Correlations & fluctuations

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June 26, 2023

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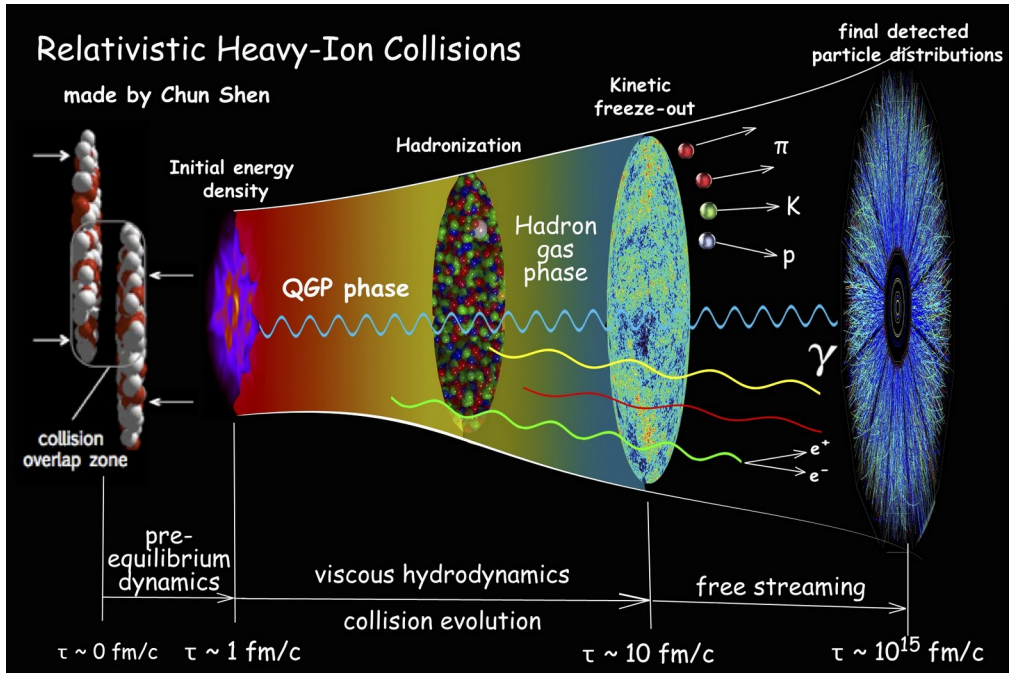
What are known unkowns in hydro models?

Typical hydro model work-flow:

- TRENTo, IP-Glasma, EKRT initial state.
- Free streaming for the pre-hydrodynamic stage or nothing.
- Viscous hydrodynamics with temperature dependent shear and bulk viscosity.
- SMASH or UrQMD as a hadronic afterburner or late hydrodynamic freeze-out



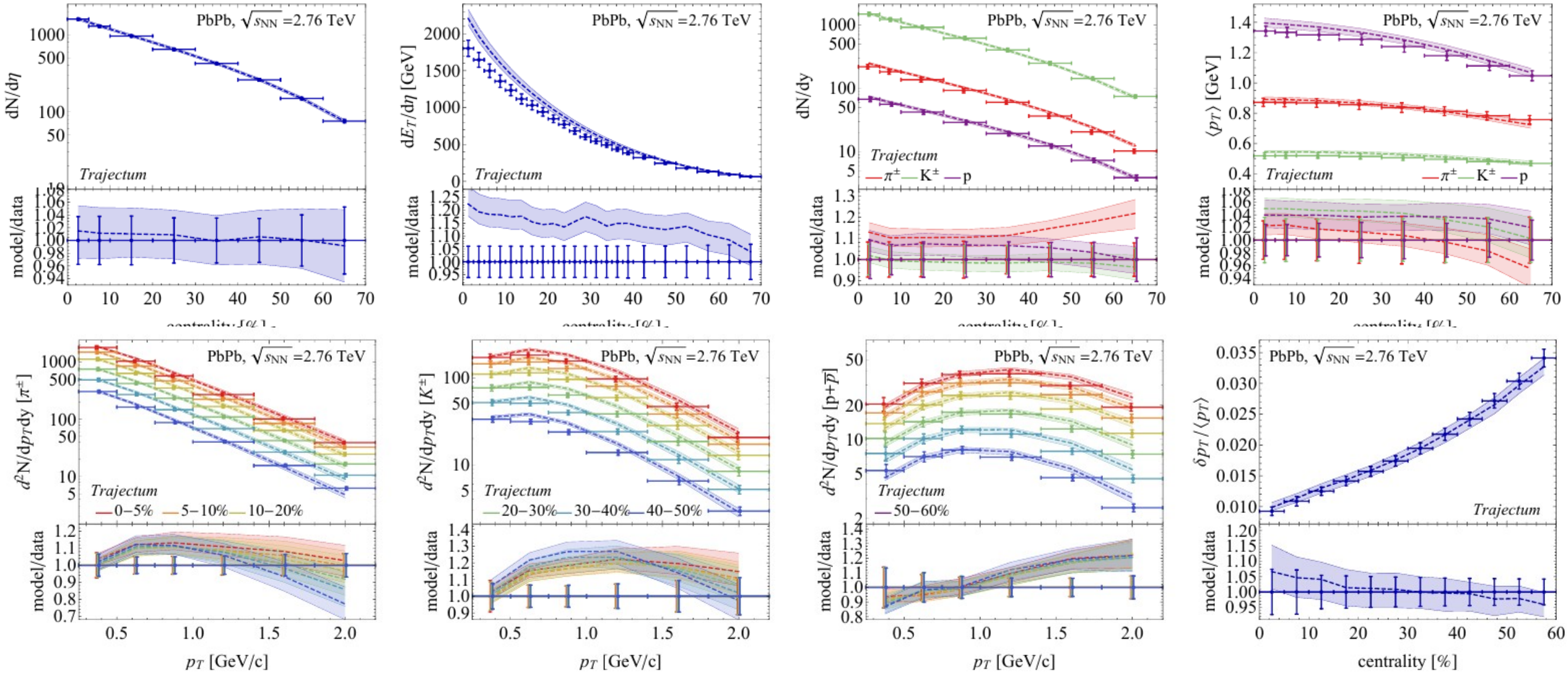
What are known unknowns responsible for model-data mismatch in:

- Transverse energy and mean pT
- pT spectra deviation
- Centrality dependent flow

Examples:

- Problems with freeze-out and particlization? Non-equilibrium corrections?
- Rapidity dependent evolution and initial conditions.
- Nuclear structure and subnucleonic fluctuations?
- Pre-equilibrium evolution and thermalization?
- High-pT (corona) contributions?

