Tracking for the BM@N Experiment and New Silicon Stations

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The second BM@N collaboration meeting

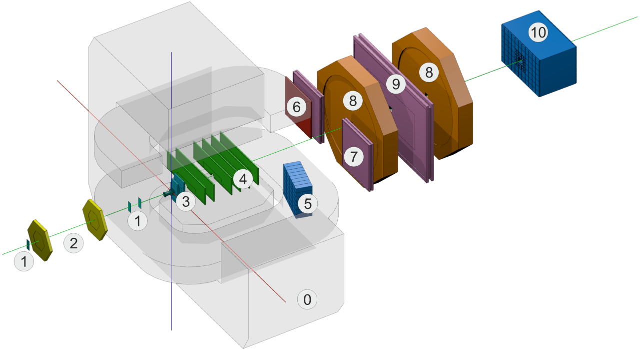
30/10/2018

Outline

- Tracking
  - Description of tracking procedure
  - Tracking QA on Monte Carlo
- Silicon Strip Detector (SSD)
  - SSD geometry
  - QA system for Λ^0
  - Feasibility study for SSD
- Tracking QA on experimental data
  - Alignment
  - Results for Ar-beam
  - Results for Kr-beam

Tracking

BM@N setup of 2018



- 0 Analyzing magnet
- 1 Trigger detectors
- 2 MWPC (Multi-Wire Proportional Chamber)
- 3 ST (Silicon Tracker)
- 4 GEM (Gas Electron Multiplier)
- 5 ECAL (Electromagnetic Calorimeter)
- 6 CSC (Cathode Strip Chamber)
- 7 TOF1 (Time-Of-Flight detector)
- 8 DCH (Drift Chamber)
- 9 TOF2 (Time-Of-Flight detector)
- 10 ZDC (Zero-Degree Calorimeter)

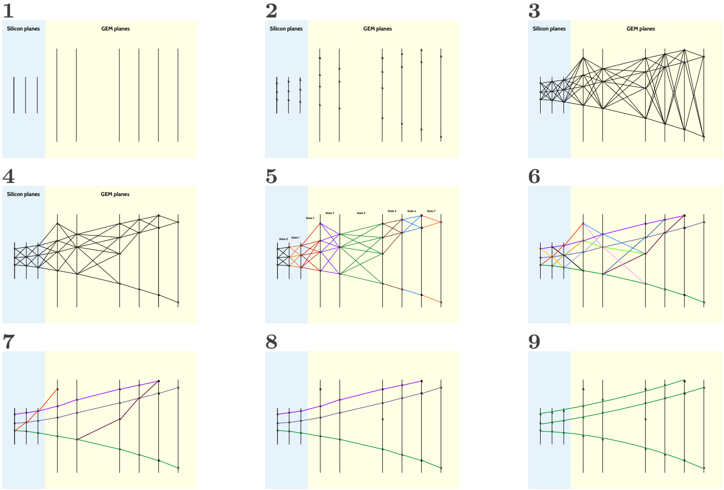
Why new tracking?

- **Previous version of tracking was based on transformation of global coordinates** $\{x, y\} \rightarrow \{\frac{x}{\sqrt{x^2+y^2+z^2}}, \frac{y}{\sqrt{x^2+y^2+z^2}}\}$
- **On the big multiplicities it became slow.**
- **Worked only with GEM hits**

General description of new Tracking

- Based on cellular automaton
  R. Frühwirth et all arXiv:1202.2761
- In this paradigm cell is two connected hits on different stations (straight line segment).
- Works with Silicon hits and with GEM hits as a whole.
- Will work with any types of hits based on the BmnHit class.

