Particle identification method in the BM@N experiment

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Outline

- Particle identification in the BM@N experiment
- Detector system of the BM@N setup
- Adding realistic effects to event simulation
- Distance method implementation
- Summary

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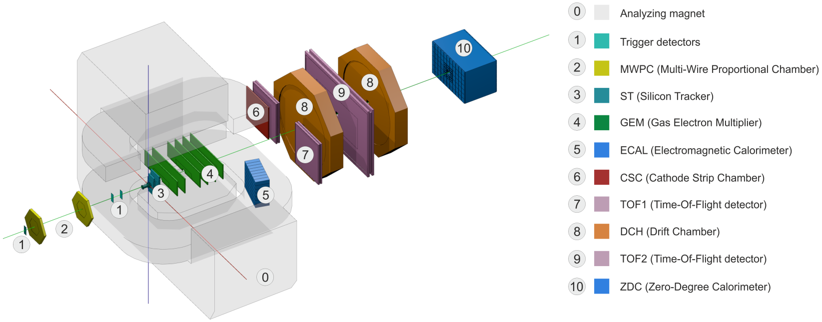
NICA (Nuclotron-based Ion Collider fAcility)

The BM@N (Baryonic Matter at the Nuclotron) is aimed at studying heavy ion collisions with fixed targets.

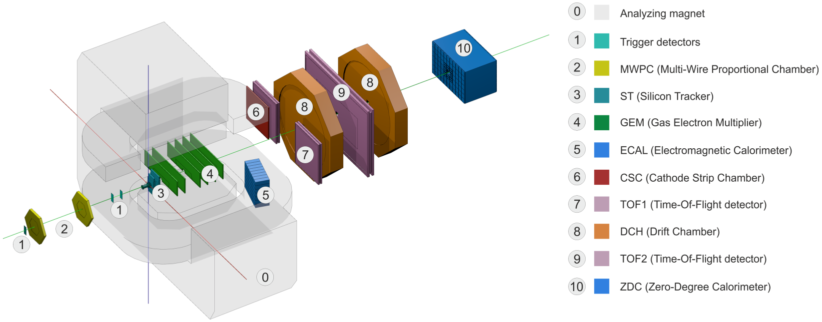
Current BM@N Run-7 geometry



Silicon + GEM (Gas Electron Multiplier)

Allows to reconstruct the momentum along the trajectories of charged particles. Rigidity $= p/q$

Current BM@N Run-7 geometry

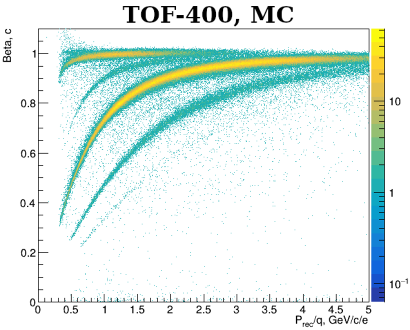


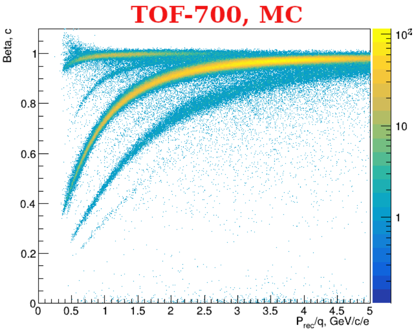
TOF(Time-Of-Flight detectors

Allows to calculate the velocity taking into account the measurement of the time. $\beta = l/tc$

Input data for the algorithm

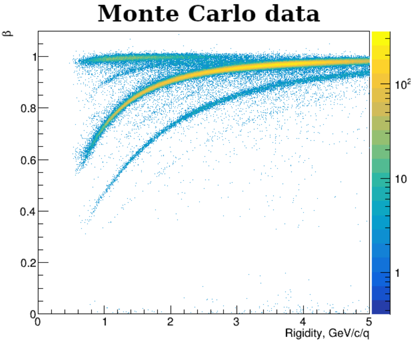
The implemented method based on magnetic rigidity and particle velocity, determines the probability for a particle to have a certain type.

