Multibin multiplicity correlations in a superposition approach

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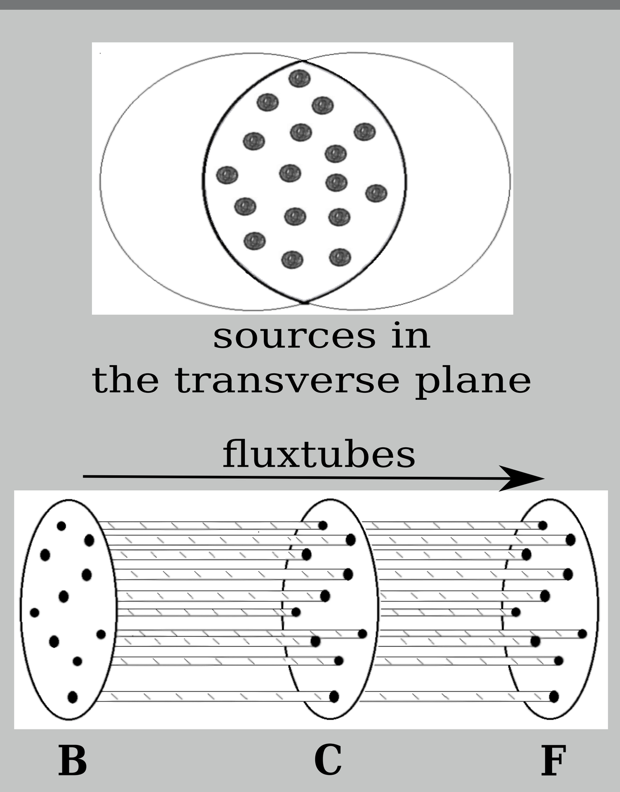
Introduction

- Multibin correlation coefficients quantify how multiplicity in various rapidity windows influence one another
- The primary goal of these analyses is to get insight into the space-time dynamics of the earliest stages of the reaction, probed via the multibin correlations

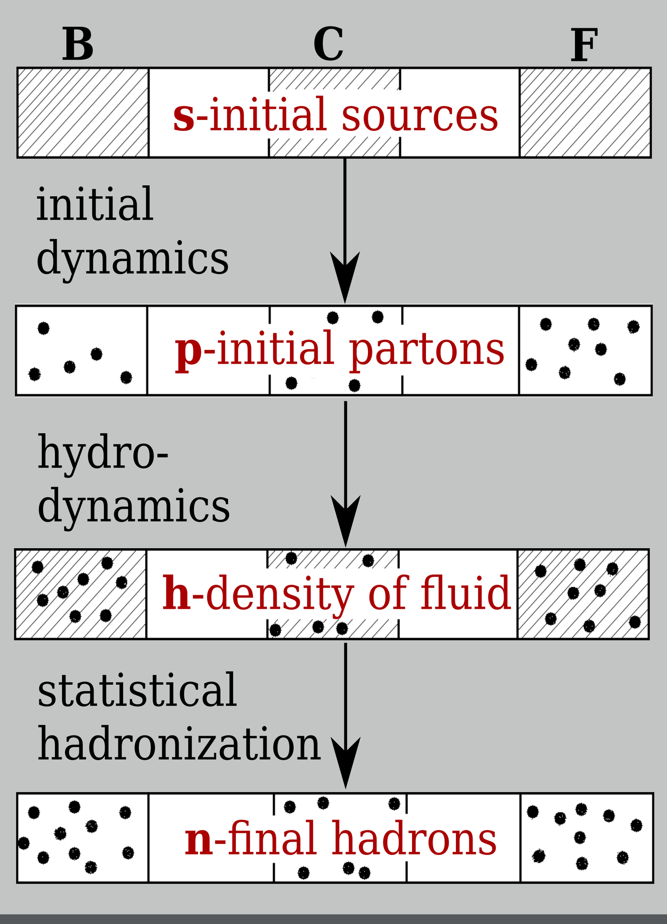
[1] A. Bialas and K. Zalewski, Phys. Rev. C 82, 034911 (2010)
[2] A. Bzdak, Phys. Rev. C 85, 051901 (2012)
[3] A. Olszewski and W. Broniowski, Phys. Rev. C 88, 044913 (2013)

The concept of the sources



- Sources in the transverse plane: wounded nucleons or binary collisions
- Concept of longitudinal strings (fluxtubes). Their number decreases with centrality
- We assume well separated F, B, and C rapidity bins, such that the particles produced in one bin do not fall into another one

Time evolution of the system



- Initial tubes extend along the forward and backward rapidity range
- Quarks and gluons (more generally partons) form from breaking fluxtubes
- Partons produced from a source have the same distribution in bins F, B, C
- The density of partons yields the initial condition for hydrodynamics
- Hydrodynamic evolution
- Statistical hadronization is carried out at freeze-out

