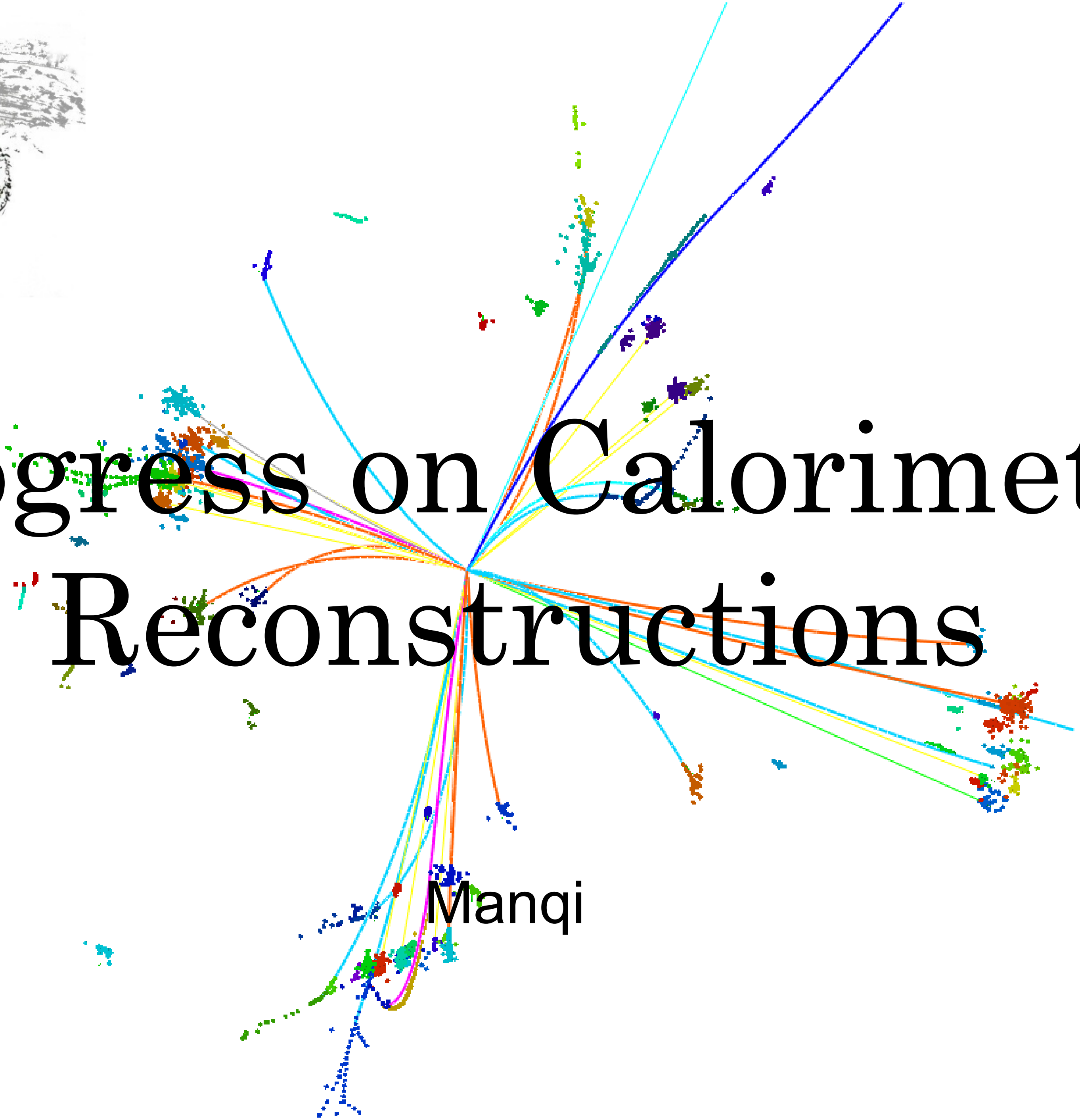
Progress on Calorimeter Reconstructions



Manqi

Outline

- Foreword:
  - Many thanks for letting me do this talk... If you got questions, pls ask the authors directly ;)
  - Sorry for not being able to include other related progress
- Daniel: New Digitization, a generic digitizer that takes care of both Silicon/Scintillator Sensor have been developed.
- Katsu: SSA, detailed comparison on JER are made
- John & Mark: Optimization Orientated & Improving Pandora from details!
- Manqi: Arbor towards now/future

