The ILD Letter of Intent: Optimisation and Performance

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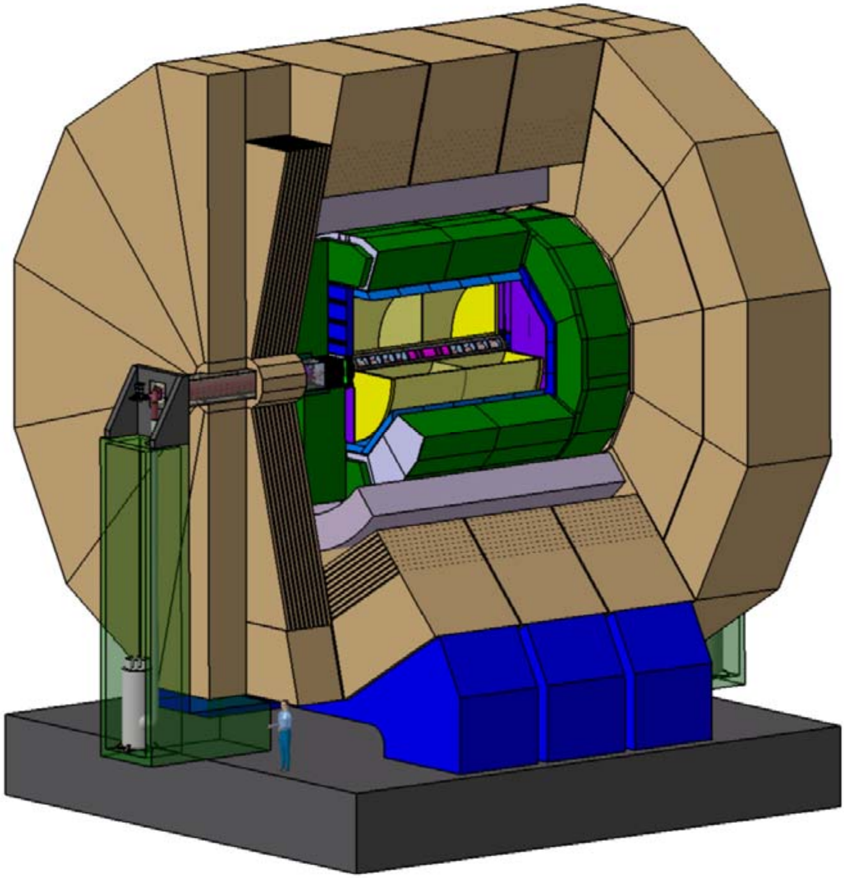
for the ILD group



This talk:

❶ Introduction
❷ Optimisation of ILD (GLD/LDC→ILD)
❸ Performance
❹ Conclusions

❶ Introduction

Design Requirements

- ILC provides a clean environment for high precision measurements
- Optimise detector to take full advantage of ILC
- Requires high precision/high efficiency tracking
- Excellent vertex tagging capabilities
- Unprecedented jet energy resolution

International Large Detector: Philosophy

- Based on high granularity particle flow calorimetry
  - confident this will provide necessary jet energy resolution
- "Large" central Time Projection Chamber (TPC)
  - proven technology; provides excellent pattern recognition in a dense track environment
- Tracking augmented by Si strip/pixels
  - extend tracking coverage + improves precision
- A high precision Vertex detector close to IP
  - for best possible heavy flavour tagging
- Close to 4π tracking/calorimetric acceptance

From GLD/LDC to ILD

History

★ Late 2007: ILD formed from previous (Asian-dominated) GLD and (European-dominated) LDC groups

★ Jan 2008: first ILD meeting (DESY Zeuthen)

★ Sep 2008: ILD baseline parameters chosen
- not always an easy process - required compromises
- choices based on physics arguments from extensive studies (the first part of this talk)
- essentially unanimous agreement !

★ Mar 2009: ILD Letter of Intent submitted, including
- current understanding of ILD performance
- wide range of physics studies

} the second part of this talk

Huge amount of work by many people !
Today I can only give a summary…
For more details see LoI, supporting documents and parallel session talks

❷ Optimisation

★ Starting point: GLD and LDC concepts

★ Many similarities:

- both conceived as detectors for particle flow calorimetry with a TPC as the central tracker

★ Significant differences:

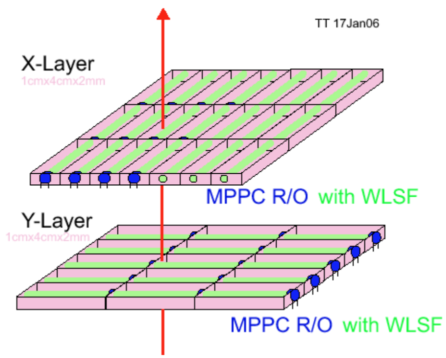
- overall parameters: size, magnetic field
- sub-detector technologies

	LDC		GLD	ILD ?
Tracker	TPC		TPC	TPC
R_{TPC} =	1.5 m		2.0 m	1.5 – 2.0 m
B =	4 T		3 T	3 – 4 T
Vertex	5 single layers		3 double layers	?
ECAL	SiW pixels		Scint strips	?
HCAL	Steel	RPC / Scint	Steel-Scint	?

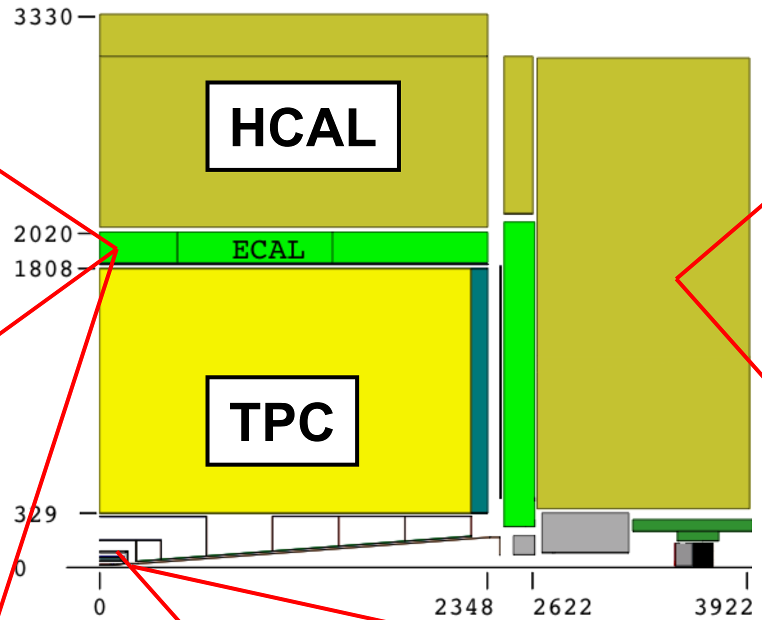
Main ILD sub-detector options

ECAL

- ★ SiW: 5×5 mm²
- ★ ScintW: strips



- ★ MAPS: digital

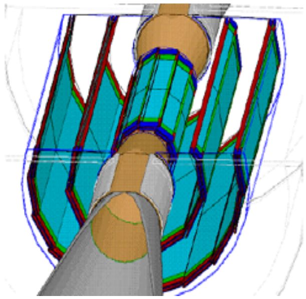


HCAL

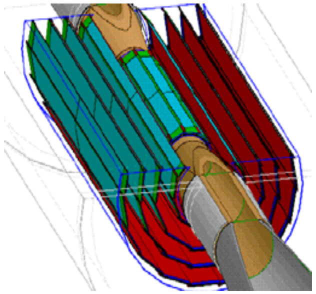
- ★ Steel Scint.
  Analogue
  3×3 cm² tiles
- ★ Steel RPC
  Digital
  1×1 cm²

Vertex Detector

- ★ 3 Double Layers



- ★ 5 Single Layers



ILD Optimisation: Strategy

★ **Scope of Optimisation:**
- Concentrate on global detector parameters:
  - radius, B-field, HCAL thickness, …

★ **Parameter space:**
- study parameters between/close to GLD and LDC

★ **Sub-detector technology:**
- At this stage we are not in a position to choose between different options – different levels of sophistication in simulation/reconstruction
- However, can demonstrate a certain technology/resolution meets the ILC goals

★ **Cost:**
- Large uncertainties in raw materials/sensors
- For this reason, do not believe optimising performance for given cost is particularly reliable at this stage
- Whilst conscious of cost, meeting the required performance/ physics goals is the main design criterion

ILD Optimisation: detector models

- ★ **Optimisation studies performed using both GLD and LDC software**
  - useful cross-check of results
  - simulated an LDC-sized detector in GLD software and *vice versa*
  - simulated an intermediate (B=3.5 T) model in each framework
- ★ **Considered 3 "benchmark" detectors in both software frameworks:**
  - Jupiter : GLD, GLDPrime, GLD4LDC
  - Mokka : LDC4GLD, LDCPrime, LDC

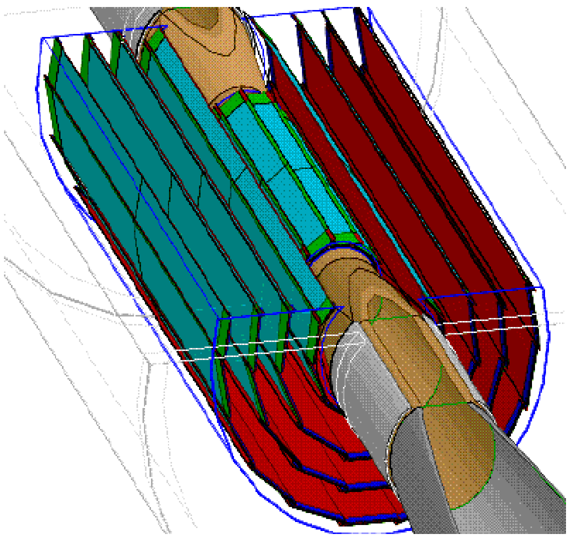
"Big" Medium "Small"

Sub-Detector	Parameter	GLD	LDC	GLD'	LDC'
TPC	R_{outer} (m)	1.98	1.51	1.74	1.73
Barrel ECAL	R_{inner} (m)	2.10	1.61	1.85	1.82
	Material	Sci/W	Si/W	Sci/W	Si/W
Barrel HCAL	Material	Sci/Fe	Sci/Fe	Sci/Fe	Sci/Fe
Solenoid	B-field	3.0	4.0	3.50	3.50
VTX	Inner Layer (mm)	17.5	14.0	16	15

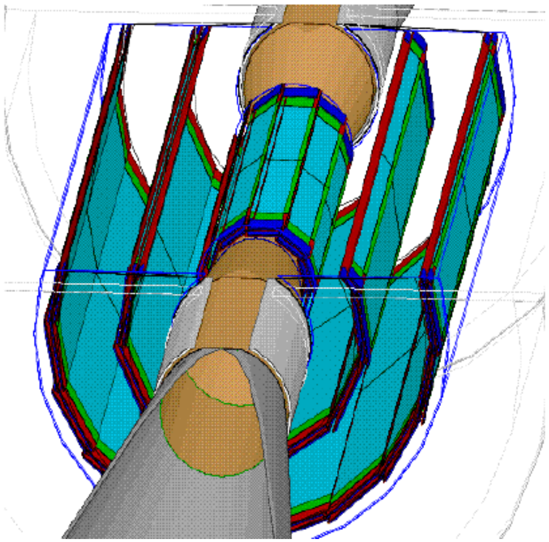
ILD Optimisation: Software

★ Significant effort to make things as realistic as possible
- Include: realistic geometry, gaps, dead material, support structures
- Not perfect, but probably a decent first order estimate

e.g. Vertex detectors in Mokka



VTX-SL: 5 single layers



VTX-DL: 3 double layers

★ NOTE: for the tracking detector point resolutions are applied in reconstruction (digitisation stage)

