ILD Detector Optimisation

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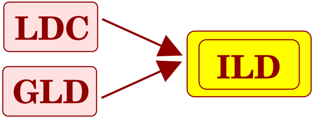
Overview

What is ILD?



GLD/LDC common features

- 'large detector concepts' → large tracking volumes for particle separation
- TPC for pattern recognition in dense track environment
- high granularity ECAL/HCAL for particle flow

GLD/LDC differences

	LDC	**GLD**	**ILD**
Tracker	TPC	TPC	TPC
Coil radius	1.6 m	2.1 m	1.5-2.0 m ?
B-field	4 T	3 T	3-4 T
ECAL	SiW	Scintillator	SiW or Scintillator
HCAL	Steel - RPC or Scintillator	Scintillator	yes

Optimisation Studies: Why and How?

1. **Main goal**:
   - find an optimal set of parameters for the ILD detector
   - demonstrate that ILD can meet ILC physics requirements
   - Initially, concentrate on global parameters like B-field and coil radius (major cost and PFA drivers)
   - But do also sub-detector studies for optimising their physics performance
2. **Optimisation strategy**:
   - wish studies which are as realistic as possible $\longrightarrow$ study signal + all SM background Monte Carlo
   - ideally include machine and underlying events background
   - use full detector simulation and reconstruction (tools available for both LDC and GLD)
   - THEN optimise costs
3. **Open questions**:
   - which parameters to optimise in view of the LoI?
   - how much will we succeed on the given time scale (expect results by end of summer 2008)

GLD and LDC Optimisation

- Priority: study the parameter space 'between' LDC and GLD
- But:
  - Scanning the full detector parameter space is very time consuming
  - More realistic approach: concentrate on the main parameters (coil radius and magnetic field)
  - GLD and LDC use different simulation and reconstruction tools, but have a common data format (`lcio`), so results can be compared directly
  - Idea: study physics performance dependence by changing parameters of GLD and LDC
    $\rightarrow$ provide cross-check of conclusions
- Advantages
  - good opportunity to exercise full reconstruction chain
  - enough to start to define ILD

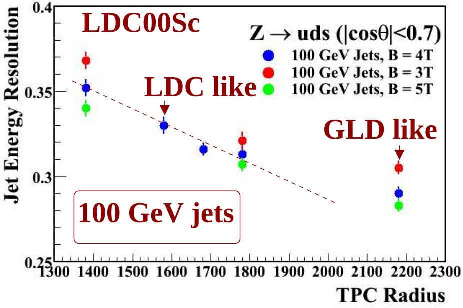
LDC'/GLD' Common Parameters

Sub-detector	Parameter	GLD	LDC	GLD'	LDC'
TPC	R_{inner} [m]	0.45	0.30	0.45	0.30
	R_{outer} [m]	2.00	1.58	1.80	1.80
	z_{max} [m]	2.50	2.16	2.35	2.35
ECAL barrel	R_{inner} [m]	2.10	1.60	1.82	1.82
	material	Sci/W	Si/W	Sci/W	Si/W
HCAL barrel	material	Sci/W	Sci/Fe	Sci/Fe	Sci/Fe
ECAL end cap	z_{min} [m]	2.80	2.30	2.55	2.55
Solenoid	B-field	3.0	4.0	3.50	3.50
VTX	inner layer [mm]	20	16	18	18

- A common point defined: GLD' and LDC' (larger LDC and smaller GLD) $\Longrightarrow$ **direct point of comparison**
- Events generation will start with LDC'

Optimisation Strategy: Global Parameters

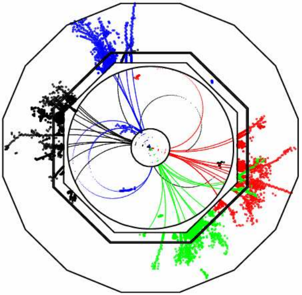
1. Ultimately want to look at physics performance
2. But also need to understand features by studying measurements like flavour tagging, PFA, etc

