

Fluctuations in High Energy Nucleus-Nucleus Collisions from Microscopic Transport Approaches

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- **Basic concepts of HSD & UrQMD**
- **NA49 data and HSD & UrQMD results**
- **Multiplicity fluctuations in projectile and target hemispheres**
- **Transparency, mixing and reflection in A+A**
- **Conclusions**

Basic concepts of HSD & UrQMD

HSD – **H**adron-**S**tring-**D**ynamics transport approach

UrQMD – **U**ltra-**r**elativistic-**Q**uantum-**M**olecular-**D**ynamics

➤ Take into account:

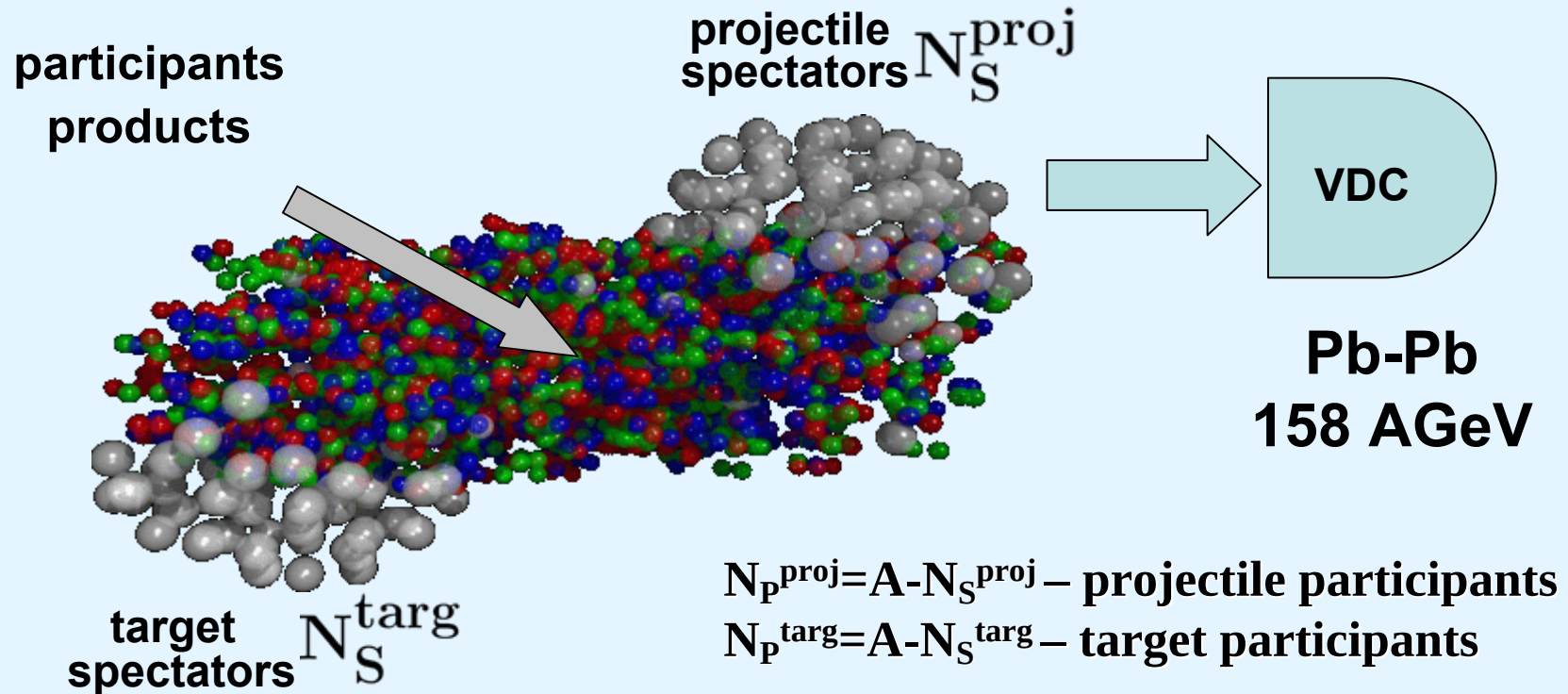
- elastic and inelastic hadronic reactions
- formation and decay of hadronic resonances
- string formation and decay

