Performance for anisotropic flow measurements of the future CBM experiment at FAIR

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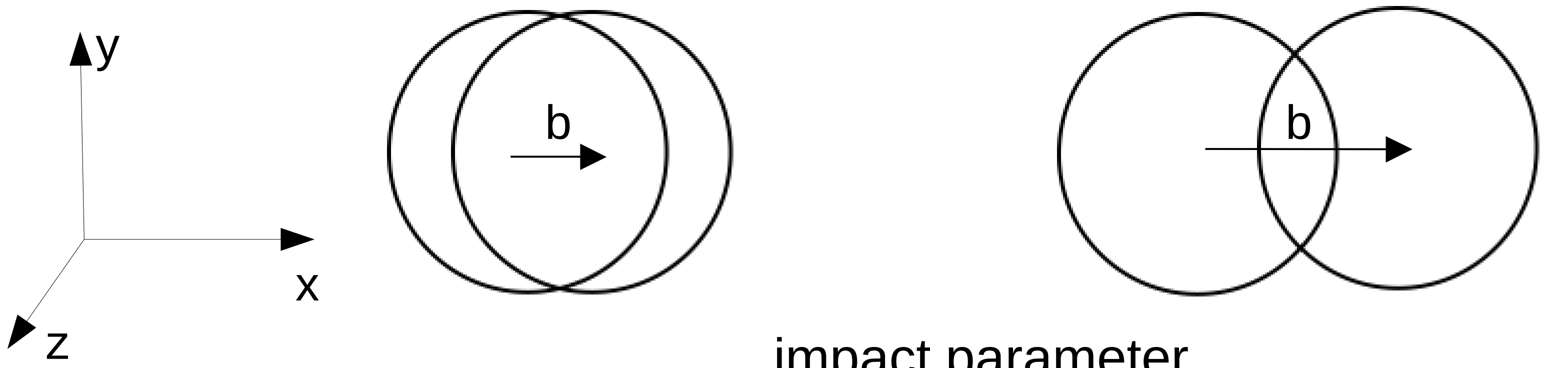
for the CBM Collaboration

Collision geometry

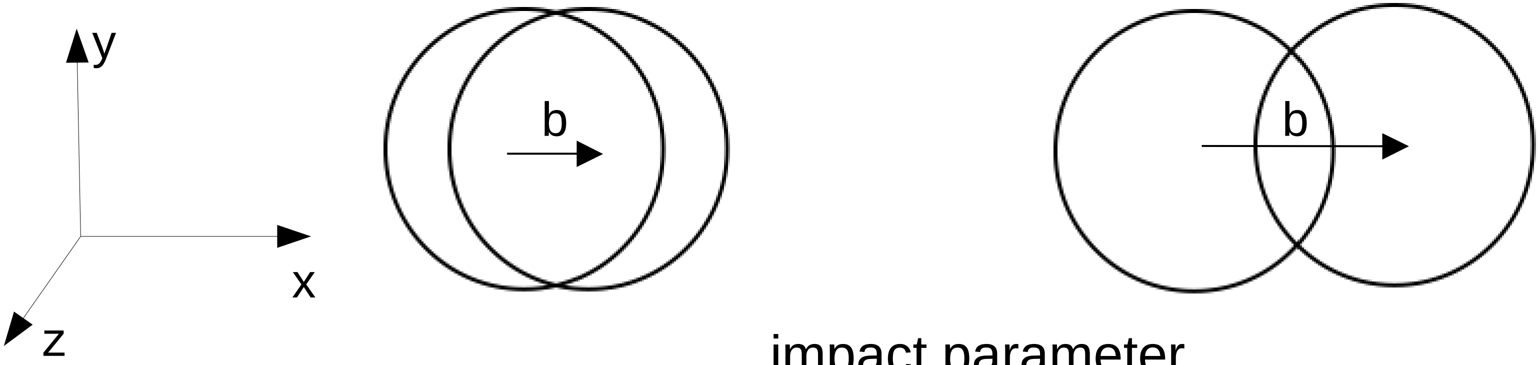


impact parameter

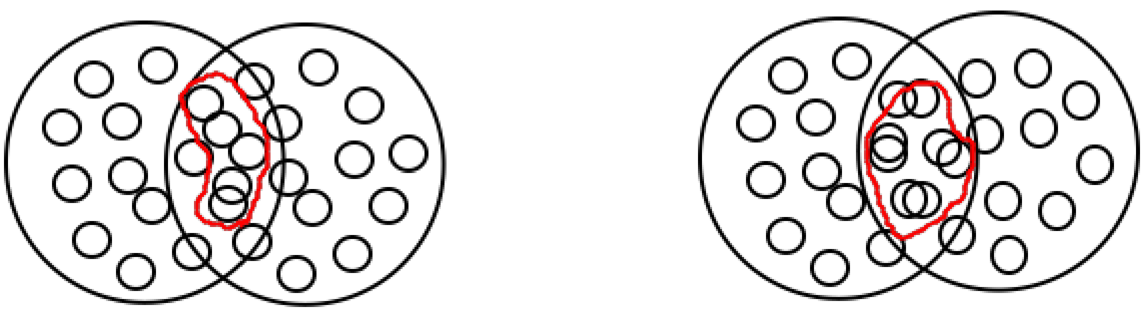
↔

energy density of the interacting matter

Collision geometry



impact parameter
↔
energy density of the interacting matter



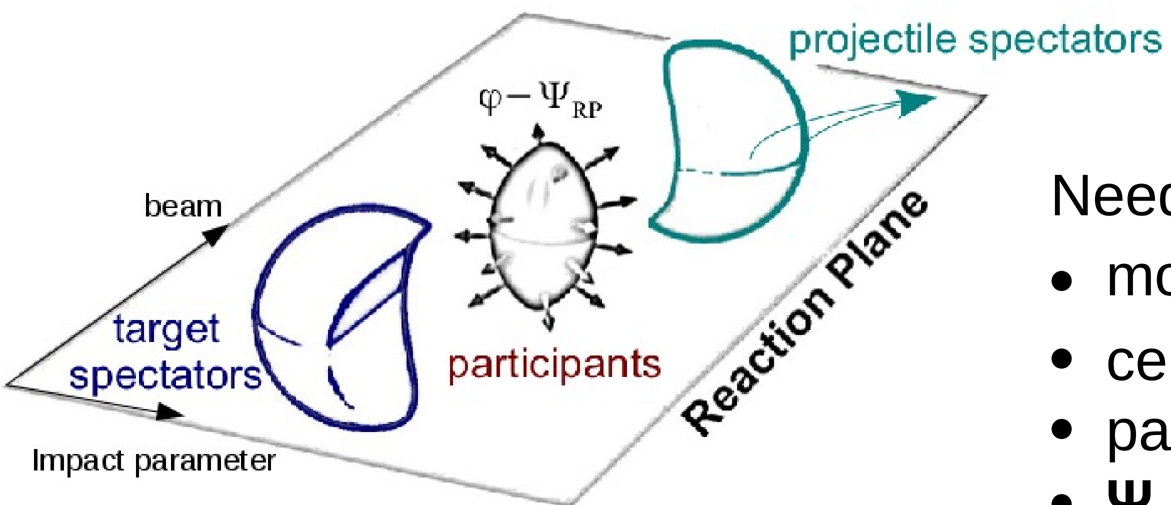
spatial asymmetry of the overlap region
↔
asymmetry of energy distribution

