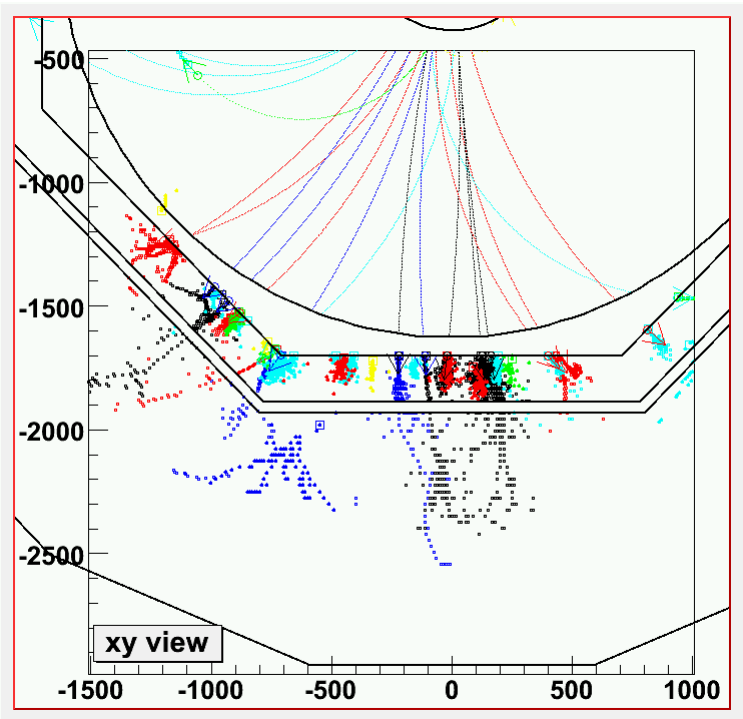
Particle Flow

Mark Thomson
University of Cambridge



Try to address:

- ★ How does PFA impact LDC design
- ★ Where are we now ?
- ★ What are the questions

❶ PFA and LDC design ?

PFA plays a special role in design of an ILC Detector

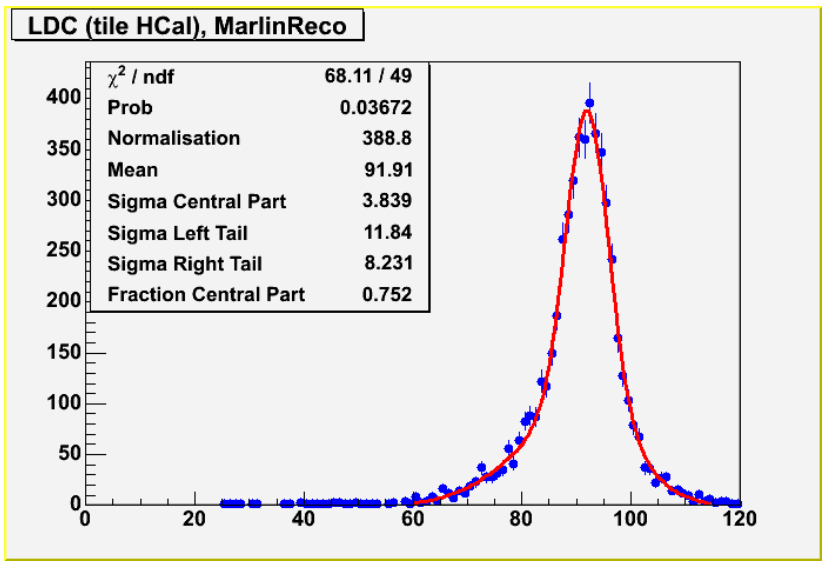
- ★ **VTX : design driven by heavy flavour tagging, machine backgrounds, technology**
- ★ **Tracker : design driven by σ_p, track separation**
- ★ **ECAL/HCAL : single particle σ_E not the main factor ➡ jet energy resolution ! Impact on particle flow drives calorimeter design + detector size, B field, …**

