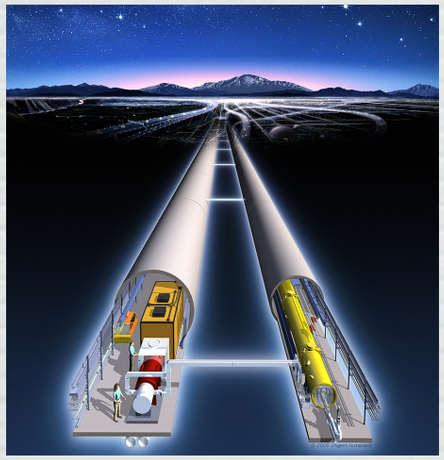
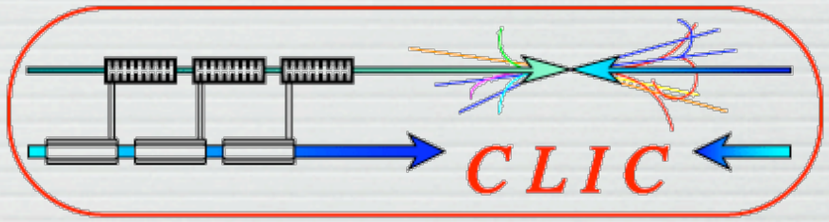




Scintillator Calorimeter for LC

Tohru Takeshita

Shinshu U. for GLDCAL & scecal+AHCAL/CALICE

ILC to CLIC

HE, BG & BX

PFA calorimeter

ECAL & HCAL

current and future study

Shinshu University

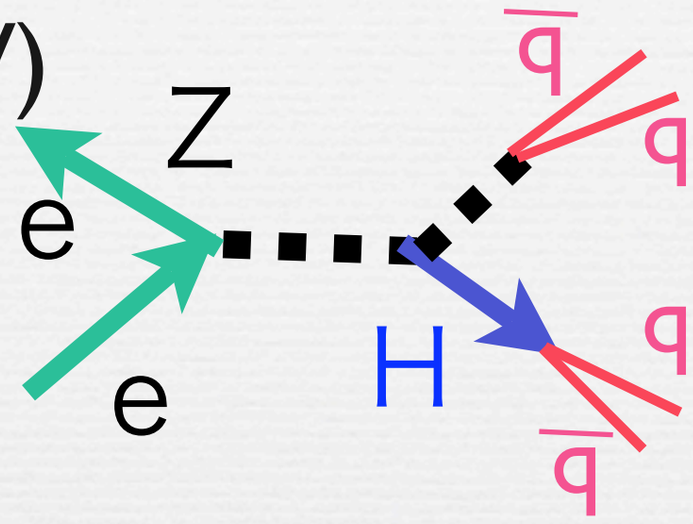
Calorimeter for ILC

TT CLIC-WS 09 @ CERN

Jet physics at HE

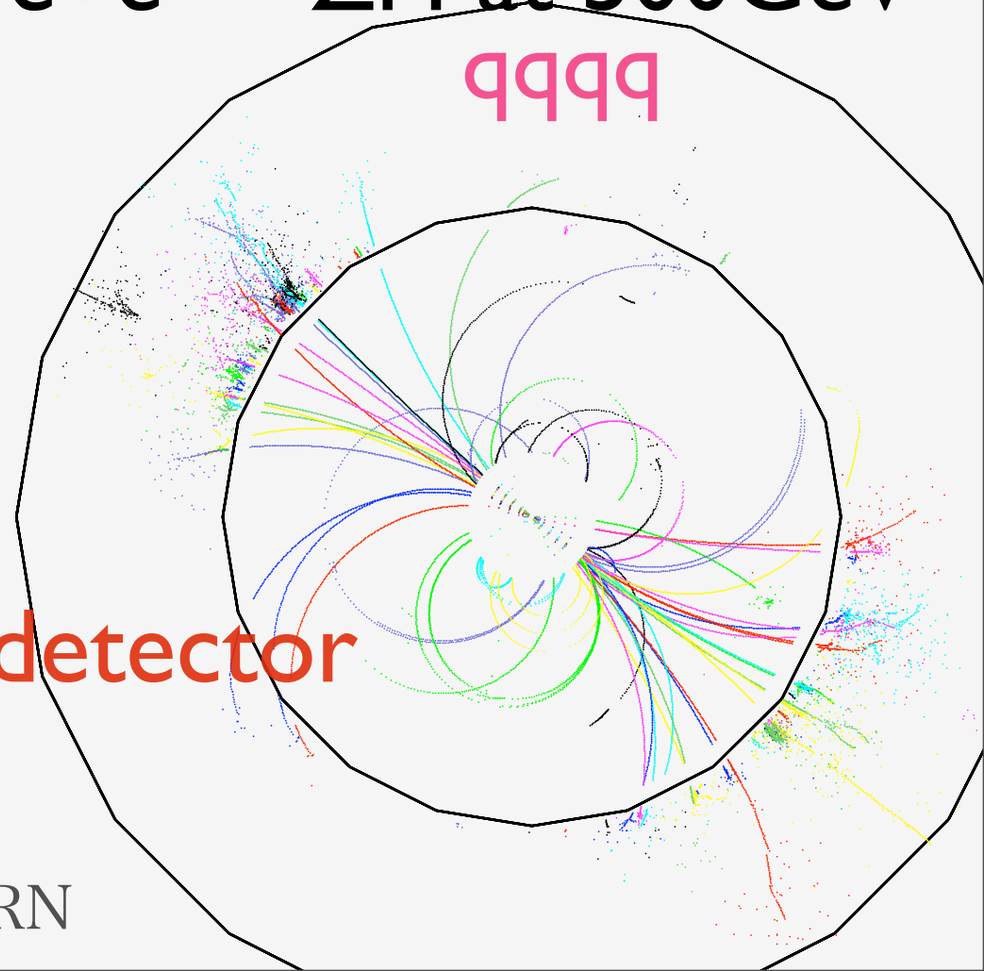
- High Energy e+ e- collision in LC (~TeV)
- relevant physics final states
  - W/Z/H/top which emerges as jets
- need to identify its origin
- required 3%~(rms jet)/Ejet
  - separate W from Z
- guiding principle : PFA
- PFA requires specifically optimal detector

severer on CLIC



e+e- > ZH at 500GeV

qqqq



Particle Flow Algorithm

- Charged particle : pion,Kaon: Tracker :65% of Ejet
- neutral : photon: ECAL :25% of Ejet
- neutral: Ko,n: HCAL: 10% of Ejet

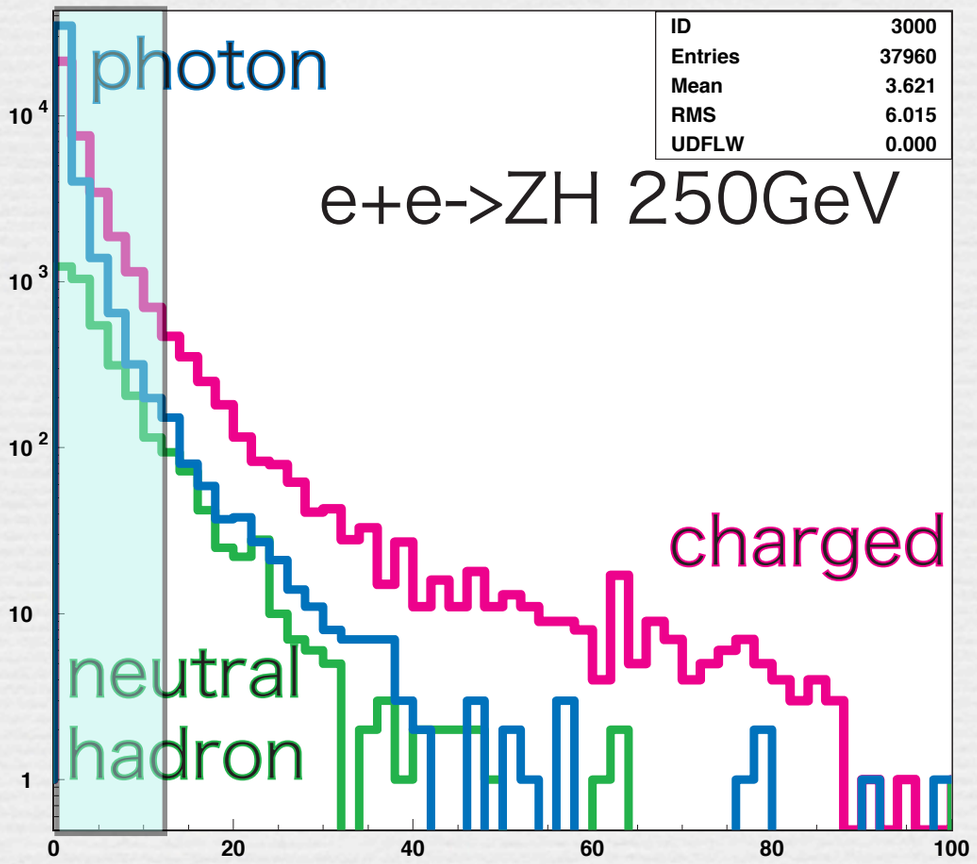
0.001@10GeV

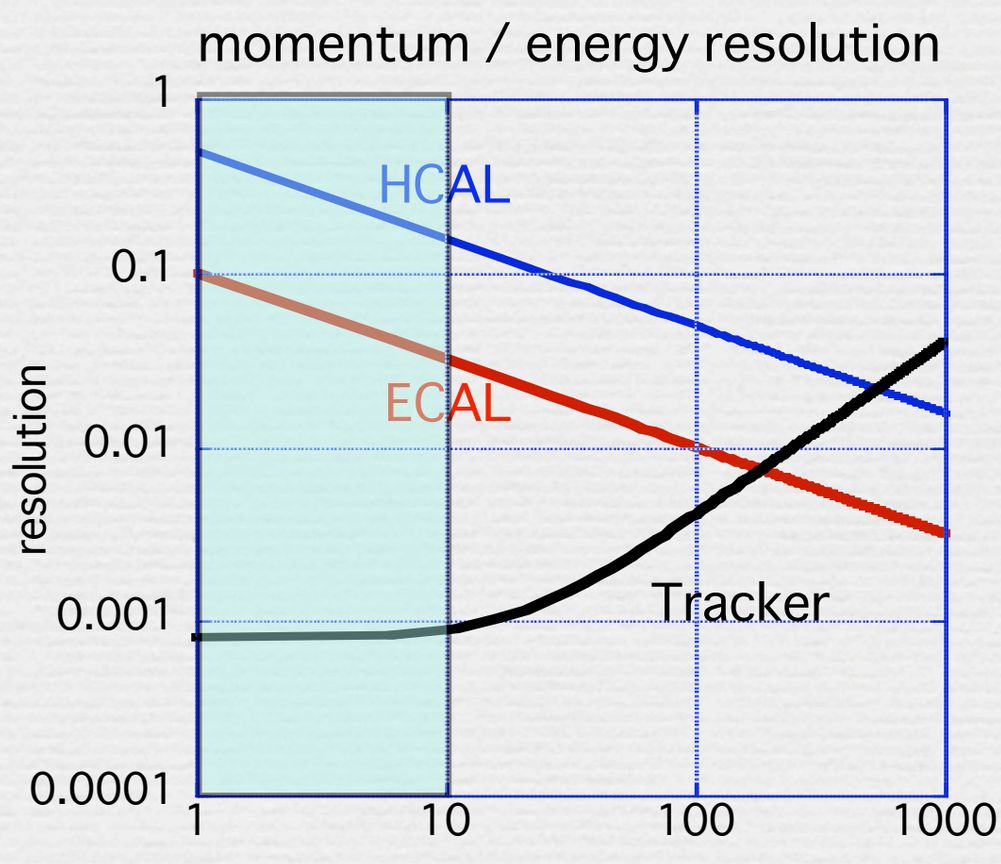
0.05@10GeV

0.2@10GeV

- jet energy resolution : HCAL

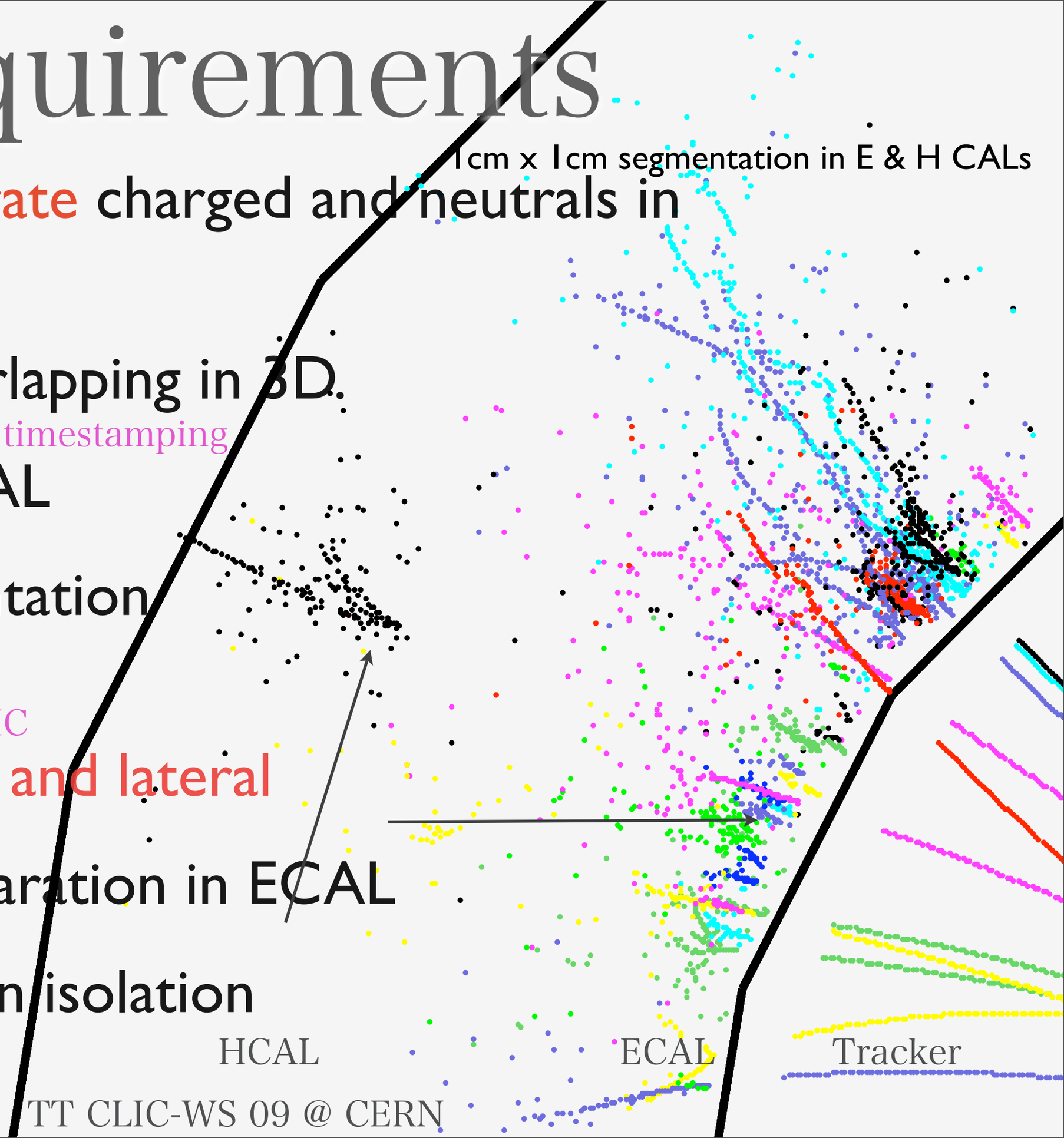
error propagation





PFA requirements

- need to separate charged and neutrals in calorimeter
  - cluster overlapping in 3D.
    4 D for CLIC with timestamping
- tracking in CAL
  - fine segmentation
    ~1x1 cm^2
    smaller on CLIC
  - longitudinal and lateral
  - photon separation in ECAL
- neutral hadron isolation

