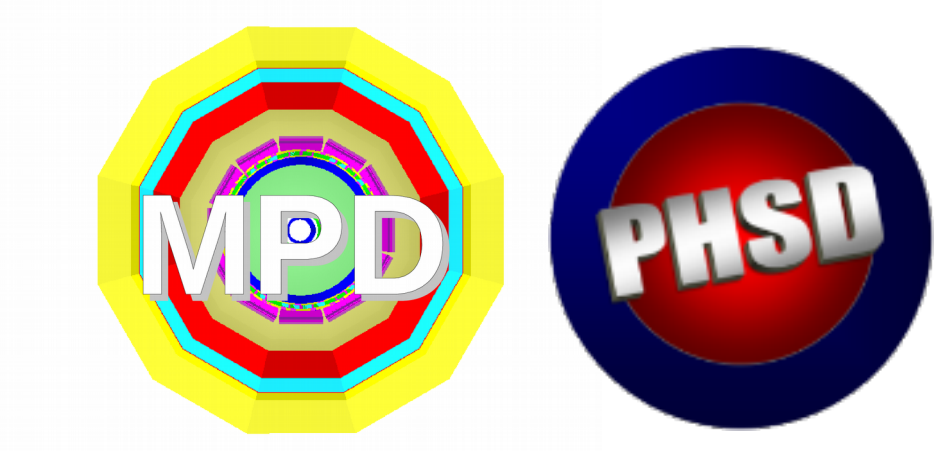
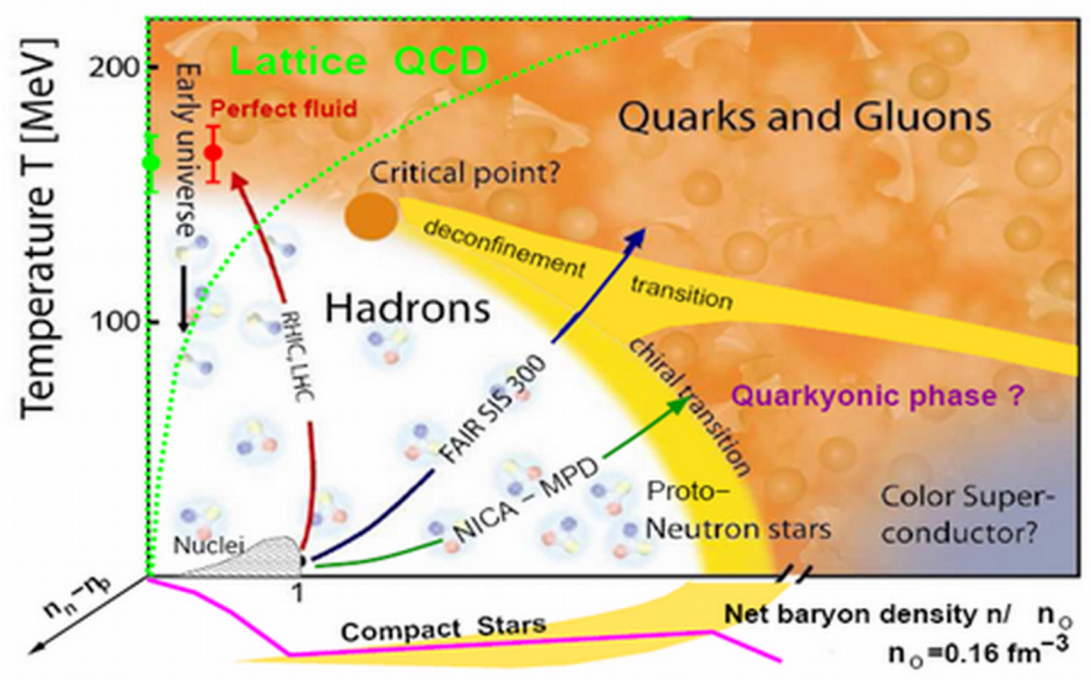
Development of models and physics analysis

V.Voronyuk (JINR, Dubna)



The main goal of the NICA project

- Explore the QCD phase diagram and properties of hadrons at high temperature or high baryon density
- Phase transition from hadronic to partonic matter

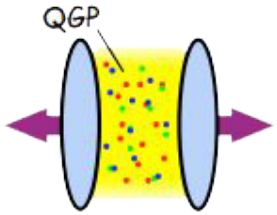


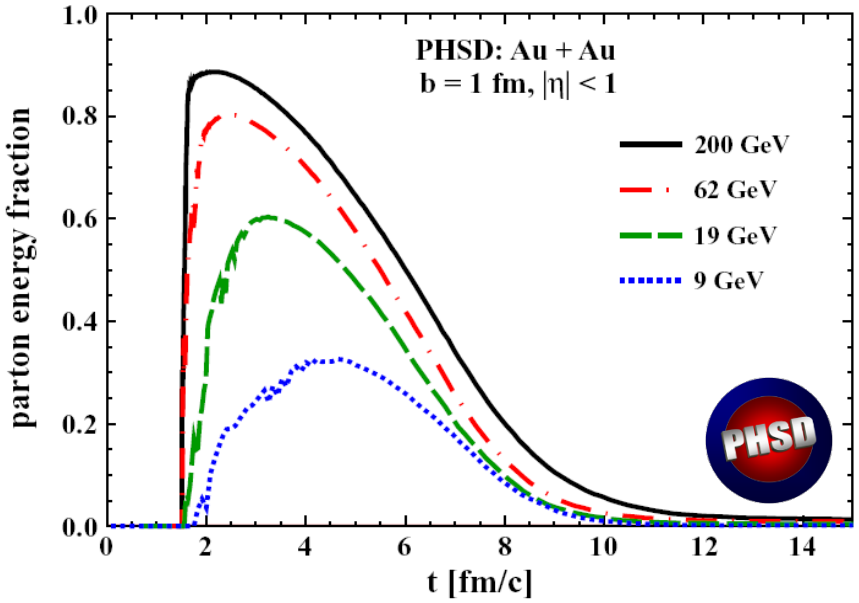
Observables

- Anisotropic flow (PHSD)
- Charged azimuthal correlations (PHSD)
- Baryon stopping power (3FD)
- Dilepton production (Urqmd+Pluto)
- Hyperon and hypernuclei production (QGSM)

Partonic energy fraction in central A+A

- At SPS, only a small part of the initial energy is converted into the QGP phase
- At top RHIC energies, the QGP phase at midrapidity contains roughly 90% of the energy

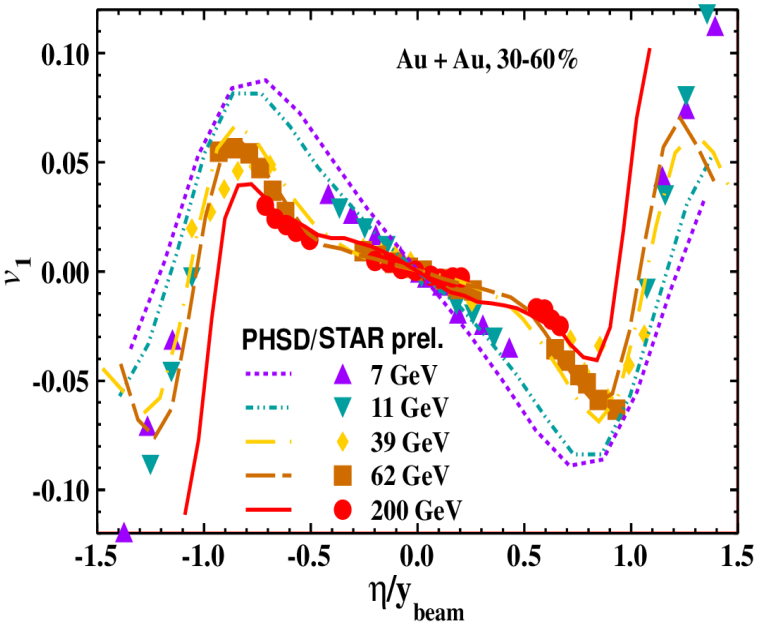


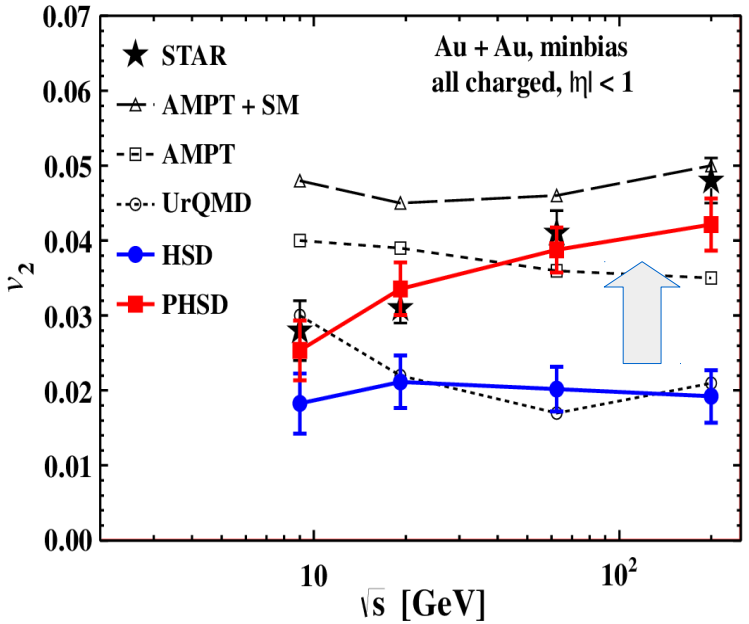


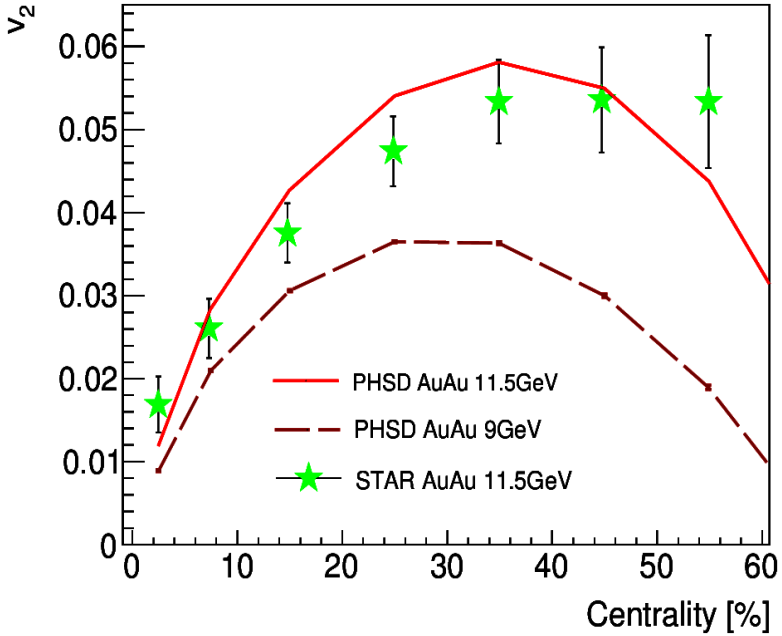
- At NICA, **25%** of initial energy is converted into the QGP phase

