Excitation functions of kinetic freeze-out temperature and transverse flow velocity in proton-proton collisions

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Outline

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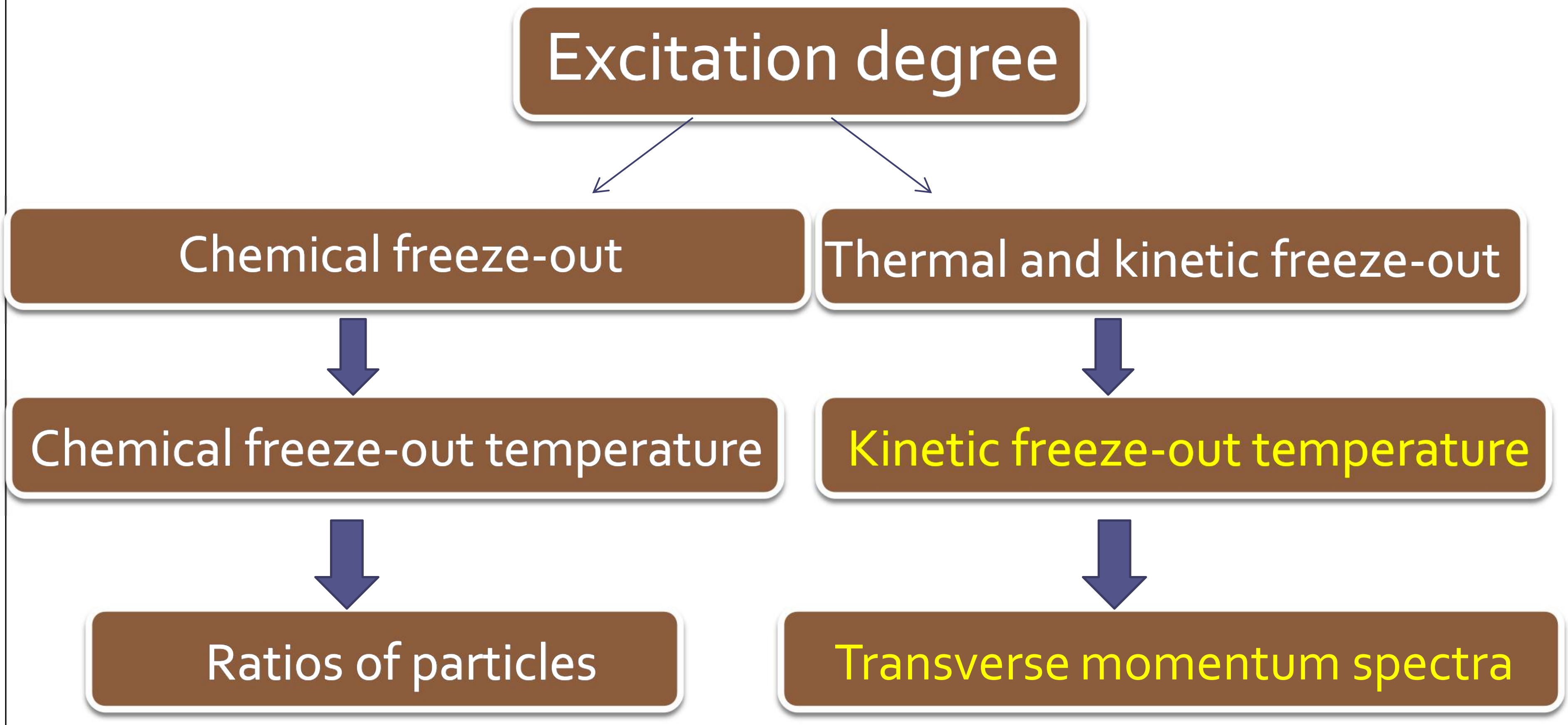

Excitation degree
Chemical freeze-out
Thermal and kinetic freeze-out
Chemical freeze-out temperature
Kinetic freeze-out temperature
Ratios of particles
Transverse momentum spectra

Bankgroud

Kinetic freeze-out temperature

Transverse momentum spectra

- Hydrodynamical model
- Blast-wave model
  - Boltzmann-Gibbs statistics
  - Tsallis statisics

- Random thermal motion reflect the excitation degree
- Transverse flow reflect the collective expansion

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- The excitation function of the kinetic freeze-out temperature is very interesting for us to study the properties of high energy collisions.