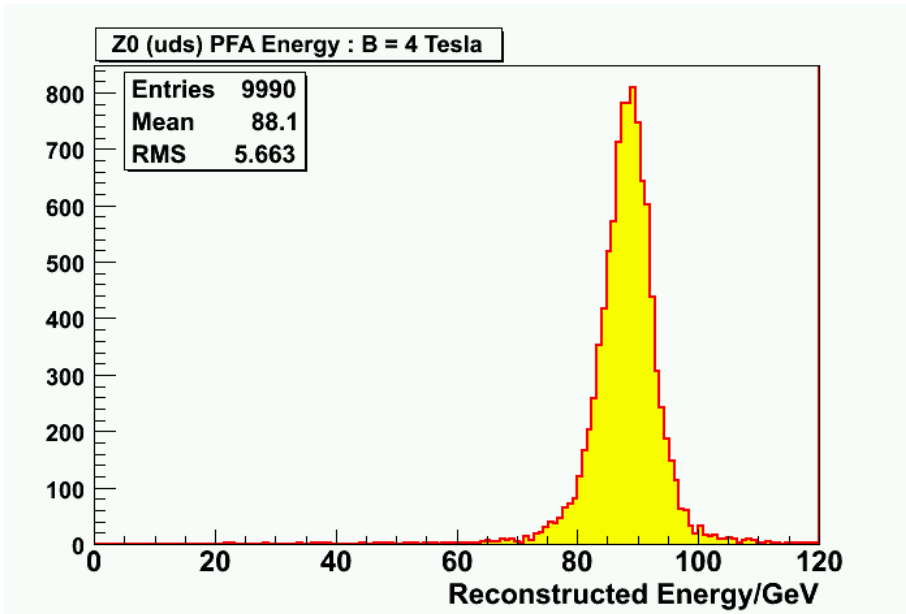
PFA is a (the?) major cost driver for the LDC

- ★ **Demonstrating that we need high granularity ECAL/HCAL is a vital part of justifying/optimising LDC**
- ★ **BUT – PFA is non-trivial**

Where are we now ?

- ★ Until very recently we did not have the software framework/tools to attempt to study PFA in the context of **LDC**
- ★ This has changed - to some extent
- ★ Now have one "established" (i.e. since Snowmass) PFA – **WOLF** + one evolving PFA - **PandoraPFA**

