Forward spectator detector for CBM

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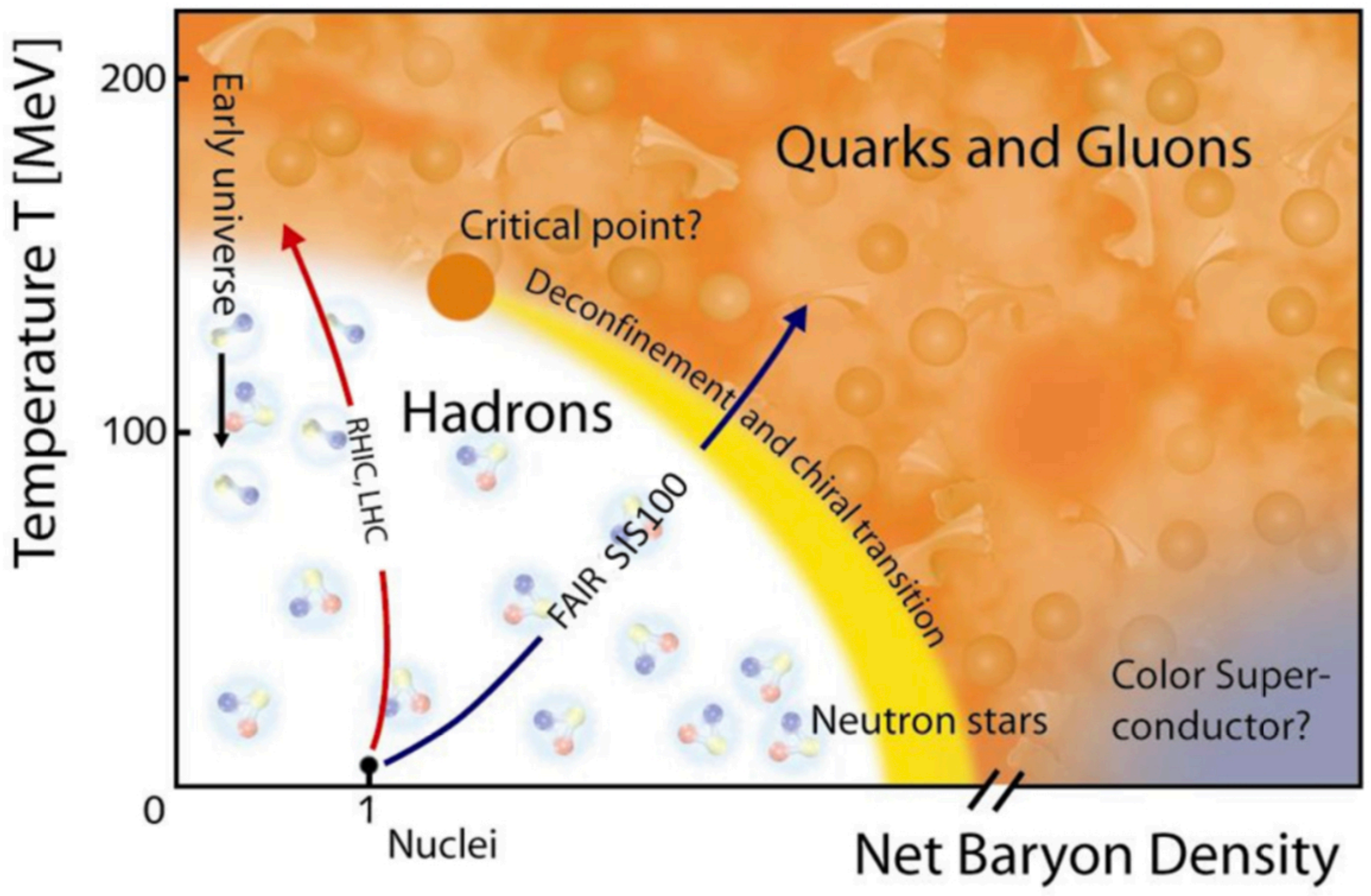
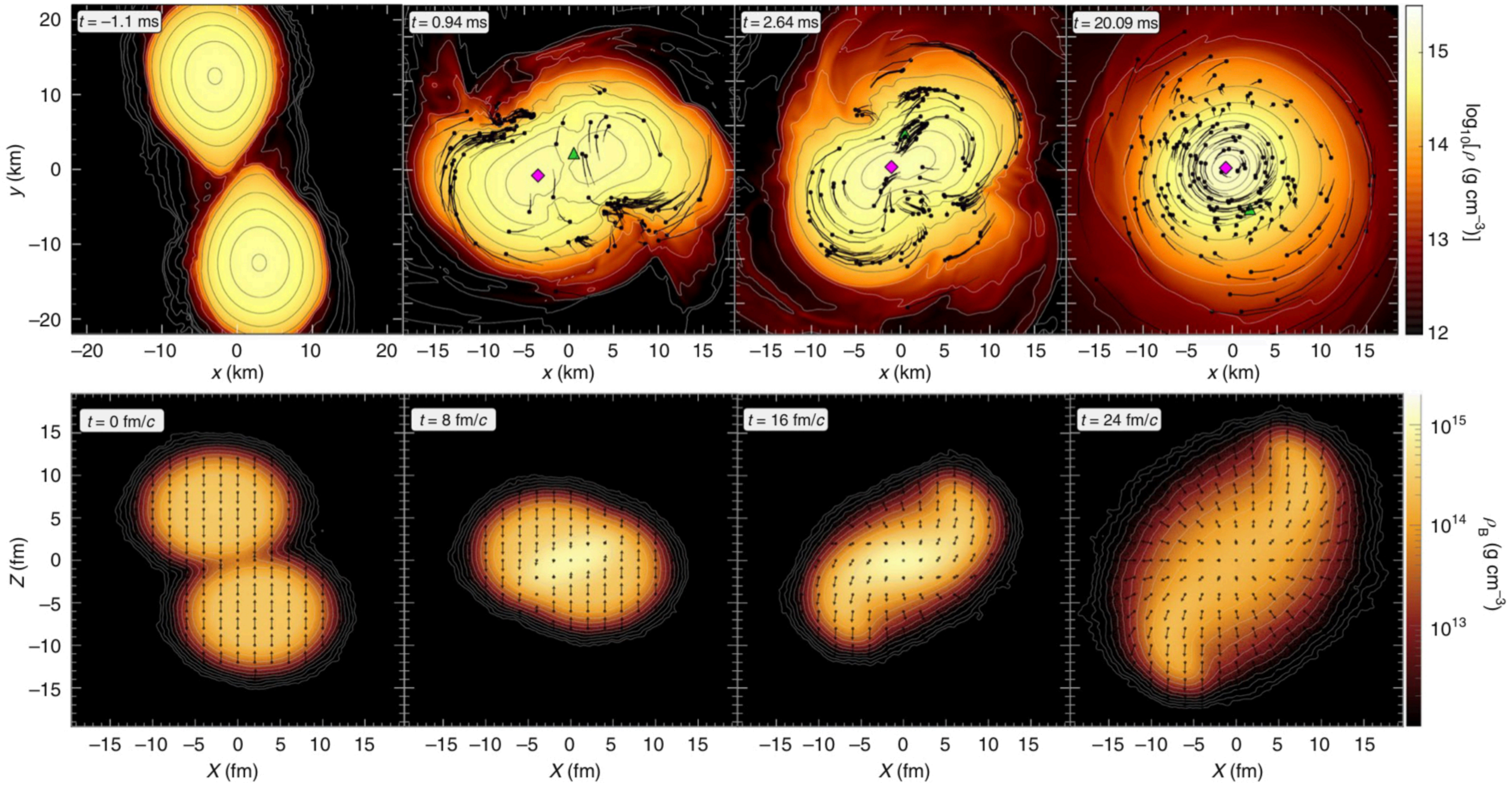
FAIR next generation scientists - 8th Edition Workshop

Motivation

- Measurement of the properties of the strongly interacting matter at high densities
- Phase diagram of strongly interacting matter
    - Phase transition and search for critical point
- Properties of neutron stars

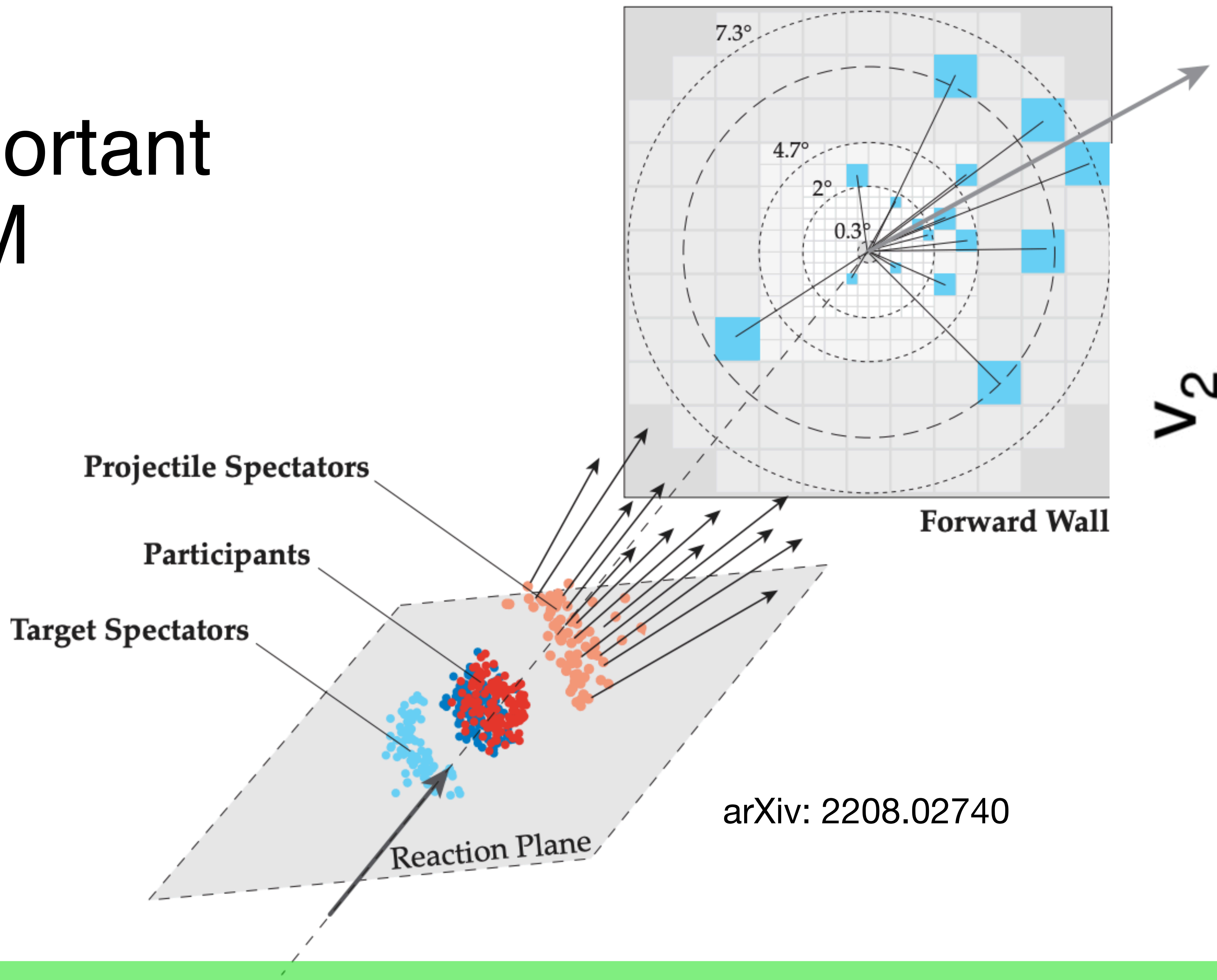




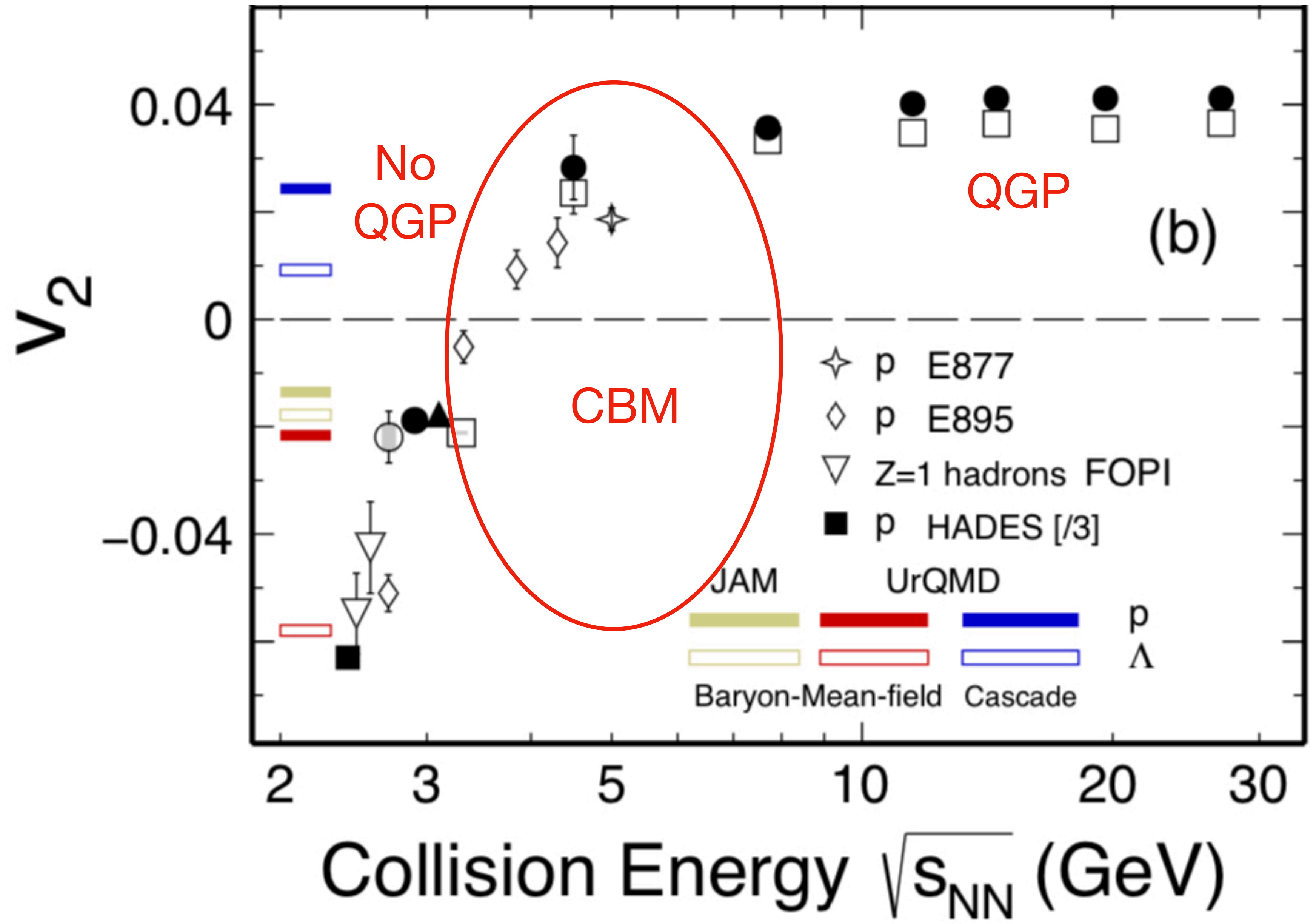
Measurement of flow

$$\rho = \frac{1}{2\pi}\left[1 + 2\sum_{n=1}^{\infty} v_n \cos(n(\phi - \psi_{ep}))\right]$$

- Flow = azimuthal anisotropy of detected particles
- One of the most important observables for CBM
- Event plane
- Projectile spectators

