12th MPI at LHC

WG3: High multiplicities and small systems

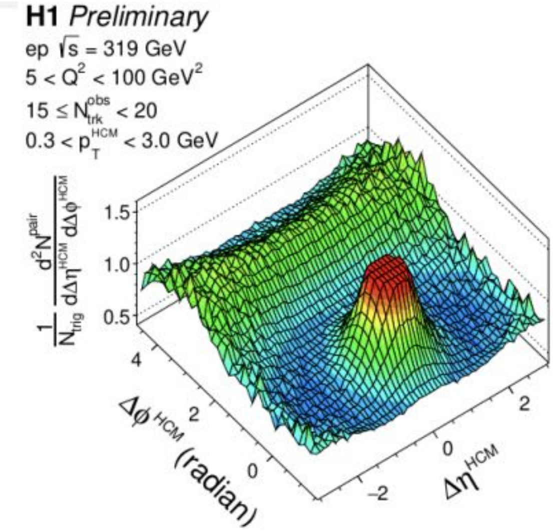
Simone Amoroso (DESY) and Grigorios Chachamis (LIP)

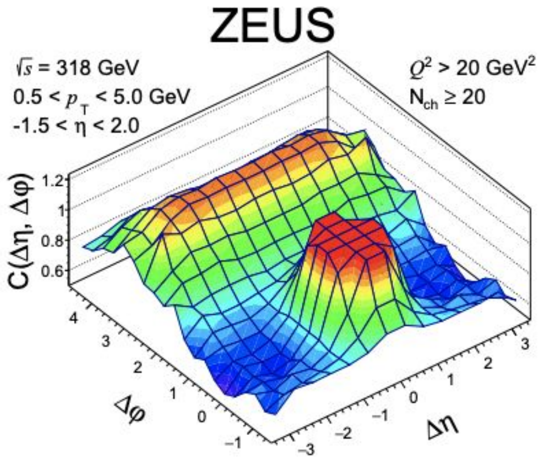
Thanks to all the speakers!

Leptons from HF decays : measurements and inferences towards small systems	Debasish Das
ALICE strange particles and fragmentation measurements	Marek Bombara
The three point asymmetric cumulants in high multiplicity pp collisions	Ran Segev
Search for collective behaviour and multiparton interactions in ep scattering at HERA	Dhevan Gangadharan
Collectivity in small systems: the initial state perspective	Alex Kovner
Collectivity in small systems at RHIC	Julia Velkovska
ALICE results on long- and short-range correlations in high multiplicity pp collisions	Jasper Parkkila
Event-shapes and the presence of jets in e+e-and pp collisions	Mike Sas
Jet quenching in small systems	Bronislav Zakharov
ATLAS and CMS results on collectivity in small-systems	Soumya Mohapatra
QCD and Relativistic Hydrodynamics from pp to AA	Jasmine Brewer
Opportunities of OO and pO collisions at the LHC	Christopher Plumberg

HERA ridge studies

- How small can a colliding system be and still show signs of collectivity?
- H1+ZEUS at Hera trying to have a say on the matter
- Classic “Ridge analysis” performed in the DIS and photoproduction regimes
  - **Ridge yields consistent with zero** in both cases





