Simulation, reconstruction and testbeam preparations

G.Mavromanolakis, University of Cambridge

Outline

- **General**
- **Simulation studies**
- **Clustering algorithm**
- **Testbeam preparation**

General - Activities

- **. Simulation**
  - : survey of various shower models in GEANT4 and GEANT3, systematic studies/comparisons for CALICE proto geometries
- **. Reconstruction**
  - : develop advanced pattern recognition algorithm for efficient calorimeter clustering
- **. Testbeam preparation**
  - : work on implementation of suitable data model
  - : design graphical user interface for monitoring/event display

Simulation

- simulation studies focused on CALICE ECAL and HCAL prototypes, to support and guide the testbeam program

- in general, studies reveal significant discrepancies among shower packages, thus preventing model independent predictions on calorimeter performance and reliable detector design optimization

- one of the main goals of the CALICE testbeam program is to resolve the situation and reduce the current large uncertainty factors

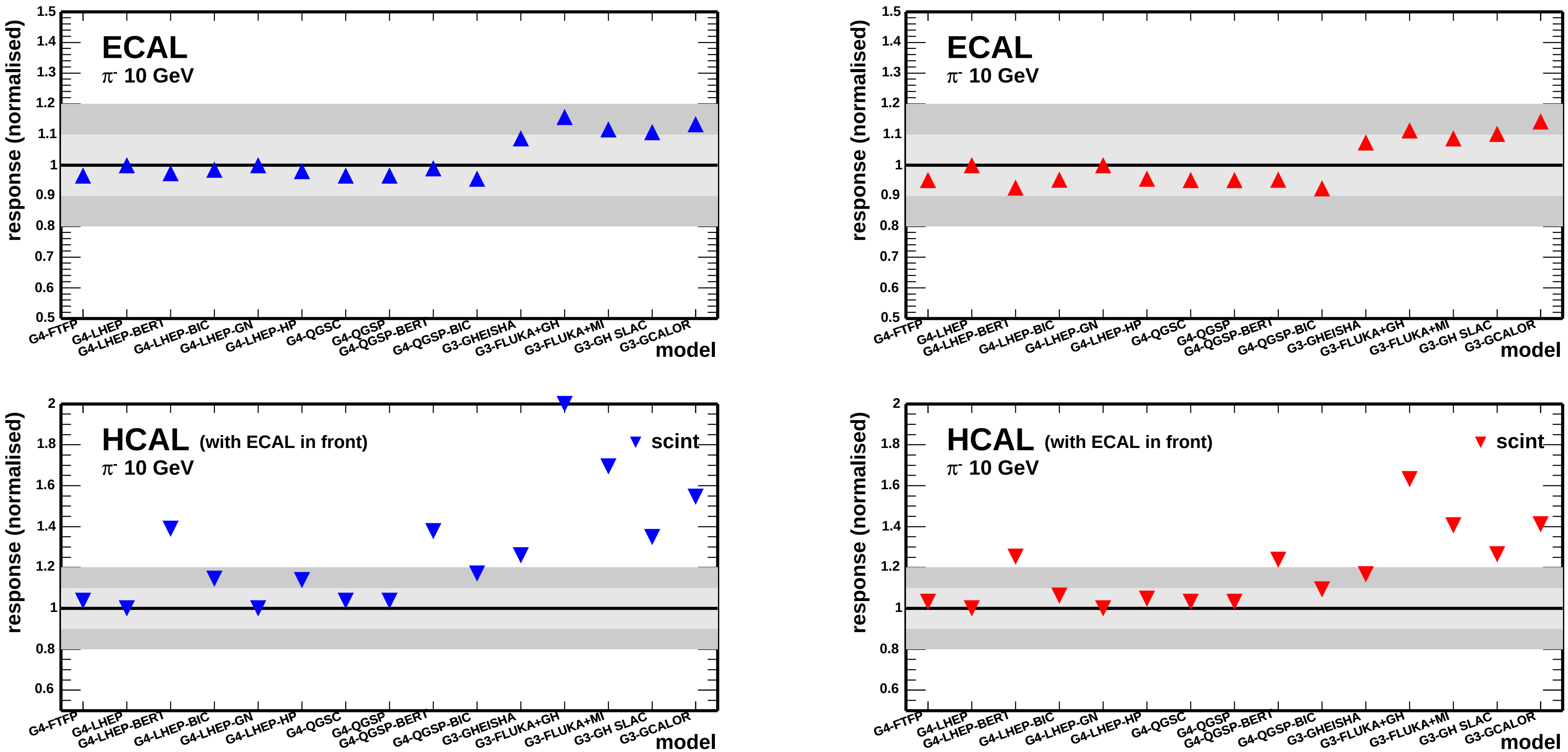
  - within this context, a proposal has been made to expose the ECAL alone to hadronic beam for inclusive measurement of shower

model tag		brief description
G3-GHEISHA	:	GHEISHA
G3-FLUKA+GH	:	FLUKA, for neutrons with $E <$ 20 MeV GHEISHA
G3-FLUKA+MI	:	FLUKA, for neutrons with $E <$ 20 MeV MICAP
G3-GH SLAC	:	GHEISHA with some bug fixes from SLAC
G3-GCALOR	:	$E <$ 3 GeV Bertini cascade, 3 $< E <$ 10 GeV hybrid Bertini/FLUKA, $E >$ 10 GeV FLUKA, for neutrons with $E <$ 20 MeV MICAP
G4-LHEP	:	GHEISHA ported from GEANT3
G4-LHEP-BERT	:	$E <$ 3 GeV Bertini cascade, $E >$ 3 GeV GHEISHA
G4-LHEP-BIC	:	$E <$ 3 GeV Binary cascade, $E >$ 3 GeV GHEISHA
G4-LHEP-GN	:	GHEISHA + gamma nuclear processes
G4-LHEP-HP	:	as G4-LHEP, for neutrons with $E <$ 20 MeV use evaluated cross-section data
G4-QGSP	:	$E <$ 25 GeV GHEISHA, $E >$ 25 GeV quark-gluon string model
G4-QGSP-BERT	:	$E <$ 3 GeV Bertini cascade, 3 $< E <$ 25 GeV GHEISHA, $E >$ 25 GeV quark-gluon string model
G4-QGSP-BIC	:	$E <$ 3 GeV Binary cascade, 3 $< E <$ 25 GeV GHEISHA, $E >$ 25 GeV quark-gluon string model
G4-FTFP	:	$E <$ 25 GeV GHEISHA, $E >$ 25 GeV quark-gluon string model with fragmentation ala FRITJOF
G4-QGSC	:	$E <$ 25 GeV GHEISHA, $E >$ 25 GeV quark-gluon string model

G3: GEANT3.21 G4: GEANT4.6.1 with hadronic physics list PACK 2.5

ECAL+HCAL scint "response" vs model, π^- 10 GeV

N cells hit | **E deposited**

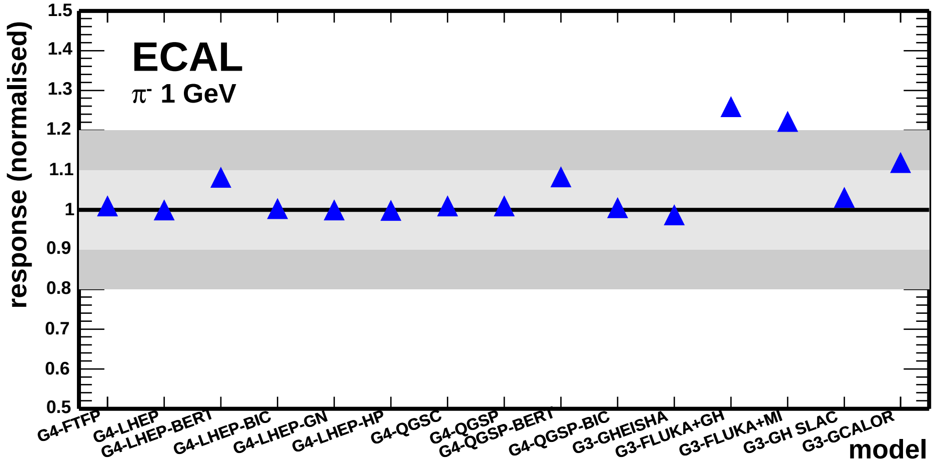


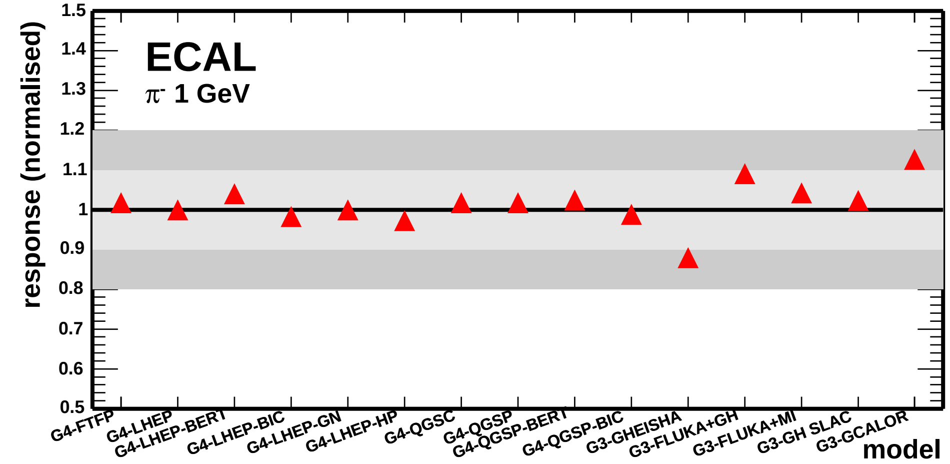
- ▷ different models predict different calorimeter response
- ▷ HCAL more sensitive than ECAL
- ▷ EM discrepancies between frameworks seen by ECAL

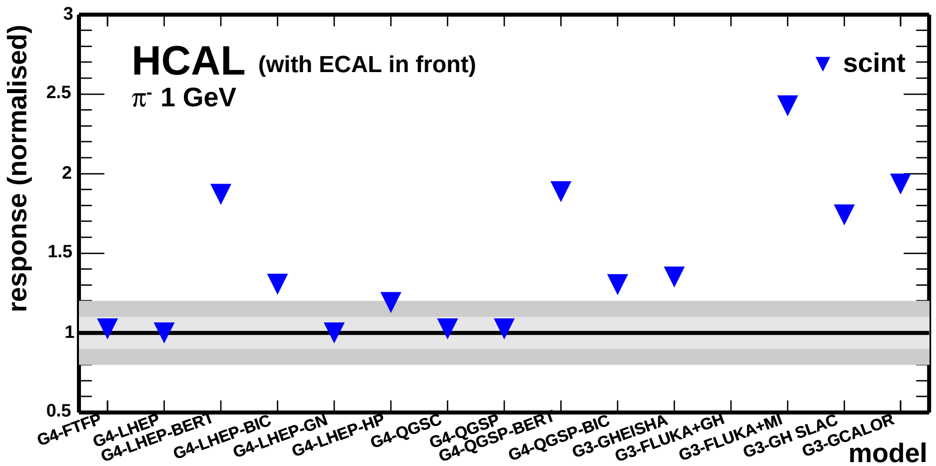
ECAL+HCAL scint "response" vs model, π^- 1 GeV

