MAPS Detector for ALICE upgrade at forward region

Daichi Kawana
College of Physics
School of Science and Engineering
University of Tsukuba, Japan
s1310853@u.tsukuba.ac.jp
daichi.kawana@cern.ch

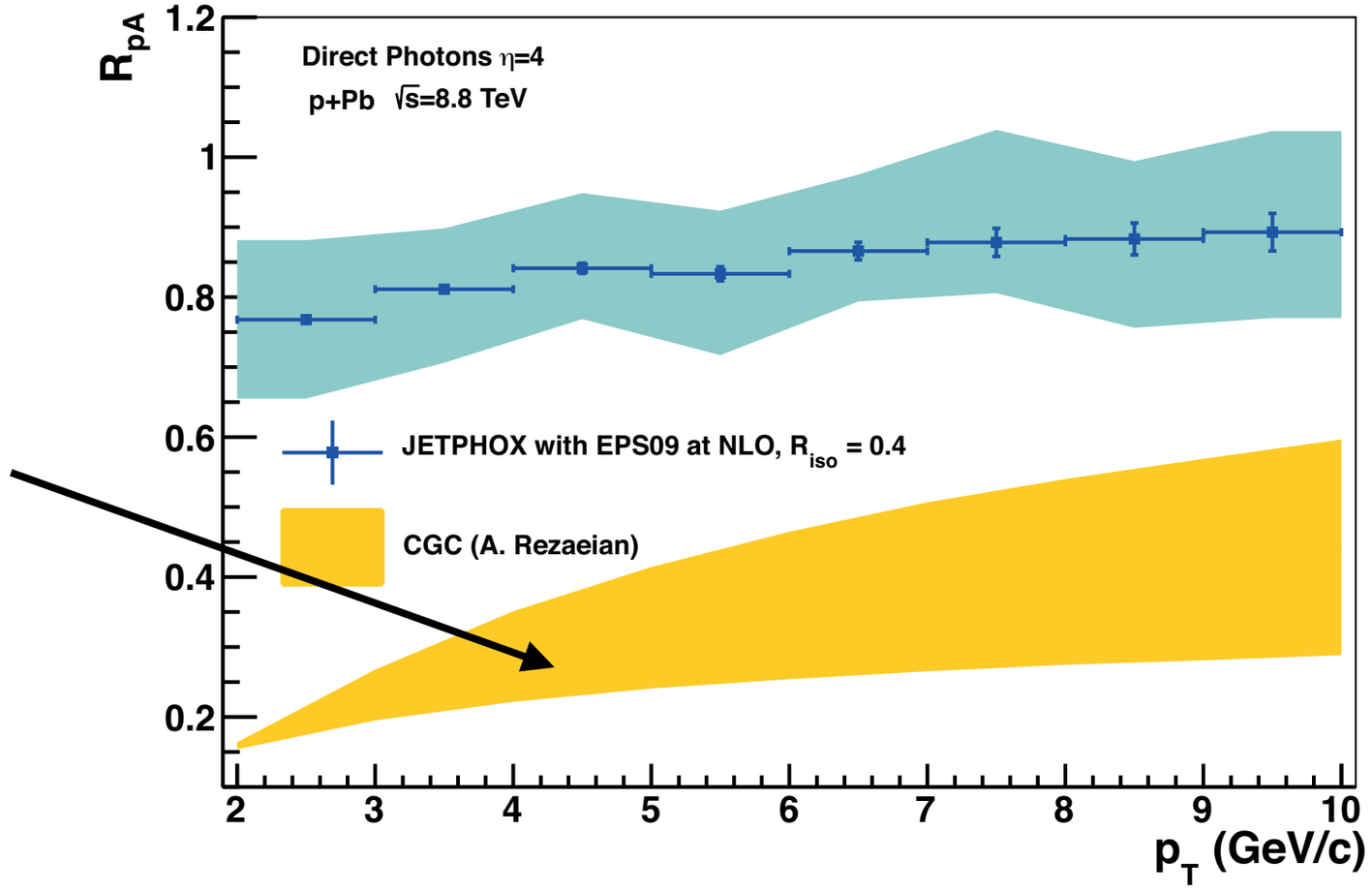
Contents

Physics motivations

✓ *At small-x, the gluon density should lead to non-linear and saturation in CGC(Color Glass Condensate) theoretical model.*
→ *understanding initial state of heavy ion collision.*

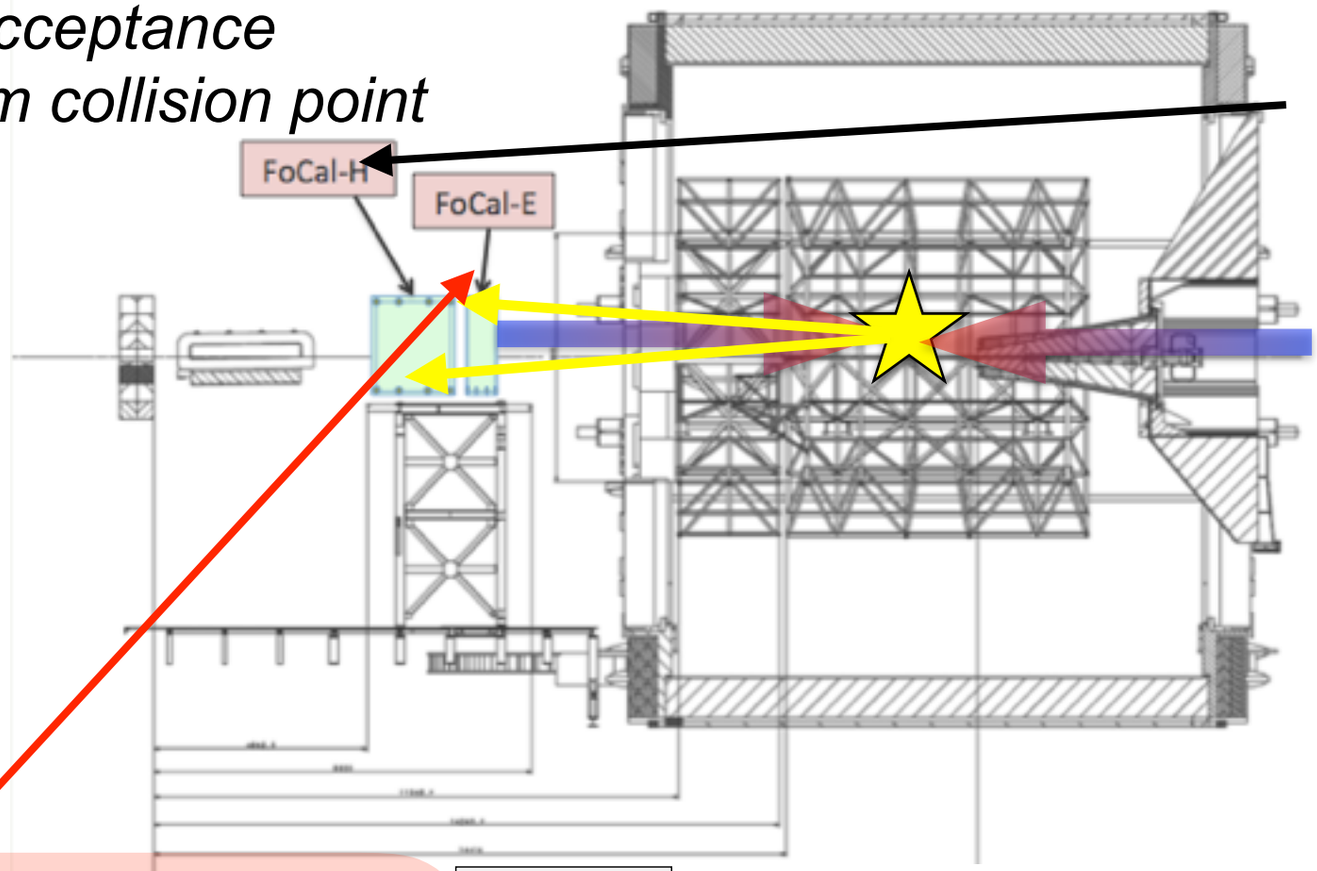
✓ *Direct photon measurement is needed at forward region.*
→ *<u>discrimination between direct photons and decay photons.</u>*

expected suppression of forward direct photons in p-Pb collisions compared with p-p collisions in CGC model.



Forward Calorimeter (FoCal)

planed FoCal acceptance
- *8 m away from collision point*
- *3.3 < η < 5.3*

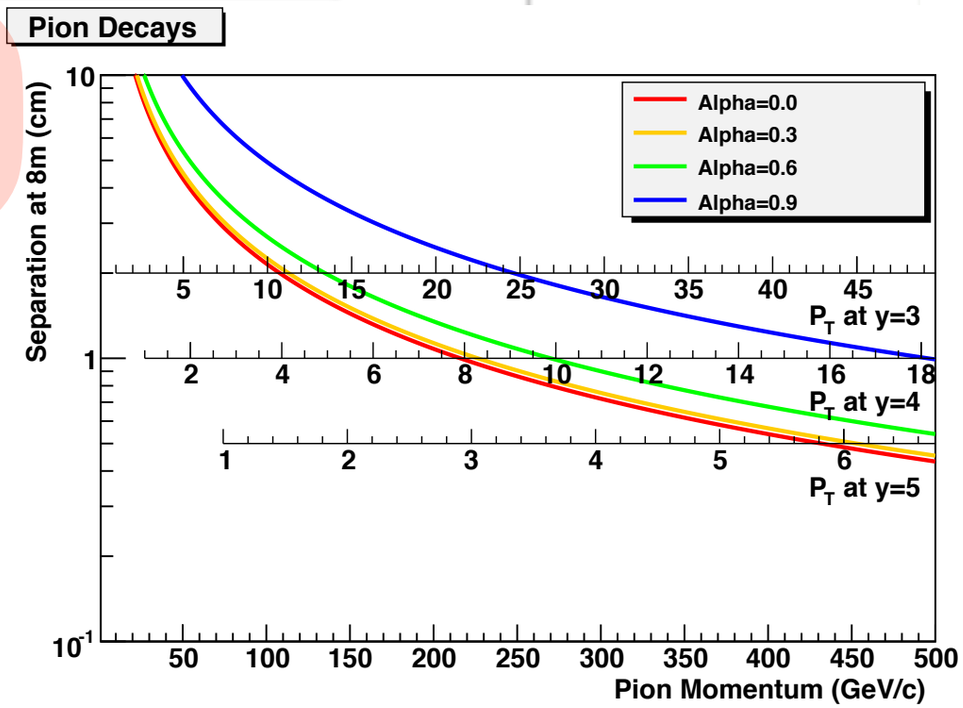


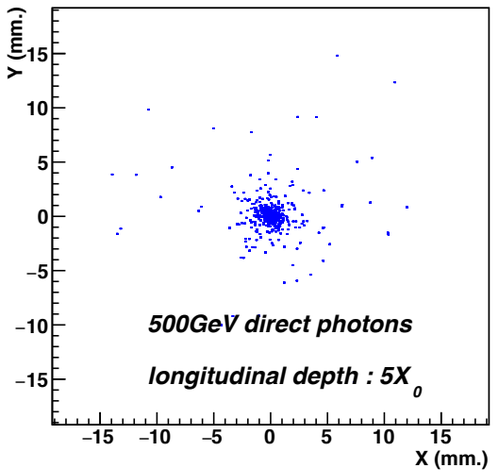
Hadronic Calorimeter
→ jet measurements

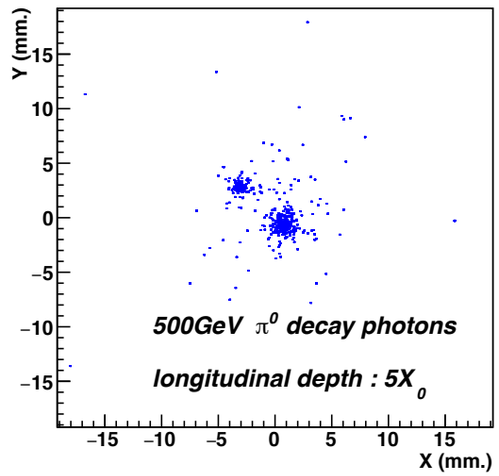
EM Calorimeter
→direct γ / π^0 measurements

✓ *separation of decay photons reaches few mm at high pT.*

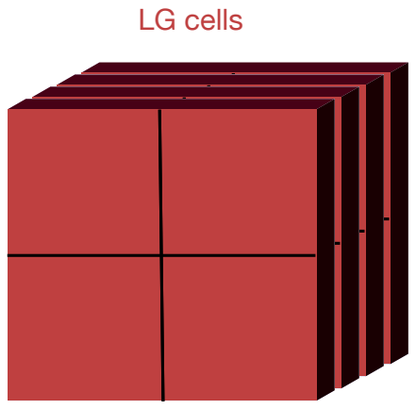
✓ *cluster measurement with high accuracy is needed.*

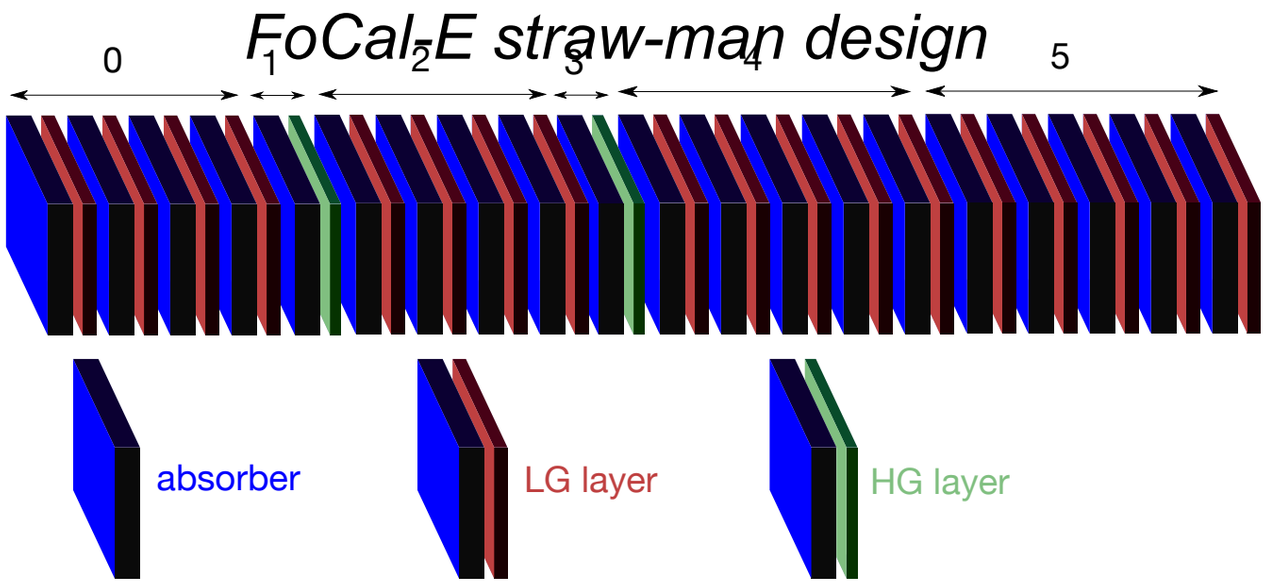


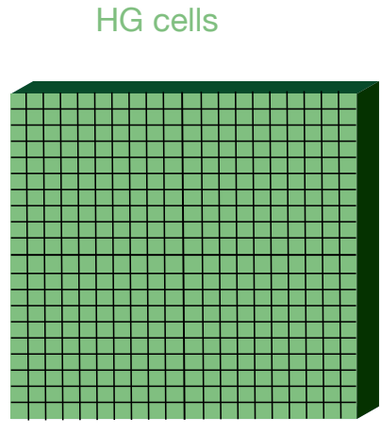




FoCal-E prototype structure

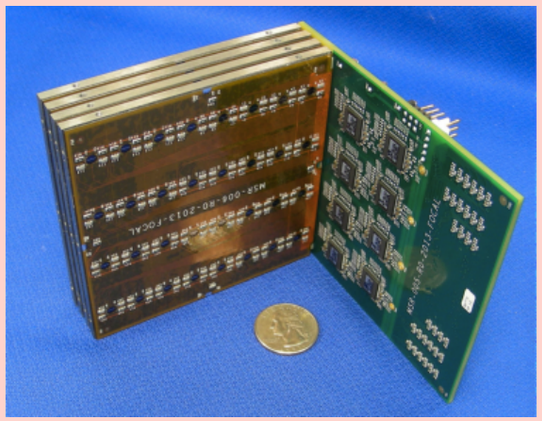






LGL (Low-Granularity Layers)

- *1 × 1 cm² Si PAD detector*
- *Si + W sampling calorimeter*
- *a LGL module is composed by four layers (summed readout)*
- *for energy measurement*

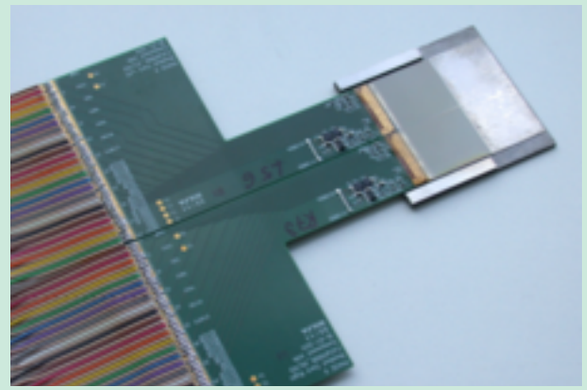


LGL prototype (Oak-Ridge national laboratory / Tsukuba group)

HGL (High-Granularity Layers)

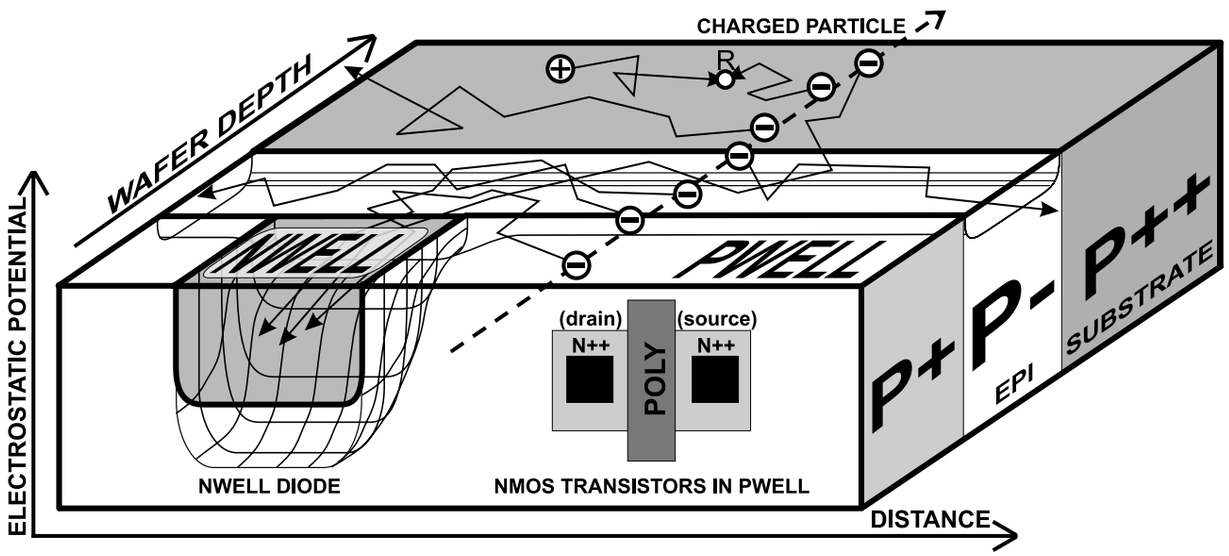
- *particle counting calorimeter*
- *Monoclinic Active Pixel Sensors(MAPS)*
- *prototype : 30 × 30 μm²*
- *for discriminating between decay photons and direct photons*

HGL prototype (Utrecht Univ.)