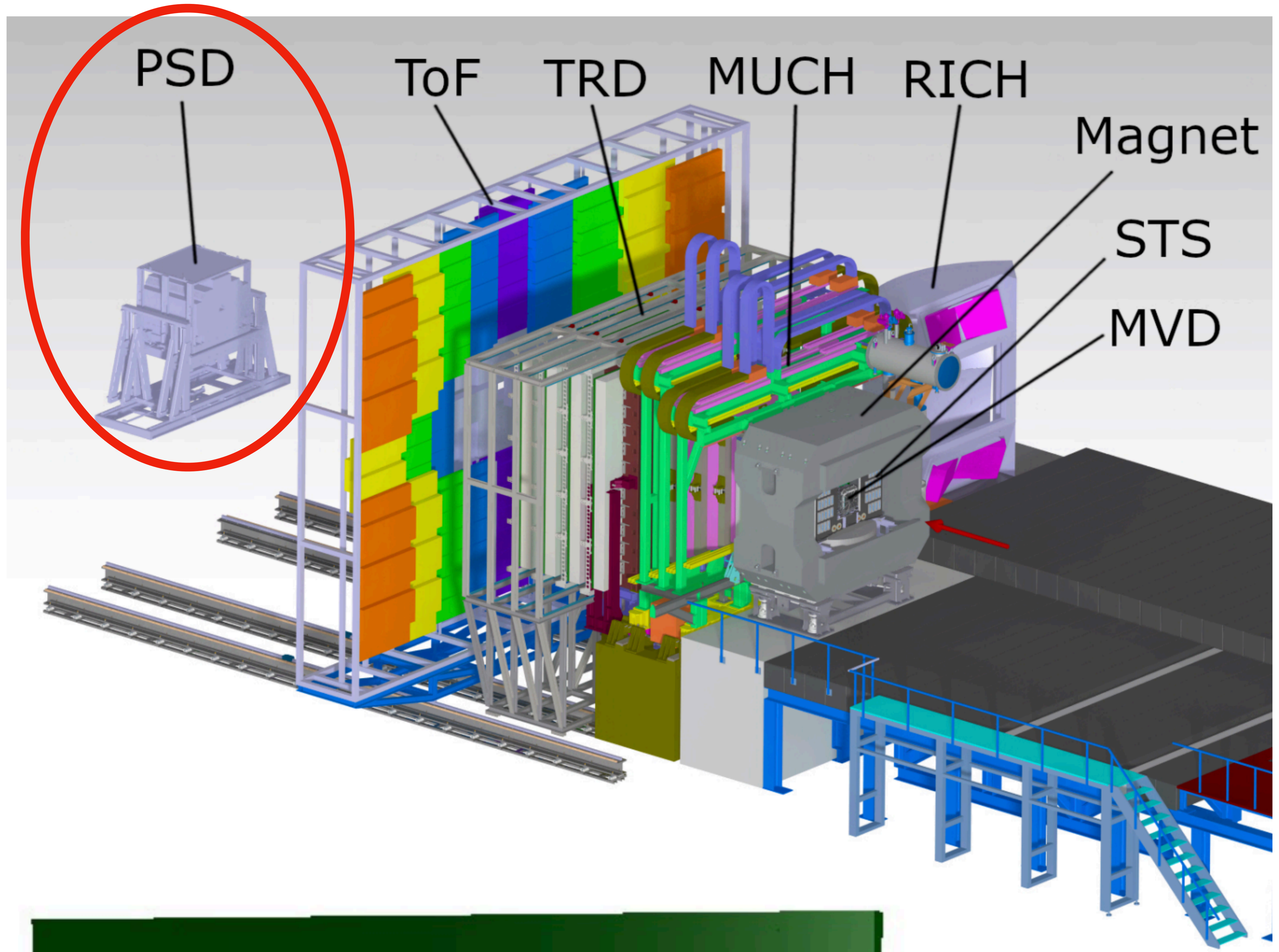


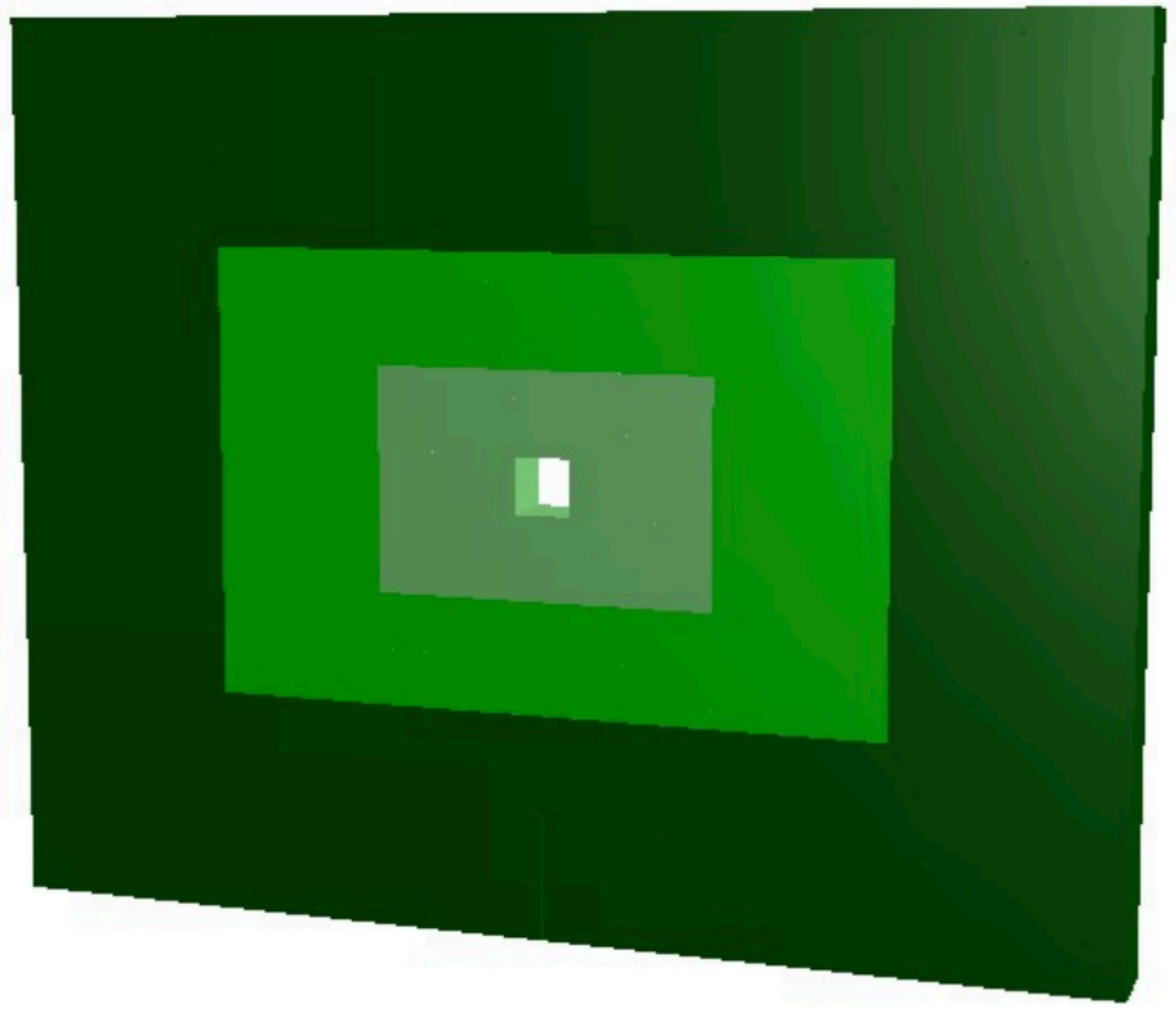
arXiv: 2208.02740



FSD detector

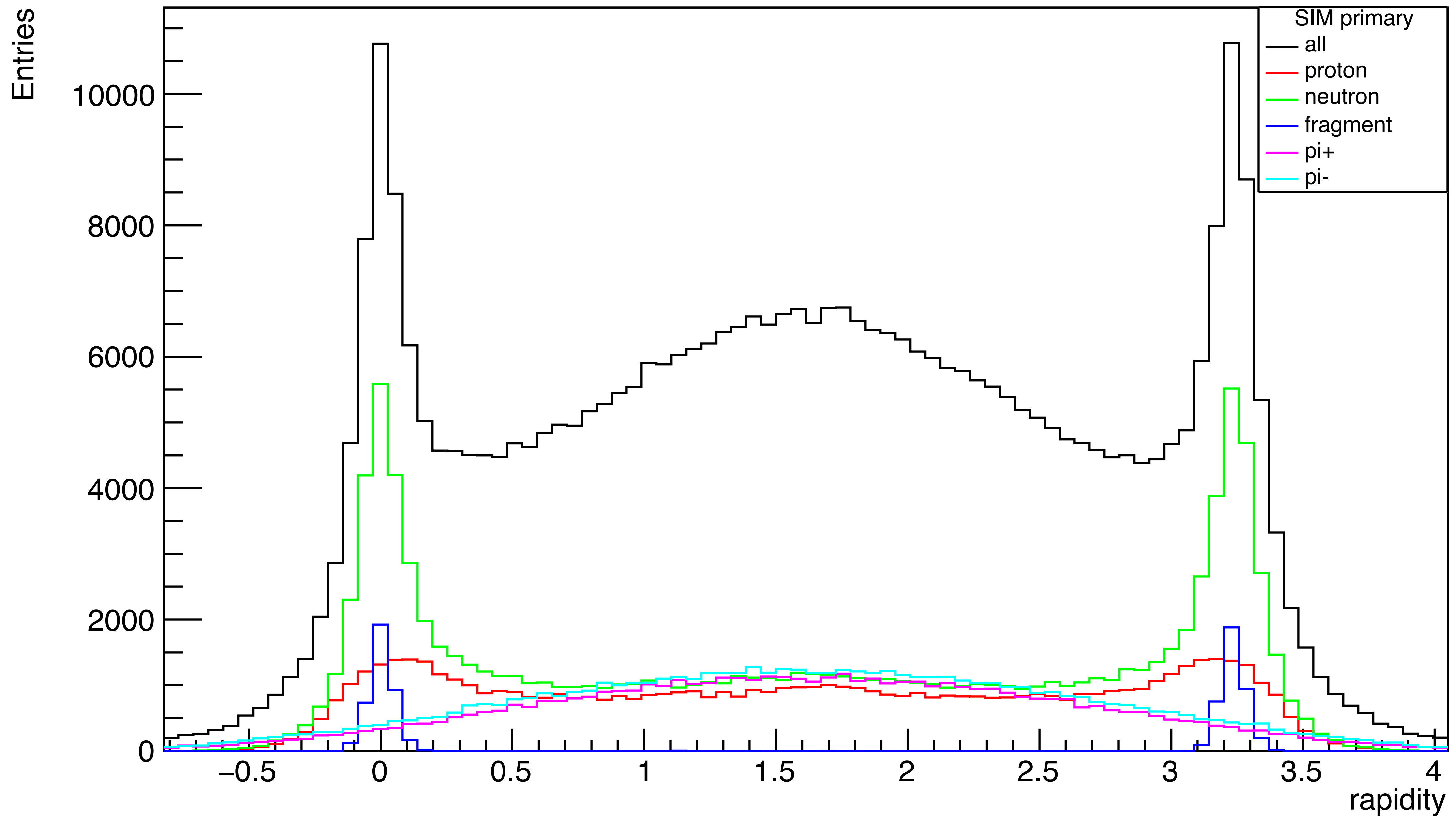
- Part of the CBM experiment
- Replacement of the PSD
- Centrality and reaction plane determination
- Scintillator based detector with PMTs
  - Measurement of protons and fragments