Improved realism of ECAL digitisation

D. Jeans (U. Tokyo), ILD@Oshu

Until now, digitisation of ILD ECAL hits has consisted of
simple **energy** and **timing** thresholds on
energy deposits in silicon / scintillator

Recently developed digitisation of ECAL hits with improved realism
- some accounting for sensor and electronics response
- bring silicon and scintillator simulations to a **similar level of realism**
- give more confidence in technology comparisons

Several parameterised effects have recently been included into the
ILDCaloDigi processor (trunk version):

<u>General</u>

Calibration uncertainties
Fraction of “dead” cells
Noise and finite dynamic range of readout electronics

Technology-specific effects:

Silicon

Fluctuations in # electron-hole pairs <--- very small effect

Scintillator/MPPC

Non-uniform response along strip
Finite photo-electron statistics <-- affects low energy hits
MPPC saturation <-- affects high energy deposits
Non-uniform MPPC pixel response

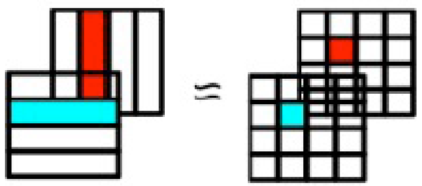
In all cases, rather simple/naive/randomised modeling,
but certainly closer to reality than what has been used until now
allows studies of implications of these effects

Updated ILDCaloDigi now in MarlinReco trunk (new helper class ScintillatorEcalDigi)
Default behaviour is unchanged,
realistic digi parameters set at run time (via steering file)

Code now undergoing independent testing by ScECAL group members
They will then decide on recommended parameters
by comparing with test-beam data

Wider use, testing, feedback and development are of course very welcome.

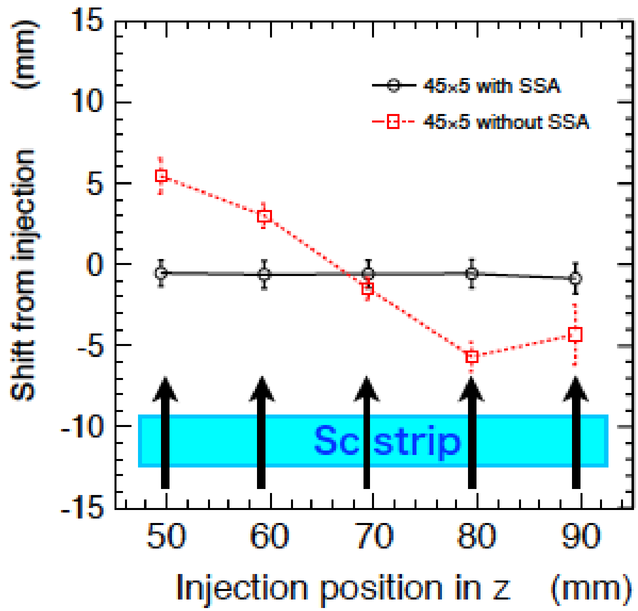
Strip Split Algorithm



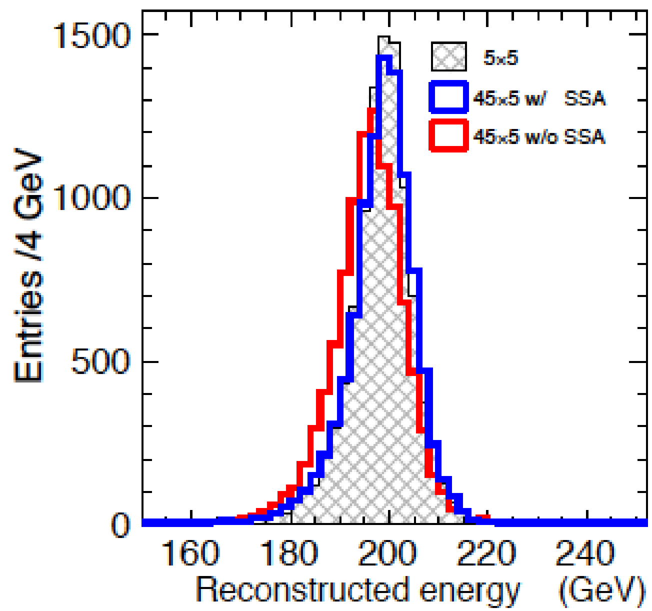
Energy deposits are redistributed into 5x5 mm^2 virtual cells referring hits in the nearest layers.

strips in the nearest layers have orthogonal direction.

