Gas Pixel: TRD + Tracker

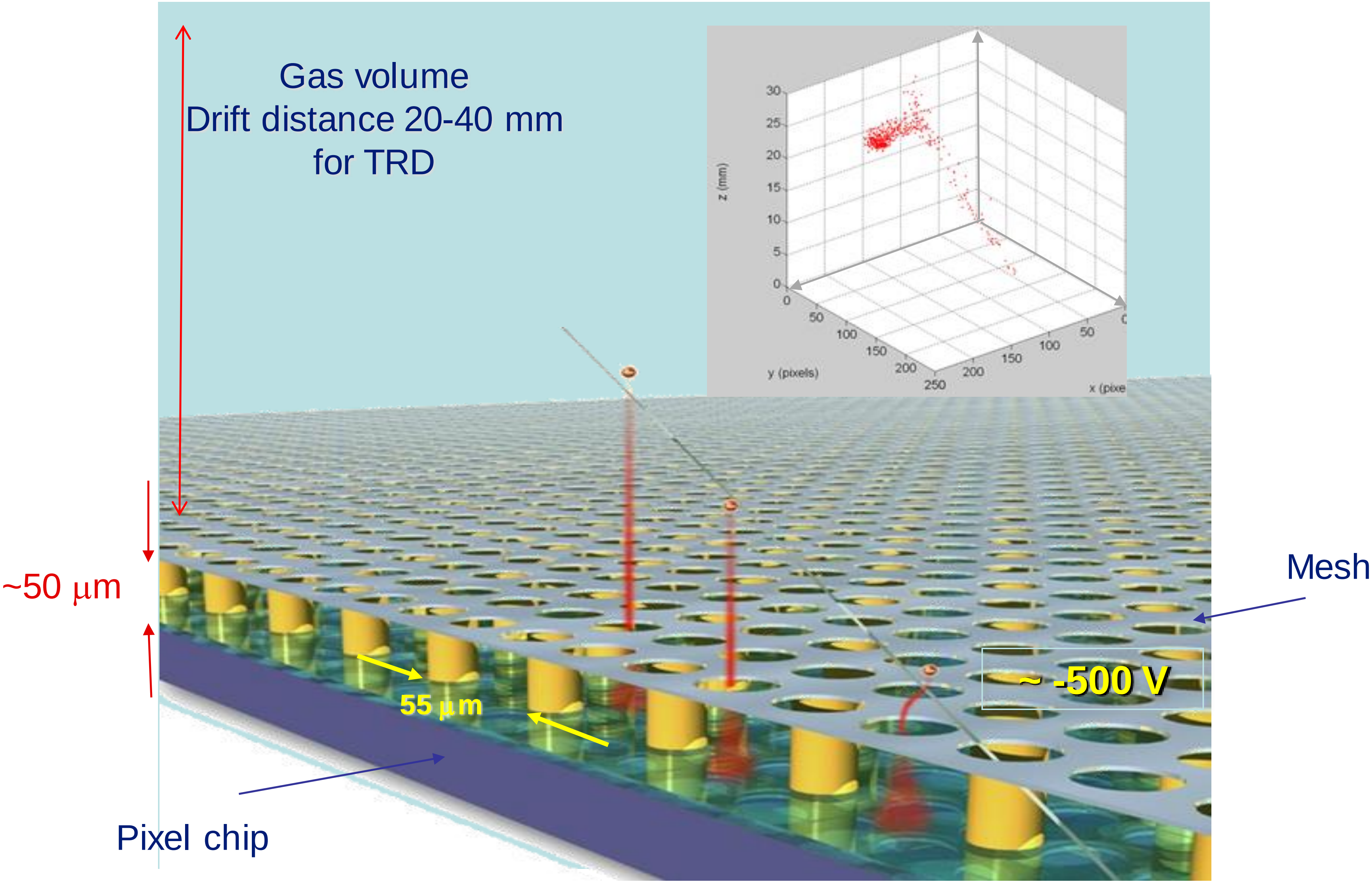
What GasPixel detectors can offer for SAS experiment.

Pixelization of the information from the particle track offers new possibilities to combine in one detector many features:

- Enhanced Transition Radiation separation
  dE/dX measurements.
- Precise coordinate measurements (well below diffusion limit).
- Track vector reconstruction.
- Very good multi-track resolution.
- Powerful pattern recognition features.

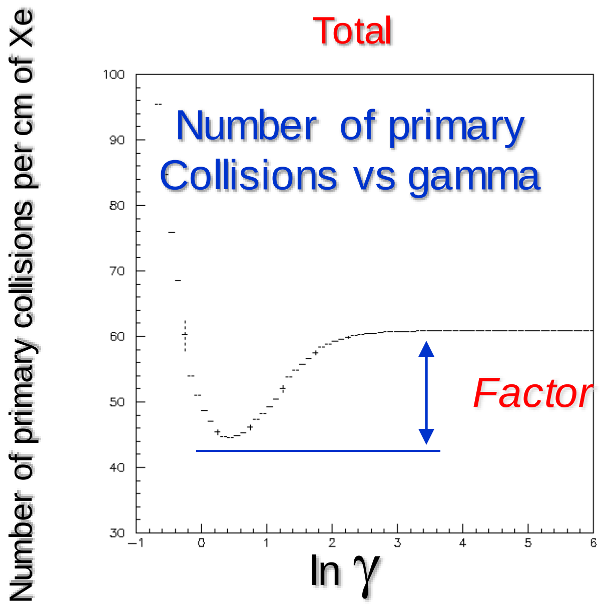
For illustration in this presentation still old results (2008) will be used.

What is the GasPixel detector?



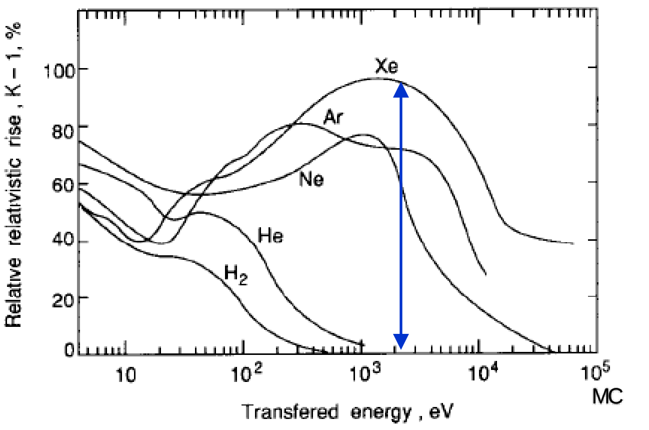
dE/dX for PID

Total



dE/dX

Number of clusters above ~1 keV
Is a actor of 2 more for plateau Ferm
than for min. ionization range



Relativistic rise vs δ-electron energy

B. Dolgoshein, NIM A326 (1993) 434

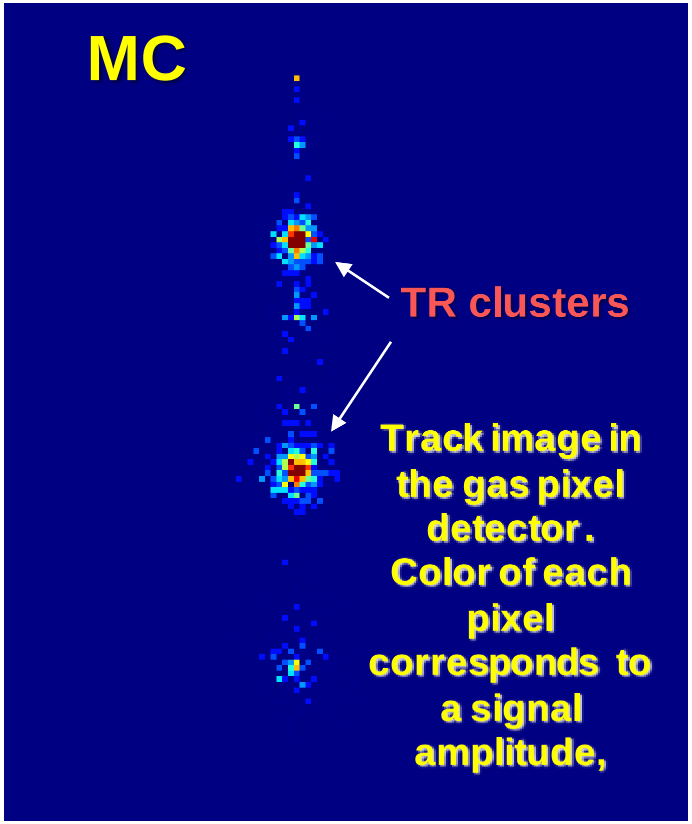
dE/dX measurements do not contribute to particle separation for γ-factors more than 1000.

For SAS a separation between low energy δ-rays and TR is the main goal.

Particle ID: TR registration:

The main point is a separation dE/dX from TR

Use the low: 1+2 ≠ 3



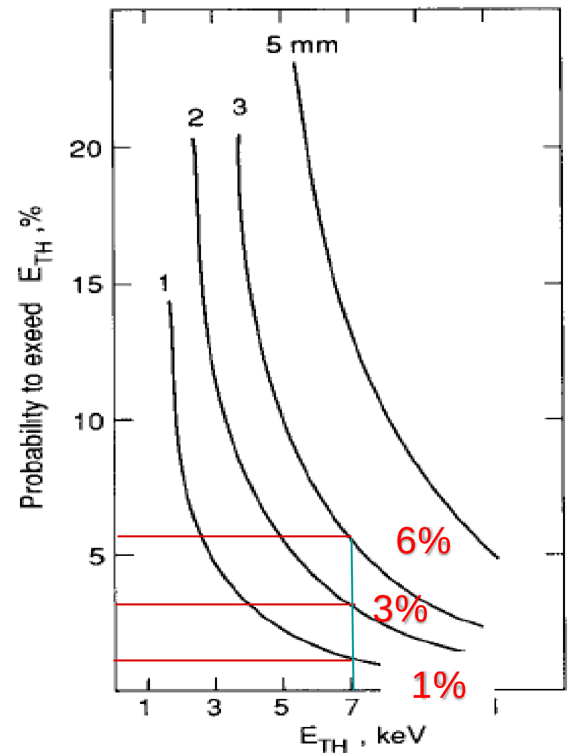


Fig. 35. Probability to exceed the threshold energy E_{TH} for Xe gas layers of different thickness by relativistic particles (Fermi plateau).

B. Dolgoshein, NIM A326 (1993) 434

Information from the gas pixel detector allows to localize clusters and measure their energy.

First test beam and MC studies (2008 setup)

No detailed optimization done, used what we had.

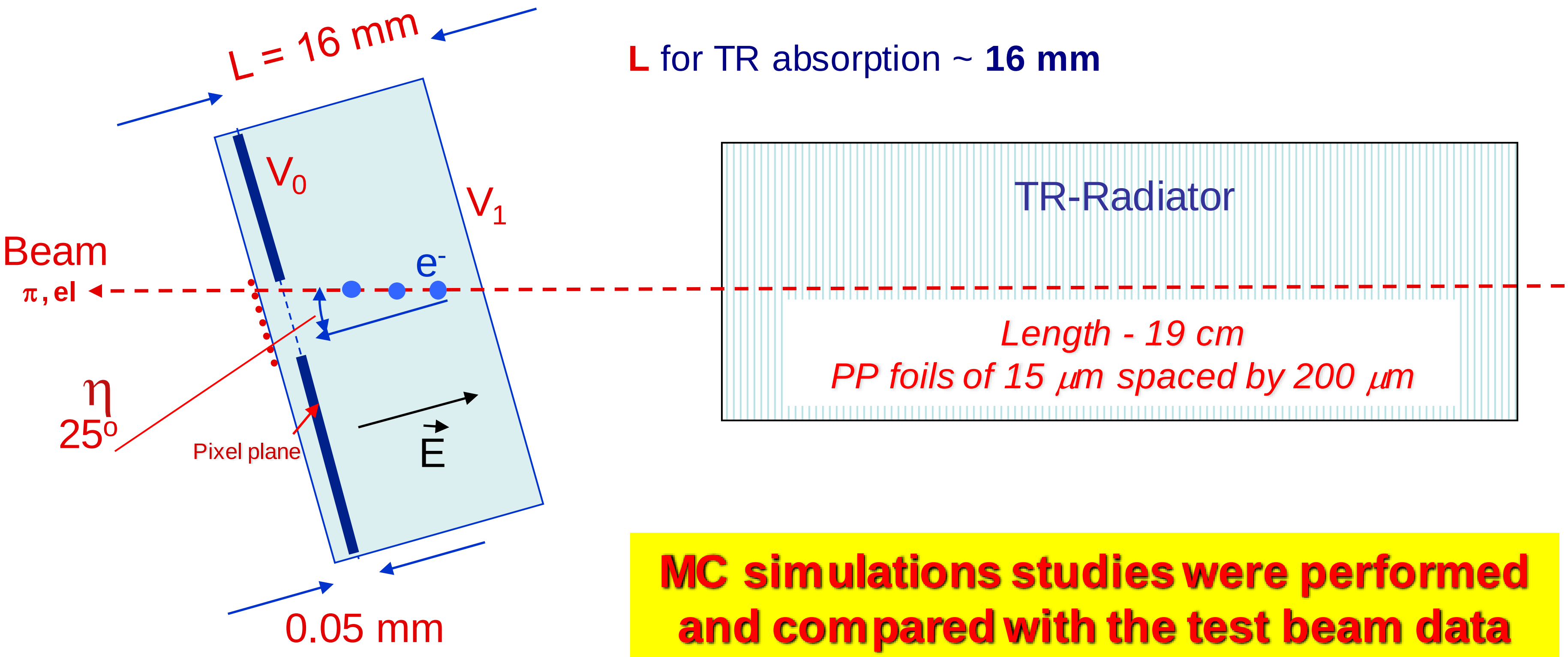
InGrid TimePix detector, 14 x 14 mm^2, 256 x 256 pixels (pixel size **55 μm**)

Two operation modes: time measurements and time-over-threshould measurements (amplitude)

Exposed to PS 5 GeV particle beam

Xe/CO2 (70/30) mixture.

