CBM performance for flow studies

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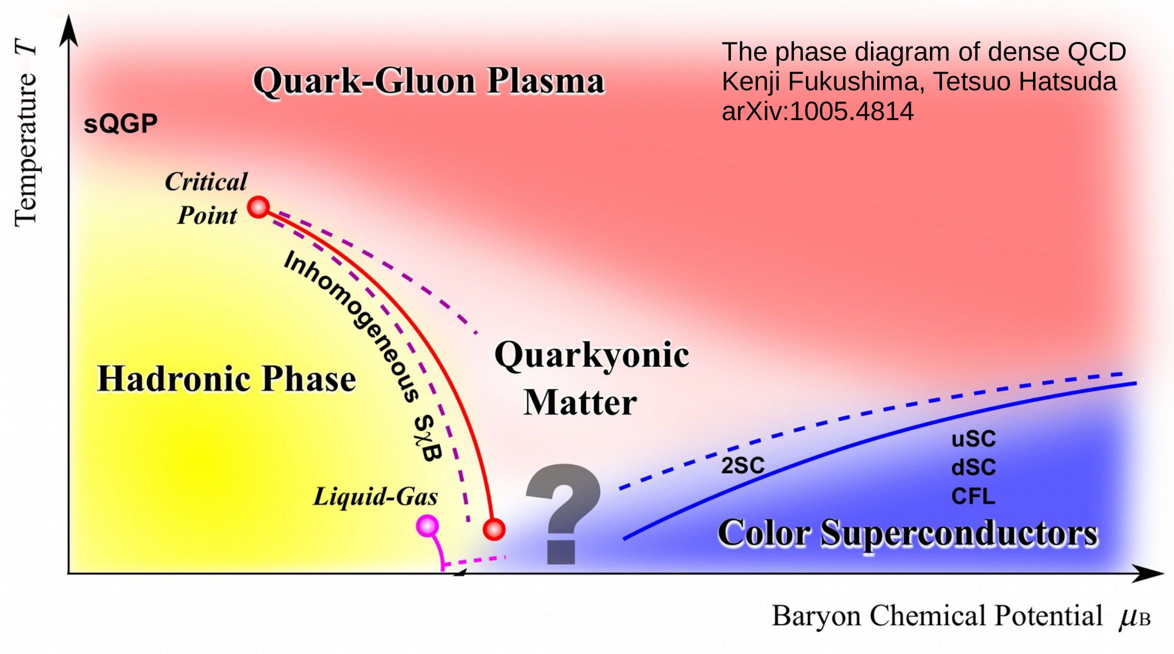
