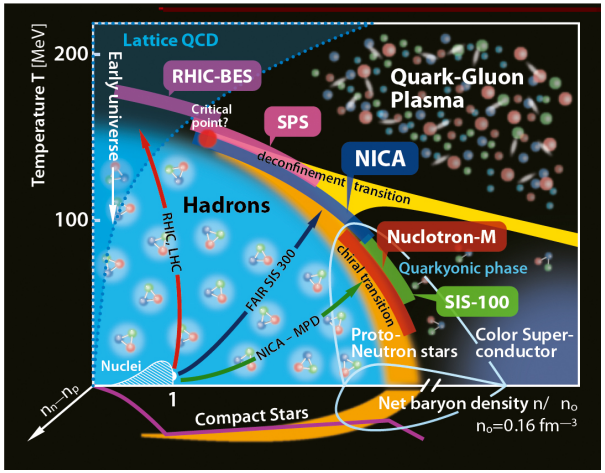

Simulation of NICA/MPD with THESEUS as an attempt to investigate effects of a QCD phase transition in the EoS on HIC observables

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on behalf of the MPD collaboration

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September 28, 2017

Outline:

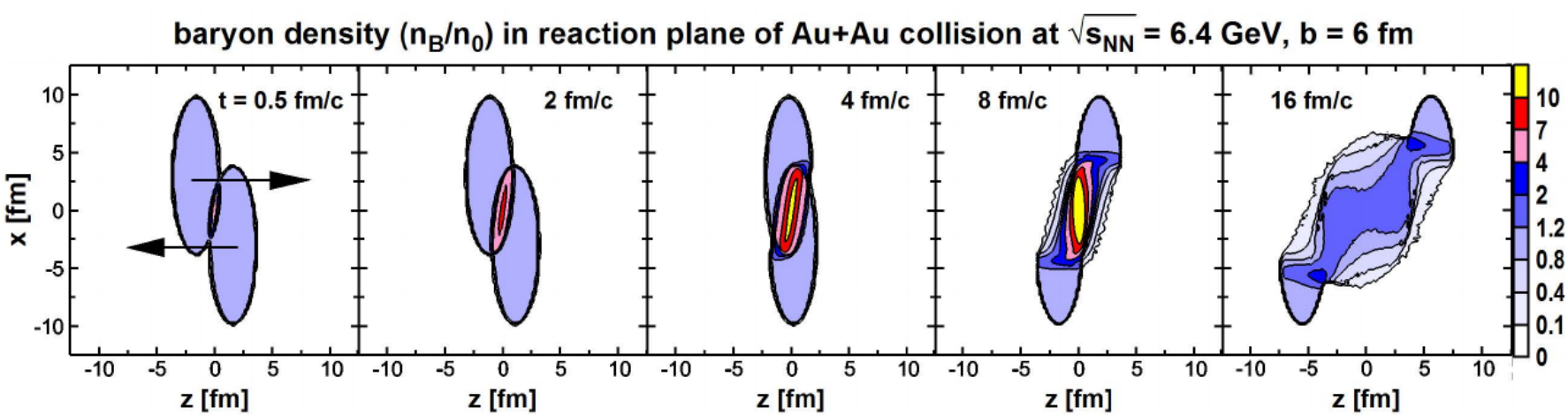
- **Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS)**
- **NICA Complex, NICA/MPD, MPDROOT ...**
- **First results on baryon stopping power and direct flow as a result of MC simulation of NICA/MPD**

Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS)

3FH → PARTICLIZATION → UrQMD CASCADE

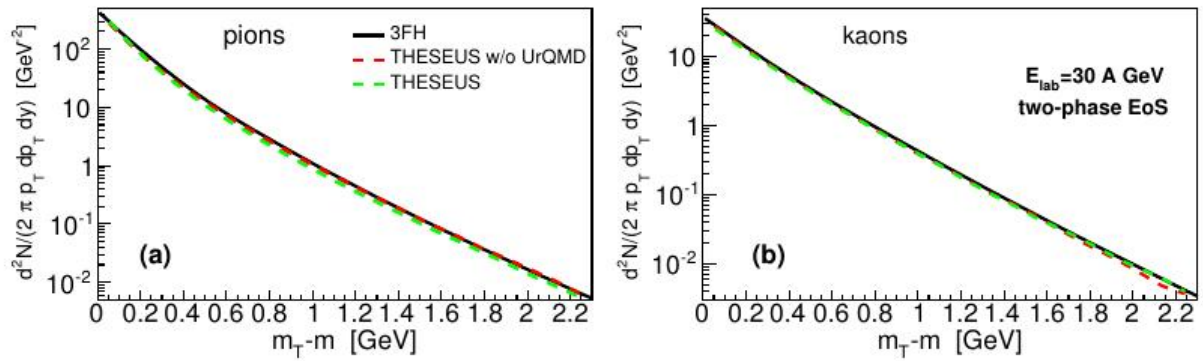
- The simulation was performed with the crossover EoS without freeze-out.
- Very high baryon densities are reached in the central region of the colliding system.

3FH-model (see report of Yu. B. Ivanov, CSQCD-VI):



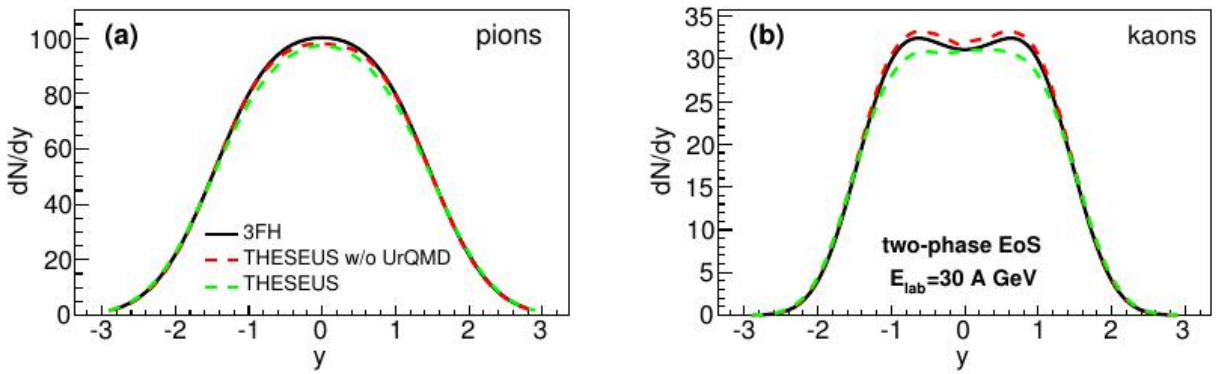
Test of the particlization and cascade routines

p_T-spectra:



AuAu @ 30 AGeV, b = 2fm, 2-phase EoS

Rapidity distribution:



UrQMD hadronic rescattering:

- leads to a slight steepening of the pion p_T-spectrum.
- smeares the double-peak structure in the kaon rapidity spectrum.

