UNIVERSITY OF BUCHAREST

VIRTUTE ET SAPIENTIA

Study of strange particle p_T spectra in heavy-ion collisions at relativistic energies

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Outline

Motivation

Blast-wave model and data used

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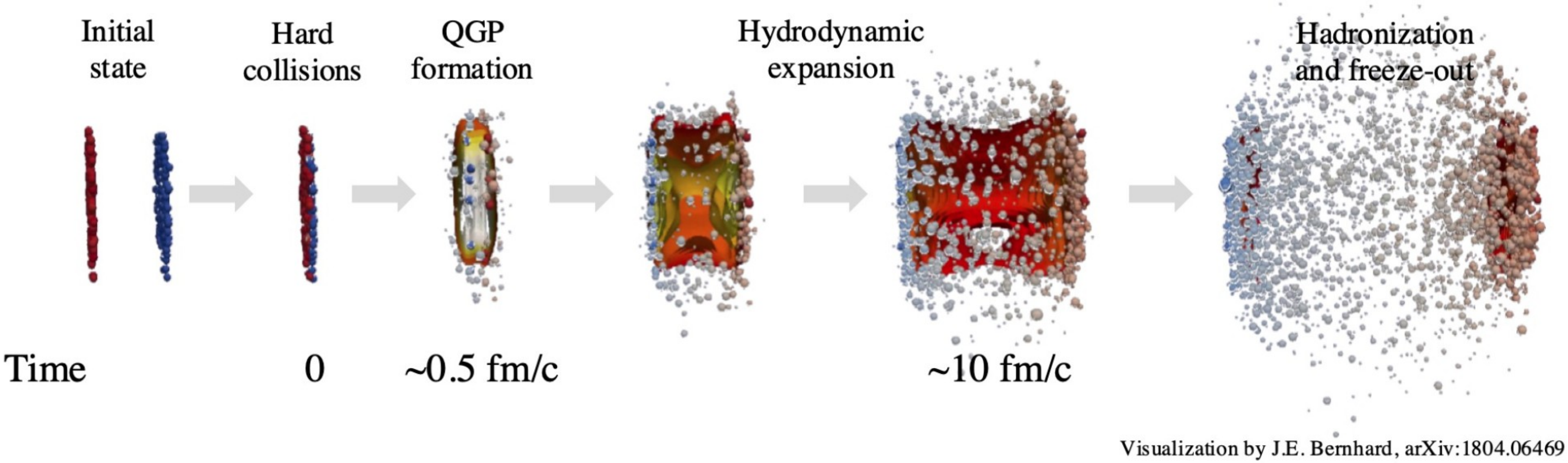
Conclusions

Heavy-ion collision evolution



- Chemical “freeze-out” (FO) → inelastic collisions among particles cease → Fireball composition is fixed (particle yields and ratios get fixed) → chemical FO temperature and baryon chemical potential

- Thermal (kinetic) “freeze-out” (FO) → elastic collisions cease → p_T and m_T spectra get “fixed” → kinetic FO temperature and average transverse flow velocity

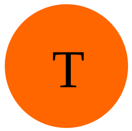
Particle source

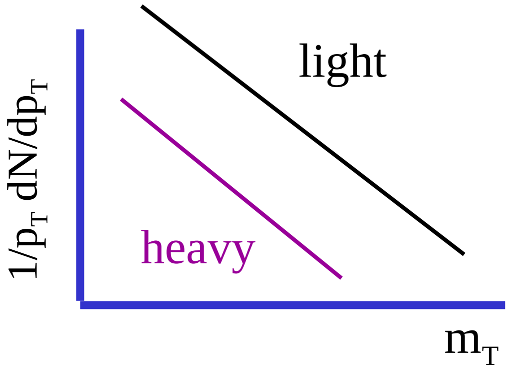
- Final state spectra → system properties at thermal freeze-out
- Thermal source → spectrum slope reflects the temperature of the fireball

$$\frac{dN}{m_T\, dm_T} \sim e^{-m_T/\mathrm{T}_{\mathrm{slope}}}$$

where $m_T \equiv \sqrt{p_T^2 + m^2}$

purely thermal source





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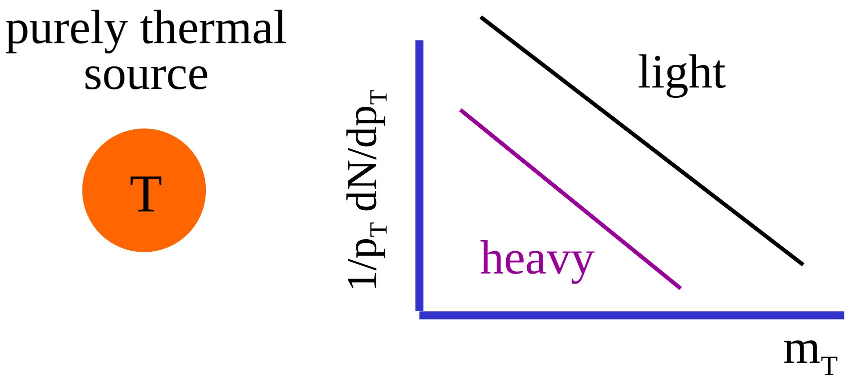