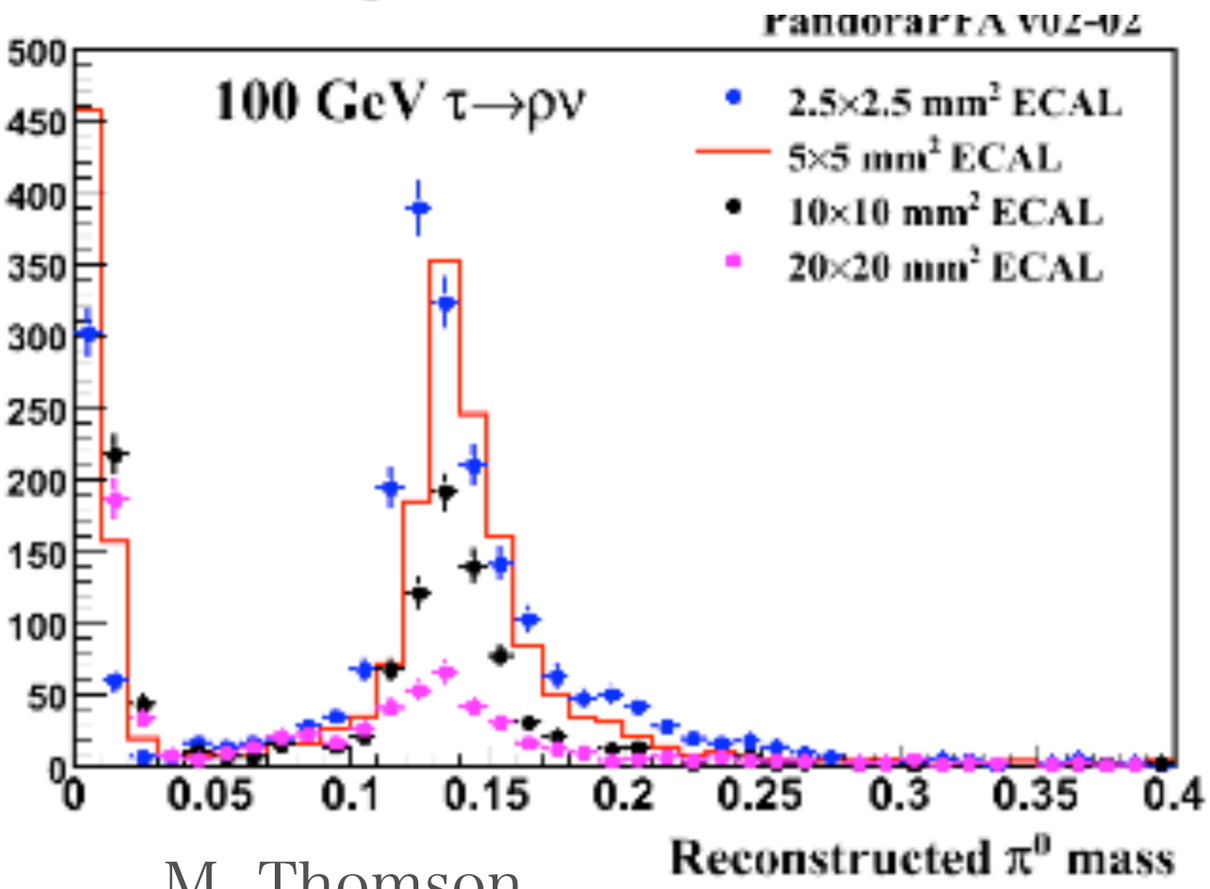


granularity

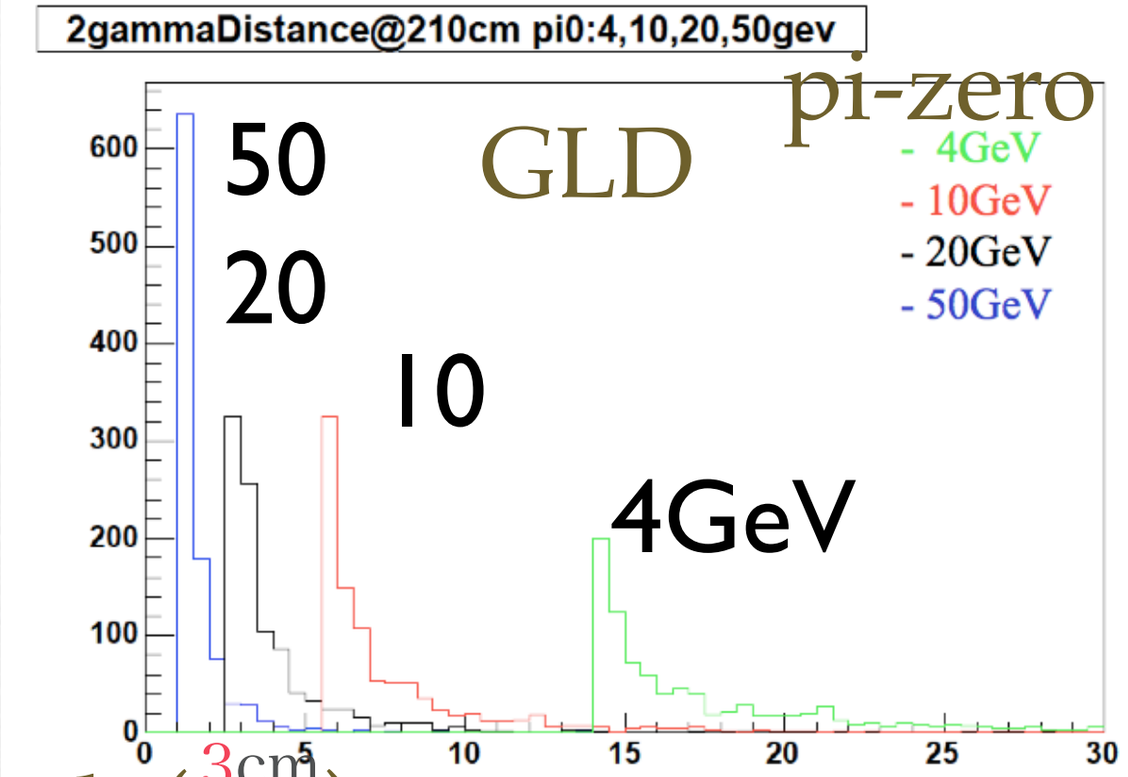
- ECAL < 1x1cm²

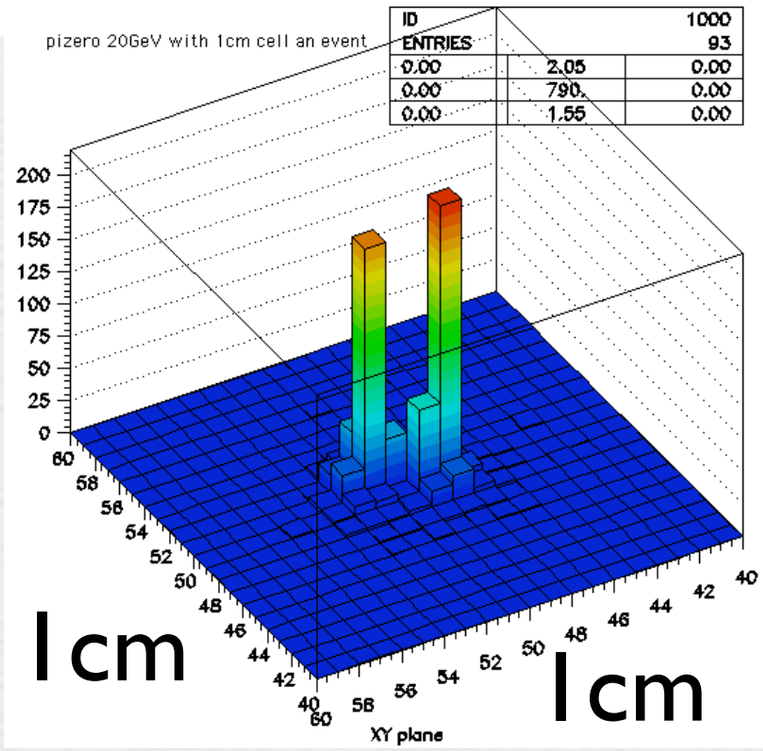
smaller on CLIC

$$\tau^- \rightarrow \rho^- \nu_\tau \rightarrow \pi^+ \pi^0 \nu_\tau$$



M. Thomson



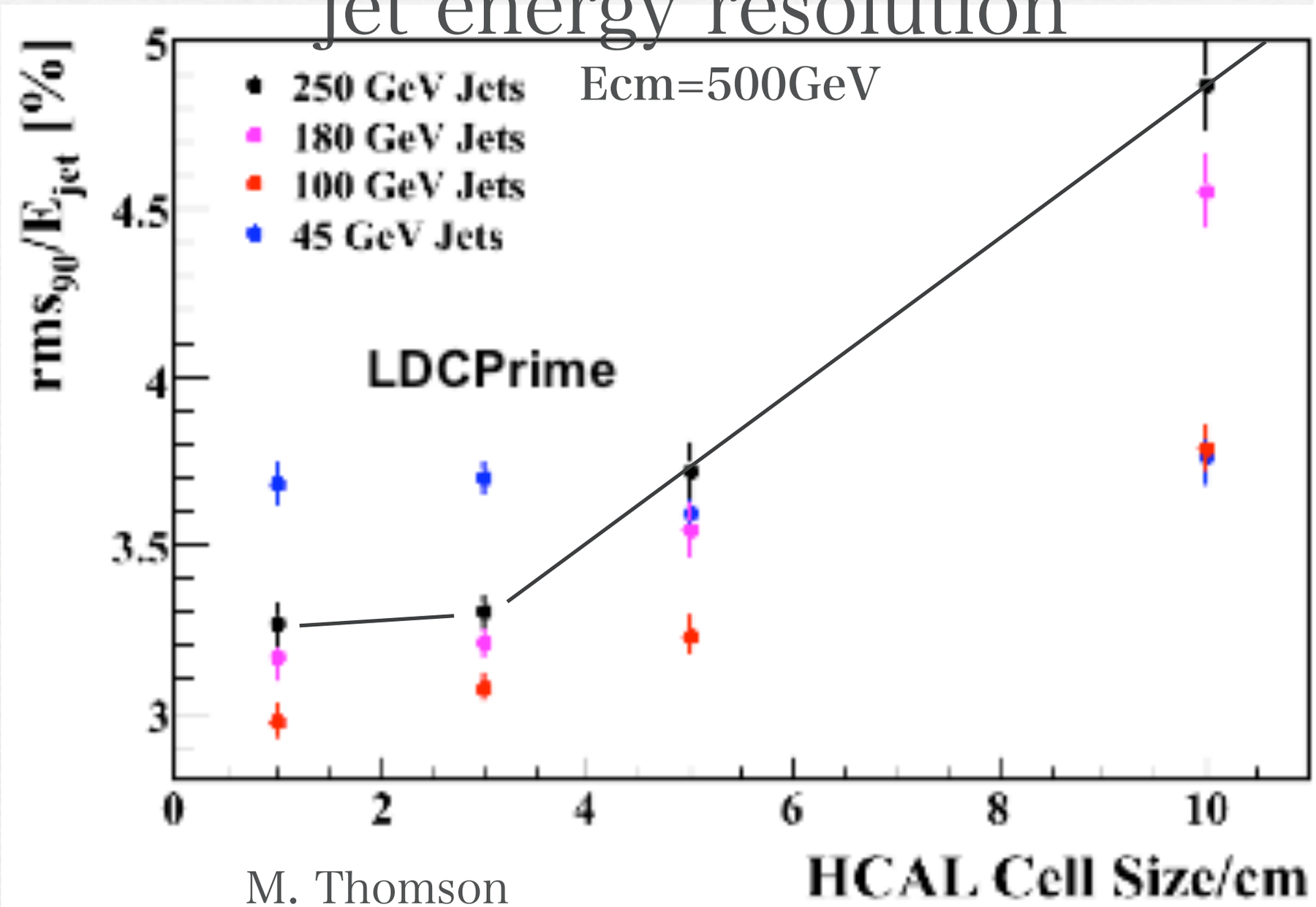


20GeV π^0

granularity

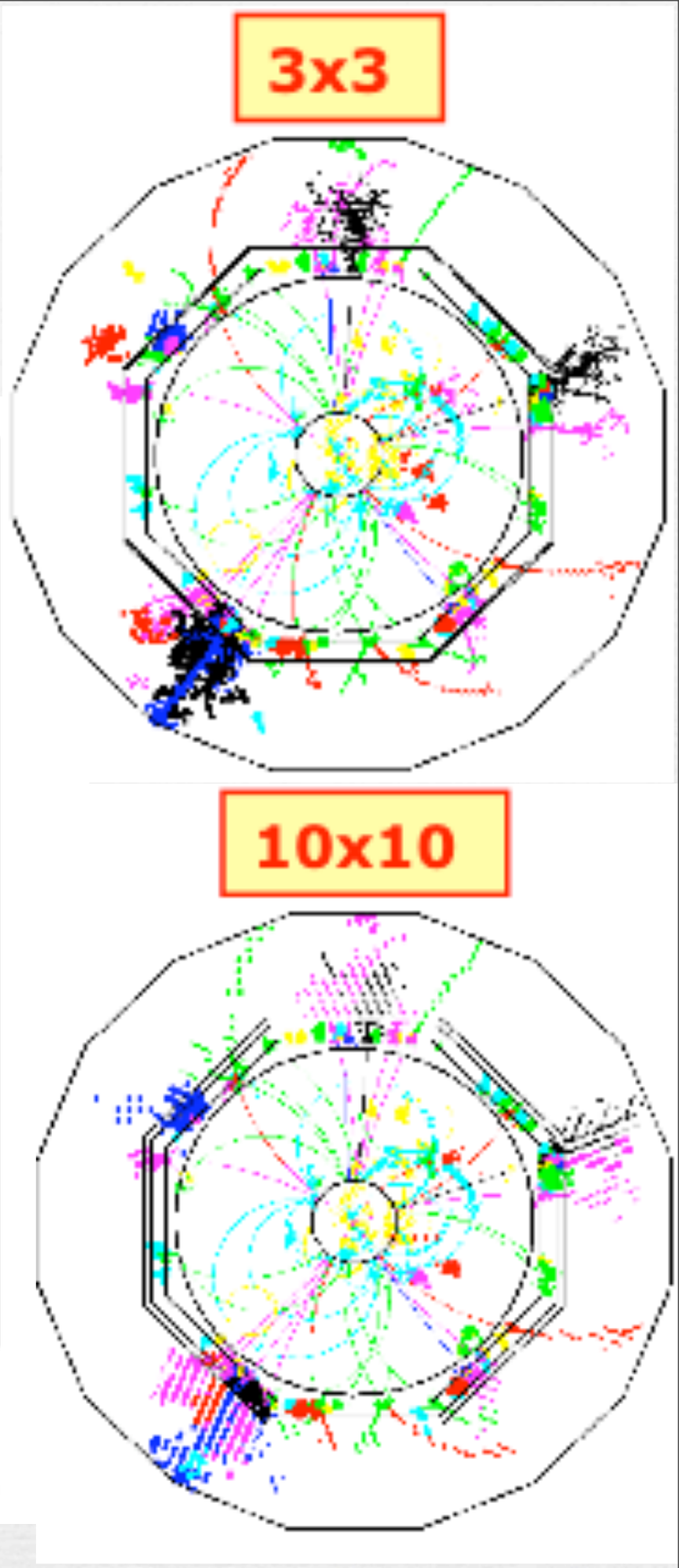
- HCAL ~ 3cm x 3cm

jet energy resolution



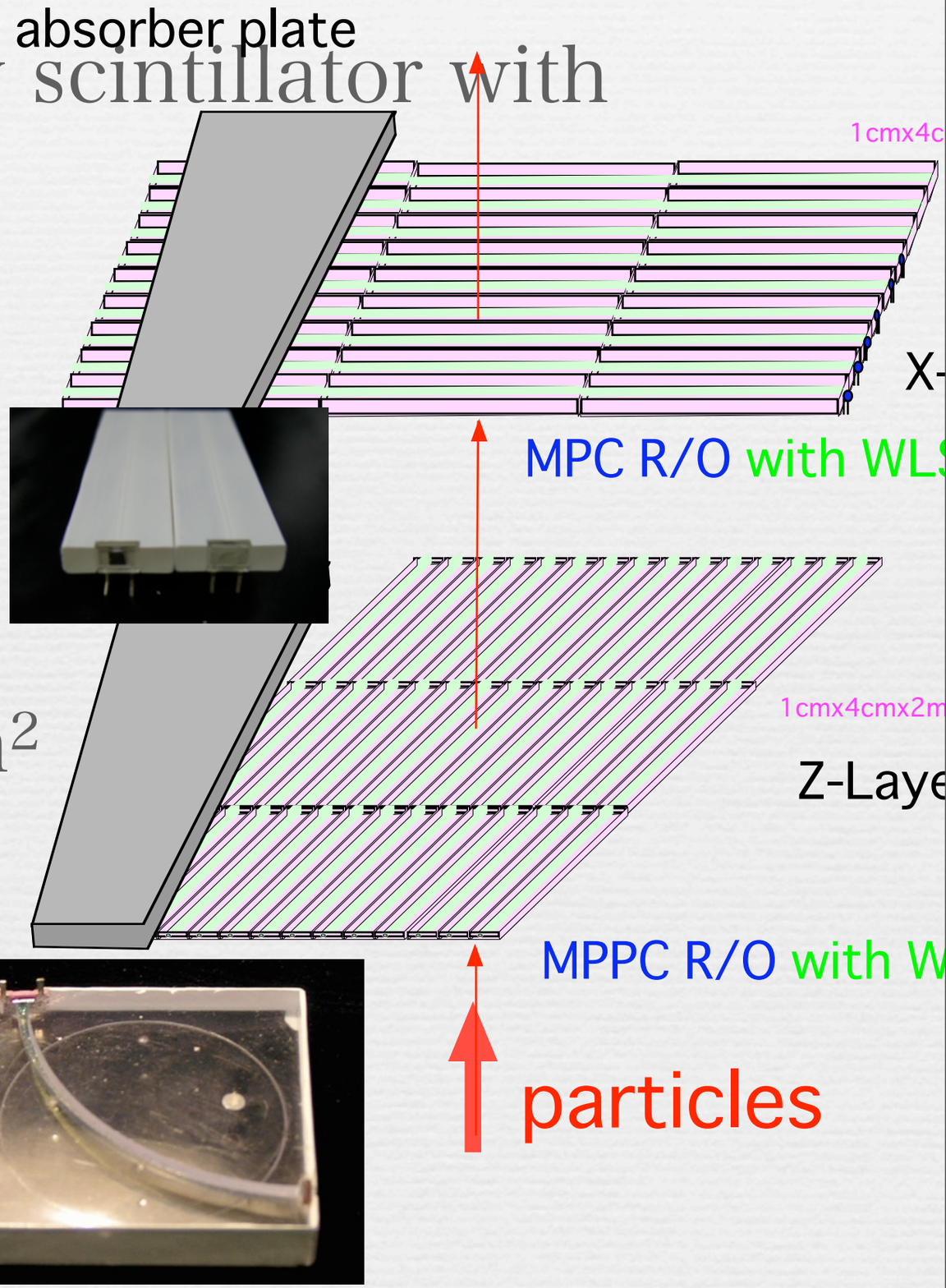
M. Thomson

no leak on CLIC



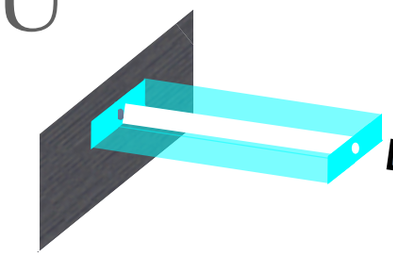
How to fulfill

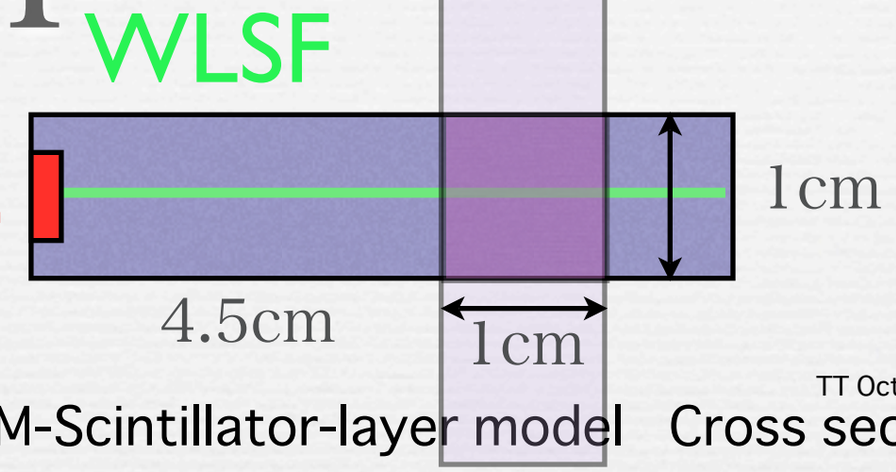
- current implementation by scintillator with Wave length shifting fiber
- ECAL : strips : extruded
  - 1cm x 4.5 cm x 0.3 cm
  - X-Y strips effective 1cm²
- HCAL : tile : molded
  - 3cm x 3cm x 0.5cm



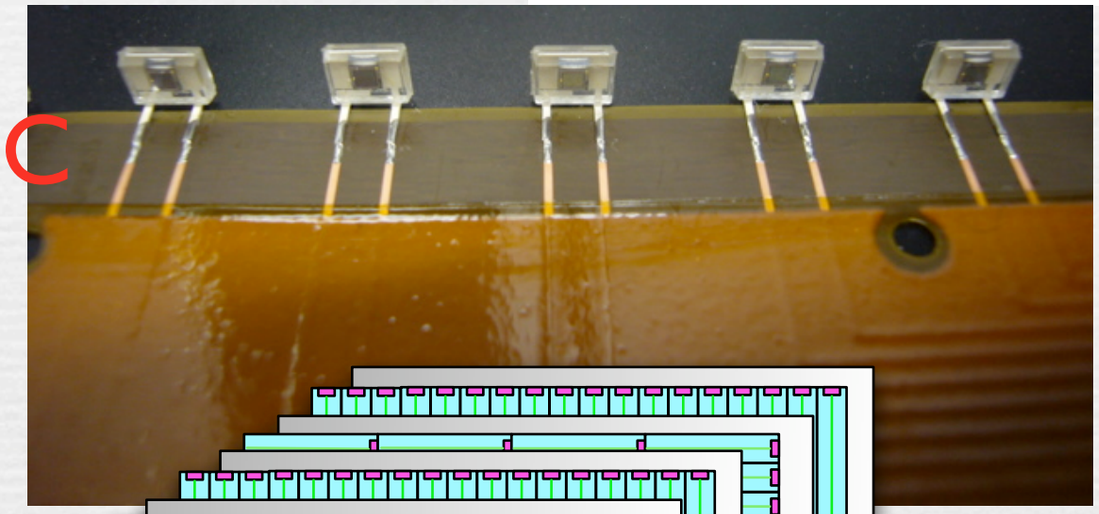
scintillator strip ECAL

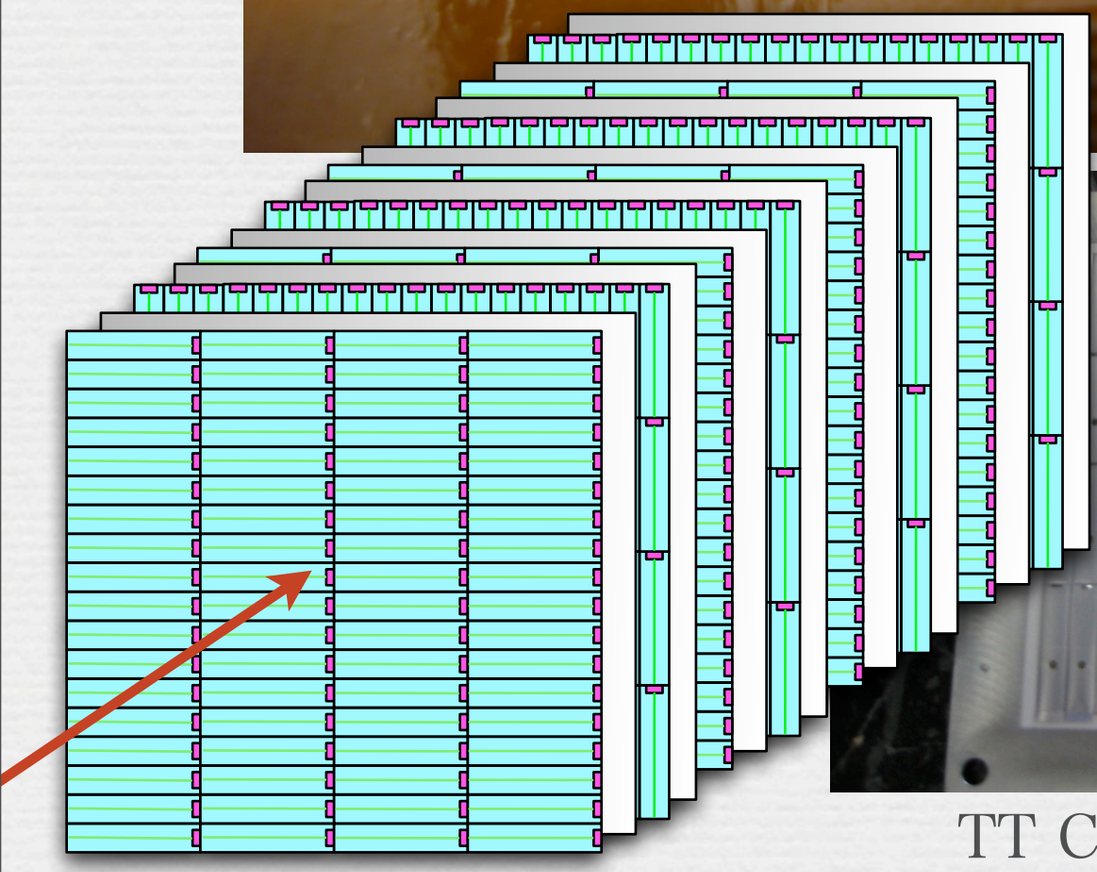
- extruded by KNU
- MPPC read out

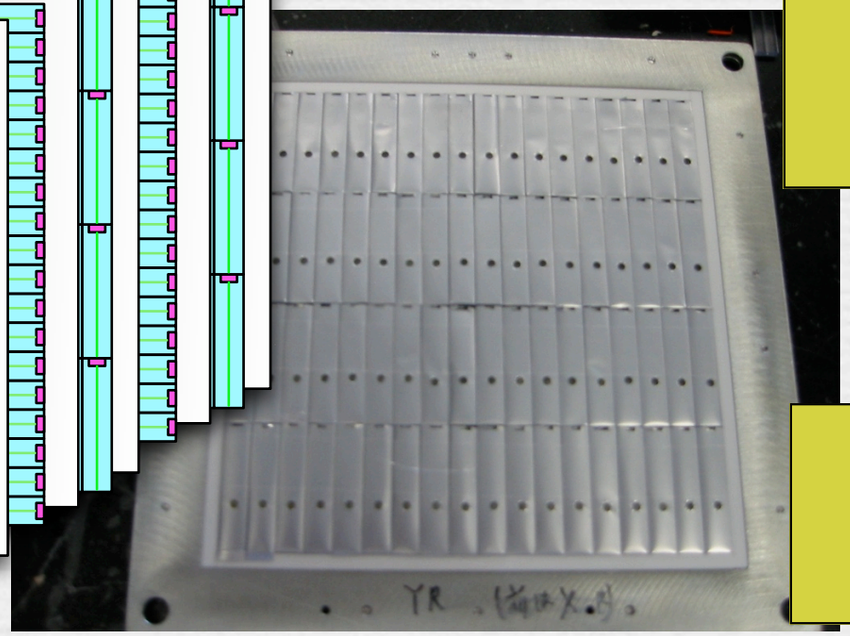




MPPC







TT Oct

EM-Scintillator-layer model Cross sec

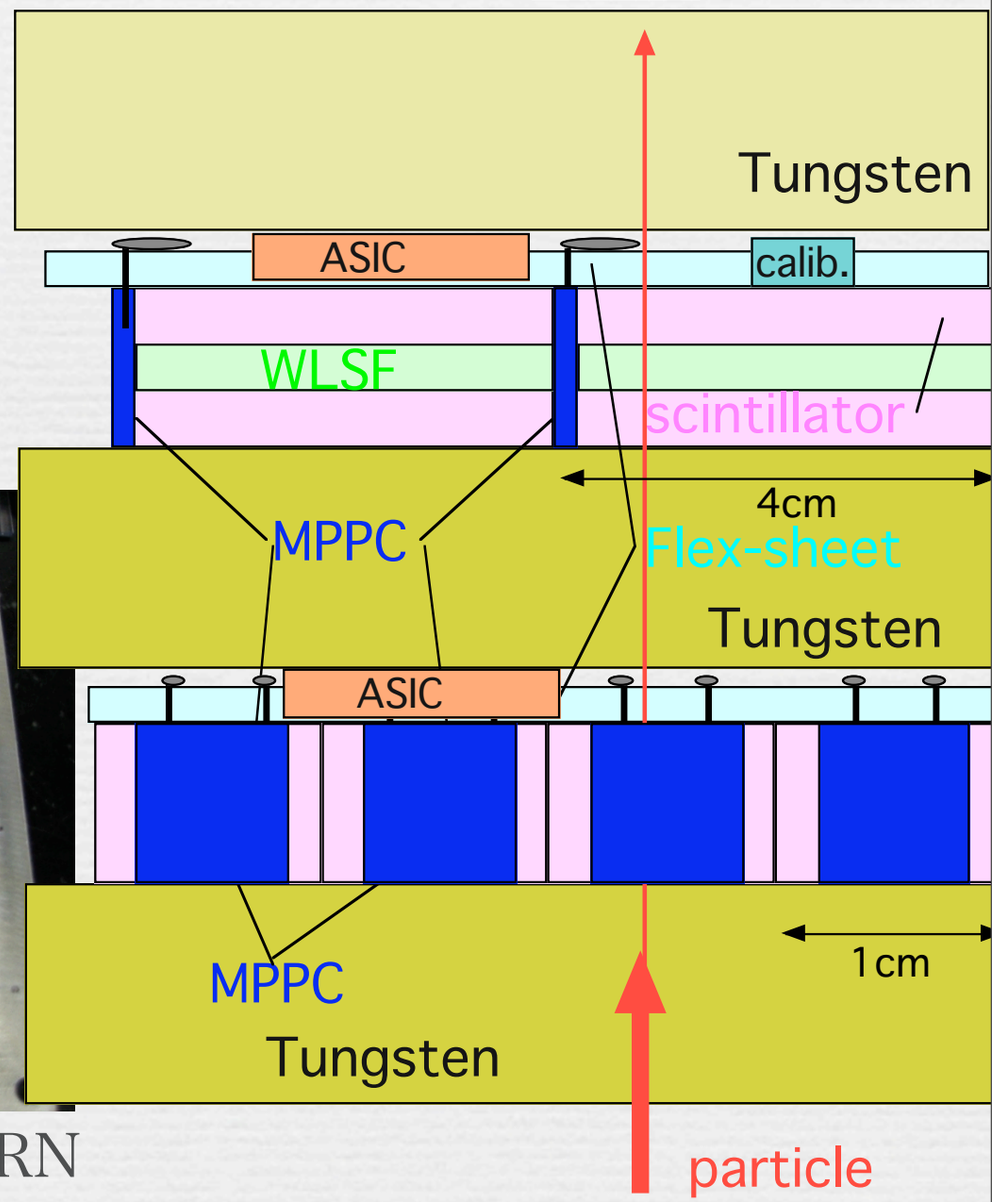
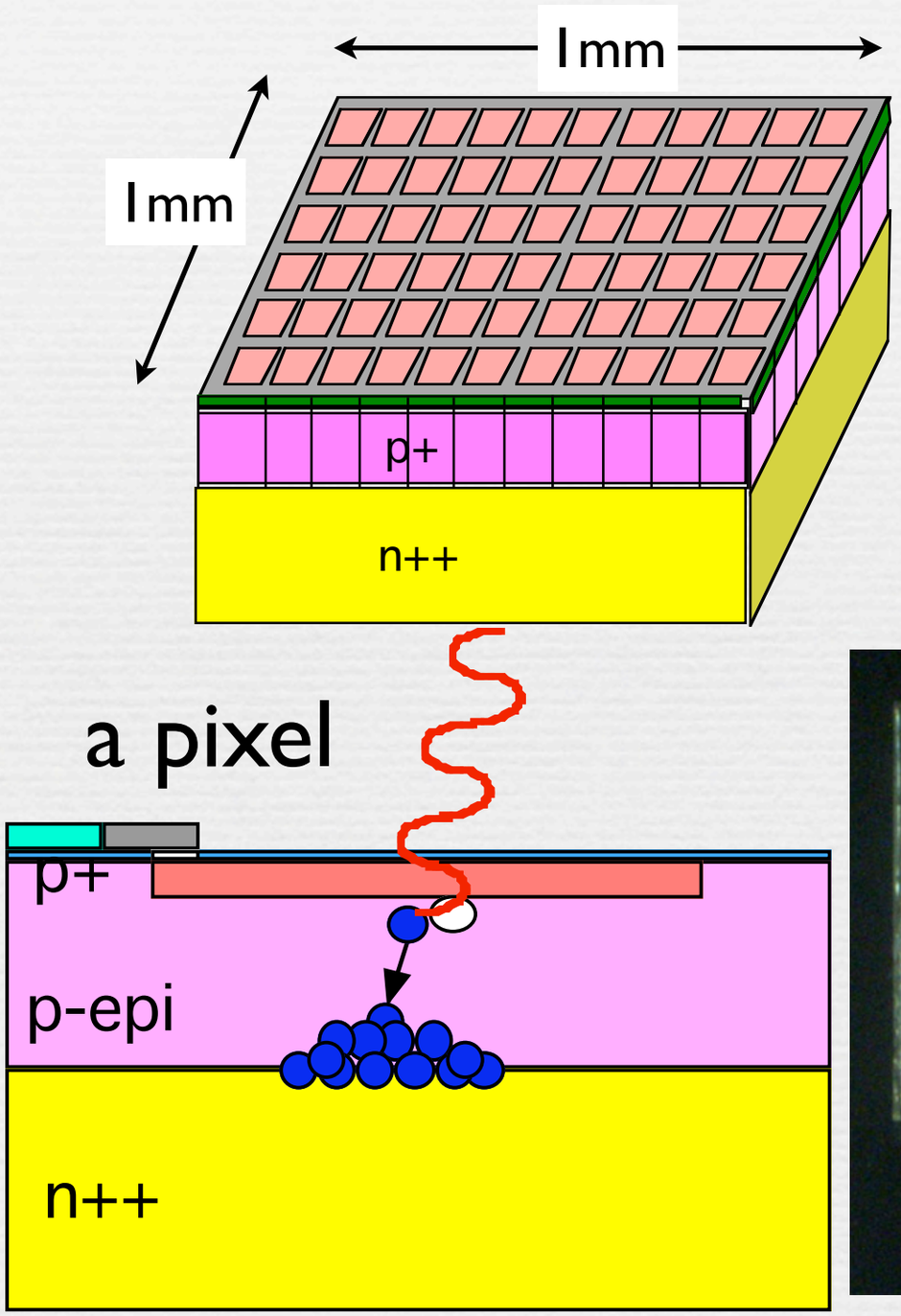


