Extracting excitation functions of related parameters in high energy collisions based on transverse momentum spectra

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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

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The transverse spectra of particles reflect partly properties of the emission source. When the reaction system is at the stage of kinetic freeze-out, the particles emitted by the source contain both contributions of thermal motion and flow effect. Thermal motion reacts to the lateral excitation of the reaction system. The flow effect reflects the dynamic collision characteristics of the system .

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The “true” temperature of the emission source should reflect only the thermal motion of the particles in the emission source. The kinetic freeze-out temperature is one of “true” temperatures. The effective temperature contains the thermal motion and flow effect.

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

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

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

Formalism and method

For the soft excitation process

The standard distribution results in the probability density distribution of p_T, m_T to be:

$$f_1(p_T) = \frac{1}{N}\frac{dN}{dp_T} = Cp_T m_T \int_{y_{\min}}^{y_{\max}} \cosh y \times [\exp(\frac{m_T \cosh y - \mu}{T} + S)]^{-1} dy$$

$$f_2(m_T) = \frac{1}{N}\frac{dN}{dm_T} = Cm_T^2 \int_{y_{\min}}^{y_{\max}} \cosh y \times [\exp(\frac{m_T \cosh y - \mu}{T} + S)]^{-1} dy$$

Formalism and method

Chemical potential

$$\mu_\pi = -\frac{1}{2} T_{ch} \cdot \ln(k_\pi)$$

$$\mu_K = -\frac{1}{2} T_{ch} \cdot \ln(k_k)$$

$$\mu_p = -\frac{1}{2} T_{ch} \cdot \ln(k_p)$$

$$\Rightarrow$$

$$k_\pi = \frac{\pi^-}{\pi^+}$$

$$k_K = \frac{K^-}{K^+}$$

$$k_p = \frac{\bar{p}}{p}$$

$$T_{ch} = T_{\lim} \frac{1}{1 + \exp\left[2.6 - \ln(\sqrt{S_{NN}}) / 0.45\right]}$$

$$T_{\lim} = 0.158 \text{ GeV}$$

Formalism and method

The experimental transverse momentum (mass) spectrum distributed in a wide range can be described by a superposition of the soft excitation and hard scattering processes.

$$f_{p_T} = \frac{1}{N}\frac{dN}{dp_T} = kf_{p_T}(p_T, T_1) + (1-k) f_{p_T}(p_T, T_2)$$

$$f_{m_T} = \frac{1}{N}\frac{dN}{dm_T} = kf_{m_T}(m_T, T_1) + (1-k) f_{m_T}(m_T, T_2)$$

Formalism and method

We obtain the kinetic freeze-out temperature by the following formula:

$$T_0 = \frac{k_0 \langle p_T \rangle}{2}$$

where, $k_0 = 0.5 - 0.01 \ln\left(\sqrt{S_{NN}}\right)$

we obtain the transverse flow velocity by the following formula:

$$\beta_T = \frac{(1-k_0)\langle p_T \rangle}{2 m_0 \overline{\gamma}}$$

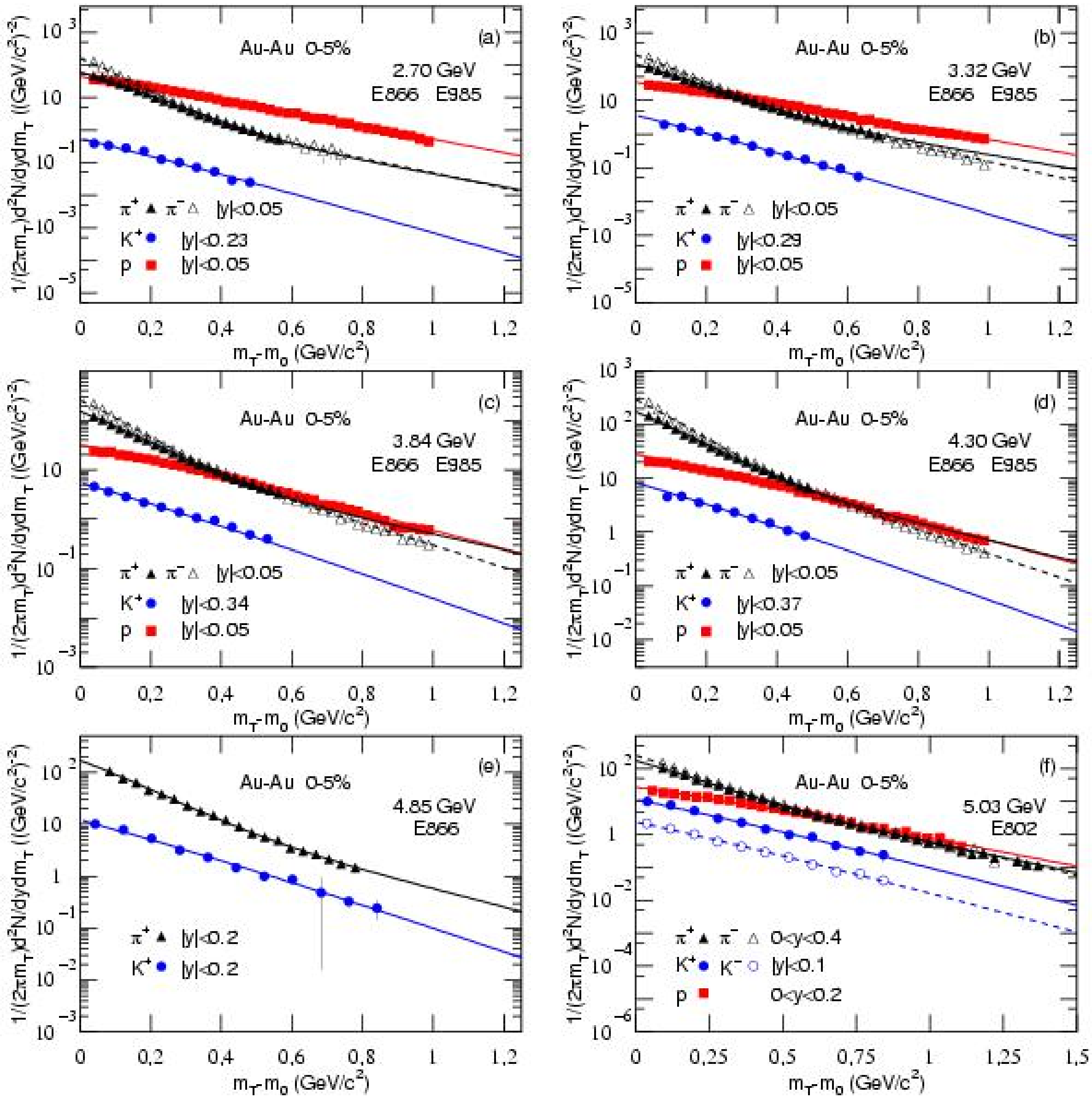
where, $\overline{\gamma}$ is the average Lorentz factor