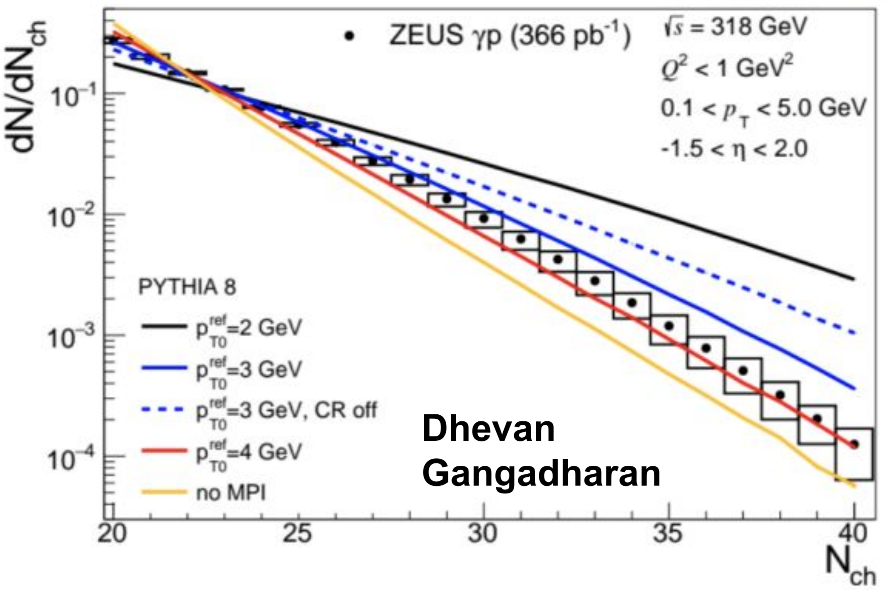
Dhevan Gangadharan

Multiparton Interactions in ZEUS

- How many Multiparton Interactions are needed for a collective behavior?
- New ZEUS measurement of charged particles distributions and dihadron correlations in photoproduction
  - Evidence for a small amount ~2 of MPI scatters

    More MPI → lower p^{ref}_{T0}

  - Paves the way to studies of color reconnection and hadronic rescattering

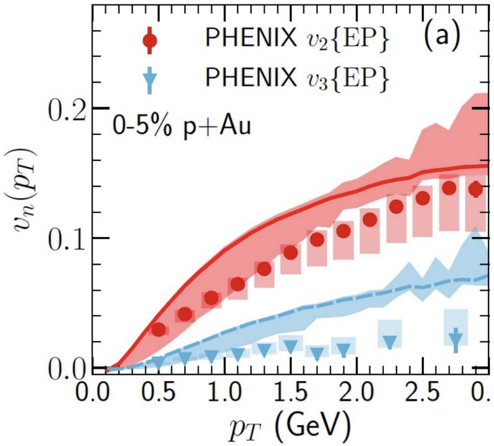


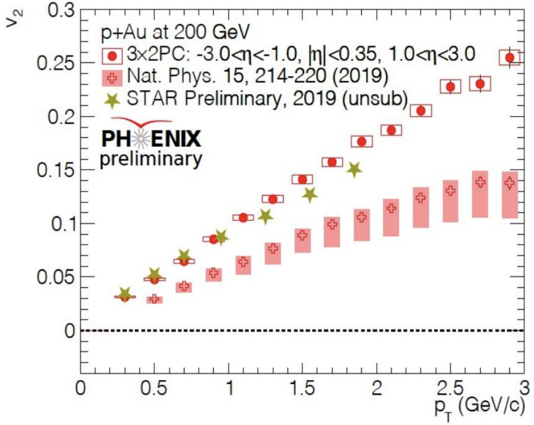
Dhevan Gangadharan

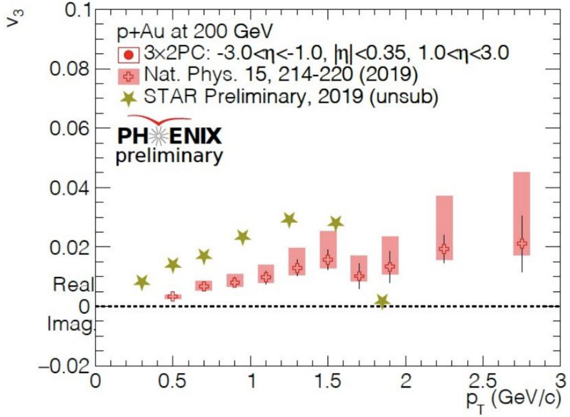
Collectivity in small systems at RHIC

- Common ridge origin between small and large systems?
- Hydro provides simultaneous description of v2 and v3 in pAu, dAu, HeAu
  - But details of initial state description also important

