Study of Digital Hadron Calorimeter

Tohru Takeshita
Shinshu Univ.

March 2006

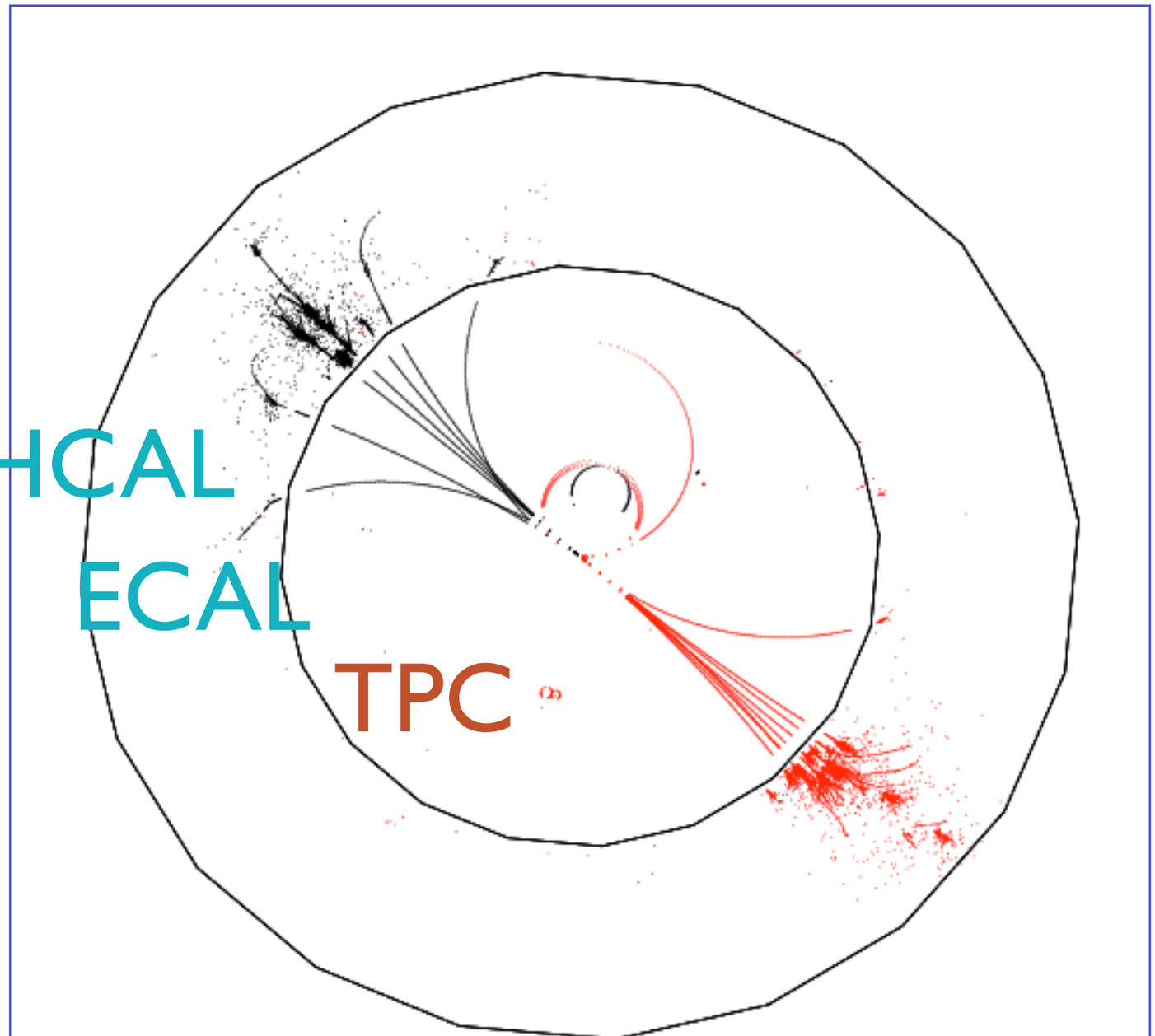
Linear collider physics
Hadron Calorimeter at LC
digital Hadron calorimeter

based on Geant4.6.2

Linear Collider Physics

clean but narrow jets final state

$$e^+e^- \rightarrow q\bar{q}\ @350GeV$$

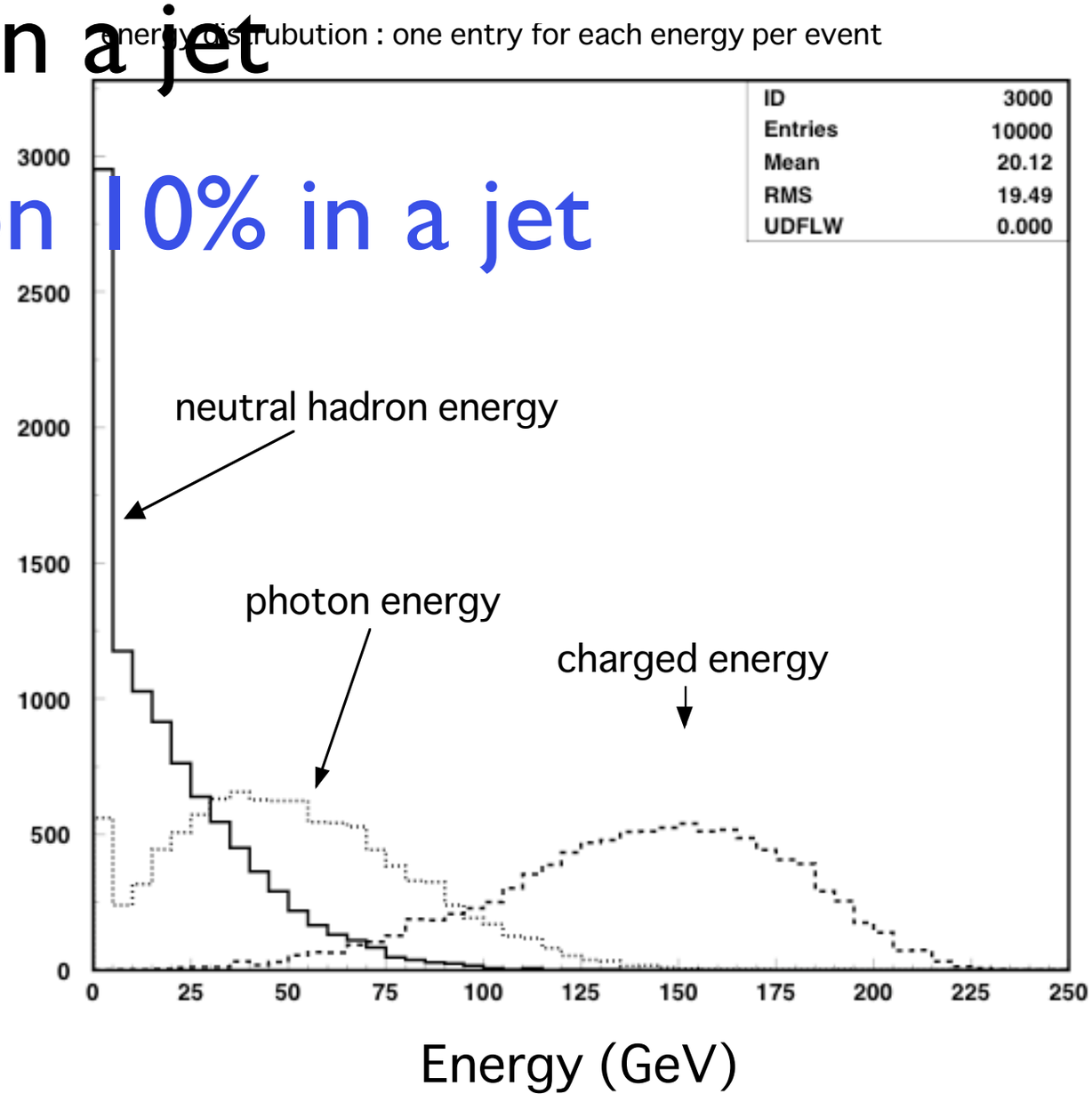


Particle Flow

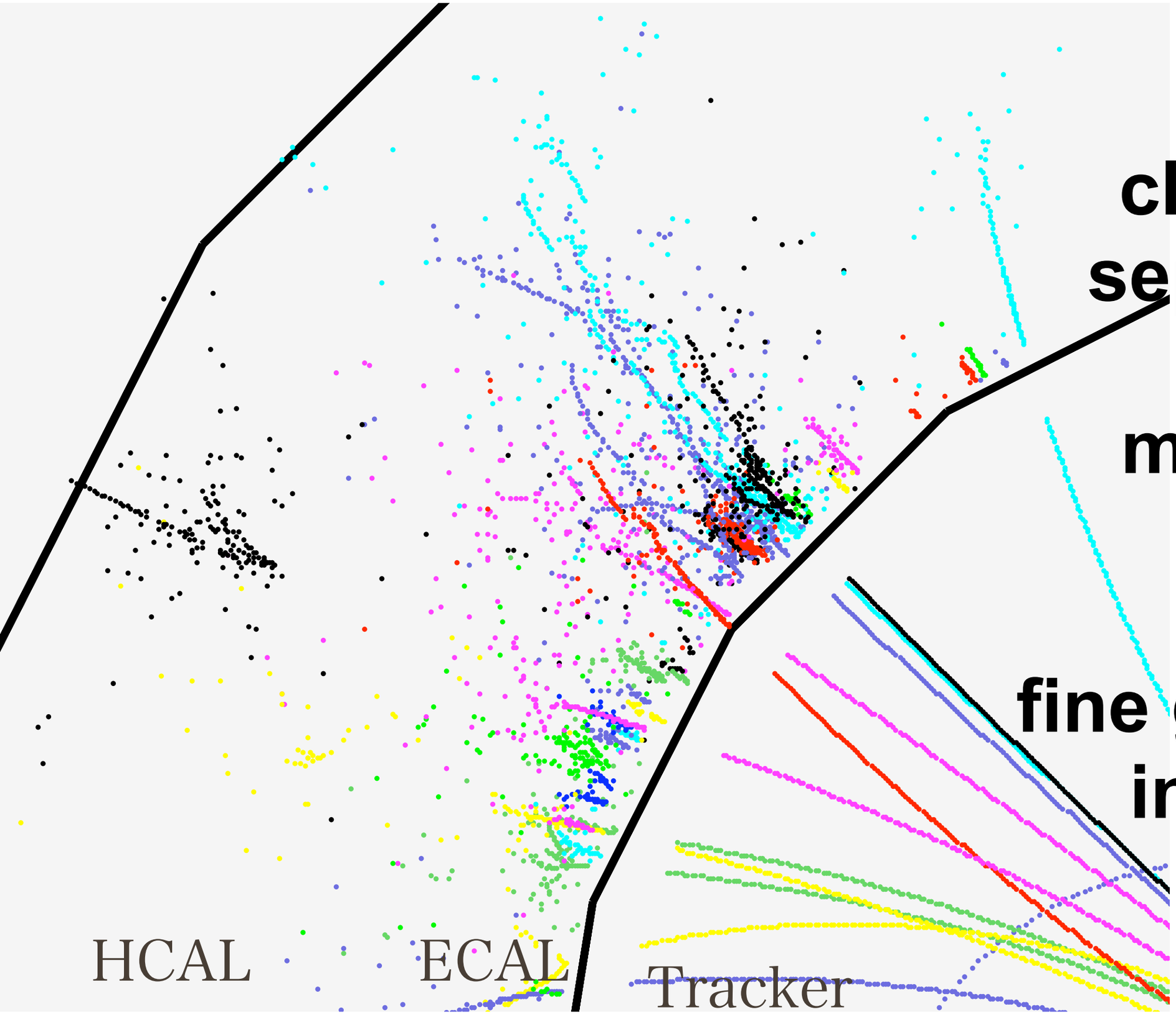
- Tracker : charged 65% in a jet
- ECAL : photon 25 % in a jet
- HCAL : neutral hadron 10% in a jet

$$e^+e^- \rightarrow WW$$

$$ECM = 250GeV$$



Particle Flow cont.



clustring, separation, and matching

need fine granularity in 3-Dim.