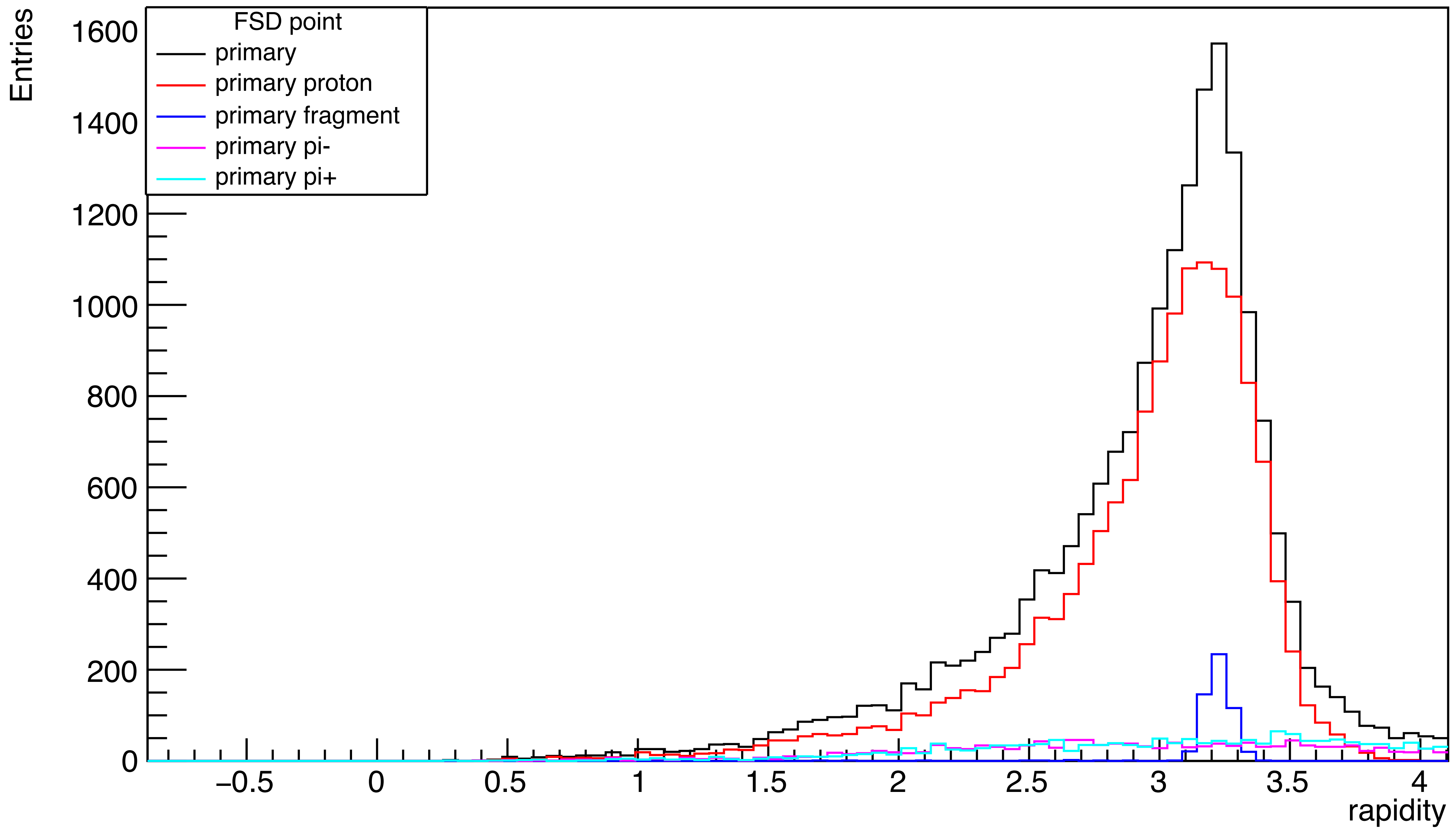


Acceptance

- DCMQGSM model, 12 AGeV collision
- Rapidity plot of primary particles

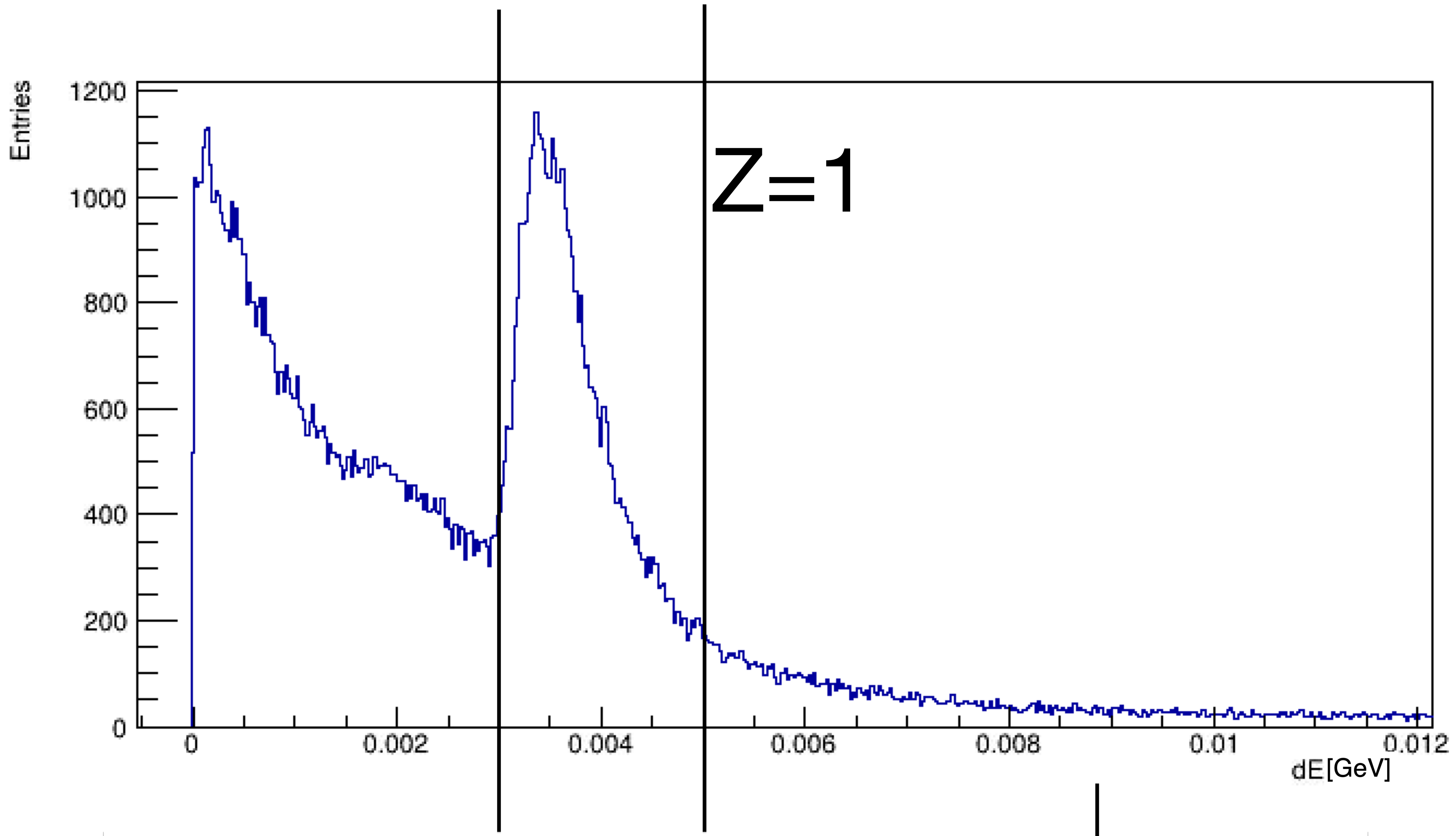


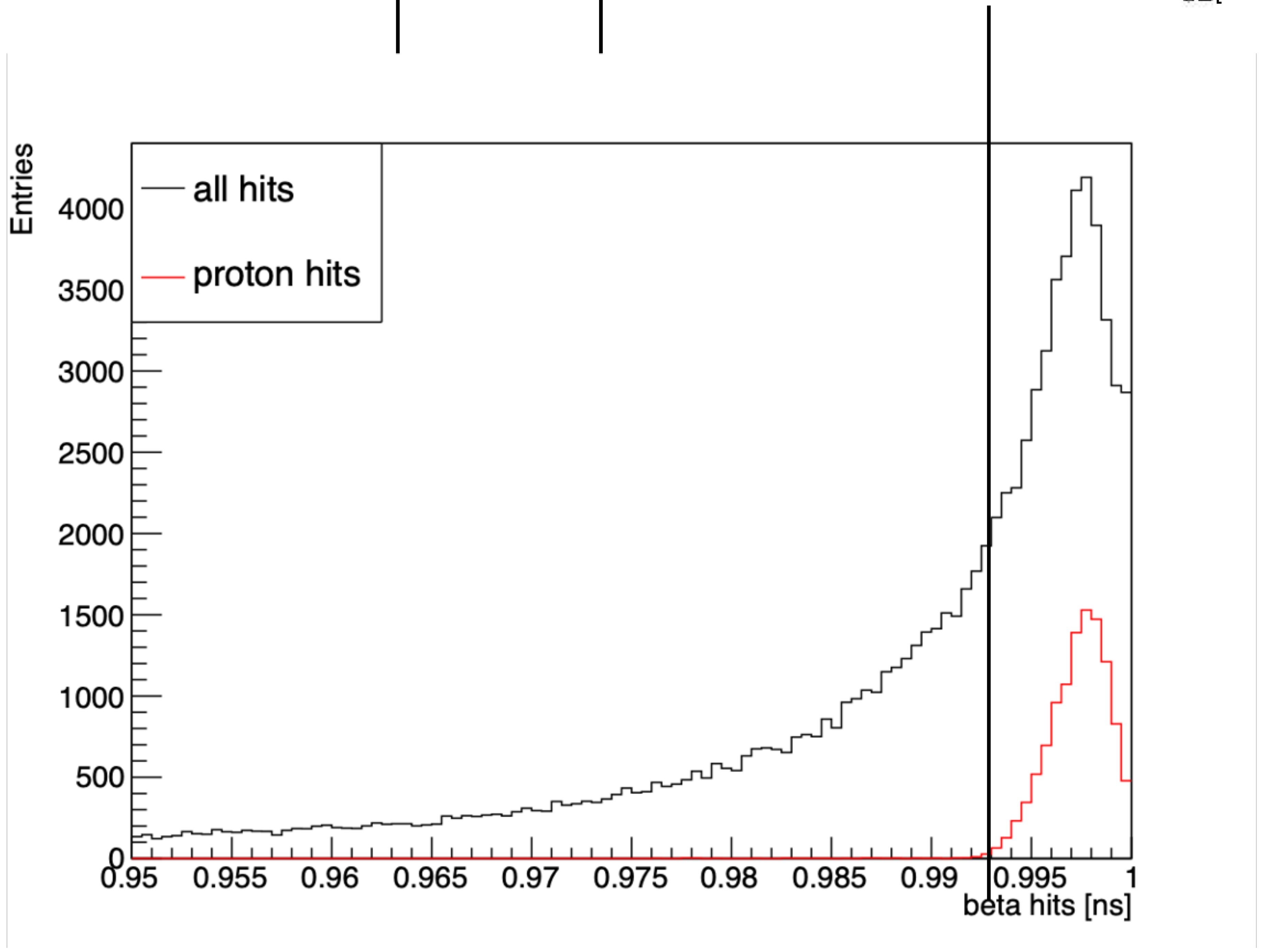
- Rapidity plot of primary particles with a point in FSD



Energy deposition in FSD

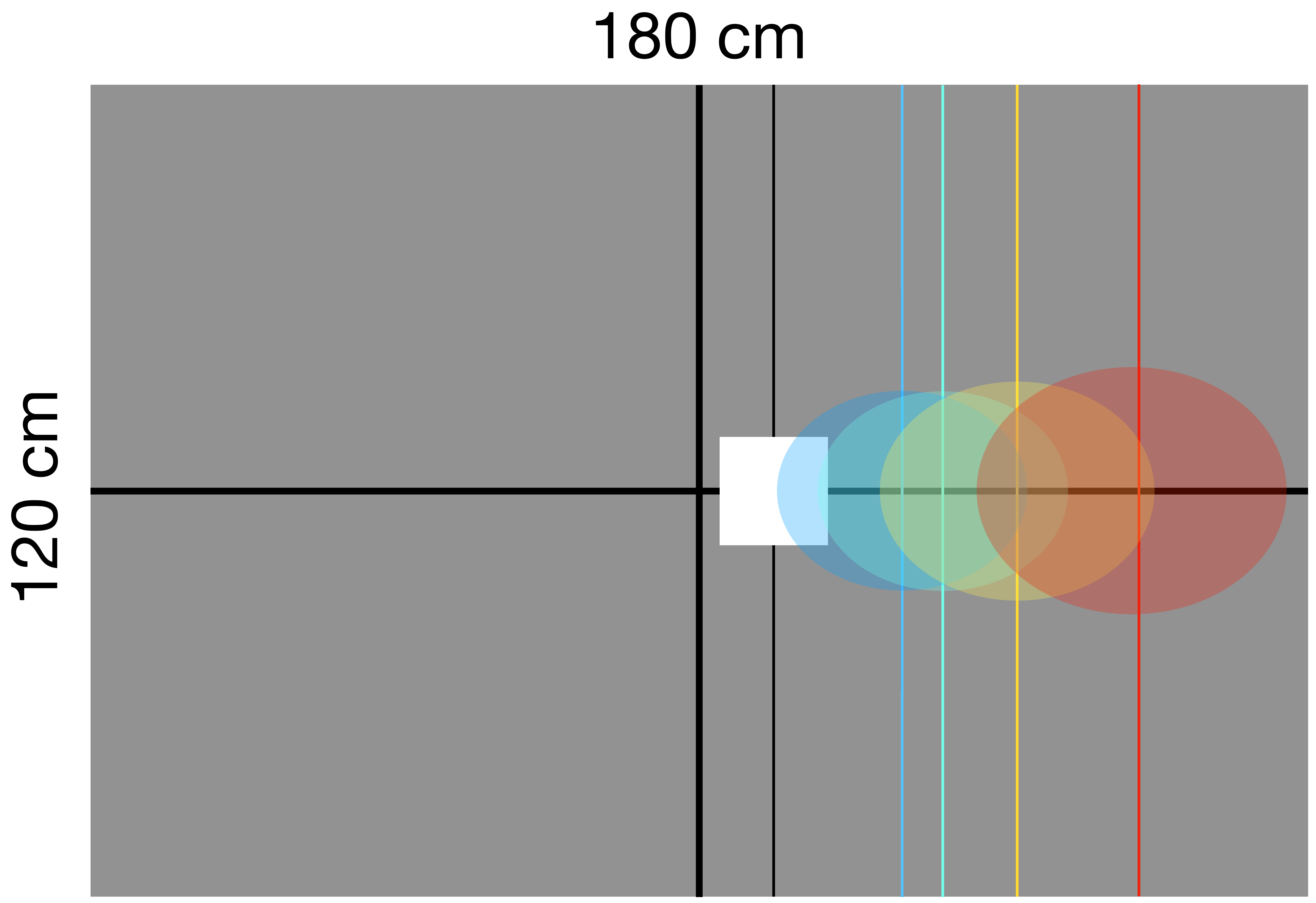
- Identification of Z=1 particles
  - dE = [3, 5] MeV
  - „beta“ of a hit > 0.993
    - Line between primary vertex and FSD hit





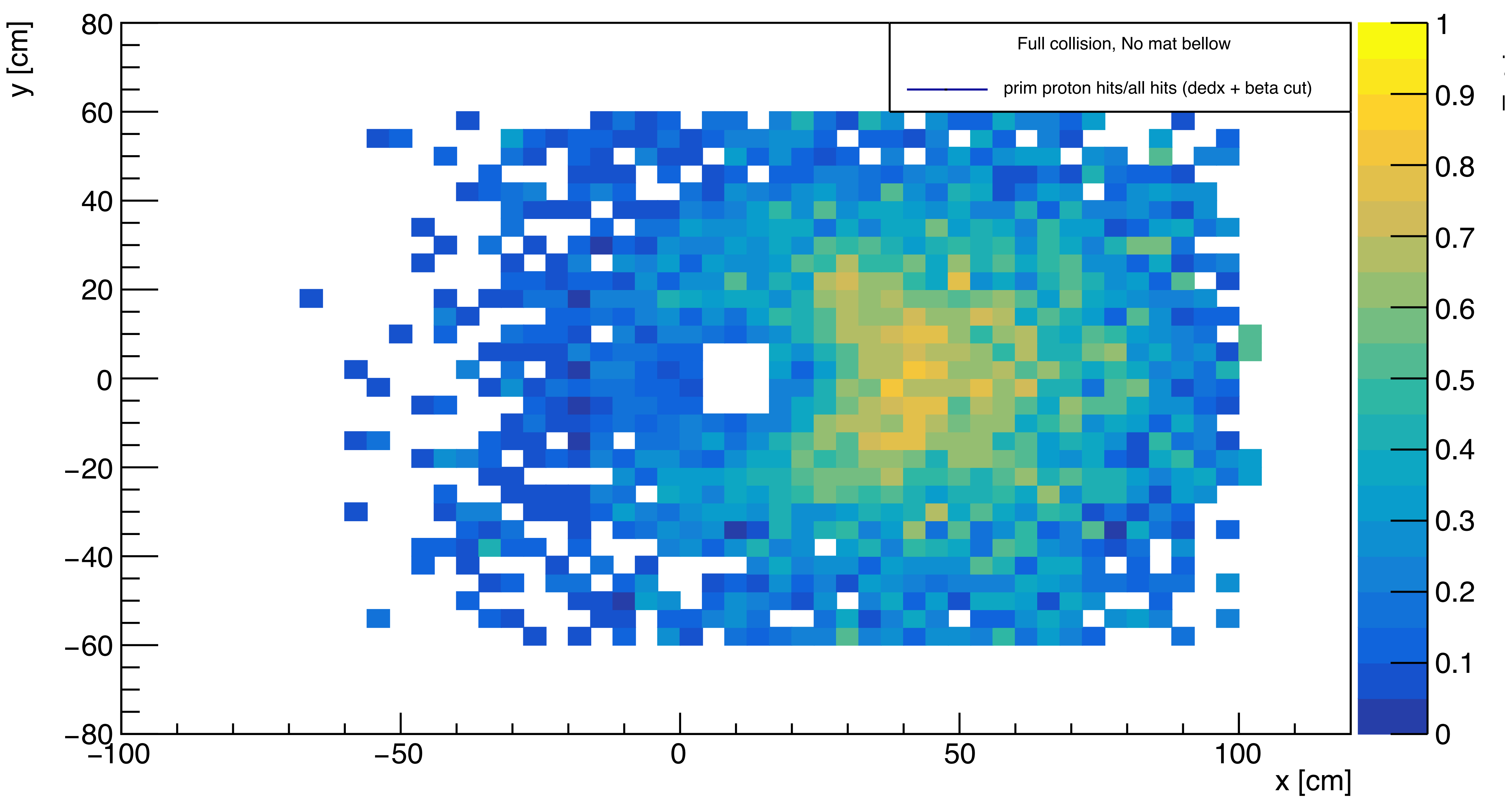
Effect of magnetic field

- Information about RP is carried by primary protons
- Different rapidities centered in different x position due to the magnetic field
- y=[3.3-3.6] -> x = 30.6 cm
- y=[3.0-3.3] -> x = 36.6 cm
- y=[2.7-3.0] -> x = 46.8 cm
- y=[2.4-2.7] -> x = 64.7 cm

