028+IC	$\hat{a}_{j}d_{k} \rightarrow \chi_{ic} v_{i}, \tilde{d}_{j}d_{k} \rightarrow \chi_{ic} e_{i}^{+}$ (IC=chargino mass state)
4D4D	$u_j d_k \rightarrow \overline{\tau}_i^+ Z^0$ , $u_j d_k \rightarrow \overline{\nu}_i W^+$ and $d_j d_k \rightarrow \overline{\ell}_i^+ W^-$
4050	$u_i \overline{d}_k \rightarrow \overline{\ell}_i^+ h^0 / H^0 / A^0$ , $u_i \overline{d}_k \rightarrow \overline{\nu}_i H^+$ and $d_i \overline{d}_k \rightarrow \overline{\ell}_i^+ H^-$
IPRDC	Process From of 4040 and 4040
4060 4070	Process Sum of 40%0 and 4080 or de and and 4080
4060 4070 4080	Process Sum of 4070 and 4080 $a_j d_k \rightarrow 0_k d_m$ and $\bar{d}_j d_k \rightarrow \bar{d}_j d_m$ , via LQD only $a_j d_k \rightarrow 0_k d_m$ and $\bar{d}_j d_k \rightarrow l d_m$ , via LQD only
1PRDC 4D6D 4D7D 4D8D 4100.99	Process Sum of 40°0 and 4080 $g_{ijk} \rightarrow u_{ijk}$ and $d_{ijlk} \rightarrow d_{ijlk}$ , via LQD only $g_{ijk} \rightarrow v_{ijk}$ and $d_{ijlk} \rightarrow t_{ij}^{+1}$ , via LQD and LLE Remarks violating supersymmetric processes via UDD
1PRDC 4D6D 4D7D 4D8D 4100-99 4100	Process Sum of 4070 and 4080 $a_{d}d_{h} \rightarrow 0_{d}d_{h} \rightarrow d_{d}d_{h}$ , via LQD only $a_{d}d_{h} \rightarrow u_{d}t_{h}$ and $d_{d}d_{h} \rightarrow t_{h}^{+}t_{h}^{-}$ , via LQD and LLE R-parity violating supersymmetric processes via UDD sincle sparticle production, sum of 4110–4150
1PRDC 4D6D 4D7D 4D8D 4100-99 4100 4110	Process Sum of 4070 and 4080 $\dot{a}_{j}d_{k} \rightarrow 0_{l}d_{m}$ and $\dot{d}_{j}d_{k} \rightarrow \dot{d}_{l}d_{m}$ , via LQD only $\dot{a}_{j}d_{k} \rightarrow v_{l}i_{k}^{-}$ and $\dot{d}_{j}d_{k} \rightarrow l_{l}^{+}i_{k}^{-}$ , via LQD only LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4180 $u_{l}d_{k} \rightarrow \frac{v_{l}^{2}d_{k}}{d_{k}d_{k}} \rightarrow \frac{v_{l}^{2}}{u_{k}}$ (all neutralinos)
IPRDC 4D6D 4D7D 4D8D 4100-99 4100 4110 4110 4110 +IN	Process Sum of 4070 and 4080 $a_jd_k \rightarrow 0_kd_{sc}$ and $a_jd_k \rightarrow d_id_{sc}$ , via LQD only $a_jd_k \rightarrow v_kf_k^-$ and $a_jd_k \rightarrow t_i^+J_k^-$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4180 $a_kd_j \rightarrow \frac{v_k}{2}d_kd_kd_k \rightarrow \frac{v_k}{2}a_k'(10 \text{ m schows})$ $a_kd_j \rightarrow \frac{v_k}{2}d_kd_kd_kd_k \rightarrow \frac{v_k}{2}a_k'(10 \text{ m schows})$
1PRDC 4DCD 4D7D 4D8D 4100-99 41D0 4110 4110 +IN 412D	Process Sum of 4070 and 4080 $a_{dd_{A}} \rightarrow u_{de_{A}}$ and $d_{dd_{B}} \rightarrow d_{de_{A}}$ , via LQD only $a_{dd_{A}} \rightarrow u_{de_{A}}$ and $d_{dd_{B}} \rightarrow t_{1}^{+}t_{1}^{-}$ , via LQD and LLE R-parity violating uppersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_{df} - \sum^{70}d_{a}, d_{dd_{A}} - \sum^{70}u_{A}$ (all neutralinos) $u_{df} - \sum^{70}d_{a}, d_{dd_{A}} - \sum^{70}u_{A}$ (all categors) $u_{df} - \sum^{70}u_{b}, d_{dd_{A}} - \sum^{70}u_{A}$ (all charginos)
IPRDC 4D6D 4D7D 4D8D 4100-99 4110 4110 +IN 4120 4120 +IC	Process Sum of 4070 and 4080 $\theta_{ij}d_k \rightarrow \eta_{ij}d_{ki} \rightarrow \theta_{ij}d_{ki}$ , via LQD only $\theta_{ij}d_k \rightarrow \gamma_{ij}T_{ki}$ and $\theta_{ij}d_{ki} \rightarrow \theta_{ij}^{2}d_{ki}$ , via LQD and LLE Reparity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_{ij}d_{j} \rightarrow T^{2}\theta_{ij}d_{j}d_{j}d_{ki} \rightarrow T^{2}_{ki}d_{ki}(110 \text{ as above})$ $u_{ij}d_{j} \rightarrow T^{2}_{ki}u_{ki}d_{j}d_{ki} \rightarrow T^{2}_{ki}d_{ki}(110 \text{ as above})$ $u_{ij}d_{j} \rightarrow T^{2}_{ki}u_{ki}d_{j}d_{ki} \rightarrow T^{2}_{ki}d_{ki}(110 \text{ as hove})$ $u_{ij}d_{j} \rightarrow T^{2}_{ki}u_{ki}d_{j}d_{ki} \rightarrow T^{2}_{ki}d_{ki}(120 \text{ as hove})$
IPADC 4D6D 4D7D 4D8D 4100-99 4100 4110 4110 4110 4120 4120 4120 4120 4120 4120	Process Sum of 4070 and 4080 $\hat{a}_{j}d_{k} \rightarrow u_{l}d_{m}$ and $\hat{d}_{j}d_{k} \rightarrow d_{l}d_{m}$ , via LQD only $\hat{a}_{j}d_{k} \rightarrow v_{l}f_{k}$ and $\hat{d}_{j}d_{k} \rightarrow t_{l}^{*}J_{k}$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110-4180 $u_{l}d_{j} \rightarrow \frac{27}{10}\hat{a}_{l}d_{j}d_{j}d_{j} \rightarrow \frac{7}{2}\hat{a}_{l}(all neutralinos)$ $u_{l}d_{j} \rightarrow \frac{27}{10}\hat{a}_{l}d_{j}d_{j}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}(all model)$ $u_{l}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}d_{j}d_{j}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}(all model)$ $u_{l}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}d_{j}d_{j}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}(all model)$ $u_{l}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}d_{j}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}(all model)$ $u_{l}d_{j} \rightarrow \frac{3}{10}\hat{a}_{l}d_{j}d_{j} \rightarrow \frac{7}{10}\hat{a}_{l}(all model)$
IFRDC 4D6D 4D7D 4D8D 4100-99 4110 4110 4110 4110 4120 4120 4120 4120 4120 4120 4120 4120 4140	Process Sum of 40°C and 40%C $\frac{g_{d}d_{A} \rightarrow u_{d}d_{w}}{d_{A}} \rightarrow \tilde{u}_{d}d_{w}$ , via LQD only $\frac{g_{d}d_{A} \rightarrow u_{d}d_{w}}{d_{A}} \rightarrow \tilde{u}_{d}d_{w}$ , via LQD only $\frac{g_{d}d_{A}}{d_{A}} \rightarrow u_{d}d_{w}$ and $\frac{g_{d}d_{B}}{d_{A}} \rightarrow \tilde{u}_{d}d_{w}$ . The second state single sparticle production, sum of 4110–4150 $u_{d}d_{-} \rightarrow \tilde{Y}^{0}d_{w}d_{d}d_{w} \rightarrow \tilde{Y}^{0}u_{v}$ (all neutralinos) $u_{d}d_{-} \rightarrow \tilde{Y}^{0}d_{w}d_{d}d_{w} \rightarrow \tilde{Y}^{0}u_{v}$ (all neutralinos) $u_{d}d_{-} \rightarrow \tilde{Y}^{0}d_{w}d_{d}d_{w} \rightarrow \tilde{Y}^{0}u_{v}$ (all charginos) $u_{d}d_{-} \rightarrow \tilde{Y}^{0}d_{w}d_{w}d_{w} \rightarrow \tilde{Y}^{0}u_{v}$ (12 as shove) $u_{d}d_{-} \rightarrow \tilde{Y}^{0}d_{w}d_{w}d_{w} \rightarrow \tilde{Y}^{0}u_{v}$
IPRDC 40060 40070 4080 4100-99 4100 4110 4110 +IN 4120 4130 +IC 4130 4140 4150	Process Sum of 4070 and 4080 $\theta_j d_k \rightarrow \eta_0 d_m$ and $\theta_j d_k \rightarrow \tilde{\eta}_j d_m$ , via LQD only $\theta_j d_k \rightarrow \eta_0 f_k^-$ and $\theta_j d_k \rightarrow \tilde{t}_j^+ d_k$ , via LQD and LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_0 d_j \rightarrow \tilde{t}_j^0 d_k, d_j d_k \rightarrow \tilde{t}_k^- q_k$ (all charginos) $u_0 d_j \rightarrow \tilde{t}_k^- \theta_k d_k d_k \rightarrow \tilde{t}_k^- q_k$ (all charginos) $u_0 d_j \rightarrow \tilde{t}_k^- u_k d_k d_k \rightarrow \tilde{t}_k^- q_k$ (12 as above) $u_0 d_j \rightarrow \tilde{t}_k^- u_k d_k d_k \rightarrow \tilde{t}_k^- q_k$ $u_0 d_j \rightarrow \tilde{t}_k^- d_k d_k d_k \rightarrow \tilde{t}_k^- q_k$ $u_0 d_j \rightarrow \tilde{t}_k^- d_k d_k d_k \rightarrow \tilde{t}_k^- q_k$ $u_0 d_j \rightarrow \tilde{t}_k^- d_k \theta_k d_k \rightarrow \tilde{t}_k^- q_k$ $u_0 d_j \rightarrow \tilde{t}_k^+ \theta_k \theta_k d_k \rightarrow \tilde{t}_k^- q_k d_k - \tilde{t}_k^- \theta_k d_k d_k + \tilde{t}_k^- W^-$
IFRDC 4060 4070 4080 4100.99 4100 4110 4110 +18 4120 4120 +120 4130 +120 4130 +120 4130 4140 4150	$\begin{array}{l} \operatorname{Process}\\ \operatorname{Sum} & cf 40^{10} \operatorname{and} 4080 \\ & & & & & & \\ & & & & & \\ & & & & & $
IPADC 4050 4050 4080 4100.99 4100 4110 4110 4110 4120 41	Process Sum of 400° arcl 4080 $\theta_{d}d_{h} \rightarrow \psi_{d}a_{h} \rightarrow \tilde{\theta}_{d}a_{h}$ , via LQD only $\theta_{d}d_{h} \rightarrow \psi_{d}a_{h}$ and $d_{d}d_{h} \rightarrow \tilde{\theta}_{d}d_{h}$ , via LQD only $\theta_{d}d_{h} \rightarrow \psi_{d}a_{h}$ Reparity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_{d}d_{-} \rightarrow \tilde{\Omega}h_{d}d_{h}d_{h} \rightarrow \tilde{\chi}h_{d}^{*}u_{h}^{*}(116 \text{ arcminos})$ $u_{d}d_{-} \rightarrow \tilde{\chi}h_{d}d_{h}d_{h} \rightarrow \tilde{\chi}h_{d}^{*}u_{h}^{*}(116 \text{ arcminos})$ $u_{d}d_{-} \rightarrow \tilde{\chi}h_{d}d_{h}d_{h} \rightarrow \tilde{\chi}h_{d}^{*}u_{h}^{*}(116 \text{ arcminos})$ $u_{d}d_{-} \rightarrow \tilde{\chi}h_{d}d_{h}d_{h}d_{h} \rightarrow \tilde{\chi}h_{d}^{*}u_{h}^{*}d_{h}d_{h} \rightarrow \tilde{\chi}h_{h}^{*}u_{h}d_{h}d_{h}d_{h}d_{h}d_{h}d_{h}d_{h}d$
IFADC 4060 4070 4080 4108.99 4100 4110 4110 4110 4120 4100 400 4	Process Sum of 4070 and 4080 $\hat{a}_j d_k \rightarrow u d_k$ and $\hat{d}_j d_k \rightarrow \hat{d}_j d_k$ , via LQD only $\hat{a}_j d_k \rightarrow v d_k^-$ and $\hat{d}_j d_k \rightarrow l_k^+ d_k$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_k d_j \rightarrow \tilde{\Sigma}^+ \hat{d}_k, d_j d_k \rightarrow \tilde{\Sigma}^+ d_k$ (all denotations) $u_k d_j \rightarrow \tilde{\Sigma}^+ \hat{d}_k, d_j d_k \rightarrow \tilde{\Sigma}^- d_k$ (all denotations) $u_k d_j \rightarrow \tilde{\Sigma}^+ u_k, d_j d_k \rightarrow \tilde{\Sigma}^- d_k$ (all denotations) $u_k d_j \rightarrow \tilde{E}^+ u_k, d_j d_k \rightarrow \tilde{\Sigma}^- d_k$ (12 as above) $u_k d_j \rightarrow \tilde{d}_k^- u_k d_j d_k \rightarrow \tilde{U}_k^- (12 as above)$ $u_k d_j \rightarrow \tilde{d}_k^- u_k d_j d_k \rightarrow \tilde{U}_k^- (12 as above)$ $u_k d_j \rightarrow \tilde{d}_k^- u_k d_j d_k \rightarrow \tilde{U}_k^- u_k d_j^- d_j d_k - \tilde{u}_k^- W^-$ $u_k d_j \rightarrow d_k^- h(P/D^-)A^0, d_j d_k - \tilde{u}_k h^D/H^0/A^0, u_k d_j \rightarrow \tilde{u}_k^- H^+,$ $u_k d_j \rightarrow u_k d_k h(P/D^-)A^0, d_j d_k - \tilde{u}_k h^D/H^0/A^0, u_k d_j \rightarrow \tilde{u}_k^- H^+,$ $u_k d_j \rightarrow u_k d_k h(P/D^-)A^0, d_j d_k - \tilde{u}_k h^D/H^0/A^0, u_k d_j \rightarrow \tilde{u}_k^- H^+,$ $u_k d_j \rightarrow u_k d_k h(P/D^-)A^0, d_j d_k - \tilde{u}_k h^D/H^0/A^0, u_k d_j \rightarrow \tilde{u}_k^- H^+,$ $u_k d_j \rightarrow u_k h(P/D^-)A^0, d_j d_k - \tilde{u}_k h^D/H^0/A^0, u_k d_j \rightarrow \tilde{u}_k H^+,$ $u_k d_j \rightarrow u_k d_{DD^-} d_k d_k h^D/D^-$
IFRDC           40560           4070           4080           4100-99           4100-99           4100           4110           4110           4110           4110           4110           4120           4120           4130           4140           4150           4150           4160           4200-99           4200-99           4200-99	Process Sum of 4070 and 4080 $\hat{q}_{dk} \rightarrow 0_{dk}$ and $\hat{d}_{j}d_{k} \rightarrow \hat{d}_{i}d_{st}$ , via LQD only $\hat{q}_{dk} \rightarrow v_{lk}^{-}$ and $\hat{d}_{j}d_{k} \rightarrow l_{l}^{+}d_{st}$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4180 $wd_{j} \rightarrow \hat{\Sigma}^{+}d_{k}d_{j}d_{k} \rightarrow \hat{\Sigma}^{+}d_{k}(111 \text{ metalinos})$ $wd_{j} \rightarrow \hat{\delta}^{+}_{k}\hat{D}^{+}_{j}d_{k}d_{k} \rightarrow \hat{T}^{+}_{k}(111 \text{ metalinos})$ $wd_{j} \rightarrow \hat{\delta}^{+}_{k}\hat{D}^{-}_{j}d_{k}d_{k} \rightarrow \hat{T}^{+}_{k}\hat{D}^{+}_{j}H^{0}/A^{0}, d_{j}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1},$ $wd_{j} \rightarrow \hat{\delta}^{+}_{k}\hat{D}^{-}_{j}d_{k}d_{k} \rightarrow \hat{T}^{+}_{k}\hat{D}^{+}_{j}H^{0}/A^{0}, \alpha_{j}d_{j} \rightarrow \hat{d}^{+}_{k}M^{-1},$ $wd_{j} \rightarrow \hat{d}^{+}_{k}\hat{D}^{+}_{j}d_{k}d_{j}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}D^{+}_{j}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow \hat{d}^{+}_{k}M^{-1}_{k}d_{k}d_{k} \rightarrow d_{k}d_{k} \rightarrow d_{k}d_{k}d_{k} \rightarrow d_{k}d_{k}d_{k} \rightarrow d_{k}d_{k}d_{k} \rightarrow d_{k}d_{k}d_{k}d_{k}d_{k} \rightarrow d_{k}d_{k}d_{k}d_{k}d_{k}d_{k}d_{k}d_{k}$
IFRDC           4D60           4D70           4D80           4100-399           4100           4110           4110           4110           4120           4130           4130           4150           4160           4160           4160           4160           4120           4200           4210           4210	Process Sum of 400° and 4080 $4gd_h \rightarrow 0gd_m$ and $d_fd_h \rightarrow d_fd_m$ , via LQD only $4gd_h \rightarrow 2gd_h^{-1}$ and $d_fd_h \rightarrow l_f^+d_h$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h^+ d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h^+ d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as above) $ud_f \rightarrow \widetilde{T}R_h^+ d_h d_h = \widetilde{T}R_h^+$ $ud_f \rightarrow \widetilde{T}R_h^+ d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as $d_h d_h \rightarrow \widetilde{T}R_h^+$ $ud_f \rightarrow \widetilde{T}R_h^+ d_h d_h \rightarrow \widetilde{T}R_h^+$ (III as $d_h d_h \rightarrow \widetilde{T}R_h^+$ $ud_f \rightarrow \widetilde{T}R_h^+$ (IIII as $d_h d_h \rightarrow \widetilde{T}R_h^+$ ) $d_h d_h \rightarrow \widetilde{T}R_h^+$ (IIII as $d_h d_h \rightarrow \widetilde{T}R_h^+$ ) Sum of 4210, 4200 and 4270 $gg(q) = G \rightarrow gg(q)$ (III partone) $d_h d_h = \widetilde{T}R_h^+$ (IIII as above)
IFRDC 40560 4070 4080 4100-99 4100-99 4100-99 4100 4110 4110 +IN 4120 4120 +IC 4130 4140 4150 4160 4200-99 4200 4210 4210 4200 40	Process Sum of 4070 and 4080 $\hat{a}_j d_k \rightarrow 0_k d_{kn}$ and $\hat{d}_j d_k \rightarrow \hat{d}_i d_{nk}$ , via LQD only $\hat{a}_j d_k \rightarrow p d_k^-$ and $\hat{d}_j d_k \rightarrow l_i^+ d_{jk}^-$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_k d_j \rightarrow \tilde{\Sigma}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (all charginos) $u_k d_j \rightarrow \tilde{\Sigma}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (all charginos) $u_k d_j \rightarrow \tilde{\Sigma}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (all charginos) $u_k d_j \rightarrow \tilde{\Sigma}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (1C as above) $u_k d_j \rightarrow \tilde{\Sigma}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (1C as above) $u_k d_j \rightarrow \tilde{\delta}^* d_k, d_j d_k \rightarrow \tilde{\Sigma}^* \tilde{\alpha}_i$ (1C as $b^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta^+ \delta$
IFRDC 4D60 4D70 4D80 4100-99 4100-99 4110 +IN 4120 4120 +IC 4130 4120 4120 4140 4150 4140 4150 4200 4210 4220 420	Process Sum of 4070 and 4080 $\hat{q}_{dk}^{-} \rightarrow u_{des}^{-}$ and $\hat{d}_{jd}^{-} \rightarrow \tilde{d}_{i}^{-} d_{s}^{-}$ , via LQD only $\hat{q}_{i}d_{k}^{-} \rightarrow u_{i}\tilde{t}_{k}^{-}$ and $\hat{d}_{j}d_{k}^{-} \rightarrow t_{i}\tilde{t}_{k}^{-}$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110-4180 $u_{i}d_{j}^{-} \rightarrow \tilde{\Omega}_{i}^{-}d_{i}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{i}$ (all neutralinos) $u_{i}d_{j}^{-} \rightarrow \tilde{\Omega}_{i}^{-}d_{i}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{i}$ (all neutralinos) $u_{i}d_{j}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{k}^{-}d_{j}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{i}$ (all neutralinos) $u_{i}d_{j}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{k}^{-}d_{j}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{i}$ (all neutralinos) $u_{i}d_{j}^{-} \rightarrow \tilde{u}_{i}^{-}d_{k}^{-}d_{k}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{k}$ (all a charginos) $u_{i}d_{j}^{-} \rightarrow \tilde{u}_{i}^{-}d_{k}d_{k}^{-} \rightarrow \tilde{\chi}^{-}\tilde{u}_{k}^{-}d_$
IFRDC 4050 4070 4080 4100-99 4100-99 4100-99 4110 4110 + IN 4120 4120 + IC 4130 + IC 4130 + IC 4150 4150 4150 4200 4210 + IC 4220 4220 4220 + IC 4250 42	Process Sum of 4070 and 4080 $4jd_h \rightarrow 0id_m$ and $d_jd_h \rightarrow d_jd_m$ , via LQD only $4jd_h \rightarrow vd_h^{-1}$ and $d_jd_h \rightarrow l_h^+d_h$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_hd_j \rightarrow \overline{L}^{+0}d_h - d_hd_h \rightarrow \overline{L}^{+0}d_h$ (101 metralizes) $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h \rightarrow \overline{L}^{+0}d_h$ (101 metralizes) $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h - \overline{L}^{+0}d_h$ (101 metralizes) $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow \overline{L}^{+0}d_hd_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow d_hd_h + l_{h}d_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow d_hd_h + l_{h}d_h - \overline{L}^{+0}d_h$ $u_hd_j \rightarrow d_hd_h + l_{h}d_h - l_{h}d_h$ $d_hd_h \rightarrow d_{h}d_h + l_{h}d_h$ $d_hd_h \rightarrow d_{h}d_h$ $d_hd_h \rightarrow$
IFRDC 4050 4070 4080 41080 4100-99 4100 4110 + IN 4120 4120 + IC 4130 4140 4150 4160 4200-99 4200 4210 4210 4210 4250	Process Sum of 4070 and 4080 $\hat{a}_{j}d_{k} \rightarrow \bar{u}_{t}d_{k} = d_{t}d_{es}$ , via LQD only $\hat{a}_{j}d_{k} \rightarrow \nu a_{t}\tilde{u}_{k}$ and $\hat{d}_{j}d_{k} \rightarrow l_{t}^{2}\tilde{u}_{i}$ , via LQD and LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4180 $ud_{j}d_{-} \rightarrow \tilde{L}^{2}d_{k}, d_{j}d_{k} \rightarrow \tilde{L}^{2}a_{i}(111 \text{ metallines})$ $ud_{j}d_{-} \rightarrow \tilde{L}^{2}d_{k}, d_{j}d_{k} \rightarrow \tilde{L}^{2}a_{i}(111 \text{ metallines})$ $ud_{j}d_{-} \rightarrow \tilde{L}^{2}d_{k}, d_{j}d_{k} \rightarrow \tilde{L}^{2}a_{i}(111 \text{ metallines})$ $ud_{j}d_{-} \rightarrow \tilde{L}^{2}a_{k}, d_{j}d_{k} \rightarrow \tilde{L}^{2}a_{i}(111 \text{ metallines})$ $ud_{j}d_{-} \rightarrow \tilde{L}^{2}a_{i}, d_{j}d_{k} \rightarrow \tilde{L}^{2}a_{i}d_{k}/h^{2}/h^{$
IFRDC 4D60 4D70 4D70 4D70 4D70 4100-99 4100-99 4110 + IR 4120 4120 + IC 4130 + IC 4130 + IC 4130 + IC 4140 4150 4150 4150 4150 4210 4210 4210 4250 4250 4250 4250 4250 4260 4260 4260 4260 4260 4260 4270 4707 4707 4707 4707 4707 470	Process Sum of 400° ard 4080 $4gd_h \rightarrow 0gd_m$ and $d_fd_h \rightarrow d_fd_m$ , via LQD only $4gd_h \rightarrow 2gq_h^{-1}$ and $d_fd_h \rightarrow l_f^+d_h$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} \rightarrow \widetilde{T}_{h}^{0}d_h$ (101 neutralinos) $4gd_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_h$ (101 neutralinos) $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_h$ (121 as above) $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_h$ (121 as above) $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_h$ $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_{h}$ /(121 as above) $ud_f \rightarrow \widetilde{T}_{h}^{0}d_h d_{h} d_{h} \rightarrow \widetilde{T}_{h}^{0}d_{h}$ ////////////////////////////////////
