Event simulation and reconstruction in the BM@N experiment

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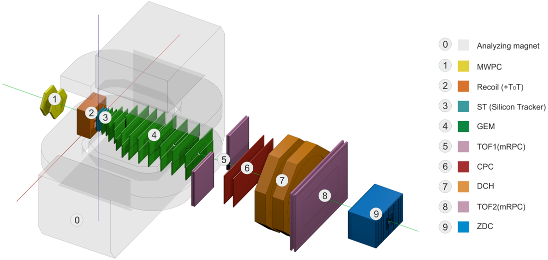
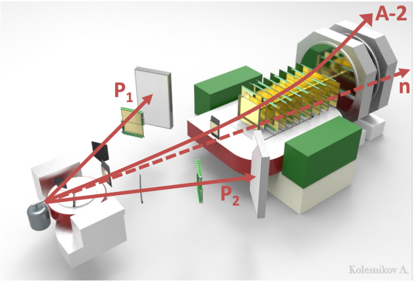
on behalf of BERDS Group

23/10/2019

BM@N setup

SRC setup





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)

Simulation

Main features of simulation

1. Event generators: simple for tests, realistic for feasibility study, specific
2. Transport code to propagate particle through detector volume
3. Type of geometry: realistic or simplified
4. Monte Carlo information production (presence of classes to produce MC points)
5. Realistic effects inside detectors:
   - Avalanches/Smearing/Clustering production
   - Lorentz shifts for detectors in magnetic field
   - Detector misalignment
   - Channel inefficiency
   - Rest non-calibration (time for TDC, pedestals for ADC, ...)
6. Digitizer to convert MC data into detector format

Monte Cralo simulation in BmnRoot

Event Generators:

- Simple generators: BOX, ION, PART, ...
- Physics generators: UrQMD, DCM-QGSM, ...
- Specific generators: SRC (under implementation)

Transport codes:

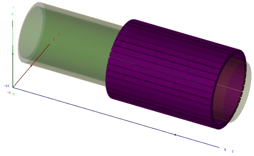
- GEANT 3
- GEANT 4
- FLUKA

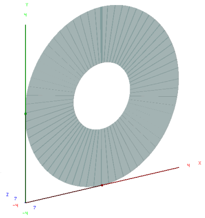
For all detector we have realistic geometry and classes to MC points and tracks production implemented

Upstream detectors

Barrel and Forward detectors

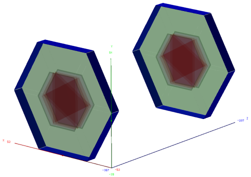
- No realistic effects
- No digitizer

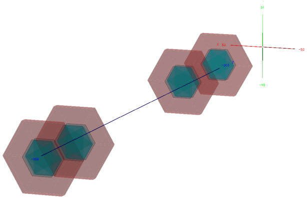




Multi-Wires Proportional Chambers

- No realistic effects
- Digitizer is prepared





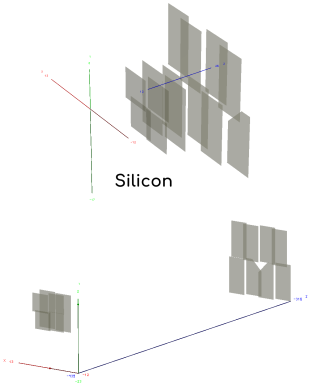
Inner tracking detectors

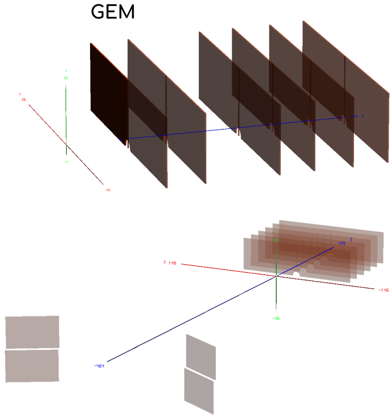
SIlicon planes

- Simplified simulation based on Gaussian smearing (no misalignment, no inefficiency)
- Digitizer is implemented

