Strongly intensive measures for multiplicity fluctuations in AA and pp collisions

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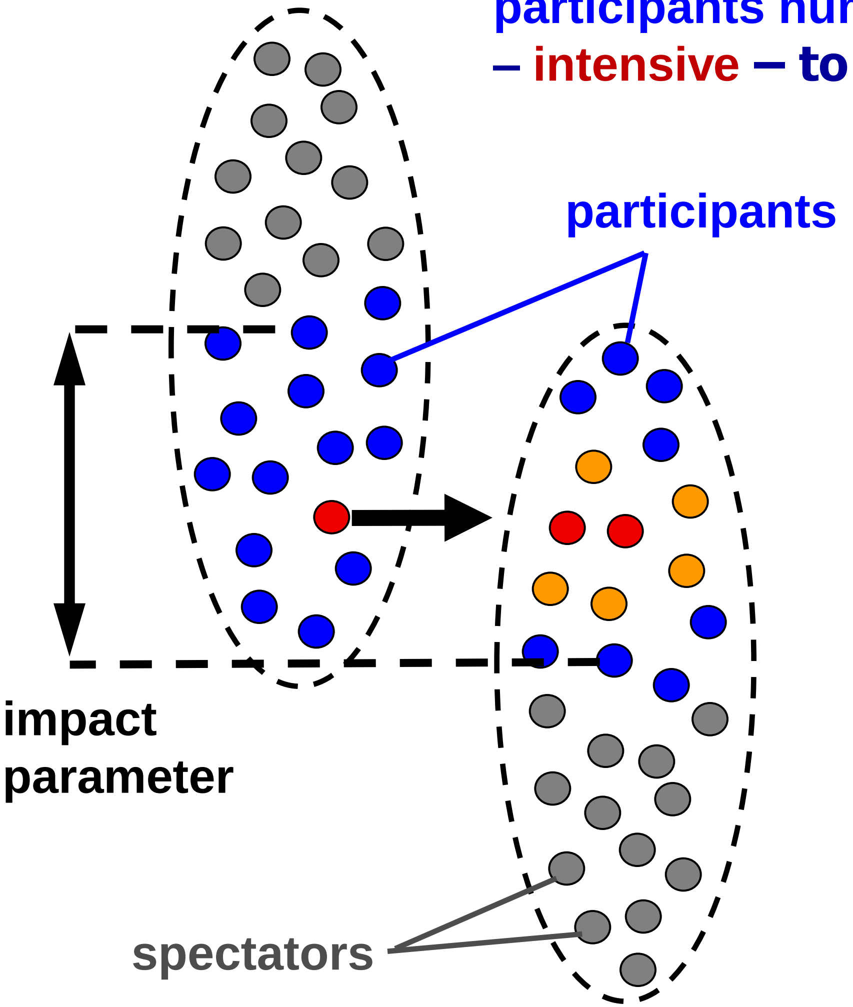
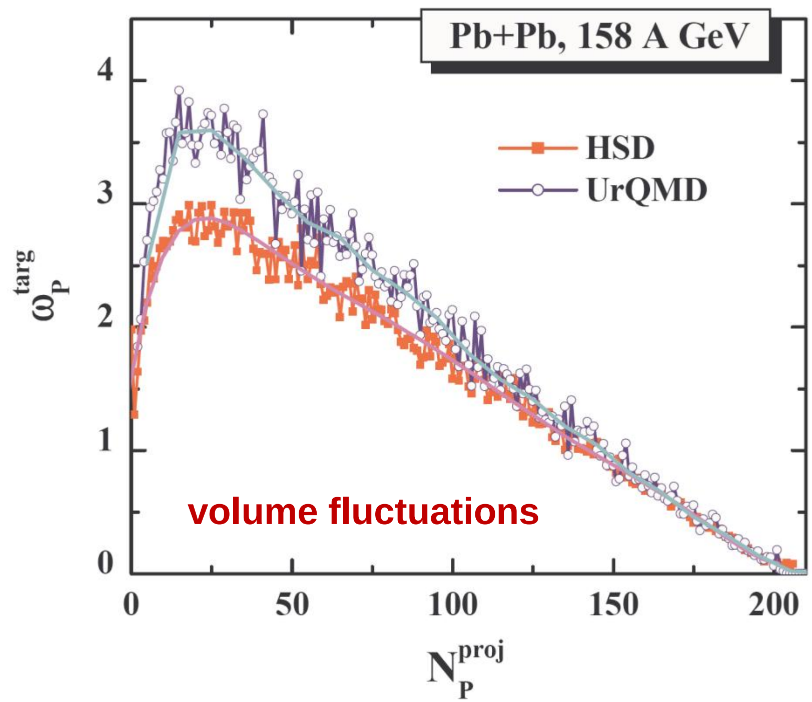
V.B., V. Konchakovski, M.I. Gorenstein, E.L. Bratkovskaya, J.Phys.G, 2013

The choice of the observable

The "right" observable should be independent of the participants number (independent of the system volume) – intensive – to compare pp,… CuCu,… AuAu,… PbPb





and independent of the participant number fluctuations (of volume fluctuations) – strongly intensive