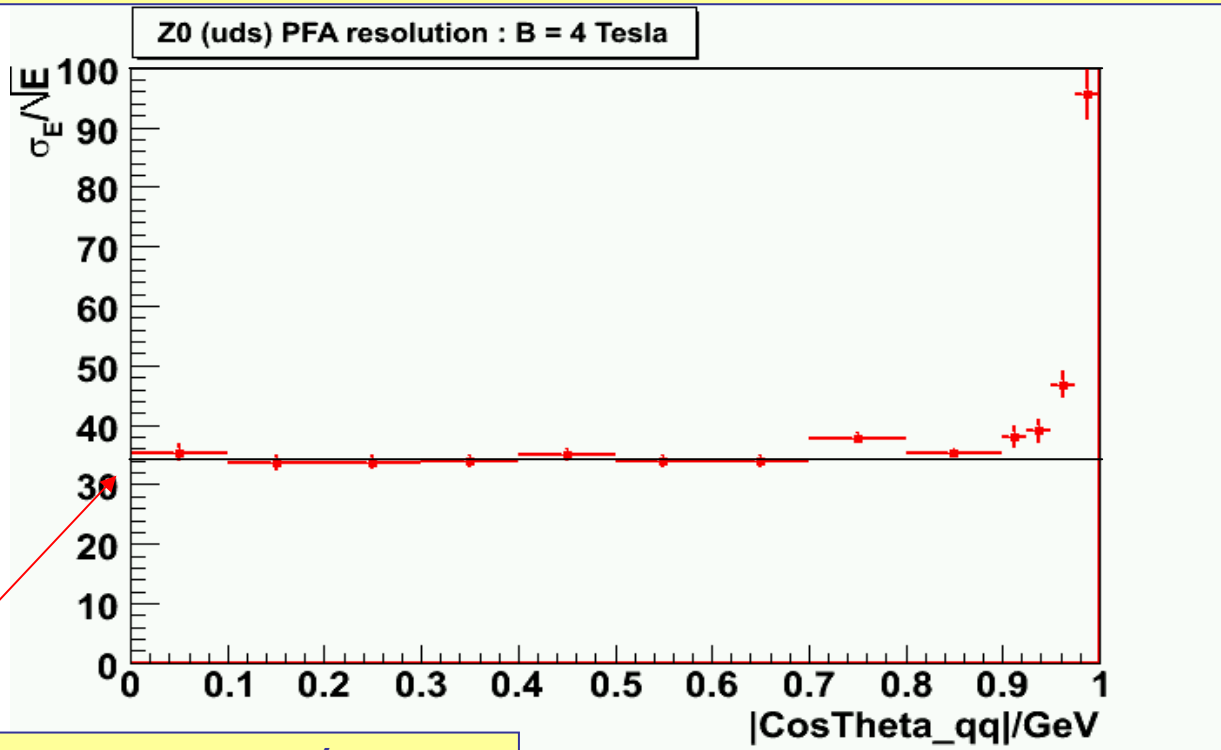




- ★ **BUT really just getting started**

Best so far….

✦ Plot resolution vs "generated" polar angle of qq system



✦ In barrel : 34 %/ √E(GeV)

★ Quite good – but these are only Z events…

★ With some work this will improve: 30-33 % in barrel

For outline document we will be able to demonstrate that LDC can deliver "target" jet energy resolution (if only for Zs)

But there are some serious Design issues

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

The A-List (in some order of priority)

1) B-field : why 3 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) Longitudinal segmentation – pattern recognition vs sampling frequency for calorimetric performance
7) Transverse segmentation ECAL/HCAL
   ECAL : does high/very high granularity help ?
8) Compactness/gap size
9) HCAL absorber : Steel vs. W, Pb, U…
10) Circular vs. Octagonal TPC (are the gaps important)
11) HCAL outside coil – probably makes no sense but worth demonstrating this (or otherwise)
12) TPC endplate thickness and distance to ECAL
13) Material in VTX – how does this impact PFA

