GRPC SDHCAL: 1 m³ Prototype construction, test beam and analysis

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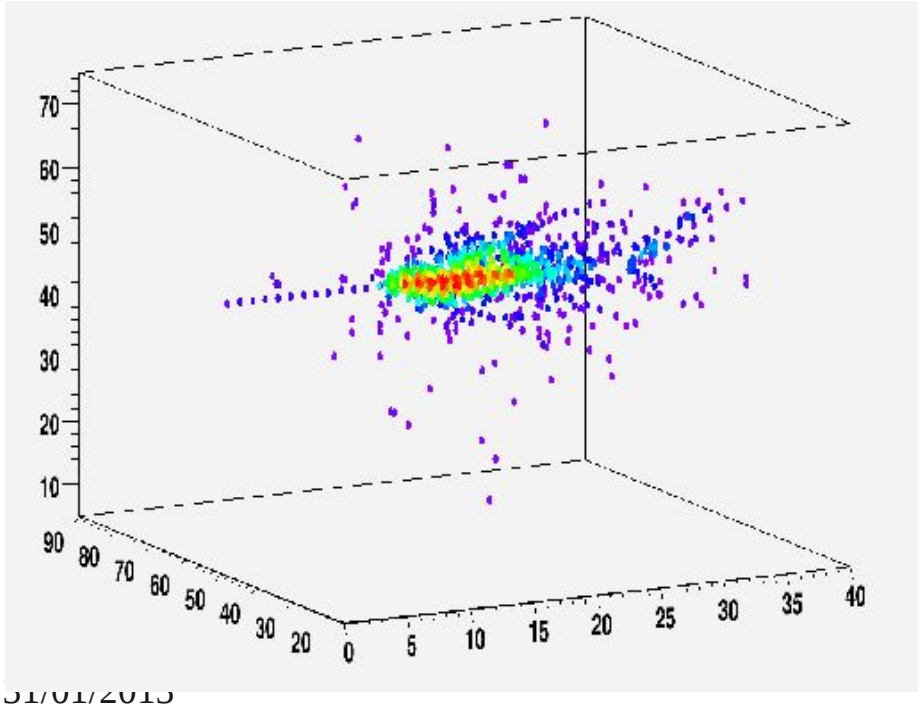
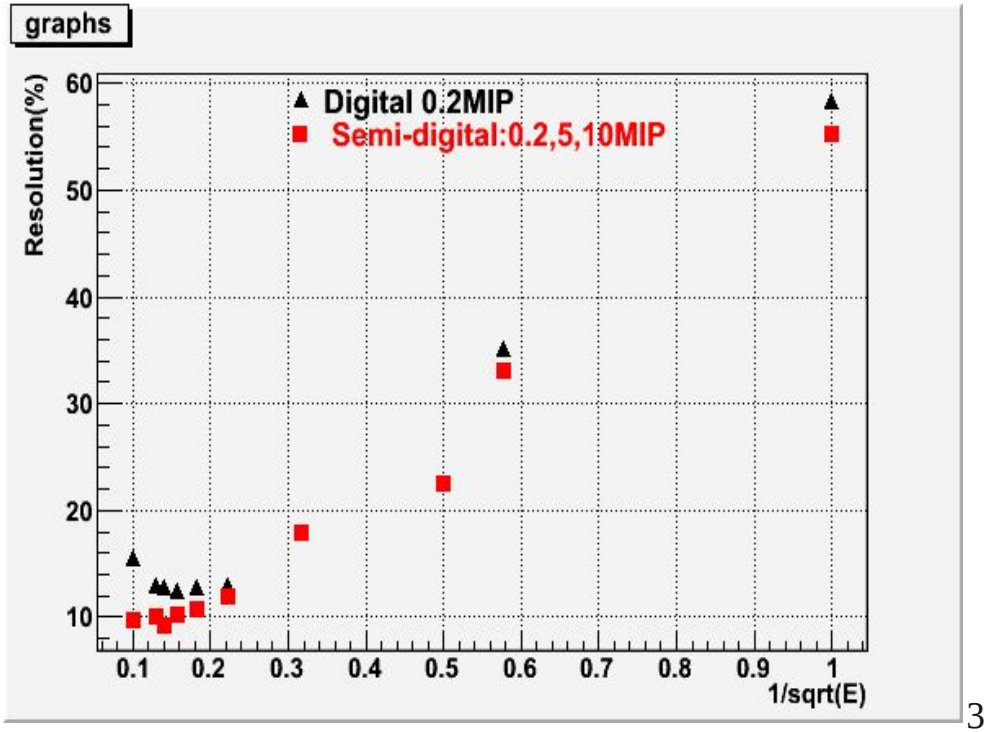
Outline

- Introduction: concept & prototype construction
- Test beam operations
- Reconstruction
- Data analysis
  - Event classification
  - Homogeneity & stability
  - Shower energy reconstruction
- On going studies: shower fine structure reconstruction
- Summary

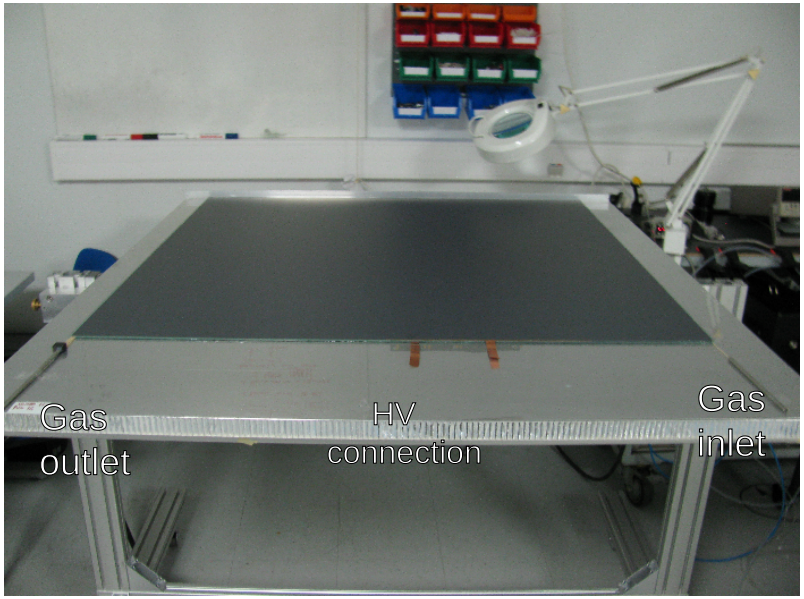
SDHCAL: Concept

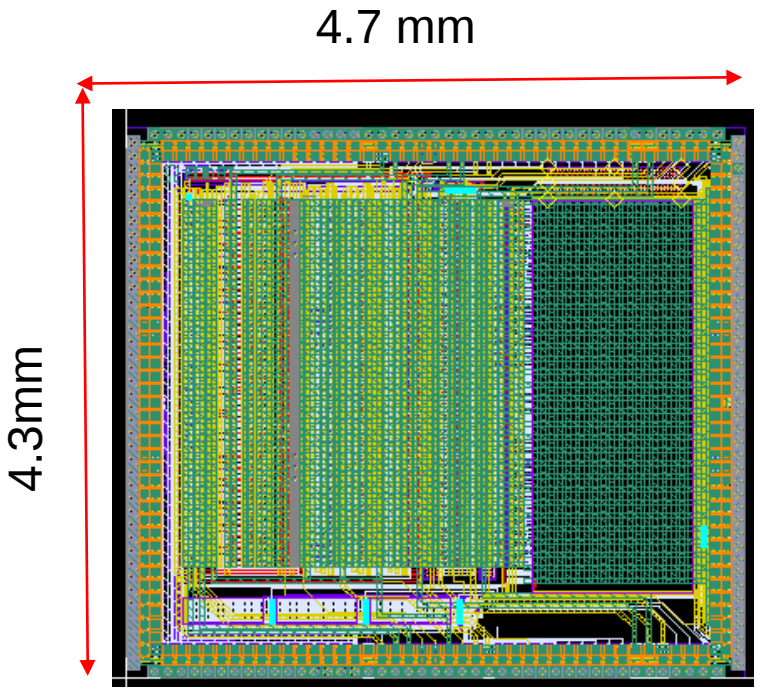
- Gaseous detector
  - Homogeneous, cost efficient
  - Digital: Ultra-high granularity with limited electronic cost
- Hit counting: saturation effect at high energy:
  - Limited avalanche size
  - Can be corrected from Semi-Digital readout

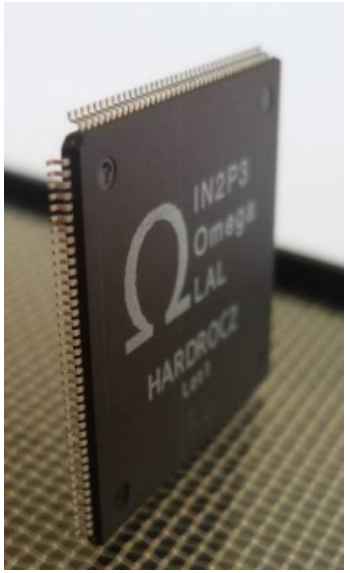




Construction







Large GRPC R&D:

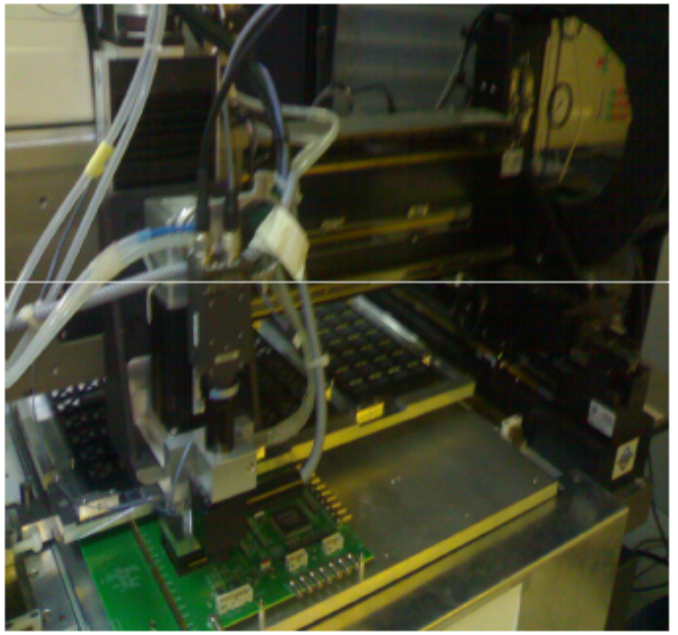
Negligible dead zone
(tiny ceramic spacers)
Efficient gas distribution system
(channeling gas inlet and outlet)
Homogeneous resistive coating
(special paint mixture, silk screen print)

