Strangeness with CBM

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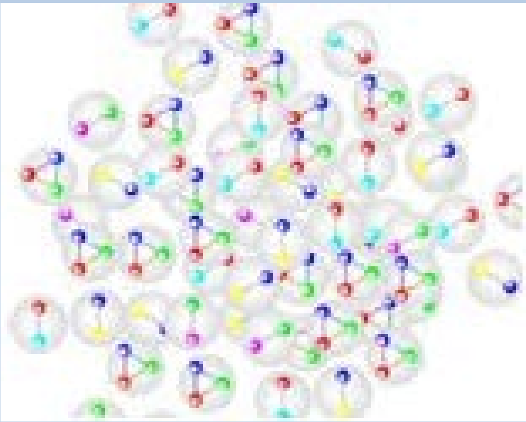
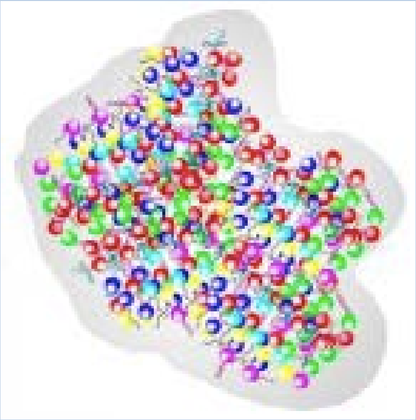
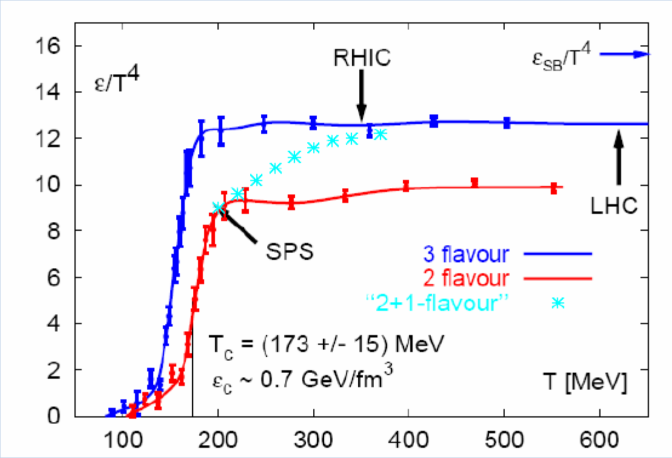
What is all about



confined matter: hadrons



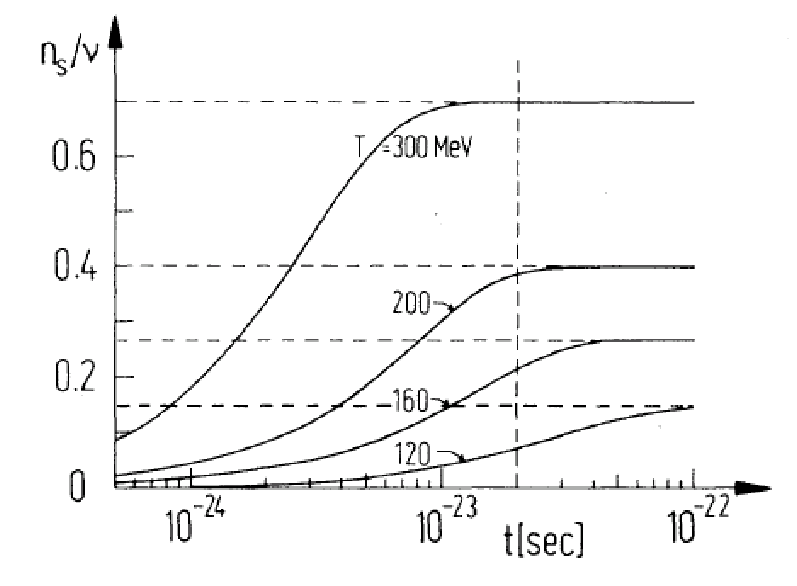
deconfined matter: quarks and gluons



Lattice QCD: phase transition at critical energy density ε_c / critical temperature T_c

Why strangeness is interesting

- No strangeness in entrance channel (nucleons): strangeness is produced in the reaction
- Hadronic production (e. g. p+p -> KΛp): $m_K \approx 500$ MeV >> T_H
- Partonic production (e.g. g + g -> s sbar): $m_s \approx 100$ MeV <= T_H



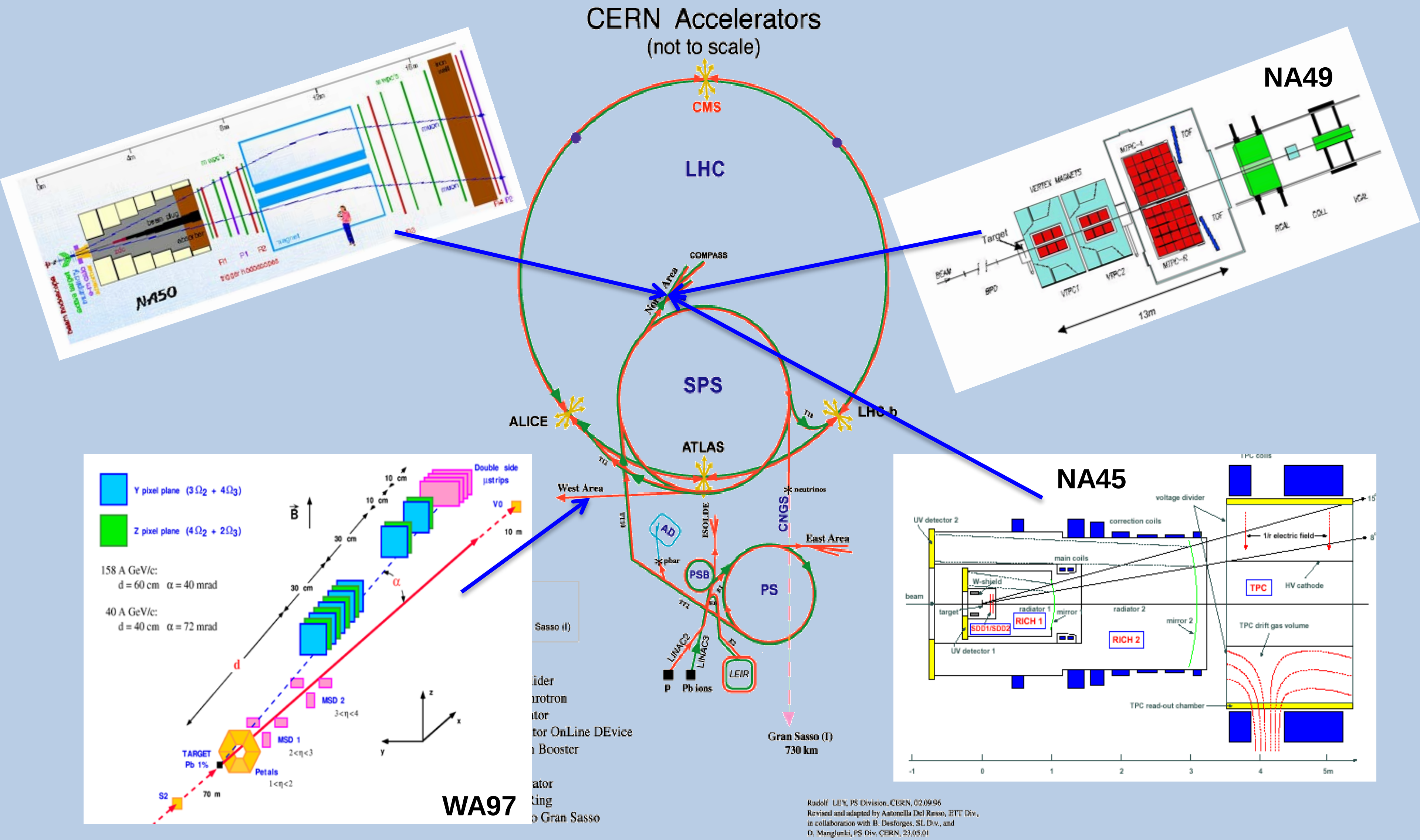
Koch, Müller, Rafelski, Phys. Rep. 142 (1986) 167

