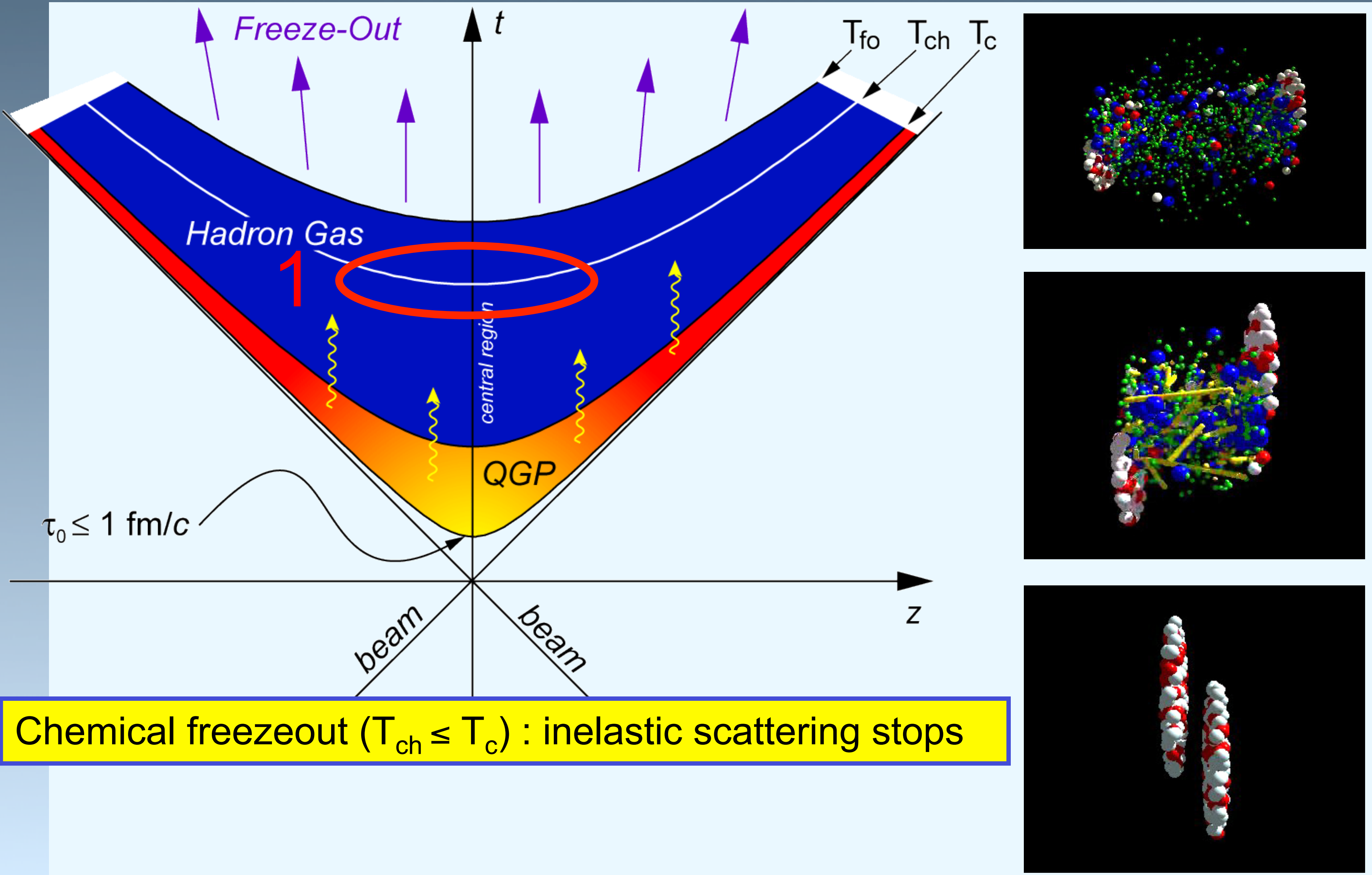
Thermal model
(particle ratios)