How well does hydro work in AA collisions?



Trajectum Nijs, van der Schee, 2206:13522

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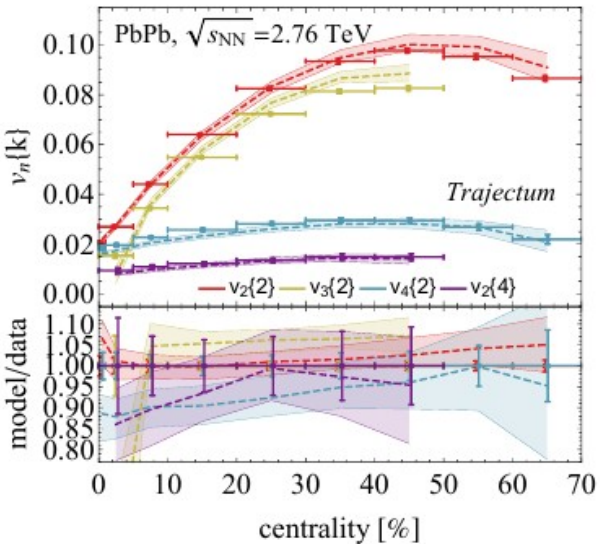

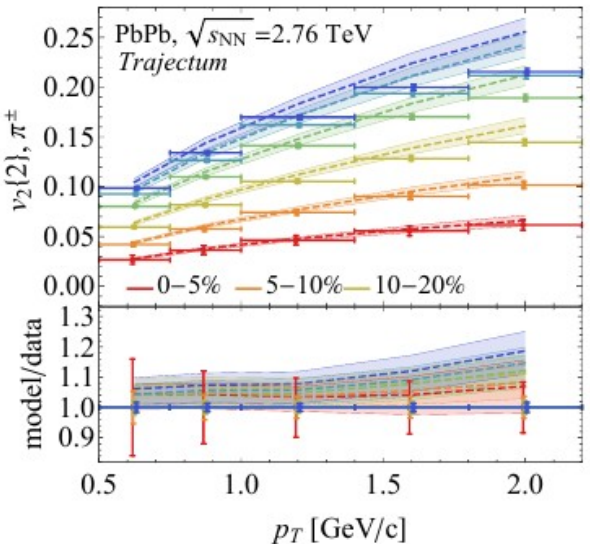

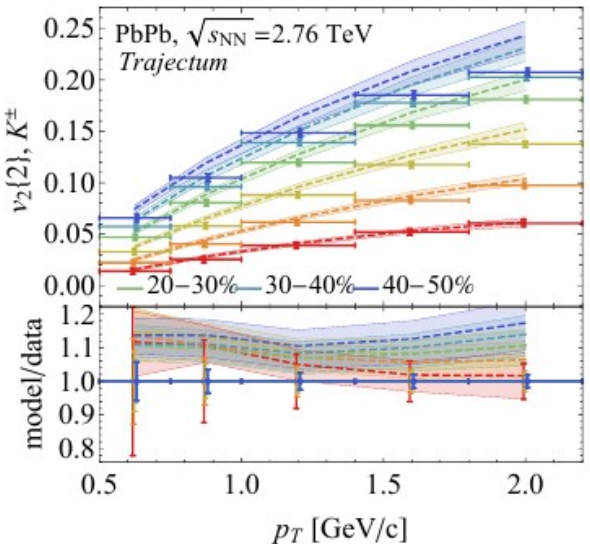

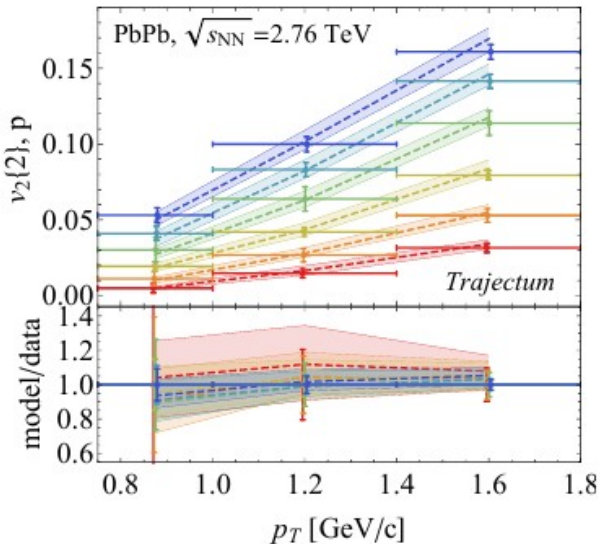