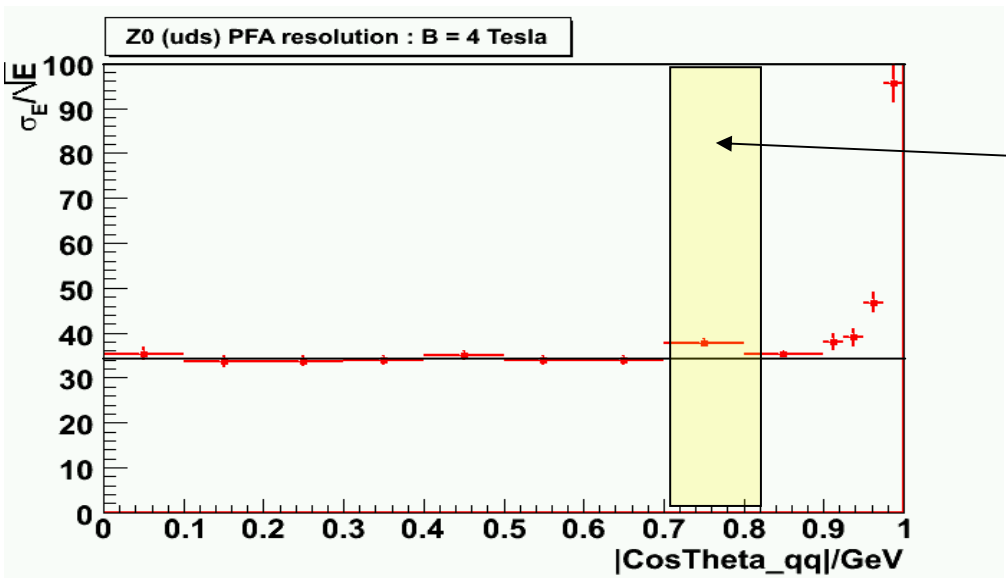
The B-List

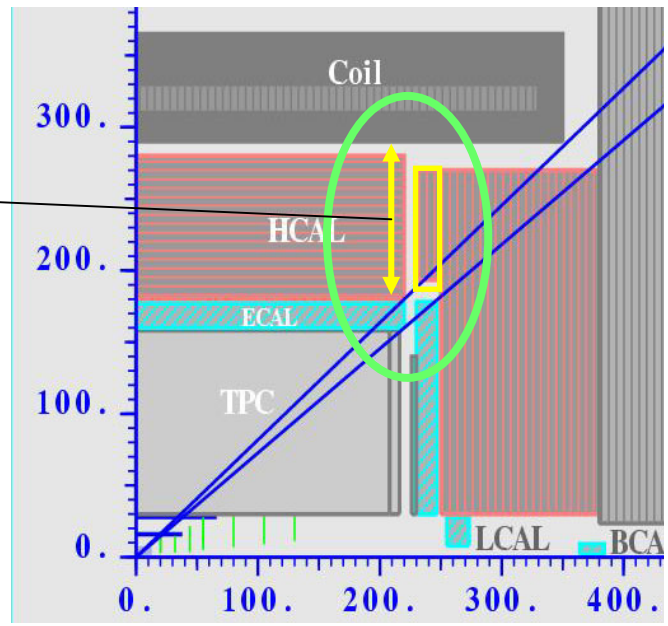
1) Impact of dead material (promote to A-list)
2) Impact (positive and negative) of particle ID - (e.g. DIRC)
3) How important are conversions, V^0s and kinks (promote)
4) Ability to reconstruct primary vertex in z

8) Gaps....

My current guesses regarding gaps:

1) **TPC-ECAL Barrel: not a significant problem (for Zs)**
2) **TPC-ECAL Endcap: nothing quantitative but this is probably important. Matching efficiency lower in Endcap (curlers). Strategy - discard unmatched tracks and rely on CAL**
3) **ECAL/HCAL Barrel-Endcap : must be very careful in this region - HCAL endcap ring vital.**





★**Barrel/endcap overlap is important - delicate issue**
gaps are not empty ! Should we add estimated material (cables/cooling) in Mokka ?

6) Interaction Lengths

- ★ At 91.2 GeV very little leakage of neutral hadrons
- ★ For higher energy jets could be a significant effect (e.g. see Felix + Marcello's talks of yesterday)
- ★ Need to come up with a realistic estimate of how many interaction lengths are required
- ★ To do this – have to try account for protection given by tail-catcher
  - ★ Need muon chambers in Mokka

9) HCAL absorber

- ★ Some indication that W would make a better HCAL absorber
  - ★ Preliminary studies in US: W gives more compact showers
- ★ Possibly cost-neutral
  - ★ Extra cost of W is offset by reduction in coil radius
- ★ Could be a significant performance effect
- ★ Engineering issues ?

There are many design/optimisation question. All need to be addressed by simulation with realistic PFAs. Woefully short of manpower.

How to start…..

Proposed first step..

- From point of view of LDC must address the big questions in the near future (i.e. NOW):
  - Size
  - Granularity (ECAL/HCAL)
- DESY set up to generate significant MC samples using the GRID
- Work already started on this