Results and discussion

Transverse momentum (mass) spectra of pion, K, and p produced at mid-(pseudo)rapidity in central nucleus-nucleus and pp collisions

Au-Au	AGS →	LHC →	RHIC
Pb-Pb	SPS →	LHC →	RHIC
pp	SPS →	LHC →	RHIC

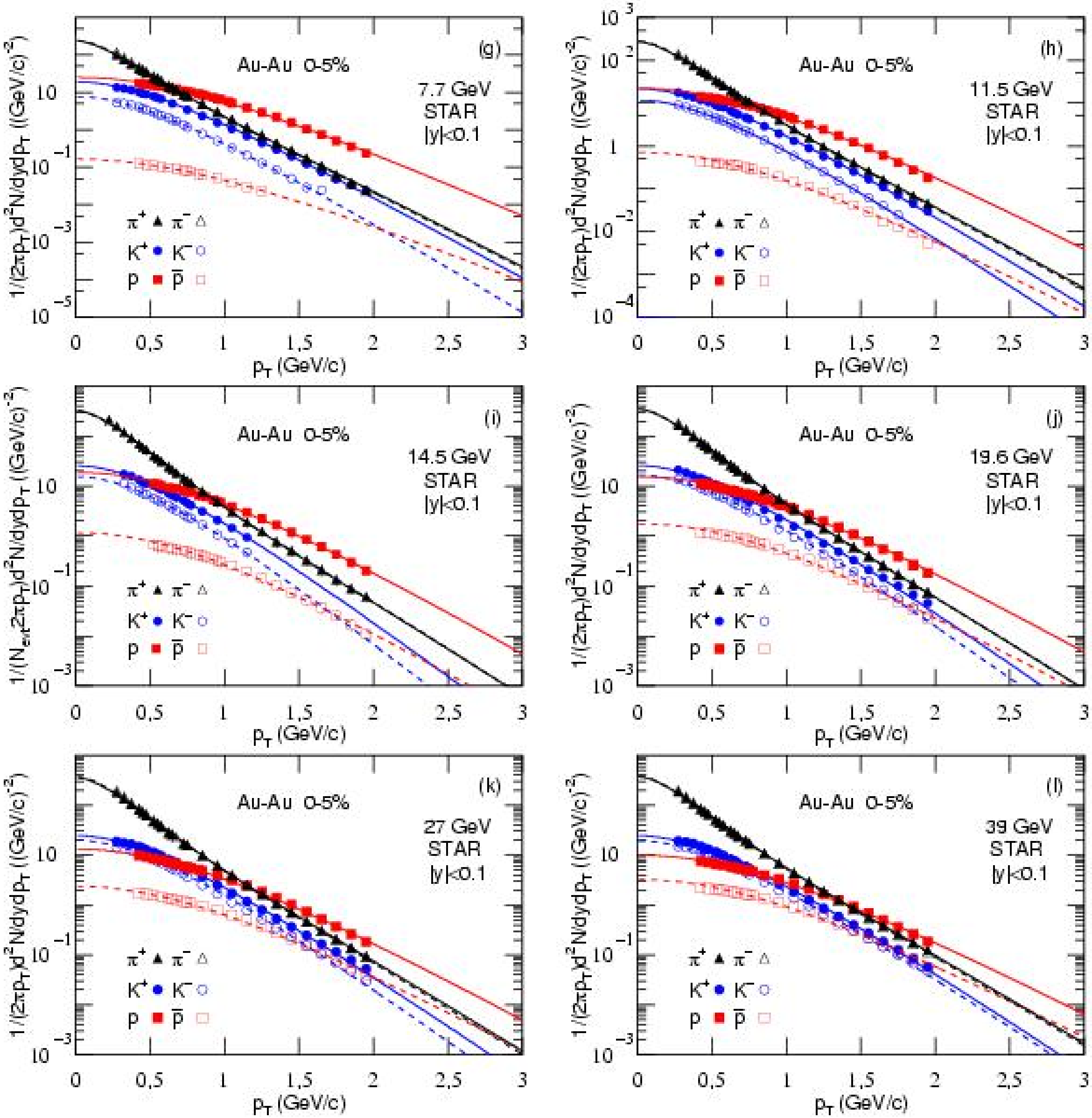
