

A 3D Hydrodynamic Assessment of Centrality Definitions and Initial-State Estimators in Light-Ion Collisions

In preparation

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Heidelberg, September 2026

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Introduction

Light Ions & centrality

- Very successful light ion collision runs at the LHC
- Light ions interesting for a plethora of topics (nuclear structure, jets, limits of fluid dynamics, ...)
- Small systems are not boost invariant

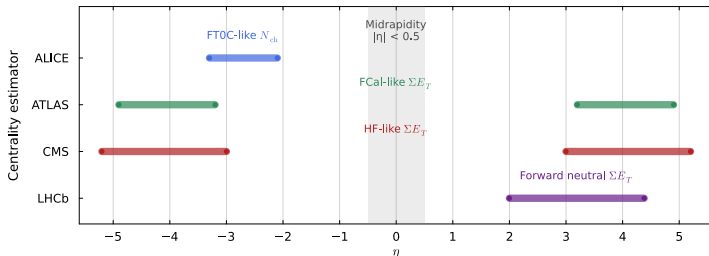
How much do different **centrality selections** change the same (simulated) observables?

Centrality definitions & model setup

Centrality definitions

Detector inspired selections applied to all events

- **ALICE**: FT0C-like N_{ch} for $-3.3 < \eta < -2.1$
- **ATLAS**: FCal-like ΣE_T of PID for $3.2 < |\eta| < 4.9$
- **CMS**: HF-like ΣE_T of PID for $3.0 < |\eta| < 5.2$
- **LHCb**: Forward neutral ΣE_T for $2.0 < \eta < 4.38$



Model setup

Setup used for 3D hydro simulations:

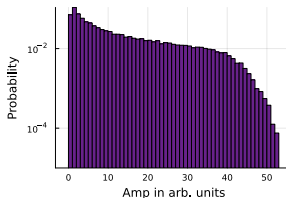
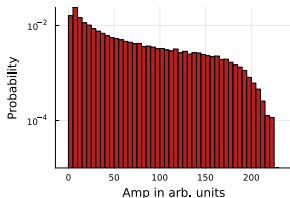
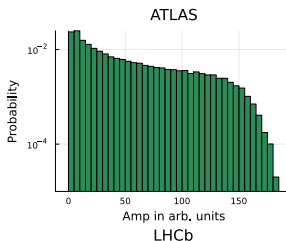
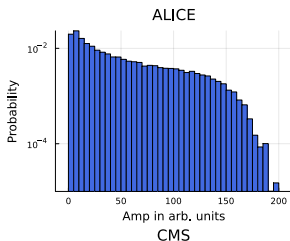
- **Trento3D** initial conditions
- Hydro evolution with **MUSIC**
- **SMASH** afterburner & resonance decays

Analysis based on **40k OO** and **40k NeNe** min. bias events at 5.36 TeV.

Parameters motivated by previous studies (2601.17234, 2306.08665); no dedicated light ion fit.

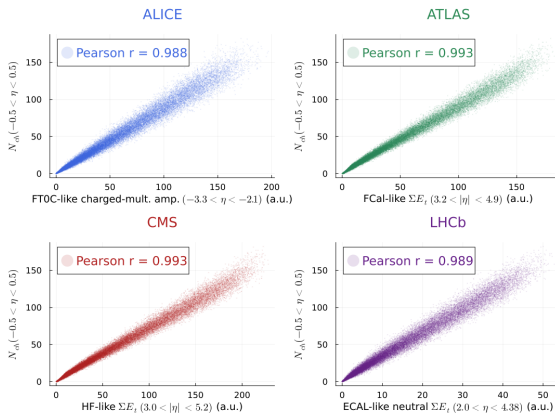
Centrality selectors

Histograms



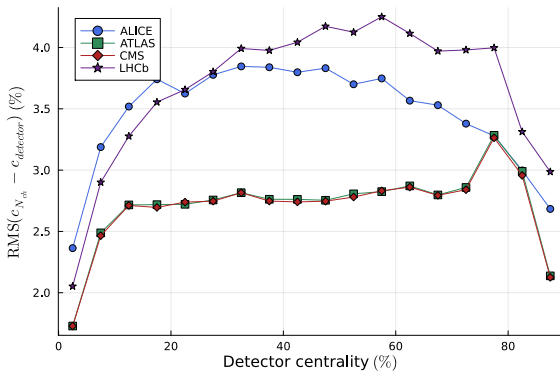
- Detector amplitudes display characteristic **horseback shape**
- Signal does not account for **detector efficiencies**