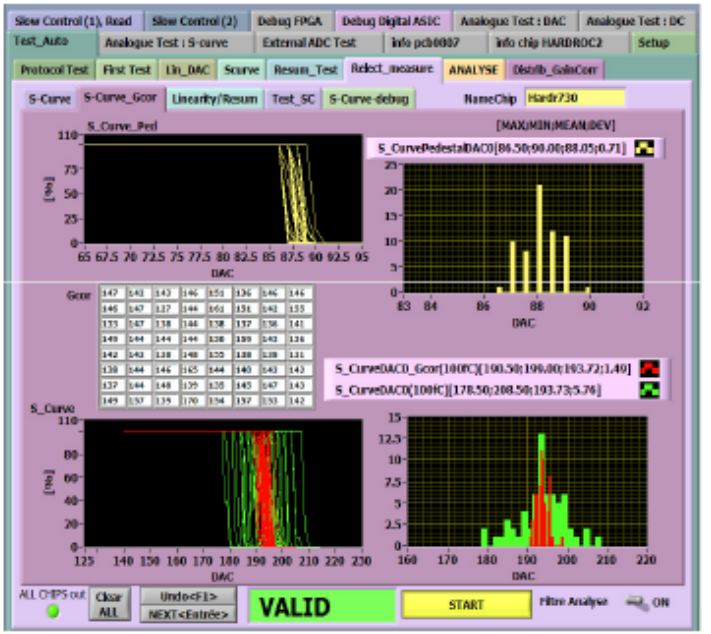
HARDROC2 ASICs

64 channels
Trigger less mode
Memory depth : 127 events
3 thresholds
Range: 10 fC-15 pC
Gain correction: uniformity
Power-Pulsed

SDHCAL prototype construction

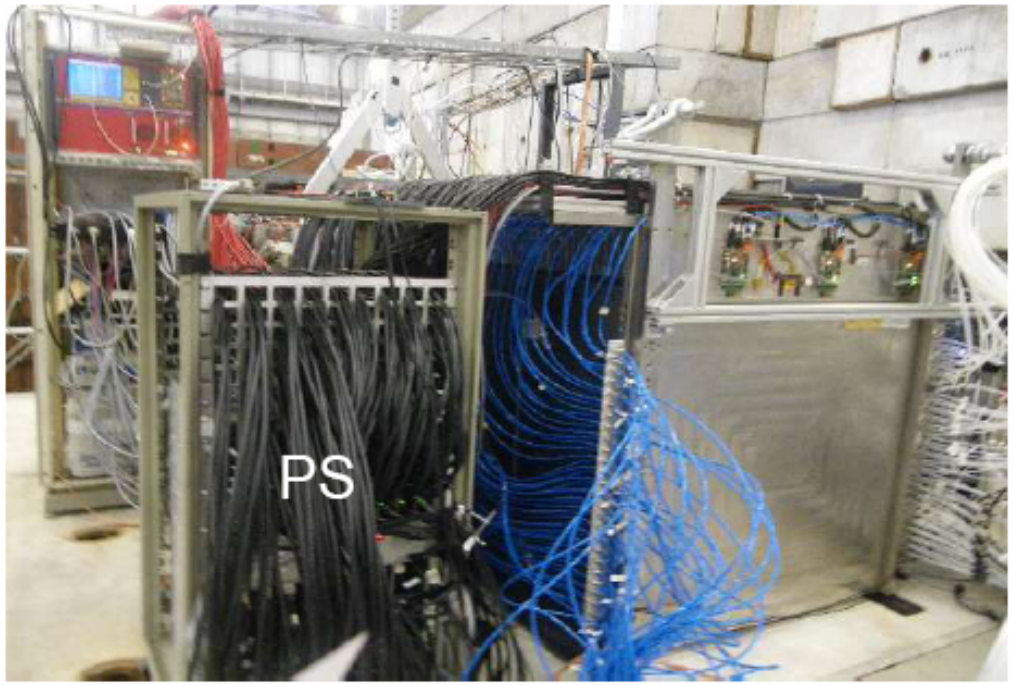
✓ 10500 ASIC were tested and calibrated using a dedicated robot(93% layout)
✓ 310 PCBs were produced, cabled and tested according to strict quality control rules

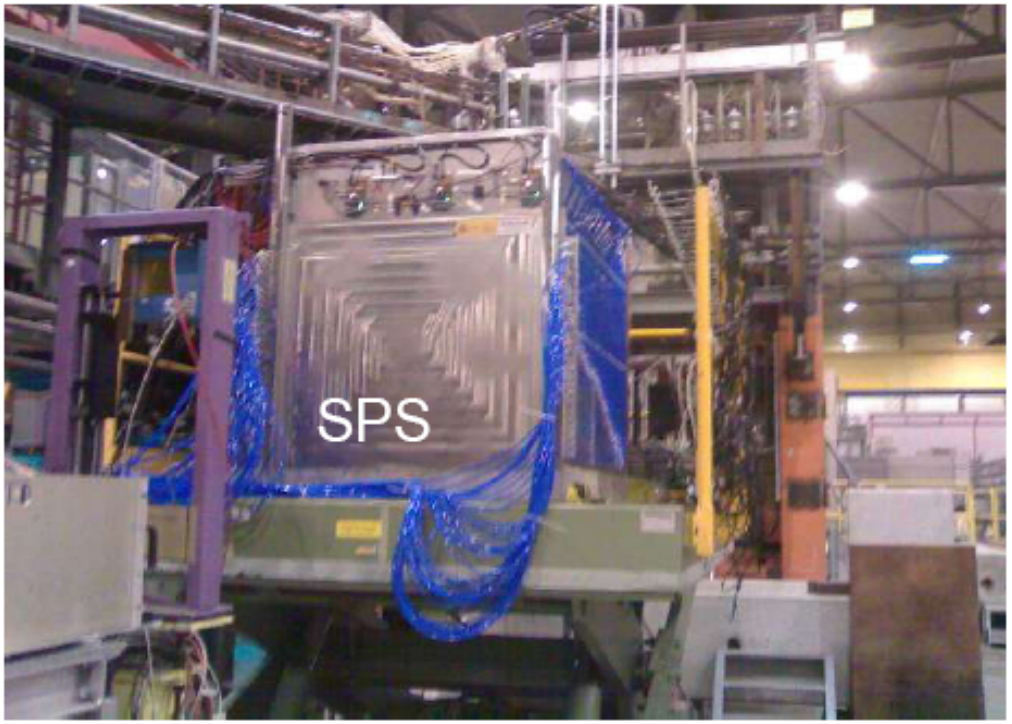




✓ self-supporting mechanical structure was conceived and built.

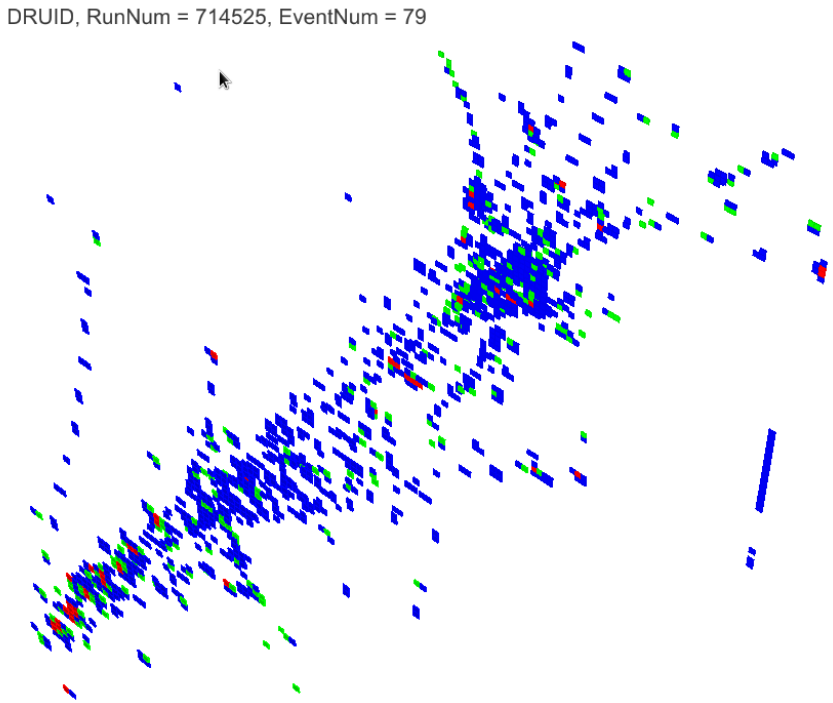
✓ 51 stainless steel 15mm thick plates with planarity <500 μm were machined and tested


PS


SPS

Test beam

- Set-up:
  - Gas: TFE 93%, CO2 5%, SF6 2%.
  - HV ~ 6.9 kV.
  - MIP induced charge ~ 1.2 pC
  - Thresholds: 0.114pC, 5pC and 15pC

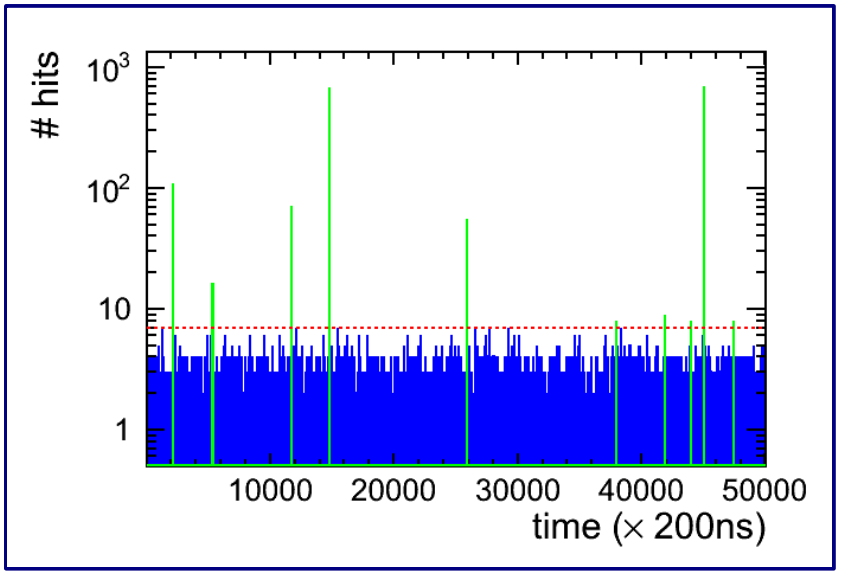


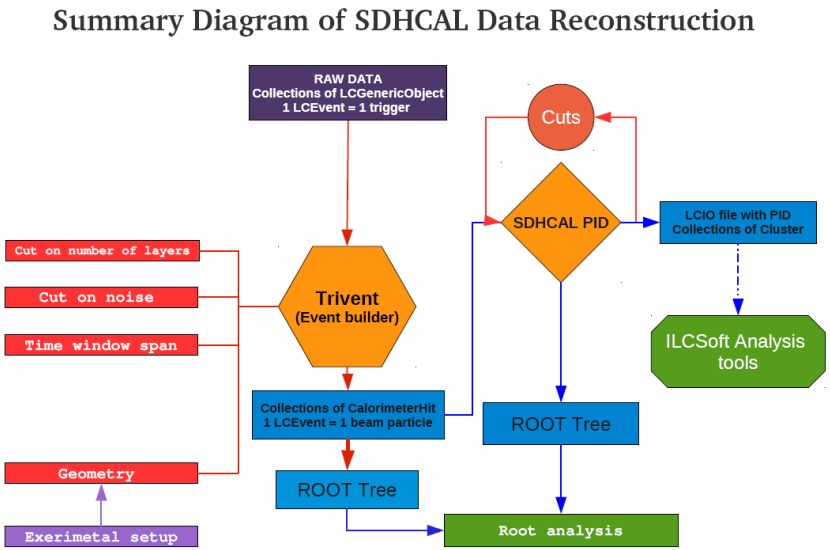
- Periods & Statistic
  - May: 2 weeks at SPS H2
  - August: 2 weeks at SPS H6
  - November: 2 weeks at SPS H2
  - Totally: > 400k pi, > 1M MIP