A theoretical view of the collision



Chemical freezeout ($T_{ch} \leq T_c$) : inelastic scattering stops

Statistical Hadronic Models

- Model says <u>nothing</u> about how system reaches chemical equilibrium
- Model says <u>nothing</u> about when system reaches chemical equilibrium
- Model makes no predictions of dynamical quantities
- Some models use a strangeness suppression factor, others not
- Model does not make assumptions about a partonic phase;

Models to evaluate T_{ch} and μ_B

Statistical Thermal Model

F. Becattini; P. Braun-Munzinger, J. Stachel, D. Magestro
J.Rafelski PLB(1991)333; J.Sollfrank et al. PRC59(1999)1637

Assume:

- **Ideal hadron resonance gas**
- **thermally** and **chemically equilibrated fireball at hadro-chemical freeze-out**

Recipe:

- ***GRAND CANONICAL*** ensemble to describe partition function ⇒ density of particles of species ρ_i
- fixed by constraints: Volume V, strangeness chemical potential μ_S, isospin
- input: measured particle ratios
- output: temperature T and baryo-chemical potential μ_B

Particle density of each particle:

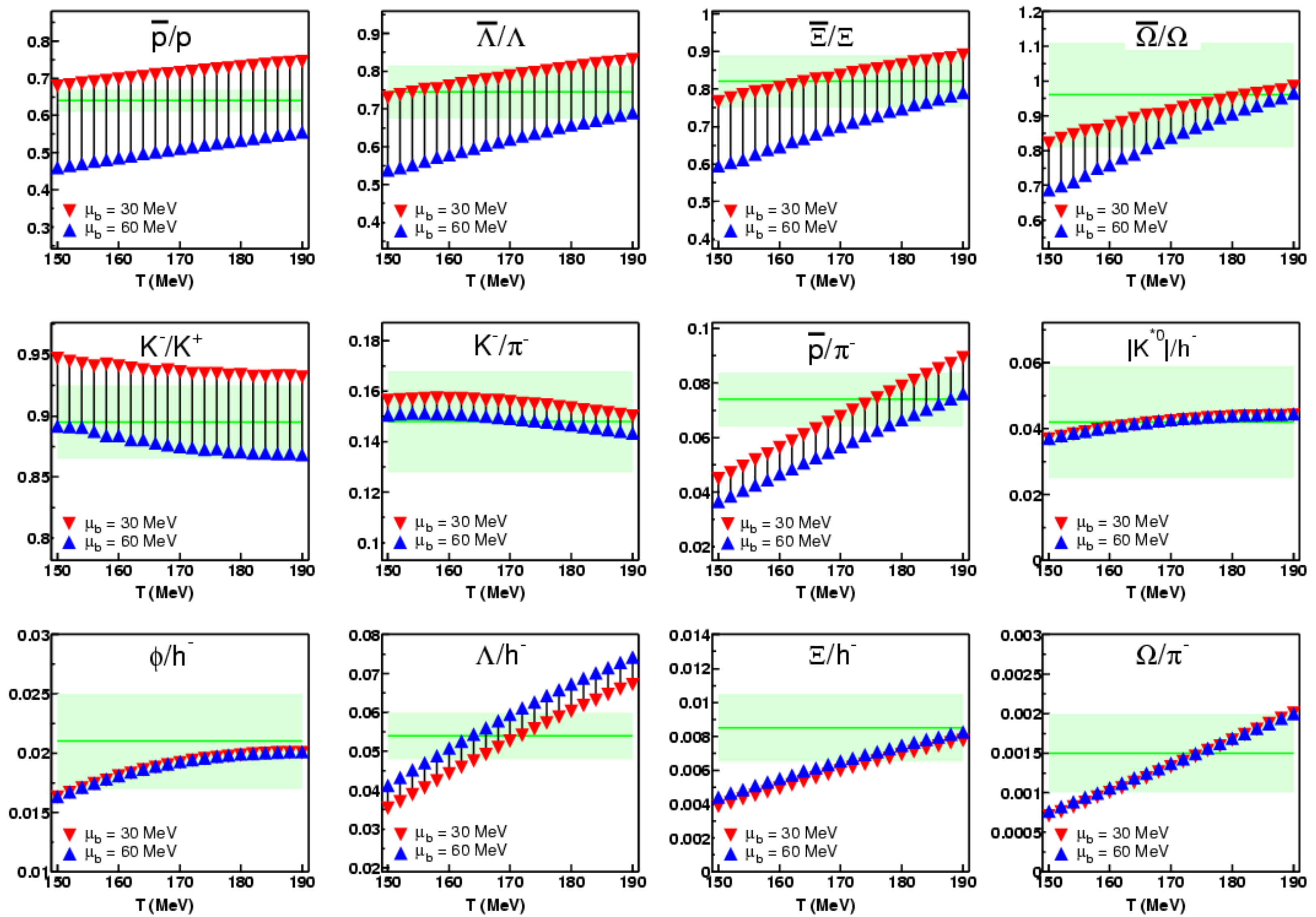
$$\rho_i = \gamma_s^{|s_i|} \frac{g_i}{2\pi^2} T_{ch}^{\ 3} \left(\frac{m_i}{T_{ch}}\right)^2 K_2(m_i/T_{ch})\ \lambda_q^{Q_i}\ \lambda_s^{s_i}$$