IFRDC 40560 4070 4080 4100-99 4100-99 4100-99 4100-410 4100-10 4120-10 4120-10 4120-410 4130 4140 4150 4200-90 4200 4100 4200	Process Sum of 4070 ard 4080 $\hat{a}_{j}d_{k} \rightarrow 0_{k}d_{m}$ and $\hat{a}_{j}d_{k} \rightarrow \hat{b}_{i}d_{m}$ , via LQD only $\hat{a}_{j}d_{k} \rightarrow \nu_{j}d_{m}$ and $\hat{a}_{j}d_{k} \rightarrow \hat{b}_{i}d_{m}$ , via LQD only LLE R-parity violating supersymmetric processes via UDD $\hat{a}_{i}d_{j} \rightarrow \hat{\Sigma}^{*}d_{k}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{\Sigma}^{*}d_{n}$ (all the attrained $\hat{a}_{i}d_{j} \rightarrow \hat{\Sigma}^{*}d_{k}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{\Sigma}^{*}d_{n}$ (all charginon) $\hat{a}_{i}d_{j} \rightarrow \hat{\Sigma}^{*}d_{k}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{\Sigma}^{*}d_{n}$ (all charginon) $\hat{a}_{i}d_{j} \rightarrow \hat{\Sigma}^{*}d_{k}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{\Sigma}^{*}d_{n}$ (all charginon) $\hat{a}_{i}d_{j} \rightarrow \hat{\Sigma}^{*}d_{n}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{\Sigma}^{*}d_{n}$ $\hat{a}_{i}d_{j} \rightarrow \hat{\delta}^{*}Z^{*}d_{n}$ , $\hat{d}_{j}d_{k} \rightarrow \hat{a}^{*}Z^{*}$ , $\hat{a}_{i}d_{j}d_{j}^{*}d_{k}^{*} \rightarrow \hat{a}^{*}Z^{*}d_{n}^{*}d_{$
IFRDC 4D60 4D70 4D70 4D70 4100-99 4100-99 4110 + IN 4120 4120 + IC 4130 + IC 4130 + IC 4130 4140 4150 4150 4200 4210 4210 4210 4220 4210 4250 4250 4250 4250 4250 4250 4250 4250 4270 4270 4271 4271 4271	Process Sum of 4070 and 4080 $\hat{a}_{j}d_{k} \rightarrow \hat{u}_{l}d_{m}$ and $\hat{d}_{j}d_{k} \rightarrow \hat{d}_{l}d_{m}$ , via LQD only $\hat{a}_{j}d_{k} \rightarrow \nu h_{k}^{-}$ and $\hat{d}_{j}d_{k} \rightarrow \hat{l}_{l}d_{m}$ , via LQD only LLE <b>R</b> -parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4180 $wd_{j} - \hat{r}^{2}d_{m}d_{j}d_{j}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{r}^{2}h_{m}d_{j}d_{j}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{r}^{2}h_{m}d_{j}d_{j}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{r}^{2}h_{m}d_{j}d_{m}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{r}^{2}h_{m}d_{j}d_{m}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{h}^{2}h_{m}d_{j}d_{m} \rightarrow \hat{r}^{2}d_{n}(111 \text{ metalinos})$ $ud_{j}d_{j} \rightarrow \hat{h}^{2}h_{m}d_{j}d_{m} \rightarrow \hat{r}^{2}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m$
IFRDC 40560 4070 4080 4100-99 4100-99 4110-99 4110-41W 4120-410 4120-412 4120-412 4120-412 4120-412 4150 4150 4150 4150 4210-4220 4250-411 4250 4250-411 4250 4250-411 4250 4271 4271 4273	Process Sum of 4070 ard 4080 $4gd_h \rightarrow 0d_m$ and $d_fd_h \rightarrow d_fd_m$ , via LQD only $4gd_h \rightarrow 2gt_h$ and $d_fd_h \rightarrow t_h^2 t_h$ , via LQD and LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (all neutralinos) $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (all neutralinos) $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (all darginos) $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (12 as above) $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (12 as above) $4d_f \rightarrow T^2 d_h d_h d_h \rightarrow T^2 d_h$ (12 as above) $4d_f \rightarrow d_h d_h d_h d_h \rightarrow T^2 d_h d_h d_h d_h d_h d_h d_h d_h d_h d_h$
IFRDC 4050 4070 4080 4100-99 4100-99 4100-99 4100-410 4100-10 4120-10 4130-410 4130-410 4130-410 4140 4150-410 4200-39 4200 4210-420 4210-420 4250-411 4250-420 4271 4273 5000	Process Sum of 4070 ard 4080 $\hat{a}_{j}d_{k} \rightarrow 0_{k}d_{m}$ and $\hat{a}_{j}d_{k} \rightarrow \hat{b}_{i}d_{m}$ , via LQD only $\hat{a}_{j}d_{k} \rightarrow v_{j}d_{m}$ and $\hat{a}_{j}d_{k} \rightarrow \hat{b}_{i}d_{m}$ , via LQD only LLE R-parity violating supersymmetric processes via UDD $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{k} - \hat{a}_{i}^{*}d_{k}$ (and $\hat{b}_{i}d_{m} \rightarrow \hat{b}_{i}^{*}d_{m}$ ) $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{k}d_{m} \rightarrow \hat{b}_{i}^{*}d_{k}$ (10 as above) $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{m}d_{m}d_{m} \rightarrow \hat{b}_{i}^{*}d_{m}$ (11 as above) $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{m}d_{m}d_{m} \rightarrow \hat{b}_{i}^{*}d_{m}^{*}$ (12 as above) $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{m}d_{m}d_{m} \rightarrow \hat{b}_{m}^{*}d_{m}^{*}$ $\hat{a}_{i}d_{j} \rightarrow \hat{b}_{i}^{*}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m}d_{m$
IFRDC 4D60 4D70 4D70 4D70 4100-99 4100-99 4110 +IR 4100 +IR 4120 4120 +IC 4120 4120 +IC 4130 4120 4120 4120 4120 4210 4210 4210 4210 4220 4220 4220 4220 4250 4250 4250 4270 4271 4271 4272 4273 5100+100+10 5100+100+100+100+100+100+100+100+100+100	Process Sum of 4070 ard 4080 $4gd_h \rightarrow 4gd_m$ and $d_gd_h \rightarrow d_gd_m$ , via LQD only $4gd_h \rightarrow 2g_h^{-1}$ and $d_gd_h \rightarrow f_h^{-1}g_h$ , via LQD only $4gd_h \rightarrow 2g_h^{-1}$ and $d_gd_h \rightarrow f_h^{-1}g_h$ , via LQD only $4gd_h \rightarrow 2g_h^{-1}$ and $d_gd_h \rightarrow f_h^{-1}g_h$ , via LQD only $4gd_h \rightarrow 2g_h^{-1}g_h^{$
IFRDC           40560           4070           4080           4100-99           4110           4110           4110           4110           4110           4110           4110           4120           4130           4130           4140           4150           4200-99           4210           4210           4220           4250           4250           4250           4270           4271           4273           5200+112           5200+12	Process Sum of 4070 ard 4080 $\hat{q}_{j}d_{h} \rightarrow 0d_{rh}$ and $\hat{d}_{j}d_{h} \rightarrow \hat{q}_{l}d_{h}$ , via LQD only $\hat{q}_{j}d_{h} \rightarrow yd_{h}^{-}$ and $\hat{d}_{j}d_{h} \rightarrow l_{l}^{+}d_{h}$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $u_{l}d_{j} \rightarrow \tilde{L}^{+}d_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ (all neutralizes) $u_{l}d_{j} \rightarrow \tilde{L}^{+}d_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ (all neutralizes) $u_{l}d_{j} \rightarrow \tilde{L}^{+}d_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ (18 as above) $u_{l}d_{j} \rightarrow \tilde{L}^{+}d_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ (17 as above) $u_{l}d_{j} \rightarrow \tilde{L}^{+}d_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}d_{h} \rightarrow \tilde{L}^{+}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}ld_{h} \rightarrow \tilde{d}_{h}ld_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}ld_{h} \rightarrow \tilde{d}_{h}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}ld_{h} \rightarrow \tilde{d}_{h}d_{h}$ $u_{l}d_{j} \rightarrow \tilde{d}_{h}ld_{h}ld_{h}ld_{h}d_{h} \rightarrow \tilde{d}_{h}ld_{h$
IFRDC           40560           4070           4080           4100-99           4110           4110           4110           4110           4110           4110           4110           4120           4130           4140           4150           4160           4200-39           4200           4210           4210           4210           4250           4250           4250           4271           4273           5100+10           5200+10	Process Sum of 4070 arcl 4080 $\hat{q}_{j}d_{k} \rightarrow \bar{q}_{0}d_{m}d_{j}d_{k} \rightarrow \bar{q}_{i}d_{m}$ , via LQD only $\hat{q}_{j}d_{k} \rightarrow \nu_{j}q_{k}^{-}$ and $\hat{d}_{j}d_{k} \rightarrow l_{i}^{+}d_{j}$ , via LQD and LLE R-parity violating supersymmetric processes via UDD $\hat{u}_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k} \rightarrow \hat{y}^{-}q_{i}$ (all charginos) $u_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k}d_{k} \rightarrow \hat{y}^{-}d_{k}$ (10 as above) $u_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k}d_{k} \rightarrow \hat{y}^{-}d_{k}$ (11 as above) $u_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k}d_{k} \rightarrow \hat{y}^{-}d_{k}$ (12 as above) $u_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k}d_{k} \rightarrow \hat{y}^{-}d_{k}$ $u_{i}d_{j} \rightarrow \hat{y}^{-}d_{k}d_{k}d_{k}d_{k} \rightarrow \hat{y}^{-}d_{k}$ $u_{i}d_{j} \rightarrow \hat{d}_{k}h^{-}(h^{0}/h^{0}/d_{j}d_{k} - \hat{u}_{k}h^{0}/H^{0}/h^{0}/a_{j}d_{k} \rightarrow \hat{d}_{k}h^{-}H^{-}$ $u_{i}d_{j} \rightarrow \hat{d}_{k}h^{-}(h^{0}/h^{0}/d_{j}d_{k} - \hat{u}_{k}h^{0}/H^{0}/h^{0}/a_{j}d_{k} \rightarrow \hat{d}_{k}^{-}H^{-}$ $u_{i}d_{j} \rightarrow \hat{u}_{i}d_{k}d_{k} \rightarrow dd_{k}$ via UDD. Claviton reasonance production Sum of 4210, 4250 and 4270 $gg/q\bar{q} \leftarrow G \rightarrow gg/q\bar{q}$ (11 partons) $gg/q\bar{q} \leftarrow G \rightarrow \gamma$ $gg/q\bar{q} \leftarrow G \rightarrow 2^{0}Z^{0}/H^{0}_{20}H^{0}_{$
IFRDC           4060           4070           4070           4070           4070           4100-99           4110           4110           4110           4110           4120           4120           4130           4130           4140           4140           4150           4200           4210           4210           4220           4250           4250           4250           4250           4270           4271           4272           52000           51000+10           52000+10           52000	Process Sum of 400° ard 4080 $4gd_h → 4gd_m$ and $d_gd_h → d_gd_m$ , via LQD only $4gd_h → 4gd_m$ and $d_gd_h → f_1^*d_h$ , via LQD only $4gd_h → 2gd_m$ and $d_gd_h → f_1^*d_h$ , via LQD only $4gd_h → 2gd_h^*d_h - f_1^*d_h$ , via LQD only LLE R-parity violating supersymmetric processes via UDD single sparticle production, sum of 4110–4150 $ud_h → f_2^*d_h d_gd_h → f_2^*d_h$ (101 metralinos) $4gd_h → f_2^*d_h d_gd_h → f_2^*d_h$ (101 metralinos) $4ud_h → f_2^*d_h d_gd_h → f_2^*d_h$ (101 metralinos) $ud_h → f_2^*d_h d_gd_h → f_2^*d_h$ (102 metron) $ud_h → f_2^*d_h d_gd_h → f_2^*d_h$ (102 metron) $ud_h → f_2^*d_h d_gd_h → f_2^*d_h$ (102 metron) $ud_h → f_2^*d_h d_{gd_h} → f_2^*d_h$ (102 metron) $ud_h → f_2^*d_h d_{gd_h} → f_2^*d_h$ (102 metron) $ud_h → f_2^*d_h d_{gd_h} → f_2^*d_h$ (102 metron) $ud_h → d_{gd_h} d_{gd_h} → d_{gd_h} d_h d_h d_h d_h → f_0^*W^-$ $ud_h → d_{gd_h} d_{gd_h} → d_{gd_h} d_h d_h d_h d_h d_h d_h d_h d_h d_h d_h$
IFRDC           40560           4070           4000           4100-99           4110           4110           4110           4110           4110           4110           4110           4110           4110           4110           4120           4130           4140           4150           4160           4200.4210           4210           4220           4220           4250           4270           4270           4273           5000           5100+10           5300           5500	$\begin{array}{l} & \operatorname{Process}\\ & \operatorname{Process}\\ & \operatorname{Sum} of 400 \ {\rm ard} 4080 \\ & \operatorname{digd}_{h} \to \operatorname{udg}_{h} \ {\rm and} \ digd_{h} \to \operatorname{digd}_{h}, \ {\rm vin} \ LQD \ {\rm only} \\ & \operatorname{digd}_{h} \to \operatorname{udg}_{h} \ {\rm and} \ digd_{h} \to \operatorname{ligd}_{h}, \ {\rm vin} \ LQD \ {\rm only} \ LLE \\ & \operatorname{R-parity violating supersymmetric processes via UDD \\ & \operatorname{single} \ sparticle production, \ {\rm sum} \ of 4110-4150 \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \left( \operatorname{III} \ {\rm as a hovo} \right) \\ & \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{digd}_{h} \operatorname{digd}_{h} \to \operatorname{If}^{*}_{h} \operatorname{udg}_{h} \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{udg}_{h} \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{udg}_{h} \to \operatorname{If}^{*}_{h} \operatorname{udg}_{h} \operatorname$
IFRDC IFRDC 4D60 4D70 4D70 4D70 4D70 4100-99 41100-99 41100-4IR 4120 4120-4IC 4120 4120-4IC 4120 4120-4IC 4120 4120-4IC 4120 4210-4IC 4250-4IC 4270-4IC 5100-4IC 5100-4IC 5510-4IC 55	$\begin{split} & \operatorname{Process}\\ & \operatorname{Process}\\ & \operatorname{Sum} d \ \mathrm{div} \mathbb{O} \ \mathrm{ard} \ \mathrm{div} \mathbb{O} \ \mathrm{div} d_{\mathrm{ev}} \to \mathrm{div}_{\mathrm{ev}} \ \mathrm{div}_{\mathrm{ev}} \mathrm{div}_$
IFRDC 4060 4070 4080 4100-99 4100-99 4110-91 4120-91 4120-11C 4120-11C 4120-11C 4120-11C 4120-11C 4120-11C 4120-11C 4120-4120 4210-420 4250-4120 4250-4120 4270 4270 4271 4272 4273 5200-112 52	$\begin{array}{l} & \operatorname{Process}\\ & \operatorname{Process}\\ & \operatorname{Sum} of 400 \mbox{ and } d_1d_k \rightarrow d_1d_{k1}, \mbox{ via LQD only}\\ & d_1d_k \rightarrow u_ld_k \mbox{ and } d_1d_k \rightarrow l_1^2d_{k1}, \mbox{ via LQD only}\\ & d_ld_k \rightarrow u_ld_k \mbox{ and } d_ld_k \rightarrow l_1^2d_{k1}, \mbox{ via LQD only}\\ & d_ld_k \rightarrow u_ld_k \mbox{ and } d_ld_k \rightarrow l_1^2d_{k1}, \mbox{ via LQD only}\\ & ingle sparticle production, sum of 4110-4150\\ & u_ld_1 \rightarrow \tilde{U}^2d_k, d_ld_k \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & u_ld_1 \rightarrow \tilde{U}^2d_k, d_ld_k \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & u_ld_1 \rightarrow \tilde{U}^2d_k, d_ld_k \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & u_ld_1 \rightarrow \tilde{U}^2d_k, d_ld_k \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & u_ld_1 \rightarrow \tilde{U}^2d_k, d_ld_k \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & u_ld_1 \rightarrow \tilde{U}^2d_k \mbox{ (III metrializes)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow gg/q\bar{q} \mbox{ (all partons)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow gg/q\bar{q} \mbox{ (all partons)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow gg/q\bar{q} \mbox{ (III metrializes)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & g_l/q\bar{q} \rightarrow G \rightarrow \mathcal{U}^2d_k \mbox{ (III metrials)}\\ & for the hard flavour single excitation (IQ as shove)\\ & Formitike photon heady flavour usingle excitation (IQ as shove)\\ & Formitike photon hasdy flavour usingle excitation (IQ as shove)\\ & After generation, IIFBG is is subprocess (ses sect. 4.6.5)\\ & Quark-photon Compotention for ight (a, d, s) L=0 macces\\ & S=0 macces cold, S=1 macces cold ight (a, d,$
IFRDC 4050 4070 4080 4100-99 4100-99 4100-99 4100 +IN 4120 +IN 4120 4130 +IC 4130 +IC 4130 +IC 4130 4150 4150 4200-92 4200 4210-10 4200 4210-10 4200 5200 500	$\begin{split} & \text{Process}\\ & \text{Process}\\ & \text{Sum of 400 ard 4080}\\ & \hat{a}_{j}d_{k} \rightarrow ud_{k} \text{ and } d_{j}d_{k} \rightarrow d_{i}d_{k}, \text{ vin LQD only}\\ & \hat{a}_{j}d_{k} \rightarrow ud_{k} \text{ and } d_{j}d_{k} \rightarrow l_{i}^{2}d_{k}, \text{ vin LQD only}\\ & \hat{a}_{j}d_{k} \rightarrow ud_{k}^{-1} \text{ and } d_{j}d_{k} \rightarrow l_{i}^{2}d_{k}, \text{ vin LQD only}\\ & \text{Inder sparsitely production, sum of 4110-4150}\\ & ud_{j}d_{j} \rightarrow \underline{1}^{2}d_{k}d_{k}d_{k} \rightarrow \underline{7}^{2}d_{k}, (111 \text{ areabout})\\ & ud_{j}d_{j} \rightarrow \underline{1}^{2}d_{k}d_{k}d_{k}d_{k} \rightarrow \underline{7}^{2}d_{k}, (111 \text{ areabout})\\ & ud_{j}d_{j} \rightarrow \underline{7}^{2}d_{k}d_{j}d_{k}d_{k} \rightarrow \underline{7}^{2}d_{k}, (111 \text{ areabout})\\ & ud_{j}d_{j} \rightarrow \underline{7}^{2}d_{k}d_{j}d_{k}d_{k} \rightarrow \underline{7}^{2}d_{k}, (121 \text{ areabout})\\ & ud_{j}d_{j} \rightarrow \underline{5}^{2}d_{k}d_{j}d_{k}d_{j}d_{k} \rightarrow \underline{7}^{2}d_{k}, (121 \text{ areabout})\\ & ud_{j}d_{j} \rightarrow \underline{5}^{2}d_{k}d_{j}d_{k}d_{j}d_{k} \rightarrow \underline{1}^{2}d_{k}^{2}, ud_{j}d_{j} \rightarrow \underline{1}^{2}d_{k}^{2} \rightarrow \underline{1}^{2}d_{k}^{2}$
IFRDC IFRDC 4070 4070 4070 4100-99 4100-99 4100 + II 4100 + III 4120 4120 + II 4120 4120 + II 4120 4120 + II 4120 4120 4200 4210 + II 4220 4210 + II 4220 4220 4210 + II 4220 4220 4220 4220 4220 4220 4220 4210 4220 4250 4271 4272 4273 5200+IIQ 5200+IIQ 5200+IIQ 5200+IIQ 5200 5510,20 5510,20 5500 5510,20 5500 5510,20 5500 5510,20 5500 5510,20 5500 5510,20 5500 5510,20 5500 5510,20 5500	Process Sum of 40°0 ard 40%0 $4gd_h → 4gd_m$ and $d_gd_h → d_gd_m$ , via LQD only $4gd_h → 4gd_m$ and $d_gd_h → f_1^*d_h$ , via LQD only $4gd_h → 2gd_m$ and $d_gd_h → f_1^*d_h$ , via LQD only $4gd_h → 2gd_h = d_gd_h → 1^*d_h$ (all neutralinos) $4gd_h → 1^*d_h d_gd_h → 1^*d_h$ (all charginos) $4gd_h → 1^*d_h d_gd_h → 1^*d_h$ (all charginos) $4gd_h → 1^*d_h d_gd_h → 1^*d_h$ (all charginos) $4gd_h → 1^*d_h d_gd_h = 1^*d_h$ $4gd_h → 1^*d_h d_gd_h → 1^*d_h$ (b) (12 s above) $4gd_h → 1^*d_h d_gd_h = 1^*d_h$ $4gd_h → 1^*d_h d_gd_h → 1^*d_h$ (12 s above) $4gd_h → 1^*d_h d_gd_h = 1^*d_h$ $4gd_h = 1^*d_h$ $4gd_h = 1^*d_h d_h d_gd_h = 1^*d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h d_h$ $4gd_h = 1^*d_h d_h d_h d_h d_h d_h d_h d_h d_h d_h $
IFRDC           40560           4070           4060           4100-99           4110           4110           4110           4110           4110           4110           4110           4110           4110           4110           4120           4130           4130           4140           4150           4150           4200           4210           4250           4250           4250           4250           4270           4271           4272           5200+112           5200+12           5200           5510,20           6000           6000+12           6000	$\begin{array}{l} & \operatorname{Process}\\ & \operatorname{Process}\\ & \operatorname{Sum} of 40^\circ 0 \ ard 40^\circ 0 \ a$
IFRDC 4050 4070 4080 4100-99 4100-99 4100-99 4100-410 4100-10 4120-10 4120-10 4120-10 4120-10 4200-90 4200 4200-90 4200 4200-420 4200 4200-420 4200 4200-420 4270 4273 4273 5200-10 5500 5510,20 6000+10	Process Sum of 4070 ard 4080 $4pd_h = 0xd_h$ and $d_jd_h = d_jd_{h_h}$ , via LQD only $4pd_h = -yd_h^{-1}$ and $d_jd_h = -l_j^{-1}d_{h_h}$ , via LQD only LLE R-parity violating supersymmetric processes via UDD ingle sparticle production, sum of 4110-4150 $4xd_j = \frac{12}{10}d_h, d_jd_h = -\frac{12}{10}d_h, d_jl = a a b a b a b a b a b a b a b a b a b$