Relaxation of s-Quarks in a QGP within few fm/c ≈ lifetime of the fireball

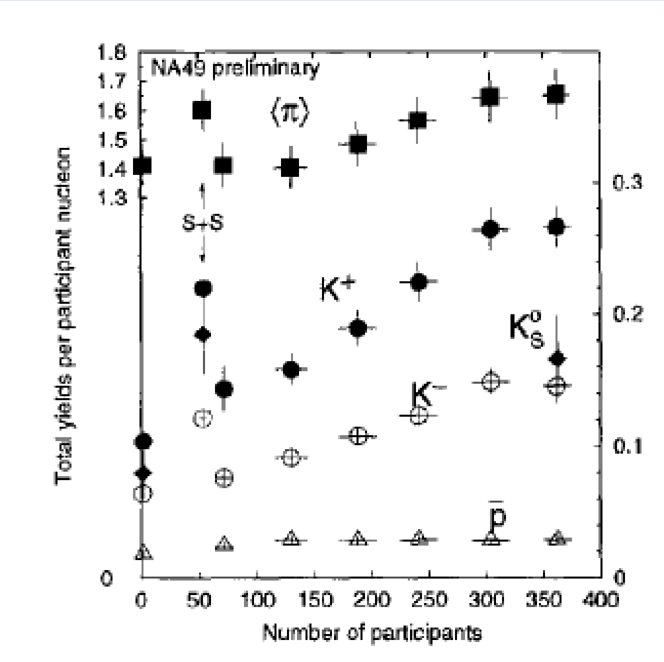
Expectation: More strangeness production in A+A relative to p+p, if QGP was formed

„Strangeness enhancement“

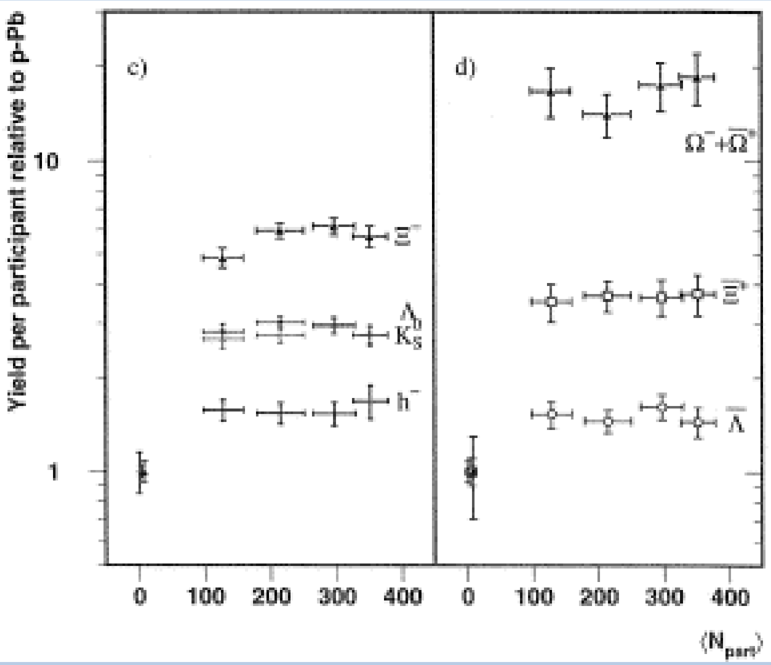
Experiments...(SPS)



