



Production de Particules Etranges du SIS au LHC

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Etretat, le 16 Septembre 2009

Content

- Strangeness enhancement:
Status today!
- Maximum in strangeness content
around 30 A GeV: Physics behind?
- Predictions für LHC

Strangeness Enhancement

1981 Rafelski and Müller

Strangeness easier produced in a QGP
than in an hadronic environment

cheapest strange hadron(s):

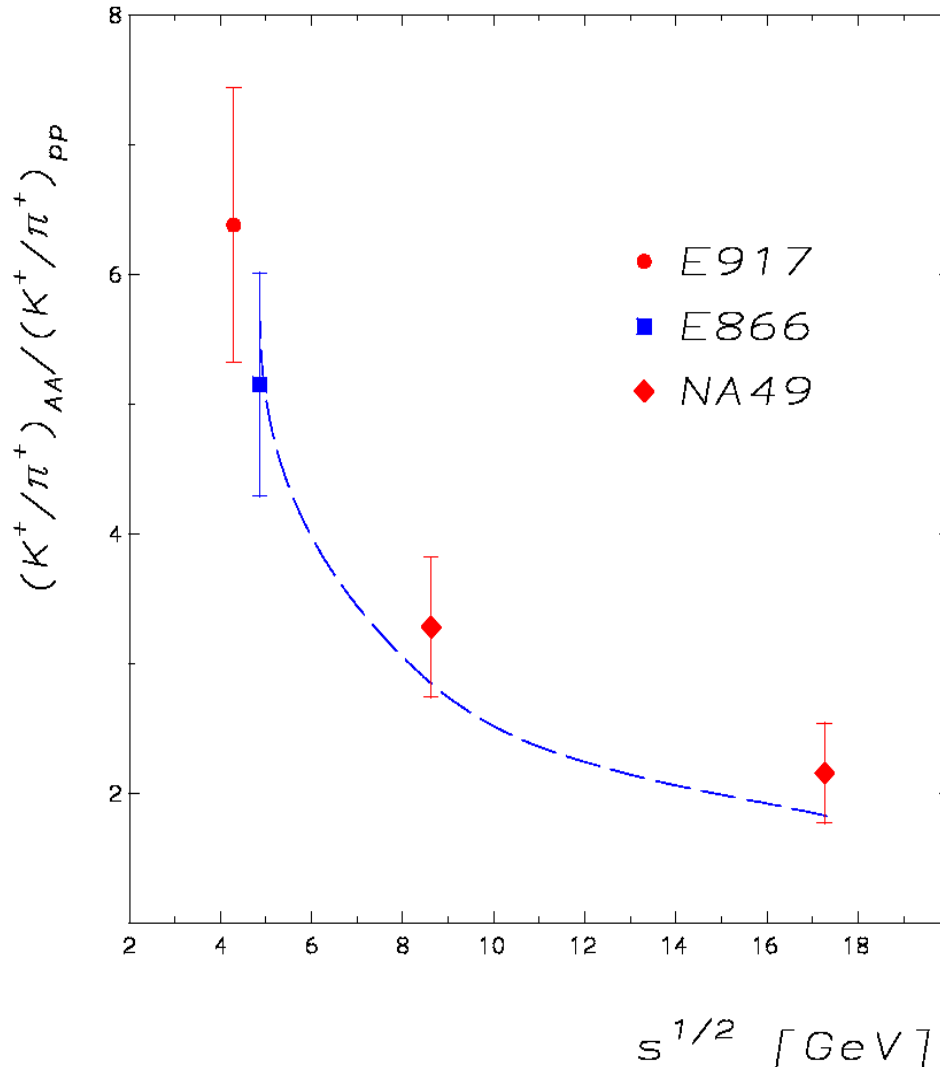
$K^+ K^-$ pair: $2 \cdot 500$ MeV

cheapest s-quarks: $2 \cdot 150$ MeV

Is it observed or not?

Initial idea: Compare pp and HI Collisions

Strangeness enhancement found already at
AGS: K^+/π^+ higher in HI than in pp.

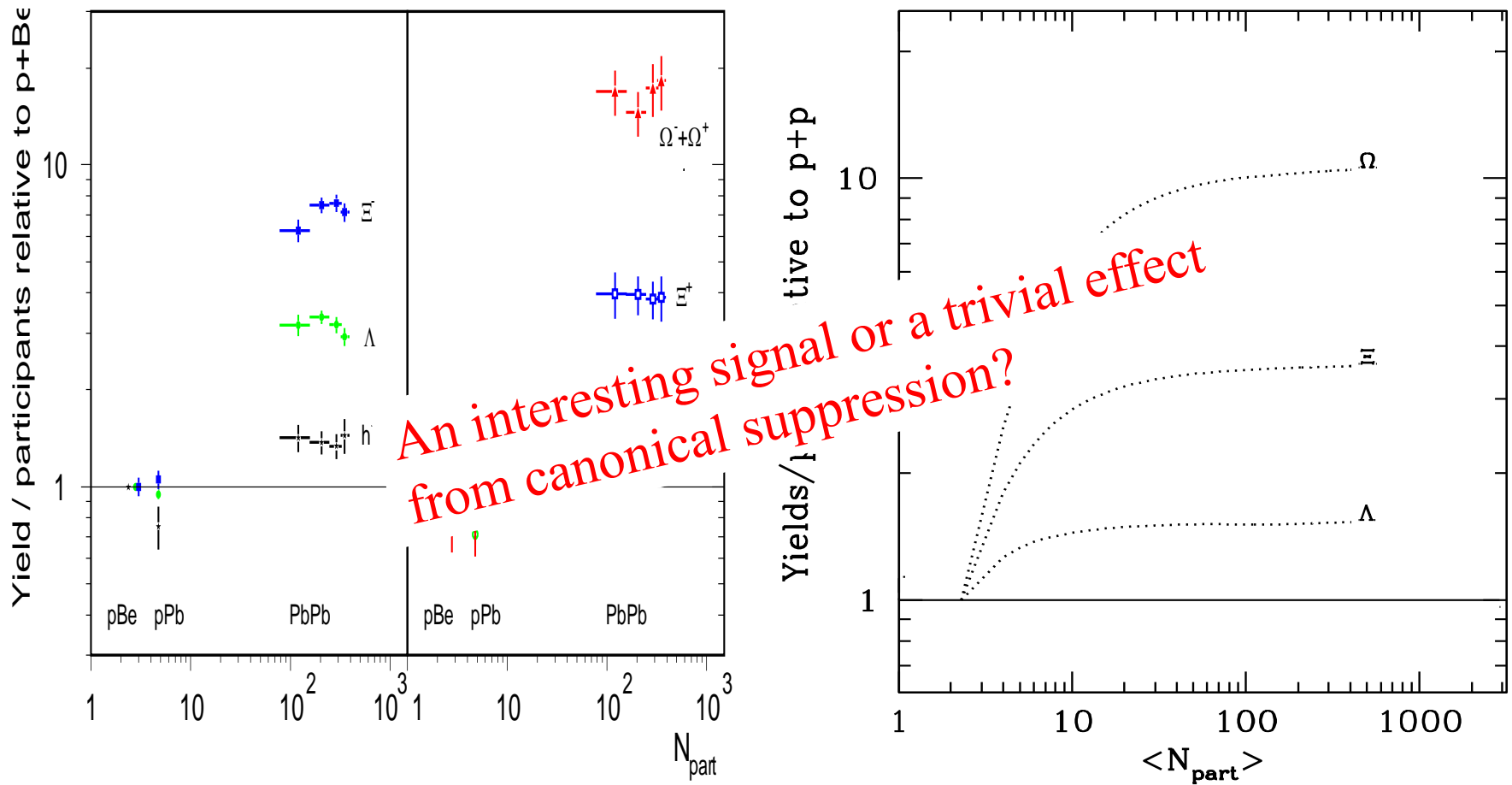


Strangeness
enhancement larger at
the lower energies!!!

Dashed line:
Statistical
model

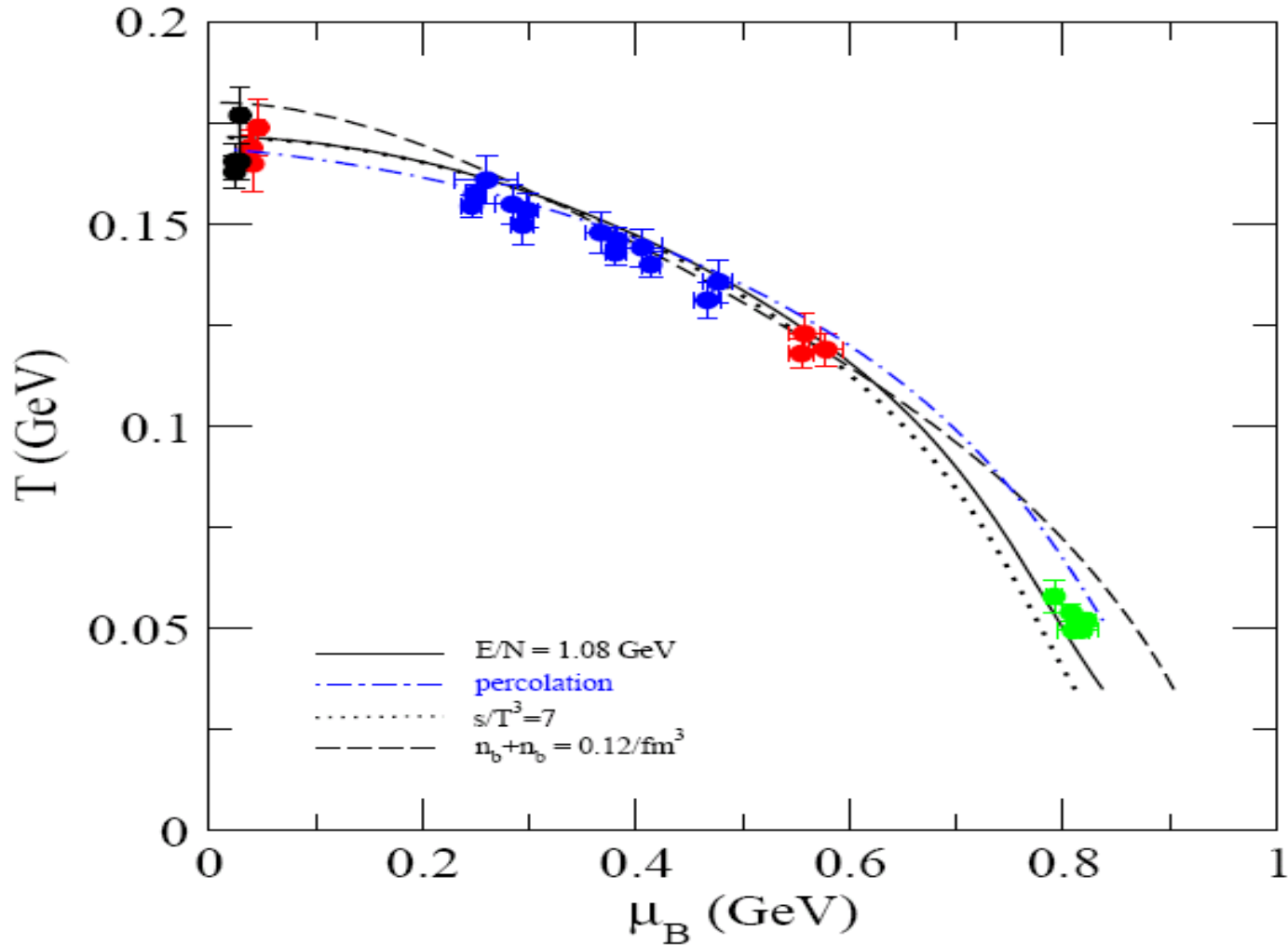
Multiple collisions
and threshold!

Strangeness Enhancement



Data: WA97 New: NA57 Theory: S. Hamieh, K. Redlich A. Tounsi, PL B486 (2000) 61

Freeze-out criteria

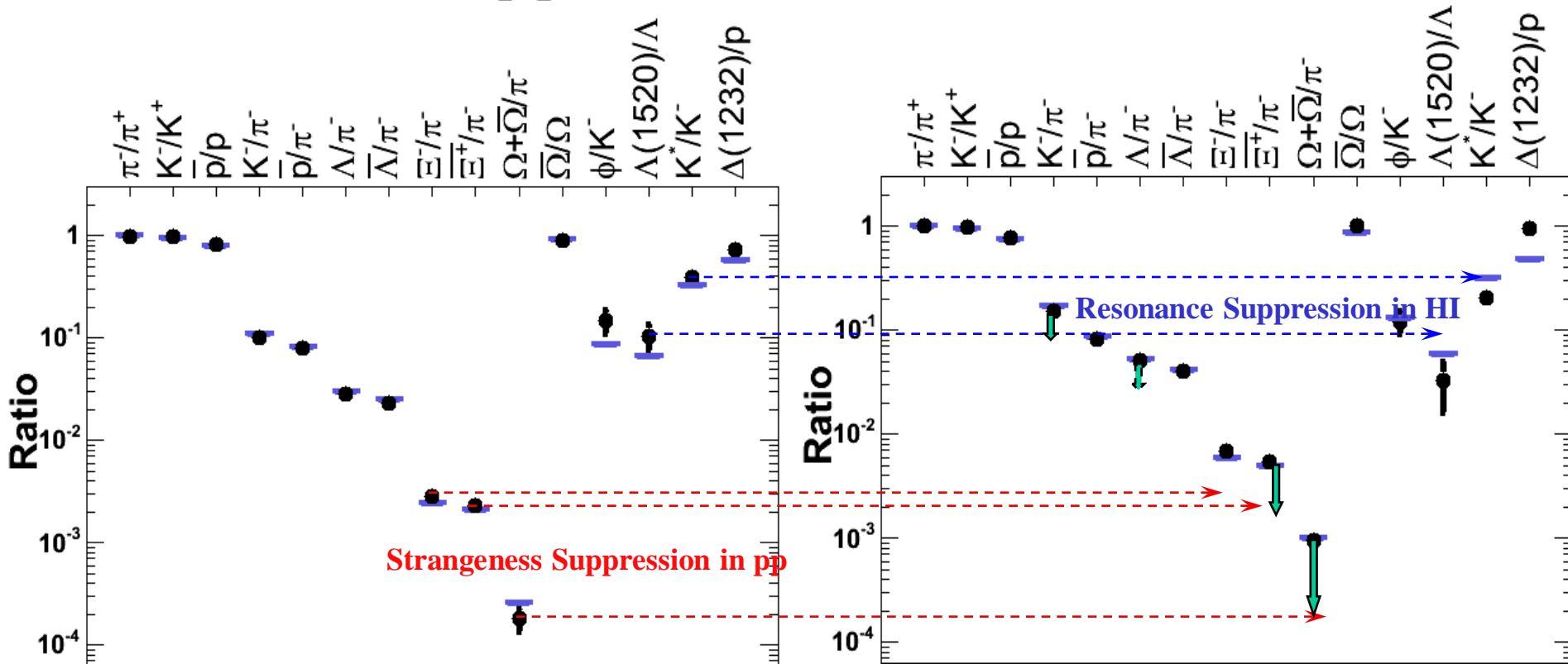


J. Cleymans, HO, K. Redlich, S. Wheaton, Phys. Rev. C73 (2006)

Statistical Model

200 GeV pp

200 GeV Au+Au



- 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

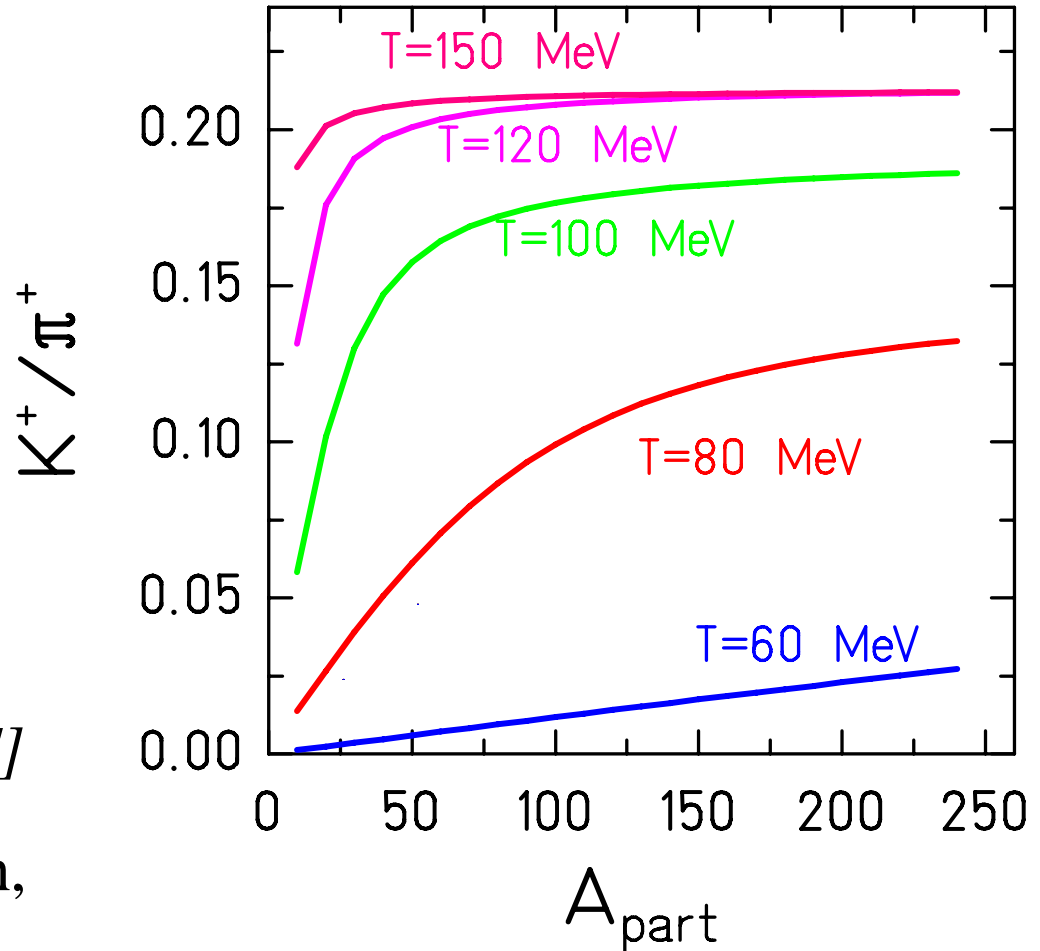


$$n(K) = \exp(-E_K/T)$$

$$[g \mathbf{V} \int \dots \exp[-(E_A - \mu_B)/T]$$

J. Cleymans, HO, K. Redlich,

PRC 60 (1999)



- Canonical stat. model gives only a qualitative description of the centrality dependence.