NICA Complex

General characteristics:

Beams - p, d ... $^{197}Au^{79+}$

Collision energy:

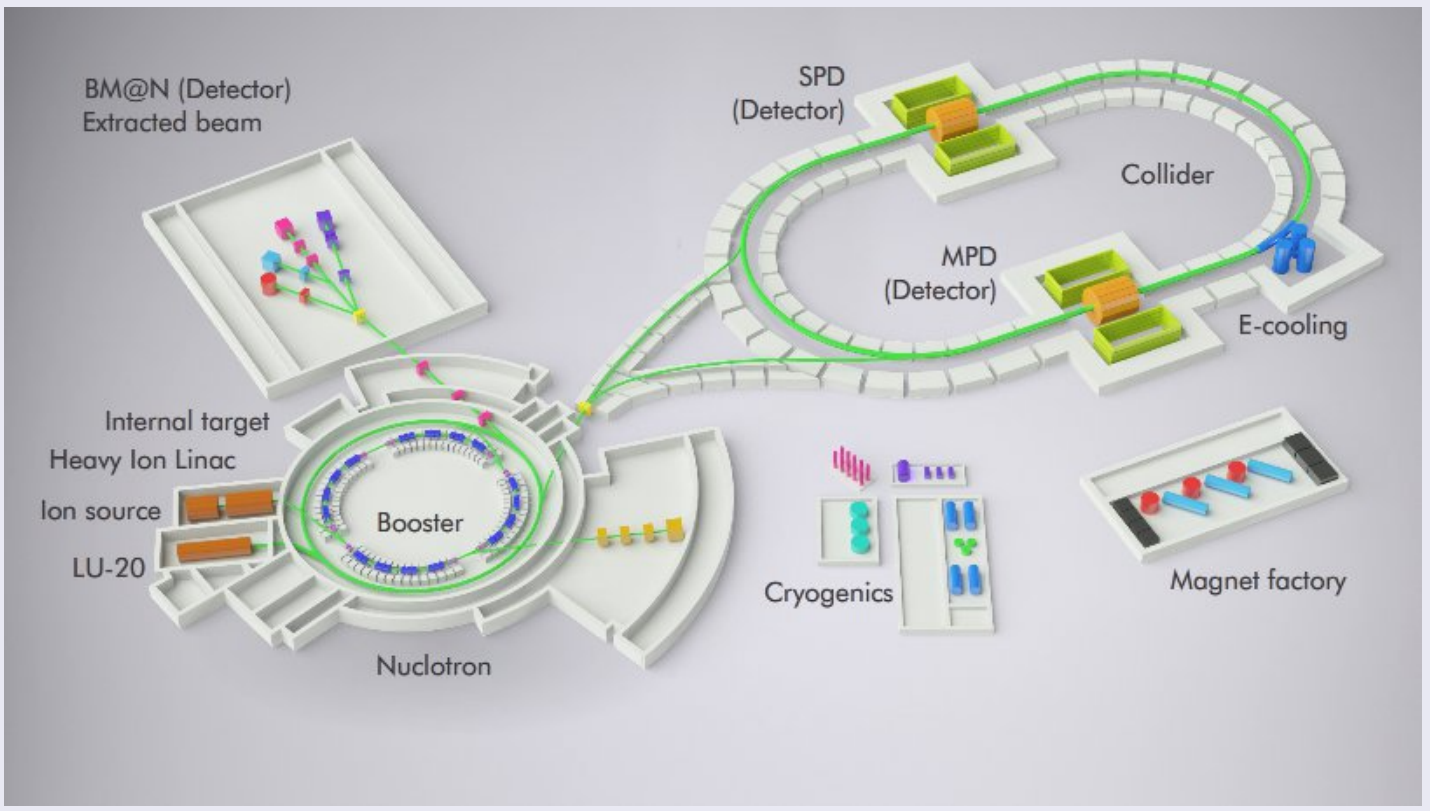
$\sqrt{s_{NN}} =$ 4 - 11 GeV $\quad E_{lab} =$ 1 - 6 AGeV

Luminosity: 10^{27} $cm^{-2}s^{-1}$ (Au), 10^{32} (p)

See report of A. Sorin, CSQCD-VI (26.09.2017)

Experiments:

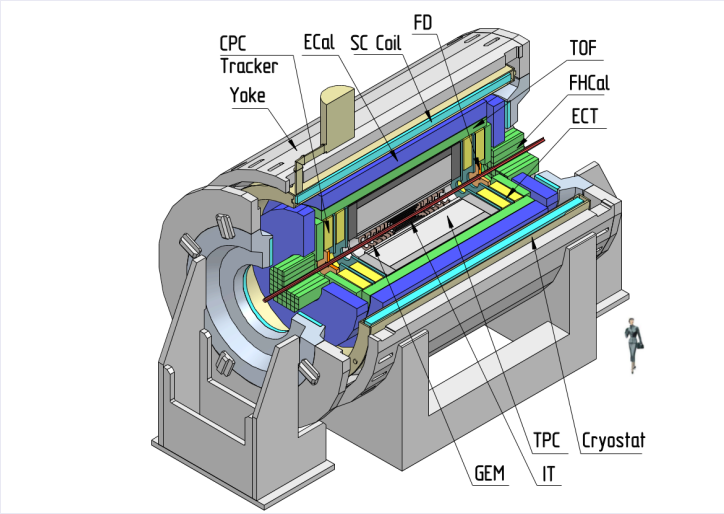
- 2 interaction points - MPD and SPD
- Fixed target experiment - BM@N



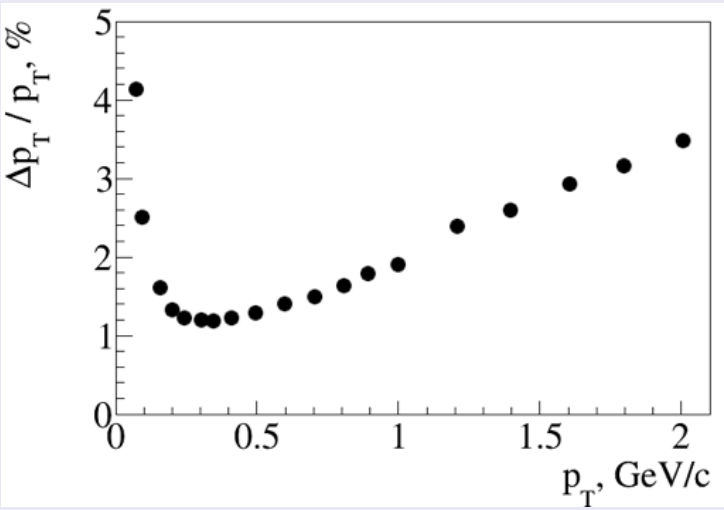
- 2017: extracted beams of heavy ions are available within the BM@N experiment
- 2019: a first configuration of the MPD setup available.
- 2023: commissioning of the fully designed NICA-complex is foreseen.

