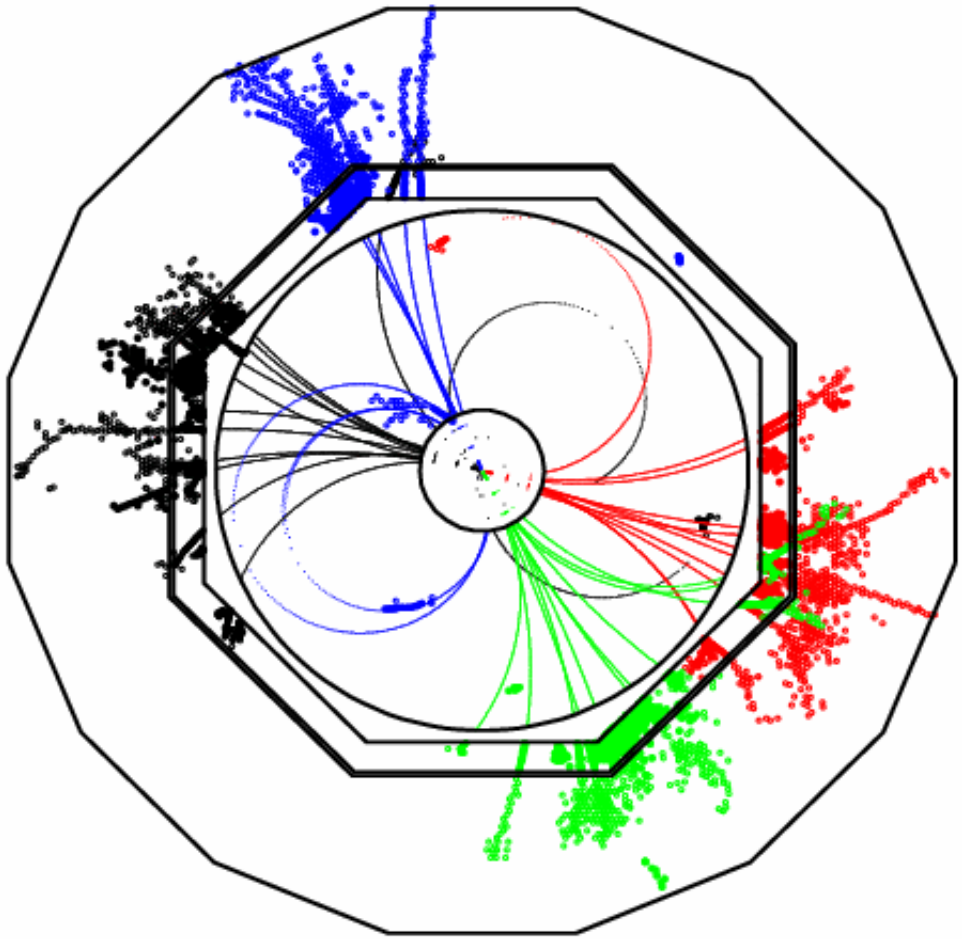
ILD Detector Optimisation Strategy

Mark Thomson
University of Cambridge



Overview:

1. What is ILD ?
2. Detector Optimisation
3. Optimisation Strategy
   - How ?
   - What ?
   - Subdetectors
   - When ?
4. Summary

❶ LDC → ILD ← GLD

★ How will GLD/LDC evolve into ILD ?

GLD/LDC have common features :

- ★ Both are Large Detector concepts, "Large" tracking volume
  - for particle separation
- ★ Both have TPC
  - for pattern recognition in dense track environment
- ★ Both have high granularity ECAL/HCAL
  - for Particle Flow

But also significant differences:

	LDC		GLD	ILD ?
Tracker	TPC		TPC	TPC
R =	1.6 m		2.1 m	1.5–2.0 m ?
B =	4 T		3 T	3–4 T
ECAL	SiW		Scint	SiW or Scint
HCAL	Steel	RPC / Scint	Scint	yes

First Goal of ILD Optimisation Study

❷ Detector Optimisation Study

Charge of Detector Optimisation Working Group:

"Investigate the dependence of the physics performance of the ILD detector on basic parameters such as the TPC radius and B-field. On the basis of these studies and the understanding of any differences observed the WG, will make recommendations for the optimal choice of parameters for the ILD detector. It is the responsibility of the WG convenors to organize this work, while the steering board will assist them in executing the charge."

Initial Goal (pre-December 2007):

- First results from detector optimisation studies by Summer 2008.
- At this time, define baseline ILD detector parameters at the level needed to start writing a LoI
- Whatever happens this is not the end of the story !
- Optimisation/Physics studies will continue through the EDR phase

in the first stage aim to:

- Convincingly demonstrate the ILD can meet ILC physics requirements
- Justifiable set of detector parameters optimised on scientific grounds

Impact of Black-December

Politics (sorry)

- December 2007 will not go down in history as an ILC highlight
- Clear that the current UK/US situation is not entirely helpful…
- Timescales for LoIs and EDRs are now less certain, likely delays to machine EDR (see FR's talk)

What does this mean for ILD optimisation ?