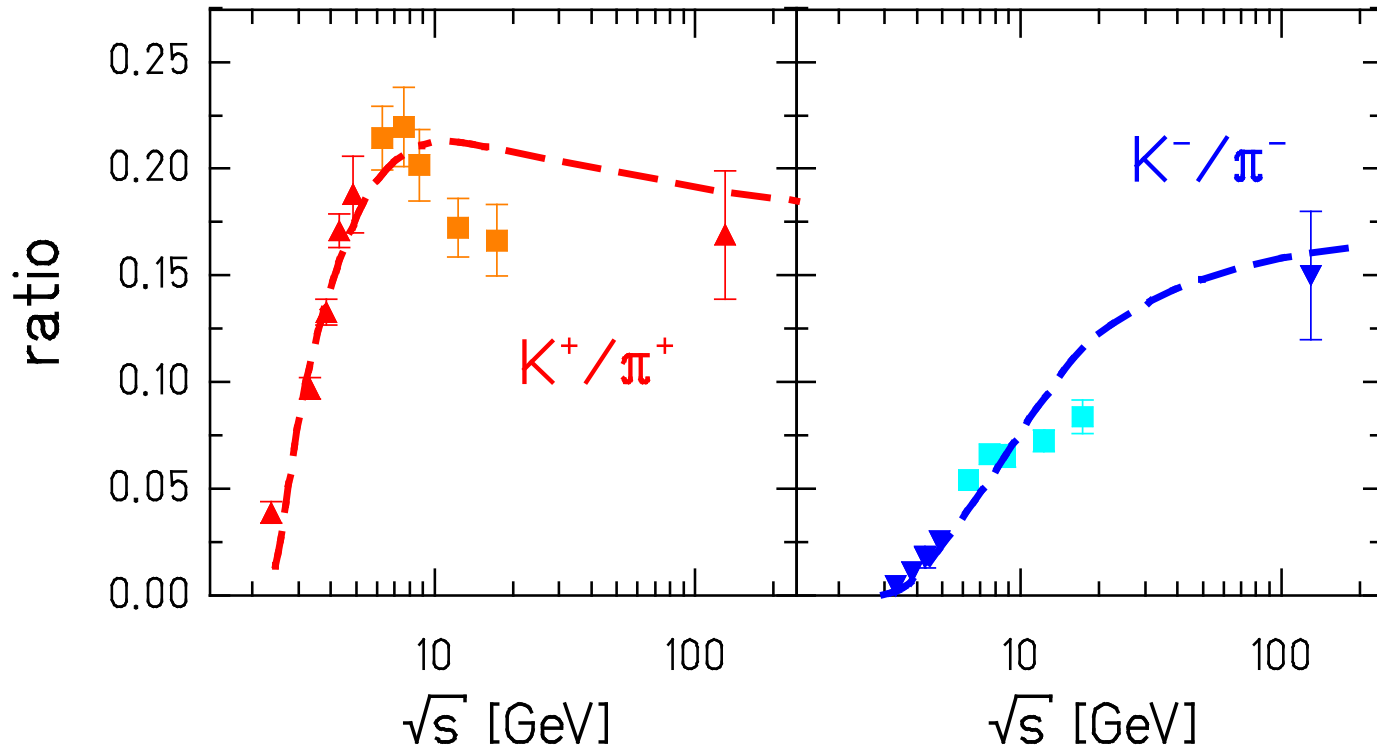
something is not correct.

Core-corona, γ_s , clustering, ...

Next, another area where the statistical model has problems

Observed maximum in strangeness around 30 A GeV

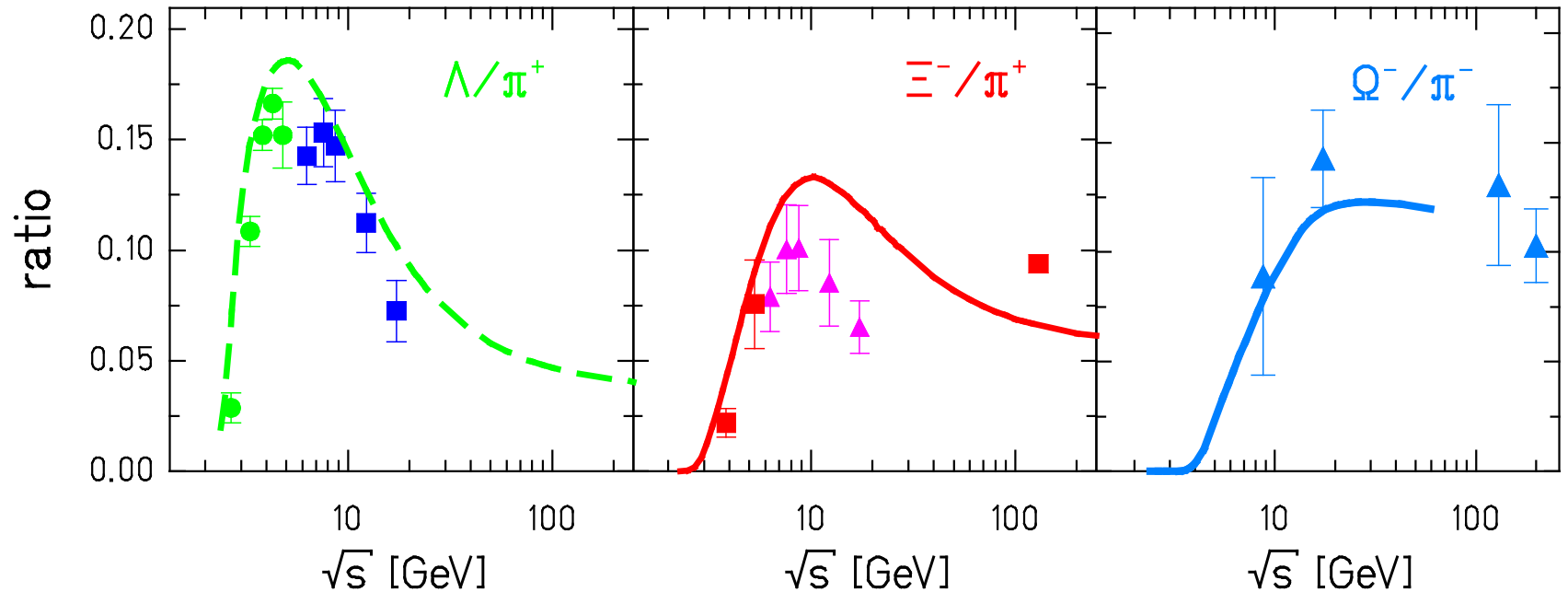
Mesons



Stat. Mod. : Only K^+/π^+ exhibits a maximum!

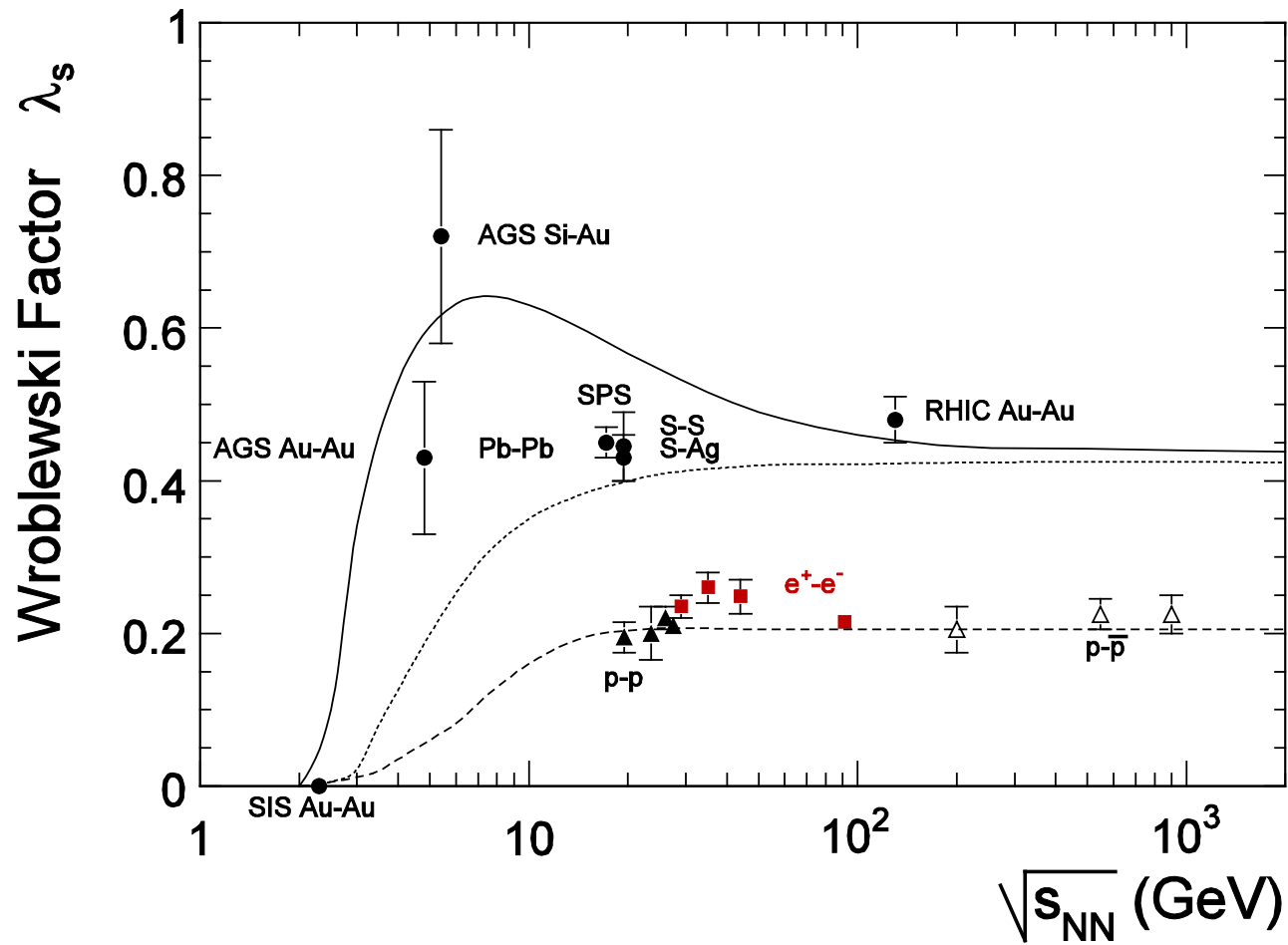
4π values from NA49 2008 publication,

Baryons



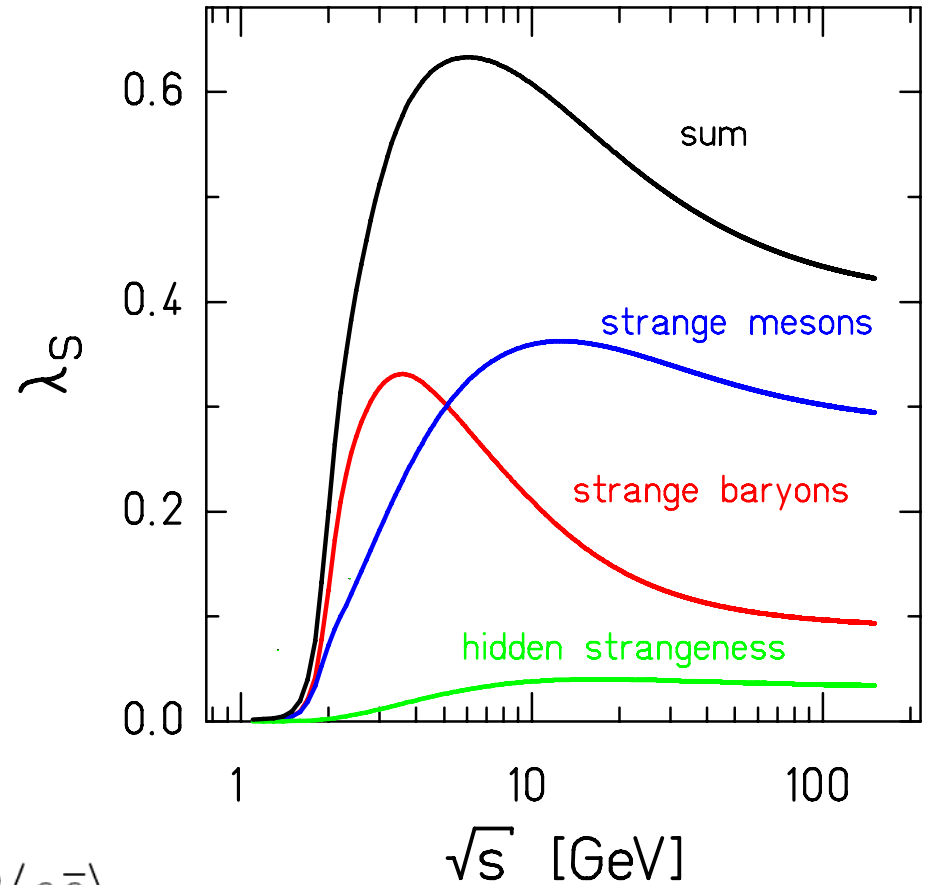
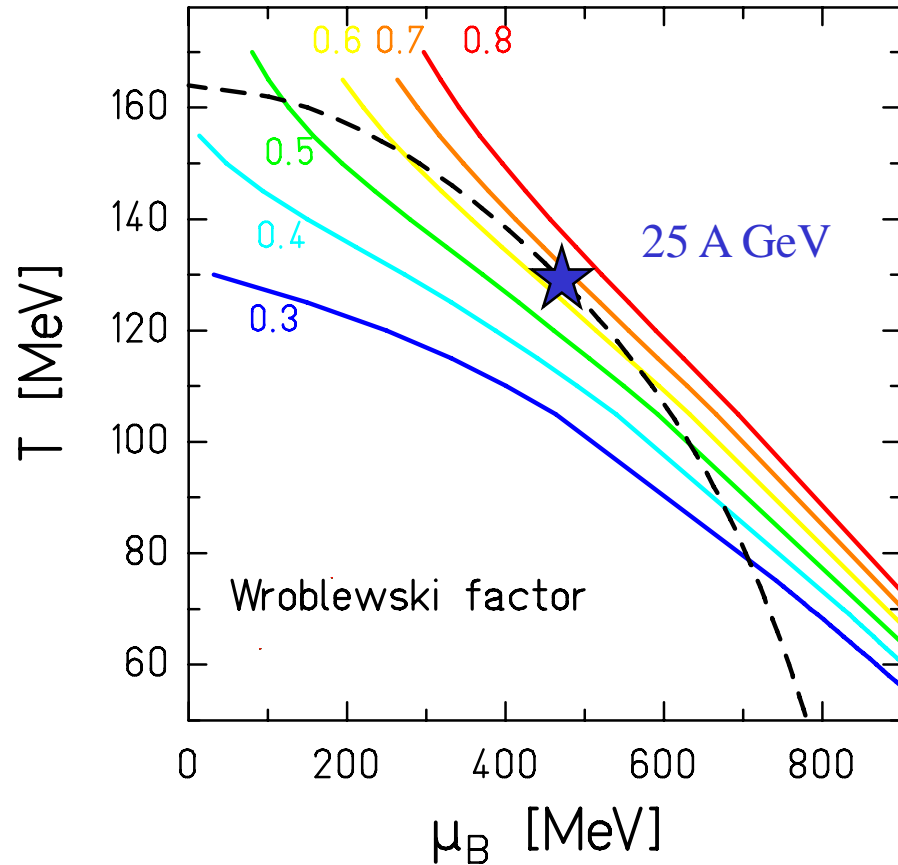
Stat. Mod. : All exhibit maxima, but at different locations

4π values from NA49 2008 publication, NA57 higher!



