ILD SiW ECAL optimisation

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Outline:
- Introduction
- Optimisation studies
  - ECAL particle separation power
  - ECAL number of layers (with reduced radius)
  - Tau analysis

Journées Collisionneur Linéaire
Grenoble – Décembre, 2014

Introduction

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

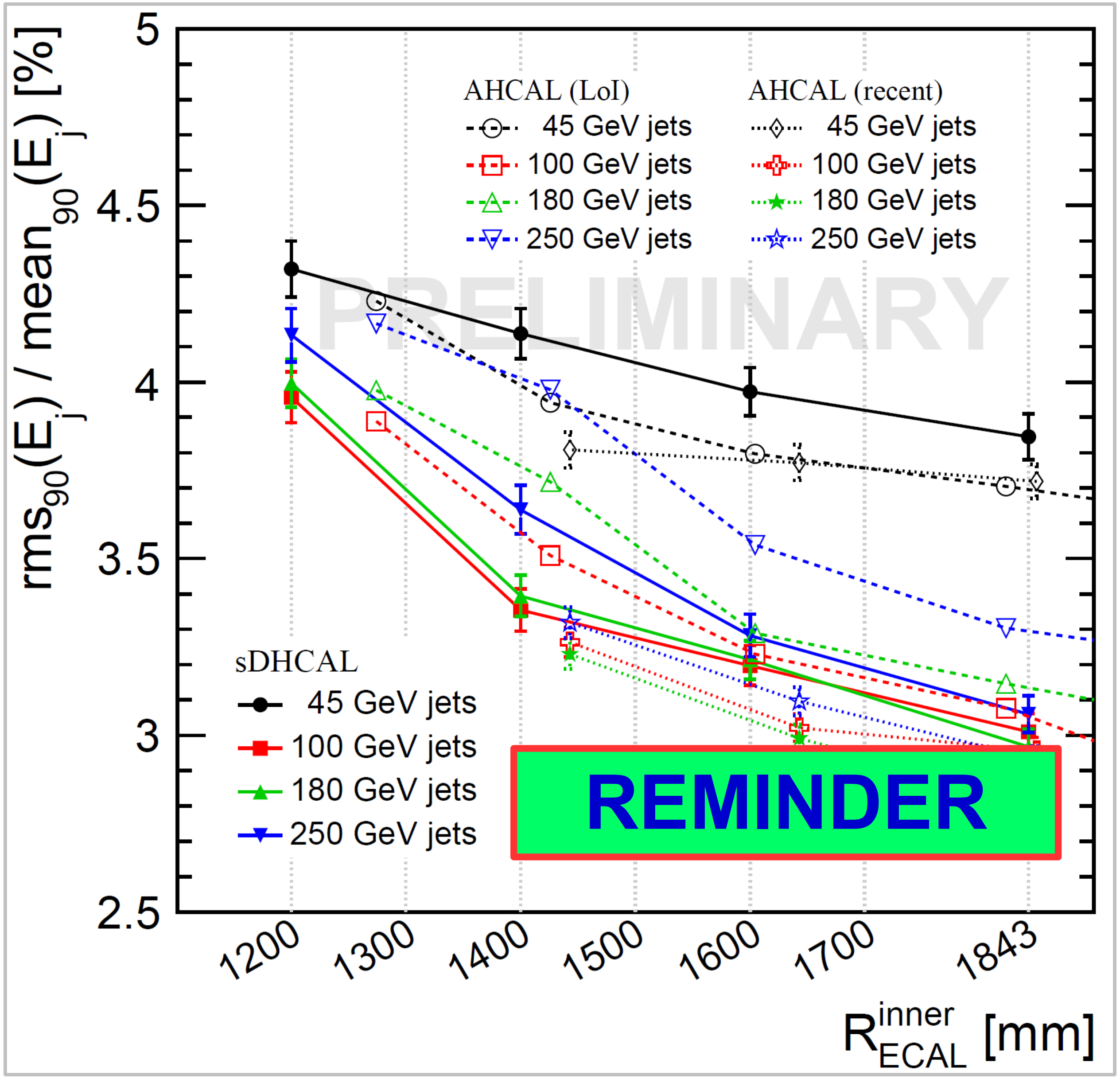
- **Optimisation efforts**:
  - Reduce ECAL number of layers (reported at LCWS12 & in DBD)
  - Reduce ECAL radius (reported at LCWS13-Tokyo & JCL 2013 – CEA Saclay)
  - →**What if we choose to reduce at same time: radius & ECAL number of layers?**

  - Tau decay (1-prong): a key for any ECAL optimisation
    - tau jet is compact
    - photon separation capability is essential
  - ECAL separation power
    - study based on simulation of ECAL prototype
    - comparison between GARLIC & PandoraPFA & Arbor

- **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
  - Photon separation studies: Garlic, Arbor

(*) ECAL simulation meeting

Reminder: Jet energy resolution vs Radius



SiW ECAL: 5×5 mm^2, AHCAL: 3×3 cm^2, sDHCAL: 1×1 cm^2

- 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 cm^2 sDHCAL
- even though, sDHCAL seems to have similar resolution at medium energies as AHCAL

SiW ECAL 30 Si layers

Reminder: Jet energy resolution vs radius

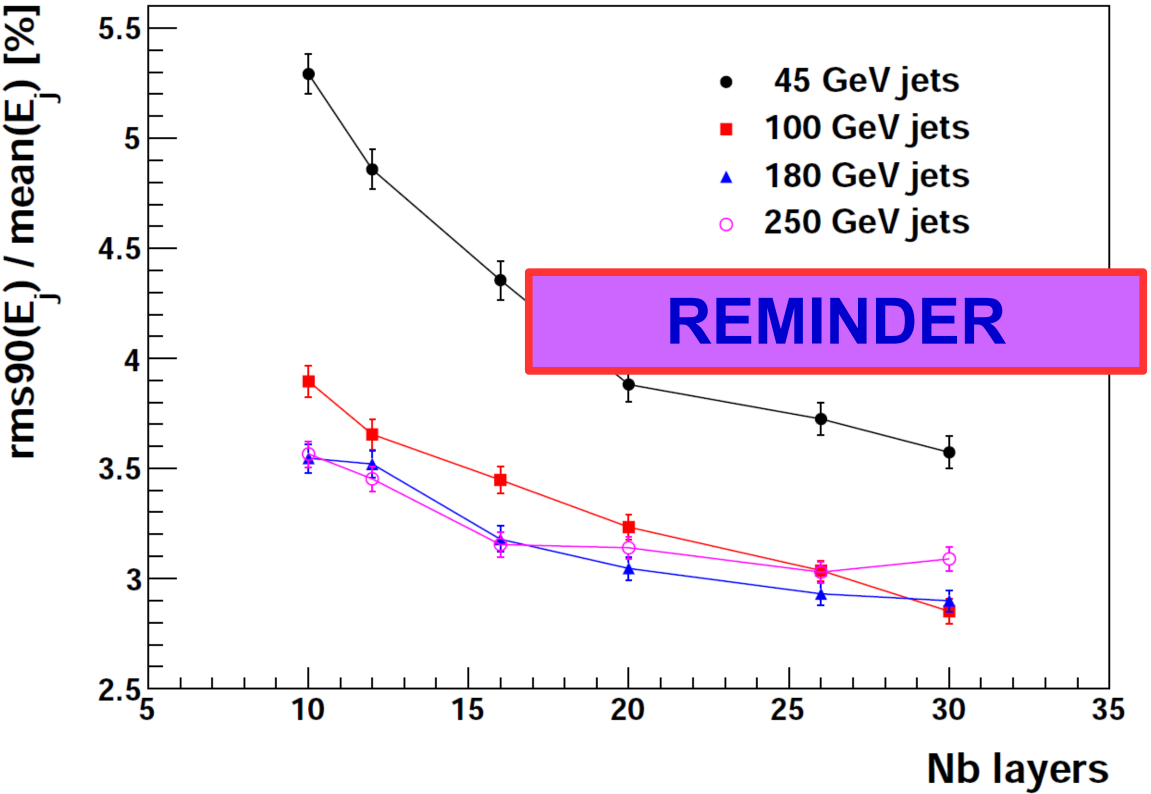
- JER is transformed to single JER and plotted as a function of number of layers for 91, 200, 360, 500 GeV Z → u/d/s.

- 9% of degradation is observed going from 30 to 20 layers for 91 GeV sample and more significant to lower number of layers
- effect is less important for higher energies

Presented at LCWS12 & ILD DBD

SiW ECAL inner radius: 1843 mm

Single JER presented in function of Nb of layers. A cut |cos(theta_jet)| < 0.7 is applied to avoid the Barrel/Endcap overlap area



Single JER shown in function of number of layers. The error bars are taken from a fit.

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

What if
we combine these two studies?

- Starting point: ILD SiW ECAL with radius at 1450 mm & 30 Si layers (5×5 mm^2 pixel size)
  sDHCAL has same thickness as in baseline design
- → performance estimation for 26 & 20 layers

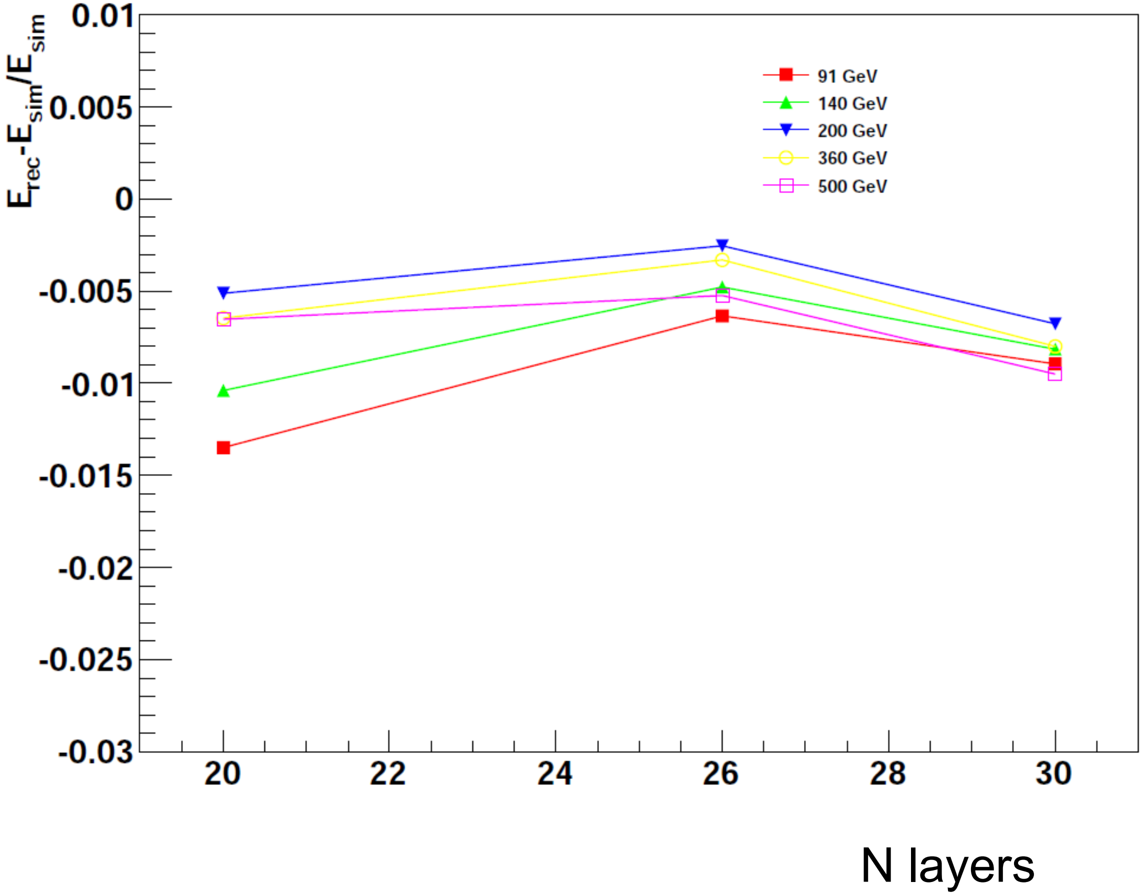
ECAL with reduced radius and reduced number of layers

- Starting point: ILD SiW ECAL with inner radius 1450 mm & 30 Si layers
- Try to reduce number of Si layers to 26 or 20 (25 or 19 W layers)

Linearity:

Better than 1.5 % for all jet energies

ECAL inner radius: 1450 mm

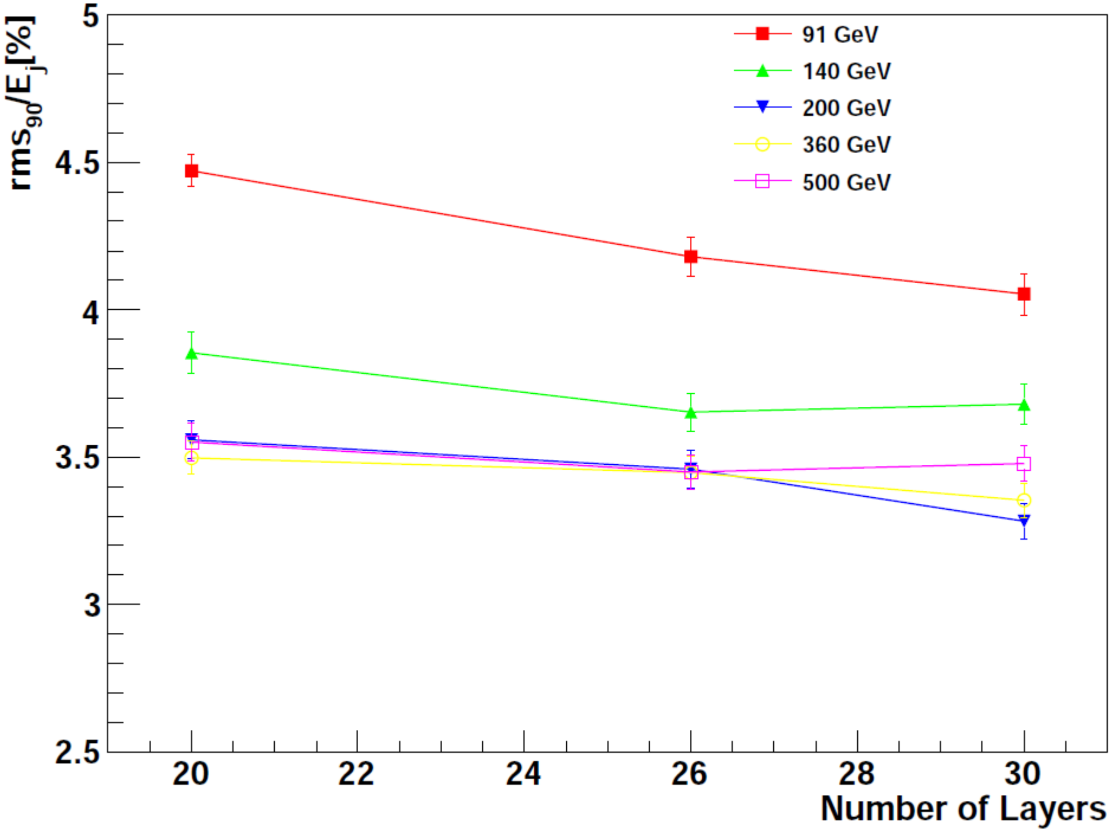


Jet energy resolution vs Number of layers

Jet energy resolution presented in terms of RMS90 as a function of number of layers.

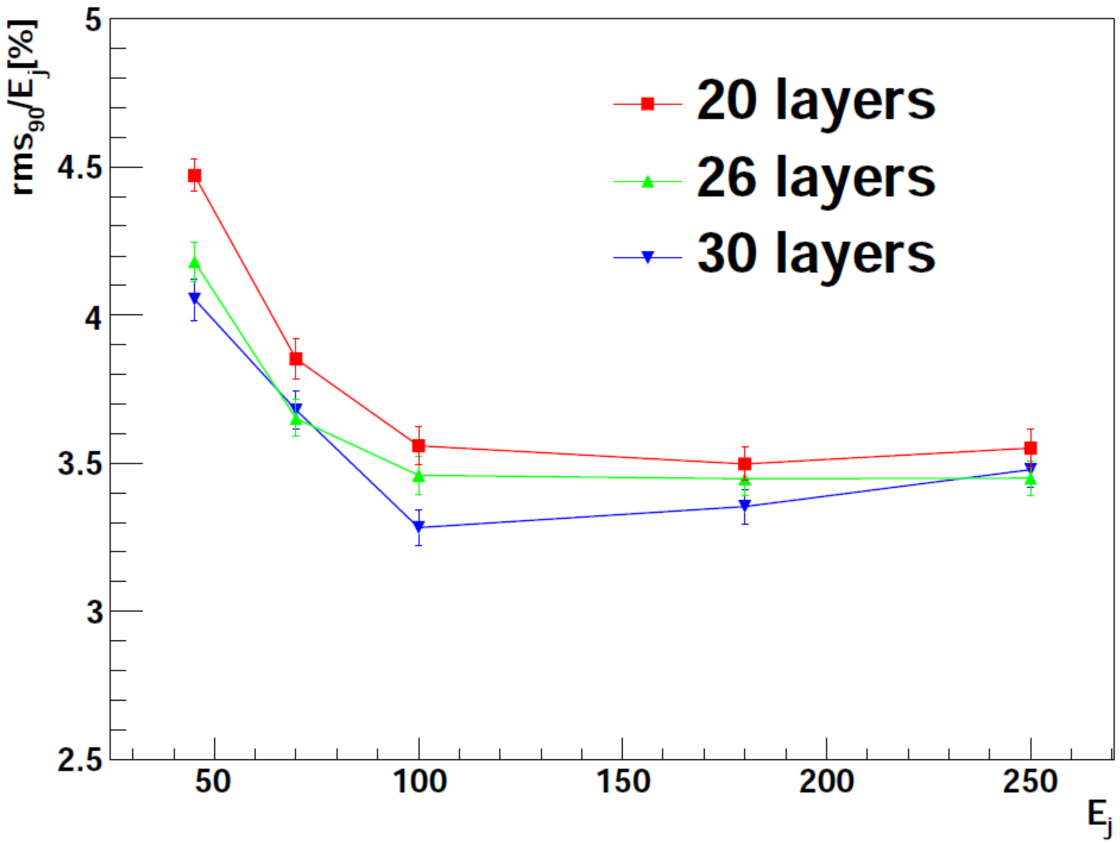
Difference of JER for 30- and 26-layer ECAL is small.

ECAL inner radius: 1450 mm



	Jet energy (GeV)				
# Si layers	91	140	200	360	500
20	4.47	3.85	3.56	3.50	3.55
26	4.18	3.65	3.46	3.45	3.45
30	4.05	3.68	3.28	3.35	3.48

JER vs generated energy



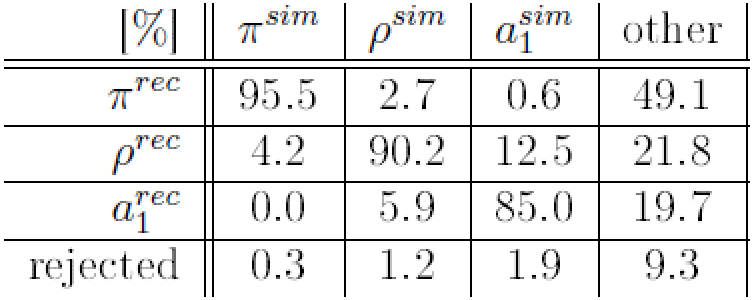
**ECAL inner radius:
1450 mm**

- At low energy, JER is dominated by intrinsic calorimeter resolution – mainly HCAL (1/sqrt(E))
- At higher energy (250GeV) confusion term dominates
  → JER increases

Tau analysis

- Tau jet is compact
- Capability of separation of photons is essential
- Study restarted for full ILD simulation with reduced SiW ECAL radius
- GARLIC is used for photon reconstruction

Aim to estimate branching fraction of different tau decay modes. (Mostly 1-prong.)



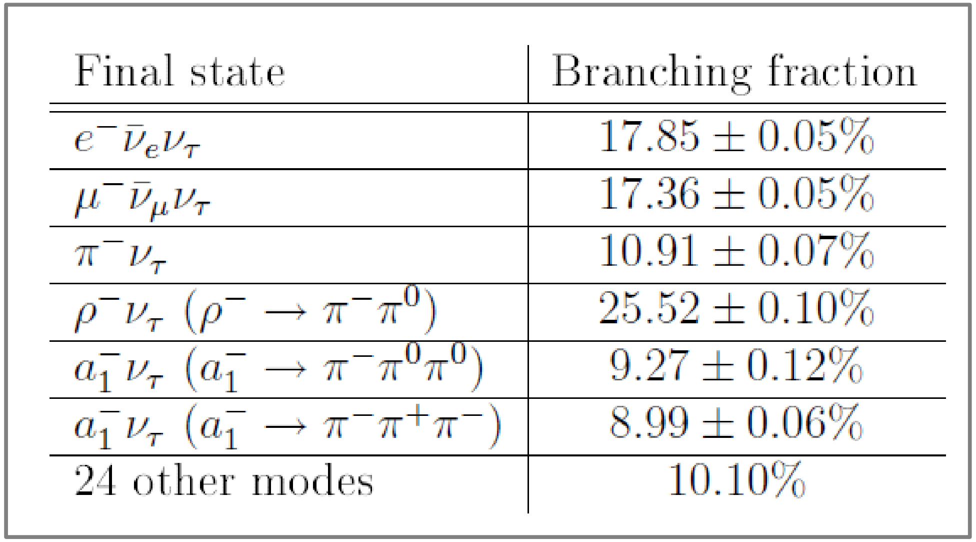
[%]	π^{sim}	ρ^{sim}	a_1^{sim}	other
π^{rec}	95.5	2.7	0.6	49.1
ρ^{rec}	4.2	90.2	12.5	21.8
a_1^{rec}	0.0	5.9	85.0	19.7
rejected	0.3	1.2	1.9	9.3

Study done for ILD baseline design
M. Reinhard's thesis

Tau decay modes

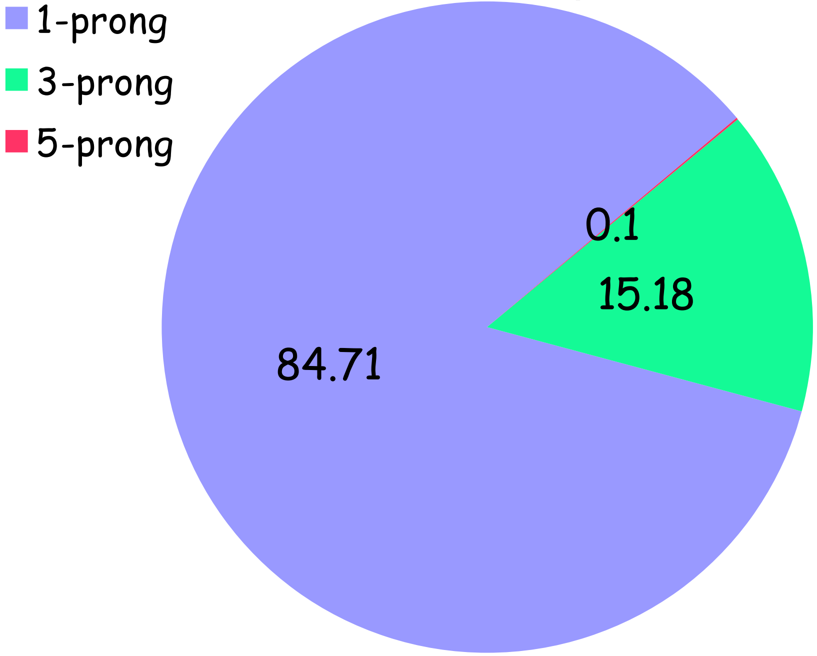
Topologically: 3 decay modes (1,3,5-prong)

1-prong: single charged pion and any number of π^0
3-prong: $\pi^+\pi^-\pi^+$



Final state	Branching fraction
$e^-\bar{\nu}_e\nu_\tau$	$17.85 \pm 0.05\%$
$\mu^-\bar{\nu}_\mu\nu_\tau$	$17.36 \pm 0.05\%$
$\pi^-\nu_\tau$	$10.91 \pm 0.07\%$
$\rho^-\nu_\tau$ $(\rho^- \to \pi^-\pi^0)$	$25.52 \pm 0.10\%$
$a_1^-\nu_\tau$ $(a_1^- \to \pi^-\pi^0\pi^0)$	$9.27 \pm 0.12\%$
$a_1^-\nu_\tau$ $(a_1^- \to \pi^-\pi^+\pi^-)$	$8.99 \pm 0.06\%$
24 other modes	10.10%

