Software development and performance studies on CLIC SiD

Peter Speckmayer,

SiD Workshop Eugene, Oregon, Nov. 2010

Outline

- HCAL optimisation results
- Tracking performance of CLIC_SID
- Jet performance of slicPandora with CLIC_SID
- Background overlay processor

HCAL OPTIMISATION, CALORIMETER ONLY

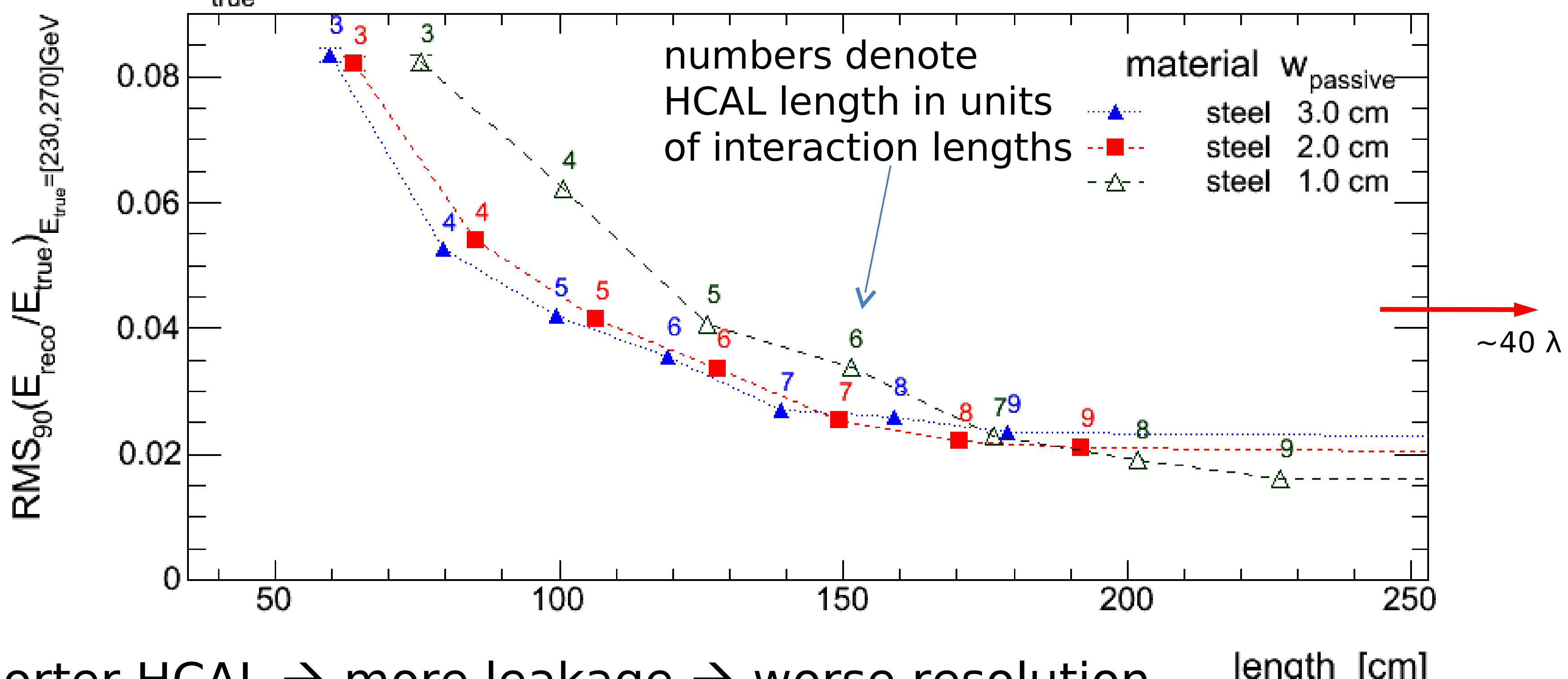
Energy reconstruction with a neural network (standalone study with HCAL only, no PFA)

(information from fine granularity of calorimeter not used)
-variables describe shower shape and size and energy
-train neural network with pion energy

-interpret length in λ as ECAL+HCAL

active: 5 mm scintillator
passive: steel, 2.5 mm G10

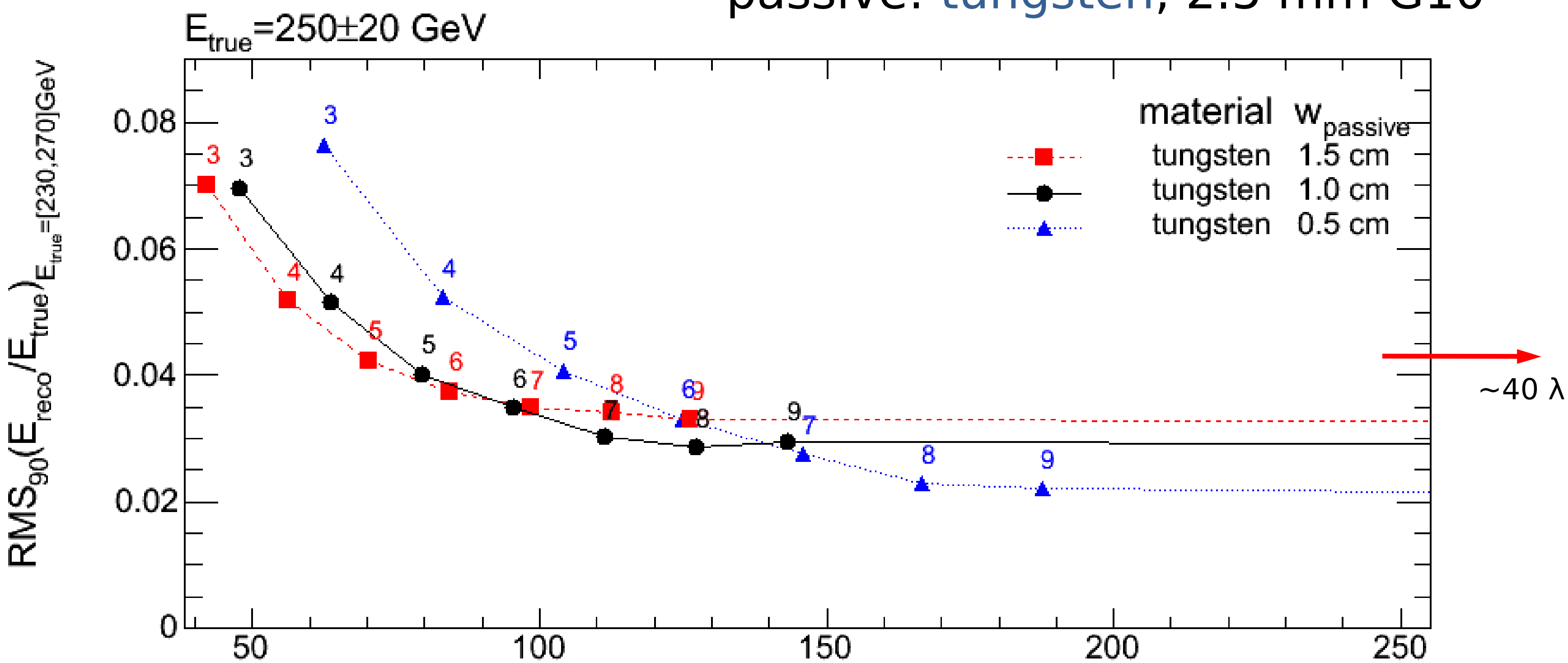
E_{true}=250±20 GeV



shorter HCAL → more leakage → worse resolution

Energy resolution in W calorimeters: 250 GeV pions

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10

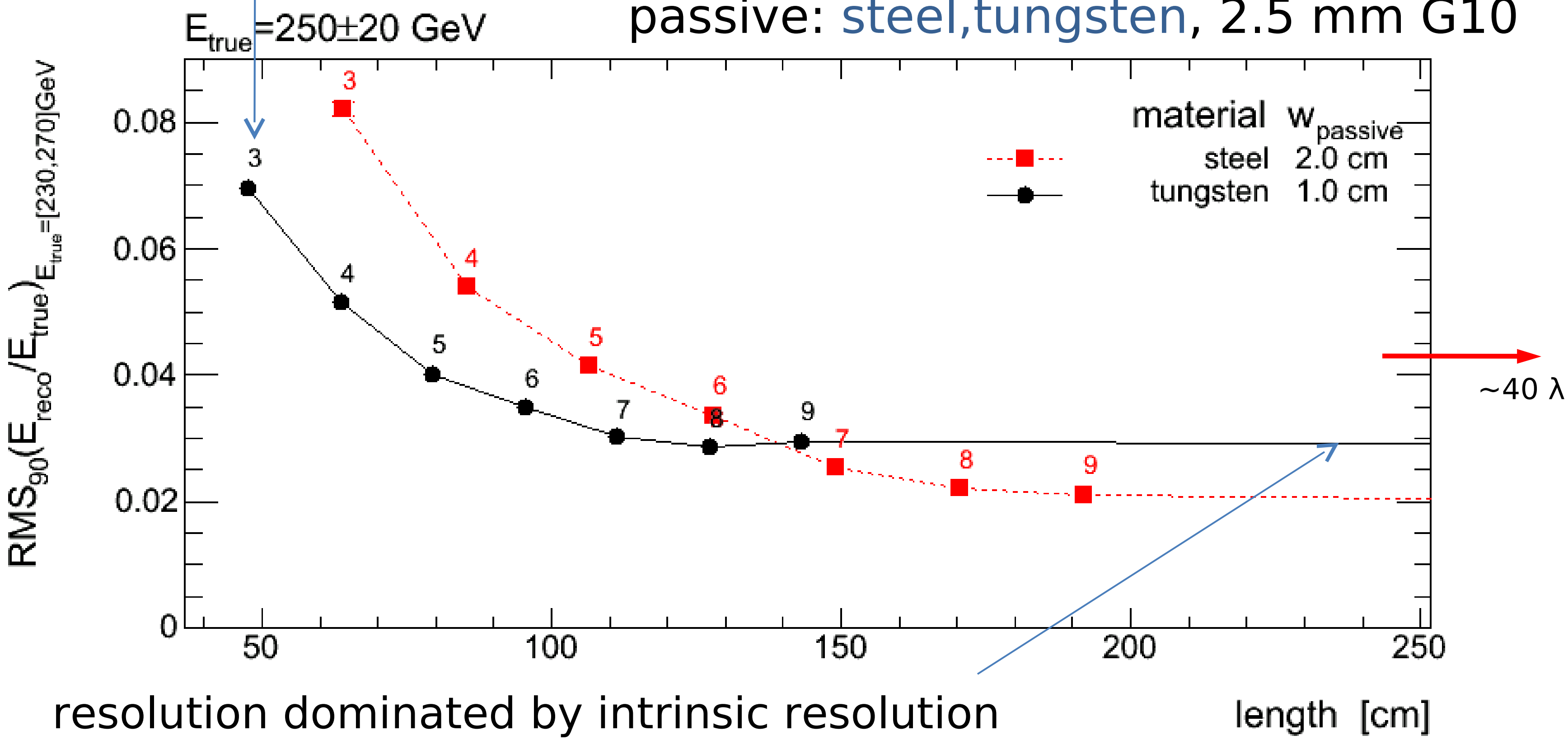


flat region reached earlier (shorter HCAL) than with steel

Energy reconstruction with neural network

resolution dominated by leakage

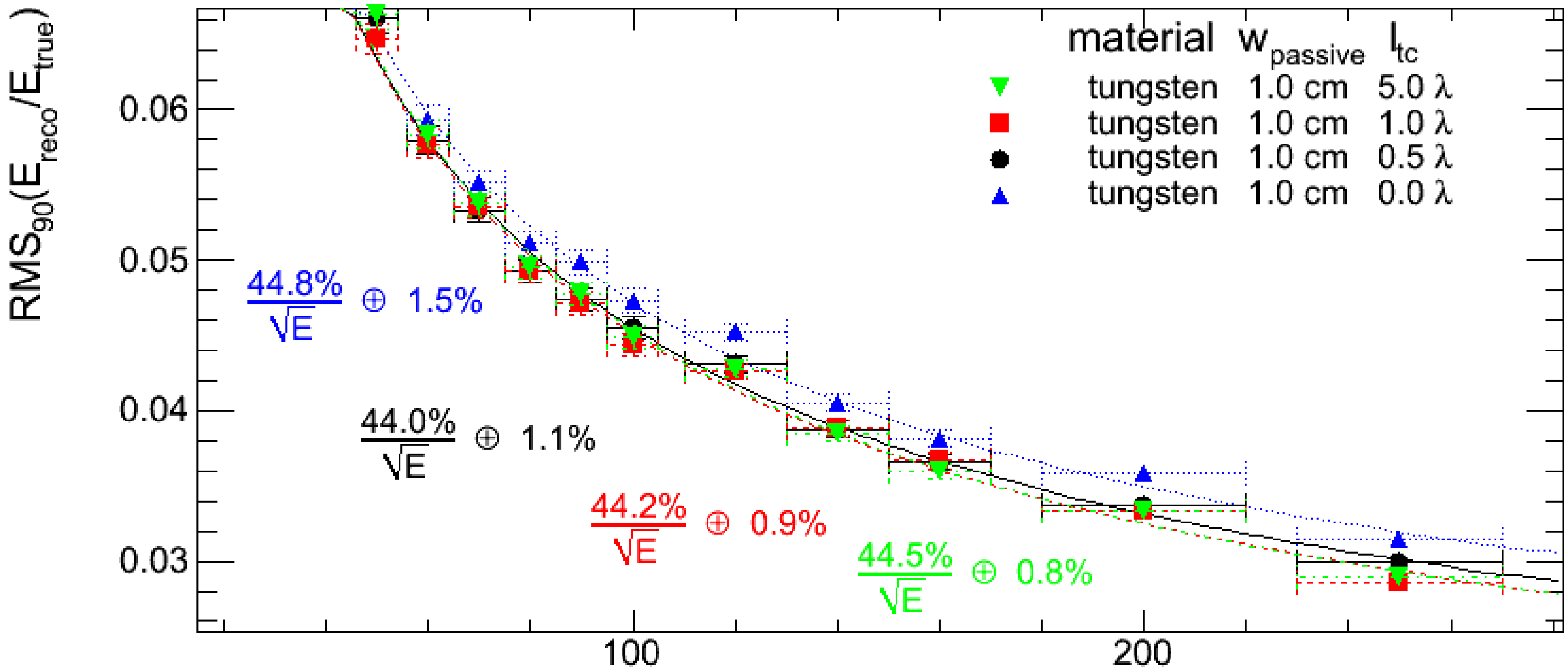
active: 5 mm scintillator
passive: steel,tungsten, 2.5 mm G10



resolution dominated by intrinsic resolution

Tail-catcher

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10



tail catchers: 0 λ, 0.5 λ, 1 λ, 5 λ
→structure as in the HCAL.
→zero λ tail-catcher implies no active material after the coil

