Potential of high granularity

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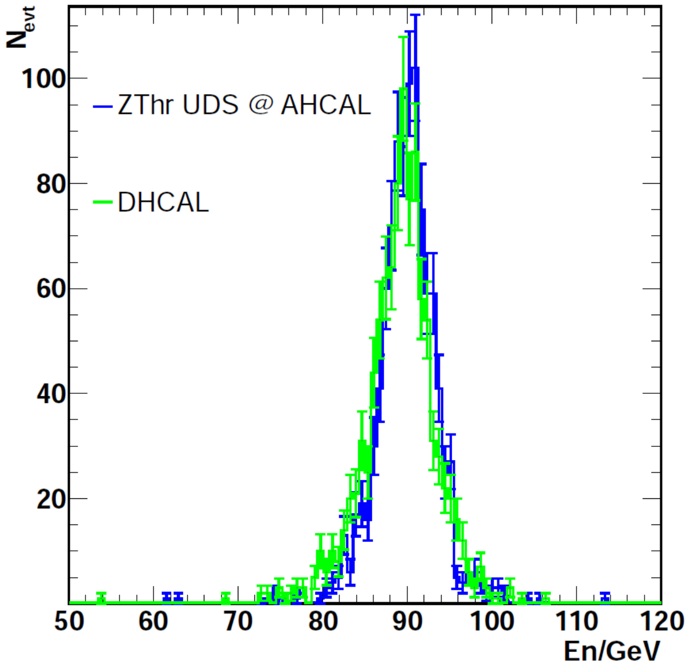
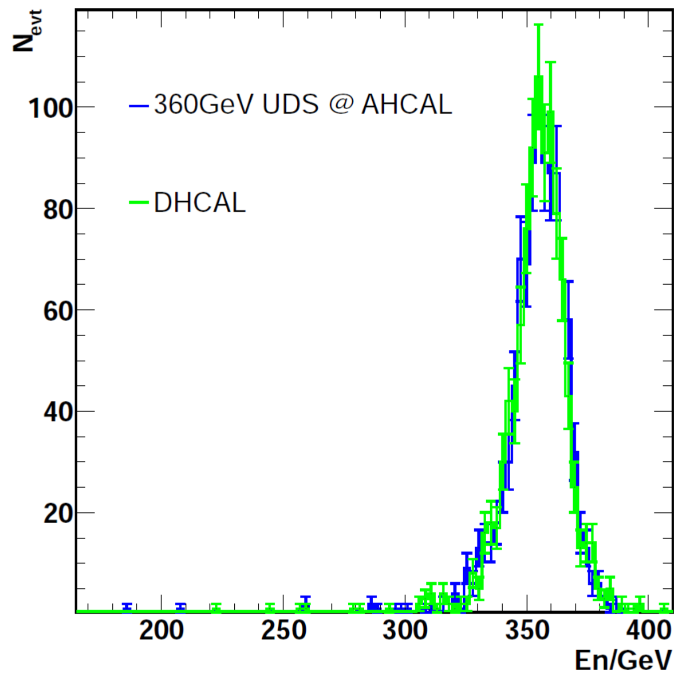
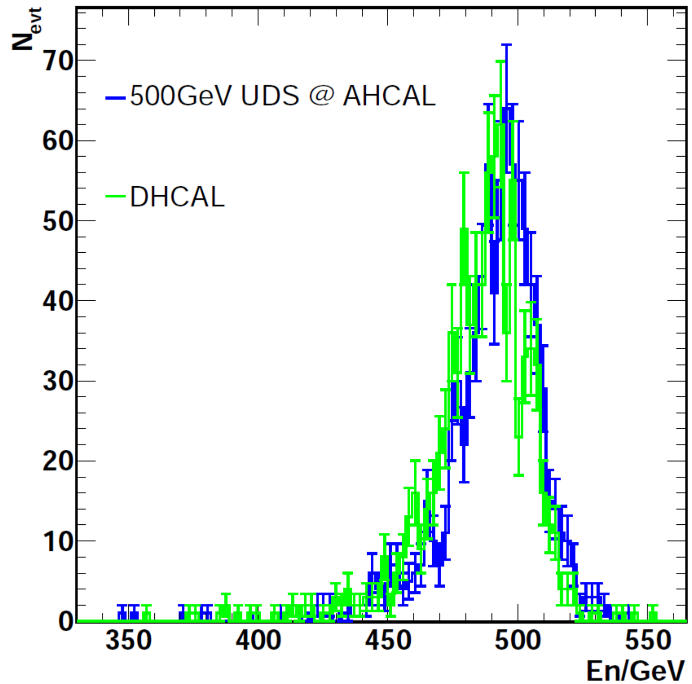
Outline

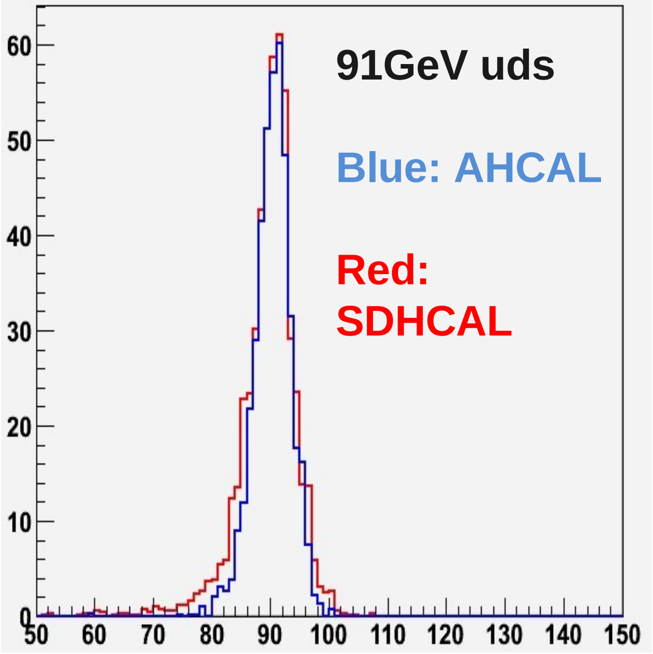
- Starting point: SDHCAL @ Pandora with default setting
- Hints to improve:
  - Utilize semi digital information
  - Better pattern recognition: MST & Hough
  - Shower reconstruction: Arbor algorithm
  - Cleaning
  - Measurement: Fractal Dimension
    - PID
    - Energy Estimation
- Summary

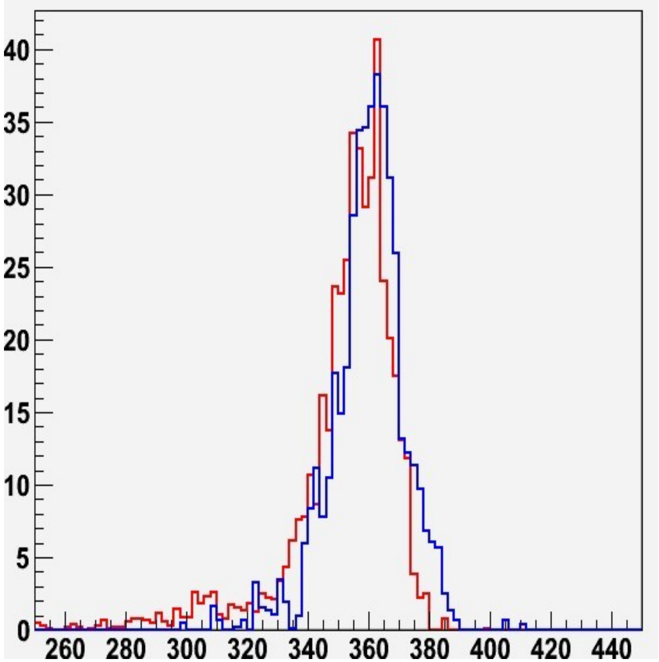
PandoraPFA @ SDHCAL







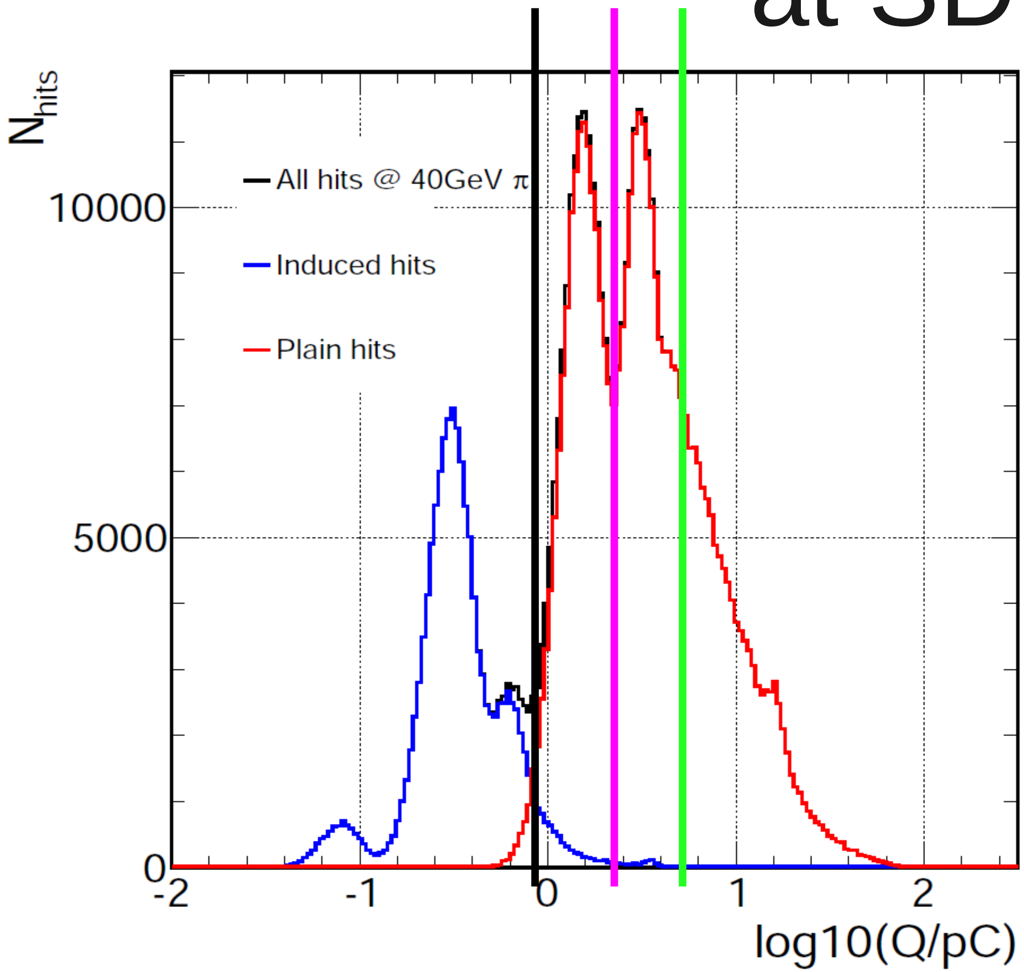


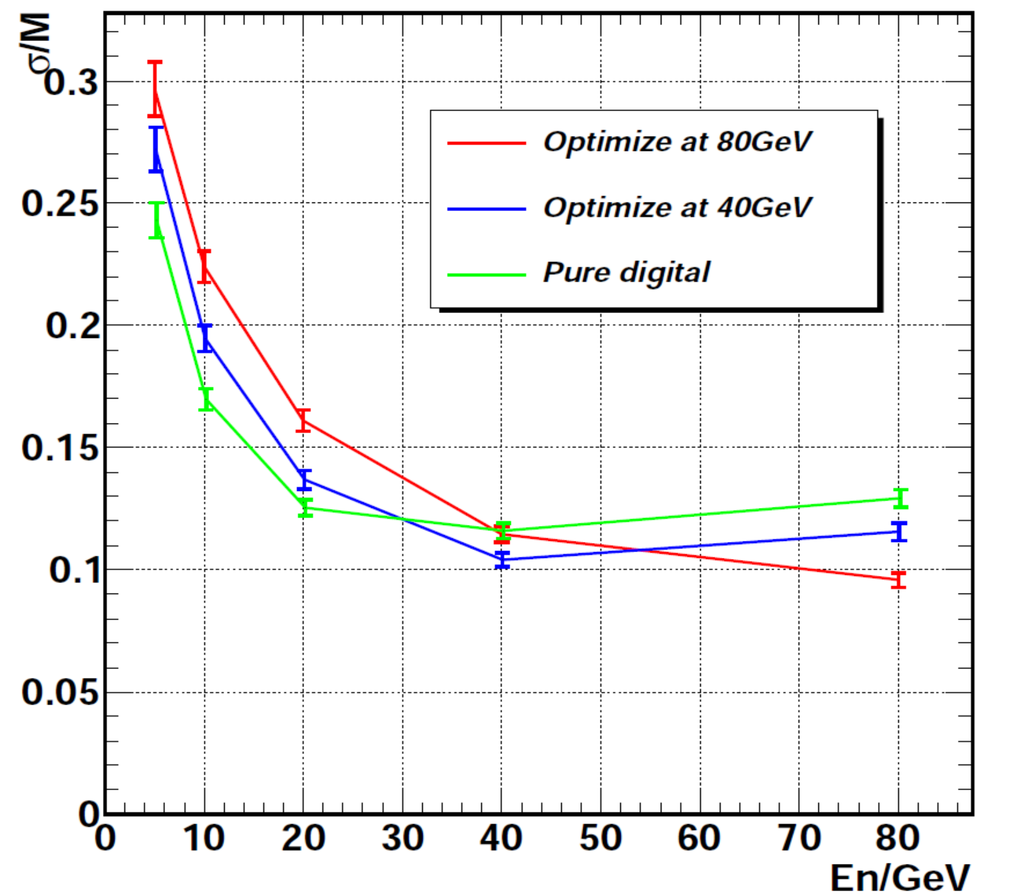


PandoraPFA @ SDHCAL: Reasonable performance with default, AHCAL optimized setting

Independent analysis done with different samples and Calibration Constants setting

