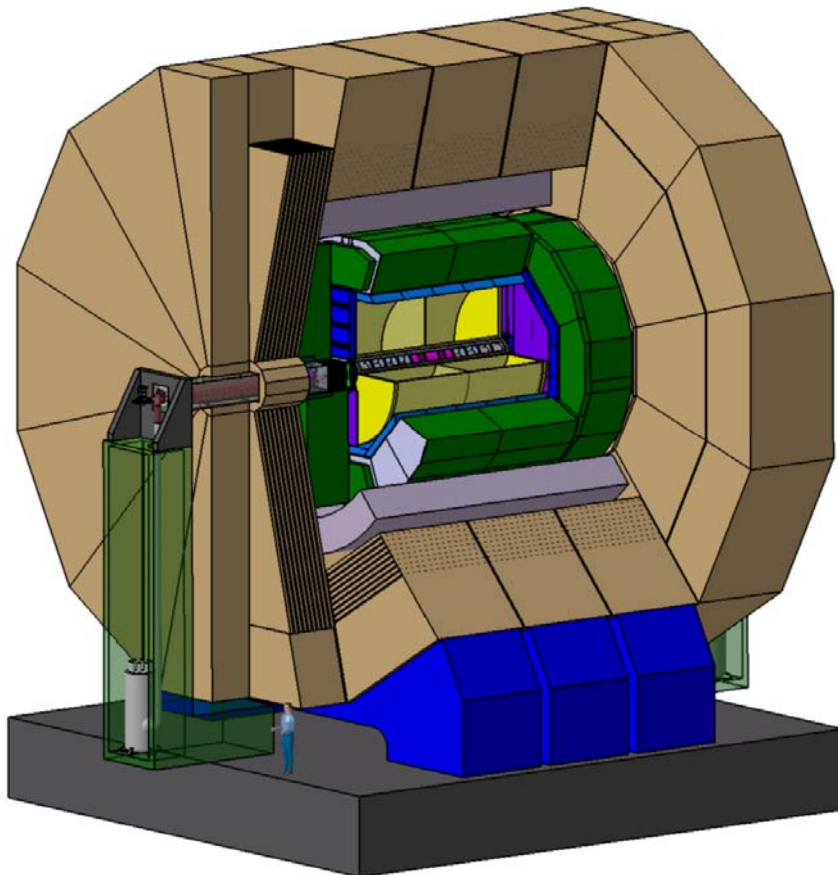


The ILD Letter of Intent: Optimisation and Performance

Mark Thomson
for the ILD group



This talk:

- 1 Introduction
- 2 Optimisation of ILD
(GLD/LDC→ILD)
- 3 Performance
- 4 Conclusions

1 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 Lol, supporting documents and parallel session talks

2 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

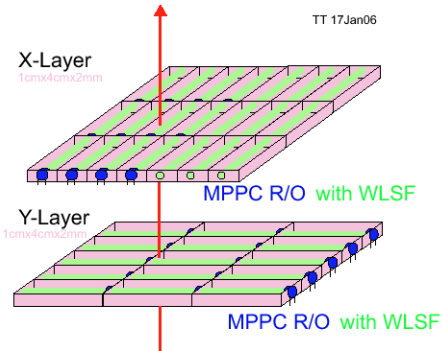
	LDC		GLD	ILD ?
Tracker	TPC		TPC	TPC
R_{TPC} =	1.5 m		2.0 m	1.5 – 2.0 m
B =	4 T		3 T	3 – 4 T
Vertex	5 single layers		3 double layers	?
ECAL	SiW pixels		Scint strips	?
HCAL	Steel	RPC	Steel-Scint	?
		Scint		

Main ILD sub-detector options

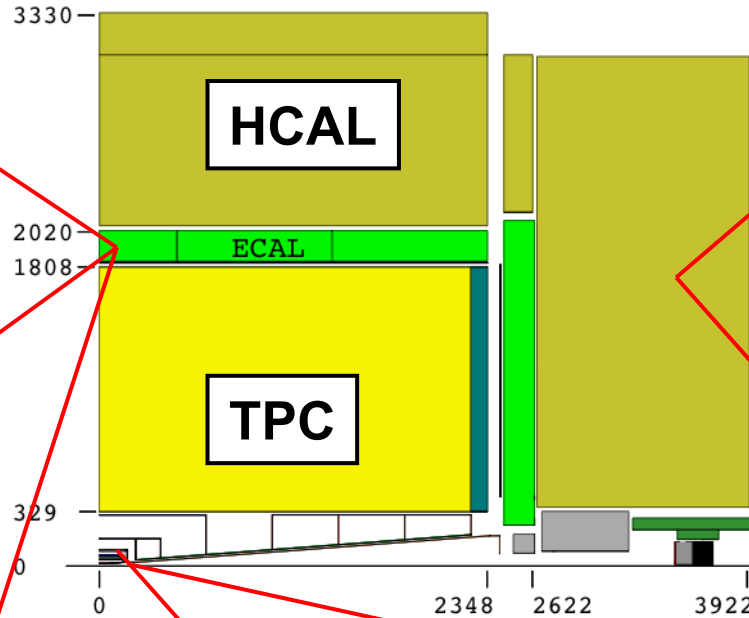
ECAL

★ SiW: $5 \times 5 \text{ mm}^2$

★ ScintW: strips



★ MAPS: digital



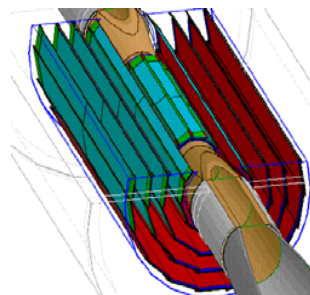
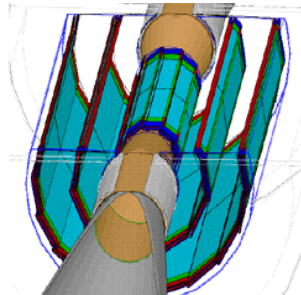
HCAL

★ Steel Scint.
Analogue
 $3 \times 3 \text{ cm}^2$ tiles

★ Steel RPC
Digital
 $1 \times 1 \text{ cm}^2$

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”

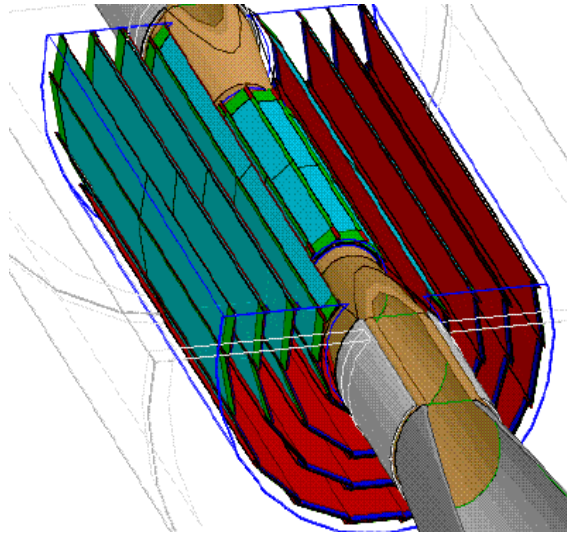
Medium

“Small”

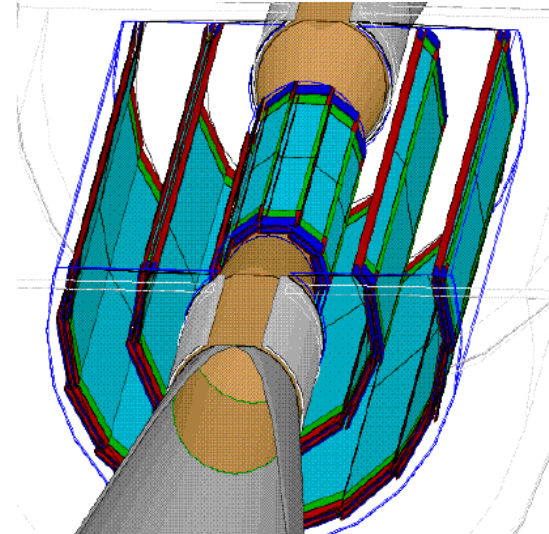
Sub-Detector	Parameter	GLD	LDC	GLD'	LDC'
TPC	R _{outer} (m)	1.98	1.51	1.74	1.73
Barrel ECAL	R _{inner} (m)	2.10	1.61	1.85	1.82
	Material	Sci/W	Si/W	Sci/W	Si/W
Barrel HCAL	Material	Sci/Fe	Sci/Fe	Sci/Fe	Sci/Fe
Solenoid	B-field	3.0	4.0	3.50	3.50
VTX	Inner Layer (mm)	17.5	14.0	16	15

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

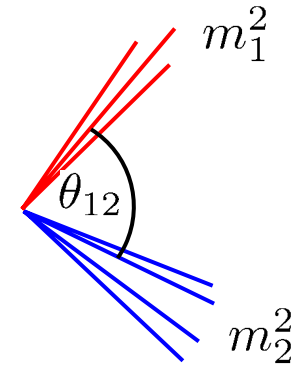
Role of Particle Flow in ILD optimisation

- ★ 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 $30\%/ \sqrt{E}$**
- ★ **Want to separate W and Z di-jet decays**
- ★ **For di-jet mass resolution of order**