All studies use sophisticated full reconstruction chain

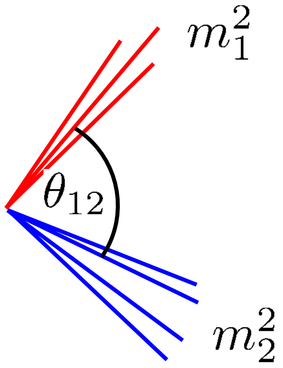
ILD Optimisation: Particle Flow

Role of Particle Flow in ILD optimisation

- ★ ILD designed for **Particle Flow Calorimetry**
- ★ Plays an important role in the detector optimisation
  - essential to that ILD meets ILC jet energy goals

ILC Jet Energy Goals

- ★ Not 30%/√E
- ★ Want to separate W and Z di-jet decays
- ★ For di-jet mass resolution of order



$$\frac{\sigma_m}{m} \approx \frac{\Gamma_Z}{m_Z} \approx \frac{\Gamma_W}{m_W} \approx 0.027$$

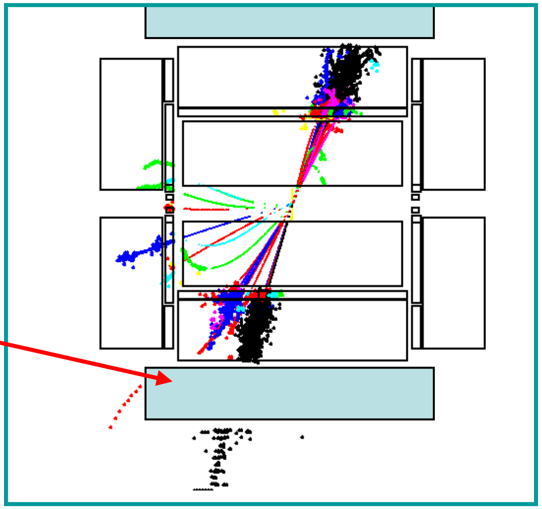
⇒ **~2.75σ separation between W and Z peaks**

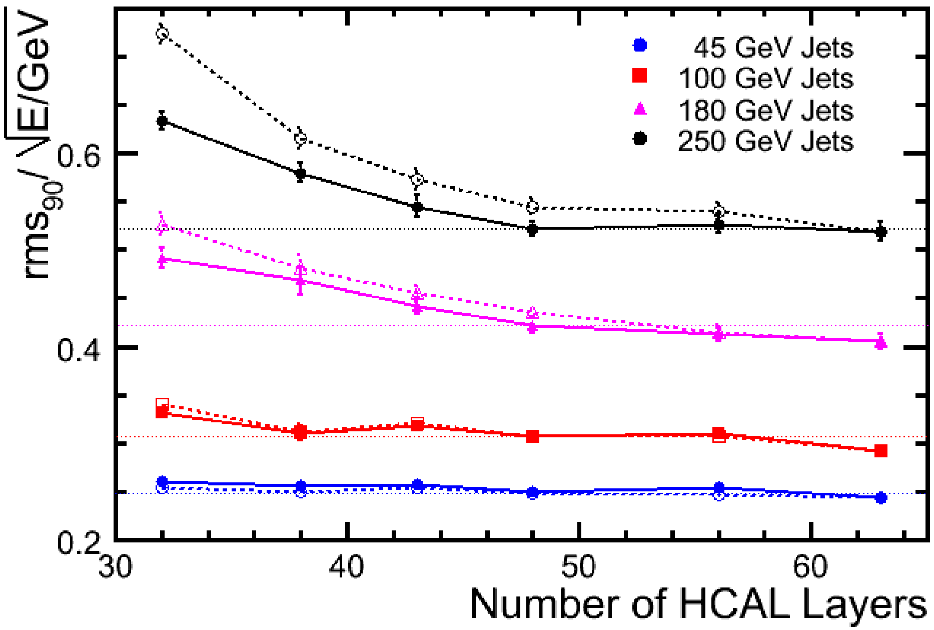
⇒ $\sigma_{E_j}/E_j < 3.8\%$

- ★ All studies use sophisticated full reconstruction, e.g. Marlin
- ★ **Note:** better jet energy resolution enables tighter cuts to be made in event selections where invariant mass cuts are important

PFA Optimisation: HCAL Depth

- ★ HCAL chosen to be sufficiently deep that leakage does not significantly degrade PFA
- ★ Studies include attempt to use muon chambers as a hadron shower "tail-catcher"
- ★ Somewhat limited by thick solenoid
- ★ Vary number of layers in LDCPrime HCAL



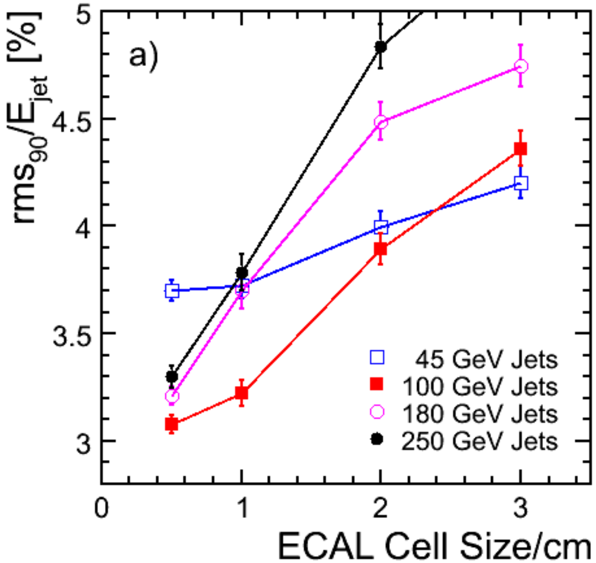


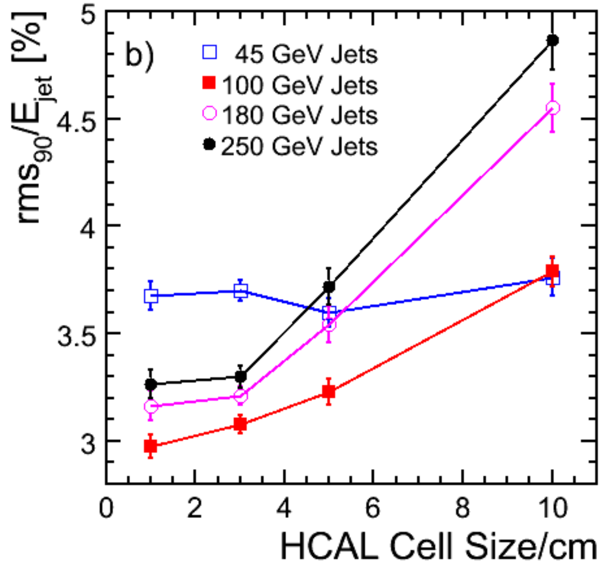
HCAL Layers	λ_I	
	HCAL	+ECAL
32	4.0	4.8
38	4.7	5.5
43	5.4	6.2
48	6.0	6.8
63	7.9	8.7

- ★ Suggests that ILD HCAL should be 43 – 48 layers (5.4-6.0 λ_I)
- ★ **48 layers chosen**

PFA Optimisation: Calorimeter Segmentation

★ Starting from LDCPrime vary ECAL Si pixel size and HCAL tile size





★ ECAL Conclusions:

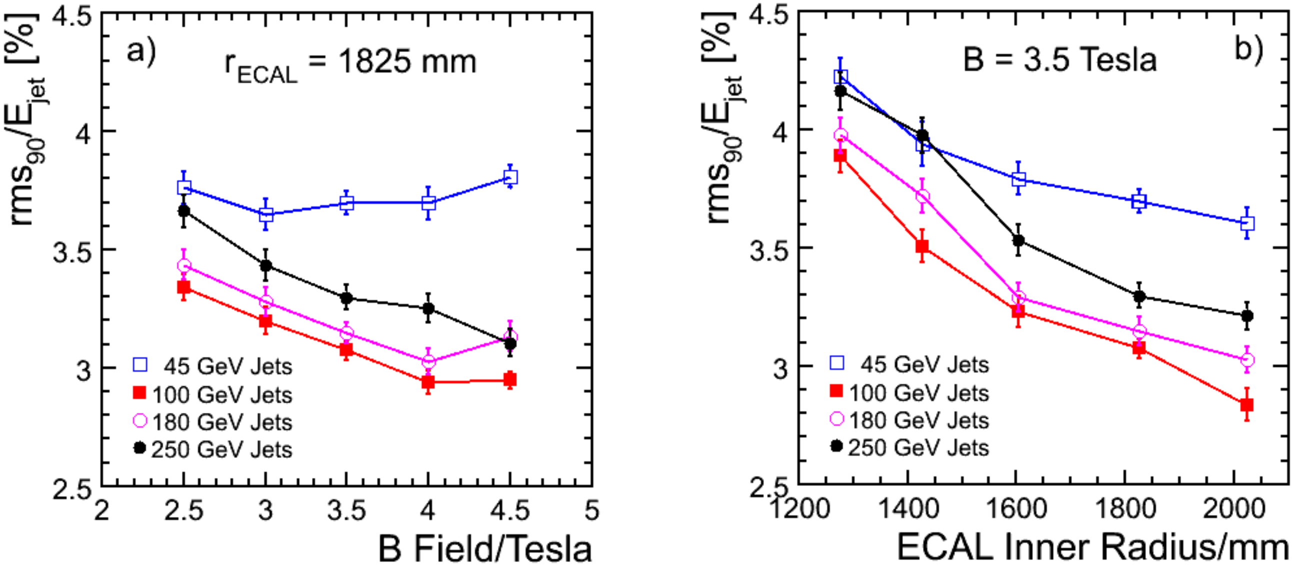
- Ability to resolve photons in current PandoraPFA algorithm strongly dependent on transverse cell size
- Require at least as fine as 10x10 mm² to achieve 3.8 % jet E resolution
- Significant advantages in going to 5x5 mm²
- For 45 GeV jets resolution dominates (confusion relatively small)

★ HCAL Conclusions:

- For current PandoraPFA algorithm and Scintillator (analogue) HCAL a tile size of 3×3 cm² looks optimal

PFA Optimisation: B vs Radius

★ **Starting from LDCPrime (B=4.0 T, r_{ECAL}=1825 mm) vary B and R**



★ **Empirically find**

$$\frac{\sigma_E}{E} = \frac{21}{\sqrt{E/\mathrm{GeV}}} \oplus 0.7 \oplus 0.004E \oplus 2.1\left(\frac{R}{1825}\right)^{-1.0}\left(\frac{B}{3.5}\right)^{-0.3}\left(\frac{E}{100}\right)^{+0.3}\%$$

Resolution | Tracking | Leakage | Confusion

★ **Conclude:**

- **R is more important than B for PFA performance**
- **Confusion term ∝ $B^{-0.3}R^{-1}$**
- **For 45 GeV jets resolution dominates (confusion relatively small)**

PFA Optimisation: B vs Radius

★ Comparing LDC, LDCPrime and LDC4GLD jet energy resolutions

Relative to LDCPrime	B/T	R/m	$B^{-0.3}R^{-1}$	Relative σ_E/E vs E_{JET}/GeV			
				45	100	180	250
LDC	4.0	1.6	1.08	1.02	1.04	1.05	1.06
LDCPrime	3.5	1.8	1.00	1.00	1.00	1.00	1.00
LDC4GLD	3.0	2.0	0.95	0.99	0.97	0.96	0.96