$1\,cm^3$

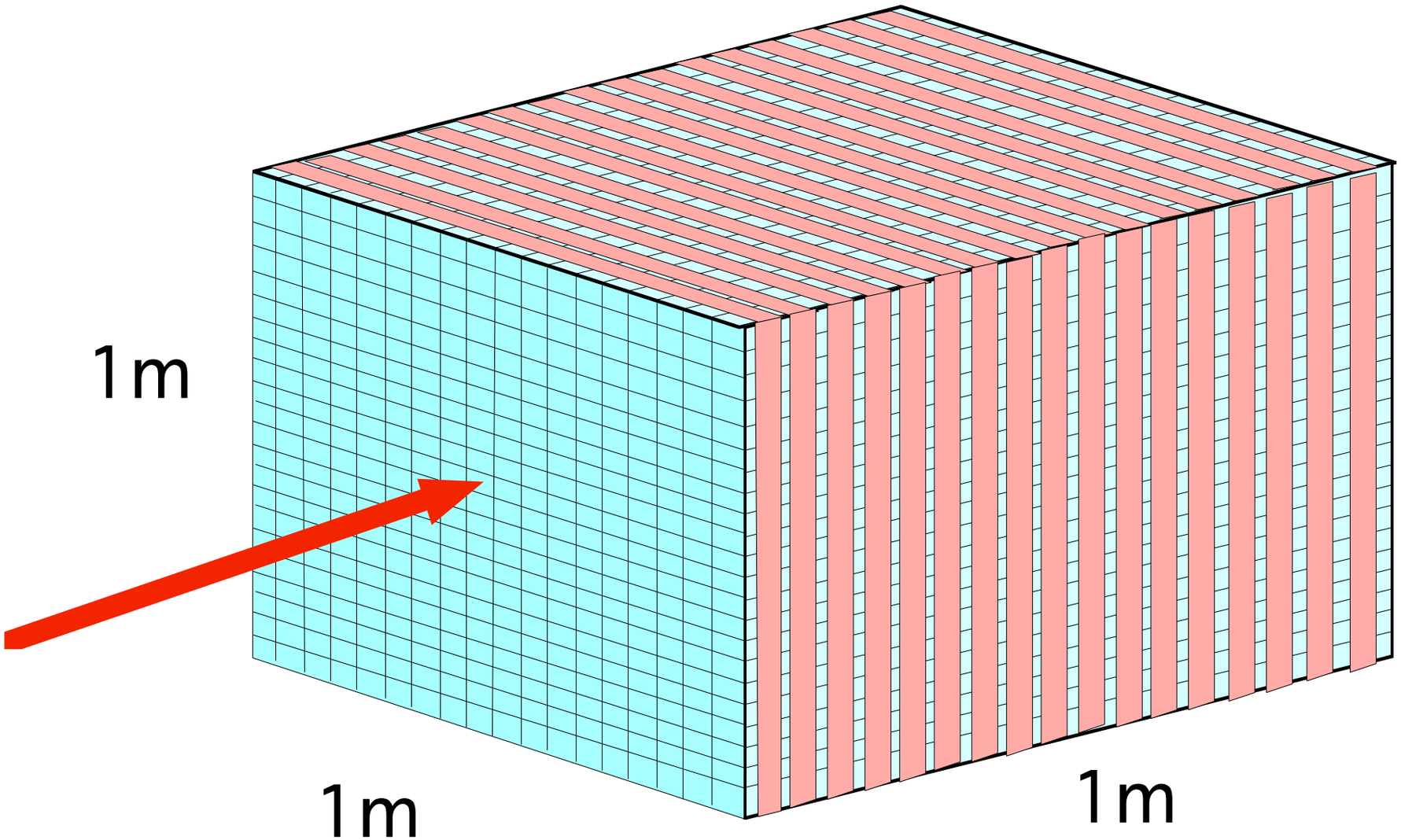
digital HCAL

- ~1cm3 granularity for PF in LC
- HCAL of ~100M channels
- need to reduce cost of electronics
- digital read out = ON/OFF at 1cm3
  = 1bit read out
- Hadron interaction= EM shower
  +pure hadronic int.

digital HCAL simulation

Test detector : 1m x 1m x 1m of 100^3 channels

A layer of 8mm Pb + 2mm scintillator ($1cm^2$)