GEM planes

- Realistic simulation based on Garfield+ (no misalignment, no inefficiency)
- Digitizer is implemented

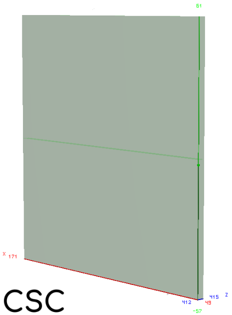




Downstream coordinate detectors

Cathod Strip Chamber

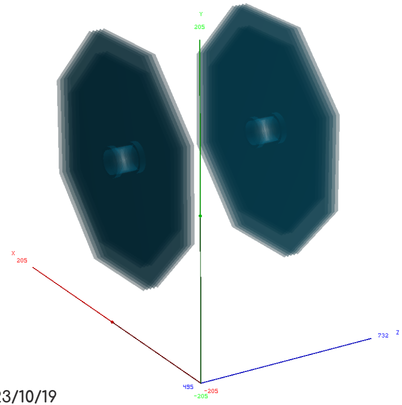
- Simplified simulation based on Gaussian smearing (no misalignment, no inefficiency)
- Digitizer is implemented



CSC

Drift CHambers

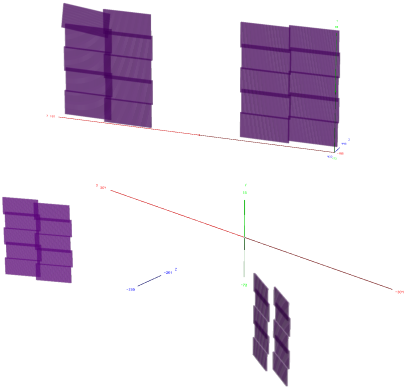
- Simplified simulation based on Gaussian smearing with distance dependence (no misalignment, no inefficiency)
- Digitizer is implemented



Time-of-Flight detectors

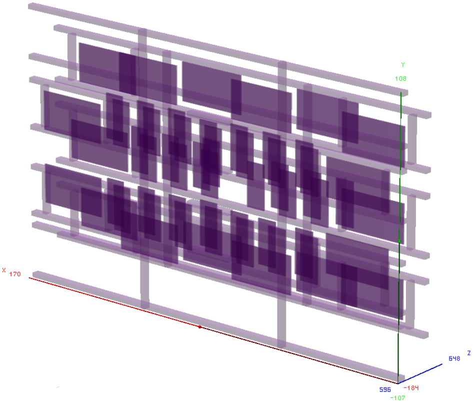
TOF-400

- Simulation effects: strips inefficiency, multichannel activation (no misalignment)
- No digitizer



TOF-700

- Simulation effects: strips inefficiency, multichannel activation (no misalignment)
- No digitizer



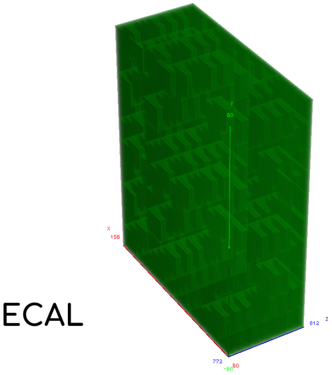
Calorimeters

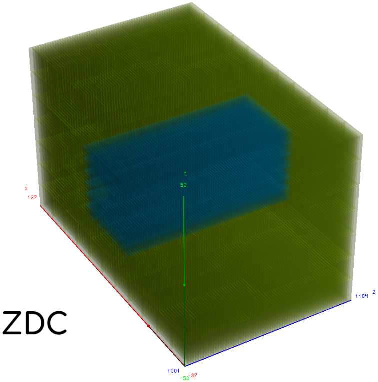
ECAL

- Simple hit producer (energy collecting in towers) (no misalignment, no inefficiency)
- No digitizer

