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Relativistic Nuclear Physics & Quantum Chromodynamics

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Event reconstruction in the BM@N experiment

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Dubna, Joint Institute for Nuclear Research

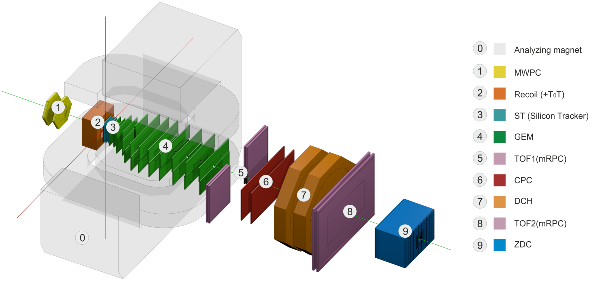
NICA/MPD parallel session, September 19

Outline

- BM@N experiment and its physics motivation
- Geometry description
- Inner tracker and a new version of tracking procedure
- Alignment of inner tracker
- Event visualization
- Conclusion

BM@N experiment

Full setup, layout

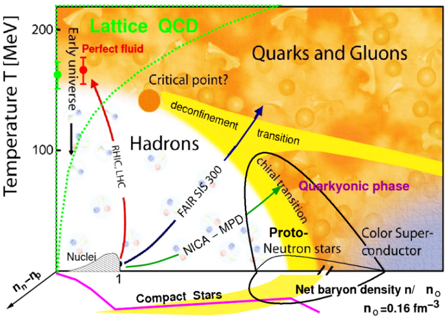


- Central tracker (Silicon tracker + GEM) inside analyzing magnet to reconstruct AA-interactions
- Outer tracker (CPC, DCH) behind magnet to link tracks from central tracker to ToF detectors
- TOF1 & TOF2 system based on mRPC and T0 detectors to identify hadrons and light nuclei
- Detectors to form T0 and beam monitors
- ZDC calorimeter to measure centrality of AA-collisions
- Electromagnetic calorimeter for γ, e^+, e^-

BM@N advantages:

- large aperture analyzing magnet
- sub-detector systems are resistant to high multiplicities of charged particles
- PID: "near to magnet" (TOF1), "far from magnet" (TOF2)

QCD phase diagram



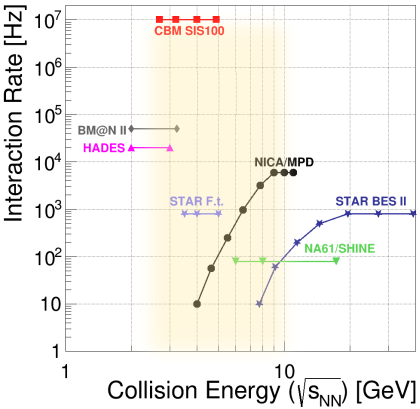
High energy:

- $N_{baryons} \approx N_{antibaryons}$
- Lattice QCD predicts crossover transition between hadronic and partonic matter
- ALICE, ATLAS, CMS, STAR, PHENIX

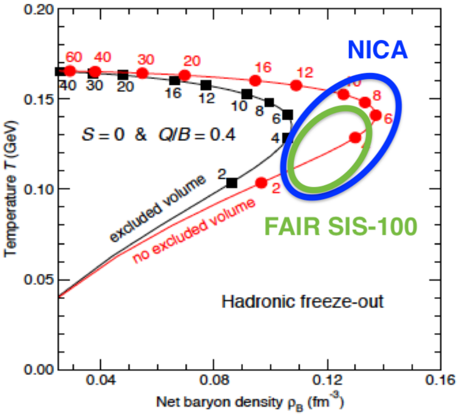
High net-baryon density:

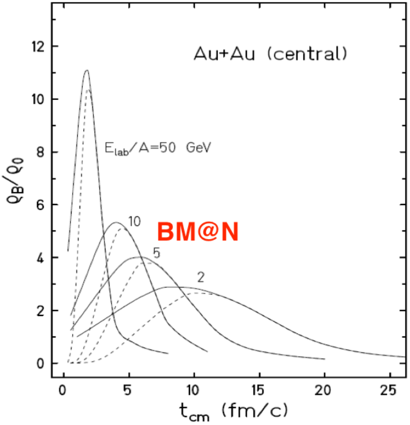
- $N_{baryons} >> N_{antibaryons}$
- Lattice QCD not applicable, models predict structures and exotic phases
- BES @ RHIC, NA61, CBM, NICA/MPD, BM@N