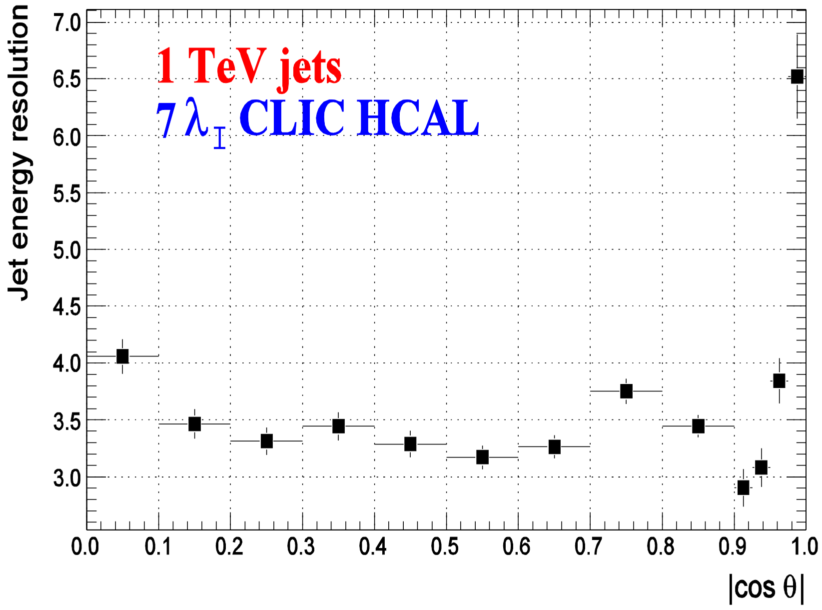
coil thickness: 2 λ
→having some tail-catcher (0.5 λ) improves resolution slightly
→effect of bigger tail-catcher is negligible

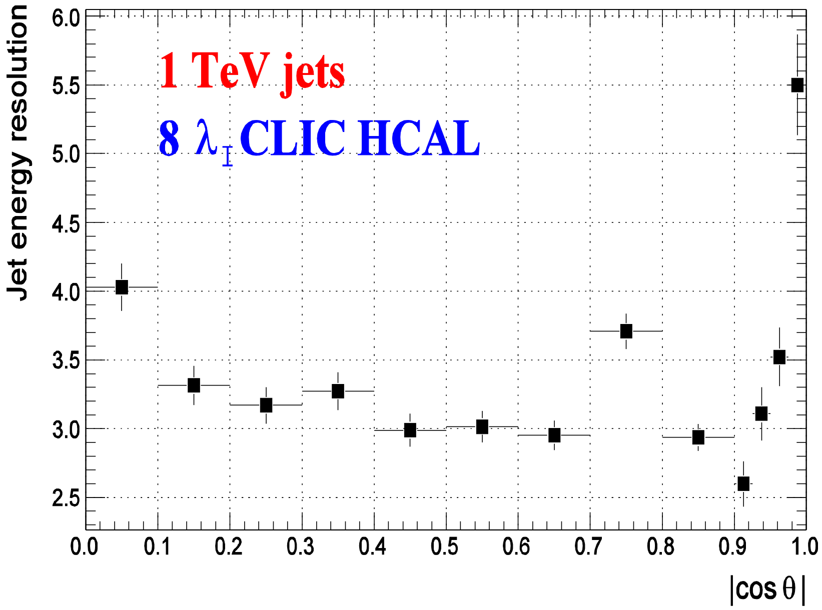
HCAL OPTIMISATION, USING PARTICLE FLOW

Energy resolutions for 1TeV jets

7λ HCAL

8λ HCAL



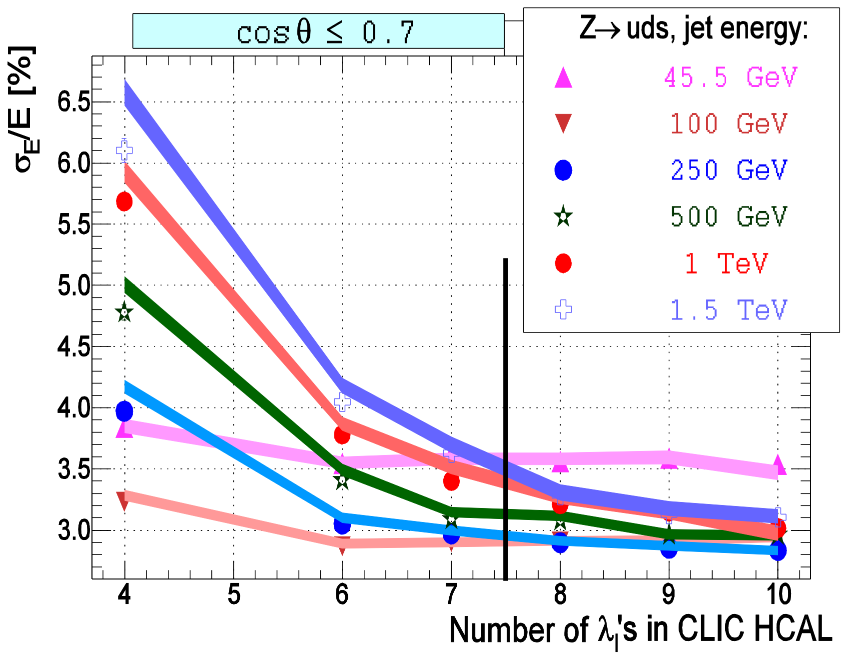


Done with CLIC_ILD (tungsten HCAL)

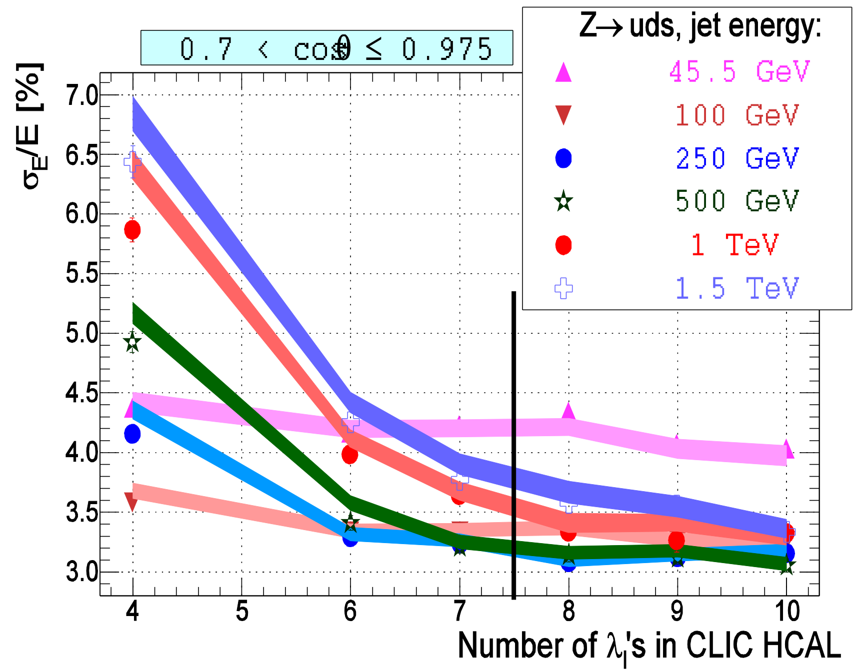
(A. Lucaci-Timoce)

Energy resolutions

Barrel



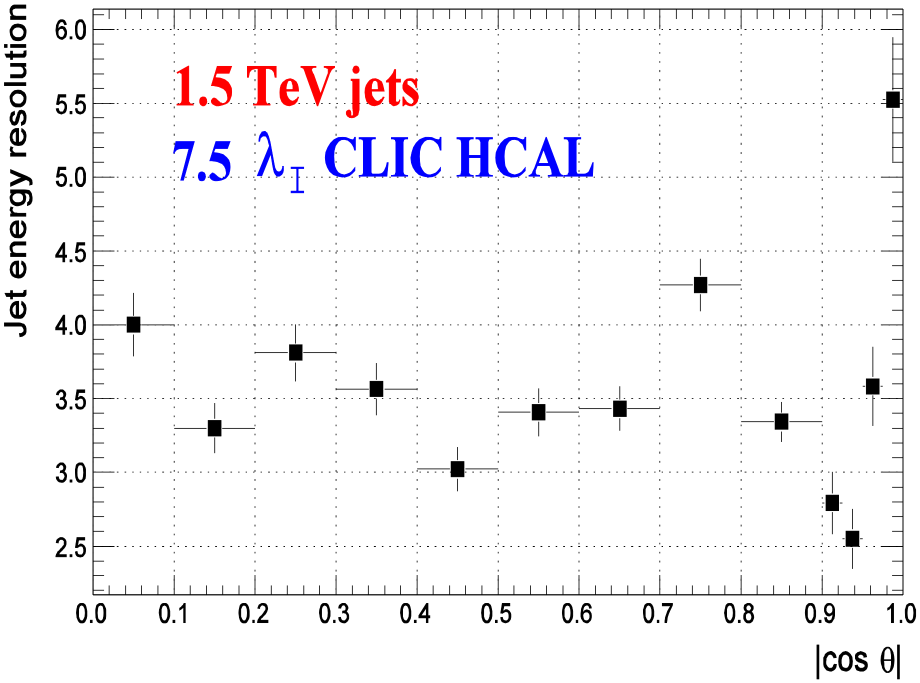
Endcap



Markers: with tail catcher; Bands: without tail catcher

HCAL depth

we choose: 7.5λ (+1λ ECAL)



TRACKING PERFORMANCE ON CLIC_SID

CLIC_SiD Detector Concept

- based on the SiD detector design for ILC:
  - full silicon tracker
  - 5 T magnetic field

- Optimized to operate at 3 TeV. Differences for tracking:
  - Higher collision energy
    - higher particle energies
    - higher jet density
    - higher occupancy in forward region
  - Higher beam induced background
    - vertex: increased inner radius from 13 mm to 27 mm
  - Higher bunch crossing and bunch train rates
    - Time stamping challenge
- Some of the issues shown at the ILWC have been adressed
  - But I'm not going into that details with plots

(C. Grefe, B. P. Valls)

Track reconstruction: the SeedTracker algorithm

- Strategies:
  - A full set of strategies is needed to cover all possible combinations of seed layers
  - An automatic strategy builder is used to ensure that all possible combinations of layers are taken into account
  - Missing strategies in endcap region fixed (behavior for StereoLayer was not correctly configured)

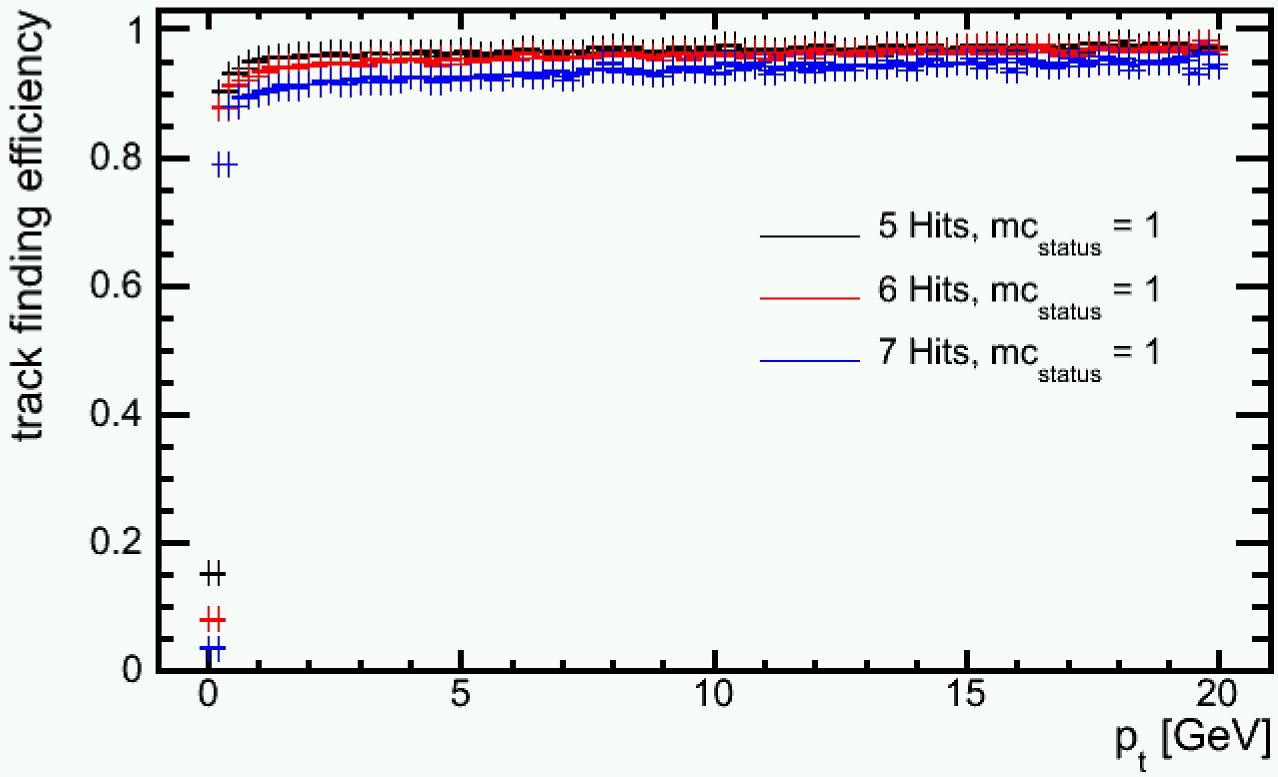
- Example: 7 hit strategy
  - requires at least 7 hits per track
  - pt > 0.2 GeV
  - impact parameter cuts: |d0|<0.5 cm and |z0|<1cm
  - quality of fit: chi2 <50

Performance

- Efficiency:
  - eff = #reconstructed tracks matching truth/#final state MC particles
- Purity:
  - purity = #hits in a reconstructed track matching truth/#total hits

