Status of Arbor PFA development for SDHCAL and ILD

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Status of SDHCAL ArborPFA

- CAN-054 : *Nearby showers separation within SDHCAL prototype detector using ArborPFA*
- Publication ongoing (JINST) (+ simulation)

Abstract

A new reconstruction algorithm called ArborPFA is developed to separate close-by hadronic showers in the SDHCAL prototype. This intends to demonstrate the capability of high granularity hadronic calorimeters such as the SDHCAL to apply efficiently the Particle Flow Algorithms in the future ILC experiments. The reconstruction algorithm we present here uses the tree structure features of the hadronic showers, that high granular calorimeters reveal, to associate clusters belonging to each hadronic shower and to reduce the confusion between two close-by showers. The results of these studies indicate a good single particle efficiency and powerful separation down to 5 cm of separation distance.

Status of SDHCAL ArborPFA

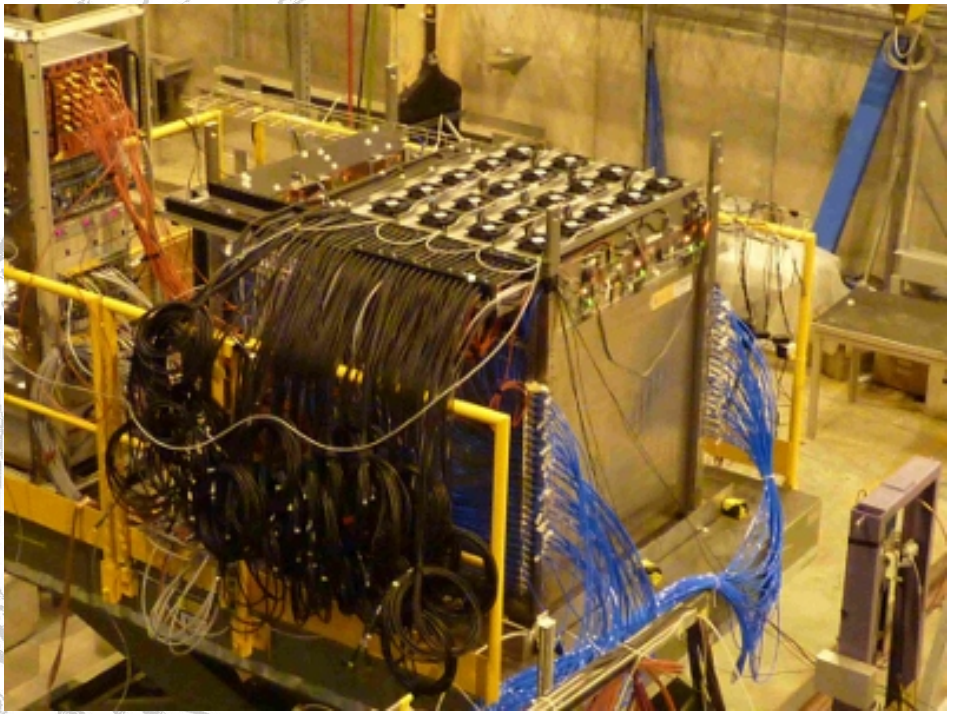
Semi Digital Hadron CALorimeter
$\sim$ 48 GRPC layers ($\sim$ m^3)
3 charge thresholds

Energy reconstruction :

$$E_{rec} = \alpha(N_{hit}).N_1 + \beta(N_{hit}).N_2 + \gamma(N_{hit}).N_3$$

χ^2 minimization from 10 GeV to 80 GeV for simulation and test beam data **separately**

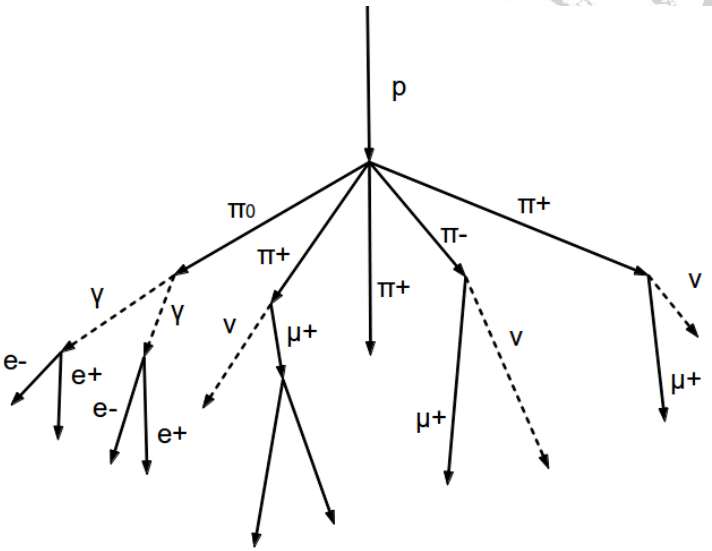
Event reconstruction, pion event selection according to SDHCAL prototype construction note.

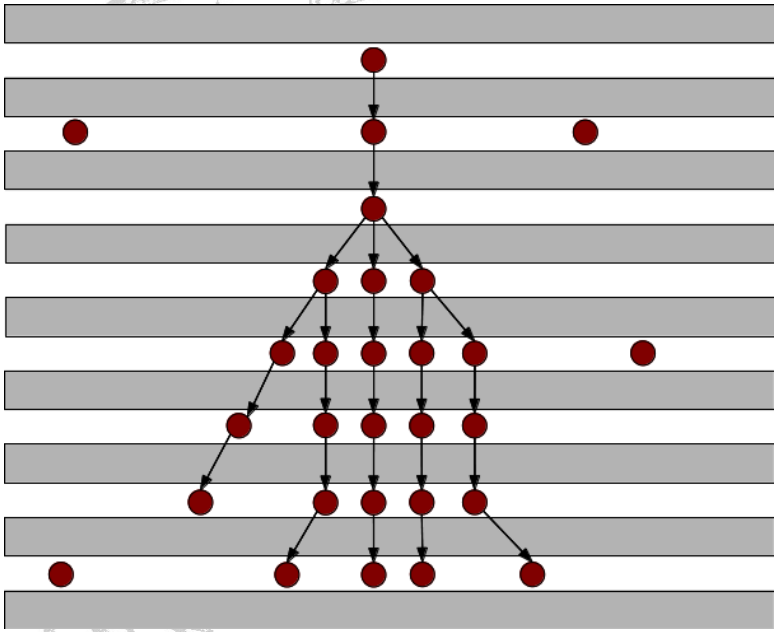


ArborPFA

Principle

Shower $\Longleftrightarrow$ Tree structure





Uses **PandoraSDK** as development toolkit and **Marlin** as running framework.

