Close-by hadronic showers study

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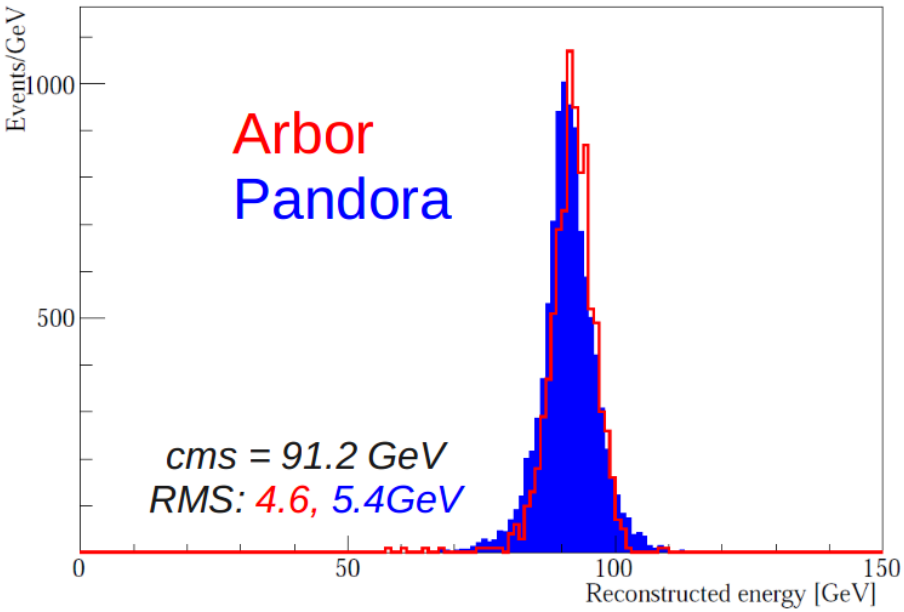
Algorithm development

Multiple reasons lead to algorithm development :

- Fine granularity ($\sim$ 1 cm^2 up to $\sim$ 0.25 cm^2) could allow us to probe the shower structure.
- Need a dedicated algorithm for shower reconstruction to achieve this goal.
- Additional algorithms could help to identify structure objects (track , core , edge , isolated hits, ...)
- Provide an additional (cross check) PFA software for the full ILD reconstruction

Idea of **tree** and **branch** structure (H. Videau , R. Manqi).
$\rightarrow$ The Arbor algorithm.

On my side : *Arbor-like* algorithm combined with additional algorithms (i.e tracking)



R. Manqi (LLR) - CHEF 2013

Algorithm development

Data set for overlay study

Data set :

- Two π^- hadronic showers overlaid in one event (2000 events).
- Geant4 simulation :
  - 10-10 GeV and 10-30 GeV
  - FTFP_BERT_HP physics list
  - Digitizer (see the talk of A. Steen)

Shower overlay :

- X direction : separated by a distance d (from 5 cm up to 30 cm by a 5 cm step) and centered
- Y direction : centered
- overlaid hits : small ratio, keep the highest threshold

Goal

Study the separation power (efficiency, recovered - measured , etc ...) of the algorithms

Algorithm development

The global reconstruction algorithm

First, prepare the event :

- Calculate hit density
- Find isolated hits
- Find calo-tracks
- Do intra-layer clustering

Then, the main part is run :

- Connector-clustering (Arbor-like)
- Cluster merging
- Isolated hit merging

PFOs $\rightarrow$ analysis

Algorithm development

Isolation and tracking

Isolation

Need to tag isolated hits to treat them apart

- Intra layer clustering : NN clustering (sharing the same edges)
- Hit density : sum of 3D neighbor thresholds (normalized to 1)
- Hit in 2D clusters with size <= 4 and mean density < 0.01 are tagged as isolated

Tracking

The method consists in layer-by-layer clustering approach

- Use only isolated clusters (all the hits)
- Connect all the clusters layer by layer that are closed together($\pm$50 mm in the transverse direction)
- Keep only the forward connector (if there is one) that have lowest angle with the backward.
- Tag hits to *"track hits"*

Algorithm development

The main clustering algorithm

Based on arbor algorithm. Use non-isolated hits for this algorithm

- Connect the layer l with l+1,2,3 with a maximum transverse distance of 30 mm (ROI)
- Compute the reference vector with the backward connectors :

$$\vec{v}_{ref} = \frac{1}{\|\vec{v}_{ref}\|} \cdot \sum_{c=1}^{n_b} \vec{v}_c . f$$