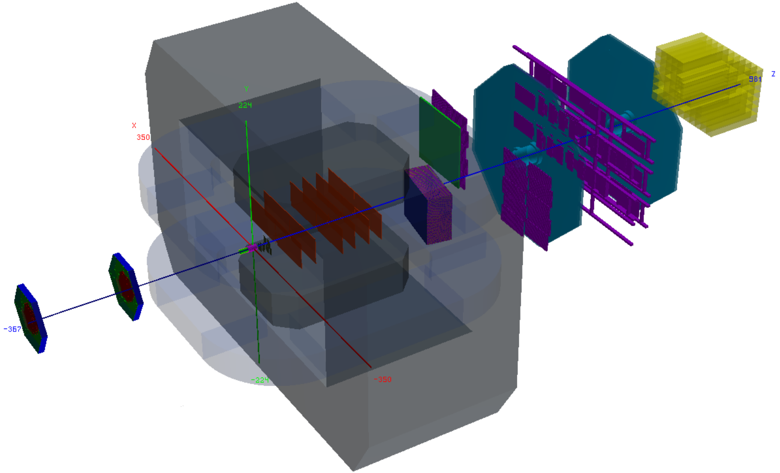
ZDC

- Simple hit producer (energy collecting in towers) (no misalignment, no inefficiency)
- No digitizer

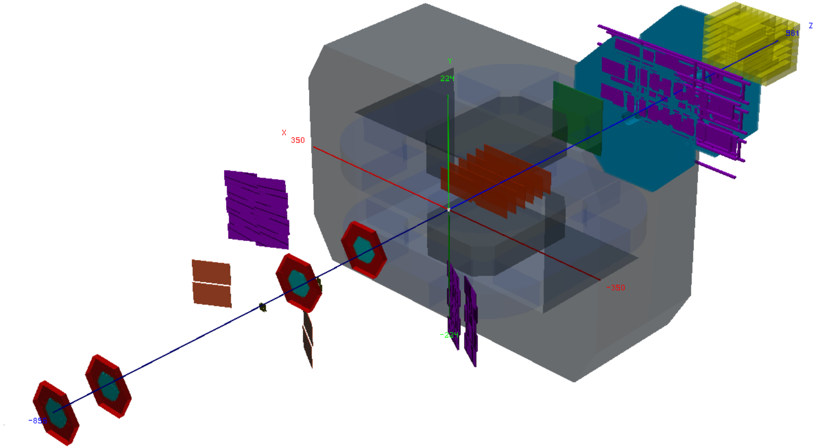




Current BM@N RUN-7 geometry



Current SRC geometry

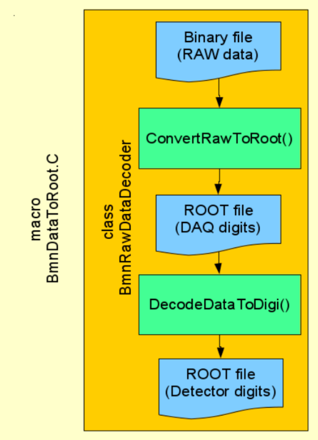


Reconstruction

Main features of event reconstruction

1. Raw data converter (for experimental data)
2. Cluster/Hit finders inside detectors
3. Local track finder
4. Global matching
5. Vertex finder
6. Particle identification

Data Processing. Converter and Decoder



First step (Data Converter):

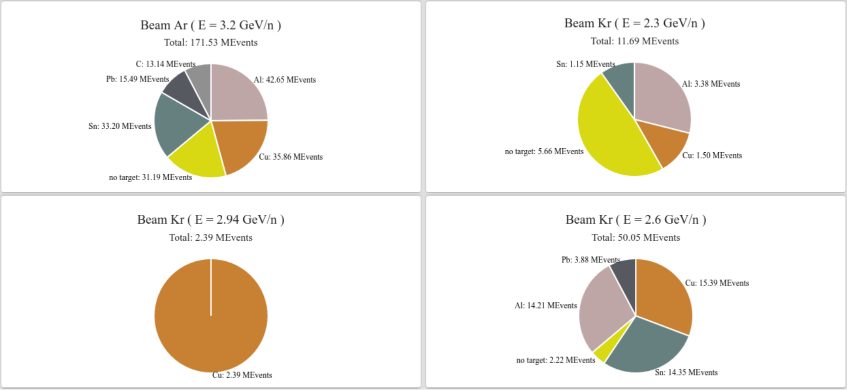
- Read a binary data file with RAW-data.
- Create «DAQ-digits» (ADC, TDC, HRB, SYNC, etc.) accordingly DAQ-data-format and write them into a tree.
- Read common parameters (event number, run number, event type, etc.) and put them into the Unified Database on fly.
- Write the tree with «DAQ-digits» into ROOT-file.