Correlation to mid rapidity



Centrality amplitudes and N_{ch} **strongly correlated** for all experiments, but different **spreads in correlation**

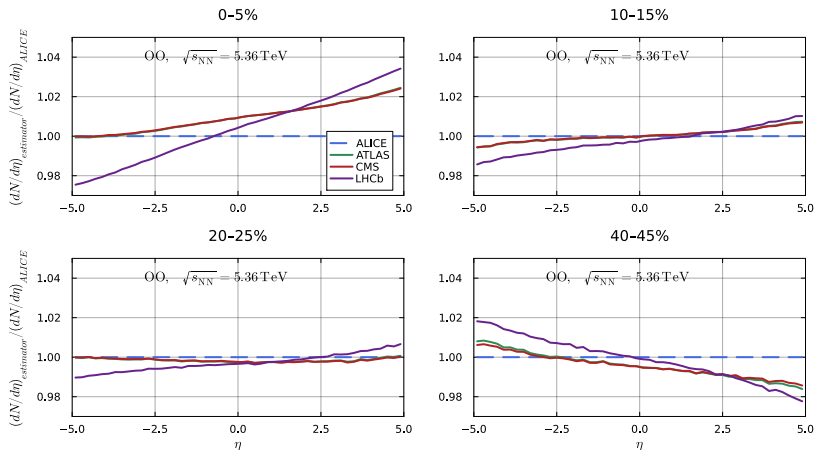
Differences in cent. assignments



Midrapidity and **forward** estimators differ by typically 2–4 centrality percentage points RMS.

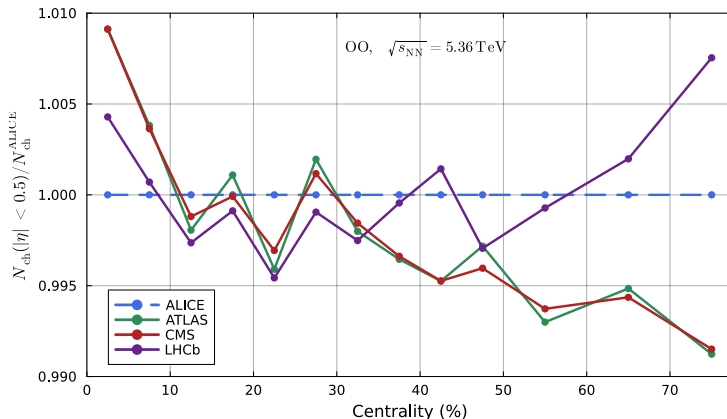
Effects on individual observables

Multiplicities



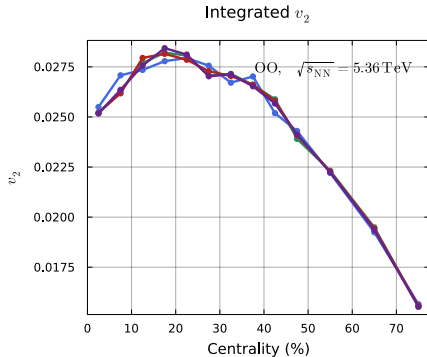
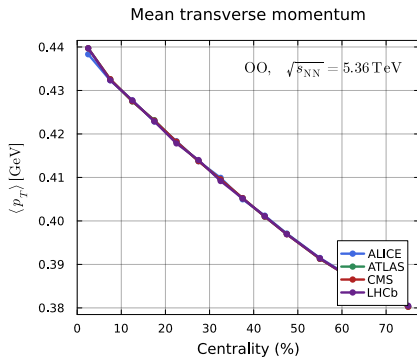
Centrality selection changes the **longitudinal profile** by a **few percent**