SDHCAL - ArborPFA

SDHCAL Arbor algorithms

SDHCAL ArborPFA release v01-04-00

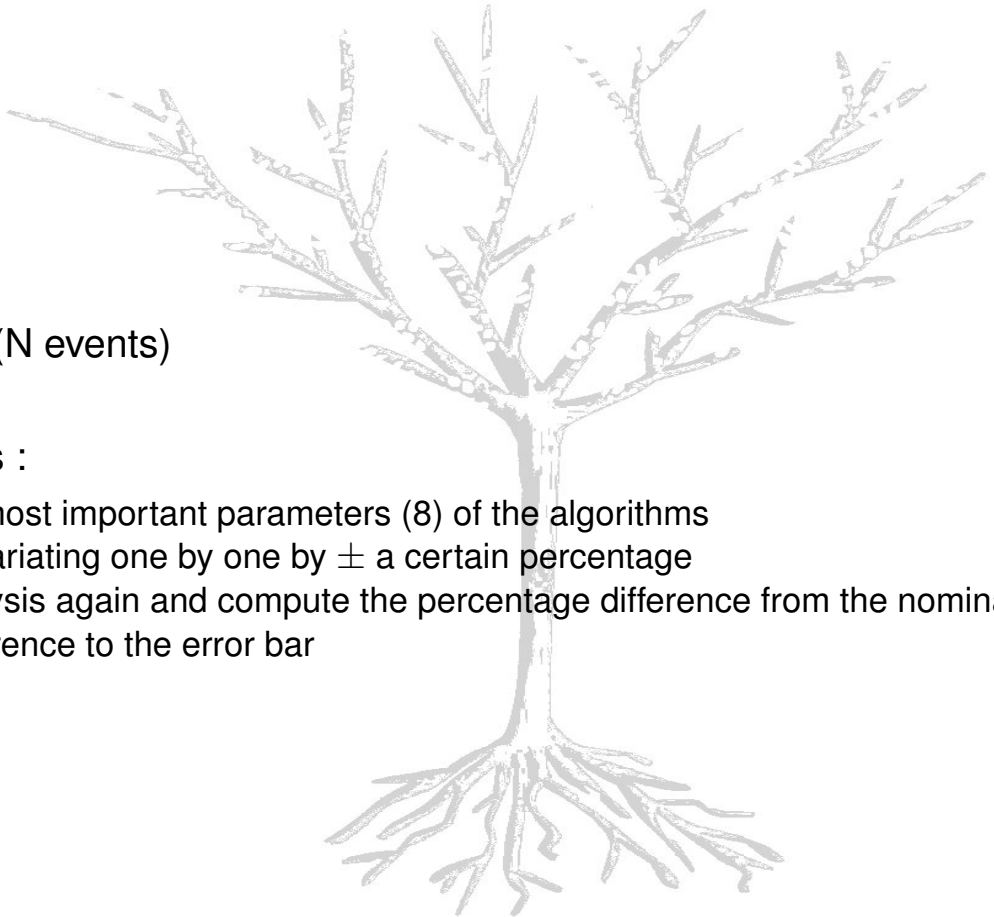
→ `https://github.com/ArborPFA/SDHCALArborPFA`

Dedicated version of SDHCAL prototype only !

1. Object Creation
2. Mip track CandidateTagging
3. Connector Clustering Algorithm
    1. Connector Iteration Algorithms
        1. Primary Track Finder (local seeding and cleaning)
        2. Connector Seeding 1
        3. Connector Cleaning 1
        4. Connector Seeding 2
        5. Connector Cleaning 2
    2. Tree Building
    3. Association Algorithms
        1. Energy Driven Track Association [E]
        2. Pointing Cluster Association [E]
        3. Neutral Tree Merging
        4. Small Neutral Merging
4. Pfo Creation