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

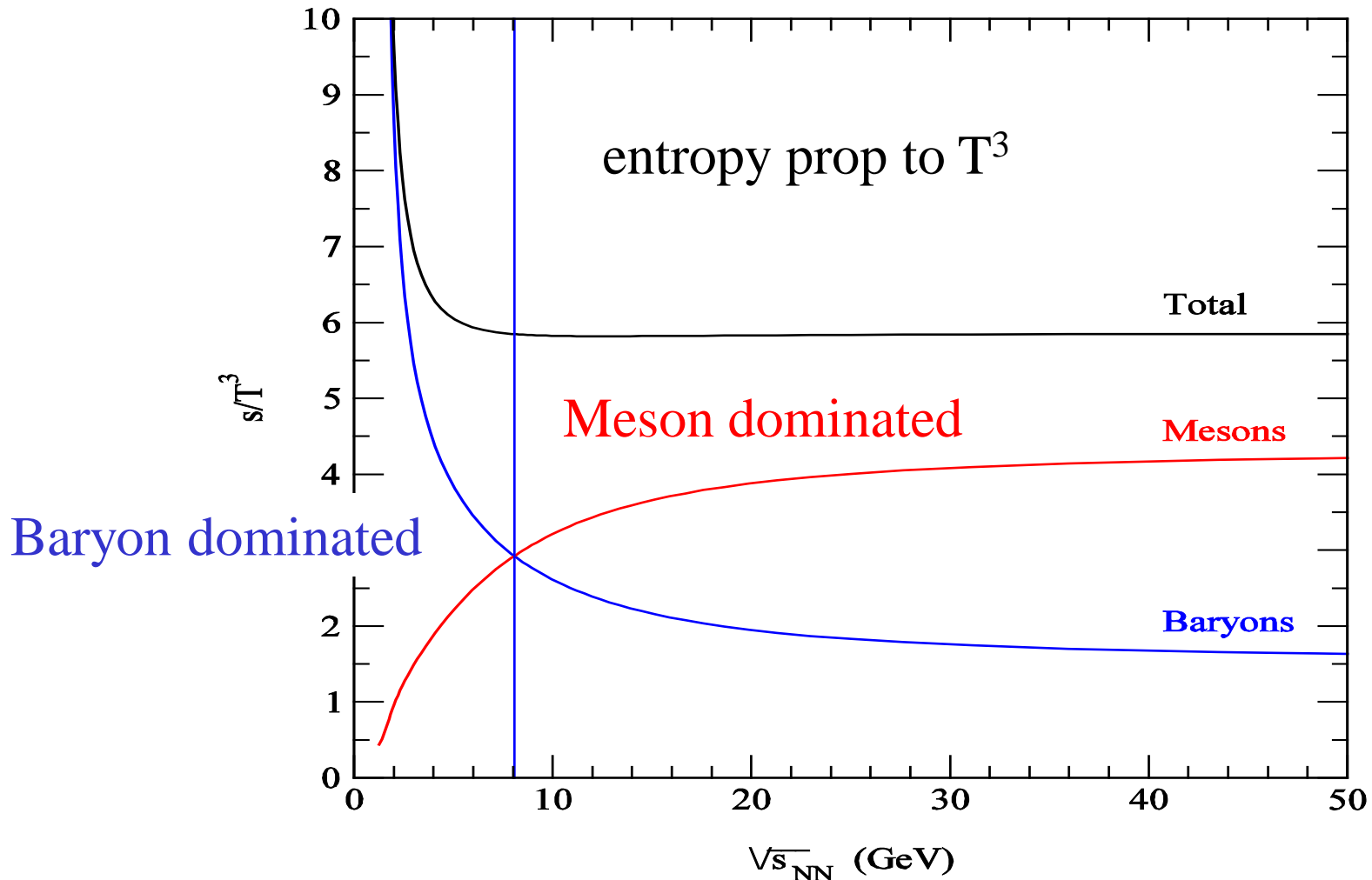
Maximum Strangeness around 30 AGeV



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

Transition from baryonic to mesonic freeze out

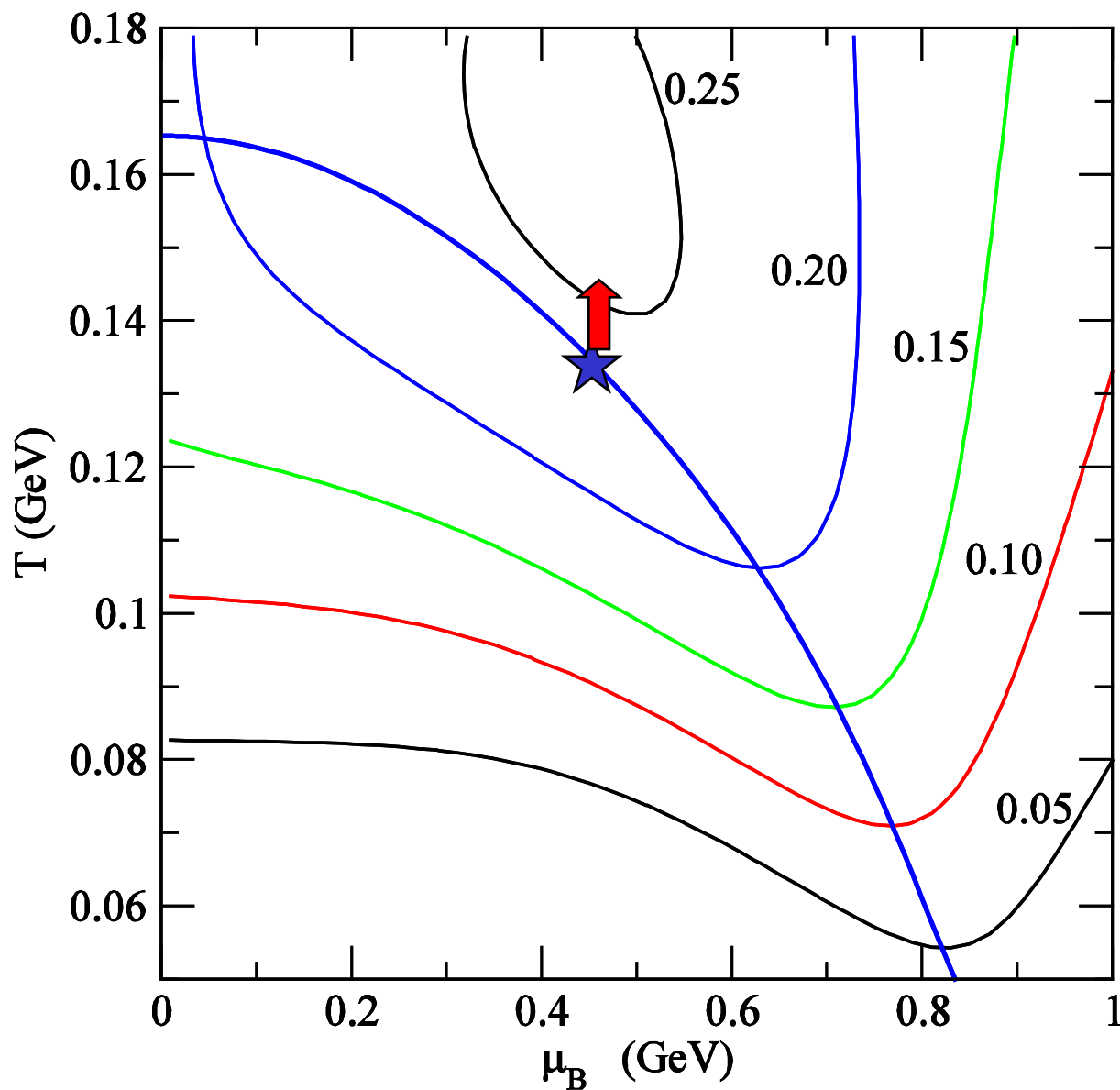
J. Cleymans, H.O., K. Redlich, S. Wheaton, Phys. Lett. B615 (2005)

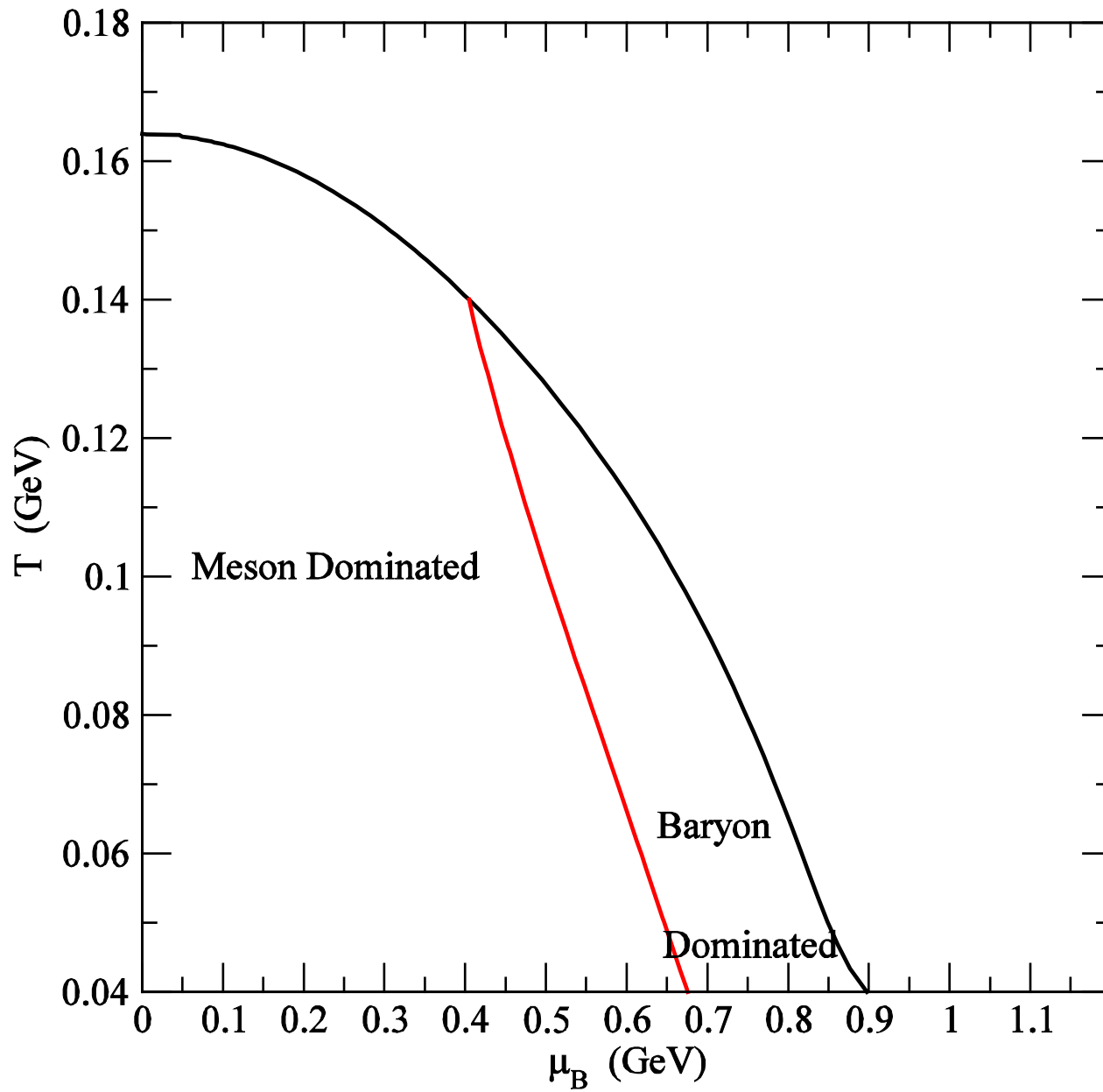


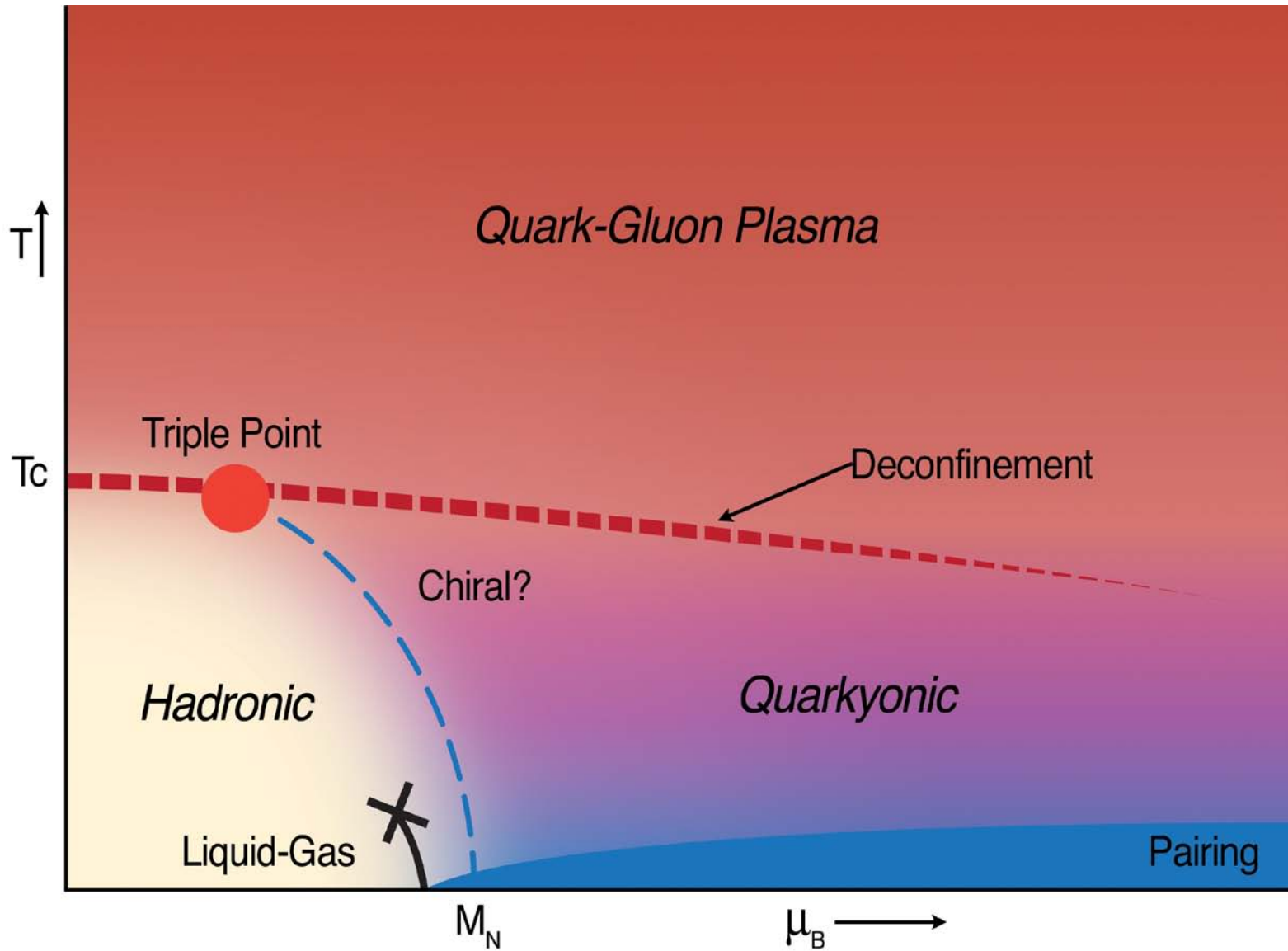
★ 25 A GeV

K^+/π^+ Ratio

S.Wheaton, et al.



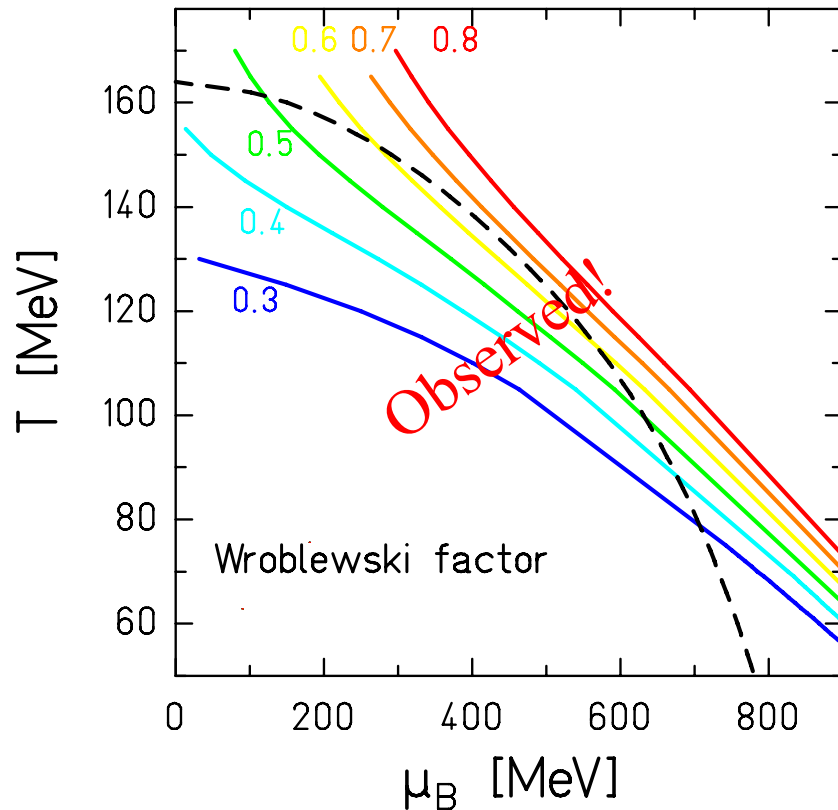




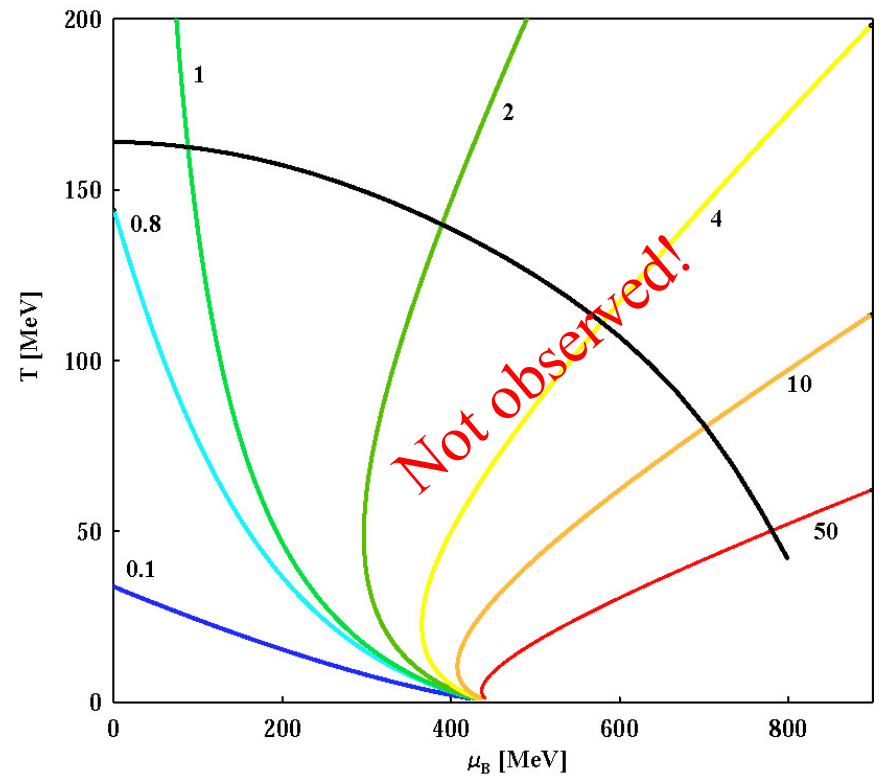
Publication in progress, results from the CPOD workshop at BNL

