Status of the ECAL reconstruction

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ECAL overview

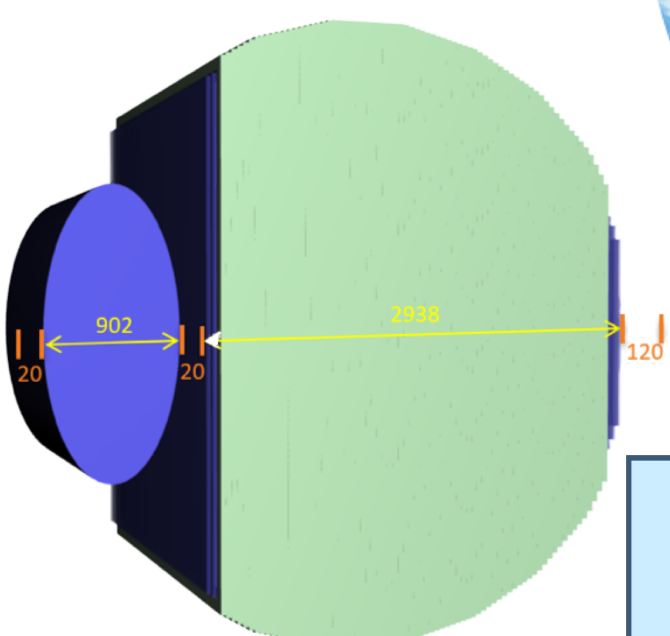
SAND employs an existing superconducting magnet successfully operated at INFN-LNF for the KLOE experiment.

