ECAL-NPOD
Performance study

Melissa AS, Shan H, Adrián IQ, Jesús MH

shan.huang@ific.uv.es

28 October 2024

This research is supported by:

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

AGENCIA ESTATAL DE INVESTIGACIÓN

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

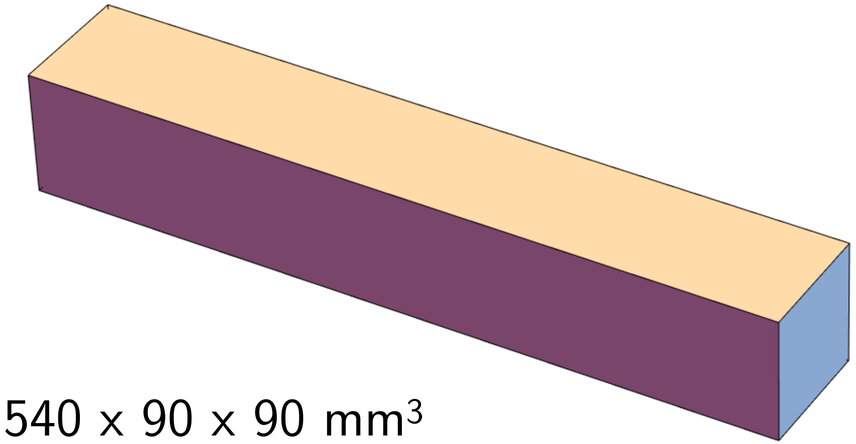
GENERALITAT VALENCIANA Conselleria d'Educació, Universitats i Ocupació

GVANEXT Fons Next Generation a la Comunitat Valenciana

Gen-T

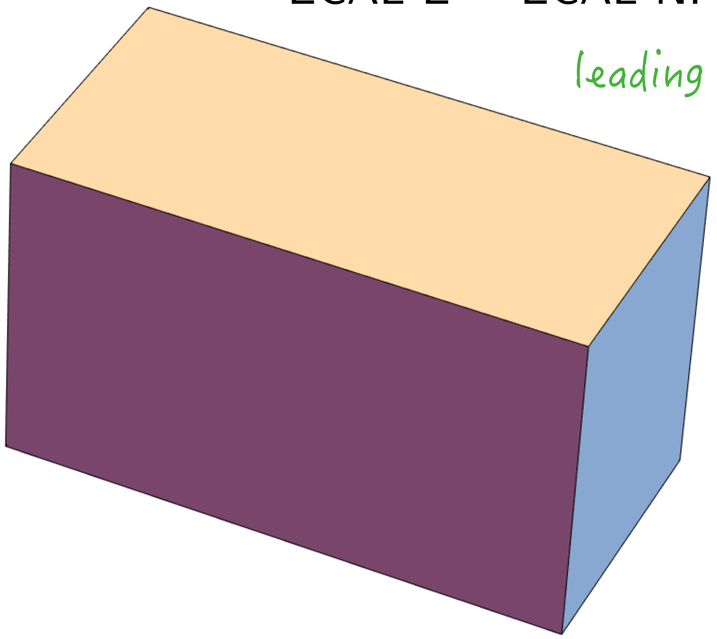
- ECAL-NPOD
- Analysis workflow (using Marlin)
  - Simulation
  - Reconstruction
  - Evaluation
- Results
  - Baseline performance
  - Vertex finding
  - Particle identification (PID by MAS)

ECAL-P/E



ECAL-E = ECAL-NPOD

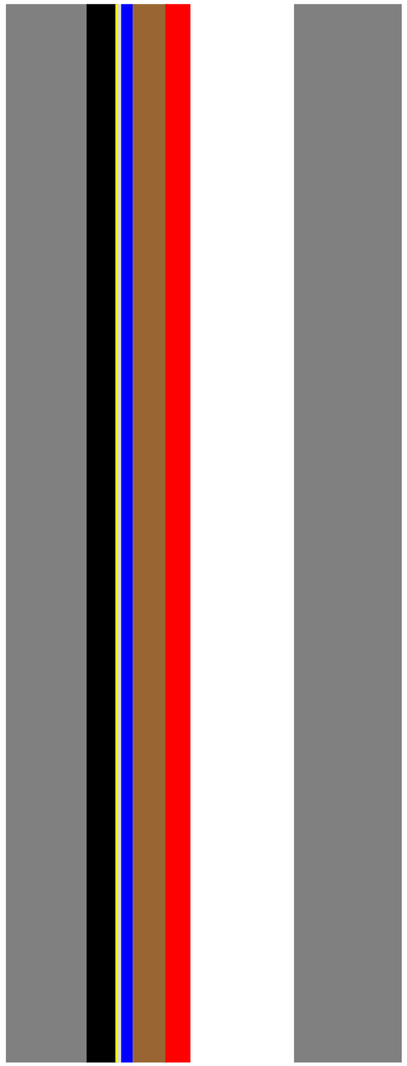
leading candidate!