Results and discussion



Central Au-Au collisions

AGS

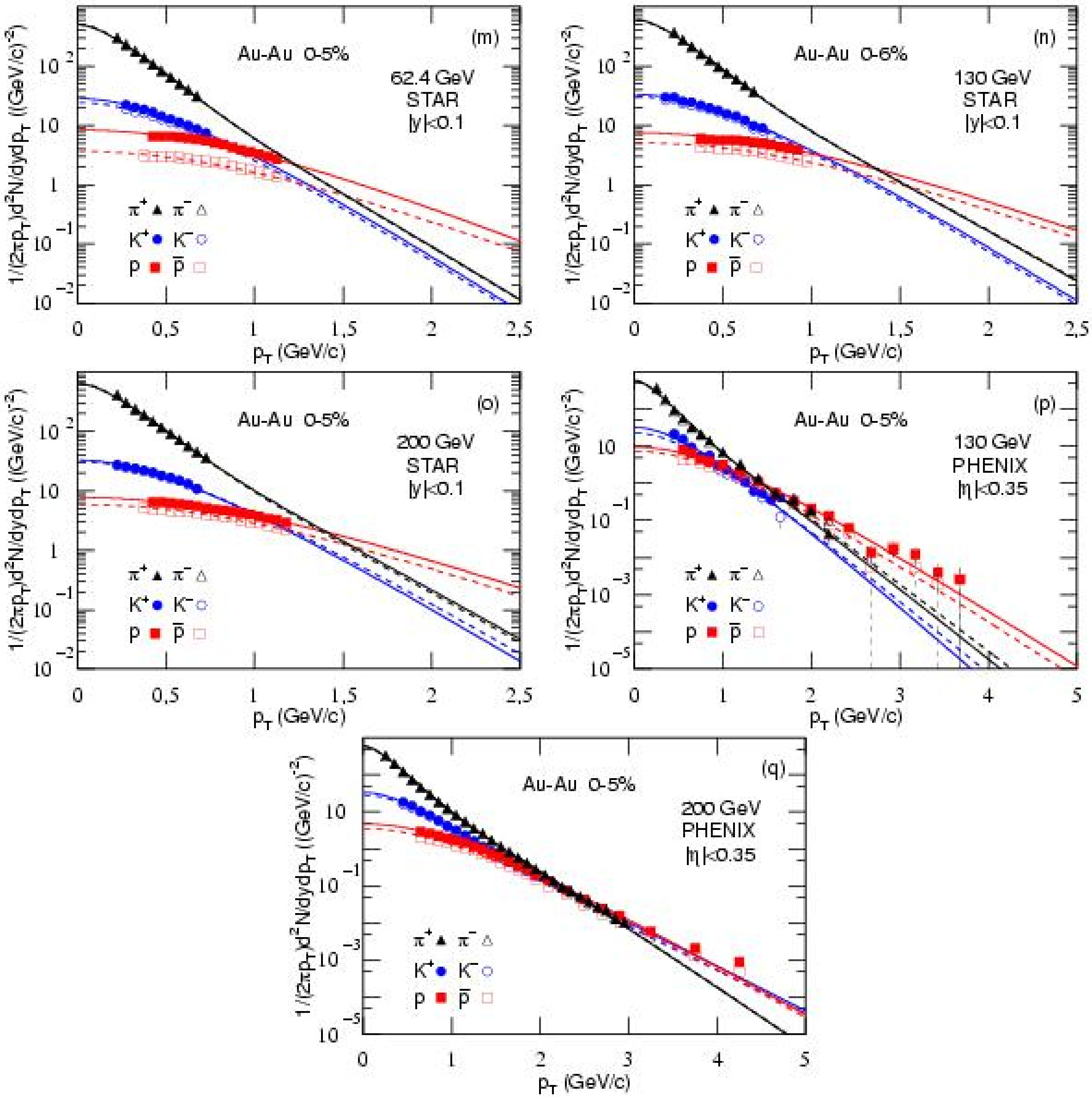
Results and discussion



Central Au-Au collisions

RHIC
LHC

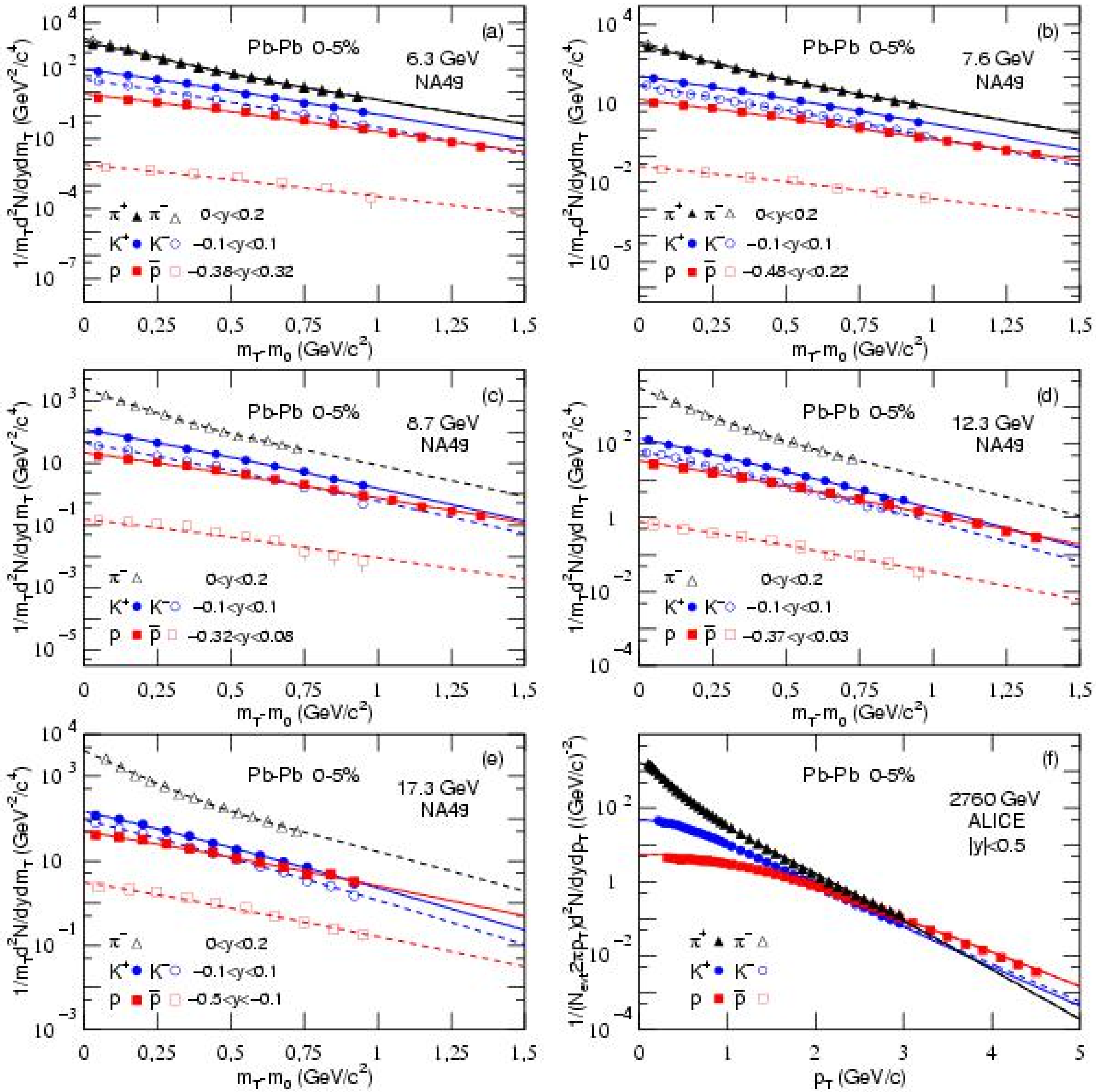
Results and discussion



Central Au-Au collisions

RHIC

