Production of Strange Particles from the Lowest to the Highest Energies

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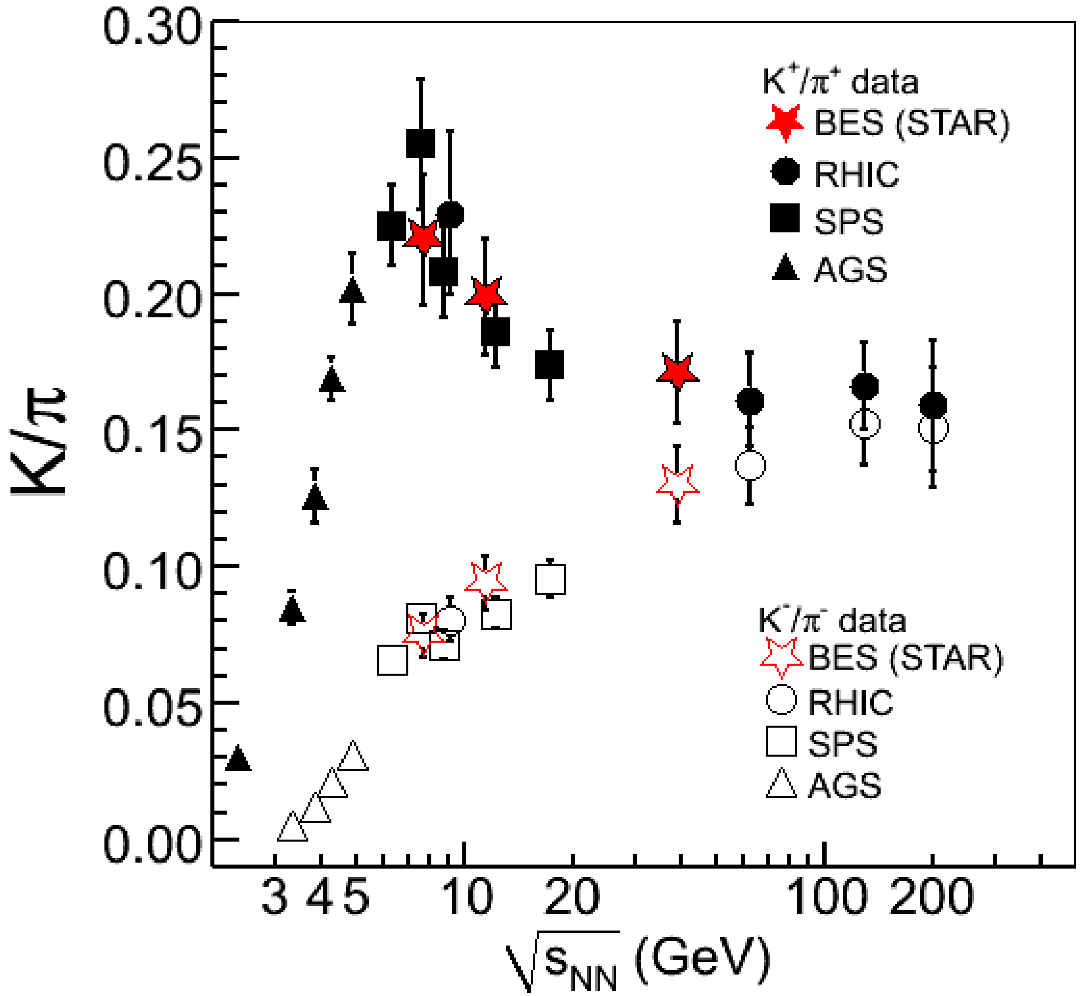
ICFP2012, Kolymbari, Creta

Outline

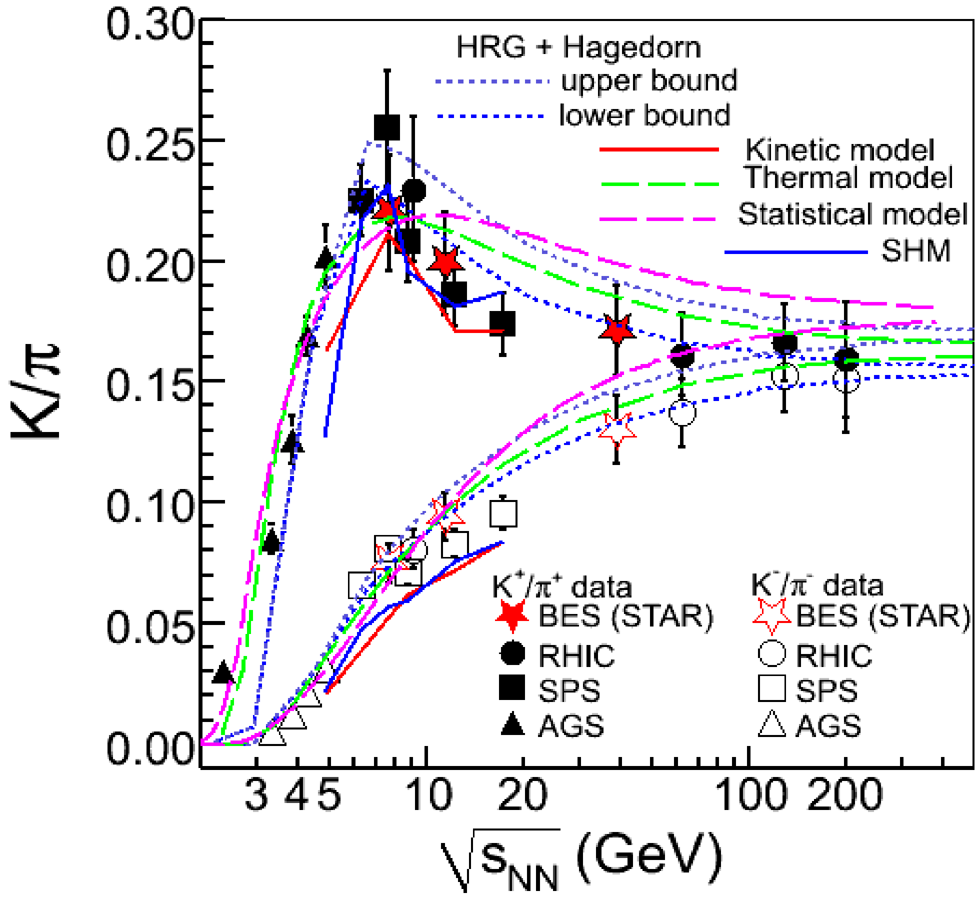
- Some comments on the maximum strangeness content and the recent results from the RHIC beam energy scan
- At which energies has the highest strangeness enhancement been observed?
- Towards LHC energies
- Finally, the stat. model does not work so well!

Maximum Strangeness content around $\sqrt{s_{NN}} \approx 8$ GeV

RHIC STAR L. Kumar QM2011



Maximum strangeness content



L. Kumar, QM2011

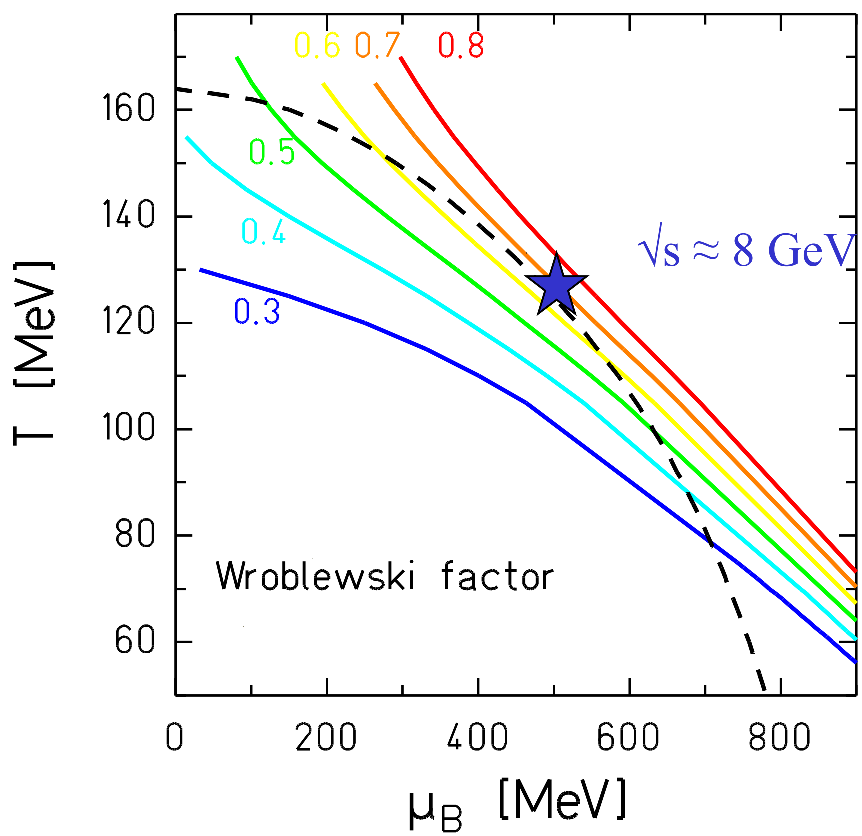
Thermal Model,

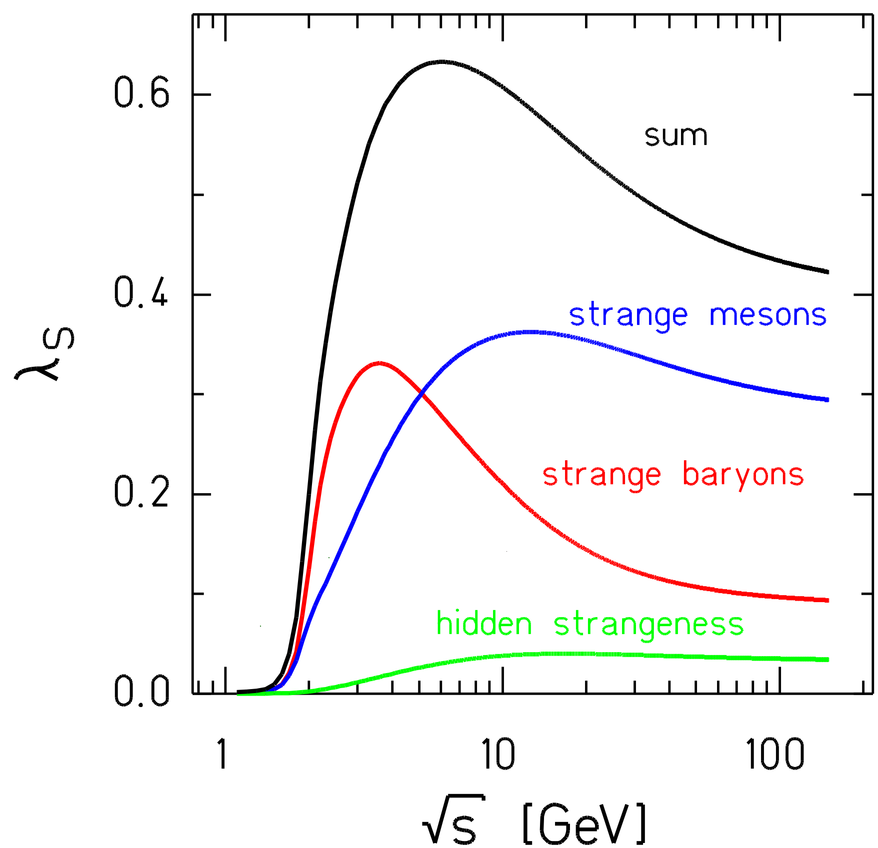
A. Andronic et al., PLB 673(2009)

Includes more states decaying into pions

Why K^+/π^+ so different from K^-/π^-?