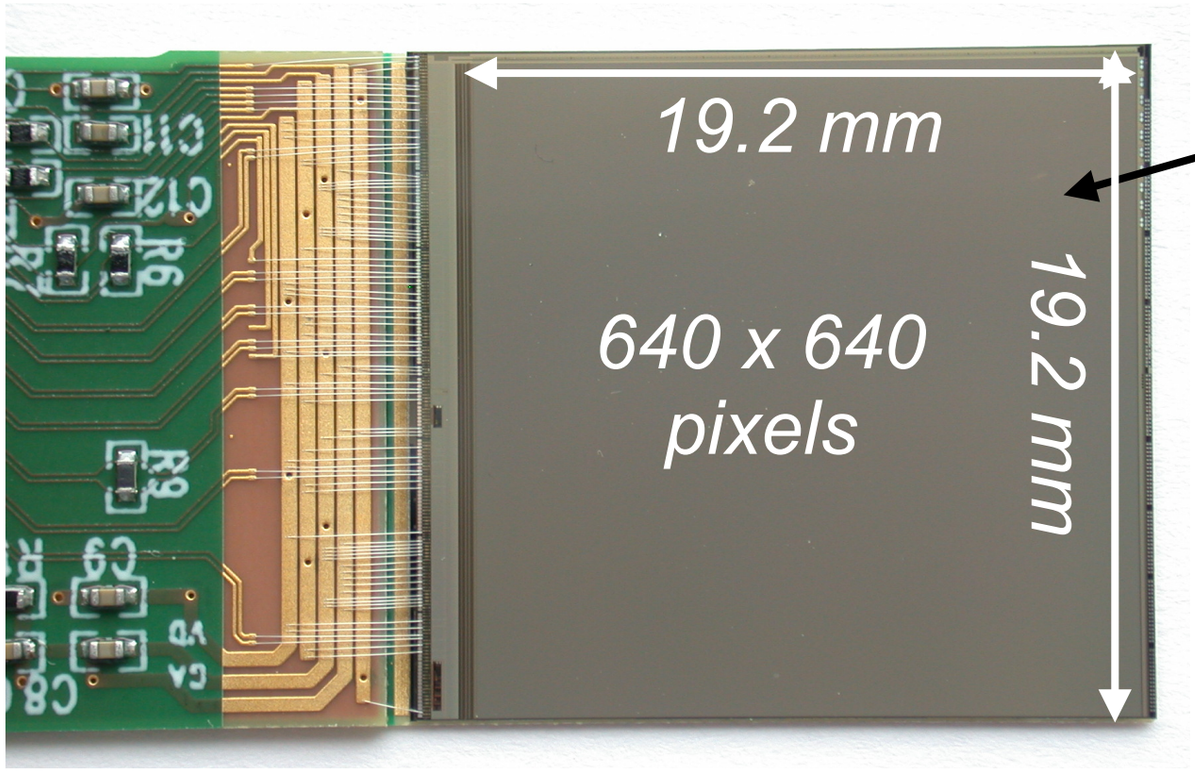
MAPS structure

MAPS
Monolithic Active Pixel Sensors



CMOS Sillicon Sensor
PHASE2 MIMOSA 23

- ✓ *energy measurements by particle counting*
- ✓ *chip level threshold setting*
  → *remove firing pixels (more methods are needed)*
- ✓ *sequential row readout*

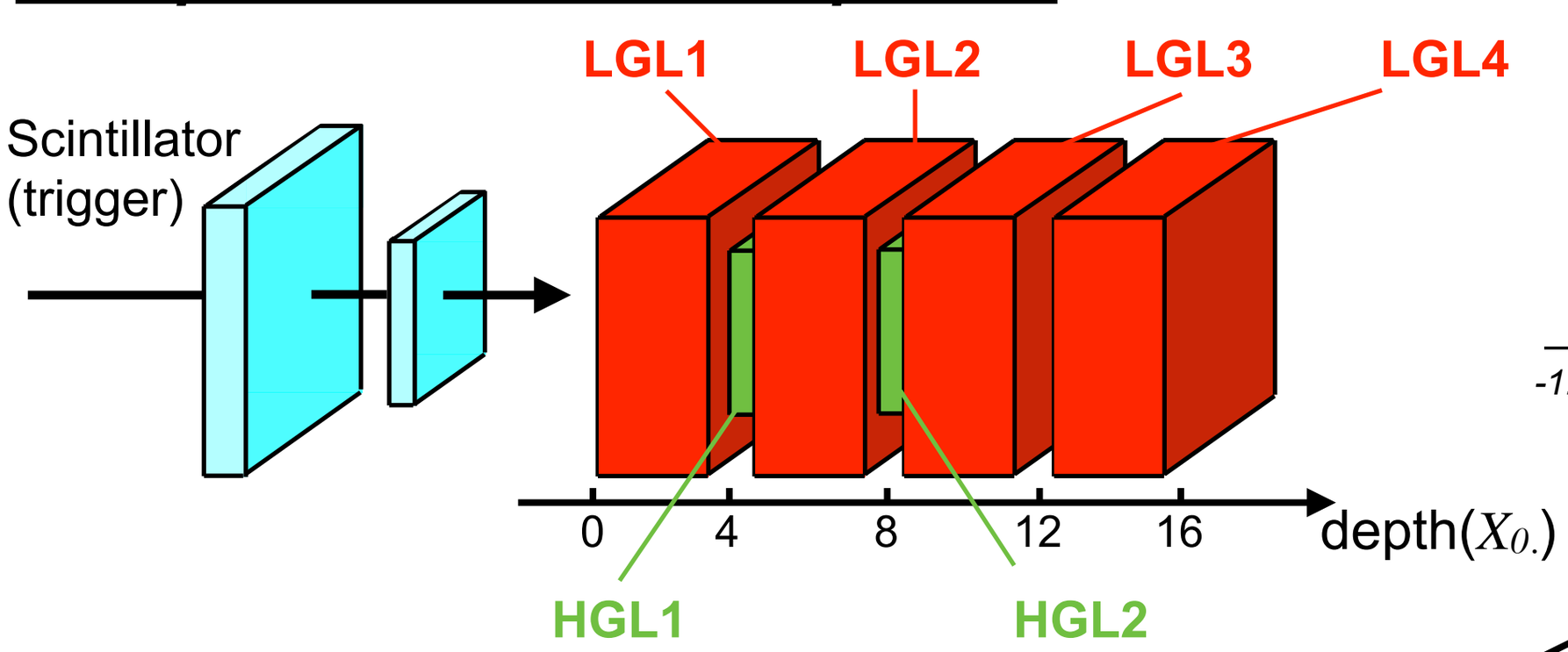


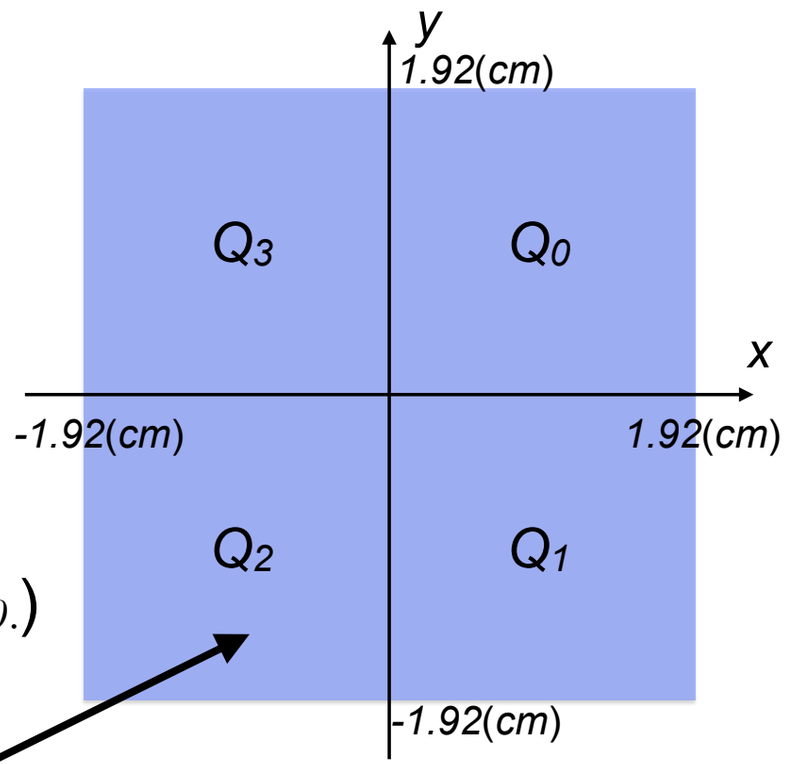
Single Chip structure

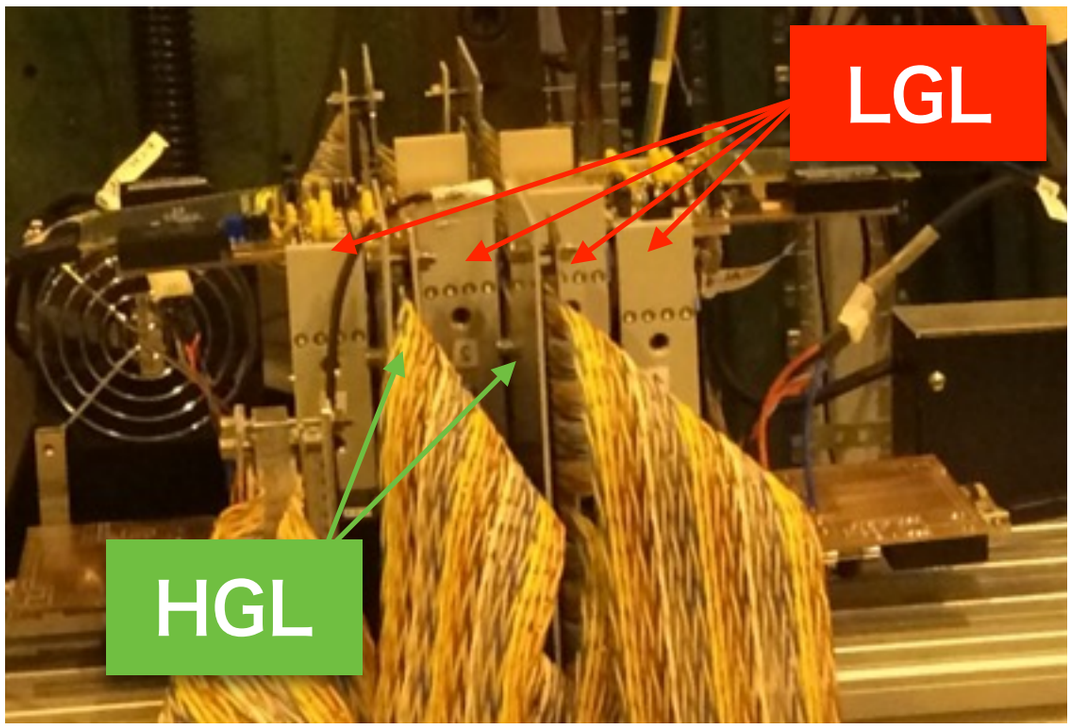
- ✓ *19.2 x 19.2 mm²*
- ✓ *640 x 640 pixels*
- ✓ *30 micro pitch*
- ✓ *4 channels (160 column)*

Test beam setup

Set up at CERN-SPS in Sep, 2016







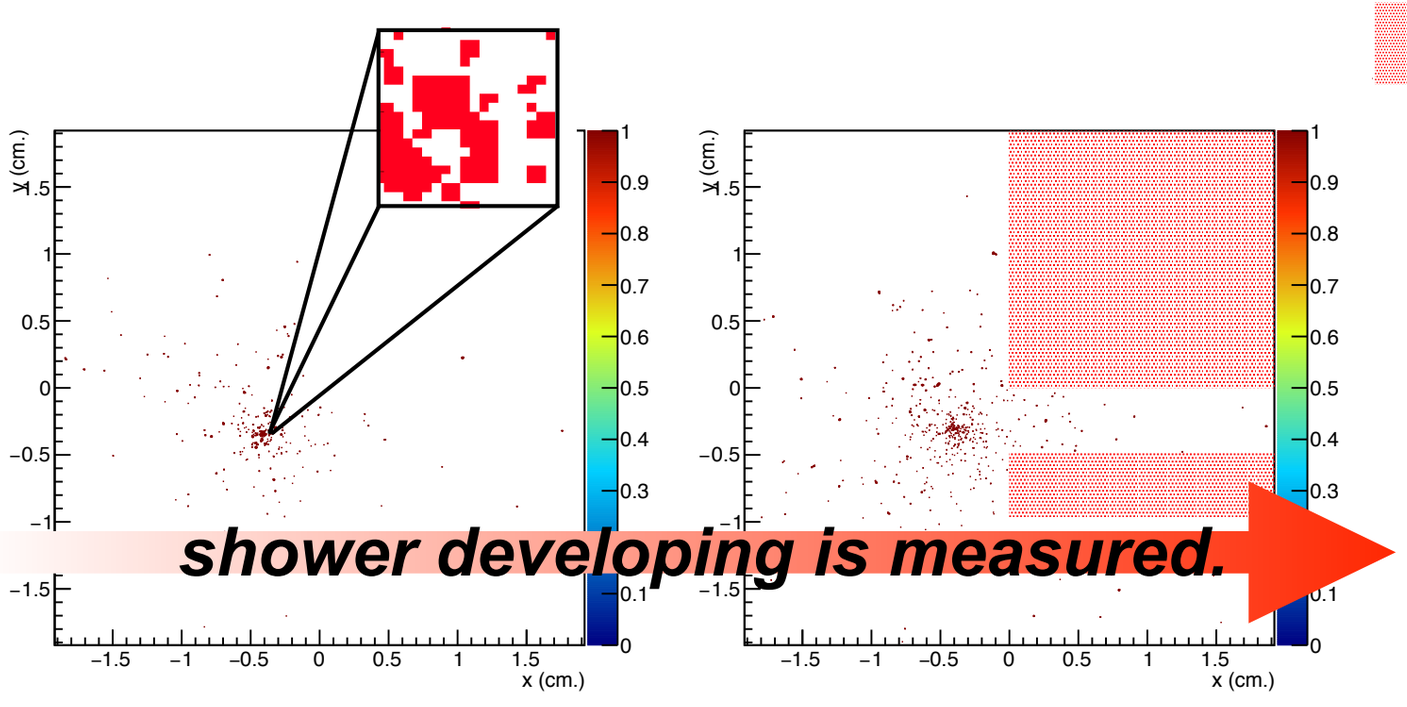
a module of HG Layer

✓ *a HG layer contains four single chips*
- *38.4 x 38.4 mm²*
- *1280 x 1280 pixels*

→ *one module = four pickle sensors*

✓ *located at $4X_0$ and $8X_0$ in this experiment*

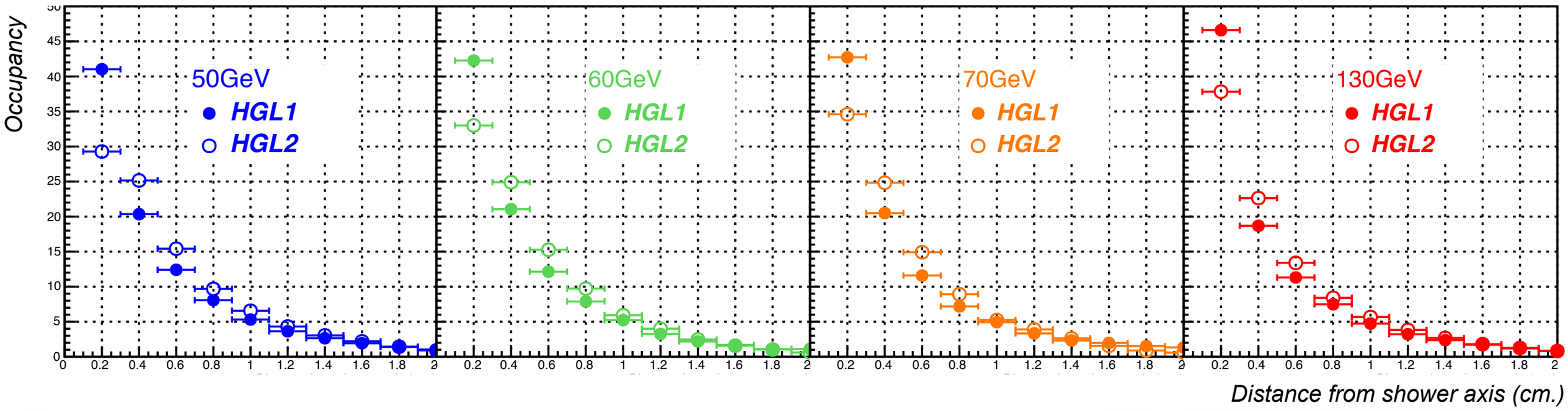
Shower measurements



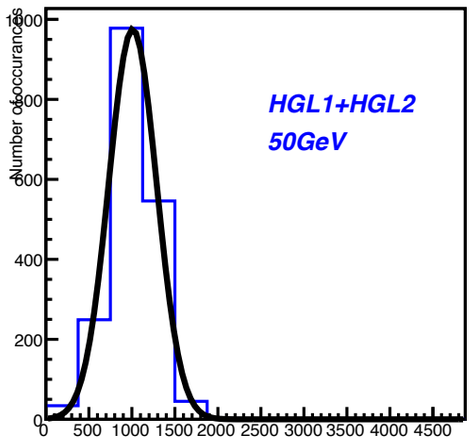
Transverse shower profile

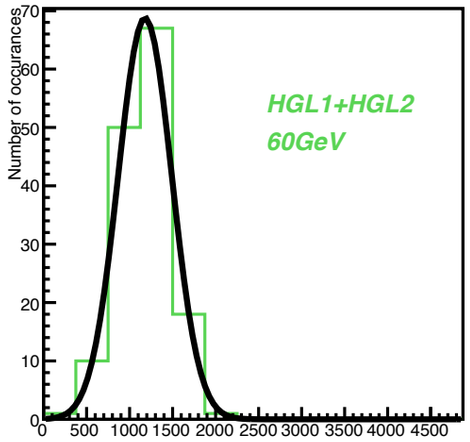
✓ show the difference of shower density.

