System-Size Dependence of Strangeness Production at 158 AGeV

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for the NA49 Collaboration

Outline

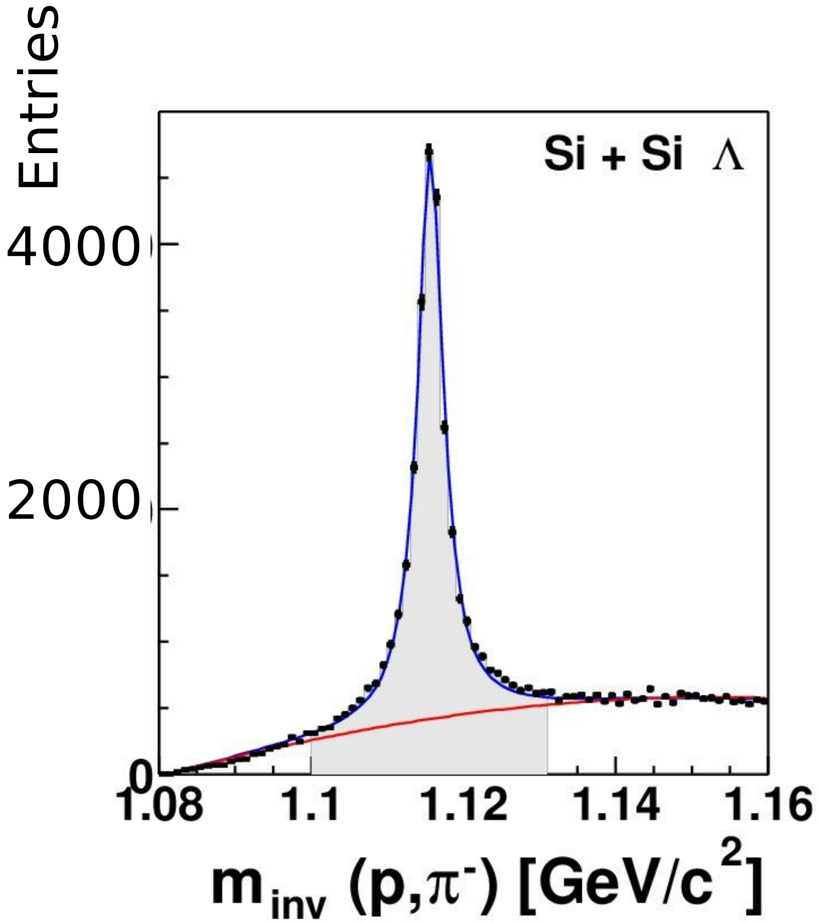
- Yields and spectra of strange hadrons and pions in p+p, C+C, Si+Si and Pb+Pb collisions at sqrt(s) = 17 GeV
- Origin of strangeness enhancement in A+A
- Chemical freeze out parameters from statistical models
- Kinetic freeze out conditions
- Summary

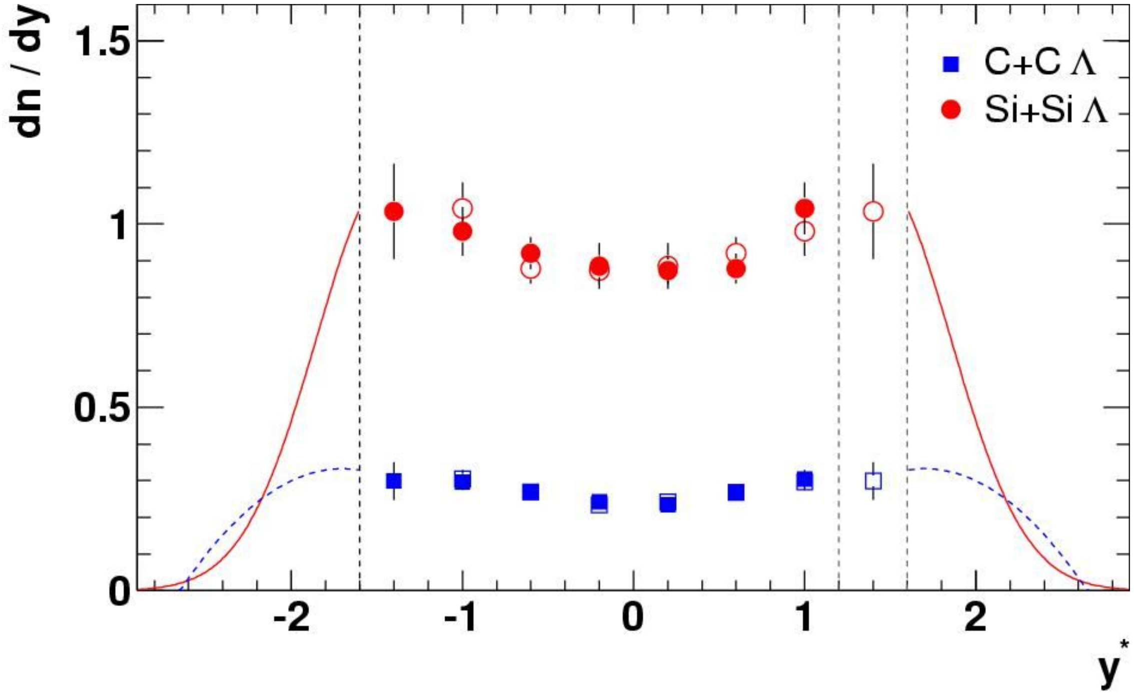
Data

New data

- C+C 15% centrality
- Si+Si 12% centrality

Spectra and yields of Λ, $\bar{\Lambda}$, ϕ, K^+, K^-, π^+, π^-





Strangeness Enhancement

$$E = \frac{\langle h \rangle_{A+A} / \langle \pi \rangle_{A+A}}{\langle h \rangle_{p+p} / \langle \pi \rangle_{p+p}}$$