"If you can keep your head when all about you are losing theirs…"

- Over the last few months we have made a lot of progress
  thanks to the hard work from many people
- We have a significant community working on software tools and preparing for physics studies – try and maintain this
- At this time we have the momentum to make rapid progress and must maintain this – the political situation might look very different in 6-12 months time.
- Propose: aim for first physics based optimisation of "global" detector parameters by **Summer 2008**

❸ Optimisation Strategy

Basic Idea:

- Detector parameters optimised for physics performance
- Studies as realistic as possible:
  - Study signal + background Monte Carlo
  - Ideally include machine and underlying event backgrounds
- Use full detector simulation and reconstruction
  the tools now exist for both LDC and GLD
- Aim to parameterize "performance" vs. R_{TPC}, B, etc… (this WG)
- THEN use cost model to optimize (results from this WG + cost WG)

(hard)

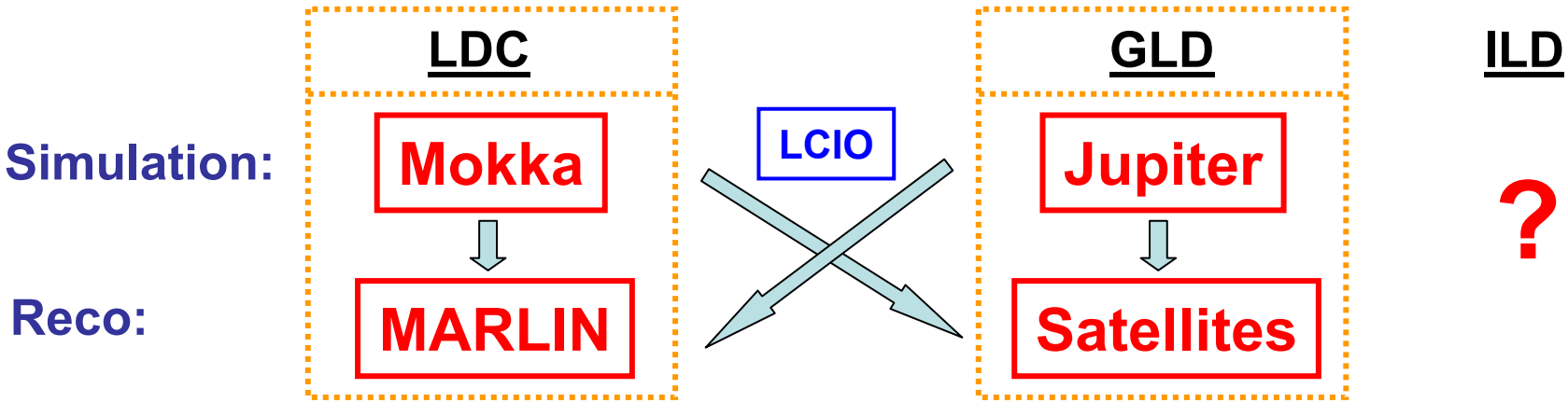
★ This is ambitious an ambitious goal !
★ Need to be realistic about what can be done for Summer 2008
★ Need to collaborate effectively
★ Plans will evolve with experience…

Questions:

- For LoI-study what parameters are we optimising ?
- In practice, how we will do this ?
- In detail, on what timescale do things need to happen ?
- Manpower ?

Optimisation Studies : How ?

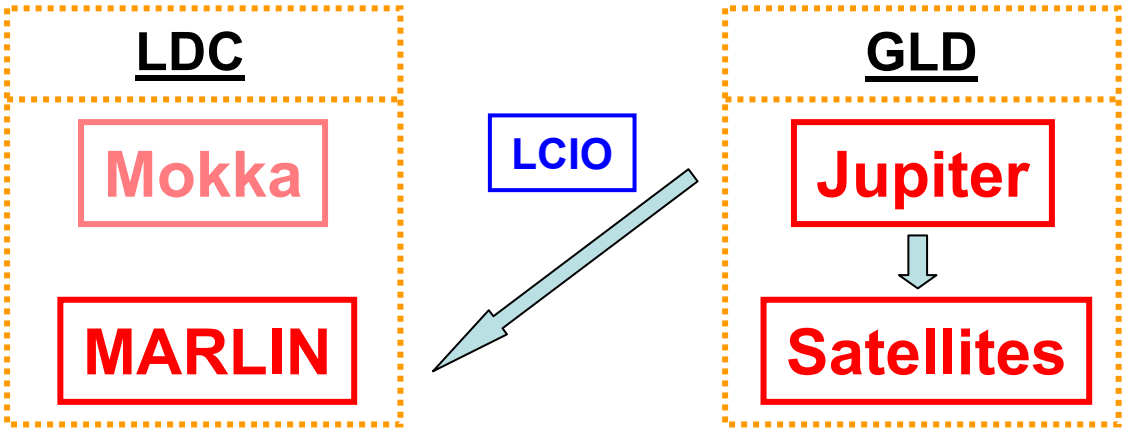
- ★ Currently GLD and LDC use different G4 simulations/ reconstruction frameworks
- ★ Connected only by common data format



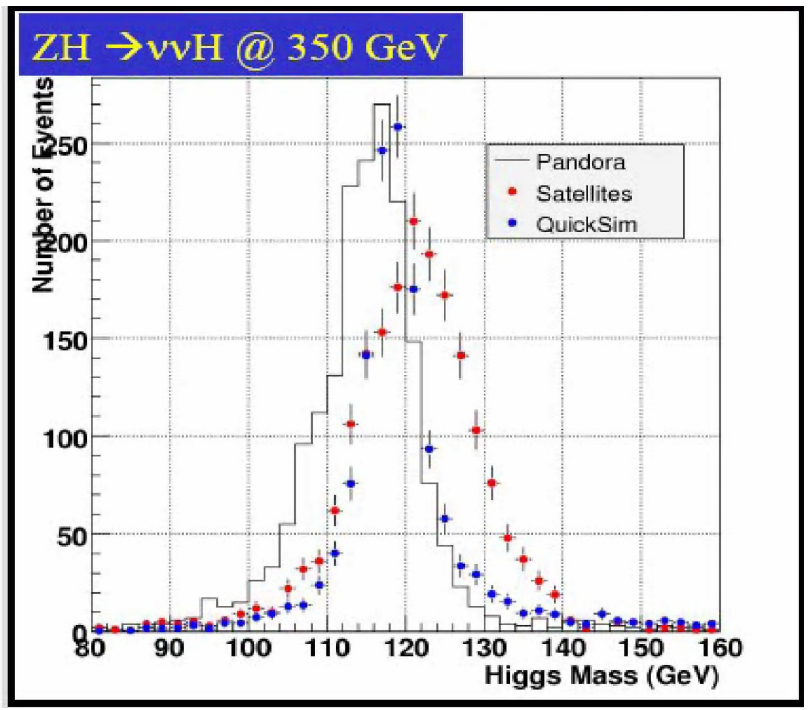
- ★ Given timescale, decided to perform ILD detector studies in context of both GLD and LDC
- ★ Study physics performance dependence by changing parameters of GLD and LDC – provide some cross check of conclusions
- ★ Can directly compare results using common LCIO data format…