Analysis

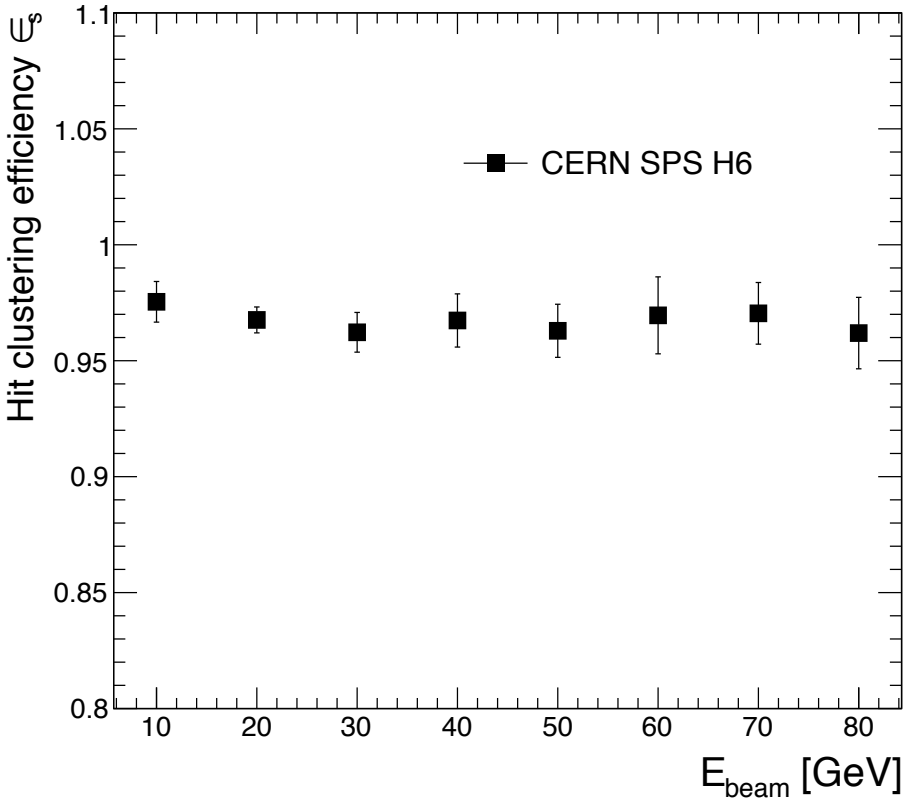
A word on error bars

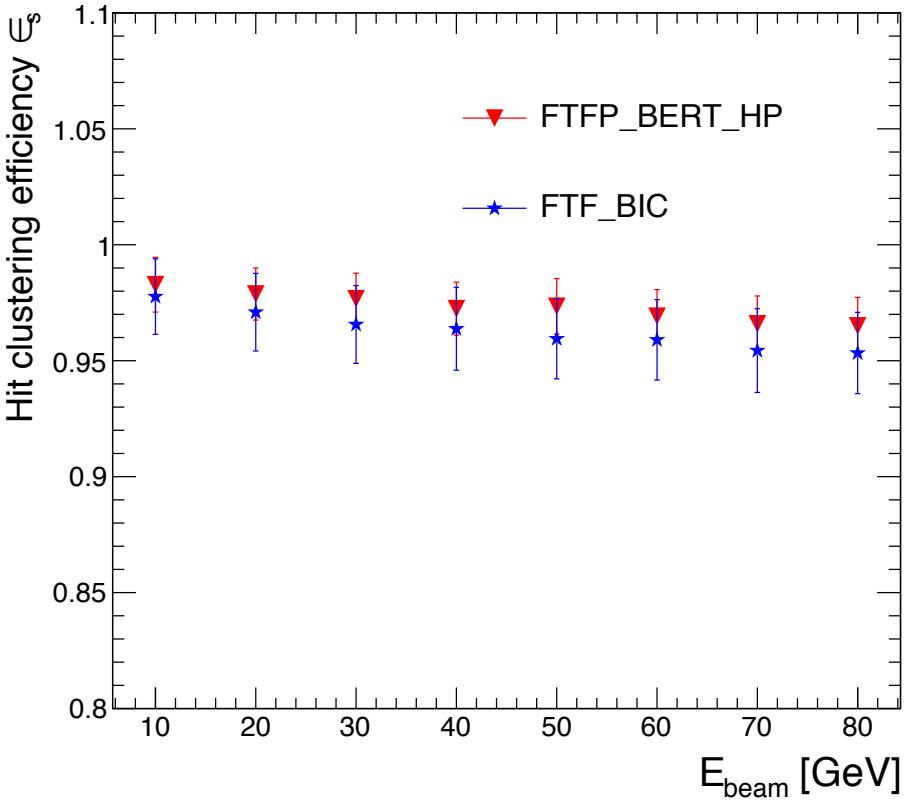


- Statistical errors (N events)
- Systematic errors :
  - Choose the most important parameters (8) of the algorithms
  - Make them variating one by one by $\pm$ a certain percentage
  - Run the analysis again and compute the percentage difference from the nominal value
  - Add this difference to the error bar