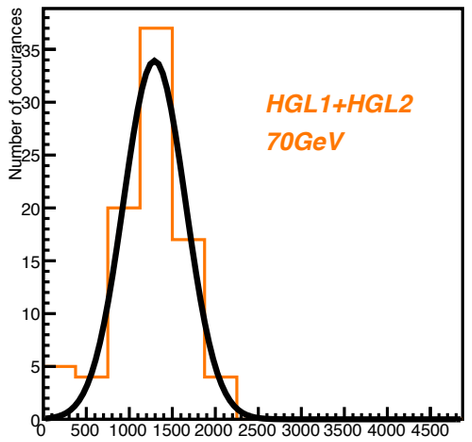
✓ Moliere radius ~ 10.5 mm is measured.

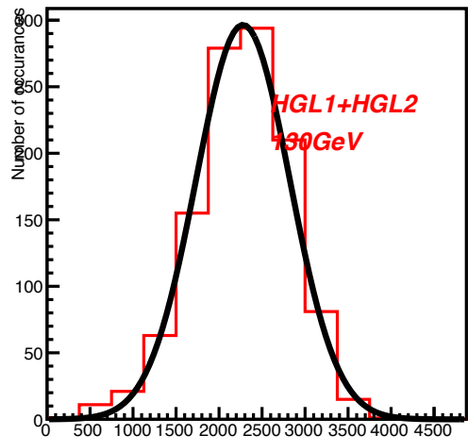


Energy dependence



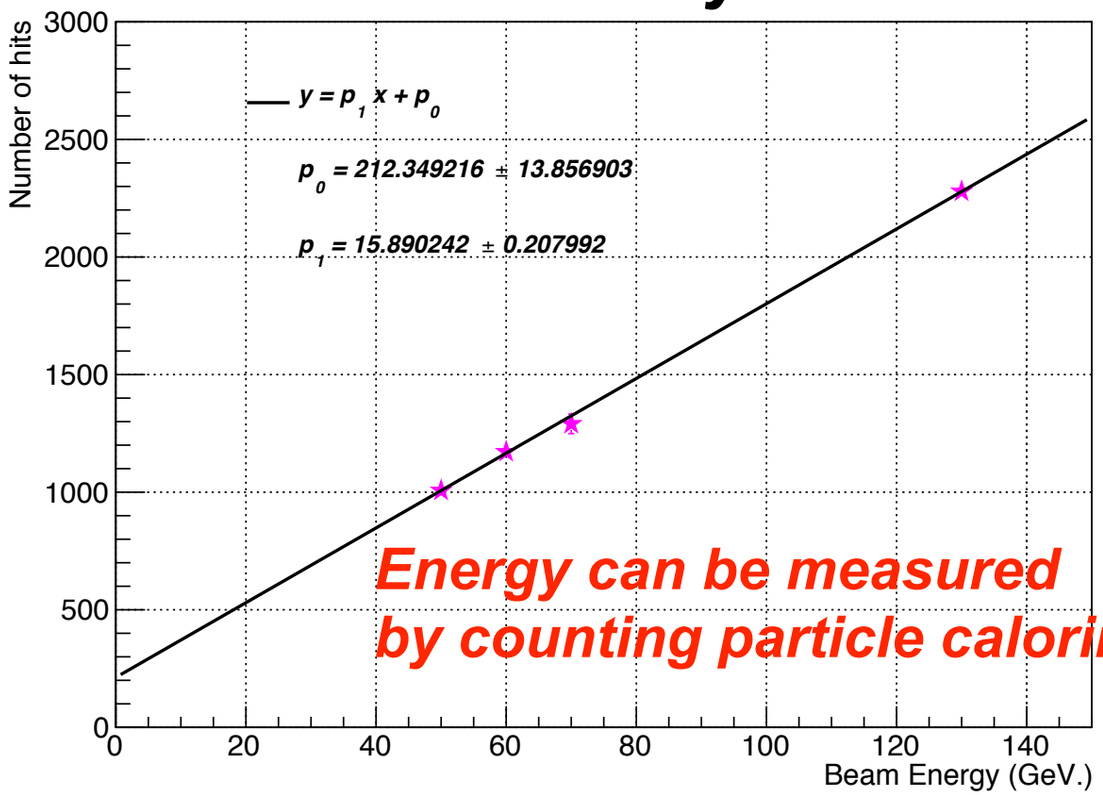






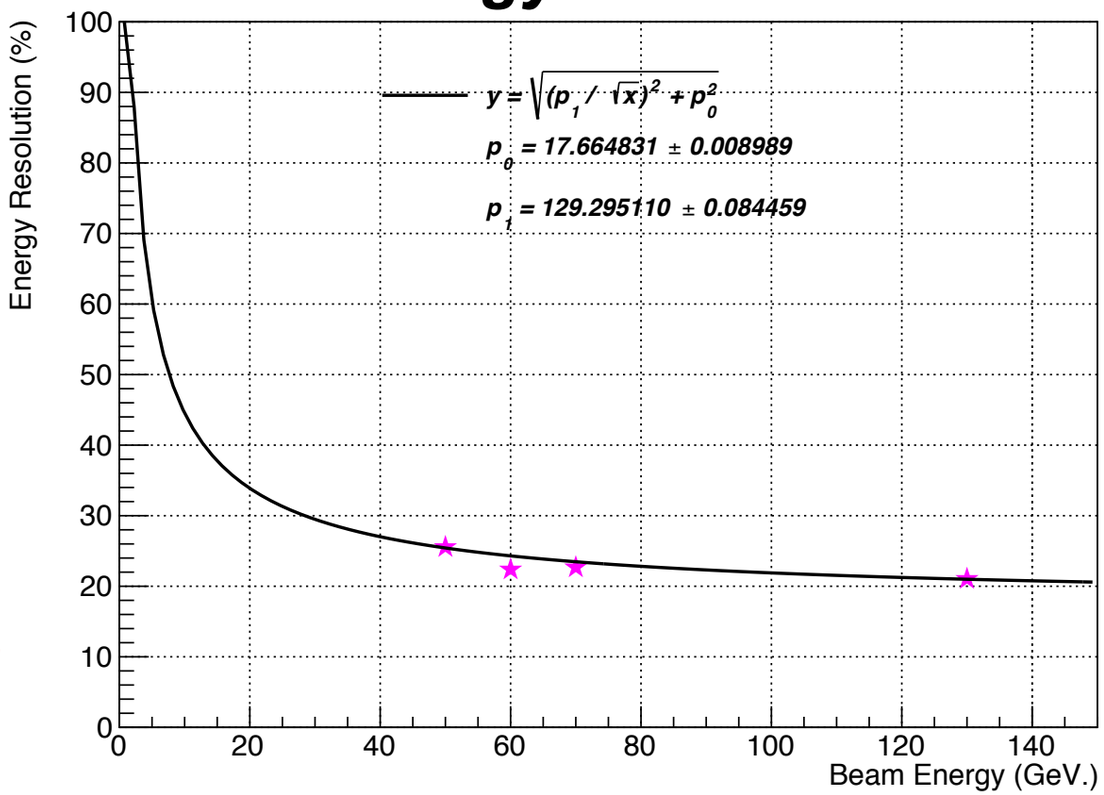
Number of hits (sum of two HGL)

Linearity



Energy can be measured by counting particle calorimeter.

Energy Resolution



✓*Number of hit pixels is depending on beam energy.*
✓*large offset and worse resolution can be seen.*
→ *lack of longitudinal depth in case of two layers set up.*

Position Resolution of center of hits

fluctuation of ΔGx,y is caused by each layers' resolution.

$$\sigma^2_{\Delta G_{x,y}} = \sigma^2_{G^{\mathrm{HGL1}}_{x,y}} + \sigma^2_{G^{\mathrm{HGL2}}_{x,y}}$$

under the assume that there is no individual differences between layers,

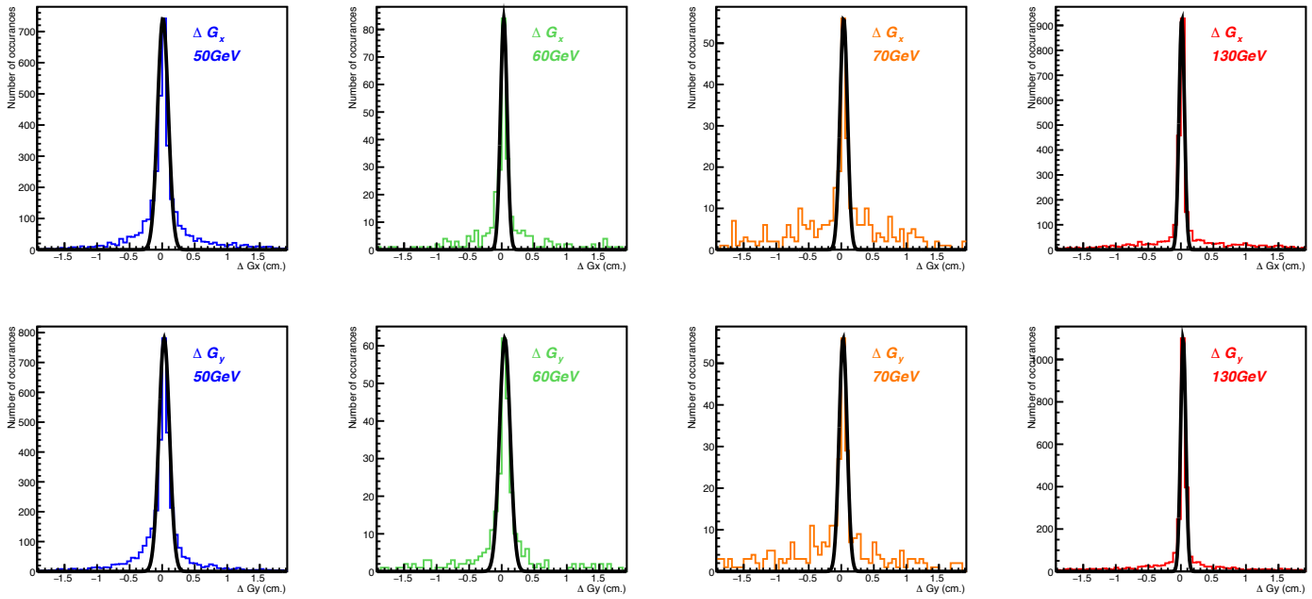
$$\sigma_{G^{\mathrm{HGL1}}_{x,y}} \simeq \sigma_{G^{\mathrm{HGL2}}_{x,y}}$$

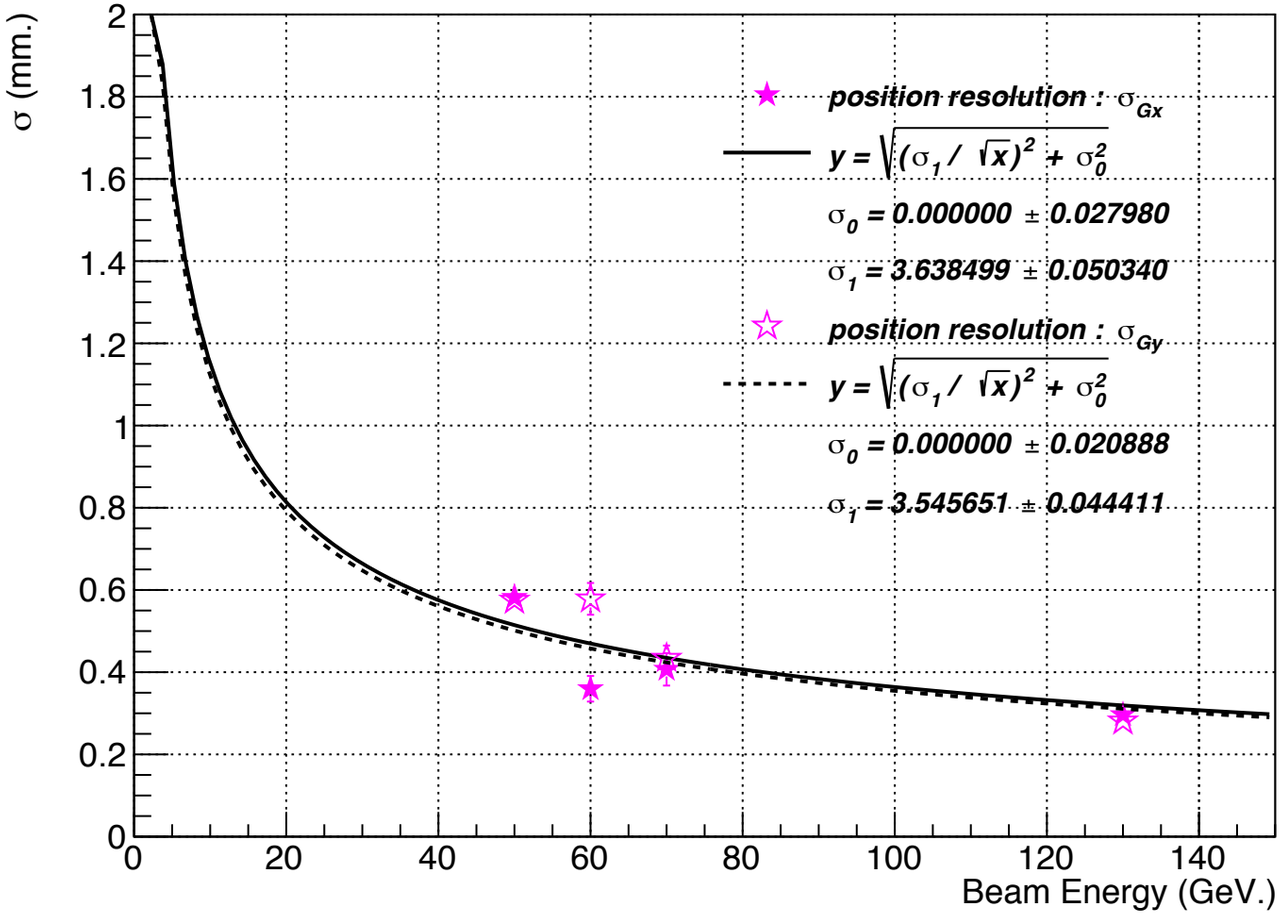
so the position resolution of $G_{x,y}$ of EM shower is

$$\sigma_{G_{x,y}} \simeq \frac{\sigma_{\Delta G_{x,y}}}{\sqrt{2}}$$

$$\sigma_{G_x} = \frac{(3.638 \pm 0.050)\mathrm{mm}}{\sqrt{E}} \oplus (0.000 \pm 0.028)\mathrm{mm}$$

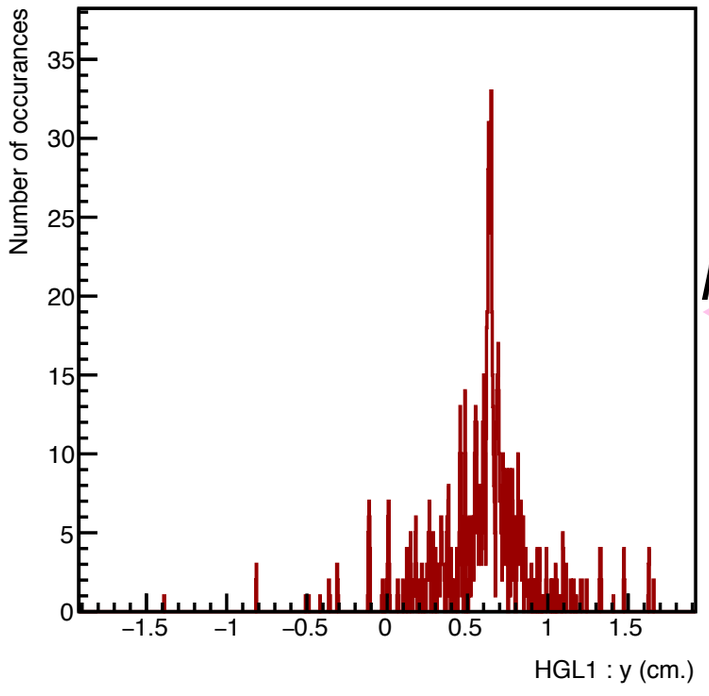
$$\sigma_{G_y} = \frac{(3.546 \pm 0.044)\mathrm{mm}}{\sqrt{E}} \oplus (0.000 \pm 0.021)\mathrm{mm}$$



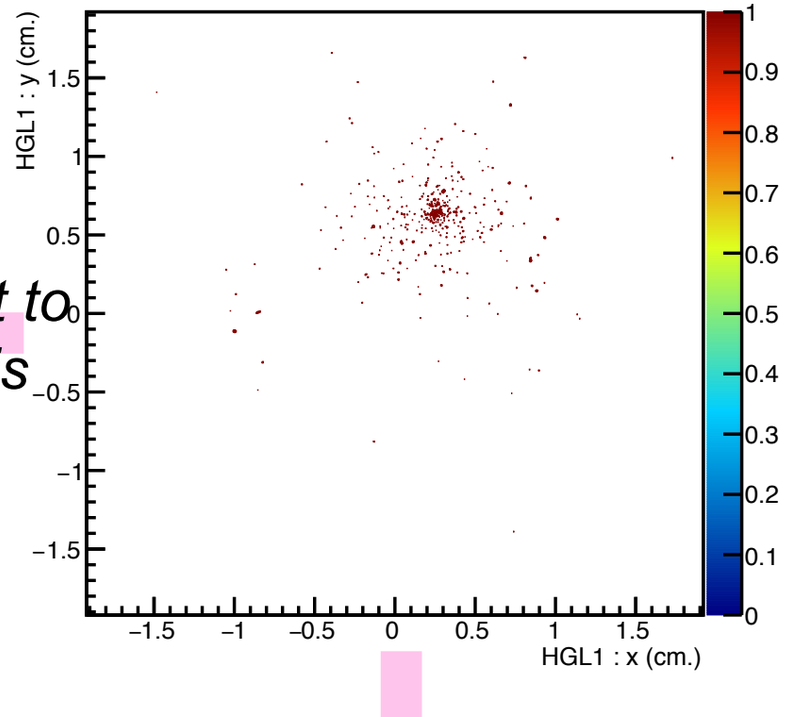


Back up

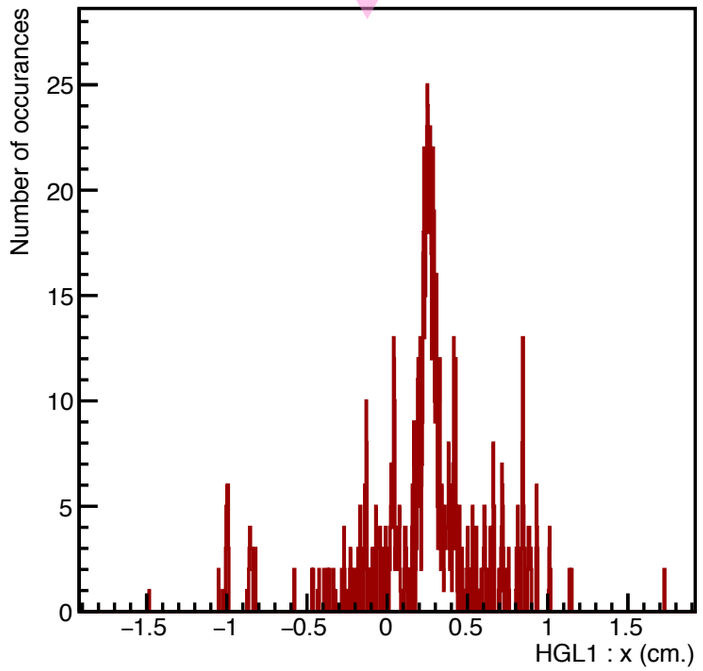
Center of hits in MAPS



Project to Y axis



Project to X axis



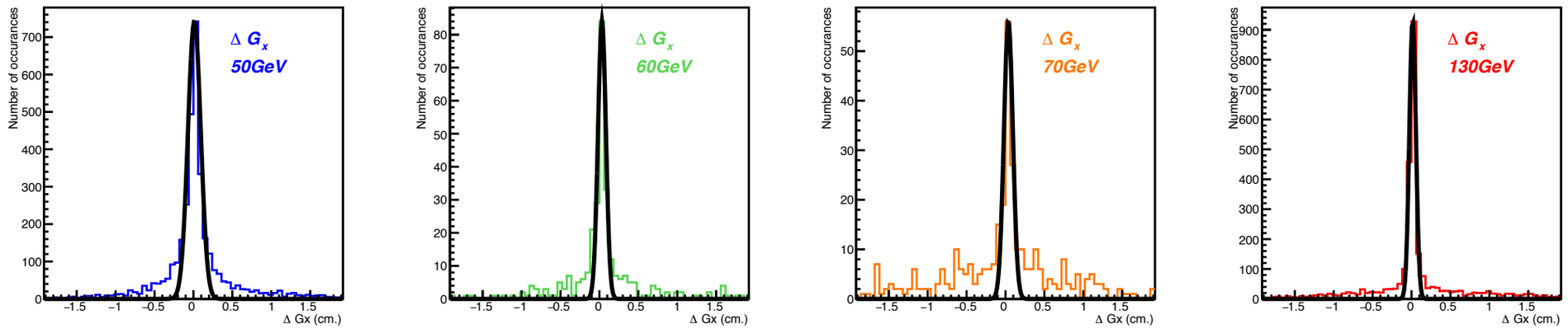
✓*Project 2D hit map to x and y axis.*
→ *the value of center of maximum bin is defined the center position of hit.*