HERWIG 6.510 31st Oct. 2005 MEAN VALUE OF WGT = 1.0844E-09 Please reference: G. Marchesini, B.R. Webber, RMS SPREAD IN WGT = 6.0525E-09 G.Abbiendi, I.G.Knowles, M.H.Seymour & L.Stanco ACTUAL MAX WEIGHT = 3.4867E-08 Computer Physics Communications 67 (1992) 465 ASSUMED MAX WEIGHT = 3.8354E-08 and G.Corcella, I.G.Knowles, G.Marchesini, S.Moretti, PROCESS CODE IPROC = 106 K.Odagiri, P.Richardson, M.H.Seymour & B.R.Webber, CROSS SECTION (PB) = 1.0844E-06 JHEP 0101 (2001) 010 ERROR IN C-S (PB) = 6.0525E-08EFFICIENCY PERCENT = 2.827 INPUT CONDITIONS FOR THIS RUN BEAM 1 (E+ ) MOM. = 174.30 BEAM 2 (E-) MOM. = 174.30 EVENT 1: 174.30 GEV/C E+ 174.30 GEV/C E-PROCESS: ON 106 PROCESS CODE (IPROC) = 106 SEEDS: STATUS: 100 ERROR: 0 WEIGHT: 1.0844E-09 2049773 & 11719155 NUMBER OF FLAVOURS 6 8 STRUCTURE FUNCTION SET = т AZIM SPIN CORRELATIONS = ---INITIAL STATE---AZIM SOFT CORRELATIONS = т QCD LAMBDA (GEV) 0.1800 = IHEP ID IDPDG IST MO1 MO2 DA1 DA2 P-Y P-Z ENERGY MASS P-X DOWN OUARK MASS = 0.3200 1 E+ -11 101 0 0 0 0.00 174.3 174.3 0.00 0 0.00 UP QUARK MASS = 0.3200 2 E-11 102 0 0 0 0 0.00 0.00 -174.3 174.3 0.00 STRANGE QUARK MASS = 0.5000 3 CMF 0 103 1 2 0 0 0.00 0.00 0.0 348.6 348.60 CHARMED OUARK MASS = 1.5500 BOTTOM QUARK MASS = 4.9500 ---HARD SUBPROCESS---QUARK MASS 174.3000 TOP = GLUON EFFECTIVE MASS = 0.7500 IHEP ID IDPDG IST MO1 MO2 DA1 DA2 P-X P-Y P-Z ENERGY MASS EXTRA SHOWER CUTOFF (Q) =0.4800 EXTRA SHOWER CUTOFF (G)= 0.1000 4 Z0/GAMA\* 23 120 1 2 5 6 0.00 0.00 0.0 348.6 348.60 PHOTON SHOWER CUTOFF = 0.4000 CLUSTER MASS PARAMETER = 3.3500 ---H/W/Z BOSON DECAYS---SPACELIKE EVOLN CUTOFF = 2.5000 0.0000 INTRINSIC P-TRAN (RMS) = THEP ID IDPDG IST MO1 MO2 DA1 DA2 P-X P-Y P-Z ENERGY MASS DECAY SPIN CORRELATIONS= т 5 TQRK 6 123 4 6 7 6 0.00 0.00 0.0 174.3 174.30 SUSY THREE BODY ME т 0.00 0.0 174.3 174.30 = 6 TBAR -6 124 4 5 9 5 0.00 SUSY FOUR BODY ME F = т HARD M.E. MATCHING = ---PARTON SHOWERS---SOFT M.E. MATCHING \_ т MIN MTM FRAC FOR ISR =1.0000E-04IHEP ID IDPDG IST MO1 MO2 DA1 DA2 P-X P-Y P-Z ENERGY MASS 1-MAX MTM FRAC FOR ISR =1.0000E-06 7 TORK 94 143 5 4 8 8 0.00 0.00 0.0 174.3 174.30 8 TORK 6 3 7 7 11 11 0.00 0.00 0.0 174.3 174.30 NO EVENTS WILL BE WRITTEN TO DISK 9 TBAR 94 144 6 4 10 10 0.00 0.00 0.0 174.3 174.30 10 TBAR -6 3 9 9 23 23 0.00 0.00 0.0 174.3 174.30 0.0000 E+ Beam polarisation= -1.0000 0.0000 E-Beam polarisation= 1.0000 0.0000 0.0000 ---HEAVY PARTICLE DECAYS---PARTICLE TYPE 21=PI0 SET STABLE IHEP ID IDPDG IST MO1 MO2 DA1 DA2 P-X P-Y P-Z ENERGY MASS 11 TORK 6 155 7 23 12 13 0.00 0.00 0.0 174.3 174.30 INITIAL SEARCH FOR MAX WEIGHT 12 W+ 24 123 11 12 14 12 50.76 -31.35 104.8 78.64 -35.3 13 BQRK 5 124 11 11 15 11 -50.76 31.35 35.3 69.5 4.95 PROCESS CODE IPROC = 106 14 W+ 24 195 12 11 19 20 50.36 -31.10 -35.0 104.5 78.64 RANDOM NO. SEED 1 = 1246579 SEED 2 = 8447766 ---PARTON SHOWERS---NUMBER OF SHOTS = 10000 NEW MAXIMUM WEIGHT = 3.8353798136424571E-08 IHEP ID IDPDG IST MO1 MO2 DA1 DA2 P-X P-Y P-Z ENERGY MASS 15 BORK 94 144 13 11 17 18 -50.36 31.10 35.0 69.8 12.28 INITIAL SEARCH FINISHED 16 CONE 0 100 13 0 -0.52 -0.85 11 0 0.0 1.0 0.00 17 BORK 5 2 15 18 36 31 -44.10 22.46 28.2 57.2 4.95 OUTPUT ON ELEMENTARY PROCESS 18 GLUON 21 2 15 29 37 38 -6.26 8.64 6.8 12.7 0.75 N.B. NEGATIVE WEIGHTS NOT ALLOWED ---H/W/Z BOSON DECAYS---NUMBER OF EVENTS = 0 IDPDG IST MO1 MO2 DA1 DA2 IHEP ID P-X P-Y P-Z ENERGY MASS NUMBER OF WEIGHTS = 10000 19 NU E 12 123 14 20 21 20 47.44 16.68 -14.0 52.2 0.00 Event Generator Physics 4 22 2.92 -47.78 52.3 20 E+ -11 124 14 19 19 -21.0 0.00 21 NU E 12 1 19 14 0 0 47.44 16.68 -14.0 52.2 0.00