Konchakovski, Gorenstein, Bratkovskaya, Greiner, J.Phys.G 2010

Intensive measures

Moments $\langle \mathrm{A^k} \rangle \equiv \sum_{\mathrm{A}} \mathrm{A^k} \cdot \mathrm{P(A)}$ **Correlation** $\rho_{\mathrm{AB}} \equiv \langle \mathrm{AB} \rangle - \langle \mathrm{A} \rangle \langle \mathrm{B} \rangle$

Particle ratios $\frac{\langle \mathrm{A} \rangle}{\langle \mathrm{B} \rangle}$ **Scaled variance** $\omega_{\mathrm{A}} \equiv \frac{\langle \mathrm{A}^2 \rangle - \langle \mathrm{A} \rangle^2}{\langle \mathrm{A} \rangle}$ $\omega_{\mathrm{Poisson}} = 1$

averaging over volume fluctuations

volume fluctuations

$$\omega_{\mathrm{A}} = \frac{\overline{\langle \mathrm{A}^2 \rangle} - \overline{\langle \mathrm{A} \rangle}^2}{\overline{\langle \mathrm{A} \rangle}} = \omega^*_{\mathrm{A}} + \frac{\langle \mathrm{A} \rangle}{\mathrm{V}} \omega_{\mathrm{V}}$$

physical fluctuations

$$\omega_{\mathrm{B}} = \omega^*_{\mathrm{B}} + \frac{\langle \mathrm{B} \rangle}{\mathrm{V}} \omega_{\mathrm{V}}$$

Gorenstein, Gazdzicki, Phys.Rev.C, 2011

Strongly intensive measures

new measure

$$\Delta^{AB} = \frac{\langle B \rangle \, \omega_A - \langle A \rangle \, \omega_B}{\langle A \rangle + \langle B \rangle}$$

independent of volume and volume fluctuations

new, similar to

$$\Sigma^{AB} = \frac{\langle B \rangle \, \omega_A + \langle A \rangle \, \omega_B - 2\rho_{AB}}{\langle A \rangle + \langle B \rangle}$$

known NA49 measure

$$\Phi = \frac{\sqrt{\langle A \rangle \langle B \rangle}}{\langle A + B \rangle} \left[\sqrt{\Sigma^{AB}} - 1 \right]$$

other popular measures are not strongly intensive

$$\sigma^2_{dyn} = \nu^{AB}_{dyn} = \frac{\langle A + B \rangle}{\langle A \rangle \langle B \rangle} \left[\Sigma^{AB} - 1 \right] \sim \frac{1}{V}$$

Gorenstein, Gazdzicki, Phys.Rev.C, 2011
V.B., Konchakovski, Gorenstein, Bratkovskaya, J.Phys.G, 2013

Model of Independent Sources

p+p collisions: $N_{\text{part}} = 2 \qquad \omega_{\text{part}} = 0$

$$n_K \cong \frac{1}{2}\langle K\rangle_{pp}, \quad n_\pi \cong \frac{1}{2}\langle \pi\rangle_{pp}, \quad \rho^*_{K\pi} \cong \frac{1}{2}[\langle K\pi\rangle_{pp} - \langle K\rangle_{pp}\langle\pi\rangle_{pp}]$$

