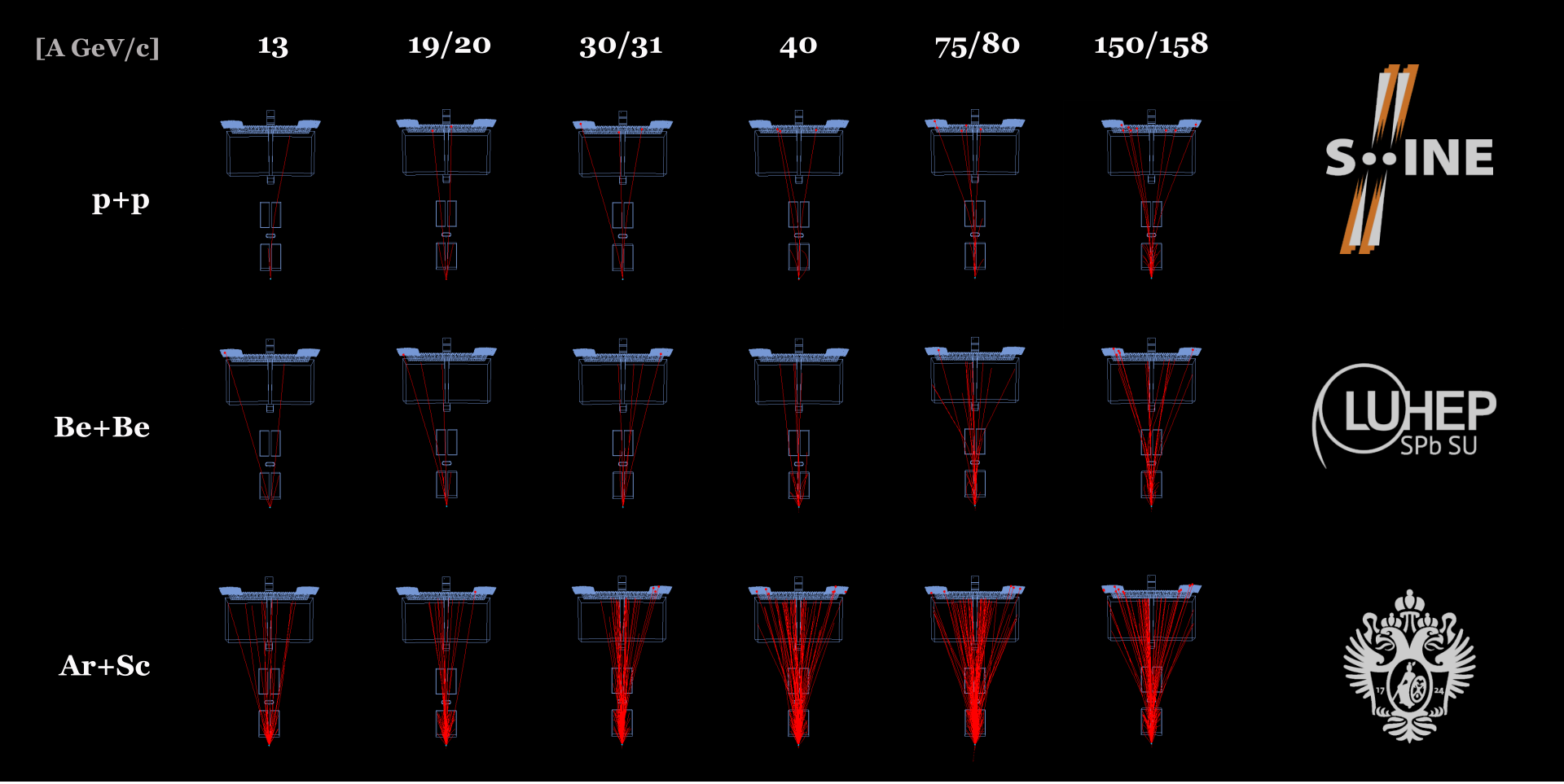


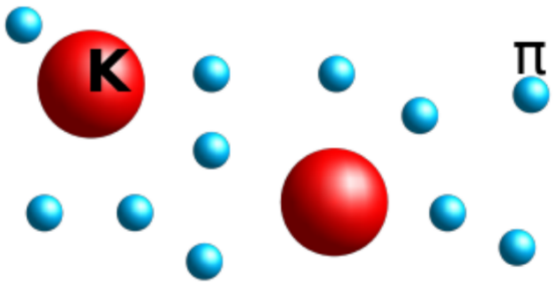
SYSTEM SIZE DEPENDENCE OF STRANGENESS PRODUCTION AT THE CERN SPS ENERGIES

Andrey Seryakov
for the NA61/SHINE collaboration
Laboratory of ultra-high energy physics
St. Petersburg State University
seryakov@yahoo.com

The work was supported by the Russian Science Foundation grant number 17-72-20045

STRANGENESS AND QGP

Confined matter:
K - mesons
$2M \approx 2 \cdot 500$ MeV

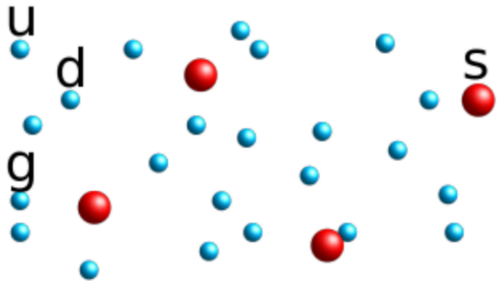


$T_c \approx 150$MeV

→

Phase transition

Deconfined matter:
(anti-)strange quarks
$2m \approx 2 \cdot 100$ MeV

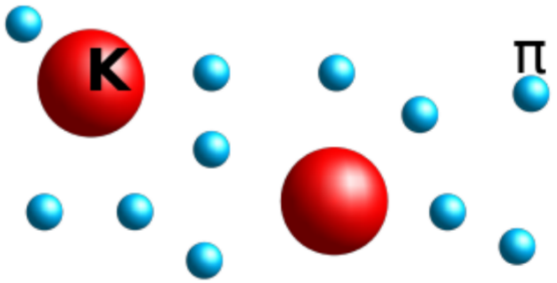


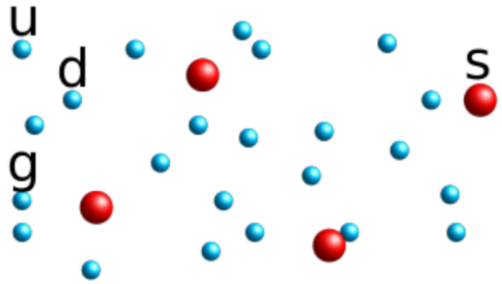
STRANGENESS IN STATISTICAL MODEL OF EARLY STAGE

$$\langle n \rangle = \frac{gV}{(2\pi)^3} \int d^3p \frac{1}{e^{E/T} \pm 1}$$

$$\approx gV \left(\frac{MT}{2\pi}\right)^{3/2} e^{-M/T} \quad \text{for heavy particles}$$

$$\approx gV \frac{2\pi^2}{4{\cdot}45} T^3 \quad \text{for light particles}$$





Gaździcki, Gorenstein, Acta Phys.Polon. B30 (1999) 2705

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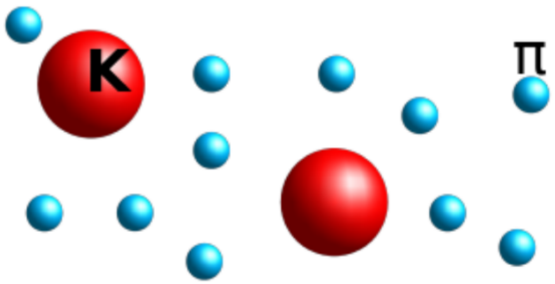
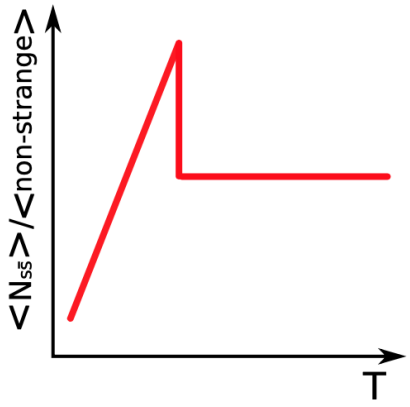
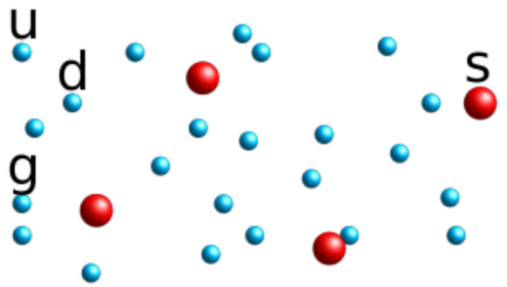


$$\frac{\langle K \rangle}{\langle \pi \rangle} \propto \frac{T^{3/2}}{T^3} \cdot e^{-M/T}$$

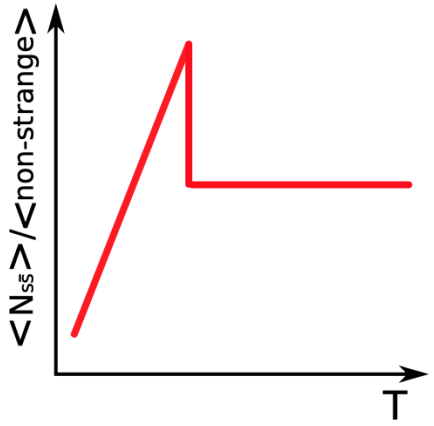


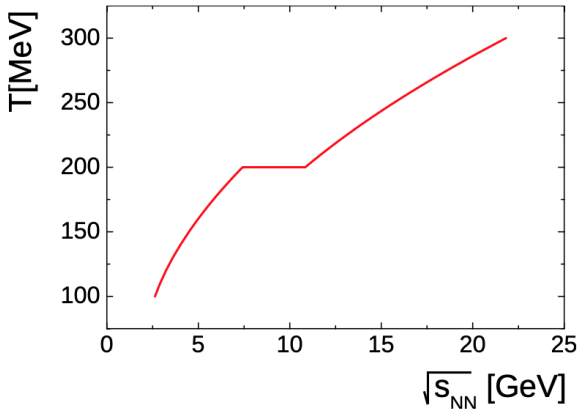


$$\frac{\langle s \rangle}{\langle u + d + g \rangle} \propto \frac{T^3}{T^3} = \text{const}(T)$$

Gaździcki, Gorenstein, Acta Phys.Polon. B30 (1999) 2705

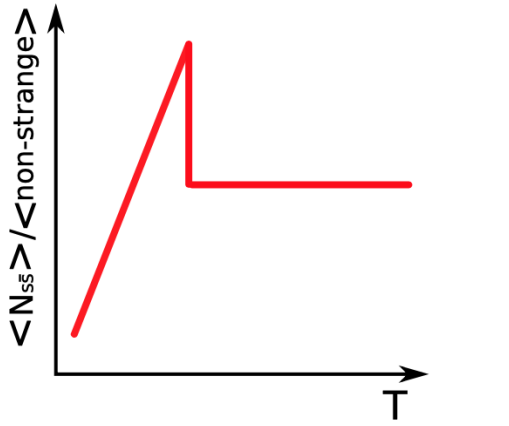
STRANGENESS IN STATISTICAL MODEL OF EARLY STAGE

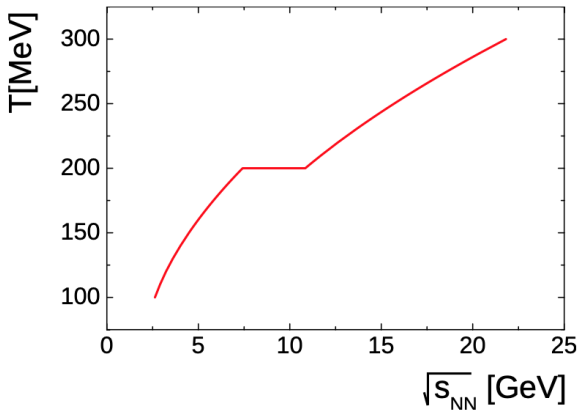


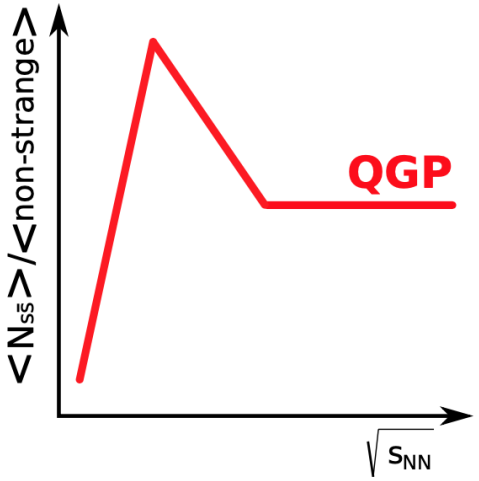


Gaździcki, Gorenstein, Acta Phys.Polon. B30 (1999) 2705

STRANGENESS IN STATISTICAL MODEL OF EARLY STAGE







Gaździcki, Gorenstein, Acta Phys.Polon. B30 (1999) 2705

STRANGENESS IN HEAVY ION COLLISIONS

How to measure $\langle N_{s\bar{s}} \rangle$?