- ECAL-P: 540 x 90 x 90 mm^3
  - X = 96 x 5.5 mm
  - Y = 16 x 5.5 mm
  - Z = 20 x 4.5 mm
- ECAL-E: 360 x 180 x 210 mm^3
  - X = 64 x 5.5 mm
  - Y = 32 x 5.5 mm
  - Z = (15−1) x 15 mm (10 mm possible)

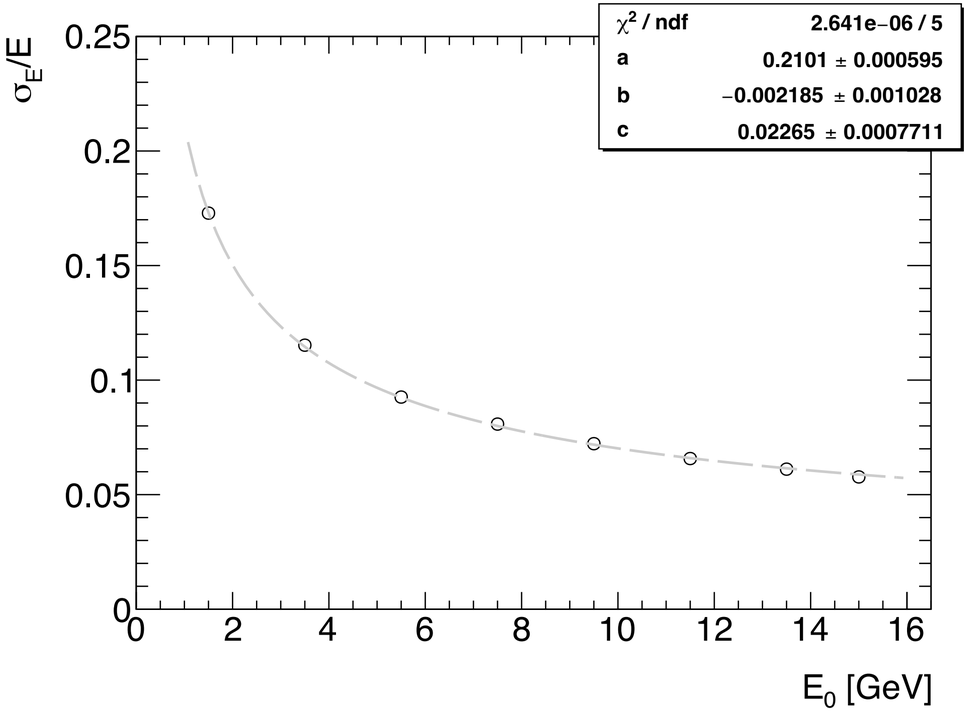
- W = 4.2 mm = 1.2 X_0
- Si = 0.500 mm

ECAL-E layer (in sim.)



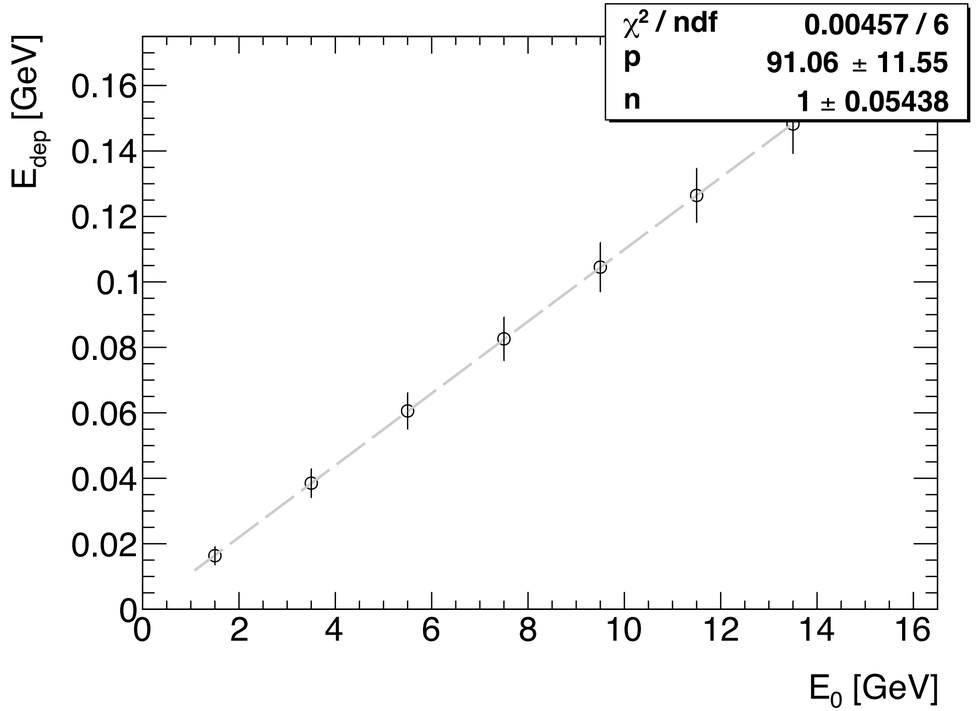
Material	d [mm]
W	4.2
C fibre	1.5
Kapton	0.1
Glue	0.1
Air	0.1
Si	0.5
Air	0.1
PCB	1.7
ASICs	1.2
Air	5.5
Total	15