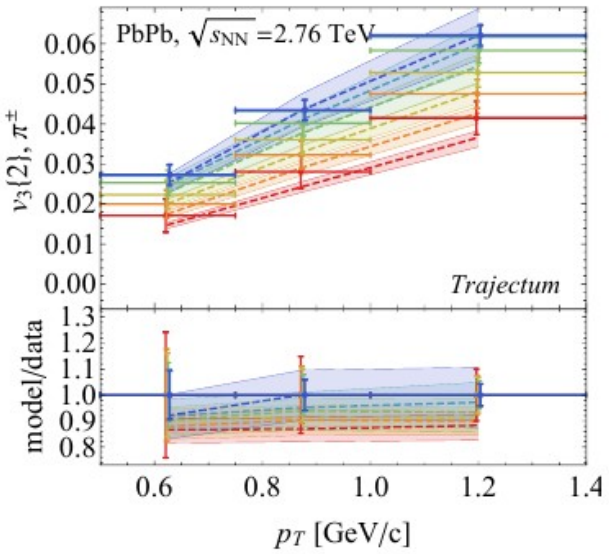

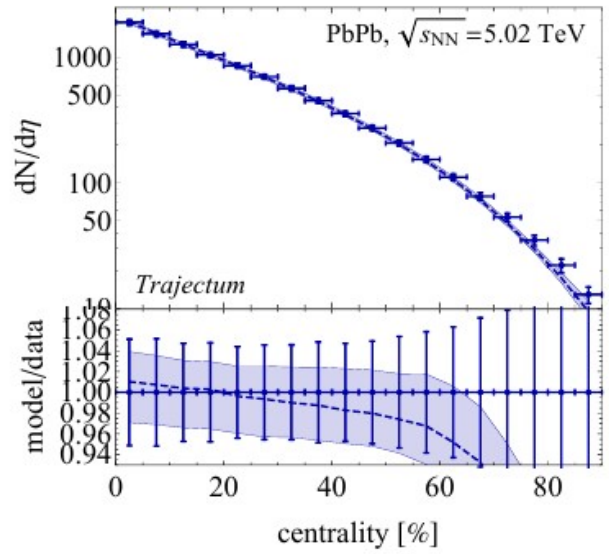

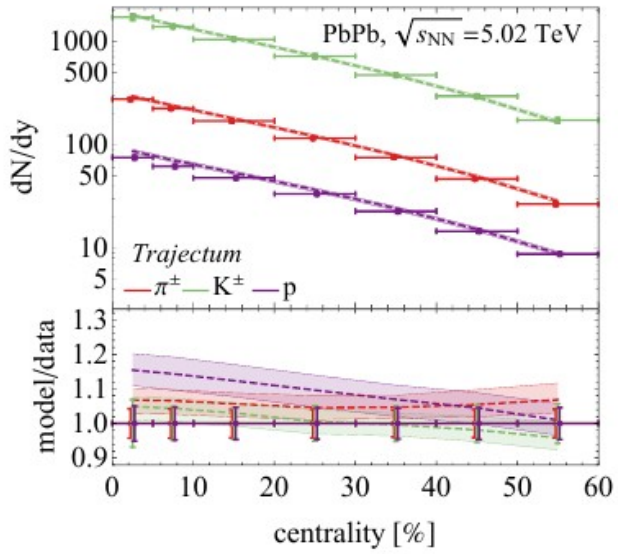

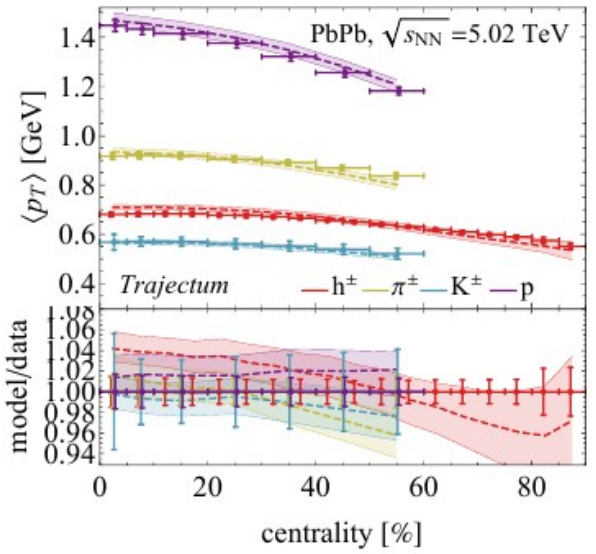

Trajectum Nijs, van der Schee, 2206:13522

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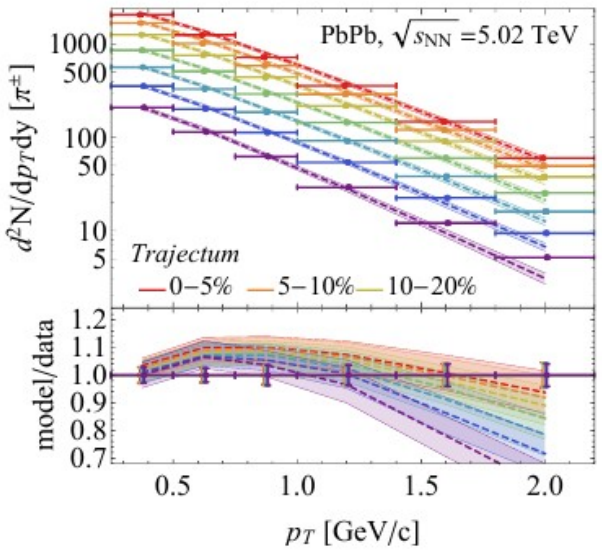