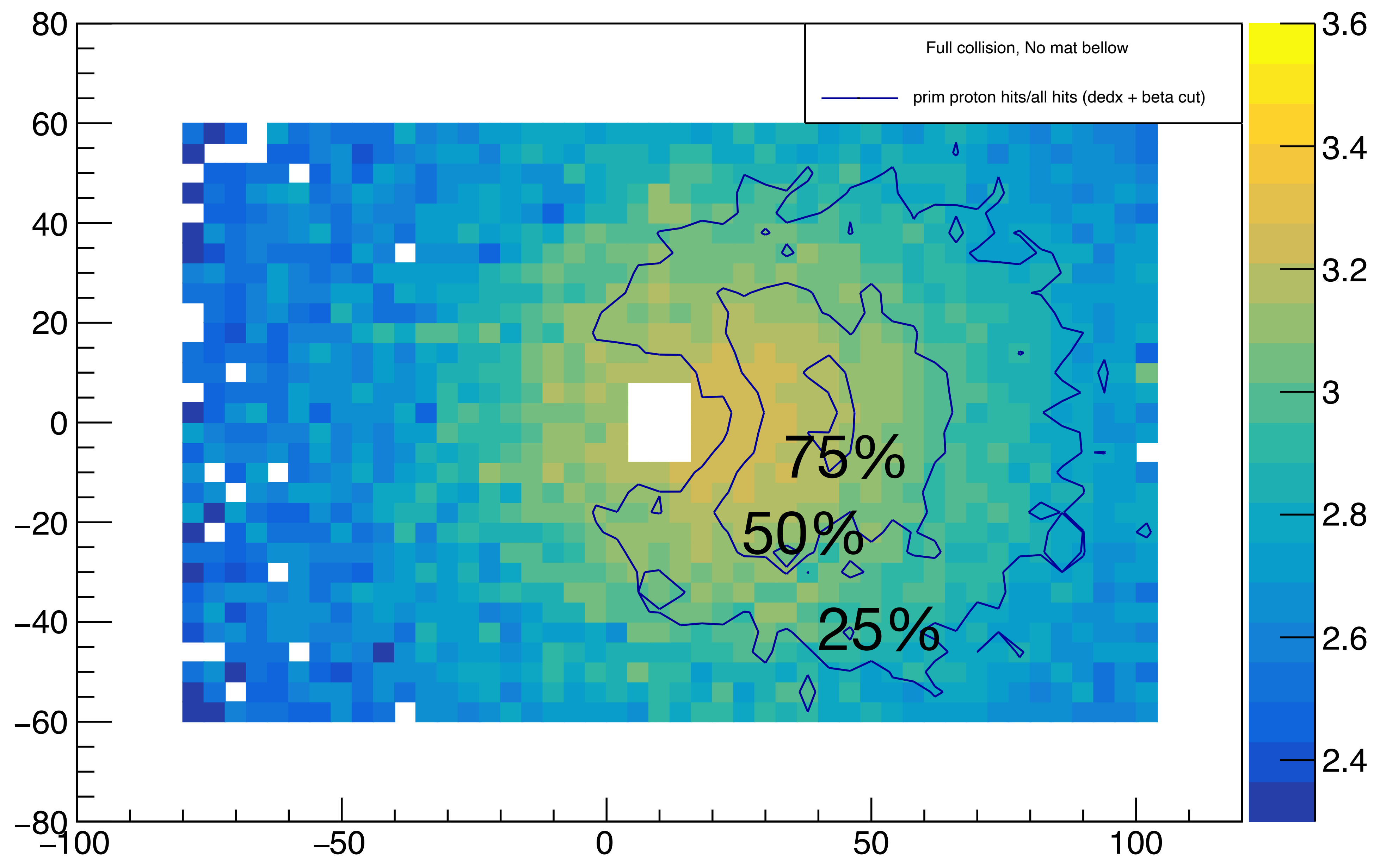


Purity of detected proton signal

- Ratio of hits from primary protons to all hits



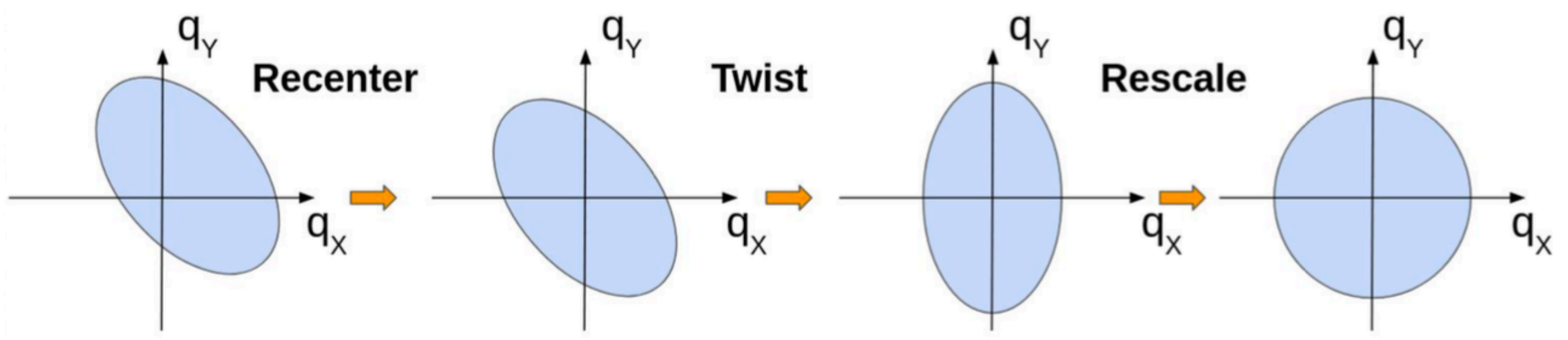
- Mean rapidity of primary protons



Measuring of event plane

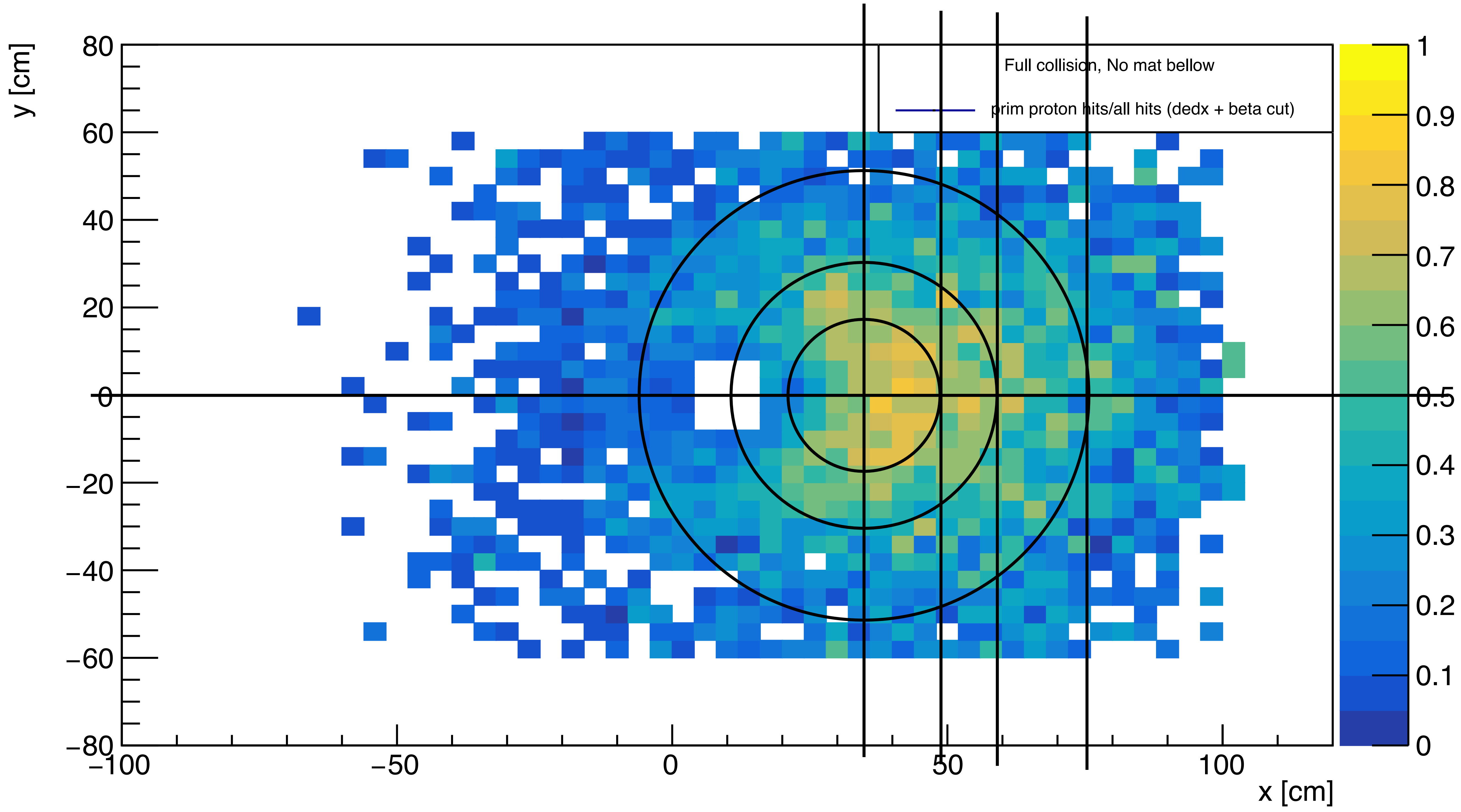
- Qn framework
  - Correcting for detector acceptance
- Definition of Q vectors
- Normalization - SP and EP
- Corrections:
  - Recenter, Twist, Rescale

$$\mathbf{u}_n = \{\cos n\varphi,\ \sin n\varphi\}, \quad \mathbf{Q}_n = \sum_{i=1}^{N} w_i \mathbf{u}_{n,i},$$



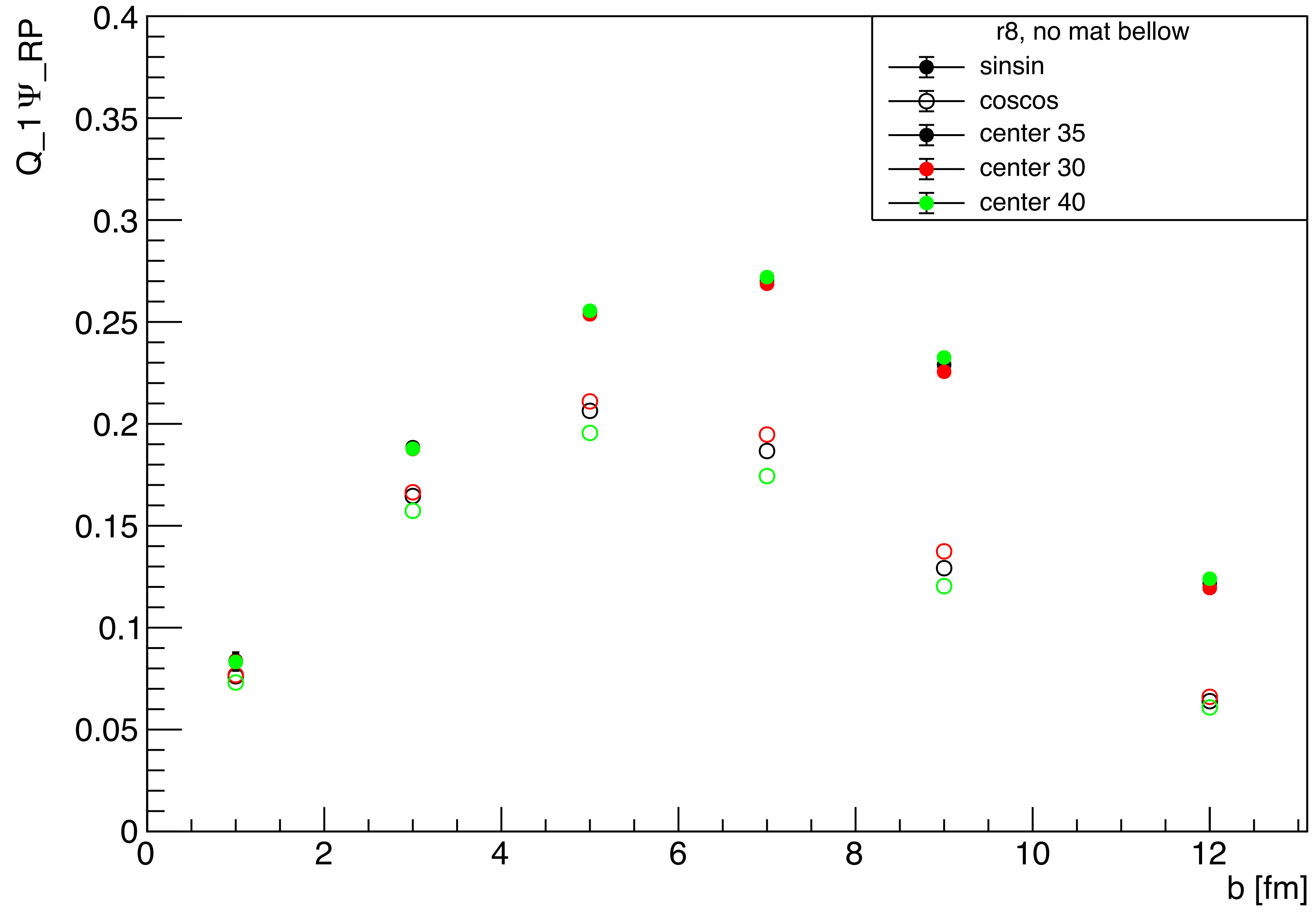
Subevents

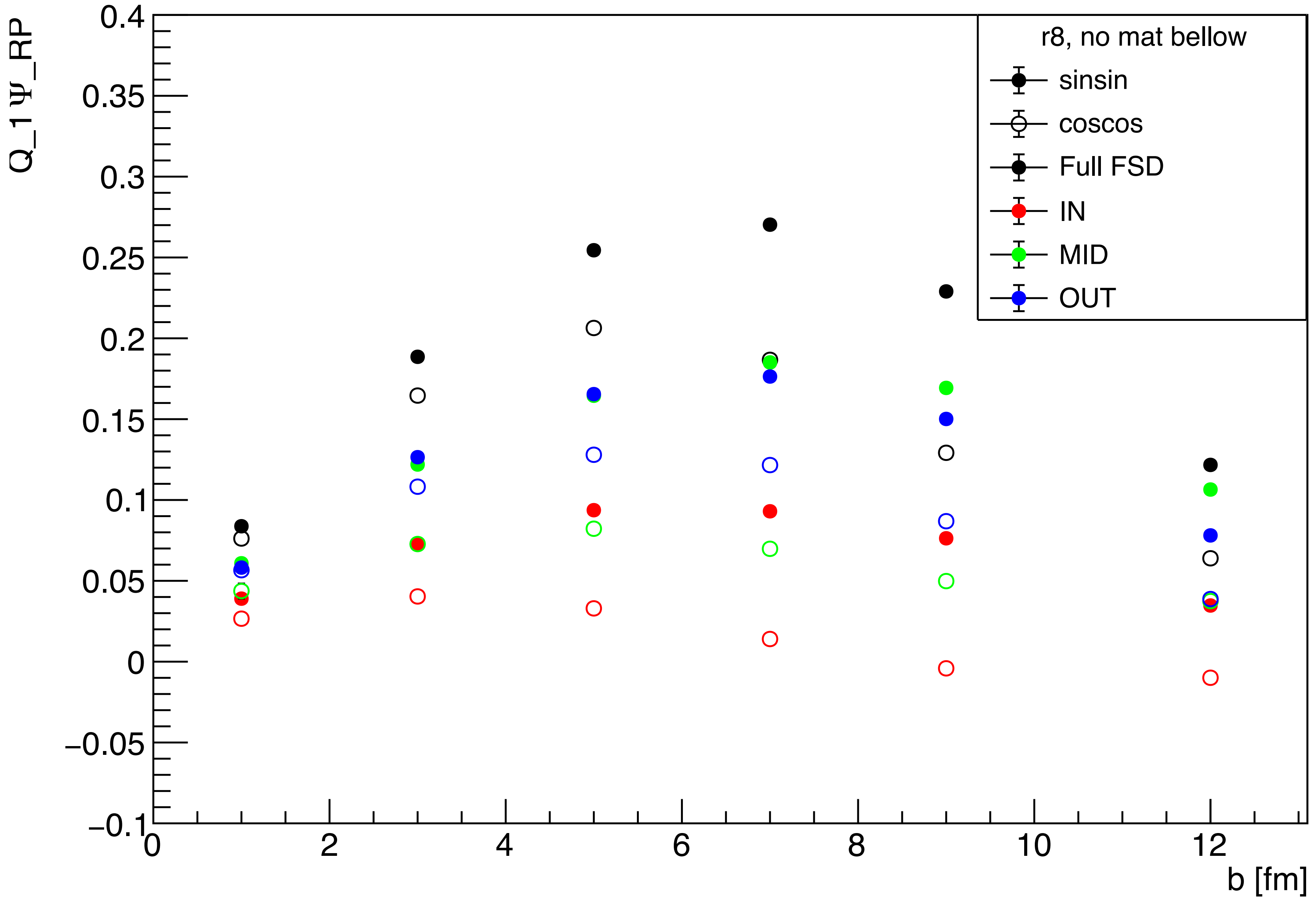
- Subevents:
  - Center: x=35 cm
  - IN=[0,14] cm (58% purity)
  - MID=[14,24] cm (42% purity)
  - OUT=[24,40] cm (23% purity)
- Same number of protons per subevent
- For systematic uncertainty estimation center varied ± 5 cm



Resolution using MC reaction plane

- Correlation of Q vector with RP from MC
  - Q vector after all corrections
- Better resolution for y-axis
- No big difference between differently selected subevents
  - Qn framework seems to work

