Non-extensive Hadron Distributions at RHIC Energy

Ürmössy Károly • MTA KFKI RMKI, ELTE
Bíró Tamás • MTA KFKI RMKI
Ván Péter • MTA KFKI RMKI

- Transverse hadron spectra from a flowing but locally equilibrated QGP.
- Extensive and non-extensive hadron distributions.

PLAN

- Confront

  Non-extensive ***200 GeV cm E AuAu RHIC***

  Thermo with ***Transverse Spectra***

- Results

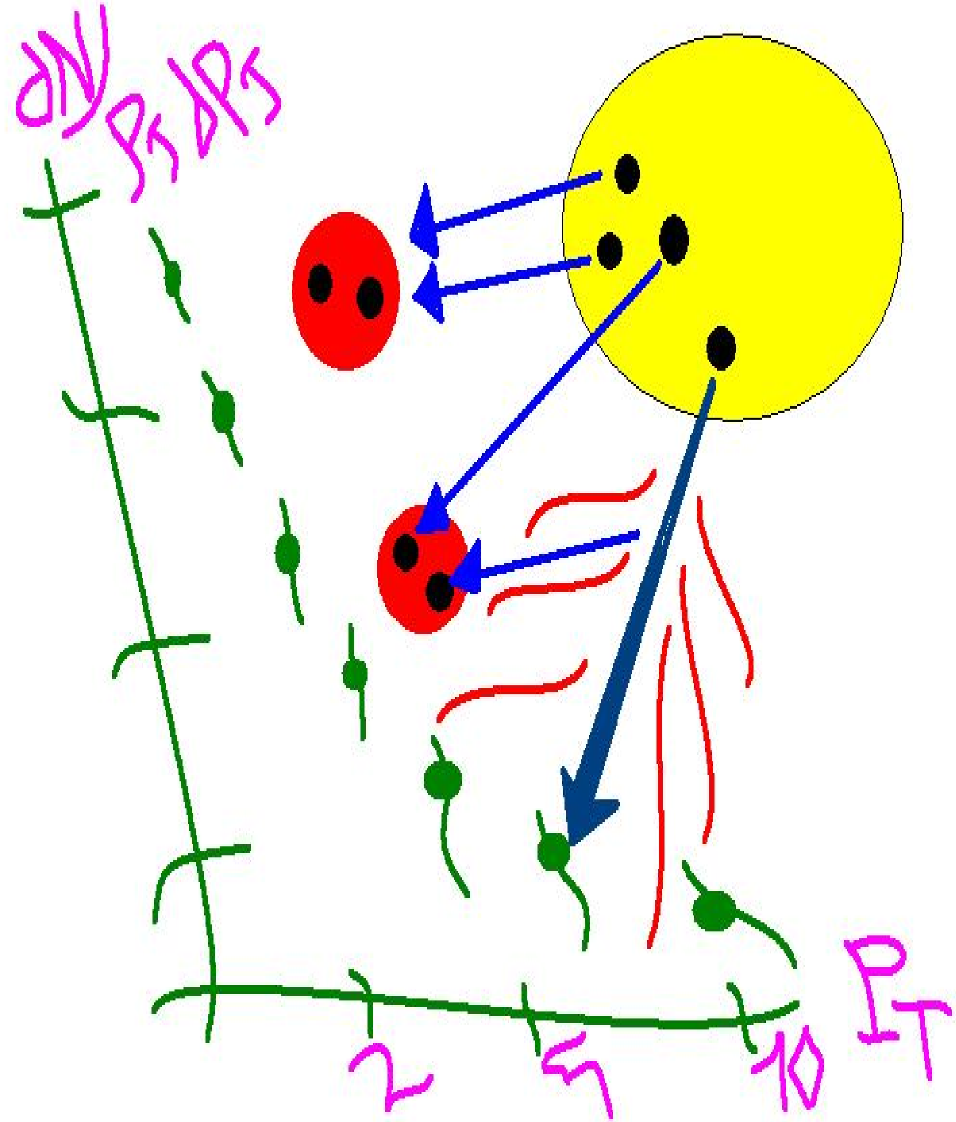
  If dN/pT*dpT at RHIC is ***thermal***

  from 0 to 2 GeV its Statistics is ***Boltzmann***

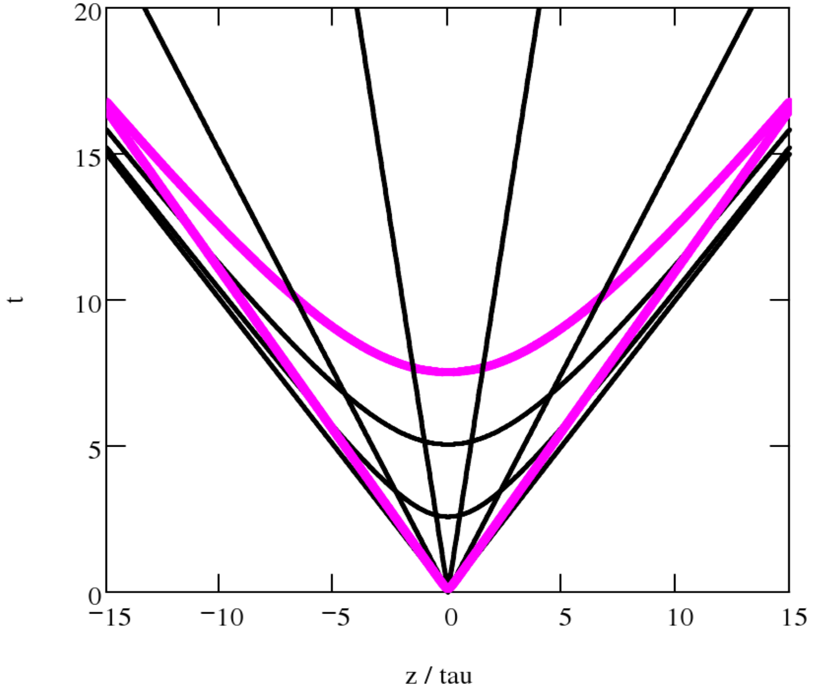
  from 0 to 5 GeV its Statistics is ***Non-ext. Tsallis***

  from 0 to 20 GeV its Statistics is ***Non-Ext. Hyper-Tsallis***

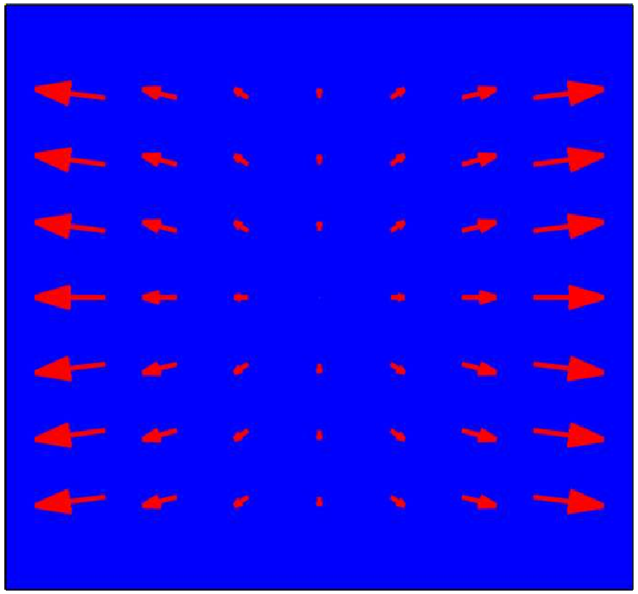
Jets and recombination or non-extensivity?



