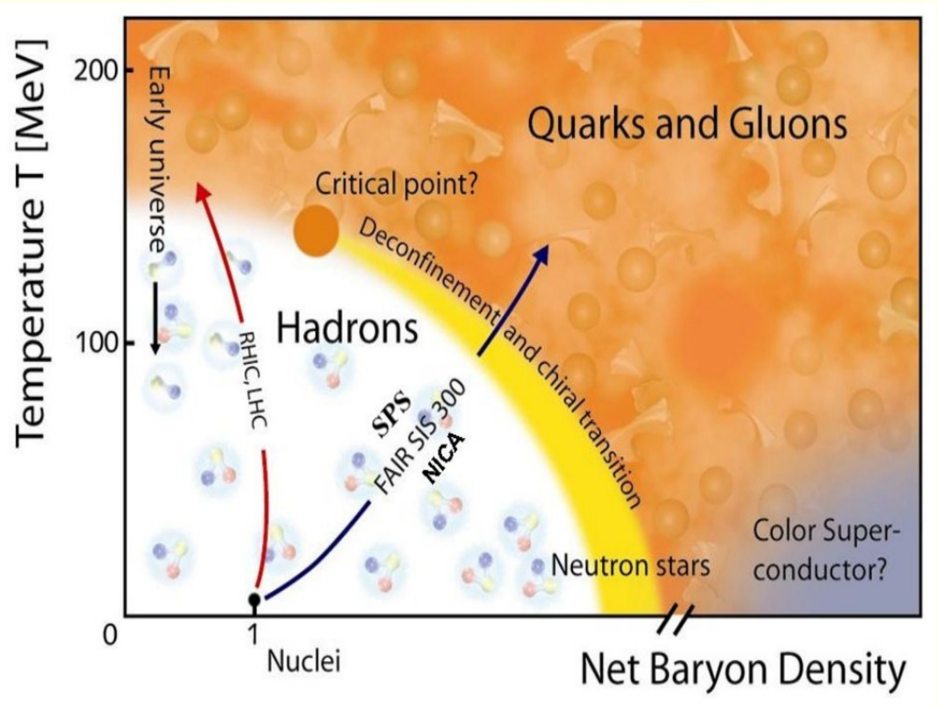
Can the MPD at NICA “see” the baryon stopping signal ?

Sergej Merts, Oleg Rogachevsky

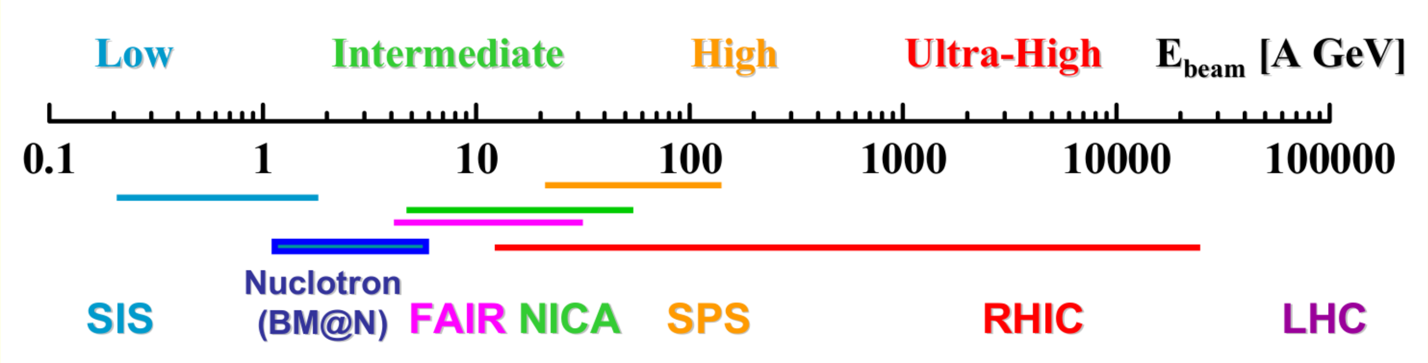
SQM 2015
Dubna



At which incident energy an onset of deconfinement happen?

What is the order of the deconfinement transition at high baryon densities?

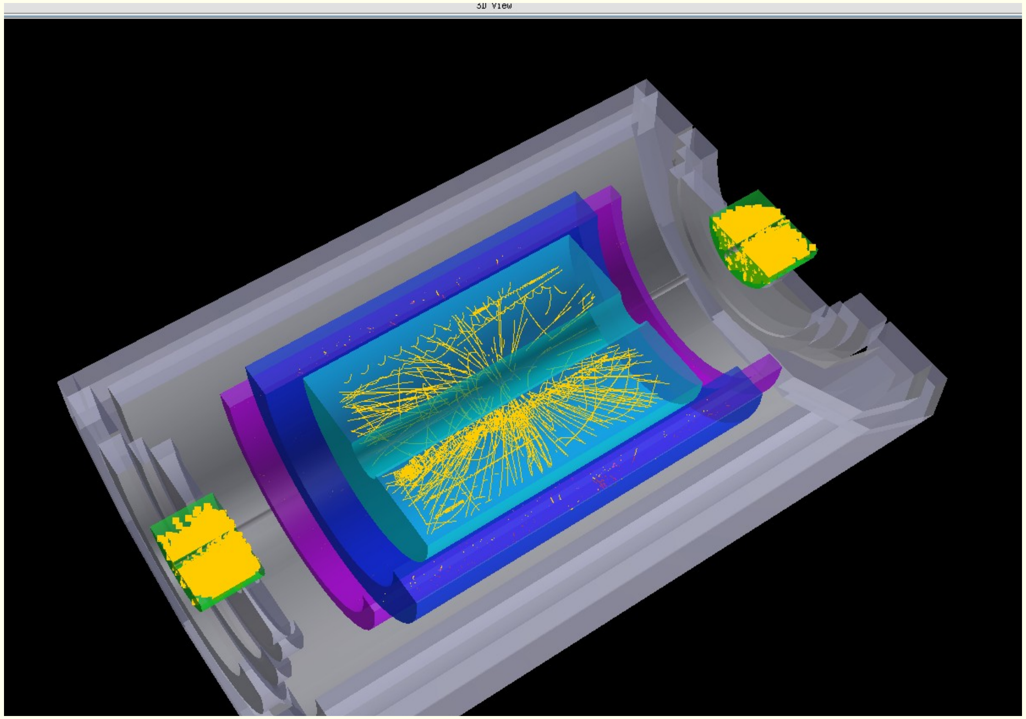
Is there a critical end point in the phase diagram?