- Althouge there are many similar studies on this topic, the results seem to be inconsistent.

- The excitation function of the chemical freeze-out temperature shows initially increases and then consistently saturates with collision energy.

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Blast-wave model

Boltzmann-Gibbs statistics and Tsallis statistics

Inelastic (INEL) or nonsingle-diffractive (NSD) *pp collisions* which are closer to peripheral nuclear collisions comparing with central nuclear collisions.

- SPS : NA61/SHINE
- RHIC : PHENIX、STAR
- LHC : ALICE、CMS

Formalism and method

For the soft excitation process

The blast-wave model with Boltzmann-Gibbs statistics results in the probability density distribution of p_T

$$f_1(p_T)=\frac{1}{N}\frac{dN}{dp_T}=C_1 p_T m_T \int_0^R r dr \times I_0\left[\frac{p_T \sinh(\rho)}{T_0}\right] K_1\left[\frac{m_T \cosh(\rho)}{T_0}\right]$$

E. Schnedermann, J. Sollfrank, U. Heinz
Phys. Rev. C 48, 2462 (1993)

Formalism and method

The blast-wave model with Tsallis statistics results in the probability density distribution of p_T

$$f_2(p_T) = \frac{1}{N}\frac{dN}{dp_T} = C_2 p_T m_T \int_{-\pi}^{\pi} d\phi \int_0^R r dr \{1 + \frac{q-1}{T_0}[m_T \cosh(\rho) - p_T \sinh(\rho)\cos(\phi)]\}^{-1/(q-1)}$$

Z.B. Tang, Y.C. Xu, L.J. Ruan, G. van Buren, F.Q. Wang, Z.B. Xu, Phys. Rev. C 79, 051901(R) (2009).

Formalism and method

For the hard scattering process

Inverse power-law

$$f_H(p_T) = \frac{1}{N}\frac{dN}{dp_T} = Ap_T\left(1+\frac{p_T}{p_0}\right)^{-n}$$

R. Odorico, Phys. Lett. B 118, 151 (1982).

Hagedorn function

$$f_H(p_T) = \frac{1}{N}\frac{dN}{dp_T} = A\frac{p_T^{\,2}}{m_T}\left(1+\frac{p_T}{p_0}\right)^{-n}$$

ALICE Collaboration (K. Aamodt *et al.*) *Phys. Lett.* B ,693, 53 (2010).

$$f_H(p_T) = \frac{1}{N}\frac{dN}{dp_T} = Ap_T\left(1+\frac{p_T^{\,2}}{p_0^{\,2}}\right)^{-n}$$

A.De Falco (for the ALICE collaboration) J. Phys. G,38, 124083 (2011).

Modified Hagedorn functions

$$f_H(p_T) = \frac{1}{N}\frac{dN}{dp_T} = A\left(1+\frac{p_T^{\,2}}{p_0^{\,2}}\right)^{-n}$$

ALICE Collaboration (B. Abelev *et al.*) *Phys. Lett. B*,708, 265 (2012).

Formalism and method

The experimental p_T spectrum distributed in a wide range can be described by a superposition of the soft excitation and hard scattering processes.

