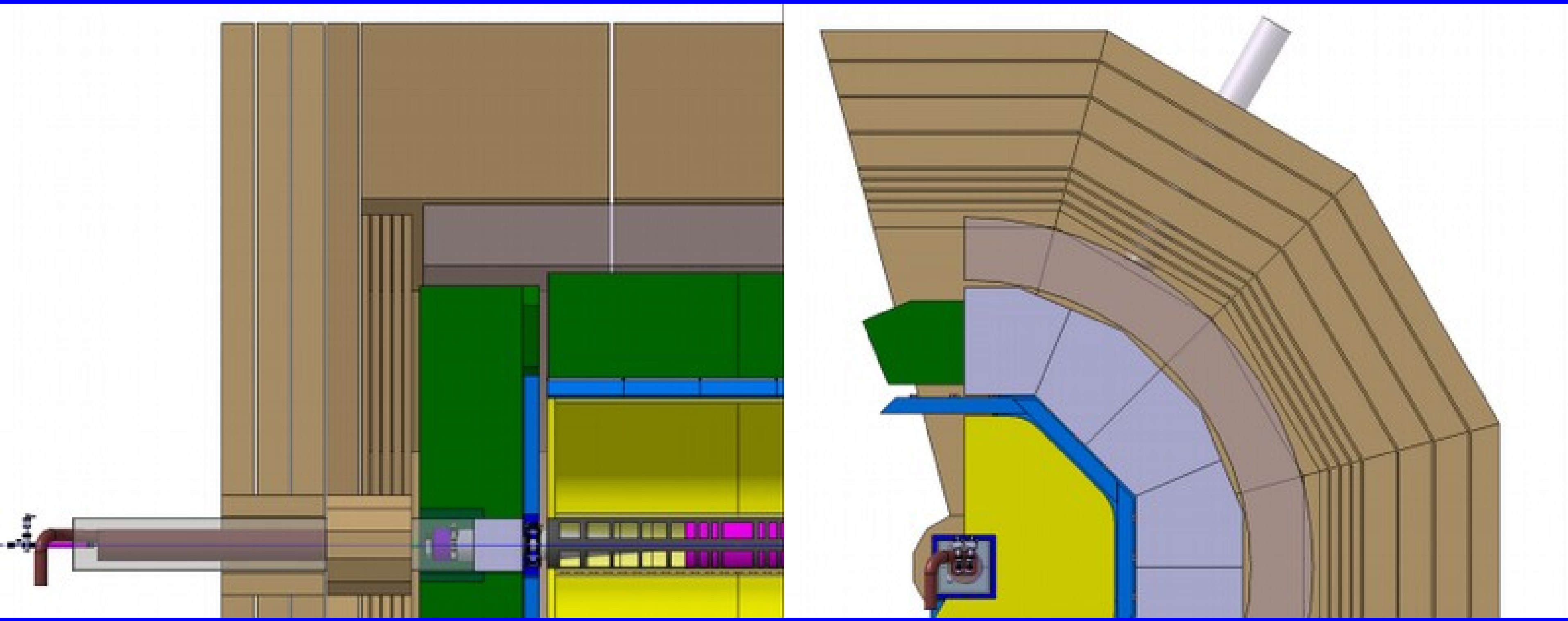
# Status and Progress of the ILD concept

## (ILD: a Large Detector for the ILC)



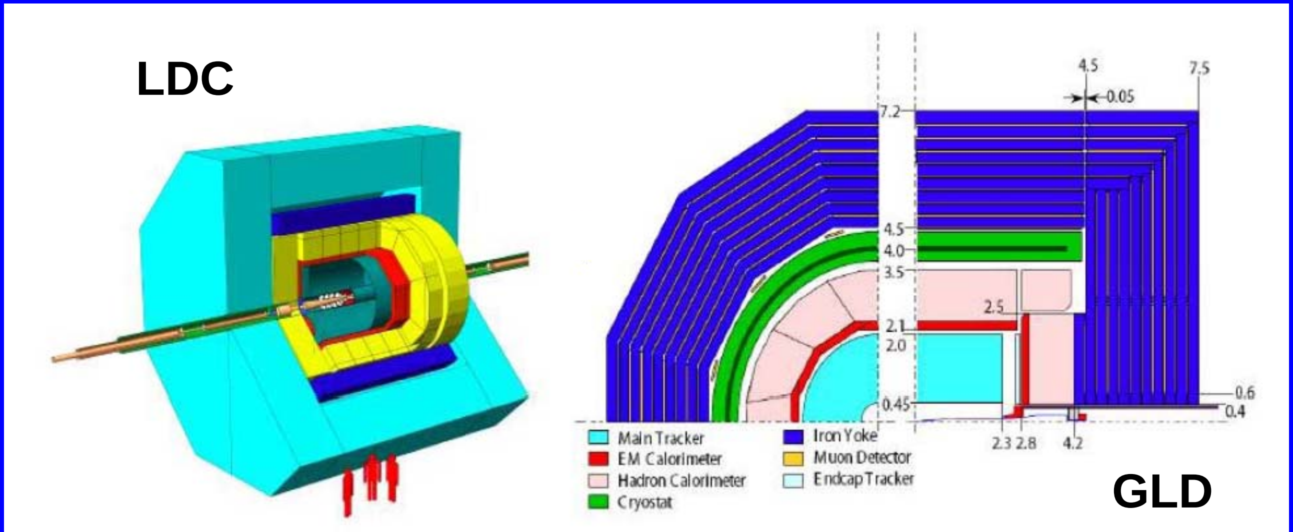
Graham W. Wilson (Univ. of Kansas)
for the ILD concept group

# Outline

- ILD History
- Introduction (GLD $\oplus$ LDC $\rightarrow$ ILD)
- Detector Concept (Broad-brush)
- Goals and Scope of Current LOI Process
- Group Organization
- Making a joint LOI a reality (Cambridge workshop)
  - Detector Sub-system Overview
  - Detector Performance Studies: Single Particles, Particle Flow
  - Status of Physics Benchmark Studies
  - Defining the ILD reference detector (ILD00)
  - A baseline model with options
- (MDI/Integration Issues ?)
- Status/Plans for Component R&D
- Summary ?

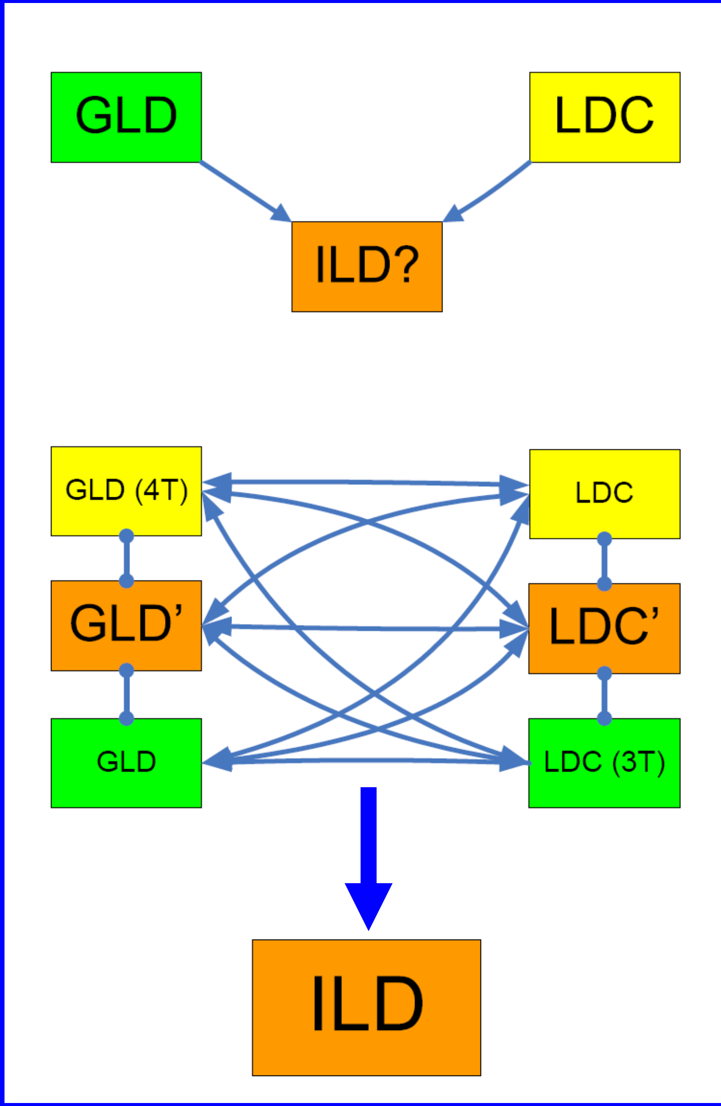
# ILD Pre-History

- Origins in the TESLA, JLC and LD detector concepts.
- First conceptual reports in the mid 90s.
- ILC Reference Design Report (RDR) 2007
  - GLD Detector Outline Document (DOD) arXiv:physics/0607154
  - LDC DOD http://www.ilcldc.org



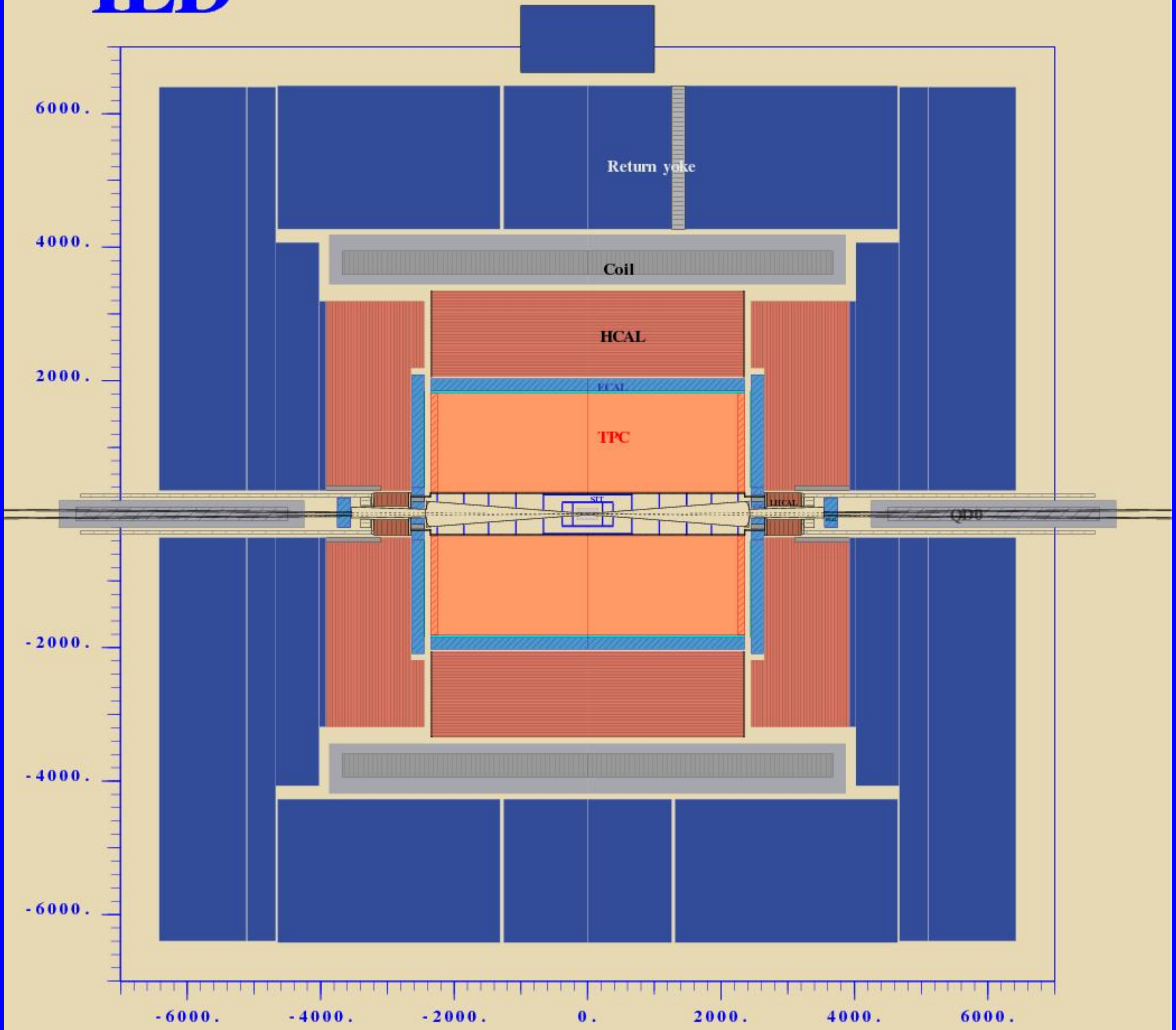
# Introduction

- ILD Conception
  - At LCWS07, we agreed to work towards a merger of the GLD and LDC detector concepts
  - Plan to (at least) explore the phase-space between GLD ($B=3T$, $R_{ECAL}=2.1m$) and LDC ($B=4T$, $R_{ECAL}=1.6m$)
- Transition Process
  - Create scalable simulation models, GLD', LDC' with intermediate parameters ($B=3.5$ T, $R_{ECAL}=1.85$ m)
    - GLD (Jupiter), LDC (Mokka)
  - Study performance as a function of major parameters
  - Reach a consensus on the ILD reference detector ?
- ILD Reality
  - We have reached a consensus at the Cambridge workshop and have agreed to move forward in a unified and pragmatic way towards the LoI.
    - A reference detector model (ILD00) with options
    - We have chosen parameters ***not*** technologies
      - Based on current best knowledge
    - Converged to one software framework under joint leadership