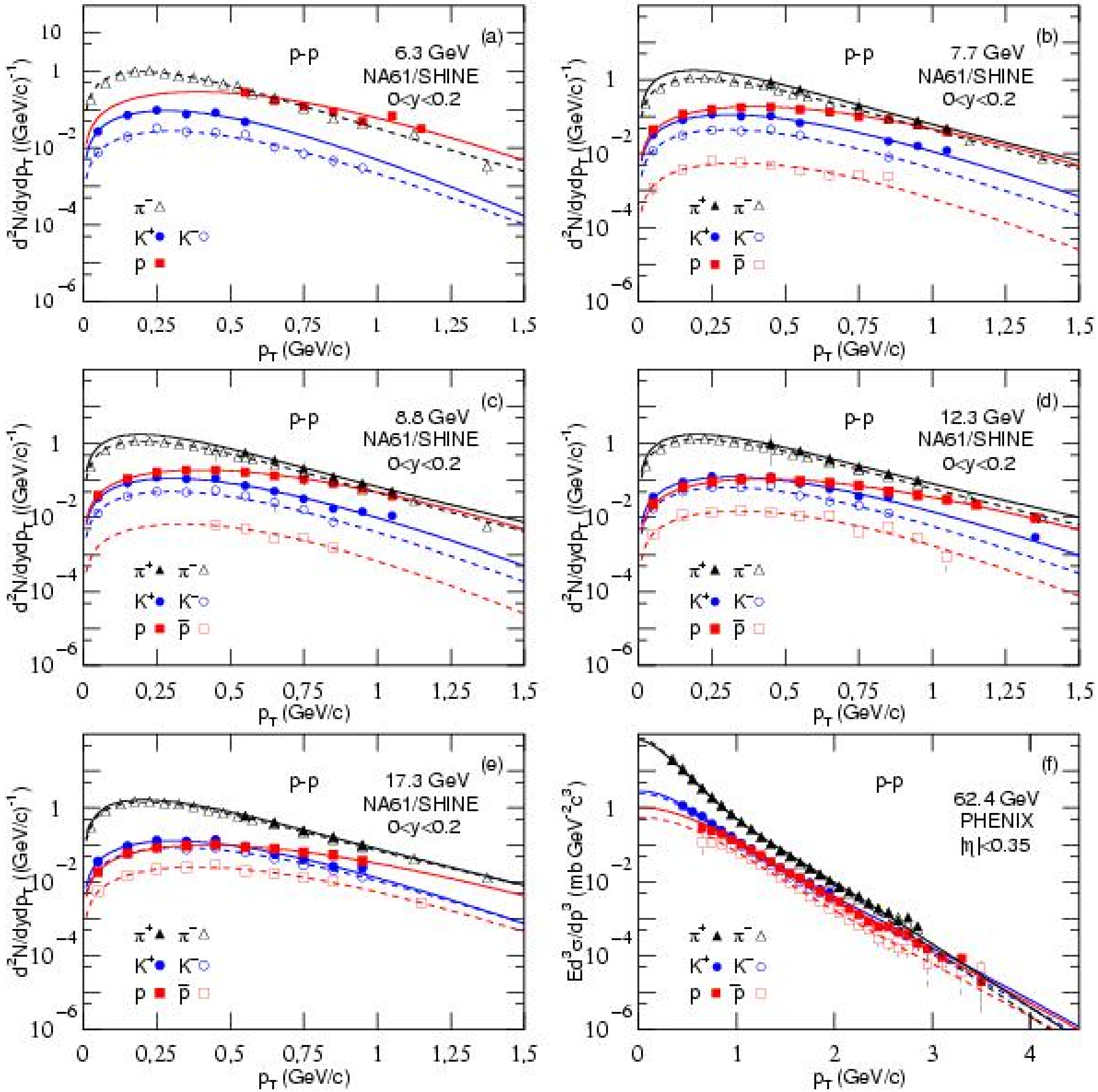
Results and discussion



Central Pb-Pb collisions

SPS
LHC

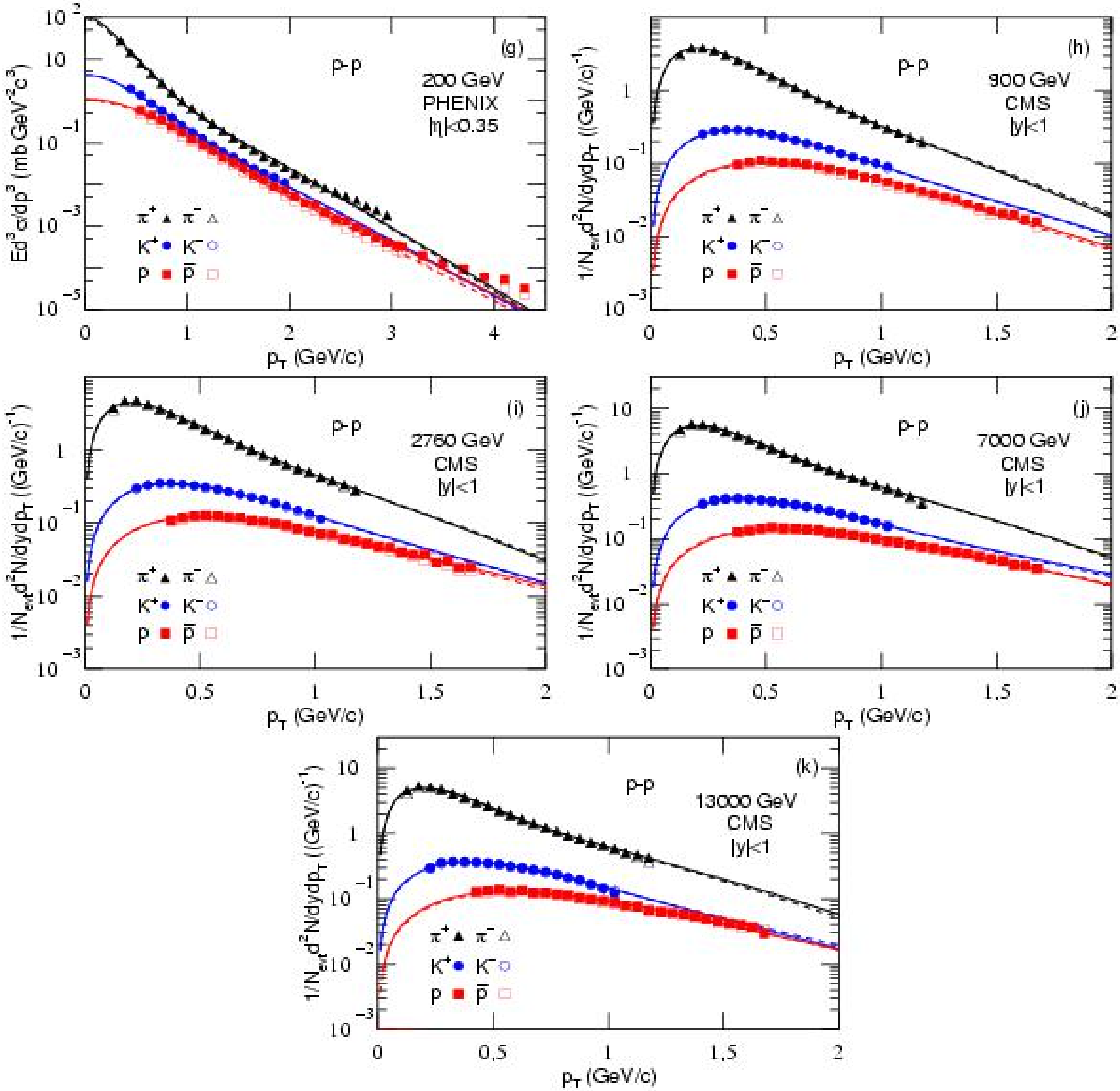
Results and discussion



INEL
pp collisions

SPS
LHC

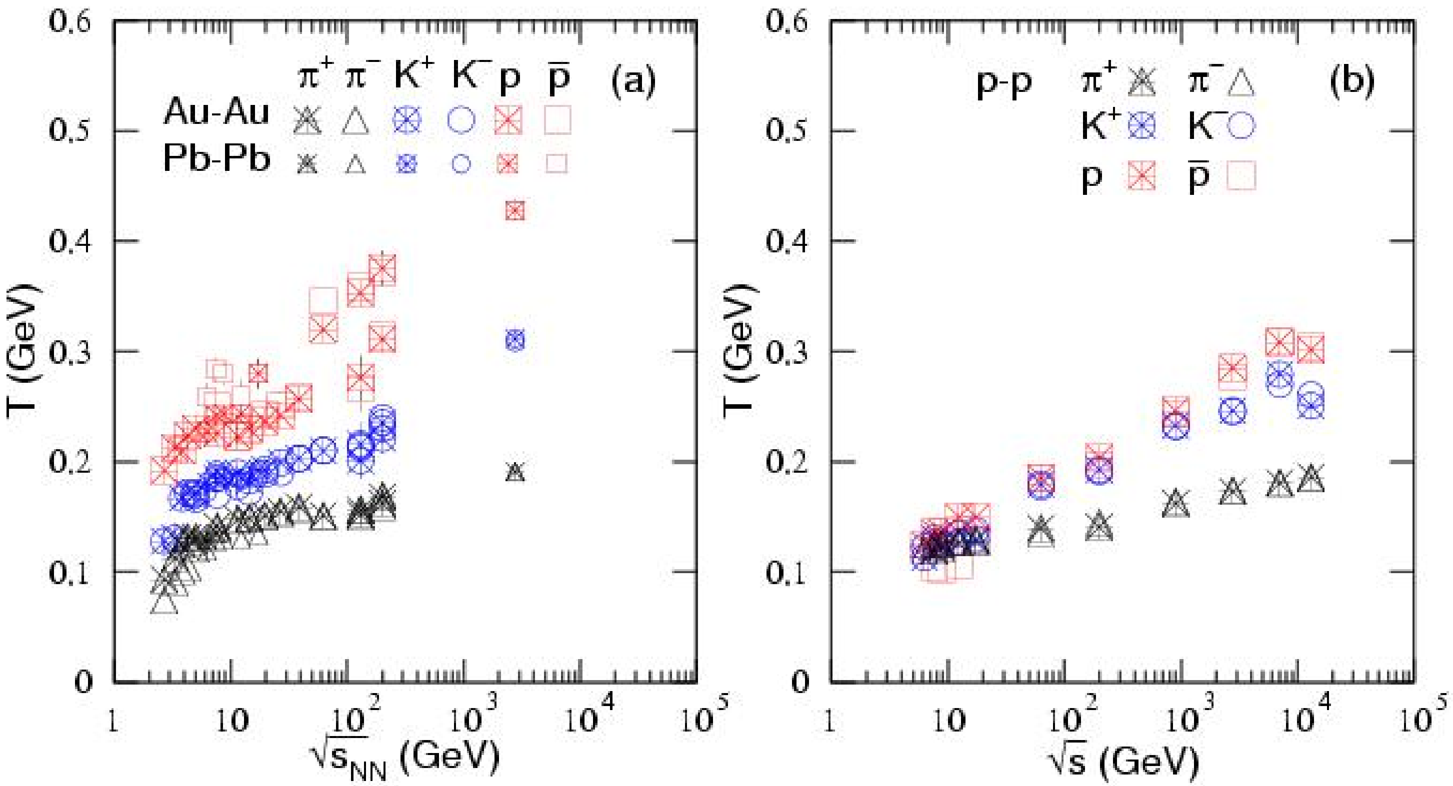
Results and discussion



