Semi-DHCAL software development: Digitization & Display

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Outline

- Introduction
  - Collaboration, Prototype&TB, Software status;
- Digitization:
  - Method
  - Cosmic ray experimental input
  - Digitization with Muon and Pion
- Event Display:
  - Motivation:
    - To Understand ILC event/shower detail
    - To Analysis reconstruction software performance
- Summary & plans

Introduction: GRPC Semi-DHCAL

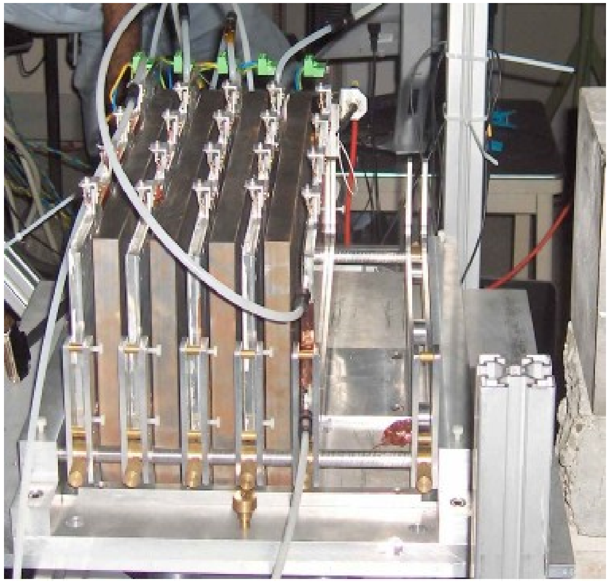
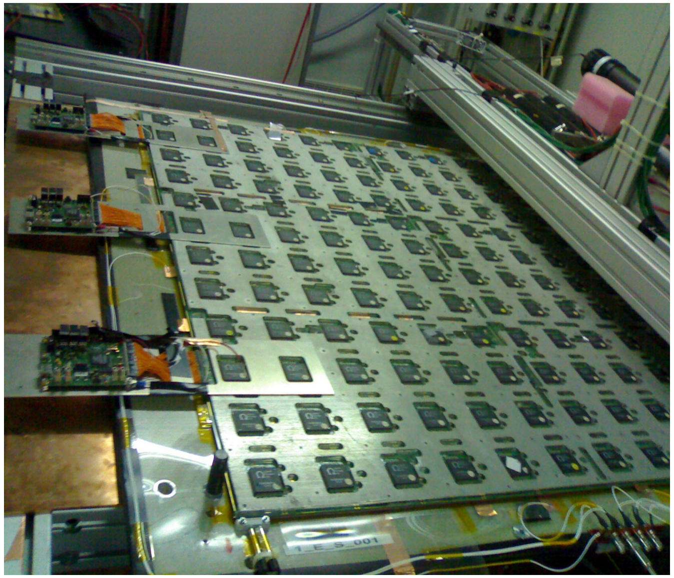
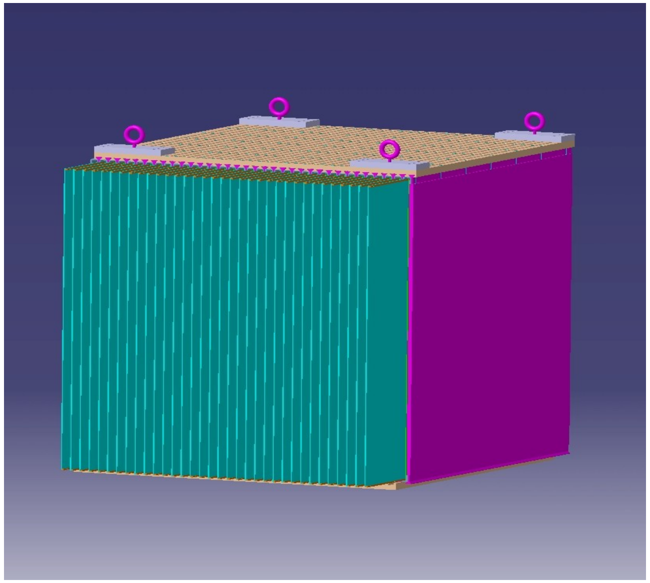
- GRPC Semi-DHCAL
  - Gaseous detector: almost free of neutron hits
  - RPC: High efficiency, homogeneous, low cost, robust, low power consumption...
  - Semi-digital: channel coded on 2 bits, High Granularity @ low electronic cost, Good performance @ High Energy expected from simulation...

- International cooperation
  - France: IPNL, LAL, LLR, LPC;
  - Russia: IHEP-Protvino
  - Spain: CIEMAT
  - Belgium: Louvain-La-Neuve, Ghent
  - China: Tsinghua
  - Tunisia: Tunis
  - Collaboration with: CERN-Bologna (MCRPC) and LAPP (DIF)
  - Communication with US DHCAL group

Prototypes & test beam

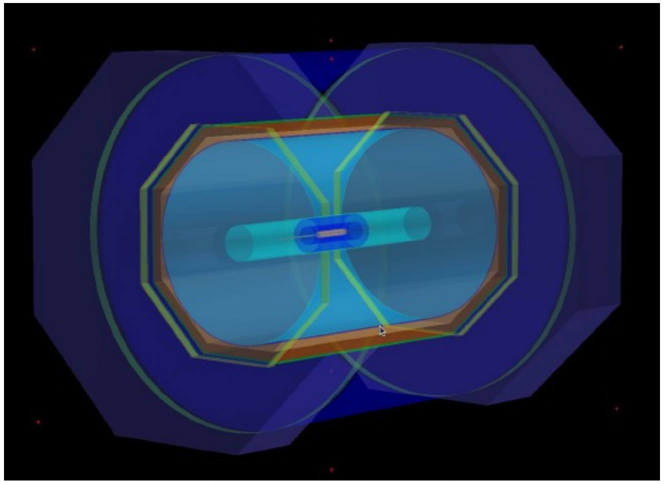
- Mini DHCAL, $m^2 \rightarrow m^3$ ANR DHCAL (end of 2010)
  - Power pulsing
  - Embedded electronics
  - Self supporting mechanic
- Toward the proof of principle for Detector Baseline Design (DBD, end of 2012)
- Validate Geant4 hadronic simulation

1k channels → 10k channels → 400k channels!

Software status

- Test beam
  - Working analysis chain based on ROOT
  - Update data format (to LCIO)
  - R & D of new DAQ system
- Simulation + Reconstruction
  - Simulation
    - M^3 prototype simulation in G4
    - (A la Videau Geometry + GRPC DHCAL) concept for ILD
    - Validate the different options with ILD geometry in Mokka
  - Digitization
    - 1st order Digitization module with cosmic ray input
    - Upgrade with efficiency, multiplicity and saturation correction
  - Reconstruction
    - Understand the hadronic shower & Reconstruction algorithm for GRPC DHCAL
    - PFA algorithm optimization for ILD with GRPC DHCAL
  - Display: module ready
- Data samples production: Central MC Generation



ILD Detector with DHCAL

Blue: tasks to be done

Digitization:

Estimate induced charge from energy deposition

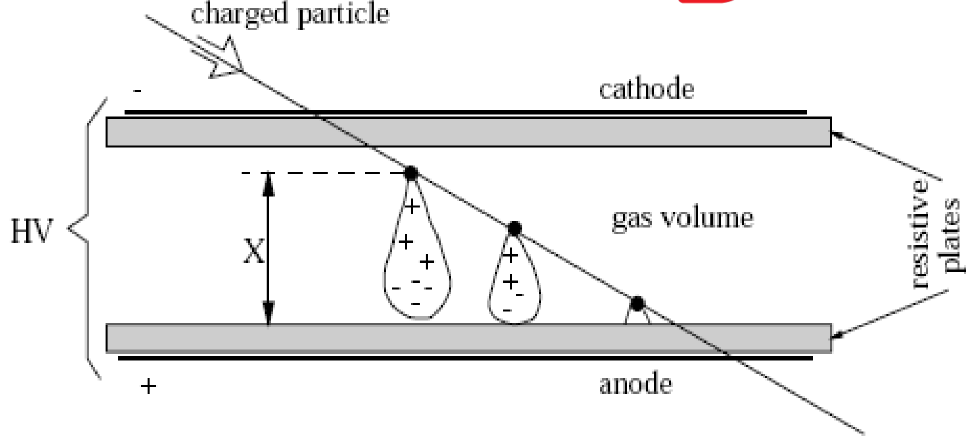
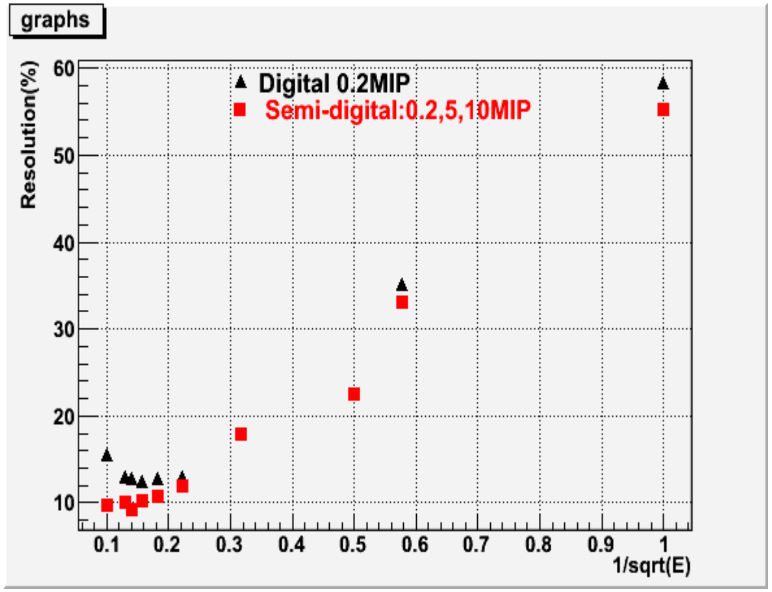


Fig. 1. Sketch of RPC gap.

- Motivation:
  - Reliable simulation
  - Important for Semi-DHCAL:
    - MC truth level: Semi-DHCAL has much better performance than DHCAL
    - Questioned by the large uncertainty in the charge inducing in GRPC avalanche development



Single Pion energy resolution with DHCAL/Semi DHCAL

Method

- Read true energy deposition from MC (eg, Mokka)
- Express true energy deposition in unit of primary ionization (E_{truth}/E_{ion}): for GRPC gas, take

$$E_{ion} = 35\text{eV}$$

Table 1

Properties of several gases used in proportional counters (from different sources, see the bibliography for this section). Energy loss and ion pairs per unit length are given at atmospheric pressure for minimum ionizing particles

Gas	Z	A	δ (g/cm³)	E_{ex}	E_i (eV)	I_0 (eV)	W_i	dE/dx (MeV/g cm⁻²)	dE/dx (keV/cm)	n_p (i.p./cm) a)	n_T (i.p./cm) a)
H_2	2	2	8.38×10^{-5}	10.8	15.9	15.	37	4.03	0.34	5.2	9.2
He	2	4	1.66×10^{-4}	19.8	24.5	24.	41	1.94	0.32	5.9	7.8
N_2	14	28	1.17×10^{-3}	8.1	16.7	15.	35	1.68	1.96	(10)	56
O_2	16	32	1.33×10^{-3}	7.9	12.8	12.	31	1.69	2.26	22	73
Ne	10	20.2	8.39×10^{-4}	16.6	21.5	21.	36	1.68	1.41	12	39
Ar	18	39.9	1.66×10^{-3}	11.6	15.7	15.	26	1.47	2.44	29.4	94
Kr	36	83.8	3.49×10^{-3}	10.0	13.9	14.	24	1.32	4.60	(22)	192
Xe	54	131.3	5.49×10^{-3}	8.4	12.1	12.	22	1.23	6.76	44	307
CO_2	22	44	1.86×10^{-3}	5.2	13.7	13.	33	1.62	3.01	(34)	91
CH_4	10	16	6.70×10^{-4}		15.2	13.	28	2.21	1.48	16	53
C_4H_{10}	34	58	2.42×10^{-3}		10.6	10.	23	1.86	4.50	(46)	195

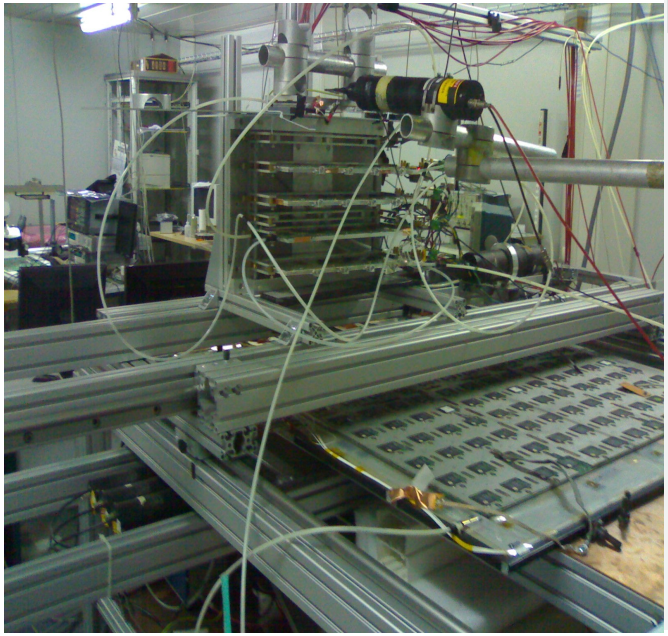
a) i.p. = ion pairs

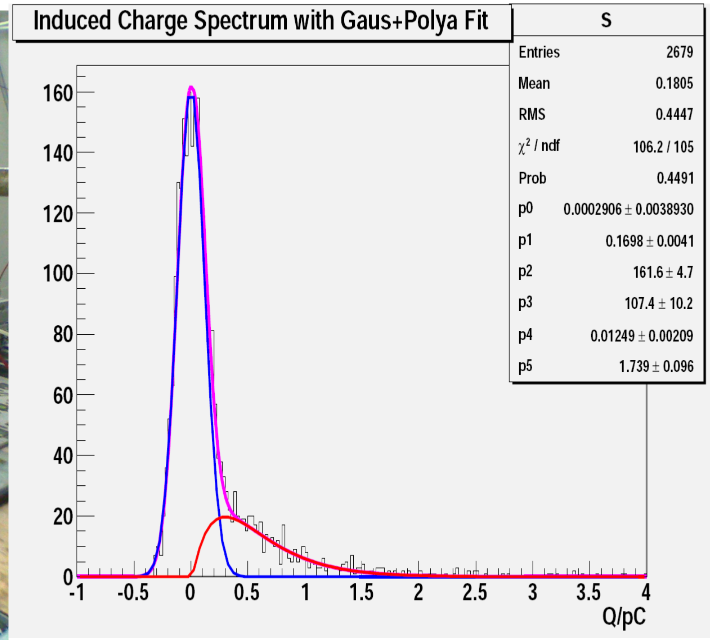
- For each ionization, estimate corresponding charge inducing with Polya function (m and G_0 to be tuned with cosmic ray experimental input)