Analysis

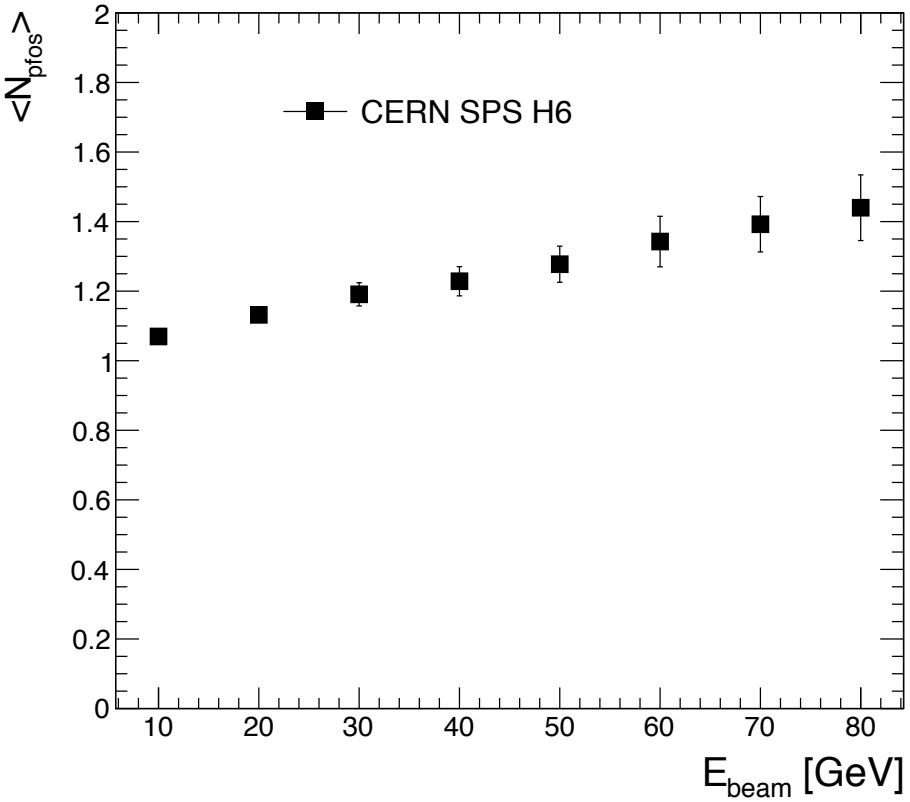
Efficiency

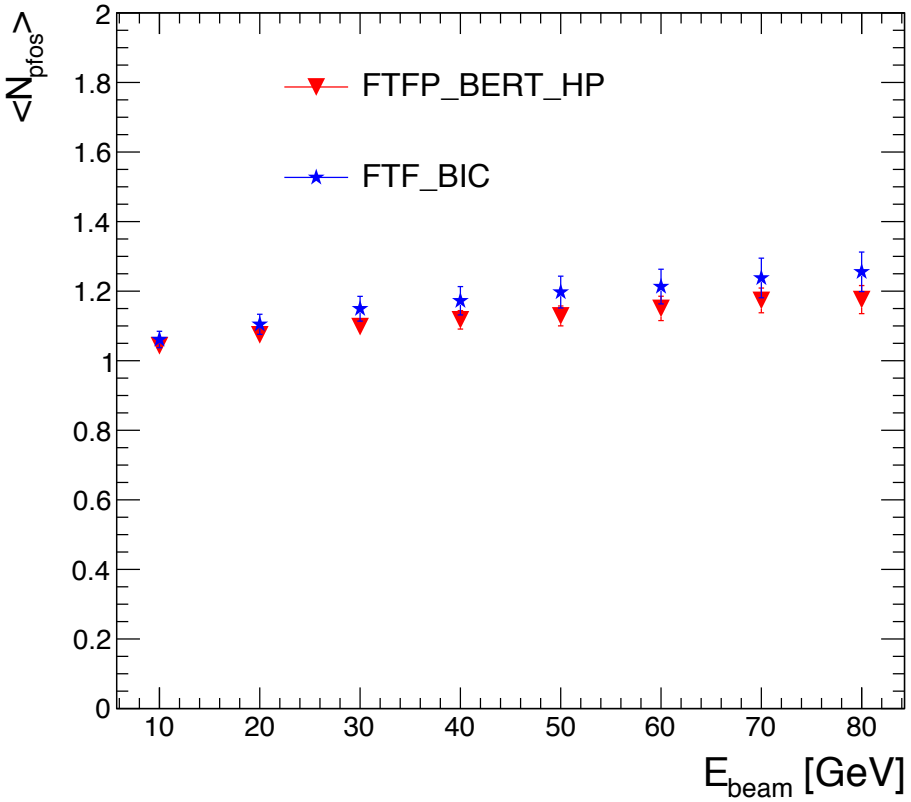




Analysis

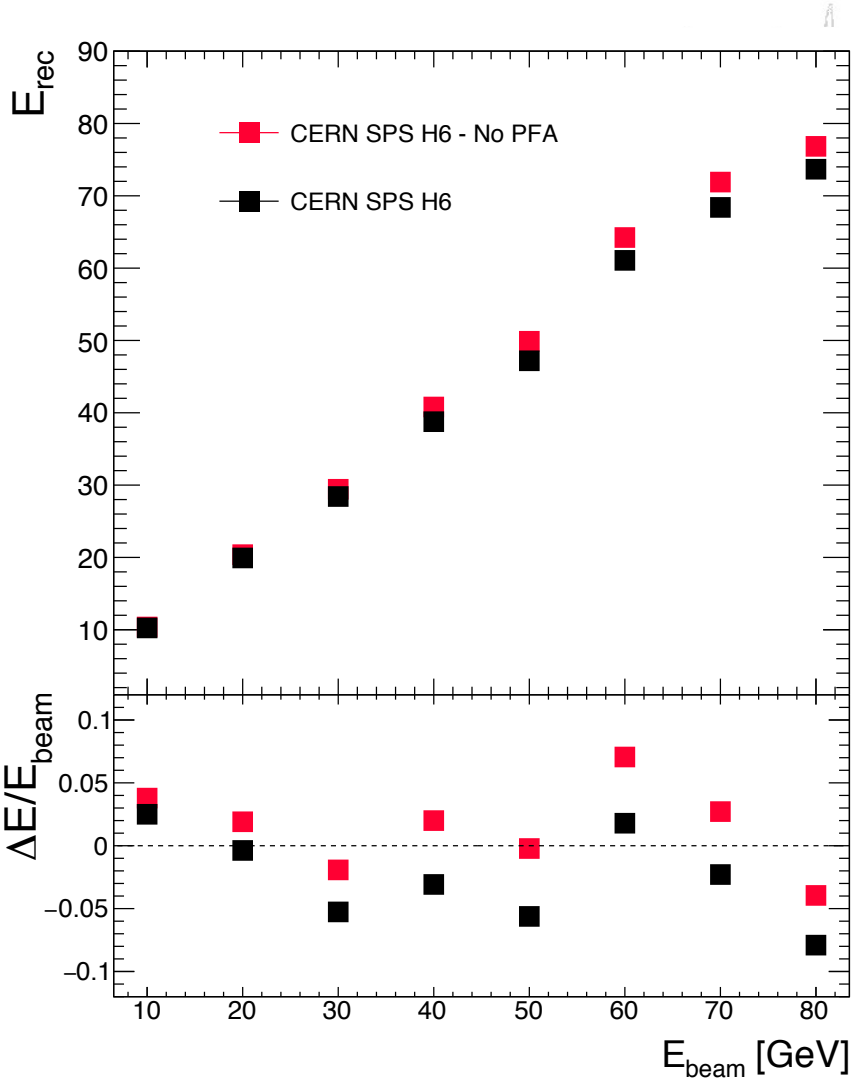
Number of PFOs

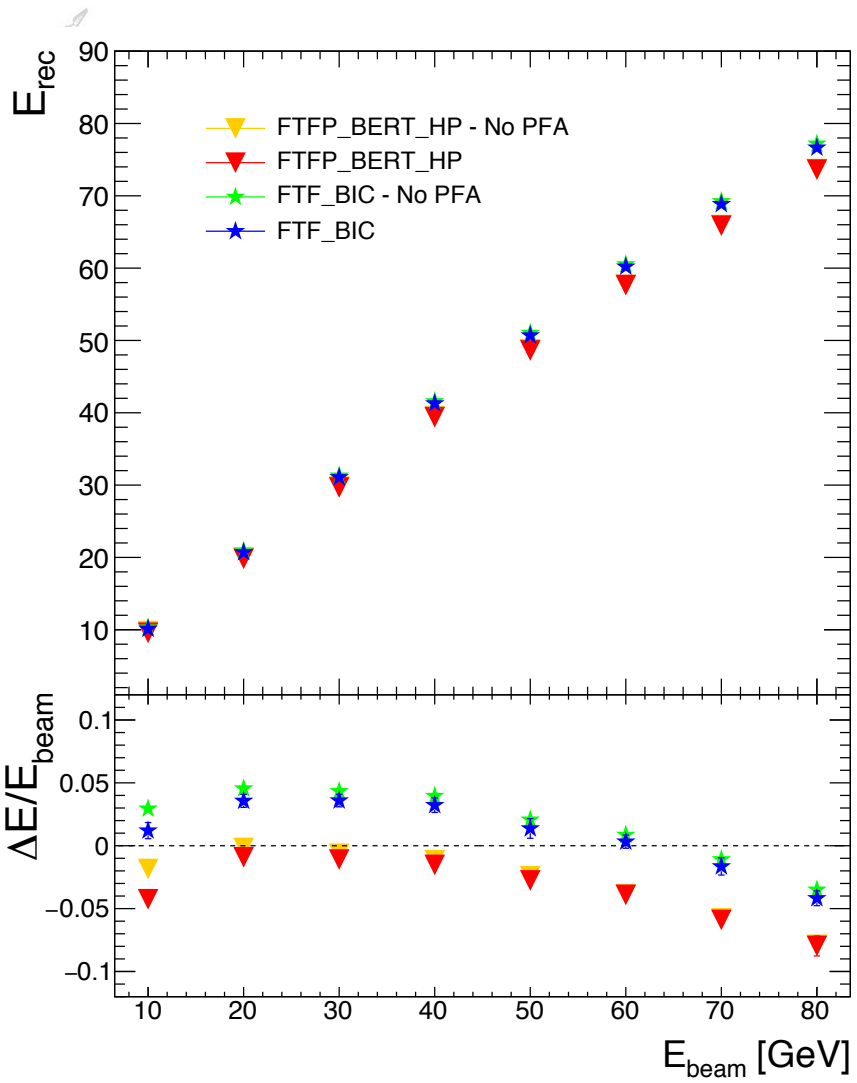




Analysis

Reconstructed energy





Analysis

Overlay event

Overlay pion shower events :

- Find entering point of both showers