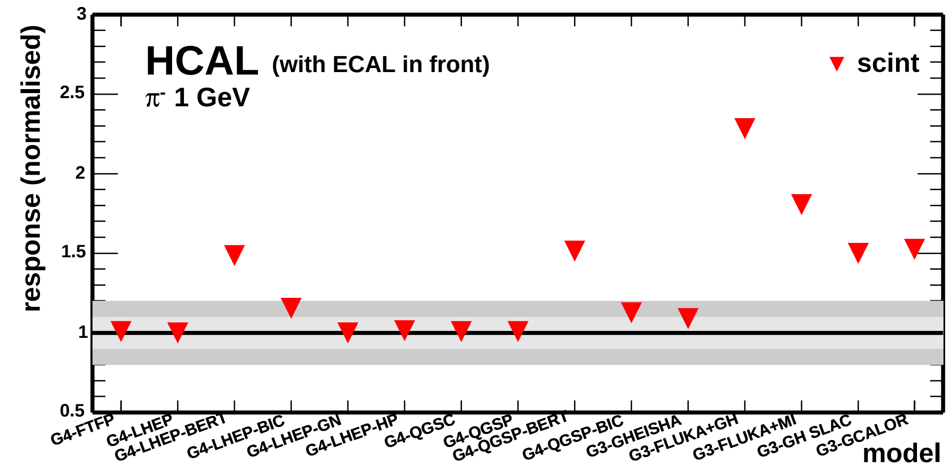
N cells hit

E deposited





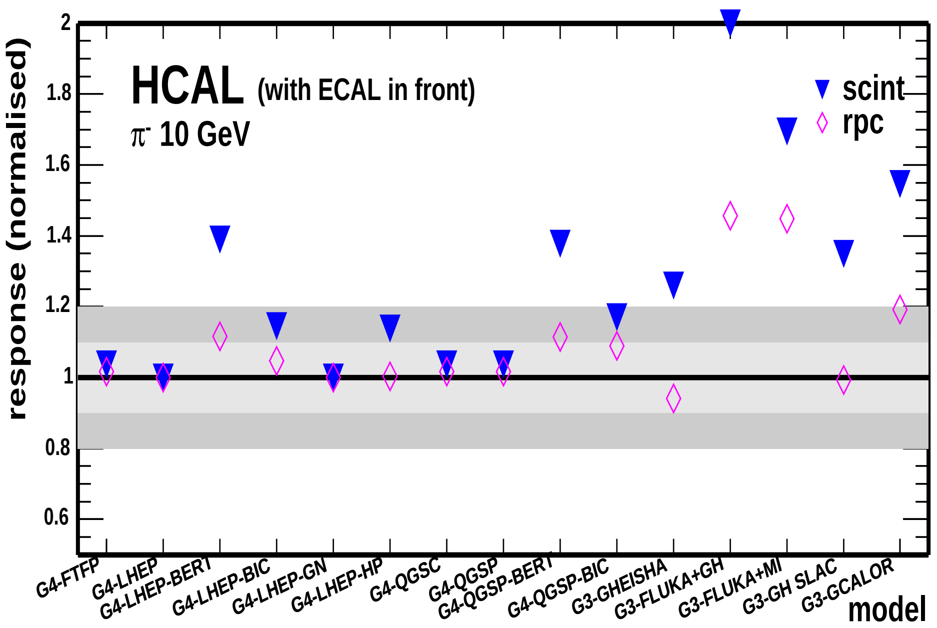




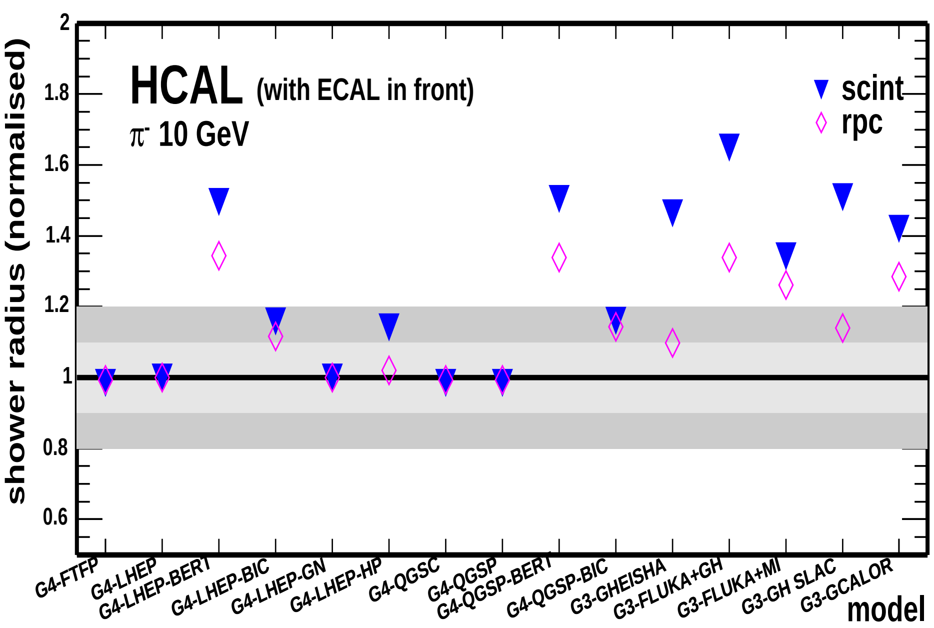
- ▷ **same pattern as at 10 GeV case, even more pronounced**
- ▷ **ECAL standalone may have some discriminating power**

HCAL rpc – HCAL scint

N cells hit



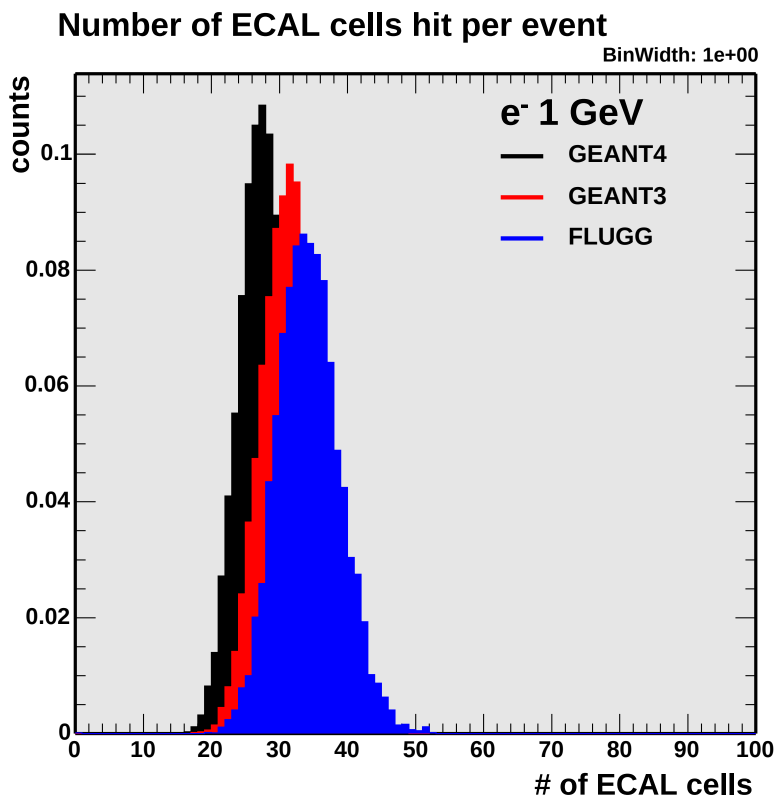
shower width



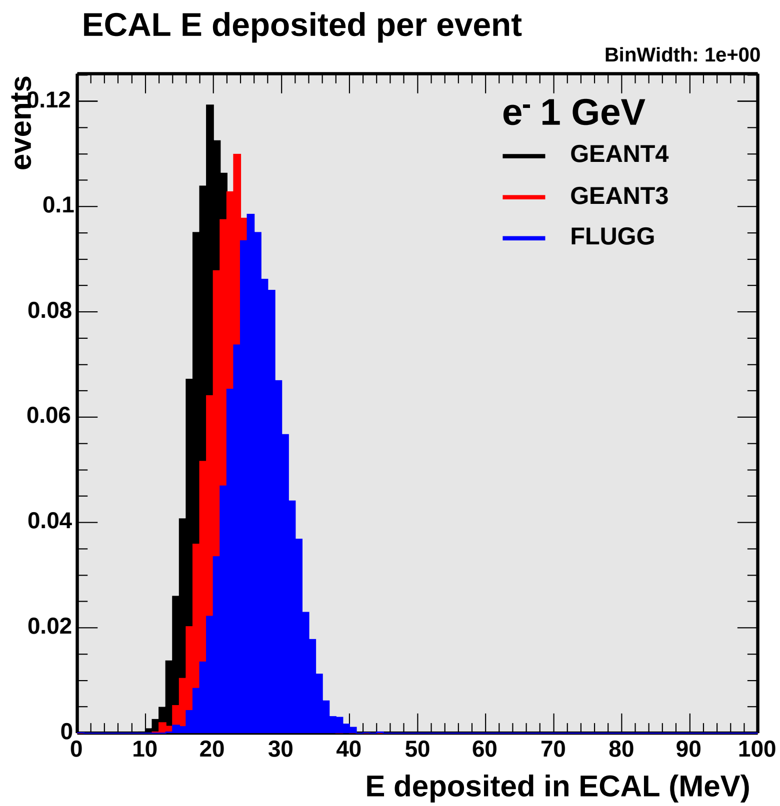
▷ **HCAL rpc less sensitive to low energy neutrons than HCAL scint**

