R&D for silicon pixel calorimeter

Takashi SAKO

(ISEE/KMI, Nagoya university)

Results and prospects of forward physics at the LHC: Implications for the study of diffraction, cosmic ray interactions, and more

11-12 February 2013
CERN
Europe/Zurich timezone

Search...

Prospects for light-ion collisions in the LHC

D.Manglunki
with help from
Ph.Baudrenghien, J.Jowett & D.Küchler

Only and most realistic estimate of light ion collision scenario at LHC
https://indico.cern.ch/event/223562/

ECR source

- The source can "deliver anything", however...
  - It takes time to commission the whole chain with new species (16 weeks minimum for LEIR/PS/SPS)
  - Switching between two species within one year is difficult (~ 4 weeks to switch ECR for completely different species) -> competition with Pb-Pb and p-Pb in LHC, and primary ions in North Area (Ar, Xe, Pb)
- Oxygen is support gas for Pb
  - One can imagine running O for a short period within Pb year
    - Opens possibility for O-O and p-O
- Other ion mixtures
  - N + O , S + O "Easy"
  - MIVOC (Metal Ions from Volatile Compounds) for Fe...

Estimations of Luminosity [cm^{-2} s^{-1}]

	O-O	N-N	S-S	Fe-Fe
b*=50 cm	2.5E+29	3.2E+29	6.2E+28	2.4E+28
b*=10 m	1.2E+28	1.6E+28	3.1E+27	1.2E+27

	p-O	p-N	p-S	p-Fe
b*=50 cm	2.0E+30	2.3E+30	9.9E+29	6.1E+29
b*=10 m	9.9E+28	1.1E+29	5.0E+28	3.1E+28

	O-N	S-O	Fe-O	Fe-N
b*=50 cm	2.8E+29	1.2E+29	7.7E+28	3.8E+28
b*=10 m	1.4E+28	6.2E+27	3.8E+27	1.9E+27

Conclusion

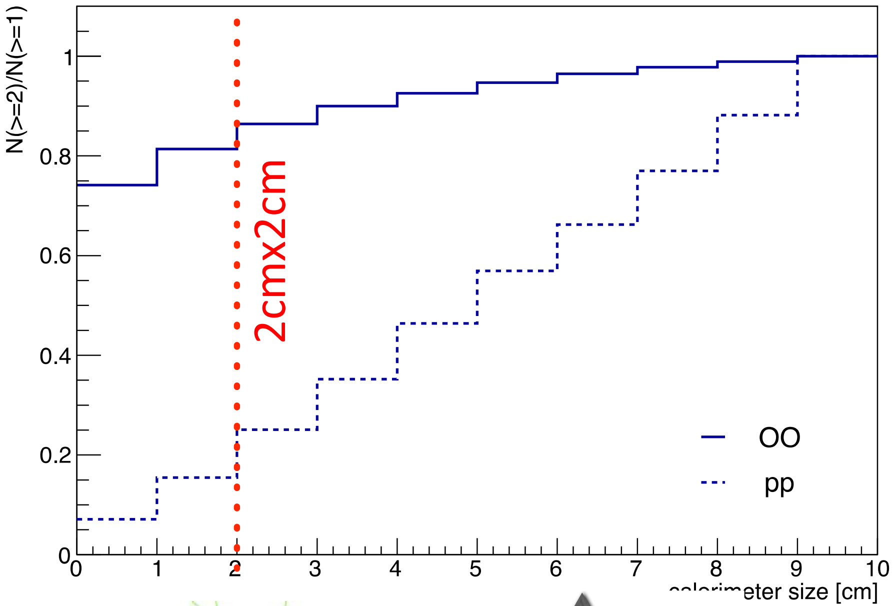
- No apparent show stopper but a serious study should be performed before going ahead
- Scheduling might dominate decision
- A second source + Linac (presently not approved) would solve some of the issues

Disclaimer

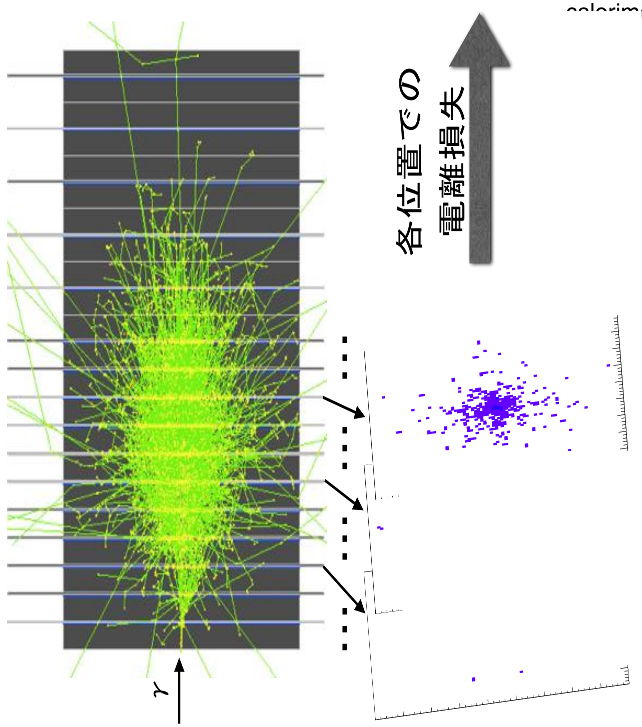
- Very preliminary
- Not endorsed by CERN management
- Only technical feasibility
- Even if feasible, scheduling an actual run would be a hard battle

Baseline of my talk

- Oxygen is most likely nucleus in LHCf light ion collisions.
- p-O measurements can be done using the current technic
- O-O collisions may require a development of new calorimeter
- Simulation study by Okuno for his master thesis, $\sqrt{s_{NN}}$=7TeV
- Training of silicon pad by Munakata for his buchelor thesis



Probability of multihit as a function of the detector size (QGSJET II-04)