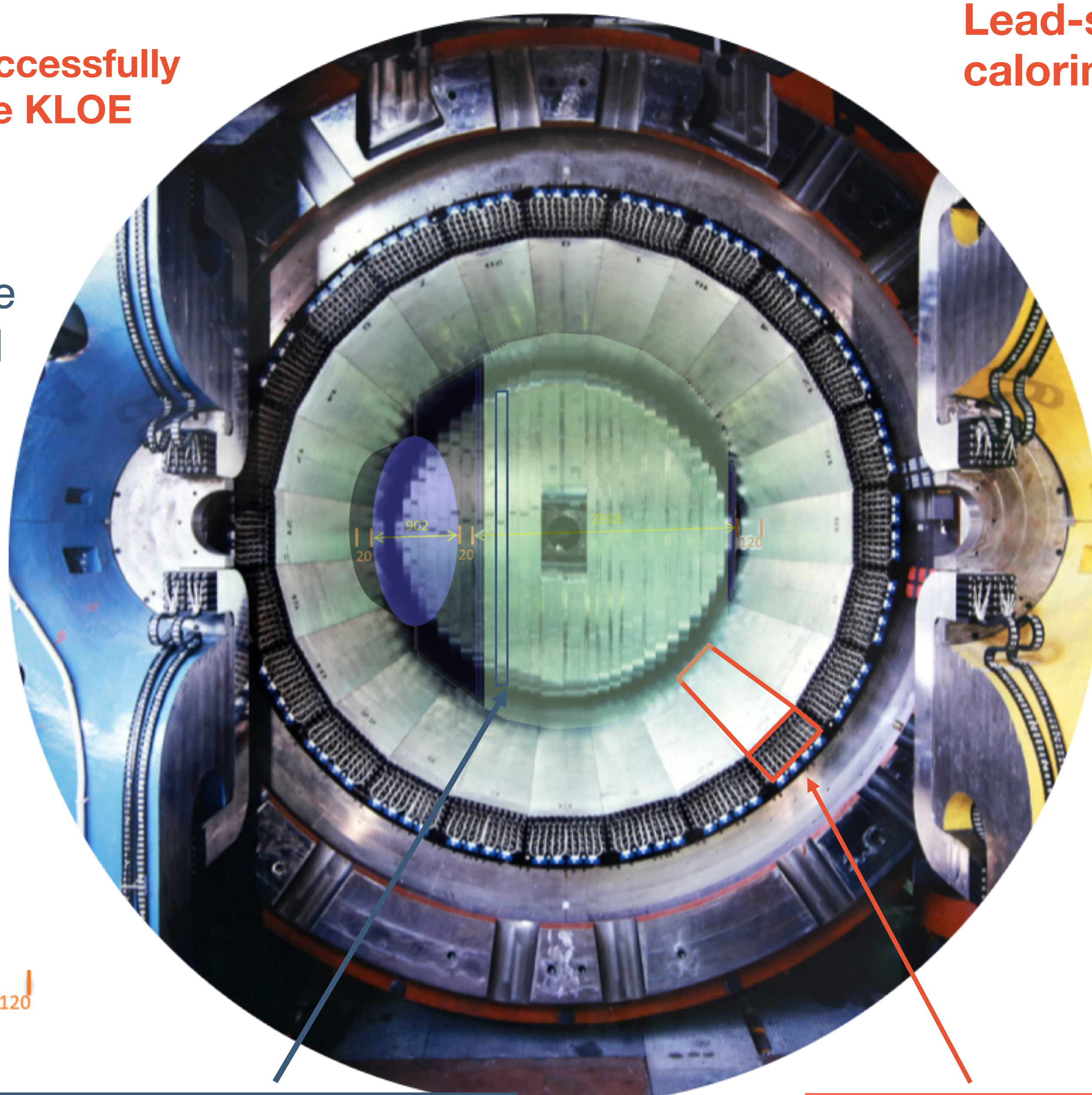
- Coil

Superconducting to produce 0.7 T over a 4.3 m long and 4.8 m diameter volume. located inside a cryostat.

- Iron yoke

~ 470 t





Lead-scintillating fiber sampling calorimeter.

All modules are composed of alternated foils

- 200 grooved lead foils, 0.5 mm thick, grooved to host fibers.
- 200 layers of cladded fibers glued together with special epoxy, 1mm diameter.

Average density ~ $5g/cm^3$, for an overall thickness of ~15 radiation lengths.

Readout at both ends of each module via PMTs

Endcap

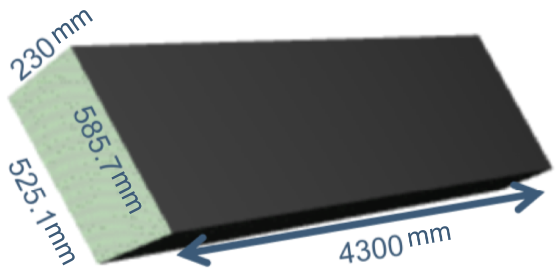
32 C-shaped, different dimensions.

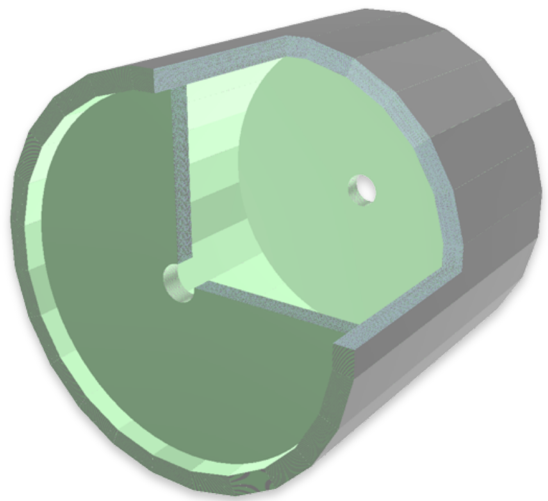
Barrel

24 modules, same dimensions.

Geometry status

Present configuration



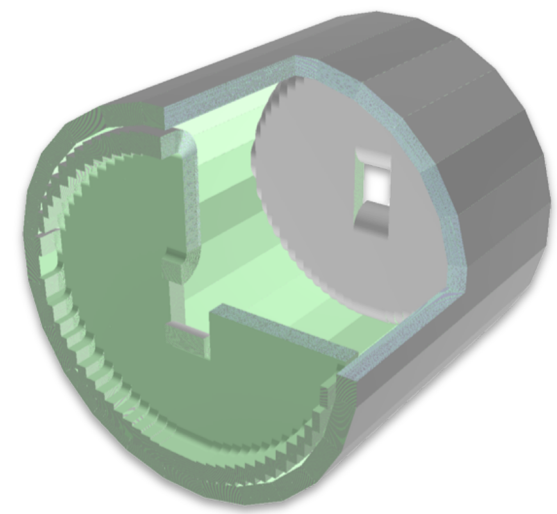


Endcaps: 2 m radius disk with a circular hole, 23 cm thick.

