Hit reconstruction in MUCH system of the CBM experiment

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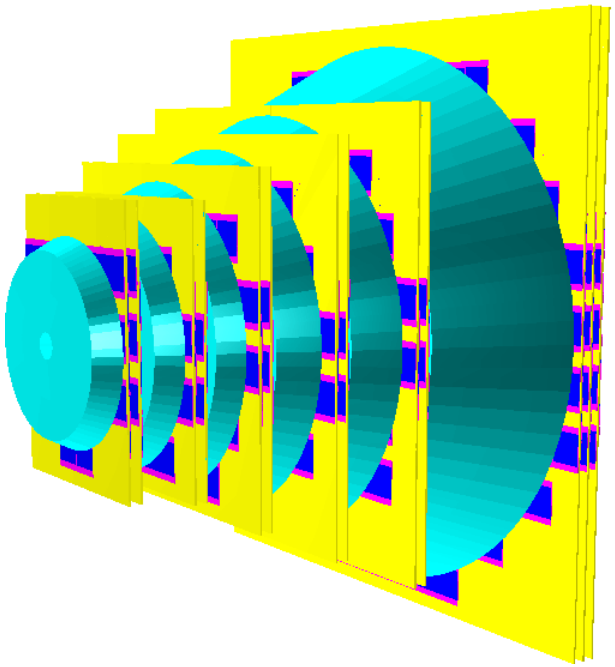
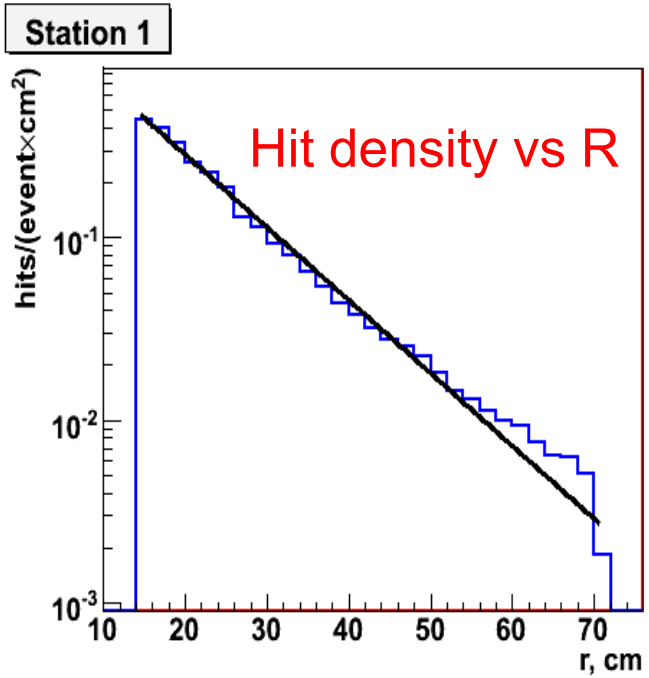
Outline

- Segmentation algorithm
- Simple digitization scheme
- Advanced digitization scheme
- Hit finding
- Quality analysis
- Conclusion

Segmentation

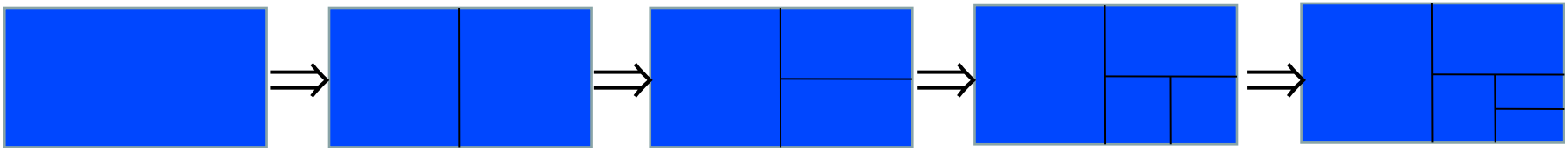


- Module design was used;
- Occupancy should be below 5%;
- Output parameters file is in ROOT format, which is compact.



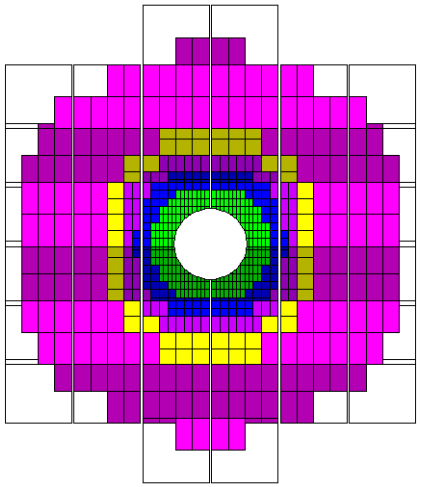
Maximum occupancy and boundaries for sigma are set by the user

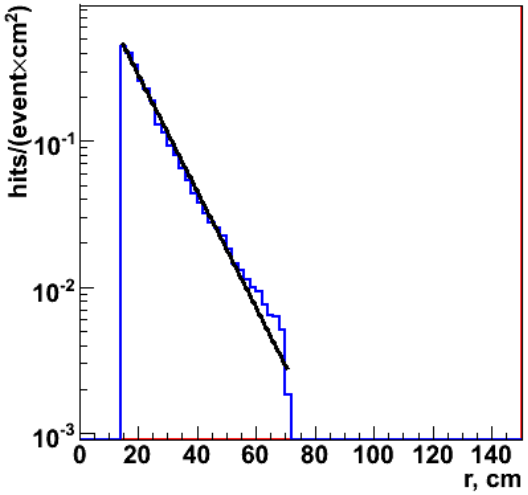
$$\mathrm{Occupancy}(R) = \mathrm{HitDensity}(R) \times S_{\mathrm{pad}} \times \bar{n}(S_{\mathrm{pad}}) < \mathrm{OccupancyMax}$$