Example: three thresholds at SDHCAL

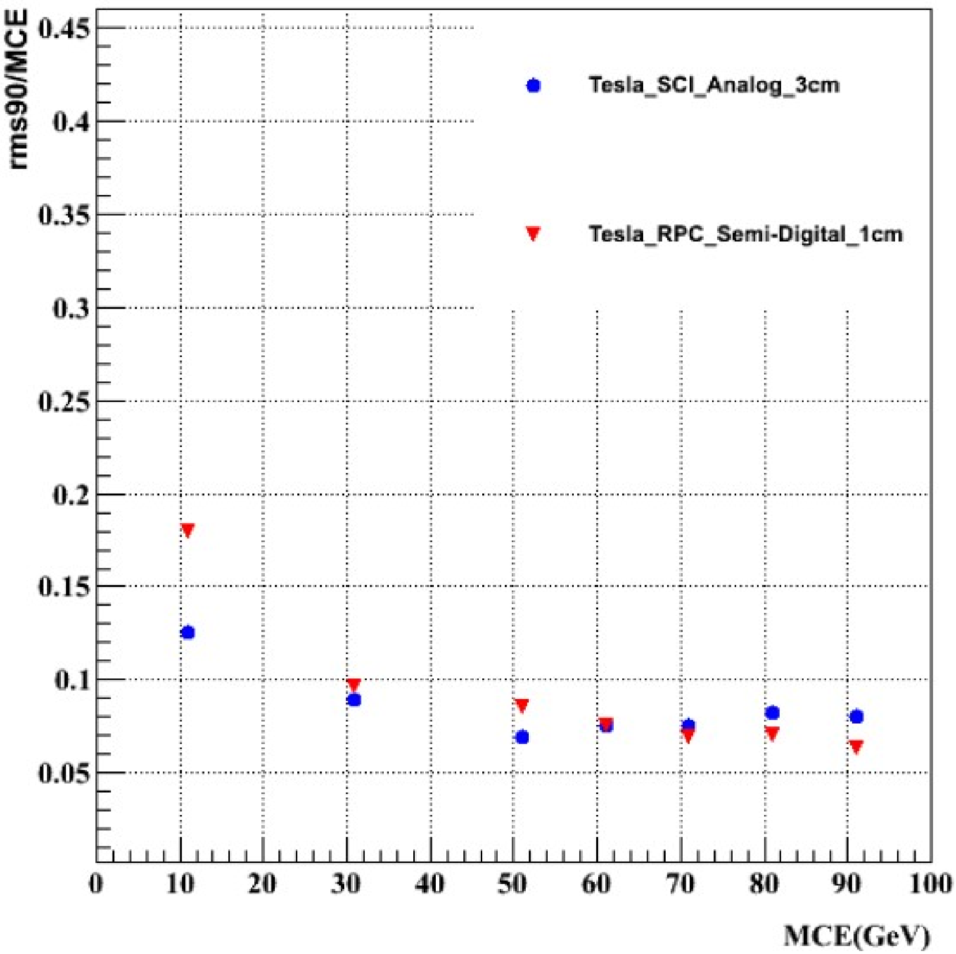


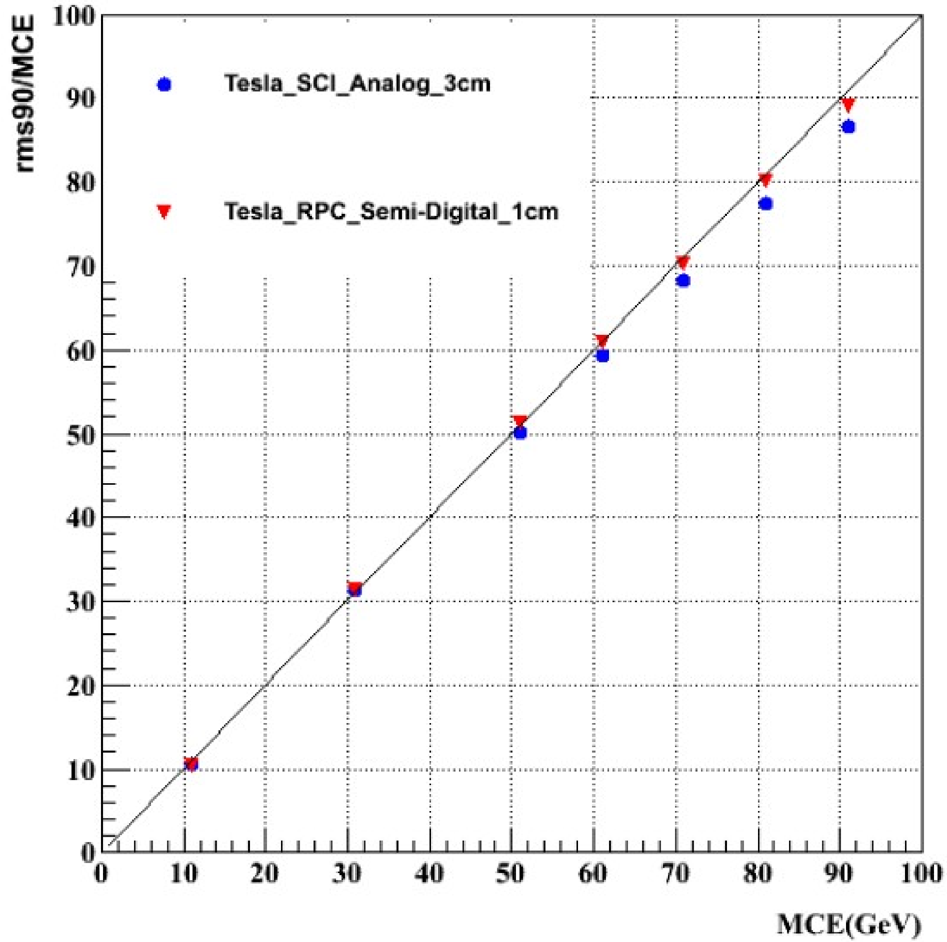


Reference: charge spectrum of 40GeV Pion after digitization with 1mm cell information. More details: https://indico.cern.ch/contributionDisplay.py?sessionId=5&contribId=28&confId=136864

Thresholds (equalize statistics of three kinds of visible hits):
1st, 0.8 pC ~ 0.5mip; 2nd, 2.11pC ~ 1.32 mips; 3rd, 4.56pC ~ 2.84 mips.

SDHCAL: potential with three thresholds





K0 reconstructed with PandoraPFA at full detector (R. Han)

SDHCAL Vs AHCAL: better linearity & better resolution @ high energy, worse resolution @ low energy

On going study: Neutral Network energy estimation with Semi-Digital information

Minimal Spanning Tree

Work from G. Grenier, Guillaume Garcia, Daniel Förster, Loïc Cousin.

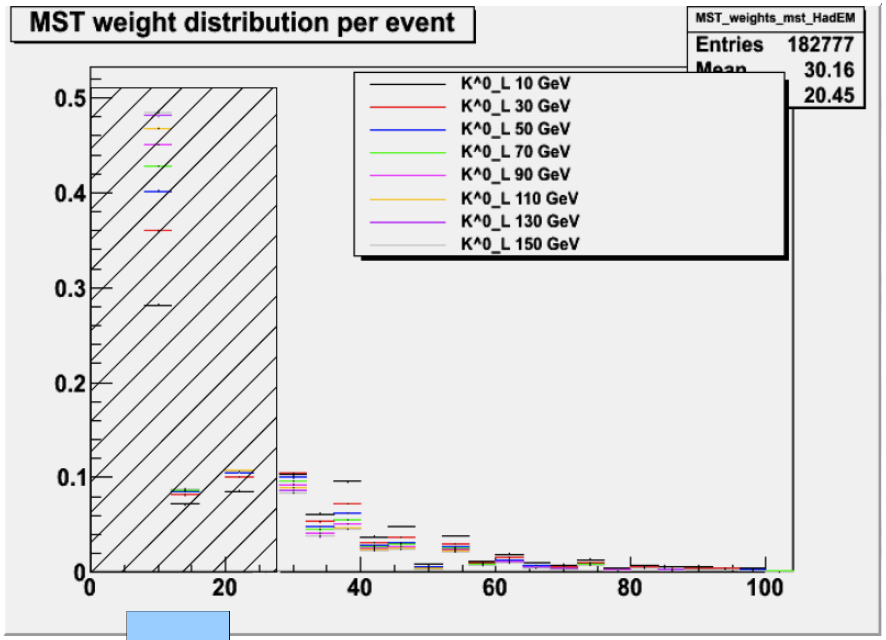
Kruskal type MST algorithm
(from C++ boost lib)

$$weight = n_{tr} d_{tr} + n_l d_l$$

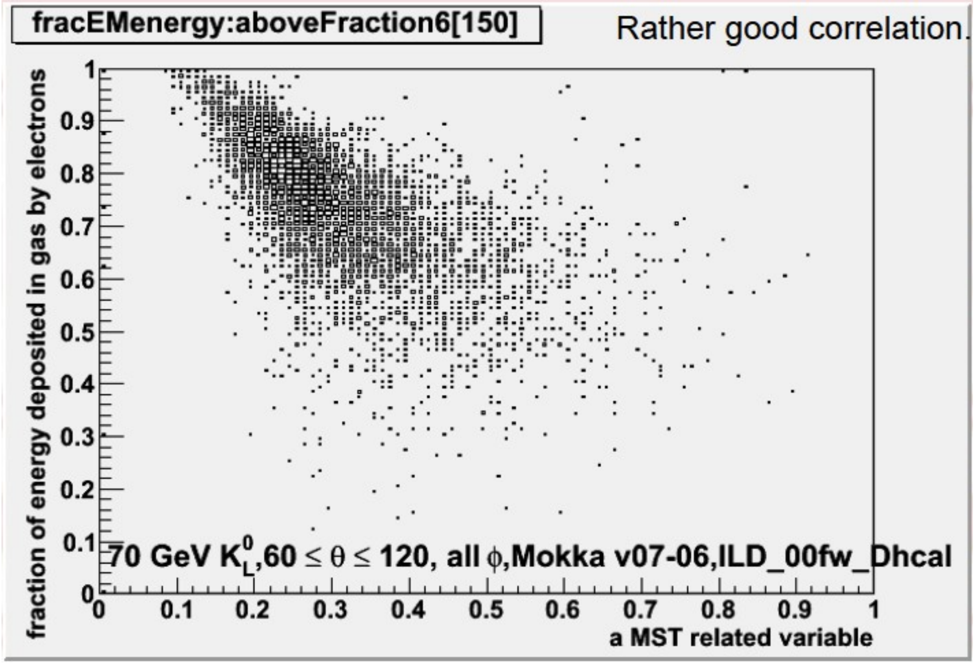
d_{tr} : distance between hits perpendicular to SDHCAL layers

d_l : distance between hits parallel to SDHCAL layers

n_{tr} and n_l are factors : varied from 0.2 to 5 by step of 0.2

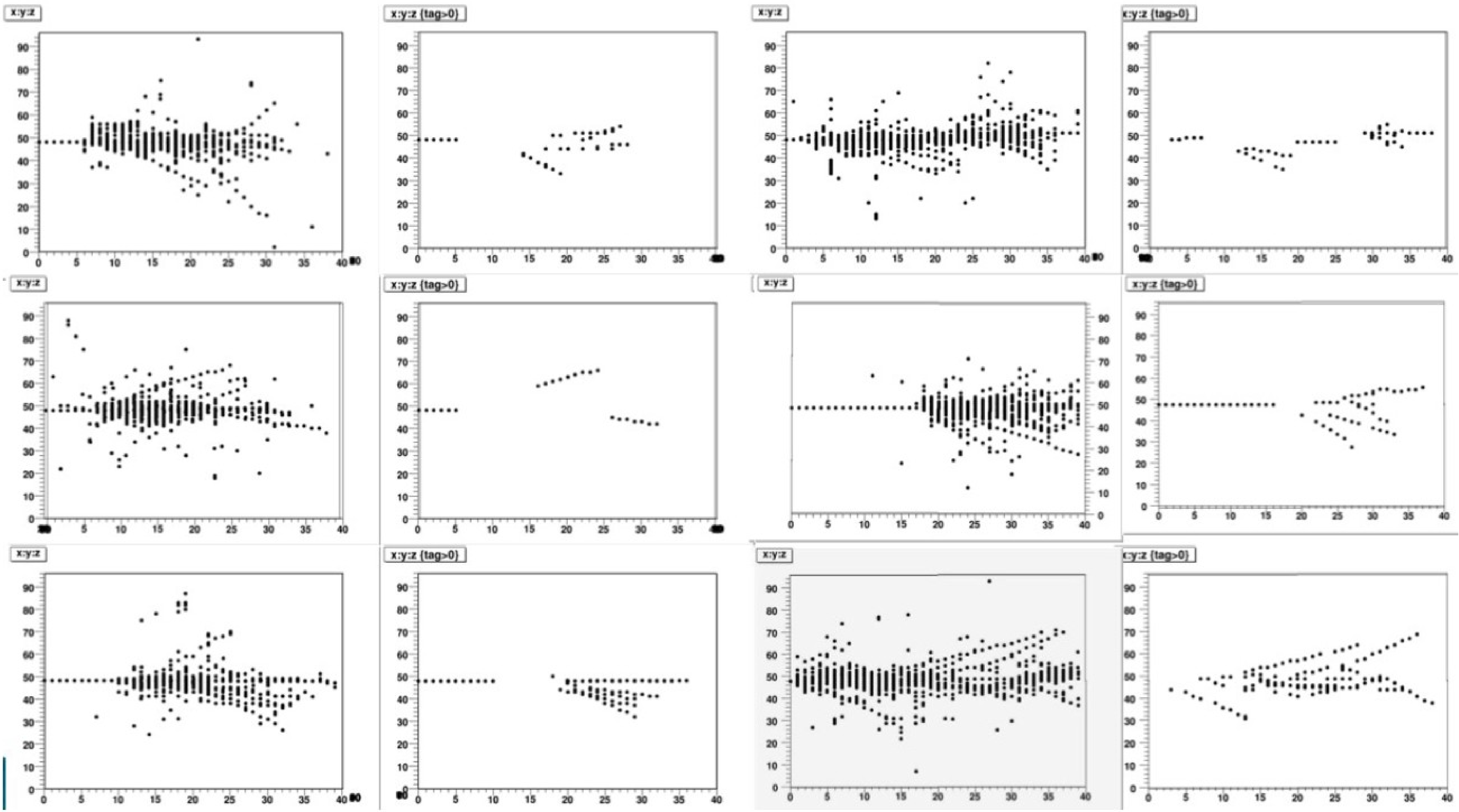


Low weights ↔ High density ↔ EM deposits



Event by event
EM fraction
(tuned on Mokka info.)

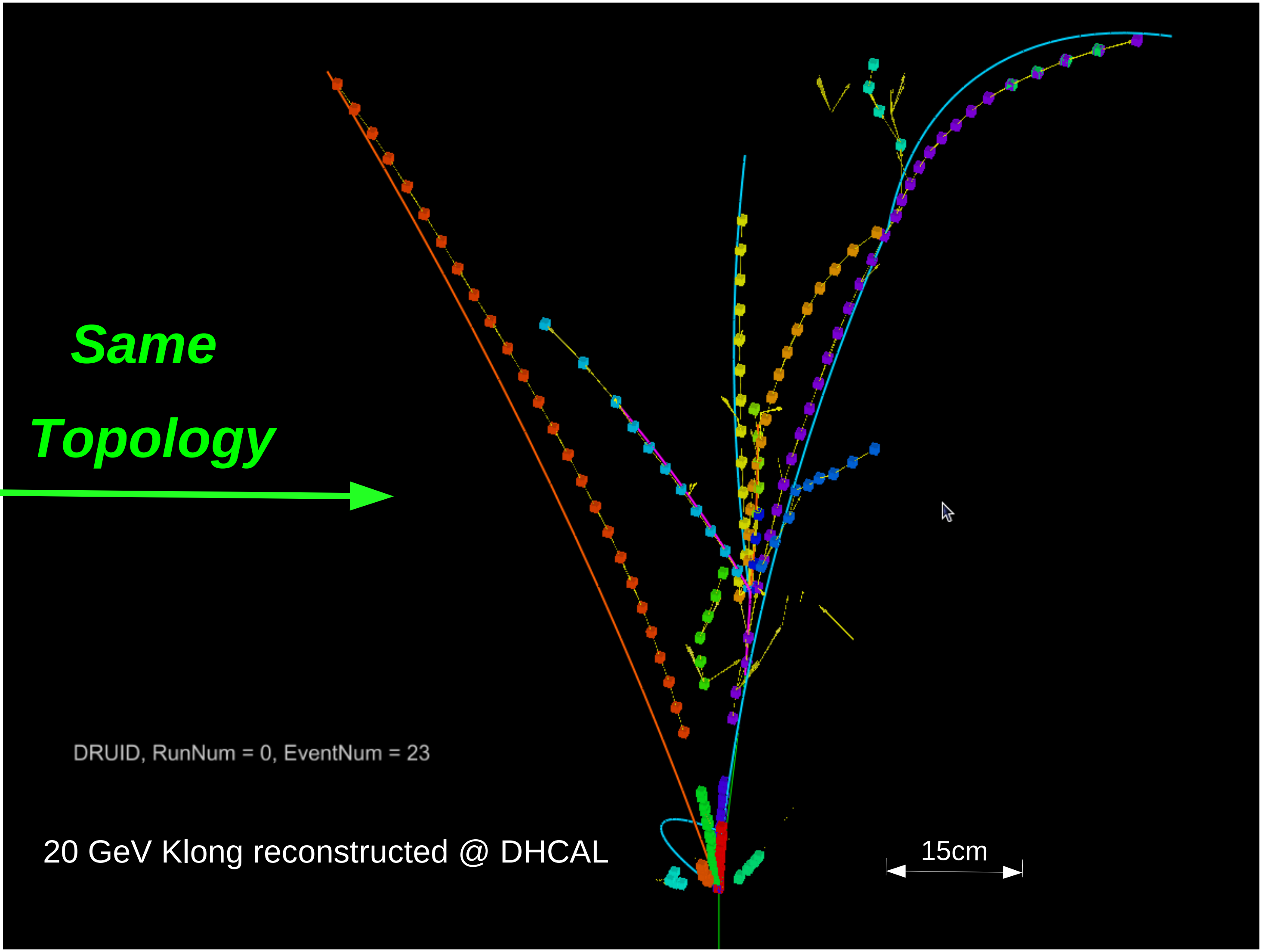
Hough Transform (HT)



Hough Transform (Imad & Yohan): MIP tagging in Hadronic shower, to be used on in-situ Calibration, alignments, efficiency monitoring...