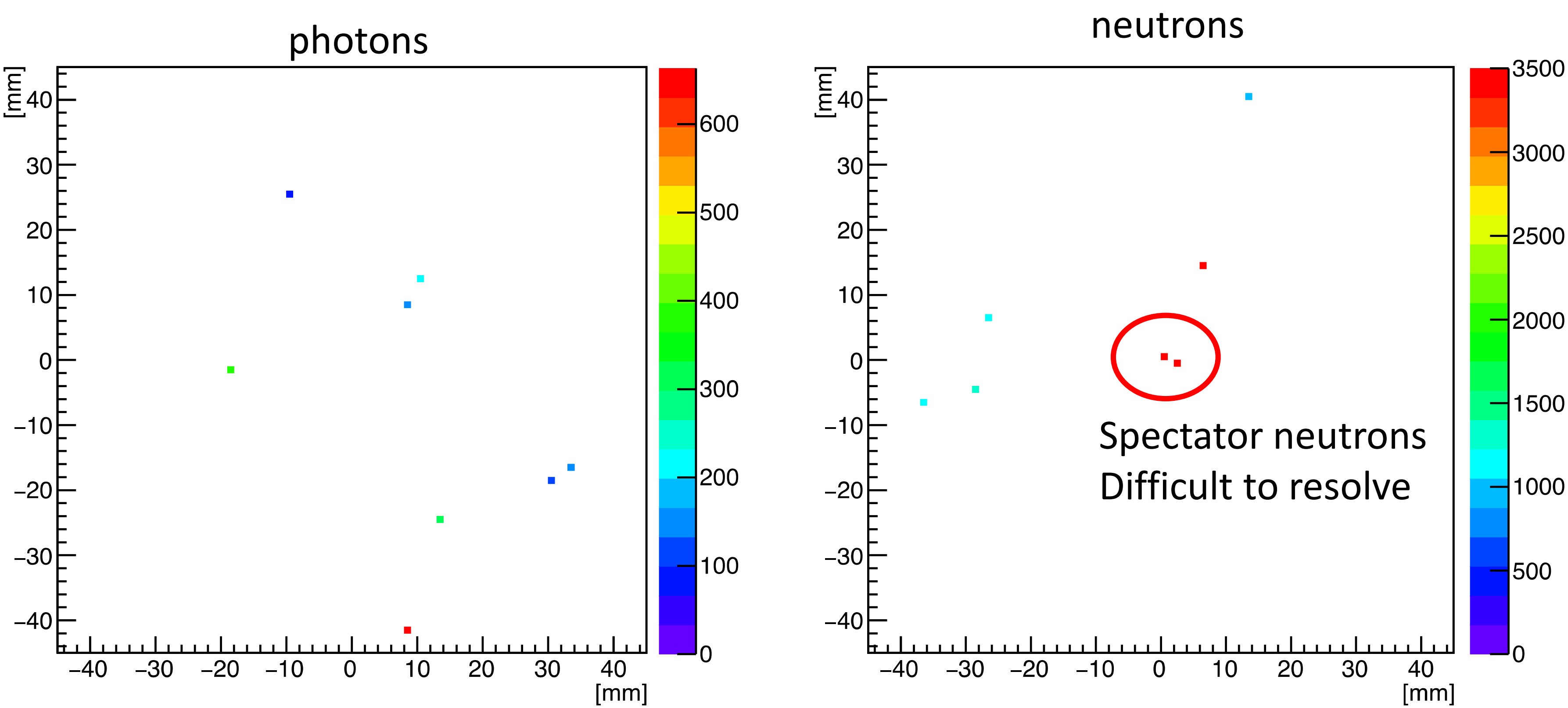
Idea is to replace all scintillator layers with silicon pixel (or silicon pad in case the pixel size is O(mm))

Advantage:

- Multihit can be resolved
- Detector acceptance can be enlarged
  => super ZDC

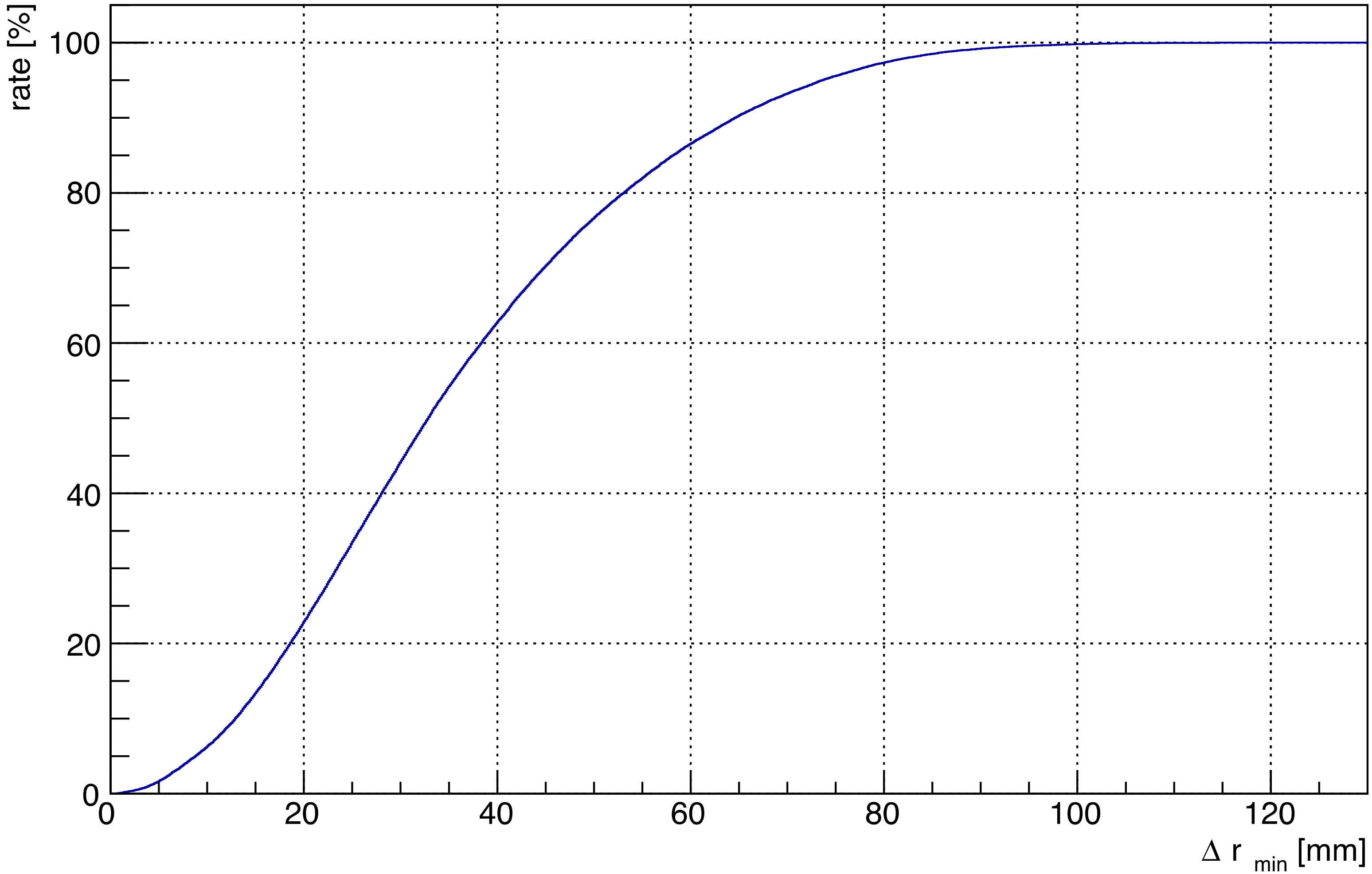
Drawback

- Too many readout channels



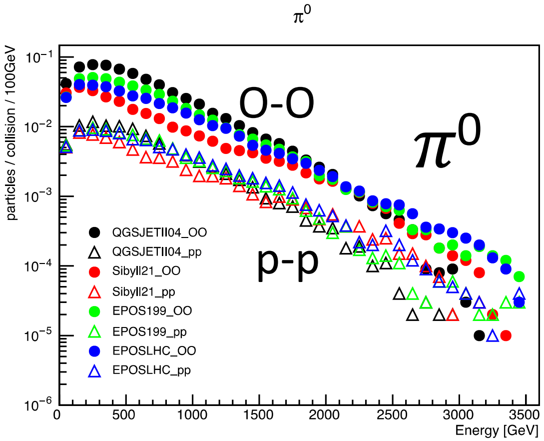
An example of the hit map in 1 collision