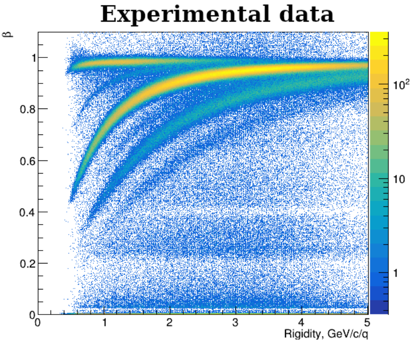




The difference of the experiment and MC

The efficiency of the algorithm was evaluated on Monte Carlo data, but it will be applied to experimental.



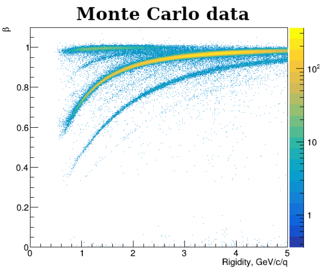


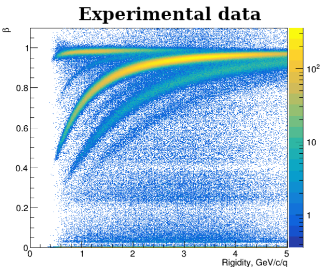
Input data are significantly different.

How to fix

In order to bring the properties of the simulated data closer to experimental, we need

- Implement selection procedures reliable experimental data
- Determine the characteristics of good experimental tracks
- Add realistic effects to Monte Carlo

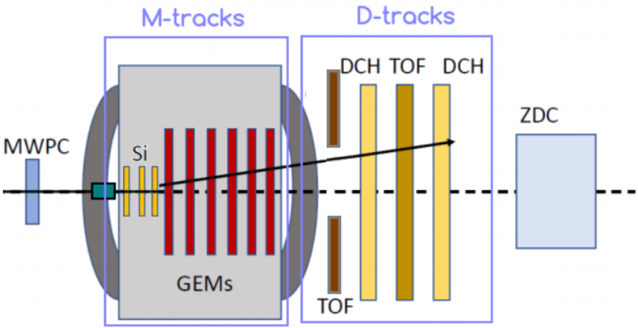




Track selection algorithm

Re-extrapolating

Propagate the inner track through its hits in silicon and GEM.



Track selection algorithm

Matching

Tracks from the magnet are matched with the DCH tracks and hits in the TOF detector.

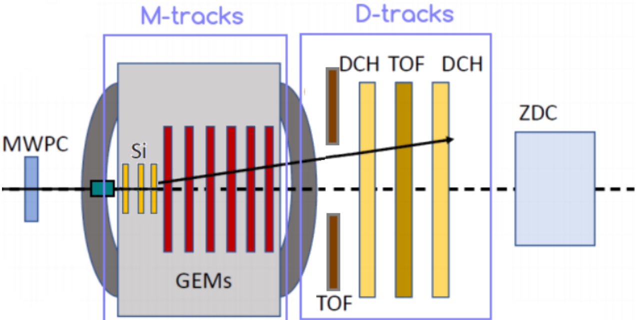
- Matching detector chain GEM $\rightarrow$ DCH $\rightarrow$ TOF700
- The track is extrapolated to each hit in the detector plane
- Calculate residuals $\Delta X = x_{track} - x_{hit}; \Delta Y = y_{track} - y_{hit};$
- Find the nearest hit

Track selection algorithm

Back propagation

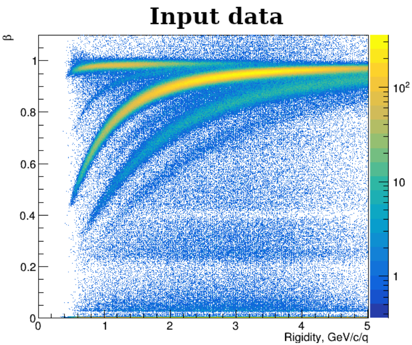
Extrapolate track from TOF detector to the vertex.