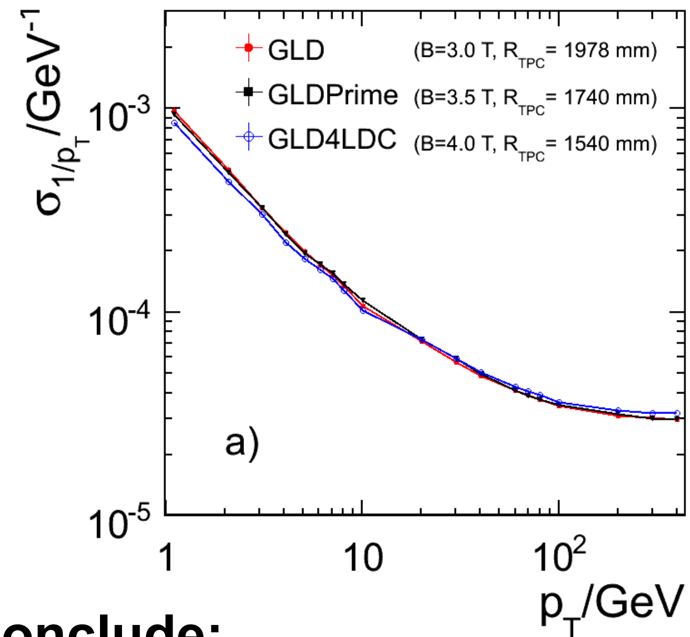
★ <u>Conclude:</u>

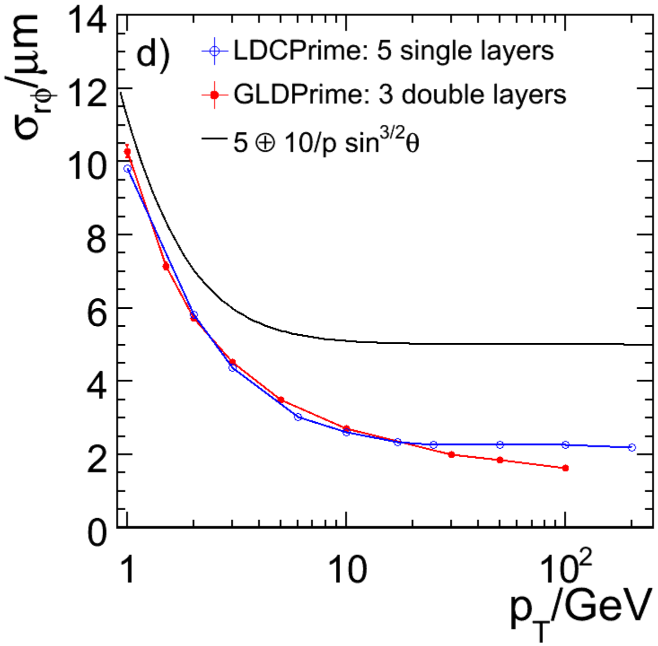
- Differences between GLD and LDC are small
- Not surprising: original detector parameters chosen such that higher B (partly) compensates for smaller radius
- Of the models considered the larger radius, lower field combination is slightly favoured, but at most 5 % differences.

B and R not only affect particle flow…

ILD Optimisation: Tracking

★ Compare GLD, GLDPrime and GLD4LDC momentum resolution and GLDPrime and LDCPrime impact parameter resolution





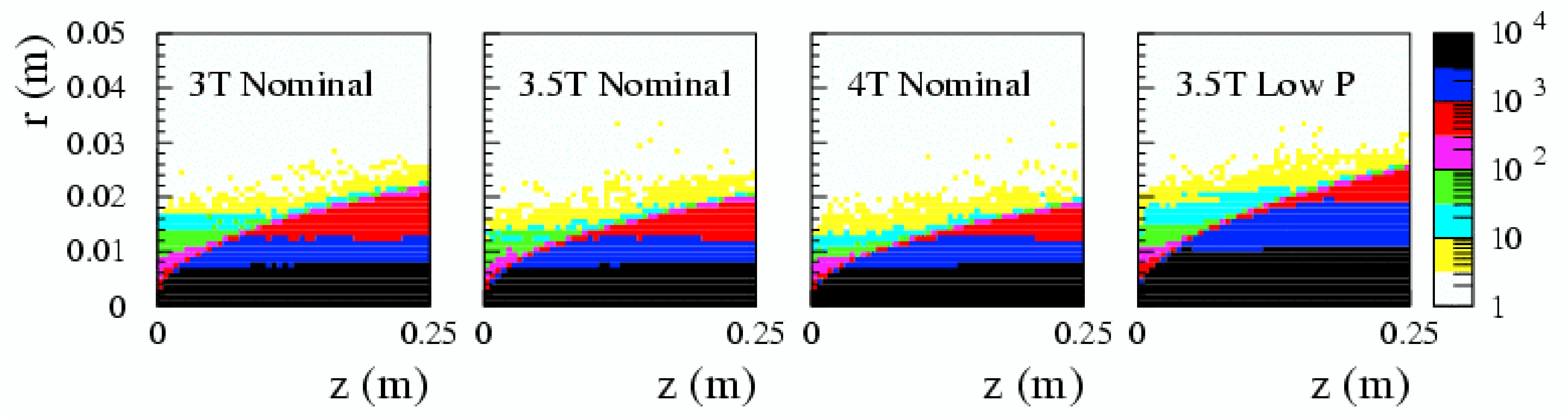
★ **Conclude:**

- All models give the required performance with only ~5-10 % differences
- For high momentum tracks:
  - LDC is favoured over GLD but only by ~5 % (larger lever arm)
  - The 3 double layer Vertex detector is favoured – two high precision points close to the IP rather than one
- Dependence on point resolution + detector layout/technology likely to be much larger than differences observed here

ILD Optimisation: Background considerations

★ Large beam background of low p_T electron/positron pairs
- Radius of pair background envelope is determined by B
- Determines the minimum inner radius of the vertex detector
- Potential to impact flavour tagging performance

★ But radius of pair background envelope scales only as √B

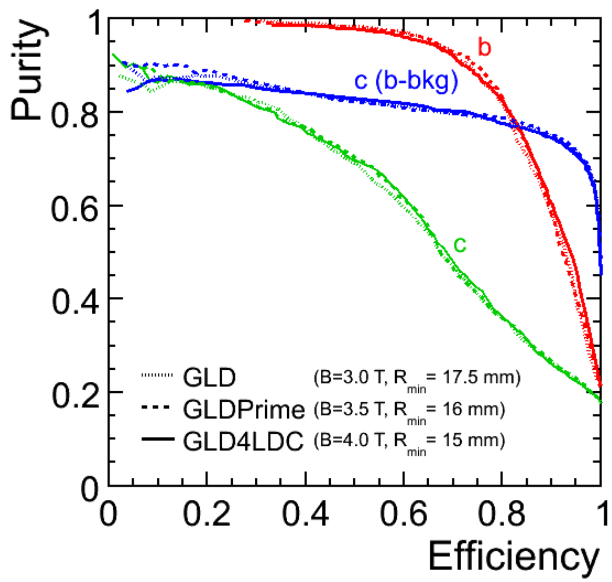


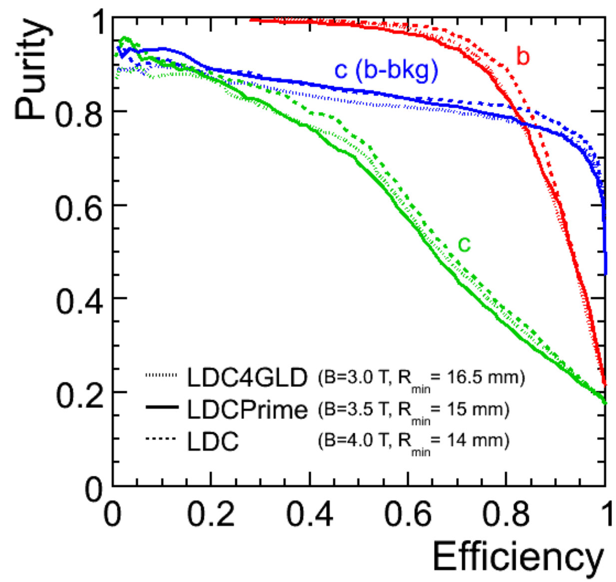
★ Dependence of **inner radius of vertex detector** is weaker than √B
- fixed clearance between background and beam pipe and beam pipe and vertex detector

★ Consequently 4 T → 3 T translates to a ~10 % difference in inner radius of vertex detector

ILD Optimisation: Flavour Tagging

- ★ **Compare flavour tagging performance for GLD and LDC based models**
  - **Differences of 2.5 mm in inner radius of beam pipe due to B field**
- ★ **Use "State-of-the-Art" LCFIVertex algorithms**
  - **ANNs separately tuned for the different detector models**
  - **NOTE: ~2% stat. uncertainties on results from ANN training/finite stats.**

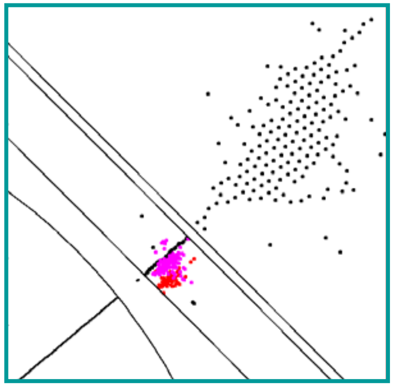


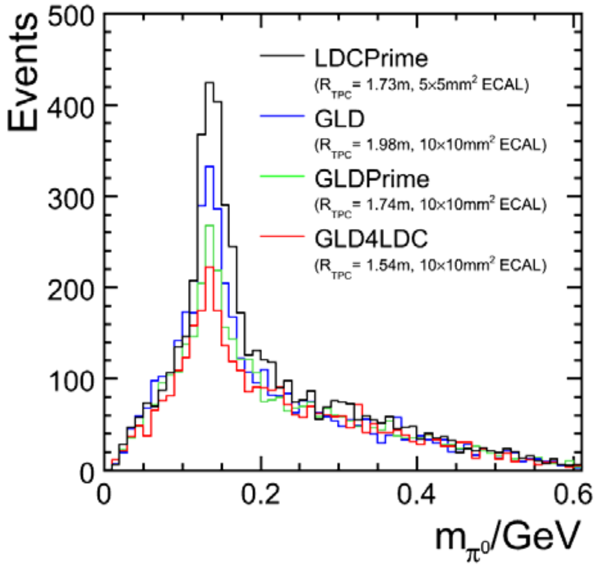


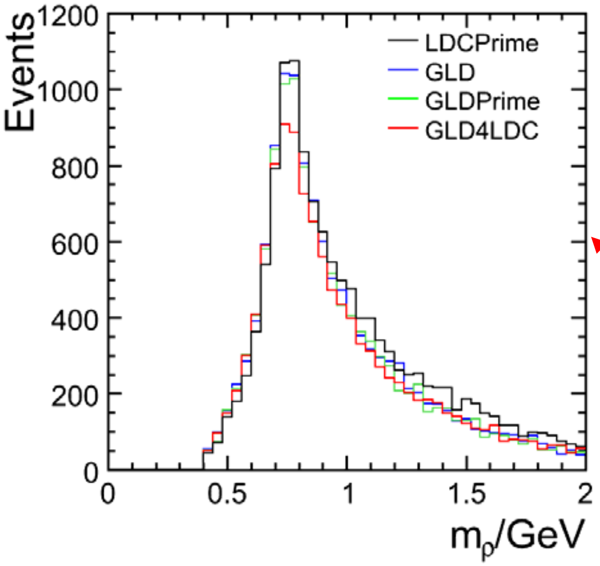
- ★ **<u>Conclude:</u>**
  - **Differences are not large**
  - **Higher B (smaller inner radius) slightly favoured – but not conclusive due to statistical uncertainties**
  - **Does not provide a strong argument for higher field**

ILD Optimisation: Physics

- ★ Also compared physics performance for GLD and LDC based models
  - Higgs mass from $e^+e^- \to ZH \to e^+e^- X / \mu^+\mu^- X$
  - W/Z reconstruction in SUSY Point 5 chargino/neutralino analysis
  - Tau reconstruction/polarisation
- ★ Only significant difference found for full reconstruction of tau decay, e.g. $\tau^- \to \rho^- \nu_\tau \to \pi^+ \pi^0 \nu_\tau$
- ★ For reconstruction of both photons from $\pi^0 \to \gamma\gamma$
  - 5×5 mm² is a significant advantage
  - larger radius also helps







- ★ But impact on physics sensitivity less pronounced

ILD Optimisation: Summary

	B/T	r_{ECAL}/m
LDC	4.0	1.6
Prime	3.5	1.8
GLD	3.0	2.0

What did we learn ? (much more detail in LoI)