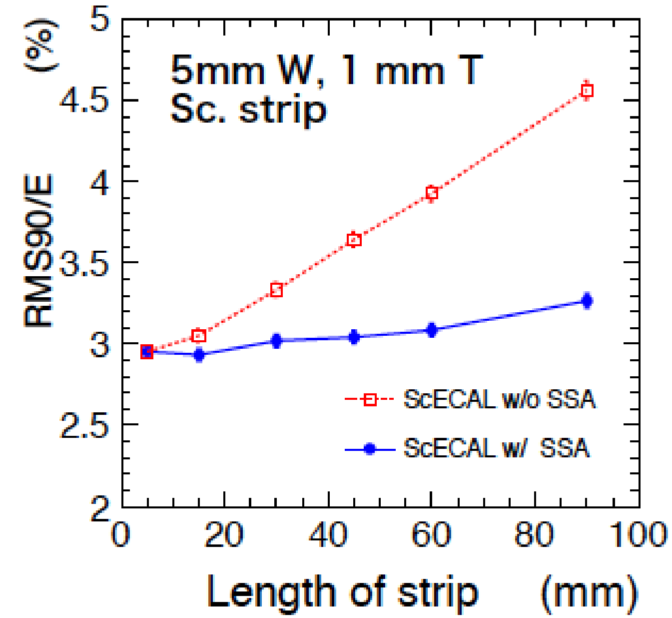
Position of 10 GeV photon



Energy sum of 2 x 100 GeV jet



Energy resln. 100 GeV Jet



Left: position accuracy and precision

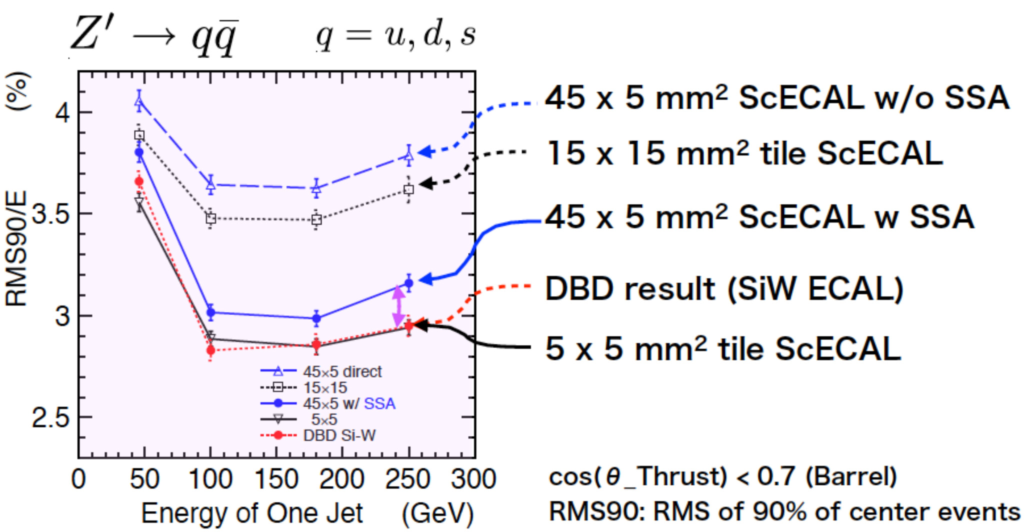
Error bar (RMS) < 1 mm w/ SSA.

Middle: Energy is recovered correctly w/ SSA.

Right: Jet energy resolution is kept w/ SSA.

