Optimising GLDC for Particle Flow

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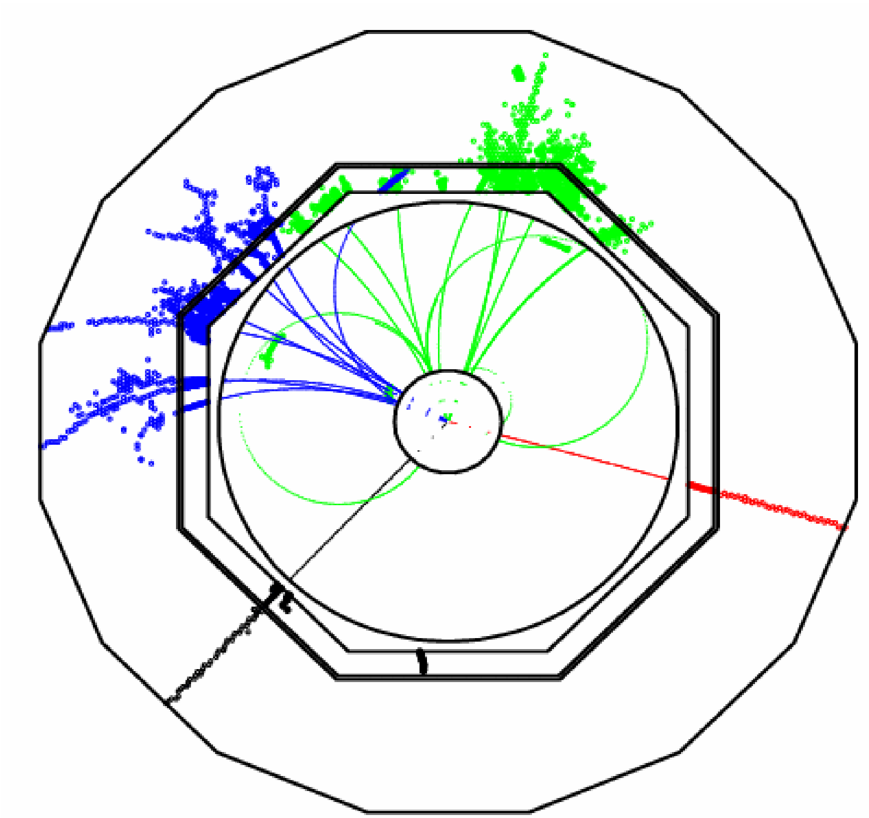


Purpose of This Talk:
- Show (again) recent studies
- GLD/LDC in the light of the above
- Parameterized performance
- Zeroth order optimisation
- Caveats
- Conclusion

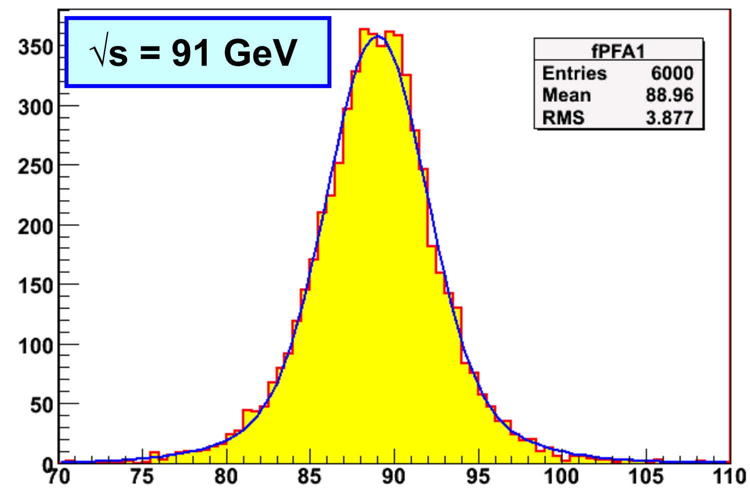
Why ?