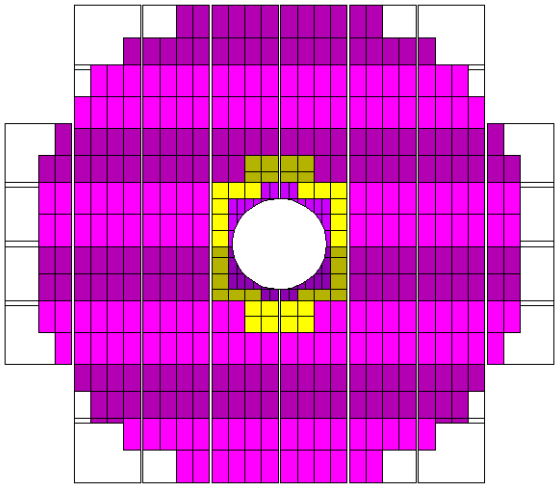
Segmented stations

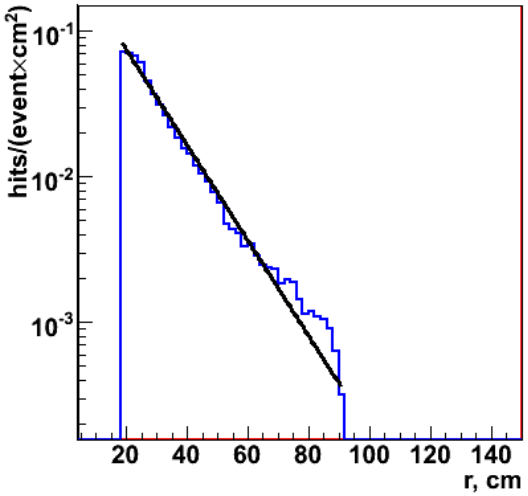
Station 1



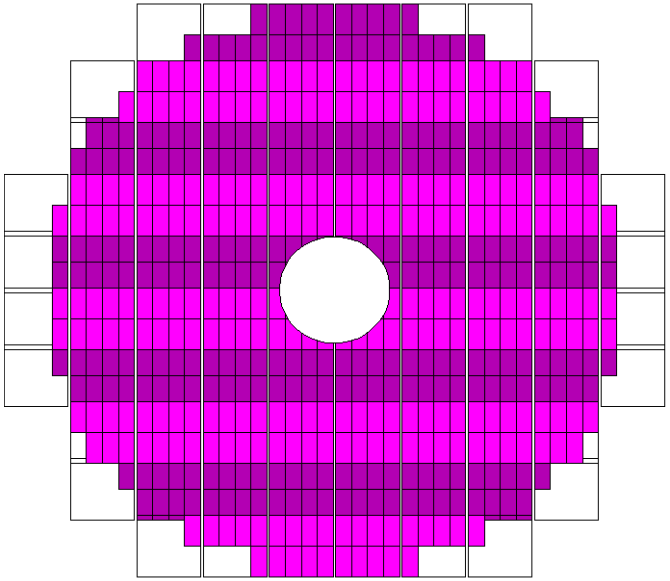


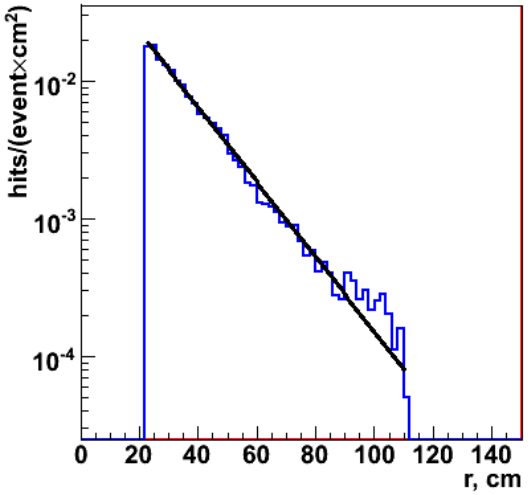
Station 2



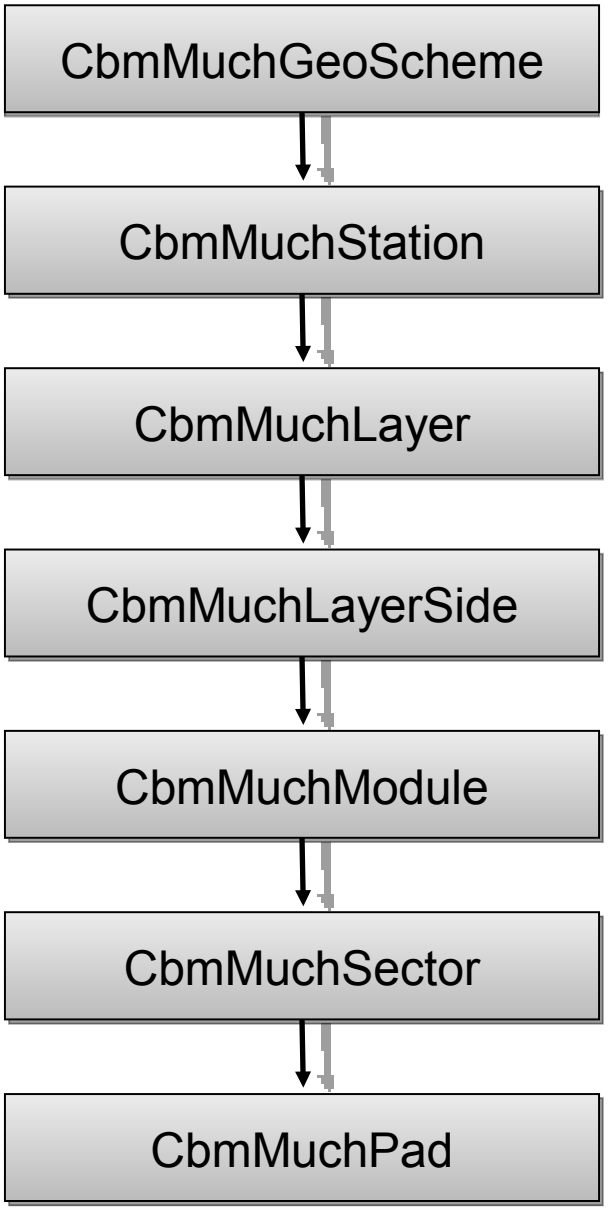


Station 3

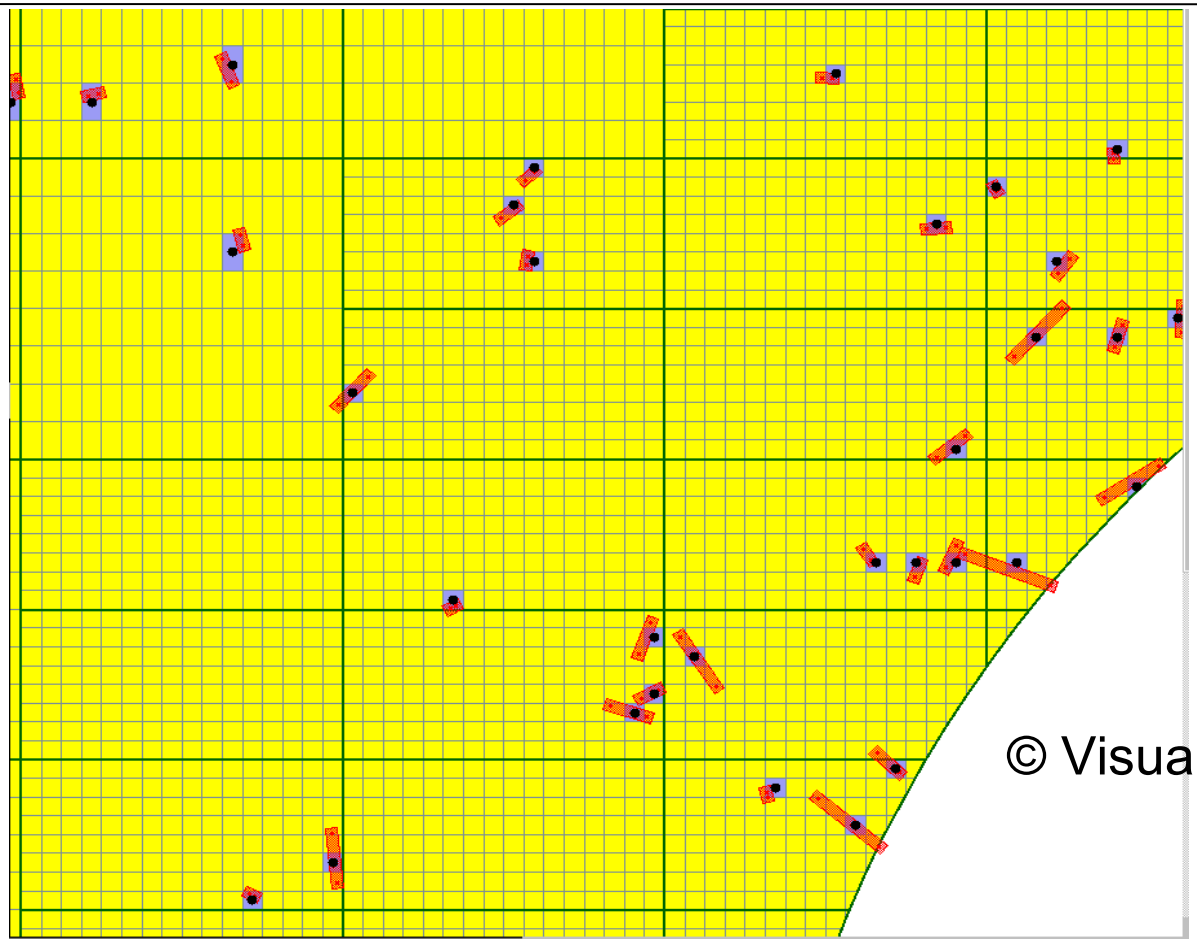




Class hierarchy



Simple digitization algorithm



Disadvantages:

- Only one pad is fired;
- Does not account for relevant physics;
- Pads do not collect charge (no charge thresholds introduced);
- No noise from the electronics taken into account;