➤ Show **good** description of :

- particle production in p-p, p-A reactions
- nuclear dynamics from low (~100 MeV)
to ultrarelativistic (21.3 TeV) energies

➤ We calculate the multiplicity fluctuation in **HSD** & **UrQMD**

Nucleons: participants and spectators



Scaled variance

$$\omega_i = \frac{\langle N_i^2 \rangle - \langle N_i \rangle^2}{\langle N_i \rangle}, \quad \text{where } i = -, +, ch$$

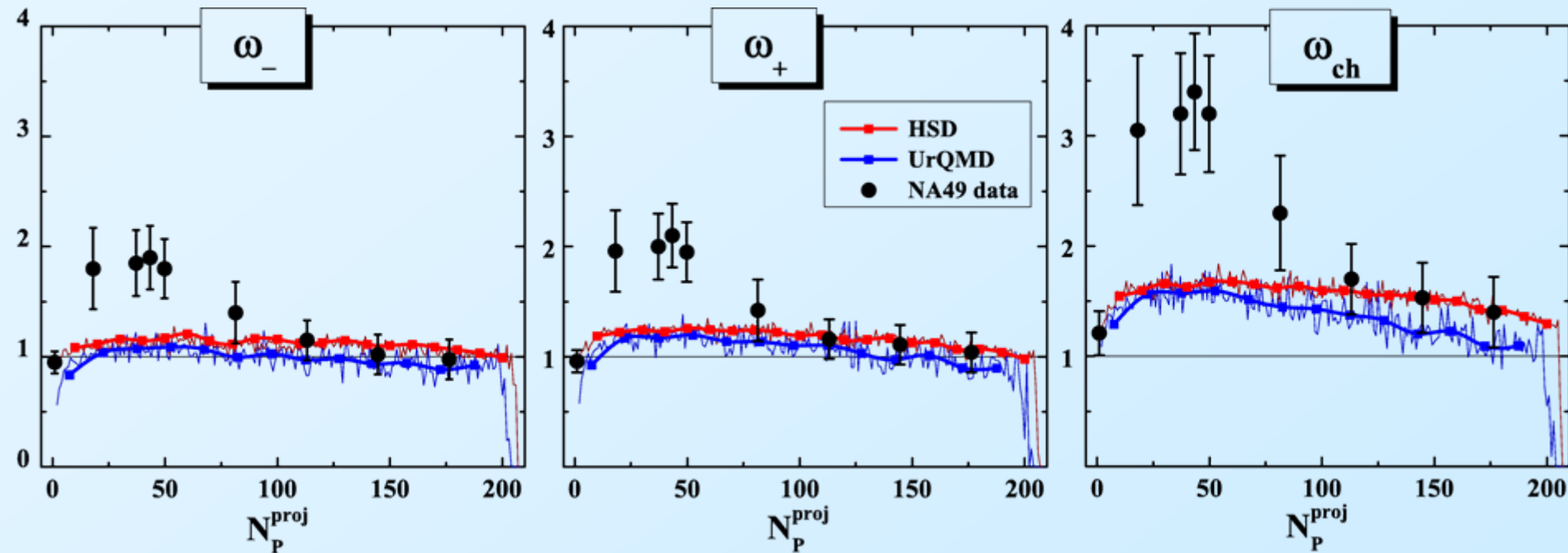
$\omega = 1$ for Poisson distribution