$$\lambda_q = \exp(\mu_q/T_{ch}), \quad \lambda_s = \exp(\mu_s/T_{ch})$$

Q_i : 1 for u and d, -1 for $\bar{u}$ and $\bar{d}$
s_i : 1 for s, -1 for $\bar{s}$
g_i : spin-isospin freedom
m_i : particle mass
T_{ch} : Chemical freeze-out temperature
μ_q : light-quark chemical potential
μ_s : strangeness chemical potential
γ_s : strangeness saturation factor

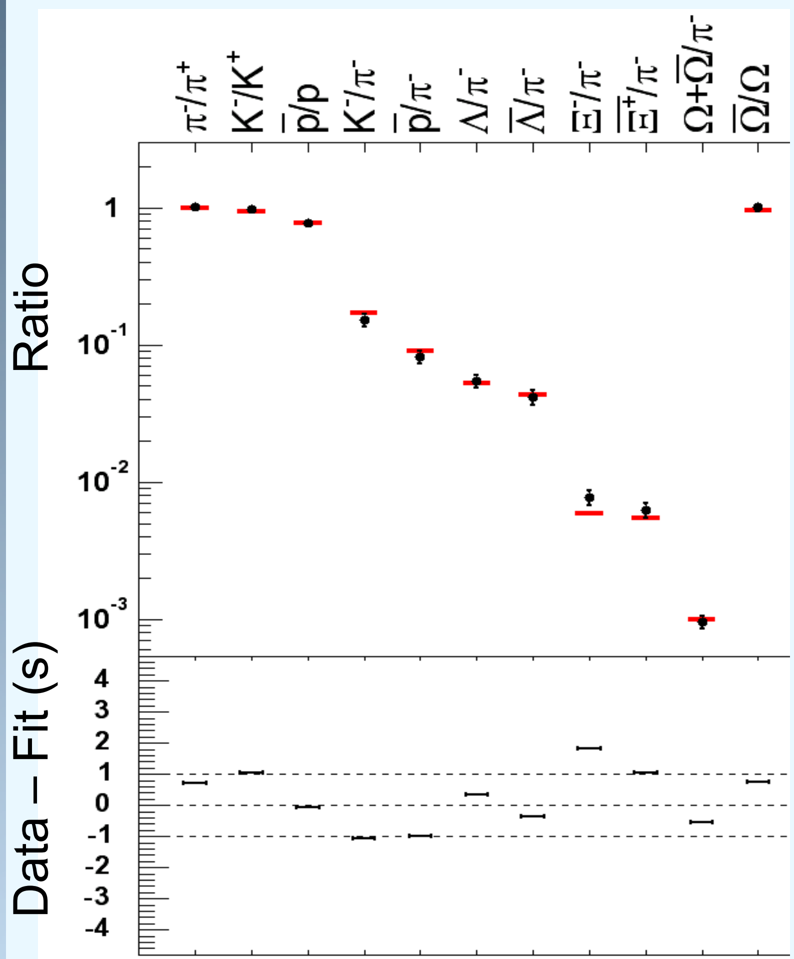
Compare particle ratios to experimental data

