Session: CGC & Lund Strings

One event generator to rule them all?

Pythia

EPOS

PHSD (Parton Hadron String Dynamics)

HIJING (Heavy-Ion Jet Interaction Generator)

HERWIG (Hadron Emission Reactions With Interfering Gluons)

AMPT (A Multi-Phase Transport Model)

SMASH / UrQMD

And the list goes on… How do I differentiate between them?

Which one of them is the best?

CGC and longitudinal dynamics

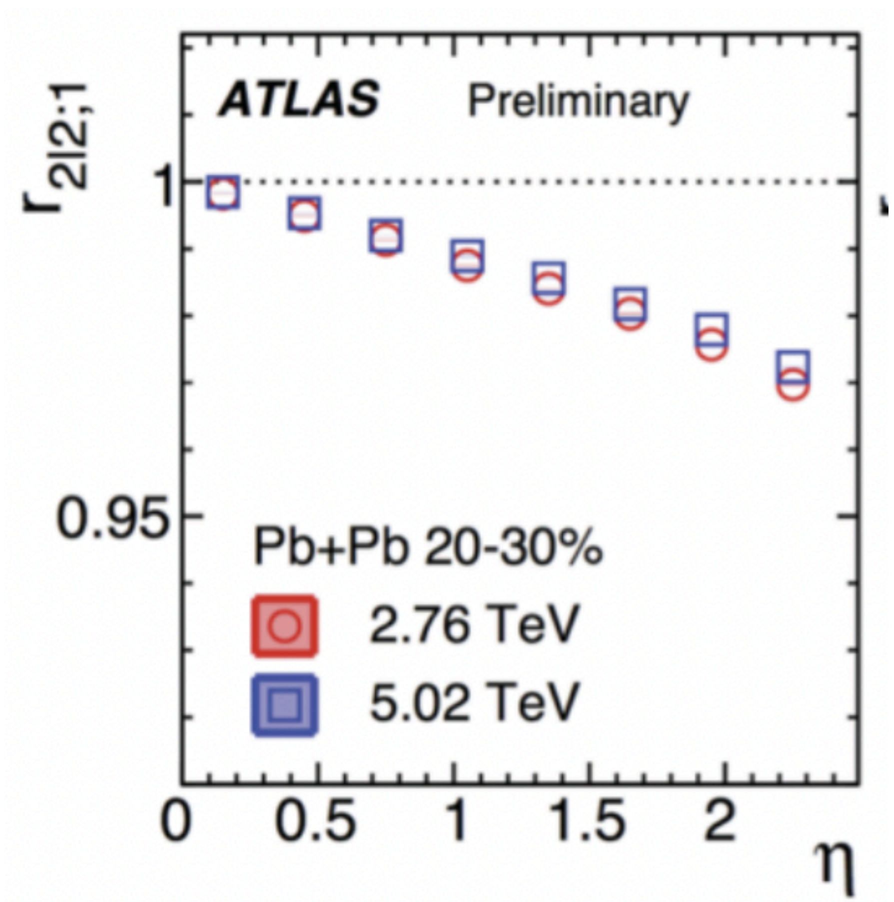
- Boost invariance (η~0) on average is reasonable assumption for symmetric high-energy collisions

- New measurements at RHIC and LHC indicates towards the presence of longitudinal dynamics

  Event plane decorrelation Phys.Rev.C 92 (2015) 3, 034911,...

  Flow decorrelation Eur.Phys.J.C 78 (2018) 2, 142 ,...

$$r_n(\eta_a,\eta_b) = \frac{\left\langle \mathrm{Re}[\boldsymbol{\epsilon}_\mathrm{n}(-\eta_\mathrm{a}).\boldsymbol{\epsilon}_\mathrm{n}^*(\eta_\mathrm{b})]\right\rangle}{\left\langle \mathrm{Re}[\boldsymbol{\epsilon}_\mathrm{n}(\eta_\mathrm{a}).\boldsymbol{\epsilon}_\mathrm{n}^*(\eta_\mathrm{b})]\right\rangle}$$



J. Jia / Nuclear Physics A 967 (2017) 51–58

Similar result for small system at RHIC energies.

