Longitudinal Fluctuations in Heavy-Ion Collisions

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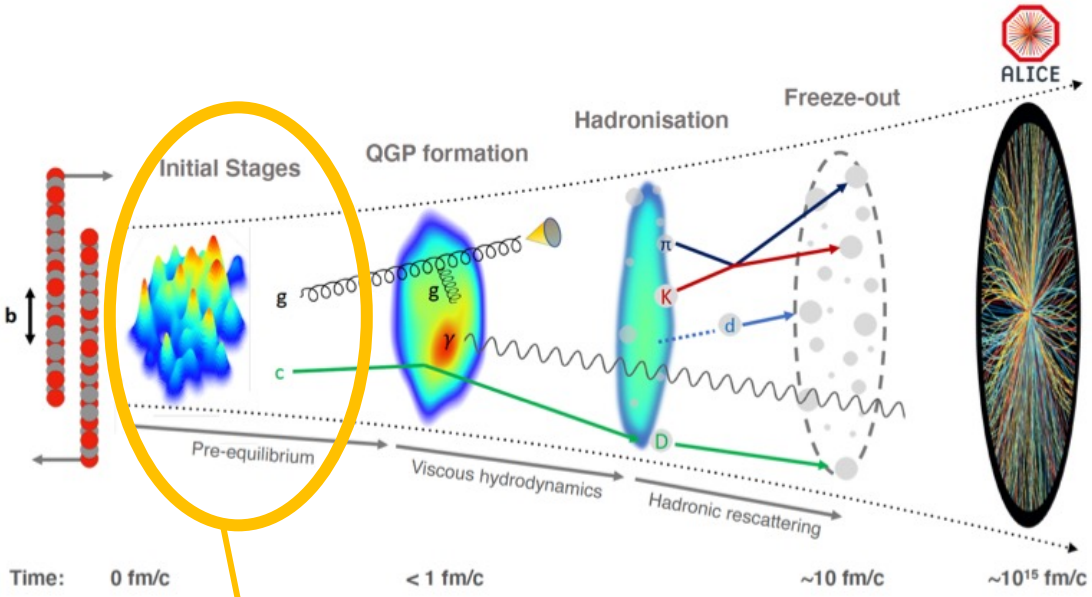
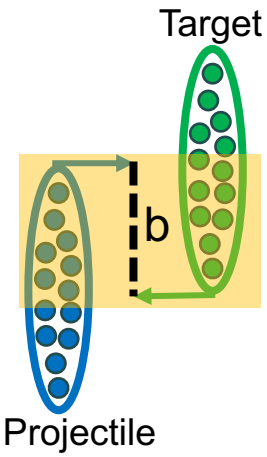
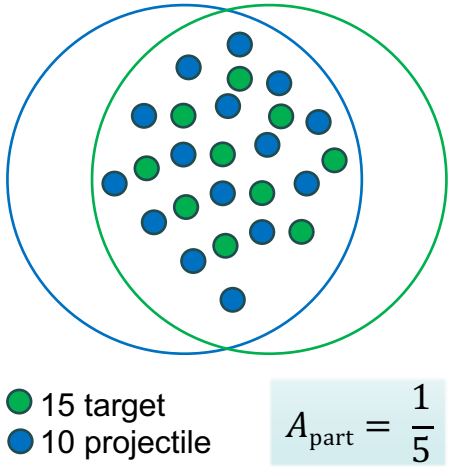
Initial State of Heavy-Ion Collisions



Soft probes (p_T<3-4 GeV):
- **Anisotropic flow**
- **Longitudinal fluctuations**

- Various theoretical models assume boost invariance
- Density fluctuations influence the early time entropy production well before the onset of the collective flow, and manifest as long-range correlations in η
- Main consequence: asymmetric density of the fireball at different η windows
  - Asymmetry in A-A collisions?





