Coalescence of quasiparticles and the robustness of this process

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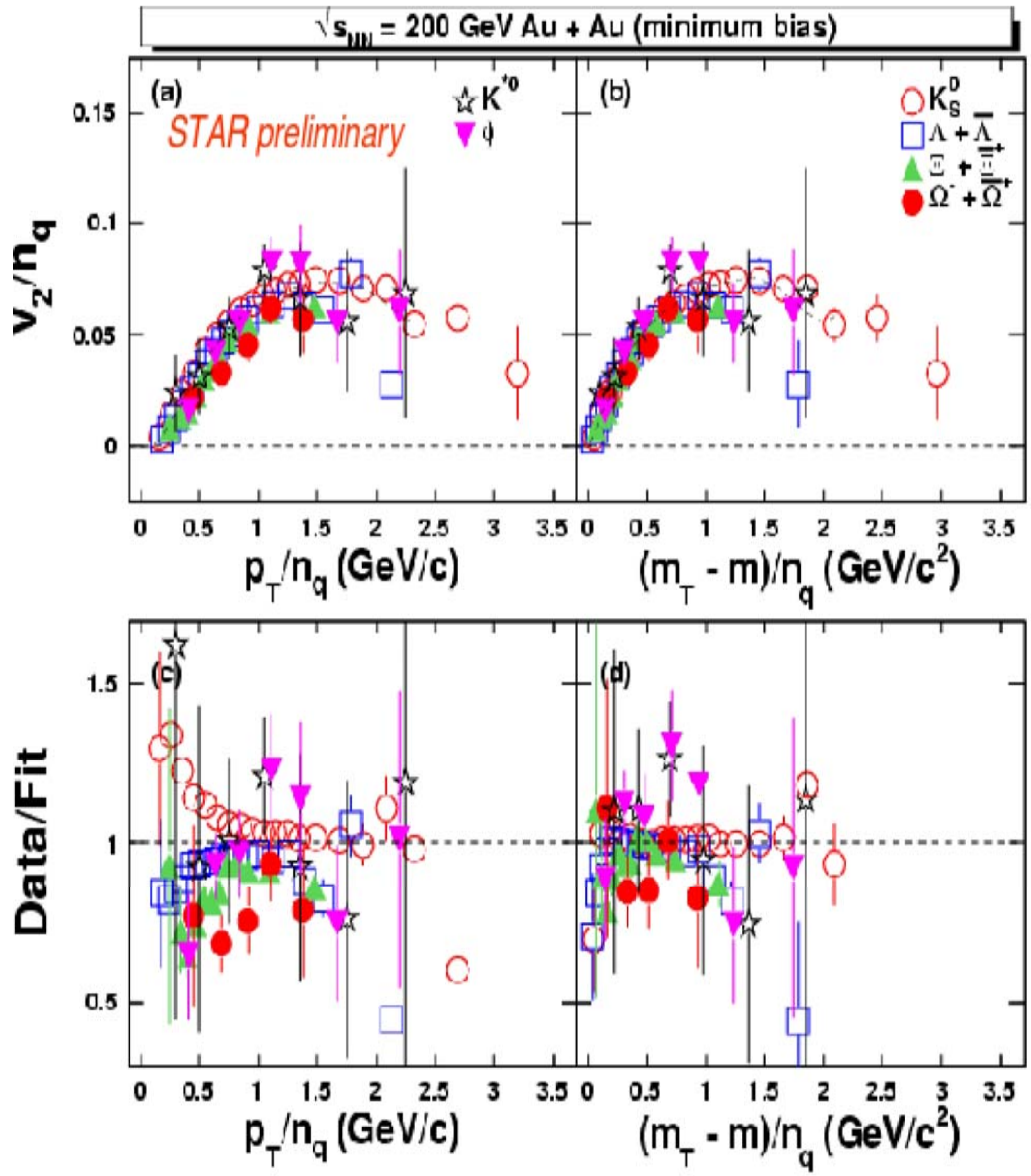
Scaling with valence quarks

- **SPS energy** →
  dN/dy, $dN/p_T dp_T$ [p_T<3 GeV]
- **RHIC energy** →
  dN/dy, $dN/p_T dp_T$ [p_T<7 GeV]
- **V_2** →
  quark coalescence!



What about the production rates and spectra?