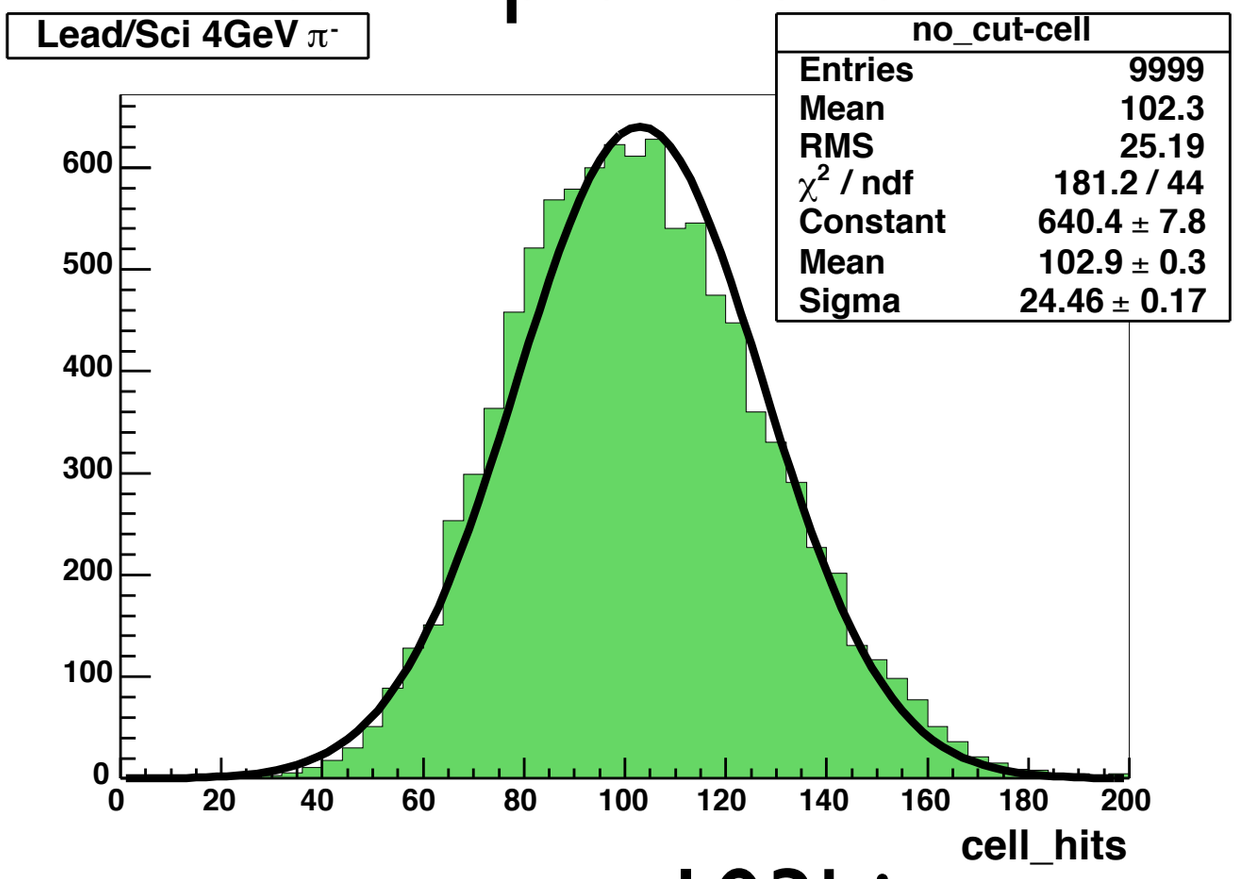


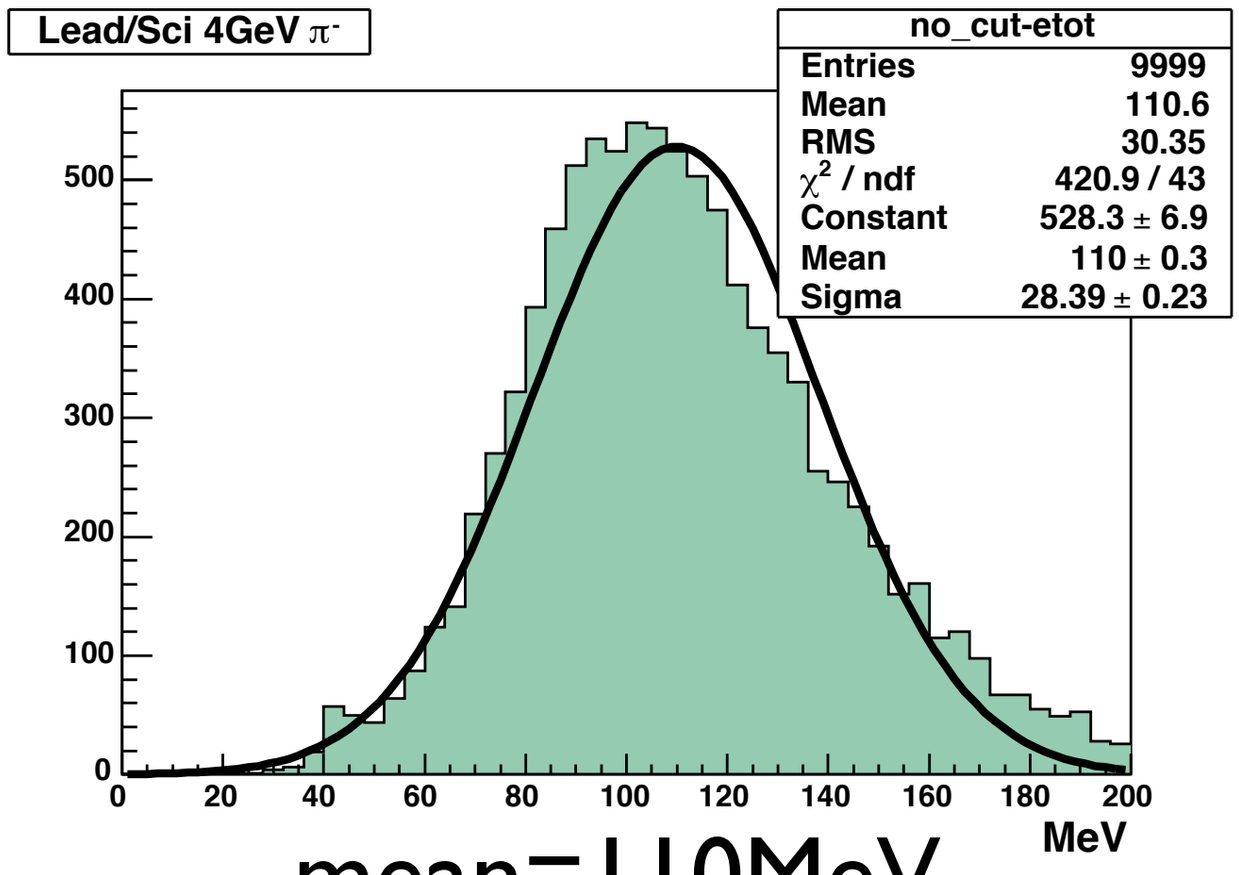
digital HCAL simulation

total hit/energy distribution

digital 4GeV pions analog

0.1Mip threshold





mean=103hit

sigma=24hit

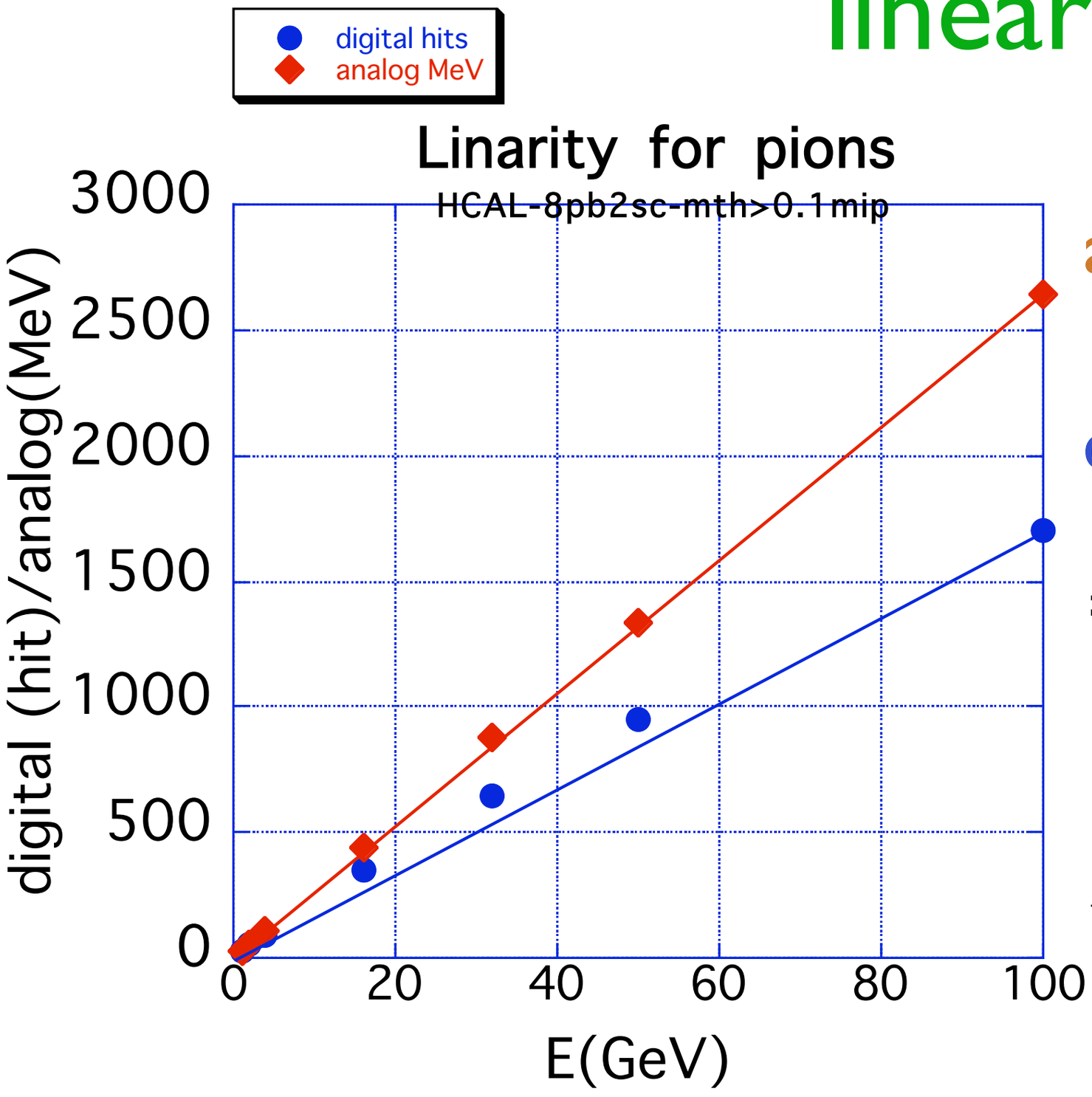
Gaussian

mean=110MeV

sigma=28MeV

digital HCAL simulation

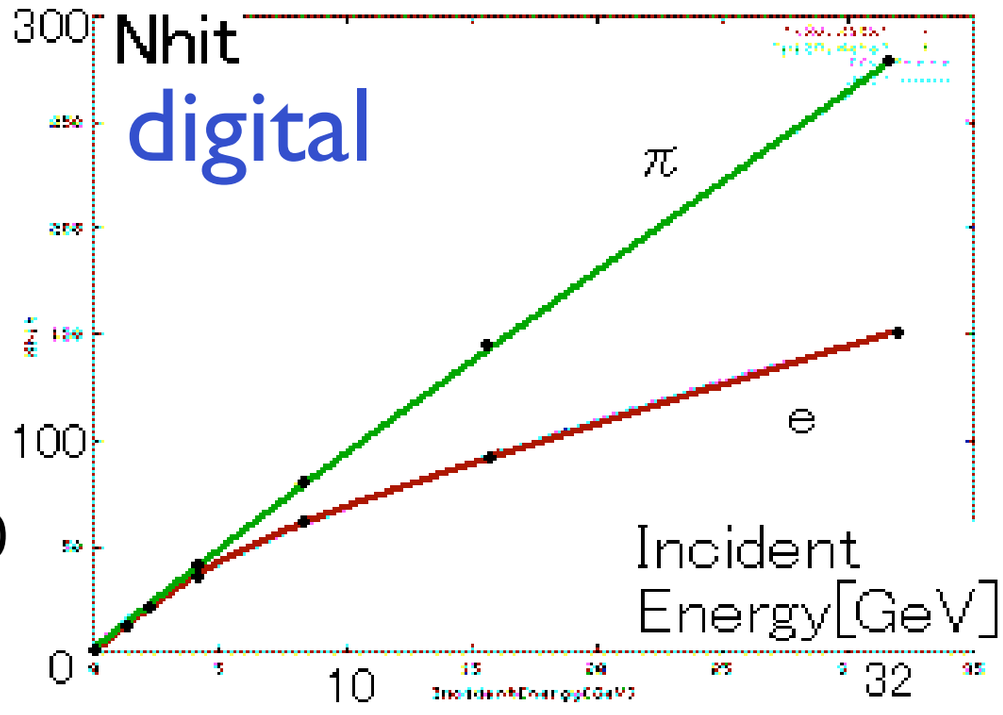
linearity for pions



analog : perfect

digital : not bad

linearity for electrons



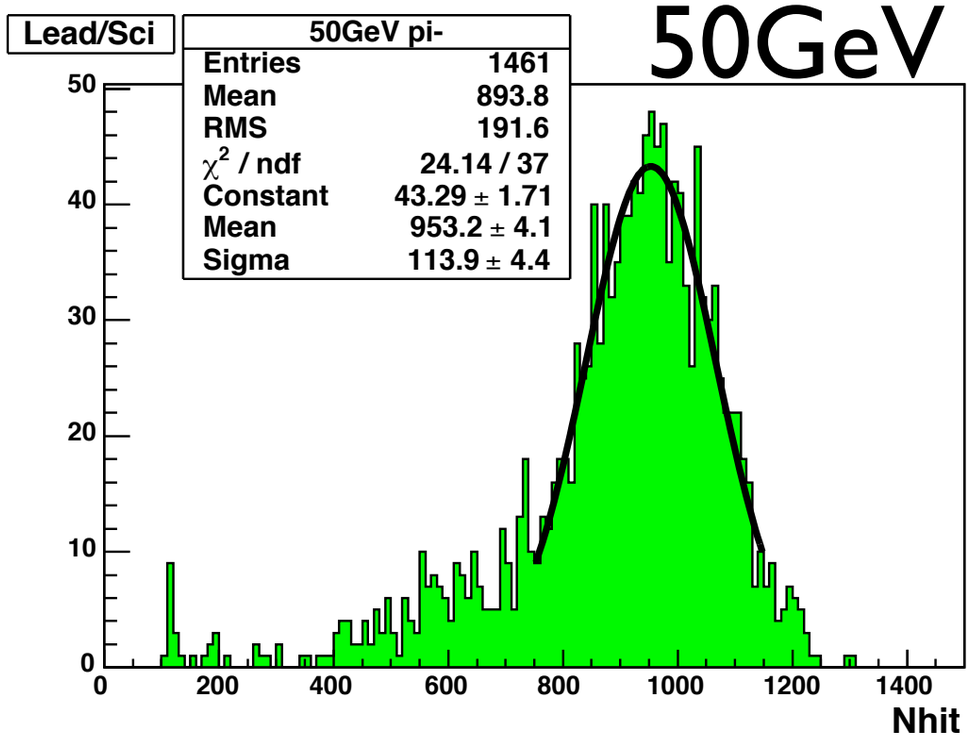
