SiW ECAL + sDHCAL dimension-performance optimisation

Trong Hieu TRAN
Laboratoire Leprince-Ringuet,
Ecole polytechnique, CNRS/IN2P3

Outline:

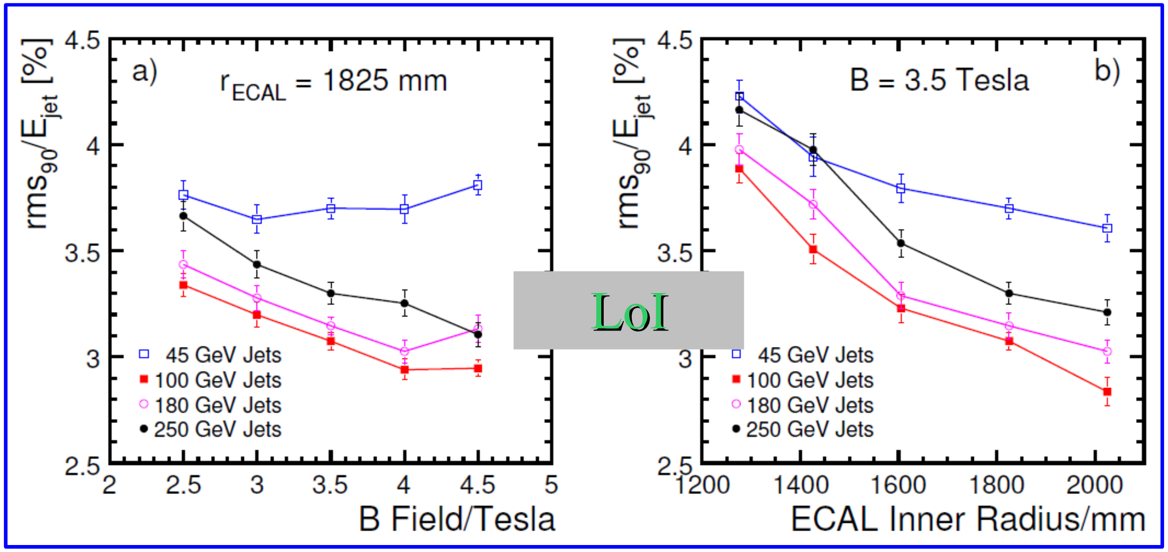
- Introduction
- ILD with reduced radius
- Preliminary
  - tracking & ECAL performances for single particles,
  - jet energy resolution
- Cross checks

LCWS 2013, University of Tokyo, Japan

Introduction

- **Motivation**
  - ILD is costly, especially SiW-ECAL & Yoke.

- **Options**:
  - Reduce ECAL number of layers (reported at LCWS12 & in DBD)
  - outer TPC radius (→ ECAL, sDHCAL, Yoke's radii correspondingly) together with length (keep ratio constant)
    similar study done for SiW-ECAL + AHCAL(M. Thomson @ LoI and recently by J. Marshall *)
  - change B-field



- **Validation of ILD models**
  - Simulation done with Mokka (Geant4).
  - Tracking performance (important input for PFA, since 60% of jet energy from charged particles)
  - PFA performance: With recent PandoraPFANew

(*) ECAL simulation meeting

Parameters

Unit: mm

R_{ECAL}^{inner}	1843	1600	1400	1200
R_{TPC}^{outer}	1808	1565	1365	1165
TPC half_Z	2350	2040	1785	1530

TPC half Z = R_{ECAL}^{inner} × 2350/1843

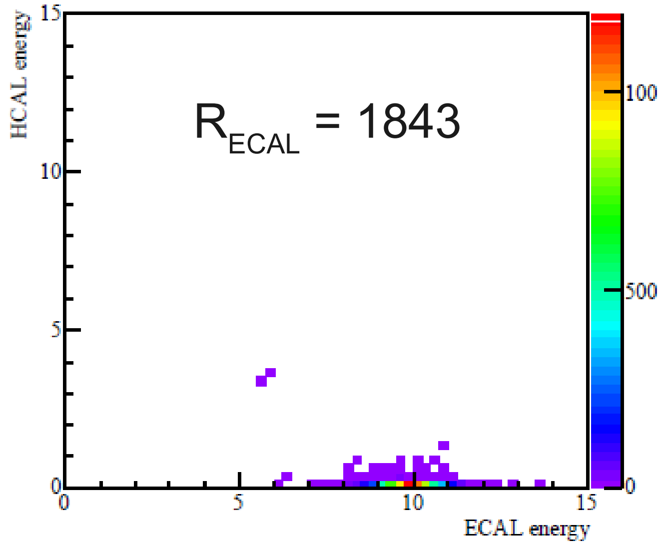
- When mention: R_{ECAL}^{inner} means that the whole ILD detector model is reduced
- For all models, ECAL, HCAL have same thickness as in baseline design
- Same B-field (3.5 Tesla), sensor size (5×5 mm^2 for SiW ECAL and 10×10 mm^2 for sDHCAL)
- SiW ECAL has 30 layers (29 Si layers)

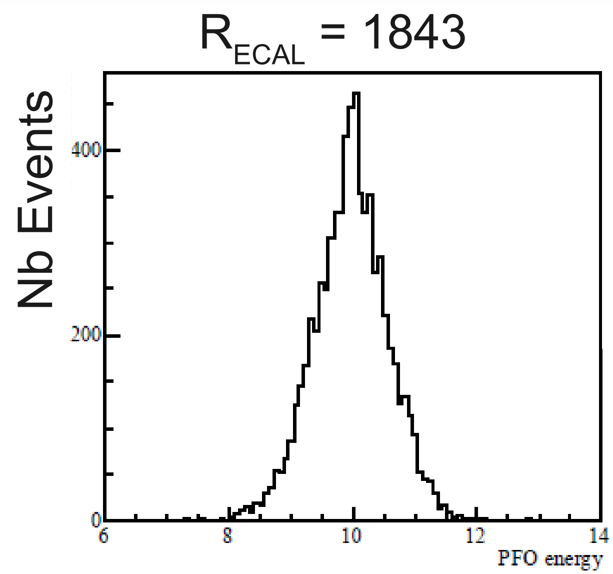
Samples & calibration procedure

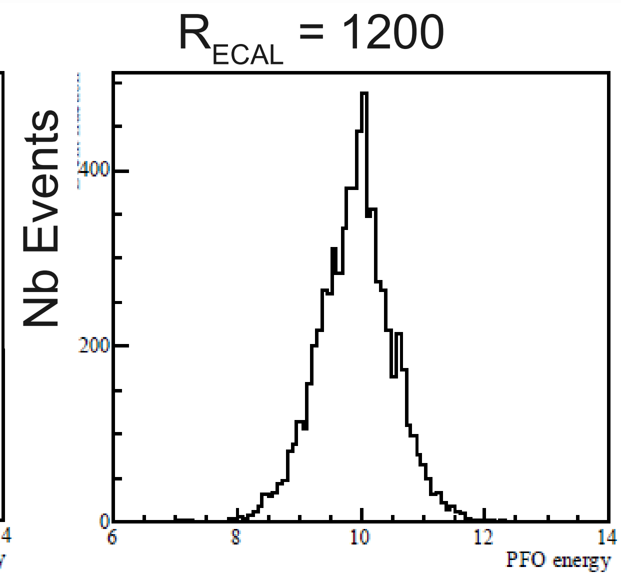
- Muon's, gamma's, K^0_L
  Energies: 1, 3, 5, 7, 10, 15, 20 – 100 GeV (step 10GeV)
  10k events for each sample
  For energy correction in function of cosθ: 100K events (gamma's, K^0_L)
  Jet: $e^+e^- \rightarrow Z \rightarrow$ qqbar (uds), energies: 91, 200, 360, 500 GeV

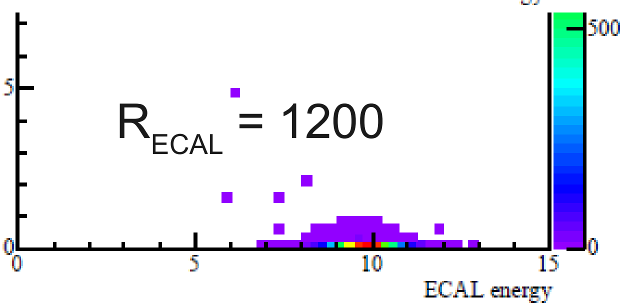
- Calibrations are done in following steps:
  1. ECAL & HCAL calibration: conversion of deposited charge to energy
  2. Pandora weights to EM and HAD energy
  3. Angular correction of energy for neutral particles & photons

ECAL + HCAL calibration. Step 1.



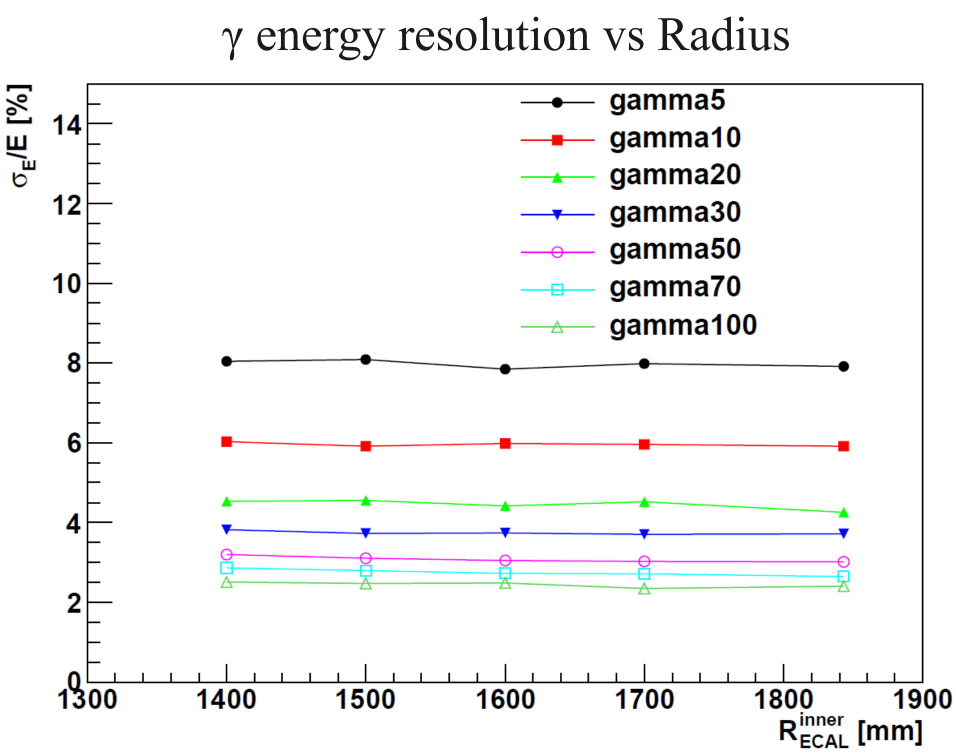






- Based on single particles
- EM calibration coefficients are adjusted from default value for every radii within 1.5%
- Hadron calibration at calorimeter energy level is fixed
  which was determined for sDHCAL prototype using 3-threshold mode: 0.114, 1.39 and 3.65 pC (cf. A. Steen's talk on sDHCAL performance)

Energy resolution for gamma



Only photons in barrel are taken into account

→ no changes in resolution for single photon events

Hadron calibration: parameter scan. Step 2.