Julia Velkovska





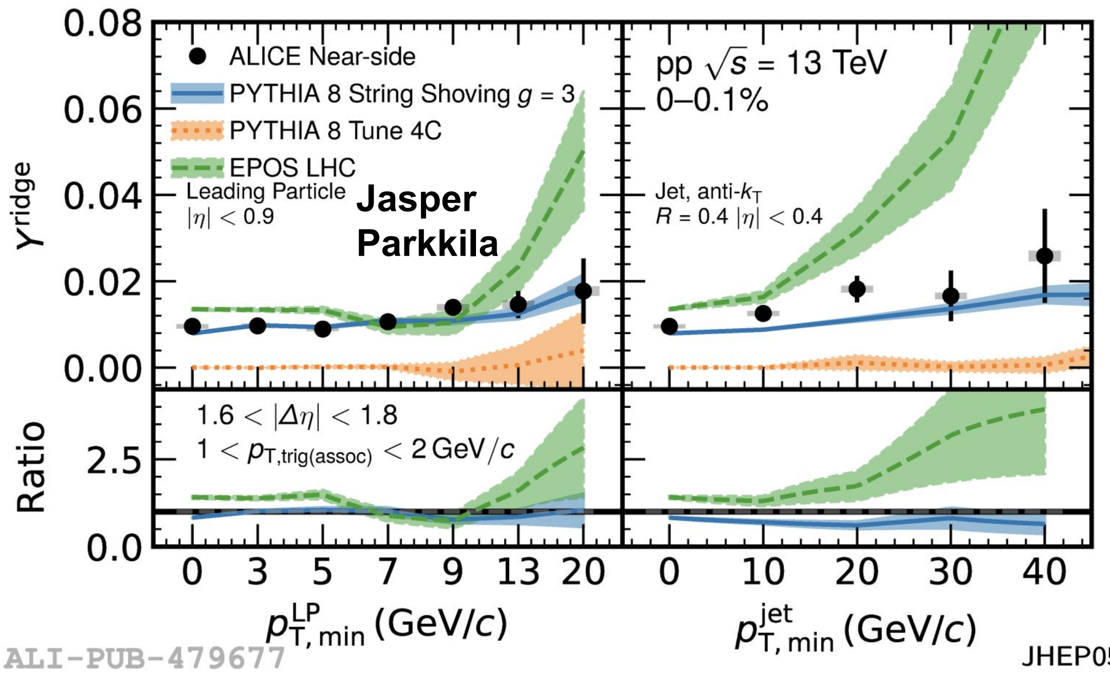


- PHENIX/STAR comparison: agreement in v2 but discrepancy in v3
- New PHENIX analysis confirms old results
  - New d+Au data in 2021, p+Au data expected in 2024,
  - Direct STAR-PHENIX comparisons with same acceptance will be possible

ALICE results on pp correlations at 13 TeV

- Constraining the impact parameter of pp collisions to further understand origin of correlations with “event-scale” selection
  - Clear ridge in high-multiplicity events, no ridge in minimum bias events
  - Increasing ridge with leading particle/jet p_T, no significant dependence for Vn
  - Comparisons with **EPOS LHC** and **PYTHIA 8** (Shoving)

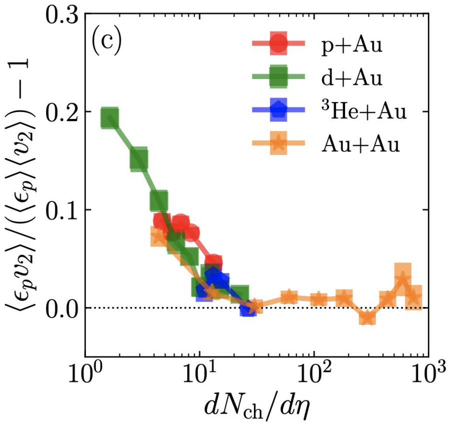
- Flow extraction with template fit is tested
  - Subtract away-side jet contribution in high multiplicity event relative to the low multiplicity term