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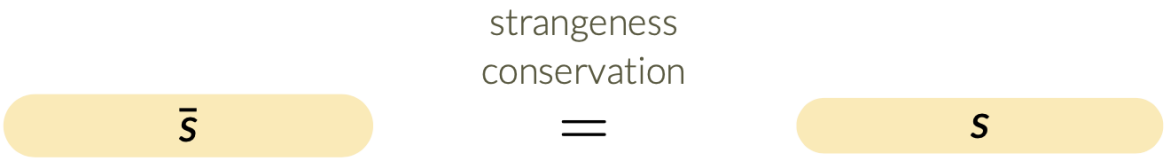

STRANGENESS IN HEAVY ION COLLISIONS

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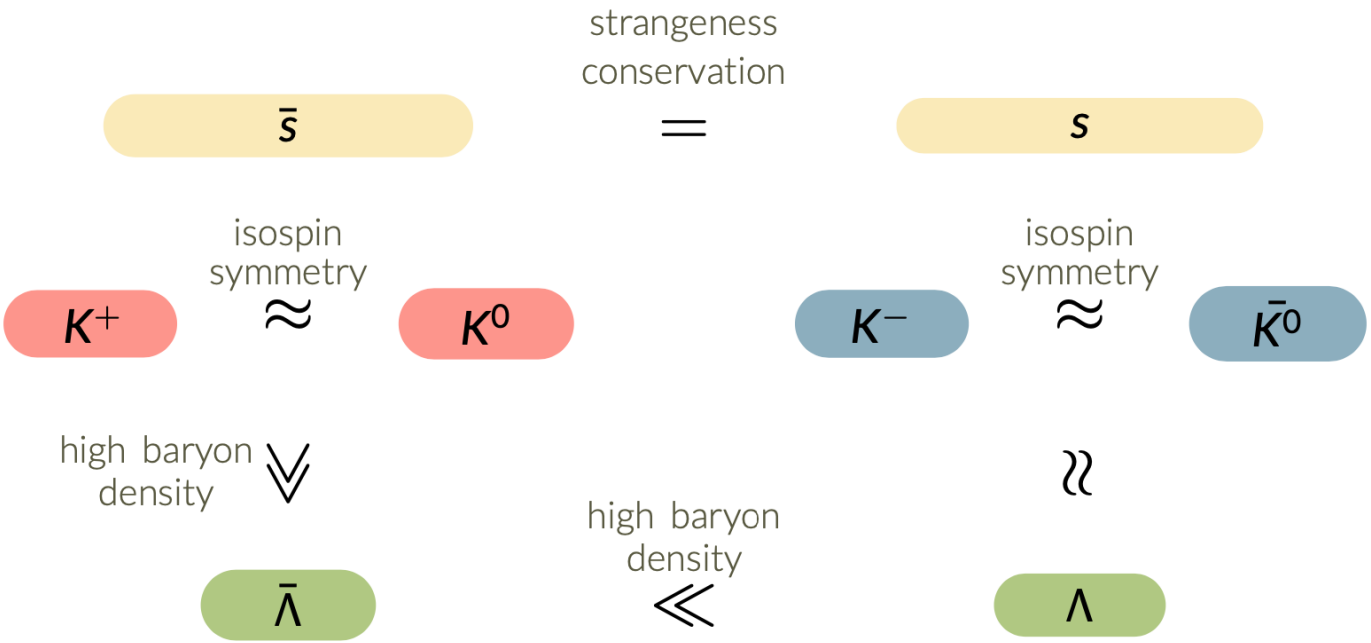

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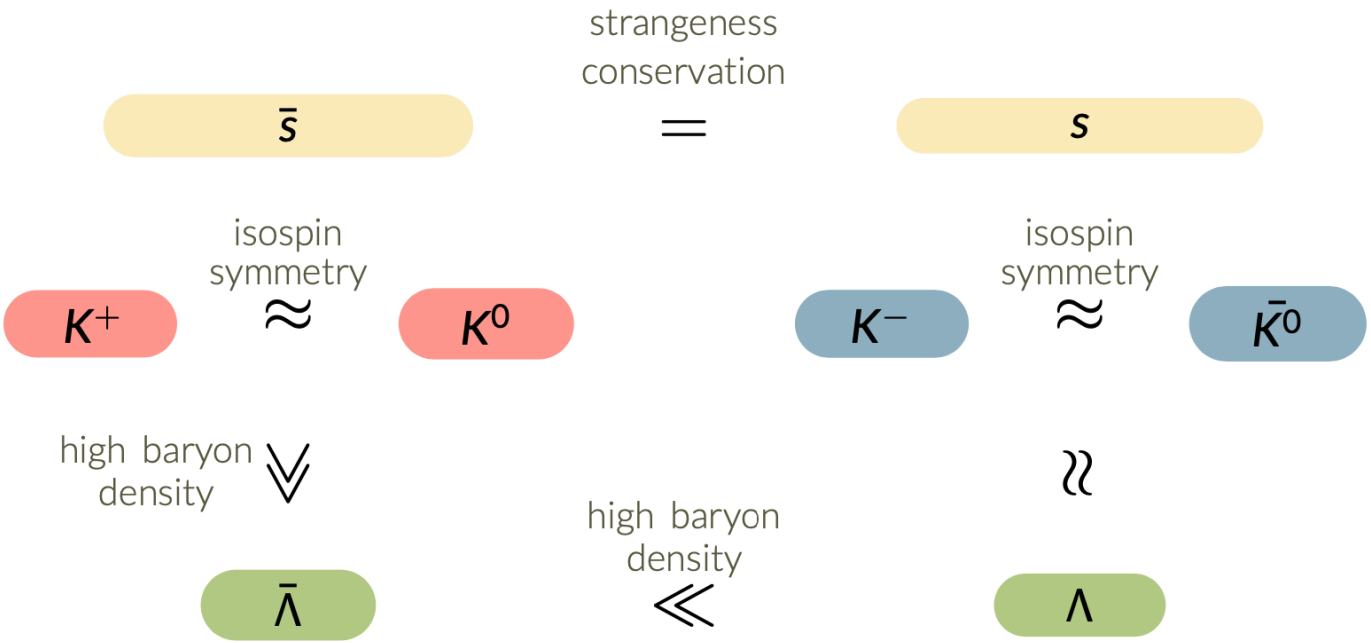
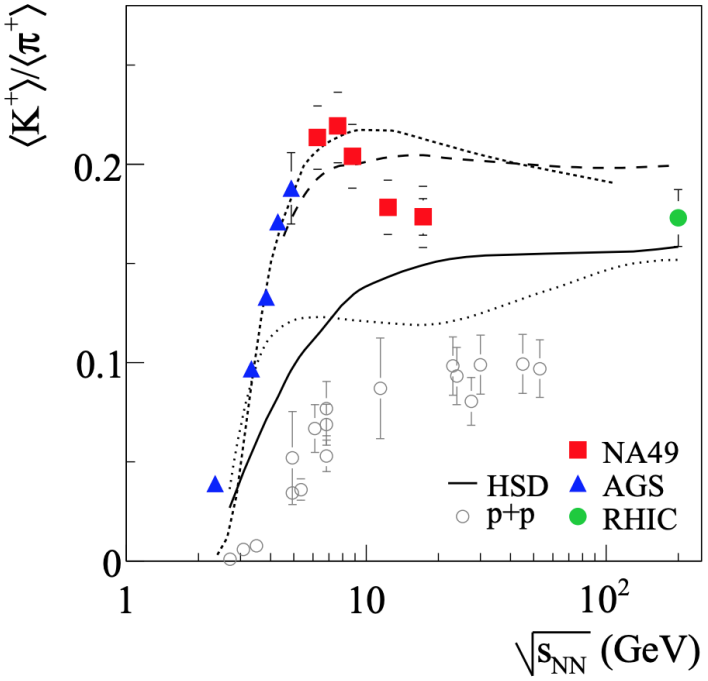


$$\langle N_{s\bar{s}} \rangle \sim < K^+ >$$

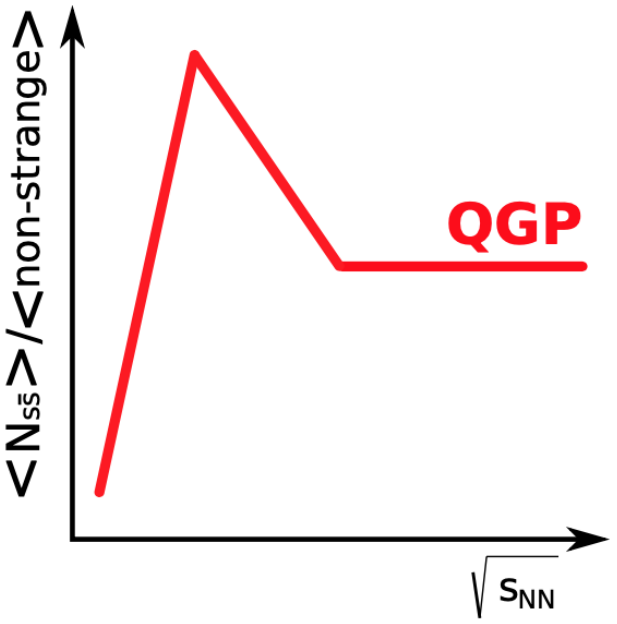
RISE OF THE MAREK'S HORN

NA49: central Pb+Pb collisions



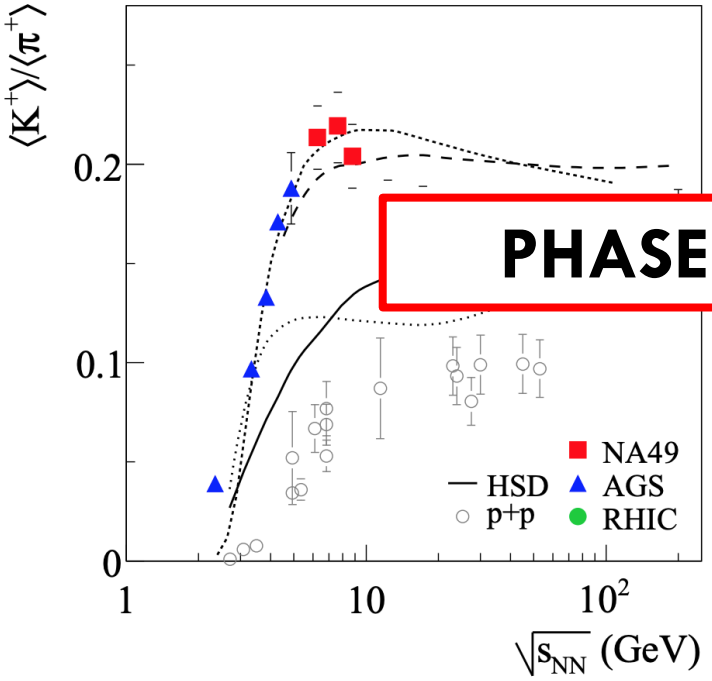
C. Alt; et al. (NA49 collaboration) (2008). Physical Review C. 77 (2): 024903. / arXiv:0710.0118.