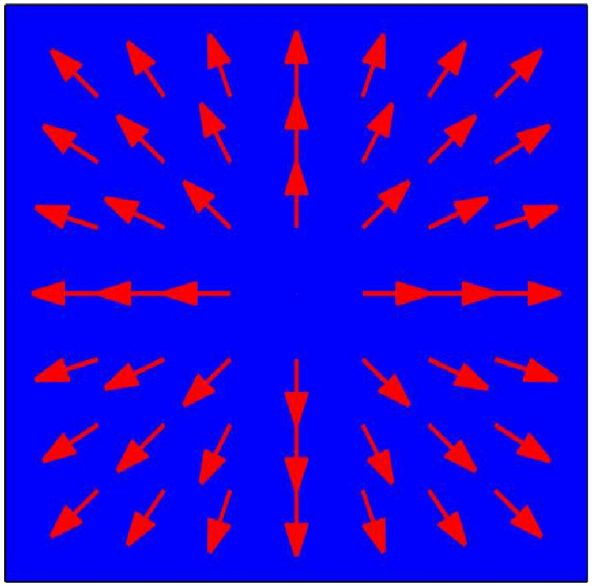
The Flow Profil of the QGP



Hadronization hyper-surface in the longitudinal direction



Longitudinal flow profile



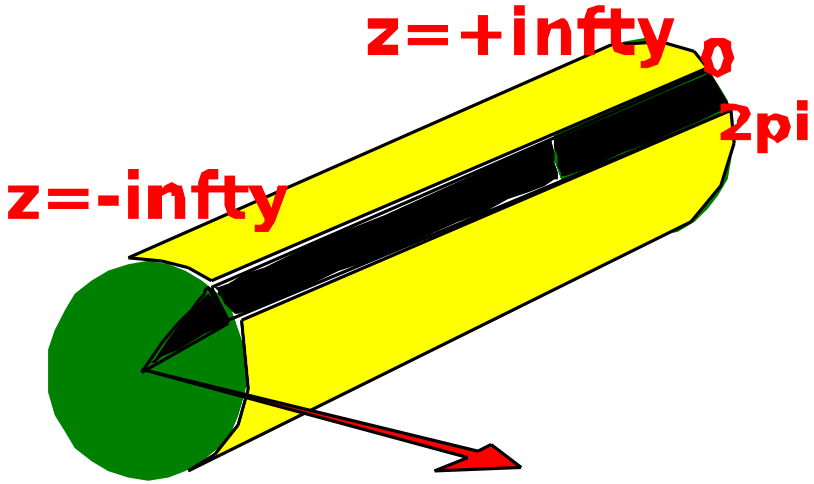
Transverse flow profile

$$u^{\mu}=(\gamma\cosh\zeta,\gamma\sinh\zeta,\gamma v\cos\alpha,\gamma v\sin\alpha),\qquad \zeta=\frac{1}{2}\ln\left(\frac{t-z}{t+z}\right)$$

Transverse Hadron Spectrum From the Locally Equilibrated Plasma

$$\left.\frac{dN}{p_T\, dp_T\, dy}\right|_{y=0} = p^0 \frac{dN}{d^3 p} = \int p_\mu\, d\sigma^\mu F(\beta p_\mu u^\mu)$$

Boundaries:



$$\frac{dN}{p_T\, dp_T} = \int_0^\infty d\zeta \int_0^\pi d\phi \left(A^v m_T \cosh(\zeta) + A^s p_T \cos(\phi) \right) F(\beta p_\mu u^\mu)$$

$$A^v = \pi R^2 \tau \rightarrow A\xi, \qquad A^s = \pi R \tau^2 \rightarrow A(1-\xi)$$

Boltzmann-Gibbs Hadron Distribution:

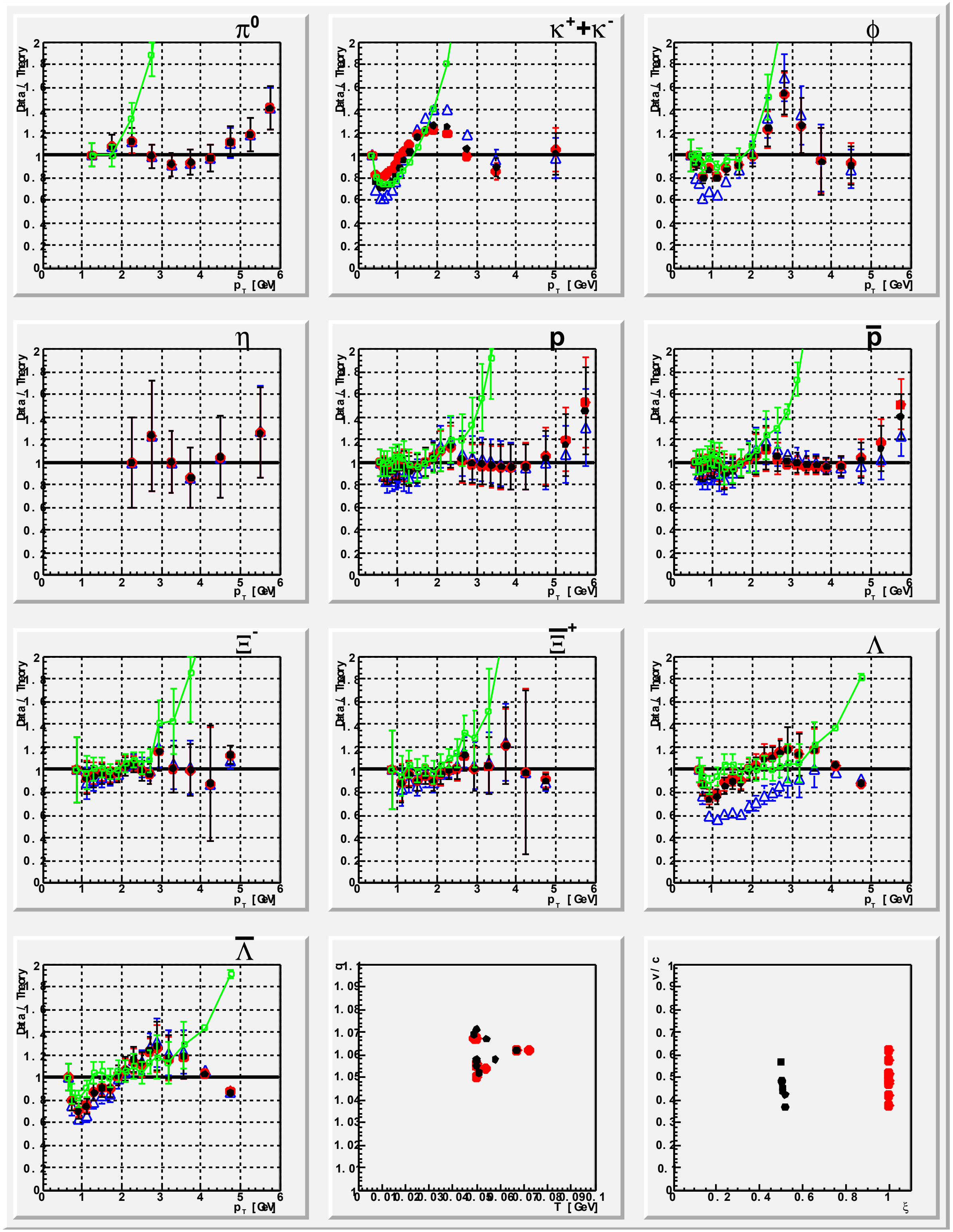
$$\frac{dN}{p_T\,dp_T} = A\,\xi\, m_T\, K_1(\beta\gamma\, m_T)\, I_0(\beta\gamma\, v p_T) + A(1-\xi)\, K_0(\beta\gamma\, m_T)\, I_1(\beta\gamma\, v p_T) \rightarrow e^{-\beta\gamma(m_T - v p_T)}$$

Tsallis Hadron Distribution:

$$\frac{dN}{p_T\,dp_T} = \frac{A^{vol}\, G_0(p_T)\, m_T + A^{surf}\, G_2(p_T)\, p_T}{\left(1+(q-1)\beta\gamma(m_T - v p_T)\right)^{1/(q-1)}} \sim \frac{1}{p_T^{1/(q-1)-1}}$$

$S^{1/2}$=200 GeV
RHIC AuAu

Data / Theory



How to go on? Maximum entropy principle

If we can derive a quasi-energy composition rule:

$$E_{12}=h(E_{1,}E_2)\rightarrow L(E_{12})=L(E_1)+L(E_2), \quad L(E)=\int^E \frac{d\tilde{E}}{h'_2(\tilde{E},0)}$$

The maximum entropy with fixed mean quasi-energy

$$max=-\int f\ln f-\beta\left(\int L(E)f(E)-L(E_0)/N\right)$$

gives

$$f(E)=\frac{\exp(-\beta L(E))}{Z(\beta)}$$

h(x,y) as the effect of the environment

Fokker-Planck approach:

$$\partial_t f = \partial_p \left(G(E) E' + \partial_p D(E) \right) f$$

With stationary sollution

$$f(E) = \frac{A}{D(E)} \exp\left(-\beta \int^{E} \frac{d\tilde{E}\, G(\tilde{E})}{D(\tilde{E})} \right)$$

Hence the connection of h and D, G:

$$G(E) = \frac{\beta D(E)}{h'_2(E,0)} - D'(E)$$

Boltzmann-Gibbs case:

$$h(E_{1,}E_2) = E_1 + E_2 \rightarrow L(E) = E$$

$$f = \exp(-\beta E)/Z$$

Tsallis case:

$$h(E_{1,}E_2) = E_1 + E_2 + a E_1 E_2 \rightarrow L(E) = \frac{1}{a} \ln(1 + aE)$$