Further comparisons

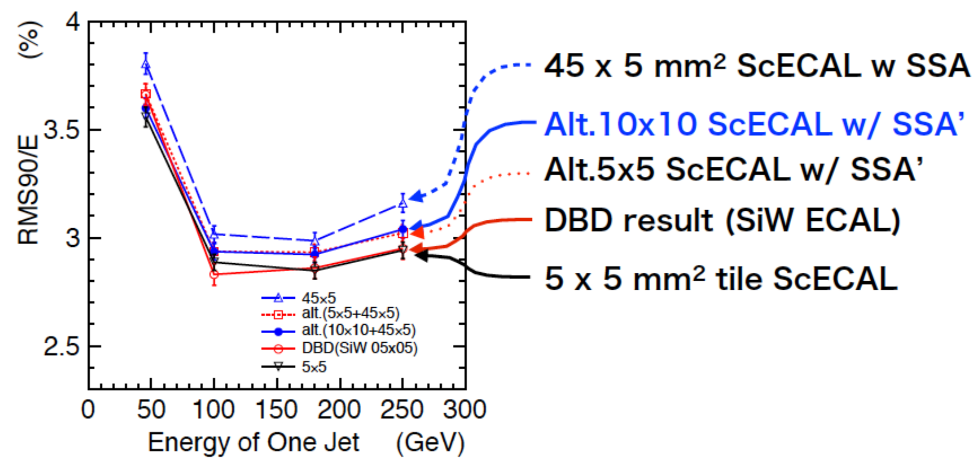
Jet energy resolution in ILD



cos(θ_Thrust) < 0.7 (Barrel)
RMS90: RMS of 90% of center events

SSA makes JER of strip ECAL close to 5 x 5 mm² tile ECAL
Difference is only 0.2-0.25%.

Jet energy resolution with "alternate tile"



ScECAL alternately replaced strip layers with 10x10 mm² layers has similar energy resolution to 5x5 mm² tile ScECAL (also DBD result with SiW ECAL) at $E_{jet} \leqq 100$ GeV, only 0.1% degrades at high energy.

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Maybe it's the time to:
test with Daniel's new Digitizer &
full-simulation analysis (I.e, Higgs signal + bkgrd) on physics channels?

Digitisation and Calibration

ADC Current
Sim Calorimeter Hits

↓

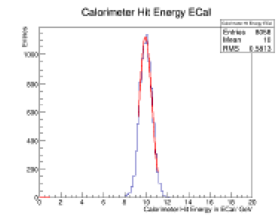
Energy Deposition
Calorimeter Hits

↓

Electromagnetic & Hadronic Energy Scale
Particle Flow Objects

ADC Current → Energy Deposition

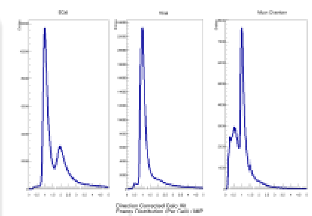
- Digitisation Constants: CalibrECal, CalibrHCal...
- Set by tuning sum of calorimeter hit energies for events (γ for ECal, KaonL for HCal) contained within specific parts of the detector.



Setting CalibrECal.

Energy Deposition → Minimum Ionising Particle

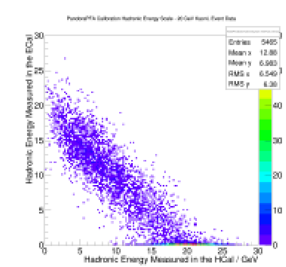
- MIP Constants: ECalToMIP, HCalToMIP and MuonToMIP.
- MIP definition used within PandoraPFA.
- Set by tuning the peak of the direction corrected calo hit energy deposition, on a per cell basis, to 1 for 10 GeV μ events.



ECal/HCal/Muon GeVToMIP Calibration.

Energy Deposition → Electromagnetic/Hadronic Energy Scale

- PandoraPFA Calibration Constants: ECal/HCal To EM/Had
- Electromagnetic/Hadronic scale set using PFO energy of contained γ/KaonL events.