- Shift the shower in Y direction by $\pm$d wrt calorimeter center
- Identify track segment hits of one of the two pions and remove them (neutral)
- Merge hits in the same collection + tag hits by shower id
- Overlaid hits : highest threshold chosen

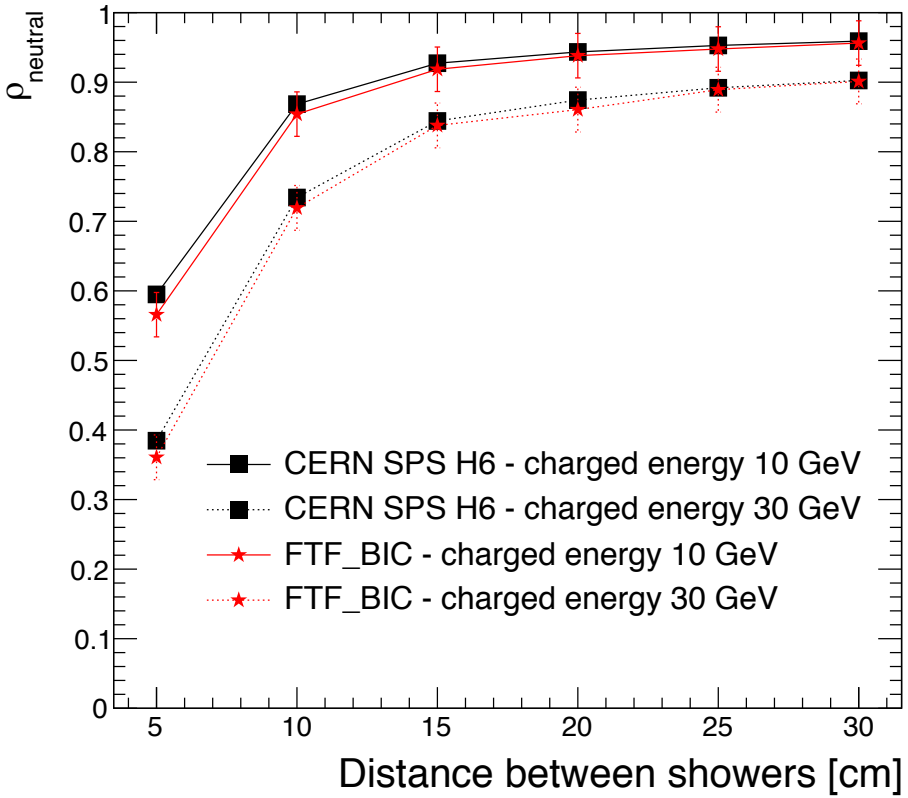
No effect on reconstructed energy after overlay