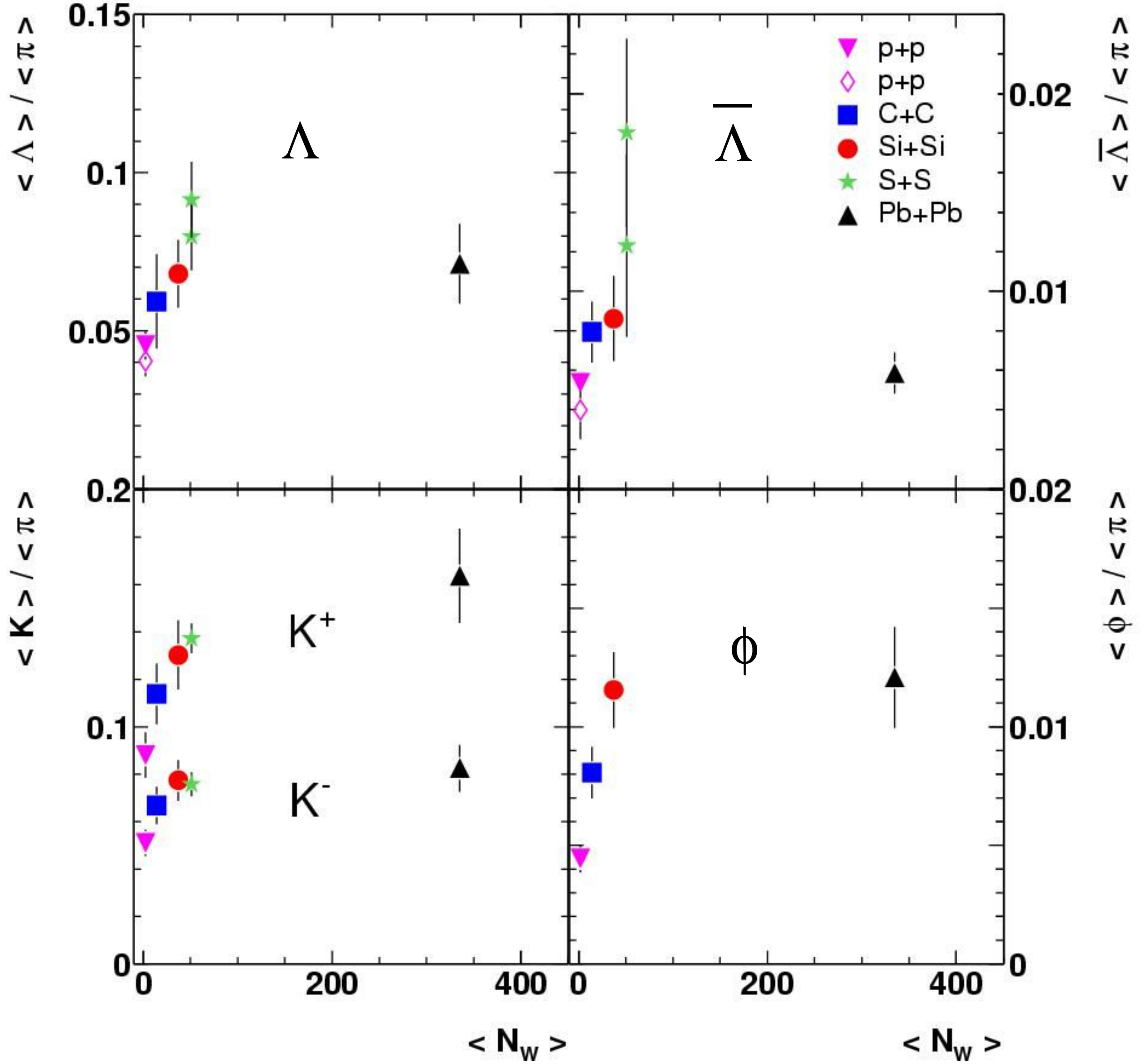
$$\langle \pi \rangle = \frac{1}{2} (\langle \pi^{+} \rangle + \langle \pi^{-} \rangle)$$

h: Λ, $\bar{\Lambda}$, K^+, K^-, ϕ

C+C: $\bar{E} = 1.4$

Si+Si: $\bar{E} = 1.7$

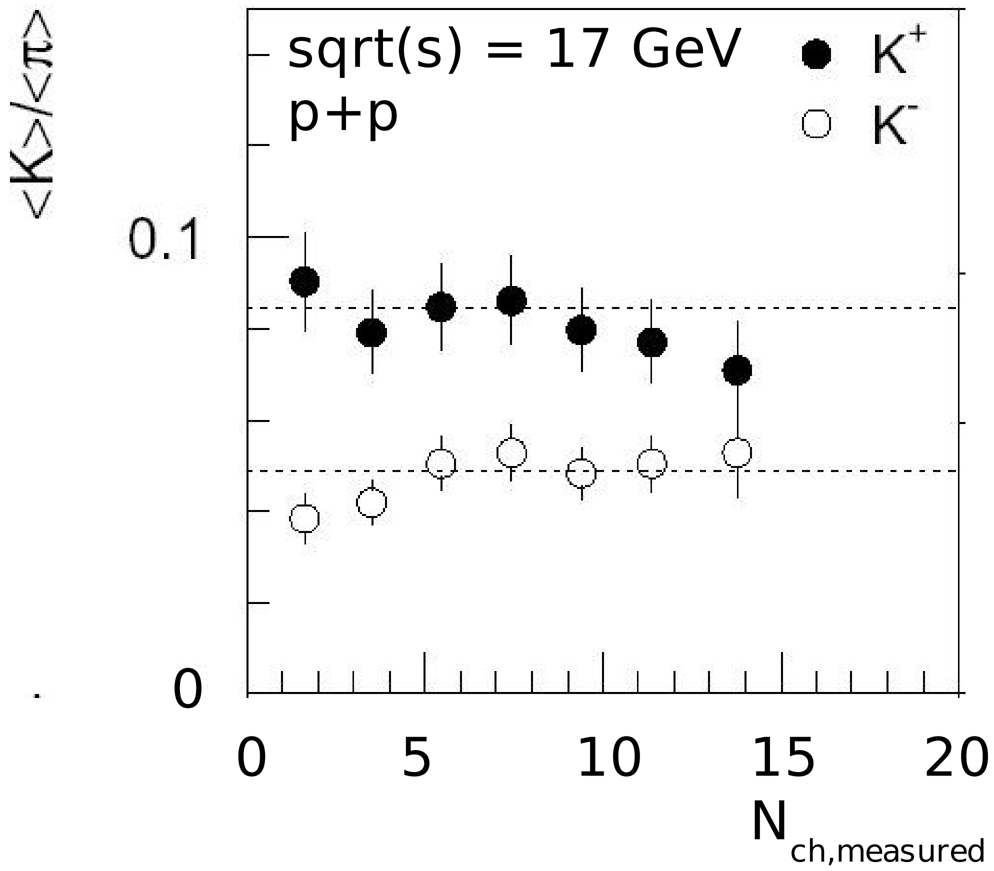
Pb+Pb: $\bar{E} = 1.8$

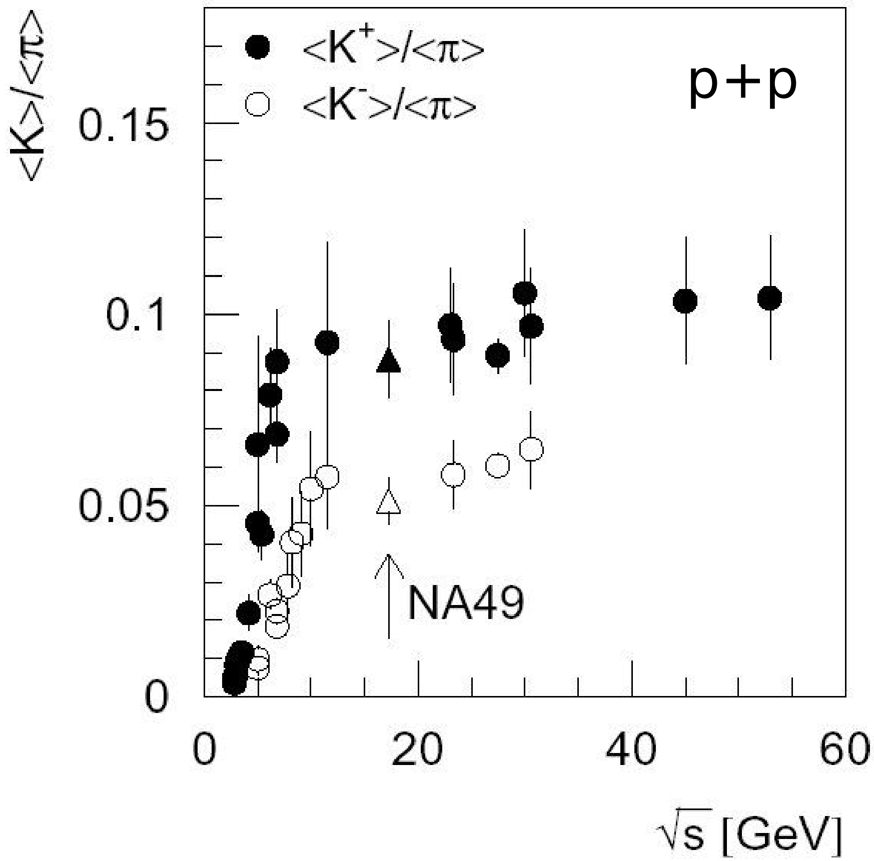


nucl-ex/0406031

Strangeness production in p+p

- Enhancement due to multiple collisions?