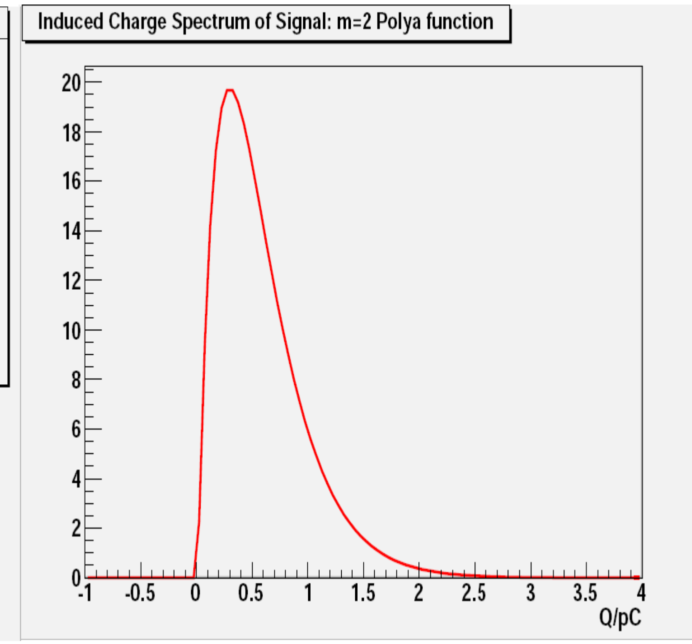
$$P(m) = \frac{m(mG/G_0)^{m-1}}{\Gamma(m)} \cdot e^{-mG/G_0}$$

- Sum induced charge over every ionization ~ total induced Charge

Cosmic ray input: Induced Charge of Mip

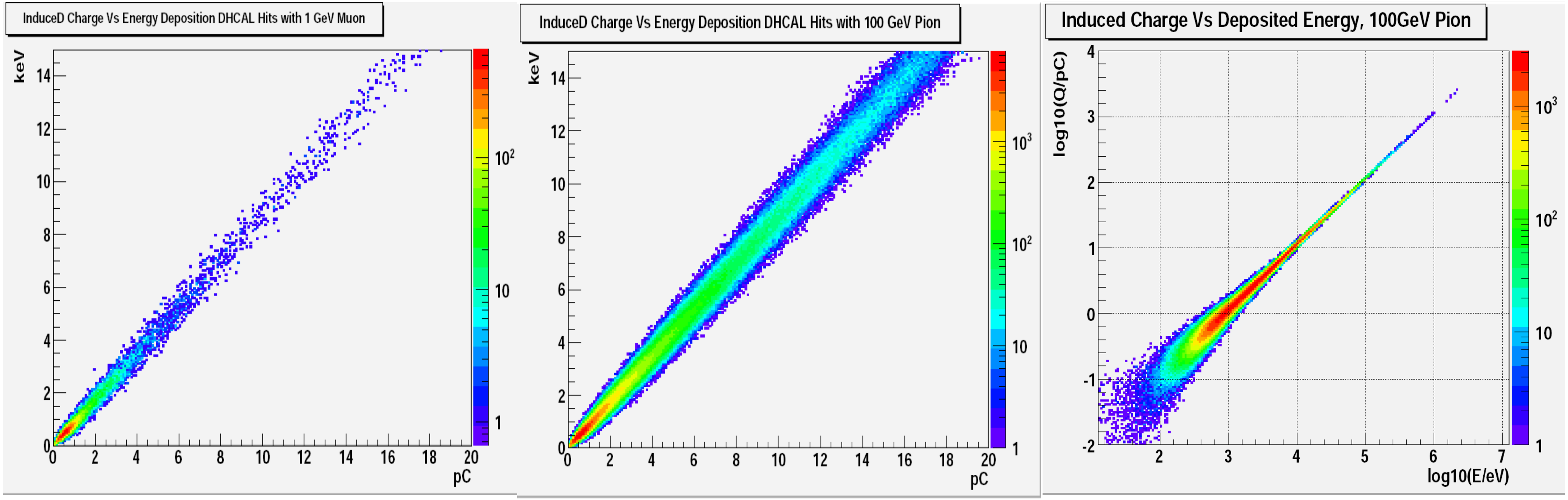






- Induced charge spectrum of ~2700 cosmic events: fit to an Gaussian noise + scaled polya signal (mean ~ 0.6 pC)
- Parameter tuning:
  - Spectrum shape: m=2
  - Mean value of induced charge: G_0 ~ 35fC (1 Mip ~ 600eV ~ 17 ionization)

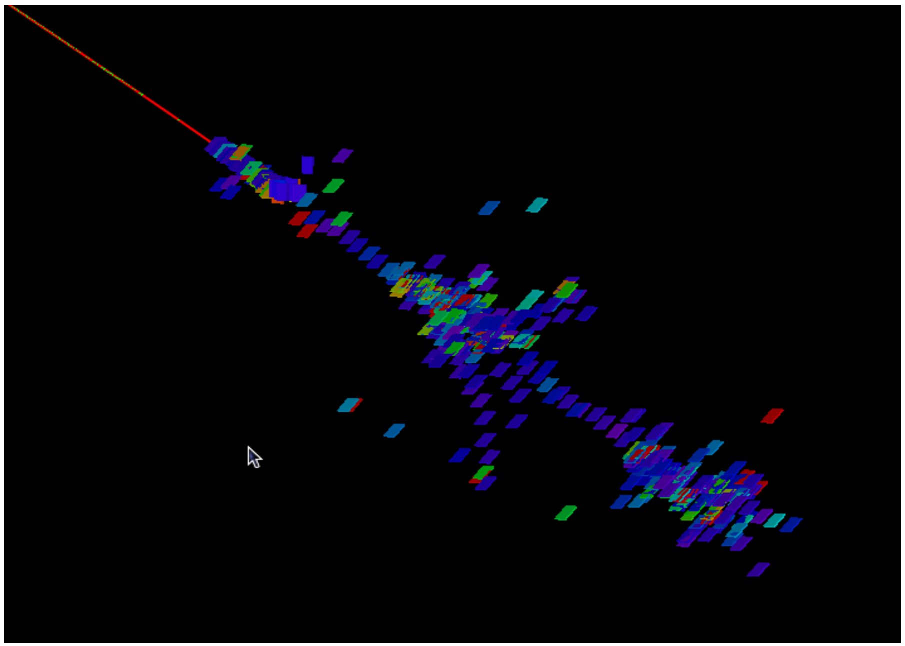
Result

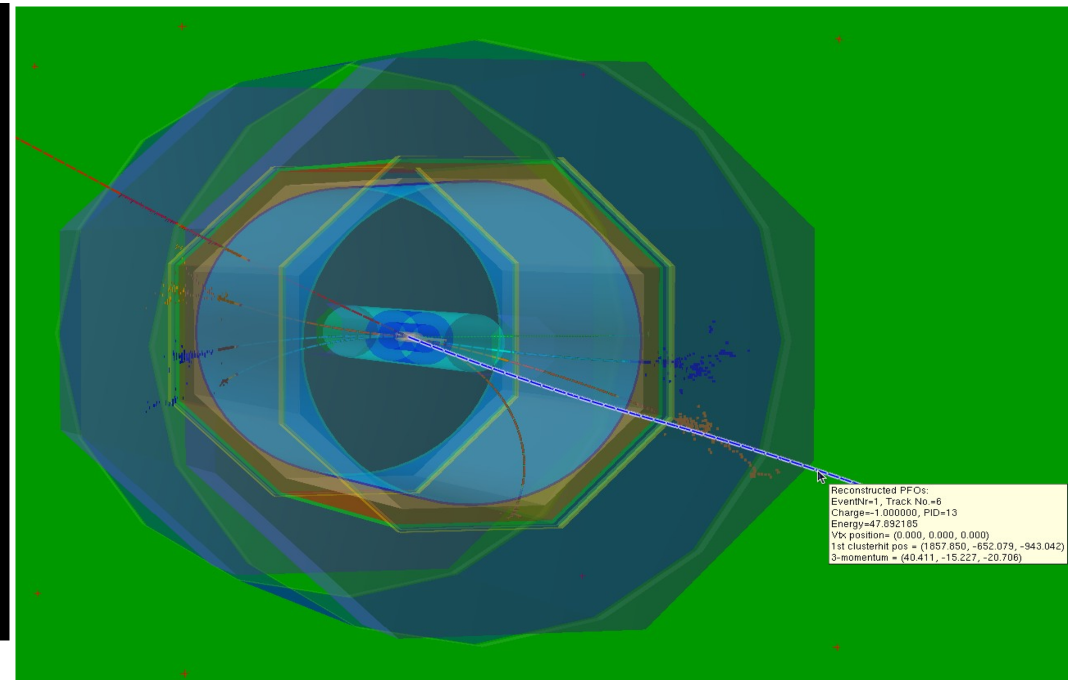


- GRPC: Large smearing at low energy deposition but nice linearity at high energy deposition → Semi-Digital HCAL keeps more information than the DHCAL → better performance
- Saturation, multiplicity, and efficiency correction effects not considered → to be upgraded
- Integrated in to standard ILC software