Ratios that constrain model parameters



D. Magestro, J. Phys G28 (2002) 1745; updated July 21

Thermal model fit to data



Created a Large System in Local Chemical Equilibrium

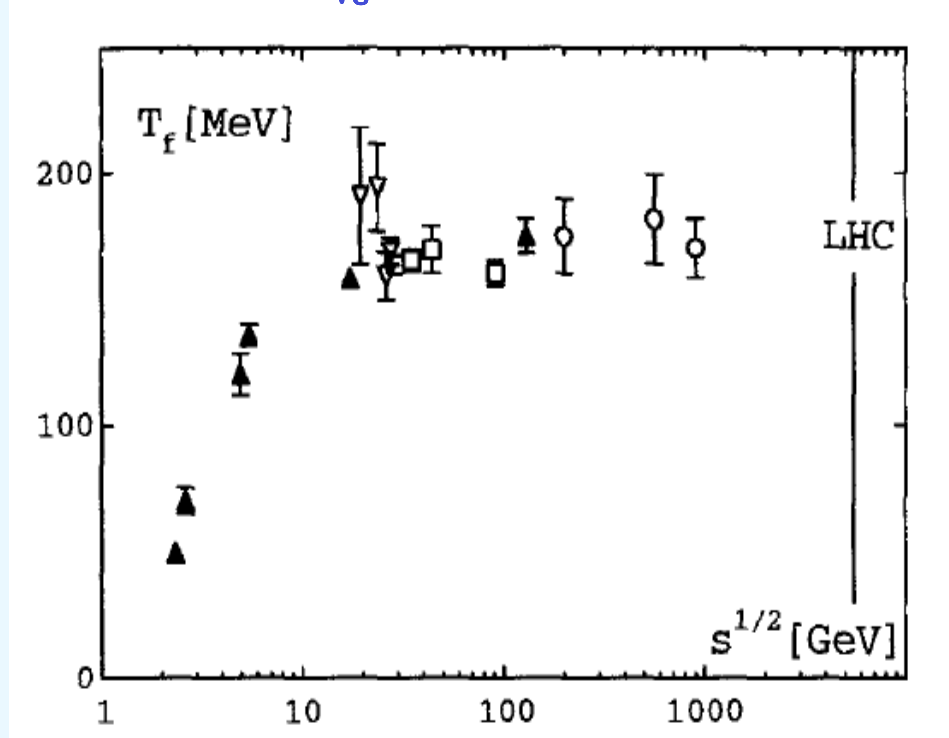
♦Particle ratios well described:

T_{ch} = 160 ± 5 MeV

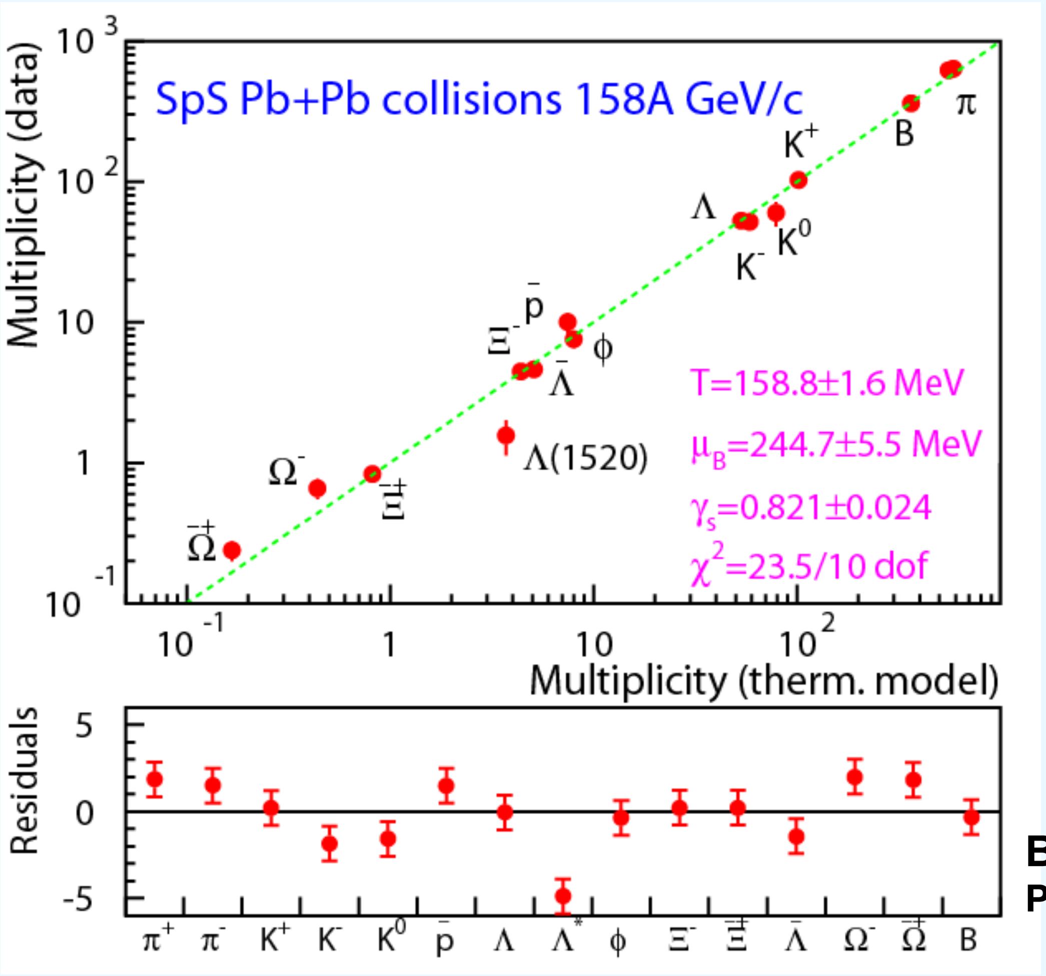
μ_B = 24 ± 5 MeV

μ_s = 1.4 ±1.4 MeV

γ_s = 0.99 ±0.07



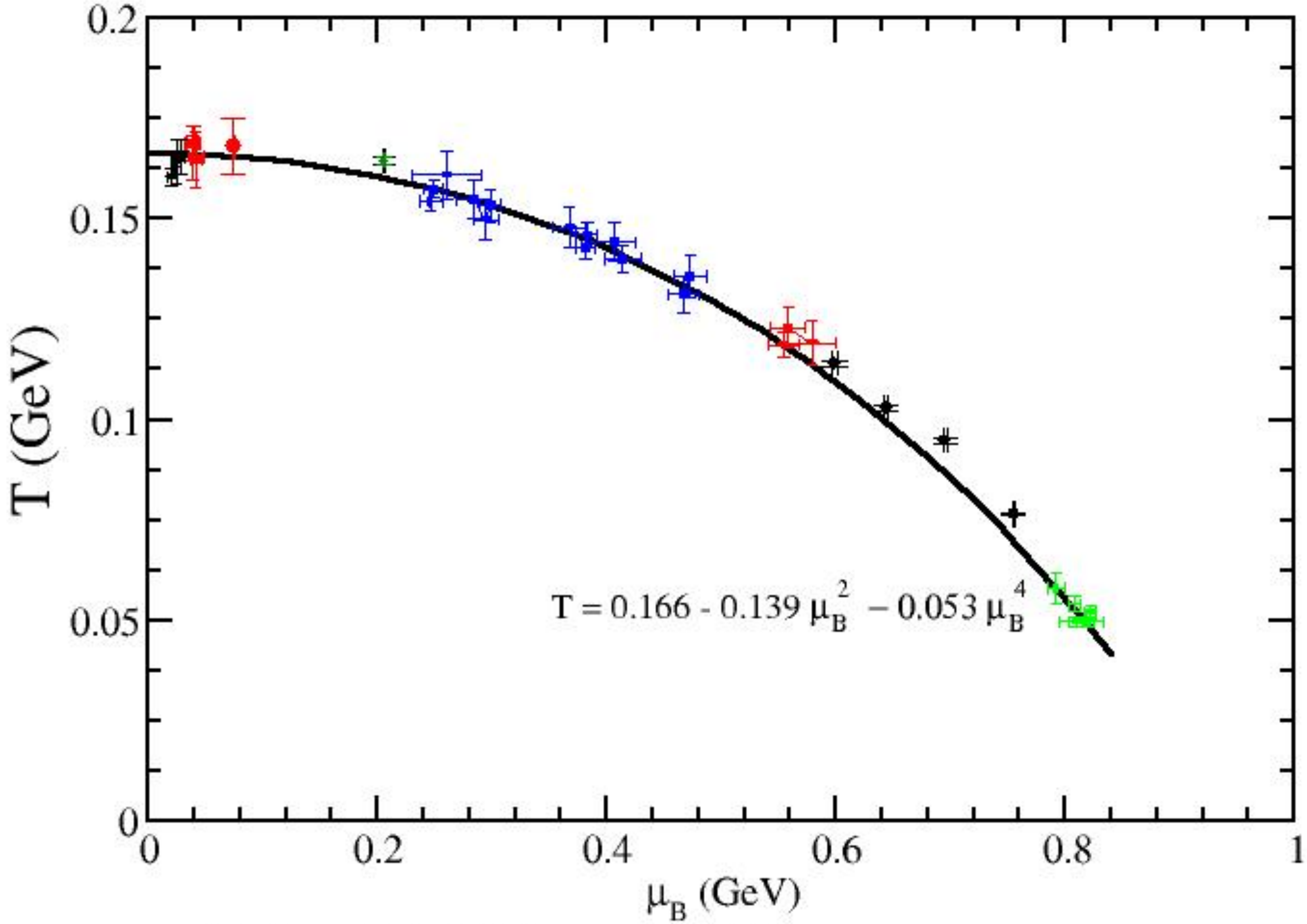
Statistical Modell



Becattini et al.,