Advanced digitization algorithm

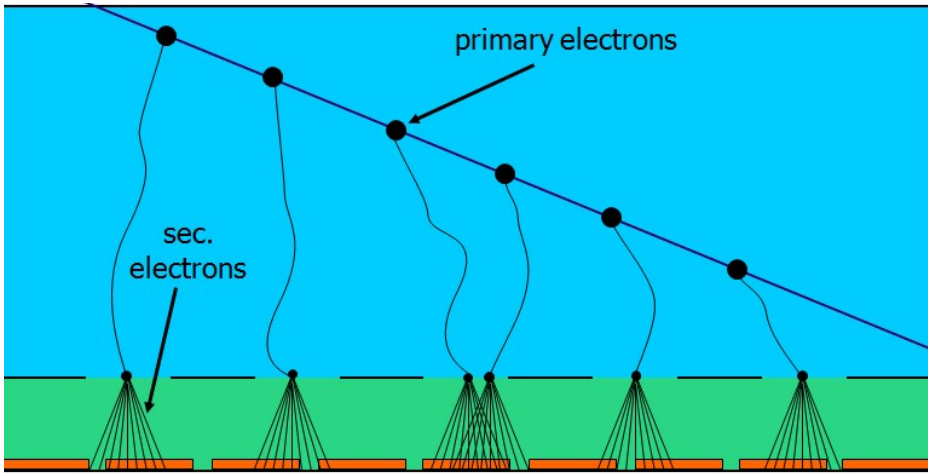
Implemented features:

- Primary electrons distributed randomly along the track (acc. to the uniform distr.);
- Secondary electrons are projected on the pad plane;
- Noise form electronics (Gaussian shape);
- Charge thresholds are introduced

  Maximal charge for muon track: $\approx 4 \times 10^5$ electrons/pad
  For 256 channel ADC one has $\approx 1.5 \times 10^3$ electrons/channel
  Minimum charge threshold: 3 channels

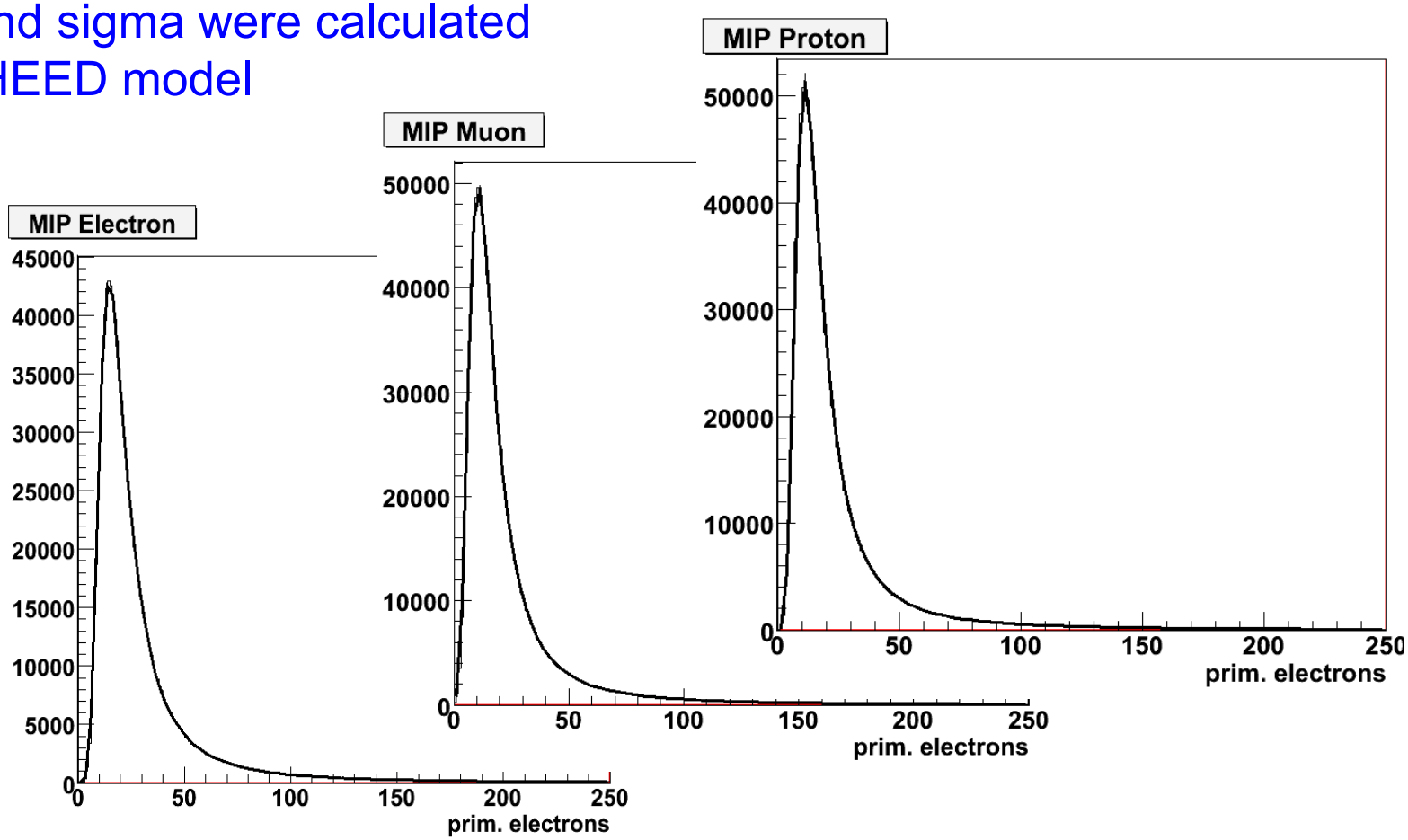
Factors not taken into account:

- Transverse diffusion of primary electrons;
- Cluster nature of primary electrons;



Fluctuations of energy loss

MPV and sigma were calculated using HEED model



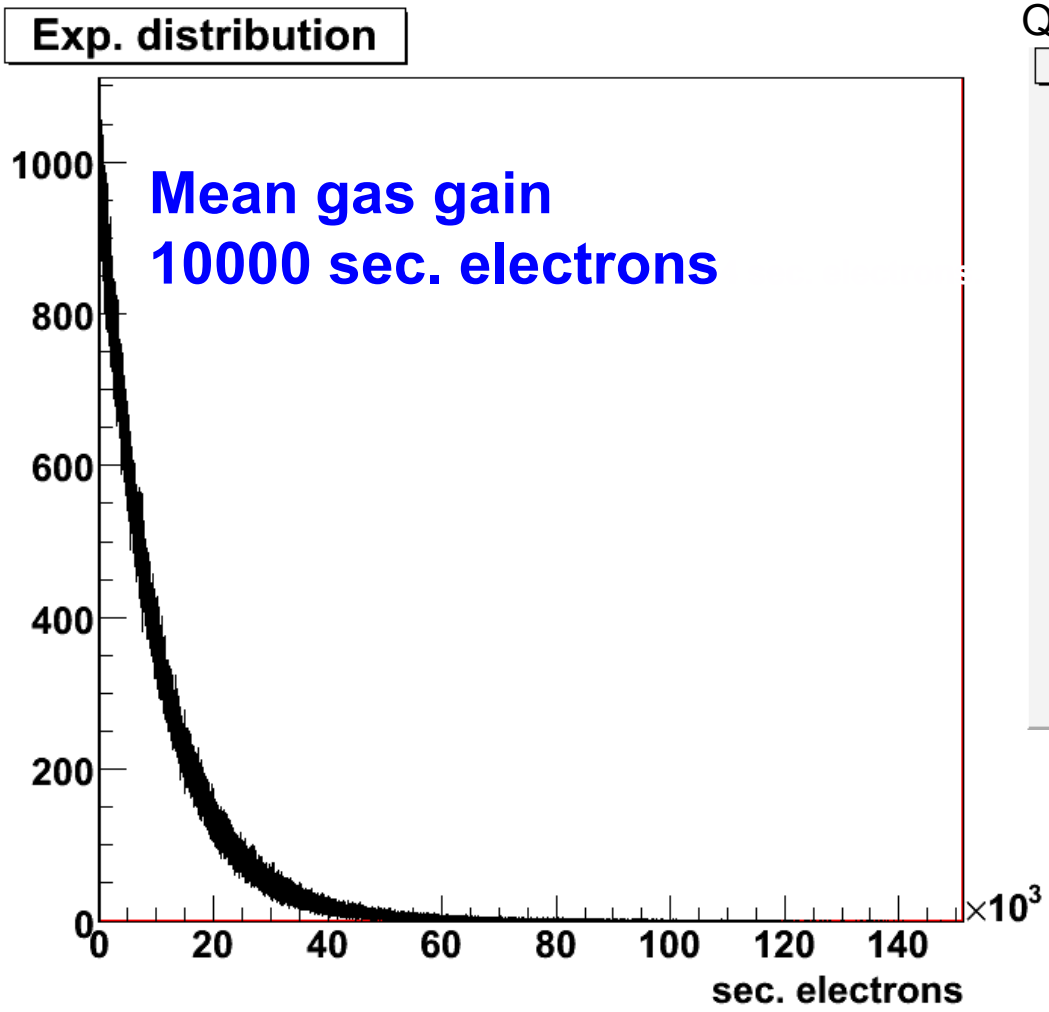
Mass scaling: $m < m_e$: $MPV_e(T \cdot m_e/m)$, $sigma_e(T \cdot m_e/m)$