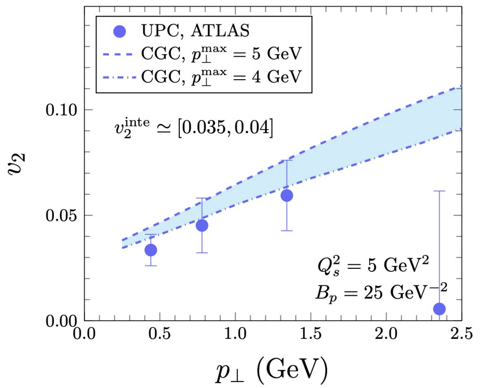


JHEP05(2021)290

Collectivity in small systems: initial state effects

- Ridge: final state (hydro, kinetic theory) or initial state effect (CGC)?
- CGC can contribute through:
  - **Classical correlations** through “color domains” and “local density gradients”
  - **Quantum correlations** through “Bose enhancement” or “gluonic HBT” dominant for hadronic projectile and nuclear target
- Quantum contribution to V2 anticorrelated with eccentricity





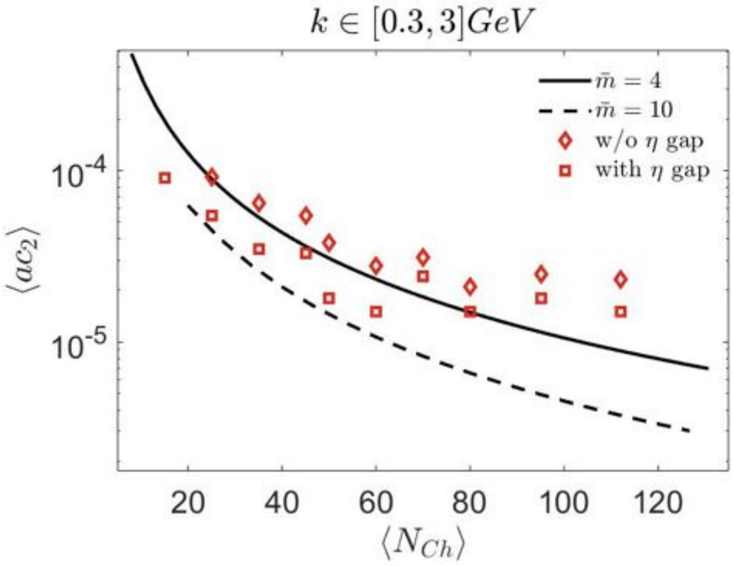
Alex Kovner

- Comparing to STAR data initial state clearly important for dN/deta<10
- ATLAS measurement of correlations in UPC shows non vanishing V2
  - Qualitative agreement with CGC predictions, but calculation still very crude

Three point asymmetric cumulants in pp collisions

- A calculation of the 3 particle asymmetric cumulant, ATLAS measured it in 2019
- Assume no initial asymmetries and no final state interactions
- Red points are from C. Zhang, J. Jia and J. Xu, Phys. Lett. B (2019)
- The results show qualitative agreement, with discrepancies at high multiplicity. The hope is that higher suppressed diagrams might improve it.