...and results



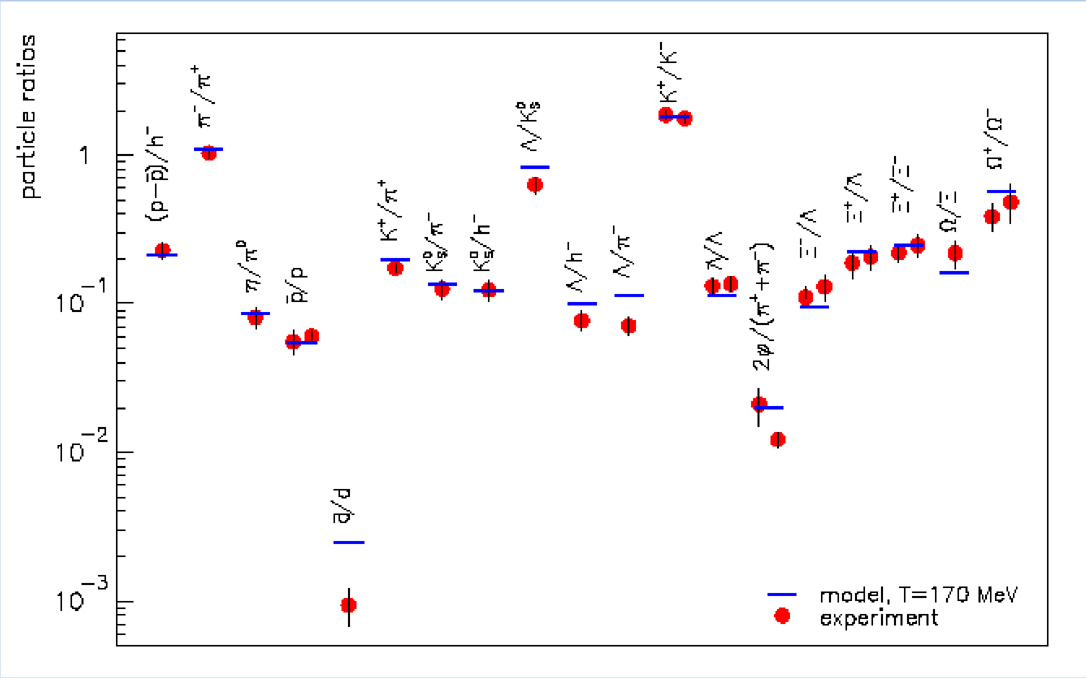
NA49, Nucl. Phys. A 661 (1999) 45



WA97, Phys. Lett. B 499 (1999) 401

- strangeness enhancement relative to p+p observed (factor 15 for Ω!)
- Hierarchy with number of strange valence quarks : E(K,Λ) < E(Ξ) < E(Ω)

But: the statistical model



J. Stachel, Nucl. Phys. A 654 (1999) 119 c

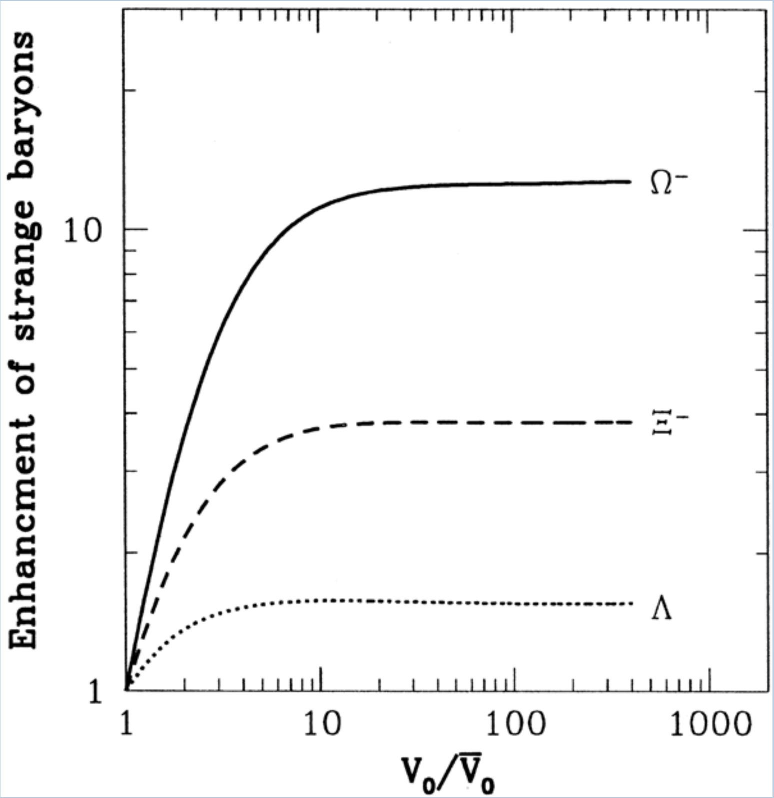
Particle multiplicities (multiplicity ratios) are well described by a hadron gas in chemical equilibrium.

Including strange particles: Ξ, Ω

Fit parameters: T_{chem}, μ_b, (V)

- Why equilibrium? Hadronic relaxation processes are not efficient enough..
- $T_{chem} \approx 170$ MeV $\approx T_c$: coincidence?
- What is the relation to strangeness enhancement?

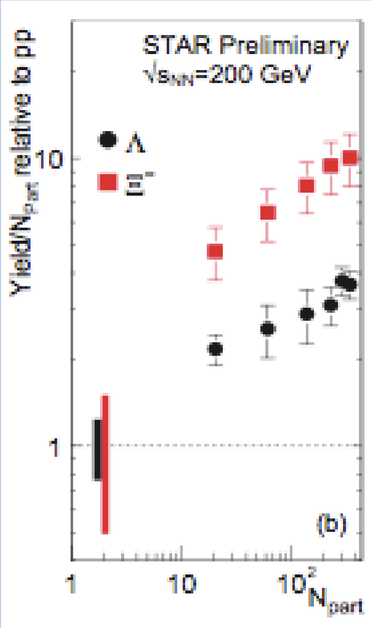
Strangeness enhancement and statistical model



S. Hamieh, K. Redlich und A. Tounsi, Phys. Lett. B 486 (2000) 61

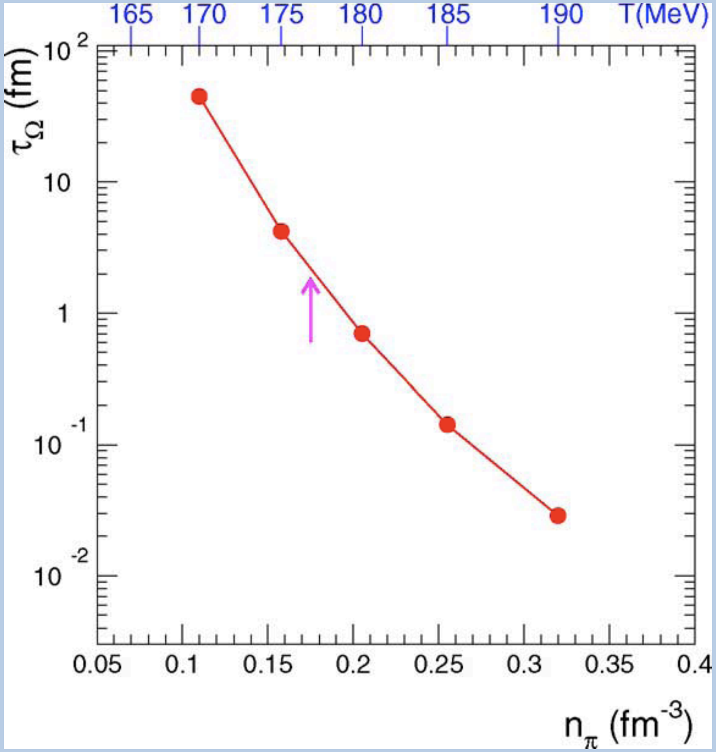
- Small systems: exact conservation of strangeness (needs canonical formulation)
- Large systems: approximation by conservation of strangeness on average: grand-canonical formulation
- Strangeness enhancement -> „canonical suppression“

Strangeness enhancement as a volume effect!