Anisotropic flow

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





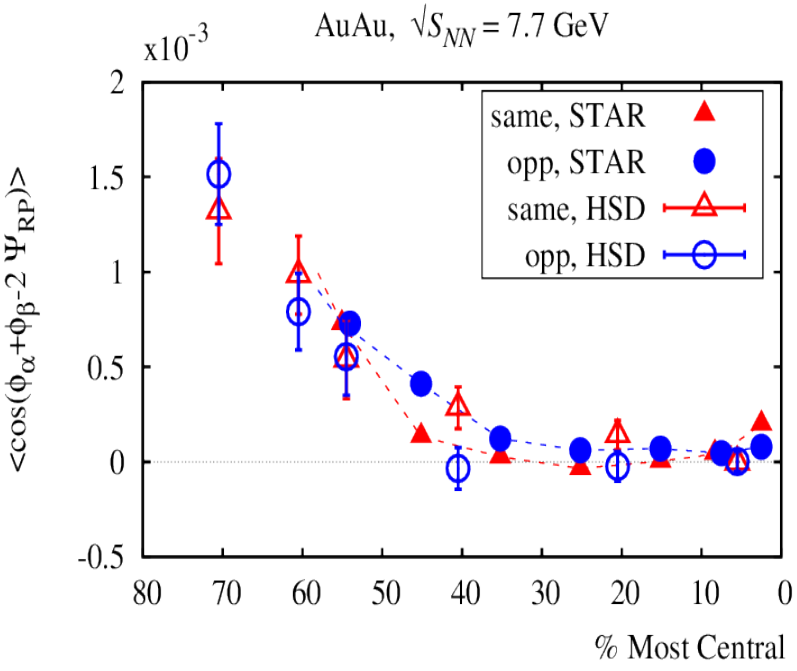


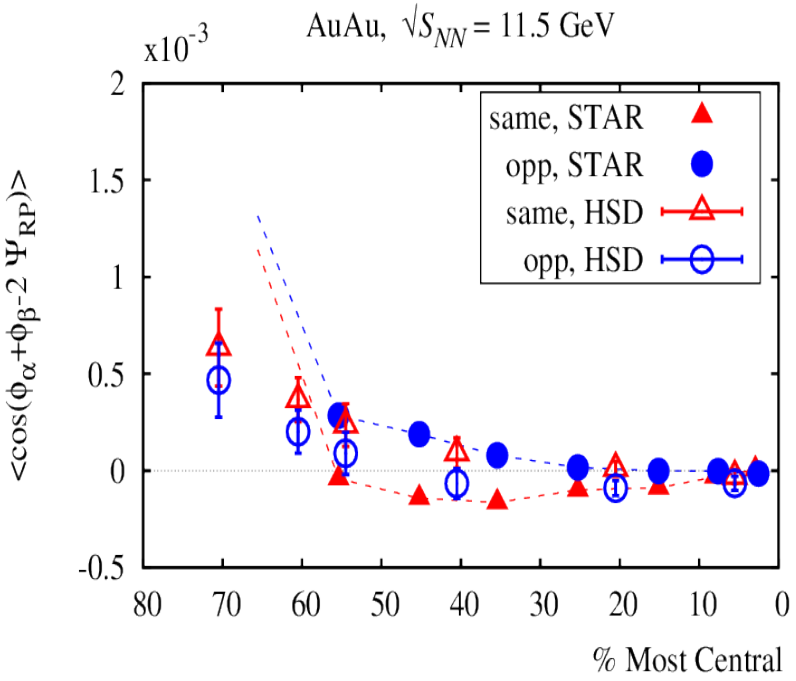
- PHSD model successfully describes direct and elliptic flow in a wide range of the collision energy

Charged azimuthal correlations (CME background)

$$\langle \cos(\phi_i + \phi_j - 2\Psi_{RP}) \rangle = \langle \cos(\phi_i - \Psi_{RP}) \cos(\phi_j - \Psi_{RP}) \rangle - \langle \sin(\phi_i - \Psi_{RP}) \sin(\phi_j - \Psi_{RP}) \rangle$$

- The pure hadronic HSD model can reasonably describe experimental trends at moderate energies 7.7 GeV and 11.5 GeV without any CP violation effects.





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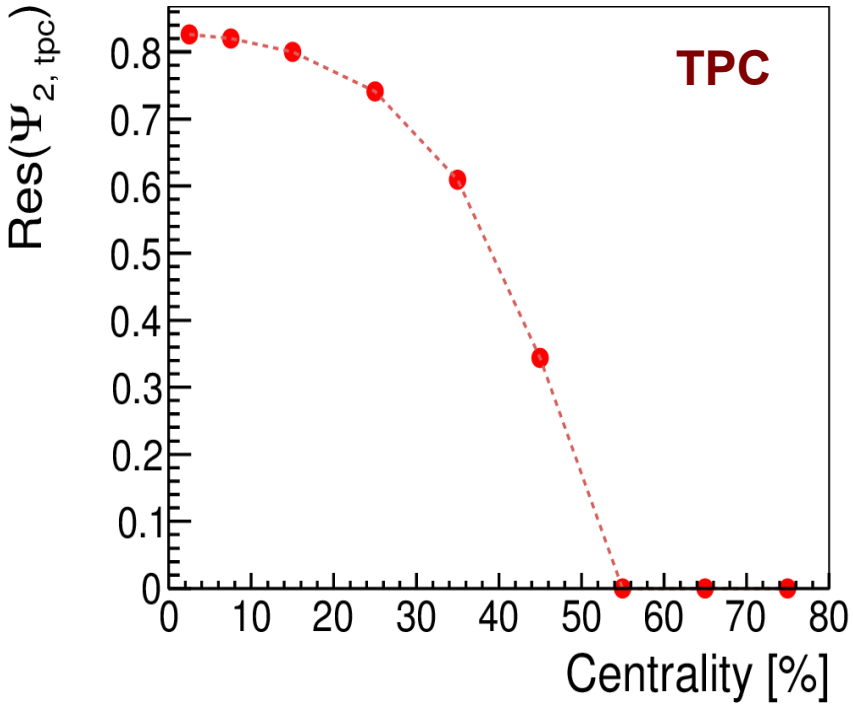
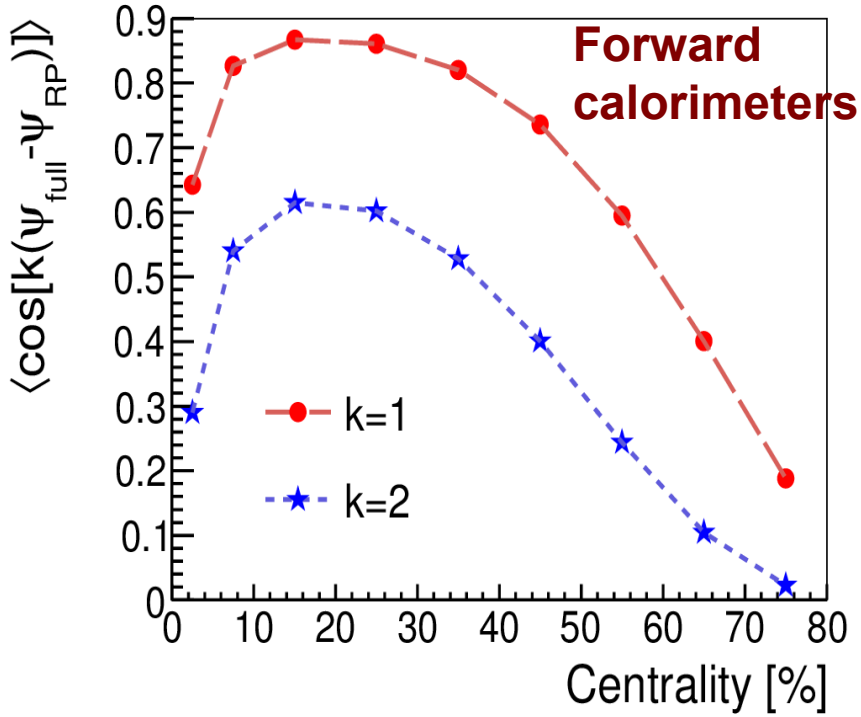
Event plane resolution from TPC and FHC

- Due to low multiplicity in peripheral collisions and small value of elliptic flow the resolution from TPC drops very fast.
- Good resolution from forward hadronic colorimeters