Second step (Data Decoder):

- Read the ROOT-file with DAQ-digits
- Read detector mappings (channel-to-strip) from the Unified Database
- Calculate pedestals and common modes of channels
- Clear noisy channels
- Decode DAQ-digits into detector-digits (BmnGemDigit, BmnTofDigit, etc.)
- Write the tree with detector-digits to a ROOT-file

BM@N:

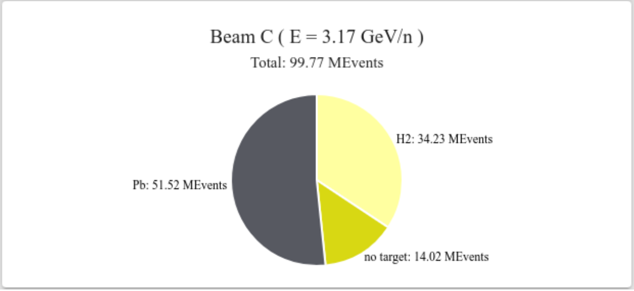
- One beam energy available for Ar-beam and three - for Kr-beam
- Set of targets used Empty, C, Al, Cu, Sn, Pb



Data Processing. RUN 2018

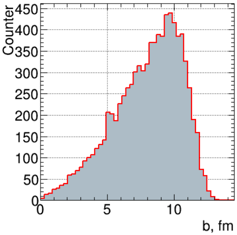
SRC:

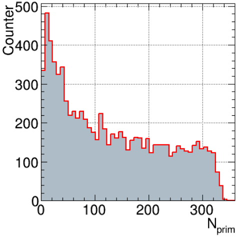
- One beam energy available for C-beam
- More than half of the collected statistics can be used for analysis

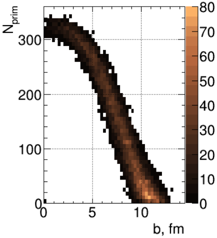


Monte Carlo data

- Generator: DCM-QGSM, ArPb (T = 3.2 GeV/n), minbias, 10k events
- Magnetic field: B = 0.59 T
- Mean reconstructable multiplicity: 25
- Maximal reconstructable multiplicity: 50







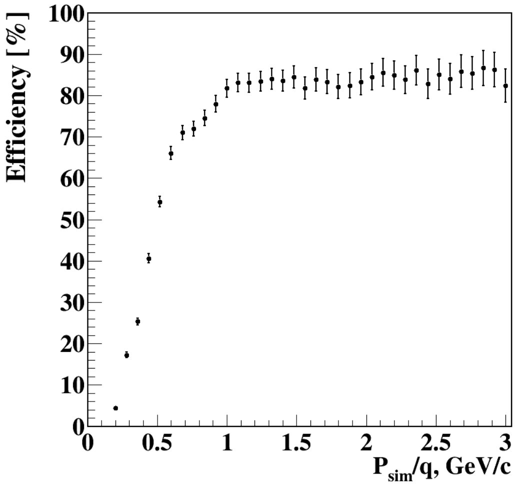
General tracking description

Current realization of the BM@N tracking is

- based on cellular automaton

  R. Frühwirth et all arXiv:1202.2761
- using two connected hits on different stations as a cell (straight line segment).
- working with Silicon hits and with GEM hits as a whole.