Superposition model and the three stage approach

- In the initial phase we assume that the parton production occurs from each source in the same manner,

$$p_A = \sum_{i=1}^{s_A} \mu_i, \quad A = B, F, C$$

- The evolution of the cell with initially p partons yields the density of fluid h at freeze-out. It may be thought of as entropy contained in the cell. When fluctuations are not too large

$$h = t_0\langle p\rangle + t_1\left(p - \langle p\rangle\right) + \mathcal{O}\left((p - \langle p\rangle)^2\right)$$

- At freezout a cell emits n hadrons into a corresponding region of phase space, with a statistical distribution superimposed over h,

$$n_A = \sum_{i=1}^{h_A} m_i$$

The moments of sources

- We introduce the moments and scaled moments of sources

$$S_{ijk} = \langle \Delta s_B^i \Delta s_C^j \Delta s_F^k \rangle, \quad \tilde{S}_{ijk} = \frac{\langle \Delta s_B^i \Delta s_C^j \Delta s_F^k \rangle}{\sqrt{\langle \Delta s_B^2\rangle \langle \Delta s_C^2\rangle \langle \Delta s_F^2\rangle}}$$

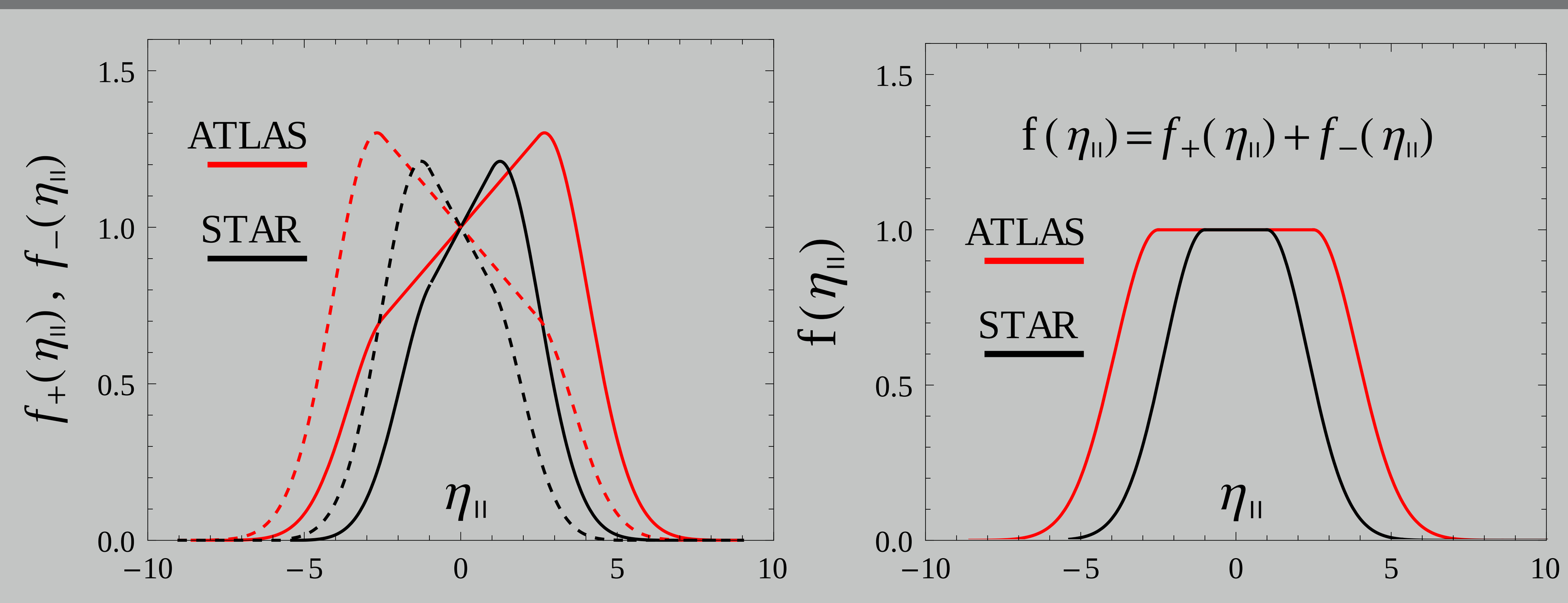
- In the three-stage approach we obtain relations between the moments of the initial sources (s) and observed hadrons (n),