EM shower identification cut

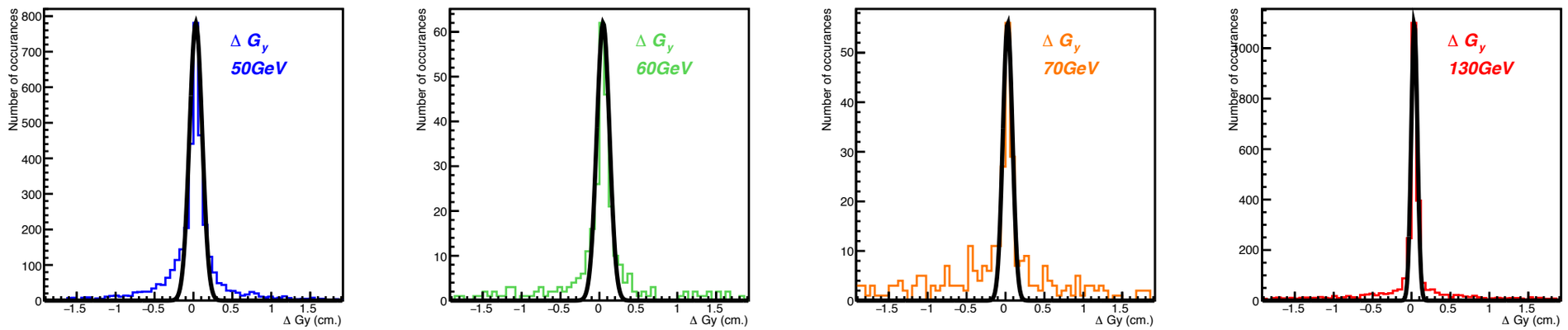
1. Straight Beam Select

✓ *gap of two layer's center of gravity*
→ $\Delta G_{x,y} = G_{x,y}^{HGL2} - G_{x,y}^{HGL1}$

✓ *Straight beam* → $|\Delta G_{x,y} - \mu| < 3\sigma$



ΔG_x (cm.)



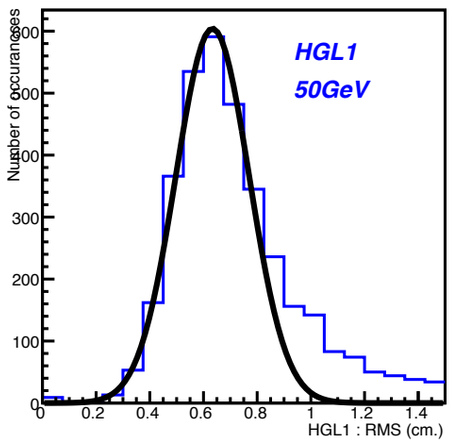
ΔG_y (cm.)

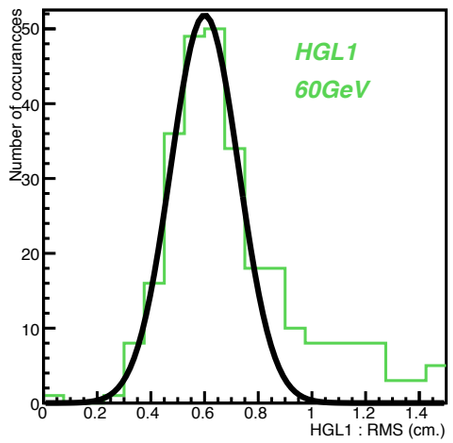
EM shower identification cut

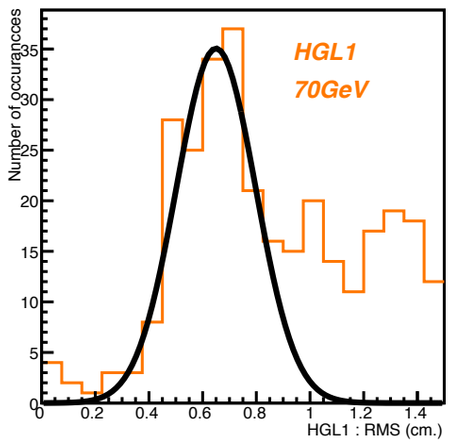
2. RMS cut

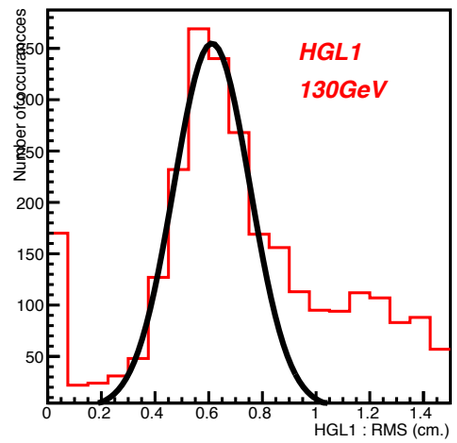
✓ *RMS(Root Mean Square) of hits map*
→ $RMS = \sqrt{(RMS_x^2 + RMS_y^2)}$

✓ *RMS Cut* → $|RMS - \mu| < 3\sigma$

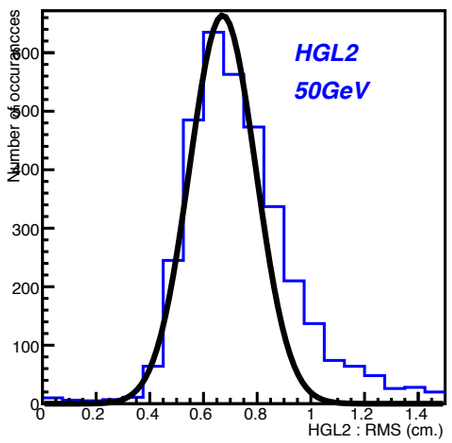


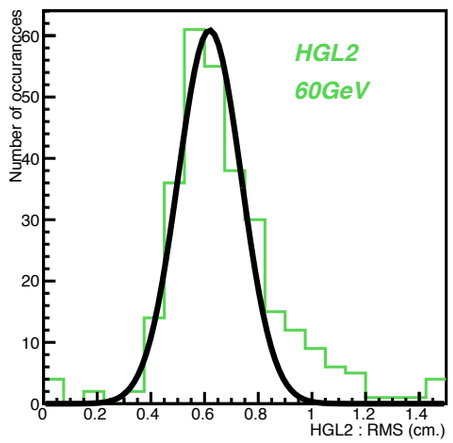


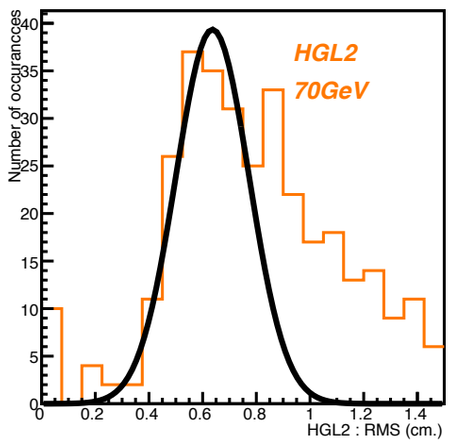


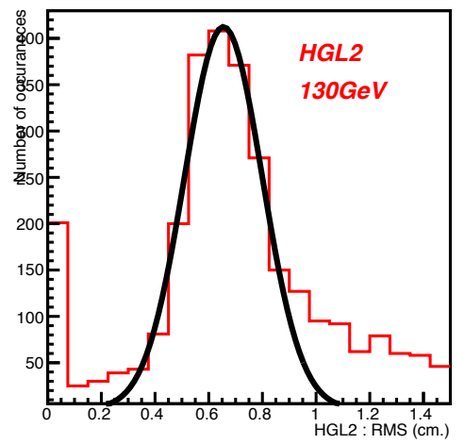


RMS(HGL1) (cm.)









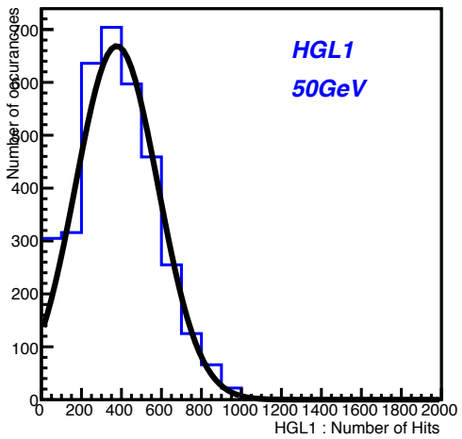
RMS(HGL2) (cm.)