Collision geometry and the transverse anisotropic flow

Asymmetry in coordinate space converts due to interaction into momentum asymmetry with respect to the symmetry plane (reaction plane - RP)

$$\rho(\varphi - \Psi_{RP}) = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos\left(n(\varphi - \Psi_{RP})\right)\right)$$

$$v_n = \langle \cos[n(\varphi - \Psi_{RP})] \rangle$$



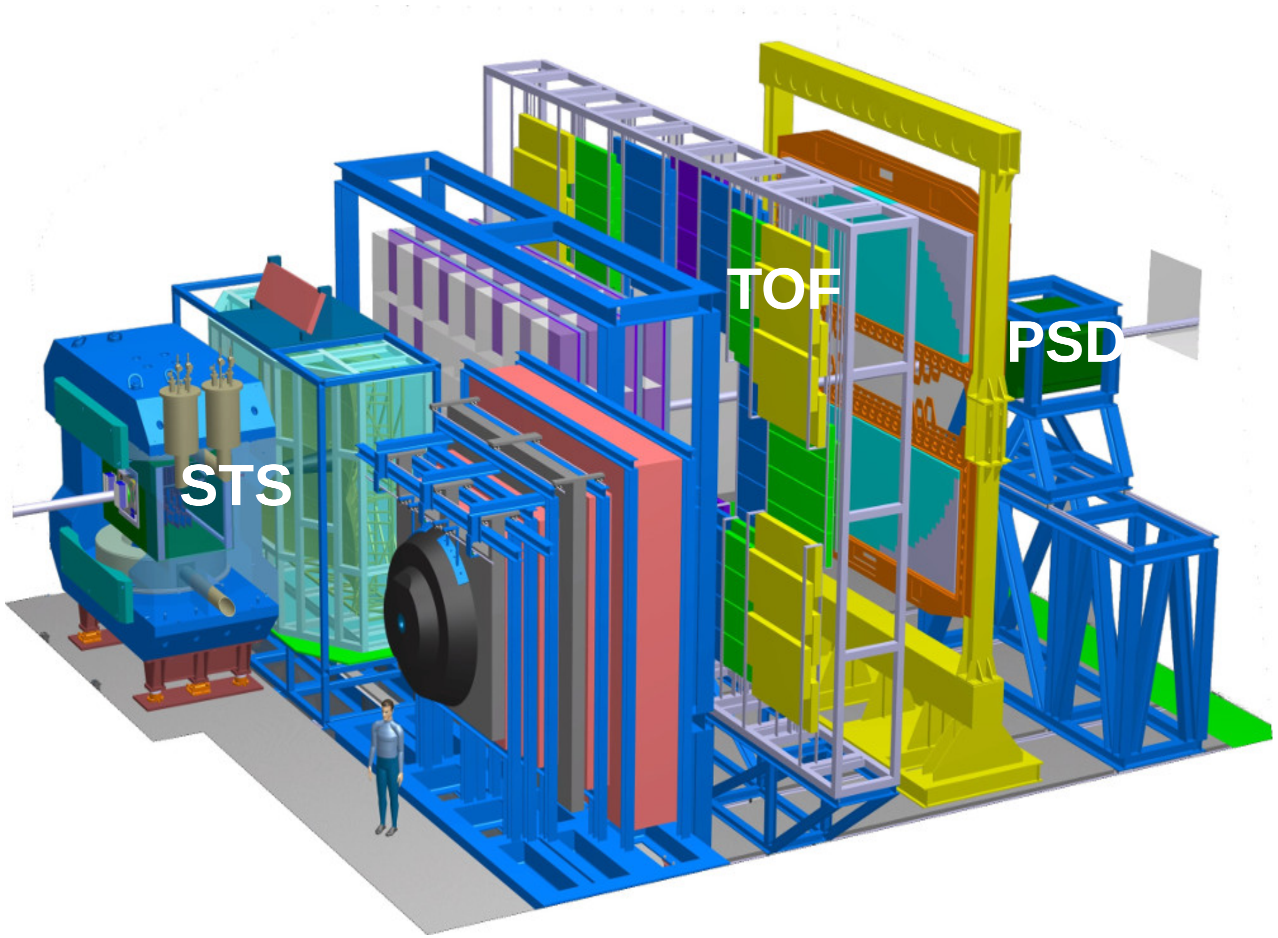
Needed components to calculate v_n:

- momentum (φ, Y, p_T)
- centrality estimation
- particle identification
- **Ψ_{RP} estimation**

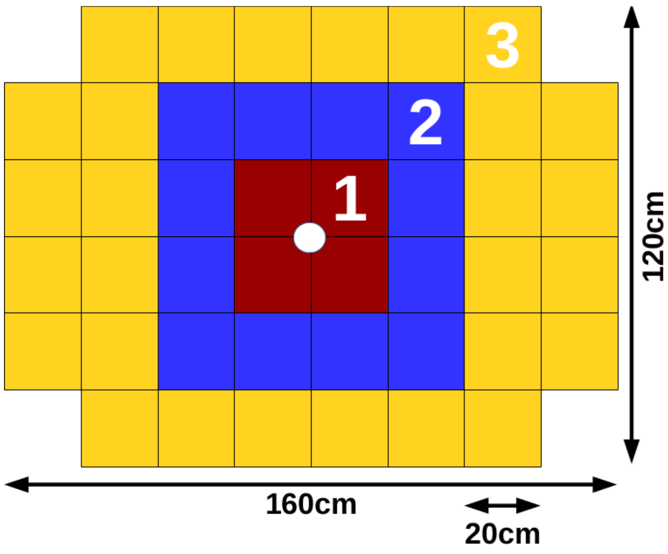
CBM detector setup

CBM subsystems needed for v_n measurements:

- Particle momentum (φ,Y, p_T): STS+MVD
- Centrality estimation: event classes defined with PSD energy or STS multiplicity
- Particle identification: TOF
- **Reaction plane (Ψ_{RP}): PSD transverse energy asymmetry / φ distribution in STS**



