

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

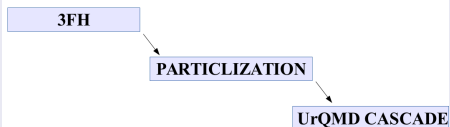
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September 28, 2017

Outline:

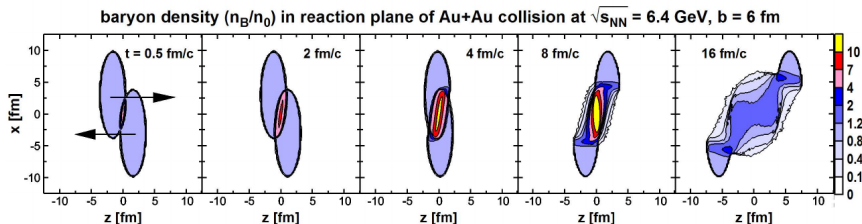
- **Three-fluid Hydrodynamics-based Event Simulator**
Extended by UrQMD final State interactions (THESEUS)
- **NICA Complex, NICA/MPD, MPDROOT ...**
- **First results on baryon stopping power and direct flow as a result of MC simulation of NICA/MPD**

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



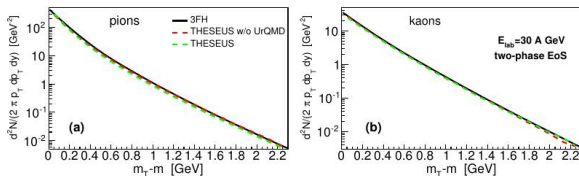
- The simulation was performed with the crossover EoS without freeze-out.
- Very high baryon densities are reached in the central region of the colliding system.

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



Test of the particlization and cascade routines

p_T -spectra:

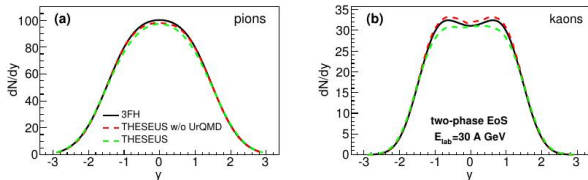


AuAu @ 30 AGeV,
 $b = 2\text{fm}$, 2-phase
EoS

UrQMD hadronic rescattering:

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

Rapidity distribution:



NICA Complex

General characteristics:

Beams - $p, d \dots {}^{197}\text{Au}^{79+}$

Collision energy:

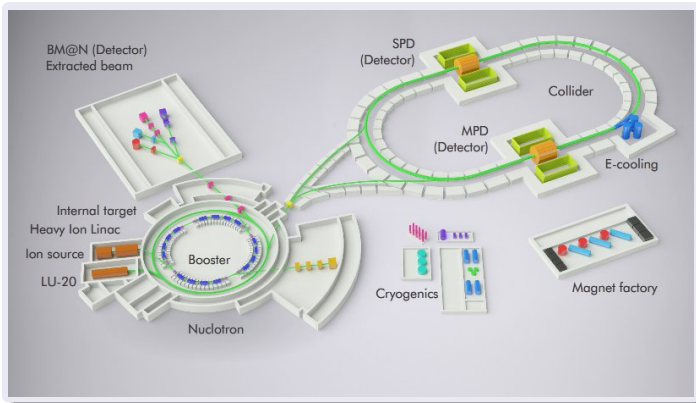
$$\sqrt{s_{NN}} = 4 - 11 \text{ GeV} \quad E_{lab} = 1 - 6 \text{ AGeV}$$

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

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

Experiments:

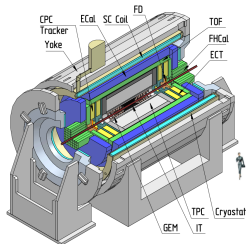
- 2 interaction points - **MPD** and **SPD**
- Fixed target experiment - **BM@N**



- **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

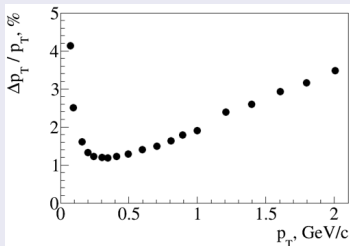
Layout:



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)

Momentum resolution:



Simulation Framework for MPD (MPDROOT)

MPDROOT

SIMULATION AND ANALYSIS FRAMEWORKS FOR MPD AND BM@N AT NICA

GENERAL

DOCUMENTS

COMPUTING

REFERENCES

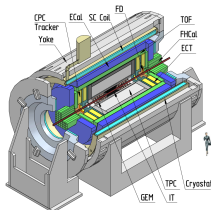
FORUM

BM@N SHIFTS

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**

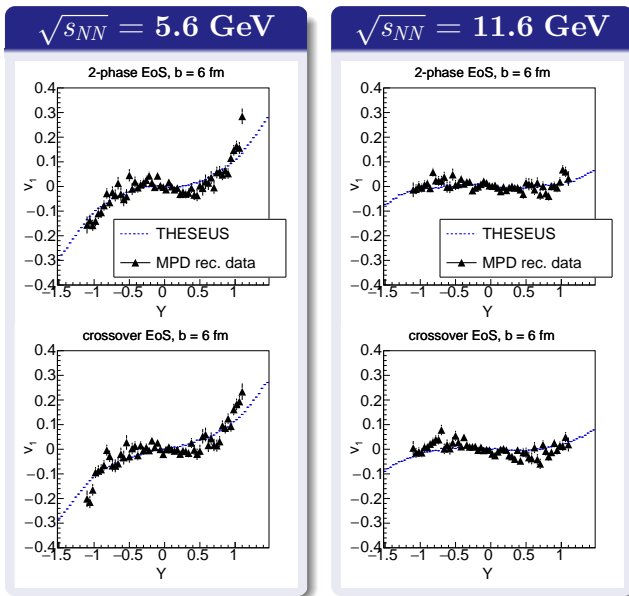
Benefits:

- 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 macros
to be used for sim
& reco have been
adopted for
THESEUS input**

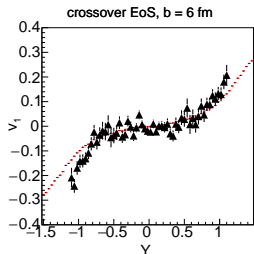
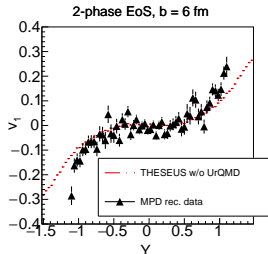
THESEUS: data sets available

Direct flow of protons (THESEUS)

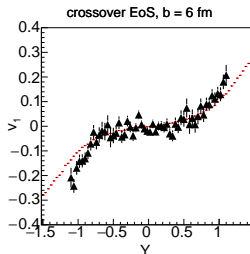
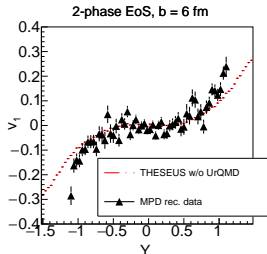


Direct flow of protons (THESEUS w/o UrQMD)

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



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



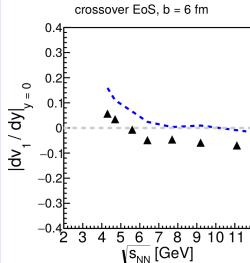
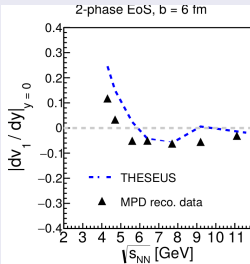
Results on reconstructed flow are preliminary: statistics should be increased, amendments in reco. algorithm are also in progress

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

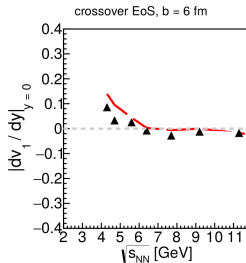
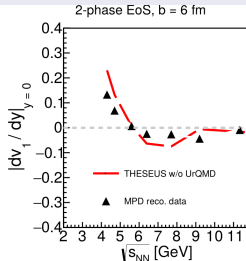
Direct flow of protons, dv_1/dy

Comparison with exp. data available:

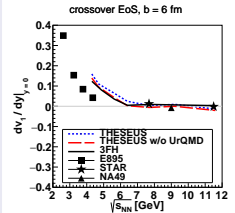
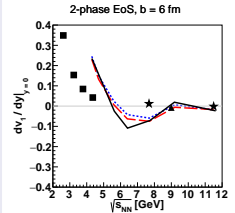
THESEUS:



THESEUS w/o UrQMD:



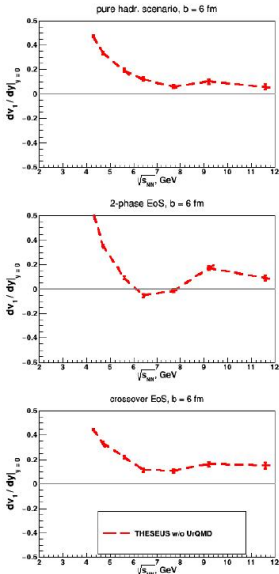
Phys. Rev. C 94, 044917 (2016)



Real PID used:

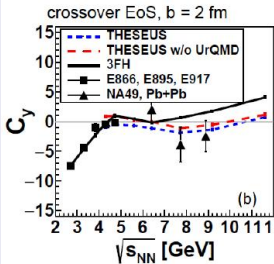
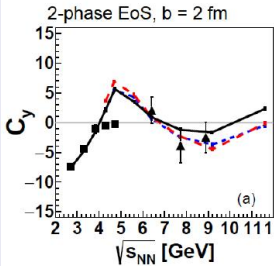
recoTrack->GetPidProbProton() > 0.9

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.

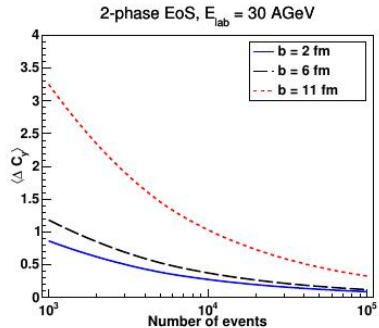
Baryon stopping signal for a first-order phase transition



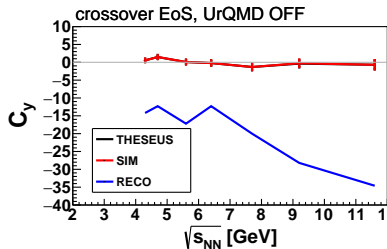
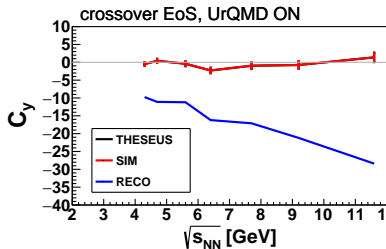
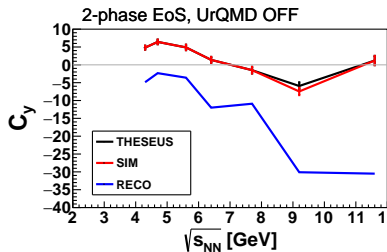
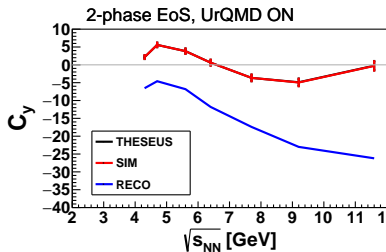
$$C_y = y_{cm}^2 \frac{d^3 N_{netProt}/dy^3}{dN_{netProt}/dy}$$

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

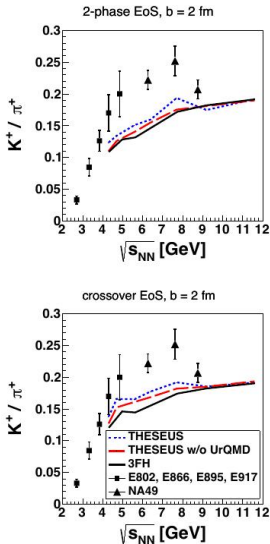
$$\Delta C_y = \frac{2y_{beam}^2}{c} \sqrt{(\Delta a)^2 + \frac{a^2}{c^2} (\Delta c)^2}$$



Baryon stopping signal for a first-order phase transition



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
- Preliminary results on NICA/MPD MC-simulations showed ...
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