				-		
22 E+	-11 1 20 14 0 0 2.	92 -47.78 -21.0 52.3	0.00	62 PI+	211 1 52 27 0 0 -0.18	2.19 0.4 2.2 0.14
				63 PI-	-211 1 53 27 0 0 0.46	3.45 0.7 3.6 0.14
	HEAVY PARTICLE DEC	AYS		65 KBAR0	-311 197 54 15 77 77 -1.98	1.28 1.3 2.7 0.50
THEP TO	TOPOG IST MOI MO2 DAI DA2 P-X	P-V P-Z ENERGY	MASS	66 RHO-	-213 197 54 15 78 79 -1.94	1.96 1.8 3.4 0.77
23 TBAR	-6 155 9 17 24 25 0.	00 0.00 0.0 174.3	174.30	67 PI-	-211 1 55 15 0 0 -1.06	2.53 1.7 3.2 0.14
24 W-	-24 123 23 24 26 24 -9.	40 -65.65 -13.2 106.5	82.28	68 PI0	111 1 55 15 0 0 -0.10	0.83 -0.1 0.9 0.13
25 BBAR	-5 124 23 23 27 23 9.	40 65.65 13.2 67.8	4.95	69 B_S0	531 1 56 27 0 0 8.62	48.35 9.9 50.4 5.37
26 W-	-24 195 24 23 32 33 -9.	37 -65.43 -13.1 106.4	82.28			
					STRONG HADRON DECAYS-	
	PARTON SHOWERS-			תד משוד		DY DZ ENEDCY MASS
		D V D 7 ENEDCV	MACC	THEP ID 70 B DBARO	-511 1 57 15 0 0 $-38$ 82	P-I P-Z ENERGI MASS
27 BRAR	94 144 25 23 29 31 9	P = I $P = Z$ ENERGI	MASS 8 66	70 <u>B_</u> DBARO 71 GAMMA	22 1 57 15 0 0 -0.59	0.30 0.3 0.7 0.00
28 CONE	0 100 25 23 0 0 -0.	95 0.08 0.3 1.0	0.00	72 K S0	310 198 58 15 80 81 -2.59	1.44 1.7 3.5 0.50
29 GLUON	21 2 27 30 39 40 -0.	06 7.48 1.6 7.7	0.75	73 PI+	211 1 59 15 0 0 -1.06	1.92 1.4 2.6 0.14
30 GLUON	21 2 27 31 41 42 0.	01 8.49 1.0 8.6	0.75	74 PI0	111 1 59 15 0 0 -0.53	0.29 0.2 0.7 0.13
31 BBAR	-5 2 27 36 43 42 9.	41 49.46 10.5 51.7	4.95	75 RHO+	213 198 60 15 82 83 -1.53	2.87 2.1 4.0 0.77
				76 PI-	-211 1 60 15 0 0 -0.42	0.95 0.2 1.1 0.14
	H/W/Z BOSON DECAY	S		77 K LO	130 1 65 15 0 0 -1.98	1.28 1.3 2.7 0.50
				78 PI-	-211 1 66 15 0 0 -0.15	0.09 0.0 0.2 0.14
IHEP ID	IDPDG IST MO1 MO2 DA1 DA2 P-X	P-Y P-Z ENERGY	MASS	79 PI0	111 1 66 15 0 0 -1.80	1.87 1.8 3.2 0.13
32 NU EBAR	-12 123 26 33 34 33 9.	82 -31.69 -45.2 56.0	0.00	80 PI+	211 1 72 15 0 0 -2.24	1.16 1.5 3.0 0.14
33 E-	11 124 26 32 35 32 -19.	19 -33.74 32.0 50.3	0.00	81 PI-	-211 1 72 15 0 0 -0.35	0.28 0.2 0.5 0.14
34 NU EBAR	-12 1 32 26 0 0 9.	82 -31.69 -45.2 56.0	0.00	82 PI+	211 1 75 15 0 0 -0.80	0.79 0.8 1.4 0.14
35 E-	11 1 33 26 0 0 -19.	19 -33.74 32.0 50.3	0.00	83 PIO	111 1 75 15 0 0 -0.73	2.08 1.4 2.6 0.13
	GLUON SPLITTING			OUTPUI	I ON ELEMENTARY PROCESS	
IHEP ID	IDPDG IST MO1 MO2 DA1 DA2 P-X	P-Y P-Z ENERGY	MASS	N.B. 1	NEGATIVE WEIGHTS NOT ALLOWED	
36 BQRK	5 158 15 44 50 43 -40.	51 20.80 26.0 52.7	4.95			
37 UBAR	-2 158 15 38 54 45 -1.	24 1.75 1.3 2.5	0.32	NUMBER	R OF EVENTS = 1000	
38 UQRK	2 158 15 46 51 37 -3.	38 4.53 3.6 6.7	0.32	NUMBER	R OF WEIGHTS = 34502	
39 UBAR	-2 158 27 40 55 47 -0.	16 1.94 0.5 2.0	0.32	MEAN V	VALUE OF WGT = 1.1127E-09	
40 UQRK	2 158 27 41 52 39 0.	16 4.05 0.8 4.2	0.32	RMS SE	PREAD IN WGT = 6.1284E-09	
41 DBAR	-1 158 27 42 52 40 0.	14 3.82 0.6 3.9	0.32	ACTUAI	L MAX WEIGHT = 3.4867E-08	
42 DQRK	1 158 27 48 53 41 0.	17 2.12 0.3 2.2	0.32	ASSUME	ED MAX WEIGHT = 3.8354E-08	
43 BBAR	-5 158 27 36 56 49 8.	19 45.00 9.3 46.9	4.95			
44 SBAR	-3 159 15 45 50 36 -1.	49 1.12 1.1 2.2	0.50	PROCES	SS CODE IPROC = 106	
45 SQRK	3 159 15 37 54 44 -2.	68 1.48 1.8 3.6	0.50	CROSS	SECTION (PB) = 1.1127E-06	
46 DBAR	-1 159 27 47 51 38 -0.	16 1.51 0.4 1.6	0.32	ERROR	IN C-S (PB) = 3.2993E-08	
47 DQRK	1 159 15 39 55 46 -0.	96 1.39 1.0 2.0	0.32	EFFICI	IENCY PERCENT = 2.901	
48 SBAR	-3 159 27 49 53 42 0.	53 3.63 0.7 3.8	0.50			
49 SQRK	3 159 27 43 56 48 0.	40 3.38 0.6 3.5	0.50			
	CLUSTER FORMATIC	N				
ТНЕР ТО	צ-ס 2גם 1גם MO1 MO2 צ-ס	P-Y P-Z ENERCY	MASS			
50 CLUS	91 183 36 44 57 58 -41	99 21.93 27.1 54 9	5.86			
51 CLUS	91 183 38 46 59 60 -3	54 6.04 4.0 8.3	2.01			
52 CLUS	91 183 40 41 61 62 0.	30 7.87 1.4 8.0	0.67			
53 CLUS	91 183 42 48 63 64 0.	70 5.75 1.0 5.9	0.85			
54 CLUS	91 183 45 37 65 66 -3.	92 3.23 3.1 6.1	1.41			
55 CLUS	91 183 47 39 67 68 -1.	16 3.36 1.6 4.1	1.28			
56 CLUS	91 183 49 43 69 69 8.	62 48.35 9.9 50.4	5.37			
	CLUSTER DECAYS-					
		<b>.</b>				
THEN ID	IDPDG IST MOI MOZ DAI DAZ P-X	P-Y P-Z ENERGY	MASS			
5/ B*BAR0	-513 197 50 15 70 71 -39.	41 20.49 25.4 51.4	5.32			
58 KU	311 197 50 15 72 72 -2.	59 1.44 1.7 3.5	0.50			Dryon Wohher
59 KHU+	213 197 51 15 73 74 -1.	J7 Z.ZI I./ J.J	0.//			BIYAH WEDDER
61 DTO	111 1 52 27 0 0 0	90 3.83 2.4 5.0	1.1/			-
OT PIO	111 1 52 2/ 0 0.	40 2.00 1.0 5.8	0.13	1		