Quark coalescence model

- **Fast rehadronization,**
  faster than hydrodynamics
- **Scaling with the number of valence quarks**
  (dN/dy, v_2)
- **ALCOR (Bíró, Lévai, Zimányi 1995)**
  - **good agreement with data**
    from SPS to RHIC
  - **Only dN/dy and hadronic ratios**
- **MICOR (Csizmadia, Lévai 1999)** $\rightarrow$ **p_T spectra**
- **Parton coalescence/recombination models**
  (Hwa, Yang 2002; Greco, Ko, Lévai 2003;
  Fries, Müller, Bass 2003; Voloshin, Molnár 2003; ...)

MICOR

- **Microscopic coalescence rehadronization model**
- **Based on quantummechanics**

$$g_{gh} = V_g \frac{-M_{h,Q'}}{2\pi} \int d^3\vec{x}_1 d^3\vec{x}_2 \cdot \tilde{\Psi}^*(\vec{x}_1, \vec{x}_2) V(\vec{x}_1 - \vec{x}_2) \phi_1(\vec{x}_1) \phi_2(\vec{x}_2)$$

  - **Incoming quark wave functions**
  - **Outgoing prehadron wave function**
  - **Effective quark potencial from the lattice results:**
    Yukawa potential, where appears the effective gluon mass (m_g):

    $\rightarrow$ $V(r) = -\frac{\alpha}{r} e^{-m_g r}$

- **g_{gh} $\rightarrow$ cross section and "σv"**

Hadron production

- Production rate = phase-space average of σv

$$\langle \sigma^h v \rangle = \frac{\int d^3\vec{p}_1 d^3\vec{p}_2 \cdot f_q(m_1, \vec{p}_1) f_q(m_2, \vec{p}_2)(\sigma(k) v_{12})}{\int d^3\vec{p}_1 d^3\vec{p}_2 \cdot f_q(m_1, \vec{p}_1) f_q(m_2, \vec{p}_2)}$$

  – Could it be local?

  – Quark momentum distribution !

    - Temperature
    - Boltzmann d., Jüttner d., Tsalis d., …

- Prehadron yield ~
  ~ „production rate” × „valence quark density”

- Prehadrons + plasma interactions
  → hadron resonances → decay of the resonances

Mesons, baryons

- Coalescence descibes 2 $\rightarrow$ 1 process
- Baryons:
  - quark + quark $\rightarrow$ diquark
  - diquark + quark $\rightarrow$ prebaryon
- Baryon producion depends on diquark's productions

$$\langle \sigma^h v \rangle_{123} \propto \frac{1}{3} \langle \sigma^h v \rangle_{12+3} \cdot \langle \sigma^h v \rangle_{1+2} + \frac{1}{3} \langle \sigma^h v \rangle_{13+2} \cdot \langle \sigma^h v \rangle_{1+3} + \\ + \frac{1}{3} \langle \sigma^h v \rangle_{23+1} \cdot \langle \sigma^h v \rangle_{2+3}$$

- Meson/meson and baryon/bayon ratios depends on the "important" parameters (m_g, T, wave functions, ..)
- Meson/baryon ratios depends on the other parameters (normalization, α_s, …)

Questions in focus

- **Production rate**
- **Production rate ratios**
- **Hadron yield ratios applying different wave functions**
- **Hadron spectra**

- **How these results depend on**
  - **Wave function model**
  - **QGP parameters: temperature, effective gluon mass**
  - **Quark momentum distributions**

Wave functions

- **In quantummechanics wave functions are important**
- **Incoming quark wave functions :**
  - **Plane wave + Plane wave**
  - **Plane wave + Gaussian ***
  - **Gaussian + Gaussian**
- **Outgoing prehadron wave functions :**
  - **Plane wave**
  - **Exponential (hydrogen like) ***
  - **Gaussian**