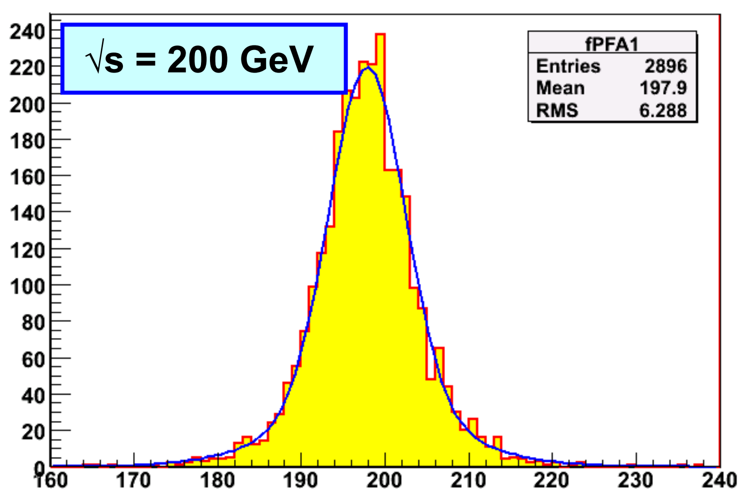
- ★ One of the main factors (the main factor?) in the design of the GLD and LDC concepts is the assumption that PFA is the way to measure jets at the ILC
- ★ **Two questions:**
  - ♦ does PFA work ? i.e. Can it deliver the ILC performance goals ?
  - ♦ what is the optimal detector ?

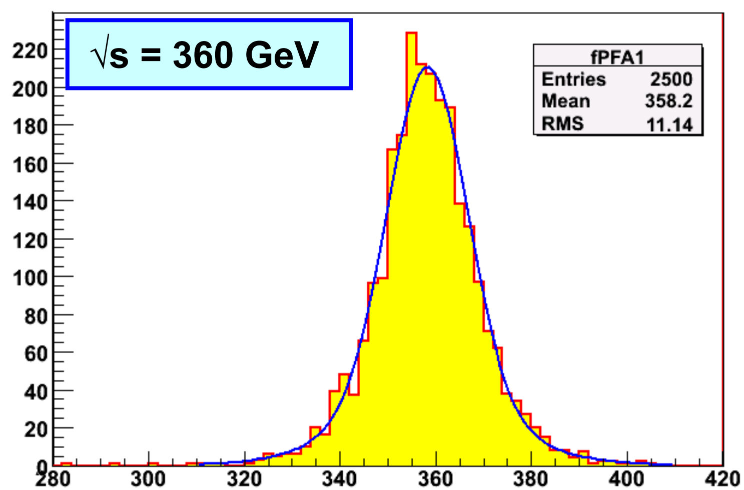
Current PFA performance

What was used:

- PandoraPFA v01-01
- LDC00Sc (TESLA)
- B = 4 T
- 3x3 cm HCAL (63 layers)
- Z → uds (no ISR)
- TrackCheater



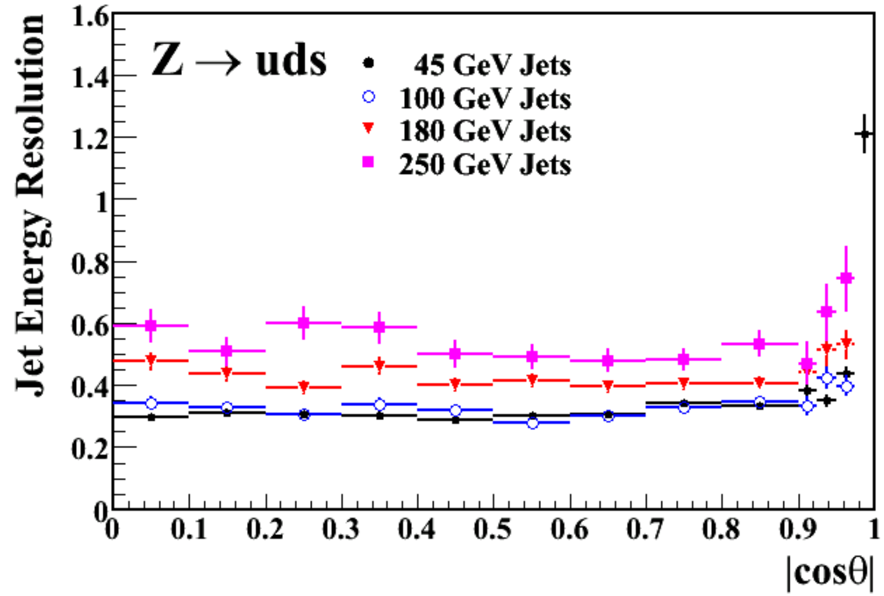




Current performance

rms90

E_{JET}	$\sigma_E/E = \alpha\sqrt{(E/GeV)}$ $\lvert\cos\theta\rvert<0.7$
45 GeV	0.295
100 GeV	0.305
180 GeV	0.418
250 GeV	0.534



For jet energies < 100 GeV
ILC goal reached !!!

For jet energies ~ 200 GeV
close to 40 %/√E(GeV) !!