NOTE: full reconstruction software now exists !

e.g.



- Very nice demonstration of Marlin processing of Jupiter GLD events
- Such cross-software studies will be very important in optimisation of ILD detector
- To do this properly – software developers need to ensure that reconstruction is optimised for both LDC and GLD



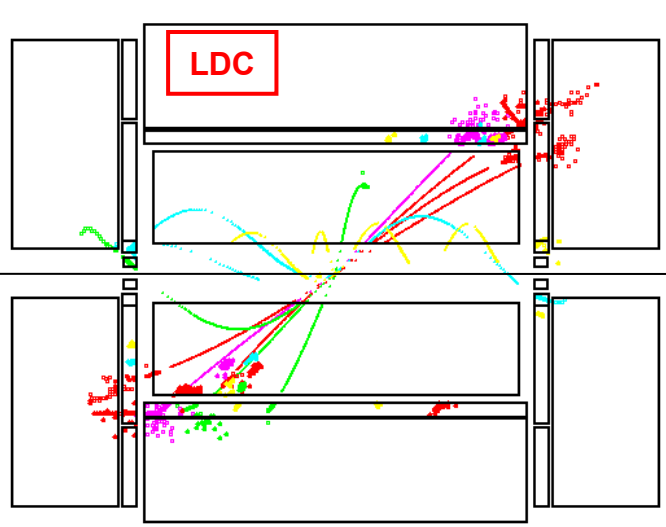
LDC'/GLD' Common Parameters

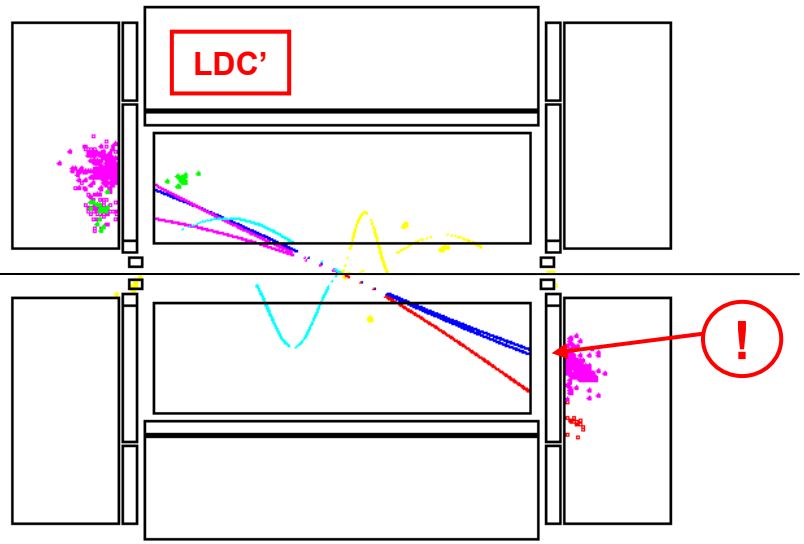
★ In addition, defined and simulated a common point: LDC' and GLD' : a larger version of LDC and a smaller version of GLD ⟹ direct point of comparison

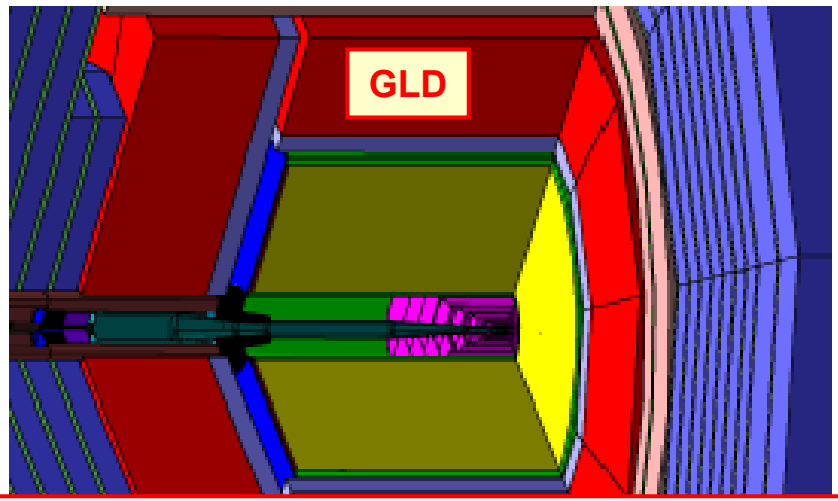
Sub-Detector	Parameter	GLD	LDC	GLD'	LDC'
TPC	R_{inner} (m)	0.45	0.30	0.45	0.30
	R_{outer} (m)	2.00	1.58	1.80	1.80
	Z_{max} (m)*	2.50	2.16	2.35	2.35
Barrel ECAL	R_{inner} (m)**	2.10	1.60	1.82	1.82
	Material	Sci/W	Si/W	Sci/W	Si/W
Barrel HCAL	Material	Sci/W	Sci/Fe	Sci/Fe	Sci/Fe
Endcap ECAL	Z_{min} (m)***	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