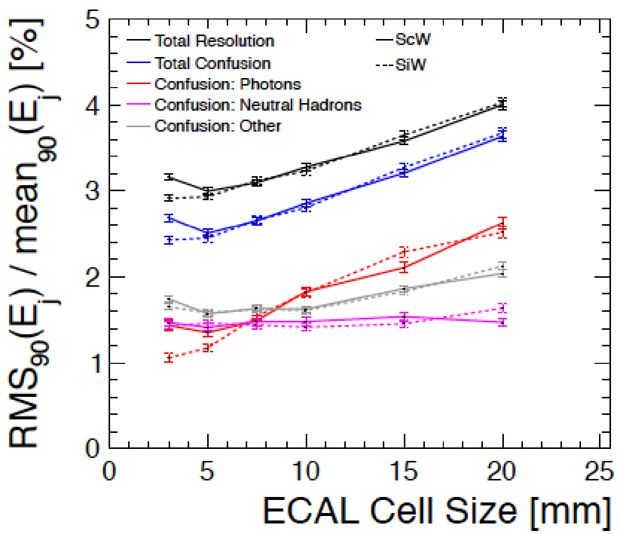


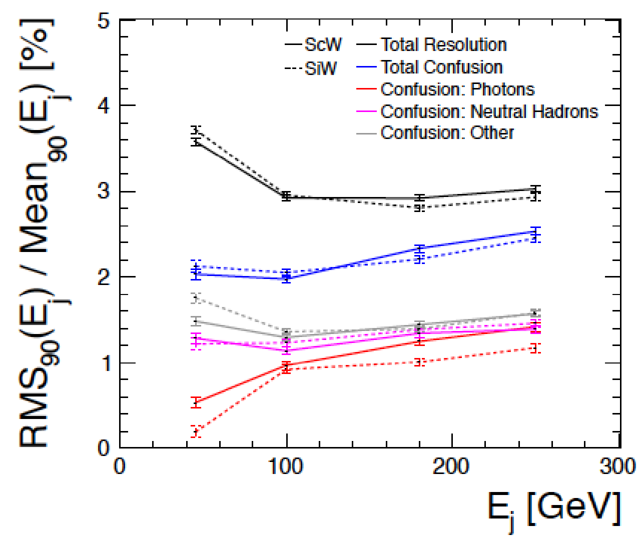
ECal/HCalToHad Calibration.

Maybe we need Automatic procedure for different geometries?

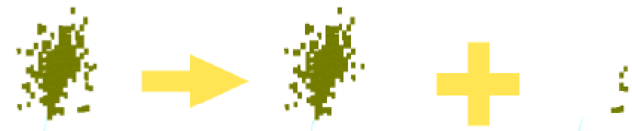
ECal Studies

- The role of the ECal is to measure the energies of photons and the early parts of hadronic showers. In a particle flow approach, it is essential to be able to distinguish energy deposits from different particles. This means fine ECal granularity is important. Combining this with use of Si as active material make the ECAL expensive.
- Recent simulation studies, in unparalleled detail, have examined the variation of jet energy resolution as a function of key ECAL parameters, for models using Si or scintillator (Sc) as the active material:
- Transverse granularity; Number of layers; Inner radius; B-Field strength and Sc thickness.
- Have also examined novel ECAL models that use Si for the first few active layers, then move to Sc deeper in the calorimeter.The Sc cell sizes can then increase with calorimeter depth.





Photon Fragmentation

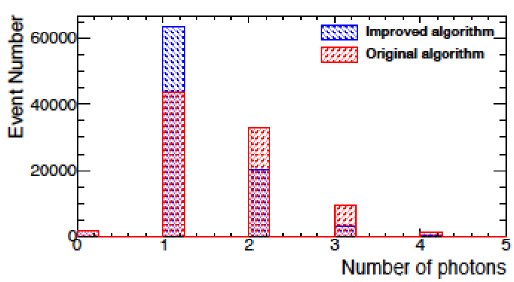


Photon Confusion

- Photon confusions occur when the PFA fails to resolve photons from nearby particles.
- To reduce photon confusion, a stand alone photon reconstruction algorithm is applied.
- However, this aggressive algorithm introduces the photon fragmentation.

Fragmentation Removal

- Photon fragments can be removed by merging selected photon pairs (also photon-neutral hadron pairs), which come from the same MC photon.
- Pairs are treated differently according to the energy of the low energy part in the pair.
- The selection criterion include: Distance separation between two clusters; Average distance separation over shared layers between two clusters; Energy of each clusters and etc.



