Separation of nearby hadronic showers using ArborPFA [CAN-054]

LCWS 2015
Whistler, Canada

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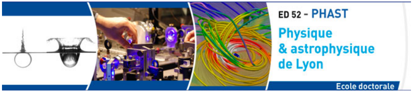


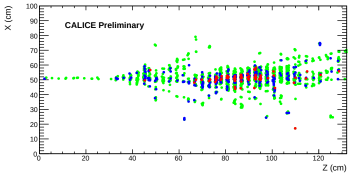
Outline

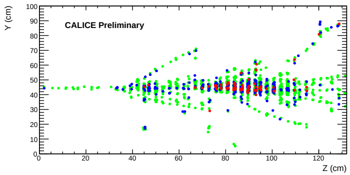
The CALICE SDHCAL prototype

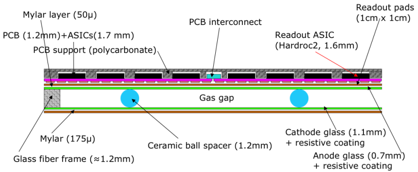
Description

Semi-Digital Hadron Calorimeter

- Sampling calorimeter
- 48 layers :
  - Steel absorber
  - Sensitive medium : GRPC
- Segmentation :
  - Transverse : 1 cm x 1 cm
  - Longitudinal : 2.67 cm (abs. + sens)
- Semi digital readout with 3 thresholds

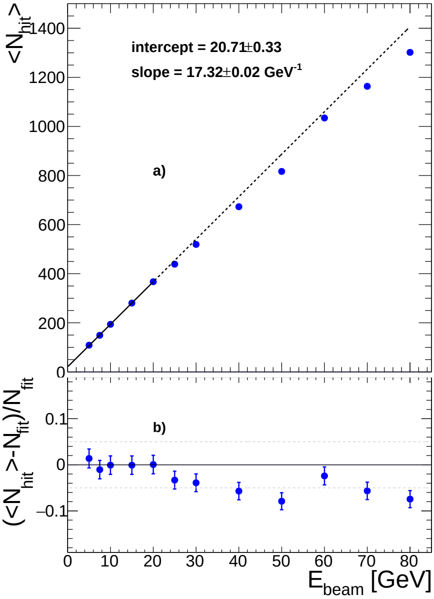


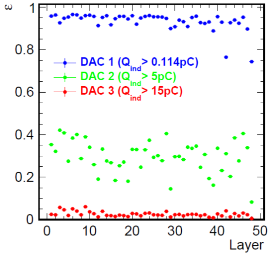


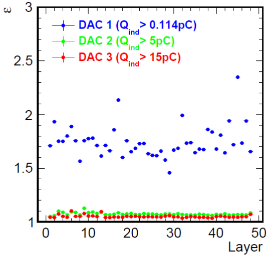


The CALICE SDHCAL prototype

Performances







CALICE SDHCAL [CAN-037]

I. Laktineh *et al.* [arXiv 1506.05316]

The CALICE SDHCAL prototype

Performances

Energy reconstruction

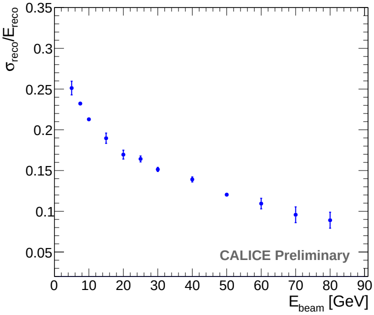
$$E = \alpha(NHit) \cdot N_1 + \beta(NHit) \cdot N_2 + \gamma(NHit) \cdot N_3 \quad (1)$$

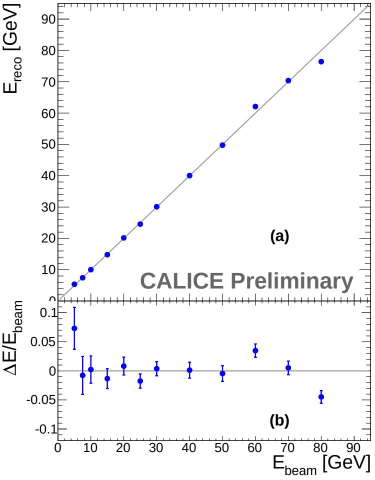
avec :

$$\alpha(NHit) = \alpha_1 + \alpha_2 \cdot NHit + \alpha_3 \cdot NHit^2 \quad (2)$$

$$\beta(NHit) = \beta_1 + \beta_2 \cdot NHit + \beta_3 \cdot NHit^2 \quad (3)$$

$$\gamma(NHit) = \gamma_1 + \gamma_2 \cdot NHit + \gamma_3 \cdot NHit^2 \quad (4)$$





