Status of the performance studies for strange hadron flow measurements in CBM at FAIR

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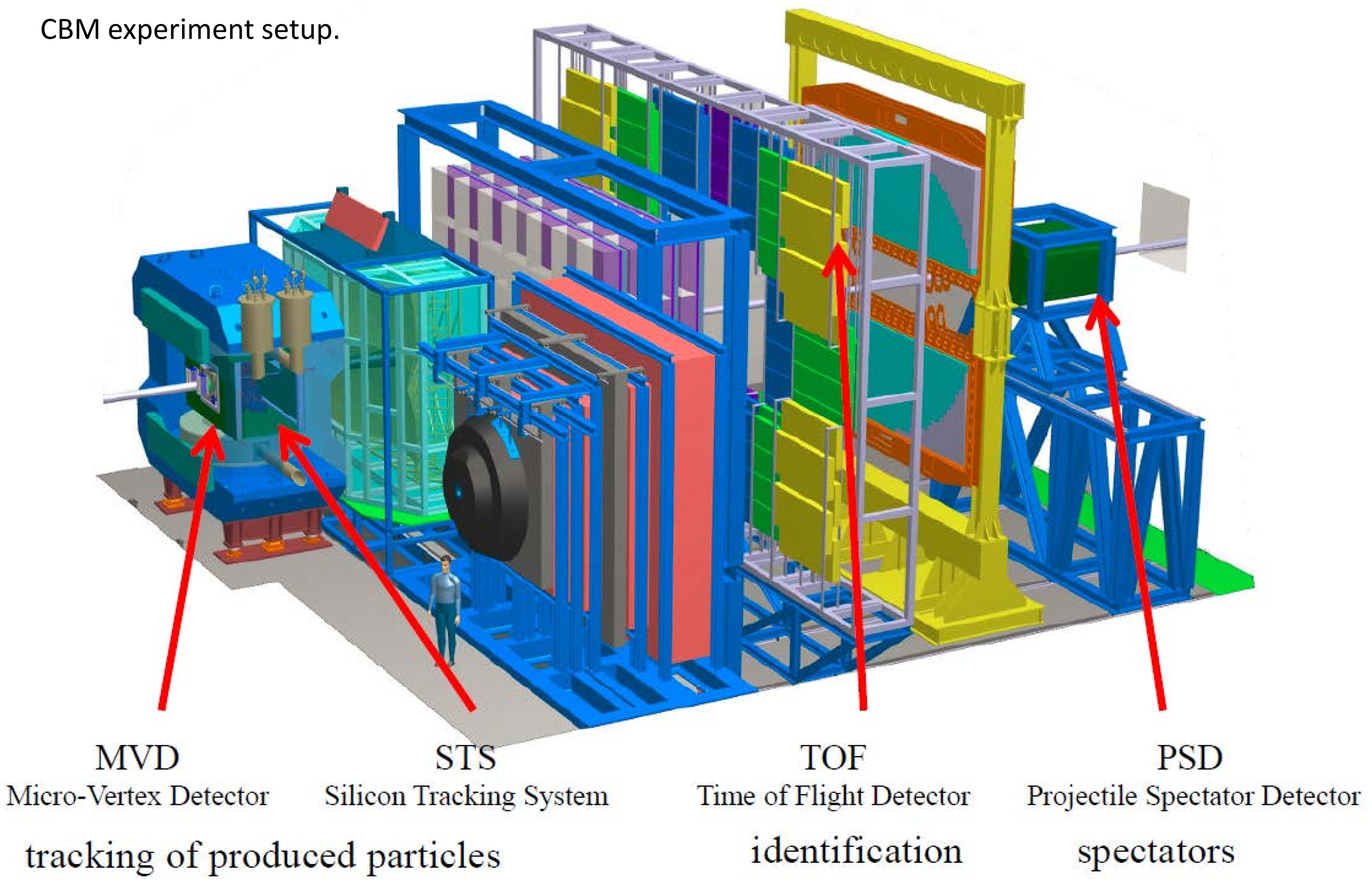
Introduction

Measurement of v_n of hadrons and especially strange and multistrange baryons is an important part of CBM physics program. These observables are speculated to be sensitive to the 1st order phase transition between QGP and hadronic matter.