Landscape of experiments exploring QCD phase diagram



Exploring high density baryonic matter with Nuclotron

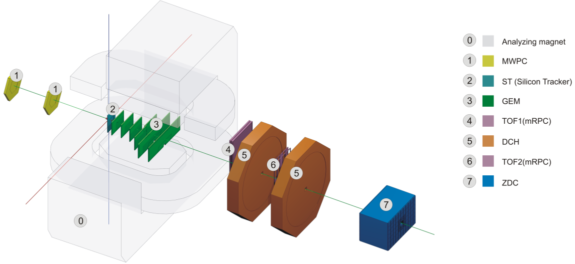


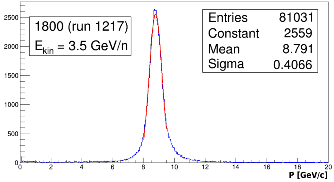


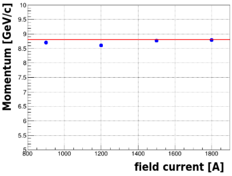
Nuclotron is well suited to study high density (dominantly baryonic) matter since at that energies baryon-dominated system exists comparatively long lifetime

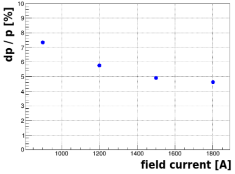
BM@N experiment at previous runs

Experimental setup at deuteron and carbons runs









BM@N and SRC, data collected in Ar/Kr run (RUN7)

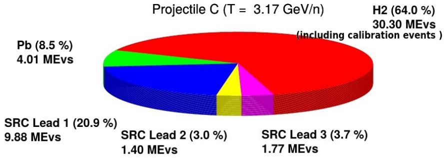
SRC:

- One beam energy available for C-beam
- More than half of the collected statistics can be used for analysis

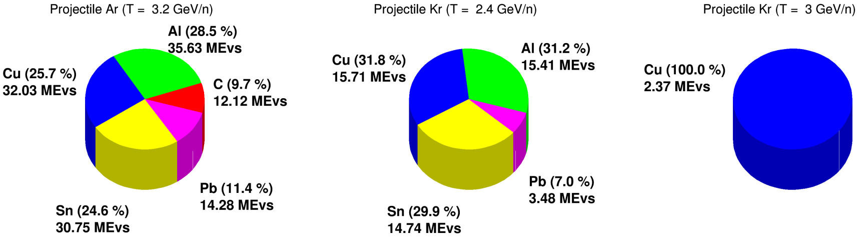
BM@N:

- One beam energy available for Ar-beam and three - for Kr-beam
- Wide set of targets used (C, Al, Cu, Sn, Pb)

SRC

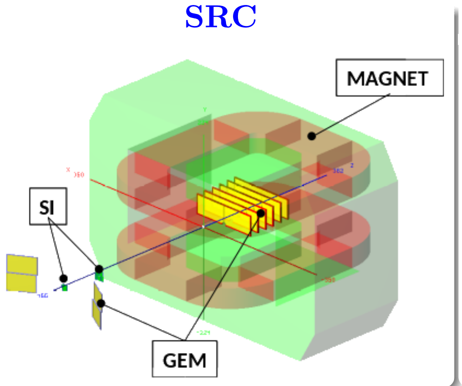


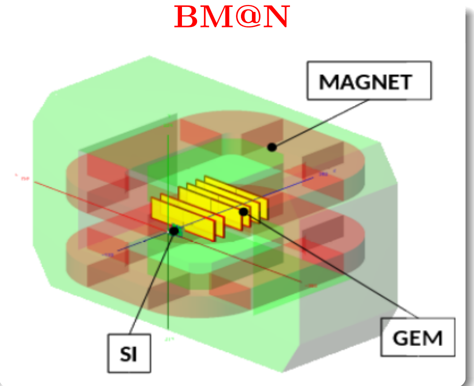
BM@N



Hit reconstruction in strip detectors

BM@N and SRC configurations @ RUN7





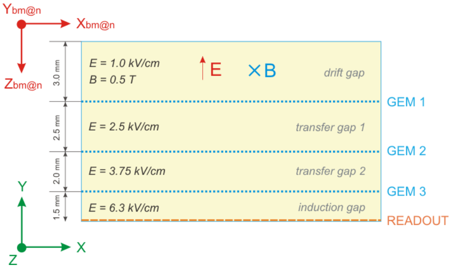
- **Inner tracker system consists of two subdetectors: GEM (Gas Electron Multiplier) and SILICON**
- **GEM detector is a set of gas-filled chambers functioning by a principle of gas electron multiplication.**
- **SILICON is a module semiconductor detector to be used for precise reconstruction of primary vertex in event.**