ECAL-E baseline



Intrinsic energy resolution

$$\frac{\sigma_E}{E_0} = \frac{a}{\sqrt{E_0/\mathrm{GeV}}} \oplus \frac{b}{E_0/\mathrm{GeV}} \oplus c$$



Intrinsic linearity

$$E_0 = pE_{\mathrm{dep}}^{n}$$

ECAL-NPOD requirement

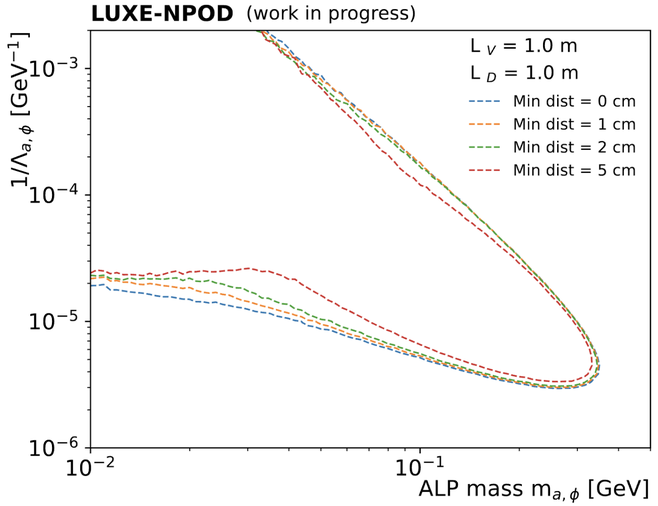
NPOD requirement:

- Energy resolution (facile digitization)
- Ability of shower separation (clustering)
- Track vector reconstruction
- Particle identification
- Background rejection

A slide from Raquel shows how shower separation affects on the NPOD sensitivity

KIT Karlsruher Institut für Technologie

NPOD signal – phase 1 (350TW)



- Dump length: 1m
- Decay volume length: 1m
- Detector radius: 1m

- Min dist: minimum separation between photons

Raquel Quishpe (raquel.quishpe@kit.edu) 2

- ECAL-NPOD
- Analysis workflow (using Marlin)
  - Simulation
  - Reconstruction
  - Evaluation
- Results
  - Baseline performance
  - Vertex finding
  - Particle identification (PID by MAS)

Simulation

- Geometry description of ECAL-E in dd4hep
- Standalone simulation done by ddsim
- Facile digitisation:
  - Hit deposit smearing 10%
  - Hit deposit cut at 1/2 MIP

Simulations for analysis:

- Mono-energetic particle sims for the baselines
- Two-particle sims for clustering
  - Parallel with various distances in between
  - From a fixed vertex with various angles
- Flat-spectrum sims for PID

Repository on https://github.com/airqui/ECALe-lcio

Reconstruction

- Baseline performance:
  - Analogue ECAL: hit has amplitude
  - Digital ECAL: there is a hit or there is not
- Clustering:
  - Nearest-neighbour clustering
  - Reclustering around cylindrical cores
- Figures-of-merit:
  - ECAL resolution and linearity
  - Efficiency of successful clustering
  - Reconstruction residues on the vertex