$$\omega_-^* = 1.5$$

$$\omega_+^* = 1.1$$

$$\omega_{ch}^* = 2.5$$

NA49 data and HSD & UrQMD results

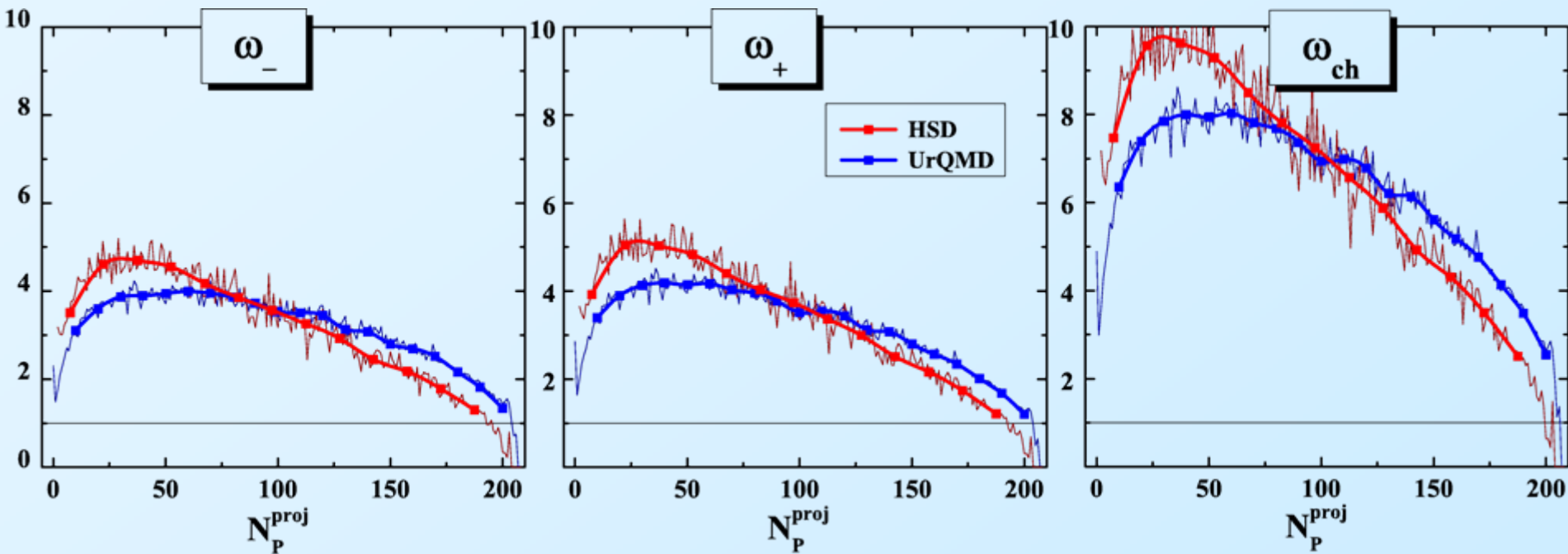


The observed by NA49 non-trivial centrality dependence of multiplicity fluctuations is not reproduced by HSD and UrQMD.

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V. K, S.Haussler, M.I.Gorenstein, E.L.Bratkovskaya, M.Bleicher, H.Stöcker

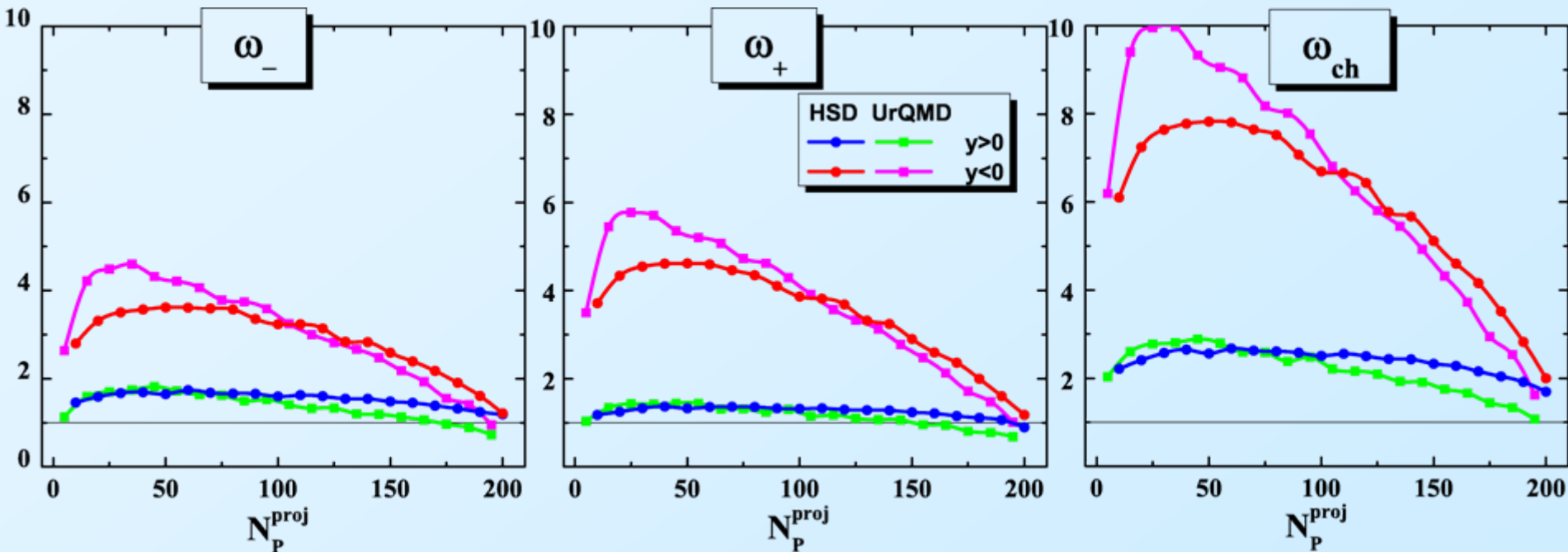
Full acceptance:



In full acceptance HSD and UrQMD show:

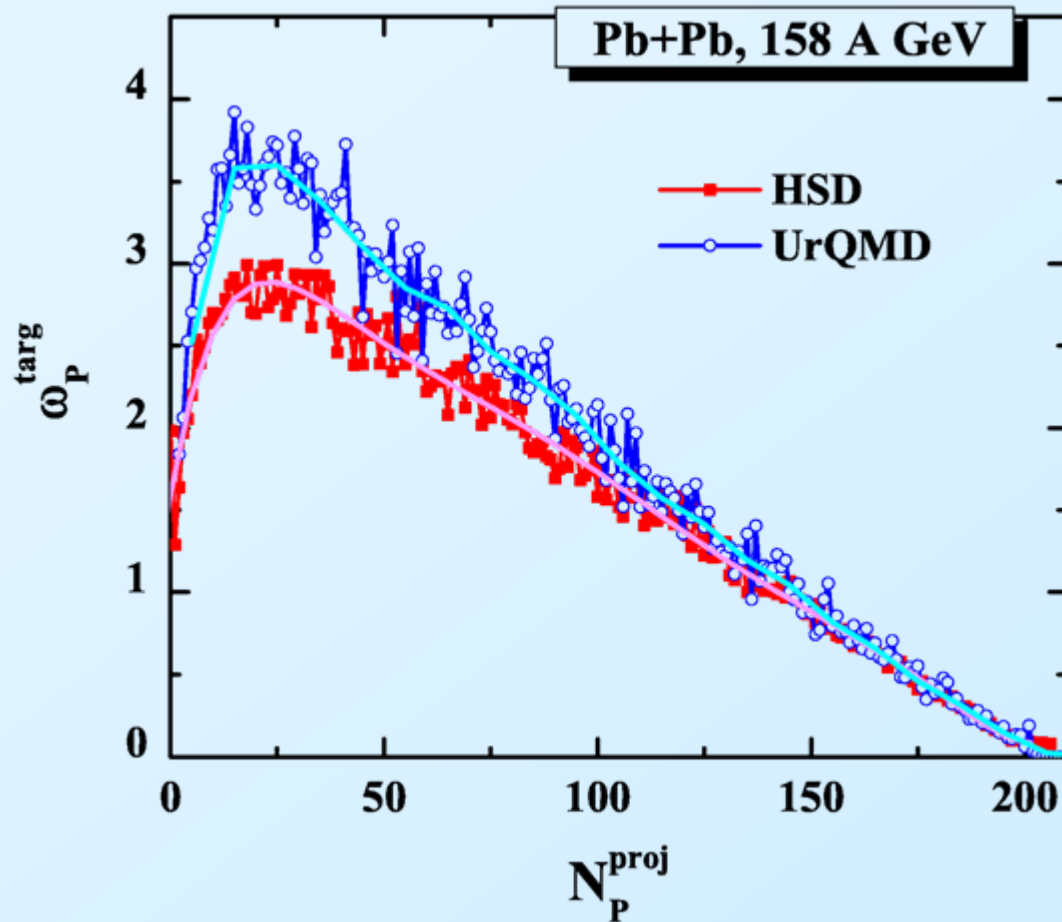
- strong multiplicity fluctuations
- strong dependence of ω on centrality (similar to experimental data)