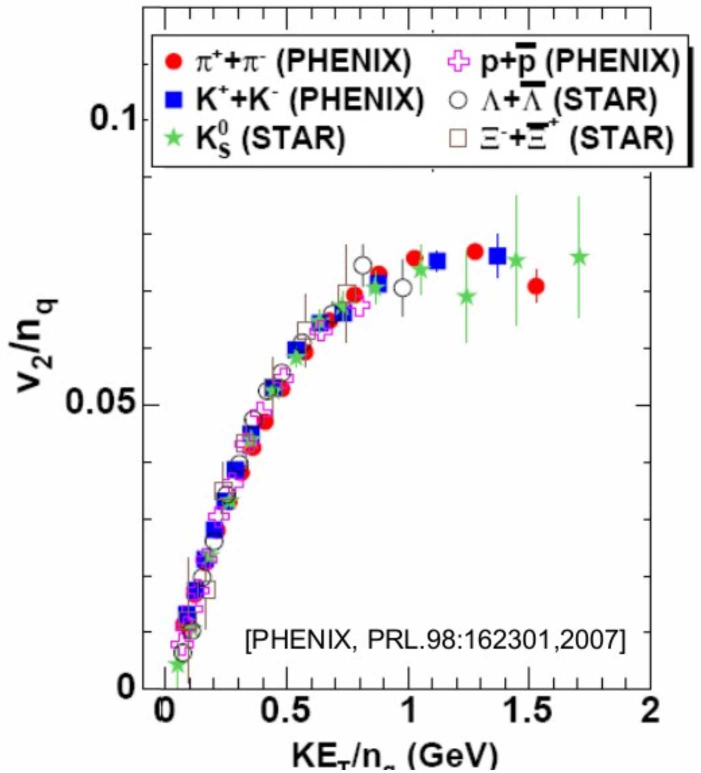
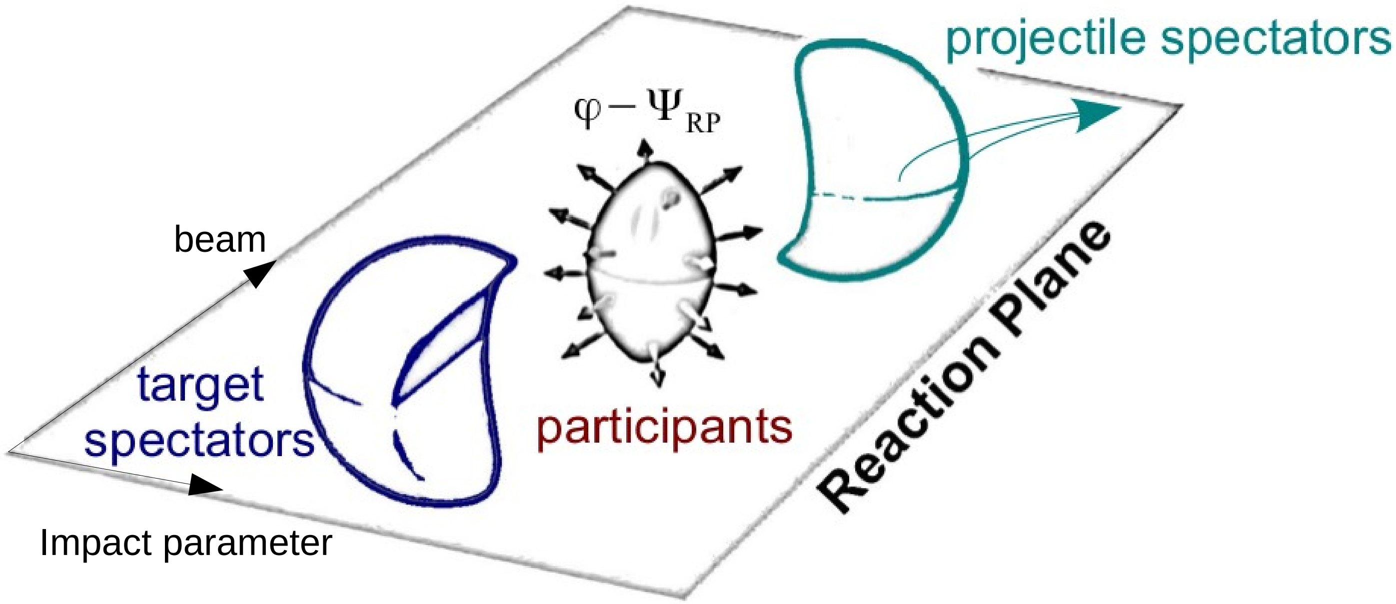
Collective flow at FAIR energies