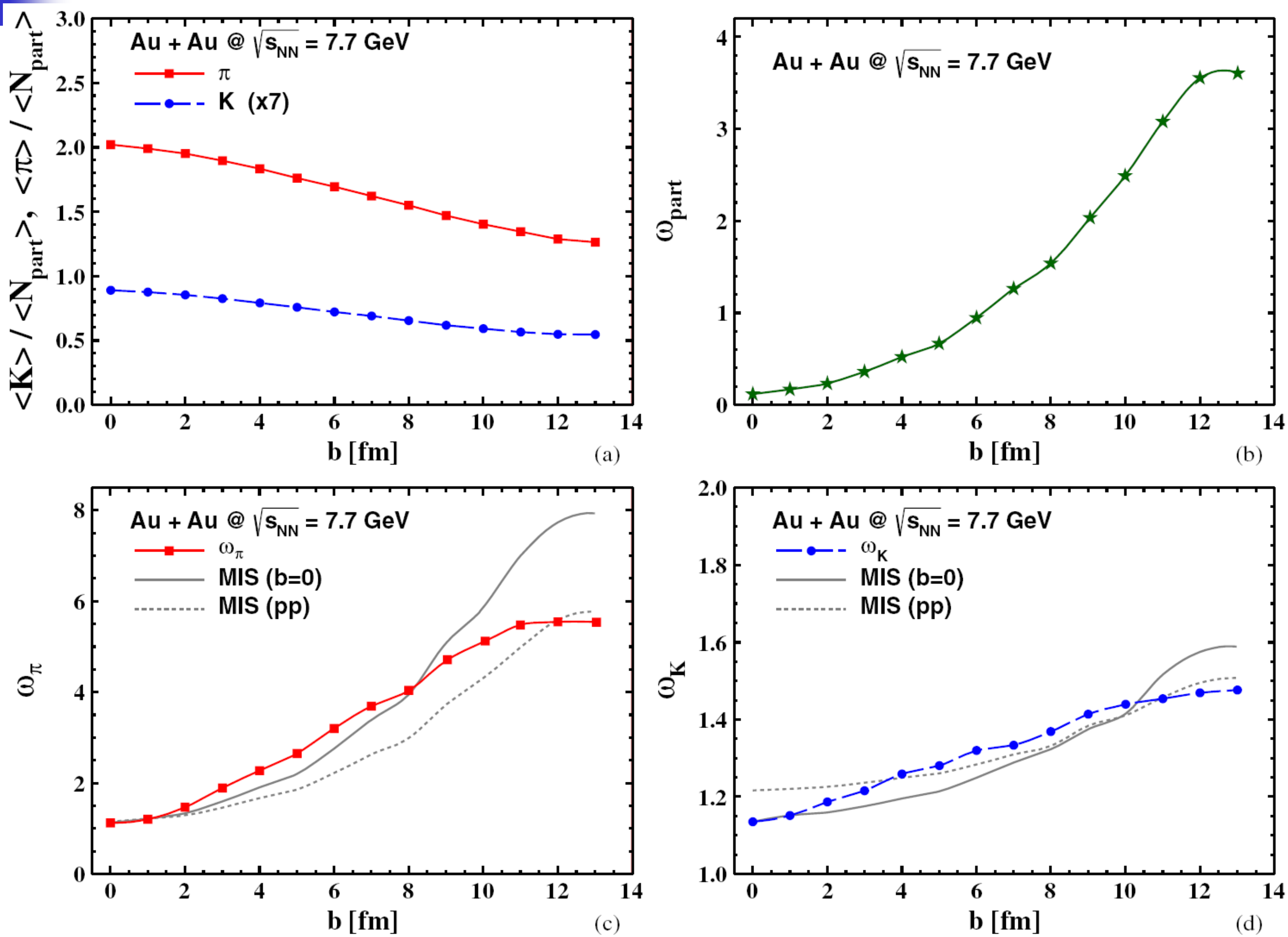
$$\omega^*_K \cong \frac{\langle K^2\rangle_{pp} - \langle K\rangle^2_{pp}}{\langle K\rangle_{pp}}, \qquad \omega^*_\pi \cong \frac{\langle \pi^2\rangle_{pp} - \langle \pi\rangle^2_{pp}}{\langle \pi\rangle_{pp}}$$

central Au+Au collisions: $\omega_{\text{part}} \ll 1$