Barrel: 24 modules 4.3 m long, 23 cm think, trapezoidal section with bases of 52 and 59 cm.

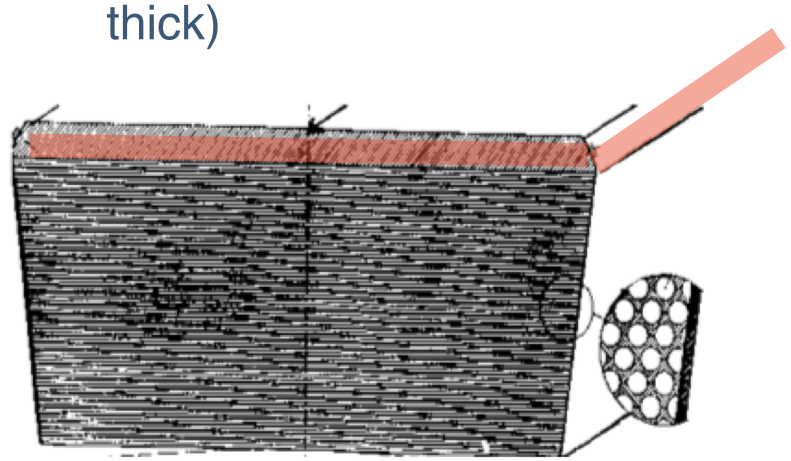
Internal module structure: 209 alternate layers of active (700 μm scintillator) and passive (400 μm Pb) material.

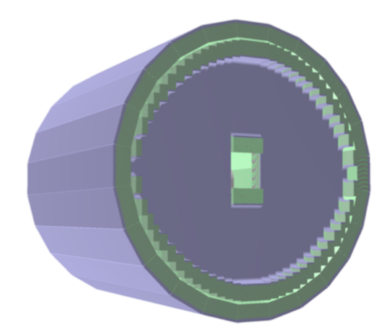
Future configuration



Endcaps: 32 modules of different lengths and widths. Straight parts [90-320] cm and curved part equal for all the modules, inner radius 10 cm, outer radius 33 cm.

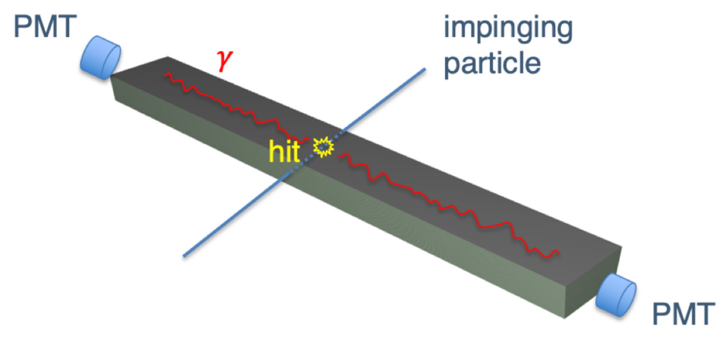
Backplate aluminum: first lead foil glued on it (2.5 cm thick)





Reconstruction workflow

Reconstruction of the signal position and time



The coordinate along the fiber z is derived by time difference between two ends while x and y are given by the center of the fired cell.

$$t^e = \frac{t^A + t^B}{2} - \frac{t_0^A + t_0^B}{2} - \frac{L}{2v} \qquad z^e = \frac{v}{2}\left(t^A - t^B - t_0^A + t_0^B\right)$$

Each cell is read by two photosensors, one per side (A,B) which collects the scintillation light guided by the optical fibers.

edep-sim simulation of energy deposited **hits.**

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ECAL digitization

Conversion into **DAQ detector digits** stored in a ROOT Ttree.