Maximum Strangeness around 30 AGeV





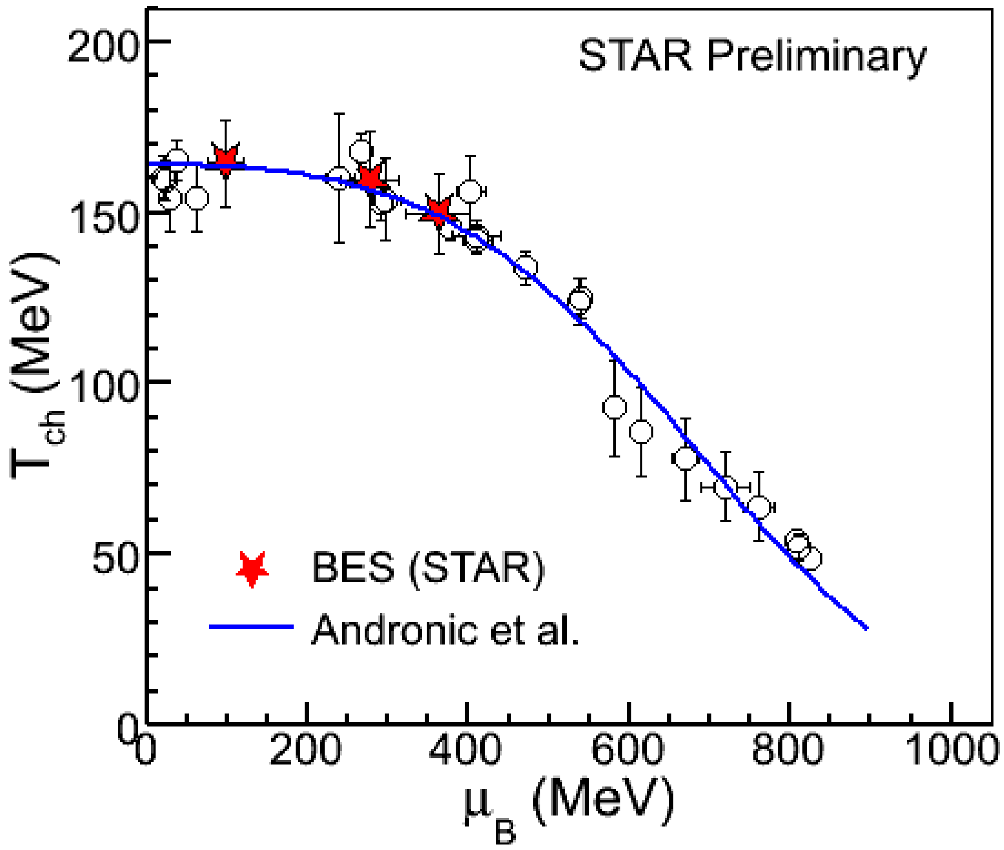
$$\lambda_s \equiv \frac{2\langle s\bar{s}\rangle}{\langle u\bar{u}\rangle + \langle d\bar{d}\rangle}$$

K^+ are produced together with a Λ, influence of μ_B

K^- together with a K^+

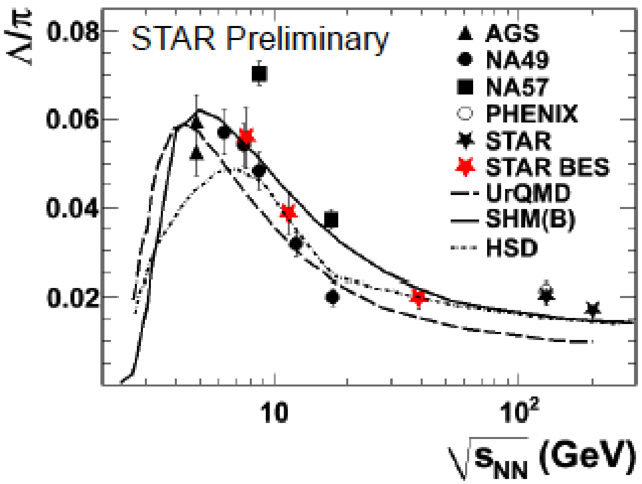
P. Braun-Munzinger, J. Cleymans, HO, K. Redlich, NPA 697(2002) 902

Freeze-out from the STAR beam energy scan

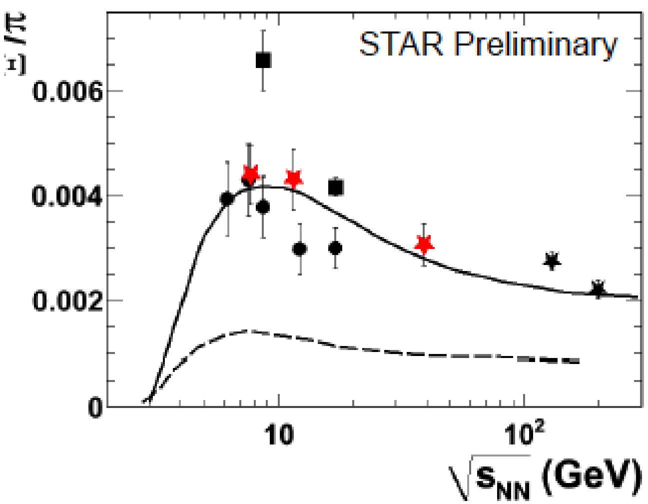


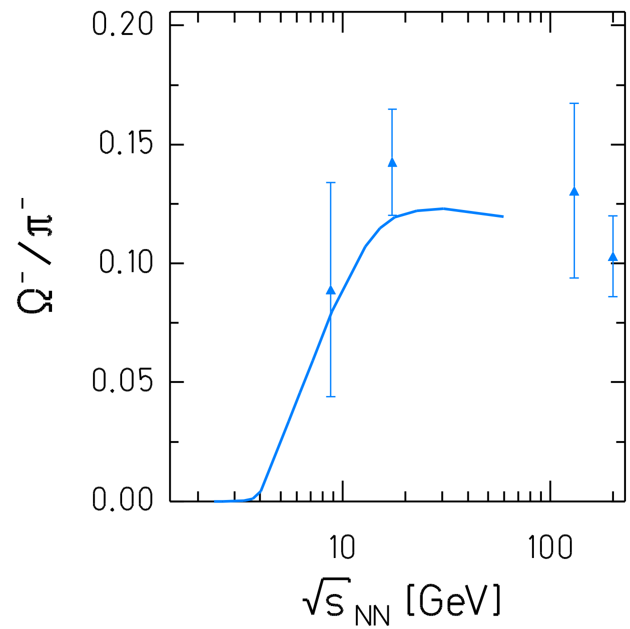
L. Kumar, QM2011

Results from STAR BES

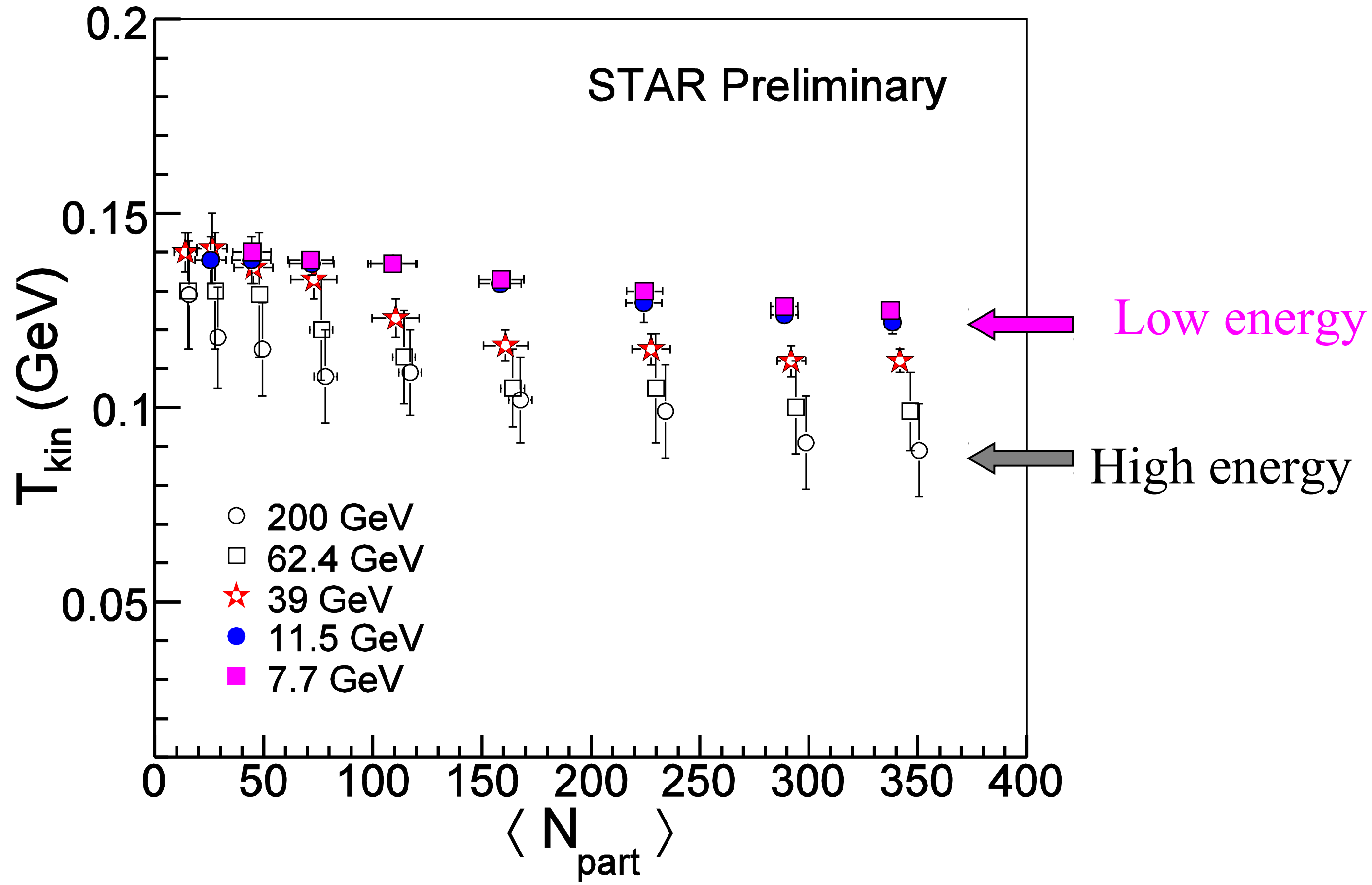


Now, we need the Ω/π ratio to see whether the maximum is at a higher $\sqrt{s_{NN}}$!