Performance studies are crucial to understand detector capabilities in advance. Several related topics are important for flow measurements as well as other physical tasks: measurement of Event plane, Centrality and Particle Identification.

CBM experiment setup.



CBM experiment at FAIR

Compressed Baryonic Matter experiment [1] at the future FAIR facility is dedicated to studies of QCD phase diagram at high baryonic densities and moderate temperatures produced at heavy-ion collisions. CBM is expected to begin taking data at FAIR in 2024.

It is believed that the critical point between 1st order phase transition and crossover is located at the region of colliding energies expected at SIS100 accelerator ($\sqrt{s_{NN}}$ = 2.7 – 4.9 GeV). Very high collision rate up to 10 MHz is expected at CBM and continuous streaming readout is proposed.

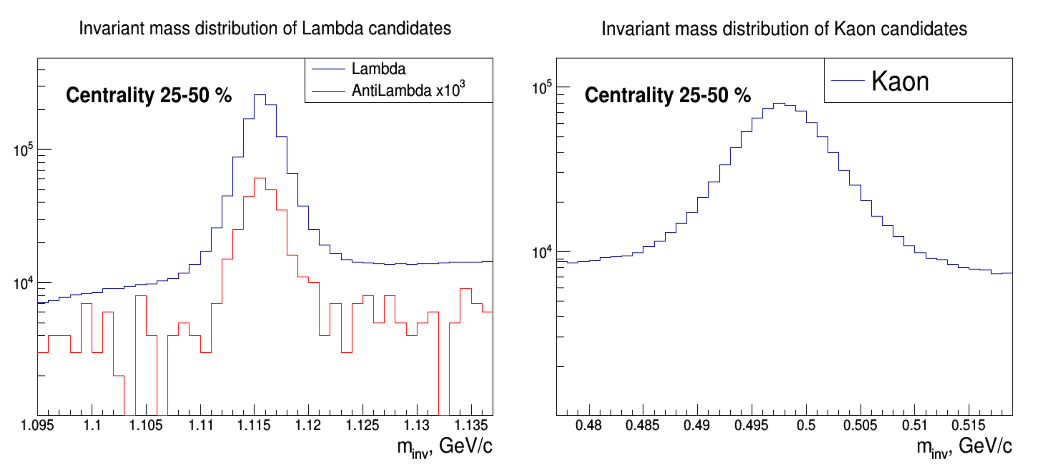
Simulation and reconstruction

10 AGeV Au-Au collisions are simulated with UrQMD generator and GEANT3 transport code.

Full simulation and reconstruction chain within CBMRoot is implemented. MDV, STS, RICH, TDR, TOF and PSD hits are reconstructed and processed. into reduced analysis tree.

KF (Kalman Filter) Particle Finder algorithm is used to identify V0 decays (Lambda, Anti-Lambda, K^0_s) in the reconstruction.