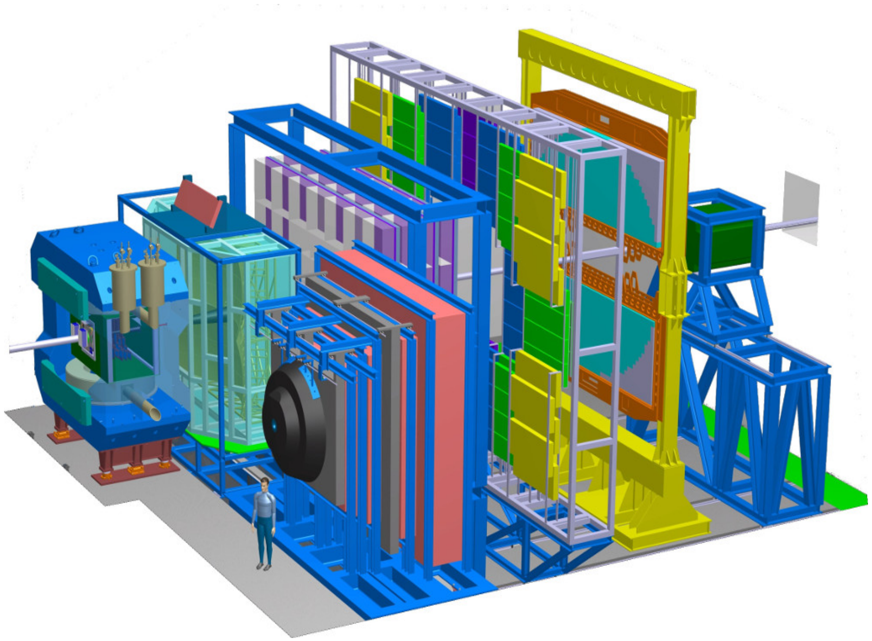
PSD transverse layout



Hole size = 10 cm
Ongoing discussion to
increase hole size to 20 cm

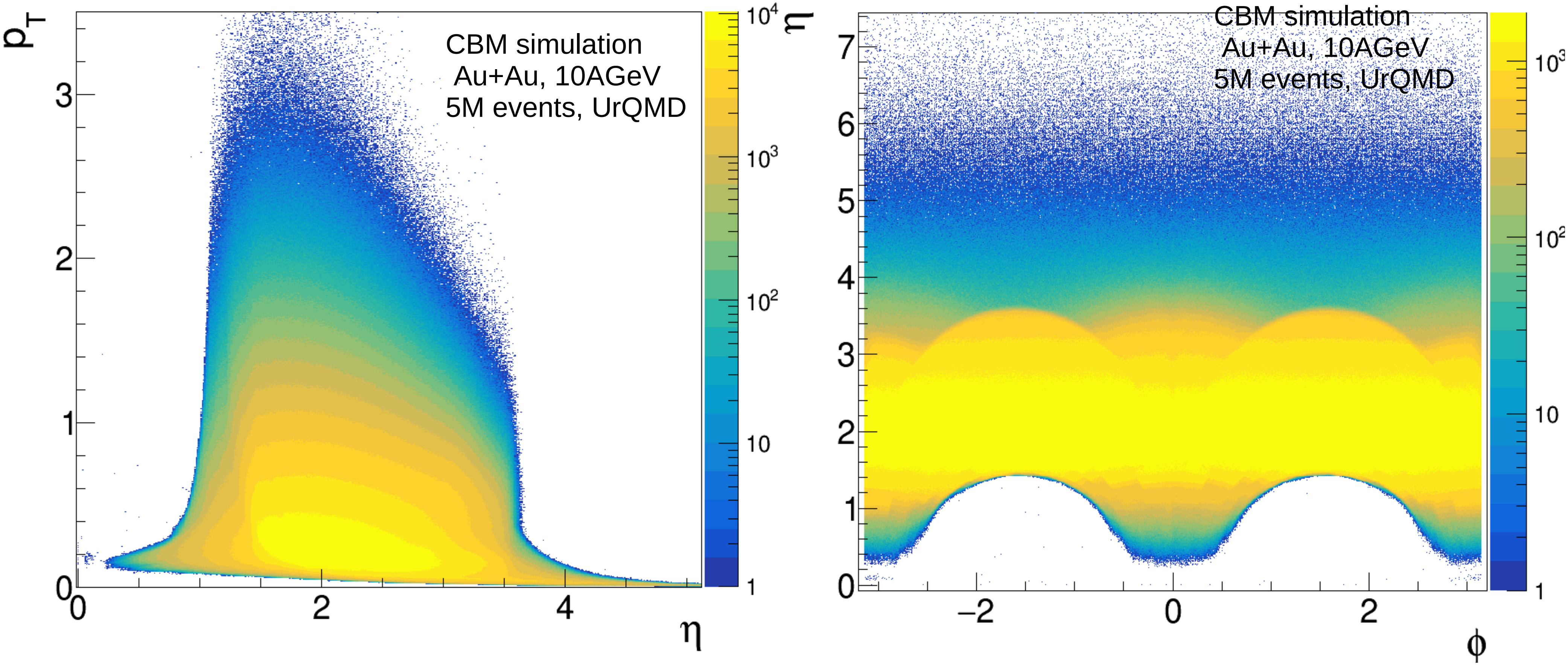
Simulation setup

Models	UrQMD (no fragments)
Centrality	mbias
System	Au-Au
Energy	10 AGeV
Statistics	5M events
CBM geometry	MVD, STS, RICH, TDR, TOF, PSD
PSD geometry	44 modules, 4 central, 10 cm hole, elongated in x
Transport code	GEANT3
Detector response	CBMRoot JUL17



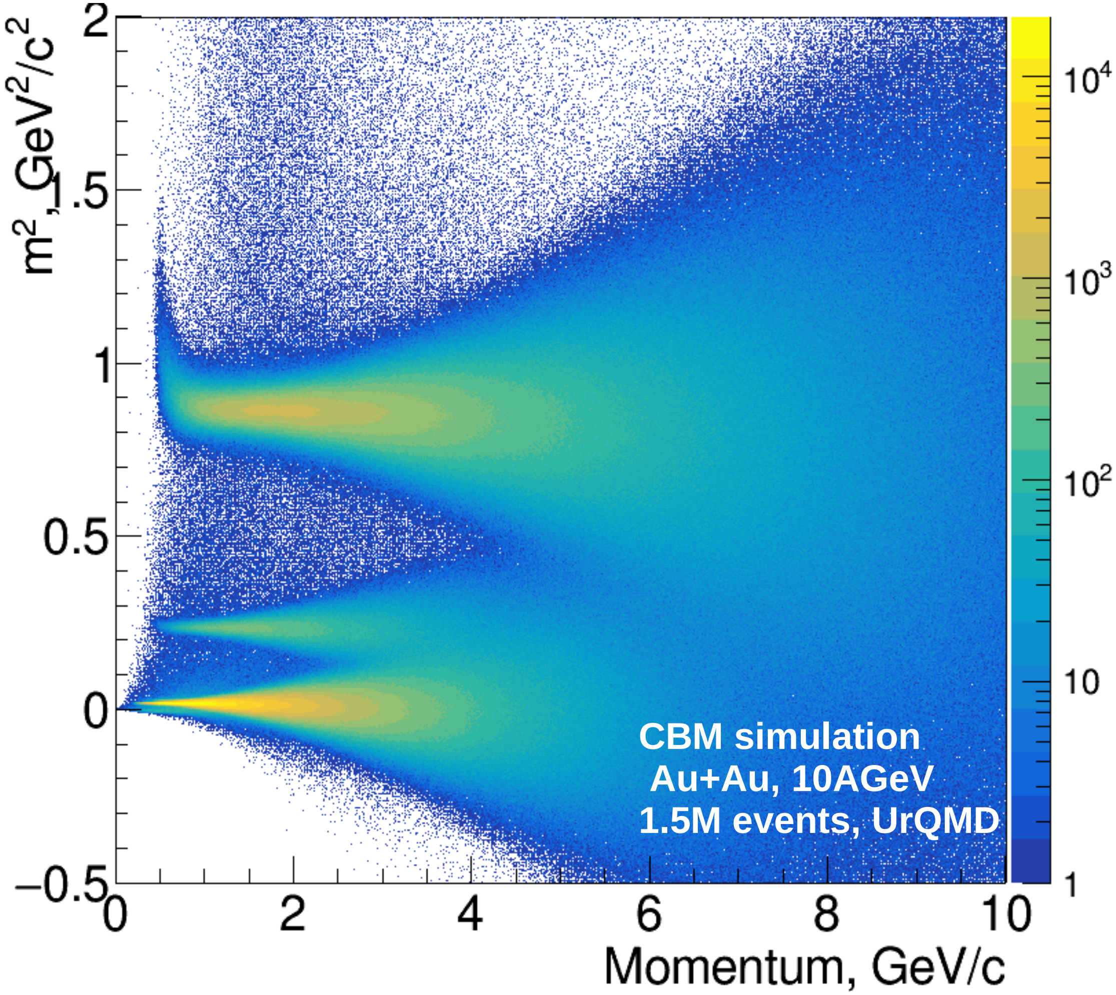
Acceptance of charged hadrons and tracks selection

- Number of hits $N_{hits} > 3$
- Fit quality $\chi^2/NDF < 3$
- $\chi^2_{vertex} < 3$