Arbor: to reconstruct shower as a tree

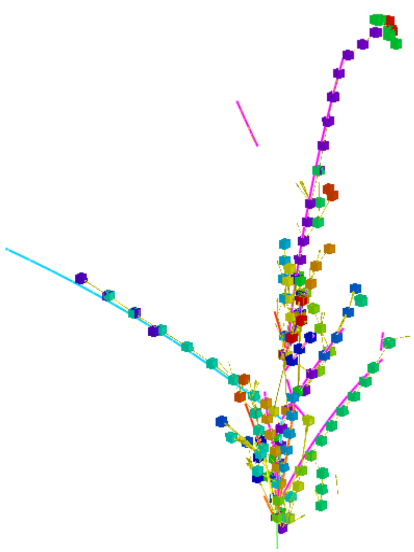
Same Topology

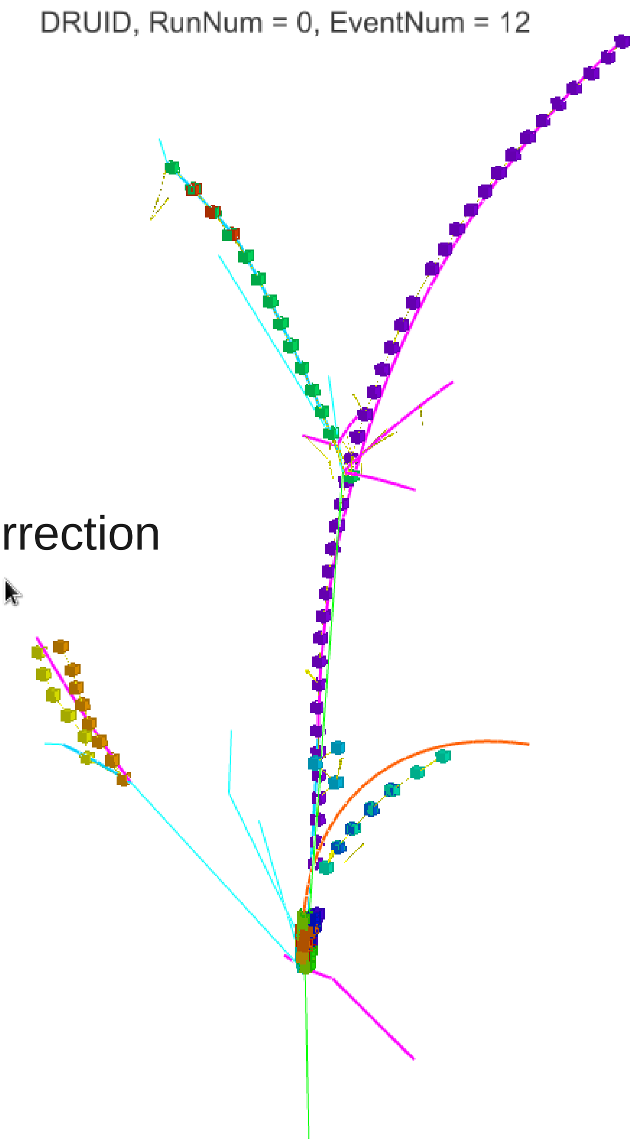


- Valid principle + many new ideas
  (Original idea from Henri Videau, in hadronic shower reconstruction @ ALEPH)

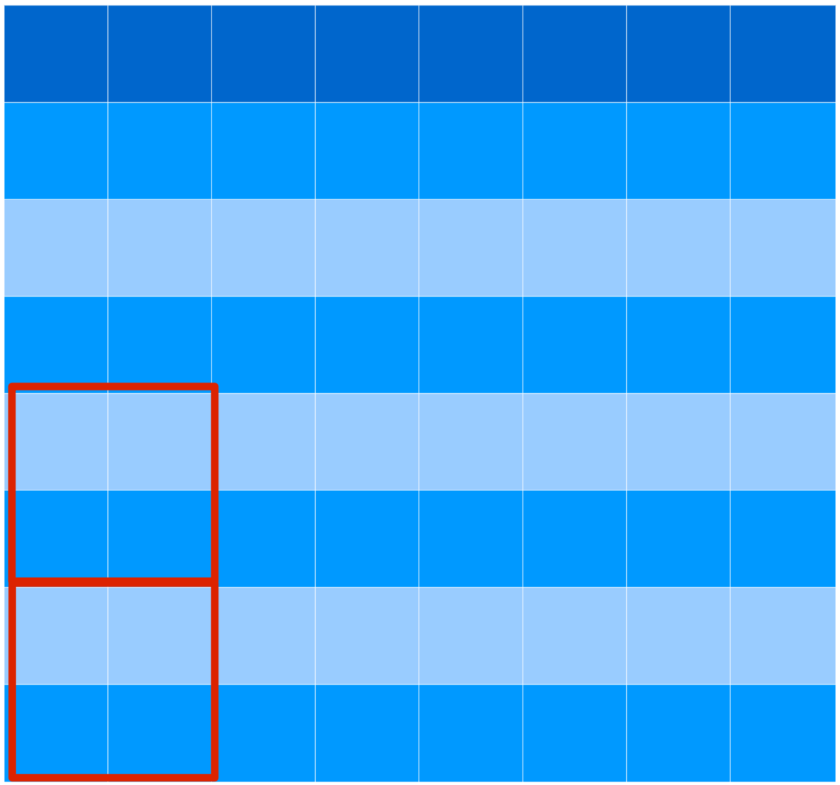
Arbor: Potential

- Shower separation
- MIP tagging & Branch Reconstruction
  - In situ Calibration/Stability monitoring
  - Kink & Pre interaction tagging
  - Better linking
  - Calo Tracks:
    - Kalman Filter ~ Energy Estimation ~ Leakage correction
    - Better balance the EM/Had hits





Shower fractal dimension: principle



Shower particle: to interact or not

shower ~ self similar *(Mandelbrot Set)*

Measure shower Fractal Dimension (FD) at high granularity calorimeter

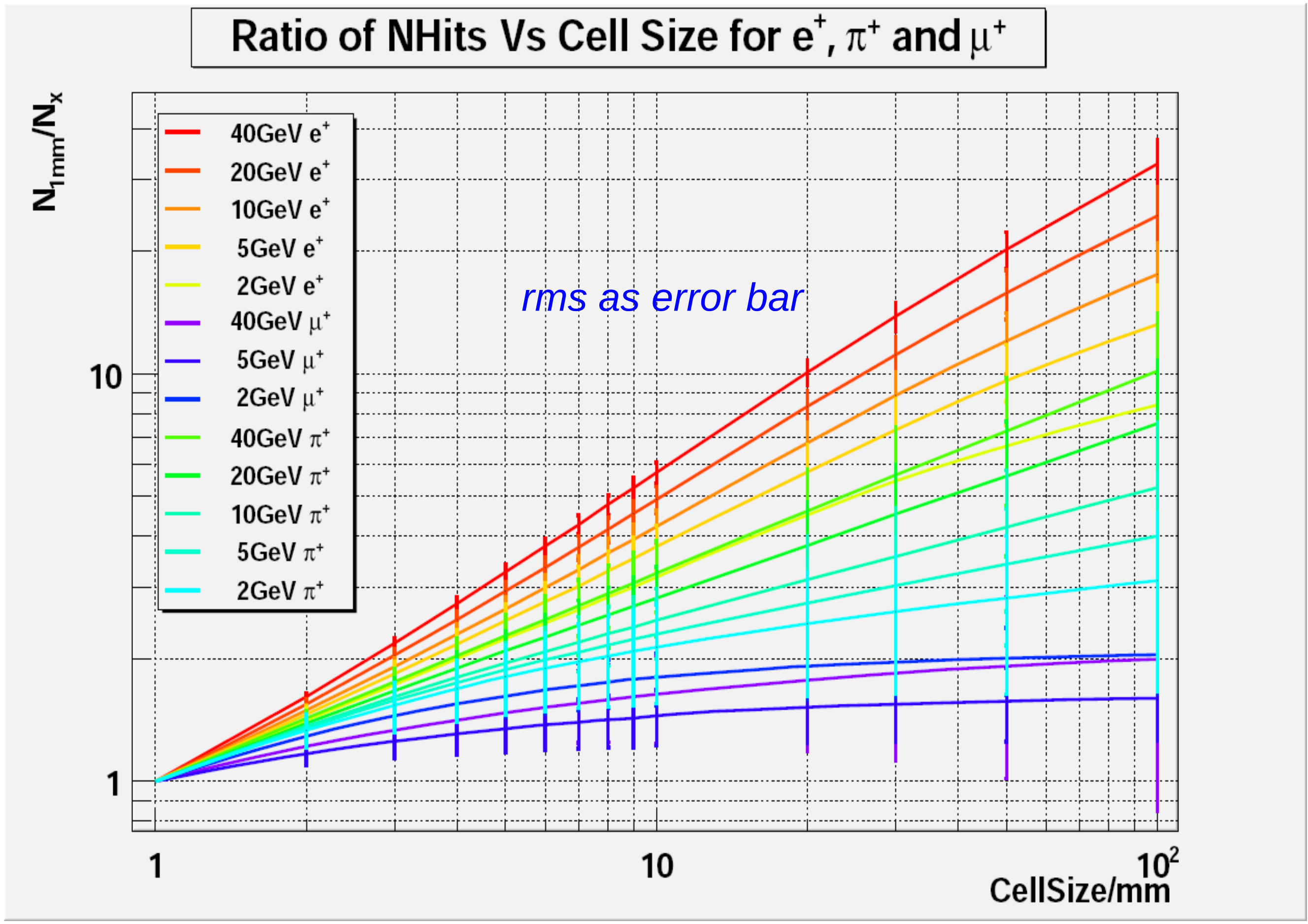
- Varying scale by grouping neighbouring cells
- Count Number of hits at different scale
  (define $RN_x = N_{1mm}/N_{xmm}$)

Shower: Self Similar

- Characteristic constant based on energy/PID:

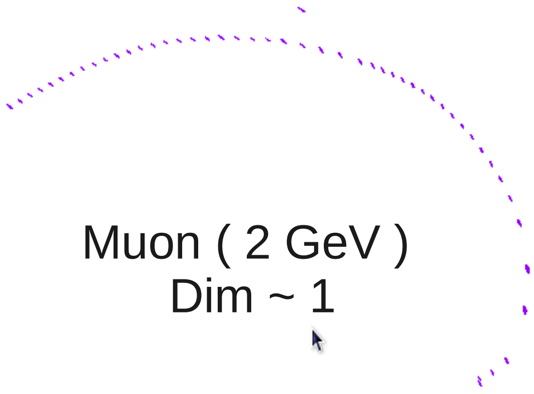
$D = \langle \ln R N_a / \ln(a) \rangle$

  - Global parameter based on local density
  - *Cell Sizes: 2 – 10, 20, 30, 50, 60, 90, 120, 150mm.*
  - *Samples: Particles shot directly to GRPC DHCAL with only B Field*



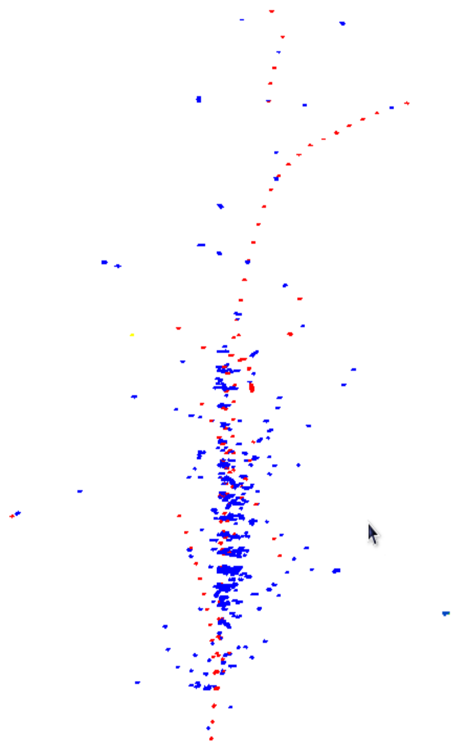
- Be observed within
  - Low scale: minimal interaction energy & sensor layer thickness (1.2mm)
  - High scale: fully containment ~ 1 hits per layer

