DEVELOPMENTS OF THE NEW ALGORITHMS AND DATA ANALYSIS METHODS FOR CHARGE PARTICLES TRACK IDENTIFICATION WITH USING MONOLITHIC ACTIVE PIXEL SENSORS

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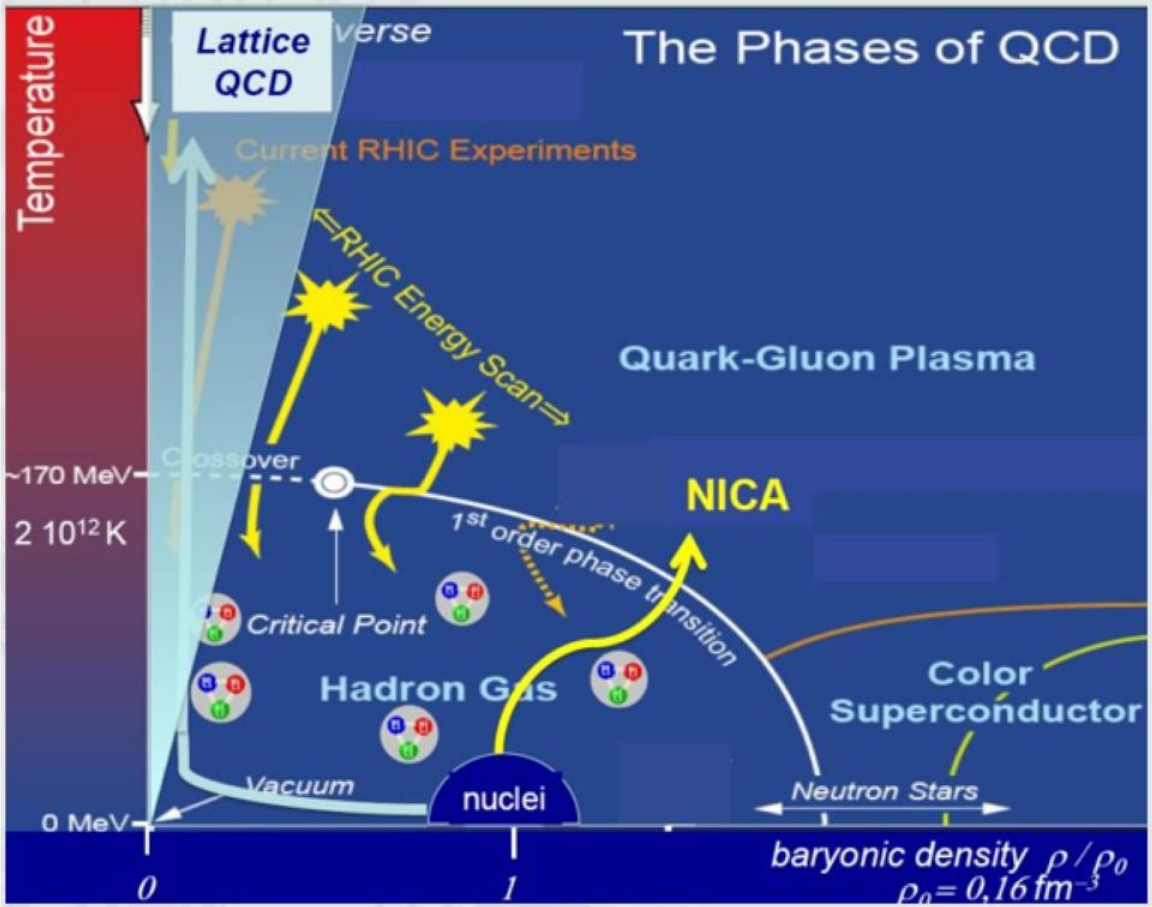
Outline

1. Physics motivation of the NICA Multi-Purpose Detector (MPD) setup
2. The concept of the Inner Tracking System of the MPD experiment
3. Experimental setup for charge particle tracking based on monolithic active pixel sensors (MAPS)
4. Charge particle tracking algorithms and data analysis
5. Cosmic ray tracking and detector alignment
6. Future plans
7. Summary

Physics motivation of the Multi-Purpose Detector (MPD) setup

Perform measurements on heavy flavour (charm) production in heavy-ion collisions to investigate phase transition mechanisms.



High baryonic density

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Particles which contain heavy quarks

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Effective registration of the decayed particles is needed

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Modelling and developing of the vertex detector concept – Inner Tracker