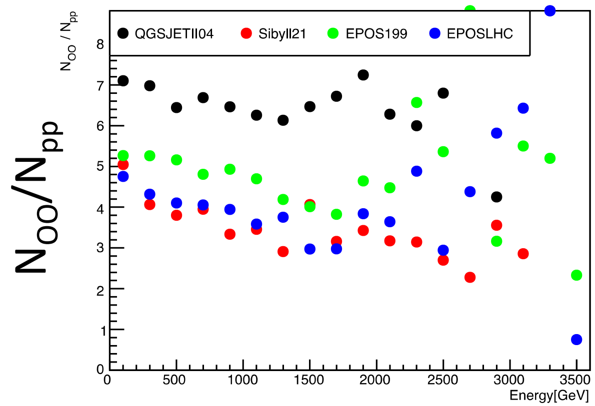
Further study is only for photons for simplicity
So they are still optimistic estimations



Accumulated distance distribution between photons
Not so much “super nearby” photon pairs
11mm is the closest photon pair distance from π^0 decay

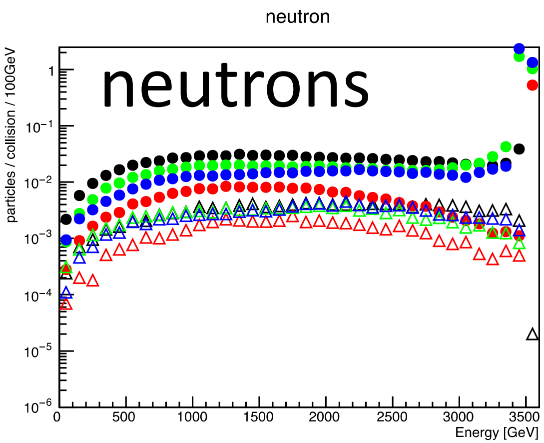
Separation power of “a few mm” is enough
(but only about photons. Neutrons are not taken into account.)

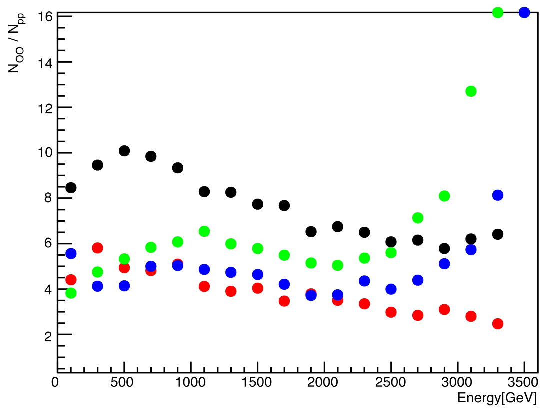


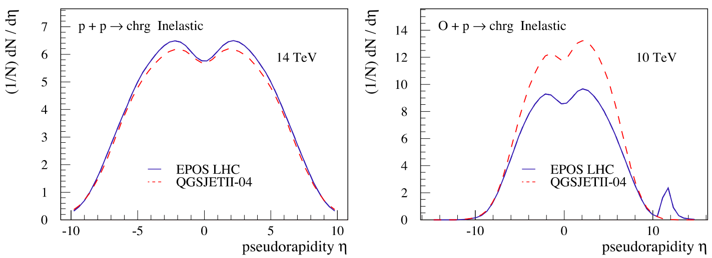


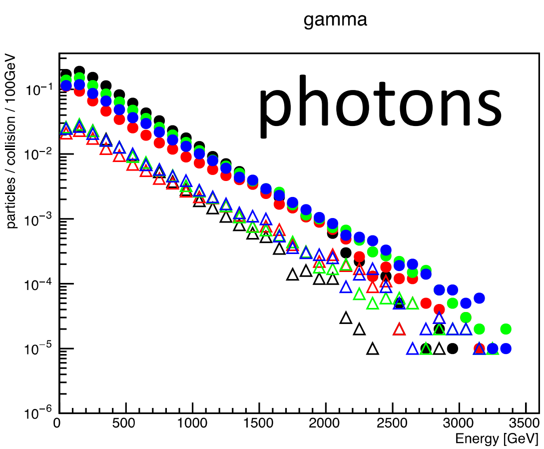
Model dependence in the nuclear effect

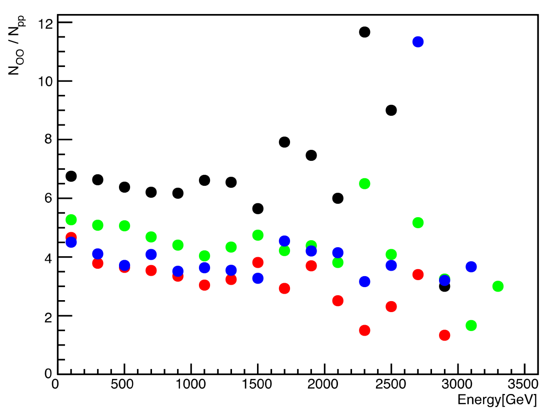
QGSJET II-04 and EPOS LHC have factor 2 difference in the nuclear effect