# ILD

27 - Oct - 08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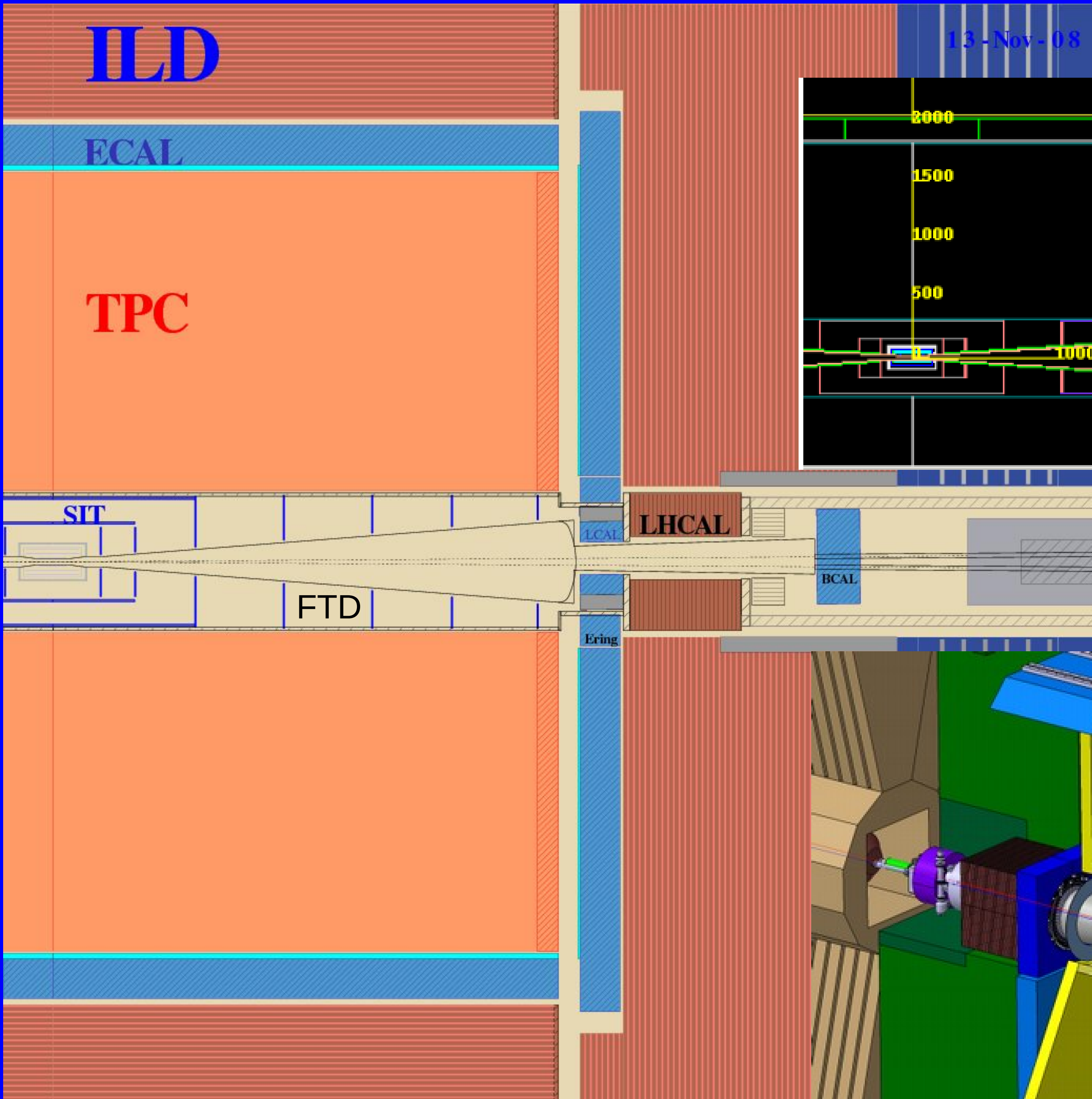
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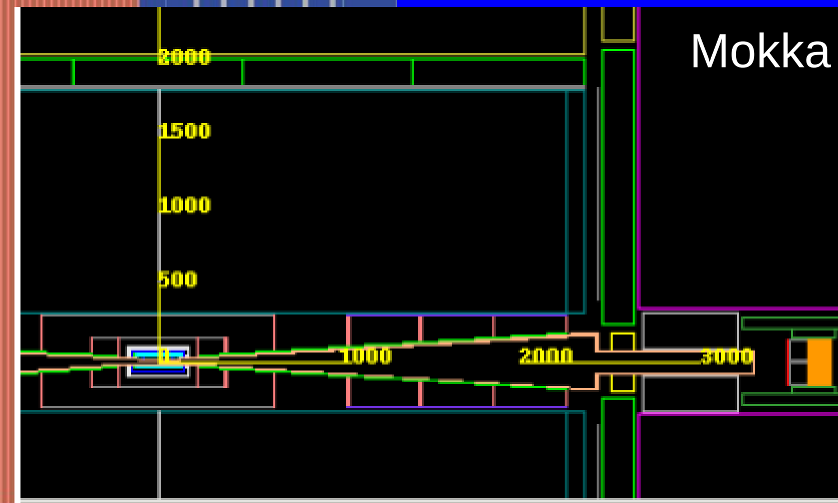
Mokka
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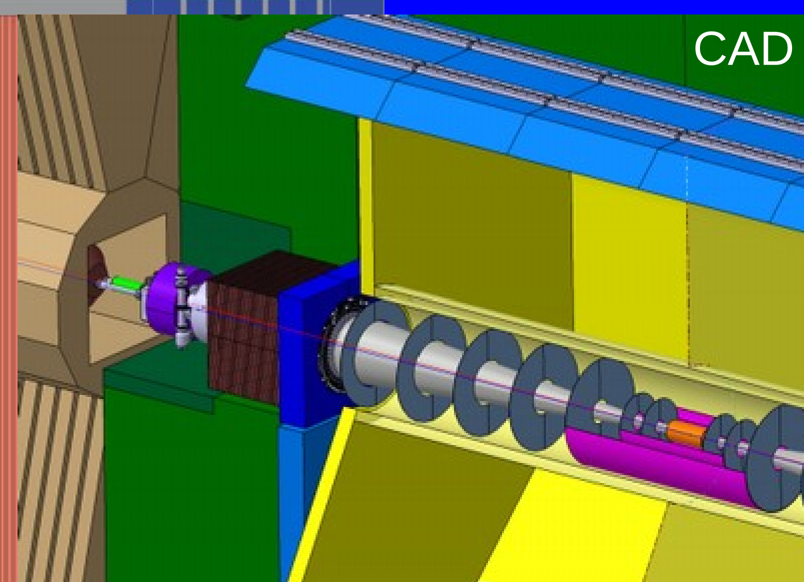
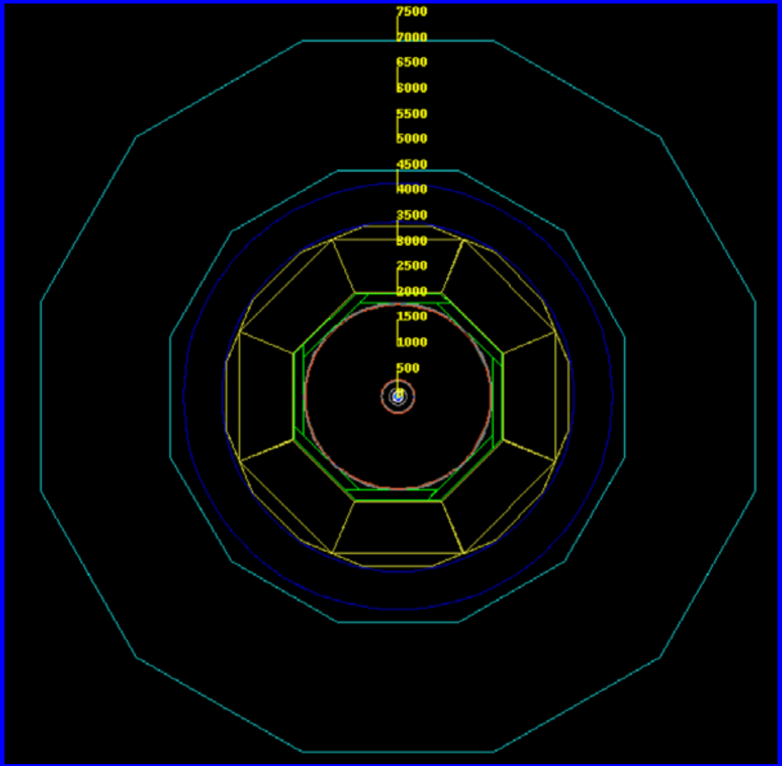
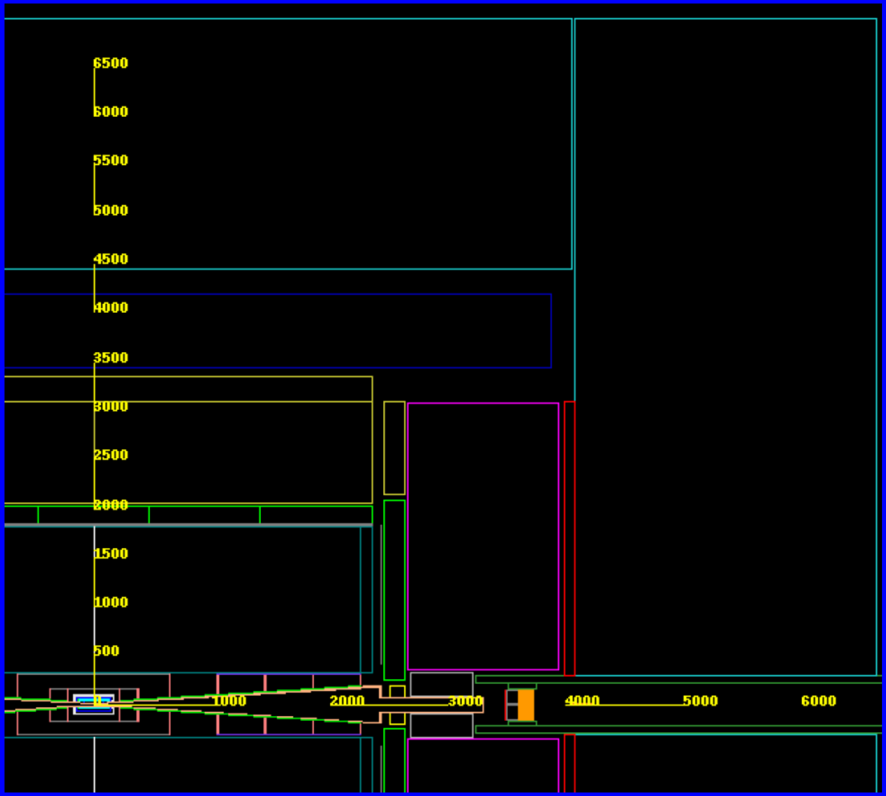
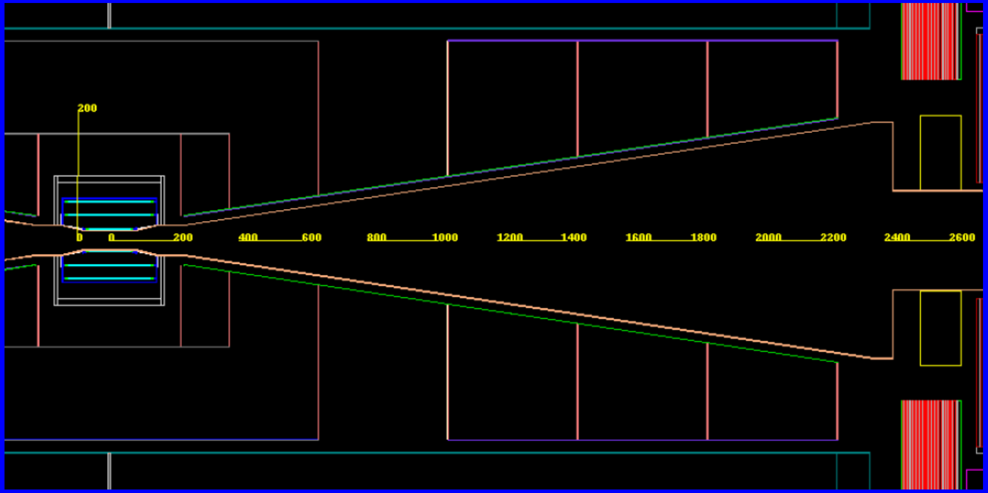

CAD

# ILD00 detector model in Mokka (G4) simulation



# ILD Organization

## Executive Board

### Management

- Joint Steering Board
  - T. Behnke, D. Karlen, Y. Sugimoto, H. Videau, G. Wilson, H. Yamamoto
- Optimization
  - Y. Takubo, M. Thomson
- MDI/Integration
  - K. Buesser, T. Tauchi
- Cost
  - H. Videau, A. Maki
- Technical Coordinators
  - M. Joré, K. Sinram, H. Yamaoka
- Software
  - F. Gaede, A. Miyamoto

### Subdetector Contacts

- Vertex Detector
  - Y. Sugimoto, M. Winter
- Silicon Tracking
  - A Savoy-Navarro, H. Park
- TPC
  - K. Fujii, R. Settles
- ECAL
  - J-C. Brient, K. Kawagoe
- HCAL
  - F. Sefkow, I Laktineh
- FCAL
  - W. Lohmann
- DAQ
  - G. Eckerlin, M. Wing

### ILD Representatives to RD Executive Board

- LOI Representatives
  - T. Behnke, Y. Sugimoto
- MDI
  - K. Buesser, T. Tauchi
- Engineering Tools
  - C. Clerc
- R&D
  - D. Chakraborty, T. Takeshita, J. Timmermans
- Physics
  - K. Desch, K. Fujii
- Software
  - F. Gaede, A. Miyamoto

ILD maintains close ties to the LCTPC, CALICE, LCFI, SILC and FCAL R&D Collaborations, and encourages continued support of those “horizontal” R&D collaborations

# ILD Detector Concept

- Physics needs drive the detector design
- Experience, particularly from LEP, points towards:
  - Particle-flow for complete event reconstruction
  - A highly redundant and reliable TPC-based tracking design emphasizing pattern recognition capabilities and low mass tracking
    - "dE/dx for free", and $V^0$ reconstruction ($K_S$, $\Lambda$, $\gamma$ conversion)
  - A fine granularity calorimeter capable of particle-flow
  - Ultra-hermetic
- Accelerator and tracking system designed with sufficient safety margin to operate reliably.

# What kind of physics ?

- Processes central to the perceived physics program :
  - f fbar at highest energy
  - Zh
  - $\nu\nu h$
  - Zhh
  - Sleptons
  - Charginos
- These will emphasize:
  - Jet energy resolution (assumed to be done with particle flow) aiming at $30\%/\sqrt{E}$ for W/Z separation
  - Hermeticity
  - Granularity
  - Leptons, taus, b, c tagging

# Detector design requirements

- Detector design should be able to do excellent physics in a cost effective way.
  - both the physics we expect, and the new unexpected world that awaits

- Very good **vertexing** and **momentum** measurements

  $\sigma_b = 5 \oplus 10/(\, p\, \beta \sin^{3/2}\theta)\ \mu m$ $\qquad\qquad$ $\sigma(1/p_T) \leq 5 \times 10^{-5}\ GeV^{-1}$

- Good **electromagnetic energy** measurement.

$$\sigma_E/E \approx 15\%/\sqrt{E\,(GeV)} \oplus 1\%$$

- The physics demands hermeticity and the physics reach will be significantly greater with state-of-the art **particle flow**
  - Close to $4\pi$ steradians.
  - Bubble chamber like track reconstruction.
  - An integrated detector design.
  - Calorimetry designed for resolving individual particles.

$$\sigma_{E_{jet}}/E_{jet} \approx 30\%/\sqrt{E_{jet}\,(GeV)}$$

# Remarks on Goals and Scope of LOI process

- Deliver a credible LOI that is "validated"
  - Can do the physics
  - Is feasible
  - Proponents are capable

Déjà vu ?

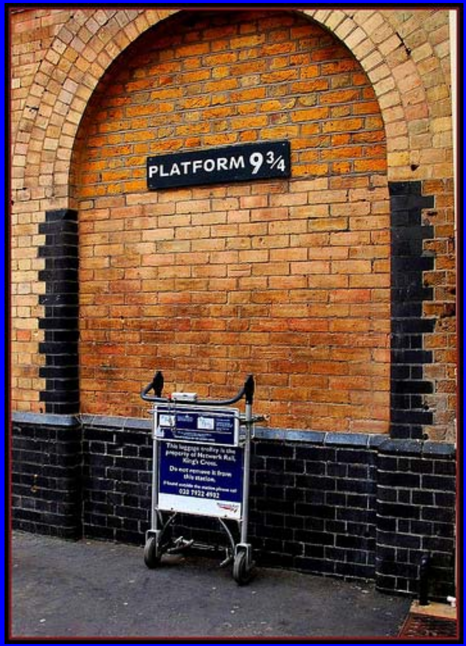
(CDR, TDR, DOD)

- But the LOI is just the next milestone in working towards a fully fledged technical design for the ILC project proposal.
- ILD puts a major emphasis on detector optimization using full realistic detector simulations
  - Justify global detector parameters
  - Identify and remedy design flaws
  - Compare technology options and foster relevant detector R&D
  - Receptive to new ideas
- Full simulation of signal and background processes
  - Comprehensive physics channel results for benchmark processes
  - AND, will revitalize the physics studies

# Making Detector Models More Realistic

- A work in progress (balance between realism and reason)
  - Buildable polygons
  - Inter-wafer gaps
  - Guard rings
  - Spaces for cables
  - Support structures
- Not usually implemented yet
  - Nuts and bolts
  - Readout electronics
  - Cooling

# Gripping people's imagination on the way to Cambridge




Sept. $10^{th}$ 2008

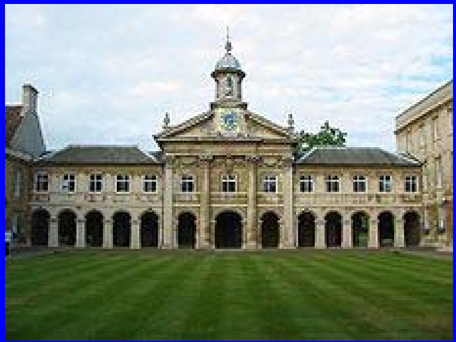
Magic was in the air, and lots of people were really interested in the field we love.

Very encouraging to see how the LHC start-up has helped to engage many people with our science.

They also seemed really interested in the results:

http://hasthelargehadroncolliderdestroyedtheworldyet.com NOPE.