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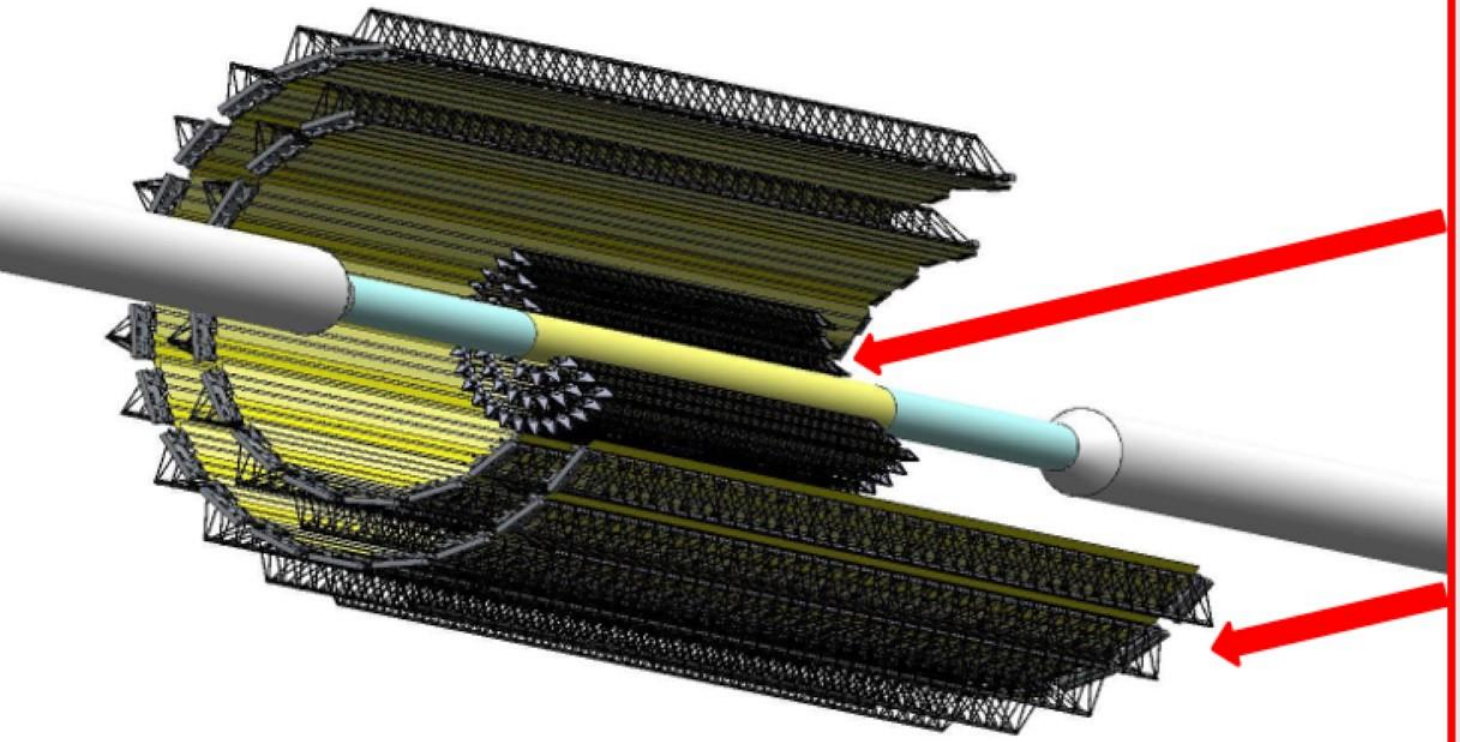
The concept of the Inner Tracking System of the MPD experiment



3 Inner Barrel (IB) layers: 12, 22 and 32 staves.

2 Outer Barrel (OB) layers: 36 and 48 staves

Total: 5 layers of Monolithic Active Pixel Sensors (MAPS)

ALICE technologies:
for IB – ALICE Middle layer staves (900mm)
for OB – ALICE Outer layer staves (1500mm)

V.I. Zherebchevsky, et al., "The concept of the MPD vertex detector for the detection of rare events in Au+Au collisions at the NICA collider", Nuclear Inst. and Methods, A 985 (2020)

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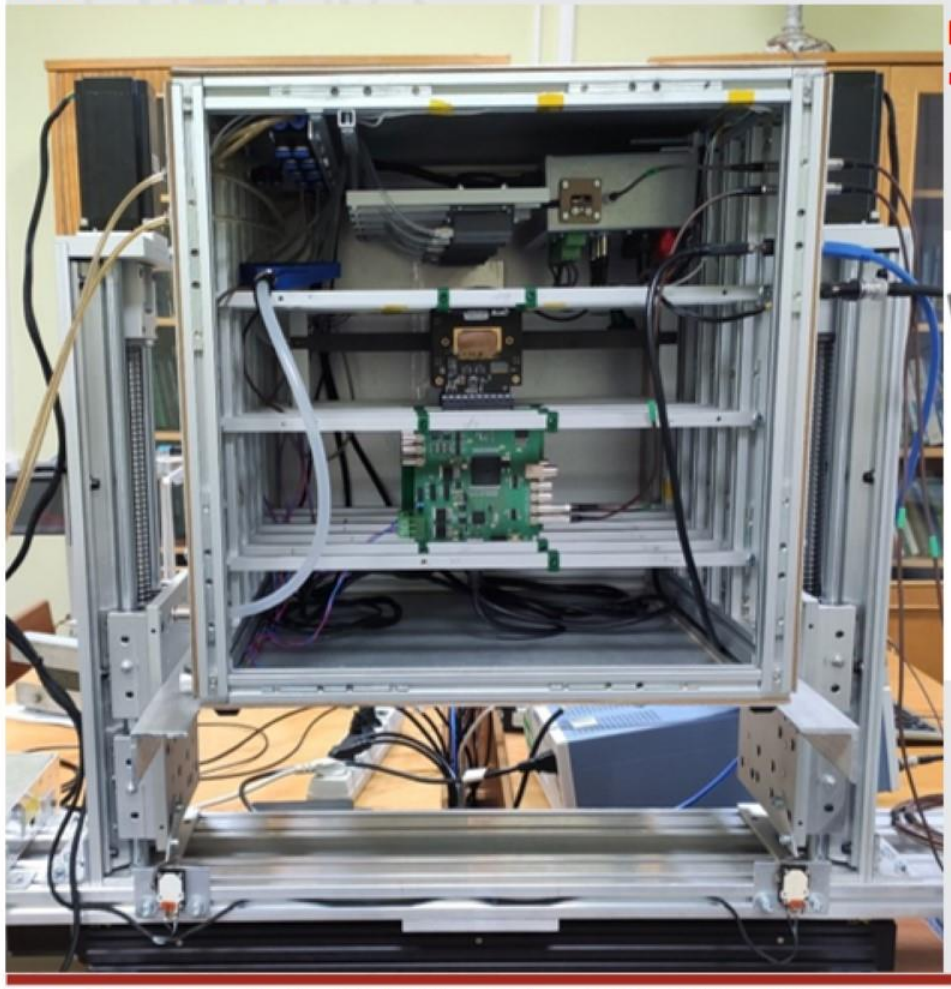
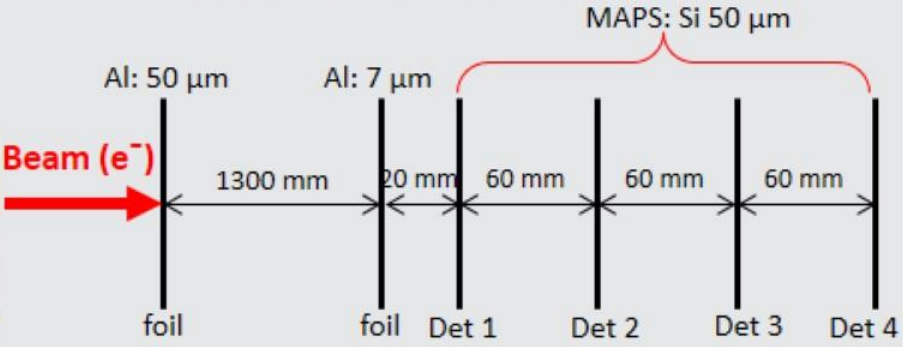
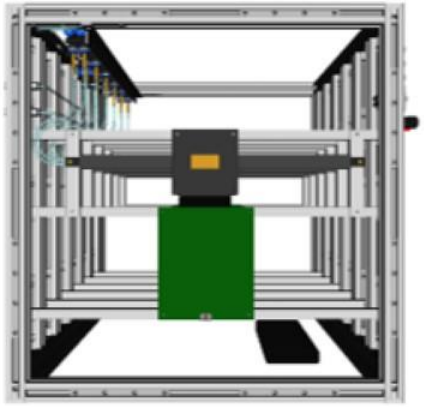
Experimental setup for charge particle tracking based on MAPS