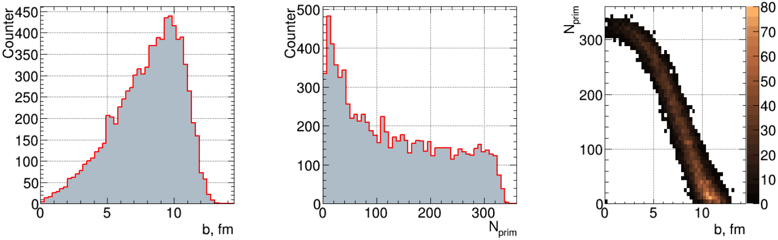
General description of new Tracking



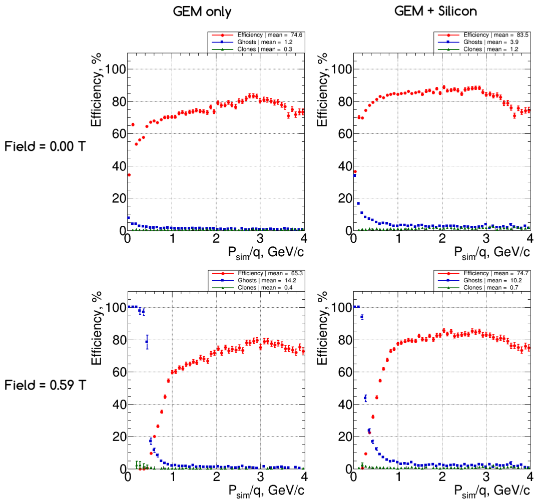
1. Stations scheme
2. Track hits and noise hits
3. All possible cells connected
4. Cells selection by their slope
5. Different states of cells
6. Cells connection w.r.t. slope difference (candidates creation)
7. Candidates selection by number of hits
8. Candidates selection by shared hits (No common hits!)
9. Refitted tracks

Tracking quality. Input parameters

- Generator: QGSM, ArPb (T = 3.2 GeV/n), minbias, 10k events
- Magnetic field: B = 0 T, B = 0.59 T
- Mean multiplicity: 130
- Primary vertex: (0.5, -4.6, -2.3)

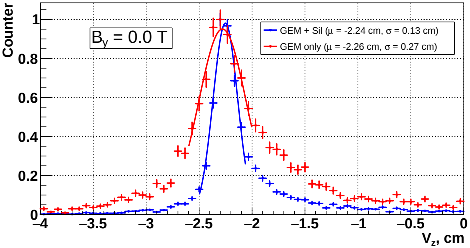


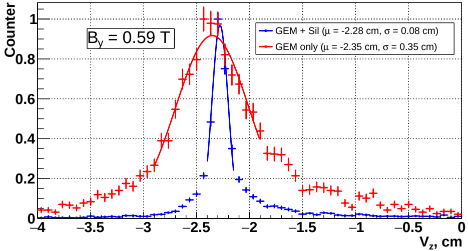
Tracking quality. Efficiency



- **Reconstructable tracks** (N_{MC}): MC-track with more then 3 points
- **Reconstructed tracks** (N_{rec}): All reconstructed tracks
- **Well tracks** (N_{well}): Reconstructed tracks more then 60% of hits corresponded to same MC-track
- **Wrong tracks** (N_{wrong}): Reconstructed tracks less then 60% of hits corresponded to same MC-track
- **Split tracks** (N_{split}): Reconstructed tracks corresponded to same MC-track
- **Efficiency:** $\frac{N_{well} - N_{split}}{N_{MC}} \cdot 100\%$
- **Percent of ghosts:** $\frac{N_{wrong}}{N_{rec}} \cdot 100\%$
- **Percent of clones:** $\frac{N_{split}}{N_{rec}} \cdot 100\%$

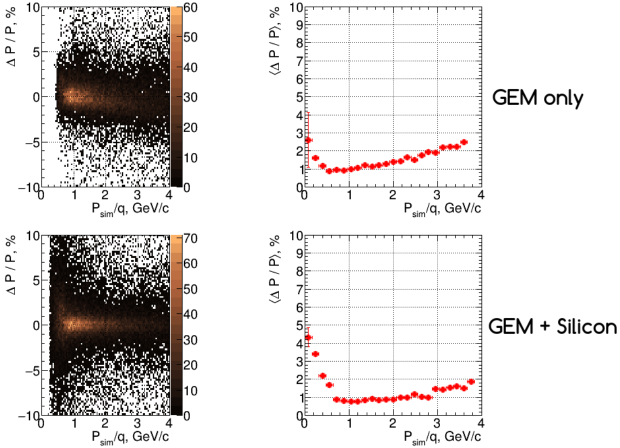
Tracking quality. Vertex





- 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

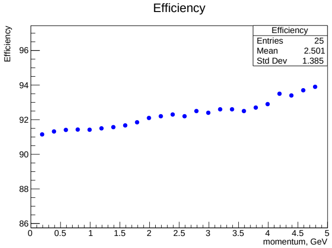
B_y [T]	SILICON	
	On	Off
0.0	64%	64%
0.59	54 %	49%