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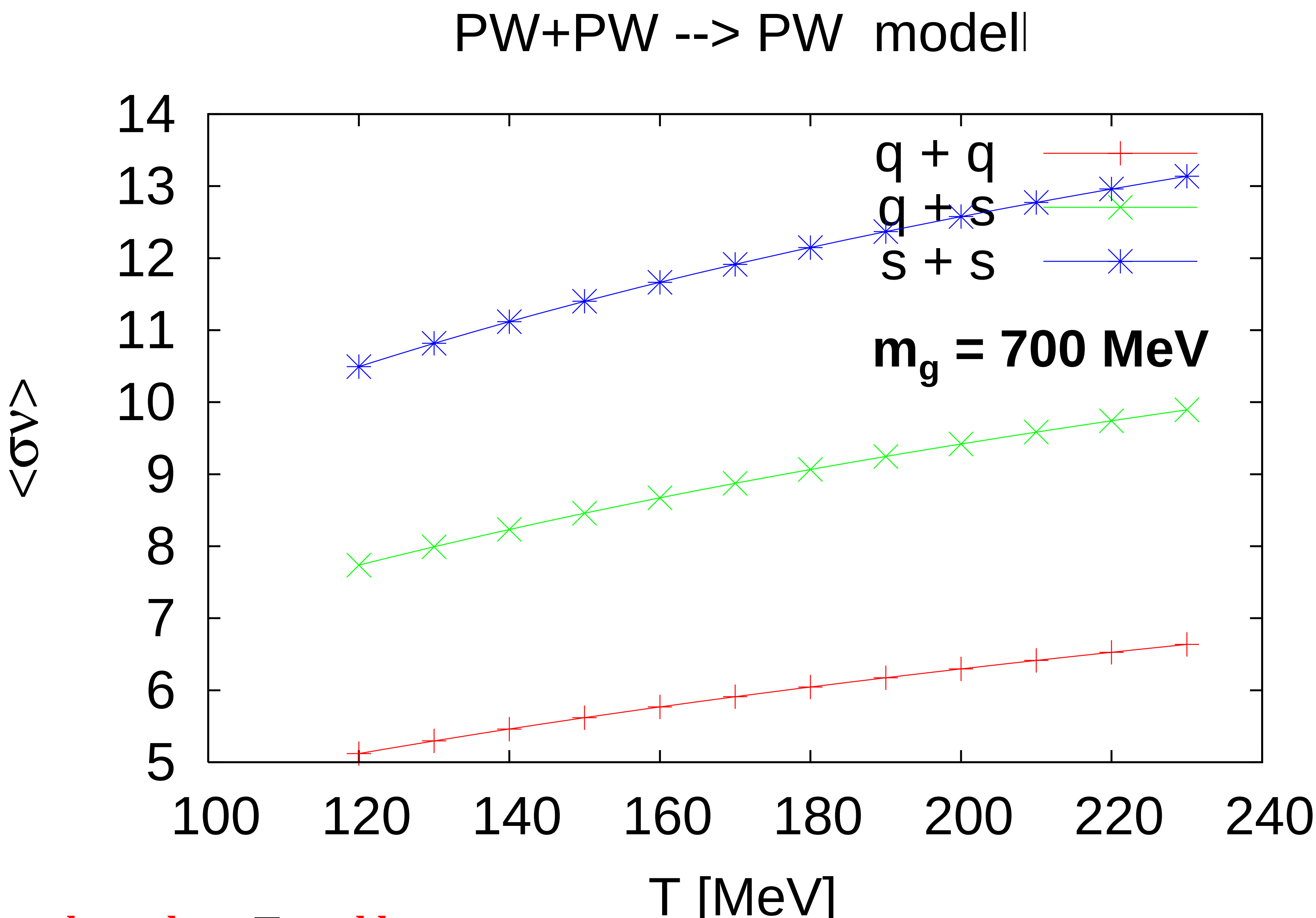
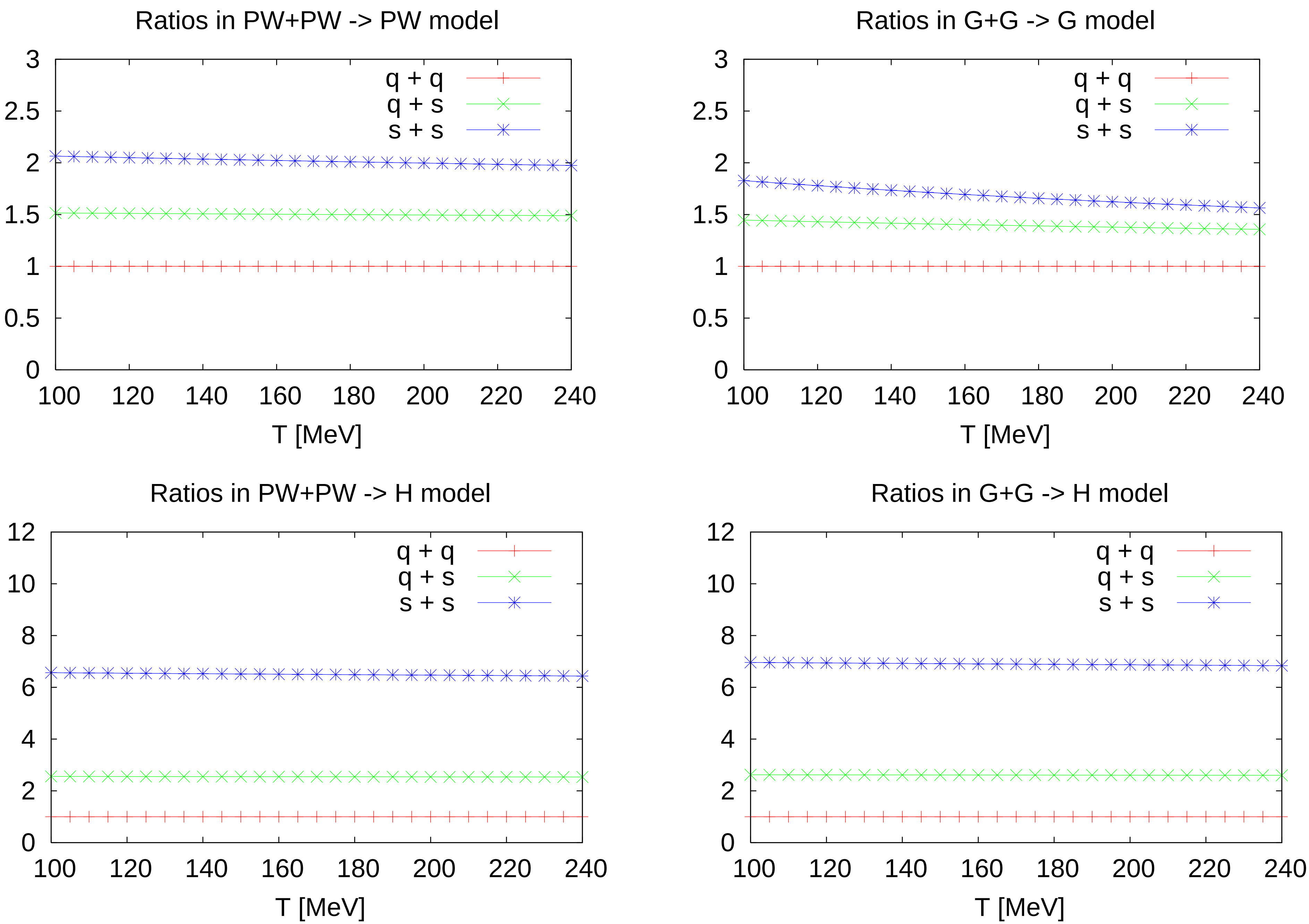
Production rate