$$\begin{aligned}
\langle n_A\rangle &= \alpha\langle s_A\rangle\\
\langle \Delta n_A^2\rangle &= \beta\langle s_A\rangle + \gamma\langle \Delta s_A^2\rangle\\
\langle \Delta n_F \Delta n_B\rangle &= \gamma\langle \Delta s_F \Delta s_B\rangle\\
\langle \Delta n_F \Delta n_C \Delta n_B\rangle &= \gamma^{3/2}\langle \Delta s_F \Delta s_C \Delta s_B\rangle\\
\langle \Delta n_F \Delta n_B^2\rangle &= \gamma^{1/2}\beta'\langle \Delta s_F \Delta s_B\rangle + \gamma^{3/2}\langle \Delta s_F \Delta s_B^2\rangle\\
\langle \Delta n_A^3\rangle &= \zeta\langle s_A\rangle + 3\gamma^{1/2}\beta'\langle \Delta s_A^2\rangle + \gamma^{3/2}\langle \Delta s_A^3\rangle
\end{aligned}$$

where the **c**- and η-independent parameters are

$$\alpha = t_0\langle\mu\rangle\langle m\rangle, \quad \beta = t_0\langle\mu\rangle \mathrm{var}(m) + t_1^2\langle m\rangle^2\mathrm{var}(\mu)$$
$$\beta' = t_1\langle\mu\rangle \mathrm{var}(m) + t_1^2\langle m\rangle^2\mathrm{var}(\mu), \quad \gamma = t_1^2\langle m\rangle^2\langle\mu\rangle^2$$
$$\zeta = t_0\mu_3(m)\langle\mu\rangle + 3t_1^2\mathrm{var}(\mu)\mathrm{var}(m)\langle m\rangle + t_1^3\mu_3(\mu)\langle m\rangle^3$$

Rapidity distribution of sources



f_+-forward, f_--backward moving wounded nucleons, f-gluons

$$f_\pm(\eta_{||}) = \exp\left(-\frac{(|\eta_{||}| - \eta_0)^2}{2\sigma_\eta^2}\,\theta(|\eta_{||}| - \eta_0)\right)\frac{y_b \pm \eta_{||}}{y_b}\,\theta(y_b \pm \eta_{||})$$

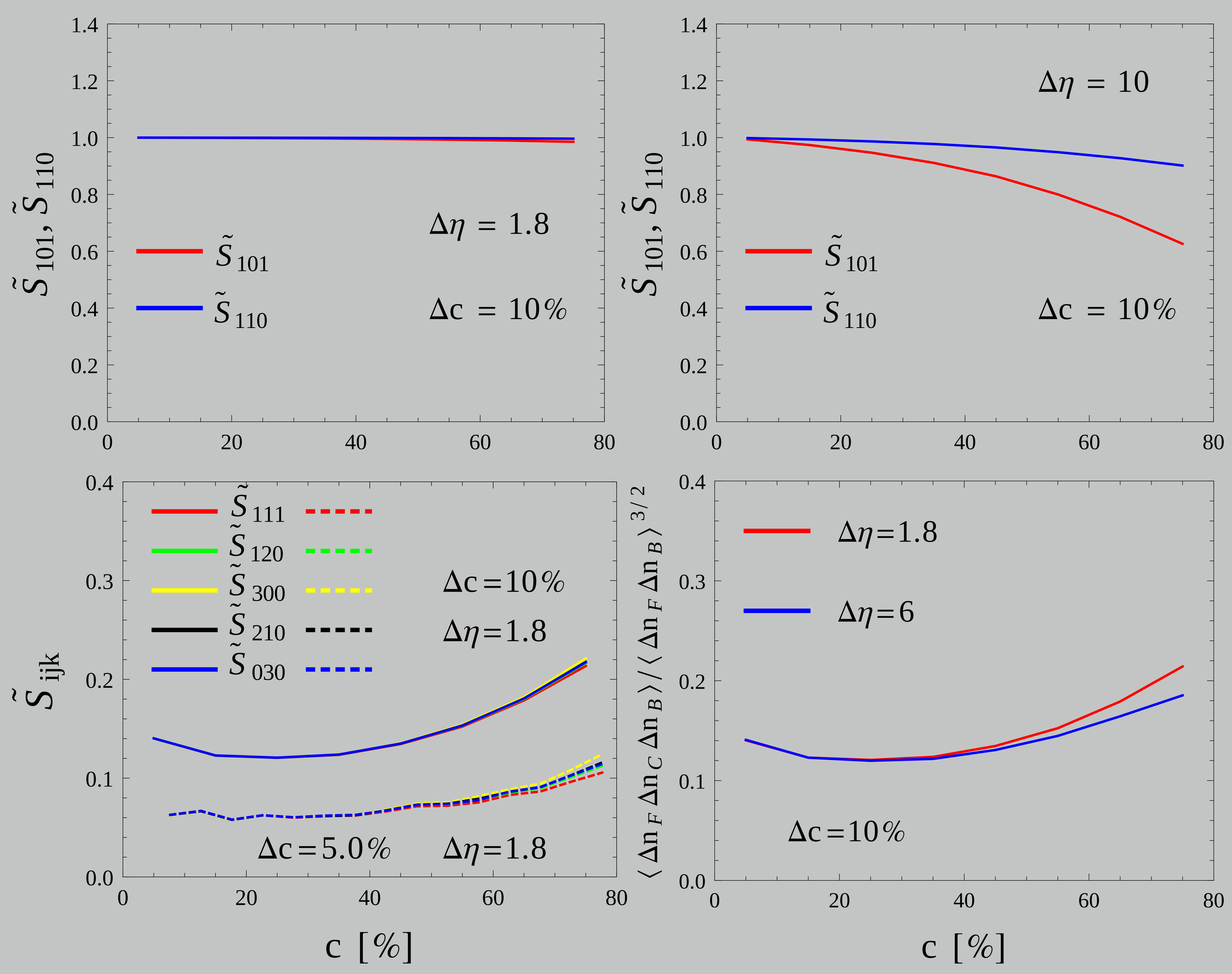
[4] A. Bialas, W. Czyz, Acta Phys. Polon. B 36 (2005)
[5] P. Bozek, I. Wyskiel, Phys. Rev. C 81 (2010)