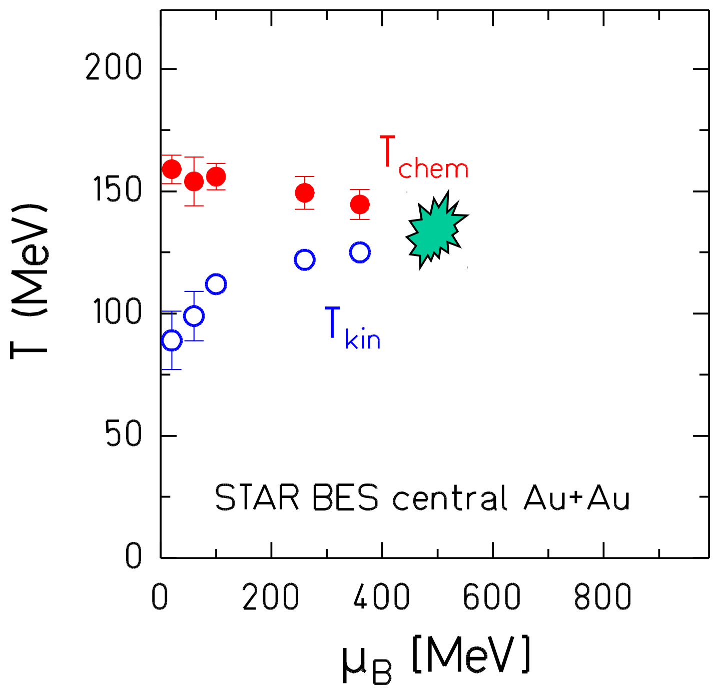


Kinetic freeze out – STAR BES



From L.Kumar CPOD 2011

Merging of T_{chem} and T_{kin}



At LHC and RHIC:

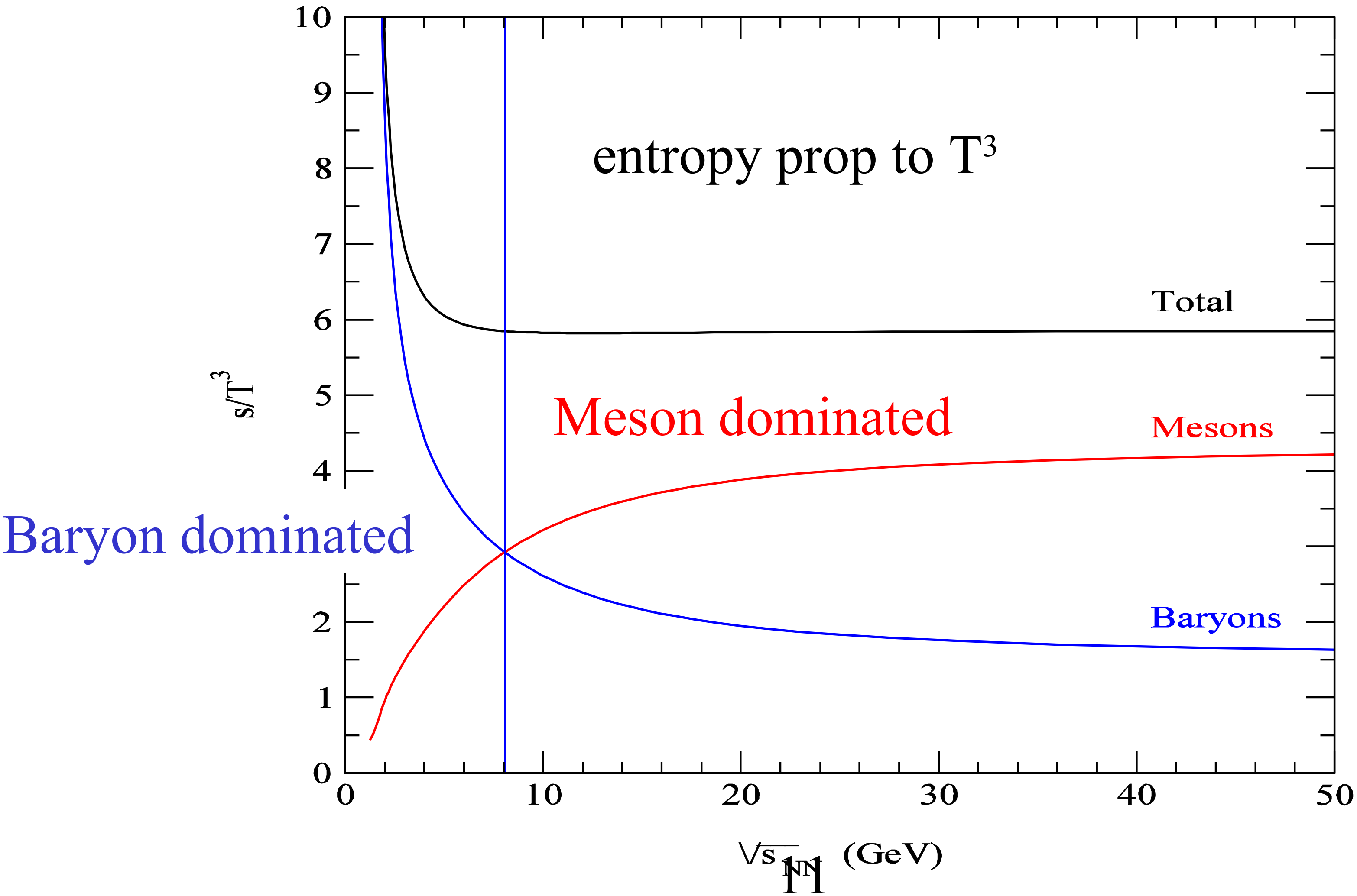
$T_{chem} > T_{kin}$

At SIS and AGS:

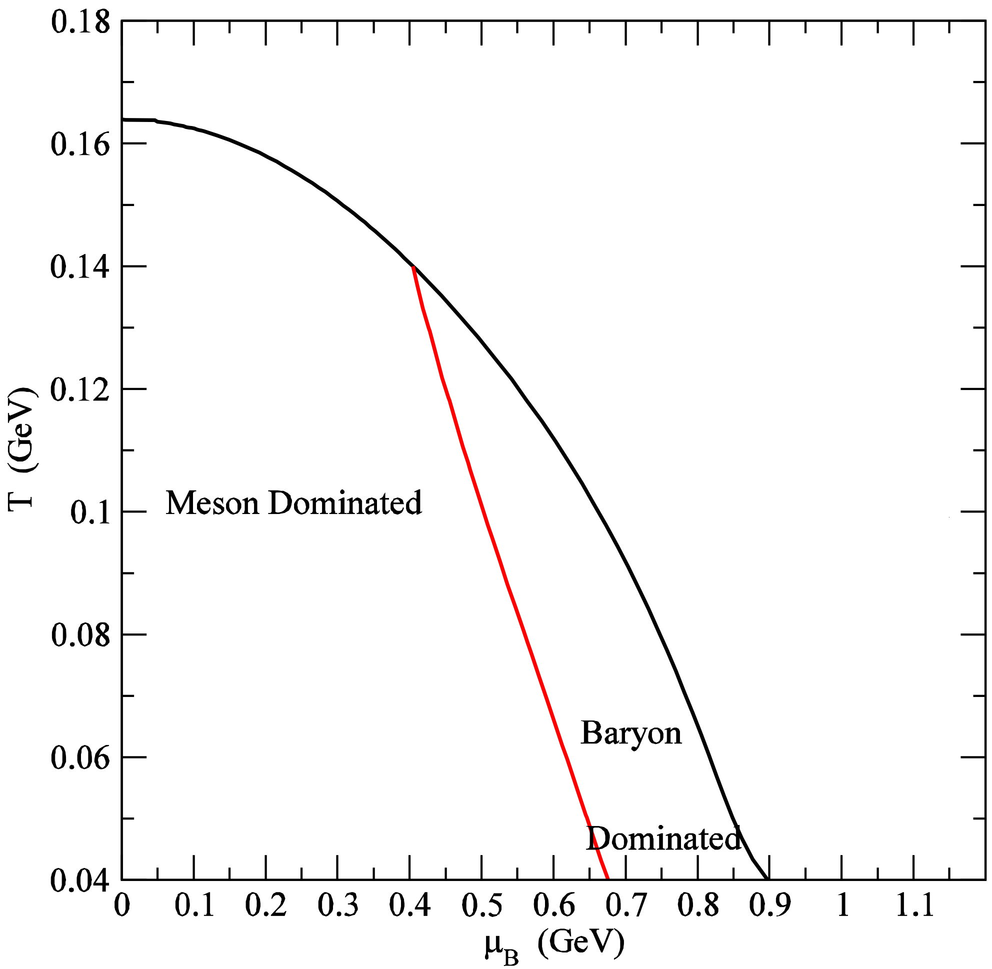
$T_{chem} = T_{kin}$

Transition from baryonic to mesonic freeze out

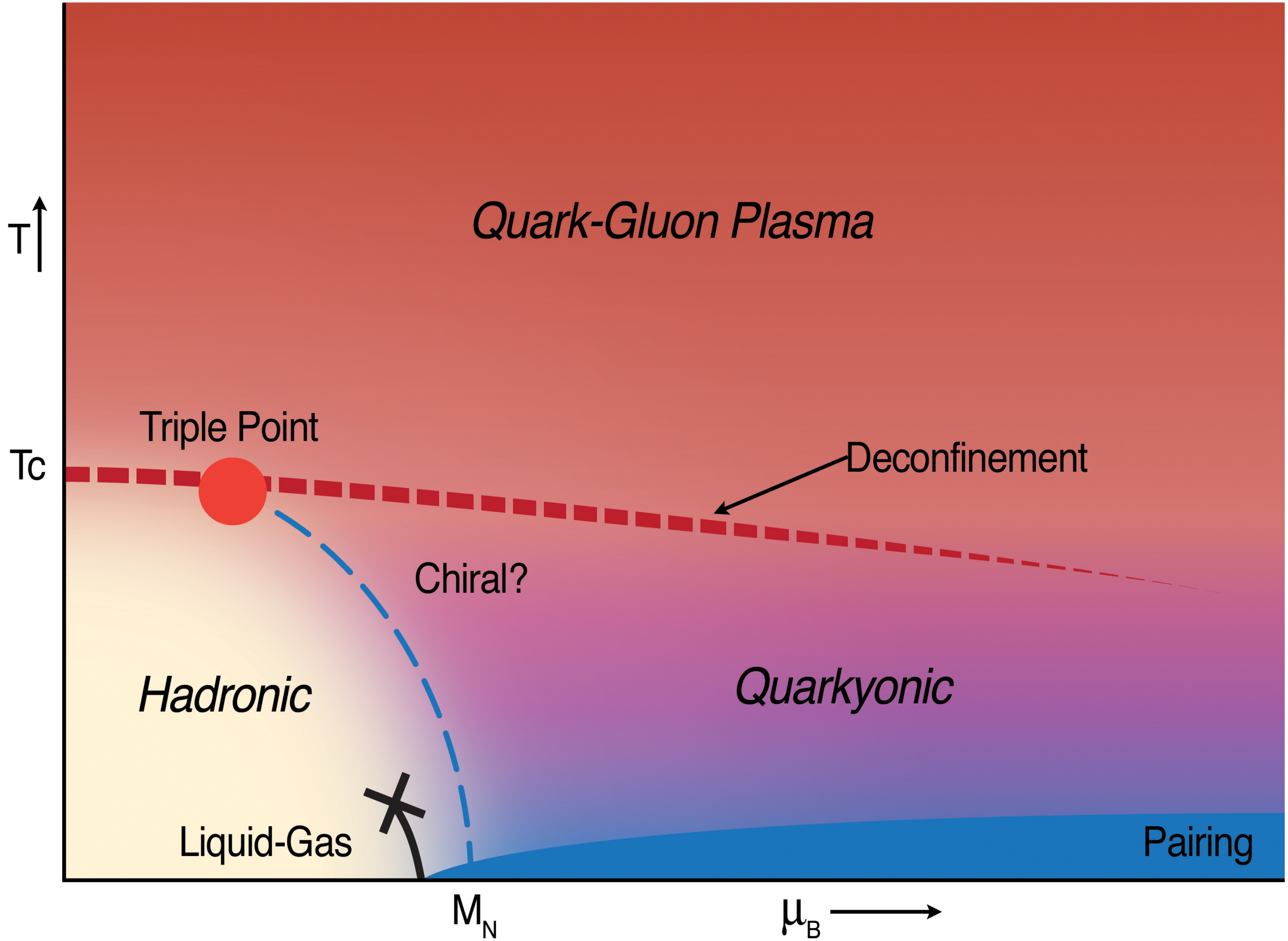
J. Cleymans, H.O., K. Redlich, S. Wheaton, Phys. Lett. B615 (2005)