MultiPurpose Detector (MPD) for $A + A$ collisions @ NICA

Layout:



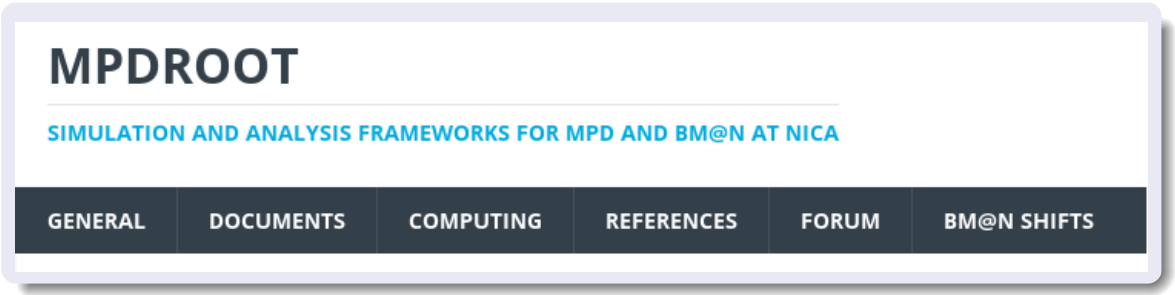
Momentum resolution:



Benefits:

- **Hermeticity, 2π-acceptance in azimuth**
- **3D-tracking (TPC, ECT)**
- **Vertex high-resolution (IT)**
- **Powerful PID (TPC, TOF, ECAL)**
  - **π, K up to 1.5 GeV/c**
  - **K, p up to 3 GeV/c**
  - **γ, e from 0.1 GeV/c up to 3 GeV/c**
- **Precise event characterization (FHCAL = ZDC) (centrality determination, reaction plane ...)**
- **Fast timing and triggering (FFD)**
- **Low material budget**
- **High event rate (up to 7 kHz)**

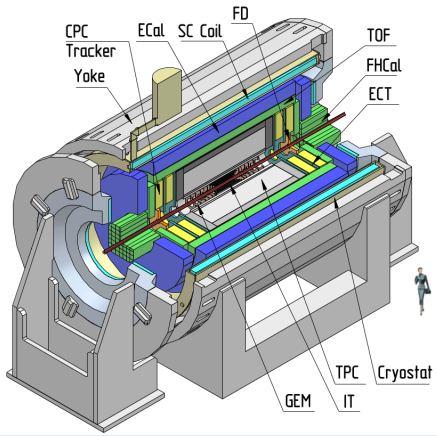
Simulation Framework for MPD (MPDROOT)



MPDROOT home web-page:

http://mpd.jinr.ru

- News
- Software repositories
- Software tests
- Forums
- Database for physics run
- E.t.c.



Physics models available:

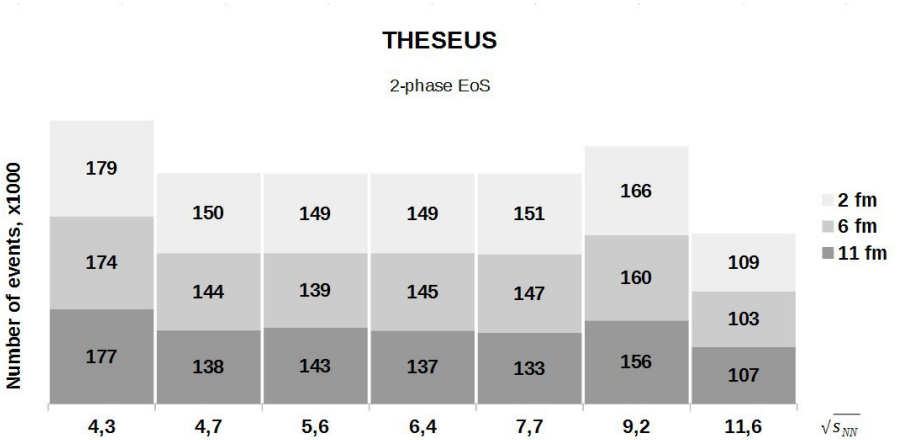
- UrQMD / Hybrid UrQMD / vHLLE + UrQMD
- QGSM / LAGQSM
- HSD / PHSD
- **THESEUS**

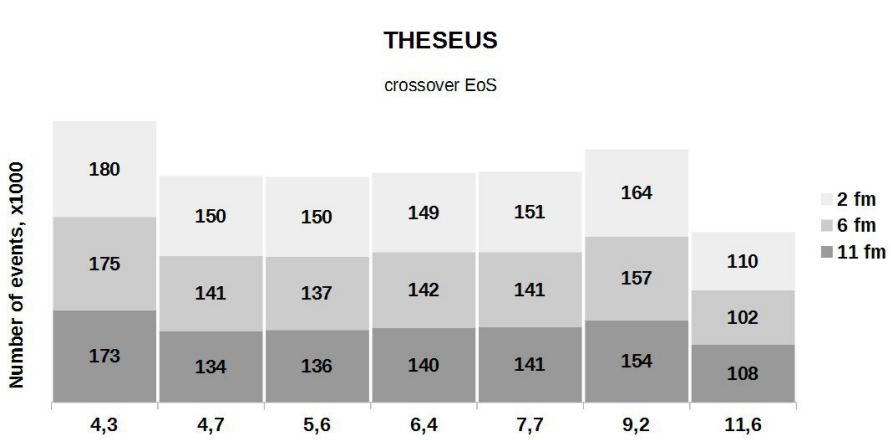
Benefits:

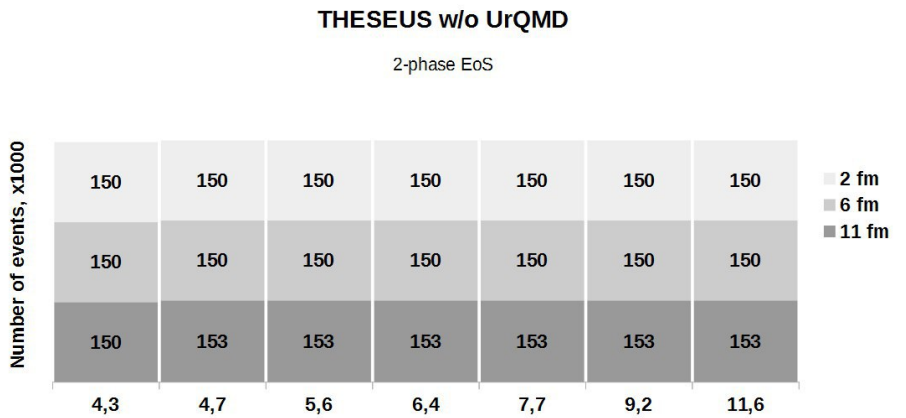
- Inherits basic properties from FairRoot, C++ classes
- Extended set of event generators for heavy-ion collisions
- Detector composition and geometry; particle propagation by GEANT3/4
- Advanced detector response functions, realistic tracking and PID included
- Event display for Monte-Carlo and experimental data

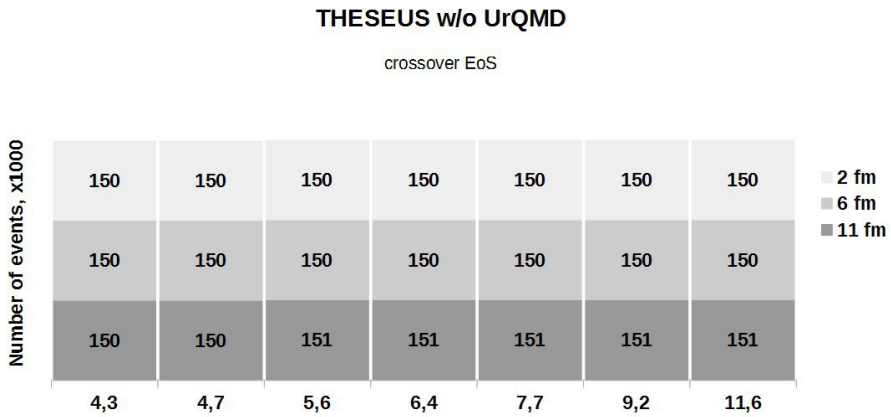
All main macroses to be used for sim & reco have been adopted for THESEUS input

THESEUS: data sets available



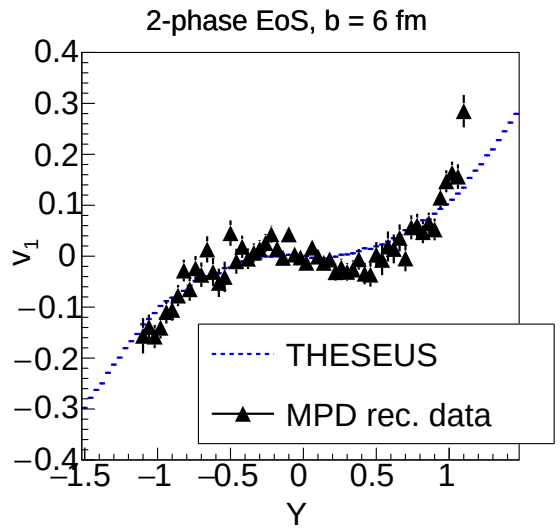


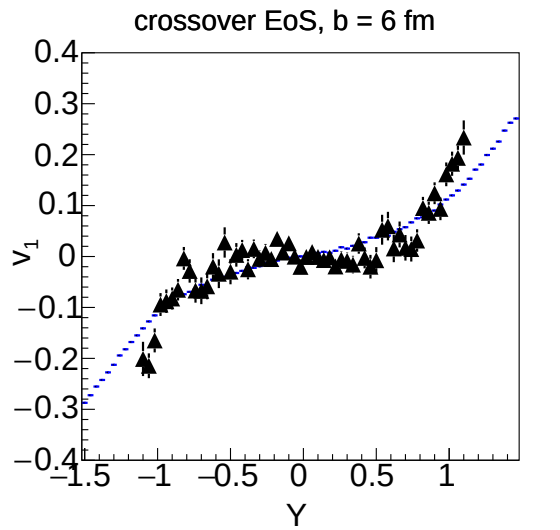




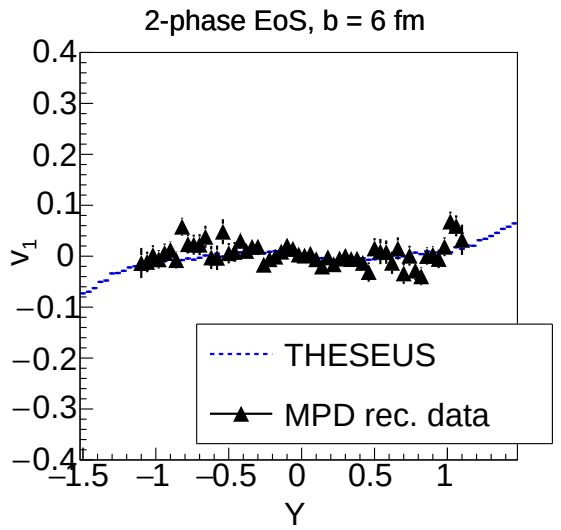
Direct flow of protons(THESEUS)