digital HCAL simulation

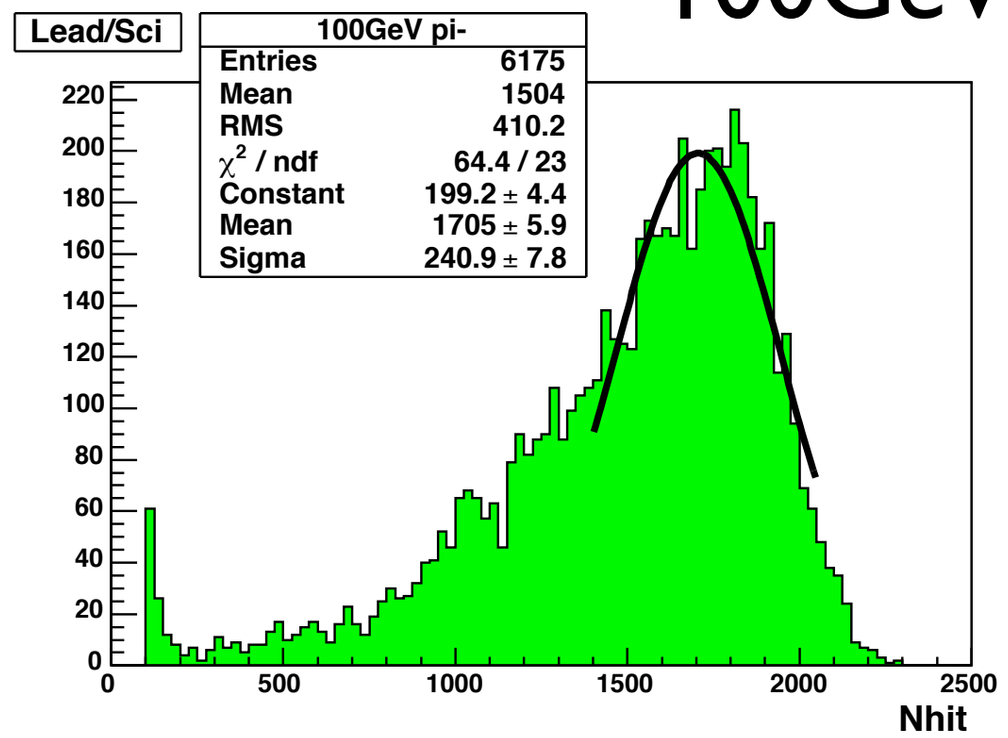
energy distribution

50GeV

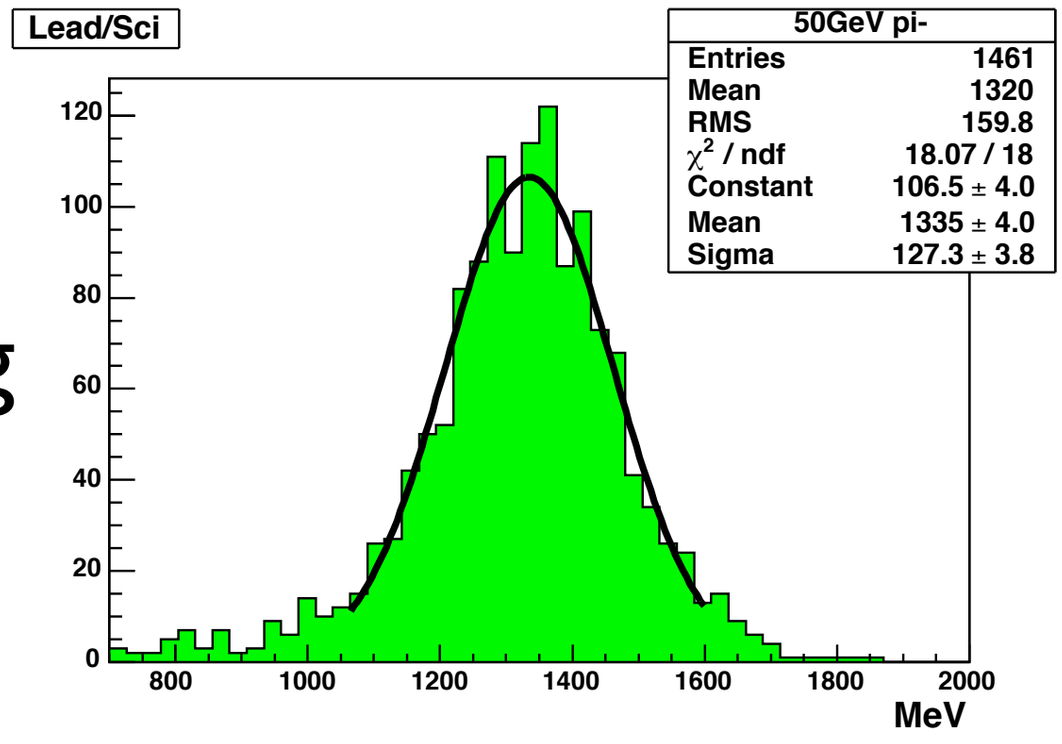
100GeV

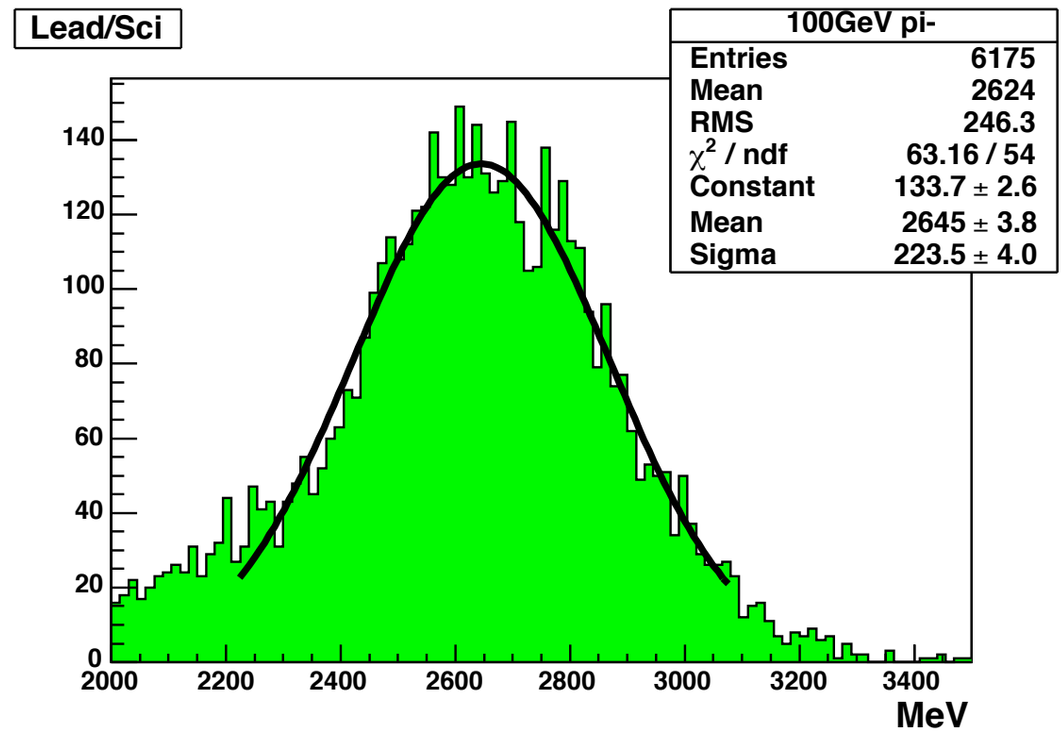
digital





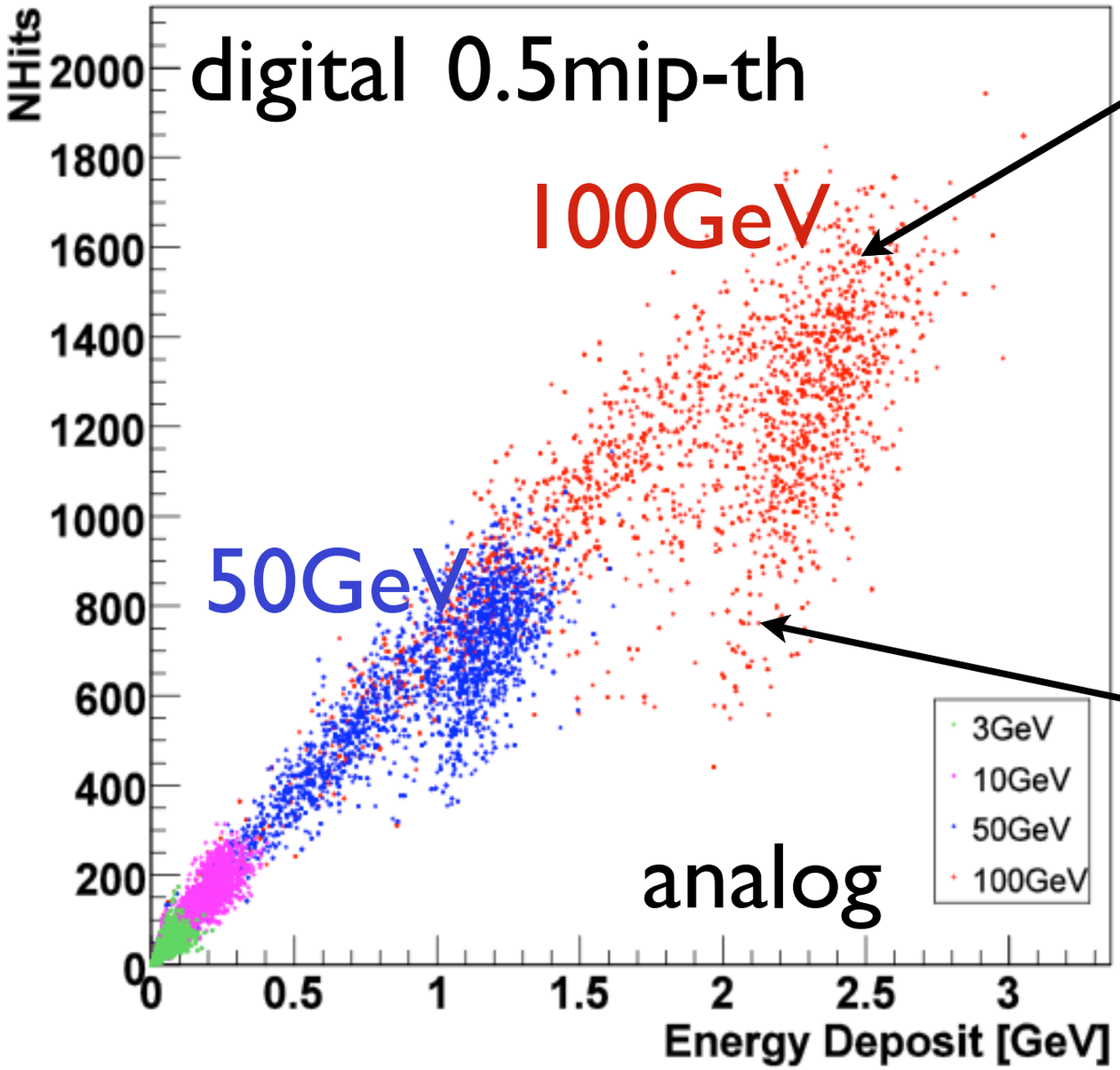
analog



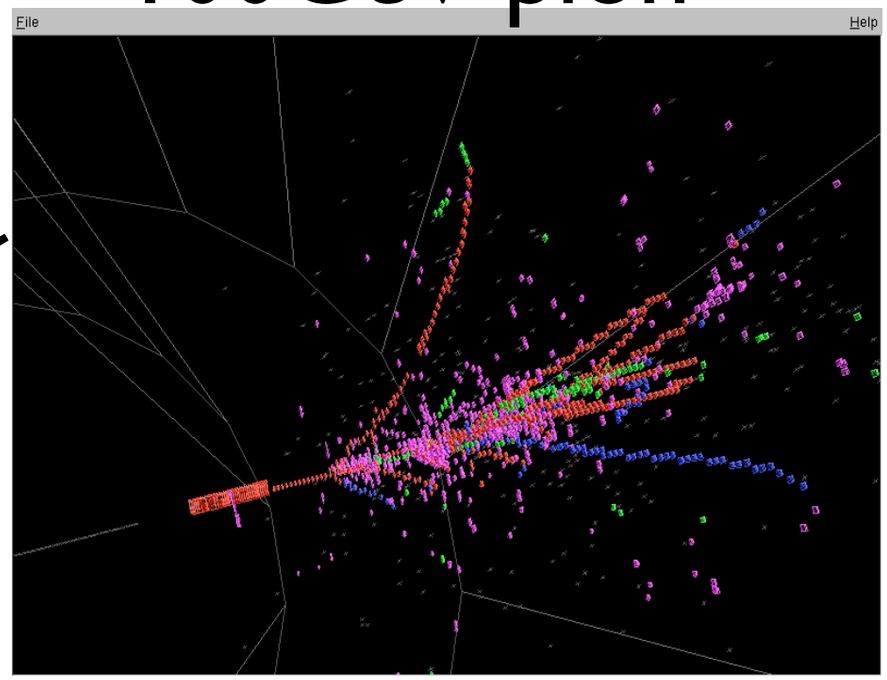


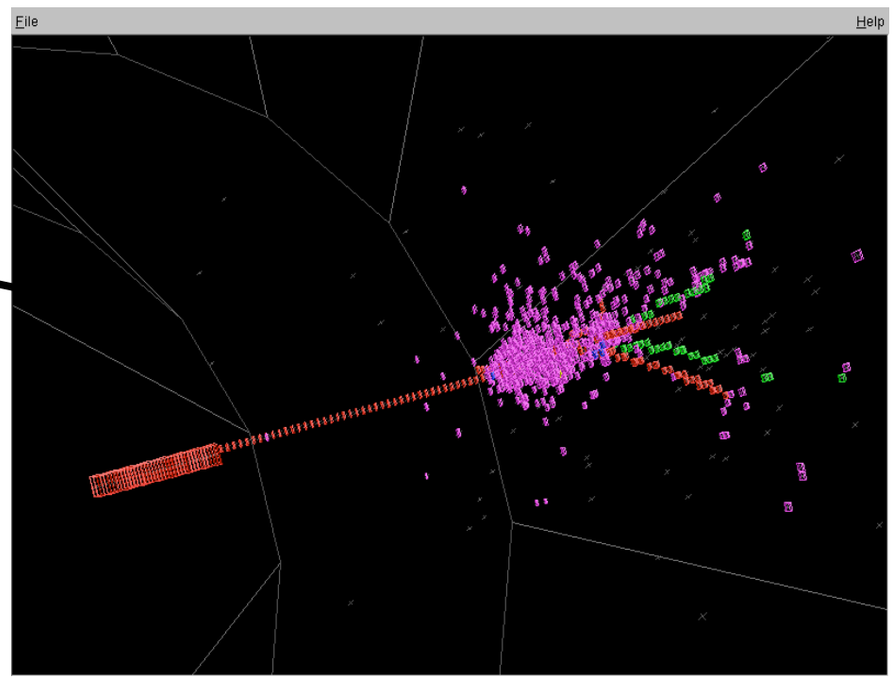
digital HCAL simulation

- analog vs digital



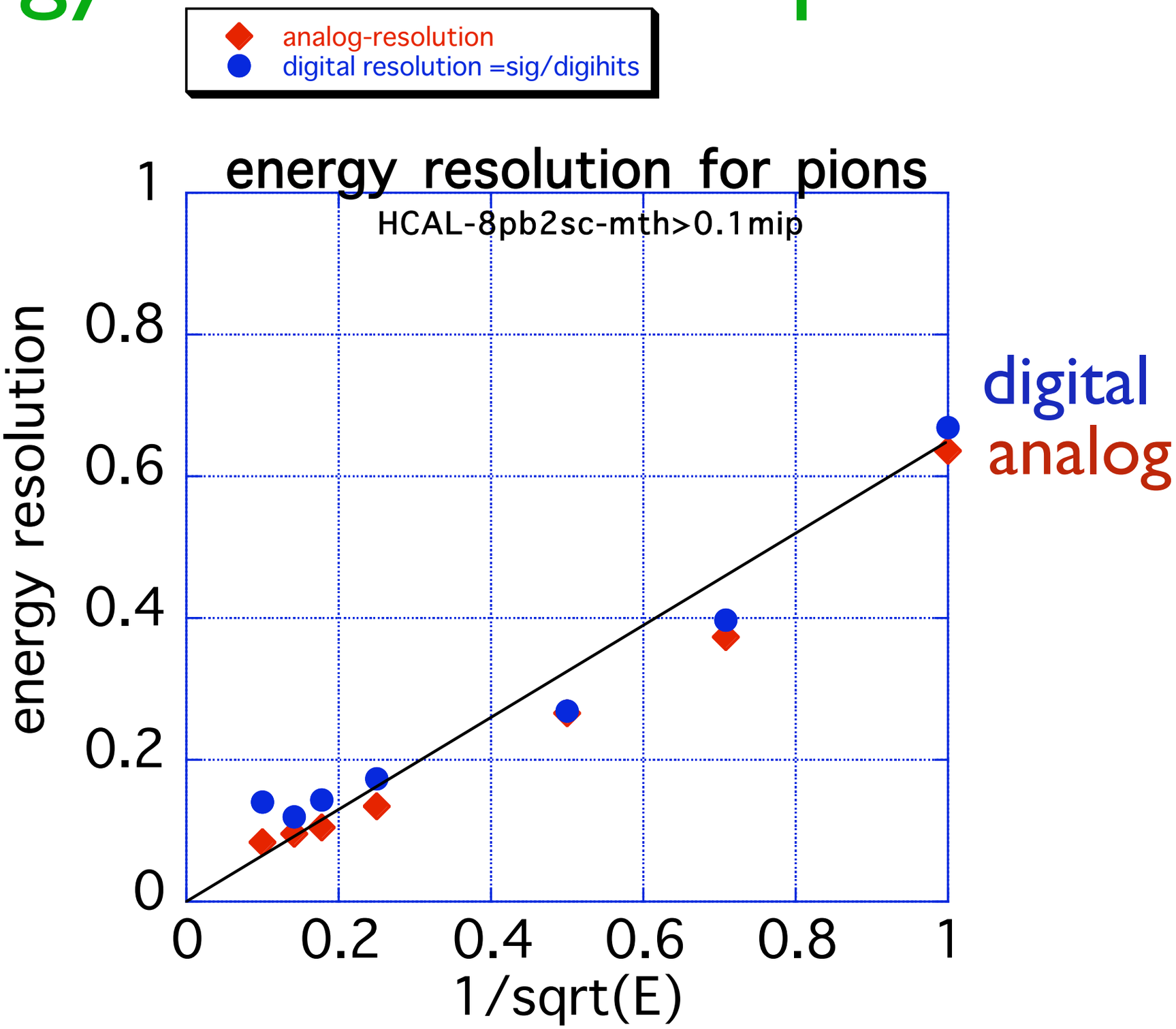
100GeV pion





digital HCAL simulation