- Typical 1 TeV ILC jet energies 50-200 GeV

- There is no doubt in my mind that PFA can deliver the required ILC jet energy performance
- **REMEMBER:** the current PFA code is far from perfect, things will get better

Detector Optimisation from PFA perspective

- ✶ PFA works !
- ✶ GLD/LDC designed for PFA – but are they optimised ?
- ✶ Attempt first optimisation studies…

Caveat:

- ★ Is the current PFA performance good enough to start to characterise the PFA performance of the LDC detector ?
- ★ Don't forget : ultimately want multiple PFA algorithms
  – check robustness of any conclusions

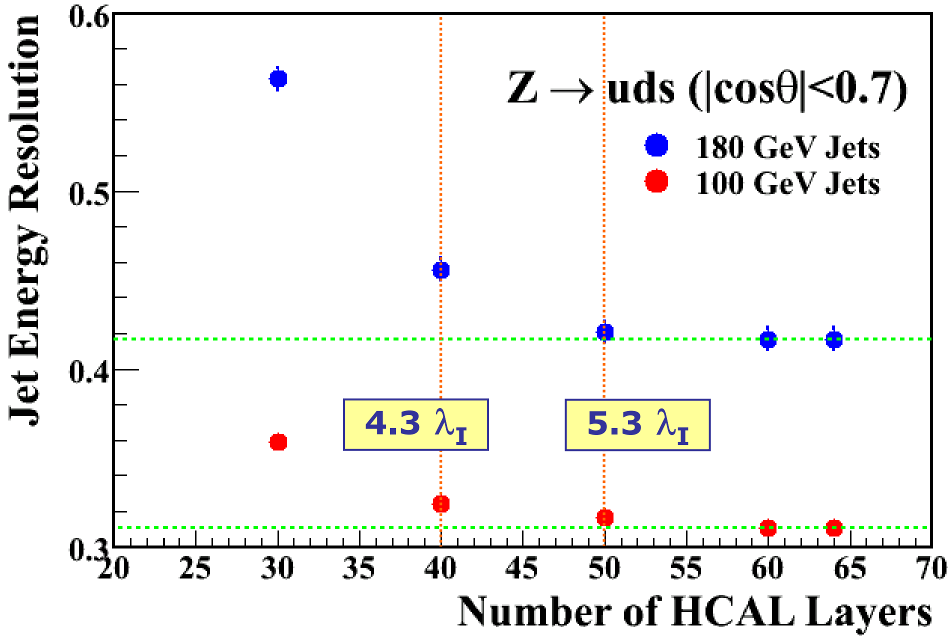
Assuming it is, what can we learn…

- ✶ All based on LDC00Sc model, but basic conclusions should apply to any PFA detector (so far barrel only)

HCAL Depth

★ Investigated HCAL Depth (interaction lengths)

- Generated **Z→uds** events with a large HCAL (63 layers)



- ♦ HCAL leakage is significant for high energy
- ♦ Argues for ~ **5 λ_I HCAL**
- ♦ Consistent with J-C's talk at LAL Paris

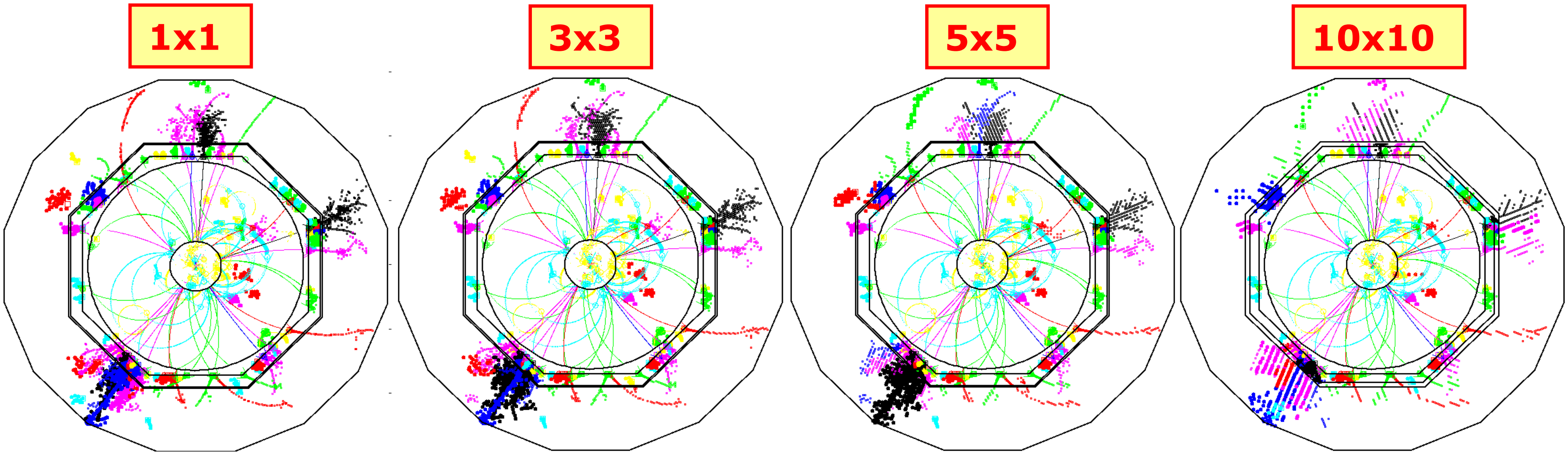
NOTE: no attempt to account for leakage – i.e. using muon hits - this is a worse case