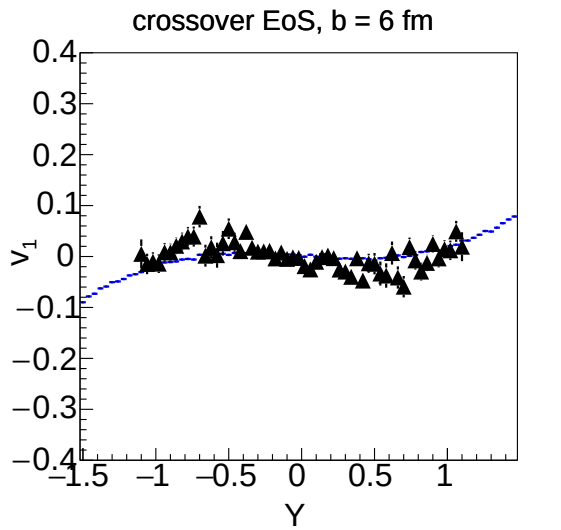
$\sqrt{s_{NN}} = 5.6$ GeV





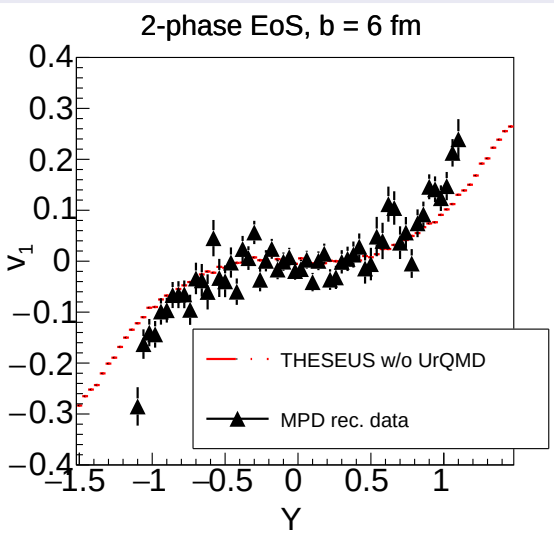
$\sqrt{s_{NN}} = 11.6$ GeV

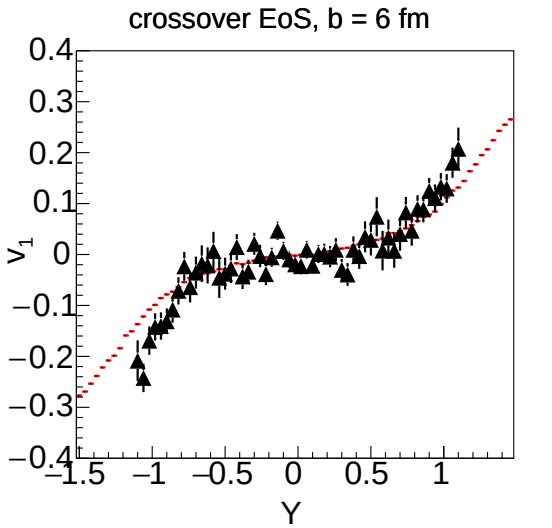




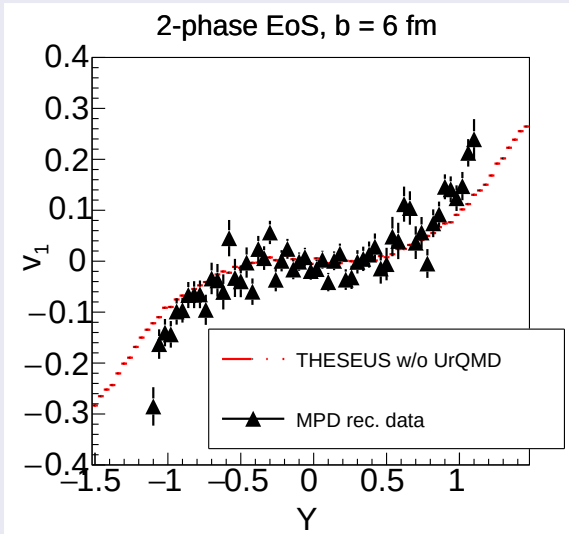
Direct flow of protons(THESEUS w/o UrQMD)

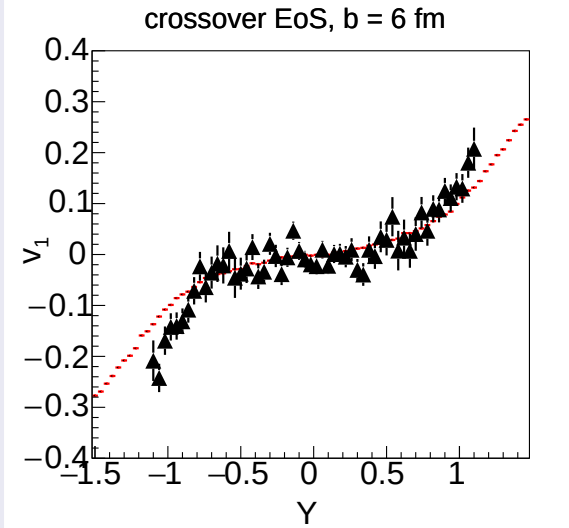
$\sqrt{s_{NN}} = 5.6$ GeV





$\sqrt{s_{NN}} = 11.6$ GeV



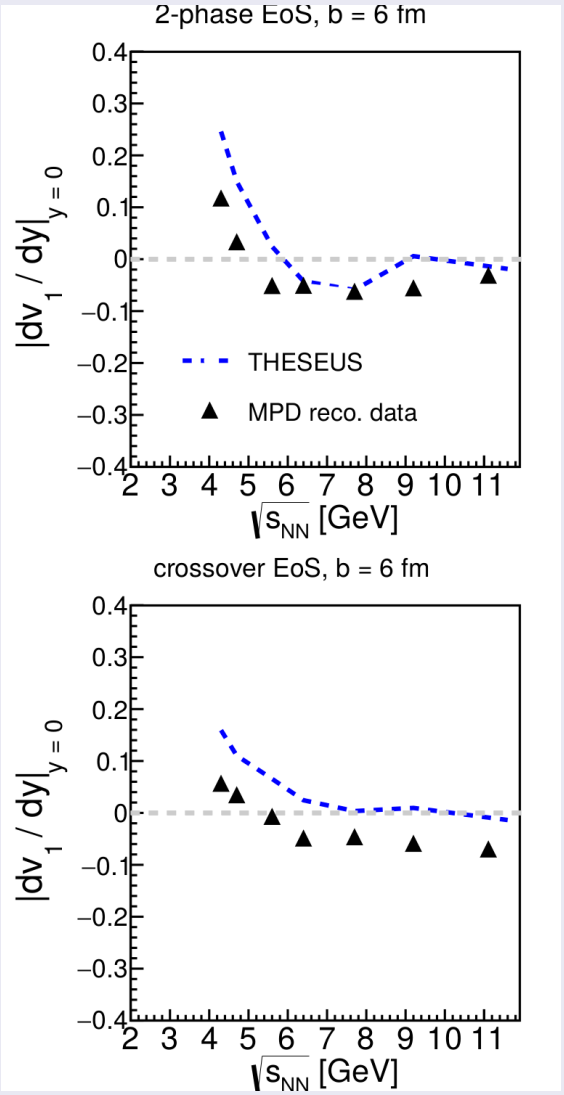


Results on reconstructed flow are preliminary: statistics should be increased, amendments in reco. algorithm are also in progress