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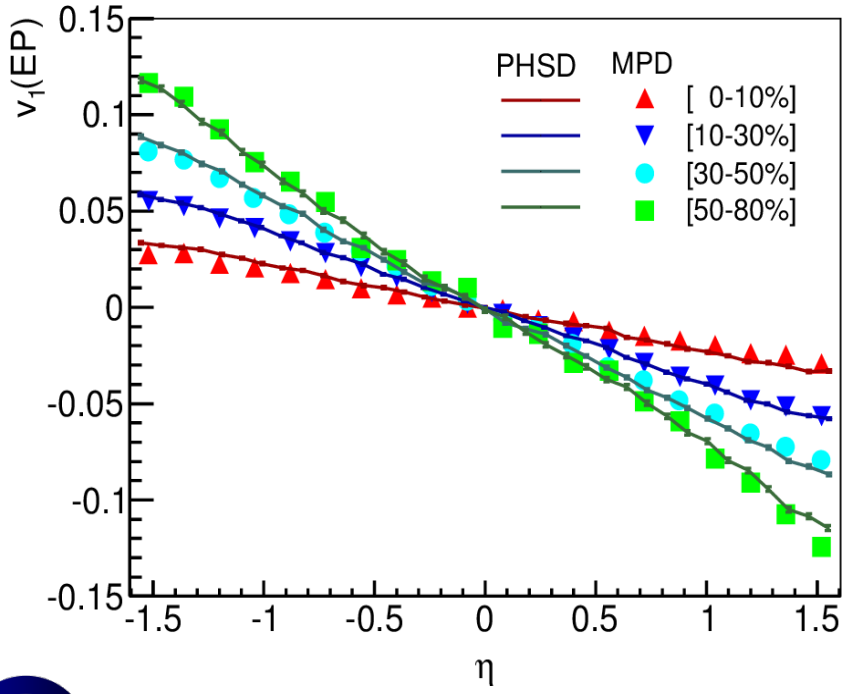
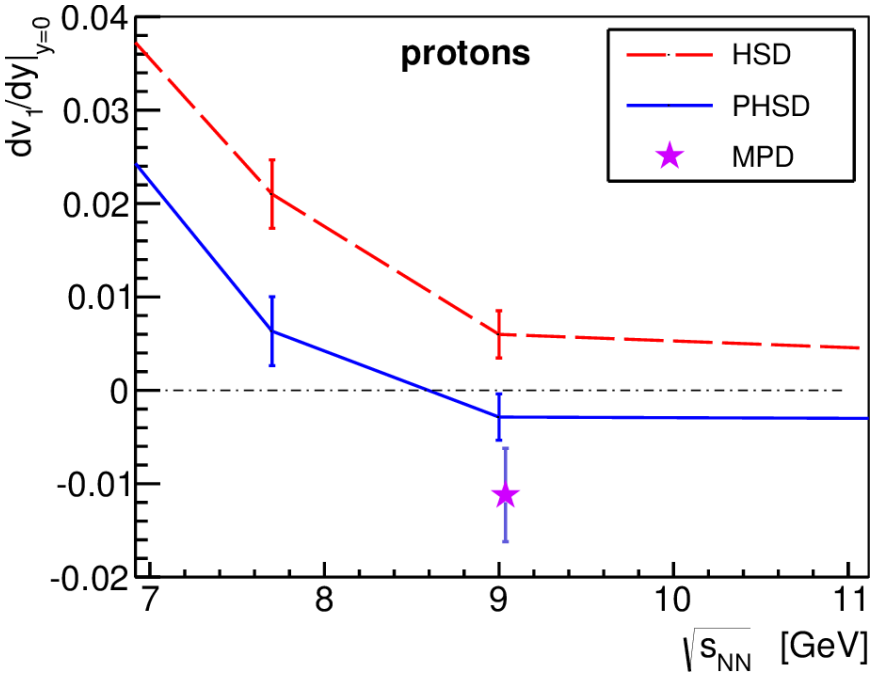
Reconstructed direct flow

- The reconstructed direct flow are in a good agreement with the MC ones.
- It is possible to investigate slope for identified particles.





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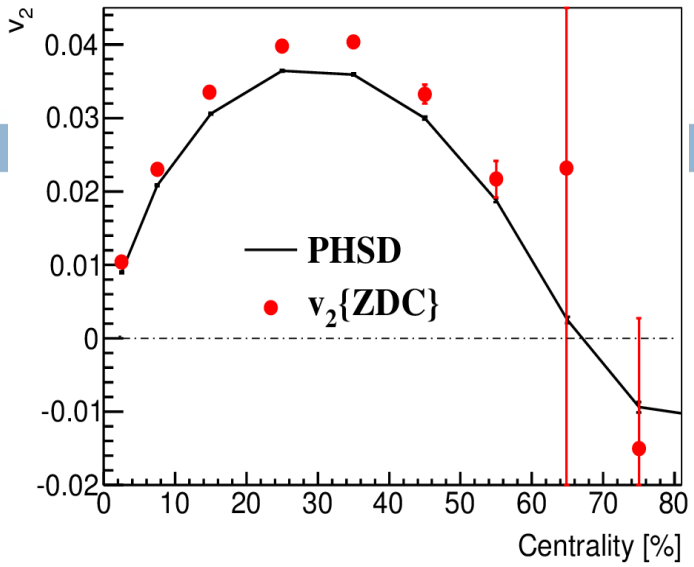
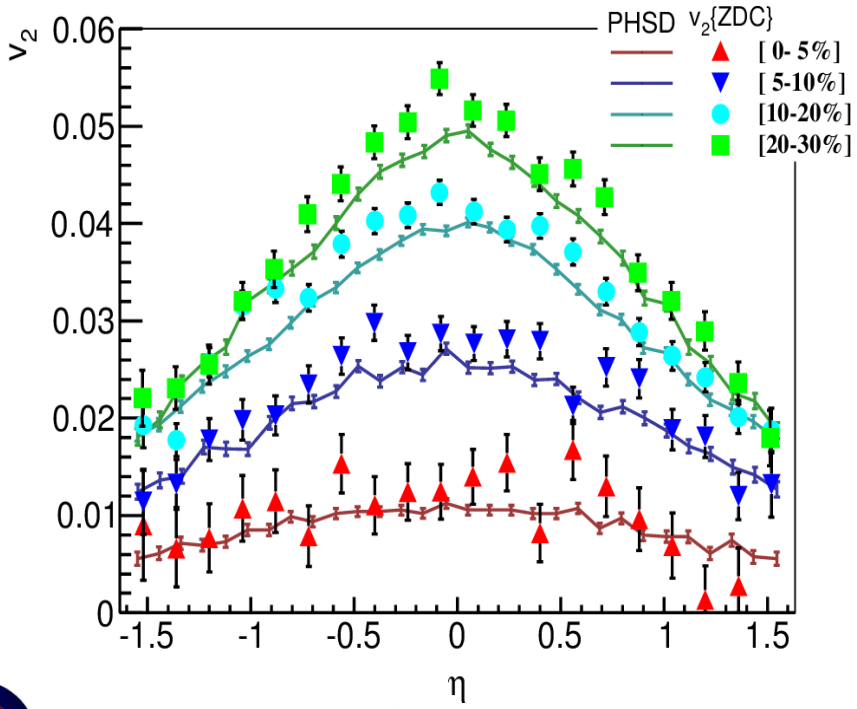
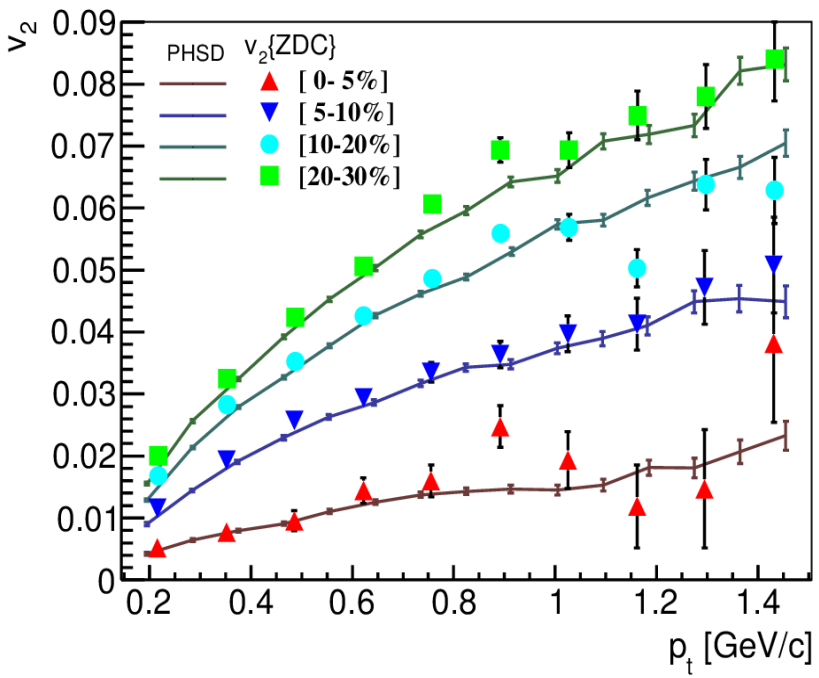
Reconstructed elliptic flow

- The reconstructed elliptic flow are in a good agreement with the MC ones.