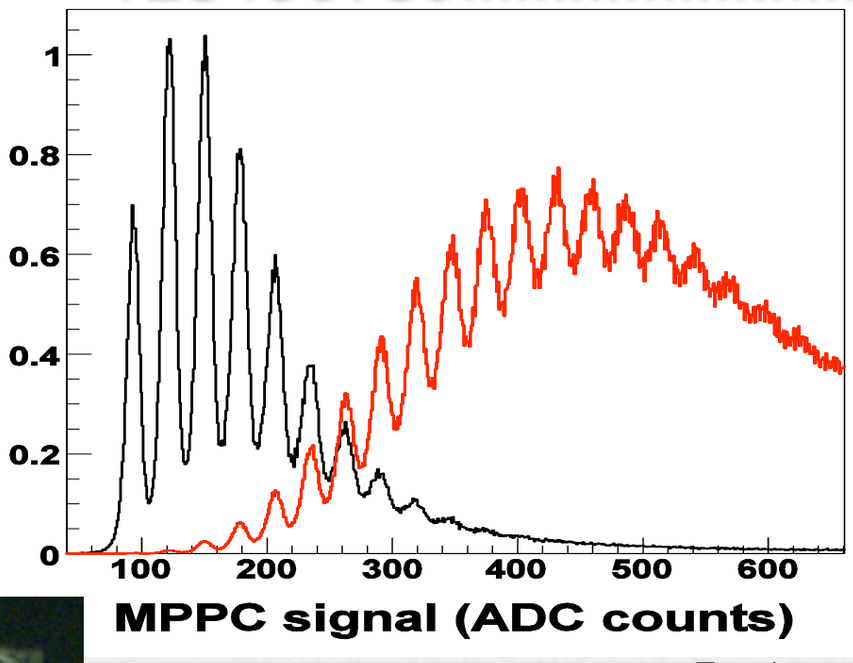
photo-sensor

- new type of photon sensor : Geiger Mode APD

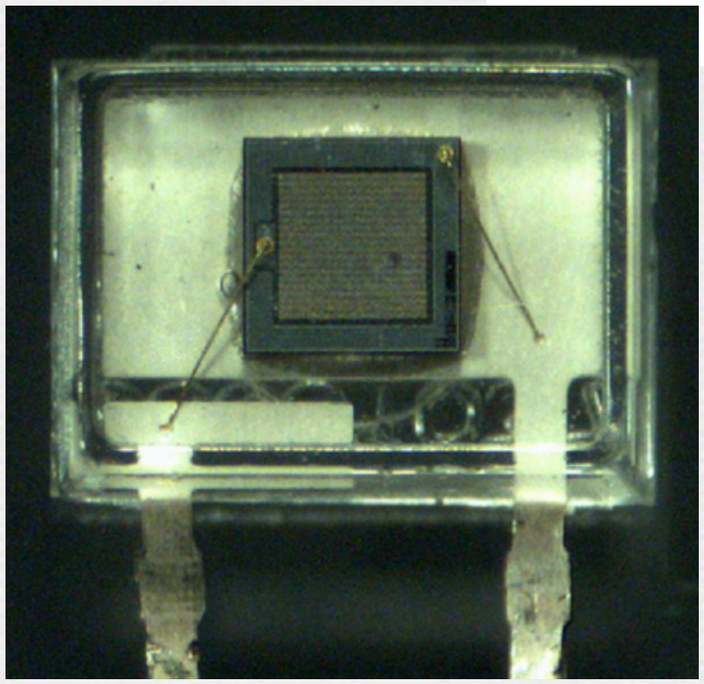


# of p. e.
= # of pix

123456789.....40



MPPC pict

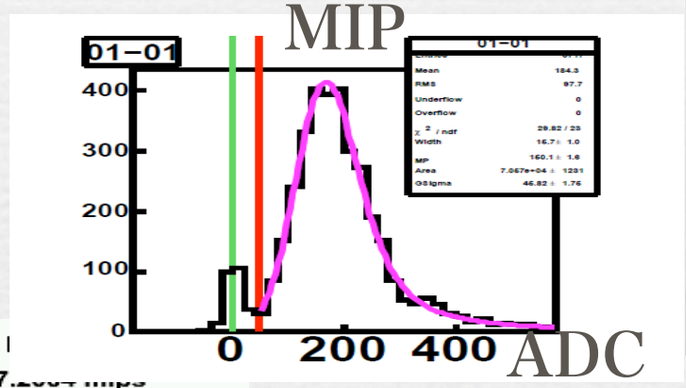


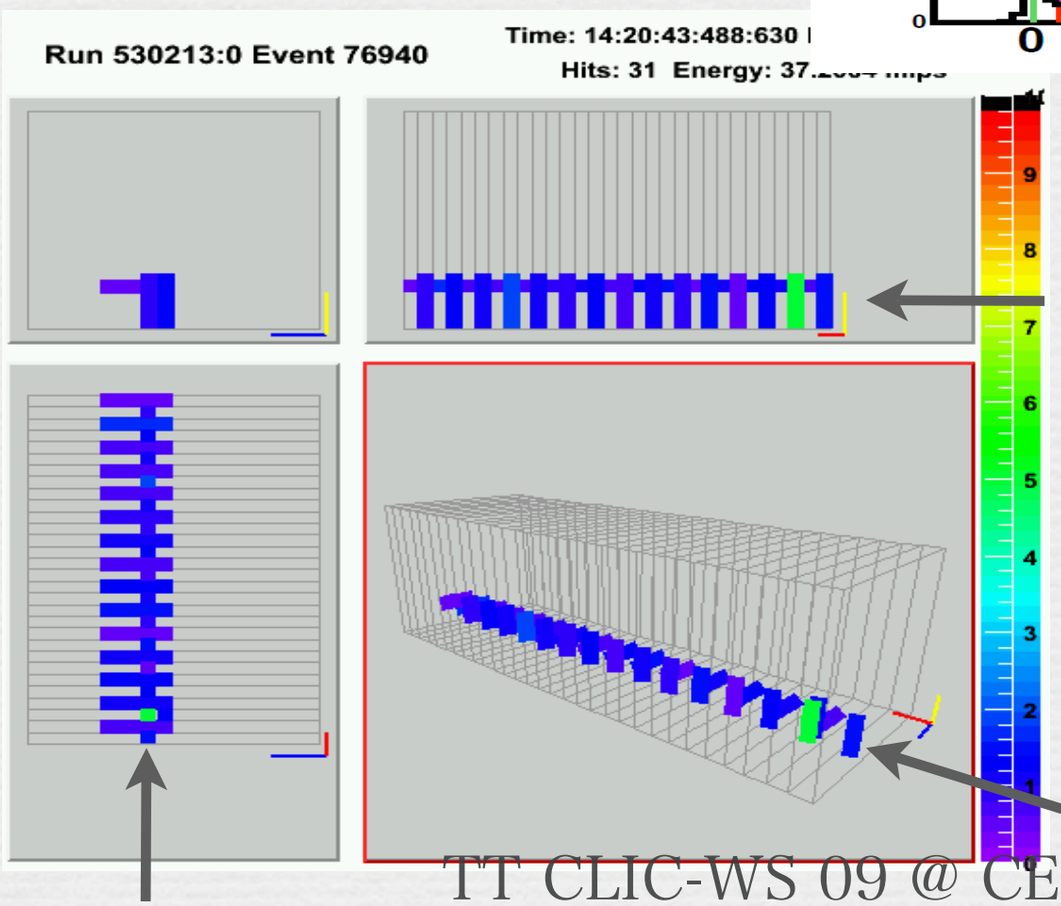
high gain ~ $10^{5\sim6}$
blue sensitive
low Voltage ~<100V
small ~1mm^2
insensitive to mag.

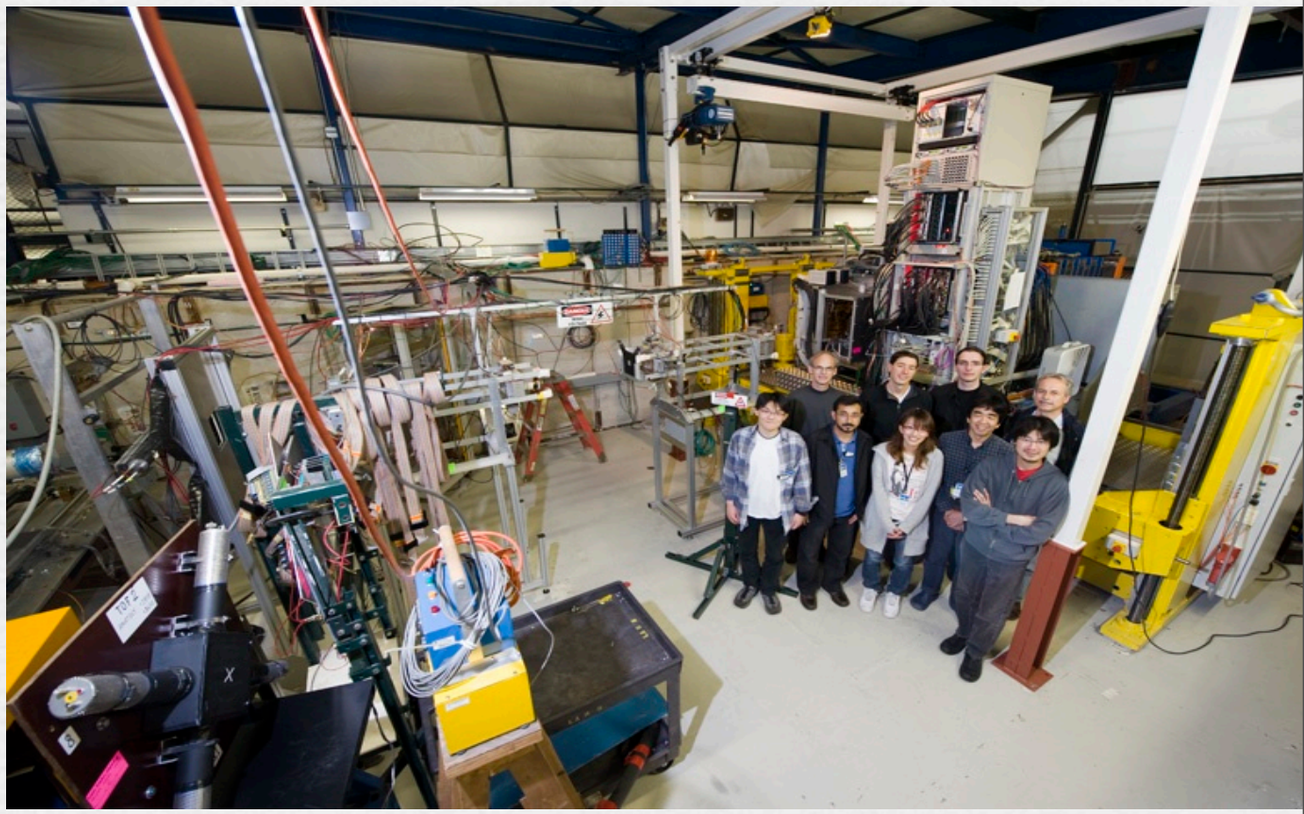
good time resolution < 1ns
more pix on CLIC

prototype module

- scintillator strip ECAL
- 18 x 18 x 26 cm^3
- tested at FNAL MT6 2008+09
- 2160 ch.





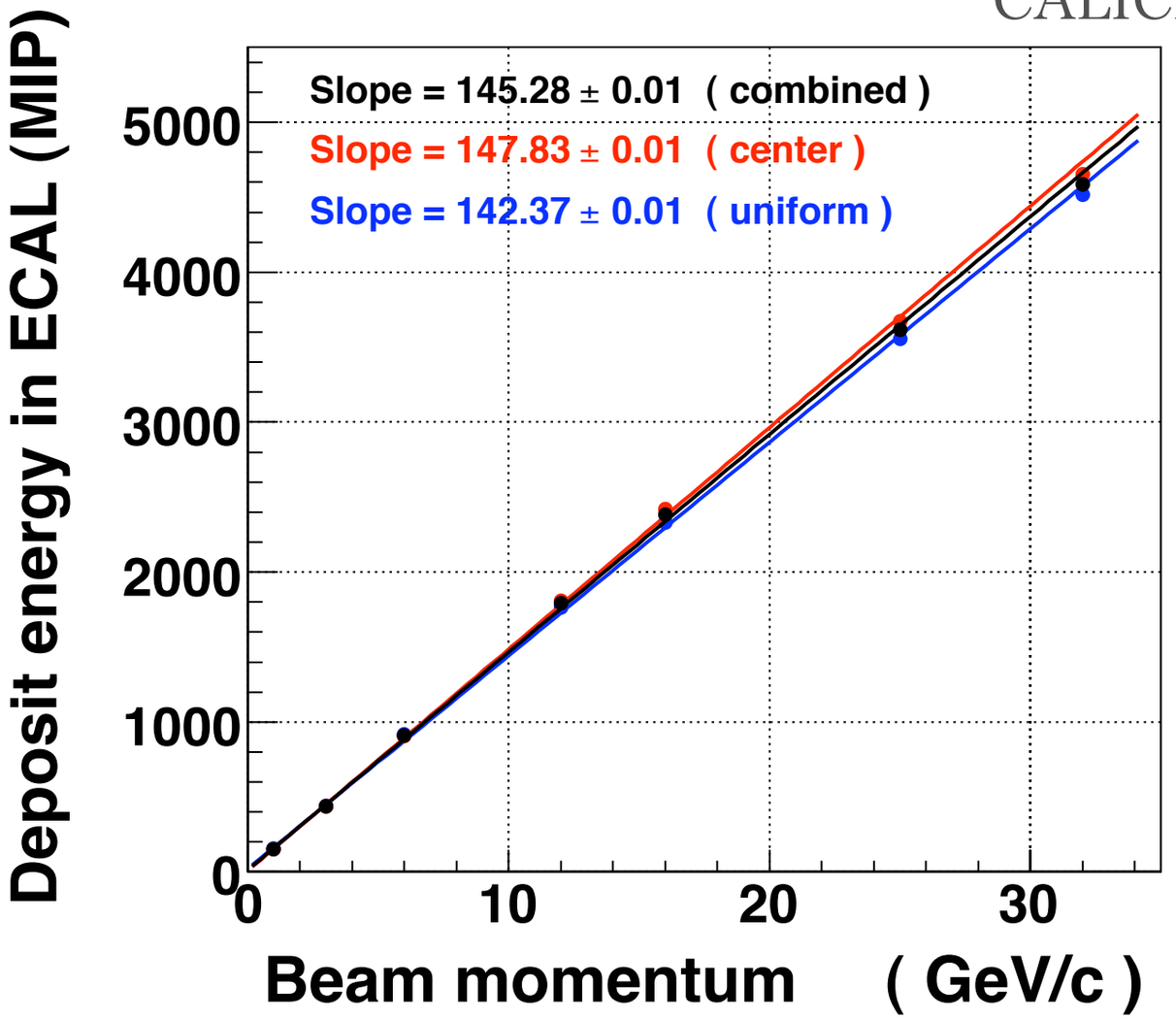


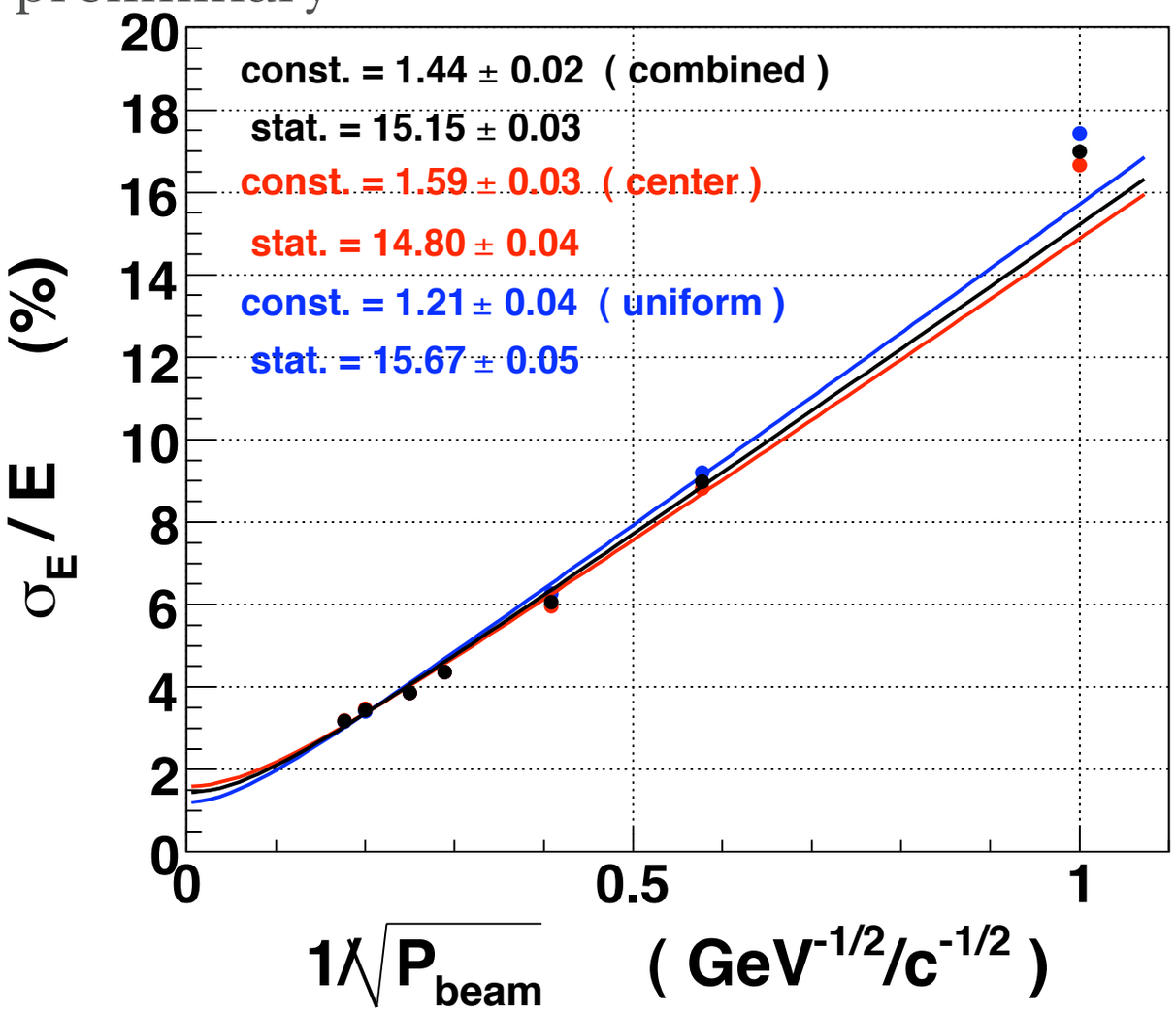
results of prototype

scintillator strip ECAL

- linearity and resolution

CALICE preliminary

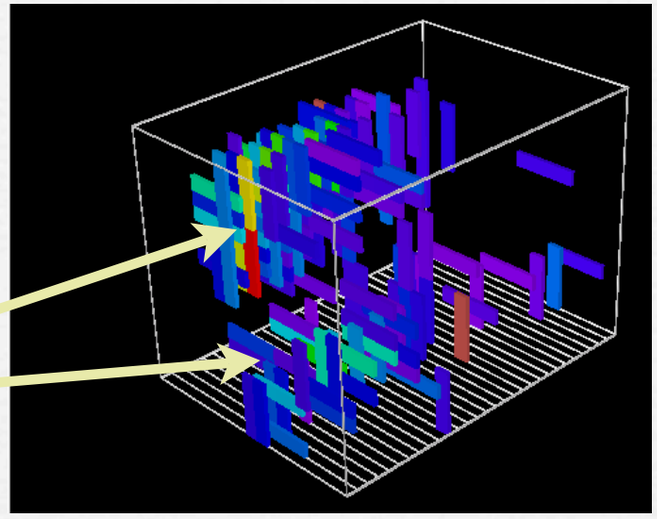


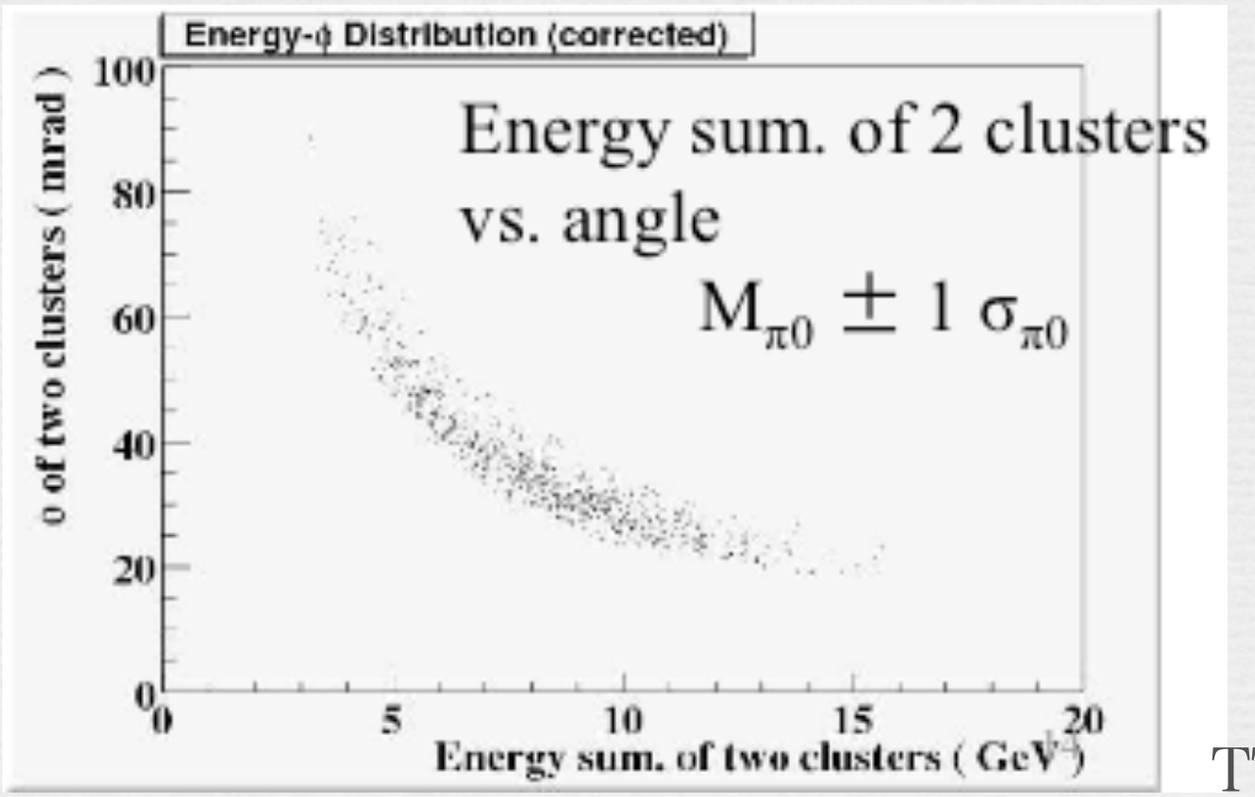


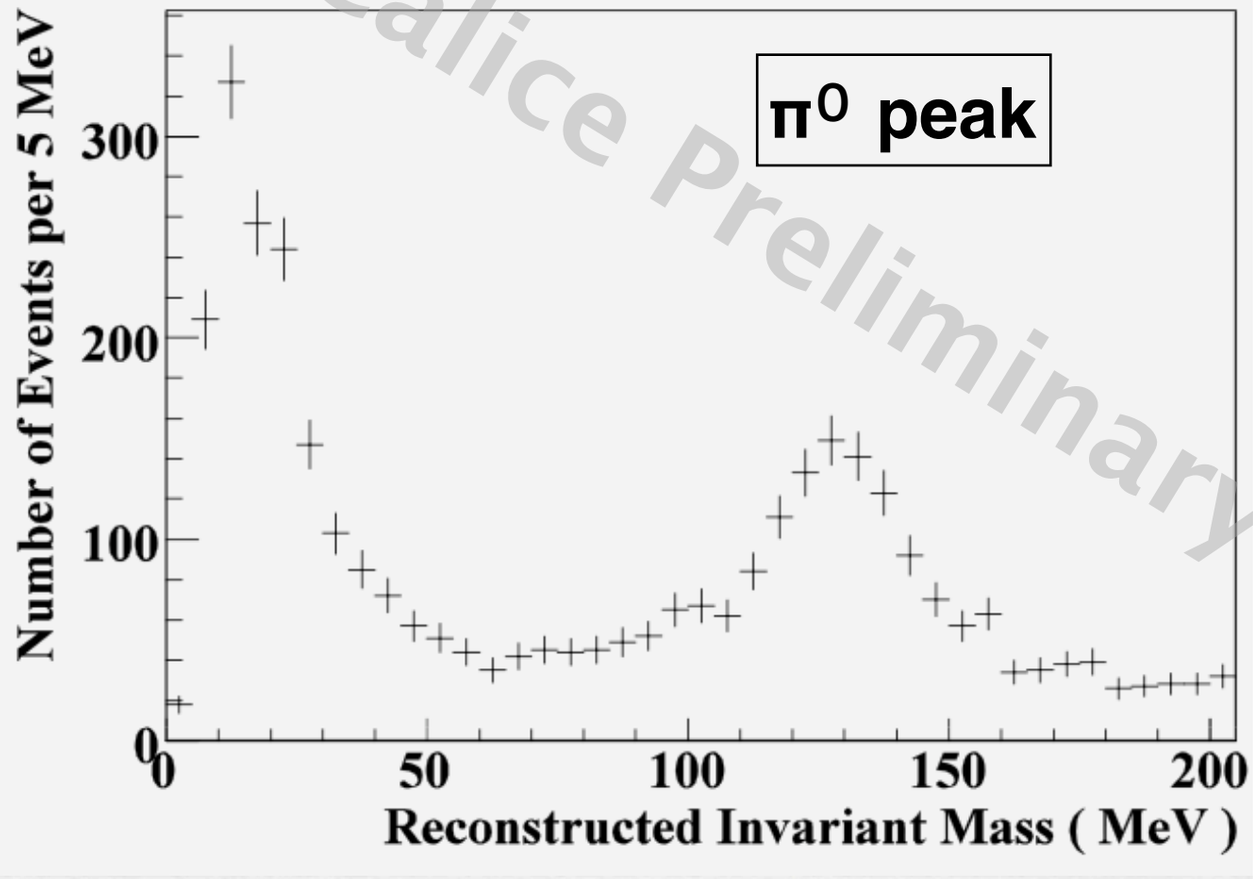
saturation effect of MPPC is corrected for each strip