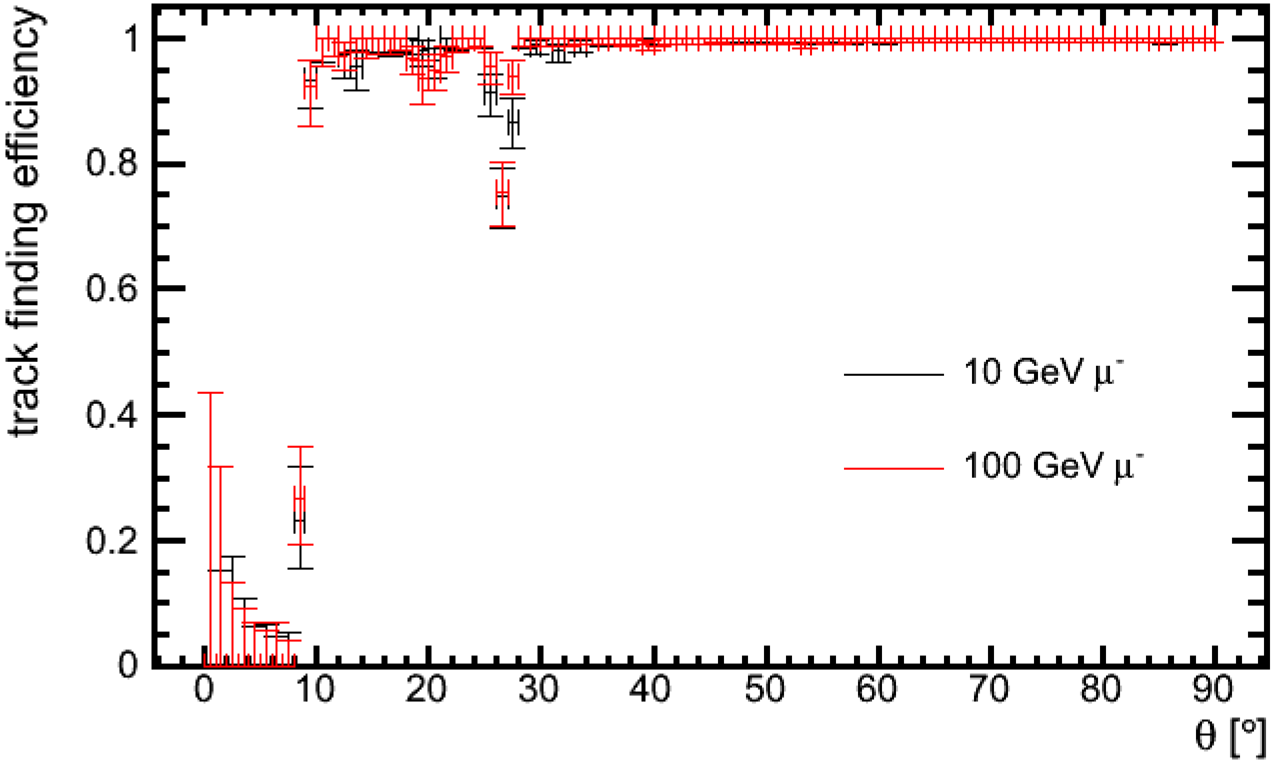
- Samples
  - Single muons, shot at different angles and energies
  - e+e → Z → qq (uds) events (3TeV)

Performance on single muons:



Track finding efficiency versus transverse momentum (Θ>8°)

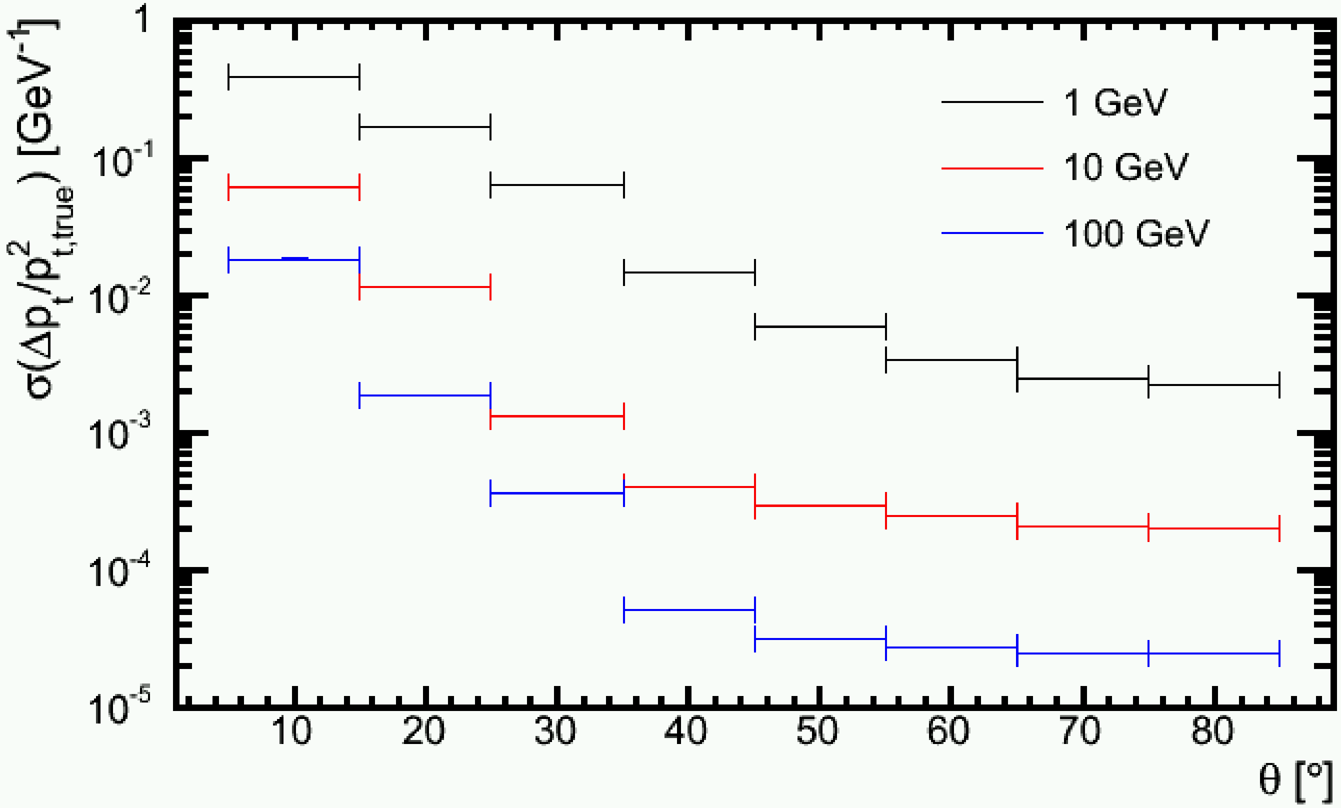
Performance on single muons:



Track finding efficiency versus angle (p_T > 0.25 GeV°)

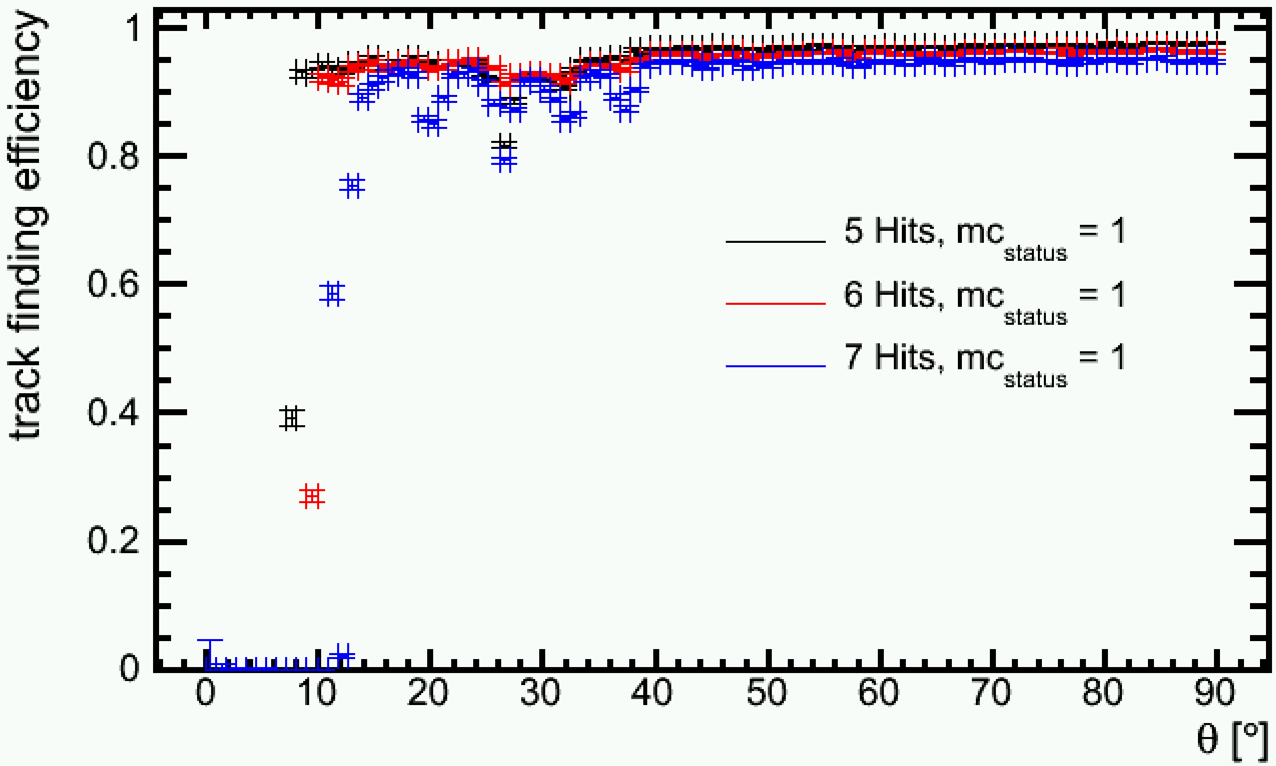
- Dip at Θ around 28° → transition region barrel-endcap in vertex
- Forward region Θ < 32°: inefficiencies not well understood

Performance on single muons:



Momentum resolution vs angle and momentum

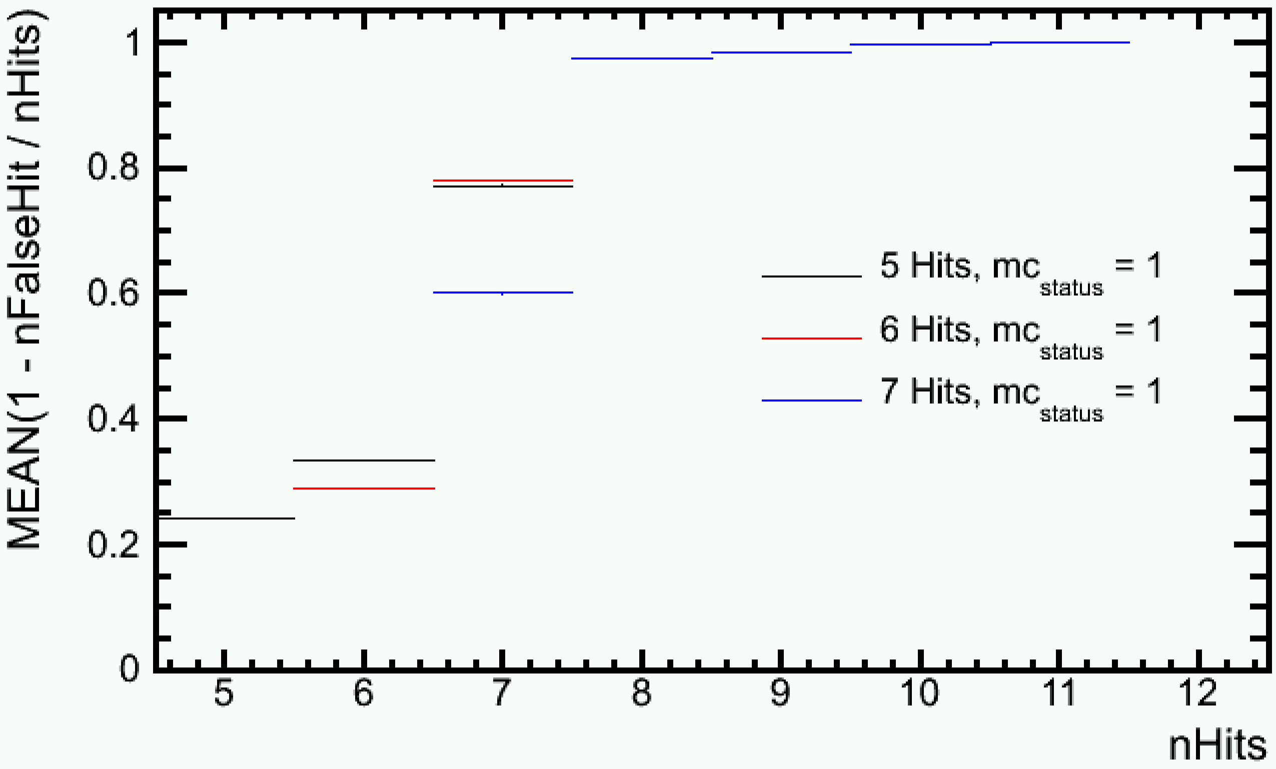
Performance on dijets:



Track finding efficiency versus angle (p_T > 0.25 GeV°), colors denote the different strategies

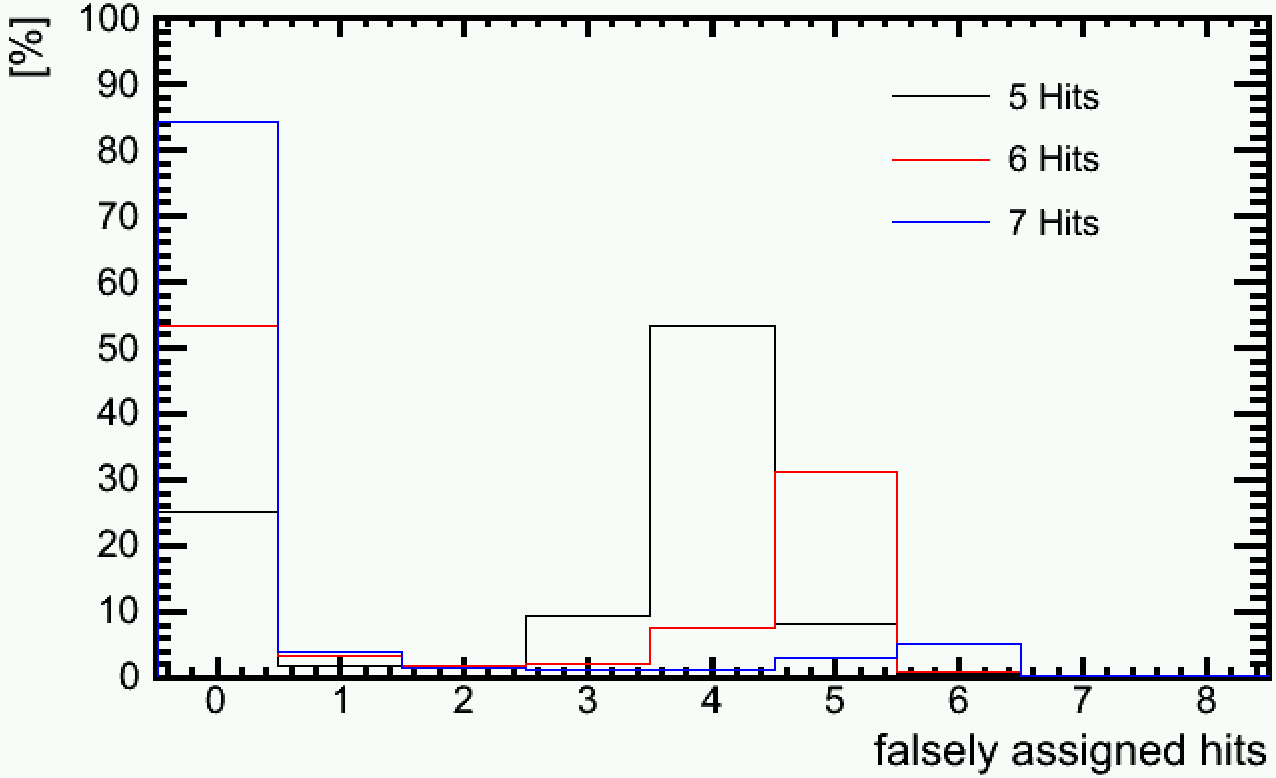
- Dip at Θ around 28° → as with single muons
- Forward region Θ < 32° → as with single muons