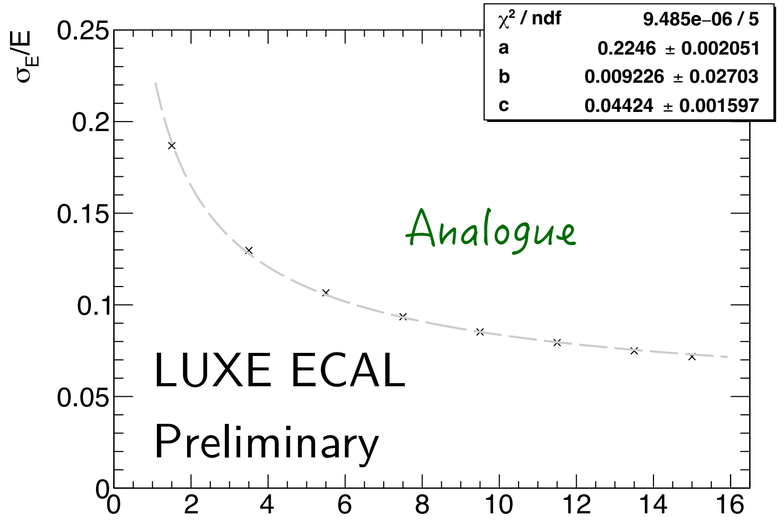
Tuneable parameters for evaluation:

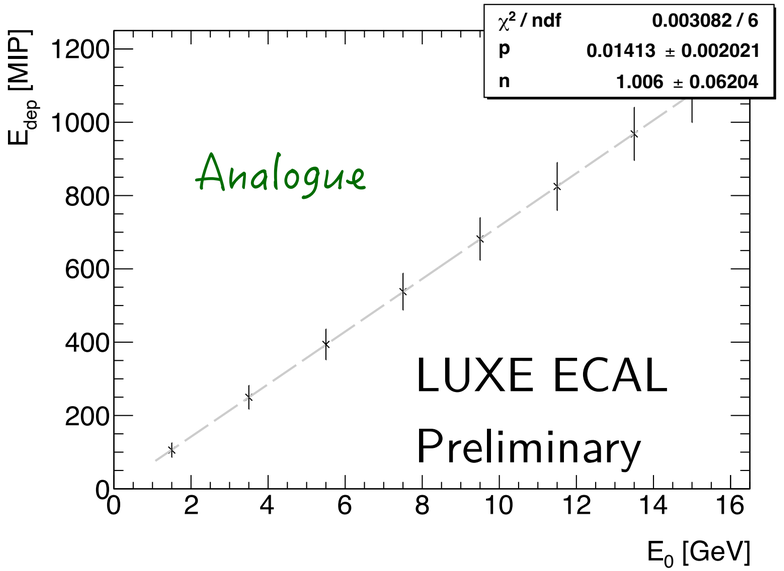
- Analogue vs digital
- NN distance
  - Cut on the distance of candidates
  - Hit deposit variable distance
- Reclustering parameters
  - Cylinder radius

Repository on https://github.com/airqui/ECALe-lcio

- ECAL-NPOD
- Analysis workflow (using Marlin)
  - Simulation
  - Reconstruction
  - Evaluation
- Results
  - Baseline performance
  - Vertex finding
  - Particle identification (PID by MAS)

Baseline: A/C & D/C





Energy resolution

$$\frac{\sigma_E}{E_0} = \frac{a}{\sqrt{E_0/\mathrm{GeV}}} \oplus \frac{b}{E_0/\mathrm{GeV}} \oplus c$$