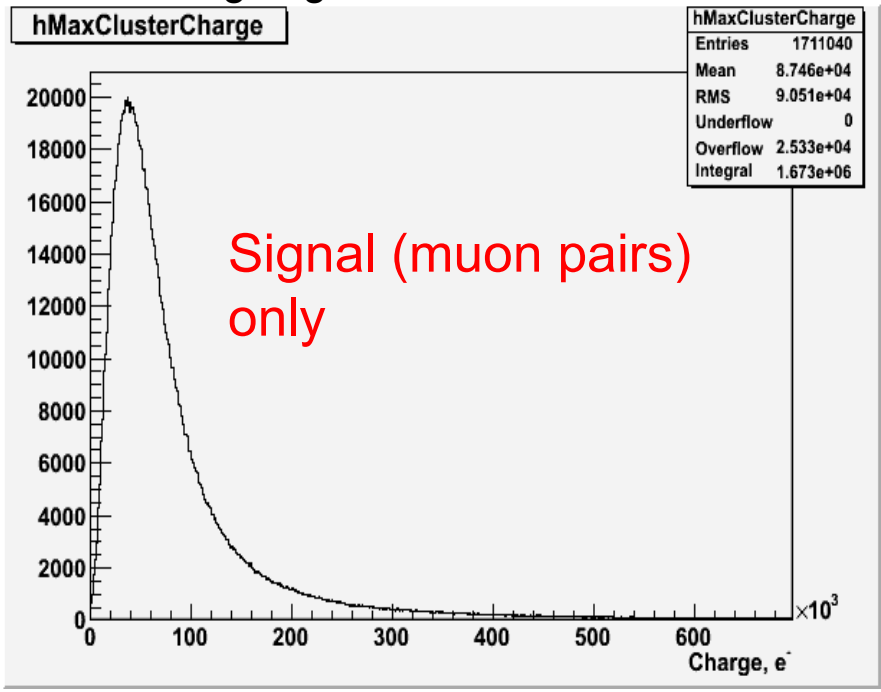
$m_e < m < m_\mu$: $MPV_\mu(T \cdot m_\mu/m)$, $sigma_\mu(T \cdot m_\mu/m)$

$m > m_\mu$: $MPV_p(T \cdot m_p/m)$, $sigma_p(T \cdot m_p/m)$

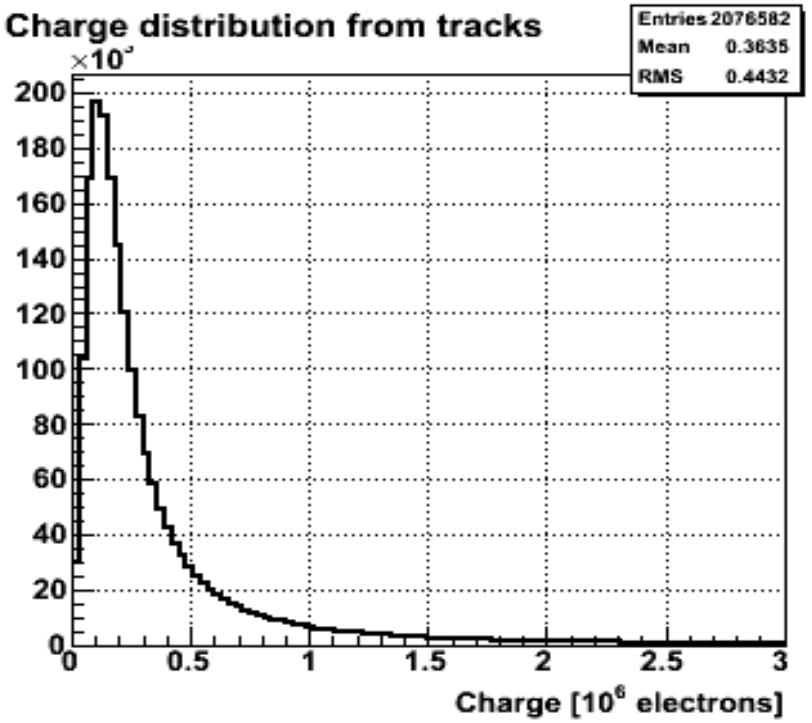
Secondary electrons

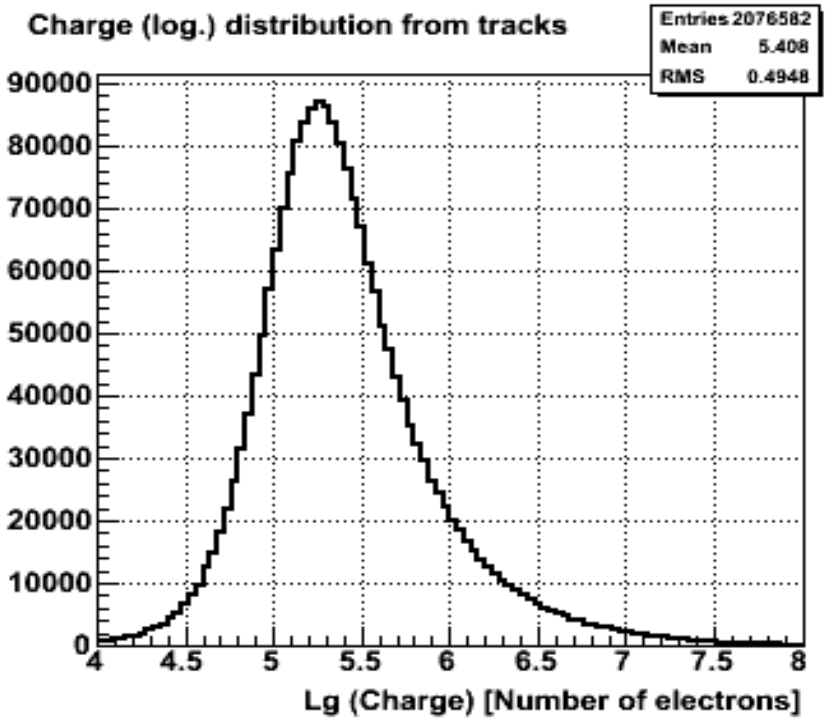
Reminder: expected CBM XYTER parameters
Maximal charge: 120,000 electrons
DAQ 8 bits
Quite small gas gain 3600