Performance on dijets:



Track purity: Fraction of true hits per track vs total number of hits assigned to track. (Color: different strategies)

Performance on dijets:



Percentage of tracks having n false hits assigned
Color: different track finding strategies

Tracking, conclusions

- Acceptance
  - Down to 7°, in good shape down to 9°
- Performance
  - Physics requirements on momentum resolution fulfilled ($\Delta p/p^2 \sim 10^{-5}$ GeV^{-1})
  - Machine induced background: robustness has been proven on earlier detector version. Has to be verified.
- Open issues
  - Dips
    - Probably due to moved helicalTrackHits at edges of pixel disks
  - charge bias in d0 verteilung
- Fixed
  - Strategy training
  - Workarond for Circular fitter problem

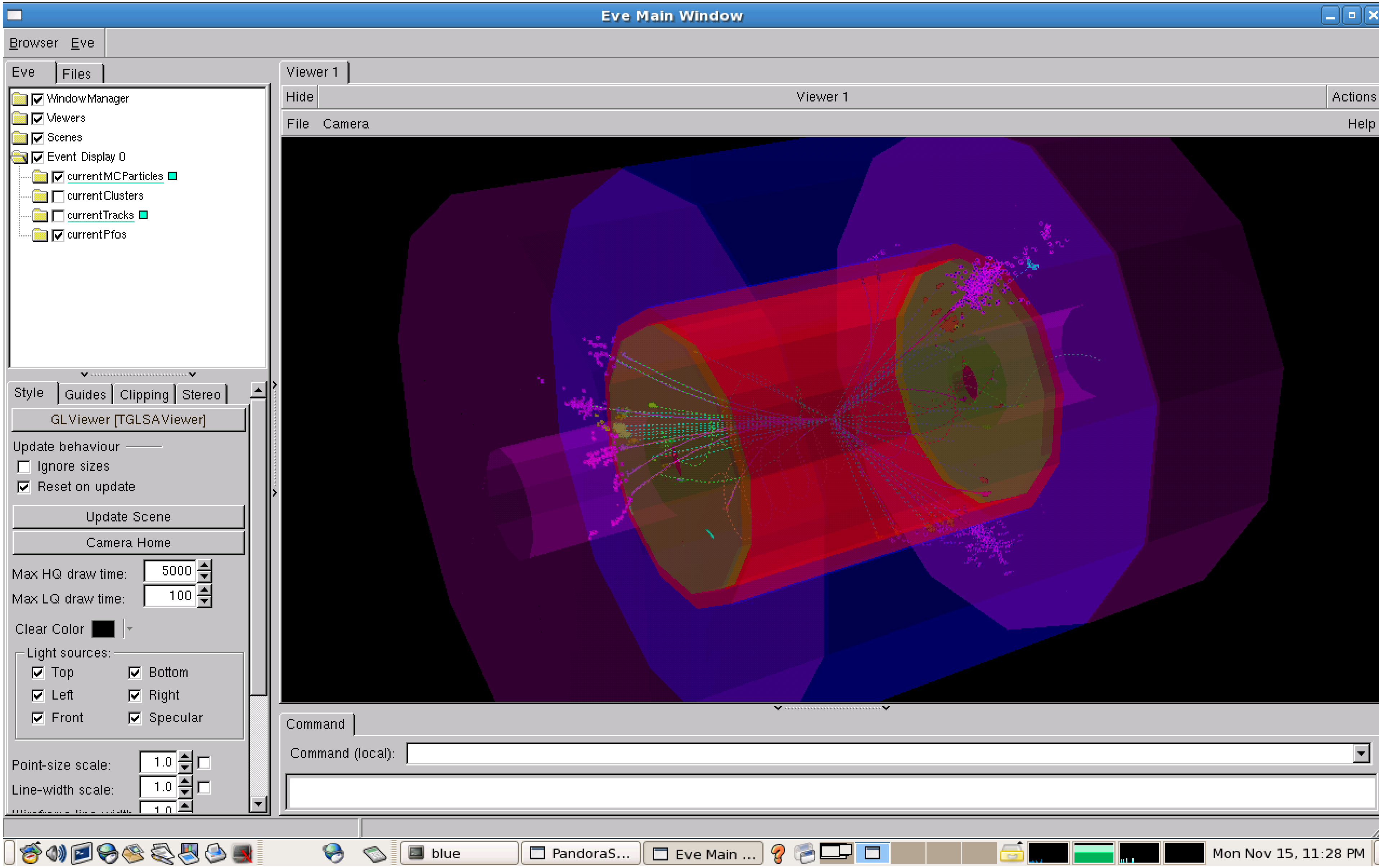
PARTICLE FLOW PERFORMANCE ON CLIC_SID

SlicPandora

- SlicPandora interfaces to Pandora
  - Provides geometry/hits/tracks to pandora
  - Gets back reconstructed particles

- Geometry with GeomConverter from compact.xml

- Pandora settings
  - By now identical to those used for CLIC_ILD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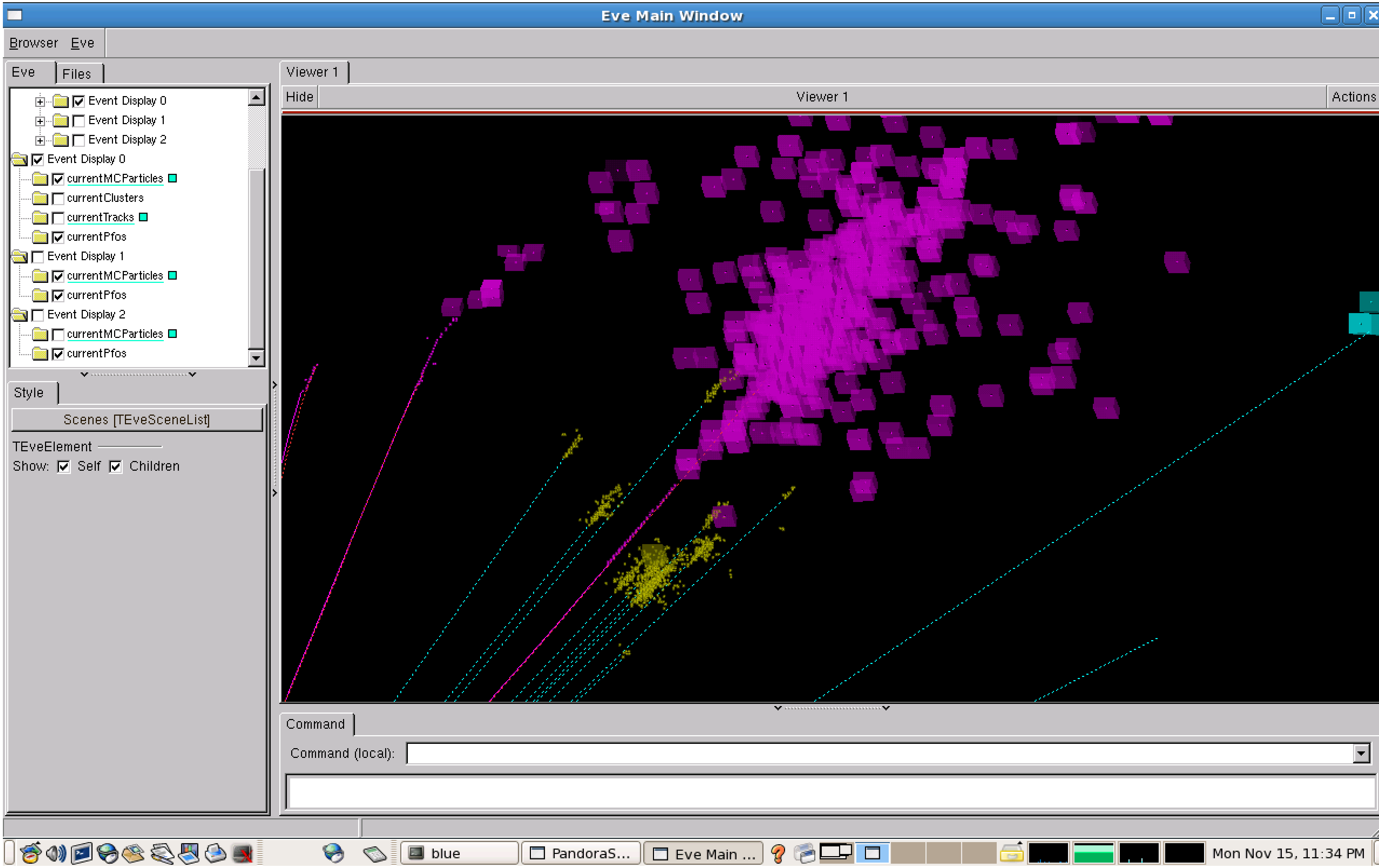
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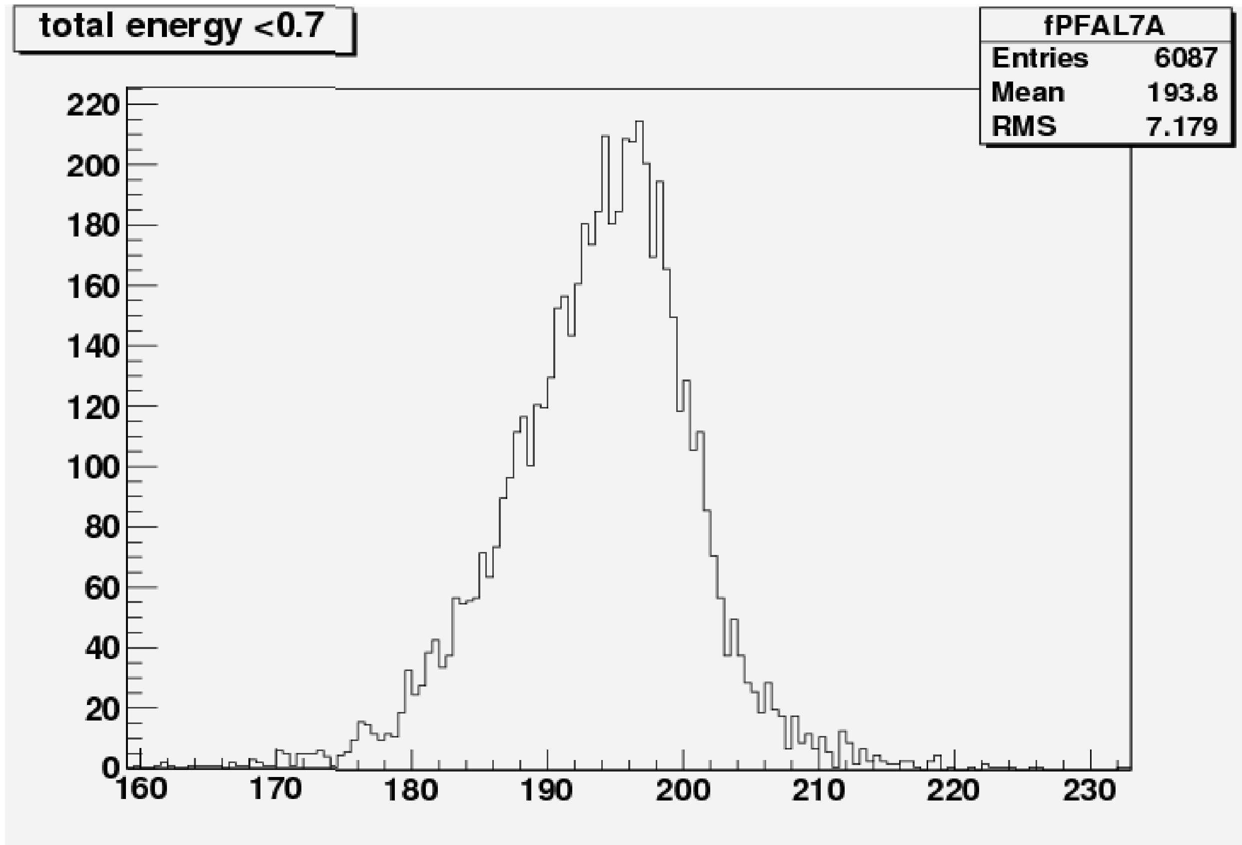
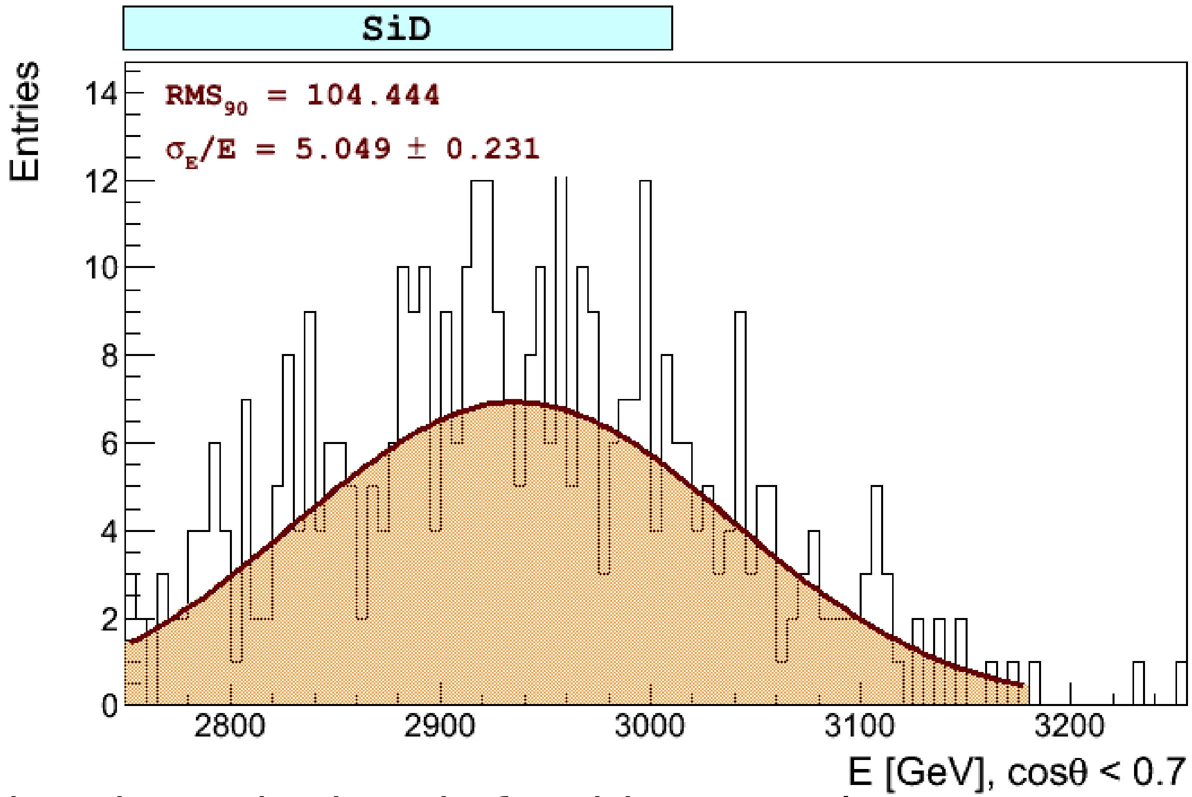
Z → uds, 200 GeV



