Probing Geometry of Ion–Ion Collisions with Roman Pot Detectors

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Forward Physics in ALICE 3
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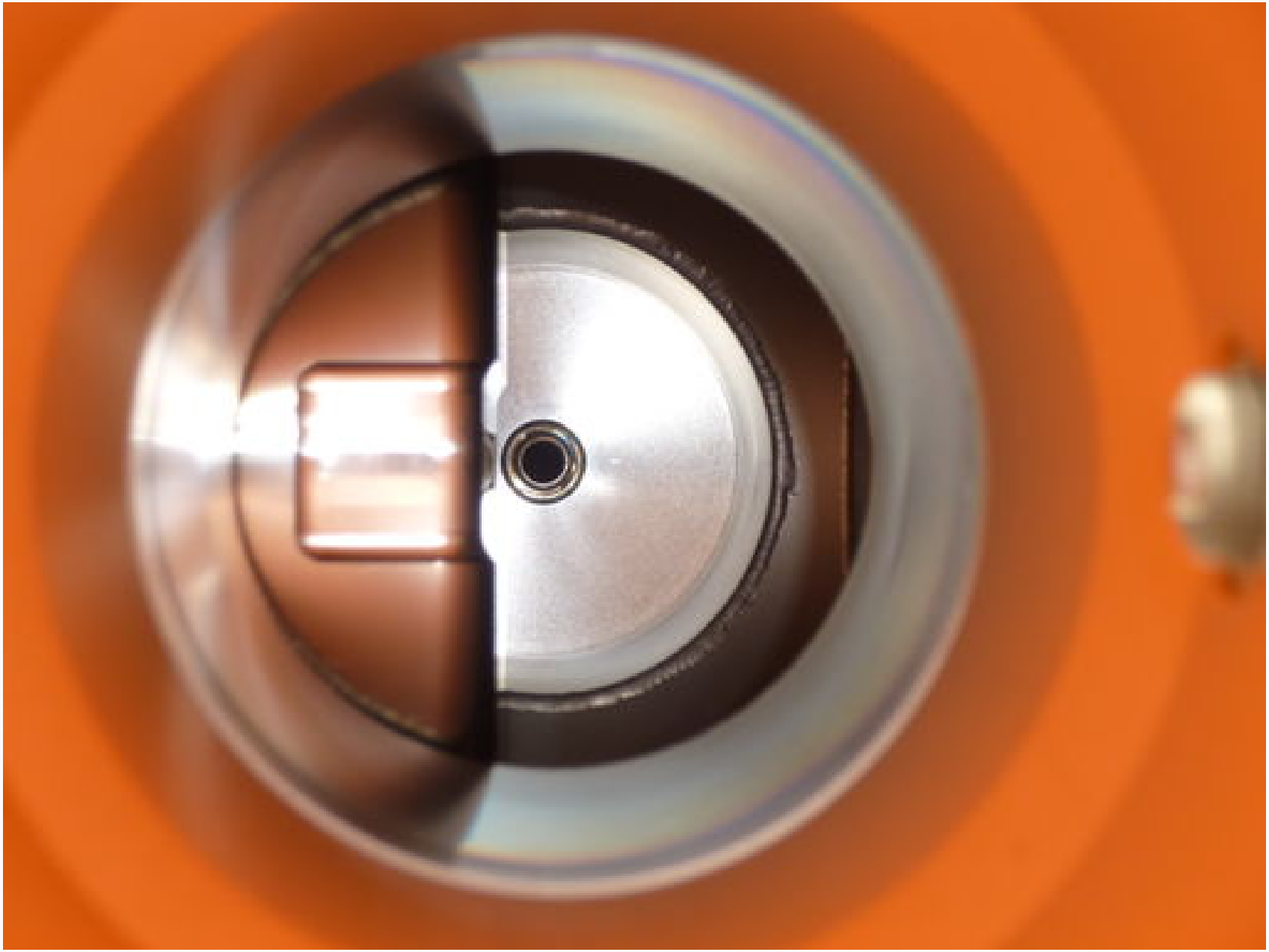
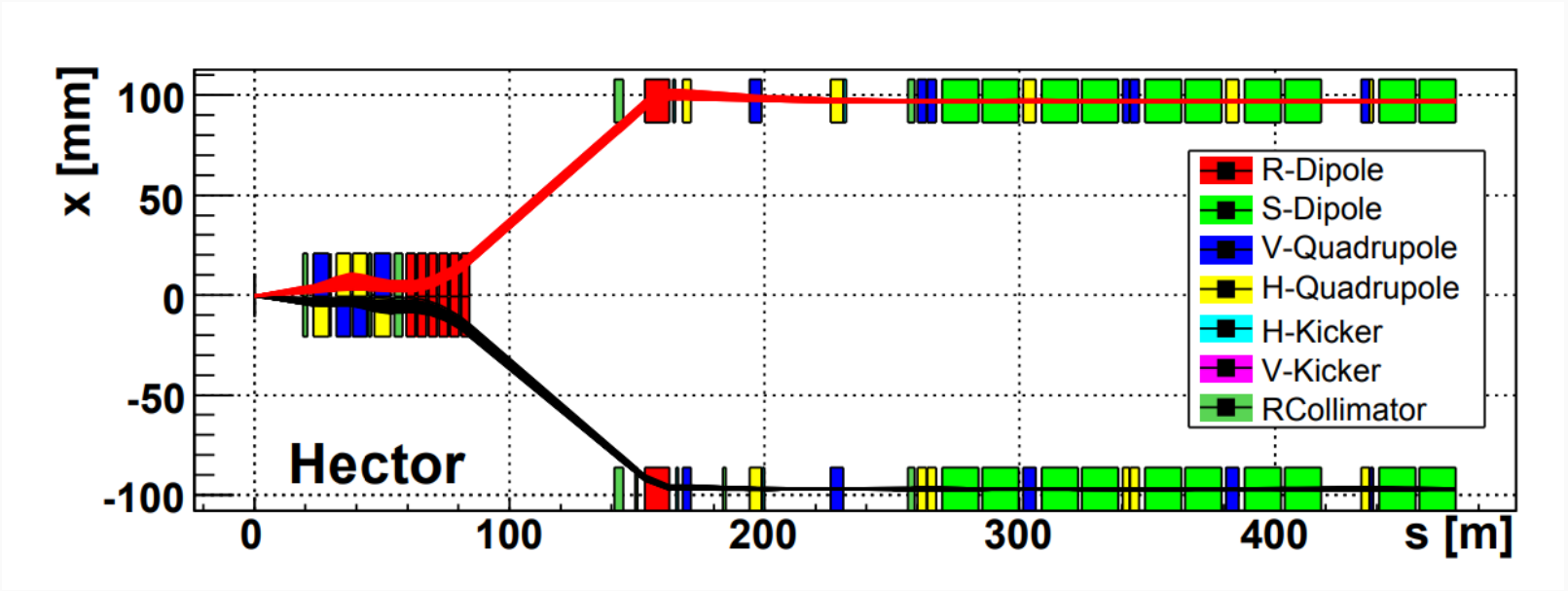
Contents