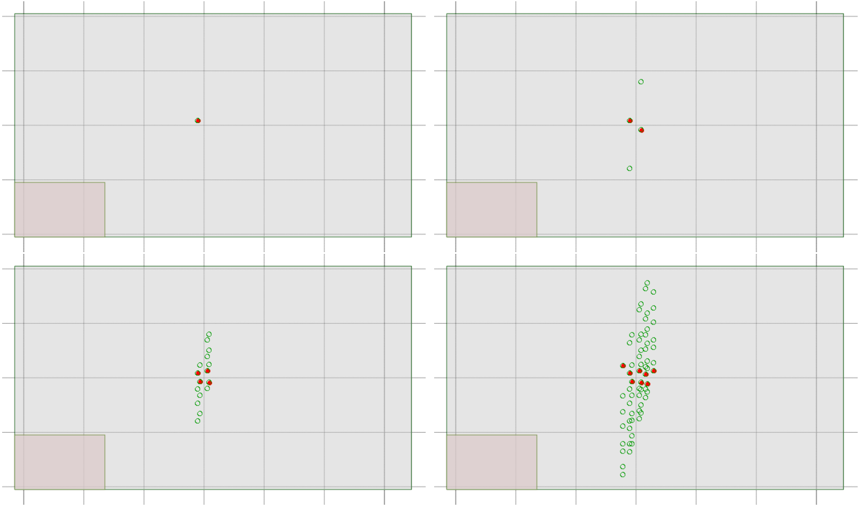
Tracking quality. Efficiency



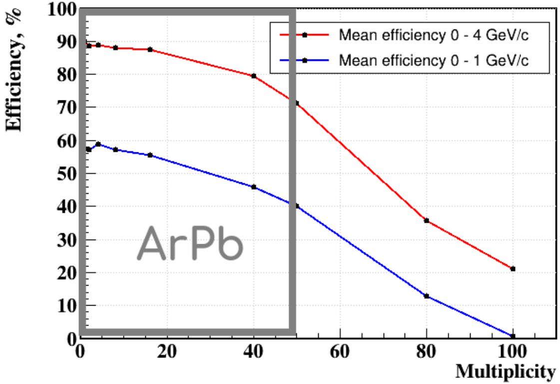
- Reconstructable tracks (N_{MC}): MC-track with more then 3 points
- Reconstructed tracks (N_{rec}): All reconstructed tracks
- Well tracks (N_{well}): Reconstructed tracks more then 60% of hits corresponded to same MC-track
- Wrong tracks (N_{wrong}): Reconstructed tracks less then 60% of hits corresponded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

Why efficiency in not high enough?

Small example



Dependence on multiplicity



Artifitial example:

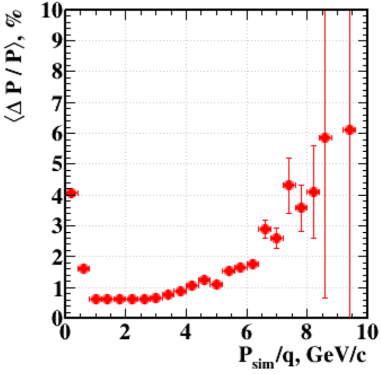
- Exact number of tracks was generated
- Uniform momentum range: 0.2-4 GeV/c
- Uniform polar angle range: 5°-20°
- Realistic effects are implemented

Efficiency

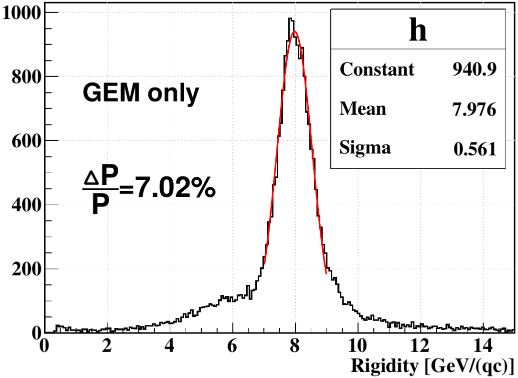
- is quite good in ArPb collision region
- is dramatically worse abroad this region