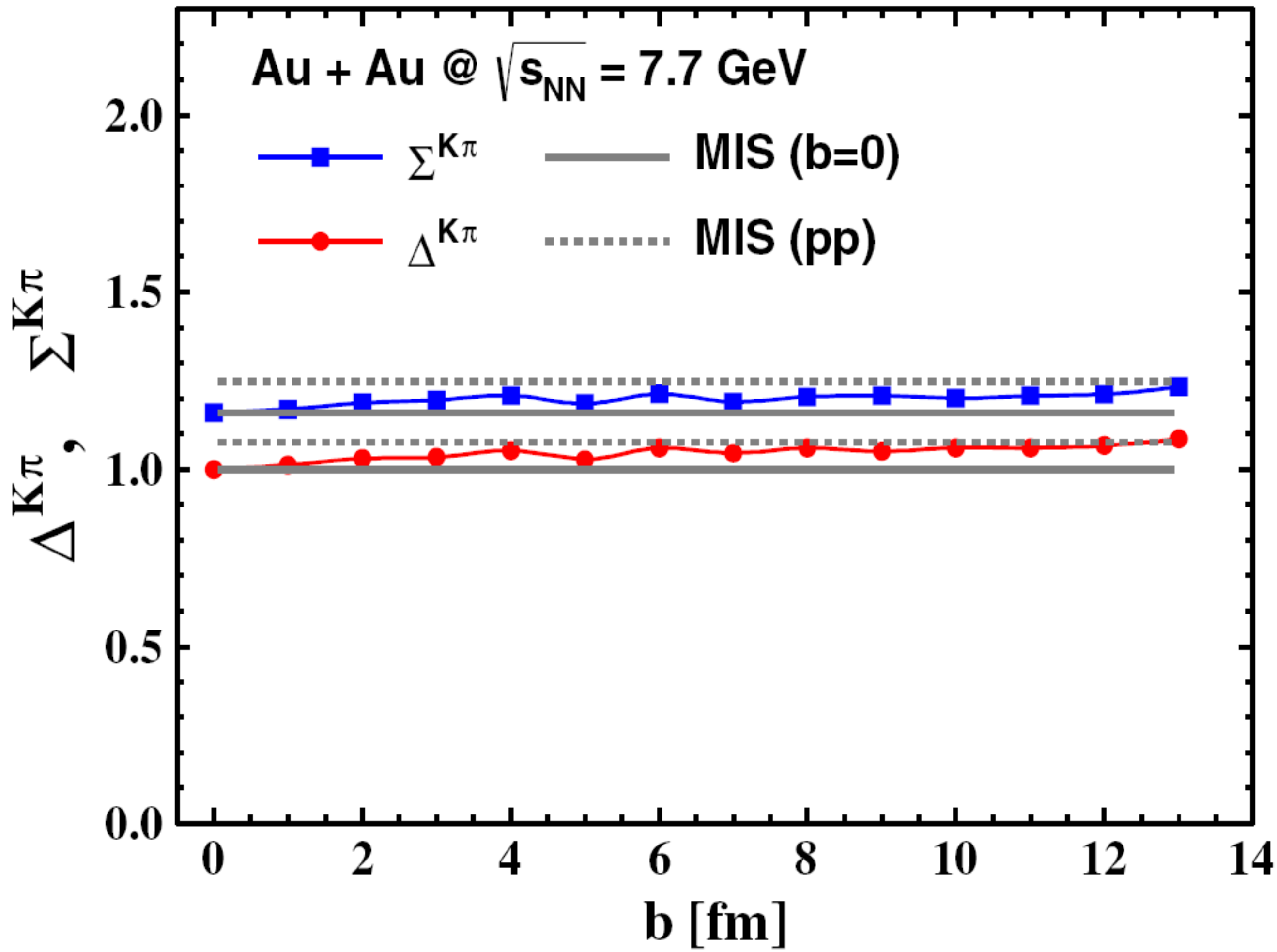
$$n_K = \frac{\langle K\rangle_{b=0}}{\langle N_{\text{part}}\rangle_{b=0}} \qquad n_\pi = \frac{\langle \pi\rangle_{b=0}}{\langle N_{\text{part}}\rangle_{b=0}} \qquad \rho^*_{K\pi} \cong \frac{\langle K\pi\rangle_{b=0} - \langle K\rangle_{b=0}\langle\pi\rangle_{b=0}}{\langle N_{\text{part}}\rangle_{b=0}}$$