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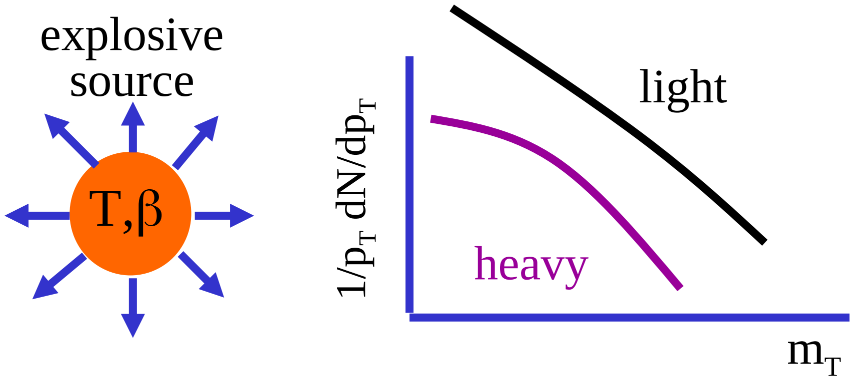


- Data → shape is different in p-p and A-A → stronger effect for heavier particles

Flow → collective motion of particles (due to high pressure arising from compression and heating of nuclear matter) superimposed on thermal motion → Blast-wave model

Blast-wave model

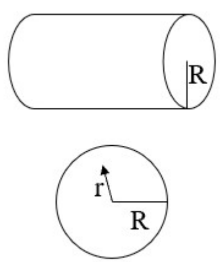
- A cylindrical expanding fireball in local thermal equilibrium, in which the particles are locally thermalized at a kinetic freeze-out temperature and are moving with a common transverse collective flow velocity (E. Schnedermann et. al, PRC48 (1993) 2462).

- The p_T spectrum of produced particles described by:

$$\frac{dN}{p_T\,dp_T} \propto \int_0^R r\,dr\,m_T I_0\left(\frac{p_T \sinh\rho(r)}{T_{\rm kin}}\right) \times K_1\left(\frac{m_T \cosh\rho(r)}{T_{\rm kin}}\right),$$

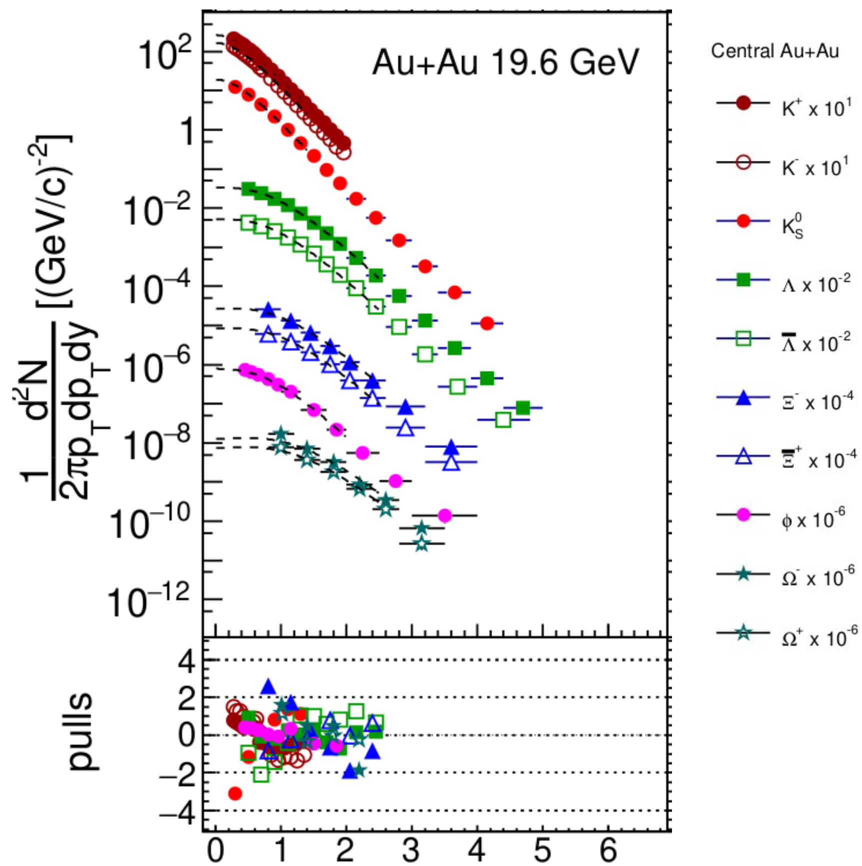
- The radial flow velocity profile parametrized as:

$$\beta_T(r) = \beta_s \left(\frac{r}{R}\right)^n$$

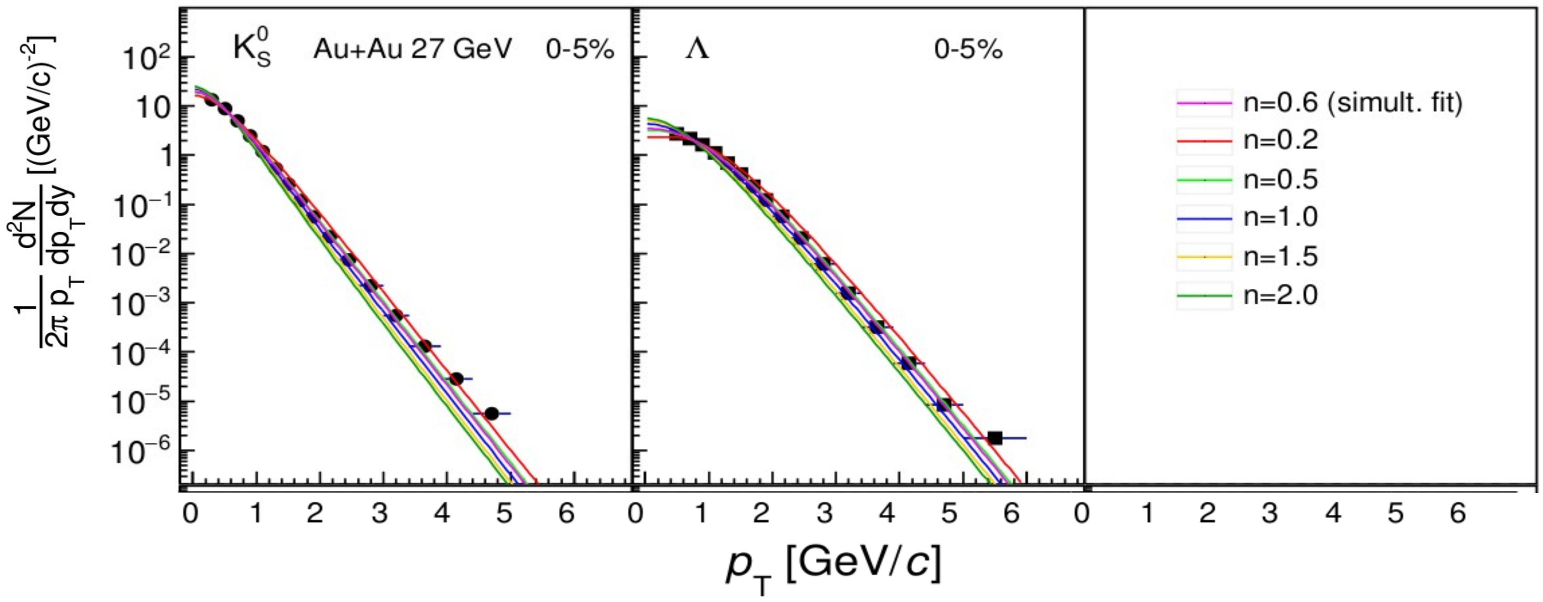


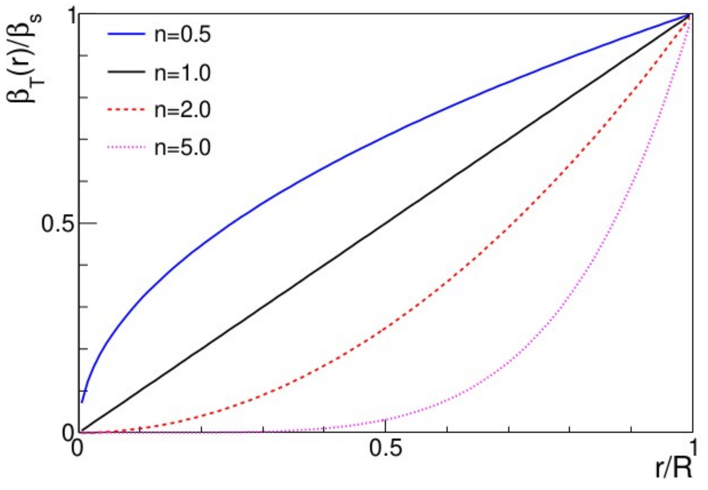
- The average transverse radial flow velocity is:

$$\langle\beta_T\rangle = \frac{2}{n+2}\beta_s$$



Blast-wave model





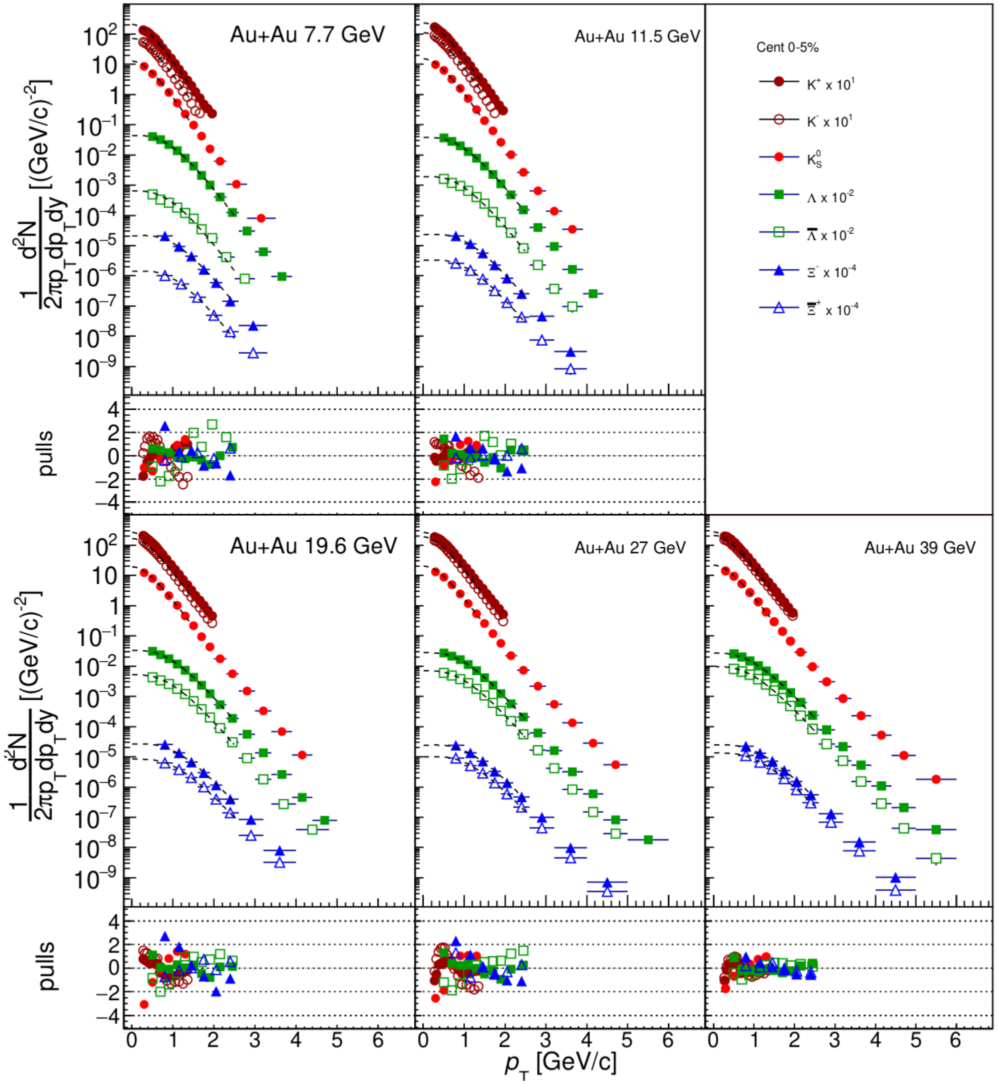
Radial flow velocity profile:

$$\beta_T(r) = \beta_s \left(\frac{r}{R}\right)^n$$

--> a smaller value of n, the curve is flatter at low p_T indicating a stronger flow velocity.