Main goal: MAPS tests: tracking
Electron beam at JINR (accelerator LINAC-200):
Run 1 – 50-60 MeV
Run 2 – 150 MeV



Geometry: telescope mode





Cooling: water, air
Trigger: two scintillators
Precise X-Y movement (3 synchronized moving stages)

More detailed:
Telescope system for the characterization and qualification of the monolithic active pixel sensors, N.A.Prokofiev

Experimental setup for charge particle tracking based on MAPS

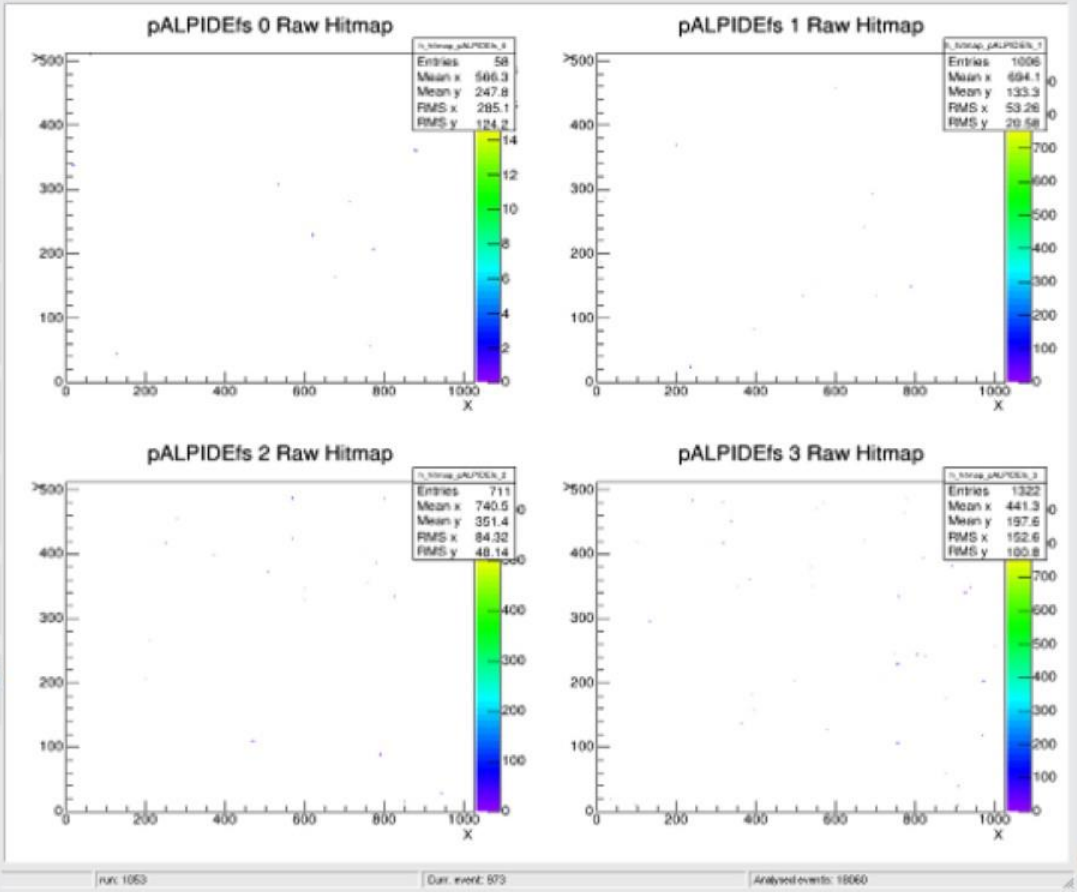
The telescope DAQ system:

- setting operating parameters and setting up the telescope's MAPS detectors

- continuous monitoring of the telescope detectors

- control of the correlation between all detector planes (next slide)