London news-stand headlines read:
"The world survives, so far"



Lots of new results at Cambridge

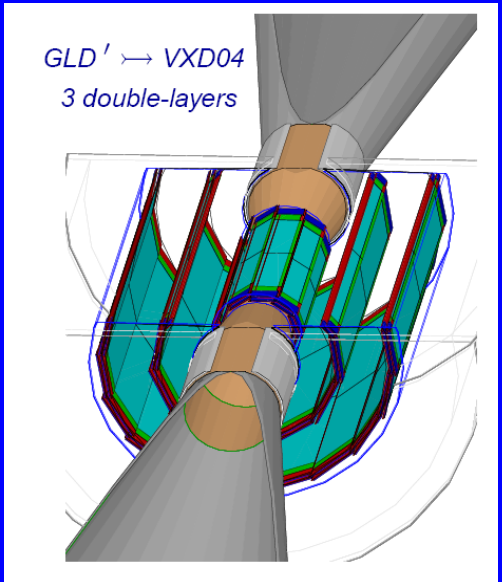
See http://ilcagenda.linearcollider.org

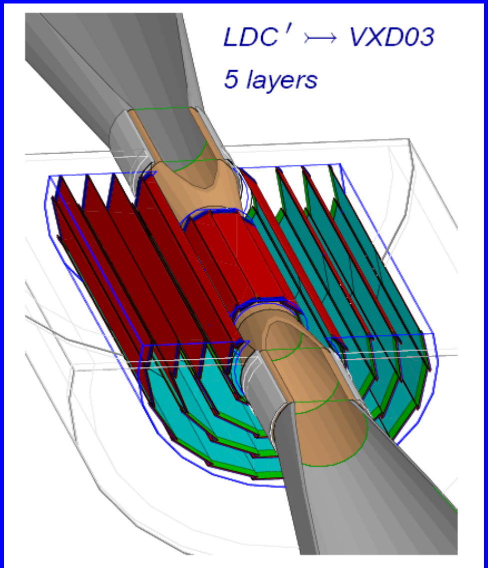
# Detector Subsystem Over-view

Quick Tour

- Vertex detector
- Silicon tracking elements
  - Silicon Inner Tracker (SIT), Forward Tracking Disks (FTD)
  - Silicon External Tracker (SET), Endcap Tracking Detector (ETD)
- TPC
- ECAL
- HCAL
- Forward Calorimeters: LCAL, BCAL, LHCAL
- Solenoid
- Instrumented Yoke

# Vertex Detector



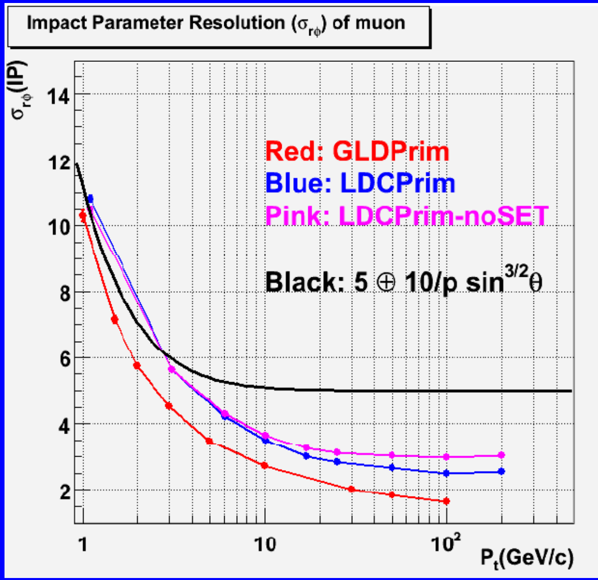




Many different technologies:

pixel sensors, readout scheme, material budget

Pairs background => Inner radius ~ √B

Studying two "technology-neutral" geometries :
3 double-layers, 5 layers




Performance studies indicate better resolution particularly at high $p_T$ for 3 double-layers.

Studies ongoing and plan to include backgrounds

Inner layer at r=1.6 cm for B=3.5 T

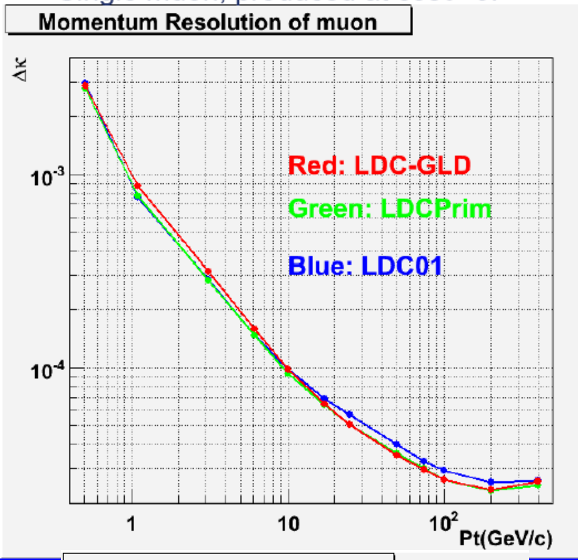
# Global Detector Optimization: Tracking

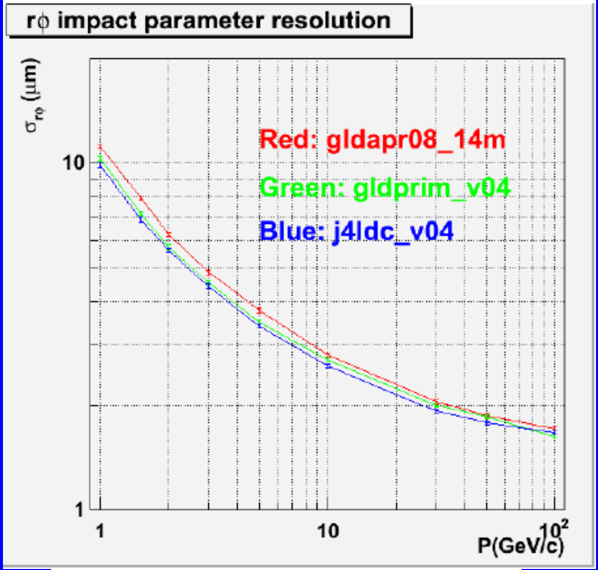
Extensive comparison studies: B(T) = 3, 3.5, 4

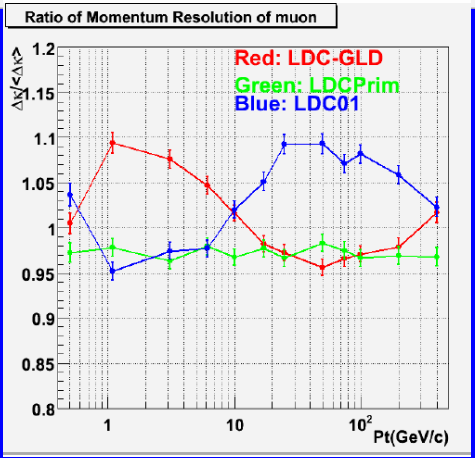
$BR_{TPC}^2$ ($Tm^2$) = 9.1, 10.5, 11.2

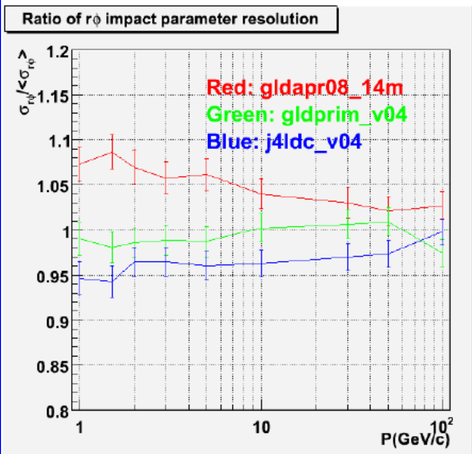
$r_1$ (cm) = 1.5, 1.6, 1.75

Single muon, produced at cosθ=0.



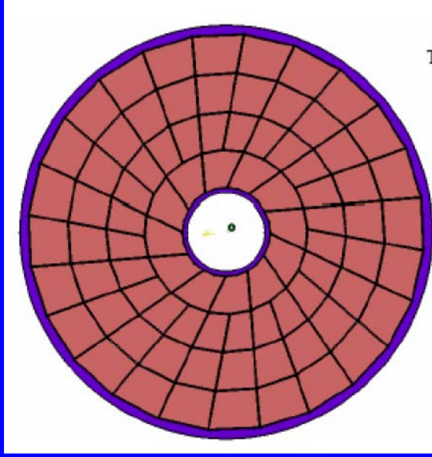




Note: most intrinsic tracking resolution studies done only with muons (also need electrons)

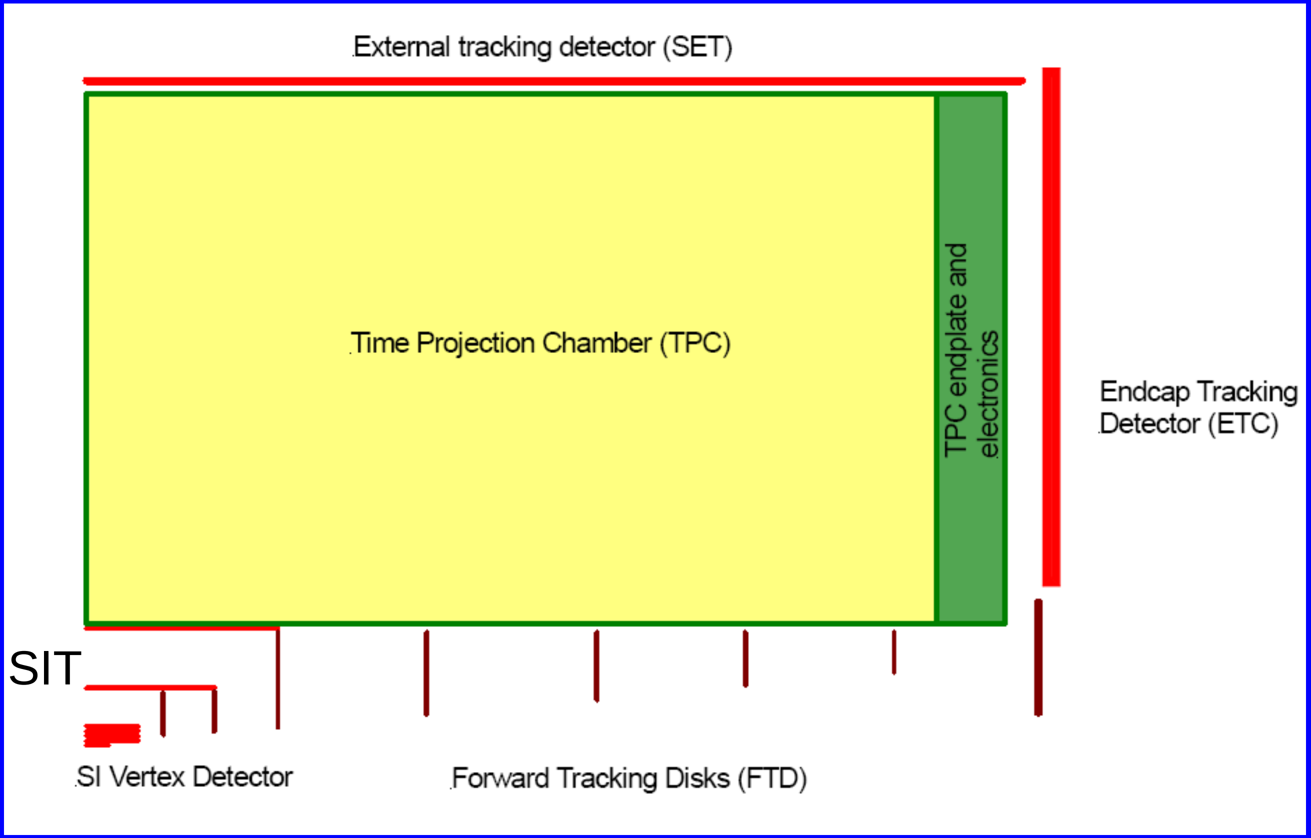
# Main Tracker: TPC



Si-trackers are supported by SiLC

Supplemented by stand-alone VTX tracking, SIT + Forward tracking disks.

SET and ETD are track-cal linking options.




$3\ 10^9$ volume pixels.

226 points per track.

Single-point resolution

50 - 75 $\mu$m r-$\phi$,

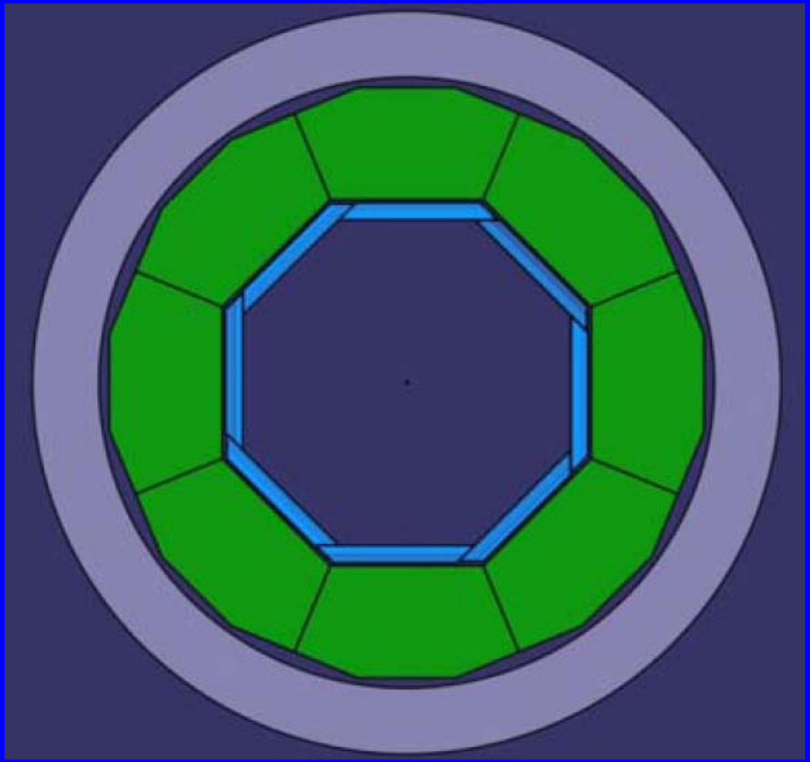
400 $\mu$m r-z

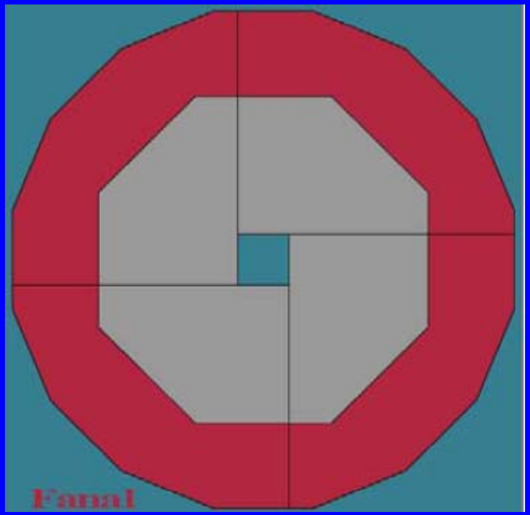
$|\cos\theta| < 0.985$

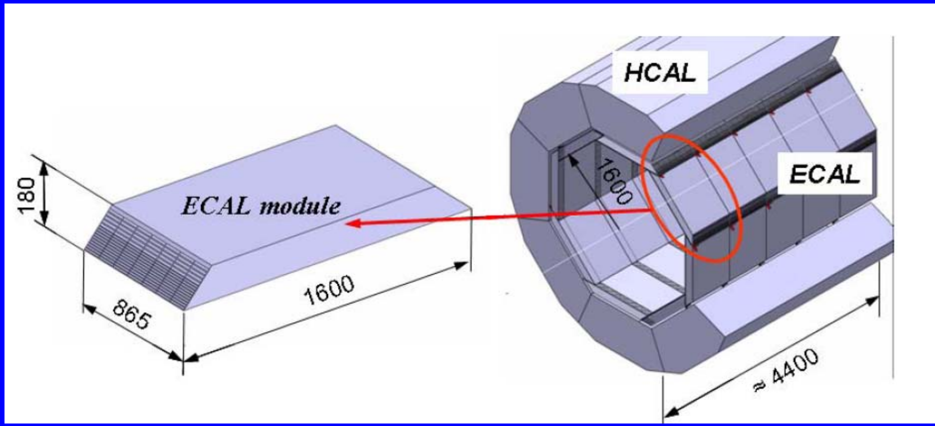
*Readout options: GEM, Micro-megas, Silicon Pixel*

SIT and FTD are essential elements of an integrated design.

# Calorimetry





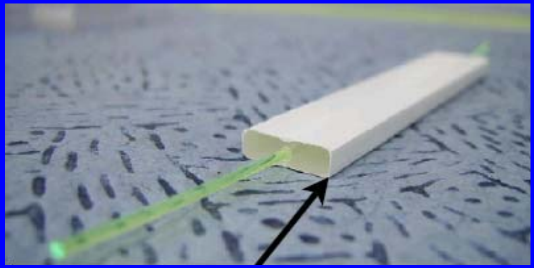

8-fold and 12-fold structures are studied.

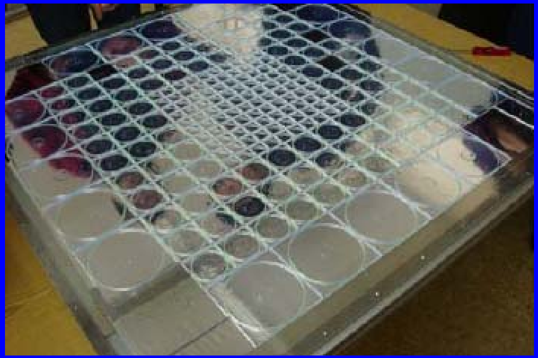
8-fold is currently most mature, 12-fold has some pros and cons.