- Photoelectrons generating the photo signals (hits time and index).
- Photo signals (side A,B) with ADC, TDC.
- Cells with photo signals.

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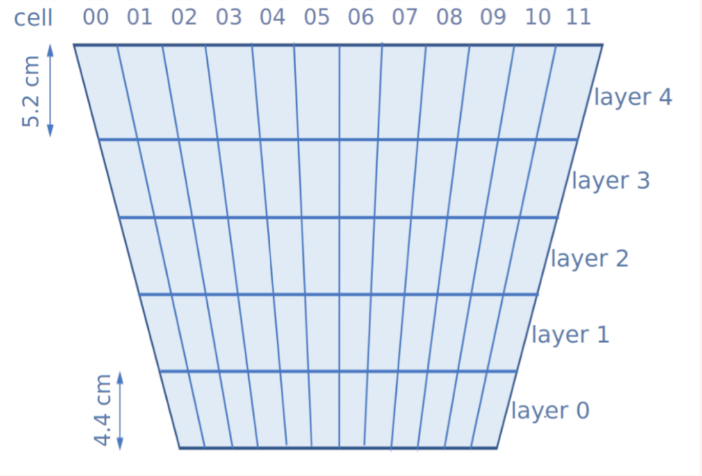
Clustering

ROOT Ttree with **cluster** of cells with photo signals.

- Cluster information.
- Cells composing the cluster.

Digitization

Reproduction of ECAL segmentation



Segmentation of the modules in 5 layers and cells of $4.4 \cdot 4.4cm^2$ granularity for a total number of 4880 readout channels.

Cell id: 20 1 11

Module barrel/endcap 00-23/30&40

Layer 0-4

Cell barrel/endcap 0-11/0-89

Signal formation

- N_{pe} number of photoelectron produced by an hit is extracted by Poisson distribution with
$$\mu_{pe} = dE \cdot E_{pe} \cdot A_l$$
- Arrival time [ns] $t_{pe} = t_{cross} + t_{decay} + d_B u_f + Gauss(1ns)$.
- ADC counts $S_i^{B,A} = N_{pe} \cdot peADC$.
- TDC: 2 options constant fraction or fixed threshold.

$\boldsymbol{i}$ cell index, $\boldsymbol{S}^{A,B}$ amplitude signal in ADC counts, $\boldsymbol{S}_{M,i}$ response in ADC counts of a MIP, $\boldsymbol{k}_e$ overall energy scale factor.

Clustering algorithm

C++ algorithm inspired by KLOE experiment.

Cells are divided in **complete** (signal on both photo sensors) and **incomplete** (with signal only in one sensor).

- **Pre-clustering**

Takes one complete cell as a seed and checks the neighbors, if are found complete cells they are added to the pre-cluster.

Pre-cluster variables are calculated.

$$E_i^{A,B} = \frac{S_i^{A,B} - S_{0,i}^{A,B}}{S_{M,i}} \cdot k_e, \quad E_i = \frac{E_i^A + E_i^B}{2}$$