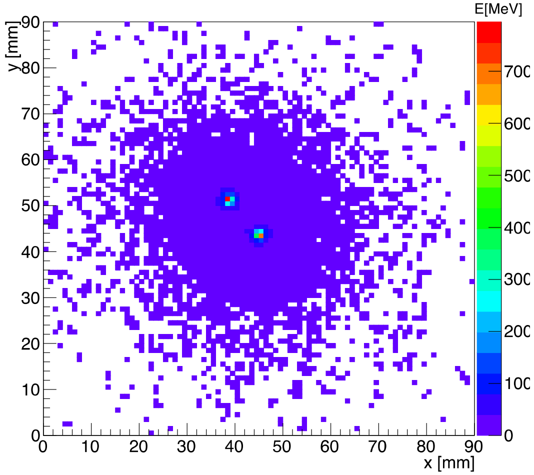






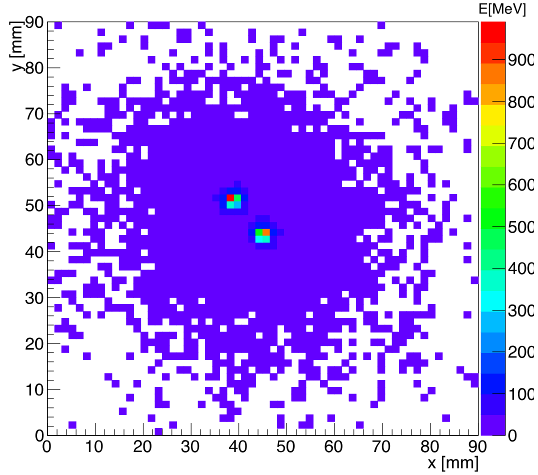
dE/dη Plot by Tanguy Pierog
For p-p vs. p-O
QGSJET II-04 vs. EPOS-LHC

1mm pixel size



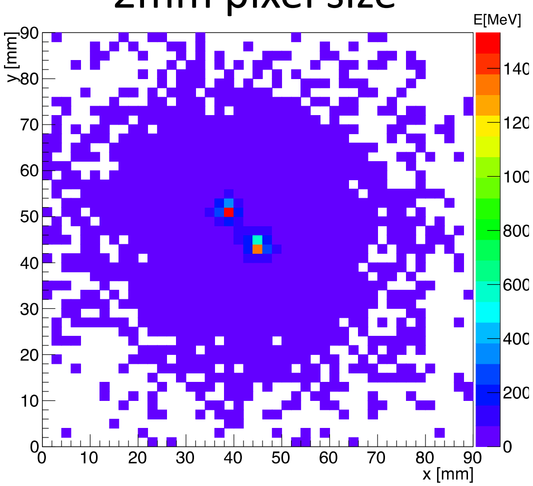
(a) ピクセルサイズ 1.0 mm

1.5mm pixel size



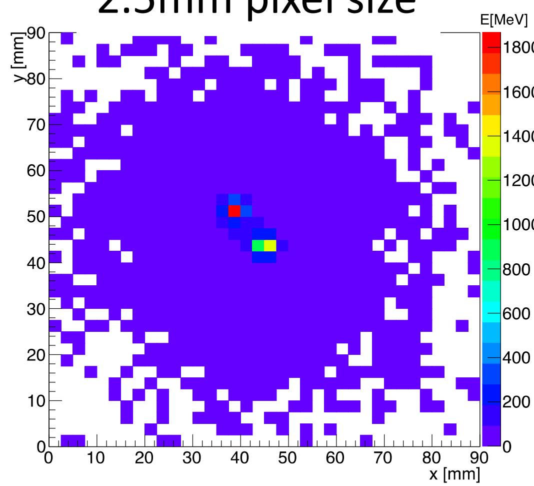
(b) ピクセルサイズ 1.5 mm

2mm pixel size



(c) ピクセルサイズ 2.0 mm

2.5mm pixel size

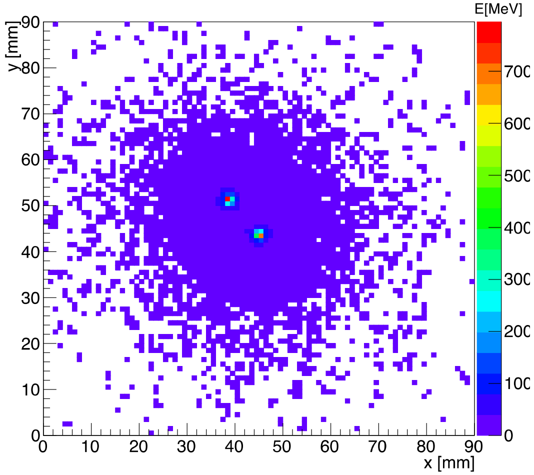


(d) ピクセルサイズ 2.5 mm

2x 1TeV photons with 1cm separation

Easy to identify even with 2.5mm pixel

1mm pixel size



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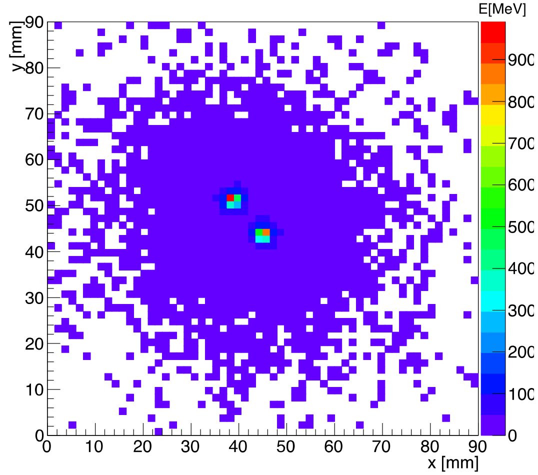
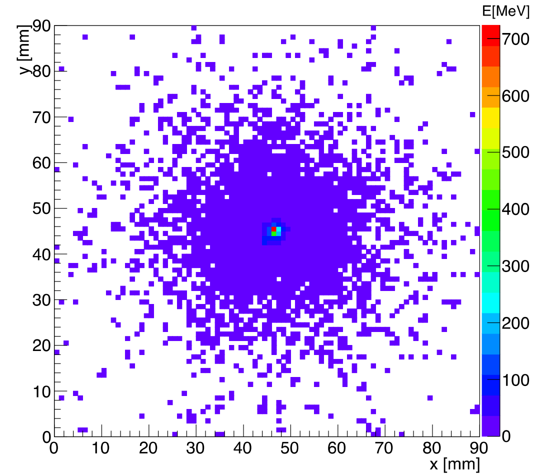
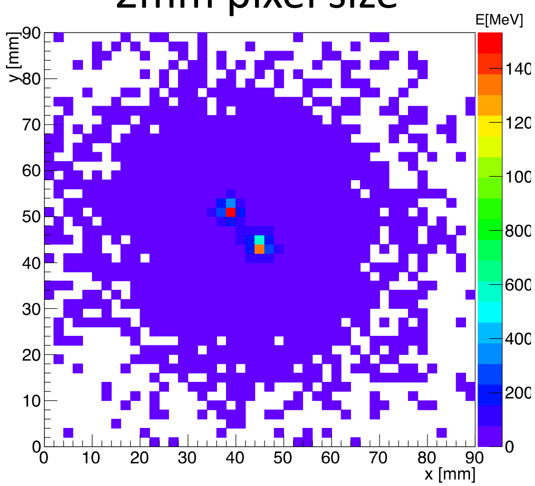