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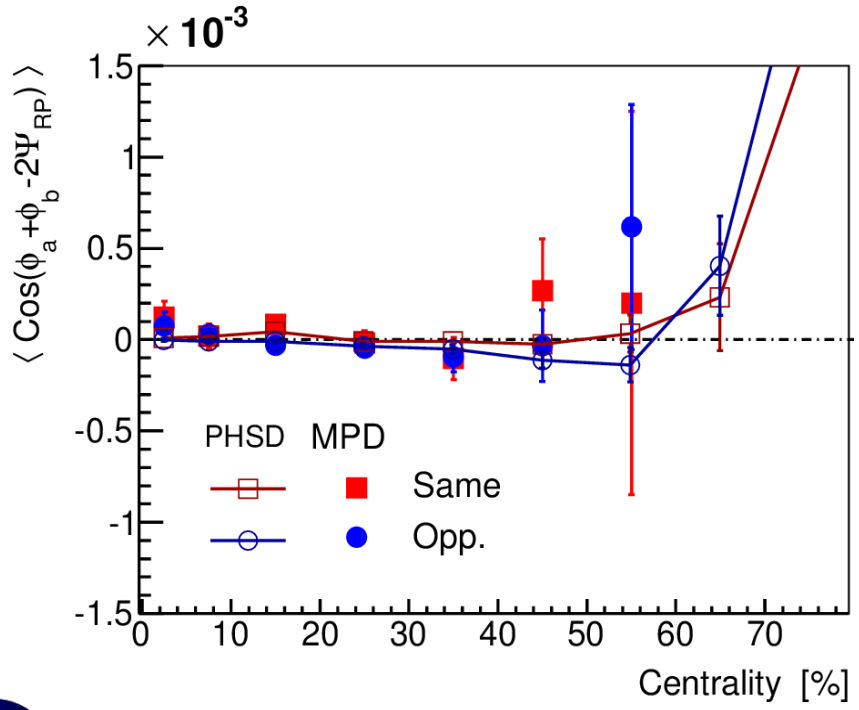
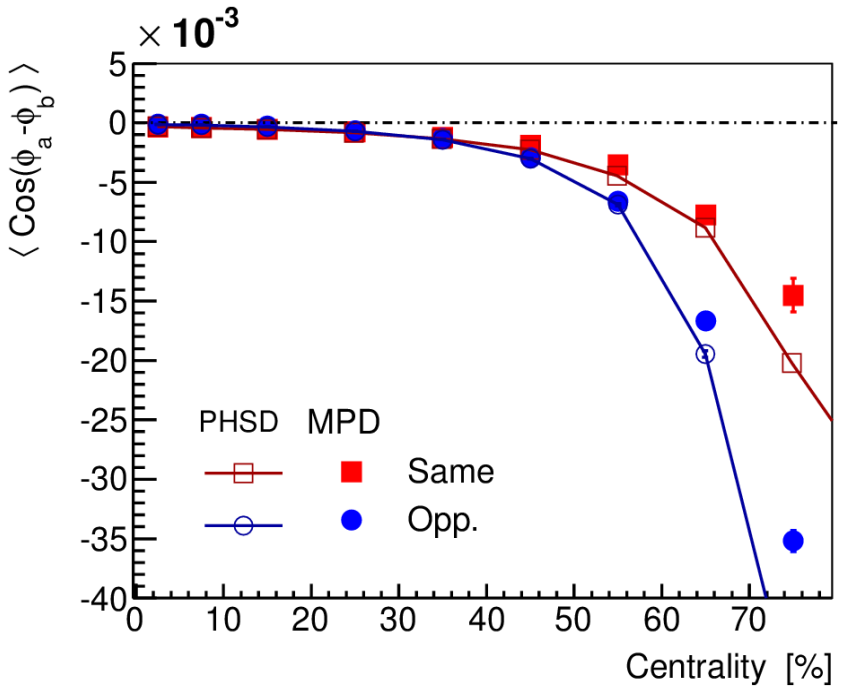
Charged azimuthal correlations

- The magnitude of correlations is a very small and requires much more statistics.
- Peripheral collisions incorporate some systematic errors.

$$\langle \cos(\phi_i + \phi_j - 2\Psi_{RP}) \rangle = \langle \cos(\phi_i - \Psi_{RP})\ \cos(\phi_j - \Psi_{RP}) \rangle - \langle \sin(\phi_i - \Psi_{RP})\ \sin(\phi_j - \Psi_{RP}) \rangle$$

$$\langle \cos(\phi_i - \phi_j) \rangle = \langle \cos(\phi_i - \Psi_{RP})\ \cos(\phi_j - \Psi_{RP}) \rangle + \langle \sin(\phi_i - \Psi_{RP})\ \sin(\phi_j - \Psi_{RP}) \rangle$$





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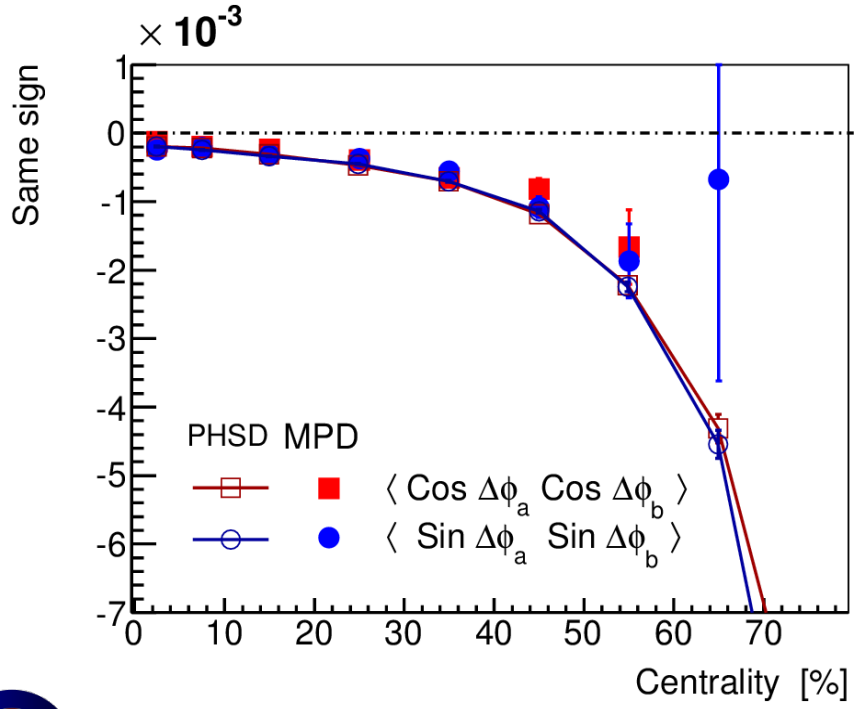
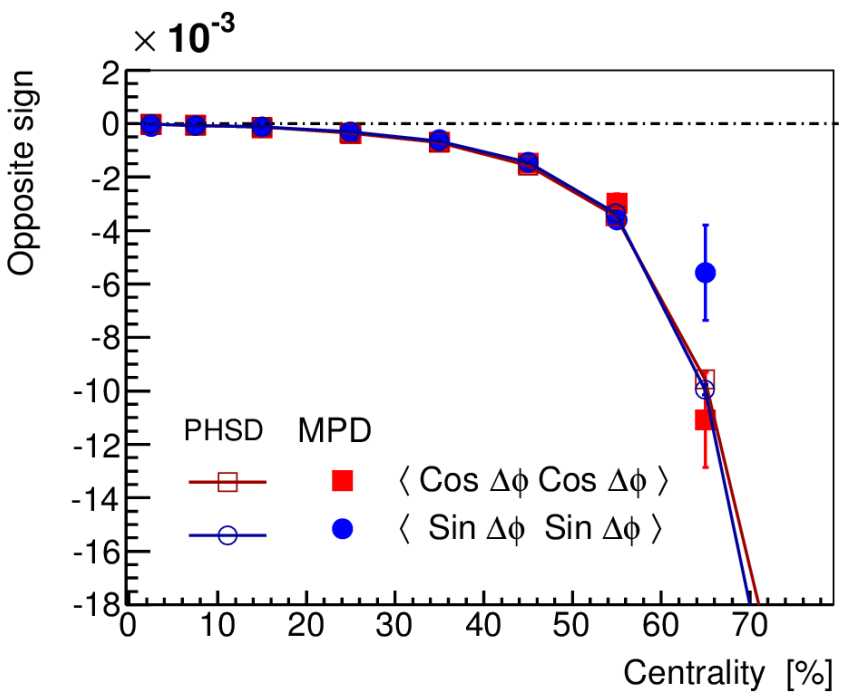
Projections of azimuthal correlations

- Peripheral collisions requires much more statistics.

$$\langle \cos(\phi_i - \Psi_{RP})\ \cos(\phi_j - \Psi_{RP}) \rangle \qquad \mathbf{in-plane}$$
$$\langle \sin(\phi_i - \Psi_{RP})\ \sin(\phi_j - \Psi_{RP}) \rangle \qquad \mathbf{out-of-plane}$$





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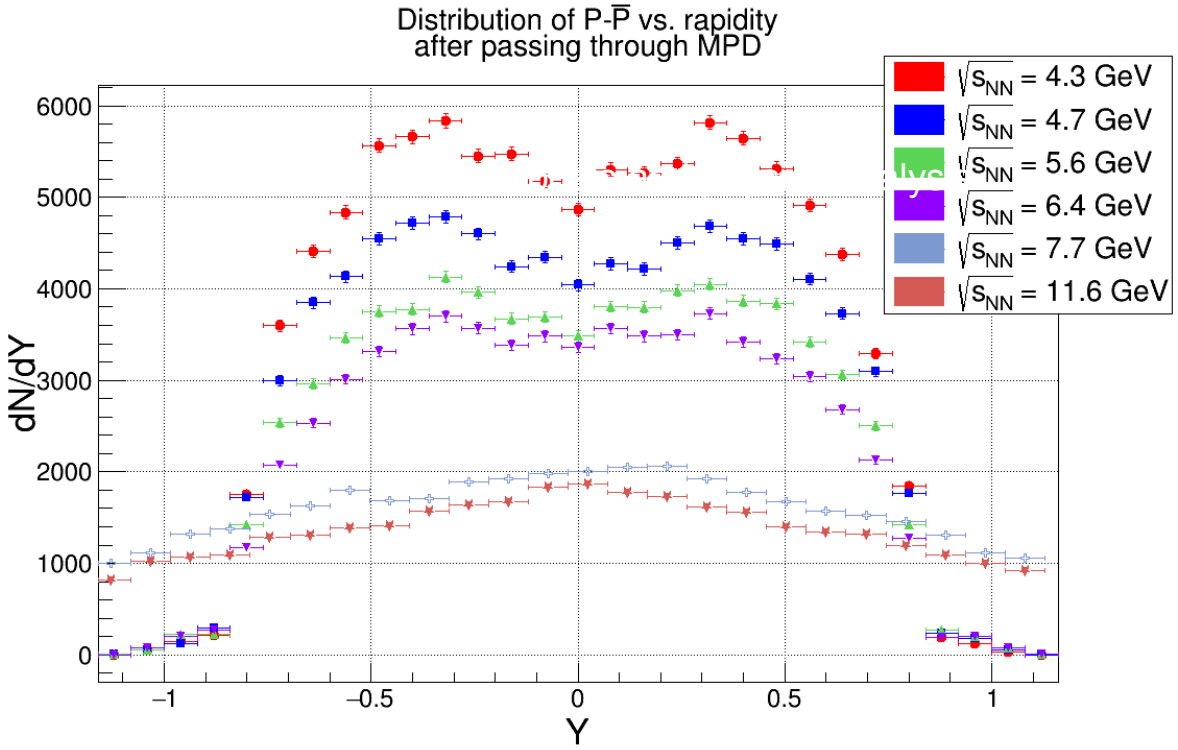
Baryon stopping power