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



$\sim 2.75\sigma$ separation between W and Z peaks

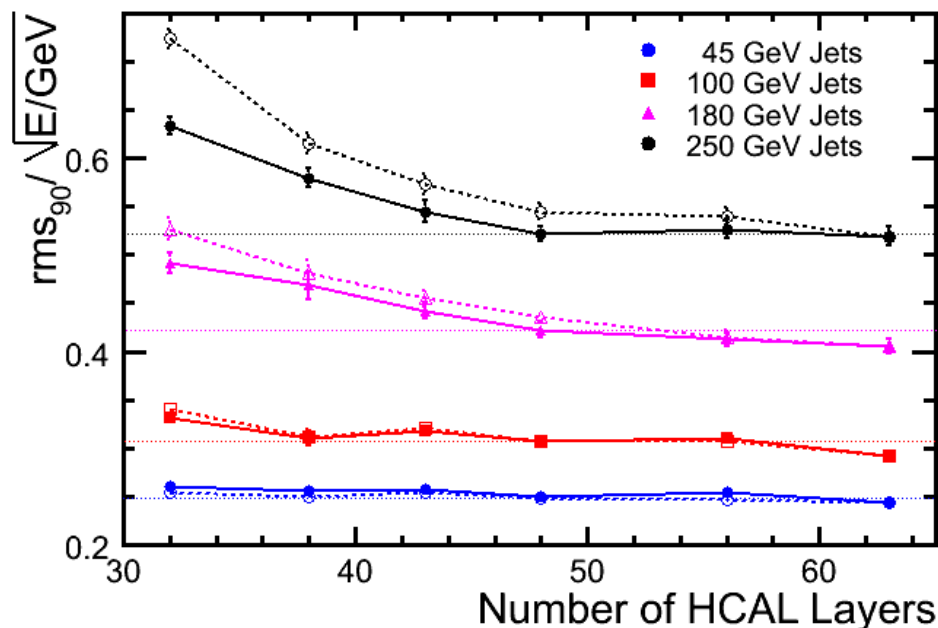
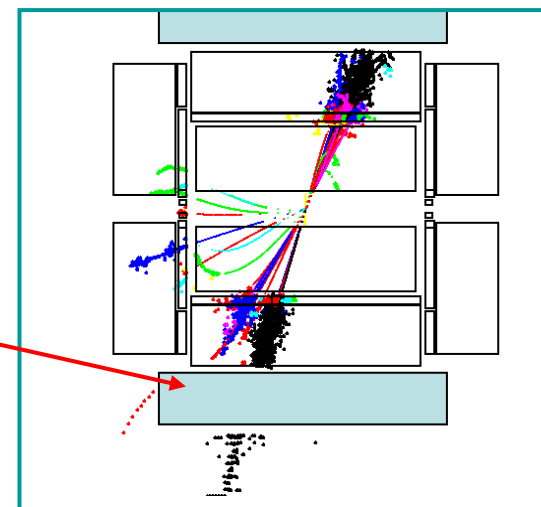


$$\sigma_{E_j}/E_j < 3.8\%$$

- ★ **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

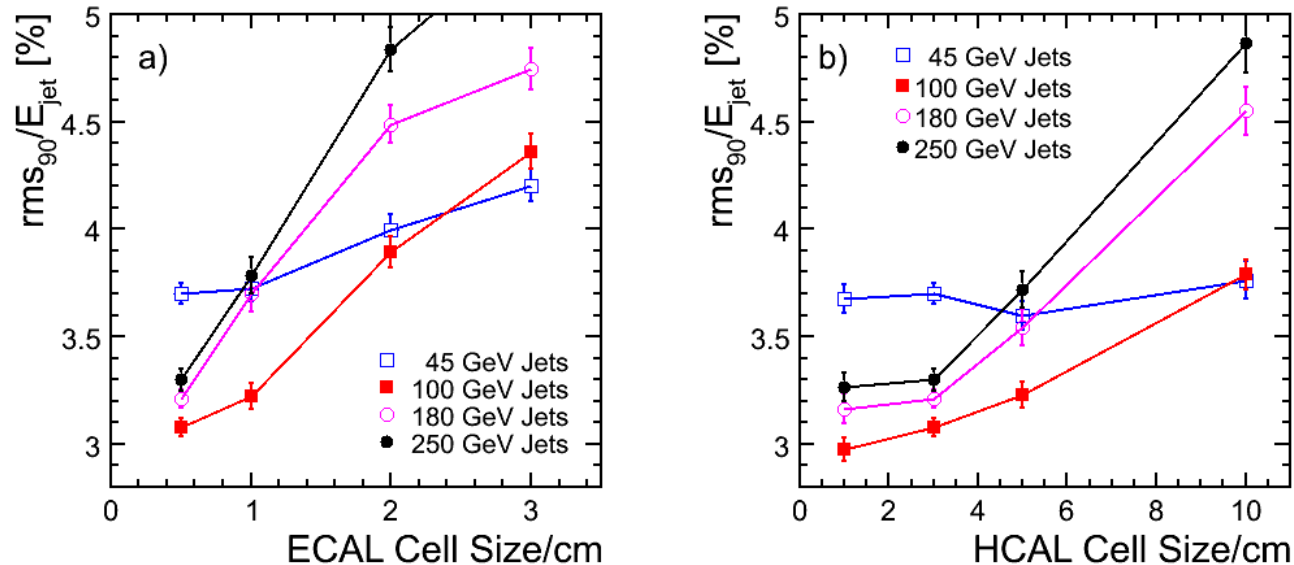


HCAL Layers	λ_I	
	HCAL	+ECAL
32	4.0	4.8
38	4.7	5.5
43	5.4	6.2
48	6.0	6.8
63	7.9	8.7

- ★ 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:

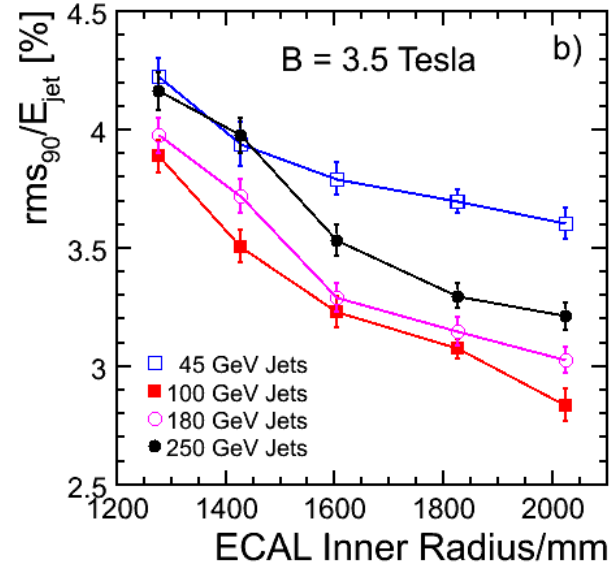
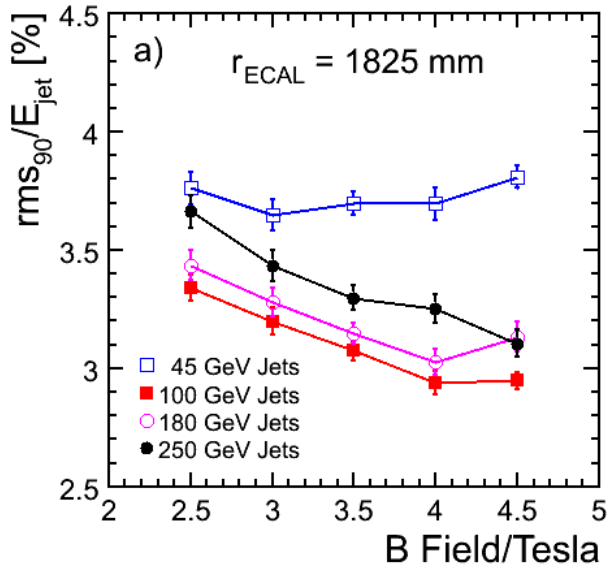
- Ability to resolve photons in **current PandoraPFA algorithm** strongly dependent on transverse cell size
- Require at least as fine as **10x10 mm²** to achieve **3.8 % jet E resolution**
- Significant advantages in going to **5x5 mm²**
- For **45 GeV jets resolution dominates (confusion relatively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

★ HCAL Conclusions:

- For **current PandoraPFA algorithm** and Scintillator (analogue) HCAL a tile size of **3x3 cm²** looks optimal

PFA Optimisation: B vs Radius

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



★ Empirically find

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

Resolution

Tracking

Leakage

Confusion

★ Conclude:

- R is more important than B for PFA performance
- Confusion term $\propto B^{-0.3}R^{-1}$
- 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

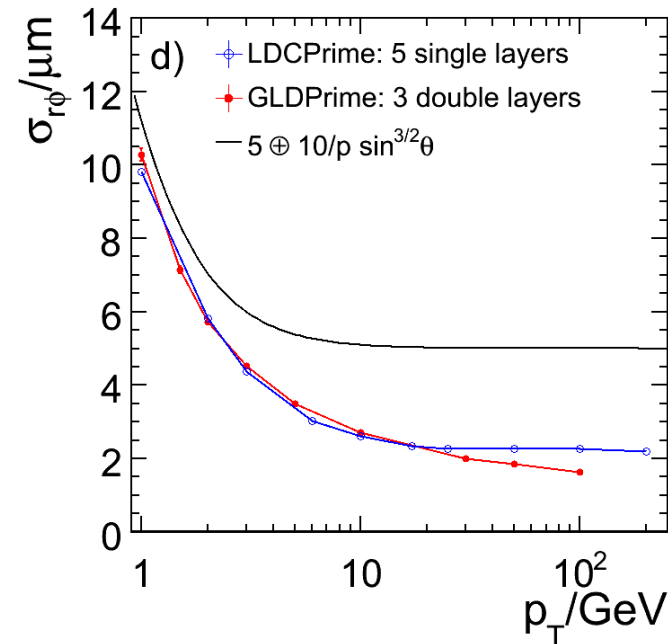
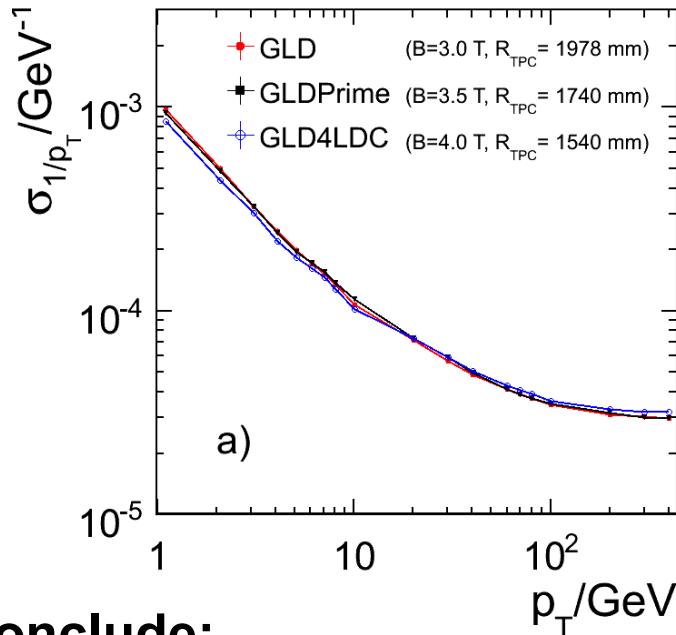
★ Conclude:

- 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

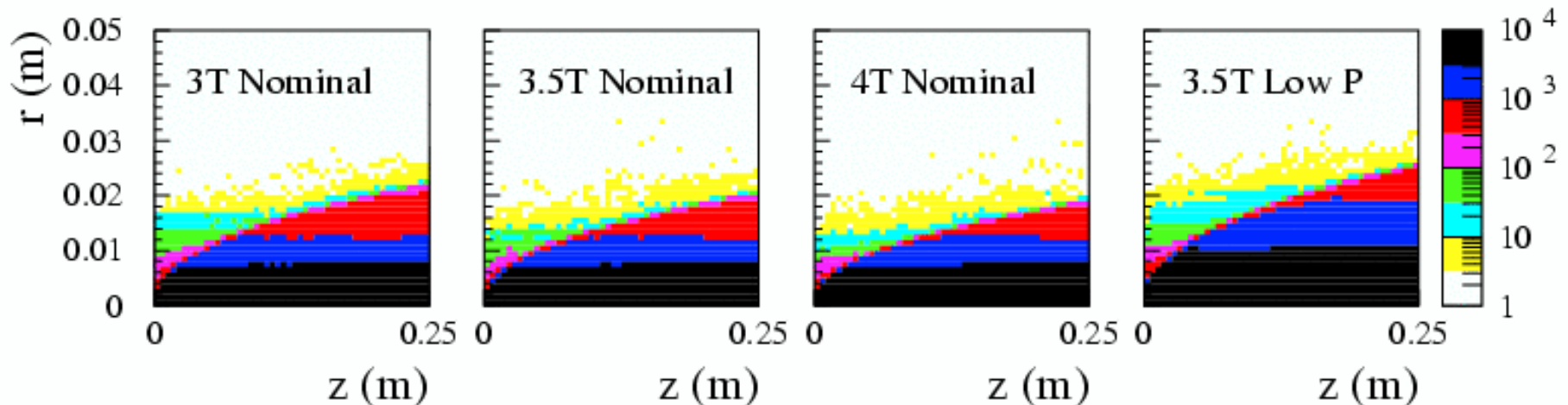


- ★ Conclude:

- 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

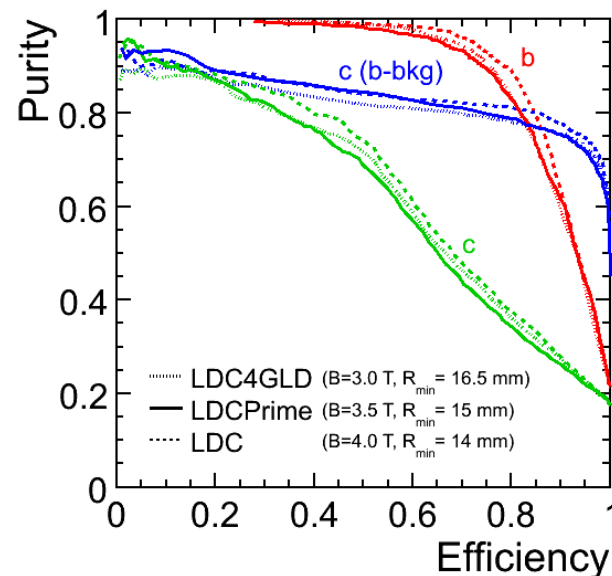
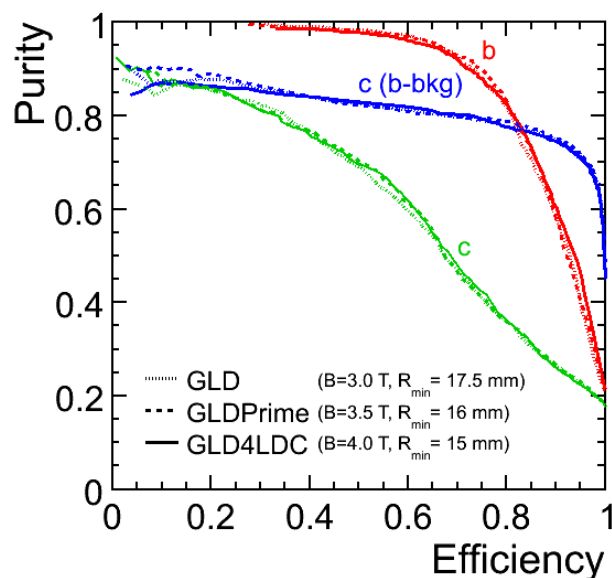
- ★ Large beam background of low p_T electron/positron pairs
 - Radius of pair background envelope is determined by B
 - Determines the minimum inner radius of the vertex detector
 - Potential to impact flavour tagging performance
- ★ But radius of pair background envelope scales only as \sqrt{B}



- ★ Dependence of inner radius of vertex detector is weaker than \sqrt{B}
 - fixed clearance between background and beam pipe and beam pipe and vertex detector
- ★ Consequently 4 T \rightarrow 3 T translates to a $\sim 10\%$ difference in inner radius of vertex detector

ILD Optimisation: Flavour Tagging

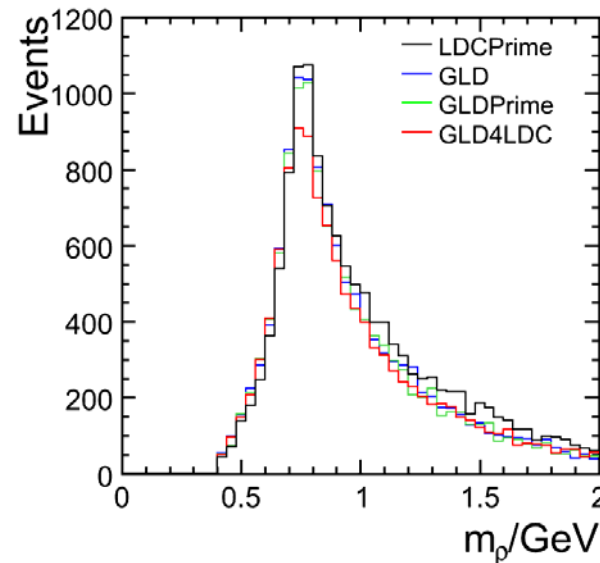
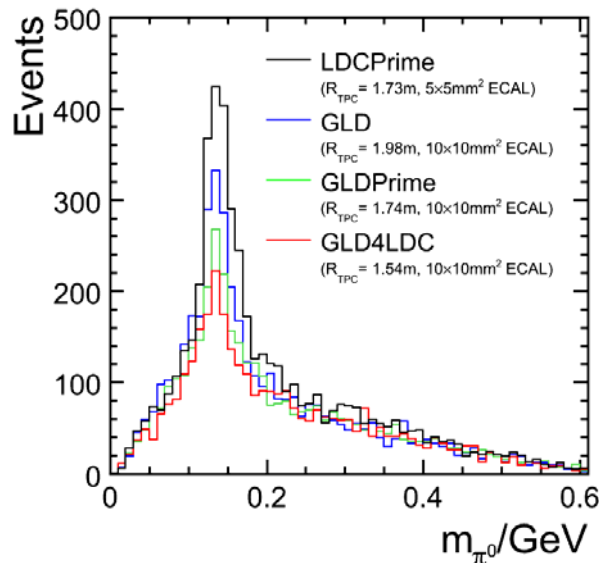
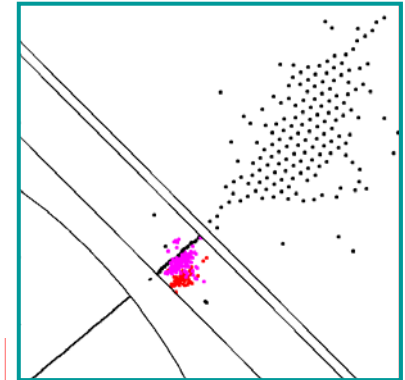
- ★ Compare flavour tagging performance for GLD and LDC based models
 - Differences of 2.5 mm in inner radius of beam pipe due to B field
- ★ Use “State-of-the-Art” LCFIVertex algorithms
 - ANNs separately tuned for the different detector models
 - **NOTE:** ~2% stat. uncertainties on results from ANN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



- ★ **Conclude:**
 - 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 $e^+e^- \rightarrow ZH \rightarrow e^+e^-X/\mu^+\mu^-X$
 - 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. $\tau^- \rightarrow \rho^- \nu_\tau \rightarrow \pi^+ \pi^0 \nu_\tau$
- ★ For reconstruction of both photons from $\pi^0 \rightarrow \gamma\gamma$
 - $5 \times 5 \text{ mm}^2$ is a significant advantage
 - larger radius also helps



- ★ But impact on physics sensitivity less pronounced

ILD Optimisation: Summary

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

- ★ 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 $< 10 \times 10 \text{ mm}^2$ ($5 \times 5 \text{ mm}^2$ preferred)
 - HCAL $\sim 3 \times 3 \text{ cm}^2$ (no obvious advantage in higher granular for analogue HCAL)

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

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
- ★ $r_{\text{ECAL}} = 1.85 \text{ m}$
 - for B = 3.5 T need $\sim 1.55 \text{ m}$ to reach jet E goal
 - then allow for uncertainties in shower simulation
 - larger radius brings performance advantages ($\sim 16 \%$ for 1.85 c.f. 1.55)
- ★ Technology
 - no selection at this stage

3 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 mm²**

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

HCAL: **3x3 cm² Scint. tiles**

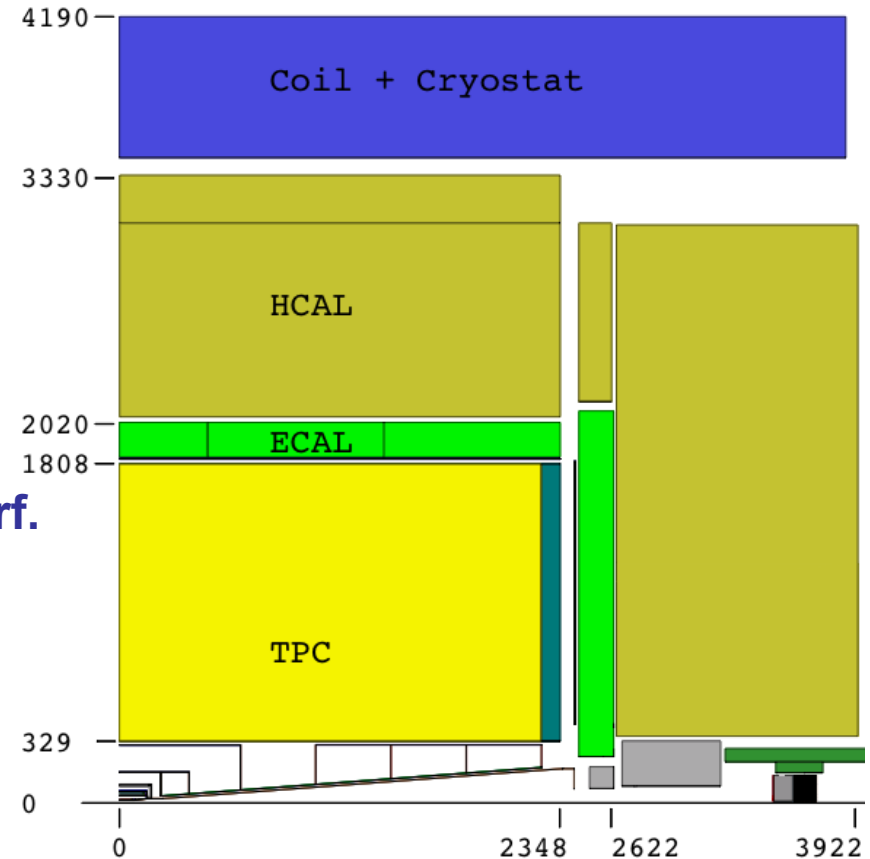
- PFA with digital/semi-digital HCAL not yet **fully** demonstrated
- First studies indicate comparable perf.