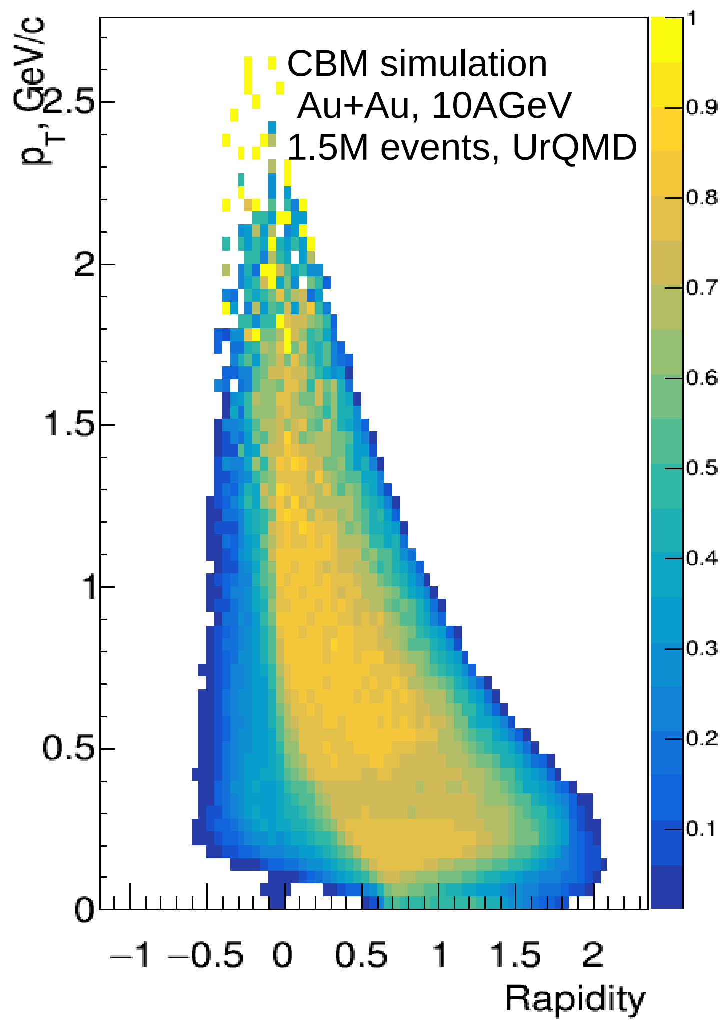


Non-uniformity of azimuthal acceptance – corrections are needed!

Particle identification (PID)

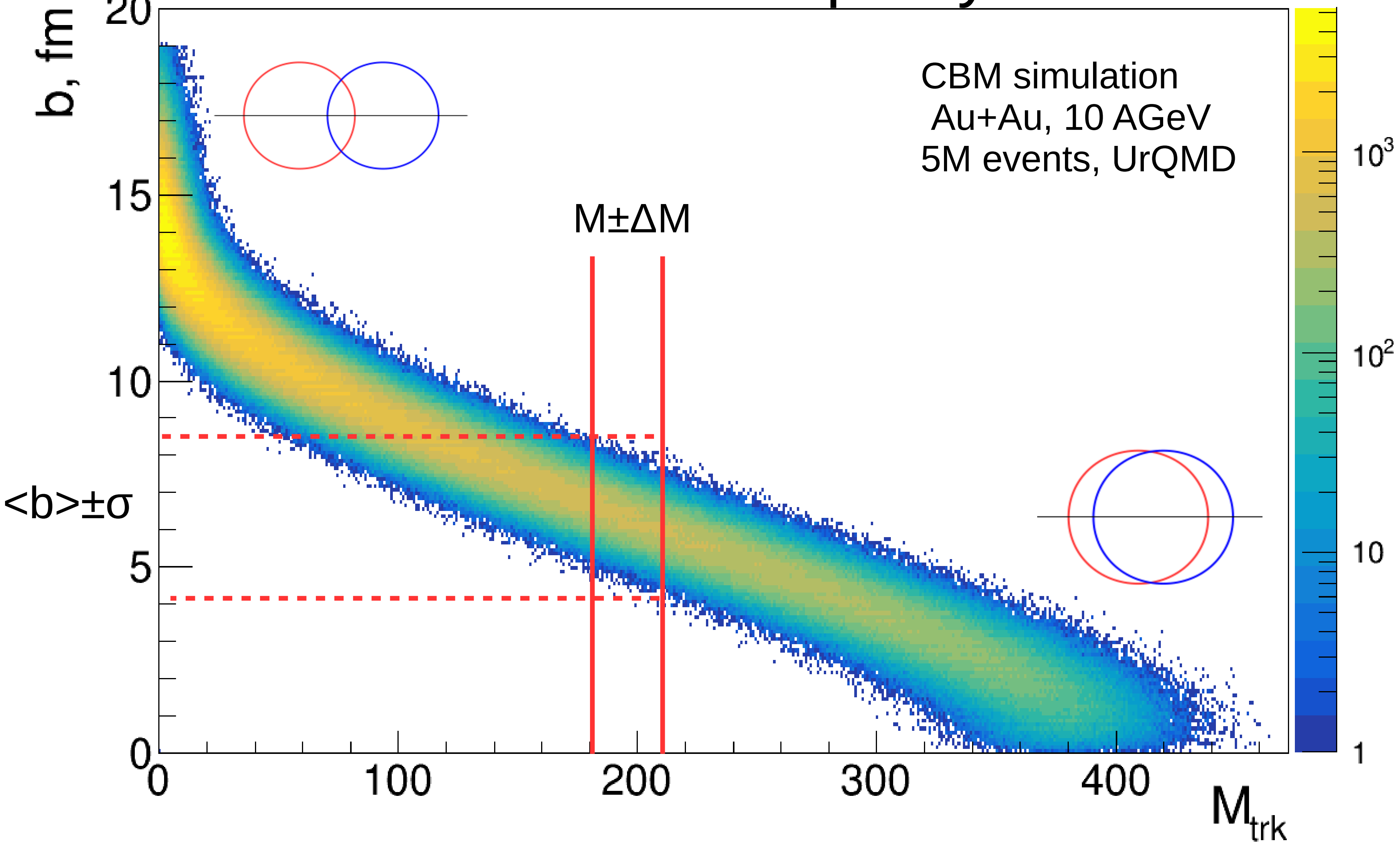


efficiency map (π^+, purity>90%)



For flow performance in this presentation MC-truth PID was used!

Centrality: estimating model parameters with measured multiplicity



Multiplicity interval M±ΔM gives impact parameter distribution b with width σ

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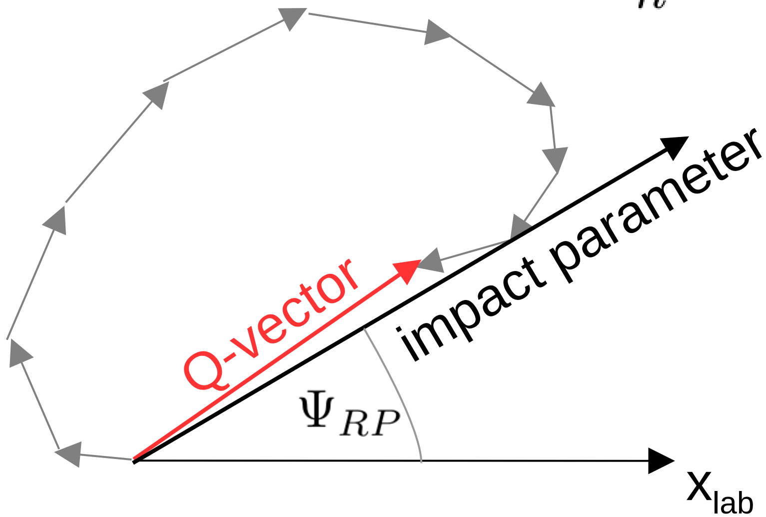
Experimental estimate of the reaction plane with Q-vector



$$v_n = \langle \cos[n(\varphi - \Psi_{RP})] \rangle$$

$$Q_x = \frac{1}{C} \sum_k w_k \cos\phi$$

$$Q_y = \frac{1}{C} \sum_k w_k \sin\phi$$

STS

Sum over all selected tracks normalized on multiplicity

$$Q_x = \frac{1}{M} \sum \cos\phi$$

$$Q_y = \frac{1}{M} \sum \sin\phi$$

PSD

Sum over group of modules normalized on total energy in group

$$\vec{Q}_{PSD_A} = \frac{1}{E_{PSD_A}} \sum_{k \in A} E_k \frac{\vec{r_k}}{|r_k|}$$