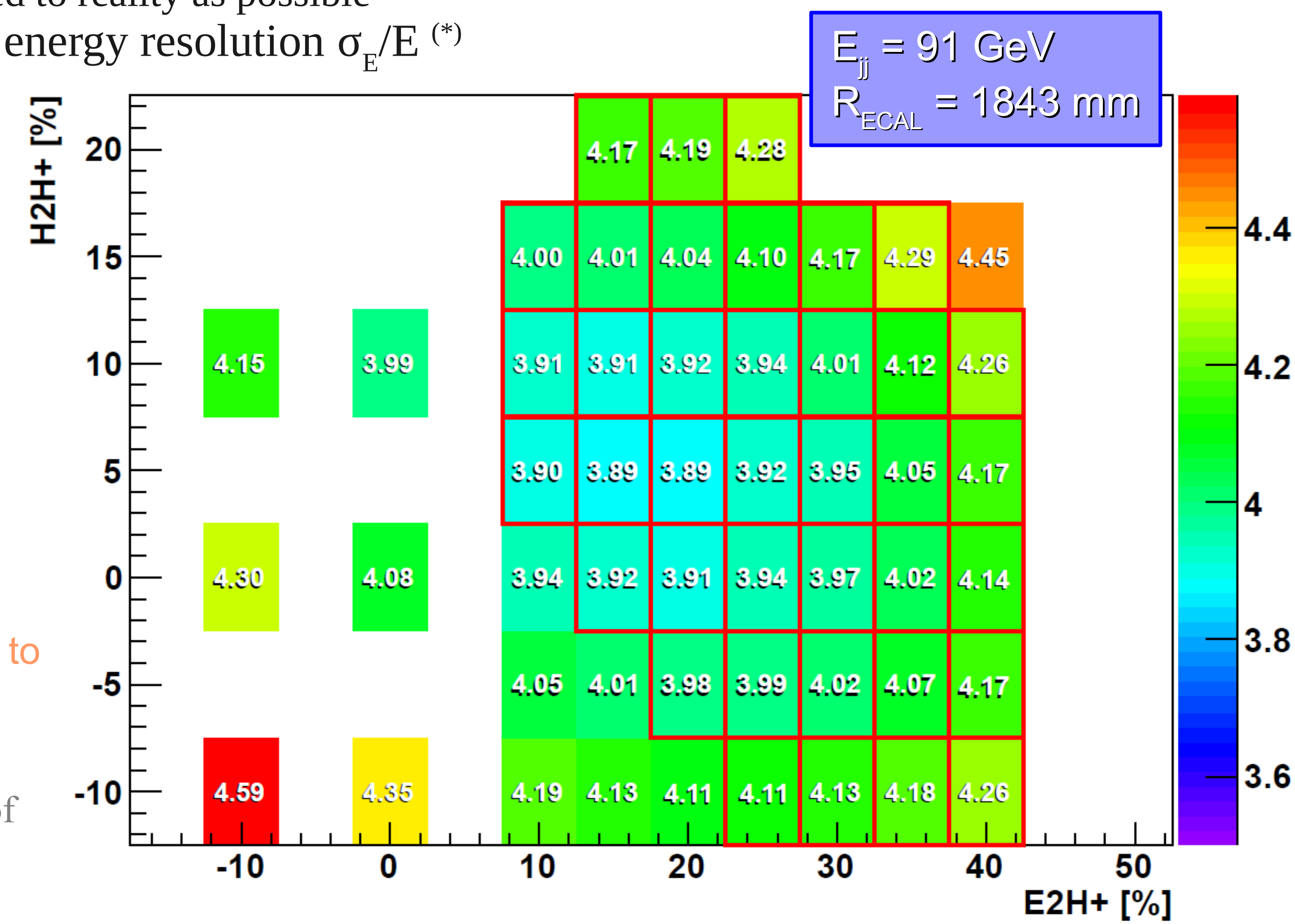
- Two calibration constants within Pandora: weights to energy deposites in ECAL and HCAL which belong to hadronic shower
- Set of parameters are chosen so that:
  - Jet energy resolution is as small as possible (for all energies)
  - mean value as closed to reality as possible
- Scan based on single jet energy resolution σ_E/E (*)

- Once close to minimum, 5% of change in HAD and EM scale does not affect significantly the resolution

red boxes: mean value differs to real value by less than 1%

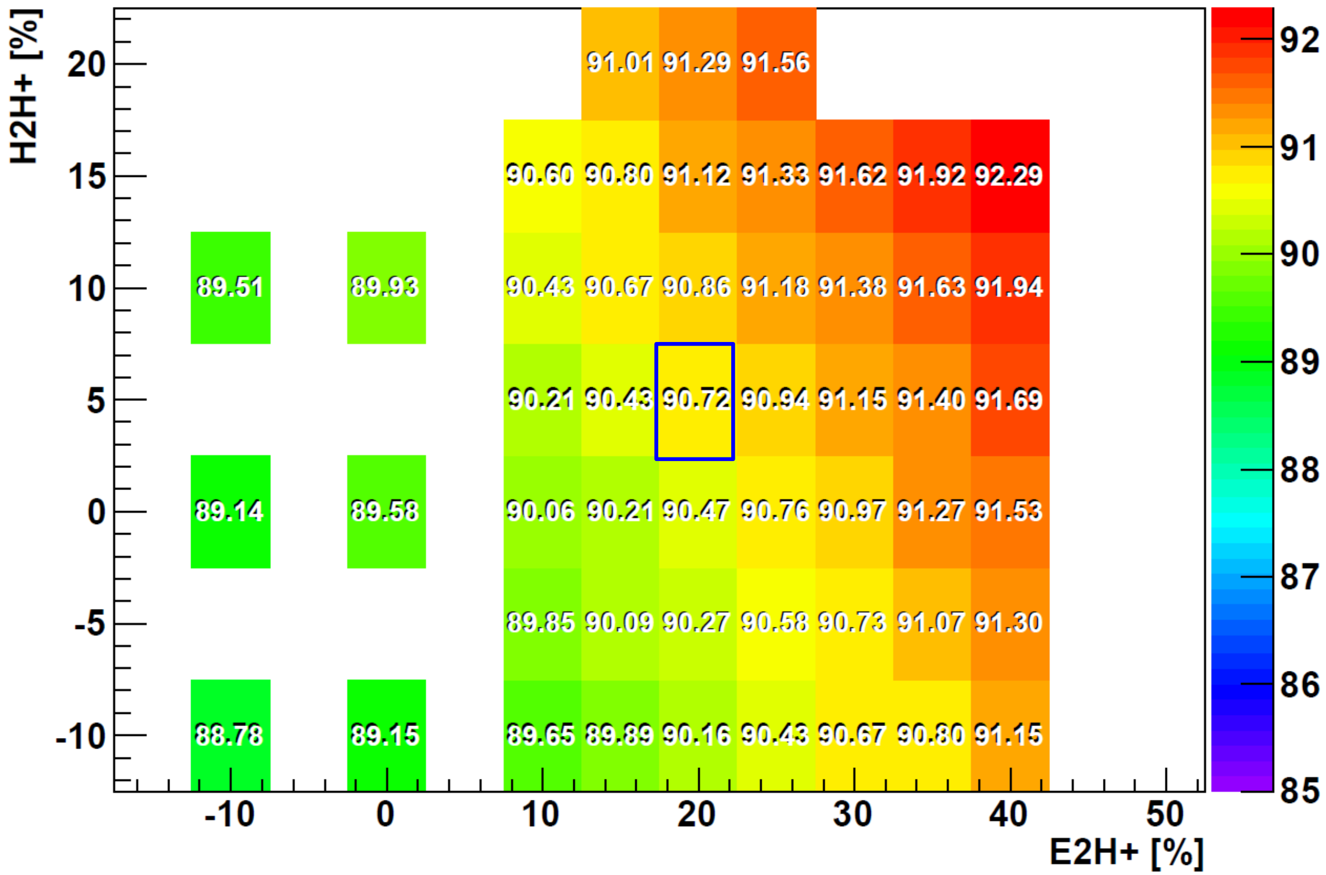
(*) the JER is expressed in terms of RMS90

$$\frac{\mathrm{rms}_{90}(E_j)}{E_j} = \frac{\mathrm{rms}_{90}(E_{jj})}{E_{jj}}\sqrt{2}$$



Hadron calibration: parameter scan (cont.)

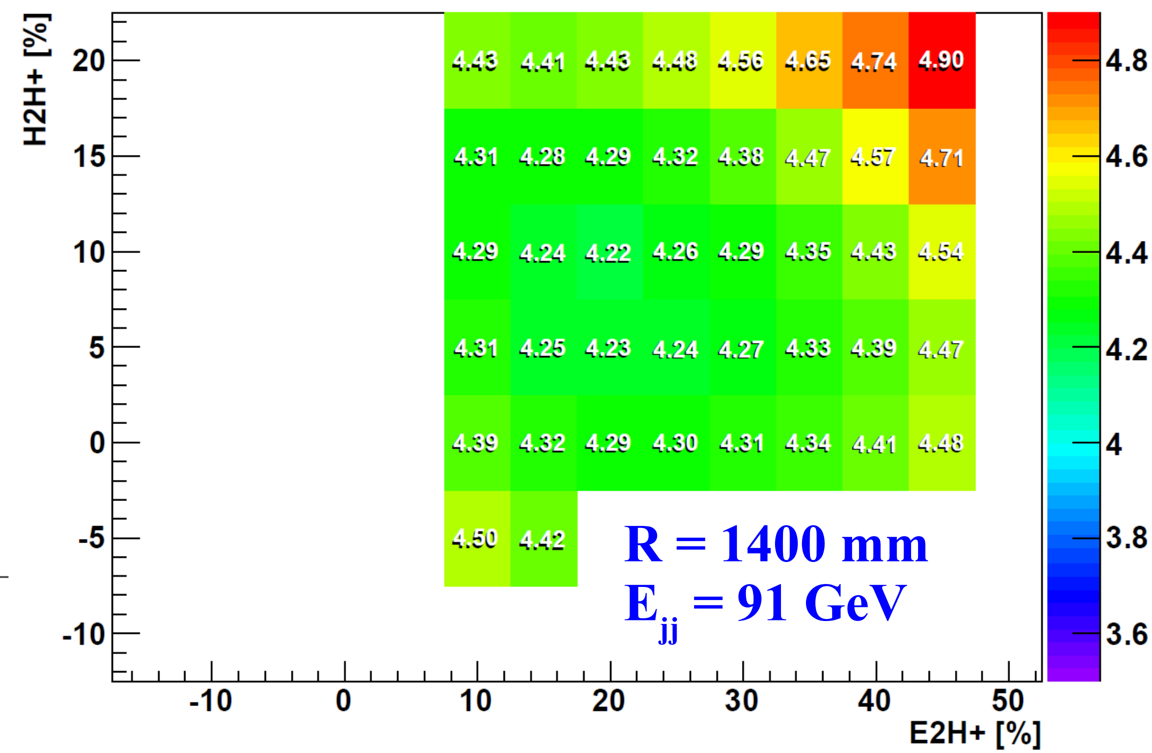
- Scanning should ensure that energy mean value is closed to generated $E_{jet\text{-}jet}$