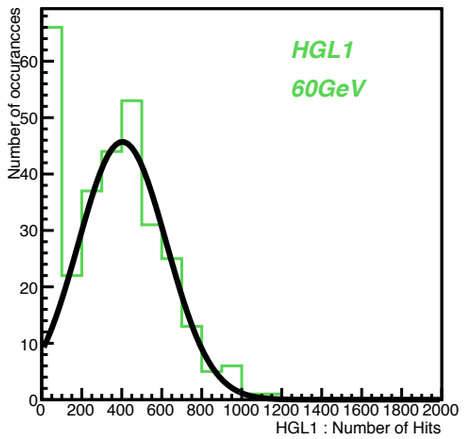
EM shower identification cut

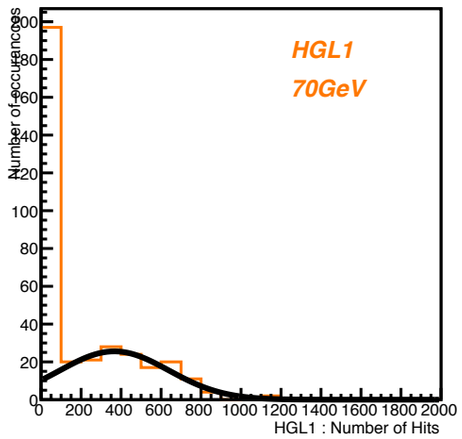
3. N_{hit} cut

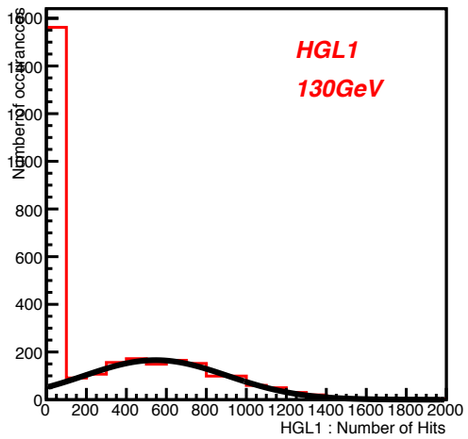
✓ N_{hit} : *number of hits*

✓ N_{hit} *Cut* → $|N_{hit} - \mu| < 3\sigma$

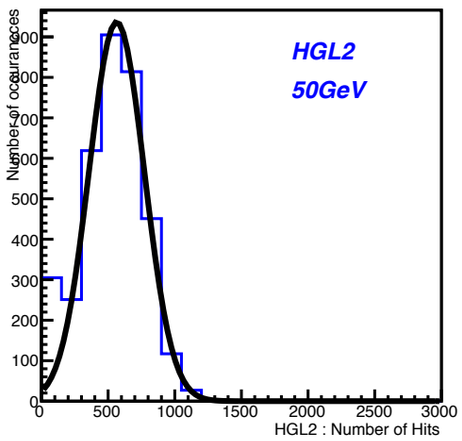


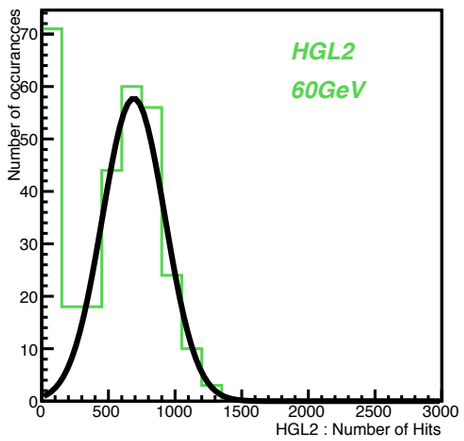


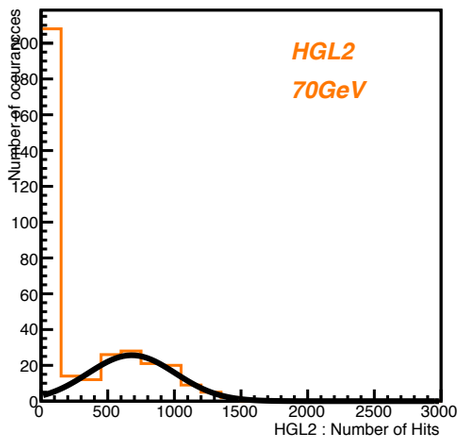


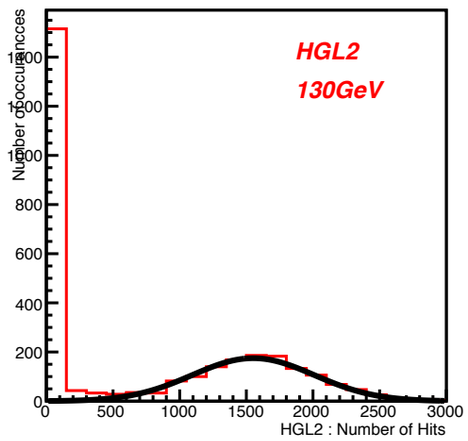


$N_{hit}(HGL1)$





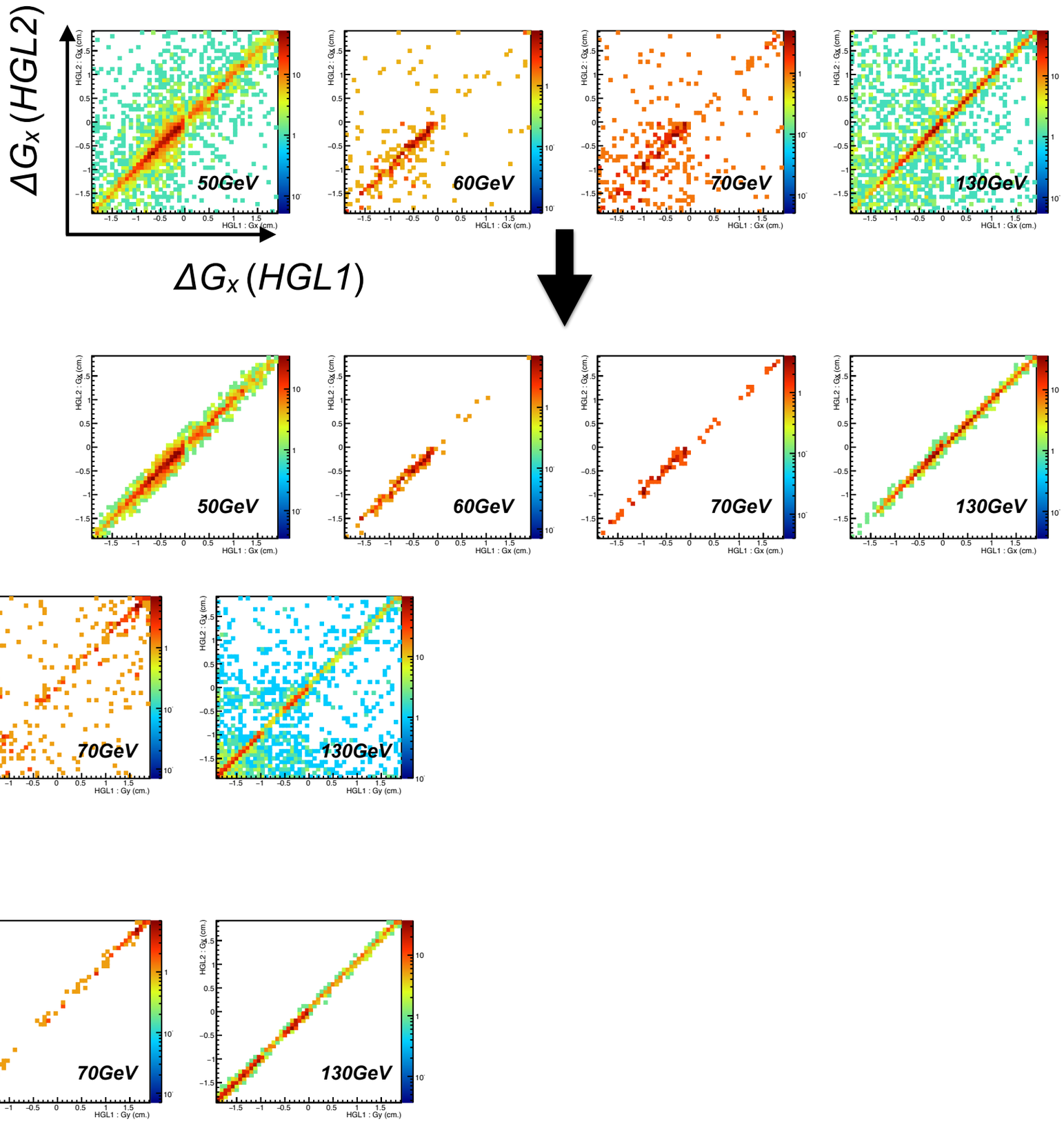


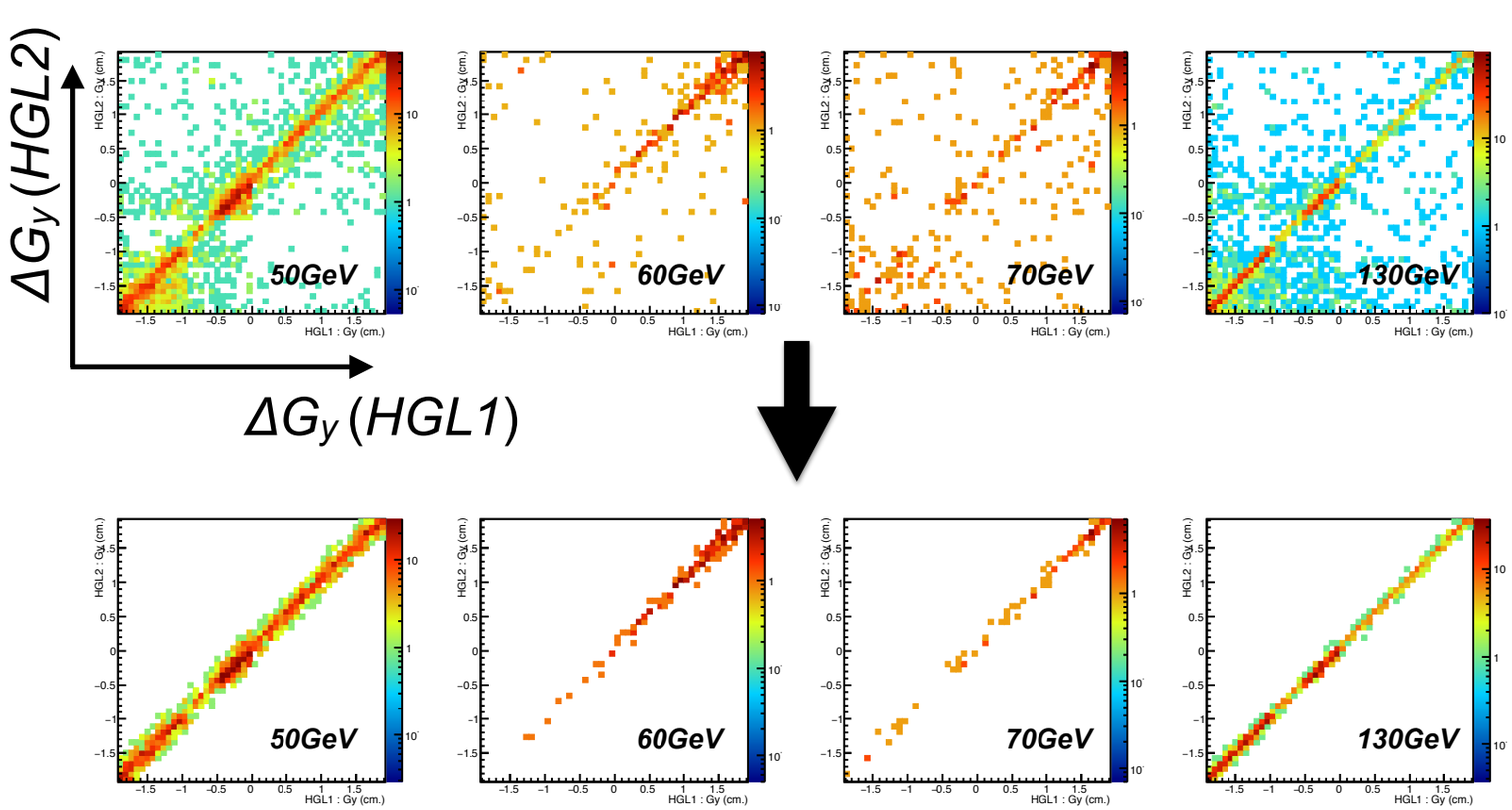


$N_{hit}(HGL2)$

Before cut / After cut

1.Straight Beam Select

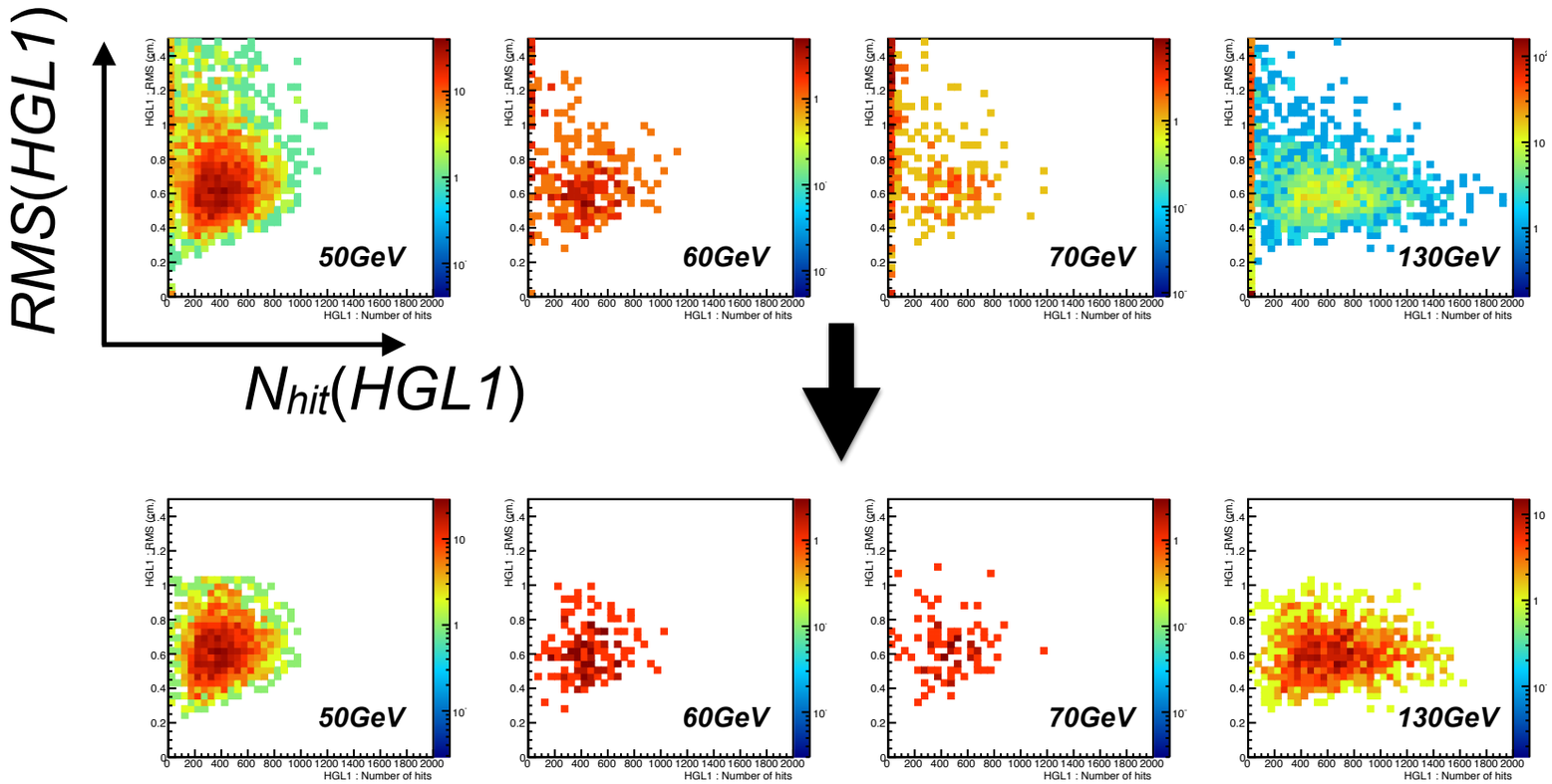


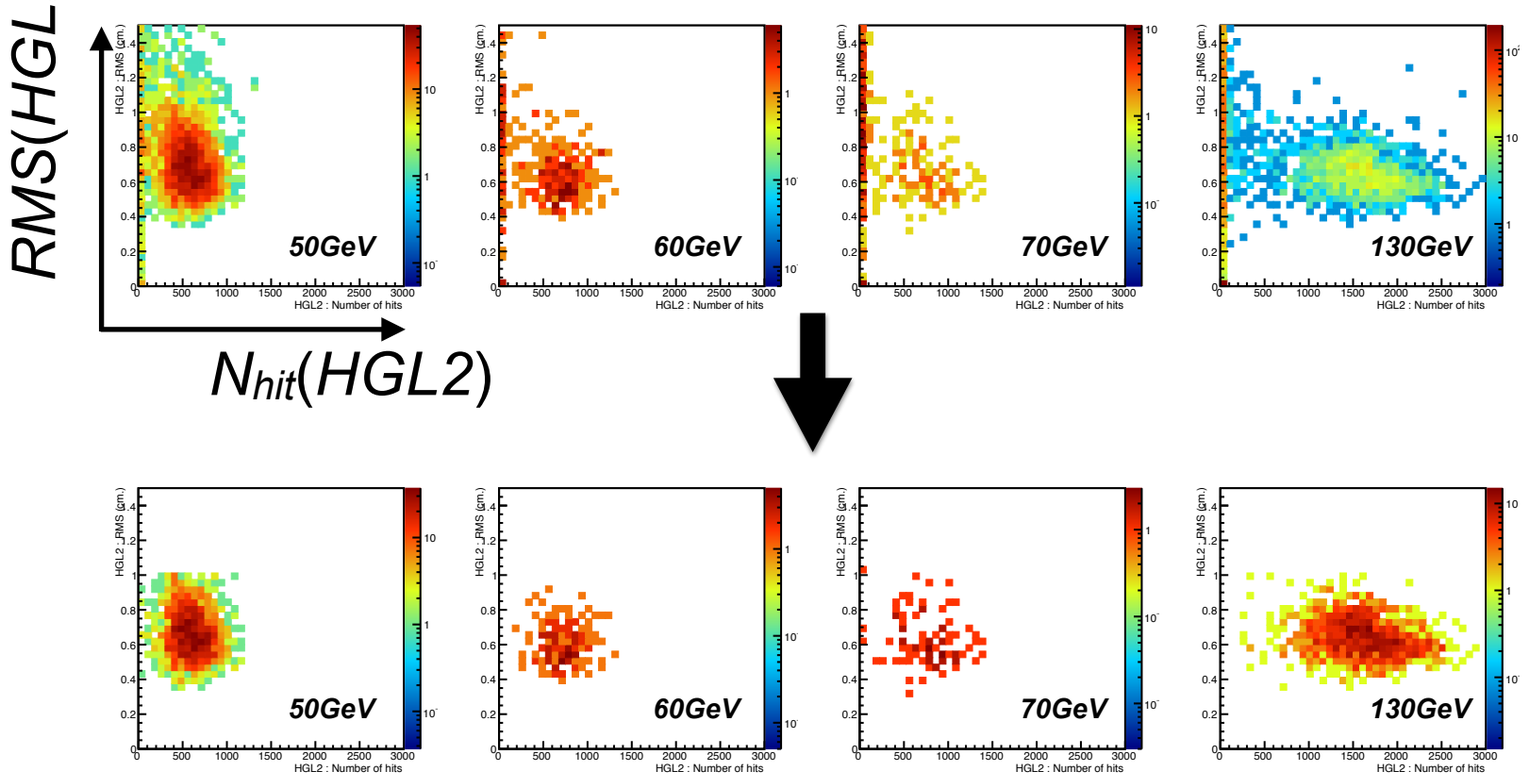


Before cut / After cut

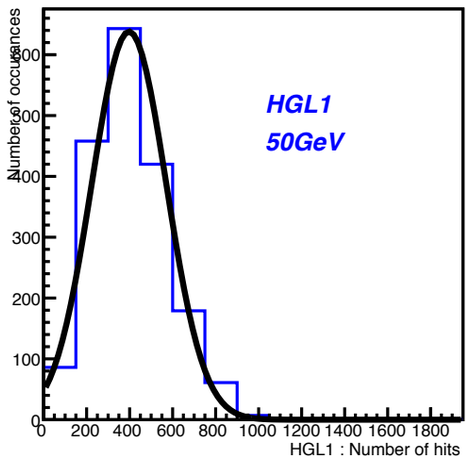
2.RMS Cut

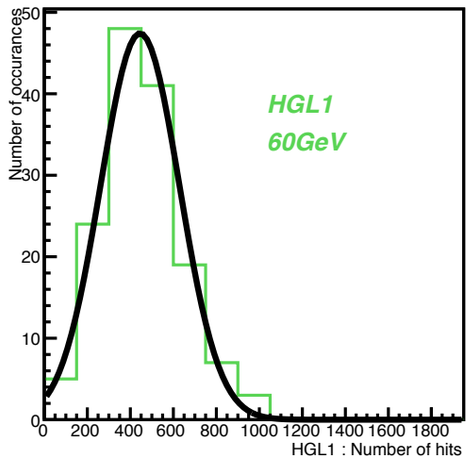
3. N_{hit} Cut

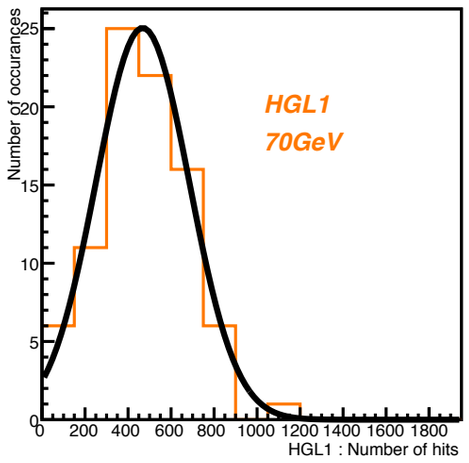


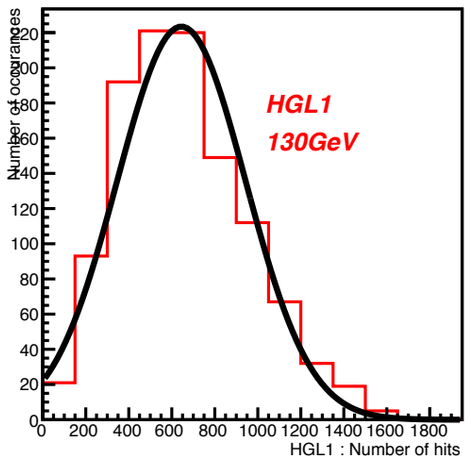


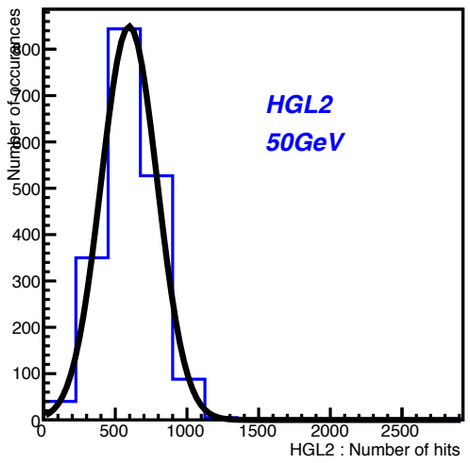
N_{hit} distribution

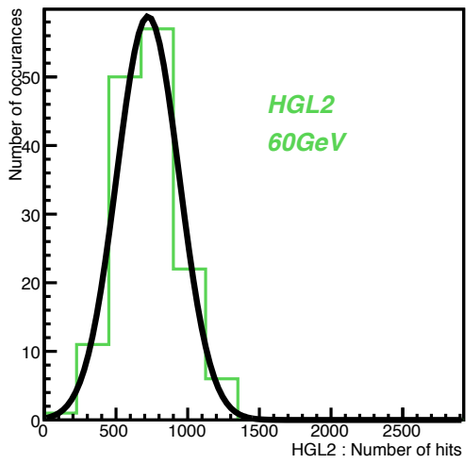


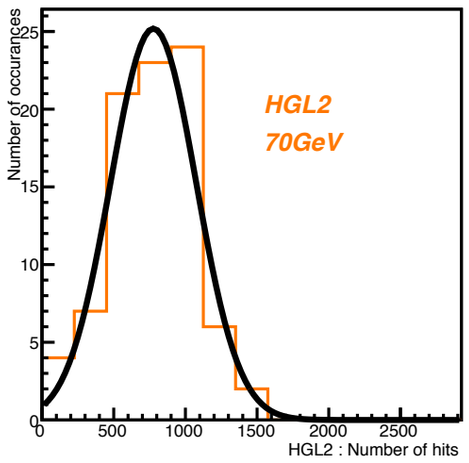


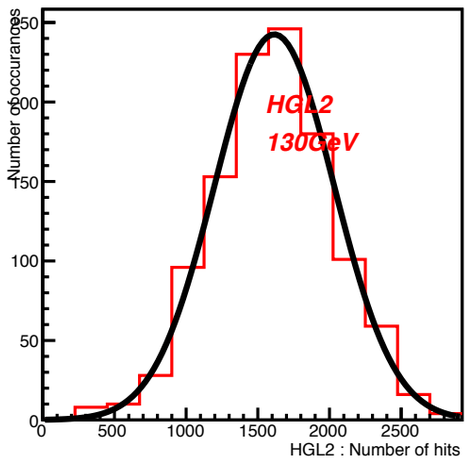