--> a larger value of n describes a steeper p_T spectrum (more peripheral collisions or for particles with smaller rest mass).

Blast-wave analysis of strange hadron spectra



--> BW fits on the p_T spectra of strange hadrons in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, 39 GeV from the STAR experiment

--> standard BW analyses -->π^+, π^-, K^+, K^-, p and anti-p spectra fits

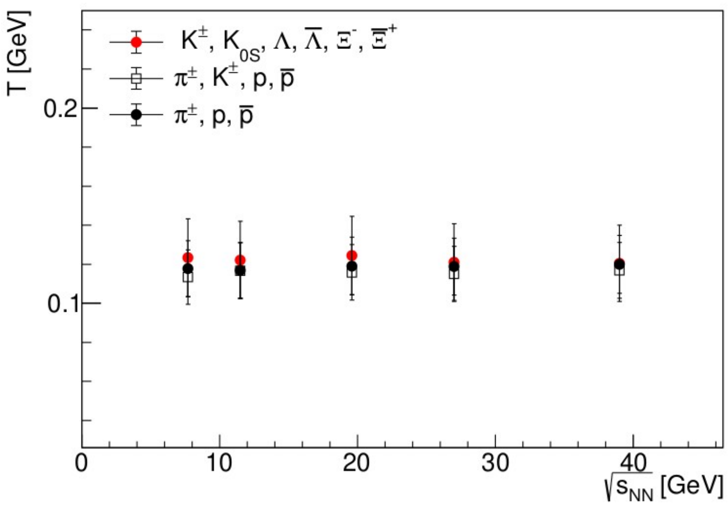
--> fit ranges: for kaons p_T<1.4 GeV/c; for strange baryons p_T<2.5 GeV/c

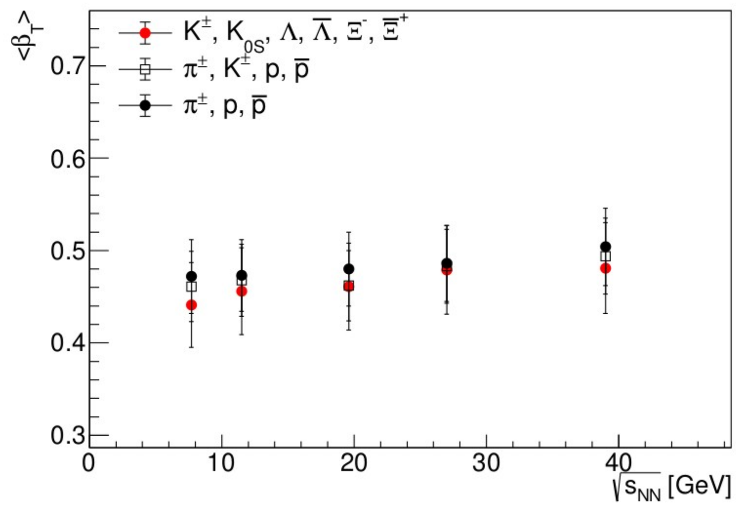
--> pulls distributions calculated as:

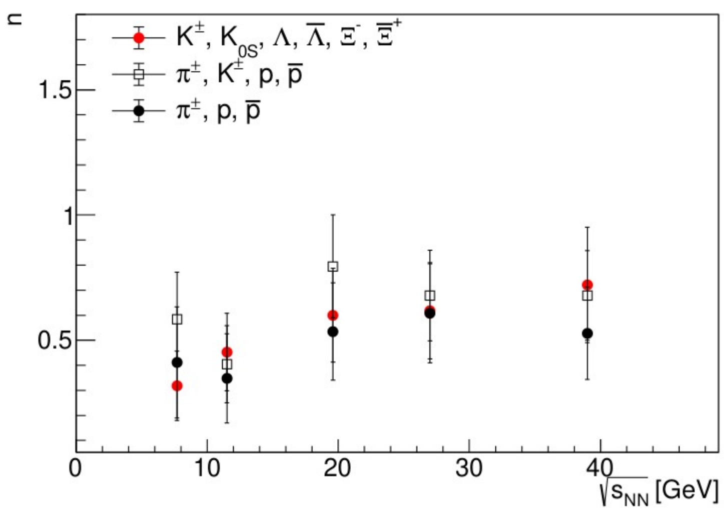
(data – fit value)/data error

J. Adam et al., STAR coll., Phys.Rev.C 102 (2020),034909; L. Adamczyk et al., Phys. Rev. C 96, 044904 (2017); L. Adamczyk et al., Phys. Rev. C 93, 21903 (2016)