Why chemical equilibrium?

- Braun-Munzinger, Stachel, Wetterich 2004: Equlibration of strangeness through collisions with more than two particles in the entrance channel (strangeness exchange reactions, e. g. 2π + 3K -> Ω);
- Extreme dependence of rates from temperature and/or density: effective only at $T \approx T_c$
- Strangeness content is determined at phase boundary.
- Equilibration of strangeness (in particular of multi-strange baryons) is indirect proof of phase transition.



P. Braun-Munzinger, J. Stachel und C. Wetterich, Phys. Lett. B 596 (2004) 61

Searching for the onset of deconfinement

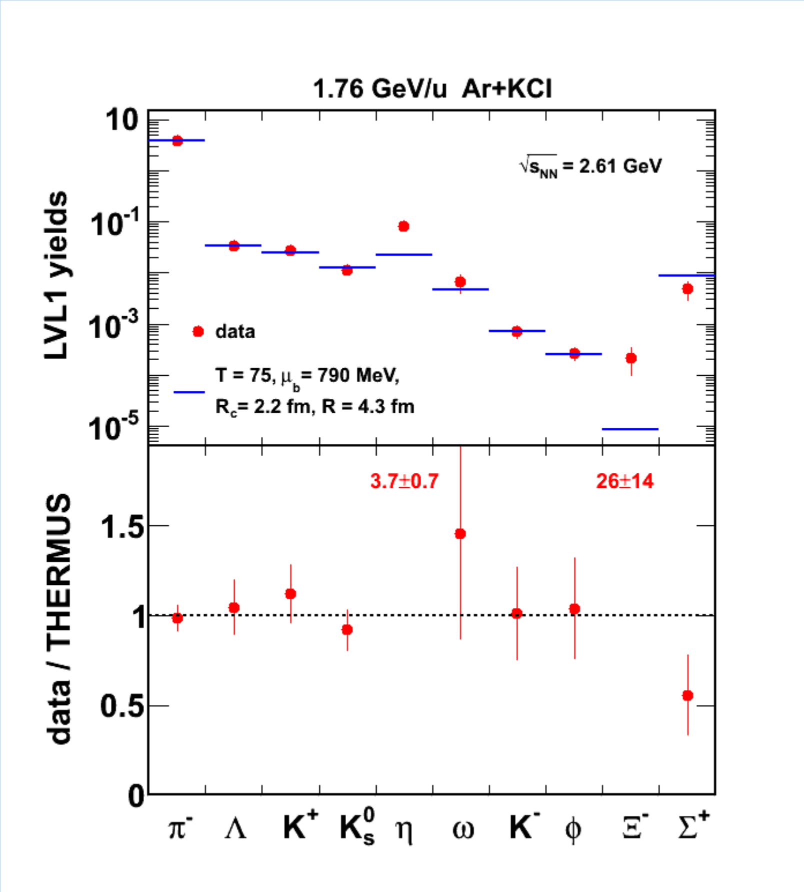
- Following the argumentation „equilibration of multi-strange baryons -> QGP“, one would search for the onset of deconfinement by measuring strange baryon abundances at lower energies.
  - Down to which collision energies does the hadron gas model hold?
- Model fits describe data at lower SPS and at AGS
  - But with a limited amount of particle species
  - Data on multi-strange baryons are scare

Breakdown of strangeness thermalisation?

HADES result for Xi^- at SIS-18 (1.76A GeV): Xi^- yield is off by an order of magnitude from the statistical model.

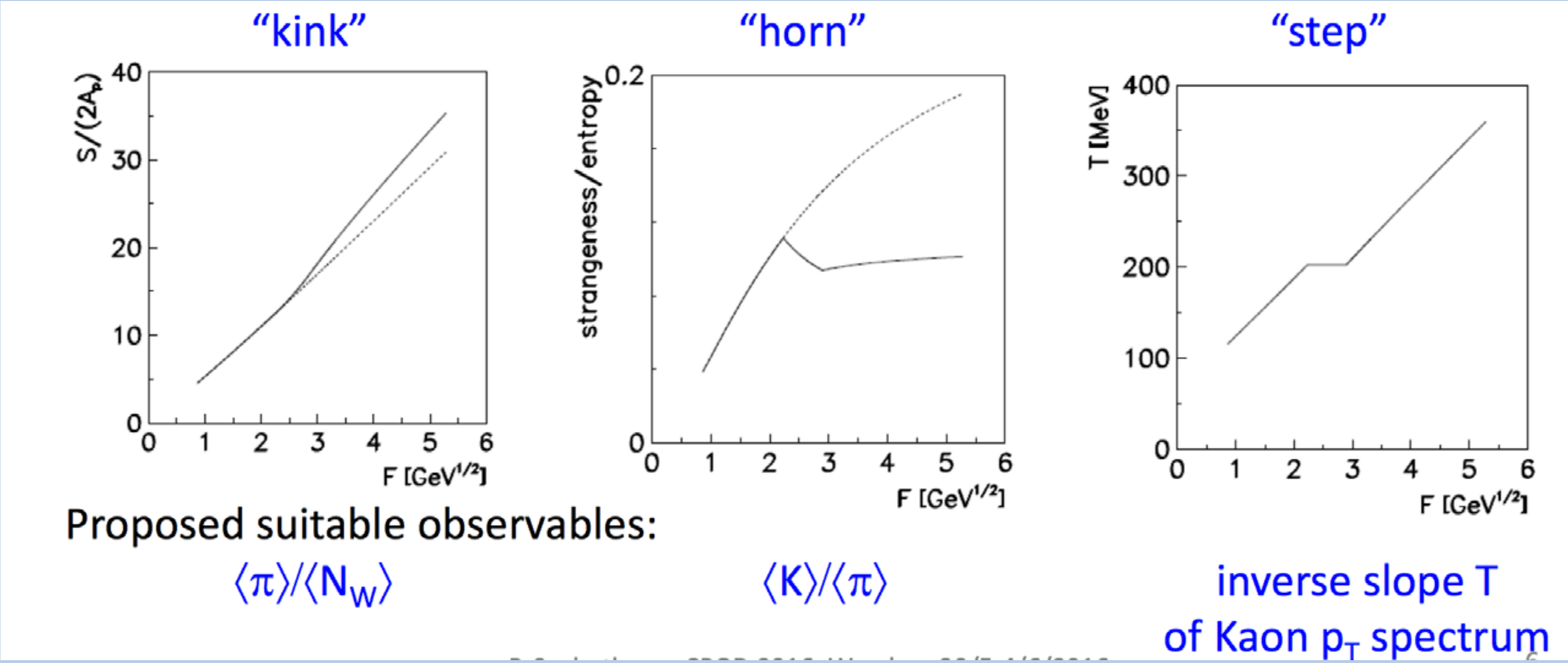
N.b.: This is deep sub-threshold. Production through multi-step processes

$$\Lambda K \rightarrow \Xi\pi \quad \Lambda\Lambda \rightarrow \Xi^- p \quad \Xi K \rightarrow \Omega\pi$$