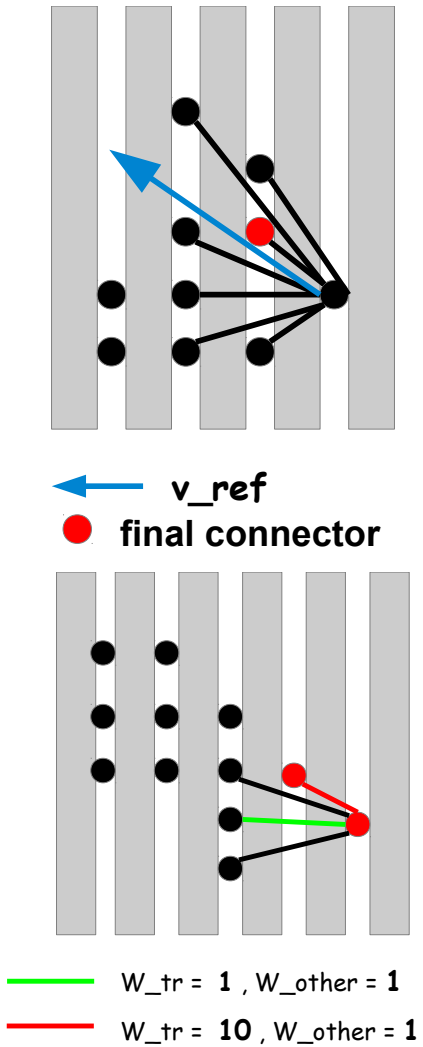
$$\text{where } f = \begin{cases} p_1 = 10 & \text{if the connected hits belong to the same track} \\ p_2 = 1 & \text{else} \end{cases}$$

- For each connector c, compute the order parameter :

$$P_{\theta,d} = angle(\vec{v}_{ref}, \vec{v}_c).\|\vec{v}_c\|$$

  and keep the smallest order parameter
- Build clusters with a recursive method

One backward connector $\rightarrow$ one solution for branching (arbor principle)



Algorithm development

Merging algorithms

Cluster merging

Intend to merge clusters into their parent ones

- Merge small clusters (size <= 25)
- If the upstream hit of a cluster is close to another cluster, they are merged together

Isolated hit merging

Each isolated hit is merged into the closest cluster

PFO Analysis

Throwing 2 particles with 10-10 GeV and 10-30 GeV energies.
Look at the 10 GeV one in both cases.
Measured energy :

$$\boxed{E_{meas} = \alpha N_1 + \beta N_2 + \gamma N_3}$$

with

$$\boxed{\alpha = \alpha_1 + \alpha_2 . N_h + \alpha_4 . N_h^2} \quad , \quad \boxed{\beta = \beta_1 + \beta_2 . N_h + \beta_3 . N_h^2} \quad , \quad \boxed{\gamma = \gamma_1 + \gamma_2 . N_h + \gamma_3 . N_h^2}$$

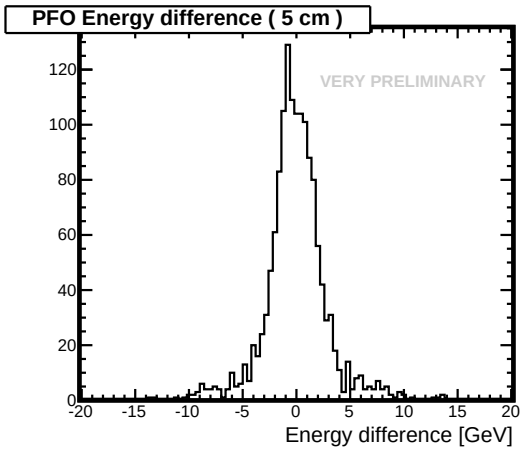
Recovered Energy : Estimated energy with the previous formula (see SDHCAL Energy talks)

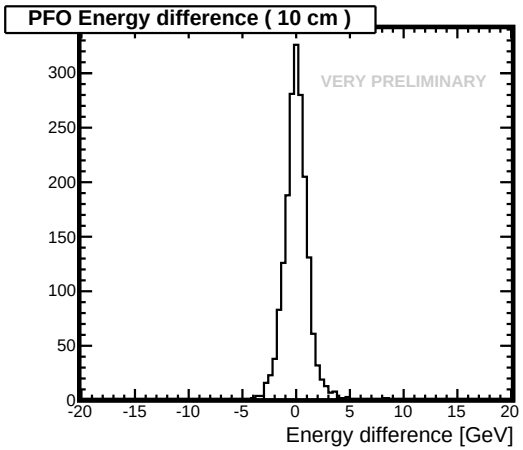
Variables of the study :