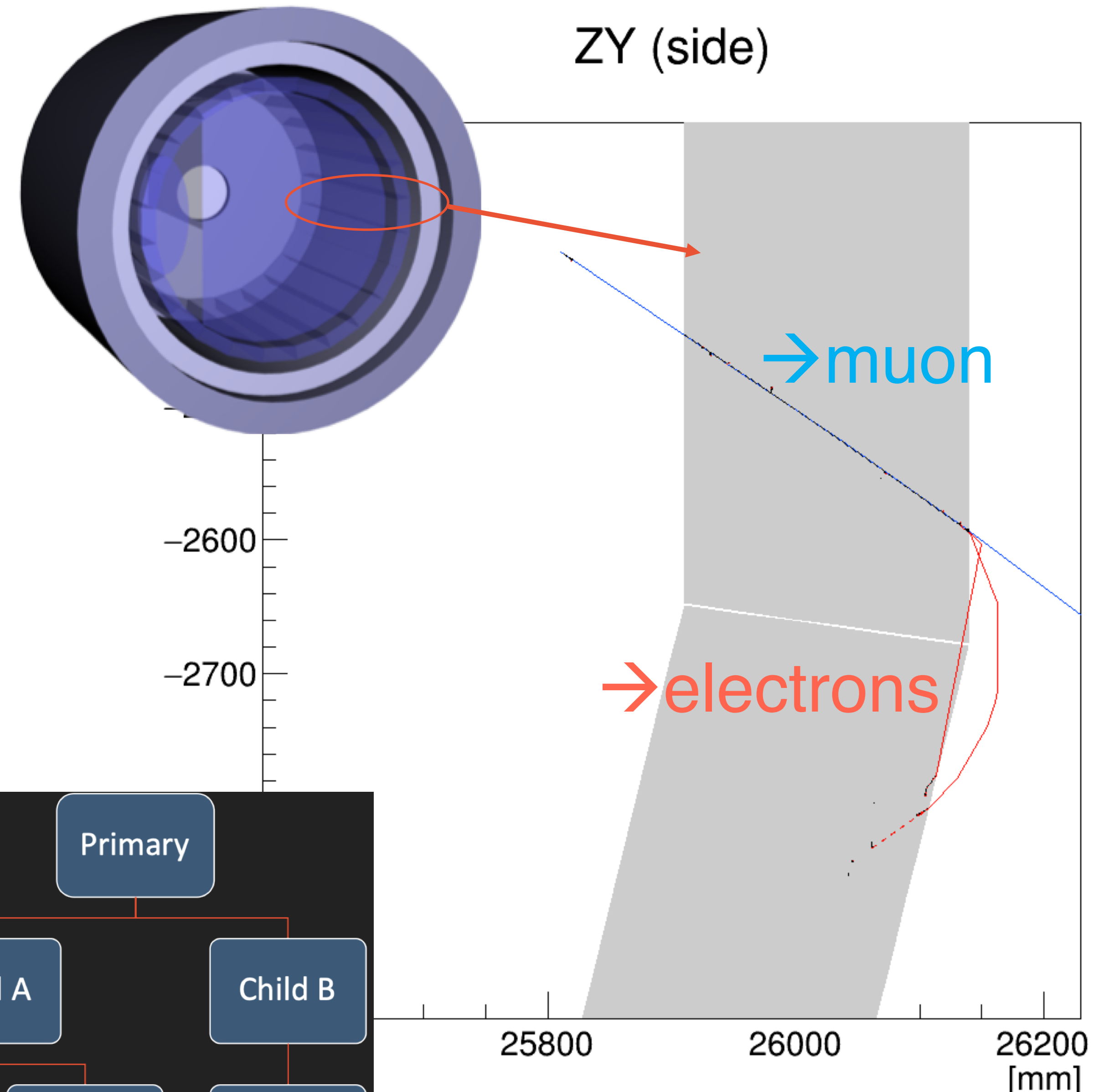
- **Splitting** compute time variance of the pre-cluster and in case of time discrepancy > 5ns divides into quadrants forming new pre-clusters.
- **Merging** compares two close pre-clusters and merges them if their spatial distance is < 40 cm and time difference < 2.5 ns.
- Adding incomplete cells to the pre-clusters, comparing cell position and closest pre-cluster centroid.

Clustering performance

Preliminary evaluation

Has been done for electron and muon tracks discrimination, using multivariate algorithms trained with simulated muon and electron particle guns originated near the ECAL.