Statistical Model of Early Stage

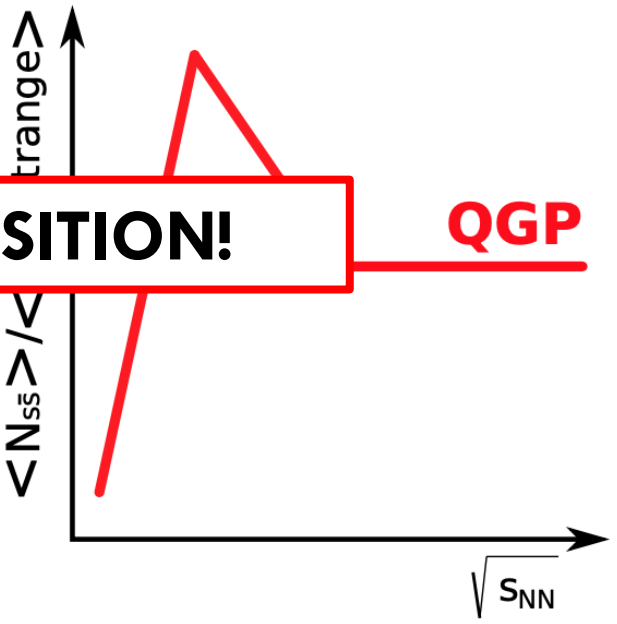


NA49: RISE OF THE MAREK'S HORN

Most central Pb+Pb collisions



SMES model

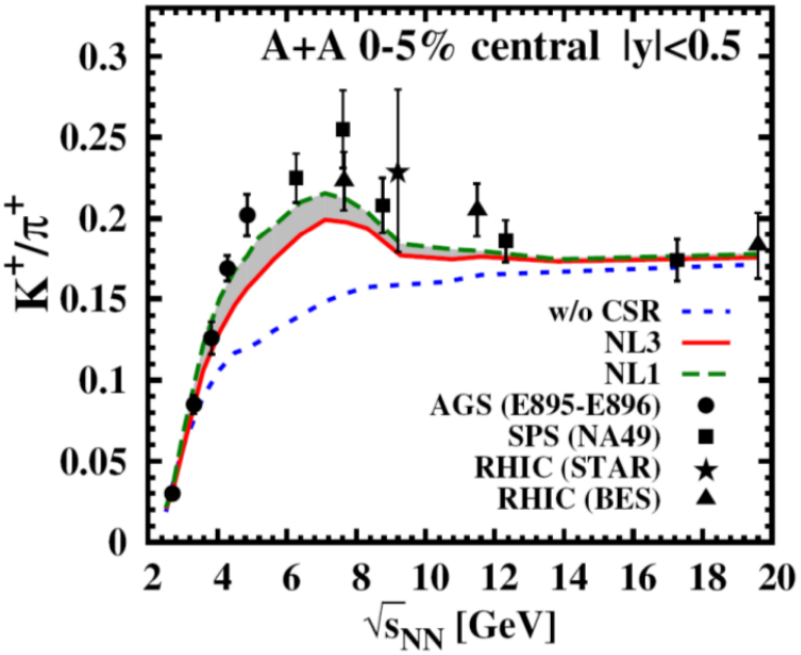


C. Alt; et al. (NA49 collaboration) (2008). Physical Review C. 77 (2): 024903. / arXiv:0710.0118.

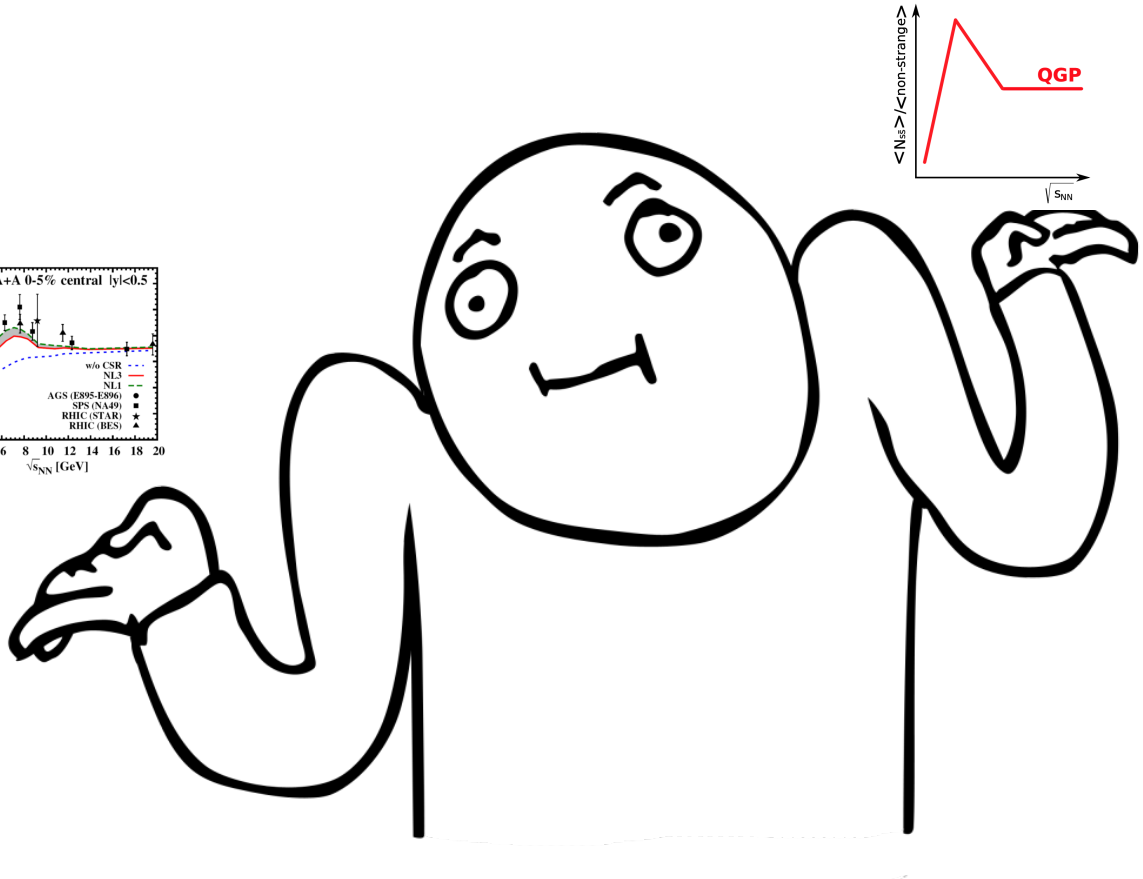
PHASE TRANSITION?

Parton-Hadron-String Dynamics with chiral symmetry restoration (PHSD CSR) in the confined phase!

Palmese et al. , PRC94 (2016) 044912



ONSET OF DECONFINEMENT? CHIRAL SYMMETRY RESTORATION?



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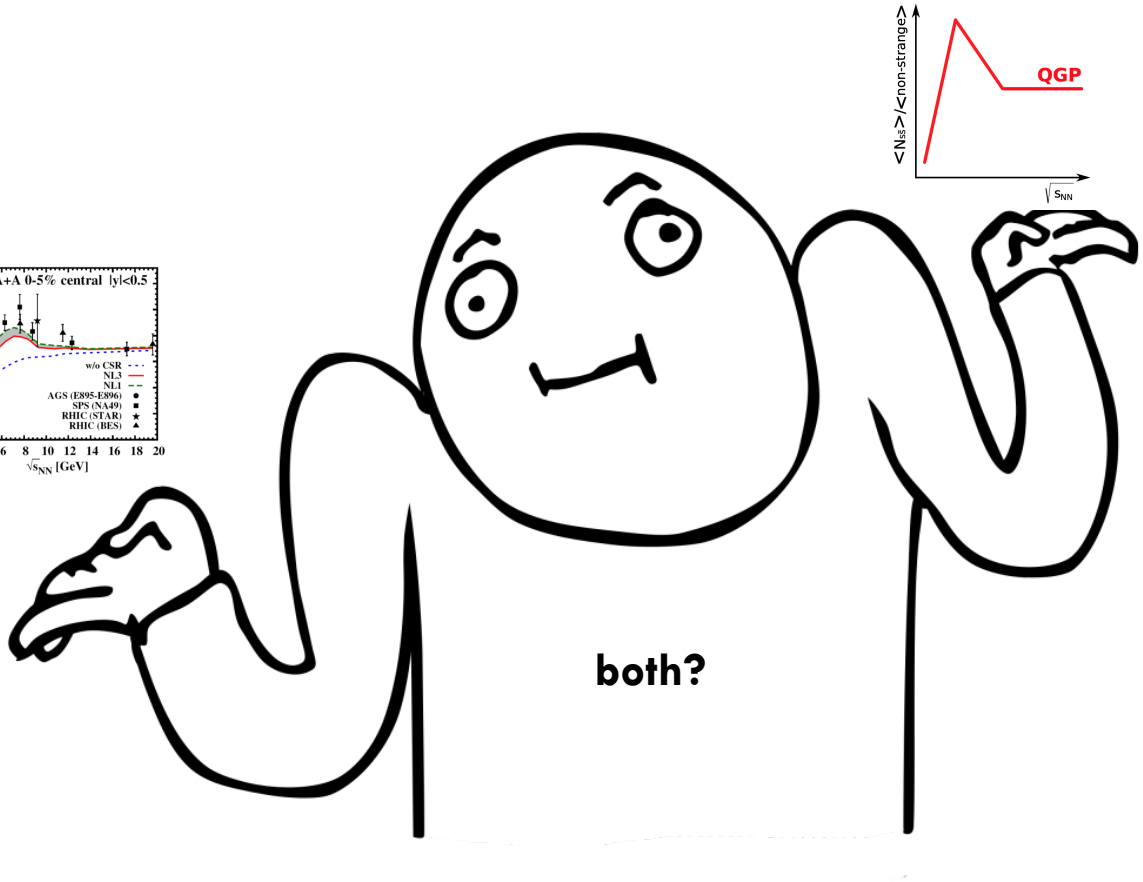
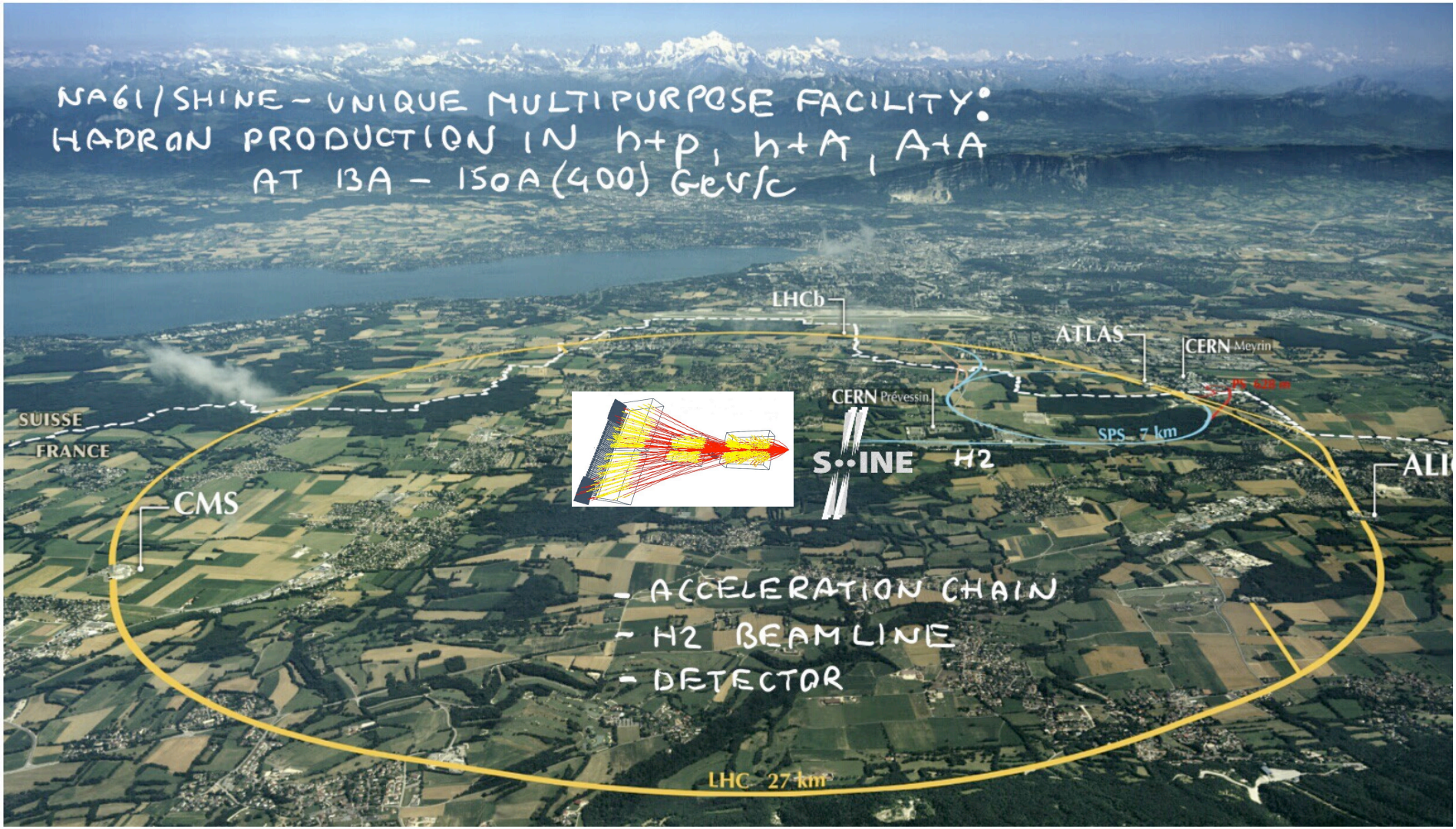
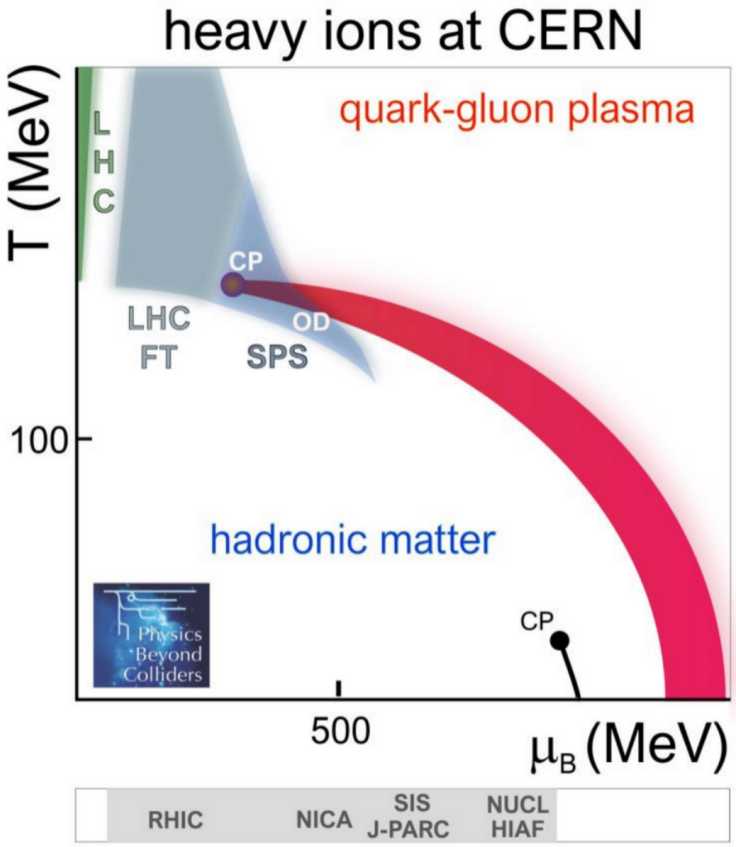