NICA experiments

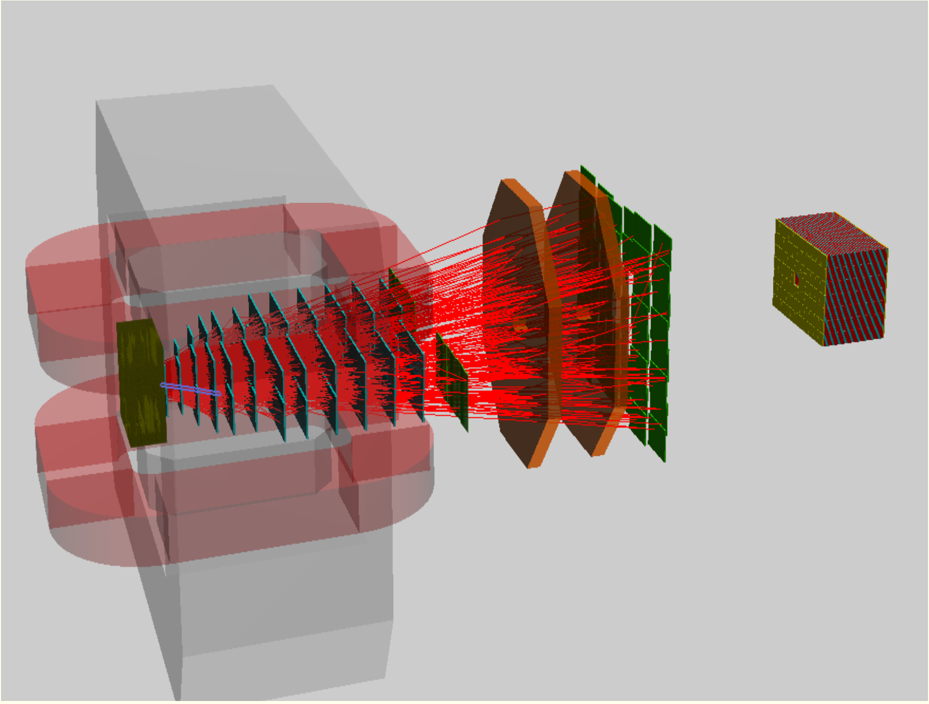
MPD

$\sqrt{s}_{NN}$ = 4 – 11 GeV



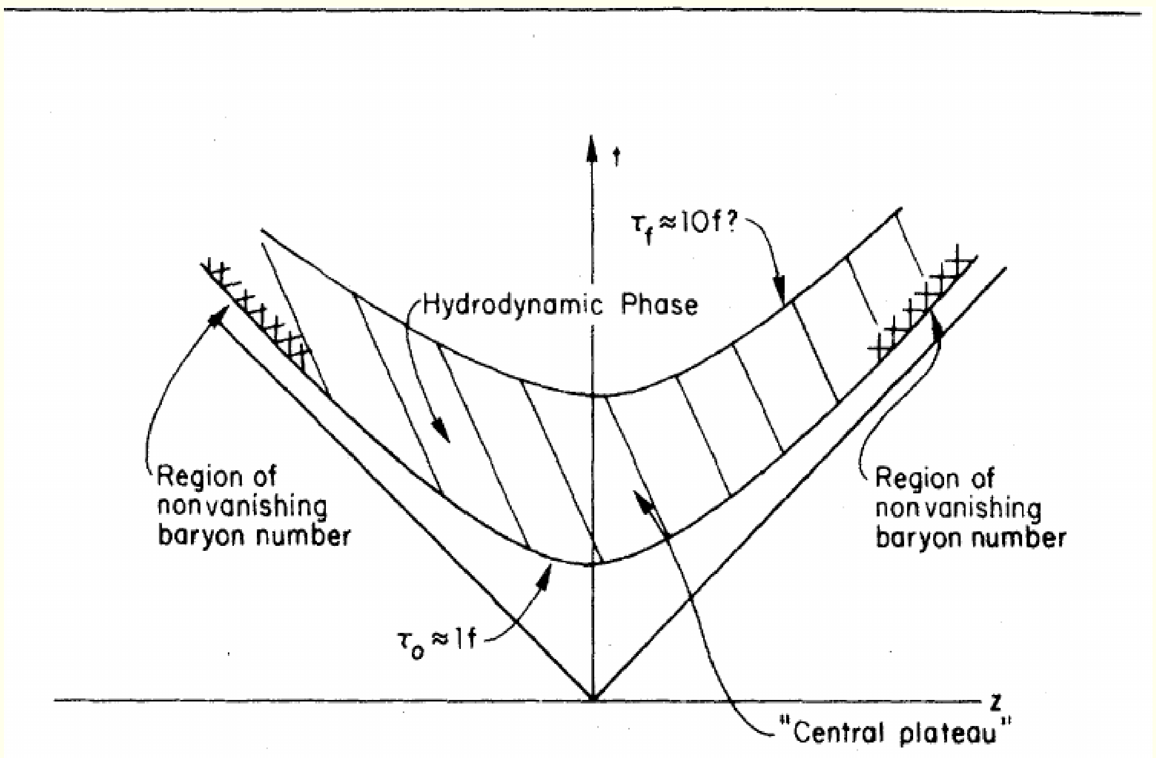
BM@N

$E_{beam} \leq$ 4.5 AGeV



Goal

*J.**D.Bjorken,PRD 27,140 (1983)***



The net-baryon rapidity distributions are though to reflect the initial distribution of baryonic matter in the very first moment of the collisions

Tools for physics simulations for NICA

I) Direct approach based on transport codes:
Particle trajectories are followed;
Properties of the medium are encoded in propagators and cross sections
→ UrQMD (Aichelin et al.),
→ PHSD (Bratkovskaya, Cassing, et al.),
→ PHSD + SACA (Bratkovskaya, Aichelin, LeFevre, et al.)
LA QGSM
SHIELD

II) Hybrid approach:
Joins hydrodynamic evolution of a (multi-)fluid system described by an EoS with
Particle transport via a procedure called “particlization” (Karpenko)
Particularly suitable for studying effects of a strong phase transition in model EoS
a) Hybrid: UrQMD + hydro + hadronic cascade (H. Petersen et al.)
→ PT in hydro stage only
b) 3-fluid hydrodynamics (Ivanov) + particlization (Karpenko)
→ PT in baryon stopping regime already!

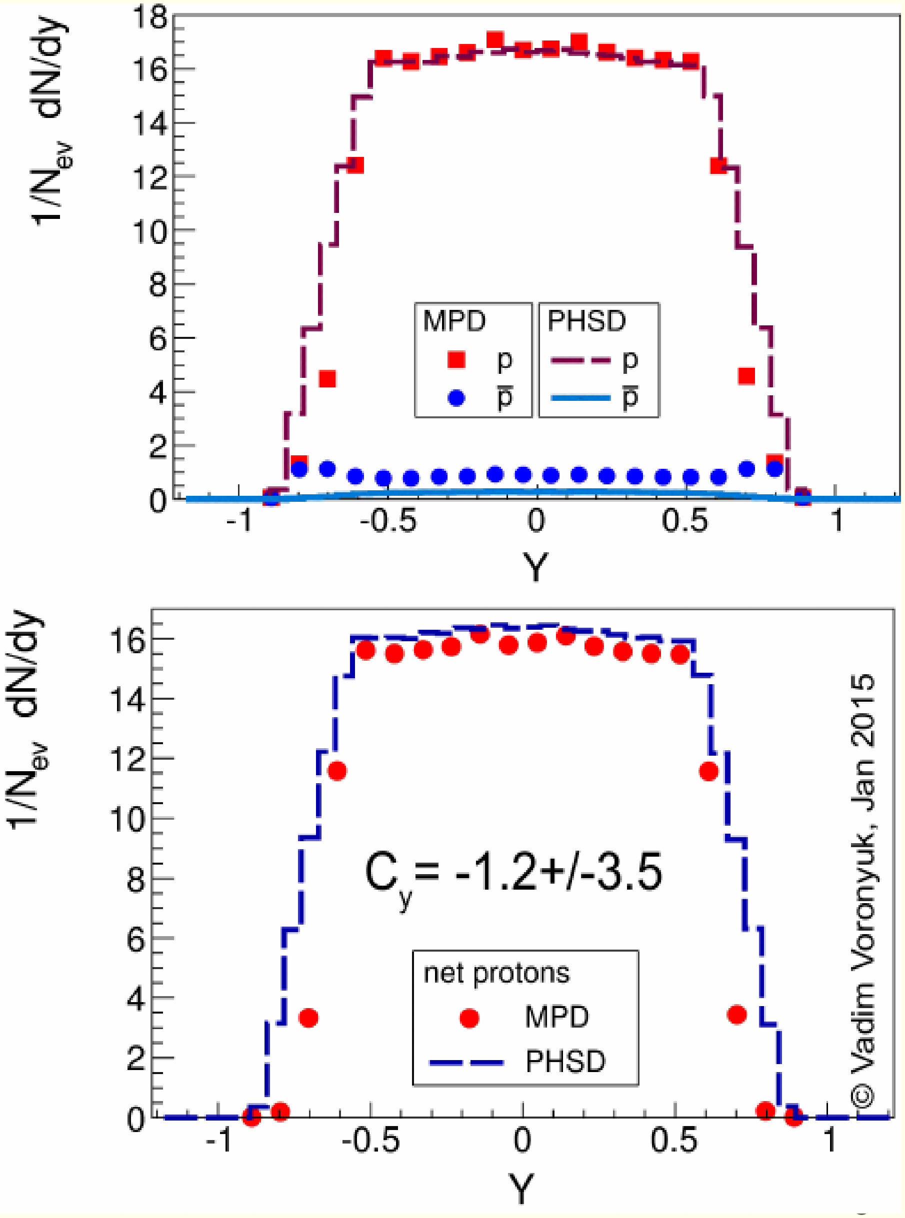
Simulation of the MPD detector response GEANT3(4)