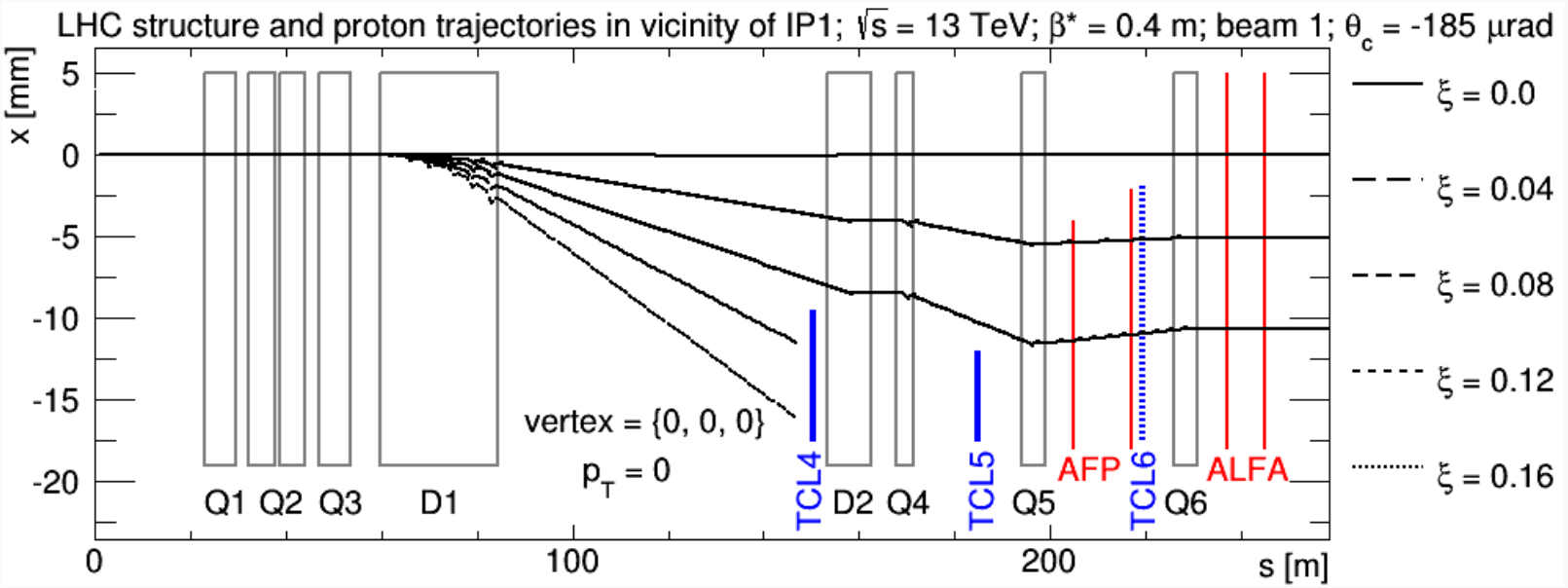
Roman Pot Deetctors



Trajectories of forward protons

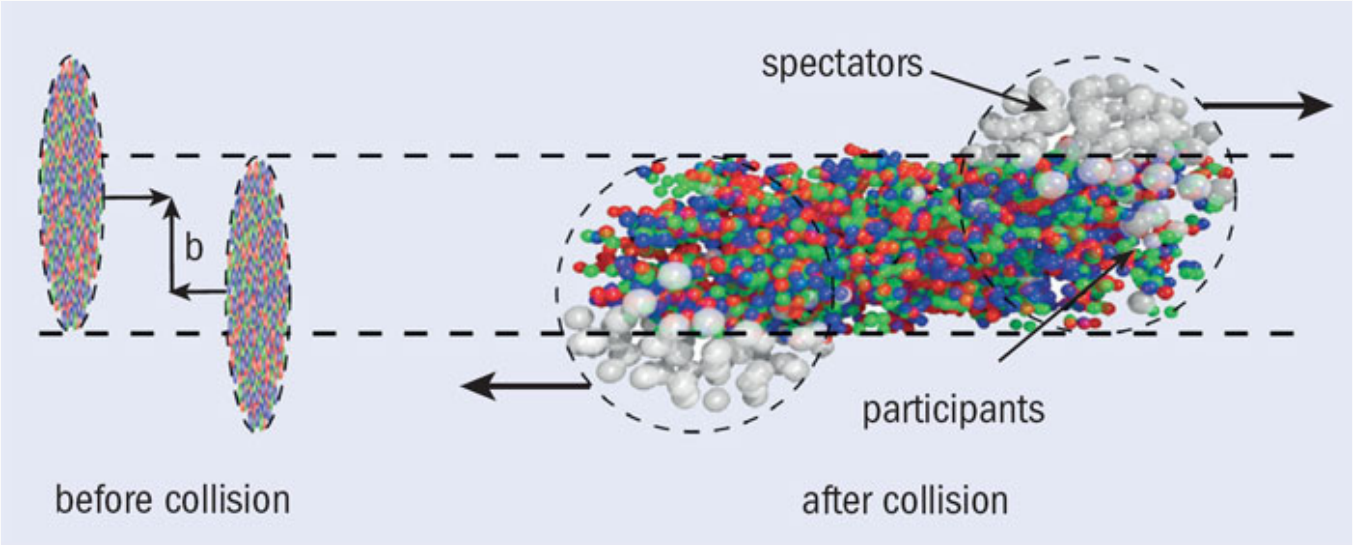


J. de Favereau de Jeneret, X. Rouby, K. Piotrzkowski [arXiv:0707.1198]



M. Trzebiński [private communication]

Heavy ion collisions



- Spectator nucleons move in the forward direction
- Trajectories similar to the ones of forward protons
- They carry the information about the initial state of the collision

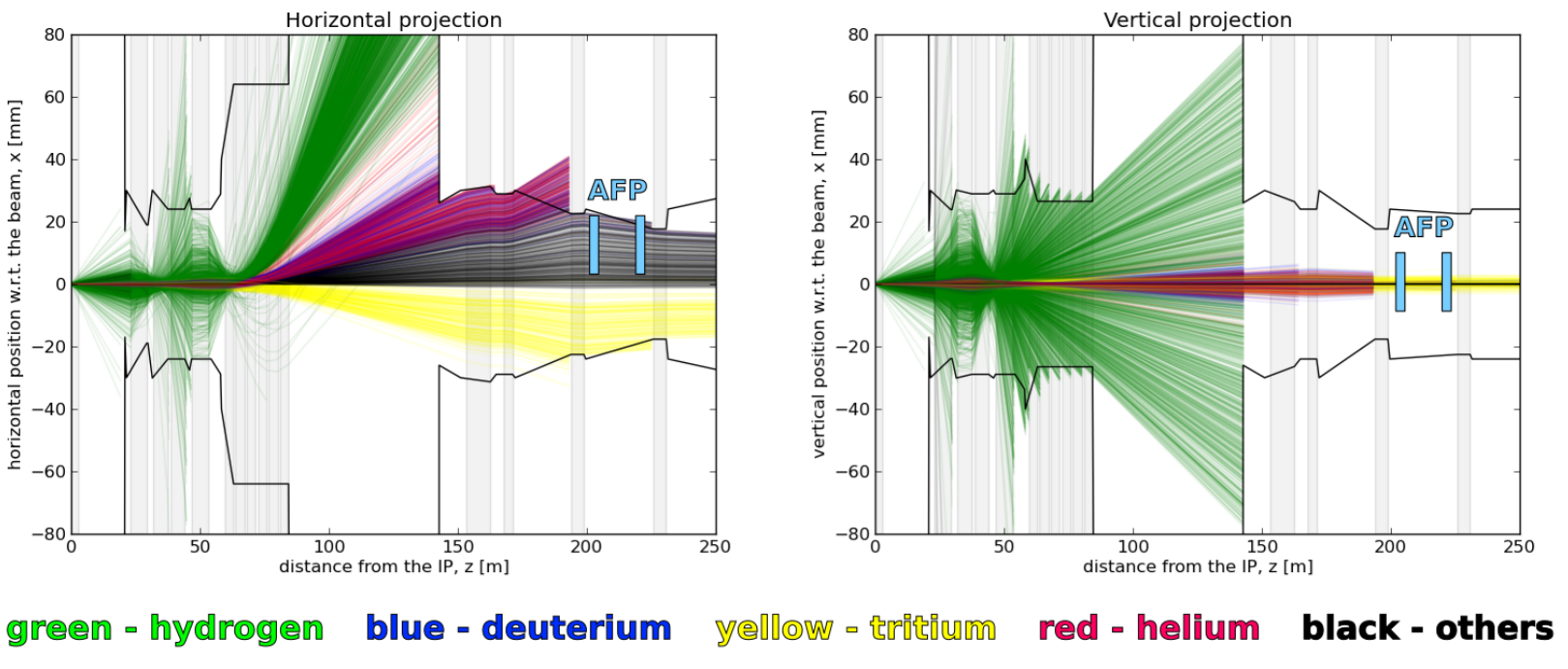
- First proposal: new detector system for RHIC
  S. Tarafdar, Z. Citron, A. Milov [arXiv:1405.4555]
- This presentation (based on [arxiv:2011.00872]):
  what can be done at LHC (PbPb) with existing detectors