PRC69 (2004) 024905

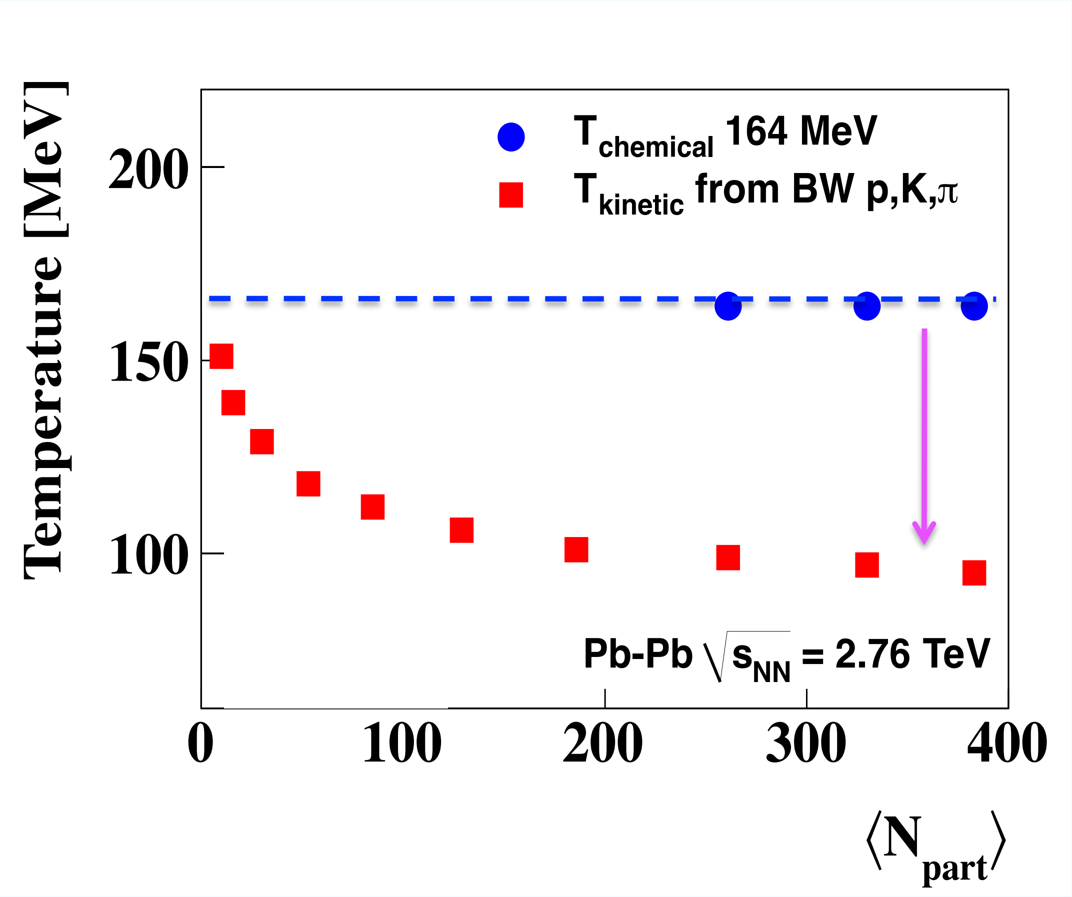
$$\langle n_j \rangle = \frac{(2J_j+1)V}{(2\pi)^3} \int d^3p \left[e^{\sqrt{p^2+m_j^2}/T + \mu\cdot q_j/T} \pm 1 \right]^{-1}$$