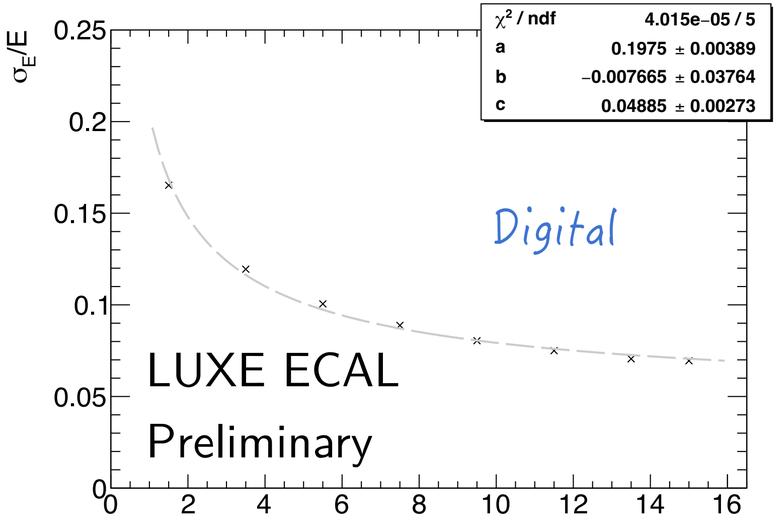
Linearity

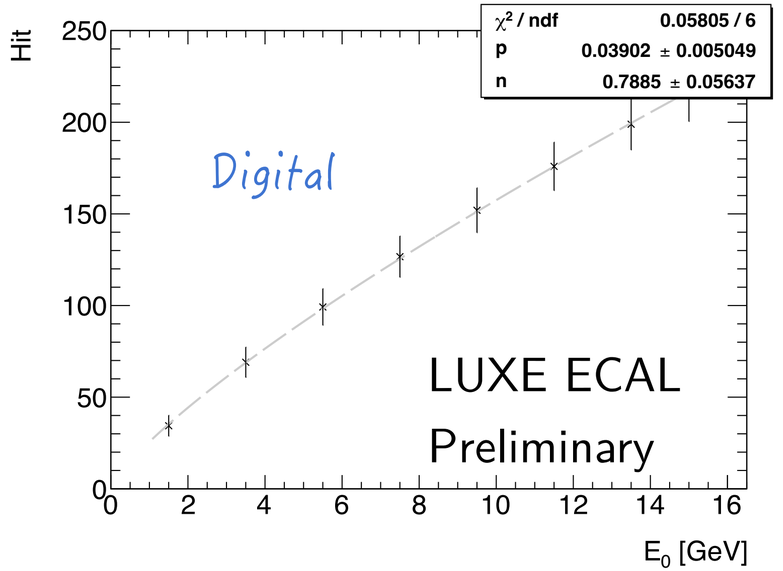
$$E_0 = pE_{\mathrm{dep}}^{n}$$

Results from single photon sims

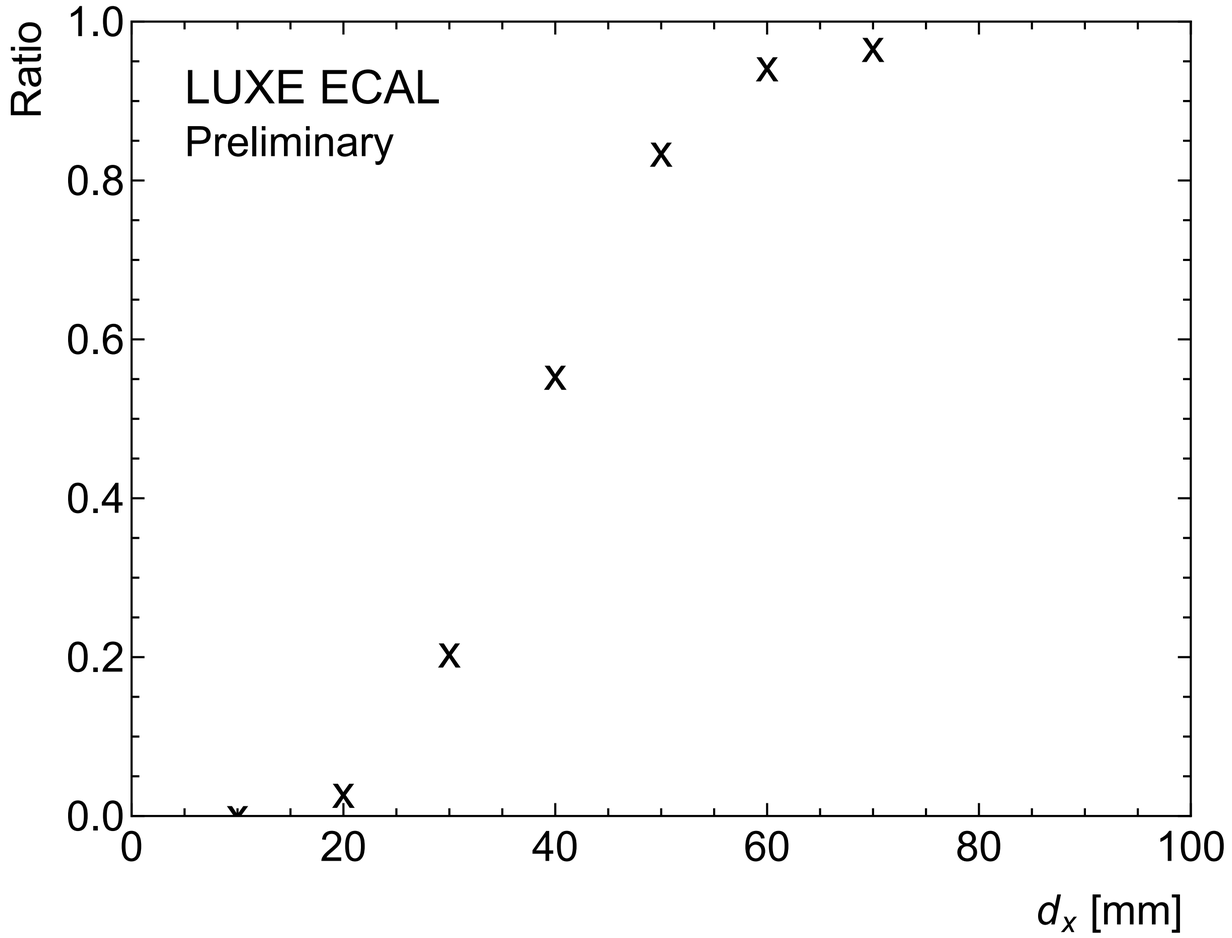
Error bar shows resolution

Analogue: E_{dep}; Digital: N_{hit}





Separation ability