★ LDC, "Prime", GLD give similar performance
- almost by "construction"
- all valid detector concepts for ILC

★ For PFlow, radius is more important than B

★ Arguments for high B are rather weak

★ For current PFlow algorithm want segmentation
- ECAL < 10×10 mm^2 (5×5 mm^2 preferred)
- HCAL ~ 3×3 cm^2 (no obvious advantage in higher granular for analogue HCAL)

Choice of ILD parameters

★ B = 3.5 T
- not a big extrapolation from CMS solenoid (larger)
- only weak arguments for higher field
- 3.0 T viable, but would like to better understand backgrounds

★ r_{ECAL} = 1.85 m
- for B = 3.5 T need ~1.55 m to reach jet E goal
- then allow for uncertainties in shower simulation
- larger radius brings performance advantages (~16 % for 1.85 c.f. 1.55)

★ Technology
- no selection at this stage

❸ ILD Detector Performance

★ Defined **detailed** GEANT4 model of ILD "software reference" model

★ For this **software model** use sub-detector models for which full reconstruction performance has been established

ECAL: SiW: 5×5 mm^2

- Advantages of high segmentation
- PFA with strip clustering not yet demonstrated (needs R&D)
- ditto PFA with MAPS ECAL

HCAL: 3x3 cm^2 Scint. tiles

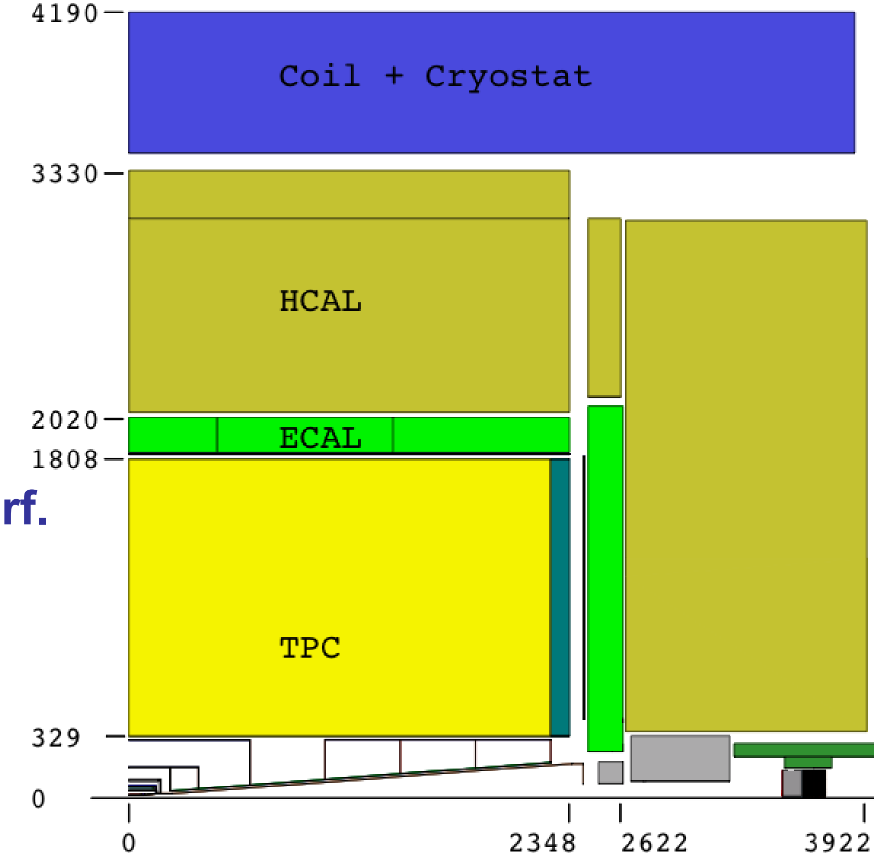
- PFA with digital/semi-digital HCAL not yet **fully** demonstrated
- First studies indicate comparable perf.

VTX: 3 double layer layout

- slightly better impact parameter res.
- Interesting to study potential pattern recognition advantages

Si Tracking: SiLC design

- coverage down to 6°

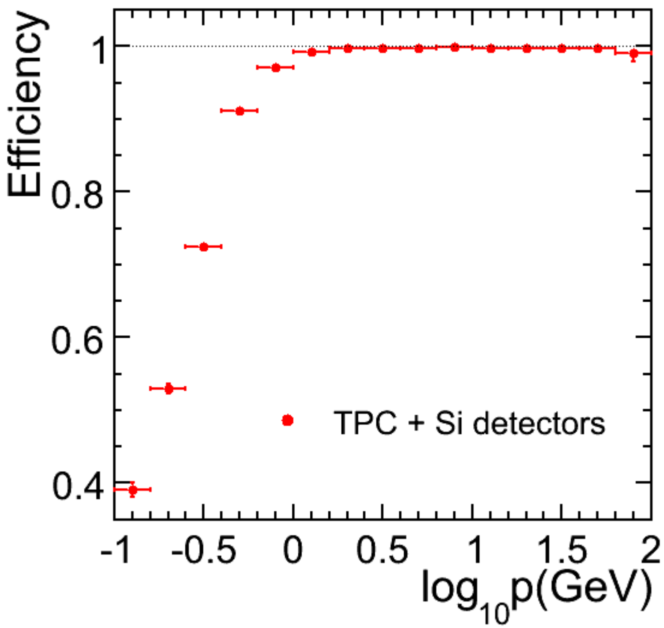


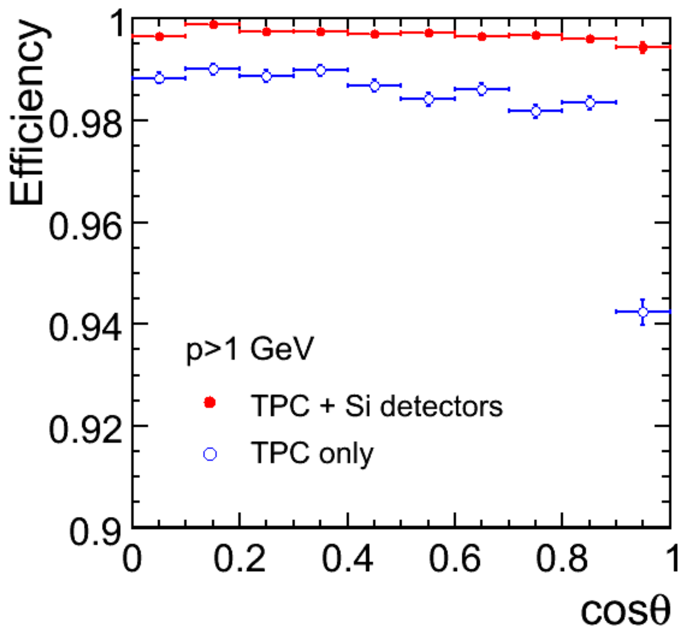
Level of detail in GEANT4 model probably as good as most TDRs !

Performance Highlights: Track Finding Efficiency

★ Achieve very high track reconstruction efficiency (full reconstruction)

★ For $e^+e^- \rightarrow t\bar{t} \rightarrow 6\ \mathrm{jets}$





TPC only plot is different to that in LoI due to a, now fixed, software issue

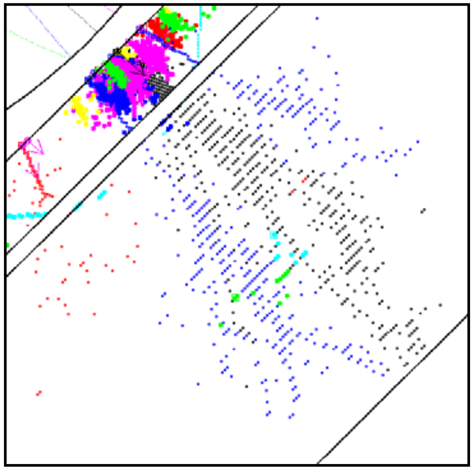
★ For (p>1 GeV) efficiency is greater than 99.5 % for any track leaving 4+ hits in tracking detectors (includes V^0s and kinks)

NOTE: beam background not included

- Subject of on-going work
- Studies to date do not indicate any problems with background
- However, studies require improvements to digitisation/reconstruction of time structure of bunch train to make solid statements

Particle Flow Performance

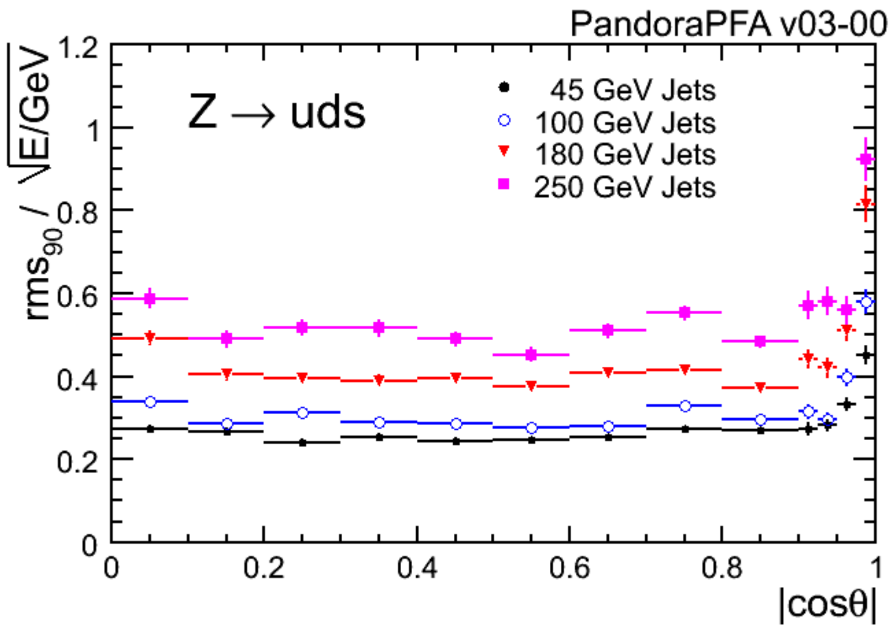
★ **Benchmarked using:**
- $Z \rightarrow u\bar{u}, d\bar{d}, s\bar{s}$ **decays at rest**
- **$|\cos\theta|<0.7$**



E_j	$\sigma(E_{jj})$	$\sigma(E_{jj})/\sqrt{E_{jj}}$	$\sigma(E_j)/E_j$
45 GeV	2.4 GeV	25 %	3.7 %
100 GeV	4.1 GeV	29 %	2.9 %
180 GeV	7.5 GeV	40 %	3.0 %
250 GeV	11.1 GeV	50 %	3.2 %