INEL
pp collisions

RHIC
LHC

Results and discussion

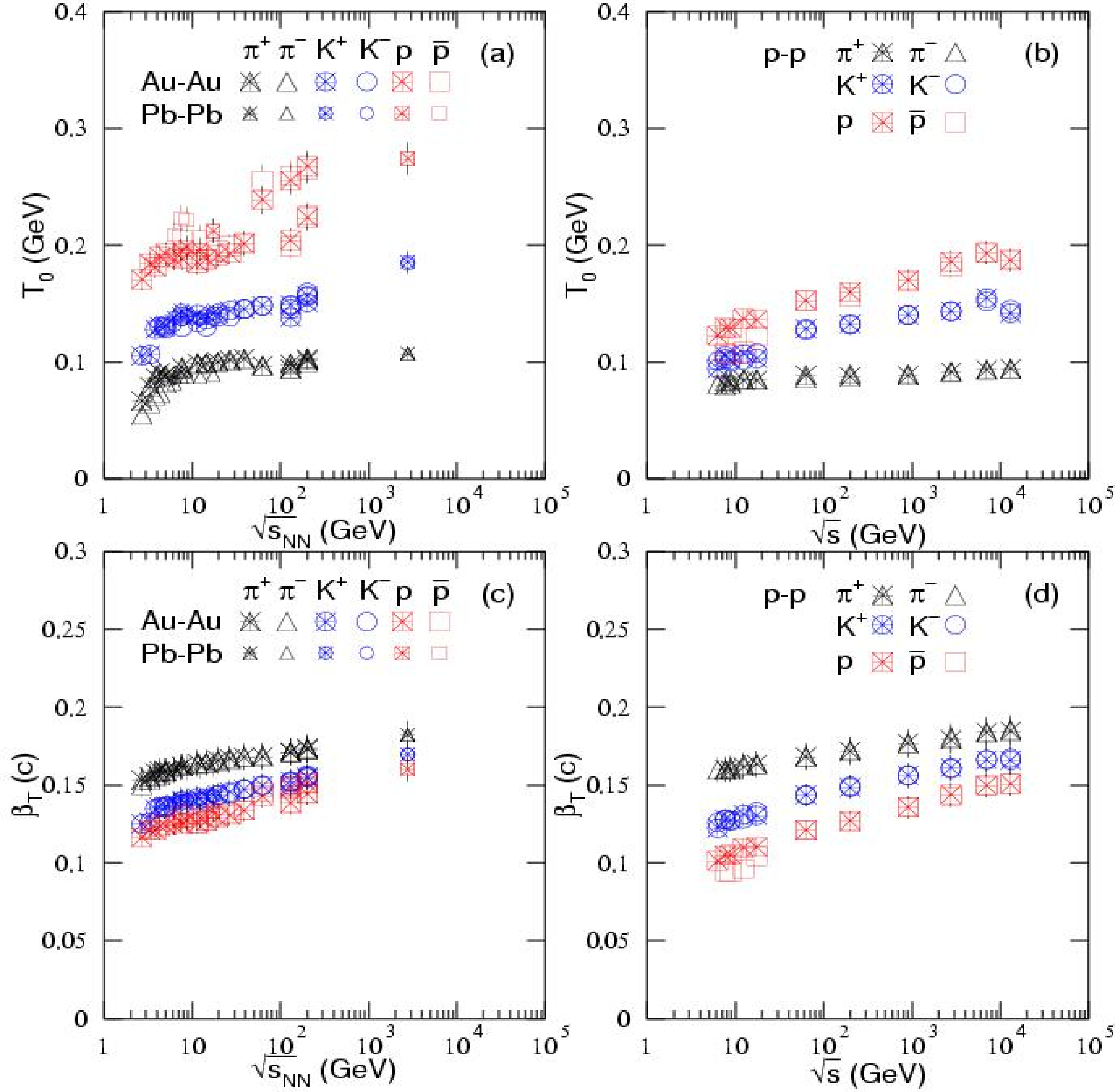


$$T = kT_1 + (1-k)T_2$$

$$\sqrt{s_{NN}} \uparrow \quad T \uparrow$$

$$T_p > T_K > T_\pi$$

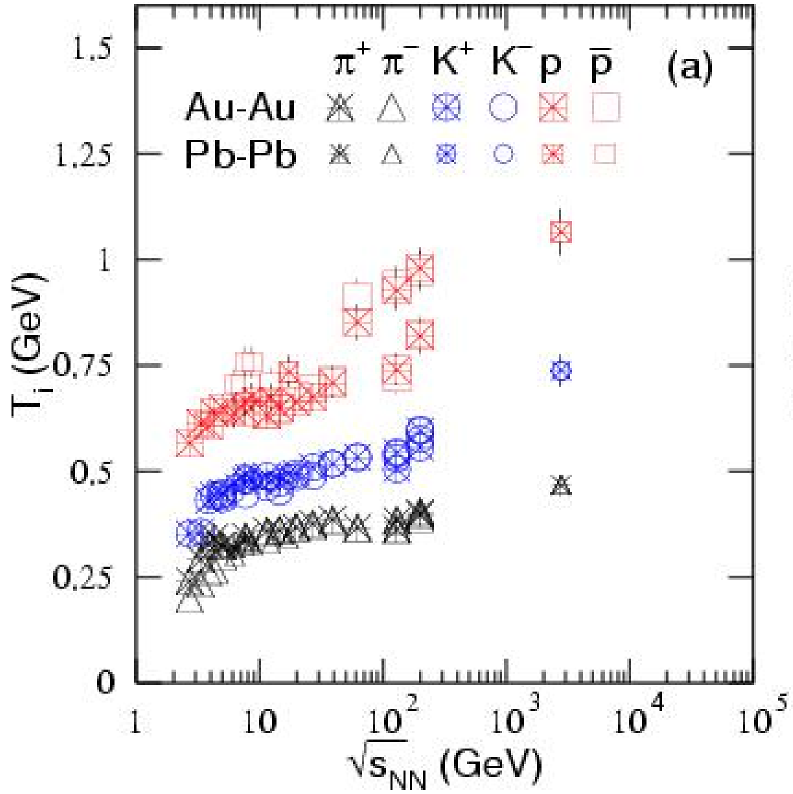
Results and discussion