7 tracks: very infrequent



Branching fraction of main decays

Sample(s)

DBD generators

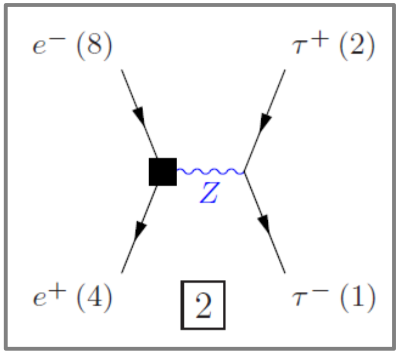
$e^+ e^- \rightarrow Z \rightarrow \tau^- \tau^+$

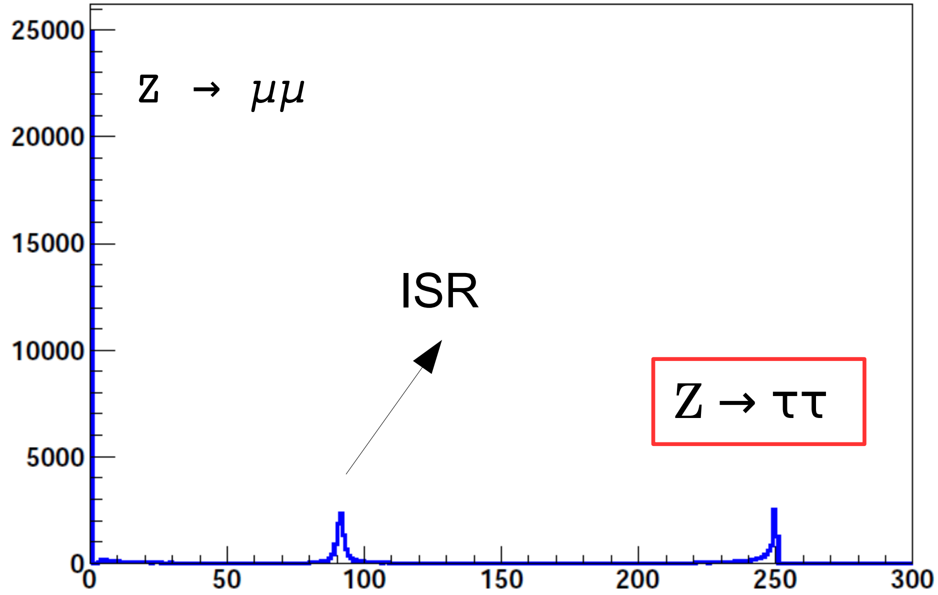
at 250 GeV C.M. energy

(mixed with

$e^+ e^- \rightarrow Z \rightarrow \mu^- \mu^+$

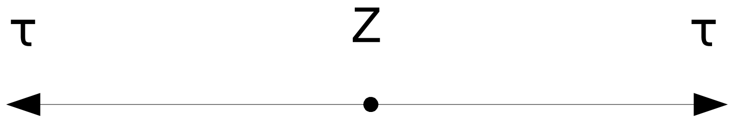
→ preselection of τ events using generator informations)





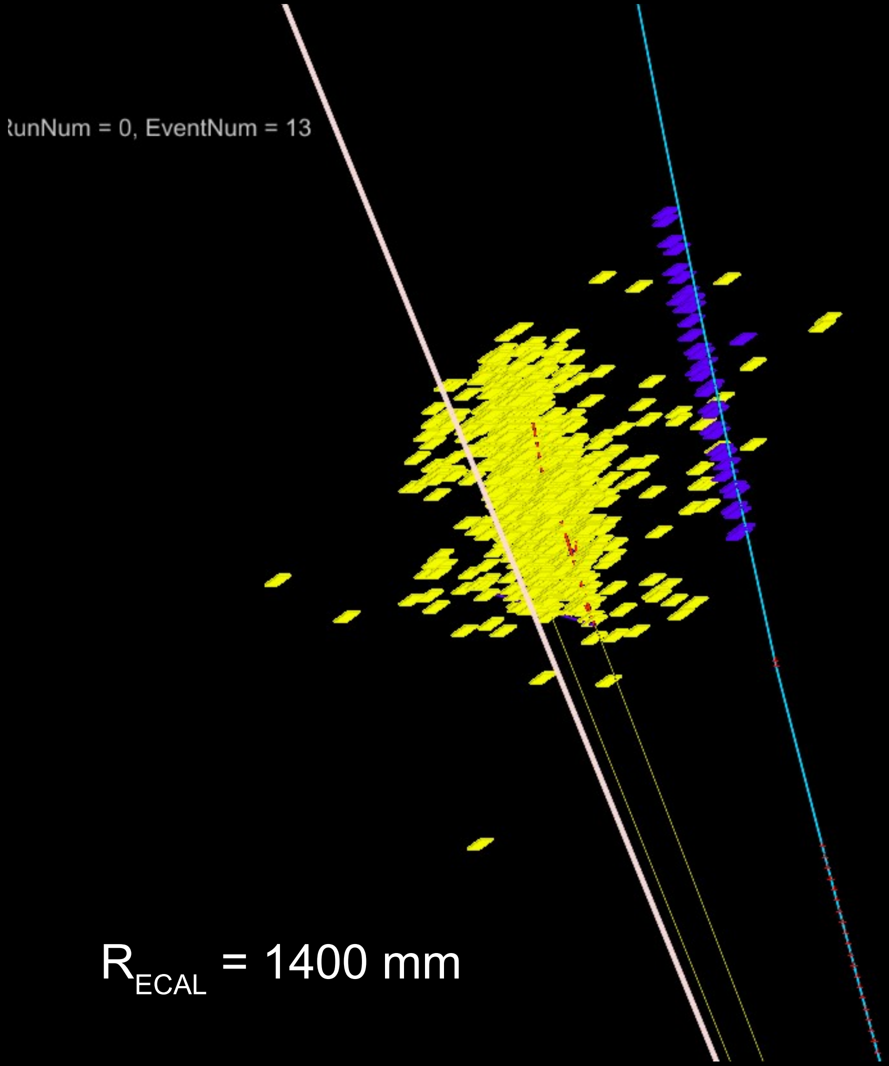
Tau-tau invariant mass

- Two independent Tau-decay are used (double statistics)

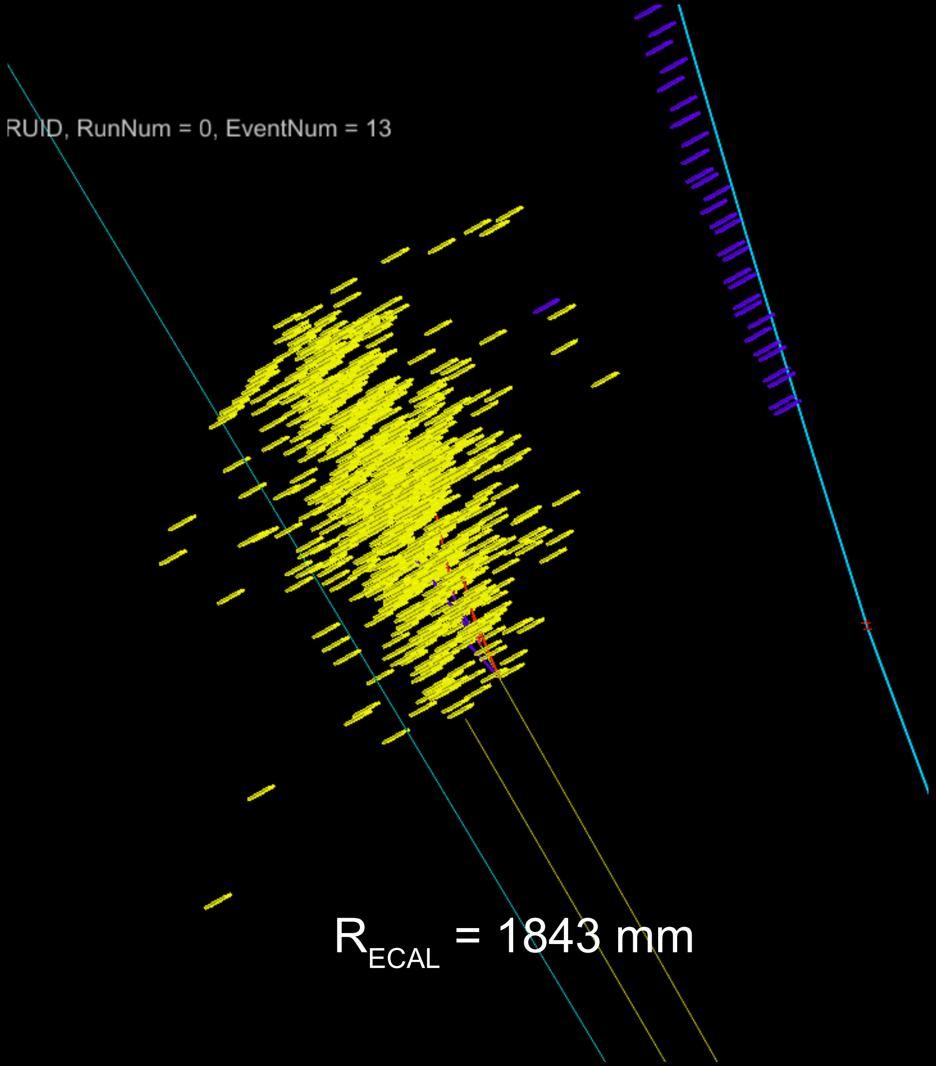


The two tau's are back-to-back in the Z-rest frame

Example (1)

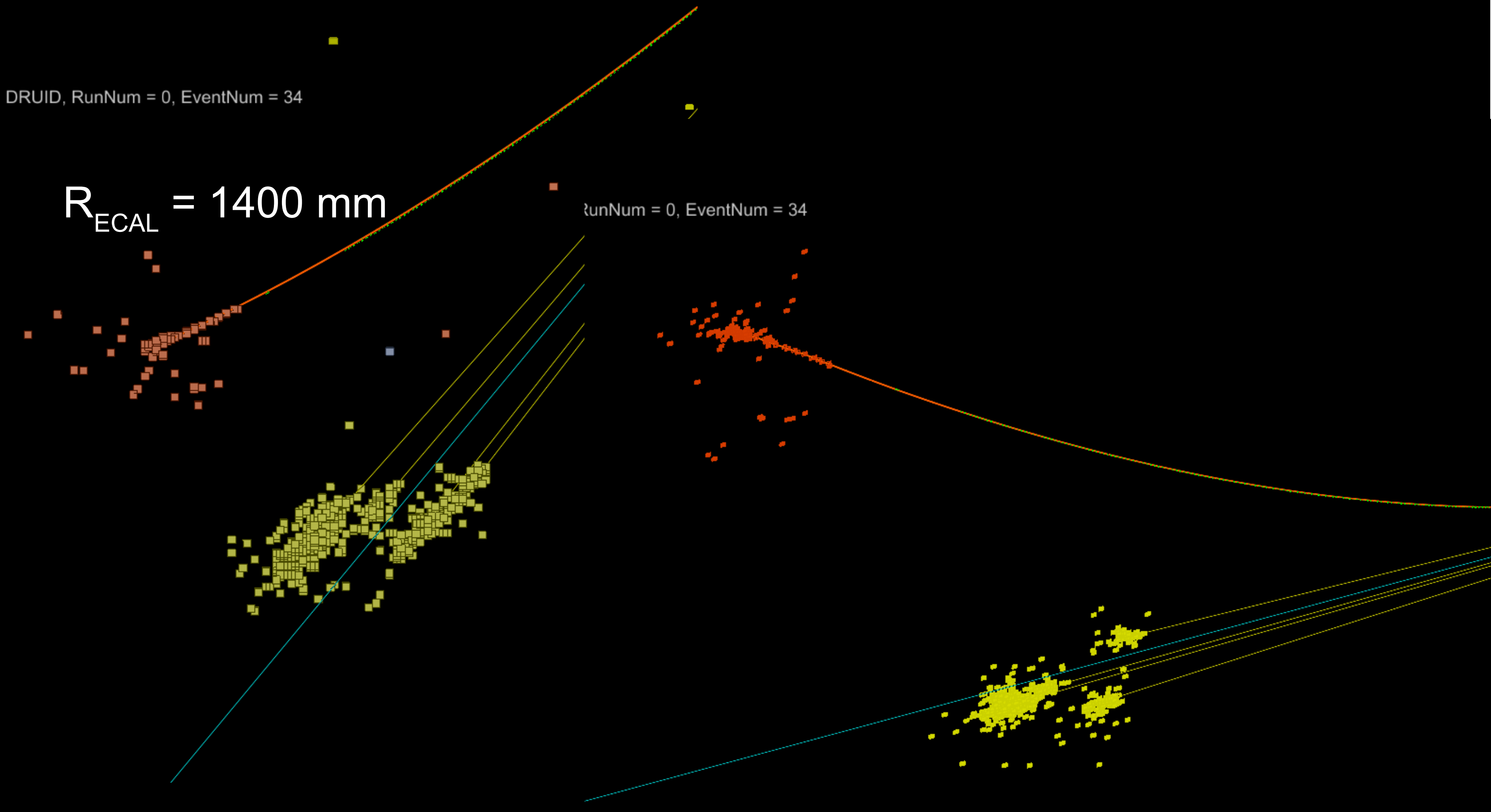


R_{ECAL} = 1400 mm



R_{ECAL} = 1843 mm

Example (2)