Strangeness Content

in a hadron gas



in a QGP



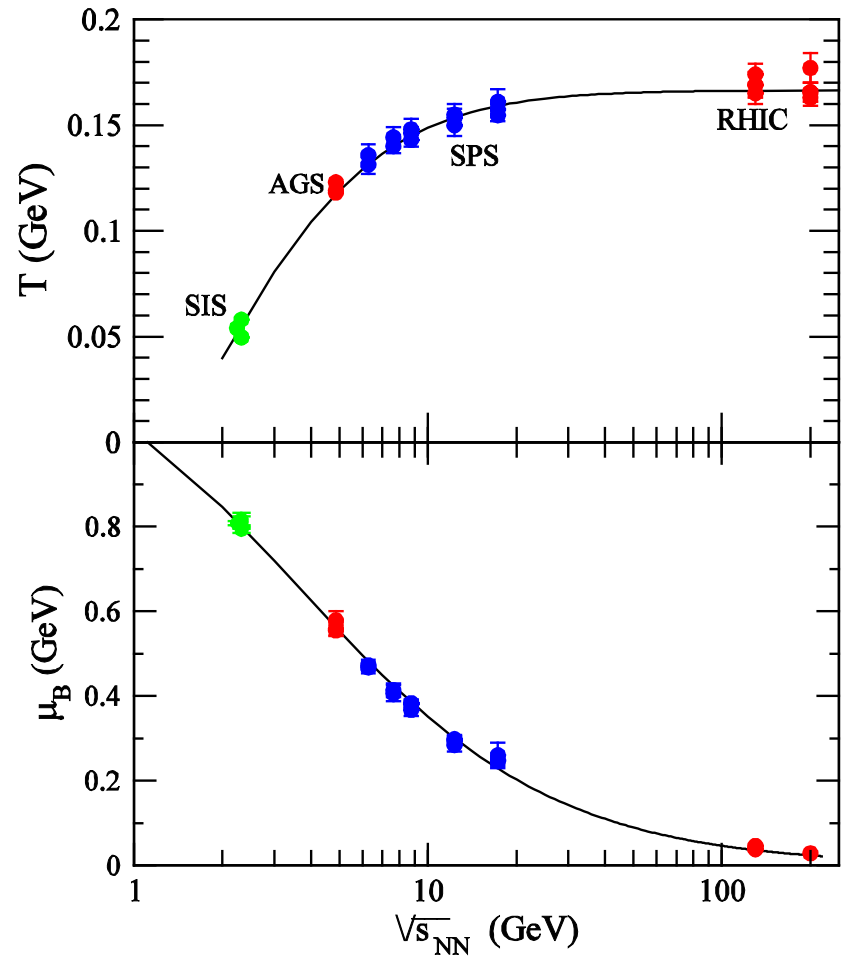
P. Braun-Munzinger, J. Cleymans,
HO, K. Redlich, NPA 697(2002) 902

A. Schmah et al., TU Darmstadt

$T - \mu_B$ – systematics

- Chemical decoupling conditions extracted from SIS up to RHIC feature common behavior
- parametrisation e.g. Nucl. Phys. A 697 (2002) 902

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



Canonical Suppression

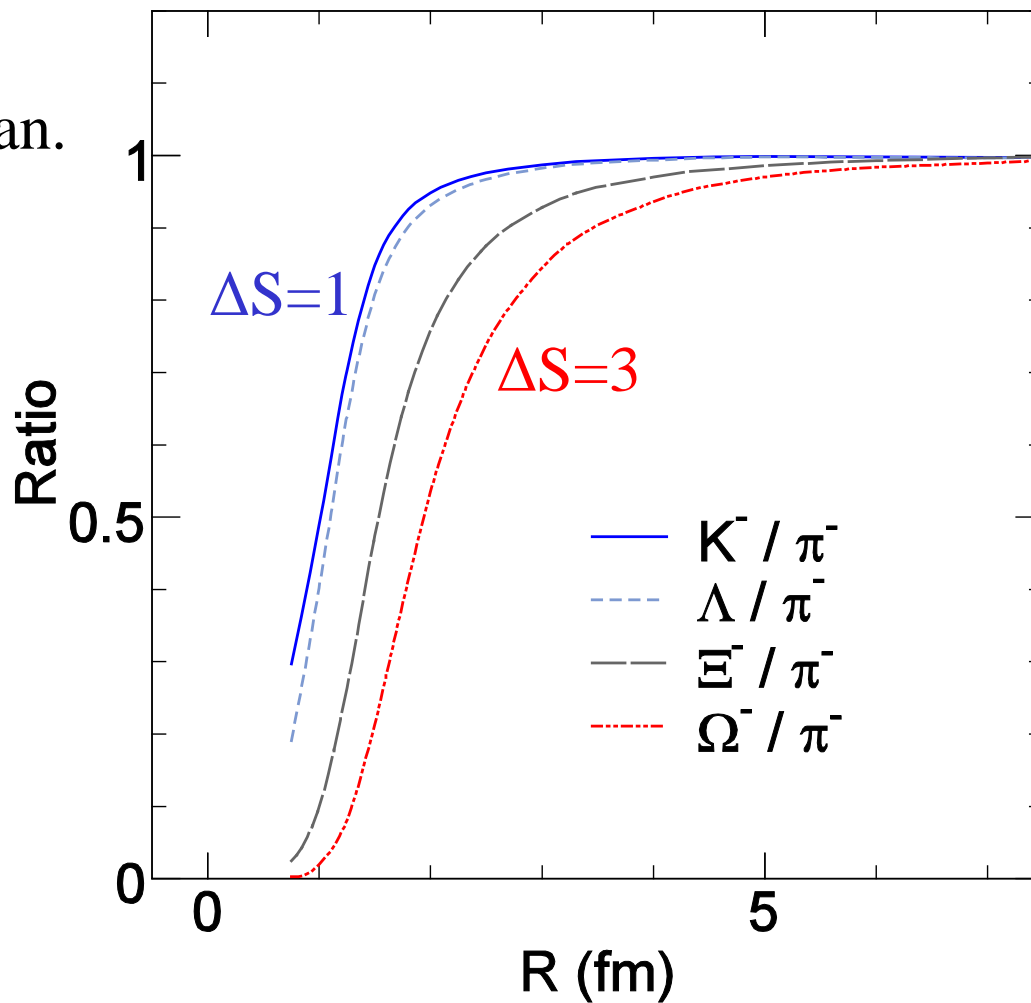
can./grand can.

Example:

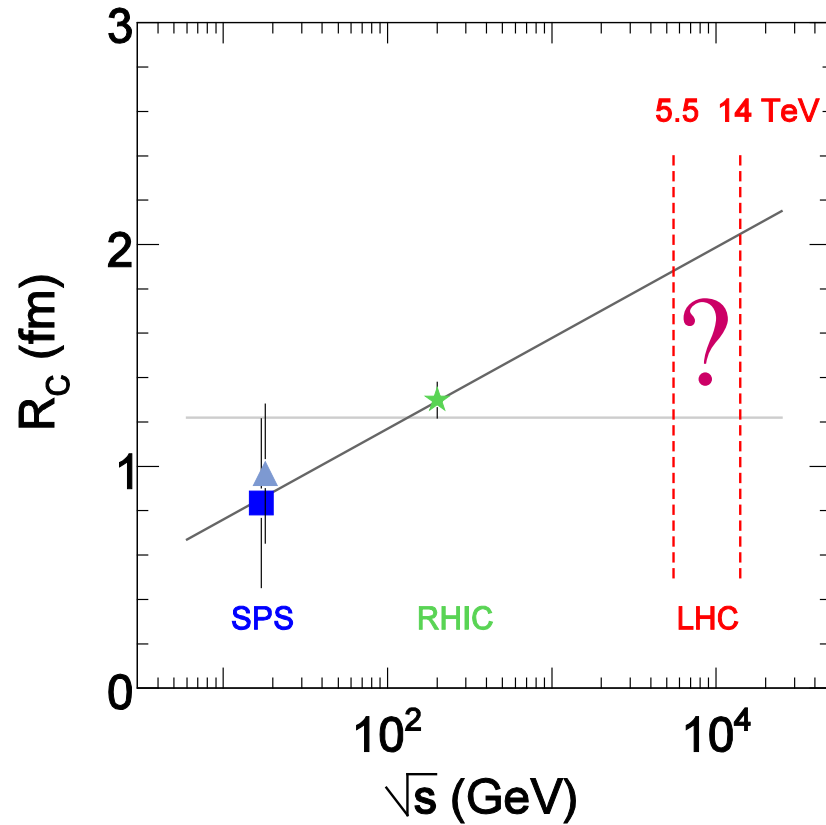
$T = 170 \text{ MeV}$

$\mu_B = 1 \text{ MeV}$

Values for LHC



Extrapolation to LHC for pp



Predictions for pp at LHC

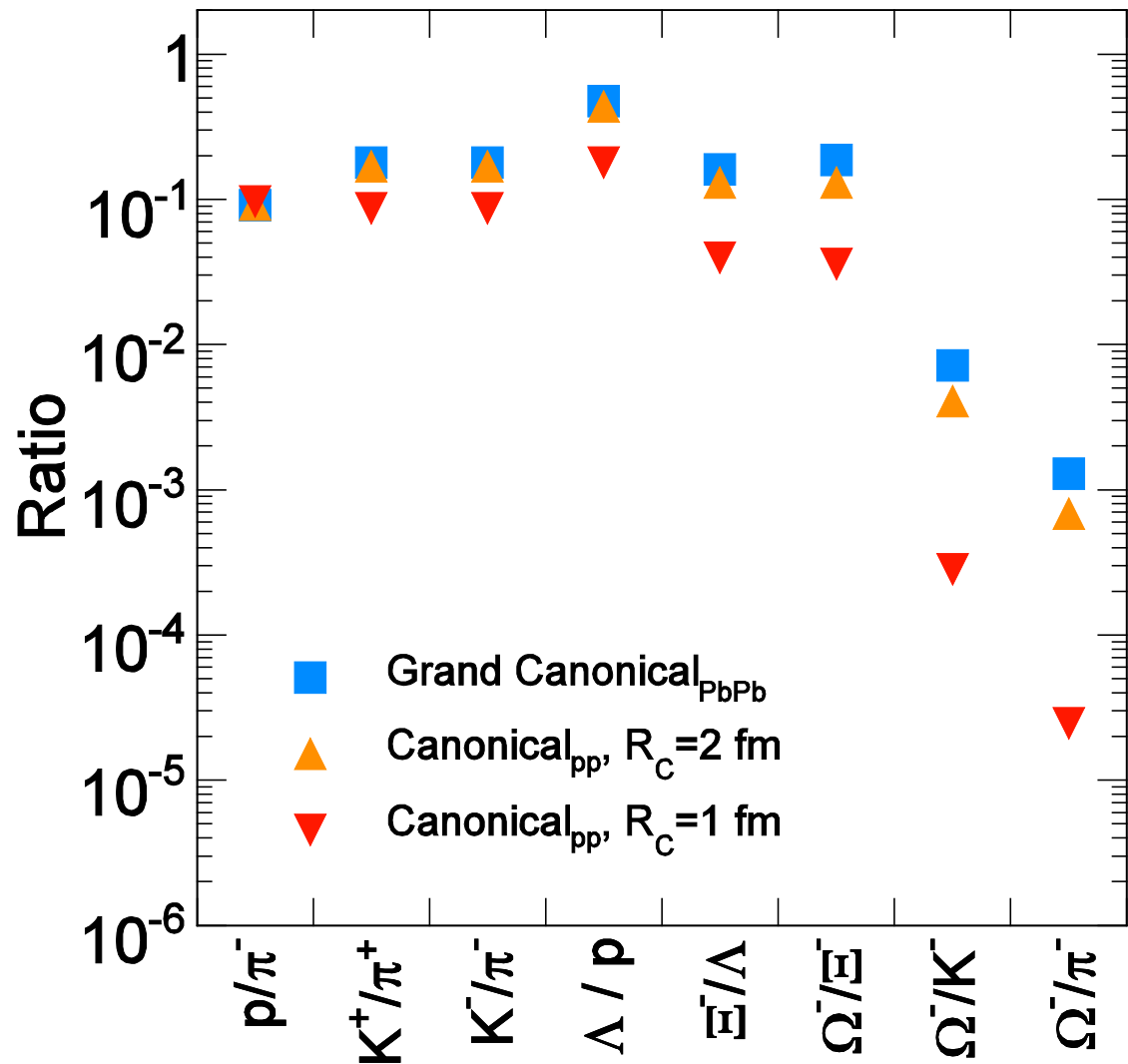
Prediction for
heavy ions:

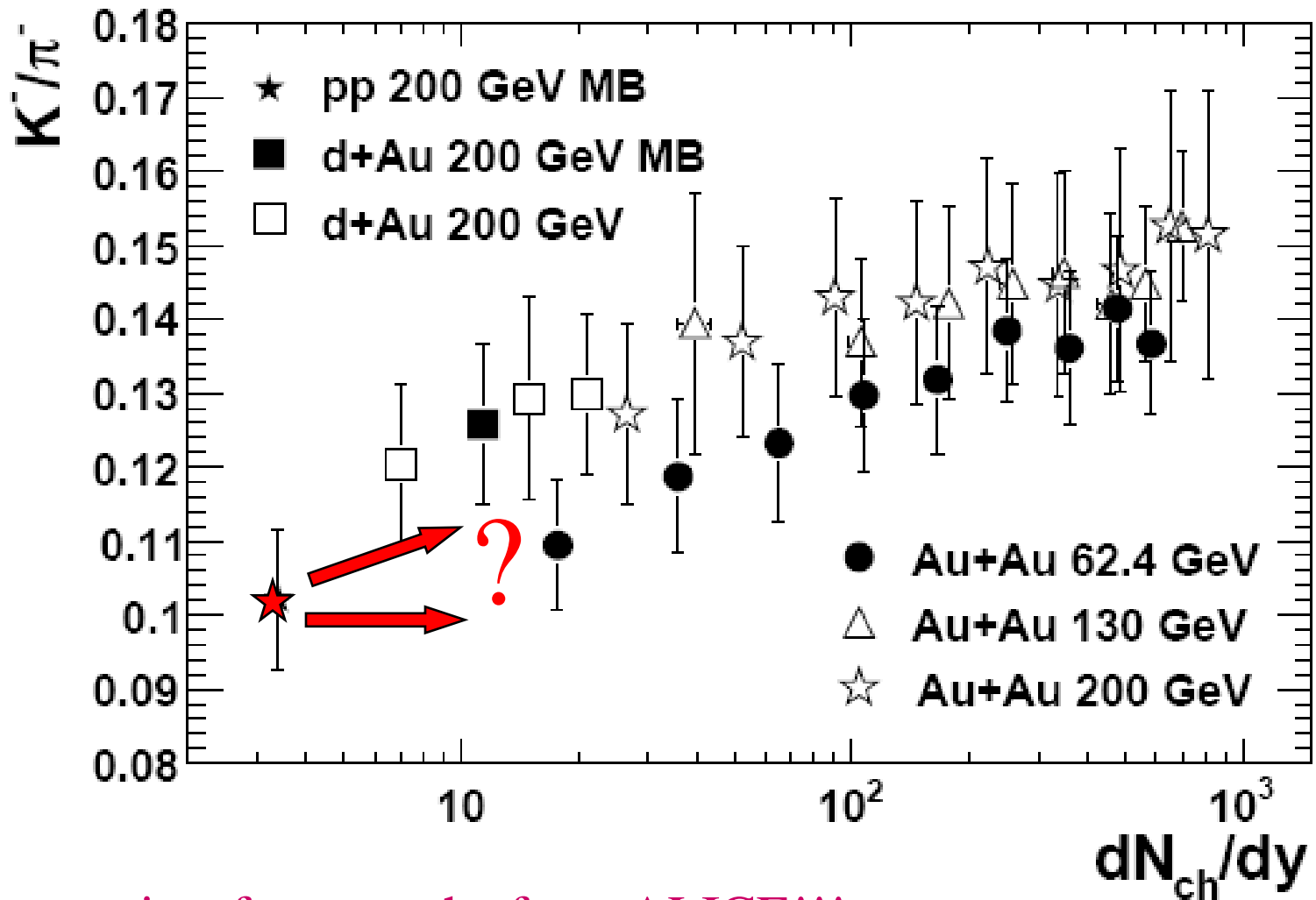
Grand can.

I. Kraus et al.,

PRC 74 (2007)

034903





Answer is a few months from ALICE!!!

STAR nucl-ex.0808.2041

Strangeness content seems to be determined by hadronic interactions
Quarks degrees of freedom ?

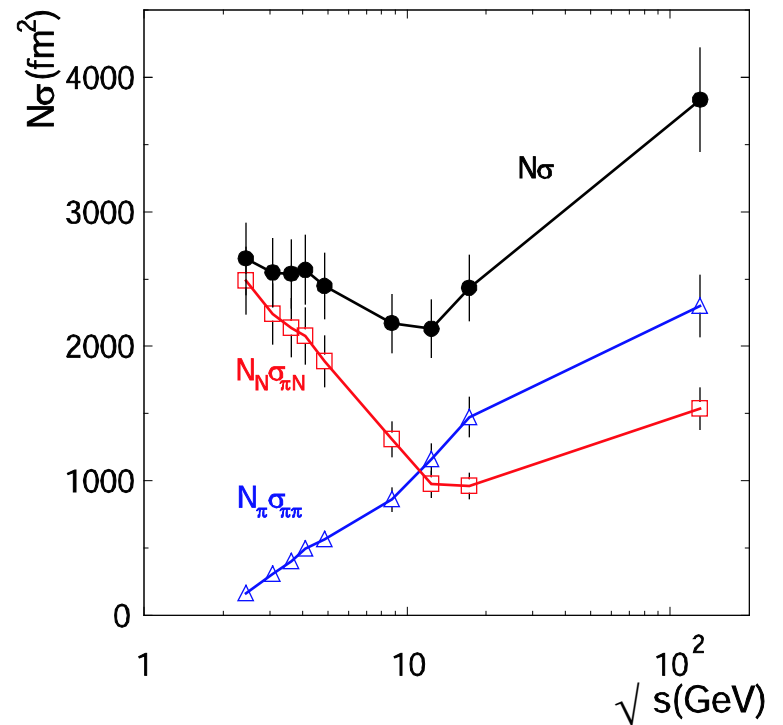
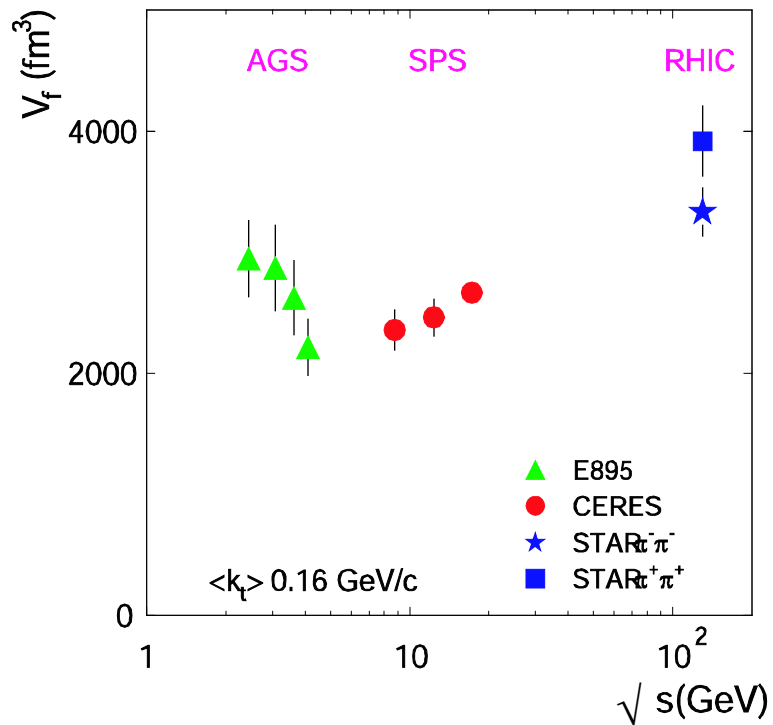
Maximum in Strangeness ~ 30 A GeV: ??