PHSD

Event set:
40k AuAu @ $\sqrt{s_{NN}}$ = 9 GeV [0-5%]

The most reliable region
|eta| < 1.2 ; 0.4 < p_t [GeV/c] < 0.8

Result:
PHSD input → GEANT+MPD
detector reproduces the rapidity distribution well

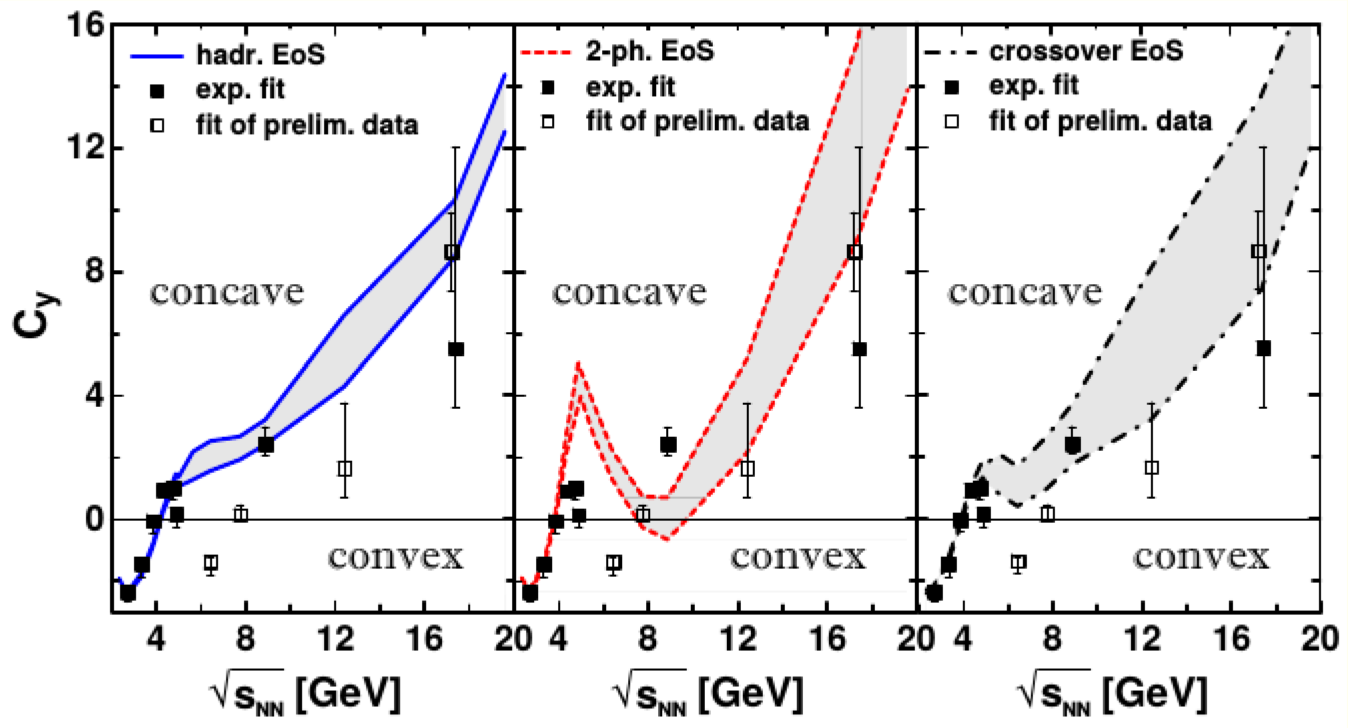


Baryon Stopping

$$C_y = \left(y^3_{\mathrm{c.m.}} \frac{d^3N}{dy^3} \right)_{y=y_{\mathrm{c.m.}}} \Big/ \left(y_{\mathrm{c.m.}} \frac{dN}{dy} \right)_{y=y_{\mathrm{c.m.}}}$$
$$= (y_{\mathrm{c.m.}}/w_s)^2 (\sinh^2 y_s - w_s \cosh y_s).$$

Yu.B. Ivanov, Phys. Rev. C 87, 064904 (2013)

a wiggle irregularity of Cy at midrapidity



Cy = reduced curvature of net-proton rapidity distribution at midrapidity

3FD conclusions

Deconfinement scenarios look preferable at $\sqrt{s_{NN}} > 4$ GeV

directed flow:
High sensitivity of the proton directed flow to the EoS
v1 indicates the crossover deconfinement transition
in a wide range of energies $4 < \sqrt{s_{NN}} < 20$ GeV.
QGP EoS's in the high-baryon-density sector should be stiffer
Similar constraint from astrophysics

elliptic flow:
Low sensitivity to the EoS.
A stronger EoS dependence for antibaryons and K^-
No qualitative signals of deconfinement

baryon stopping, i.e. net-proton rapidity distributions:
Irregularity signals deconfinement onset (no reliable data yet)

3+1D viscous hydro-cascade model (Hybrid UrQMD)

PHYSICAL REVIEW C 91, 064901 (2015)

3+1D viscous hydro+cascade model was applied for A+A collisions at RHIC Beam Energy Scan energies (s = 7.7 − 39 GeV), and for SPS energy points

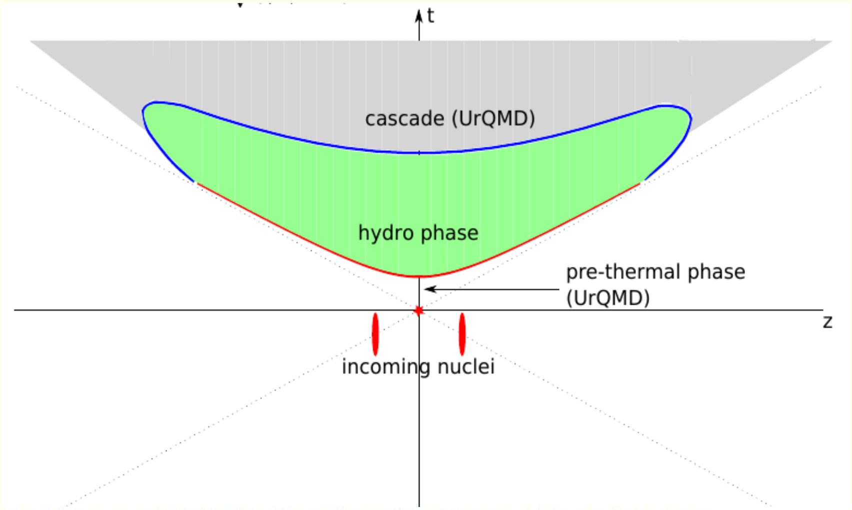
Cascade-hydro-cascade approach:

Initial state: UrQMD cascade

S.A. Bass et al., Prog. Part. Nucl. Phys. 41 255-369, 1998

Hydrodynamic phase: numerical 3+1D hydro solution via original relativistic viscous hydro code

Iu. Karpenko, P. Huovinen, M. Bleicher, arXiv:1312.4160



Hydro starts at $\tau = \sqrt{t^2 - z^2} = \tau_0$ (red curve): $\tau_0 = \frac{2R}{\gamma v_z}$

$\{T^{0\mu}, N_b^0, N_q^0\}$ of fluid = averaged $\{T^{0\mu}, N_b^0, N_q^0\}$ of particles

Fluid → particle transition

$\varepsilon = \varepsilon_{sw} = 0.5$ GeV/fm^3 (blue curve):

$\{T^{0\mu}, N_b^0, N_q^0\}$ of hadron-resonance gas = $\{T^{0\mu}, N_b^0, N_q^0\}$ of fluid