Energy dependence





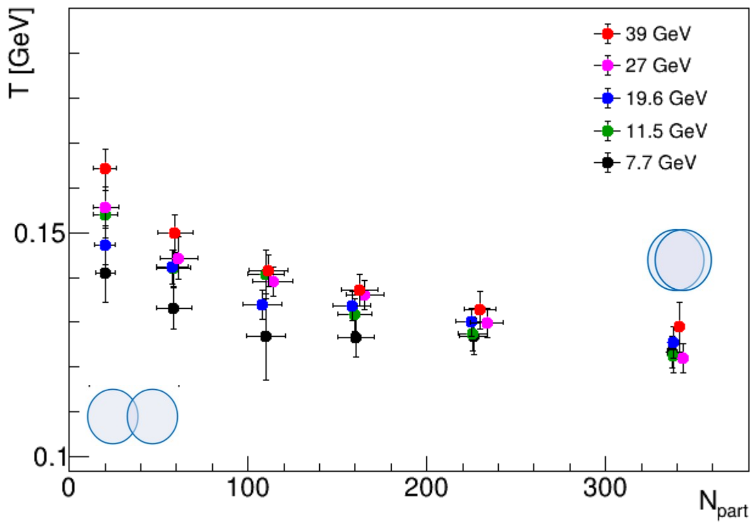


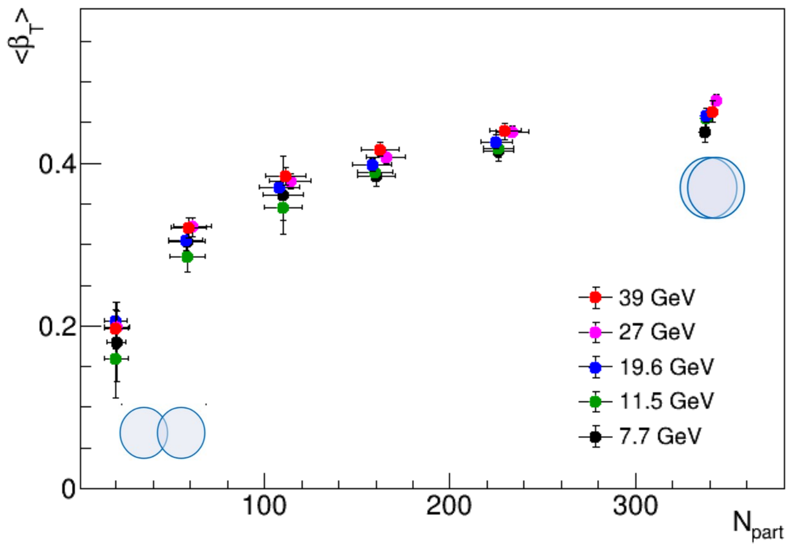
--> similar T and $\langle\beta_T\rangle$ within errors in this energy range for strange, non-strange and bulk hadrons --> indicate common freeze-out conditions for the strange/non-strange hadrons

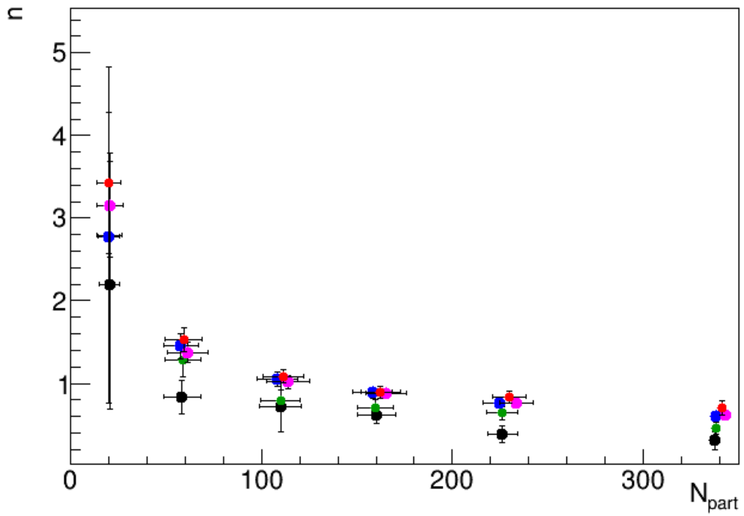
--> very weak energy dependence of T and $\langle\beta_T\rangle$ parameters