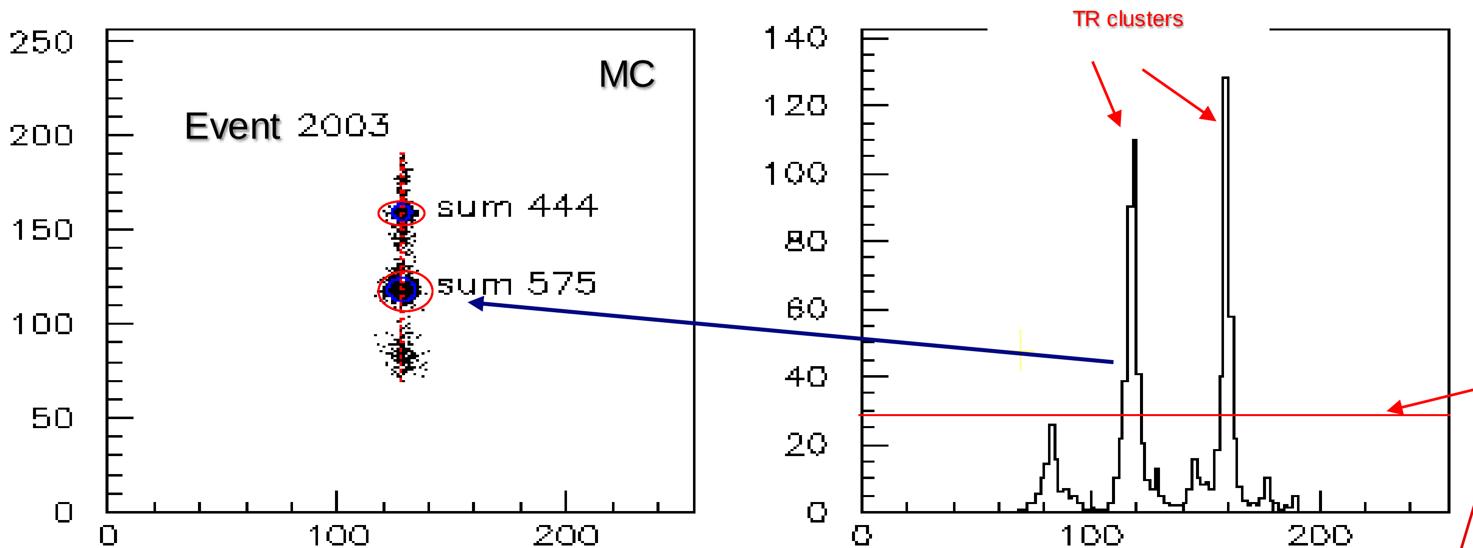
L for TR absorption ~ **16 mm**



MC simulations studies were performed and compared with the test beam data using the same analysis tools.

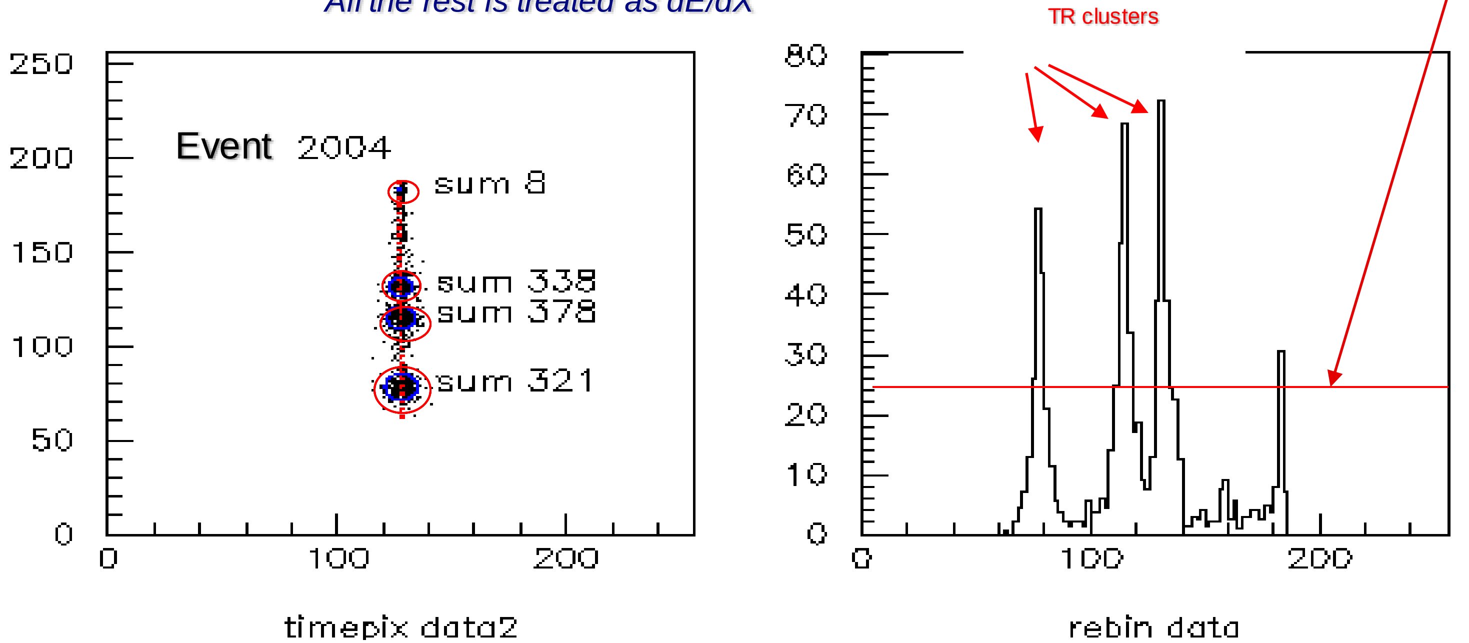
Preliminary
MC

Cluster identification



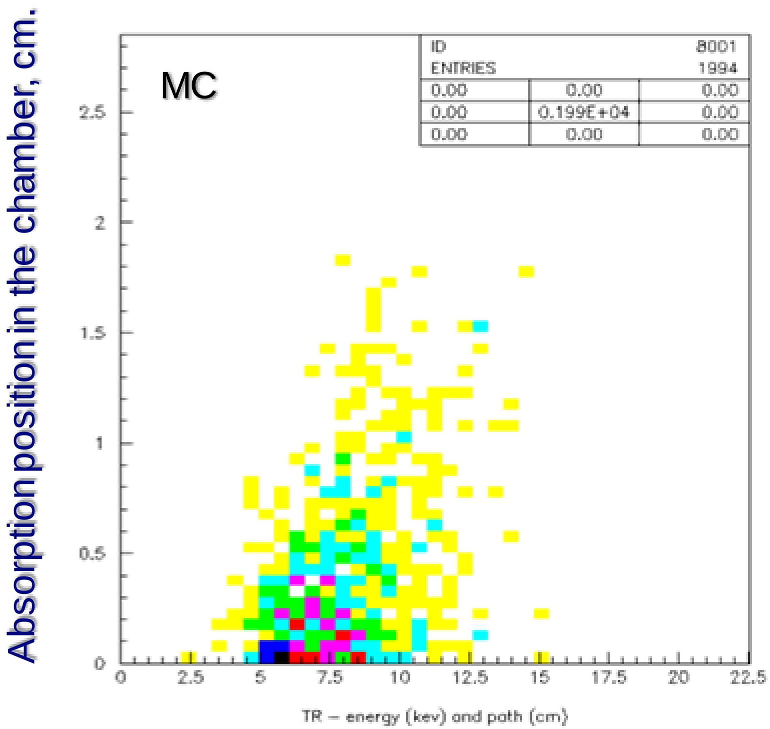
Threshold to detect candidates to the TR clusters (30 in this units).

Total number of electrons in the area with $R=\sigma_T$ is calculated
All the rest is treated as dE/dX

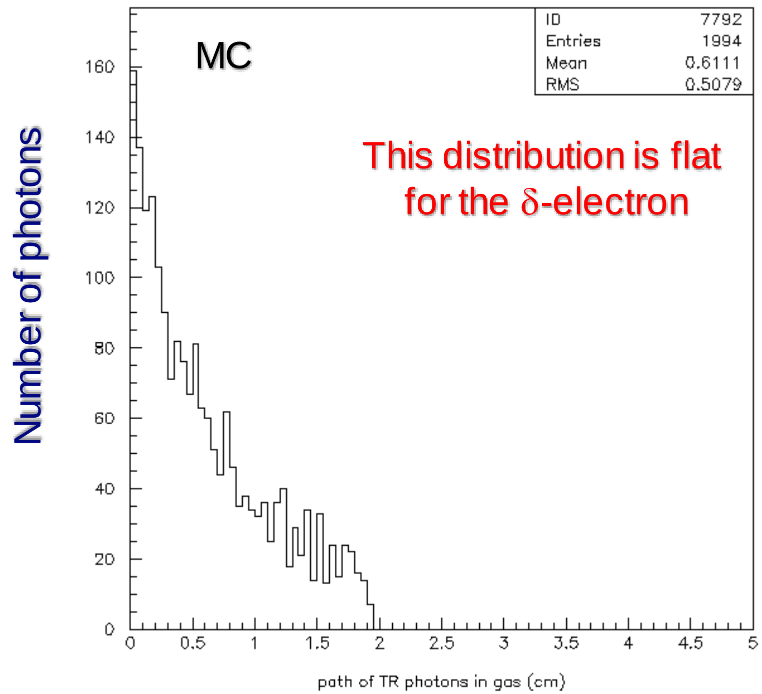


More information for analysis

TR absorption in the chamber.
Exact cluster position can be reconstructed from time measurement and its position along track projection. For this the less electron diffusion the better



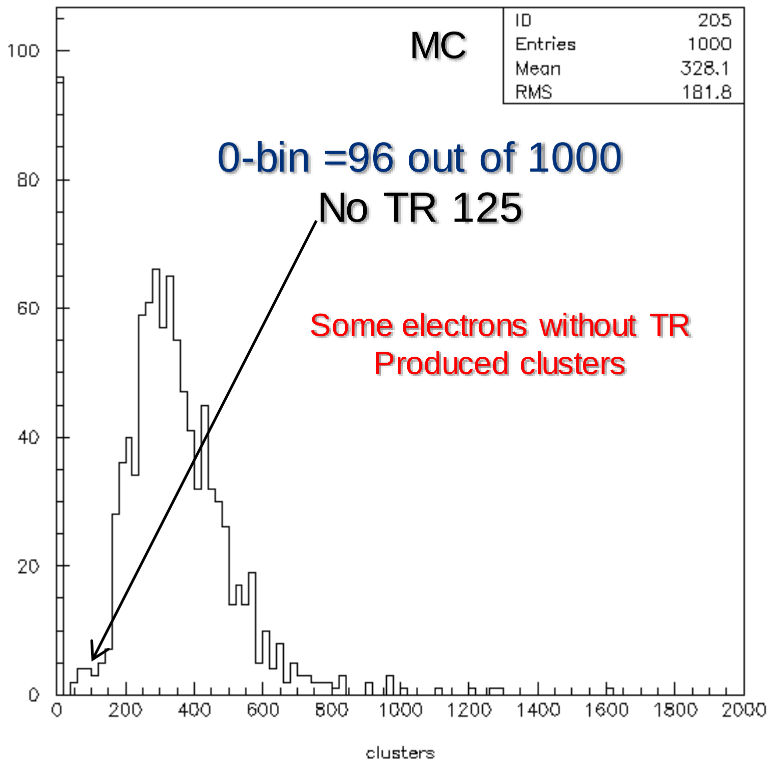
X-ray energy, keV.



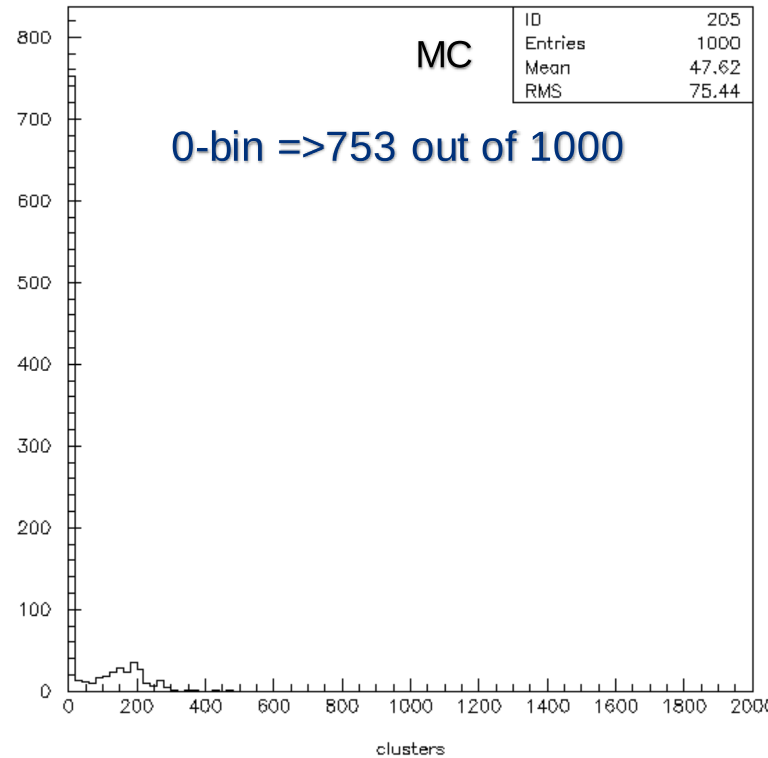
Number of the TR photons absorbed in the chamber vs depth.