Calice SDHCAL [CAN-037 addendum 1]

ArborPFA
Software package

PandoraPFA structure (arXiv `phys.ins-det/1506.05348`)

- PandoraSDK : toolkit for generic PFA development
- PandoraMonitoring (optionnal) : ROOT Eve event display designed for PFA
- LCContent : the algorithm contents (cone clustering, pandora associations, etc ...)
- MarlinPandora : Marlin processor implementation for LCContent

Current version of ArborPFA designed for CALICE SDHCAL.
Version of this study : v01-04-00 (https://github.com/**SDHCAL**/ArborPFA.git)
Provides a dedicated API for Arbor algorithms built on top of PandoraSDK APIs.

ArborPFA package forseen structure

Version v02-00-00
Hosted at https://github.com/**rete**/ArborPFA.git
Full detector purpose
Match the PandoraPFA package structure :

- PandoraSDK : toolkit for generic PFA development
- PandoraMonitoring (optionnal) : ROOT Eve event display designed for PFA
- **ArborContent** : the algorithm contents (connector seeding, cleaning, tree associations ...)
- **MarlinArbor** : Marlin processor implementation for ArborContent

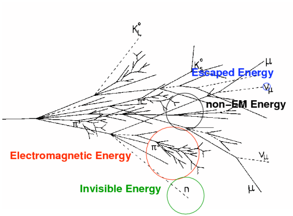
ArborPFA
Principle

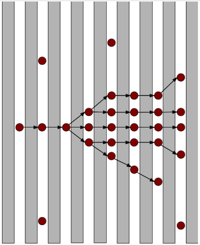
Principle

Particle Flow Algorithm based on hadronic shower **tree-like topology**.

ArborPFA
Principle

Principle
Particle Flow Algorithm based on hadronic shower **tree-like topology**.

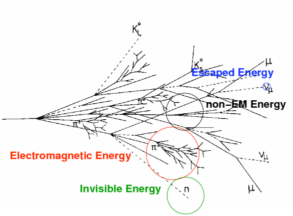


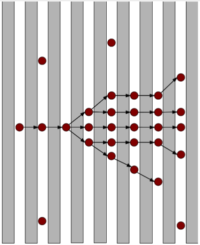


ArborPFA
Principle

Principle

Particle Flow Algorithm based on hadronic shower **tree-like topology**.





Some definitions

- **Object** : *Node* linked by one or many connector(s) (+ seeds and leaves)
- **Connector** : Oriented *link*. Links two objects
- **Flow direction** : Connector orientation, backward or forward
- **Tree** : Set of objects linked by connectors. For each object :
  - 0 or 1 backward connector
  - 0 or many forward connector(s)

$\rightarrow$ Implies a unique tree structure solution (1 seed per tree)

ArborPFA
The algorithms

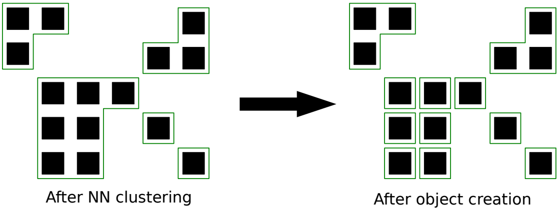
① Object creation

■ Create objects, ready to be connected.

- Nearest Neigbours clustering in each layer
- If cluster size <= 4, cluster = 1 object
- If cluster > 4, each cluster hit = 1 object

Allows to :

- overcome the track hit multiplicity in gaseous calorimeters
- decrease the size of the problem. NHit $\rightarrow$ NObject ($<$ NHit)
- accelerate the connection procedure



ArborPFA

The algorithms

Tree building

Iteration phase :

- Connector creation between objects (seeding)
- Connector cleaning to obtain a tree structure (cleaning)

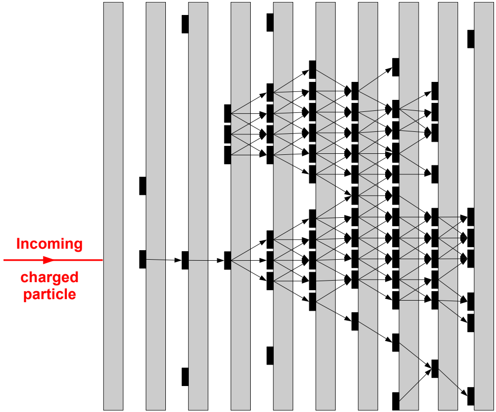
Repeat the two previous algorithms as much as needed.