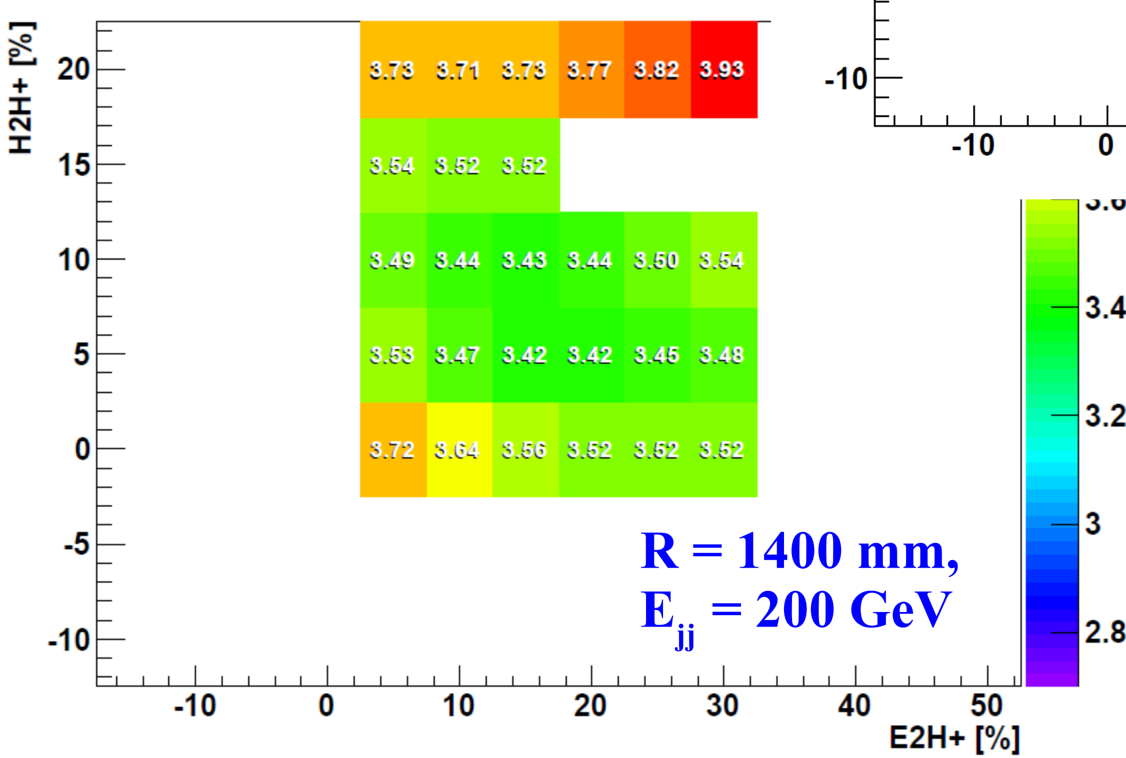


- **Scan results show that:**
  - EM scale should be increased by 20%
  - HAD scale should be increased by 5%

Hadron calibration: parameter scan (cont.)

- Scan repeats for :
  - all radii
  - for energies 91, 200 and part of 500 GeV
- Optimal for JER always at +20% for EM scale and +5% for Had scale

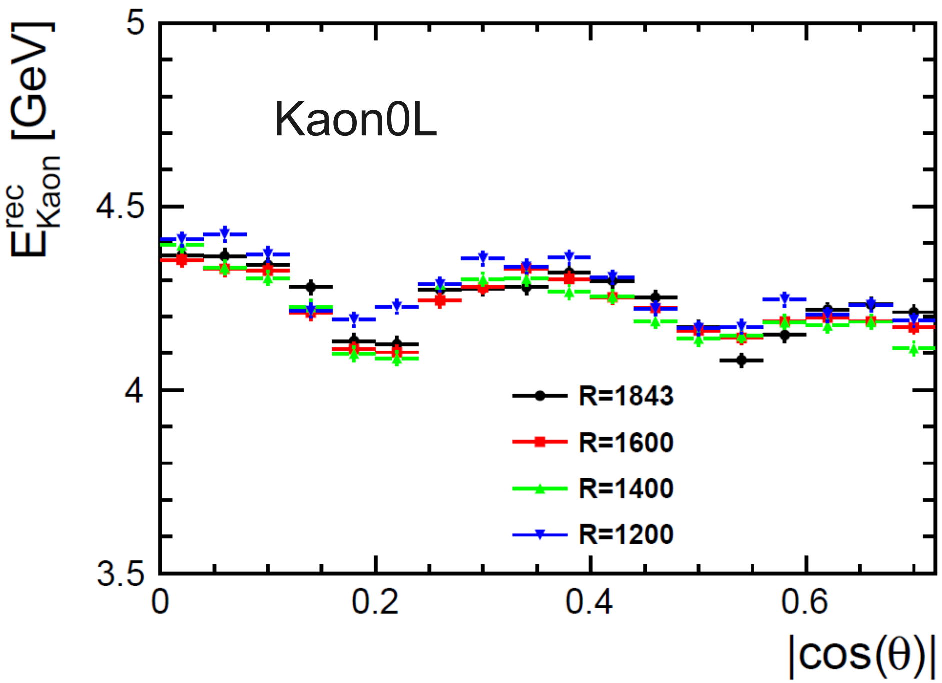


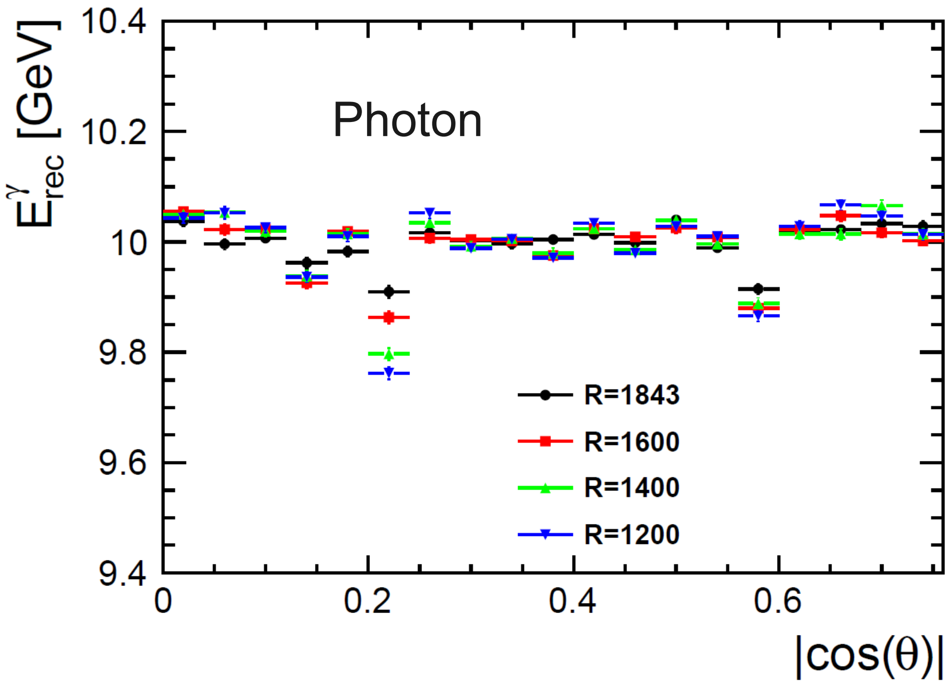


- Variation of JER is <1% if change scale by 5%

Angular energy correction. Step 3.

- Mean value of energy shows a significant dependence on polar angle, especially for lower value of radius: due to gap between modules (ECAL+HCAL), alveolar structures (ECAL), ...



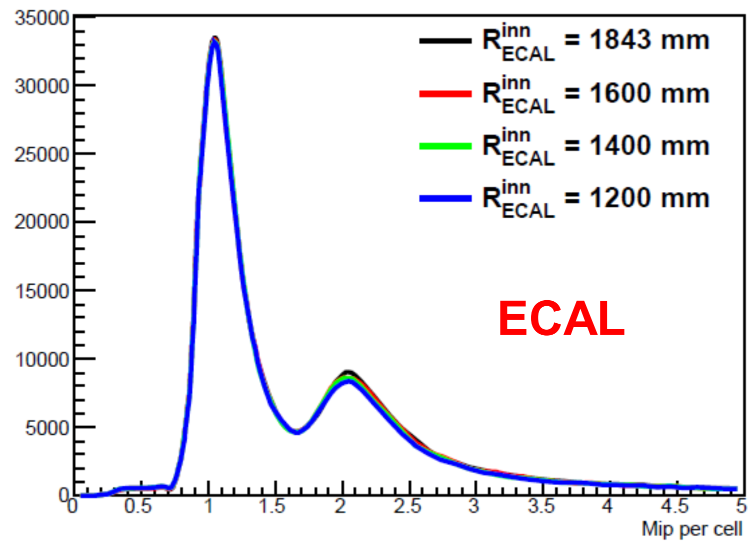


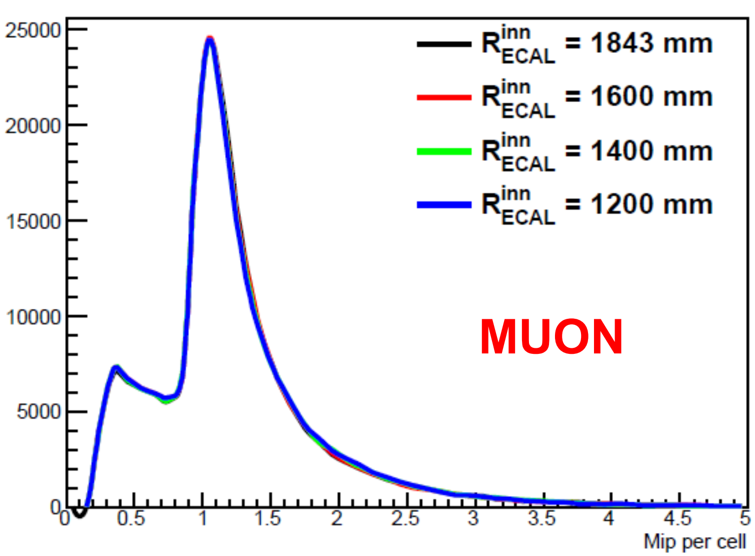
Effect of correction on JER

E_{jj} (GeV)	R_{ECAL}	before	after	E_{jj} (GeV)	R_{ECAL}	before	after
91	1843	3.89	3.85	500	1843	3.12	3.06
	1400	4.23	4.14		1400	3.71	3.64