Strangeness reconstruction

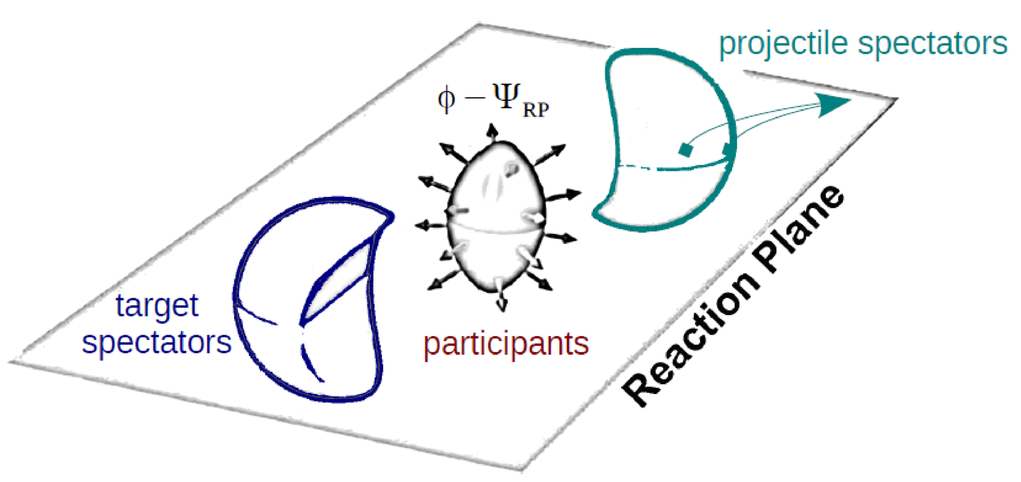


Invariant mass distributions for Λ and $\bar{\Lambda}$ (left) and K^0_s (right).

v_n extraction

Anisotropic transverse flow is the effect of azimuthal anisotropic particle production with respect to the reaction plane.

$$\frac{dN}{d(\phi-\Psi_{RP})} \sim 1 + 2\sum_{i=1} v_n(p_t,\eta)\cos[n(\phi-\Psi_{RP})]$$

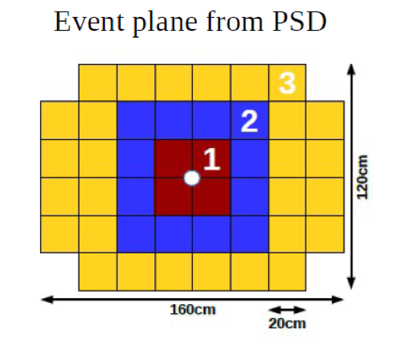


Scalar product method is used to extract flow coefficients v_n. In this method Q-vectors of subevents corresponding to 3 groups of PSD modules or STS subevents separated in rapidity are correlated with particle's unit vector. Correction on resolution factor R is used to obtain true v_n values.

$$v_n^{obs} = \langle u_i Q_i \rangle, v_n^{true} = v_n^{obs}/R$$

Invariant mass method to separate flow contribution of decaying particles from flow of combinatorial background is implemented. In this method v_n is calculated for each bin in invariant mass as well as signal to background ratio. v_n of combinatorial background is estimated in the regions outside mass peak and v_n of signal is obtained with formula:

Event plane from PSD



Three groups of PSD modules

$$v_n^S = v_n^{meas} + \frac{Bg}{S}(v_n^{meas} - v_n^{Bg})$$

Q-vector Corrections framework is based on [2]. Several corrections, such as gain equalization, recentering, alignment, could be applied in order to correct for detector acceptance non-uniformity effects.

Centrality determination

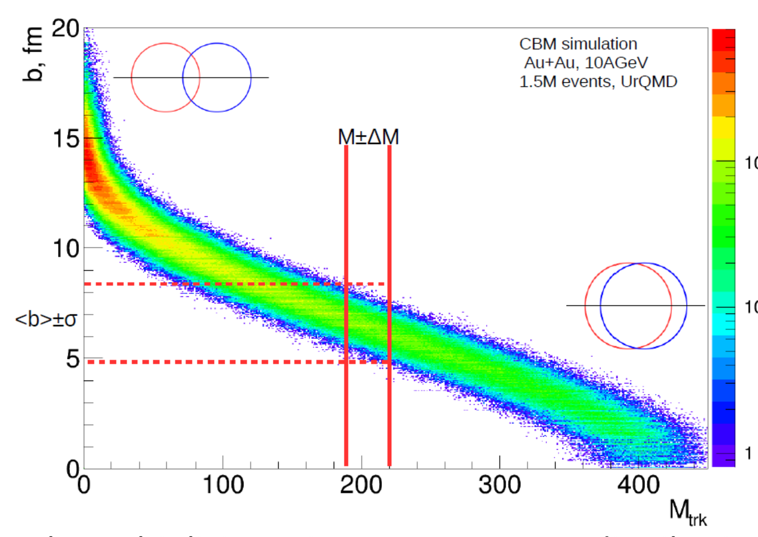
Centrality is needed to obtain event classes for different impact parameter b intervals. In CBM centrality can be obtained with:

a) PSD energy
b) STS track multiplicity
c) Combined 2D distribution

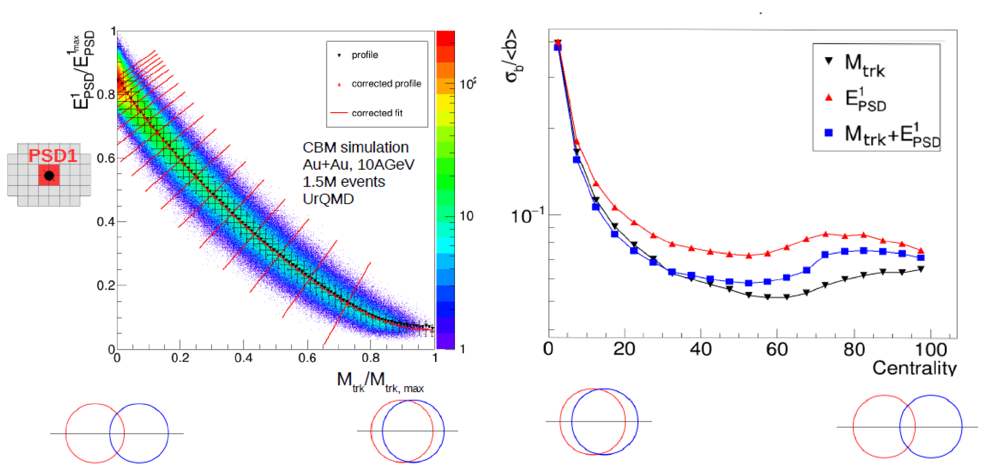
For 1D distributions the fitting procedure with Negative Binomial Distribution is used. N_{coll} and N_{part} parameters are obtained with Glauber Monte-Carlo model.

For 2D distributions an iterative procedure is used for profiling, fitting, perpendicular profiling.

It is shown that by using a combined 2D estimator one can improve impact parameter resolution for central collisions (0-30% centrality).



STS tracks multiplicity vs impact parameter distribution.

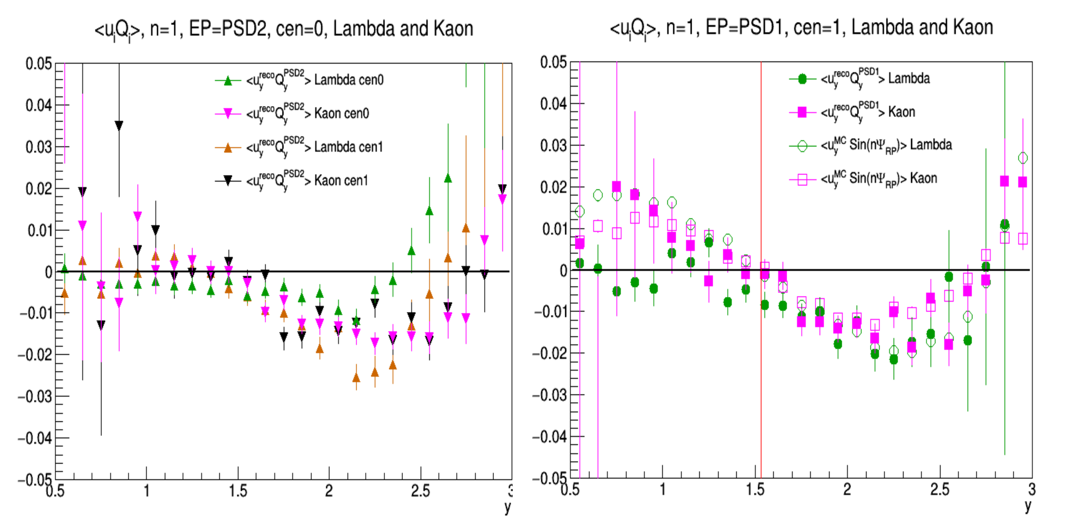


2D distribution of STS tracks multiplicity and energy in PSD could be used as a centrality estimator (left). Resolution of the impact parameter for different centrality estimators.