# Calorimetry Technologies

All are studied by CALICE

- ECAL (24 $X_0$ : 20 + 10)
  - Silicon-W
    - transverse cell-size 5mm X 5mm
  - Scintillator-W with MPPC readout
    - 10mm X 40 mm X 2mm strips
  - Digital: MAPS
- HCAL
  - Analog : Scintillator + Stainless Steel.
    - Tiles with Si-PM readout
    - 5mm Sc, 3cm X 3cm.
  - Digital : Gas + Stainless Steel.
    - RPCs or GEMs, 1cmX 1cm





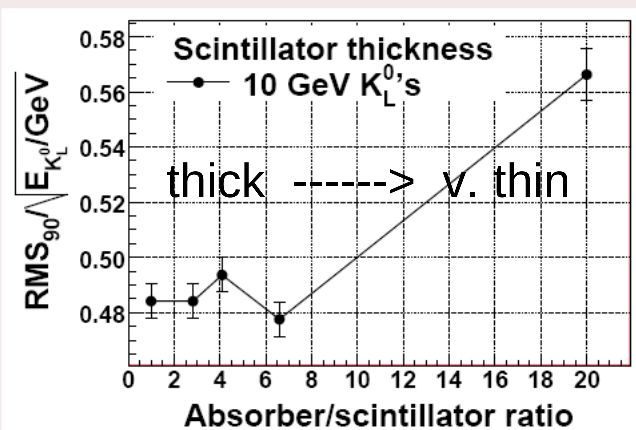
# HCAL Optimization

Studies of neutral hadron and jet energy resolution as detector parameters are varied: scintillator thickness, sampling frequency, size of dead areas.

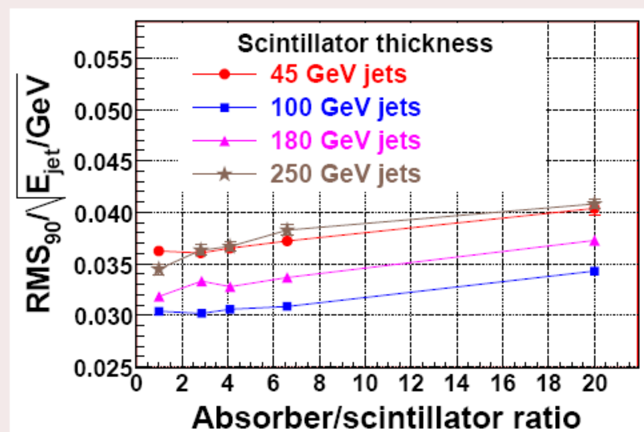
## Scintillator Thickness with PFA

- Default configuration: 20 mm absorber + 5 mm scintillator i.e. $\mathrm{absorber/scintillator} = 4$
- Modify scintillator thickness (everything else unchanged)

For $K_L^0$'s used for calibration:




For $Z \rightarrow u\bar{u},\ d\bar{d},\ s\bar{s}$:




- $Z \rightarrow u\bar{u},\ d\bar{d},\ s\bar{s}$: $\Longrightarrow$ Small differences ($< 5\%$) in jet energy resolution for $\mathrm{absorber/scintillator} < 7$

Angela Lucaci-Timoce ILD Optimization Meeting - September 2008, Cambridge 7

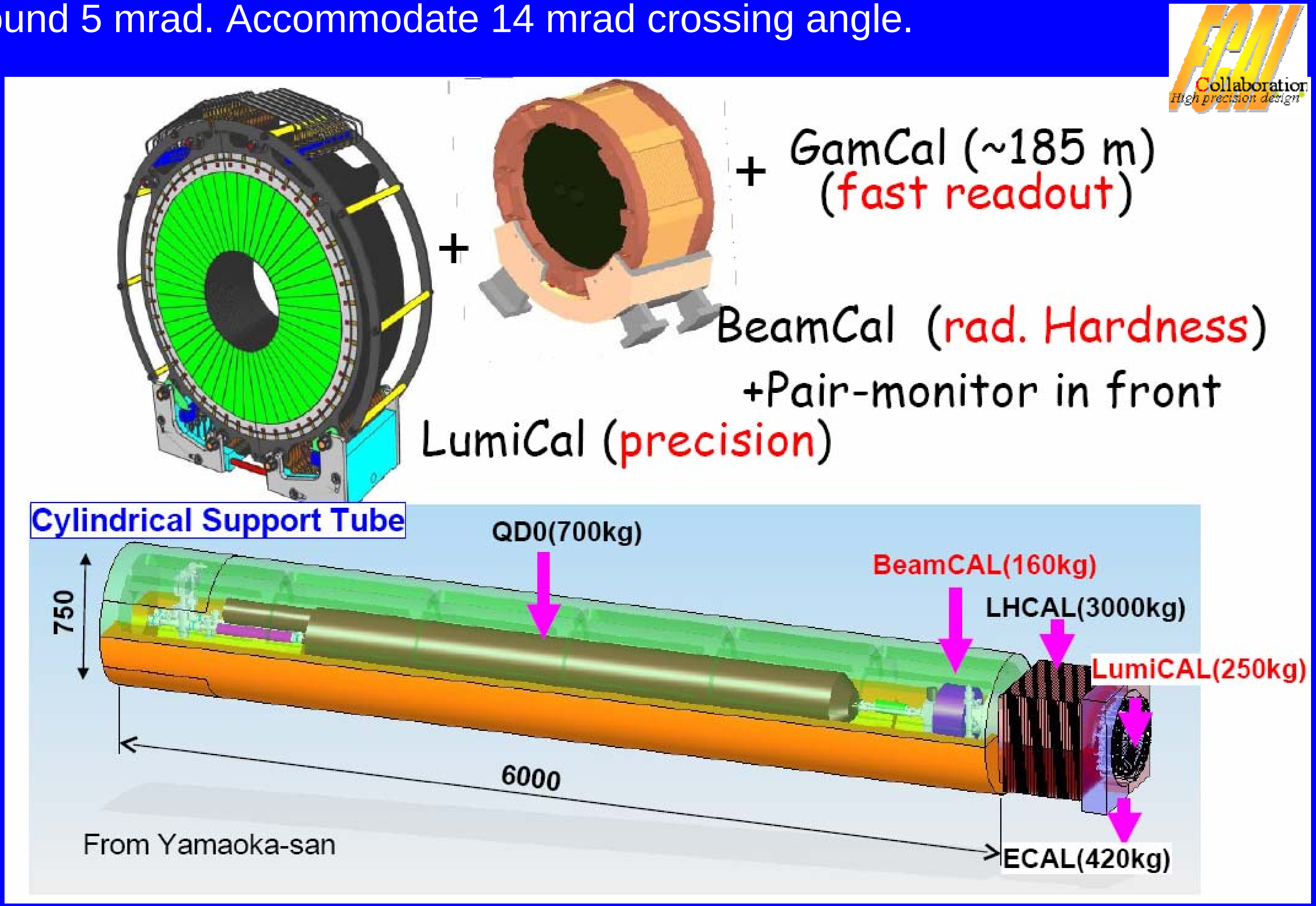
Similar studies by all sub-detectors are actively encouraged.

Can help focus detector R&D on pressing issues for the overall detector design.

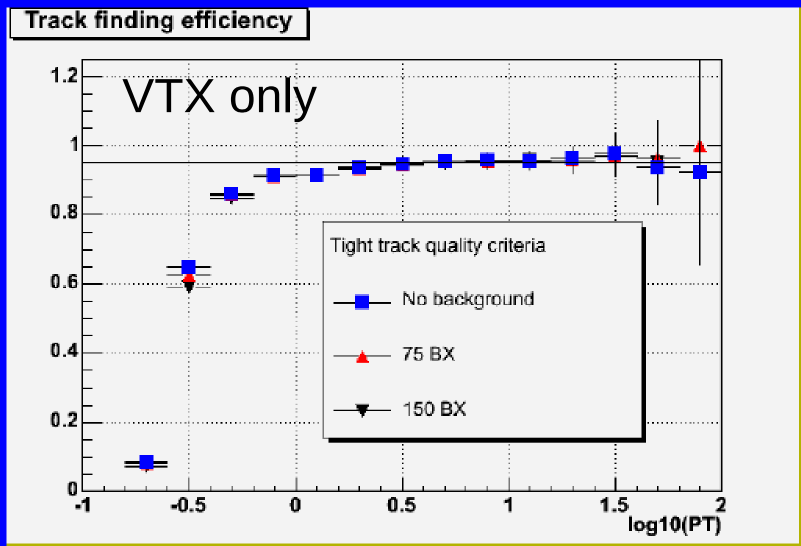
Note: also need confidence in description of hadronic showers

# Forward Region

Goals: Measure precision luminosity and provide hermeticity down to around 5 mrad. Accommodate 14 mrad crossing angle.

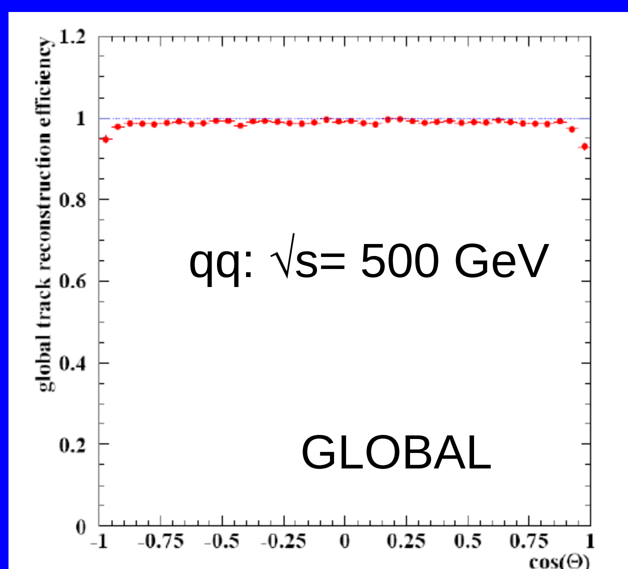


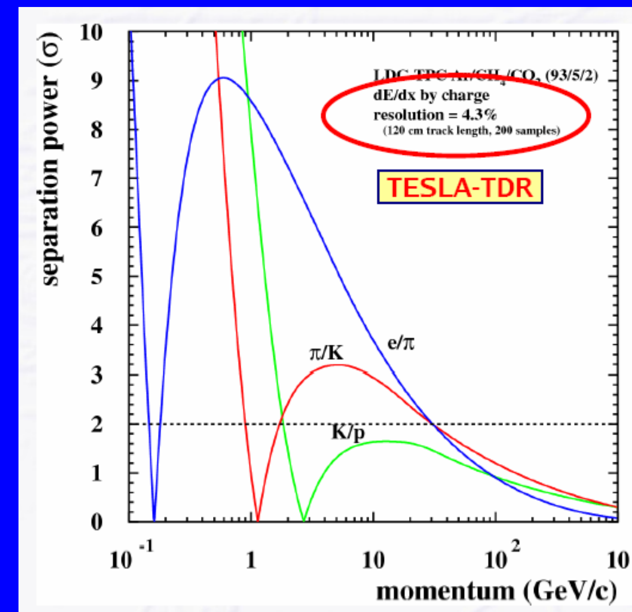
# Overall Tracking Performance




High efficiency.

Can be improved further.




dE/dx performance similar to ALEPH, OPAL

Expected occupancy < 0.5%

Should be robust to ×20.

# Particle Flow Algorithm (PFA) Performance

Updated performance numbers based on more realistic/buildable detector model.

Gaps, cracks etc.

Note: track reconstruction inefficiencies are included (no cheating)

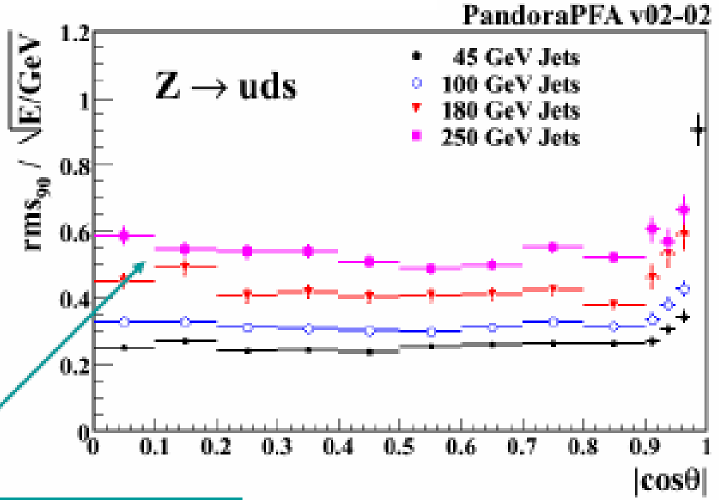
## ❶ PFA Performance

**Studies in this talk start from:**

- ★ Use standard Mokka LDCPrime model : LDCPrime_02Sc
- ★ OPAL tune of Pythia
- ★ Full reconstruction chain:
  - PandoraPFA v02-02 (essentially the released version)
  - FullLDCTracking

PandoraPFA v02-02

| $E_{JET}$ | $\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$ | $\sigma_E/E_j$ |
|---|---|---|
| 45 GeV | 24.9 % | 3.7 % |
| 100 GeV | 30.7 % | 3.1 % |
| 180 GeV | 43.0 % | 3.2 % |
| 250 GeV | 52.2 % | 3.3 % |




Leakage not completely negligible ?



See David Ward's talk tomorrow for more details

# Starting to understand PFA (and how to improve it further)

Measure performance using various amounts of MC truth information

| Algorithm | $\sigma_E/E$ | | | |
|---|---|---|---|---|
| | 45 GeV | 100 GeV | 180 GeV | 250 GeV |
| PandoraPFA | 3.7 % | 3.1 % | 3.2 % | 3.3 % |
| +CheatedTracks | 3.6 % | 3.0 % | 3.1 % | 3.2 % |
| +CheatedPhotons | 3.6 % | 2.8 % | 2.7 % | 2.7 % |
| +CheatedNeutralHs | 3.4 % | 2.4 % | 2.1 % | 2.0 % |
| +PerfectFragRem | 3.2 % | 2.3 % | 2.1 % | 2.0 % |
| PerfectPFA | 3.1 % | 2.1 % | 1.7 % | 1.6 % |

Estimate contribution from each source

| Contribution | $\sigma_E/E$ | | | |
|---|---|---|---|---|
| | 45 GeV | 100 GeV | 180 GeV | 250 GeV |
| Calo. Resolution | 3.1 % | 2.1 % | 1.5 % | 1.3 % |
| Leakage | 0.1 % | 0.5 % | 0.8 % | 1.0 % |
| FullLDCTracking | 0.7 % | 0.7 % | 1.0 % | 0.7 % |
| Photons "missed" | 0.4 % | 1.2 % | 1.4 % | 1.8 % |
| Neutrals "missed" | 1.0 % | 1.6 % | 1.7 % | 1.8 % |
| Charged Frags. | 1.2 % | 0.7 % | 0.4 % | 0.0 % |
| "Other" | 0.8 % | 0.8 % | 1.2 % | 1.2 % |

**Comments:**

- ★ For 45 GeV jets, jet energy resolution dominated by ECAL/HCAL resolution
  - ▪ don't expect much dependence of $\sigma_E/E$ on B, R etc.
- ★ Track reco. not a large contribution (FullLDCTracking ≈ CheatedTracking)
- ★ "Satellite" neutral fragments not a large contribution
  - ▪ efficiently identified and removed by normal FragmentRemoval alg.
- ★ Leakage only becomes significant for high energies (more on this later)
- ★ Missed neutral hadrons dominant confusion effect
- ★ Missed photons, important at higher energies (somewhat surprising !)