--> n increases slowly with energy

Centrality dependence





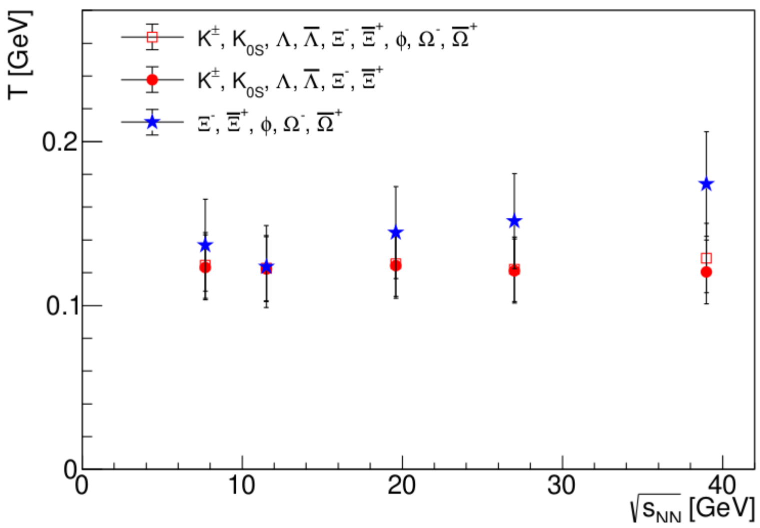


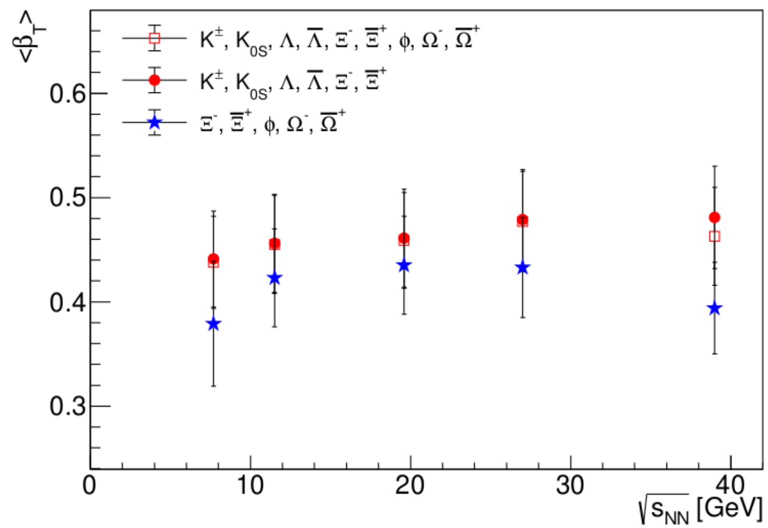
--> at a given energy, in more central collisions, lower T and larger $<\beta_T>$

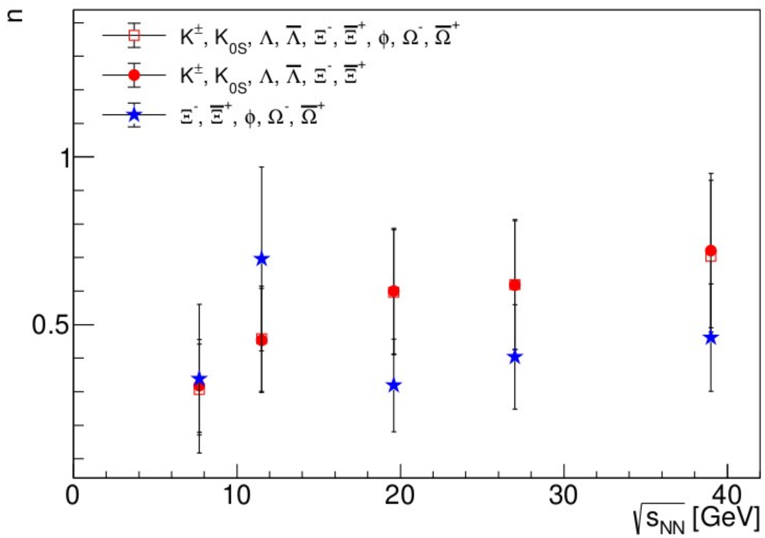
--> T and $<\beta_T>$ are anticorrelated

--> n increases în peripheral collisions --> different shape of p_T spectra

Particle-type dependence



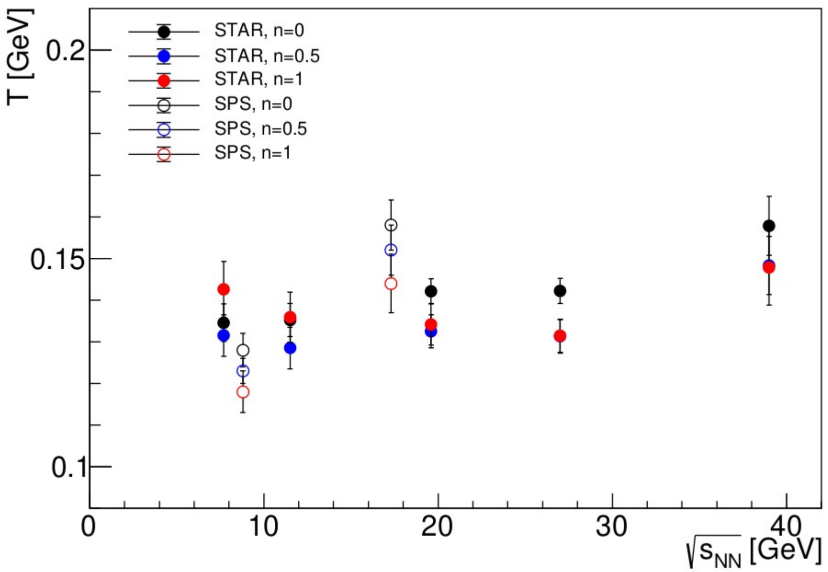


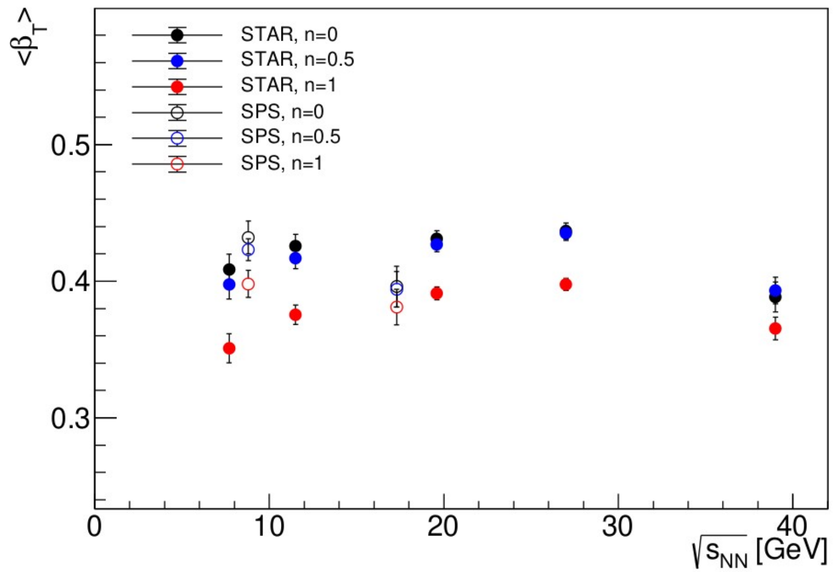


--> similar values for $K^{+/-}$, K_{0S}, Λ, anti-Λ, $Ξ^-$, $Ξ^+$ and $K^{+/-}$, K_{0S}, Λ, anti-Λ, $Ξ^-$, $Ξ^+$, φ, $Ω^-$, $Ω^+$ groups --> larger uncertainties on φ, $Ω^-$, $Ω^+$ data compared to the more abundant strange particles species do not influence strongly the global fit