DRUID: 3D display for ILD

- Motivation:
  - To understand the ILC events & jet/shower details
  - To understand/analysis reconstruction algorithm performance





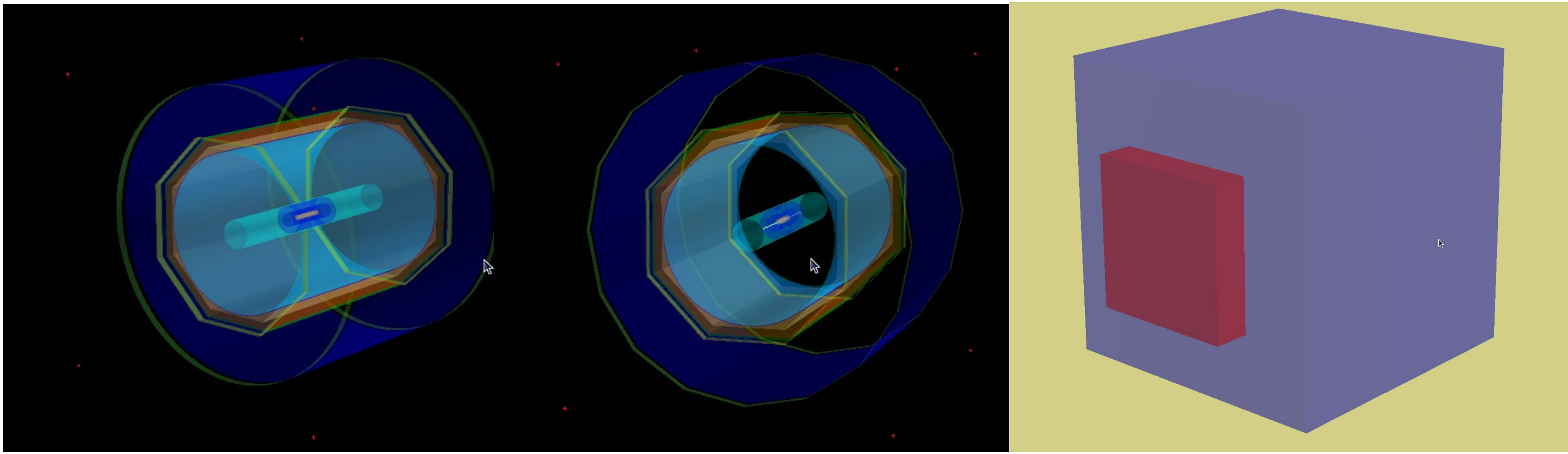
Left: shower created by 100GeV pion
Right: 230GeV Z(μμ)H(ττ) event

Developed by Manqi, Vincent, Gabriel & Jayant

- Based on ROOT TEve class (developed for LHC event display)
- Visualize detector geometry, MC/reconstructed Particle, simulated/reconstructed hits in arbitrary combination and various style

Input & Geometries

- Input:
  - LCIO (data file) + GEAR (geometry file)

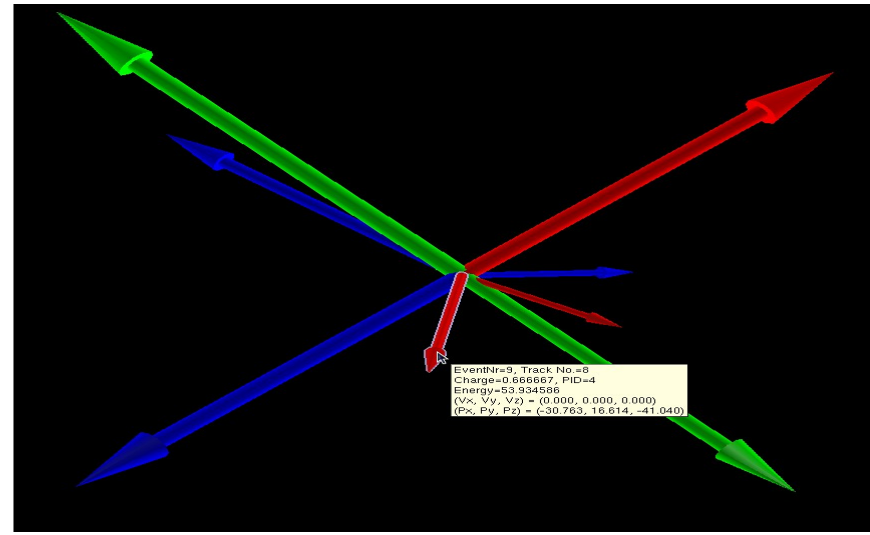


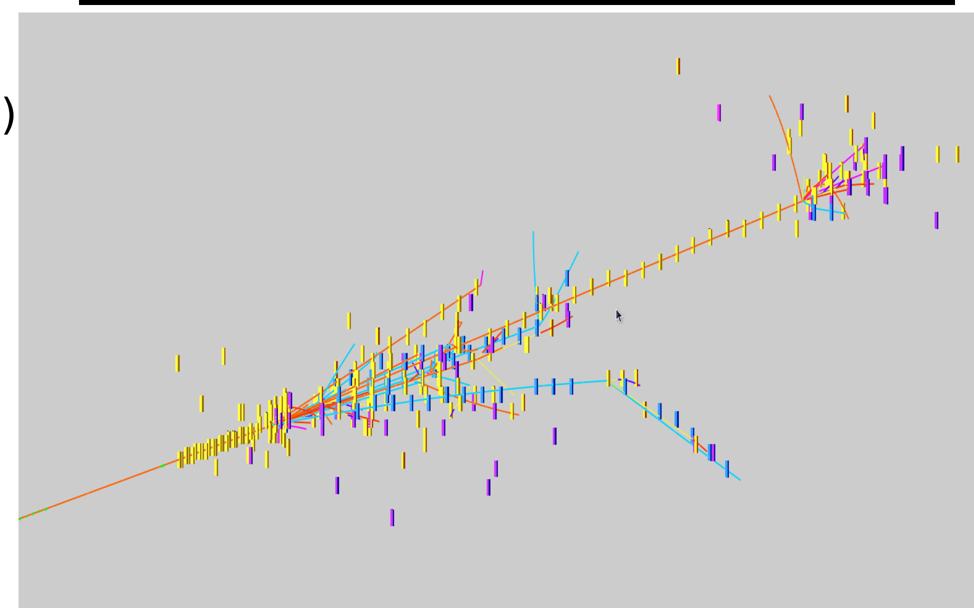
Left to Right: a la Videau, TESLA (DHCAL EndCap dismounted) & Test Beam

- Supported geometry
  - ILD with TESLA/a la Videau HCAL;
  - General test beam frame (parameters not tuned);
- Mount/dismount sub detectors interactively in GUI;