$$\omega^*_\pi \cong \omega_\pi(b=0) \qquad \omega^*_K \cong \omega_K(b=0)$$

Centrality Dependence at 7.7 GeV

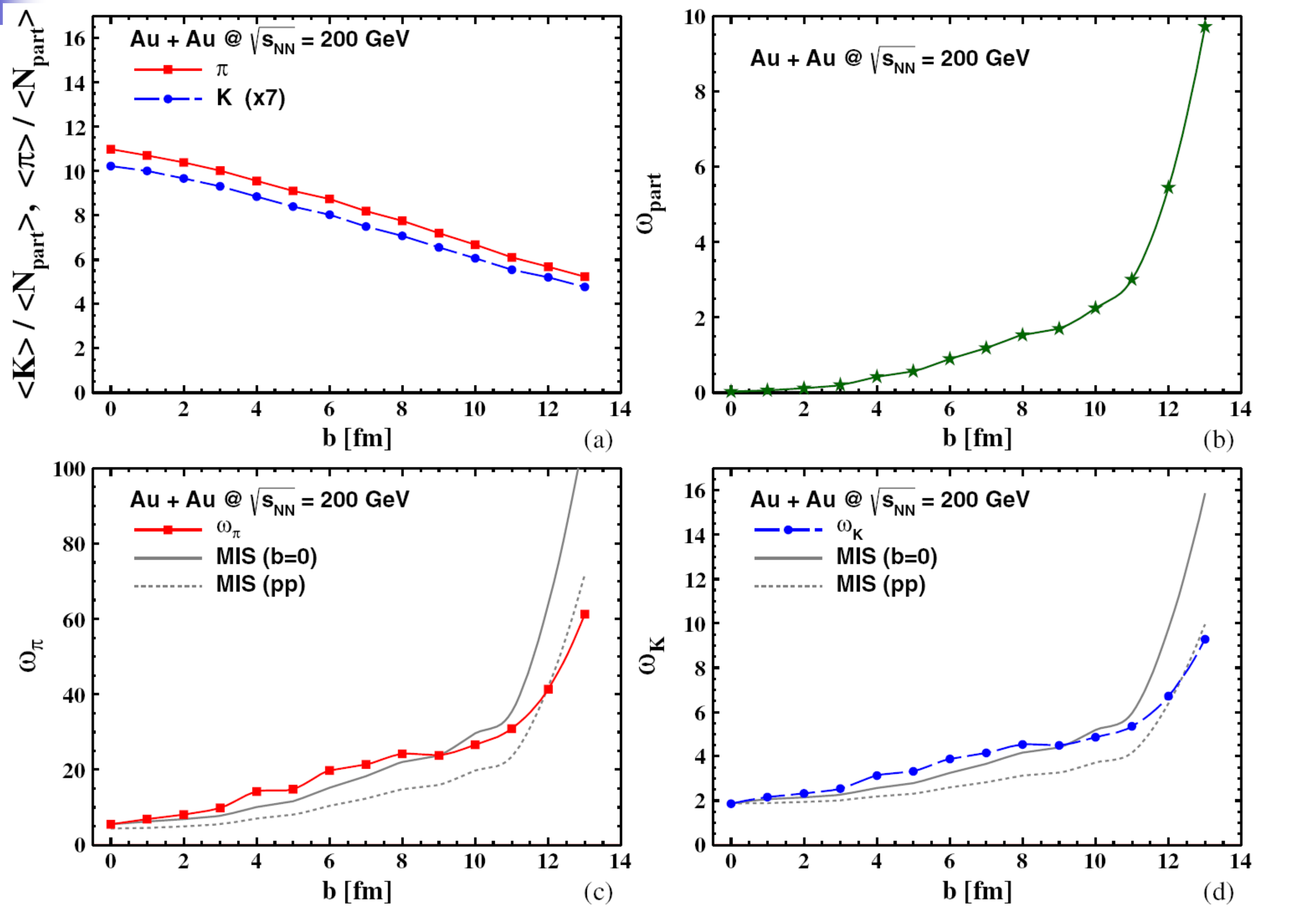


Centrality Dependence at 7.7 GeV

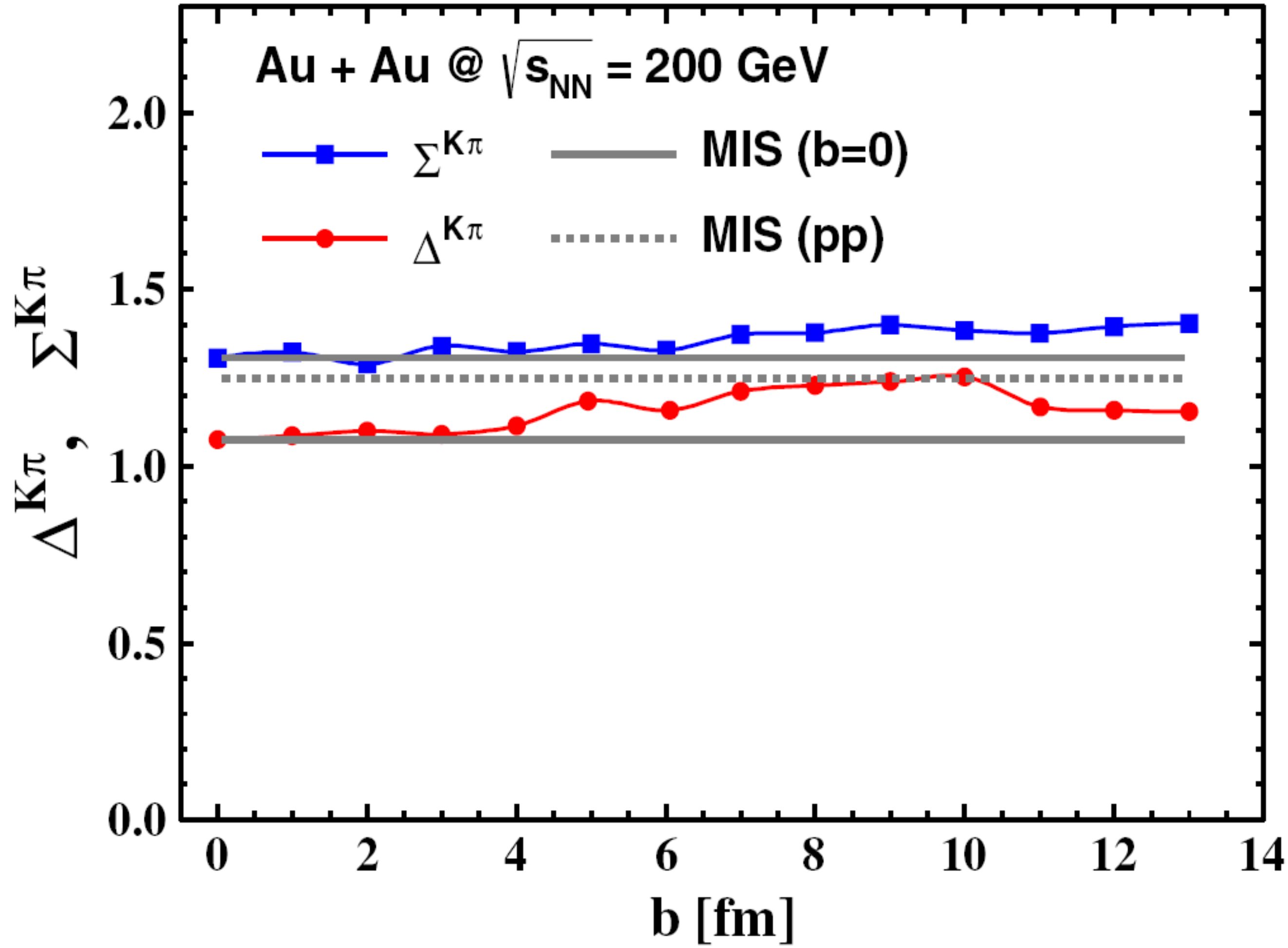


Participant number fluctuations are canceled out in the strongly intensive measures.