Charge distribution



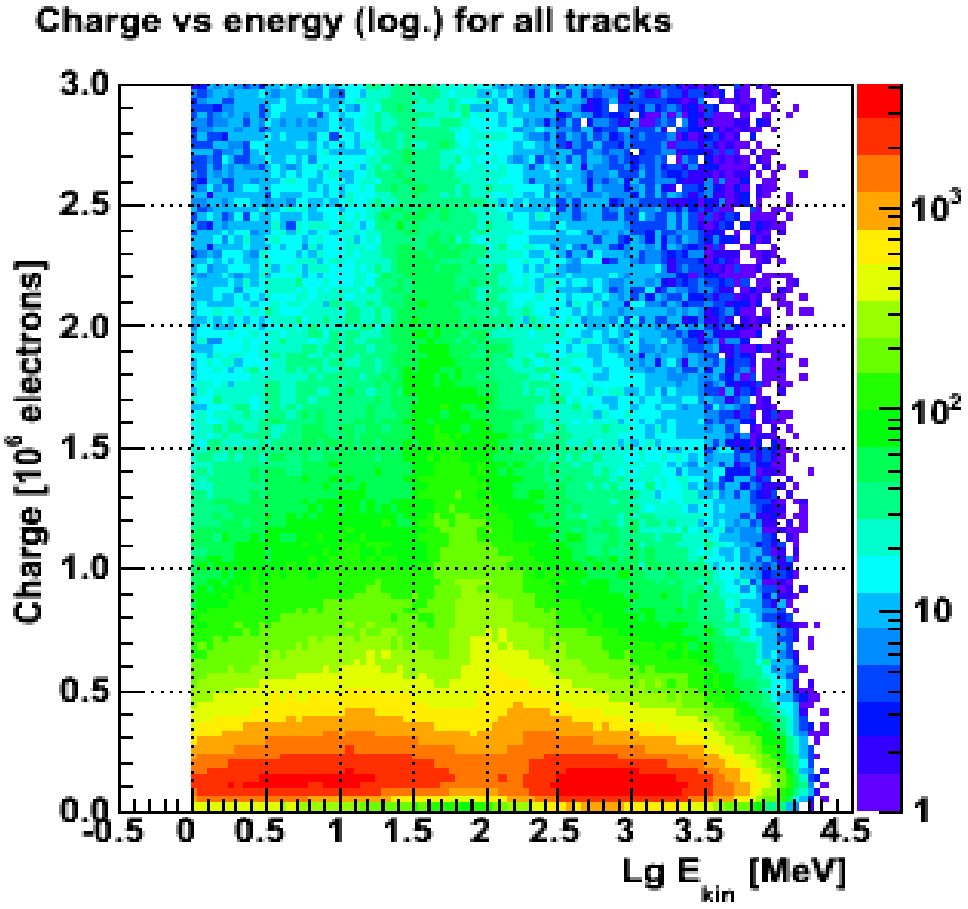


Mean charge: $3.6 \cdot 10^6$ (In average 36 primary electrons)

Factors contributing to the charge dispersion:

- Particle type
- Particle energy
- Track length variation
- Number of “primary” electrons generated according to Landau distribution with a given MPV and sigma (dependent on Particle energy and type)
- Gas gain fluctuations in accordance with exponential distribution with mean value of 10000

Energy dependence of the charge

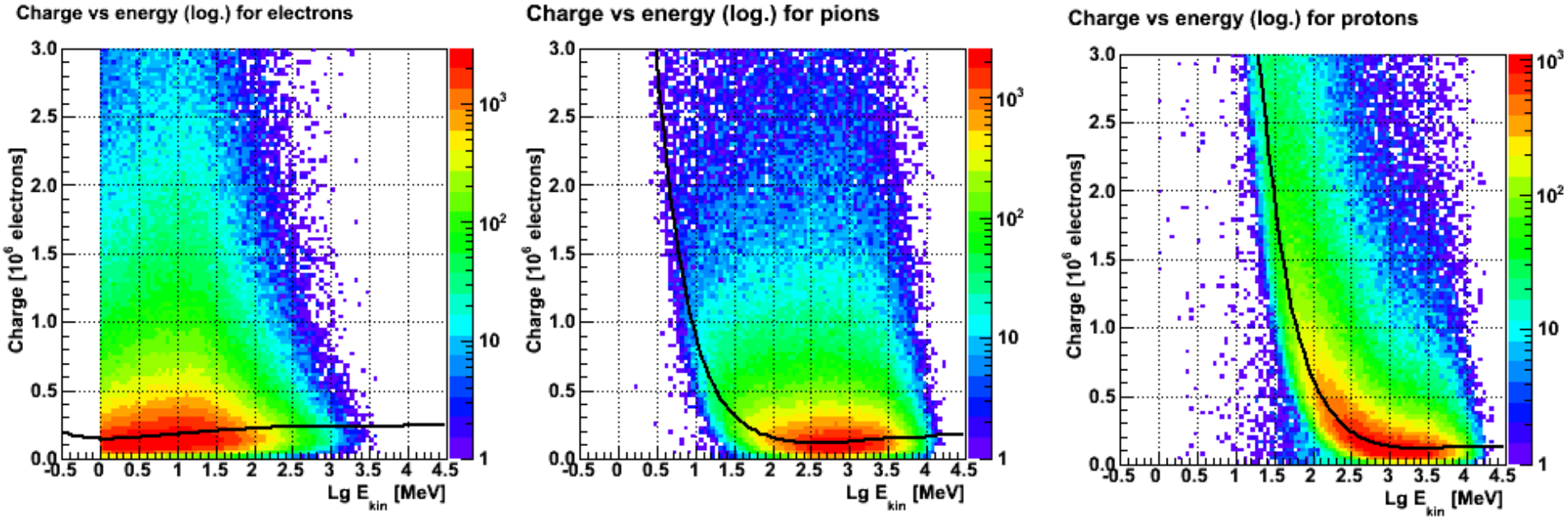


X axis – decimal logarithm of track energy measured in MeV
Y axis – charge generated by track (number of secondary electrons)

The sharp cut-off at Log E equal to 0 (or equivalently 1 MeV) is due to the geant3 minimum energy cut

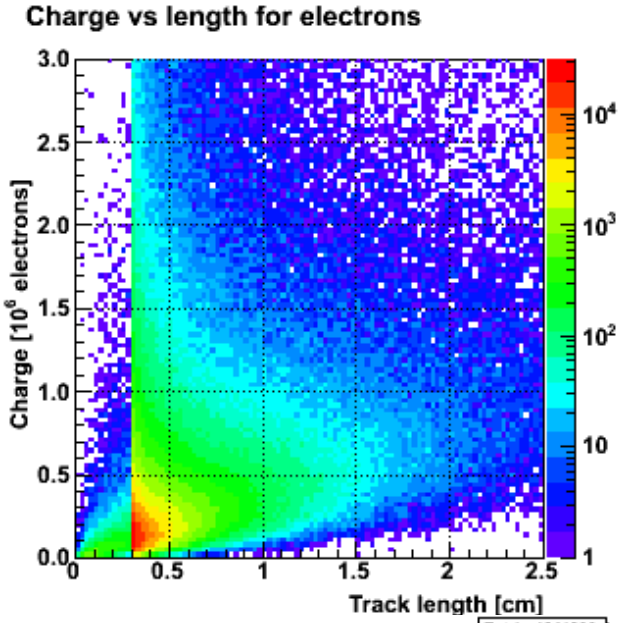
Energy dependence of the charge

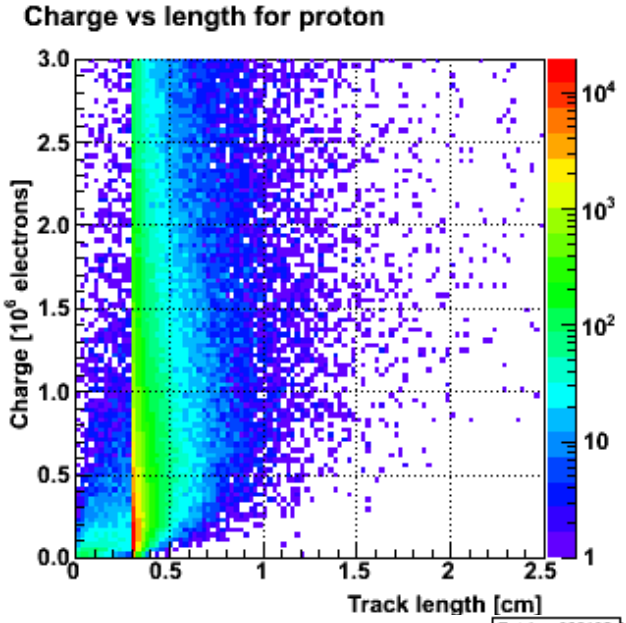
Charge vs energy distributions for different particle types:

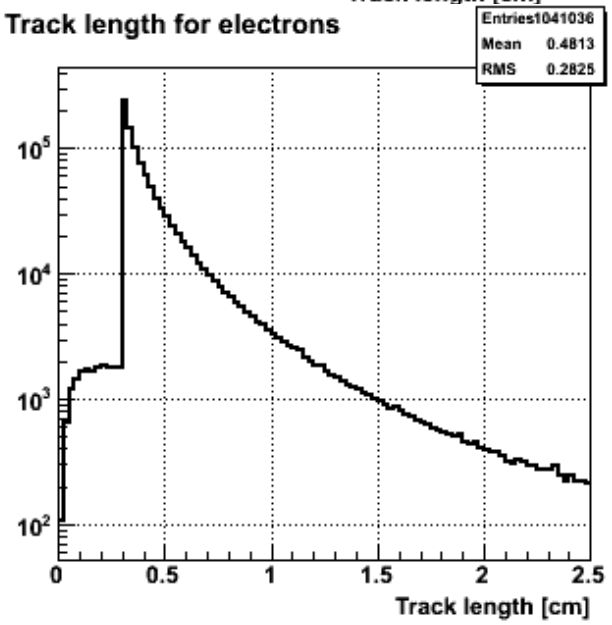


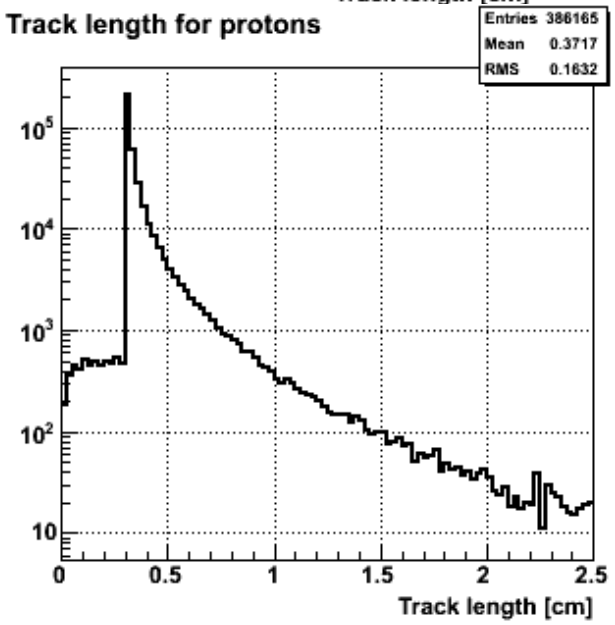
- Solid lines correspond to MPV energy dependencies built in the simulation (MPV curve is proportional to Bethe-Bloch in the first approximation)
- These plots demonstrate the consistency of the simulation
- Electrons are most sensitive to 1 MeV cut-off
- Detailed studies of the electron cut-off dependency are desired

Charge vs. track length









- Sensitive gap of the detectors is 3 mm
- Difference in the track length is caused by the track slope
- The large track length is usually caused by secondaries
- Track lengths smaller than 3 mm are due to edge effects
- Mean length for electrons: 4.8 mm
- Mean length for protons: 3.7 mm

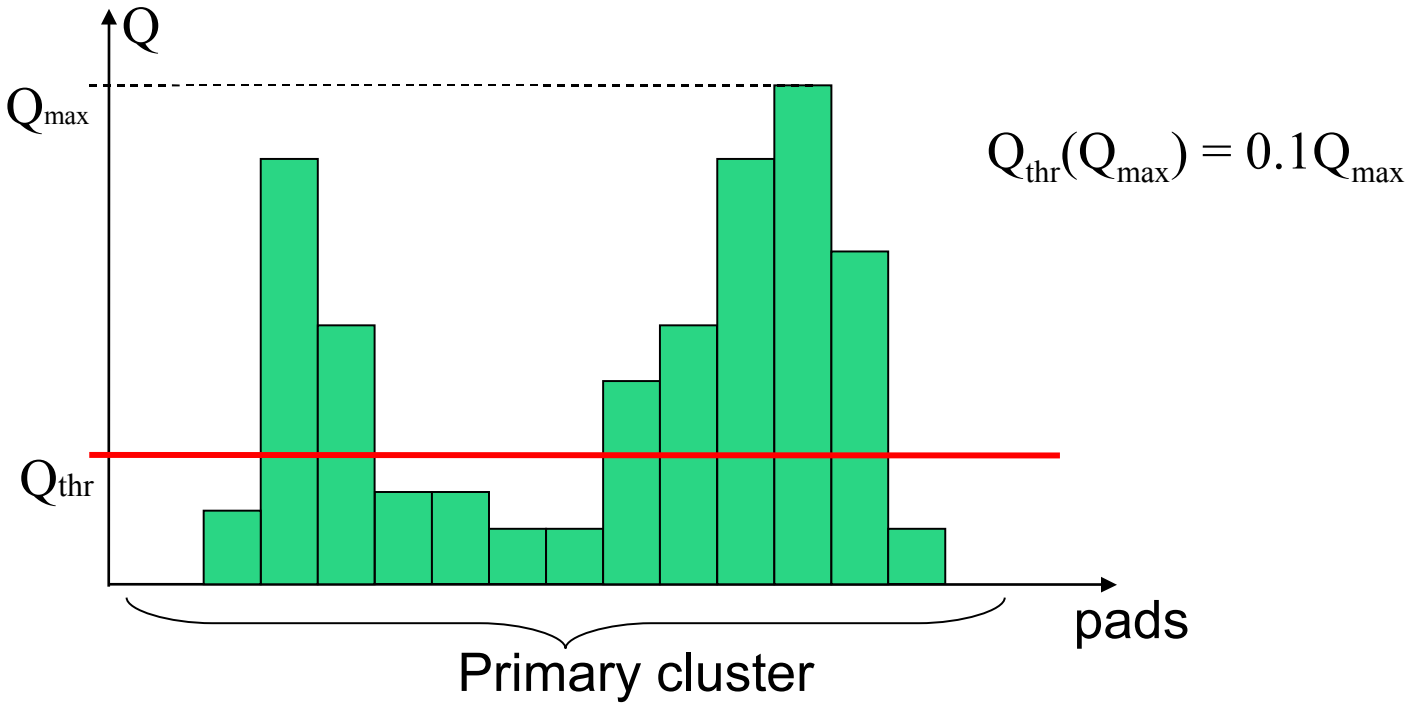
Cluster deconvolution

Hit coordinates:

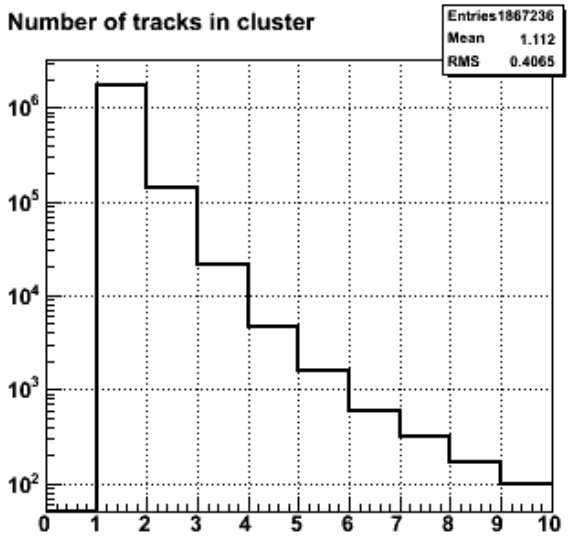
$$x_{hit} = \frac{\sum_{iPad} x_{iPad} \cdot q_{iPad}}{\sum_{iPad} q_{iPad}} \; ; \; y_{hit} = \frac{\sum_{iPad} y_{iPad} \cdot q_{iPad}}{\sum_{iPad} q_{iPad}}$$

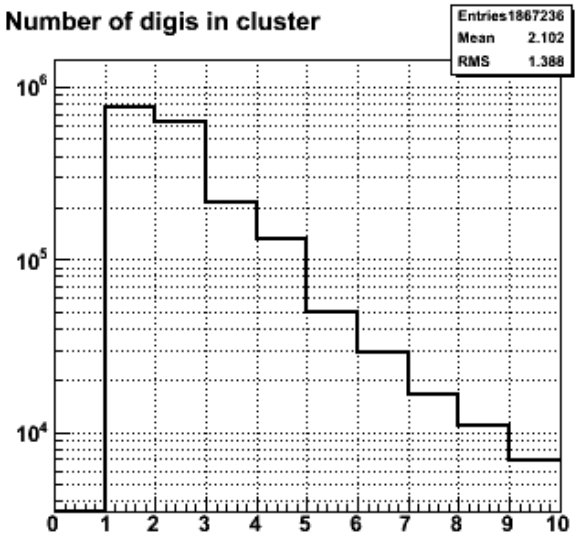
Hit errors:

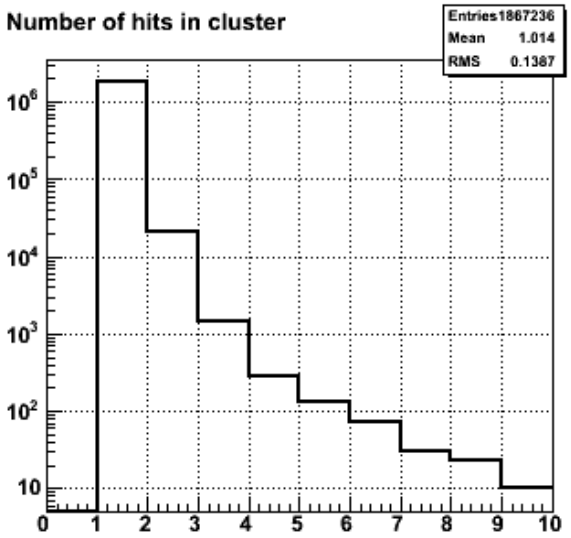
$$\Delta x_{hit} = \frac{(pad\ \ width)_{\min}}{\sqrt{12}} \; ; \; \Delta y_{hit} = \frac{(pad\ \ length)_{\min}}{\sqrt{12}}$$