Mip calibration: muon's at 10 GeV

- Mip calibration: how energy in calorimeters are translated in to MIP energy
- Controlled by equivalent number of mips per cell for each event

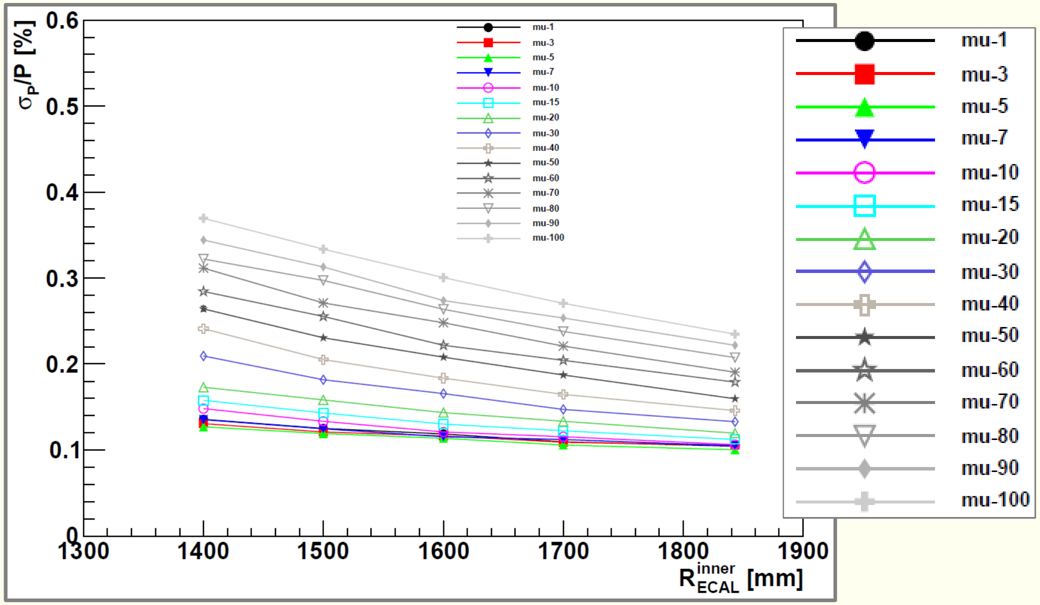




- Double-peak structure for ECAL mip due to two sections with different sampling fractions

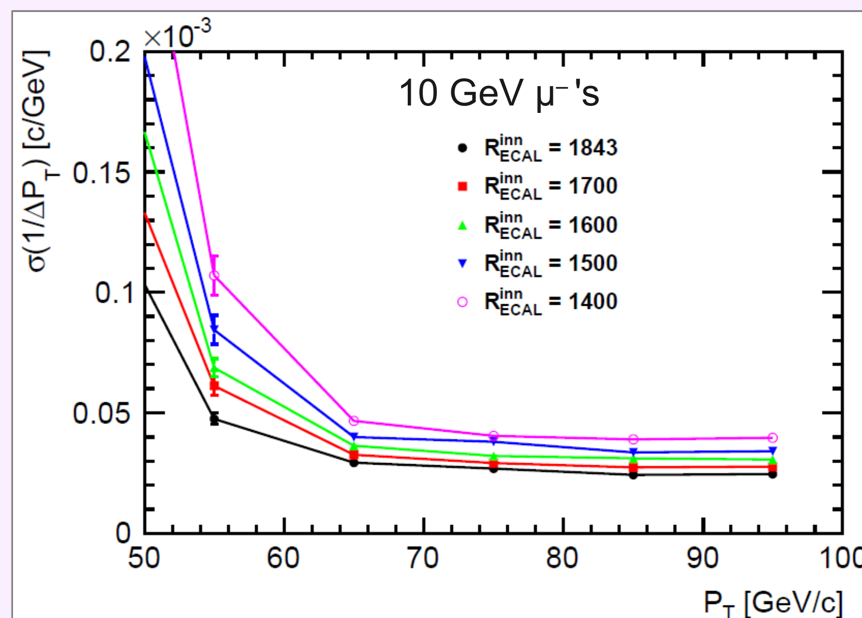
- **Very small difference in MIP calibration between different radii. (Fluctuation.)**

Single particle resolution: muon's



Momentum resolution of muons' at different energies for different radii.
Degradation by, e.g., 40% for muons' at 50 GeV.

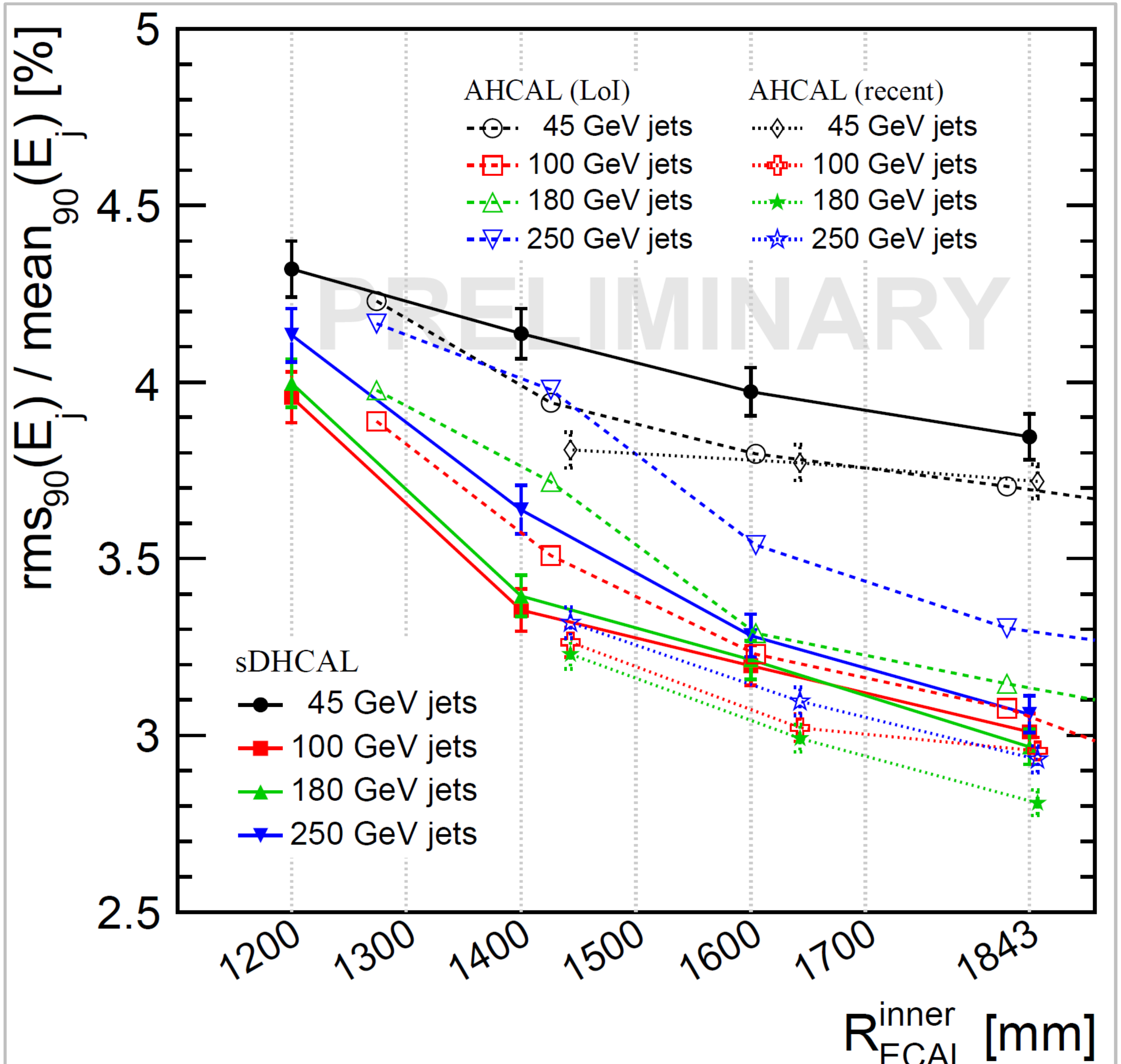
Or in terms of resolution of $1/P_T$ of track.
Degradation in $1/P_T$ resolution by ~60% from radius 1843 to 1400 mm.



Performance:

Jet energy resolution

Jet energy resolution vs Radius



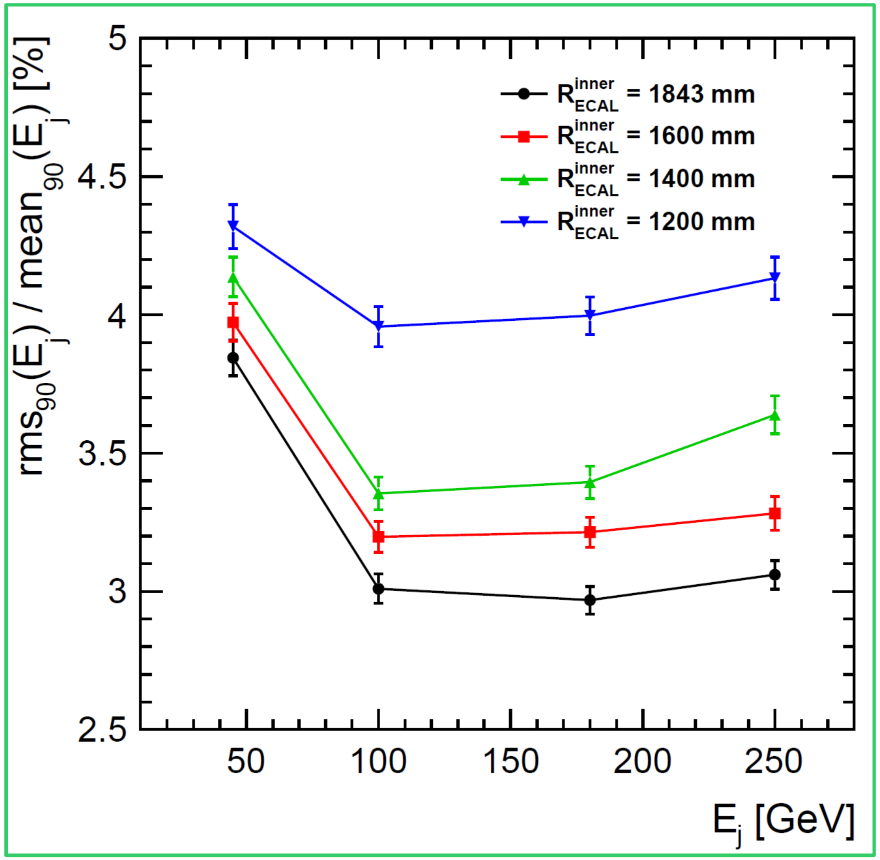
SiW ECAL: 5×5 mm², AHCAL: 3×3 cm², sDHCAL: 1×1 cm²

- JER is determined using Z → uds (Z decaying at rest– qqbar)
- CM energies: 91, 125, 200, 380, 500 GeV → Jet energies: 45, 62, 100, 180, 250 GeV

- This study: **solid lines**, PandoraPFANew v0.09
- Results for AHCAL @ LoI – **dashed lines**, PandoraPFA
- recent updates for AHCAL – **dotted lines**, PandoraPFANew v0.12 (cf. J. Marshall's talk.)