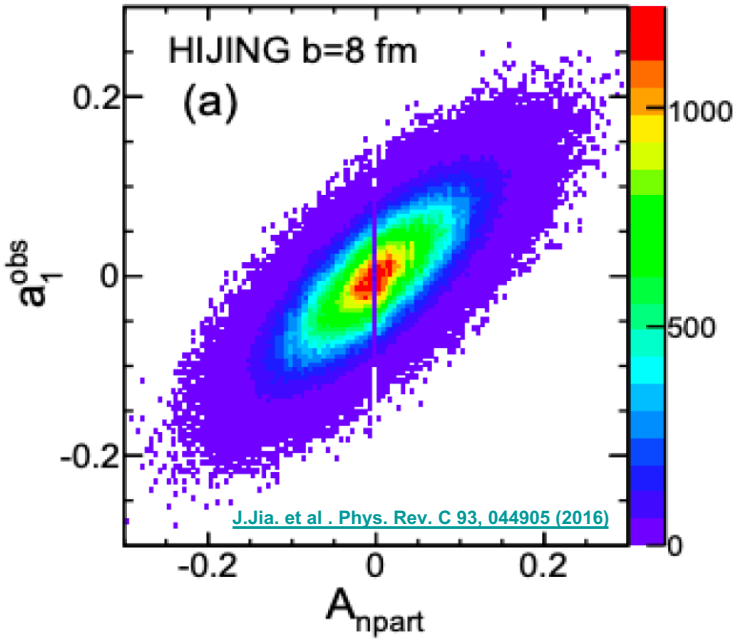
$$A_{\mathrm{part}} = \frac{N_{\mathrm{part}}^{\mathrm{F}} - N_{\mathrm{part}}^{\mathrm{B}}}{N_{\mathrm{part}}^{\mathrm{F}} + N_{\mathrm{part}}^{\mathrm{B}}}$$