R. Holzmann, CBM Physics Workshop, April 2010

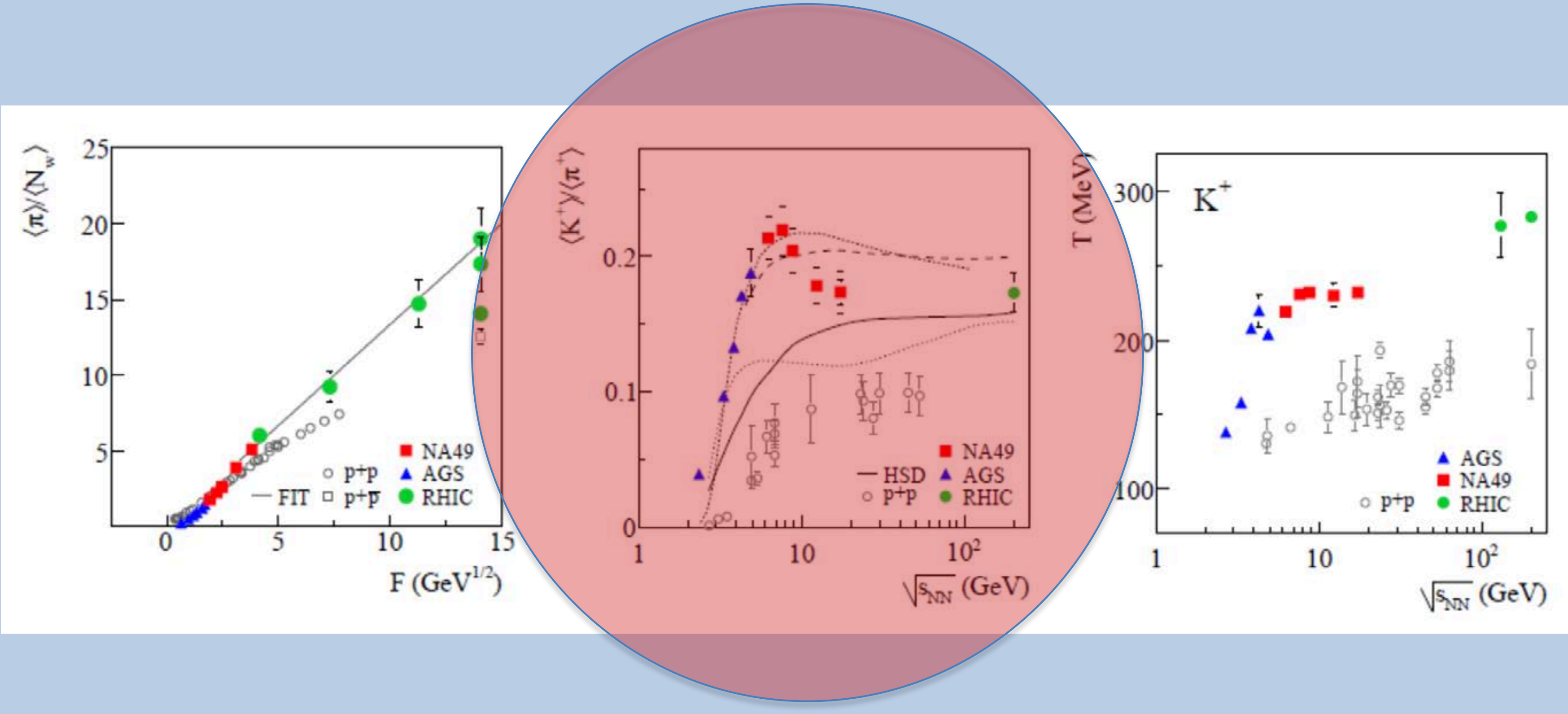
The search for the onset



"Statistical Model of the Early Stage":

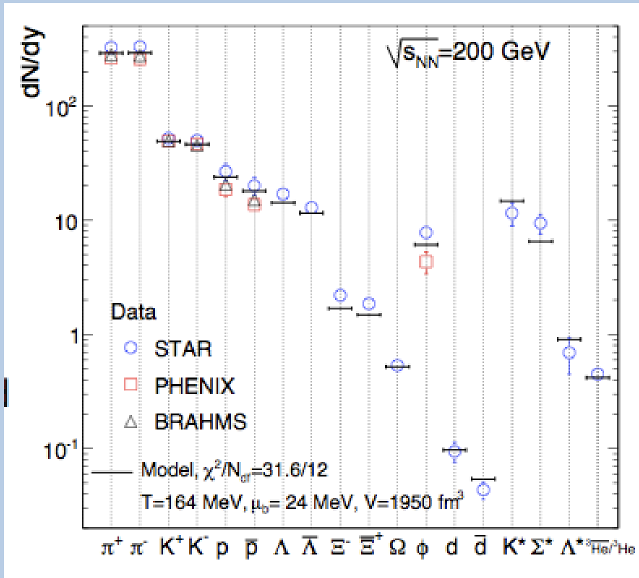
- "Early stage" (hadronic / partonic) im thermal equilibrium
- First-order phase transition at ε_c/T_c
- Mixed phase around ε_c