W. Zhao, S. Ryu, C. Shen, and B. Schenke, Phys. Rev. C 107 014904 (2023)

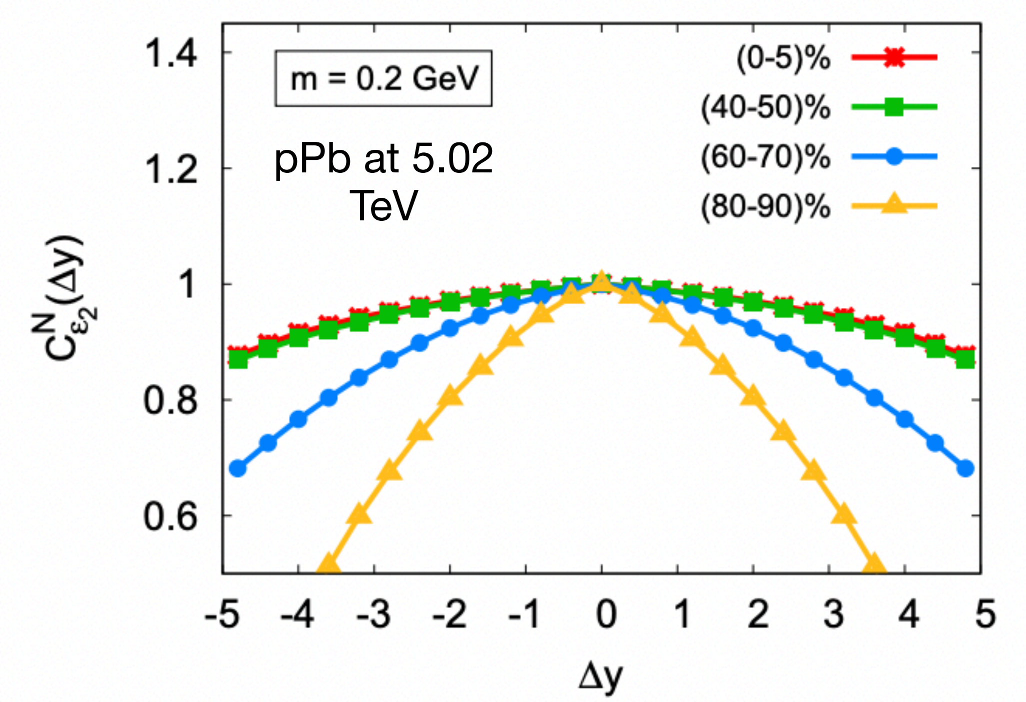
Can we compare these results with Pythia and EPOS?

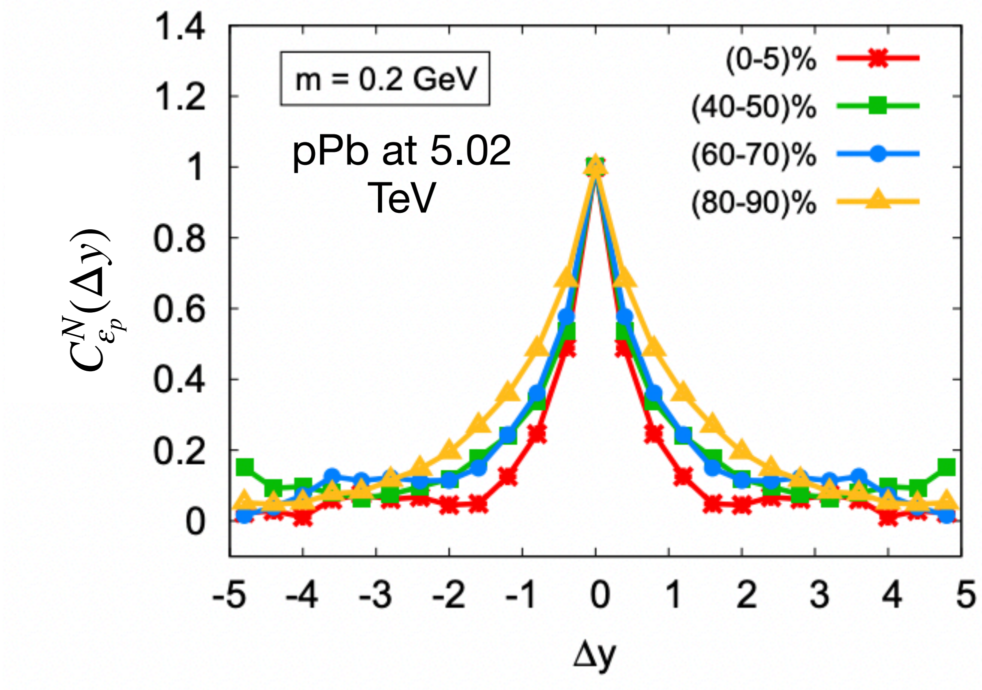
What is the underlying physics?
—> Fluctuations, ….