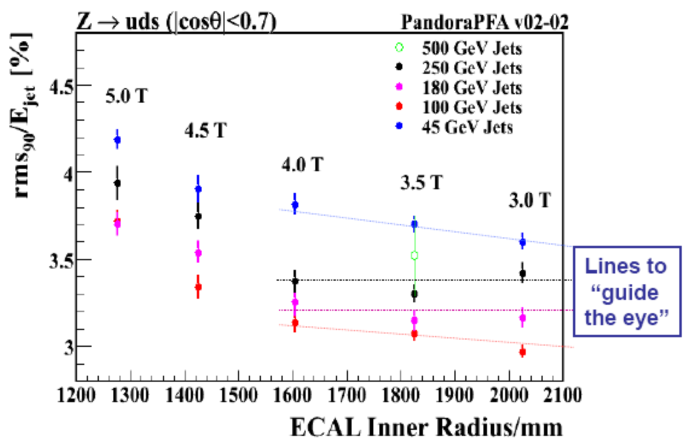
ILD Workshop, 11/9/2008 Mark Thomson 6

For more details, see Mark's talk at the Cambridge meeting

# Compare Global Detector Designs with 2 implementations

## LDC vs LDCPrime vs LDC4GLD

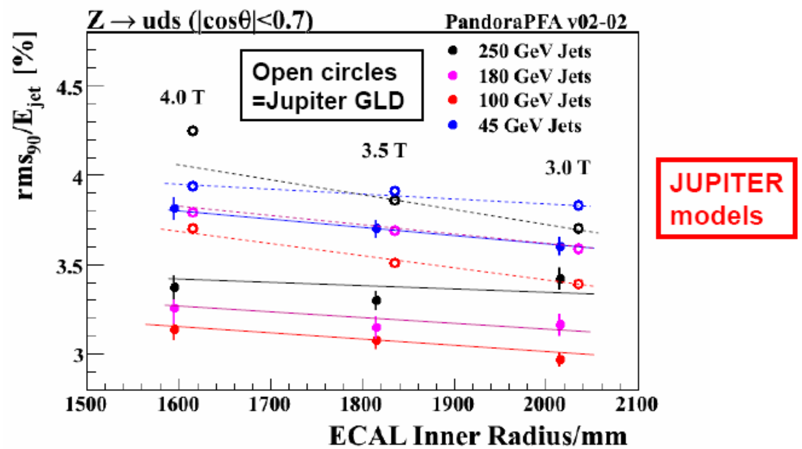
★ Direct Comparison of LDC, LDCPrime and GLD




★ In terms of jet energy resolution: LDC ≈ LDCPrime ≈ "LDC4GLD"

## GLD vs GLDPrime vs J4LDC

★ Can compare with similar J4LDC, GLDPrime, GLD studies (Taikan Suehara)




★ In terms of jet energy resolution: GLDPrime ≈ "GLD"
: J4LDC worse but thin HCAL

Fairly modest differences among these models which are between LDC and GLD.

# PFA Bottom-Line

(with current understanding, algorithm and simulation)

## B vs. R Interpretation

★ All results shown are **fairly** well described by (best fit) $\chi^2/\text{dof} = 48/52$

$$\frac{\sigma_E}{E} = \frac{\mathbf{0.21}}{\sqrt{E}} \oplus 0.01 \oplus 0.02 \left(\frac{R}{1825}\right)^{-1.0} \left(\frac{B}{3.5}\right)^{-0.35} \left(\frac{E}{100}\right)^{+0.4}$$

Resolution | Tracking/Leakage/Fragments | Confusion

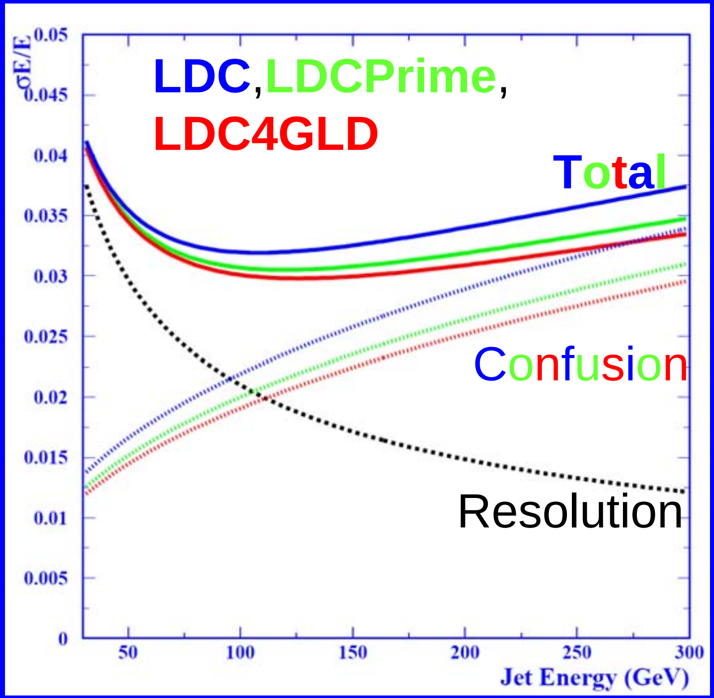
★ R is more important than B

★ Use parameterisation for comparison of LDC, LDCPrime, LDC4GLD

| Relative to LDCPrime | Confusion | Relative $\sigma_E/E$ vs $E_{JET}$/GeV | | | |
|---|---|---|---|---|---|
| | | 45 | 100 | 180 | 250 |
| LDC | 1.06 | 1.02 | 1.03 | 1.05 | 1.06 |
| LDCPrime | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| LDC4GLD | 0.95 | 0.99 | 0.98 | 0.97 | 0.96 |

- LDC4GLD slightly (< 4 %) better than LDCPrime
- But LDC, LDCPrime, LDC4GLD differences are small

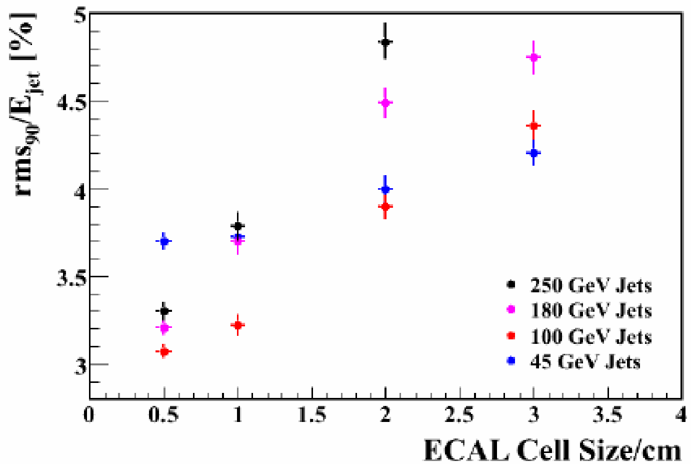




# ECAL Granularity

## Optimisation: ⑤ ECAL Segmentation

- ★ Start from LDCPrime with 5×5 mm² SiW ECAL pixel size
- ★ Investigate 10×10mm², 20×20mm² and 30×30mm²
  - Note: required changes in PandoraPFA clustering parameters




- ★ Performance is a strong function of pixel size
- ★ Probably rules out segmentation of >10×10mm² !!!!

⚠ Is latest version of PandoraPFA optimal for larger pixels ?
- no obvious problems seen yet…

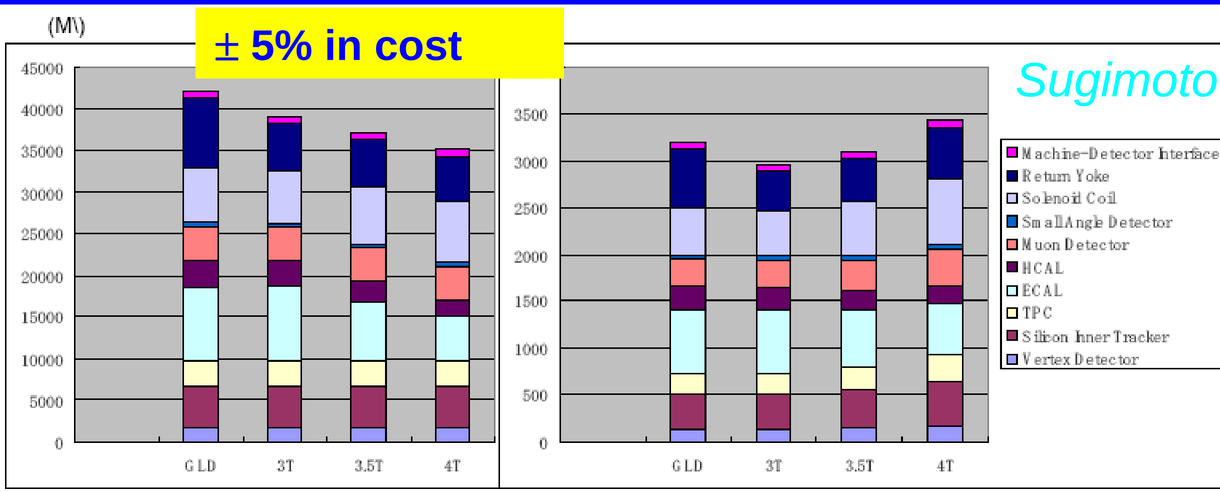
ILD Workshop, 11/9/2008 Mark Thomson 18

ECAL segmentation appears to be rather important

Needs further study and clarification

# Cost

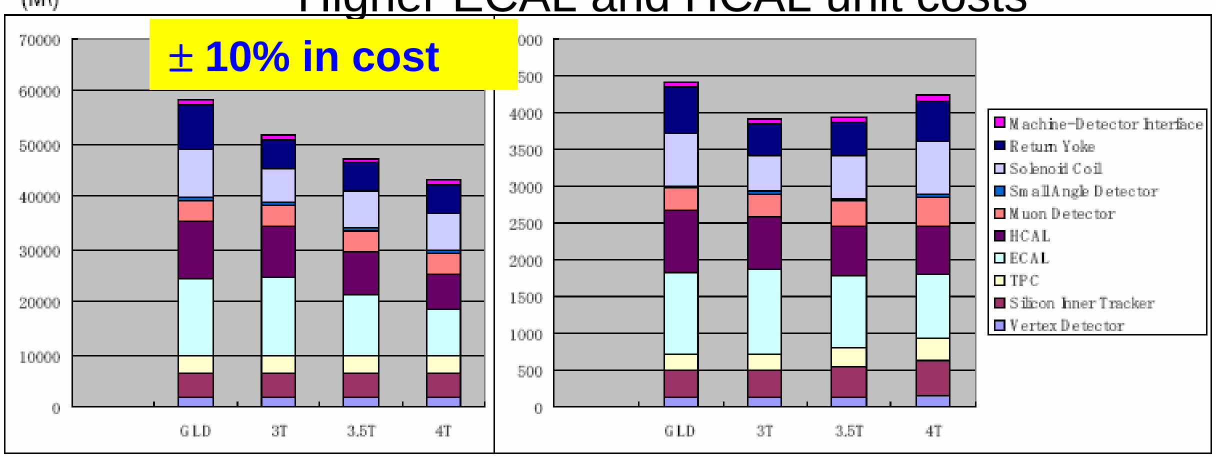
## GLD Cost Model




Cost

Cost normalized by $BR^2$

Higher ECAL and HCAL unit costs




Cost

Cost normalized by $BR^2$

LDC cost model gives ± 15% wrt LDC' ( R scaling only).

Conclusion: higher performance costs more.

Uncertainties in unit costs and actual detector technologies
=> inappropriate to over-emphasize cost now.

Let's emphasize understanding how to make the detector better, and how this impacts the physics capabilities

# Status/Plans for Benchmark Studies

| | | |
|---|---|---|
| 10:05 | [21] Tau analysis | Dr. SUEHARA, Taikan |
| 10:30 | [45] A study of the sensitivity of the ILC to the neutralino2 in the di-muon final state. | Mr. D'ASCENZO, Nicola |

**Physics based optimisation/benchmarking II - Queen's building lecture theatre (11:15-13:00)**

| time | [id] title | presenter |
|---|---|---|
| 11:15 | [30] ZH Recoil Mass | ITO, Kazutoshi |
| 11:35 | [34] Higgs Branching Ratio from ZH -> Hll | GRIMES, Mark |
| 12:00 | [38] ZH --> qqbb study with neural network | Dr. YAN, Wenbiao |
| 12:25 | [41] Sensitivity to the Higgs self-coupling with full simulation | Mr. GIANNELLI, Michele |

**Physics based optimisation/benchmarking III - Queen's building lecture theatre (14:15-16:00)**

| time | [id] title | presenter |
|---|---|---|
| 14:15 | [36] SUSY Analysis | Dr. SUEHARA, Taikan |
| 14:35 | [37] Chargino/Neutalino fully hadronic analysis | Dr. KAEFER, Daniela |
| 14:55 | [39] WW scattering at 1000GeV | Dr. YAN, Wenbiao |
| 15:15 | [35] ttbar 500GeV benchmarking | Dr. IKEMATSU, Katsumasa |
| 15:40 | [40] Top pair production at the ILC | Mr. MOLL, Andreas |

**Towards ILD - Queen's building lecture theatre (16:30-18:30)**

| time | [id] title | presenter |
|---|---|---|
| 16:30 | [42] Summary of Physics based detector optimisation studies | Dr. TAKUBO, Yosuke |

Many talks at Cambridge studying physics performance with fully simulated samples of signal and background with the LDC and GLD based samples.

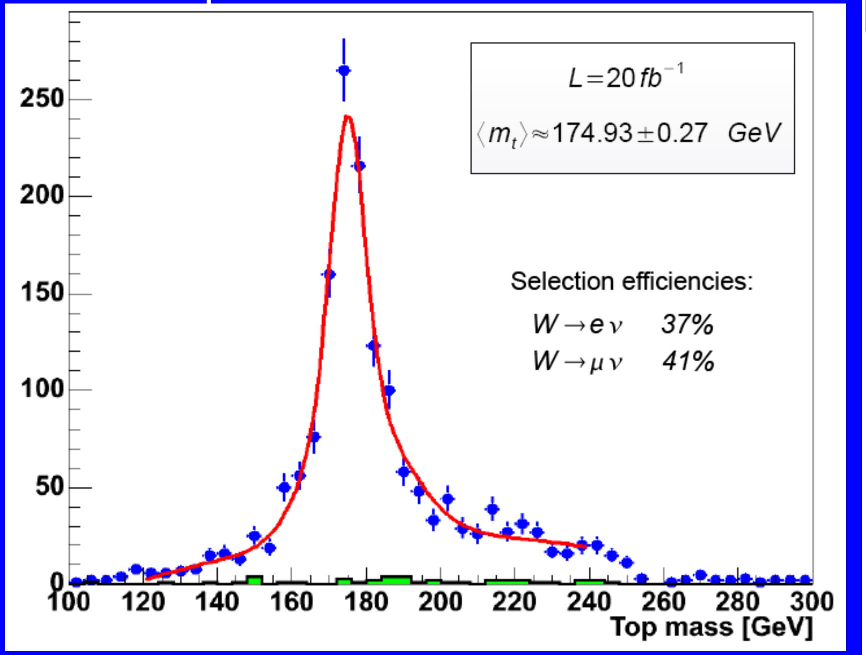
All benchmarks processes have strong groups working on them. We also expect several results in addition to the benchmarks

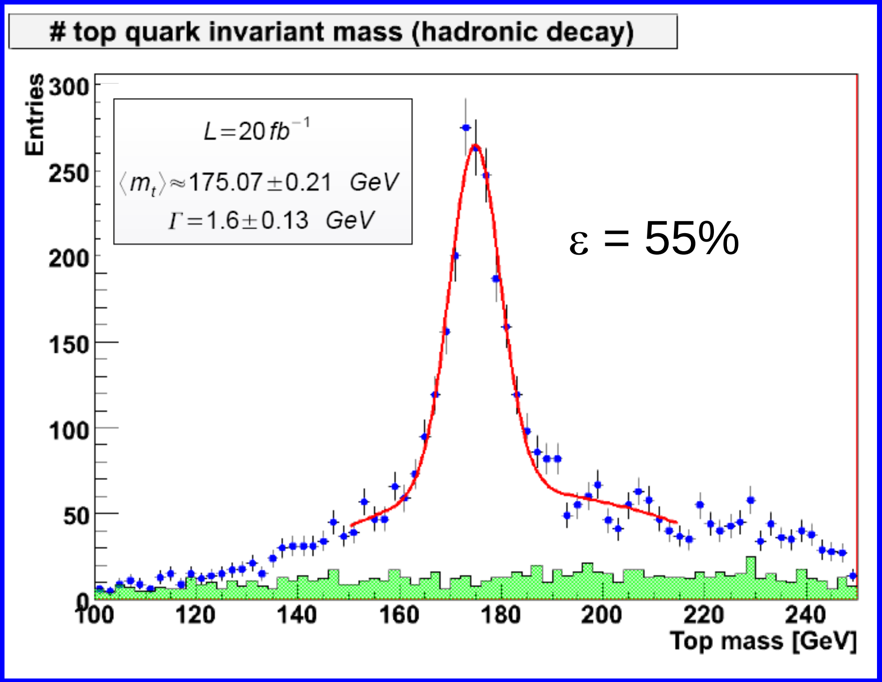
# BenchMark 5: top-pair production

√s = 500 GeV. Full simulation, LDC' detector model

*Moll, Raspereza*

semi-leptonic channel



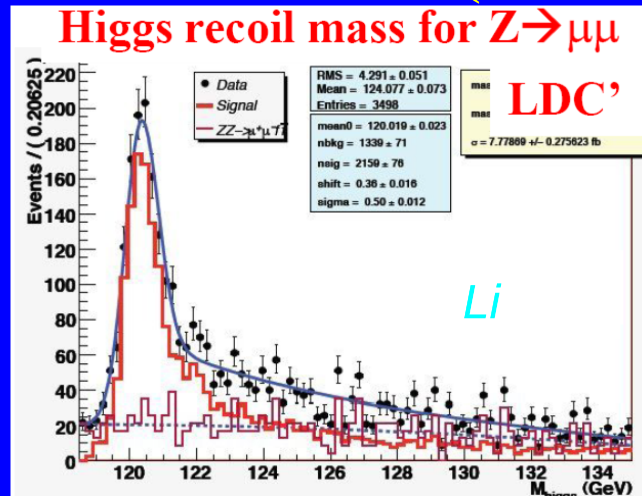




Analysis uses Pandora PFA, b-tagging (LCFI), and kinematic fit.