Cluster statistics





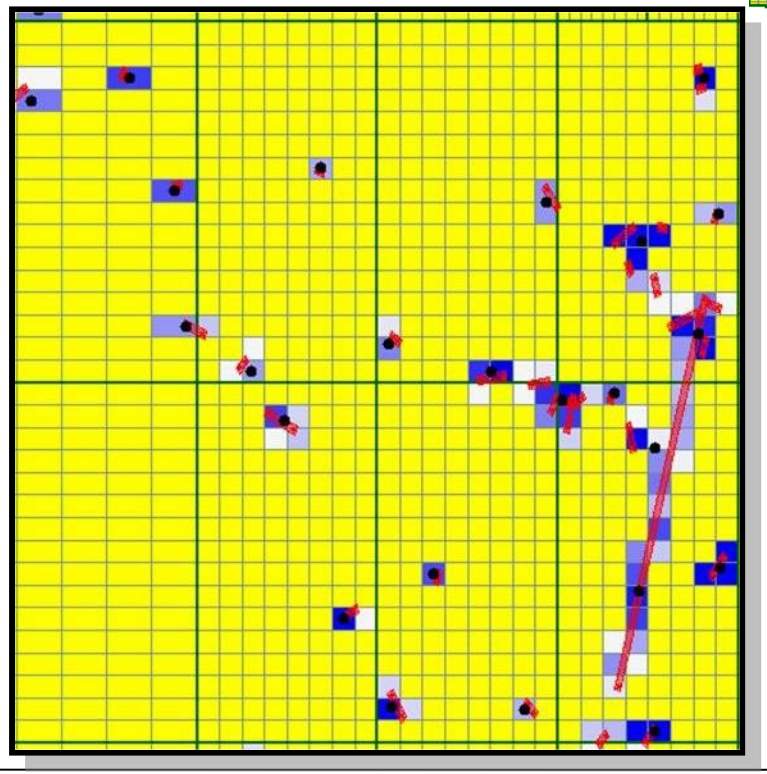


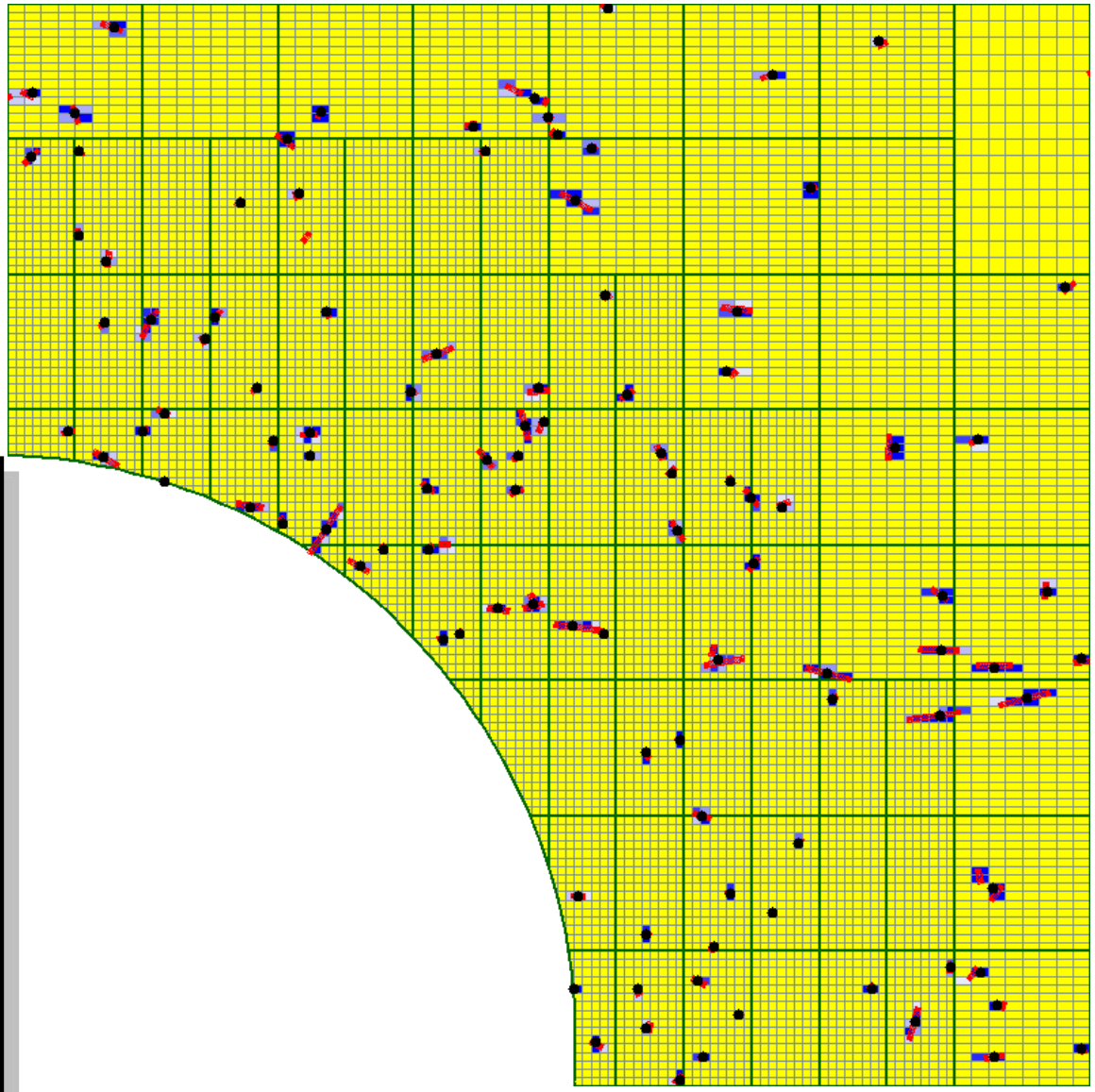
- Mean number of generated MC points contributing to one cluster: 1.11
- Mean number of fired pads in one cluster: 2.10
- Mean number of reconstructed hits produced in one cluster: 1.01