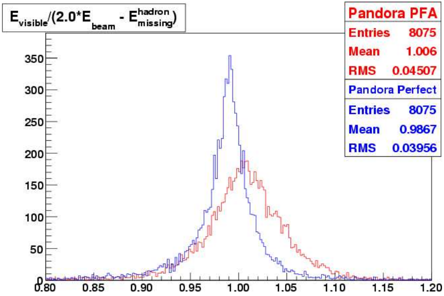


3. PFA suggests: larger radius, higher magnetic fi eld
4. But cost wants: smaller radius, lower magnetic fi eld
5. Radius more important than B-fi eld

Optimisation Caveats

1. Studies of low level performance measurements are useful. But how much survives at physics level?
2. E.g. $e^+e^- \rightarrow \nu\bar{\nu}W^+W^- \rightarrow \nu\bar{\nu}qqqq$, $\sqrt{s} = 800$ GeV
3. Compare visible energy from PFA with expected energy, i.e. after removing neutrinos/forward tracks+clusters (Wenbiao Yan)

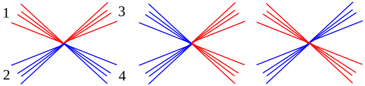




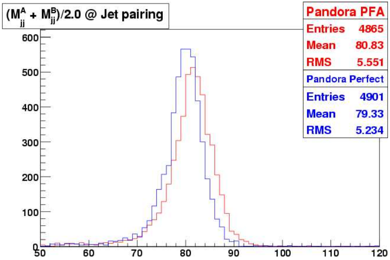
4. Pandora Perfect gives better energy resolution that Pandora PFA, as expected. Does this difference survives at physics level (i.e. after jet fi nding/jet pairing)?

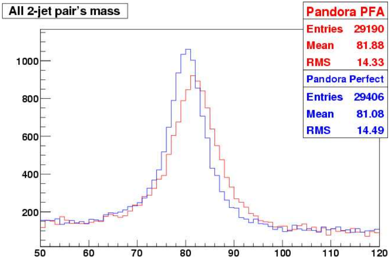
Optimisation Caveats - continued

- Force events into 4 jets (Durham)
- Plot masses of the two *W*'s formed from the 3 possible jet-pairings



- Choose pairing with smallest mass difference
- Plot average mass of the two *W*'





- In this case: Pandora PFA $\sim$ Perfect PFA
- Jet finding 'dillutes PFA performance' $\Longrightarrow$ optimisation needs care!

Subdetectors Questions (I)

1. **B-field**: why 4 T? Does B help jet energy resolution?
2. **ECAL inner radius/TPC outer radius**
3. TPC length/aspect ratio
4. Tracking effi ciency - forward region
5. **How much HCAL** - how many interaction lengths (4, 5, 6...)?
6. Impact of dead material
7. **Longitudinal segmentation** - pattern recognition vs sampling frequency for calorimetric performance
8. **Transverse ECAL/HCAL segmentation** ; ECAL: does high/very high granularity help?
9. Compactness/gaps sizes
10. HCAL absorber: steel vs. W vs. Pb vs. U
11. Circular vs. octogonal TPC (are the gaps important?)
12. HCAL outside coil
13. TPC endplate thickness and distance to ECAL
14. Material in VTX: how does this impact PFA?

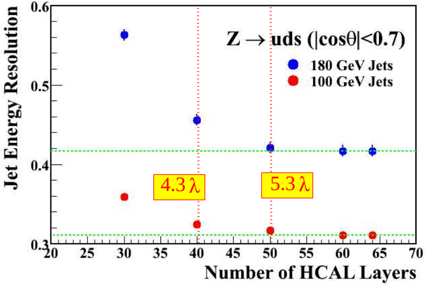
Subdetectors Questions (II)

Your contribution:

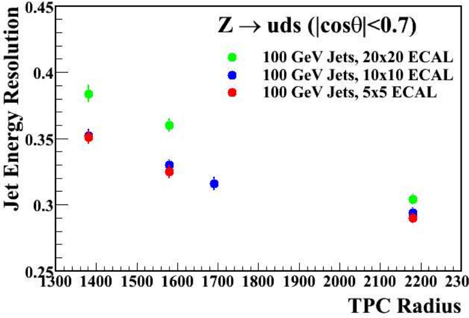
What about a similar list for Vertex?