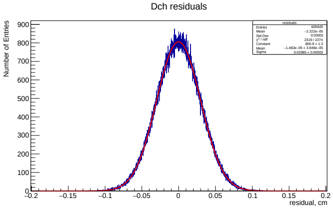


Use of silicon:

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

Tracking for DCH





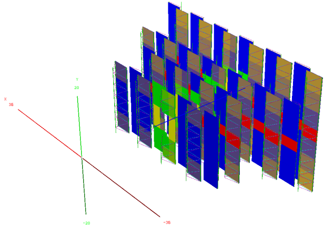
Test of DCH on Monte Carlo:

- The same tracking based on cell automaton (with small modifications).
- Only tracks passed through both chambers are taken into account.
- Mean efficiency is about 93%.

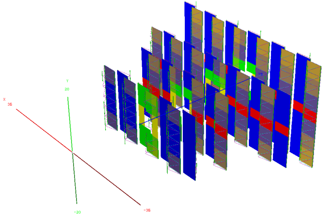
Silicon Strip Detector (SSD)

SSD tested geometries

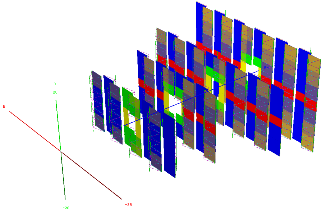
SSD v18a



SSD v18b



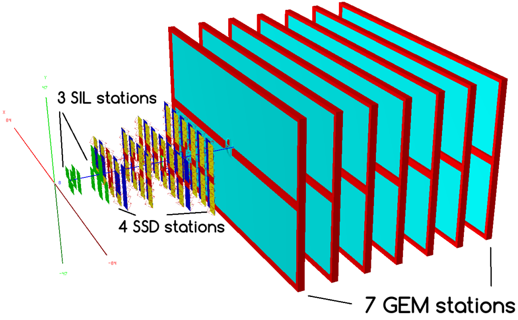
SSD v18c



z-positions of stations.
v18a: {30, 40, 50, 60} cm
v18b: {30, 45, 60, 75} cm
v18c: {30, 50, 70, 90} cm

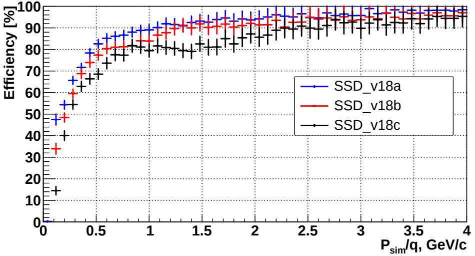
by Evgeny Lavrik.

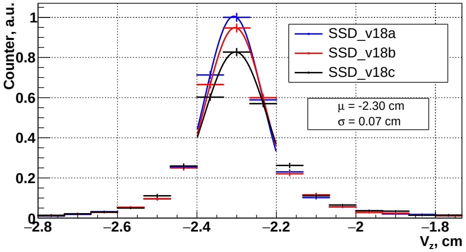
Geometry to test SSD



- Possibility to work with SIL, SSD and GEM hits in different combinations added into tracking.
- Only Hit Producer is implemented for SSD right now (no realistic effects, no fakes, etc.).
- In the nearest future we plan to port codes with realistic effects implementation from CbmRoot to BmnRoot.