Electron/Pion separation

Electrons



Pions



Total number of electrons in the clusters for electrons and pions (20 GeV)

Now we have detailed information about the track structure

How to use it?

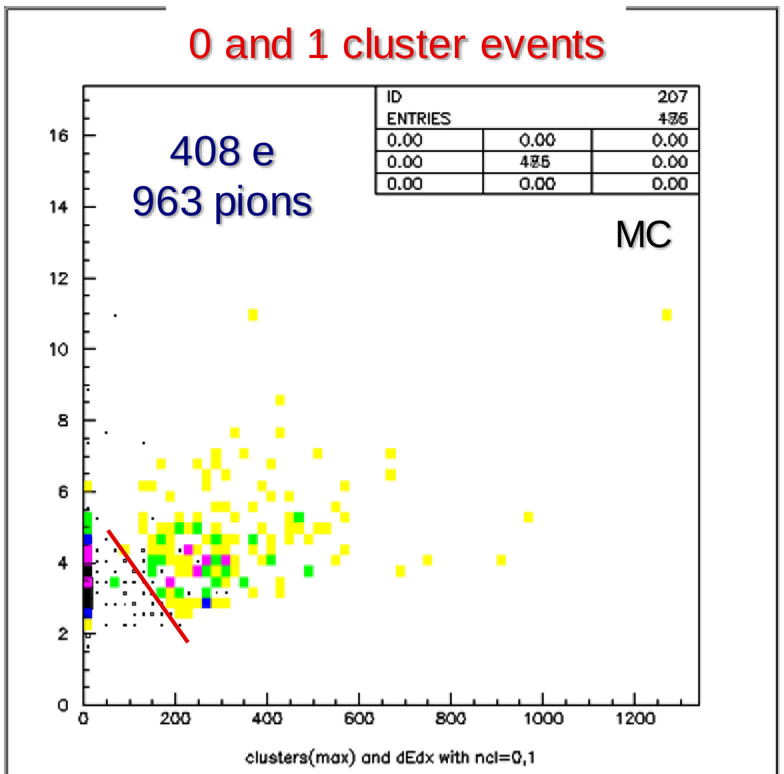
Electron/Pion separation

The best is likelihood method but other algorithms almost as powerful can be used.

Some exercise (far to be a complete analysis)

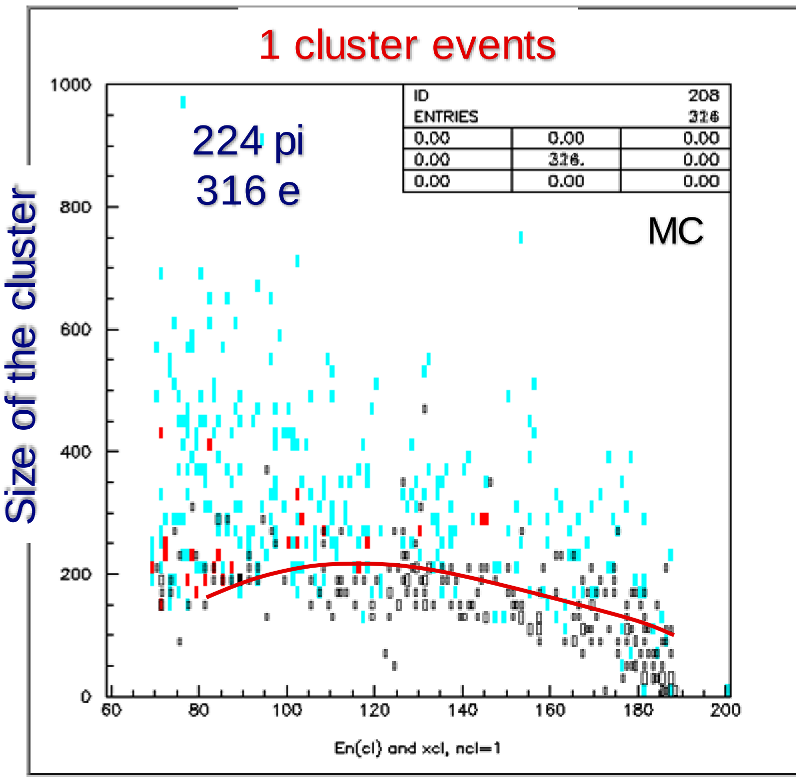
Two classes of events:

1. *Events with 0 or 1 cluster.*
2. *Events with more then 1 clusters.*



Normalised dE/dX

Size of the cluster



Size of the cluster

Pixel position

Black –pions, *Colour -electrons*

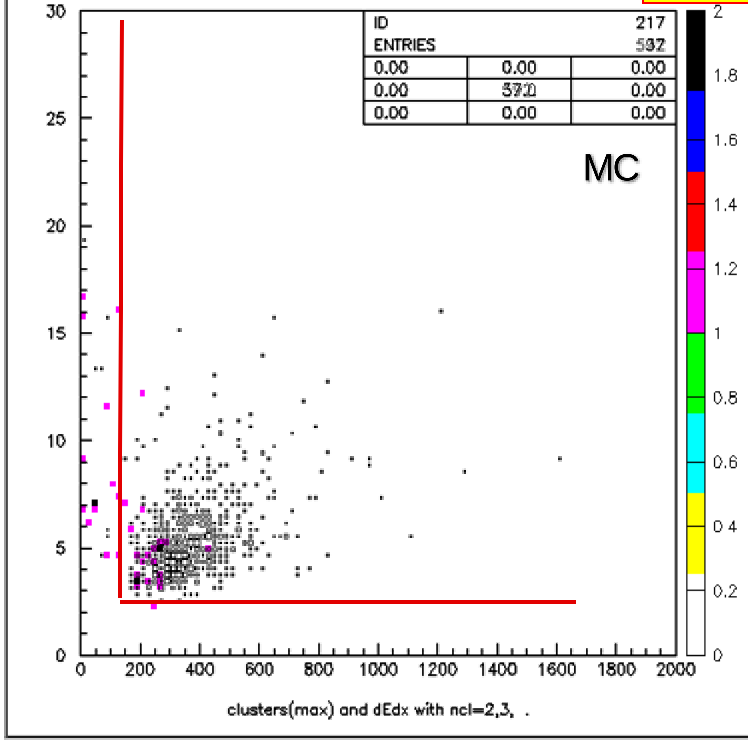
Electron/Pion separation

2 and more clusters

37 pi (3.7%)   592 e (59%)

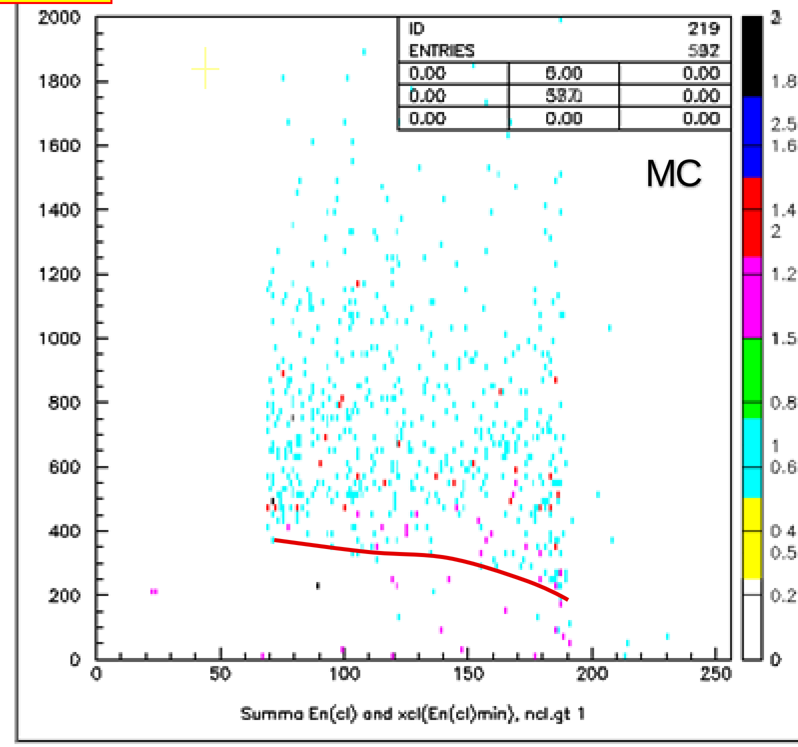
Pions are in pink

Normalised dE/dX



Size of the maximum cluster

Sum of the clusters



Pixel position for the cluster with lowest energy

Very simplified approach gives pion rejection factor >10 at electron efficiency slightly less than 90% for already one radiator-chamber set

Combining all available information in the likelihood product will significantly improve separation for thick chambers

Test beam studies.

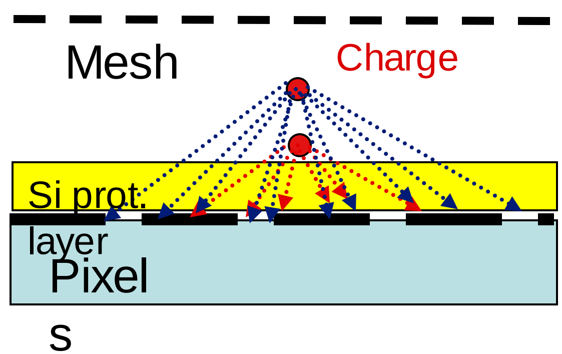
Operation parameters

May 2008 test chamber:

- InGrid technology
- Drift distance= 16 mm
- V_{drift} = 3800 V
- E_{drift}= 2000 V/cm
- V_{amp} ~470 V
- Gas gain ~ 800 – 3500
- Protection layer 30 μm
- Amplification gap - 50 μm
- Orientation: 25 degree to the beam and horizontal.
- Gas Mixtures
- Ar/CO2
- Xe/CO2
- He/Isobutane
- DME/CO2

For the gas mixture 70%Xe+30%CO_2

Total drift time ~ 300 ns
Ion signal ~ 80 ns
Transverse diffusion σ_T ~240 μm/$cm^{1/2}$
Longitudinal diffusion σ_L ~120 μm/$cm^{1/2}$



Electronics operating threshold: ~ 800 el.

Gas gain range: 800 – 1800
Geometry + induced charge effect

Effective threshold > 1600 el.
OR > 1 primary electron.

Estimated efficiency for 1 primary electron was ~30%

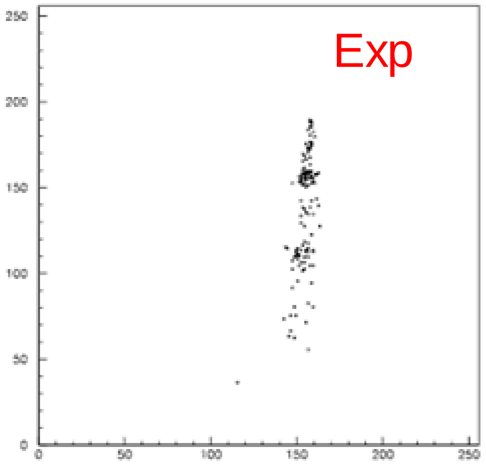
Test beam studies (5 GeV).

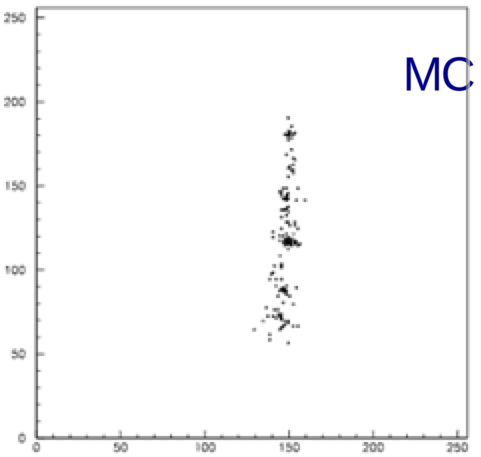
Comparison EXP data with MC

Particle tracking including all interactions + geometry - GEANT3
Ionisation losses - PAI model
TR generation - ATLAS TRT code

After all only 3 basic parameters were tuned to fit the MC model to the experimental data:

- ***Diffusion coefficient*** *- was chosen to match a track widths.*
- ***Threshold*** *- tuned to satisfy number of fired pixels.*
- ***Energy scale*** *- scaled using calibration factor.*