## **Production/Decay Spin Correlations**

• eg top quark pairs in e+e- annihilation:



$$\begin{split} \mathcal{M}|\mathcal{M}|^{2} &= \rho_{\kappa_{1}\kappa_{1}'}^{1}\rho_{\kappa_{2}\kappa_{2}'}^{2}\mathcal{M}_{\kappa_{1}\kappa_{2};\lambda_{t}\lambda_{t}}^{e^{+}e^{-}\rightarrow t\bar{t}}\mathcal{M}_{\kappa_{1}'\kappa_{2}';\lambda_{t}'\lambda_{t}'}^{*e^{+}e^{-}\rightarrow t\bar{t}} \\ |\mathcal{M}_{\text{total}}|^{2} &= \frac{\mathcal{M}_{\lambda_{t}}^{t\rightarrow b\ell\nu}\mathcal{M}_{\lambda_{t}'}^{*t\rightarrow b\ell\nu}}{\mathcal{M}_{\lambda_{t}}^{t\rightarrow b\ell\nu}\mathcal{M}_{\lambda_{t}'}^{*t\rightarrow b\ell\nu}} \\ \mathcal{M}_{\lambda_{t}}^{t\rightarrow b\ell\nu}\mathcal{M}_{\lambda_{t}'}^{*t\rightarrow b\ell\nu}\mathcal{M}_{\lambda_{t}'}^{*c\lambda_{t}'}\mathcal{D}_{d}^{\lambda_{d}\lambda_{d}'} \\ \mathcal{F}_{prod}^{t}\mathcal{P}_{prod}^{prod} \underbrace{correlations}_{c}\mathcal{P}_{ab\rightarrow cd}^{*\lambda_{c}\lambda_{d}'} \\ \text{included, by factorized,} \\ stope-by=stop_{c}\lambda_{a} \text{lgorithm}_{c}' \\ \mathcal{O}_{c} \text{ decay}} \mathcal{M}_{c}^{c} \text{ decay}, \end{split}$$

## **Production/Decay Spin Correlations**

• eg top quark pairs in e+e- annihilation:

Correlation between lepton and beam

Correlation between lepton and top

**Event Generator Physics 4** 



## **PYTHIA 6**

- Current status:
- Version 6.410 released on January 30th 2007
  - http://www.thep.lu.se/~torbjorn/Pythia.html
  - ~ 73,000 lines of FORTRAN
- Some features:
  - Many built-in SM and BSM processes
  - Les Houches accord interface for arbitrary hard processes
  - Mass effects in gluon emission ( != dead cone )  $\rightarrow$  see later
  - Option of virtuality- or k<sub>T</sub>-ordered shower
  - Multiple interaction models for min bias and underlying events

### Subprocess summary

Processes	Examples
QCD & related	
Soft QCD	low- $p_{\perp}$ ; diffraction
Hard QCD	$qg \to qg$
Open heavy flavour	$q\overline{q}  ightarrow t\overline{t}$
Closed heavy flavour	${\tt gg}  ightarrow {\tt gJ}/\psi$
$\gamma\gamma$ physics	$\gamma q  ightarrow q g$
DIS	$\gamma^* q  o q$
$\gamma^*\gamma^*$ physics	$\gamma_{\rm T}^* \gamma_{\rm L}^* \to q \overline{q}$
Electroweak SM	_
Single $\gamma^*/Z^0/W^\pm$	${ m q}\overline{ m q} ightarrow \gamma^*/{ m Z}^0$
$(\gamma/\gamma^*/Z^0/W^\pm/f/g)^2$	$q\bar{q} \rightarrow W^+W^-$
Light SM Higgs	$gg \rightarrow h^0$
Heavy SM Higgs	$Z^0_L Z^0_L  ightarrow W^+_L W^L$
SUSY BSM	
h <sup>0</sup> /H <sup>0</sup> /A <sup>0</sup> /H <sup>±</sup>	$q\overline{q} \rightarrow h^0 A^0$
SUSY	$q\overline{q}'  ightarrow  ilde{\chi}_i^0  ilde{\chi}_i^{\pm}$
R SUSY	$\tilde{\chi}_i^0 \rightarrow bcs$
Other BSM	
Technicolor	$q\overline{q}'  ightarrow \pi^0_{tc} \pi^\pm_{tc}$
New gauge bosons	$q\overline{q}  ightarrow \gamma^*/Z^0/Z'^0$
Compositeness	$q \overline{q}  ightarrow { m e}^{\pm} { m e}^{*\mp}$
Leptoquarks	$qg \to \ell L_\mathbf{Q}$
H <sup>±±</sup> (from LR-sym.)	$q\bar{q} \rightarrow H^{++}H^{}$
Extra dimensions	$gg  ightarrow G^*  ightarrow e^+e^-$