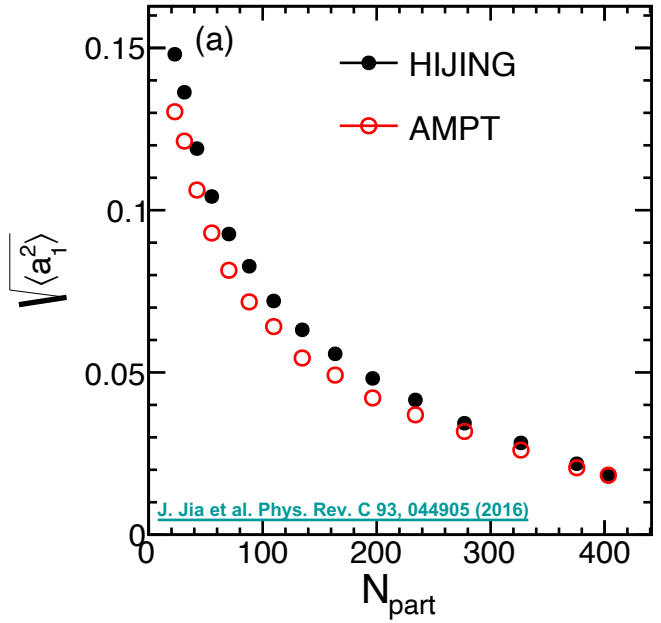
Previous Analyses

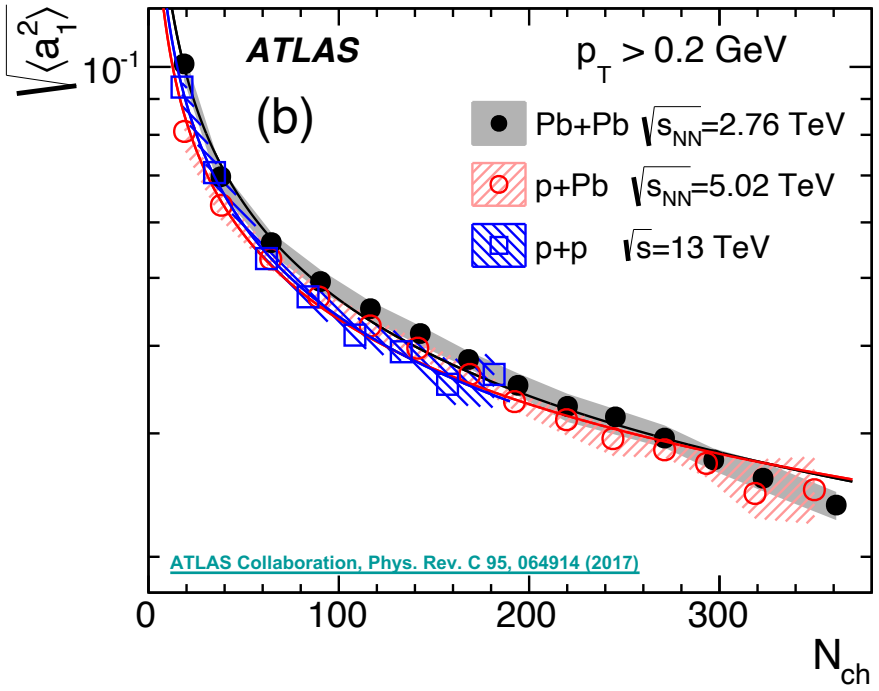
- The η of the final particle distribution is sensitive to EbyE longitudinal fluctuations
- Decompose longitudinal fluctuations with orthogonal polynomials, e.g. Legendre polynomials (A. Bzdak & P. Bozek, Phys. Rev. C 93, 024903 (2016))

$$R(\eta) = \frac{N(\eta)}{\langle N(\eta)\rangle} = 1 + \sum_{n=1}^{\infty} a_n T_n(\eta)$$

- AMPT model includes collective effects, while HIJING does not
  - Longitudinal fluctuations do not depend on whether the QGP is present, hence asymmetry may be related to the initial state
- ATLAS found that $\langle a_1^2 \rangle \sim 1/N_{\mathrm{ch}}$ and is numerically similar for p+p, p+Pb and Pb+Pb collisions with $|\eta| < 2.4$







Single-particle longitudinal decomposition

- For a rapidity range $[-Y, Y]$, a_n can be directly extracted EbyE

$$a_n = \int_{-Y}^{Y} \sqrt{\frac{1}{Y}\left(n+\frac{1}{2}\right)}\,(R(\eta)-1)\,P_n\left(\frac{\eta}{Y}\right)d\eta$$