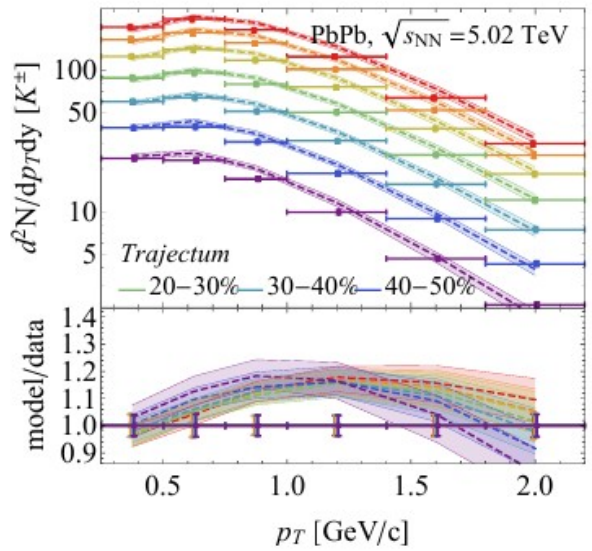

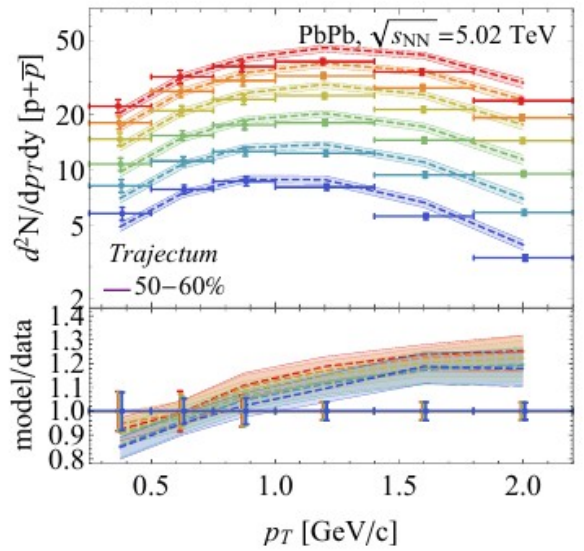

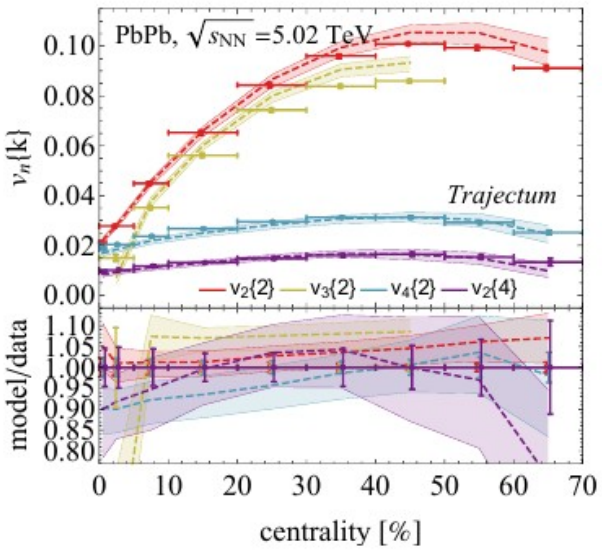

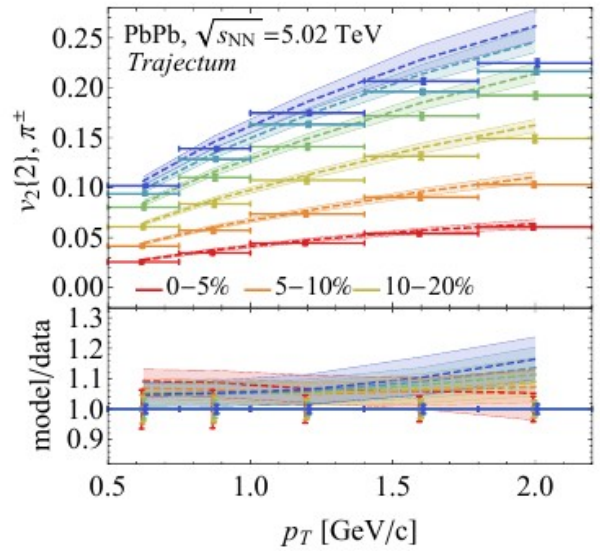

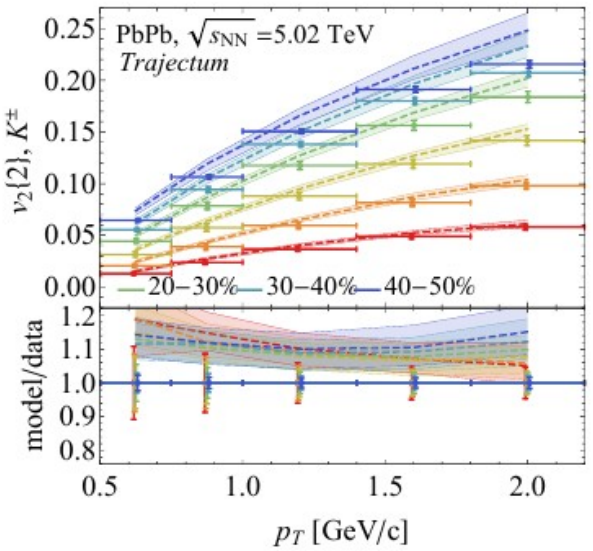