Transition from baryonic to mesonic freeze out

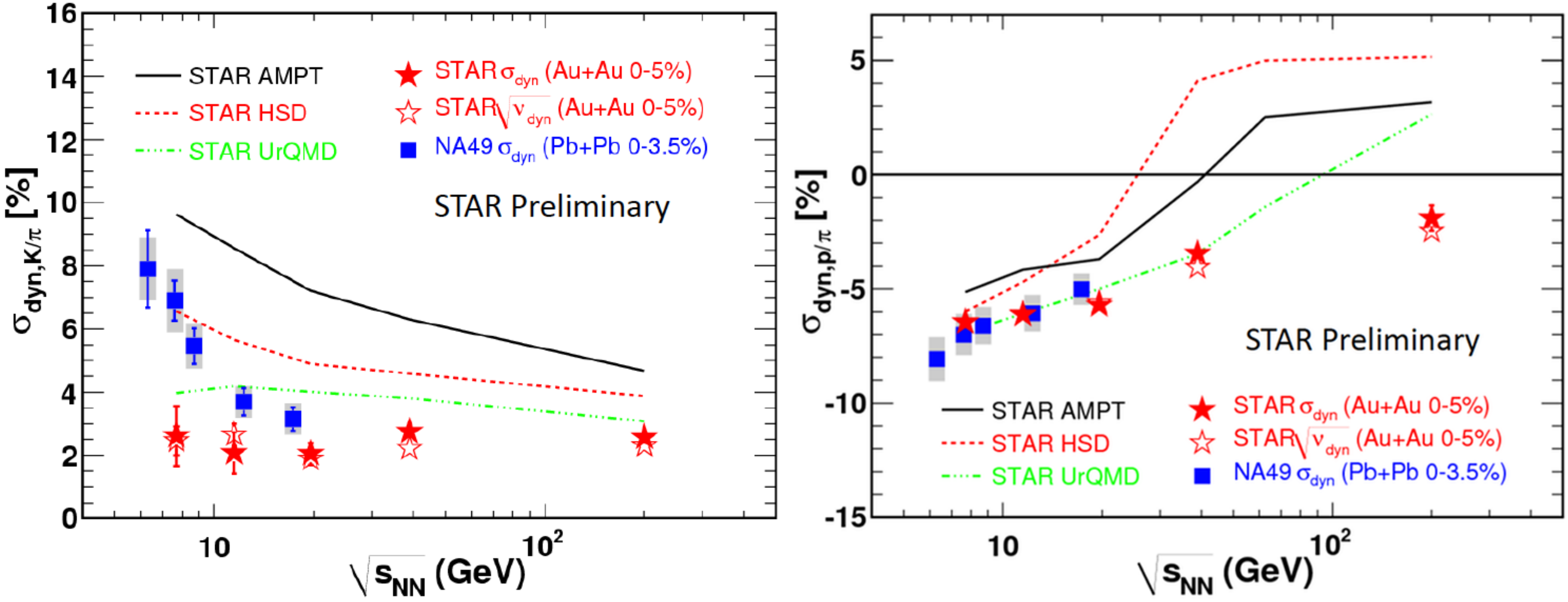


J. Cleymans et al., Phys.Lett. B615 (2005) 50



Quarkyonic matter, A. Andronic et al., Nucl.Phys. A837 (2010) 65

Fluctuations as a test of the critical point



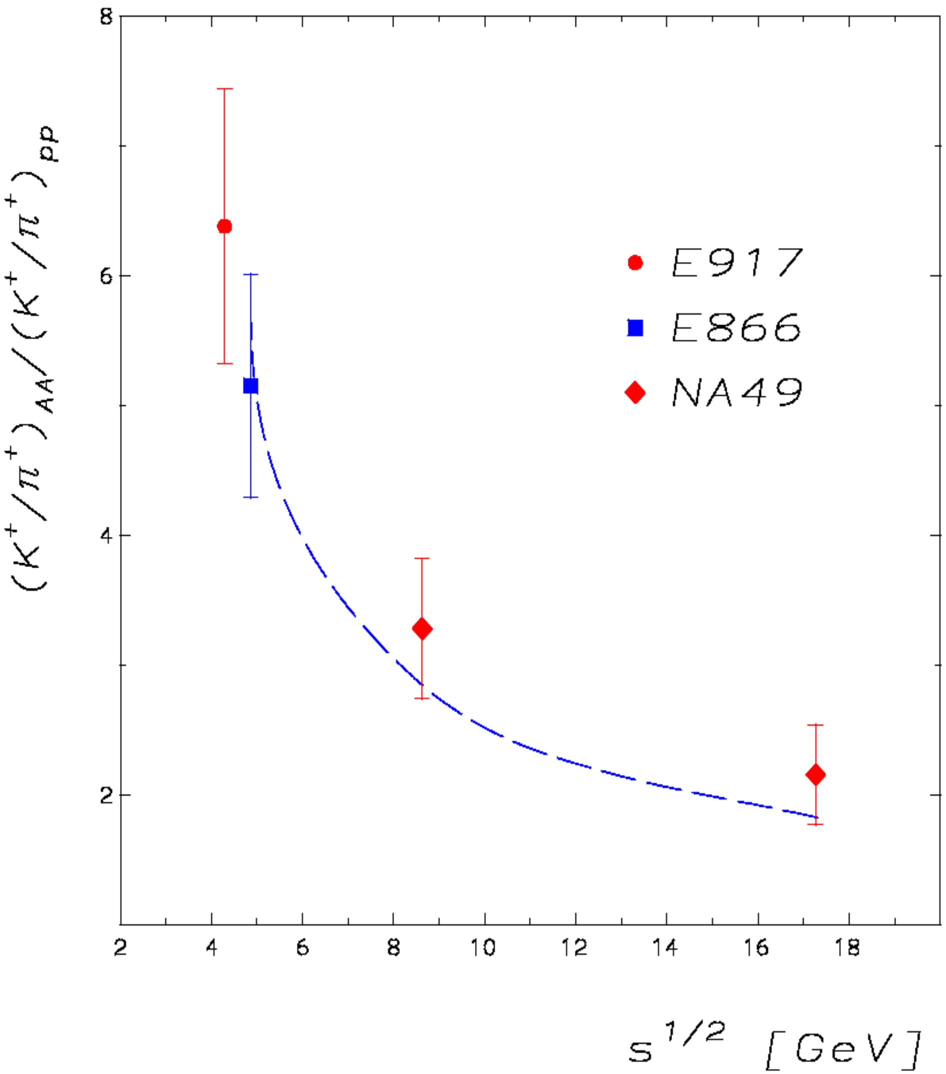
No signal of a critical point!!!!!! (?)

STAR, A. Schmah CPOD2011

At which energy has the highest strangeness enhancement been observed?

$(X(S)/\pi)_{HIC} / (X(S)/\pi)_{pp}$

Strangeness enhancement larger for lower energy



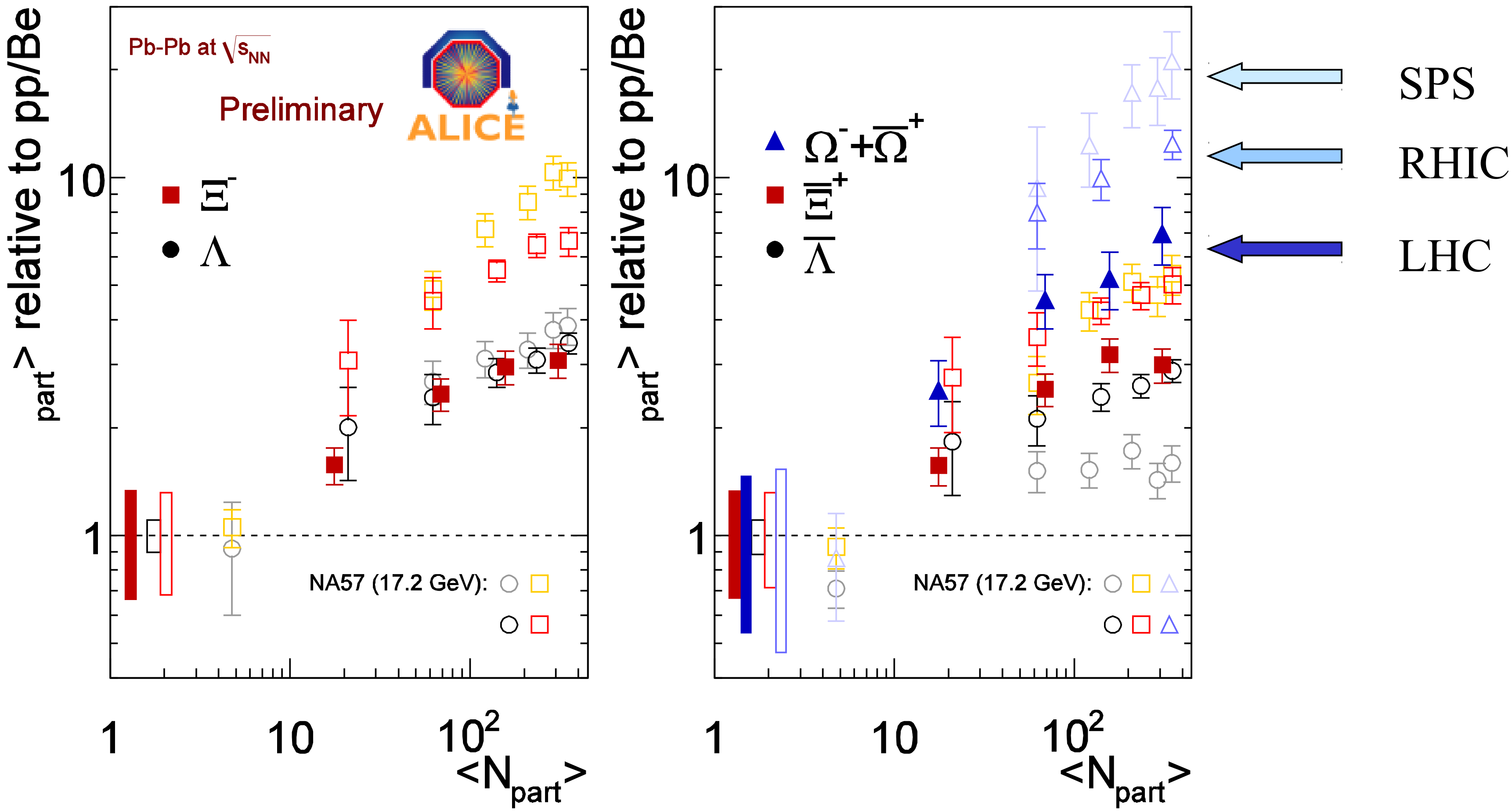
Dashed line:

Statistical model

K. Redlich

At LHC: ≈1.5

Strangeness Enhancement

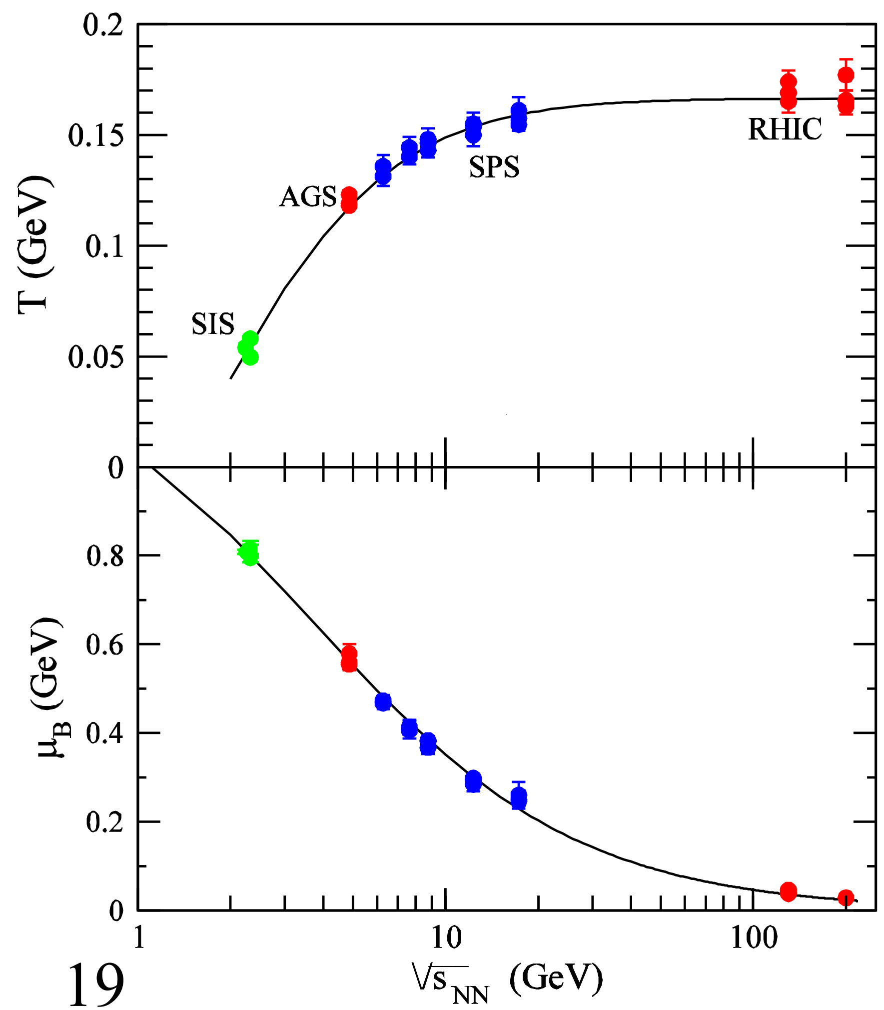


Towards LHC energies!

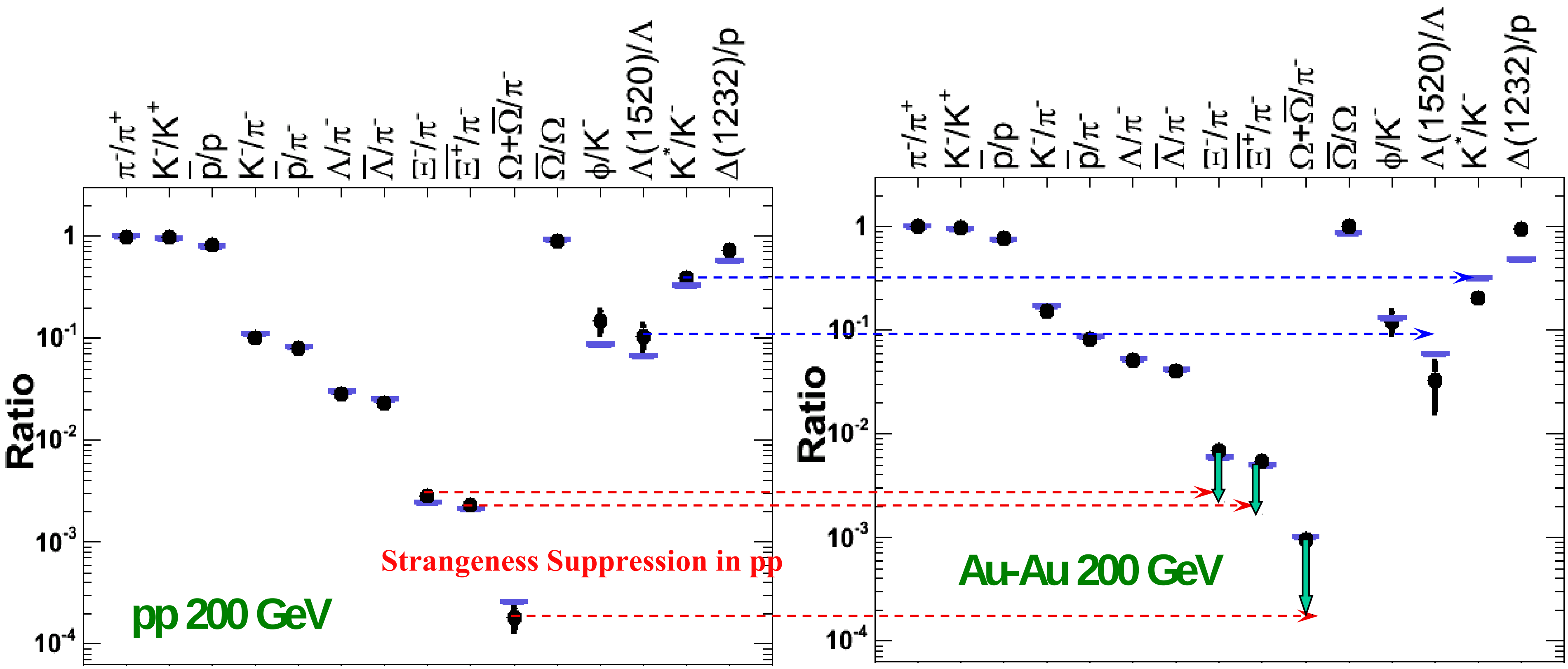
Towards LHC energies

- Chemical decoupling conditions extracted from SIS up to RHIC feature common behaviour
- Similar to Andronic et al., Nucl. Phys. A 772 (2006) 167

J. Cleymans, HO, K. Redlich, S. Wheaton, Phys. Rev. C 73 (2006) 034905



Statistical Model for pp and HIC



- In *pp* particle ratios are well described using canonical description
- In *Au+Au* only stable particle ratios are well described

Canonical Approach

Pion density

$n(\pi) = exp(-E_\pi/T)$

Strangeness is conserved!