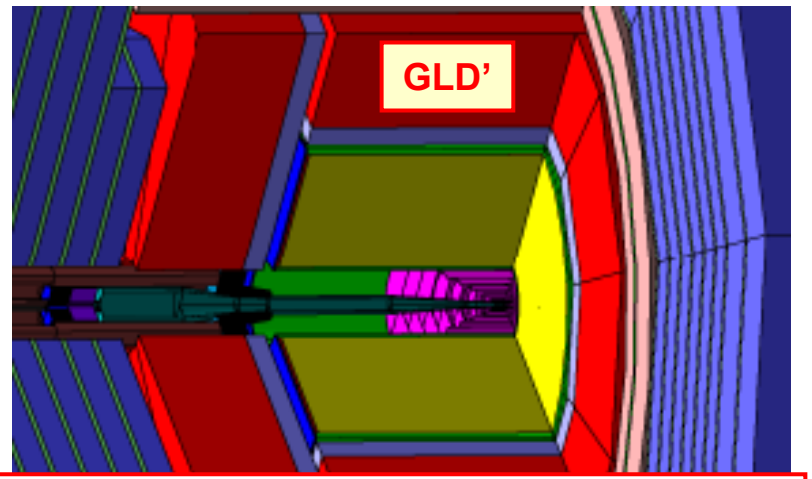
Region between VTX and TPC unchanged – time
*GLD TPC z_{max} = 2.3+0.2 m for readout (included in LDC z_{max})
**Fixed by TPC outer radius – LDC assumes slightly less space
***Fix ECAL z_{min} and allow this to determine TPC z_{max}

★LDC/LDC' in Mokka and GLD/GLD' in Jupiter are now implemented





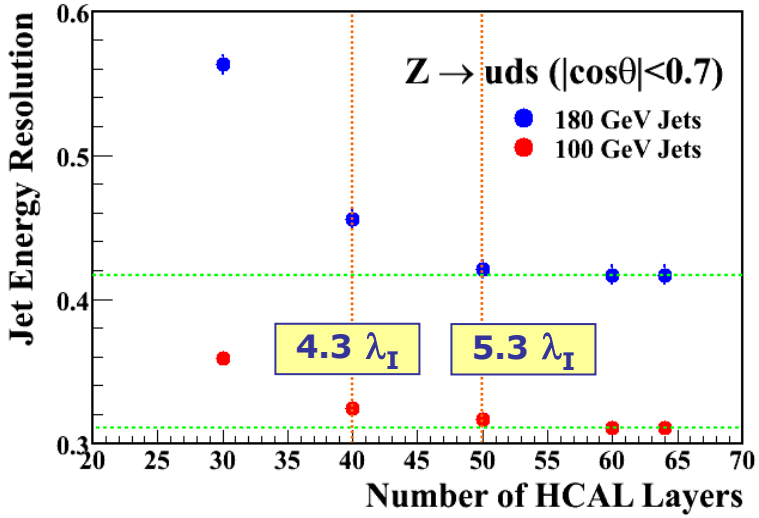


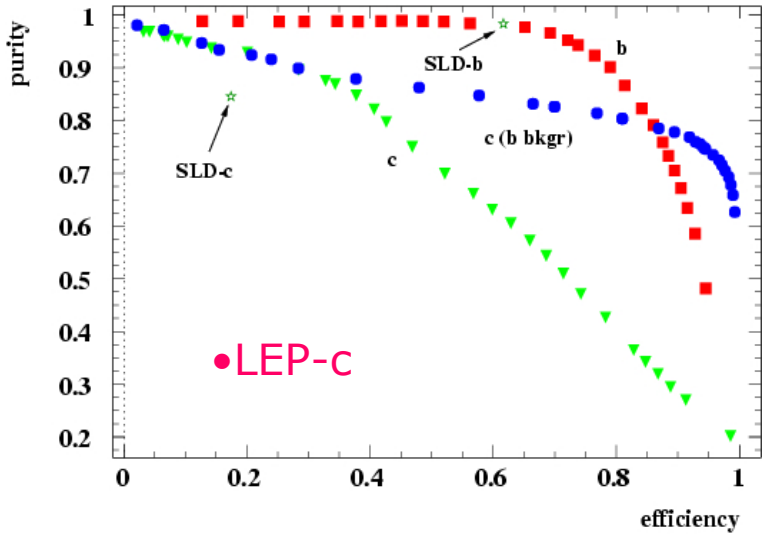


Q : Which models do we use as starting point for studies ?
GLD and LDC (the tools are ready and "validated") or GLD' and LDC' (not the current plan)

Optimisation Strategy : What ?

★ Not working in the dark - e.g. existing PFLOW/Tracking/Vertex studies





★ Good reasons to believe **ILD** can deliver the required performance

Optimisation priorities

★ Study parameter space "between" LDC and GLD

★ To study the full matrix of detector parameter space (R, B, L, …) would prove very time consuming – be realistic