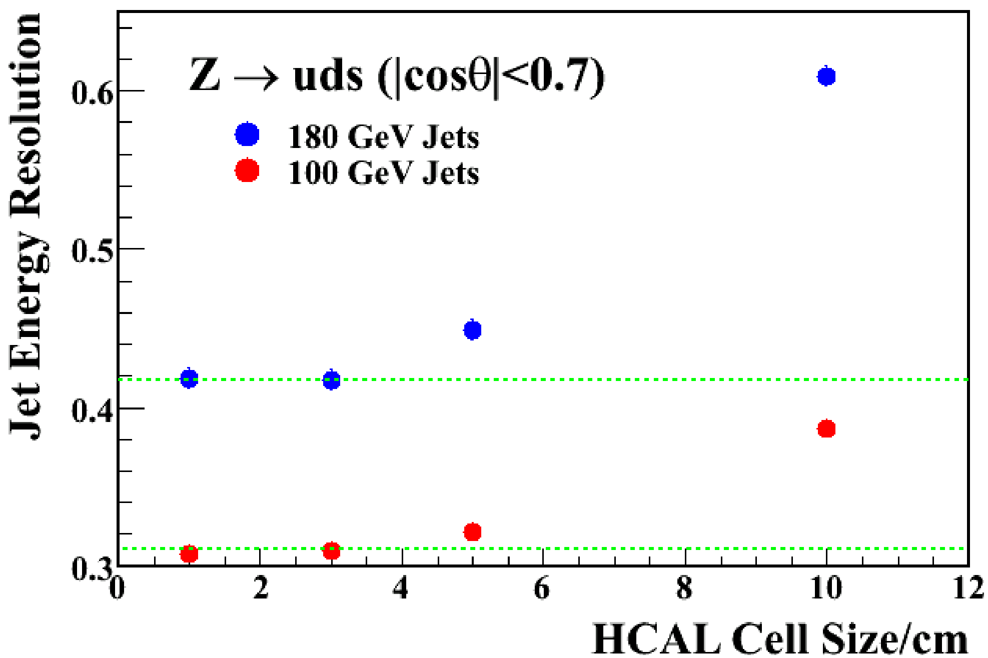
Increase number of HCAL layers in "default" LDC model

Also study alternative with current HCAL depth to study use of muon chamber as tail-catcher (personpower?)

I doubt this is an option unless the coil can be made "thin"

✶ Analogue scintillator tile HCAL : change tile size 1x1 → 10x10 mm^2





"Preliminary Conclusions"