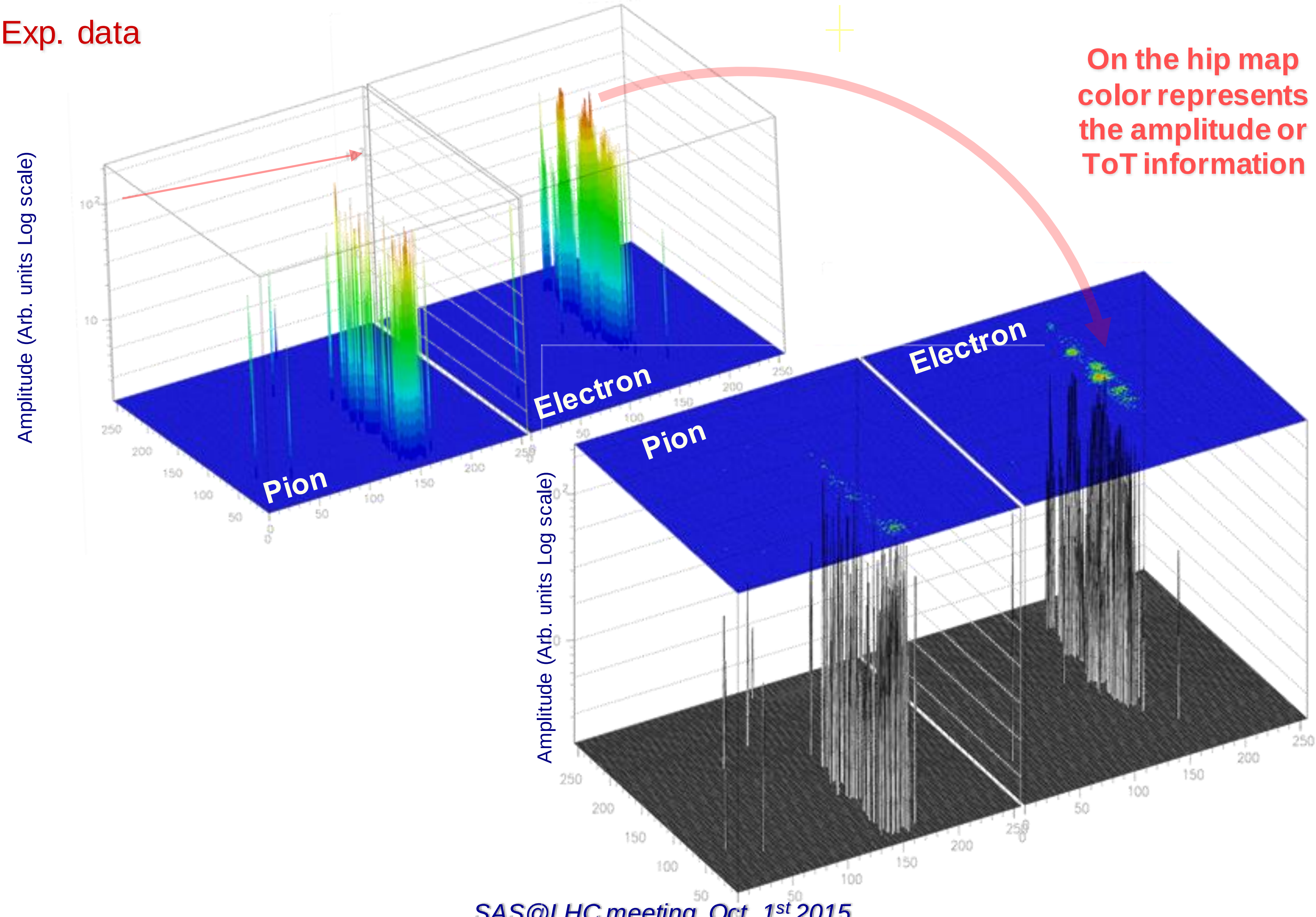




Particle Identification.

***Time-Over-Threshold* representing a signal amplitude was measured for each pixel**

Exp. data

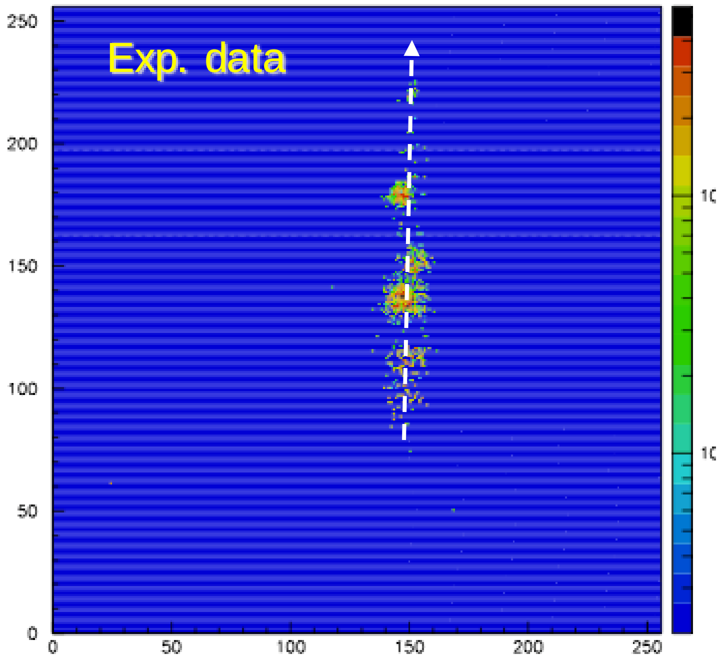


Particle Identification

Methods

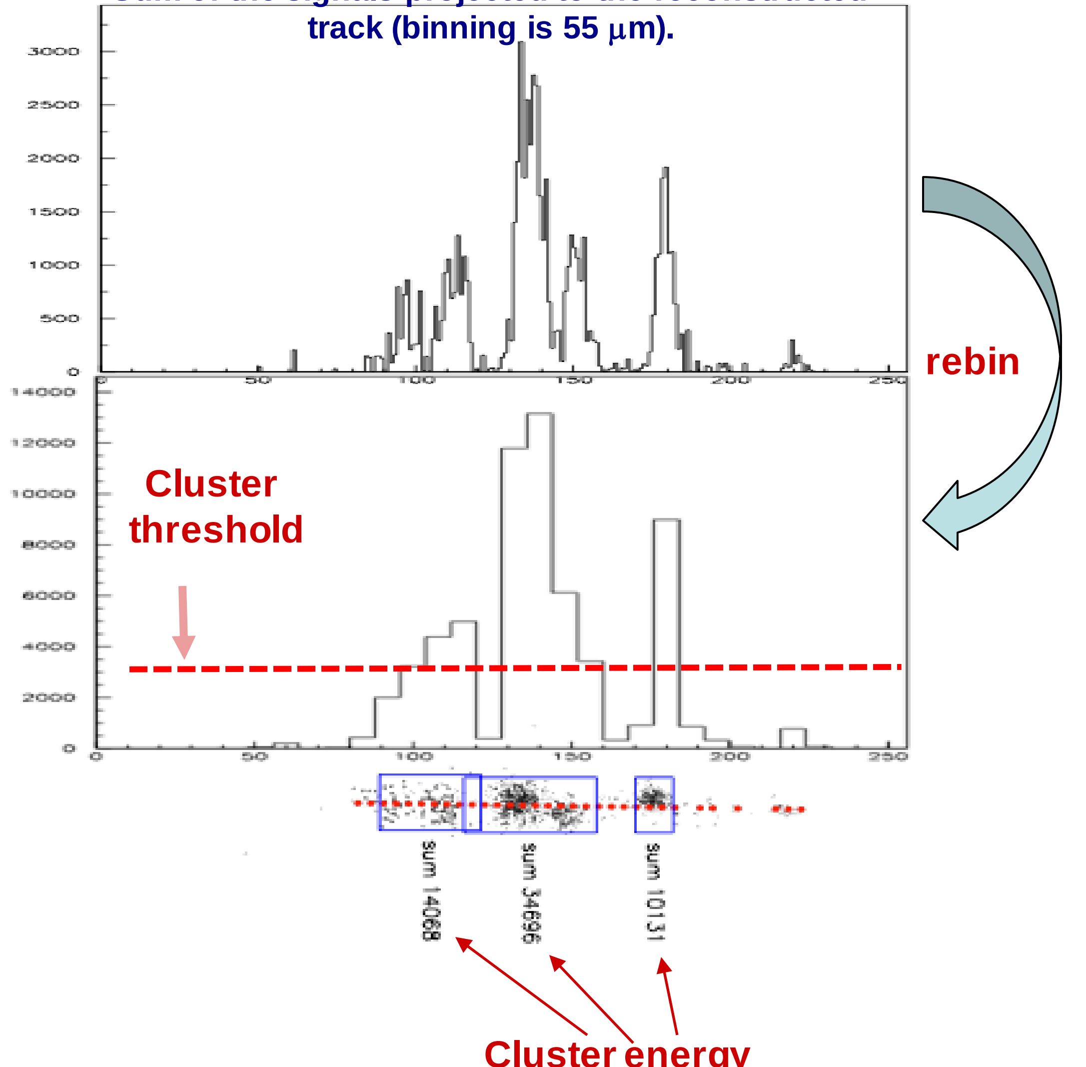
1. A total energy method

The amplitudes of all the pixels on track are summed.



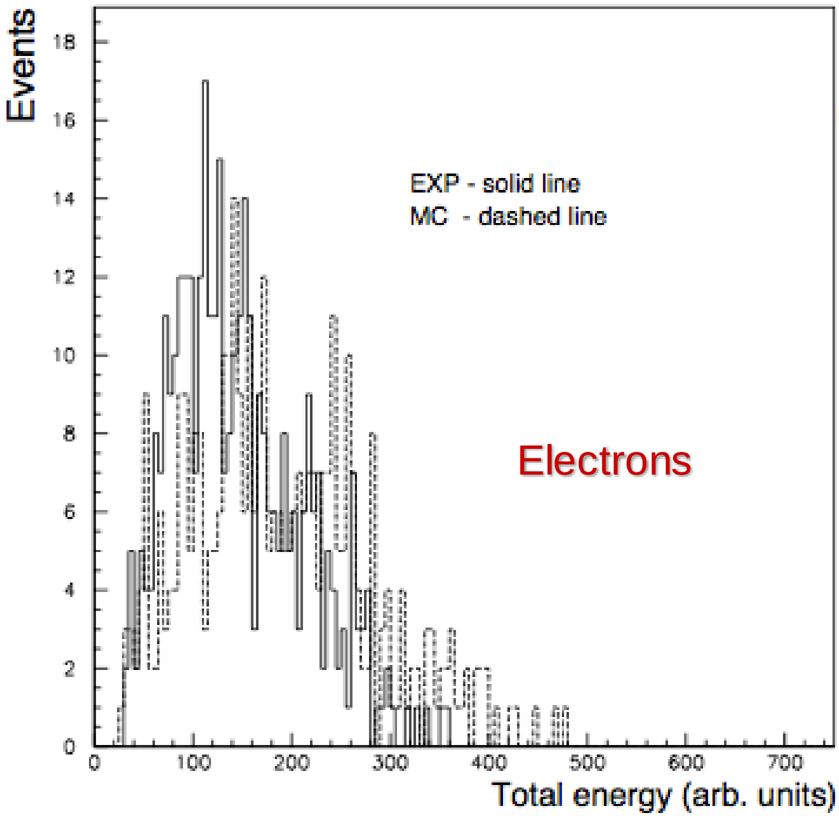
2. Cluster method

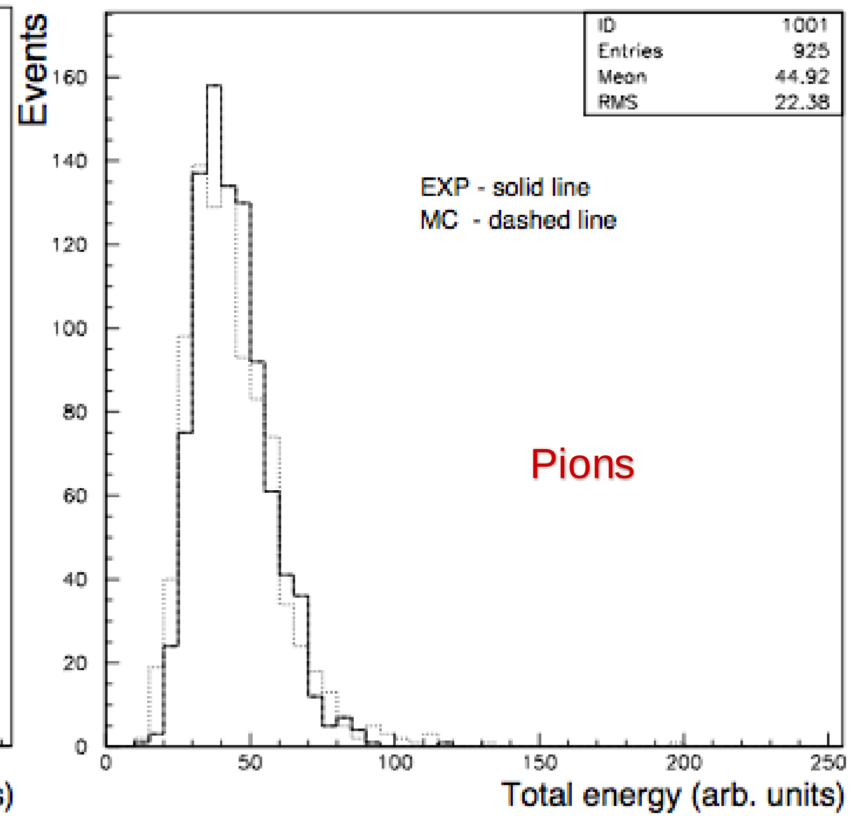
Sum of the signals projected to the reconstructed track (binning is 55 μm).



Test beam results

Particle Identification: Total energy.