Preliminary Answers to Some Subdetectors Questions

- HCAL depth



- ECAL transverse granularity



Monte Carlo Generation (I)

1. Every analysis in the context of ILD optimisation will need a good (fully simulated) SM sample
2. In the end, 'beam' backgrounds (beam + $\gamma\gamma$) must be included in physics analysis
3. Initially, develop analysis without 'beam' backgrounds (tools for including it should be developed in parallel)
4. Start with SM signal and backgrounds generation
5. Strategy:
   - set up a complete production chain (simulation + digitisation + reconstruction, including PF) on the **grid**
   - use databases for the production management
   - place the data on the grid storage elements (for the moment only at DESY, but there is work going on for saving the data also in Japan and North America)
   - provide web interfaces for data search
     `http://www-flc.desy.de/simulation/database/`
6. This is a considerable effort

Monte Carlo Generation (II)

1. Signals outside the SM have to be produced individually
2. There is information how to:
   - set up Whizard exactly the same way as done for the SM sample
   - set the same beam structure and fragmentation for any other generator
3. All signals (SM and outside SM) should be included in the same database
4. Production plans:
   - start with SM calibration events (Z at 91.2 and 500 GeV, $t\bar{t}$ at 350 GeV) and single particle samples
   - advantage: time for testing the reconstruction chain while the 'real' physics events are simulated
   - start simulating several 10000 events for each sample (time for people to do more debugging)
   - then run the rest in the order of priorities (to be discussed)
   - do calibration
   - run digitisation and reconstruction (including Pandora PFA)

LDC Production (Philip Bechtle)

Possible signals or backgrounds	σ	No. events
$e^+e^- \rightarrow 4\,f$	$50\ \mathrm{fb}^{-1}$	5 M
$e^+e^- \rightarrow 6\,f$	$200\ \mathrm{fb}^{-1}$	400 k
$e^+e^- \rightarrow 2\,f$	$20\ \mathrm{fb}^{-1}$	2.5 M
$e^+e^- \rightarrow hX$	$50\ \mathrm{fb}^{-1}$	75 k
Calibration samples		
Light quark 2 f at 91.2 GeV		20000 events
$t\bar{t}$ (6 f) ar 350 GeV		20000 events
Backgrounds		
$\gamma\gamma \rightarrow X$	$0.1\ \mathrm{fb}^{-1}$	1 M
$e^+e^- \rightarrow \gamma\gamma\ (n \times \gamma)$	$10\ \mathrm{fb}^{-1}$	0.5 M
$\nu\nu(n \times \gamma)$	$20\ \mathrm{fb}^{-1}$	1.5 M
$e^+e^- \rightarrow e^+e^-$	$0.1\ \mathrm{fb}^{-1}$	0.2 M
$e^+\gamma \rightarrow e^+\gamma$	$0.1\ \mathrm{fb}^{-1}$	0.6 M
rest	$1\ \mathrm{fb}^{-1}$	0.6 M

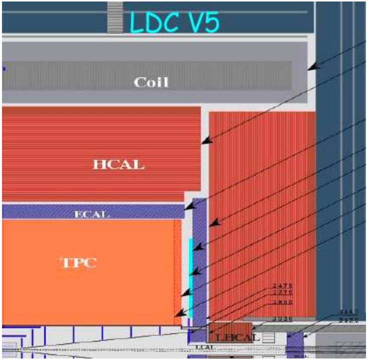
- Optimisation studies not restricted to this list
- Should be driven by optimisation needs and physics interests of the involved people

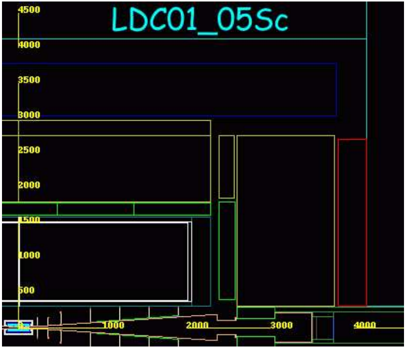
GLD Production (Akiya Miyamato)

- Not suffi cient resources in Japan to do all SM processes
- Concentrate on signal samples
- Use knowledge from LDC results with critical background processes