Centrality Dependence at 200 GeV

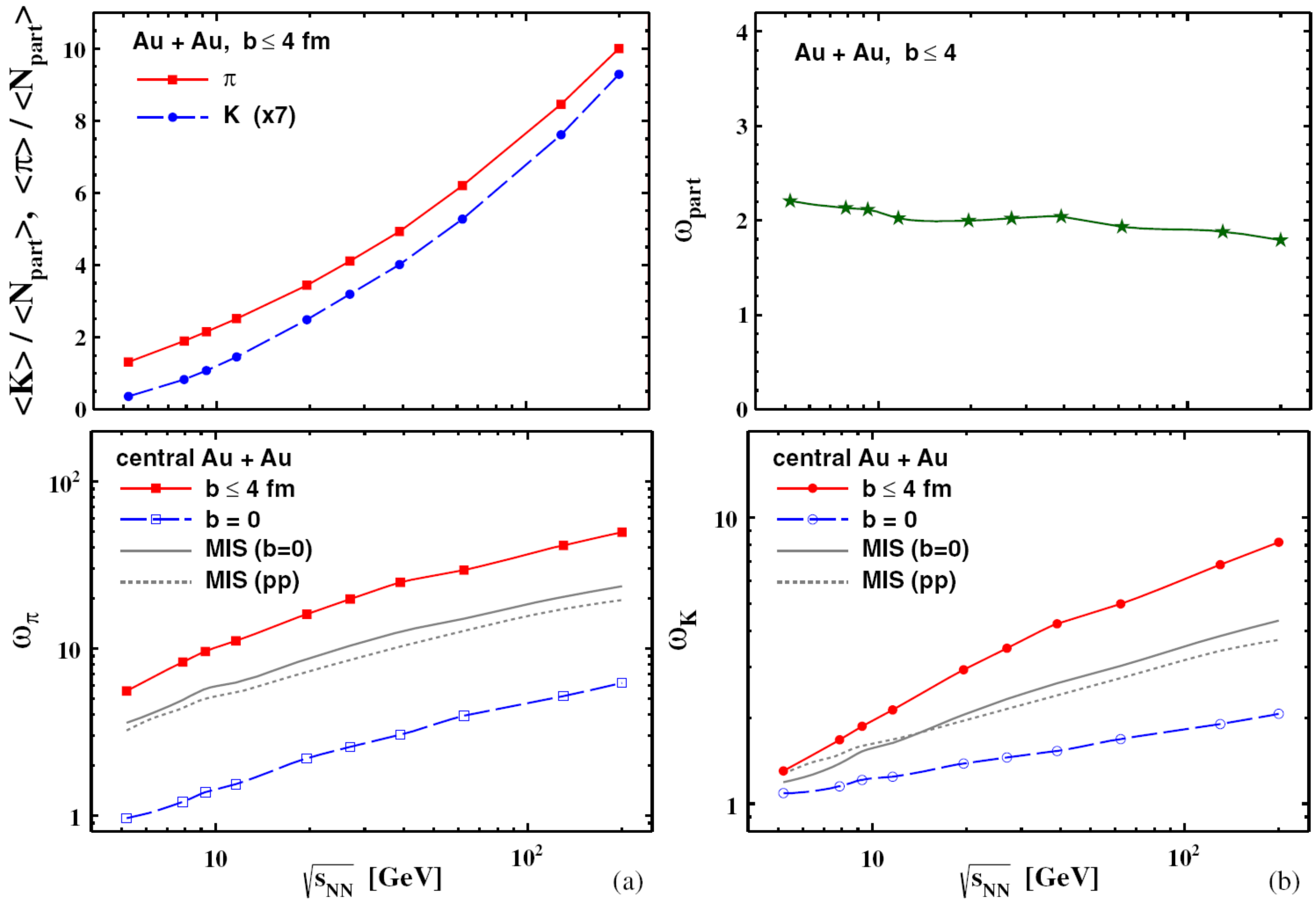


Centrality Dependence at 200 GeV

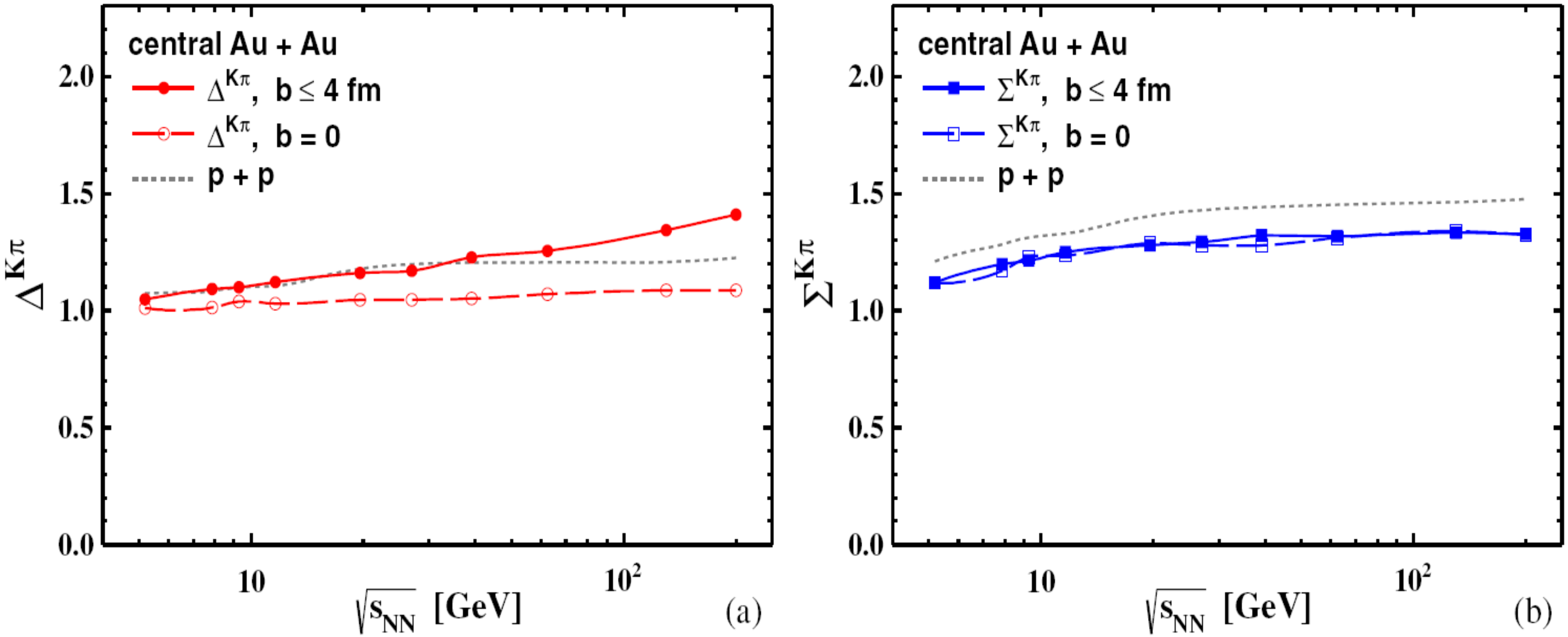


Participant number fluctuations are canceled out in the strongly intensive measures.