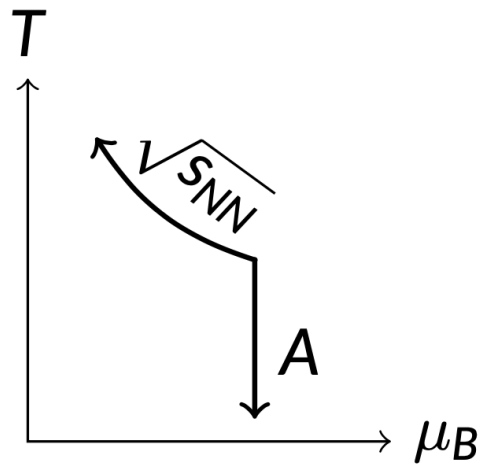
Meanwhile at CERN …



SEARCH FOR THE CRITICAL POINT AT CERN

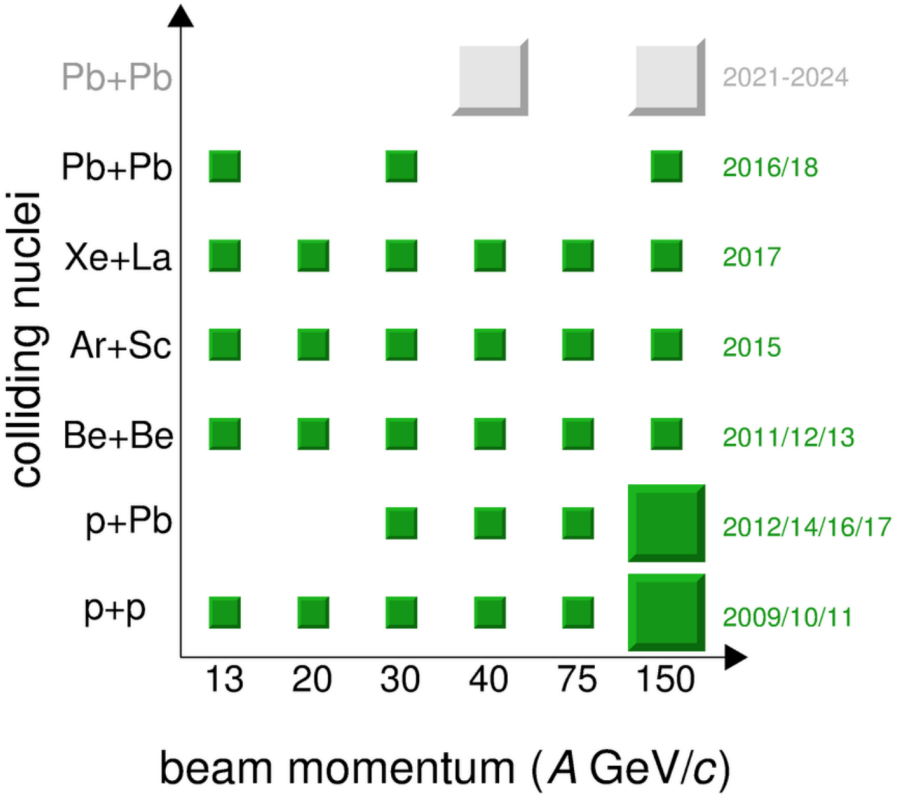


NA61/SHINE experiment:
Energy and system size scan program



Becattini, Manninen, Gaździcki
Phys. Rev. C 73, 044905 (2006)

SEARCH FOR THE CRITICAL POINT AT CERN



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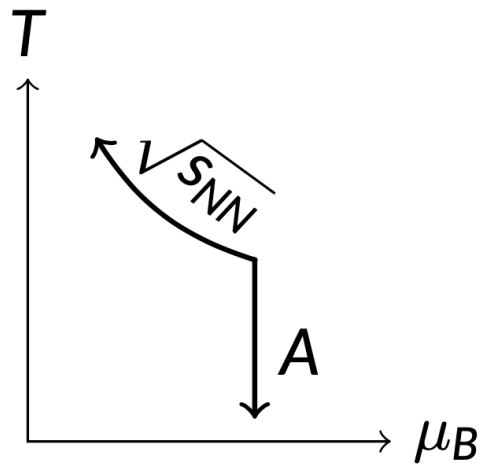

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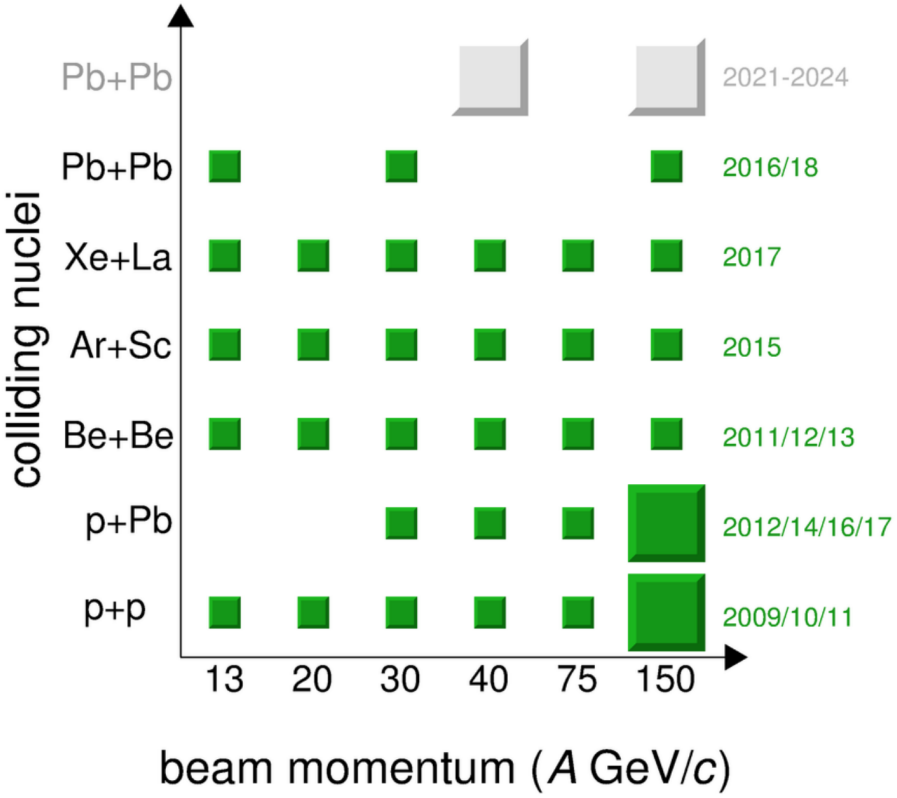

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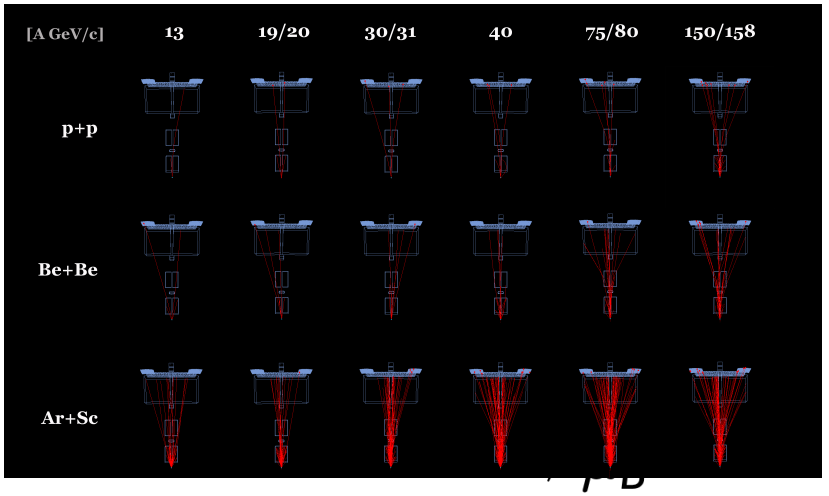