Temperature dependence of the meson production rate



The rate depends on T weakly

Production rate ratios

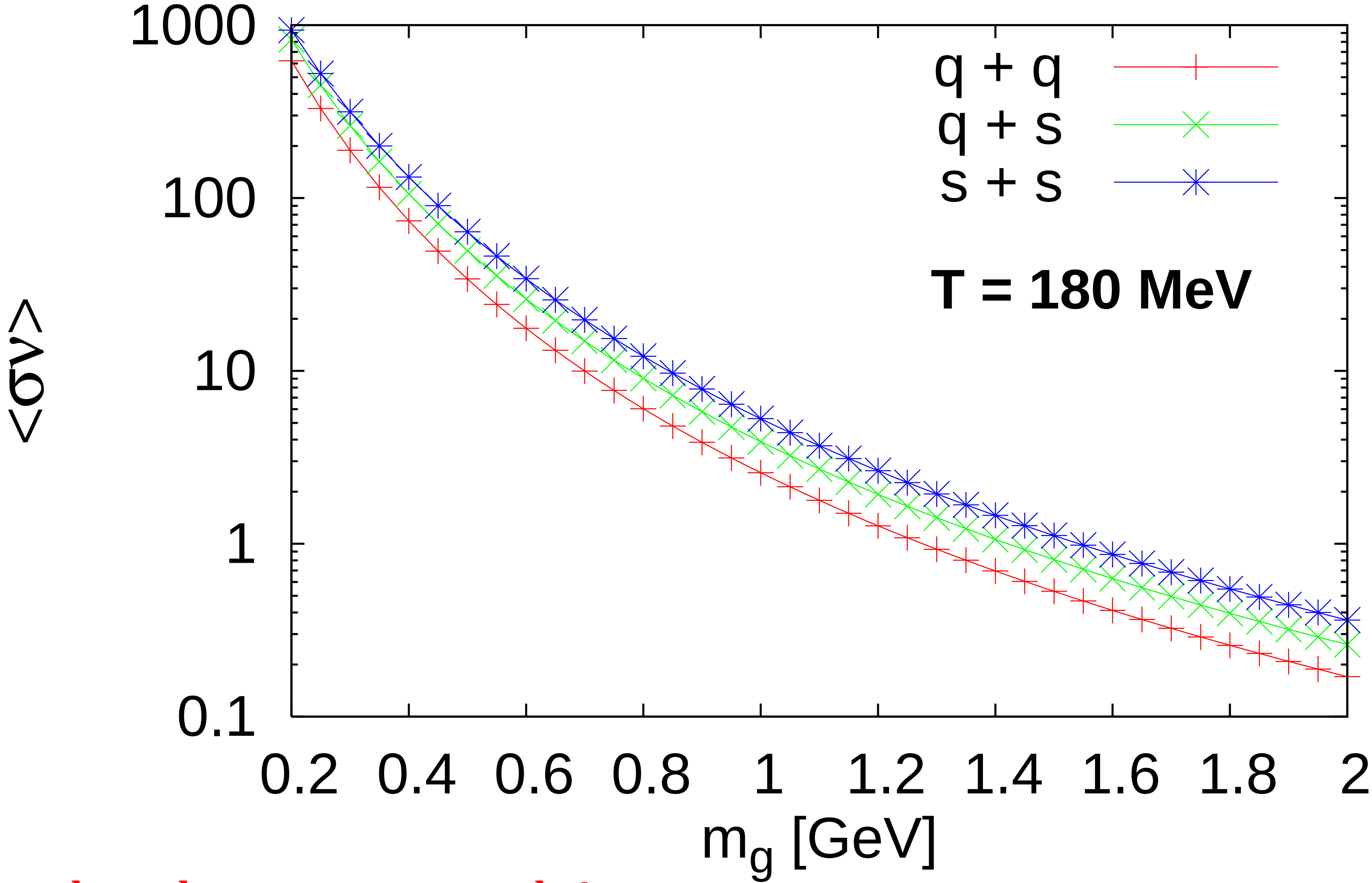


Production rate

Quark-quark potential : Yukawa with thermal gluon mass (m_g)