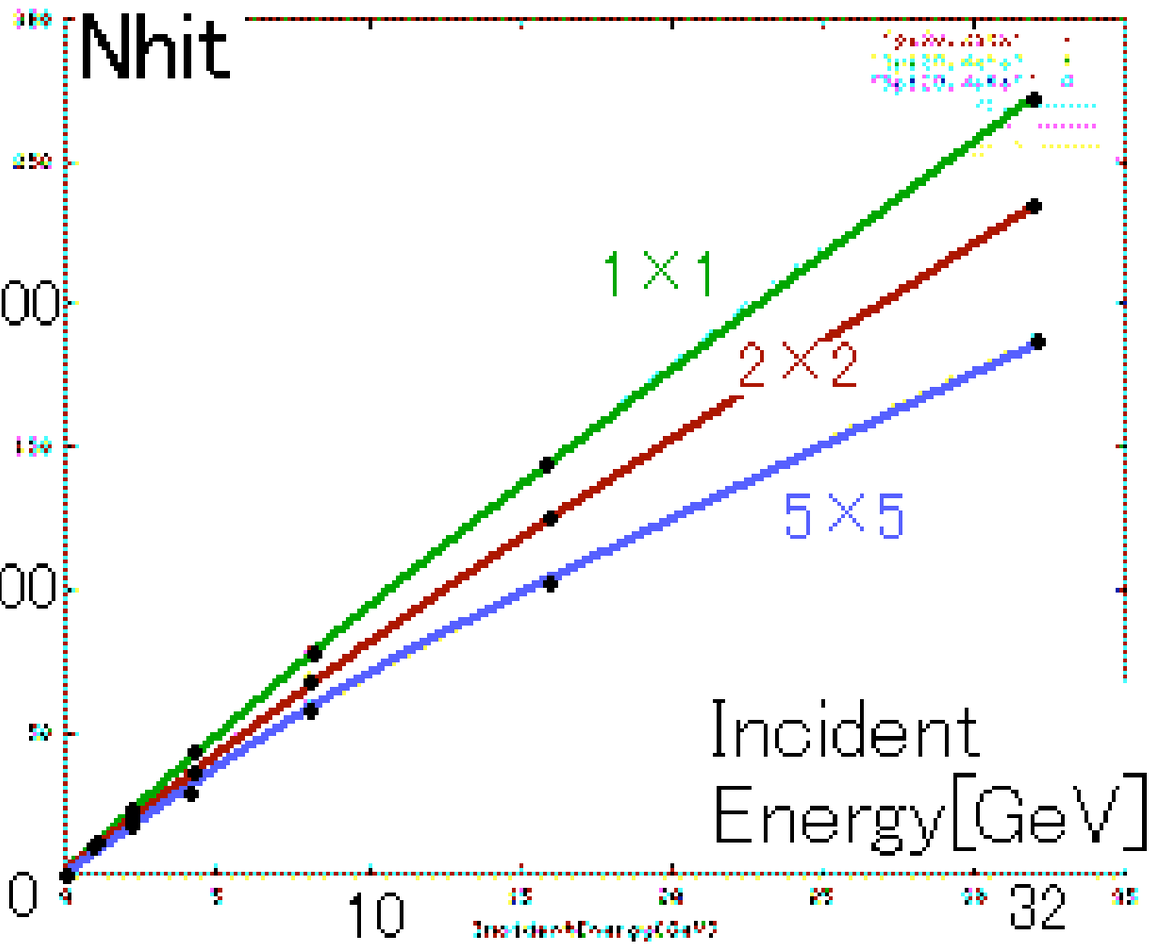
energy resolution for pions



digital HCAL simulation

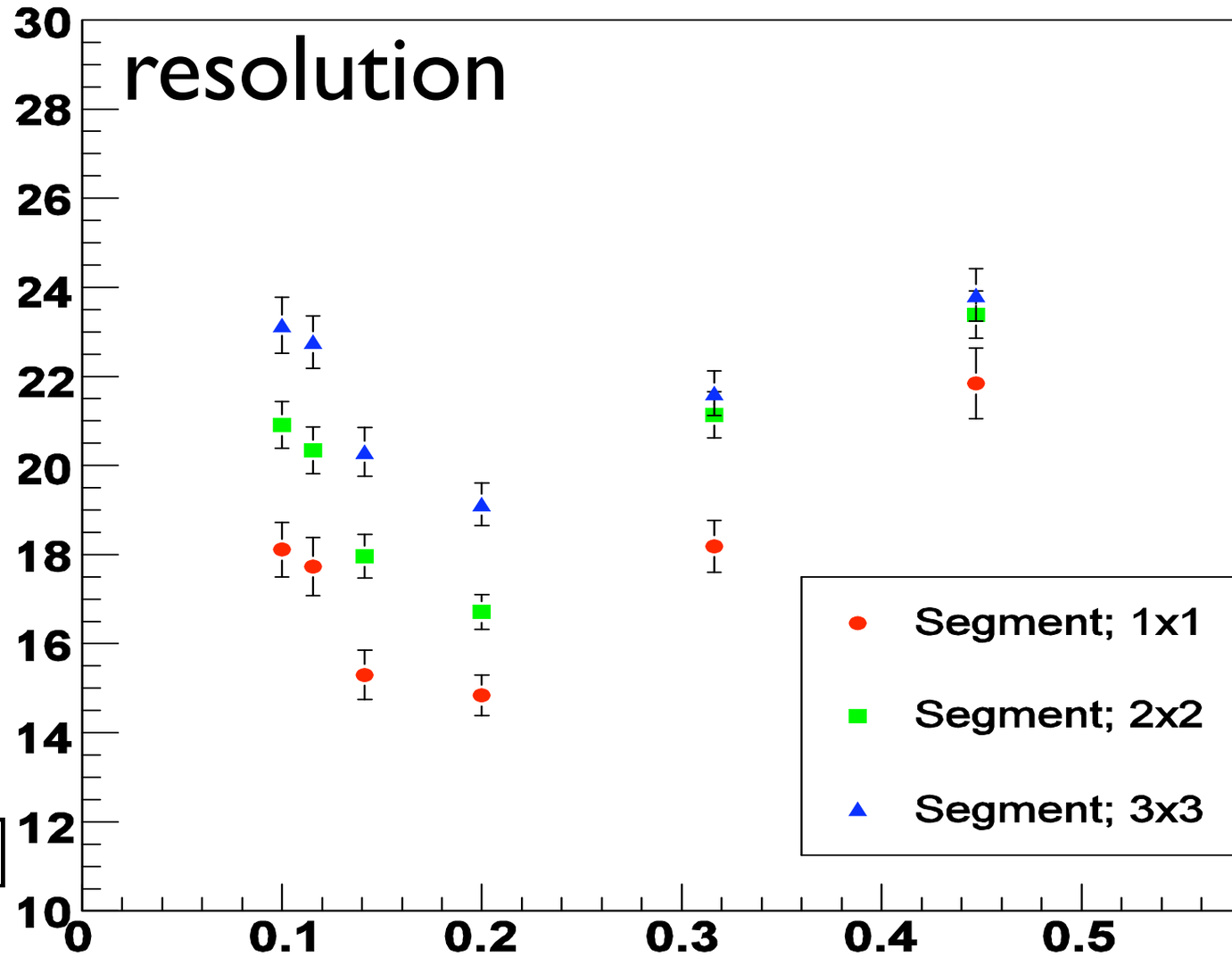
segmentation size

linearity



E(GeV)

Eth=2mip

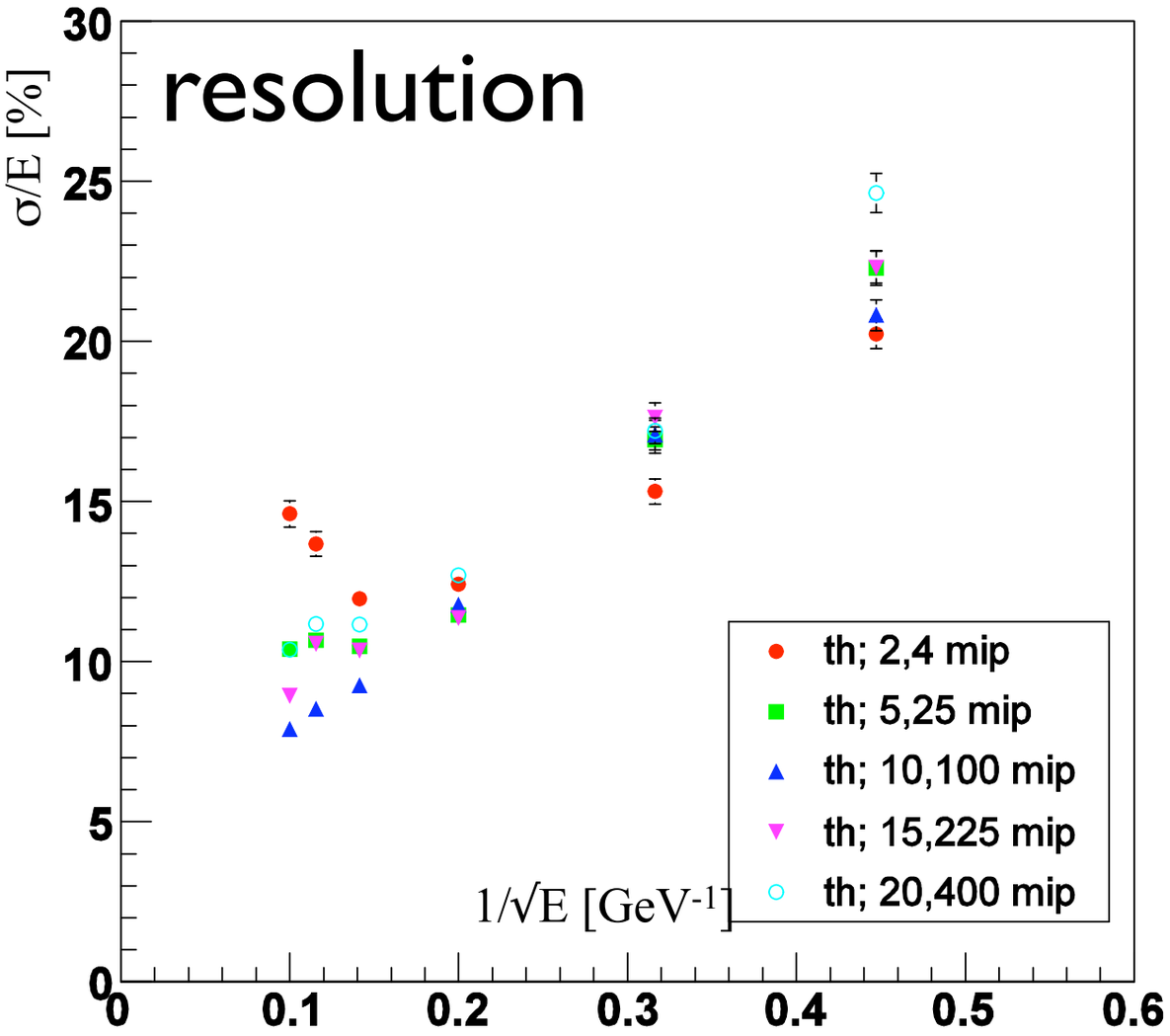


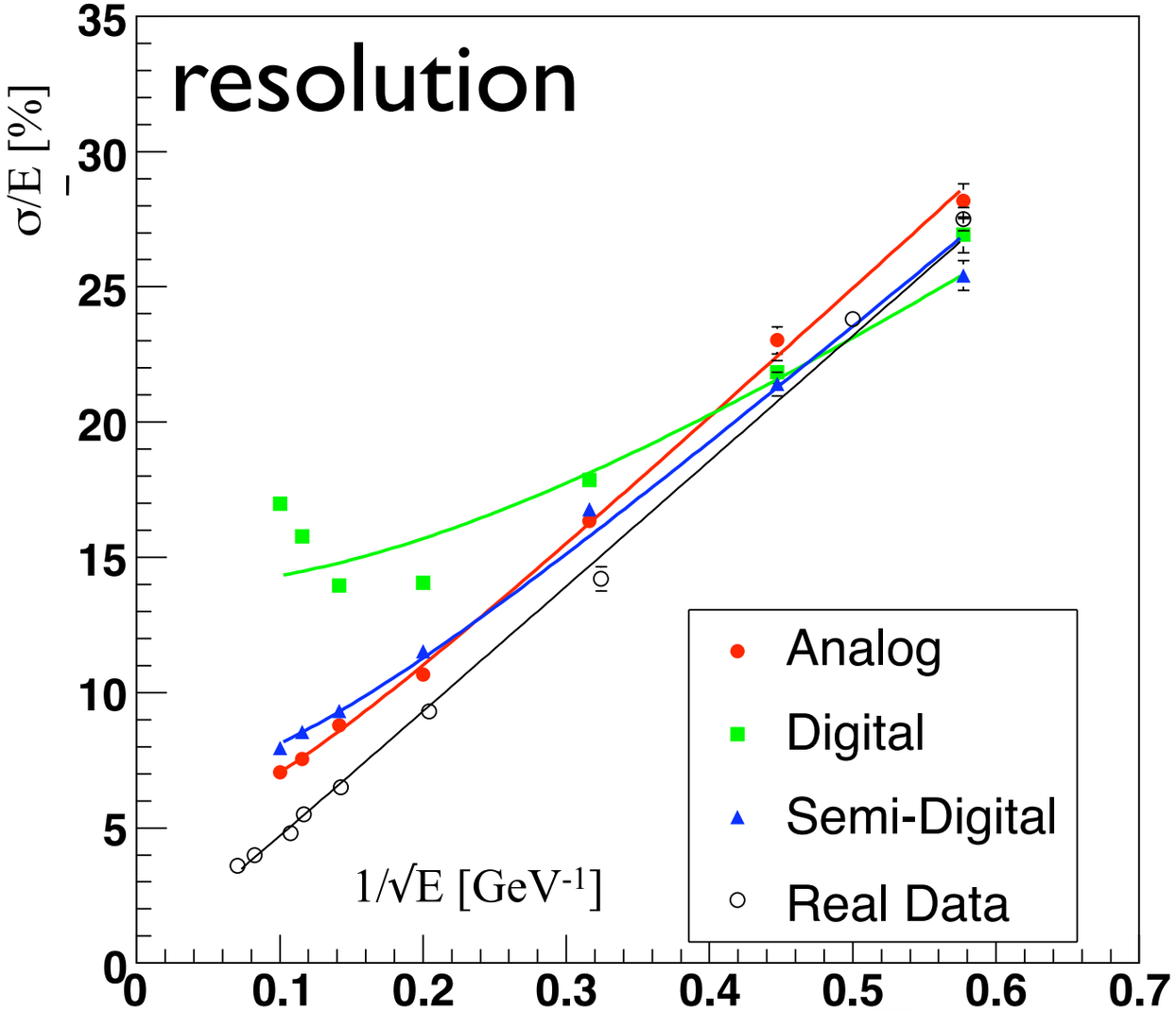
1/sqrt(E)

Eth=0.5mip

semi(2bits)-digital HCAL

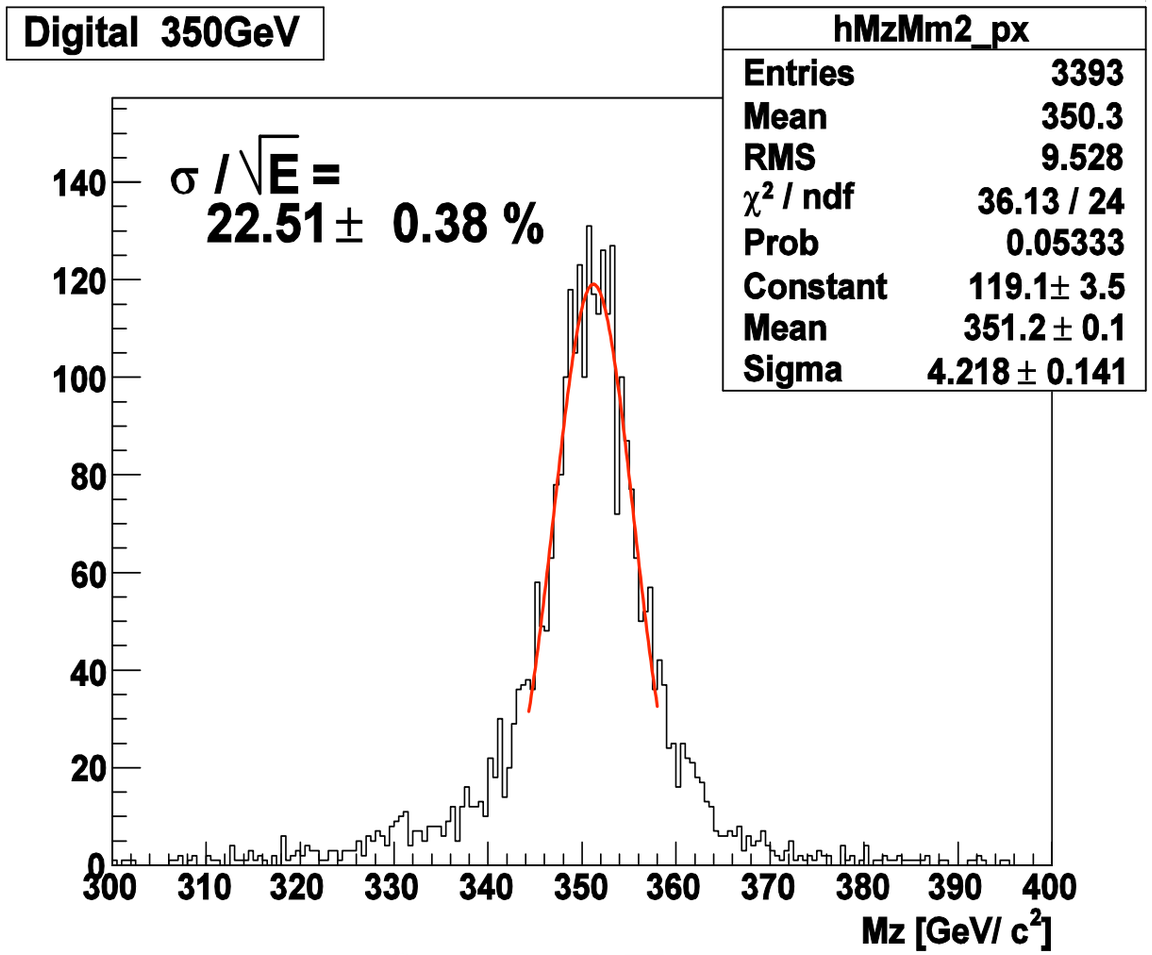
- 0.5MIP < EnergyDeposit ≤ 10MIP = 1 hit
- 10MIP < EnergyDeposit ≤ 100MIP = 10 hits
- 100MIP < EnergyDeposit= 100 hits