Equations of state for hydrodynamic phase

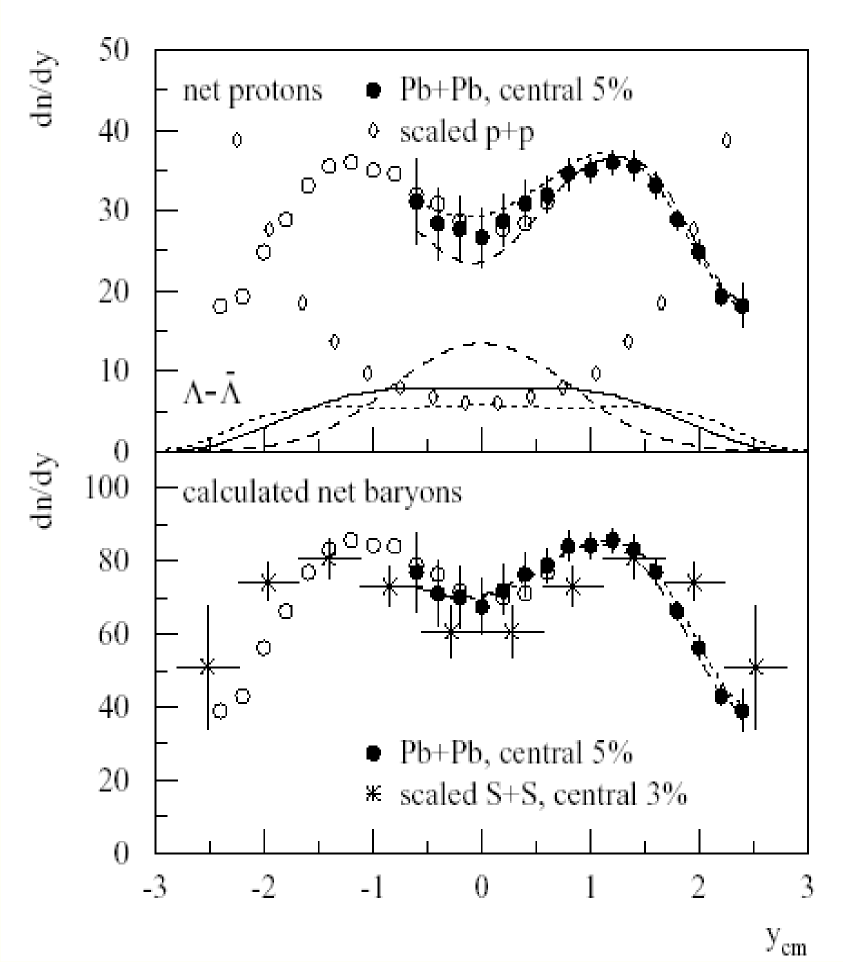
- Chiral model
  - coupled to Polyakov loop to include the deconfinement phase transition
  - good agreement with lattice QCD data at $\mu_B = 0$, also applicable at finite baryon densities
  - (current version) has crossover type PT between hadron and quark-gluon phase at all μ_B
- Hadron resonance gas + Bag Model (a.k.a. EoS Q)
  - hadron resonance gas made of u, d quarks including repulsive meanfield
  - the phases matched via Maxwell construction, resulting in 1[st] order PT

J. Steinheimer, S. Schramm and H. Stocker, J. Phys. G 38, 035001 (2011);
P.F. Kolb, J. Sollfrank, and U. Heinz, Phys.Rev. C 62, 054909 (2000).

Central Pb-Pb from NA49

Phys.ReV.Lett.82,2471(99)

Pb-Pb at 158 A.GeV/c

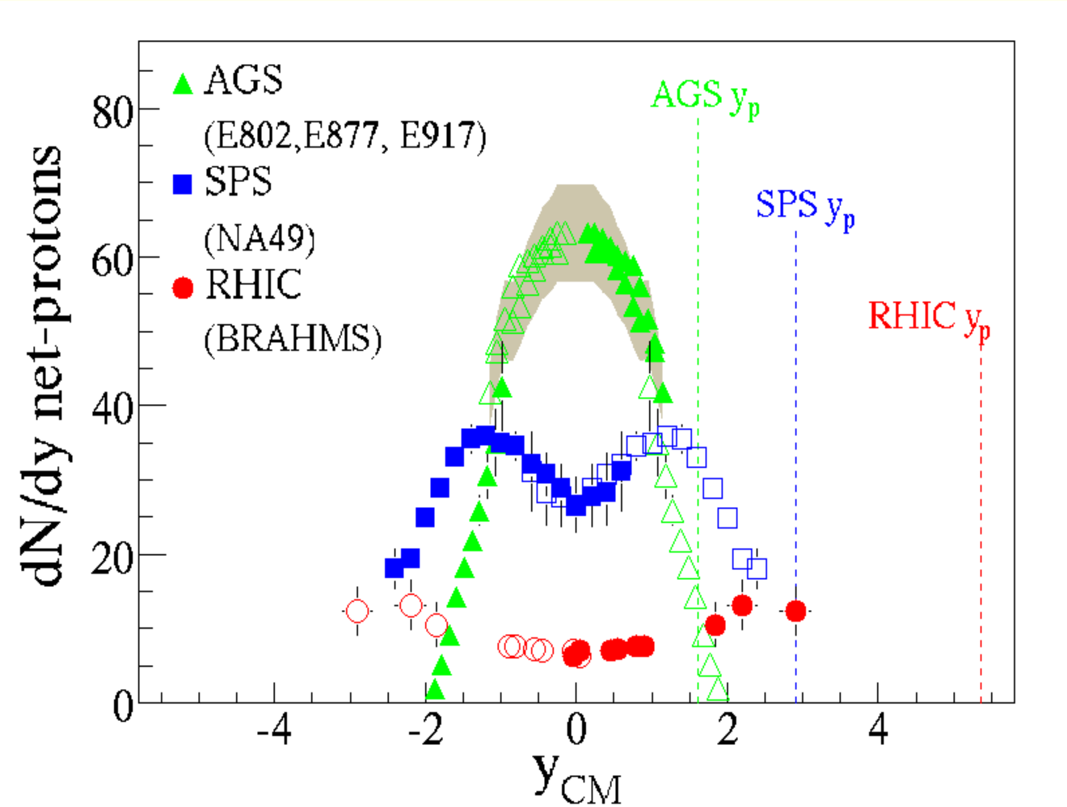


Rather large but not complete stopping.

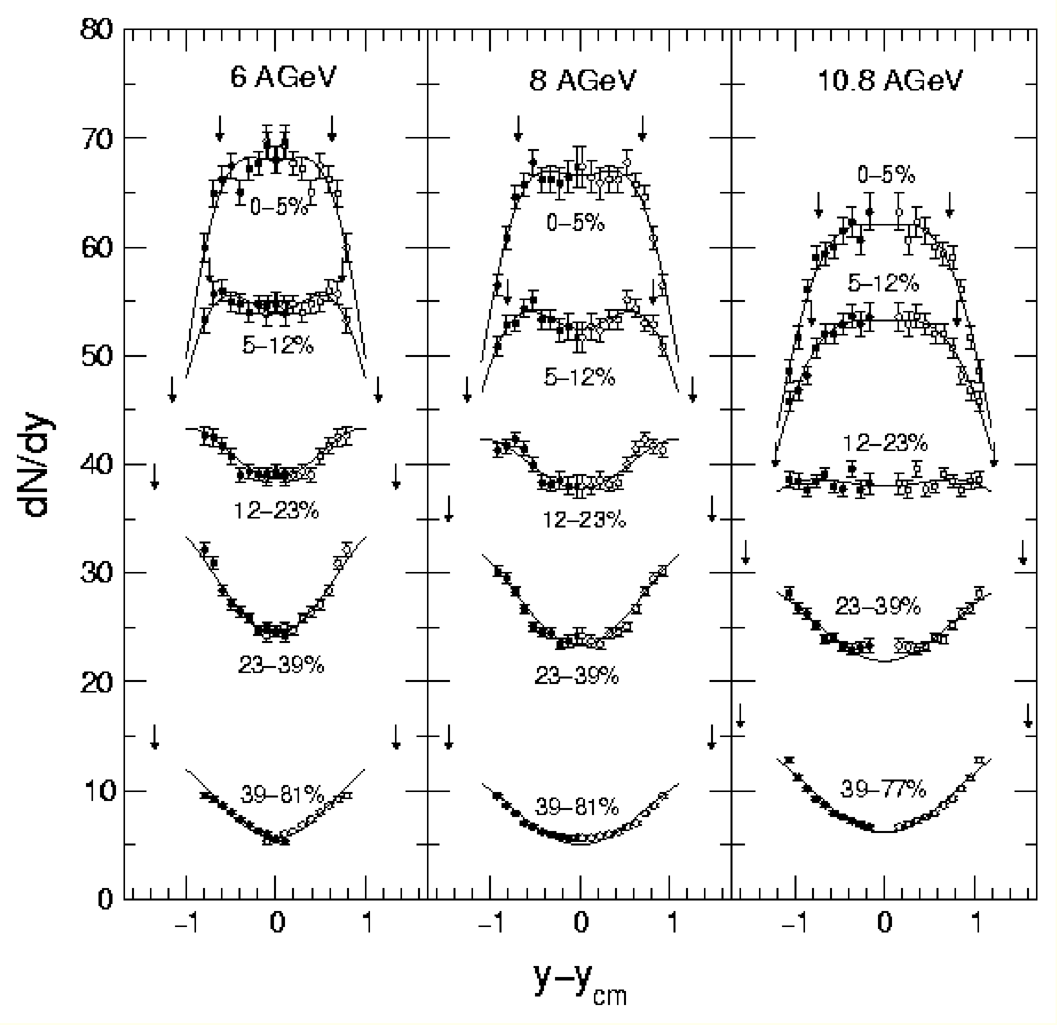
The rapidity loss δy = 1.76 ± 0.05 for PbPb and for SS: 1.63 ± .16.