discrepancies between frameworks at em level

N cells hit



E deposited

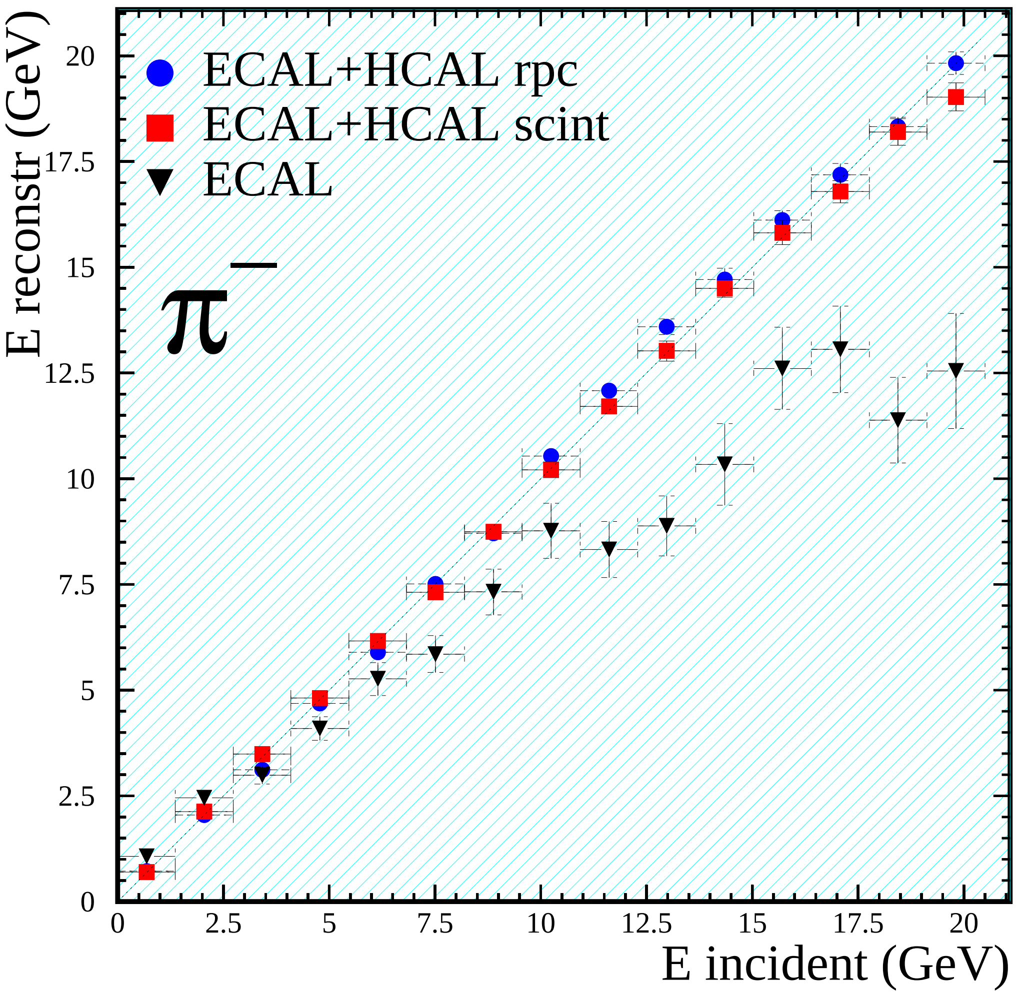


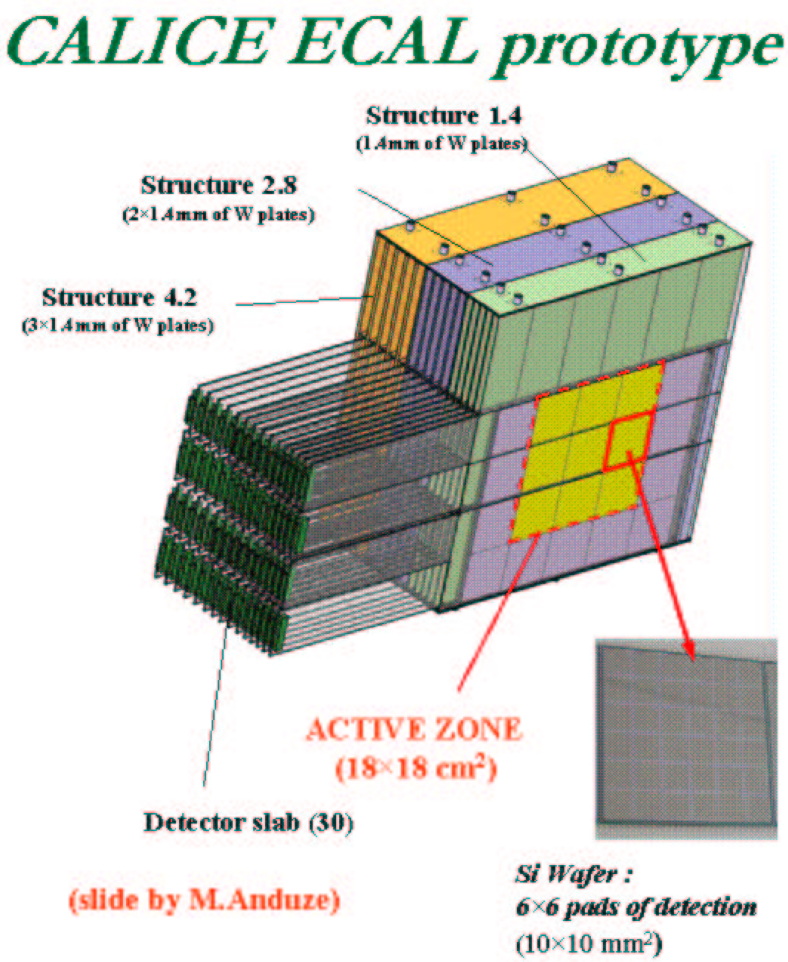
GEANT3 14% higher than GEANT4

FLUGG 24% higher than GEANT4

GEANT3 14% higher than GEANT4

FLUGG 30% higher than GEANT4

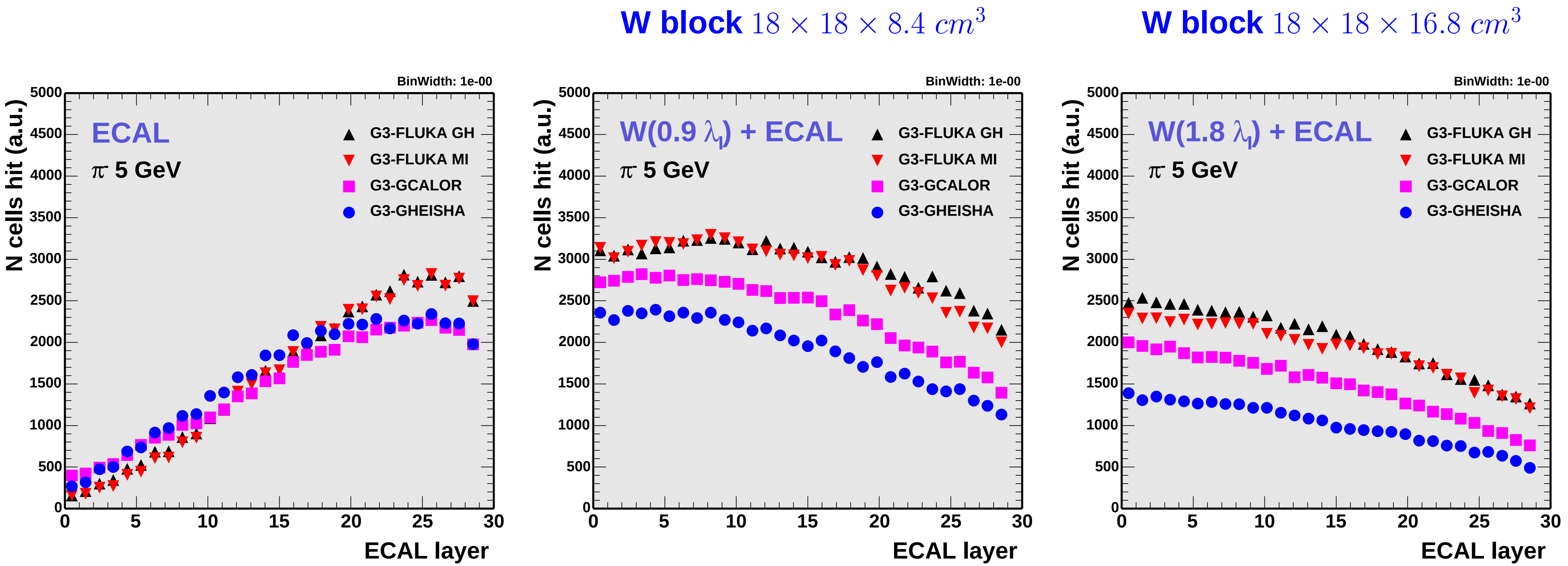




(slide by M.Anduze)

- ▷ **combine ECAL+HCAL to study hadronic shower development**
- ▷ **is it worth exposing ECAL alone to lower energy hadrons?**

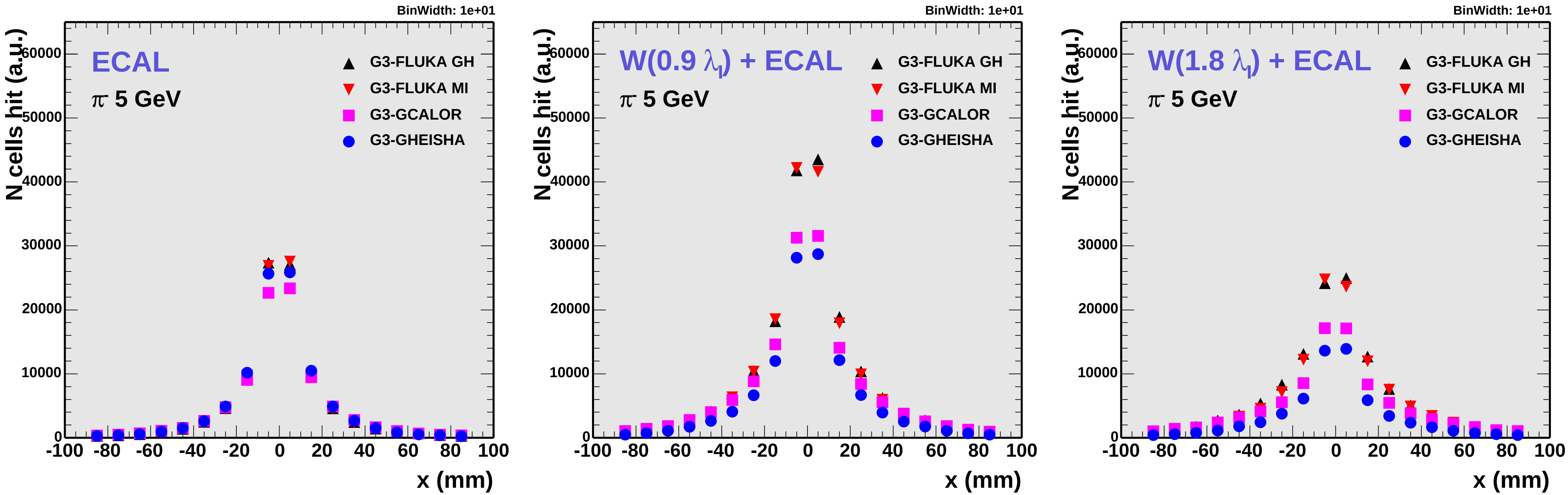
shower longitudinal profile by W block + ECAL



- ▷ differences among models start to show up at the end of ECAL
- ▷ use W block to have similar shower development as in ECAL
- ▷ models clearly distinguishable with block of W in front of ECAL
- ▷ combine "photos" to reveal inclusive longitudinal profile

shower transverse profile by W block + ECAL

W block $18 \times 18 \times 8.4\ cm^3$ W block $18 \times 18 \times 16.8\ cm^3$



- ▹ **front face $18 \times 18\ cm^2$ segmented into $1 \times 1\ cm^2$ cells, sufficient to record shower's core**
- ▹ **differences more pronounced with a block of matter in front of ECAL**

Calorimeter clustering

▶ . **particle flow paradigm**

: highly granular em and hadr calorimeters to allow very efficient pattern recognition for excellent shower separation and pid within jets to provide excellent jet reconstruction efficiency

▶ .

: software development (**calorimeter clustering, track finding, track-shower matching**) to play a very crucial role

▶ . **current activity**

: algorithm based on MST theory has been developed to exploit a "top-down and then bottom-up" approach to calorimeter clustering