Multiplicities at mid-rapidity



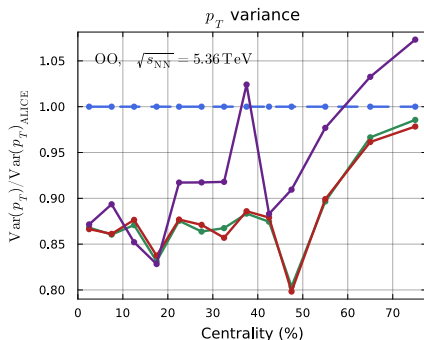
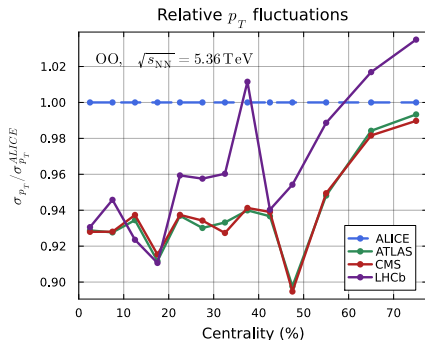
N_{ch} at mid rapidity **minimally affected** by centrality definition

$\langle p_T \rangle$ and v_2



Bulk observables at mid rapidity are robust against centrality selection effects

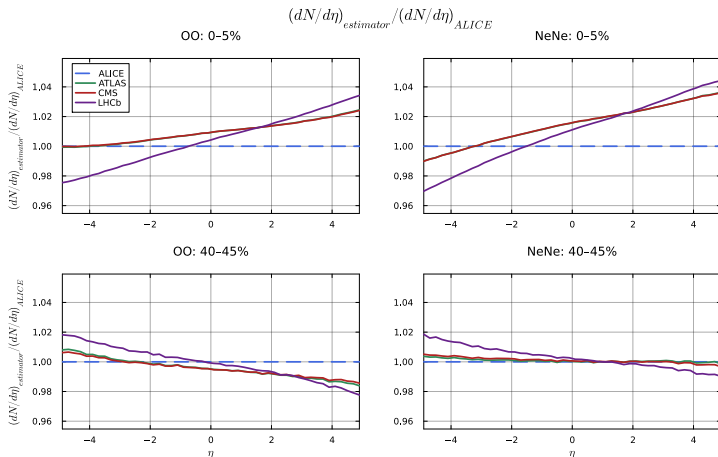
p_T variance and fluctuation



Higher order and fluctuation related observables are **very sensitive** to centrality selection and show differences up to

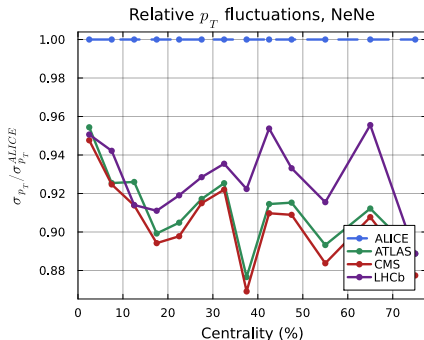
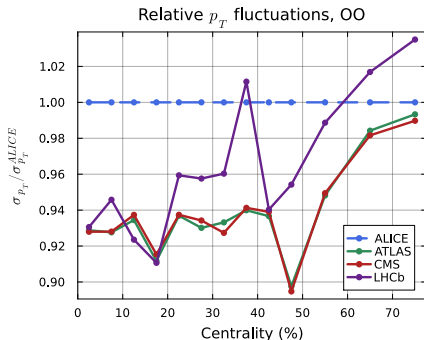
20%

NeNe collisions



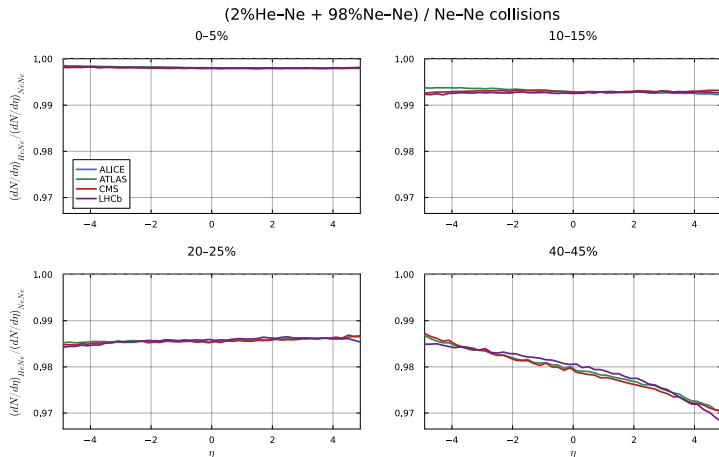
Different centrality estimators find **same trends** for **longitudinal** and **bulk observables** for **OO** and **NeNe**

NeNe collisions



Fluctuation observables depend on the estimator in both O-O and Ne-Ne at the 5 – 20% level.