- PandoraPFANew is not optimized for 1×1 cm² sDHCAL
- even though, sDHCAL seems to have similar resolution at medium energies as AHCAL

Jet energy resolution vs E_{jet}



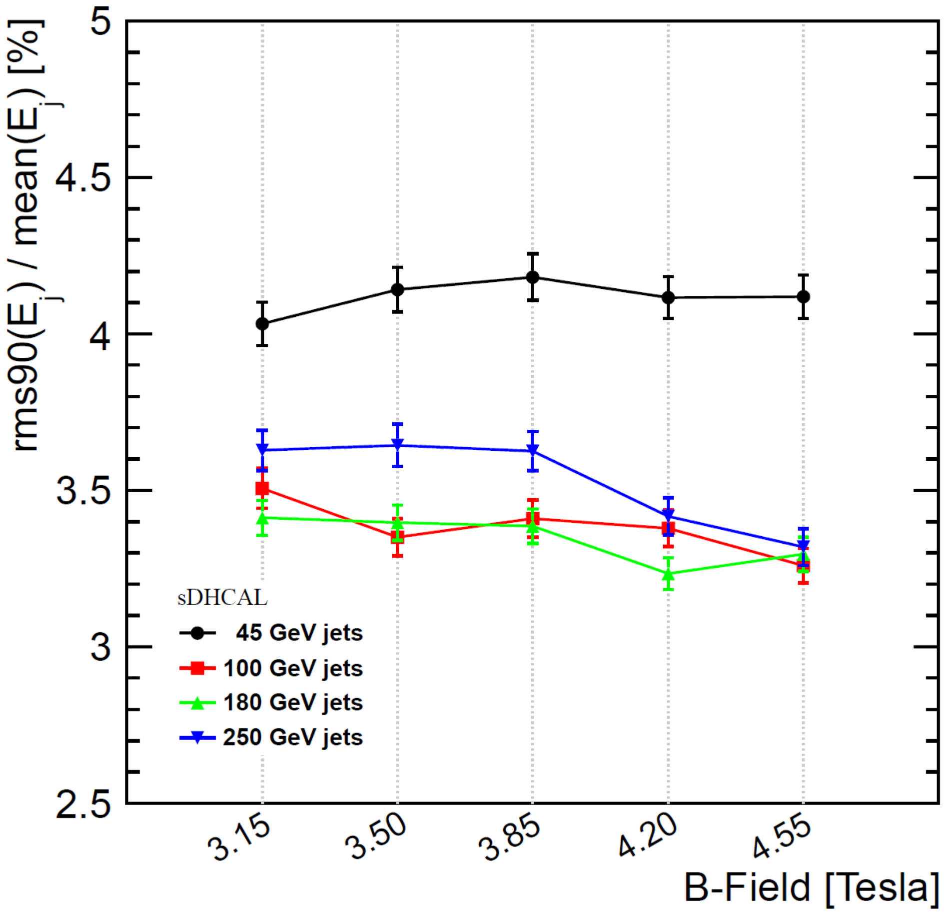
- At low energy, JER is dominated by intrinsic calorimeter resolution – mainly HCAL (1/sqrt(E))
- At higher energy (250GeV) confusion term dominates → JER increases
- R=1200 mm does not seem to be a good option

Further cross-checks

- DHCAL in analog mode
- Effect of tracking on PFA performance
- Magnetic field

Change of B-field

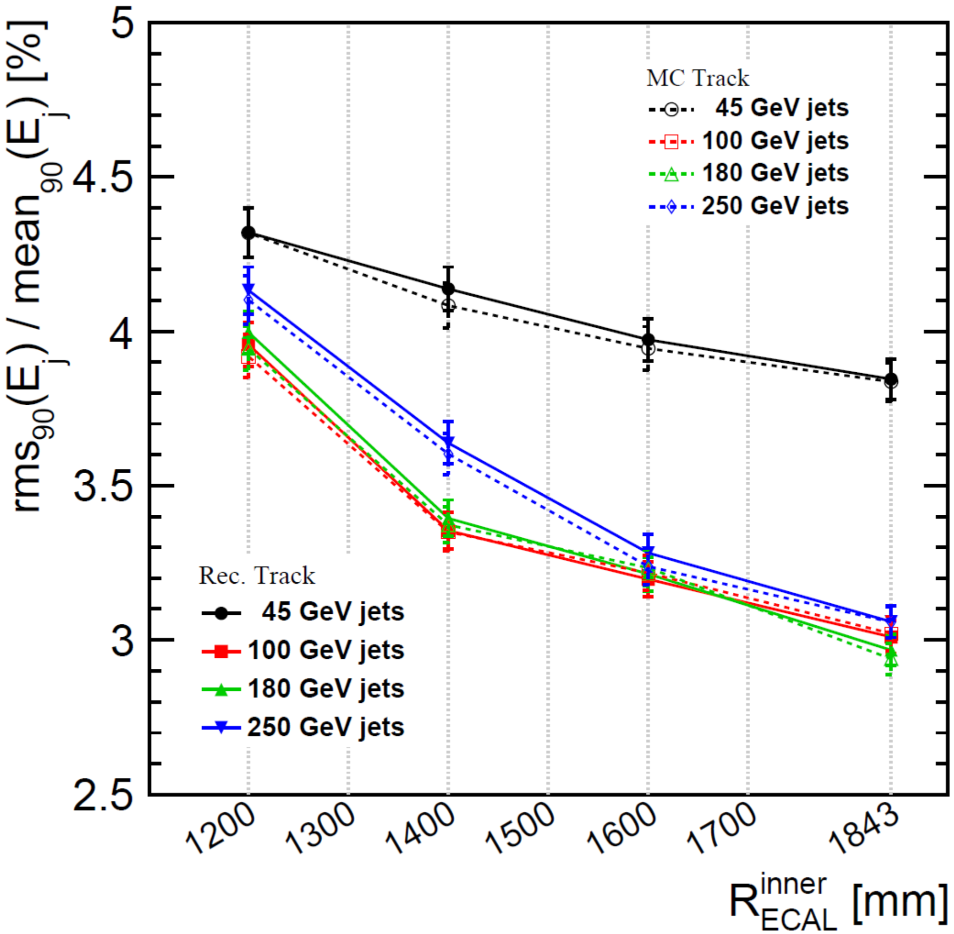
- ILD with Ecal inner radius at 1.4 m is chosen for the study
- Change default B field (3.5 T) by a factor of 0.9, 1.1, 1.2 and 1.3 → 3.15, 3.85, 4.20 and 4.55 T



R_{ECAL} = 1400 mm, 29 Si layers, 5×5 mm²
sDHCAL 10×10 mm²

- Improvement at high energies – confusion reduced
- For low energy (45 GeV), improvement at low B-field: at higher B-field, loose of low energy tracks

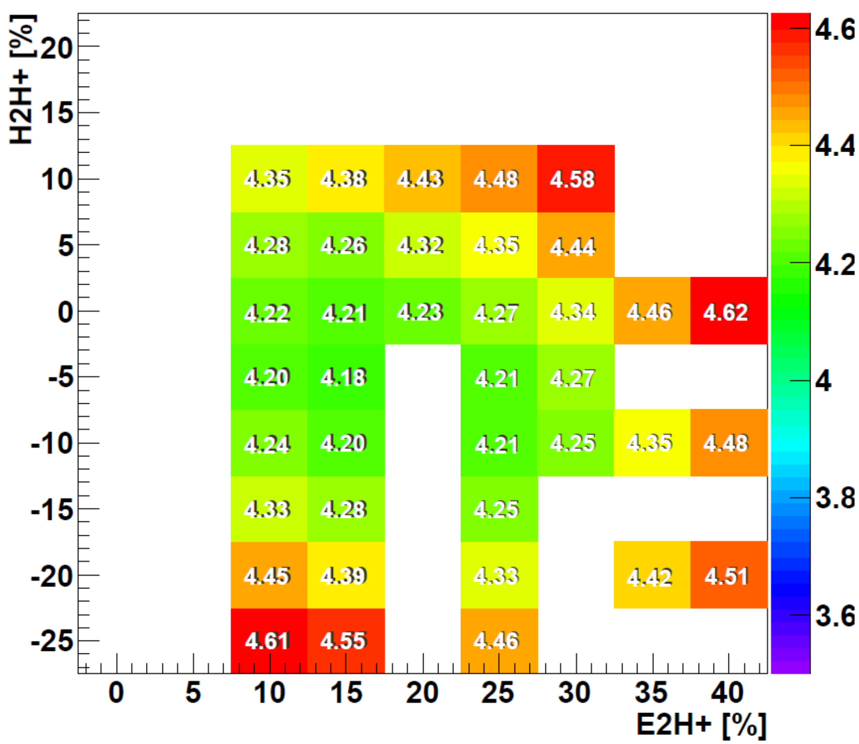
Effect of tracking on JER

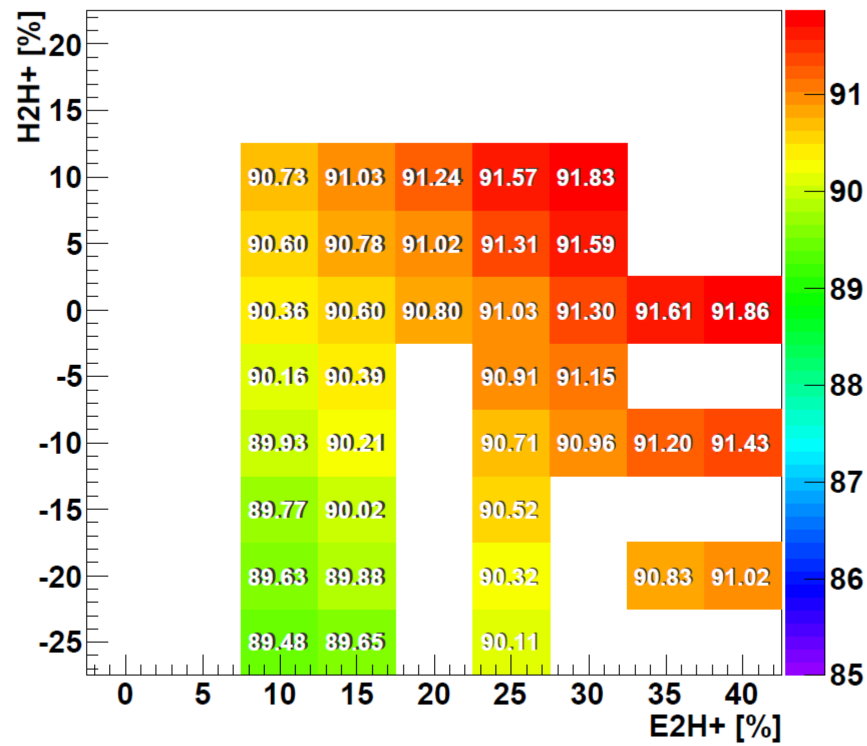


- Tracking performance degrades for small radii → effect on PFA performance need to be checked
- Use MC truth tracks as input for PandoraPFA
- Slight difference observed but not dramatic