Introduction – theory

▸ **minimal spanning tree**

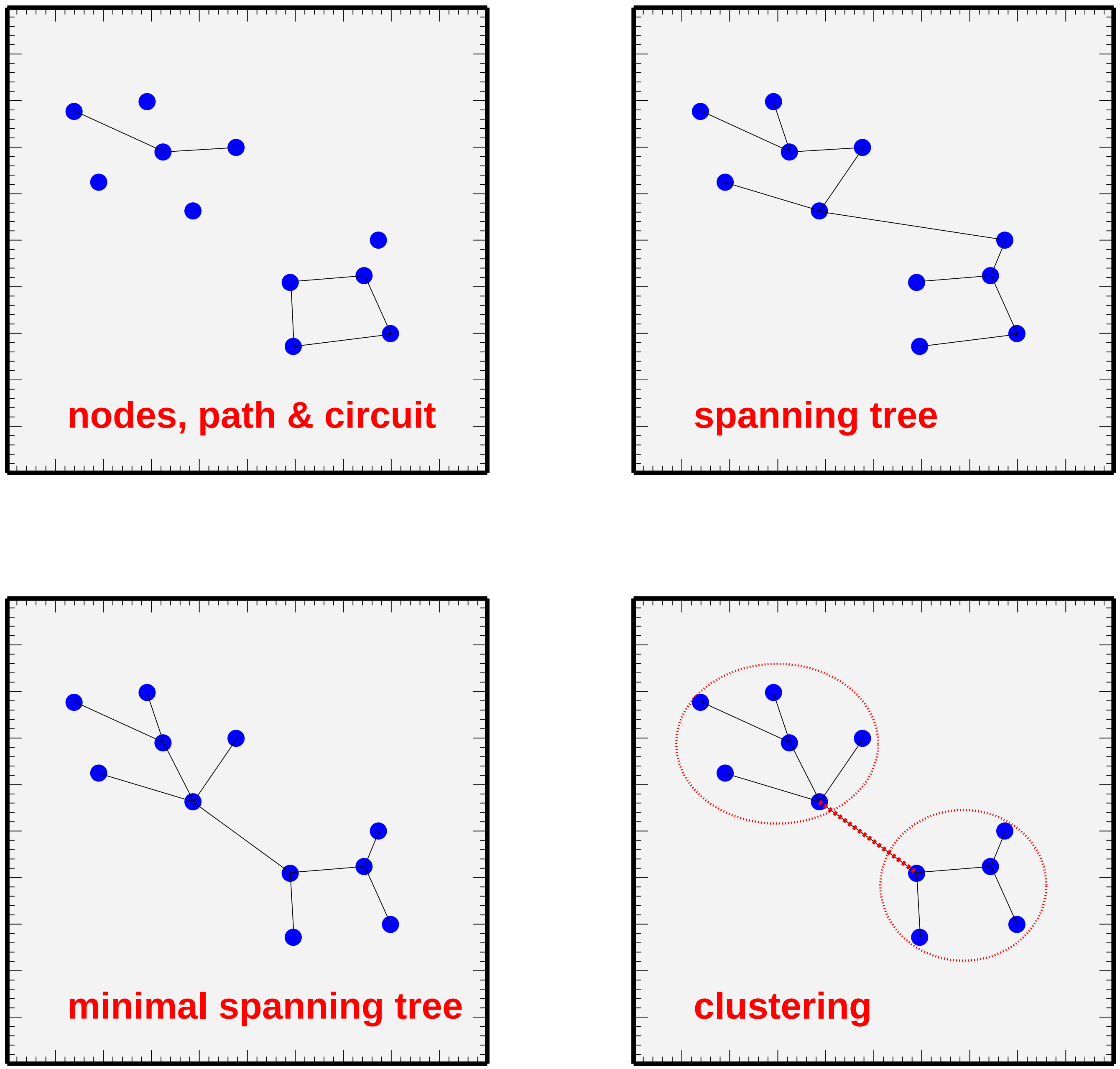
: a tree which contains all nodes with no circuits and of which the sum of weights of its edges is minimum

▸ **properties**

: unique for the given set of nodes and the chosen metric

: deterministic, no dependence on random choices of nodes

: invariant under similarity transformations that preserve the monotony of the metric


nodes, path & circuit
spanning tree
minimal spanning tree
clustering

MST Clustering – Main steps

▶. metric

define a metric	:	metric defines configuration space
	:	not necessarily euclidean
fill distance matrix	:	lower triangular N^2 matrix

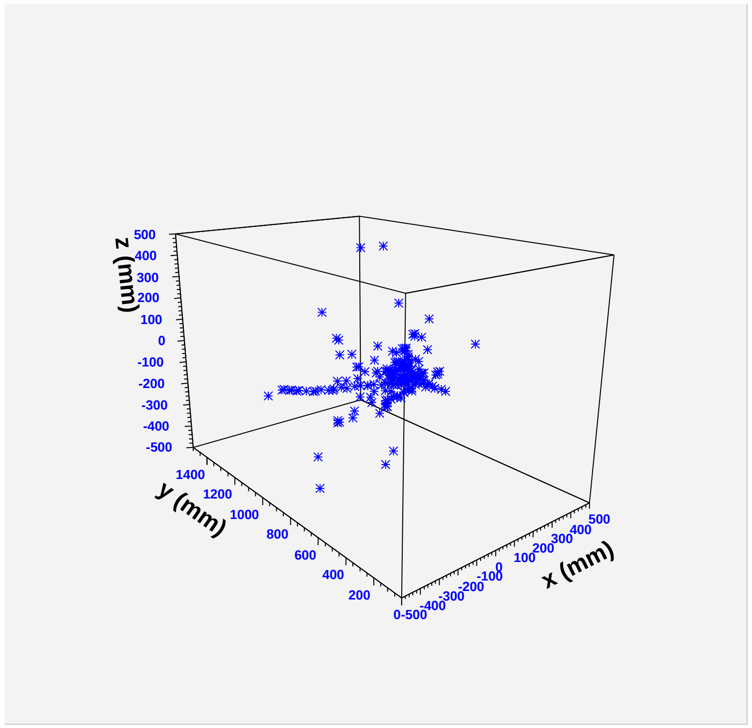
▶. MST

construct the MST	:	apply Prim's algorithm

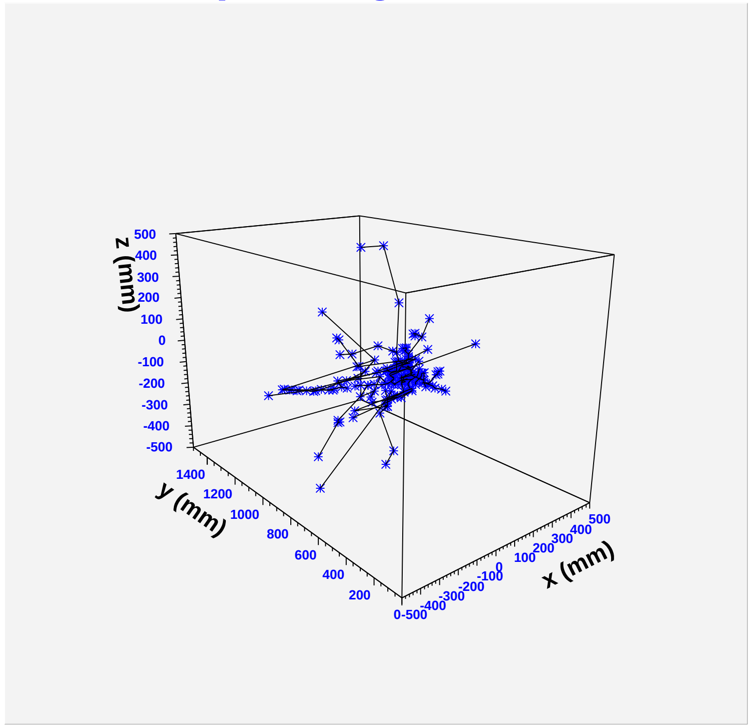
▶. clustering

set cut	:	"proximity" bound between nodes belonging to the same cluster
find clusters	:	single linkage cluster analysis
	:	i.e. go through MST and cut branches with length above cut

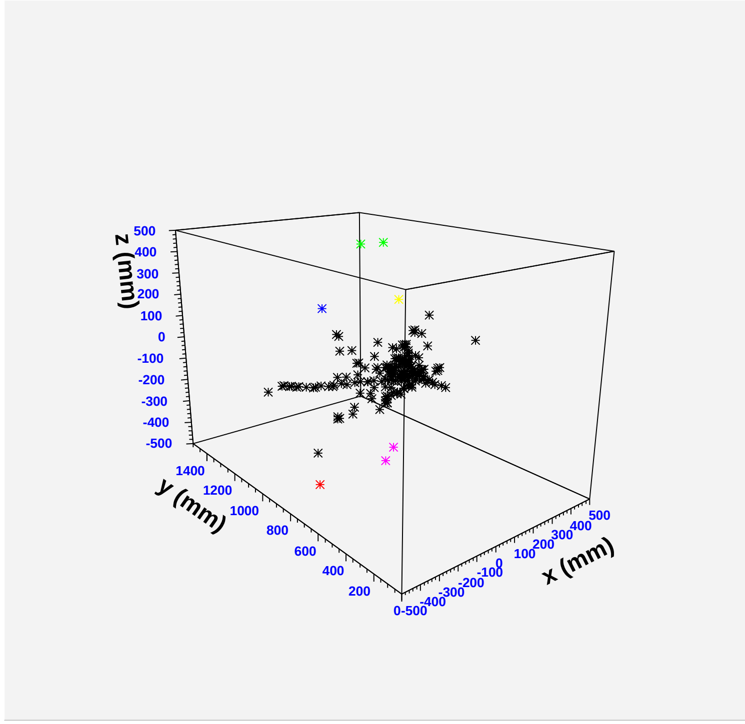
nodes

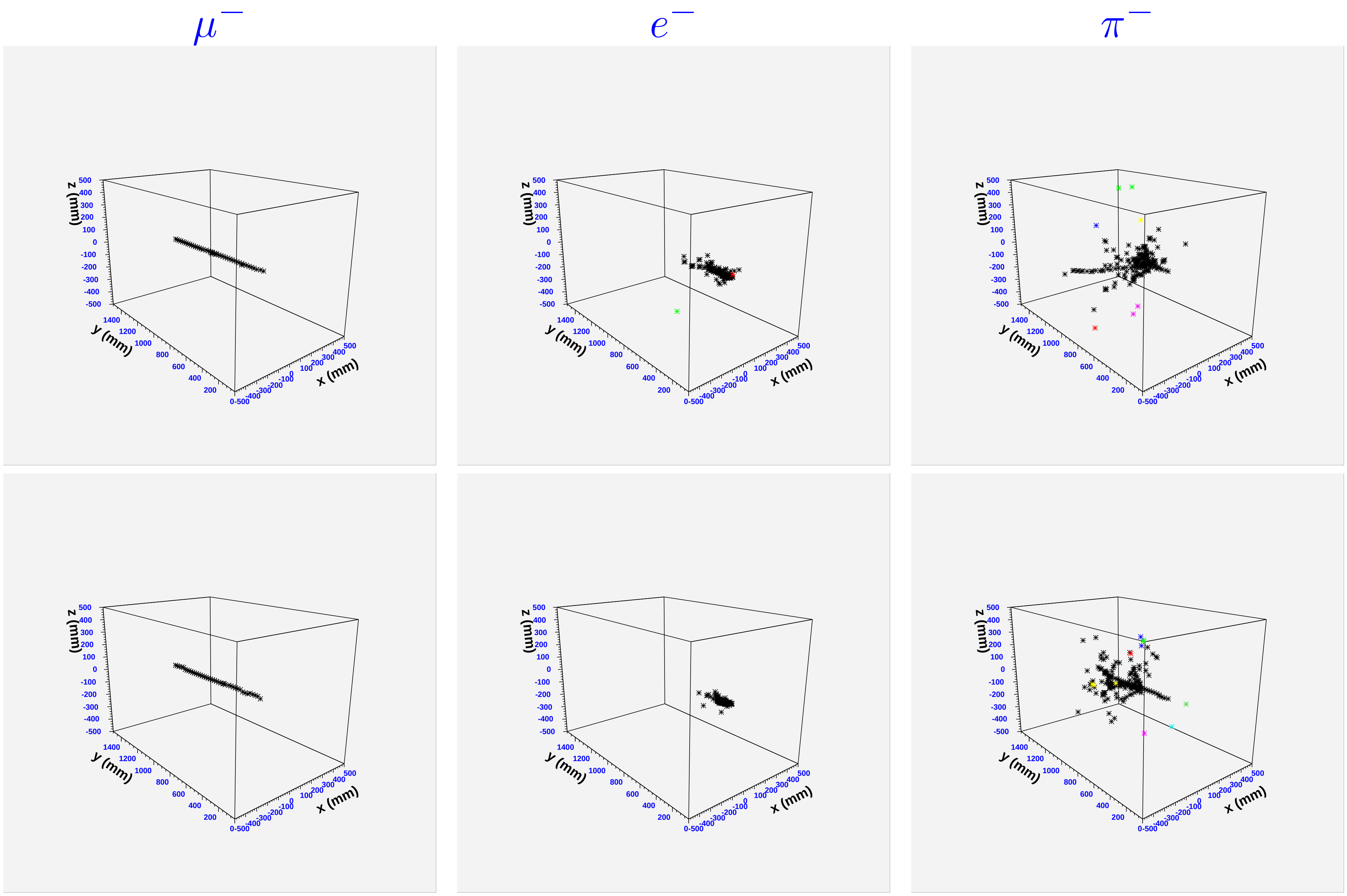


minimal spanning tree



clustering





μ^-
e^-
π^-
z (mm)
y (mm)
x (mm)