Event Generator F

No. Subprocess	No. Subprocess	No. Subprocess	No. Subprocess
Hard OCD processes	Light SM Biggs	New gauge bosons:	227 $f_{\ell_{1}} \rightarrow \tilde{\mathbf{x}}_{1}^{\pm} \tilde{\mathbf{x}}_{1}^{\pm}$
11 $f_{f_1} \rightarrow f_{f_2}$	$3  f_{i}\bar{f}_{i} \rightarrow h^{0}$	141 $f_{i}\bar{f}_{i} \rightarrow \gamma/Z^{9}/Z^{0}$	228 $f_{\ell_{\tau}}^{\ell_{\tau}} \rightarrow \tilde{\chi}_{\tau}^{\pm} \tilde{\chi}_{\tau}^{\pm}$
12 $f_{1}f_{2} \rightarrow f_{2}f_{3}$	$24$ $f_{i}\bar{f}_{i} \rightarrow Z^{0}h^{0}$	142 $f\bar{f} \rightarrow W'^+$	229 $f_*f_* \rightarrow \tilde{y}_* \tilde{y}_*^{\pm}$
13 $f_{c} \rightarrow gg$	$26  f.\overline{f}_{c} \rightarrow W^{\pm}h^{0}$	$144  f.f. \rightarrow R$	230 $f \bar{f}_A \rightarrow \bar{y}_A \bar{y}_B^{\pm}$
$28  f_{ab} \rightarrow f_{ab}$	$102  qq \rightarrow b^0$	Technicolor:	231 $f_{1} \rightarrow v_{1}v_{2}^{\pm}$
$53$ $rr \rightarrow f_{1}\overline{f}_{1}$	$103 \rightarrow b^0$	140 gg > 0	$232  f_{1} \xrightarrow{7} \sqrt{3} x_{1}$
68 gr -> gr	110 $ff \rightarrow h^0$	101 660	
Soft OCD processes	111 $f.\overline{f} \rightarrow ch^0$	$101  t_i t_i \rightarrow p_{ic}$	$1233$ $4ij \rightarrow \chi_1\chi_2$
91 alartic contering	$111$ $112 \rightarrow gn$ 119 $f_{eff} \rightarrow f_{h0}$	192 $I_{4}I_{j} \rightarrow \rho_{te}$	$234  i_1 \rightarrow \chi_2 \chi_2$
91 classic staticiting	$112$ $13 \rightarrow 10$	193 $f_i f_i \rightarrow \omega_{ic}^{\nu}$	$235$ $t_1 t_2 \rightarrow \chi_3 \chi_2$
92 single diffraction (A D)	$113$ gg $\rightarrow$ gr	194 $\mathbf{i}_i \mathbf{f}_i \rightarrow \mathbf{i}_k \mathbf{f}_k$	$236  i_i f_j \to \chi_1 \chi_2^-$
1 35 single diffraction (AA)	$121 \text{ gg} \rightarrow Q_k Q_k n^*$	195 $f_i f_j \rightarrow f_k f_l$	237 $f_i f_i \rightarrow g \chi_1$
94 double distraction	$122  \mathbf{q}_{i}\mathbf{q}_{i} \rightarrow \mathbf{Q}_{k}\mathbf{Q}_{k}\mathbf{n}^{\circ}$	$361  f_i f_j \rightarrow W_L^+ W_L^-$	238 $f_4 f_4 \rightarrow \tilde{g} \tilde{\chi}_2$
95 JOW-p1 production	123 $t_i t_j \rightarrow t_i t_j n^{\circ}$	$362  f_i f_i \rightarrow W_L^{\pm} \pi_{ic}^{\pm}$	239 fdfi → ğx̃z
Open neavy navour:	$124  t_i t_j \rightarrow t_k t_l h^{-1}$	$363  f_i \bar{f}_i \rightarrow \pi_{tc}^+ \pi_{tc}^-$	240 $f_4 f_4 \rightarrow \tilde{g} \tilde{\chi}_4$
(also fourth generation)	Heavy SM Higgs:	364 $f_i \bar{f}_i \rightarrow \gamma \pi_{tc}^0$	241 $f_i \bar{f}_j \rightarrow \bar{g} \chi_1^{\pm}$
$31  1_1 1_2 \rightarrow Q_k Q_k$	$5 Z^0 Z^0 \rightarrow n^0$	365 $f_i \overline{f}_i \rightarrow \gamma \pi'_{ta}^G$	242 $f_i \tilde{f}_j \rightarrow \tilde{g} \tilde{\chi}_2^{\pm}$
$8Z gg \rightarrow Q_k Q_k$	8 W <sup>+</sup> W <sup>-</sup> →h <sup>2</sup>	$366  f_i \bar{f}_i \rightarrow Z^0 \pi_W^0$	243 $f_i \overline{f}_i \rightarrow \tilde{g} \tilde{g}$
83 $q_i t_j \rightarrow Q_k t_l$	71 $Z_{L}^{\circ}Z_{L}^{\circ} \rightarrow Z_{L}^{\circ}Z_{L}^{\circ}$	367 $f \bar{f} \rightarrow 7^0 \pi^{10}$	244 gg $\rightarrow \vec{g}\vec{g}$
84 $g\gamma \rightarrow Q_k Q_k$	72 $Z_L^o Z_L^o \rightarrow W_L^- W_L^-$	368 $f_{\tau} \rightarrow W^{\pm} \pi^{\mp}$	246 $f_{ig} \rightarrow \tilde{q}_{iL}\tilde{\chi}_1$
$ 85  \gamma\gamma \to F_kF_k $	$73  Z_{\rm L}^{\rm o} W_{\rm L}^{\rm o} \rightarrow Z_{\rm L}^{\rm o} W_{\rm L}^{\rm o}$	$370  f_{f_{2}} \rightarrow W^{\pm}Z^{0}$	247 $f_{ig} \rightarrow \bar{q}_{iR}\bar{\chi}_1$
Closed heavy flavour:	$   76  W_L^+ W_L^- \to Z_L^3 Z_L^0   $	$371  t_{i}\bar{t}_{i} \rightarrow W^{\pm}\pi^{0}$	248 $f_{ig} \rightarrow \tilde{q}_{iL} \tilde{\chi}_2$
86 gg $\rightarrow J/\psi g$	$\begin{array}{cccc} 77 & W_L^{\pm}W_L^{\pm} \rightarrow W_L^{\pm}W_L^{\pm} \end{array}$	979 f.f	249 $f_{ig} \rightarrow \tilde{q}_{iR}\tilde{\chi}_2$
$87 \text{ gg} \rightarrow \chi_{0c} \text{g}$	BSM Neutral Higgses:	070 11 - x - x - x - x - x - x - x - x - x	250 $f_{ig} \rightarrow \tilde{q}_{iL} \tilde{\chi}_{3}$
88 gg $\rightarrow \chi_{1c}g$	151 $f_i \bar{f}_i \rightarrow H^0$	$373$ $41j \rightarrow \pi_{10}\pi_{10}$	251 $f_{ig} \rightarrow \tilde{q}_{iR}\tilde{\chi}_2$
89 gg $\rightarrow \chi_{2c}g$	$152 \text{ gg} \rightarrow \text{H}^0$	$3/4$ $i_1 i_j \rightarrow \gamma \pi_{tc}$	252 $f_{45} \rightarrow \tilde{q}_{4L}\tilde{\chi}_{4}$
$104 \text{ gg} \rightarrow \chi_{0c}$	$153 \gamma \gamma \rightarrow H^0$	$3i3$ $1ij \rightarrow L^{\circ}\pi_{ic}$	253 $f_{iR} \rightarrow \tilde{q}_{iR} \tilde{\chi}_4$
$105 \text{ gg} \rightarrow \chi_{2c}$	171 $f_i \overline{f}_i \rightarrow Z^0 H^0$	$370  I_i I_j \rightarrow W^* \pi_{tc}^0$	254 $f_{\ell E} \rightarrow \tilde{q}_{\ell I}, \tilde{\chi}_{1}^{\pm}$
106 gg $\rightarrow J/\psi\gamma$	$172 f_i \overline{f}_j \rightarrow W^{\pm} H^0$	$377  f_i f_j \rightarrow W^{\pm} \pi'^{\circ}_{ic}$	256 fig $\rightarrow \hat{q}_{ij} \hat{x}_{j}$
$107 g\gamma \rightarrow J/\psi g$	$173  f_i f_j \rightarrow f_i f_j H^0$	Compositeness:	258 fig → ğerğ
108 $\gamma\gamma \rightarrow J/\psi\gamma$	$174 f_i f_j \rightarrow f_k f_j H^0$	146 eγ → e'	259 $f_{4}g \rightarrow \tilde{q}_{4}g \tilde{g}$
W/Z production:	181 gg $\rightarrow Q_k \overline{Q}_k H^0$	147 dg → d*	261 $f_{eff} \rightarrow f_{eff}$
$1  \hat{1}_i \bar{f}_i \rightarrow \gamma^* / Z^0$	$182 q_i \overline{q}_i \rightarrow Q_k \overline{Q}_k H^0$	148 ug → α*	262 $f_{i} \rightarrow \bar{f}_{a} \bar{f}_{a}$
$2  i_i \bar{t}_j \rightarrow W^{\pm}$	183 $f_i \bar{f}_i \rightarrow g H^0$	167 $q_i q_j \rightarrow d^* q_k$	263 $f_1f_2 \rightarrow f_1f_2 +$
$22$ $i_1 \bar{f}_1 \rightarrow 2^0 Z^0$	184 $f_{ig} \rightarrow f_{i}H^{0}$	168 $q_i q_j \rightarrow u^* q_i$	$264  a\pi \rightarrow \tilde{t}_{1}\tilde{t}_{1}^{*}$
23 $f_i \overline{f}_i \rightarrow Z^0 W^{\pm}$	185 gg $\rightarrow$ gH <sup>0</sup>	169 $q_i \overline{q}_i \rightarrow e^{\pm} e^{\pm}$	265 $gg \rightarrow t_0 t_0$
$25 f_i \overline{f}_i \rightarrow W^+W^-$	156 $f_i \bar{f}_i \rightarrow A^0$	$165  \mathbf{f}_i \mathbf{f}_i (\to \gamma^* / \mathbf{Z}^0) \to \mathbf{f}_k \mathbf{f}_k$	271 $f_{eff} \rightarrow \tilde{q}_{eff} \tilde{q}_{eff}$
15 $f_i \overline{f}_i \rightarrow g Z^0$	157 $gg \rightarrow A^0$	$166  f_i f_j (\to W^{\pm}) \to f_k f_l$	272 $f_i f_i \rightarrow \tilde{q}_{iR} \tilde{q}_{iR}$
16 $f_i \bar{f}_i \rightarrow g W^{\pm}$	158 $\gamma \gamma \rightarrow A^0$	Leptoquarks:	273 $f_{af_{i}} \rightarrow \tilde{q}_{iz}\tilde{q}_{iB} +$
$30 f_i g \rightarrow f_i Z^0$	176 $f_4 \overline{f}_5 \rightarrow Z^0 A^0$	145 $q_i \ell_j \rightarrow L_Q$	274 $f_{a}\bar{f}_{a} \rightarrow \bar{0}_{a} \tau \bar{0}_{a}^{\dagger} \tau$
$31  f_i g \rightarrow f_k W^{\pm}$	$177 f_4 \overline{f}_4 \rightarrow W^{\pm} A^0$	162 $qg \rightarrow \ell L_Q$	275 $f_{i}f_{i} \rightarrow \tilde{q}_{i}p\tilde{q}_{i}p$
19 $i_i \bar{I}_i \rightarrow \gamma Z^0$	178 $f_i f_j \rightarrow f_i f_j A^0$	163 $gg \rightarrow L_QL_Q$	276 $f\bar{f}_{a} \rightarrow \bar{n}_{a}r\bar{n}_{a}^{\dagger}a+$
20 $f_i \bar{f}_j \rightarrow \gamma W^{\pm}$	179 $f_i f_j \rightarrow f_k f_l A^0$	164 $q_i \overline{q}_i \rightarrow L_Q L_Q$	$277  f\bar{f}_{1} \rightarrow 5 \times 6^{+}r$
$35 f_i \gamma \rightarrow f_i Z^0$	186 $gg \rightarrow Q_k \overline{Q}_k A^0$	SUSY:	$271  111 \rightarrow 432432$
36 $f_i \gamma \rightarrow f_k W^{\pm}$	187 $q_1\overline{q}_1 \rightarrow Q_1\overline{Q}_1 A^q$	$201  f_i \bar{f}_i \rightarrow \bar{e}_L \bar{e}_L^*$	$\frac{1}{10}  \frac{1}{10} \rightarrow \frac{1}{10} \frac{1}{1$
69 $\gamma \gamma \rightarrow W^+W^-$	188 $f_{i}\bar{f}_{i} \rightarrow \epsilon A^{0}$	202 $f_i \bar{f}_i \rightarrow \bar{e}_R \bar{e}_R^*$	$279 \text{ gg} \rightarrow \mathbf{q}_{iL}\mathbf{q}_{iL}$
70 $\gamma W^{\pm} \rightarrow Z^0 W^{\pm}$	189 $f_i g \rightarrow f_i A^0$	203 $f_i \bar{f}_i \rightarrow \tilde{e}_L \tilde{e}_R^* +$	200 gg -7 4i k 4i k
Prompt photons:	190 $gg \rightarrow gA^0$	204 $f_i \bar{f}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$	$201  046 \rightarrow 0146E$
14 $f_i \overline{f}_i \rightarrow g \gamma$	Charged Higgs:	205 $f_i \overline{f}_i \rightarrow \mu_R \mu_R^*$	$204  \text{Dy}_{4} \rightarrow D_2 \text{Q}_{4} R$
18 $f_i \bar{f}_i \rightarrow \gamma \gamma$	143 $f_i \bar{f}_j \rightarrow H^+$	206 $f_i \bar{f}_i \rightarrow \bar{\mu}_L \bar{\mu}_R^* +$	$283  \mathbf{pq}_i \to \mathbf{p}_1 \mathbf{q}_{iR} + \mathbf{p}_2 \mathbf{q}_{iL}$
29 $f_i g \rightarrow f_i \gamma$	161 $f_{ig} \rightarrow f_{i}H^{+}$	207 $f_4 \overline{f}_4 \rightarrow \overline{\tau}_1 \overline{\tau}_1^*$	284 $b\dot{q}_{i} \rightarrow b_{1}\ddot{q}_{iL}$
114 gg $\rightarrow \gamma\gamma$	Higgs pairs:	208 $f_i \bar{f}_i \rightarrow \bar{\tau}_2 \bar{\tau}_2^*$	285 $b\bar{q}_{i} \rightarrow b_{2}\bar{q}_{iR}$
115 $gg \rightarrow g\gamma$	$297$ $f_1f_2 \rightarrow H^{\pm}h^o$	209 $f_i \bar{f}_i \rightarrow \bar{\tau}_1 \bar{\tau}_2^* +$	$286  b\bar{q}_i \rightarrow b_1 \bar{q}_i^* R + b_2 \bar{q}_i^* L$
Deep inelastic scatt.:	298 $f_1f_2 \rightarrow H^{\pm}H^0$	210 $f_i \bar{f}_i \rightarrow \bar{l}_L \bar{\nu}_i +$	$287  q_i \overline{q}_i \rightarrow b_1 b_1^*$
$10  f_i f_j \rightarrow f_i f_j$	299 $f_1f_1 \rightarrow A^0h^0$	211 $f_i \vec{f}_j \rightarrow \vec{\tau}_1 \vec{\nu}_i +$	288 $q_i \overline{q}_i \rightarrow b_2 b_2^*$
99 $\gamma^* f_i \rightarrow f_i$	$300  f_1 \bar{f}_1 \rightarrow A^0 H^0$	212 $f_i \bar{f}_j \rightarrow \tilde{\tau}_3 \bar{\nu}_r^* +$	$289  gg \rightarrow \tilde{b}_1 \tilde{b}_1$
Photon-induced:	$f_{i}f_{i} \rightarrow H^{+}H^{-}$	213 f.t. → v.v.	290 $gg \rightarrow \tilde{b}_2 \tilde{b}_2^*$
33 $f_i \gamma \rightarrow f_i g$	Left-right symmetry	214 $f_{i}\overline{f}_{i} \rightarrow \tilde{\nu}_{-}\tilde{\nu}_{-}$	291 bb $\rightarrow \tilde{b}_1 \tilde{b}_1$
34 $f_4 \gamma \rightarrow f_1 \gamma$	341 $l_{\ell}l_{s} \rightarrow H^{\pm\pm}$	216 $f_{L} \rightarrow \tilde{r}_{1} \tilde{r}_{1}$	292 bb $\rightarrow \tilde{b}_2 \tilde{b}_2$
54 $g\gamma \rightarrow f_k \overline{f}_k$	342 $L_{\ell_1} \rightarrow H^{\pm\pm}$	$217  f_{\nu}\bar{f}_{\nu} \rightarrow \tilde{r}_{2}\tilde{r}_{2}$	293 bb $\rightarrow \tilde{b}_1 \tilde{b}_2$
58 $\gamma \gamma \rightarrow f_k \bar{f}_k$	343 $\ell^{\pm}\gamma \rightarrow \Pi^{\pm\pm}e^{\mp}$	218 $f_1 \rightarrow \bar{v}_2 \bar{v}_3$	294 bg $\rightarrow \tilde{h}_{1}\tilde{g}$
131 $f_i \gamma_T \rightarrow f_{ig}$	$344$ $l^{\pm}\gamma \rightarrow \Pi^{\pm\pm}\sigma^{\mp}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$205$ br $\rightarrow b_0 \tilde{r}$
132 $f_1\gamma_1^* \rightarrow f_1g$		210 411 - X1X4	1 200 UK -7 028
133 $f_{1}\gamma_{1}^{*} \rightarrow f_{1}\gamma_{2}$	$t_i \gamma \rightarrow n_L \mu'$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$290  DD \rightarrow D_1D_2 +$
134 $f_1\gamma_1^* \rightarrow f_1\gamma_2$	$247$ $\ell_1^{\pm}$ $T_R^{\pm}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Extra unitensions:
135 $g\gamma_{+}^{*} \rightarrow f_{-}^{*} \overline{f}_{-}$	$\begin{array}{ccc} \sigma_{1} & \epsilon_{\mathbf{i}} & \gamma \to \mathbf{H}_{L}^{\tau} \\ 249 & \delta^{\pm} \sigma \to \mathbf{U}^{\pm\pm} - \overline{\tau} \end{array}$	222 $t_i t_i \rightarrow \bar{\chi}_1 \bar{\chi}_4$	$391  t_i t_i \rightarrow G^*$
136 $g\gamma^* \rightarrow f_{i}f_{i}$	$240$ $\xi_1^- \gamma \rightarrow \Pi_R^- \gamma^+$	223 $f_i f_i \rightarrow \tilde{\chi}_2 \tilde{\chi}_3$	$392 \text{ gg} \rightarrow G^*$
137 $\gamma_{m}^{\mu}\gamma_{m}^{\mu} \rightarrow f_{c}f_{c}$	$1 349  H_I \rightarrow H_L \cdot H_L$	224 $f_i f_i \rightarrow \tilde{\chi}_2 \tilde{\chi}_4$	$393  q_i q_i \rightarrow g G^*$
$138 \sim 2^{\circ} \sim 15$	$350  t_i t_i \to \mathbf{H}_R  \mathbf{H}_R$	225 $f_i f_i \rightarrow \tilde{\chi}_3 \tilde{\chi}_4$	$394  q_ig \rightarrow q_iG$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$226  f_i \bar{f}_i \rightarrow \bar{\chi}_1^{\pm} \bar{\chi}_1^{\mp}$	$395 \text{ gg} \rightarrow \text{gG}^*$
$140 \qquad \gamma_{1} \gamma_{T} \rightarrow i_{1}i_{1}i_{1}i_{1}i_{1}i_{1}i_{1}i_{1}$	$352$ $f_1 f_2 \rightarrow f_2 f_1 H_R^{-1}$		
$\gamma_L \gamma_L \rightarrow \gamma_l \tau_l$	$1353$ $t_4 t_4 \rightarrow Z_R^{\prime}$	$\rightarrow \approx 250$	processes
$\psi \psi \psi \gamma \rightarrow q_{k''}$	$354  f_i f_j \rightarrow W_R$		