$$f_3(p_T) = k f_s(p_T) + (1-k) f_H(p_T)$$

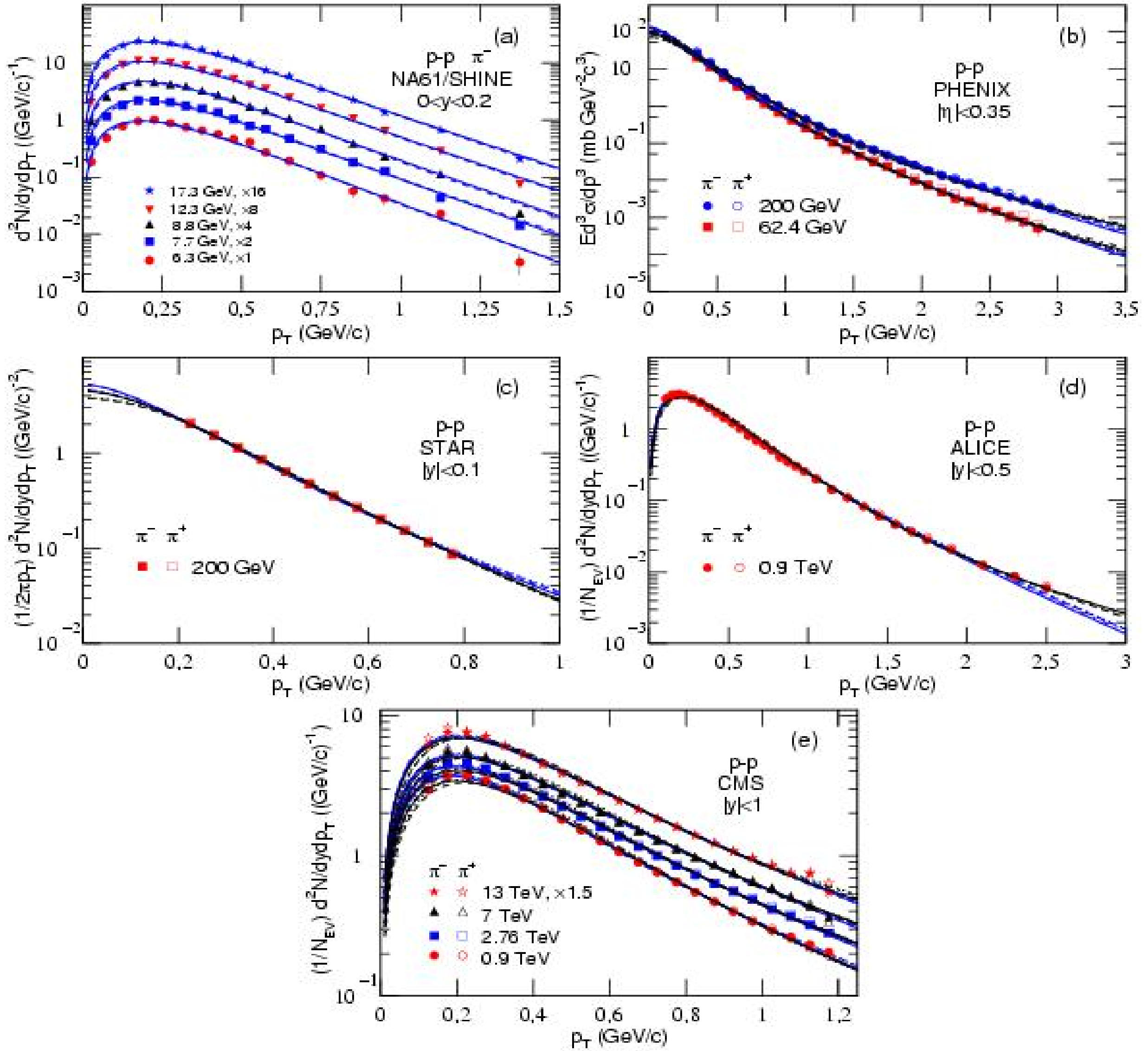
$$f_4(p_T) = A_1 \theta(p_1 - p_T) f_S(p_T) + A_2 \theta(p_T - p_1) f_H(p_T)$$

Results and discussion

Transverse momentum spectra of π^- and π^+ produced at mid-(pseudo)rapidity in pp collisions at high center-of-mass energies.