Objects & Option

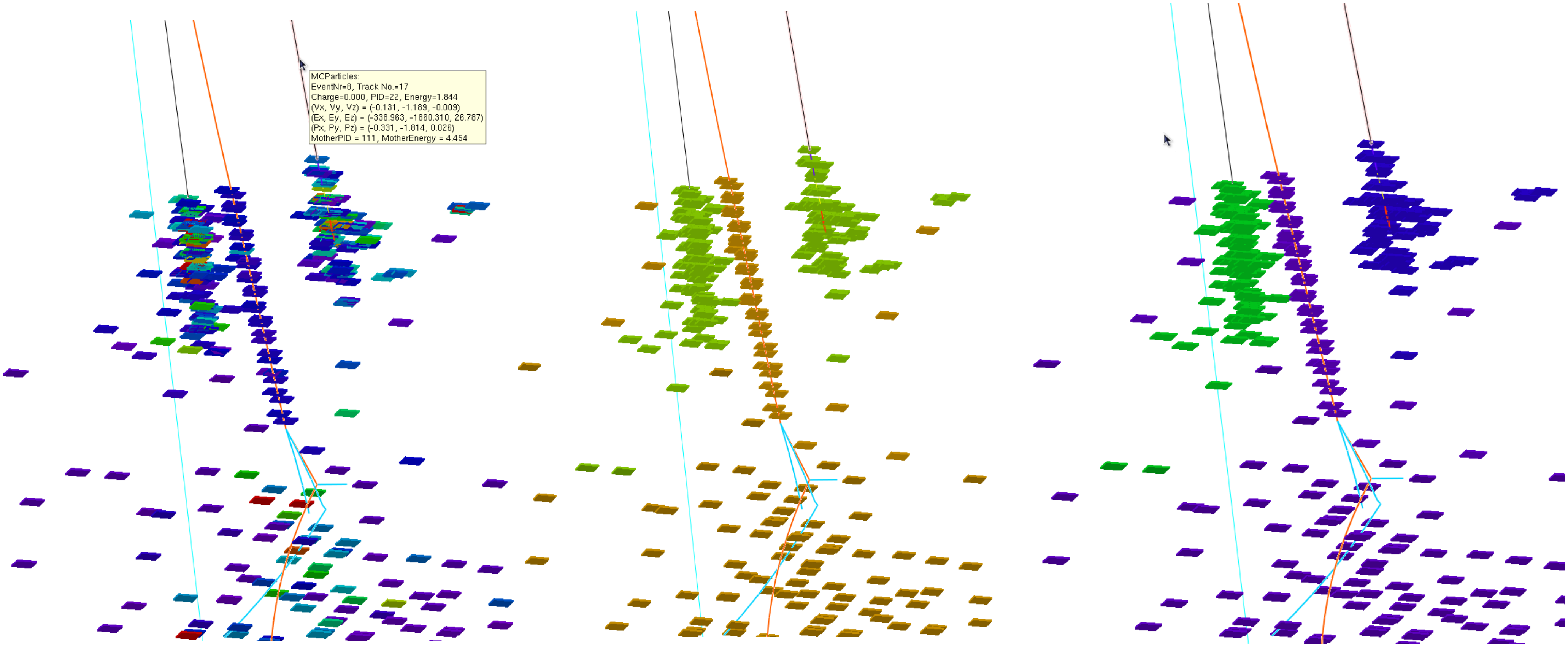
- Objects:
  - Detector Geometry;
  - Event type: Mother particle at the VTX
  - Detector hits:
    - MC: Simulated Hits
    - Reco: +Digitized/Clustered Hits
  - Estimated tracks:
    - MC: MCParticle
    - Reco: +Reconstructed Particles (PFOs)





- Options:
  - General 3D options: Zoom, Rotate, Projection, Light source & background…
  - For Individual objects:
    - Display/hidden by itself or group
    - Pick up & read attached information

Style: Hits Color

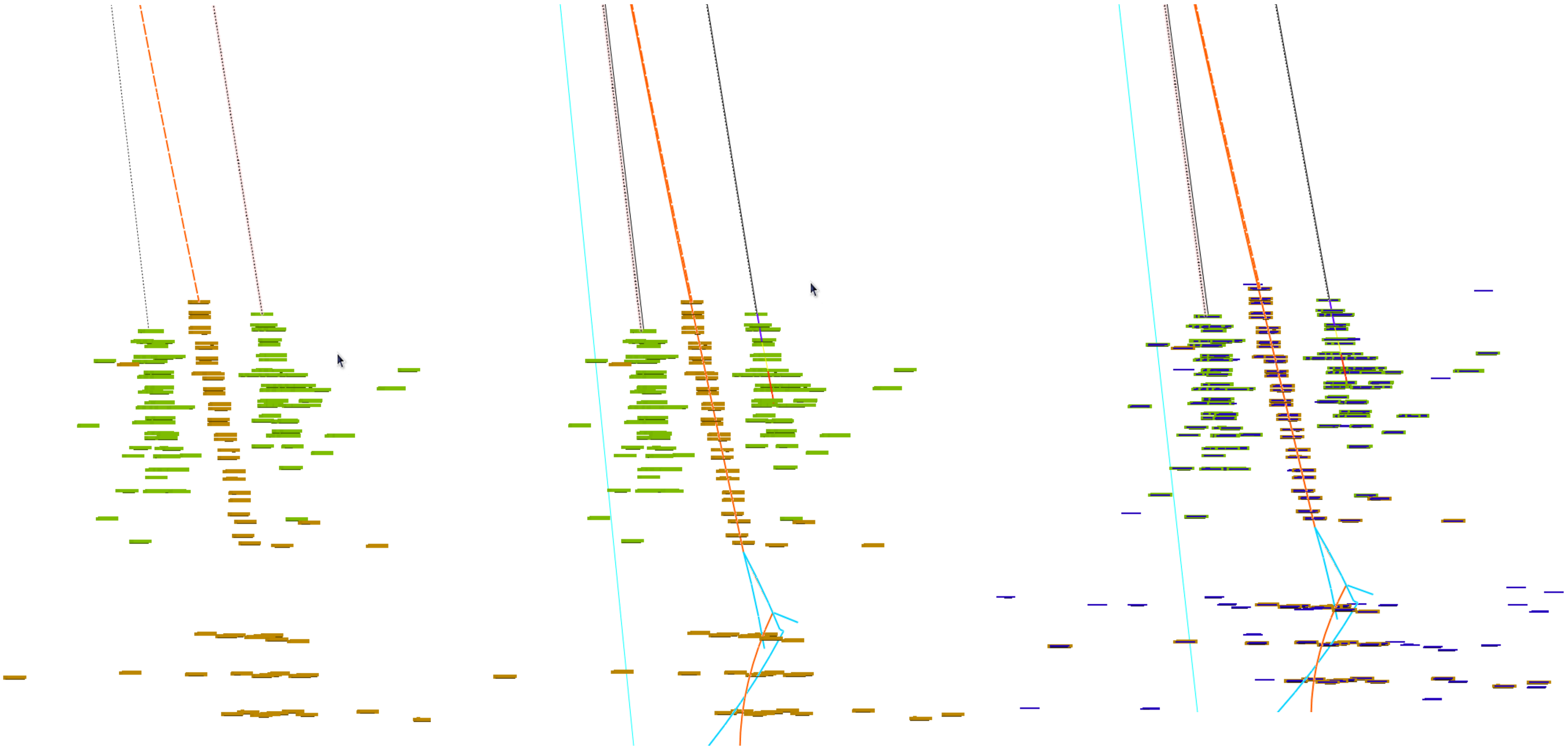


Tau jet ($\tau \rightarrow \nu+\pi^0+\pi^+$) with different color option: energy, PID & index

- Uniformed Color
- Particle Index (to distinguish closed hits created by same kind of particle)
- Energy (energy deposition, dE/dx, or according to thresholds...)
- PID: the particle passing through or mother particle from VTX

Understand/Analysis reconstruction software performance

Display reconstructed & MC objects simultaneously:



Same tau jet, from left to right:
- *PFO (+associated Digitized Hits);*
- *PFO (+associated Digitized Hits) + MCParticle;*
- *PFO (+associated Digitized Hits) + MCParticle + MC Calo Hits (with uniform blue color);*

Summary

- Software development of GRPC SDHCAL is progressing at steady pace with the Hardware
- ILD display and 1st order digitization module is developed
- Druid: available at LLRForge
  https://llrforge.in2p3.fr/svn/Druid or
  https://polywww.in2p3.fr/~ruan/ILDDisplay/Druid_1.2.tar.gz

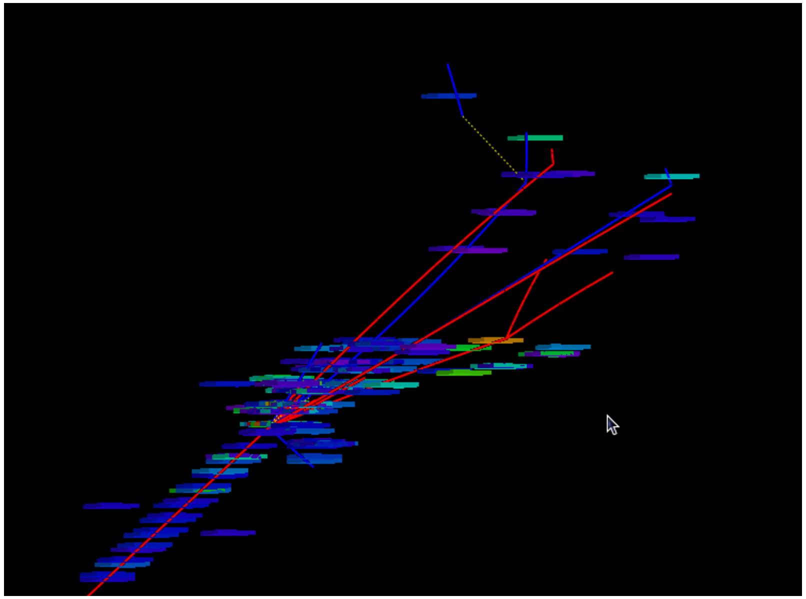
To do list

- 2nd Version of digitization: taken into account the GRPC efficiency correction, multiplicity & saturation effects
- PFA algorithm development for the ILD with SDHCAL
- Druid: Manual & Update with new geometries

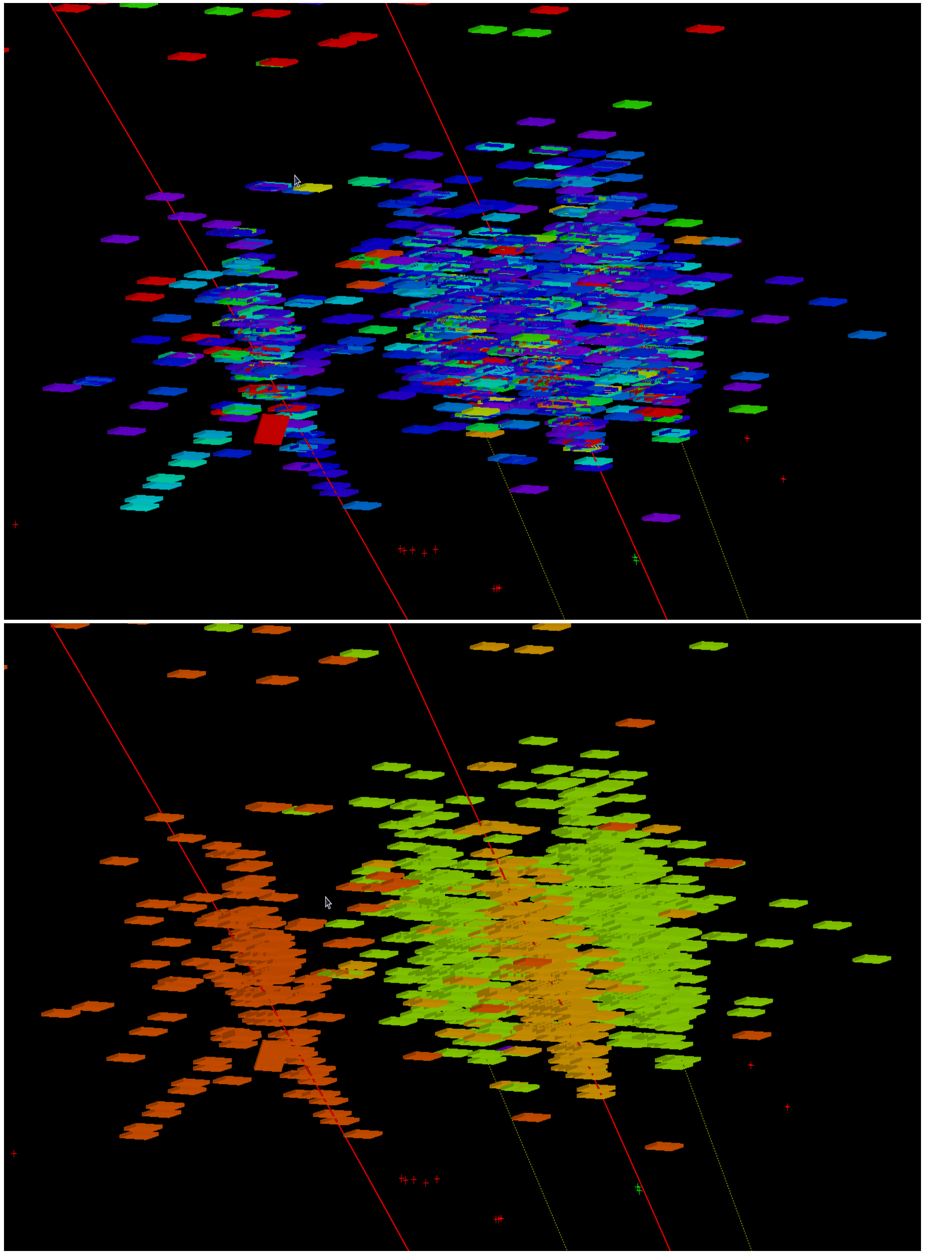
Back up slides

Mokka option

- Mokka option: (*Thanks to G. Musat*)
  - Keep tracks generated inside calorimeter region: allows to study shower detail (highly increase the size of data file)
  - Suspends tracks that enter Dhcal: allows detailed comparison of different HCAL options
  - Local copy, not yet committed to repository