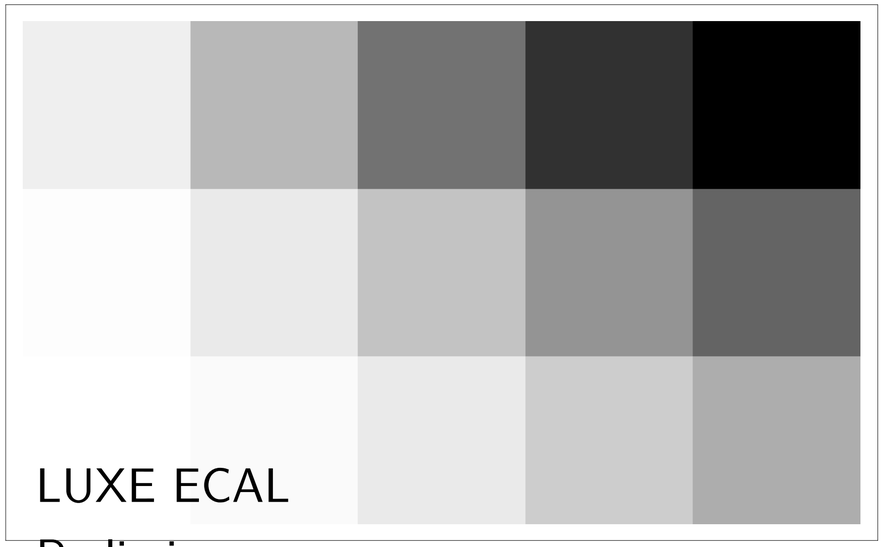
- Results from two-photon sims at 3.5 GeV
- Photons are parallel to each other and perpendicular to the surface of the ECAL
- Photons are separated with d $\pm$ 5$\sqrt{2}$ mm
- Ratio = $N_{\text{two-cluster-event}}$ / $N_{\text{total-event}}$