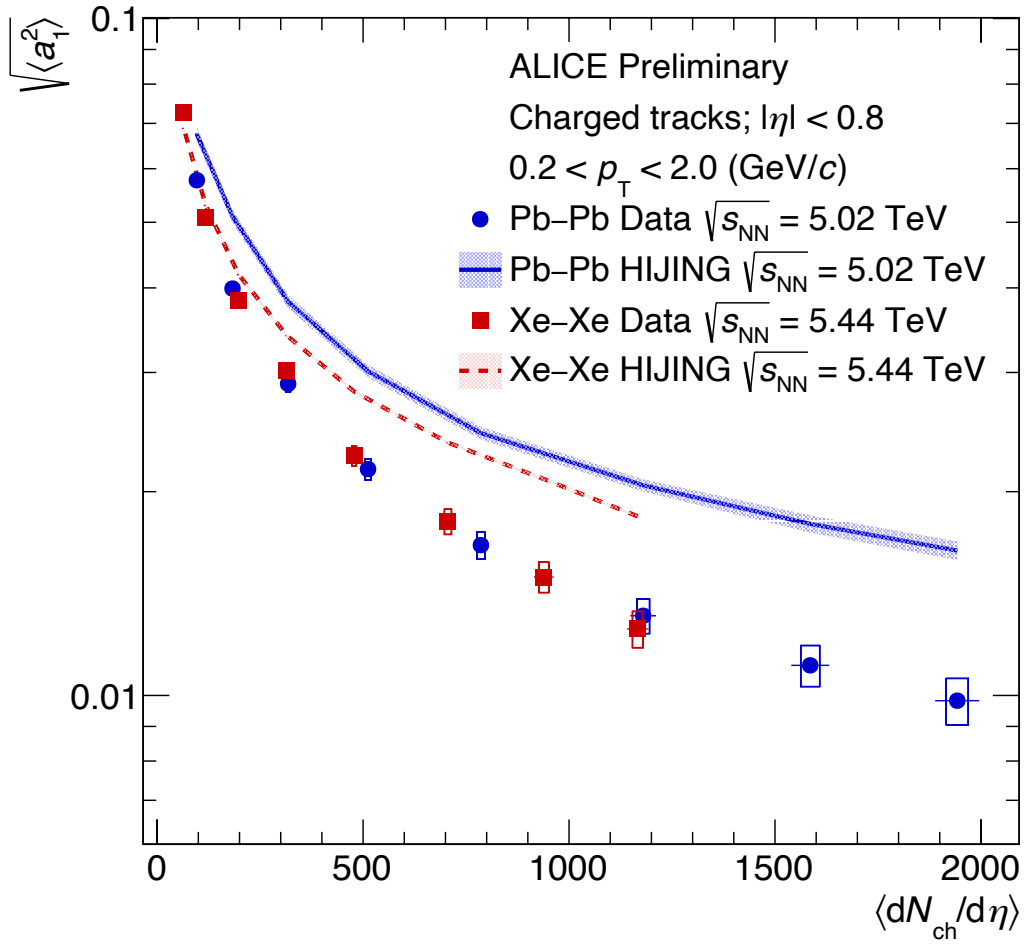
- Statistical noise subtraction carried out with a realistic background generated from the observed η distribution

$$\langle a_n^2 \rangle = \left\langle (a_n^{obs})^2 \right\rangle - \langle (a_n^{ran})^2 \rangle$$

- Model (HIJING) where the nuclear participants generate asymmetries is disfavored
- Universal scaling fitting to $c/N_{\mathrm{ch}}^{\alpha}$

	α
Pb-Pb Data	0.531±0.003
Pb-Pb HIJING	0.456±0.075
Xe-Xe Data	0.532±0.020
Xe-Xe HIJING	0.471±0.016

First look in longitudinal coefficients in ALICE



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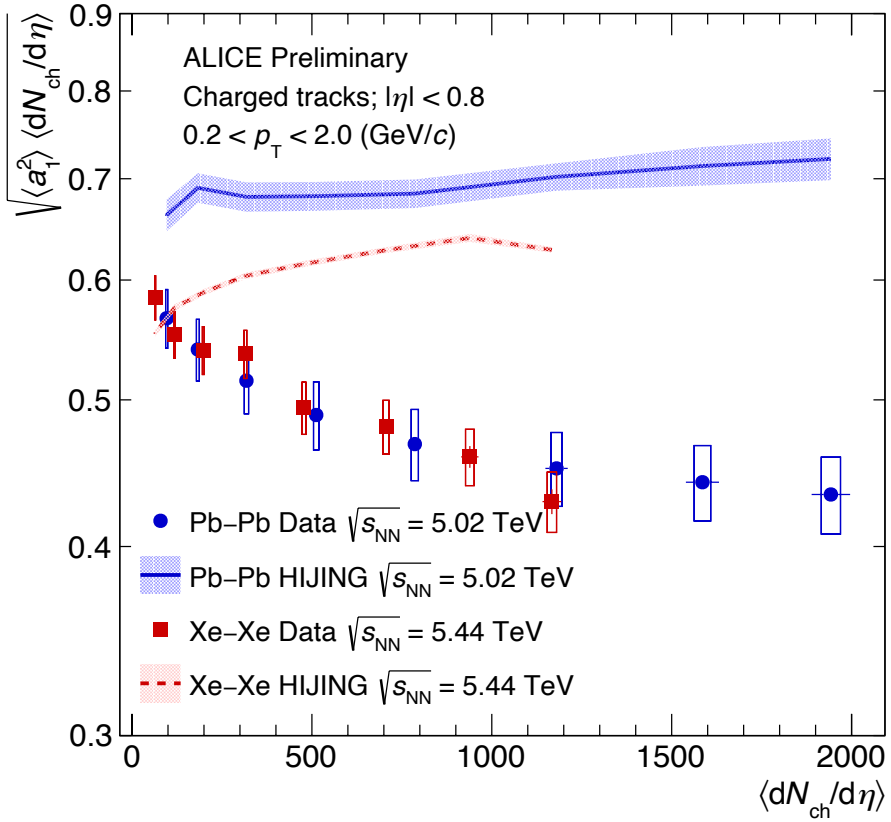
First look in longitudinal coefficients in ALICE