DHCAL in analog mode

- Take energy as proportional to deposited charge (like AHCAL) in gas
- Recalibration:
  - Conversion factor (charge → energy)
  - Scanning also performed
- However minimum of JER is ~4.18, far from what given with digital mode (hit counting)





Summary

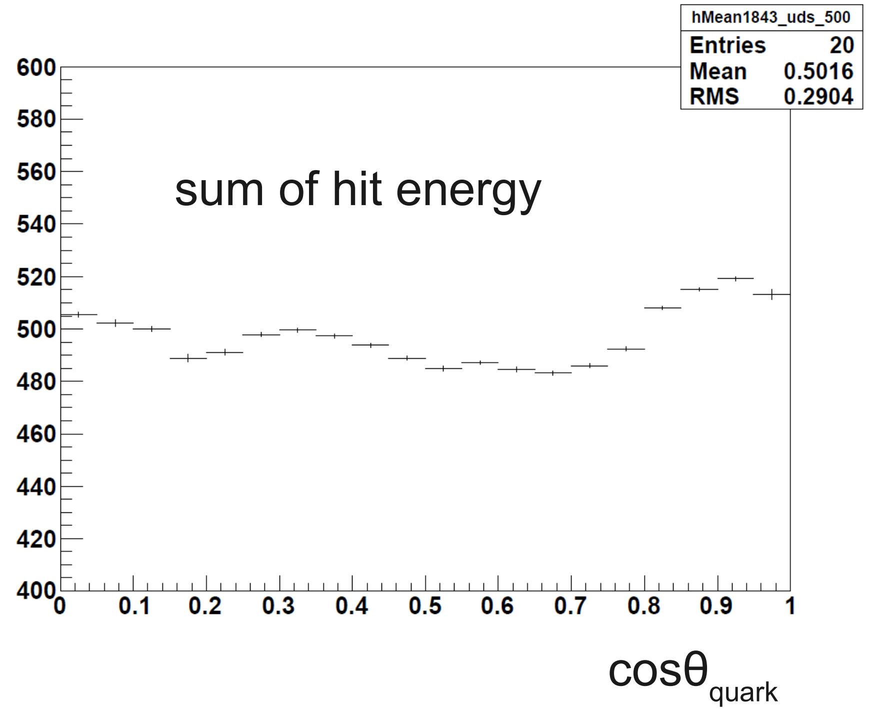
- Performance SiW-ECAL and sDHCAL for different radii studied in Mokka and Pandora
- Calibration was performed for every radii
  - for single particles
  - internal Pandora weights to Hadronic & electromagnetic components (2-dimension scan)
- If choose to reduce radius from 1.8 to 1.4m, JER increases:

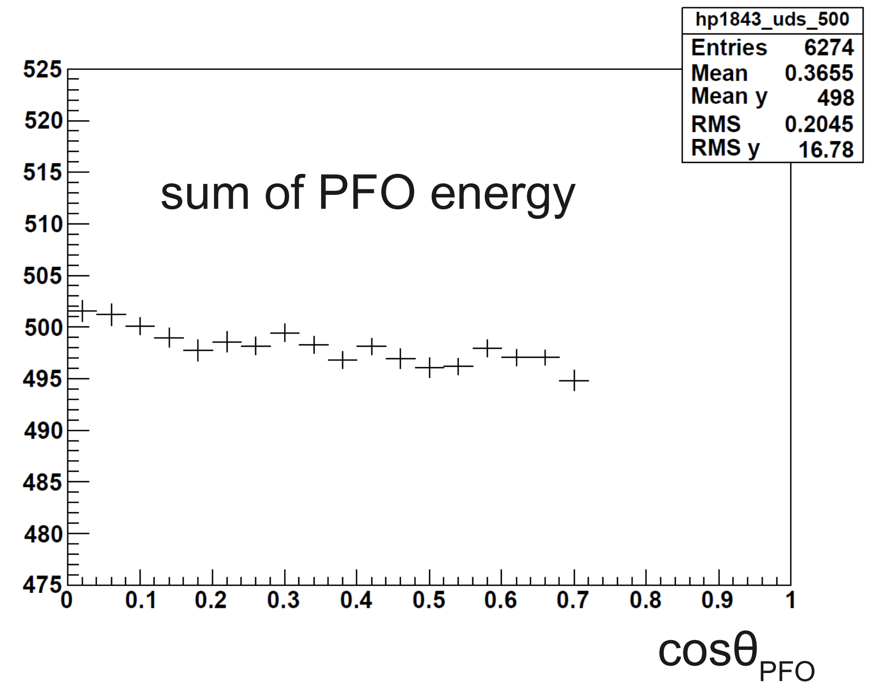
R_{ECAL} (mm)	E_{jet} (GeV)			
	45	100	180	250
1843	3.85	3.01	2.97	3.06
1400	4.14	3.35	3.39	3.64

However,
  - we should mention that potential of high granularity is still not fully explored
  - we may allow degradation but we gain in price as a function of R^2 !
- Several cross-checks have been done:
  - Effect of tracking: negligible to JER
  - Magnetic field: small effect for highest energy jets
  - DHCAL in analog mode: hit counting seems better than energy counting
- Future plan:
  - extend study with **1.4 m** for Ecal inner radius and with **19 Si layers**
  - add jet energy point at 62 GeV (in progress, some features not fully understood)