Result: factor of 2.5 improvement in sensitivity over hadronic-only study of PRD 67, 074011 (2003)

# BenchMark 1 (ZH →ll X )

√s=230 GeV

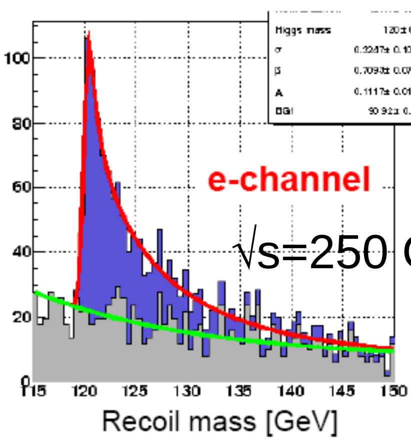



Li

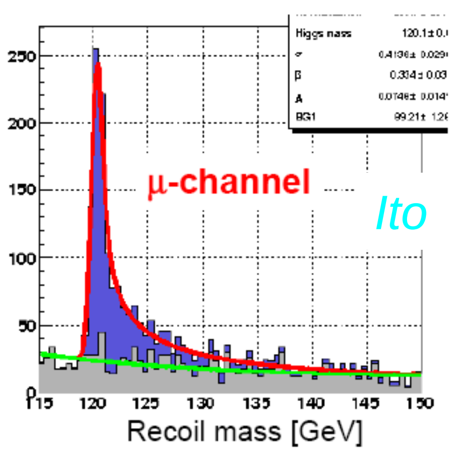
| | $e^+e^-$ | $\mu^+\mu^-$ |
|---|---|---|
| $\Delta M_H$ (MeV) | 66 | 33 |

Improvements expected in the electron channel

- Background parameter is fixed except for normalization.




√s=250 GeV




Ito

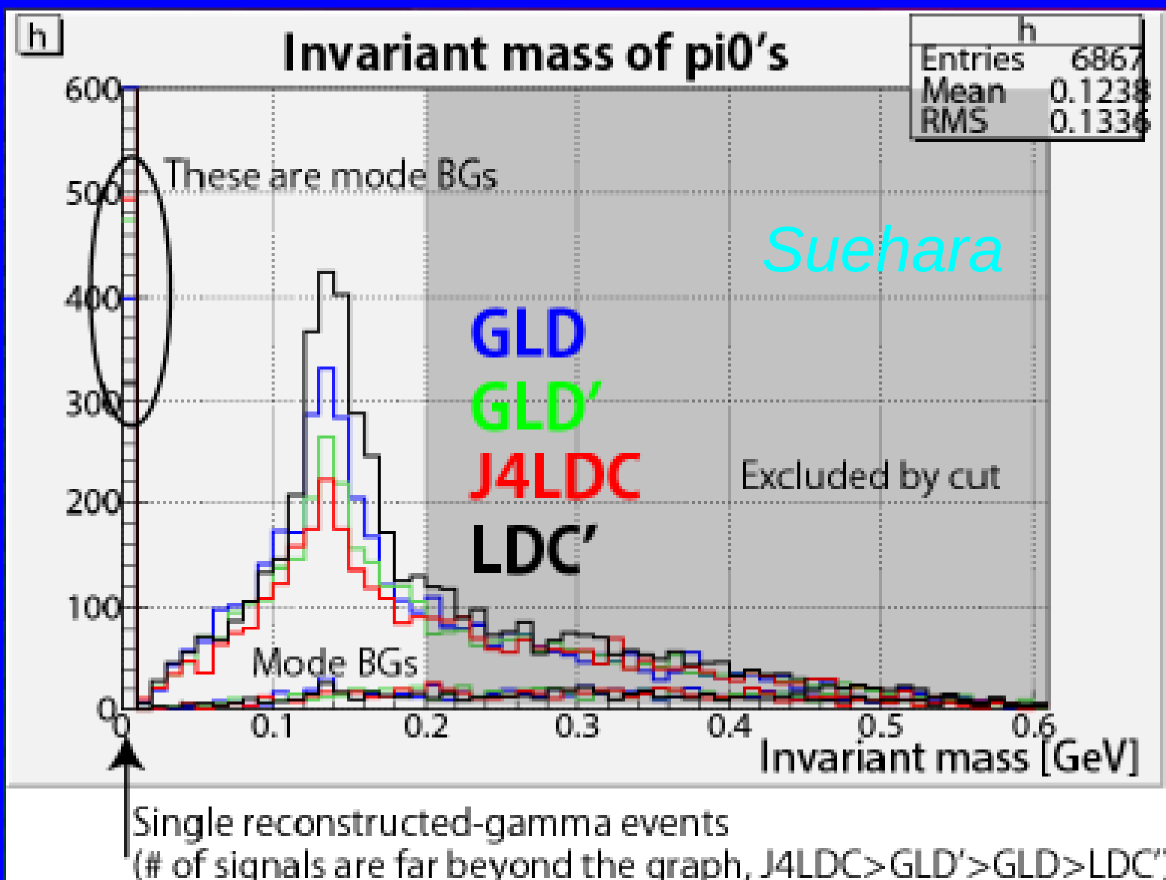
- Electron channel
  - Measurement accuracy for 250 fb$^{-1}$:
    - $M_H$ = 120.0 +/- 0.10 GeV
    - σ(ZH) = 7.5+/- 0.35 fb
- Muon channel:
  - Measurement accuracy for 250 fb$^{-1}$:
    - $M_H$ = 120.1 +/- 0.041 GeV
    - σ(ZH) = 7.7 +/- 0.29 fb

The electron channel is an excellent test of the ability to track electrons as they bremsstrahlung.

We need to put more emphasis on electron momentum meeasurement in the single particle studies when investigating the tracker/calorimeter tradeoffs.

# BenchMark 4

$e^+ e^- \rightarrow \tau^+ \tau^-$ ($\sqrt{s}$= 500 GeV)




GLD > GLD' > J4LDC

(larger is better with same segmentation)

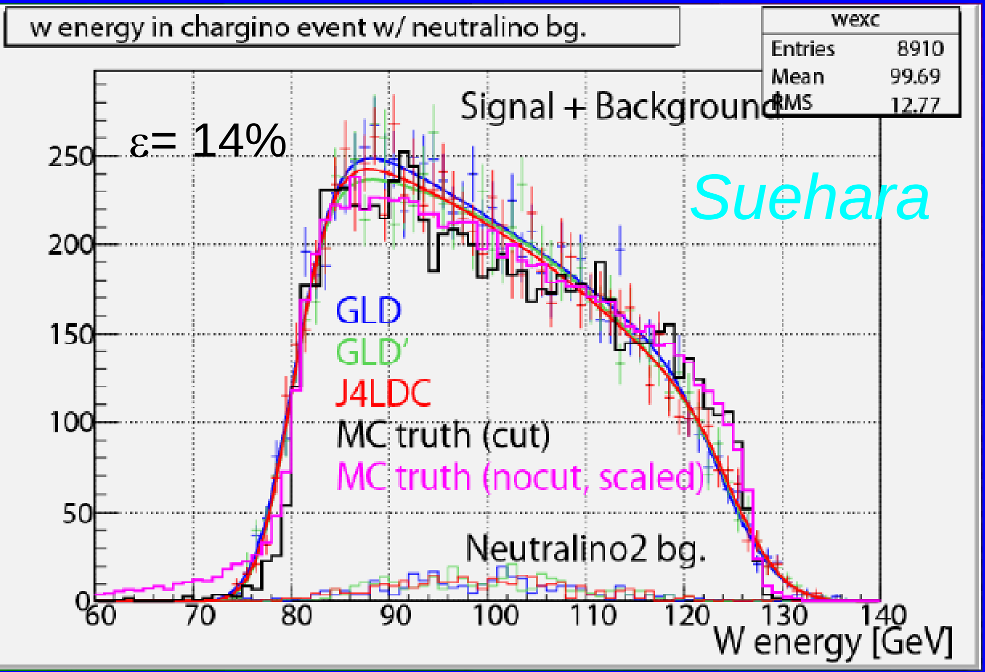
5 mm Si significantly better than 10 mm Scintillator for $\pi^0$s from 250 GeV taus

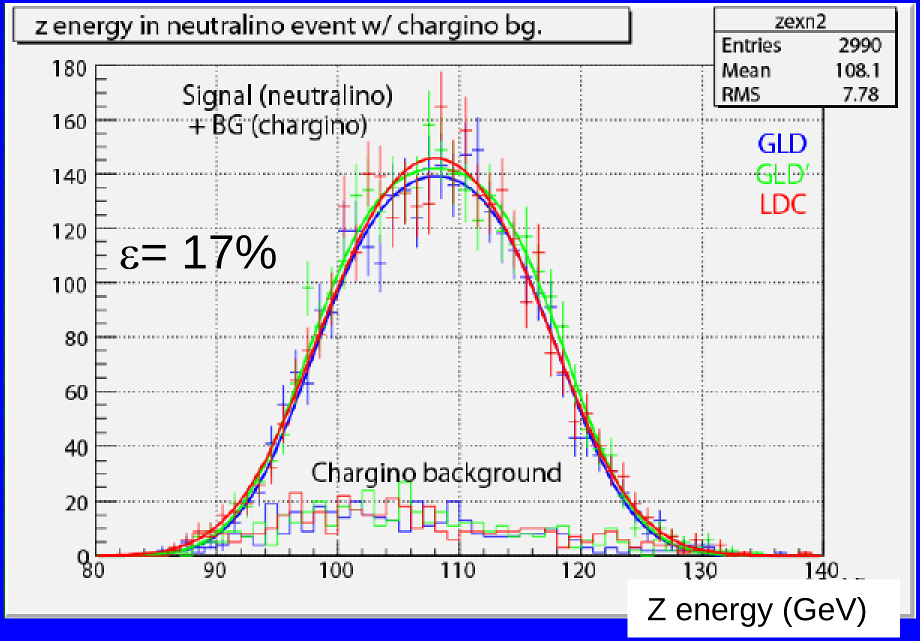
# BenchMark 6

$C_1\, C_1 \rightarrow W^+\, W^-\, N_1\, N_1$ $\quad$ $N_2\, N_2 \rightarrow Z\, Z\, N_1\, N_1$

Masses (GeV): C1(210), N2(211), N1(117)

Here consider all-hadronic decay modes at √s=500 GeV




WW/ZZ separation rather good.

Room for improvement in efficiency.

Also analysis in progress by Kaefer making extensive use of kinematic fits. See talk at LCWS08 (Wed 11.15 AM)

# Decisions

- Based on the studies presented at Cambridge, we came to a consensus to move forward with a detector with B= 3.5 T (nominal) and $R_{ECAL}$= 1.85 m.
- In many cases the sub-detector technology is likely to play the biggest role in the performance.
- Arguments for Larger
  - PFA
  - high $p_T$ muon momentum resolution
  - $\pi^0$ reconstruction ($\tau$)
- Arguments for Smaller
  - Impact parameter at low $p_T$
  - Cost
  - Bkgd. Sensitivity of VTX (needs more study)

# Reference Detector/Technologies/Options

- Reference Detector model chosen. Dimensions and segmentation are specified to serve as a basis for the performance studies to be presented in the LoI.
  - We have specified a reference detector for the simulations needed for the performance and physics studies.
  - There are several technologies with the potential to achieve the specified performances, so no decisions on technology have been made at this point.
- VTX: <u>3-double layer</u>, 5-layer
- TPC Geometry: <u>Cylindrical</u>, Rounded Polygon
- Si-tracking: Include SET&ETD
- ECAL: <u>Silicon</u>, Scintillator, MAPS
- HCAL: <u>Analog (Scintillator),</u> Digital (Gas)
- CAL Geometry : <u>Octagon</u>, Dodecagon
- Yoke Instrumentation: Coarse Tail-Catcher
- LCAL: Si-W
  - Underlined options are those chosen for the simulation model for the mass production
    - Also reflects maturity of associated simulation model / reconstruction.
  - We plan on including all of the options listed in the LoI.

# Plans for BenchMark Studies

- First round of partial benchmark studies done.
  - Powerful software framework and dedicated analyzers already getting impressive results with full simulation and reconstruction N years before beam.
  - Sometimes some insights on detector optimization
- We have recently frozen the updated ILD00 simulation model in Mokka.
  - Main substantive differences are:
    - 3 doublet-layer VXD model
    - Instrumented LHCAL
    - Sparsely instrumented yoke
    - Tighter correspondence with CAD model
- Starting mass generation of simulated samples with ILD00 on the GRID.
- Updated reconstruction will become the next focus.
  - Will need checking
- Starting to see benefits of working in a more unified way.
- We fully expect to have comprehensive results on the benchmark channels for the LoI.

# Designing a Detector with Margin

- Our primary concern at this stage is making sure the performance of the designed detector meets or exceeds those currently envisaged for the physics
  - Design philosophy is cost-conscious and physics optimized, not cost optimized
- We have chosen to keep a solenoid engineered for 4T capability with a nominal field of 3.5T
- We have chosen to increase the depth of the HCAL (6.8 $\lambda$)
  - More margin for higher energy jets / higher $\sqrt{s}$
- We have chosen an ECAL cell size of 5mm X 5mm.
- We are studying the merits of the additional tracking sub-detectors
  - Increased precision, redundancy, more material

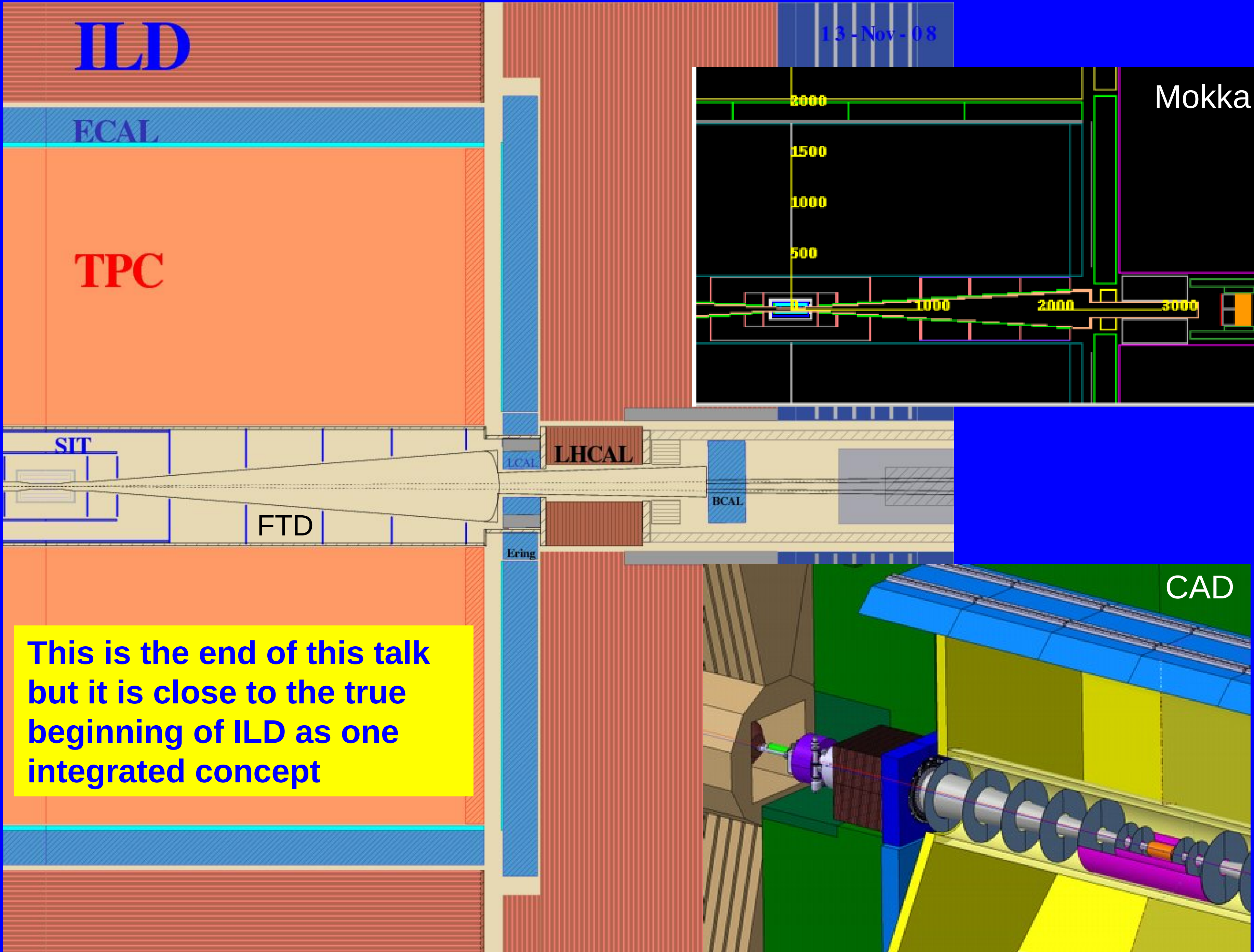
# MDI/Integration

- Anything to say here ??