--> larger T and smaller $<β_T>$ for multi-strange hadrons ($Ξ^-$, $Ξ^+$, φ, $Ω^-$, $Ω^+$) --> a double (sequential) kinetic freeze-out scenario due to separate decoupling multi-strange particles --> different interaction cross-section of multi-strange particles with the bulk of the system

Comparison with SPS data





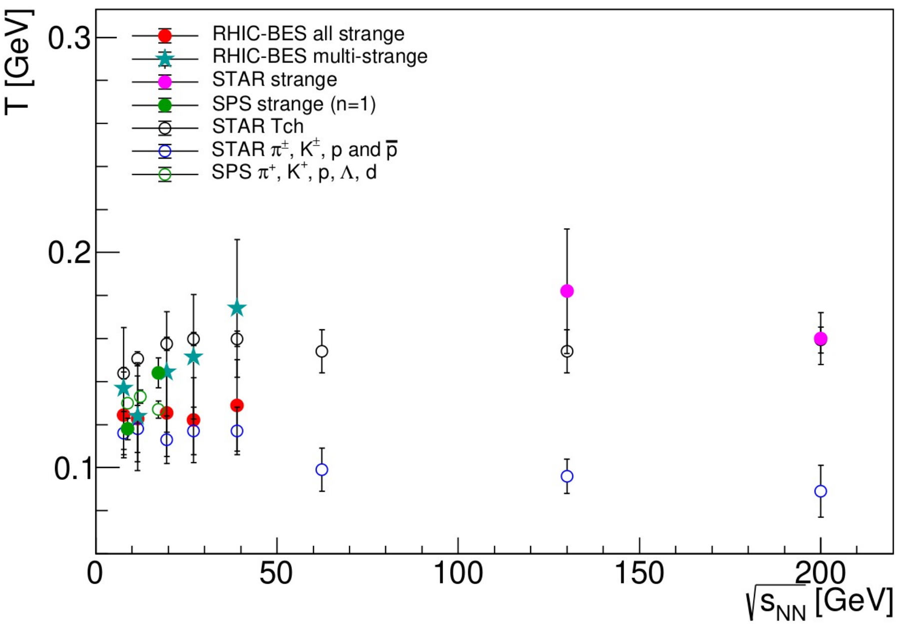
--> NA57-SPS results obtained from BW fits on K_{0S}, Λ, anti-Λ, Ξ^-, Ξ^+, Ω^-, and Ω^+ spectra in Pb+Pb collisions at 8.8 GeV and 17.3 GeV with fixed flow profile at n = 0, 0.5 and 1

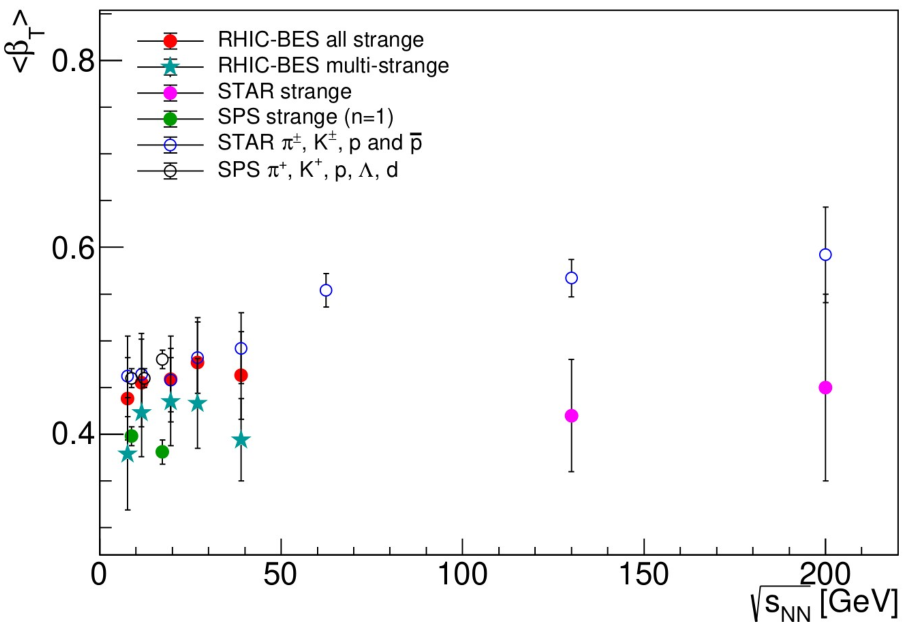
--> values of $\langle\beta_T\rangle$ larger for smaller values of n exponent

--> results consistent with NA57-SPS results

G. E. Bruno (NA57 Collaboration), J. Phys. G 31, S127 (2005); F. Antinori et al. (NA57 Collaboration), J.Phys.G 30, 823 (2004)