Number of reconstructed photons improved in the one MC photon sample, preliminary result.

Results

- Removing photon fragments will improve the photon identification, which will aid physics analyses.
- An example is the leptonic Tau decay modes separation, which relies on the photon separation.

HCal Studies

- In a particle flow approach the role of the HCal is to measure the energy of neutral hadrons.
- Optimisation studies relating to the HCal are in progress.
- As for the ECal studies the overall figure of merit determining the quality of the detector will be the jet energy resolution.

Ongoing studies

Optimisation of the HCal for the ILD detector model will be performed by varying:

- Number of HCal Layers.
- Thickness of the HCal Layers.

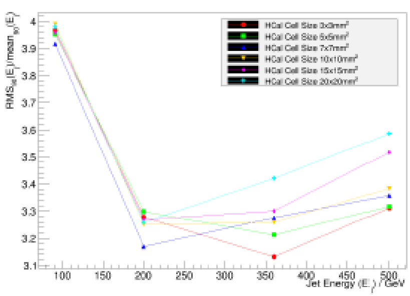
For these initial studies the detector parameters will be varied such that the total number of nuclear interactions lengths, λ_I, in the HCal remains constant at ~ 6.

Future studies

There are also plans for further detailed studies of the HCal, which will vary:

- The total number of λ_I within the HCal.
- The longtudinal granularity of the HCal.

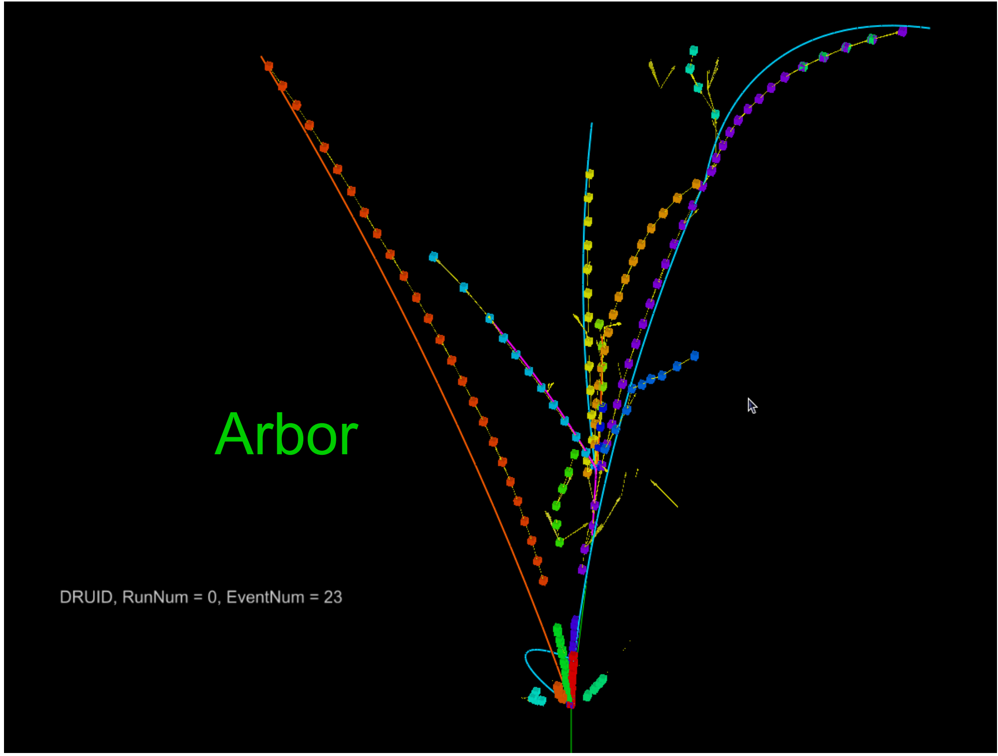
The exact details of these studies is still under discussion.