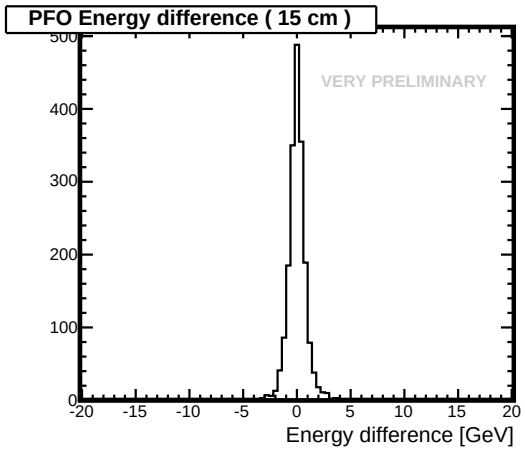
- Algorithm efficiency : AlgoEff = (nbOfPfos == 2)
- Energy difference : EDif = (recE - measE)
- Mean, RMS RMS_{90} of Energy difference

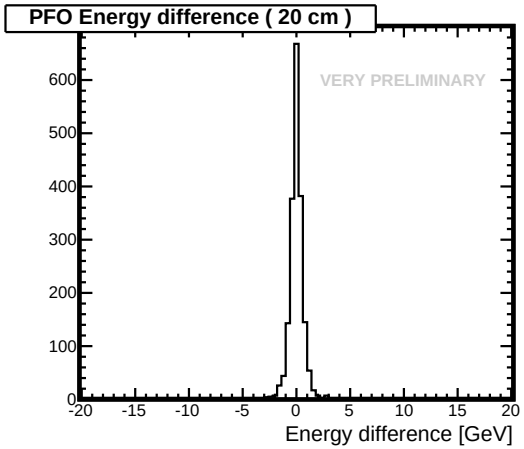
PFO Analysis

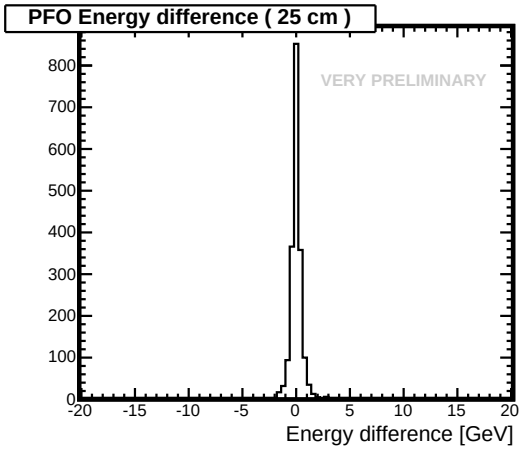
10 GeV confusion

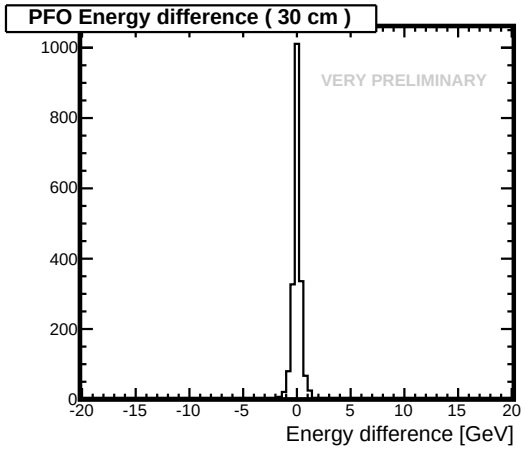






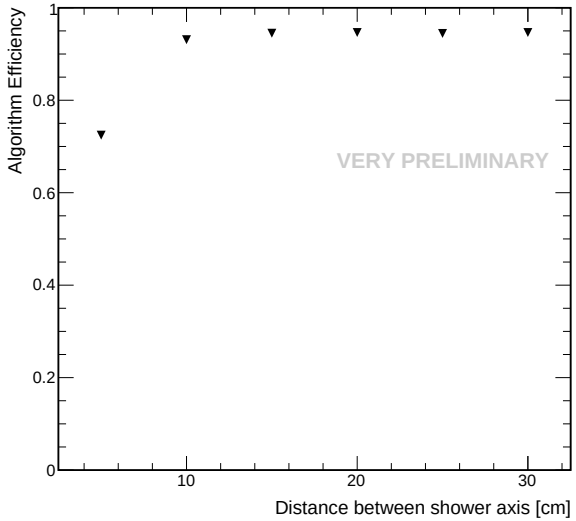


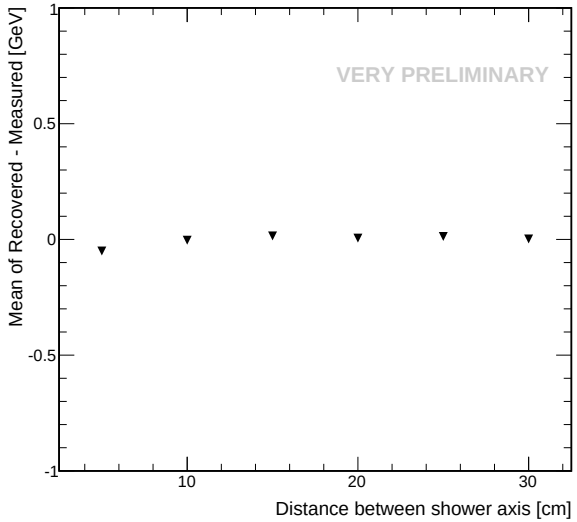