π^0 reconstruction

- target in pion beam to make π^0
- find two isolated clusters
- calculate its mass
- with different Eπ

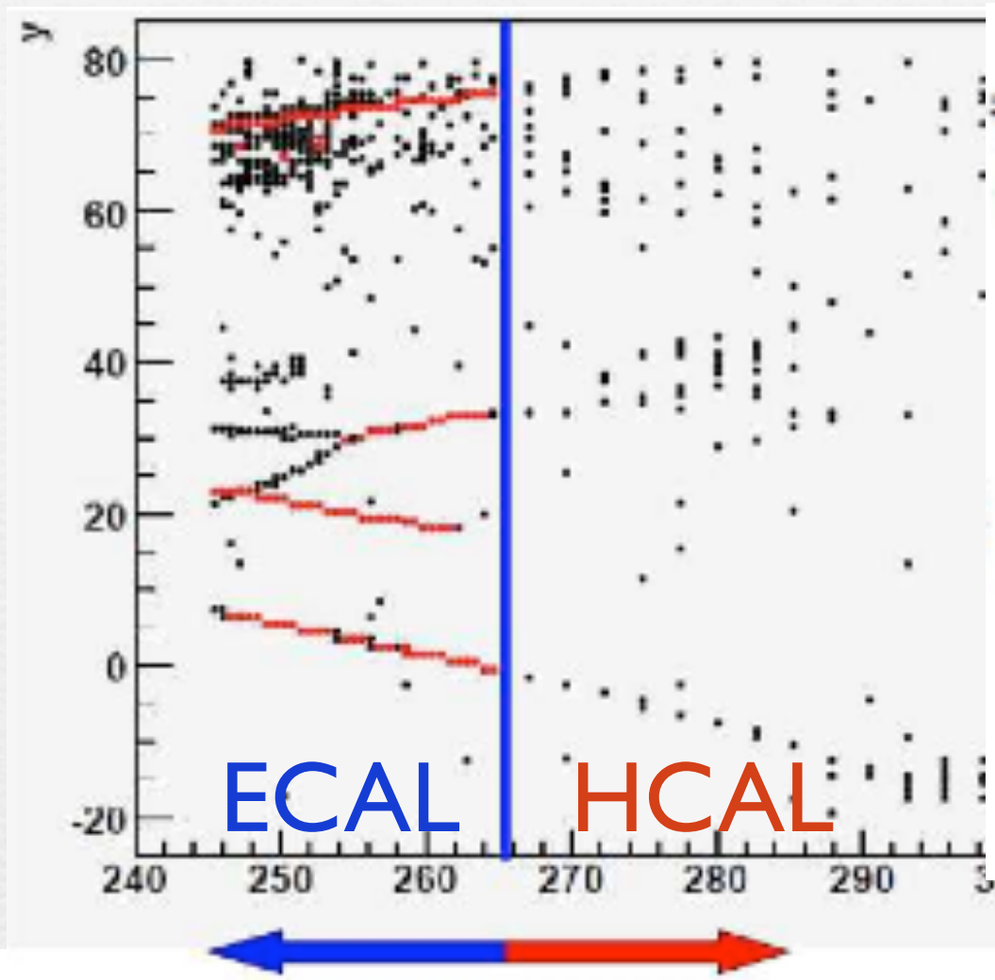


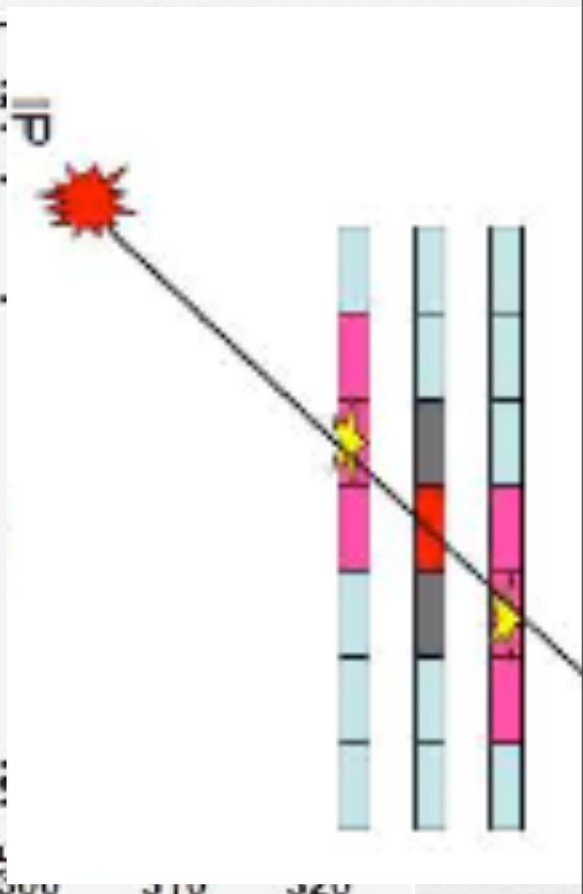




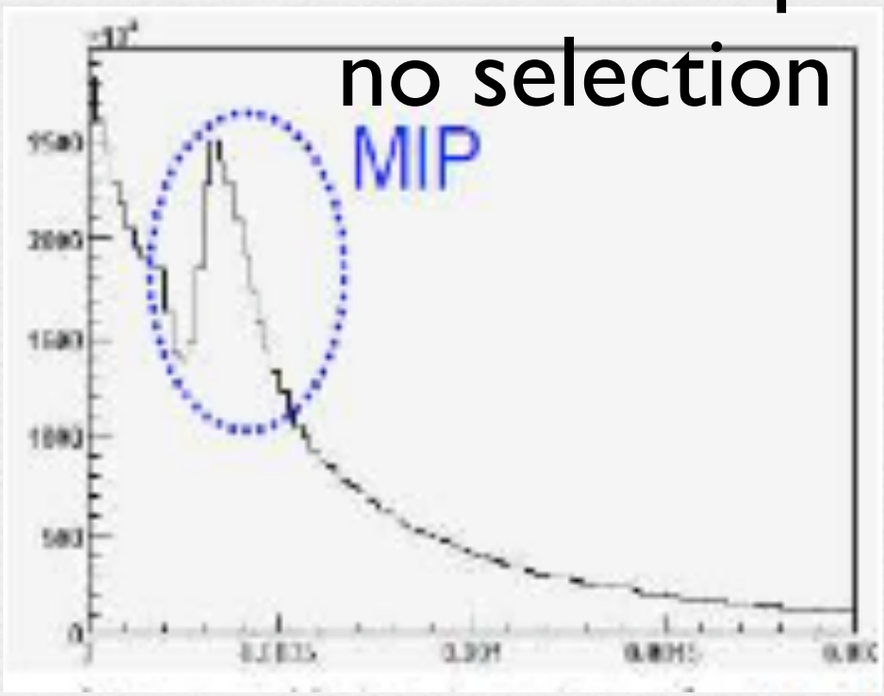
in situ calibration

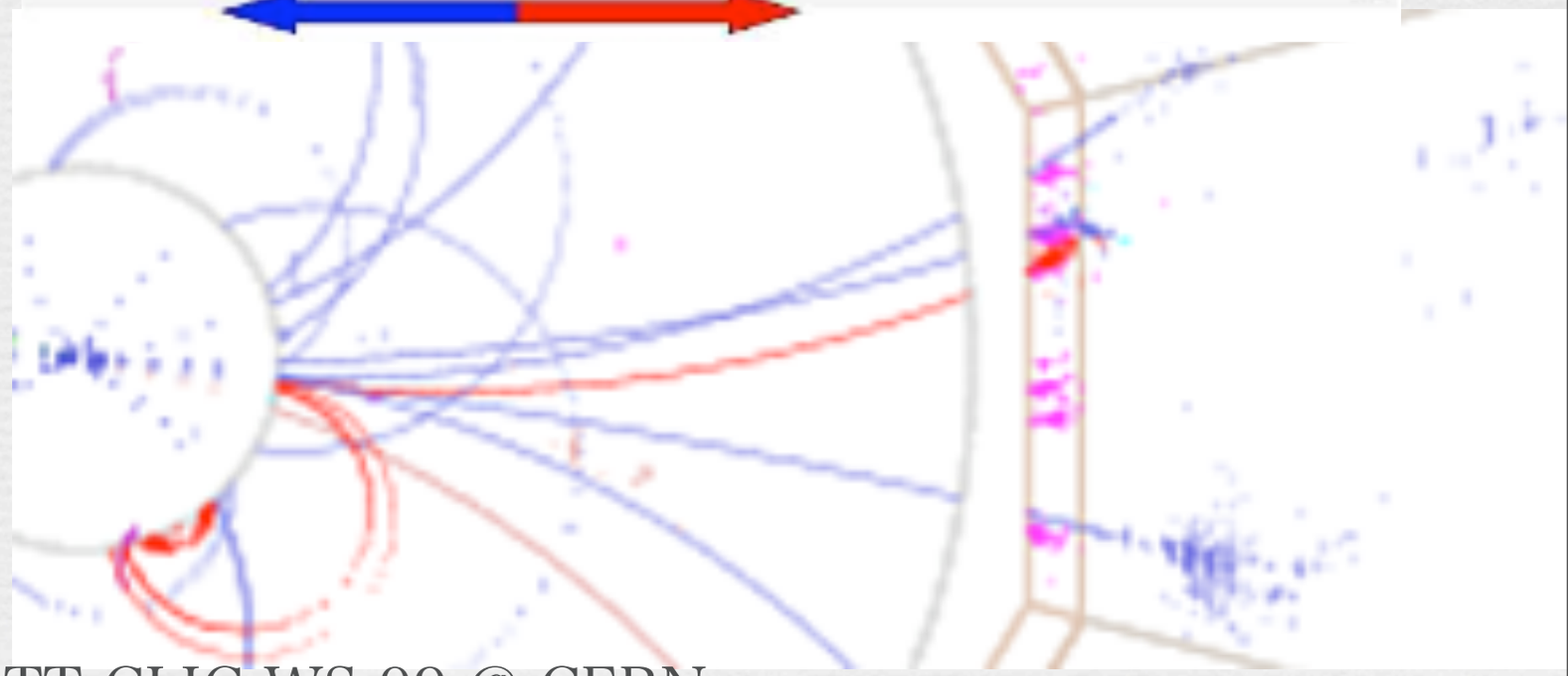
- use hadron tracks in ECAL
- simulation study
- 100 hits / strip
- 100 pb^{-1} at Z pole





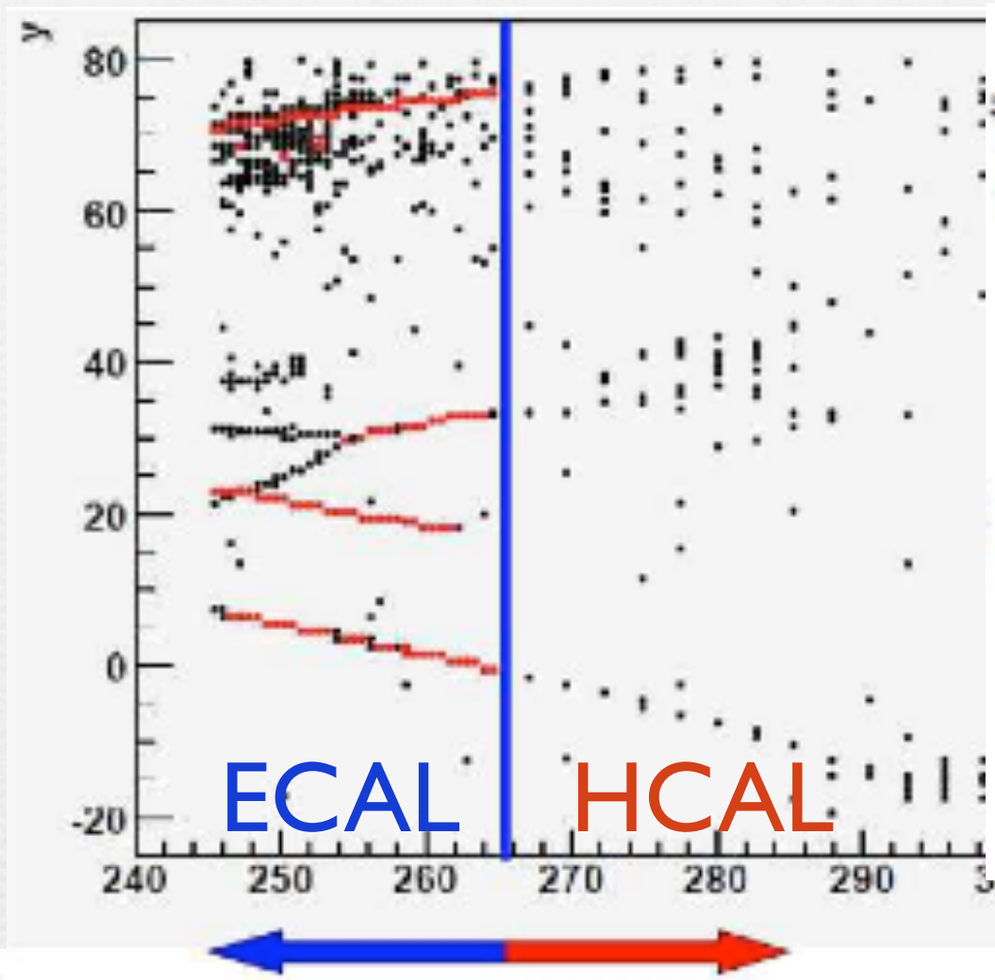
dE/dx /strip
no selection

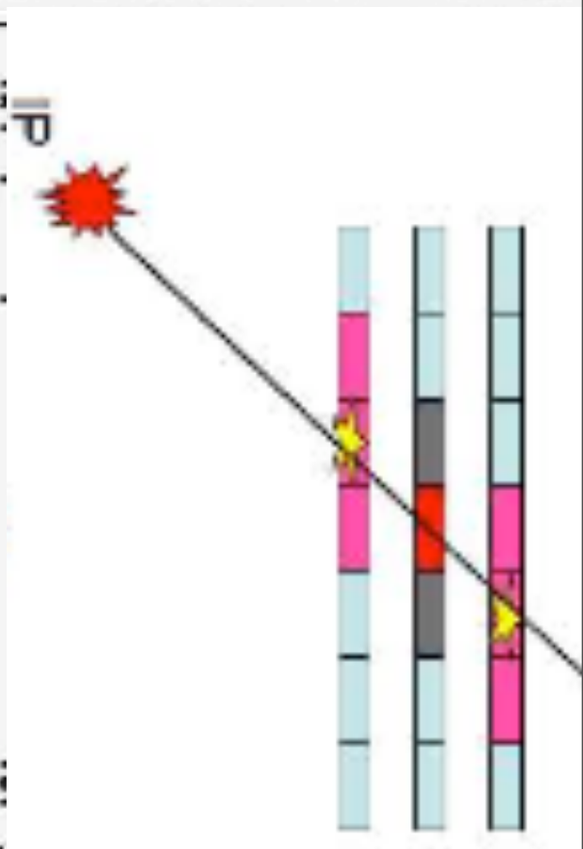




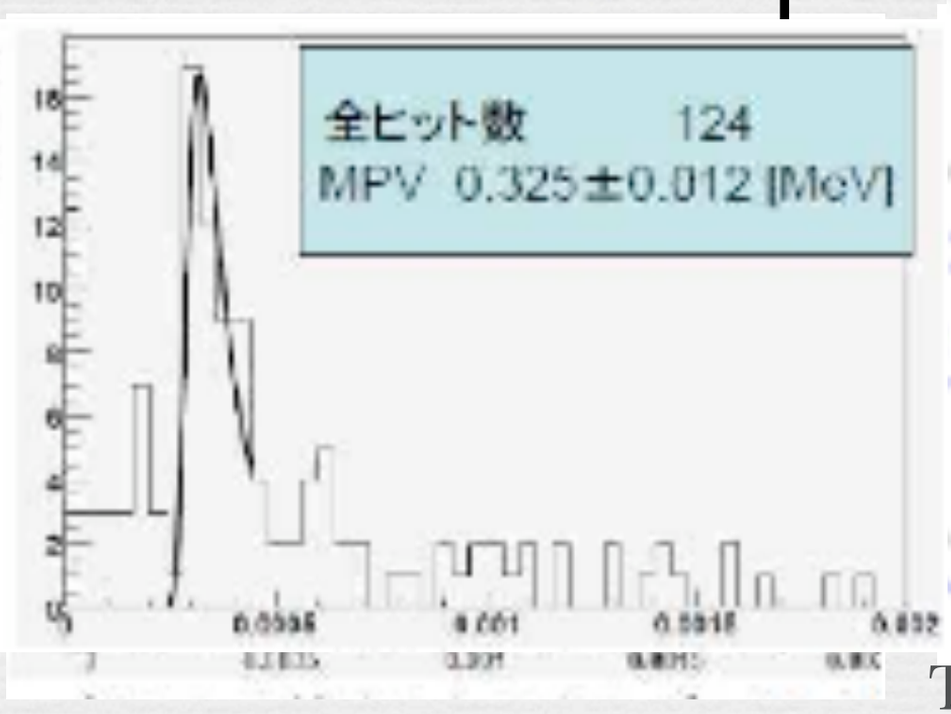
in situ calibration

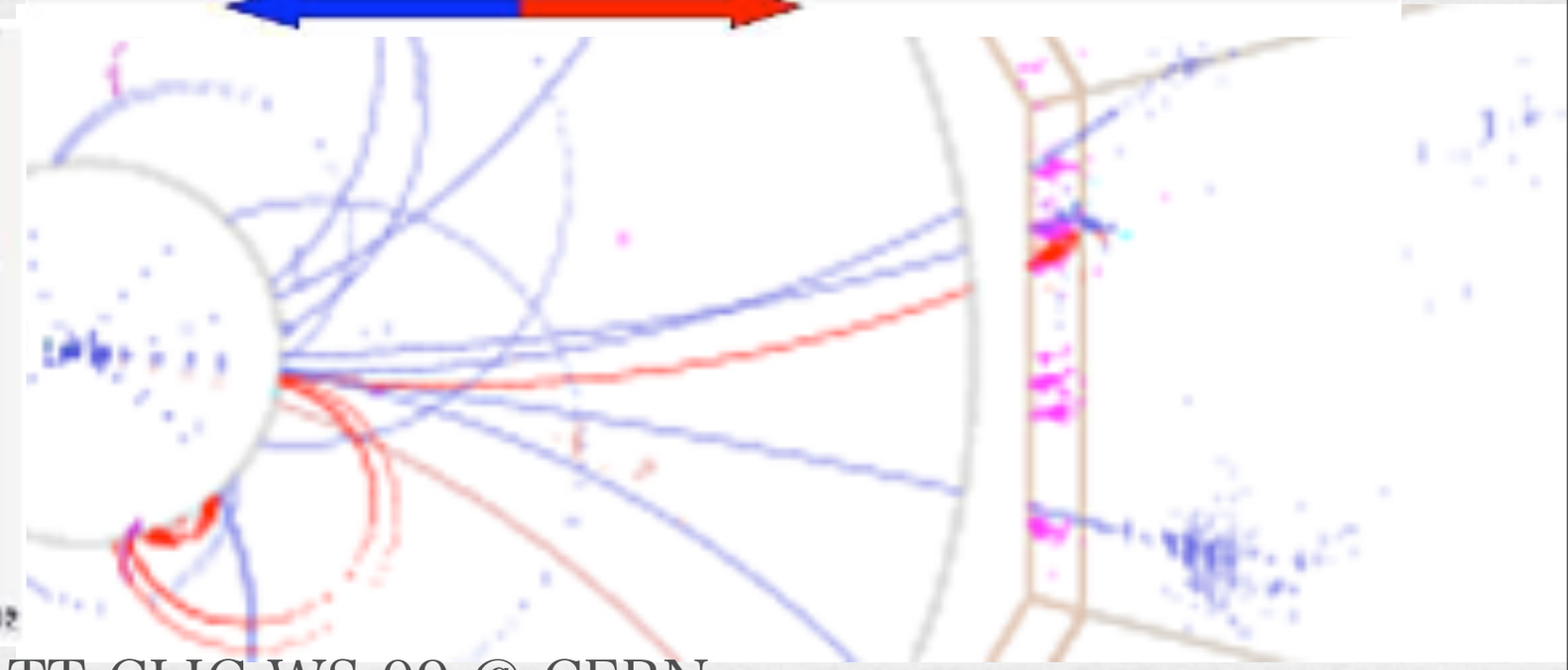
- use hadron tracks in ECAL
- simulation study
- 100 hits / strip
- 100 pb^{-1} at Z pole