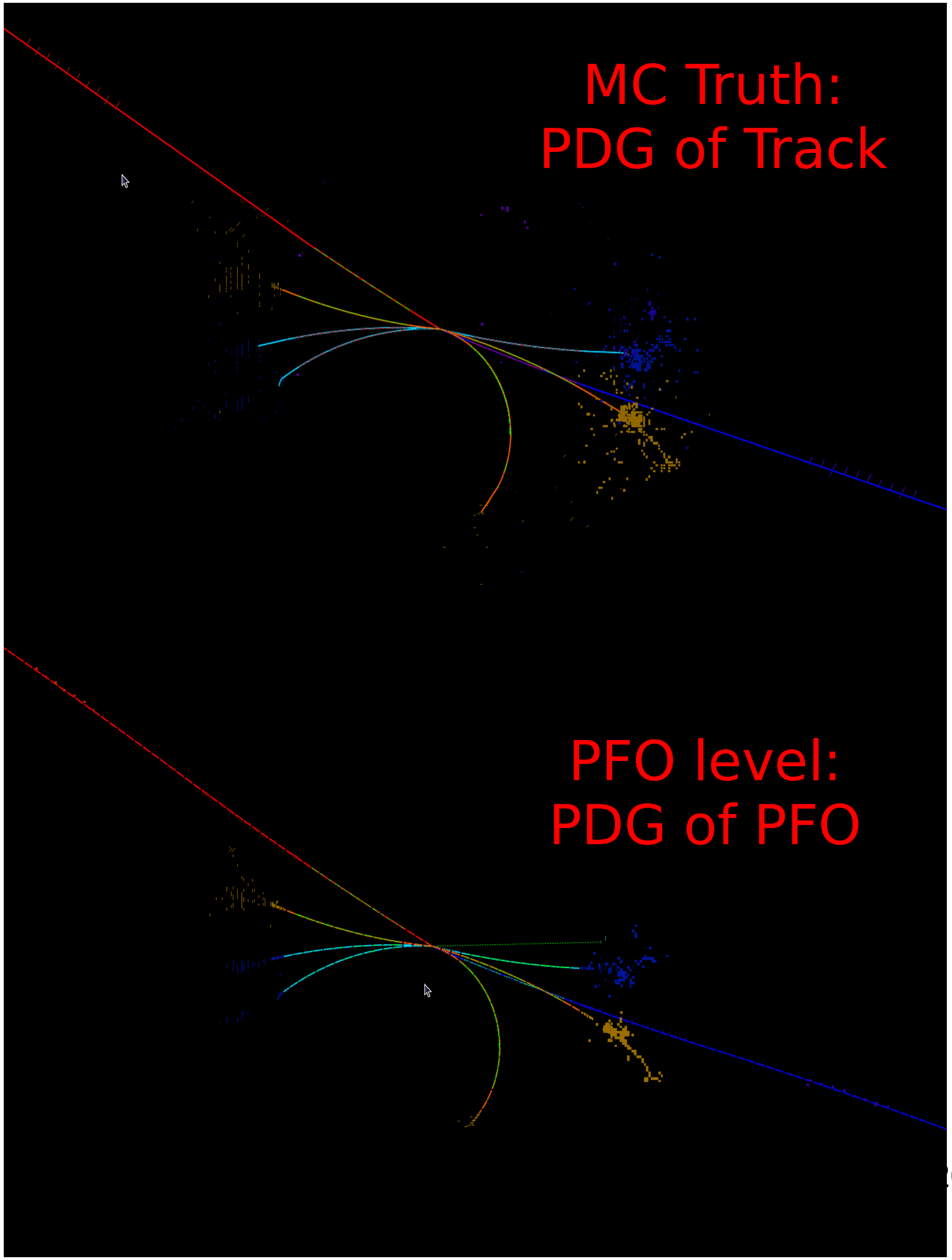


Style: MC objects



- Detector Hits Color:
  - Uniformed Color
  - Particle Index (to distinguish closed hits created by same kind of particle)
  - Energy
    - Energy deposition or dE/dx
    - SDHCAL Hits: according to different Thresholds
  - PID
    - The particle passing through
    - The origin of the hit: PID of the mother (from VTX or from TPC)

Style: Reco objects

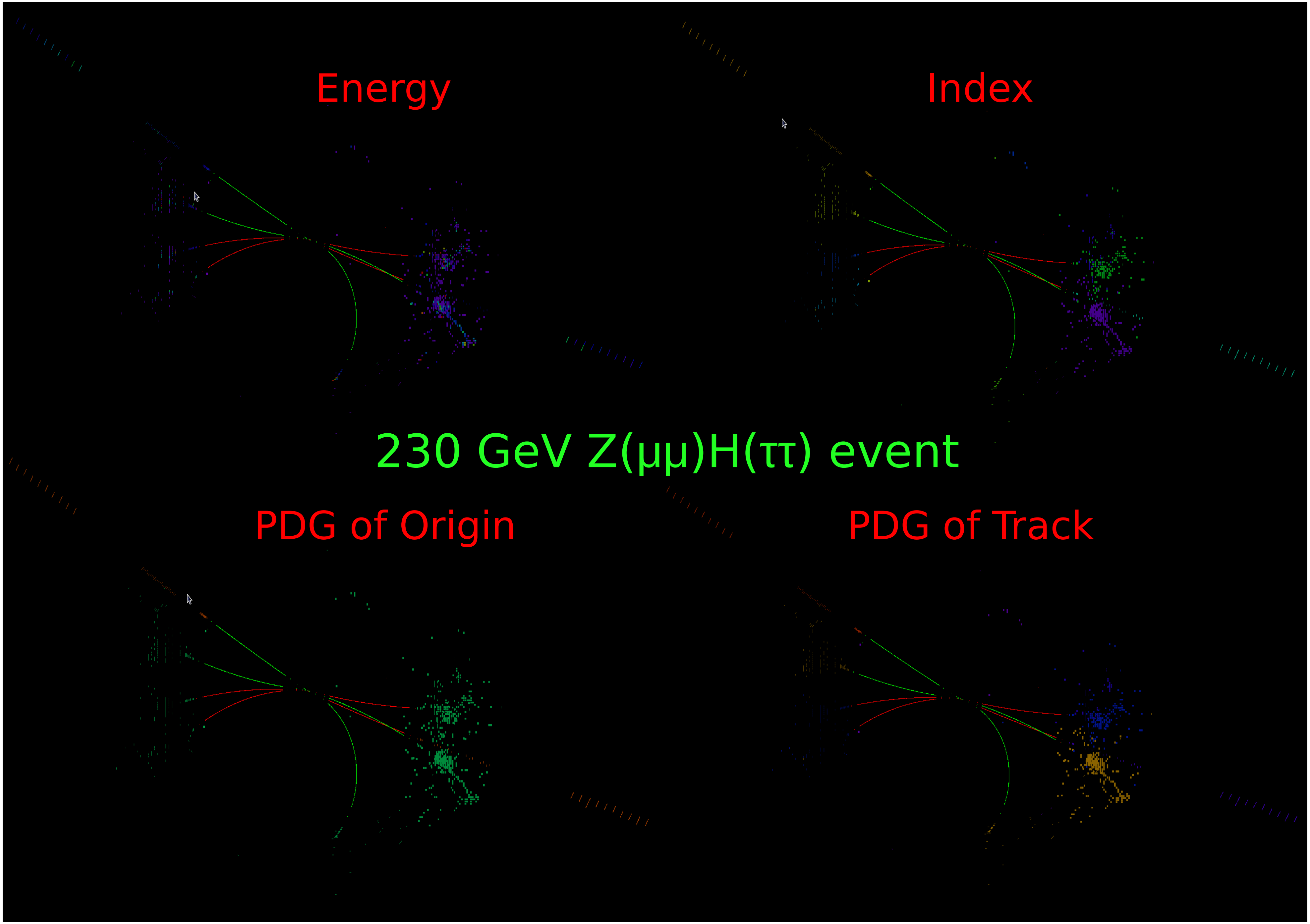


- Digitized Detector Hits
  - Color with energy deposition (dE/dx)