Becattini, Manninen, Gaździcki
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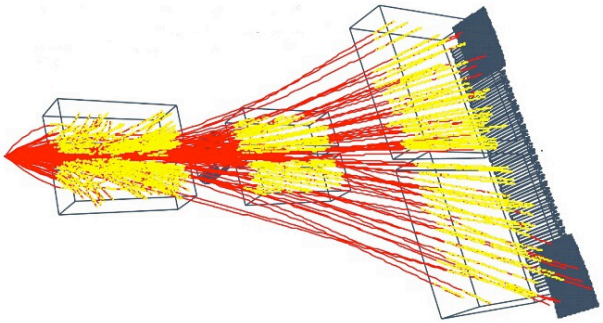
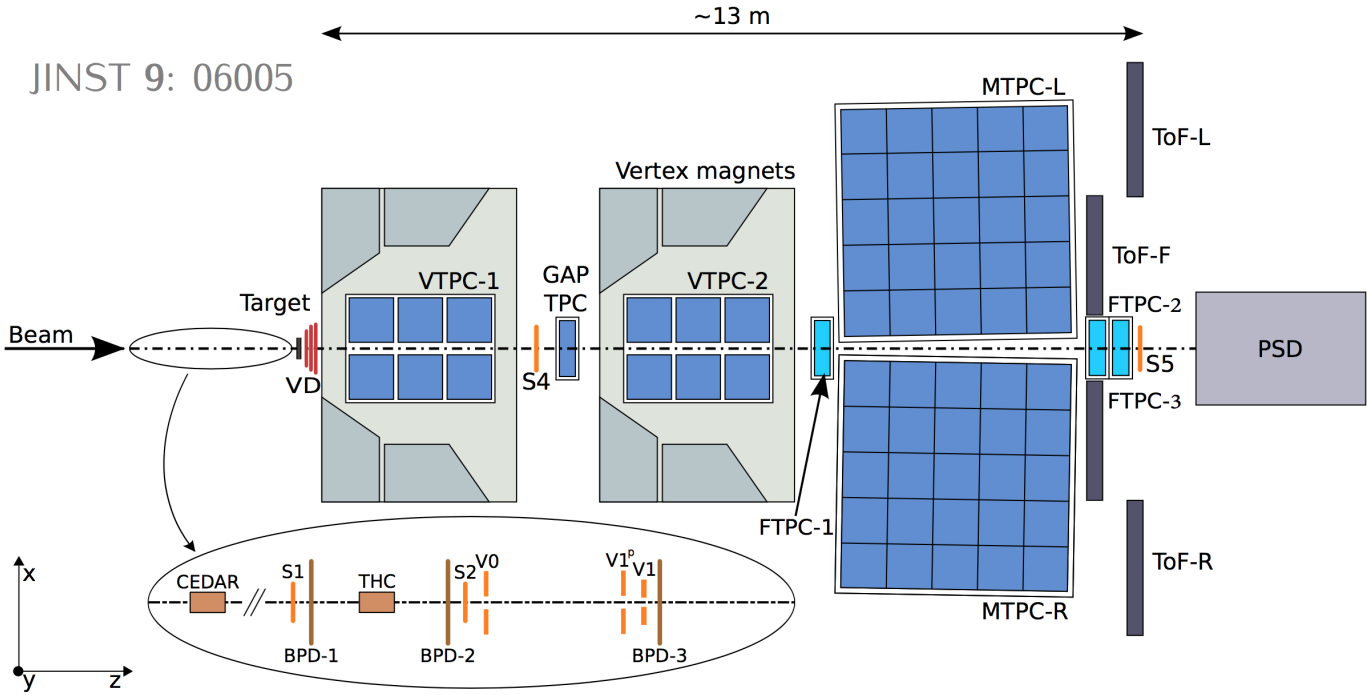
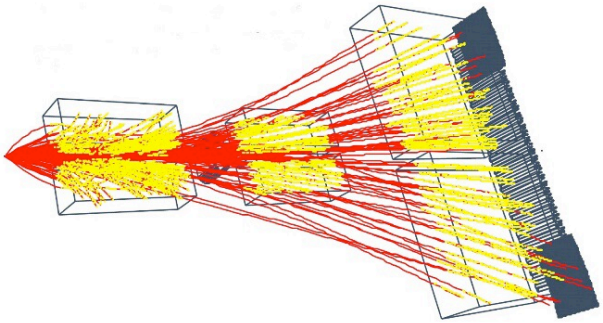


NA61/SHINE DETECTOR (2018)

JINST 9: 06005





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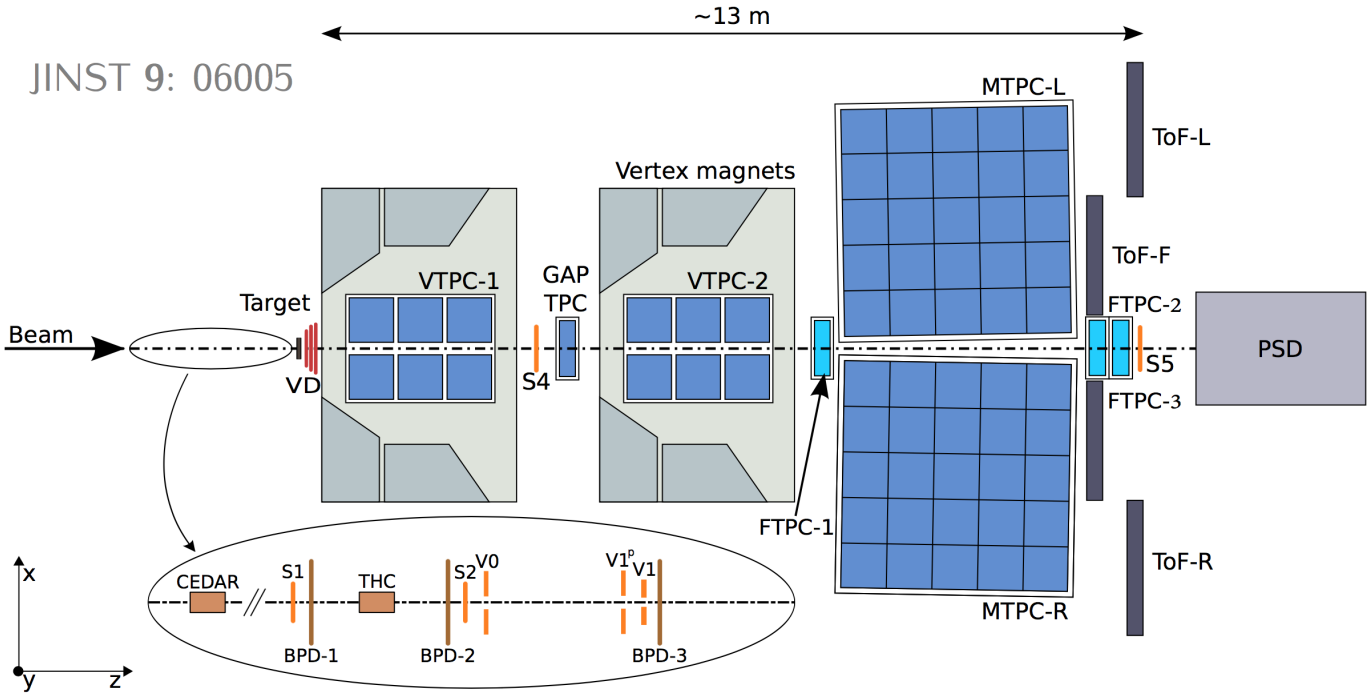
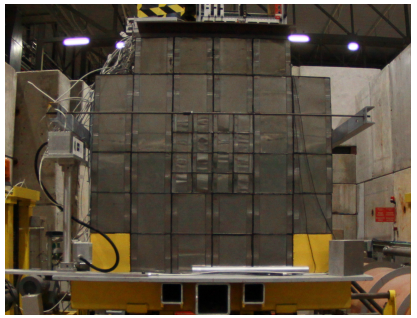
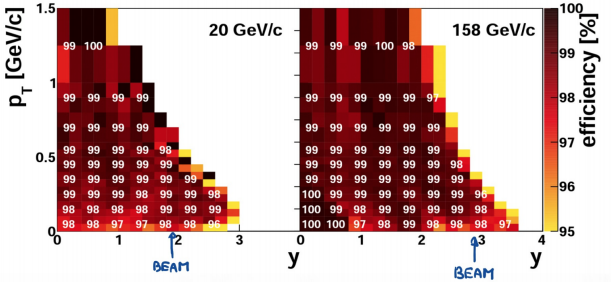




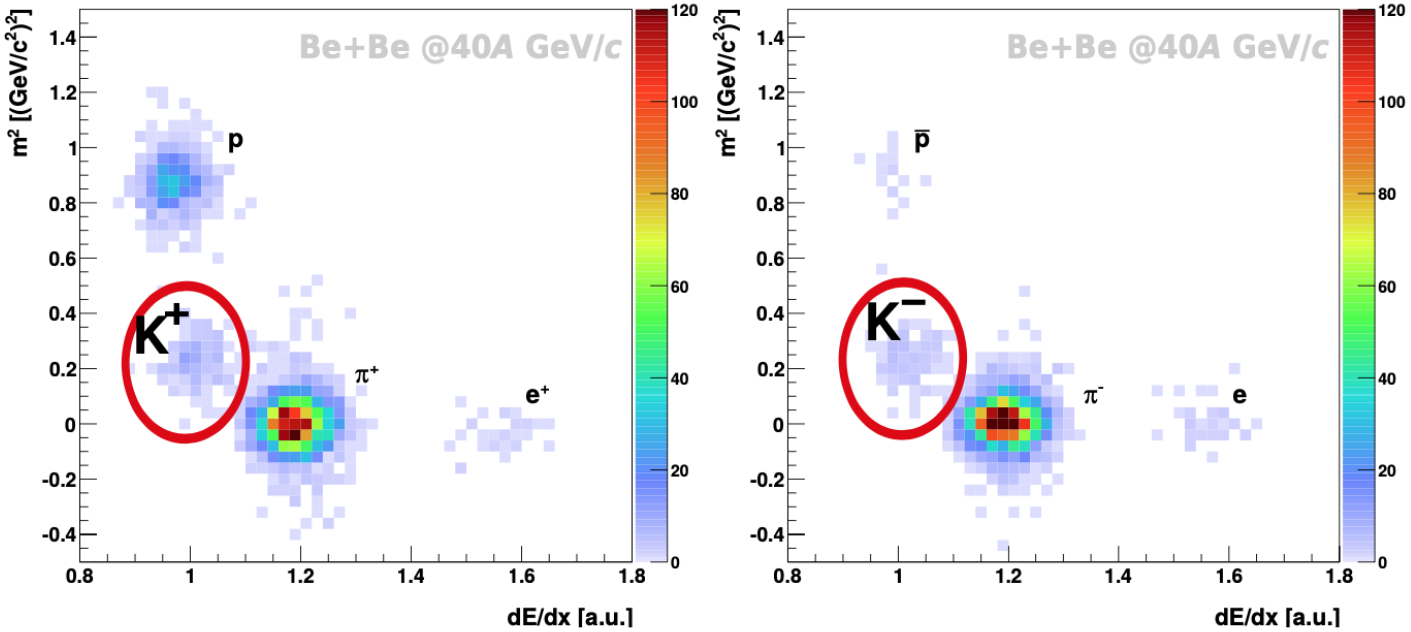


- Large acceptance in forward hemisphere (down to pt = 0)
- High tracking efficiency (> 90%)
- High momentum resolutions

Eur.Phys.J. C74 (2014) no.3, 2794

NA61/SHINE PARTICLE IDENTIFICATION

ToF-dE/dx

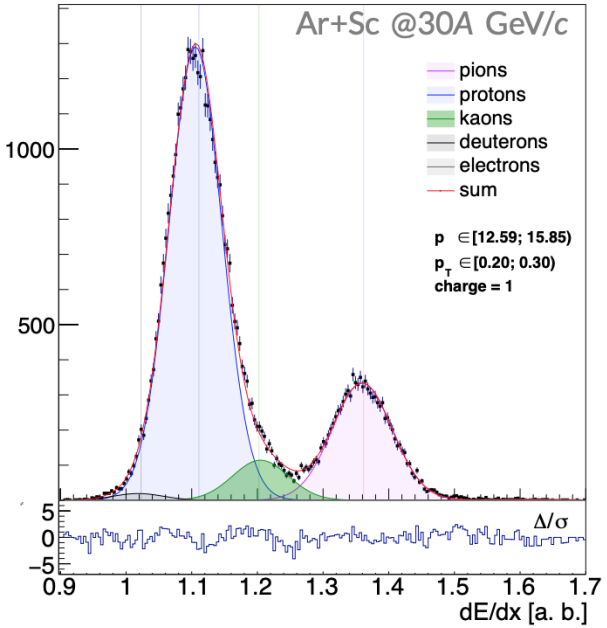


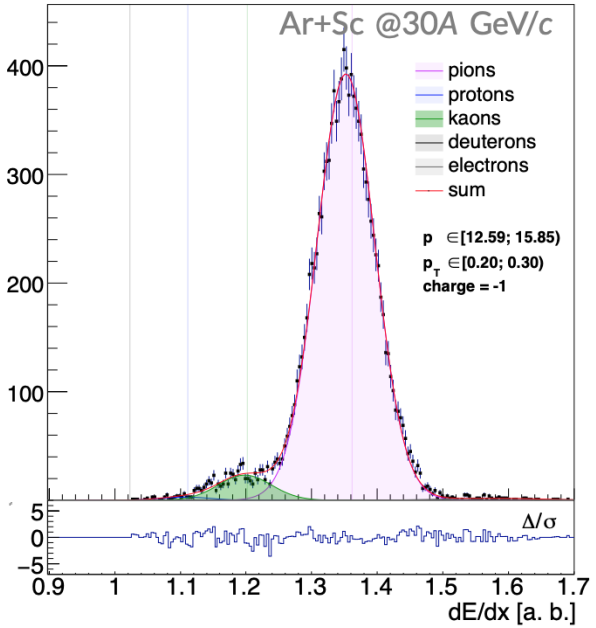
Very good separation.