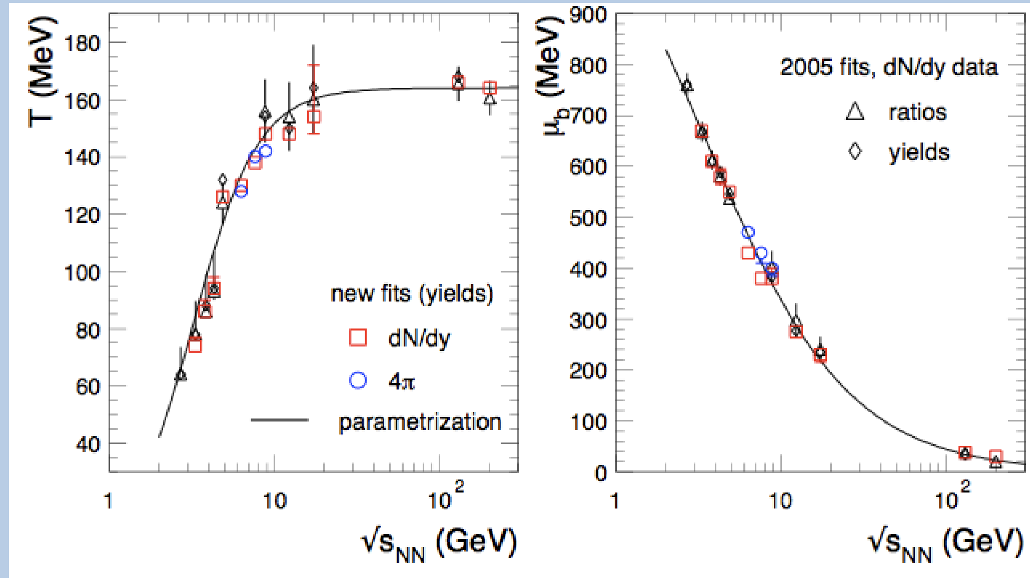
Results at SPS (NA49)



Evidence for the onset of deconfinement at 30A GeV ?

What about the statistical model?

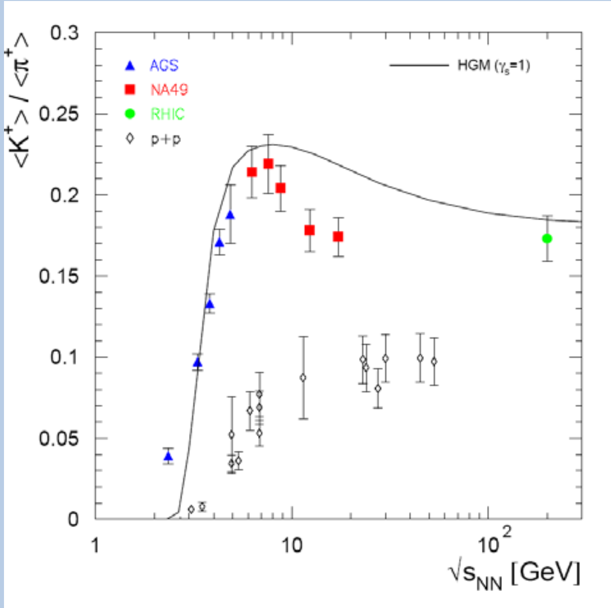




- Fits for many collision energies: SIS, AGS, SPS, RHIC
- T, μ_b monotonic functions of $\sqrt{s_{NN}}$
- T saturates at $\sqrt{s_{NN}} \approx 10$ GeV; $T_{limit} \approx 160$ MeV