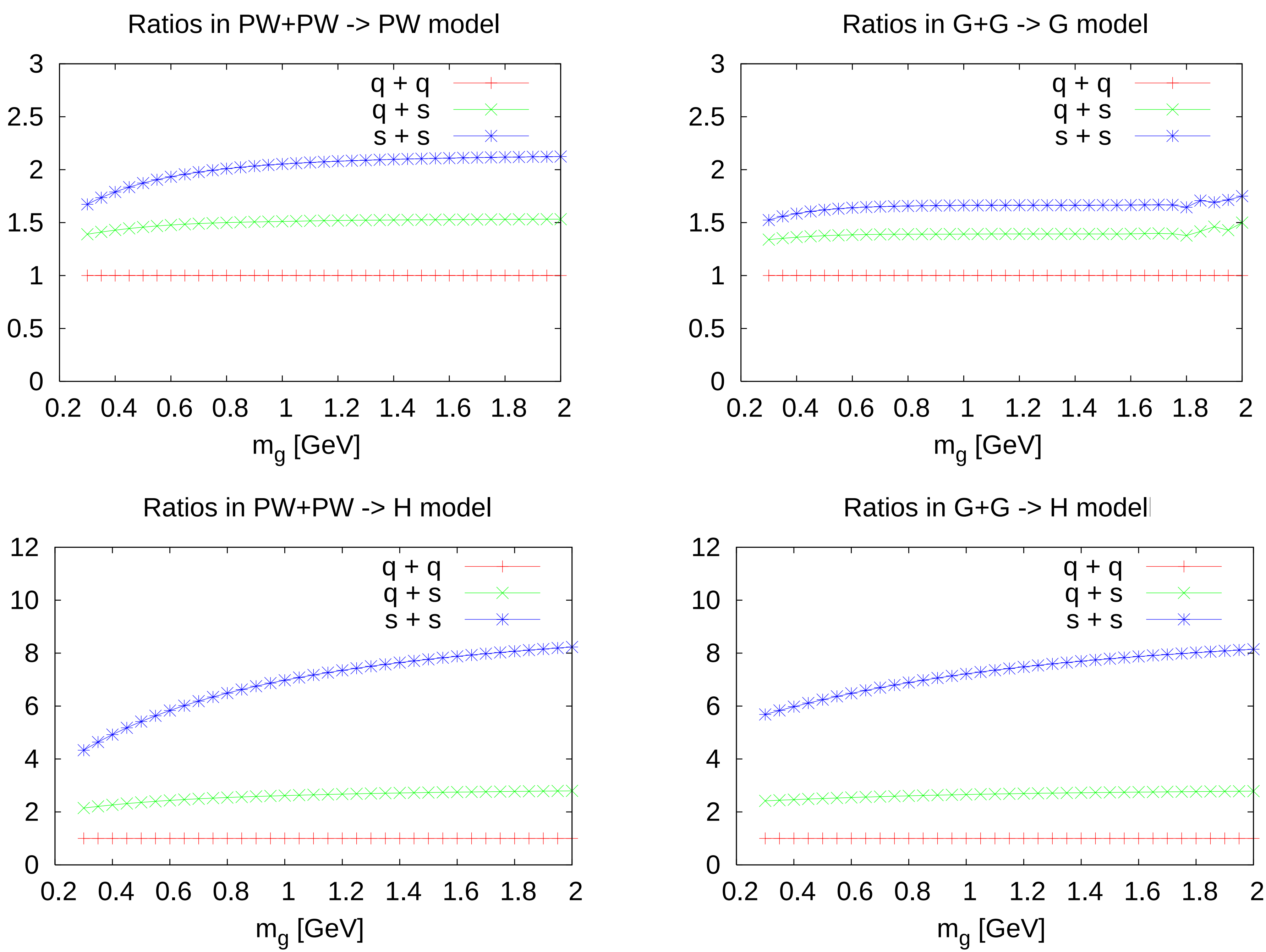
PW : Plane wave

PW+PW --> PW model



The rate depends on m_g very strongly !