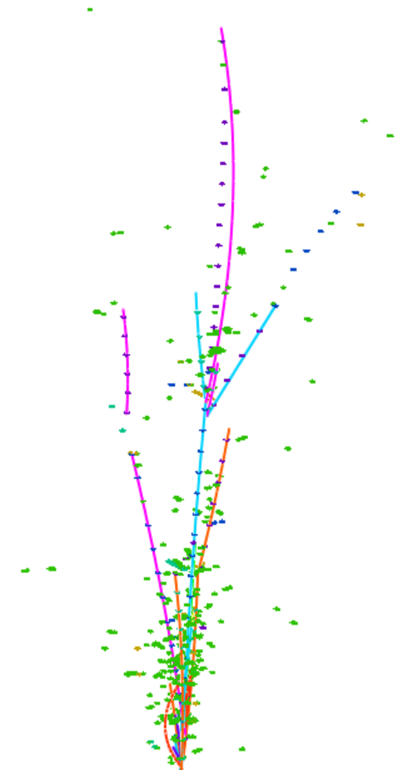
Fractals in Nature



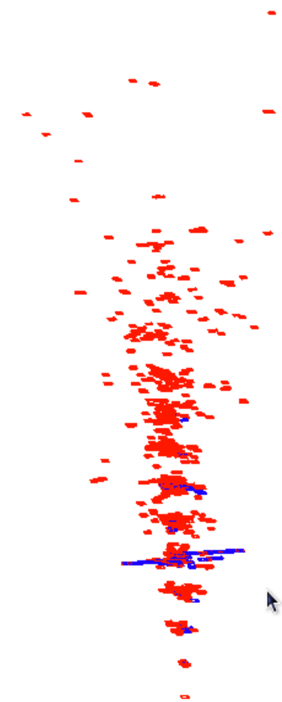
Muon (2 GeV)
Dim ~ 1

Straight line:
Dim = 1

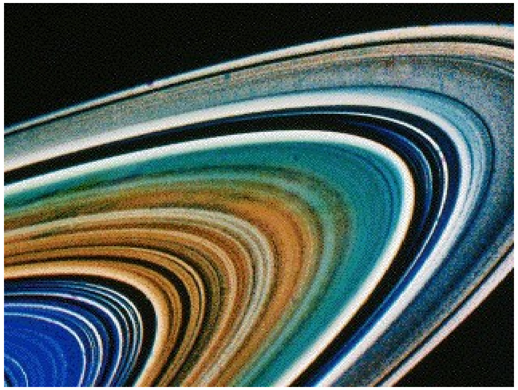


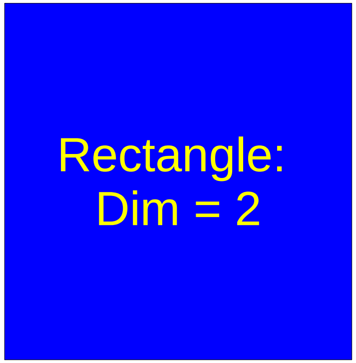


Hadrons: Dim(pi) < Dim(K0) ~ 1.5

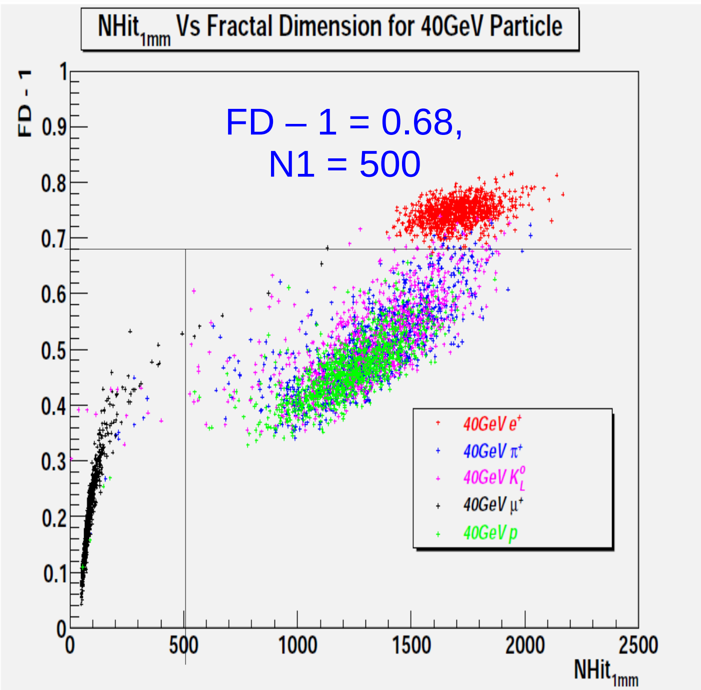


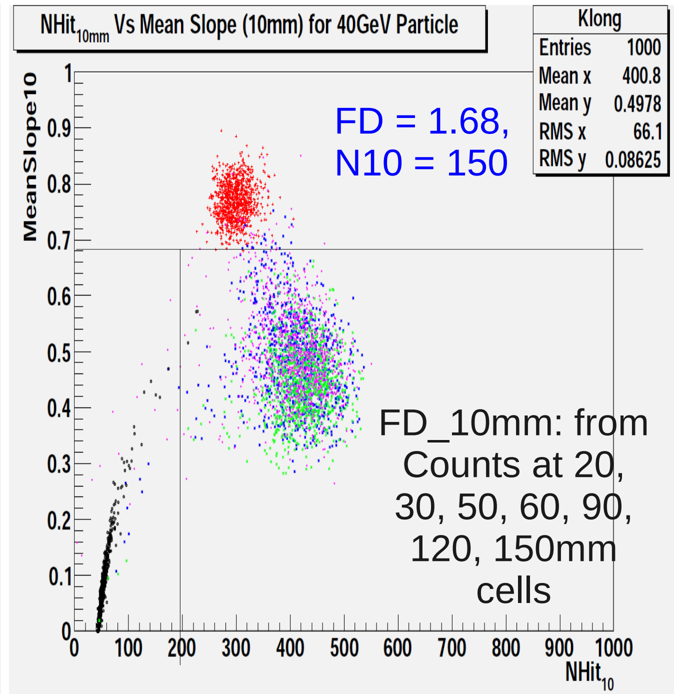
Positron (40GeV)
Dim ~ 1.75

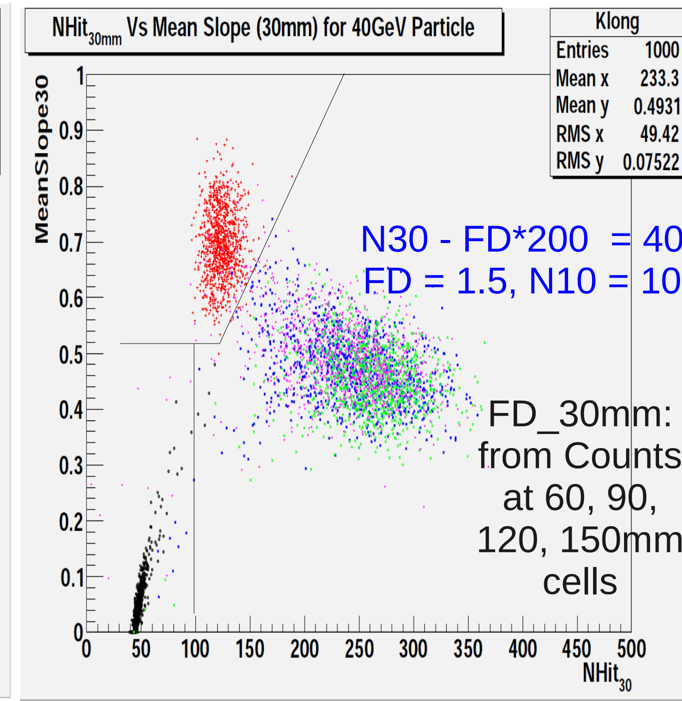




Potential tool for PID







FD together with other info (Nhits): Clear separation at different scales

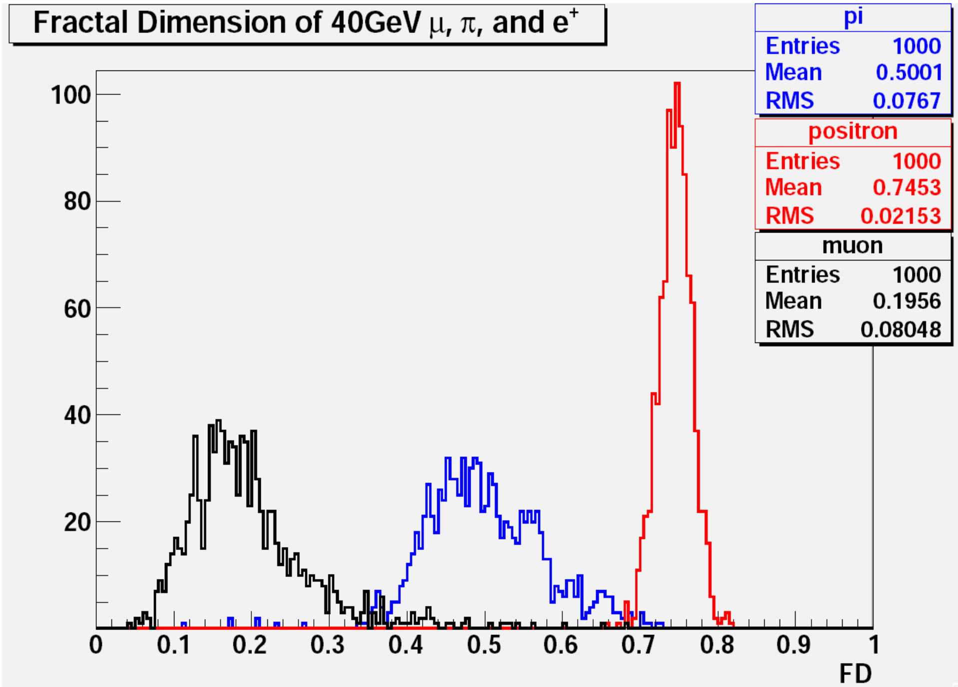
Remark: Energy dependent Cuts, easier for charged particles

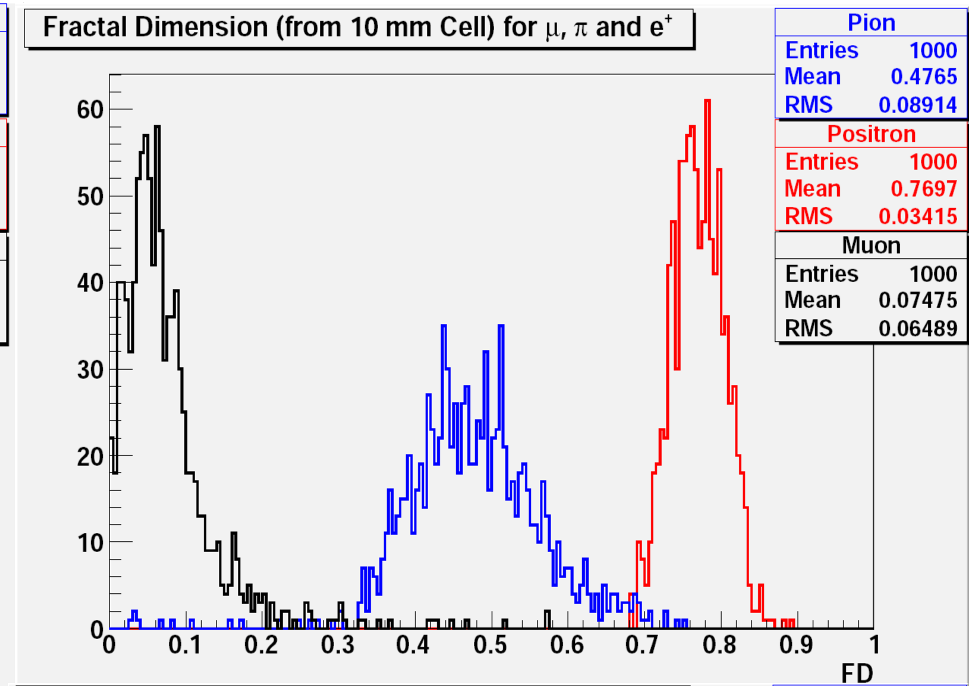
1mm	e+	u	h
e+	998	0	2
u	1	994	5
h	15	14	971

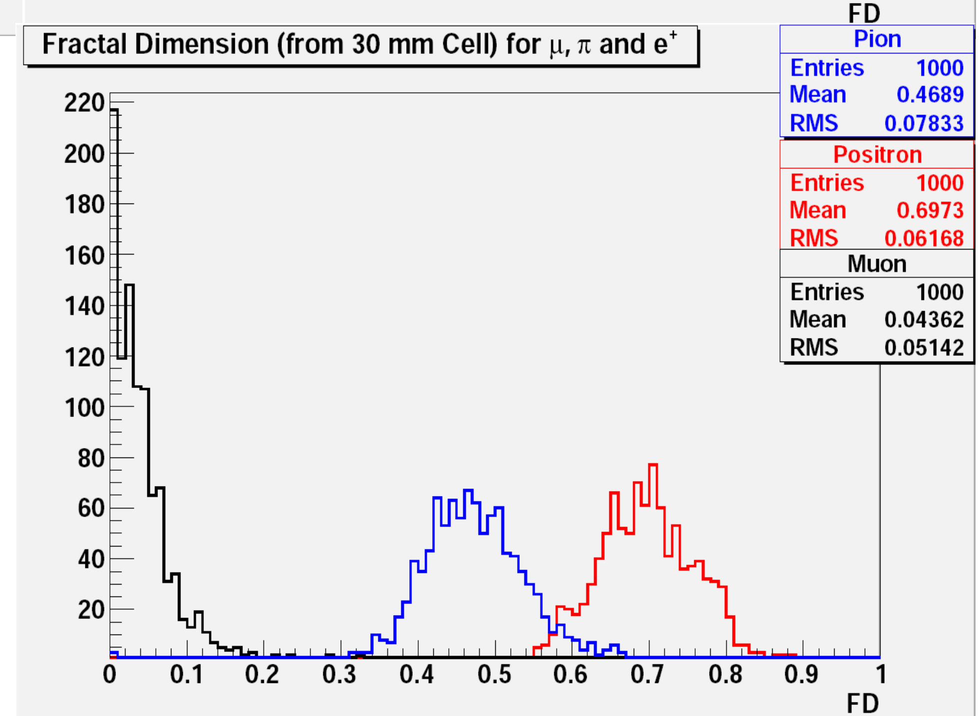
10mm	e+	u	h
e+	1000	0	0
u	0	995	5
h	17	14	969

30mm	e+	u	h
e+	1000	0	0
u	0	996	4
h	18	11	971

FD @ different size







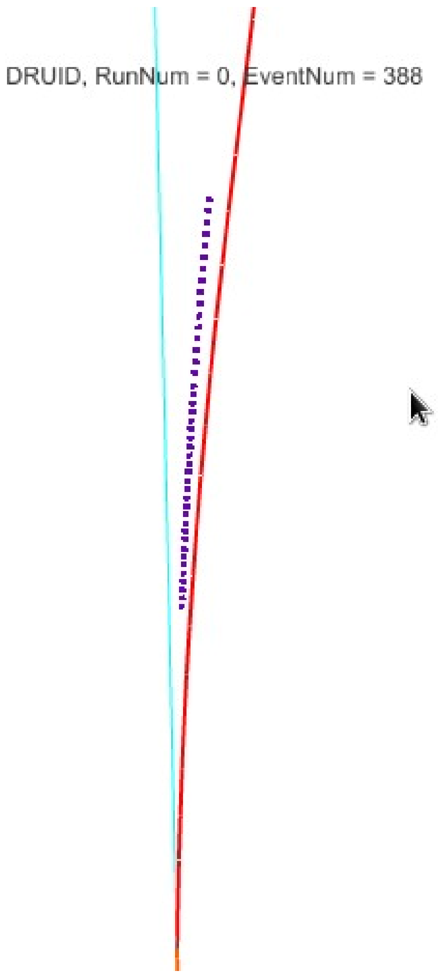
From FD(1mm) to FD(10/30mm):

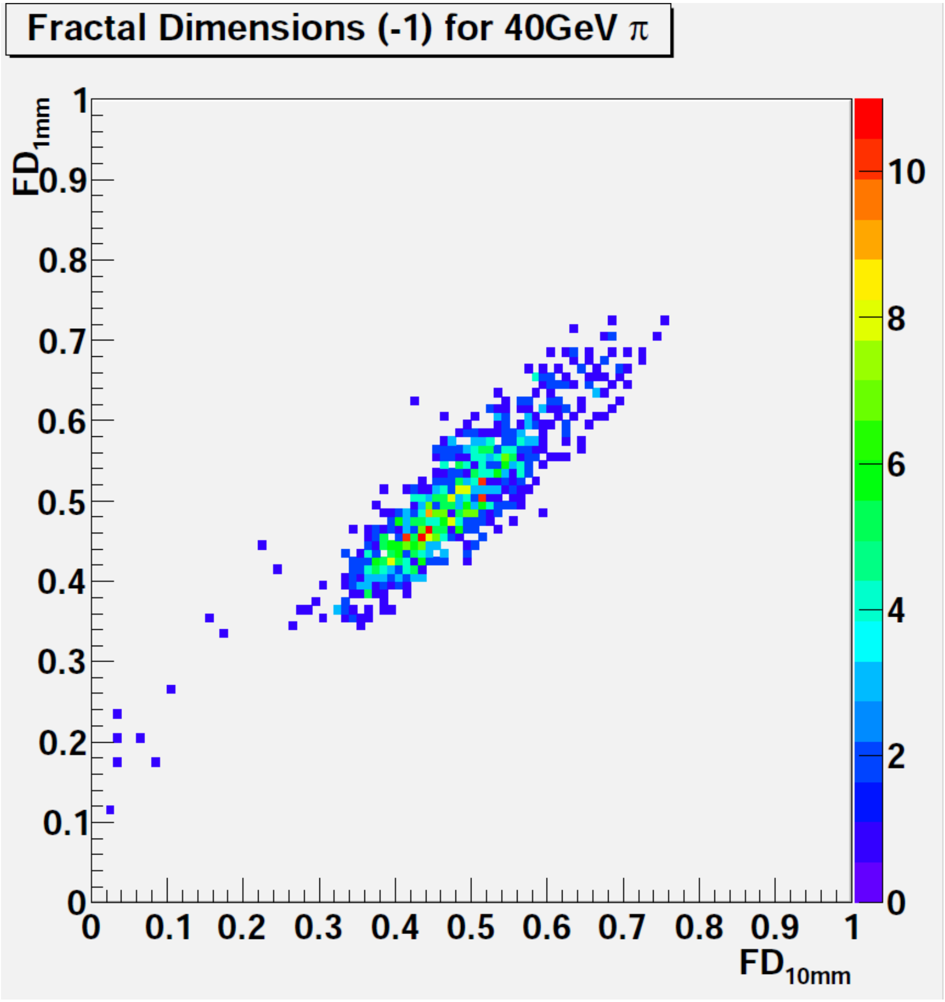
Positron Peak Smeared

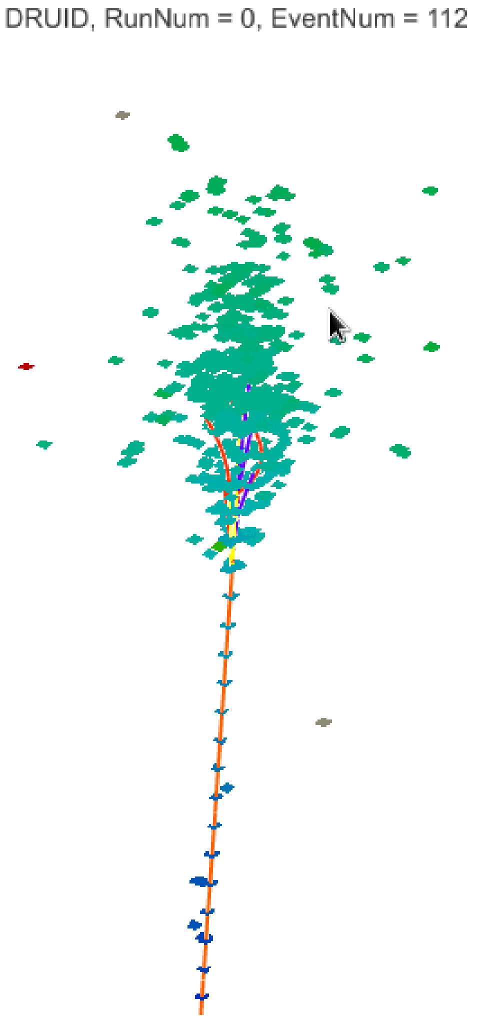
Better μ – h separation: μ acts more like a line (FD = 1); (Anyhow *we can create large cells from small ones...*)