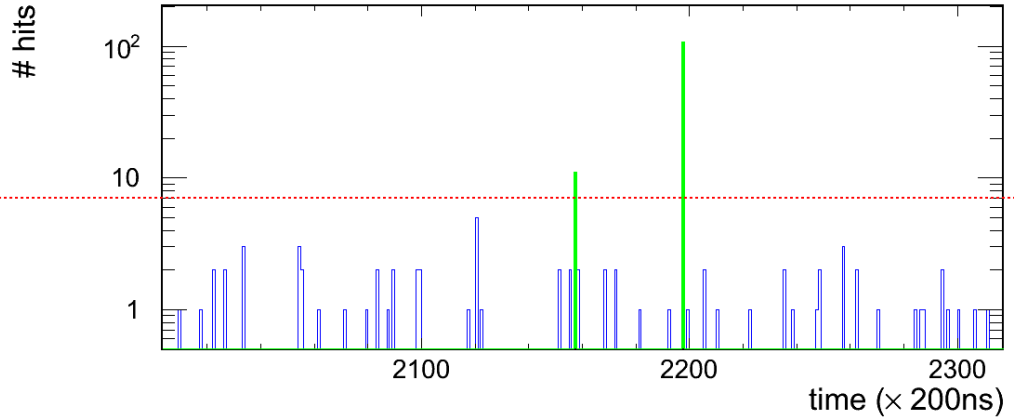
- Available on CALICE grid: /grid/calice/SDHCAL/TB/CERN

Reconstruction

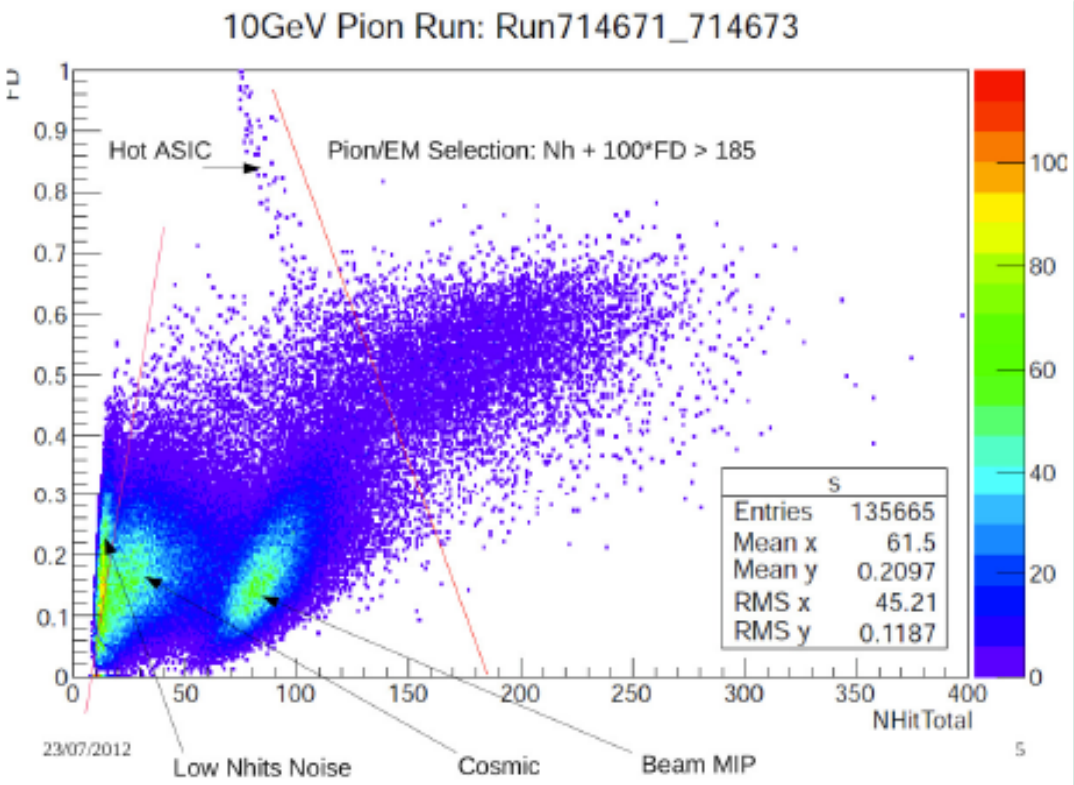
- GRPC: almost noise free
  - Cubic meter: ~0.35 Hit/200ns, without threshold/gain optimization
  - Read memory (~10 ms): tag event with > 7 hits per 200ns
  - Everything recorded: noise, cosmic, mip...
- Mature reconstruction chain (DAQ -> LCIO): Trivent

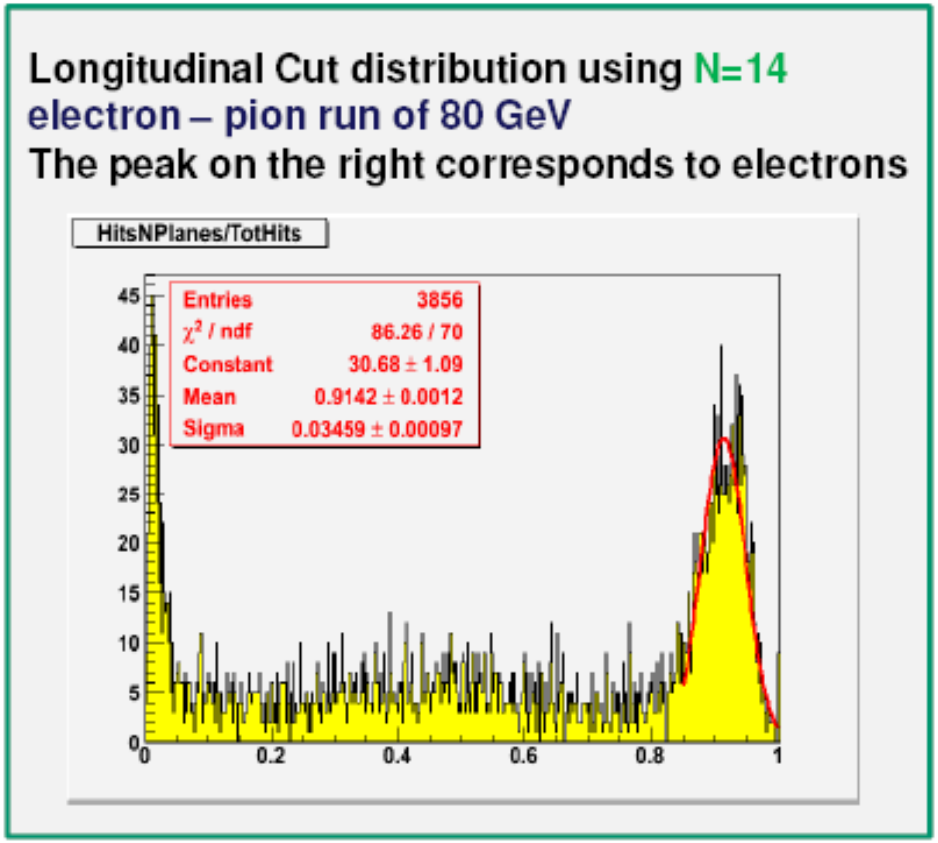






Pattern tagging & Event classification

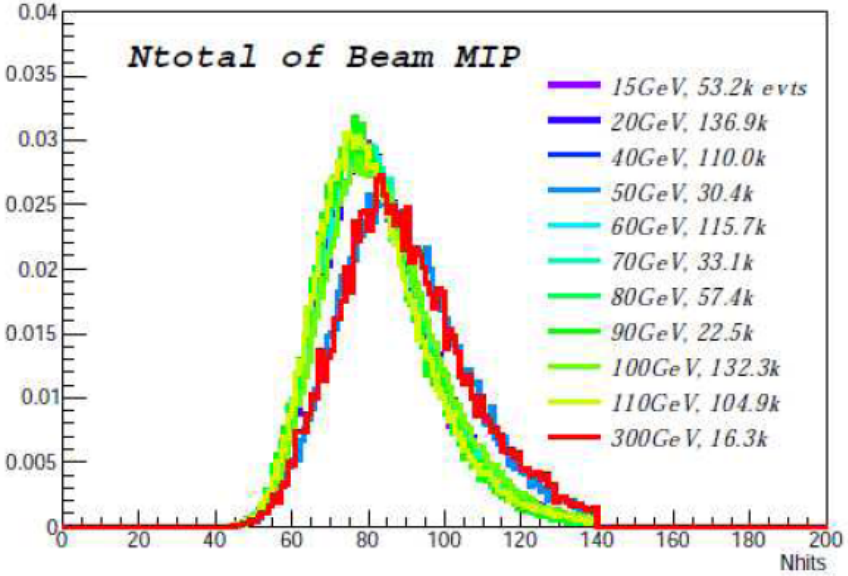


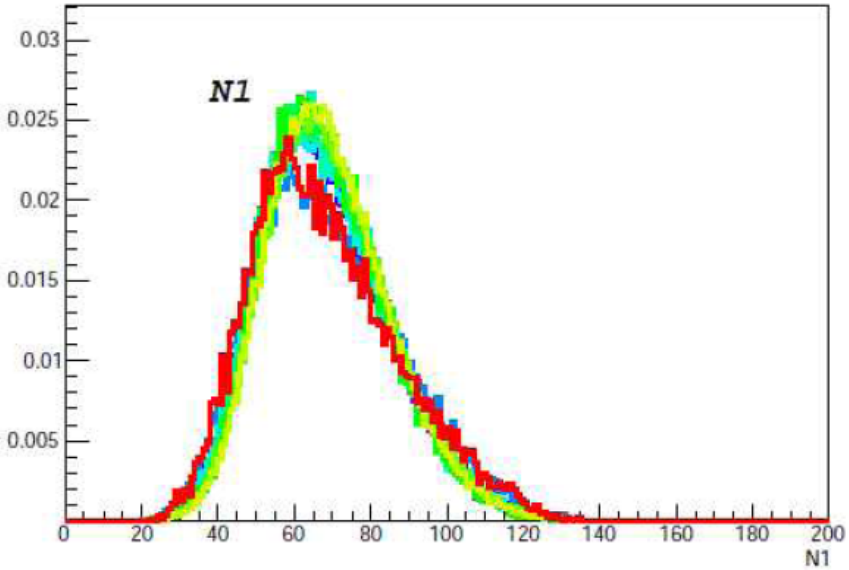


Tag different events - for different analysis

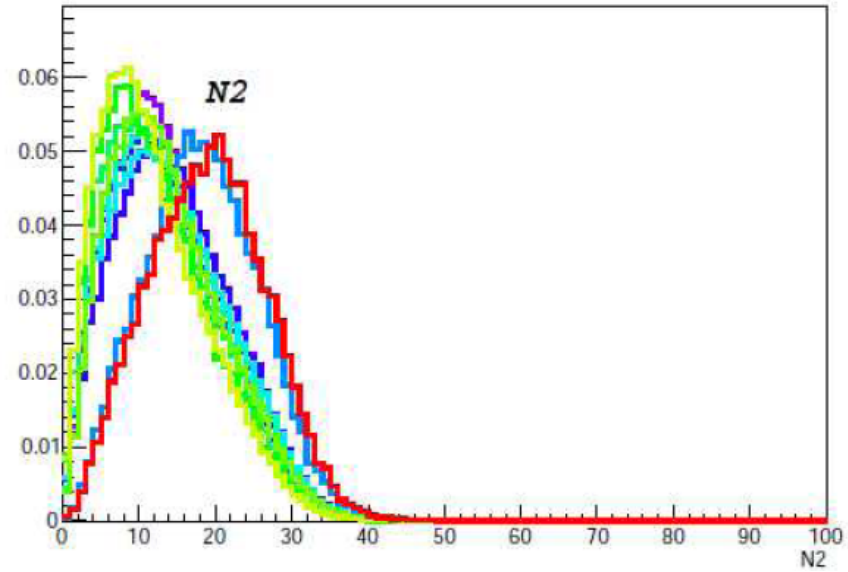
MIP: global homogeneity, efficiency & multiplicity
Noise: statistic pattern analysis
Cosmic: angle measurement
EM/Hadronic: energy resolution