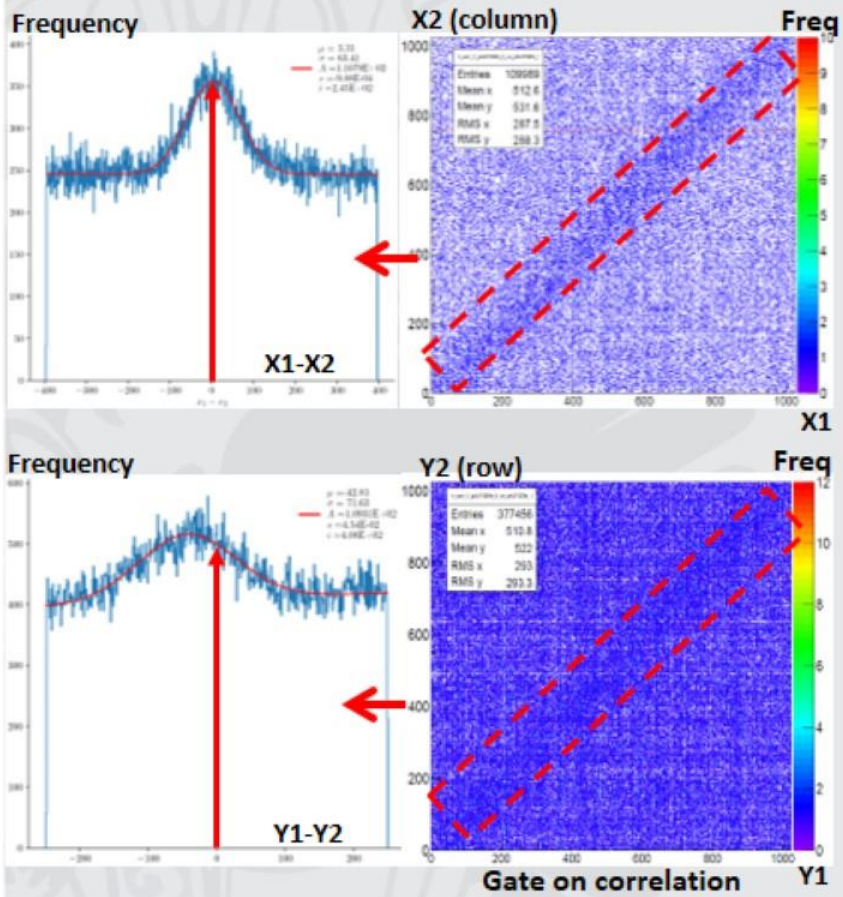
- data recording with information about the operating mode of the sensors and their temperature.



Experimental setup for charge particle tracking based on MAPS

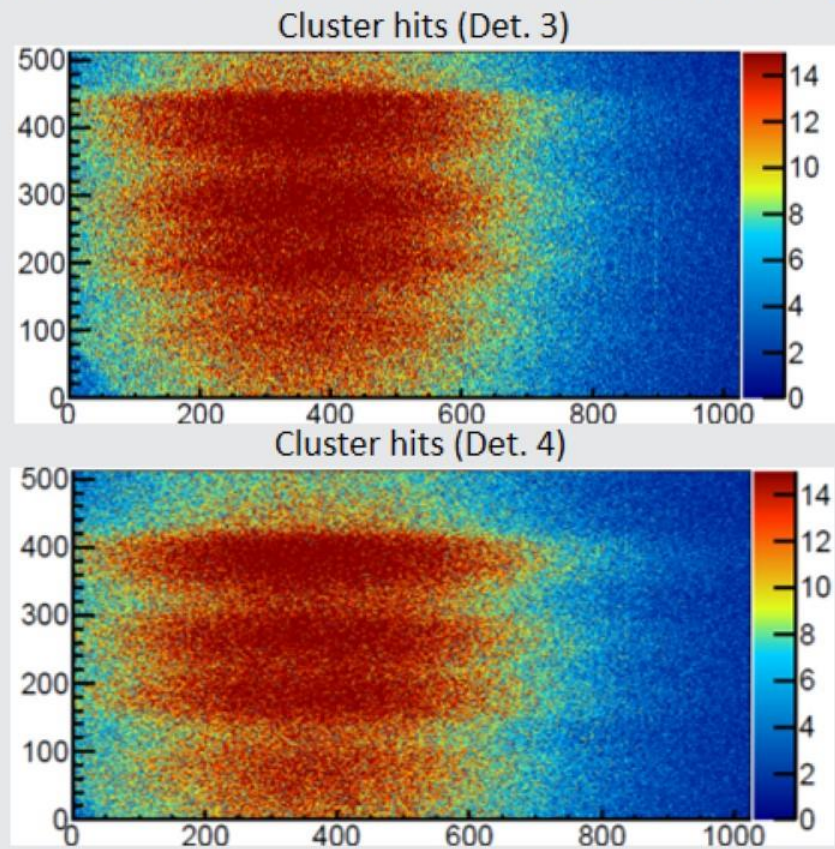
Results of the MAPS testing at LINAC-200:

Correlations of pixel clusters between the detector planes:



Silicon pixel detectors for the ITS of MPD experiment at the NICA collider, V.I. Zherebchevsky et al., NUCLEUS 2020

The results of high beam intensity and low energies:

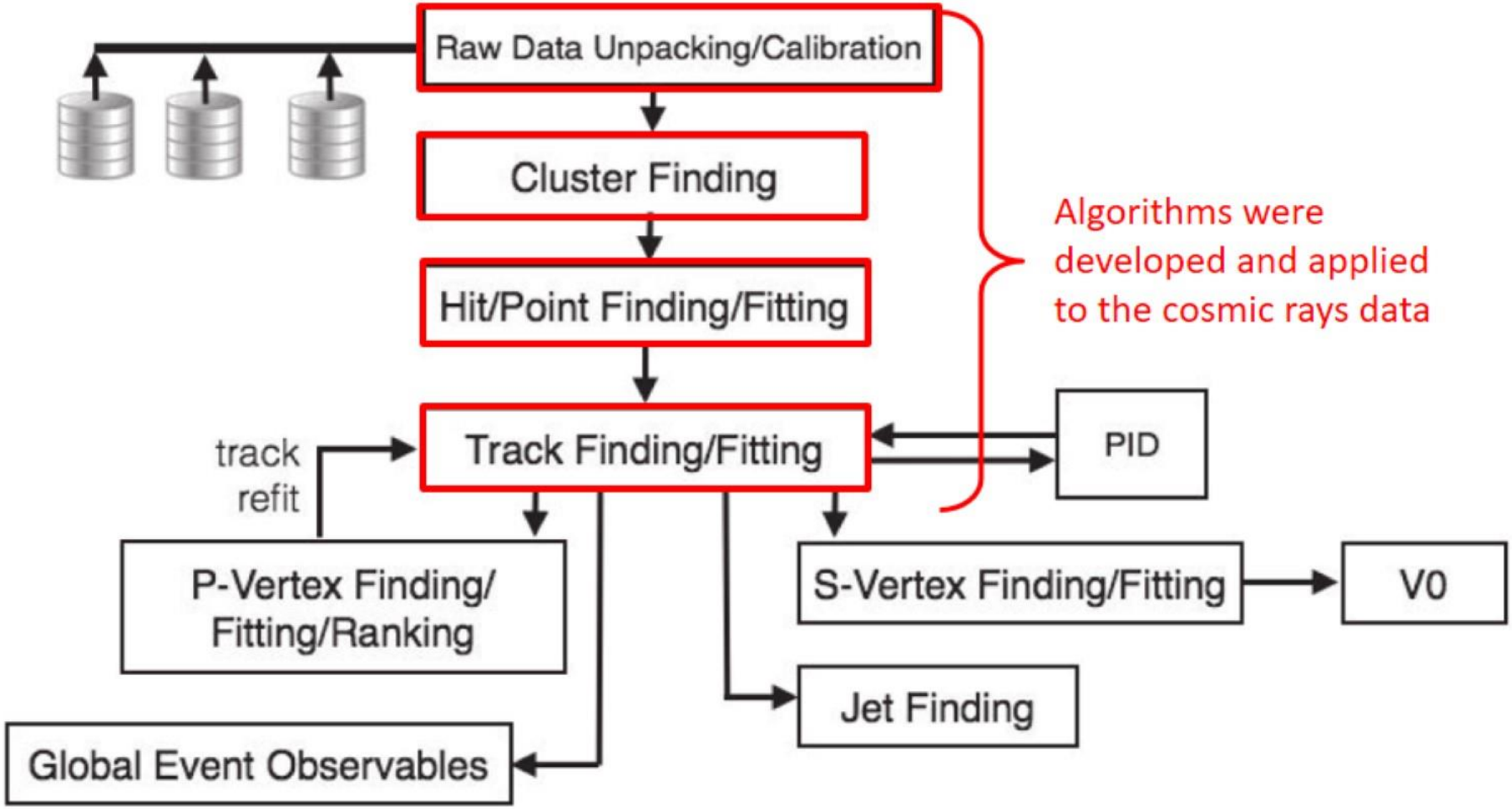


Water cooling was replaced by air cooling to obtain better tracking
(More detailed: **Telescope system for the characterization and qualification of the monolithic active pixel sensors,** N.A.Prokofiev)

The next step is tracking!

Charge particle tracking algorithms and data analysis

First tests of tracking algorithms: cosmic rays



C. Pruneau, Data Analysis Techniques for Physical Scientists, Cambridge: Cambridge University Press, 2017

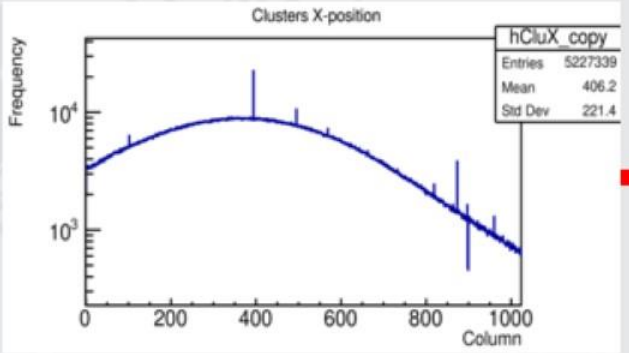
Cosmic ray tracking and detector alignment

The raw data unpacking:

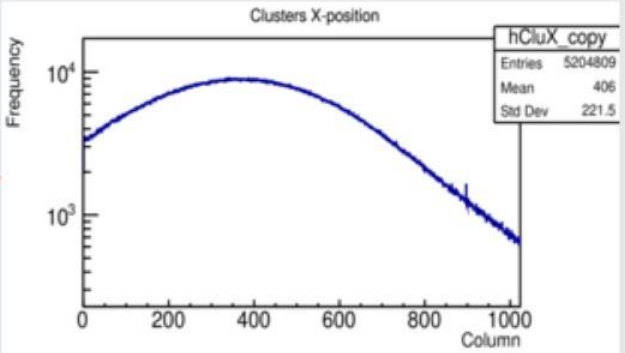
Creating an output file with coordinates of triggered pixels by events and detector planes.

Masking:

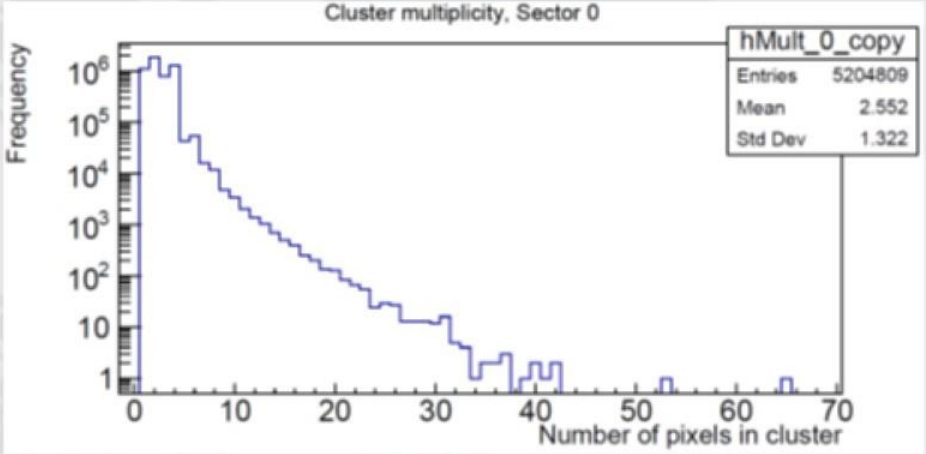
Using statistical analysis to select and mask noisy pixels.