π: continuous distribution from MIP to EM

Extreme Cases: Pion

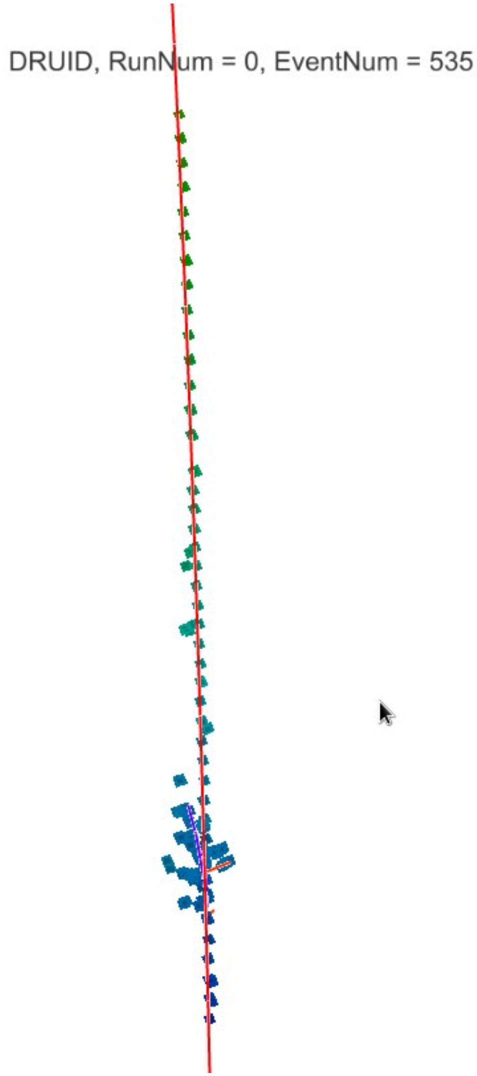


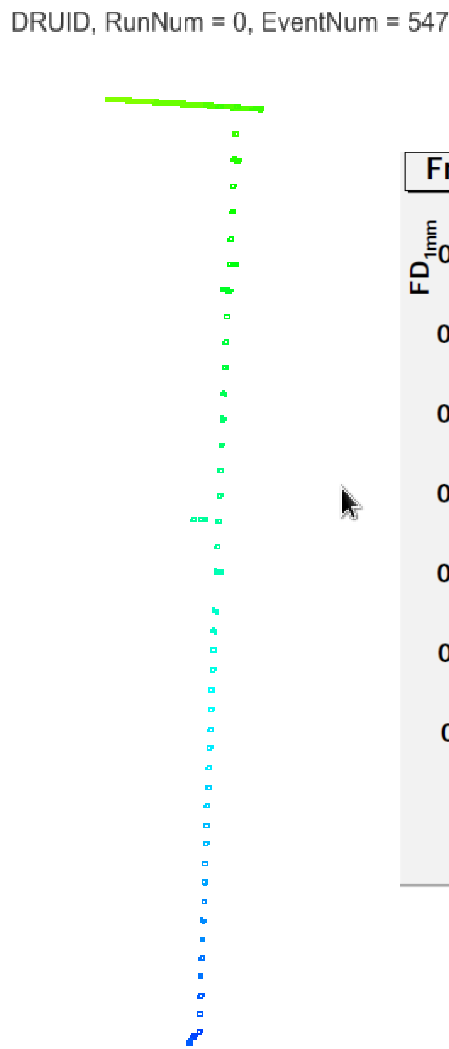


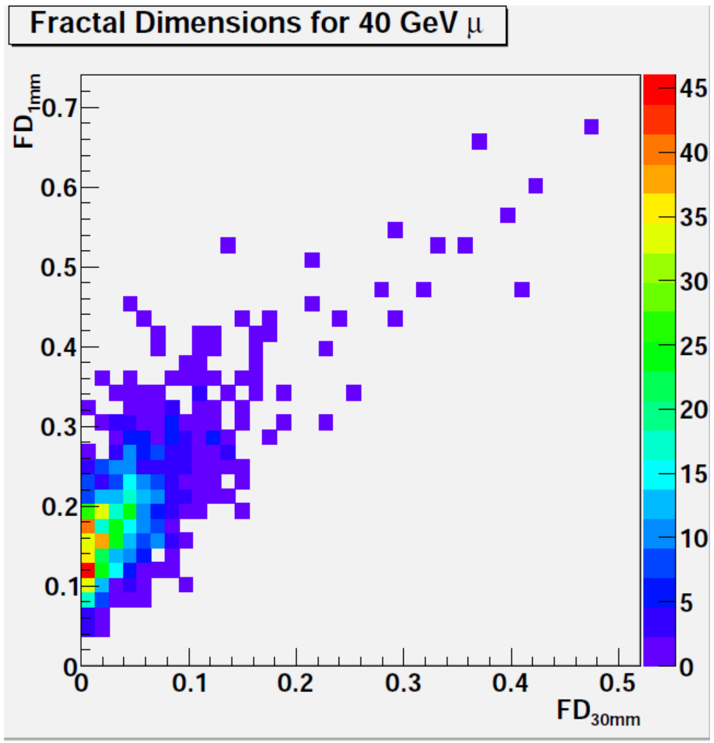


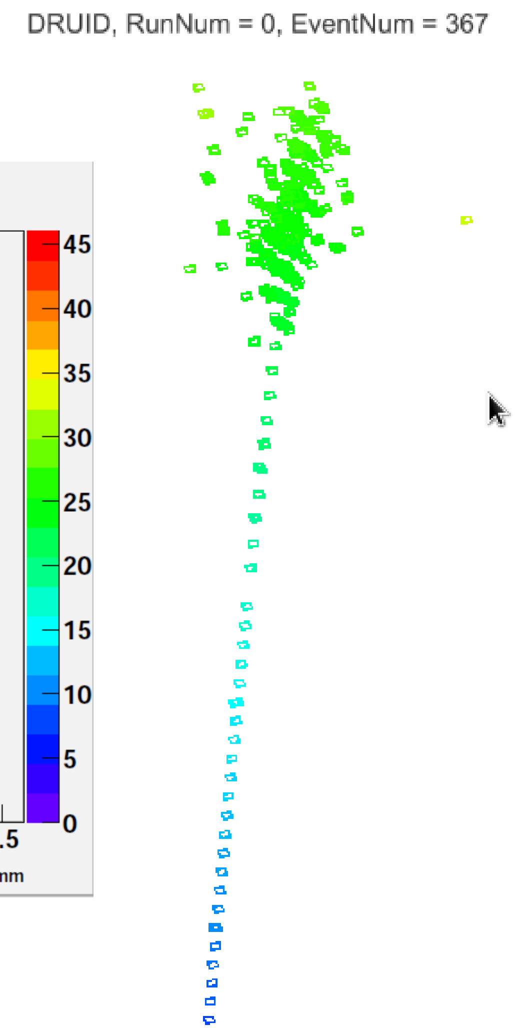
- Pion: MIP, Pion decay;
- EM interaction (pi + N = P + pi0); partially identified by interaction point tagging

Extreme Cases: Muon



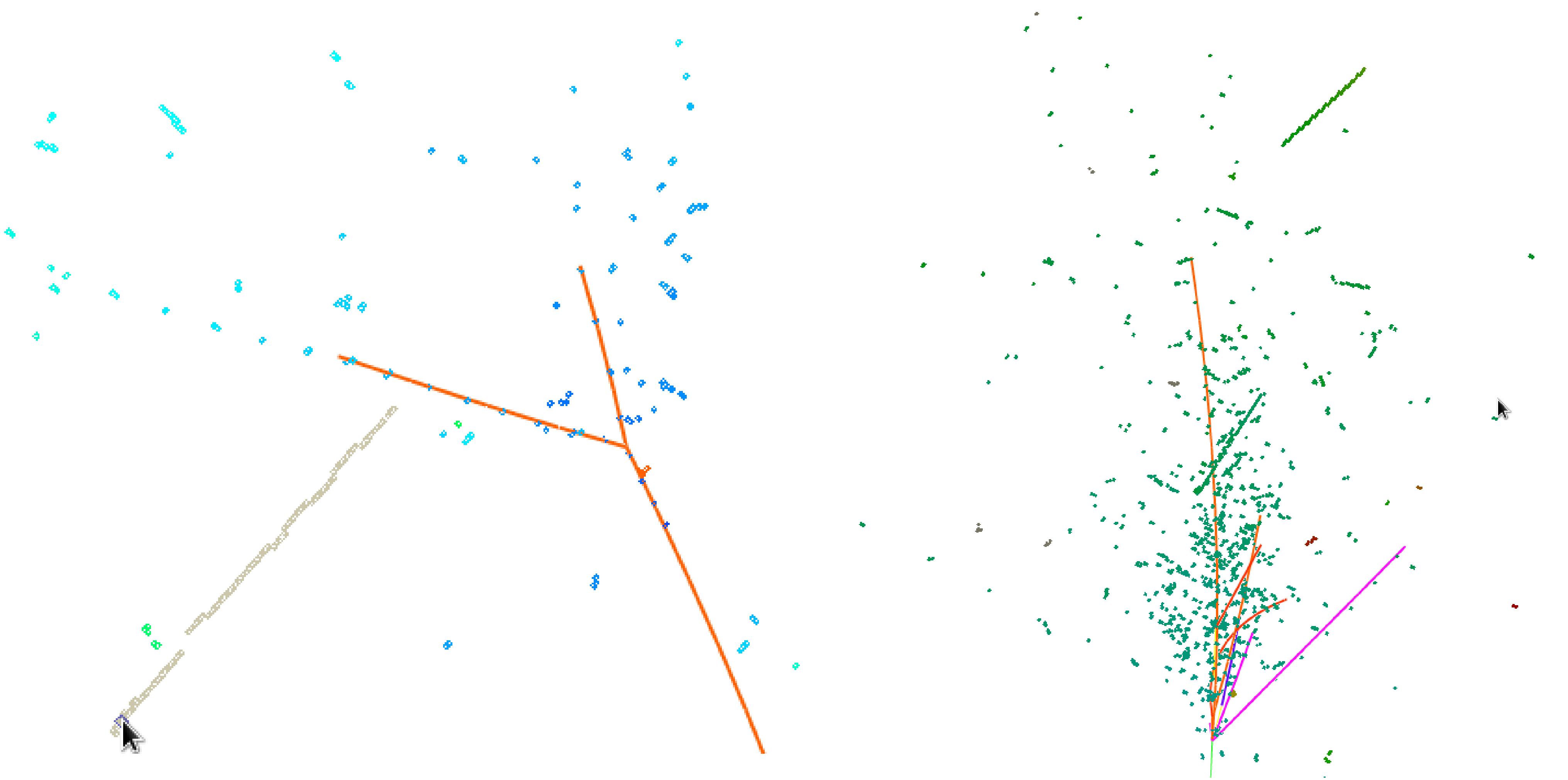






Together with Nhit information: to identify Muon radiation & String noise...

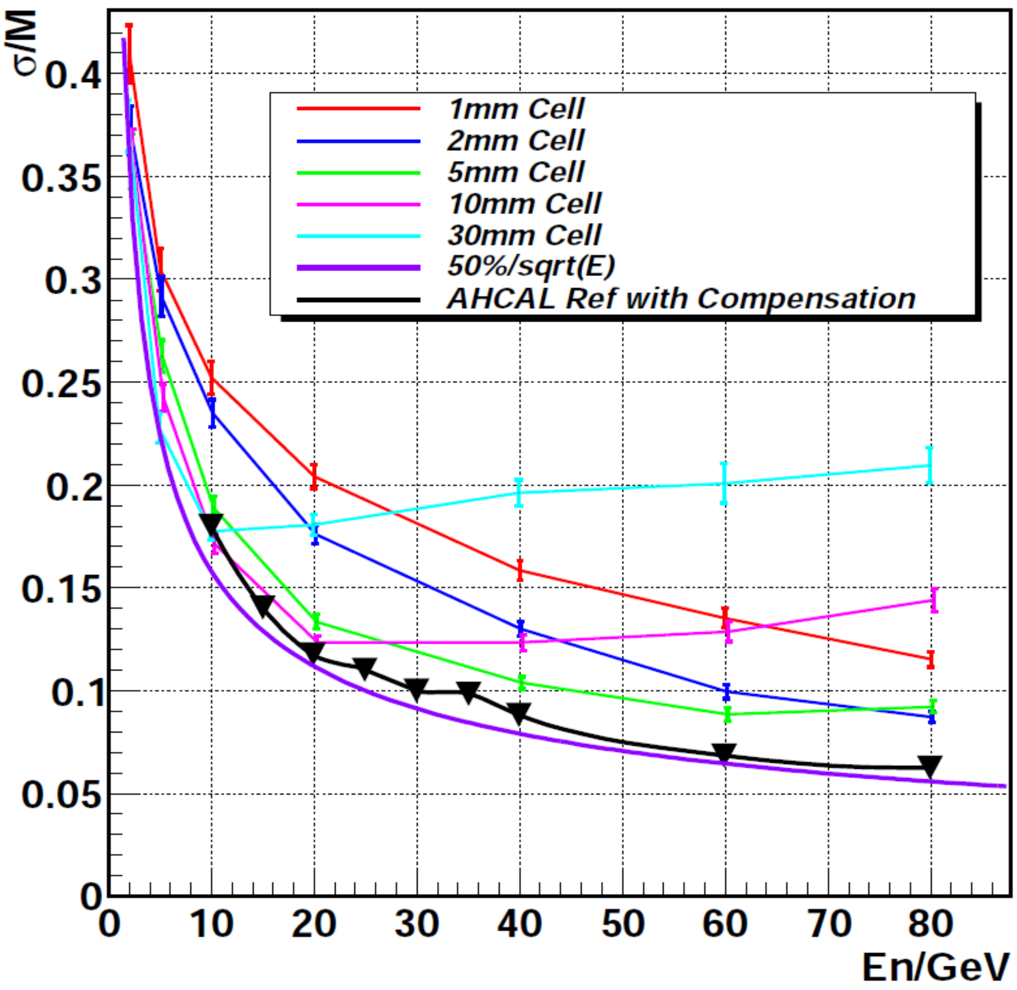
Noise cleaning

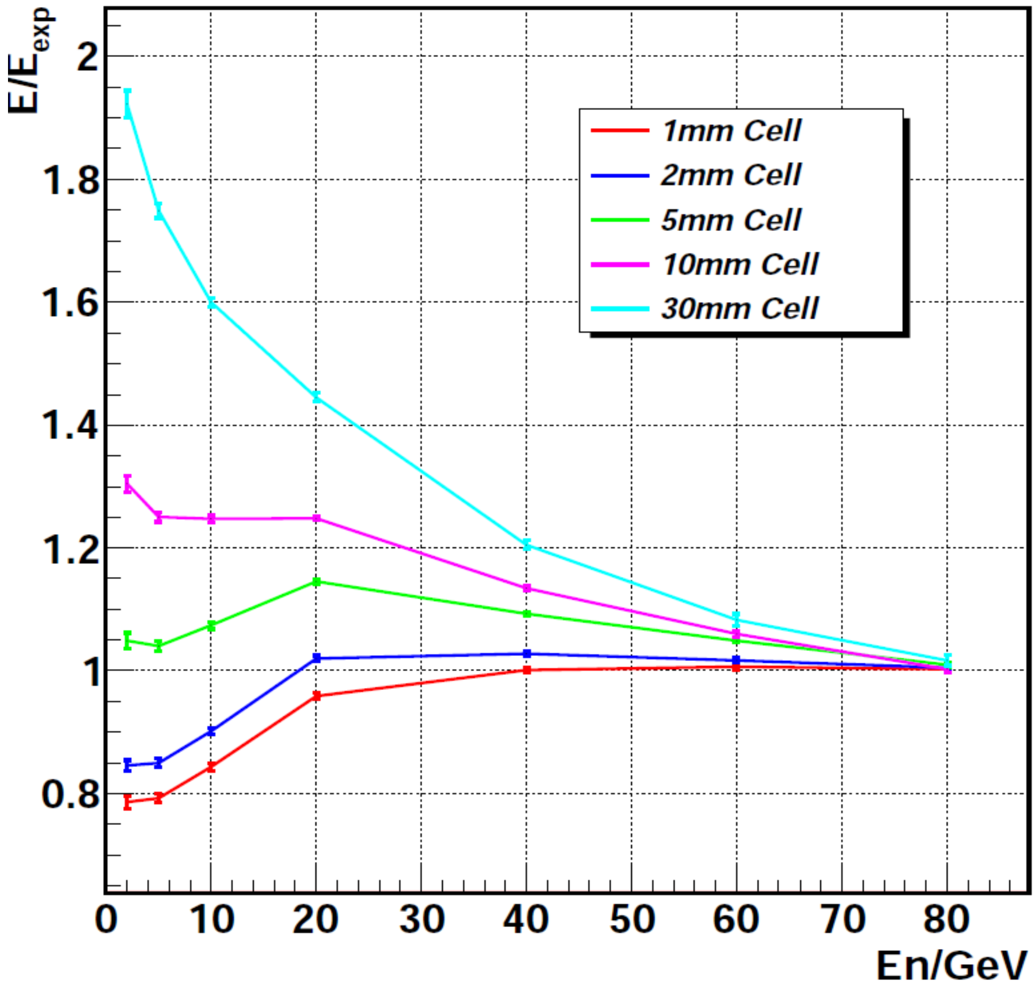


String Noise: Typical in gaseous detector: charged particle tripped In the gas layer (display of 1mm hits Information)

Roughly improve 5% - 10% on Energy Resolution by Cleaning

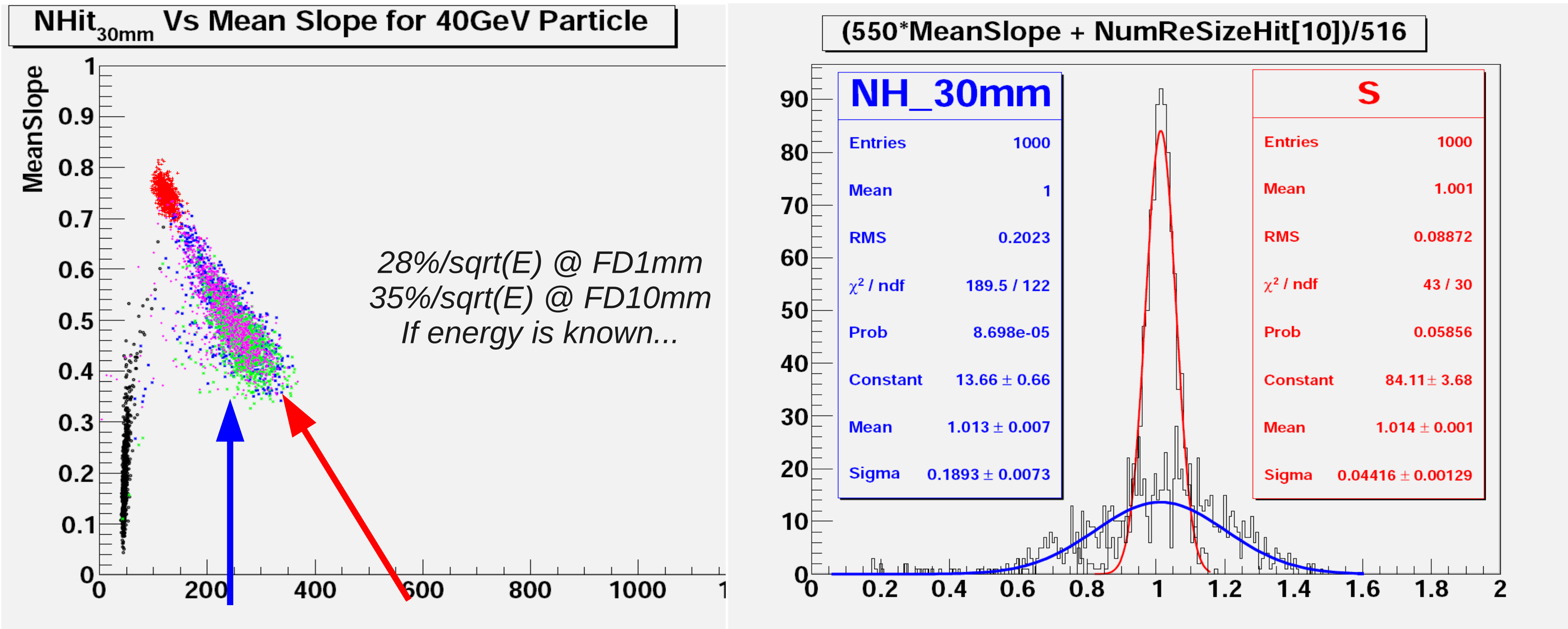
Energy Estimation with Naive Counting





σ/M: Large cell better at low energy & Smaller cell at high energy.
Linearity: Better at 2 – 5 mm, stronger saturation effects at larger cell...
Naively: 5mm seems a nice choice...