Global idea : create an initial tree structure to start with. Then alterate the latter by creating more optimized connections.

ArborPFA
The algorithms

② Connector creation 1

■ For each object, we look for nearby objects in the 3 next layers within a distance of 45 mm. A connection is then created for each of them.



ArborPFA

The algorithms

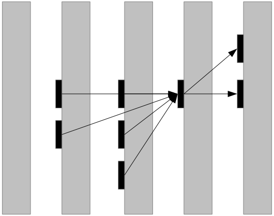
③ Connector cleaning 1

- Clean connectors to create a tree structure.

ArborPFA
The algorithms

③ Connector cleaning 1

■ Clean connectors to create a tree structure.
For each object :



ArborPFA
The algorithms

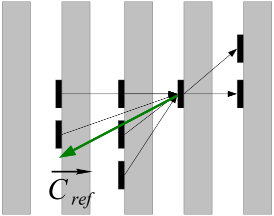
③ Connector cleaning 1

■ Clean connectors to create a tree structure.

For each object :

- Computation of the reference direction :

$$\vec{C}_{ref} = w_{bck} . \sum_{\sigma} \sum_{b} \vec{c}_{b,\sigma} - w_{fwd} . \sum_{\delta} \sum_{f} \vec{c}_{f,\delta} \quad (5)$$



ArborPFA

The algorithms

③ Connector cleaning 1

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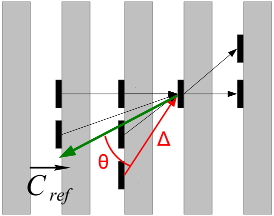
- For each object in the backward direction, we define the κ order parameter :

$$\kappa = \left(\frac{\theta}{\pi}\right)^{p_\theta} . \left(\frac{\Delta}{\Delta_{max}}\right)^{p_\Delta} \quad (6)$$



ArborPFA
The algorithms

③ Connector cleaning 1

■ Clean connectors to create a tree structure.
For each object :

- Computation of the reference direction :

$$\vec{C}_{ref} = w_{bck} \cdot \sum_{\sigma} \sum_{b} \vec{c}_{b,\sigma} - w_{fwd} \cdot \sum_{\delta} \sum_{f} \vec{c}_{f,\delta} \quad (5)$$

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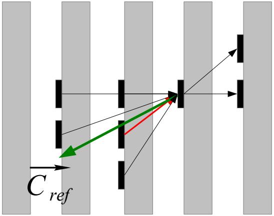
- The connector with the smallest κ is kept.



ArborPFA

The algorithms

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For each object :

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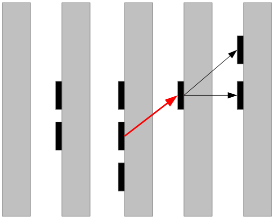
- The connector with the smallest κ is kept.
- **At the end of the algorithm**, the other connectors are deleted.



ArborPFA

The algorithms

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$$\vec{C}_{ref} = w_{bck}.\sum_{\sigma}\sum_{b}\vec{c}_{b,\sigma} - w_{fwd}.\sum_{\delta}\sum_{f}\vec{c}_{f,\delta} \quad (5)$$

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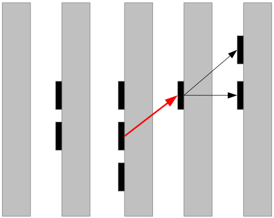
- The connector with the smallest κ is kept.
- **At the end of the algorithm**, the other connectors are deleted.

→ Formation of a tree structure.

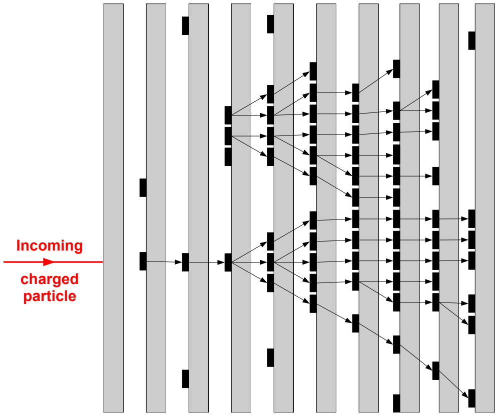


ArborPFA

The algorithms

④ et ⑤ Connector alignment

■ From the latest tree structure, more connections are created. This creates an alignment within the shower. A second connector cleaning is then performed to obtain a final tree structure.