Contents

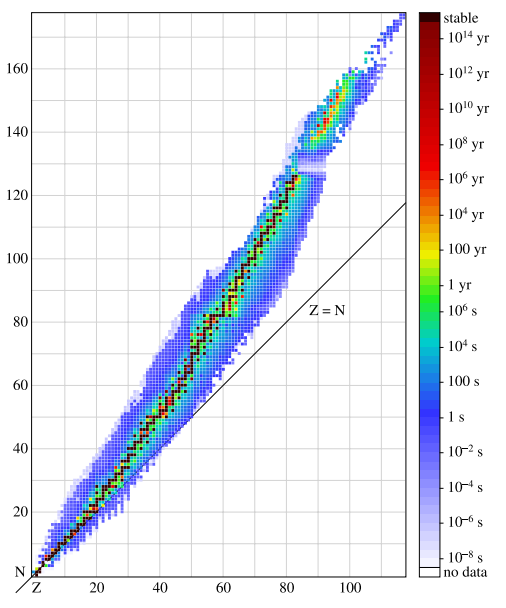
Trajectories of nuclear fragments

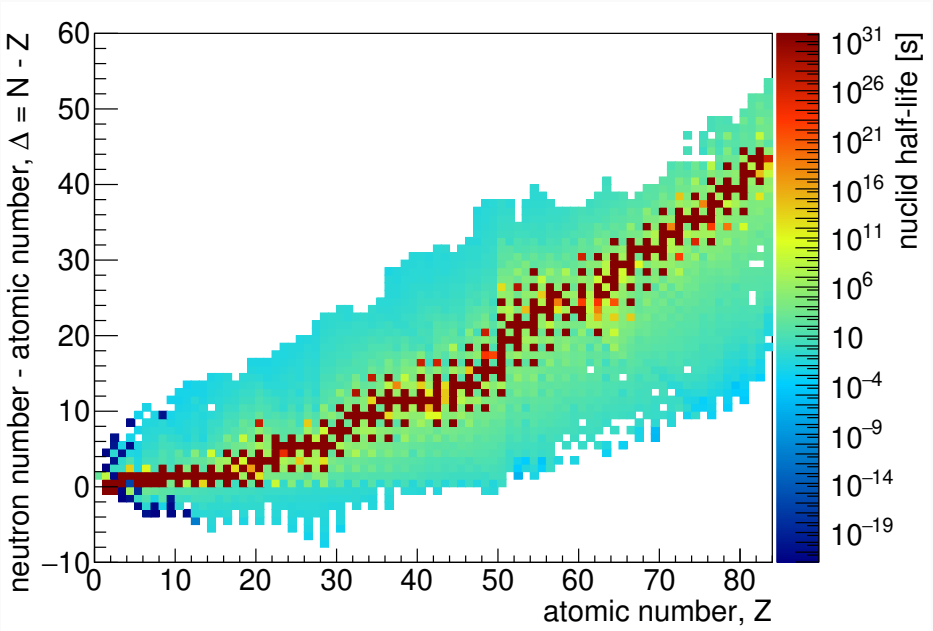
- Simulation software (Mad-X) allows transport of beam particles only (not of particles of different kinds, i.e. for Pb beam one cannot directly calculate trajectories of other nuclei)
- Trick: find the momentum of the beam particle that would have the same trajectory as the particle in question

$$p' = \frac{q_{\text{beam}}}{q_{\text{particle}}} p_{\text{particle}}$$



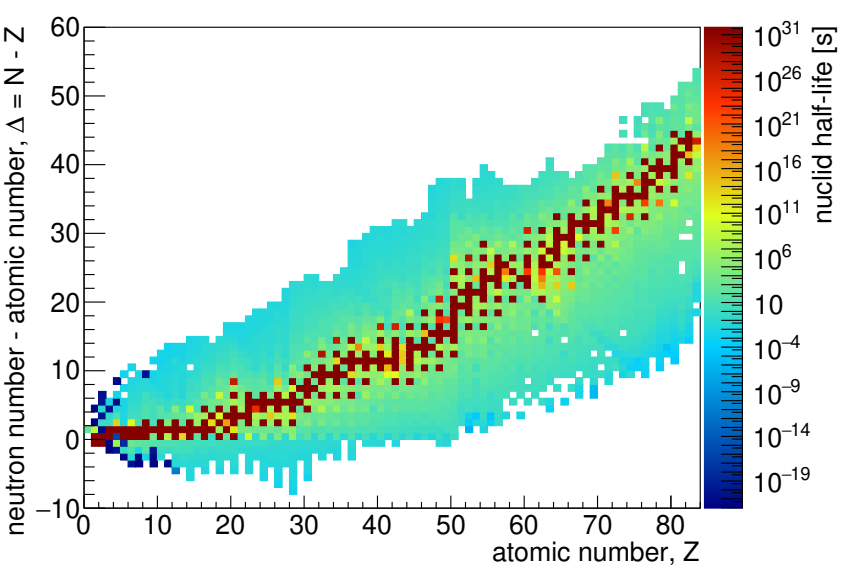
Half-life of nuclei

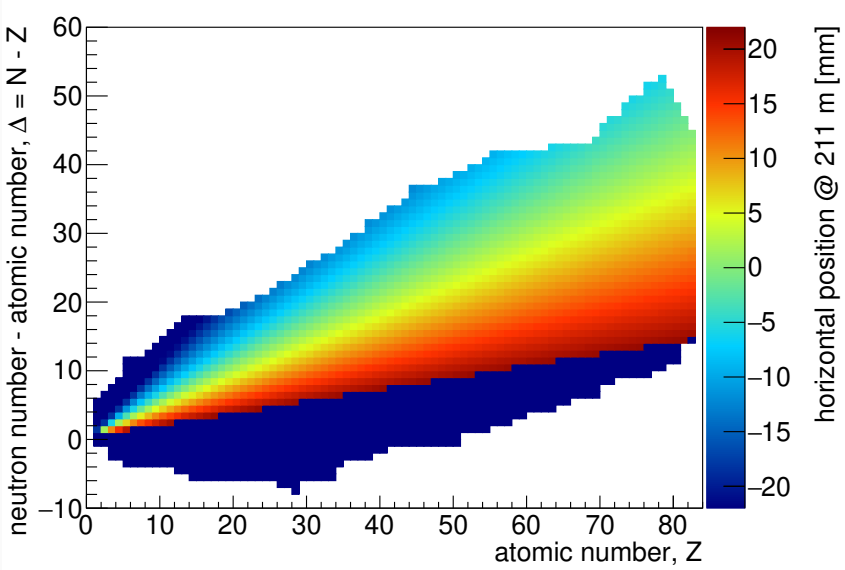


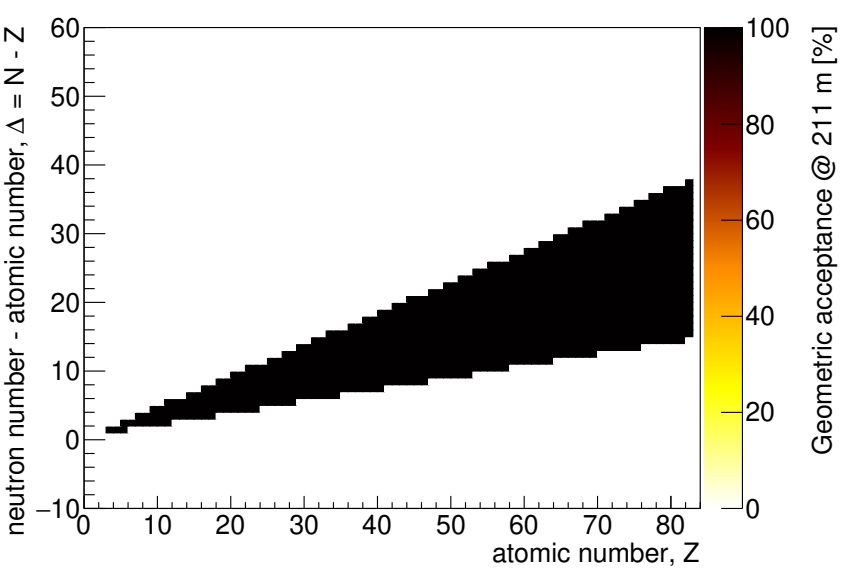


- Spectators can be produced in a form of long- or short-lived nuclei
- Proper time between production and reaching forward proton detectors ($\sqrt{s_{NN}} = 5$ TeV, detectors ∼200 m away): ∼ 0.3 ns
- Vast majority of possibly produced nuclear fragments will reach the detectors, even the short-lived ones

Which nuclear fragments could be detected?