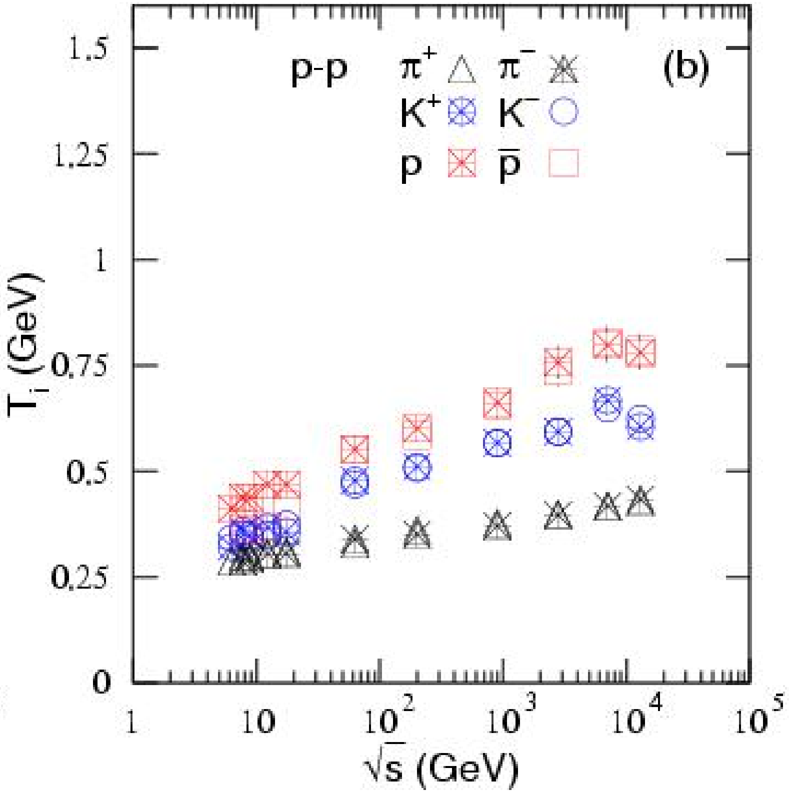


$$T_0 = \frac{k_0 \langle p_T \rangle}{2}$$

$$\beta_T = \frac{(1-k_0)\langle p_T \rangle}{2m_0\overline{\gamma}}$$

Results and discussion





$$T_i = \sqrt{\frac{\langle p_T^2 \rangle}{2}}$$

$$T_{i_p} > T_{i_K} > T_{i_\pi}$$

Summary and Conclusion

- The pp collisions show similar behaviors to nucleus-nucleus collisions.

- Excitation functions of T, T_i, T_0 show the relation p>K>pion.

- As the center-of-mass energy increasing from a few GeV to a few TeV, the effective temperature continues to increase. The kinetic freeze-out temperature increases rapidly from a few GeV to about 10 GeV, then slowly from about 10 GeV to a few TeV.

- 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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