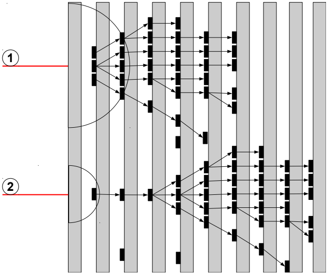
ArborPFA

The algorithms

⑥ Track-to-tree association

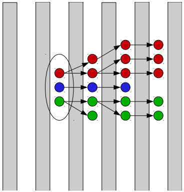
■ Association between tracks and trees performed with simple criteria :

- Distance between a tree seed and track extrapolation to the calorimeter front face.
- Track momentum - tree energy comparison
- Handling of special cases as early interactions



⑦ Neutral tree merging

■ Interaction of neutral particles in an absorber.
→ Many seeds in the same layer, thus many reconstructed trees instead of a single one.
Seeds belonging to this kind of configuration are **identified** and their trees **merged**.



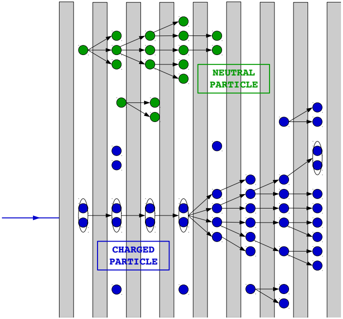
ArborPFA

The algorithms

⑧ Pointing trees association

■ Association between neutral (daughter) trees and charged or neutral (parent) trees as a function of their main axis (3D linear fit over object positions) and their energies.

- D.C.A between axes.
- D.C.A between axis and barycentre
- Energy criteria (charged parent tree case)



⑨ Small neutral tree merging

■ Small trees (NObj < 20) are merged in the closest bigger tree (NObj $\geq$ 20).

⑩ *Particle Flow Objects* creation

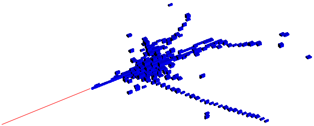
■ Creation of reconstructed particles :

- one track (if charged particle)
- one tree

Single particle reconstruction

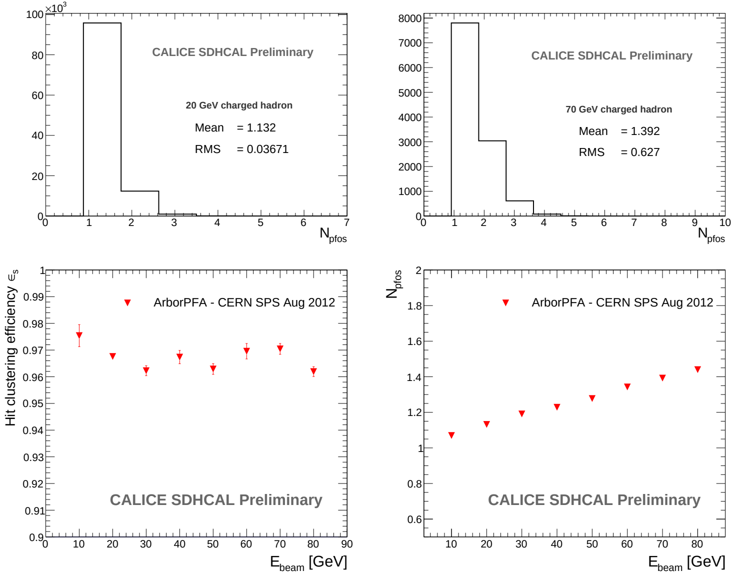
Reconstruction inputs

- Data : CERN SPS 2012 - August-September
- Particles : $h^{\pm}$
- Energies : [10 ; 80] GeV by steps of 10 GeV
- "Fake" track generated :
  - $\vec{p} = (0, 0, E_{beam})$
  - Entry point $\vec{e}$: barycentre (b_x, b_y) of hits in the 5 first layers $\rightarrow \vec{e} = (\mathrm{b}_x, \mathrm{b}_y, \mathrm{z}_{front})$
- No magnetic field ($\vec{B} = \vec{0}$ T)