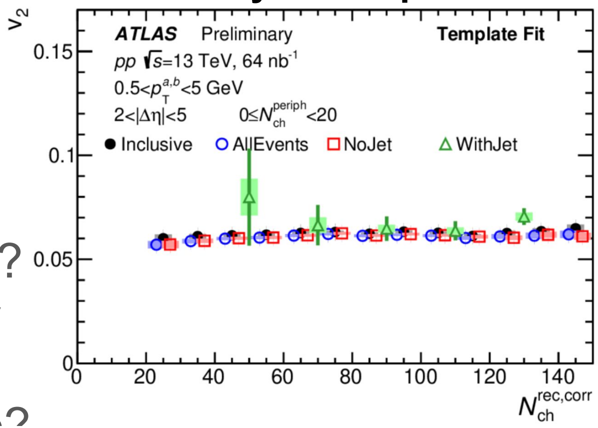
Ran Segev

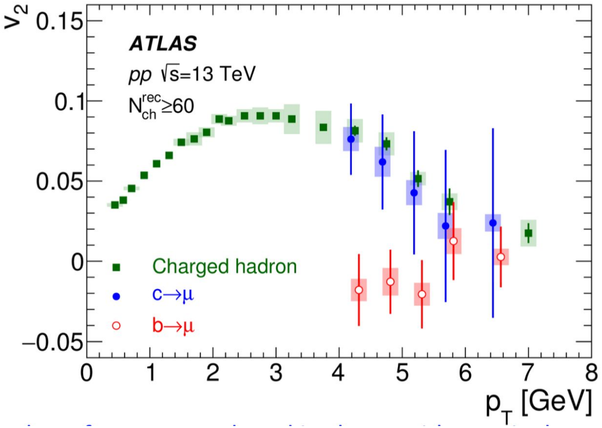


ATLAS and CMS results on collectivity in small-systems

- Ridge in pp collisions: collective (hydro) behavior or semi-hard processes (saturation) ?
- Selecting/rejecting events with semi-hard processes (low-pT jets) should enhance/weaken the ridge.
  - Event classes: **withJet**, **NoJet**, **AllEvents**, **Inclusive**
- Ridge dependence on the collision impact parameter?
  - Select pp events with small impact parameter by requiring a Z-boson in the event (high Q^2)
- Do HF hadrons in pp collisions also show this feature?
- Photon Ion and photon proton collisions
  - Stronger away-side correlation observed in γp events compared to minbias pPb.
  - v2 in γ+Pb systematically smaller than in p+Pb and pp collisions at similar multiplicity

Soumya Mohapatra





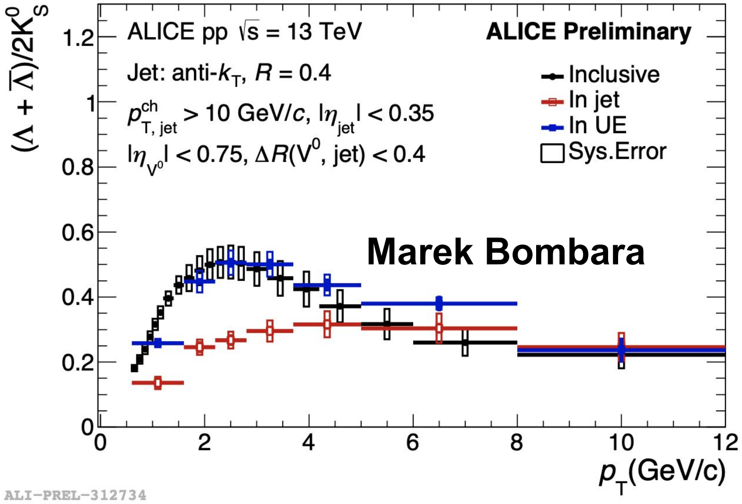
ATLAS and CMS results on collectivity in small-systems

- Multiple recent measurements from ATLAS and CMS investigate collectivity in small collision systems.
- ATLAS measured v_2-v_4 in *pp* collisions when rejecting tracks in the vicinity of low-p_T jets.
  - The p_T-integrated v_2 only decreases marginally (2-5%) when rejecting the jet associated tracks.
  - No significant change for p_T<3 GeV: low-p_T v_n not affected by presence/absence of jets.
- ATLAS measured v_2 in *pp* events tagged with a *Z*-boson.
  - Studies impact-parameter dependence of ridge.
  - No significant modification from *inclusive* events observed.
- ATLAS and CMS : also measured HF v_2 in *pp* events.
  - *charm* v_2 consistent with inclusive hadrons, *bottom* v_2 consistent with zero.
- CMS & ATLAS : 2PC measurements in γ+*p* and γ+Pb events.
  - Smallest collision systems at the LHC.
- CMS : multiple measurements of strange and HF collectivity in *p*+Pb