Masking



Cluster analysis:

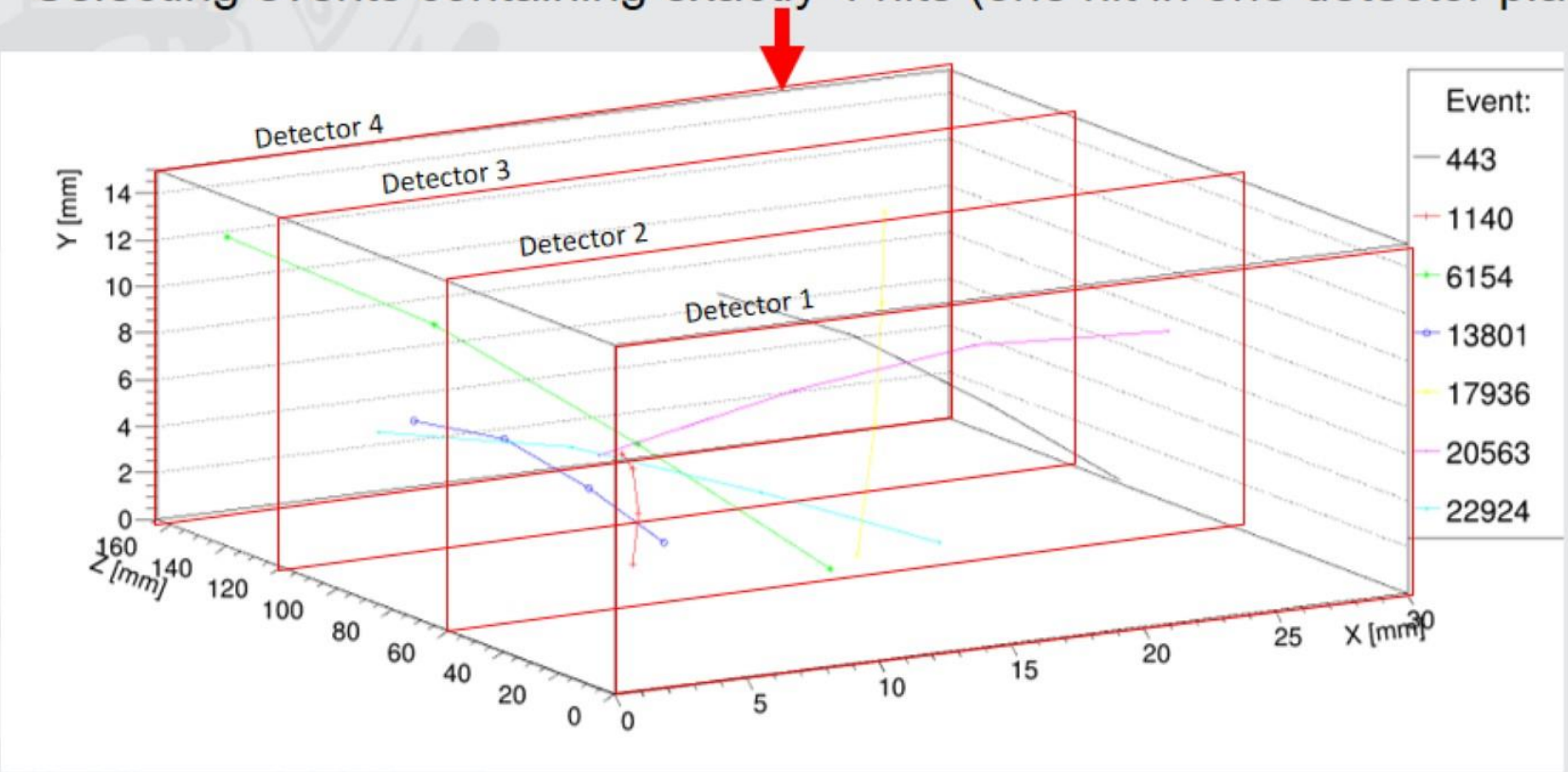


Search for groups of pixels directly adjacent to each other and the corresponding characteristics of clusters: center of mass, multiplicity, uncertainties of coordinates of the center of mass.

Cosmic ray tracking and detector alignment

Cosmic rays: high energy particles → tracks are straight + low intensity → the simplest track finding method can be applied!

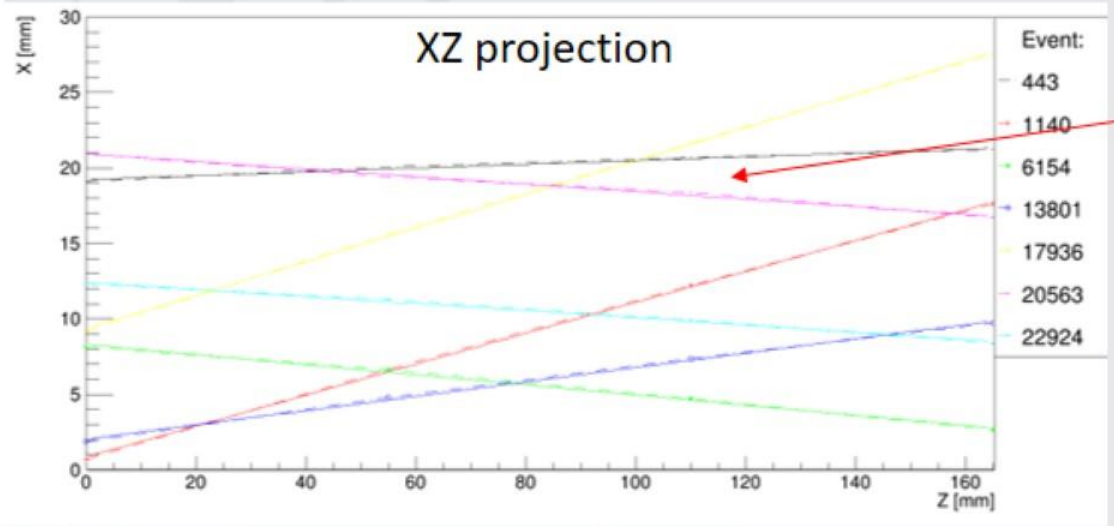
1. Selecting only the events present in all four detector planes
2. Selecting events containing exactly 4 hits (one hit in one detector plane)