E_k - energy deposit in the module

r_k - center of the PSD module

Event plane and scalar product methods

$$v_n = \langle \cos[n(\varphi - \Psi_{RP})] \rangle$$

- v_n with respect to symmetry plane estimated using group of particles (subevent) A:

$$v_n(A;i) = \frac{\langle 2 u_i Q_i^n(A) \rangle}{R_i^n(A)} \qquad \vec{u} = (\cos(n\varphi), \sin(n\varphi)) \quad i = (x, y)$$

- Correction factor (resolution) $R_i^n(A)$ is calculated via correlations

  → modified 3-subevent method with mixed harmonics:

$$R_i^n(A;B,C,D) \propto \sqrt{\frac{\langle Q_i^1(A) Q_i^1(B) \rangle \langle Q_i^1(A) Q_i^1(C) Q_i^2(D) \rangle}{\langle Q_i^1(B) Q_i^1(C) Q_i^2(D) \rangle}}$$

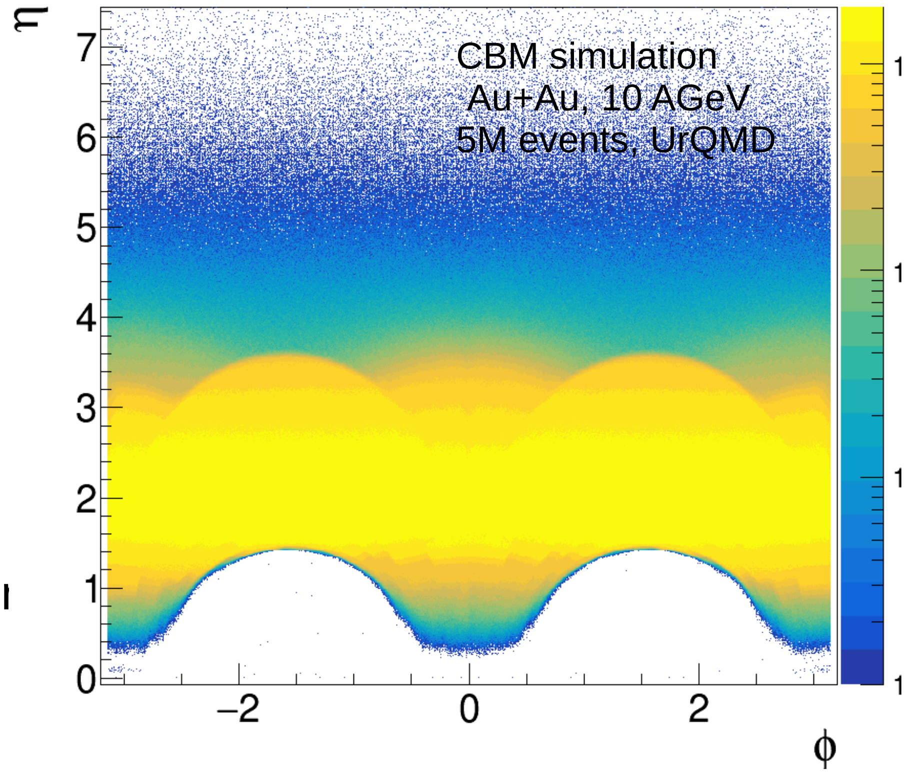
QnVector Corrections Framework

- Developed for ALICE by
  J. Onderwaater, V. Gonzalez, I. Selyuzhenkov
  https://github.com/jonderwaater/FlowVectorCorrections

- Applies corrections* for azimuthal acceptance non-uniformity
  → corrections calculated from reconstructed azimuthal distributions

- Recentering, twist, rescaling, and rotation corrections are applied separately in different event classes

- Allows to monitor effects of applied corrections



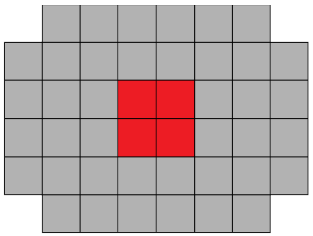
Framework configuration:
- ✓ recentering
- ✓ twist
- ✓ rescaling

*PRC77 034904 (2008)

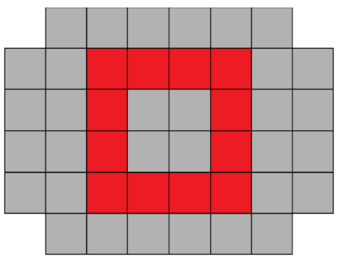
PSD resolution (event plane)

$$R_1^{EP} = \langle [Q_1^x \cos(\Psi_{RP}) + Q_1^y \sin(\Psi_{RP})] / |Q_1| \rangle$$