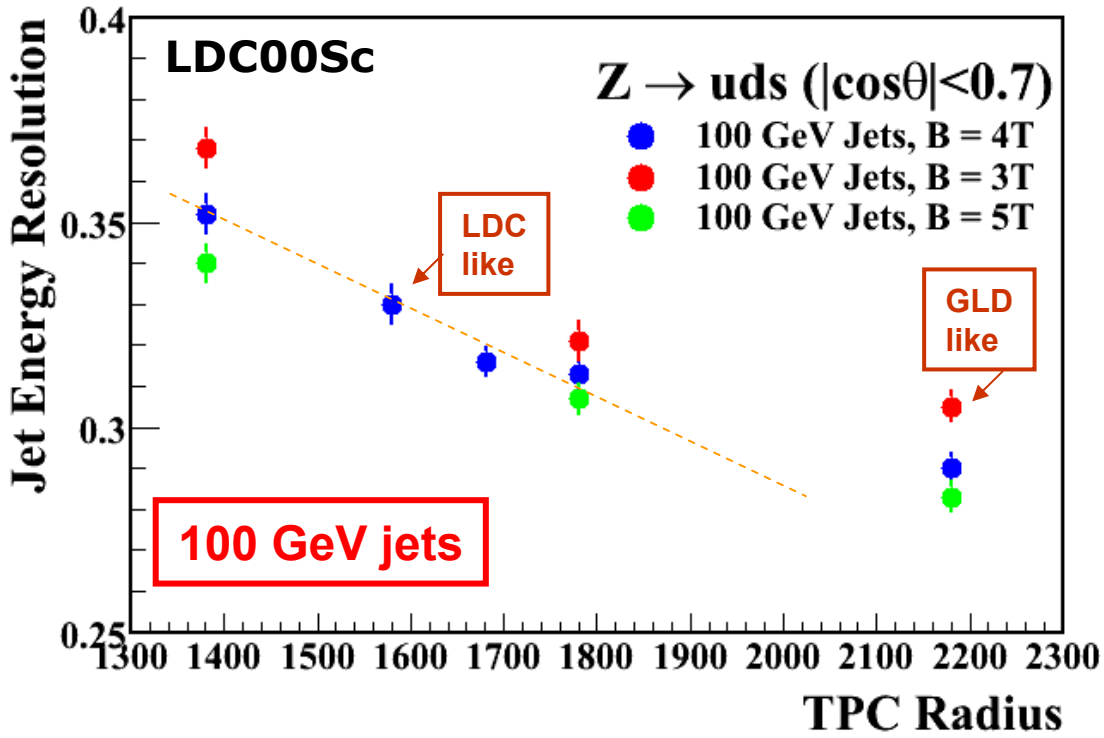
★ Initially concentrate on main parameters (**R** and **B**)

- will need to do this to exercise full reconstruction chain

★ But also want to investigate impact of **sub-detector design**… see later

Optimisation Strategy : Global parameters

- ★ Ultimately want to look at physics performance
- ★ But also need understand features by studying lower level performance measures, e.g. Flavour-tagging, PFA,…



Radius more important than B-field

see later

PFA suggests : size ⇑ B ⇑

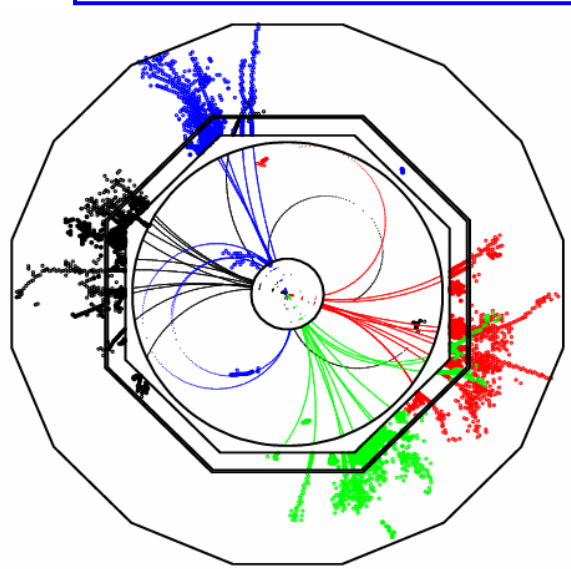
Cost wants : size ⇓ B ⇓

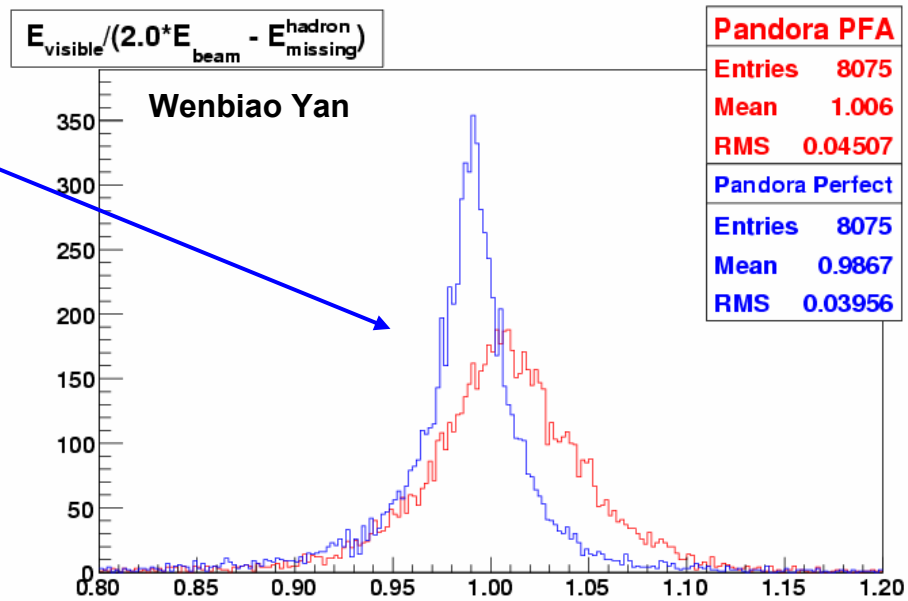
★ **Studies of low level performance measures are useful. CARE: but how much survives through to physics level performance ?**

e.g. $e^+e^- \to \nu\bar{\nu}W^+W^- \to \nu\bar{\nu}qqqq$ $\sqrt{s} = 800\,\mathrm{GeV}$