FD for Energy Estimation



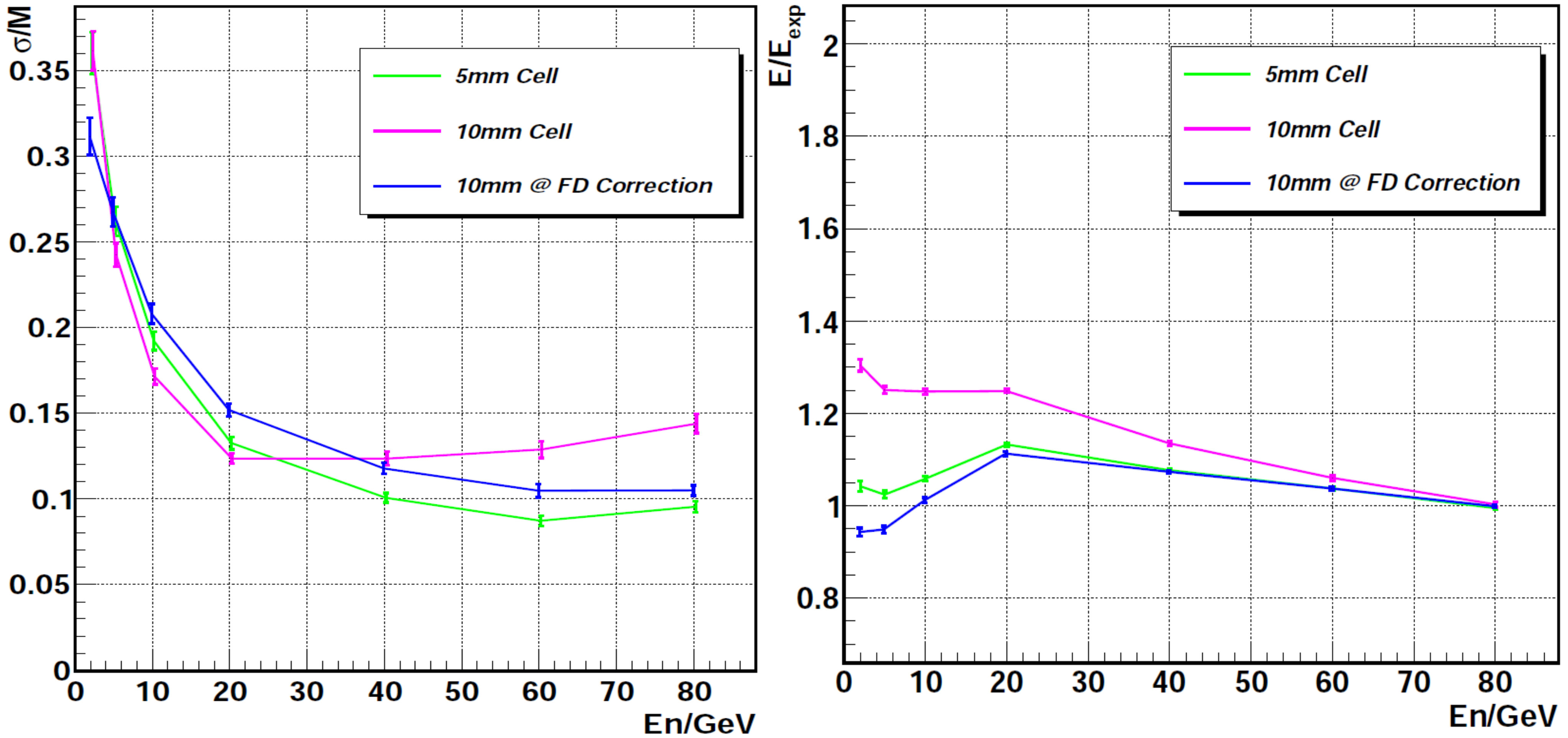
- For example: Compensation based on the correlation of NH_30mm & FD1mm:

  E = a * NH_30 + b * FD ~ 30%/sqrt(E)! But...

- Correlation coefficient depending on Energy: b ~ 0.0266*E. To measure cluster energy of charged particle (with track info): check matching

- A set of energy independent (LO) estimator: E = a' * NH_x/(1 – FD*b')

Energy Estimation with FD Correction

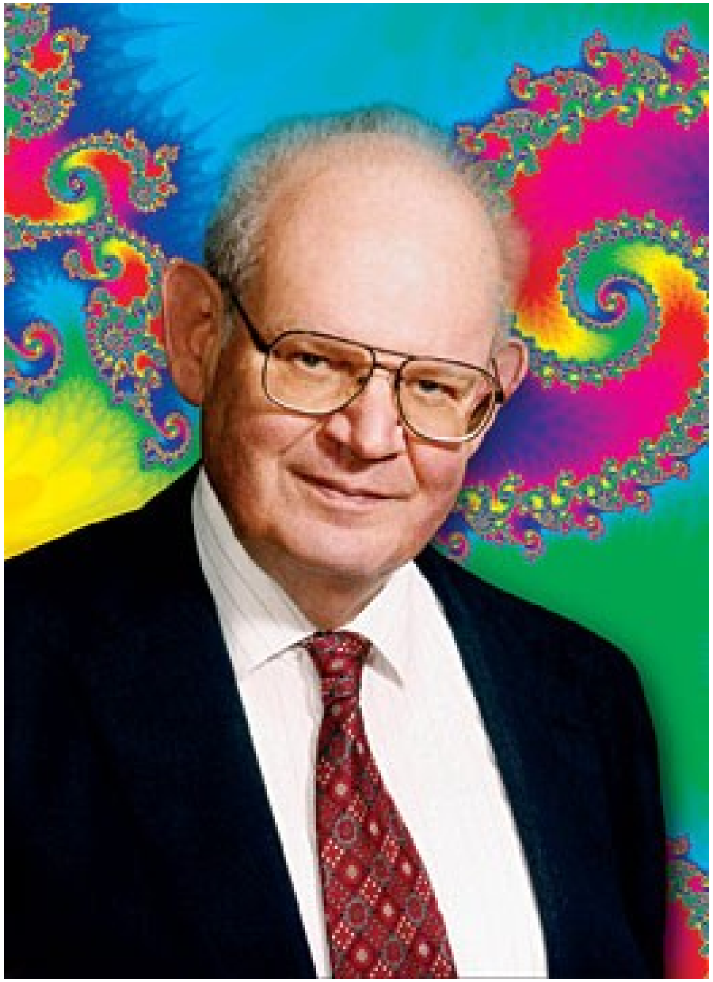


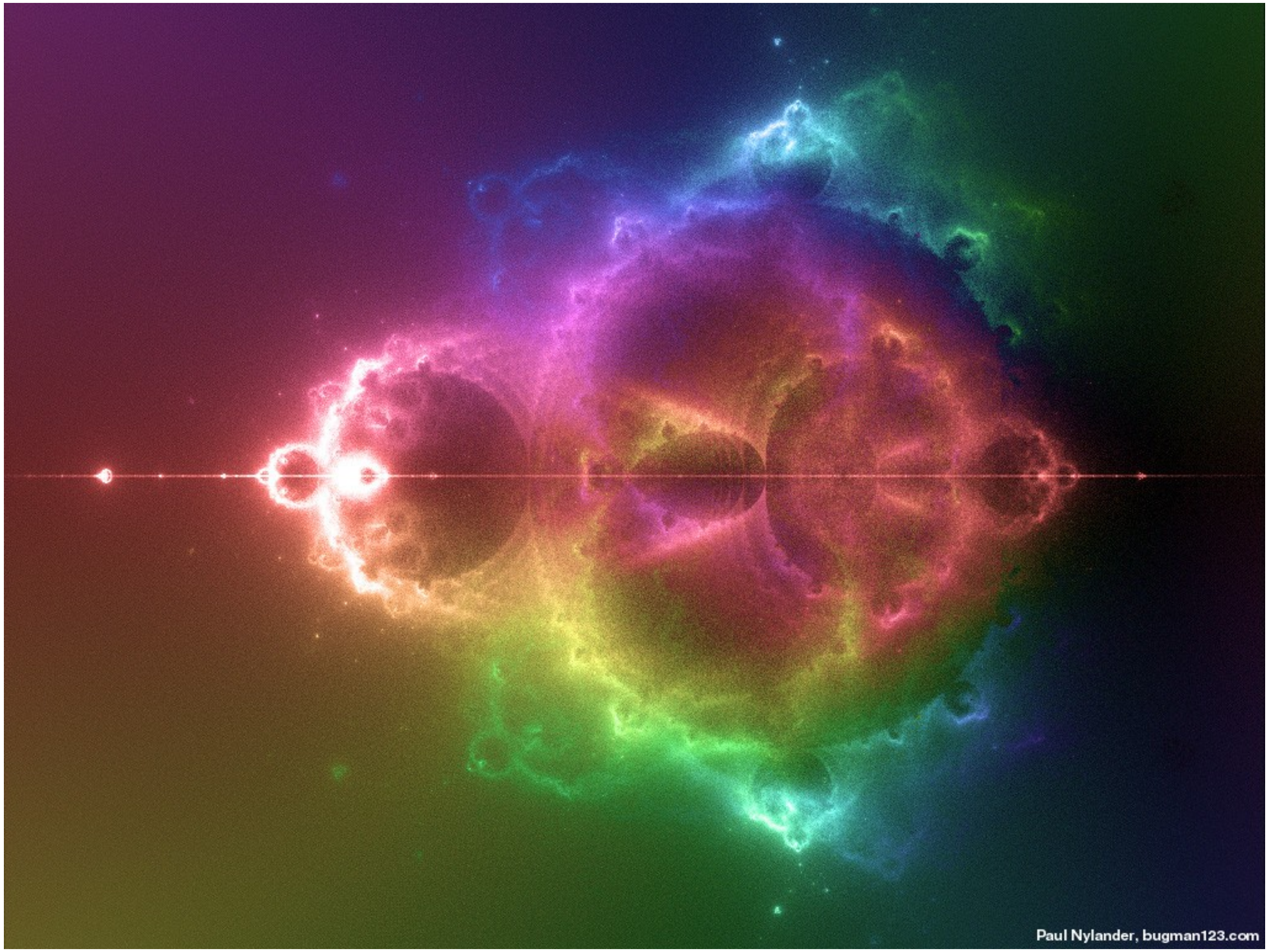
Hand put Energy Estimator with FD: NH10/(1-0.65*FD10)
Energy resolution improved at high energy: ~ saturation effect correction
Linearity improved: closed to 5mm Cell

Summary

- SDHCAL: ~ AHCAL with default AHCAL-optimized setting at PandoraPFA

- **Huge potential to improve:**
  - SDHCAL: Properly using 3 thresholds
  - Noise Cleaning
  - Pattern recognition at high granular: MST & Hough
  - Arbor:
    - Better separation, identification
    - Energy Estimation, Leakage correction
  - Fractal Dimension:
    - Promising PID
    - linking check & energy estimation
    - Not fully investigated...
  - Your dreamed but never realised algorithms





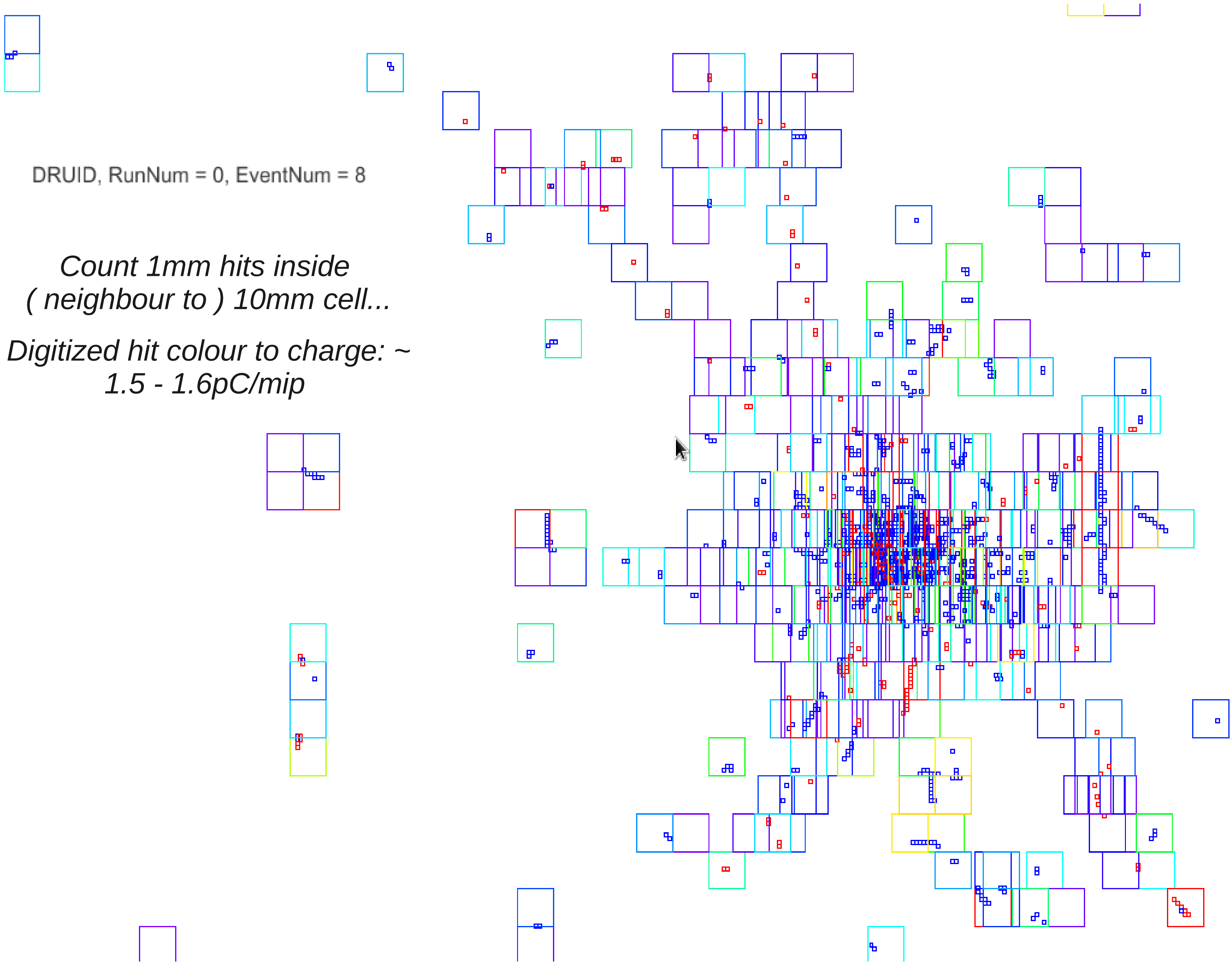
Special Thanks to ...