Top-down and then bottom-up clustering

▶ **in brief**

: use MST clustering algorithm with loose cut to perform coarse clustering

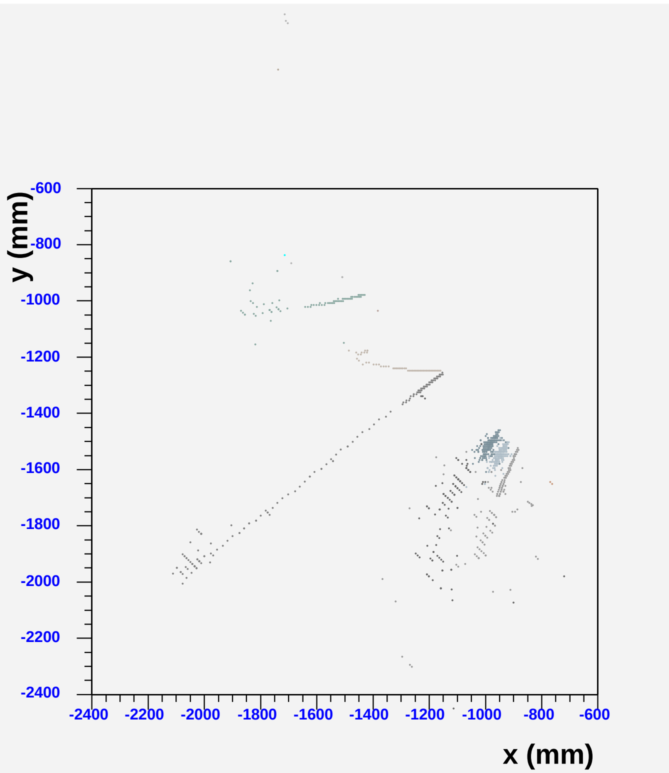
: go through MST clusters found in previous step and refine using a cone like clustering algorithm

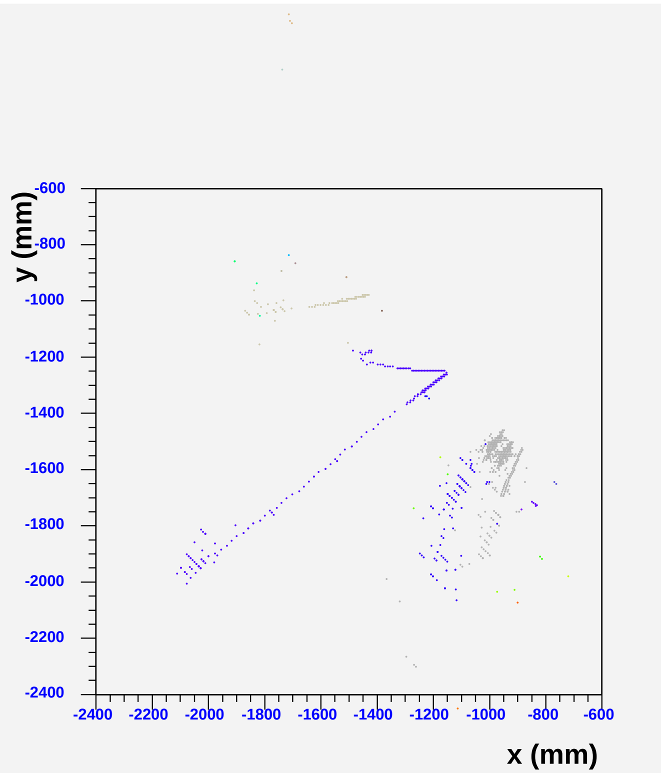
▶ **advantages of top-down and then bottom-up approach**

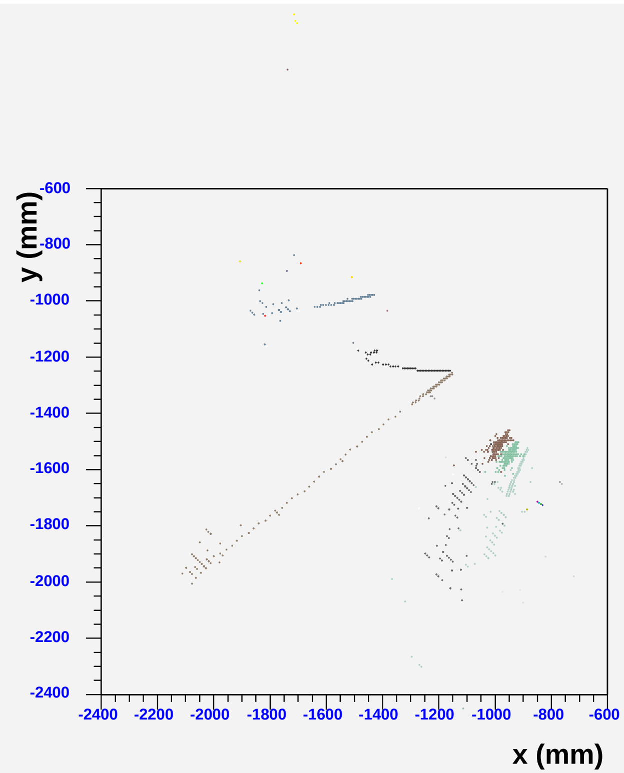
: speed because of preclustering, vital for a very granular calorimeter even if its occupancy is low

: geometry independence (or at least no strict bindings)

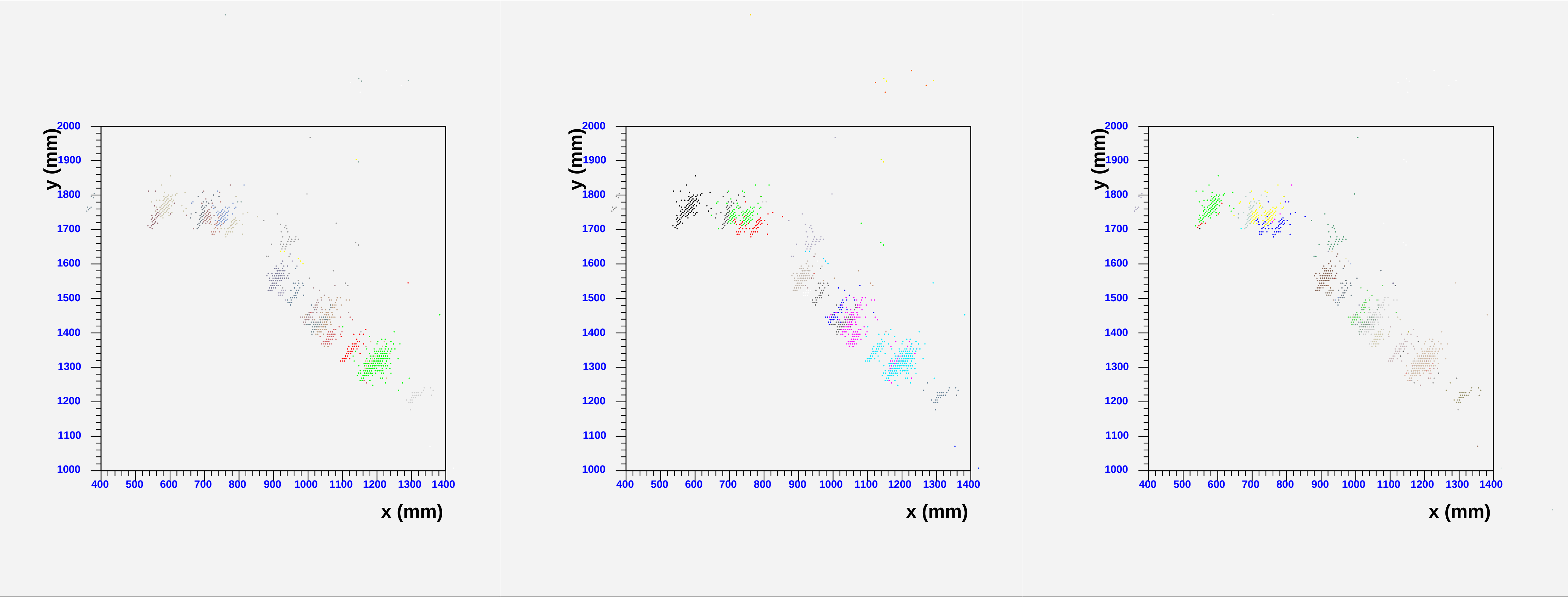
: efficiency (hopefully)