Understanding of hadronization processes!

pp at LHC: many particles created! Volume will become very big! Canonical suppression still valid? Production via jets will dominate!

Freeze-Out Volume from HBT

D. Adamova et al., CERES, PRL 90 (2003)

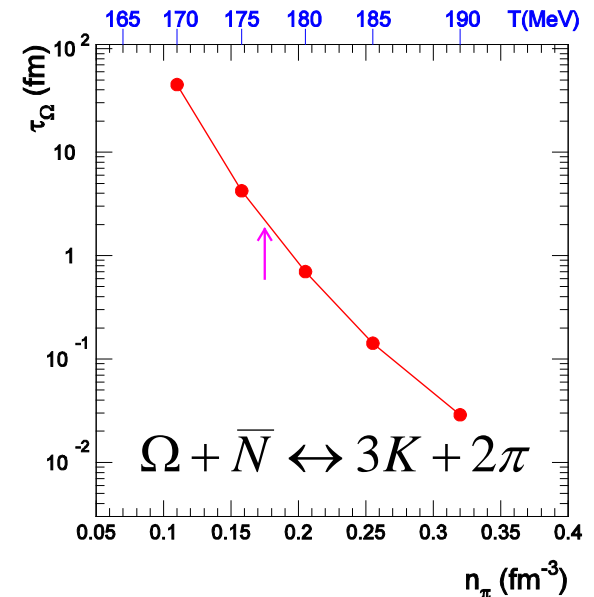


Summary

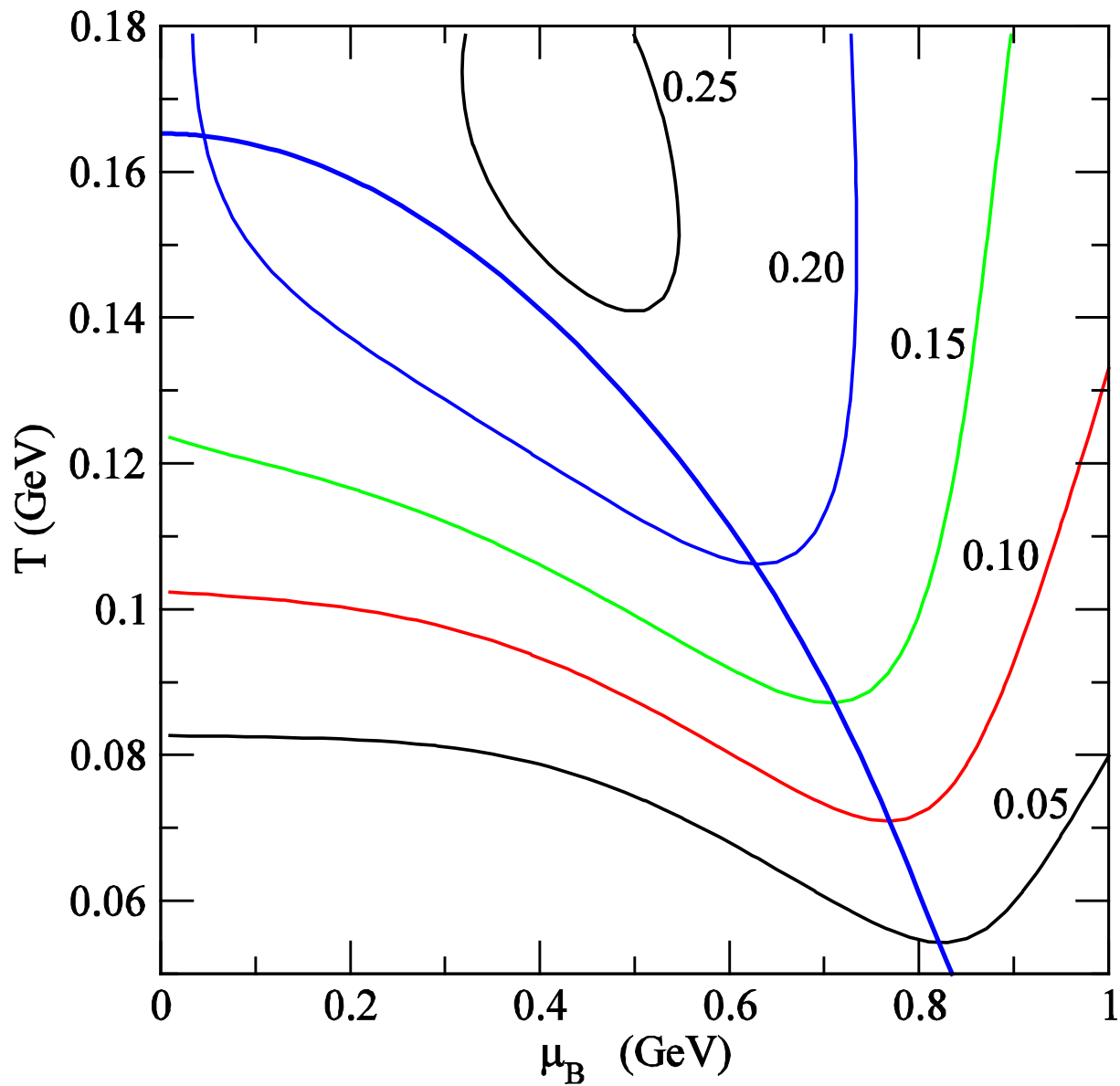
- Strangeness content seems to be determined by hadronic interactions
- Quarks degrees of freedom ?
- Maximum in Strangeness ~ 30 A GeV: ??
- pp at LHC: many particles created! Volume will become very big! Canonical suppression still valid? Production via jets will dominate!
- Understanding of **hadronization process!**

Hadronisation Process

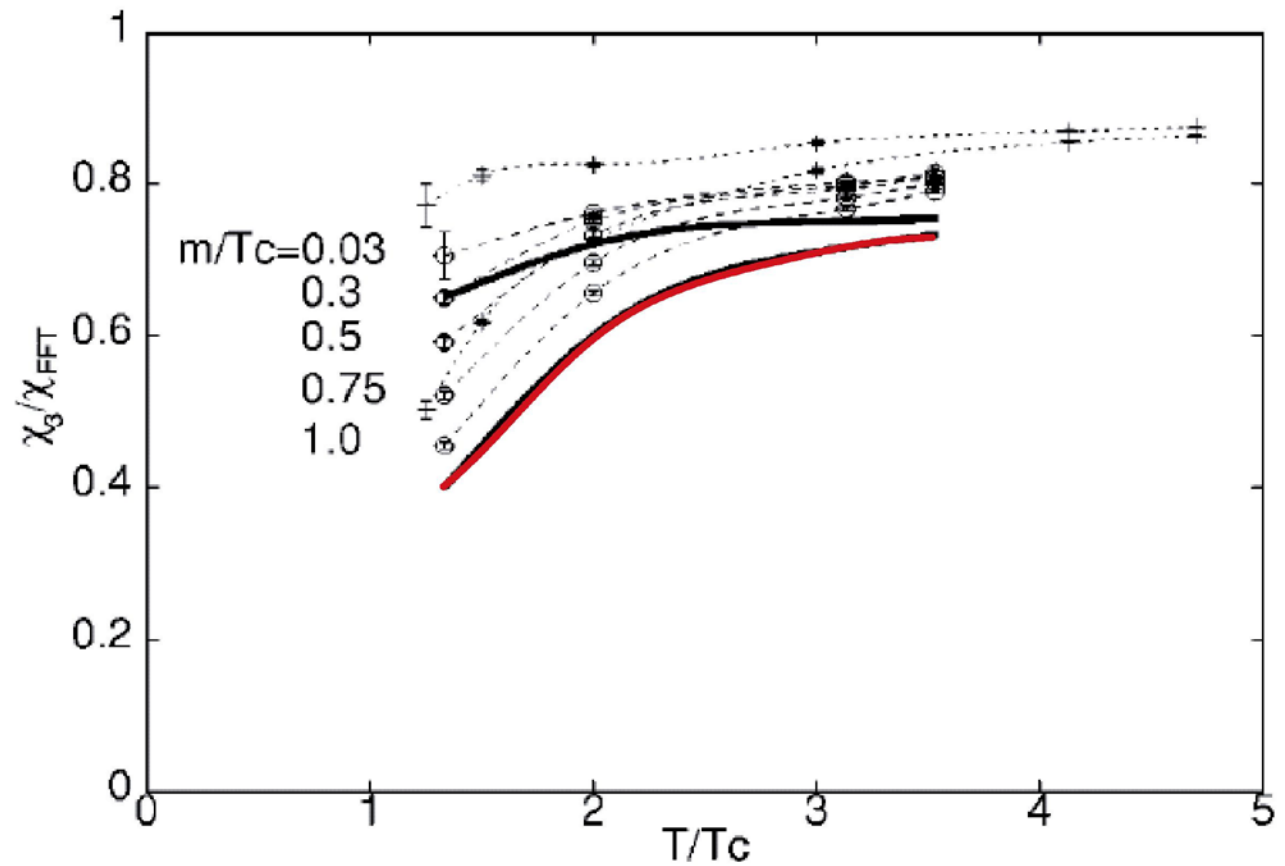
- "Born into equilibrium"
 - R. Stock, Phys. Lett. B 456 (1999) 277
 - hadron production according to phase space
 - no dynamics
- Fast thermalisation due to multi-hadron collisions
 - P. Braun-Munzinger, J. Stachel, Chr. Wetterich, Phys.Lett. B596 (2004) 61
 - C. Greiner J. Phys. G27 (2001) L95



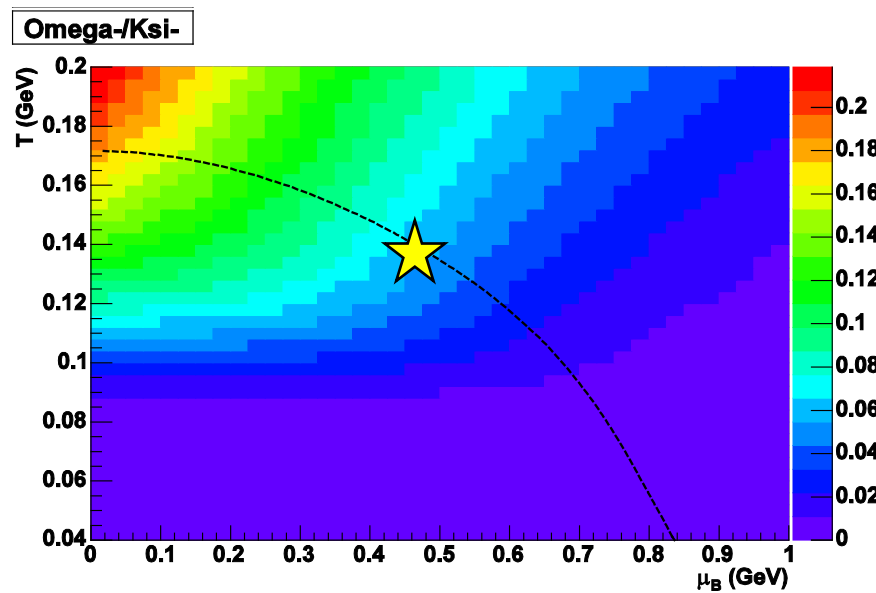
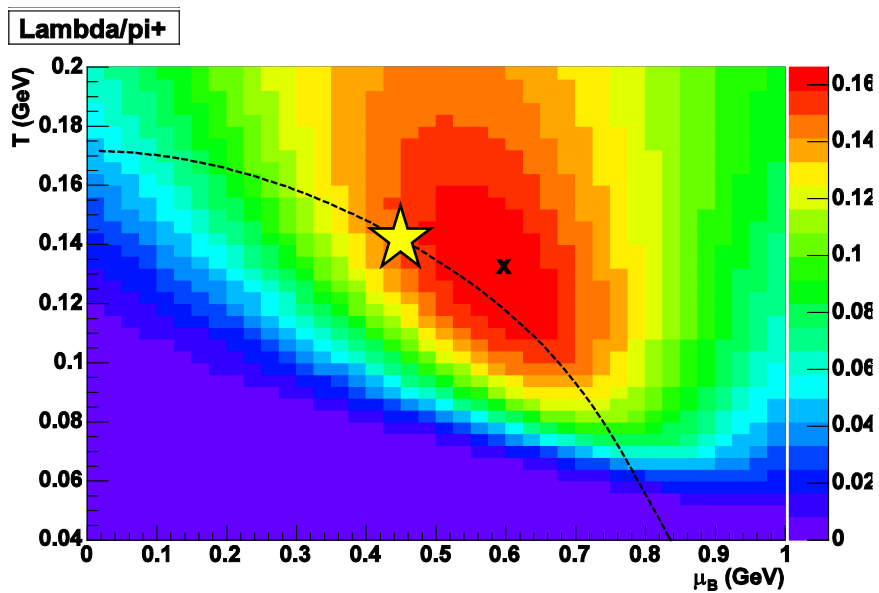
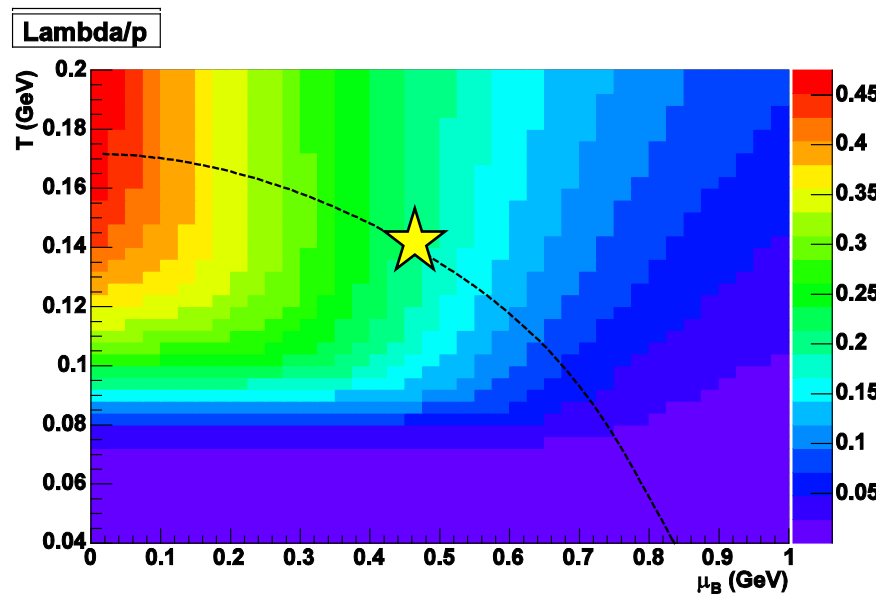
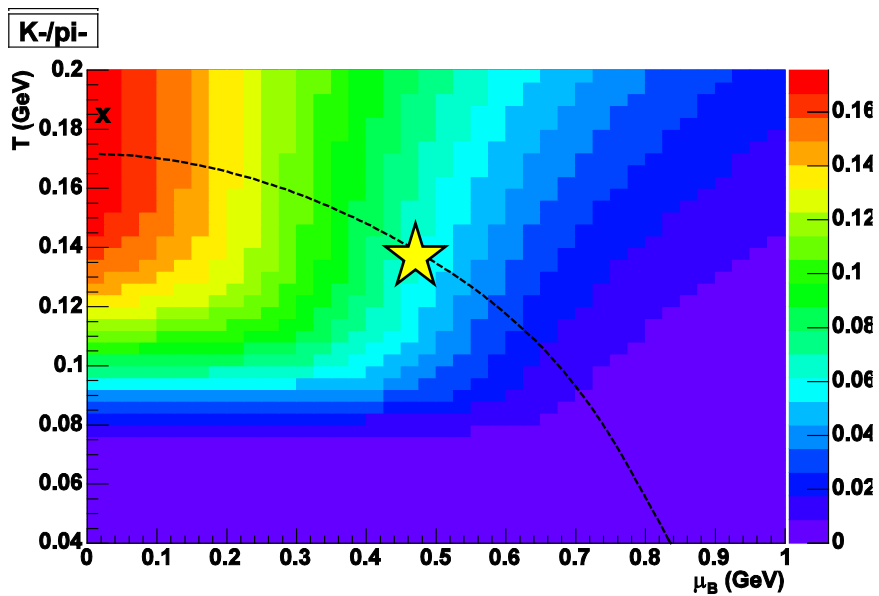
K^+/π^+ Ratio