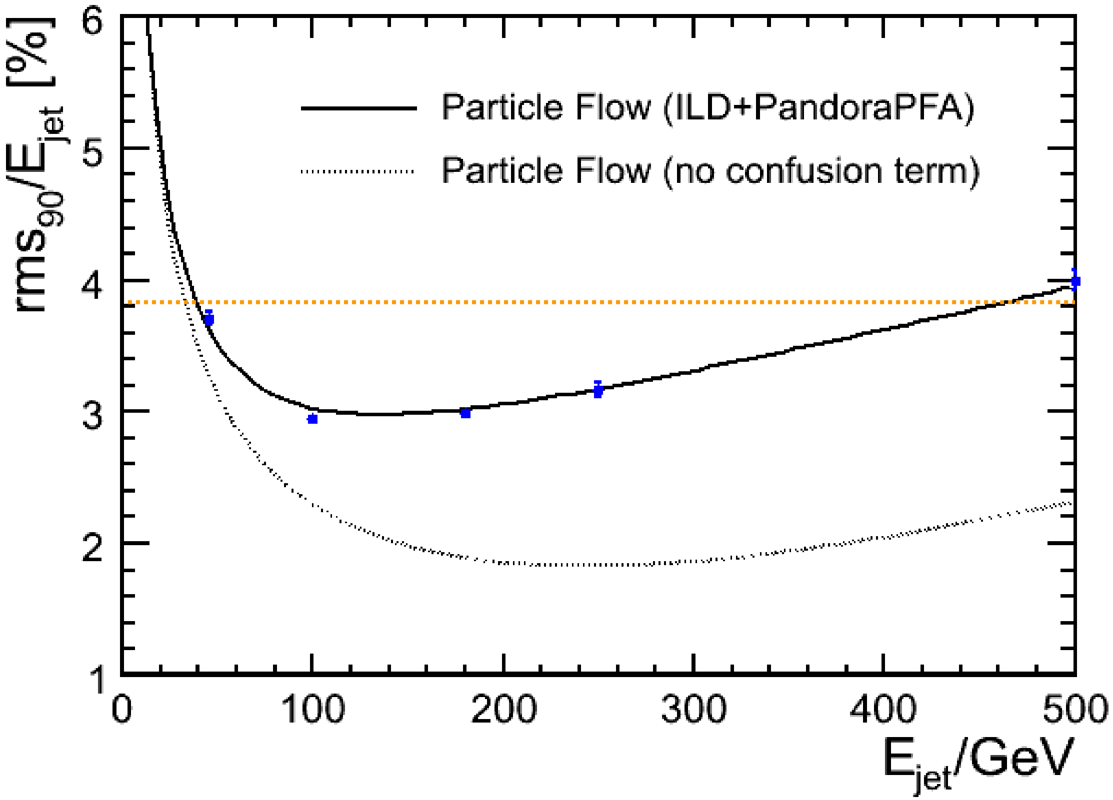
di-jet (columns $\sigma(E_{jj})$, $\sigma(E_{jj})/\sqrt{E_{jj}}$) — jet (column $\sigma(E_j)/E_j$)

NOTE:
- $\sigma_E = rms_{90}$
- In terms of statistical power $rms_{90} \times 1.1 \approx$ Gaussian equiv.
- No strong angular dependence down to $\cos\theta$~0.975



★ **Previously argued aiming for $\sigma(E_{jet})/E_{jet} < 3.8$ %**

★ **ILD meets this requirement for 40-400 GeV jets**



Excellent jet energy resolution is a strength of ILD !

ILD Physics Performance

ILD Physics Studies:

- Extensive set of analyses developed for LoI
  - "benchmark" and many other processes
- All use full simulation/reconstruction
- Large scale grid-based MC production ~30M events !
- Based on StdHep files generated at SLAC
- Two experienced reviewers assigned to each analysis to give some level of feedback/quality assurance

A lot of impressive work from many people !

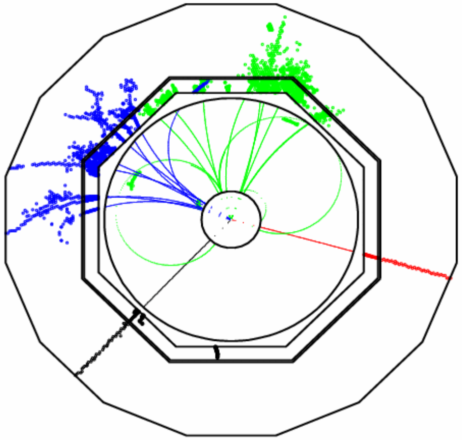
Caveats:

- Different analyses have different levels of sophistication
- Not the ultimate performance that can be achieved
  - don't draw too strong conclusions yet
  - except perhaps – that ILD is an excellent general purpose detector for the ILC

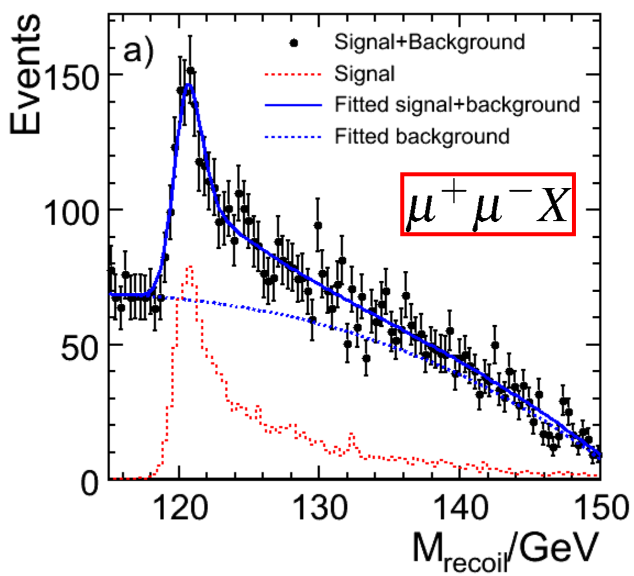
Due to time constraints can only give "highlights" here…
Significantly more in the LoI

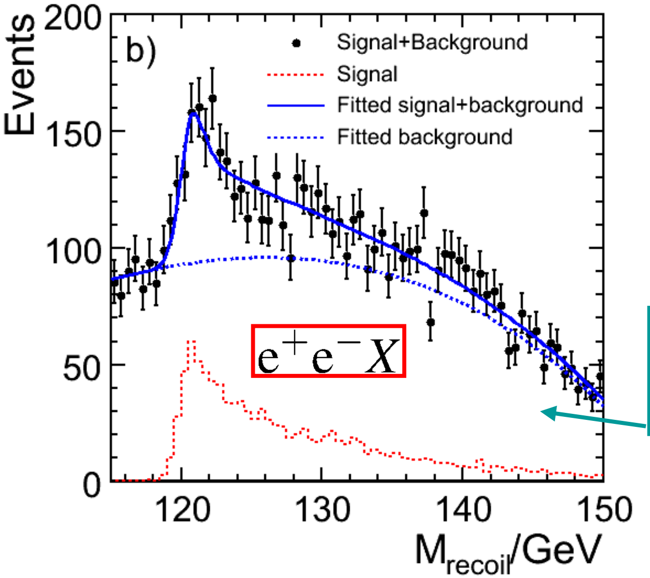
$e^+e^- \to HZ$: Higgs Recoil Mass

- ★ **Model independent determination of Higgs mass from Higgsstrahlung events at $\sqrt{s}$ = 250 GeV**
- ★ **Measure four-momentum of Z from its decays to $e^+e^-/\mu^+\mu^-$**
- ★ **Determine Higgs four momentum from recoil mass assuming $\sqrt{s}$ = 250 GeV for underlying e^+e^- collision**
- ★ **Resolution limited by:**
  - **momentum resolution**
  - **beamstralung**
  - **+bremβtrahlung for electron final state**



- ★ **Select events using only information from di-lepton system**





(250 fb^{-1})

Significant Bhabha background

Model independent results:

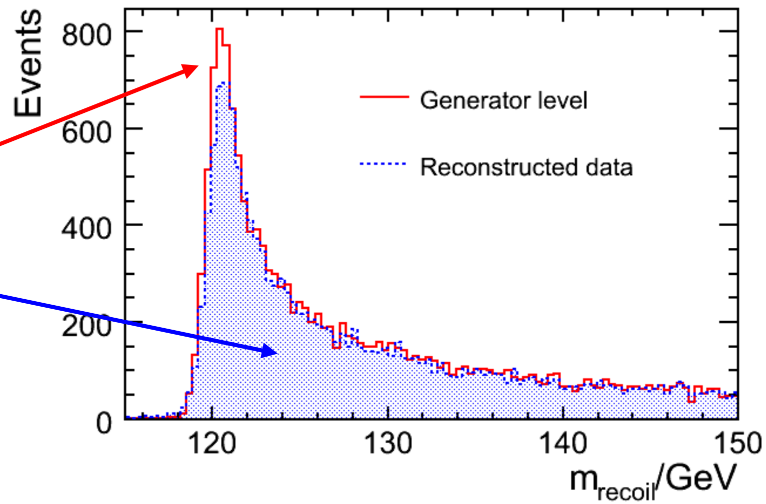
Pol(e^-,e^+)	Channel	$\sigma(m_H)$	Cross-section (LoI)
-80 %, +30%	$\mu\mu$X	85 MeV	±0.70 fb (6.6 %)
	eeX	150 MeV	±1.15 fb (9.8%)

⇒ $\sigma(m_H)$ = 74 MeV

★ In Model Dependent analysis (i.e. assuming SM Higgs decays) SM background ~ halved ⇒ $\sigma(m_H)$ = 67 MeV

Relation to detector performance

- This is a benchmark analysis for momentum resolution performance
- Beamstrahlung and beam energy spread also impact recoil mass resolution
- Width of $\mu\mu$X recoil mass peak:
  - **730 MeV** for perfect resolution
  - **870 MeV** after reconstruction
- Here beam effects dominate !
- **NOTE:** mc generation assumed 0.3 % Gaussian beam energy spread

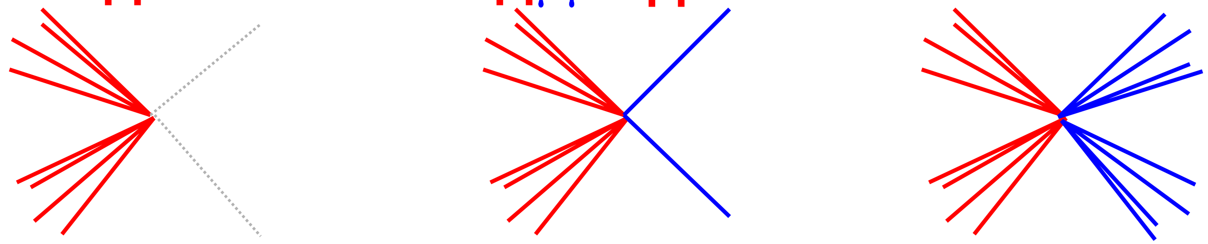


Interpretation depends strongly on whether lumi. spectrum is realistic

$e^+e^- \rightarrow HZ$: Higgs Branching ratios

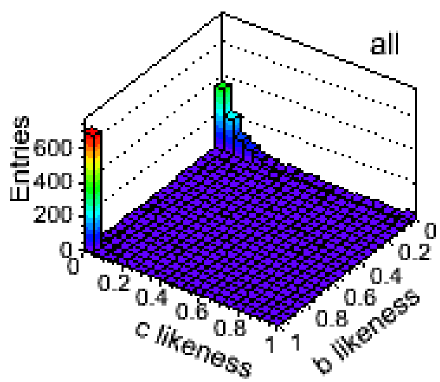
- ★ **Determine BR(H→bb), BR(H→cc), BR(H→gg) from Higgs-strahlung events**
- ★ **Test of flavour tagging performance**
- ★ **Cut based selections of three HZ decay topologies**

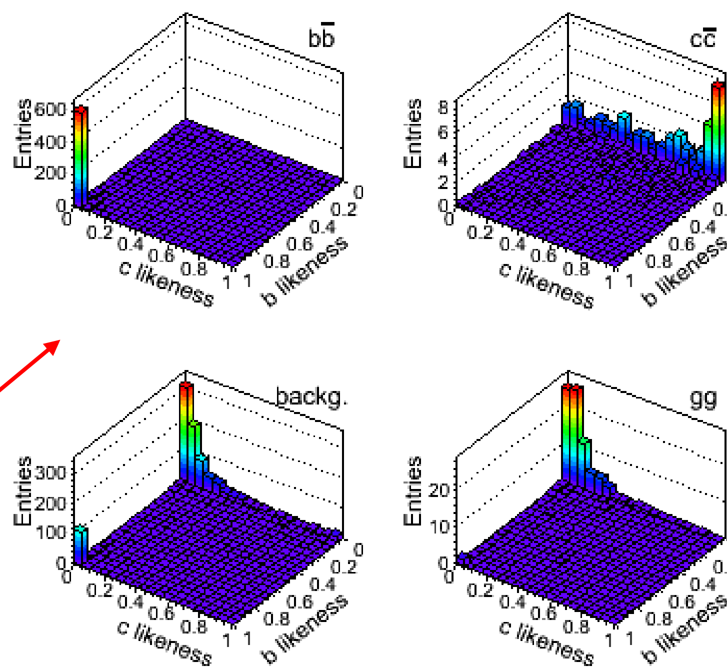
qqνν **qqμμ / qqee** **qqqq**



- ★ **Apply b-tags and c-tags to jets from candidate Higgs decay**

  e.g. qqqq analysis:
  - **Combine b (or c) tags from the two jets**
  - **Plot b-likeness vs. c-likeness**