More on centrality estimation at CBM can be found in [3].

Results

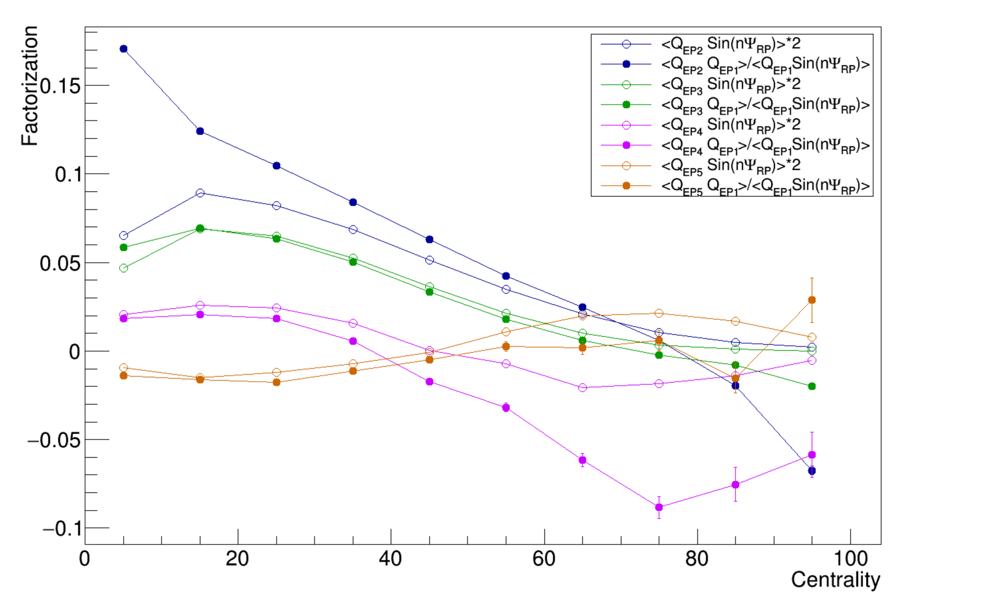
Directed flow (v_1) of protons, Lambdas and K^0_s is extracted for MC and reco particles. MC PID is used for protons, KFParticle Finder reconstruction is performed for V0 particles.



Left: $v_1(y)$ for Λ and K^0_s for centralities 0-25% and 25-50%. Right: $v_1(y)$ for Λ and K0s from the MC and reco particles correlated with RP and Q-vectors from PSD1 subevent.

A dedicated study to investigate Q-vector factorization was performed. It was shown that factorization is kept for $\langle Q_1Q_3\rangle$ for mid-central collisions.

Factorization, y axis



$\langle Q_iQ_j\rangle/\langle Q_i Sin(n\Psi_{RP})\rangle$ and $\langle Q_i Sin(n\Psi_{RP})\rangle$ compared for different subevents. EP1-EP3 – PSD, EP4 – STS forward, EP5 – STS backward.

Conclusions

First performance studies with UrQMD model and CBMROOT detector response simulations were carried out. Centrality framework is developed and collective flow methods are implemented to extract directed flow of protons, Lambda baryons and K^0_s mesons in Au+Au collisions of 10 AGeV expected at the future SIS100 accelerator.

We observe the difference between model distributions and the ones obtained with PSD Q-vectors due to Q-vector factorization breaking.

Literature

[1] CBM Collaboration, Eur. Phys. J. A 53 (2017) 60
[2] I. Selyuzhenkov, S. Voloshin, PRC77 034904 (2008)
[3] V. Klochkov, I. Selyuzhenkov, J.Phys.Conf.Ser. 798 (2017) no.1, 012059

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