Hit finding results

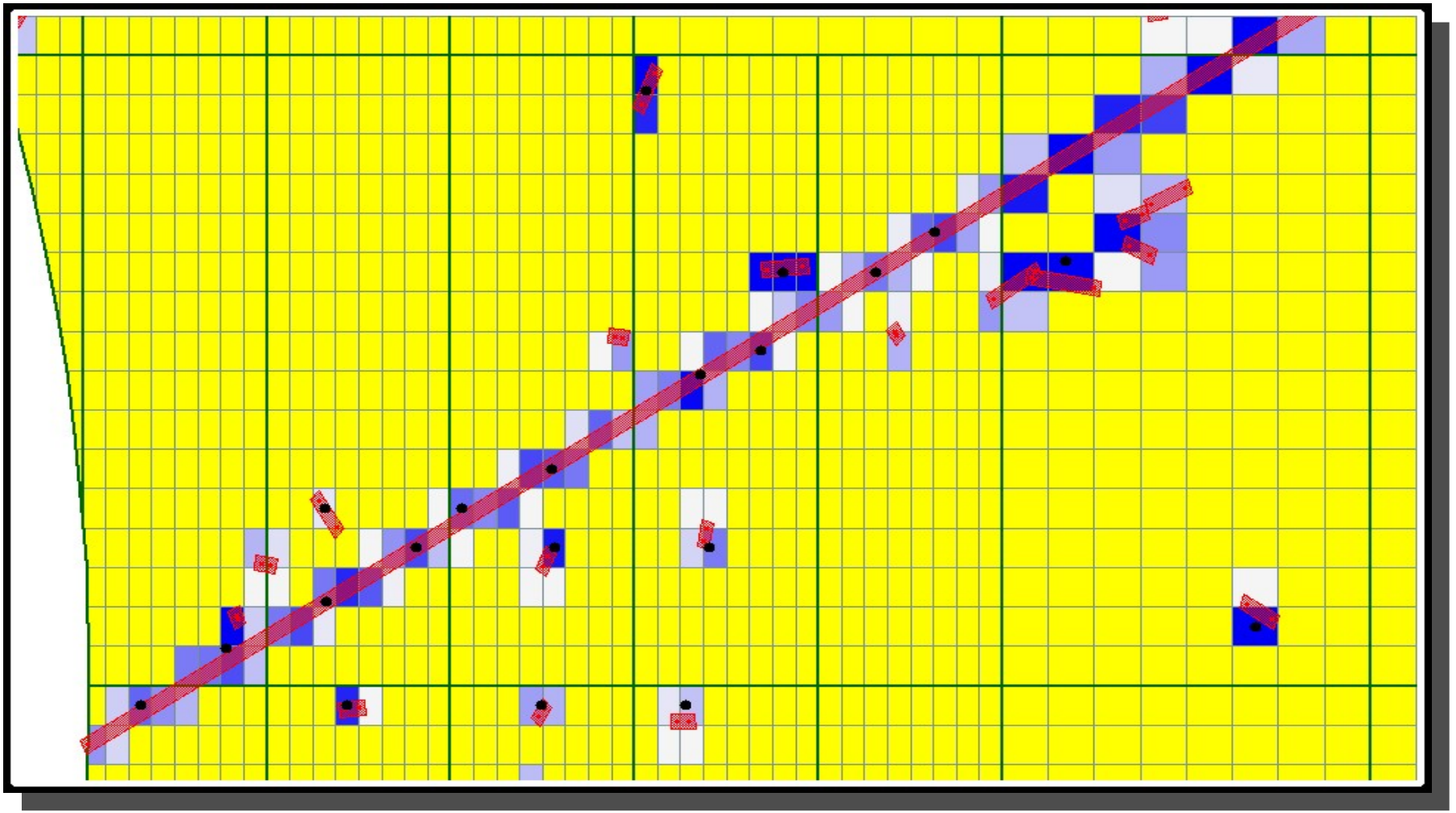
– fired pads

≈ 3000 MC points/event





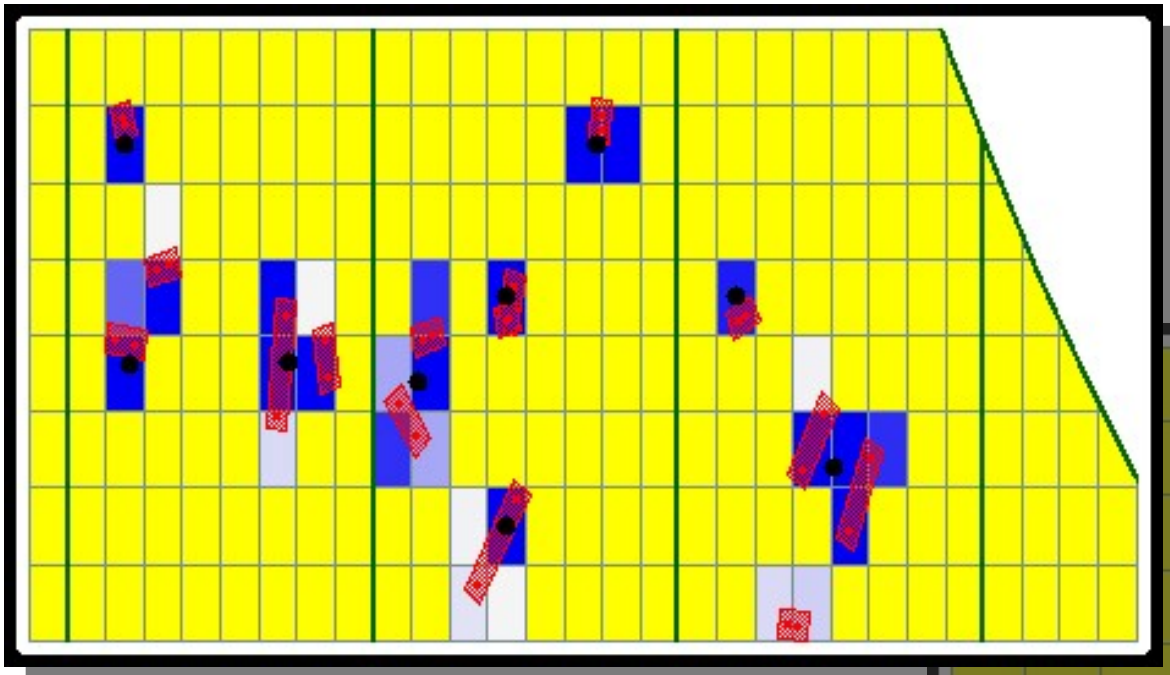
Fake hits

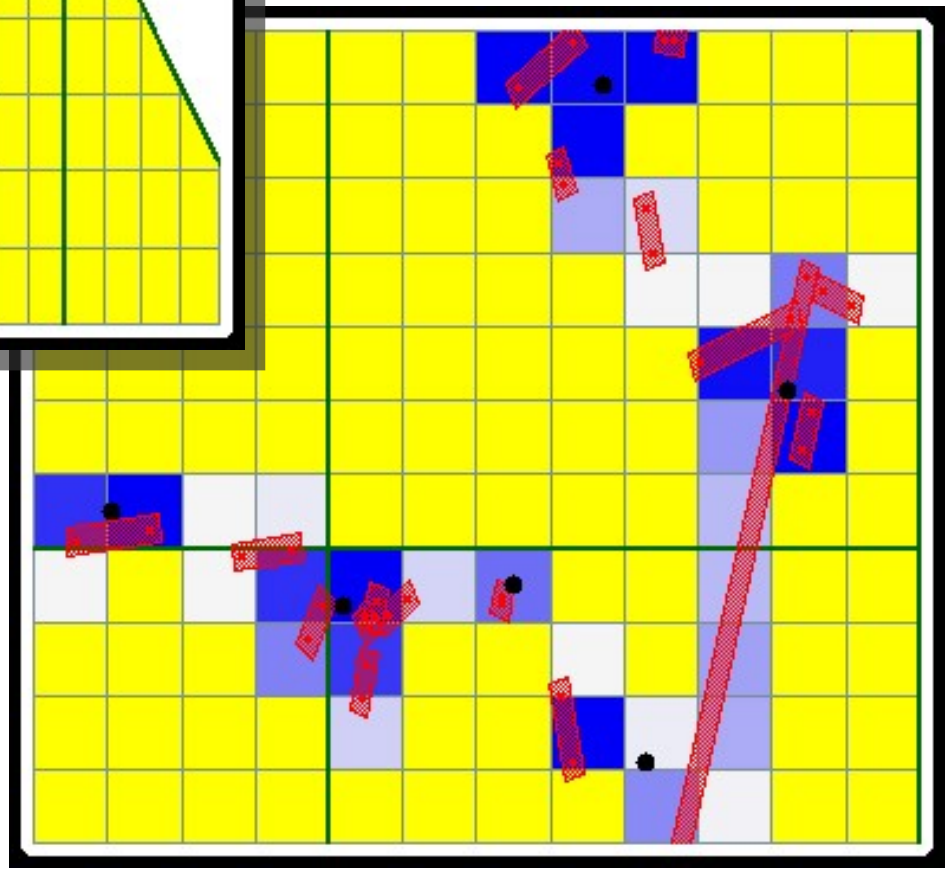


Fake hits – number of reconstructed hits is larger than the number of tracks which formed the cluster

~ 0.3%

Lost hits





Lost hits – number of reconstructed hits is less than the number of tracks which formed the cluster

~ 10.1%

Conclusion: the naive hit finding algorithm should be improved

Conclusion

Main results:

- Automatic segmentation scheme is developed;
- Two digitization procedures are presented;
- Hit reconstruction algorithm is implemented based on the cluster deconvolution algorithm;
- Results of quality analysis of hit reconstruction is presented.

Future plans:

- Development of flexible segmentation scheme;
- Optimization of digitization parameters for selected gas mixtures (implementation of cluster nature of prim. electrons);
- Optimization of the software with respect to tracking requirements;
- Optimization of digitization parameters according to the beam tests;
- Development of advanced cluster deconvolution algorithm;
- Study the influence of number of ADC channels on hit finding results.