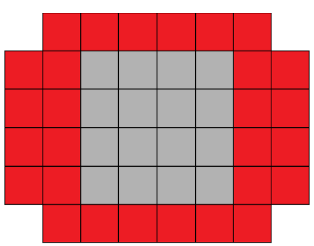
PSD1

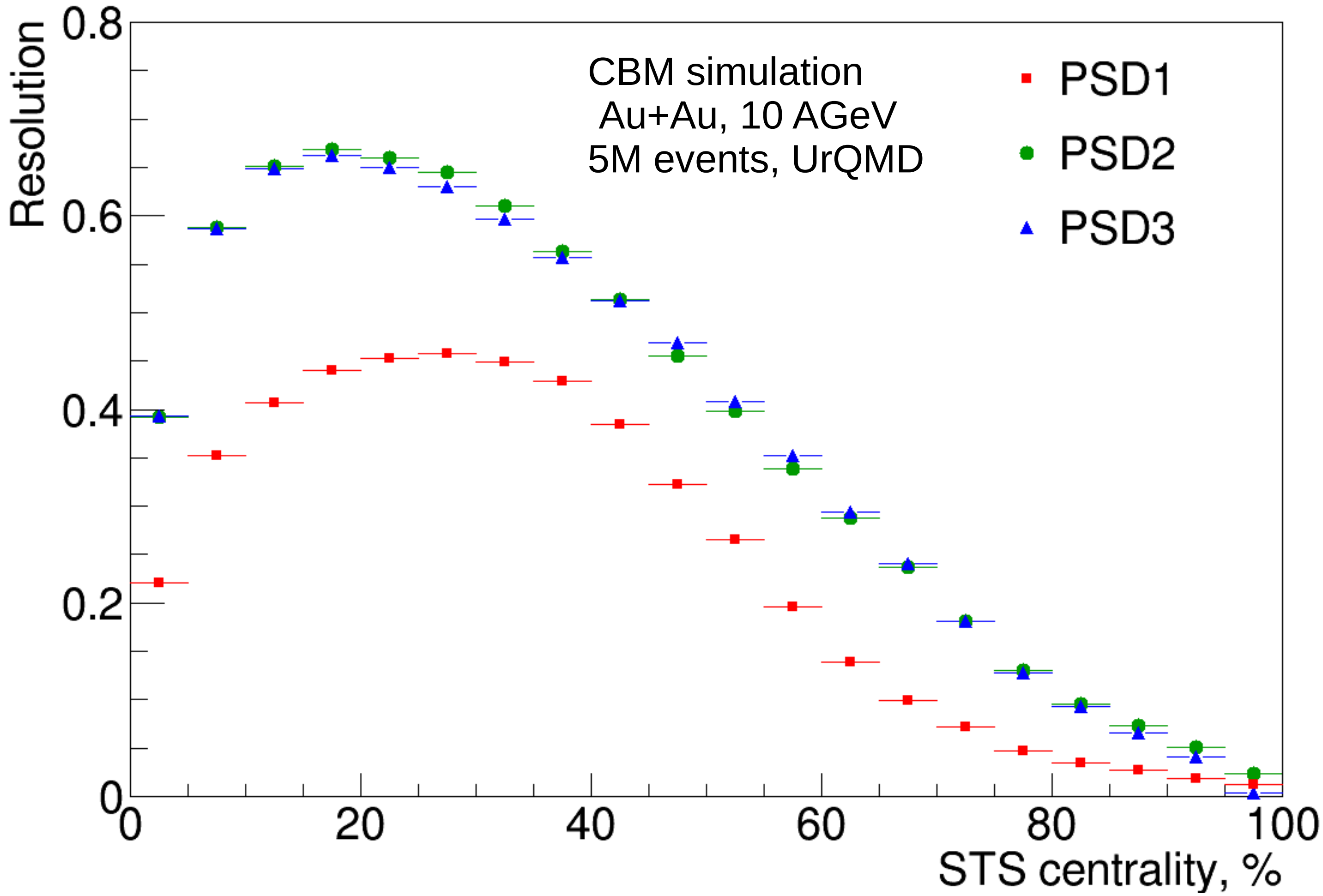


PSD2



PSD3

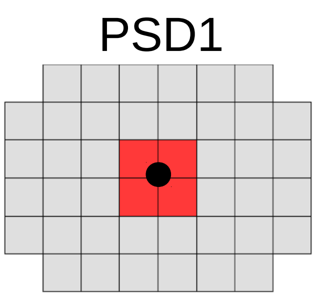


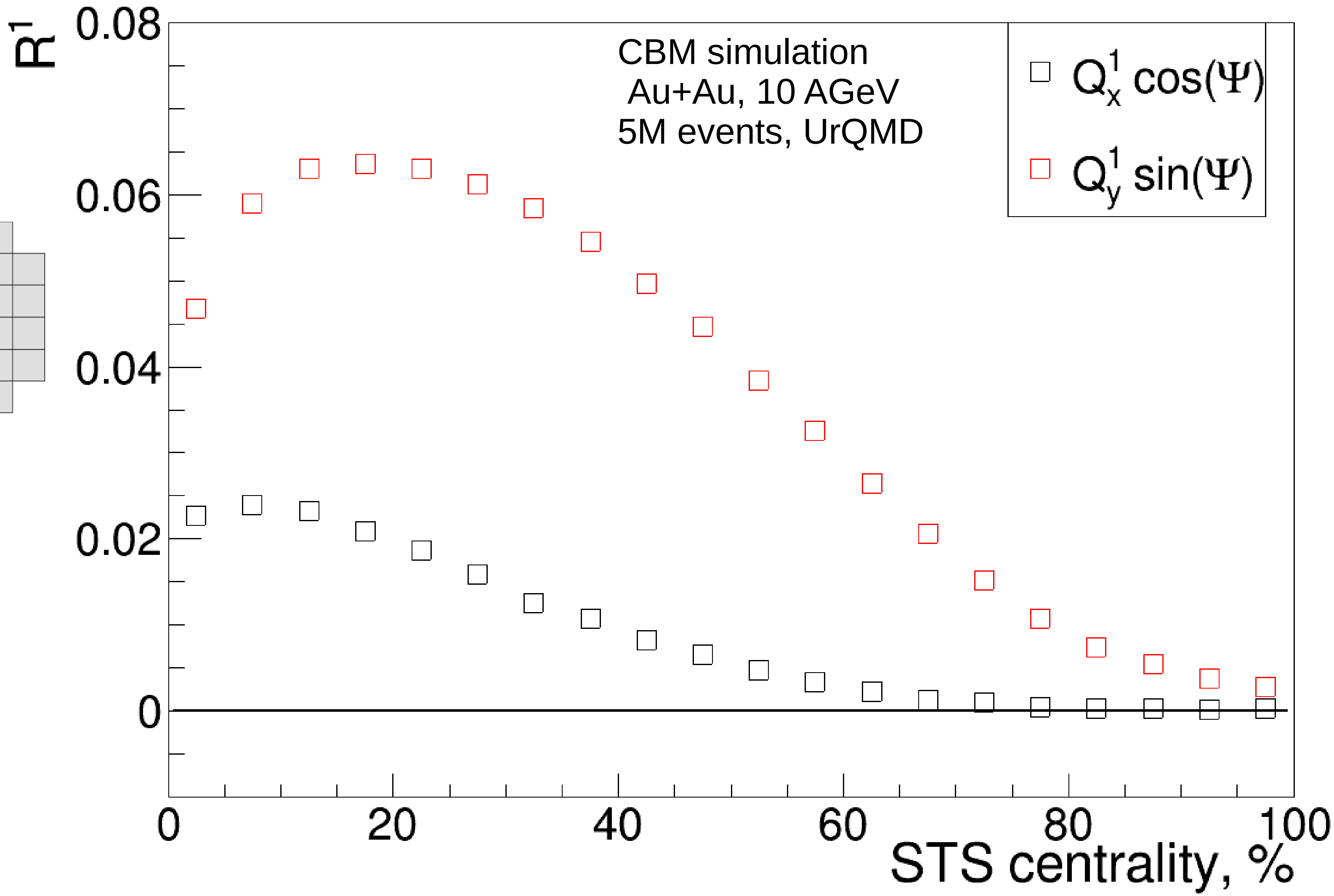


PSD resolution is affected by magnetic field and acceptance of PSD subevents

Effect of CBM magnet field (scalar product)