DRUID, RunNum = 0, EventNum = 34

R_{ECAL} = 1400 mm

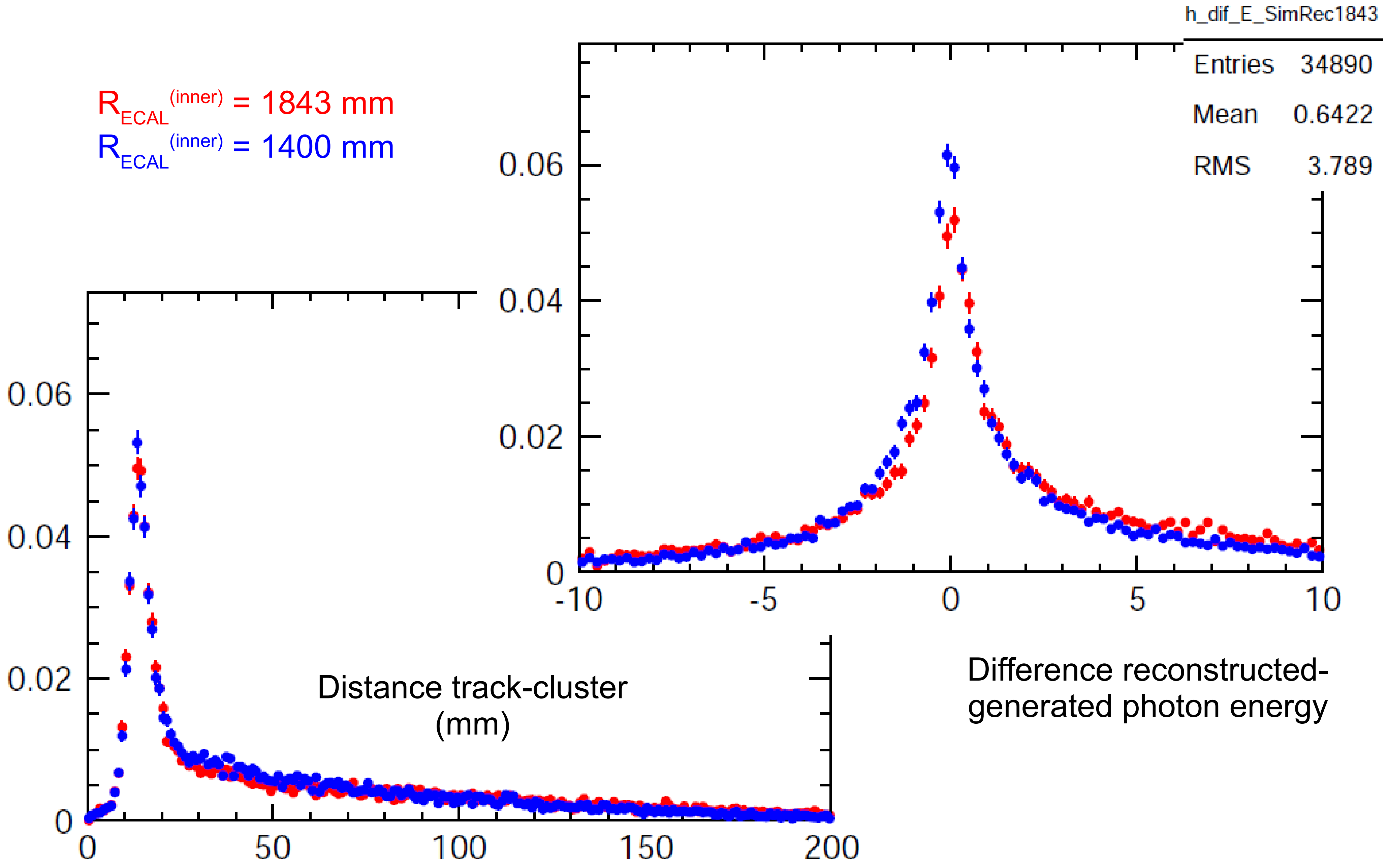
unNum = 0, EventNum = 34

R_{ECAL} = 1843 mm

Reconstruction quality

$R_{ECAL}^{(inner)} = 1843$ mm

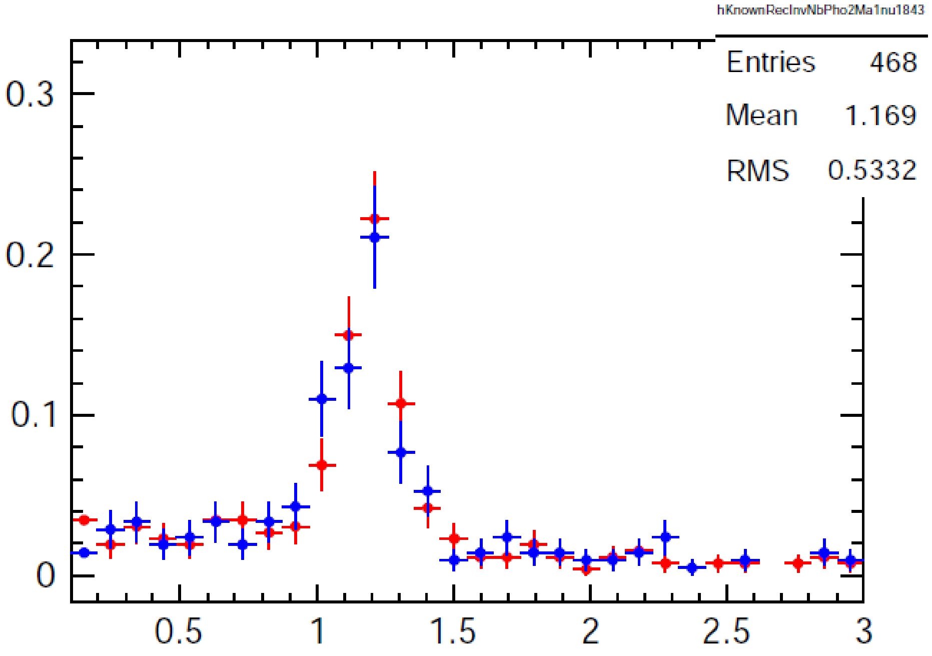
$R_{ECAL}^{(inner)} = 1400$ mm

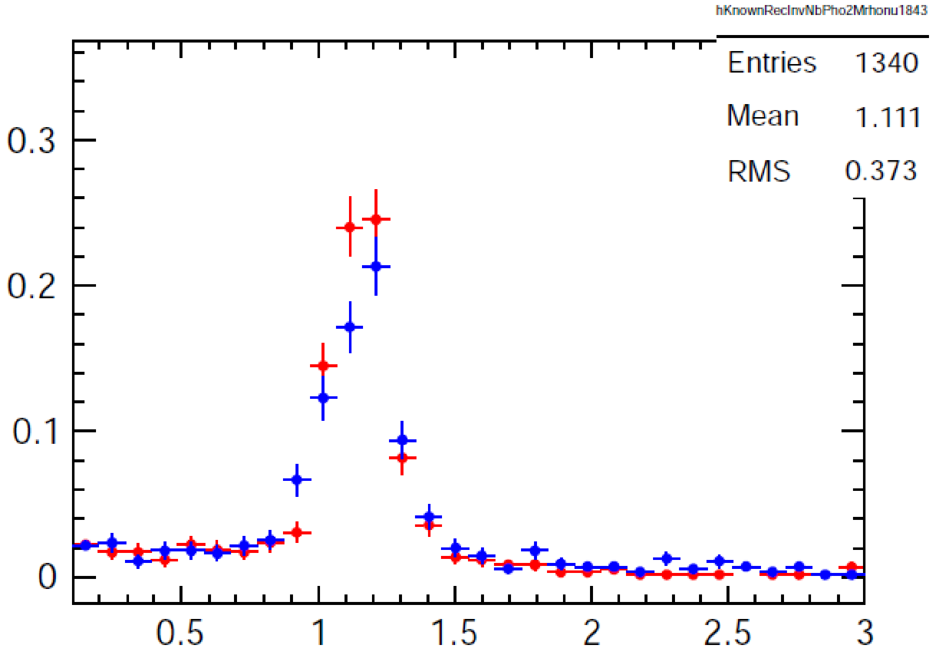


Distance track-cluster (mm)

Difference reconstructed-generated photon energy

Comparison R=1843 vs R=1400 mm: invariant mass

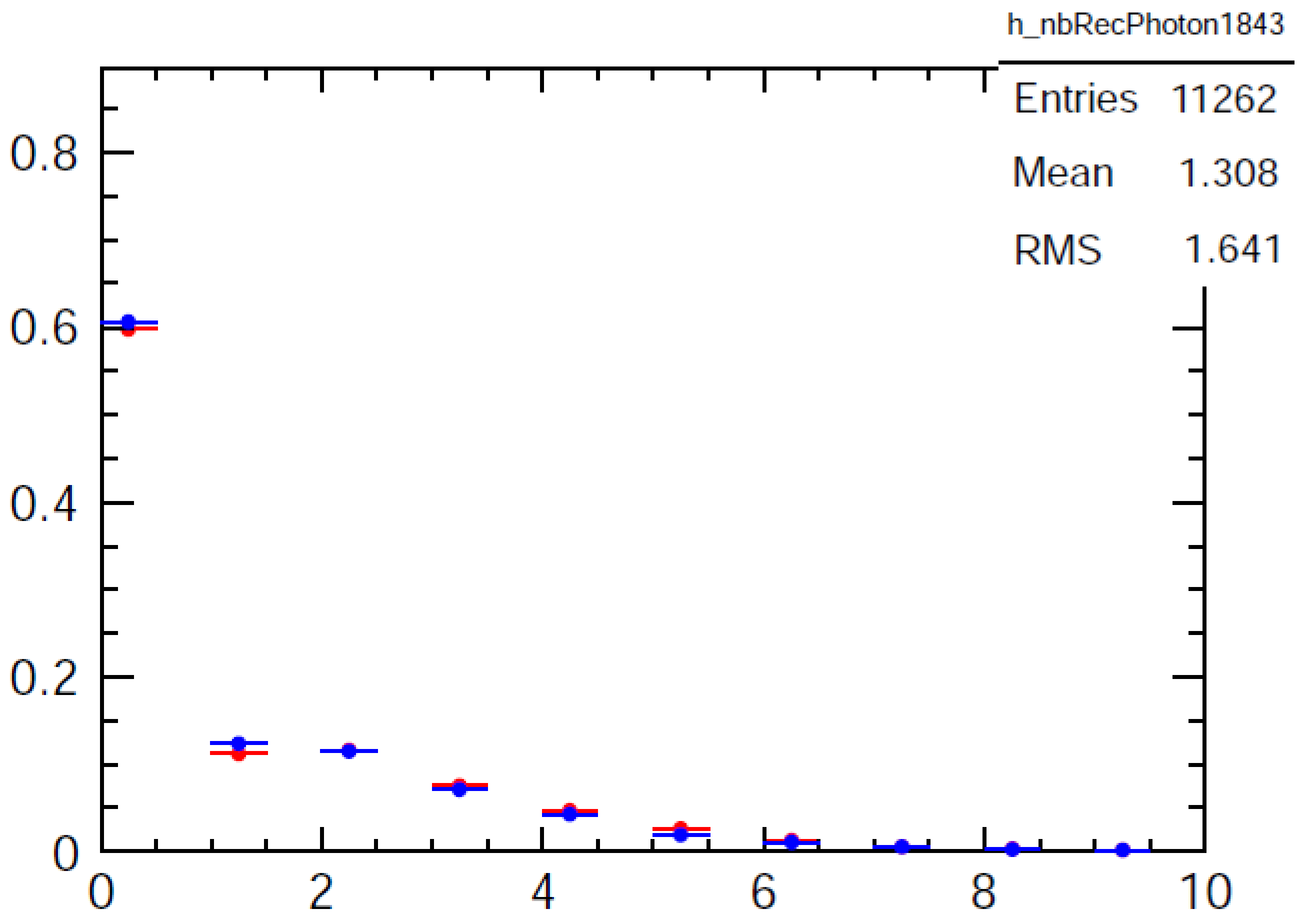




Tau invariant mass for decay τ → ρν.