(b) ピクセルサイズ 1.5 mm



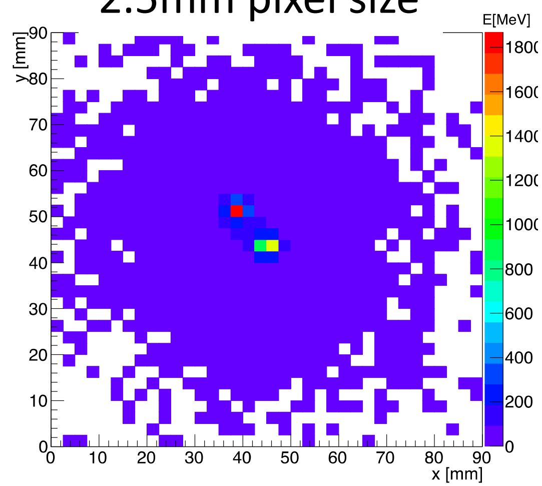
100GeV+1TeV with 2.8mm separation
1mm pixel

2mm pixel size



(c) ピクセルサイズ 2.0 mm

2.5mm pixel size



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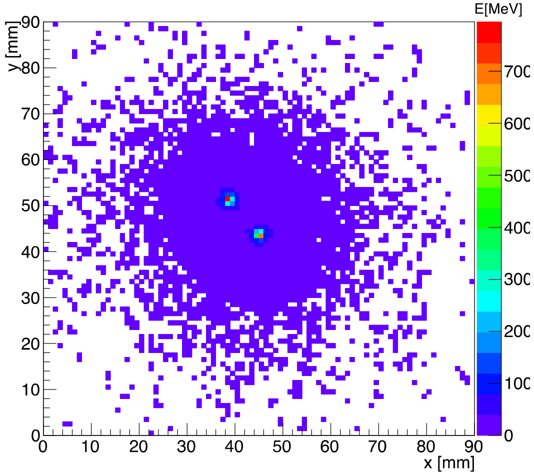
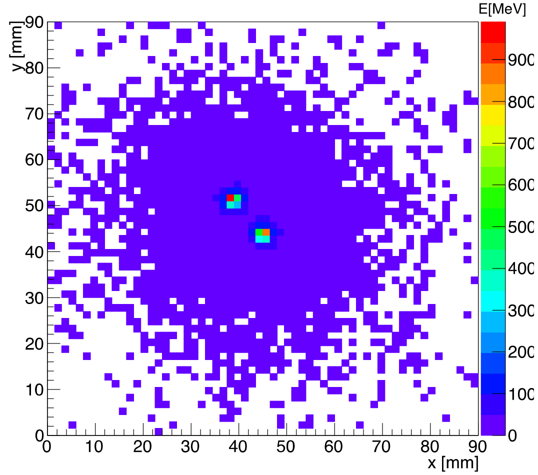


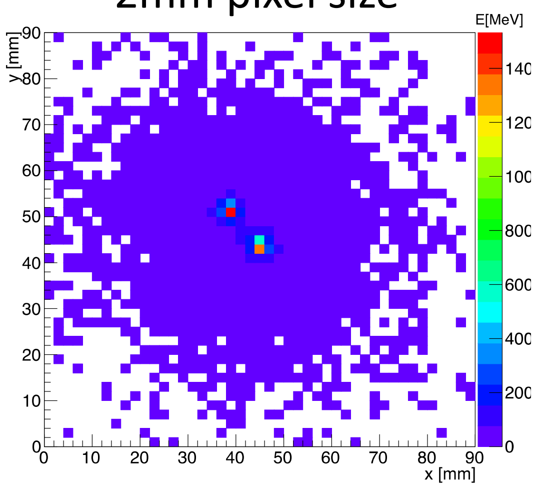
(a) ピクセルサイズ 1.0 mm

1.5mm pixel size



(b) ピクセルサイズ 1.5 mm

2mm pixel size



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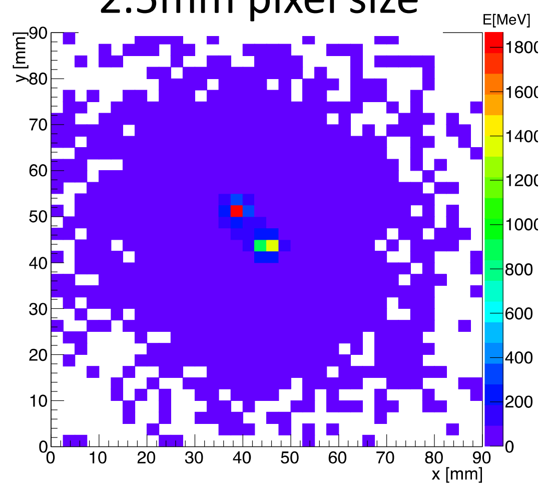
2.5mm pixel size



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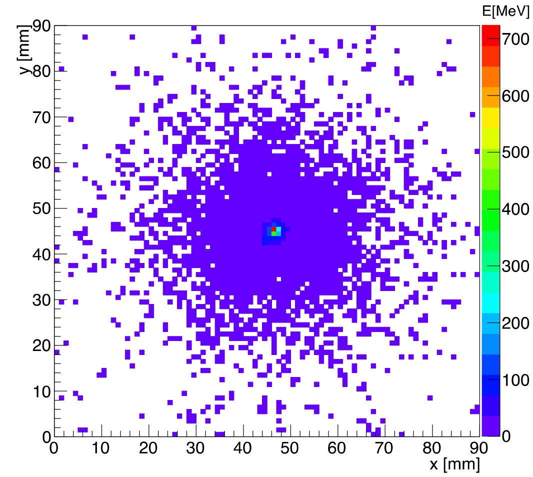
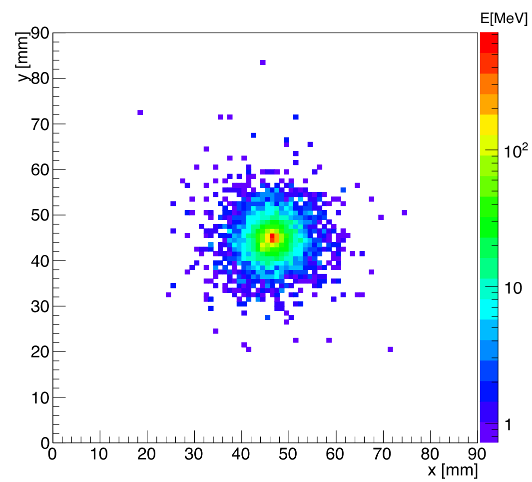
2x 1TeV photons with 1cm separation
Easy to identify even with 2.5mm pixel