Towards realistic simulation of GEM tracker

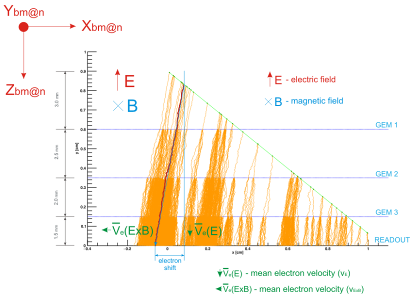
Simulation of GEM response: Garfield++

- Garfield++ is a framework for micro-simulation of physical processes in gas detectors
- A charge particle passing through GEM chamber detecting volume ionizes electrons in gas
- Multiplayer GEM-cascades form avalanches which drift to readout-plane and fire strips

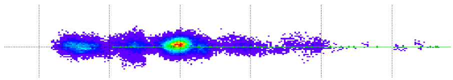
Simulation parameters in Garfield++



Structure of BM@N GEM chamber and simulated electron avalanches

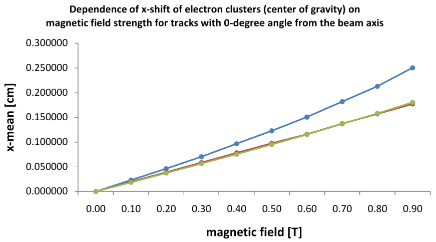


Profile of electron avalanche at the readout-plane (cluster)



Towards realistic simulation of GEM tracker

Aim: to obtain a mean shift of electron clusters (Lorentz shift) as a function of magnetic field and gas mixture ($ArCO_2$, ArC_4H_{10})



- Lorentz shift has a tendency to increase with increasing of magnetic field
- Taking into account Lorentz shift allows us to increase reconstruction efficiency

All possible realistic effects to be included in simulation if necessary:

- Lorentz shift
- Remain misalignment
- Detector inefficiency

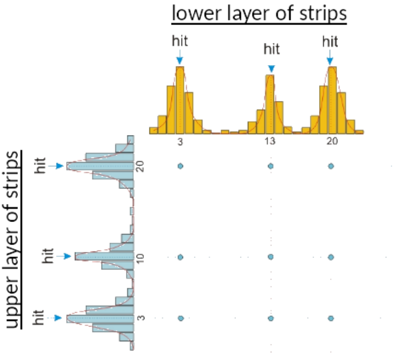
Hit reconstruction in strip detectors

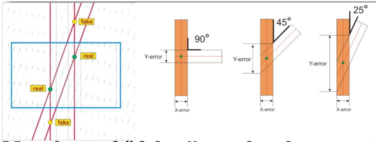
1 Clusterization

- Search for strip clusters is done by "peak-valley-peak" method for each strip layer
- Center of a found strip cluster is calculated by "center-of-gravity" method

2 Reconstruction

- Real coordinates are being found when crossing all strips pertaining to each layer and using the center positions of previously found clusters
- Obtained intersections that belong to a strip layer we are considering are supposed to be “hits”
- "Hits" we have found at the previuos step have a fraction of not only real ones ("fakes")





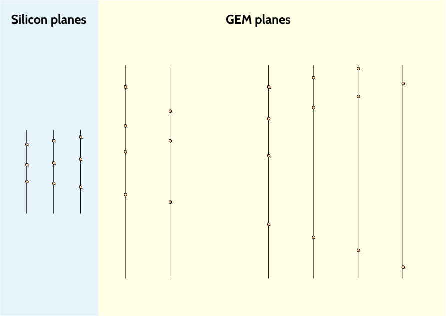
Number of "fakes” can be decreased by decreasing angle between strips in two readout planes (upper and lower layers)

Tracking

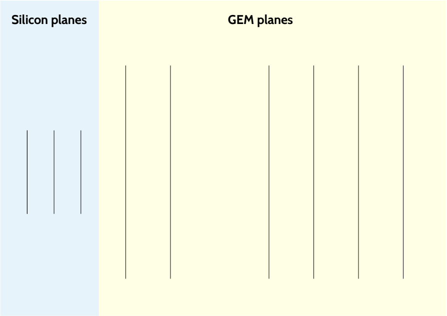
CellAutoTracking, algorithm

- Based on cellular automaton
- Applicable to inner tracker (GEM and silicon hits simultaneously)