$R_{1,x}^{SP} = Q_1^x \cos(\Psi_{RP})$ $R_{1,y}^{SP} = Q_1^y \sin(\Psi_{RP})$

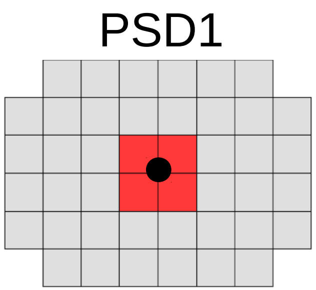


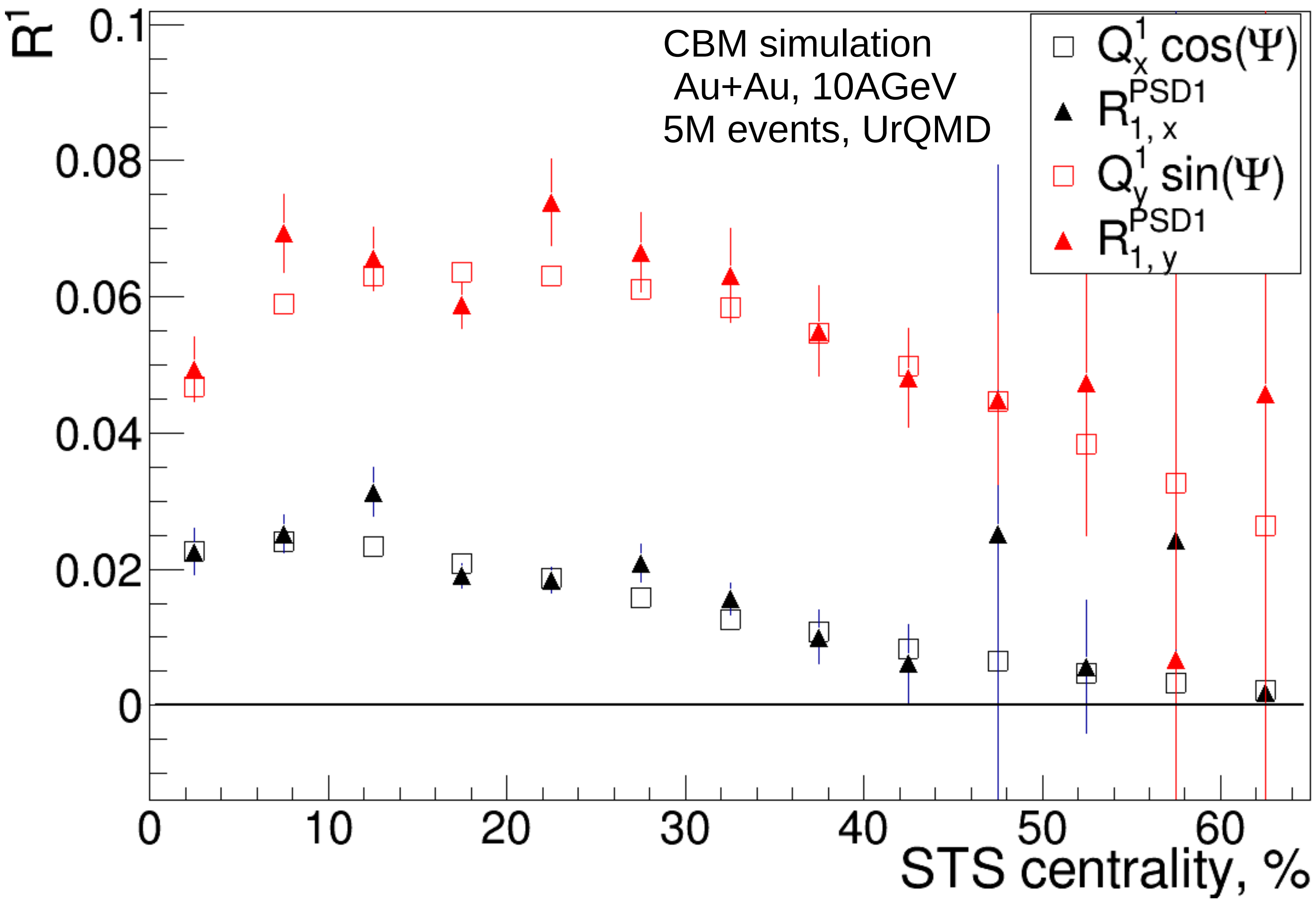


Different x-y sensitivity due to the magnetic field

Data driven extraction of R_1 (scalar product)

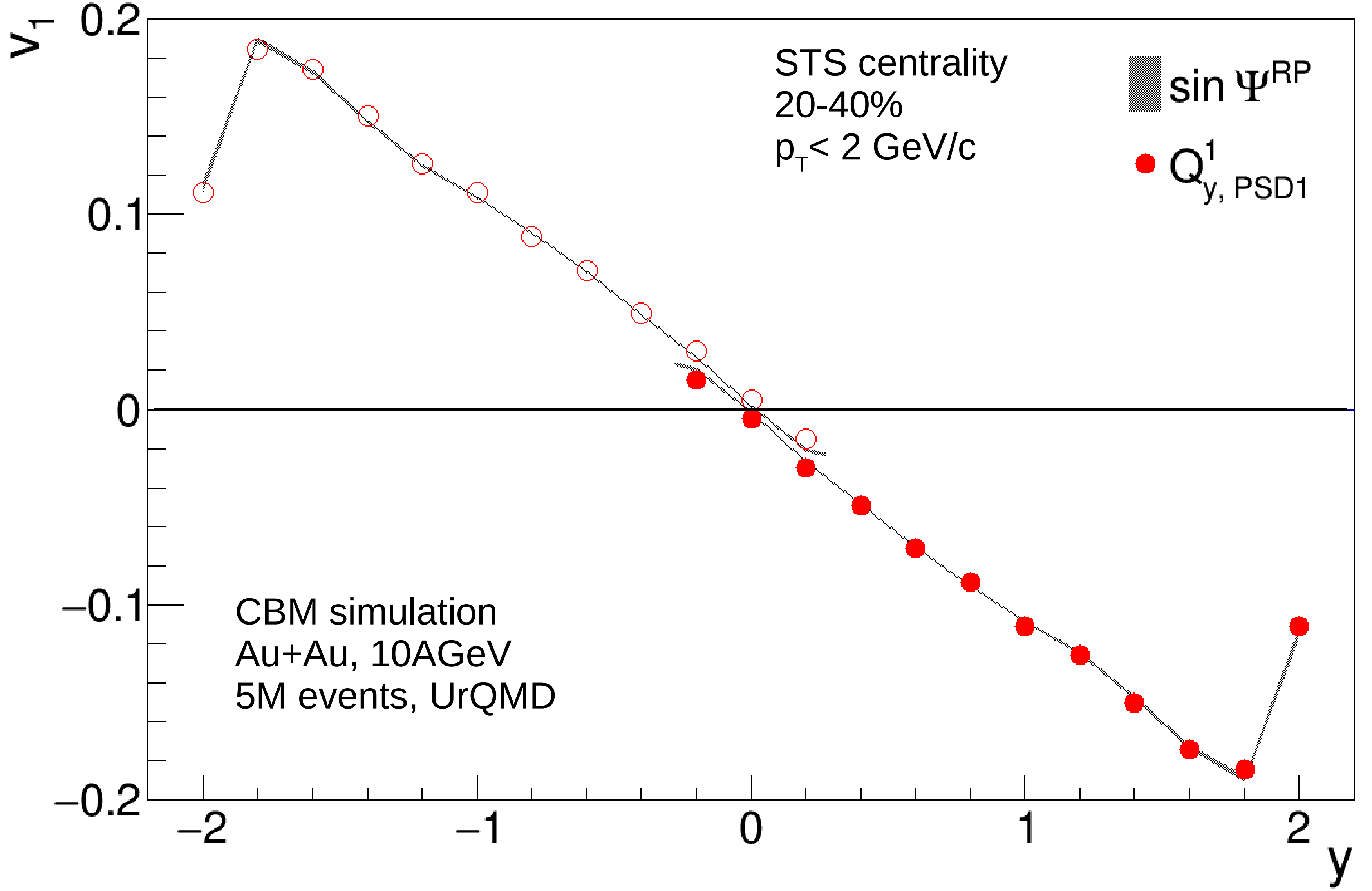
$$R^{SP}_{1,i}(A;B,C,D) \propto \sqrt{\frac{\langle Q^1_i(A)Q^1_i(B)\rangle\langle Q^1_i(A)Q^1_i(C)Q^2_i(D)\rangle}{\langle Q^1_i(B)Q^1_i(C)Q^2_i(D)\rangle}}$$





Mixed harmonic calculation removes/suppresses contribution from non-flow

$\pi^- v_1$ vs rapidity



Statistical errors from correction factor are not propagated.
Good agreement between simulated and reconstructed values

Summary

- Reaction plane reconstruction with mixed harmonic method is implemented and results compared to MC-true
- Results for π^- v_1 with event plane from PSD are presented