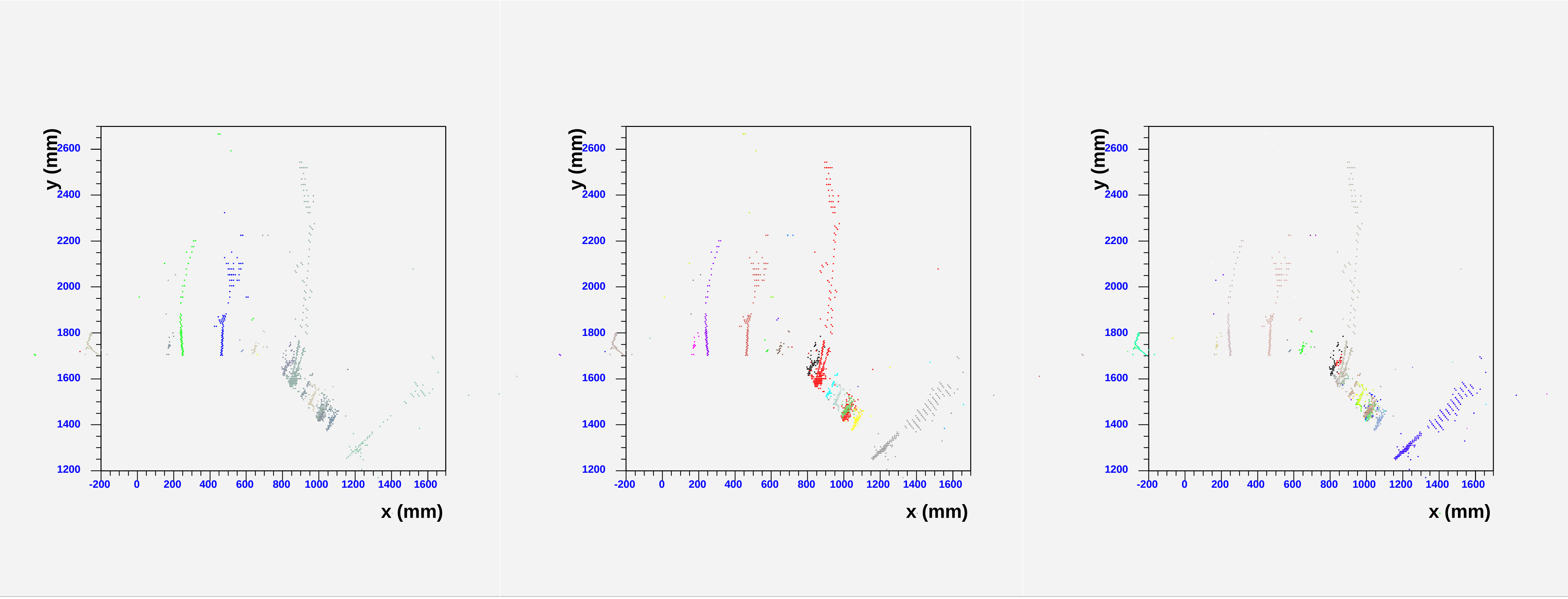




true clusters **after mst clustering** **final reconstructed clusters**



true clusters **after mst clustering** **final reconstructed clusters**



true clusters | after mst clustering | final reconstructed clusters

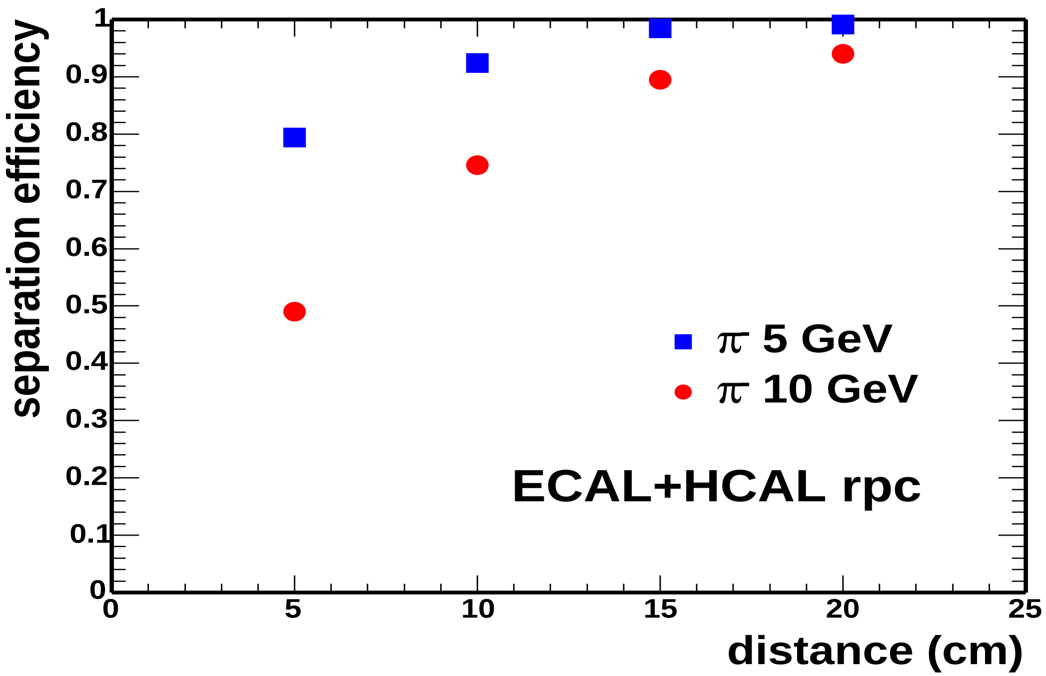
Performance evaluation

▶ .

: π^- pairs at 10 GeV or 5 GeV on CALICE ECAL+HCAL RPC prototypes

: ECAL, HCAL cellsize 1 $\times$ 1 cm^2, cell threshold = 0.5 mip

: satisfactory performance given the fact that the algorithm is seedless and both ECAL and HCAL hits are treated as digital in clustering



separation quality

: use V.Morgunov, A.Raspereza concept

: shoot pairs of particles with fixed energy and at given distance from each other, how well the algorithm reconstructs the showers

: "separation quality = fraction of events in which reconstructed energy of the shower lies in the range $E_{true} \pm 3\sigma$, where σ is the nominal energy resolution of the shower without a close by shower"

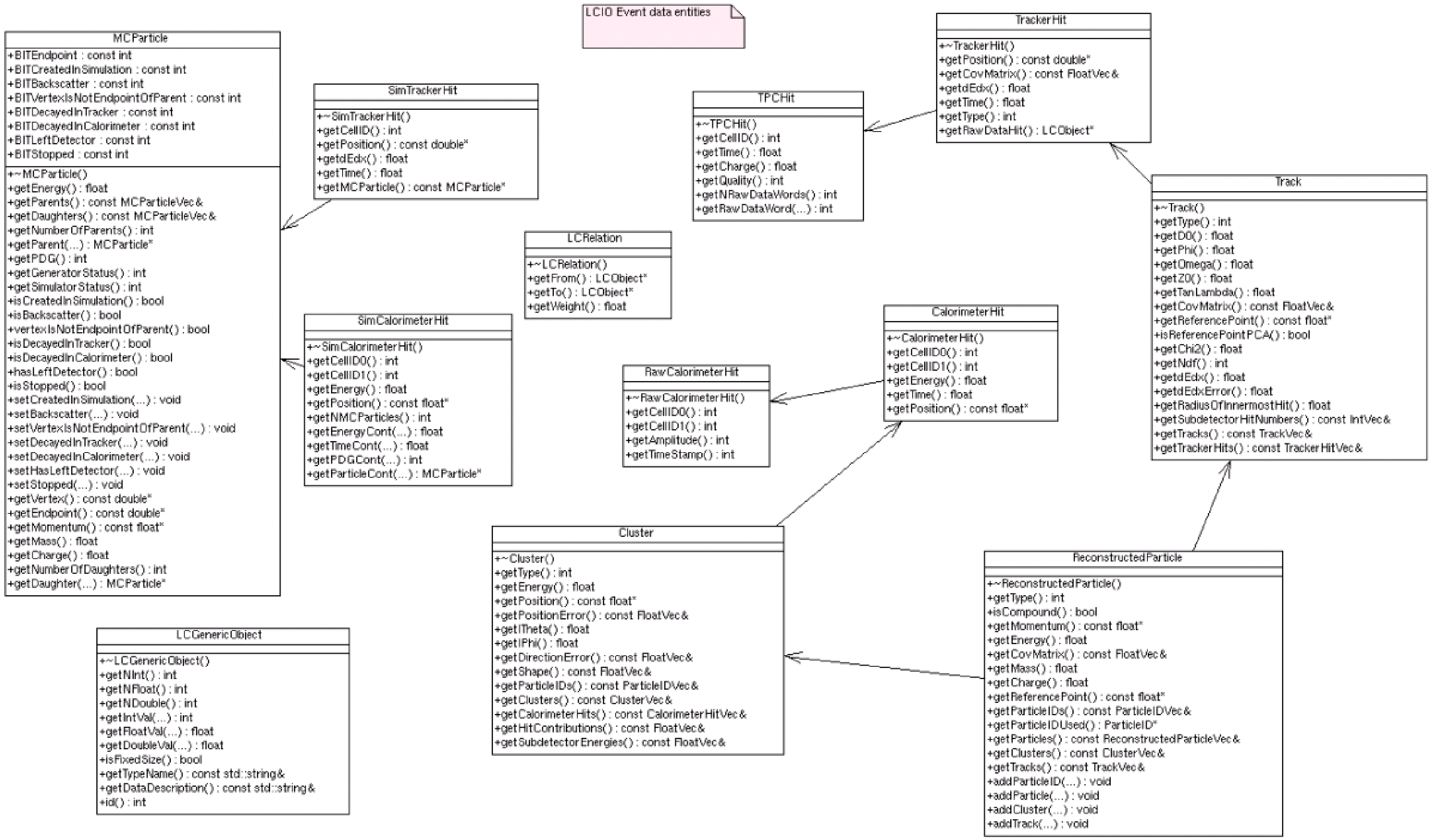
Testbeam data model

- proposing a **data model** for the CALICE testbeam program
  - persistency
  - flexible implementation
  - simple user interface
  - efficiency

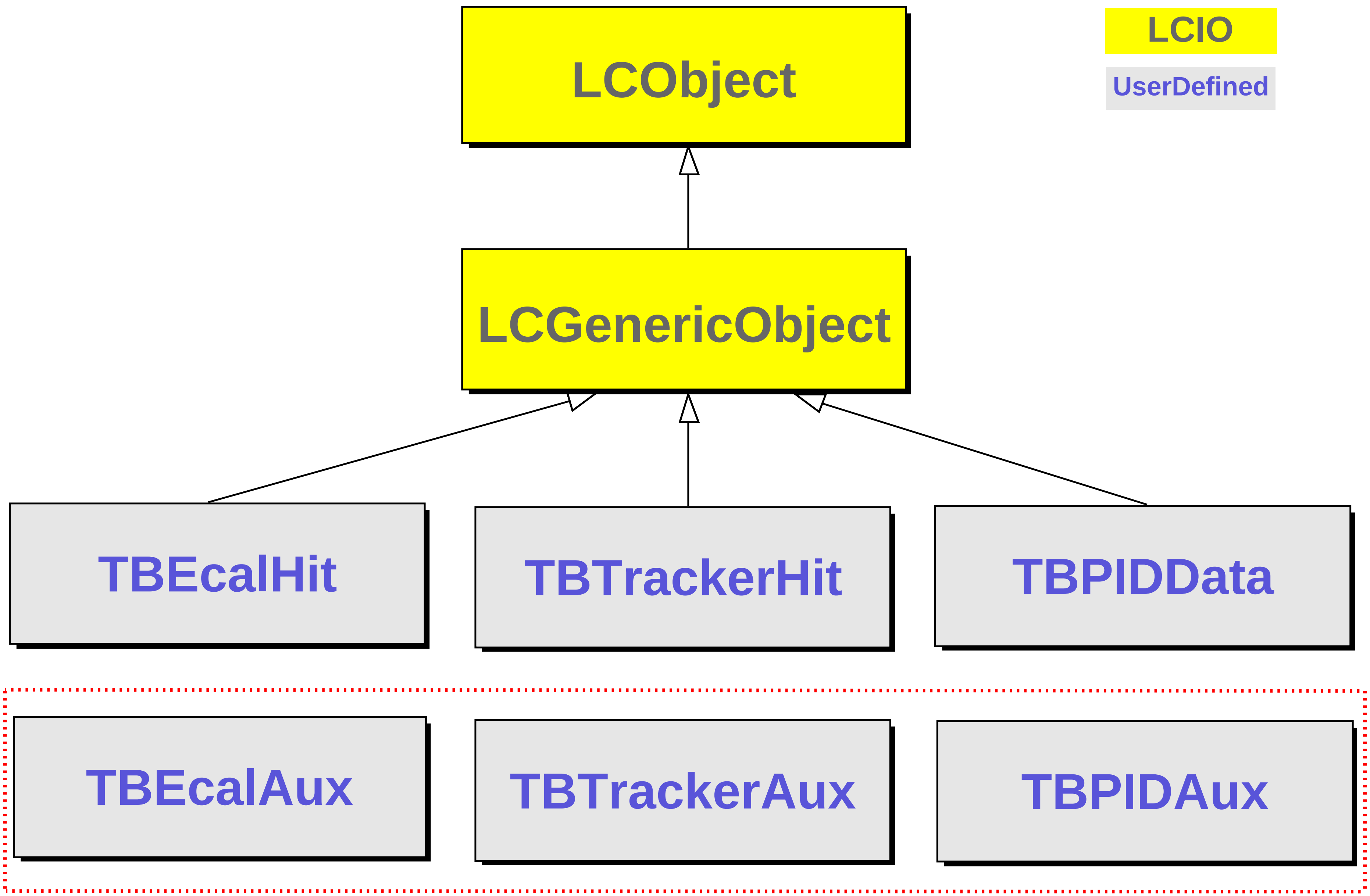
- use LCIO and ROOT frameworks for some simple test implementation and benchmarking

- general conversion scheme (from raw/simulation data to analysis data) has been discussed/decided