- CBM@FAIR covers the high net-baryon density area of the QCD phase diagram (SIS100 energies for Au+Au are 2-5 GeV per nucleon in C-o-M system)
- Anisotropic flow is sensitive to evolution of QCD matter in heavy-ion collisions: → equation of state, phase transition, critical point, partonic degrees of freedom
- CBM will allow precise measurements of identified particles flow harmonics

Collision geometry and the transverse anisotropic flow



- Initial spatial asymmetry leads to asymmetry in momenta
- Reaction plane has to be estimated via measured angular distributions

  → spectators and produced particles can be used for the RP estimates

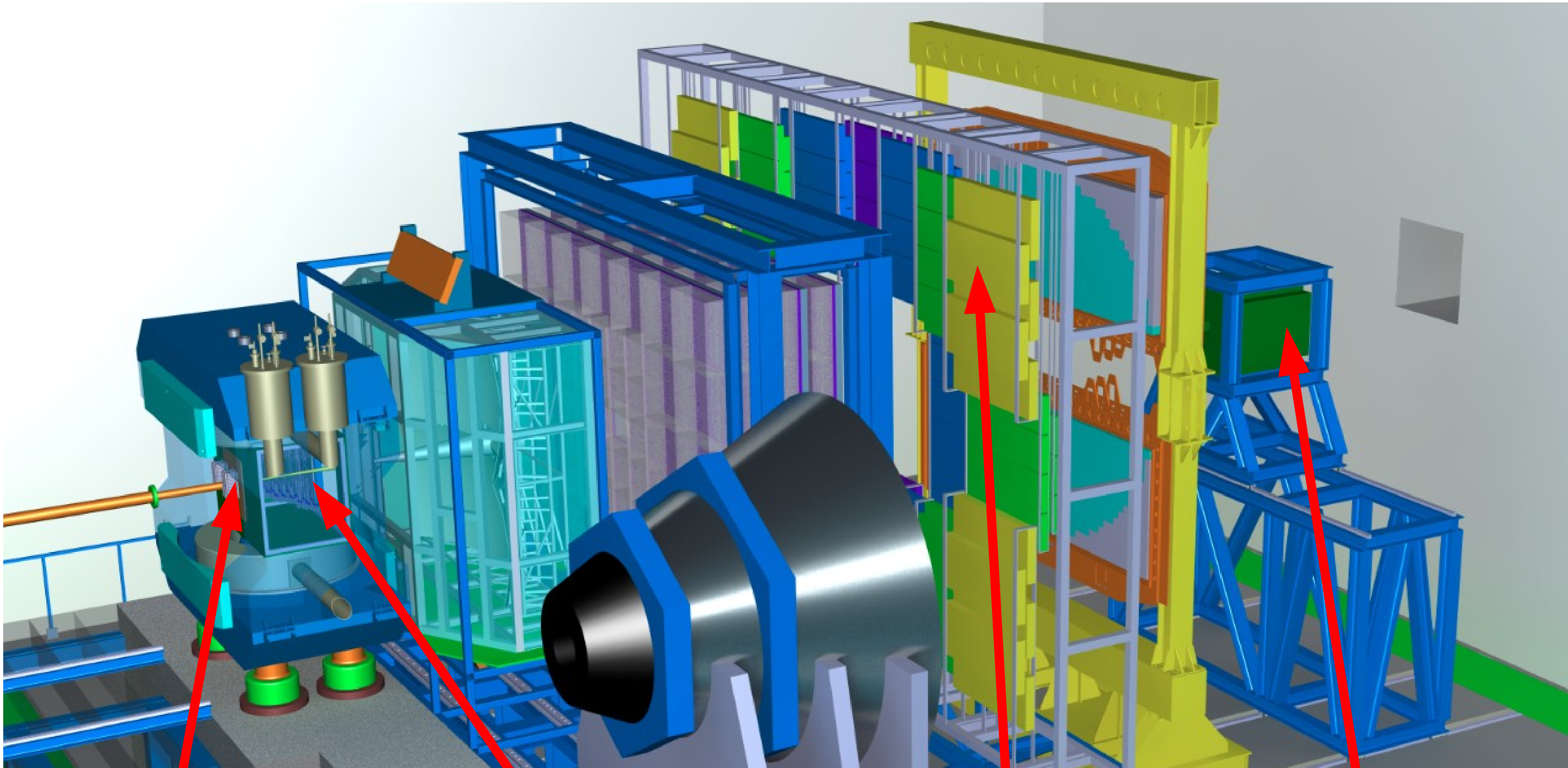
$$\rho(\varphi - \Psi_{RP}) = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos\left(n(\varphi - \Psi_{RP})\right)\right)$$

φ - azimuthal angle

Ψ_{RP} reaction plane angle

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

Compressed Baryonic Matter experiment at FAIR



MVD	STS	TOF	PSD
Micro-Vertex Detector	Silicon Tracking System	Time of Flight Detector	Projectile Spectator Detector