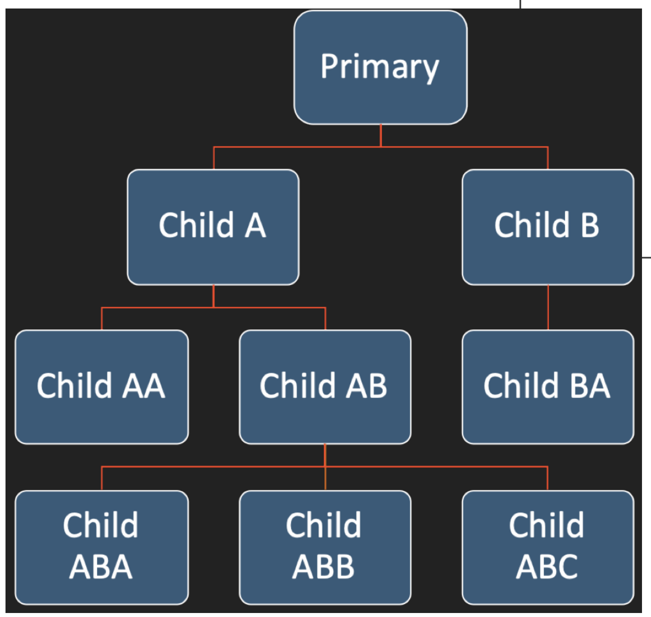
Multivariate analysis has been applied to ν_μ -dominated beam sample to see the capabilities of the muon track/electron discrimination with **no conclusive results**.



First step

Define which true MC particle has generated each cluster present in the ECAL.

- Which particle is entering in the ECAL.
- Create tree structure of the cluster parent-daughter relations.