$$\lambda_s \sim \chi_s/\chi_u$$



★ 25 A GeV



S. Wheaton et al., to appear

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Helmut Oeschler

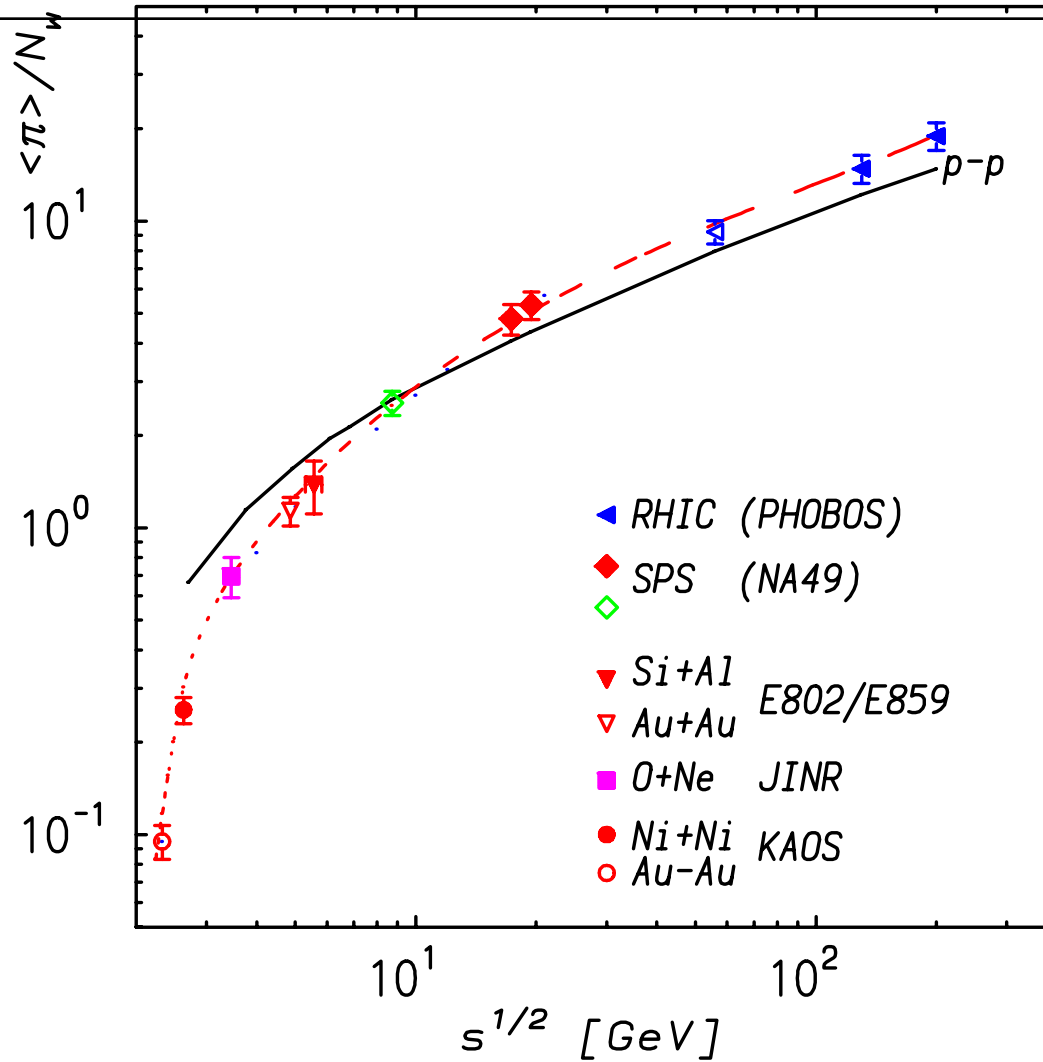
Darmstadt University of Technology

Etretat, le 16 Septembre 2009

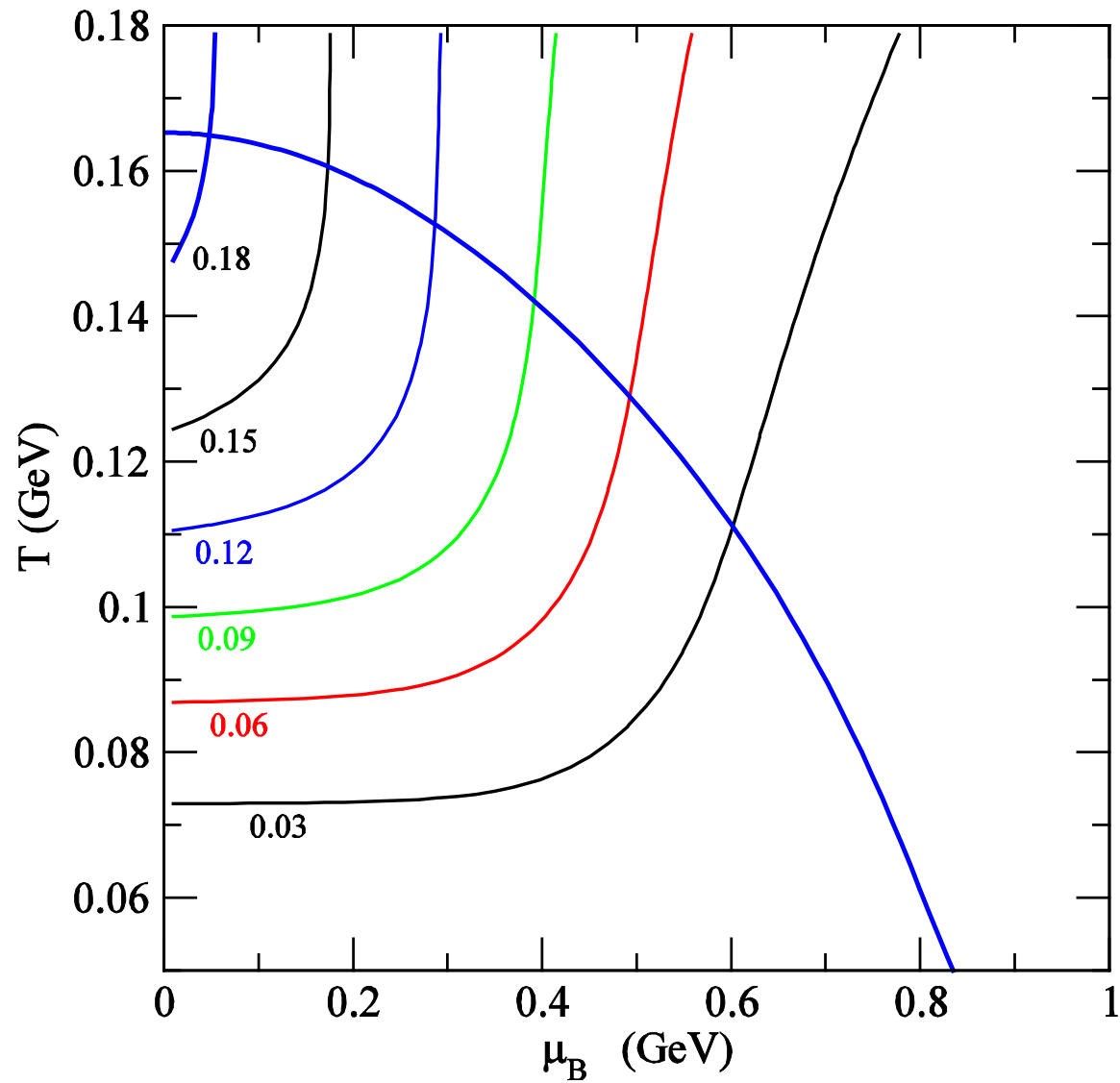
Final conclusion

Problems worthy of attack,
prove their worth by hitting back!

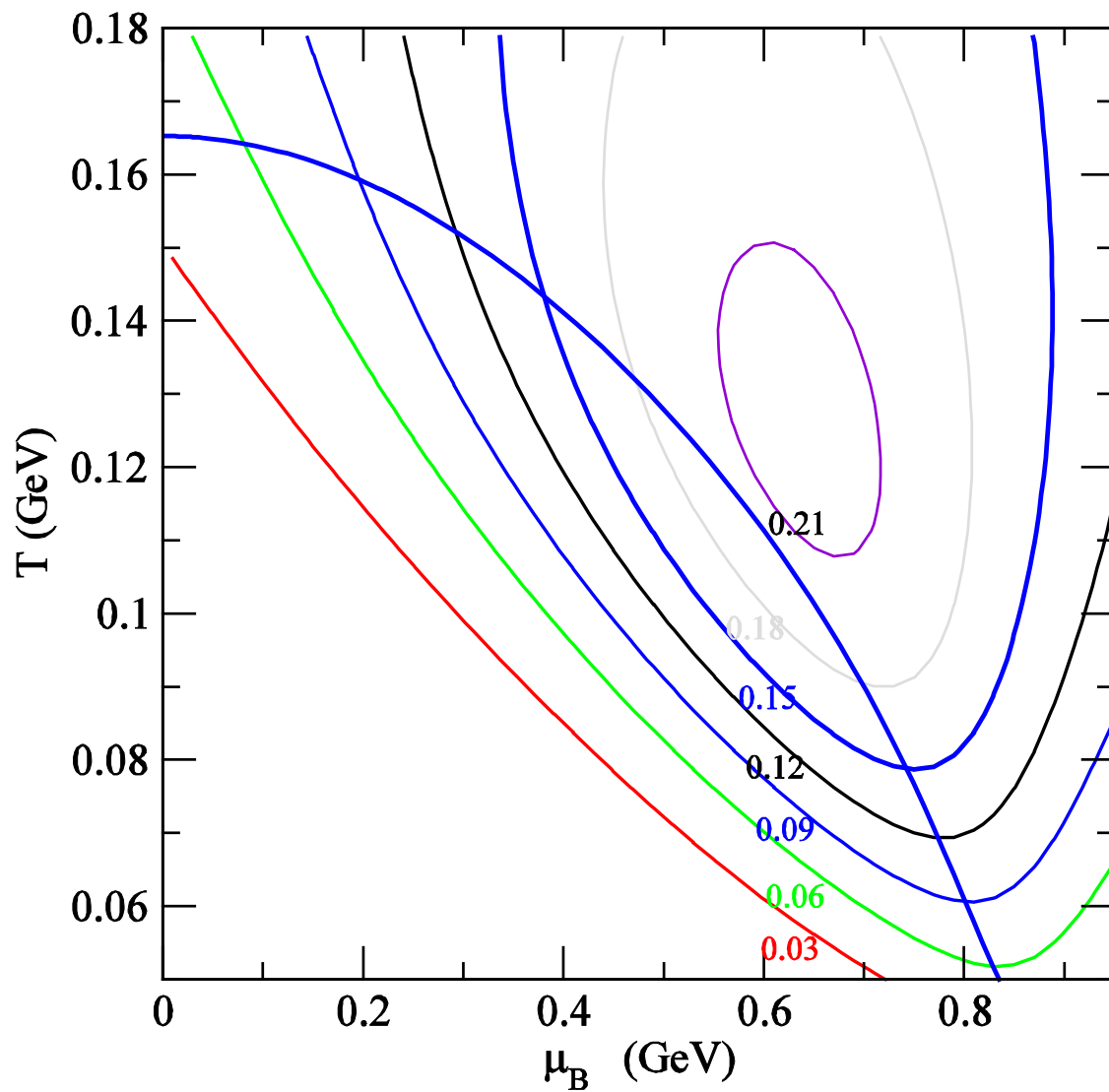
Pion Multiplicity



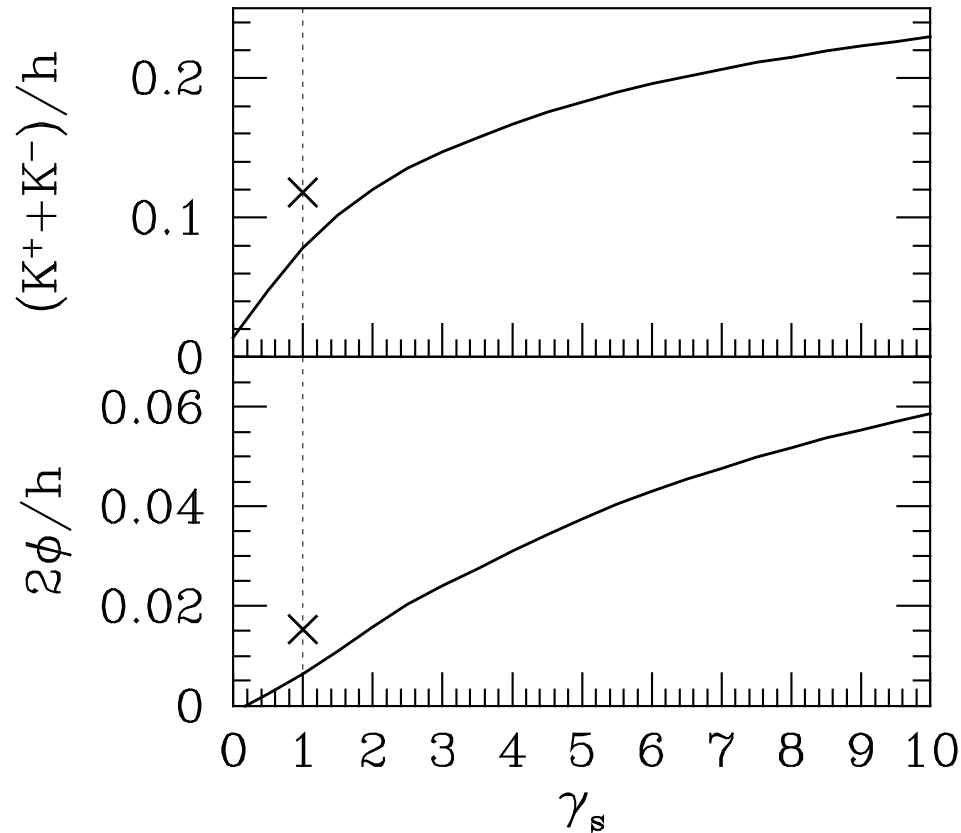
K^-/π^+ Ratio



Λ/π^+ Ratio



Strangeness enhancement at LHC?

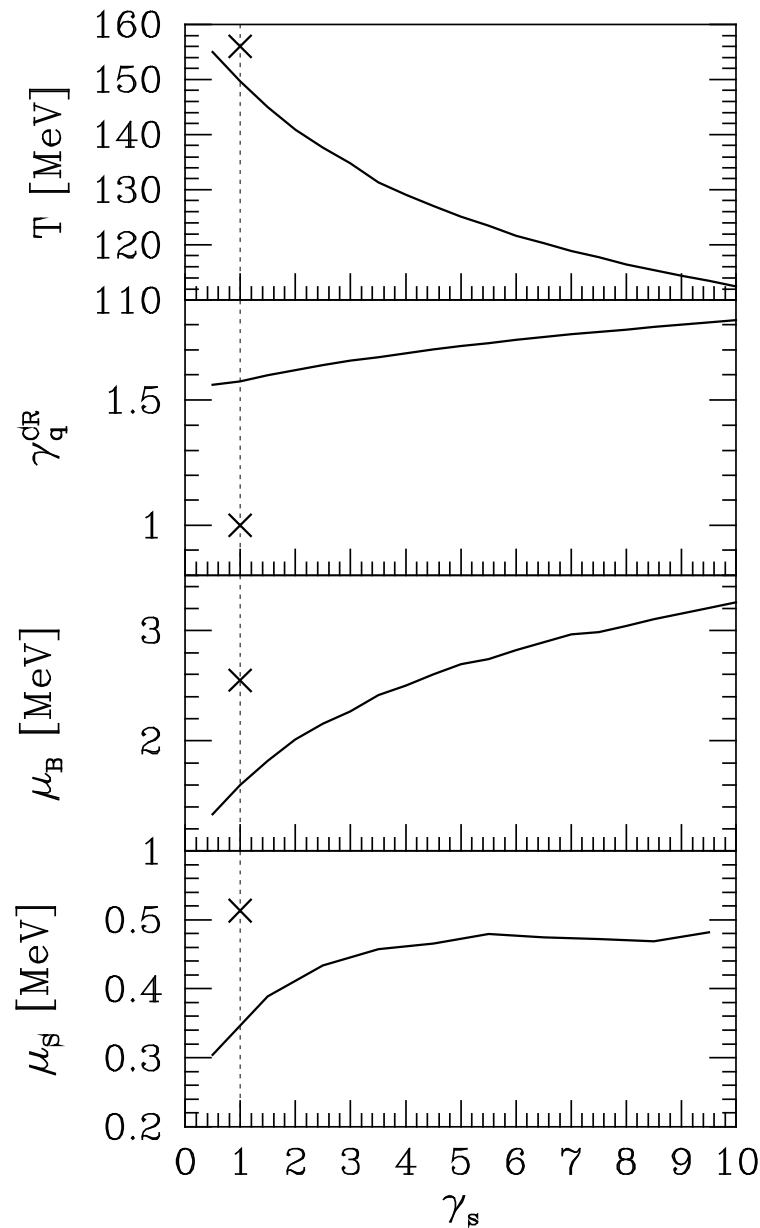


LHC:

γ_s is
expected
to be
around 3 -5

J. Rafelski and J. Letessier, Eur. Phys. J. C45 (2006)

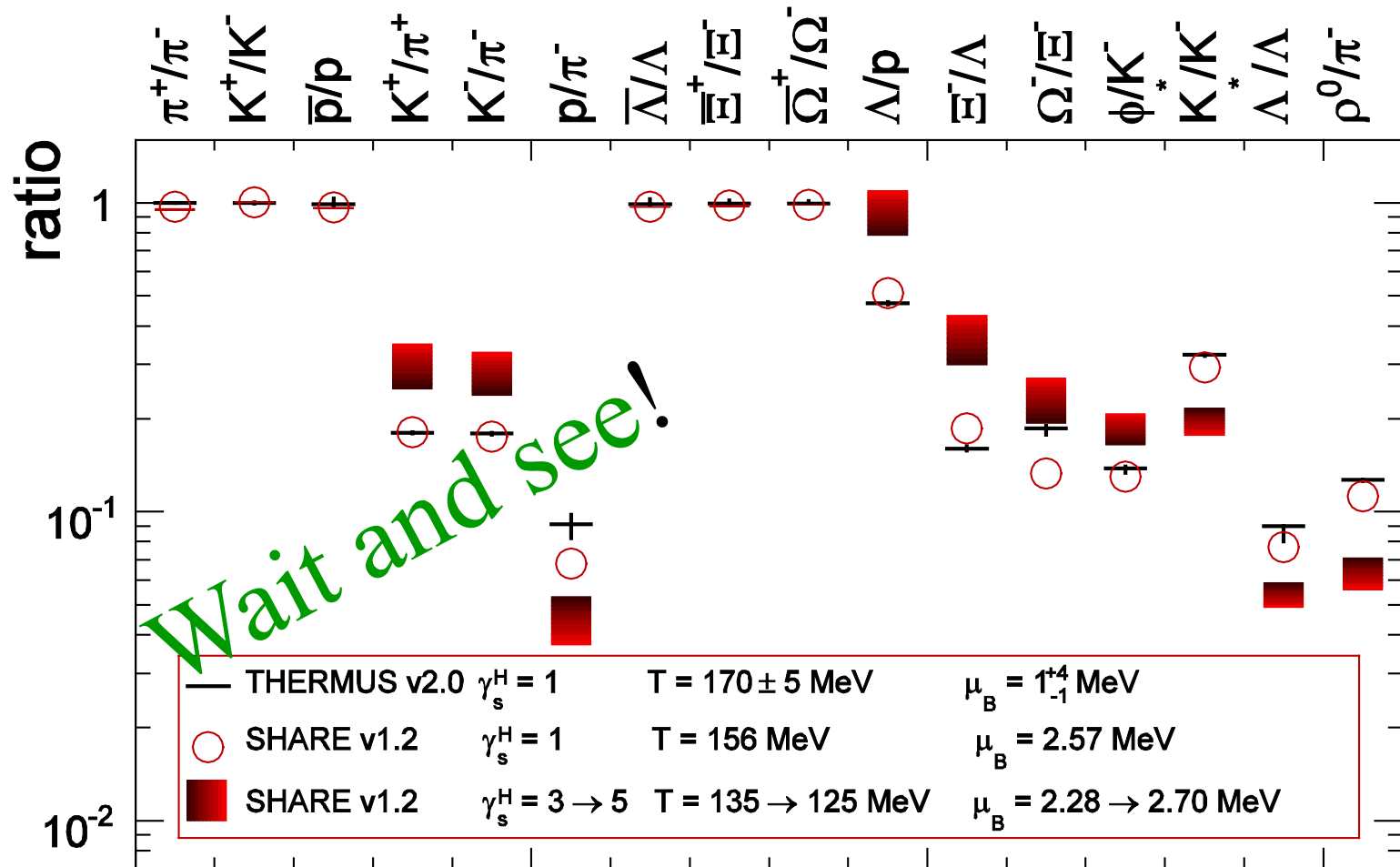
J. Rafelski and J. Letessier,
Eur. Phys. J. C45 (2006)