Data comparison



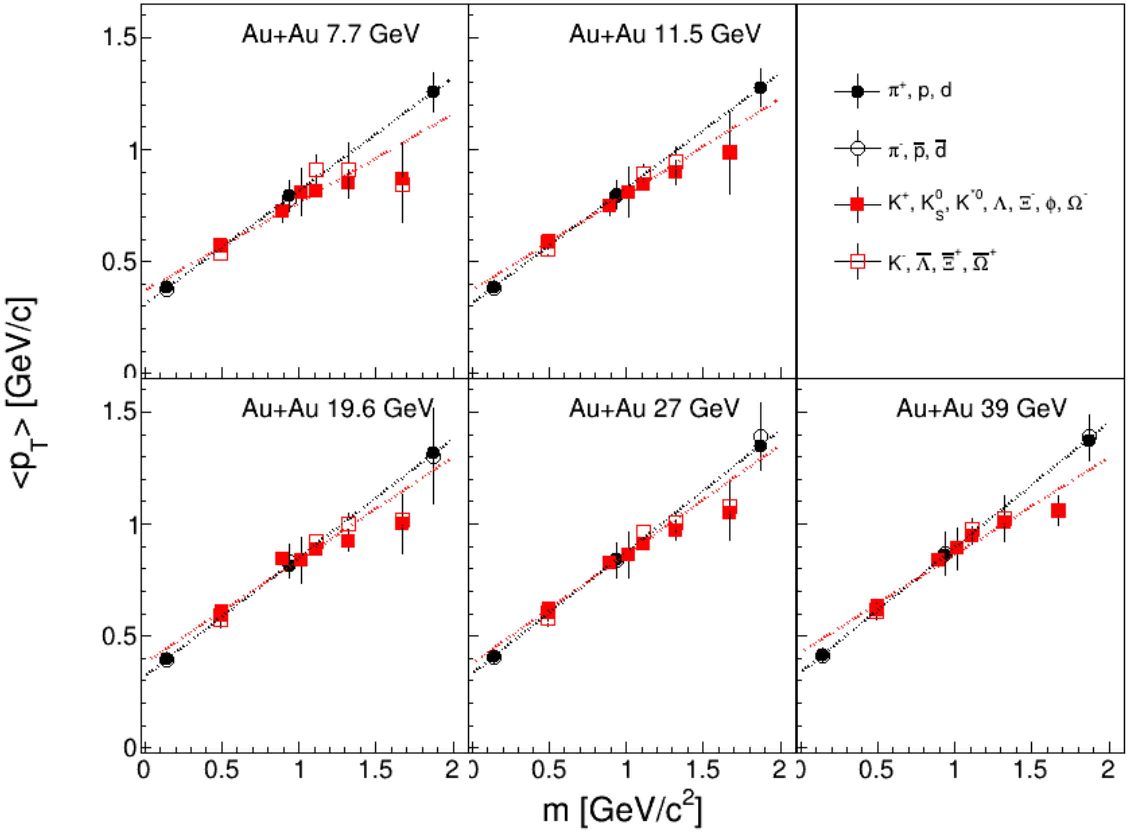


--> multi-strange particles at RHIC-BES energies decouple from the system in the vicinity of the chemical freeze-out --> the kinetic freeze-out of multi-strange hadrons is close to the chemical freeze-out in this energy range.

--> multi-strange hadrons $<\beta_T>$ smaller than bulk hadrons $<\beta_T>$ --> multi-strange hadrons $<\beta_T>$ can give an estimate of the radial flow velocity in the system at chemical FO.

M. van Leeuwen (NA49 Collaboration), Nucl.Phys. A 715, 161 (2003); B. I. Abelev et al. (STAR Collaboration), Phys. Rev. C 79, 034909 (2009); L. Adamczyk et al. (STAR Collaboration), Phys. Rev. C 96, 044904 (2017); O. Barannikova (STAR Collaboration), Acta Phys.Hung. A 24, 39 (2005); O. Barannikova (STAR Collaboration), arXiv:nucl-ex/0403014; J. Adams et al. (STAR Collaboration), Phys. Rev. Lett. 92, 182301 (2004); G. E. Bruno (NA57 Collaboration), J. Phys. G 31, S127 (2005); F. Antinori et al. (NA57 Collaboration), J.Phys.G 30, 823 (2004)

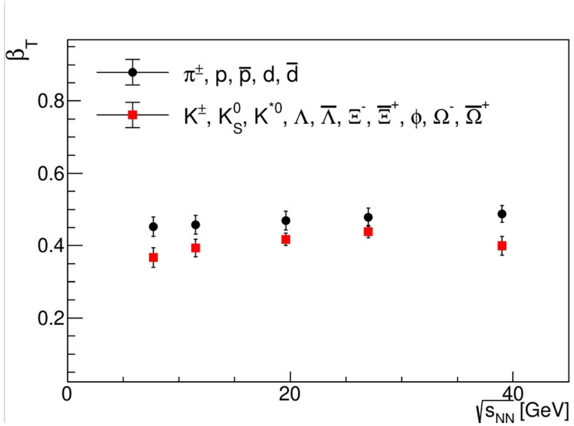
Mean transverse momentum



$<p_T>$ increases with mass for all BES energies --> transverse collective flow --> larger p_T kick for particles with higher mass

--> different slopes for non-strange and strange hadrons

$$\langle p_T \rangle = C' + m\,\beta_T' = C' + m_0 \gamma_T'\,\beta_T'$$



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Conclusions

- An earlier decoupling for multi-strange particles → a sequential kinetic freeze-out of particles dictated by their hadronic interaction cross-sections.

- Centrality dependence of T and $\langle\beta_T\rangle$ for strange hadrons → the system cools and has an expansion of increasing magnitude in more central collisions → $\langle\beta_T\rangle$ of strange particles decreases from central to peripheral collisions while T shows opposite behaviour, as in the case of non-strange/bulk hadrons.

- In most central Au+Au collisions at RHIC-BES energies, $\langle p_T\rangle$ increases with particle mass indicating the presence of the radial flow in the system → two different linear trends can be observed for non-strange hadrons and strange hadrons separately.