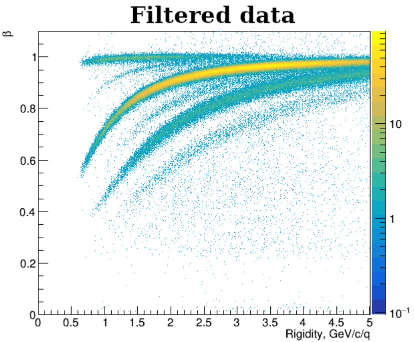
- Get time of flight from a TOF hit
- Calculate velocity $\beta = l/tc$
- Save track parameters if it belongs to the vertex range



Before/After

- Vertex in range
  $V_x \in (-2, 4)$cm; $V_y \in (-6, -1)$cm; $V_z \in (-5, 5)$cm
- $\geqslant 1$ Silicon + $\geqslant 4$ GEM + 1 DCH + 1 TOF Hits
- Back extrapolation with parameter update



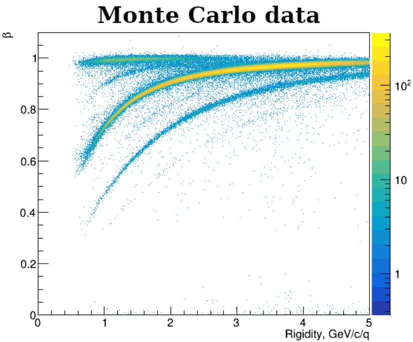


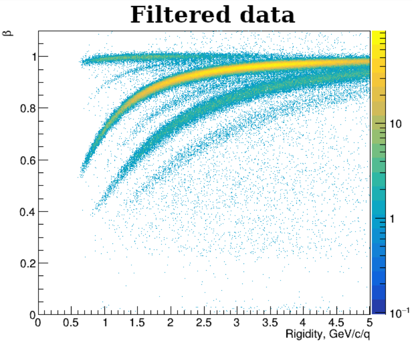
BM@N

Exp and MC comparison parameters

Data parameters

- Number of hits in Silicon and GEM tracks
- Station efficiency
- Residuals





Comparison of Exp and MC

Monte Carlo
- Generator: DCMSMM
- System: Ar + Cu
- Energy: 3.2 AGeV
- Selected tracks only

Exp data
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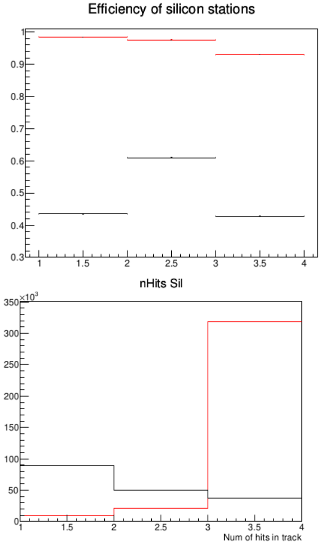
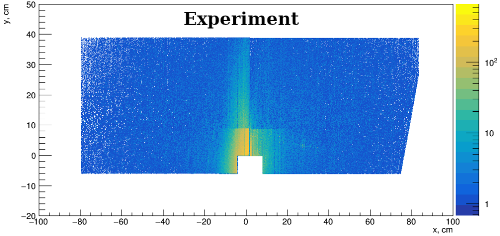
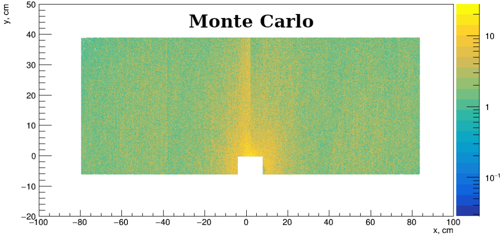


How to reduce efficiency?

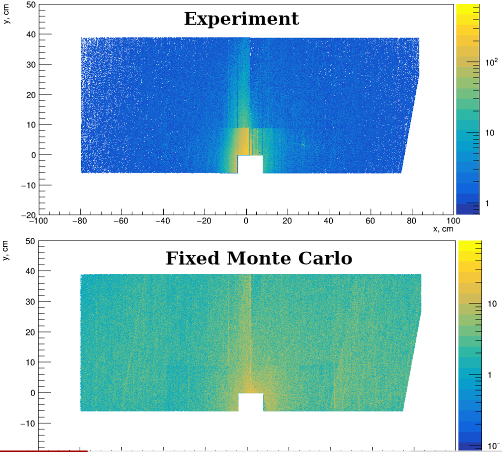
The efficiency of a station depends on 1)Tracks passed through the station and 2) Tracks in acceptance.