Kaon density

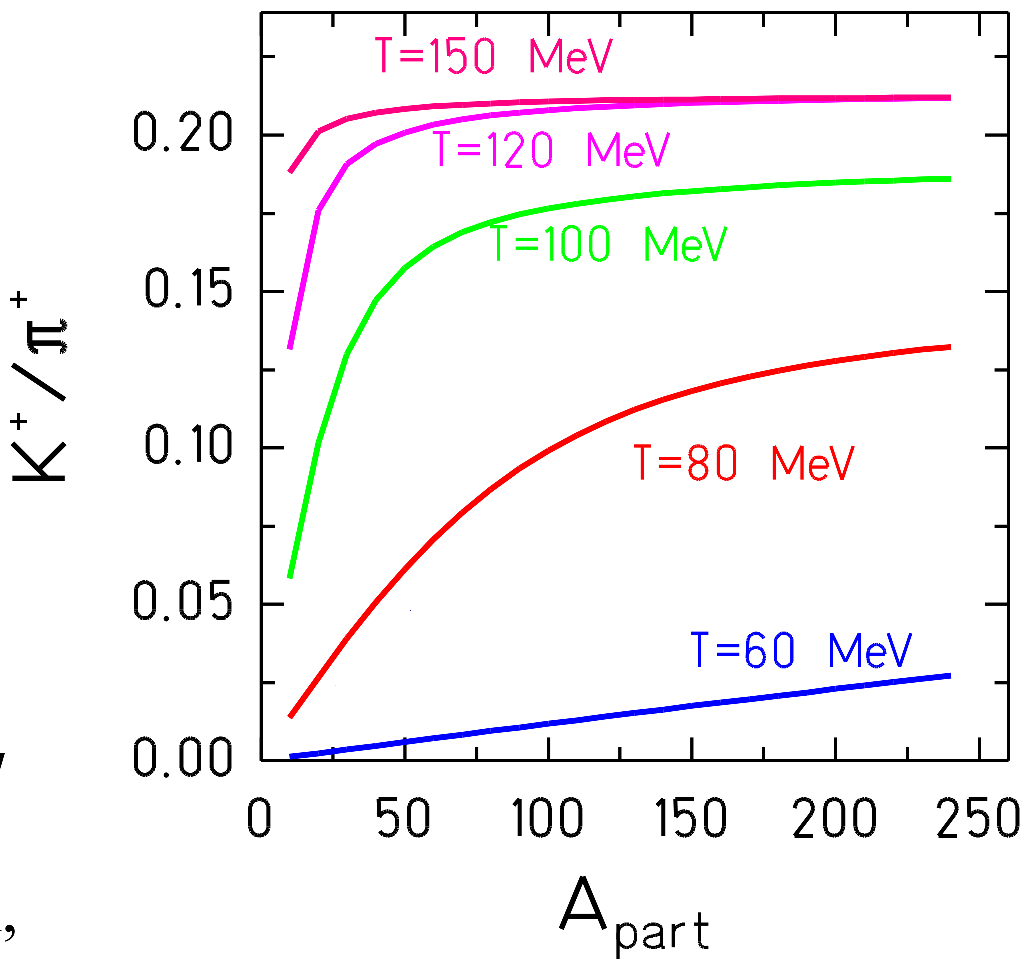
$NN \rightarrow N\, \Lambda\, K^+$

$n(K) = exp(-E_K/T)$

$[g\, V \int \ldots exp[-(E_\Lambda - \mu_B)/T]$

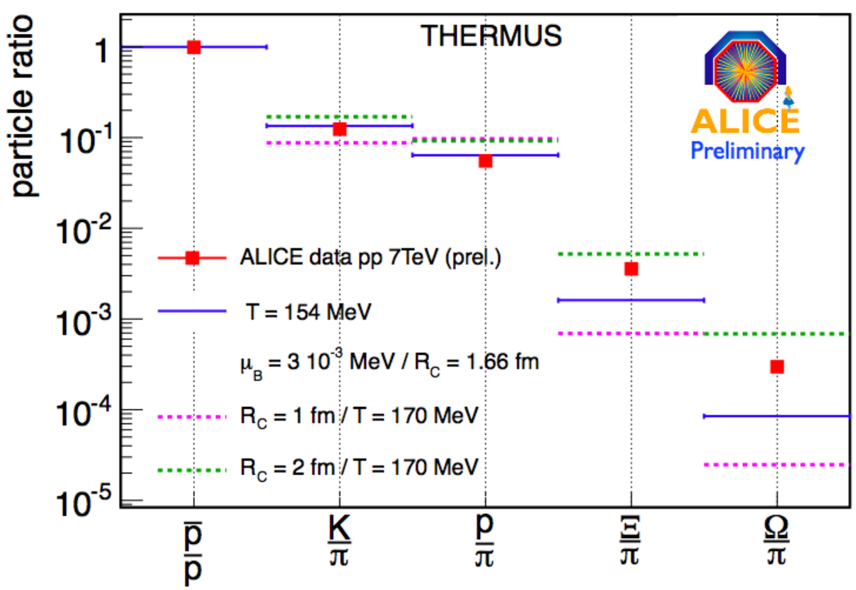
J. Cleymans, HO, K. Redlich,

PRC 60 (1999)

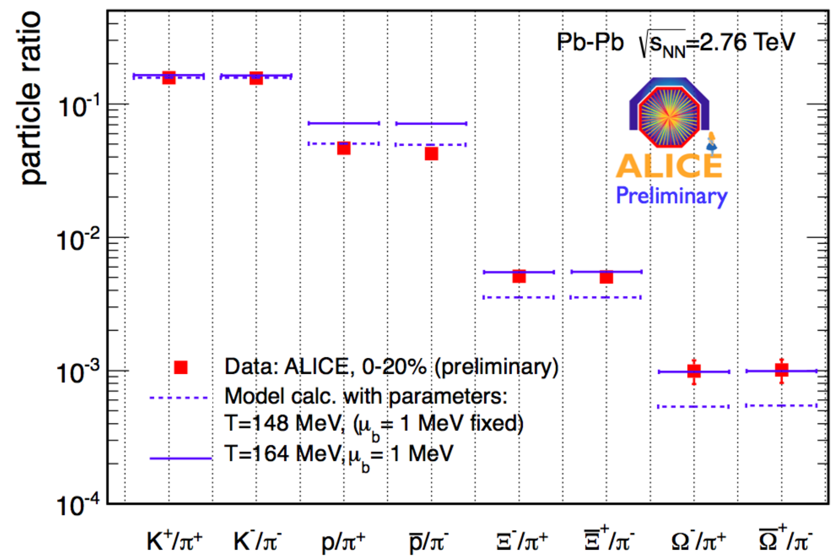


LHC Energies

pp 7 TeV



Pb-Pb 2.76 TeV



p/π the same in pp and Pb-Pb,

BUT lower than expected from stat. models

K/π in pp is lower than in Pb-Pb, expected from stat. model!

Strangeness is okay!

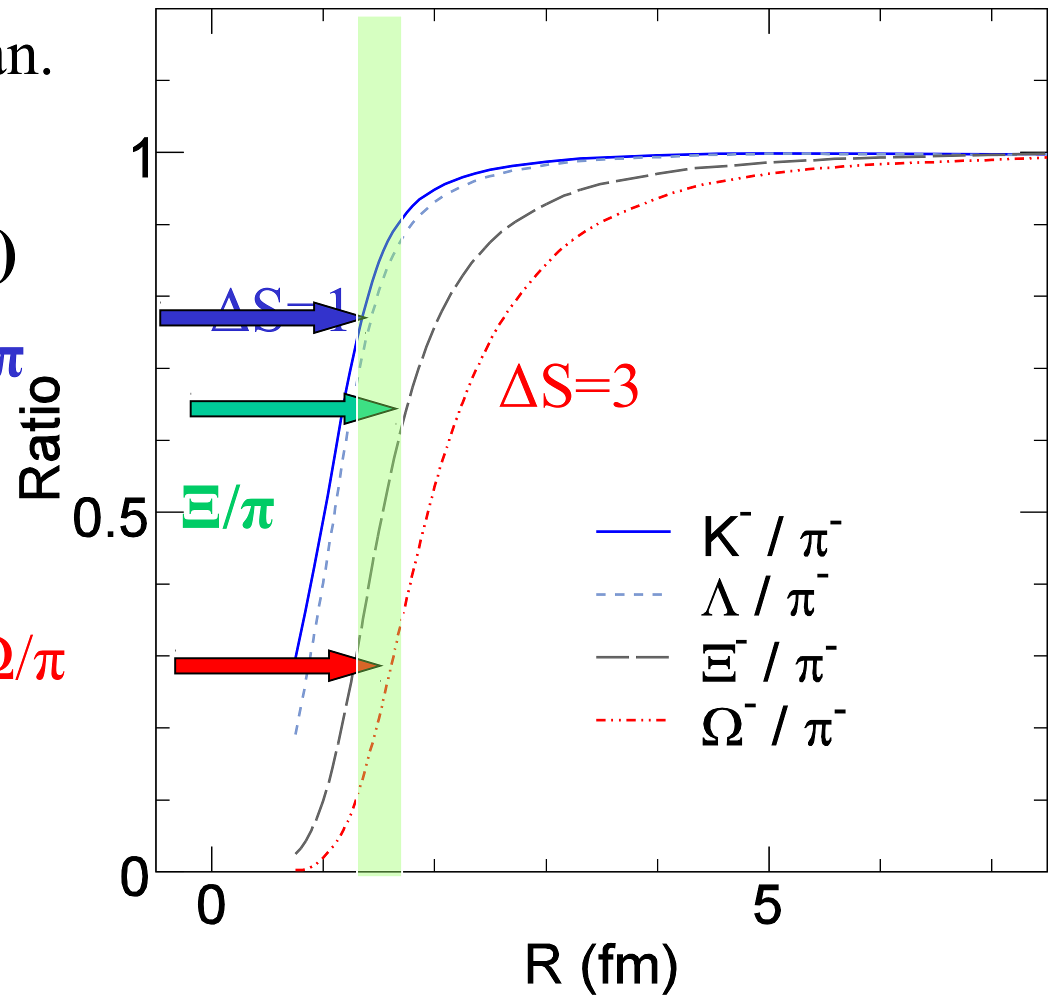
Testing Canonical Suppression at LHC

can./grand can.

Measured ratio(pp)/ratio(PbPb)

K/π

Ω/π



Example:

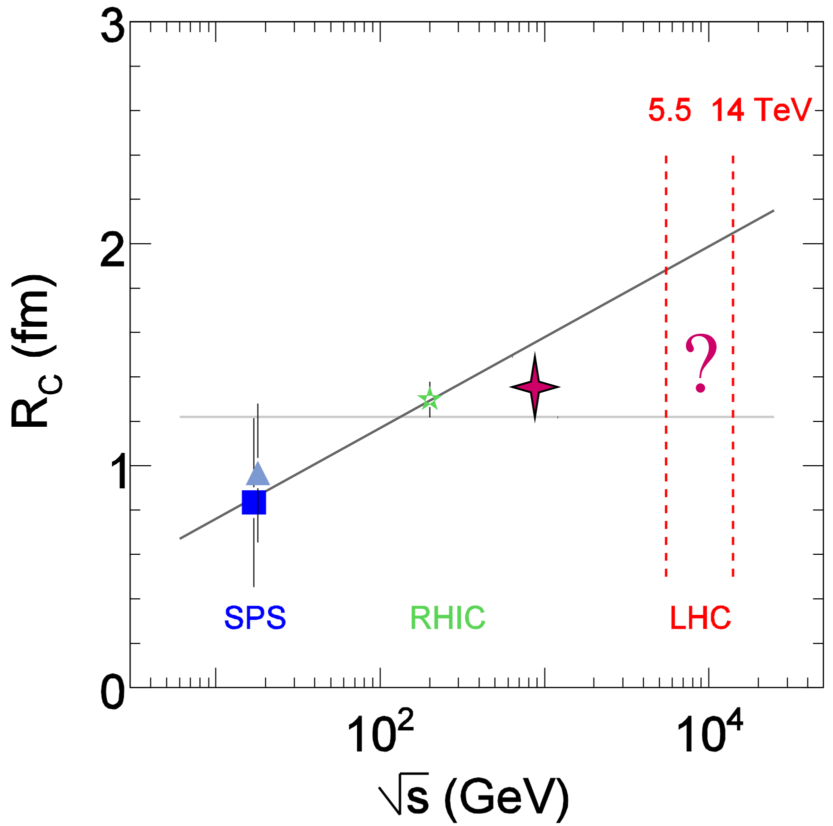
T = 170 MeV

$\mu_B = 1$ MeV

Values for LHC

Prediction:I. Kraus et al., PR C 79 (2009) 014901

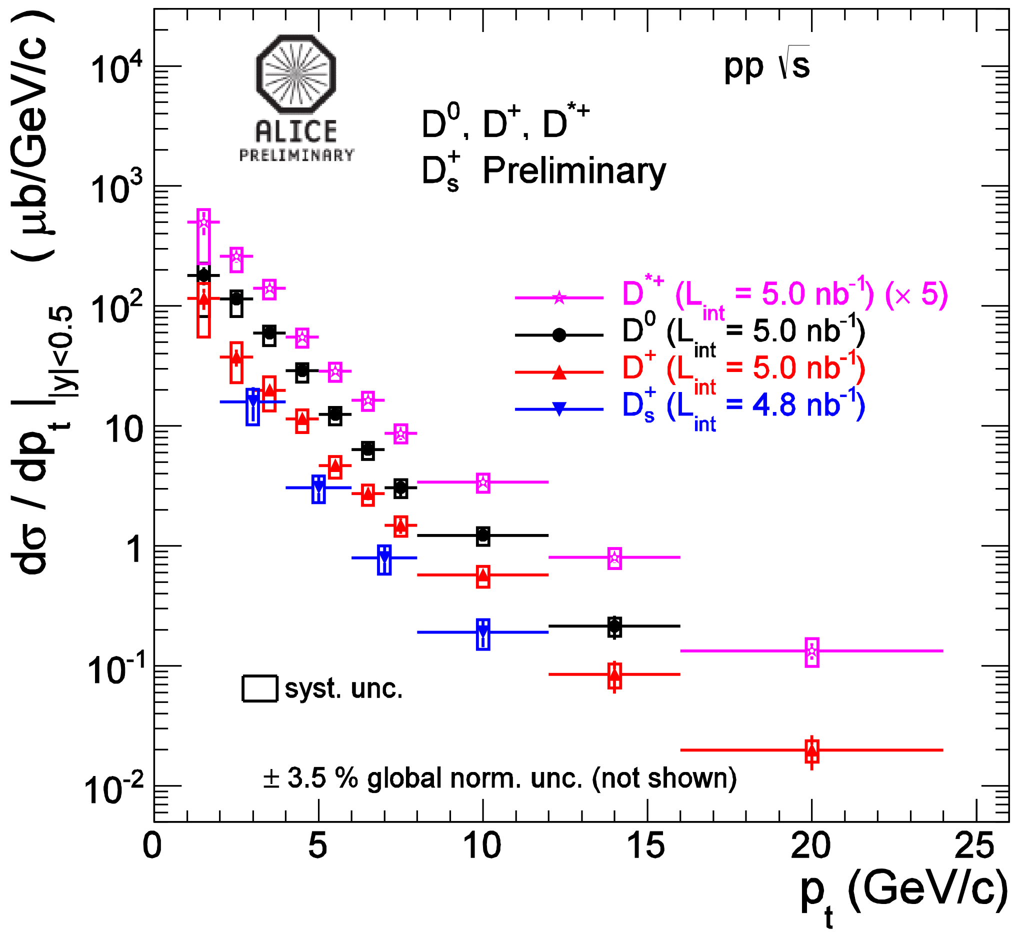
Correlation Radii at LHC



pp 900 GeV thermal fit: arXiv:1102.2745

Next: high-multiplicity events in pp 7 TeV !!!???