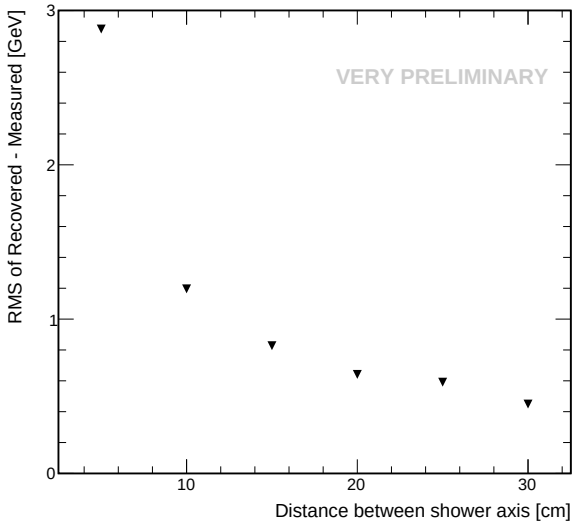


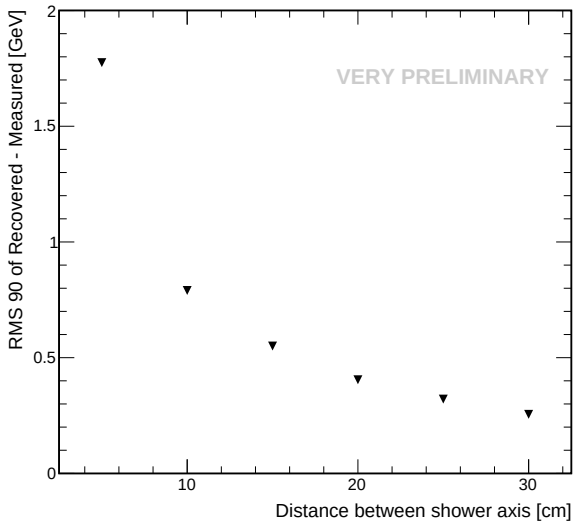
PFO Analysis

10 GeV confusion



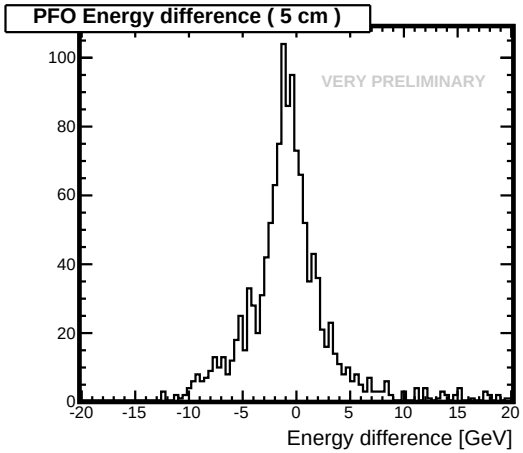


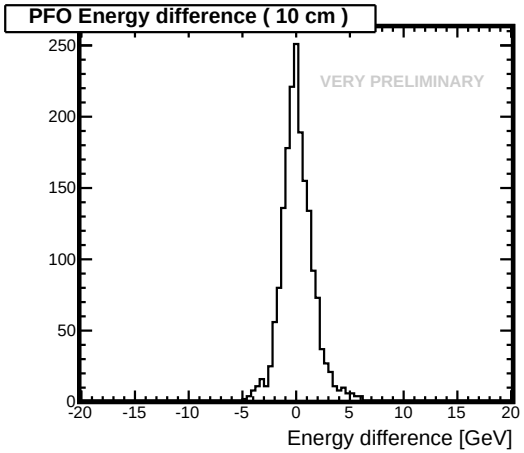


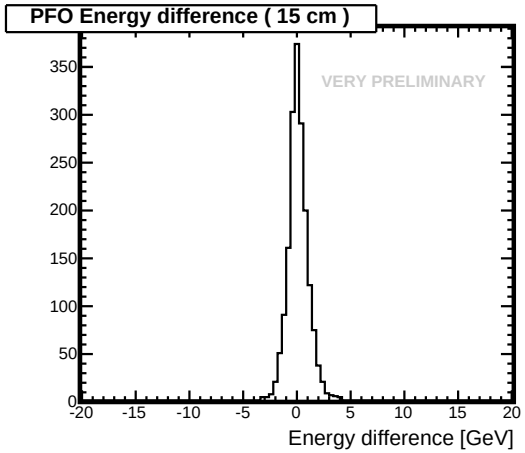


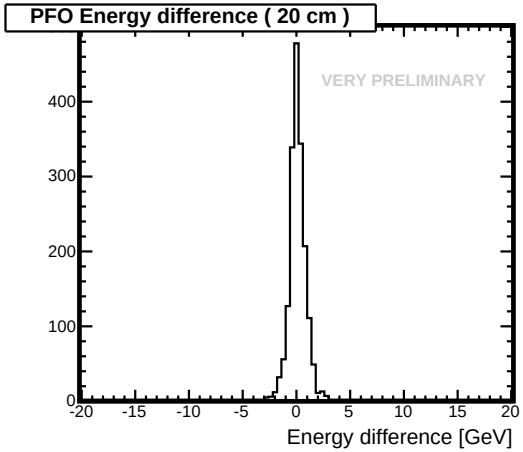
PFO Analysis

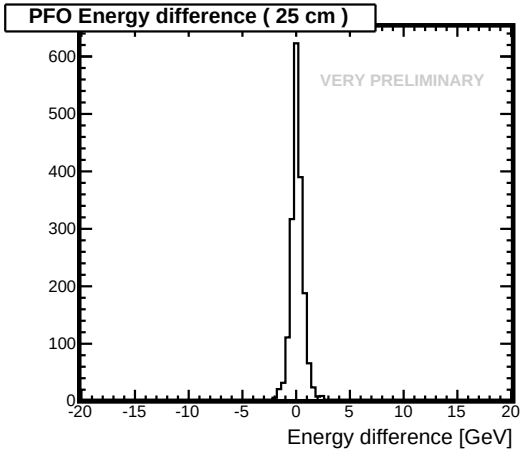
30 GeV confusion

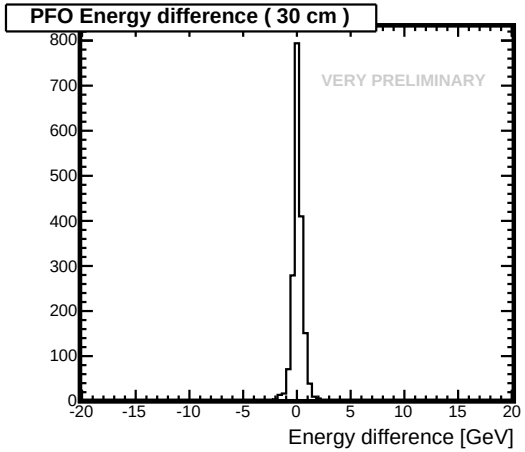












PFO Analysis