- Mixed model, $a = 0.1 - 0.15$

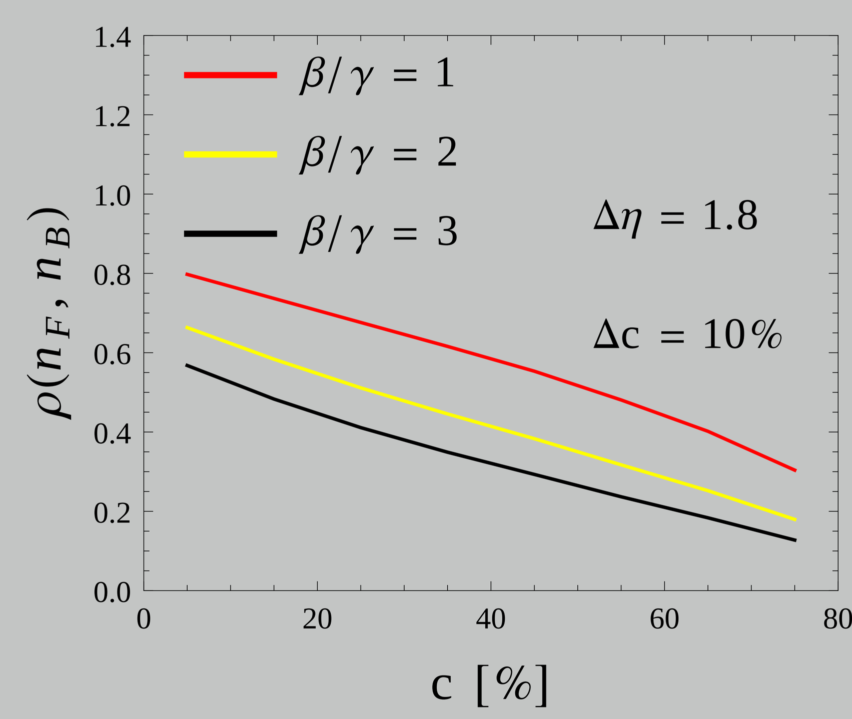
$$s(\eta_{||}) = \frac{1-a}{2}\left(f_+(\eta_{||})\,N_{W,B} + f_-(\eta_{||})\,N_{W,F}\right) + a\left(\frac{f_+(\eta_{||}) + f_-(\eta_{||})}{2}N_{bin}\right)$$

Results and predictions from GLISSANDO

- Centrality determined from the central bin C
- $\Delta\eta$ is the separation of F and B bins, bin width = 0.2
- Results depend on Δc, but same choice as in the experiment can be made



$$\rho(n_F, n_B) \equiv \frac{\langle \Delta n_F \Delta n_B\rangle}{\sqrt{\langle \Delta n_F^2\rangle\langle \Delta n_B^2\rangle}} = \frac{\tilde{S}_{101}}{\sqrt{\left(1 + \frac{\beta}{\gamma}\frac{\langle s_F\rangle}{\langle \Delta s_F^2\rangle}\right)}\sqrt{\left(1 + \frac{\beta}{\gamma}\frac{\langle s_B\rangle}{\langle \Delta s_B^2\rangle}\right)}}$$



- Natural fall-off with centrality from $\langle s_A\rangle / \langle \Delta s_A^2\rangle$

Conclusions

- Within a three stage superposition model we have derived simple formulas which link statistical properties of the distribution of initial sources (wounded nucleons, gluons) with the number of the observed hadrons
- May fit multiplicities, variances, and higher-order multi-bin correlations. This will provide information of the properties of the overlaid distributions and the parameters of hydrodynamics

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