- mean: 194 GeV, single jet energy resolution: 3.77% (using 3x3 cm^2 analog readout)

Z → uds, 3 TeV



- calibration done „by hand“ for this example
- results for the default calibration are considerably worse
  - Re-check calibration
- Full chain on the grid now working
  - slic → lcsim → slicpandora+pandora → pandoraAnalysis and/or lcsim

EVENT OVERLAY

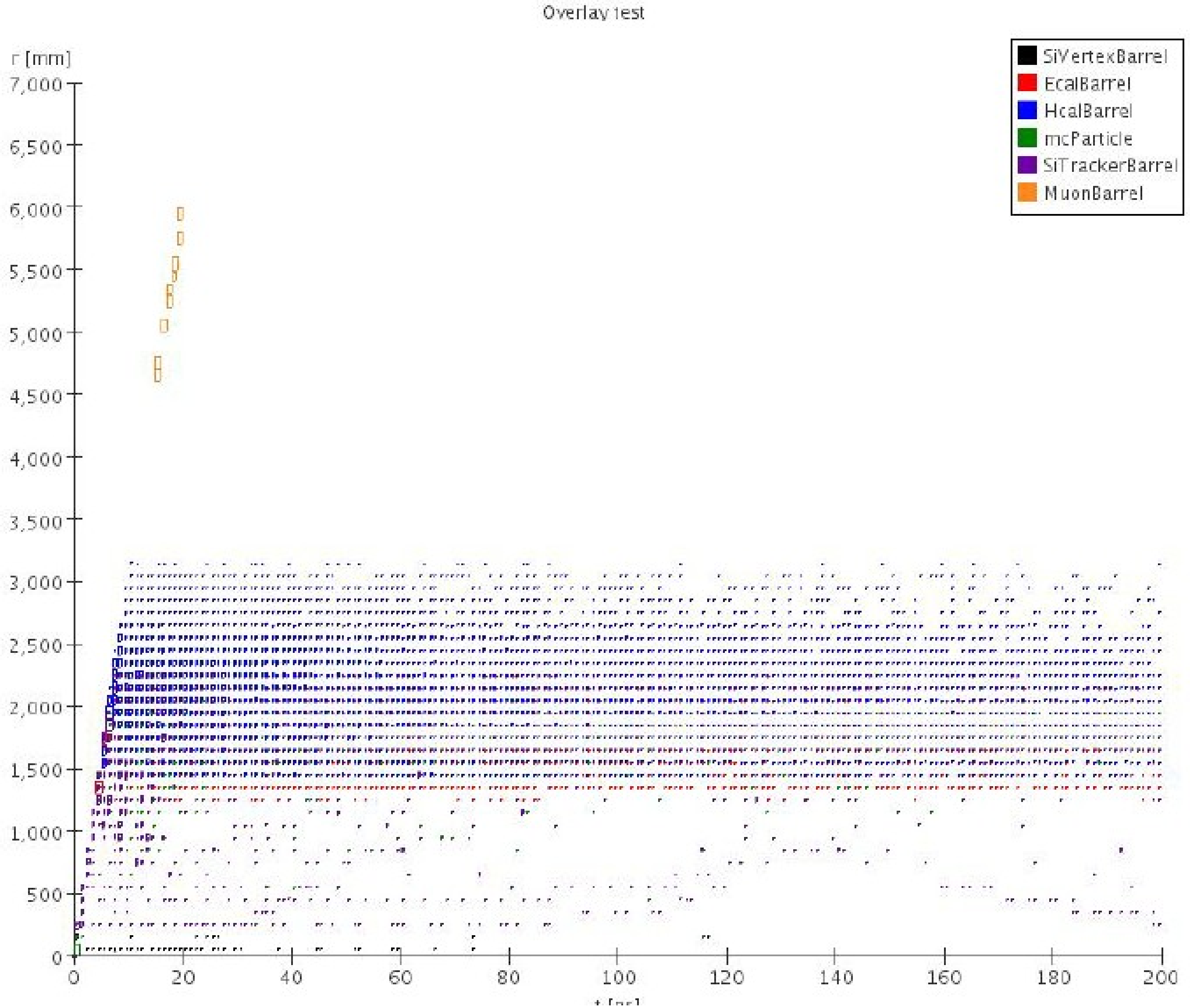
Status of event overlay

- CLIC bunch train structure + time stamping
  - Subdetectors have differing time stamping behaviour
  - Have to overlay several bunch crossings

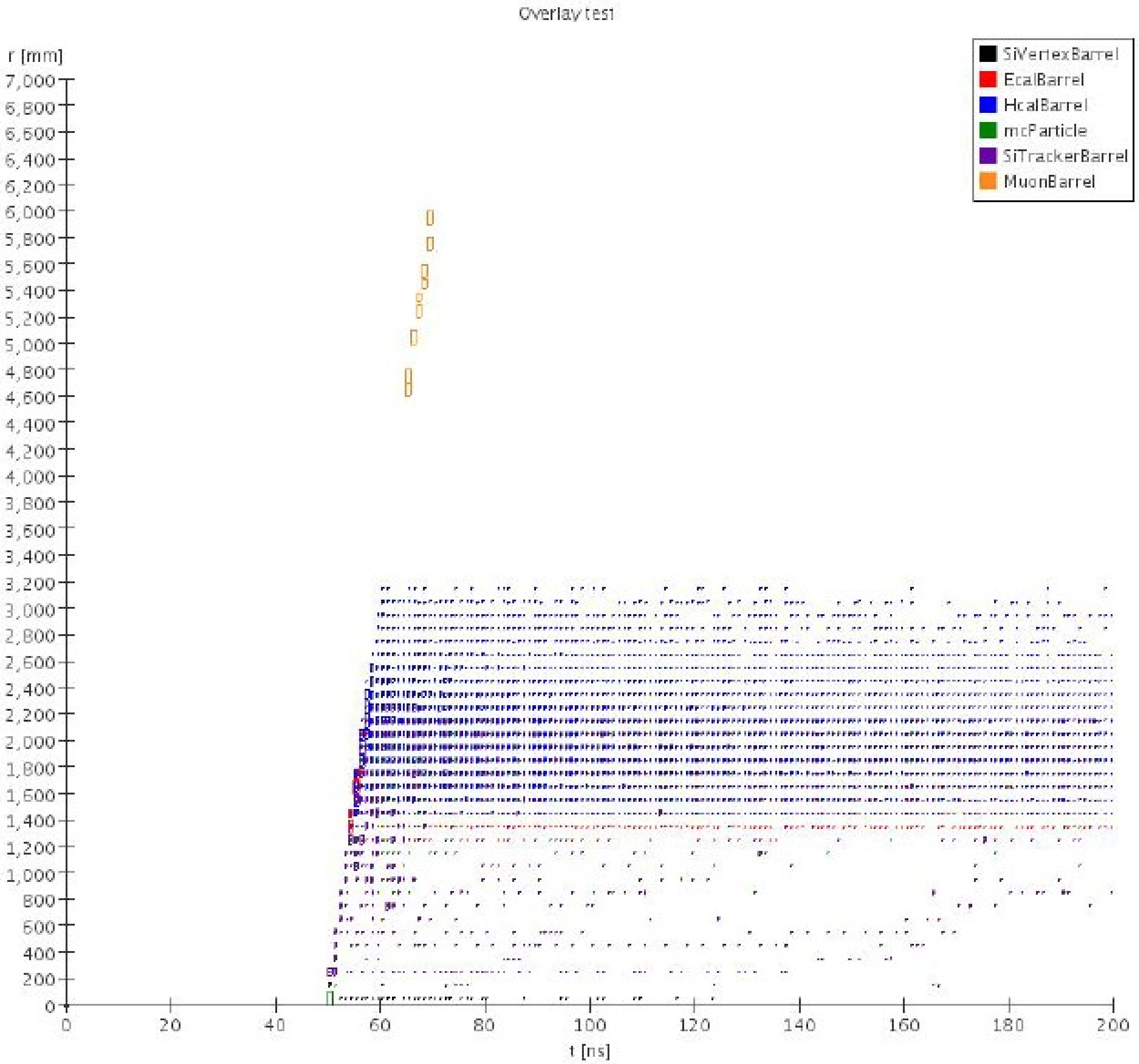
- First implementation in LCSim
  - Merging of collections (MCParticle, SimTrackerHit, SimCalorimeterHit, GenericObject)
  - Shifting events in time, depending on their bunch crossing
  - Removal of hits outside of relevant readout window (time of flight corrected)
  - Random or user placement of signal in the bunch train

(C. Grefe, P. Schade)