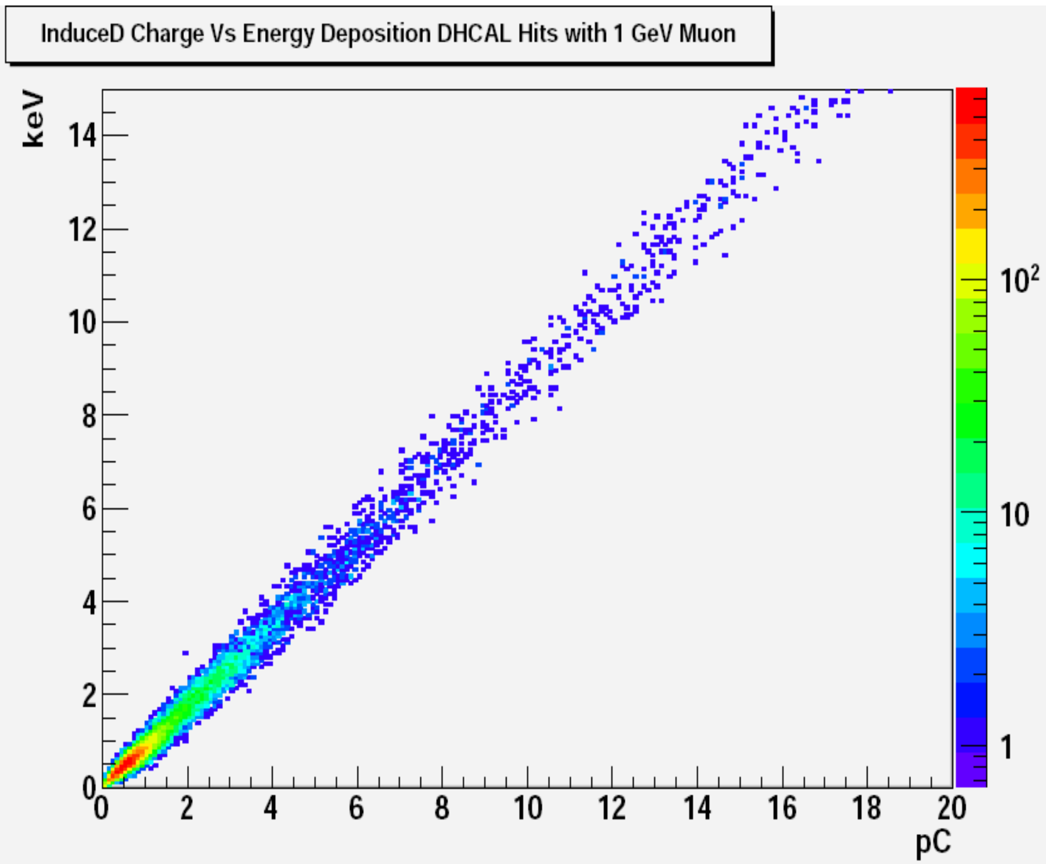
- Reconstructed Particle (*using PFO as standard*):
  - Reconstructed Particle :: PandoraPFO, displayed as Tracks;
  - PFO associated Hits color:
    - Uniform color;
    - PDG information of PFO: PFO → Clusters & Tracks → Hits;
    - Particle Index;

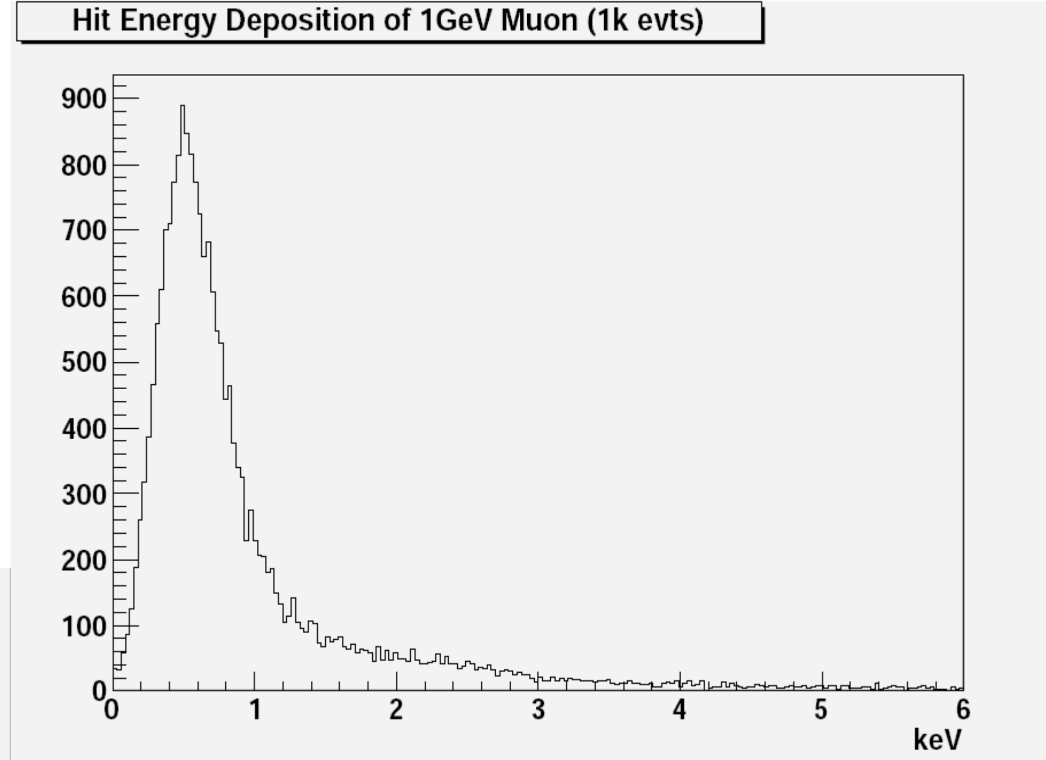
- To analysis reconstruction software performance: display reconstructed & MC objects simultaneously.

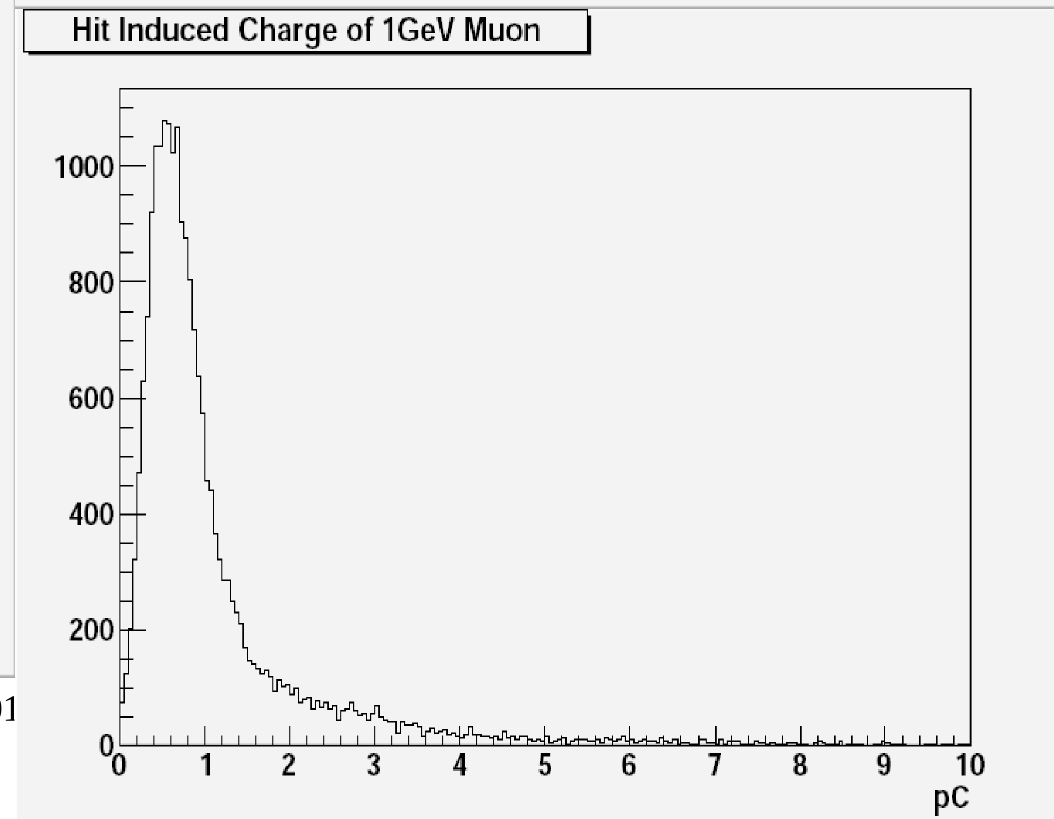
Different option with MC hits



Digitization with 1 GeV Muon







Digitization with 100 GeV Pion