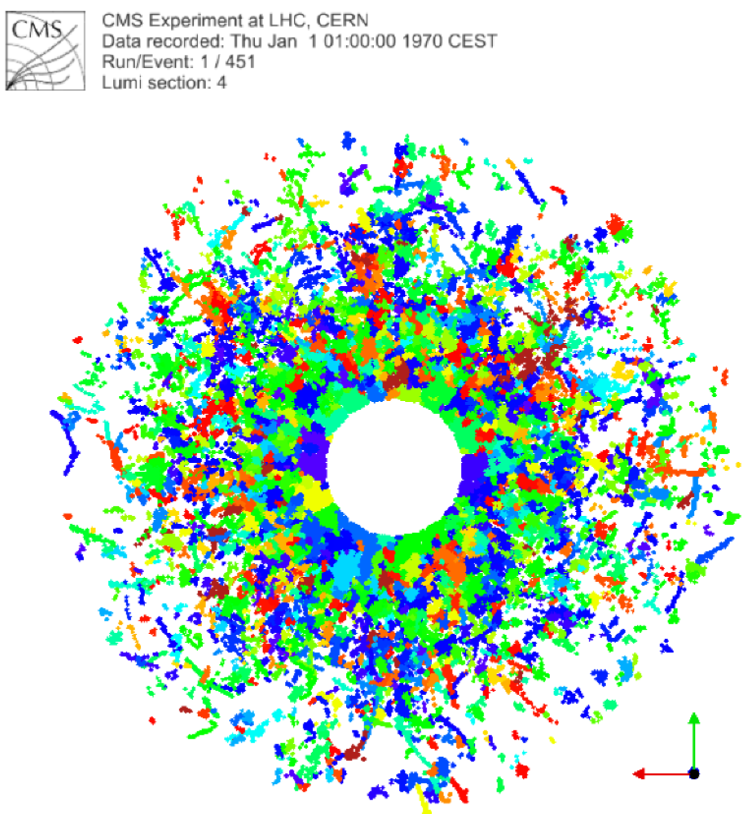


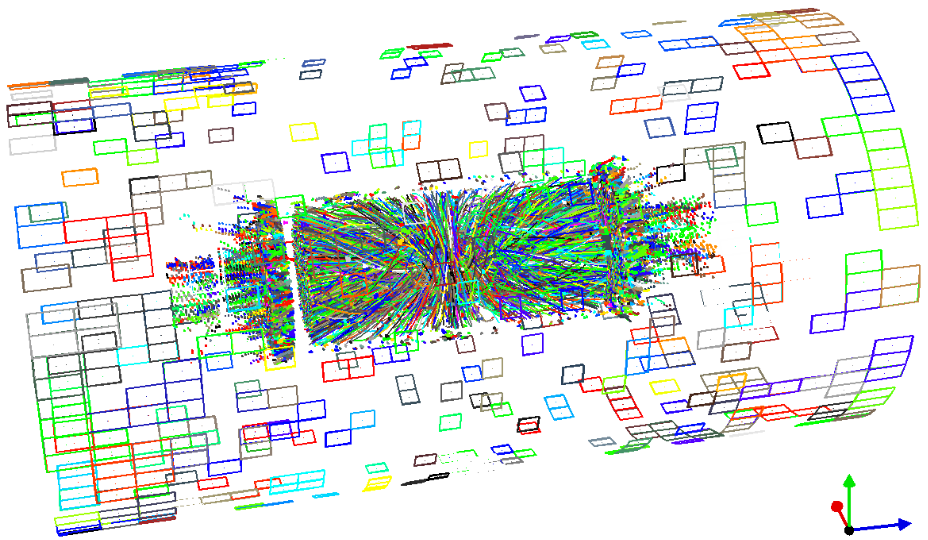
Jet energy resolution vs Jet Energy for a variety of different HCal cell sizes. Preliminary data as digitisation and PandoraPFA calibration have not been correctly implemented.