Net-p energy systematic

At RHIC the mid-rapidity region is almost net-proton free. Pair baryon production dominates at RHIC.



Au+Au collisions at AGS

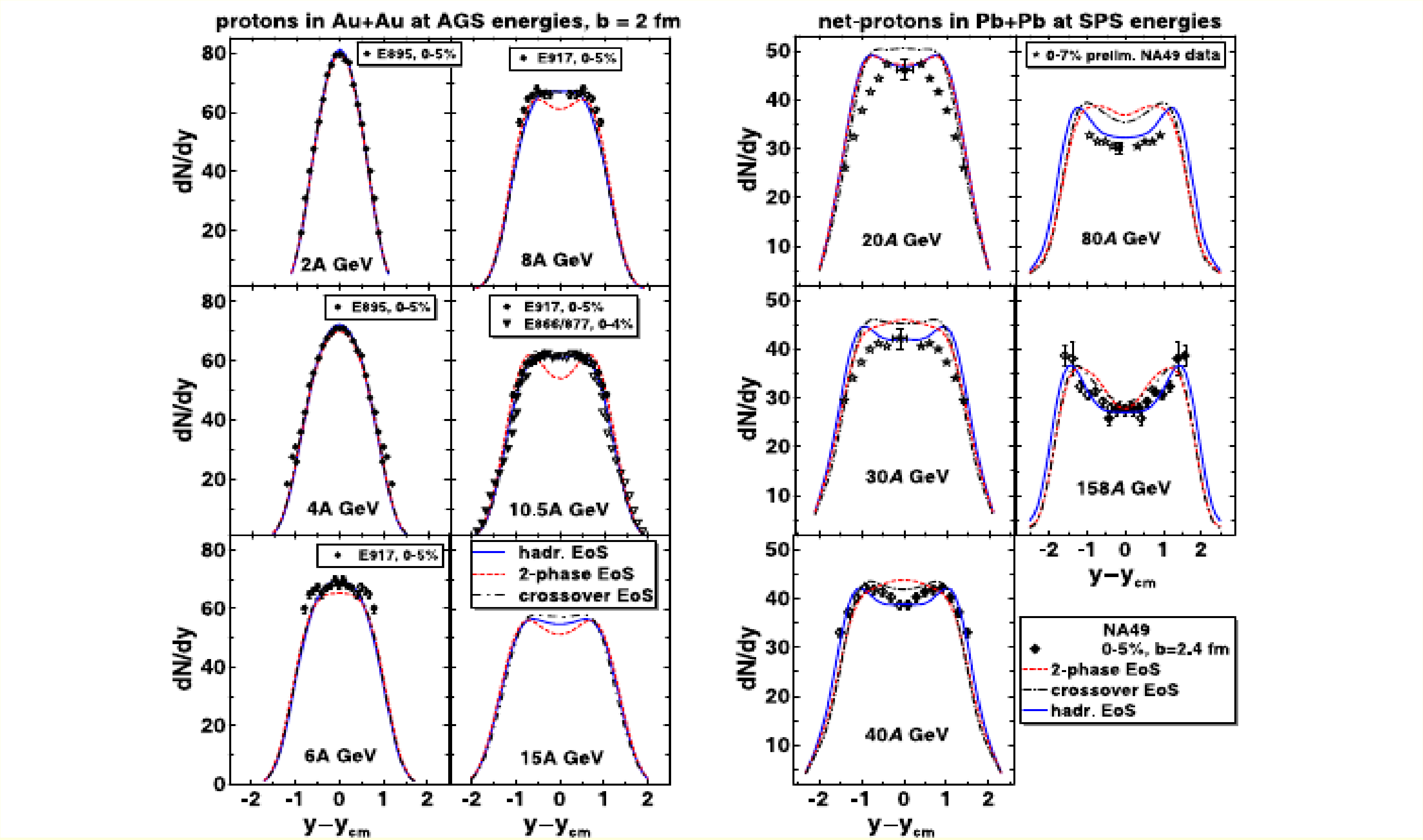


p+p picture is recovered in peripheral collisions

In central collisions the rapidity distribution peaks at mid-rapidity

Strong centrality dependence.