$$f = (1 + aE)^{-\beta/a}/Z$$

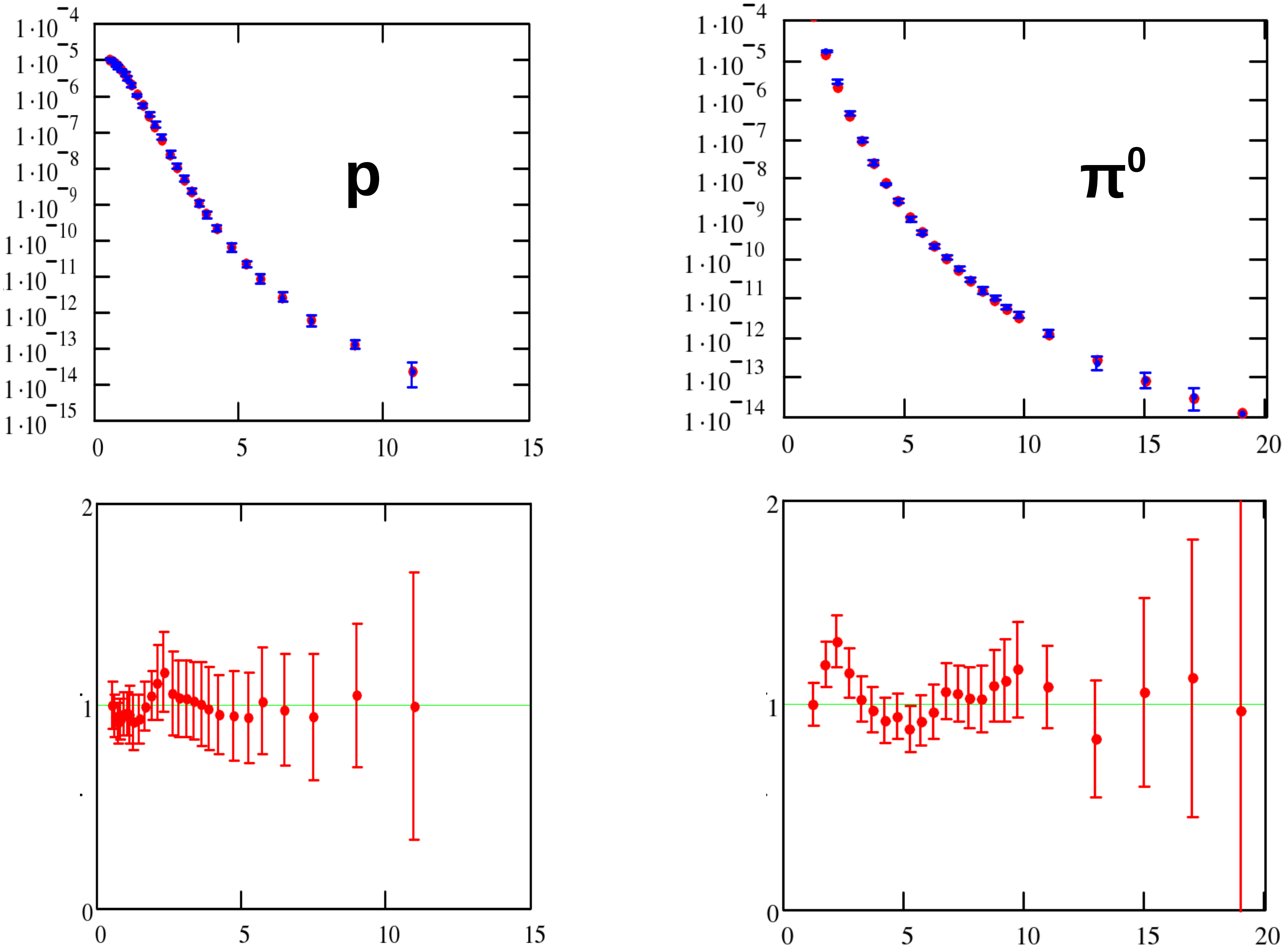
Hyper-Tsallis case:

$$h(E_{1,}E_2) = E_1 + E_2 + a E_1 E_2 + b/2(E_1^2 E_2 + E_2^2 E_1)$$

$$L(E) = \frac{1}{\alpha} \ln\left(\frac{2 + (a-\alpha)E}{2 + (a+\alpha)E}\right) \qquad f = \left(1 - \frac{2\alpha E}{2 + (a+\alpha)E}\right)^{\beta/\alpha}/Z$$

$$\alpha = \sqrt{a^2 - 2\mathrm{b}}$$

Hyper-Tsallis Fittings



Conclusion

- Either by a ***stochastic transport*** or by a ***non-extensive thermo model*** the $s=(200\ GeV)^2$ RHIC AuAu transverse spectra can be described well.

References

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