Arbor PFA

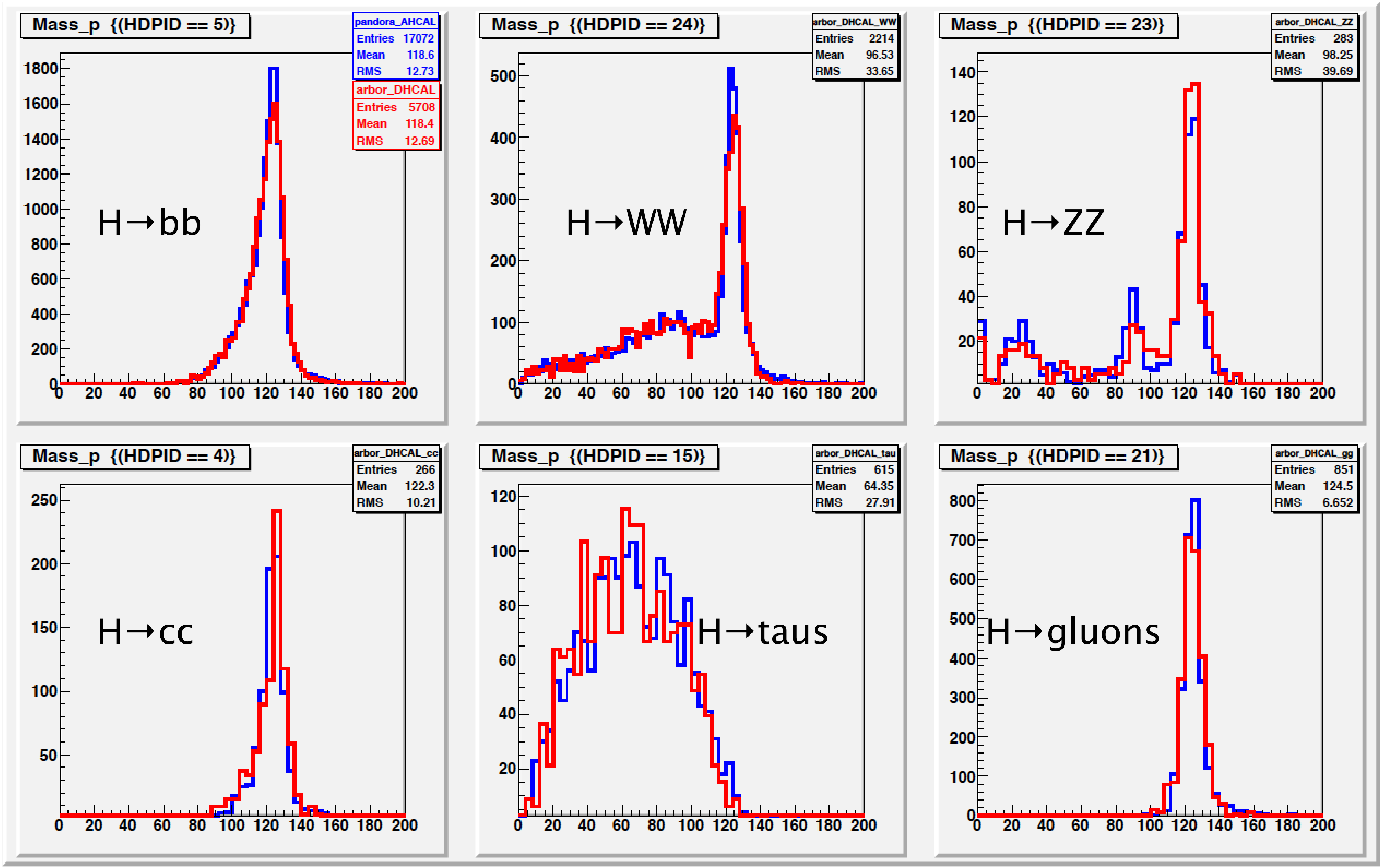
- Rewritten: core & matching
- Generic PFA
  - Excellent separation & sub-shower structure recognition
- Breakthrough at speed: ~ 40 second to process an event with ~100k hits (eg, CMS with 140 Pile up)







Arbor @ vvH event



Arbor, 10k events normalized to Pandora Statistic (~30 k)
Arbor_DHCAL: energy estimation with hit counting
Pandora_AHCAL: official sample (ILD_DST @ ILD_o1_v05)

Summary

- Progress towards better understanding of detector performance & detector optimization and algorithm optimization
  - Reliable modeling (Digitization)
  - Detailed performance studies
  - Confusion/Energy estimation tuning
  - Fast, Generic PFA
- We are on the way, to fully draw out the physics potential from our ultra-high granularity – Exciting!