Soumya Mohapatra

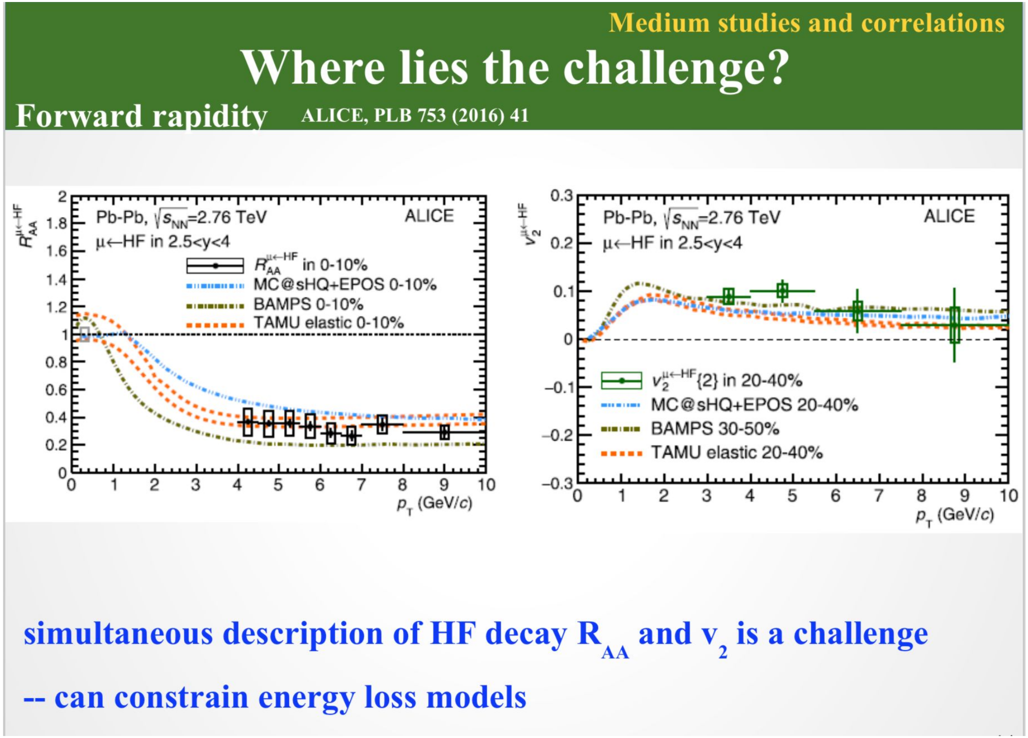
ALICE strange particles and fragmentation measurements

- Strange particle enhancement clearly visible for high multiplicity pp collisions
    - Overlap with pPb/PbPb results, raise with ⟨dNch/dη⟩ independent of collision type and energy
    - hierarchy of the enhancement only determined by the hadron strangeness
- **Role of jets and UE ?**
    - pT spectra of strange hadrons harder in jets (near-side) than in UE (out-of-jet) or inclusive (full) sample
    - Enhancement in ratios of pT spectra caused by soft processes
    - *Ξ*/K0 yield ratio shows an enhancement as a function of multiplicity in out-of-jet and full samples (both mutually consistent), inconclusive whether or not the near-side jet sample contributes to enhancement



Leptons from HF decays

- Heavy quarks are good probes: Hard probes even at low pT (they do not change flavor while interacting with the QCD medium)
  - In high-energy A+A collisions, bottomonium suppression “golden probe” for QGP
  - No suppression in pA collisions, more precise data needed