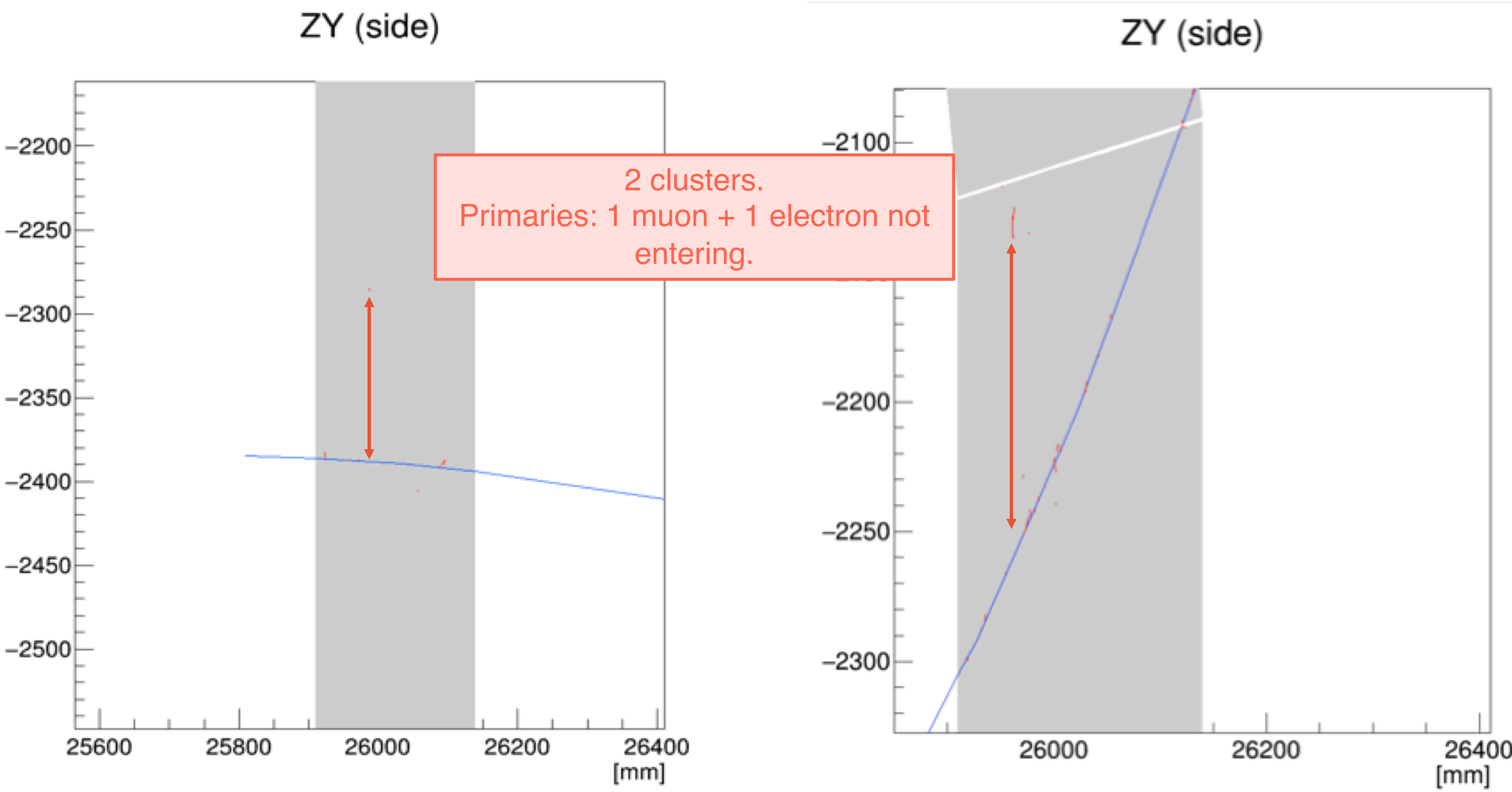


Adding an entry
→ Primary particle.

Clustering performance

1000 events of simulated muon particle guns, generated near the ECAL barrel.

1468 clusters, 105 clusters with no entering primary.