Ongoing activities and outlook

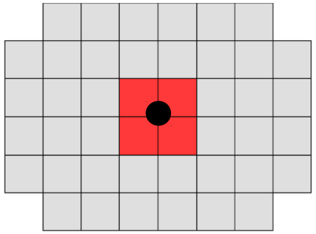
- Extending Flow analysis framework

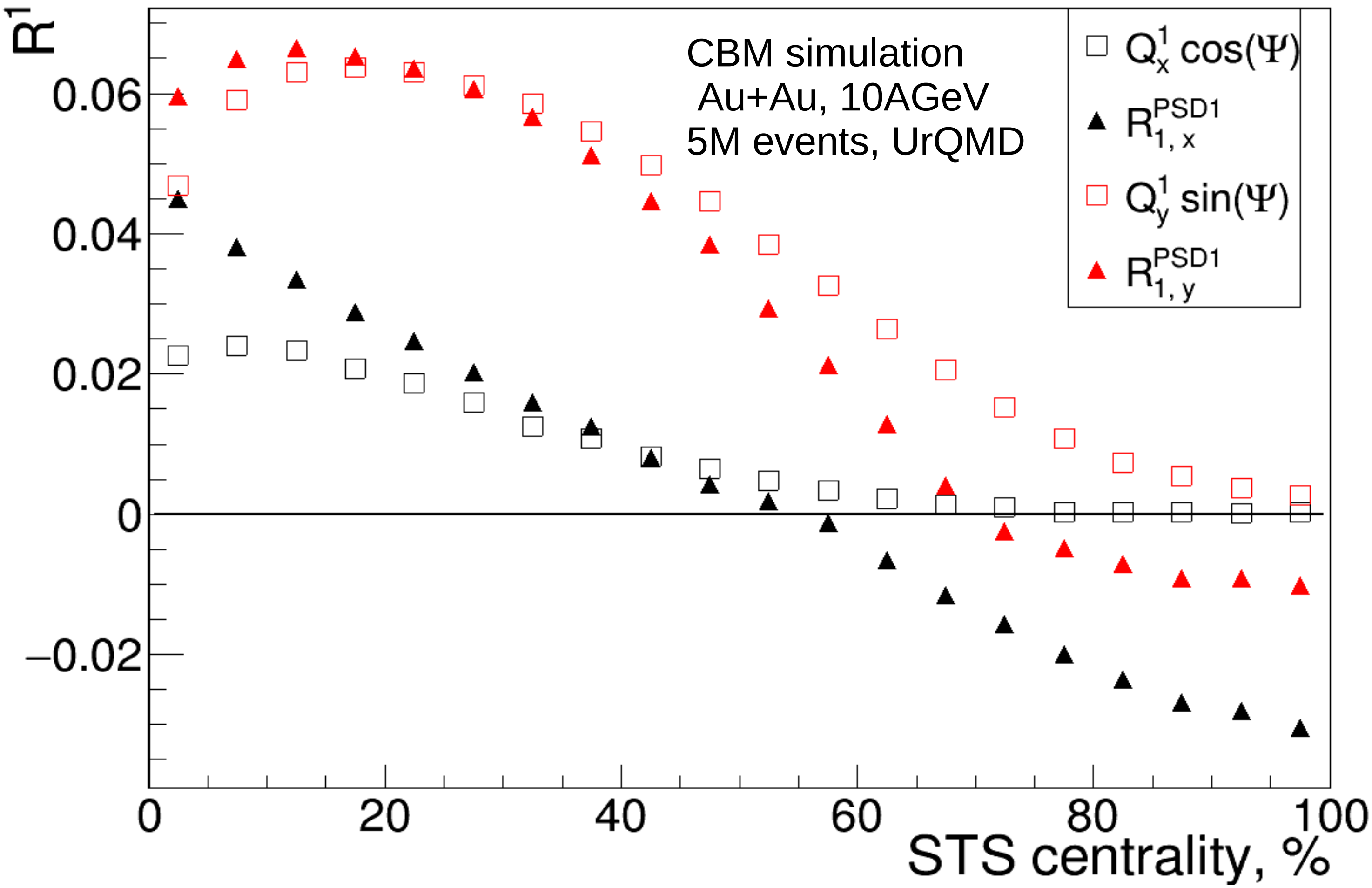
  (joint development with ALICE – Lukas Kreis, GSI)
- Testing with NA61/SHINE data (Projectile Spectator Detector similar to CBM)
- Include particle identification with TOF for all species (pions, protons, kaons)
- Use spectators for centrality determination
- Study other harmonics
- Apply p_T/rapidity dependent efficiency correction

Correction factor

$$R_i^n(A;B,C)=\sqrt{2\frac{\langle Q_i^n(A)Q_i^n(B)\rangle\langle Q_i^n(A)Q_i^n(C)\rangle}{\langle Q_i^n(B)Q_i^n(B)\rangle}}$$

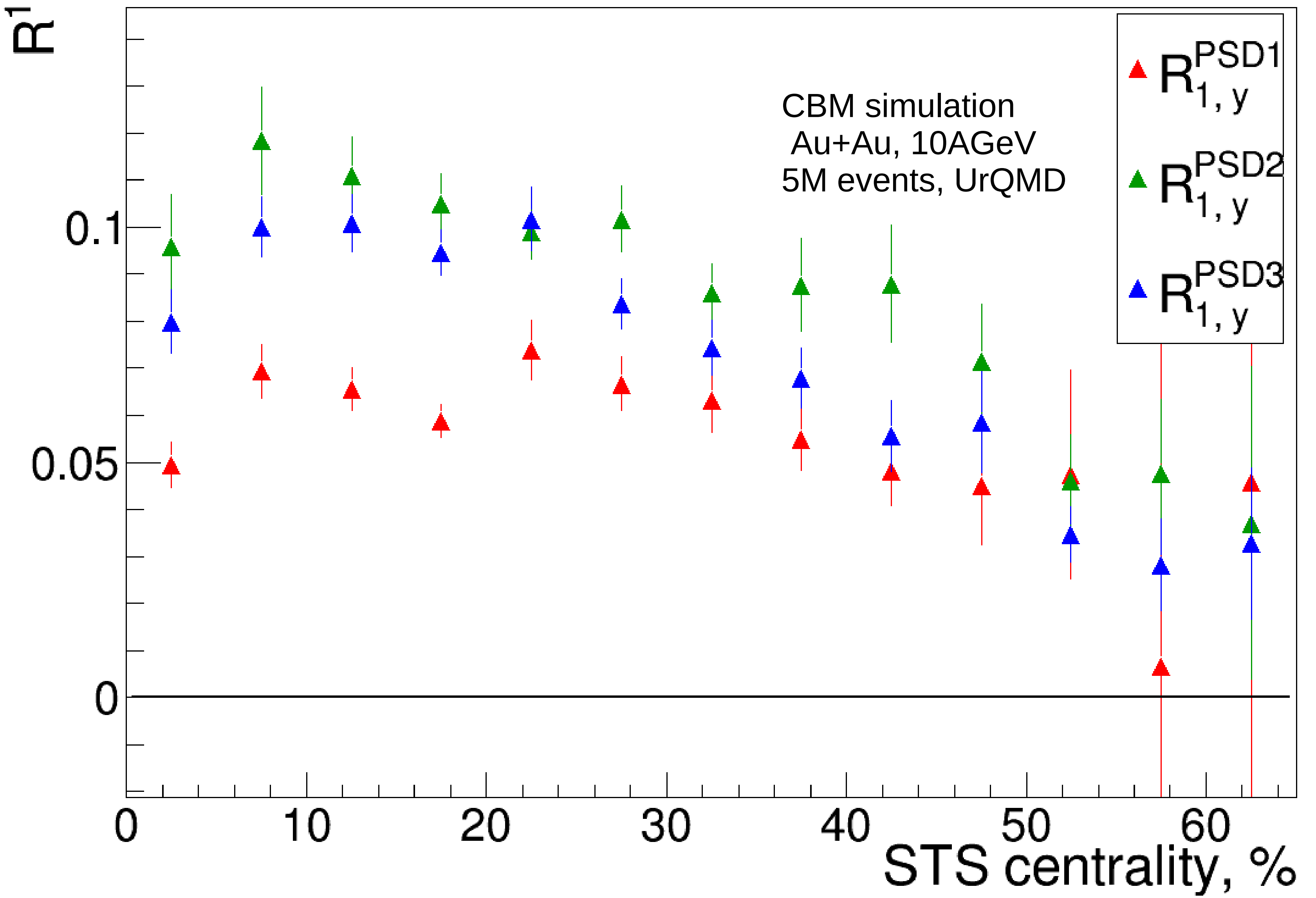
PSD1





Large differences between true and reconstructed correction factor due to non-flow correlations (momentum conservation)

Correction factor for y-component



Central part has worse resolution. Can be improved with higher granularity