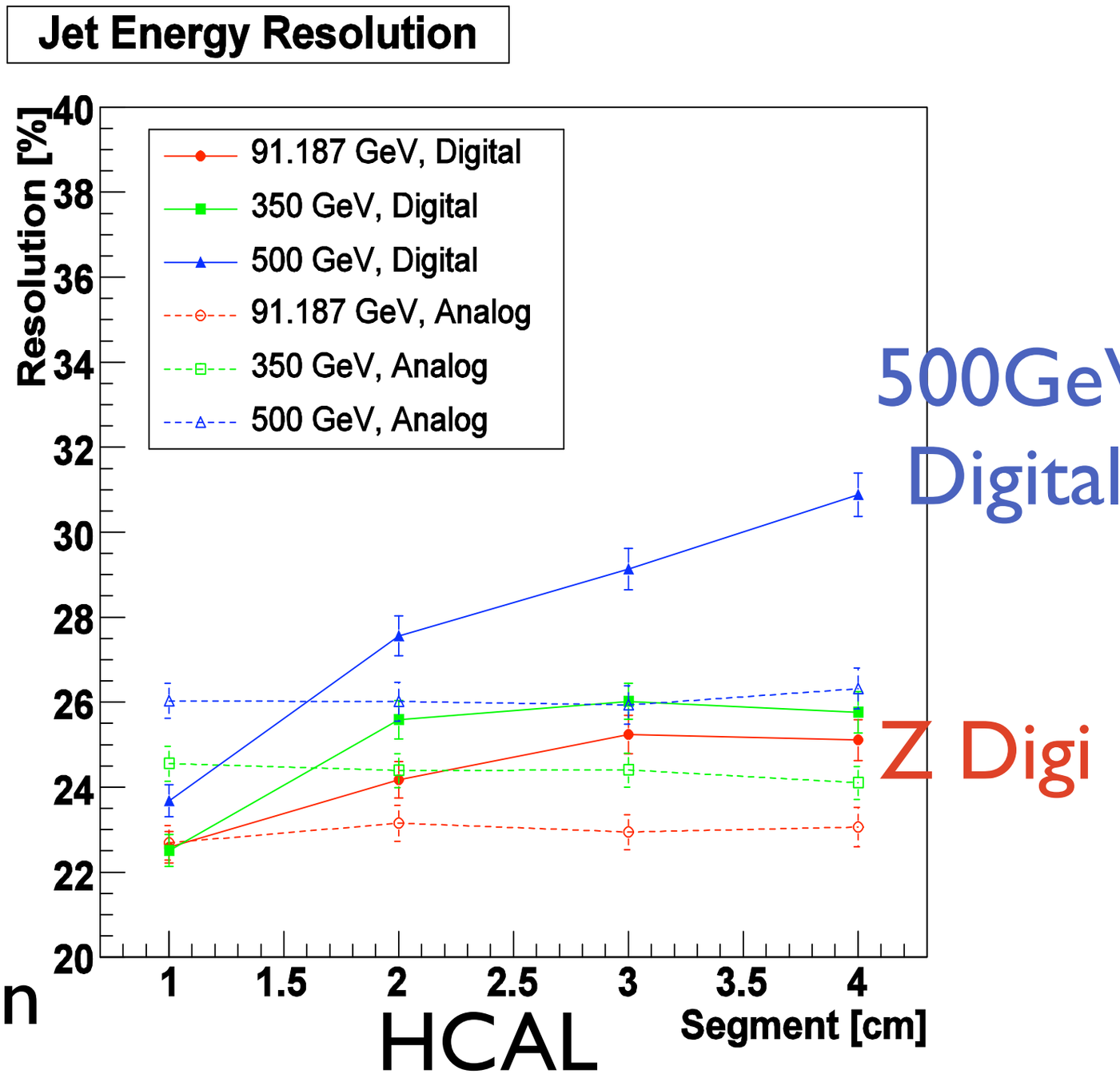
Jet energy resolution by DHCAL

$e^+e^- \rightarrow q\bar{q}\ @350GeV$



perfect PF

1cm x 1cm segmentation



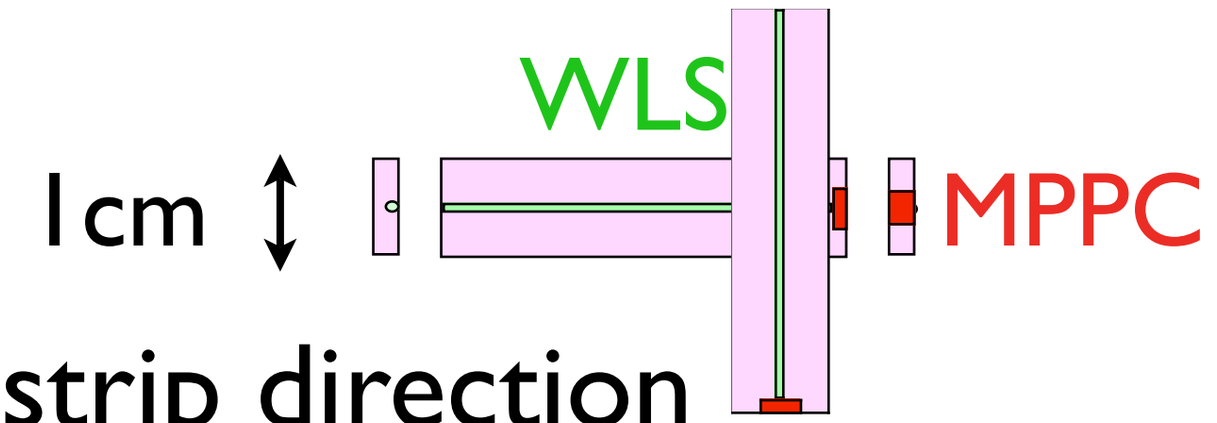
500GeV

Digital

Z Digi

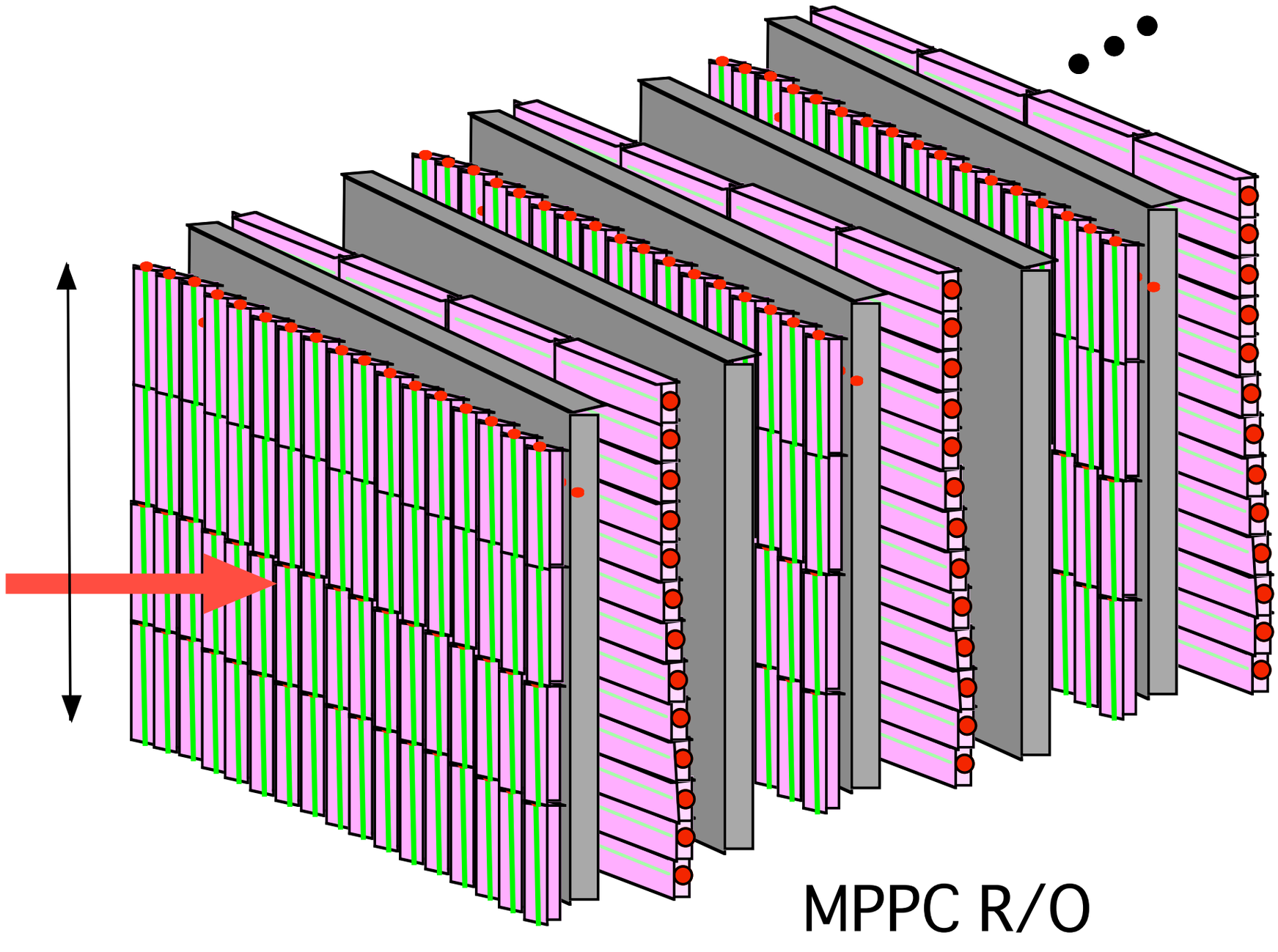
hardware approach toward DHCAL

- scintillator strips



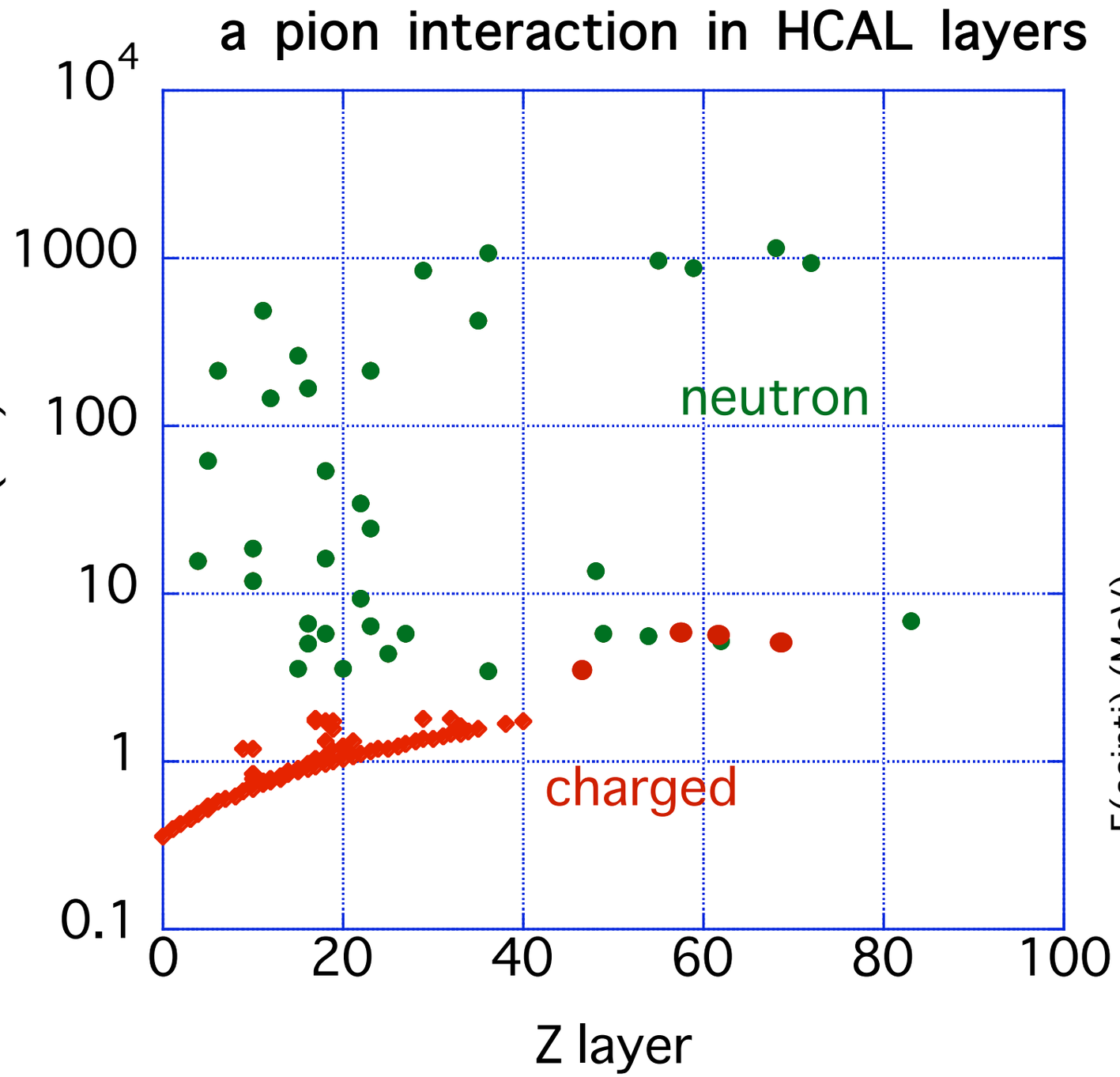
  - homogeneous in strip direction
    - to reduce cost
      - long strip <> multiple hits in a strip
    - photon sensors in strong magnetic field
      - MPPC