Distribution of s and c quarks



$\mathbf{D^{+}_{s}/D^{0}} \approx 0.2$

(JHEP 01 (2012) 128)

Stat. Model = 0.35 GC

Ratio canonical/GC ≈0.7 (from K/π in Pb-Pb and pp)

To see yields of $\mathbf{D^{+}_{s}/D^{0}}$ in PbPb!!

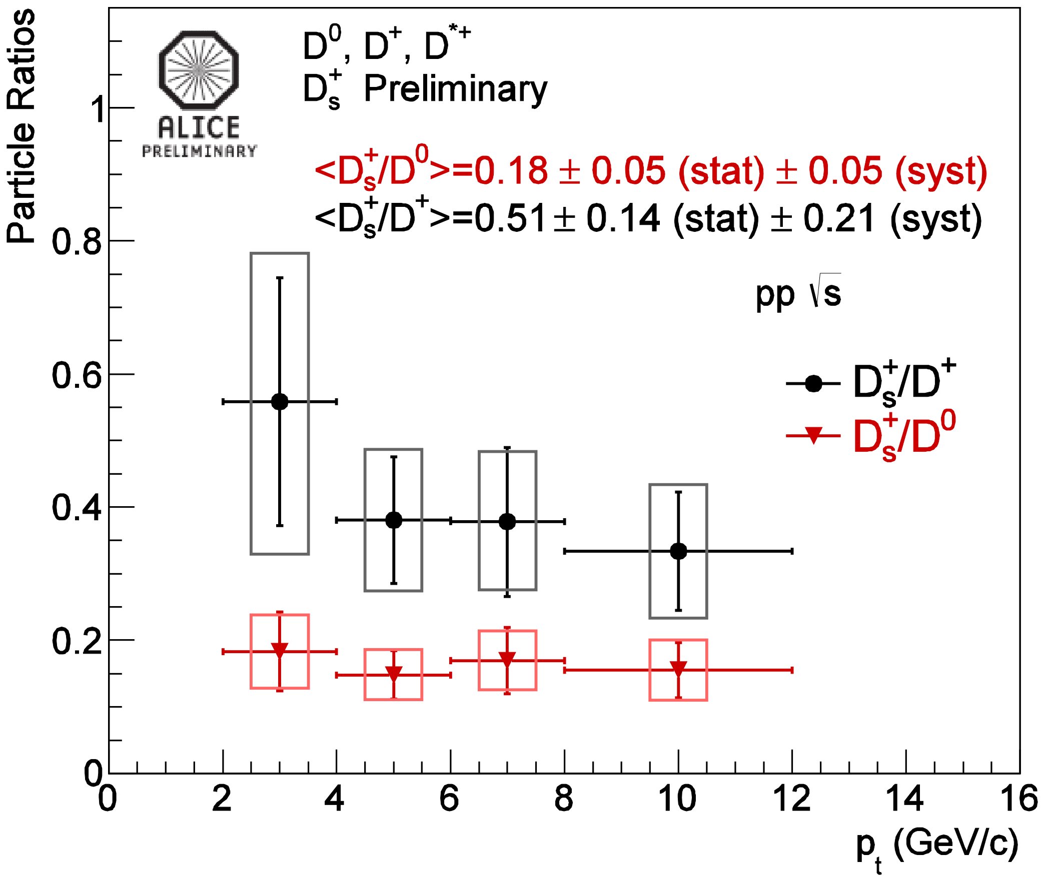
conclusions

- Strange particles are an excellent tool to study many properties of nuclear matter and of the phase transition
- Maximum strangeness content around $\sqrt{s} \approx 8$ GeV and the recent results from beam energy scan
- What is changing? The various changes are NOT always exactly at the same $\sqrt{s}$!!!

- At the LHC: PbPb: strangeness okay, p too low
- pp: canonical suppression seems okay, p too low, same as in PbPb.
- Distribution of s quark in D mesons

Back up

D mesons in pp at 7 TeV



D+s/D0

ALICE ≈ 0.2

(JHEP 01 (2012) 128)

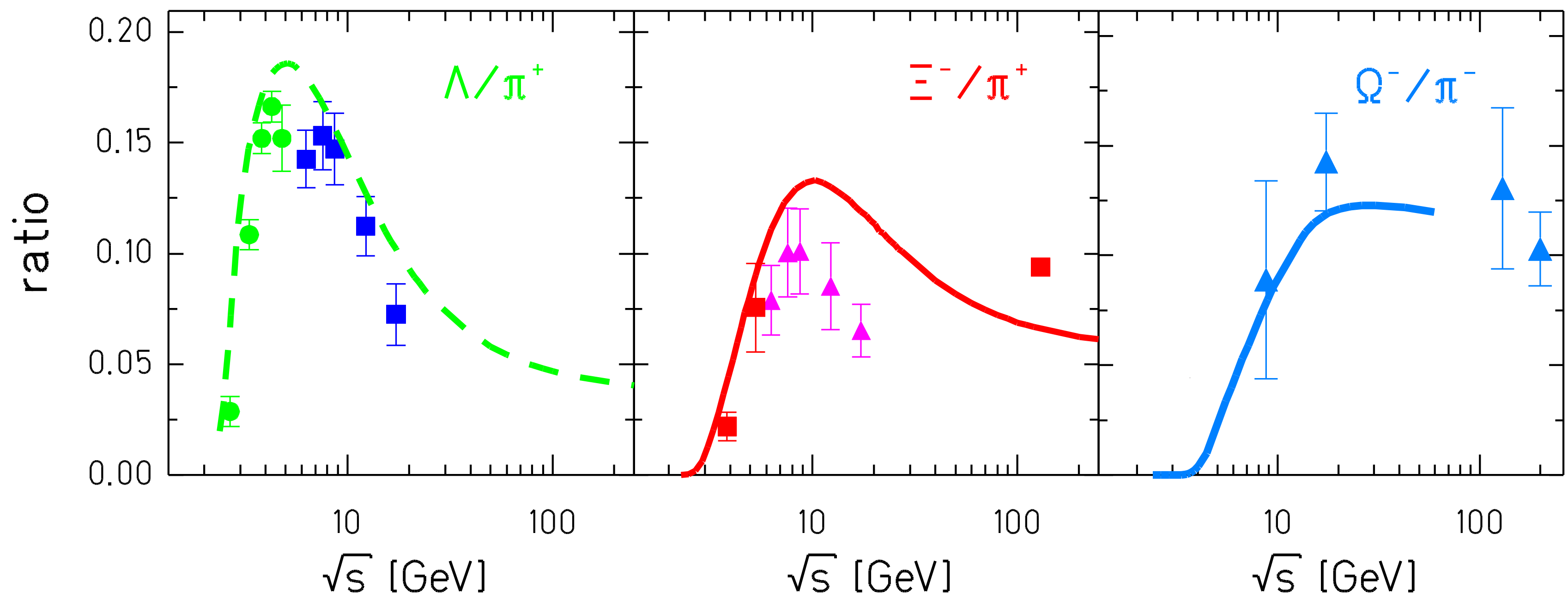
Stat. Model = 0.35 GC

Ratio canonical/GC

≈0.7 (from K/π in Pb-Pb and pp)

To see yield of D in PbPb!!

Baryons



Stat. Mod. : All exhibit maxima, but at different locations

4π values from NA49 2008 publication, NA57 higher!

Predictions for LHC

Prediction for
heavy ions:

Grand can. (blue)