合作组	能量(GeV)
NA61/SHINE	6.3 7.7 8.8 12.3 17.3
PHENIX	62.4 200
STAR	200
ALICE	900
CMS	900 2760 7000 13000

$$f_3(p_T) = kf_s(p_T) + (1-k) f_H(p_T)$$



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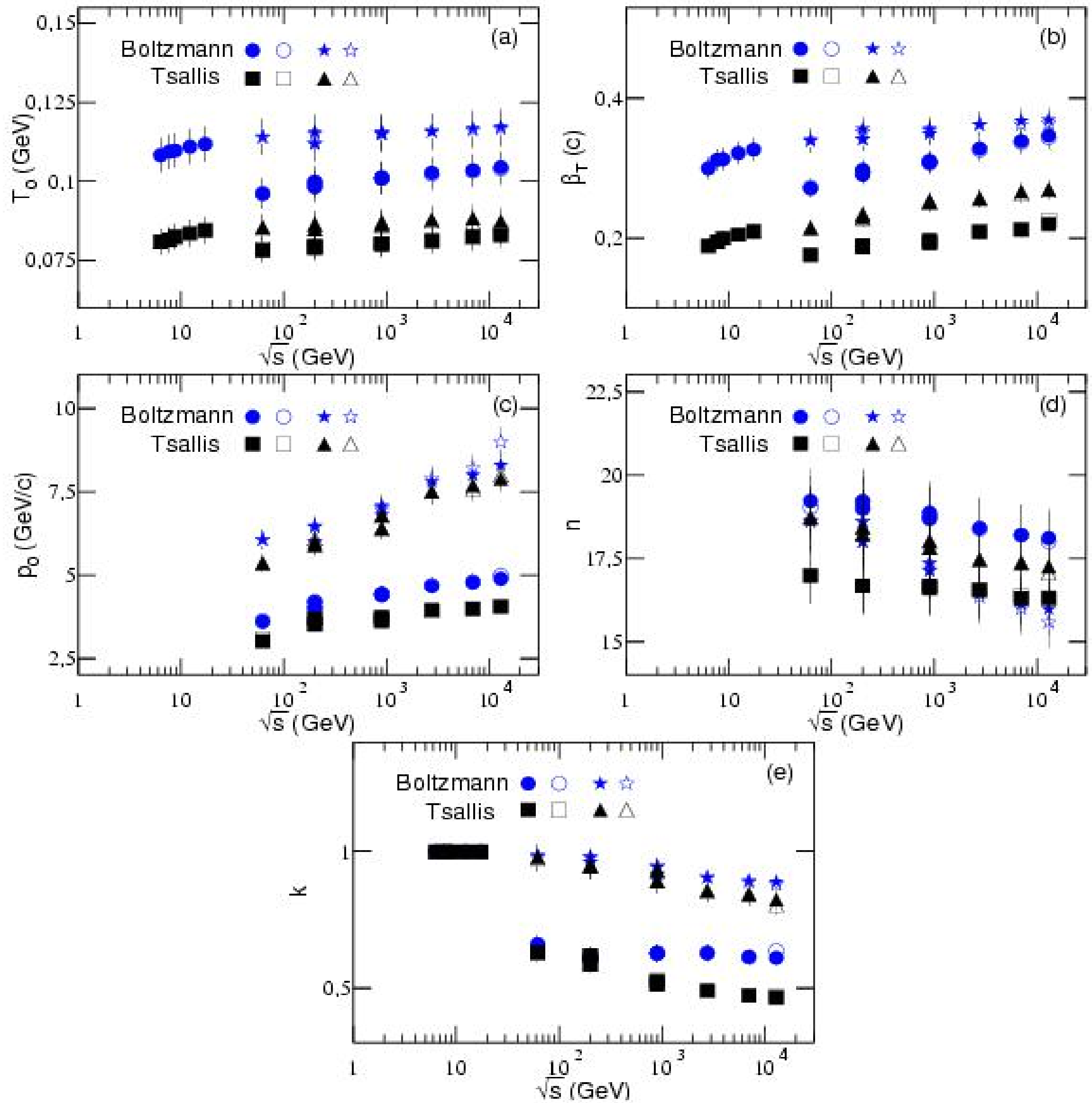