# Status / Plans for Component R&D

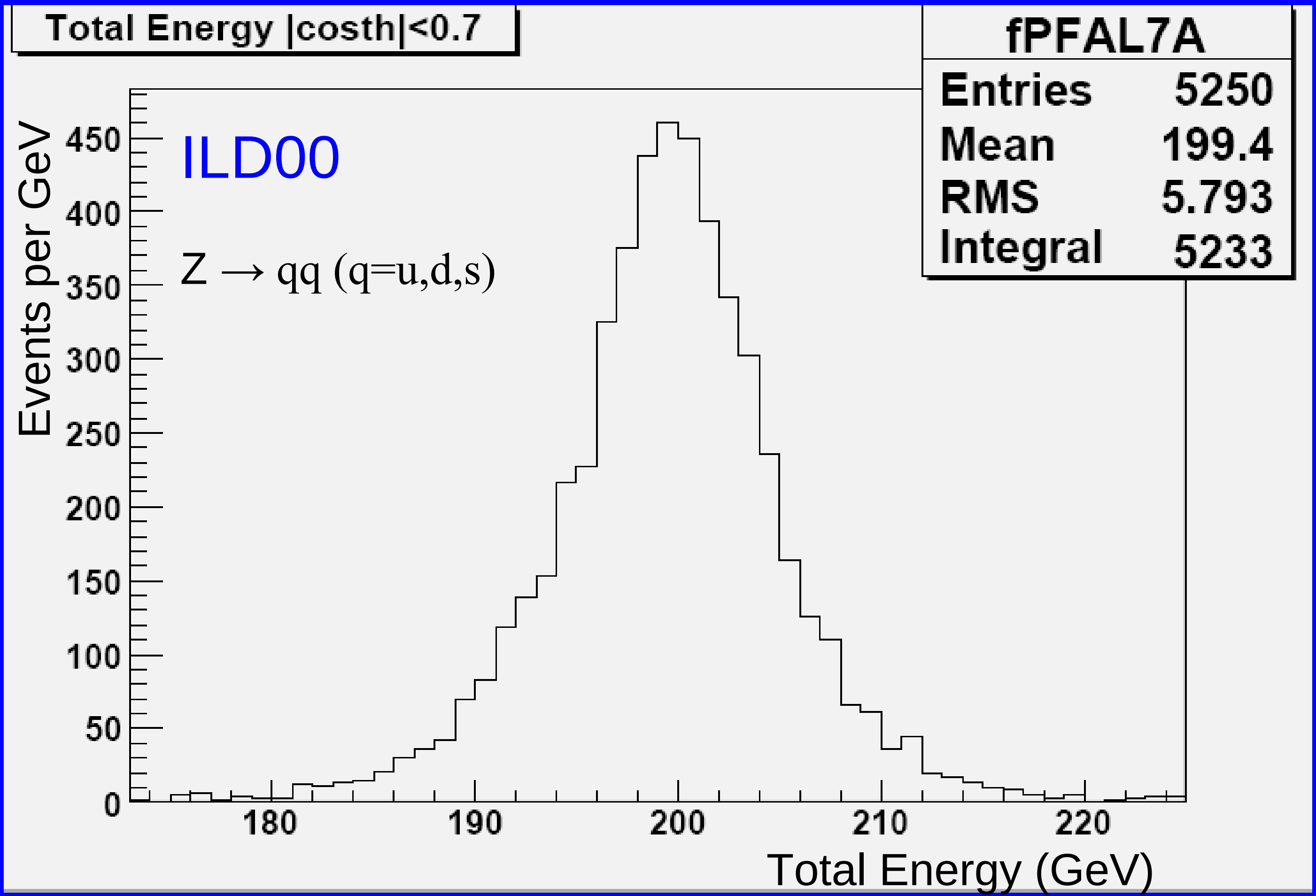
- ILD has close ties to the on-going R&D work in the "horizontal" R&D collaborations: LCTPC, SILC, CALICE, LCFI and FCAL
- Most of the R&D is done by the R&D collaborations
- ILD does not at this point have its own R&D program
- With funding problems, it is difficult for many people to participate as fully as they would like in both
  - Detector R&D
  - Detector Concept Development
- We should re-visit this question once the LOI is submitted. We expect that the detector optimization process will lead to a better appreciation of the most relevant detector R&D issues.

# Need a Summary Slide ?

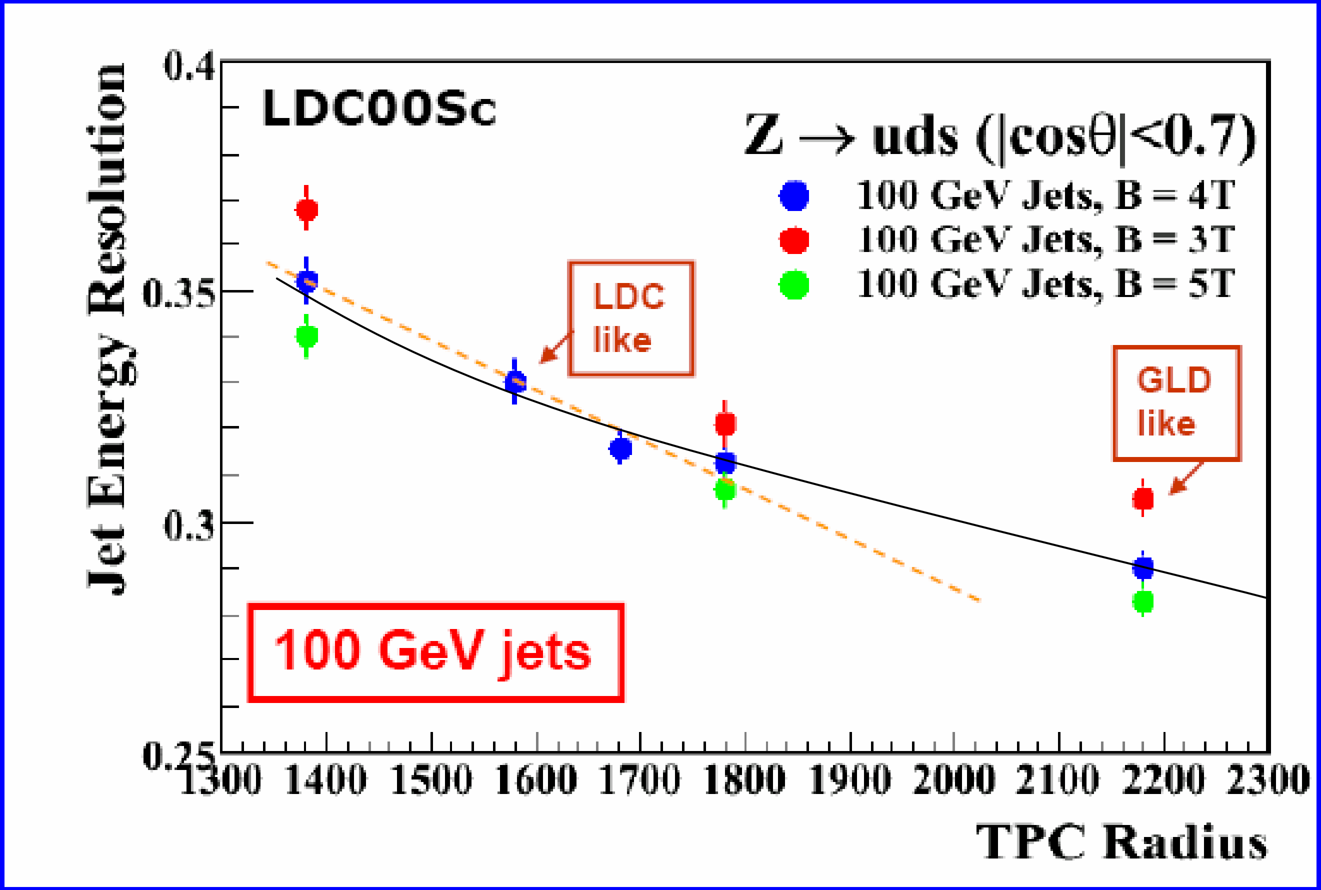



**This is the end of this talk but it is close to the true beginning of ILD as one integrated concept**

# Extra Slides


Total Energy |costh|<0.7
fPFAL7A
Entries 5250
Mean 199.4
RMS 5.793
Integral 5233
ILD00
Z → qq (q=u,d,s)
Events per GeV
450
400
350
300
250
200
150
100
50
0
180
190
200
210
220
Total Energy (GeV)

# Particle-flow → Detector directions ?

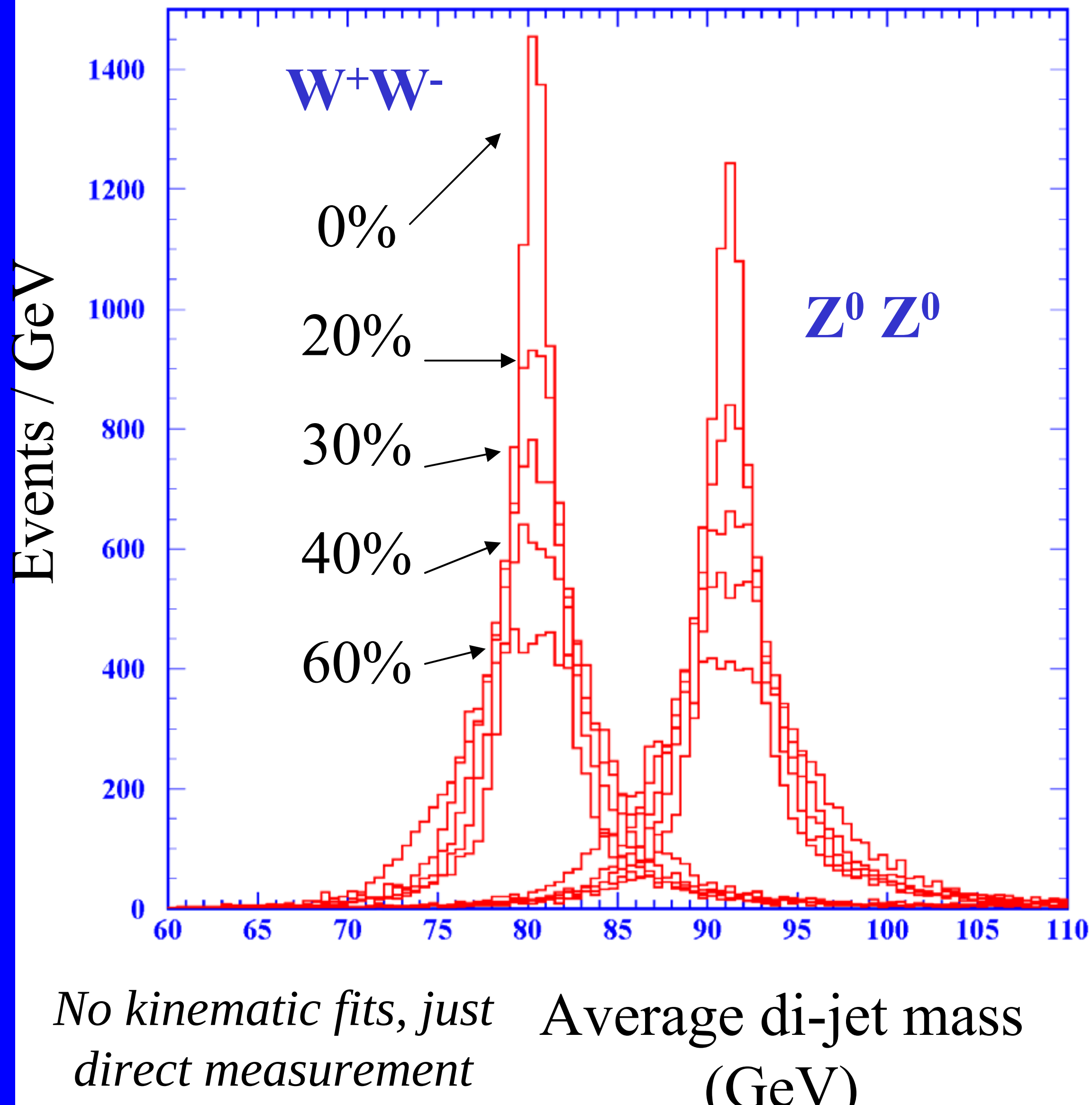



Higher R much more valuable than high B.

Presumably the decreasing slope implies that intrinsic resolution not confusion starts to dominate at high R.

(The ultimate PFA would potentially have very little dependence on B, R)

# Di-jet mass distribution vs $E_{jet}$ resolution




*No kinematic fits, just direct measurement*

Comparing $e^+e^- \rightarrow WW$ and

$e^+e^- \rightarrow ZZ$ at $\sqrt{s}$=300 GeV

(hadronic decays only, assume WW:ZZ = 1:1 for illustration, and assuming perfect assignment of particles to bosons)

*Reality = 7:1 !*

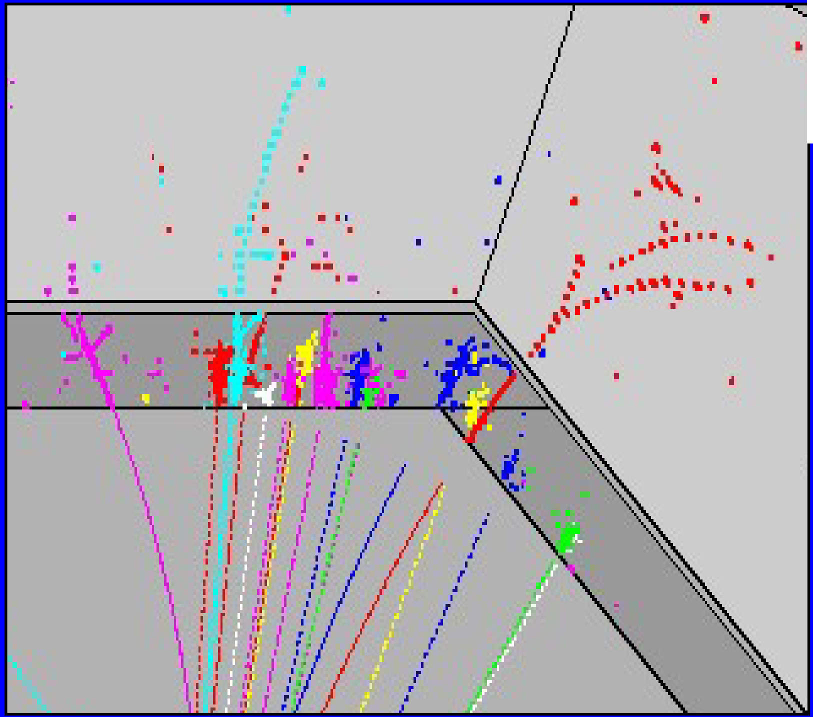
$\sigma(E_{jet})$ = xx%$\sqrt{E_{jet}(GeV)}$

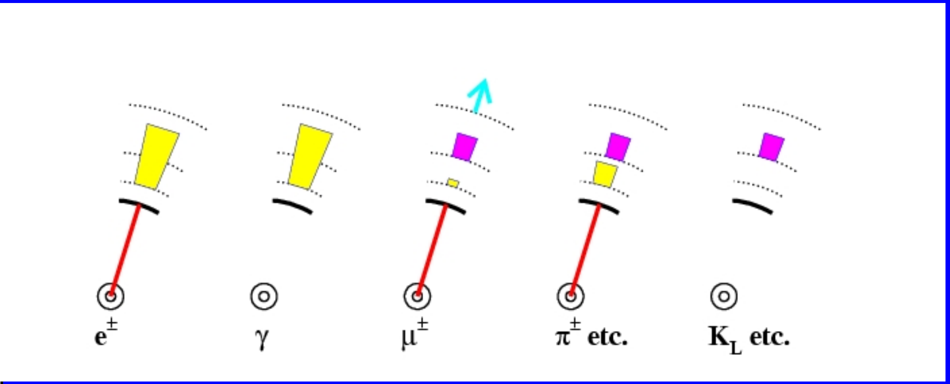
**30%$\sqrt{E_{jet}}$ is a good target for 75 GeV jets. Physics ($\Gamma_W$=2 GeV) may demand even more !**