(Limited statistics due to low fraction of tau decay in the sample.
To be updated.)

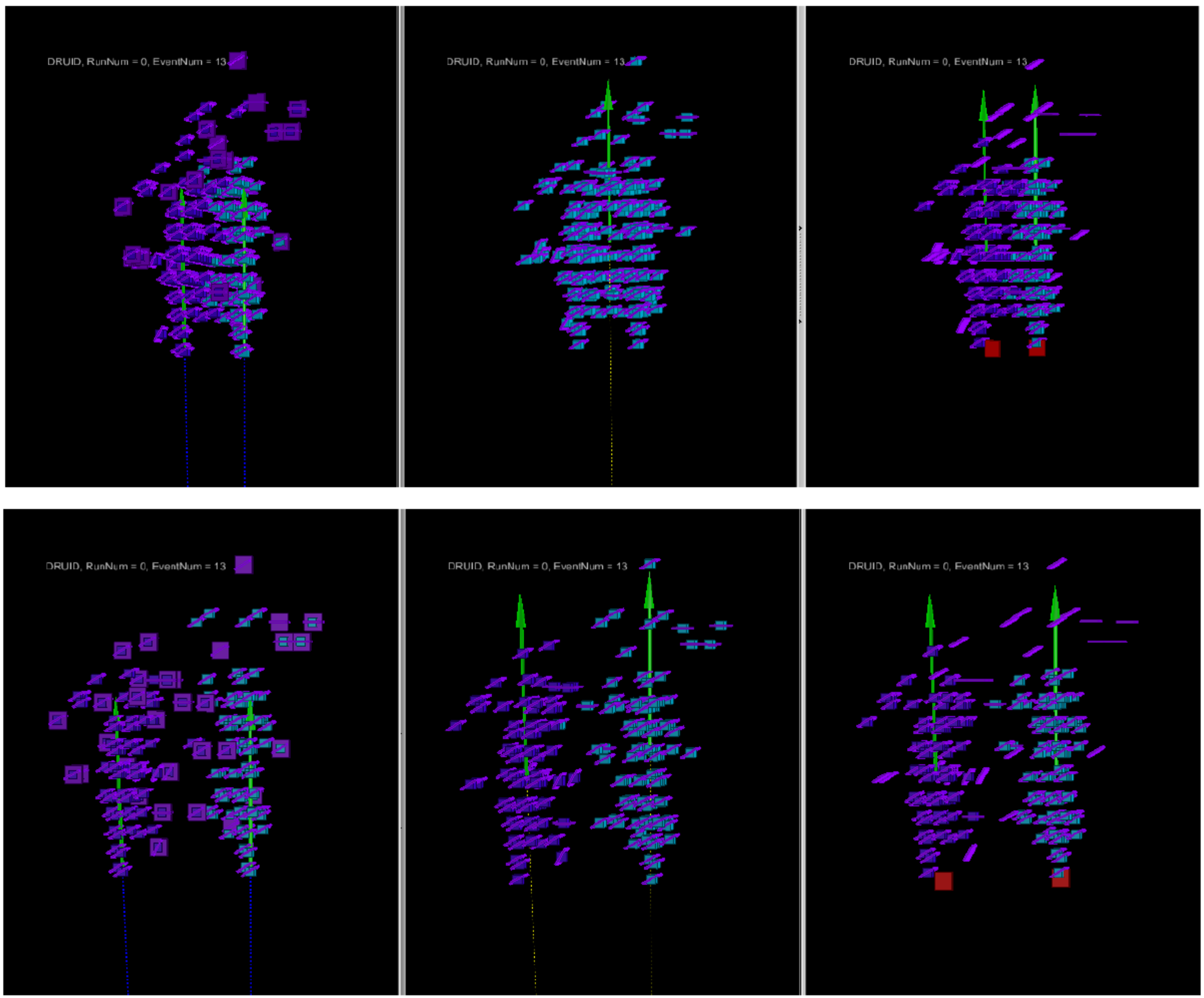
Comparison R=1843 vs R=1400 mm: Nb of reconstructed photons



Particle separation power

- Task: e^+-e^+, e^+-h^+ shower separation
  - TB FNAL'11 data, cannot be shown, absence of CALICE NOTE:(
  - comparison with MC (only ECAL in TB geometry)
- Event creation and reconstruction:
  - transition TB geometry → ILD geometry
  - **overlay**: particle + shifted paricle (by 0,1,...,11 cells , CellSize=1x1cm^2)
  - absence of tracks: $e^+ \rightarrow \gamma$ and $\pi^+ \rightarrow$ MC track was created in ILD geometry
- "Correct" separation (for each reconstructed particle):
  - Reconstructed Energy = Initial Energy ±20%
  - Reconstructed Barycentre = Initial Barycentre $\pm 5mm$

Event display: $\gamma+\gamma$ at 4+4 GeV



Shift = 2cm

Shift = 6cm

Reconstruction: ARBOR (left), PANDORA (middle), GARLIC (right)

$\gamma - \gamma$ separation

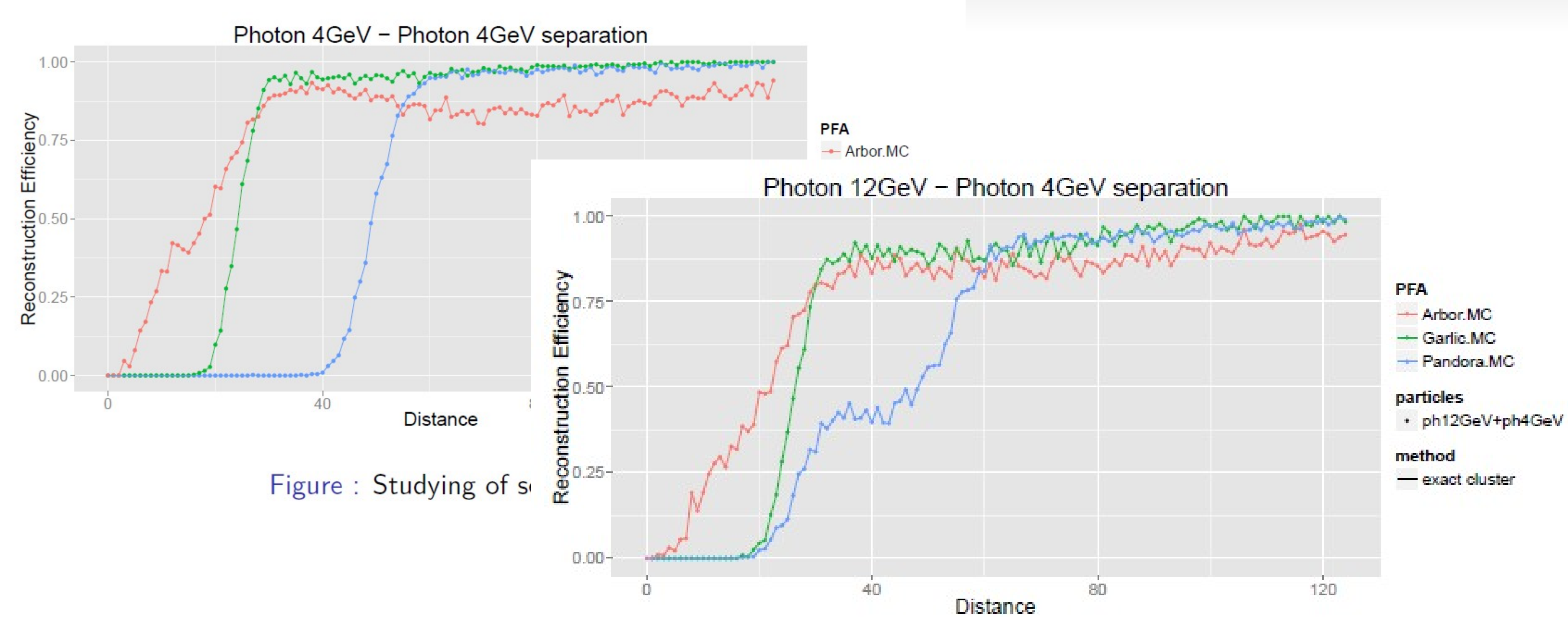
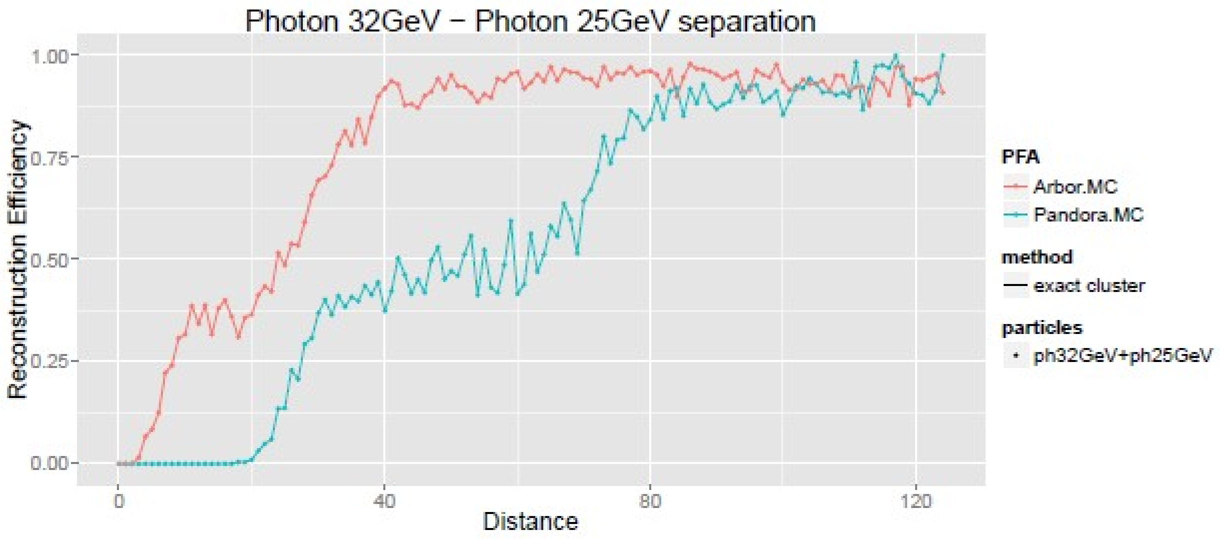