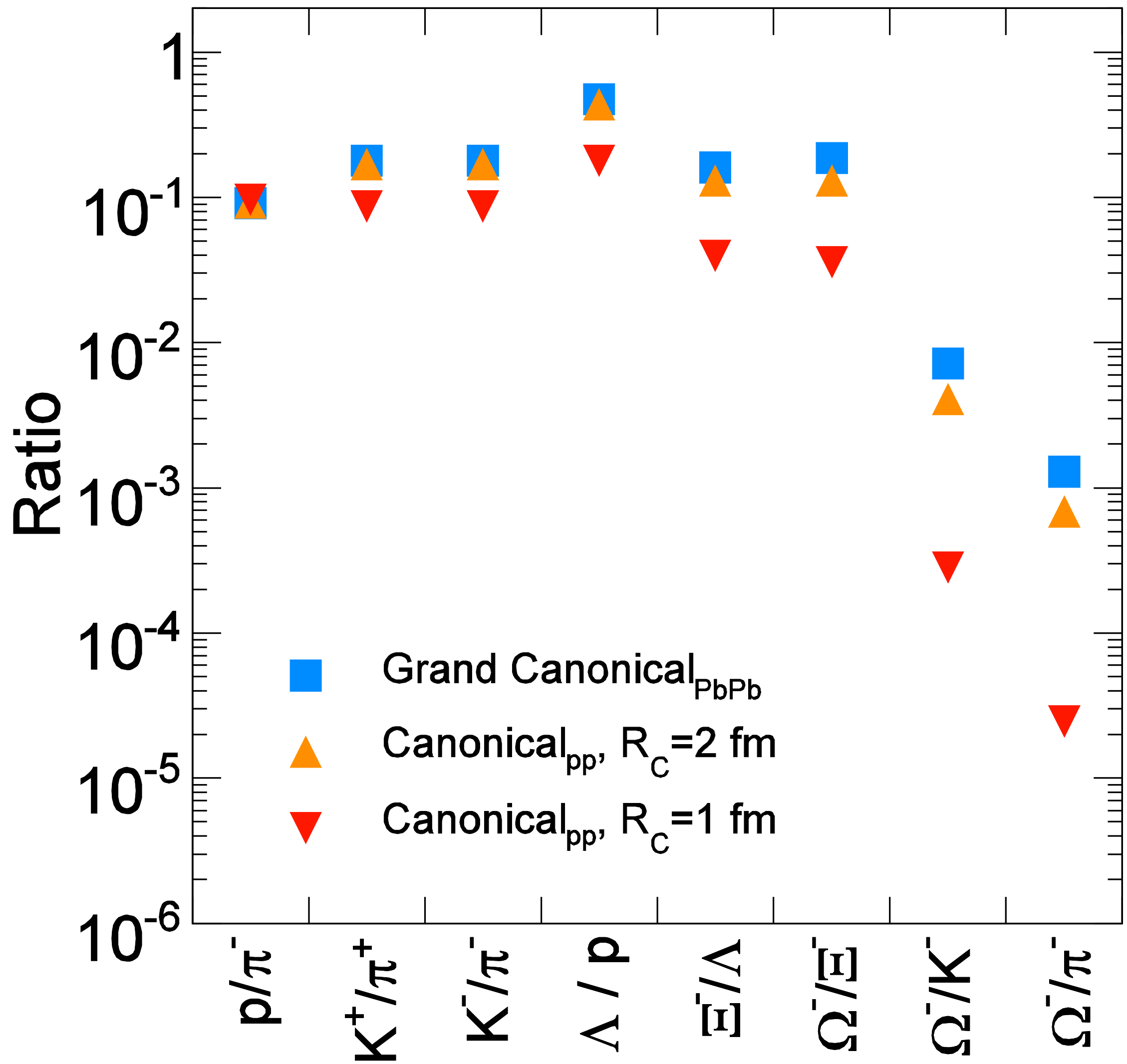
I. Kraus et al.,

PRC 74 (2007)

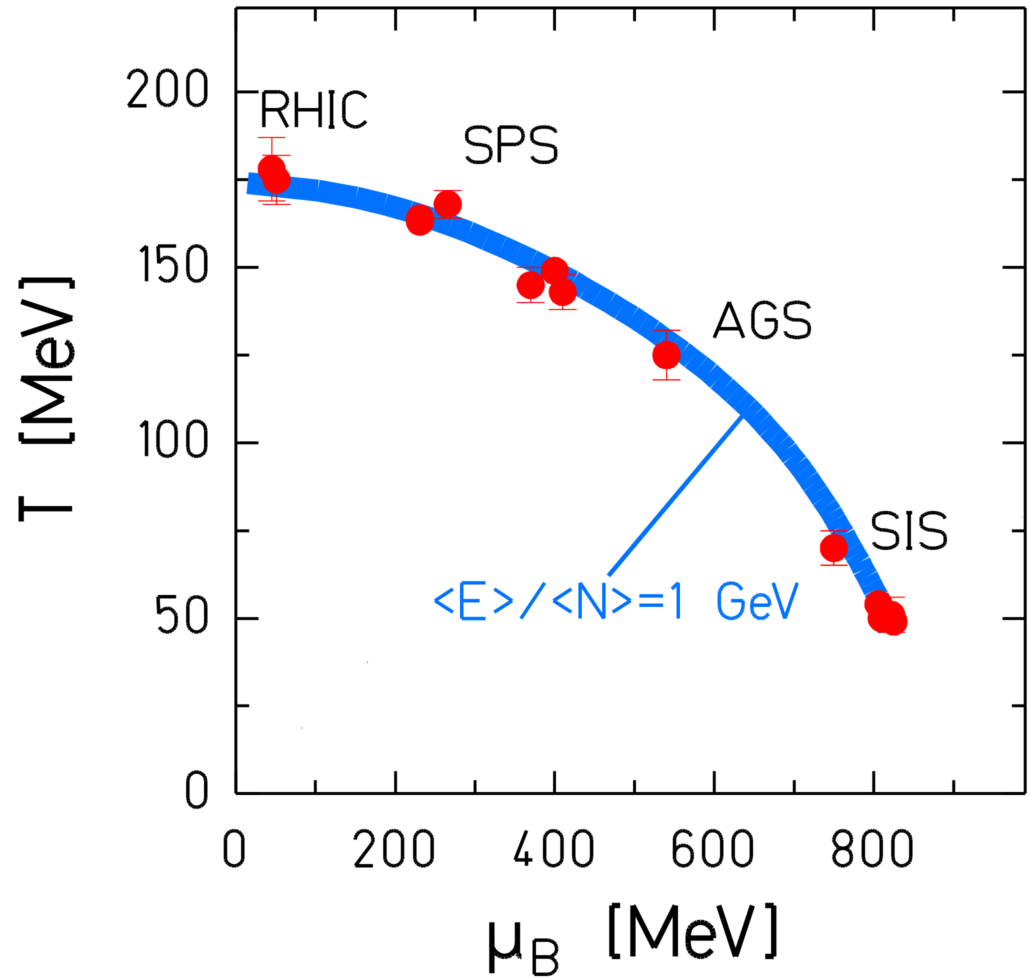
For pp collisions:

Canonical (yellow
and red)

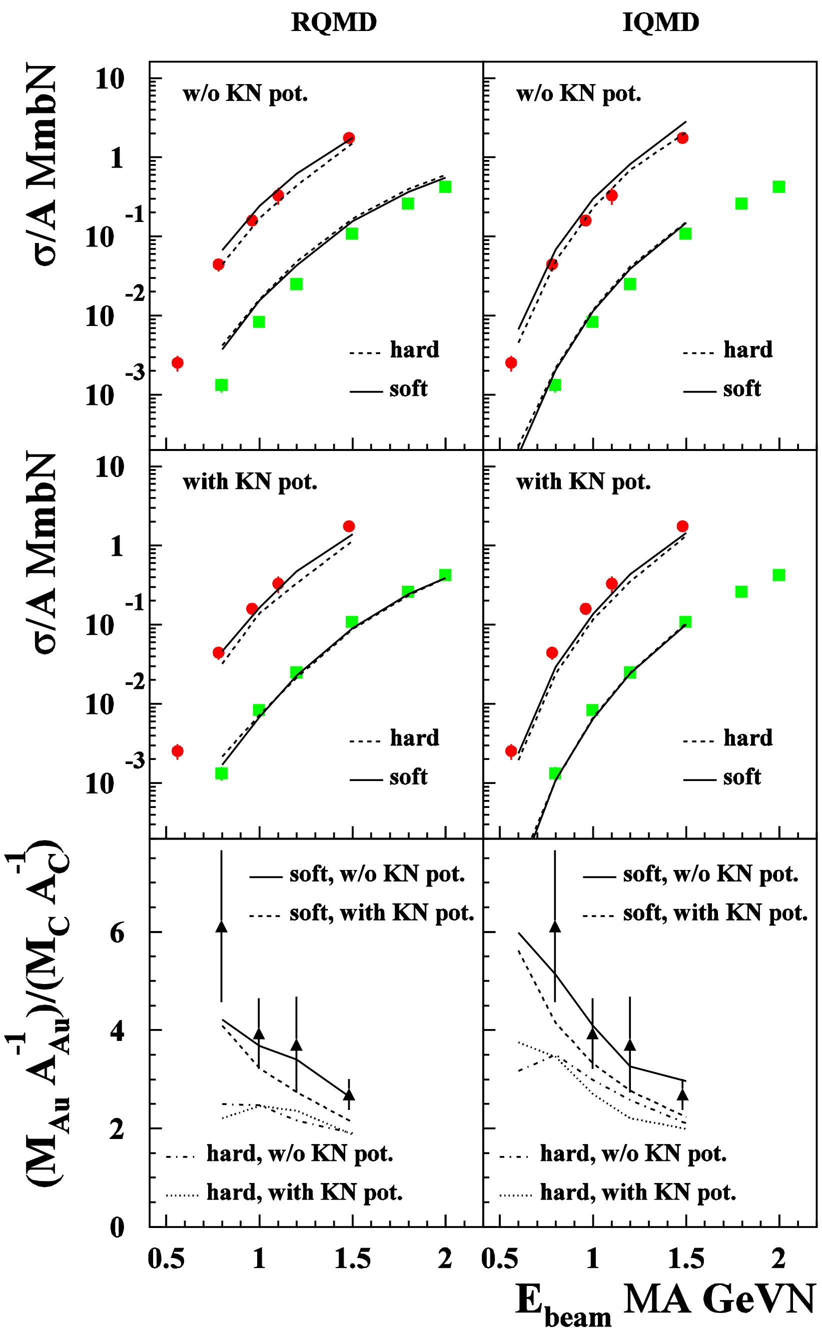
IK PRC 79 (2009)

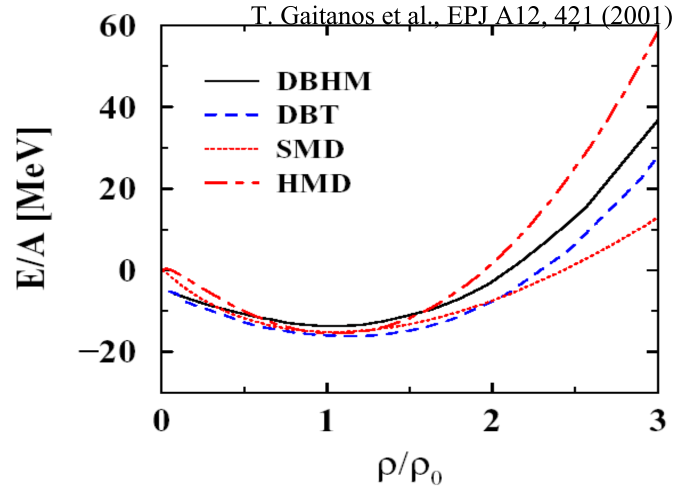


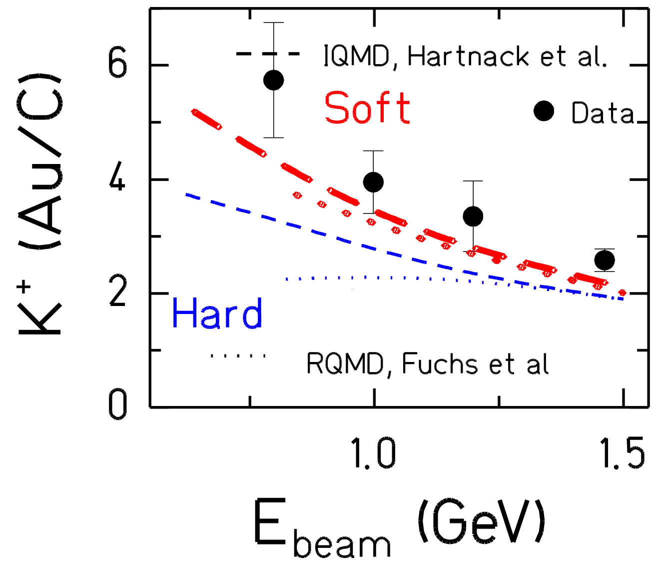
Chemical Freeze Out



J. Cleymans and K. Redlich, PRL 81 (1998) 5284







Results confirmed also with several calculations and other observables!

C. Hartnack, HO, J. Aichelin, PRL 96 (2006) C. C. Hartnack, et al., arXiv:1106.2083 [nucl-th]