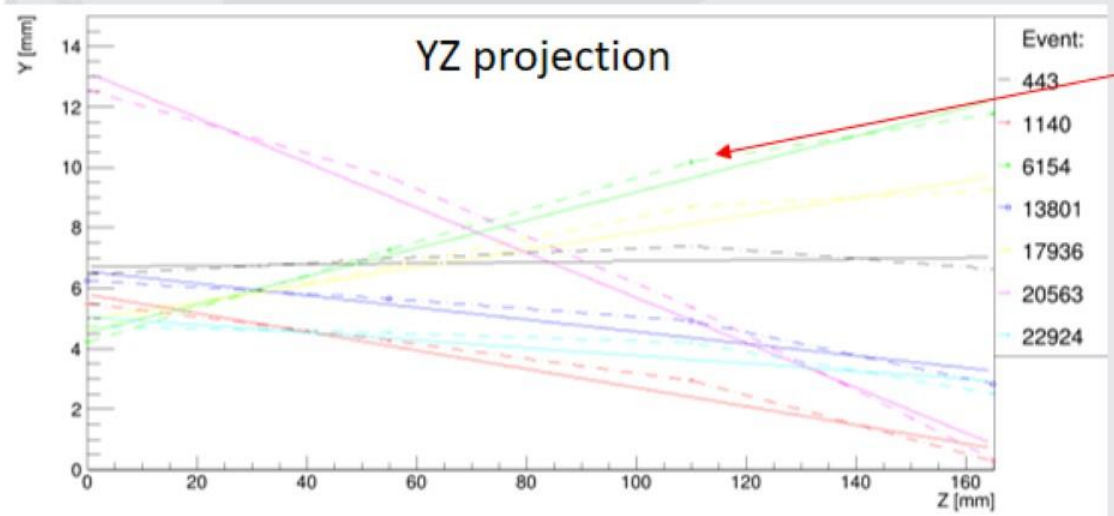
Total count: 196 cosmic tracks were found using this method

Cosmic ray tracking and detector alignment

Linear track approximation:

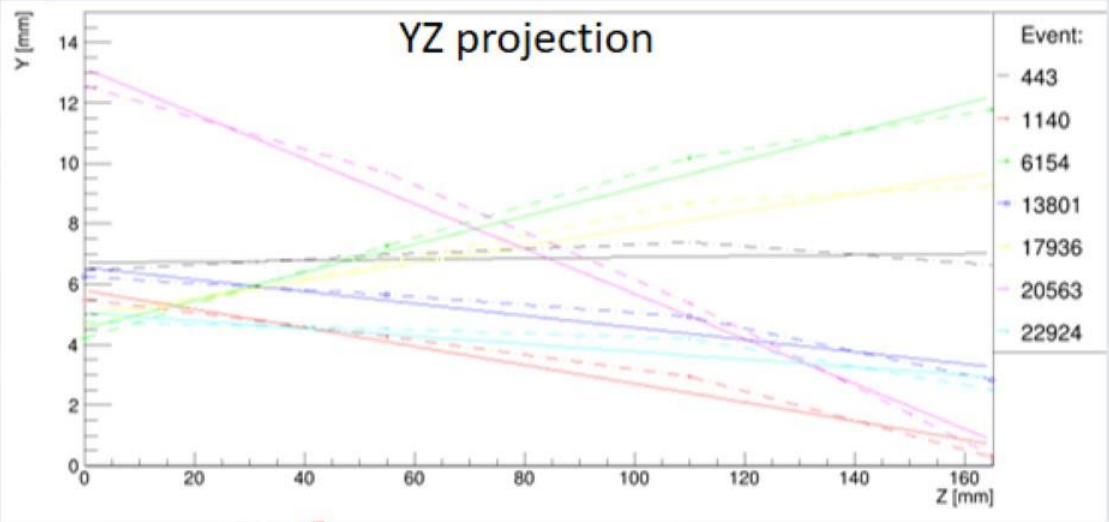


Hits match with their linear approximations
The mean value of the distribution of residuals for all detector planes does not exceed 0.2 mm.