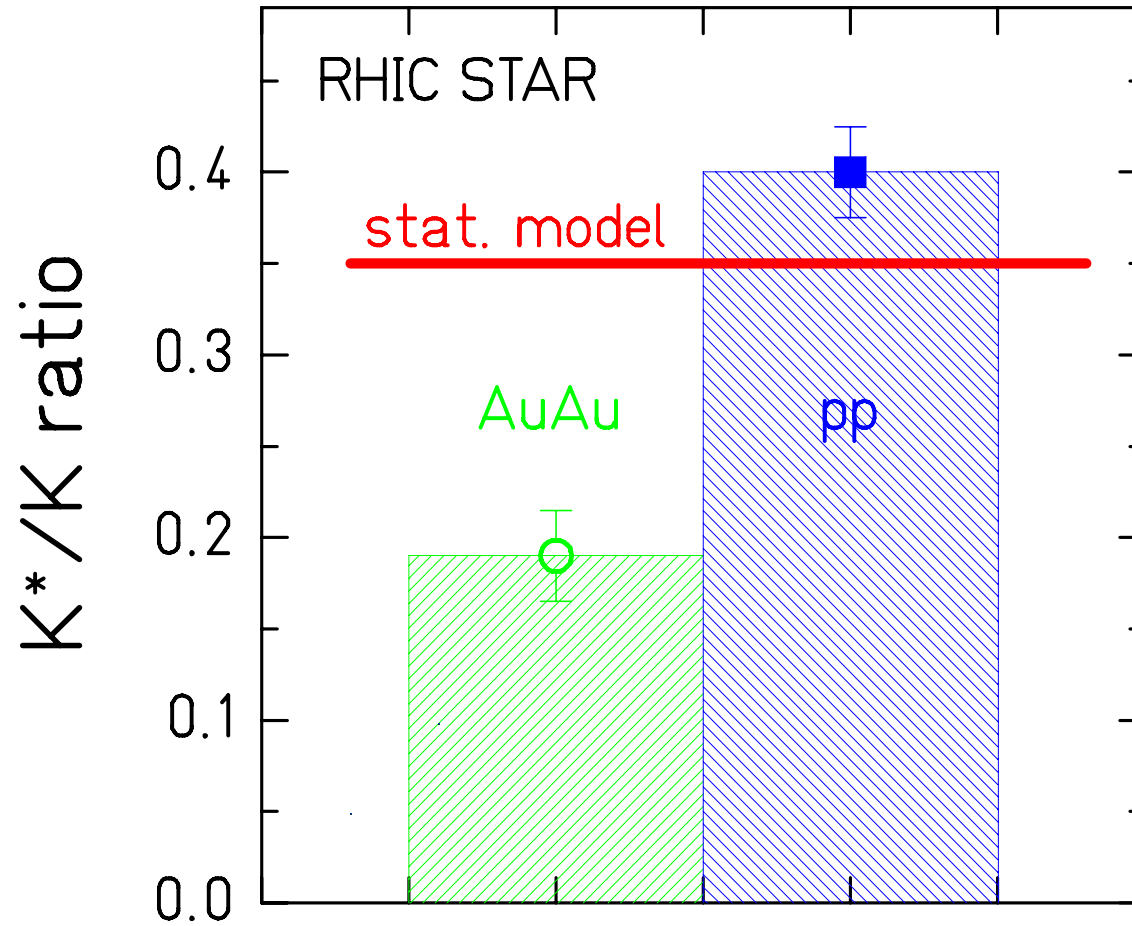
Attention:

T decreases with
increasing γ_s

ALICE Estimates : Equilibrium vs Non Eq. particle ratios



K^*/K at RHIC



Statistical Model for low T

KaoS Data: M. Mang et al.

Pions/ A_{part} constant

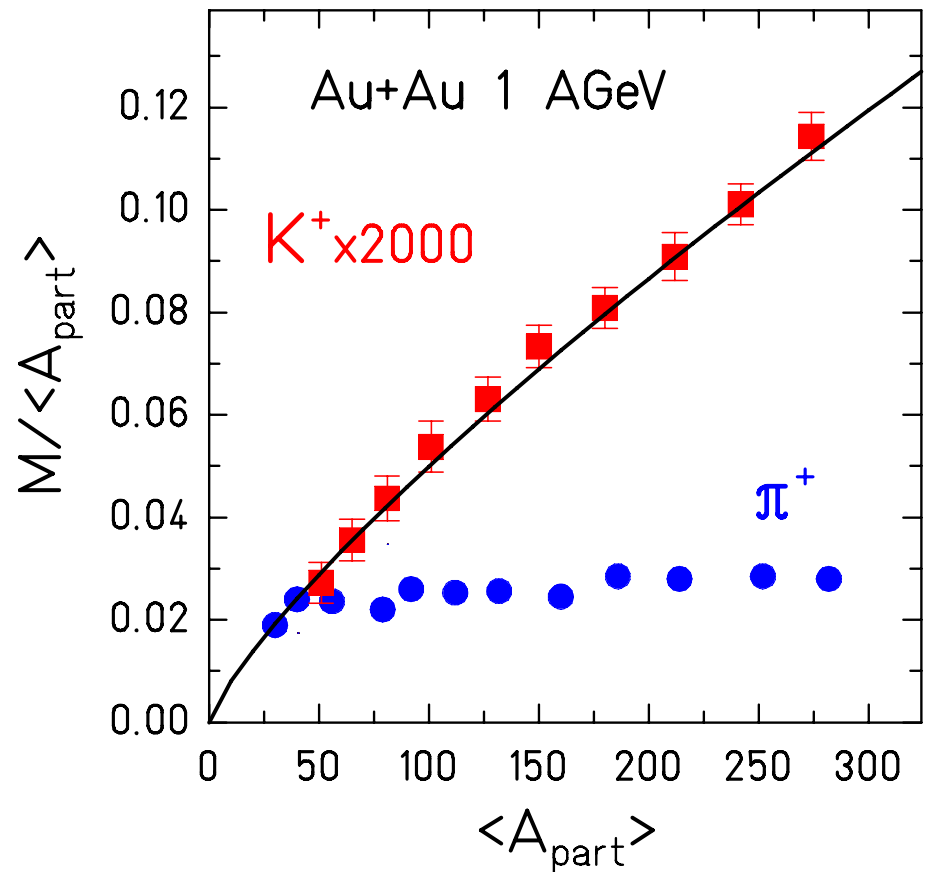
grand-canonical!

Kaons/ A_{part} rising

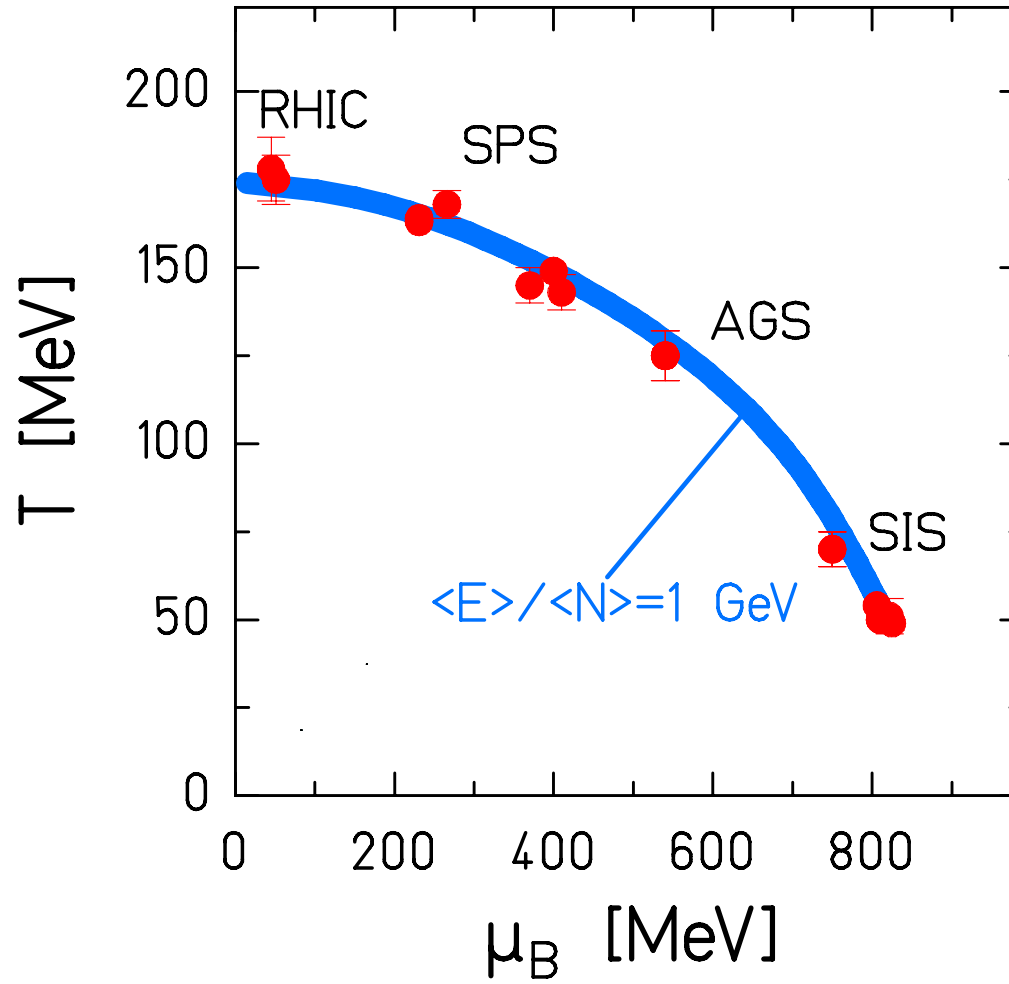
▾ canonical!

J. Cleymans, HO, K. Redlich,

PRC 60 (1999)

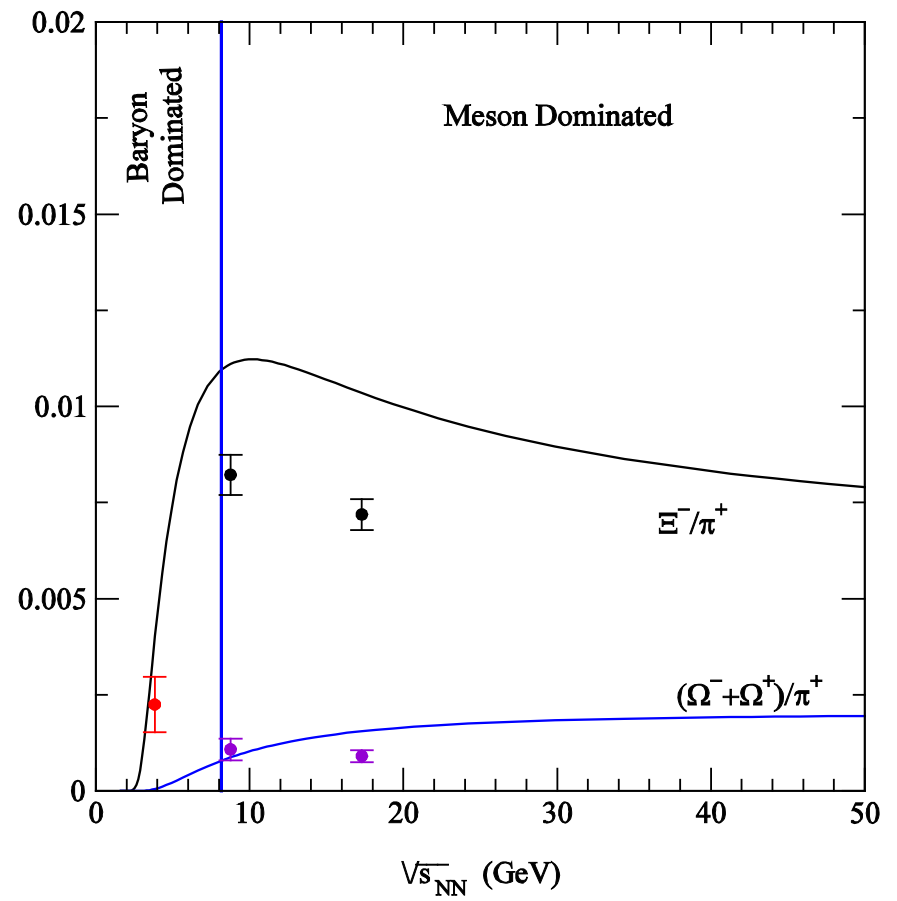
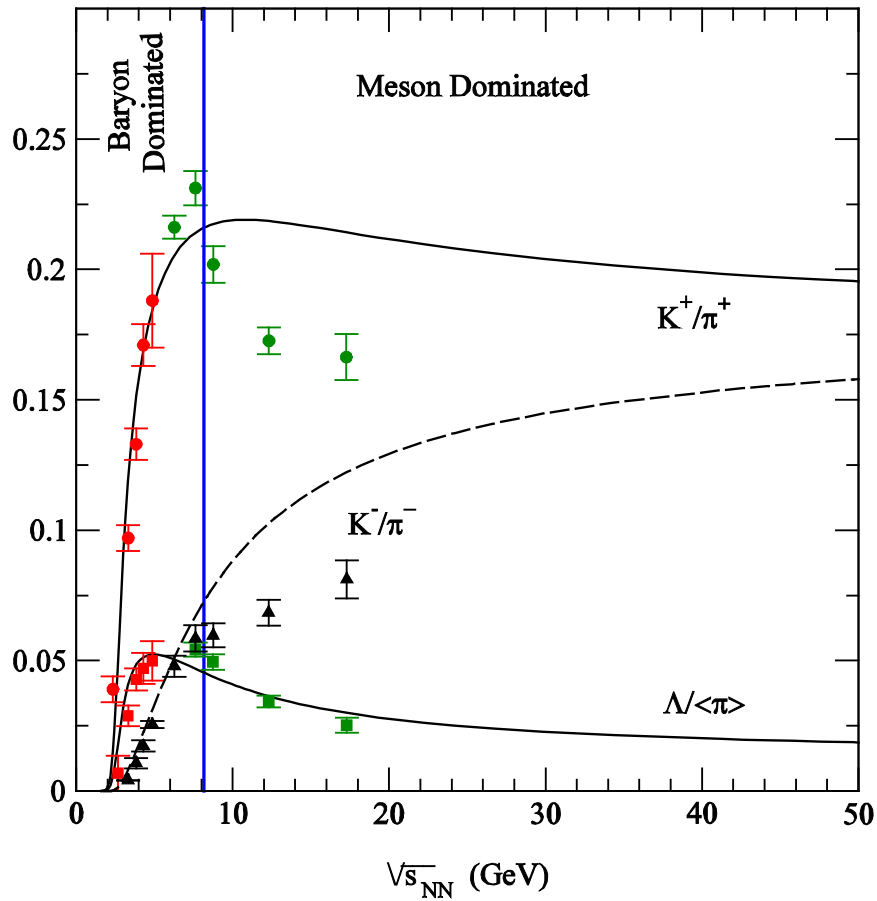