C.Hoehne PhD thesis http:// archiv.ub.uni-marburg.de/diss/z2003/0627/

- Neither higher inelasticity nor shifted c.m. energy causes strangeness enhancement

Strangeness production in A+A

- UrQMD: small fraction of enhancement due to rescattering
- Empirical scaling with escape length, nucleon or collision density

hep-ex/0102004
J. Phys. G 27 (2001) 397
Nucl. Phys. A 715 (2003) 474c

➔ Overlapping strings

Nucl. Phys. B 245 (1984) 449
Z. Phys. C 38 (1988) 187

➔ Higher strangeness production

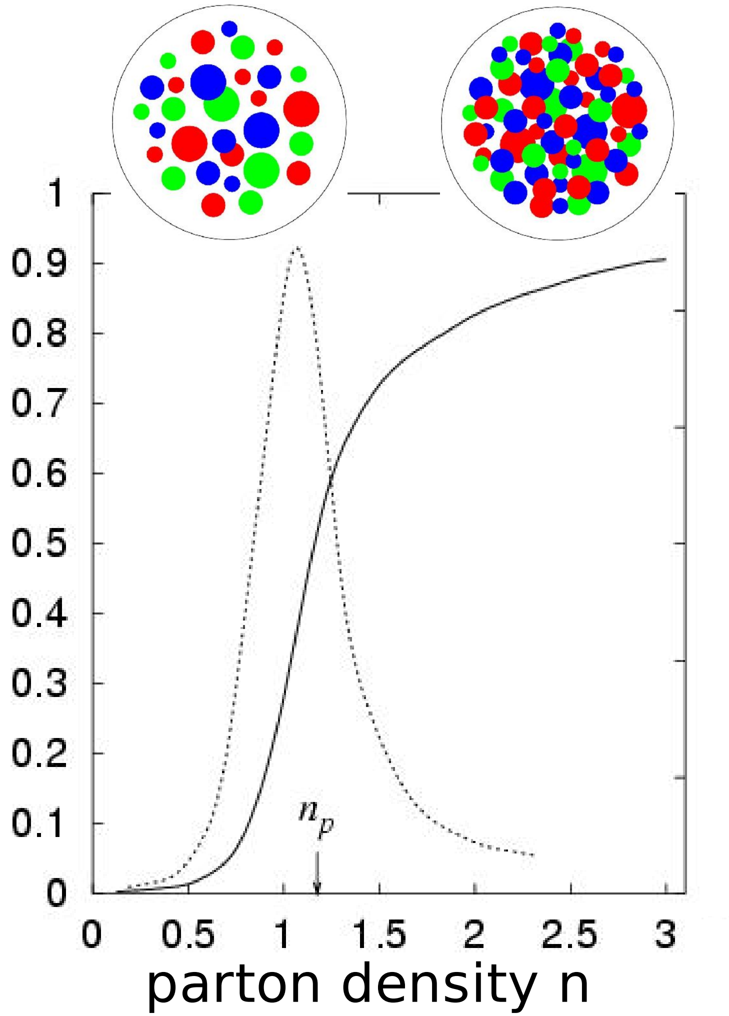
➔ Assumption of co-existence of 2 types of particle sources:
  - p+p kind of hadronic particle source
  - Pb+Pb type of connected clusters