Chemische Freeze-Out Kurve



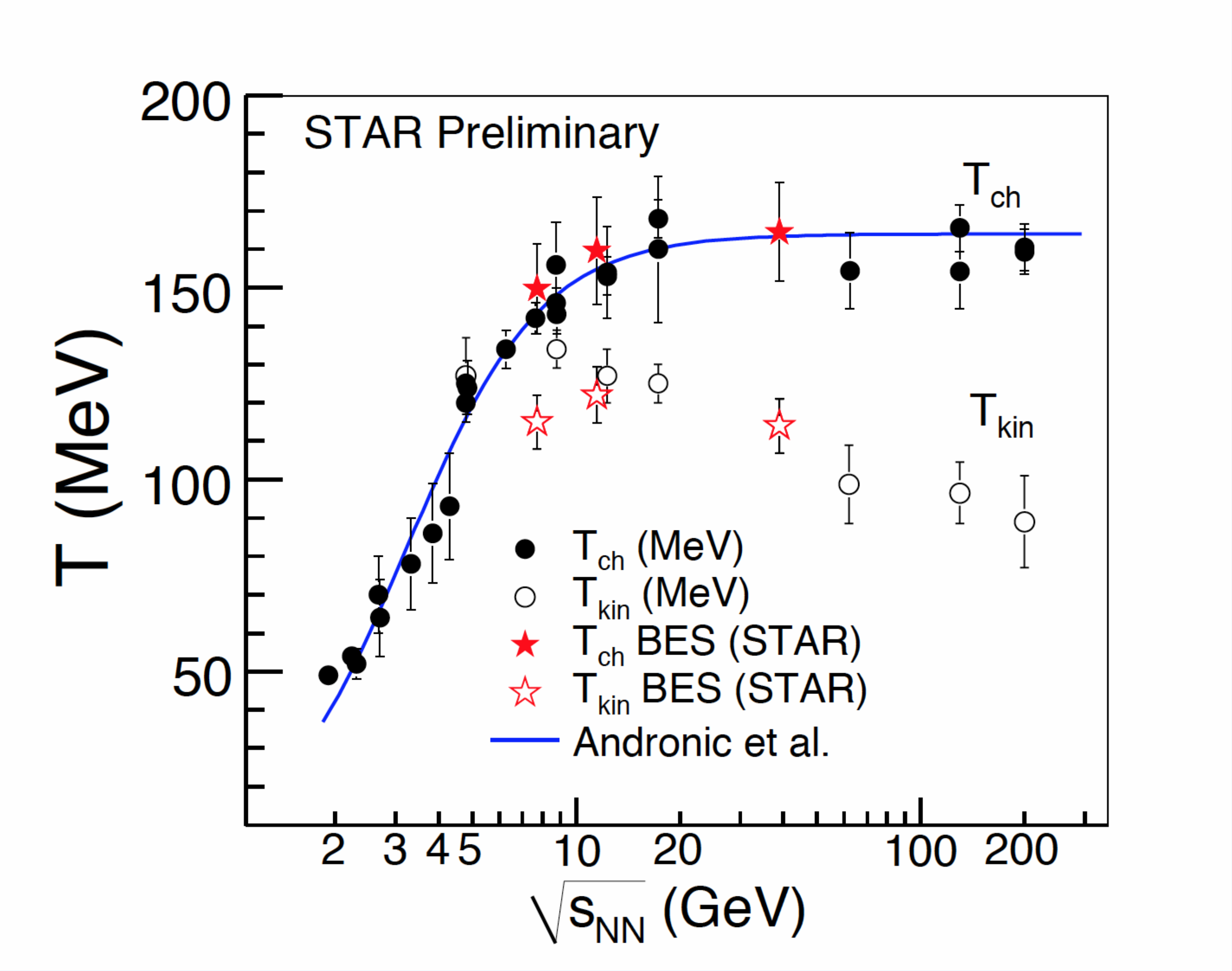
J.C., H. Oeschler, K. Redlich, S. Wheaton hep-ph/0511094