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°

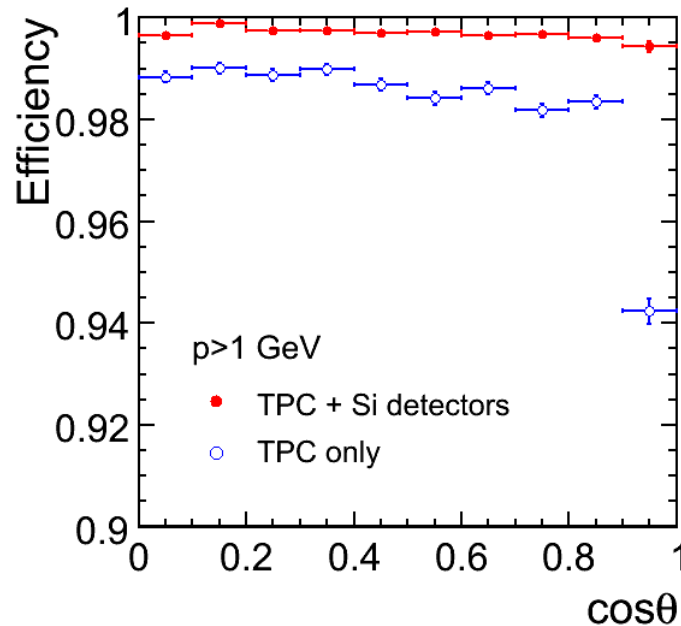
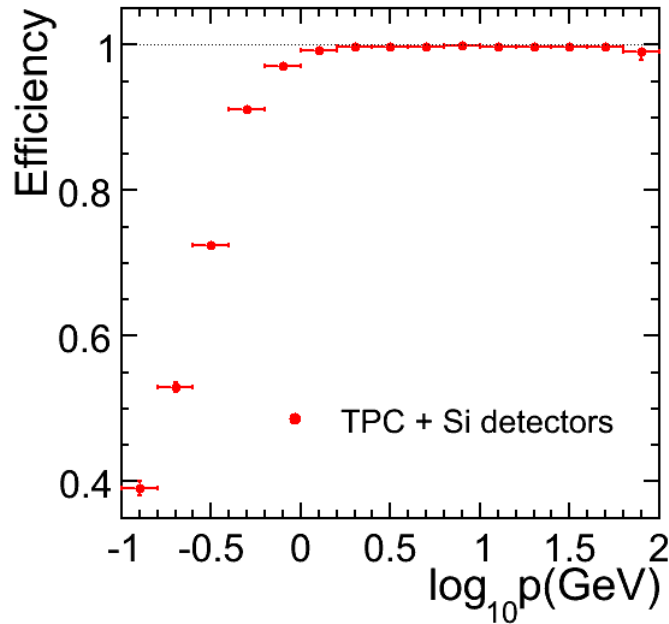


Level of detail in GEANT4 model probably as good as most TDRs !

Performance Highlights: Track Finding Efficiency

★ Achieve very high track reconstruction efficiency (full reconstruction)

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



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

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

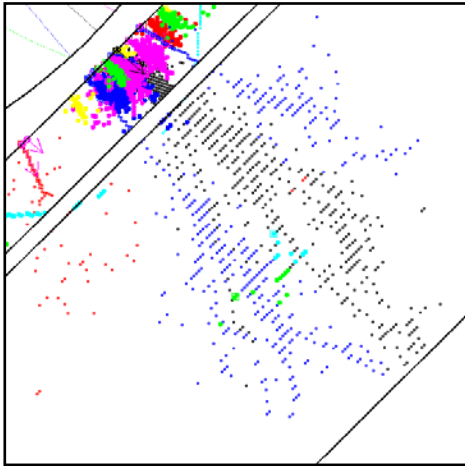
NOTE: beam background not included

- 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
- $|\cos\theta| < 0.7$

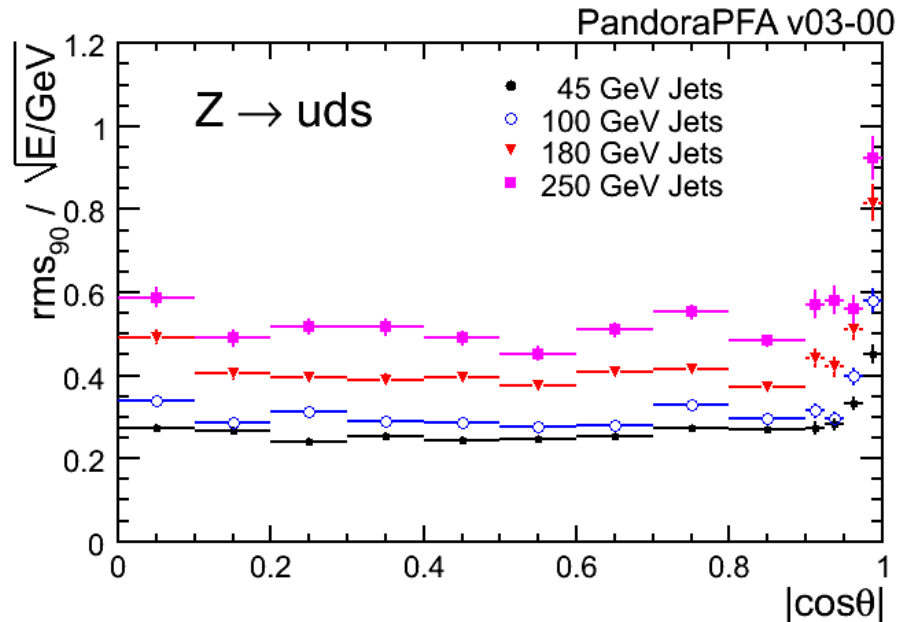


E_j	$\sigma(E_{jj})$	$\sigma(E_{jj})/\sqrt{E_{jj}}$	$\sigma(E_j)/E_j$
45 GeV	2.4 GeV	25 %	3.7 %
100 GeV	4.1 GeV	29 %	2.9 %
180 GeV	7.5 GeV	40 %	3.0 %
250 GeV	11.1 GeV	50 %	3.2 %

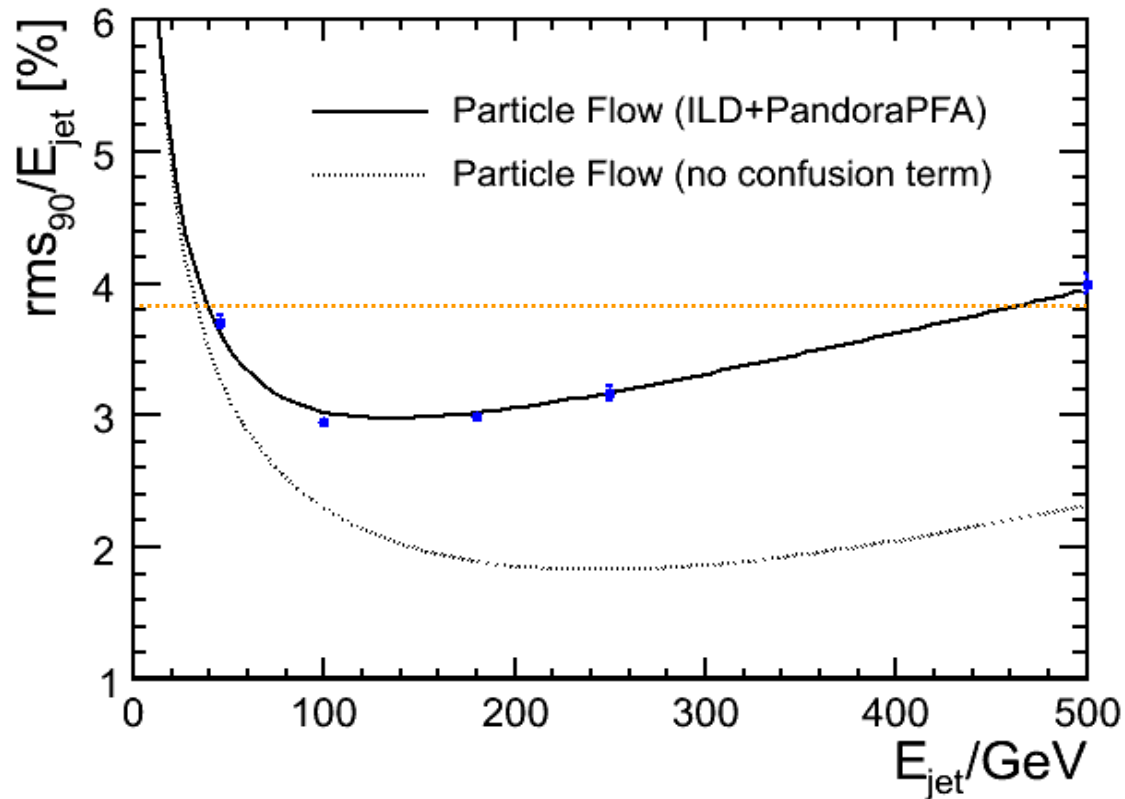
di-jet
jet

NOTE:

- $\sigma_E = \text{rms}_{90}$
- In terms of statistical power $\text{rms}_{90} \times 1.1 \approx \text{Gaussian equiv.}$
- No strong angular dependence down to $\cos\theta \sim 0.975$



- ★ Previously argued aiming for $\sigma(E_{\text{jet}})/E_{\text{jet}} < 3.8 \%$
- ★ **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 Lol
 - “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 !