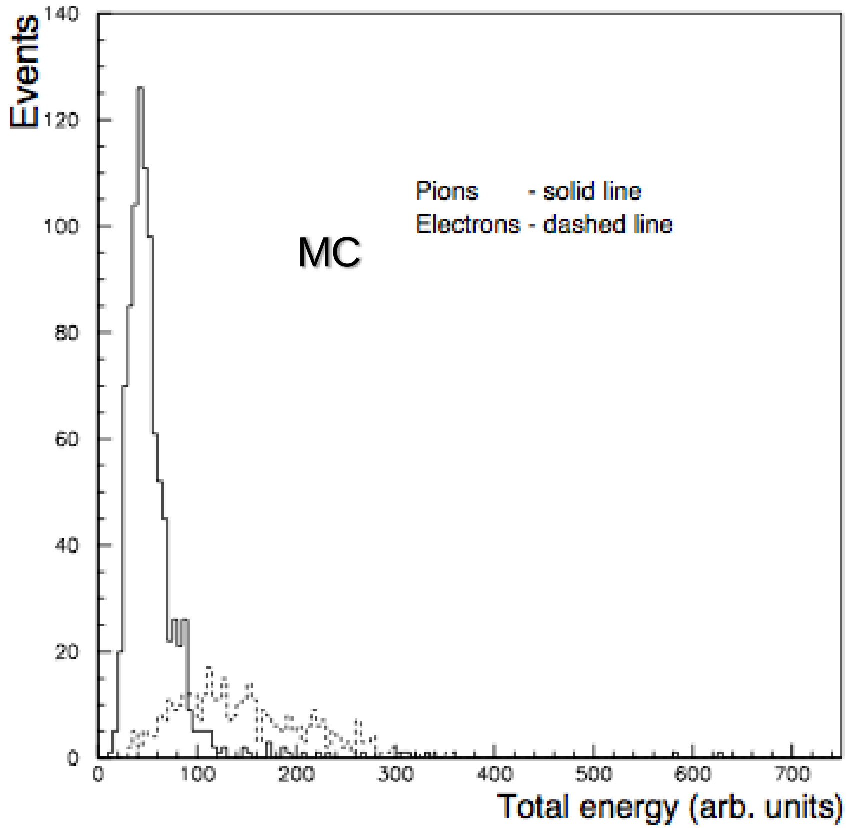


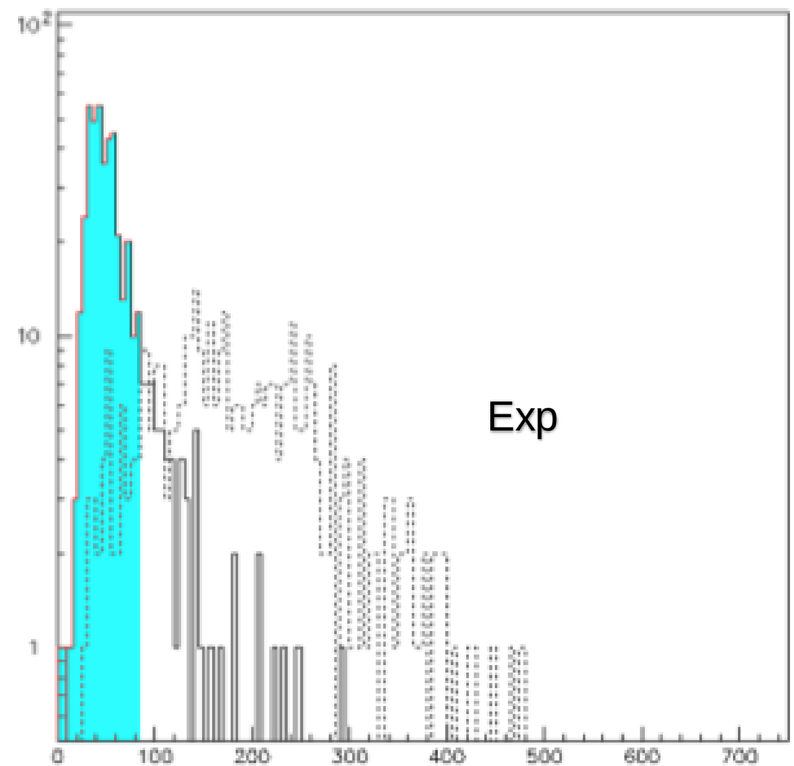


Distribution of a total ionization on the particle track for electrons and pions.
Comparison MC and Data

Test beam results

Particle Identification: Total energy.

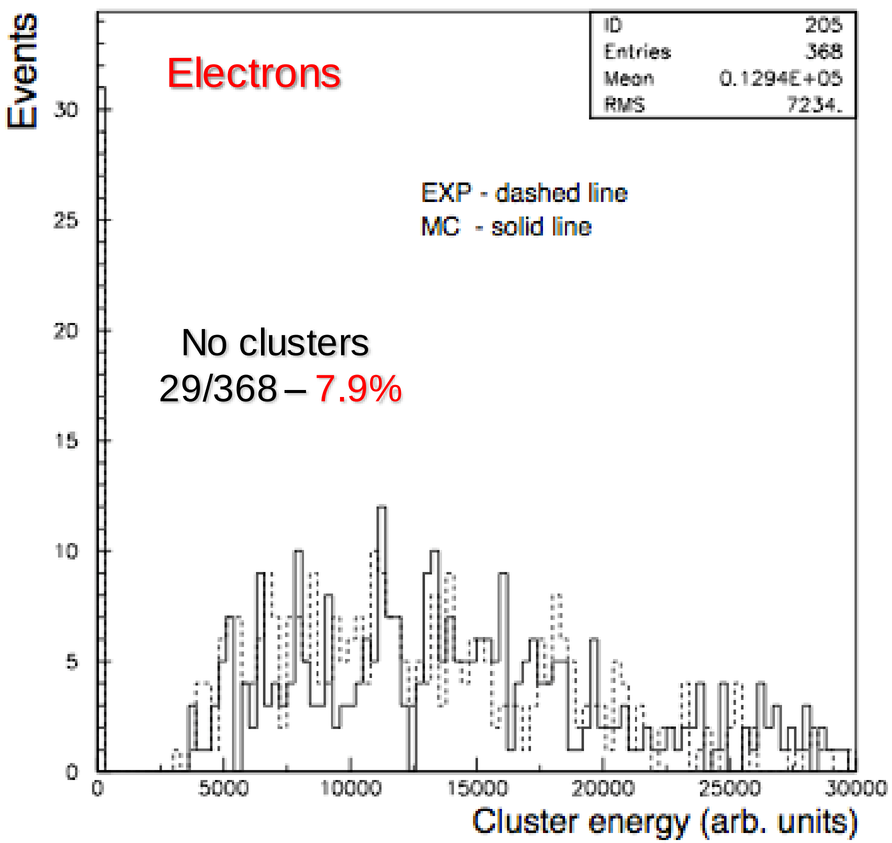


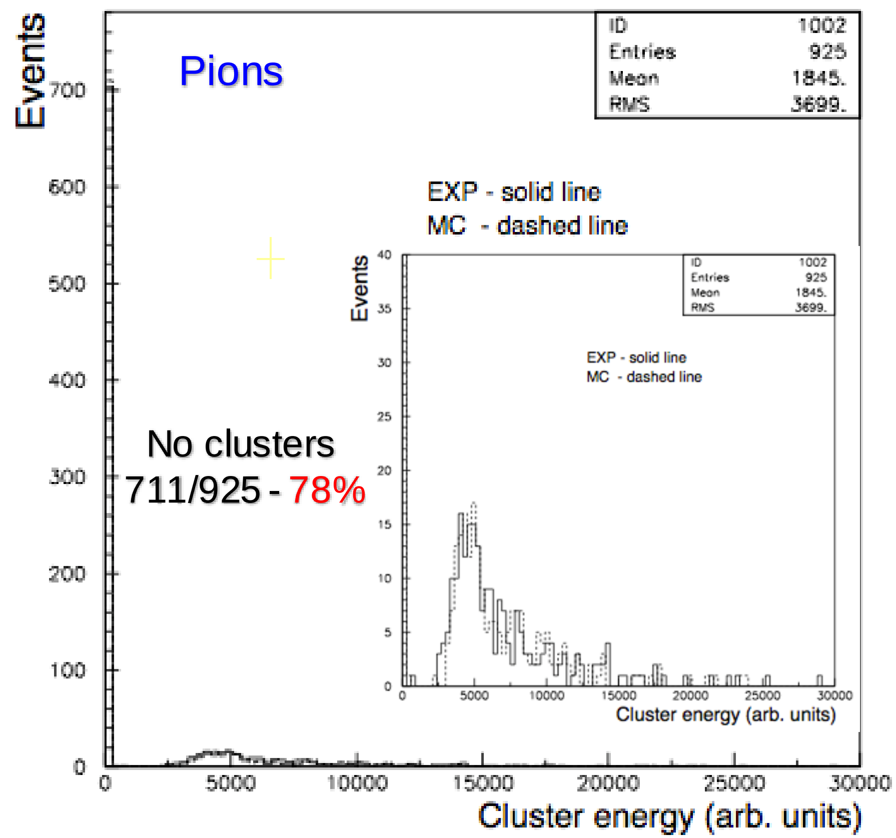


Distribution of a total ionization on the particle track for electrons and pions
Electron/pion separation.

Test beam results.

Particle Identification: Cluster counting



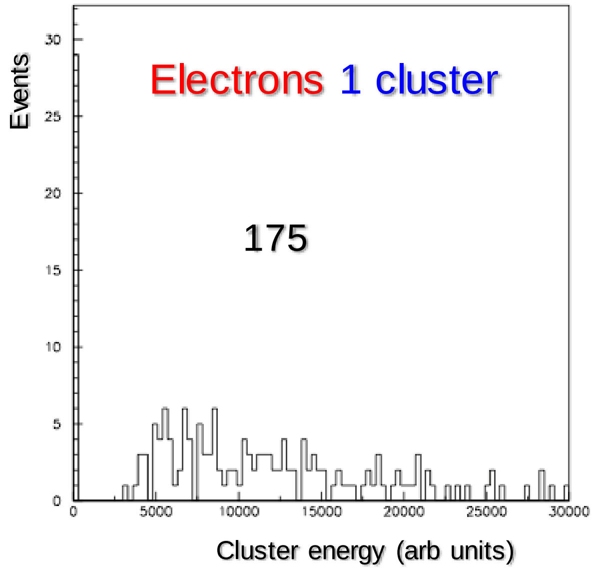


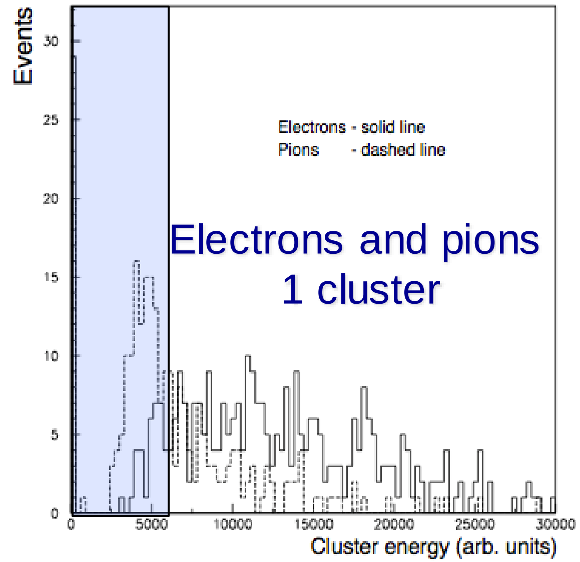
Cluster energy distribution on the particle track for electrons and pions

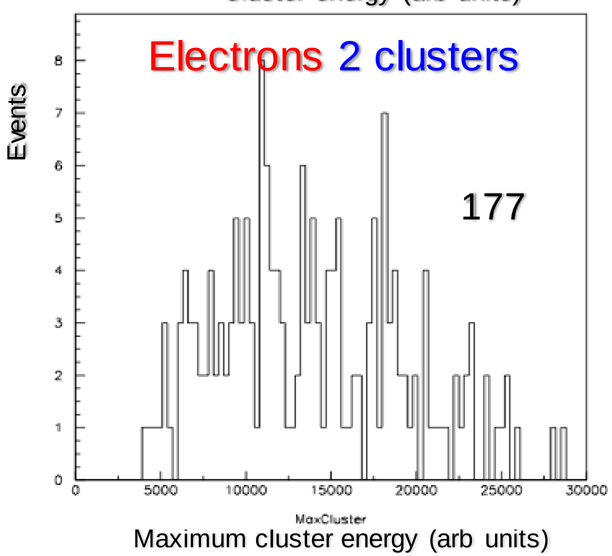
Test beam results

Particle Identification: Cluster counting

Cluster energy distribution on the particle track for electrons and pions





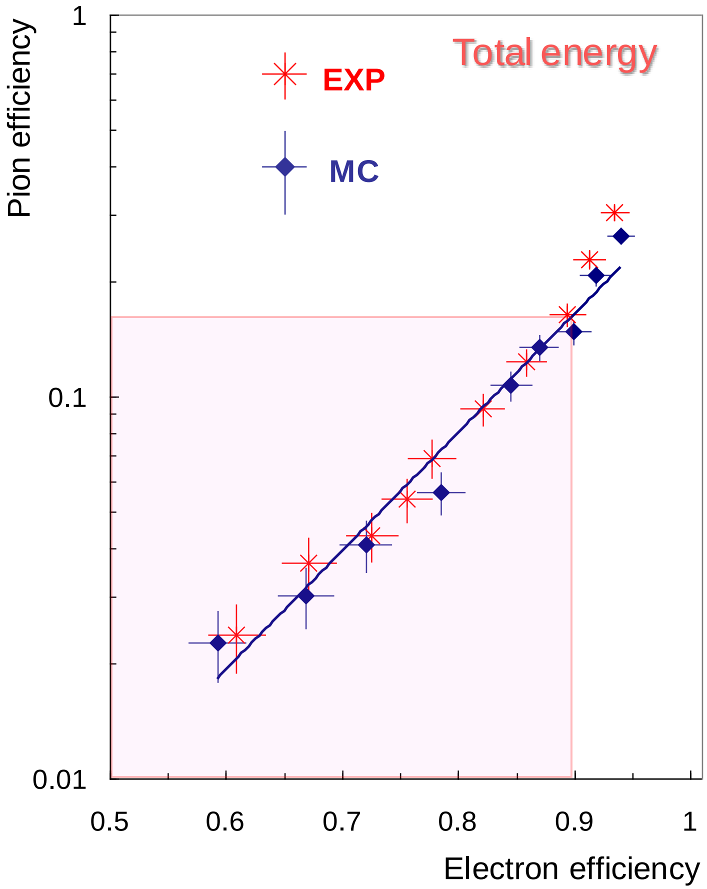


For PID additional CUT on the cluster energy is applied,.