Production rate ratios



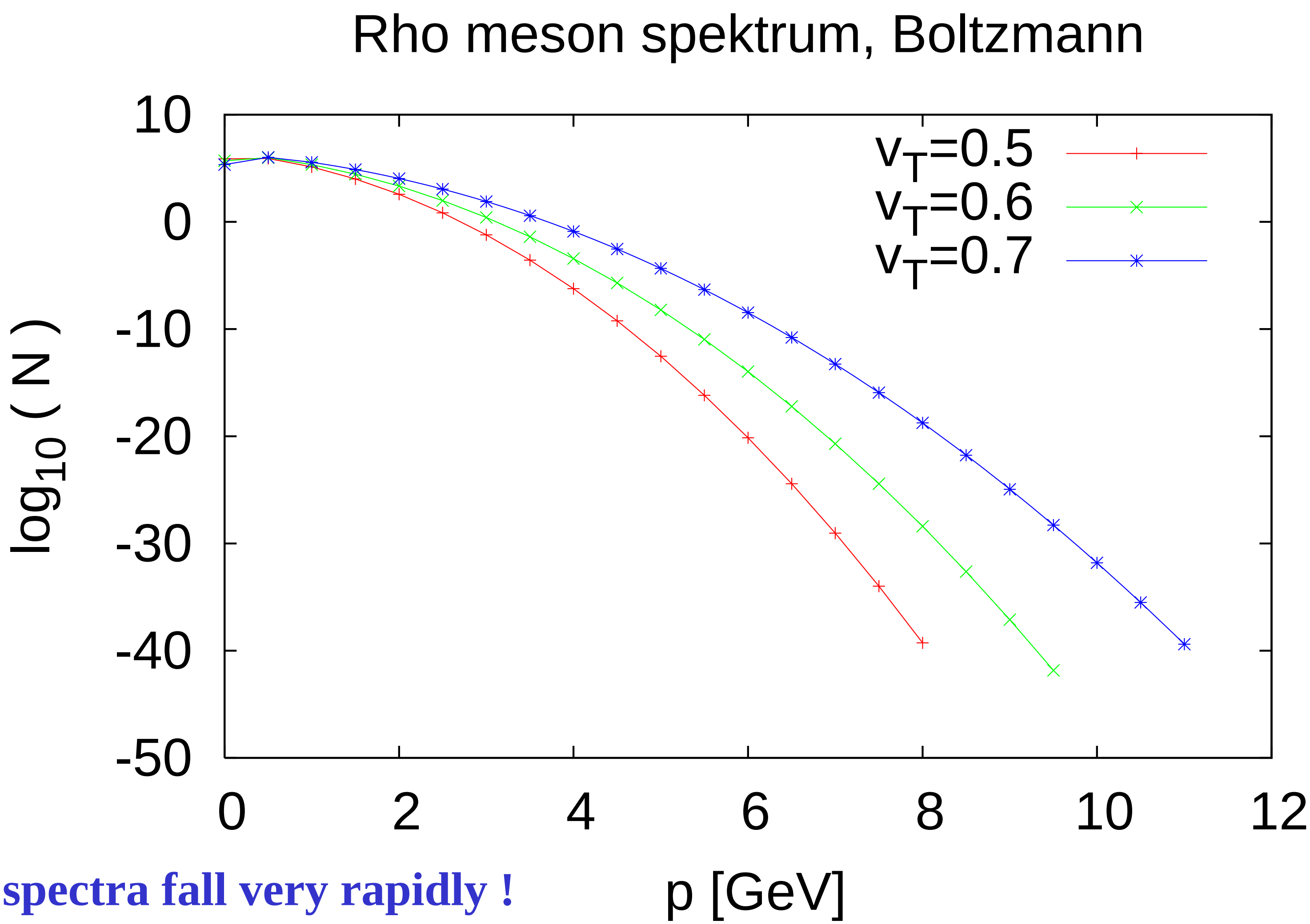
Hadron spectra

- Local coalescence !
- Prehadron momentum from the quarks momenta
  - Boltzmann distribution,
  - Jüttner distribution,
  - Tsalis distribution
- A hadron has the same momentum as it's prehadron