# What is particle flow ?

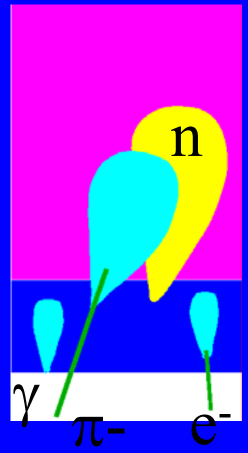
See Henri Videau's talk at Paris LCWS for a thorough introduction

Particle-by-particle event reconstruction





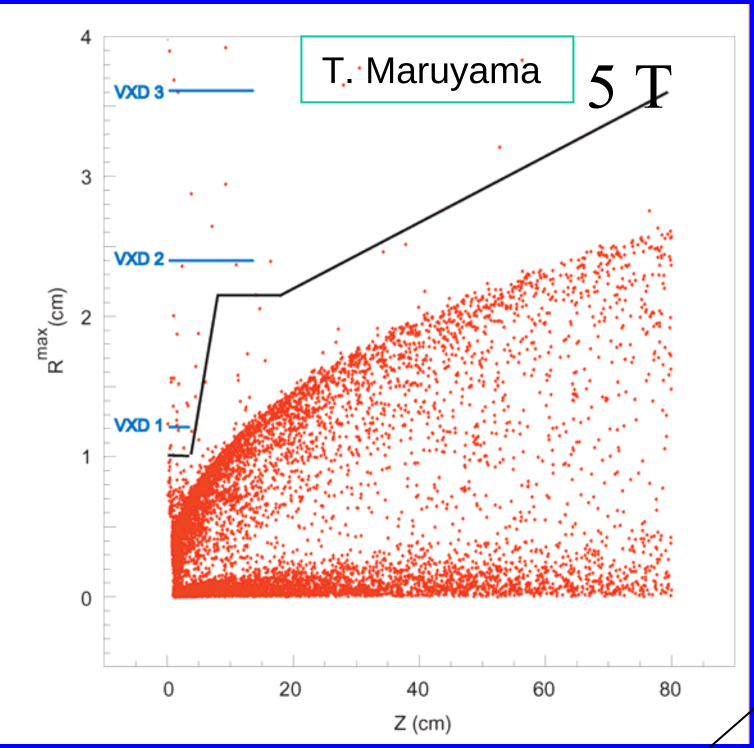

T E T T H



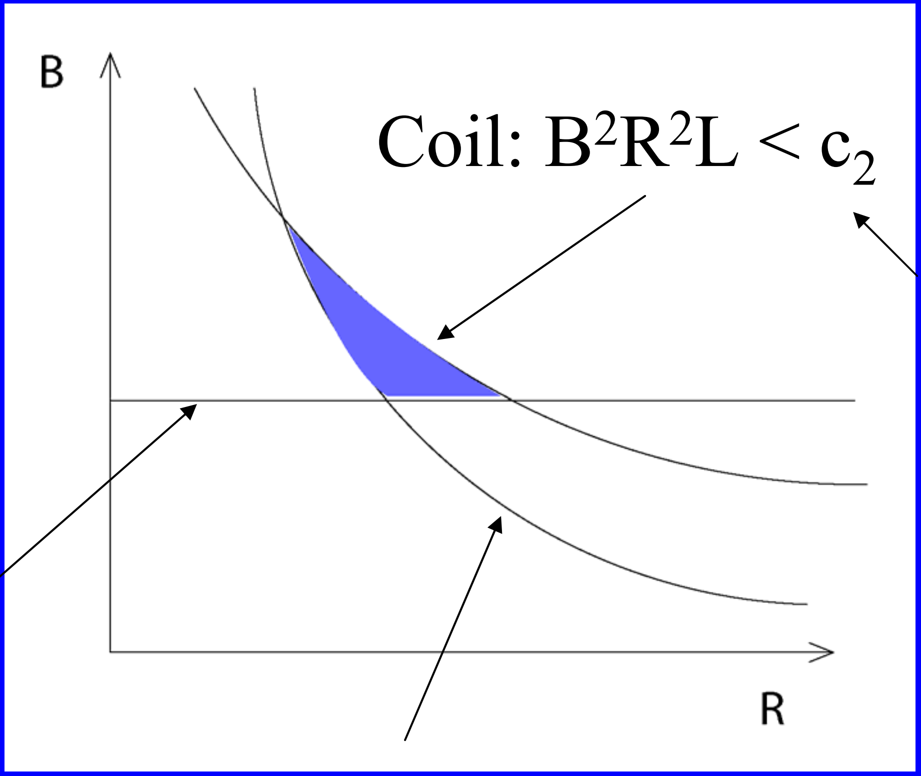

HCAL

ECAL

# Large or small detector ?




A naïve approach



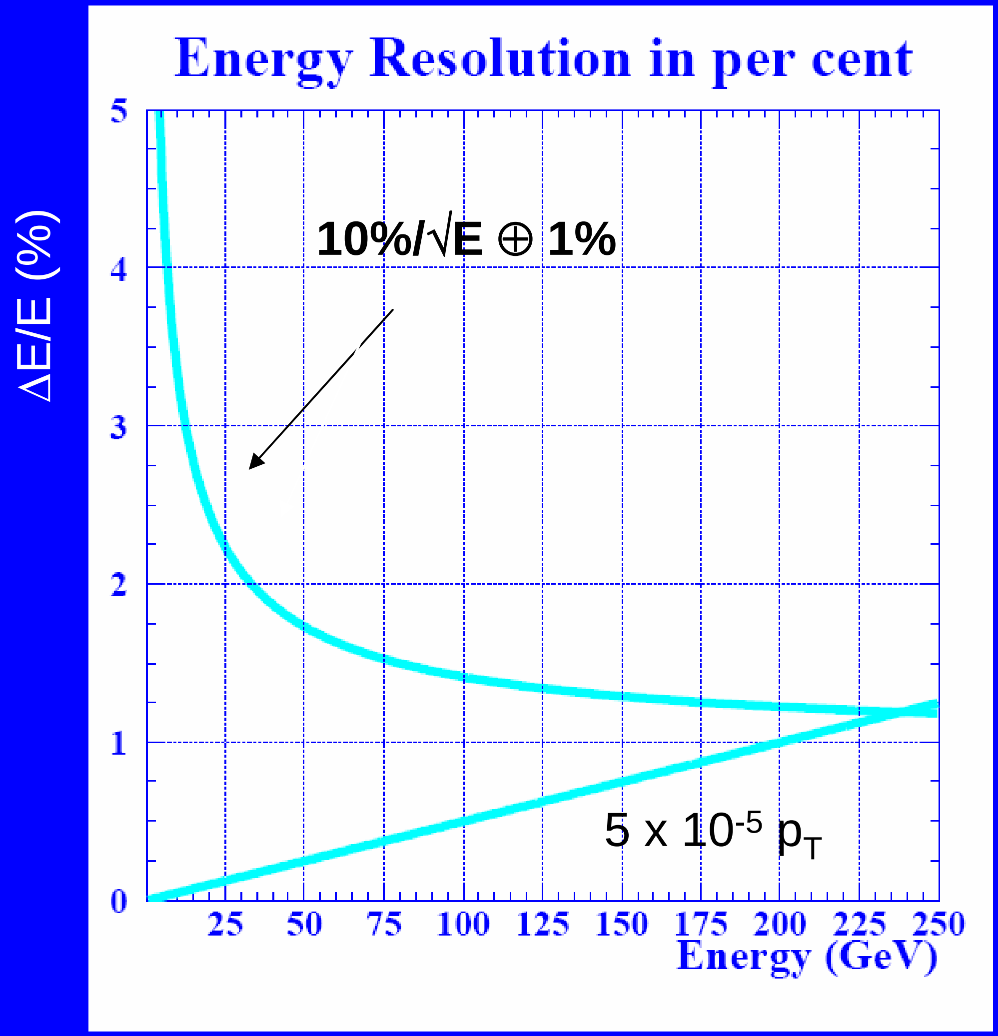

(R. Frey, LCWS2004)

The pairs background and the VXD inner radius
$\Rightarrow$ minimum B

Particle flow: $BR^2 > c_1$ ??

Momentum resolution : $BR^2 > c_3$

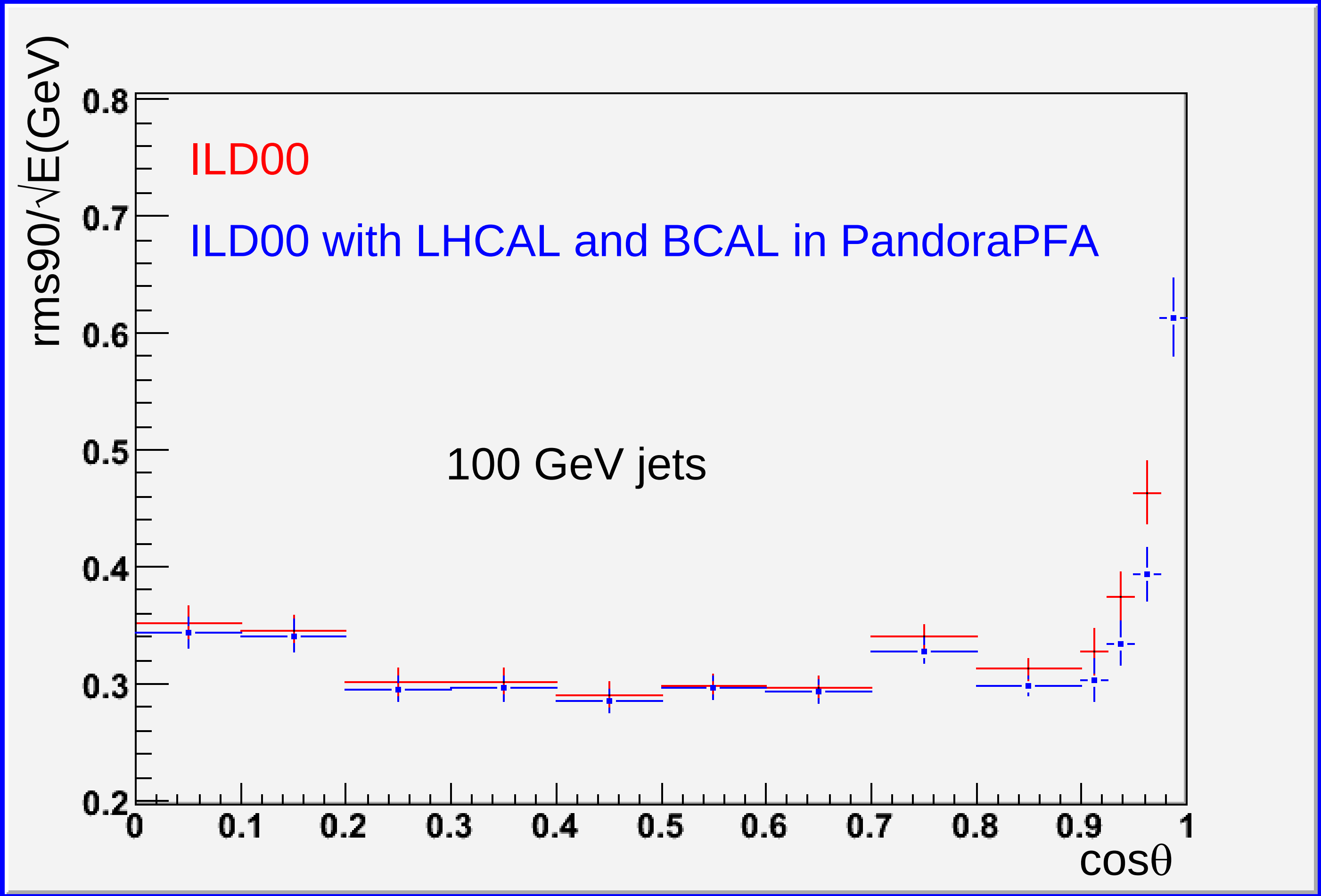
# Comparison of tracker momentum resolution with ECAL energy resolution vs Energy




Even for electrons, the tracker should do better than the calorimetry …… (modulo bremsstrahlung ….)

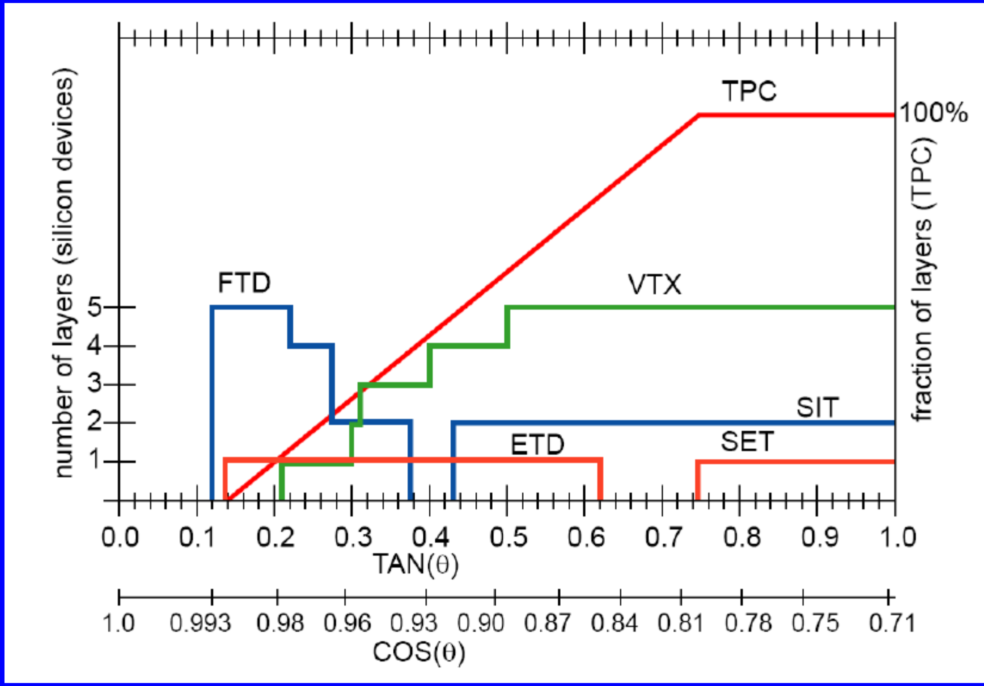
For charged pions, it is even clearer that intrinsic calorimeter charged pion resolution is not the issue IF we have a highly efficient tracker and can identify which energy depositions in the calorimeters are caused by charged pions.

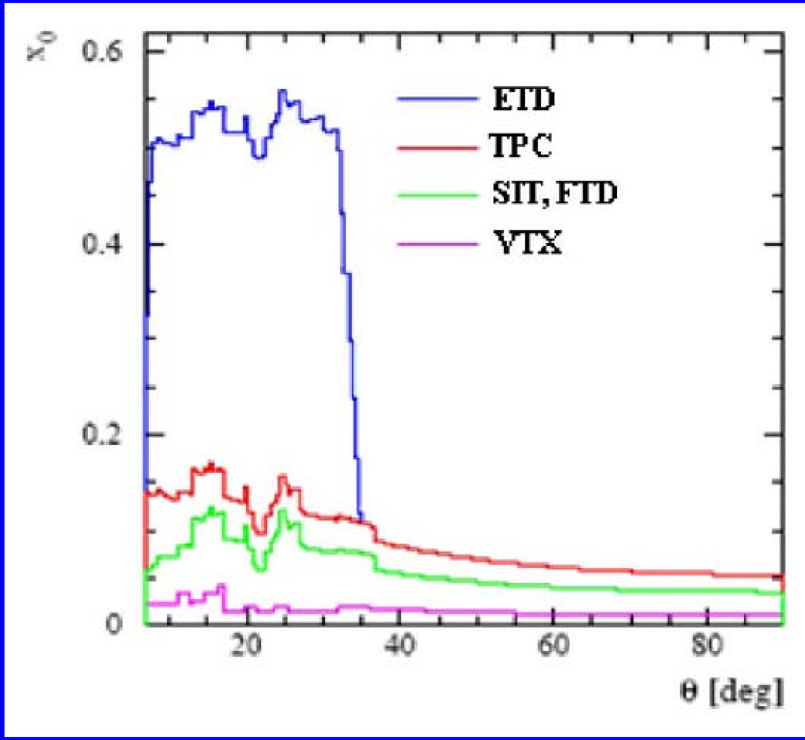
# LHCAL quoi ?




Marked improvement in homogeneity at forward angles

# Tracking: Acceptance + Material




Forward tracking disks should ensure good quality track reconstruction to the edge of the TPC acceptance.

(ETD material only an issue for track-cal matching).

Does the VTX have enough layers if it is also needed for reconstruction of soft tracks ?

# 1. LCTPC performance goals

- R&D plans/options

Present goals based on results from small prototypes using cosmics or beams at KEK, DESY, CERN. Three options left →