100GeV+1TeV with 2.8mm separation
1mm pixel

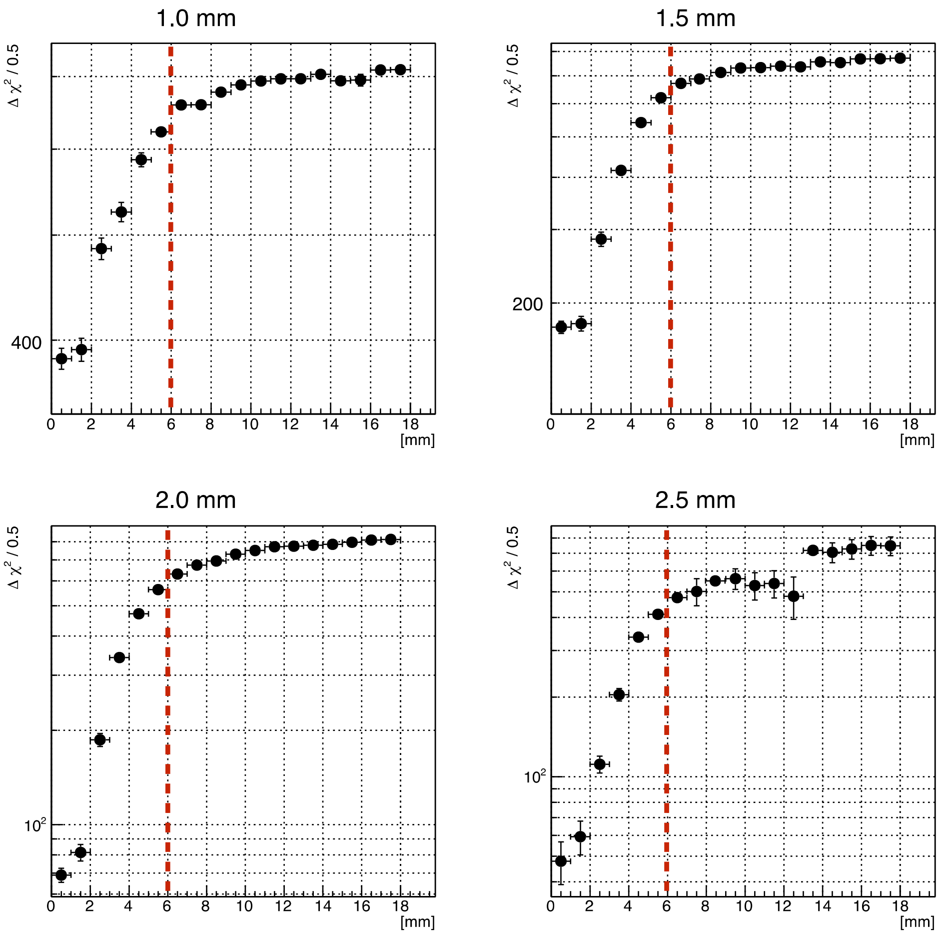


Can we resolve them?

Single hit fitting vs. multi-hit fitting

$$\frac{1}{2\pi}\left[\frac{\gamma}{((x-x_0)^2+(y-y_0)^2+\gamma^2)^{1.5}}\right]\times A+B$$

$$\frac{1}{2\pi}\left[\frac{\gamma_0}{((x-x_0)^2+(y-y_0)^2+\gamma_0^2)^{1.5}}\right]\times A_0+\frac{1}{2\pi}\left[\frac{\gamma_1}{((x-x_1)^2+(y-y_1)^2+\gamma_1^2)^{1.5}}\right]\times A_1+B$$



$\Delta\chi^2$ as a function of separation for different pixel sizes

Always 1TeV + 100GeV photons

Above separation of 6mm, $\Delta\chi^2$ does not change very much

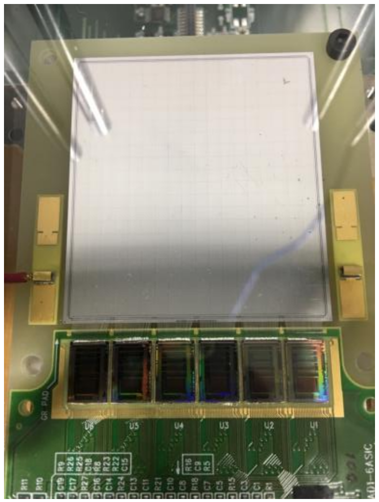
Result is almost independent from the pixel size

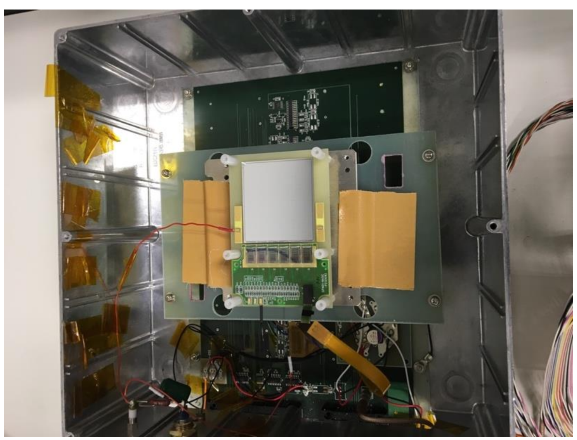
Only in case of 2.5mm pixel size, many events failed fitting

Conclusions

- O-O collision is technically feasible at LHC, and experimentally challenging in terms of multihit
- Silicon pixel (or pad) with "few mm" separation power is required
- A calorimeter with "2mm" pad size will be a solution (we do not need sub-mm pixels)
- More detailed performance must be studies with
  - Effect of neutrons
  - Realistic noise, dynamic range and linearity (electronics)
  - Sophisticated analysis algorithm

Exercize with a silicon pad





Pixel developed for Astro-H Compton camera
and for Compton camera for radio activity survey