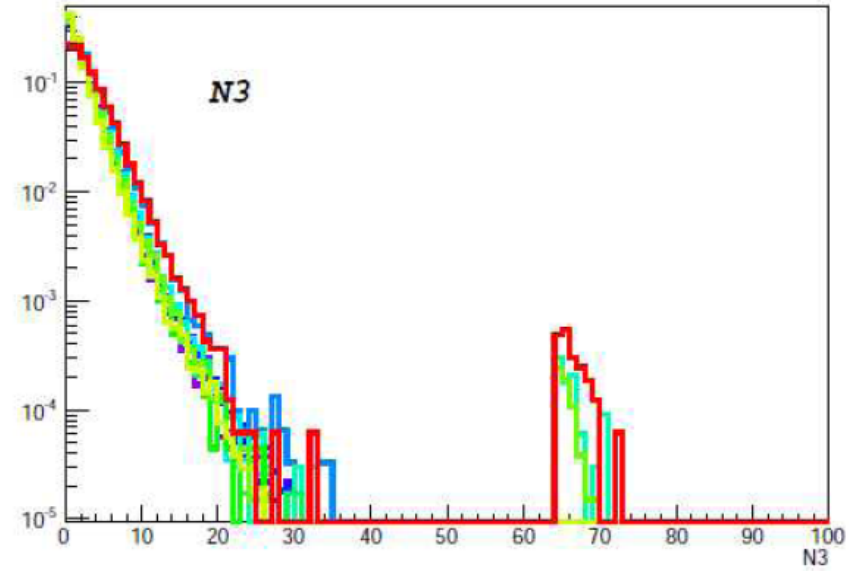
Stability: Nhits





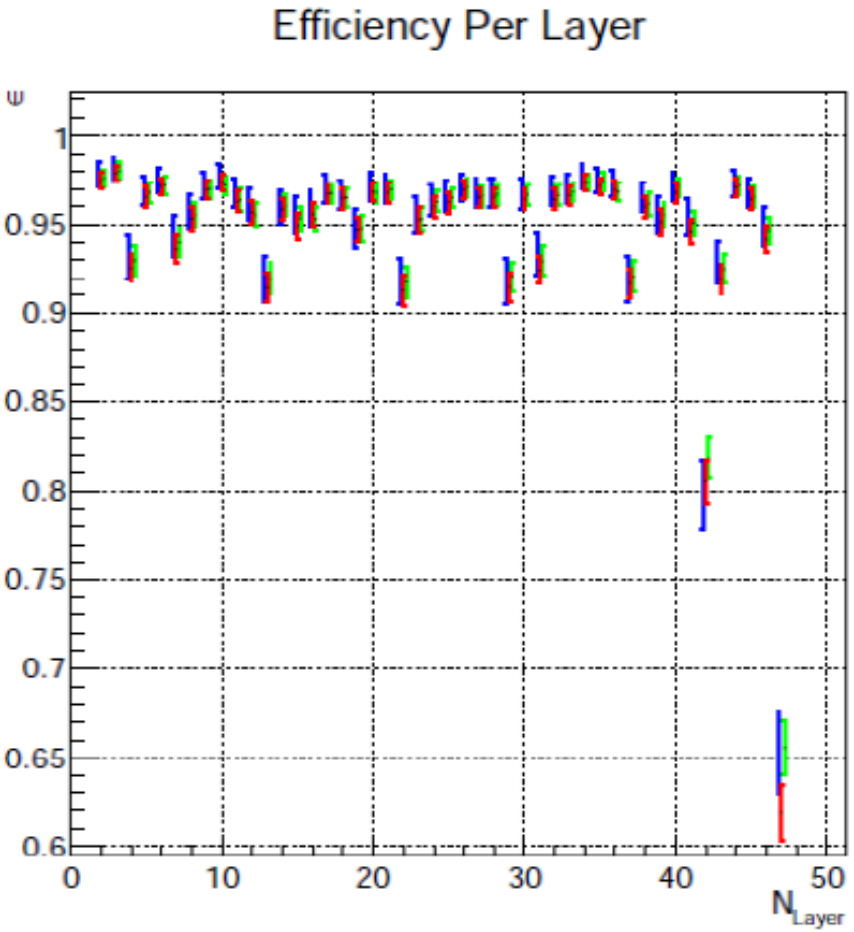
Number of hit profiles for beam MIPs in pion runs