- Exploding fireball (v_T)
- Boost with the velocity-field (locally)
  - spherical symmetry,
  - Björken flow,
  - hydro model

Hadron spectra

Applying classical Boltzmann distributon

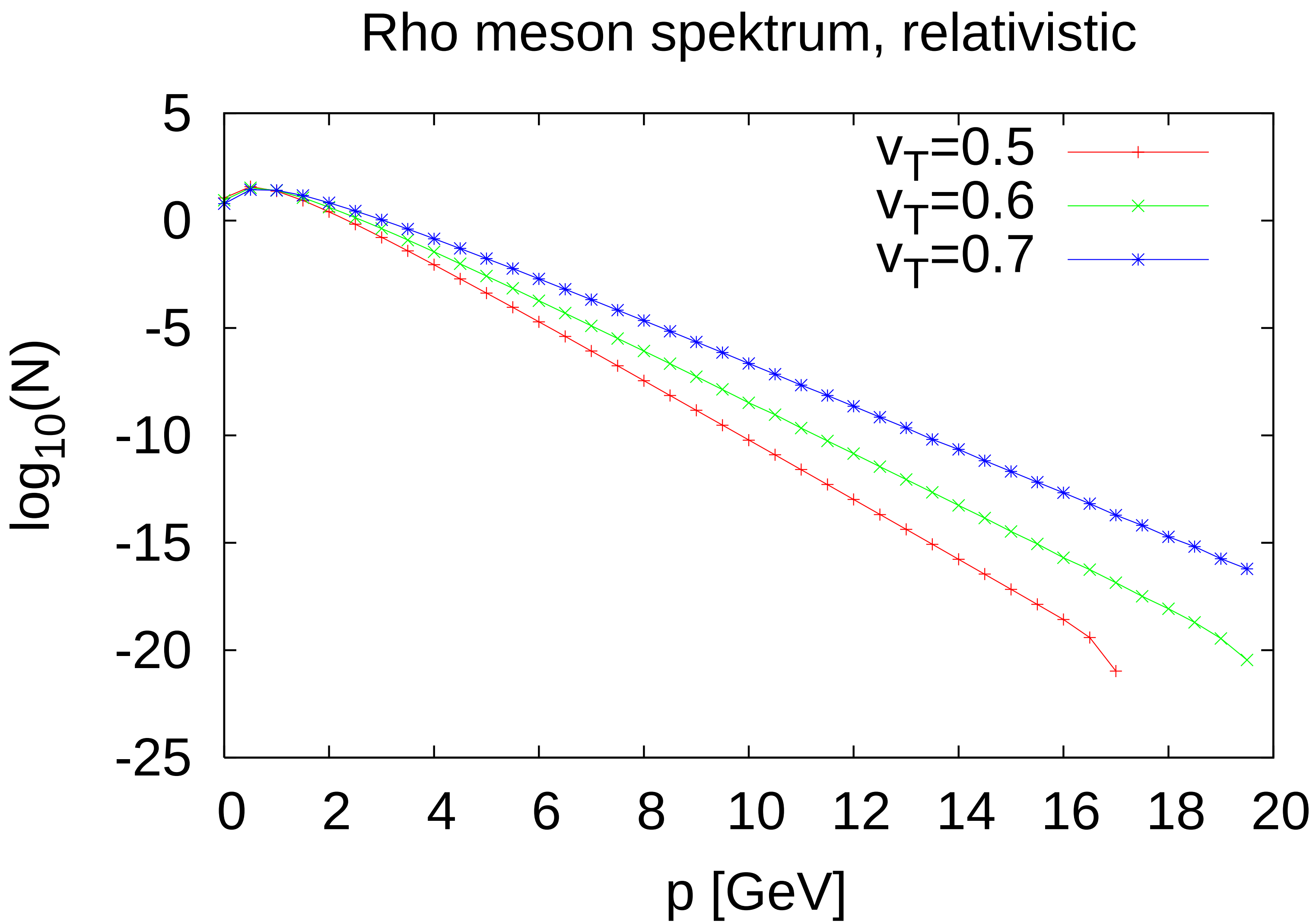
→ the hadron spectra are independent on the initial wave function