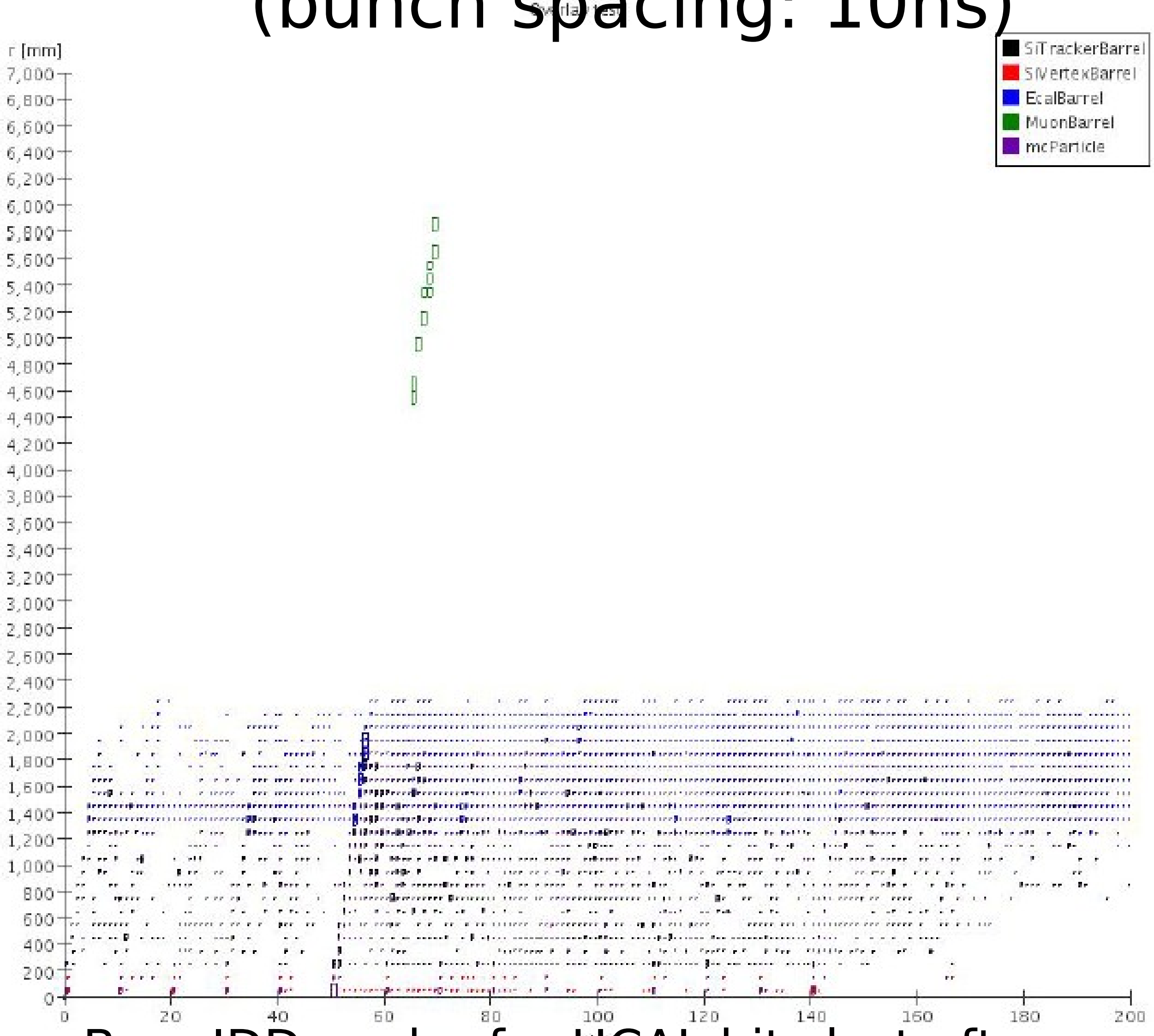
Time structure of single tt @ t=0ns



Time structure of single tt @ 50ns

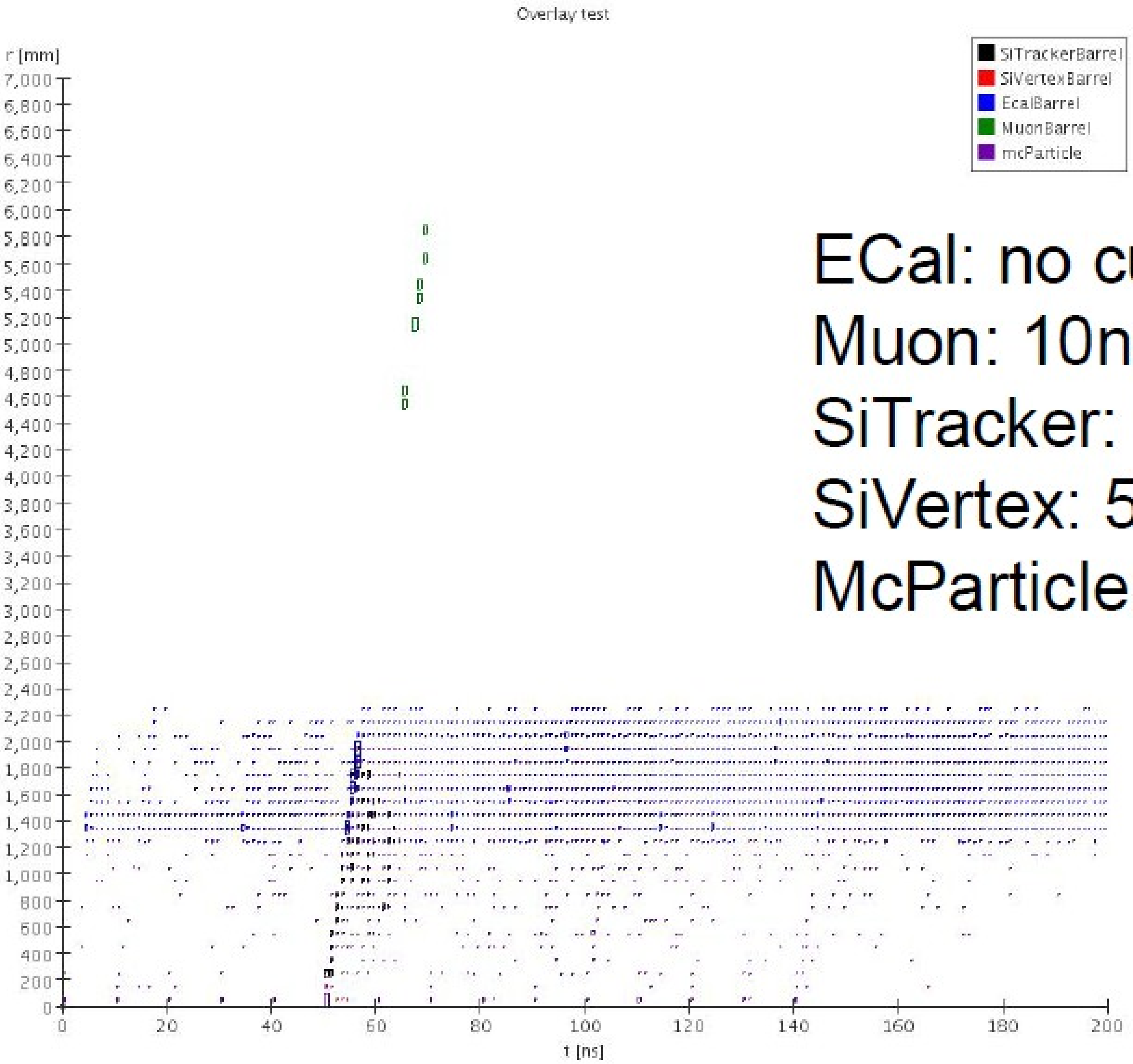


Overlayed 15BX of Z → uds @ 91GeV (bunch spacing: 10ns)



Bug: IDDecoder for HCAL hits lost after merging; fixed since today

Introduce time window per readout collection



ECal: no cut

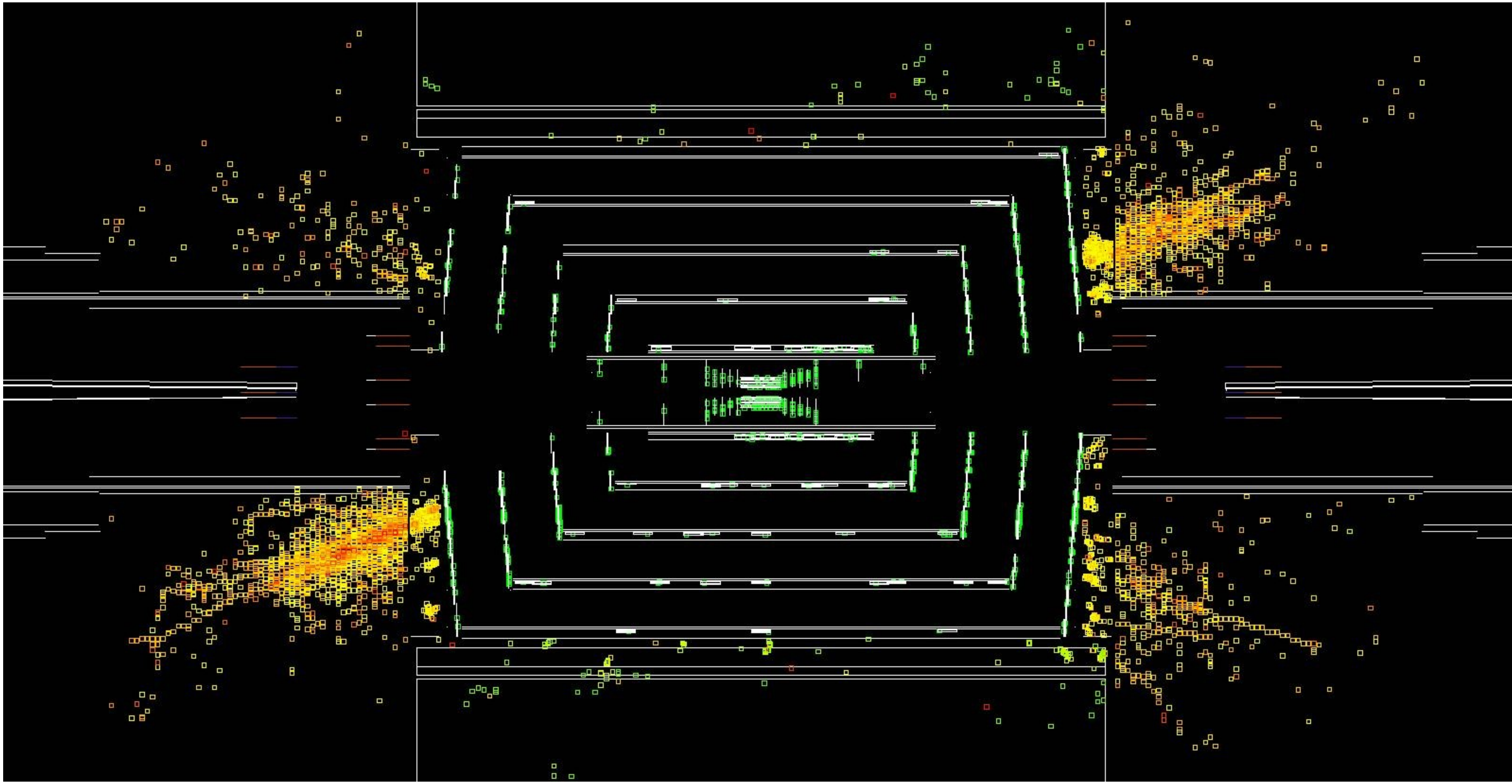
Muon: 10ns

SiTracker: 10ns

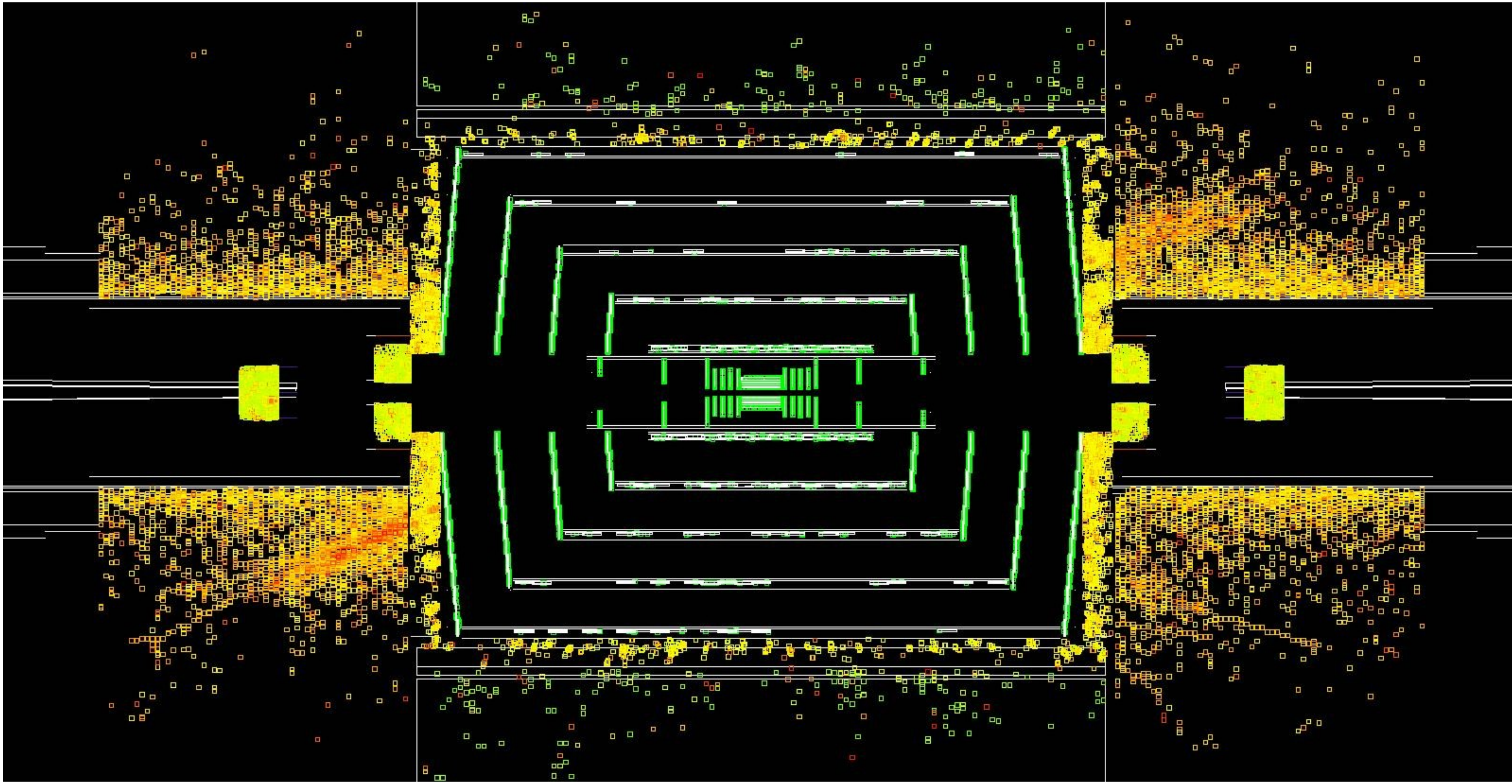
SiVertex: 5ns

McParticle: no cut (always)

Z → uds, 500 GeV



Z → uds, 500 GeV + 20BX γγ → h bkg



Event Overlay Plans

- Communication with digi drivers (automatic setting of readout windows)
- Add an LCRelation to keep track of source of MCParticles (signal or type of background)
  - Add a helper class to take care of the truth matching for all kinds of hits through the MCParticle relation
- Fix problem with CellID/DetectorElement in Hcal hits (position somehow lost during merging) → fixed since today
- Improve performance → not good yet
- P. Schade started to look into the Marlin version. Starting with LCSim version as baseline.

Summary

- **HCAL depth studied**
  - _ Calorimeter only
  - _ PFA

    → same conclusion → choose 7.5λ

- **Tracking**
  - _ Acceptance down to 7°
  - _ Meets physics requirements

- **Particle Flow performance**
  - _ SlicPandora+Pandora working (see talk from J. McCormick)
  - _ Full chain slic+lcsim+slicpanodora/pandora+... now working on the grid

- **Event Overlay**
  - _ First implementation

Backup

HCAL depth and material

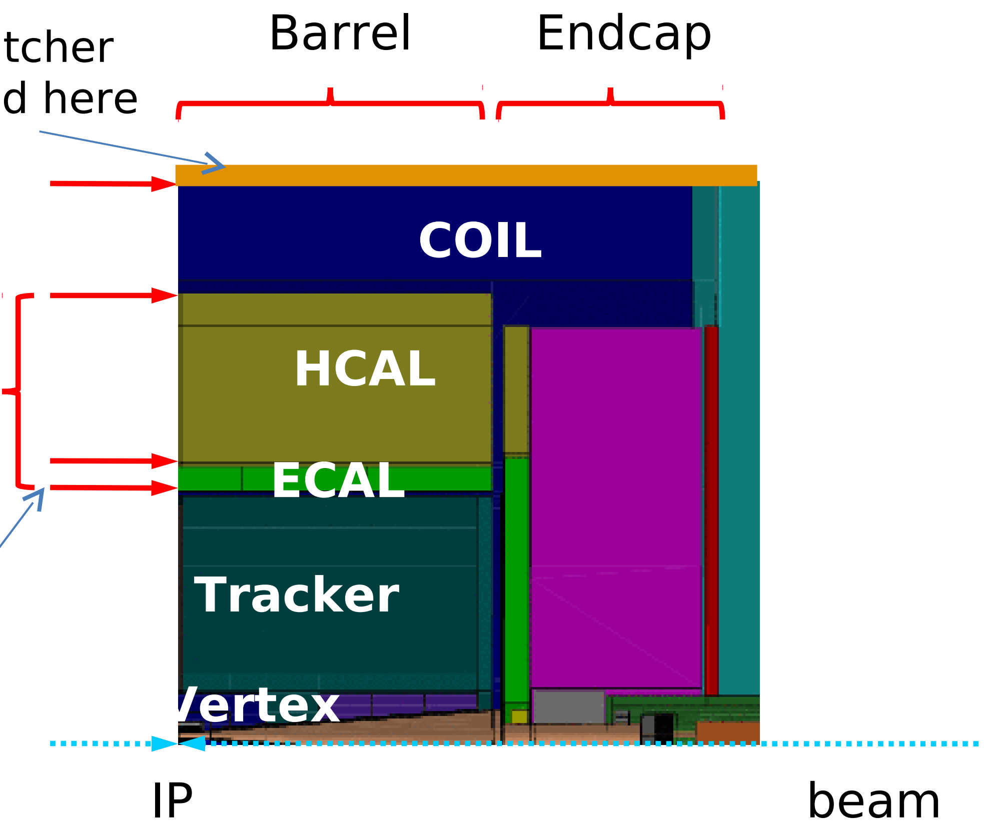
Calorimetric resolution driven by intrinsic resolution and by leakage

to reduce leakage:
→deeper calorimeter
→denser calorimeter
(more interaction lengths)

depth limited by feasible coil size:
→larger coil with smaller B-field
→larger B-field with smaller coil