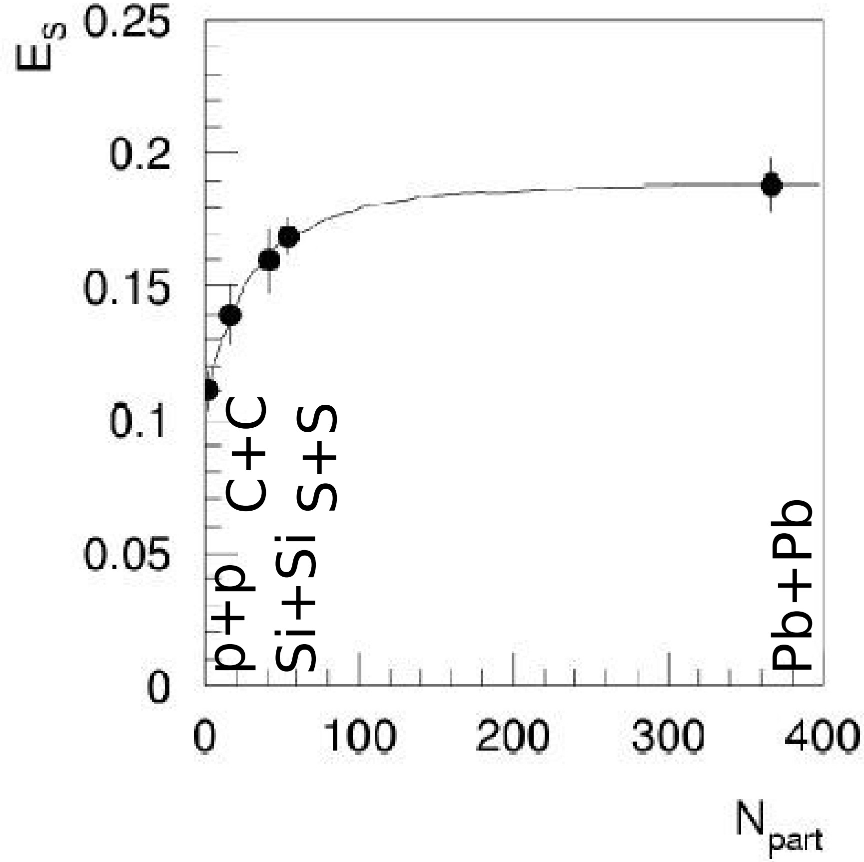
Percolation theory

2 dim area of connected clusters

$$\frac{S_{cl}}{S_{tot}}$$

Total overlap area of nuclei





$\frac{S_{cl}}{S_{tot}}$ changes rapidly around percolation point n_p

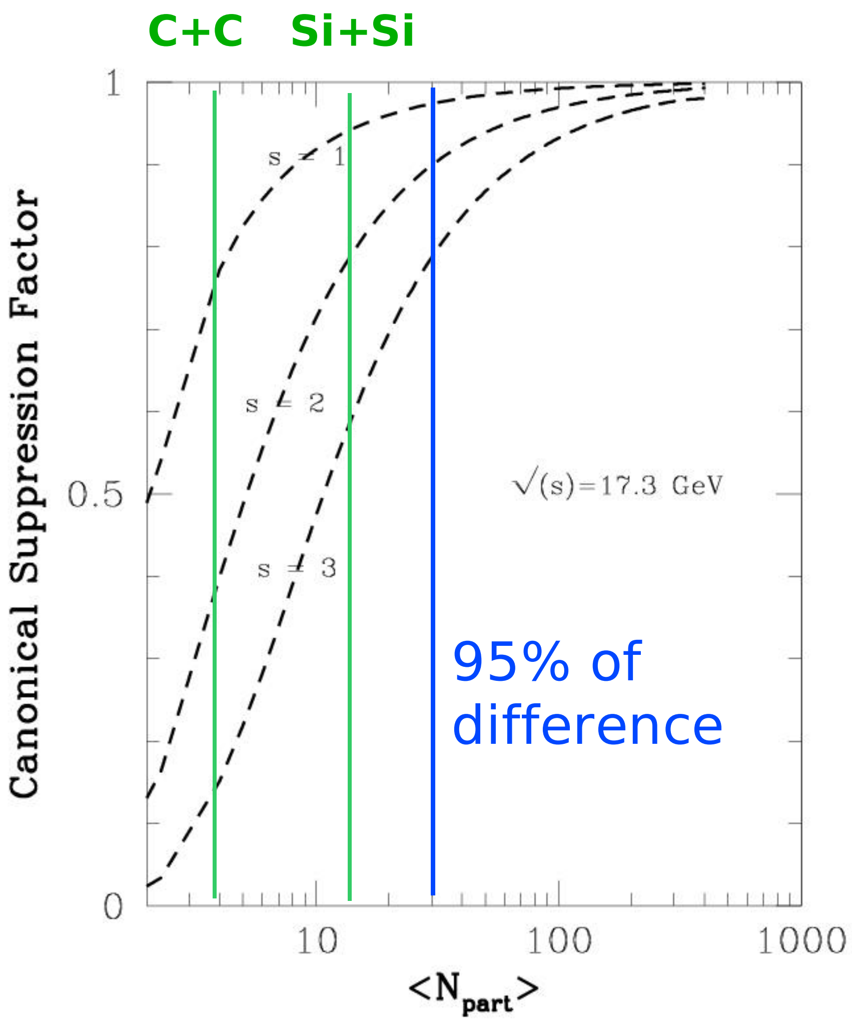
$$E_S = \frac{\langle \Lambda \rangle + 2\langle K^+ \rangle + 2\langle K^- \rangle}{1.5\left(\langle \pi^+ \rangle + \langle \pi^- \rangle\right)}$$

Nucl. Phys. A 715 (2003) 3c, hep-ph/0212046

C. Hoehne, priv. comm.

Statistical model: canonical suppression

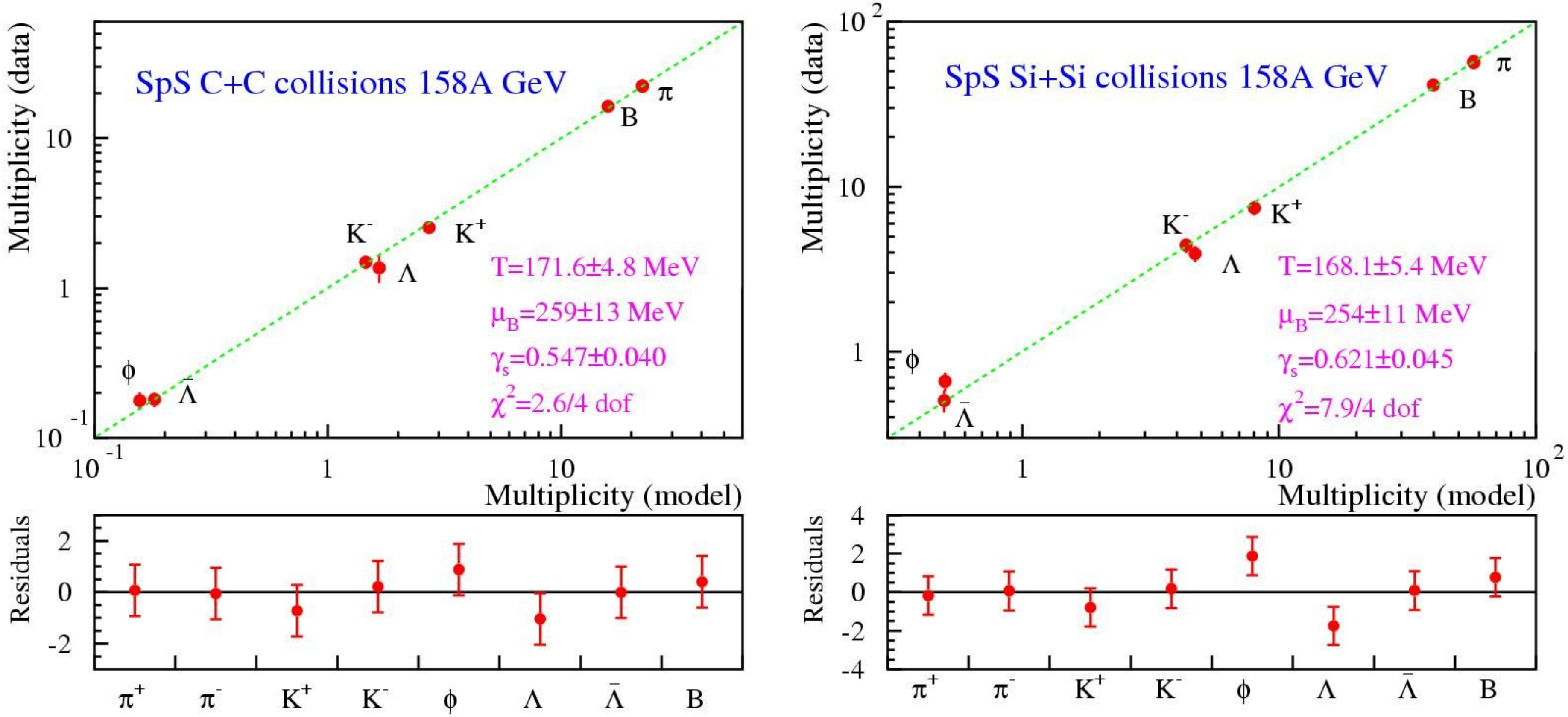
- Canonical strangeness suppression vanishes at
  - Npart ≈ 65 in data
  - Npart ≈ 30 in model
- At sqrt(s) = 17 GeV the fireball is spread over 3 units of rapidity
  Phys. Rev. Lett. 82 (1999) 2471
- Connected clusters might be limited to smaller volumes
  - Si+Si: E = 1.7 ↔ Npart ≈ 15
  - C+C: E = 1.4 ↔ Npart ≈ 4