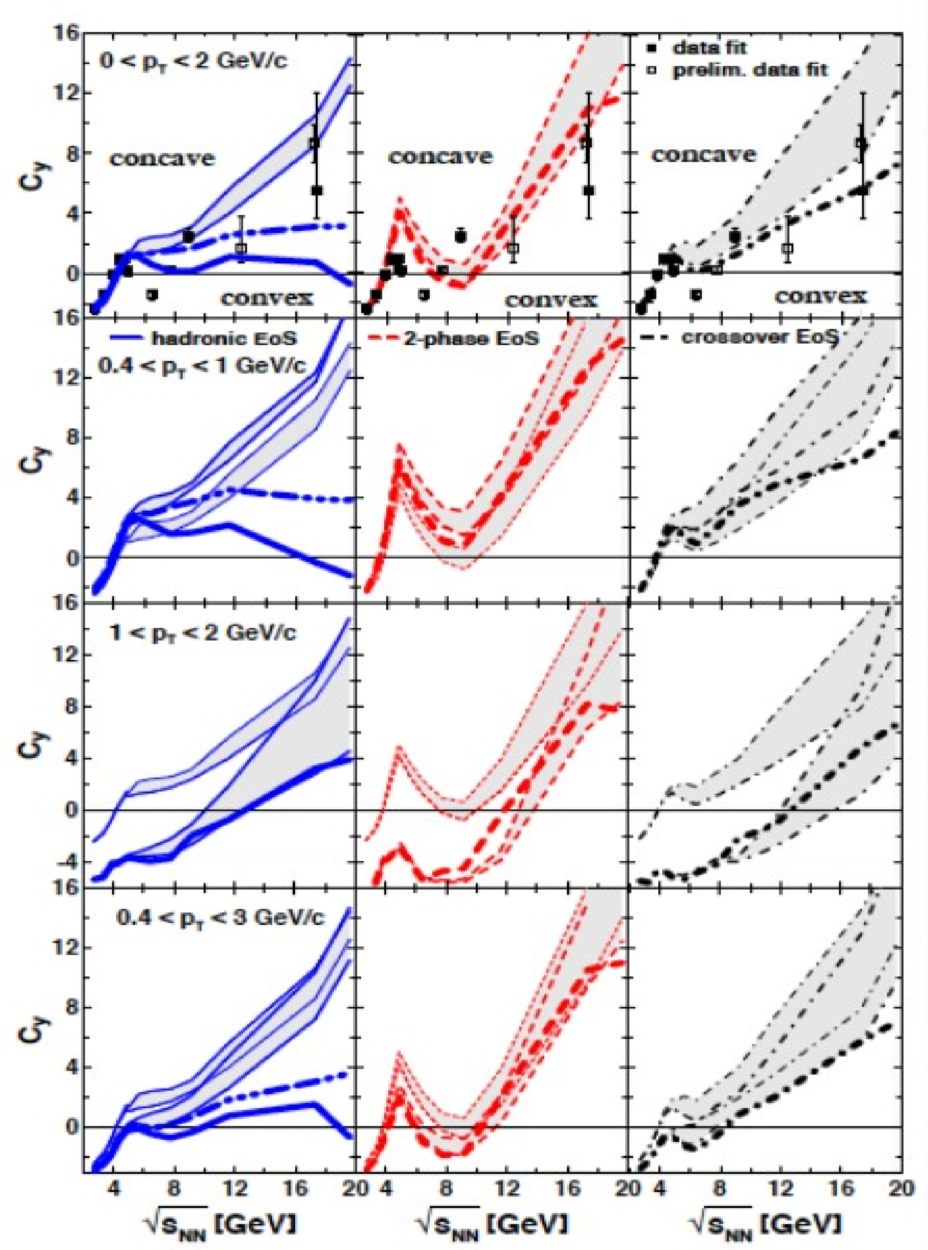
3FD & experiments



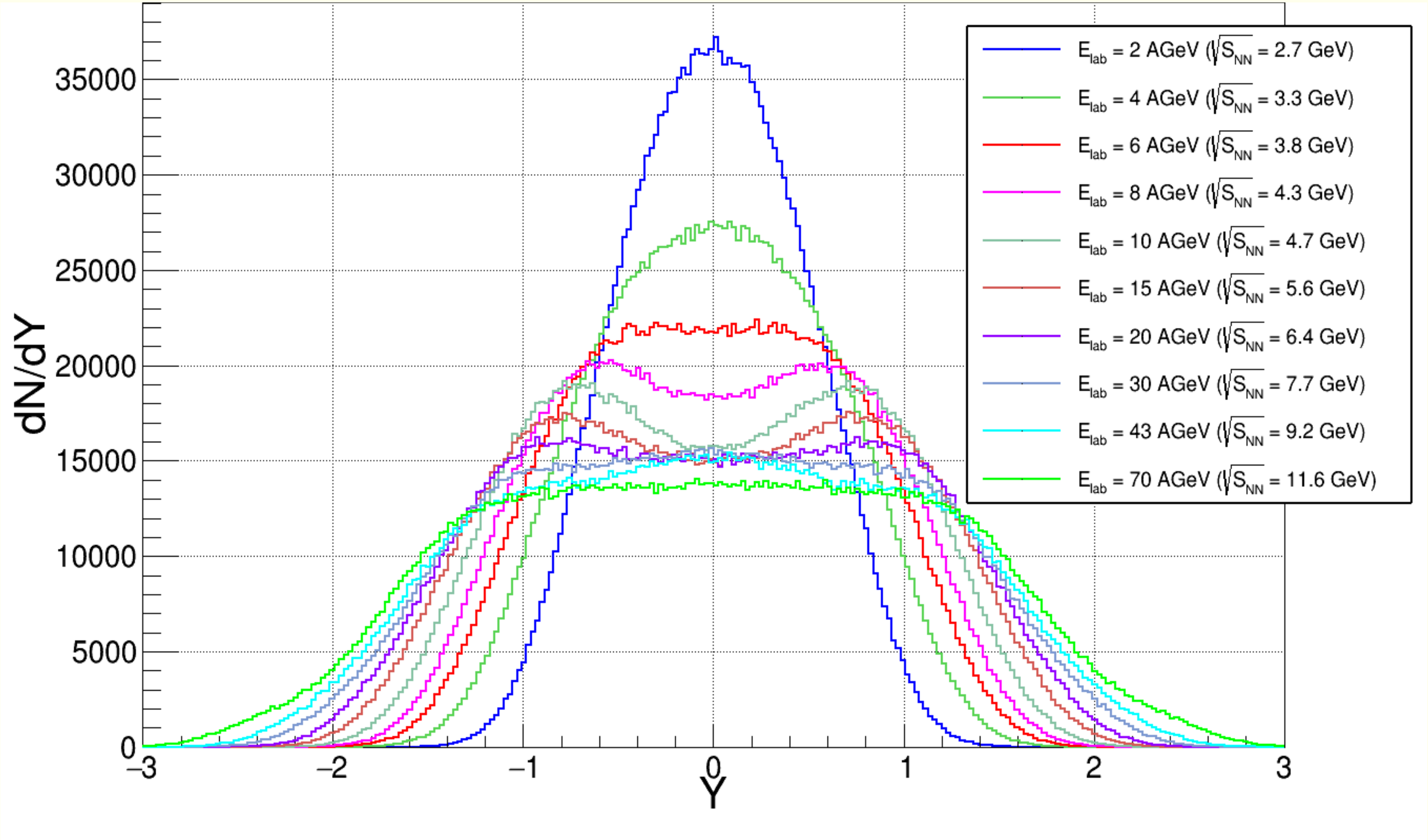
robustness

Yu. Ivanov & D. Blaschke,
arxiv:1504.03992

- “wiggle” formed in the nonequilibrium compresion
stage of the collision, where pT only in 3FH
- robust against serious p cuts
T- at high p (1 - 2 GeV/c) in convex region
T- at low p (0.2 - 1 GeV/c) in concave region
T- required accuracy in Cy determination: ΔCy < 2