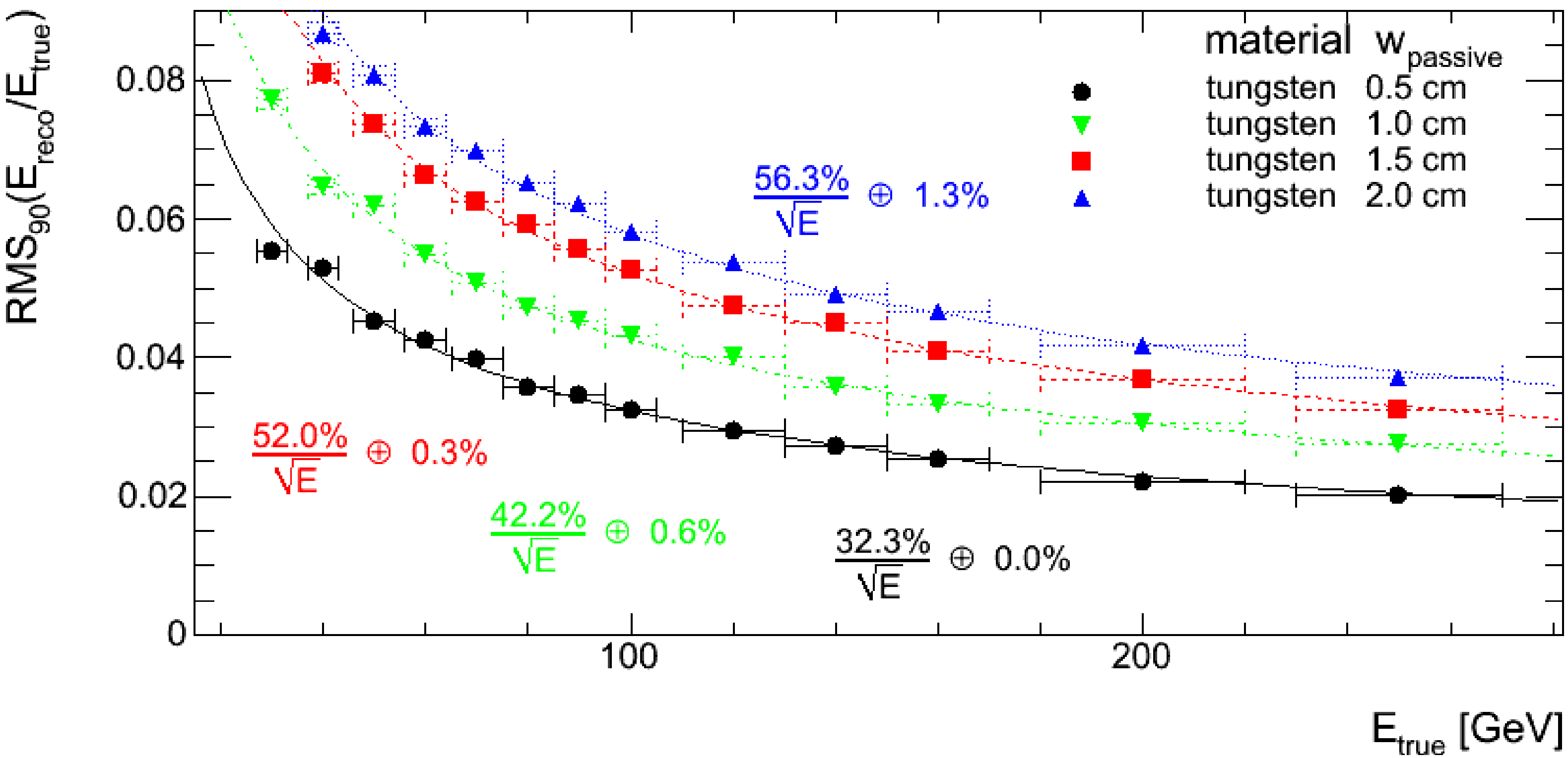
depth limited by tracker size:
→larger tracker →better p-resolution

tail-catcher located here



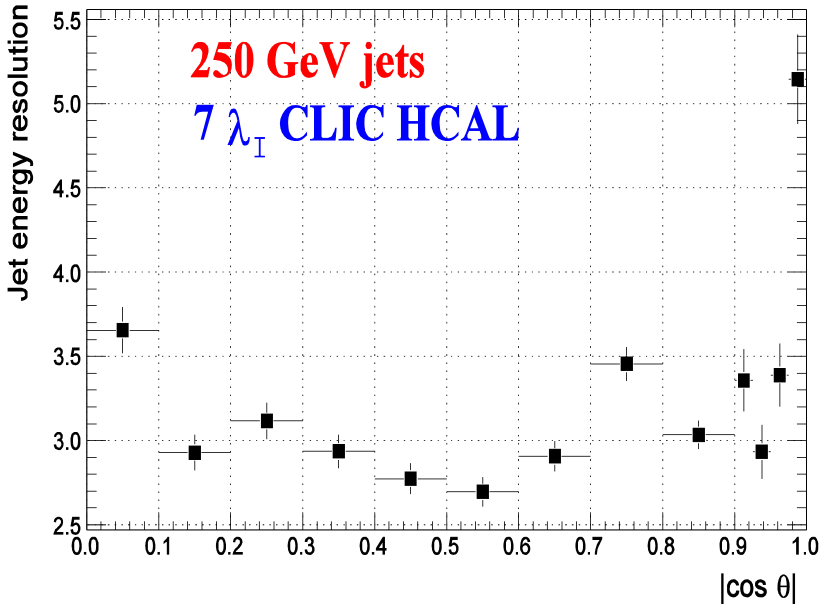
Energy resolution in a long W-calorimeter (>20 λ)