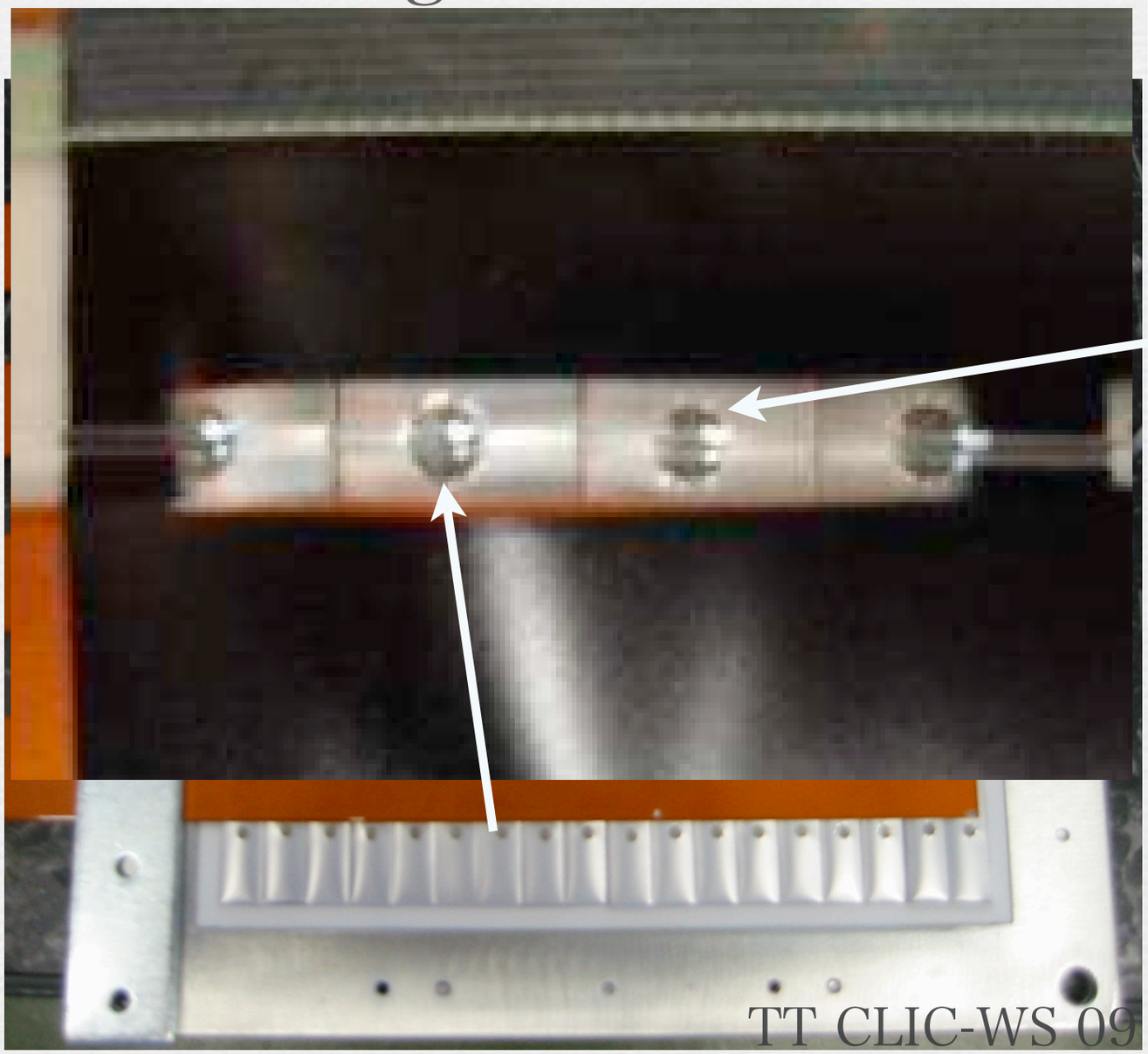
dE/dx /strip

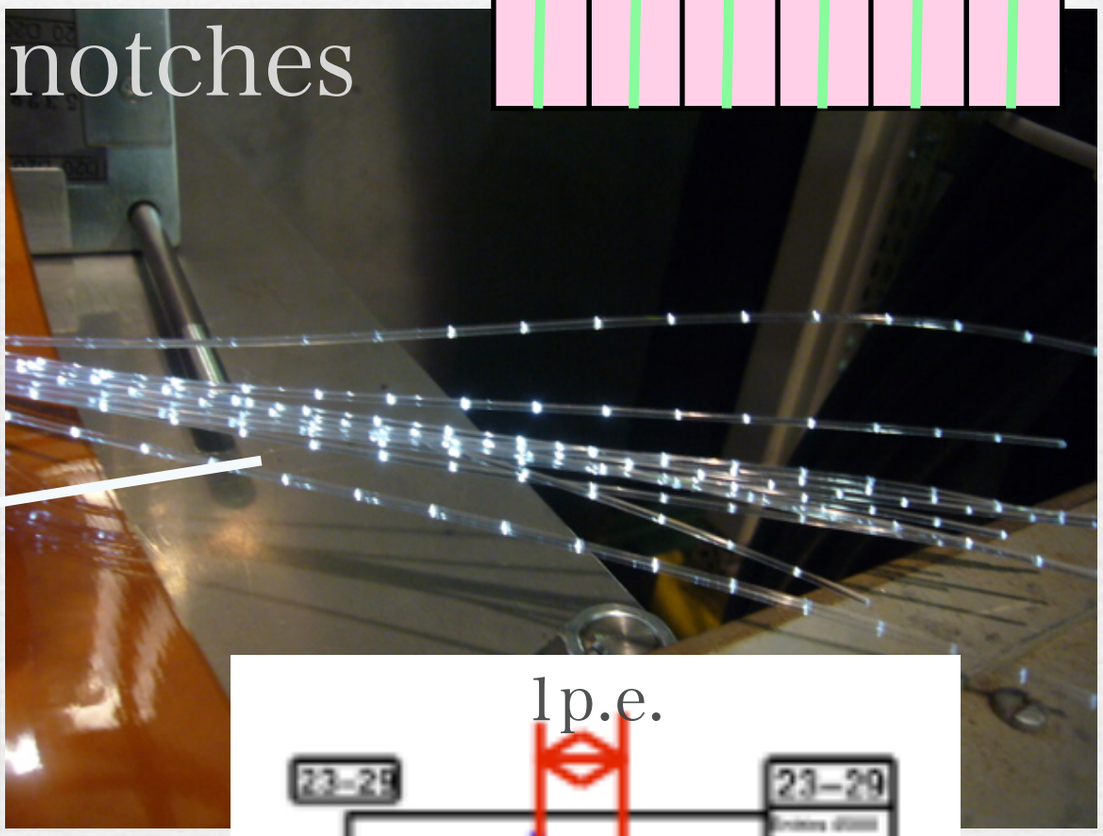


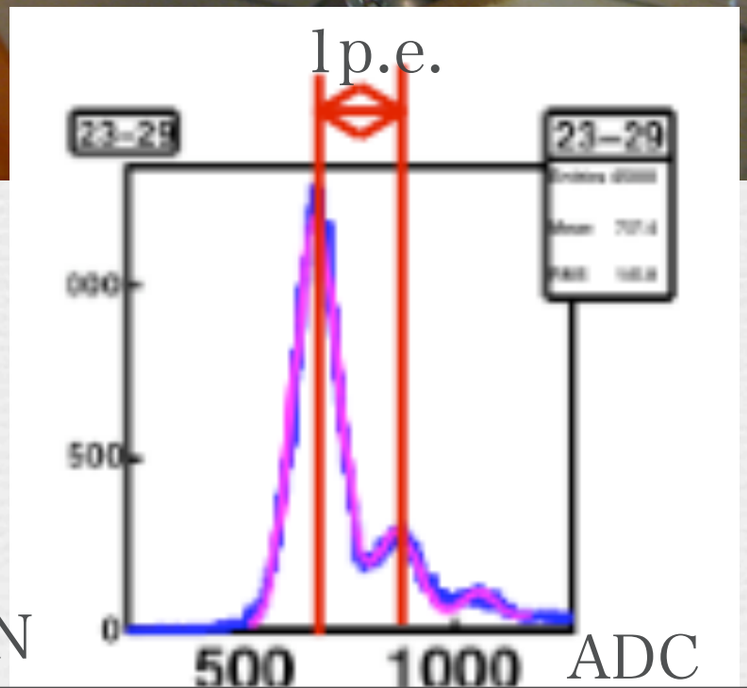


monitoring system

- MPPC has auto-gain calibration capability
- to monitor 1 p.e. w/o LED
- LED though clear fiber with notches

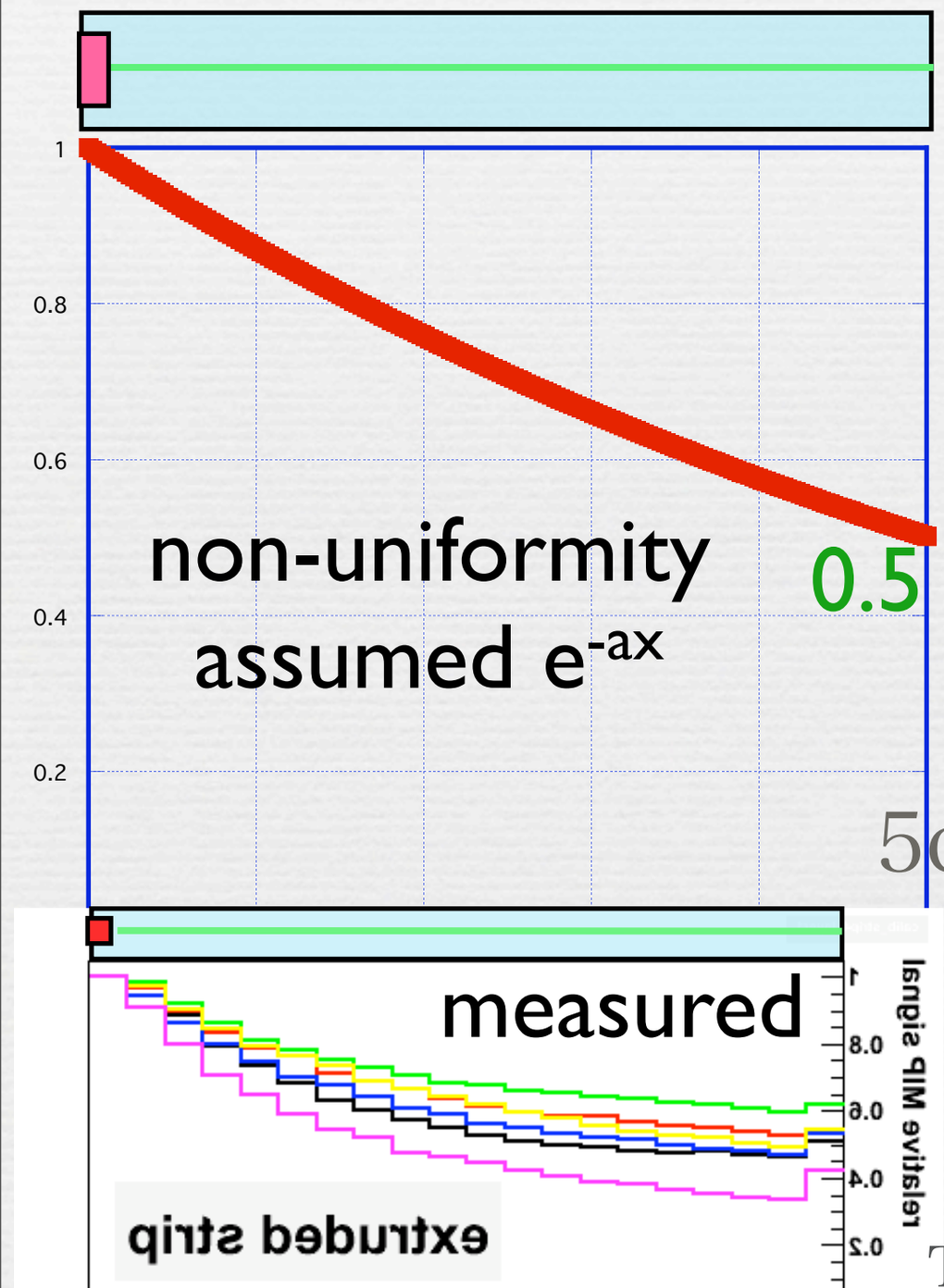


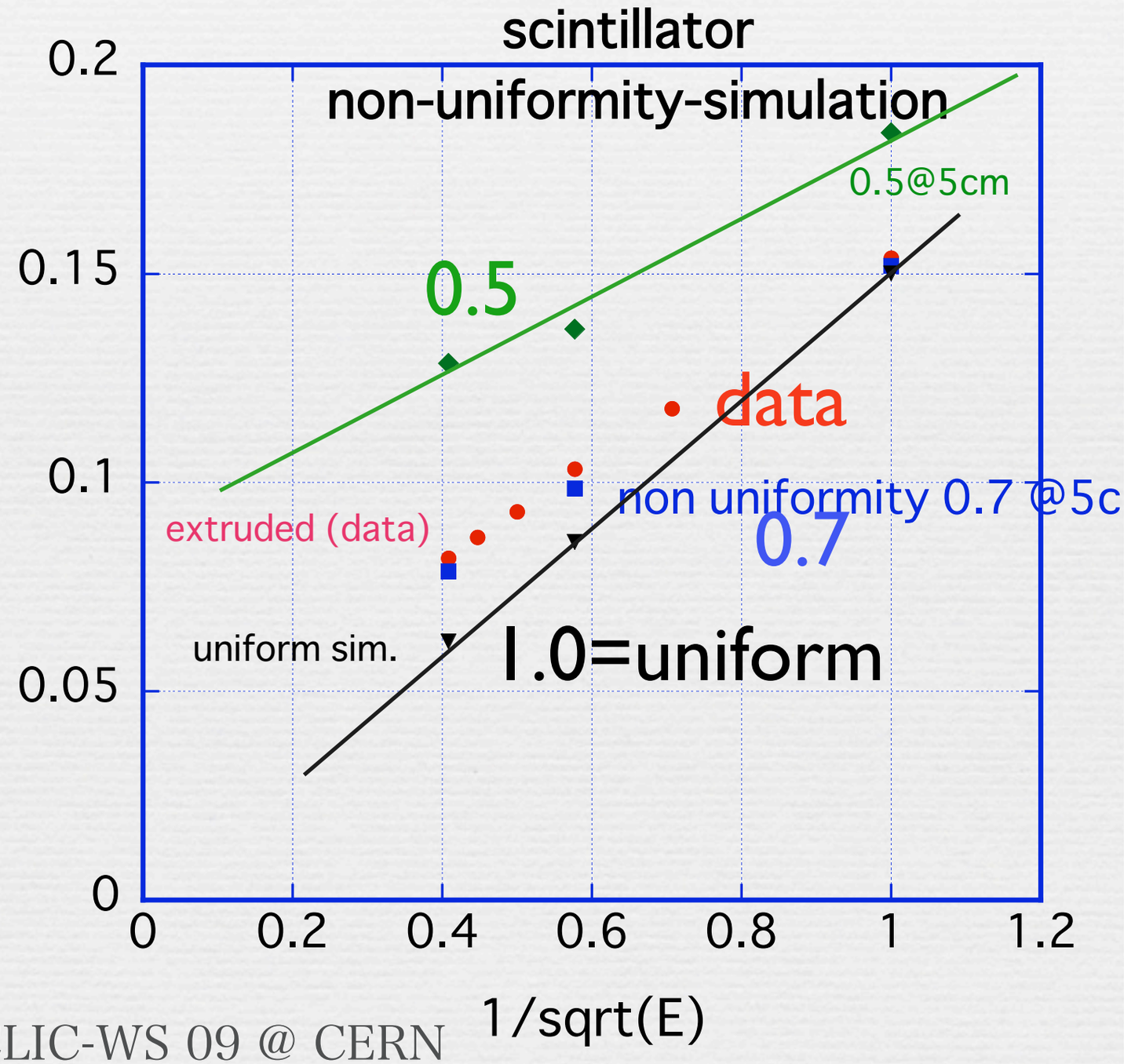




non-uniformity effect

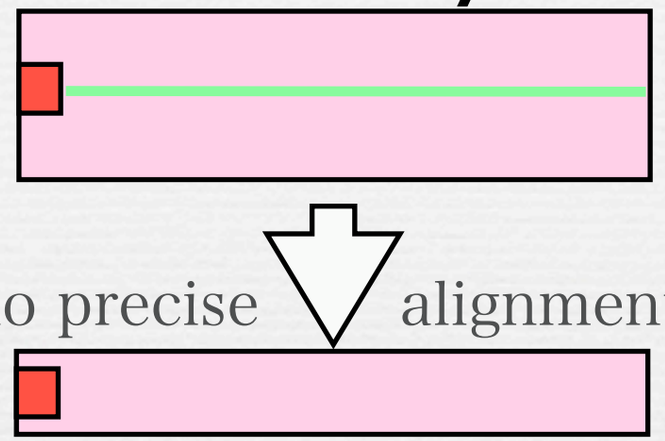
- non uniformity of scintillator causes constant term in energy resolution



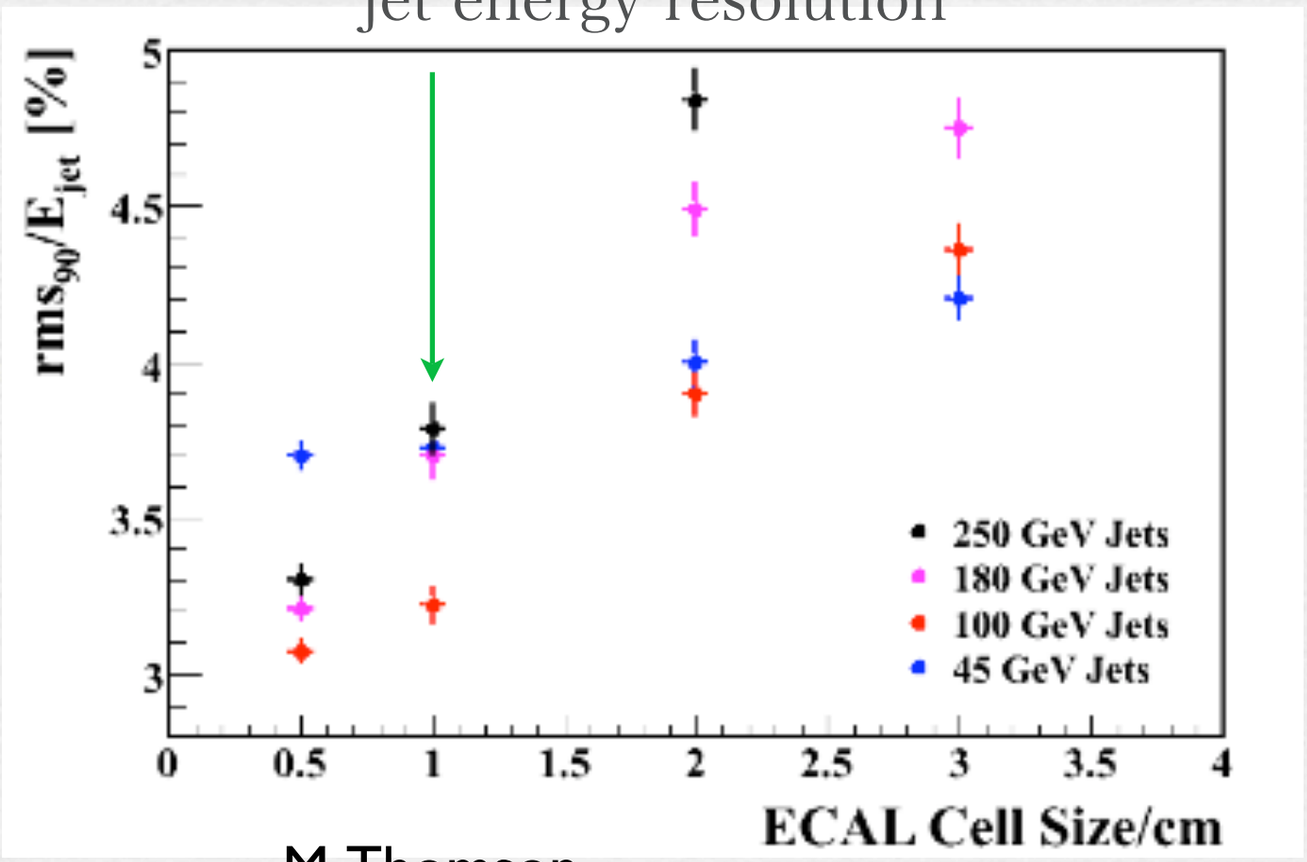


Further segmentation ECAL

- 5mm width is favored by current PFA study
- WLSF-less configuration
- which looks promising