- **Fit using templates to give exclusive σ**

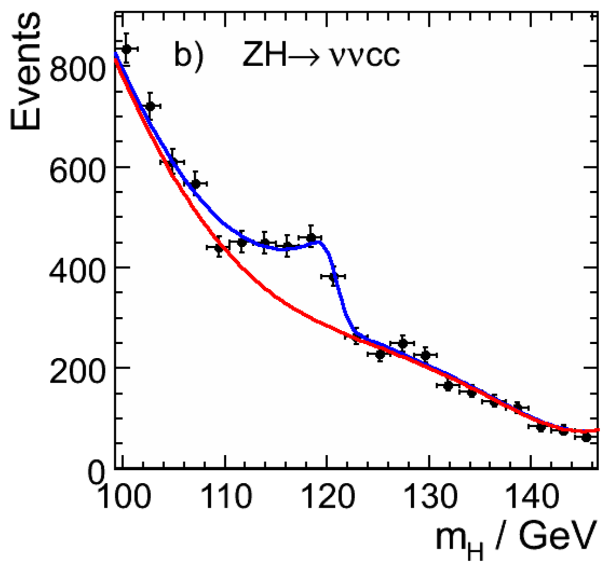
★ Combine with $\sigma(e^+e^- \to HZ)$ from model independent analysis (for LoI 5 % uncertainty) to give BRs

Channel	Br(H→bb)	Br(H→cc)	Br(H→gg)
ZH→qqcc		30 ⊕ 5 %	
ZH→ννqq	5.1 ⊕ 5 %	19 ⊕ 5 %	
ZH→llqq	2.7 ⊕ 5 %	28 ⊕ 5 %	29 ⊕ 5 %
Combined	5.5 %	15 %	29%

★ Results broadly consistent with Tesla TDR (taking into account different lumi. and different √s)

Relation to detector performance

- Current sensitivities probably more a measure of sophistication of the analysis rather than ultimate detector performance, i.e. can improve ⇒ multi-variate (e.g. ANN)
- nonetheless, good performance achieved
- NOTE: in **vvqq** analysis Higgs di-jet mass resolution feeds into final sensitivity



Chargino and Neutralino Production at √s = 500 GeV

★ Chargino and neutralino production in the **SUSY "point 5" scenario** provides a benchmark for jet energy resolution

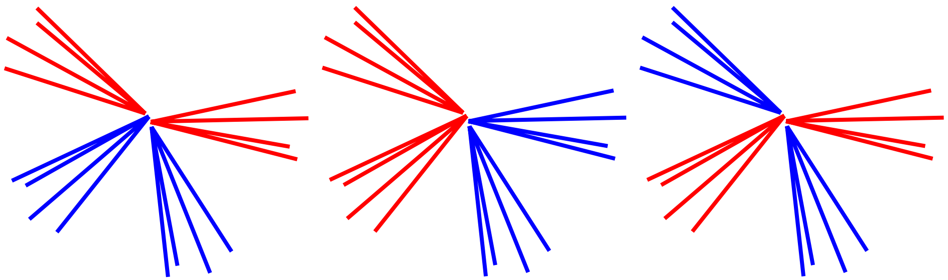
★ $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ and $e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to ZZ\tilde{\chi}_1^0\tilde{\chi}_1^0$ result in final states with four jets and missing energy

★ Neutralino process is challenging: cross section ~10% chargino

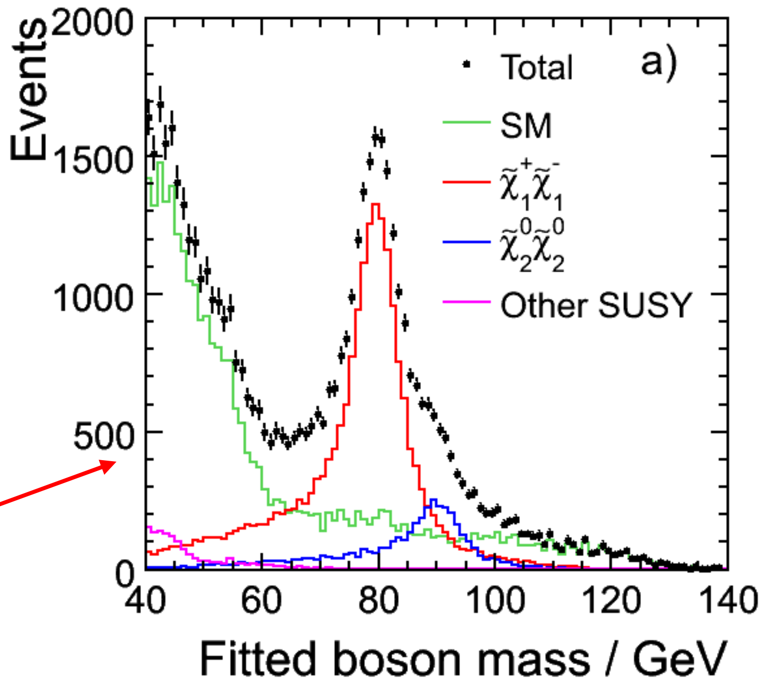
Analysis:

Only time to describe one of two analyses in LoI: method i)

- Select 4 jet + missing E events
- Three possible jet-pairings



- Kin. fit assuming common di-jet mass for two bosons applied to each jet-pairing
- Jet-pairing giving highest fit prob used
- Fit mass distribution to i) SM, ii) chargino and iii) neutralino components to get cross sections



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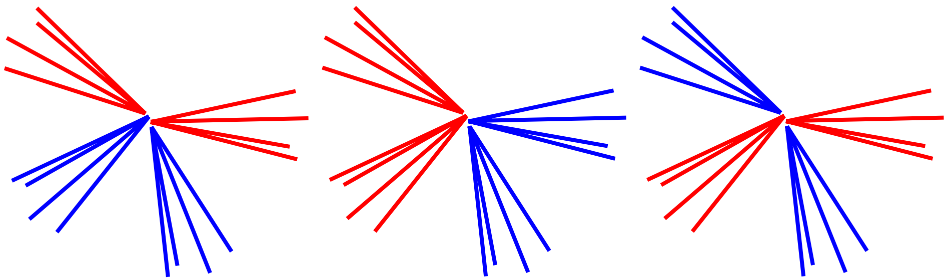

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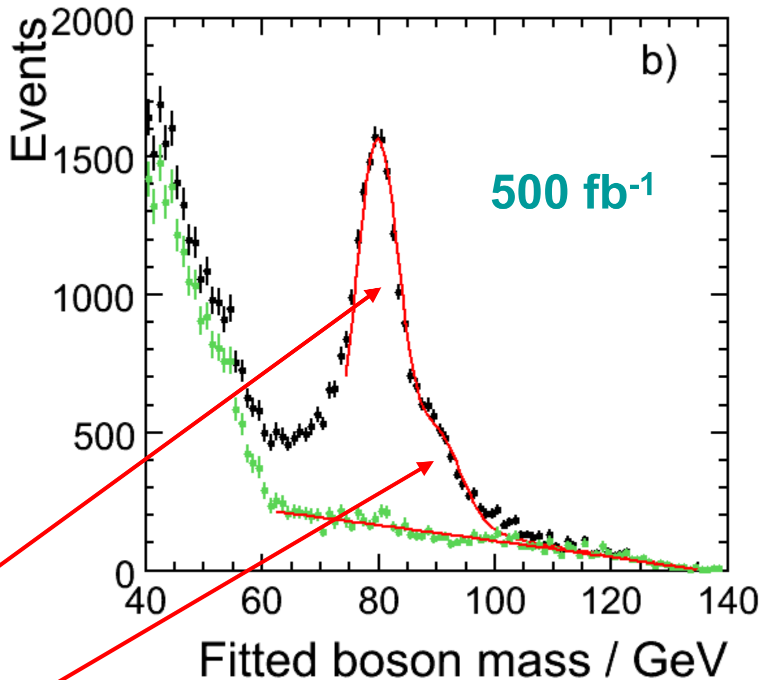
- Fit mass distribution to i) SM, ii) chargino and iii) neutralino components to get cross sections



$$\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0)$$ **0.6 %**

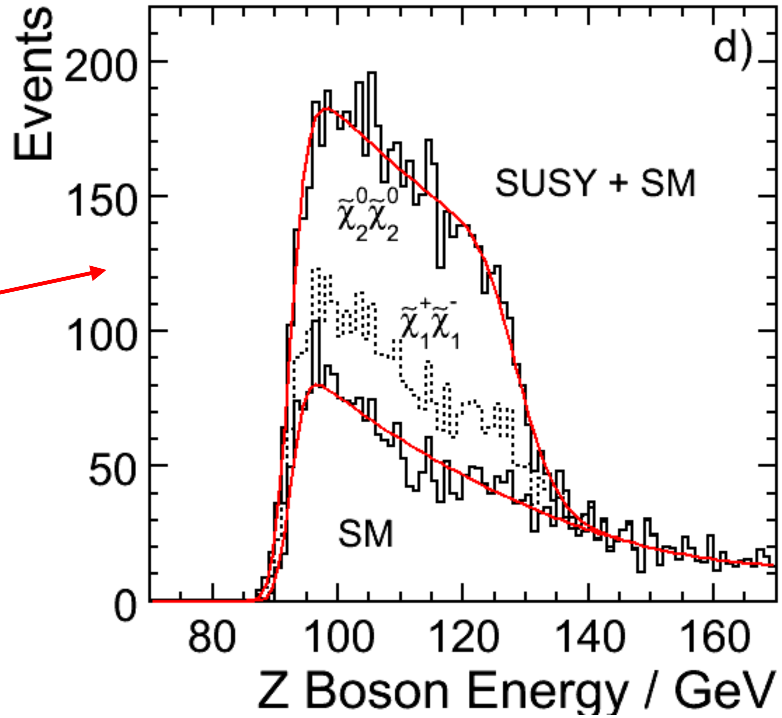
$$\sigma(e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to ZZ\tilde{\chi}_1^0\tilde{\chi}_1^0)$$ **2.1 %**

(method ii)

NOTE: Good jet energy resolution essential to extract neutralino signal from much larger chargino "background"

- ★ Gaugino masses can be reconstructed from decay kinematics
  e.g. $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$
  where masses of $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ from kinematic edges of Z energy dist.
- ★ Excellent ILD jet energy resolution allows a sample of $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$ to be isolated from background
- ★ Neutralino + chargino samples give:

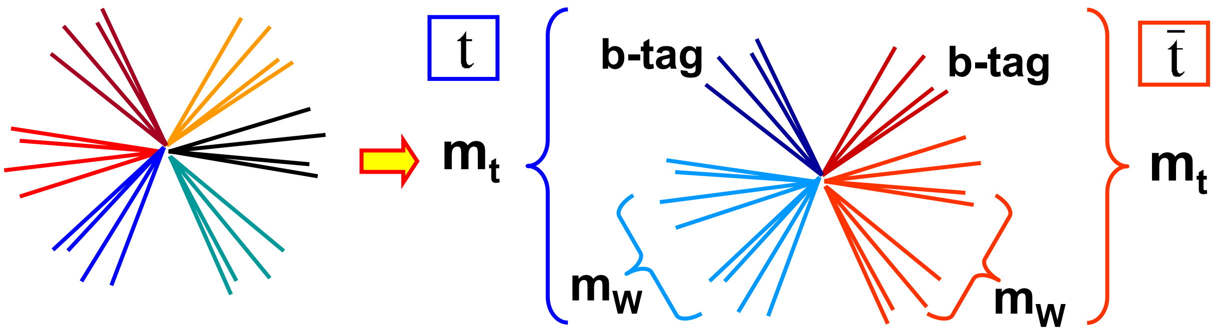
$$m_{\tilde{\chi}_1^\pm} : \pm 2.4\,\mathrm{GeV}$$
$$m_{\tilde{\chi}_1^0} : \pm 0.8\,\mathrm{GeV}$$
$$m_{\tilde{\chi}_2^0} : \pm 0.9\,\mathrm{GeV}$$