Back Up Slides

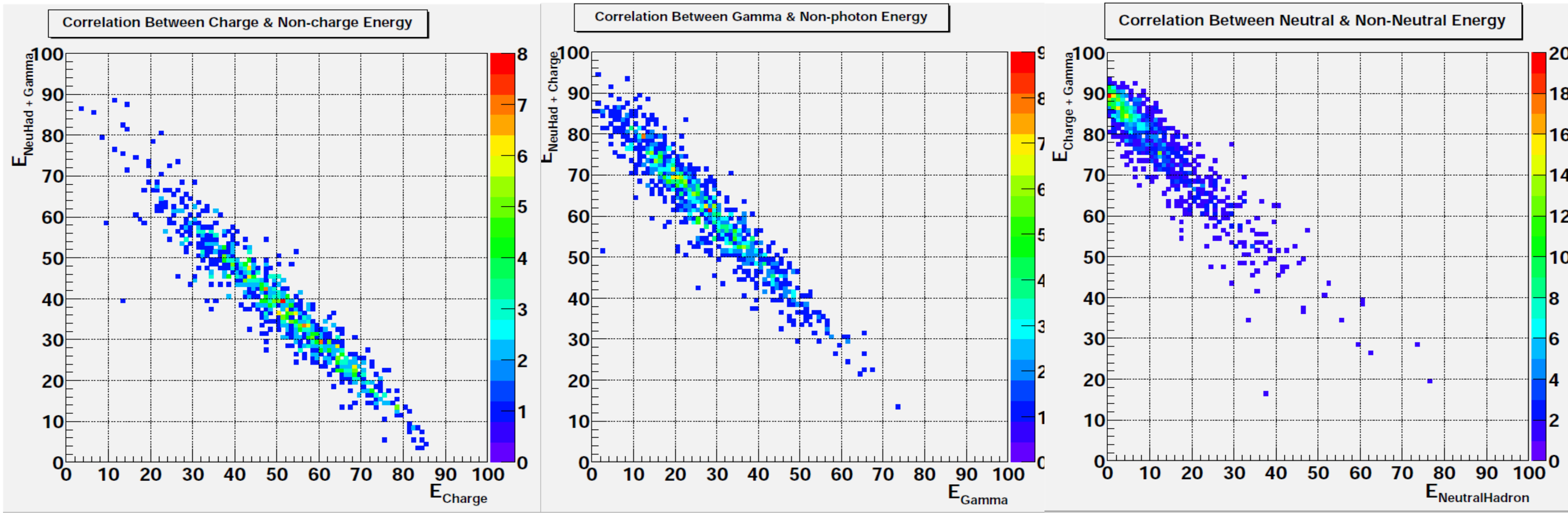
DRUID, RunNum = 0, EventNum = 8

Count 1mm hits inside
(neighbour to) 10mm cell...

Digitized hit colour to charge: ~ 1.5 - 1.6pC/mip

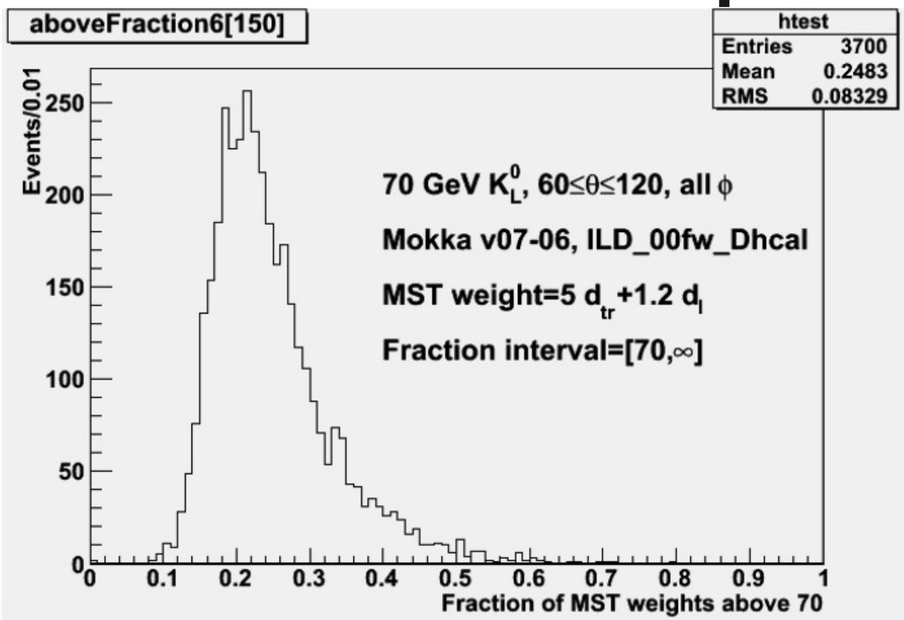


Calibration Constant



- Divided PFOs into Charged, Gamma and Neutral Hadrons: Calibration Constant Tuned to Satisfy Correlation Coefficient ~ 1: 1 hit = 150MeV
- Preliminary Digitization: provide overall efficiency ~ 98%

SW compensation with MST



« non EM fraction » distribution for 1 set of params (d_{tr}, d_l, cut)

What is the best ?

Vary them & check response wrt K^0_L energy

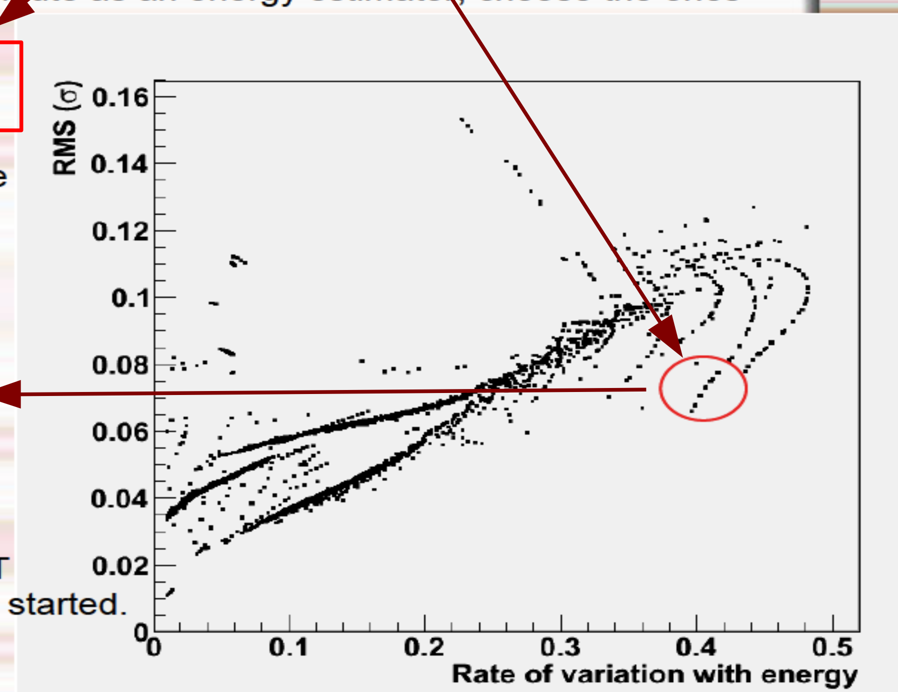
To pick up a set of variables to contribute as an energy estimator, choose the ones that :

- Vary the most with K^0_L energy
- Has smaller standard deviation

Usually, the 2 conditions go opposite

Selected MST variables so far :
n_l=0.2, n_{tr}=4 to 5,
fraction integral=[70,∞] or [100,∞]

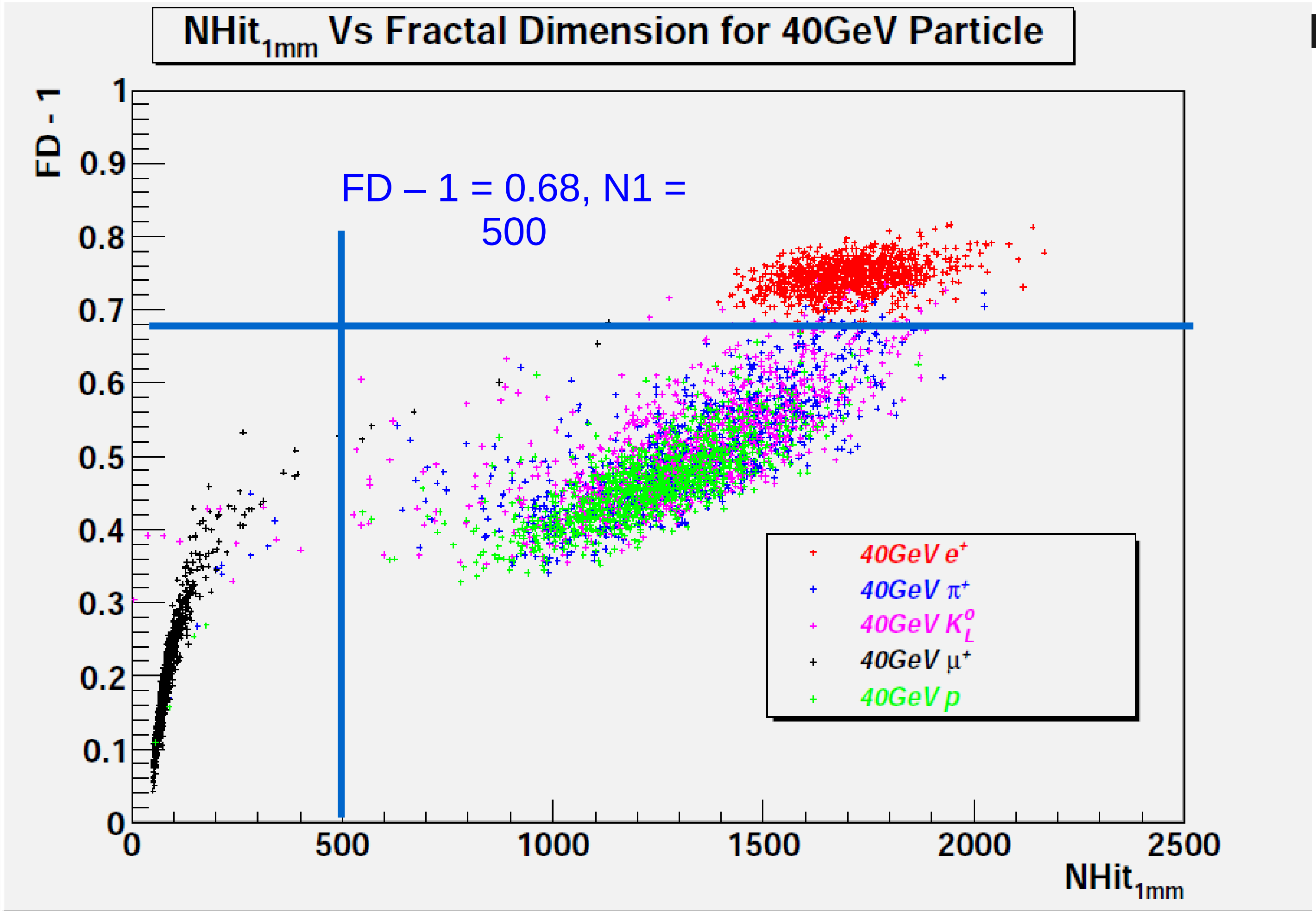
First attempt to see how energy resolution changes by including MST variable in Neural Network have just started.



1^{st} attempt

23/05/2011

Potential tool for PID

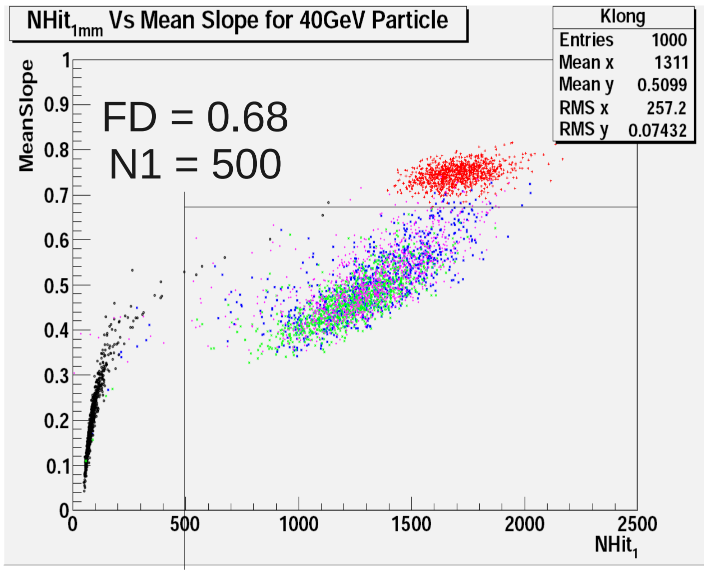


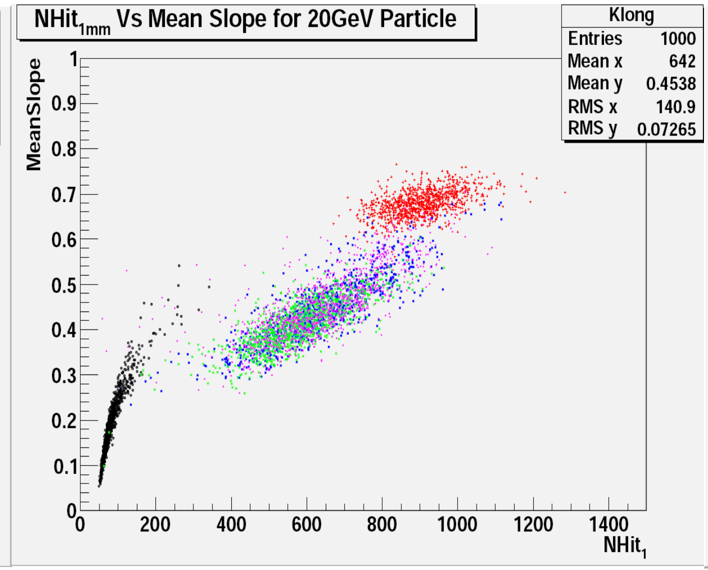
Handput Cut on Calo info @ 1mm Cell

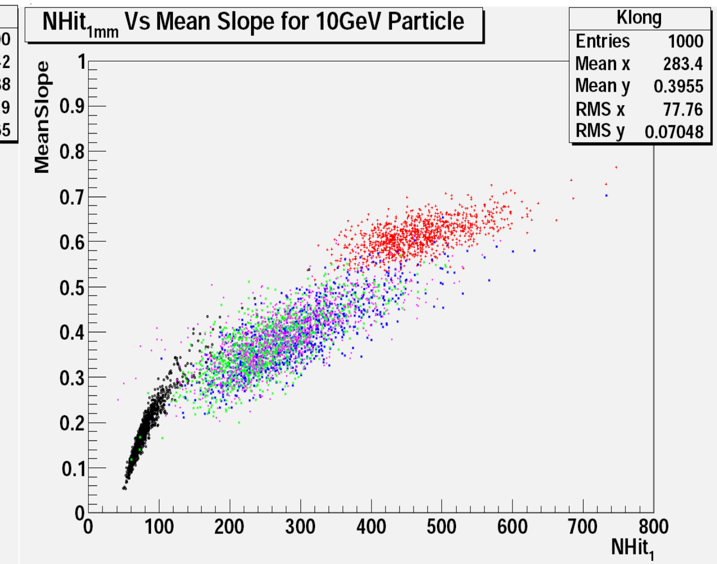
	e+	u	h
e+	998	0	2
u	1	994	5
h	15	14	971

Characteristic Parameter for PID: to be used together with other information.