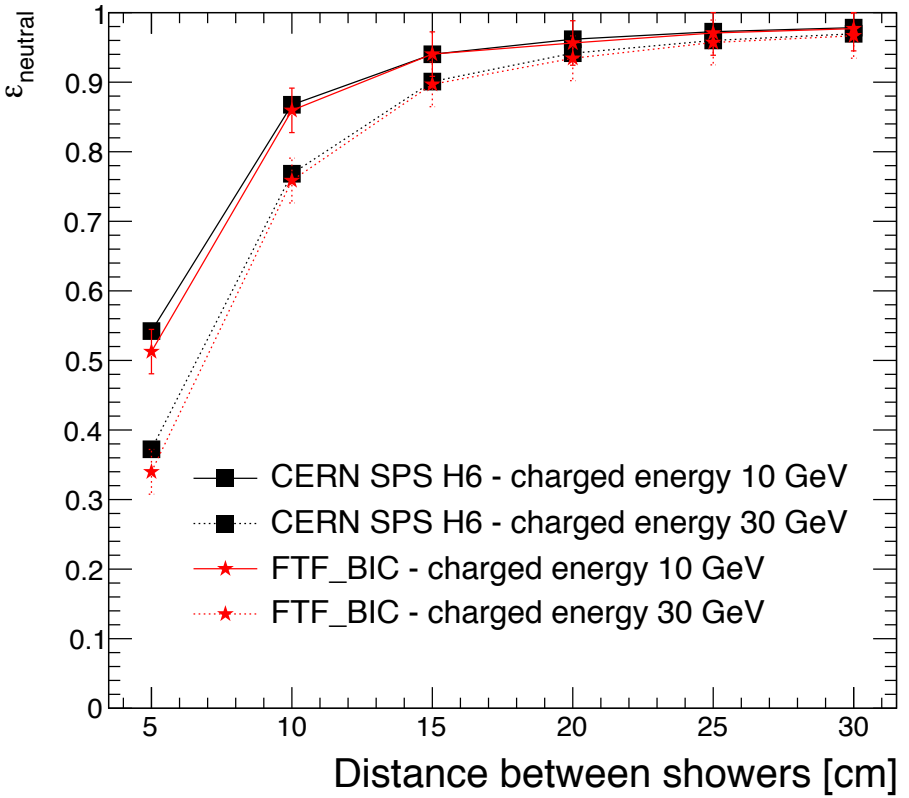
Track generation similar to single particle.
Observables as performance estimator :

- Efficiency
- Purity
- N_{pfos}
- $P_{n>0}$
- Mean E_{rec}-E_{meas}

Analysis

Overlay event- Efficiency and purity

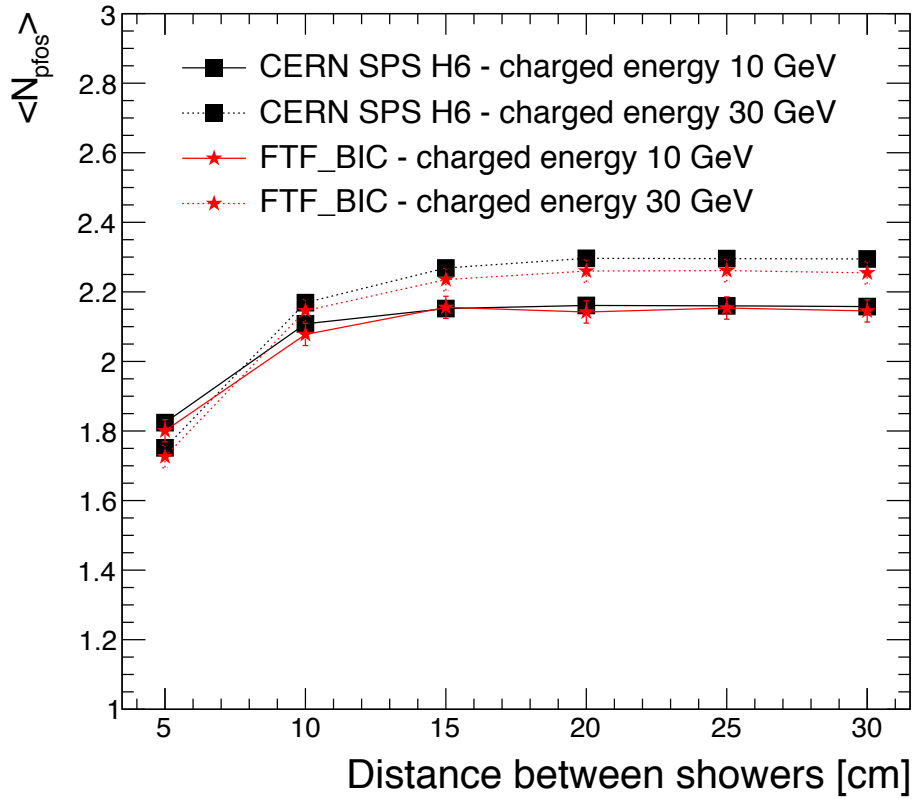




SmallNeutralTreeMerging effect visible on purity.
Using the distance between parent and daughter trees, no energy information (that should be used here !)