18x20 pads with about 2.5mm pad size

Readout by 6 VA chips, each having 64 channels

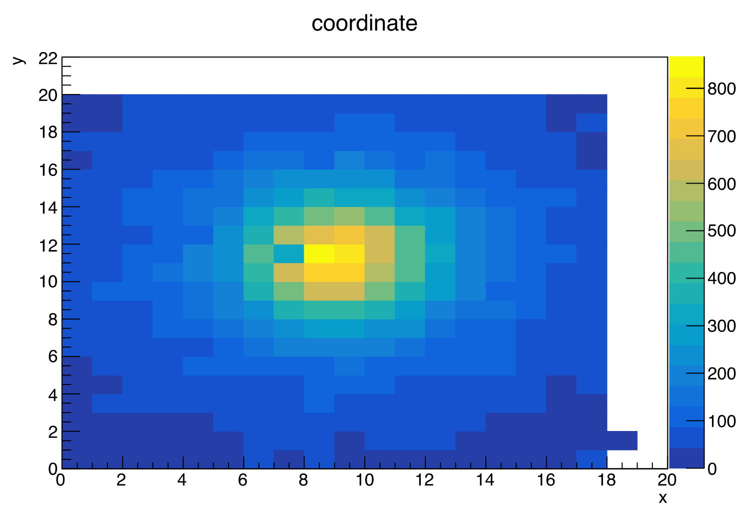
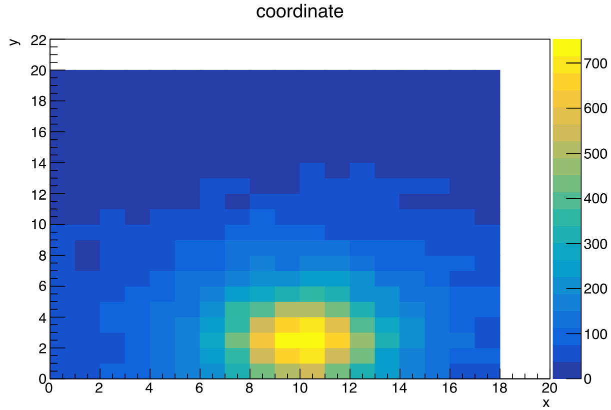
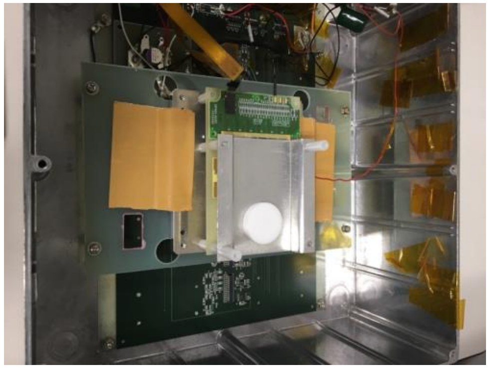
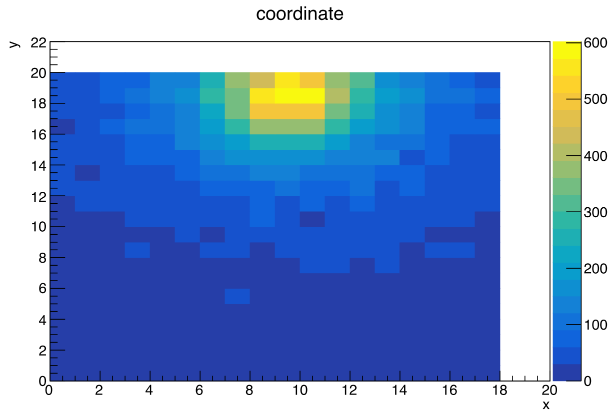
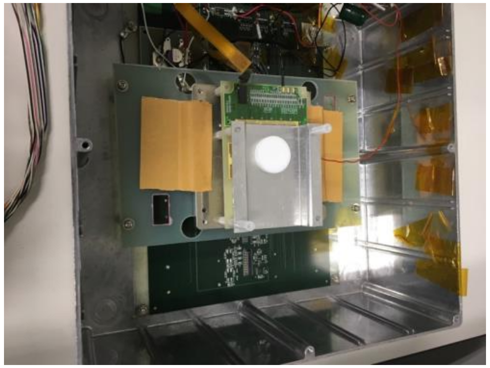


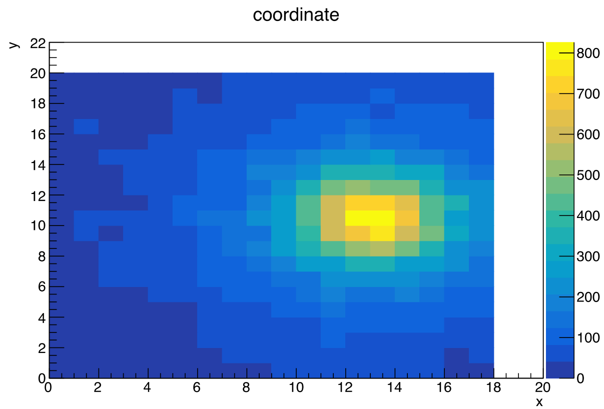
Image of a ^{57}Co source placed above the sensor











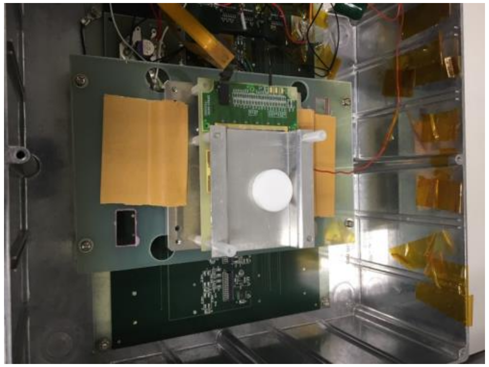
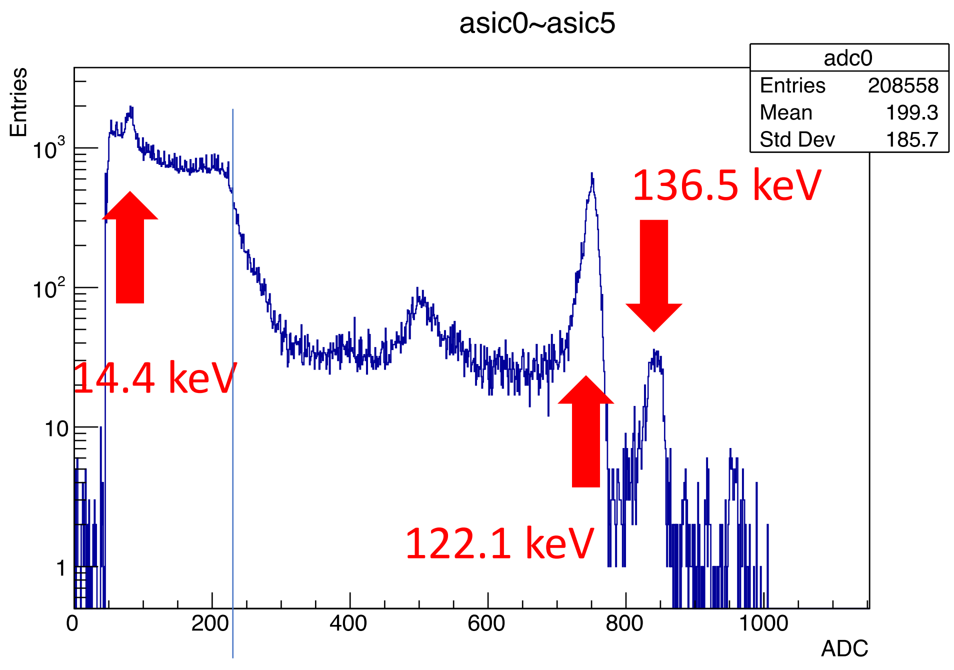
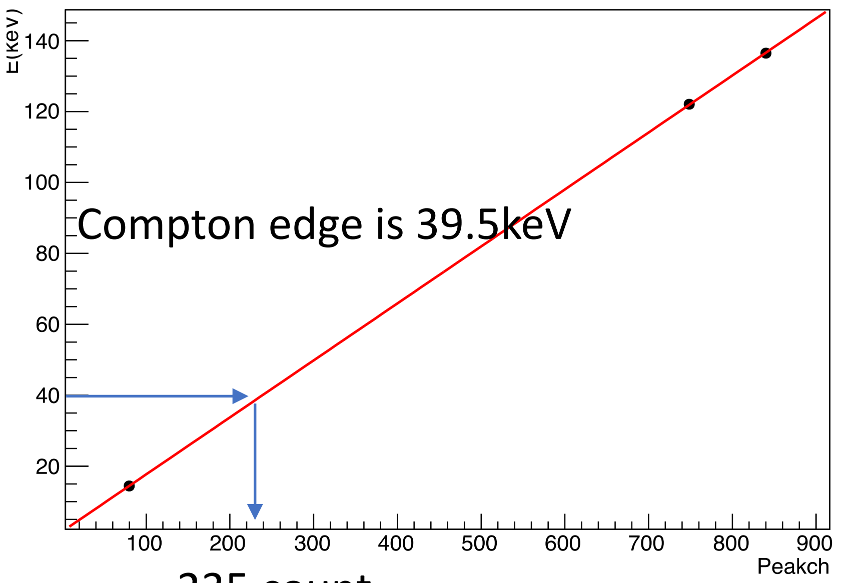