Chemical Freeze-out vs centrality

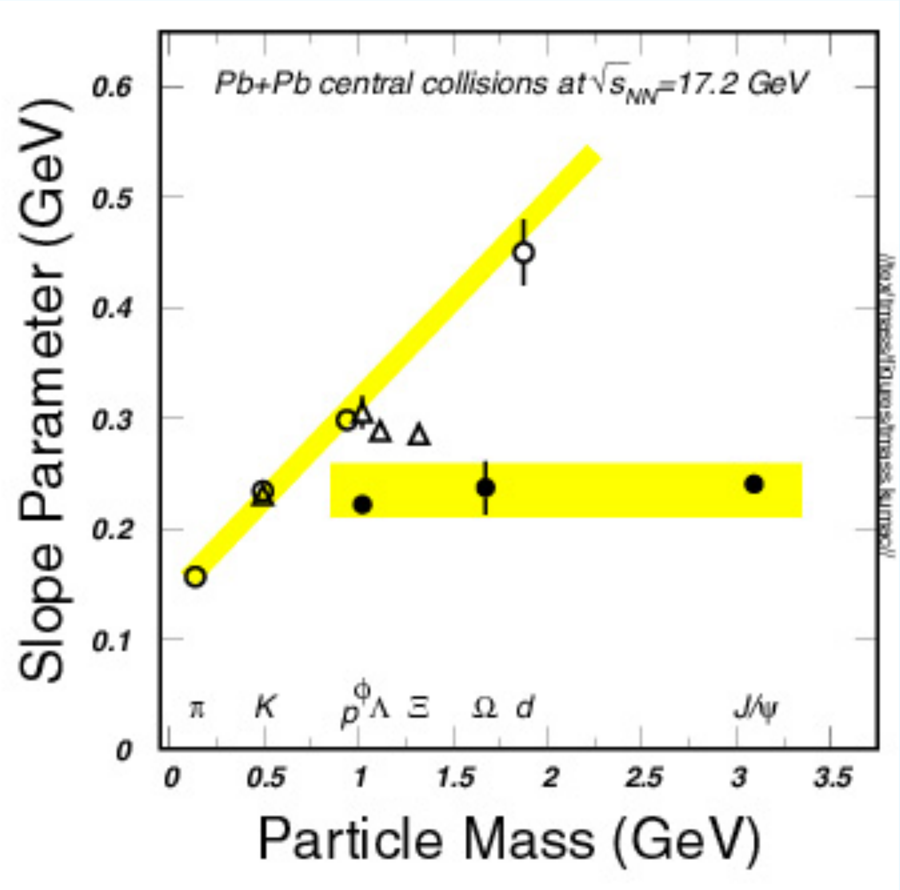


Collektive Effects (Flow)

Radial Flow: Energy dependence T_{kin}



Radial Flow



$$T_{eff} \approx T_0 + mV_t^2$$