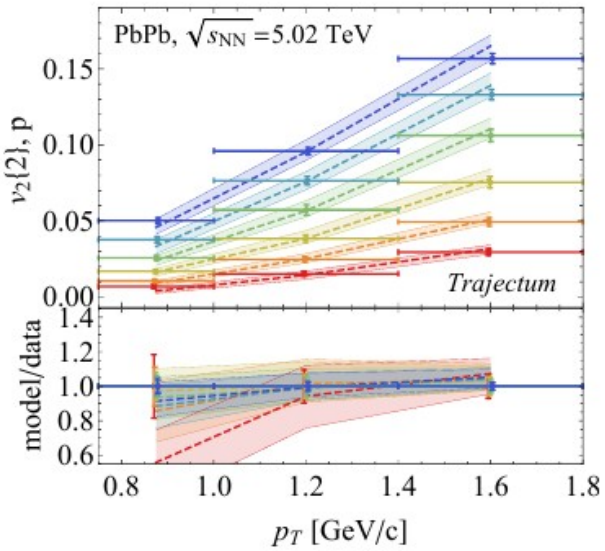

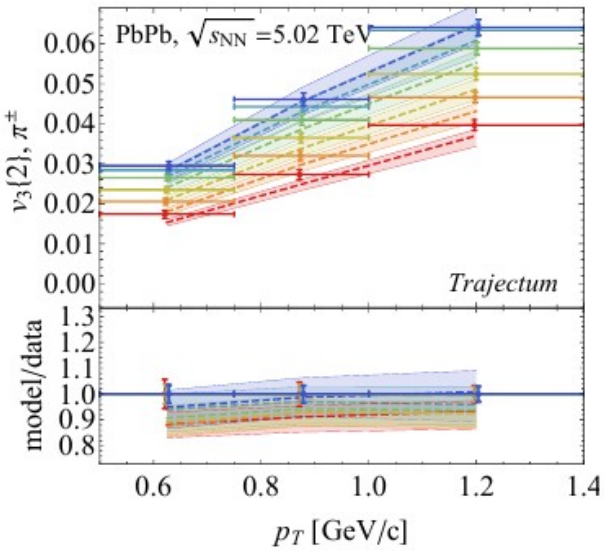

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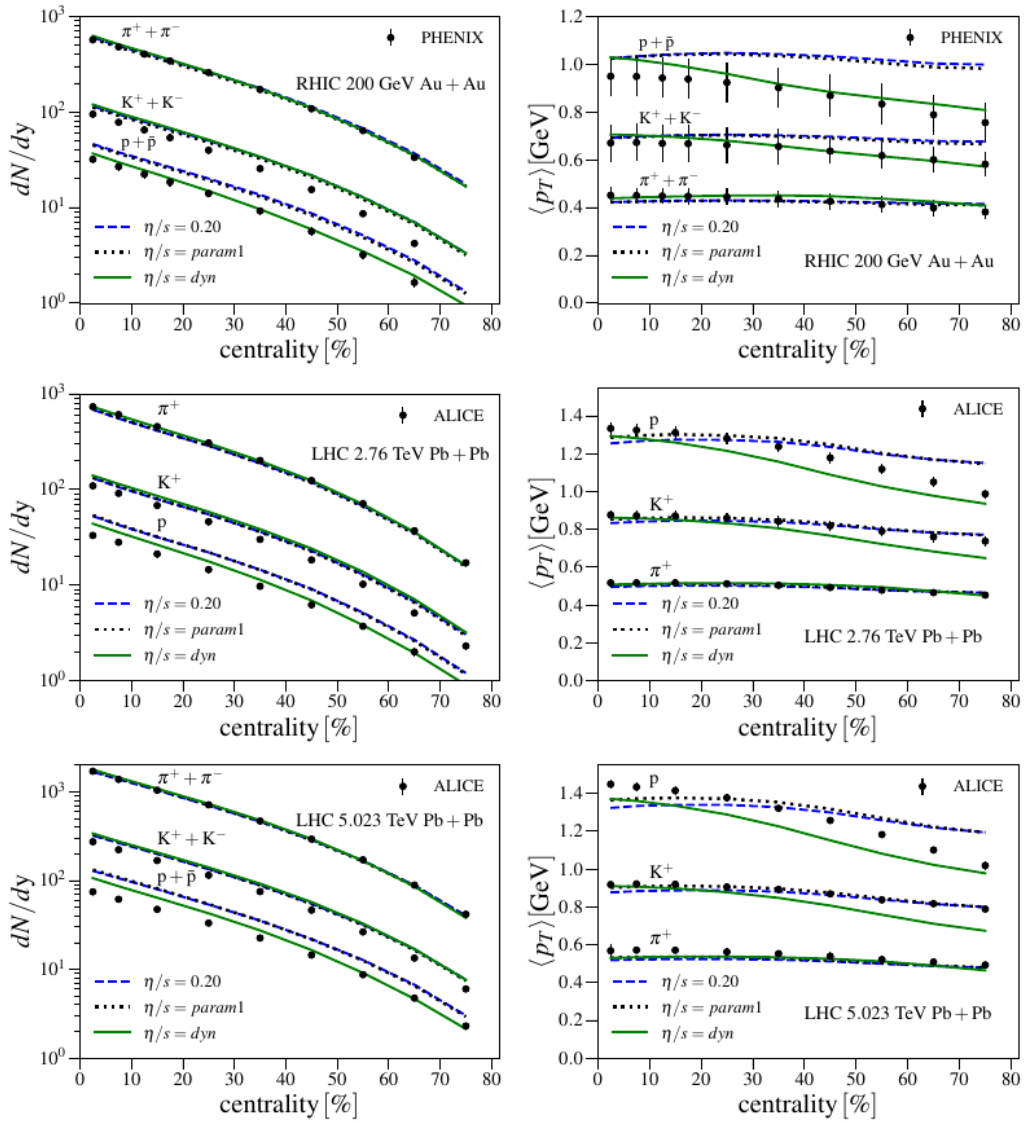