Hits in inner tracker



Inner tracker configuration

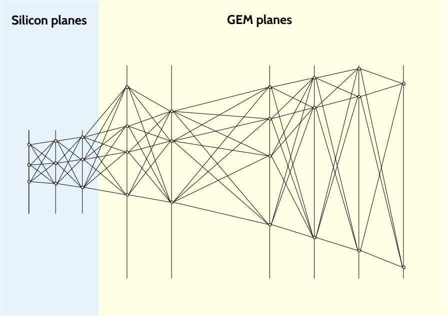


To get more, see:

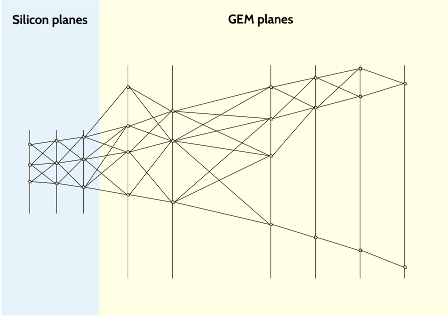
R. Glattauer, R. Frühwirth, J. Lettenbichler and W. Mitaroff arXiv:1202.2761

CellAutoTracking, creation of cells

1. "All-to-all" connection



2. Remove cells with big slopes

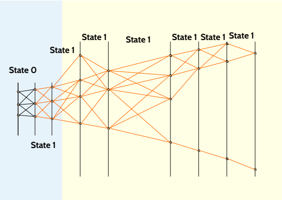


CellAutoTracking, calculation of states

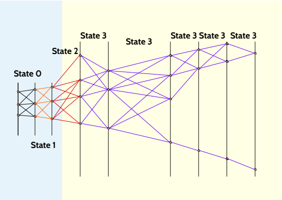
Loop over cells:

- All cells have a zero-state in the beginning
- If a left neighbour has the same state and common hit with current cell $\rightarrow$ state of current cell is increased by 1

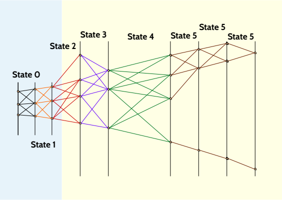
Iteration 1



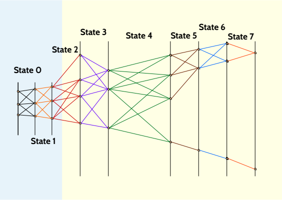
Iteration 3



Iteration 5

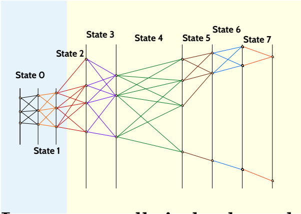


Iteration 7



CellAutoTracking, connection of cells

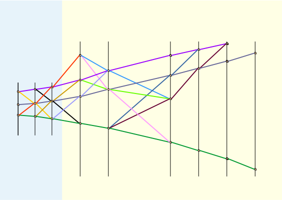
Last iteration



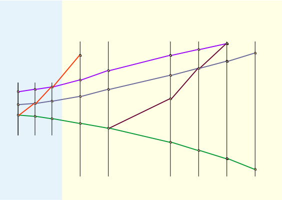
Loop over cells in backward direction:

- Left neighbour has a less state than current one
- Difference between its slope and slope of current cell is minimal for all left neighbours
- Left neighbour is in validation gate

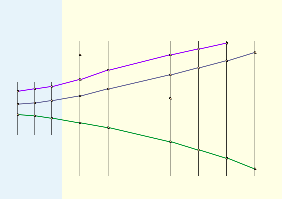
1. Creation of candidates



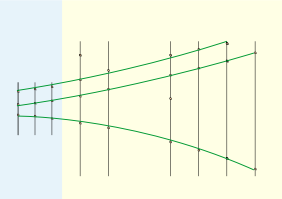
2. Remove candidates with $N_{hits} < 4$