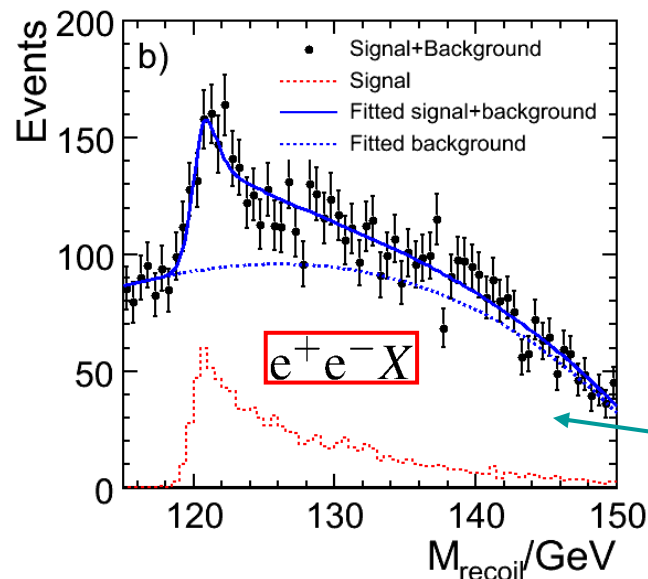
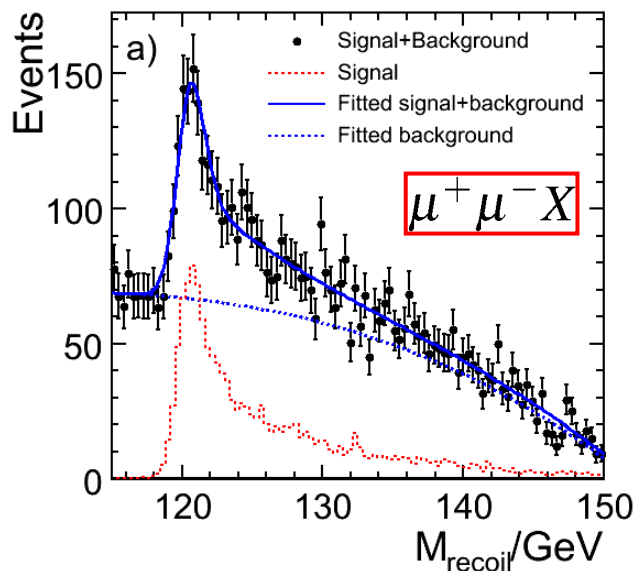
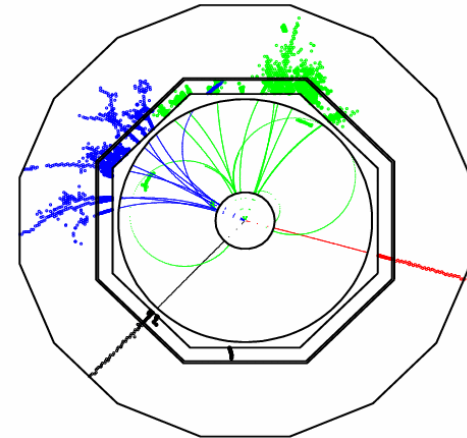
Caveats:

- 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 Lol**

$e^+e^- \rightarrow HZ$: 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**
 - **beamstrahlung**
 - **+bremßstrahlung** 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 (Lol)
-80 %, +30%	$\mu\mu X$	85 MeV	± 0.70 fb (6.6 %)
	eeX	150 MeV	± 1.15 fb (9.8%)



$$\sigma(m_H) = 74 \text{ MeV}$$

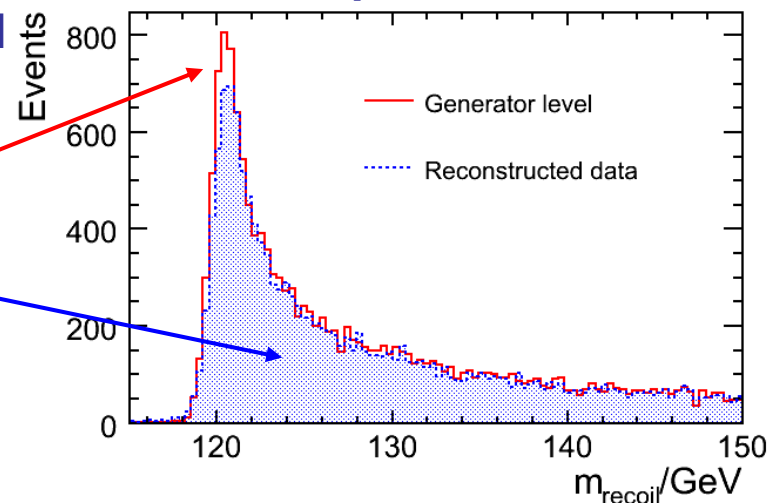
★ In **Model Dependent** analysis (i.e. assuming SM Higgs decays) SM background \sim halved



$$\sigma(m_H) = 67 \text{ MeV}$$

Relation to detector performance

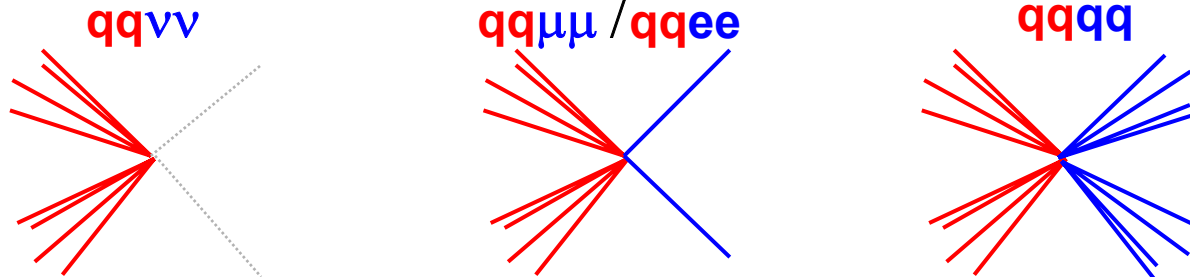
- This is a benchmark analysis for momentum resolution performance
- Beamstrahlung and beam energy spread also impact recoil mass resolution
- Width of $\mu\mu X$ recoil mass peak:
 - 730 MeV for perfect resolution
 - 870 MeV after reconstruction
- **Here beam effects dominate !**
- **NOTE:** mc generation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



Interpretation depends strongly on whether lumi. spectrum is realistic

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

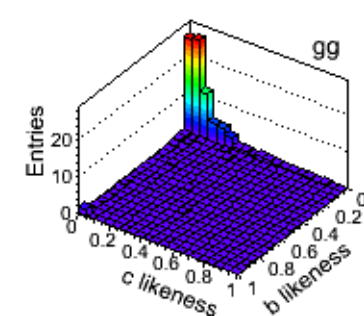
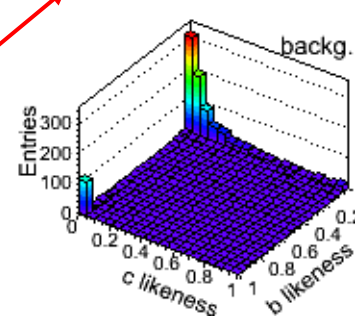
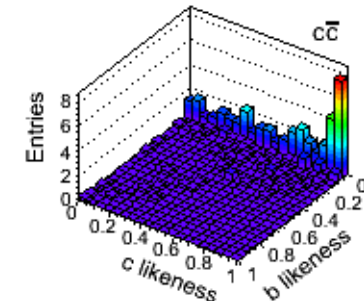
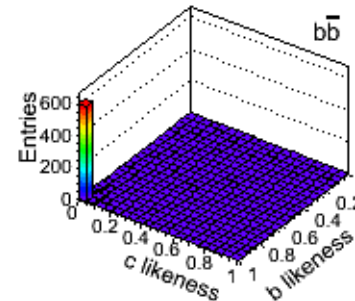
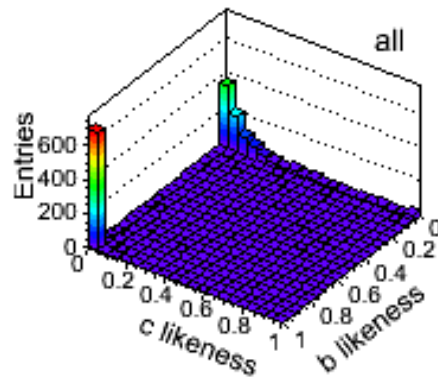
- ★ Determine $BR(H \rightarrow bb)$, $BR(H \rightarrow cc)$, $BR(H \rightarrow gg)$ from Higgs-strahlung events
- ★ Test of flavour tagging performance
- ★ **Cut based selections** of three **HZ** decay topologies



- ★ 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

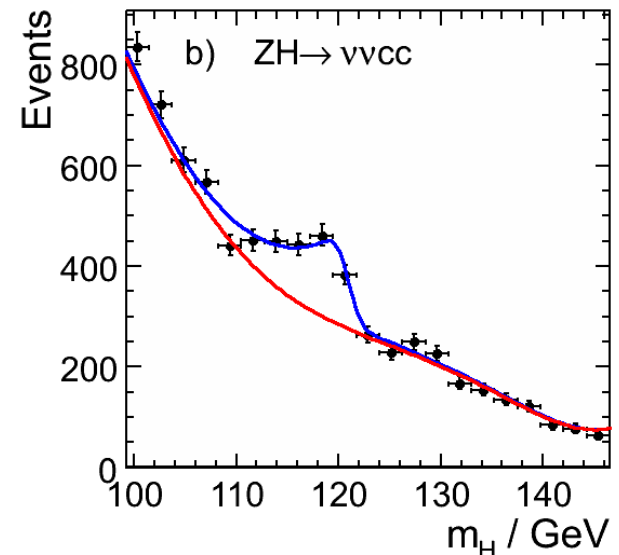
★ Combine with $\sigma(e^+e^- \rightarrow HZ)$ from model independent analysis (for \mathcal{L} 5 % uncertainty) to give BRs

Channel	Br(H→bb)	Br(H→cc)	Br(H→gg)
ZH→qqcc		30 ⊕ 5 %	
ZH→vvqq	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 \sqrt{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