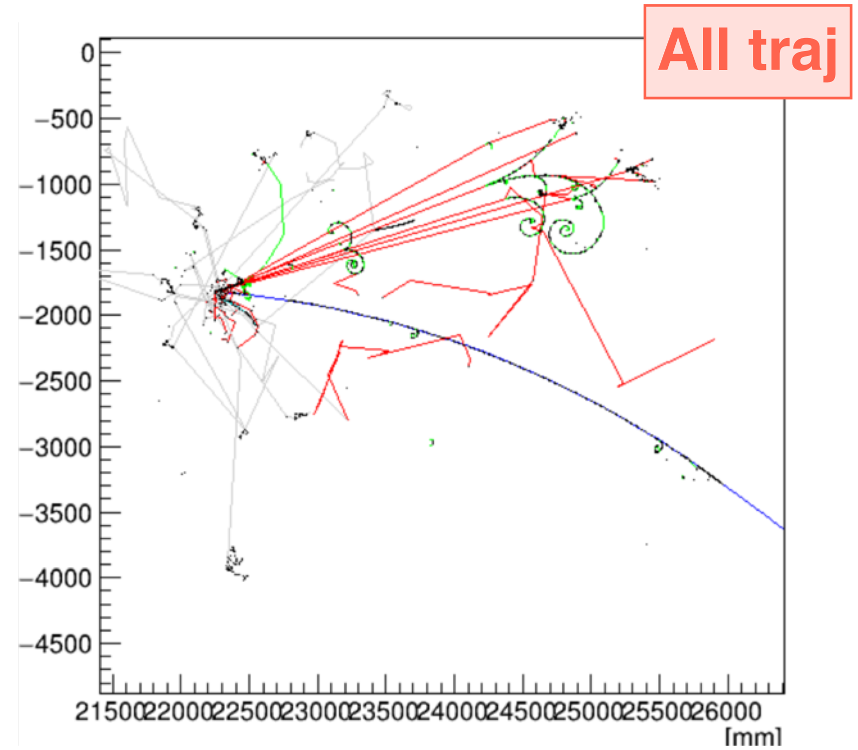


EDEPReader tool

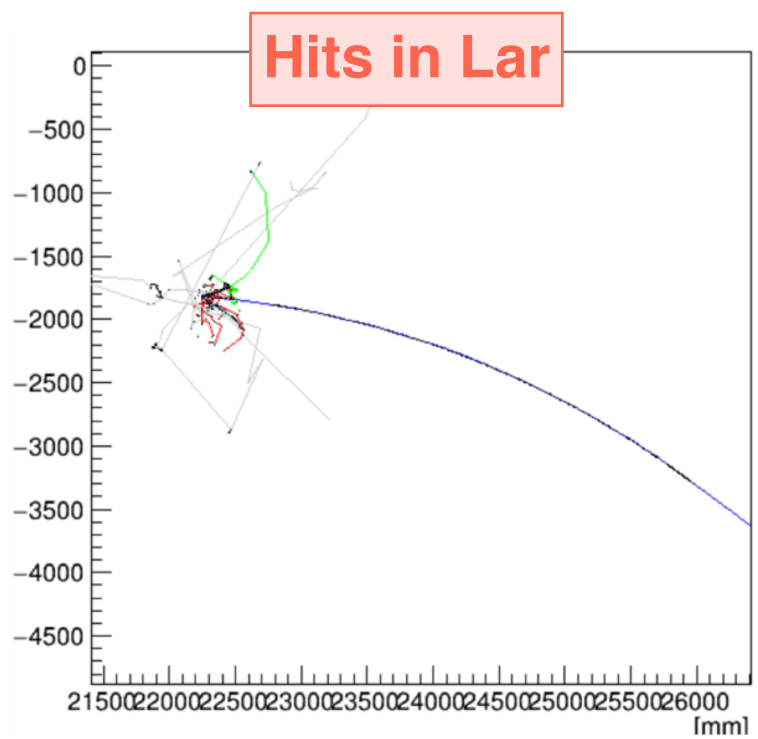
Info provider C++ tool to handle the edep-sim MC truth
https://baltig.infn.it/dune/edep-reader

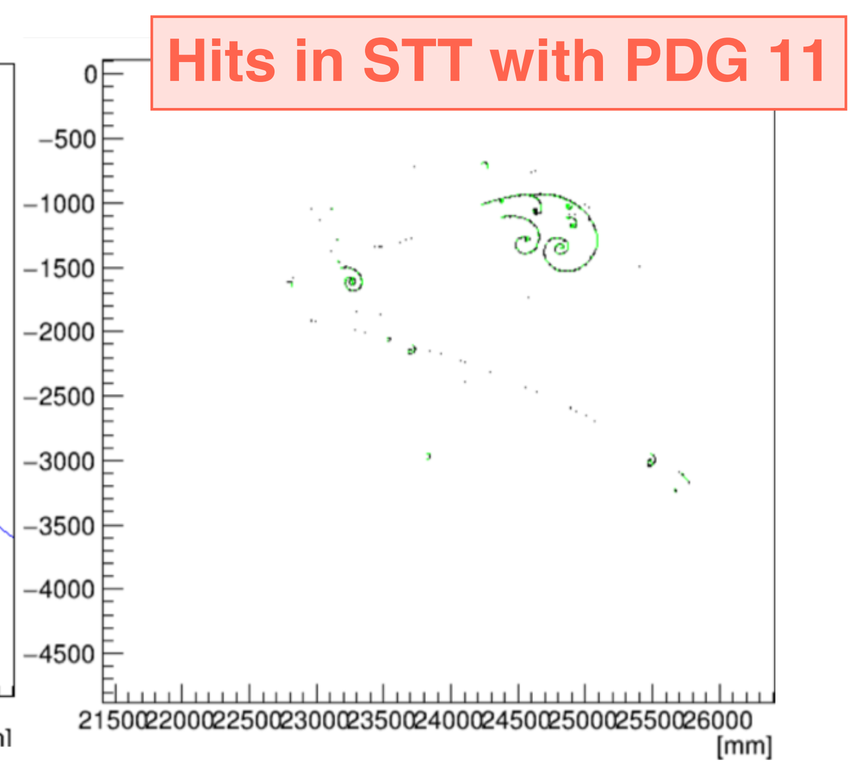
- It loads the info of one edep-sim event and build a tree structure of trajectories with parent-child relation.

- Provides easily to use functions to filter particle information from Trajectories:
  - GetParent()
  - IsEntering()
  - HasHitsInDetector()
  - …



Not limited to edep-sim objects. Could be extended to be used for other data structures.





Conclusions

- ECAL endcap geometry ready for integration.
- Energy, position and time of energy deposits in cells are reconstructed using signals of PMTs on both ends.
- Clustering algorithm has been developed and the performances are under evaluation in order to perform particle identification in ECAL as standalone detector and eventually in combination with the others SAND sub-detectors.
- EDEPReader tool developed to easily handle MC truth.

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Thank you for the attention!