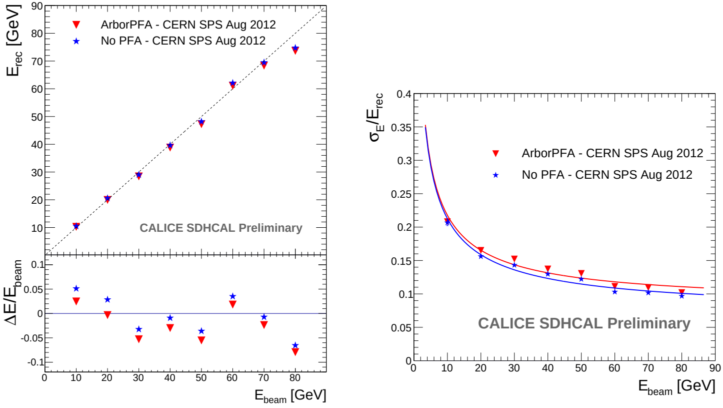
Single particle analysis

Efficiency and Npfos



Single particle analysis

Reconstructed energy and resolution



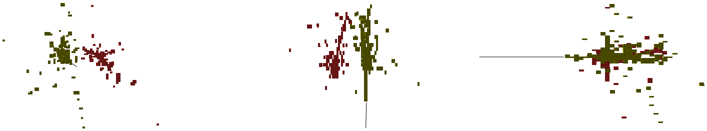
Overlaid particles

Overlay of two hadronic events

- Same data set
- Particle 1 energy : 10 GeV
- Particle 2 energies : [10 ; 50] GeV by steps of 10 GeV

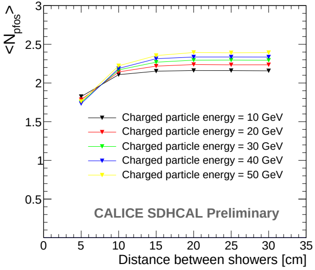
Overlay algorithm :

- Determination of entry points and barycentres.
- Removal of hits belonging to the primary track segment of particle 1 (10 GeV)
- Shower re-centered in calorimeter (x and y) and $\pm$ d/2 shift in the x direction
- Overlaid hits : the highest threshold is kept
- Hits are tagged 1, 2 or 3 (overlaid)



Overlaid particles

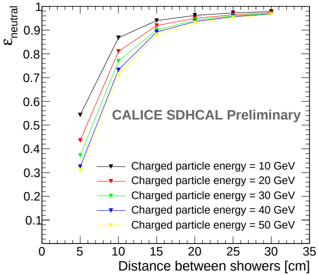
Efficiency and purity

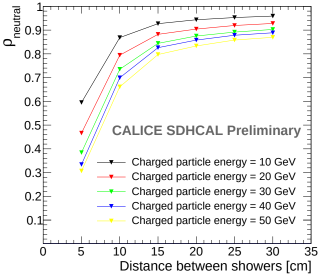


Efficiency and purity

$$\varepsilon = \frac{Nhit_{good}}{Nhit_{ini,tot}} \quad (7)$$

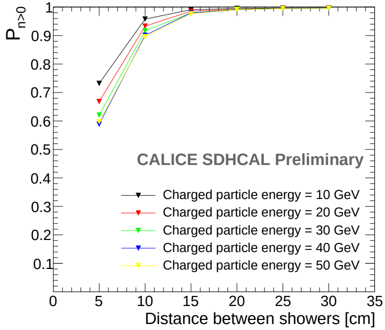
$$\rho = \frac{Nhit_{good}}{Nhit_{rec,tot}} \quad (8)$$

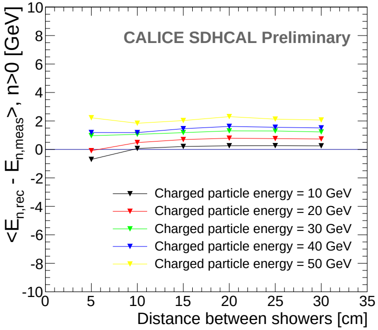




Overlaid particles

Probability and energy





Conclusion and roadmap

Conclusion

- Particle flow algorithm development based hadronic shower tree topology for the SDHCAL prototype
- Performance extraction for single particle - OK
- Performance extraction for two overlaid particles - OK till 5 cm

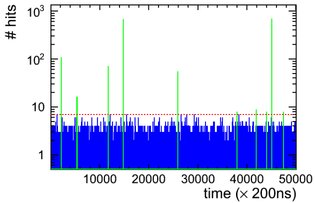
Roadmap

- Correction of some algorithms $\rightarrow$ re-extract performances (to do)
- Implementation for ILD-like detectors :
  - Angular correction for connections (advanced)
  - Implémentation for ECal (started)
  - Muon reconstruction (to do)
  - Photon reconstruction $\rightarrow$ GARLIC
  - Energy calibration (ECal + HCal) (to do)
- Physics performances :
  - Jet energy resolution and scale (to do)
  - W - Z separation
  - Physics channel e+e- $\rightarrow$ HZ

Thanks for your attention !