Image follows the real location of the source

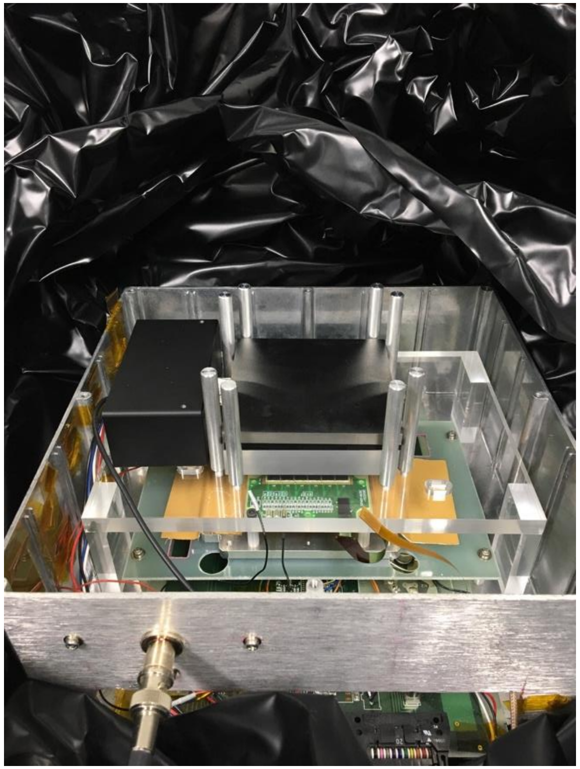


235 count

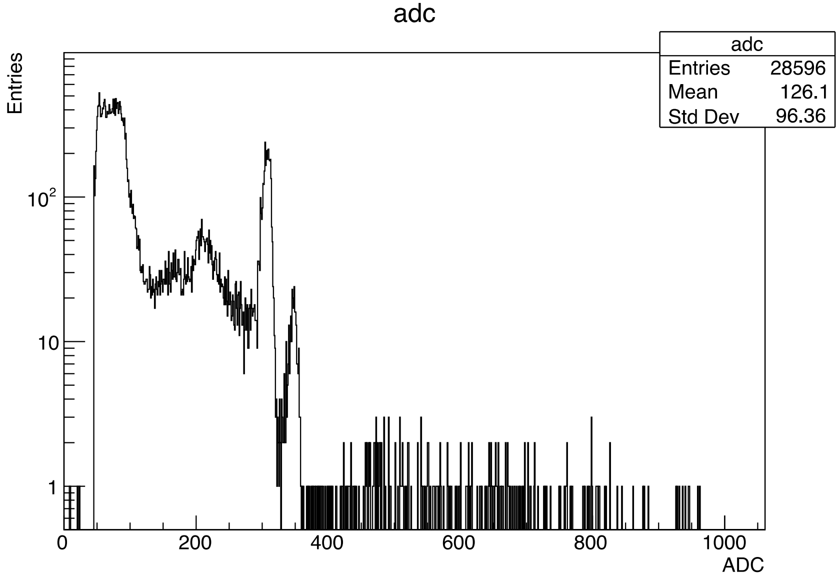


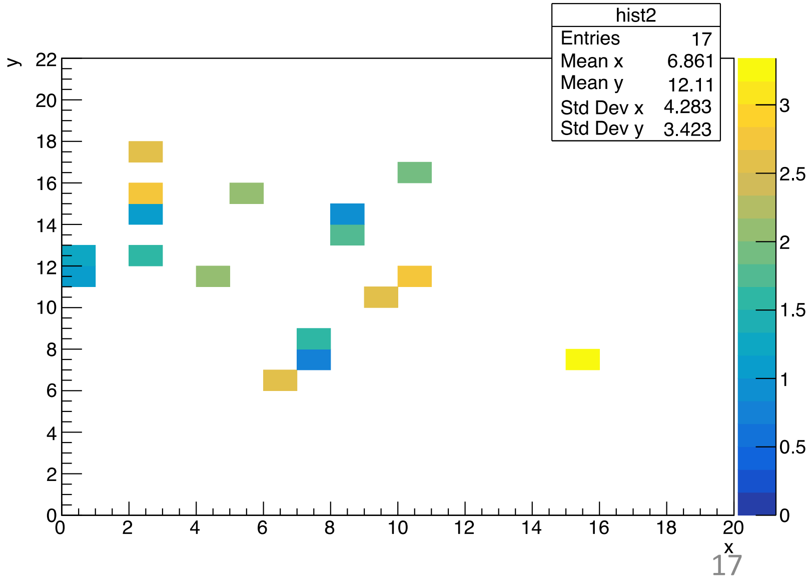
235 count

- Very nice energy resolution (not important for us…)
- 1 MIP corresponds to 120keV
- 10 bit Dynamic range corresponds only 1.3 MIP…



- CR Shower observation with Tangsten+scintillator system
- Slightly low gain mode operation (up to 3MIPs)
- Shower-like event coincided with the largest ADC event observed in the scintillator data





Conclusions

- We learn the handling of silicon detector (but using an existing package…)
- Next step
  - Electronics with a wide dynamic range and fast readout speed
  - Multi-layer silicon pad calorimeter
  - Beam test