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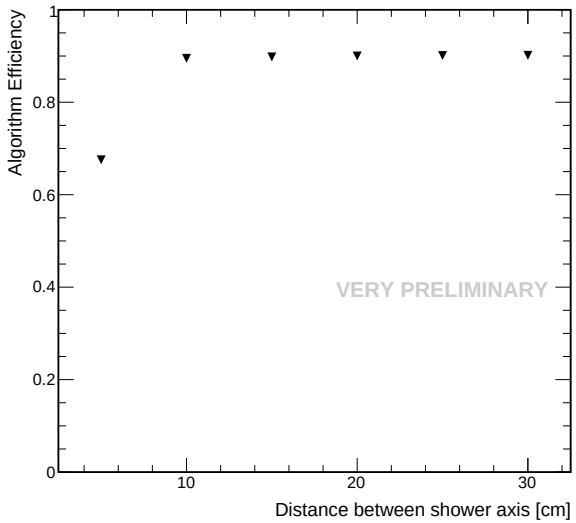

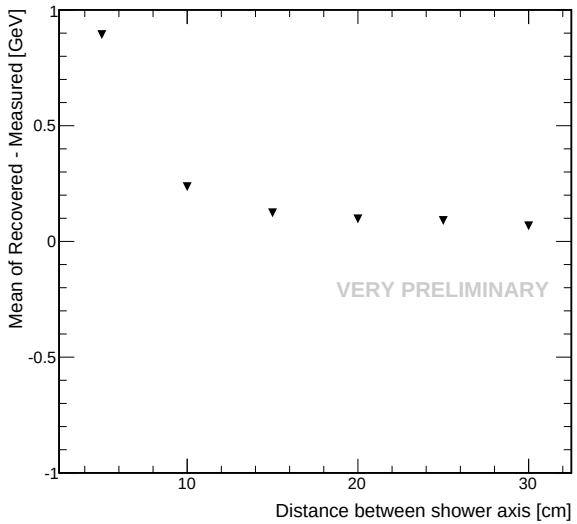

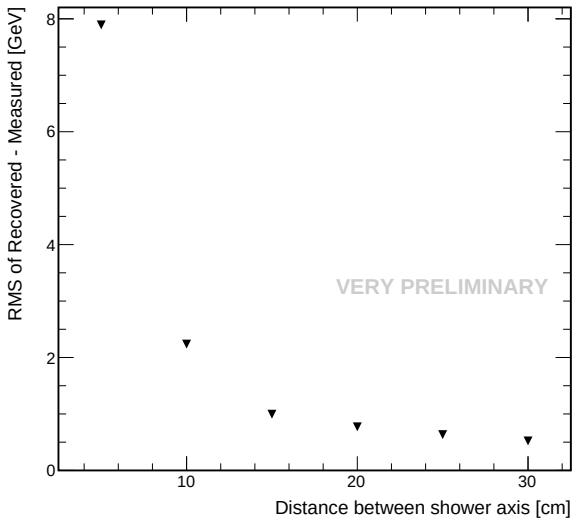

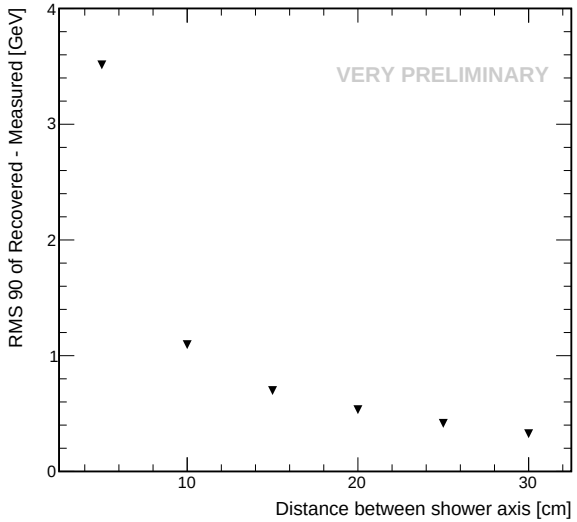

Ongoing work

In the short term ($\simeq$ 3 months)

- Understand the behavior of the connector clustering algorithm (bad effects , connector choice , etc ...)
- Add incoming track information as a seed (position , direction , momentum)
- SDHCAL data comparaison
- Include more information in energy reconstruction (track weight, etc...)
- Overlay procedure : overlaid hit threshold study (loss of information)

For the long-term (the whole PhD thesis)

- Include ECal in front of HCal
- Do the same study for ECal and ECal+HCal with additionnal algorithms (ecal-hcal connection)
- Run full Mokka simulation and study jet energy resolution
- Apply this new PFA to the $e^+e^- \rightarrow HZ$ channel