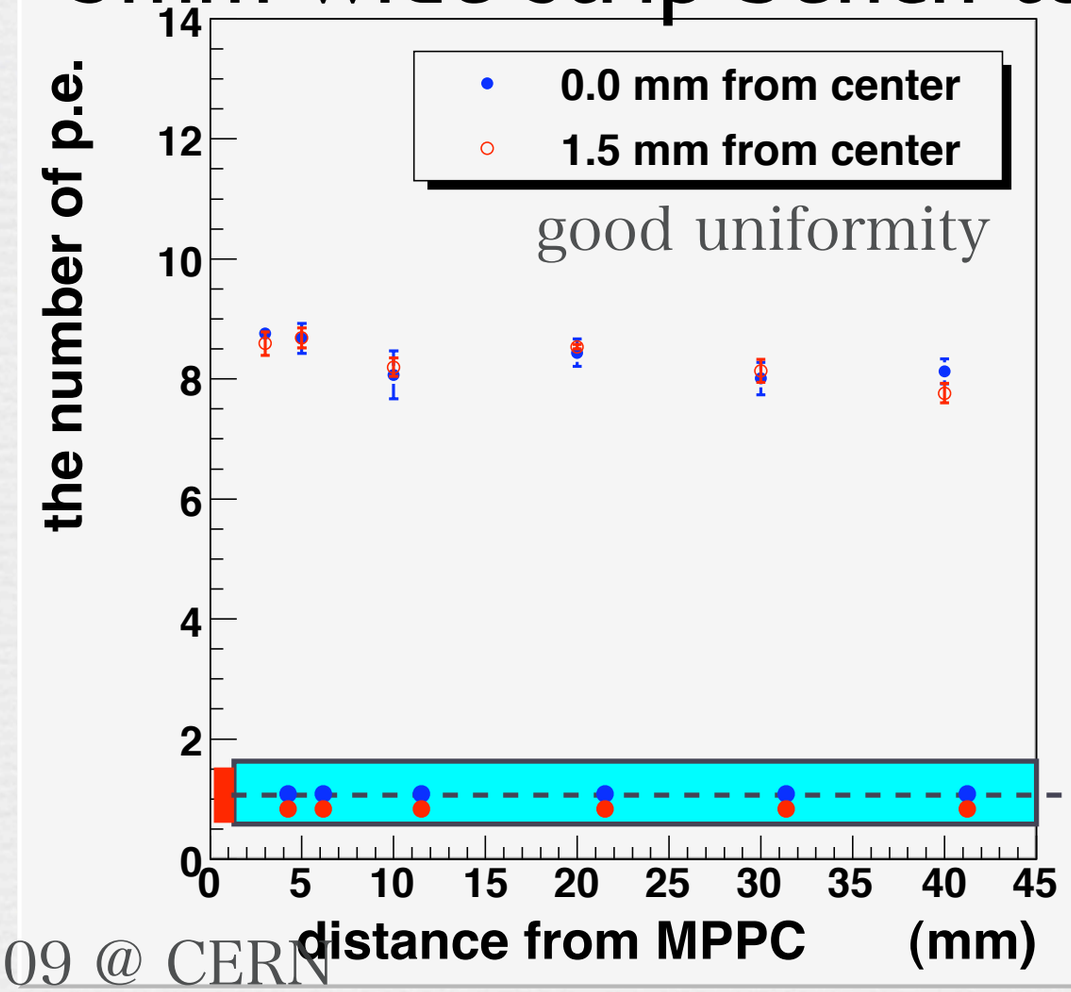
jet energy resolution



M. Thomson

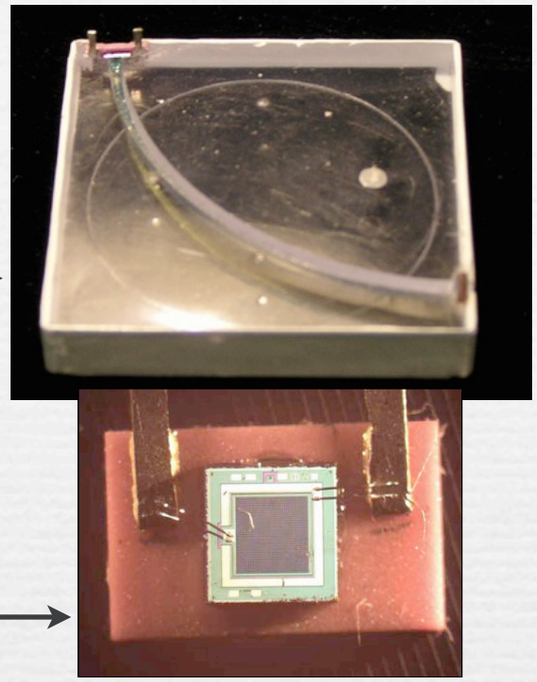
severer on CLIC

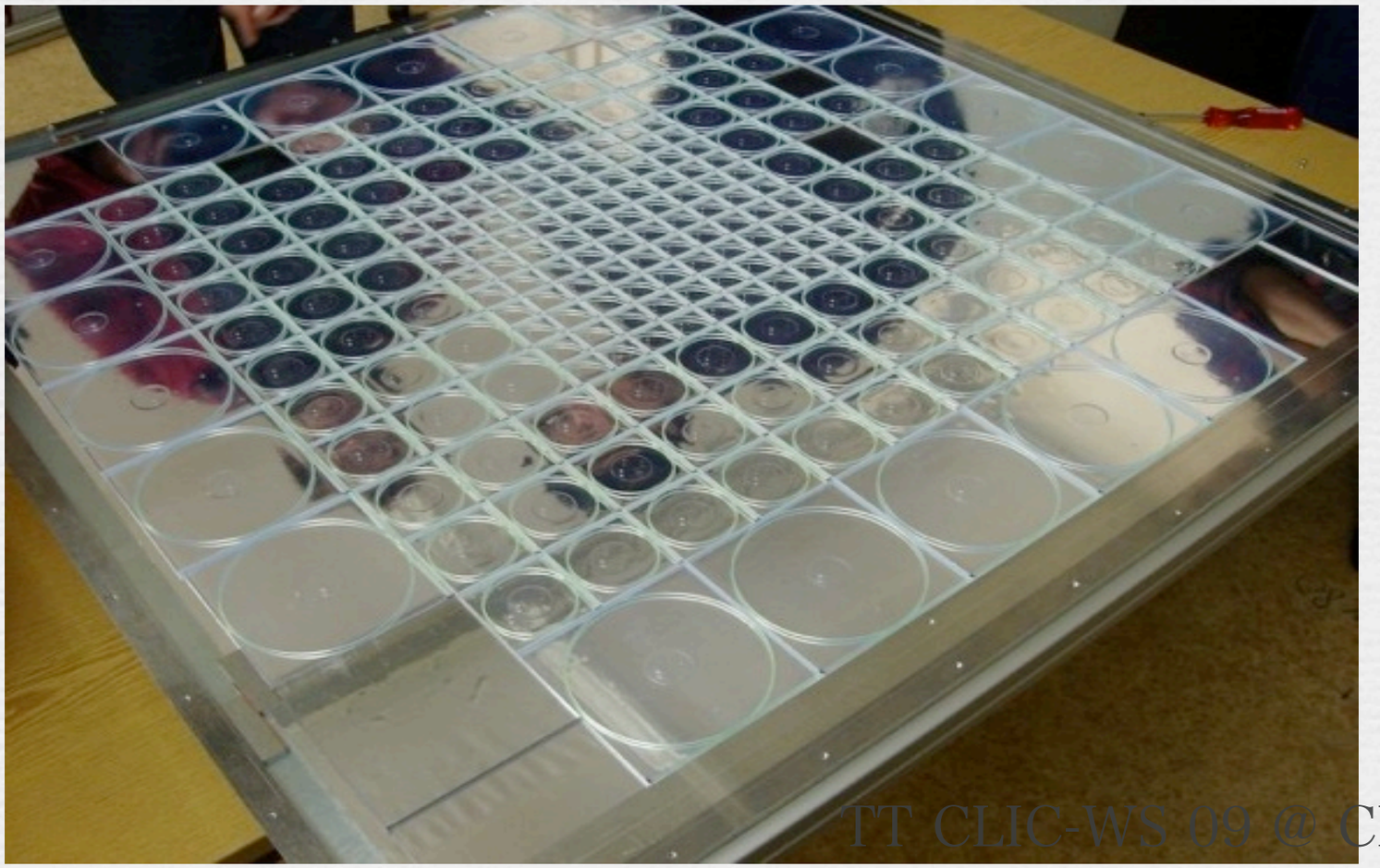
5mm wide strip bench test

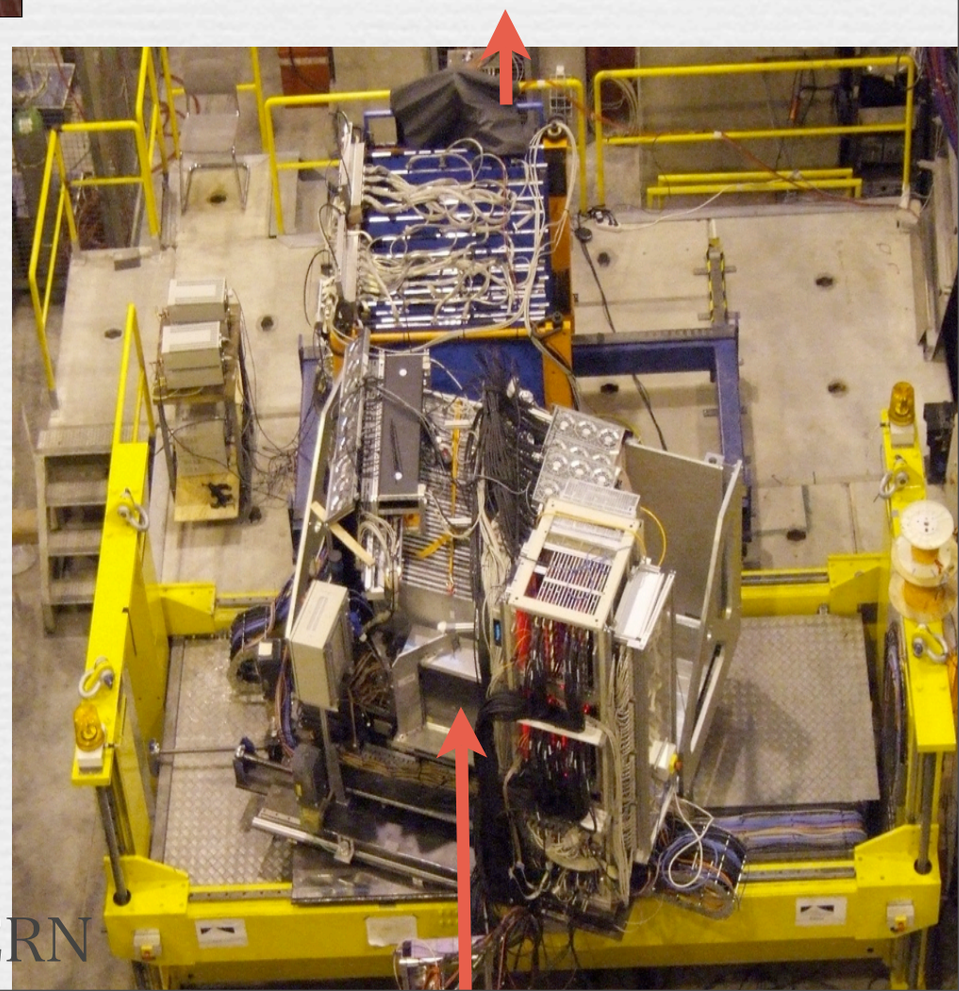


scintillator HCAL

- CALICE AHCAL
- scintillator tiles
- 3cm x 3cm x 0.5cm
- with SiPM

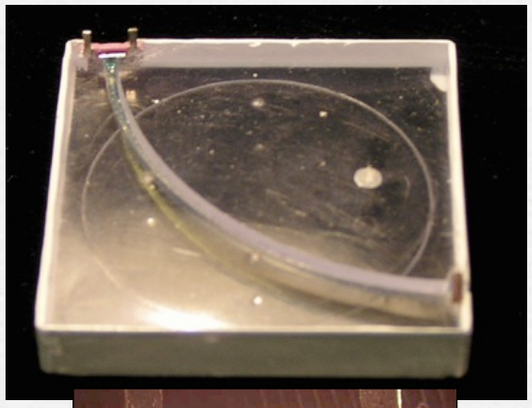


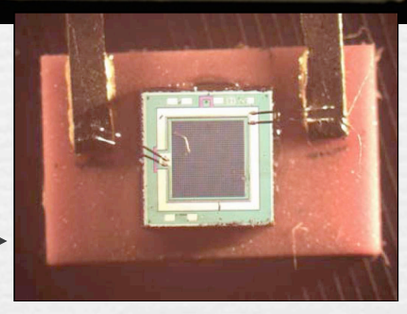


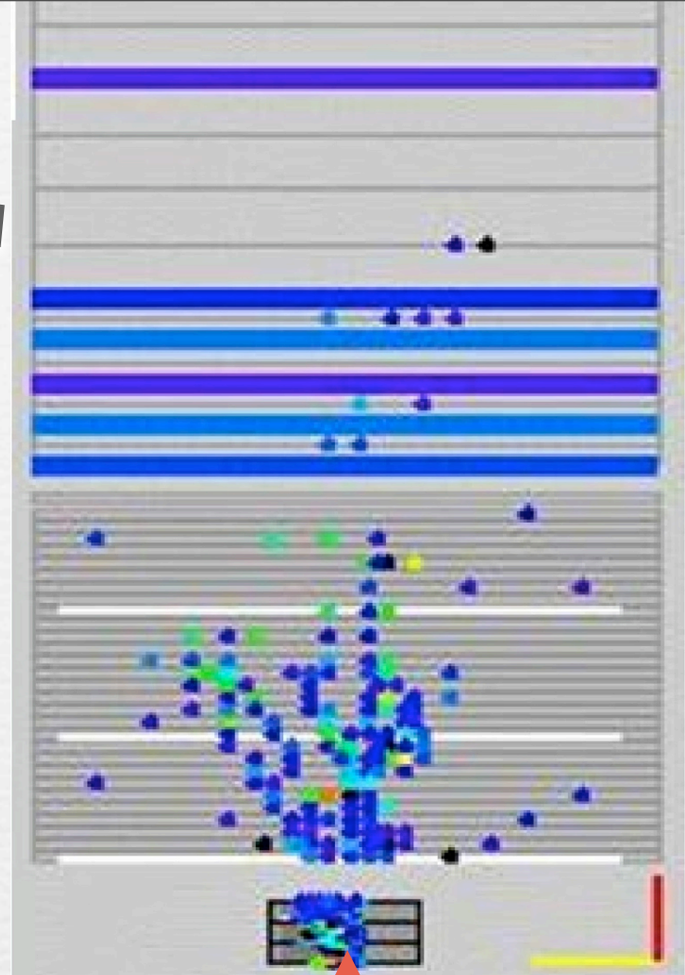


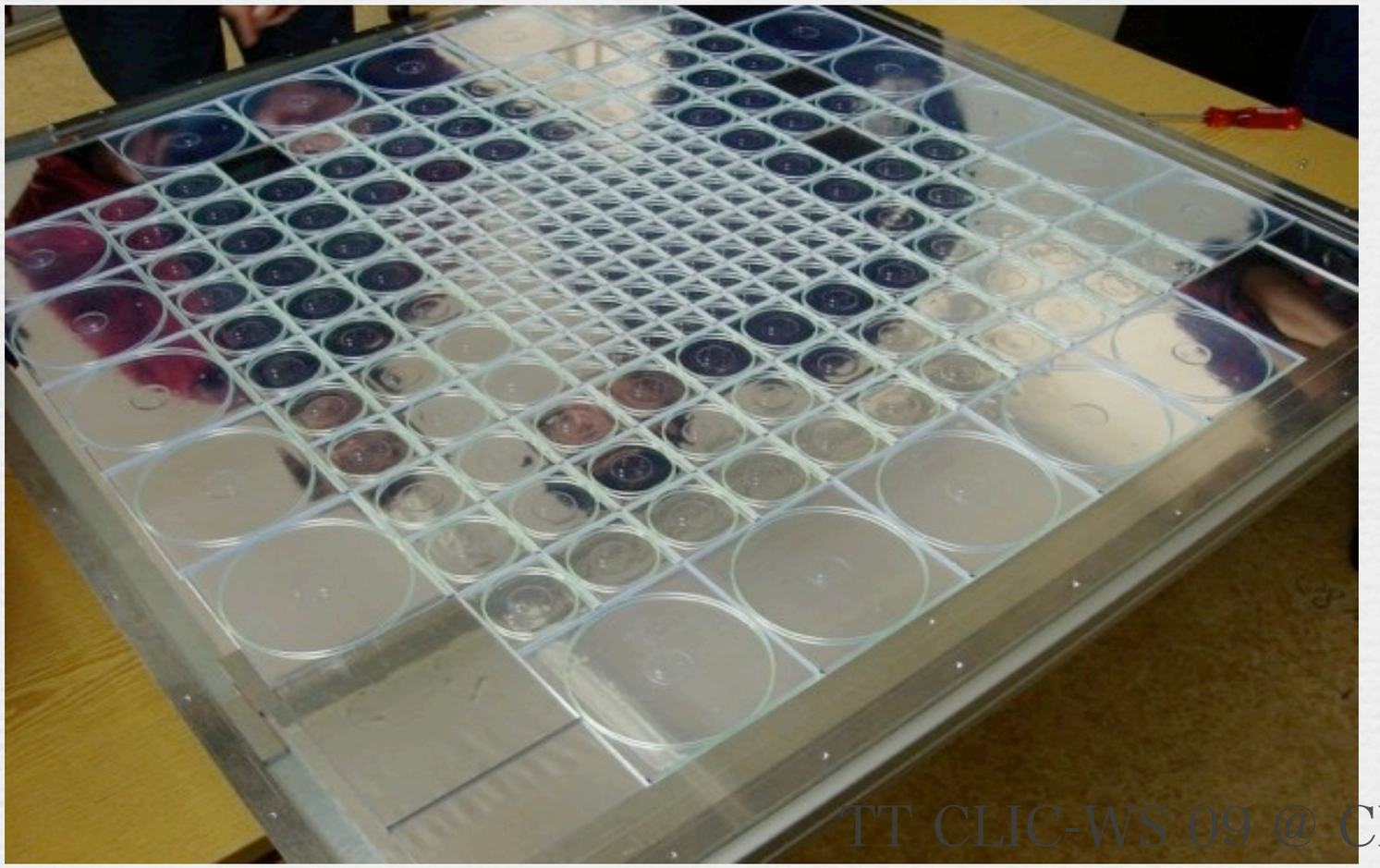
scintillator HCAL

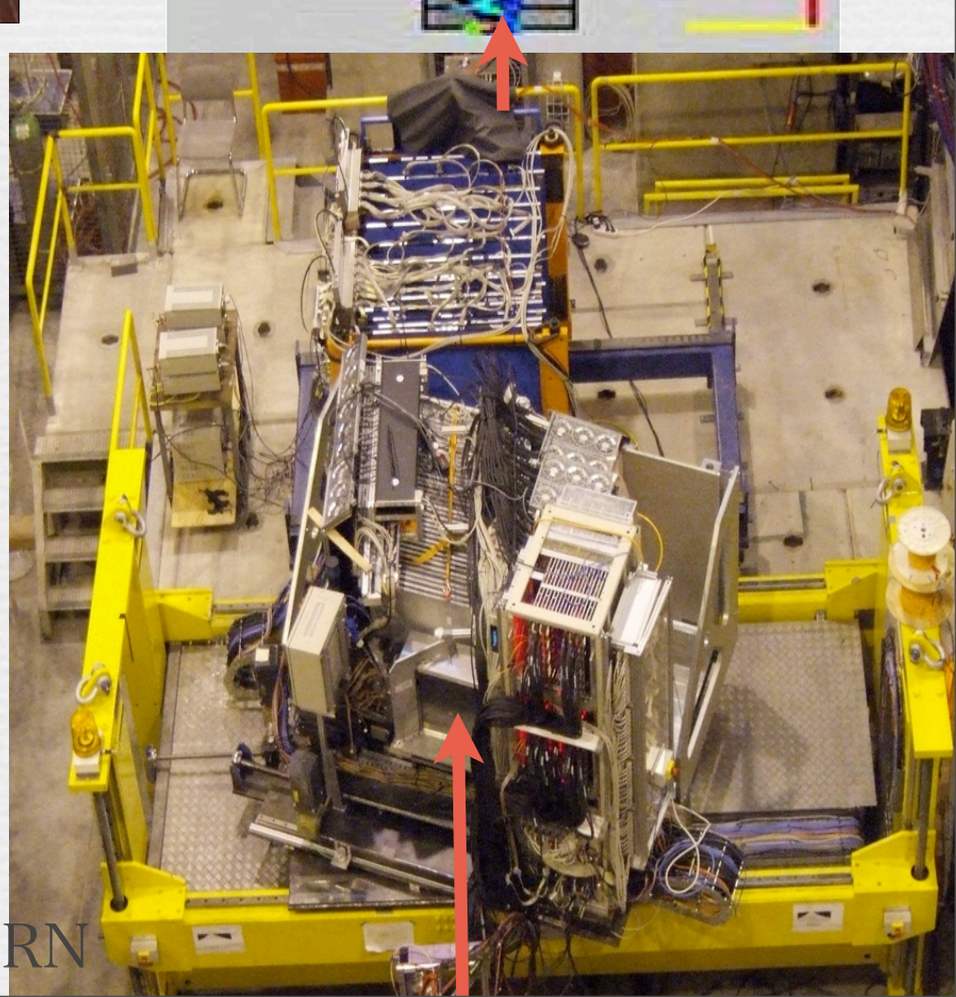
- CALICE AHCAL
- scintillator tiles
- 3cm x 3cm x 0.5cm
- with SiPM