Only 1% of pions have 2 clusters

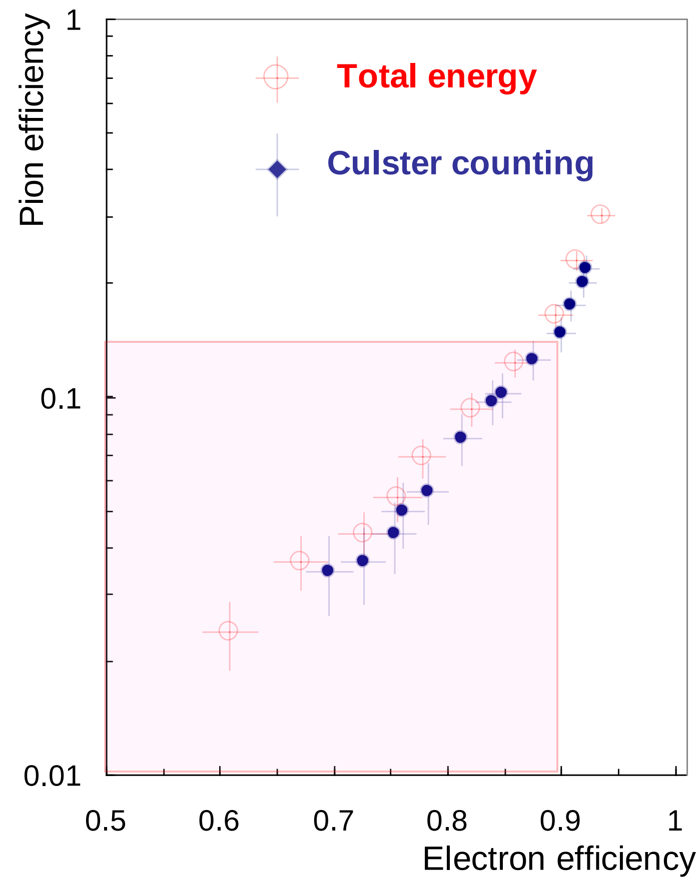
Particle Identification

Rejection facto (one detector layer)



Pion registration efficiency as a function of electron efficiency.

For 90% electron efficiency pion rejection factor is **~7** for the total energy method.

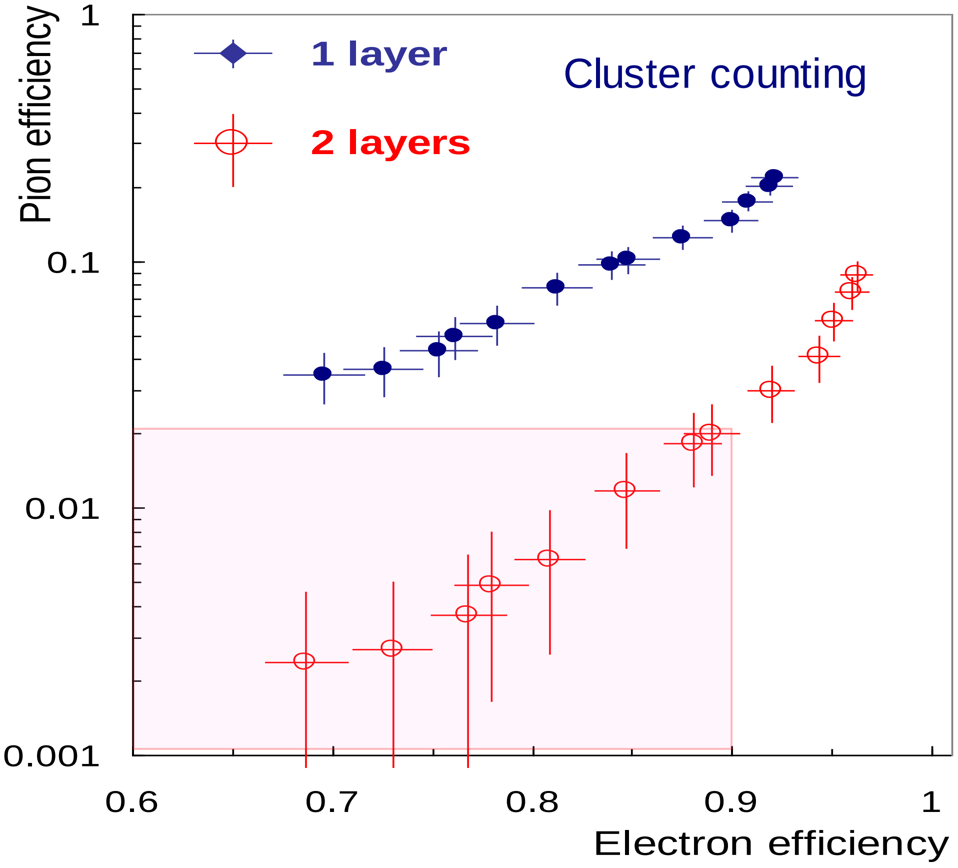


Pion registration efficiency as a function of electron efficiency for the total energy method and cluster counting method.

Cluster counting method has a bit larger rejection power.

Particle Identification

Rejection factor with cluster counting method



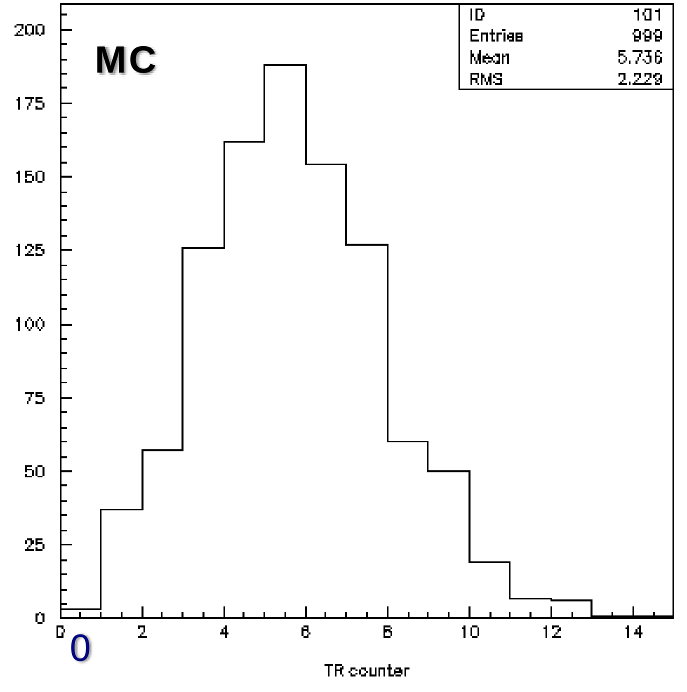
Pion registration efficiency as a function of electron efficiency for 1 and 2 layers of the detector. Cluster counting method.

TRD with two detector layers (total thickness ~ 40 cm) allows to achieve rejection factor of **~ 50** for 90% electron efficiency.

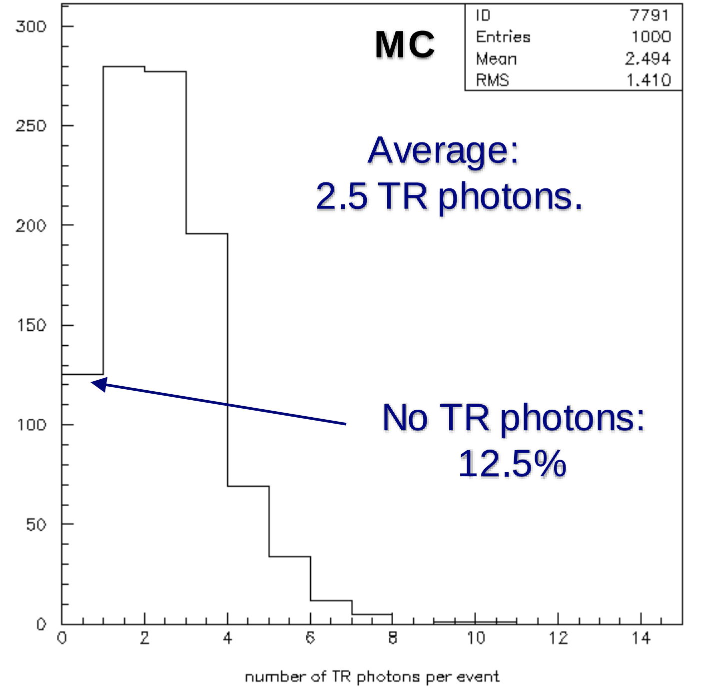
The radiator is one of the biggest issues for the compact detectors.

Particle ID.

TR generation and absorption (test beam set-up).



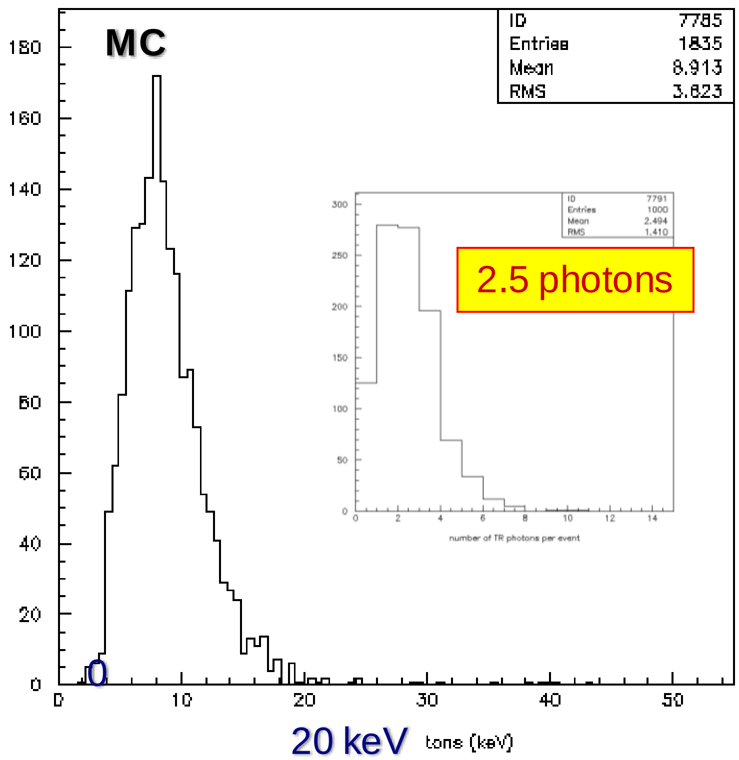
Number of photons at the radiator output



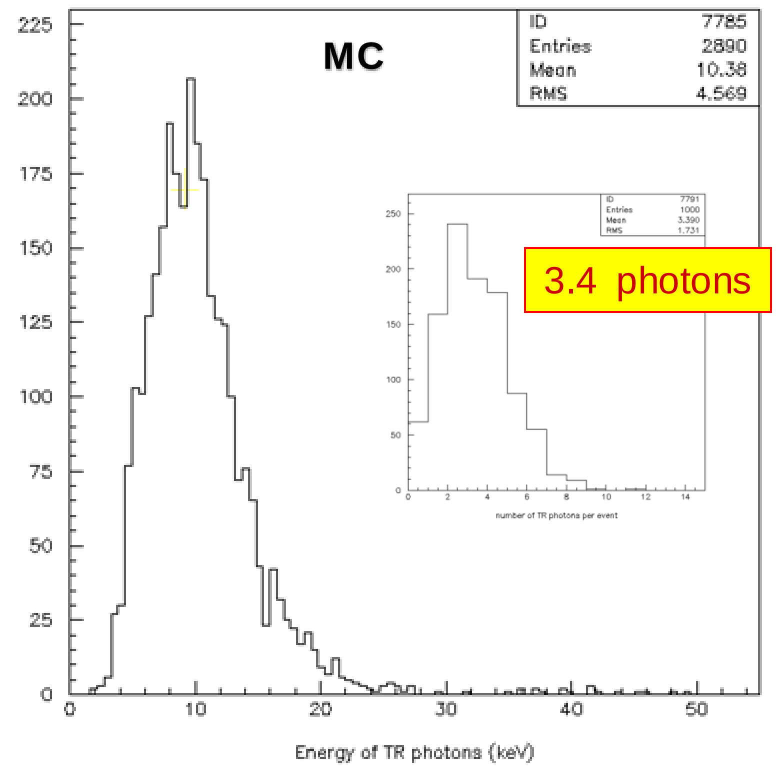
Number of detected photons in one layer per event (test beam chamber)

Particle ID.

TR generation and absorption.