3. Remove short cand. with $N_{shared} > 0$

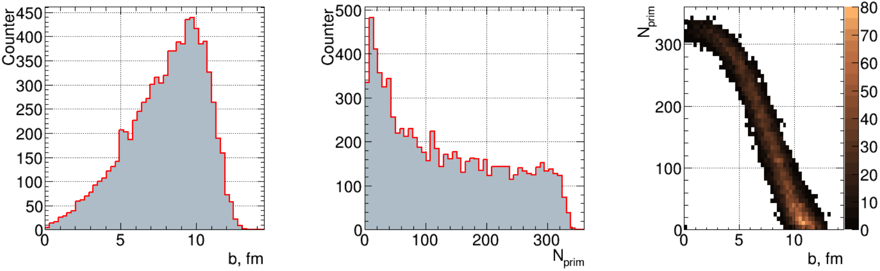


4. Refit candidates by Kalman Filter



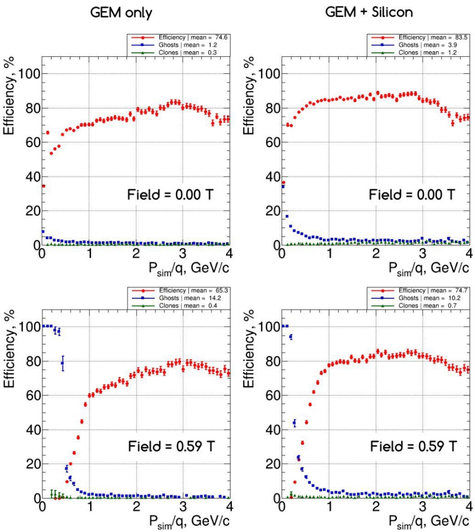
CellAutoTracking, input for QA

- **Inner tracker data, RUN7 geometry used**
- **Generator: LAQGSM, ArPb (T = 3.2 GeV/n), minbias, 10k events**
- **Magnetic field: B = 0 T and B = 0.59 T**
- **Mean multiplicity: 130**
- **Primary vertex: V_p = (0.5, -4.6, -2.3)**



CellAutoTracking, quality assurance (QA)

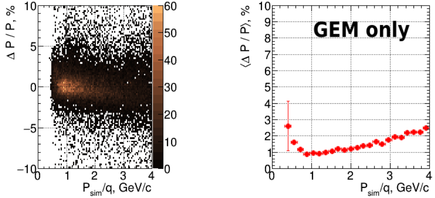
Efficiency

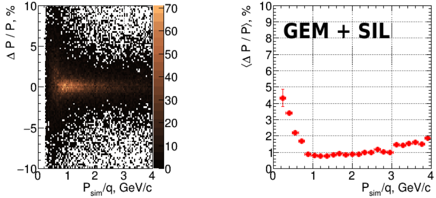


- **Efficiency:** $\frac{N_{well} - N_{split}}{N_{MC}} \cdot 100\%$
- **Percent of ghosts:** $\frac{N_{wrong}}{N_{rec}} \cdot 100\%$
- **Percent of clones:** $\frac{N_{split}}{N_{rec}} \cdot 100\%$
- N_{MC} **is a set of Monte Carlo tracks (MC-tracks) with more than 3 hits in inner tracker**
- N_{rec} **is a set of all reconstructed tracks**
- N_{well} **is a sample of reconstructed tracks where each track has more than 60% of hits that correspond to the same MC-track**
- N_{wrong} **is a sample of reconstructed tracks where each track has less than 60% of hits that correspond to the same MC-track**
- N_{split} **is a number of reconstructed tracks corresponding to the same MC-track**

CellAutoTracking, QA

Momentum resolution



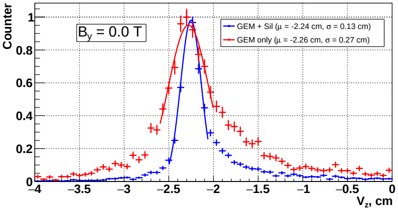


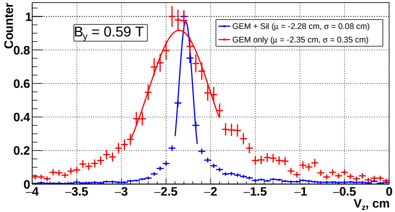
Use of silicon:

- Allows one to obtain un unbiased estimate for all values of momentum in a wide range
- Improves mom. resolution, especially at high momenta

CellAutoTracking, QA

Primary vertex





Primary vertex is reconstructed by method of virtual planes

- Use of silicon leads to a more precise reconstruction of primary vertex V_p
- Effect becomes significant when reconstructing tracks in magnetic field

Vertex efficiency

B_y [T]	SILICON	
	On	Off
0.0	64%	64%
0.59	54 %	49%

Alignment

Alignment

The package based on formalism of Millepede II with all its features and allows one to include / exclude different subdetectors from alignment (GEM, silicon).