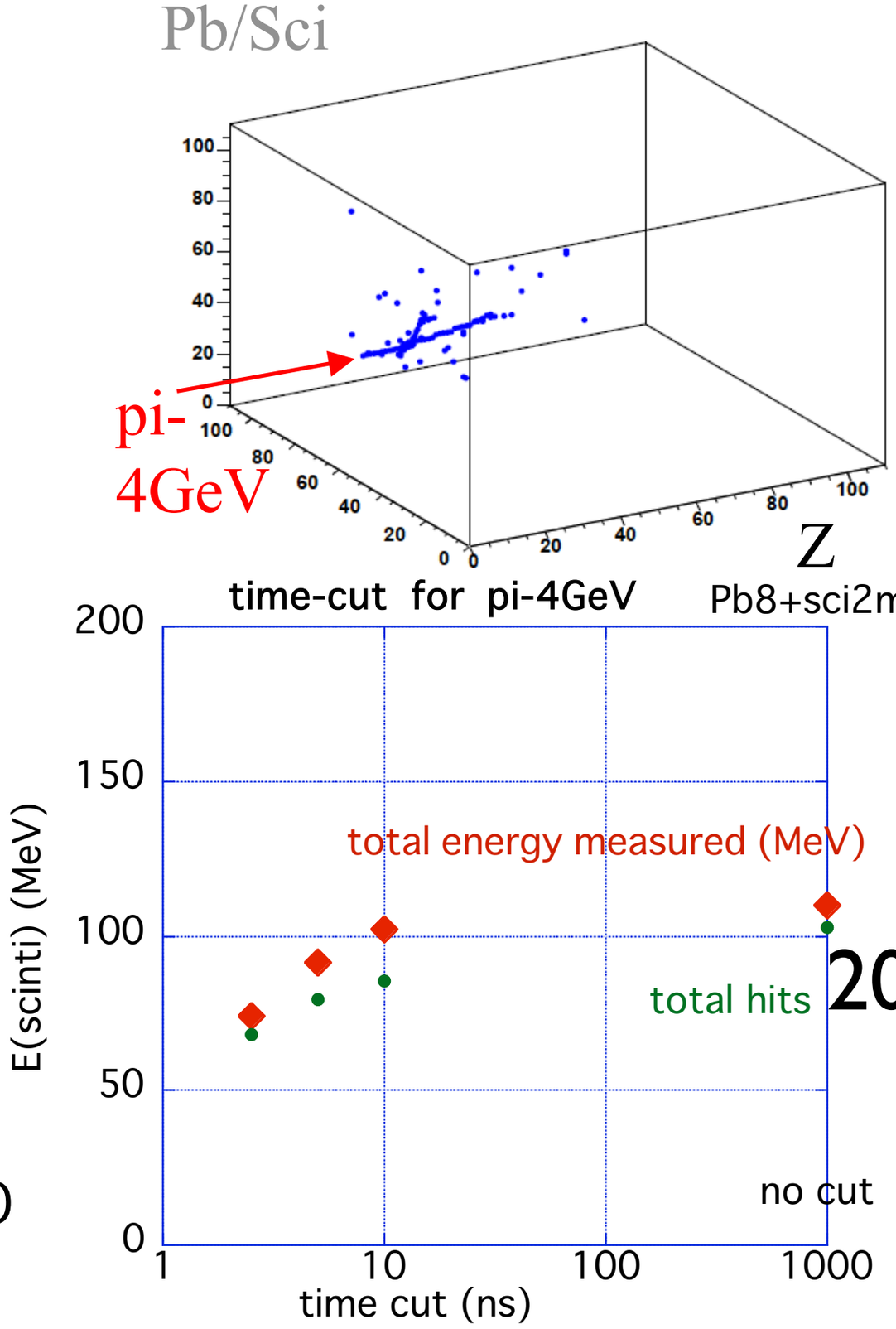
scintillator strip DHCAL



scintillator strip DHCAL

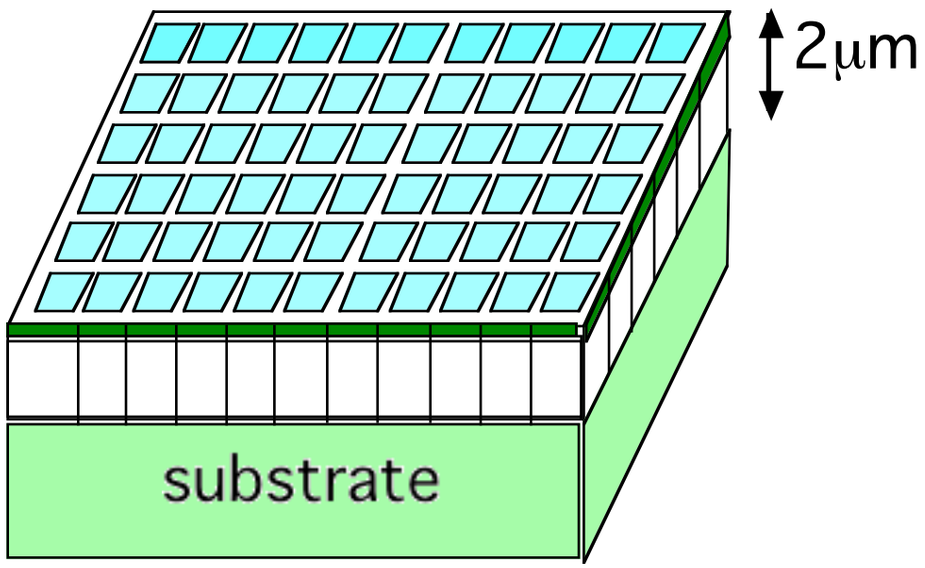
neutron sesitive

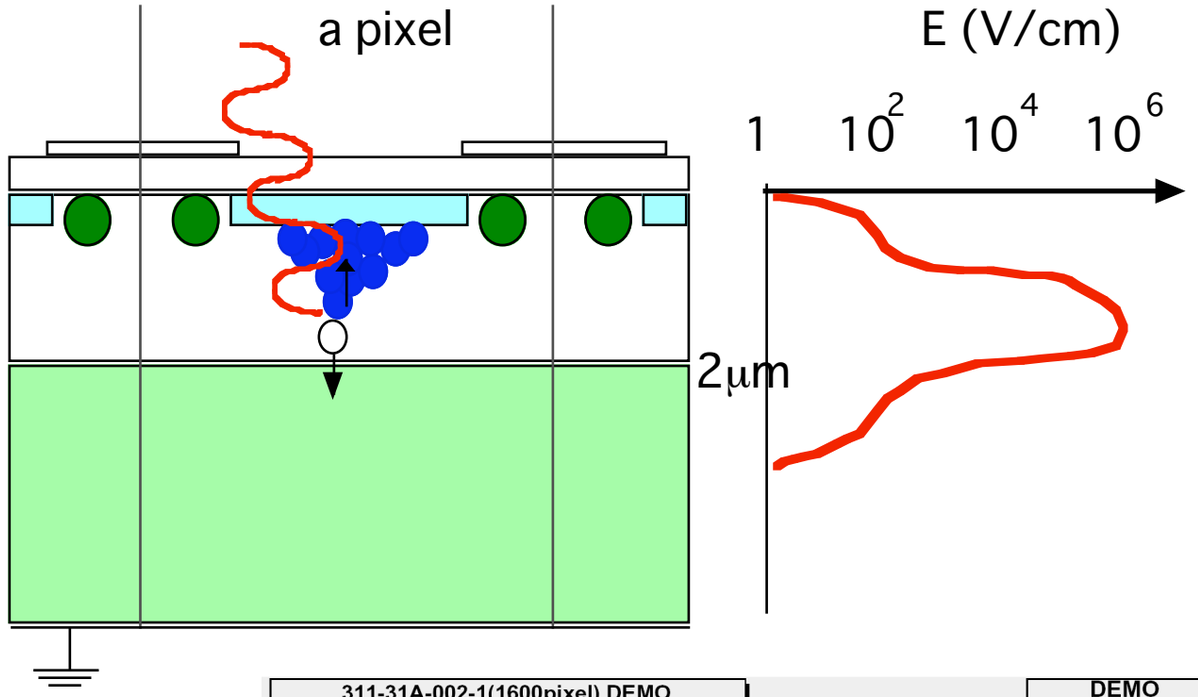


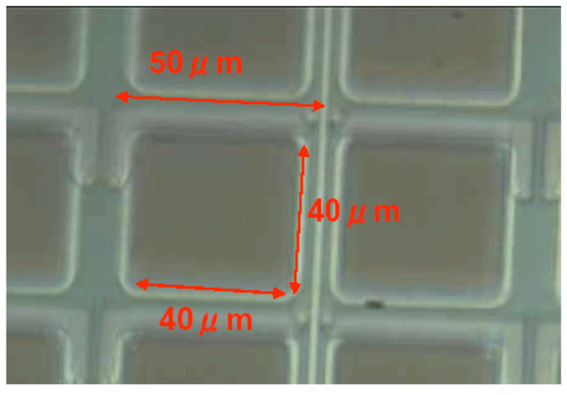


MPPC development

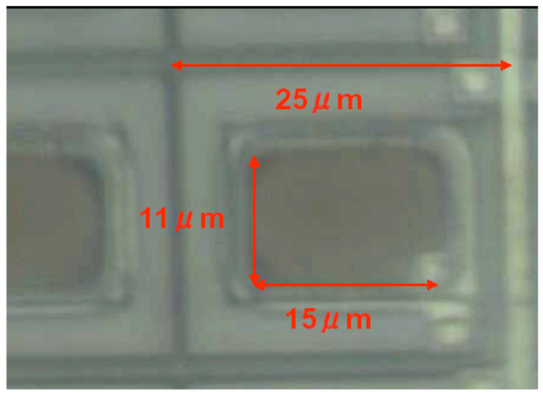
semiconductor pixel photon sensor with Geiger or Limited Geiger Mode