♦ **First compare visible energy from PFA with expected (i.e. after removing neutrinos/forward tracks+clusters)**

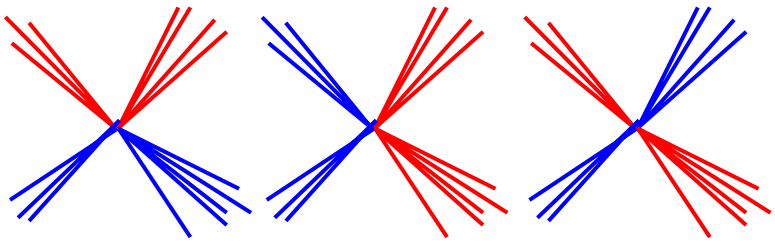
♦ **PerfectPFA gives better energy resolution than PandoraPFA (as expected)**



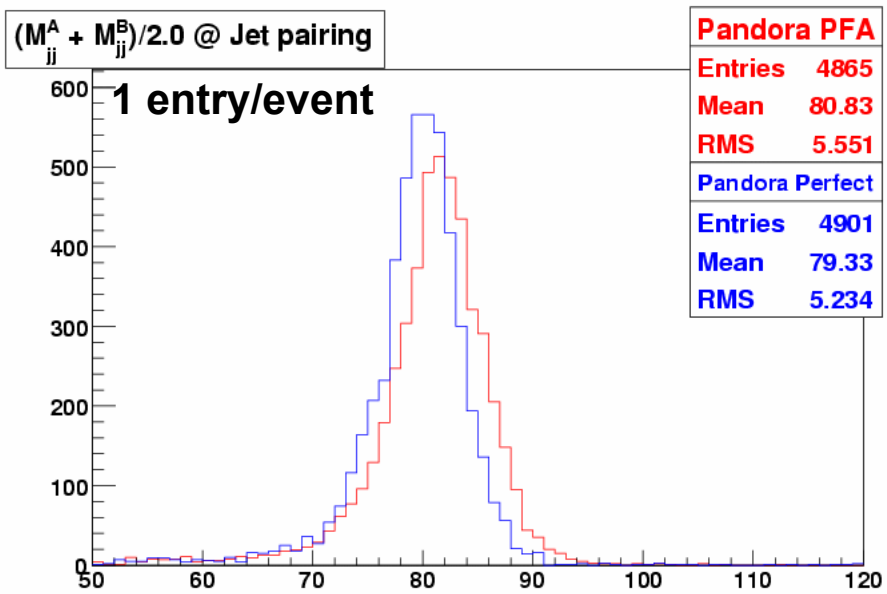


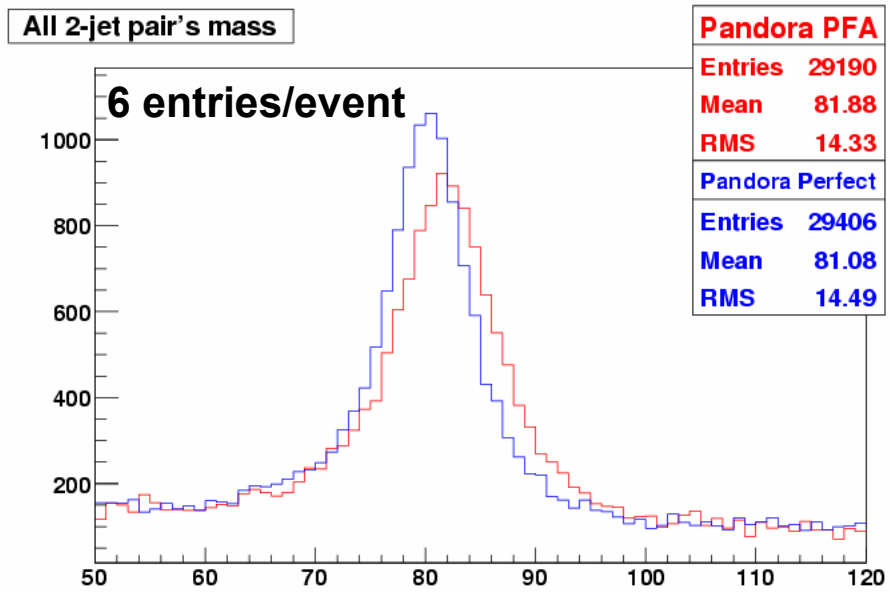
★ **Does this difference make it through to a physics analysis (i.e. after jet finding/jet pairing) ?**

★Force event into 4 jets (Durham)
★Plot masses of the 2 Ws formed from the 3 possible jet-pairings



HERE: PandoraPFA ~ PerfectPFA





★Choose pairing with smallest mass difference
★Plot average mass of the 2 Ws

HERE: PandoraPFA ~ PerfectPFA

⇒ **Jet-finding "dilutes PFA performance"**

OPTIMISATION NEEDS CARE

Need to get a better understanding of relation between low level performance (e.g. Flavour-tag, PFA) and physics performance – this is only just starting.

Optimisation Strategy : Sub-detectors

- ★ Initial studies will concentrate on global parameters, i.e. B, R
- ★ These are major cost and PFA drivers
- ★ But also want to investigate important aspects of sub-detectors
- ★ Something we should discuss at this meeting

e.g. for PFA, what are the main detector questions ?