- The 3-fluid dynamic model (3FD) associates the ``wiggle"-behavior of rapidity distribution with a first-order phase transition.
- The 3FD model with particlization procedure used for the UrQMD3.4 model



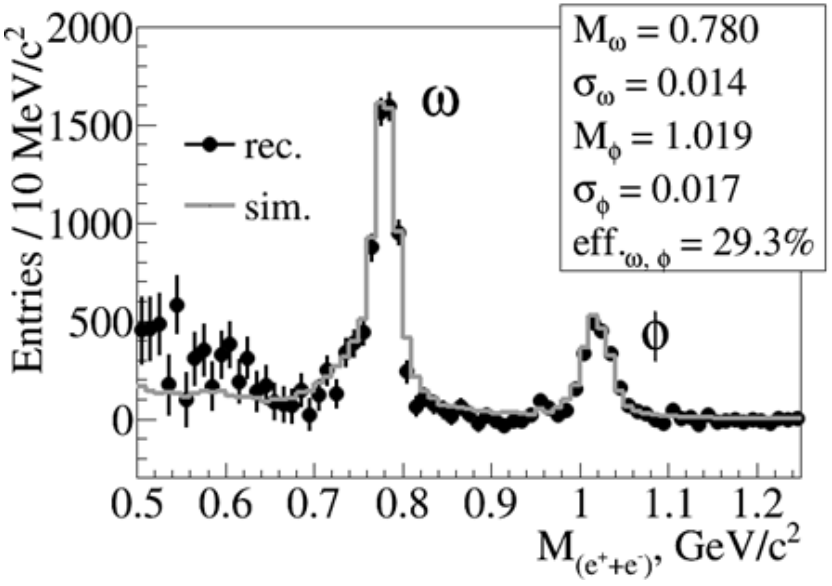
3FD – Yu.Ivanov P.Batuk particlization - Iu.Karpenko

Dilepton production

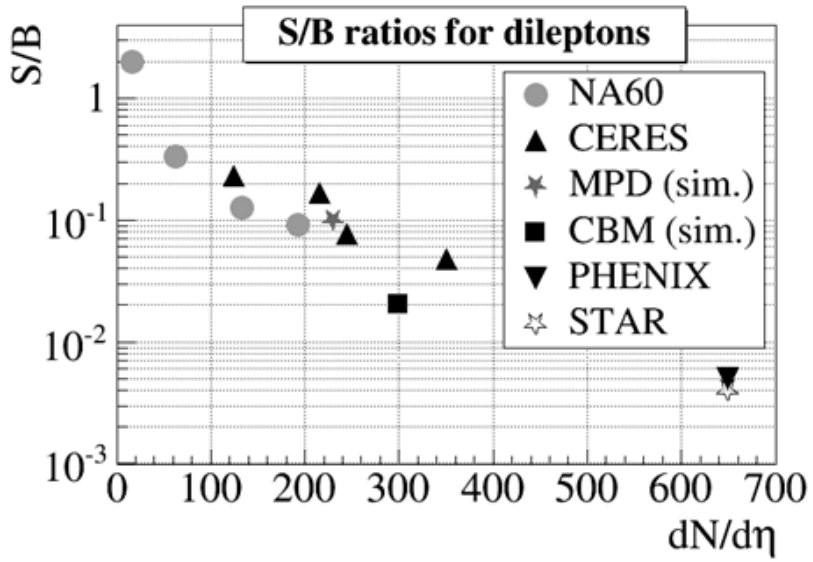
- Background-subtracted invariant mass distributions (left) of electron-positron pairs from central Au+Au collisions at the MPD.
- Signal-to-Background (S/B) ratio (right) from heavy-ion experiments as a function of total charged multiplicity.

V.Vasendina, A.Zinchenko

MPD: TPC+TOF+EMC



Urqmd+Pluto



The overall signal-to-background ratio was found to be close to 10%

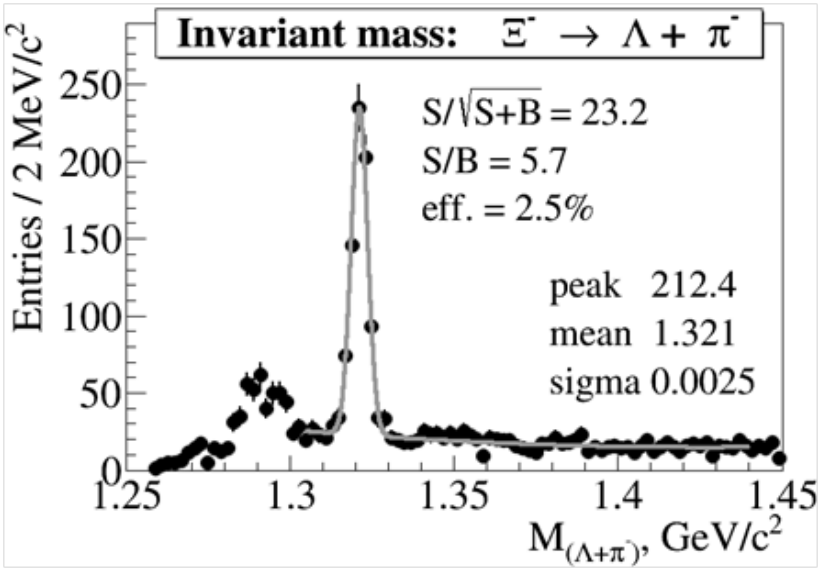
Hyperon and hypernuclei production

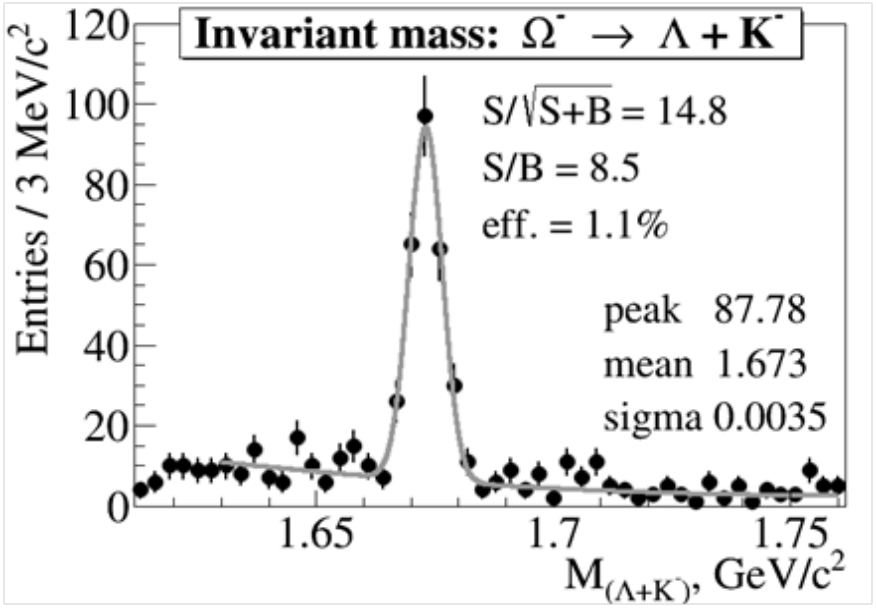
- Au Au collision at 9GeV

DCM-QGSM

MPD: TPC+TOF

M.Ilieva, V.Kolesnikov

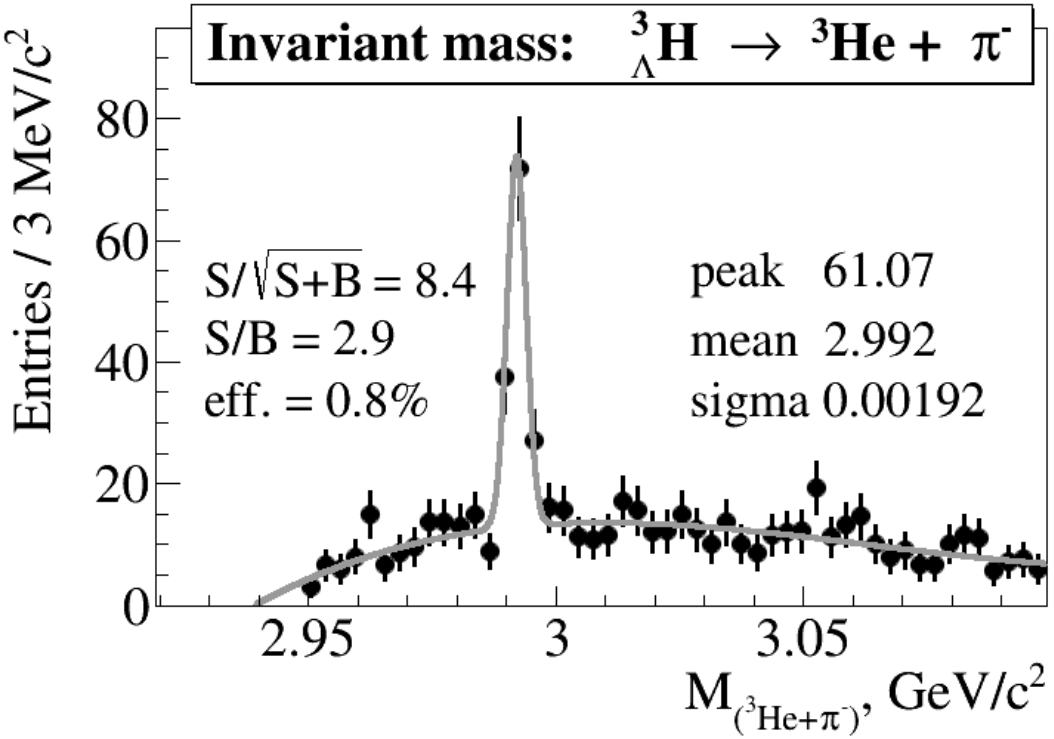




We have estimated the expected yields of particle species under interest for 10 weeks of the data taking at the nominal NICA collider luminosity of ~10^7 and ~10^6 for Ξ^- and Ω^-, respectively.