Possible signals at $\sqrt{s} = 500$ GeV
$e^+e^- \rightarrow \tau$ pair $e^+e^- \rightarrow$ top pair chargino, neutralino, smuon pair production
Possible signals at $\sqrt{s} = 250$ GeV
$e^+e^- \rightarrow ZH \rightarrow e^+e^-H,\ \mu^+\mu^-H$, $M_H = 120$ GeV, $\sqrt{250}$ GeV, $\sigma = 250\ \mathrm{fb}^{-1}$ $e^+e^- \rightarrow ZZ \rightarrow eeZ,\ \mu\mu Z$ $e^+e^- \rightarrow ZH \rightarrow \nu\nu Z,\ qqH$
Calibration samples
Single particle: $\gamma,\ K_L^0,\ \mu$ *uds* events (no ISR): $\sqrt{s} = 91.18$, 200, 300, 500 GeV, 10 k events $c,\ b$ events (no ISR): $\sqrt{s} = 91.18$, 200, 300, 500 GeV, 10 k events

Case Study: HCAL in LDC (Mokka)

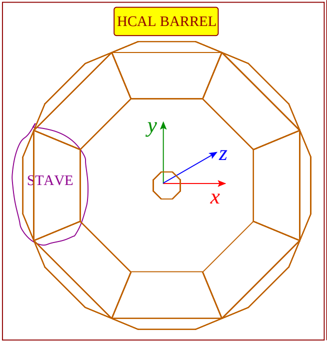


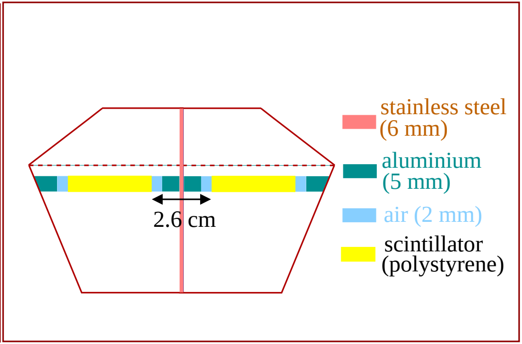


- LDC detectors progressed a lot
- Case study: HCAL
- One of the fi rst changes: HCAL ring (Paulo Mora) to cover the gap between HCAL barrel and endcaps

HCAL Preparation for Optimisation

1. Sustained work in the last months on the HCAL description in Mokka:
   - closer to 'reality'
   - more flexible (i.e. introduce steering parameters to allow optimisation studies)
2. New: layer support structure in the barrel and additional gap in the middle of the module
   - dimensions about half of the engineering values
   - need to study the impact on PFA

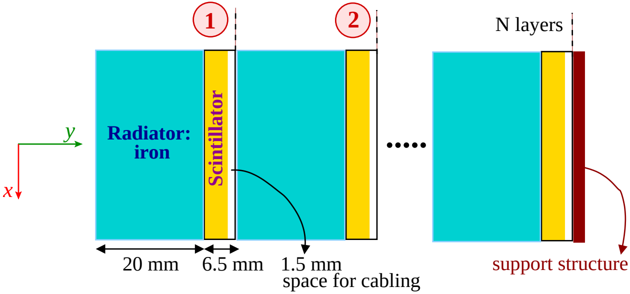




Possible HCAL Optimisation Studies: Sampling

Study sampling effects by changing:

1. **Absorber material**
   - current sampling structure: 20 mm Fe : 5 mm scintillator (4:1)

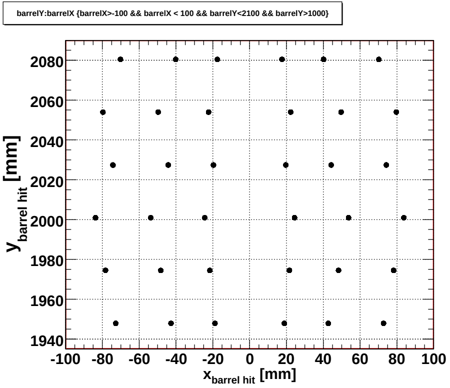


   - check other materials: Fe vs Pb vs W

2. **Absorber/scintillator thickness**

Possible HCAL Optimisation Studies: Tiles Sizes

1. Current status: $3 \times 3\ \mathrm{cm}^2$ scintillator tiles in the middle of a layer, plus fractional tiles at the edges - $x_{fractional\ tile} \in [1.5\ \mathrm{cm}, 3\ \mathrm{cm})$
2. $\Longrightarrow$ Staggering of hits in $x - y$ (but alignment in z)