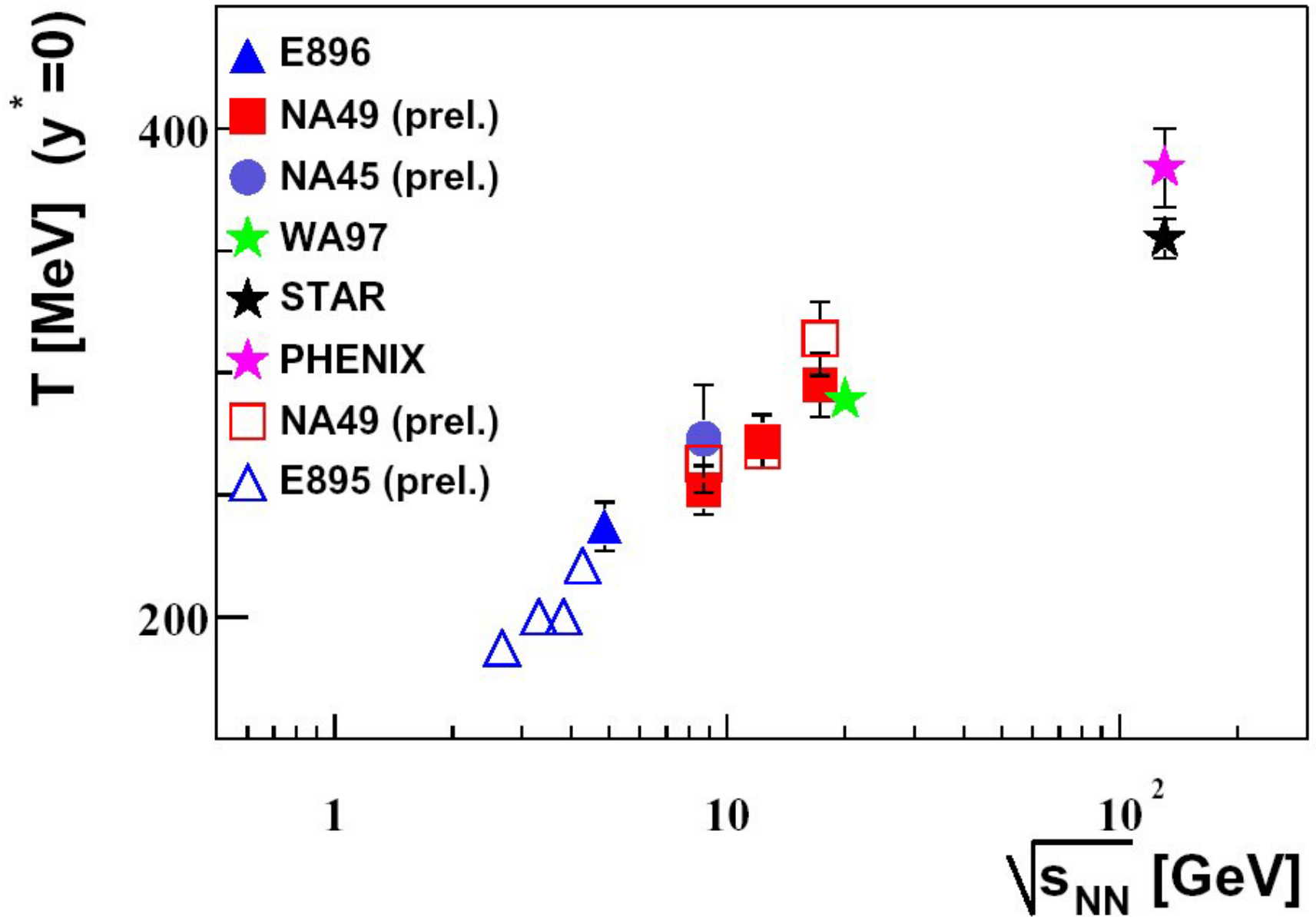
Chemical Freeze Out



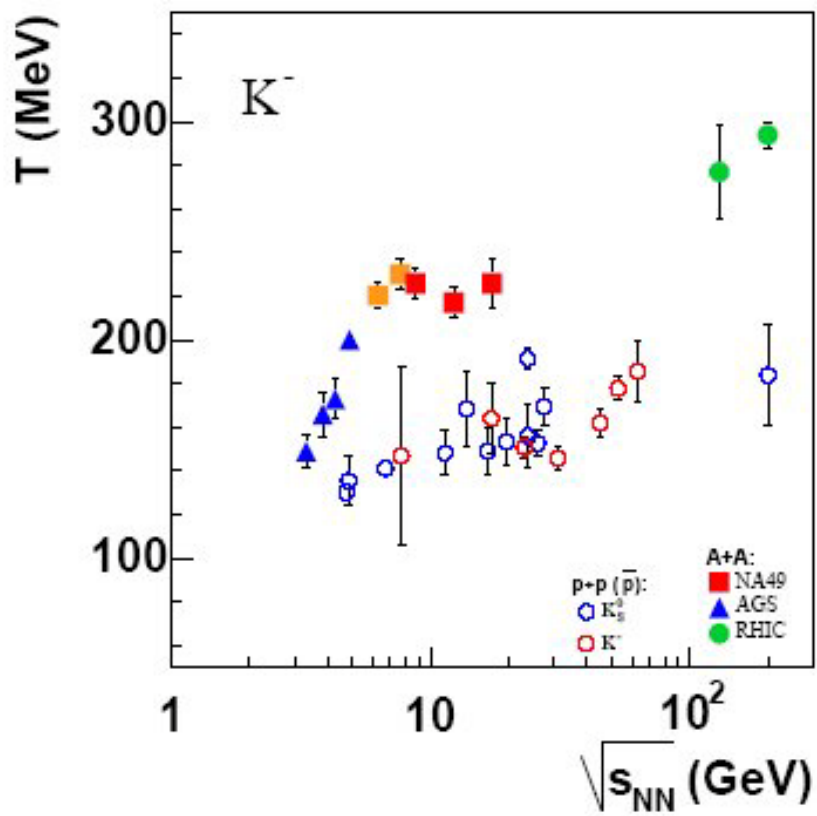
J. Cleymans and K. Redlich, PRL 81 (1998) 5284

Transition

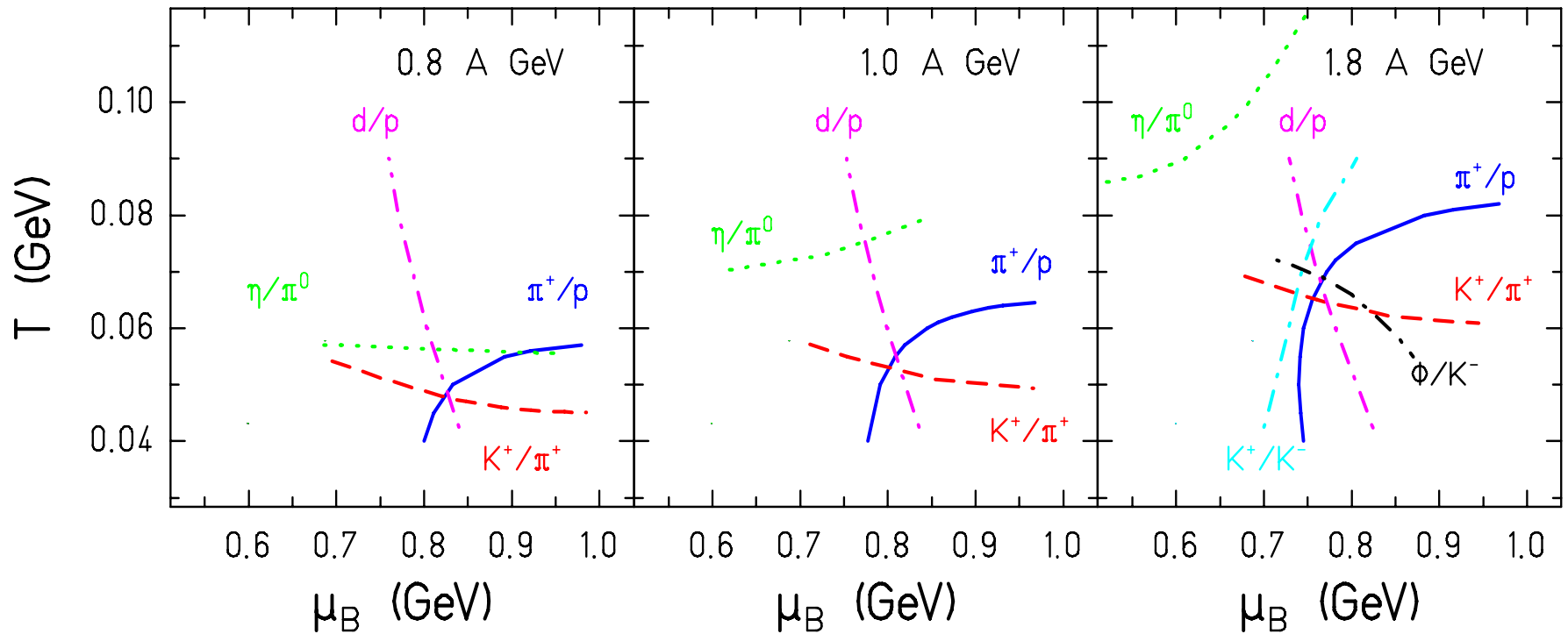




A. Mischke, Ph.D. thesis

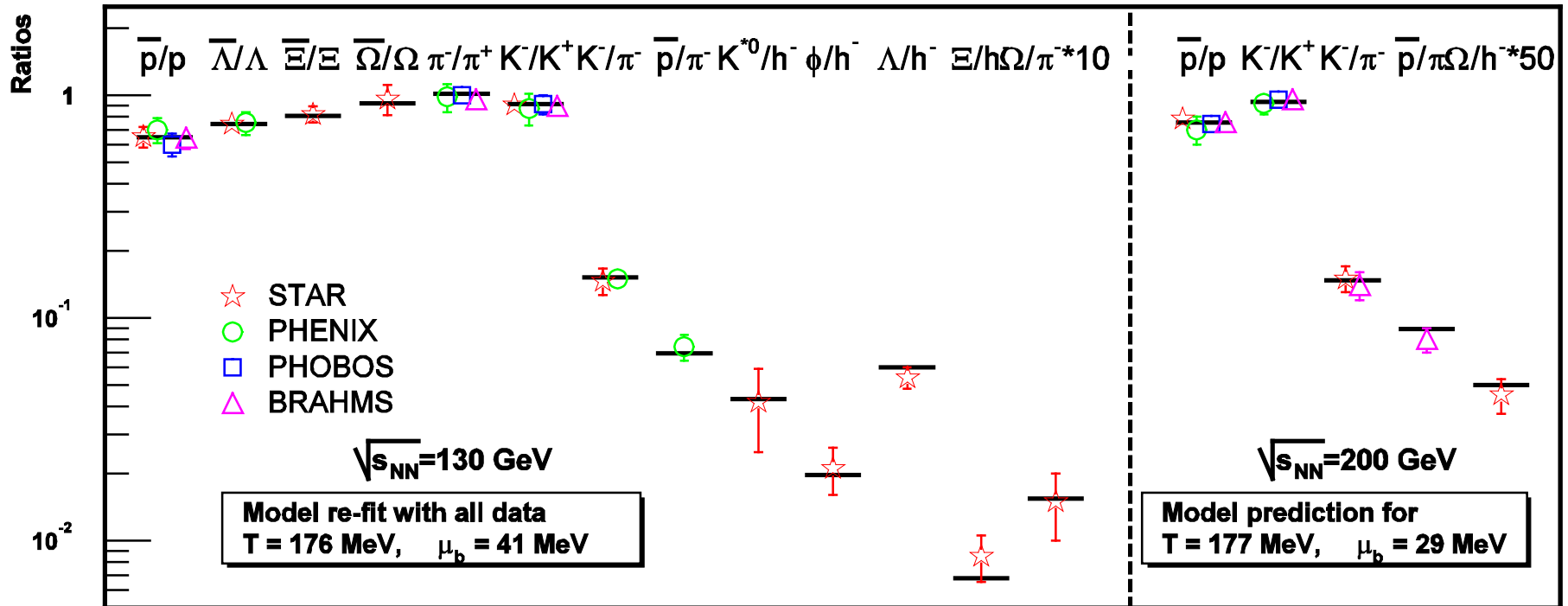


Statistical Model for SIS



J. Cleymans, H. O., K. Redlich, PRC 59 (1999)

Statistical Model

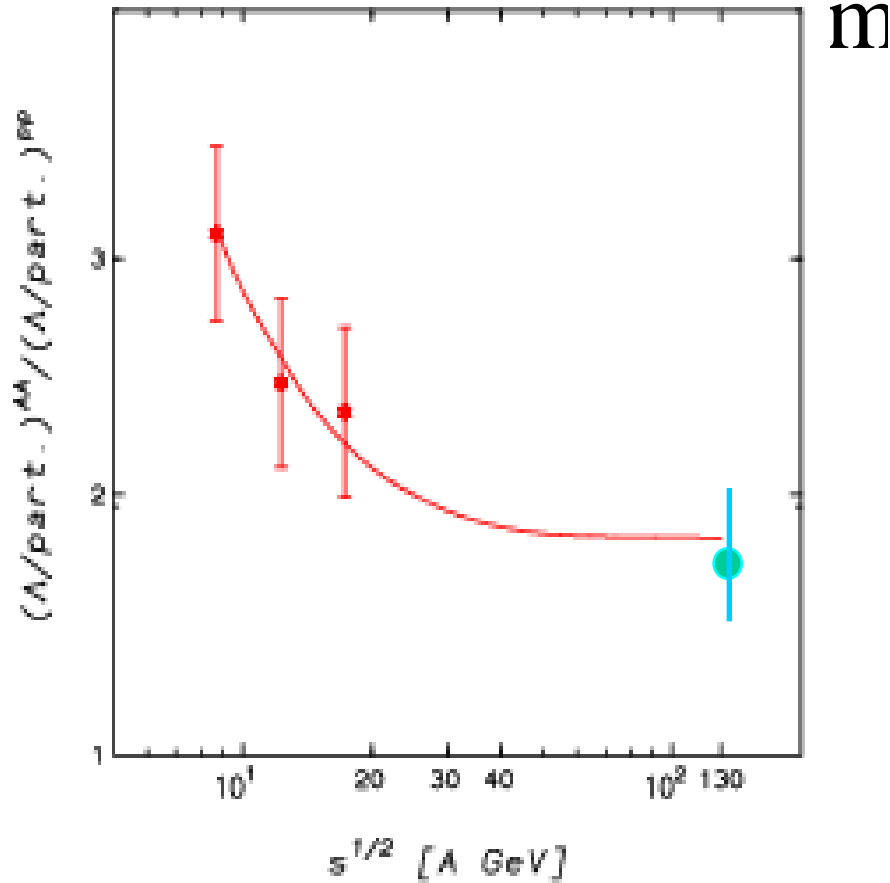


P. Braun-Munzinger, D. Magestro, K. Redlich, J. Stachel, PL B518 (2001) updated

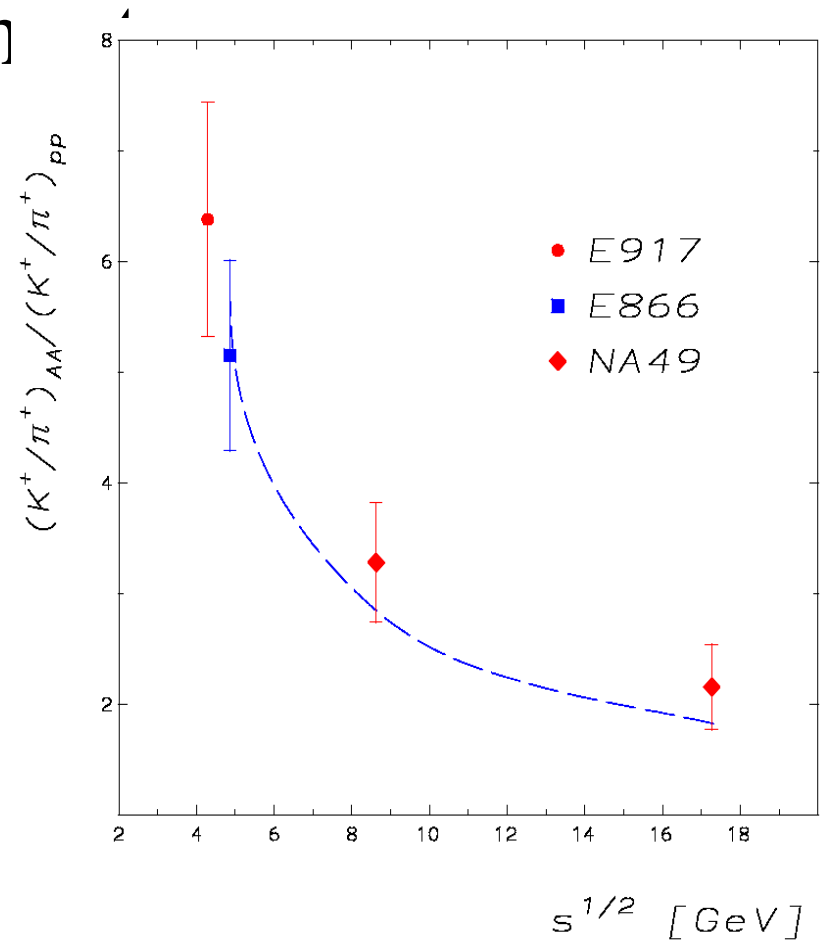
Energy

dependence of strangeness

A. Mishke, A. Tounsi & K.R

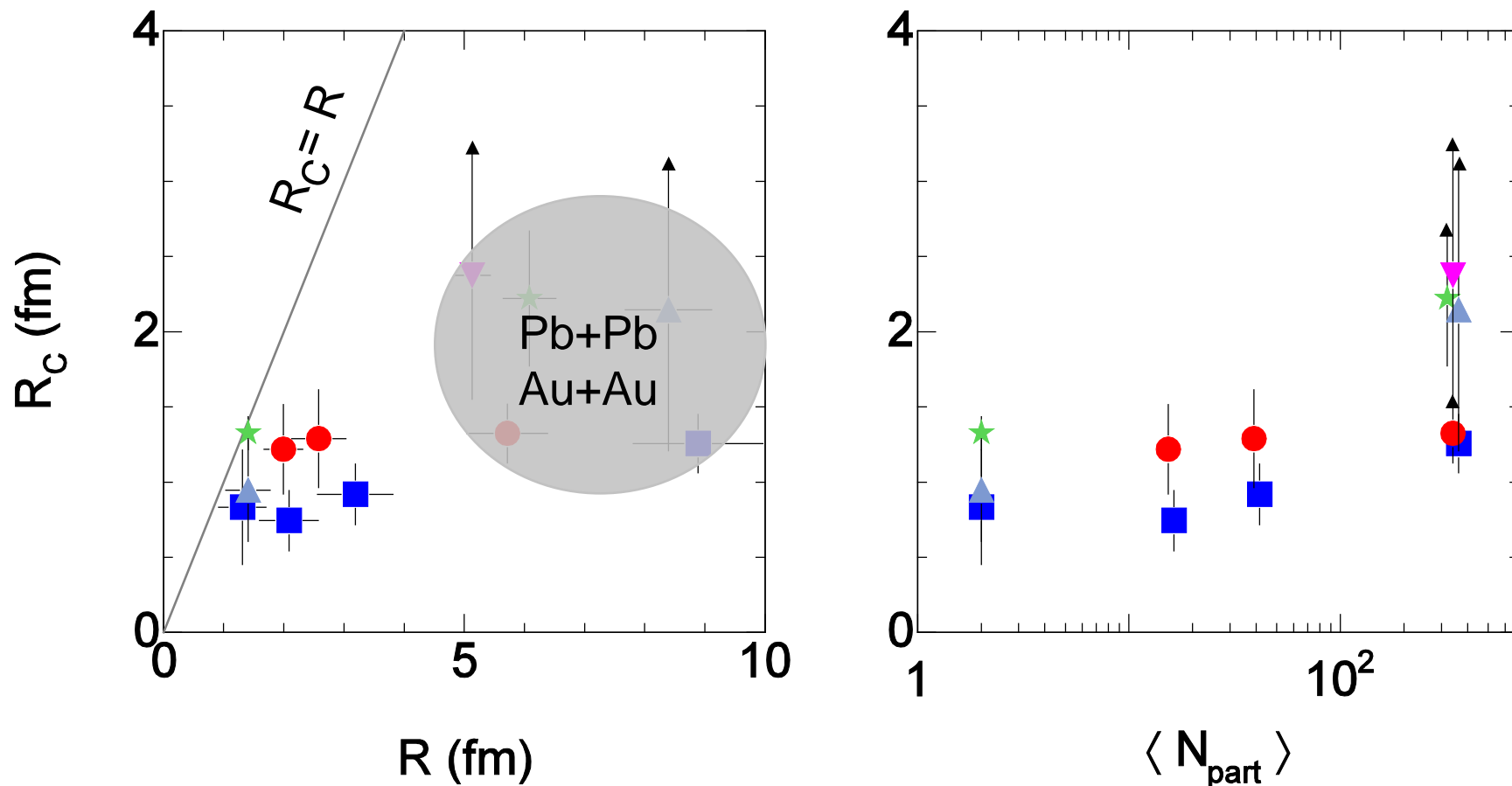


m



Strangeness enhancement
larger for lower energy

System size (and energy dep.) of cluster size



- A+A: clusters smaller than fireball
- R_C not well defined for $R_C \geq 2$ fm because suppression vanishes

Statistical Model