CGC and short range correlations

Initial state anisotropy decorrelates more quickly (faster for high multiplicity) relative to geometry (faster for low multiplicity)

B Schenke, S Schlichting, PS Phys.Rev.D 105 (2022) 9, 094023





$$\varepsilon_n(y) = \frac{\int d^2\mathbf{r}_\perp T^{\tau\tau}(y,\mathbf{r}_\perp)\ |\mathbf{r}_\perp|^n e^{in\phi_{\mathbf{r}_\perp}}}{\int d^2\mathbf{r}_\perp T^{\tau\tau}(y,\mathbf{r}_\perp)\ |\mathbf{r}_\perp|^n},$$

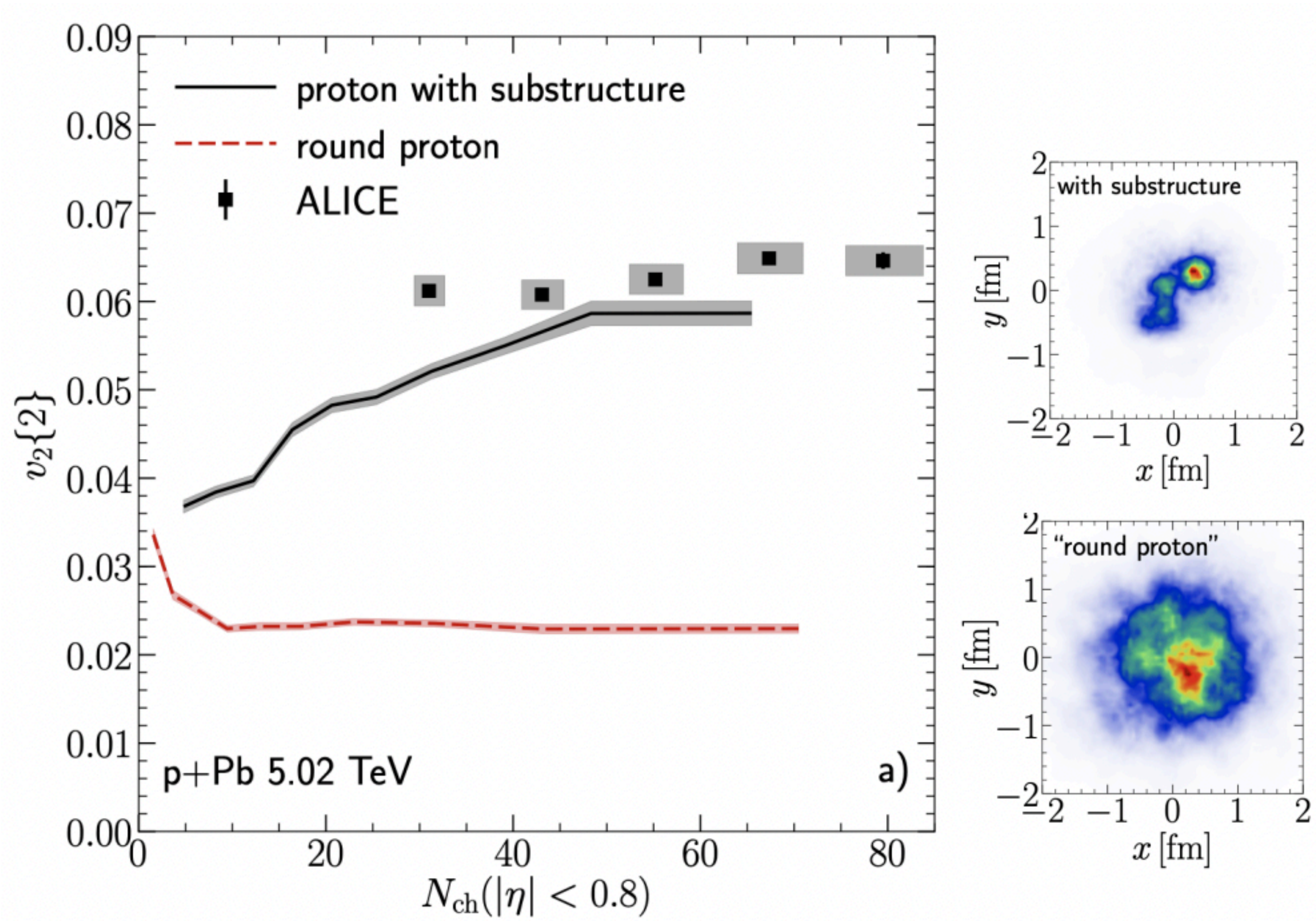
$$\varepsilon_p(y) = \frac{\int d^2\mathbf{r}_\perp\ T^{xx}(y,\mathbf{r}_\perp) - T^{yy}(y,\mathbf{r}_\perp) + 2iT^{xy}(y,\mathbf{r}_\perp)}{\int d^2\mathbf{r}_\perp\ T^{xx}(y,\mathbf{r}_\perp) + T^{yy}(y,\mathbf{r}_\perp)}$$