- Scale to $\alpha = 0.5$, the observed data suggests that $N_{\mathrm{ch}}^{\mathrm{rec}}$ grows more slowly compared to the total clusters from the projectile and target



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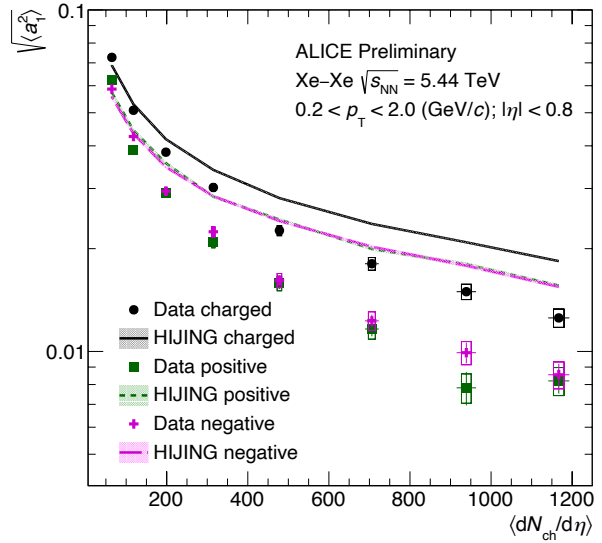
- Charge conservation effects and impact of resonances from like-sign charged tracks



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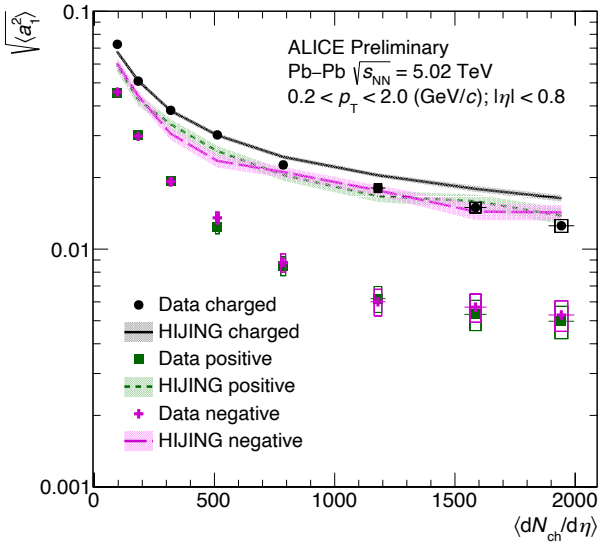

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Summary:

- First measurement of longitudinal coefficient a_1 in ALICE
- a_1 represents the forward-backward asymmetry among the participants
- Results are qualitatively comparable to ATLAS
- Universal multiplicity scaling following $\sqrt{\langle a_1^2 \rangle} \sim 1/N_{\mathrm{ch}}^{\alpha}$; $\alpha \sim 0.5$
- Stronger asymmetry from charged hadrons, compared to positive or negative
  - Higher-order coefficients (a_2, a_3) may be of interest to measure, physics behind is yet to be understood