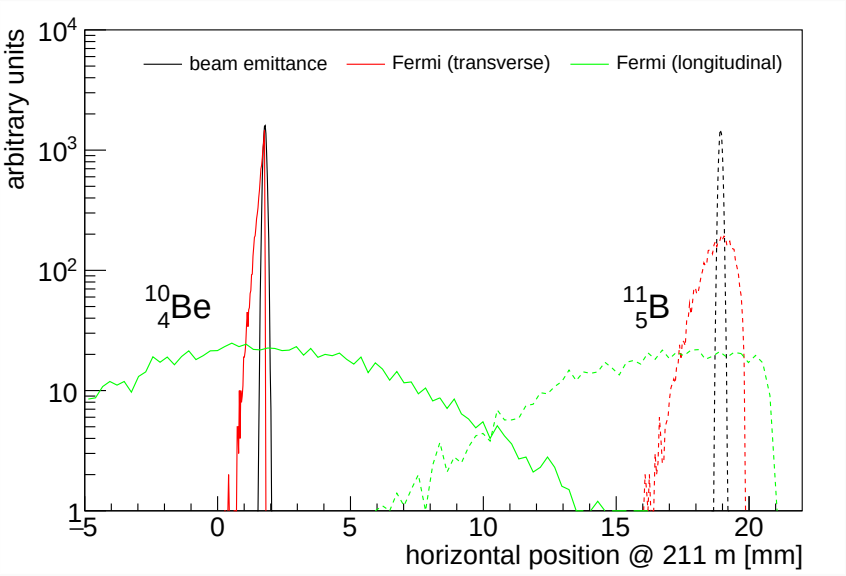


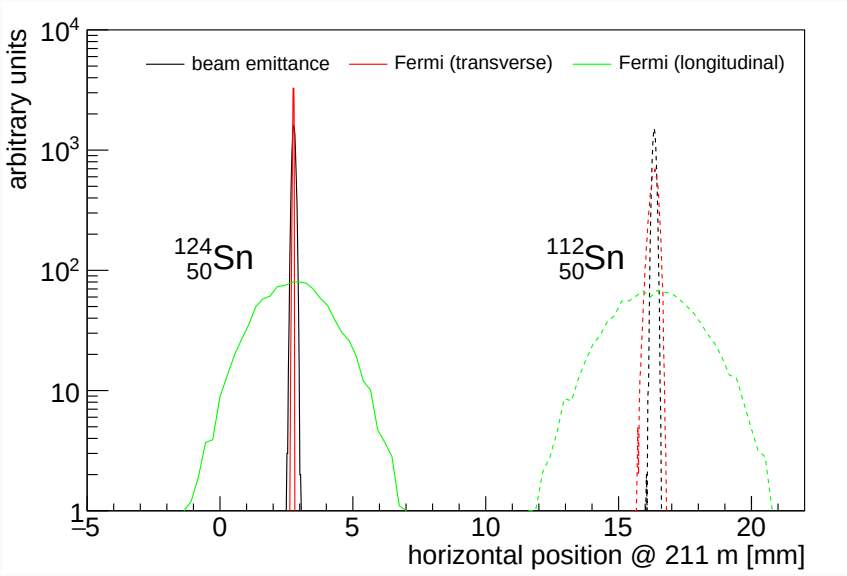


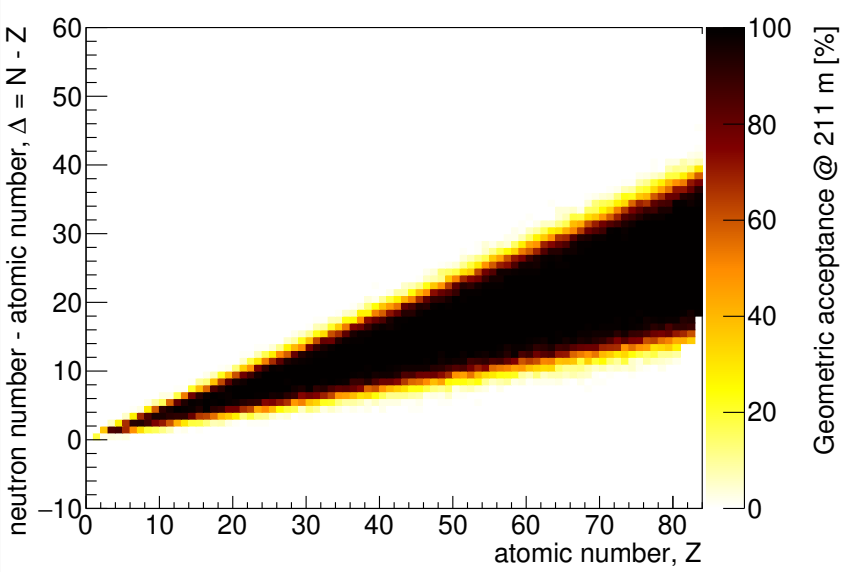


- Some losses at LHC apertures
- 3 mm distance between RP and beam assumed (19σ + 500 µm)
- A significant part of known nuclei can be detected

Spread of positions

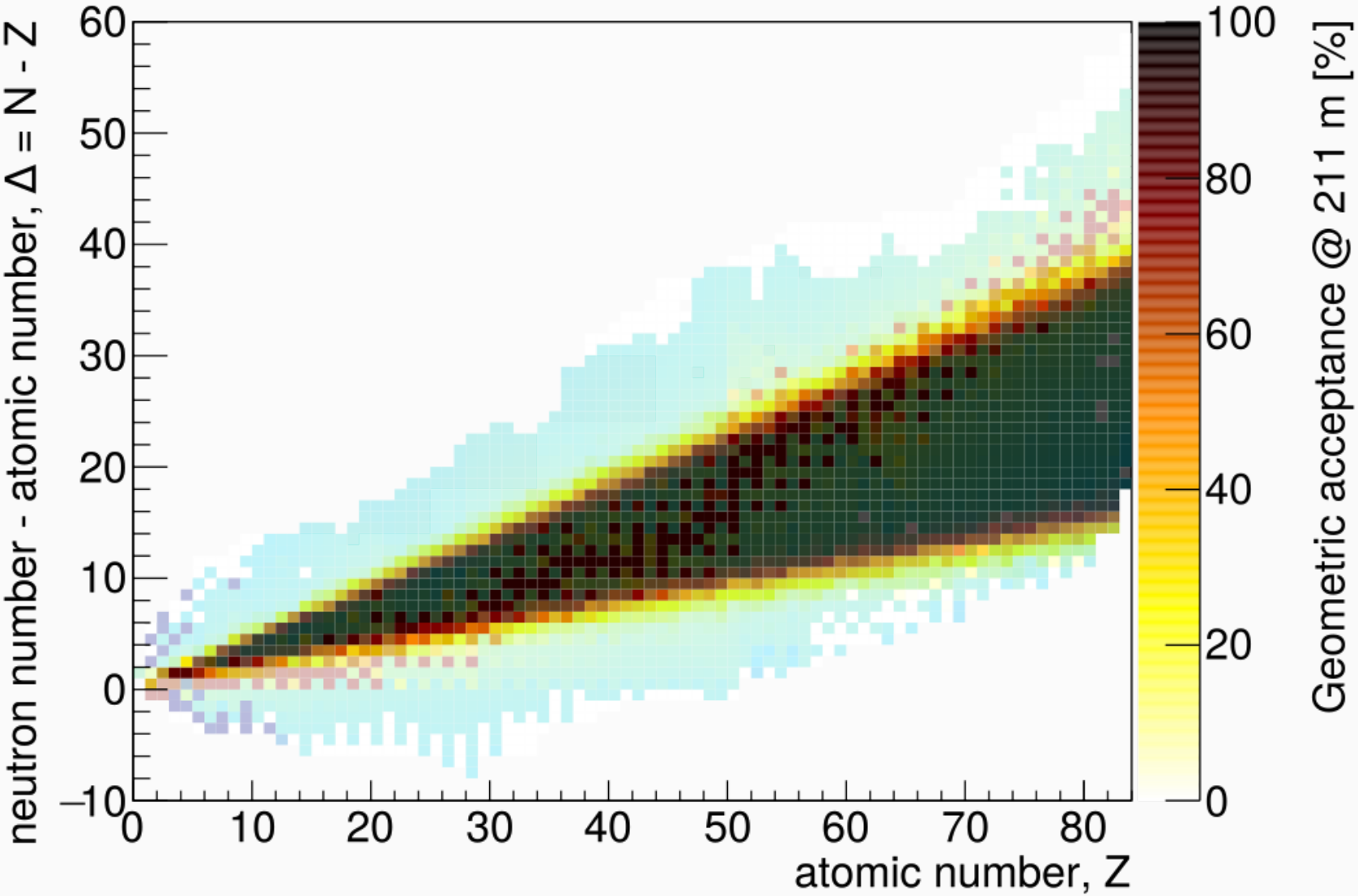






- Smearing effects:
  - beam emittance
  - Fermi motion inside the incoming nucleus
- Biggest effect from the longitudinal Fermi motion
- Acceptance with smearing effects similar to the ideal one