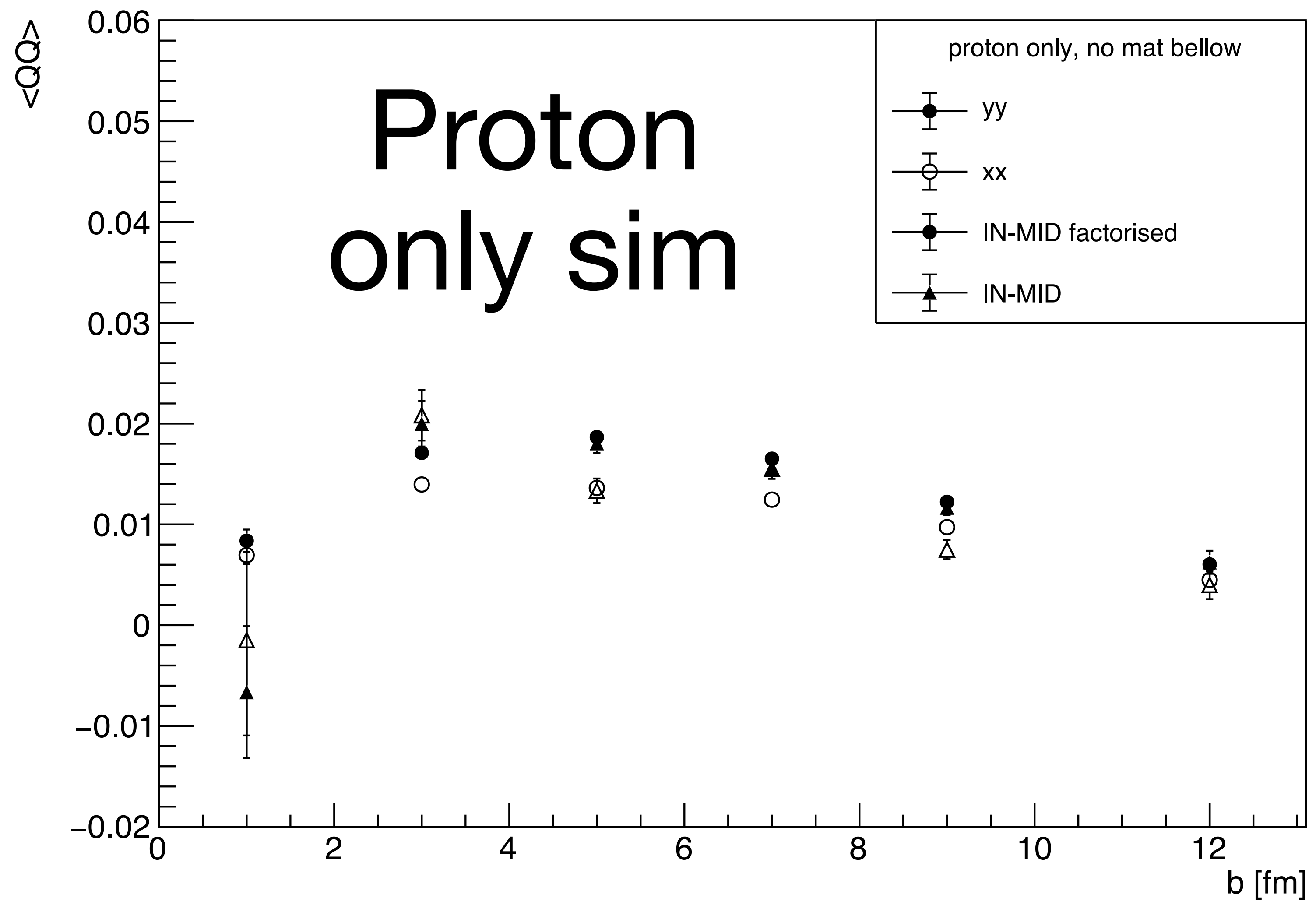


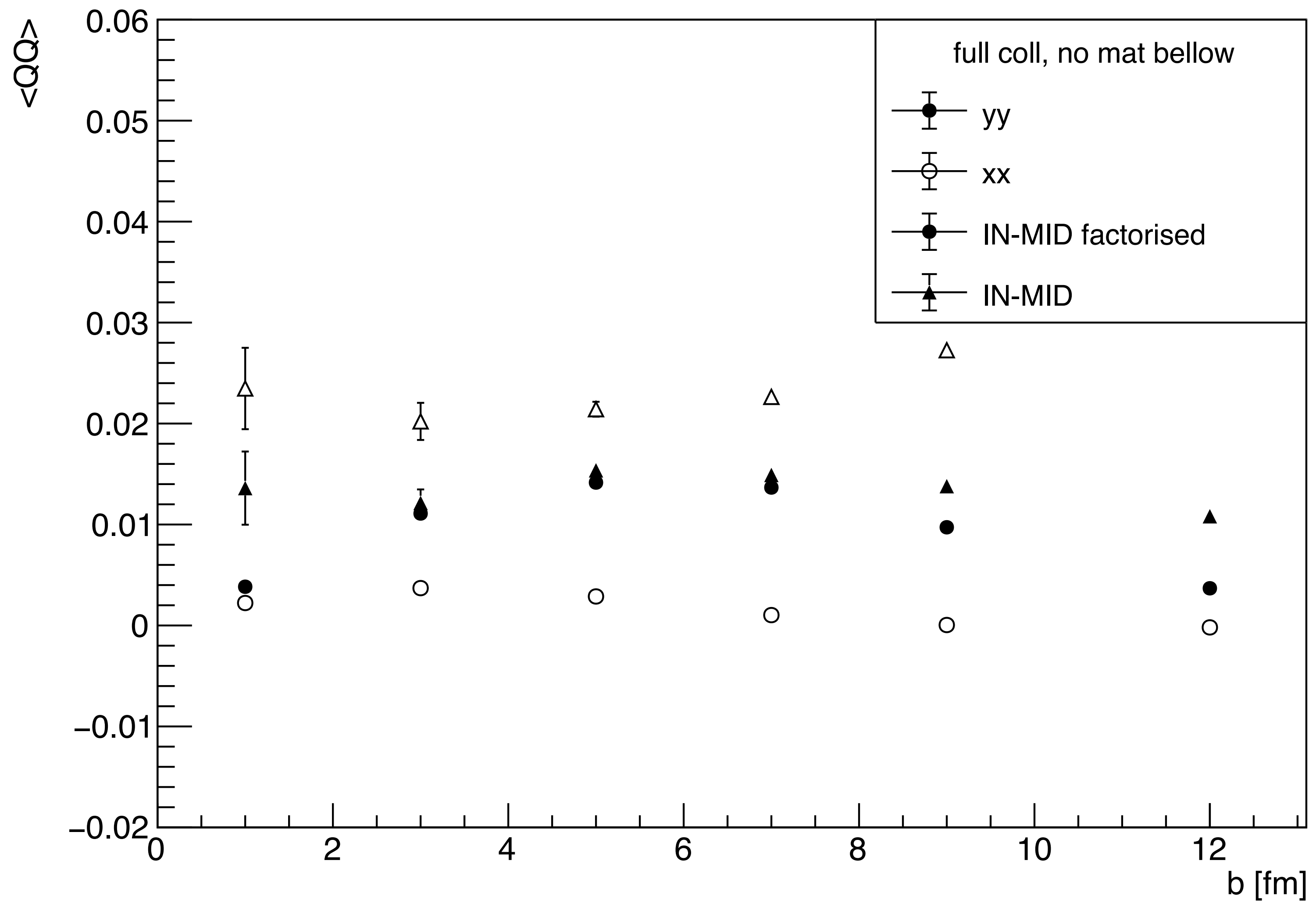


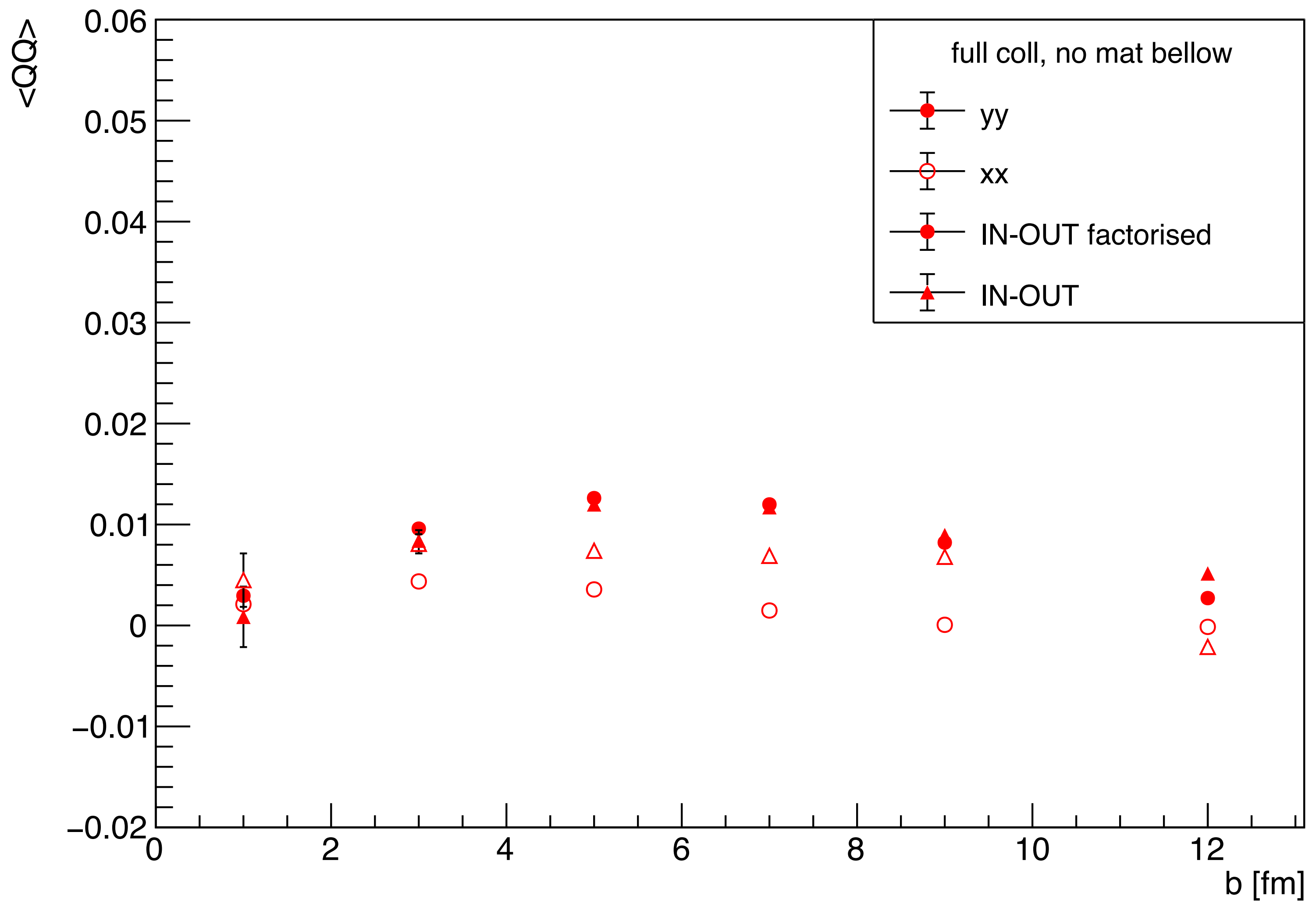
Factorisation

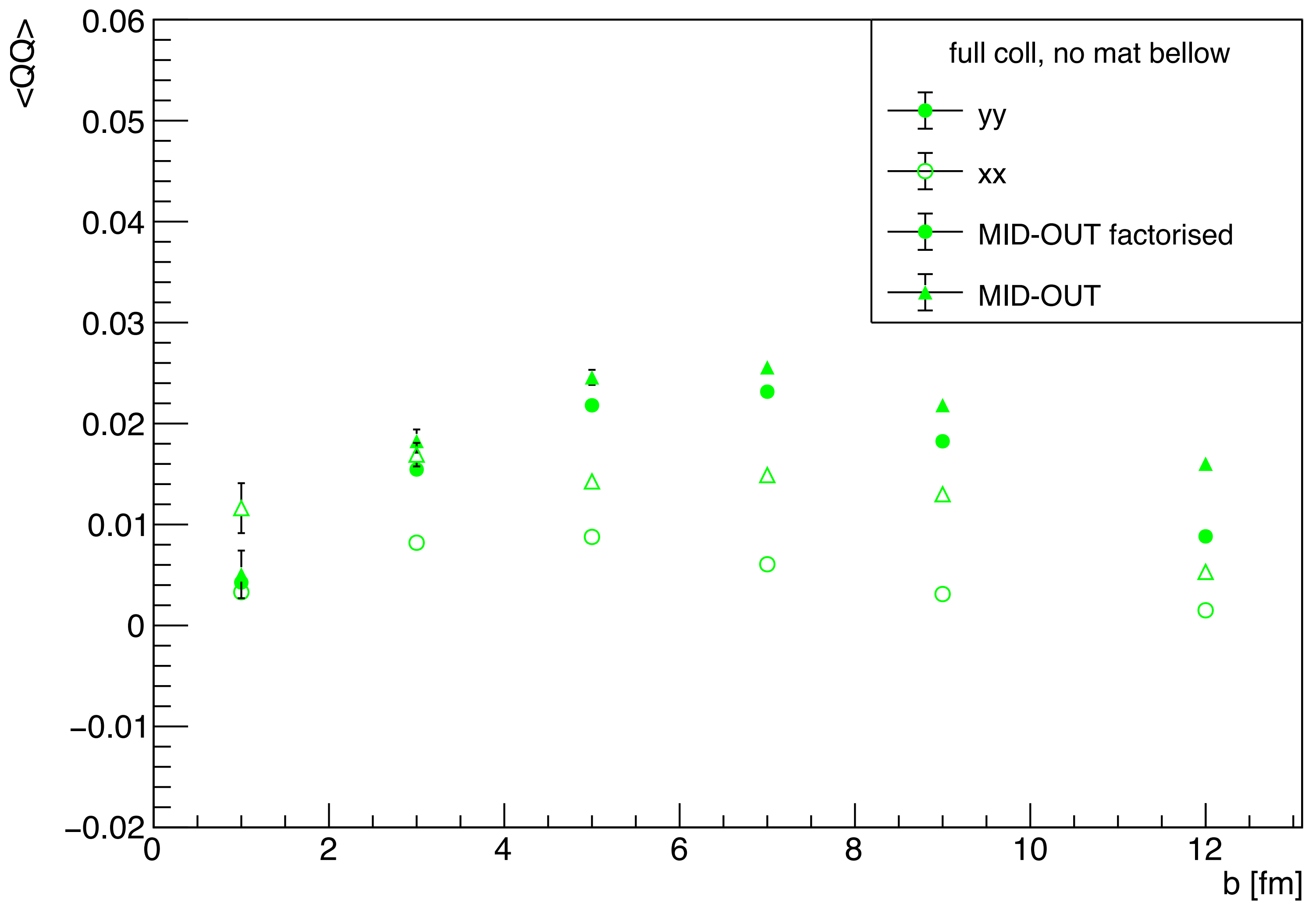
- Checking correlation between subevents
  - Can partially be of physics origin
- Good agreement for pure protons simulation
- Full event
  - yy component works well
  - Difference observed in xx term

$$\langle \mathbf{Q}_n^A \mathbf{Q}_n^B \rangle = \langle \mathbf{Q}_n^A \mathbf{\Psi}_n^{\mathrm{RP}} \rangle \langle \mathbf{Q}_n^B \mathbf{\Psi}_n^{\mathrm{RP}} \rangle,$$