NOTE: results correlated as mass differences better determined than mass sums

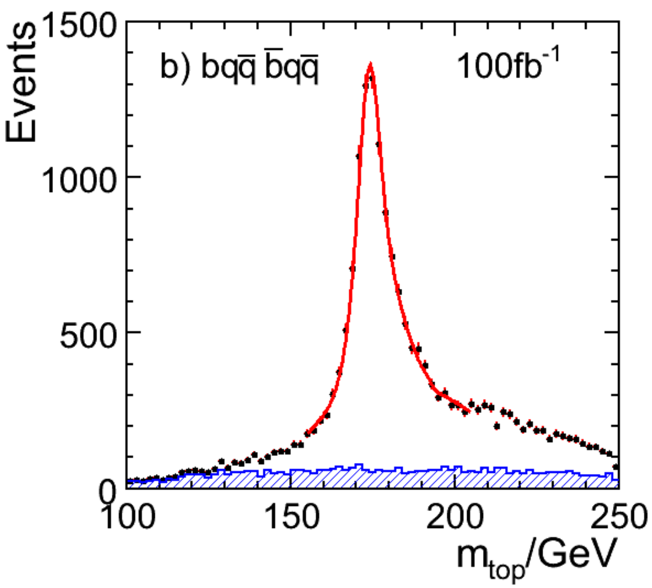
Top production at $\sqrt{s}$ = 500 GeV

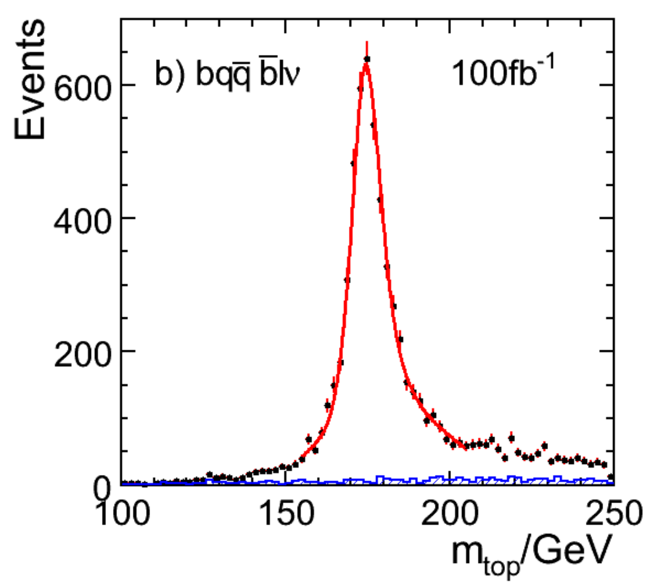
- ★ **At $\sqrt{s}$ = 500 GeV** top mass determined from direct reconstruction of final state
- ★ Fully-hadronic $t\bar{t} \rightarrow (bq\bar{q})(\bar{b}q\bar{q})$ and semi-leptonic $t\bar{t} \rightarrow (bq\bar{q})(\bar{b}\ell\nu)$
- ★ Main analysis issue is that of jet combinatorics



Use:
- b-tagging
- Invariant masses

- ★ Final mass from kinematic fit using chosen jet associations





500 fb^{-1}

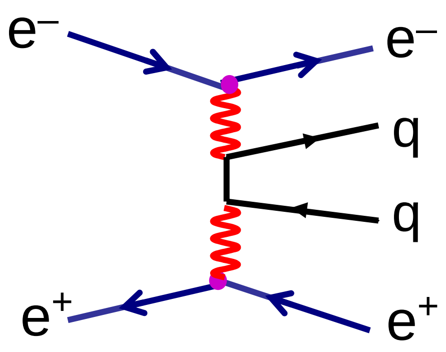
$$m_t \; : \; \pm 30\,\text{MeV}$$

Stau production at √s = 500 GeV

★ For SUSY SPS1a' parameters $e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0\tau^+\tau^-$ gives a relatively low visible energy final state (E_τ ~ 40 GeV)

★ Analysis requires:

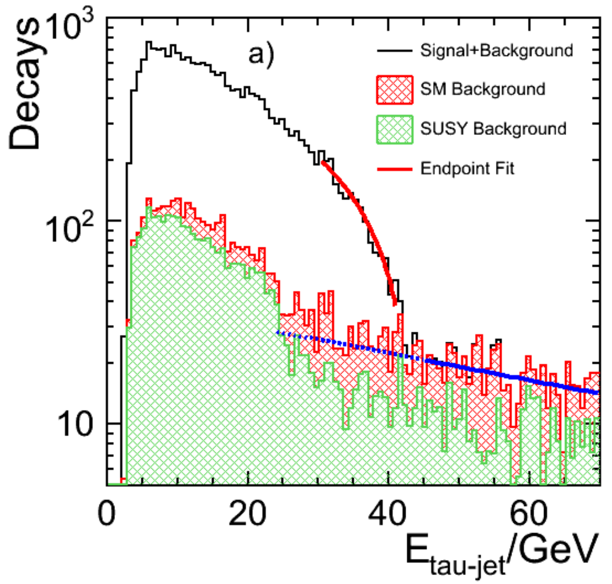
- precise tracking of low momentum particles
- good particle identification
- hermeticity



★ Main analysis issue is very large two photon background

★ Reduced to acceptable level by vetoing forward electron/positron in Beam Calorimeter

★ Fit to endpoint of spectrum (mainly $\tau \to \pi\nu$ decays)



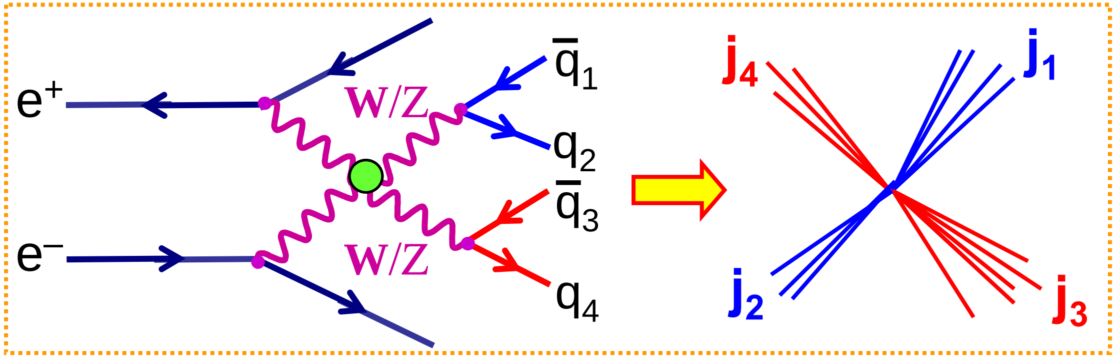
$$m_{\tilde{\tau}_1} \; : \; \pm 100\,\mathrm{MeV} \oplus 1.3\sigma_{m_{\mathrm{LSP}}}$$

★ Post LoI: included beam background, precision essentially same

and finally…WW-scattering at √s = 1 TeV

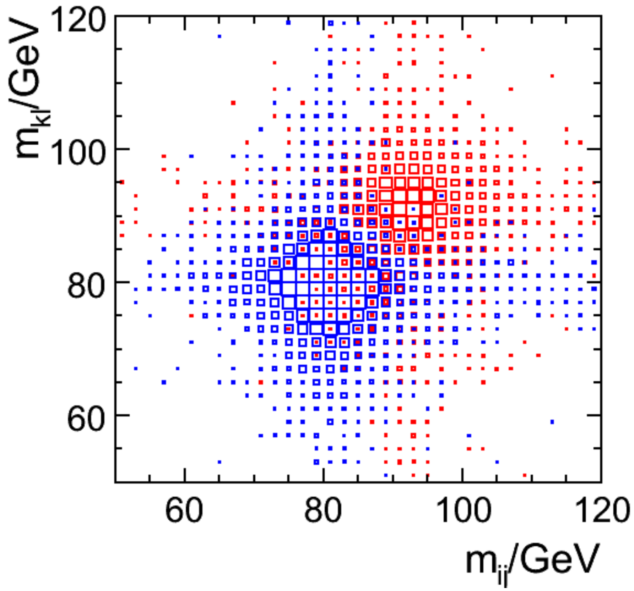
★ **Study** $W^+W^- \to W^+W^-$ **and** $W^+W^- \to ZZ$ **in** $e^+e^- \to \nu\overline{\nu}W^+W^-$ **and** $e^+e^- \to \nu\overline{\nu}ZZ$

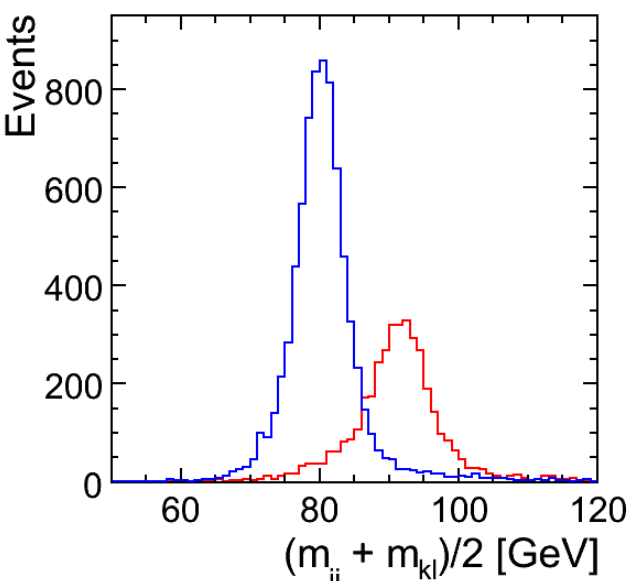
★ **jets + missing energy**



★ **"Classic" benchmark for jet energy resolution**

★ **At 1 TeV clear separation is obtained between W and Z peaks with ILD**





★ **Limits on anomalous couplings similar to earlier fast simulation studies**

Physics Summary

- Only had time to give a flavour of physics studies in ILD LoI
- Whilst the results do not represent the ultimate precision achievable, they:

Demonstrate the high level of performance of ILD

Demonstrate that ILD is an excellent general purpose detector concept for the ILC

Analysis	$\sqrt{s}$	Observable	Precision	Comments
Higgs recoil mass	250 GeV	$\sigma(e^+e^- \to ZH)$	0.5 fb (5.1 %)	Model Independent
		m_H	74 MeV	Model Independent
		m_H	67 MeV	Model Dependent
Higgs Decay	250 GeV	$Br(H \to b\bar{b})$	$2 \oplus 5\,\%$	includes 5 %
		$Br(H \to c\bar{c})$	$14 \oplus 5\,\%$	from
		$Br(H \to gg)$	$29 \oplus 5\,\%$	$\sigma(e^+e^- \to ZH)$
$\tau^+\tau^-$	500 GeV	$\sigma(e^+e^- \to \tau^+\tau^-)$	0.3 %	$\theta_{\tau^+\tau^-} > 178°$
		A_{FB}	±0.003	$\theta_{\tau^+\tau^-} > 178°$
		P_τ	±0.015	$\tau \to \pi\nu$ only
Gaugino Production	500 GeV	$\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-)$	0.6 %	
		$\sigma(e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0)$	2.1 %	
		$m(\tilde{\chi}_1^\pm)$	2.4 GeV	from kin. edges
		$m(\tilde{\chi}_2^0)$	0.9 GeV	from kin. edges
		$m(\tilde{\chi}_1^0)$	0.8 GeV	from kin. edges
$e^+e^- \to t\bar{t}$	500 GeV	$\sigma(e^+e^- \to t\bar{t})$	0.4 %	$(bq\bar{q})$ $(\bar{b}q\bar{q})$ only
		m_t	40 MeV	fully-hadronic only
		m_t	30 MeV	+ semi-leptonic
		Γ_t	27 MeV	fully-hadronic only
		Γ_t	22 MeV	+ semi-leptonic
Smuons in SPS1a'	500 GeV	$\sigma(e^+e^- \to \tilde{\mu}_L^+\tilde{\mu}_L^-)$	2.5 %	measurements
		$m(\tilde{\mu}_L)$	0.5 GeV	
Staus in SPS1a'	500 GeV	$m(\tilde{\tau}_1)$	$0.1\,\text{GeV} \oplus 1.3\sigma_{LSP}$	
WW Scattering	1 TeV	α_4	$-1.4 < \alpha_4 < 1.1$	
		α_5	$-0.9 < \alpha_5 < +0.8$	