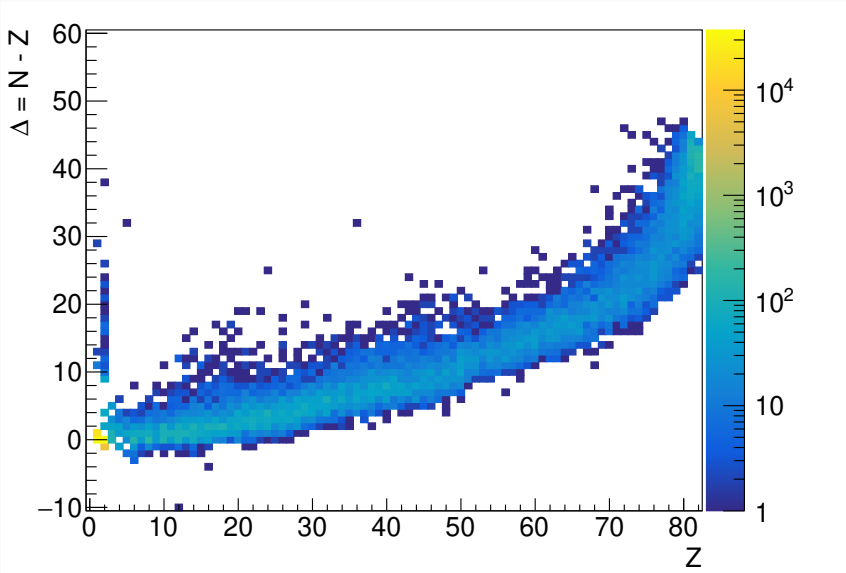
Acceptance of existing ATLAS Forward Proton detectors



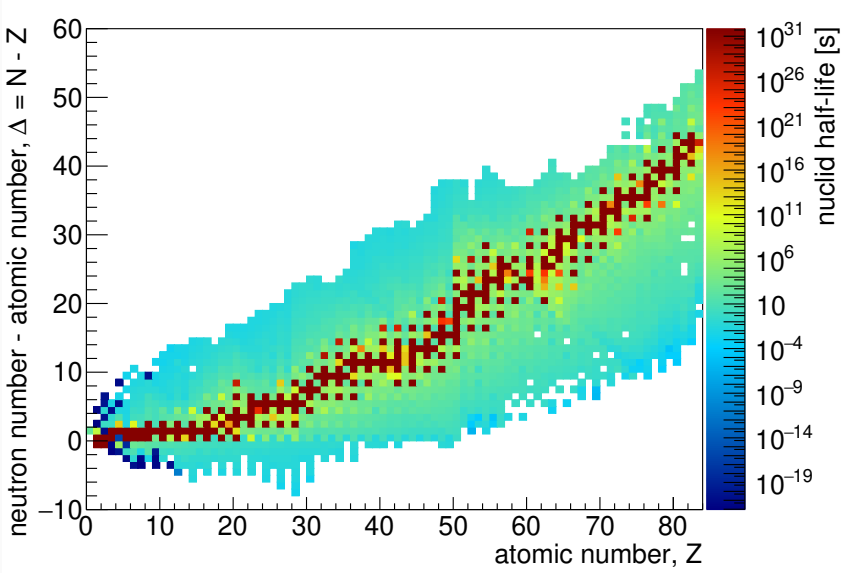
Contents

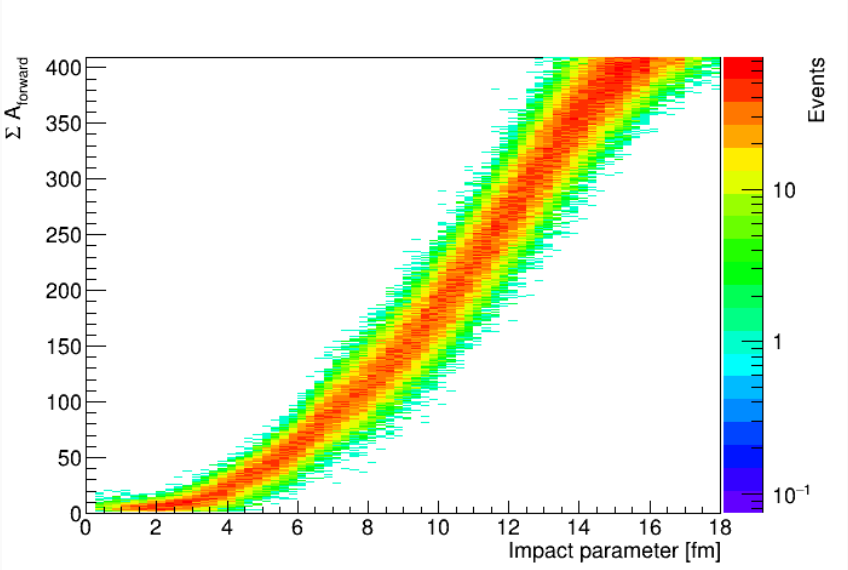
Produced fragments

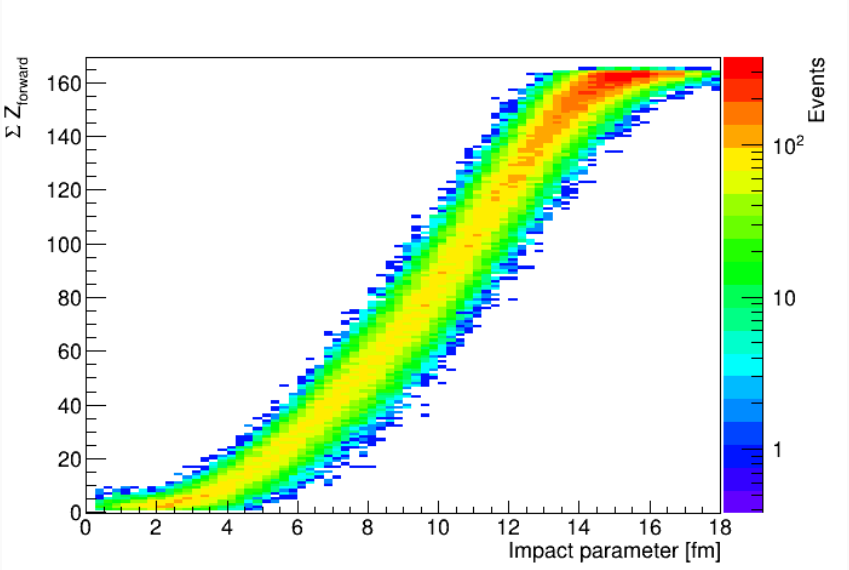
DPMJET:



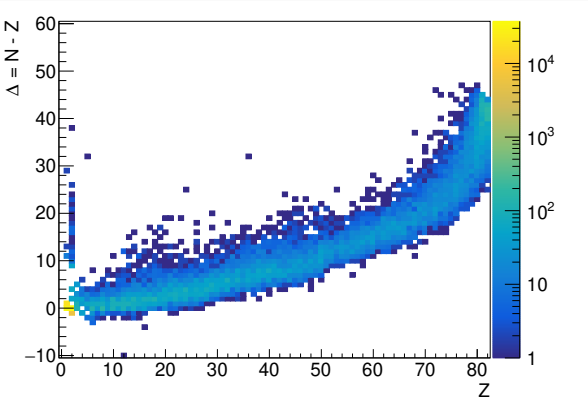
All known:

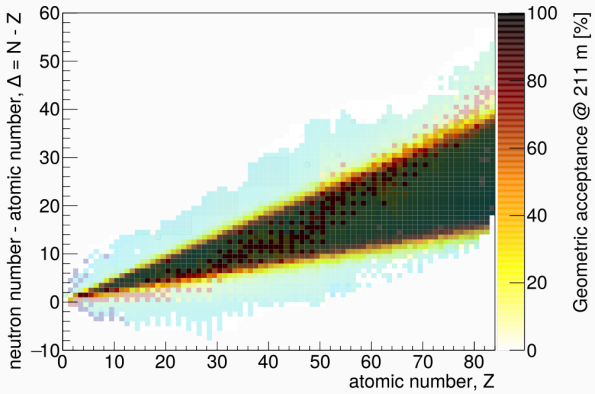


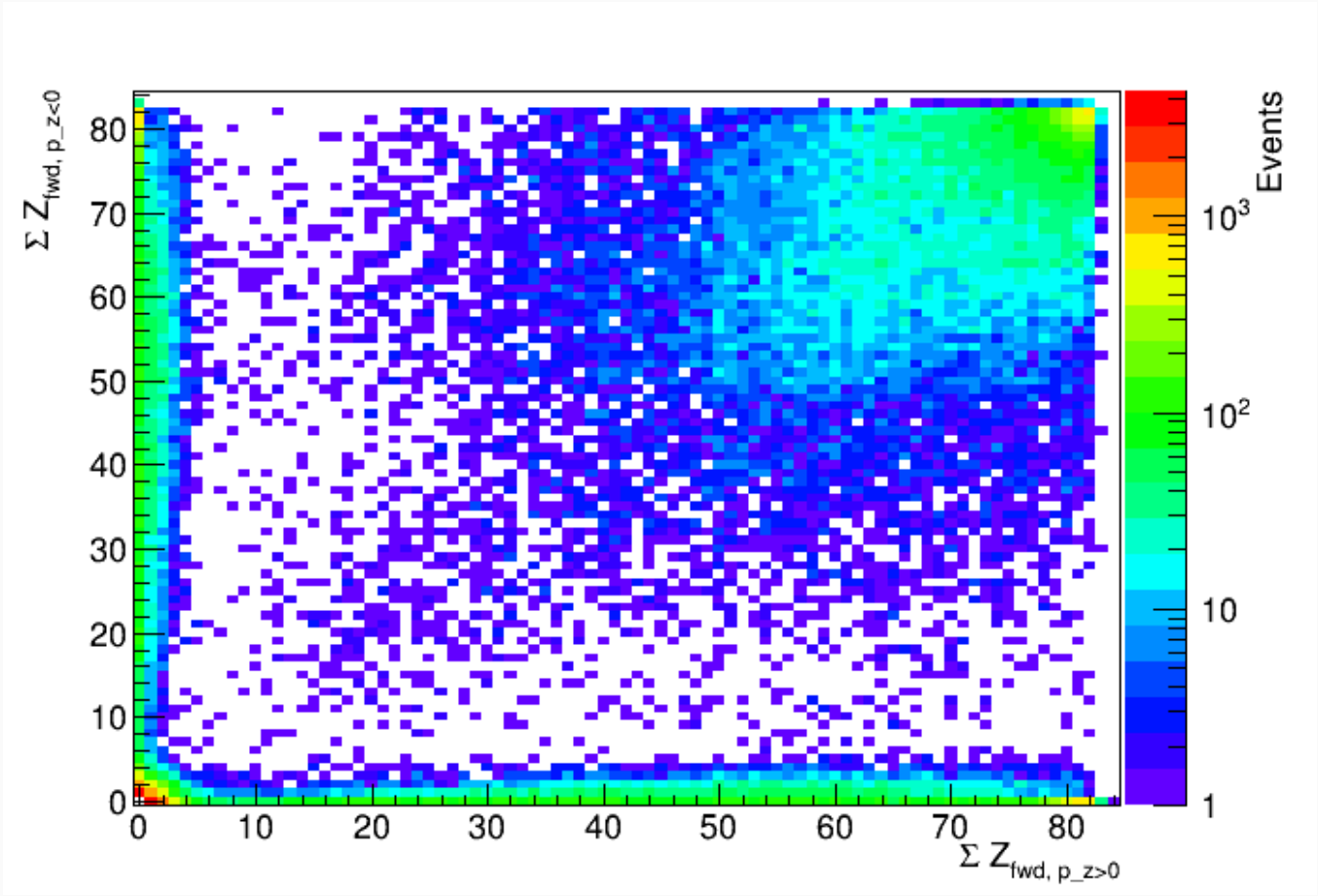




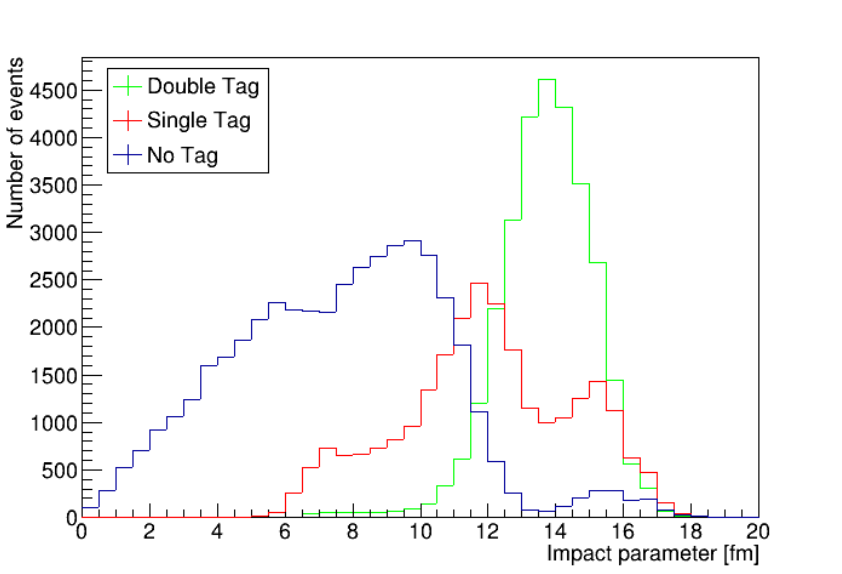
Limited acceptance of detectors

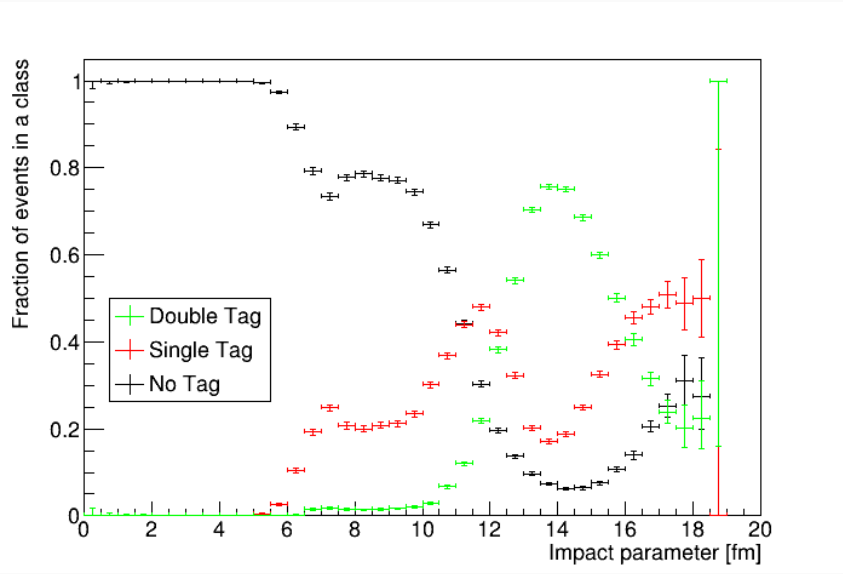


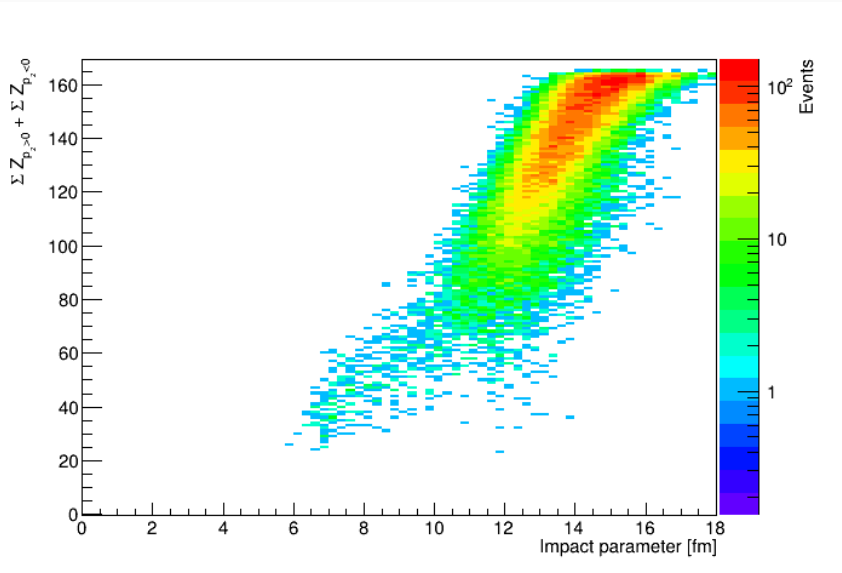


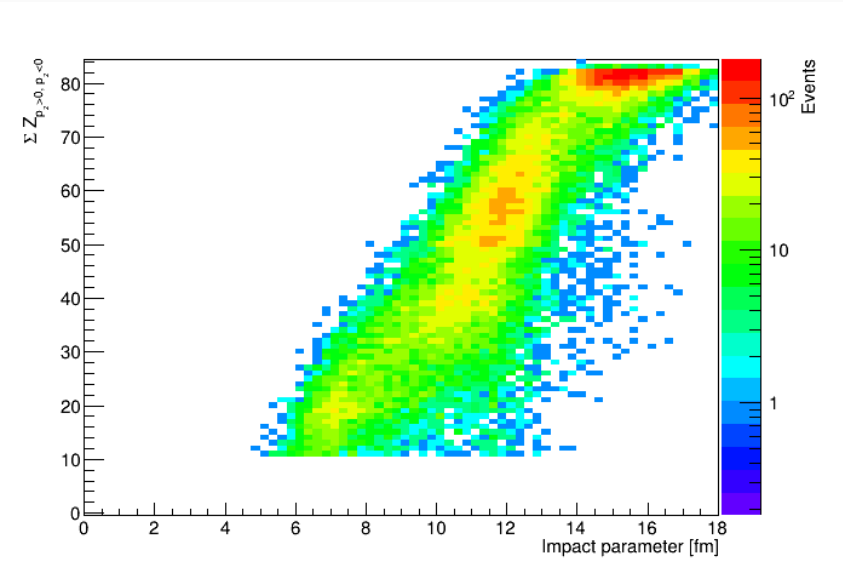


Geometry dependence

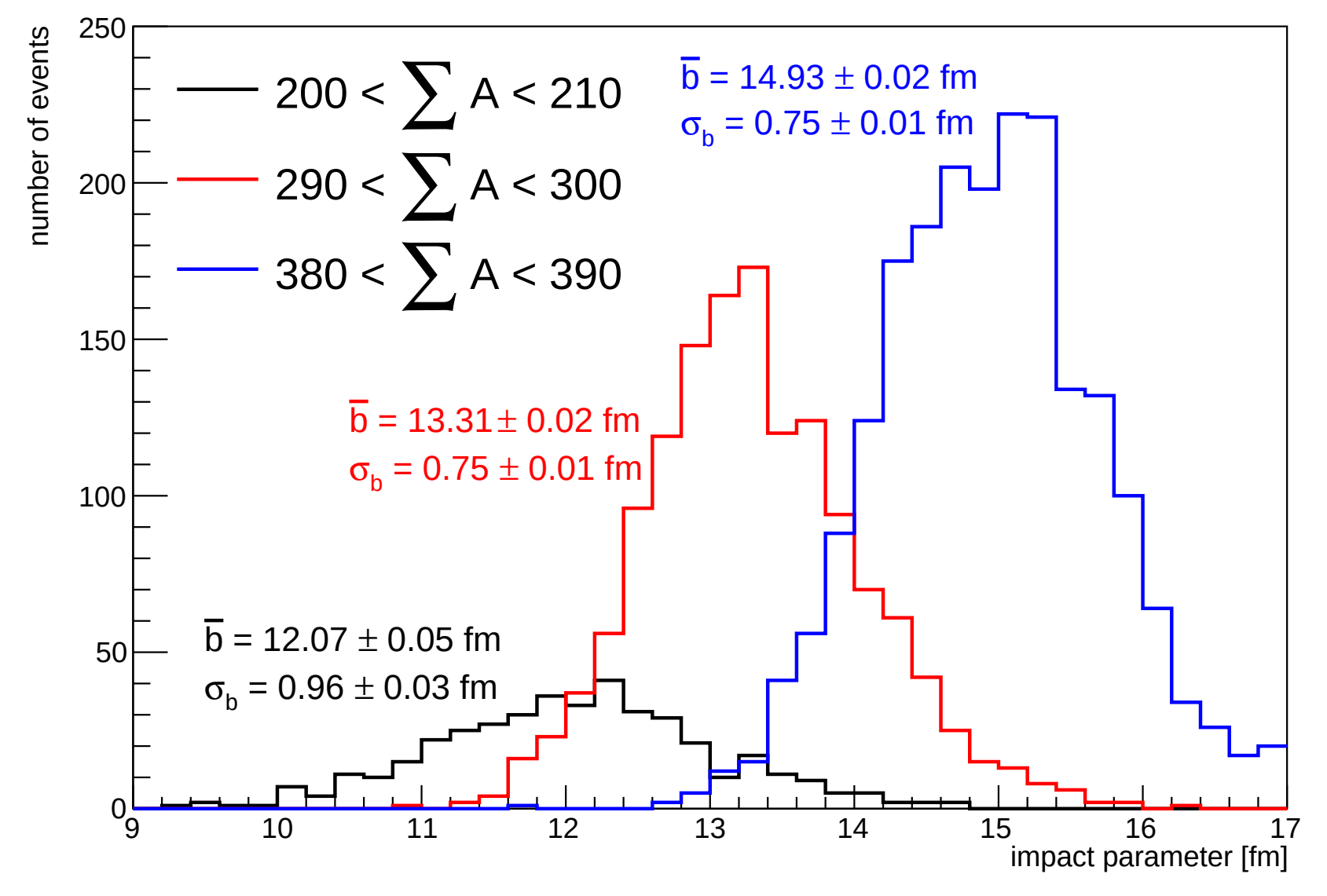




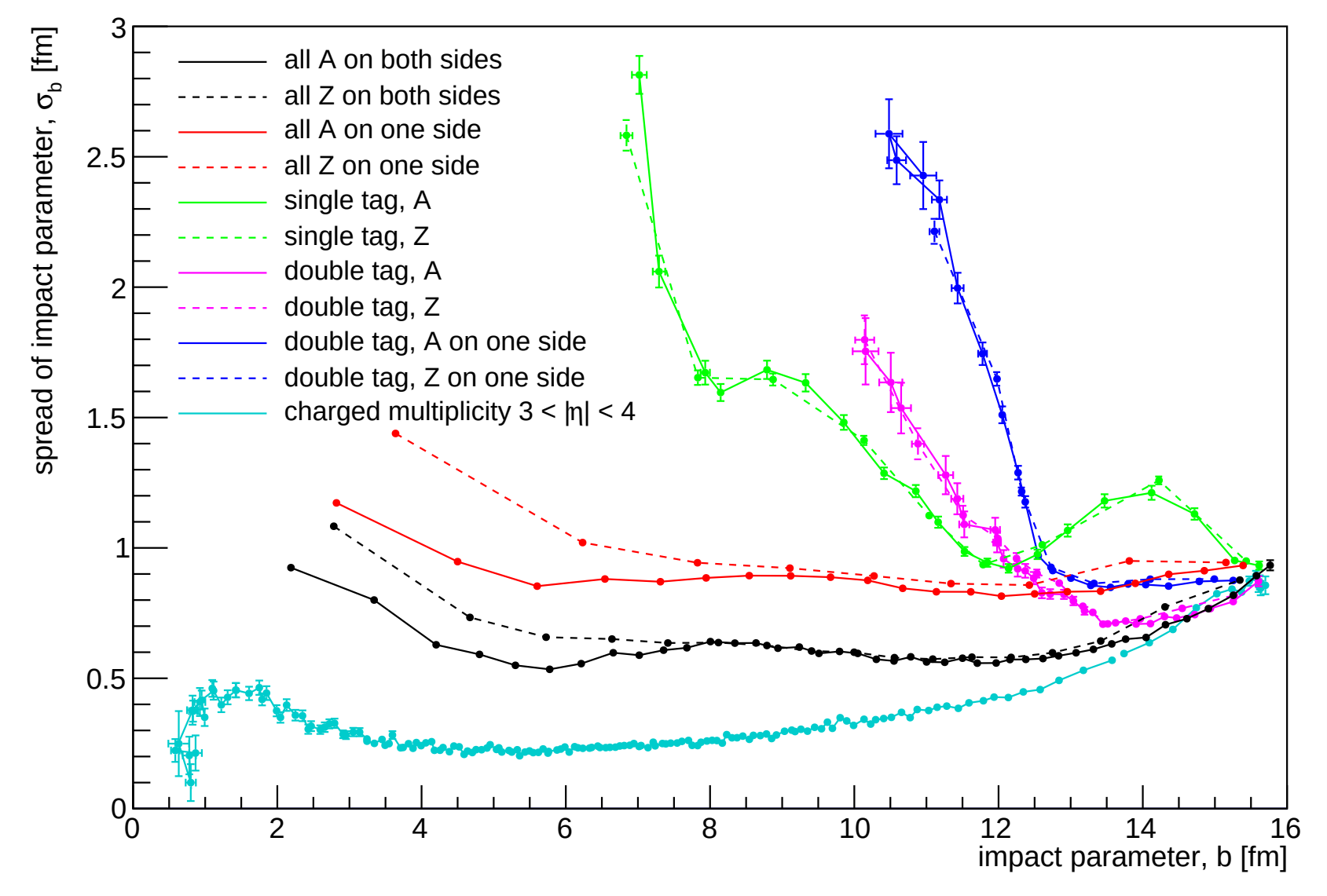