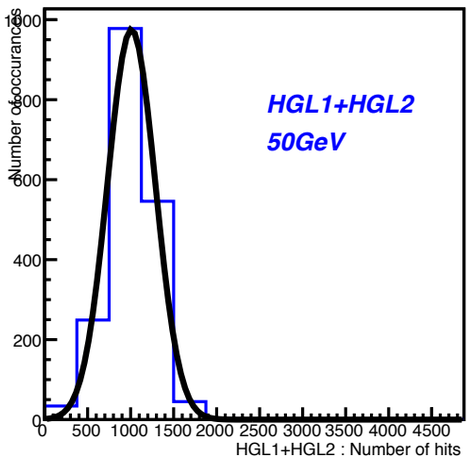


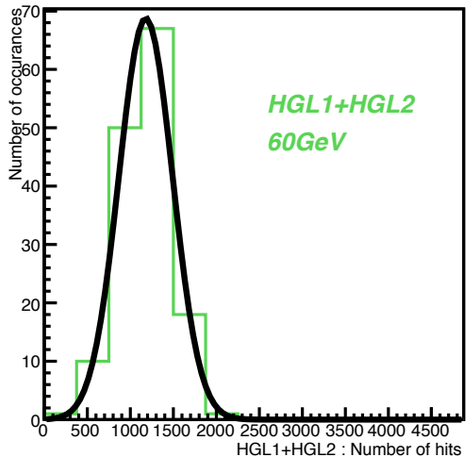


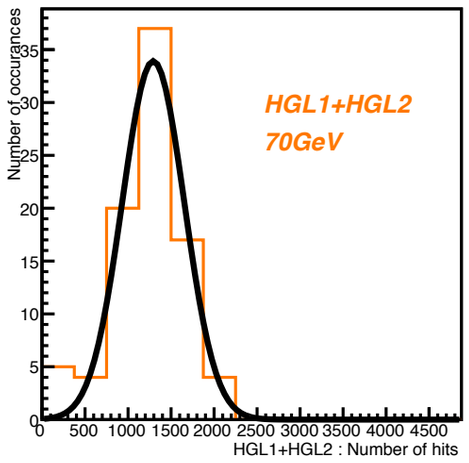


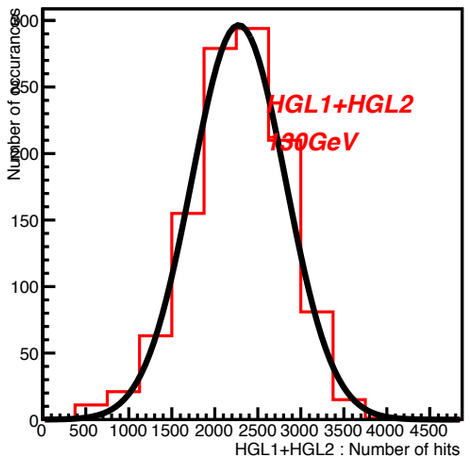




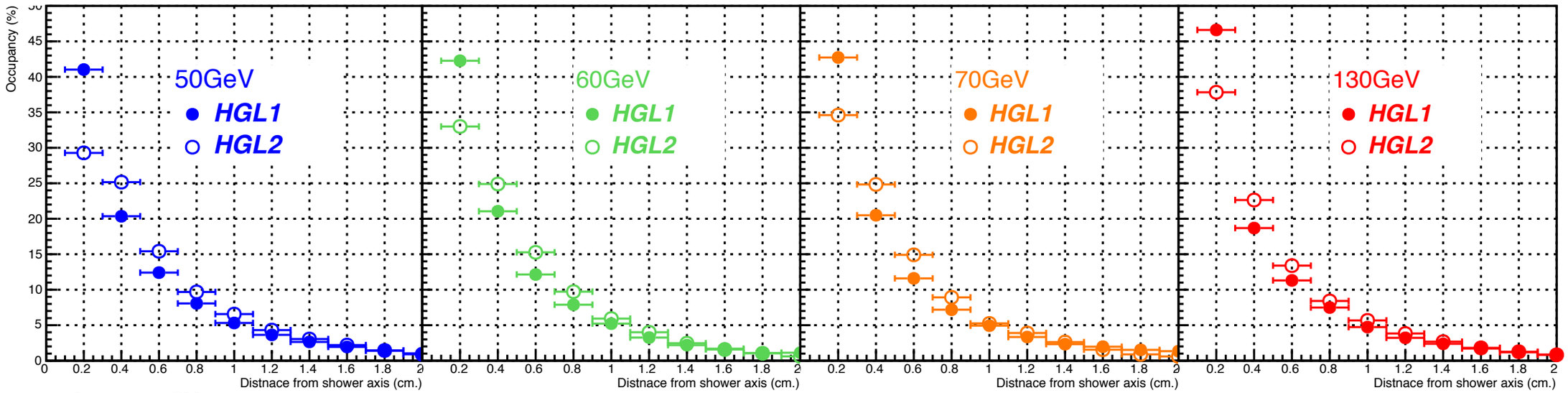








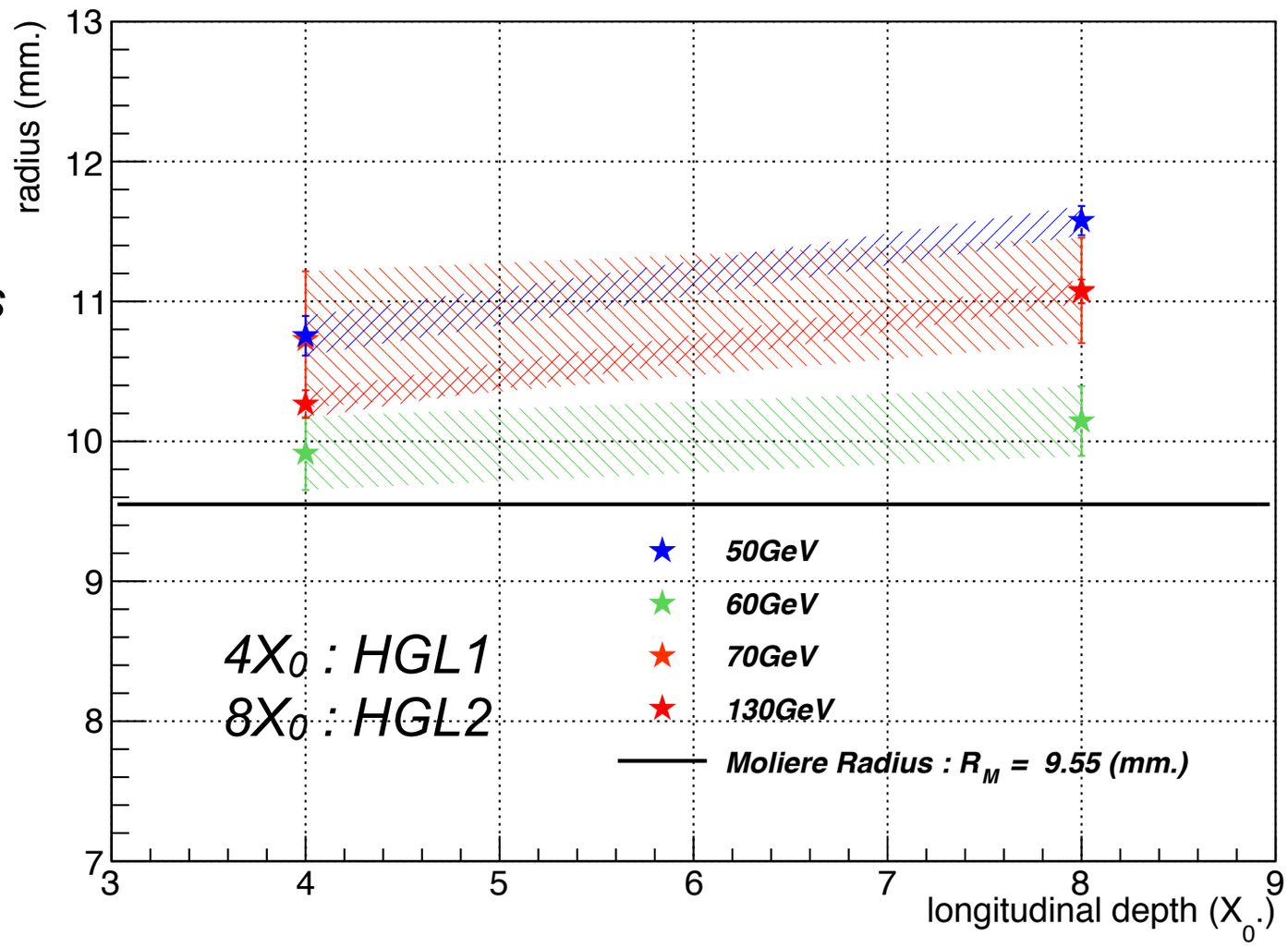
Shower profile



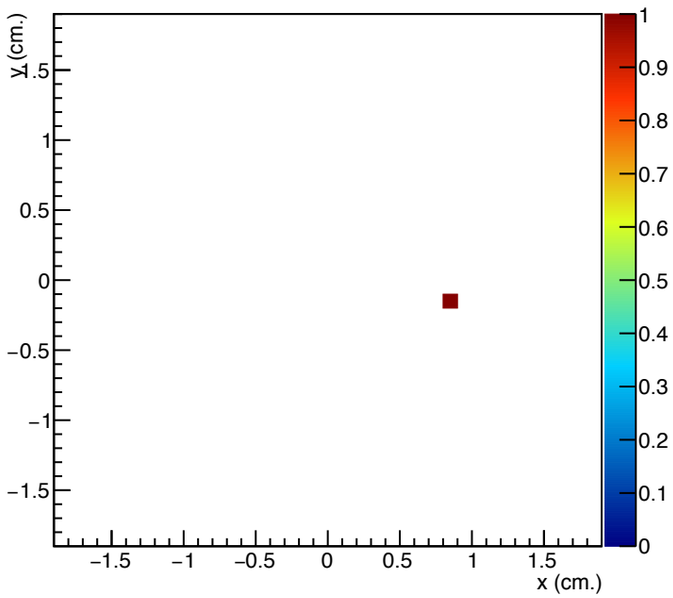
Lateral profile

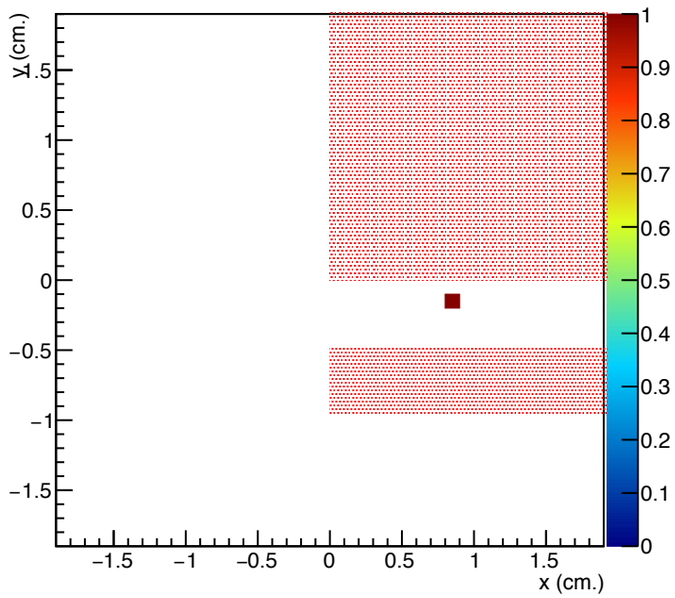
90% in all hits distribution from shower axis (for the comparison of Moliere Radius)

- ✓ *Lateral profile in HGL1 is sharper than HGL2 →shower core*
- ✓ *Lateral and longitudinal shower profiles are consistent.*



Hadron response





パンチスルーするハドロンの特徴

✓飛跡がストレートである

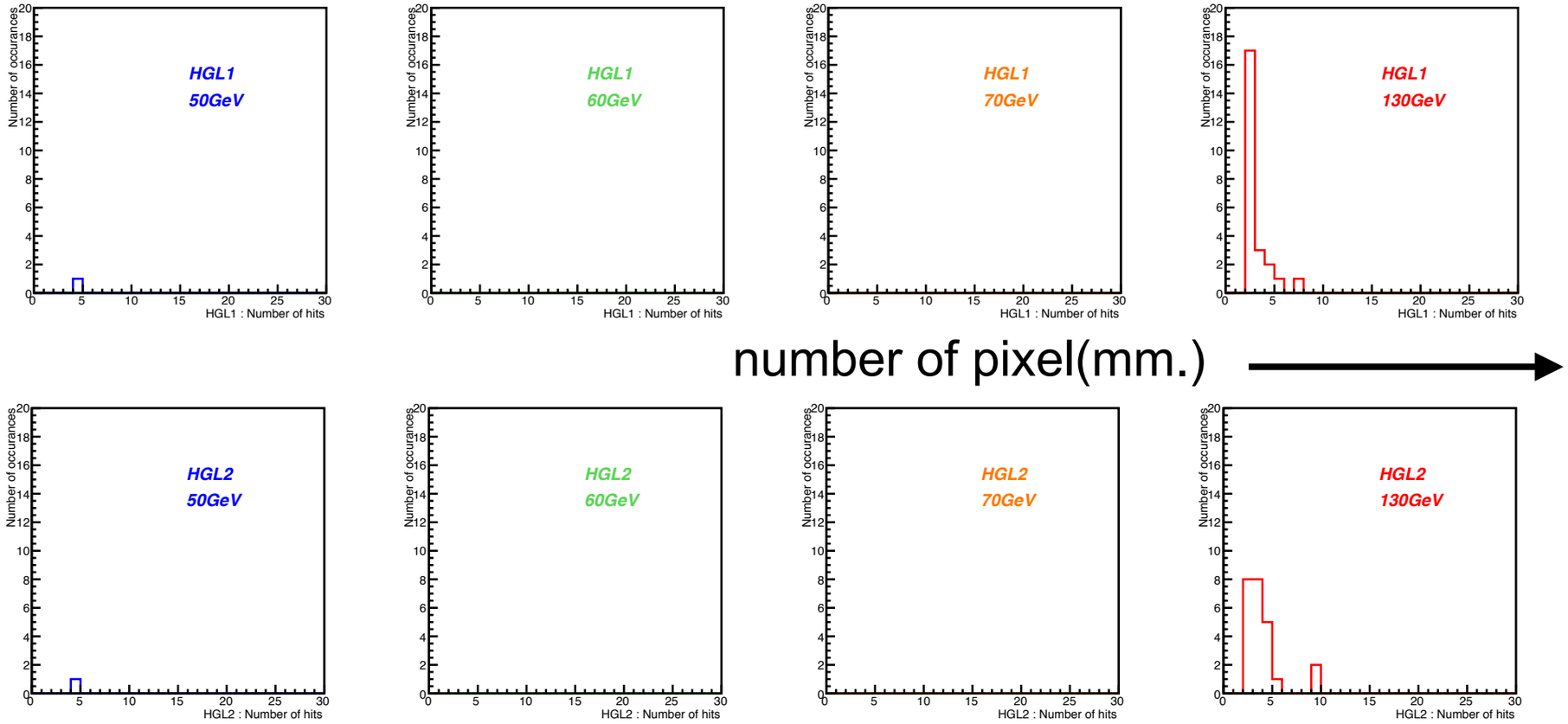
✓分布は数点に集中する→*RMS*は小さい

✓シャワーを起こさないので、数*pixel*程度のヒット数

パンチスルーするハドロンのヒット数分布

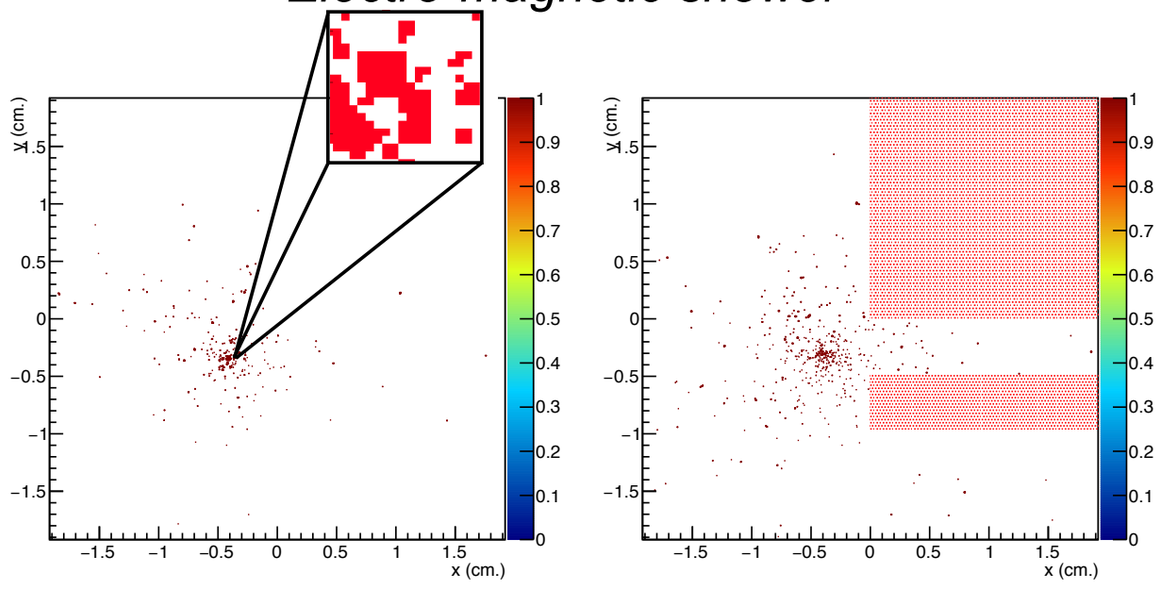
(上:HGL1、下:HGL2)

HGLにおけるMIPレスポンスか…??

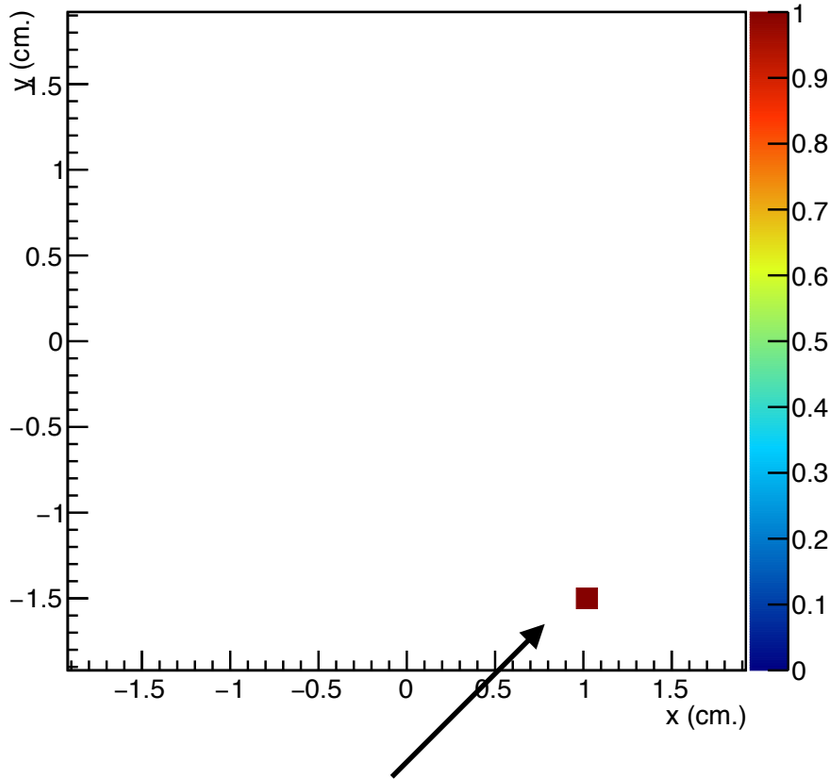


Hadronic Shower display

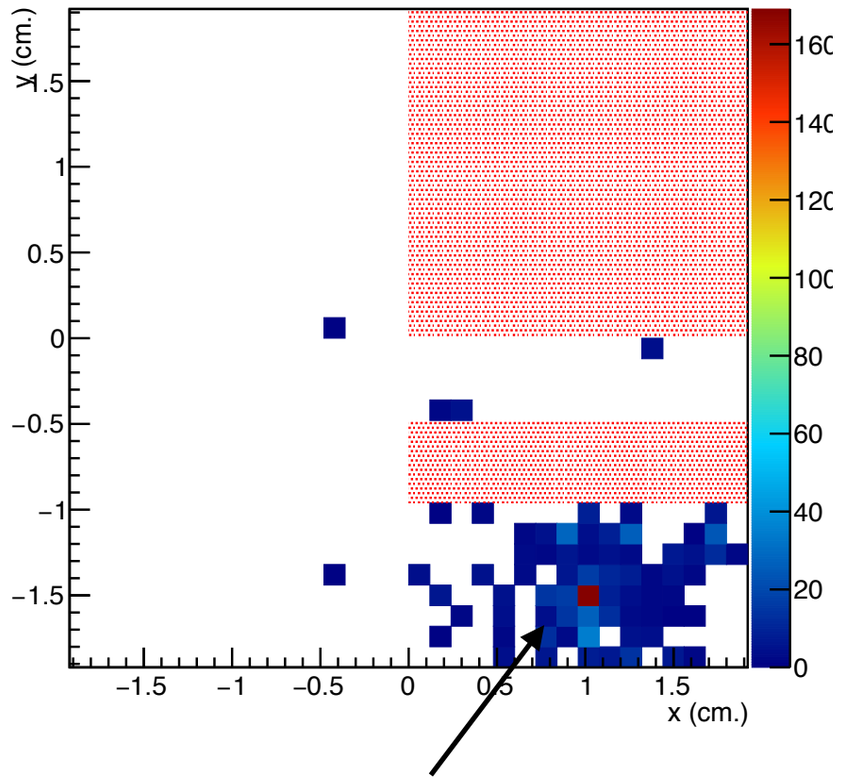
Electro-magnetic shower



Hadronic shower



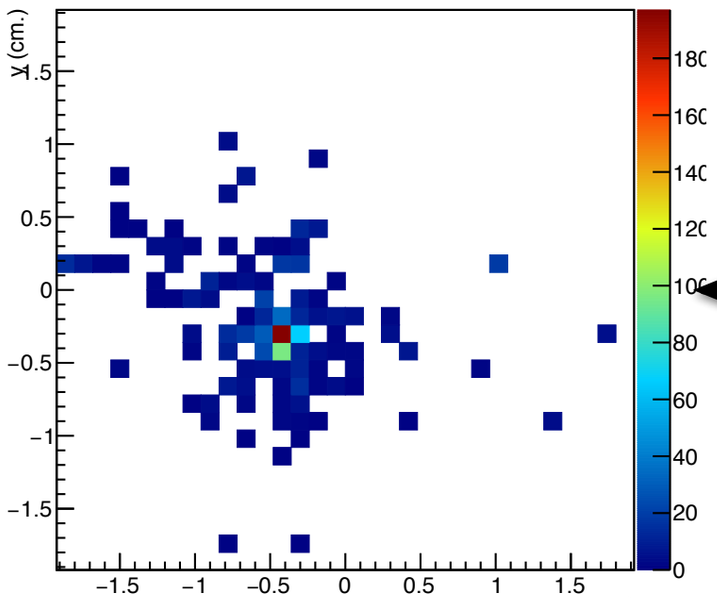
particle goes thorough HGL1 without producing shower