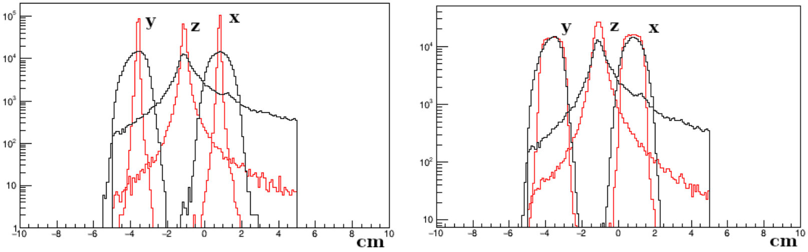
Adding dead strips

- A list of non-working strips was received
- Strips from this list were disabled during the simulation stage.



Smearing vertex

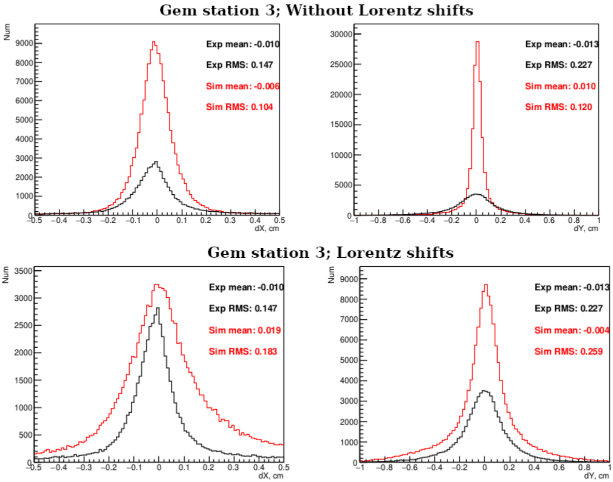
Initially, the peaks of the vertex coordinates are very narrow and high.



The vertex width was obtained from experimental data and added to the simulation.

Lorentz shifts

Lorentz shifts simulate the displacement of electron avalanches in a magnetic field. Residuals become wider.



Comparison of Exp and MC

Monte Carlo

- Generator: DCMSMM
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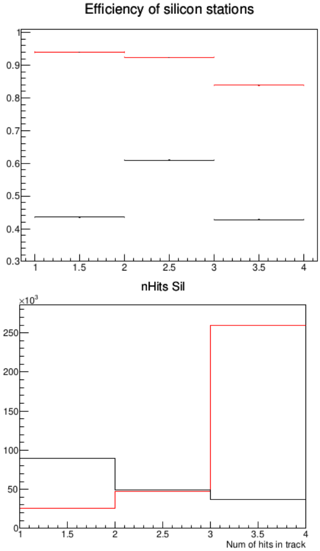
- Smearing Vertex
- Lorentz Shifts
- Dead strips