Backup slides

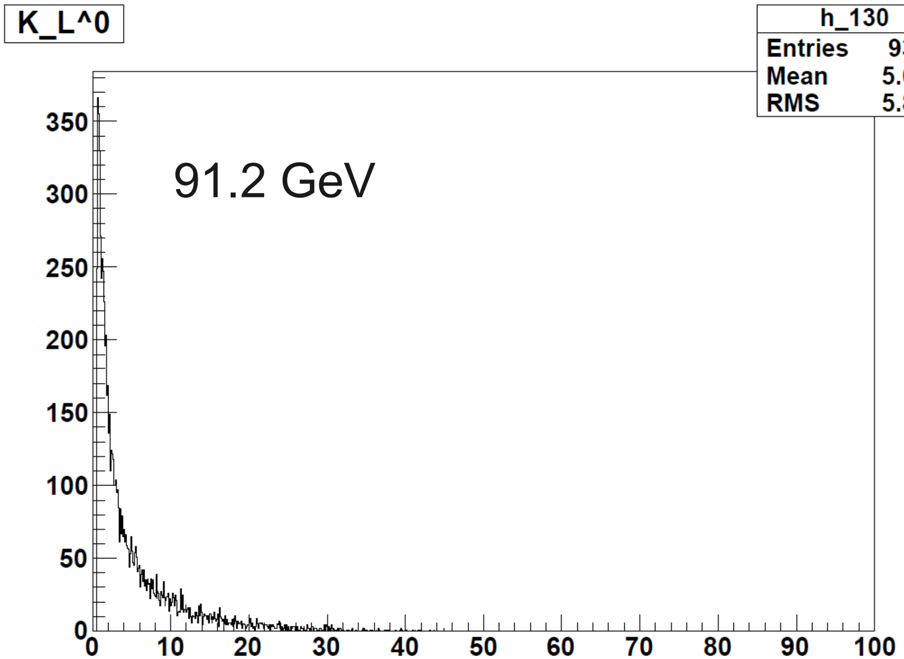
Dependence of energy on cosΘ

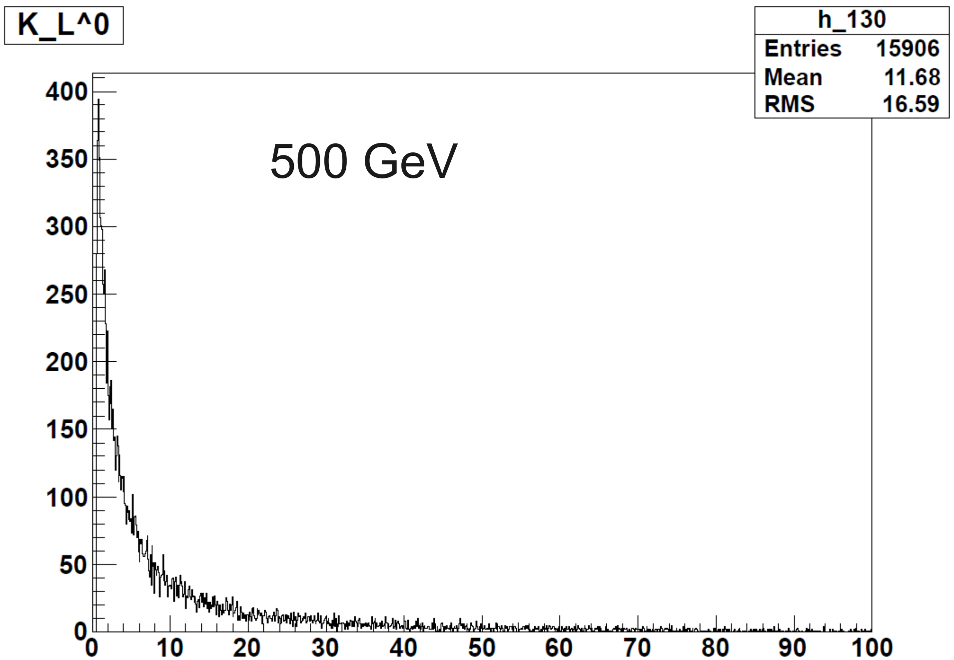




- Large dependence on costheta
-

Kaon 0L in jets

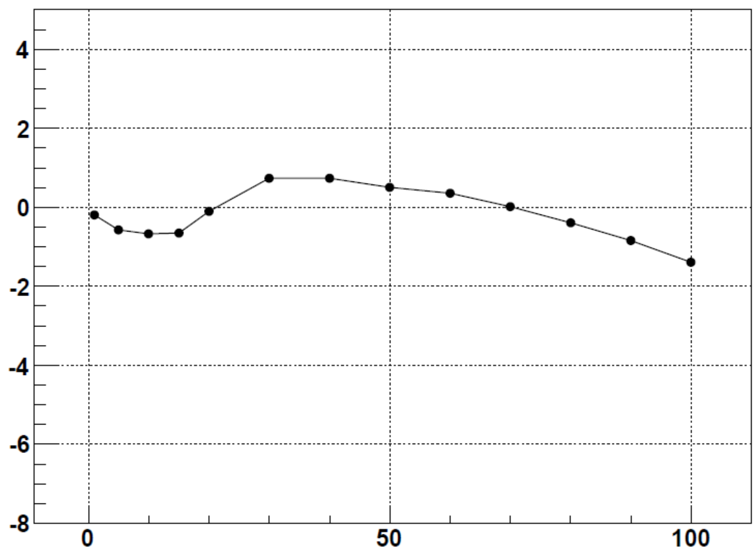


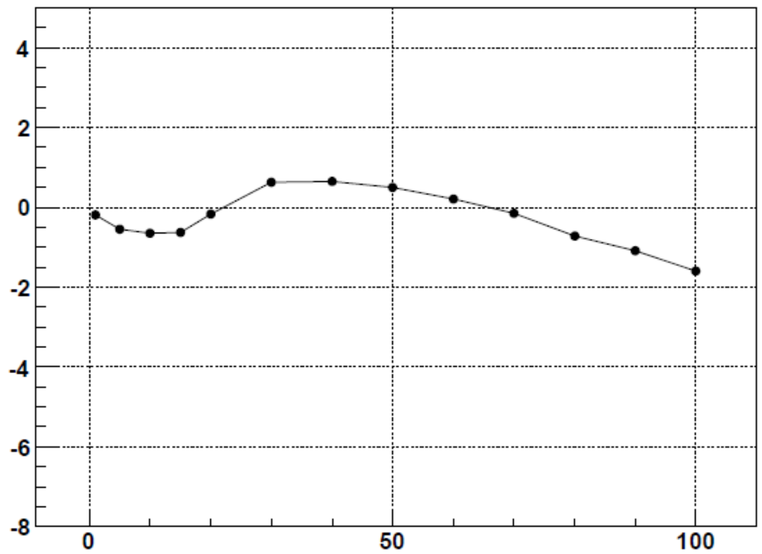


Had calibration

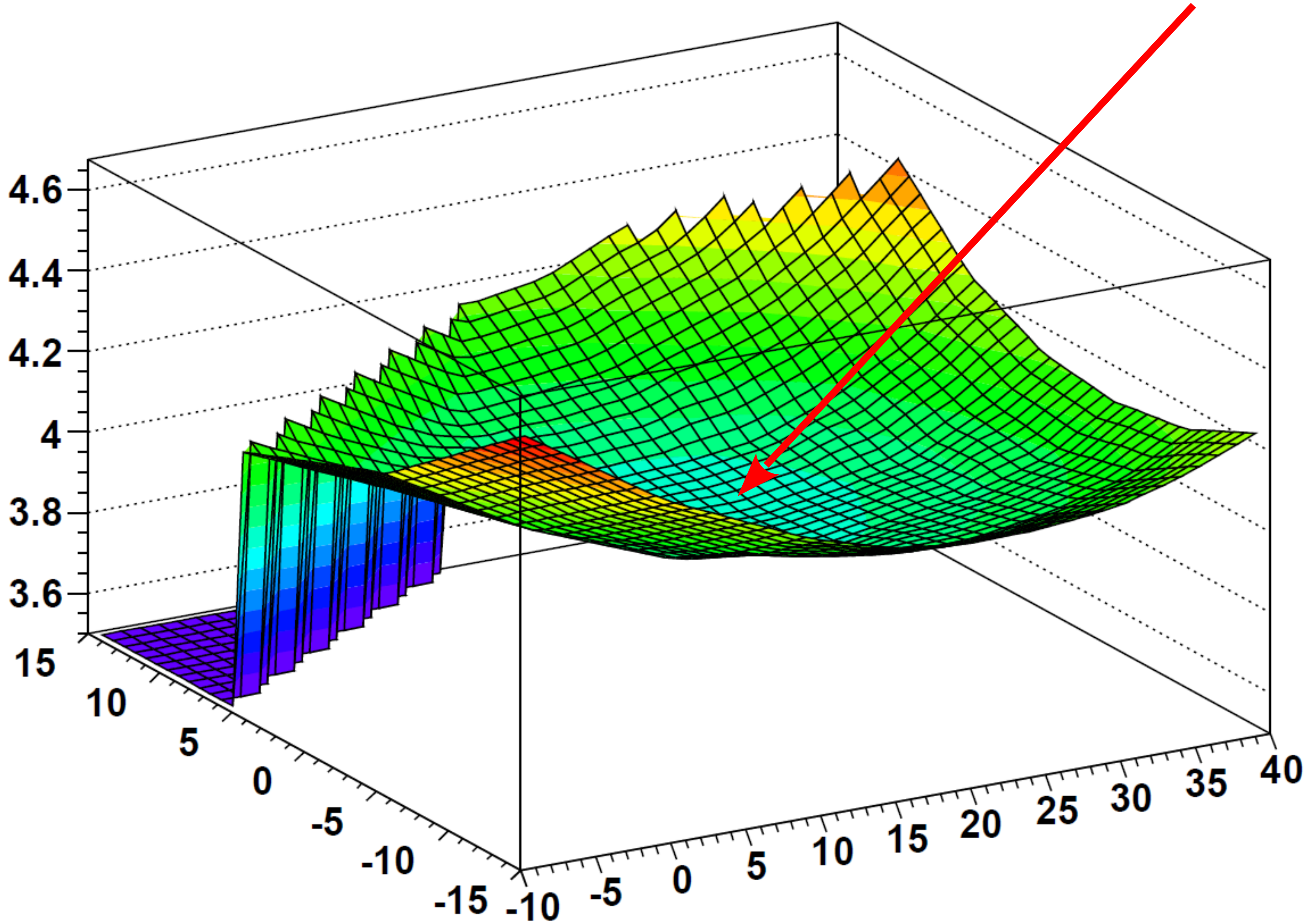
- Procedure:
  - Chi2 method
  - sum of energy in calo = Ecal Energy + (N_1 t_1 + N_2 t_2 + N_2 t_2)
  - $\chi^2 = \Sigma (E_{rec} - E_{sim})^2 / E_{sim}$
  -