tracking of produced particles | identification | spectators

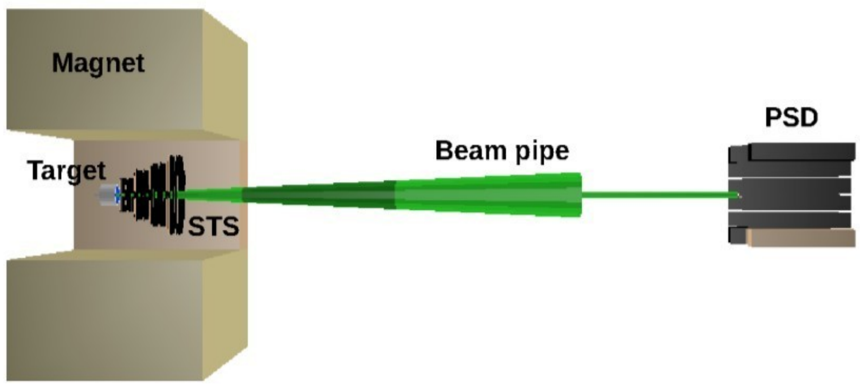
Simulation setup

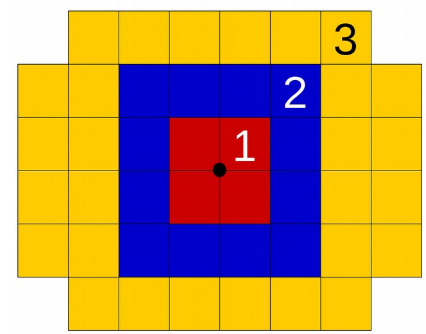
Collisions: Au+Au @ E_{beam} = 10 AGeV

Detector response: GEANT4

Event generator: DCM-QGSM

- Includes fragment simulation
- Reproduces measured flow





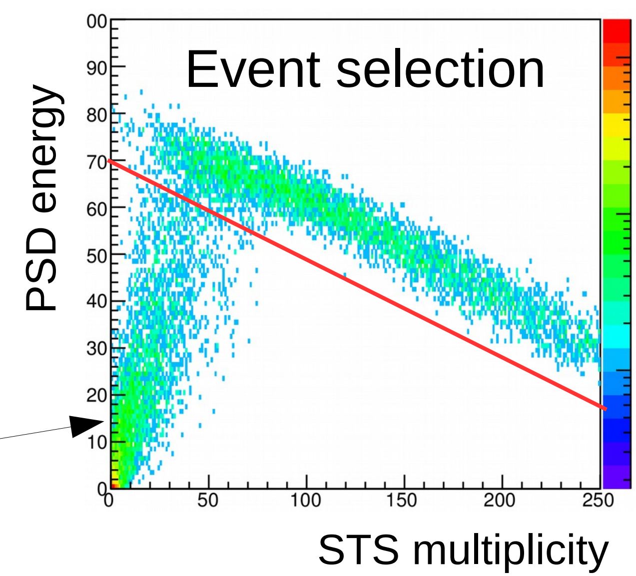
PSD geometry

- 44 modules
- Hole for the beam in the center

STS track selection:

- Good quality tracks selection
- Fitted to the primary vertex
- $\chi^2/NDF < 3$
- $1.5 < \eta < 3$

Fragment simulation with DCM-QGSM

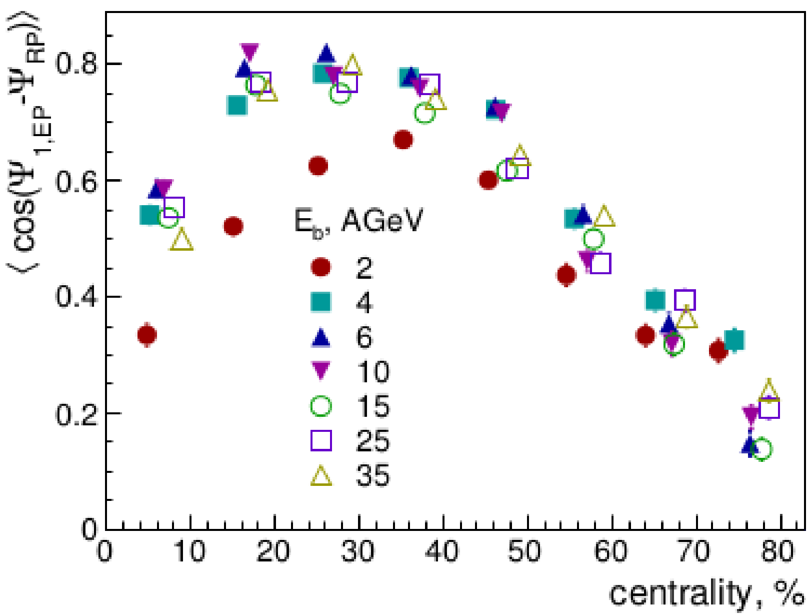


Heavy fragments pass into the hole (~45% of events)