Figure : Studying of s



γ – hadron separation

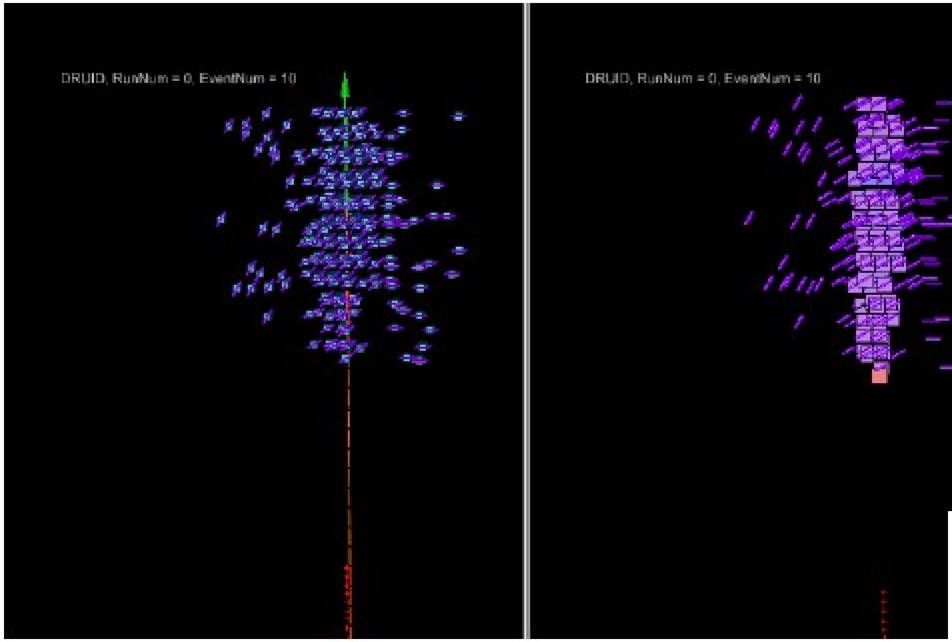


Figure : Reconstruction: PANDORA (left), GARLIC (righ

Shift=0 cm

Shift=10 cm

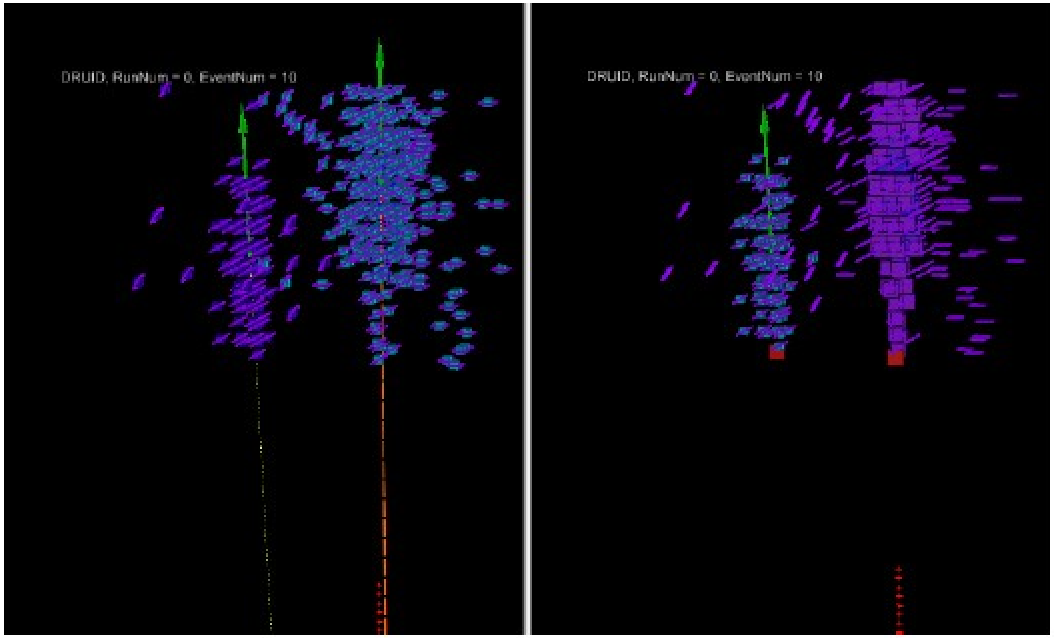
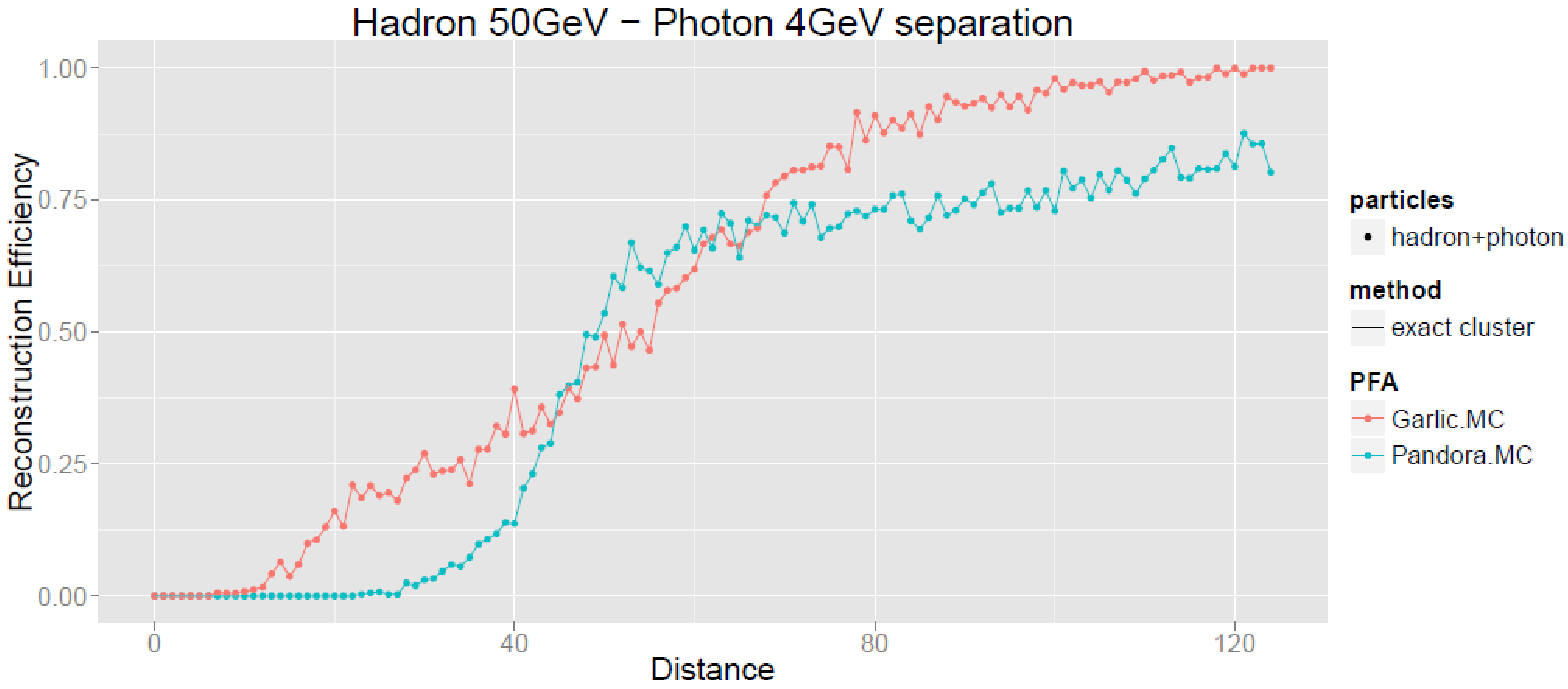


Figure : Reconstruction: PANDORA (left), GARLIC (right)

γ – hadron separation

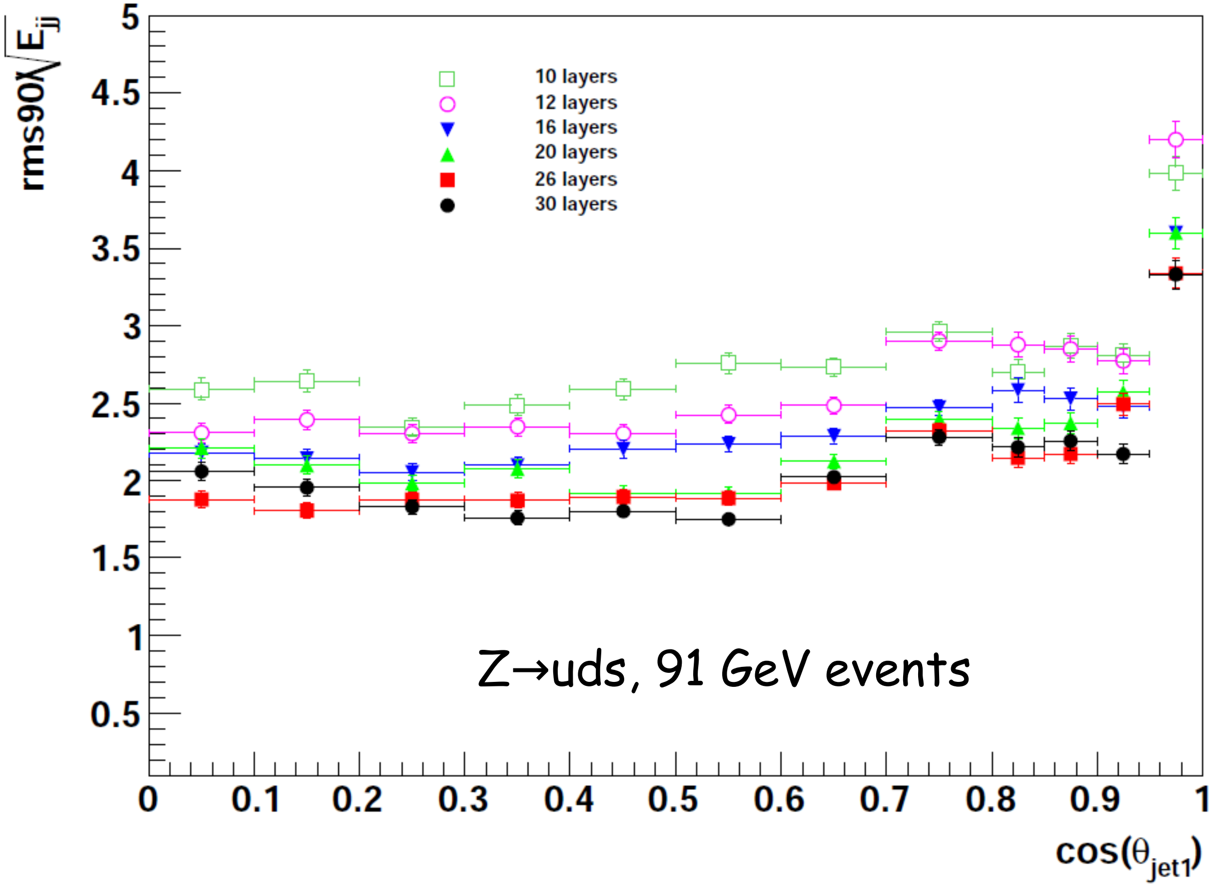


Summary

- Performance studies
  - ECAL reduced number of layers with $R_{ECAL}^{(inner)}$ = 1450mm
  - Ongoing: tau jet reconstruction (1-prong)
  - Particle separation:
- Reduction of SiW ECAL layers:
  - Difference in term of performance for 25 and 29 W layers ECAL (R=1450mm) is small
- First look at tau decay with ECAL inner radius 1843 mm and 1400:
  - Visually, the separation of tau jet photons is less clear for R=1400m
  - However, Garlic is still able to give reasonable number of photons
  - Analysis is to be updated with (much) higher statistics
    and to be extended to sqrt(s)=500 GeV
- Particle separation power:
  - GARLIC and ARBOR seems to be better than PandoraPFANew
  - A couple of issues to be understood → CALICE NOTE (on test beam data)

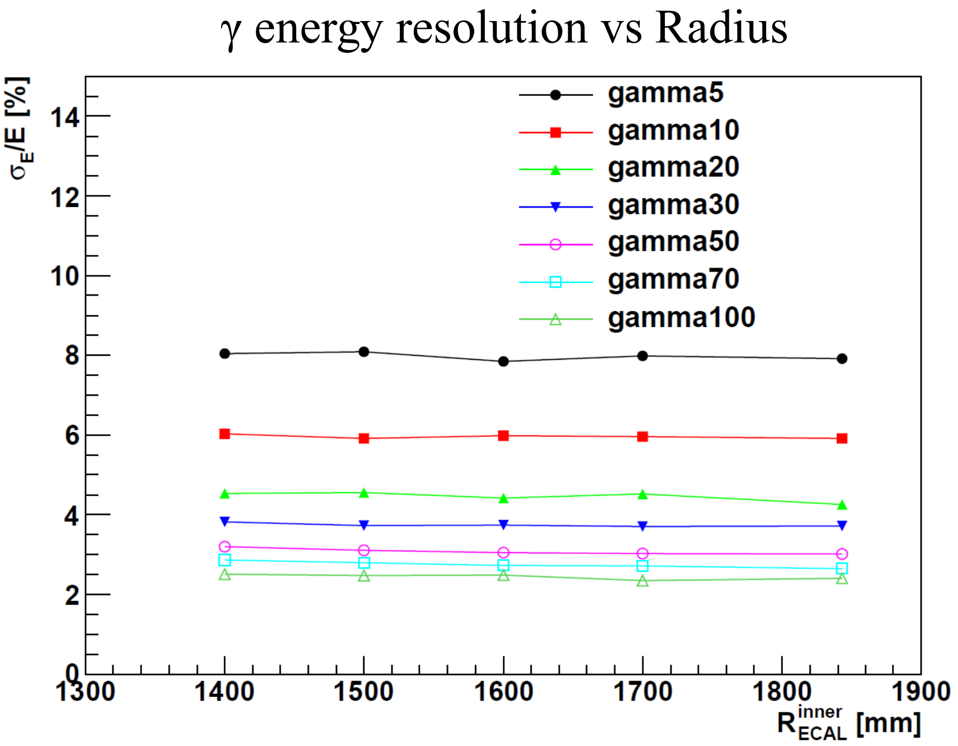
Backup slides

Jet energy resolution vs cos(θ_jet)