(at Snowmass LDC/GLD/SiD came up with list of questions)

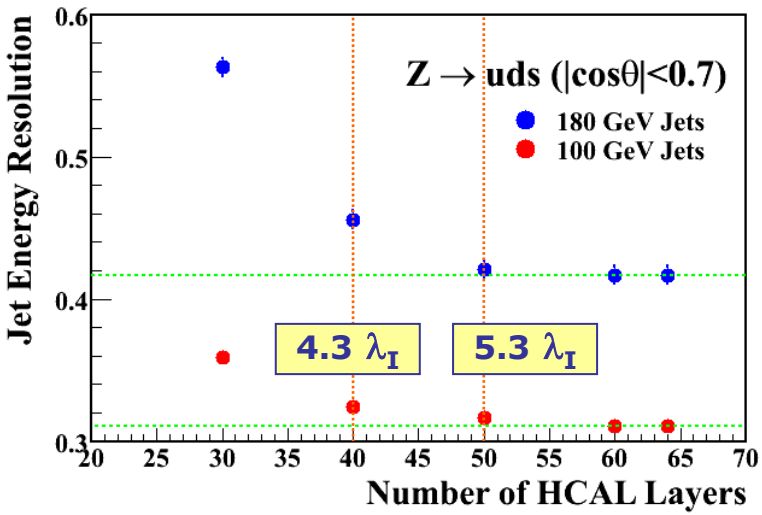
★Have "answers" to some of these questions (marked in green)

The A-List (in some order of priority)

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 efficiency – forward region
5) How much HCAL – how many interactions lengths 4, 5, 6…
6) Impact of dead material – see my talk on Wednesday
7) Longitudinal segmentation – pattern recognition vs sampling frequency for calorimetric performance
8) Transverse segmentation ECAL/HCAL
   ECAL : does high/very high granularity help ?
9) Compactness/gap size
10) HCAL absorber : Steel vs. W, Pb, U…
11) Circular vs. Octagonal 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

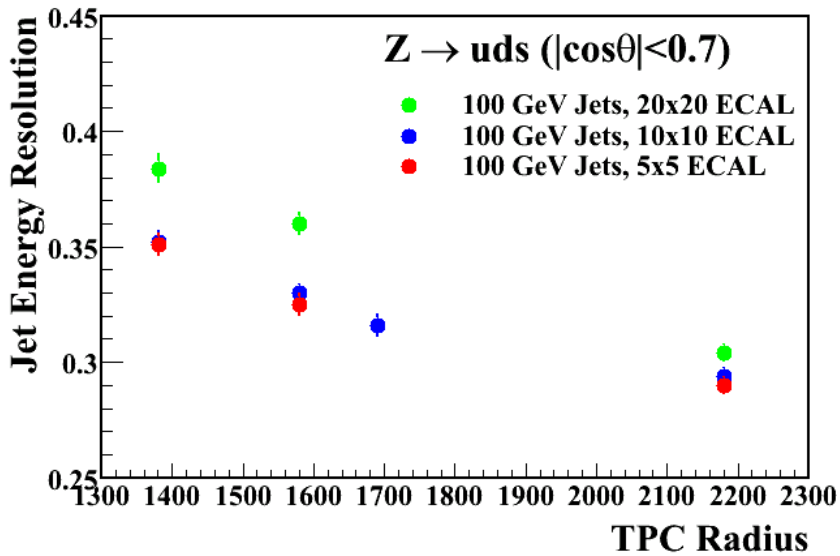
★How about a similar list for Vertex and Tracking ?

Some preliminary answers to some PFA questions, e.g.



HCAL depth

ECAL transverse granularity



Optimisation Strategy : Sub-detectors

- ★ Generating a full set of SM/signal samples with even one detector model will be non-trivial
- ★ Will not be possible to generate full SM sets for many models
- ★ Sub-detector groups need to come up with a wish-list:
  - ♦ What detector parameters need study ?
  - ♦ Minimal set of samples to be used (i.e. important signal)
  - ♦ Will not be possible to generate full SM sets for many models
    - need to be realistic in what can be achieved
- ★ In sub-detector sessions at this meeting we should discuss what the optimisation studies can do for the sub-detectors)
- ★ Ideally want prioritised list…
- ★ AND ultimately alternative sub-detector models in Mokka/Jupiter
  - they won't just appear…

Monte Carlo Generation

- ★ The detector optimisation studies (for different detector parameters) will require multiple large MC data-sets (large integrated-CPU)
- ★ Intend to generate samples centrally (use of GRID will be vital)
  - **benefit:** avoids unnecessary repetition of work
  - there already exists a proposal for SM background samples (should be discussed at another meeting)
  - base samples on SLAC STDHEP files to provide commonality with other concept studies (already a lot of discussion)
- ★ Ideally run reconstruction centrally (use of GRID will be vital)
  - **benefit:** ensures correct reconstruction versions/steering
  - **benefit:** some physics analysis could start from reconstructed PFOs
- ★ Backgrounds:
  - **Ultimately:** must include "beam" backgrounds (beam + $\gamma\gamma$) in physics analysis
  - **Initially:** develop analyses without "beam" backgrounds
  - **In parallel:** develop tools for including backgrounds – file merging etc, walk before running…

Detector Optimisation: channels

- Already a lot of discussion of "benchmark channels"
- Final choice will take into account input from the concepts
- Evolving from initial suggestion from RD and WWS Detector Roadmap group which was to use "minimal list" of hep-ex/0603010:

0. $\text{Single } e^{\pm}, \mu^{\pm}, \pi^{\pm}, \pi^0, K^{\pm}, K^0_S, \gamma : \ 0 < |\cos\theta| < 1.0, \ 0 < p < 500\,\text{GeV}/c$
1. $e^+e^- \to f\bar{f}, \ f = e, \tau, u, s, c, b \text{ at } \sqrt{s} = 91, 350, 500, 1000 \text{ GeV}$
2. $e^+e^- \to Zh \to \ell^+\ell^- X : m_h = 120\,\text{GeV} \text{ at } \sqrt{s} = 230/350(?)\,\text{GeV}$
3. $e^+e^- \to Zh, h \to c\bar{c}, \tau^+\tau^-, WW^* : m_h = 120\,\text{GeV} \text{ at } \sqrt{s} = 350\,\text{GeV}$
4. $e^+e^- \to Zhh \ : m_h = 120\,\text{GeV} \text{ at } \sqrt{s} = 500\,\text{GeV}$
5. $e^+e^- \to \tilde{e}^+_R\tilde{e}^-_R \text{ at Point 1 at } \sqrt{s} = 500\,\text{GeV}$
6. $e^+e^- \to \tilde{\tau}^+_1\tilde{\tau}^-_1 \text{ at Point 3 at } \sqrt{s} = 500\,\text{GeV}$
7. $e^+e^- \to \tilde{\chi}^+_1\tilde{\chi}^-_1/\tilde{\chi}^0_1\tilde{\chi}^0_1 \text{ at Point 5 at } \sqrt{s} = 500\,\text{GeV}$

- Current list is somewhat different – more on this later today…

- However, ILD detector optimisation studies not restricted to this list
- Should be driven by optimisation needs and physics interests of those involved (aim to maximise participation in this study)

Optimisation Strategy : Who ?

PHYSICS ANALYSES:

★ Potentially a lot of interest in ILD physics analyses (see Wednesday)
★ I believe we have the effort to perform an extensive study

Here we are in good shape

"SUPPORT"

★ **BUT**, also need effort in developing reconstruction tools:

Vertex Reconstruction	LCFI, …
Particle Flow	Cambridge, DESY
Tracking	DESY-Zeuthen/MPI
Particle ID	DESY-Zeuthen/MPI
Lumi Cal.	Krakow
Forward Tracking	Indiana/Loiusiana

★ In addition to developing these tools – will need ensure they work for the different detector models…

Could do with more effort ?

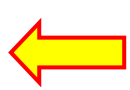
Optimisation Strategy : When ?

- ★Performing physics-based detector optimisation studies on the "timescale of the LoI" is not going to be easy…
- ★People need to start developing analyses using current detector models and reconstruction tools (there may be a few problems)
- ★Will soon need move to "mass production" – validation of MC models is a very high priority
- ★And requires a lot of thought…
  - make sure the simulation is right before generating large MC sample:
    e.g. for recoil mass in $Zh \to \ell^-\ell^+X$ may benefit from very good momentum resolution – ensure SET is included in LDC simulation ?
  - validation of reconstruction is also important(multiple times)
  - how to include of backgrounds (with time structure.)
- ★Want first results well in advance of "LoI deadline"…

⇒ **Strawman timetable…**

Working backwards (as was presented in October)…

Task	"Deadline"	Status
Final version of Letter of Intent	Oct 08	
Refine results and LoI performance section	Aug 08	
First draft of LoI physics performance section	Jul 08	
Define ILD Baseline Parameters ! Need	May 08	
Physics Optimisation Results	May 08	
Preliminary results for TILC 08 (Sendai)	Mar 08	
Status reports of Physics Studies ILD mtg. (Europe)	Jan 08	
Start of mass reconstruction of physics samples	Jan 08	
Validation of reconstruction software	15th Dec 07	
Start of mass generation of physics samples	1st Dec 07	
GLD'/LDC' in Mokka/Jupiter	1st Dec 07	
Define GLD'/LDC'	15th Nov 07	In progress
Check Mokka/Jupiter LCIO compatibility	15th Nov 07	
LDC baseline in Mokka	15th Nov 07	In progress
GLD baseline in Jupiter	15th Nov 07	Done
Define LDC v5 baseline parameters		Done (final?)
Define GLD baseline parameters		Done
Start Developing physics analysis	ASAP	In progress



Where are we now ?

Task	"Deadline"	Status
Define ILD Baseline Parameters !	Summer 08	
Physics Optimisation Results	May 08	
Preliminary results for TILC 08 (Sendai)	Mar 08	
Status reports of Physics Studies ILD mtg. (Europe)	Jan 08	Wednesday
Start of mass reconstruction of physics samples	Jan 08	
Validation of reconstruction software	15th Dec 07	Started
Start of mass generation of physics samples	1st Dec 07	
GLD'/LDC' in Mokka/Jupiter	1st Dec 07	Done
Define GLD'/LDC'	15th Nov 07	Done
Check Mokka/Jupiter LCIO compatibility	15th Nov 07	
LDC baseline in Mokka	15th Nov 07	Done
GLD baseline in Jupiter	15th Nov 07	Done
Define LDC v5 baseline parameters		Done
Define GLD baseline parameters		Done
Start Developing physics analysis	ASAP	In progress

Current Goal

Production

A lot of progress since October !

- ★ So far an impressive start to this effort !
  thanks to many people in this room…
- ★ At this point, let's not get distracted by the background politics
- ★ For the first time we are in a position where we can study ILC detector performance with full detector simulation
- ★ Important to maintain the momentum towards ILD design by Summer 2008
- ★ Over the next months we will learn a great deal about how to design an ILC detector

❹ Summary

- There is a lot of ground to cover in the next months
- Let's not get distracted (where possible) by politics !
- Need to demonstrate ILD can deliver the required physics performance and determine "optimal" detector parameters
- Need to get "sub-detector community" integrated into the simulation/physics studies – a possible "hot topic" for this meeting
- Given the timescale we cannot expect to do everything in this first phase (we are not in the EDR phase yet)
- Important not to be overly ambitious – if by Summer 2008 we have well-justified choice of the detector's size and B-field based on physics we should view this as a success
- Hope for more, e.g. improved understanding of sub-detector design on physics performance c.f. sub-detector performance

For this workshop…

Refine the questions we want to ask…