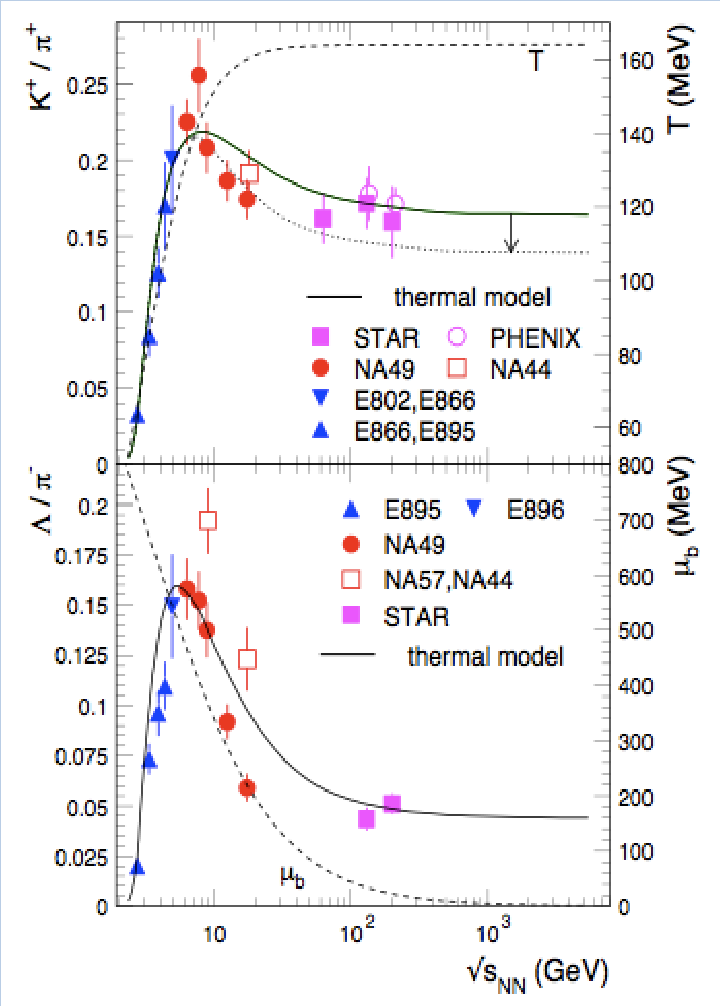
The „horn“ in the statistical model

2006



A. Andronic, P. Braun-Munzinger und J. Stachel, Nucl. Phys. A 772 (2006) 167

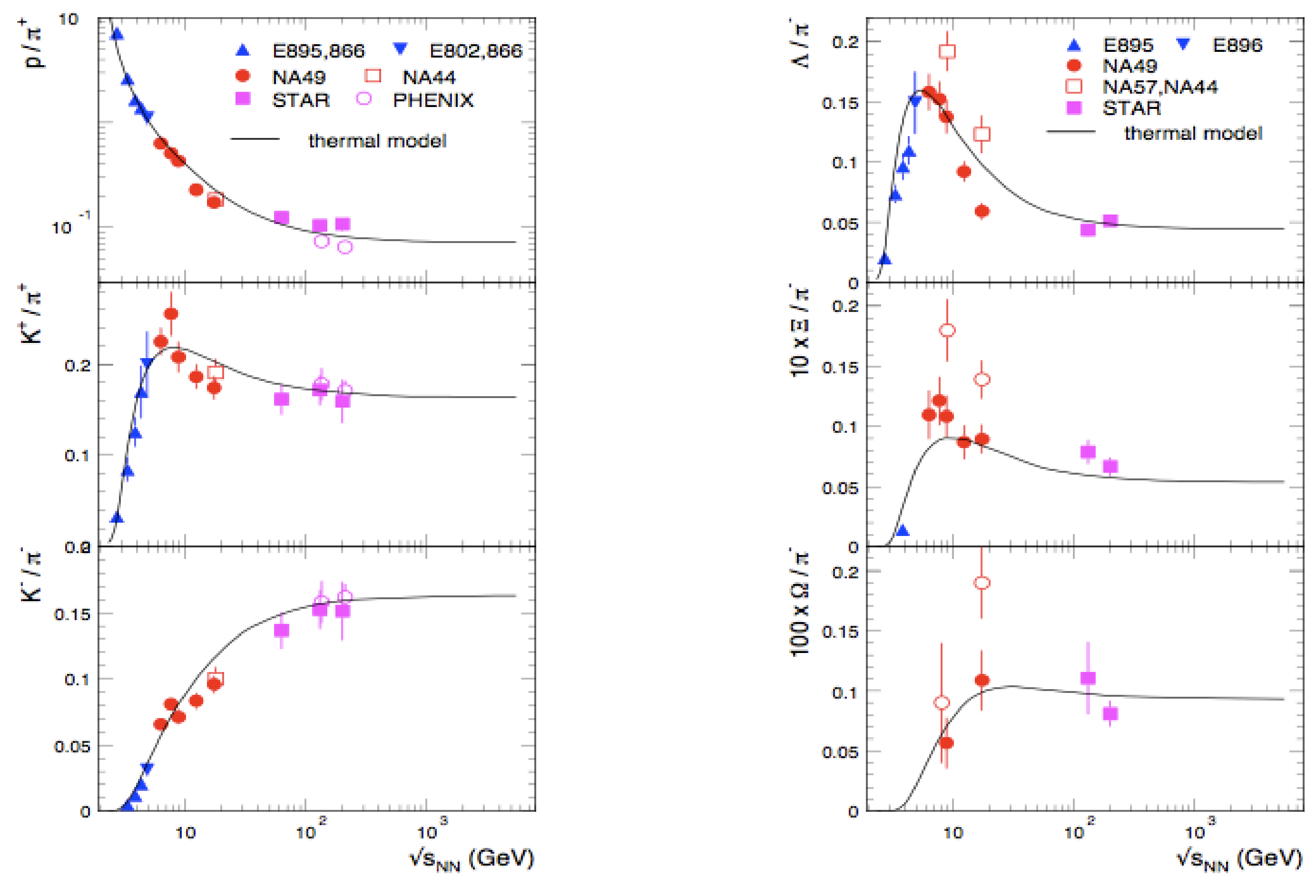
2009



A. Andronic, P. Braun-Munzinger und J. Stachel, Phys. Lett. B 673 (2009) 142

- Broad maximum at ≈ 30A GeV (interplay of T and μ_b)
- No satisfactory description of the K/pi energy dependence
- Improvement when including high-mass resonances

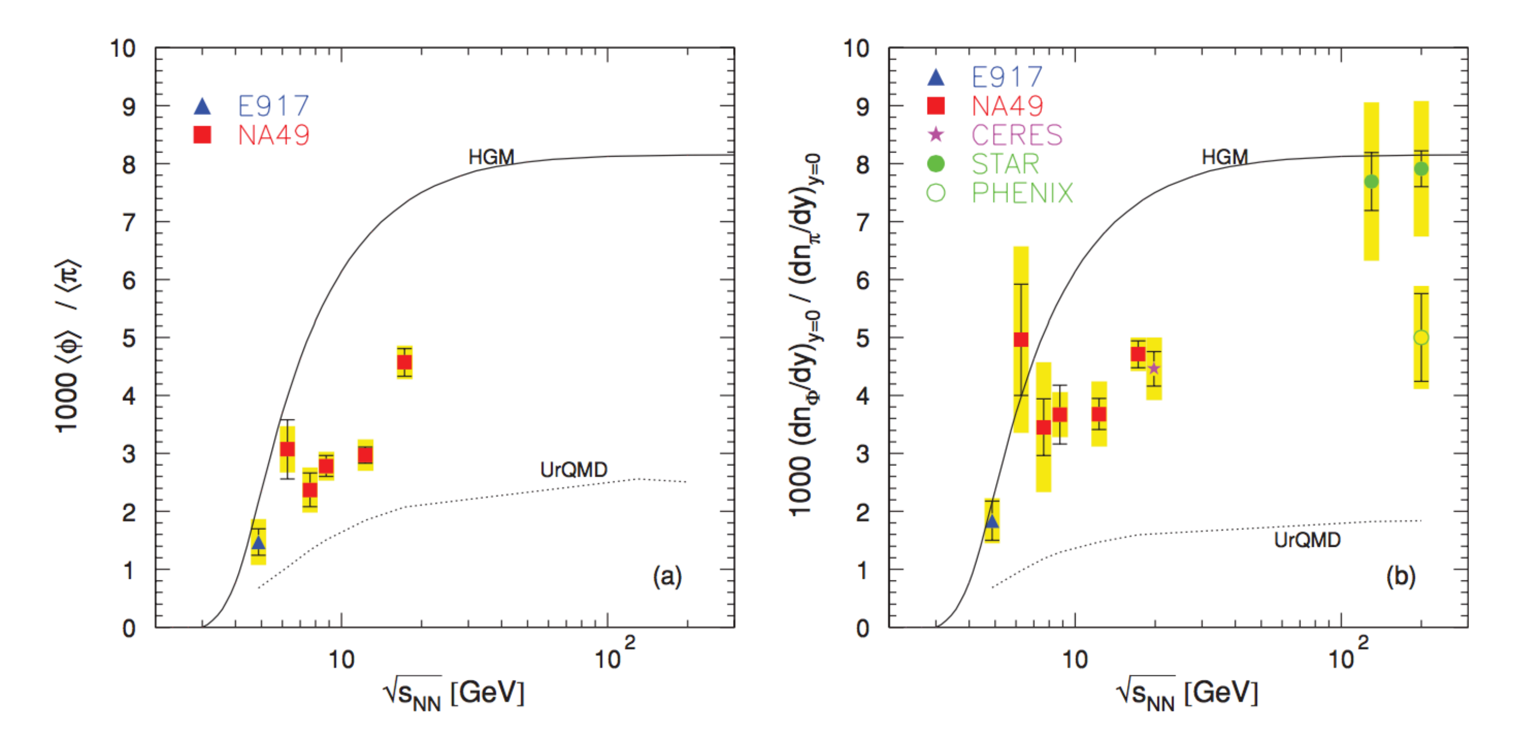
The need for data on multi-strange baryons



A long-lasting debate: pure hadronic description or signal of drastic change in matter properties?

Data on multi-strange baryons will be decisive!