3FD + part. 1st order PT
Net-protons from AuAu



3FD + part. 1st order PT
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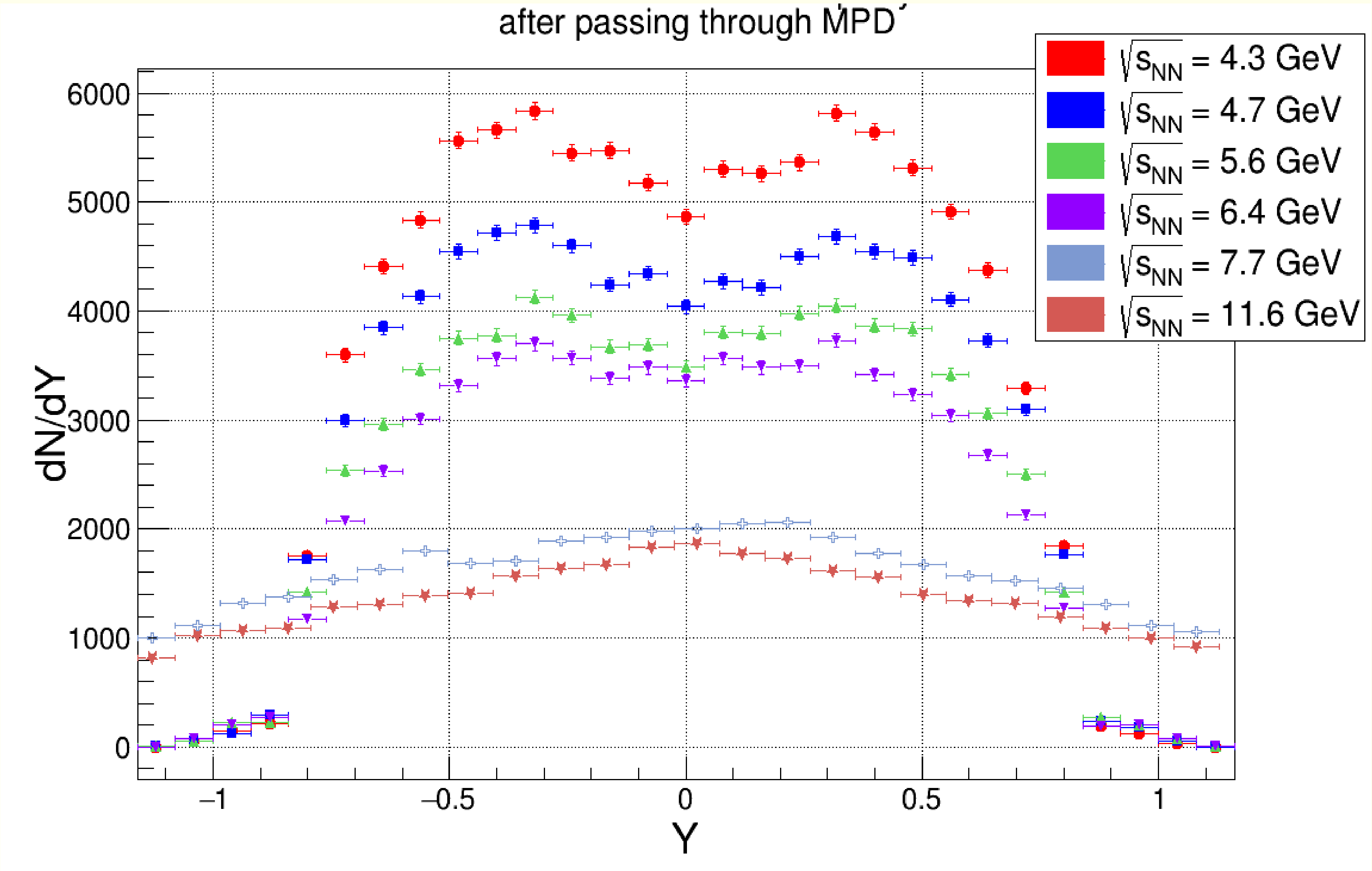
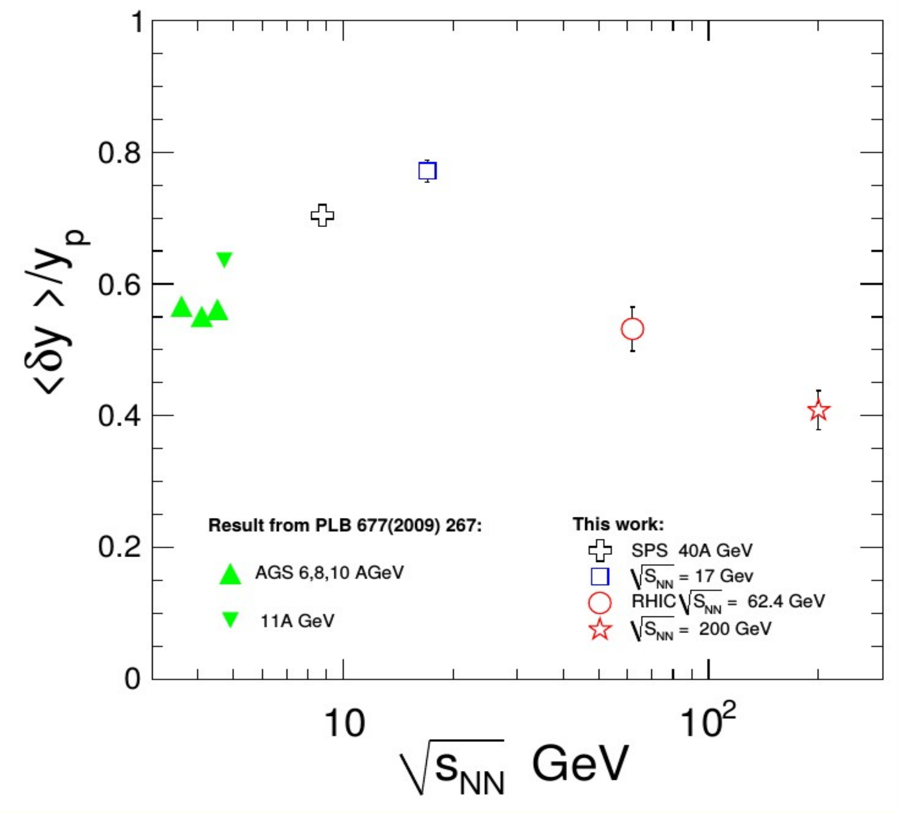
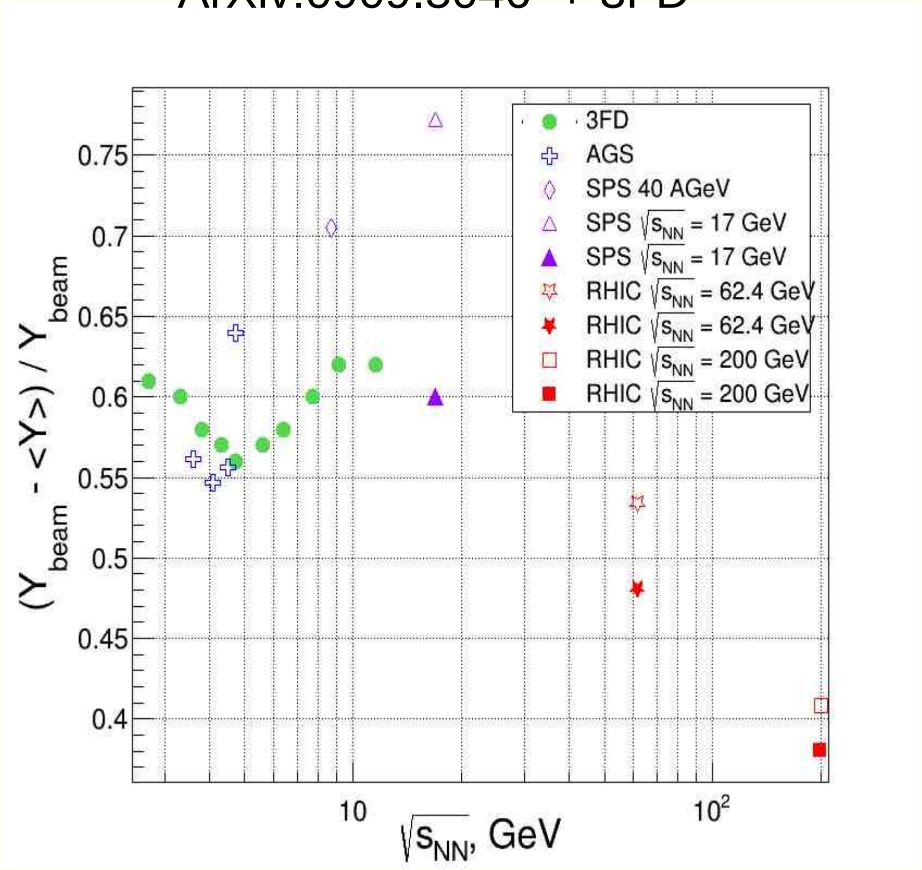