$V = 3.5\ fm^3 \cdot N_{part}$

J. Phys. G 28 (2002) 2095

Statistical model: chemical freeze-out

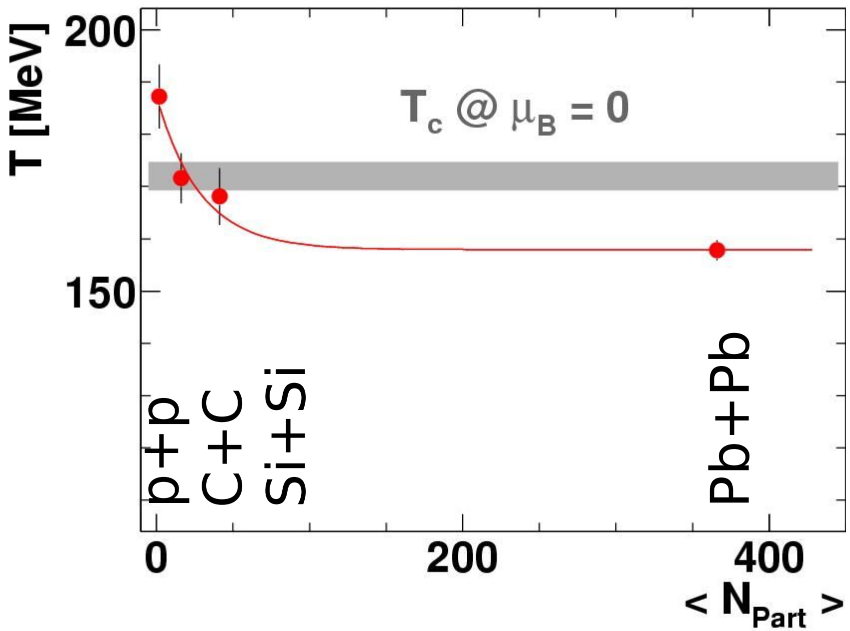


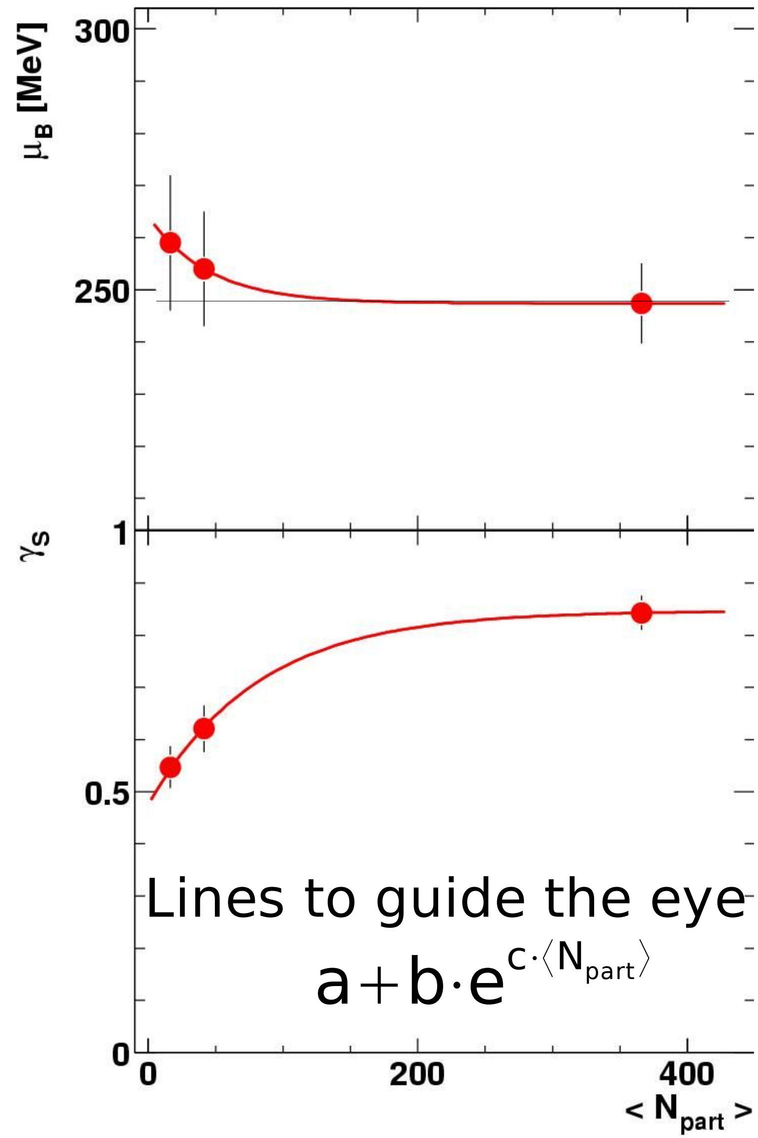
F. Becattini, priv.comm.

- Particle multiplicities are in agreement with an equilibrated resonance gas with suppressed strangeness production γ_s

System size dependence at freeze-out

- μ_B does not dependent on size
- γ_s follows enhancement
- T_{ch} higher in small systems
  - Less inelastic rescattering?
  - Caused by γ_s?