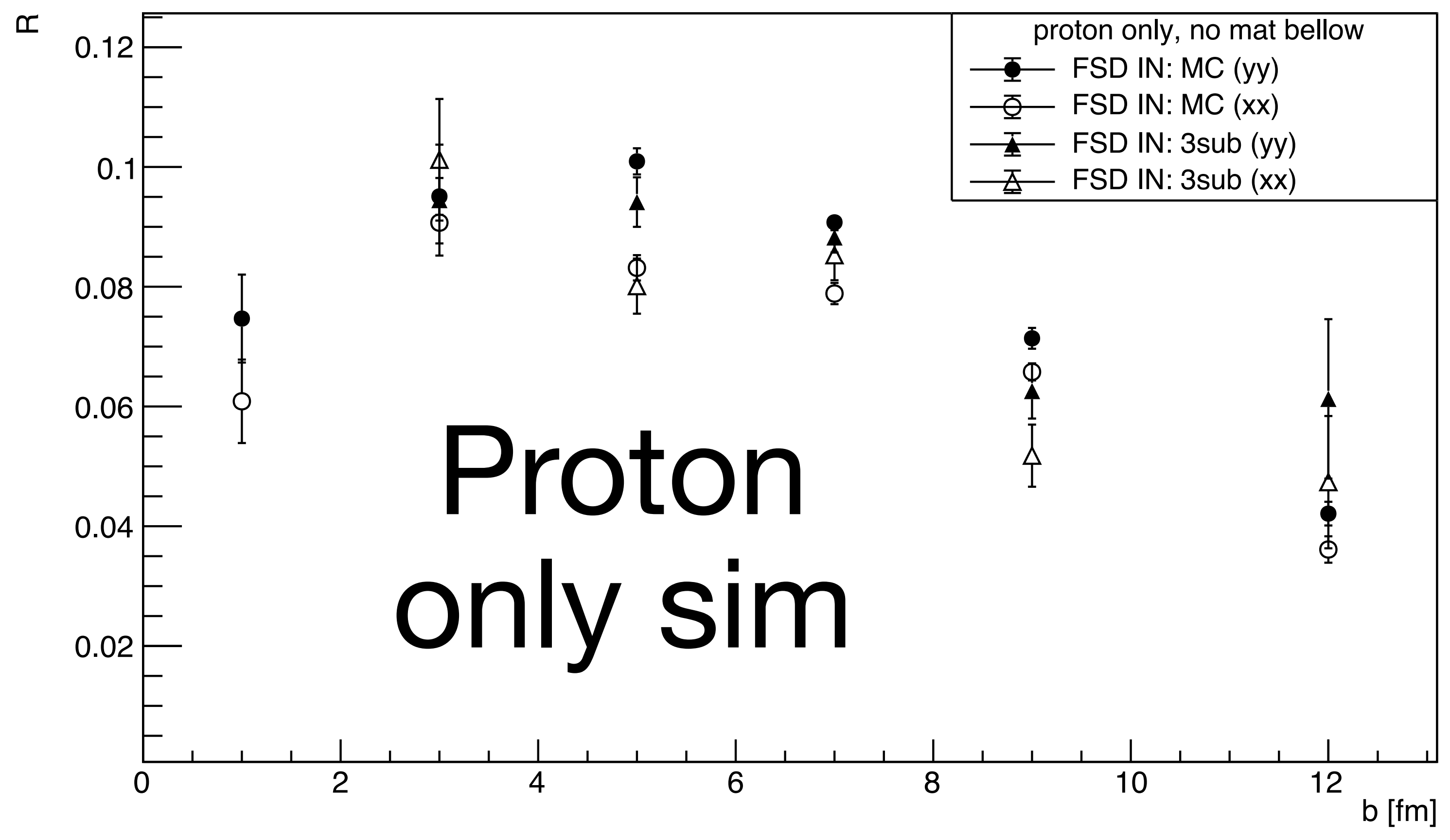


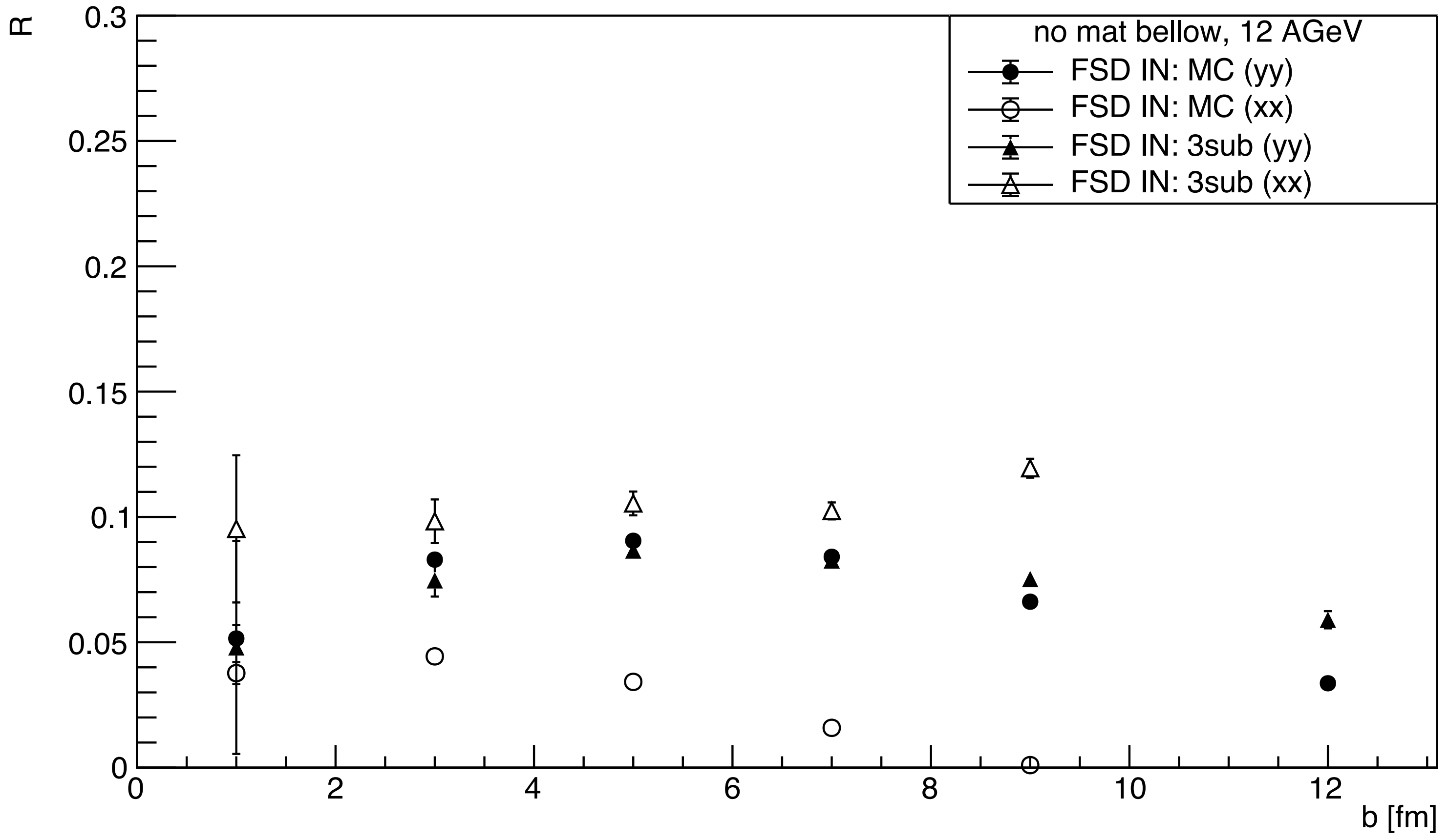


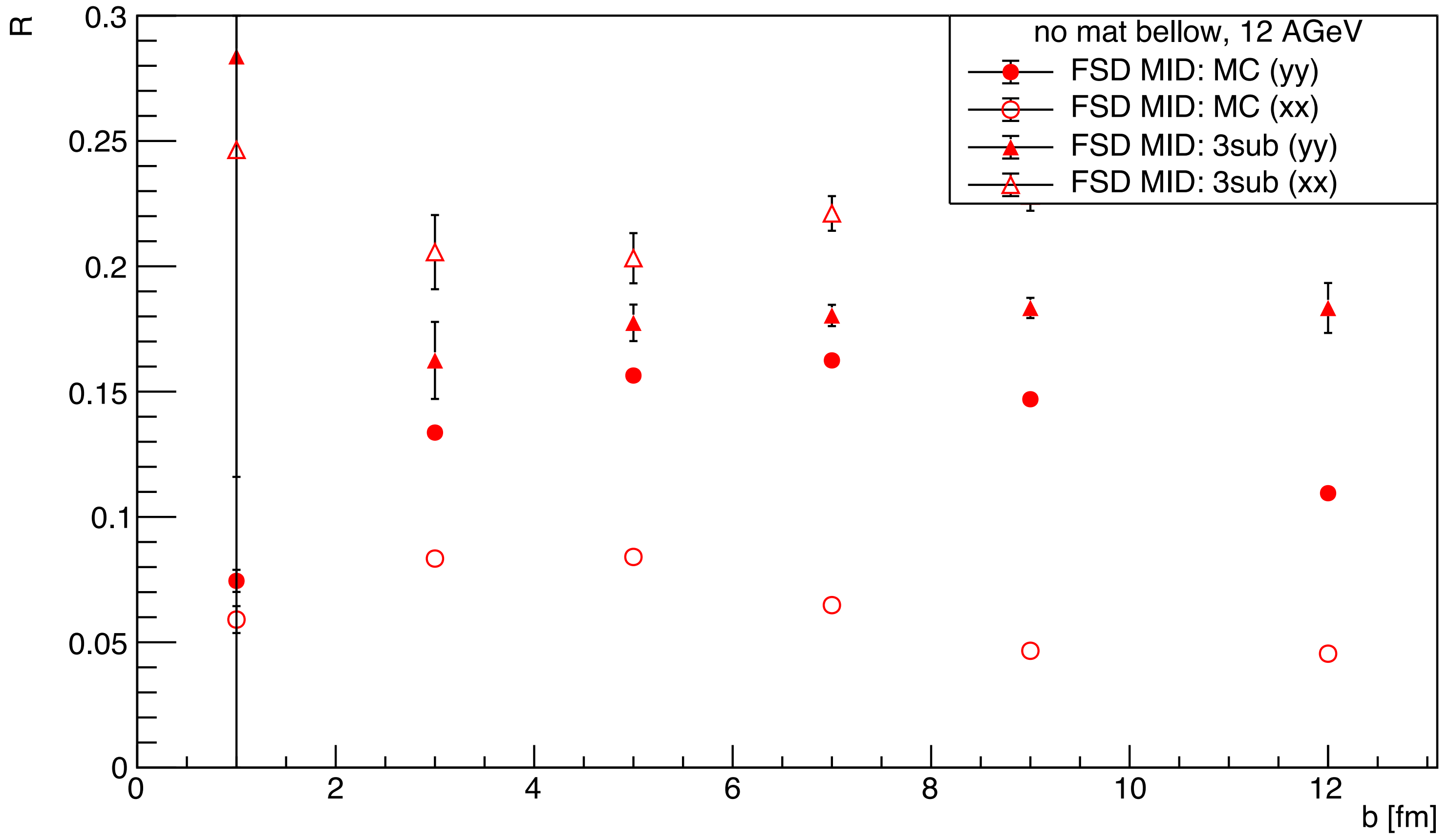
Resolution 3 subevents method

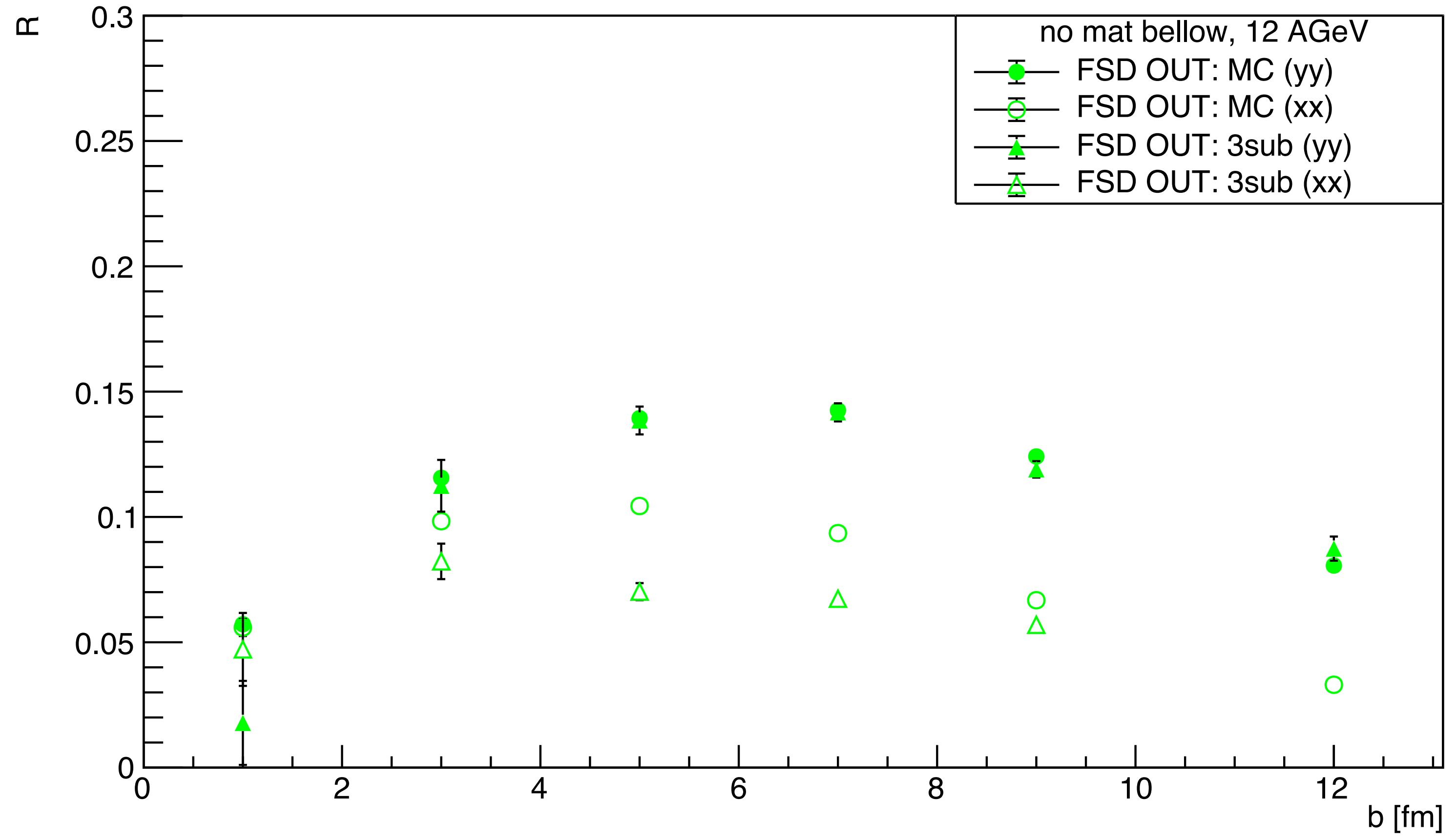
- Resolution obtained from data
- Compared to MC
- Good agreement for pure proton simulation
- xx difference not caused by rapidity shift
- In full event difference in xx term - likely caused by background

$$R^A_{n,\alpha} = \sqrt{\frac{\langle Q^A_{n,\alpha} Q^B_{n,\alpha}\rangle \langle Q^A_{n,\alpha} Q^C_{n,\alpha}\rangle}{\langle Q^B_{n,\alpha} Q^C_{n,\alpha}\rangle}},$$





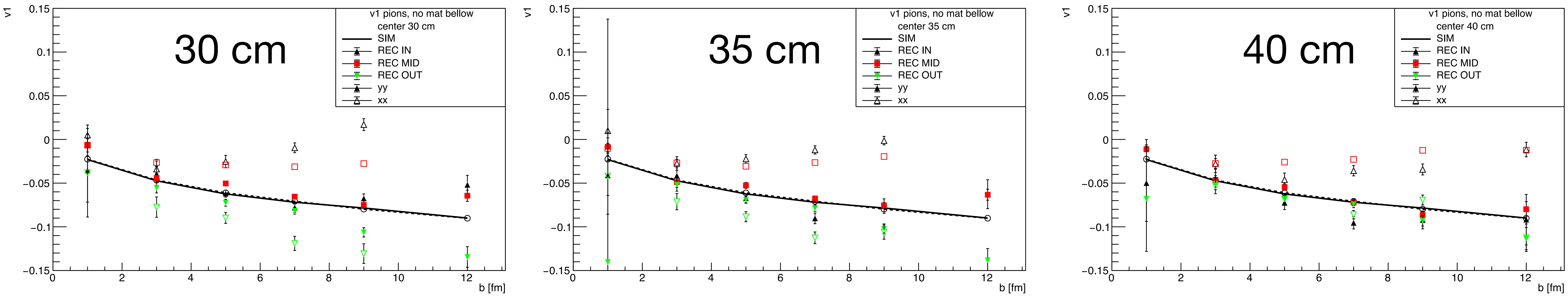




Measuring of v1 for pions

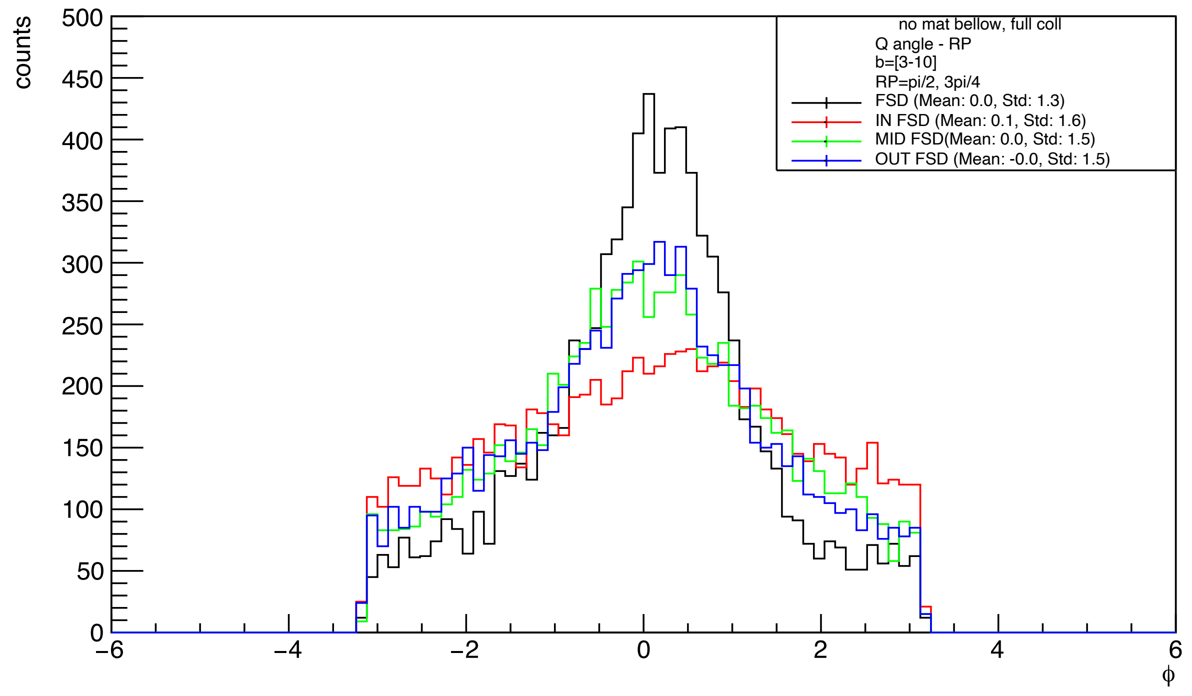
- v1 of pions in rapidity 2.4-2.6
    - Angle of pions from MC
- Good agreement when using yy-term
    - Not sensitive to the position of subevents center
- xx-term does not agree - under study

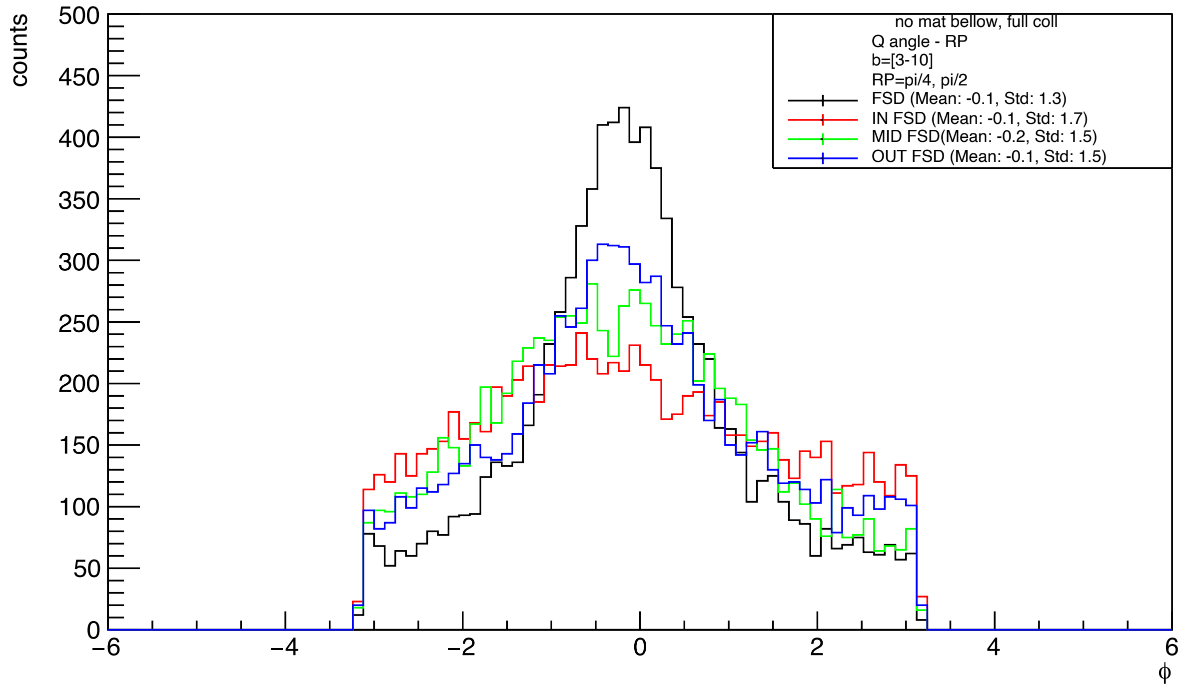
$$v_{n,\alpha} = \frac{2\langle q_{n,\alpha} Q_{n,\alpha} \rangle}{R_{n,\alpha}},$$