- 3x3 cm^2 cell size ☺

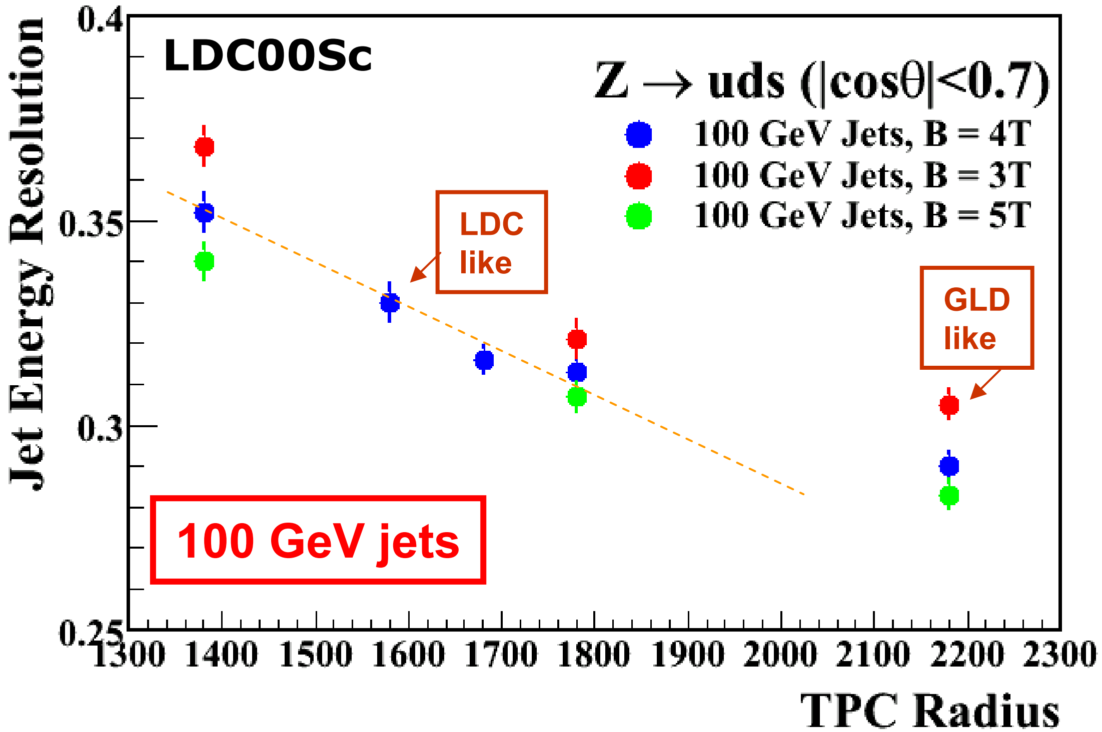
→ **No change**

Could probably decrease segmentation deeper in HCAL (any significant cost benefit ?)

Scintillator vs RPC HCAL

- Next item on job list…
- Serious lack of personpower (i.e. a fraction of 1)
- Will get done over Summer

Radius vs Field



Radius more important than B-field

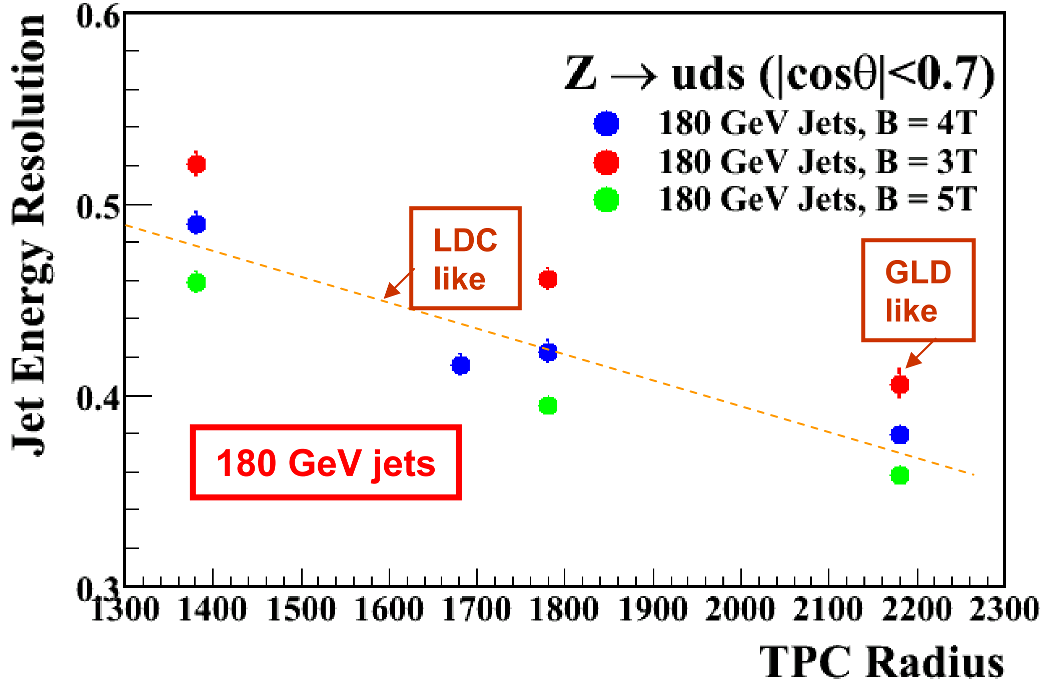
see later

Suggests : size ⇧
B ⇩

Cost benefit of going to 3.0 T or 3.5 T ?