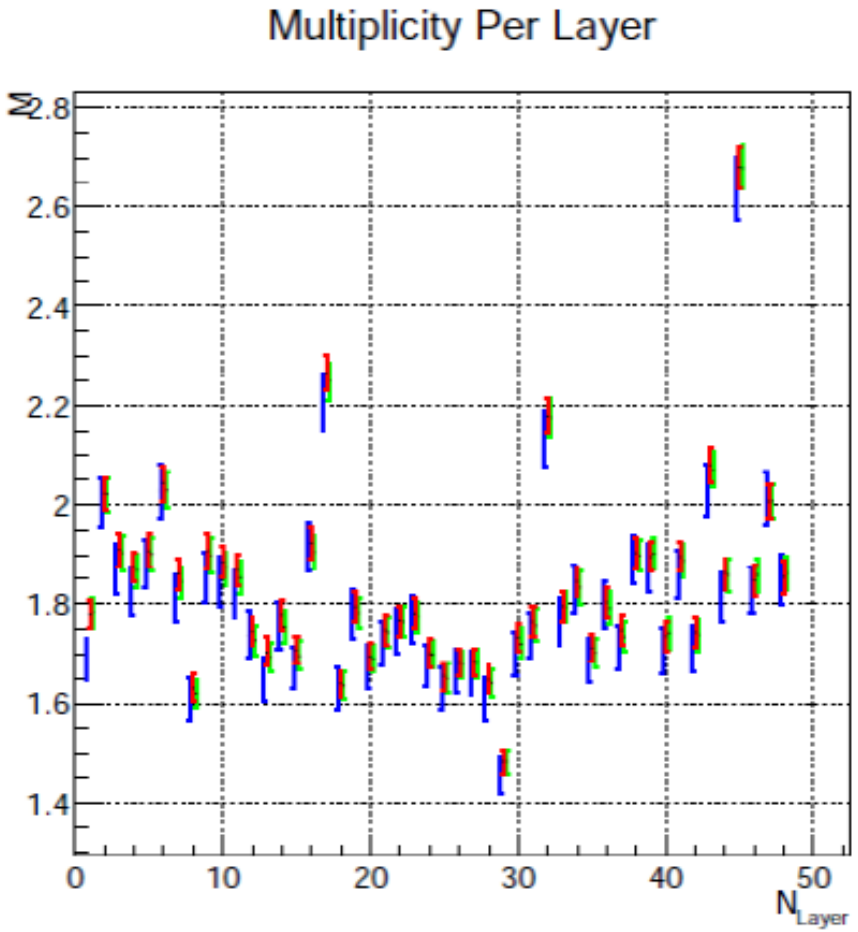




Stabilized versus time/run number

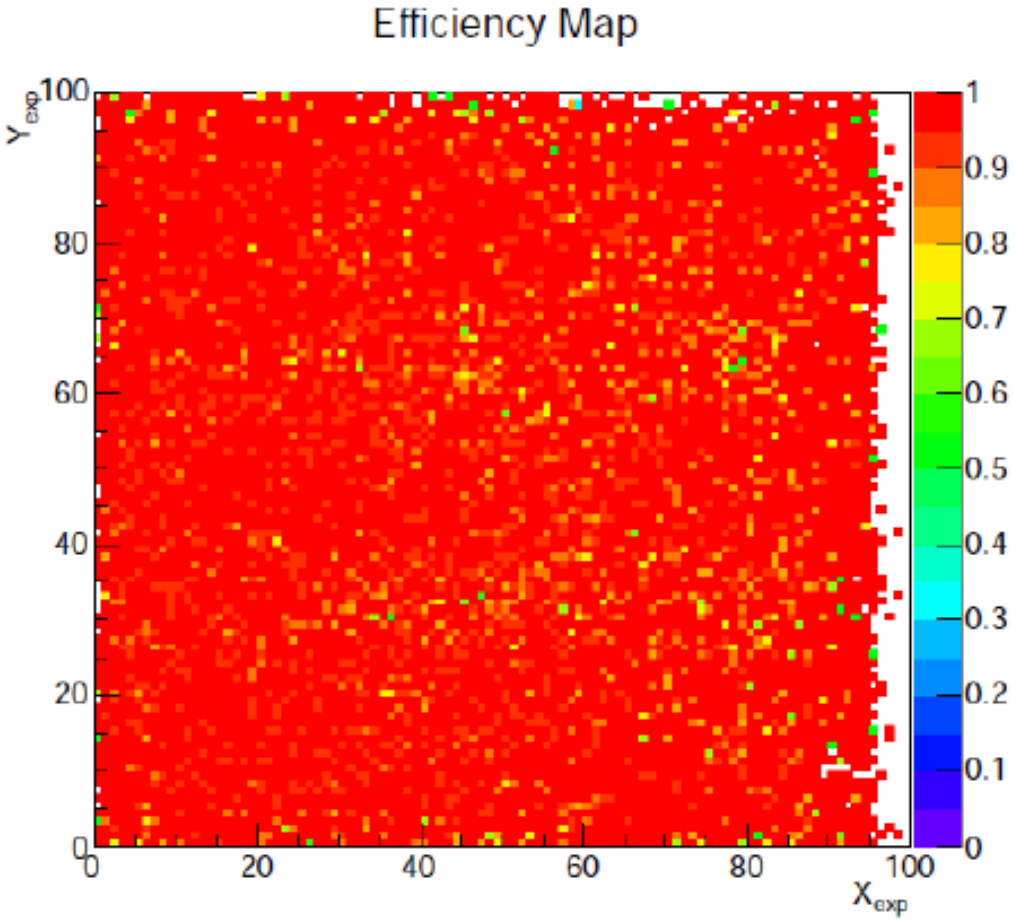
Stability: eff & Mul

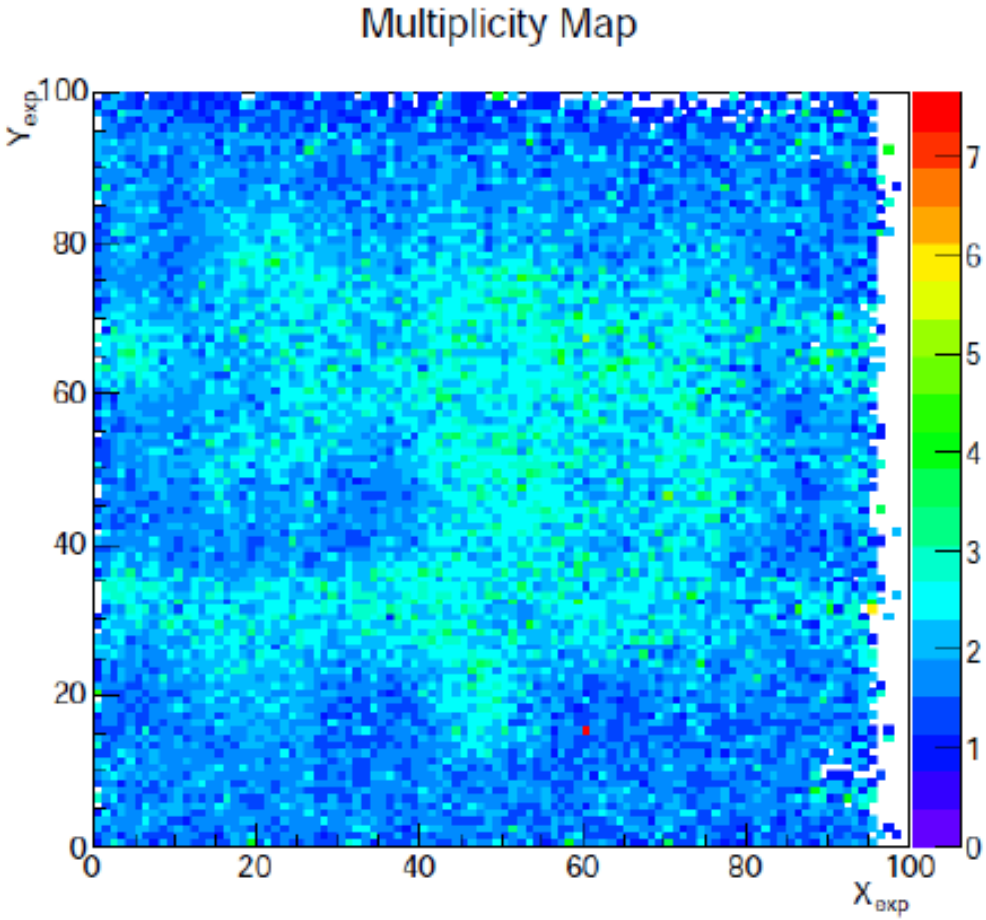




Stable with sensible fluctuation (error bar scaled by 10 times)
15 GeV Pion (714439, 4441): 43797 long beam mip evts
20 GeV Pion (714565, 4573): 103109 evts
60 GeV Pion (714551, 4552, 4553): 98960 evts

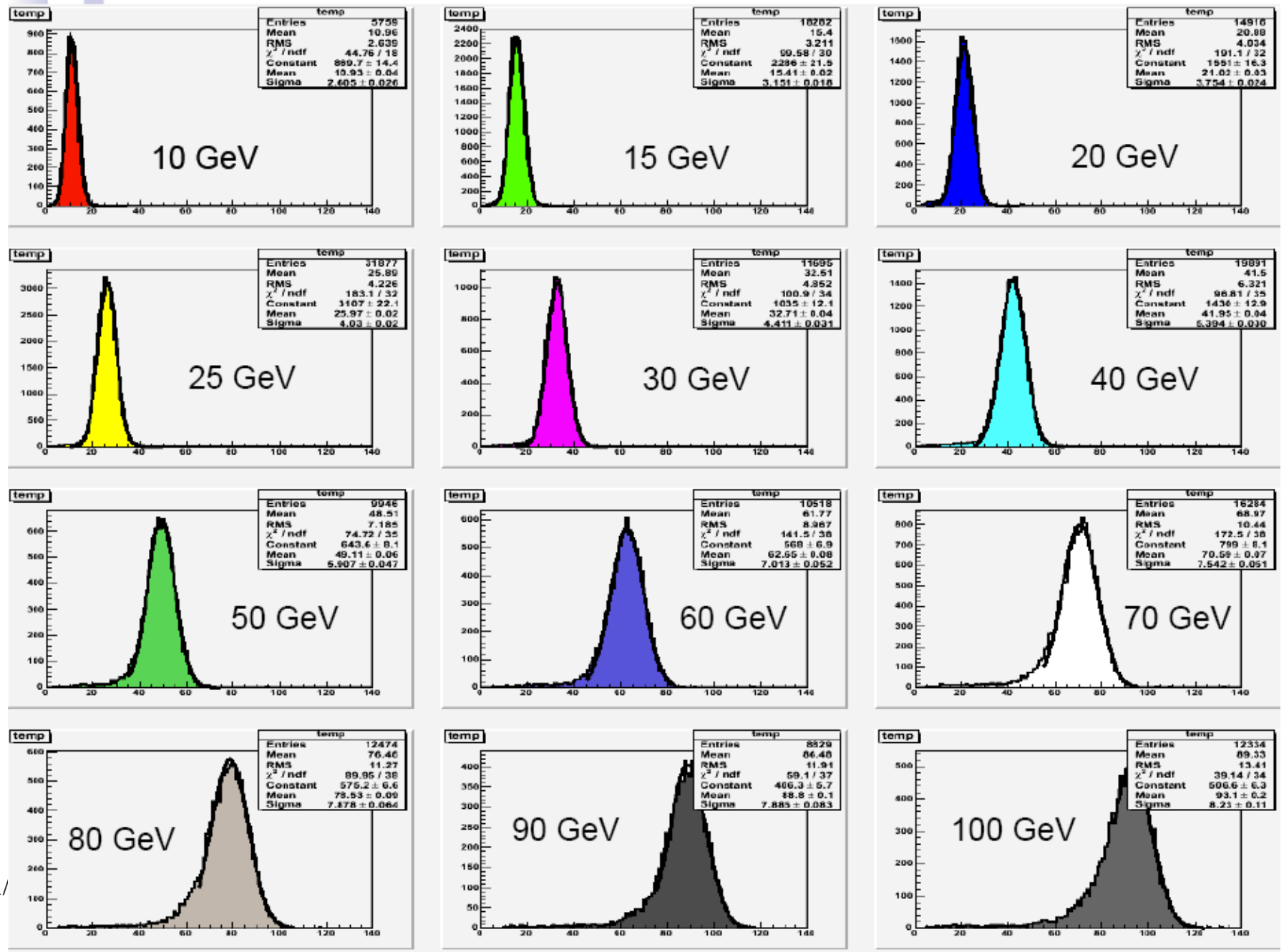
Detector homogeneity



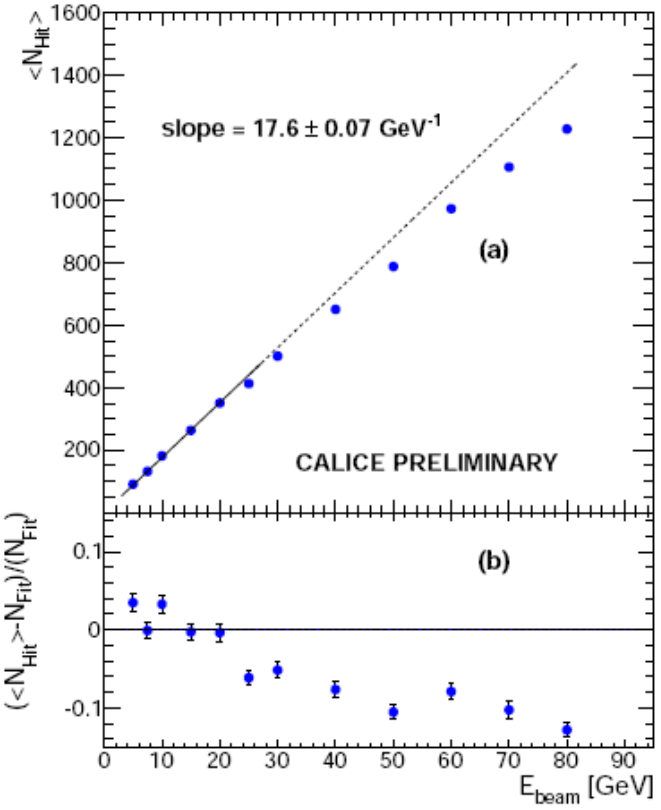


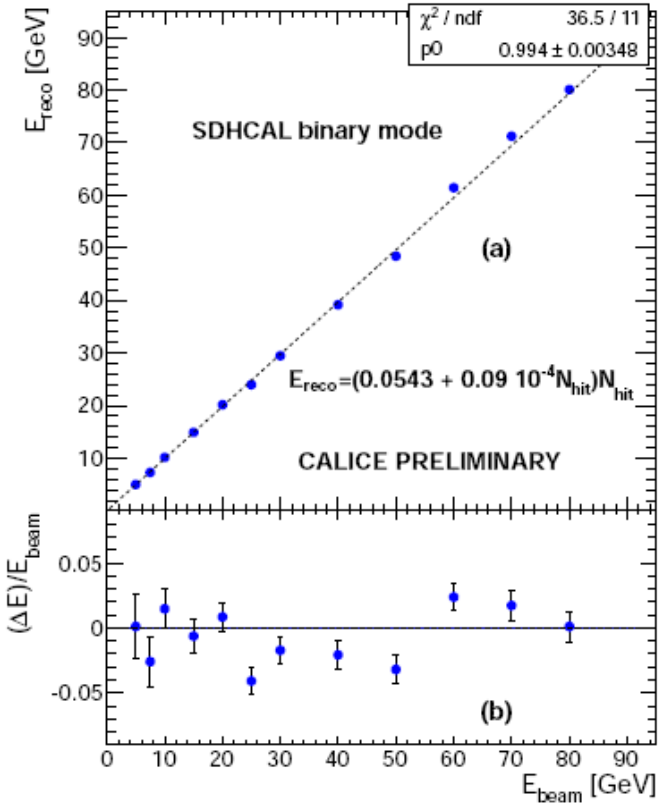
Homogeneous with sensible geometrical structure
Be kept for future studies: gain correction, threshold optimization, etc