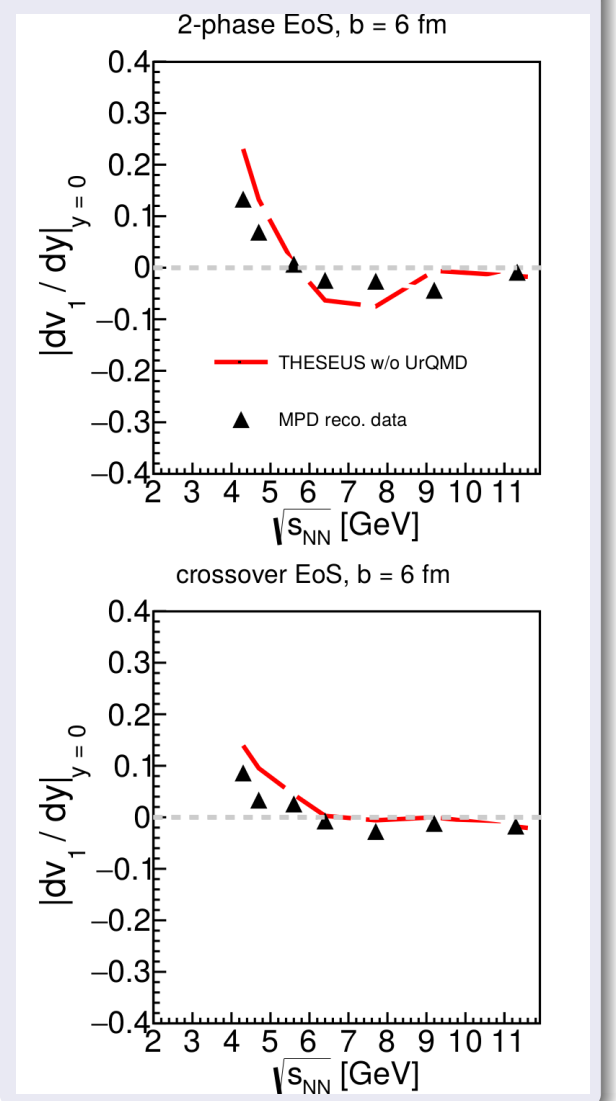
Reco output coincides better in midrapidity region with model input when no UrQMD rescatterings are taken into account

Direct flow of protons, dv_1/dy

THESEUS:

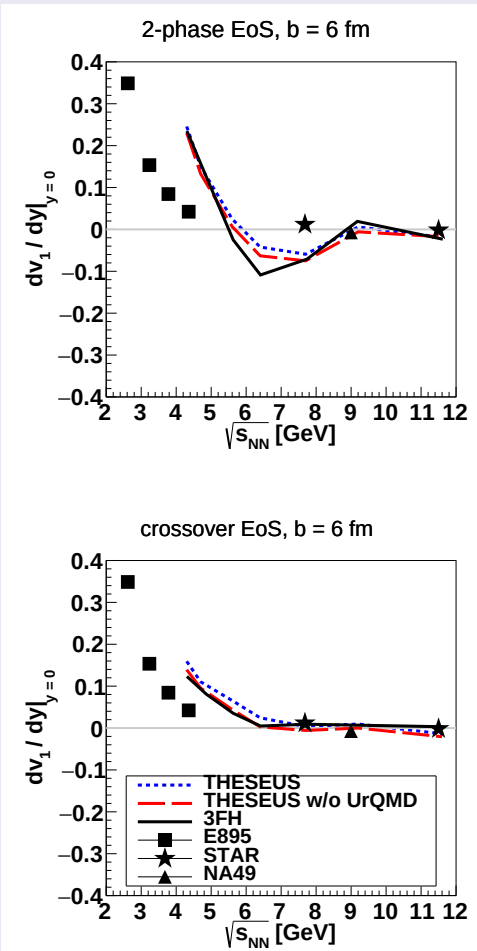


THESEUS w/o UrQMD:



Comparison with exp. data available:

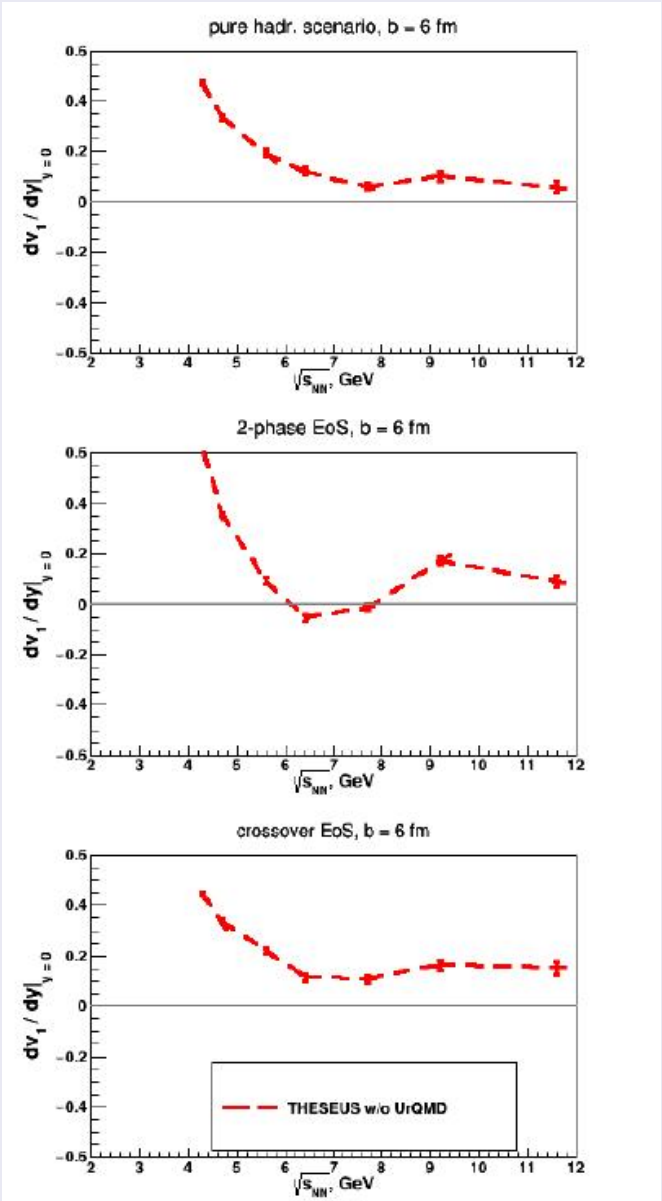
Phys. Rev. C 94, 044917 (2016)



Real PID used:

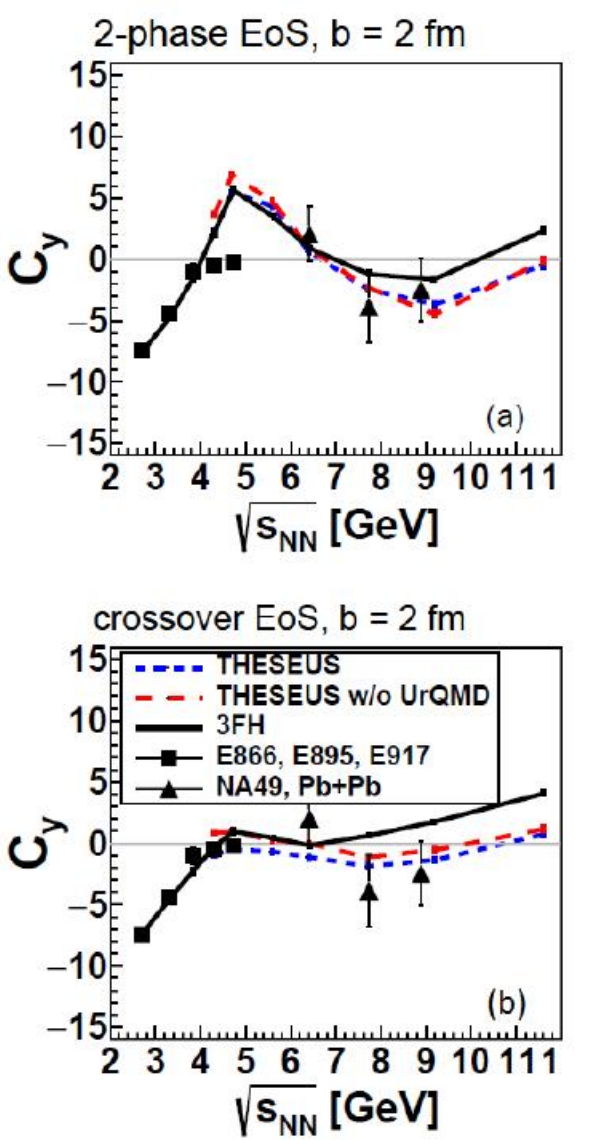
recoTrack->GetPidProbProton() > 0.9

Direct flow of light clusters, dv_1/dy



- **Light clusters (d, t, h, α) can be important indicators for the properties of matter produced in HIC at NICA since they probe the phase space more locally.**
- **There is an antiflow for $\sqrt{s_{NN}} = 6 - 7$ GeV only for the case of the 2-phase EoS while two alternative EoS without a first order phase transition do not exhibit the antiflow.**

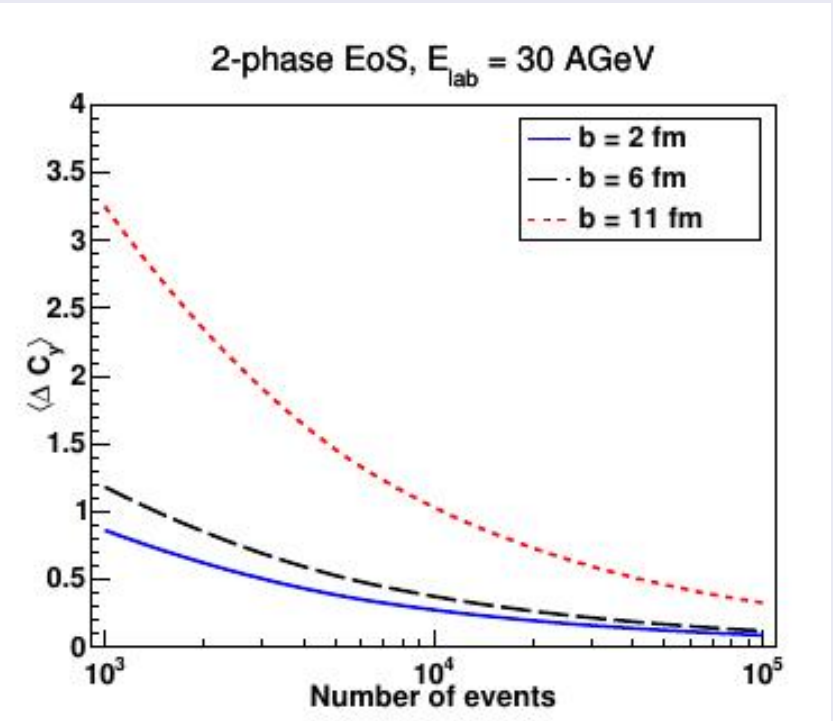
Baryon stopping signal for a first-order phase transition



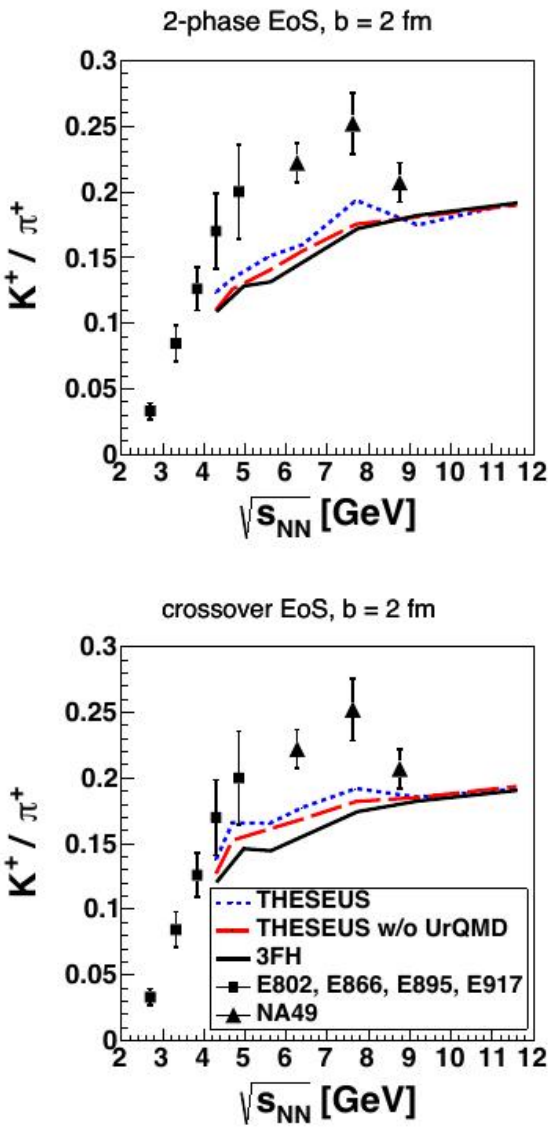
$$C_y = y_{cm}^2 \frac{d^3 N_{netProt}/dy^3}{dN_{netProt}/dy}$$

$$C_y = \frac{y_{beam}^2 2a}{c} \quad (P_2(y) = ay^2 + by + c)$$

$$\Delta C_y = \frac{2y_{beam}^2}{c}\sqrt{(\Delta a)^2 + \frac{a^2}{c^2}(\Delta c)^2}$$



Do we have "horn"?