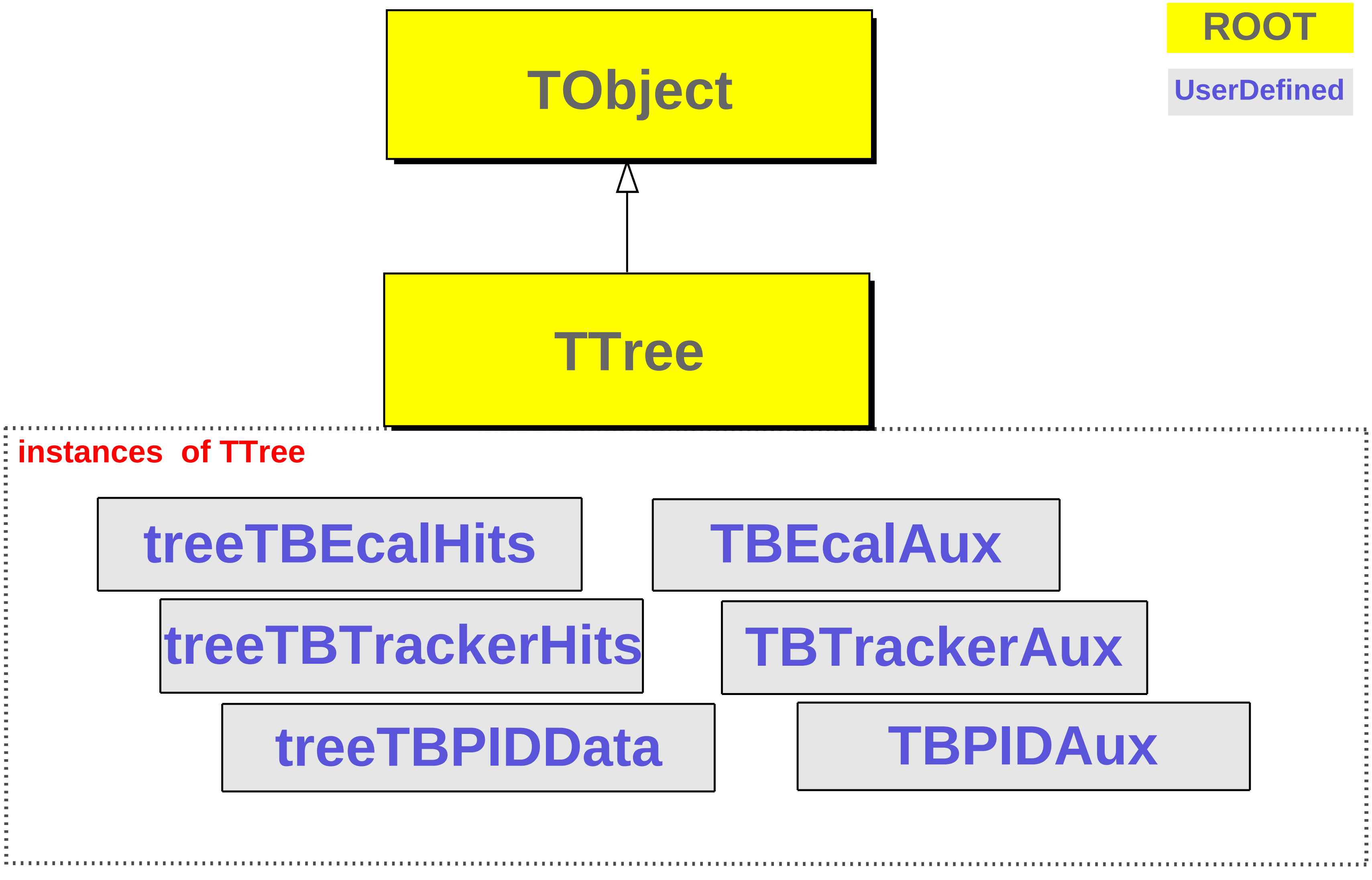
LCIO event data entities (v01-03)



CALICE testbeam data model



alternative ...



Benchmarks

▶ **. configuration**

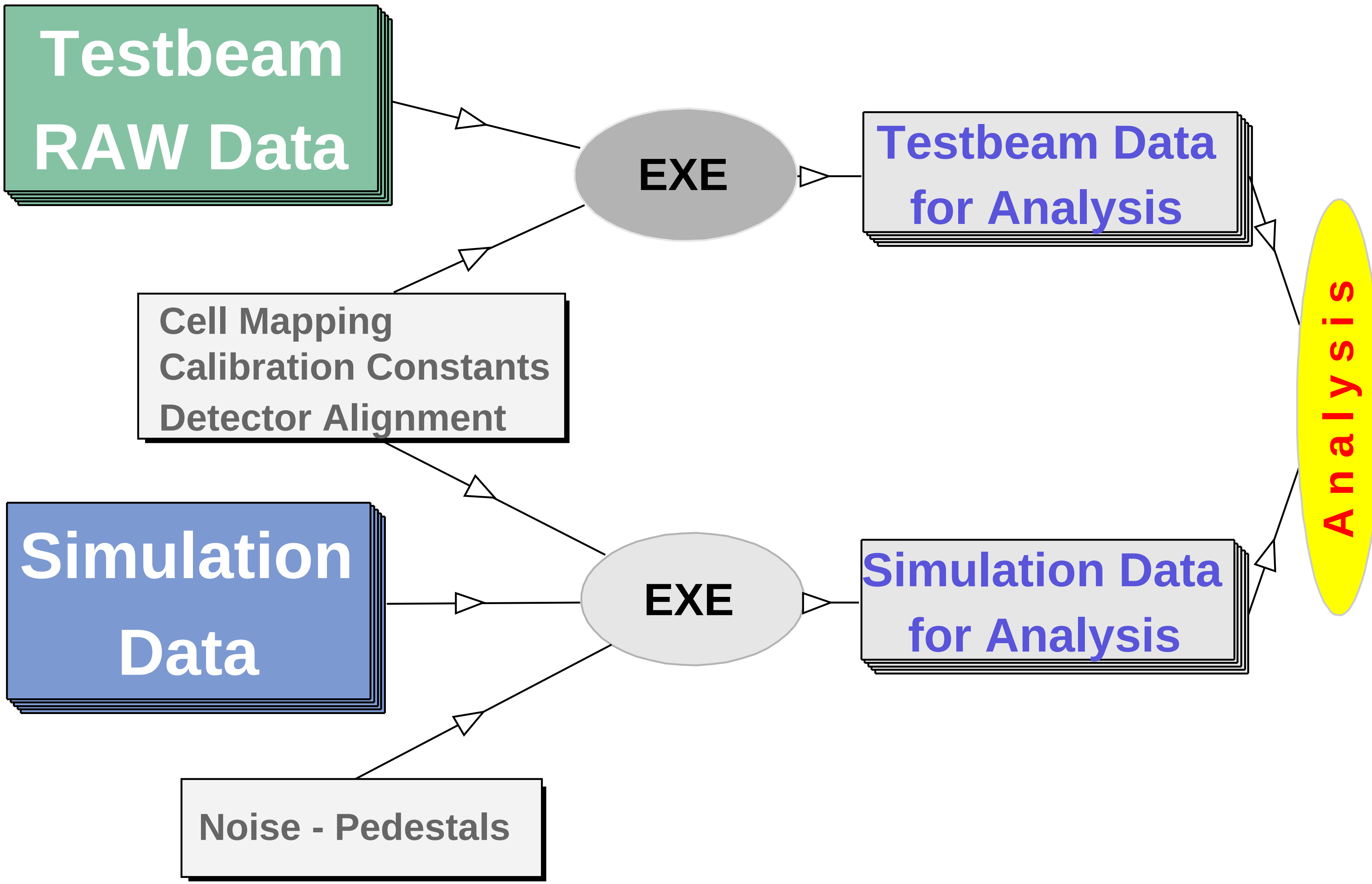
▷ machine: Linux P4 2.66 GHz / 512 MB RAM

▷ libs: ROOT v4.00/08 and LCIO v01-03

▷ task: write/read 1 ROOT tree or 1 LCIO collection
of N events $\times$ 100 hits (1 hit = 3 integers + 3 floats)

		LCIO	ROOT
100k events	**size (MB)**	**28**	**4**
	time write (sec)	**64**	**9**
	time read (sec)	**71**	**19**
500k events	**size (MB)**	**139**	**19**
	time write (sec)	**365**	**48**
	time read (sec)	**328**	**95**

Data flowchart



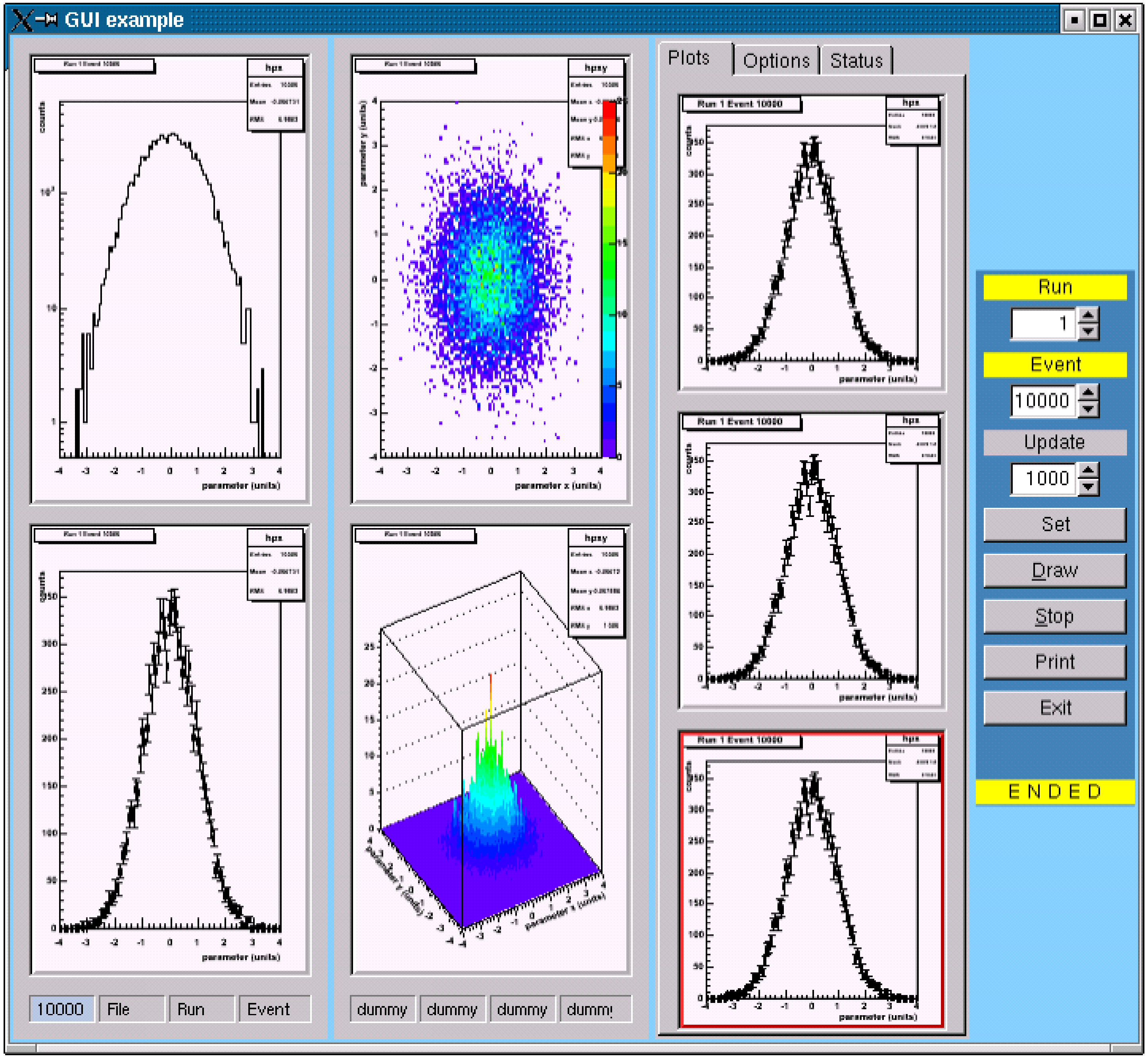
Graphical User Interface

- .
  cross-platform GUI application under development for
  - online histogramming
  - basic analysis
  - monitoring
  - event display