HeNe collisions



Transmutation affects **peripheral collisions** more strongly,
weak dependence on centrality selector

Conclusion & Outlook

Conclusion

- **Bulk observables** at midrapidity **robust** against different centrality determinations
- **Higher correlation observables** more **sensitive** to centrality determination
- Centrality determination introduces **asymmetric longitudinal bias** based on centrality window
- Centrality definition based on **mid-rapidity** alone can introduce **bias/mislabeling**
- **OO** and **NeNe** display **similar** trends

Outlook

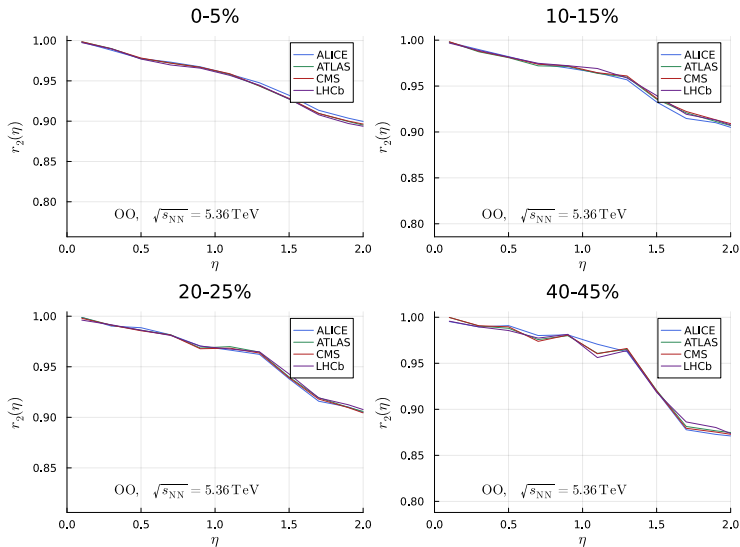
- Detector efficiency, material budget, mapping etc effects not accounted for
→ **Additional effects** on observables possible
- So far analysis only for charged particle observables
→ Include **identified particle observables** into sensitivity study
- More statistics needed for final verdict on some observables

Thank you for your attention!

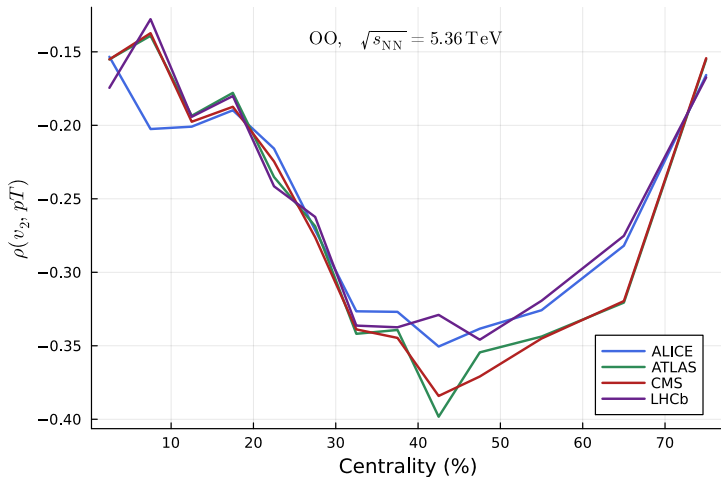
Backup

00 observables

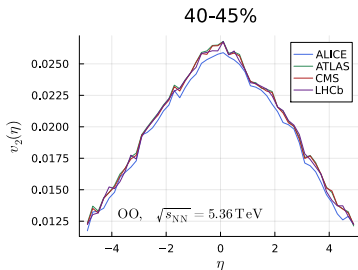
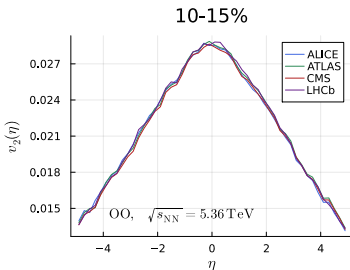
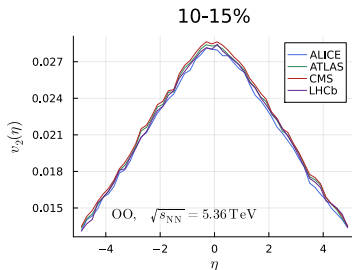
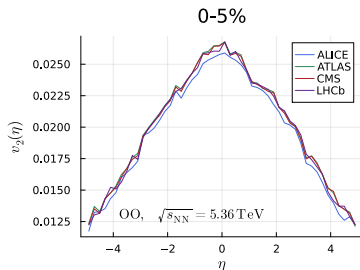
Longitudinal decorrelation