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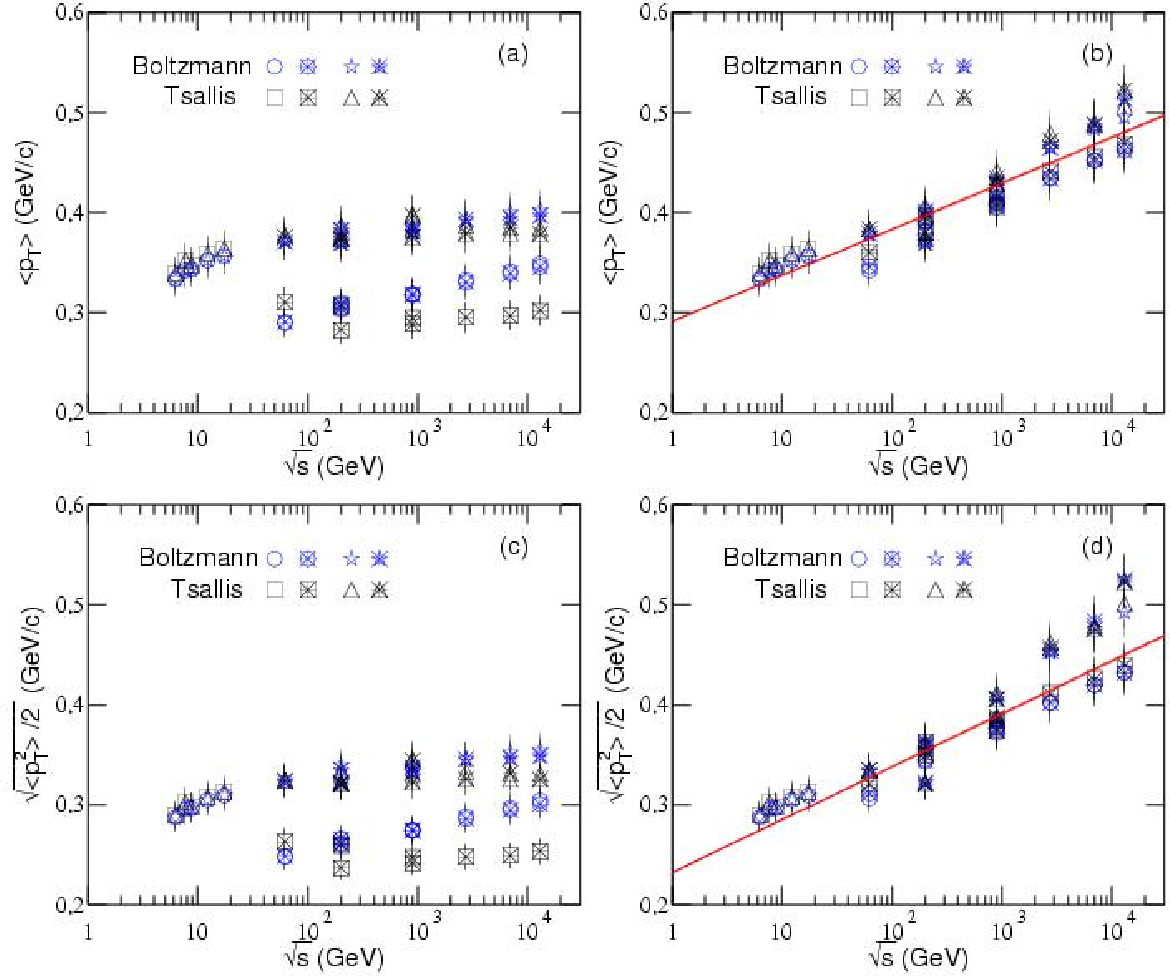
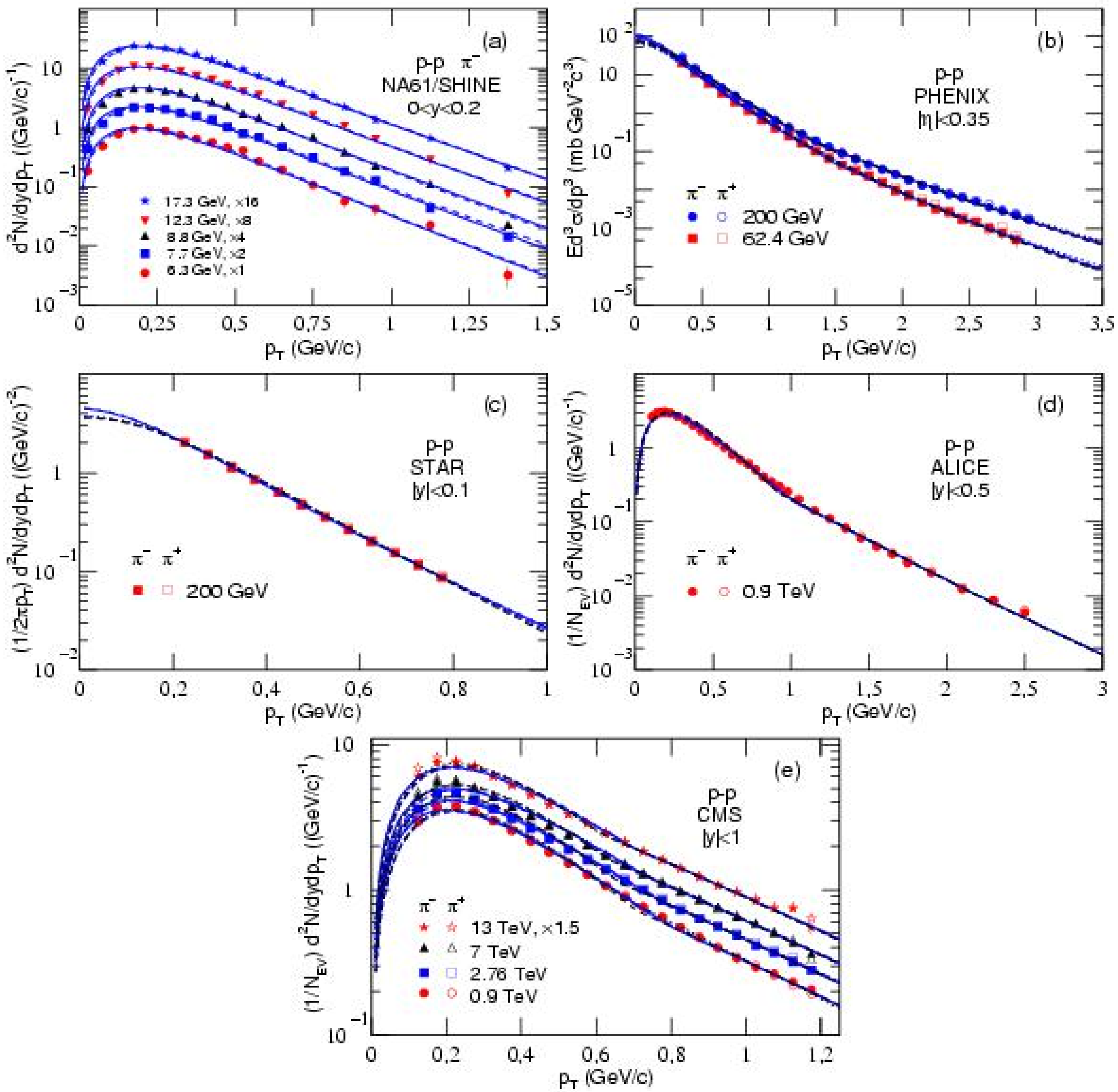