Multiplicity fluctuations in projectile and target hemispheres



- Fluctuations in target hemisphere are much larger than in projectile hemisphere
- There is no N_p^{proj} dependence of fluctuations in projectile hemisphere but there is strong N_p^{proj} dependence for target hemisphere

The scaled variance for the fluctuations of the number of target participants N_P^{targ}



$$N_P^{\text{tar}} \neq N_P^{\text{proj}}$$
$$\langle N_P^{\text{tar}} \rangle = N_P^{\text{proj}}$$

In each sample with $N_P^{\text{proj}} = \text{const}$ the number of target participants N_P^{targ} fluctuates considerably.

These fluctuations originate from:

- geometrical fluctuations
- probabilistic character of collisions

Model of independent sources

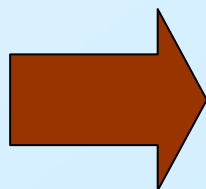
Let: ω_i^* is not depend on N_P

$$\overline{N}_i = N_P n_i$$

$$n_i = \frac{\langle \overline{N}_i \rangle}{\langle N_P \rangle} \quad \text{- the particle number of i-th type per participant}$$

$$\omega_i = \omega_i^* + \frac{1}{2} \omega_P^{tar} n_i, \quad \text{where} \quad i = -, +, ch$$

HSD
N+N
158 GeV



**the fluctuation
from one source**

$$\begin{aligned} \omega_-^* &= 1.5 \\ \omega_+^* &= 1.1 \\ \omega_{ch}^* &= 2.5 \end{aligned}$$

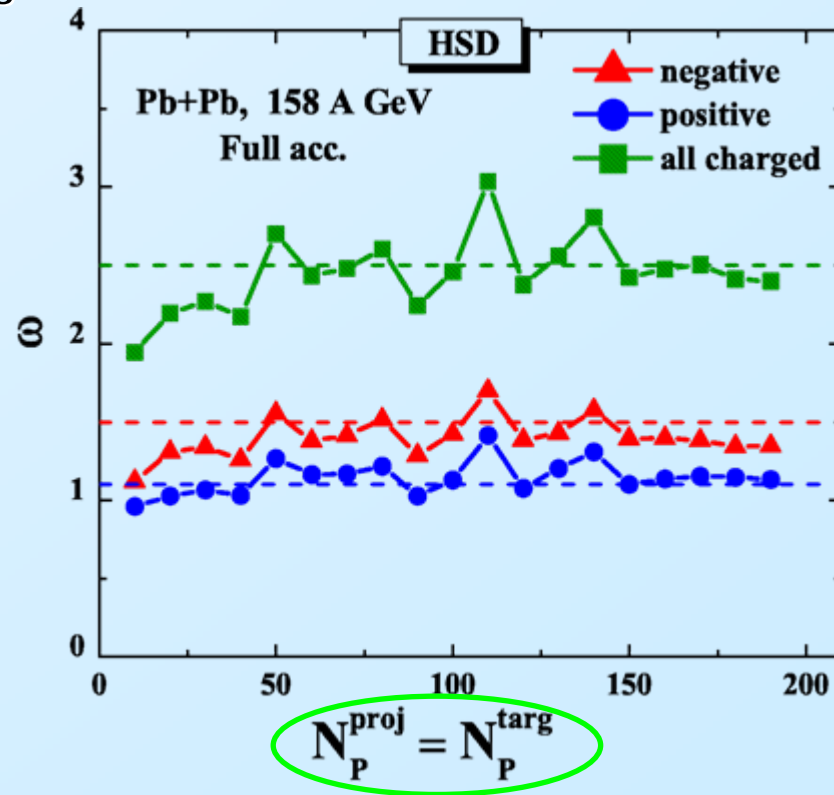
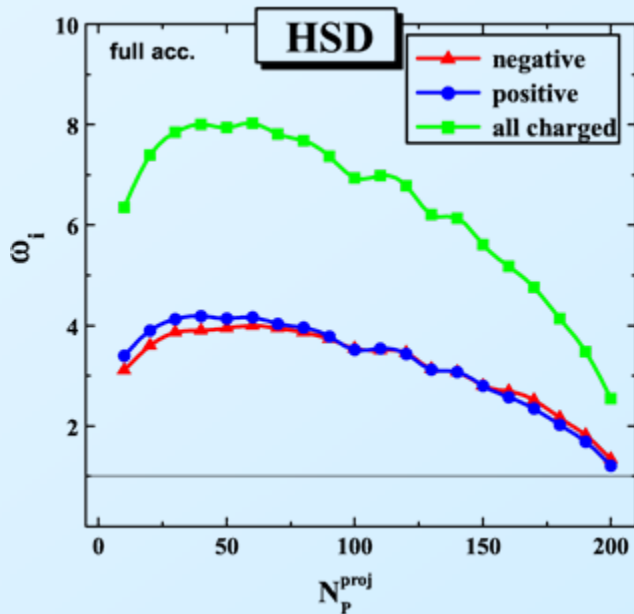
HSD at $N_p^{\text{proj}} = N_p^{\text{targ}} = \text{const}$