Tracking efficiency and vertex resolution



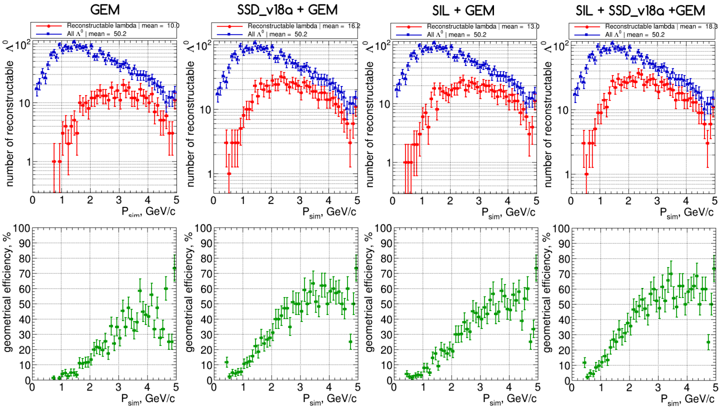


- The highest efficiency can be obtained with the shortest baseline (v18a).
- Vertex resolution is similar for all configurations.

Quality assurance system for Λ^0 reconstruction

- based on tracking QA system
- works in 3 modes:
  - MC_ONLY. It gives information about geometrical efficiency, Λ^0 acceptance, ...
  - MC + RECO. It gives MC_ONLY information + efficiency of Λ^0 reconstruction ...
  - EXP + RECO. It gives only set of distributions with reconstructed Λ^0 ...
- saves results as html-report
- easy to extend for other decays

Quality assurance system for Λ^0 reconstruction



- **BLUE**: All Λ^0 hyperons
- **RED**: Reconstructable Λ^0 - each decay product has at least 4 hits
- **GREEN**: Eff = Rec. Λ^0 / All Λ^0

Tracking QA on experimental data

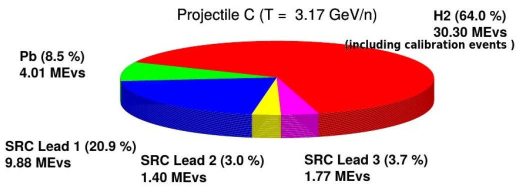
BM@N and SRC, data collected in Ar/Kr run (RUN-7)

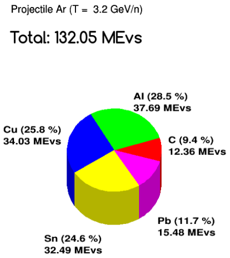
SRC:

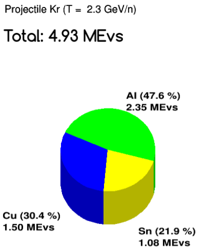
- One beam energy available for C-beam
- More than half of the collected statistics can be used for analysis

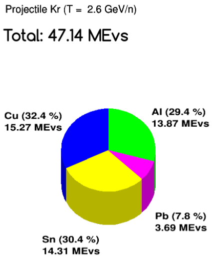
BM@N:

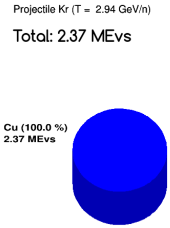
- One beam energy available for Ar-beam and three - for Kr-beam
- Set of targets used C, Al, Cu, Sn, Pb











Alignment

ALCOPACK (ALignment COrrection PACKage)

- is developed as a part of BmnRoot framework
  `https://git.jinr.ru/nica/bmnroot/tree/dev`
- based on formalism of Millepede II
  `http://www.desy.de/~blobel`
- allows to include/exclude different planes of subdetectors

Generalized straight-line model of track:

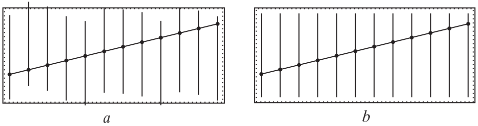
$$u_i^j = x_0^j \cos\alpha_i + t_x^j \cos\alpha_i + y_0^j \sin\alpha_i + t_y^j z \sin\alpha_i + \Delta u_i + (t_x \cos\alpha_i + t_y \sin\alpha_i)\Delta z$$

Alignment

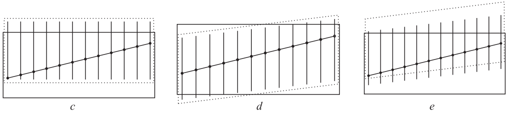
Chosen weights to prevent detector shift:

- $w_i^1 = \cos\alpha_i$ - 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

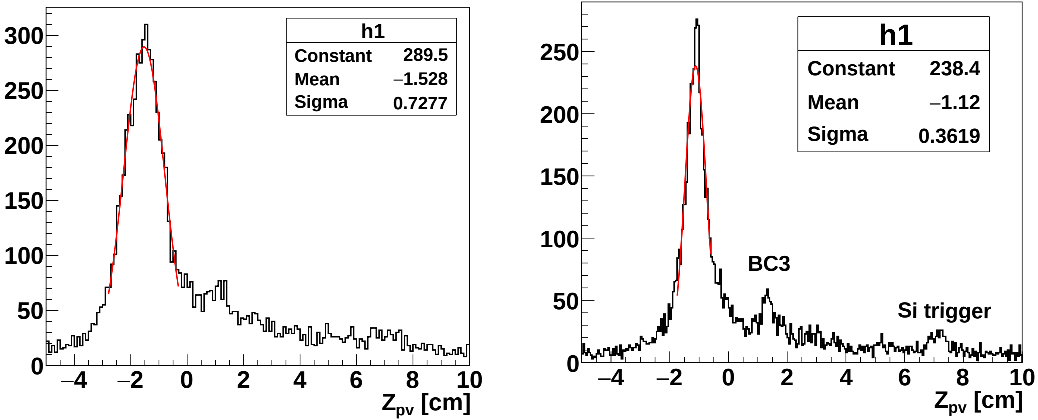
Misaligned and aligned detector

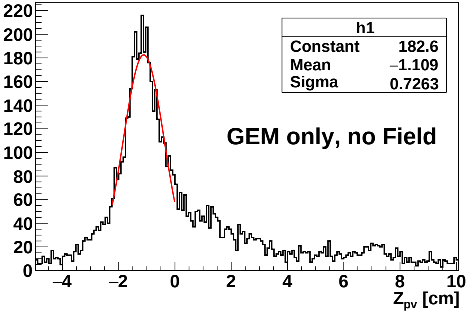


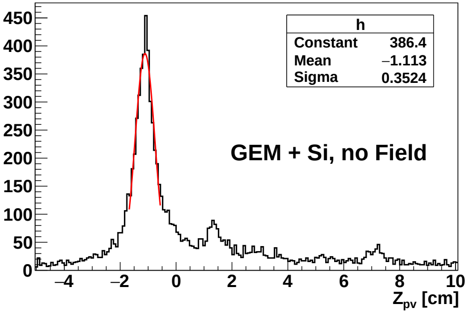
Also solutions but not desirable



Vertex. Before and after alignment



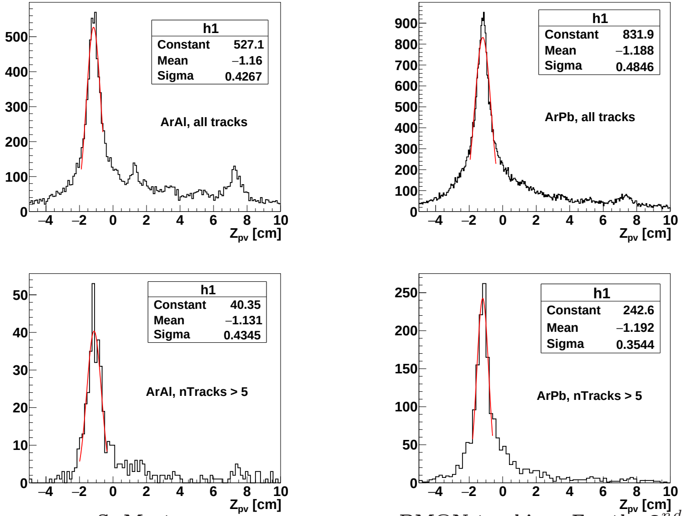




Parameters:

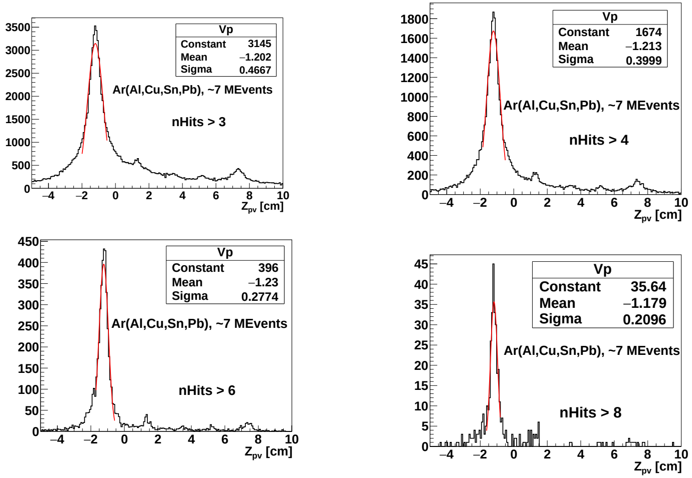
- Set: 200 kEvents
- Beam: Ar
- Target: Al

Vertex. vs. N tracks



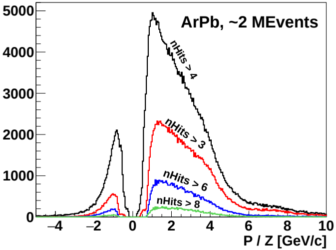
- nTracks is number of tracks participating in PV reconstruction
- Less multiplicity gives higher secondary vertises
- nTracks cut reduces background significantly
- nTracks cut doesn't affect on vertex width for Al

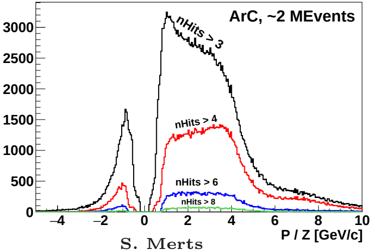
Vertex. vs. number of hits on track

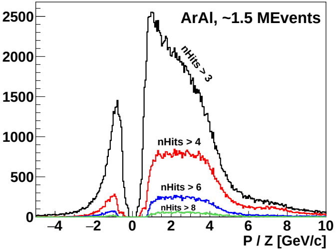


- Skip events if at least one track has nHits $<$ cut
- nHits cut reduces background significantly
- Default value is nHits $>$ 3

Momentum distribution vs. nHits cut

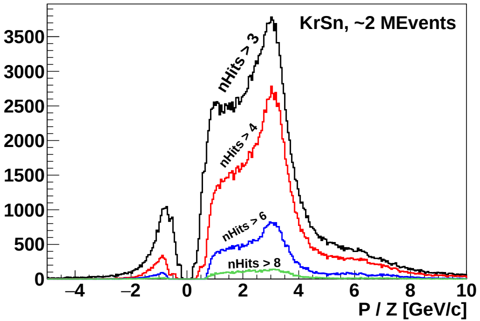


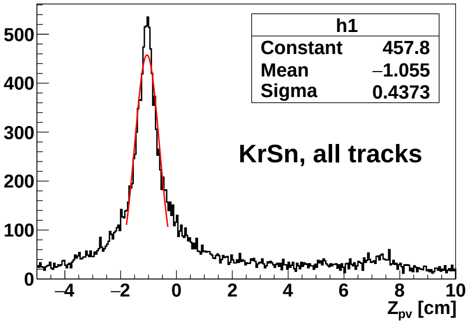




- More multiplicity gives less peak of spectators.

First look at data with Krypton beam





Summary

- BmnRoot framework is being developed by our group. It containes different algorithms used for data decoding, hit producing (with realistic effects), a package for alignment procedure (ALCOPACK), instruments to operate with databases, data visualisation etc.
- The proposed tracking successfully passed QA procedure with MC input and was used for methodological studies with existing experimental data.
- Three possible configurations of SSD were cosidered. First preliminary results were obtained. The work is in progress.
- Useful tool to study two-particle decays with different data species (MC, MC + RECO, REAL DATA) was developed.

Thank you!