Not to forget: the phi meson

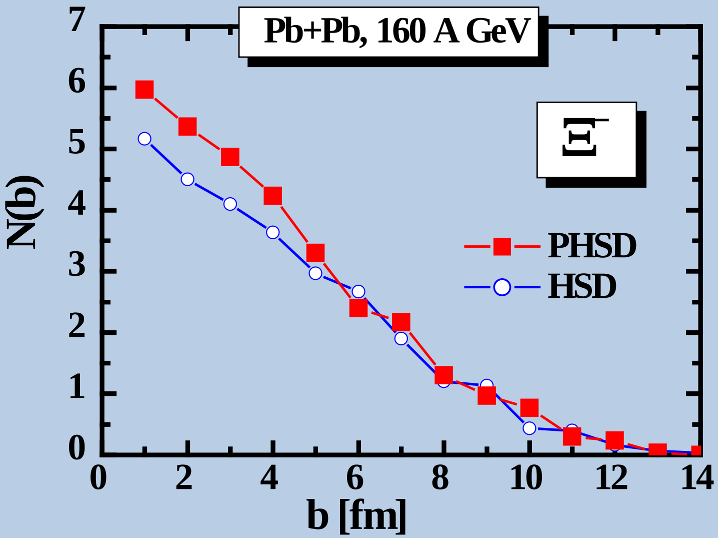


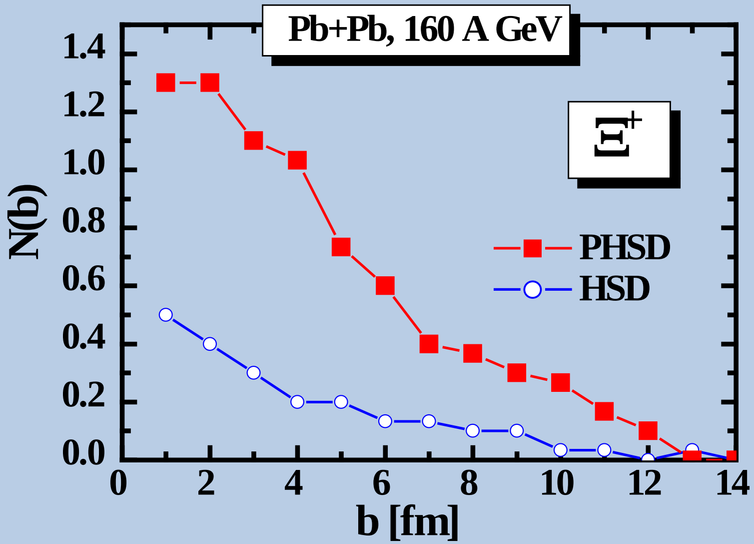
- s-sbar: strangeness-neutral in a hadronic picture; double-strange in a partonic view
- No satisfactory description of the excitation function neither by statistical model nor by microscopic transport
- – HADES (sub-threshold): good description by statistical model

What about strange anti-baryons?

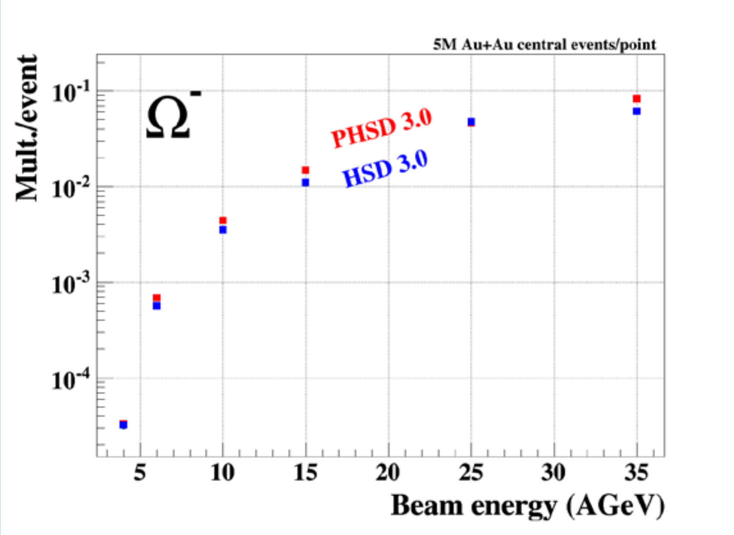
At large net-baryon density, the production of anti-baryons is heavily suppressed. This is not the case in a deconfined phase.

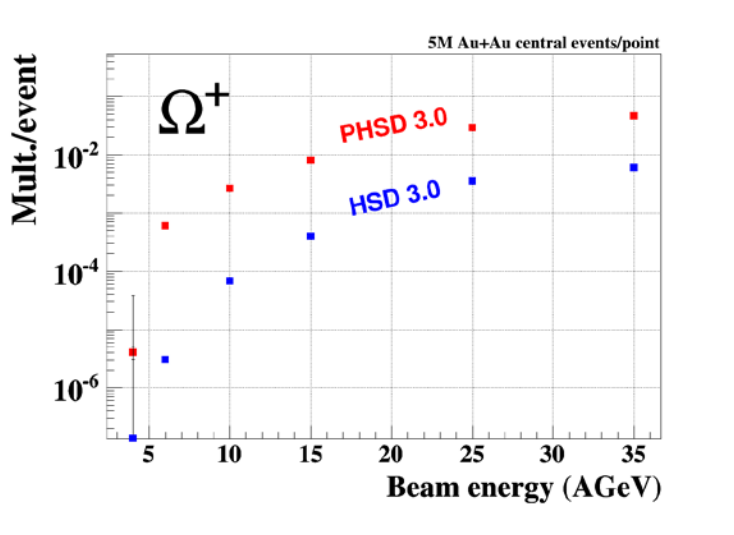
pHSD model: microscopic transport; assumes QGP in fireball regions where a critical energy is exceeded
For comparison: HSD (pure hadronic)
At top SPS energy: small effect on Xi, huge effect on anti-Xi.





Strange anti-baryons at CBM energies





”Enhancement” of strange-anti-baryons is expected to be much stronger at lower energies!

Summary

- Strangeness below top-SPS energy is far from being understood.
- Many open questions:
  - Does thermalisation hold at lower energies?
  - Can the „horn“ be fully understood in terms of the statistical model?
  - What are the production mechanisms near or below threshold?
- A systematic measurement of multi-strange hadrons is most promising to answer those questions
  - CBM, BM@N, MPD, NA61, STAR
- Multi-strange anti-baryons are probably even more sensitive
  - CBM is probably the only experiment able to address these