Analysis

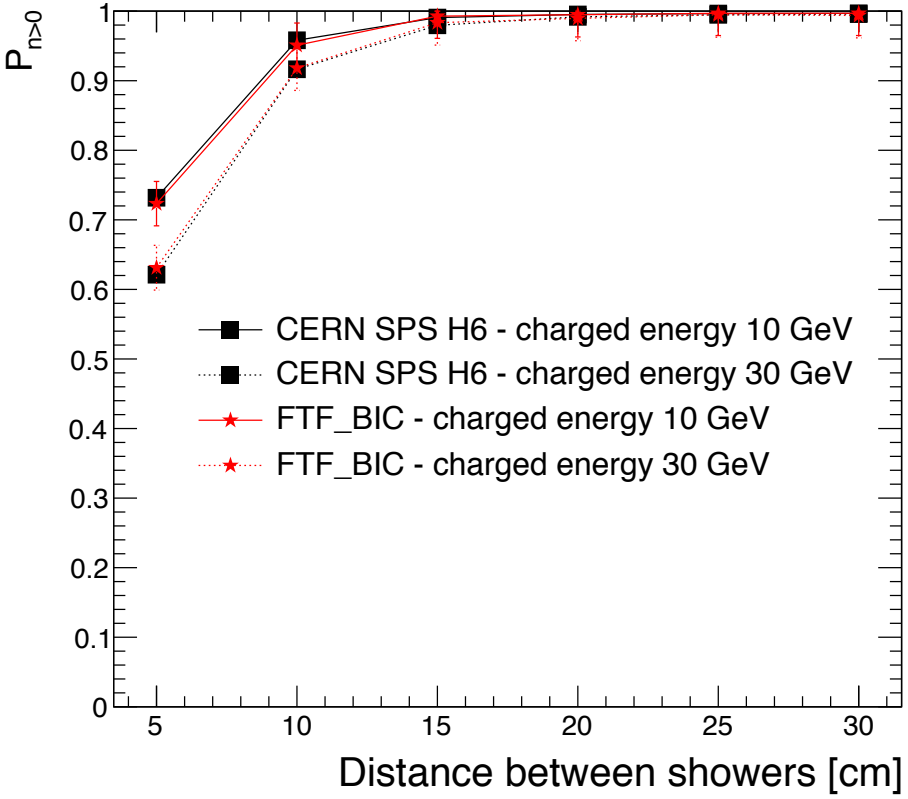
Overlay event- Number of PFOs

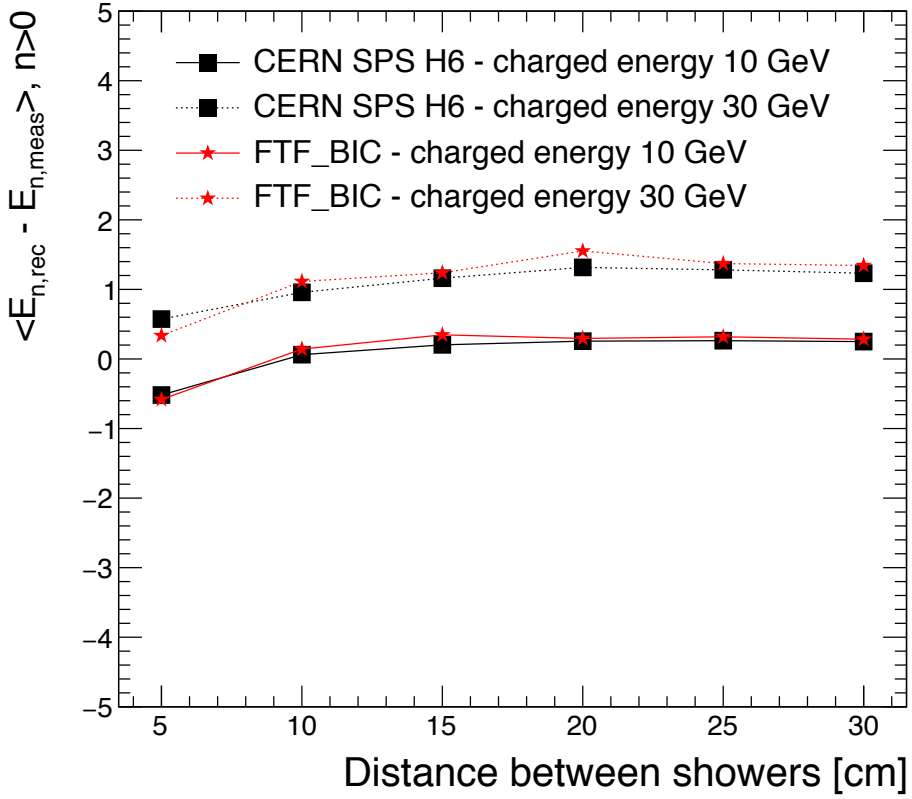


Compatible with $N_{pfo,n,single} + N_{pfo,ch,single}$ at large distance.
As expected decreasing with the separation distance

Analysis

Overlay event

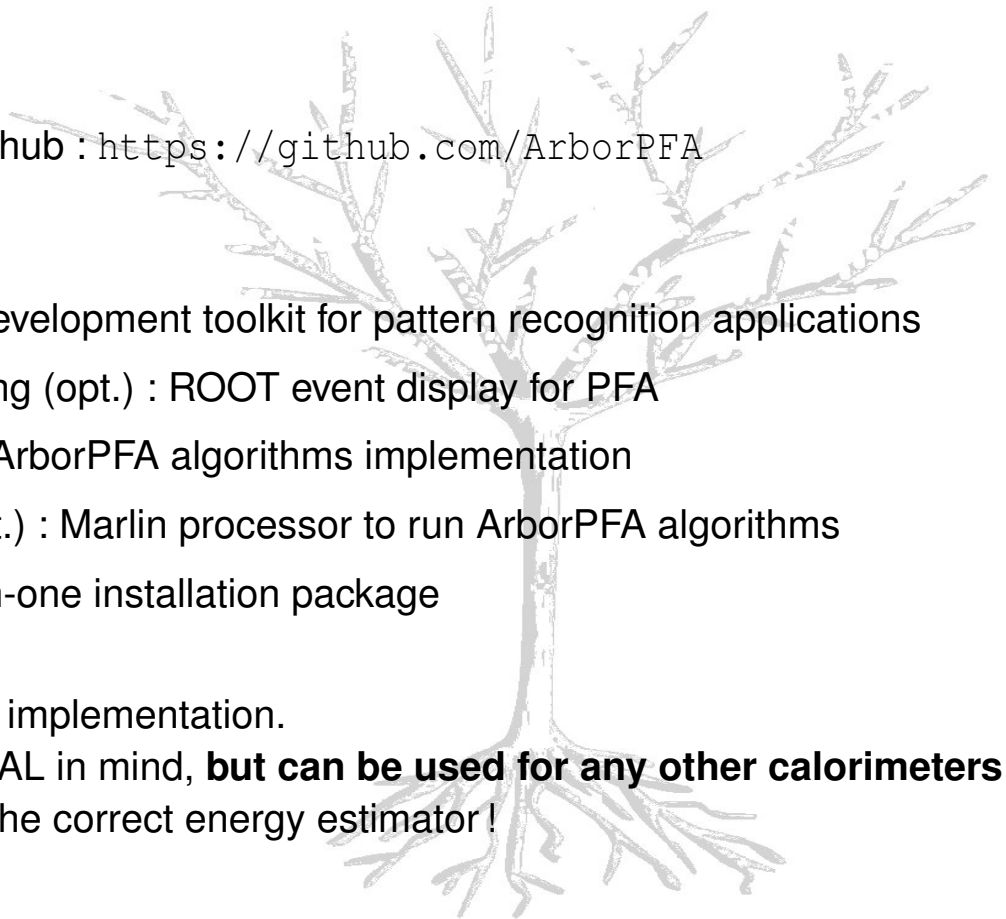




- 10 GeV neutral + 30 GeV charged : still 60% of neutral recovery
- Binary-like behavior at small separation distances : good separation or complete merging (event topology)