- Cost related to stored energy: Stored energy ~ LB^2R^2

Radius vs Field



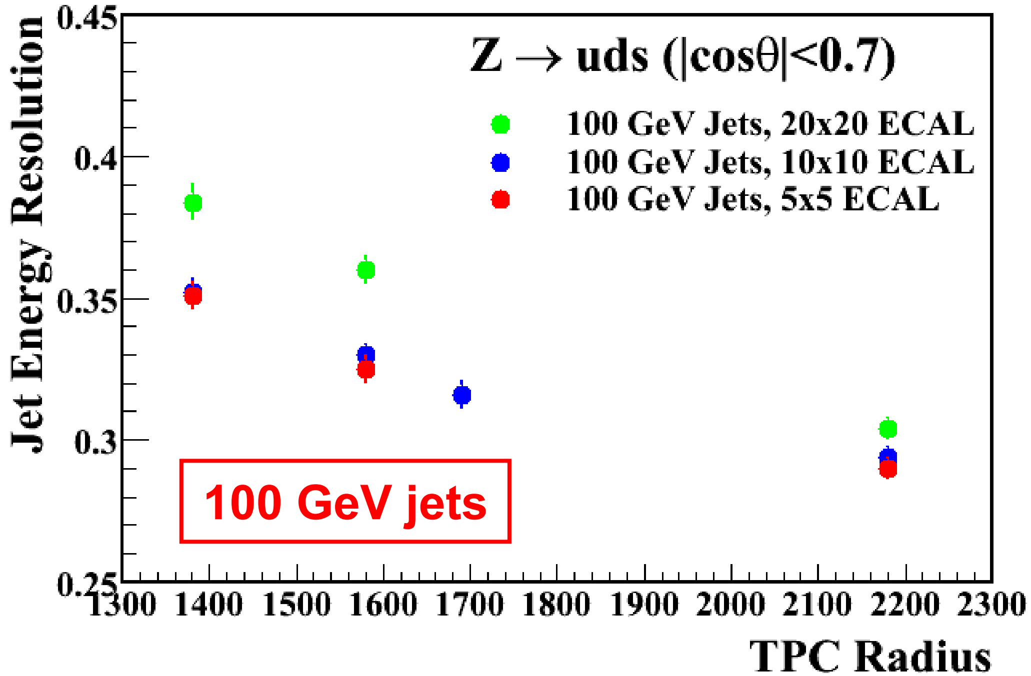
Radius is even more important for higher energy jets

⇨ **LDC too small - or is it…?**

- ★ **One of the main motivations for the design of LDC is PFA**
- ★ **The L in LDC and GLD stand for LARGE – currently from the point of view of PFA the LDC detector is probably not large enough…**
- ★ **Doesn't address cost-performance optimisation**

ECAL Transverse Granularity

- Z → uds events @ 200 GeV with different ECAL segmentation: 5x5, 10x10, 20x20 [mm^2]



<u>With PandoraPFA</u>

- 20x20 segmentation looks too coarse
- What is GLD's effective ECAL segmentation ?
- For 100 GeV jets, not a big gain going from 10x10 → 5x5mm^2

[for these jet energies the contributions from confusion inside the ECAL is relatively small – need]

Parameterized Performance

★ LDC Jet energy performance found to depend mainly on:
- HCAL thickness
- TPC Radius
- B-field

★ Plots shown on previous page can be parameterized by:

100 GeV Jets

$$\alpha = 0.315\left(\frac{B}{4}\right)^{-0.19}\left(\frac{R}{1.68}\right)^{-0.49}\left(1+6.3e^{-\frac{N}{8.0}}\right)$$

180 GeV Jets

$$\alpha = 0.42\left(\frac{B}{4}\right)^{-0.31}\left(\frac{R}{1.78}\right)^{-0.61}\left(1+21.6e^{-\frac{N}{7.1}}\right)$$

★ NOTE:
- Different parameterization for different energy (increased dependence as confusion/leakage become more important)
- Very different from naïve $B^{-1}R^{-2}$ dependence (much weaker)
- BUT roughly same ratio i.e. $B^{-\alpha}R^{-2\alpha}$

Detector Optimisation

- ★ Using these performance measures can attempt a very crude cost optimisation…
- ★ For now build a very simple cost model
- ★ DO NOT TAKE TOO SERIOUSLY AT THIS STAGE
  - aim to learn something new…
  - very fresh
- ★ Use simplified LDC cost model as starting point

System	Fractional Cost	Proportional to
ECAL	0.29	Active area
Solenoid+Yoke	0.21	$U^{0.66} = (LR^2B^2)^{0.66}$
HCAL	0.16	Volume
TPC	0.08	Fixed
SiT/FTD	0.06	Fixed
Vertex	0.025	Fixed
Muon	0.025	Fixed
FCAL	0.02	Fixed
Other	0.12	Fixed

★ Using these dependencies can construct cost as function of:
- ♦ TPC radius, R
- ♦ B-field, B
- ♦ Number of HCAL layers, N

Caveat : PLEASE don't take too seriously at this stage

★ Can now ask the question "for a given cost, what is the optimal choice of LDC parameters?"