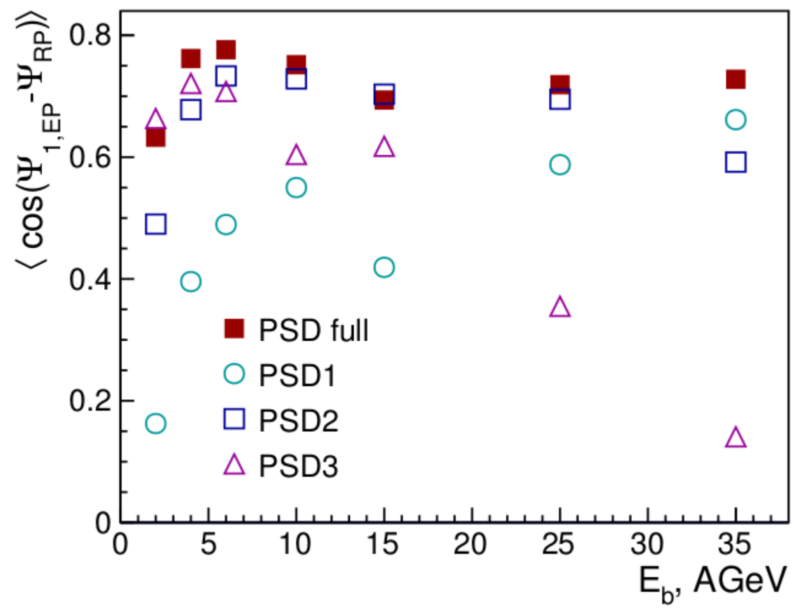
Previous investigations of PSD performance

Flow performance was investigated in PSD Technical Design Report
http://repository.gsi.de/record/109059
Demonstrated good reaction plane resolution with PSD

1st harmonic resolution correction factor for PSD



PSD subevents resolution correction factor

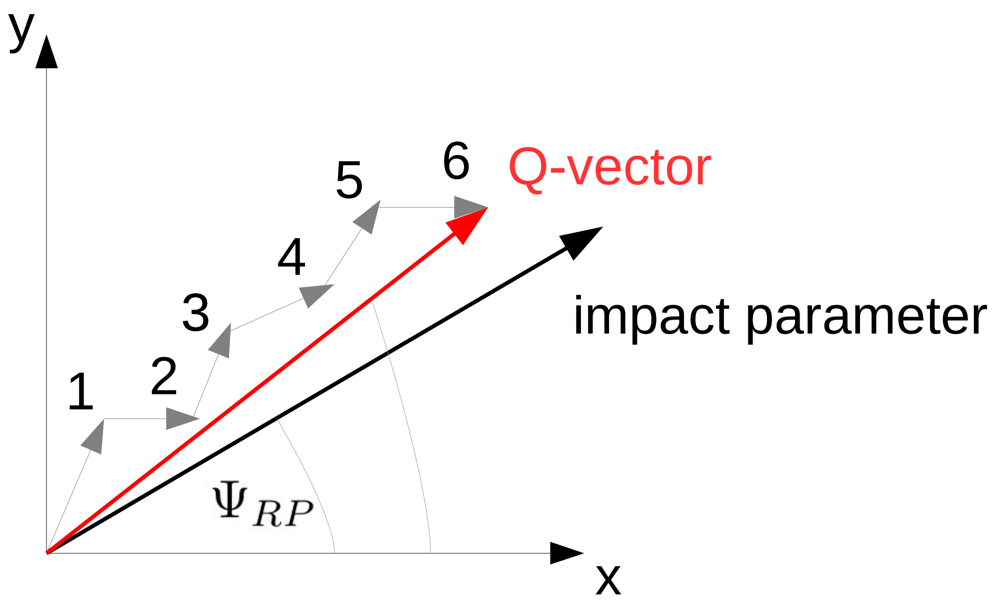


In this presentation, extended studies:

- Adopt flow correction framework developed previously for ALICE
- Study systematic bias due to the choice of the PSD subevents:

→ Q-vector corrections and biases in extraction of the resolution corrections

Experimental estimate of the reaction plane with Q-vector



$$Q_x = \sum_k w_k \cos\varphi$$

$$Q_y = \sum_k w_k \sin\varphi$$

STS

Sum over all selected tracks

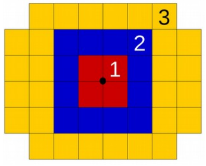
$$\vec{Q}_{STS} = \sum \frac{\vec{p_T}}{|p_T|}$$

p_T - track transverse momentum

PSD

Sum over modules in PSD subevents (A = 1,2,3)