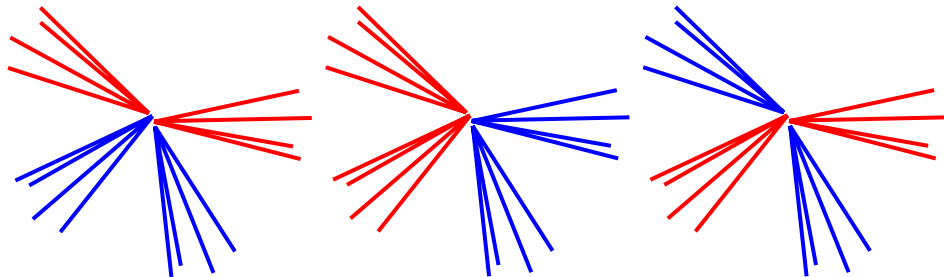
Chargino and Neutralino Production at $\sqrt{s} = 500$ GeV

- ★ Chargino and neutralino production in the **SUSY “point 5”** scenario provides a benchmark for jet energy resolution
- ★ $e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow W^+W^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ and $e^+e^- \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_2^0 \rightarrow ZZ \tilde{\chi}_1^0 \tilde{\chi}_1^0$ result in final states with four jets and missing energy
- ★ Neutralino process is challenging: cross section $\sim 10\%$ chargino

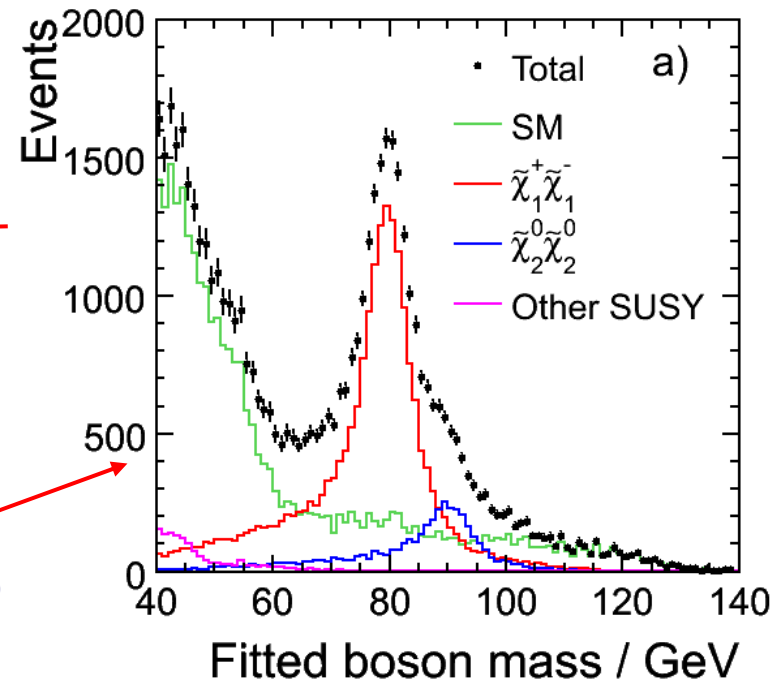
Analysis:

Only time to describe one of two analyses in Lol: 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

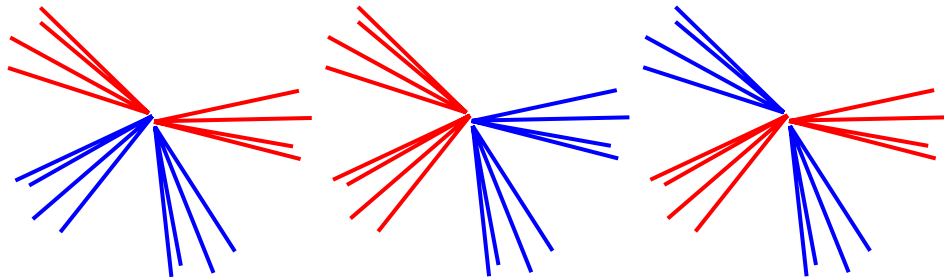


Chargino and Neutralino Production at $\sqrt{s} = 500$ GeV

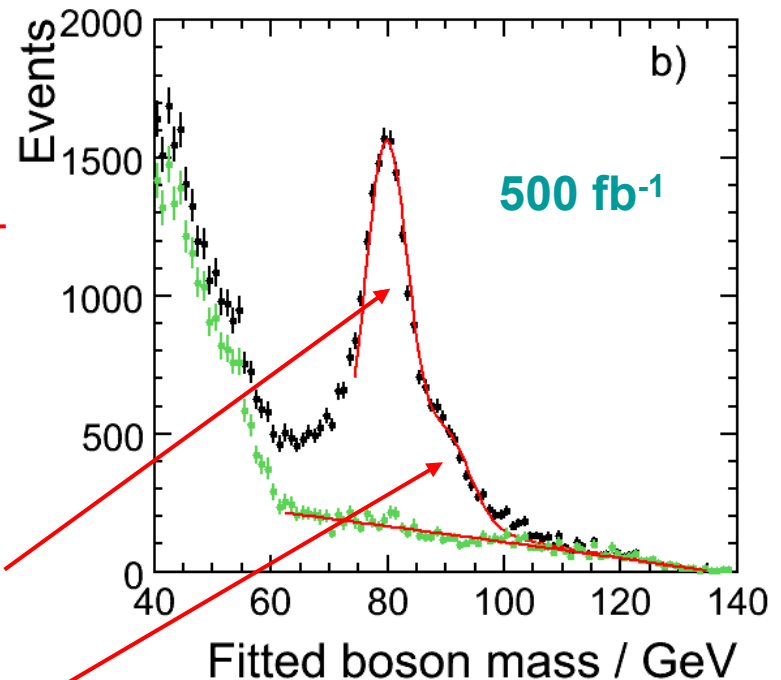
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$$\begin{aligned} \rightarrow & \sigma(e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow W^+W^- \tilde{\chi}_1^0 \tilde{\chi}_1^0) \\ & \sigma(e^+e^- \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_2^0 \rightarrow ZZ \tilde{\chi}_1^0 \tilde{\chi}_1^0) \end{aligned}$$

0.6 %

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. $\tilde{\chi}_2^0 \rightarrow Z\tilde{\chi}_1^0$

where masses of $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ from kinematic edges of Z energy dist.

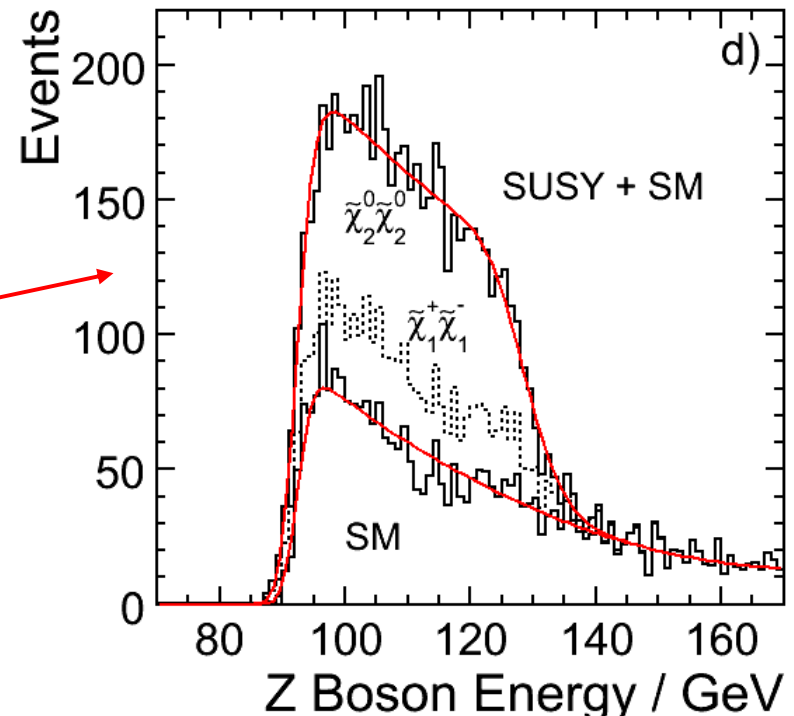
★ Excellent ILD jet energy resolution allows a sample of $\tilde{\chi}_2^0 \rightarrow Z\tilde{\chi}_1^0$ to be isolated from background

★ Neutralino + chargino samples give:

$$m_{\tilde{\chi}_1^\pm} : \pm 2.4 \text{ GeV}$$

$$m_{\tilde{\chi}_1^0} : \pm 0.8 \text{ GeV}$$

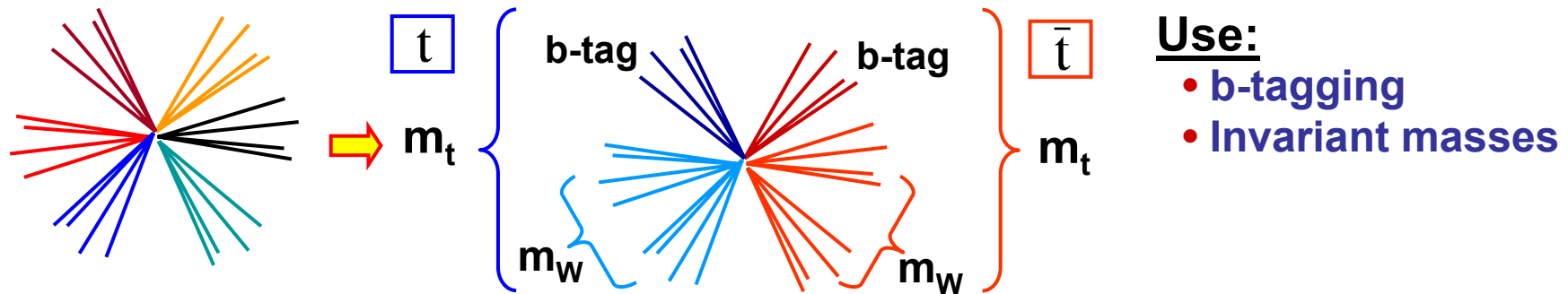
$$m_{\tilde{\chi}_2^0} : \pm 0.9 \text{ GeV}$$