Hyperon and hypernuclei production

- Au Au collision at 5AGeV – high baryonic density



DCM-QGSM

MPD: TPC+TOF

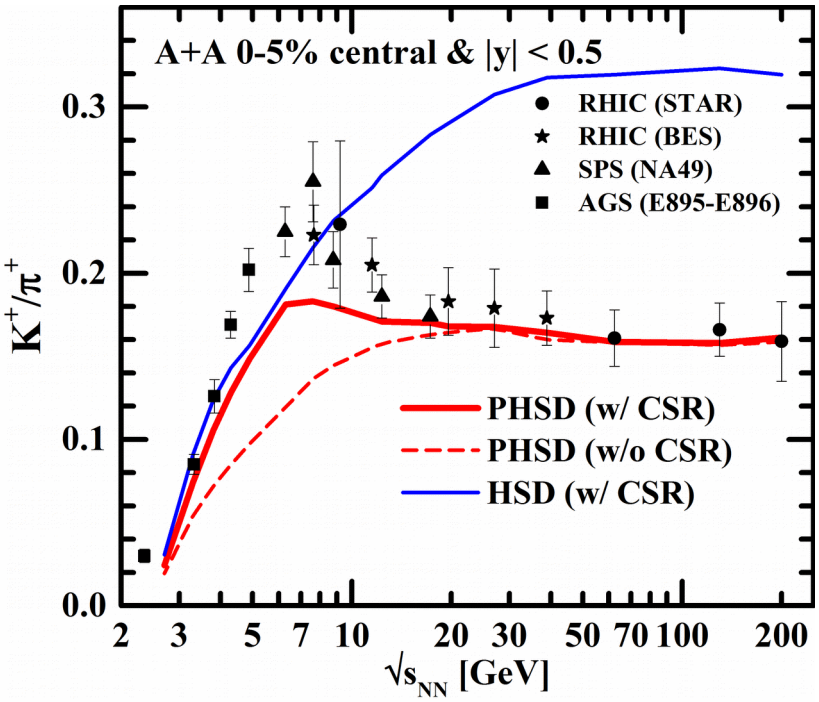
M.Ilieva, V.Kolesnikov

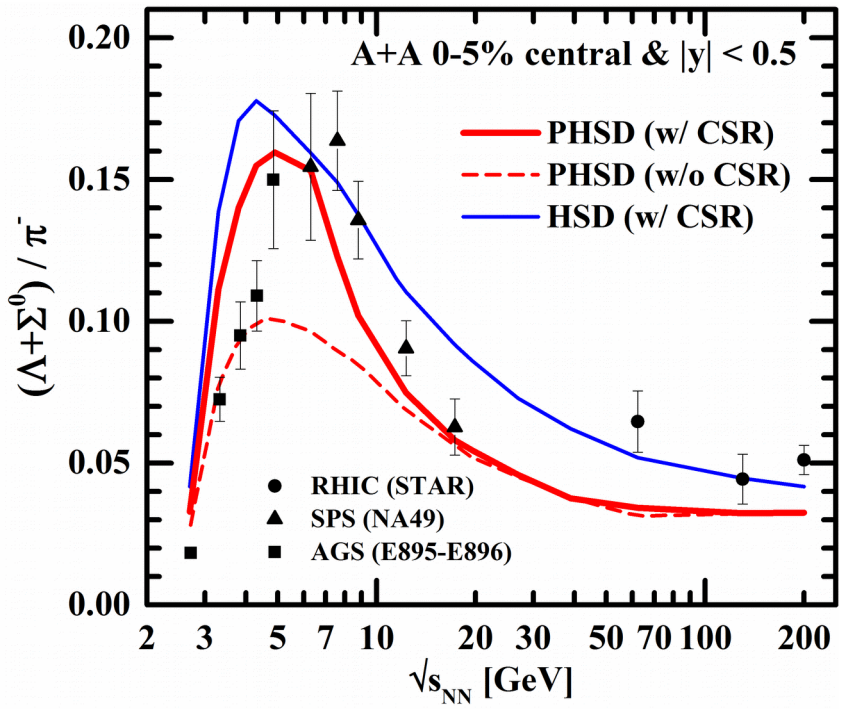
These results demonstrate a good sensitivity of the MPD setup for hypernuclei: with a typical event rate of 6 kHz for the nominal NICA luminosity we will able to register about 10^5 hypertritons in a week of the data taking.

Chiral symmetry restoration in the hadronic phase

- The strangeness enhancement seen experimentally at FAIR/NICA energies probably involves the approximate **restoration of chiral symmetry in the hadronic phase**

W.Cassing, A.Palmese, P.Moreau, E.L.Bratkovskaya – **arXiv:1510.04120 [PRC]**

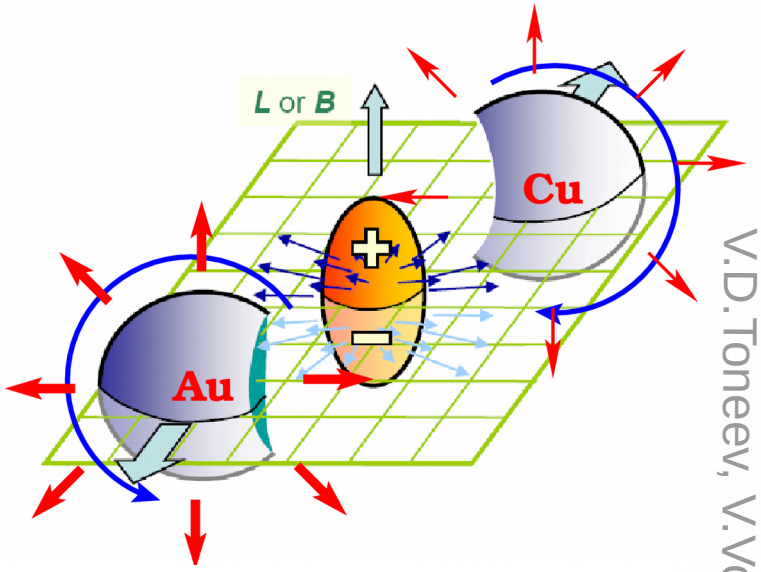


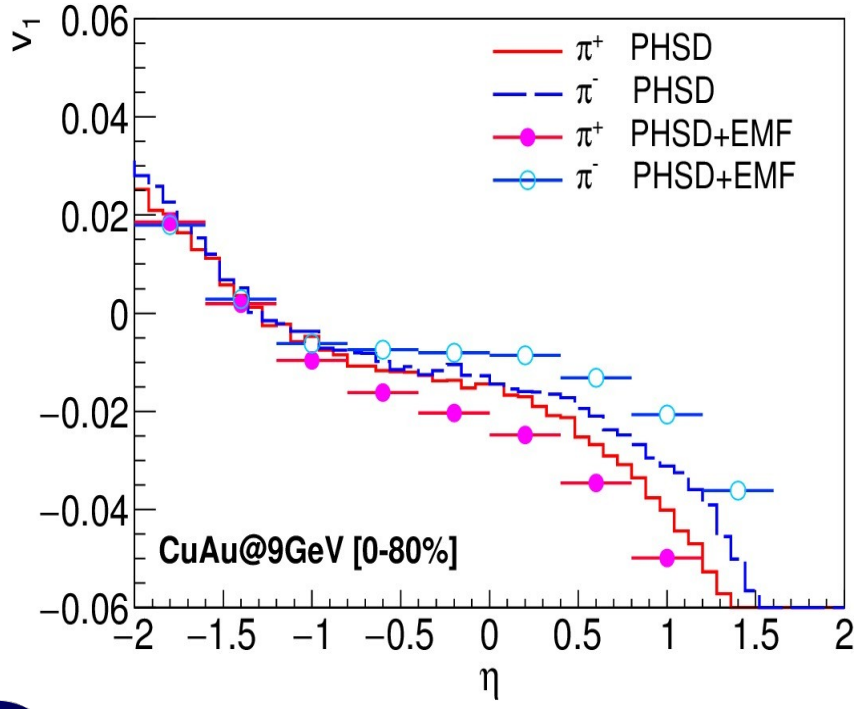


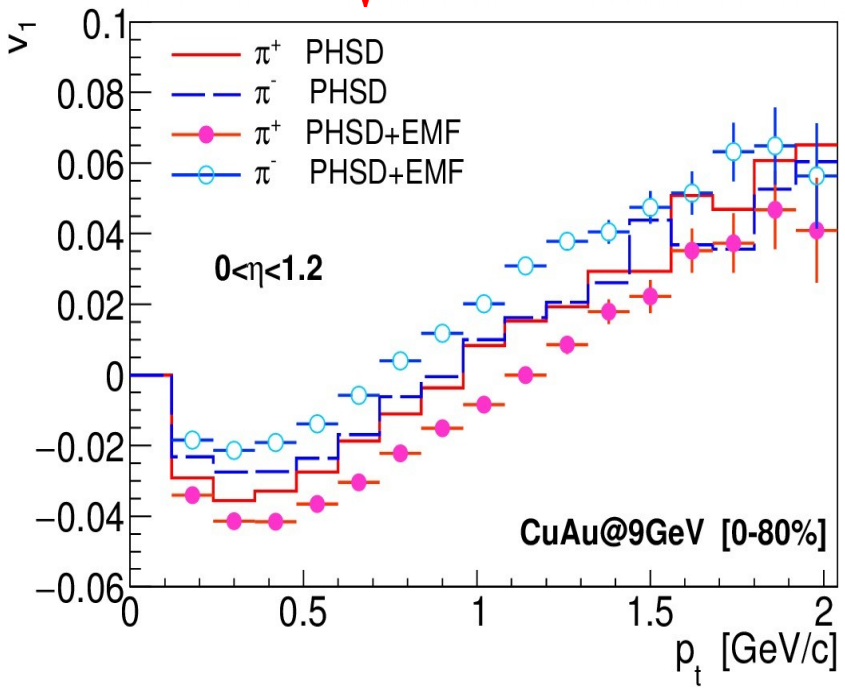
A.Palmese, W.Cassing

Strong electromagnetic field

- No visible effects in symmetric Au-Au collisions.
- Splitting of the direct flow for particles with the same mass but opposite electric charges in Cu-Au collisions.