p_T - v_2 correlations

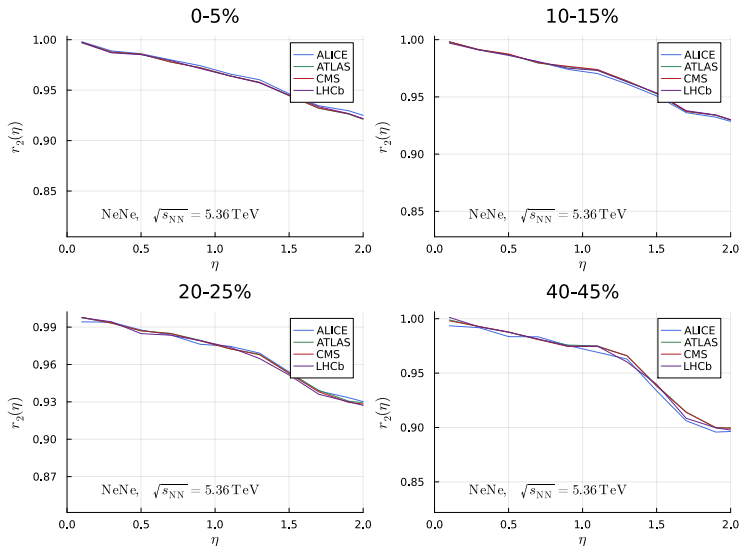


Flow coefficient

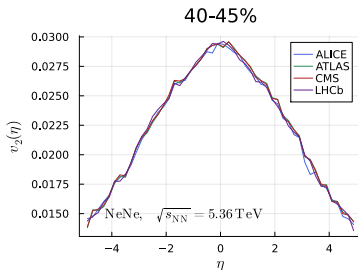
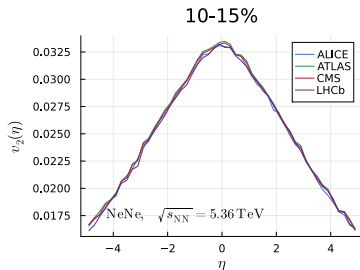
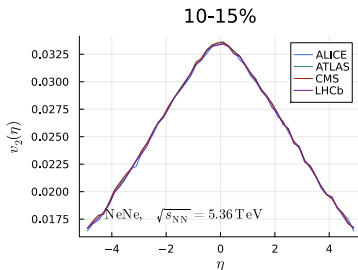
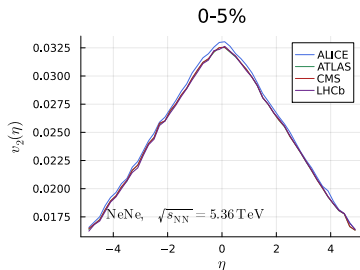


NeNe observables

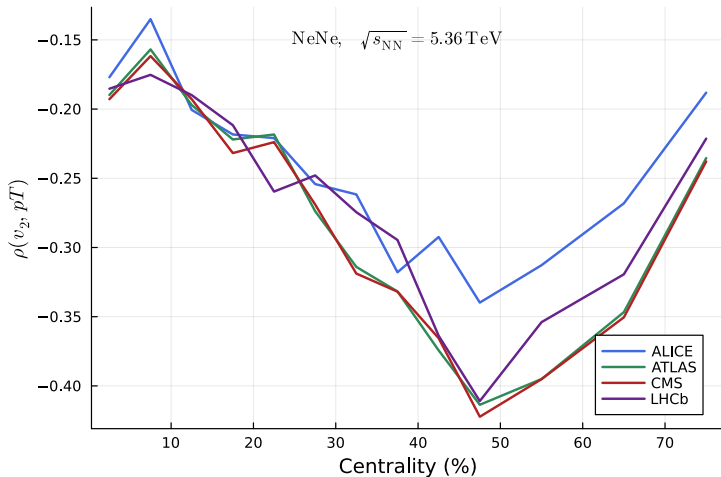
Longitudinal decorrelation



Flow coefficient



p_T - v_2 correlations



Bulk observables