ILD - ArborPFA

Current status- packages



Software hosted on github : `https://github.com/ArborPFA`

Sub-packages :

- PandoraSDK : Development toolkit for pattern recognition applications
- PandoraMonitoring (opt.) : ROOT event display for PFA
- **ArborContent** : ArborPFA algorithms implementation
- **MarlinArbor** (opt.) : Marlin processor to run ArborPFA algorithms
- **ArborPFA** : All-in-one installation package

Full size HEP detector implementation.
Developed with SDHCAL in mind, **but can be used for any other calorimeters**
$\rightarrow$ Need to switch-on the correct energy estimator !

Still in development ...

ILD - ArborPFA

Current status- Algorithms

Basic algorithms from SDHCAL ArborPFA kept and modified to match a full size HEP detector.

Additional features :

- Connector seeding completely reviewed to be more generic
  - Same implementation in ECal and HCAL. (Use granularity and cell size to differentiate them)
  - Gap crossing handled by pseudo layer calculation (better for HCal Ring region !)
  - No more dependencies on longitudinal distances in algorithms -> massive use of pseudo-layering !
  - Dedicated connector seeding for charged and neutral particles
- Neutral fragment removal currently being reviewed
- **Re-Clustering recently added !** Recluster when :
  - Missing energy in charged cluster
  - Energy excess in charged cluster

No physics performance plots for the moment.
To come very soon :

- Jet energy resolution
- SDHCAL energy calibration

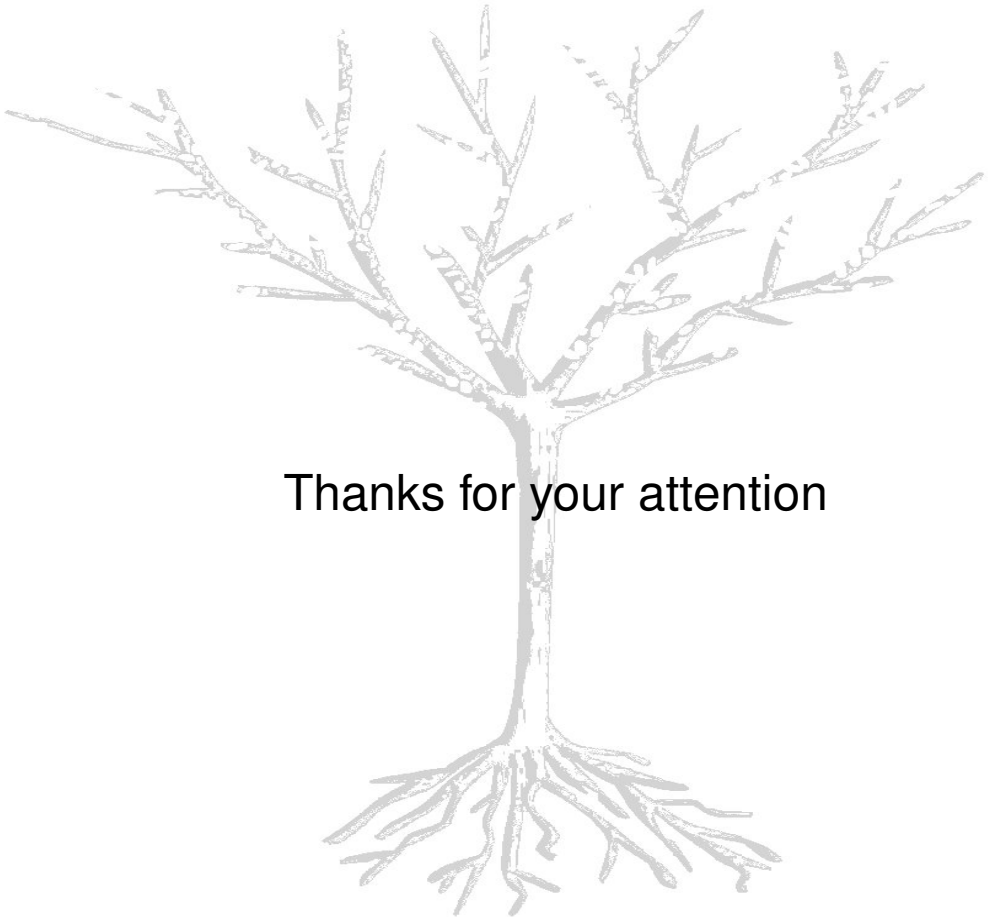
Conclusion and foreseen work

Conclusion :

- SDHCAL ArborPFA implementation :
  - Algorithms behavior understood
  - Overlaid particles separation showed good results until 5 cm -> will be improved by using re-clustering
  - Comparison between Monte-Carlo and beam-test data is consistent
- ArborPFA for full size HEP detectors :
  - Algorithms re-structured for ECal and gap crossing regions (ECal barrel -> ECal endcap -> HCal ring -> HCal barrel)
  - Re-clustering functionalities added with two implementations -> More to come
  - Still in development -> physics results to come very soon

Current and foreseen work :

- Paper submission for SDHCAL ArborPFA results soon
- Full size HEP detectors implementation :
  - Corrections on fragment removal needed
  - Topological reclustering (no energy information) to come
  - Physics performance using ILD_v05_o2 (SDHCAL) : JER, JES, confusion extraction (perfect PFA)
  - DD4HEP : Geometry OK (T. Kurca), need SDHCAL digitizer (G. Grenier) to move on DDMarlinArbor



Thanks for your attention