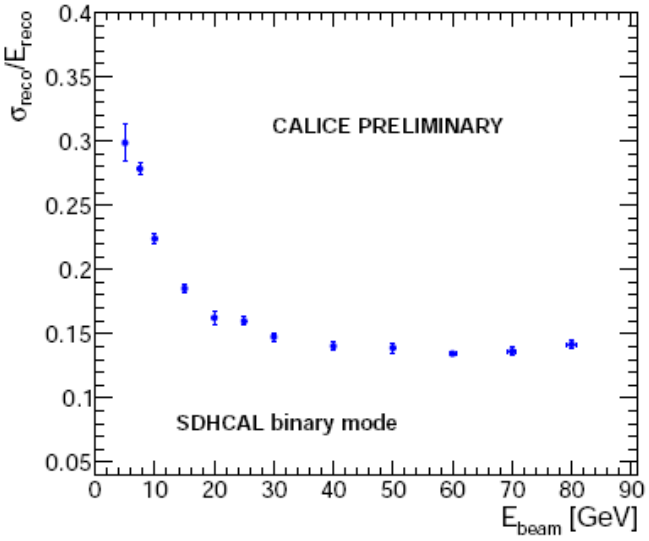
Pion sample: energy response



Start from hit counting

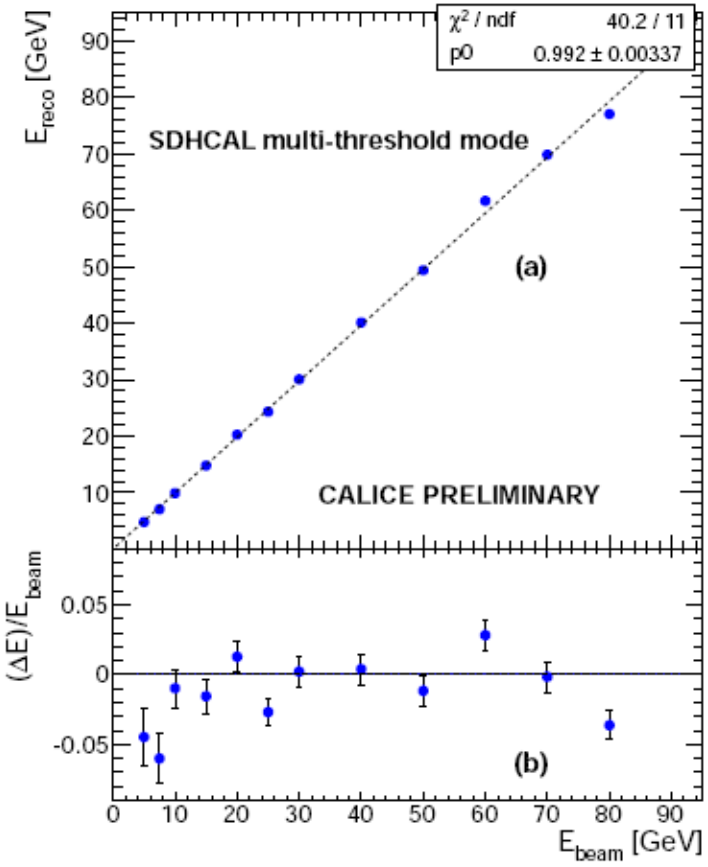


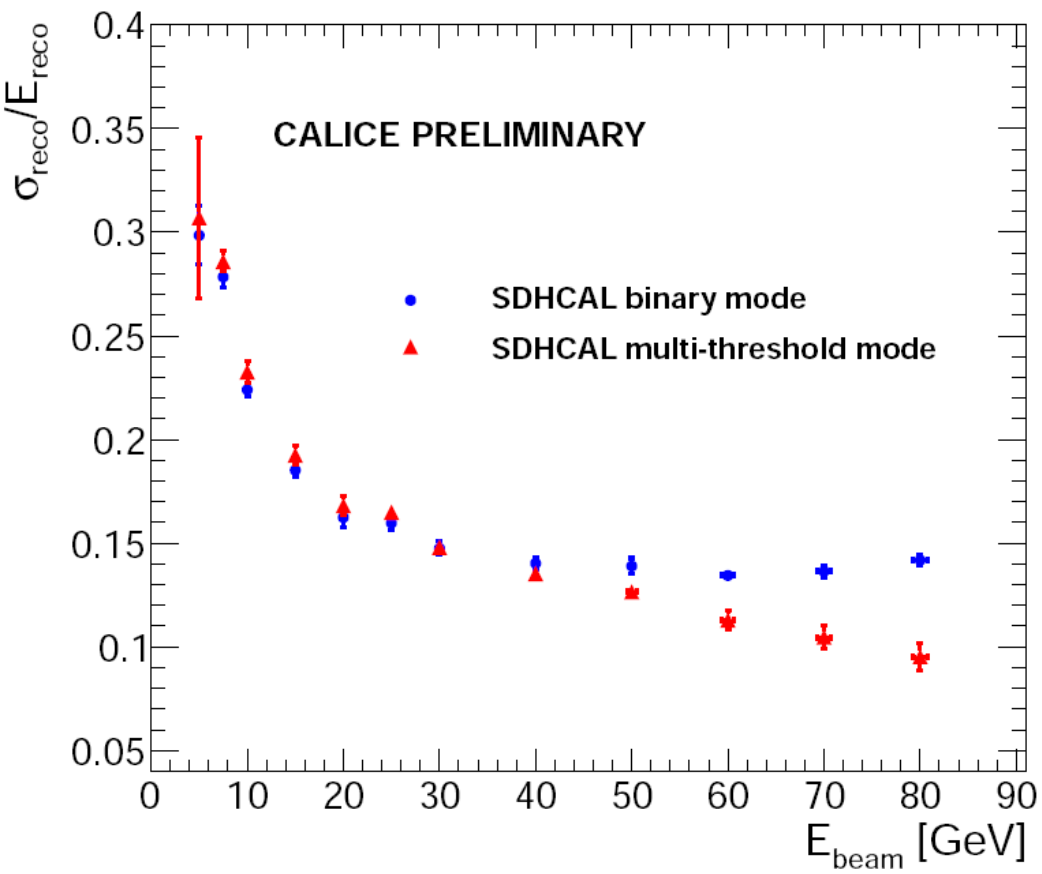




Energy estimation by hit counting: good resolution at low energy,
Significant saturation effect at high energy.
Corrected by quadratic function: energy resolution dominated by constant term at high energy

Using 3 different thresholds

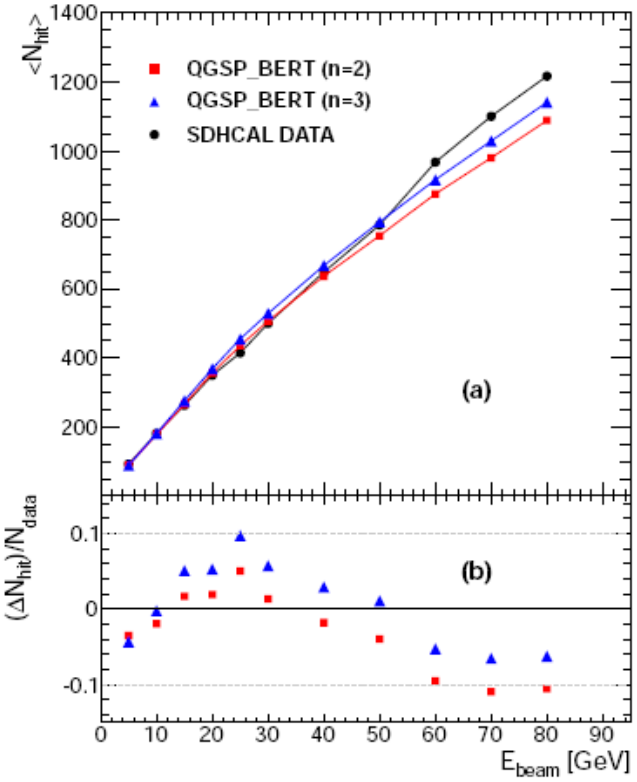


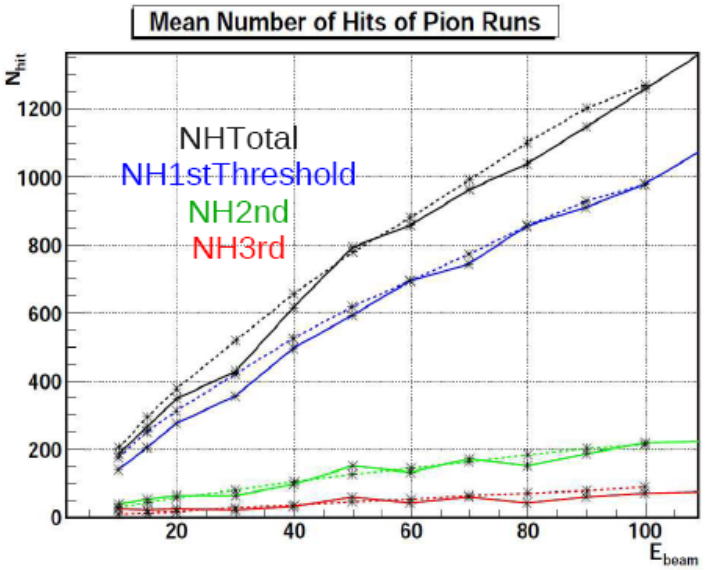


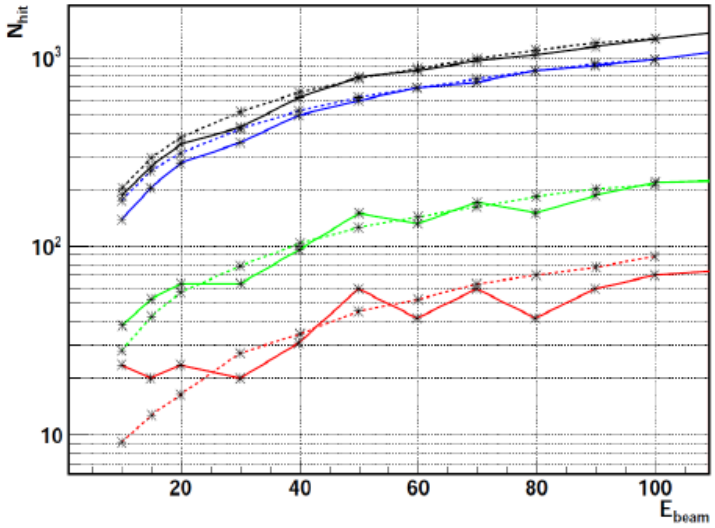
Method: E = a*N1 + b*N2 + c*N3, a, b, c quadratic functions of total number of hits

SDHCAL Prototype: repeated simulation prediction on saturation correction

Modelling of response & Digitizer development



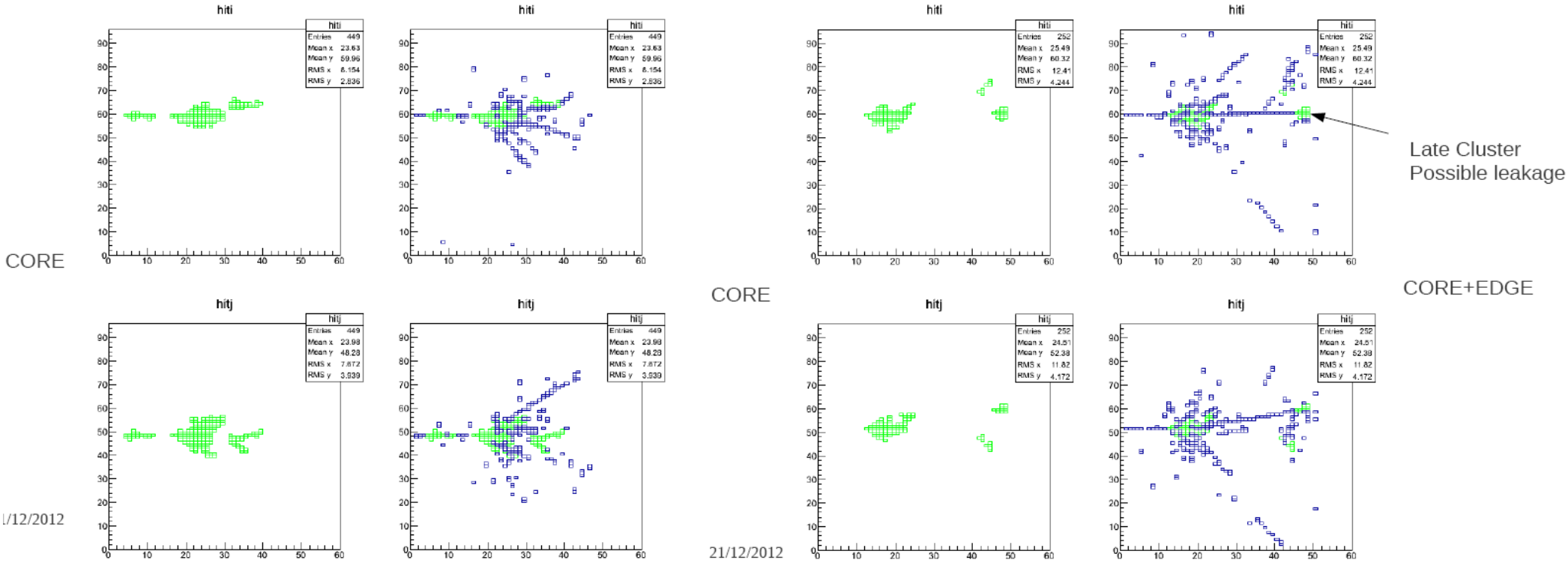




Two different approaches:
Using 1mm simulated cell: reproduce Nhits at different thresholds.
Using spatial distribution (multi-Gaussian): reproduces global number of hits