Spectrum TR absorbed in 1.6 cm thick chamber



Spectrum TR absorbed in 4 cm thick chamber

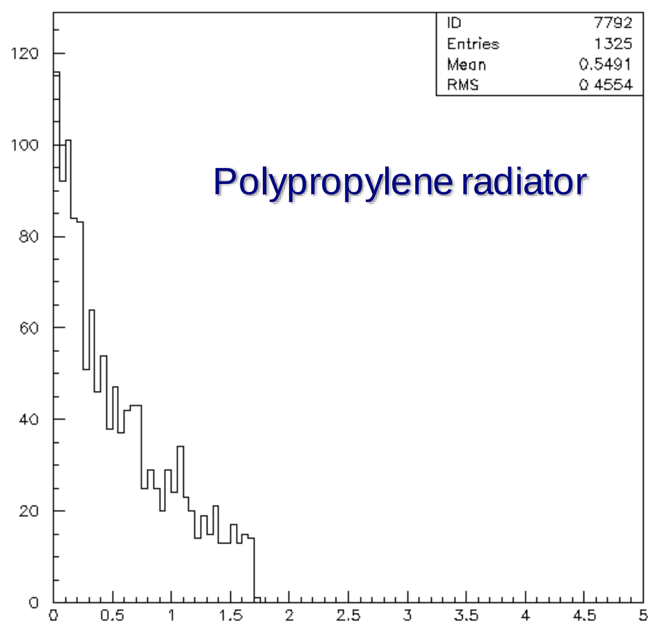
Number of detected photons in inserts.
For 4 cm chamber 6% electrons have no TR cluster

Particle ID.

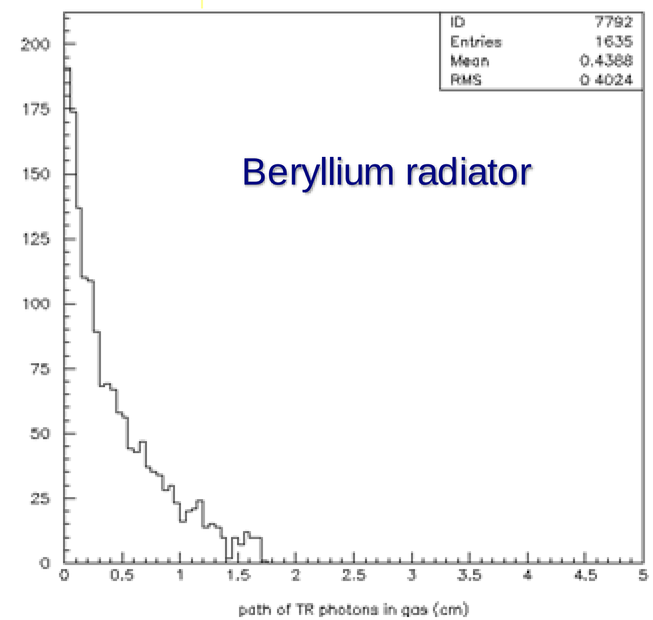
TR generation and absorption

For 1-2 layer detector the biggest problem is the compact radiator which should provide a soft photon spectrum.

Be - Li materials?



MC

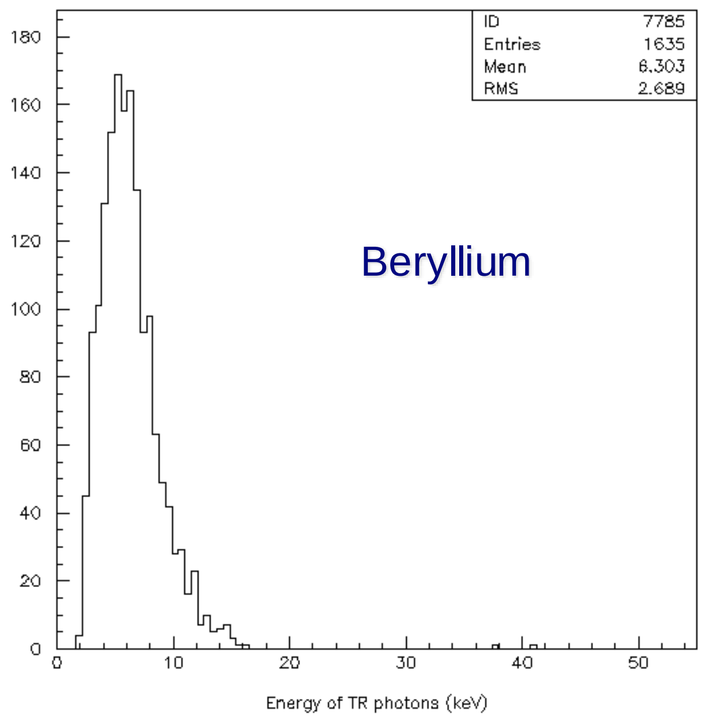


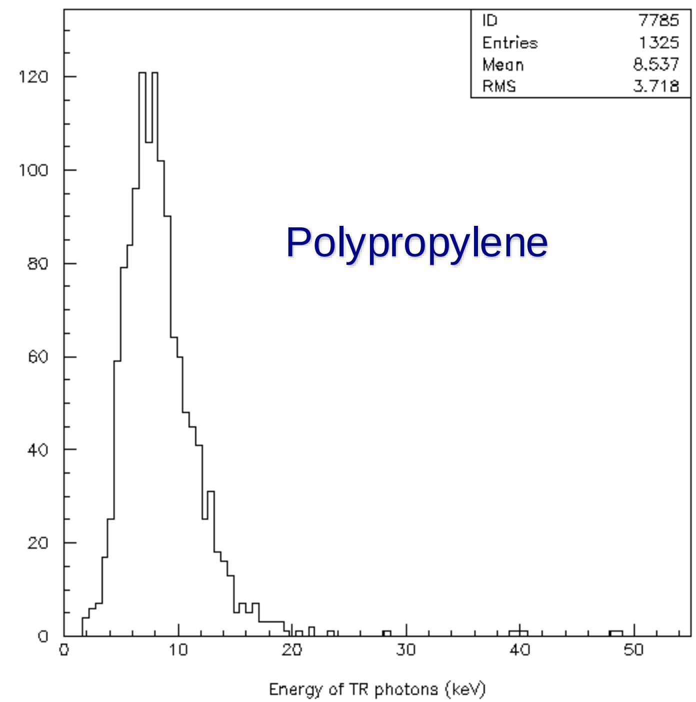
Number of absorbed photons as a function of the pass in the gas in **1.7 cm** chamber (70%Xe + 30% CO_2).

Particle ID.

TR generation and absorption

Radiators: 17μm/100μm/9 cm





Spectrum of absorbed TR for different types of radiator.

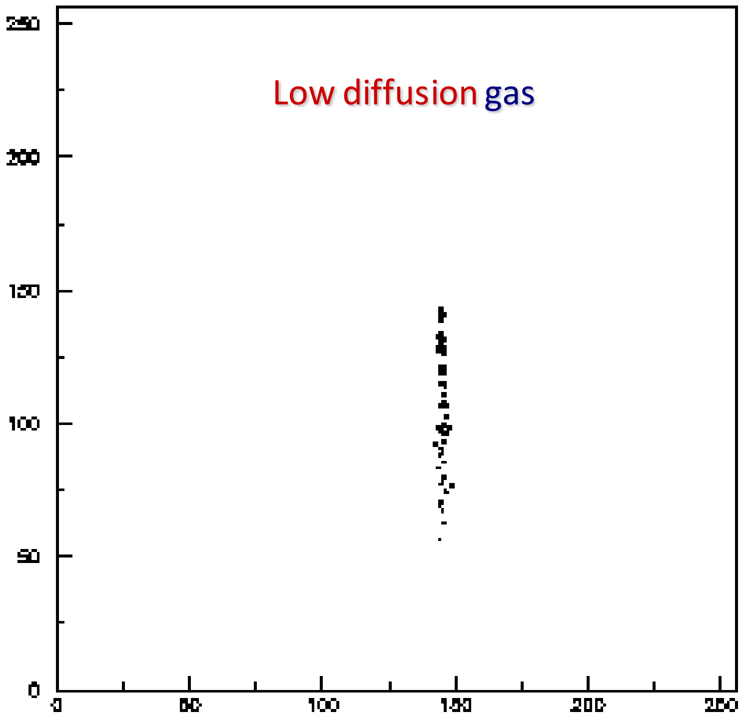
There is a way to get a compact radiator with good TR yield
But much more optimisation and test work is required.

GasPixel:
Tracking properties.

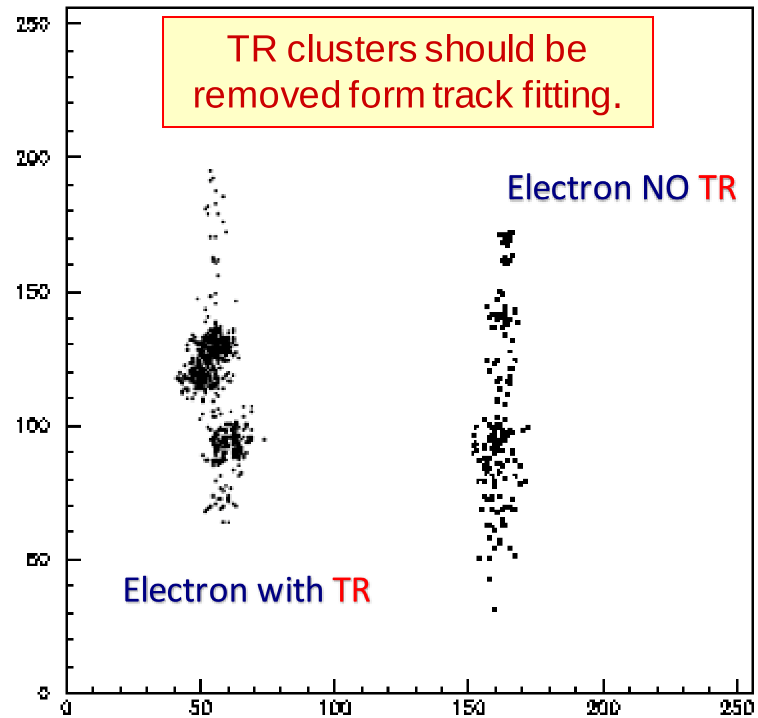
Tacking.

Results strongly depend on the gas properties.

DME/CO_2 (50/50),
19° incident angle



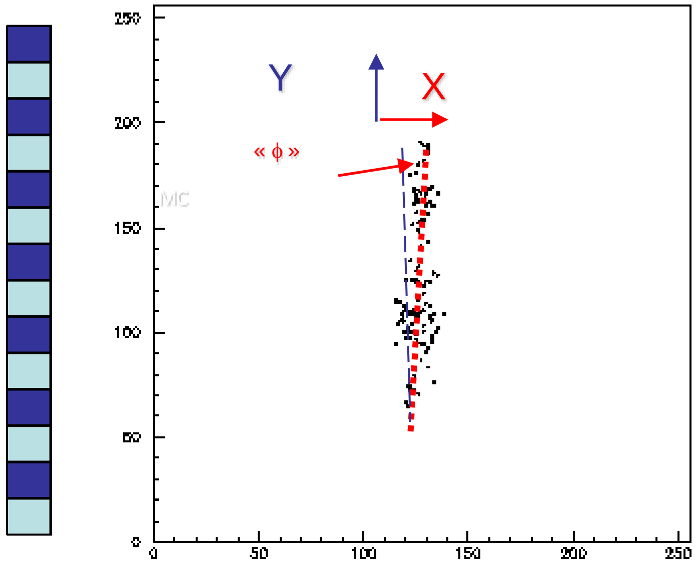
Xe/CO_2 (70/30),
19° incident angle



Apart of detector geometry a track reconstruction accuracy depends on diffusion, single electron efficiency and also on a presence of the TR clusters.

Tacking.

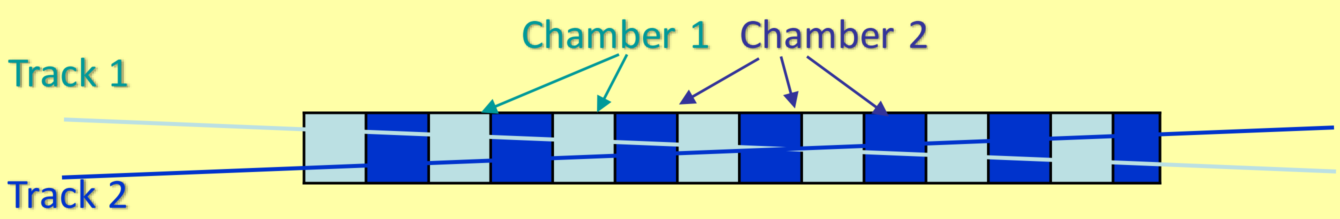
Technique used for the tacking property studies.



How well we understand the results?
The answer is in MC simulations which use the same technique.

What we can measure with the beam without reference detector?

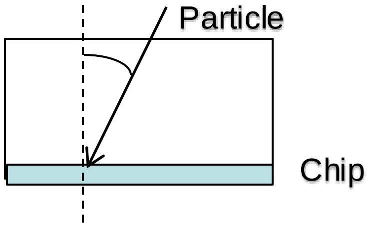
Represent the chamber as two independent interleaved units and measure parameters of two "tracks" (pseudo-tracks) reconstructed independently!