★ Cost unit = 1 DCR LDC detector

First "conclusions"…

★ For all input costs HCAL optimised to approximately 5 λ at the expense of decreased radius

★ Optimal detector size is not necessarily large e.g. ask for a detector costing 1.2 LDCs:

B [T]	R/m	α_{180}
3.0	1.9	0.45
4.0	1.8	0.43
5.0	1.7	0.42

VERY VERY PRELIMINARY
VERY VERY PRELIMINARY
VERY VERY PRELIMINARY

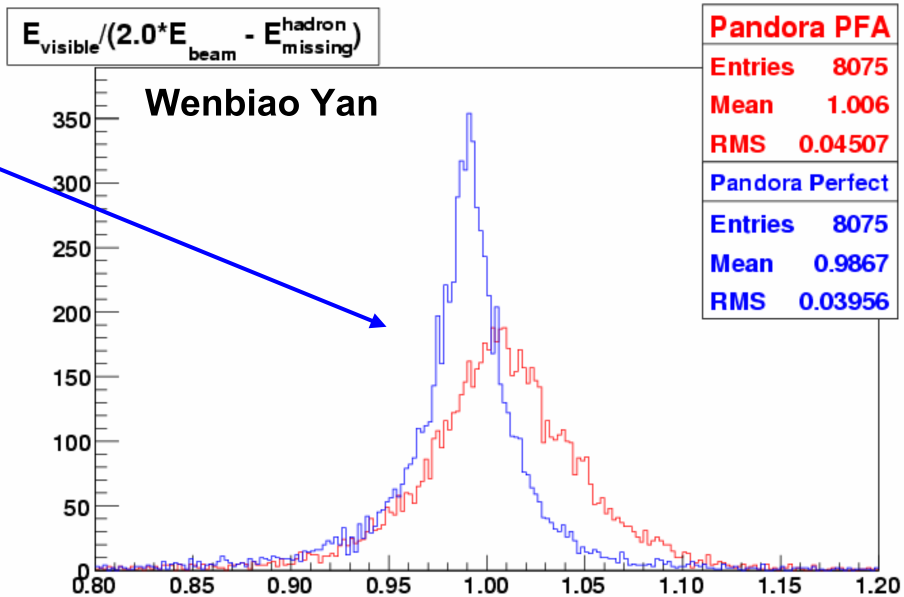
- Rather weak dependence
- Here might say "choose B = 5 T"
- BUT VERY dependent on input assumptions e.g. precise cost of nominal LDC ECAL

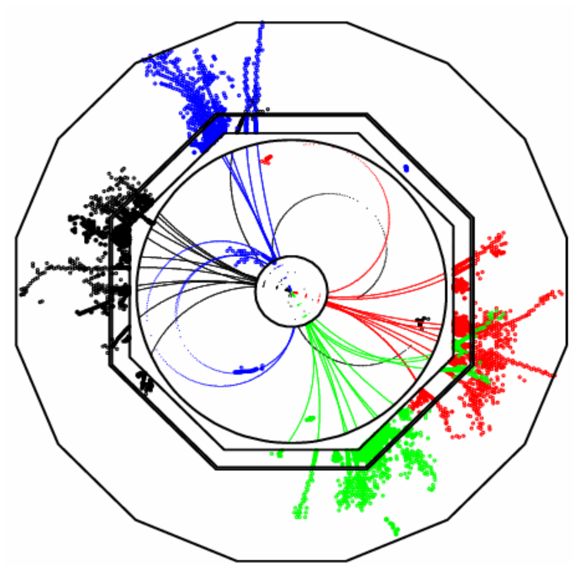
BUT : Need to optimise the physics not "energy resolution"

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

★ 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)