Energy Dependence for 10% most central collisions

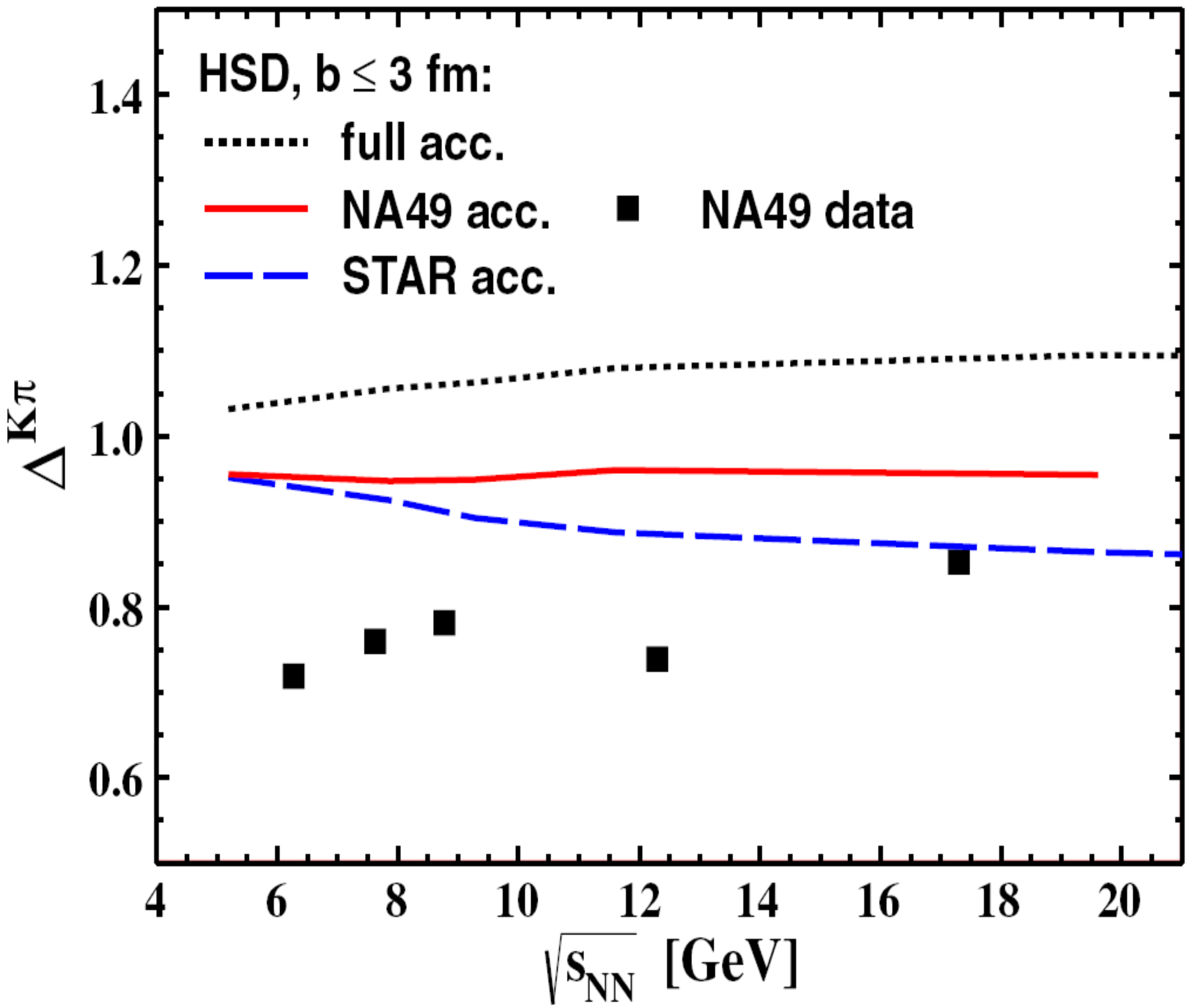


Energy Dependence for 10% most central collisions



Participant number fluctuations are almost canceled out in the strongly intensive measures.