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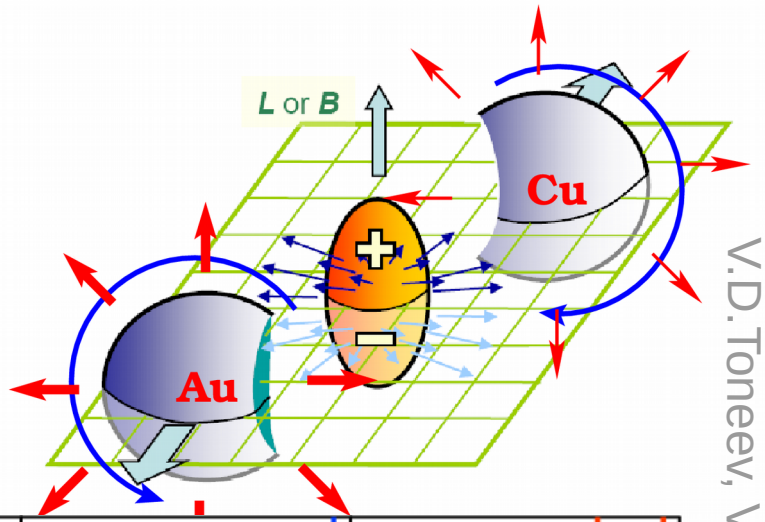
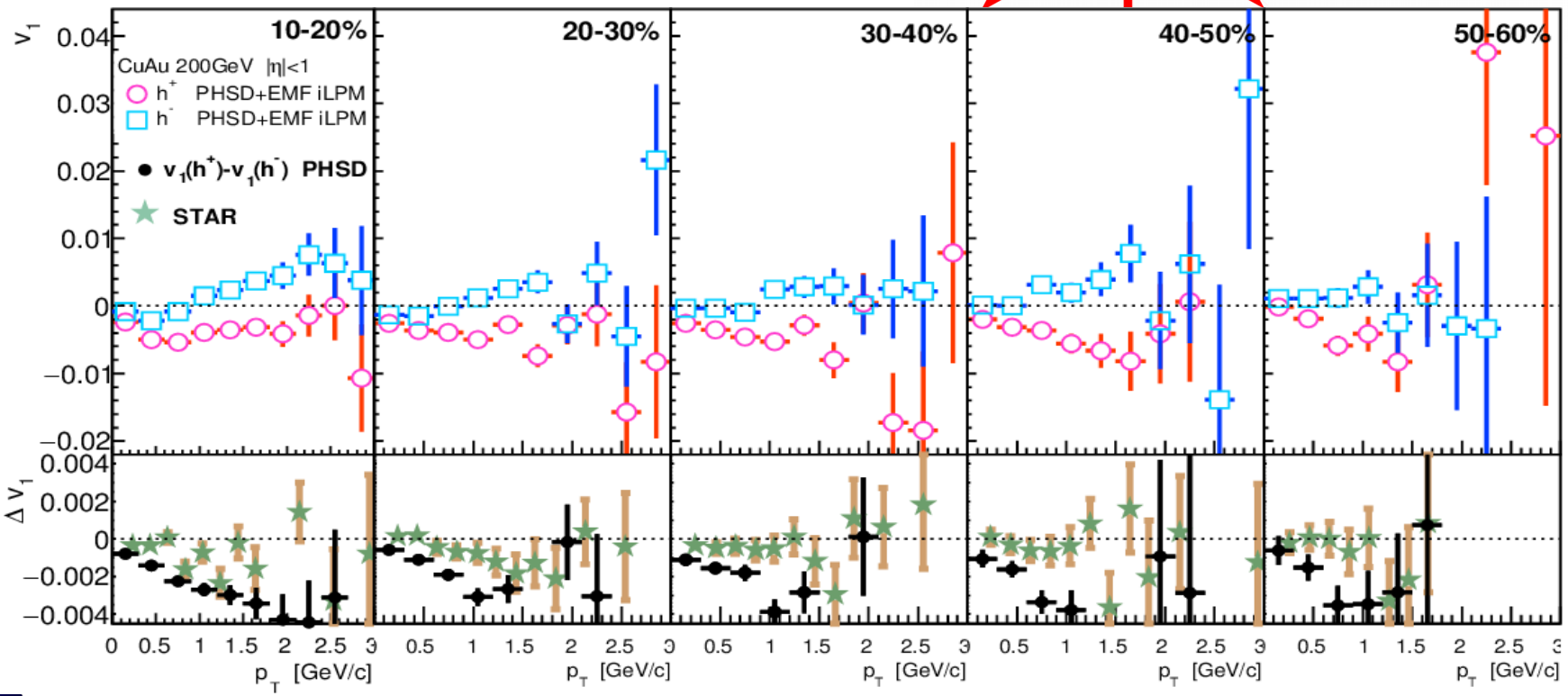
Strong electromagnetic field

- Aug 2016





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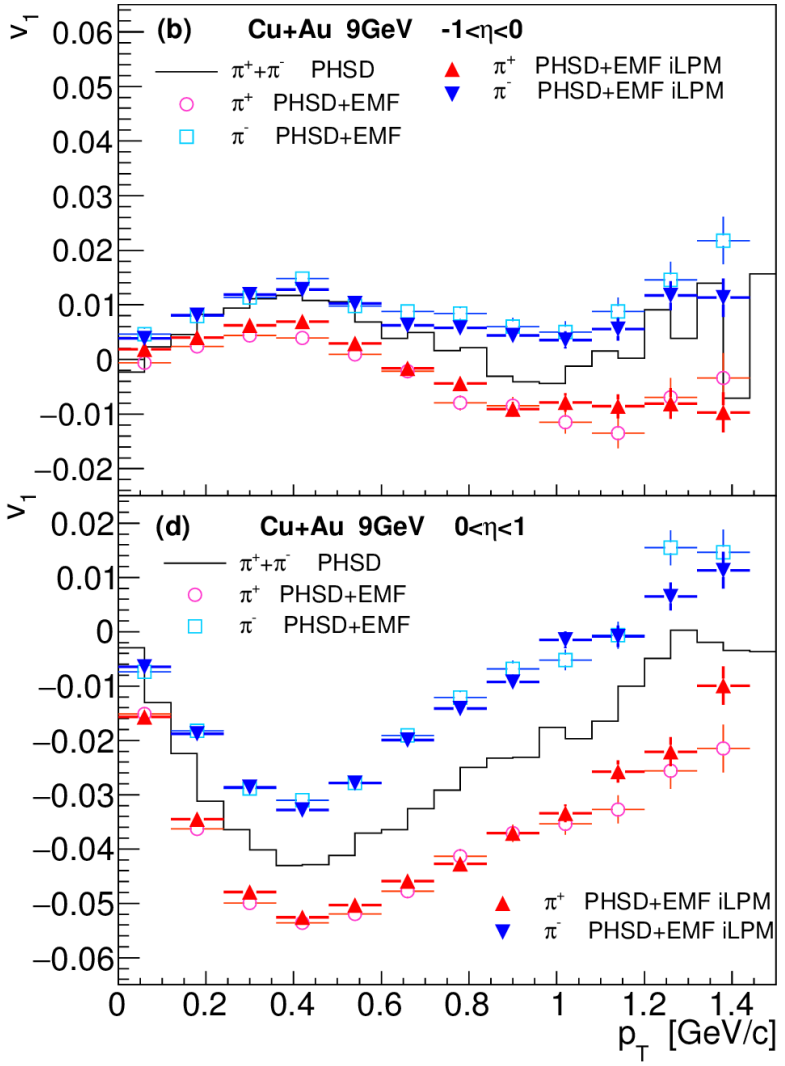
Strong electromagnetic field

- For NICA the magnitude of flow is much high.
- iLPM effect is suppressed.
- Presumably, NICA will be more preferable for this exploration.



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Conclusion

- The considered designs of the NICA experiments are well suited to provide a variety of experimental data for the critical assessments of the nuclear matter phase transition in the low-temperature and high baryonic density domain of the QCD phase diagram.

- Chiral symmetry restoration provides big improvement concerning the description of the hadronic dynamics in PHSD.
- Strong electric field leads to a splitting of the direct flow v_1 for particles with the same mass but opposite electric charges. At the NICA energies the magnitude of splitting effect is the same as at RHIC, but value of direct flow is larger. Presumably, NICA will be more preferable for this exploration.