Backup

Particle reconstruction and event selection

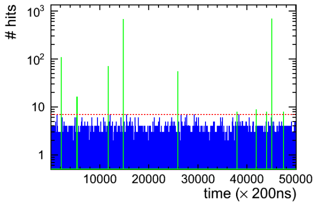


Reconstruction : *clustering* en temps

- Minimum NHit : 7
- Time window : $\pm$ 2

Backup

Particle reconstruction and event selection



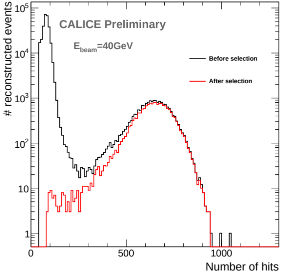
Reconstruction : *clustering* en temps

- Minimum NHit : 7
- Time window : $\pm$ 2

Hadronic event selection

No cherenköv detector $\rightarrow$ topological selection

- Muon : $NHit/N_{layer} > 2.2$
- Neutral particles : NHit $\in$ 5 first layers ≥ 4
- Radiative muons : $\frac{N_{touched\ \ layers}/RMS>5cm}{N_{touched\ \ layers}} < 20\ \%$
- Electrons : $Z_{begin} \geq 5$ and $N_{touched\ \ layers} \geq 30$

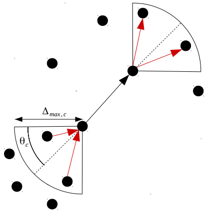


Backup

ArborPFA - Second connector iteration

⑥ et ⑦ Connector alignment

- From the previous tree structure, more connectors are created.



Backup

ArborPFA - Second connector iteration

⑥ et ⑦ Connector alignment

- From the previous tree structure, more connectors are created.

⑦ Connector cleaning 2

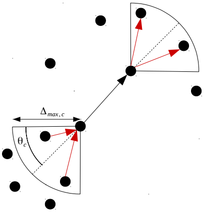
- Similar second connector cleaning.

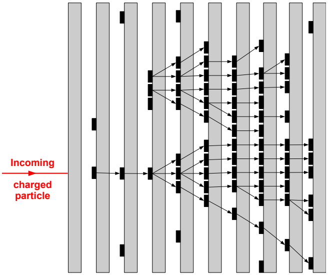
One difference : cleaning performed layer per layer starting from the last one, with $\delta = 2$

$\rightarrow$ Connector aligned with forward connections.

+

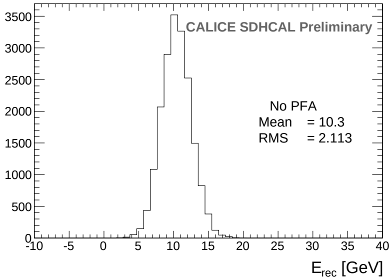
$\rightarrow$ Tree structure !

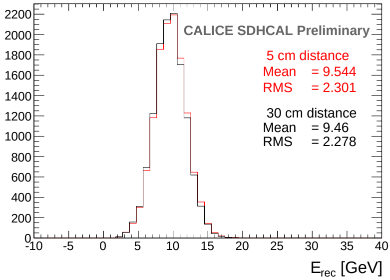




Backup

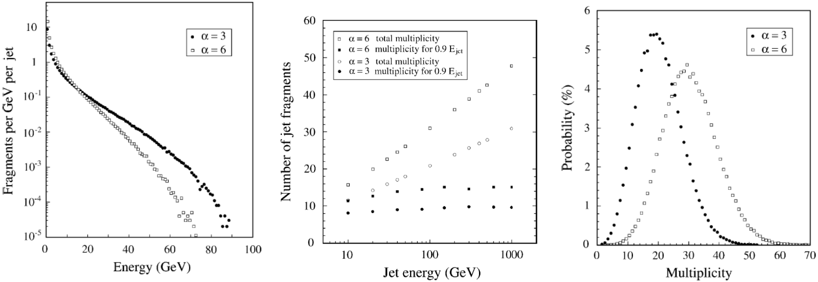
Overlaid hits approximation





Backup

100 GeV jets statistics



O. Lobban, A. Sriharan, R. Wigmans, NIM. **A495** (2002) 107-120