Comparison to NA49 and STAR



NA49 data - 3.5%

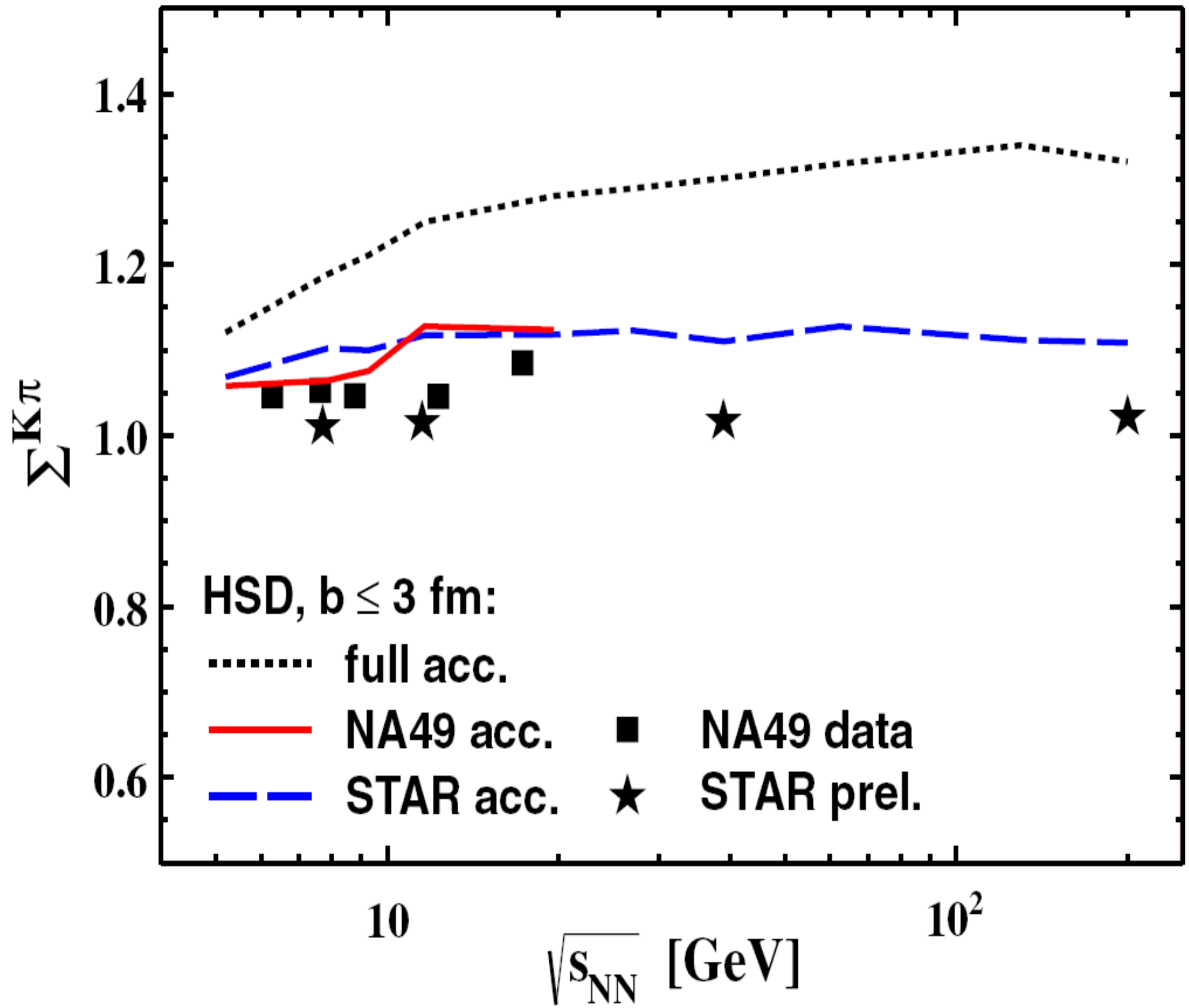
STAR data - 5%

HSD b ≤ 3 - 5%

of the most central collisions

HSD results depend monotonously on collision energy and cannot explain the bump (dip) in the NA49 data

Comparison to NA49 and STAR



NA49 data - 3.5%

STAR data - 5%

HSD b ≤ 3 - 5%

of the most central collisions

HSD gives higher values, but describes $\Sigma^{K\pi}$ reasonably well

Conclusions:

- Participant number fluctuations are canceled out in the strongly intensive measures
- Scaled variances become useless for wide centrality samples because of the participant fluctuations
- The $\nu_{\rm dyn}$ depends on the average number of participants and is inconvenient for the system size scan program
- The HSD describes $\Sigma^{K\pi}$ reasonably well, but does not reproduce the behavior of $\Delta^{K\pi}$
- The centrality window can be enlarged from current 3–5% of the most central collisions to at least 10% using strongly intensive measures