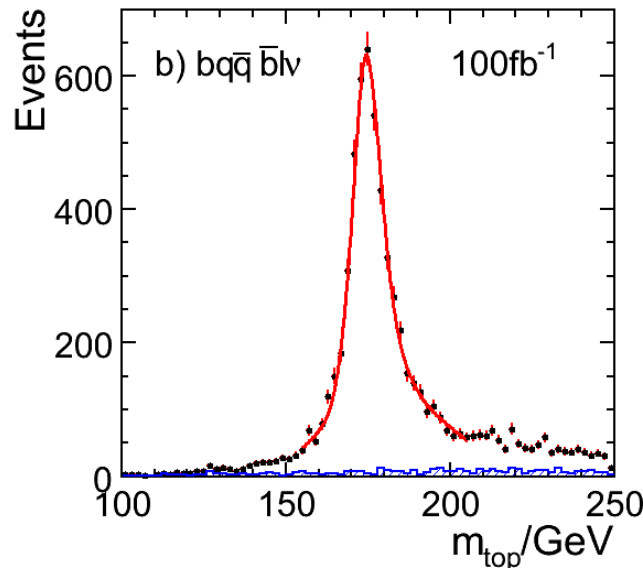
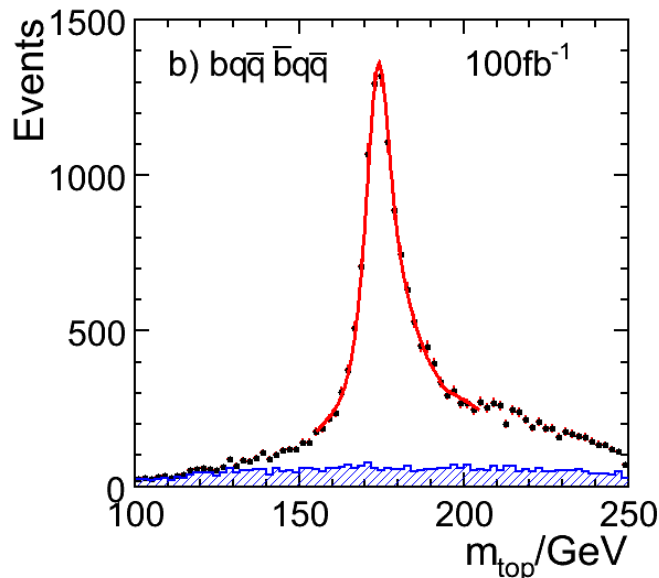
NOTE: results correlated as mass differences better determined than mass sums

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



- ★ Final mass from kinematic fit using chosen jet associations



500 fb^{-1}

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

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

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

★ Analysis requires:

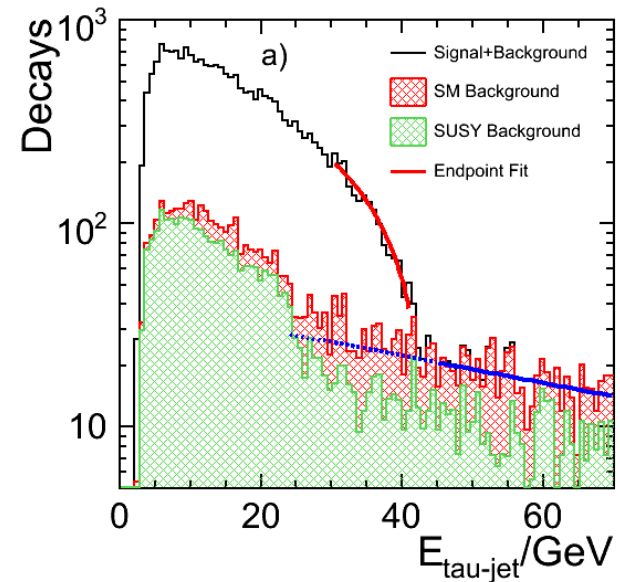
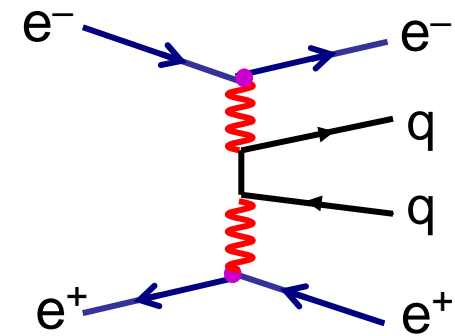
- precise tracking of low momentum particles
- good particle identification
- hermeticity

★ 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 $\tau \rightarrow \pi \nu$ decays)

⇒ $m_{\tilde{\tau}_1} : \pm 100 \text{ MeV} \oplus 1.3 \sigma_{m_{\text{LSP}}}$

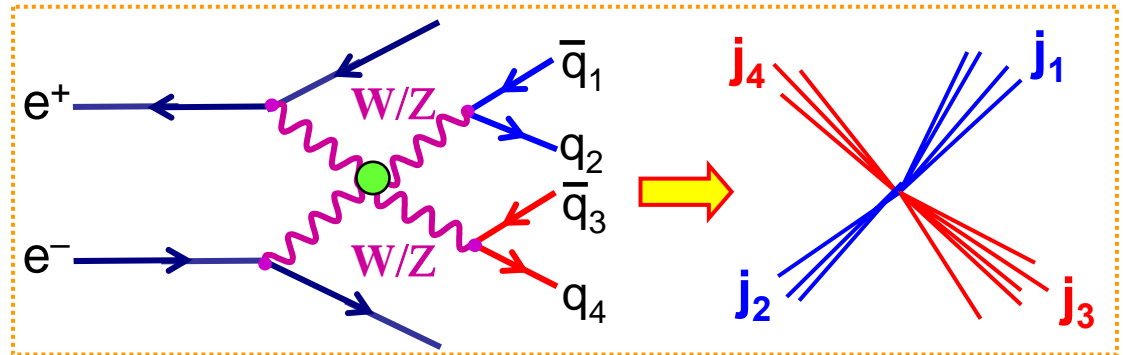


★ Post Lol: included beam background, precision essentially same

and finally...WW-scattering at $\sqrt{s} = 1$ TeV

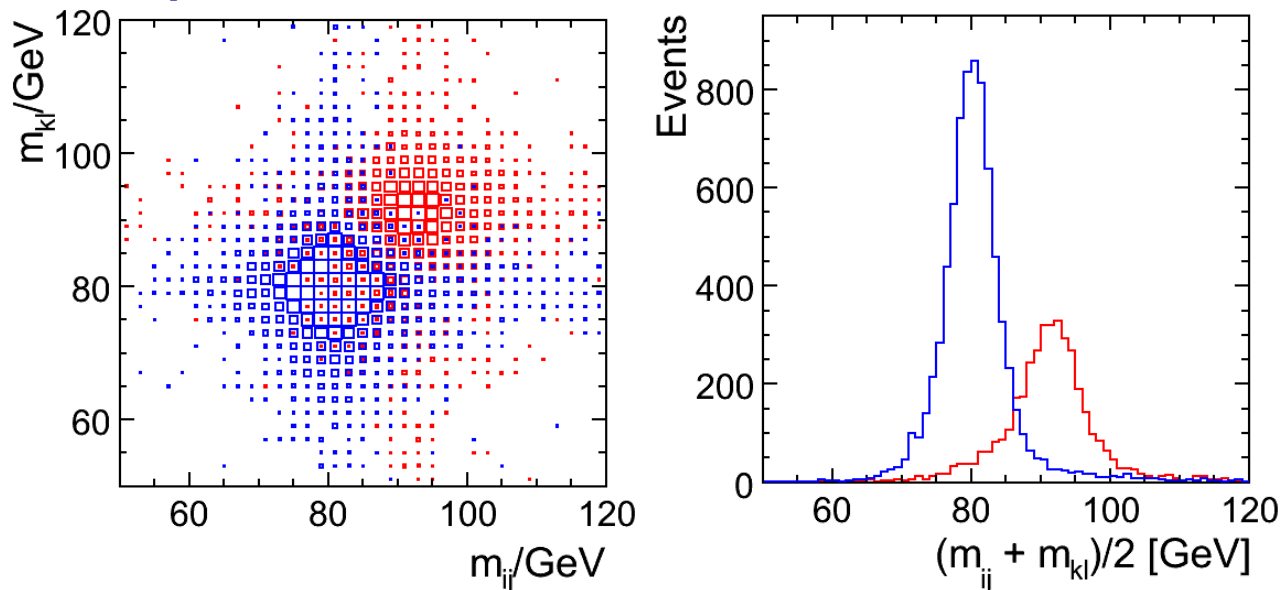
★ Study $W^+W^- \rightarrow W^+W^-$ and $W^+W^- \rightarrow ZZ$ in $e^+e^- \rightarrow \nu\bar{\nu}W^+W^-$
and $e^+e^- \rightarrow \nu\bar{\nu}ZZ$

★ 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 Lol
- 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	$\sigma(e^+e^- \rightarrow ZH)$	0.5 fb (5.1 %)	Model Independent
		m_H	74 MeV	Model Independent
		m_H	67 MeV	Model Dependent
Higgs Decay	250 GeV	$Br(H \rightarrow b\bar{b})$	$2 \oplus 5\%$	includes 5 % from $\sigma(e^+e^- \rightarrow ZH)$
		$Br(H \rightarrow c\bar{c})$	$14 \oplus 5\%$	
		$Br(H \rightarrow gg)$	$29 \oplus 5\%$	
$\tau^+\tau^-$	500 GeV	$\sigma(e^+e^- \rightarrow \tau^+\tau^-)$	0.3 %	$\theta_{\tau^+\tau^-} > 178^\circ$
		A_{FB}	± 0.003	$\theta_{\tau^+\tau^-} > 178^\circ$
		P_τ	± 0.015	$\tau \rightarrow \pi\nu$ only
Gaugino Production	500 GeV	$\sigma(e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-)$	0.6 %	from kin. edges from kin. edges from kin. edges
		$\sigma(e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0)$	2.1 %	
		$m(\tilde{\chi}_1^\pm)$	2.4 GeV	
		$m(\tilde{\chi}_2^0)$	0.9 GeV	
$e^+e^- \rightarrow t\bar{t}$	500 GeV	$m(\tilde{\chi}_1^0)$	0.8 GeV	
		$\sigma(e^+e^- \rightarrow t\bar{t})$	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
Smuons in SPS1a'	500 GeV	Γ_t	22 MeV	+ semi-leptonic
		$\sigma(e^+e^- \rightarrow \tilde{\mu}_L^+\tilde{\mu}_L^-)$	2.5 %	measurements
Staus in SPS1a'	500 GeV	$m(\tilde{\mu}_L)$	0.5 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	$-0.9 < \alpha_5 < +0.8$	