NNDistance

d = 20 mm

d = 50 mm

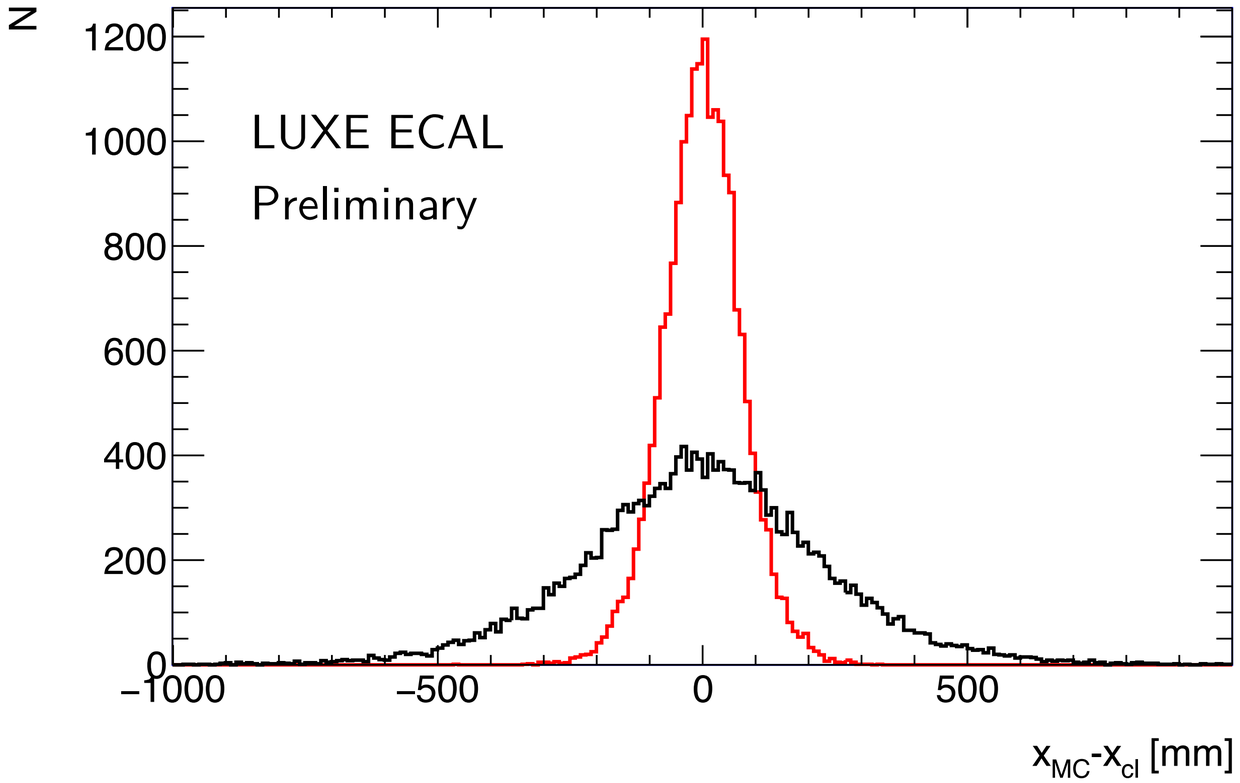
dCut = 16, 18, 20 mm



eCut = 1, 2, 3, 4, 5 MIPs

- Same dataset as the previous
- Greyscale shows the clustering efficiency
- dCut: to connect two hits within a given distance
- eCut: to connect a hit about a given E_{dep}

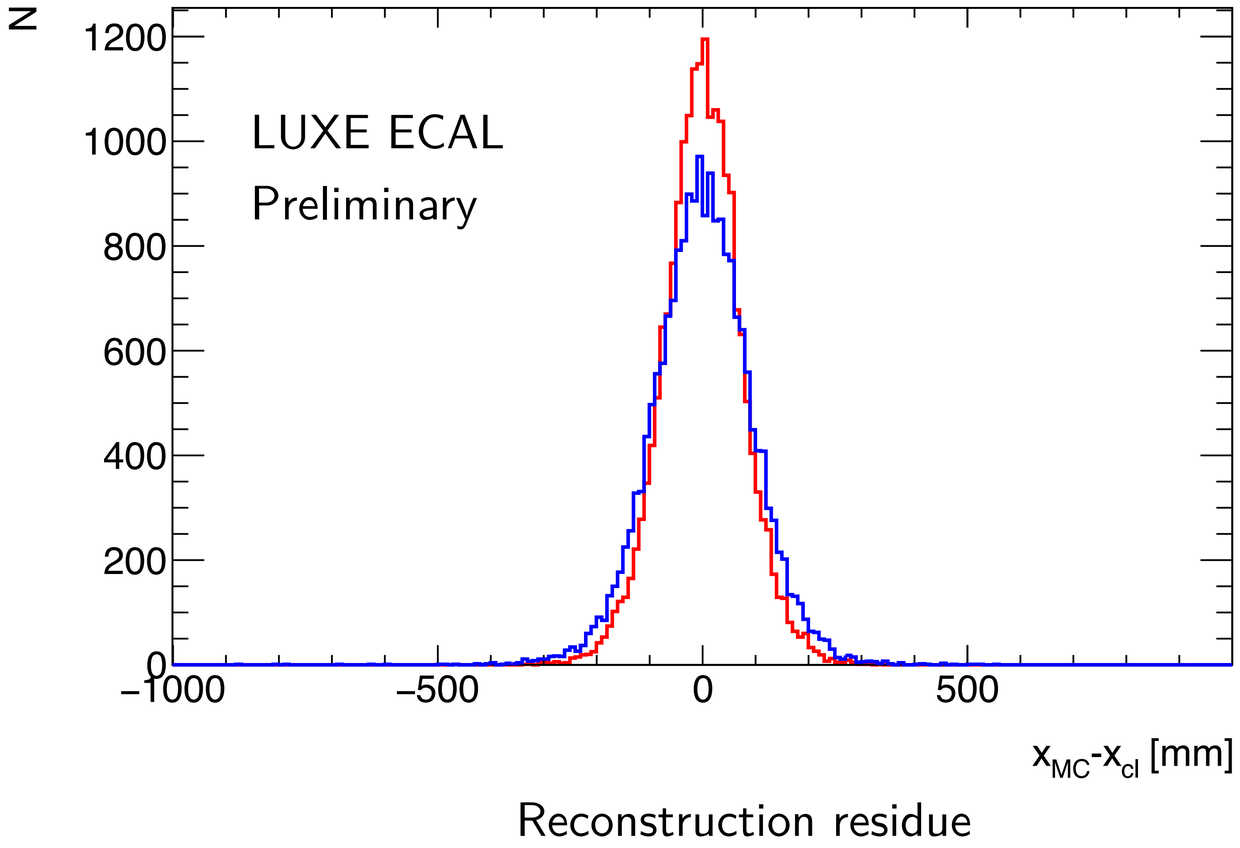
Cylinder width



Reconstruction residue

- Results from two-photon sims at 3.5 GeV
- Photons are from a same vertex at 2.5 m away from the front surface of the ECAL
- Black: naive NNClustering
- Red: re-clustering with only the hits within the Moliere radius (85%) of the core