t_i : thresholds
N_i : nb of hits corresponding to threshold t_i



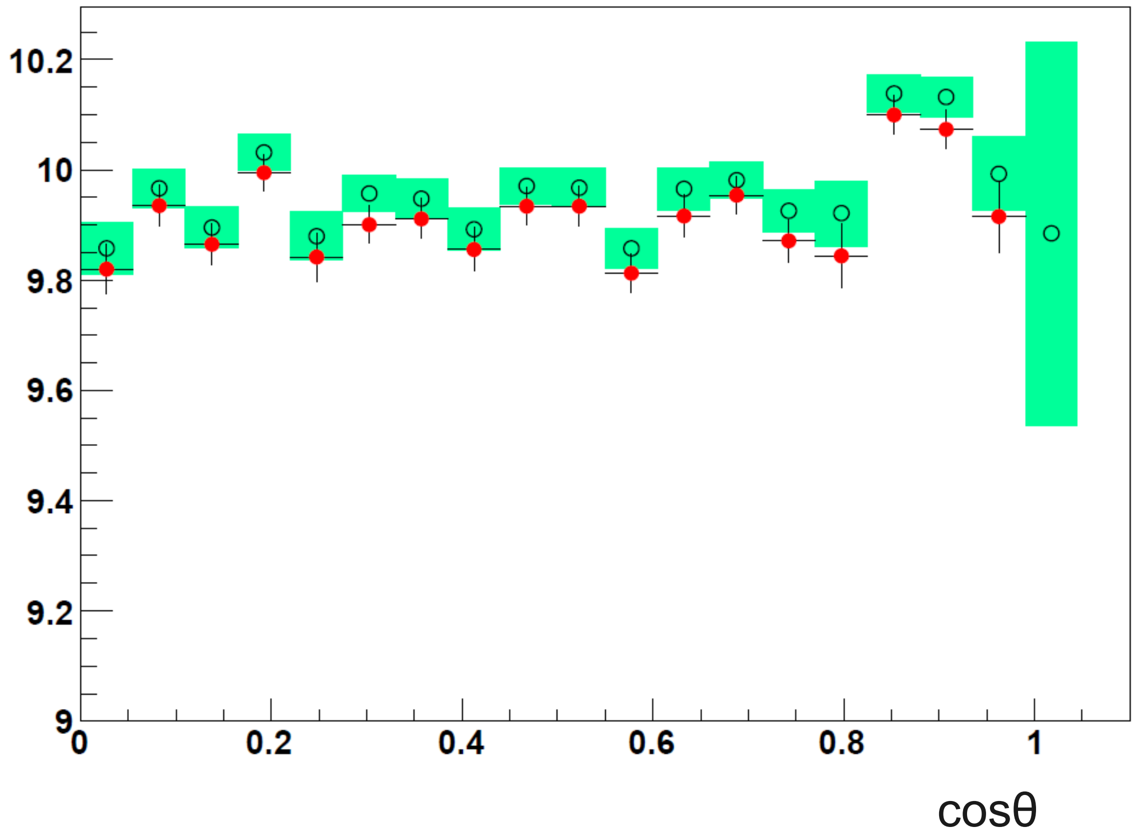


Pandora hadronic parameter scan



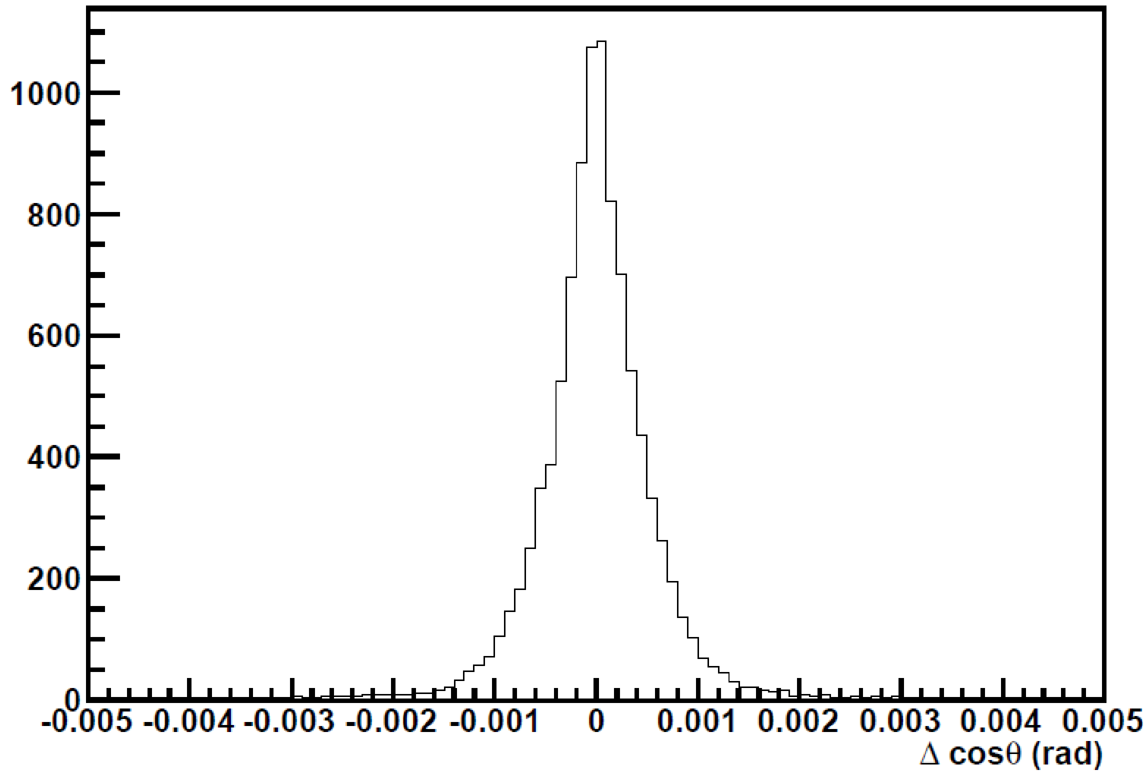
"Valley" is broad.
Once parameters approach minimum, JER does not change significantly

Pandora hadronic parameter scan



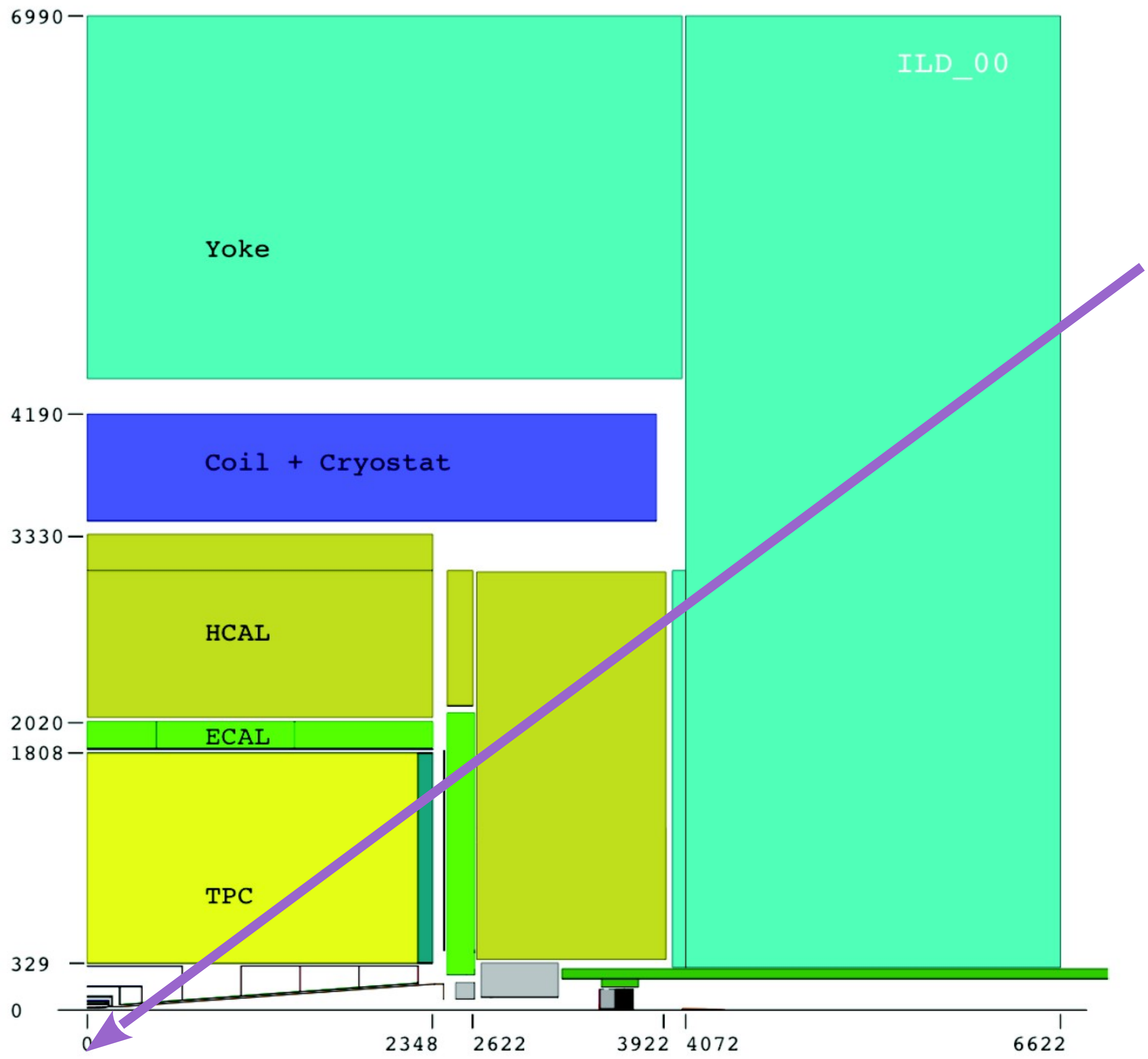
Comparison PFO energy & hit energy. Photons' at 10GeV

Energy correction vs cosθ



- Difference of **reconstructed** and **generated** photon polar angle.
- Average is less than 1mrad
- → safe enough to do a correction in function of cosθ

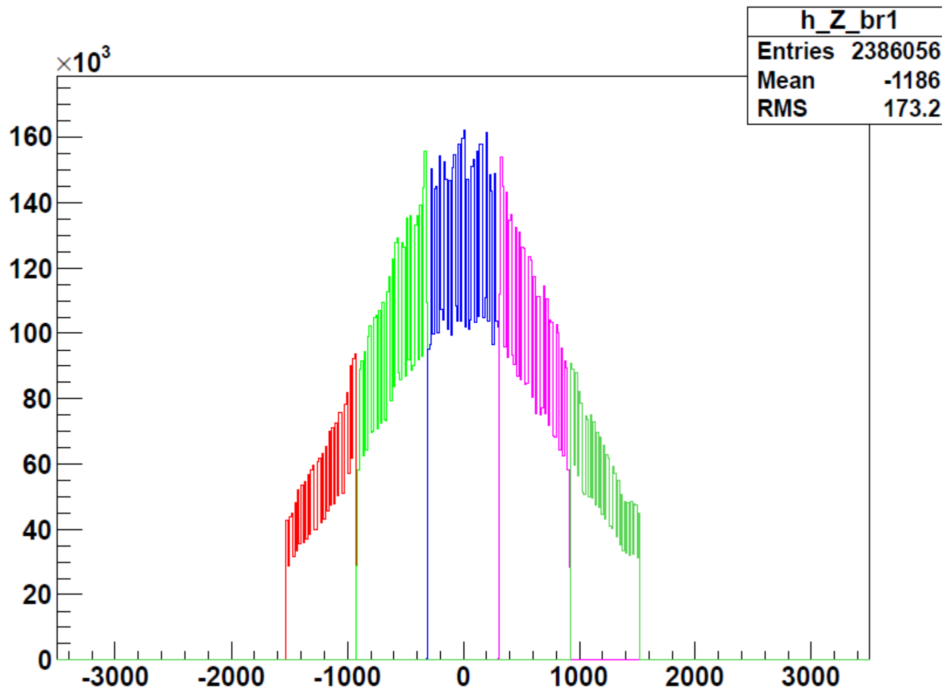
ILD layout



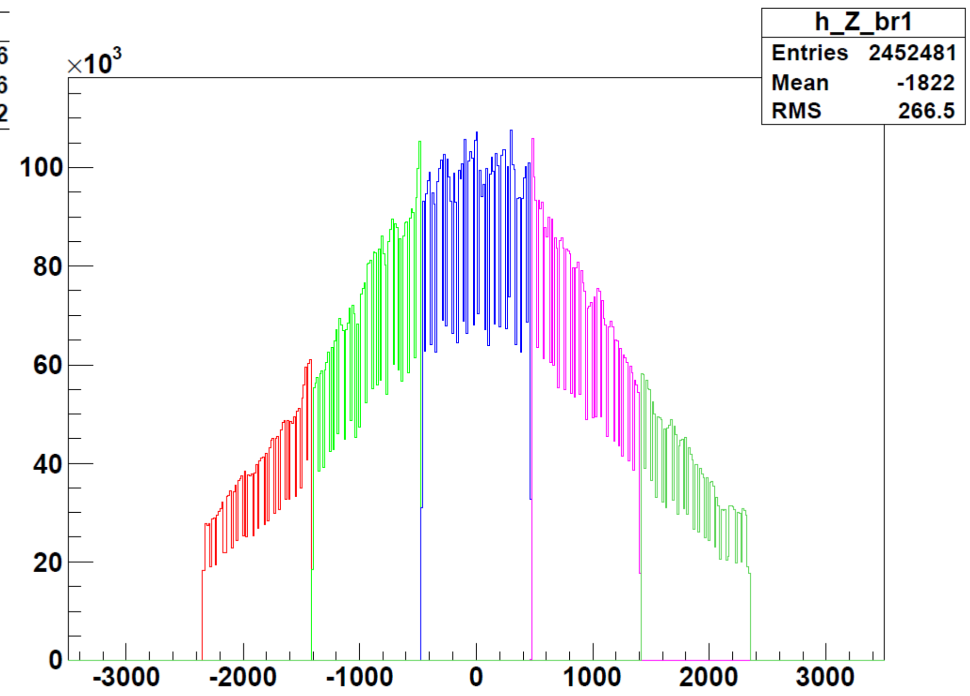
ILD_00
Yoke
Coil + Cryostat
HCAL
ECAL
TPC
6990
4190
3330
2020
1808
329
0
0
2348
2622
3922
4072
6622

Half-Z reduction

Hit Z distribution



R=1200mm, halfZ=1530 mm



R=1843, halfZ=2350 mm