THANK YOU FOR YOUR ATTENTION

Application of PHSD model to MPD detector

- «Stage 1» geometry: TPC+ZDC

- Event set: Au+Au 9GeV 0.6M
- The position of primary vertex: $\sigma_x = \sigma_y = 0.1\,cm \quad \sigma_z = 24\,cm$
- The reaction plane angle is randomly distributed.

The event selection cuts	
Vertex z position	$\lvert v_z \rvert < 72$ см
Vertex radius r cut	$v_r < 0.43$ см
The track selection cuts	
Pseudo-rapidity η	$\lvert \eta \rvert < 1.6$
Number of hits	> 25
Lower transverse momentum p_t	$p_t > 0.15$ GeV/c
DCA	DCA<2 cm

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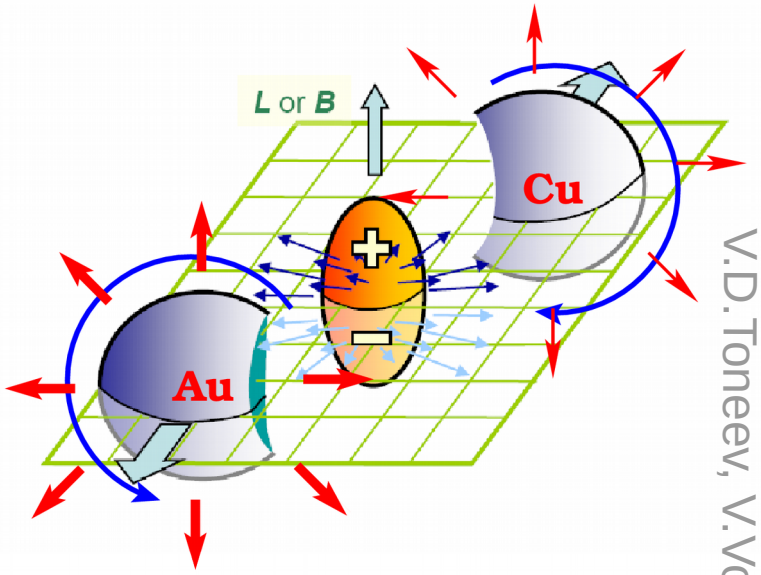
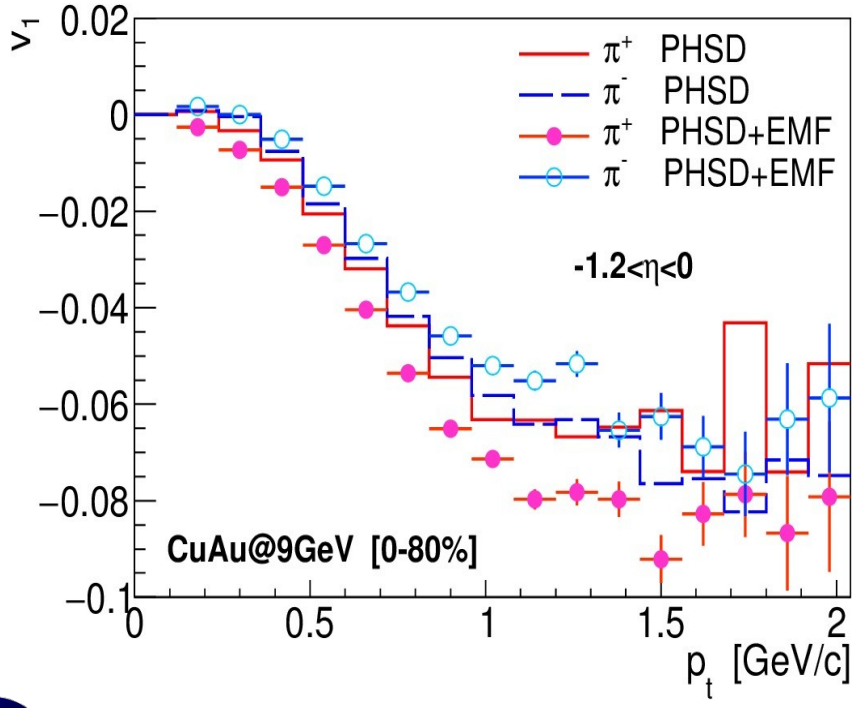
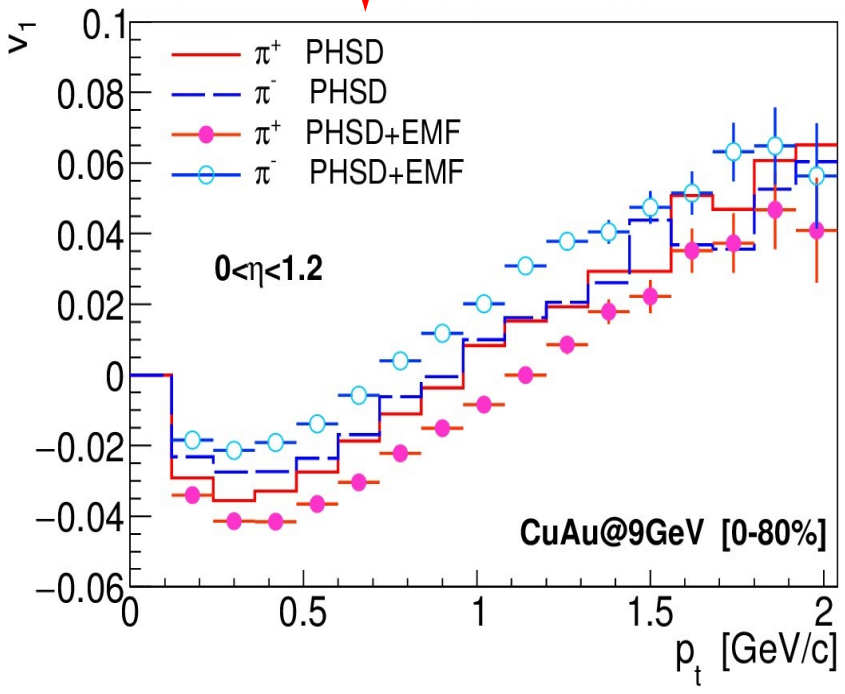
Strong electromagnetic field

- No visible effects in symmetric Au-Au collisions.
- Splitting of the direct flow for particles with the same mass but opposite electric charges in Cu-Au collisions.







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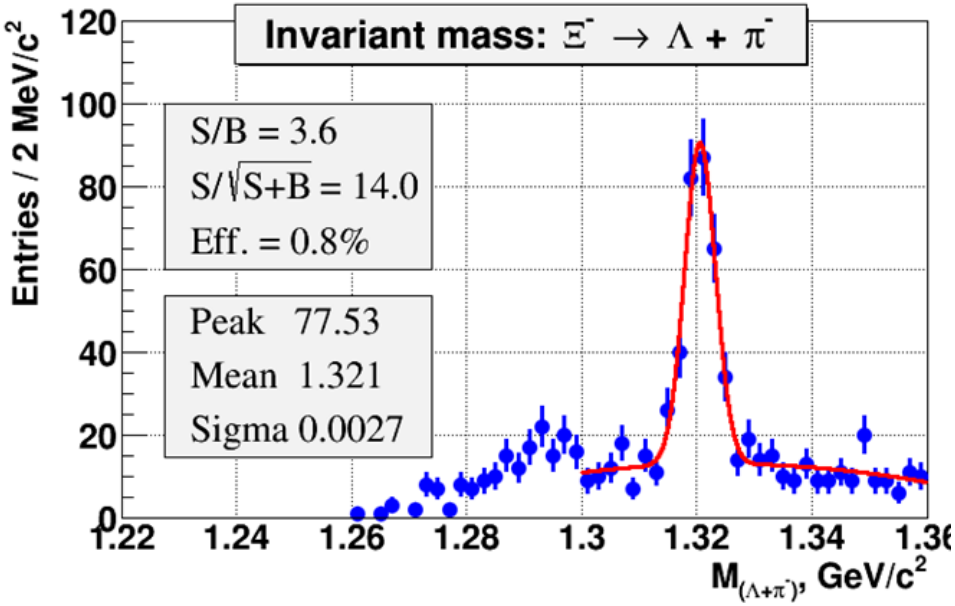
Hyperon and hypernuclei production

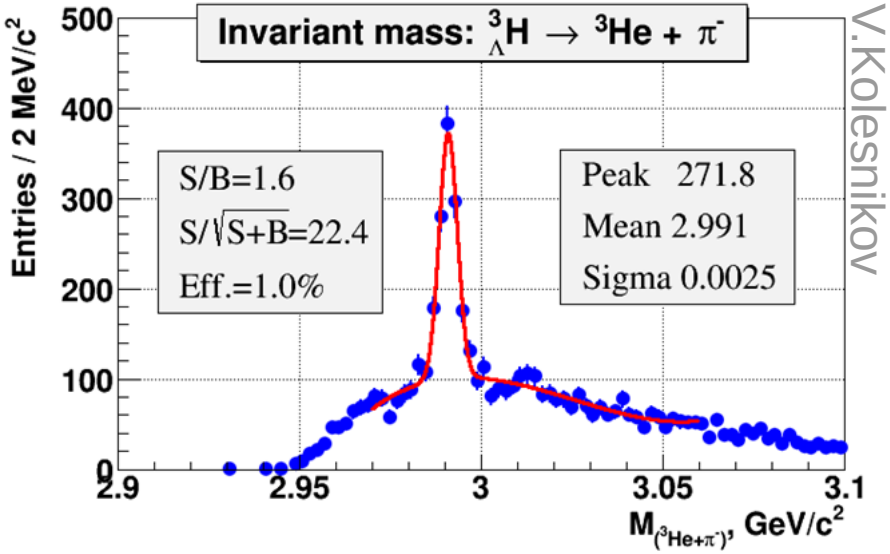
Pb Pb collision at 4.5AGeV

DCM-QGSM

BM@N

M.Ilieva, V.Kolesnikov





We expect to have for a month of the data taking a statistics of ~10^6 hyperons

Reconstructed elliptic flow

- The reconstructed elliptic flow are in a good agreement with the MC ones.