- Jet energy resolution presented in function of cos(θ) of first jet
- No significant problem found among full region of cos(θ)
- Example for Z→uds 91 GeV sample

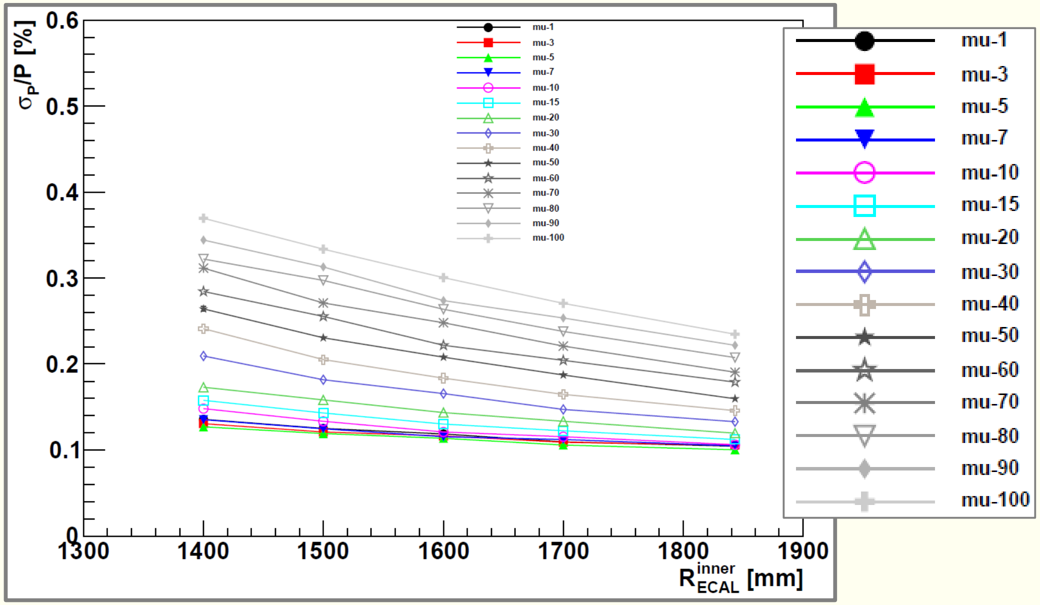
Energy resolution for gamma



Only photons in barrel are taken into account

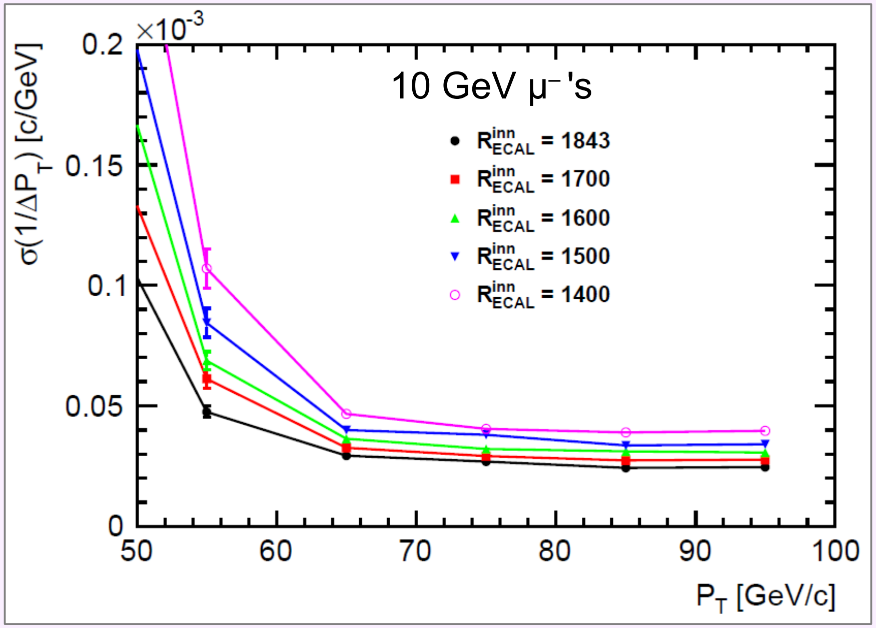
→ no changes in resolution for single photon events

Single particle resolution: muon's

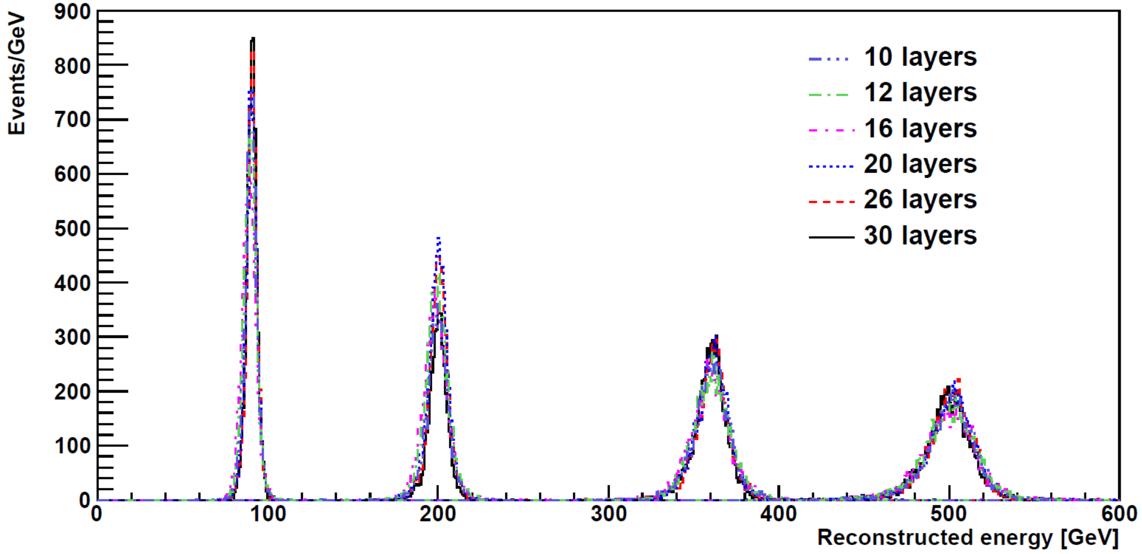


Momentum resolution of muons' at different energies for different radii.
Degradation by, e.g., 40% for muons' at 50 GeV.

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.



Z → uds events: linearity

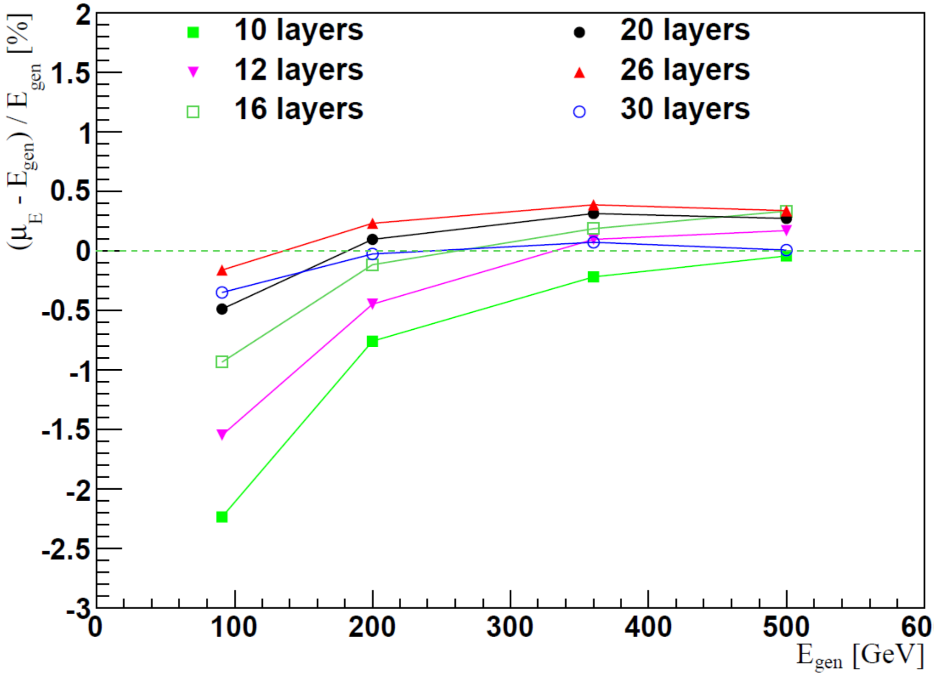


- Distributions of reconstructed total jet energy for all ECAL models and for events at c.m. energies 91, 200, 360, 500 GeV are shown.
- Reasonable mean values obtained.

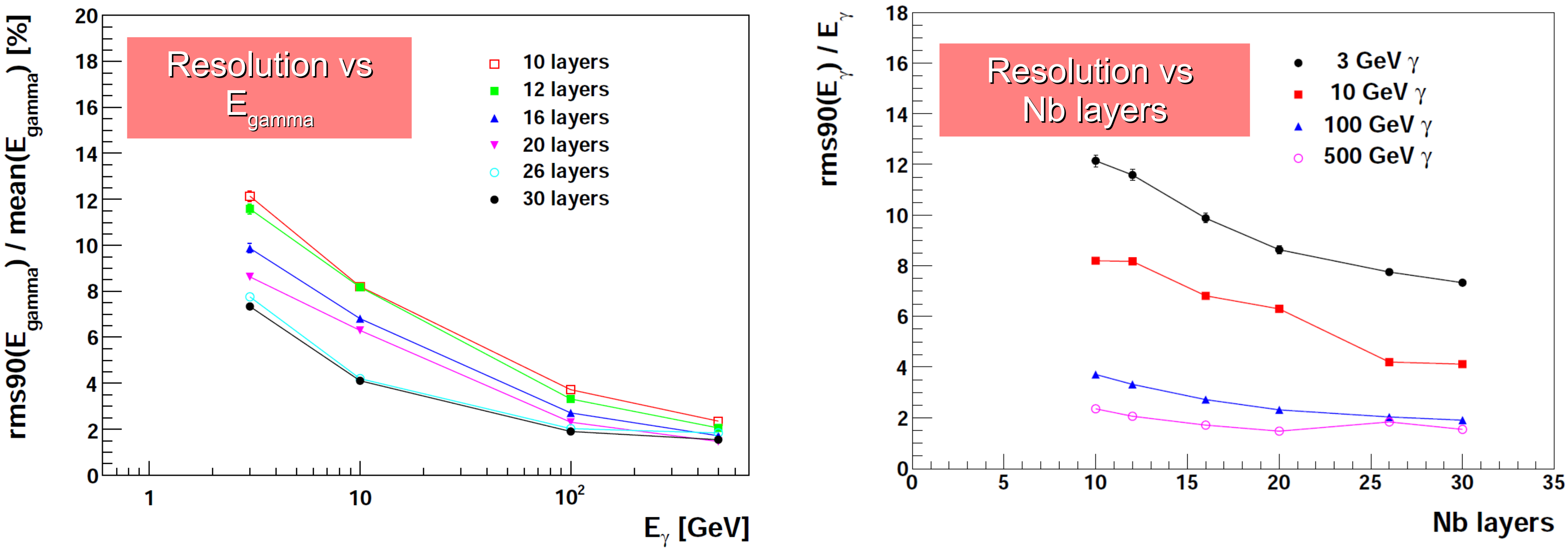
- Residual value $(\mu_E - E_{gen})/E_{gen}$ shown in% as a function of E_{gen}

  where μ_E is the central value of the distribution and E_{gen} the generated jet energy

- Linearity within 5 ‰ for 30-26-20 layers and significantly degraded for other ECAL models