Event Generator Pl

### User program structure

#### 1) Initialization step

- select process(es) to study
- modify physics parameters:  $m_t$ ,  $m_h$ , ...
- set kinematics constraints
- modify generator performance
- initialize generator
- book histograms

#### 2) Generation loop

- generate one event at a time
- analyze it (or store for later use)
- add results to histograms
- print a few events

#### 3) Finishing step

- print deduced cross-sections
- print/save histograms etc.

#### Higgs production with PYTHIA

```
C...Arithmetic in double precision; integer functions; PYDATA.
      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
      INTEGER PYK, PYCHGE, PYCOMP
      EXTERNAL PYDATA
C... The event record and other common blocks.
      COMMON/PYJETS/N, NPAD, K(4000, 5), P(4000, 5), V(4000, 5)
      COMMON/PYDAT2/KCHG(500,4), PMAS(500,4), PARF(2000), VCKM(4,4)
      COMMON/PYSUBS/MSEL, MSELPD, MSUB(500), KFIN(2,-40:40), CKIN(200)
      COMMON/PYPARS/MSTP(200), PARP(200), MSTI(200), PARI(200)
C... Physics scenario.
      MSEL=0
                       ! Mix subprocesses freely
      MSUB(102)=1
                       ! g + g -> h0
      MSUB(123)=1
                       ! f + f' -> f + f' + h0
                       ! f + f' -> f'' + f''' + h0
      MSUB(124) = 1
      PMAS(25,1)=300D0 ! Nominal Higgs mass.
C...Run parameters.
                       ! Number of events
      NEV=1000
                       ! CM energy of run
      ECM=14000D0
                       ! Minimum Higgs mass.
      CKIN(1)=200D0
                       ! Maximum Higgs mass.
      CKIN(2)=400D0
C...Switch off unnecessary aspects (for faster simulation).
      MSTP(61)=0
                       ! No initial-state showers
                       ! No final-state showers
      MSTP(71)=0
                       ! No multiple interactions
      MSTP(81)=0
                       ! No hadronization
      MSTP(111) = 0
C...Initialize and book histogram(s).
      CALL PYINIT('CMS', 'p', 'p', ECM)
      CALL PYBOOK(1, 'Higgs mass distribution',80,200D0,400D0)
C...Generate events and look at first few.
      DO 200 IEV=1,NEV
        CALL PYEVNT
        IF(IEV.LE.1) CALL PYLIST(1)
C...Find Higgs and fill its mass. End event loop.
        DO 150 I=7.9
          IF(K(I,2).EQ.25) CALL PYFILL(1,P(I,5),1D0)
      CONTINUE
  150
  200 CONTINUE
C...Final output.
      CALL PYSTAT(1) ! Print cross section table
                       ! Print histogram(s)
      CALL PYHIST
      END
```

**Event Generator F** 

\*\*\*\*\*\* \*\*\*\*\* \*\* \*\* \*\* \*\* \*\* \*....\* Welcome to the Lund Monte Carlo! \*\* \*\*\*\*!!\*\*\*\*\*\*\*\*\*\*\* \*\* \*\* \*\* \* PPP Y Y TTTTT H H III \*\* \*\* \* PP YY Т H н Ι AA \*\* PPP Y ннннн AAAAA \*\* т Ι \*\* \*\* Ρ Y Т н н I A A \*\* \*\* P Y Т H H III A ۸ \*\* \*\* \*\* \*\* 11 \*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 11 This is PYTHIA version 6.210 \*\* !\* -><- \* ŧt Last date of change: 25 Sep 2002 \*\* 11 \*\* 11 11 \*\* 11 \*\* H. 11 11 Now is 3 Nov 2002 at 13:23:46 \*\* \*\* !! \*\* 11 \*\* 11 Disclaimer: this program comes \*\* 11 1 h \*\* \*\* 11 11 without any guarantees. Beware \*\* \*\* 11 hh 11 of errors and use common sense \*\* 11 11 11 when interpreting results. \*\* \*\* 11 11 \*\* \*\* Copyright T. Sjostrand (2001) \*\* 11 \*\* \*\* \*\* \*\* An archive of program versions and documentation is found on the web: \*\* \*\* http://www.thep.lu.se/~torbjorn/Pythia.html \*\* \*\* \*\* \*\* When you cite this program, currently the official reference is \*\* \*\* T. Sjostrand, P. Eden, C. Friberg, L. Lonnblad, G. Miu, S. Mrenna and \*\* \*\* E. Norrbin, Computer Physics Commun. 135 (2001) 238. \*\* \*\* The large manual is \*\* \*\* T. Sjostrand, L. Lonnblad and S. Mrenna, LU TP 01-21 [hep-ph/0108264]. \*\* \*\* Also remember that the program, to a large extent, represents original \*\* \*\* physics research. Other publications of special relevance to your \*\* \*\* studies may therefore deserve separate mention. \*\* \*\* \*\* \*\* Main author: Torbjorn Sjostrand; Department of Theoretical Physics 2, \*\* Lund University, Solvegatan 14A, S-223 62 Lund, Sweden; \*\* phone: + 46 - 46 - 222 48 16; e-mail: torbjorn@thep.lu.se \*\* \*\* \*\* Author: Leif Lonnblad: Department of Theoretical Physics 2, \*\* Lund University, Solvegatan 144, S-223 62 Lund, Sweden; \*\* \*\* \*\* phone: + 46 - 46 - 222 77 80; e-mail: leif@thep.lu.se \*\* \*\* Author: Stephen Mrenna; Computing Division, Simulations Group, \*\* Fermi National Accelerator Laboratory, MS 234, Batavia, IL 60510, USA; \*\* \*\* phone: + 1 - 630 - 840 - 2556; e-mail: mrenna@fnal.gov \*\* de ele \*\* Author: Peter Skands; Department of Theoretical Physics 2, \*\* Lund University, Solvegatan 144, S-223 62 Lund, Sweden; \*\* \*\* \*\* phone: + 46 - 46 - 222 31 92; e-mail: zeiler@thep.lu.se \*\* \*\* \*\* \*\* de de \*\*\*\*\* \*\*\*\*\*

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I		I				
I PYTHIA	will be initialized for a p on p collider	I				
I at	14000.000 GeV center-of-mass energy	I				
I		I				
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\*\*\*\*\*\*\* PYMAXI: summary of differential cross-section maximum search \*\*\*\*\*\*\*\*

	3223II		لاخدىده	**************	-
I			I		I
I	ISUB	Subprocess name	I	Maximum value	I
I		•	I		I
					1212
I			I		Ι
Ī	102	g + g -> h0	I	1.3350E-08	I
1	123	f + f' -> f + f' + h0	I	1.1535E-08	I
I	124	f + f' -> f" + f"' + h0	I	2.4378E-08	I
I			I		I
	*****				

Event listing (summary)

I	particle/	jet	KS	KF	orig	р_ж	р_у	PZ	E	m
1 2	!p+! !p+!		21 21	2212 2212	0 0	0.000	0.000 0.000-	7000.000	7000.000 7000.000	0.938 0.938
							<u> </u>			
3	lgt		21	21	1	-0.563	-1.015	184.296	184.300	0.000
4	lg!		21	21	2	-0.683	-0,161	-121.731	121.733	0.000
5	lg!		21	21	3	-0.563	-1.015	184.296	184.300	0.000
6	lgt		21	21	4	-0.683	-0.161	-121.731	121.733	0.000
7	1h01		21	25	0	-1.246	-1.176	62.566	306.033	299.564
8	19+1		21	24	7	12.840	-99.922	-11.519	157.993	121.160
9	I₩-1		21	-24	7	-14.086	98.746	74.085	148.040	80.486
10	tau+!		21	-15	8	-29.129	-60,885	-54.158	86.555	1.777
11	inu tau!		21	16	8	41.969	-39.037	42.639	71.438	0.000
12	141		21	1	9	30.402	25.174	9.757	40.660	0.330
13	!ubar!		21	-2	9	-44.488	73.572	64.328	107.379	0.330
			/	*====	××====		*****		**********	
14	(h0)		11	25	7	-1.246	-1.176	62.566	306.033	299.564
15	(₩+)		11	24	8	12.840	-99.922	-11.519	157.993	121.160
16	(W-)		11	-24	9	-14.086	98.746	74.085	148.040	80.486
17	tau+		1	-15	10	-29.129	-60.885	-54.158	86.555	1.777
18	nu_tau		1.	16	11	41.969	-39.037	42.639	71.438	0.000
19	d _	A	2	1	12	30.402	25,174	9.757	40.660	0.330
20	ubar	v	1	-2	13	-44.488	73.572	64.328	107.379	0.330
21	vu 1	Å	2	2203	1	-0.025	0.695	5678.842	5678.842	0.771
22	d	v	1	1	2	0.262	0.010	-1888.460	1888.460	0.330
23	å	Á	2	1	1	0.588	0.320	1136.861	1136.861	0.330
24	uu_1	¥	1	2203	2	0.421	0.151	-4989.808	4989.808	0.771
					**===		*********			
			sum:	2.00		0.00	0.00	0.00	14000.01	14000.01

**Event Generator F** 

I Subprocess	I I I	Number of po	lints	I I I I	I Sigma I I
I I I N:о Туре I	I I I	Generated	Tried	I I I	
I .	I			1	I
I 0 All included subprocesses	Ι	1000	9642	I	5.126E-09 I
I 102 g + g -> h0	I	756	2672	1	3.799E-09 I
I 123 f + f' -> f + f' + h0	I	68	2243	I	3.500E-10 I
I 124 f + f' -> f" + f"' + h0	I	176	4727	1	9.763E-10 I
I	I			I	I

#### \*\*\*\*\*\*\*\*\* PYSTAT: Statistics on Number of Events and Cross-sections \*\*\*\*\*\*\*\*\*\*

\*\*\*\*\*\*\*\*\* Fraction of events that fail fragmentation cuts = 0.00000 \*\*\*\*\*\*\*\*\*