Shower: fine structure reconstruction

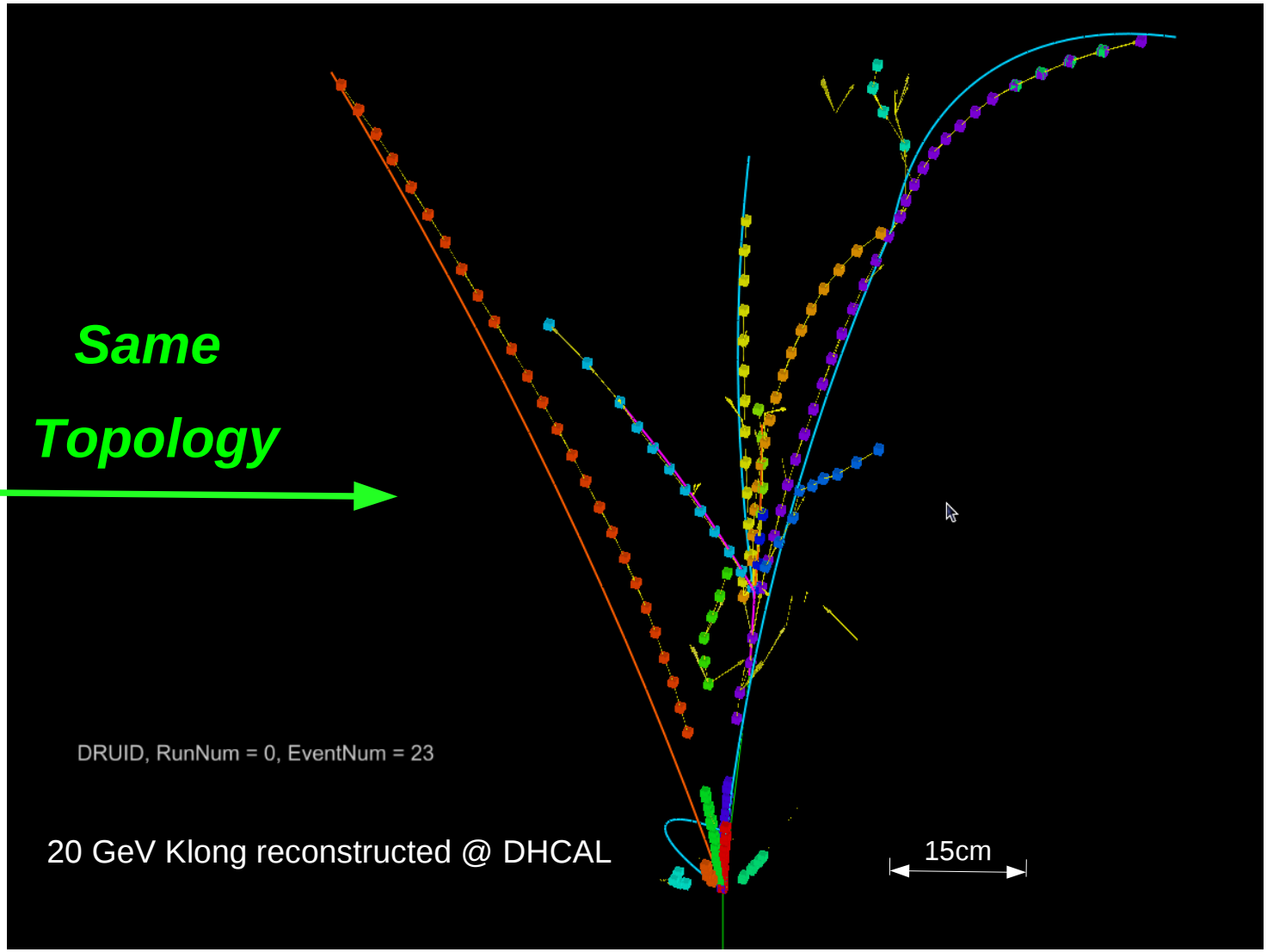
Ultra-high granularity: how to properly use the recorded information??



Sobel fitter: Distinguish the core and edge part of a hadronic shower from local density

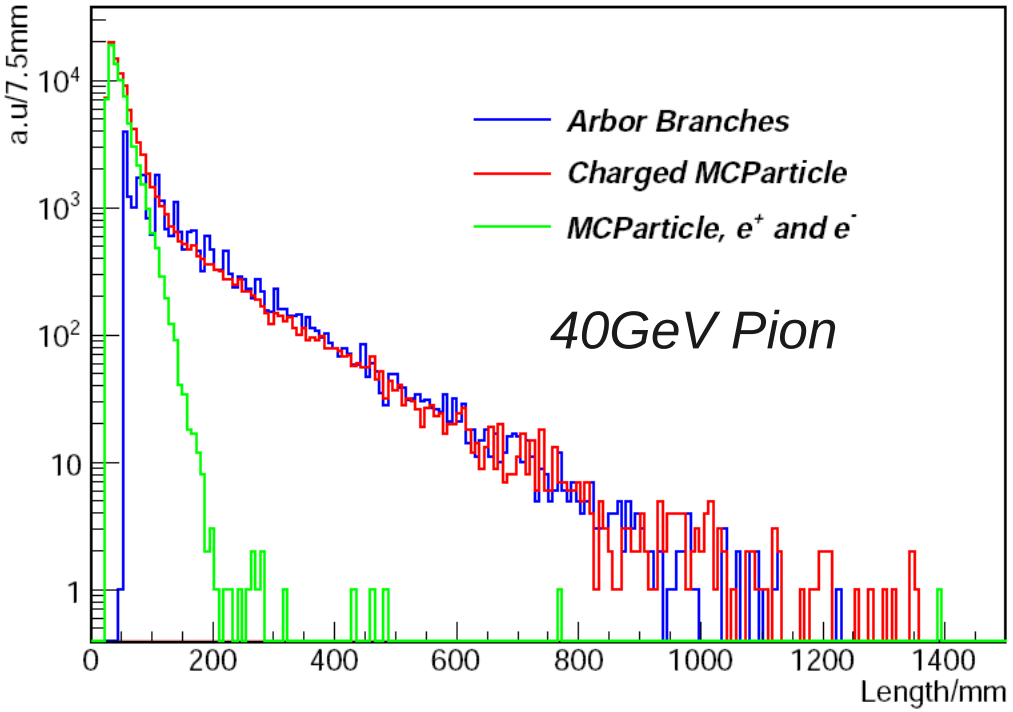
Arbor: shower ~ tree

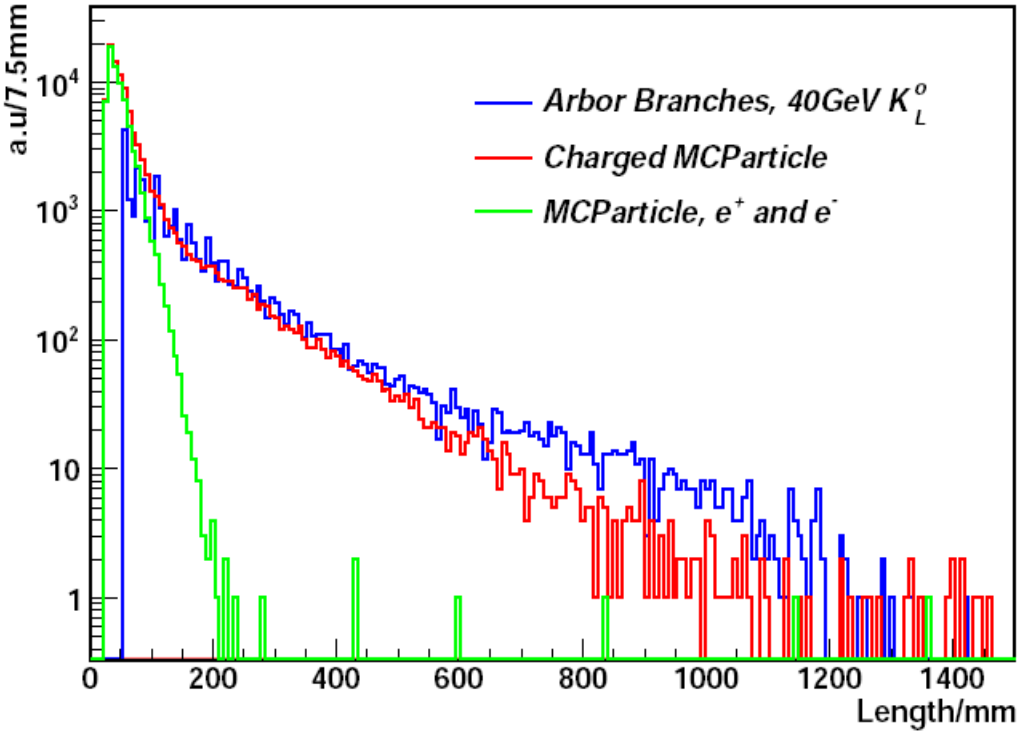
Same Topology



- *Start from Micro structures: Full usage on high granular information*
- *Original idea from Henri Videau, in hadronic shower reconstruction @ ALEPH*

Branch Length: Arbor vs MCTruth





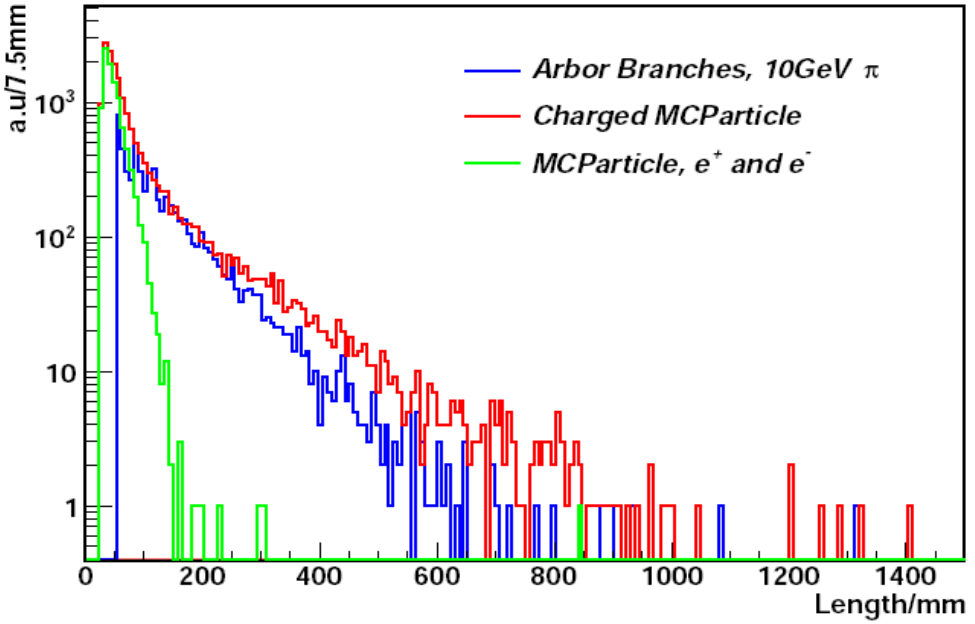
Length Definition:
MCParticle, spatial distance from Vertex to EndPoint.
Arbor: sum of spatial distance between neighbouring hits.