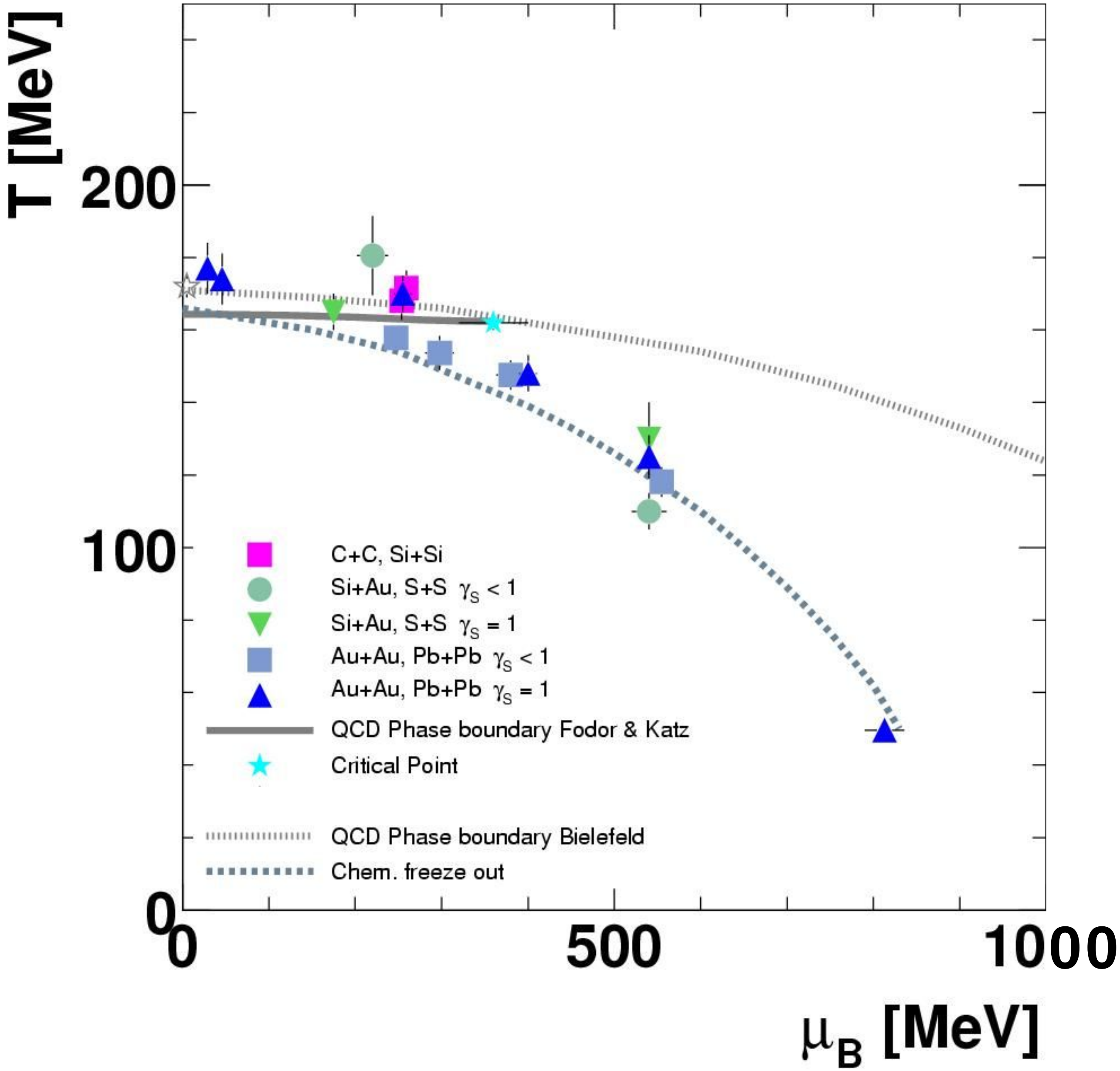




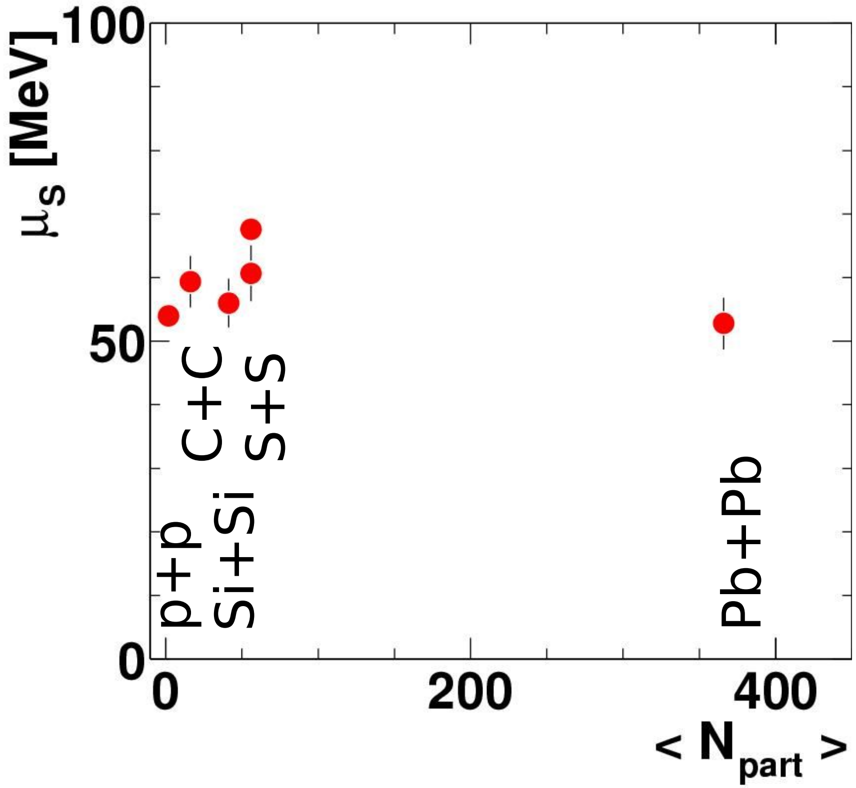
p+p, Pb+Pb: Phys. Rev. C 69 (2004) 024905

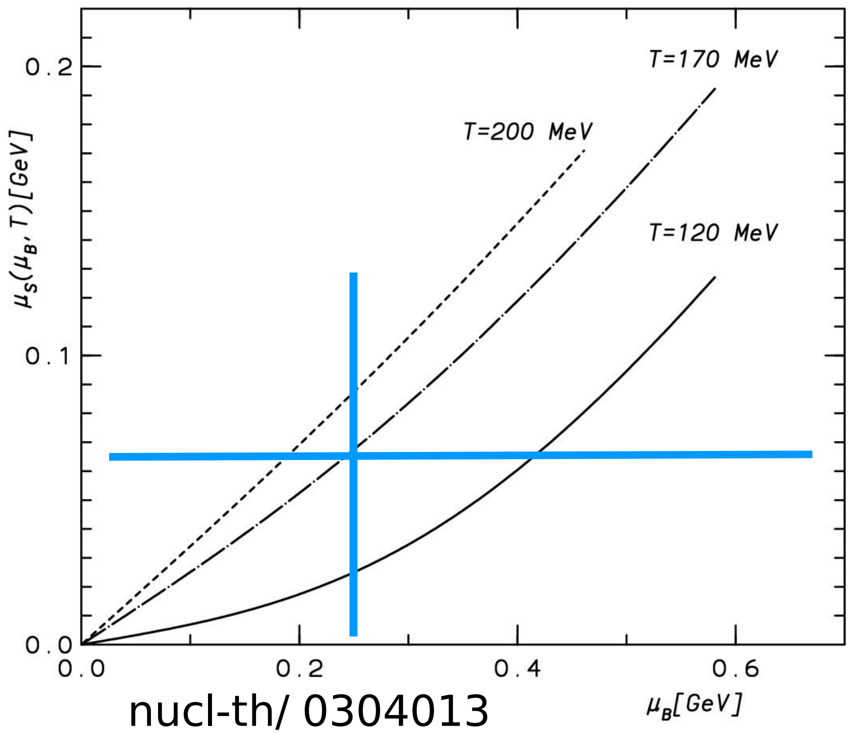
QCD phase diagram

- Small systems freeze out in the vicinity of the phase boundary
- Only little rescattering in small systems possible
- Statistical equilibrium can be reached in 2 ways
  - Hadronisation process
  - Hadronic rescattering in high density enviroment



Strange Baryon Potential





nucl-th/ 0304013

- μ_S from particle ratios:

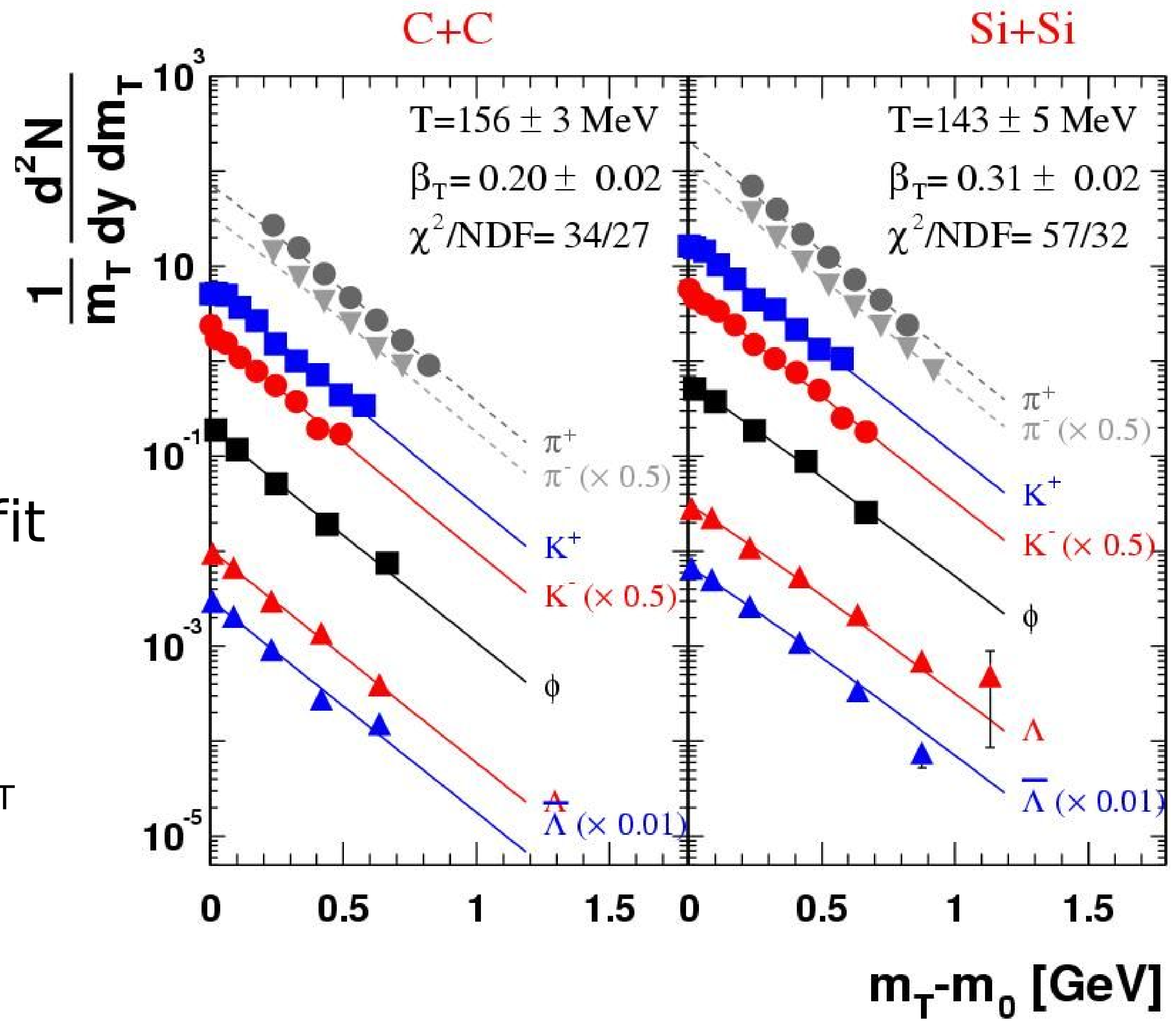
$$\frac{\langle \Lambda \rangle}{\langle \bar{\Lambda} \rangle} \cdot \left(\frac{\langle K^- \rangle}{\langle K^+ \rangle} \right)^2 = \exp\left(6 \cdot \frac{\mu_s}{T} \right)$$

$$\mu_S = \frac{1}{3}\mu_B - \mu_s$$

Z. Phys. C 61 (1994) 659

- Independent of system size
- $\mu_S > 0$
- In agreement with statistical model

Blast wave fit

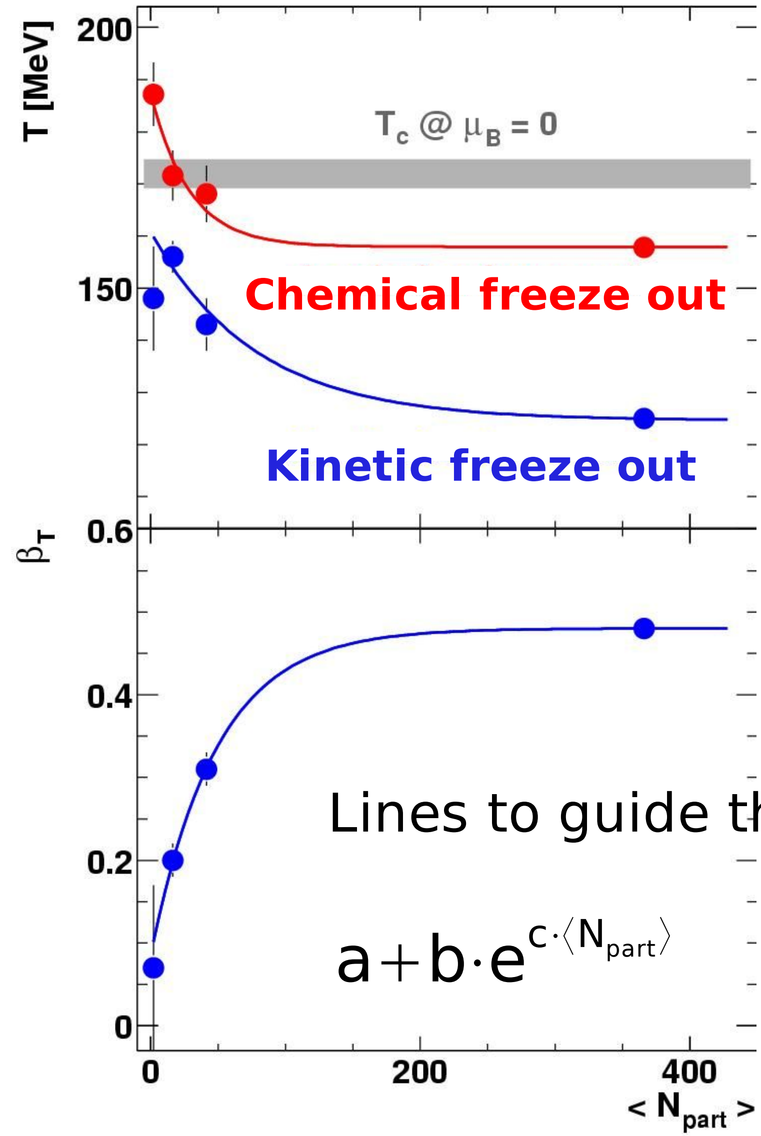


- Simultanious fit of all particles except π
- Here: const. β_T

Blast wave model: Phys. Rev. C 48 (1993) 2462

System size dependence at freeze-out

- T_{ch} higher in small systems
  - Less inelastic rescattering?
  - Caused by γ_s?
- Blast wave fit: T_{kin}, β
  - Less elastic rescattering in small systms?
  - Correlation between T_{kin} and β?



Lines to guide the eye

$$a + b \cdot e^{c \cdot \langle N_{part} \rangle}$$

T_{ch} p+p, Pb+Pb: Phys. Rev. C 69 (2004) 024905
T_{kin}, β p+p: v.Leeuwen, priv. Comm.
T_{kin}, β Pb+Pb: Nucl. Phys. A 715 (2003) 161c