Histogram n	0 1 H	iggs mass	distribution				2002-
1.90*10** 2				44			
1.80+10++ 2				XX			
1.70+10++ 2				XX			
1.60+10++ 2				XX			
1.50+10++ 2				XX			
1.40*10** 2				XX			
1.30+10++ 2				XX			
1.20+10++ 2				XX9			
1.10+10++ 2				5XXX			
1.00+10++ 2				XXXX			
0.90+10*+ 2				XXXX			
0.80*10** 2				XXXX			
0.70+10++ 2				XXXX3			
0.60+10++ 2				8XXXX8			
0.50+10++ 2				XXXXXX			
0.40+10++ 2				3XXXXXX			
0.30+10++ 2				6XXXXXXX81			
0.20+10++ 2				¥XXXXXXXXX86			
0.10+10++ 2	1 1	1 11	2 2 1223926375X	<b>XXXXXXXXXXXX</b> 77	B67324 4	1114 212	121 115 1
Contents							
+10++ 2	0000000000	000000000	000000000000000000000000000000000000000	000011110000000	0000000000	00000000000	000000000000000000000000000000000000000
*10** 1	0000000000	000000000	000000000000000000000000000000000000000	123508816221100	0000000000	00000000000	000000000000000000000000000000000000000
*10** 0	0000100001	010001100	202012239263750	463854493818677	8673240400	1114021200	0121011501
*10**-1	000000000	000000000	000000000000000000000000000000000000000	000000000000000000000000000000000000000	0000000000	000000000000000000000000000000000000000	000000000000000000000000000000000000000
Low edge							
*10** 2	2222222222	2222222222	222222222222222222222222222222222222222	222222333333333333	33333333333	33333333333	3333333333
*10** 1	0000111122	223333444	455556666777788	3899999000011112	2223333444	4555566667	7778888995
*10** 0	0358035803	580358035	803580358035803	580358035803580	3580358035	8035803580	3580358035
Entries =	1000	Mean	- 3.0152E+02	Underflow =	0.0000E+	00 Lo	wedge =
All chan =	1.0000E+03	Ras	= 1.6320E+01	Overflow =	0.0000E+	00 Hi	.gh edge =

**Event Generator F** 

## Mass Effects in PYTHIA

- Dead cone only exact for
- emission from spin-0 particle, or
- infinitely soft emitted gluon

colour	spin	$\gamma_5$	example
$1 \rightarrow 3 + \overline{3}$	—	—	(eikonal)
$1 \rightarrow 3 + \overline{3}$	$1 \rightarrow \frac{1}{2} + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	$Z^0 \to q \overline{q}$
$3 \rightarrow 3 + 1$	$\frac{1}{2} \rightarrow \frac{1}{2} + 1$	$1,\gamma_5,1\pm\gamma_5$	$t \to bW^+$
$1 \rightarrow 3 + \overline{3}$	$0 \rightarrow \frac{1}{2} + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	${\rm H}^0 \to {\rm q} \overline{\rm q}$
$3 \rightarrow 3 + 1$	$\frac{1}{2} \rightarrow \frac{1}{2} + 0$	$1,\gamma_5,1\pm\gamma_5$	$t\tobH^+$
$1 \rightarrow 3 + \overline{3}$	$1 \rightarrow 0 + 0$	1	$Z^0\to \widetilde{q}\overline{\widetilde{q}}$
$3 \rightarrow 3 + 1$	$0 \to 0 + 1$	1	${\bf \tilde{q}} \rightarrow {\bf \tilde{q}}' W^+$
$1 \rightarrow 3 + \overline{3}$	$0 \to 0 + 0$	1	$H^0  o \widetilde{q} \overline{\widetilde{q}}$
$3 \rightarrow 3 + 1$	$0 \rightarrow 0 + 0$	1	$\tilde{q}\to \tilde{q}' H^+$
$1 \rightarrow 3 + \overline{3}$	$\frac{1}{2} \rightarrow \frac{1}{2} + 0$	$1,\gamma_5,1\pm\gamma_5$	$\chi  ightarrow q\overline{\widetilde{q}}$
$3 \rightarrow 3 + 1$	$0 \rightarrow \frac{1}{2} + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	$\mathbf{\tilde{q}}  ightarrow \mathbf{q} \chi$
$3 \rightarrow 3 + 1$	$\frac{1}{2} \rightarrow 0 + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	$t \rightarrow \tilde{t}\chi$
$8 \rightarrow 3 + \overline{3}$	$\frac{1}{2} \rightarrow \frac{1}{2} + 0$	$1,\gamma_5,1\pm\gamma_5$	$\tilde{g} \to q \overline{\tilde{q}}$
$3 \rightarrow 3 + 8$	$0 \rightarrow \frac{1}{2} + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	$\tilde{q} \to q \tilde{g}$
$3 \rightarrow 3 + 8$	$\frac{1}{2} \rightarrow 0 + \frac{1}{2}$	$1,\gamma_5,1\pm\gamma_5$	$t\to \tilde{t}\tilde{g}$

- In general, depends on
- energy of gluon
- colours and spins of emitting

particle and colour partner

 $\rightarrow$  process-dependent mass corrections



**Event Generator Physics 4** 

# **PYTHIA Underlying Event Models**

Parameter	Value	Description
MSTP(81)	0,10,20	Multiple-Parton Scattering off, for old, intermediate & new models
	1,11,21	Multiple-Parton Scattering on, for old, intermediate & new models
MSTP(82)	1 2	Multiple interactions with fixed probability & abrupt cut-off PTmin=PARP(81) or smooth turn-off at PARP(82)
MSTP(82)	3	Multiple interactions with varying impact parameter & hadronic matter overlap with single Gaussian matter distribution, with smooth turn-off at PARP(82)
MSTP(82)	4 5	Multiple interactions with varying impact parameter and a hadronic matter overlap with double Gaussian matter distribution (governed by PARP(83) and PARP(84)), or distribution $\propto \exp(-b^d)$ , $d = \text{PARP}(83)$ , both with smooth turn-off at PARP(82)

# Tuning PYTHIA to the Underlying Event

- Rick Field (CDF): keep all parameters that can be fixed by LEP or HERA at their default values. What's left?
- Underlying event. Big uncertainties at LHC...



# Leading Jet: "MAX & MIN Transverse" DensitiesPYTHIA Tune AHERWIG



Charged particle density and PTsum density for "leading jet" events versus E<sub>T</sub>(jet#1) for PYTHIA Tune A and HERWIG.

### LHC predictions: JIMMY4.1 Tunings A and B vs. PYTHIA6.214 – ATLAS Tuning (DC2)



**Event Generator Physics 4** 

# **Object Oriented Event Generators**

- ThePEG: Toolkit for High Energy Physics Event Generation, used by Herwig++ (and ARIADNE++?)
- Herwig++: Physics improvements from HERWIG 6
- PYTHIA 8: Implementation of physics of PYTHIA 6 plus some improvements
- SHERPA: Completely new event generator

# Herwig++ Status

- The current release 2.0, S. Gieseke et. al. hep-ph/0609306 includes:
  - Initial-State showers;
  - Top Decay Shower;
  - UA5 Soft Underlying event model;
  - QED Radiation;
  - Many important hadron-hadron matrix elements.
- This version can be used for hadron collider physics.

- After this version there are a number of features which we still need to include:
  - JIMMY multiple scattering model for the underlying event;
  - different kinematic reconstruction procedures for the shower;
  - BSM Physics;
  - new hadron decay model;
  - spin correlations throughout the simulation.

In order for the simulation to be as good as, or better than, the FORTRAN for everything.

# Hard Processes and New Physics

- In the FORTRAN each hard process and decay matrix element was typed in by hand.
  - Isn't a good use of time.
  - Meant that models of new physics were very hard to include.
- In the C++ we have used an entirely different philosophy.
  - A C++ helicity library based on the HELAS formalism is used for all matrix element and decay calculations.
  - Code the hard  $2 \rightarrow 2$  matrix elements based on the spin structures.
  - Code the 1→2 decays in the same way and use phase space for the  $1 \rightarrow 3$  decays to start with.
  - Easy to include spin correlations as we have access to the spin unaveraged matrix elements.

### M Gigg and P Richardson hep-ph/0703199



**Event Generator Physics 4** 

# **New Physics: UED**



# Hadron Decays



• The program includes detailed modelling of many decays

# **Future Shower Improvements**

- In addition to the other features one of the main reasons for going to C++ was to allow improvements to the shower algorithm.
  - CKKW matrix element matching
  - The multi-scale shower
  - MC@NLO
  - The Nason approach to MC@NLO

# Nason Approach to MC@NLO



O Latunde-Dada, S Gieseke, B Webber, JHEP02 (2007) 051, hep-ph/0612281

# Herwig++ Summary

- Herwig++ is now ready for hadron collisions.
- Many further improvements are planned.
- There will be a new release in the summer which will include the new simulation of BSM physics, hadron decays and some shower improvements.
- In the near future the C++ simulation will replace the FORTRAN.

### **PYTHIA** history

- 1978: work begun on JETSET: string fragmentation in  $e^+e^-$
- 1982: work begun on PYTHIA: hadron collisions on top of JETSET
- 1997: the two program combined under PYTHIA label
- today: PYTHIA 6.410, 75 000 lines of code, 580 pp manual (JHEP), author team: Torbjörn Sjöstrand, Stephen Mrenna, Peter Skands
- intensely used for LEP, Tevatron, LHC (since 1990!), ...

... but

- only add, never subtract
- $\Rightarrow$  has become bloated and unmanageable
- is in Fortran 77, so not understood by young people
- 1998: C++ PYTHIA 7 begun  $\implies$  THEPEG, physics stalled
- Sep 2004: C++ PYTHIA 8 begun
- $\sim$ 1 sub-subversion per working week (T. Sjöstrand on "sabbatical")
- March 2007: PYTHIA 8.080
- < end 2007: PYTHIA 8.100; overtakes PYTHIA 6 as "current" (?)

### **PYTHIA 8 status**

#### task

administative structure hard processes, internal resonance decays hard processes, external SUSY(+more) parameters initial-state showers final-state showers matching ME's to showers multiple interactions beam remnants & colour flow parton densities string fragmentation decays & particle data **Bose-Einstein** analysis graphical user interface tuning

#### status

operational; extensions planned only small selection; more needed primitive; work needed interfaces to LHA F77, LHEF, PYTHIA 6 primitive SLHA2 operational operational some exists, much more needed operational; extensions planned operational; alternatives to come only 2 internal, but interface to LHAPDF operational; improvements planned operational; may need updates still to be done some simple tools; may be enough operational; could be extended major task for MCnet postdocs!

### **Current PYTHIA 8 structure**



# Introducing SHERPA

### Physics of SHERPA T.Gleisberg, S.Höche, F.K., A.Schälicke, S.Schumann and J.C.Winter, JHEP 0402 (2004) 056 New event generator, written from scratch in C++. Matrix elements from AMEGIC, combined with own parton shower implementation (F.K., A.Schälicke and G.Soff, arXiv:hep-ph/0503087; similar to shower in PYTHIA) Hadronization of Pythia interfaced, will be replaced by own cluster model (J.Winter, F.K. and G.Soff, Eur. Phys. J. C**36** (2004) 381) Tested in a number of processes (highlights see below). A few other implementations exist for specific channels. イロト イロト イヨト イヨト F. Krauss

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## Automatic cross section calculators

### Example: AMEGIC++

F.K., R.Kuhn, G.Soff, JHEP 0202 (2002) 044.

- Uses helicity method + multi-channeling.
   Operational mode: 2 runs.
  - Generation run:
    - Generate Feynman diagrams,
    - construct and simplify helicity amplitudes,
    - produce integration channels,
    - write out library files.
  - Compile & link libraries.
  - Production run:
    - cross section calculations,
    - parton level events.

### Implemented & tested models: SM, MSSM, ADD.

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## Standard Model @ Linear Collider

### Consistency of HELAC/PHEGAS & AMEGIC++

T.Gleisberg, F.K., C.Papadopoulos, A.Schälicke and S.Schumann, Eur. Phys. J. C 34 (2004) 173



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## MSSM

### Automated tools

K.Hagiwara *et al.*, arXiv:hep-ph/0512260;

- 3 validated tools for MSSM studies: (S)MadGraph, O'Mega/Whizard & Amegic;
- completely different approaches & notations;
- SUSY spectra through SLHA interface;
- checked roughly 500 pair-production processes;
- some simple studies for LHC and LC.

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## Comparison with data from Tevatron

### $p_{\perp}$ of Z-bosons in $p\bar{p} \rightarrow Z + X$

Data from CDF, Phys. Rev. Lett. 84 (2000) 845



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# Azimuthal decorrelations of jets at the Tevatron

### Idea Distributions @ Run II Check QCD radiation pattern $\frac{d^{0}}{d^{0}} \frac{d^{0}}{d^{0}} \frac{d^{0}}{d^{$ $\begin{array}{l} \mapsto \ p_{T}^{max} > 180 \ GeV \ (x8000) \\ \mapsto \ 130 \ < p_{T}^{max} < 180 \ GeV \ (x400) \\ \models \ 100 \ < p_{T}^{max} < 130 \ GeV \ (x20) \\ \mapsto \ 75 \ < p_{T}^{max} < 100 \ GeV \end{array}$ $\Delta \phi_{\text{dijet}}$ Sherpa رم 10<sup>2</sup> مانافد 10<sup>2</sup> 10 10<sup>-1</sup> 10<sup>-2</sup> $10^{-3}$ **3/4** π $\pi/2$ $\Delta \phi_{\text{dijet}}$

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Comparison with other codes



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## Conclusions

- Get to know your Monte Carlo!
- Remember what is fixed by LEP and HERA data
- Question what isn't
- Tevatron data crucial testing ground
- The next generation is here...
  - Software improvements
  - Physics improvements