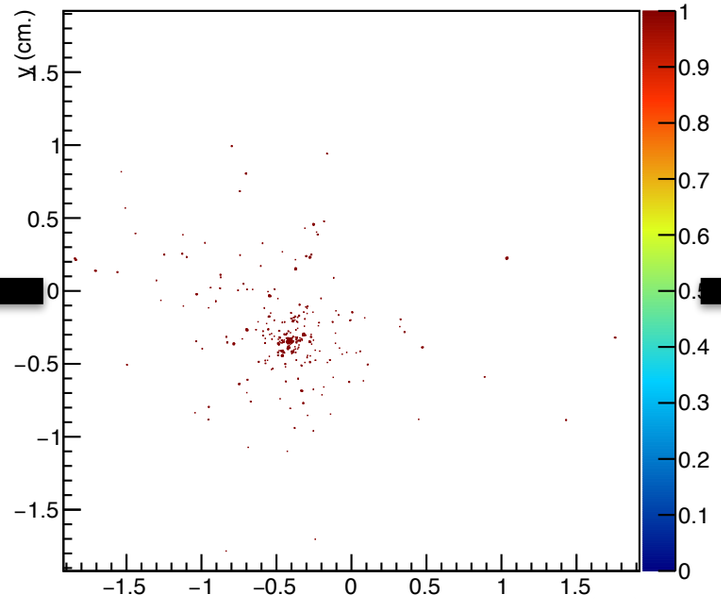


Shower occurs at the position of HGL2

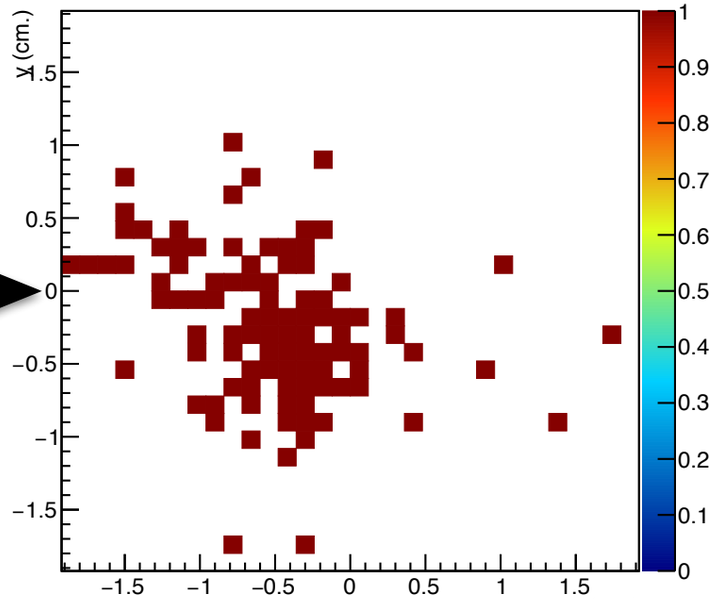
Roughing the pitch of pixels

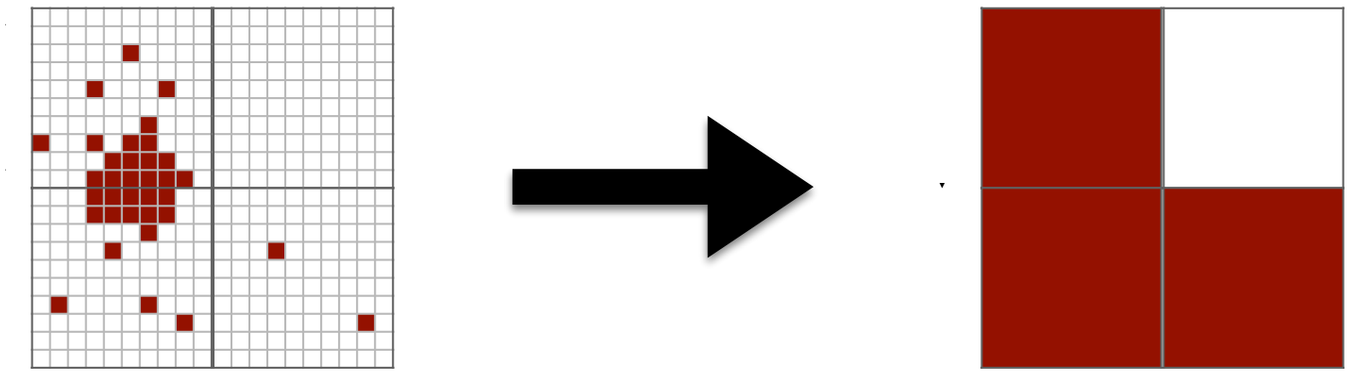
ヒット数の重みあり





ヒット数の重みなし

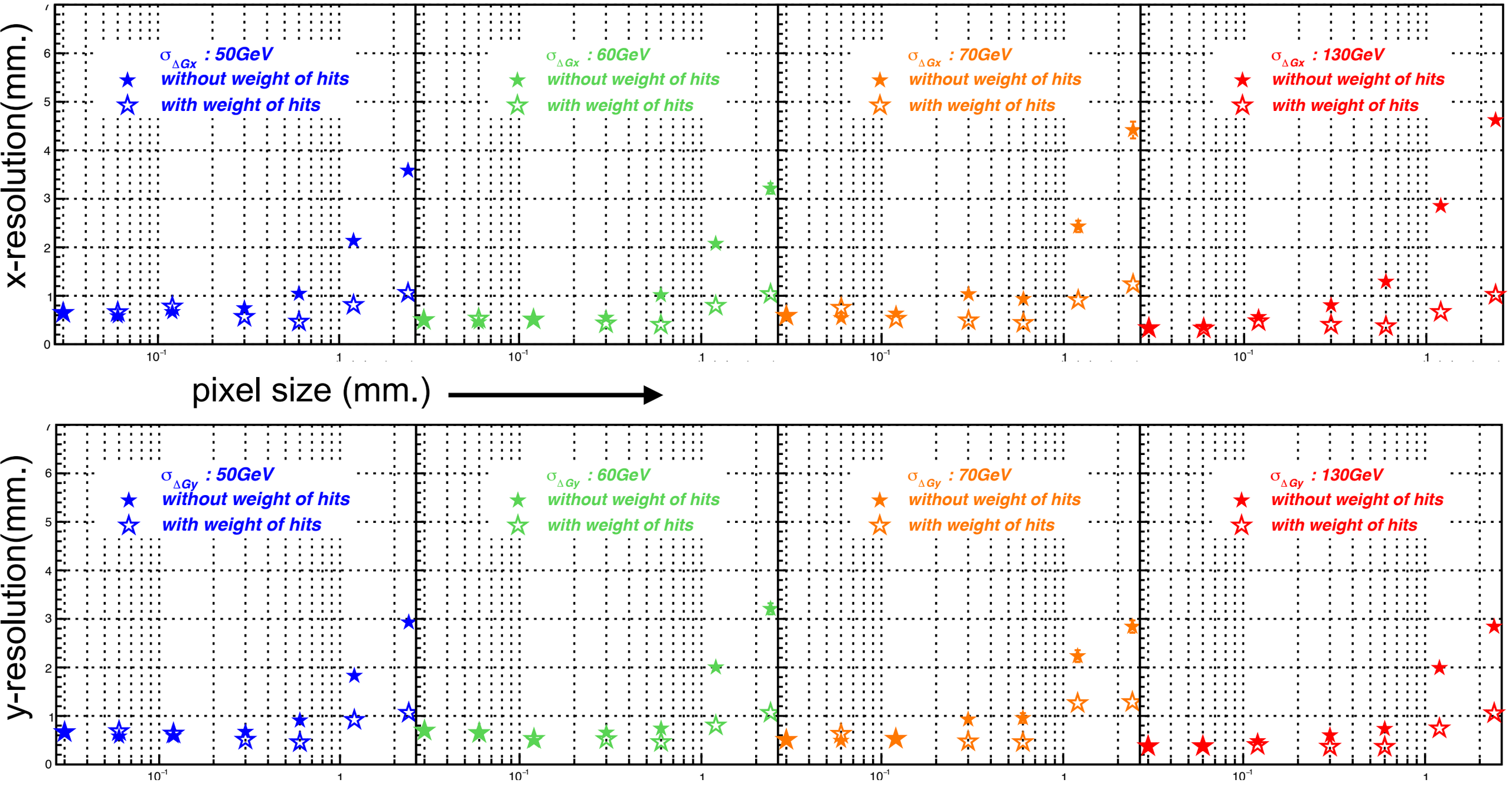




✓*30μm*の*Si pixel*では読み出し処理に膨大な時間がかかり、そのため*1mm*程度にまとめてデータを読み出すことが考えられている。

★*30μm pitch*のデータを***pixel*を粗くしたデータに再構成**し、重心の分解能を評価。

pitch dependence of position resolution



✓ヒット数情報を読み出せば十分高い分解能を維持できる!!

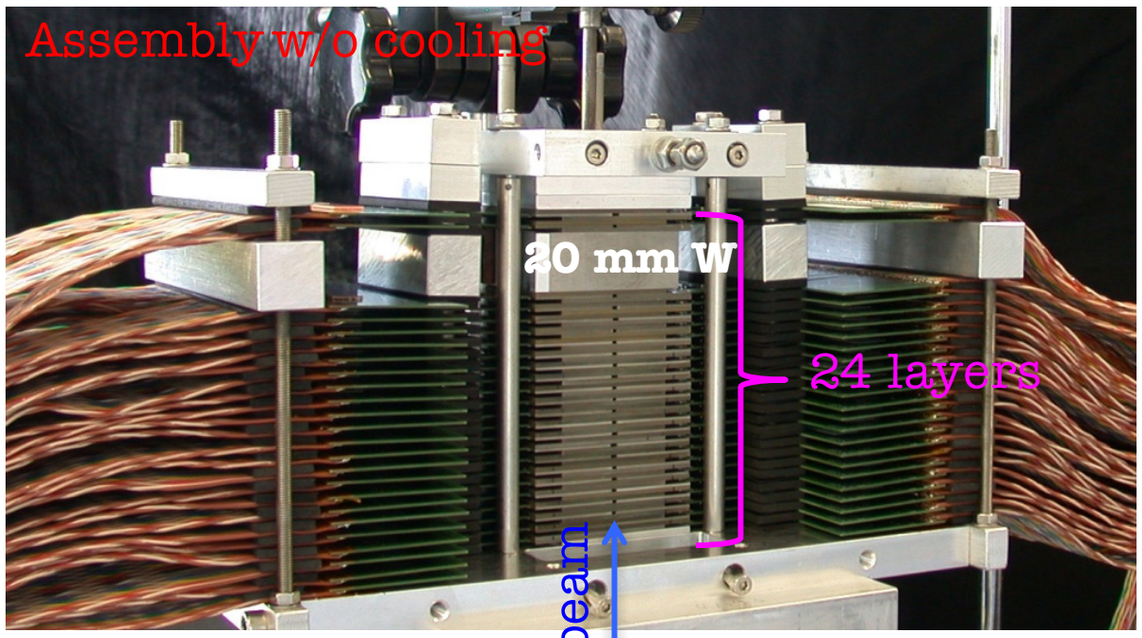
✓1mmピッチでも光子識別が可能といえる

☆ ヒット数の重みなし

★ ヒット数の重みあり

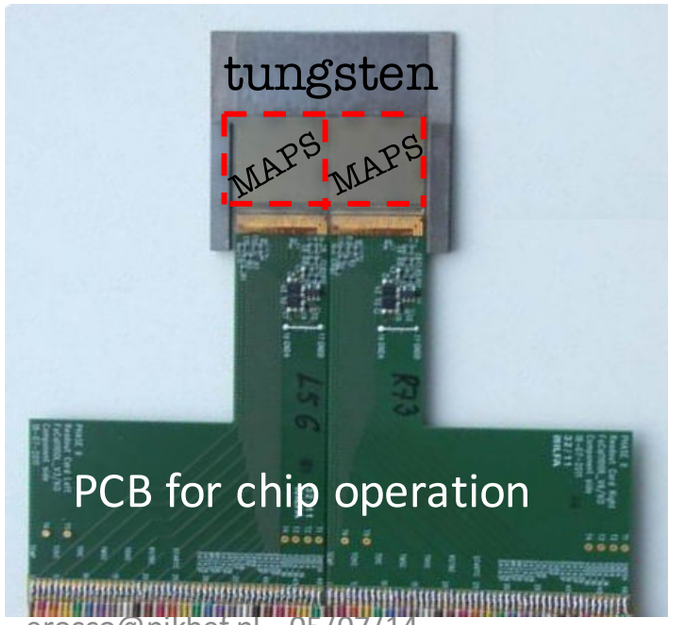
Reference data (Utrecht Univ.)

The fully digital prototype

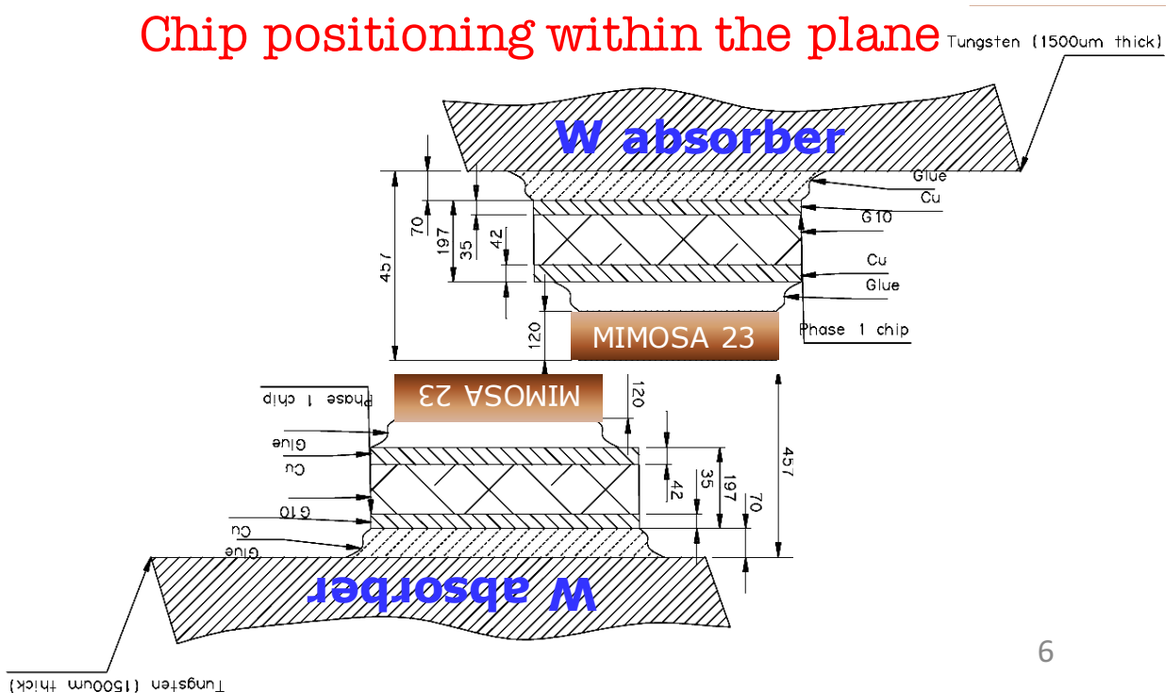


24 layers -> 28 X_0
4 chips per layers -> 96 chips
39 M pixels
Compact design 4x4x11,6 cm^3
Molière radius: R_M= 11 mm
Raw data rate 61 Gb/s
managed by several FPGA (D. Fehlker et al., 2013 JINST 8 P03015)