Very efficient PID in mid-rapidity region.

NA61/SHINE PARTICLE IDENTIFICATION

dE/dx

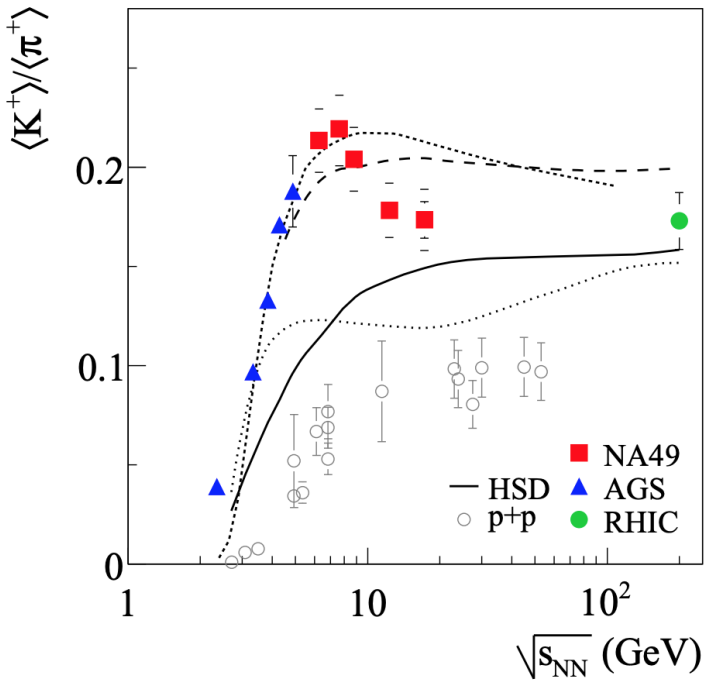




Probability PID.

Applicable in forward-rapidity region.

WHAT HAPPENS IN SMALL SYSTEMS?



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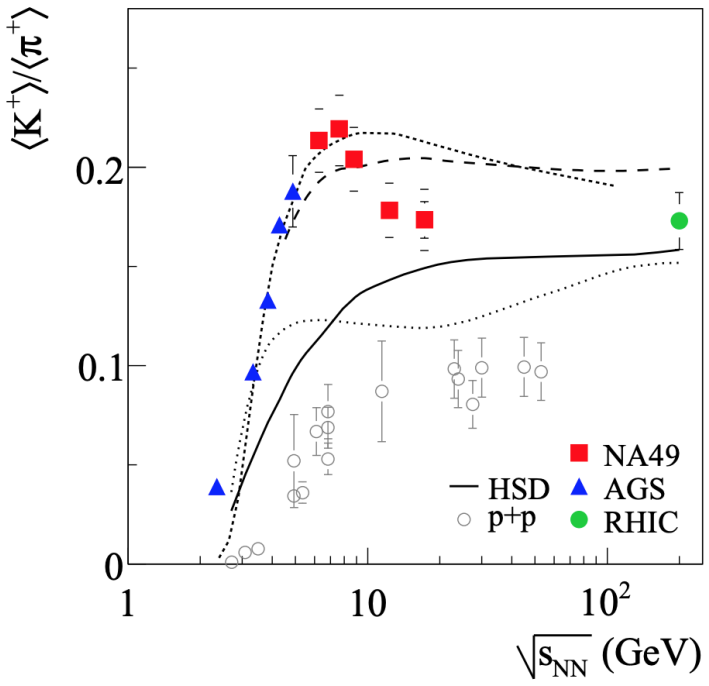
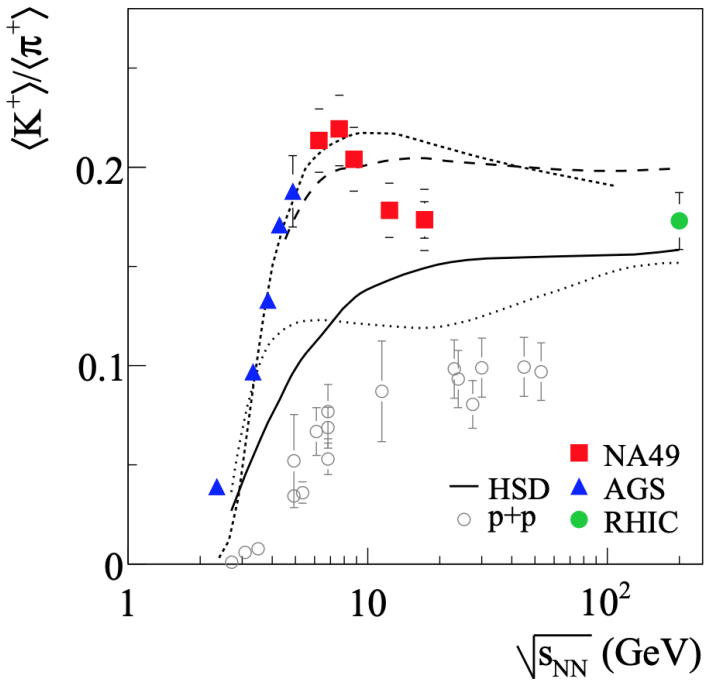


- **Onset of deconfinement?**

WHAT HAPPENS IN SMALL SYSTEMS?



- **Onset of deconfinement?**
- **Onset of fireball?**

DATA

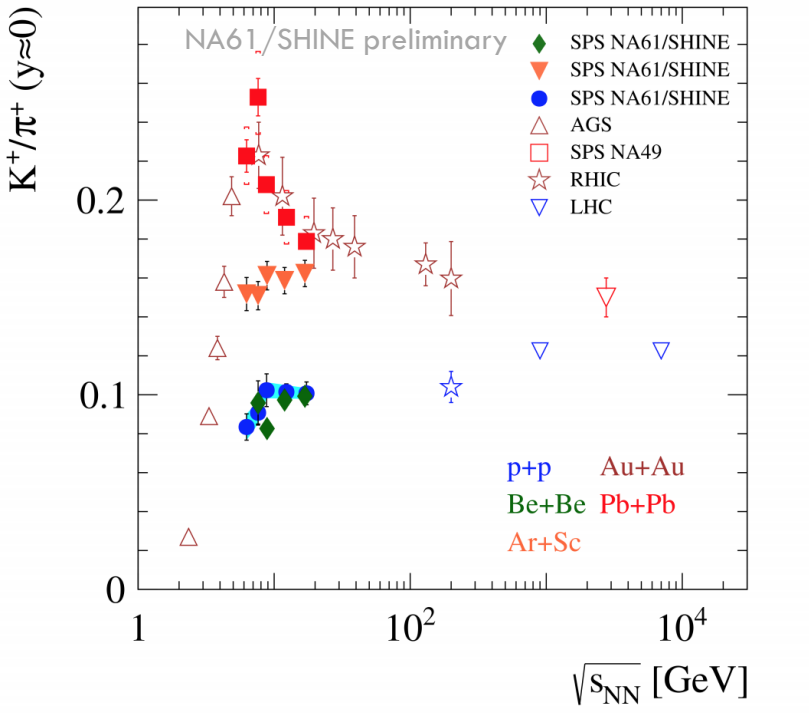
NA61/SHINE:

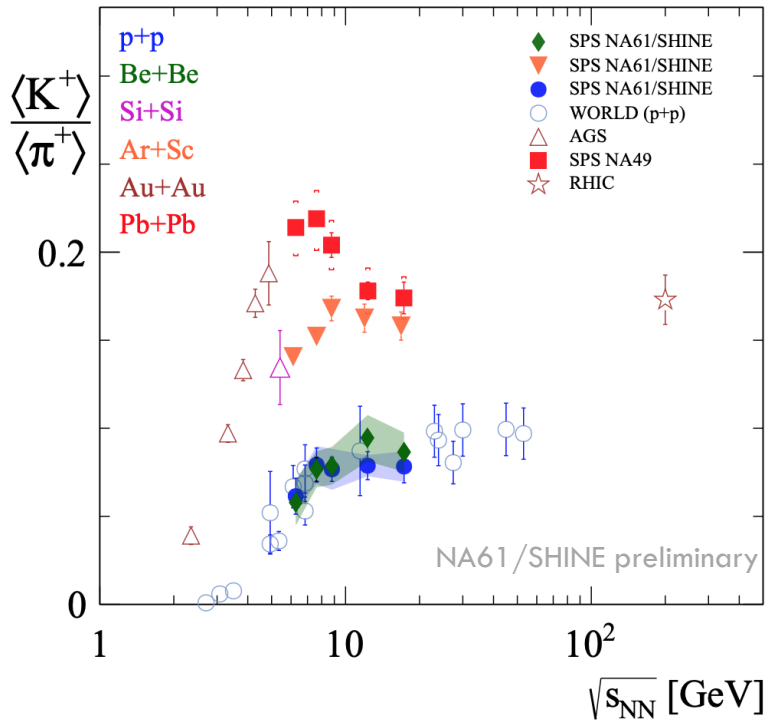
- p+p [Eur. Phys. J. C74 (2014) 2794, Eur. Phys. J. C77 (2017) 671]
- Be+Be, preliminary [Nucl. Phys. A 967, 35 (2017)]
- Ar+Sc, preliminary [SQM 2019, arXiv:1911.01398]

World data on Pb+Pb, Au+Au, C+C, Si+Si and p+p:

- NA49 [Phys.Rev. C77, 024903 (2008)], [Phys.Rev. C66 (2002) 054902], [Phys.Rev. C86 (2012) 054903] [Eur. Phys. J. C68 (2010) 1], [Eur. Phys. J. C45 (2006) 343]
- ALICE [Phys. Lett. B736 (2014) 196], [Eur. Phys. J. C71 (2011) 1655], [Phys. Rev. Lett. (2012) 109]
- STAR [Phys. Rev. C79 (2009) 034909], [Phys. Rev. C96 (2017) 044904]
- BRAHMS [Phys. Rev. C72 (2005) 014908]
- p+p world data [Z. Phys. C65 (1995) 215], [Phys. Rev. C69 (2004) 044903]

WHAT HAPPENS IN SMALL SYSTEMS?

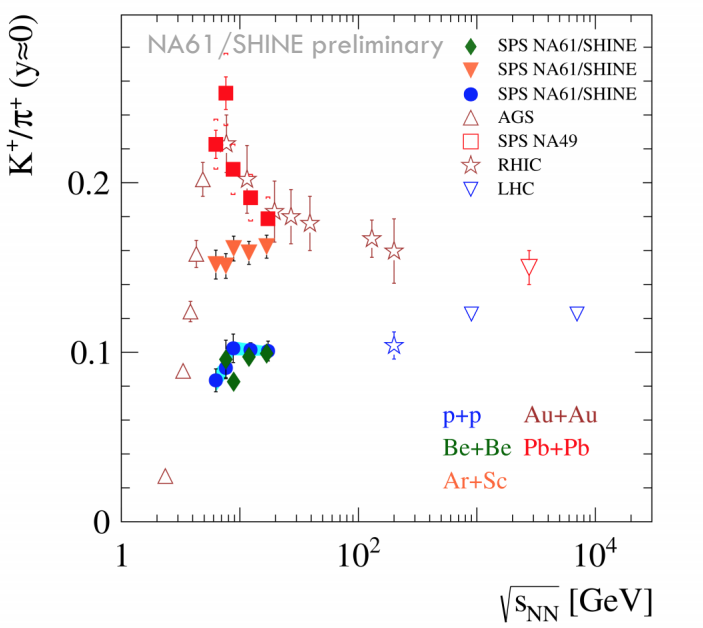




- Rapid change in the K +/π + ratio in Pb+Pb collisions at the CERN SPS (NA49)
- Plateau like structure visible in p+p, Be+Be and Ar+Sc (NA61/SHINE)
- Central Be+Be ~ p+p

CONCLUSIONS

- The plateau like structure has been observed in p+p, Be+Be and Ar+Sc
- Be+Be ~ p+p
- No horn structure in Ar+Sc!