Can we come up with an observable for studying short range correlations?

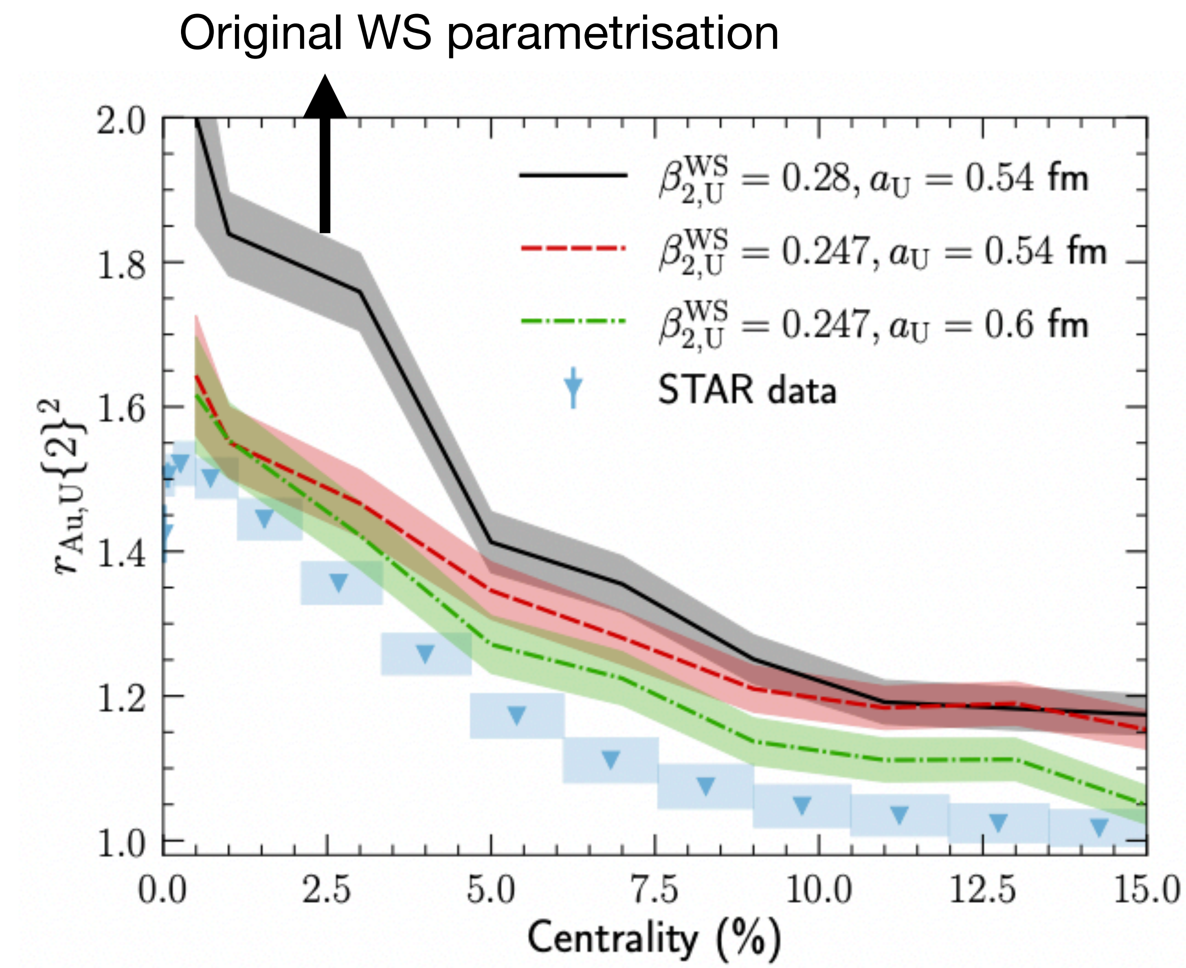
Can Pythia get these short range correlations? (And be our saviour 🤐?)