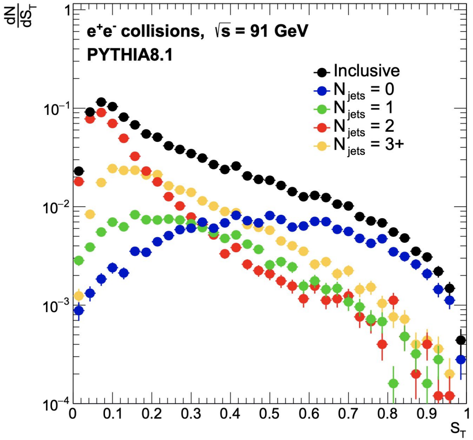


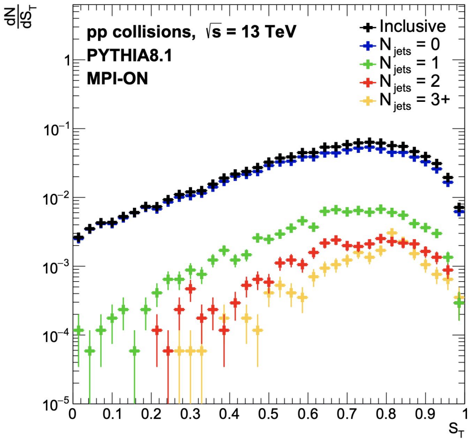
Debashish Das

Event shapes and jets from ee to pp collisions

- Can we use event shapes to discriminate between jet topologies (e+e-) and to distinguish soft contributions from underlying event (pp)?
- MC based study for different beams and energies
- As known, transverse sphericity can discriminate jet-categories in e+e-
- In pp collisions, not the case anymore
  - Spherical collisions tend to contain higher energetic fragmented partons
  - Strong correlation between sphericity and the number of MPI scatters, but even stronger correlations with the particle multiplicity

Mike Sas





Jet quenching in small systems

Bronislav Zaharov

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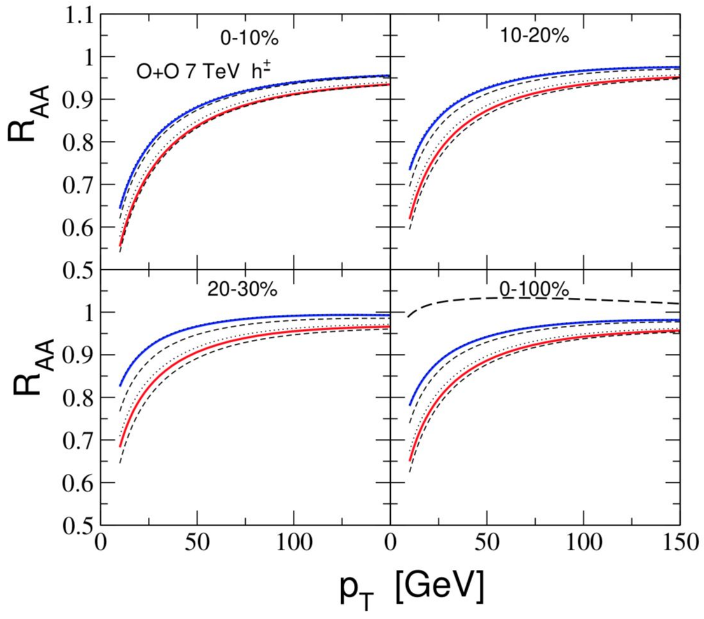
- Radiative and collisional energy losses modify jet evolution. Both these mechanisms should be treated on even footing. $\Delta E_{coll} << \Delta E_{rad}$.
- The theoretical uncertainties in jet quenching calculations are rather large. Choose to study R_{AA} (nuclear modification factor)
- Calculate the medium suppression for the small-size plasma in pp collisions
- Assuming that there is mini-QGP formation in pp collisions, is that effect visible on R_{AA} via its A-dependence (PbPb, OO data)?
- In OO collisions, the scenarios for R_{AA}- R_{AA}^{PDF} with and without mini-QGP formation do differ
- Difficult to discriminate with future LHC due to theoretical uncertainties of R_{AA}^{PDF} and the p_T-dependence which is similar for the two scenarios.