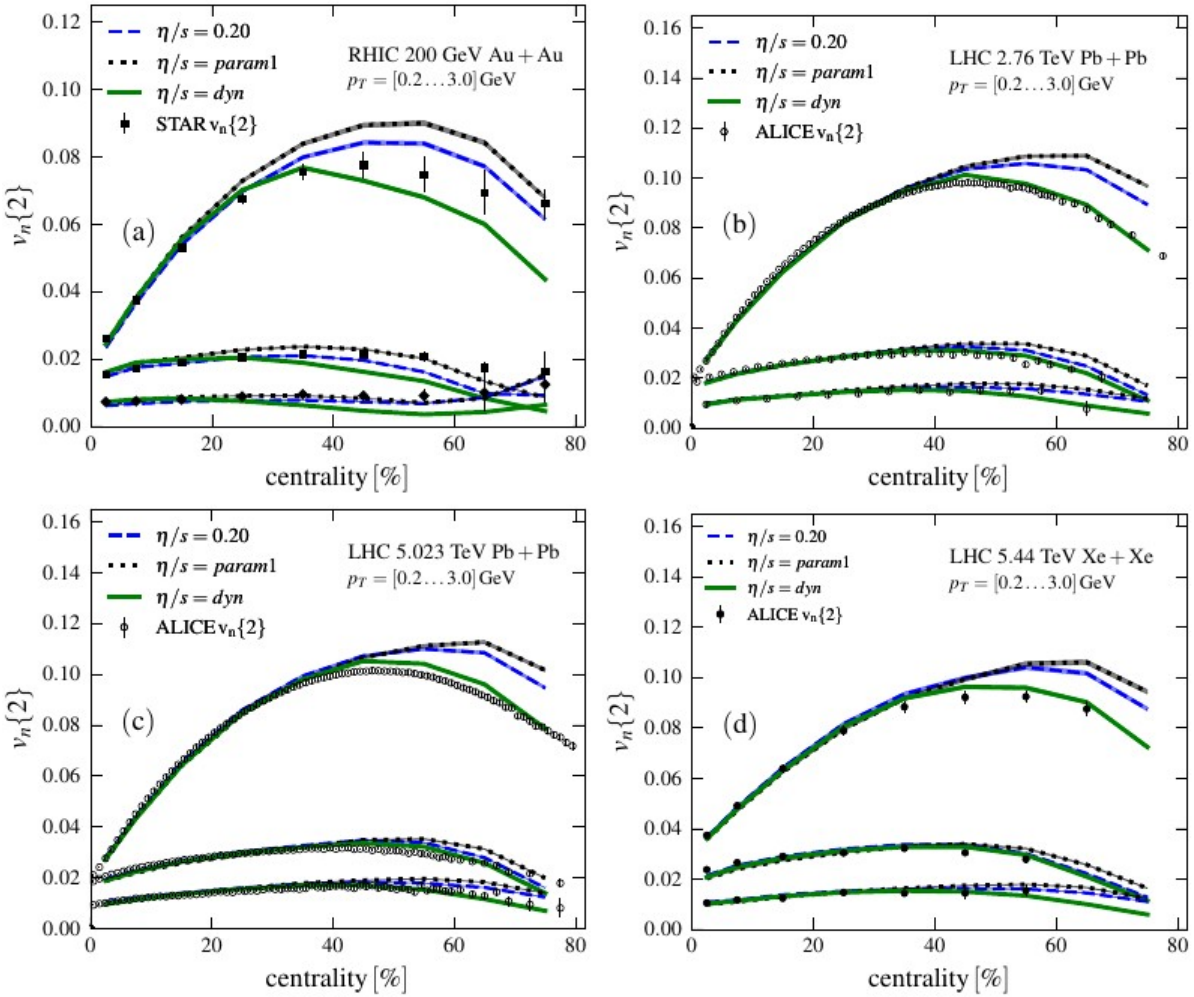

Hirvonen, Eskola, Niemi, 2206:15207

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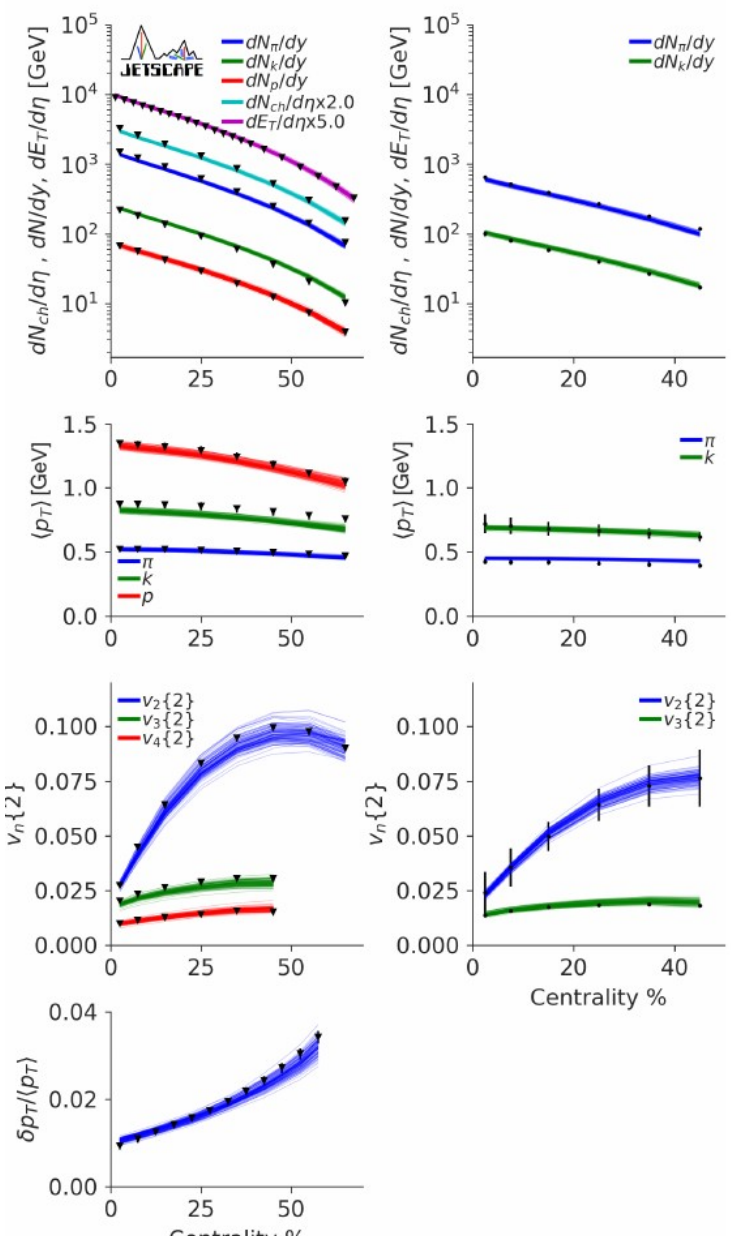