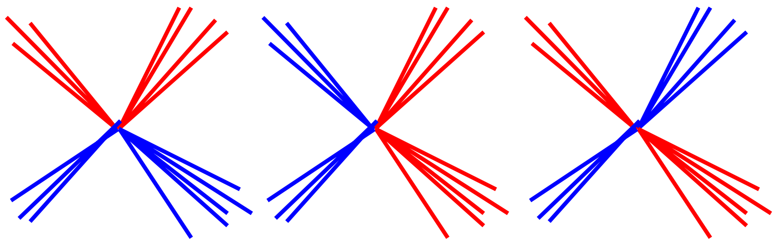




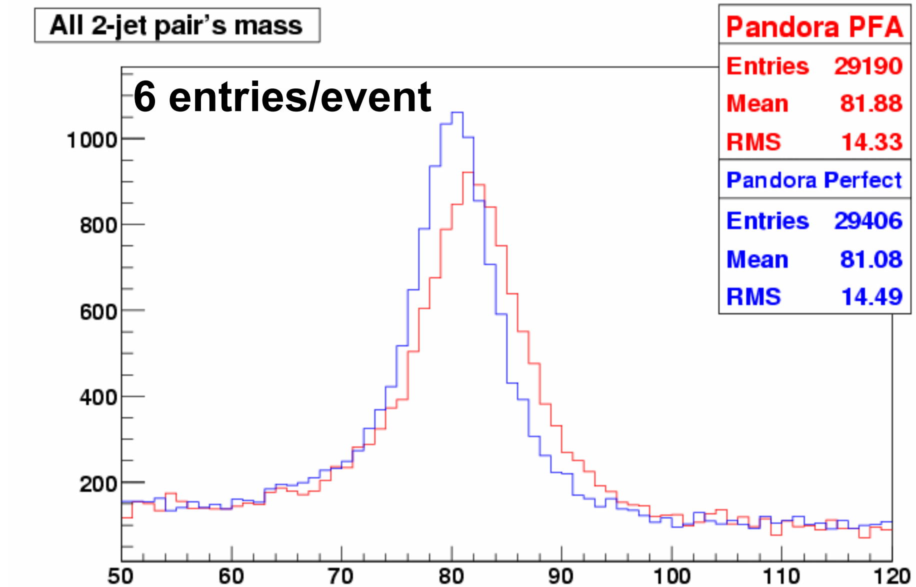
★ Does this difference make it through to a physics analysis (i.e. after jet finding/ jet pairing) ?

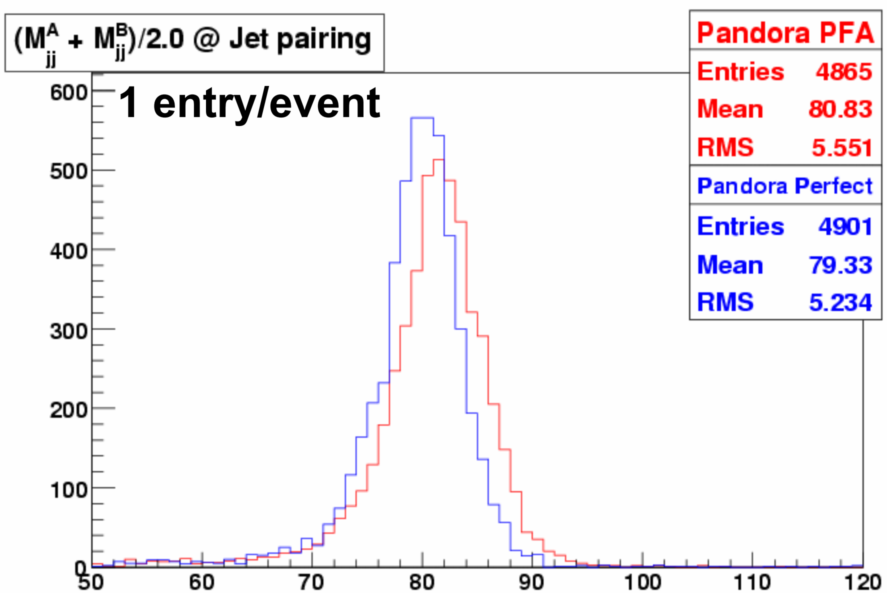
★Force event into 4 jets (Durham)

★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

Conclusions

★ At this stage should not under-design the detector
★ Be careful to get locked into a non-ideal design at LoI/EDR stage
★ Cost is optimisation is going to be very difficult needs:
  - Needs to be performed at physics level
  - Needs a sophisticated cost model

From point of view of PFA and cost optimisation, <u>a first look</u> suggests a rather shallow minimum, i.e. not a huge difference between small B=3, medium B=4 and large B=5

A serious study requires a lot of effort !
Combined GLD + LDC manpower would help

Fin

Other Design issues for PFA

(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
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

★ What about the other issues…