A/C vs D/C



Reconstruction residue

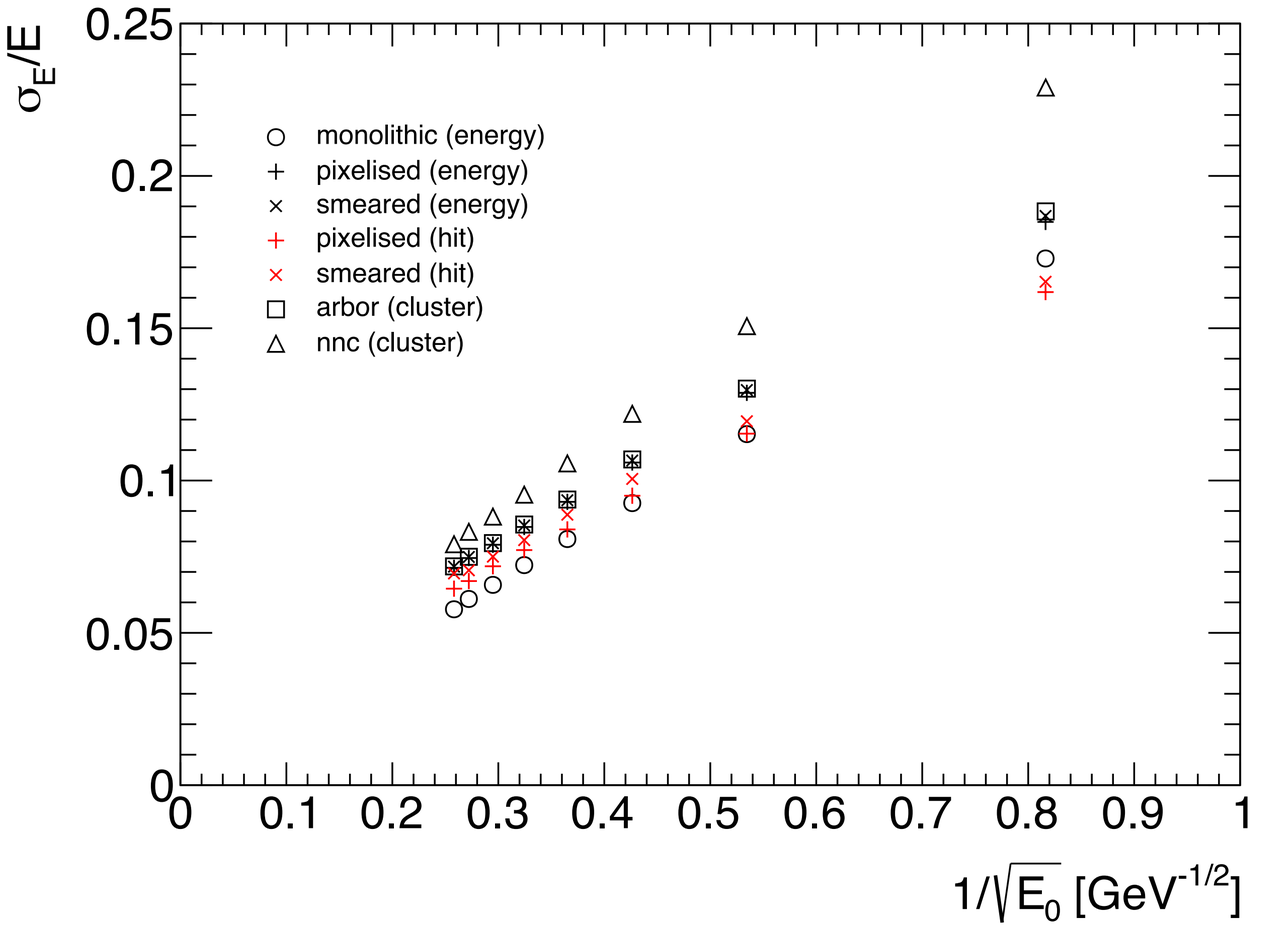
- Results from two-photon sims at 3.5 GeV
- Photons are from a same vertex at 2.5 m away from the front surface of the ECAL
- Red: fitting the track with E_{dep} info.
- Blue: fitting the track with hit info.

Preliminary summary

- Obtained a valid work flow for ECAL analysis
- ECAL-NPOD Performance in a close vicinity of NPOD requirements
  - More analysis is ongoing: many parameters to play with
  - Preliminary results show great improvement from our first estimates
  - Next step: towards vertex reconstruction and uncertainties on ALP sensitivity

Backups

ECAL-E resolution



Separation ability