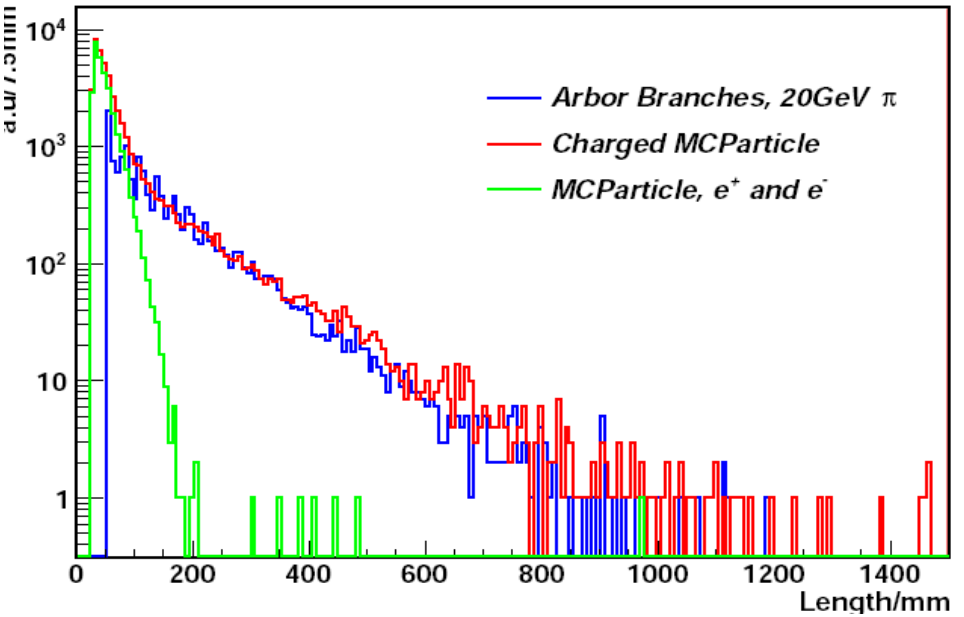
Technical:
1, Leading branch veto: By definition Arbor tag the longest possible branch: vetoed by the condition of starting from the first layer. Efficient for pi, not for Klong
2, For long Arbor branch: a natural cutting algorithm should be interesting

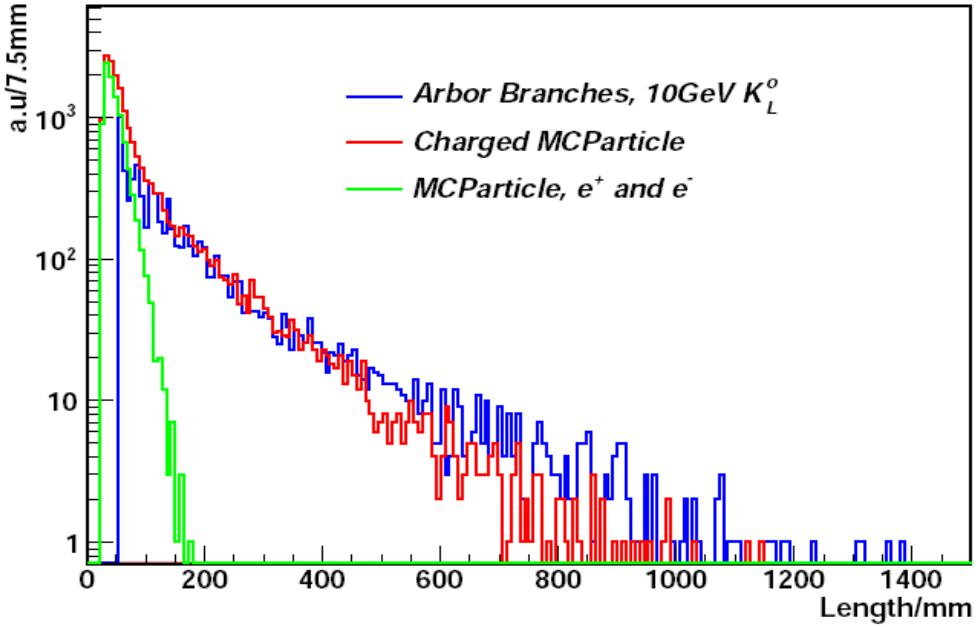
Summary

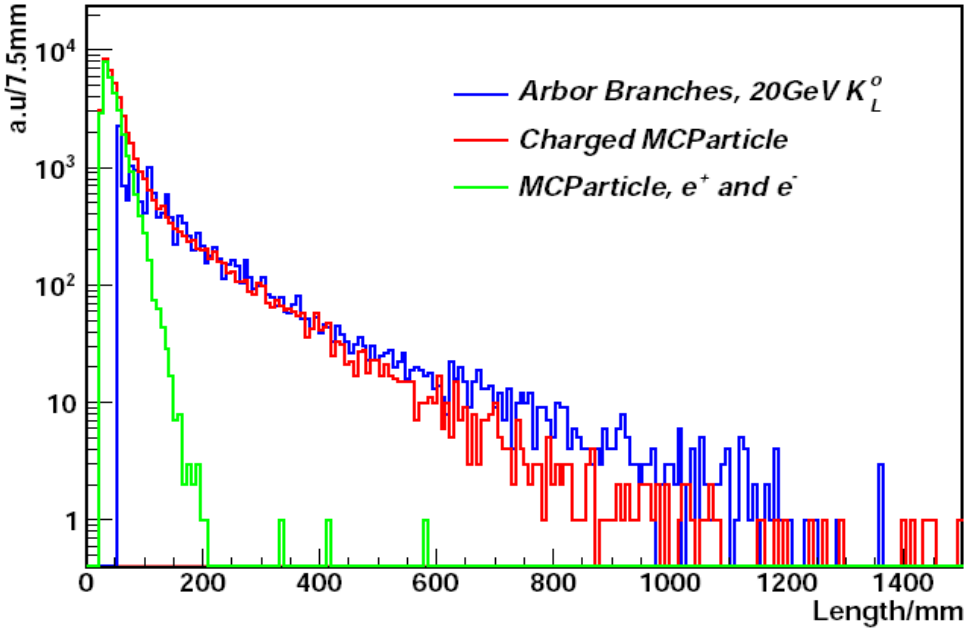
- SDHCAL Prototypes have been successfully reconstructed and intensively tested at various condition
  - Huge statistic of test beam data are available
  - New technologies are tested (power-plusing, semi-conductive glass plate, self-supporting mechanics)
- Analysis
  - Sophisticated event classification algorithm developed
    - Noise: very low rate – can be improved
    - MIP/Cosmic: stable & homogeneous response
    - Showers: lead to the development of software compensation algorithms
  - Digitizer: test beam observation successfully reproduced
  - Advanced reconstruction: on going study
- One step further...

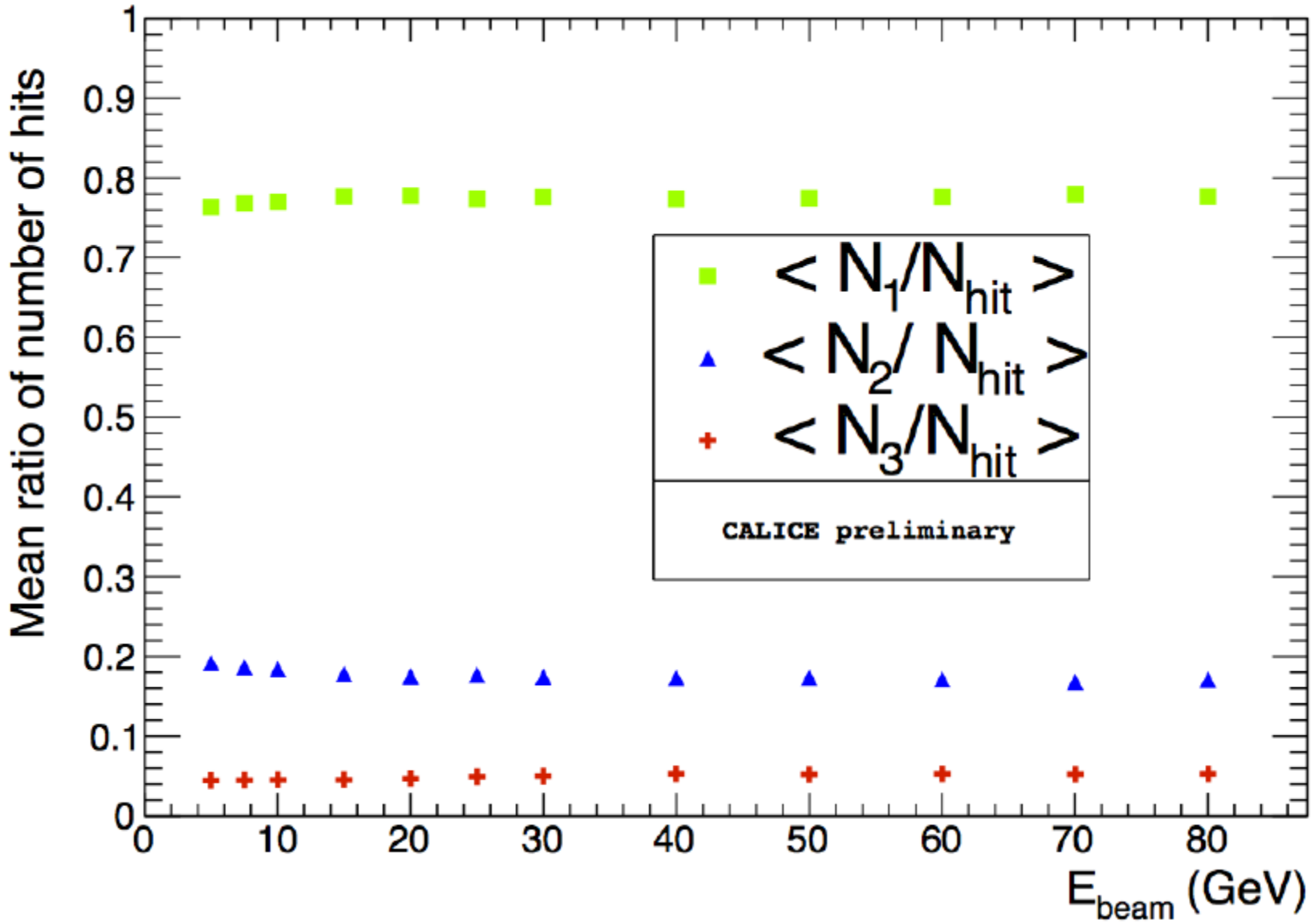
Branch Length @ different energy










Mean ratio of number of hits
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
E_beam (GeV)
< N1/Nhit >
< N2/ Nhit >
< N3/Nhit >
CALICE preliminary