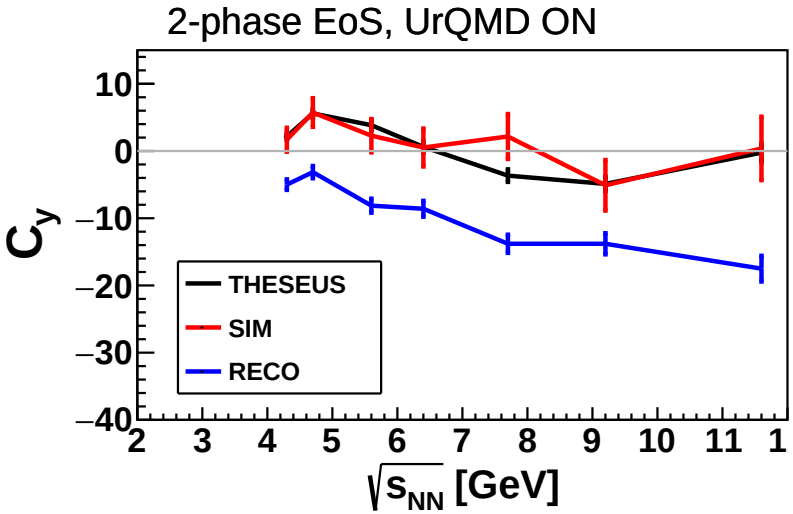
- As the 3FH-model itself, also THESEUS in its present version is not yet capable of describing the ”horn” effect discovered in the NA49 data for the K^+/π^+ ratio.
- No MC-simulations of NICA/MPD w.r.t. to "horn” done.

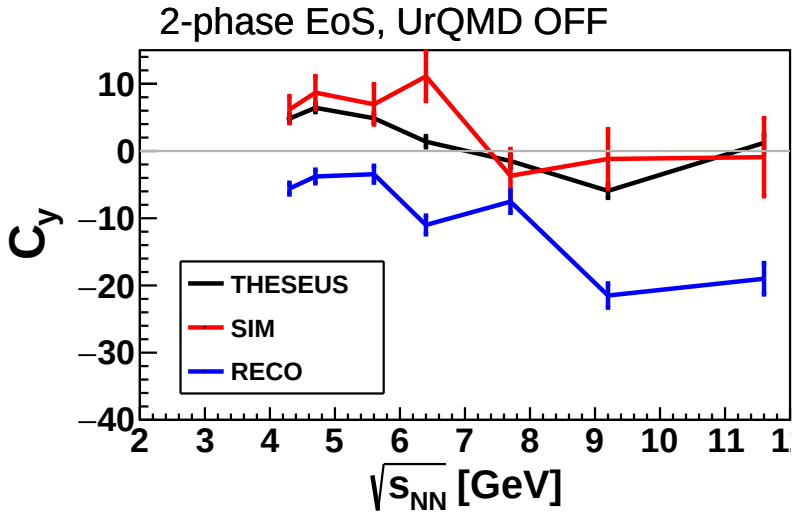
Conclusion

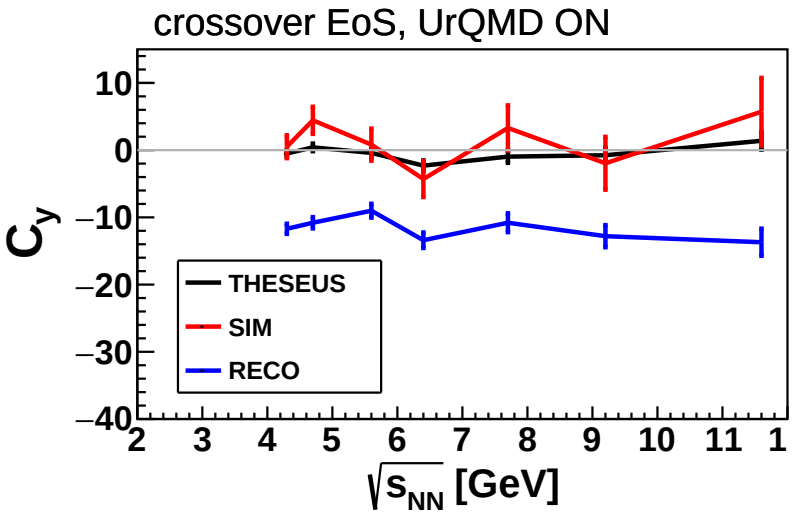
- **Activities concerning creation of a standalone code including 3FH + Particlization + UrQMD-cascade in a one chain are in progress**
- **A simulator program we are developing looks siutable to be used when searching a critical behaviour of the colliding system.**
- **Preliminary results on NICA/MPD MC-simulations showed that we are able to reproduce model input in course of reconstruction, but many adjustments of the algorithm should be done.**
-

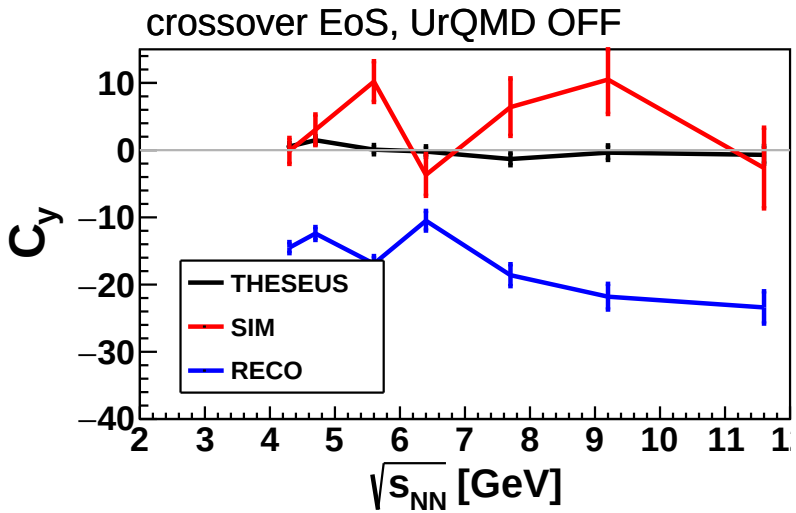
BACKUP

b = 2 fm


2-phase EoS, UrQMD ON
C_y
$\sqrt{s_{NN}}$ [GeV]
THESEUS
SIM
RECO


2-phase EoS, UrQMD OFF
C_y
$\sqrt{s_{NN}}$ [GeV]
THESEUS
SIM
RECO


crossover EoS, UrQMD ON
C_y
$\sqrt{s_{NN}}$ [GeV]
THESEUS
SIM
RECO


crossover EoS, UrQMD OFF
C_y
$\sqrt{s_{NN}}$ [GeV]
THESEUS
SIM
RECO