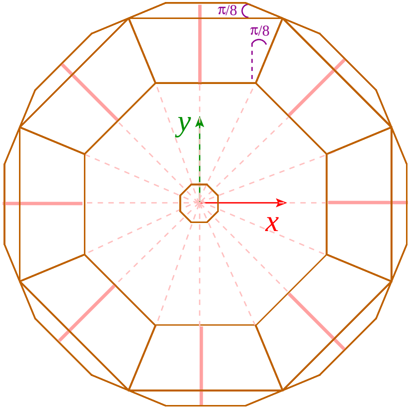


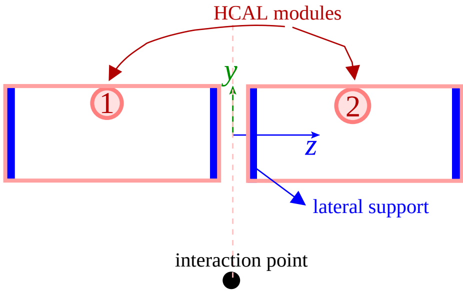
$\Longrightarrow$ No reconstruction algorithm should assume alignment!

3. Replace $3 \times 3\ \mathrm{cm}^2$ cells by $6 \times 6\ \mathrm{cm}^2$ in the last 12/24 layers

Possible HCAL Optimisation Studies: Non-pointing Cracks (I)

1. Current status: ϕ and z pointing cracks in the barrrel
2. Neutral particles not bent by magnetic fi eld $\rightarrow$ escape detection

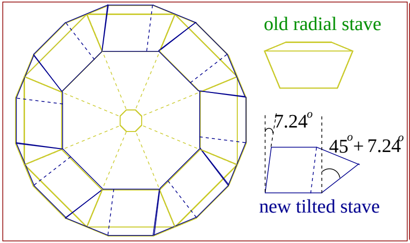


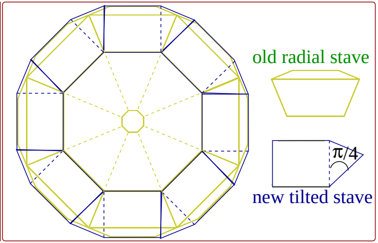


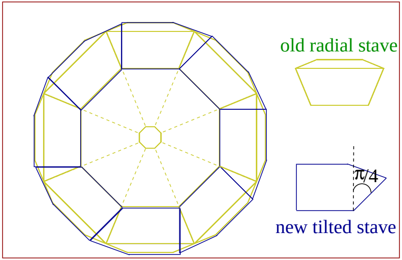
3. $\Longrightarrow$ Doubt that we will ever build an HCAL with pointing geometry...

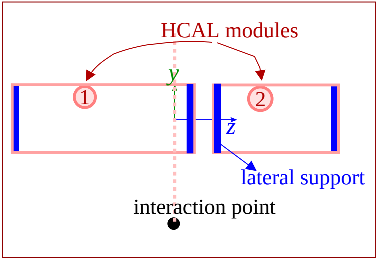
HCAL Optimisation: Non-pointing Cracks (II)

1. Imaginary non-pointing geometries (on a back of a paper, don't take them too serious):









2. $\Longrightarrow$ Waiting for input from the engineers

Conclusions and Overview

1. Detector models:
    - last week tagged Mokka version for LDC models
    - plan to start production with LDC' model (common points with GLD)
    - GLD/GLD' implemented in Jupiter
2. Monte Carlo production:
    - production chain on grid ready
    - web interface for production info available
    - generator files will be mostly copied to DESY storage elements
    - we have a proposed list of priorities for the type of events to be first generated (to be rediscussed within their groups)
3. Optimisation studies:
    - expect results by the end of summer 2008
    - but they will continue through 1010/1012
    - major efforts have been done, but still a lot ahead of us

Acknowledgments

Thank you for ideas and/or material: Mark Thomson, ...