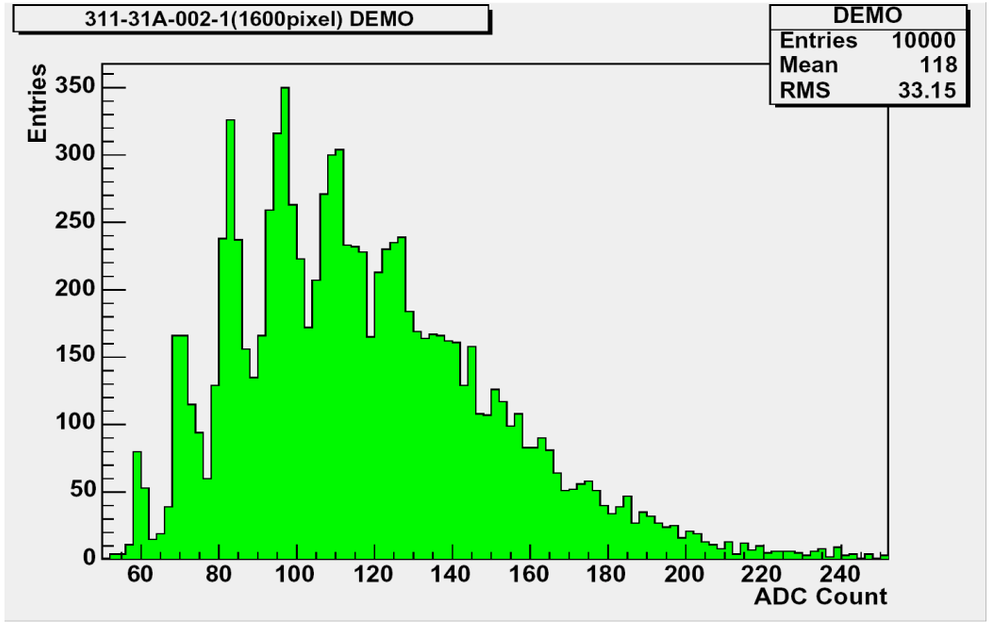




400pixel



1600pixel

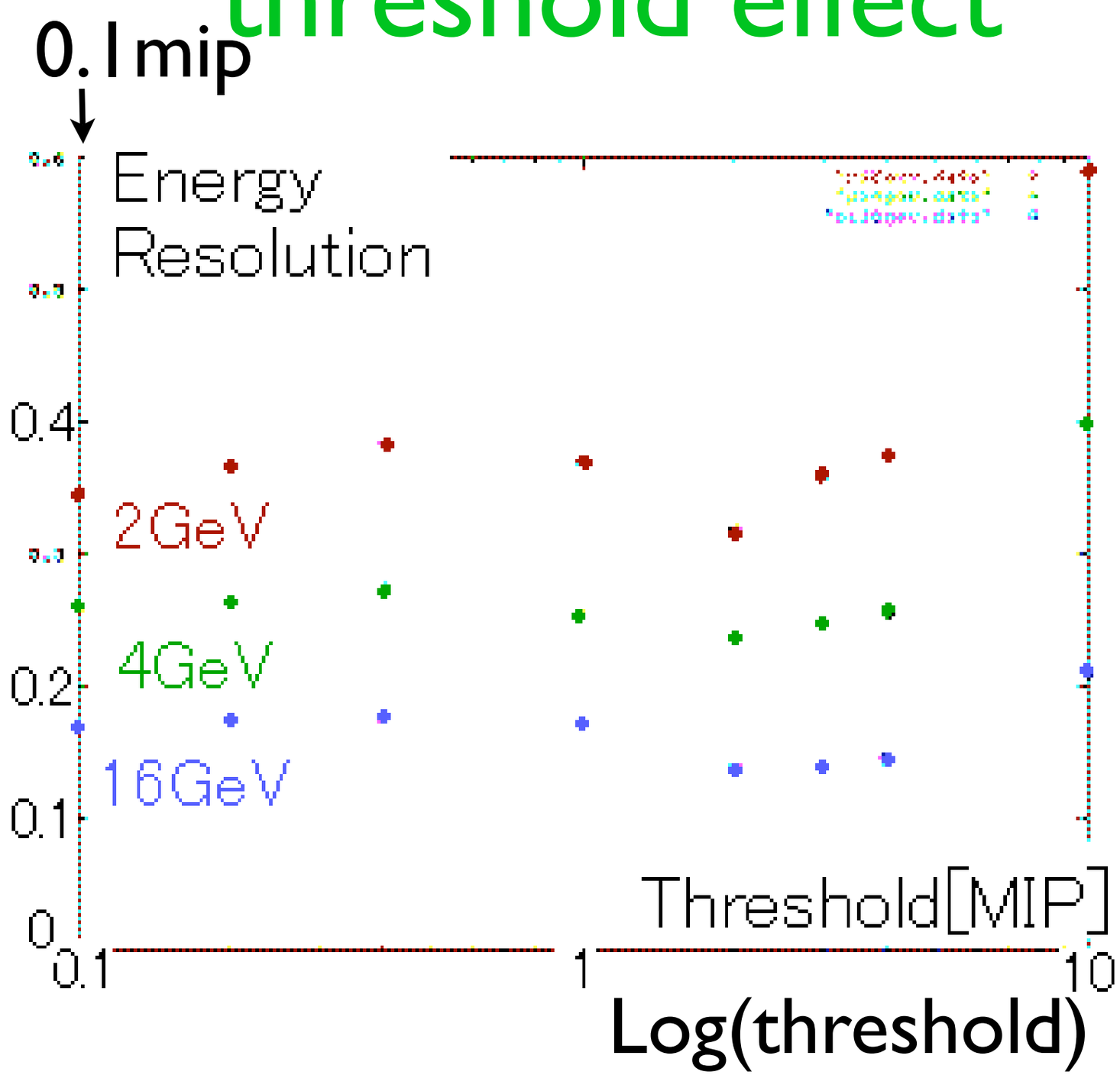


summary

- Digital Hadron Calorimeter investigated
- single particle responses are tested
  - pure digital (1bit) HCAL is not sufficient
  - semi-digital (2bit) HCAL seems to give similar to analog CAL
- Hardware trial is underway
  - test is needed with analog read out and simulate digital case

digital HCAL simulation

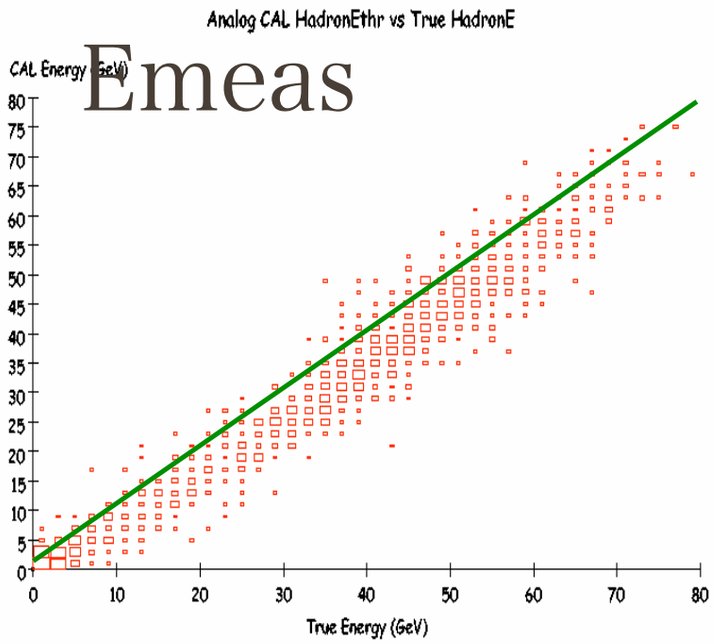
threshold effect



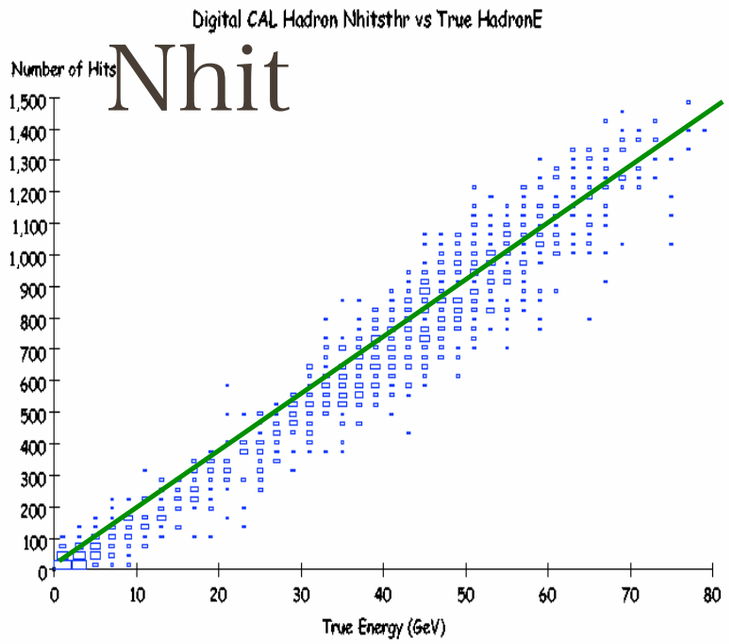
US-digital

HCAL (US) : RPC Digital-HCAL, PFA

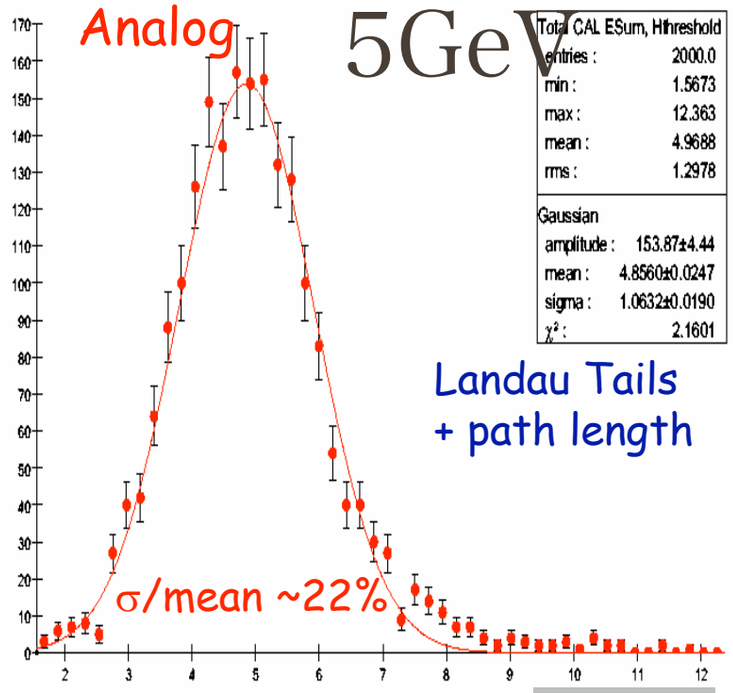
$e^+e^- \rightarrow Z \rightarrow q\bar{q}$

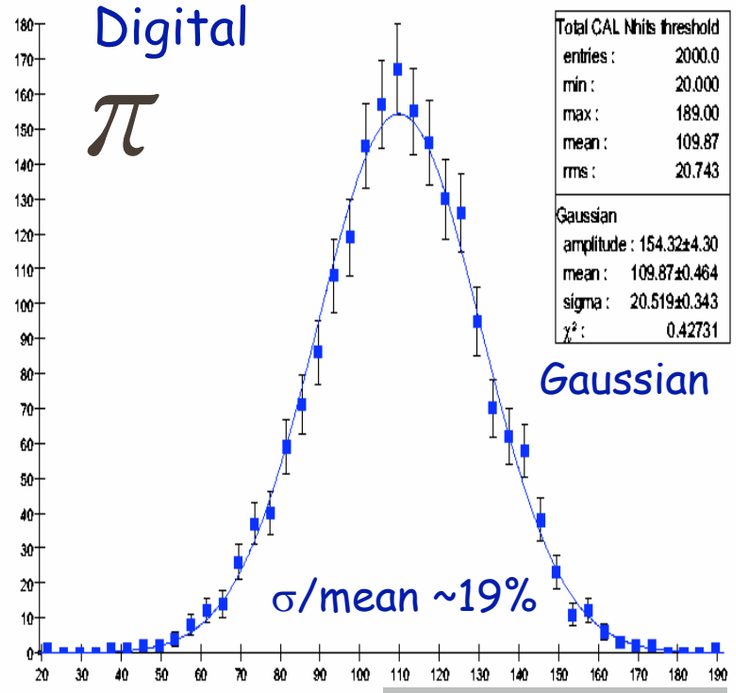


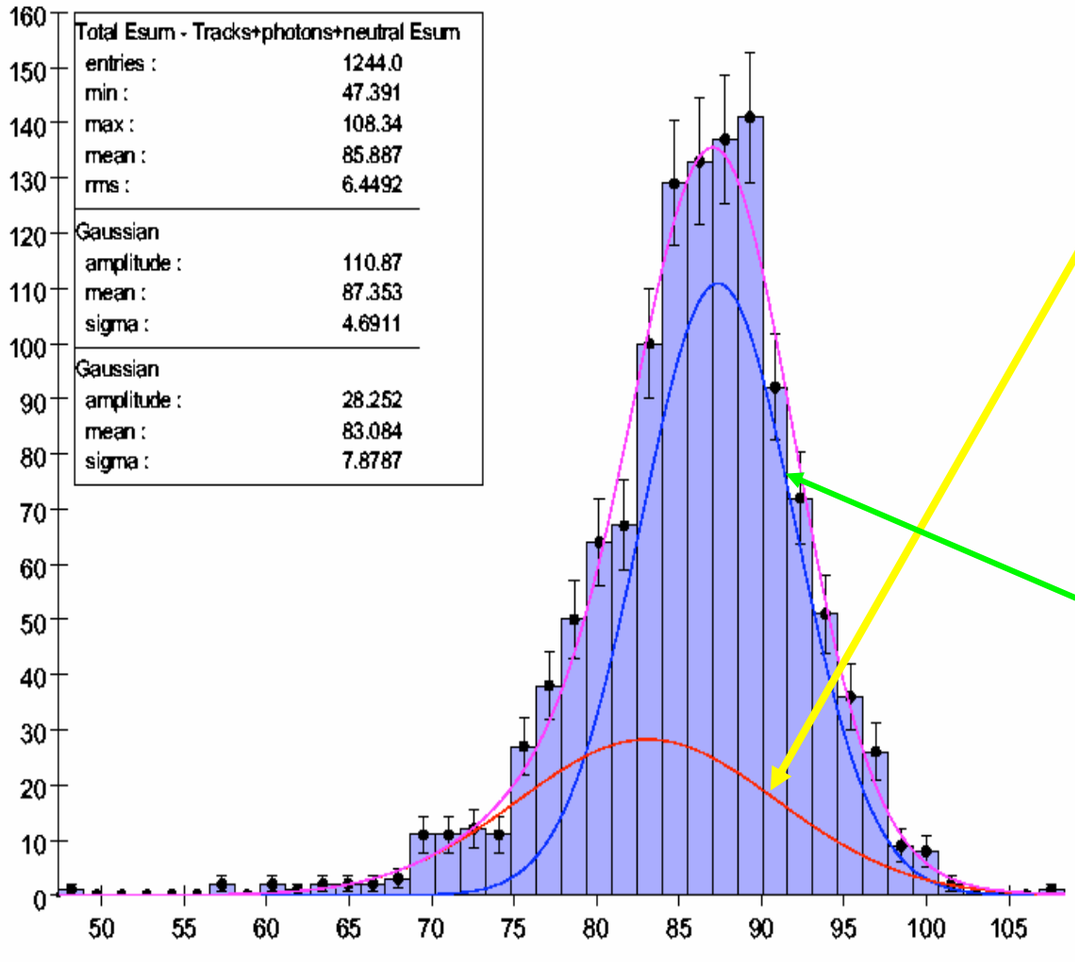
Emeas



Nhit







$\sigma = 3.8 GeV\,(neutrals) \oplus 1.2\,(\gamma)$