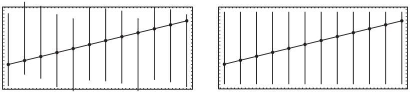
Generalized straight-line model of track:

$$u_i^j = x_0^j \cos\alpha_i + t_x^j \cos\alpha_i + y_0^j \sin\alpha_i + t_y^j z \sin\alpha_i + \Delta u_i + (t_x \cos\alpha_i + t_y \sin\alpha_i)\Delta z$$

Chosen weights to prevent det. shift:

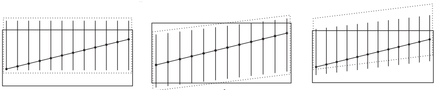
- $w_i^1 = \cos\alpha_i$ - **shifts** (x_0)
- $w_i^2 = z_i \cos\alpha_i$ - **shearings** (t_x)
- $w_i^3 = \cos\alpha_i$ - **shifts** (y_0)
- $w_i^4 = z_i \sin\alpha_i$ - **shearings** (t_y)
- $w_i^5 = 1$ - **overall shift in Z**
- $w_i^6 = z_i$ - **scaling in Z**

Misaligned and aligned detector



a b

Also solutions but not desirable

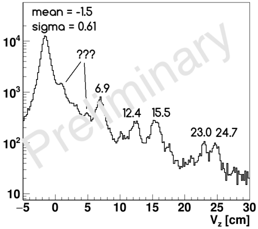


c d e

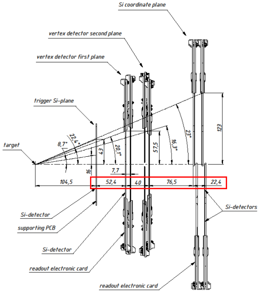
Test of alignment, RUN7

- Ar + C(Cu, Al, Sn, Pb) $\to$ X without magnetic field (more than 10000 kEvents used)
- Set of all possible trigger conditions used

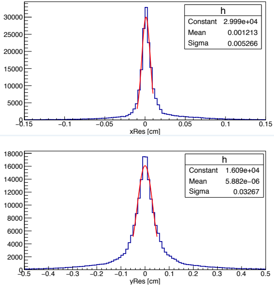
Vertex (only GEM)



Positions of detectors



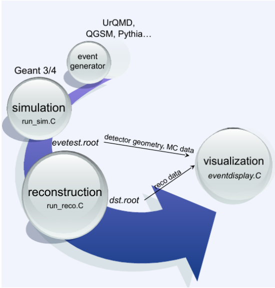
Residuals in GEM

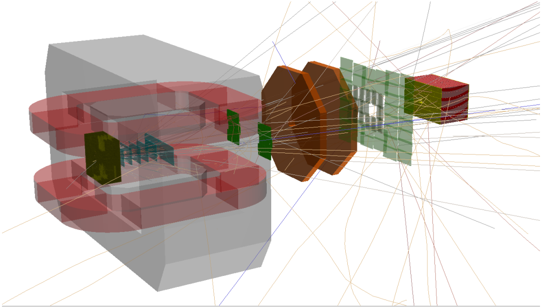


Event visualization

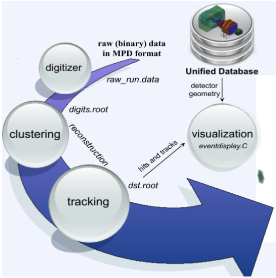
Data processing for offline Event Display

Sim & Reco





Reco



- The Event Display has been developed for graphical representations of the NICA experiments in offline as well as online mode and integrated into the BmnRoot software.
- The visualization system gives an opportunity to visually check the developed algorithms for reconstruction and physical analysis of data.

Conclusion

- **Instruments and algorithms to be used for description of detector geometry, alignment procedure in automatic mode, hit production in strip detectors (GEM, silicon), event visualization already developed and can be used.**
- **Feasibility study with Monte Carlo input performed with new tracking showed good QA-results, thus allowing one to use the tracking when real experimental data processing.**

Thank you for your attention!