Slopes of pt spectra

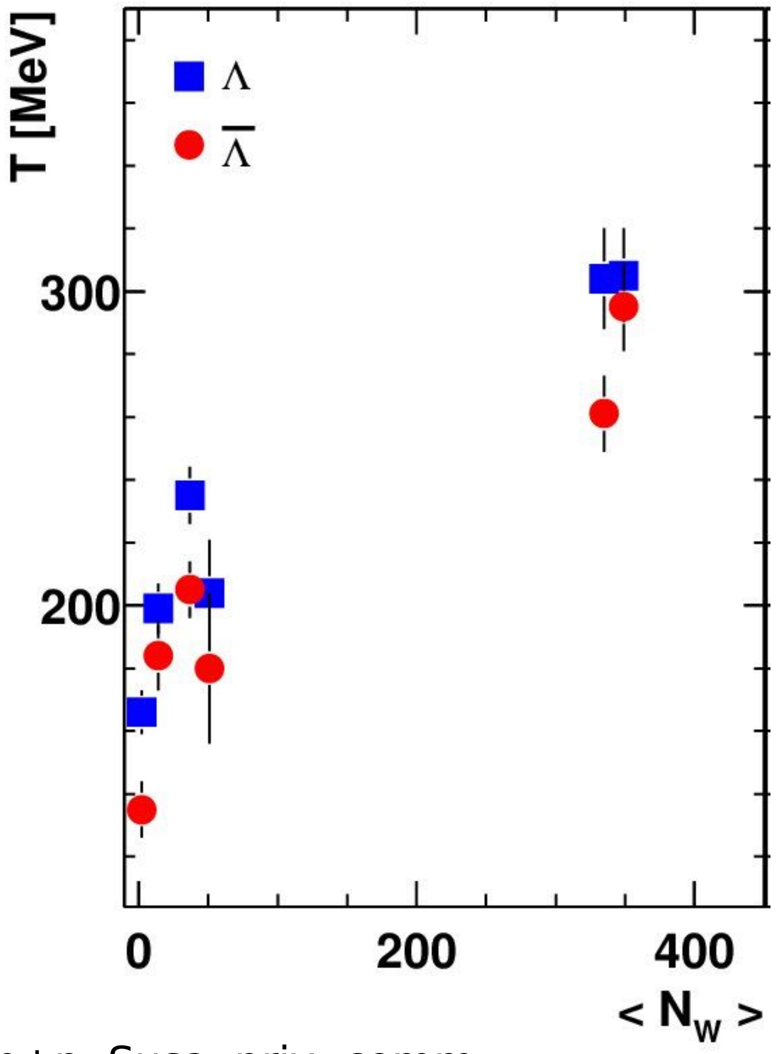
- Exponential fit

$$\frac{dn}{dp_t} \propto p_t \cdot e^{-m_t/T}$$

- $T_{\Lambda} > T_{\bar{\Lambda}}$

→ Energy conservation in p+p?

→ Cause in Pb+Pb?



p+p: Susa, priv. comm.
S+S: Z. Phys. C 64 (1994) 195
Pb+Pb: nucl-ex/0403036,
Phys. Rev. Lett. 93 (2004) 022302

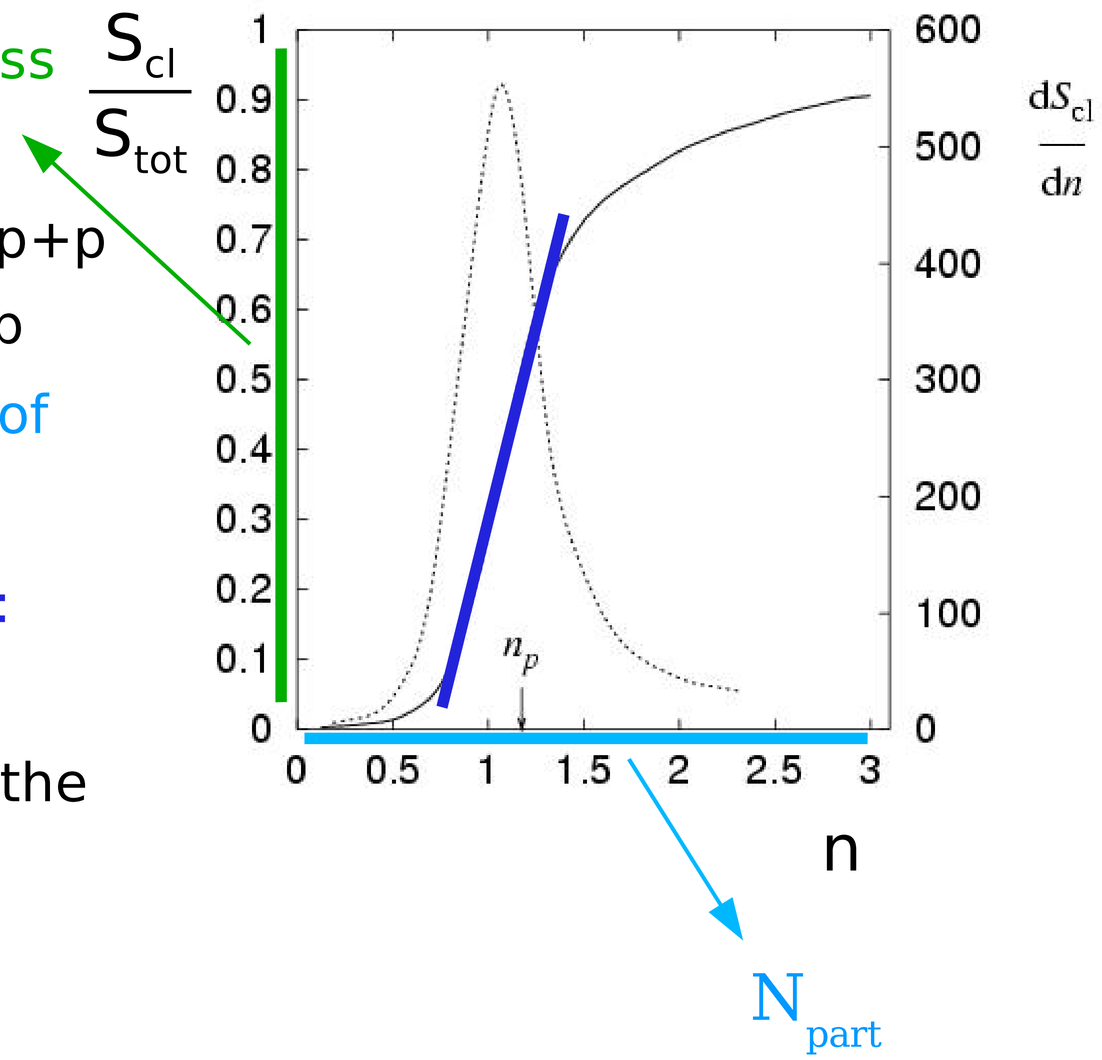
Summary

- Strangeness enhancement in A+A compared to p+p
  - Can not be explained with p+p nor rescattering
  - Empirical scaling works with density
  - Overlapping strings cause
    - Higher colour field strength
    - Reduction of canonical suppression
  - Result in higher strangeness production
  - Created clusters are smaller than the fireball

- Freeze out
  - Yields are described by hadron gas model with $\gamma_S < 1$
  - Small systems decouple at higher T_{ch} and T_{kin} than the larger ones
  - μ_B and μ_S are indepent of system size
  - Radial flow increases with system size
  - Energy conservation effect in small systems?

Percolation / Experiment

- Relations needed:
  - Cluster size S_{cl} ↔ strangeness production:
    - Single strings: S.P. as in p+p
    - Clusters: S.P. as in Pb+Pb
  - Parton density n ↔ number of participants N_{part} → VENUS
  - Cluster area S_{cl} ↔ density n: sensitive on Parameters:
    - Distribution of strings in the overlap area → VENUS
    - String radius → 0.25 fm



Strangeness production

- Other picture:
  - Clusters vary also in string density
  - Assume linear increase of string constant κ with density
  - increase of colour field strength in clusters
  - Reproduces data in the same way