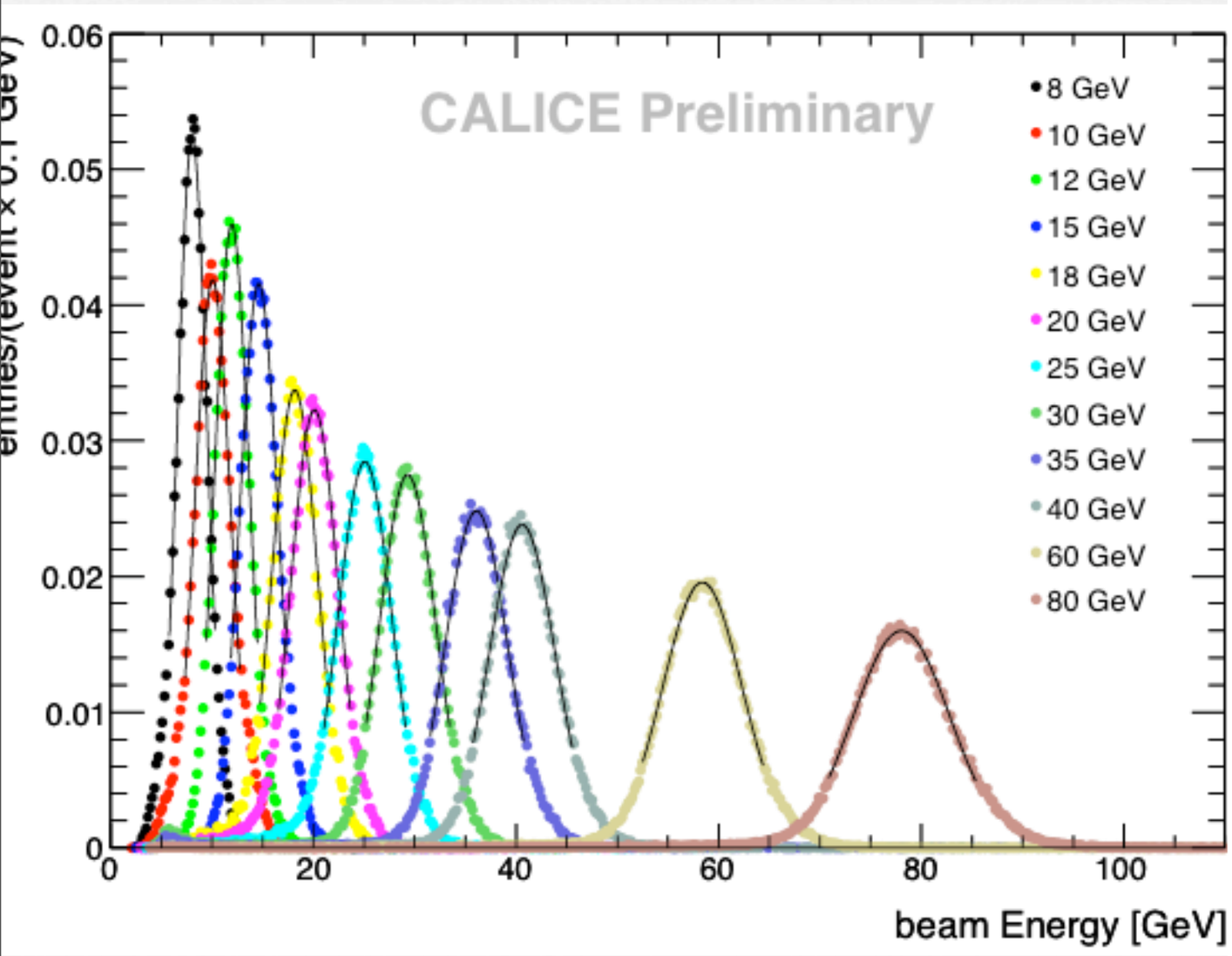


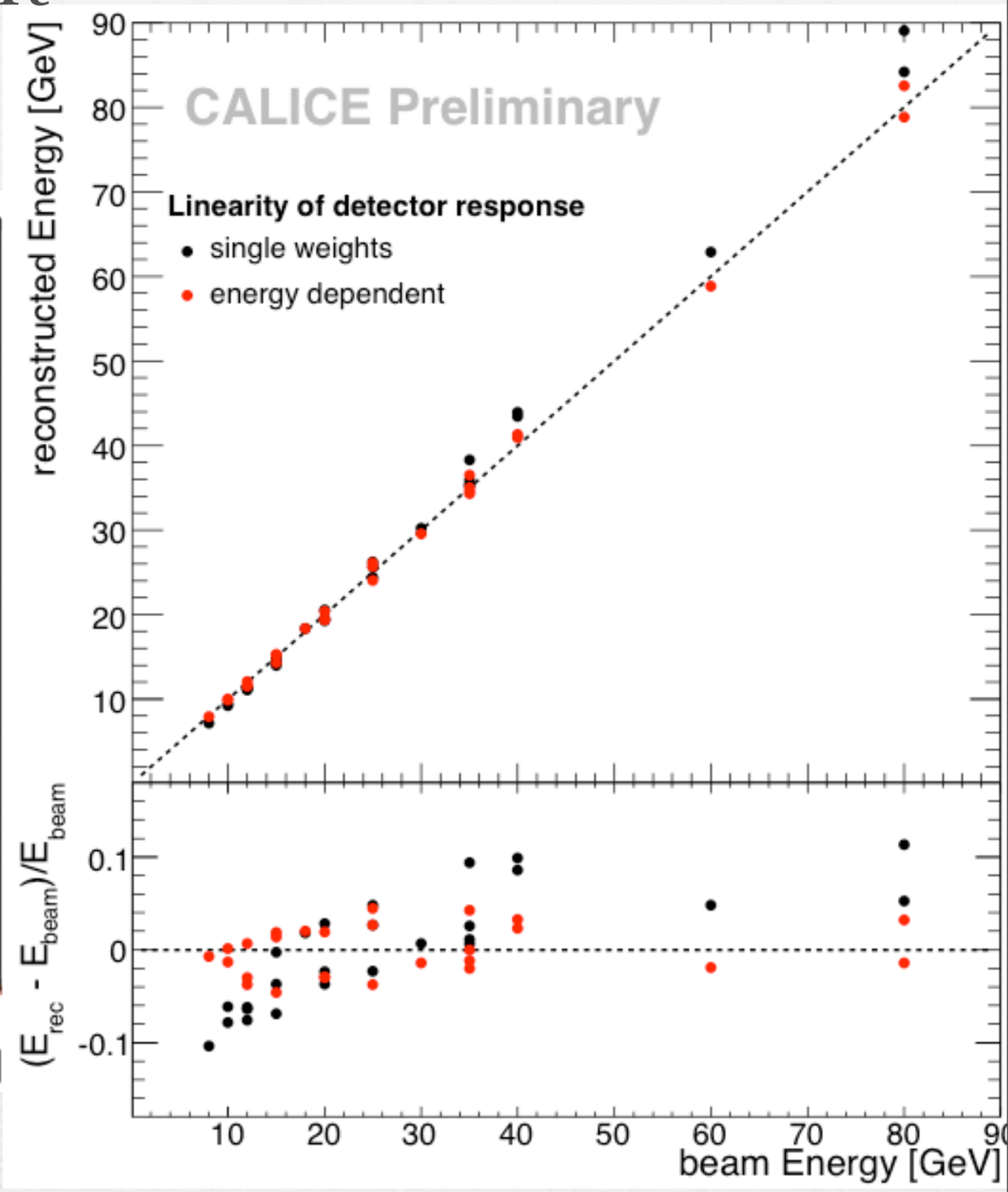




results of AHCAL

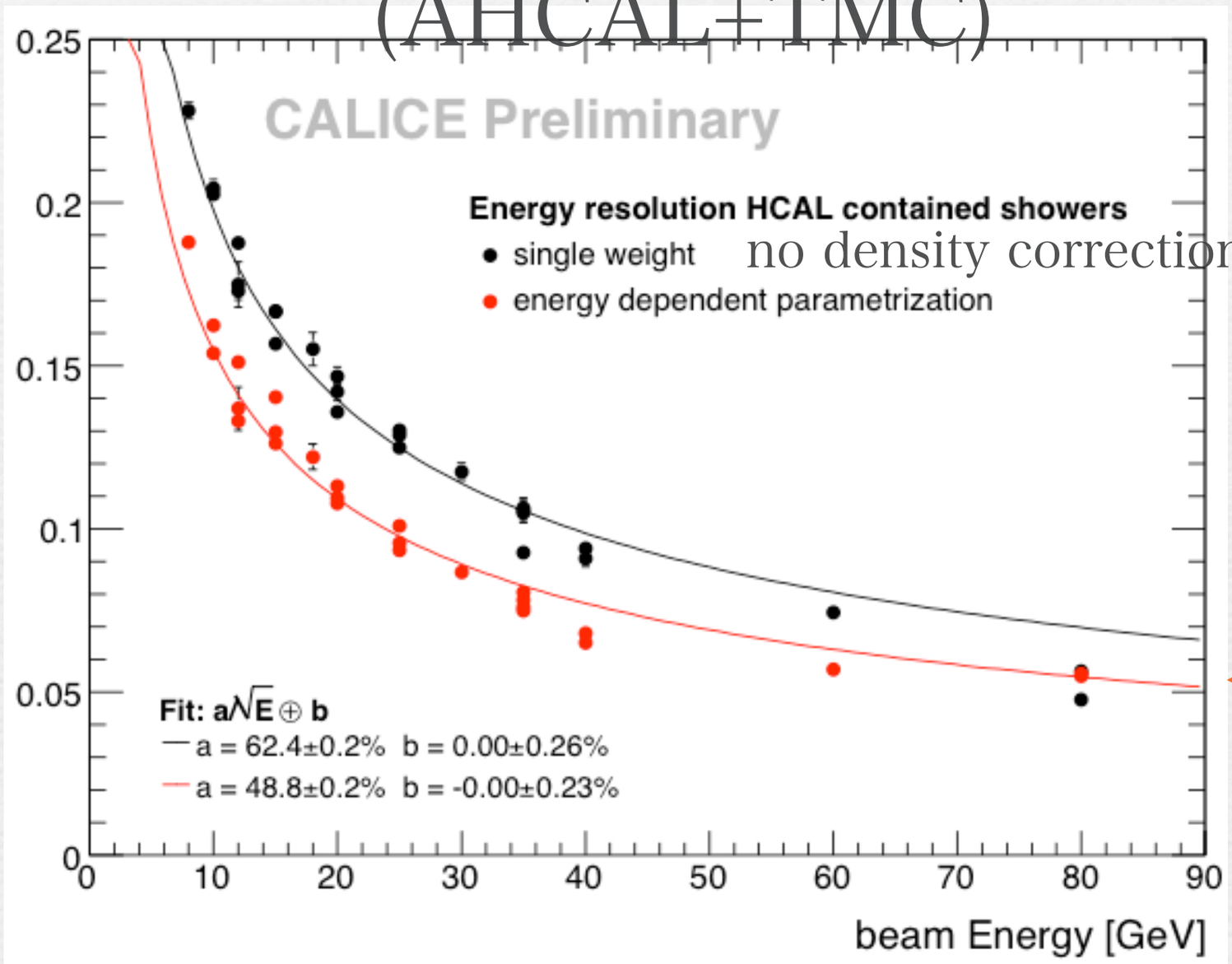
pion energy measurement





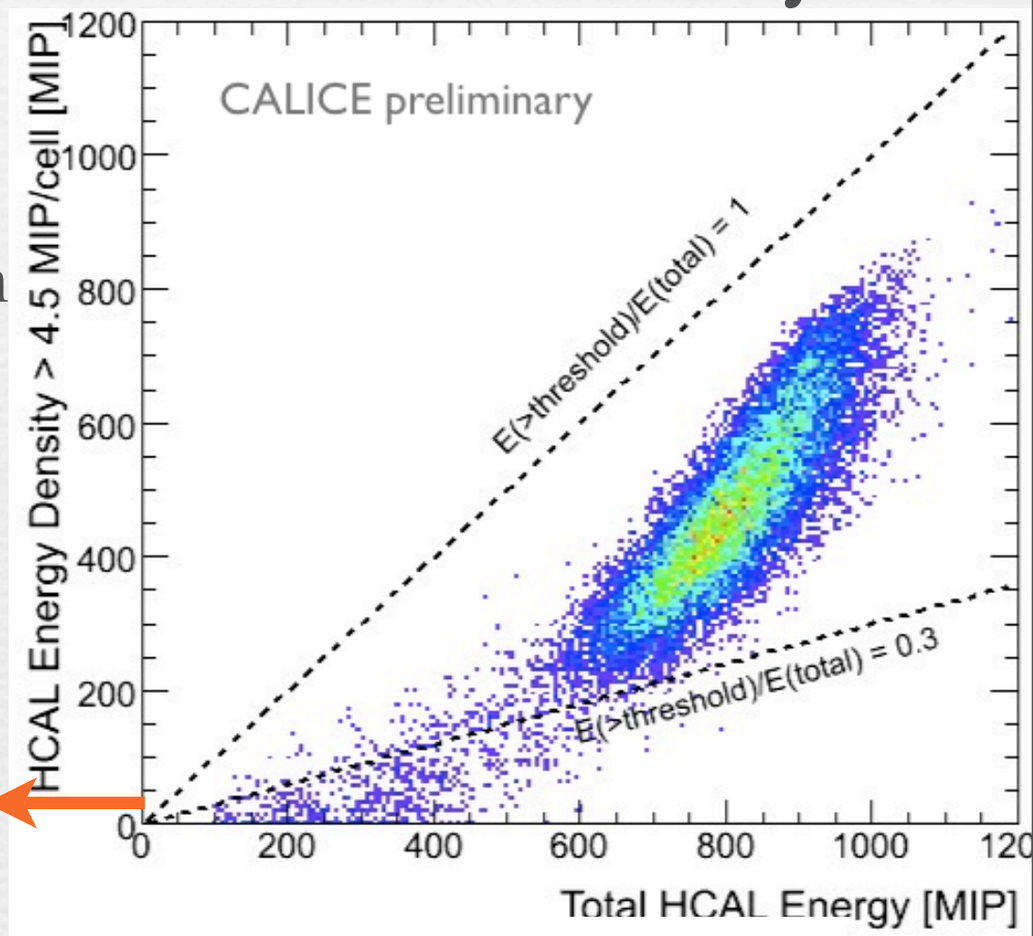
results of AHCAL cont.

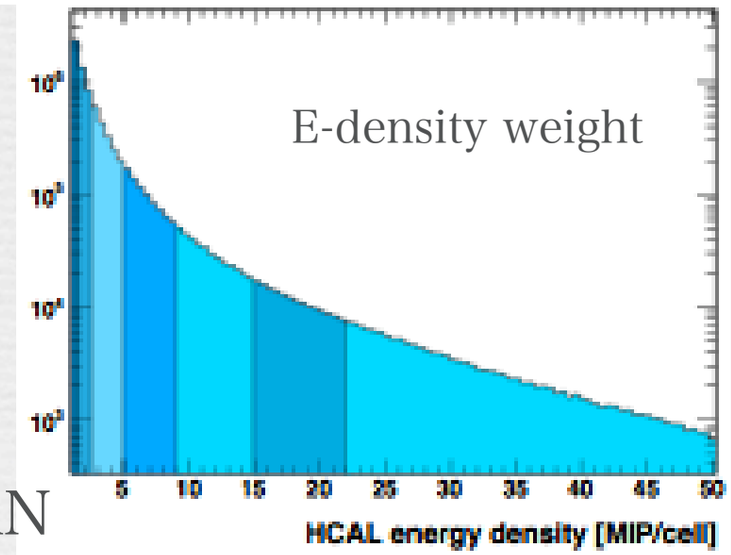
energy resolution (AHCAL+TMC)



sum of E-density

no density correction



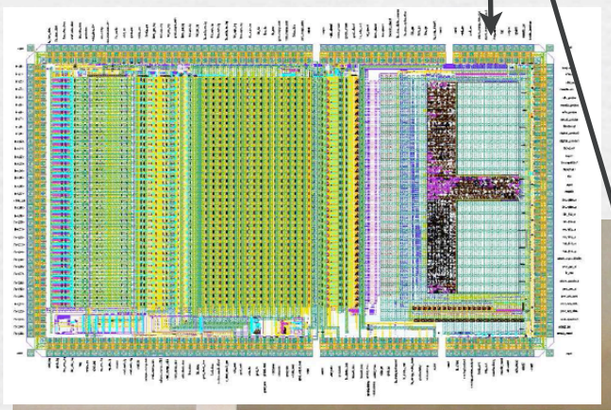


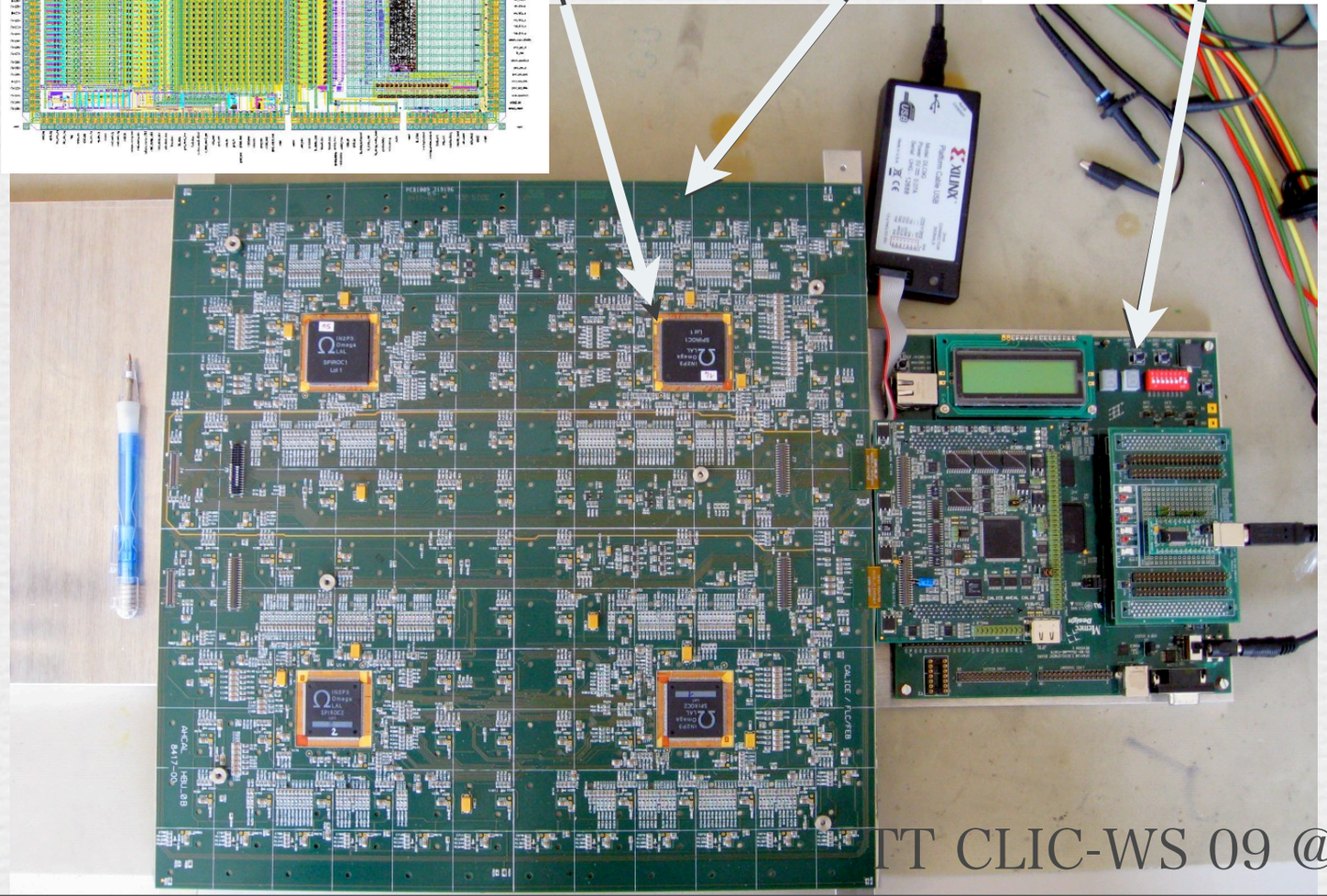
49%/sqrt(E)

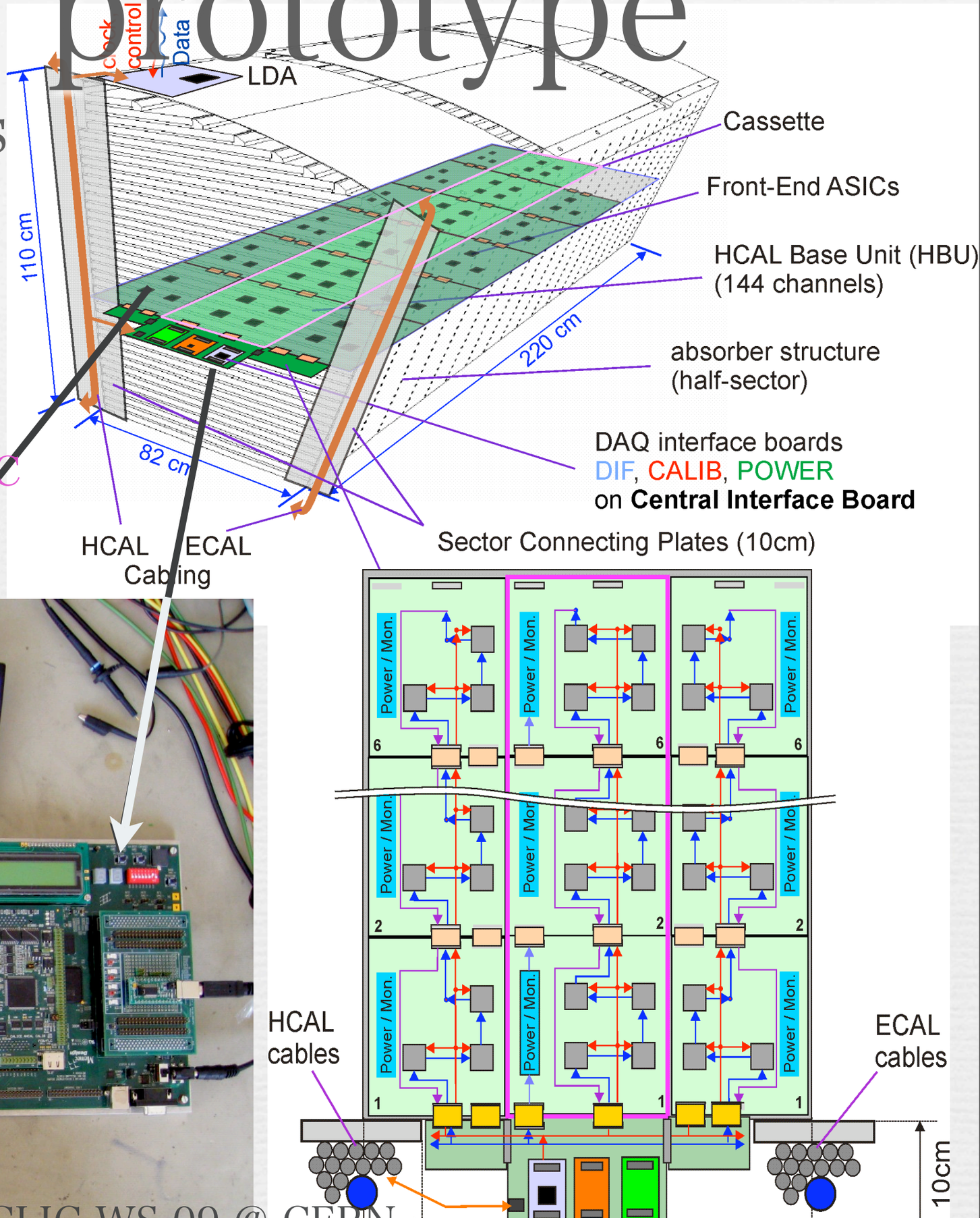
next gen. prototype

- combined electronics in a layer
- new SPIROC
- power pulsing

timing on CLIC

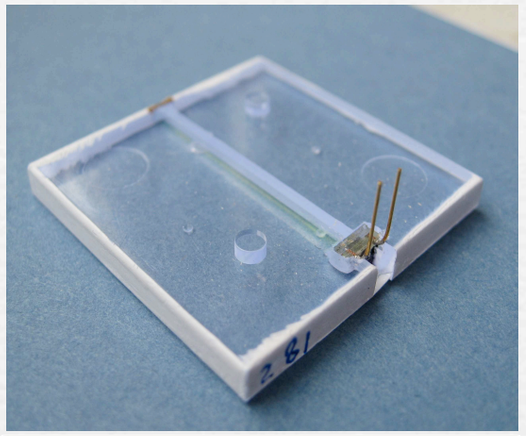


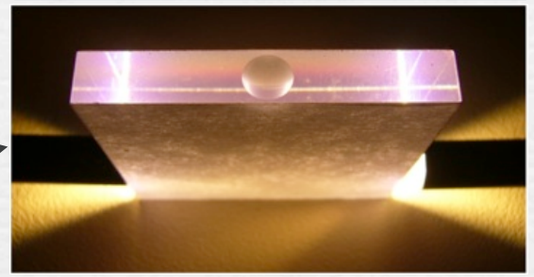


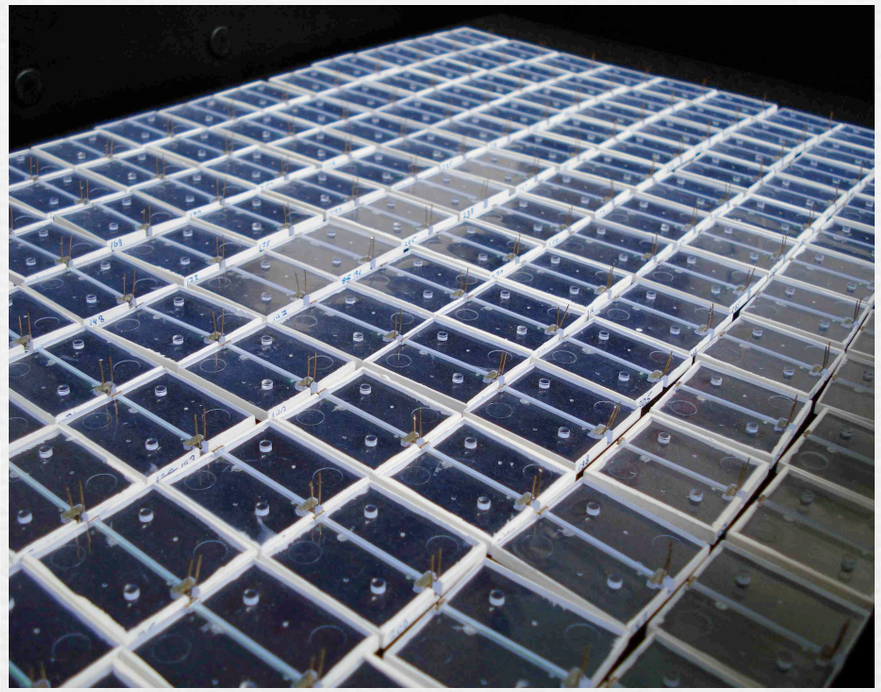


next gen. scintillator

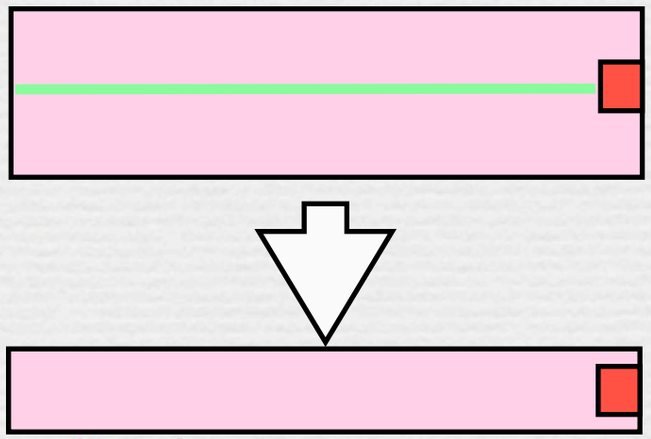
- tile
  - with WLSF
  - w/o WLSF with dimple