Momentum resolution

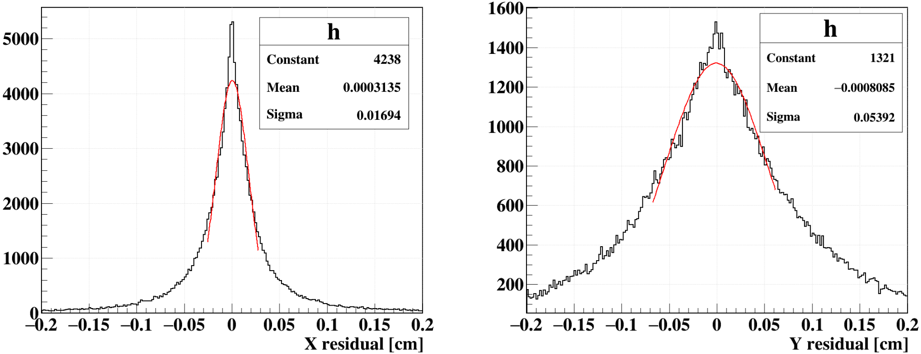
Simulated data



Experimental data



GEM residuals

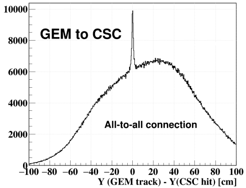


Downstream Matching

Common algorithm of matching

Step 1. Alignment:

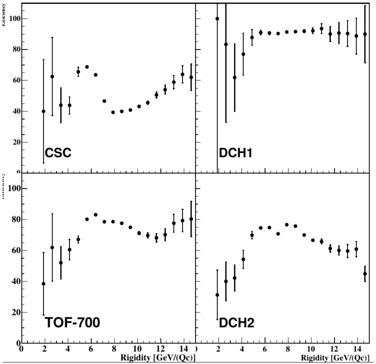
- Propagate each track to plane with hits
- Create track-to-hit (all-to-all) connections
- Calculate and fit residuals $\rightarrow$ $\mu_x, \mu_y, \sigma_x, \sigma_y$
- Shift all hits by μ_x, μ_y

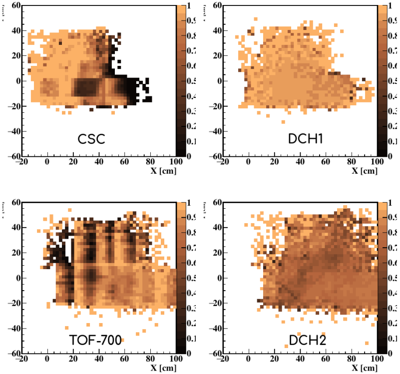


Step 2. Matching:

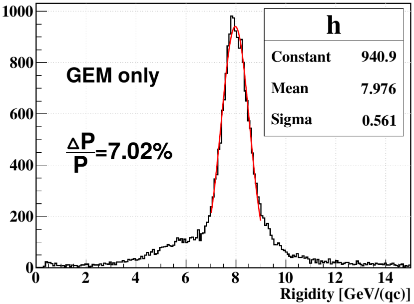
- Propagate each track to plane with hits
- Find the nearest hit in $\pm 3\sigma_x$ and $\pm 3\sigma_y$
- Update track parameters by connected hit information:
  - Track length
  - Last position, T_x, T_y at last position, Momentum
  - Covariance matrix
  - χ^2
  - Number of hits, NDF
  - Velocity (β) for TOF-700

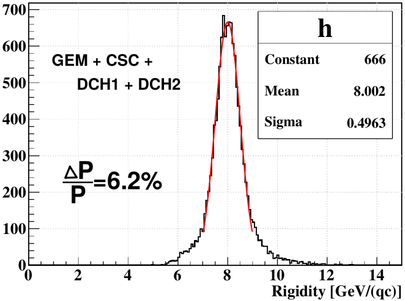
Efficiency (CSC example):
N(GEM+CSC+DCH1+TOF700+DCH2) / N(GEM+DCH1+TOF700+DCH2)





Effect of matching. Momentum Resolution





Summary

- Full set of detectors has realistic geometry in ROOT-format
- Some set of detectors has full chain of simulations from MC-points to realistic digits
- All stand-alone data decoders moved into one unified decoding chain
- Two tracking algorithms implemented in BmnRoot software
- Experimental momentum resolution is in good agreement with MC
- Global tracking significantly improves quality of track parameters estimation