Samples for PFA optimisation

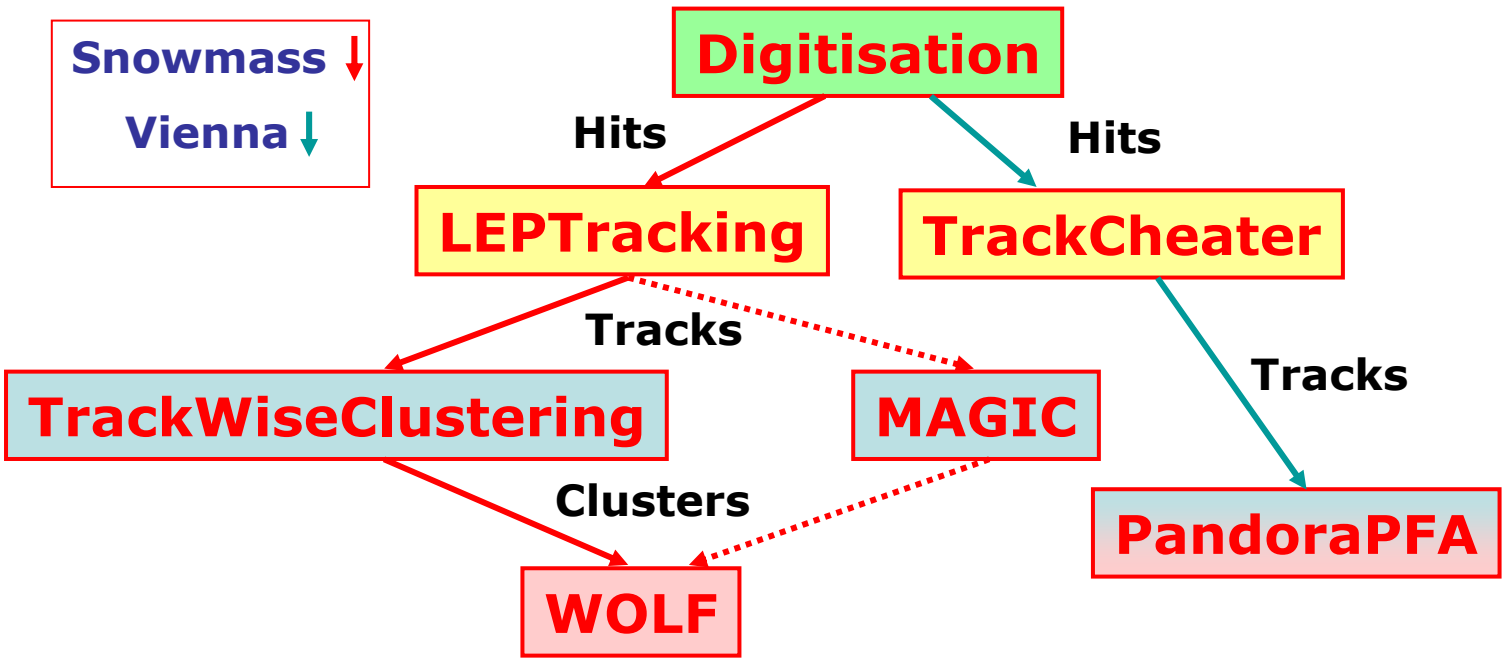
- Z at 91.2 GeV
- Z at rest with $E_Z = M_Z$ = 350, 500, 1000 GeV (probe PFA perfomance for more collimated jets – VERY HIGH PRIORITY)

Proposed samples (large variations to try and understand trends)

- **B-field :** LDC with B = 3, 4, 5 T
- **TPC Radius:** LDC with R_{tpc} at -40cm, nominal, +40cm
- **TPC Length:** LDC with L_{tpc} at -50cm, nominal
- **Material:** LDC with extra 0.5 radiation lengths at TPC endplane
  LDC with 0.1 radiation lengths in VTX silicon

- The purpose of these samples is to start to understand what really drives PFA performance with full simulation
- Need answers on timescale of Bangalore

Do we have the tools ?



★**not bad, but there are "holes"....**

Real forward tracking — **Non-trivial ! ~0.5 person-year ?**

New PFAs — **- current clustering paradigm could be non-optimal**

★ **If we are to come up with design "recommendations" need multiple algorithms - non-trivial ~N person-years**

From point of view of PFA and detector optimisation - Vertexing not vital

Summary

- ★ PFA is absolutely vital to the justification/optimisation of LDC
- ★ Developing PFAs is highly non-trivial
  - delicate – must avoid trap of optimising detector to flaws in algorithm
- ★ ESSENTIAL that we start to address the main issues (size/field/granularity) as soon as possible

My opinion : don't yet really know what drives PFA performance
Must start getting quantitative answers

Organisation...

- ★ Set up monthly PFA phone meeting (partly done)
  - global scope (LDC/SiD/GLD) – many good ideas being developed.
- ★ Propose "Simulation Tools/Physics Studies" meeting in Spring 2006 (Cambridge in April is one option).
  - Along lines of DESY software meetings, but with the focus on (LDC?) optimisation/physics studies.