+ photon final states (GMSB/WIMPS)
+ Littlest Higgs
+ beam polarisation from WW

❹ Conclusions

★ **ILD is powerful general purpose detector for the ILC based on particle flow calorimetry**

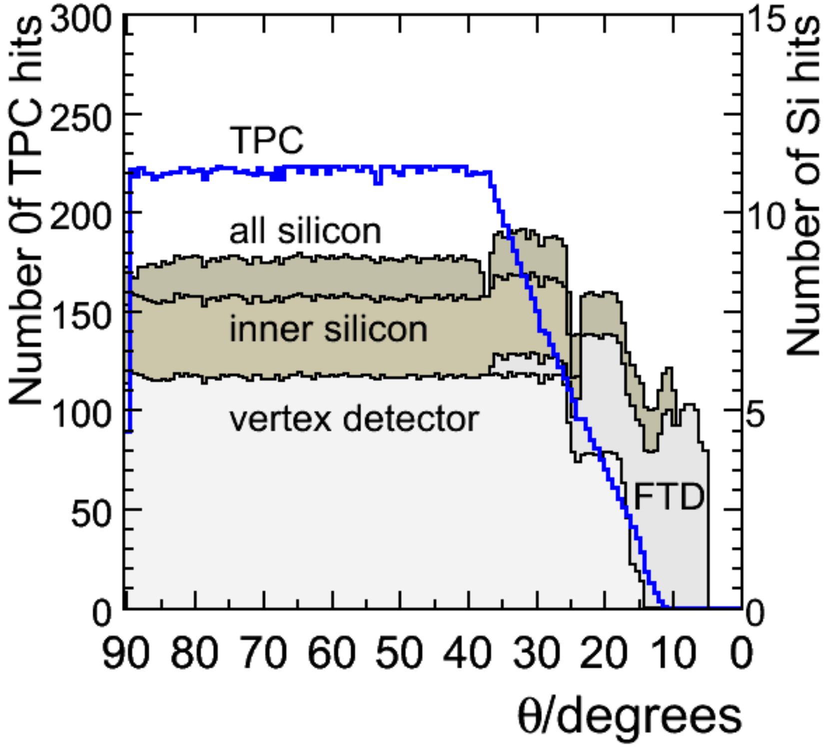
★ **The ILD parameters were chosen on the basis of an extensive series of optimisation studies**
- **now have a much better understanding of the performance issues**

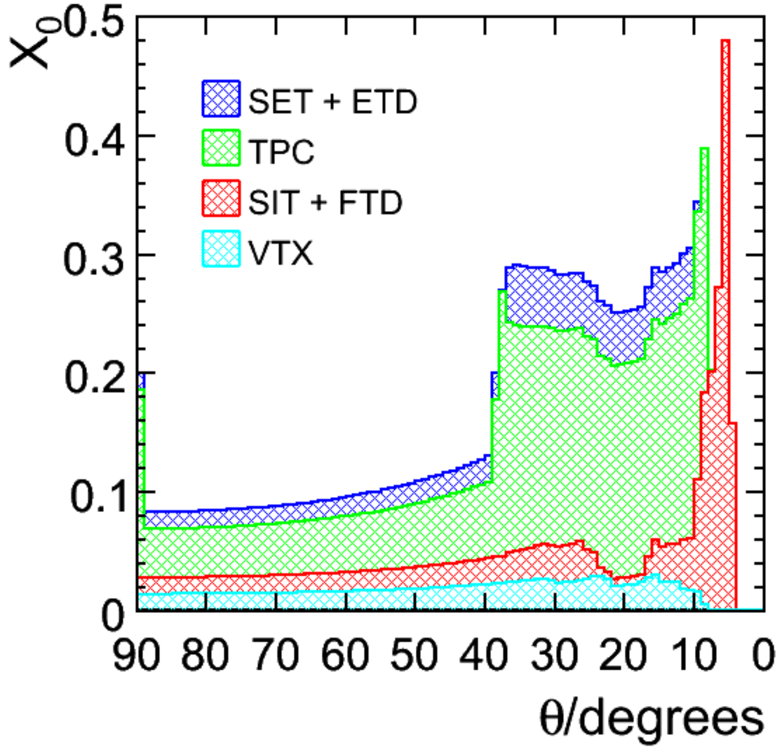
★ **ILD meets the performance goals for a detector at the ILC**
- ***highly performant tracking***
- ***excellent flavour tagging capability***
- ***unprecedented jet energy resolution***

★ **ILD physics studies have started in earnest, and the results presented in the LoI hopefully demonstrate the general purpose nature of the concept**

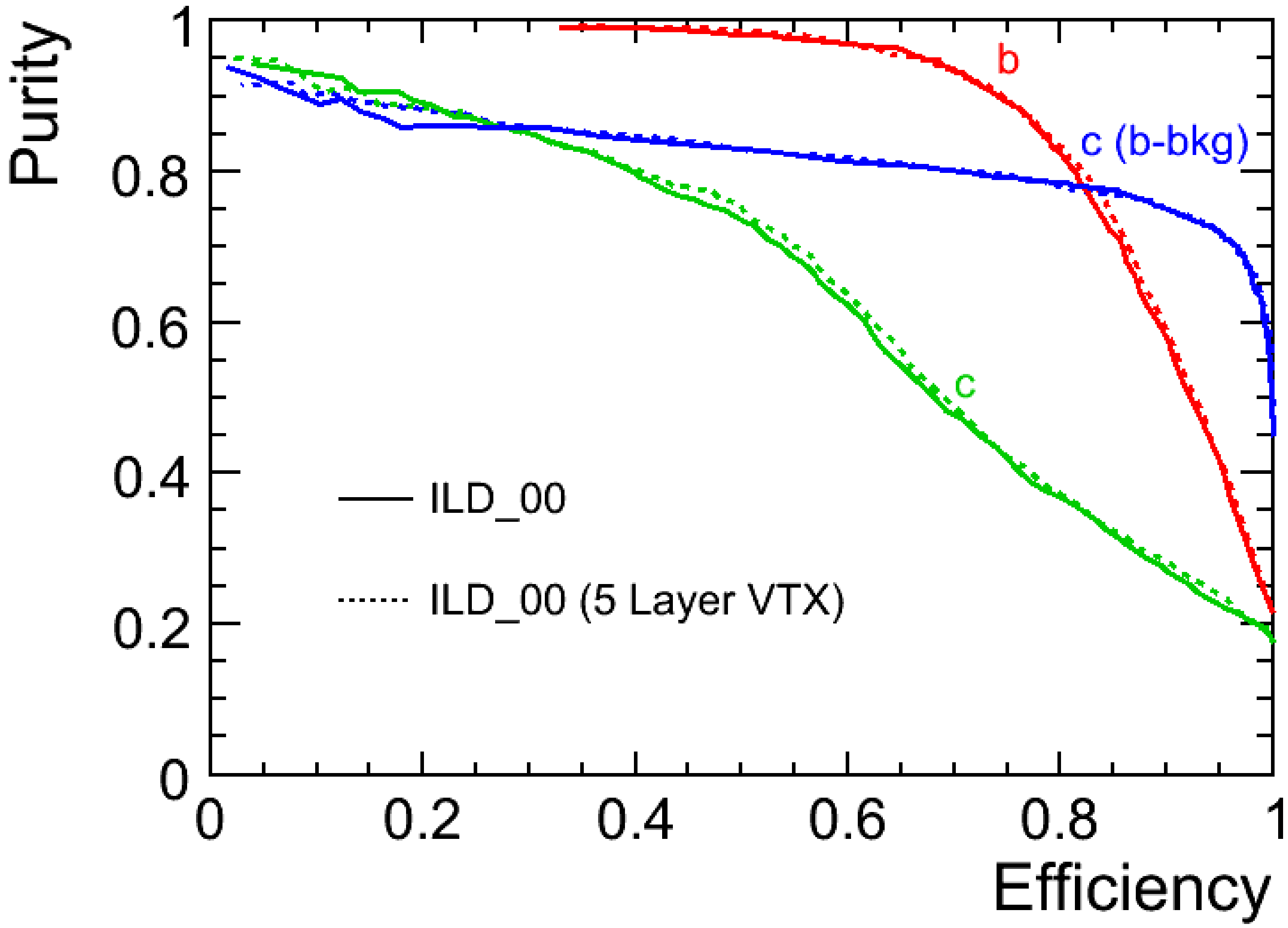
Over to Sugimoto-san…

Backup slides: tracking coverage and material

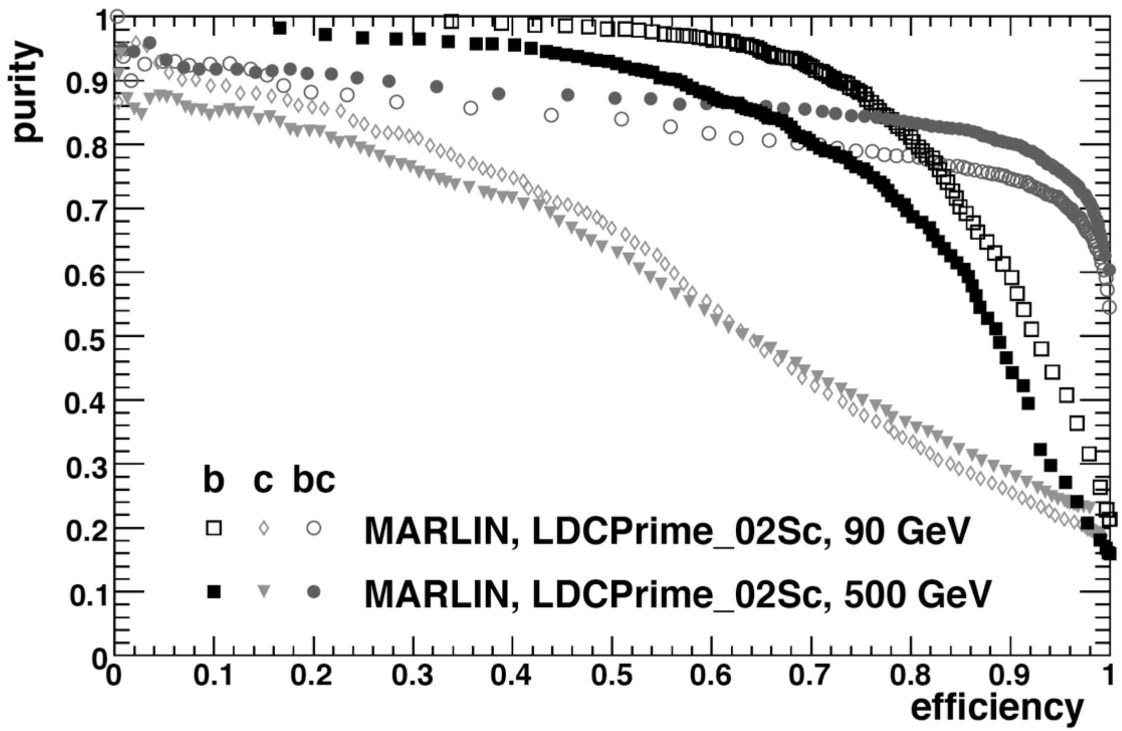




Bacjup: ILD Flavour Tagging Efficiency



Backup : Flavour tagging: higher energies



★ANNs were not tuned for 250 GeV jets

Flavour composition	91.2 GeV	500 GeV
bb	22%	15%
cc	17%	25%
uu, dd, ss	61%	60%

Backup: ILD Tau Pairs