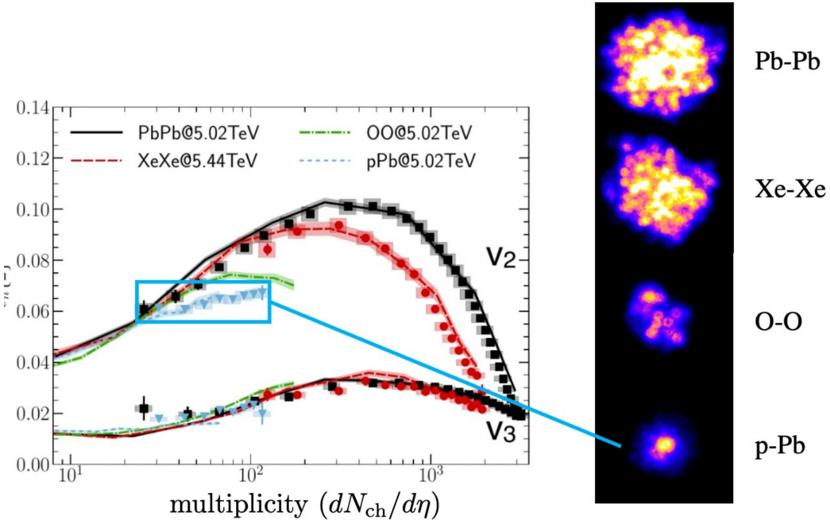
7 TeV OO collisions

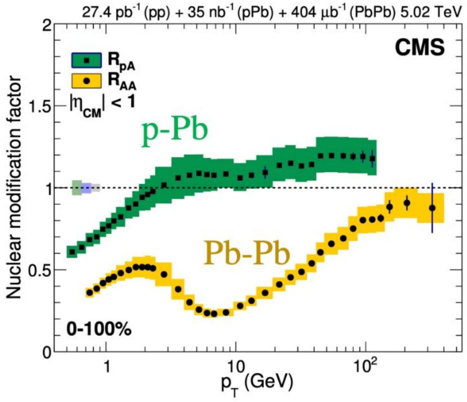


Opportunities of OO and pO collisions at the LHC

- Feasibility studies for an LHC Oxygen run (cern.ch/OppOatLHC)
- Can provide **unique constraints on soft sector** observables
  - OO: similar multiplicity to pPb but heavy-ion-like geometry
  - More compact, hotter than PbPb at the same multiplicity
- And new opportunities In the hard sector
  - Possibility to measure the energy loss in small systems

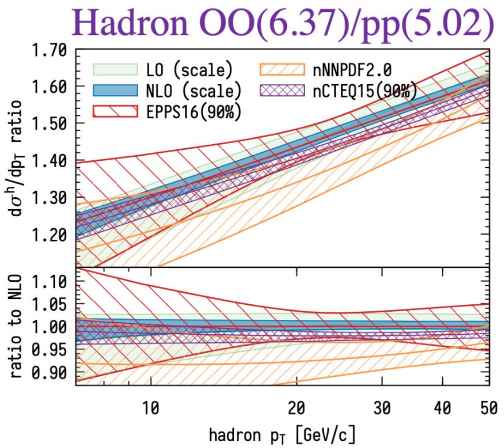
Jasmine Brewer

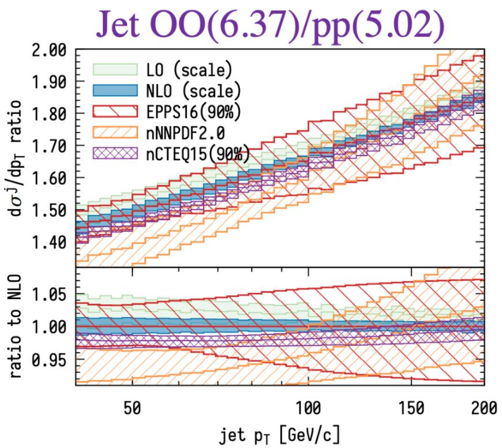




Opportunities of OO and pO collisions at the LHC

- Opportunities for hard probes measurements without a pp reference
- ~ few-5% uncertainties on constructing a reference either from pQCD or from a data-driven interpolation
  - pQCD has few-% uncertainties, but is not identical to interpolation
  - Uncertainties on interpolation require fitting with 3 energies
- Bypass constructing a reference: OO/pp at different energies
  - good cancellation of pQCD scale uncertainties. nPDF uncertainties dominant





Jasmine Brewer

QCD and Relativistic Hydrodynamics from pp to AA

- How to test the applicability of Hydro to small and intermediate systems?
- Knudsen and inverse Reynolds numbers, both need to be <<1. Assuming that spacetime gradients and non-equilibrium corrections are small, one can identify 3 types of fluid cells: blue (causal), purple (maybe causal or acausal) and red (acausal). Check different models and different systems (pPb, OO, PbPb)
- Enforcing relativistic causality will lead to measurable changes in parameter ranges favored by data.
- Causality violation should be included in hydro codes and analyses!
- Better variables needed
    - space-time observables (HBT) and momentum-space observables

Christopher Plumberg

Most definite causality violations resolved in the first 15% of the evolution