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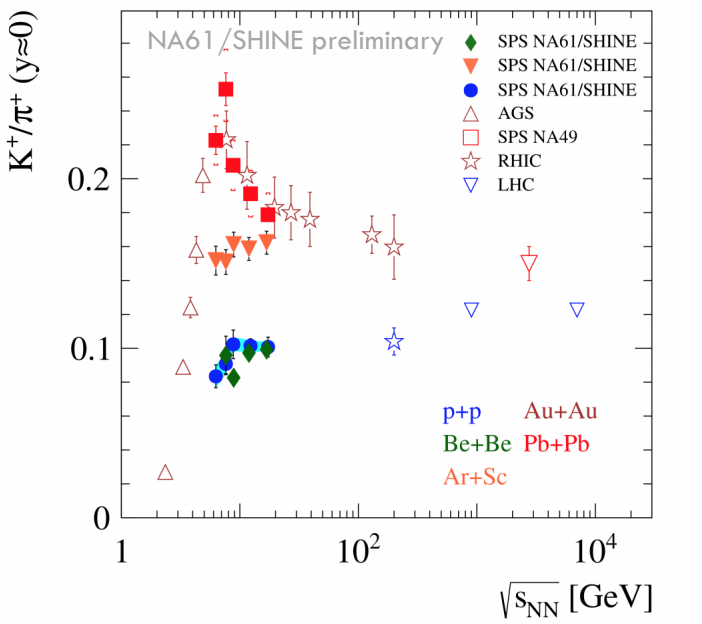
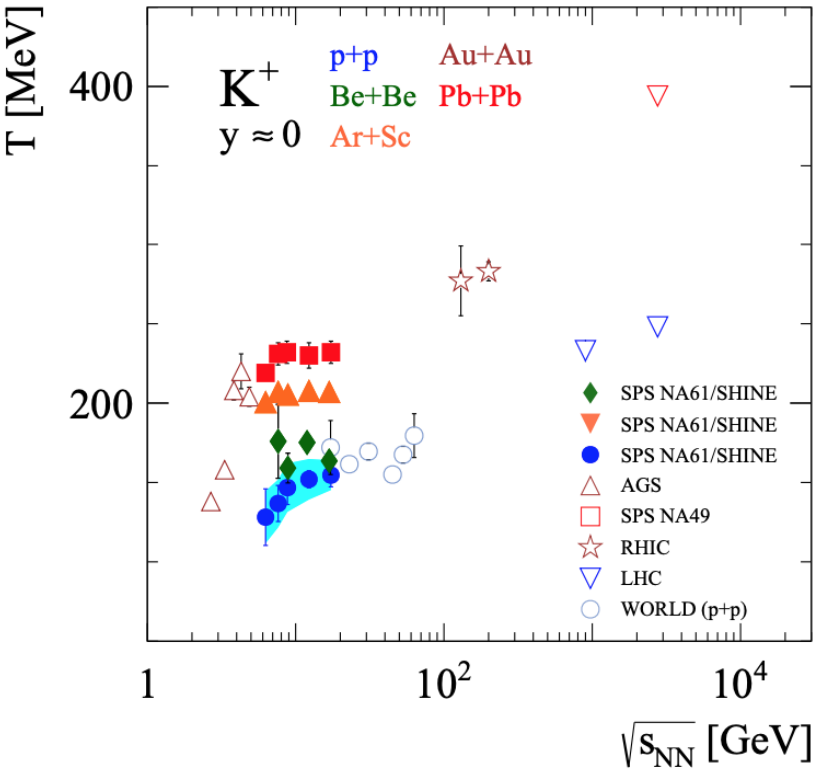
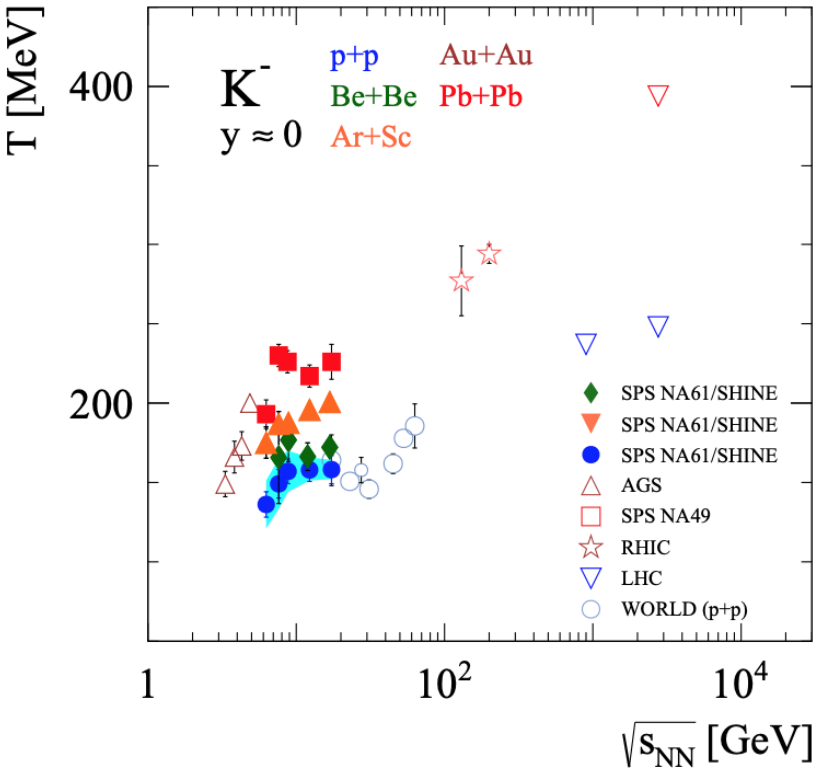


Looking forward for the new Xe+La data and for model comparisons!

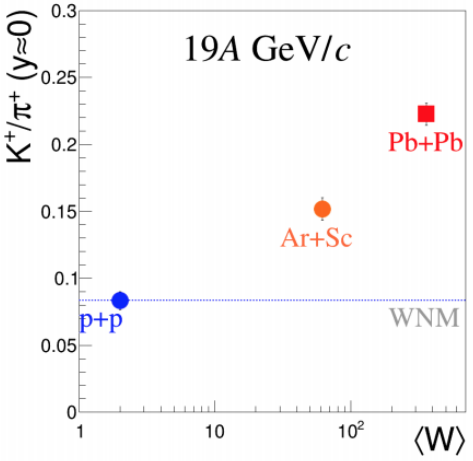

STRANGER_RESULTS
FROM_SHINE

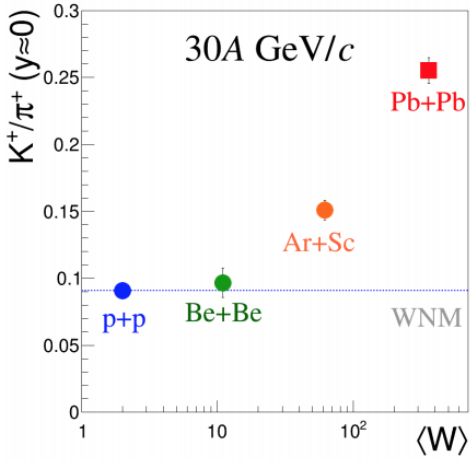


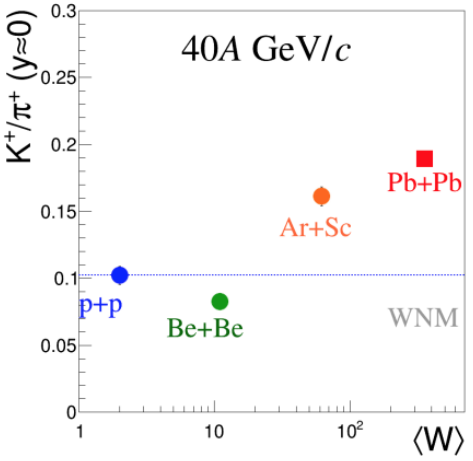


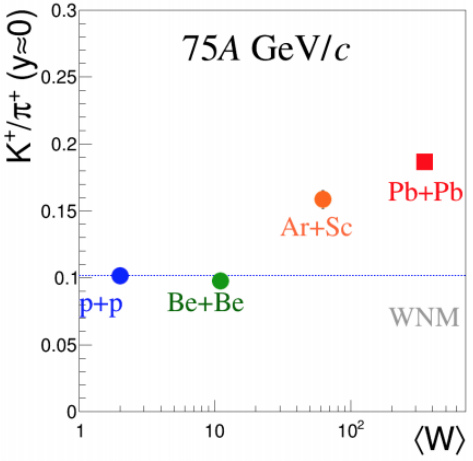
- Intermediate plateau in the increase with $\sqrt{s_{NN}}$ of the inverse slope parameter of $K^{\pm}$ spectra in Pb+Pb is observed
- Predicted due to mixed phase of hadron gas and QGP (*APP* **B30**, 2705 (1999))
- Similar structures are visible in other systems
- Level of plateau grows with system size

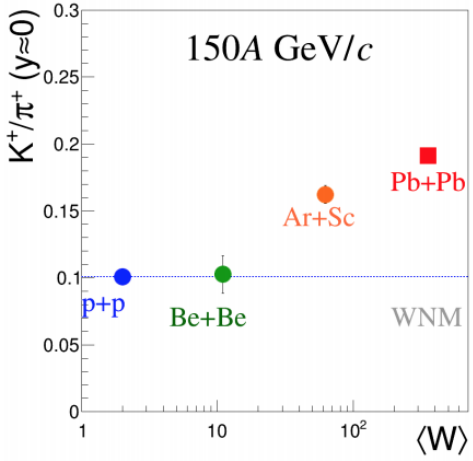
NA49, *PRC* **66**, (2002), NA49, *PRC* **77**, (2008), NA61/SHINE, *EPJC* **74** (2014), NA61/SHINE, *EPJC* **77** (2017)