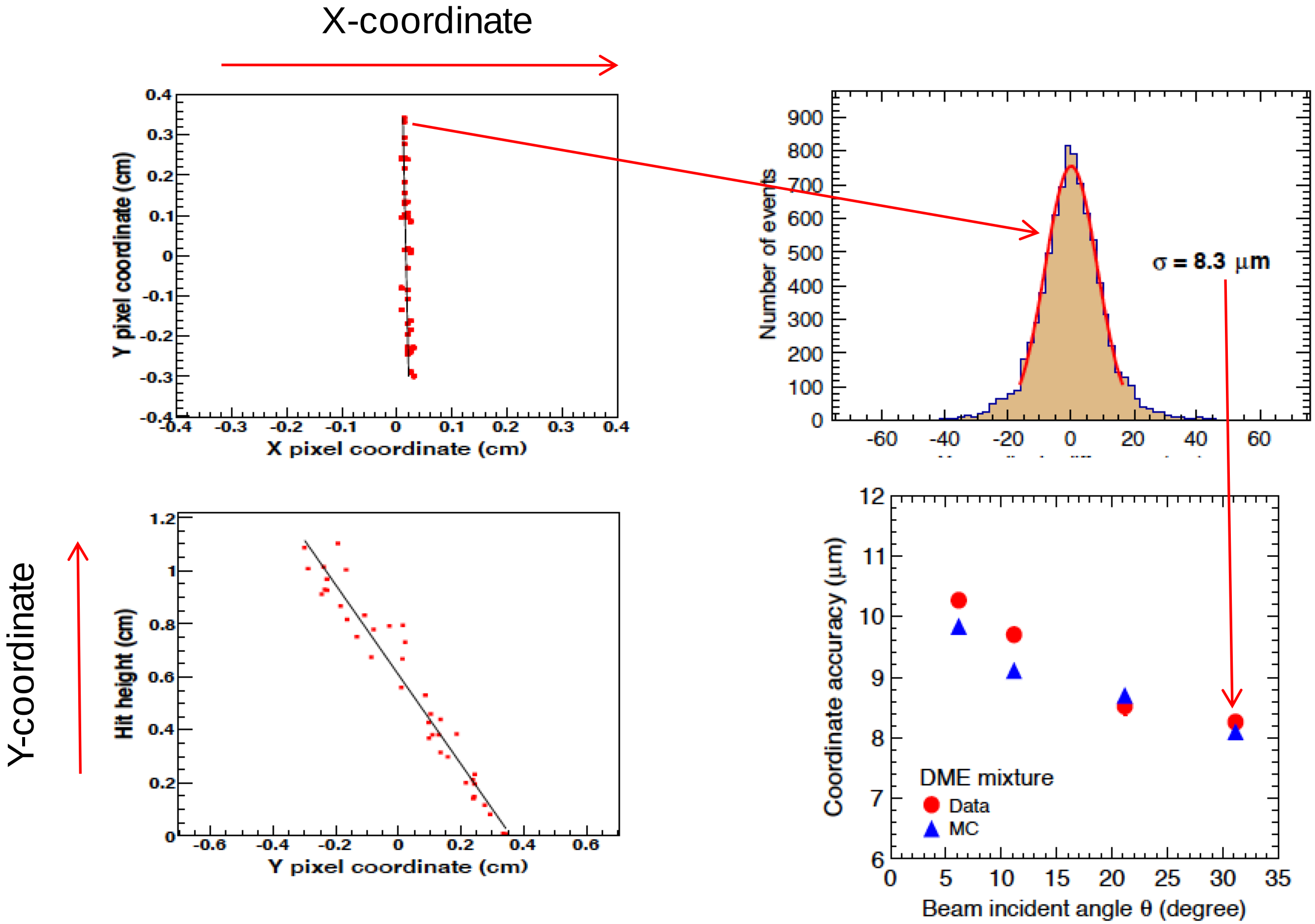
A real resolution is about ½ of the measured one with this method.

Test beam results: Tacking.

Low diffusion gas.



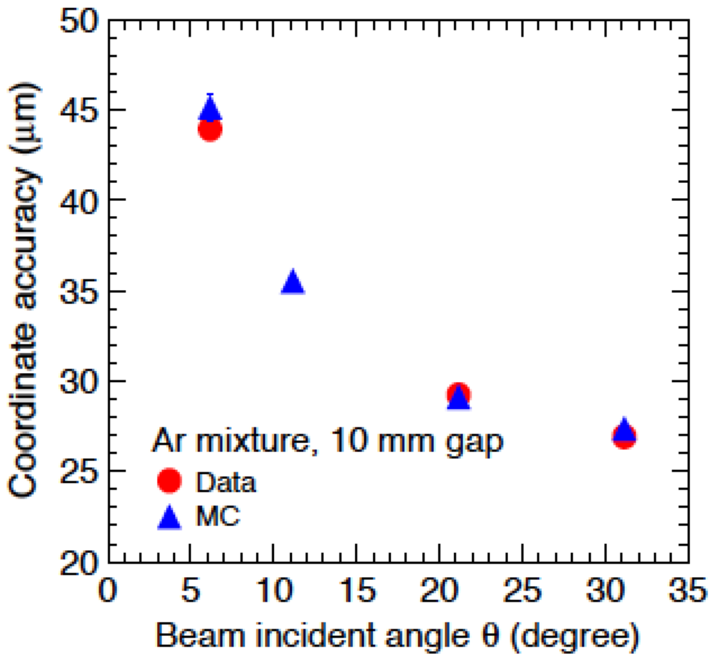
DME/CO2 (50/50),.



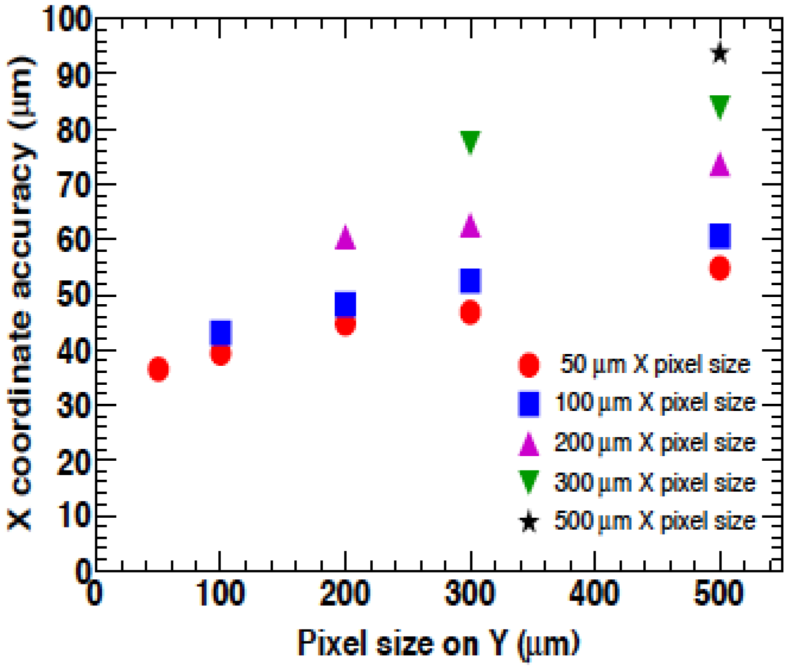
Test beam results: Tacking.

Low diffusion gas.

Gas with Large diffusion: Ar



~30 μm coordinate accuracy can be obtained



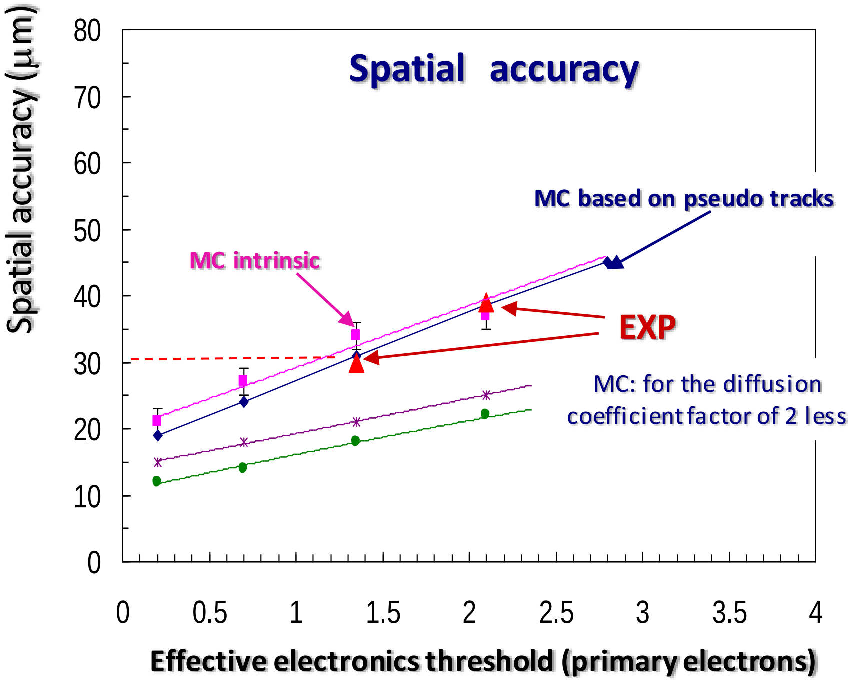
Pixel size can be increased
For the gas with diffusion pixel size of 100x200 μm will provide coordinate accuracy ~50 μm)

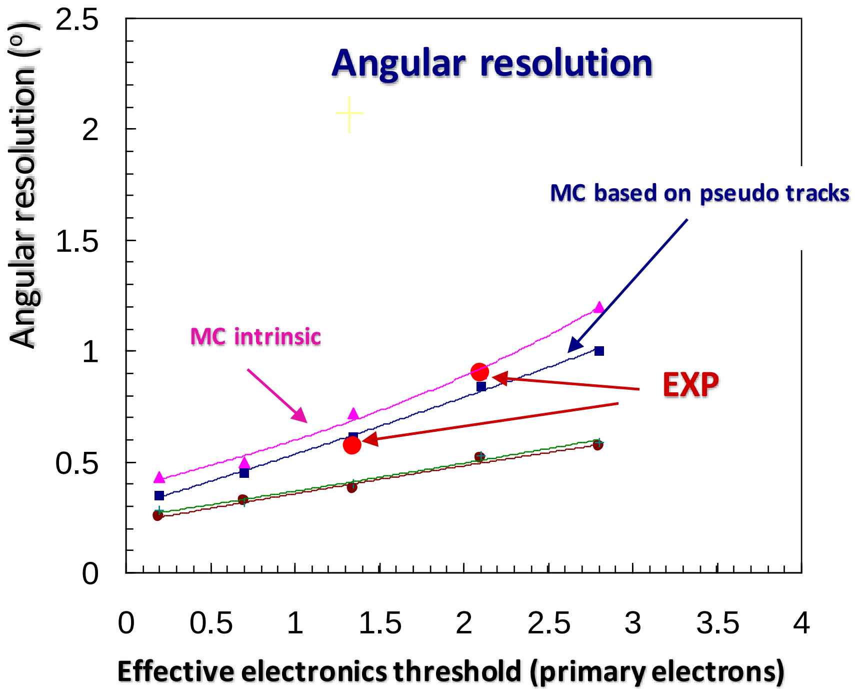
Test beam results: Tacking.

Xe - mixture

Xe mixture: Pions, 5 GeV,, 55 μm pixel, 240 μm diffusion.

25° of incident angle





Intrinsic special accuracy of the gas pixel detector (MC and EXP).

Intrinsic angular resolution of the gas pixel detector. (MC and EXP).

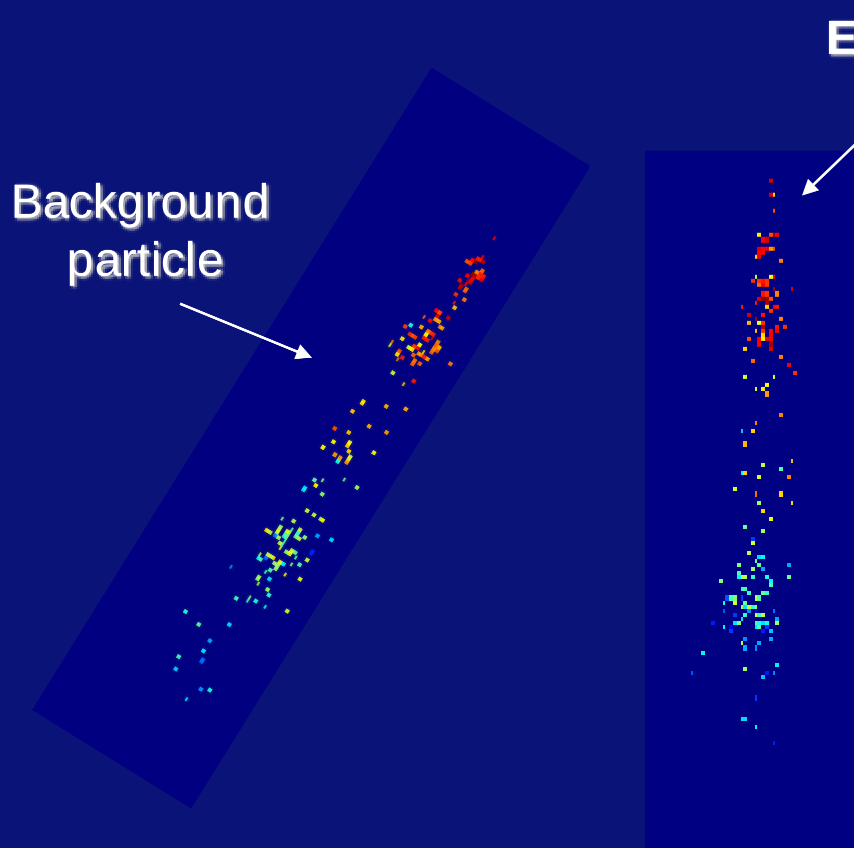
30 μm space accuracy and 0.6 ° angular resolution obtained in the experiment for Xe based mixture (without radiator) .

It is a bit worse (~55 μm, 0.9°) for electrons with TR clusters but effect still to be studied in details

Operation in multi particle environment.

Track projection on the pixel plane

Color code reflects hit arrival time



Particles are well separated if distance between them >1 mm. For shorter distances events should be removed from analysis

Conclusions.

1. Gas pixel technology offers wide range of possibilities for particle identification.

2. This detector provides also precise tracking information and has very good multi-particle separation power.

3. 10 radiator/detector layers would give ~25-35 detected photons with known energy -> that is almost spectrum measurements!

4. Definitely, optimization which exploits all possibilities of these detectors should be done for gamma factor measurement properties.