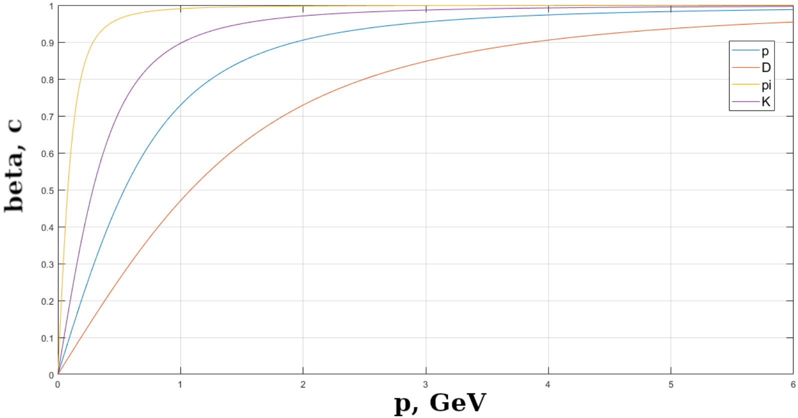
Exp data

- System: Ar + Cu
- Energy: 3.2 AGeV



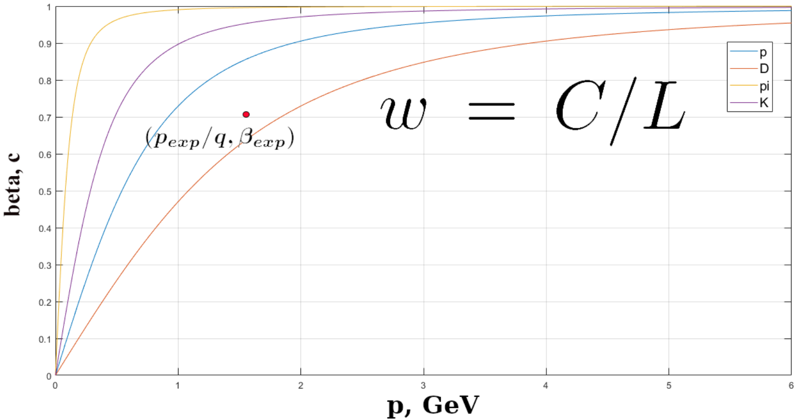
PID algorithm description

Method based on calculation of distance between experimental velocity and theoretical one for each particle type.



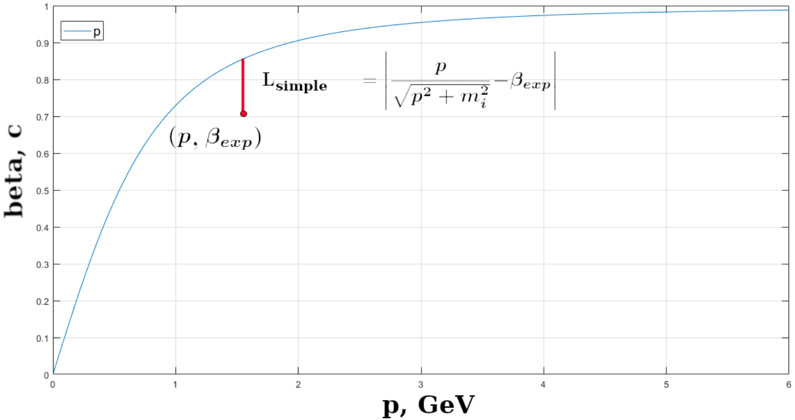
PID algorithm description

The probability with which a particle will belong to a certain type is calculated by the formula $w_i = C/L_i$, where $C = 1/\sum \frac{1}{L_i}$ and L is the distance to the theoretical curve.



PID algorithm description

Distance is calculated as the difference between theoretical and experimental velocity $L_i = |\beta^i_{th} - \beta_{exp}|$.



Efficiency and contamination

$\text{Efficiency} = \frac{N_{true}}{N_{sim}}$

$\text{Contamination} = \frac{N_{false}}{N_{id}}$

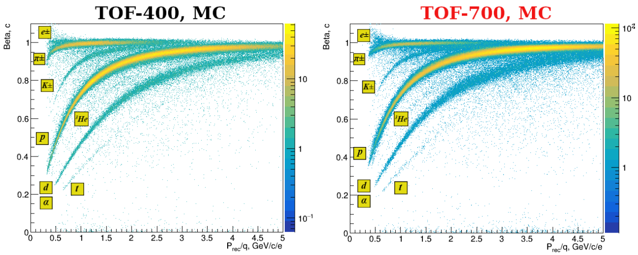
N_{true} - number of correctly identified particles of a given type

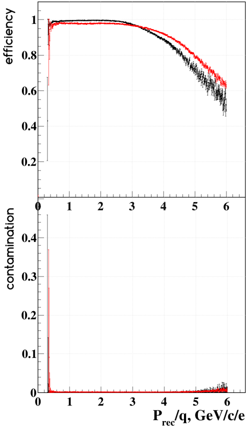
N_{false} - number of falsely identified particles of a given type

N_{sim} - total number of simulated particles of a given type

$N_{id} = N_{true} + N_{false}$ - total number of particles identified as a given type

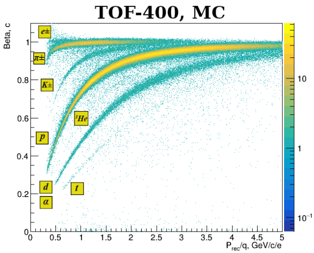
Protons

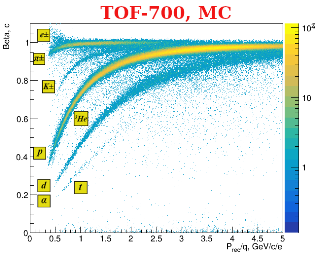


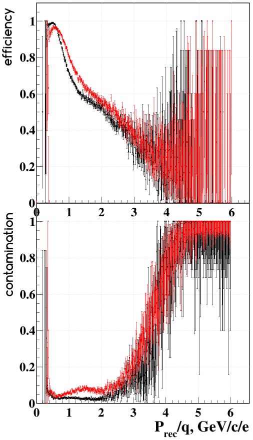


Protons are mixing with kaons and pions after 3 GeV/c but are still well identified