CGC, nuclear and nucleon structure

$$r_{\mathrm{Au,U}}\{2\}^2 \equiv \frac{\langle v_2^2 \rangle_{\mathrm{U+U}}}{\langle v_2^2 \rangle_{\mathrm{Au+Au}}}$$



B. Schenke, Rept. Prog. Phys. 84, 082301 (2021)



W Ryssens, G Giacalone, B Schenke, C Shen
Phys. Rev. Lett. 130, 212302 (2023)

WS parametrisation need not help

How do we deal with these things using Pythia/EPOS?

—> Are they already implemented?

Pythia with CGC(?)

What would a CGC person want: **Gluon multiplicity —> Hadron multiplicity (?)**

PROCESS AVAILABLE* :

1. Most used: IP Glasma (or 3+1D Glasma) + MUSIC + UrQMD
   3+1D IP Glasma is based on high energy factorisation. Rapidity dependence from JIMWLK. Stitched together patches of different rapidity. **Do we know its limitation?**

2. DIPSY (learned from this workshop) —> Color swing equivalent to saturation (?)
   Can I use two DIPSY sheets and solve the CYM equation?

3. As pointed by Yasushi (yesterday):

   (A.) k_T factorisation (DHJ + Lund String for p+p/A 😁 and MCKLN for AA ⛔)

   (B.) Yang-Mills + particle (Bjoern et al, NOTE: No Cherenkov instability in Phys. Rev. D 103, 014003 (2021))

Can we ask for:

Use CGC type (MV model or something more refined) as initial condition in Pythia OR get initial condition from Pythia (something along the line of Wigner distribution)

* only talking about the one that we discussed.

BACKUP: Pythia with CGC(?)

Can we ask for:

Use CGC type (MV model or something more refined) as initial condition in Pythia

$$\left\langle \rho^a_{A/B}(x^\pm, \mathbf{x}_\perp)\rho^b_{A/B}(x'^\pm, \mathbf{x}'_\perp)\right\rangle = \underbrace{g^2\mu^2_{A/B}}_{\text{strength of color charges } Q_s \propto g^2\mu} \quad \delta^{ab} \quad \underbrace{T_R\left(\frac{x^\pm + x'^\pm}{2}\right)}_{\text{longitudinal profile Gaussian of width } R} \quad \underbrace{U_\xi(x^\pm - x'^\pm)}_{\text{long. correlations Gaussian of width } \xi} \quad \underbrace{\delta^{(2)}(\mathbf{x}_\perp - \mathbf{x}'_\perp)}_{\text{transverse correlations}}$$

longitudinal structure

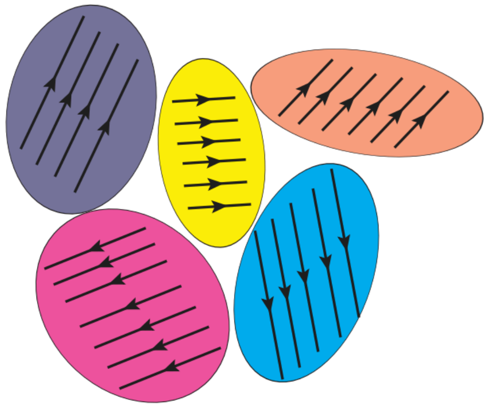
Is there a way to set the transverse and longitudinal structure using Wigner distribution (Ambitious?)

$$r_{n|n;k}(\eta) = \frac{\left\langle [v_n(-\eta)v_n(\eta_{\text{ref}})]^k \cos kn(\Phi_n(-\eta) - \Phi_n(\eta_{\text{ref}}))\right\rangle}{\left\langle [v_n(\eta)v_n(\eta_{\text{ref}})]^k \cos kn(\Phi_n(\eta) - \Phi_n(\eta_{\text{ref}}))\right\rangle},$$

Different mechanisms have been proposed:

1. Initial state correlations

2. Response to initial geometry



AND / OR

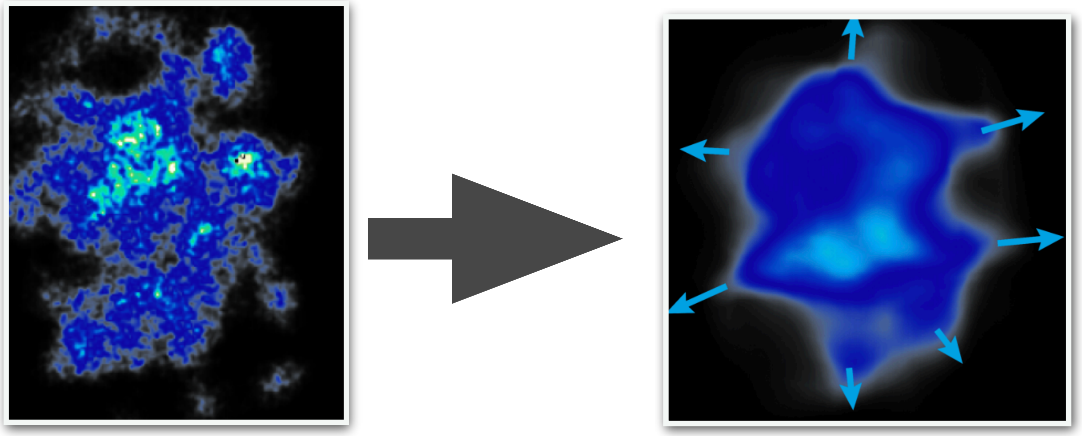


Figure: T Lappi, B Schenke, S Schlichting, R Venugopalan JHEP 1601 (2016) 061
A Dumitru, A Giannini, Nucl. Phys. A933(2014) 212
A Dumitru, V Skokov, Phys Rev. D91 (2015) 074006
A Dumitru, L McLerran, V Skokov, Phys Lett B743 (2015), …

Figure: B Schenke talk SQM 2016
P Bozek, W Broniowski PRC 88 (2013) 014903
J Nagle, R Belmont, S H Lim, B Seidlitz, 2107.07287, …

Other possible explanations:

C Andres, A Moscoso, C Pajares, Phys.Rev.C 90 (2014) 5, 054902, E Shuryak, I Zahed, Phys.Rev.D 89 (2014) 9, 094001, J Bjorken, S Brodsky, A Goldhaber, Phys.Lett.B 726 (2013) 344-346, …