For $N_p^{\text{proj}} = N_p^{\text{targ}}$ it follows

$$\omega_p^{\text{targ}} = 0$$

and fluctuations in A+A collisions are dominated by the fluctuations of the particle number in a single N+N collision.

$$\omega_i = \omega_i^* + \frac{1}{2} \omega_p^{\text{targ}} \eta_i$$



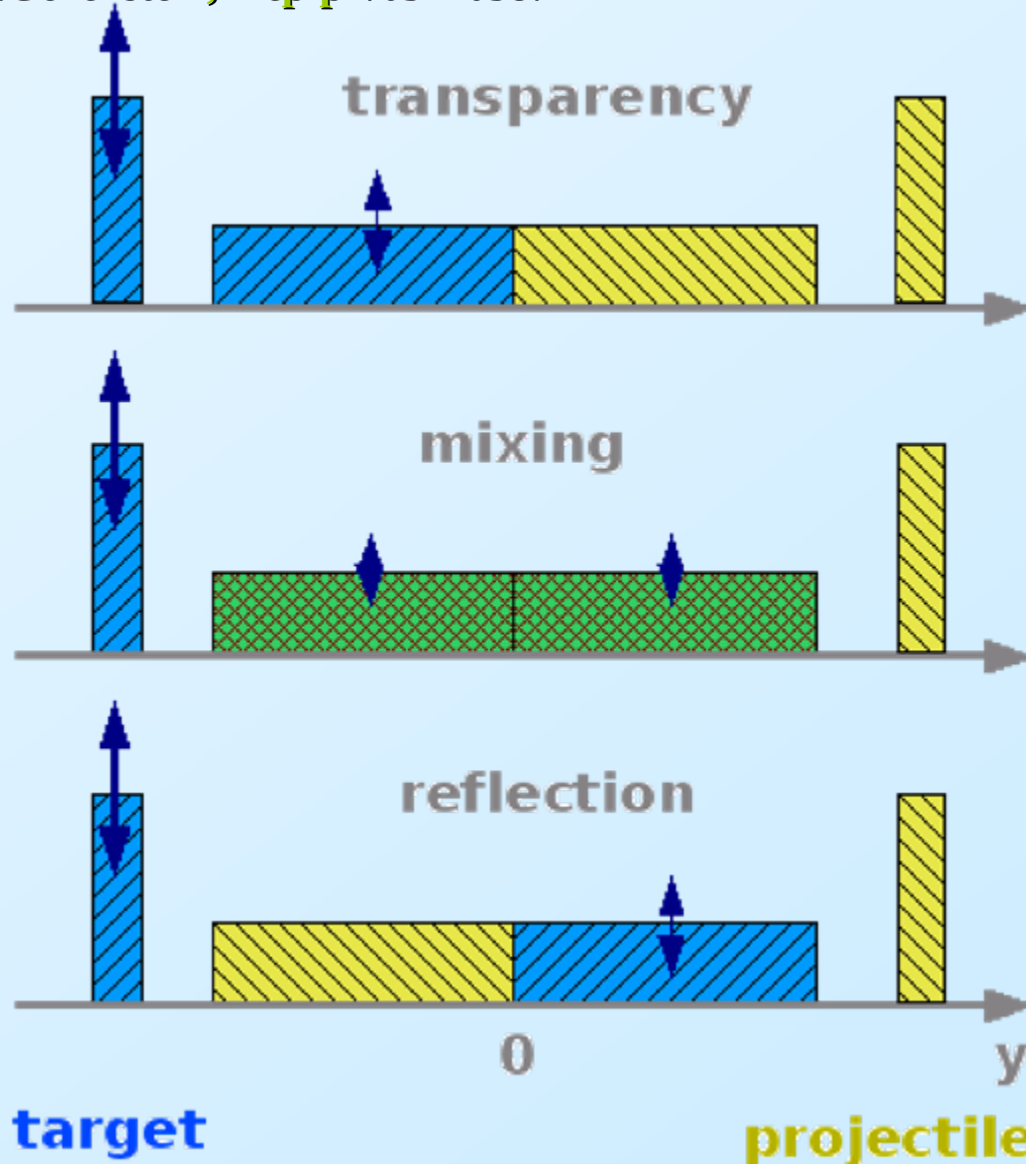
$$\omega_{ch}^* = 2.5$$

$$\omega_-^* = 1.5$$

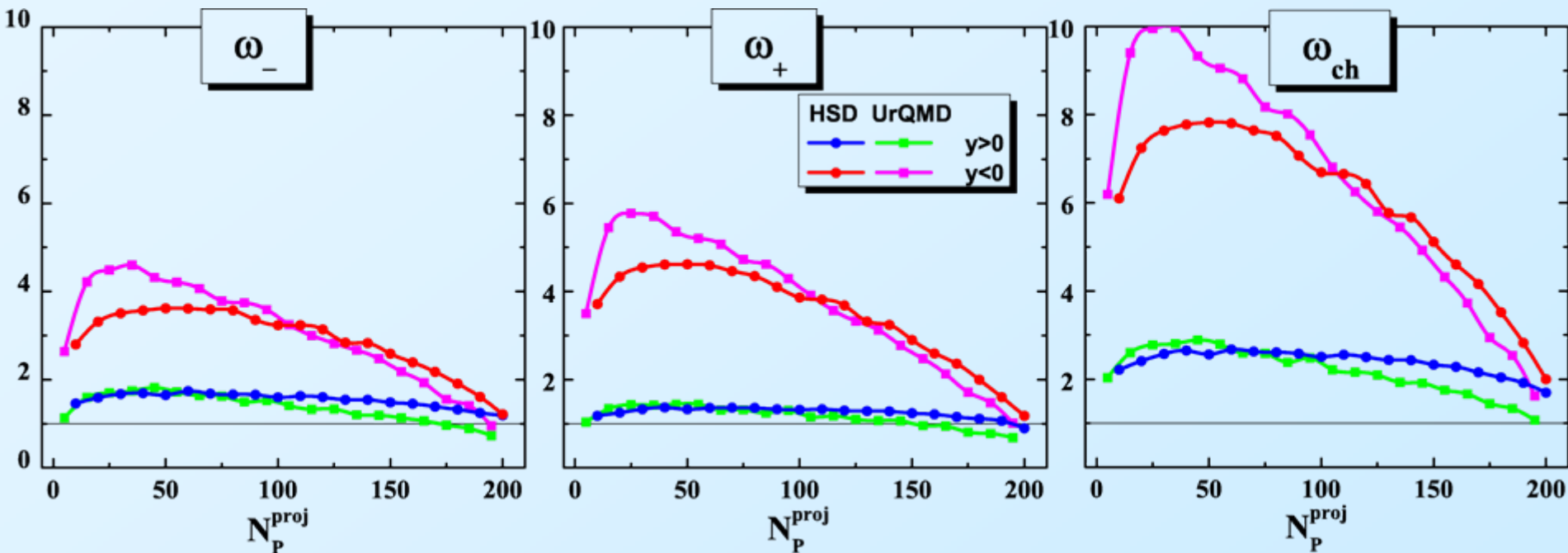
$$\omega_+^* = 1.1$$

Transparency, mixing and reflection in A+A

M.Gazdzicki, M.Gorenstein, hep-ph/0511058:

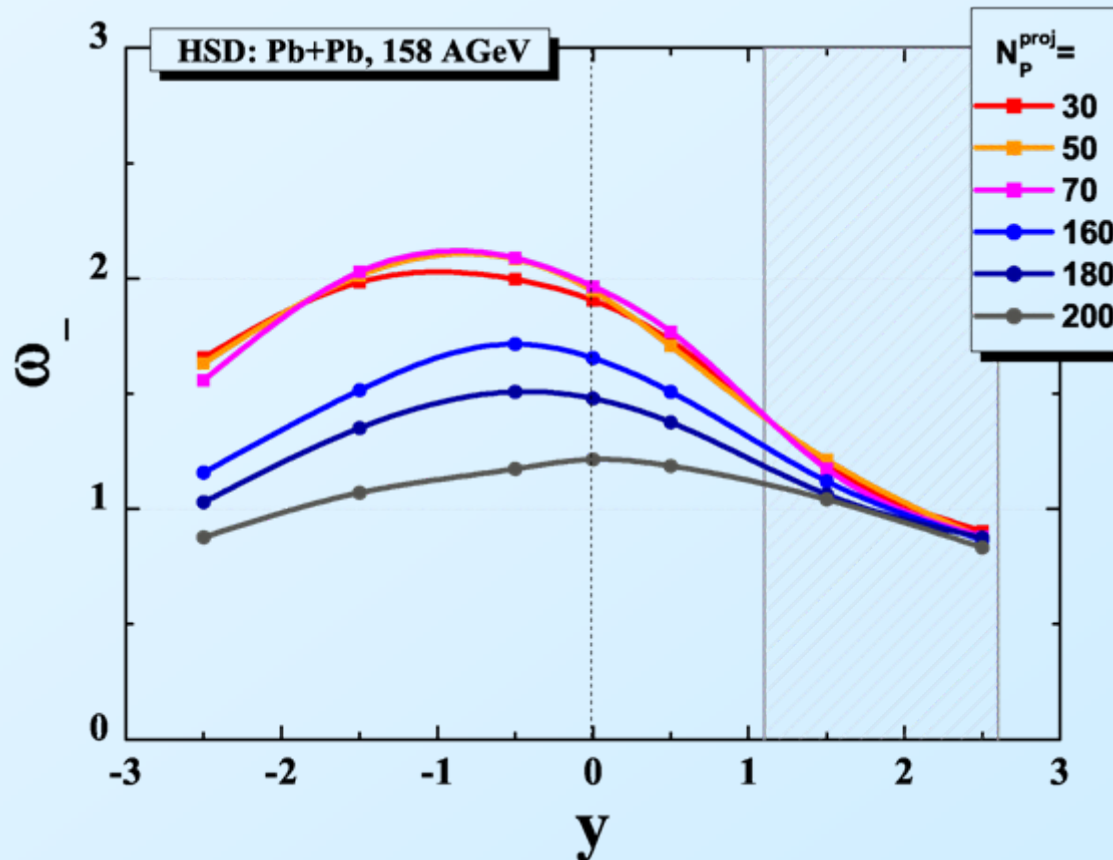


HSD & UrQMD in projectile and target hemispheres



- HSD & UrQMD are **too transparent** and can not explain the NA49 data.
- Experimental data are close to the **mixing** scenario for 158 Pb+Pb

Multiplicity fluctuations versus rapidity



- We do not see the centrality dependence of multiplicity fluctuations in the NA49 rapidity interval ($1.1 < y < 2.6$)
- In the projectile hemisphere the centrality dependence is only seen near midrapidity ($0 < y < 1$)

Conclusions:

- The fluctuations of **number of participants** strongly influence the multiplicity fluctuations.
- Fixation of number of projectile participants **cannot** kill the volume fluctuations in the system for peripheral collisions. **Only at $N_p^{\text{proj}} \approx A$** these fluctuations become small.
- HSD and UrQMD models are **too transparent** and cannot reproduce the NA49 results for Pb-Pb 158 AGeV on multiplicity fluctuations.
- A **comparison** of the fluctuations in the **projectile and target hemisphere** at $N_p^{\text{proj}} = \text{const}$ tells us about hadron's mixing. It gives us quantitative measure of the mixing.
- The fluctuations of the **baryonic number** and **electric charge** are also important for understanding the mechanisms of A+A collisions [nucl-th/0606047]
- Related analysis in comparison with RHIC data are in progress.

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