Pions

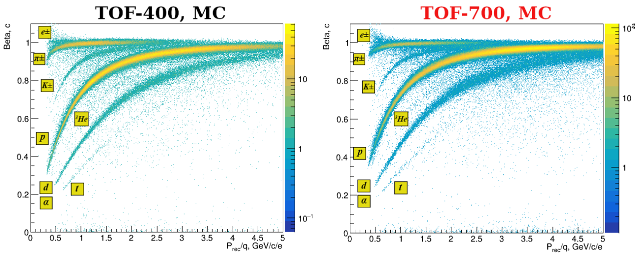


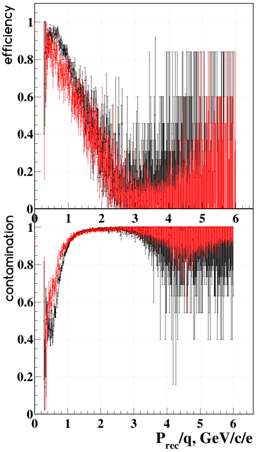




Electrons have a big impact on efficiency

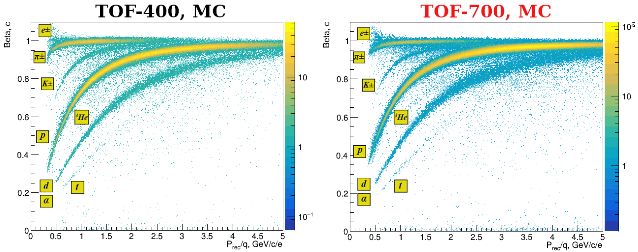
Electrons

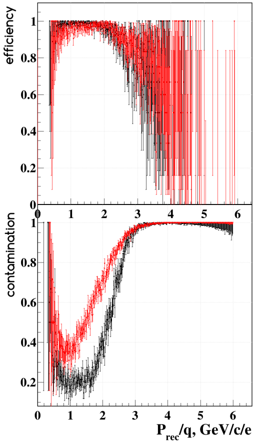




It is practically impossible to separate electrons due to the closeness of the pion line

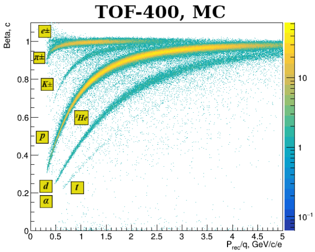
Kaons

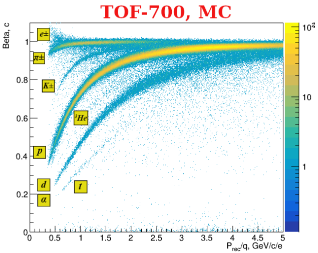


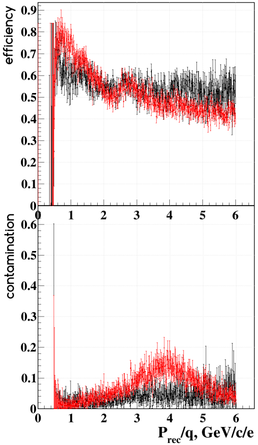


Quite good separation up to 3 GeV/c, but high level of contamination

Deuterium and 4He







Deuterium are mixed with 4He. So, efficiency is around 50%.

Strengths and Weaknesses

Strengths

- Executes quickly
- Gives a probabilistic estimate
- High efficiency for protons and kaons at low momenta.

Weaknesses

- Decreased efficiency when merging clusters at large momenta
- Cannot separate pi from e
- Not enough information to split d and α

Ways to improve efficiency

- Take into account the a priori particle distribution densities depending on the momentum

Summary

- Algorithms for filtering experimental data have been implemented
- Realistic effects have been added to the modeling process
  - Smearing Vertex
  - Lorentz Shifts
  - Dead strips
- Particle identification method was implemented and tested

Thank you for the attention!