Centrality determination in carbon beam data for BM@N experiment with Zero Degree Calorimeter (ZDC)

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Centrality determination for BM@N with ZDC

BM@N experiment at NICA acceleration complex

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BM@N setup

BM@N experiment schematic view

**impact parameter “b”**
(distance between nuclei centers)

Fixed target experiment (ion-ion collision)

projectile spectators
(to be detected with ZDC)

Simulation of C+C @4AGeV

Energy in ZDC, [GeV]

Impact parameter, [fm]

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Zero Degree Calorimeter (ZDC) at BM@N

ZDC modules

Central part with 36 modules 7.5 x 7.5 cm$^2$
Outer part with 68 modules 15 x 15 cm$^2$

ZDC module structure

- ZDC modules with light collection by WLS plate and does not have a longitudinal segmentation.
- Calibration: on cosmics only

64 layers of 5 mm scint. + 10 mm Pb
Centrality determination for BM@N with ZDC

Experimental data:
- single ion selection:
  1) \( n_{\text{Hits}} \text{ in BC2} = 1, \ n_{\text{Hits}} \text{ in T0} = 1 \)
  2) no fake trigger: \( n_{\text{Hits}} \text{ in VETO} = 0 \)
  3) \( n_{\text{Hits}} \text{ in BD} \geq 2 \) (in trigger)

Simulation in GEANT4 (MB – min. biased):
- all detectors in place (TOF + DCH)
- DCM-QGSM model, C+C@4 AGeV reaction
- event selection with BD detector
  \( \left(n_{\text{Hits}}\text{BD} \geq 2 \right) \)

C beam contamination

Exp. (multiplicity) trigger BD\(\geq2\) affects MB and selects \(\sim 50\%\) most central events
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Experimental data from C+C @ 4AGeV

Carbon from beam

Total energy in ZDC

~10% of all events

Trying to reject the C ions..

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1) Exp. data (events selected with dE/dx counter)

“Centrality” 0 - 40% $\rightarrow E_{cut} \sim 35$ GeV

(NOTE: this is not true centrality of all MB events! This is 0-40% of centrality for specially selected events)

2) Comparison with simulation

Impact parameter spectra

most “b-central” events selected

all events (MB) $E_{cut} \sim 31.1$ GeV
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Centrality selection for all experimental data with C beam contamination:

→ energy asymmetry method

\[
\text{Energy asymmetry} = \frac{E_{\text{ZDC inner}} - E_{\text{ZDC outer}}}{E_{\text{ZDC inner}} + E_{\text{ZDC outer}}}
\]

ZDC inner part

ZDC outer part

events with C beam ions

0-40% centrality
→ asymmetry < 0.01

MC +BD

exp. data
all events

exp. data
MC

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Machine Learning technique

NEW method:
ML technique for event selection
- train on empty target

ML: interaction
ML: beam

- significant difference in data and MC
  (probably the calibration of ZDC needs to be improved) → the work is in progress..

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Conclusions:

- centrality estimation was done for C+C @ 4AGeV in BM@N experiment

- several methods for centrality determination have been tested:
  1) full energy in forward hadron calorimeter (ZDC)
  2) energy asymmetry in ZDC

- ML technique has been tested for carbon beam event rejection

Thank you for your attention!

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