$$\vec{Q}_{PSD_A} = \sum_{k \in A} E_k \vec{r_k}$$



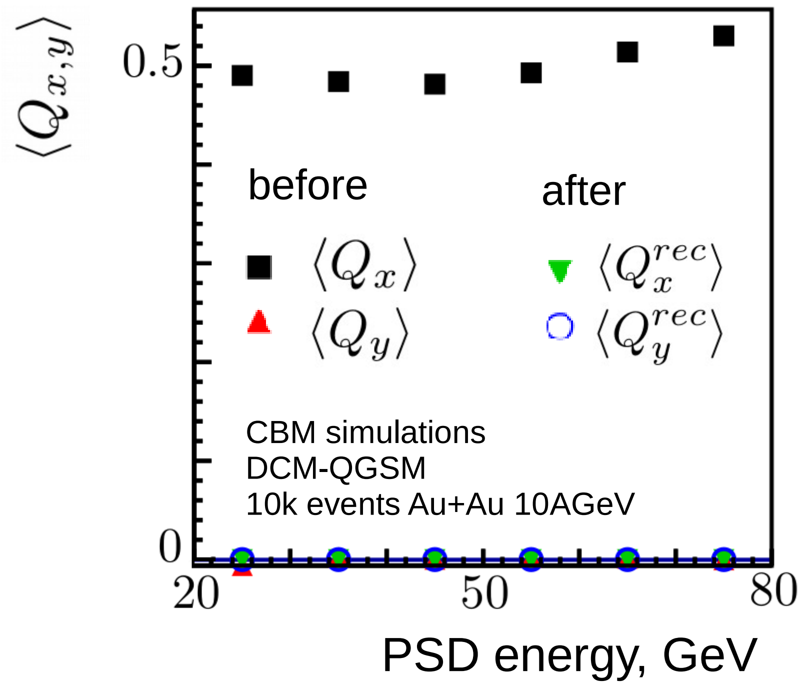
E_k - energy deposit in the module

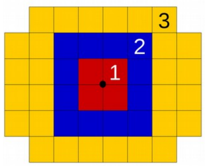
r_k - center of the PSD module

Corrections for detector azimuthal non-uniformity

CBM magnet introduce strong bias - smearing fragment distribution in PSD

Average Q-vector for PSD1 (central) subevent





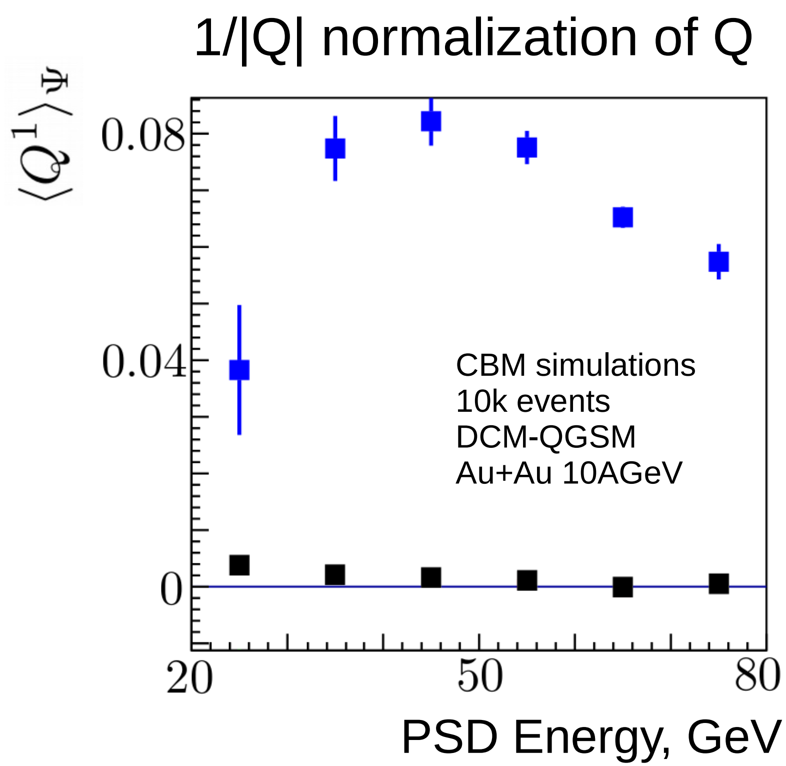
PSD Q-vectors are recentered as a function of the PSD energy:

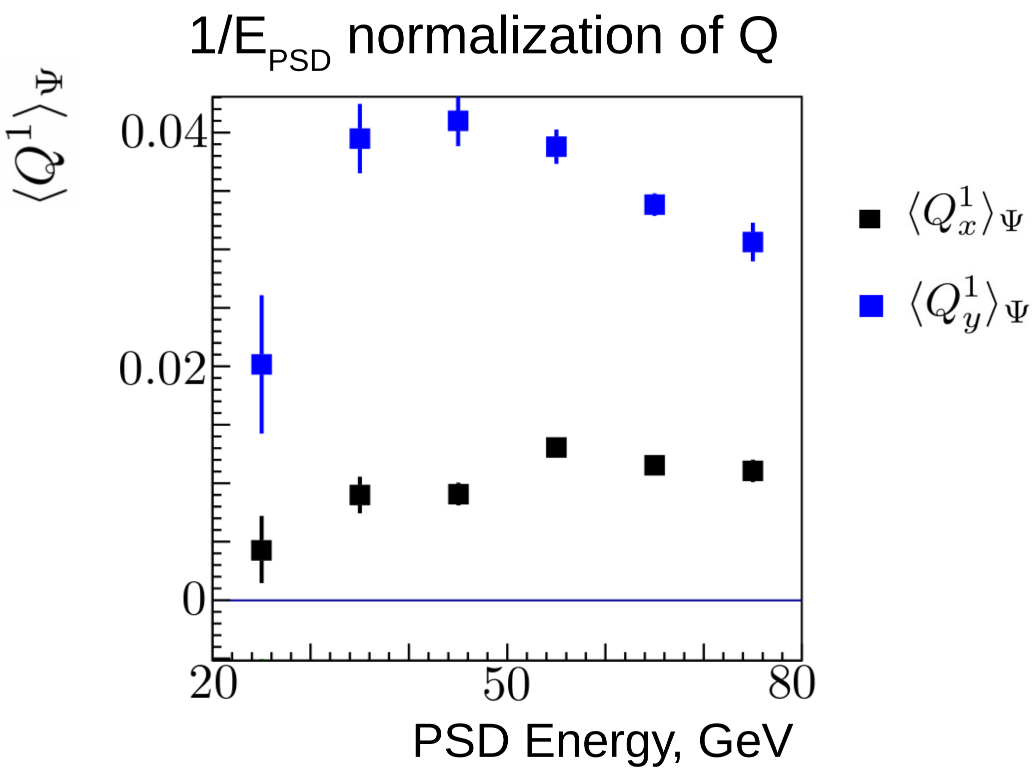
$$Q_n(A) \rightarrowtail Q_n(A) - \langle Q_n(A) \rangle$$

Adopted QnVector corrections framework developed for ALICE
by J. Onderwaater and I. Selyuzhenkov
source: https://github.com/jonderwaater/FlowVectorCorrections

Q-vector sensitivity to reaction plane

Projections of the Q-vector components ($Q_x \cos\Psi_{RP}$ and $Q_y \sin\Psi_{RP}$) quantifies experimental sensitivity to reaction plane





- Correlations in x direction are distorted because of the CBM magnet
- Reaction plane sensitivity depends on Q-vector normalization:

→ Q-vector with 1/M normalization has a better senstivity

Biases in the Q-vector correlations

subevent correlations $\langle Q_i^A Q_i^B \rangle \overset{?}{=} \frac{1}{2}\langle Q_i^A \rangle_\Psi \langle Q_i^B \rangle_\Psi$ product of Q-vector projection on reaction plane

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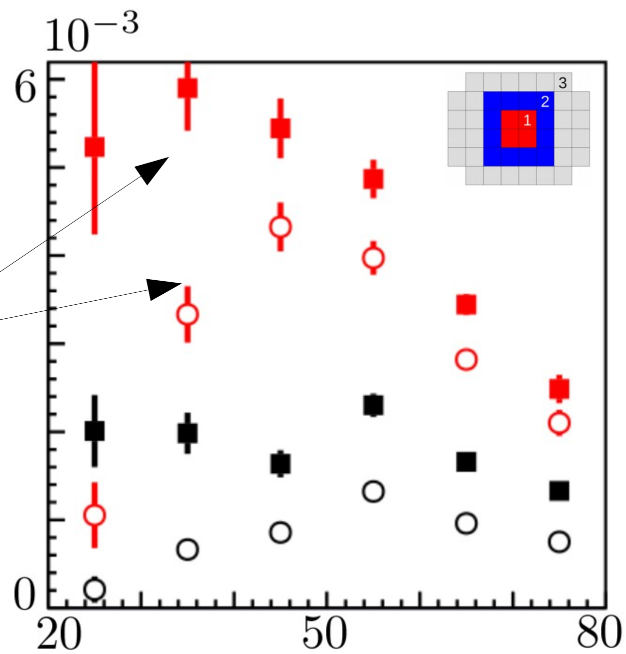
Neighboring PSD subevents (1 and 2)