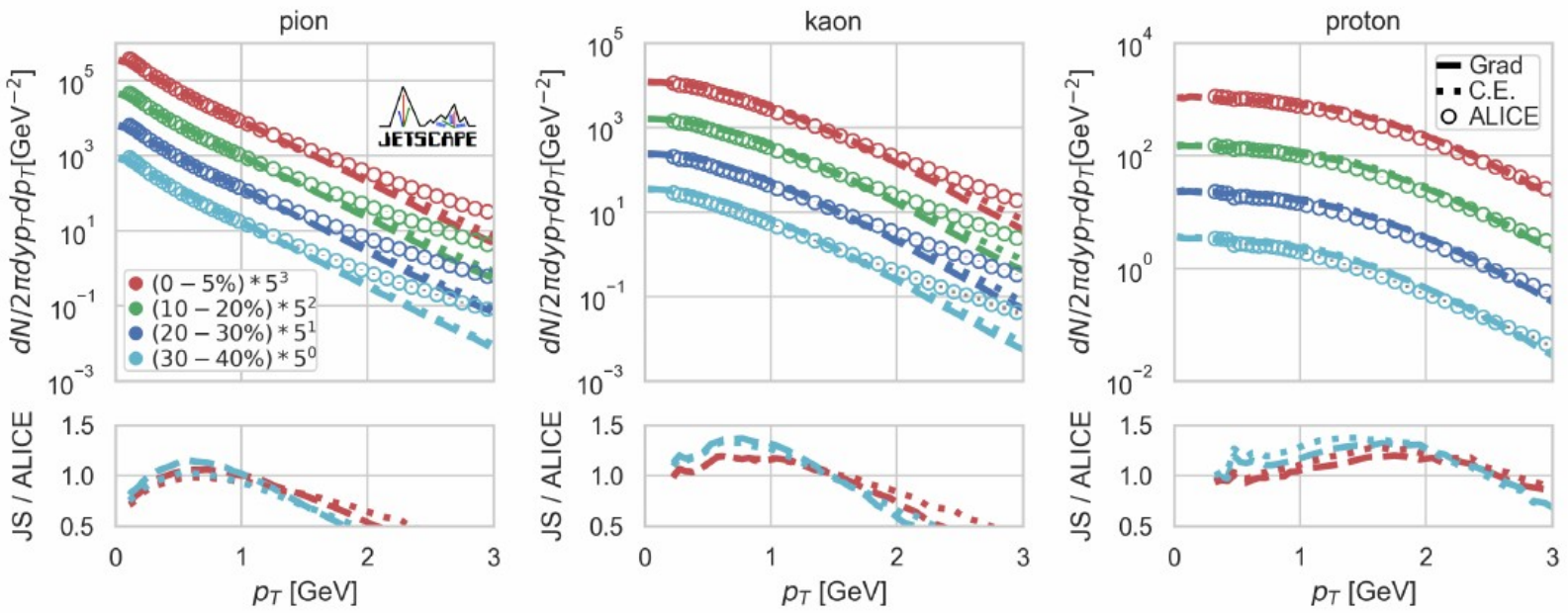

JETSCAPE, 2011.01430

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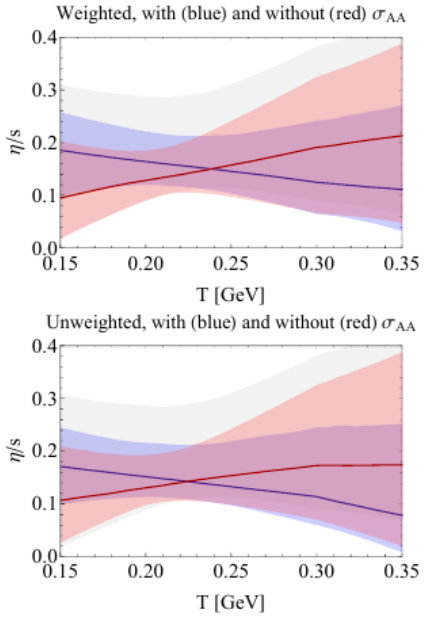
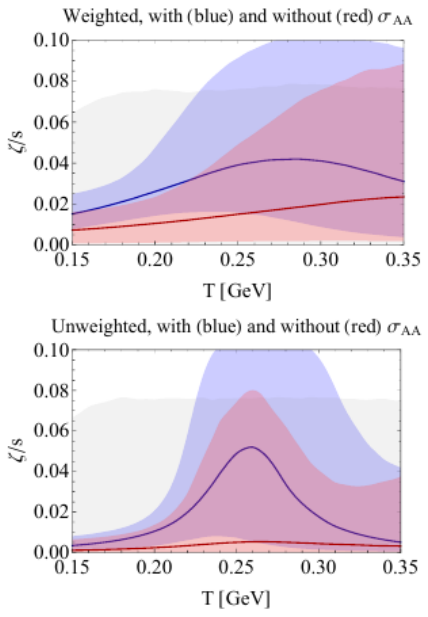
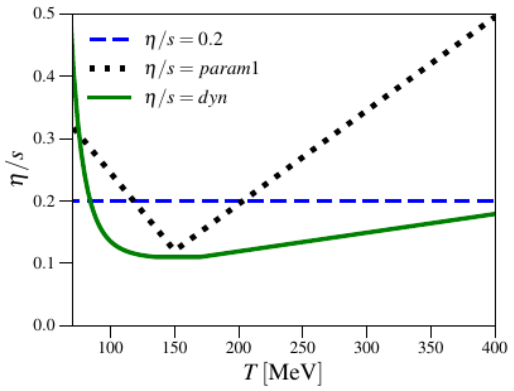
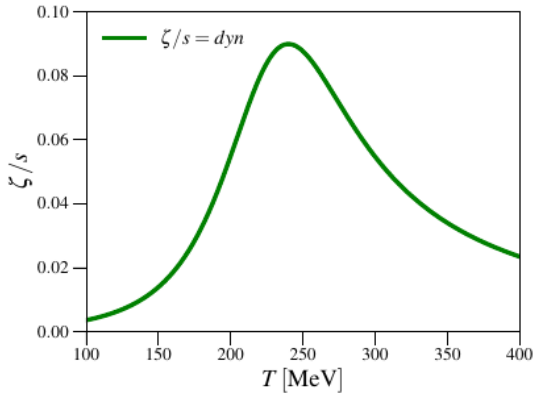
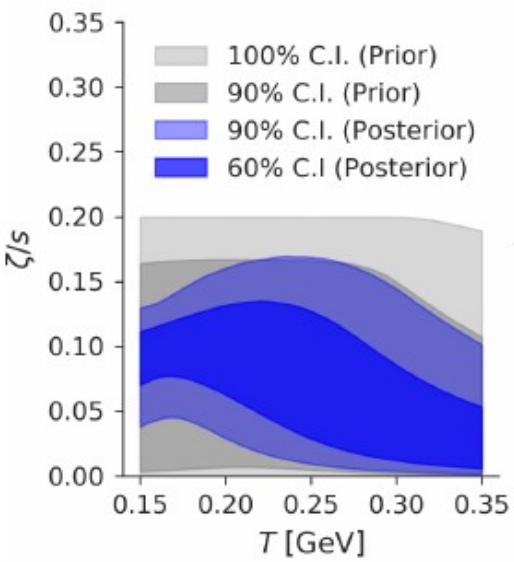
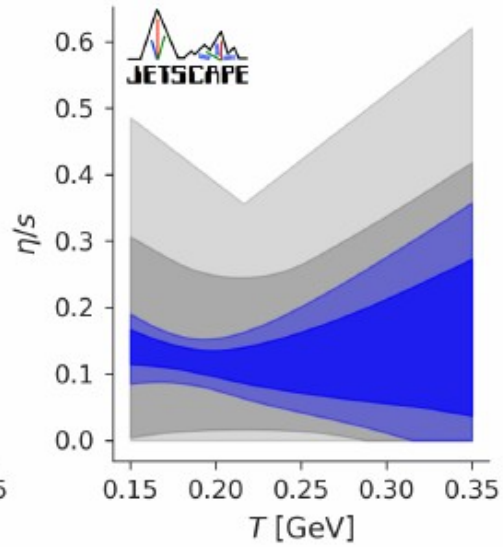