These spectra fall very rapidly !

Hadron spectra

Applying Jüttner distributon



Hadron ratios

Modell	N_s/N_q	K^*/ρ	ϕ/K^*	Σ^*/Δ	Ξ^*/Σ^*	Ω/Ξ^*
Boltzmann d.						
PW+PW>PW	0.448	0.671	0.600	0.790	0.700	0.644
PW+PW>H	0.235	0.598	0.600	0.848	0.785	0.746
PW+PW>G	0.474	0.686	0.600	0.791	0.690	0.628
G+G>PW	0.441	0.668	0.600	0.790	0.702	0.648
G+G>H	0.227	0.593	0.600	0.849	0.791	0.753
G+G>G	0.503	0.700	0.600	0.791	0.681	0.614
Jüttner d.						
PW+PW>PW	0.401	0.701	0.600	0.857	0.721	0.644
PW+PW>H	0.206	0.624	0.600	0.928	0.815	0.752
PW+PW>G	0.424	0.706	0.600	0.843	0.708	0.631
G+G>PW	0.396	0.701	0.600	0.862	0.724	0.647
G+G>H	0.201	0.620	0.600	0.931	0.819	0.757
G+G>G	0.435	0.712	0.600	0.845	0.706	0.627
ALCOR		0.434	0.391	0.574	0.506	0.442

Hadron ratios *

Modell	N_s/N_q	K^*/ρ	ϕ/K^*	Σ^*/Δ	Ξ^*/Σ^*	Ω/Ξ^*
Boltzmann d.						
PW+PW>PW	0.291	0.436	0.390	0.513	0.455	0.419
PW+PW>H	0.153	0.389	0.390	0.551	0.510	0.485
PW+PW>G	0.308	0.446	0.390	0.514	0.448	0.408
G+G>PW	0.287	0.434	0.390	0.513	0.456	0.421
G+G>H	0.148	0.385	0.390	0.552	0.514	0.490
G+G>G	0.327	0.455	0.390	0.514	0.443	0.399
Jüttner d.						
PW+PW>PW	0.260	0.456	0.390	0.557	0.469	0.419
PW+PW>H	0.134	0.405	0.390	0.603	0.529	0.489
PW+PW>G	0.275	0.459	0.390	0.548	0.460	0.410
G+G>PW	0.258	0.456	0.390	0.560	0.470	0.420
G+G>H	0.131	0.403	0.390	0.605	0.532	0.492
G+G>G	0.283	0.463	0.390	0.549	0.459	0.408
ALCOR		0.434	0.391	0.574	0.506	0.442

Summary

- Fast rehadronization by quark coalescence
- Quantummechanical description
- Robustness in hadron ratios for different
  - wave functions
  - parameters (temperature, effective gluon mass, ...)
  - and quark momenta distributions
- Specta are given by the fireball velocity profile

Outlook

- Include resonance decay
- Study different fireball velocity-fields
- Spectra dependence on fireball density distribution
- Periferial collisions
- Test further quark momenta distributions