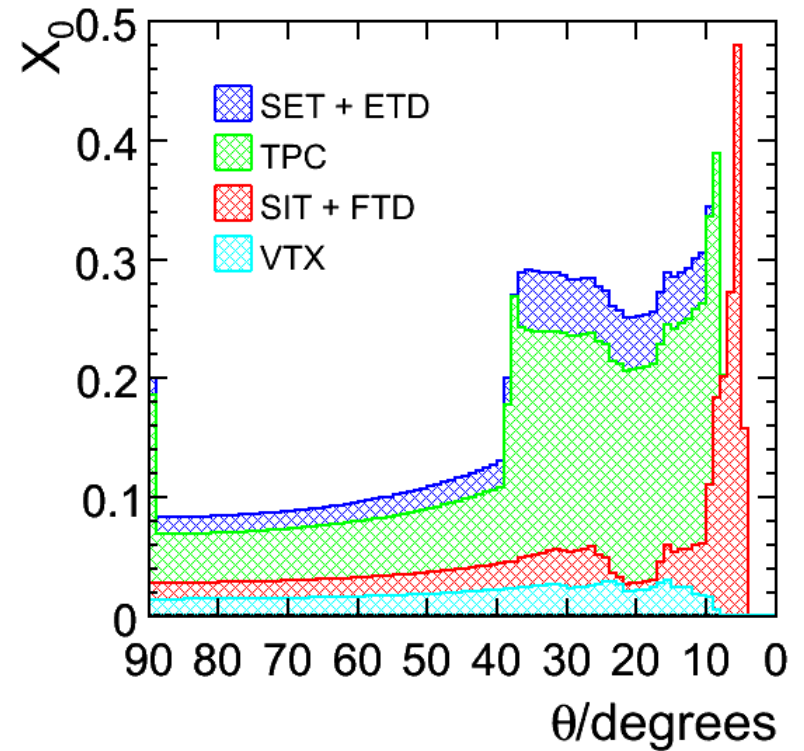
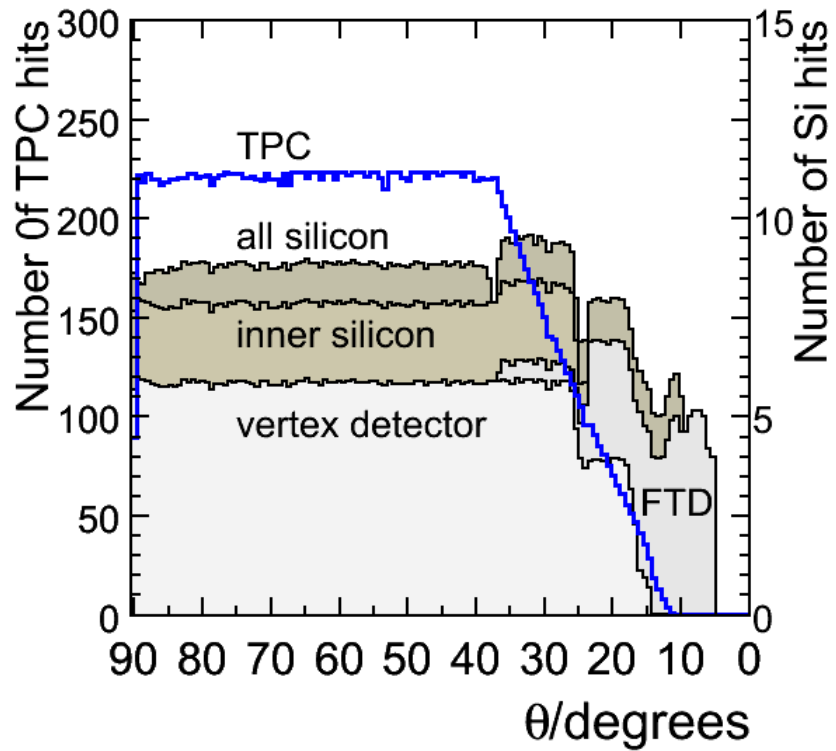
- + photon final states (GMSB/WIMPS)
- + Littlest Higgs
- + beam polarisation from WW

4 Conclusions

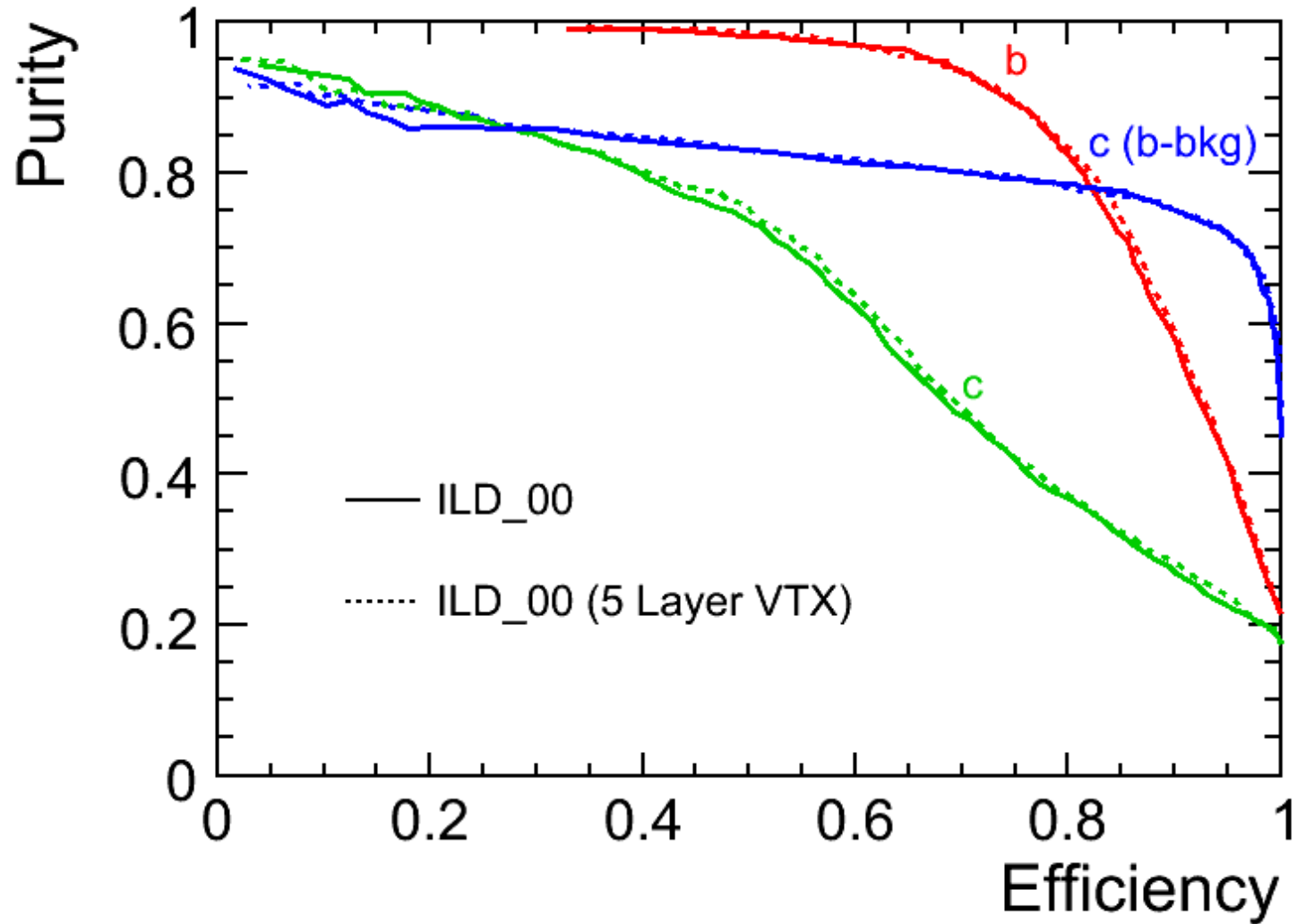
- ★ **ILD is powerful general purpose detector for the ILC based on particle flow calorimetry**
- ★ **The ILD parameters were chosen on the basis of an extensive series of optimisation studies**
 - now have a much better understanding of the performance issues
- ★ **ILD meets the performance goals for 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...

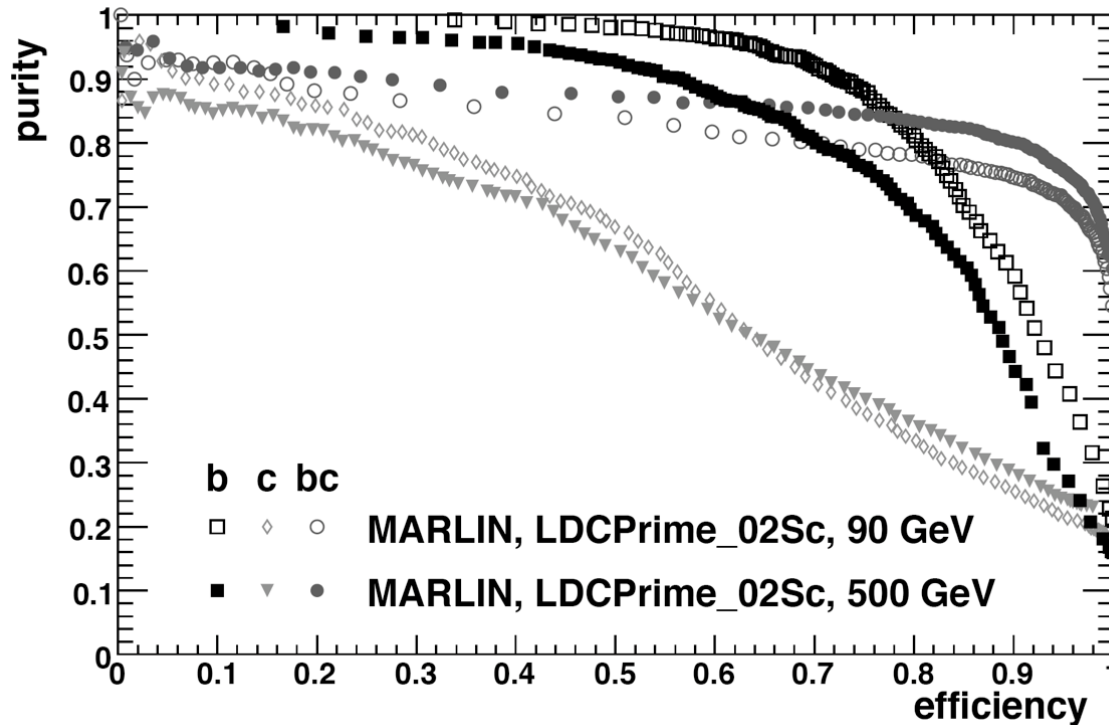
Backup slides: tracking coverage and material



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