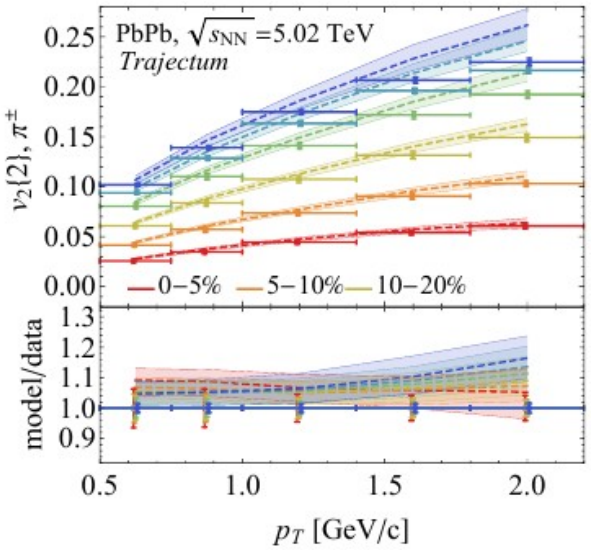


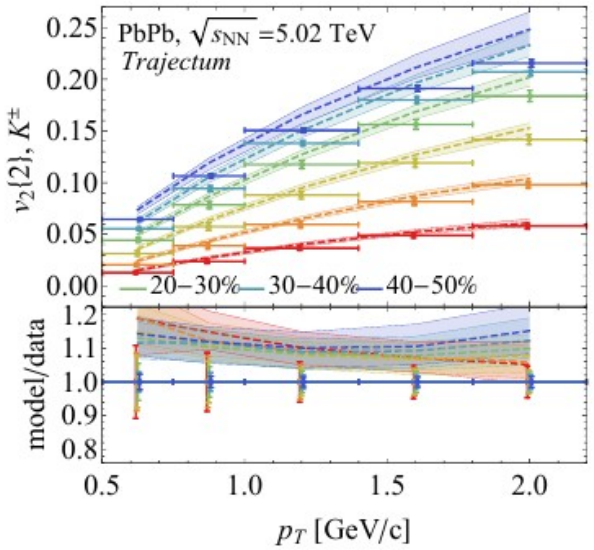


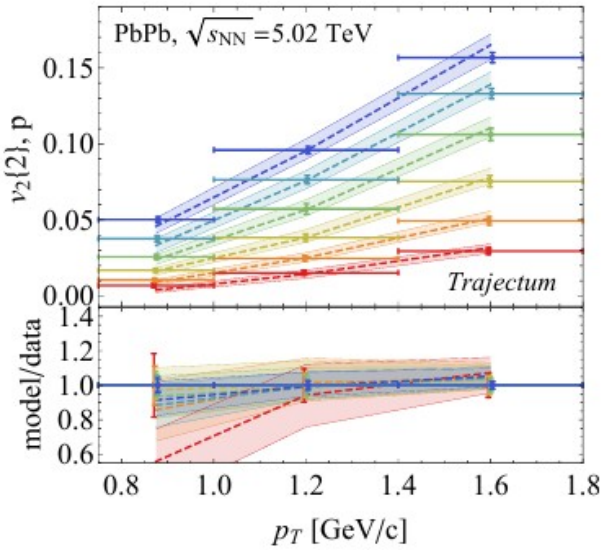
Can we agree on any QCD property with specified uncertainty?
What is missing to provide a „textbook“ knowledge of QCD?

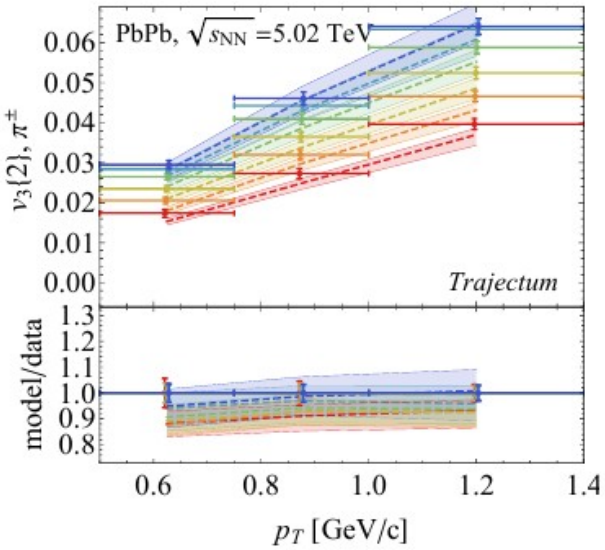
We should study energy, not particle flow!

- There are no pions in QGP!
- Particle number is not conserved at hadronization.
- Identified particle modelling relies on the control of hadronic processes
- Using energy (or other QCD concerved charges) would simplify model-data comparison, e.g. EKT kinetic theory in small systems.









We should study energy, not particle flow!

- **2-point energy-energy correlator of a p-p jet** (as a function of the **angle**):

$$\frac{d\Sigma^{(n)}}{d\theta} = \frac{1}{\sigma}\sum_{i,j}\int dE_{i,j}\,\frac{d\sigma_{ij}}{dE_i dE_j d\theta}\,\frac{E_i^n E_j^n}{Q^{2n}}$$

Hard scale of the process

Inclusive cross section to produce two particles i and j

- **Angular scales** in the 2-point correlator **map into time scales** in the evolution of the jet:

Lee, Meçaj, Moult 2205.03414

Komiske, Moult, Thaler, Zhu 2201.07800

$R_L = \sqrt{\Delta\phi^2 + \Delta\eta^2}$