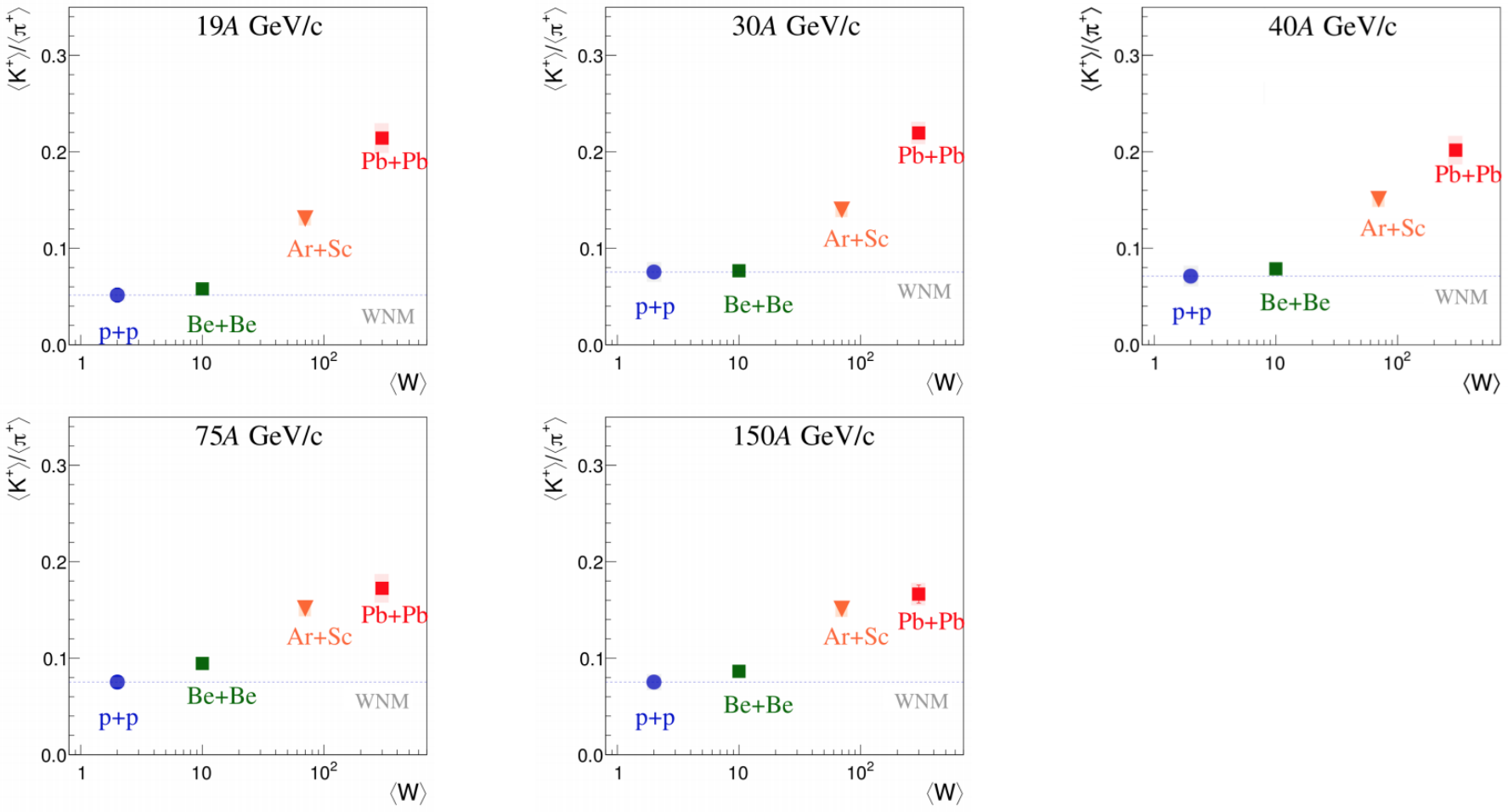






- Ar+Sc data are significantly higher than p+p≈Be+Be results
- Ar+Sc is closer to Pb+Pb, than to smaller system results
- Difference between Ar+Sc and Pb+Pb results is smaller for higher beam momenta

Wounded Nucleon Model: A. Bialas, M. Bleszynski, W. Czyz, *Acta Phys.Polon.* **B8** (1977)

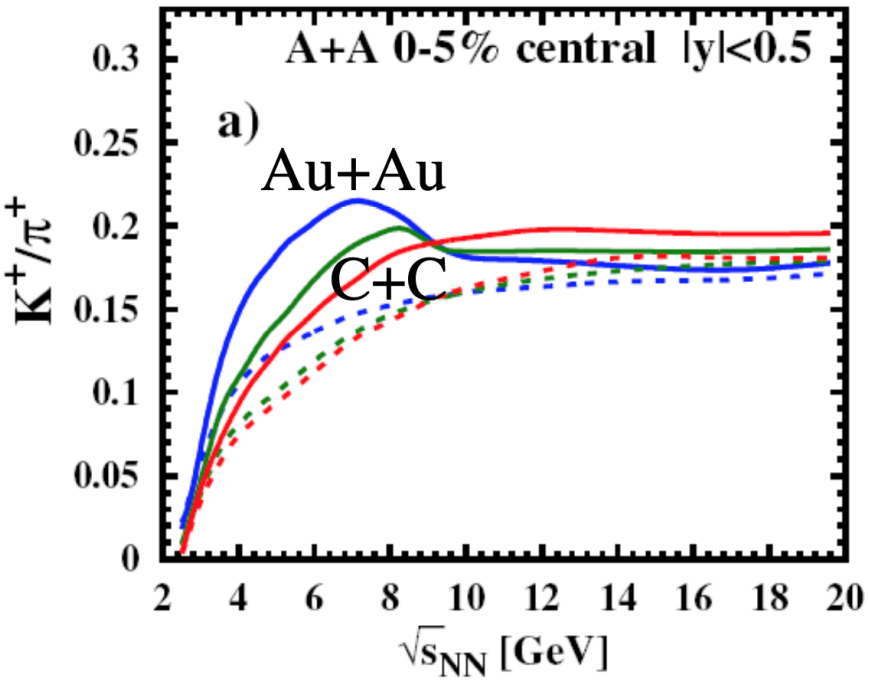


Similar as at mid-rapidity:

- Ar+Sc data are significantly higher than p+p≈Be+Be results
- Ar+Sc is closer to Pb+Pb, than to smaller system results
- Difference between Ar+Sc and Pb+Pb results is smaller for higher beam momenta

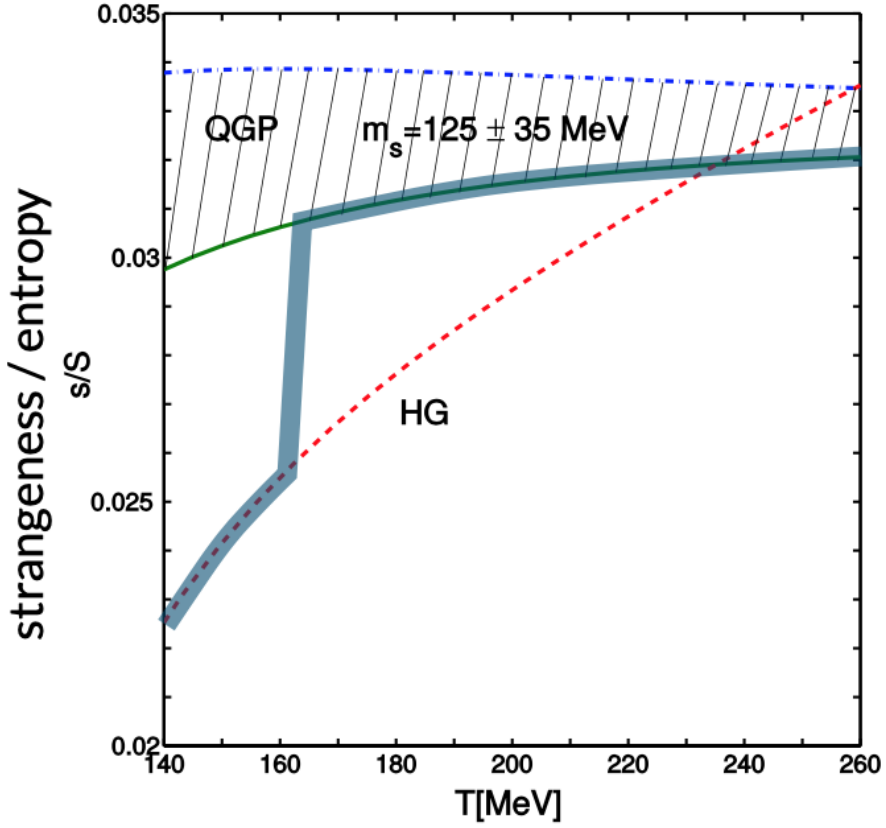
Wounded Nucleon Model: A. Bialas, M. Bleszynski, W. Czyz, *Acta Phys.Polon.* **B8** (1977)

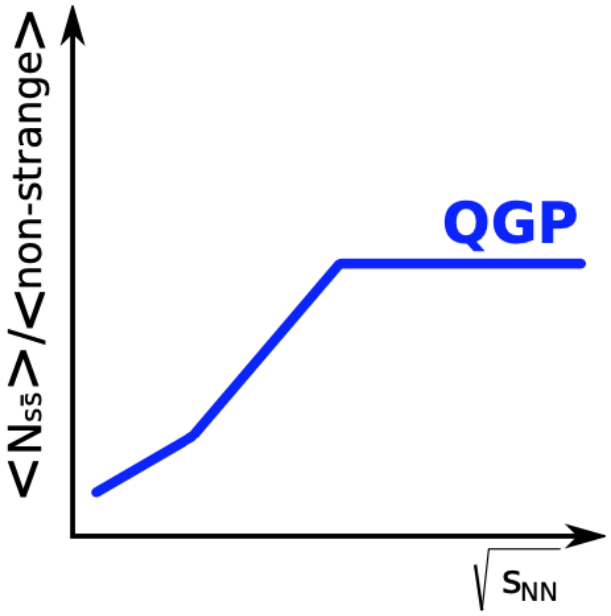
PHSD



A. Palmese et al., PRC94 (2016) 044912

Rafelski-Müller Dynamical Approach



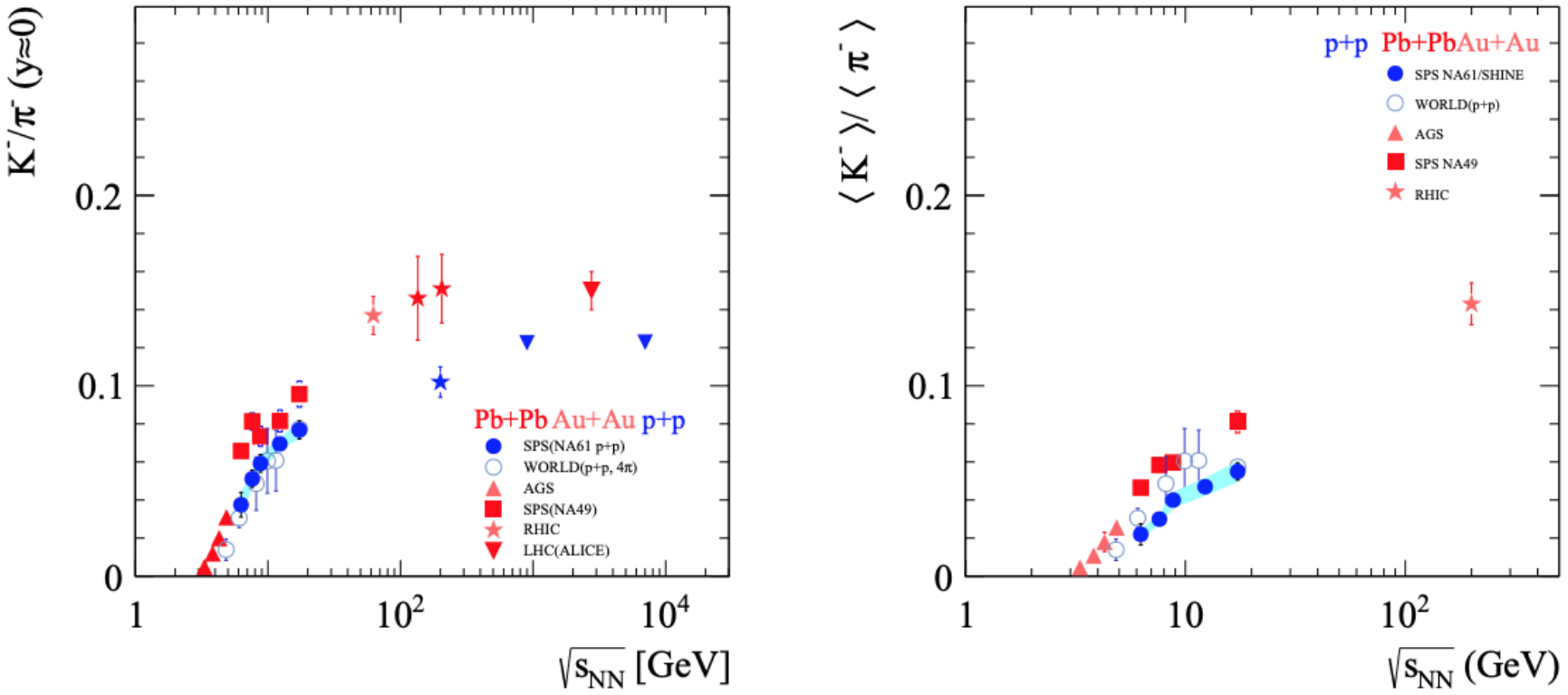


- Equilibrium value reached in QGP ← fast strangeness production.
- No enhancement in the confined phase ← slow strangeness production in whole hadronic region.

Glendenning, Rafelski; Phys. Rev. C 31 (3) (1982) 823

Kuznetsova, Rafelski; Eur. Phys. J. C 51 (2007) 113

Fig. 3. Energy dependence of the K^-/π^- ratio in inelastic p+p interactions as well as central Pb+Pb and Au+Au collisions at mid-rapidity (*left*) and in the full phase-space (*right*).



COMPARISON WITH URQMD 3.4