Summary

- FSD is a key detector for the CBM experiment
- Geometry of CBM (dipole magnetic field) is challenging for reconstruction of reaction plane
- Using Qn tools, event plane can be reconstructed, and I have showed you first results on flow of pions
- Next steps:
  - Study effects of background
  - Centrality studies


no mat bellow, full coll
Q angle - RP
b=[3-10]
RP=pi/2, 3pi/4
FSD (Mean: 0.0, Std: 1.3)
IN FSD (Mean: 0.1, Std: 1.6)
MID FSD(Mean: 0.0, Std: 1.5)
OUT FSD (Mean: -0.0, Std: 1.5)
counts
φ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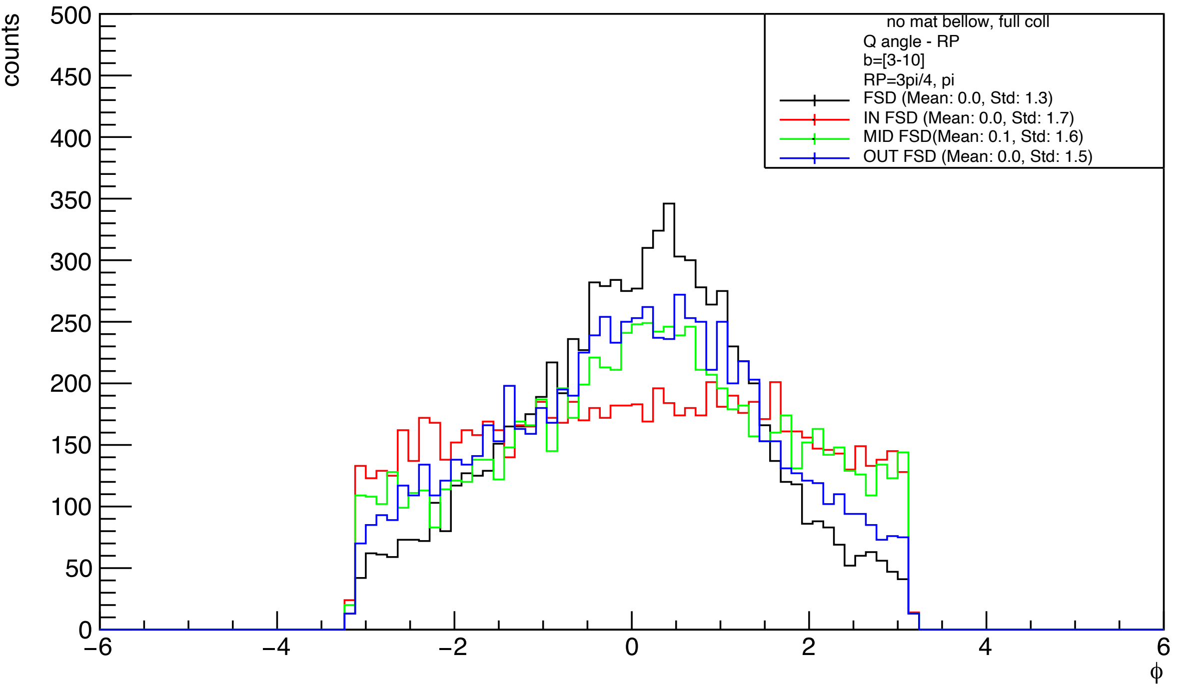
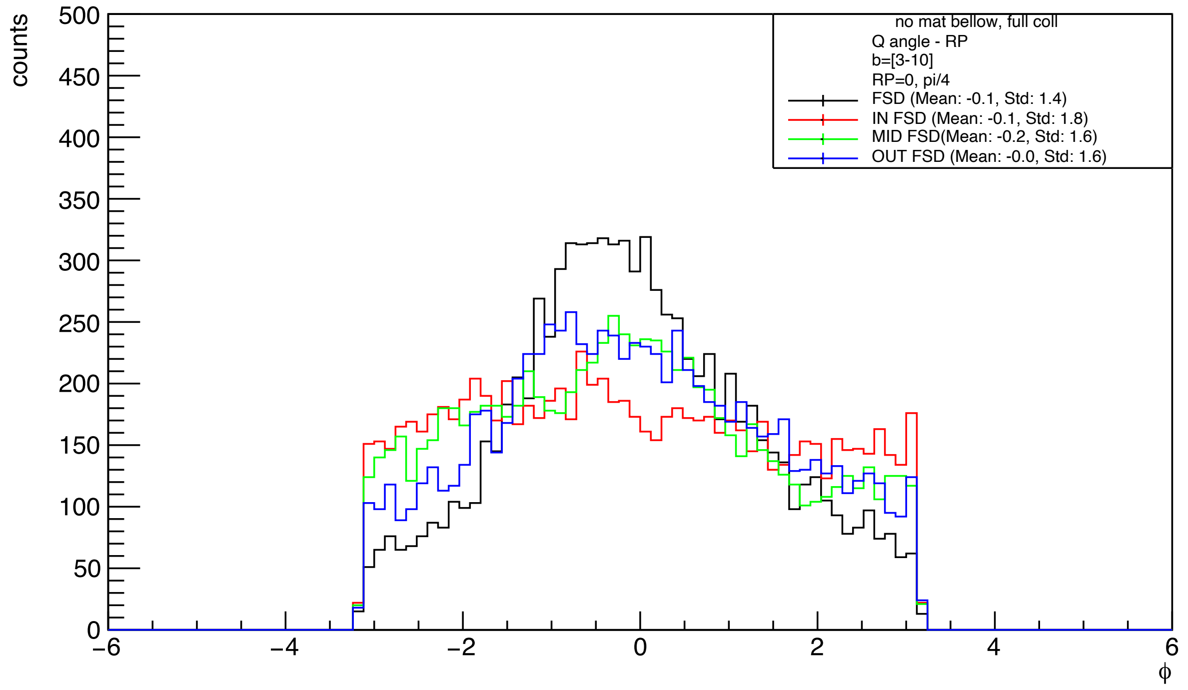
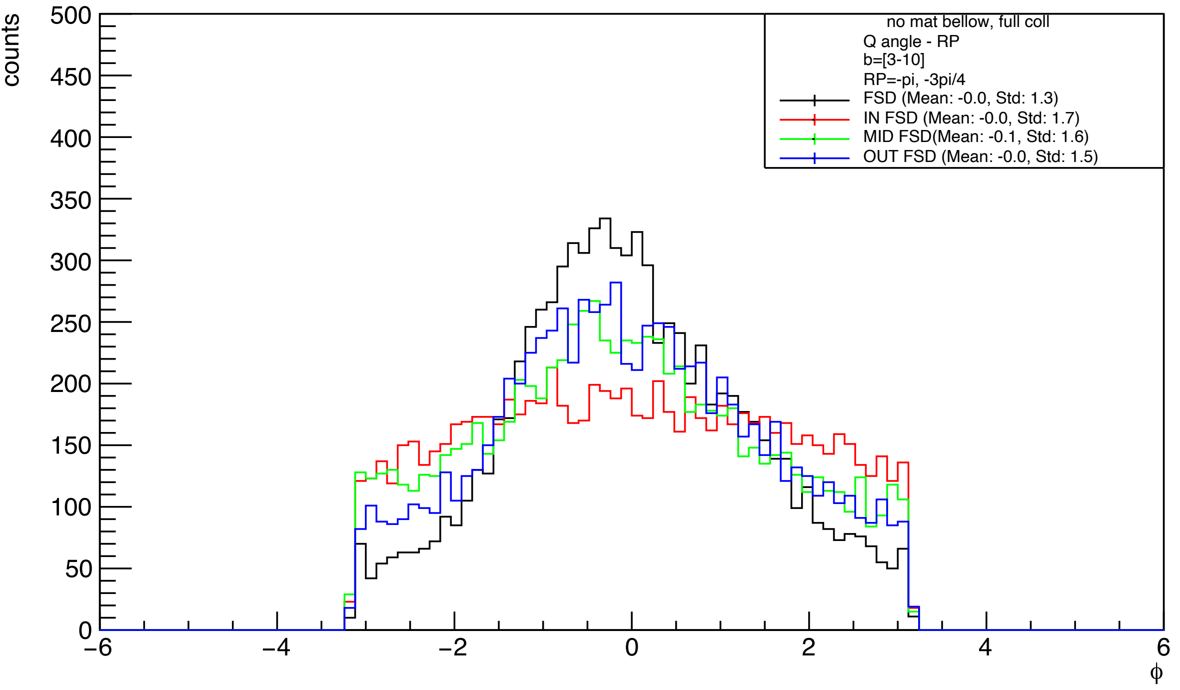
Q angle - RP
b=[3-10]
RP=pi/4, pi/2
FSD (Mean: -0.1, Std: 1.3)
IN FSD (Mean: -0.1, Std: 1.7)
MID FSD(Mean: -0.2, Std: 1.5)
OUT FSD (Mean: -0.1, Std: 1.5)
counts
φ


no mat bellow, full coll
Q angle - RP
b=[3-10]
RP=3pi/4, pi
FSD (Mean: 0.0, Std: 1.3)
IN FSD (Mean: 0.0, Std: 1.7)
MID FSD(Mean: 0.1, Std: 1.6)
OUT FSD (Mean: 0.0, Std: 1.5)
counts
φ