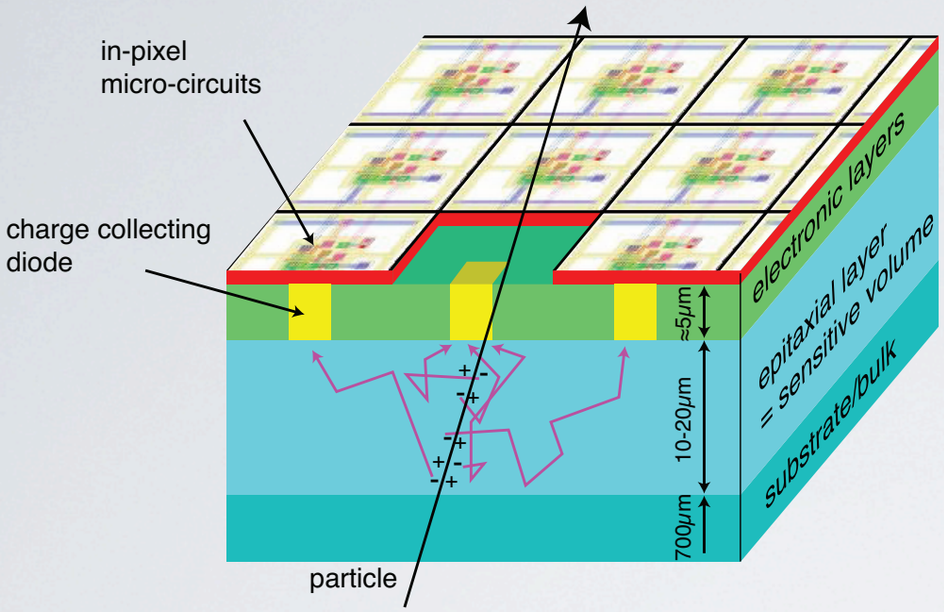
Half module

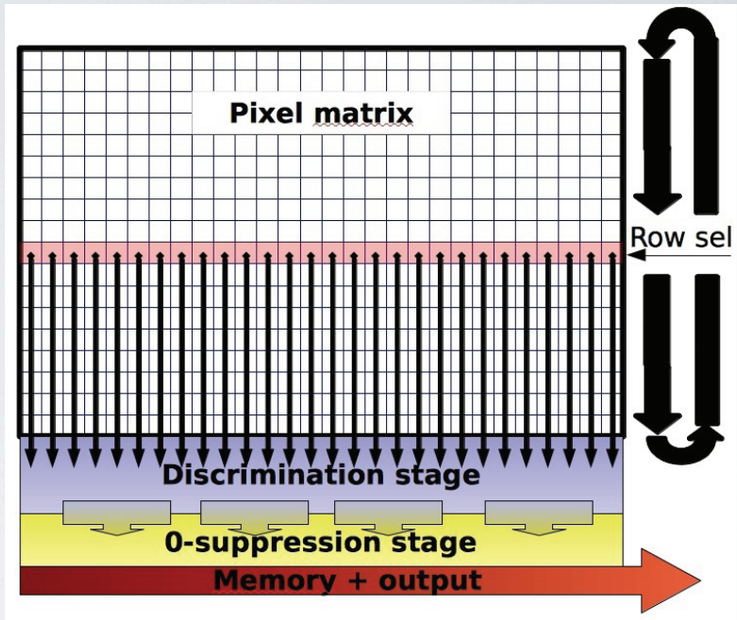


Chip positioning within the plane



CMOS Sensor



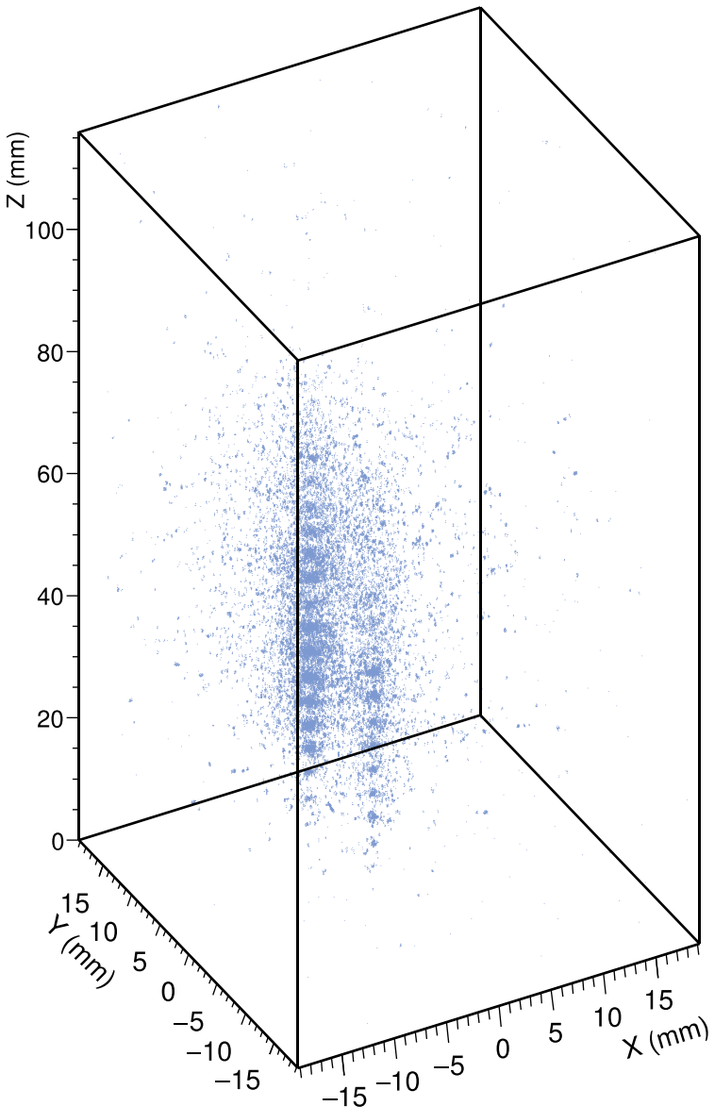


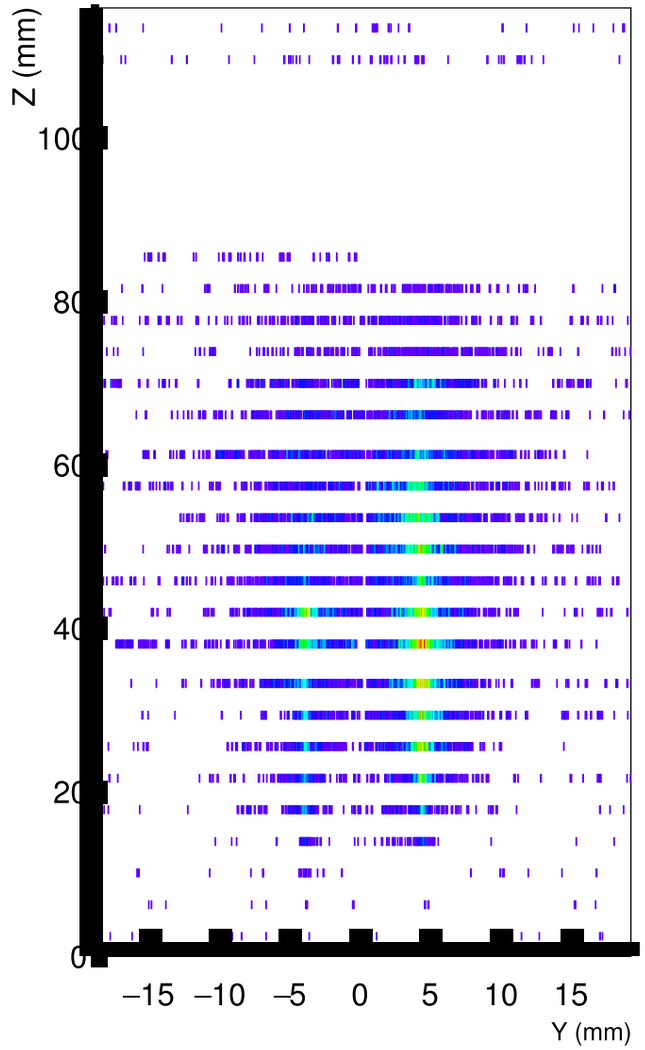
- Monolithic Active Pixel Sensors: Mimosa (IPHC Strasbourg)
  - here: MIMOSA23 (PHASE 2)
- rolling shutter: 640 μs total RO time
- digital readout
  - likely algorithm for real detector:
    on-chip hit count in macro pixel of 1 mm^2,
    for 30 μm pixels equivalent to 10bit analog value

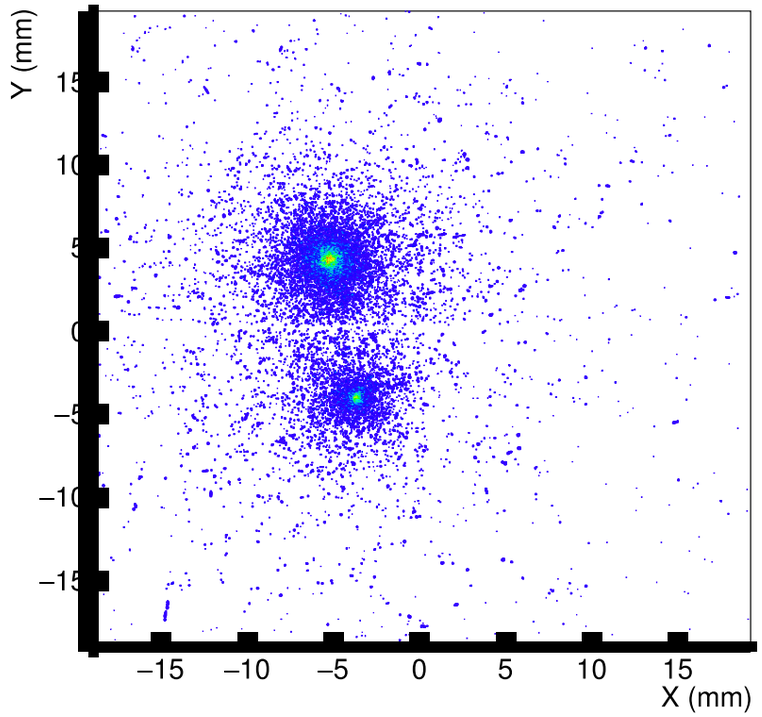
chip size	19.5 x 21 mm^2
active area	19.2 x 19.2 mm^2
pixels	640 x 640
pitch	30 x 30 μm

Event Display

- single event (244 GeV) with pile up (!)

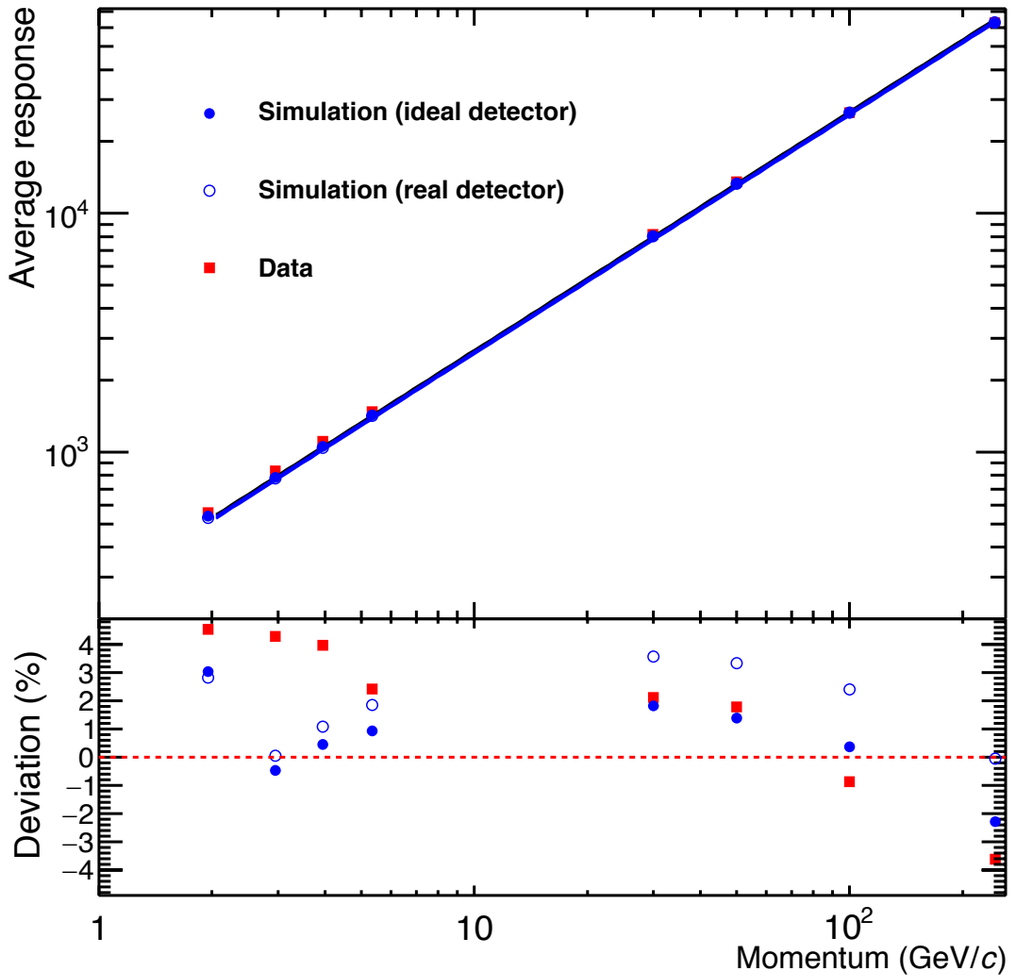


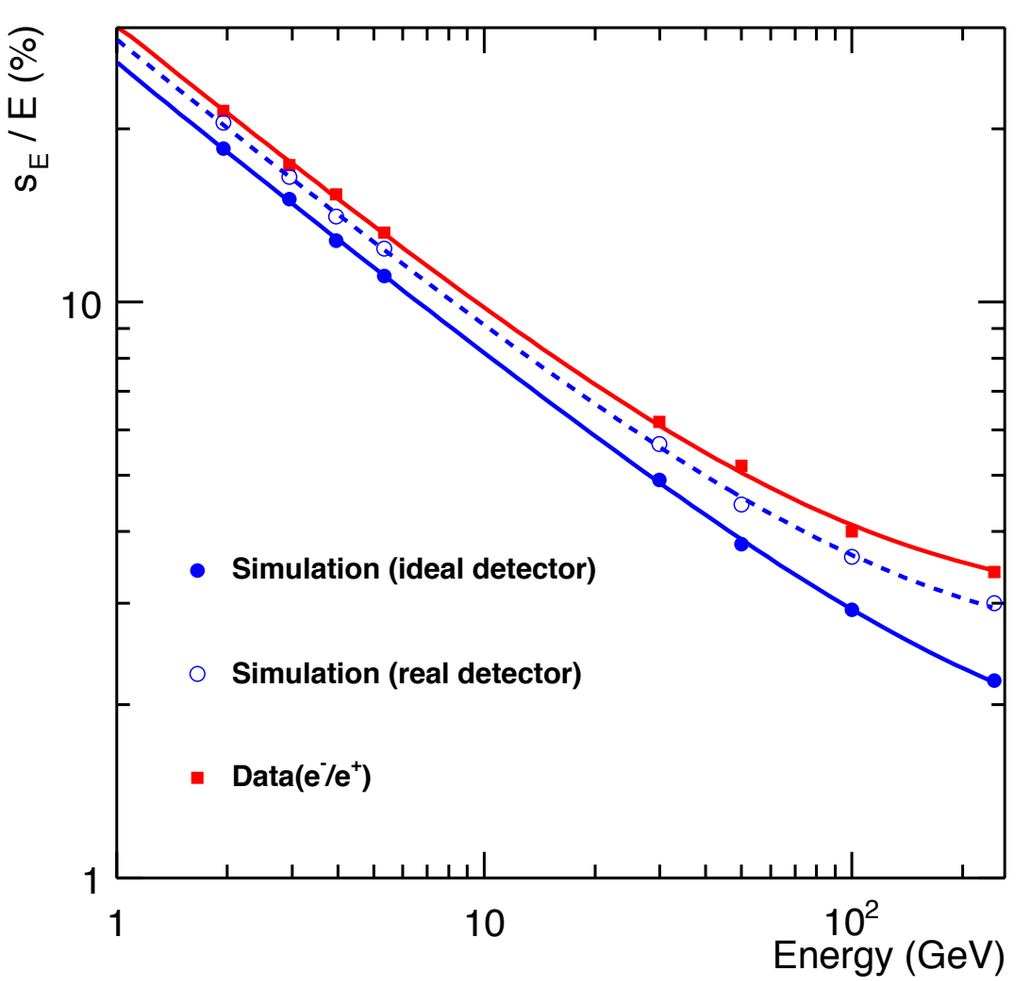




2

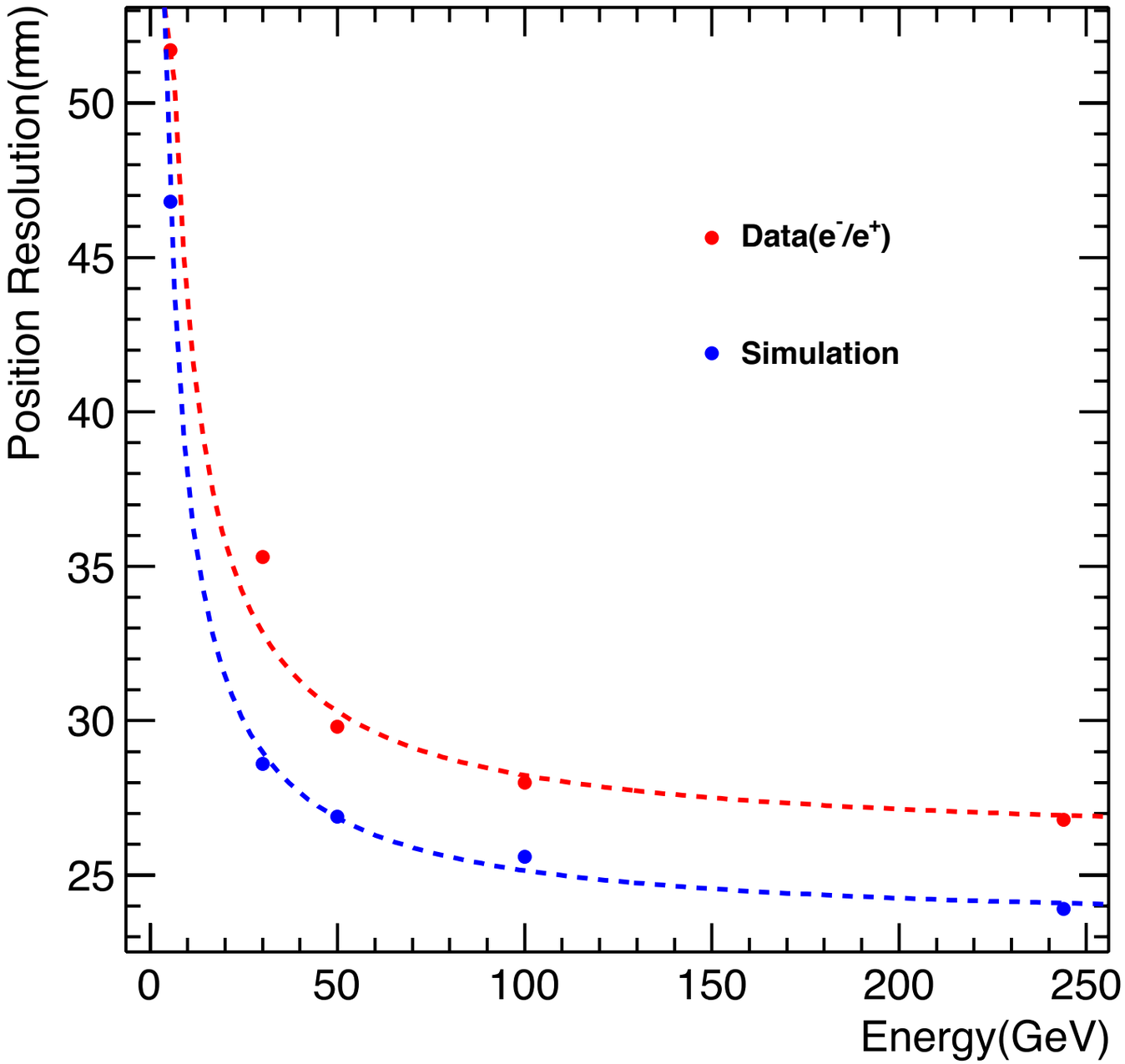
Energy Linearity and Resolution





4

Shower Position Resolution



- resolution defined as width of residuals between
  - layer 0 cluster position and
  - shower center of gravity from layers > 0

Shower Profiles

- Hit densities as a function of radial distance for different layers (i.e. shower depth)