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10

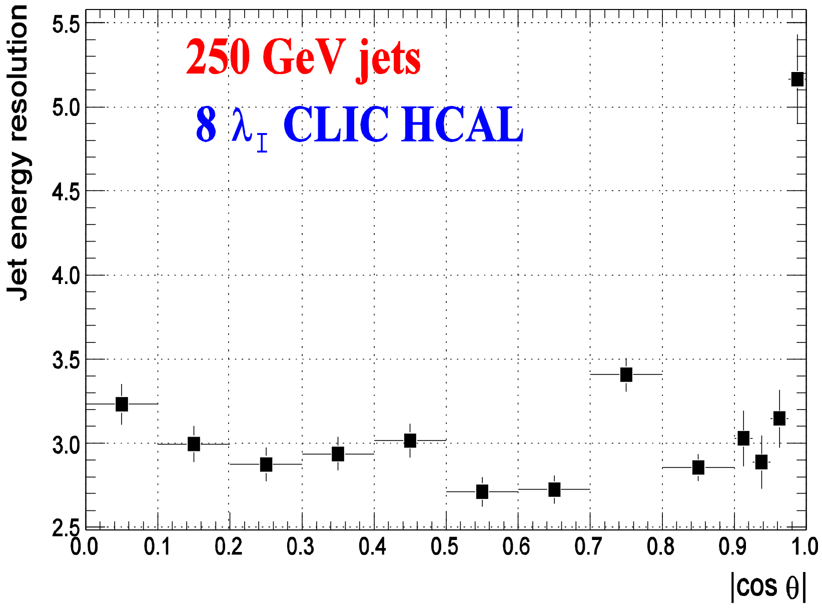


Energy resolutions for 250GeV jets

7λ HCAL



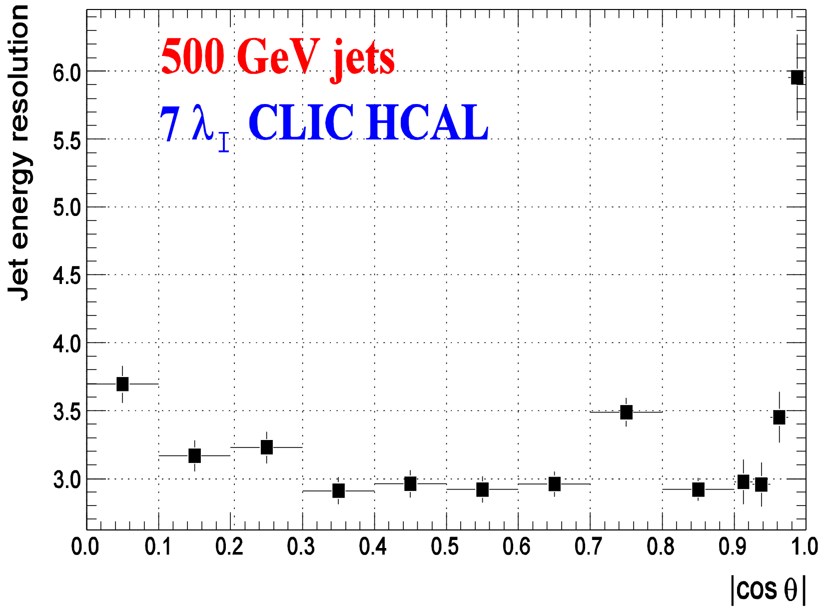
8λ HCAL



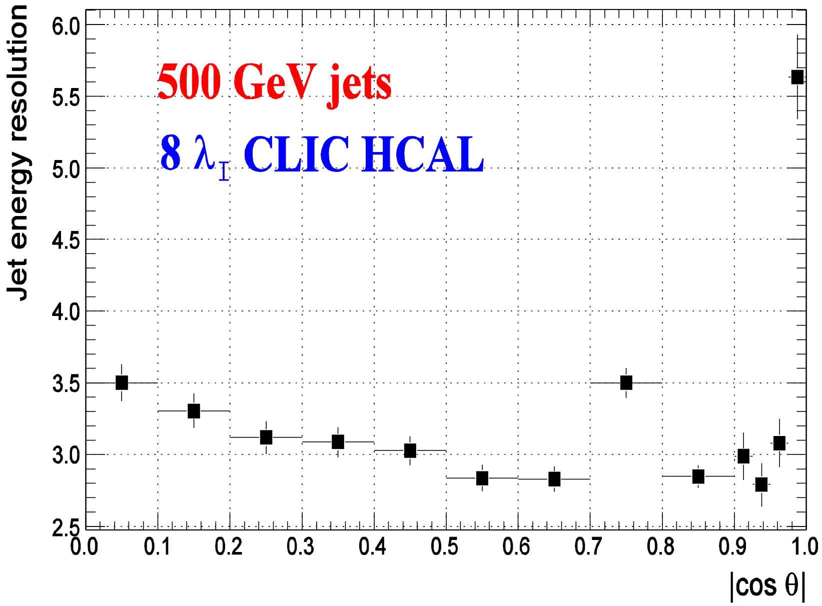
Done with the ILD detector

Energy resolutions for 500GeV jets

7λ HCAL



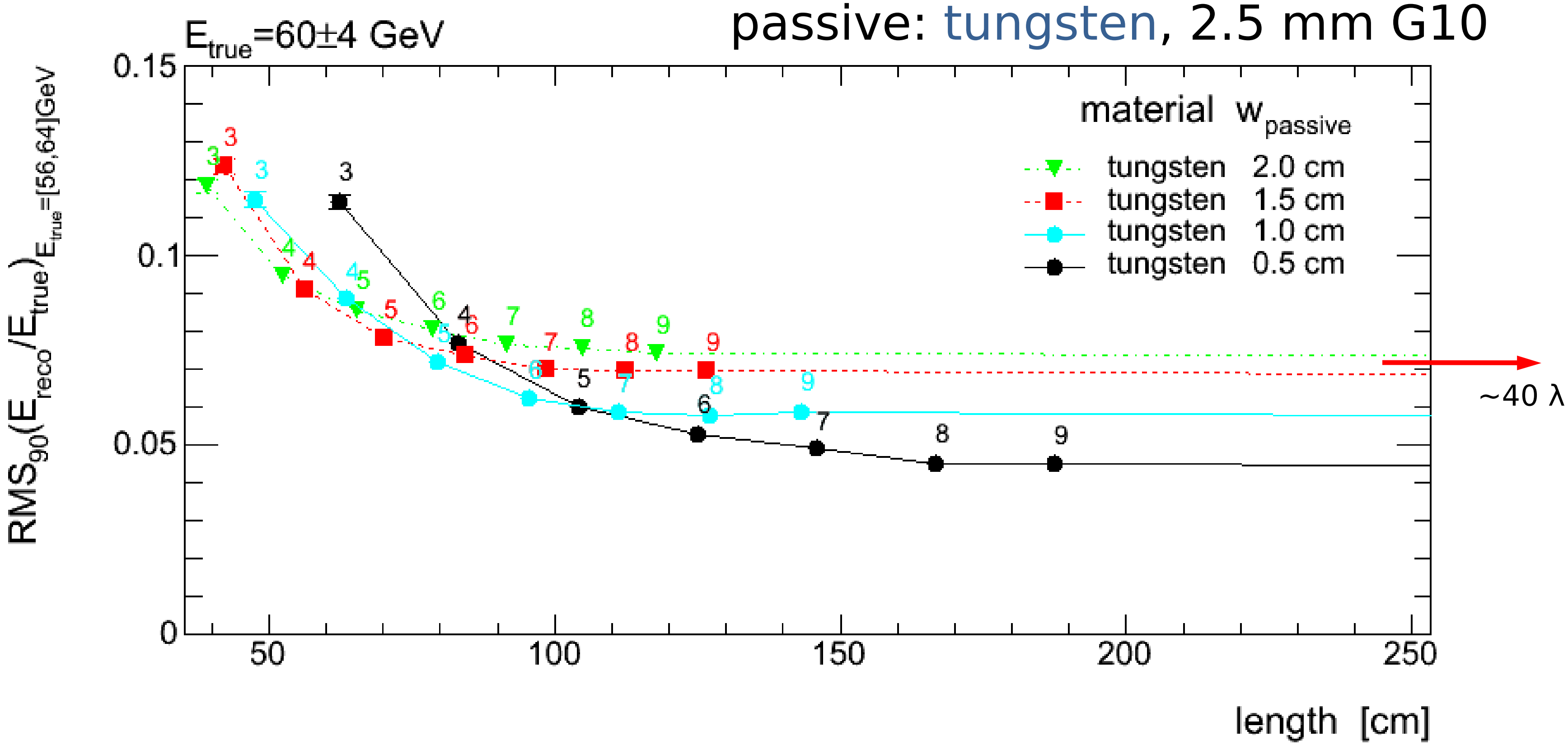
8λ HCAL



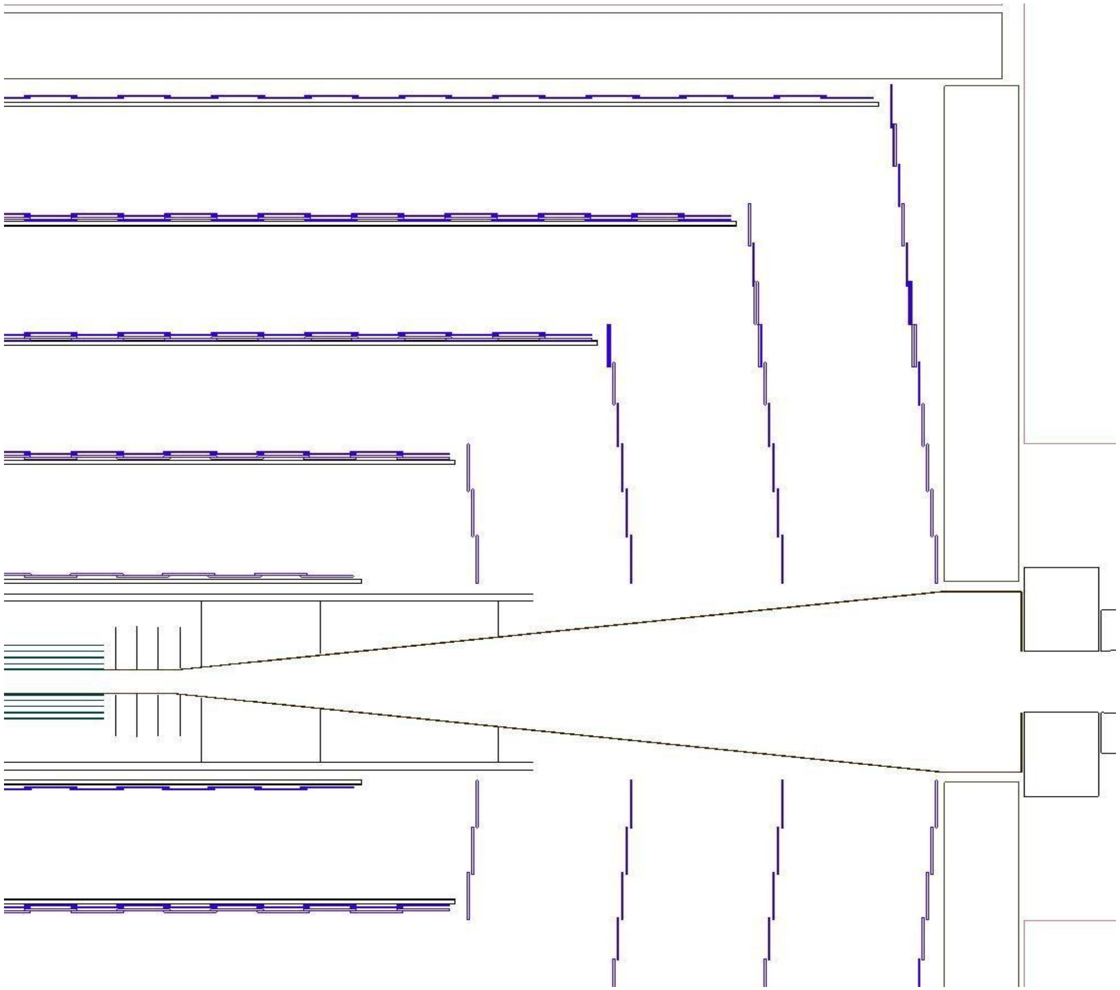
Energy resolution in W calorimeters: 60 GeV pions

lower energy → flat region reached earlier
(less interaction length needed to contain clusters)

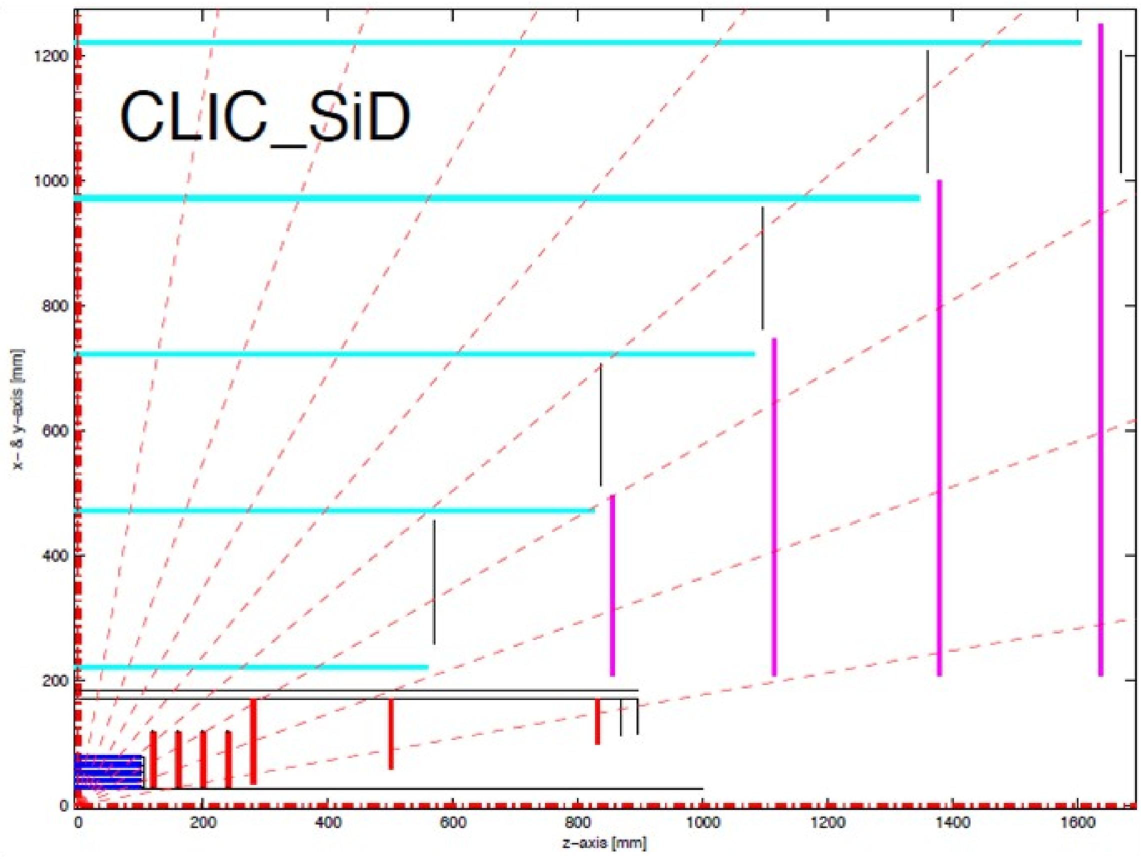
active: 5 mm scintillator
passive: tungsten, 2.5 mm G10

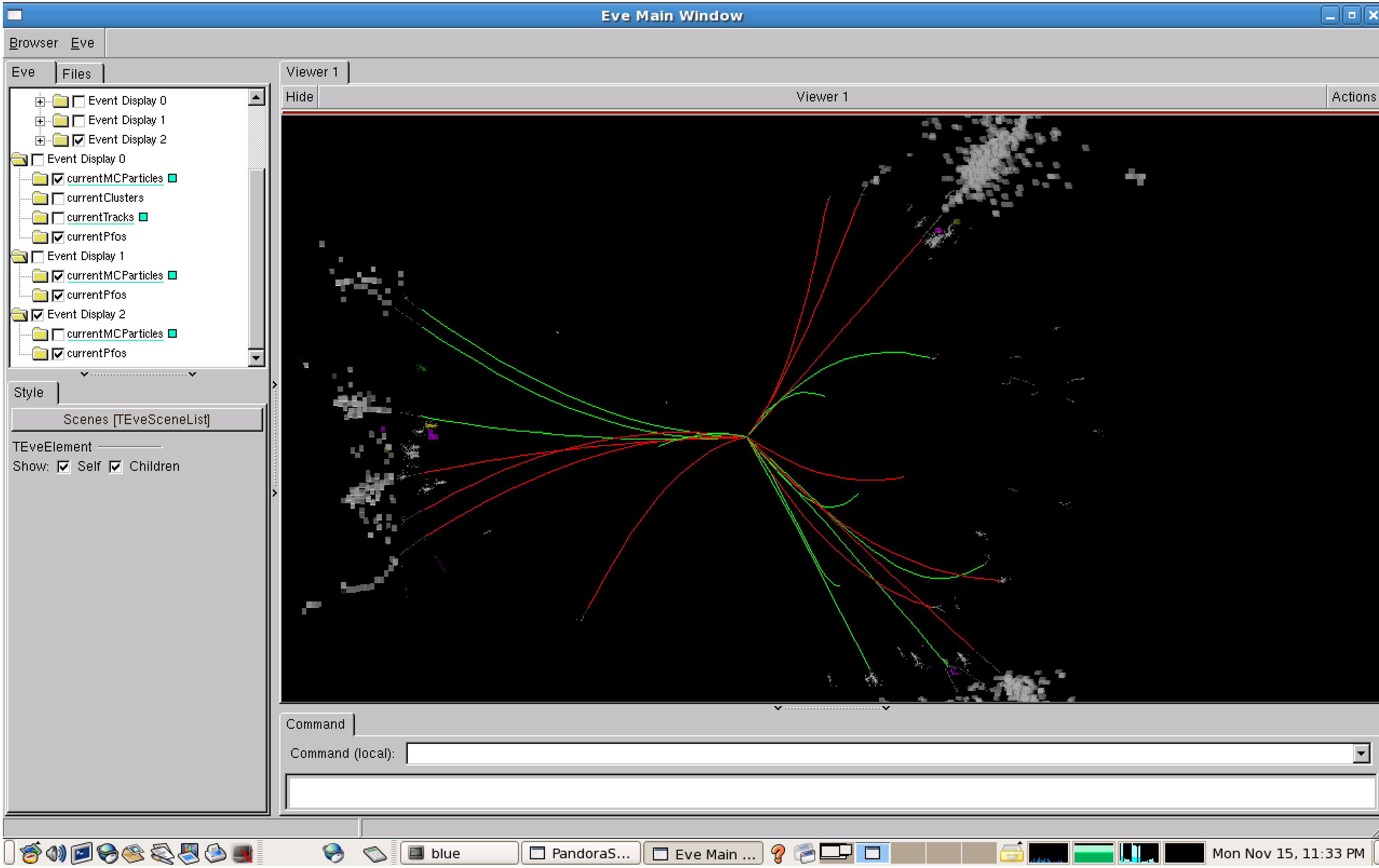


CLIC_SiD tracking system



Tracking system, simplified

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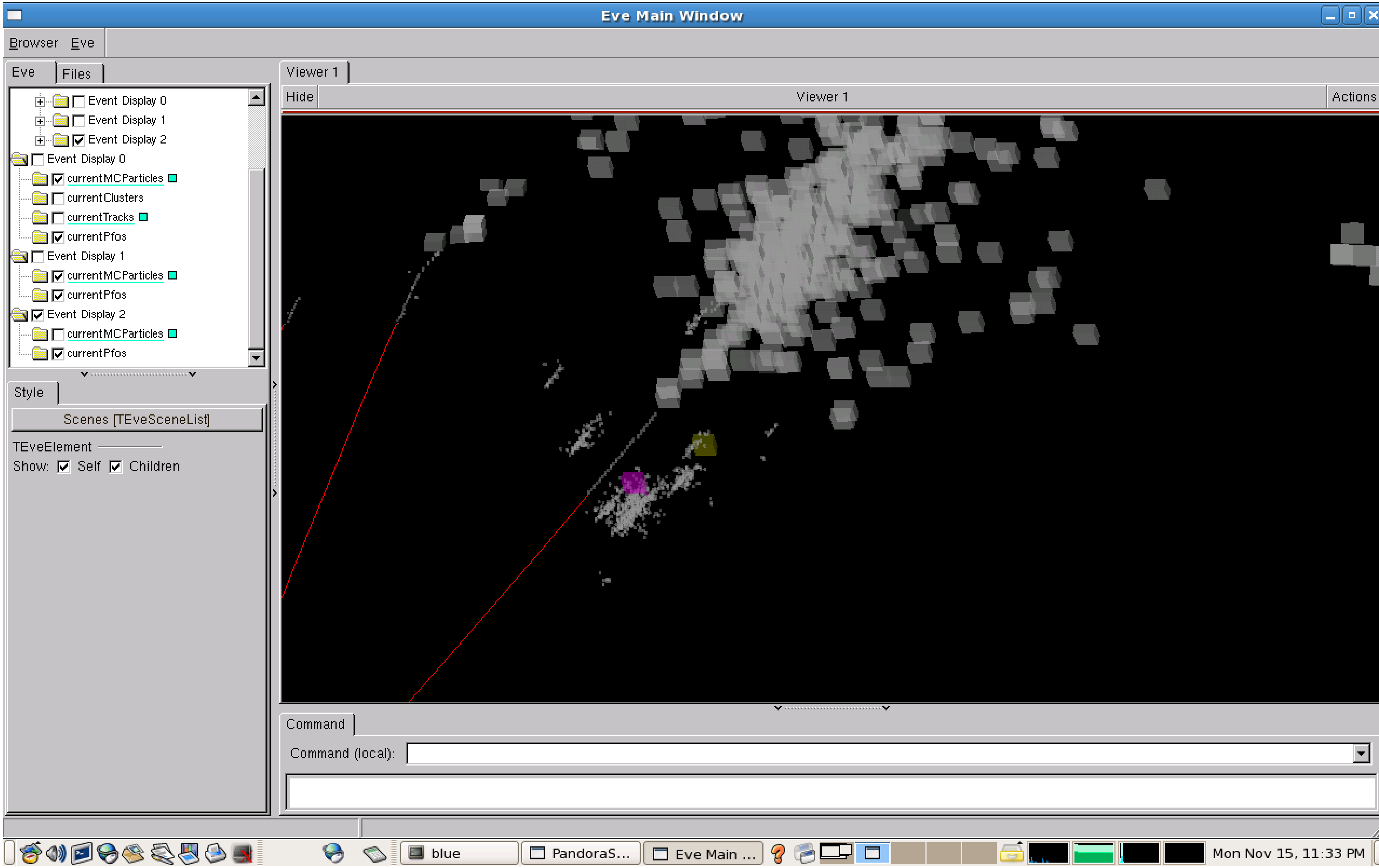
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Background: 3.2 gamma-gamma → hadron, 30BX, bunch spacing 5ns, Signal: 1 single muon