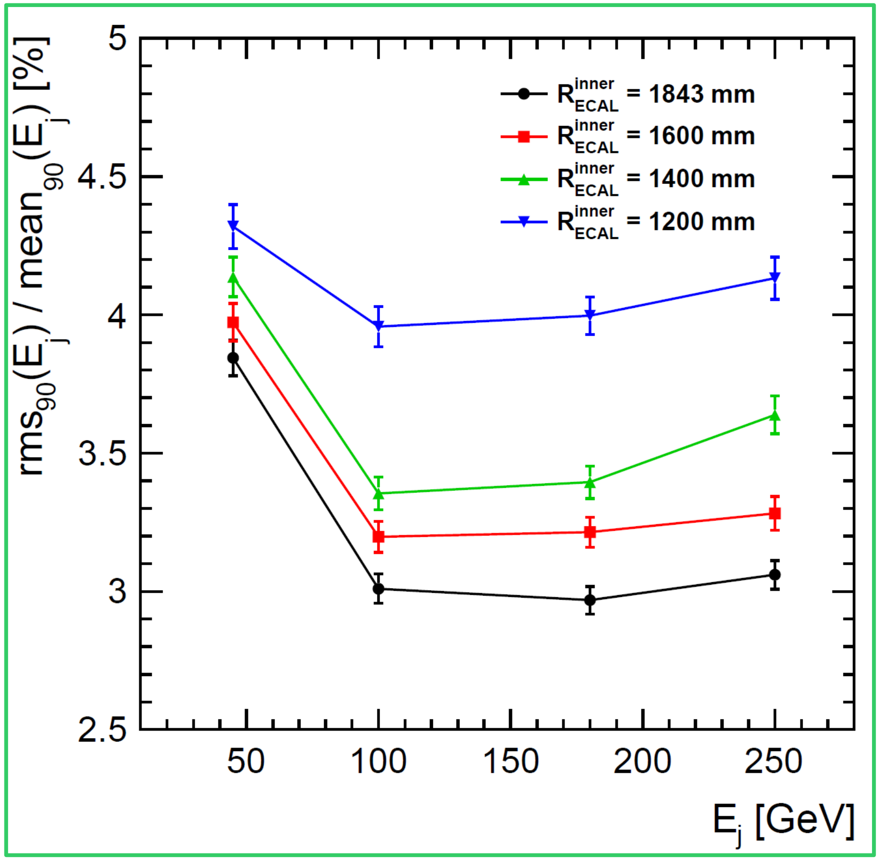


Photon energy resolution



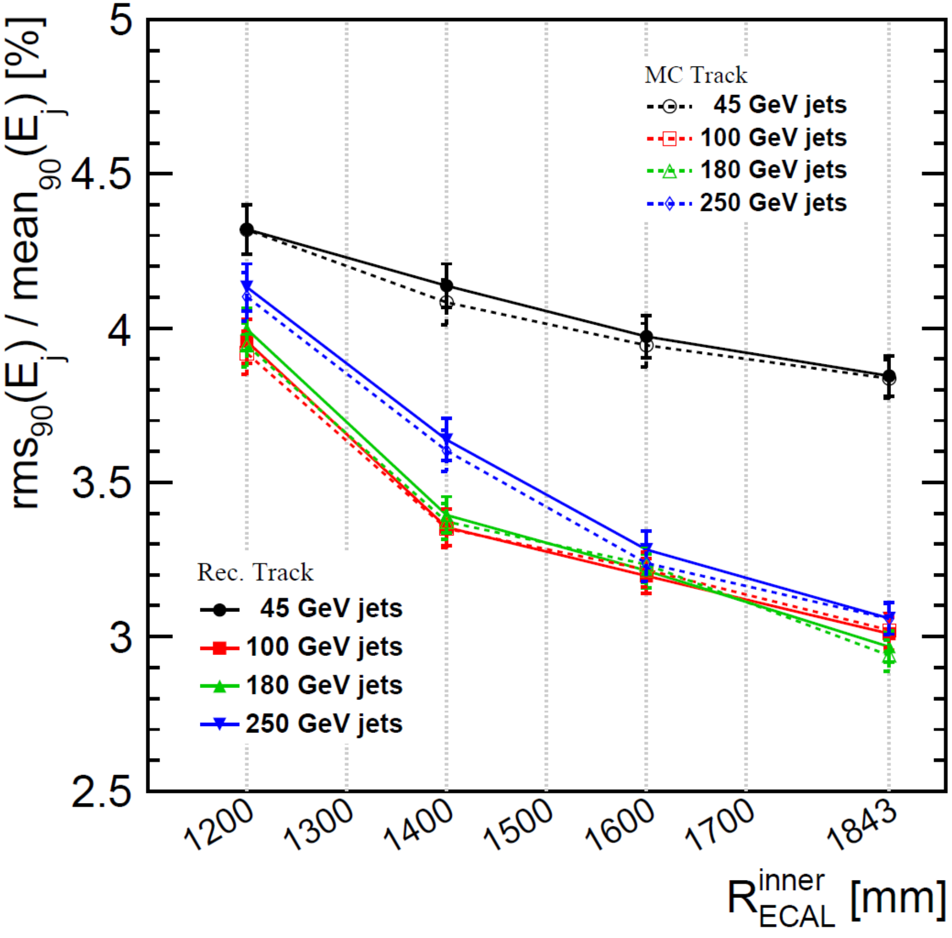
- Photon energy resolution shown in function of generated photon energy for different ECAL models (left) and in function of number of layers for different energy (right)
- Slight degradation observed going from 30 to 20 layers and quite significant with smaller number of layers (16 downto 10)

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

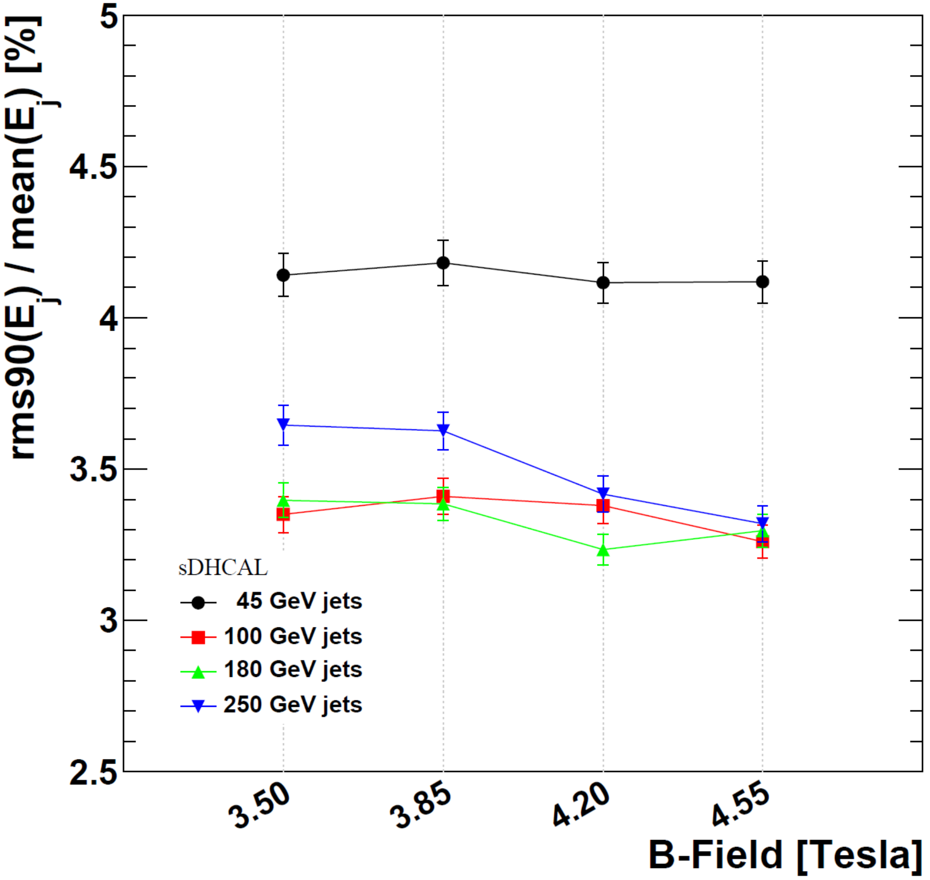
Effect of tracking on JER



- 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

Change of B-field

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



- Improvement at high energies – confusion reduced

R_{ECAL} = 1400 mm, 29 Si layers, 5×5 mm^2
sDHCAL 10×10 mm^2

JER for different ILD setups

30 Si layers

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

R_{ECAL}^{inner} =
1450 mm

	Jet energy (GeV)				
# Si layers	91	140	200	360	500
20	4.47	3.85	3.56	3.50	3.55
26	4.18	3.65	3.46	3.45	3.45
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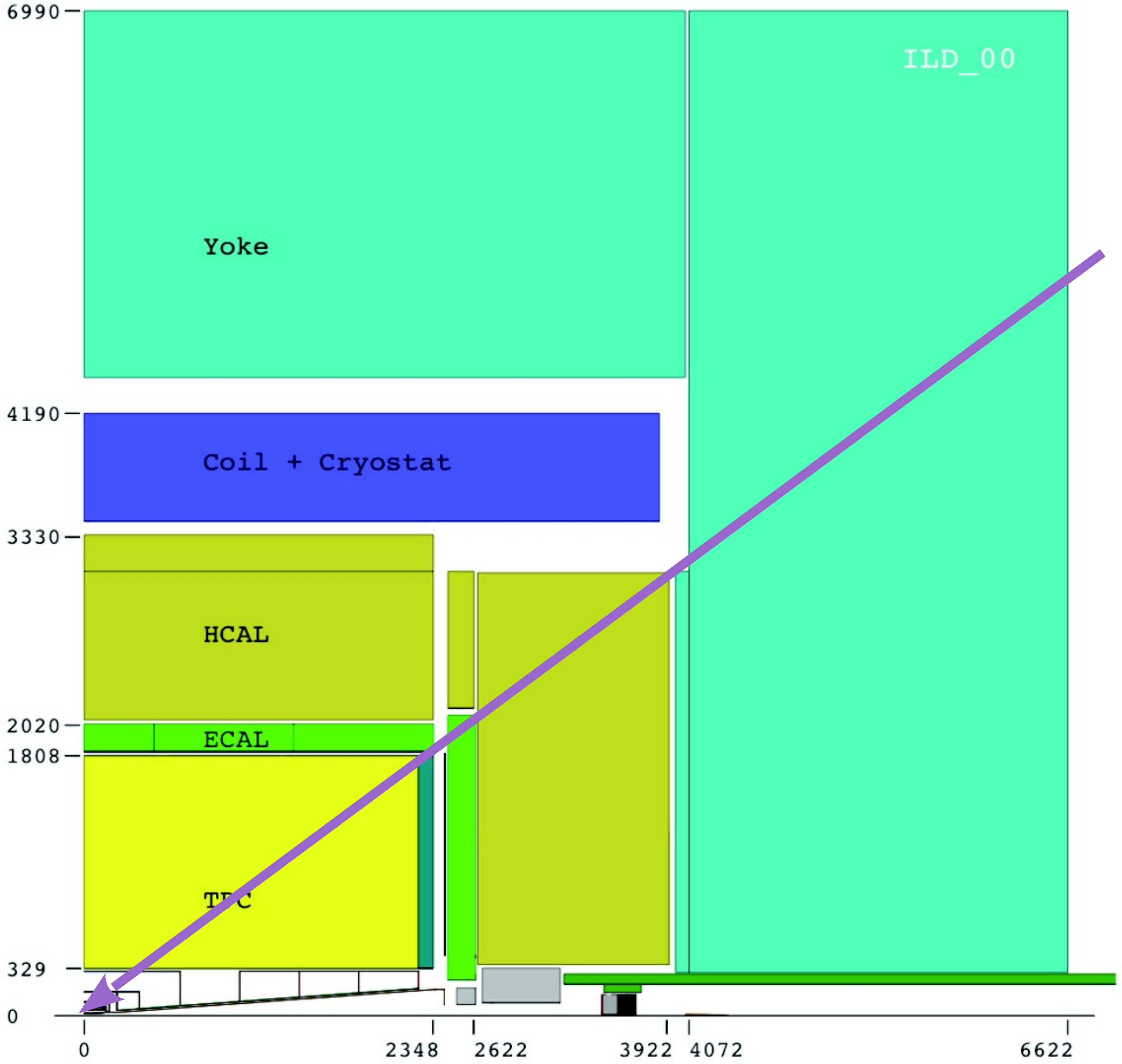
ILD layout


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