$$f_4(p_T) = A_1\theta(p_1 - p_T) f_S(p_T) + A_2\theta(p_T - p_1) f_H(p_T)$$



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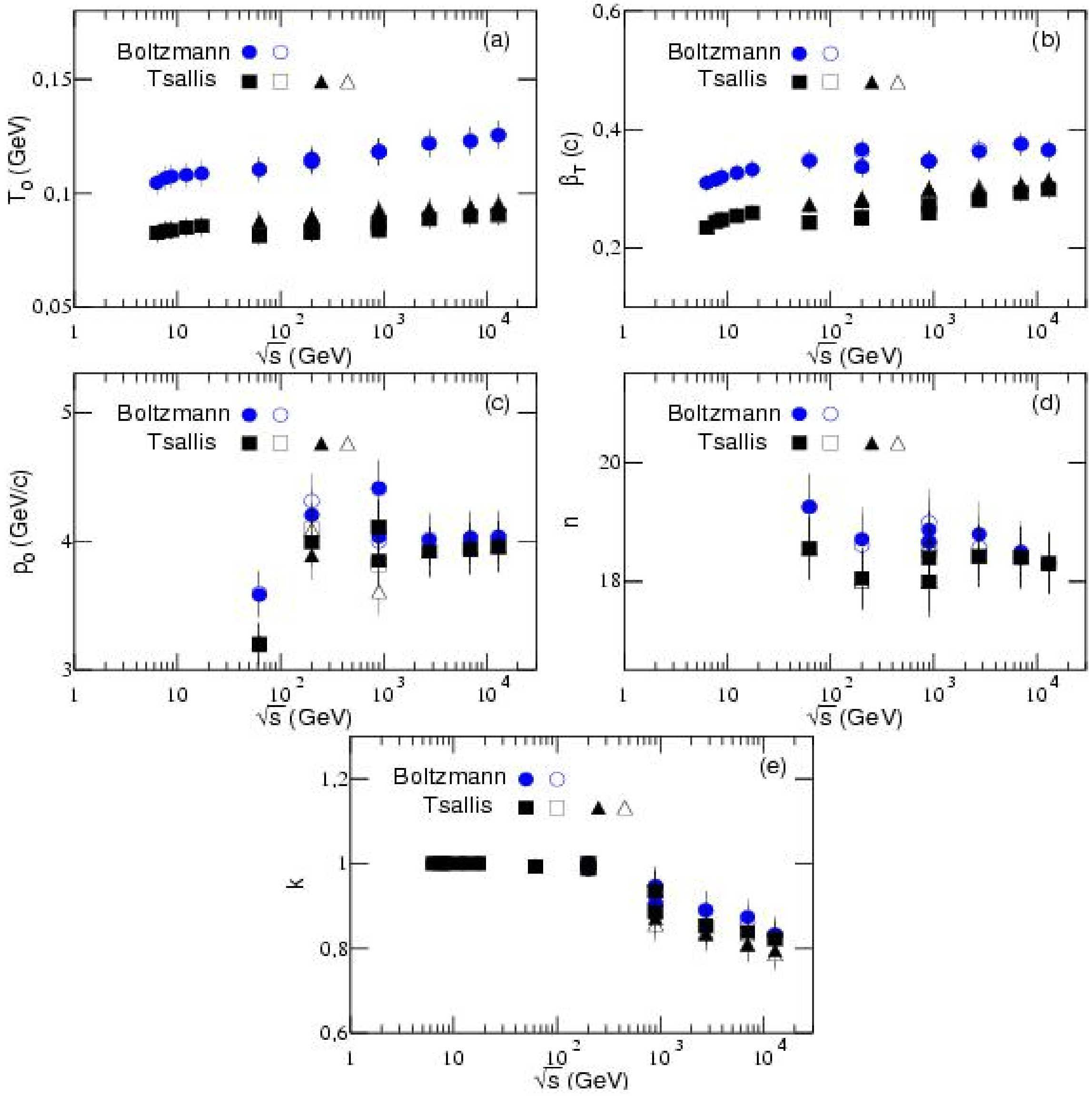
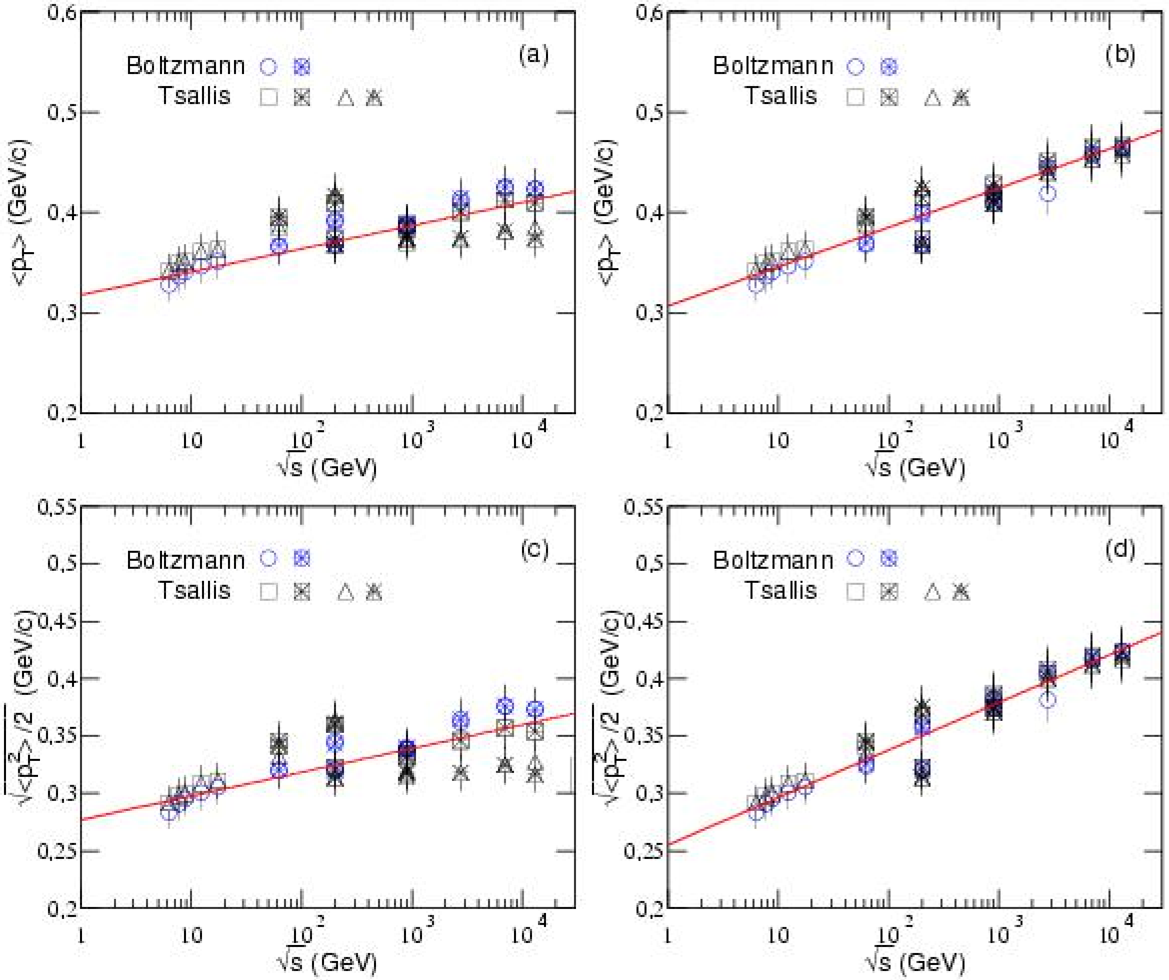


$$f_4(p_T) = A_1\theta(p_1 - p_T) f_S(p_T) + A_2\theta(p_T - p_1) f_H(p_T)$$



Summary and Conclusion

➢ Excitation functions of T_0 and β_T
Blast-wave model with Boltzmann-Gibbs show a hill at $\sqrt{S}\approx$10GeV, a drop at dozen of GeV, and an increase from dozes of GeV to above 10 TeV.
Blast-wave model with Tsallis only have a very low hill.

➢The mean transverse momentum and the initial temperature increase approximately linearly with the increase of logarithmic collision energy.

➢ At around 10 GeV, a transition from a baryon-dominated to a meson-dominated intermediate and final state takes place.
From dozes of GeV to above 10 TeV, a transition from a meson-dominated to a parton-dominated intemidiate takes place.

➢ It is a long-term target to search for the critical energy at which a parton-dominated intermediate state appears initially.

Thanks for your attention!

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