Relative mean rapidity loss

arXiv:0909.5046

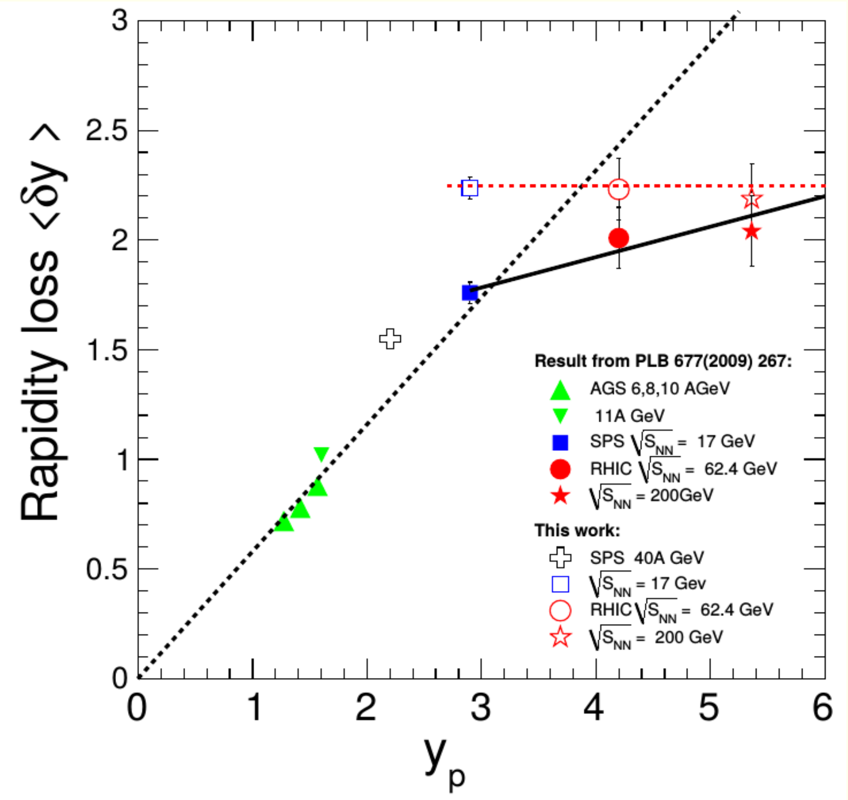


ArXiv:0909.5046 + 3FD

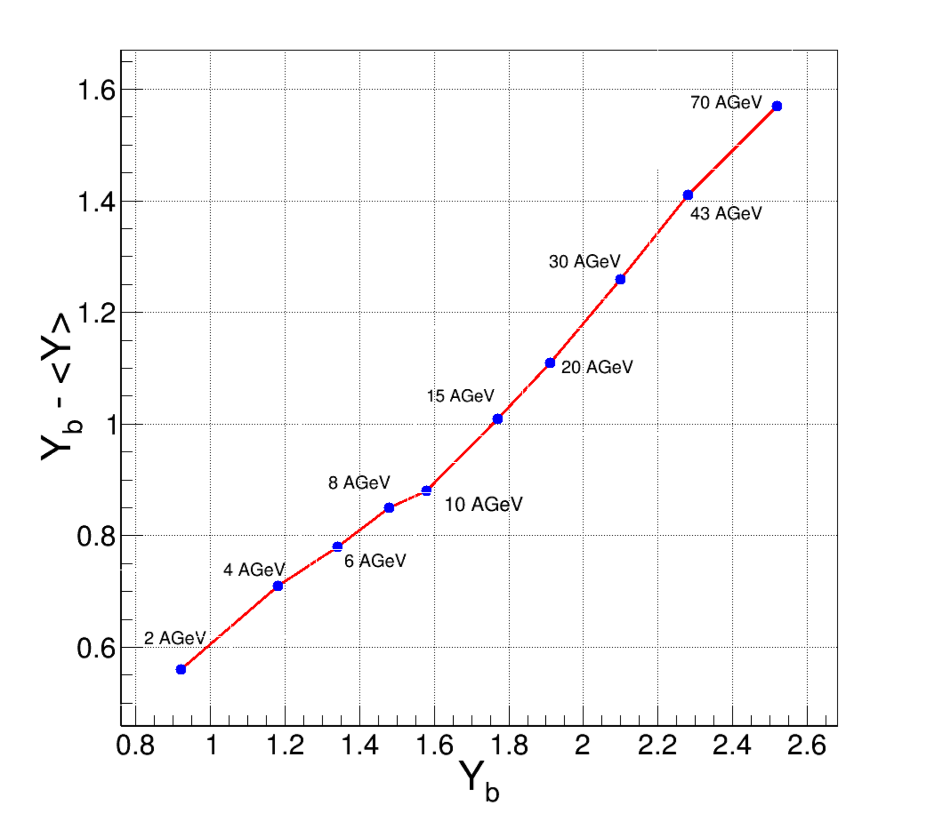


Beam rapidity dependence

arXiv:0909.5046



3FD

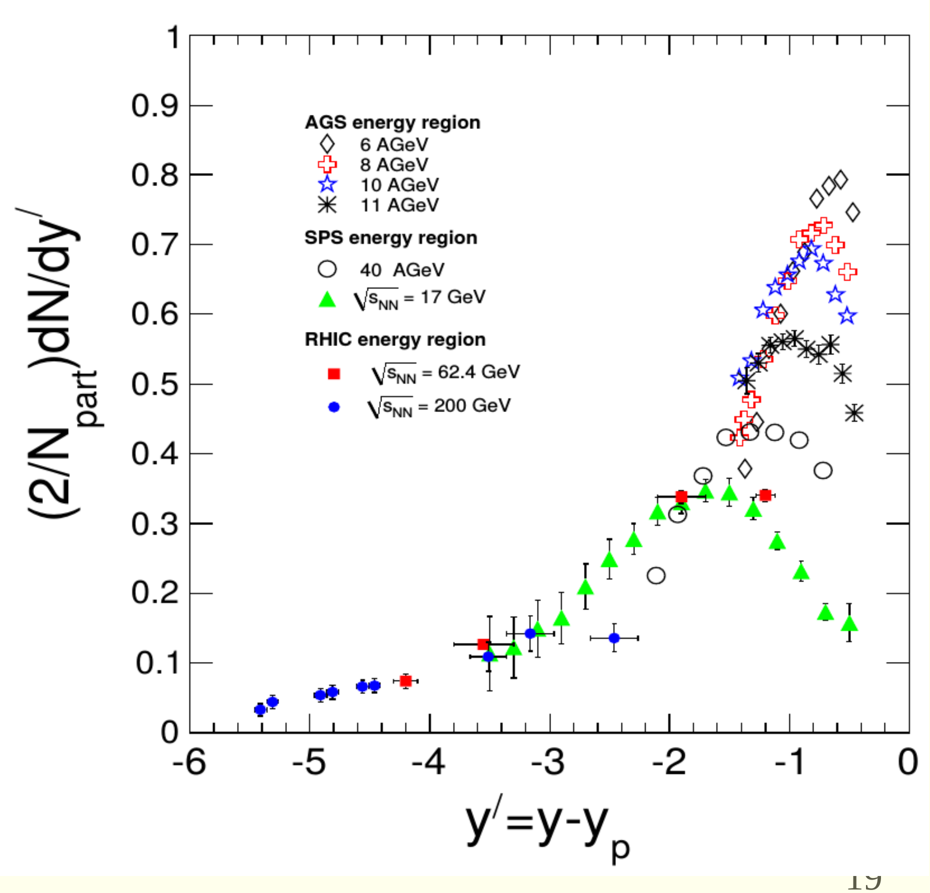


net-baryon rapidity density

$$\frac{2}{N_{part}} \frac{dN^{B-\bar{B}}}{dy'}$$

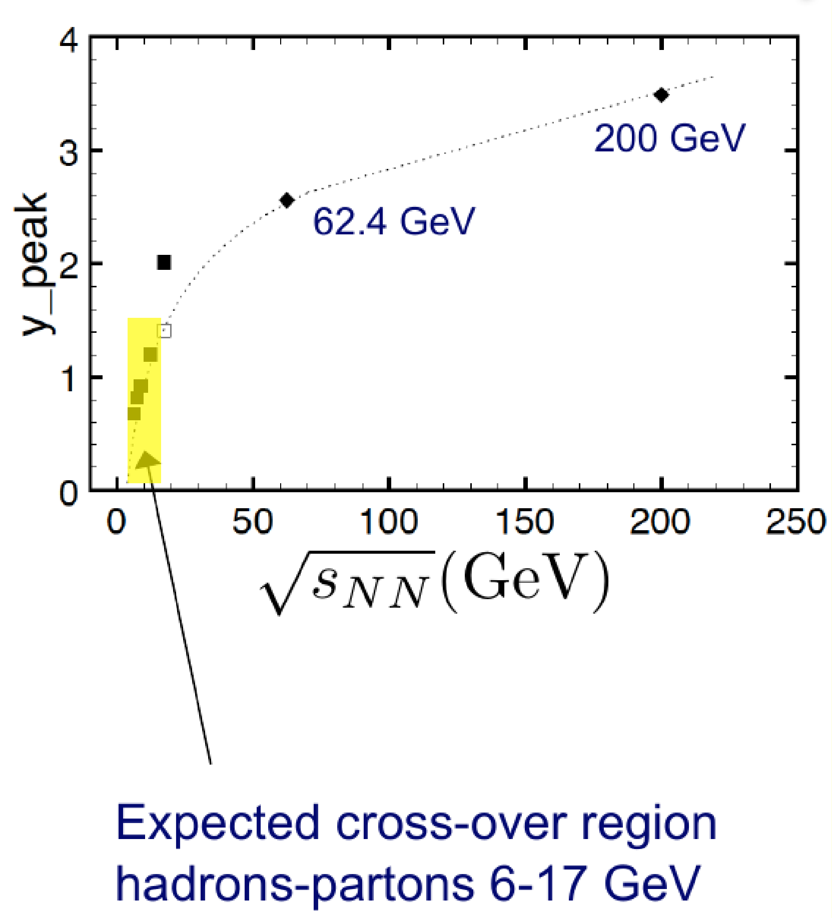
Normalized projectile net-baryon rapidity density

- the rapidity distribution peaks at lower y ′ values with higher colliding energies from AGS to top SPS energy.
- the mean rapidity loss increases with beam energy



Cross-over region

Georg Wolschin



Data from

Phys. Lett. B 677, 267 (2009)

NA49 PRL 82, 2471 (1999)

NA49 2010 (C. Blume et al.)

Thank you for attention