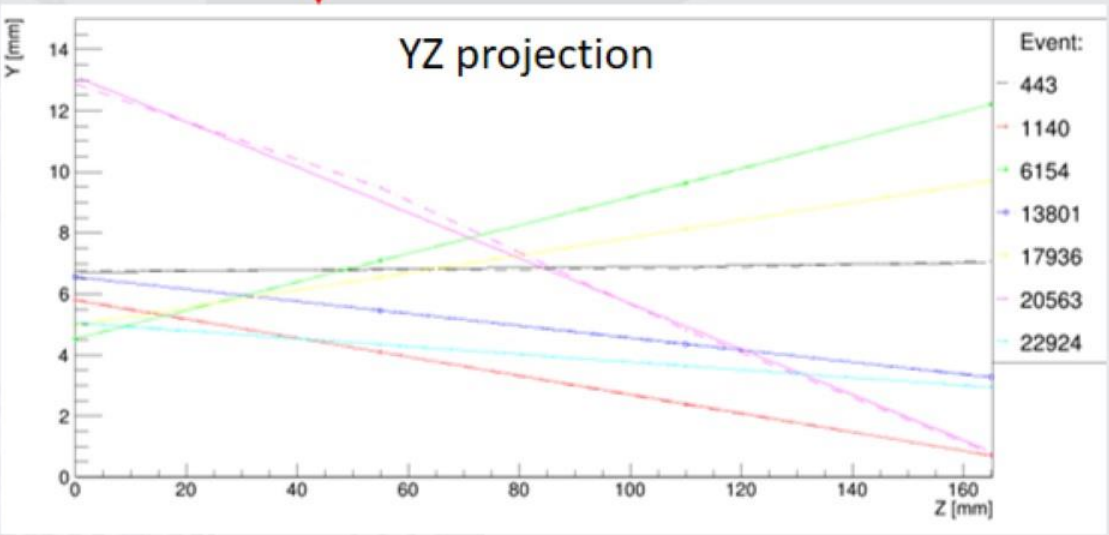


Detector misalignment:
hits deviate from linear approximations
The mean value of the distribution of residuals for all detector planes is about 0.5 mm – the detector positions need to be calibrated!

Cosmic ray tracking and detector alignment



Detector Alignment – 4 iterations



Calibration of the relative position of the detectors:

1. All track hits were linearly approximated.
2. Histograms of the cluster center coordinates residuals from their linear approximations were plotted for each detector plane.
3. The mean value of the residual distribution was subtracted from the cluster coordinates for each plane.
4. The steps 1-2 were repeated, at 3-4 iterations the results converged.

Results:

Mean value R of the residual distribution for XZ and YZ projections is ≤ 5μm.

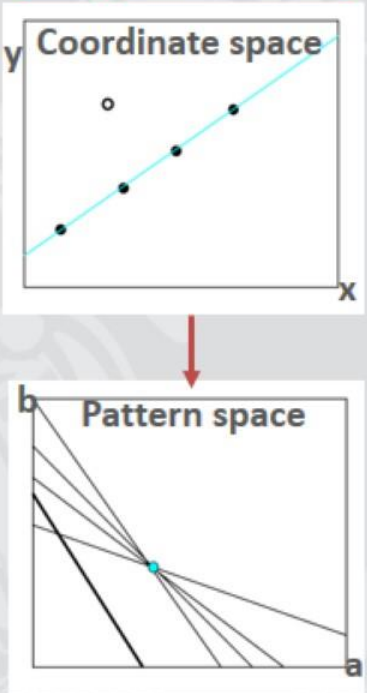
Future Plans

The method applied to the cosmic ray track finding has a number of disadvantages:

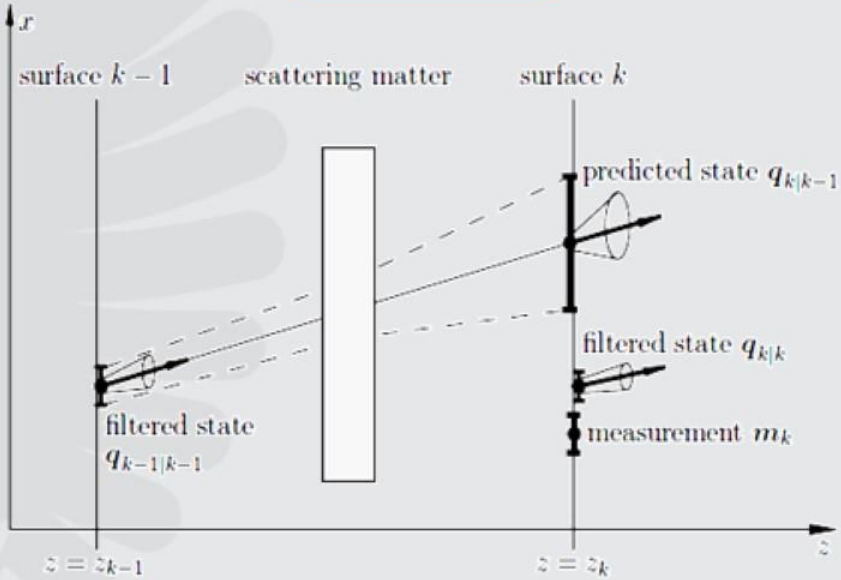
It does not consider events contained in each detector plane more than once (i.e. some tracks are lost) → therefore this method is not suitable for high event intensities.

Since the next goal is to test the MAPS for charged particle tracking at high intensities, it is necessary to develop and apply to the LINAC-200 experiment data some of the advanced methods of track finding:

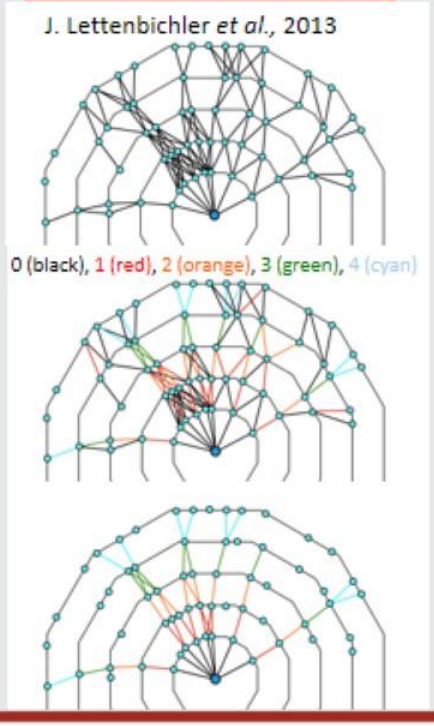
Hough Transform



Kalman Filter



Cellular automaton



Tracking, Jérôme Baudot, ESIPAP 2020

Summary

- The experimental set-up for the characterization of MAPS for the NICA MPD Inner Tracker has been developed, constructed and tested at the LINAC-200 with electron beam in a telescope mode.
- The telescope DAQ system and the data analysis methods were developed (the raw data unpacking, masking and cluster analysis methods).
- A track finding algorithm was applied for cosmic rays tracking.
- The detector alignment method was applied.

Thank you for your attention!

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