Correlation with NHits_1mm



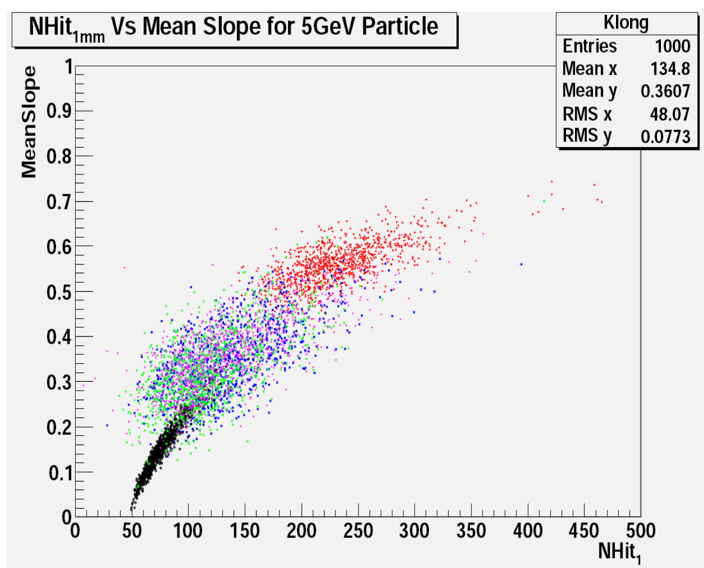


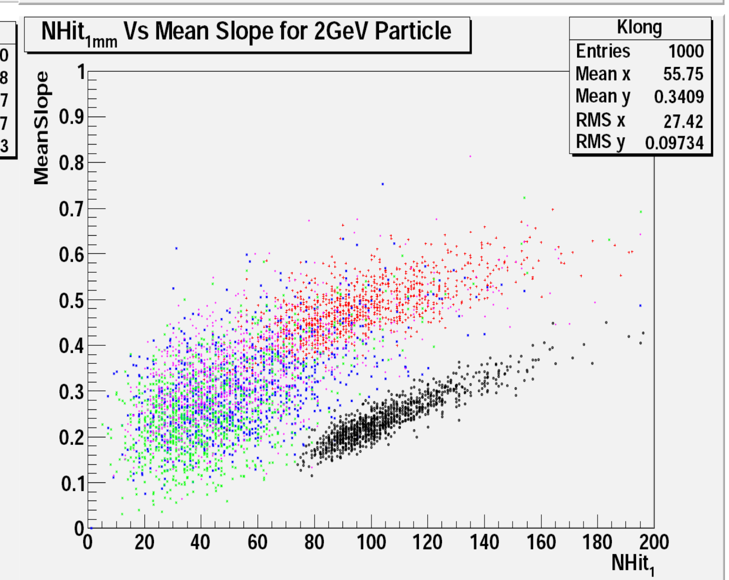


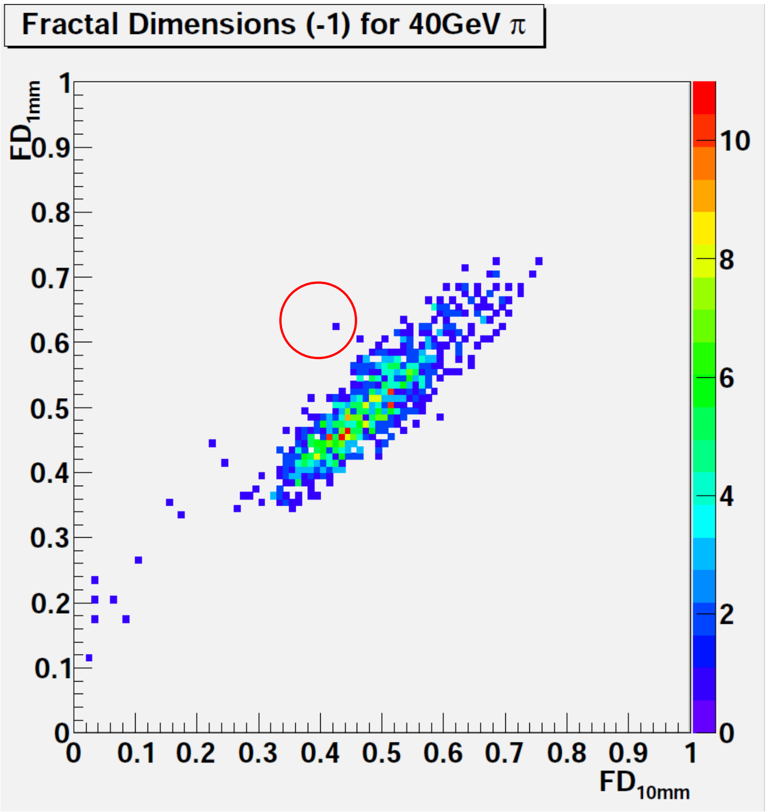
- Hand put cut @ 40GeV

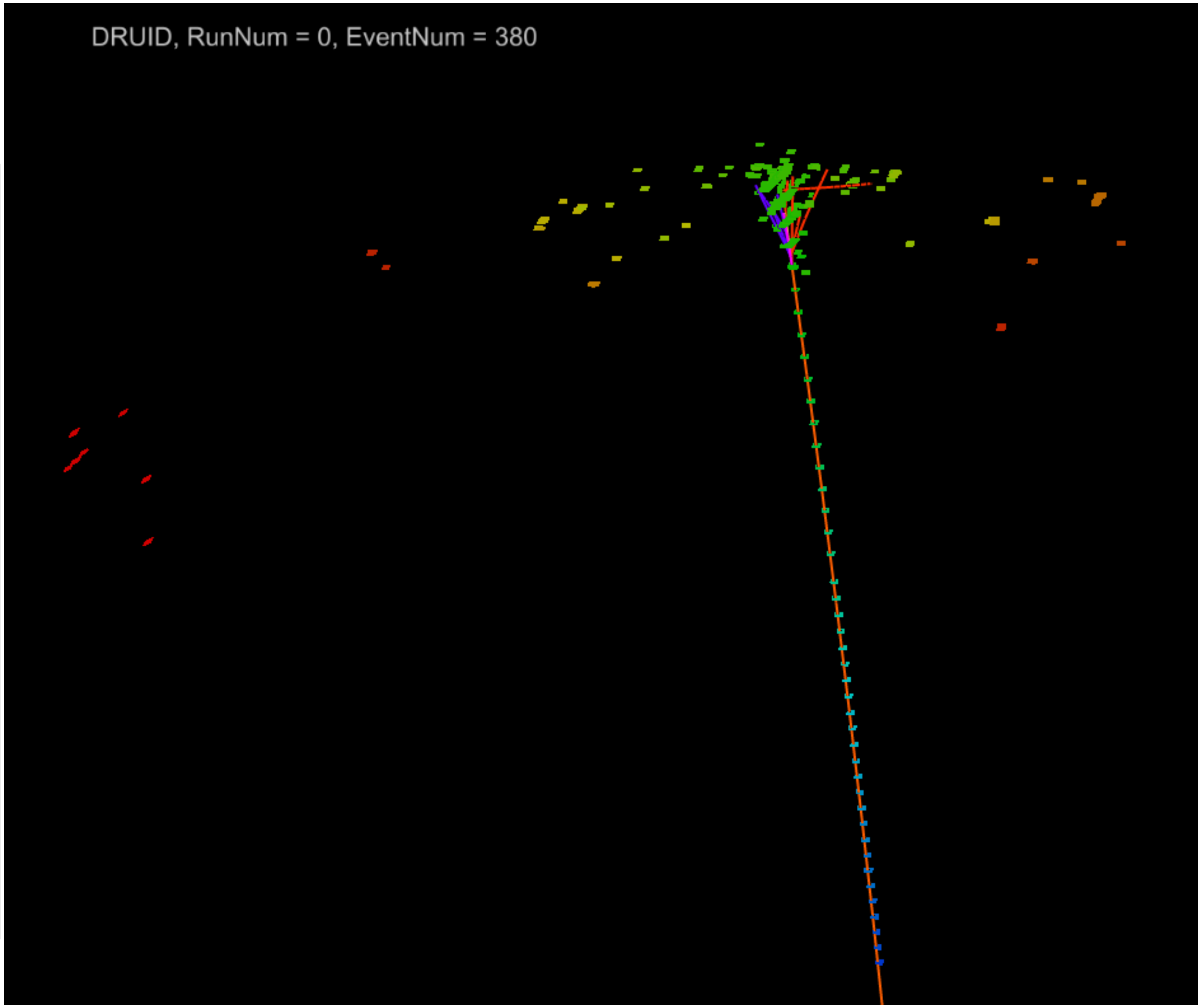
	e+	u	h
e+	998	0	2
u	1	994	5
h	15	14	971

- PID potential: even feasible at low energy



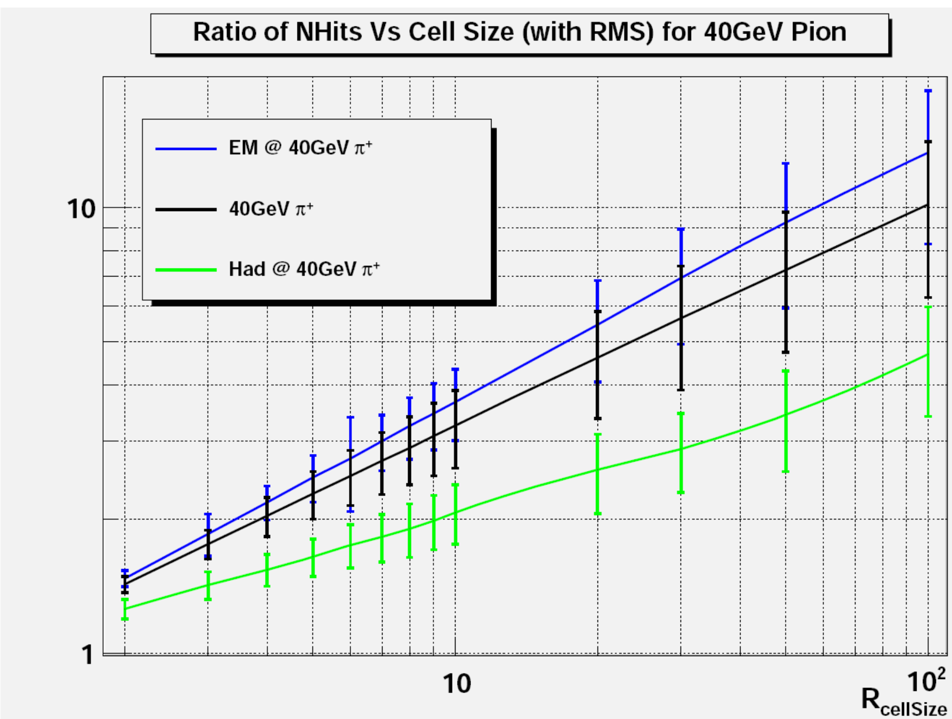


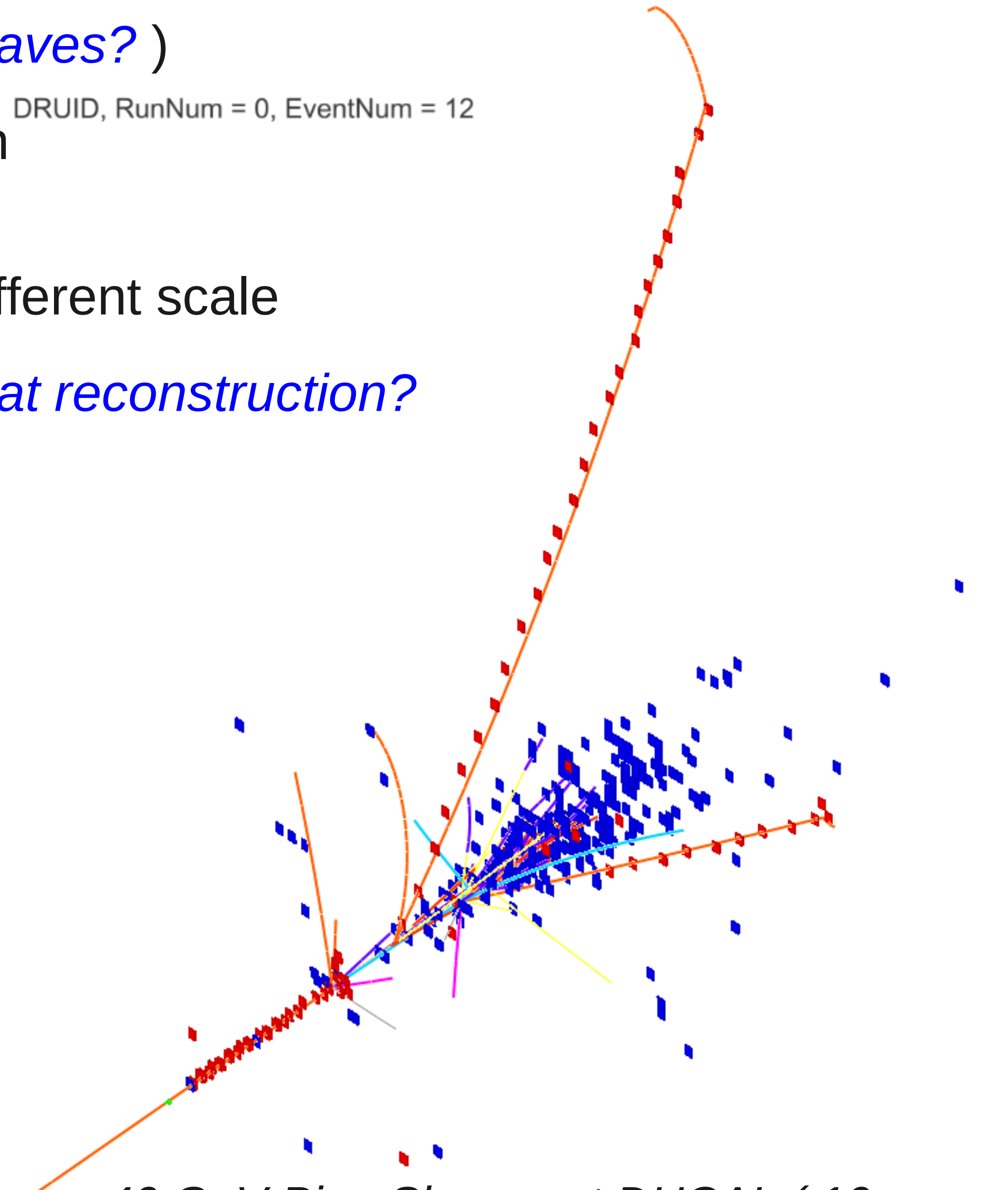

Fractal Dimensions (-1) for 40GeV π
FD1mm
FD10mm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10


DRUID, RunNum = 0, EventNum = 380

EM/MIP @ hadronic shower

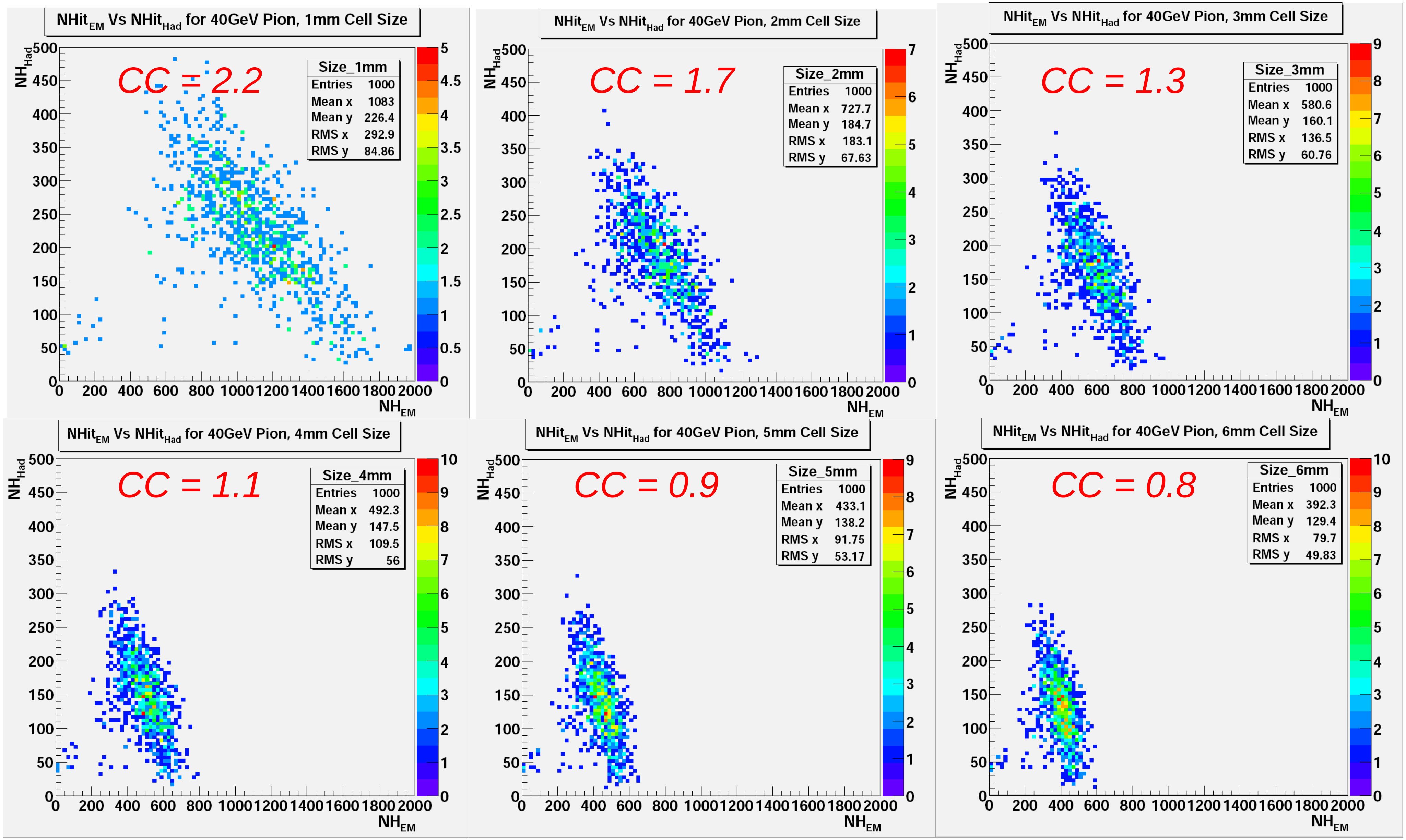
- Hadronic Shower = MIPs + EM core (*leaves?*)
- MIPs: loose ~ smaller Fractal Dimension
  EM: compact ~ large Fractal Dimension
- EM/MIP Ratio/Correlation changes at different scale
- *Possibility & method of identify EM/MIP at reconstruction?*





40 GeV Pion Shower at DHCAL (10 mm Cell Size)

Hadronic shower: EM/MIP @ different Scale



*Energy Estimator: NH_EM + CC*NH_Had:* ***CC = 1*** *~ total hits*

Hadronic shower: EM/MIP @ different Scale