no mat bellow, full coll
Q angle - RP
b=[3-10]
RP=0, pi/4
FSD (Mean: -0.1, Std: 1.4)
IN FSD (Mean: -0.1, Std: 1.8)
MID FSD(Mean: -0.2, Std: 1.6)
OUT FSD (Mean: -0.0, Std: 1.6)
counts
φ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Q angle - RP
b=[3-10]
RP=-pi, -3pi/4
FSD (Mean: -0.0, Std: 1.3)
IN FSD (Mean: -0.0, Std: 1.7)
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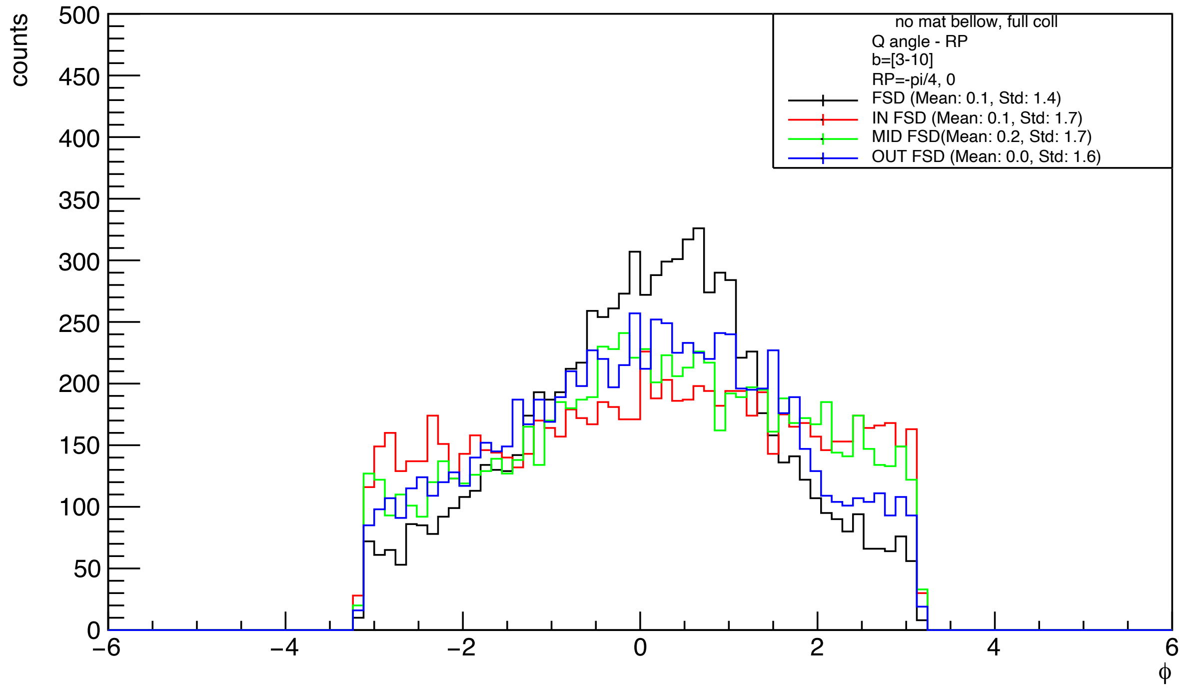
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Q angle - RP
b=[3-10]
RP=-pi/4, 0
FSD (Mean: 0.1, Std: 1.4)
IN FSD (Mean: 0.1, Std: 1.7)
MID FSD(Mean: 0.2, Std: 1.7)
OUT FSD (Mean: 0.0, Std: 1.6)
counts
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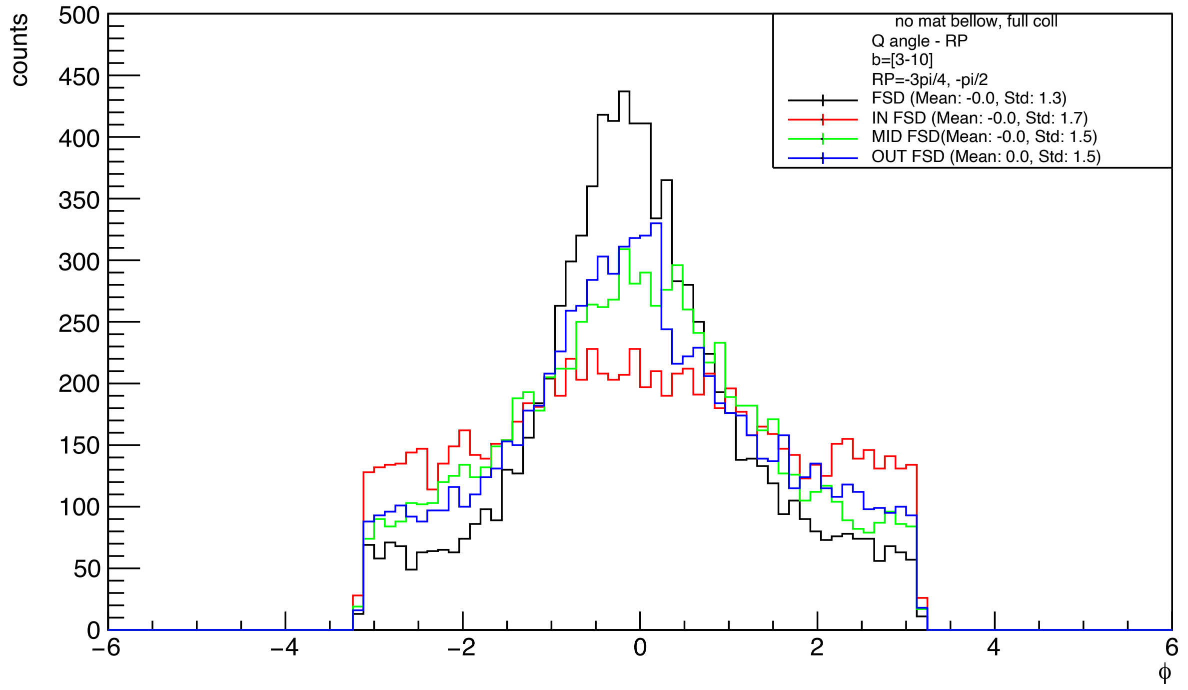
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b=[3-10]
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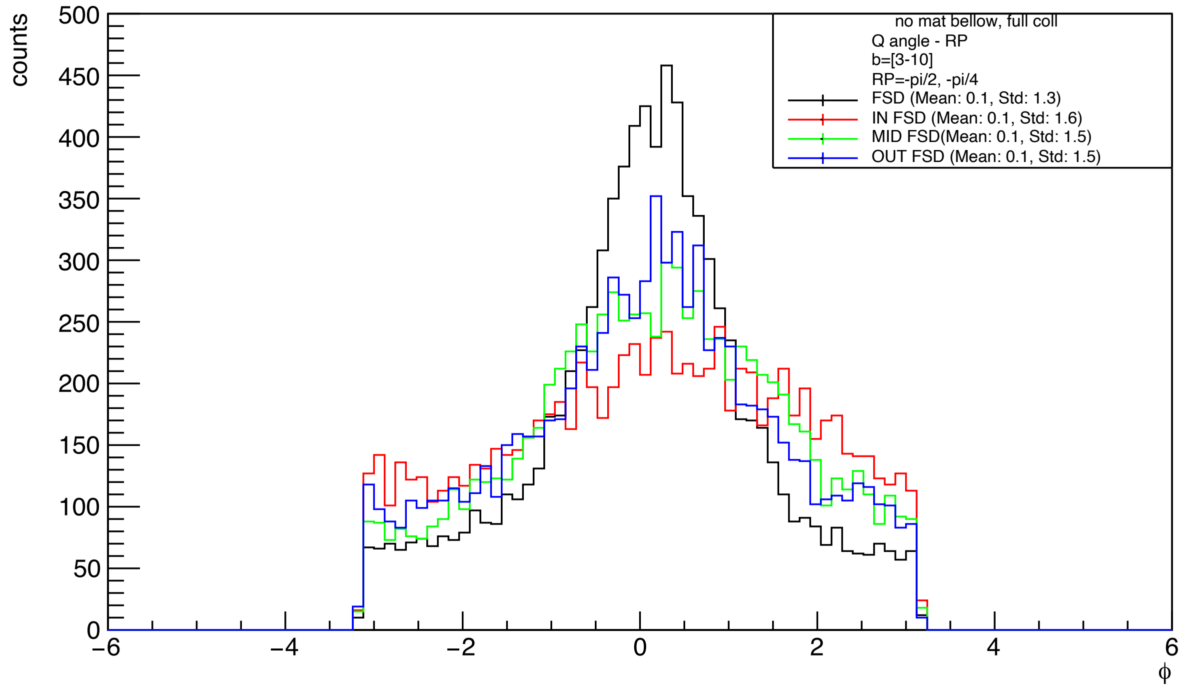
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RP=-pi/2, -pi/4
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MID FSD(Mean: 0.1, Std: 1.5)
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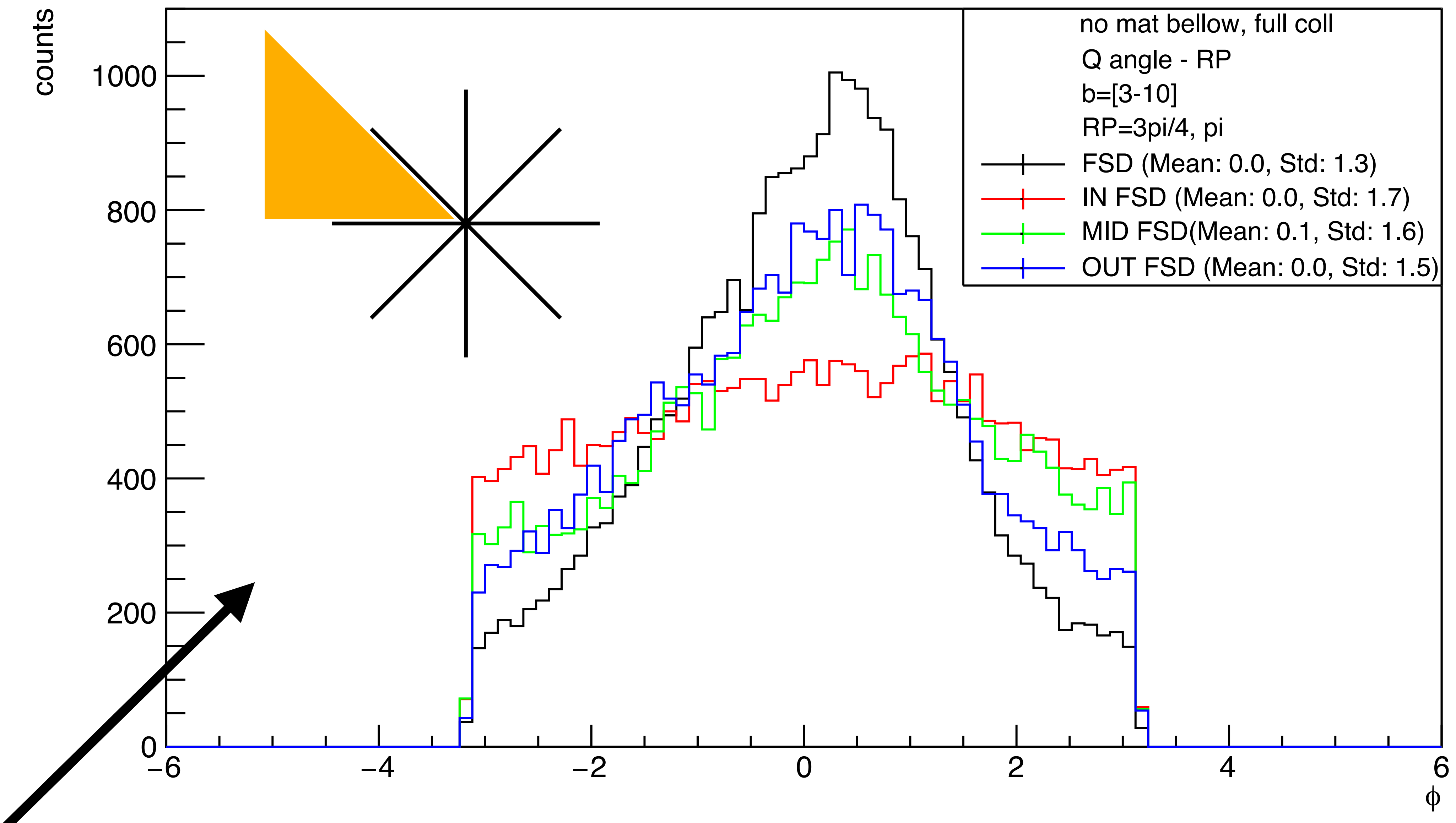
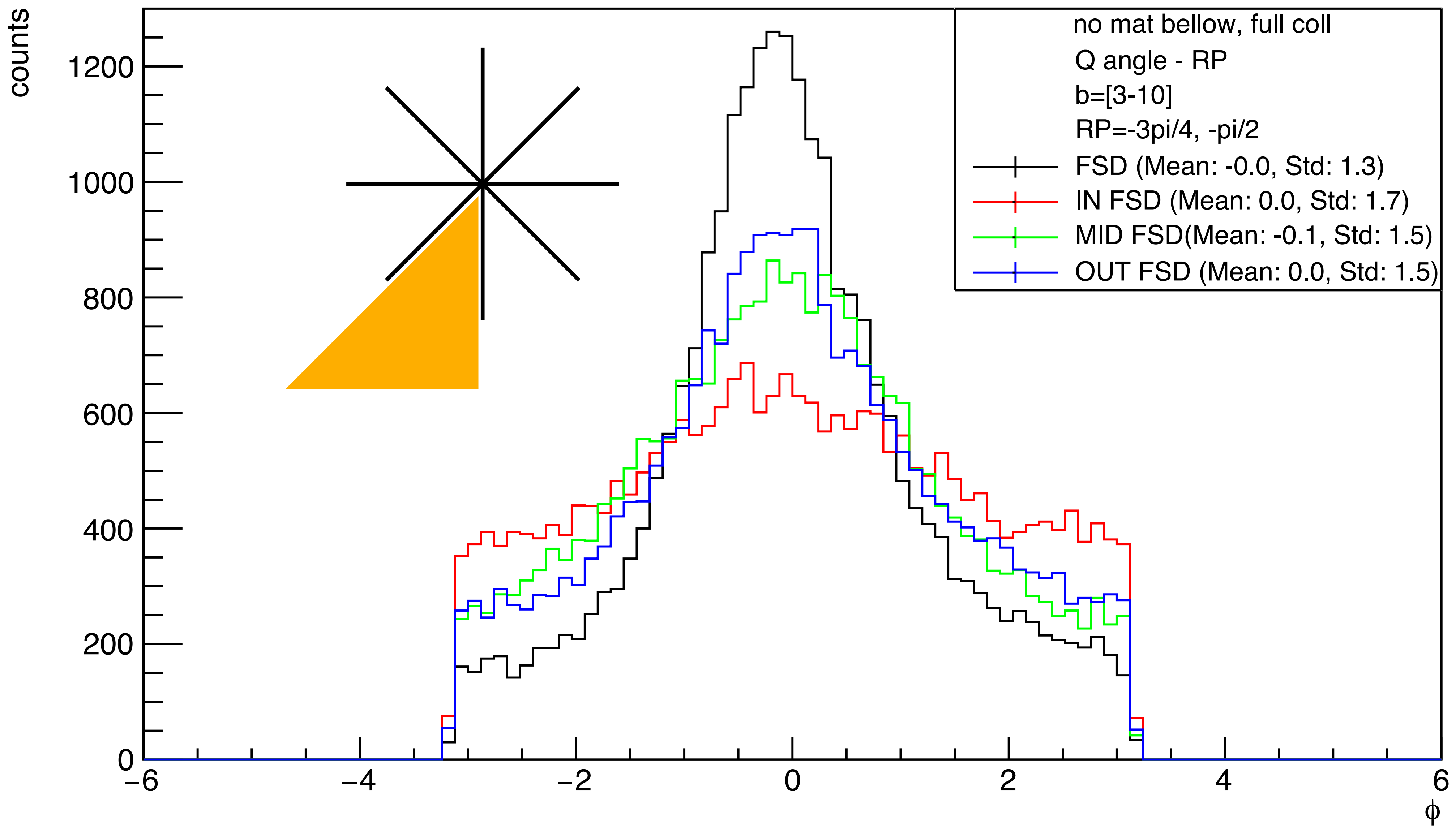
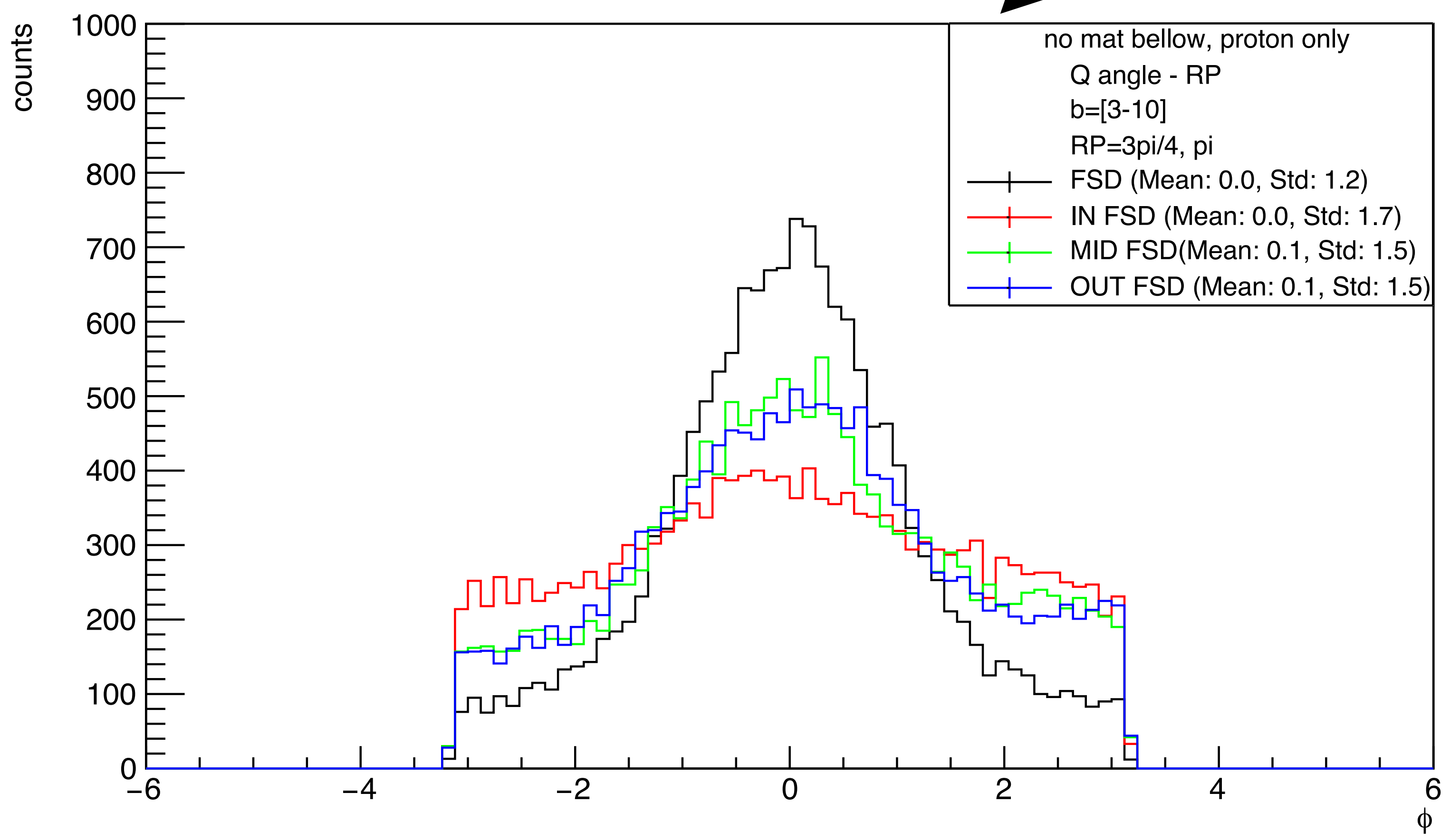
φ

Resolution using MC reaction plane

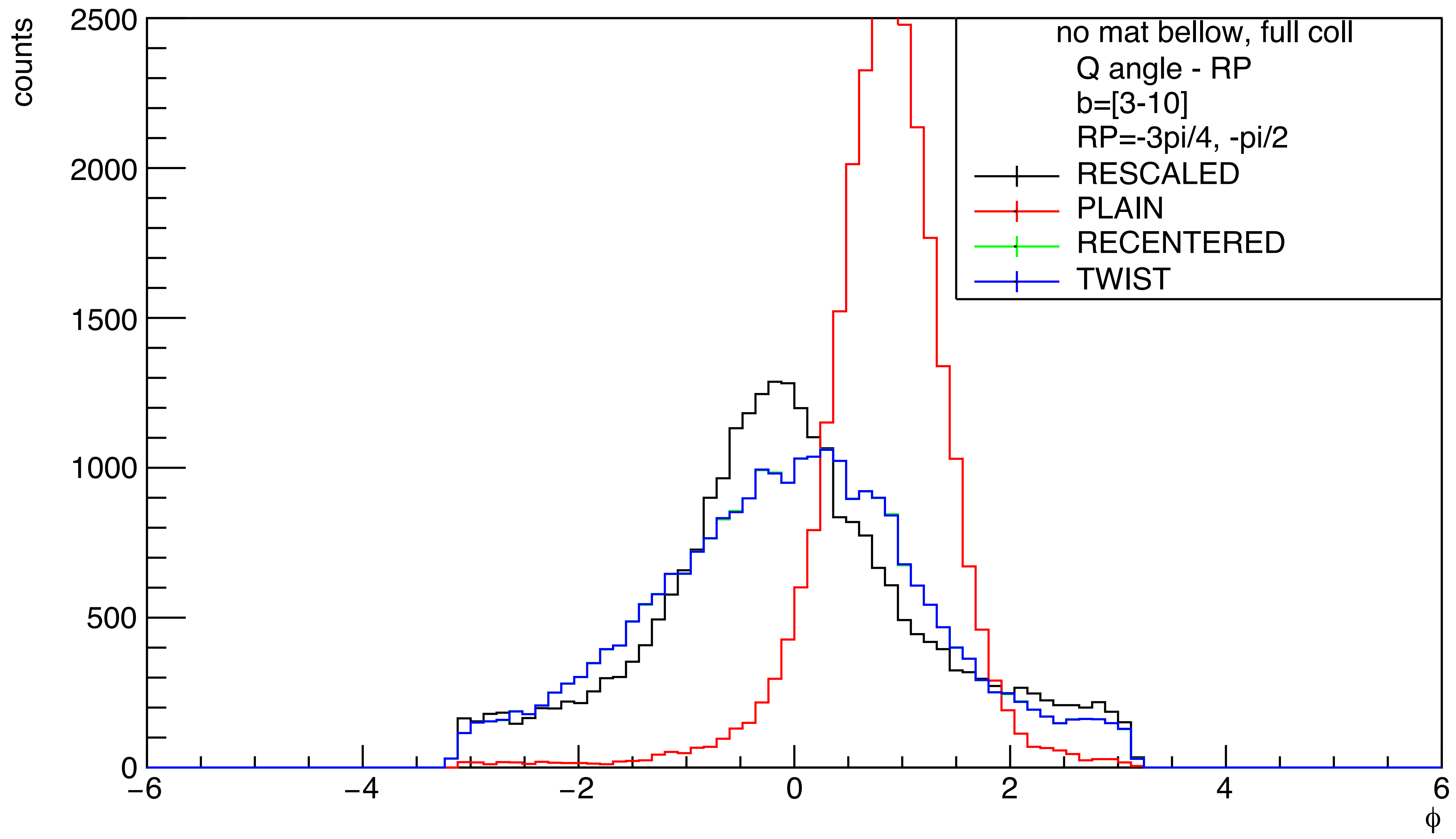
- Correlation of Q vector with RP from MC
  - Q vector after all corrections
- No big difference between differently selected subevenst
  - Qn framework seems to work







Corrections



Charge deposition