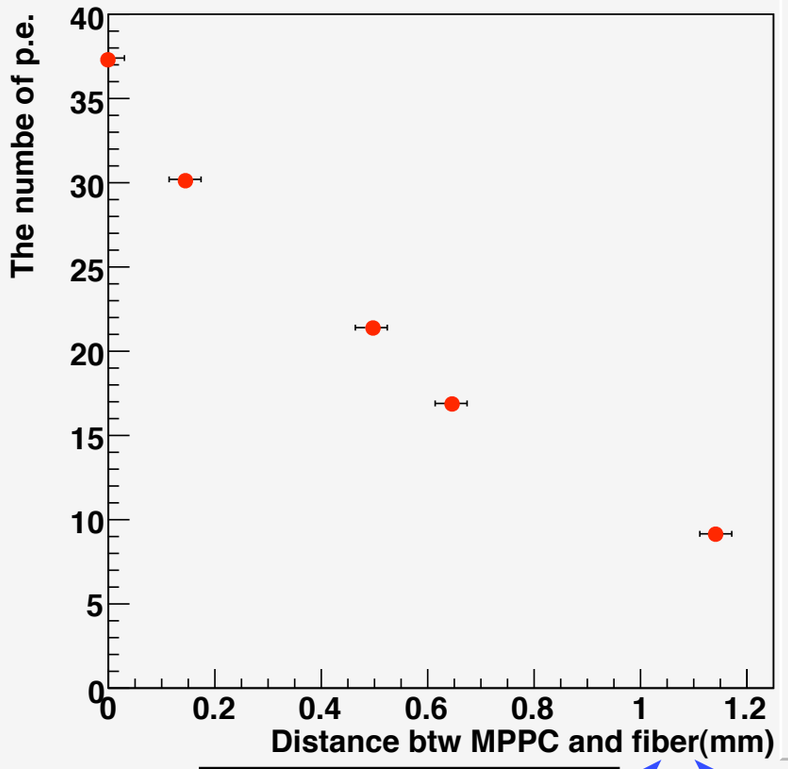


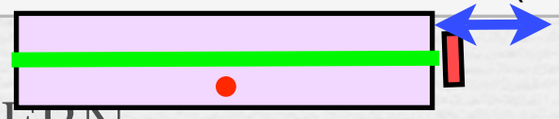


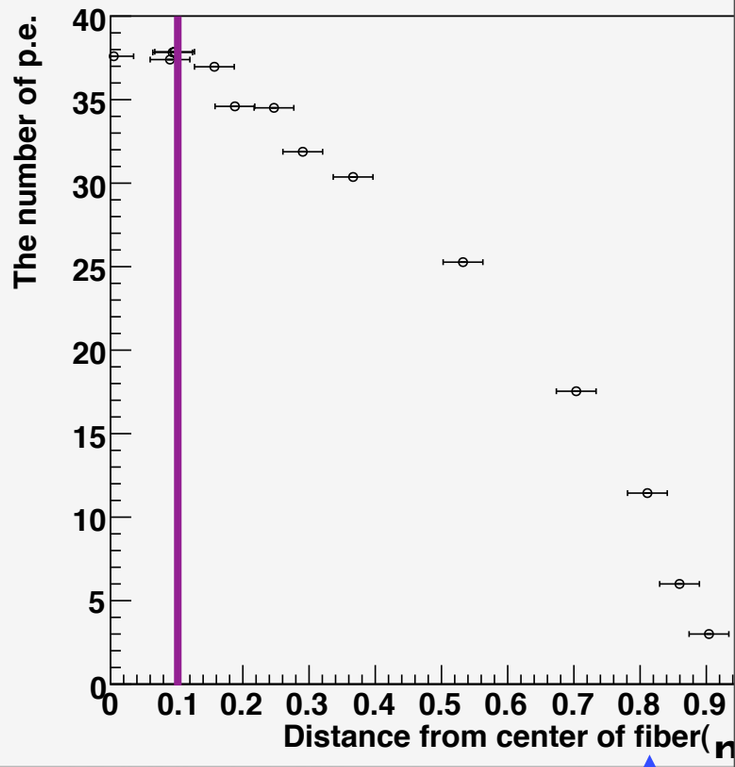
- strip
  - without WLSF

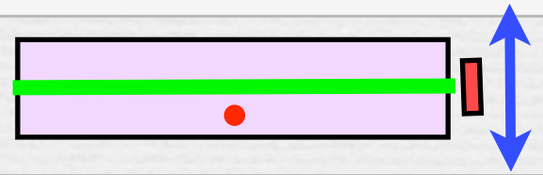


severer on CLIC



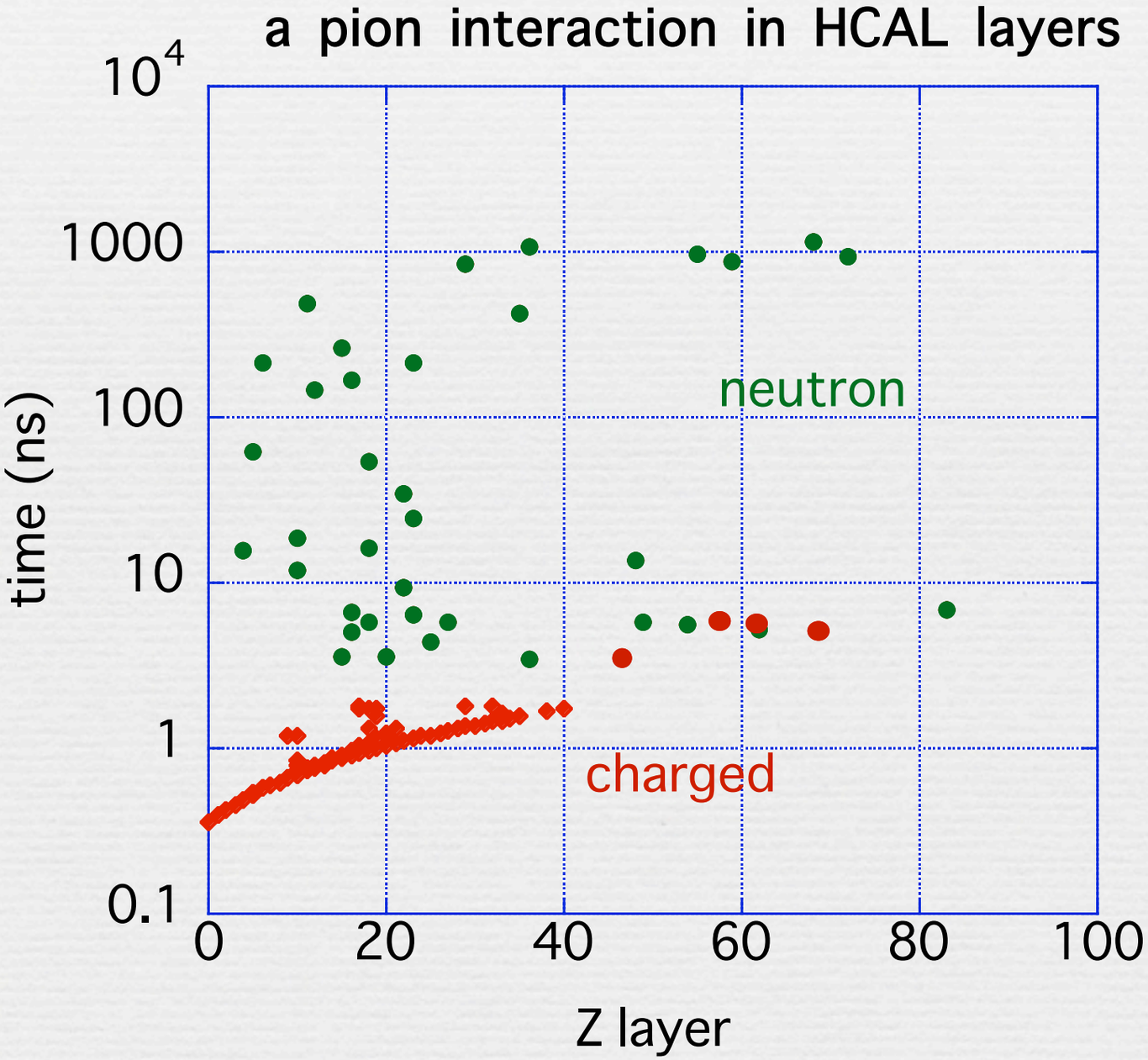


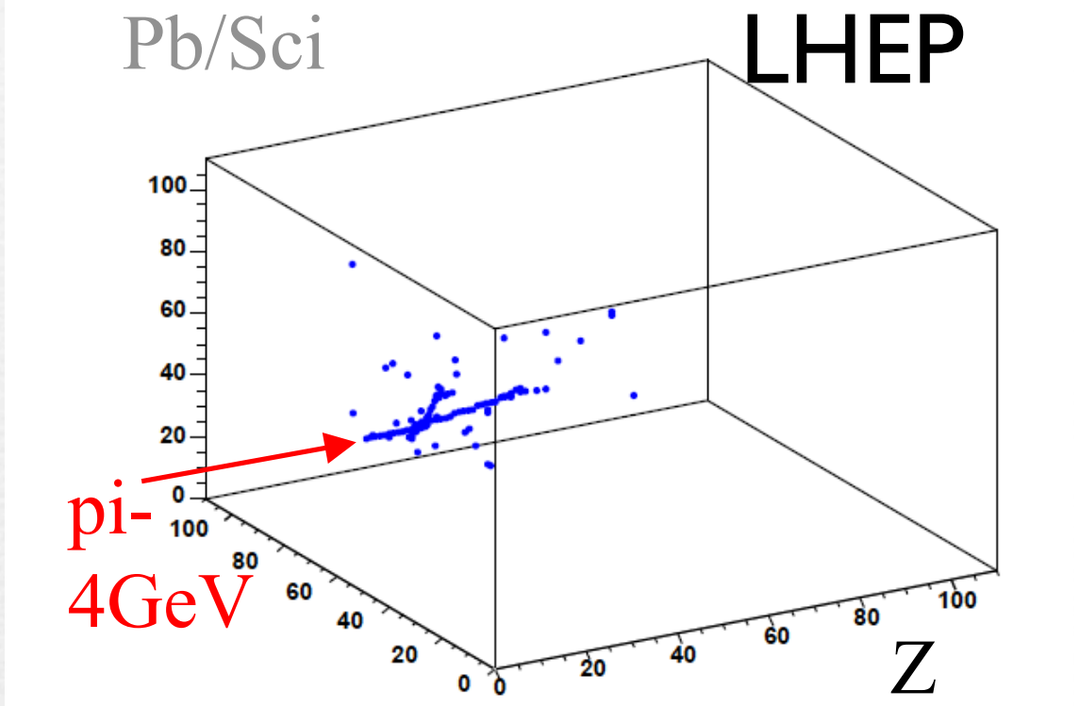


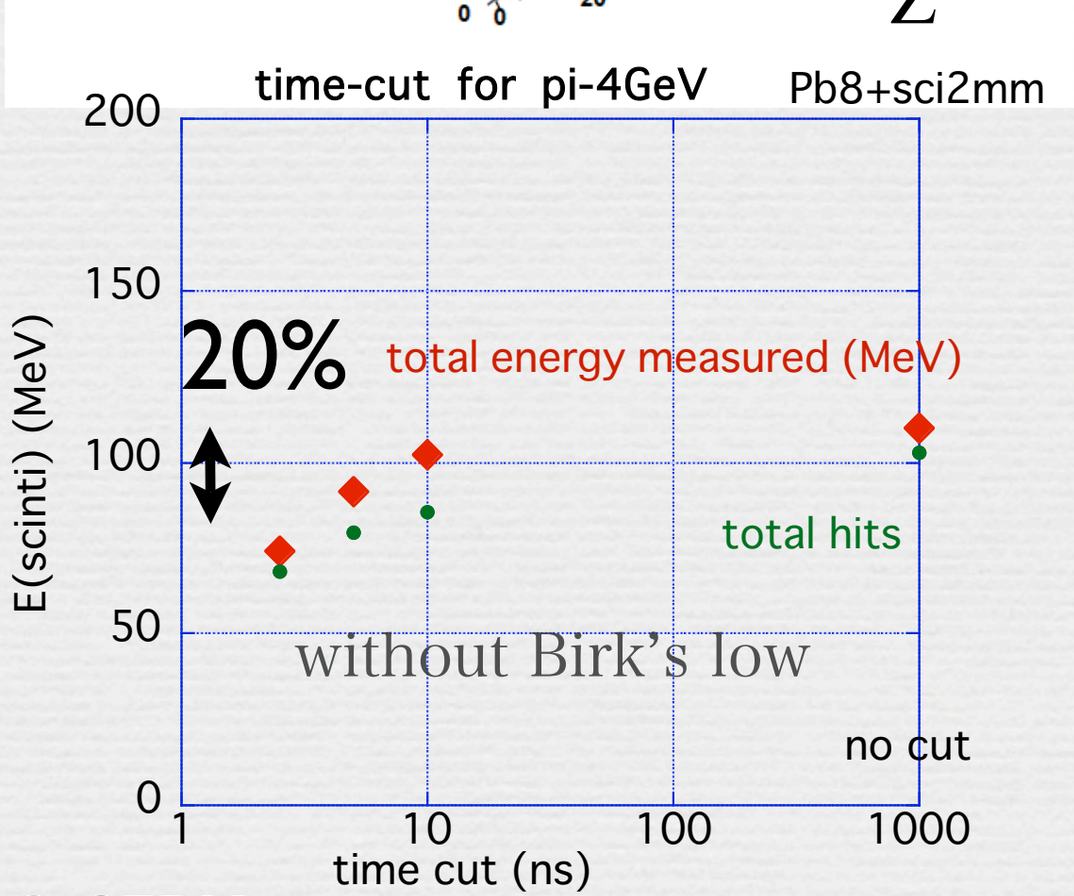


scintillator HCAL

- problem with neutrons







summary & for CLIC

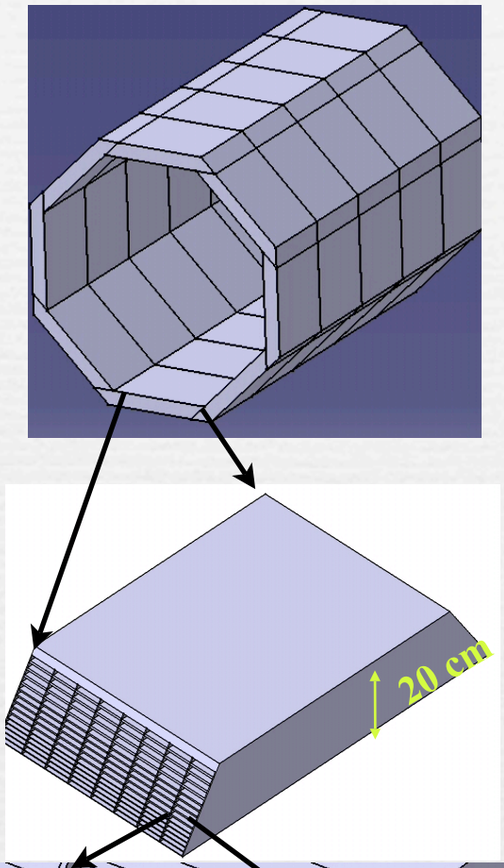
- investigating scintillator calorimeters
- with PFA idea (segmentation) for LC
- current R/O with WLSF for ECAL&HCAL
- basic performances look good enough
- both linearity and resolution
- combined layer (electronics +active)
- higher E collisions require finer segmentation

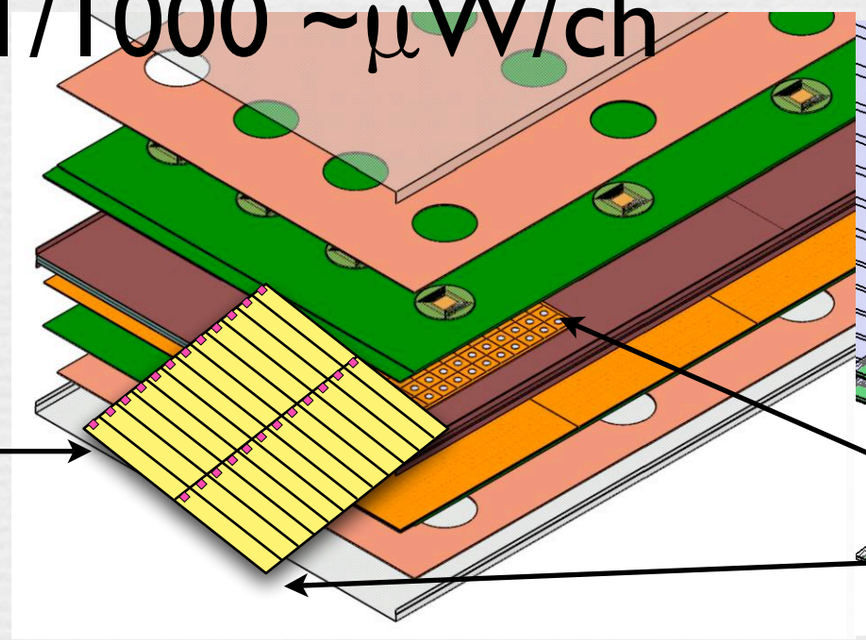
  with time stamping capability 4D detector
- neutron contribution should be in mind

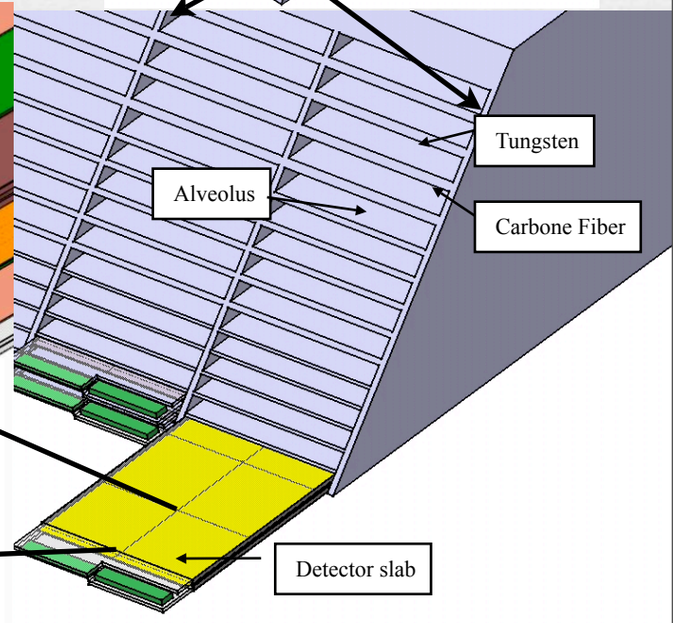
  severer on CLIC but time resolution will help

ECAL for ILC

- Tungsten : small Moliere radius ~1cm
  - need less gap between layers
  - read out elex. within layers
    - Amp, Shaper +15 bit ADC
    - power pulsing : 1/1000 ~μW/ch
- sensor :
  - Scintillator strip



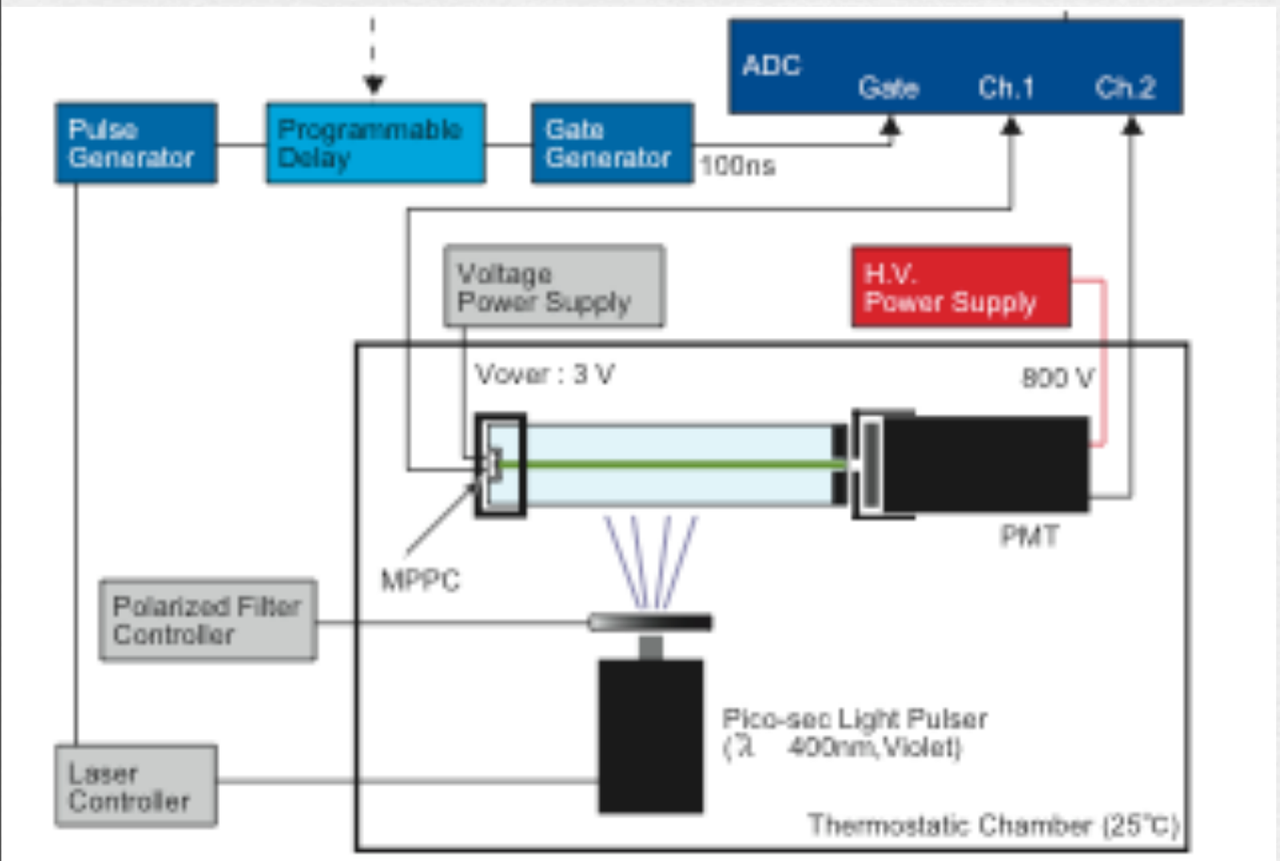




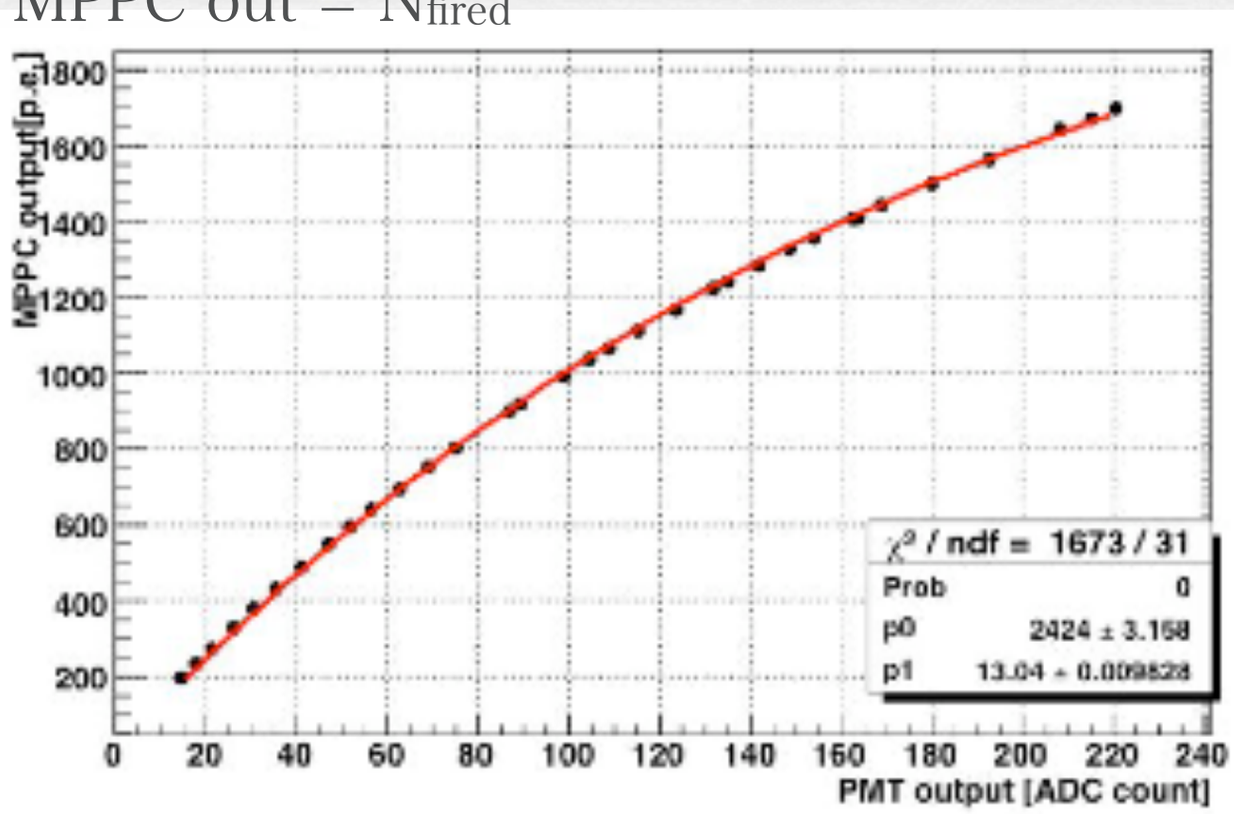
MPPC saturation

- saturation curve measured
- by UV laser with scintillator + WLSF
- a MPPC & a PMT

$$N_{fired} = N_{p0}(1 - \exp(\frac{-p1Ntrue}{N_{p0}}))$$



MPPC out = N_{fired}

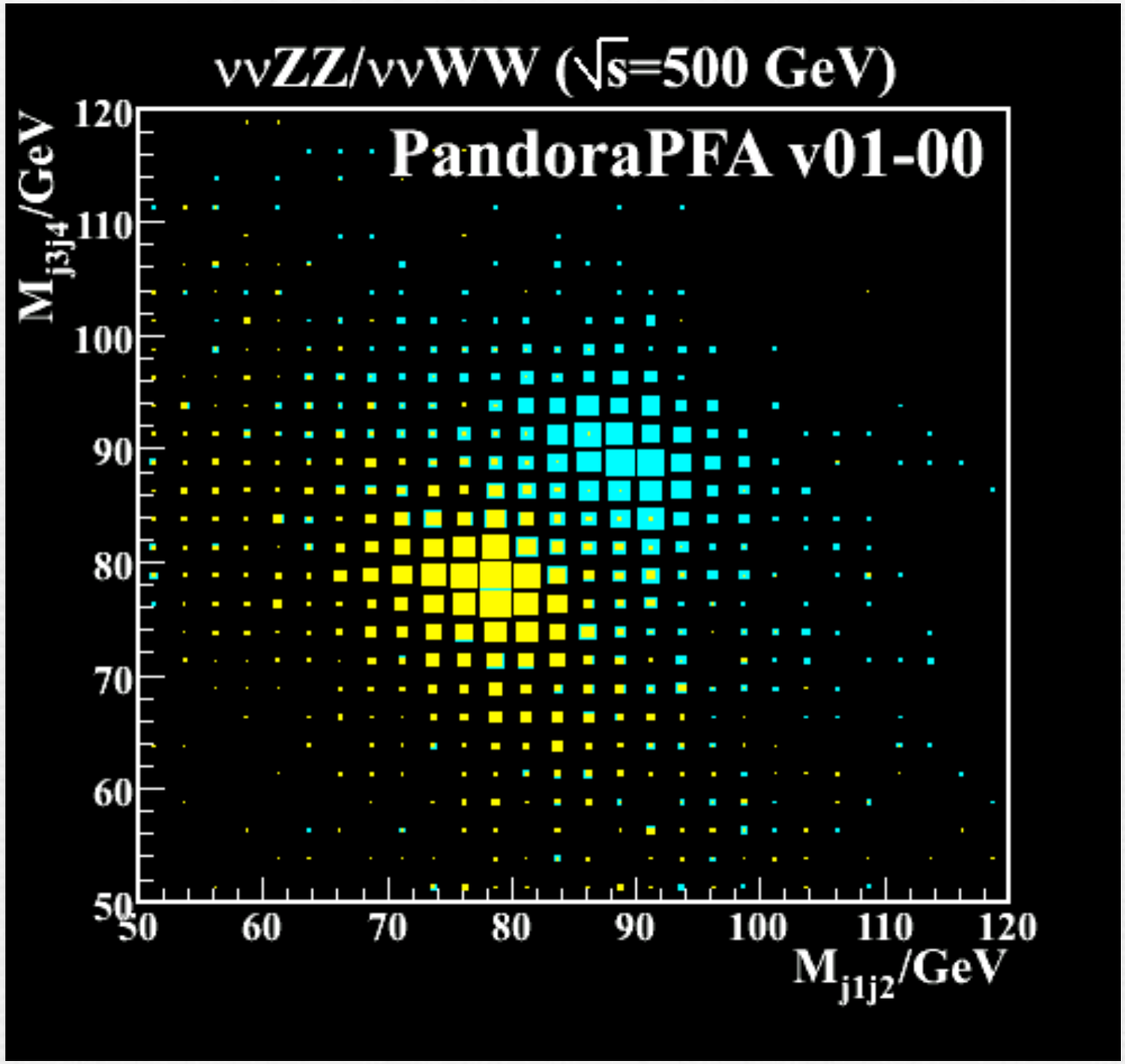


PMT out = p1Ntrue

N_{p0}=2424

PFA W/Z separation

M. Thomson



ECAL discussion

- Dynamic range : electronics & Photon sensor
  MPPC non linearity