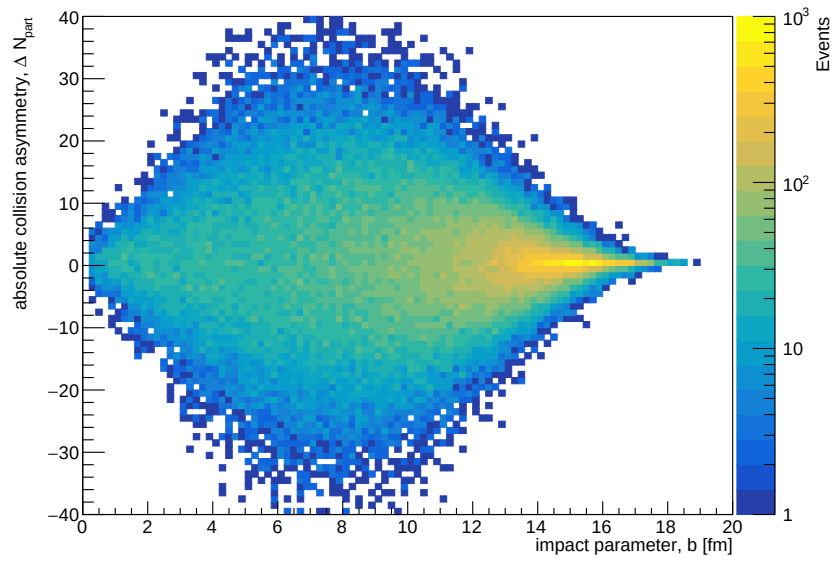
Reconstructing impact parameter

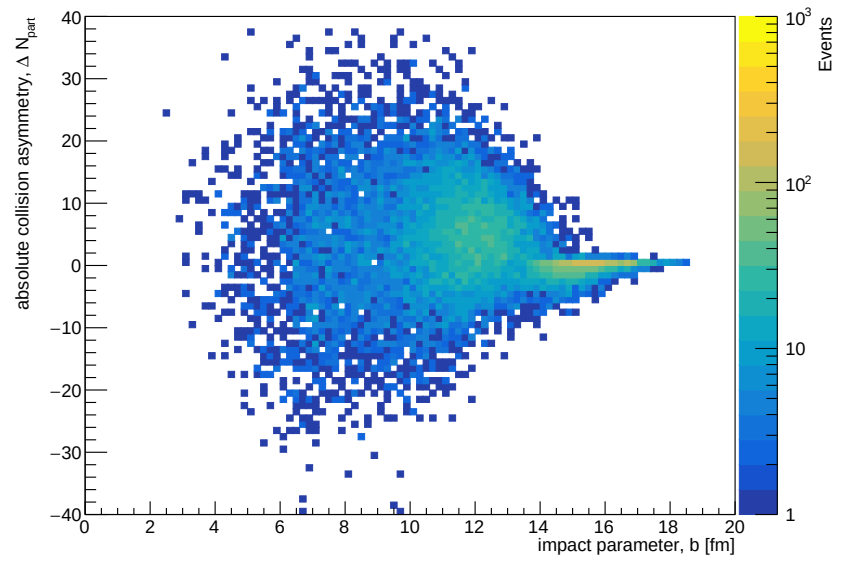


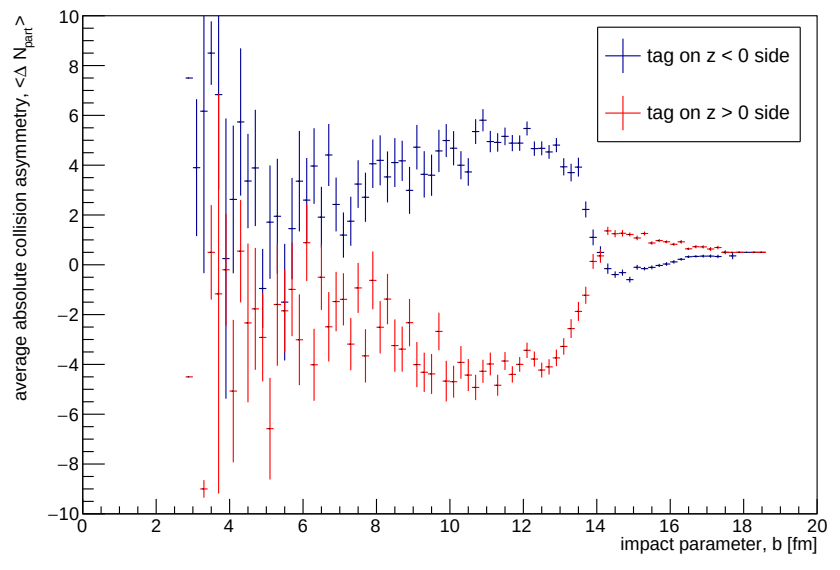
Impact parameter resolution

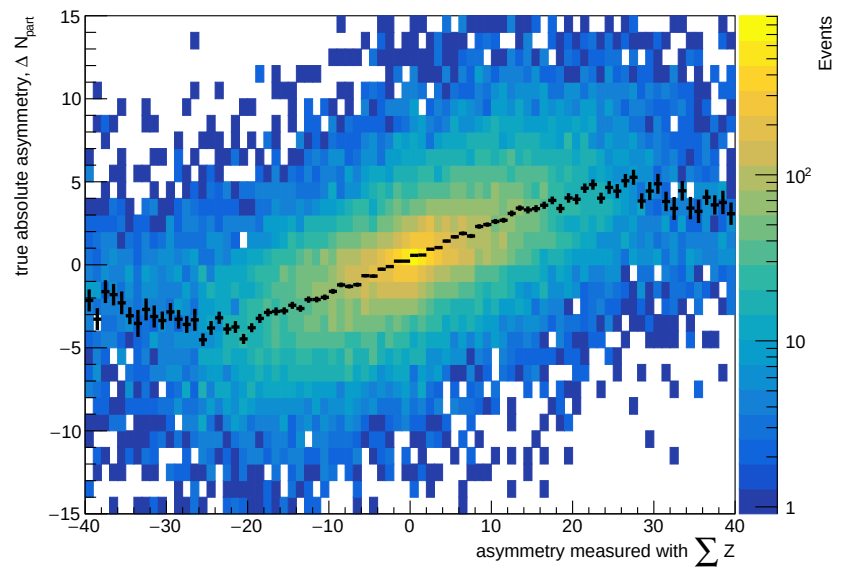


Collision asymmetry









Contents

Conclusions

- Unexpected physics case for RPs in HI physics
- High boost $\rightarrow$ search for new, ultra-short-lived nuclei?
- Sensitivity to collision geometry
  - impact parameter / centrality
  - asymmetry
  - supplementary to other methods
  - Only partial acceptance – not all spectators can be detected, some modelling needed
- Detectors
  - no room for calorimetry in RP
  - charge measurement via dE/dx?
  - tracking detectors are not tested with heavy nuclear fragments; not clear how they would respond