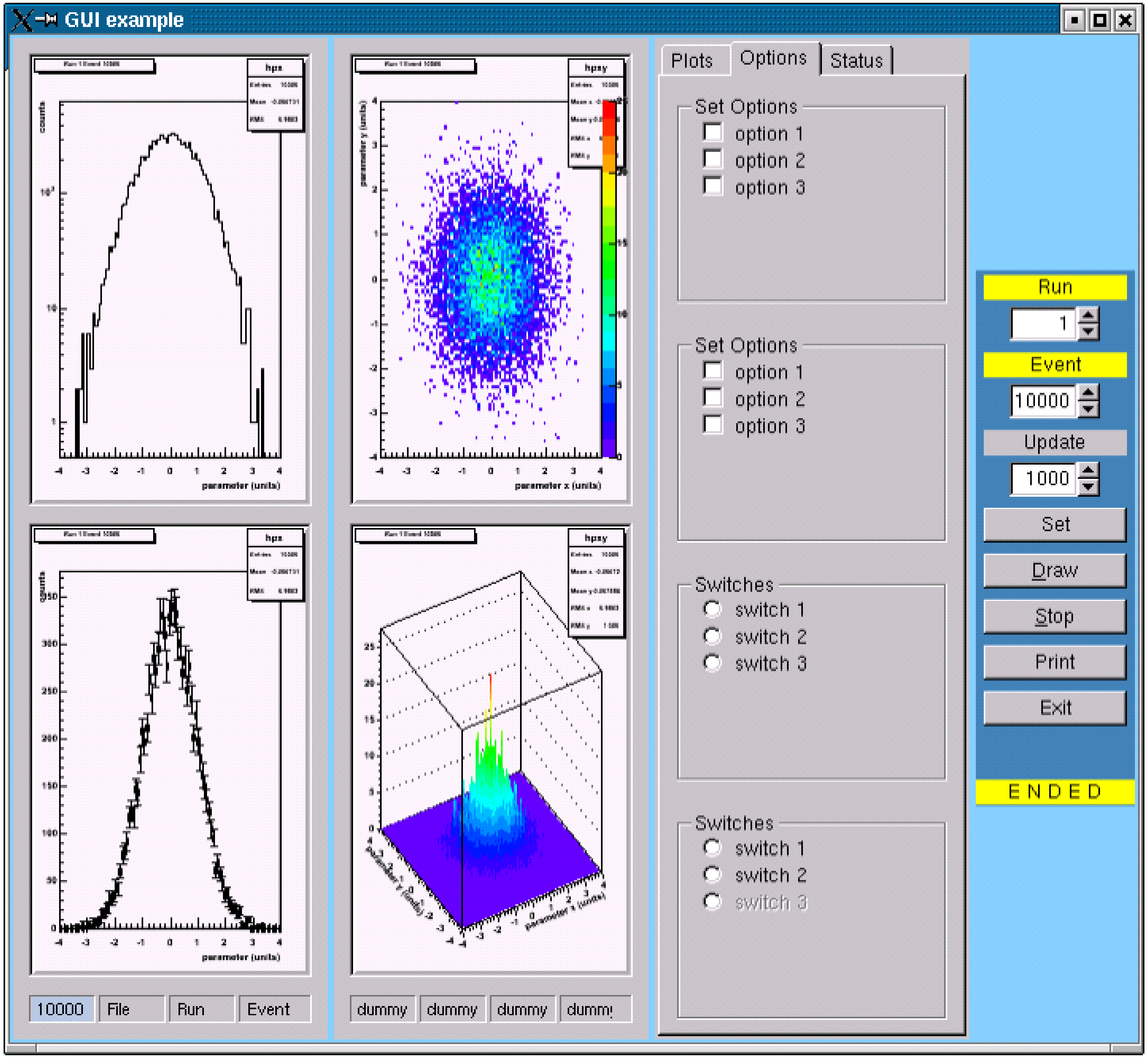
- .
  using ROOT GUI classes based on Xclass'95 widget library
  (`http://xclass.sourceforge.net`)

- .
  basic layout has been implemented and tested on
  Redhat 7.3 (gcc 3.2.3 or 2.96) with ROOT 4.00 or 3.10

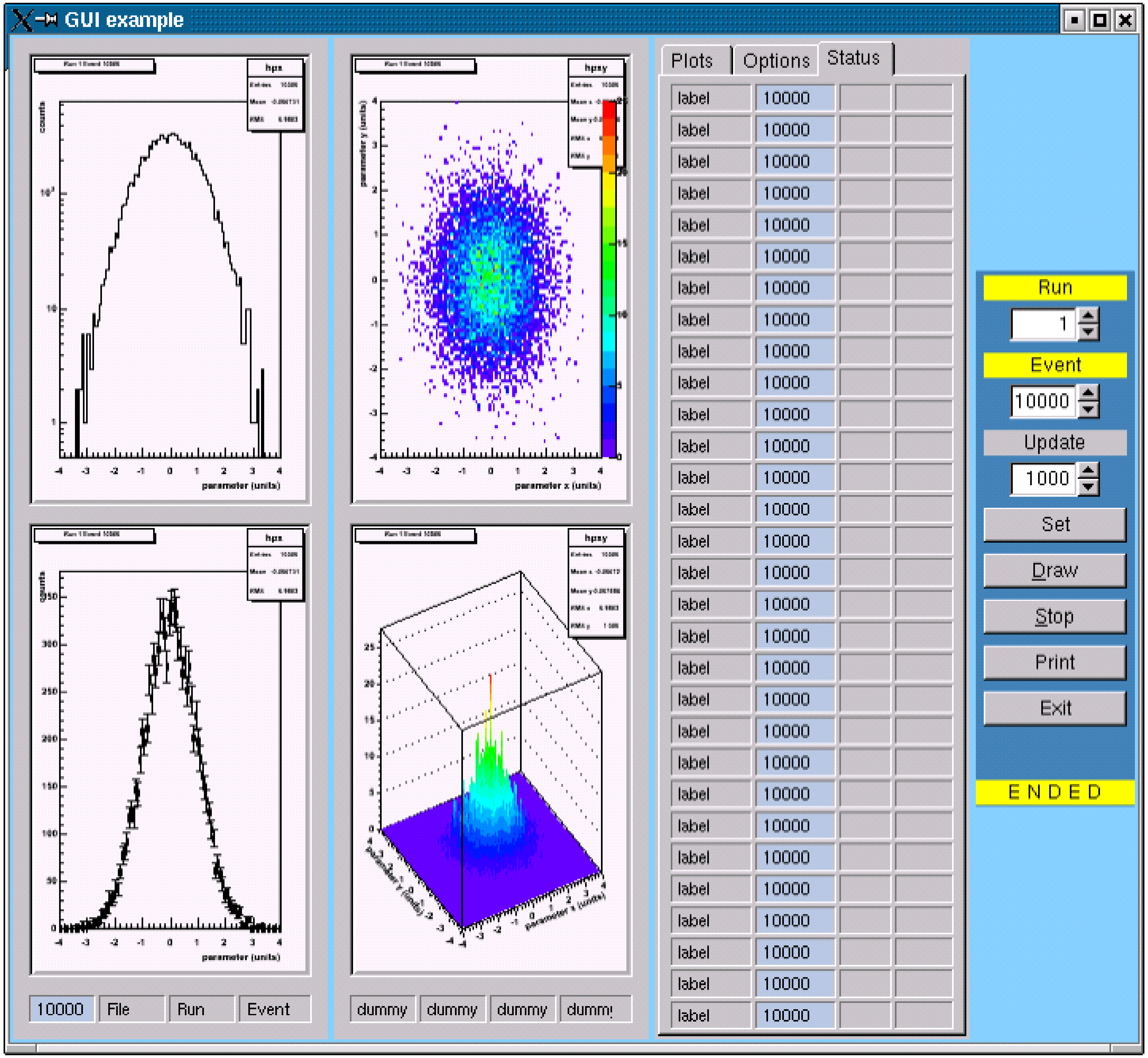
GUI: histograms and action widgets



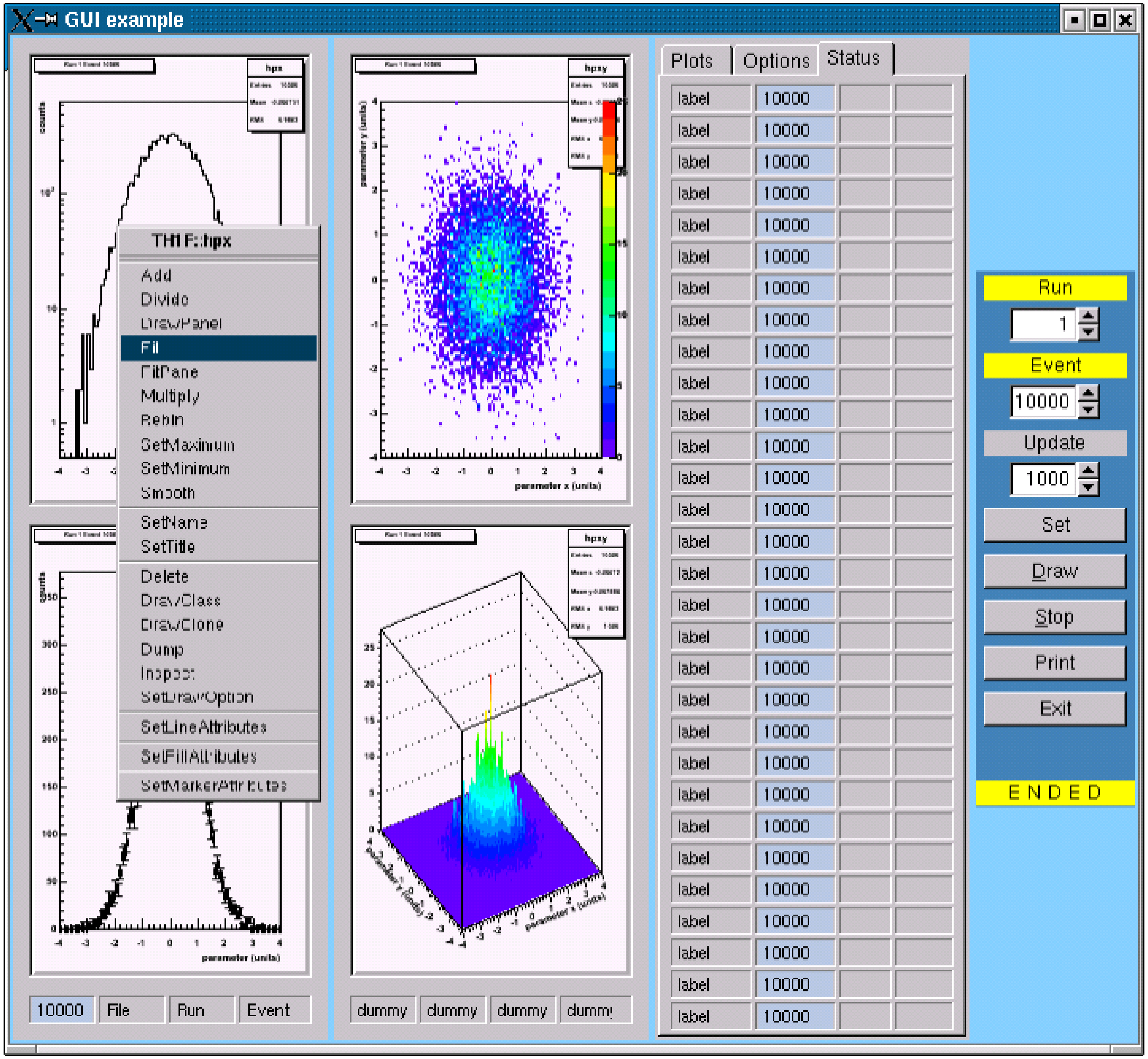
GUI: tabs for expanded info, settings



GUI: status table



GUI: active pads to invoke ROOT actions



Summary

▶ . **Simulation**

: current poor understanding of hadronic shower development leads to significant discrepancies among available packages and does not permit reliable model independent predictions

: testbeam data will help to test-validate-improve simulation code

▶ . **Reconstruction**

: calorimeter clustering algorithm is being developed and first performance tests are satisfactory

▶ . **Testbeam preparation**

: work on testbeam related software to support the running and analysis phase has started and rapid progress is expected