biased



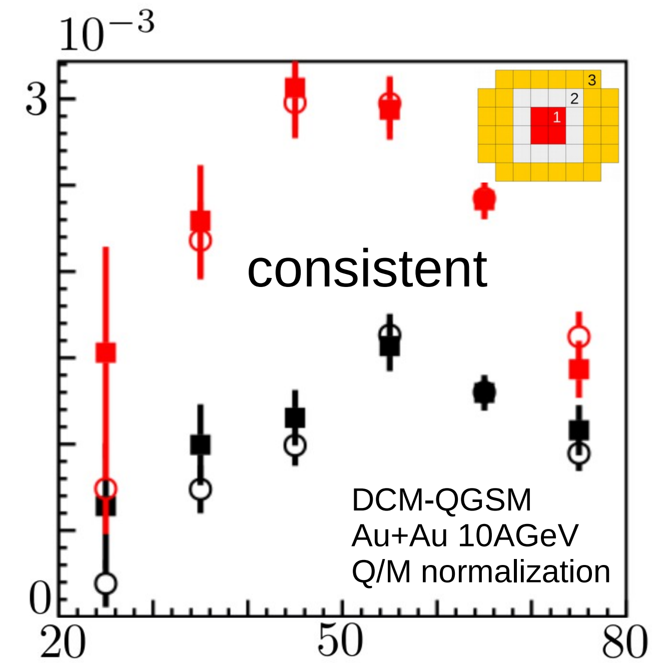
$\langle Q_i^A Q_i^B \rangle$

■ x ■ y

$\frac{1}{2}\langle Q_i^A \rangle_\Psi \langle Q_i^B \rangle_\Psi$

○ x ○ y

Subevents with a gap (1 and 3)



- Biased correlation for neighboring PSD subevents
  → “auto”-correlations due to hadron shower of the same particles
- Consistent correlation between subevents with a gap

Reaction plane resolution for different subevents

MC-true $2\langle Q_x^A \rangle_\Psi \overset{?}{=} \sqrt{2\frac{C_x^{AB} C_x^{AC}}{C_x^{BC}}}$ reconstructed with subevent correlations

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Resolution correction factor for PSD1 (central) subevent

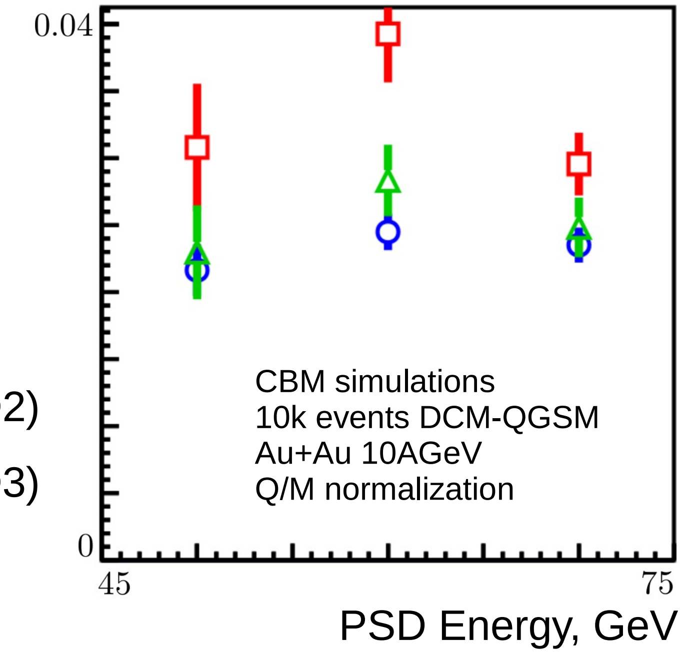
MC-true

○ $2\langle Q_x^A \rangle_\Psi$

Reconstructed

□ R_x (STS, PSD2)

△ R_x (STS, PSD3)



- Choice of neighboring subevents has ~ 40% bias
- Resolution from correlation between separated subevents is consistent with MC-true resolution

Conclusions

- CBM performance for flow measurements is studied with different subevents from PSD and STS subdetectors:
  - ✓ Sensitivity to the reaction plane of the central PSD modules depends on Q-vector normalization
  - ✓ Using neighboring subevents introduce ~ 40% bias
  - ✓ Using correlations between separated subevents reproduces MC-true reaction plane resolution

Future plans

- Investigate flow for identified hadrons (protons, pions, kaons) with CBM TOF detector and using realistic centrality estimates [centrality: talk by V. Klochkov & I. Selyuzhenkov on Tuesday]
- Test effects of higher order Q-vector corrections using Q-vector framework developed for ALICE
- Investigate systematic bias due to non-flow effects
- Explore effects of flow fluctuations with spectators

Thank you for the attention