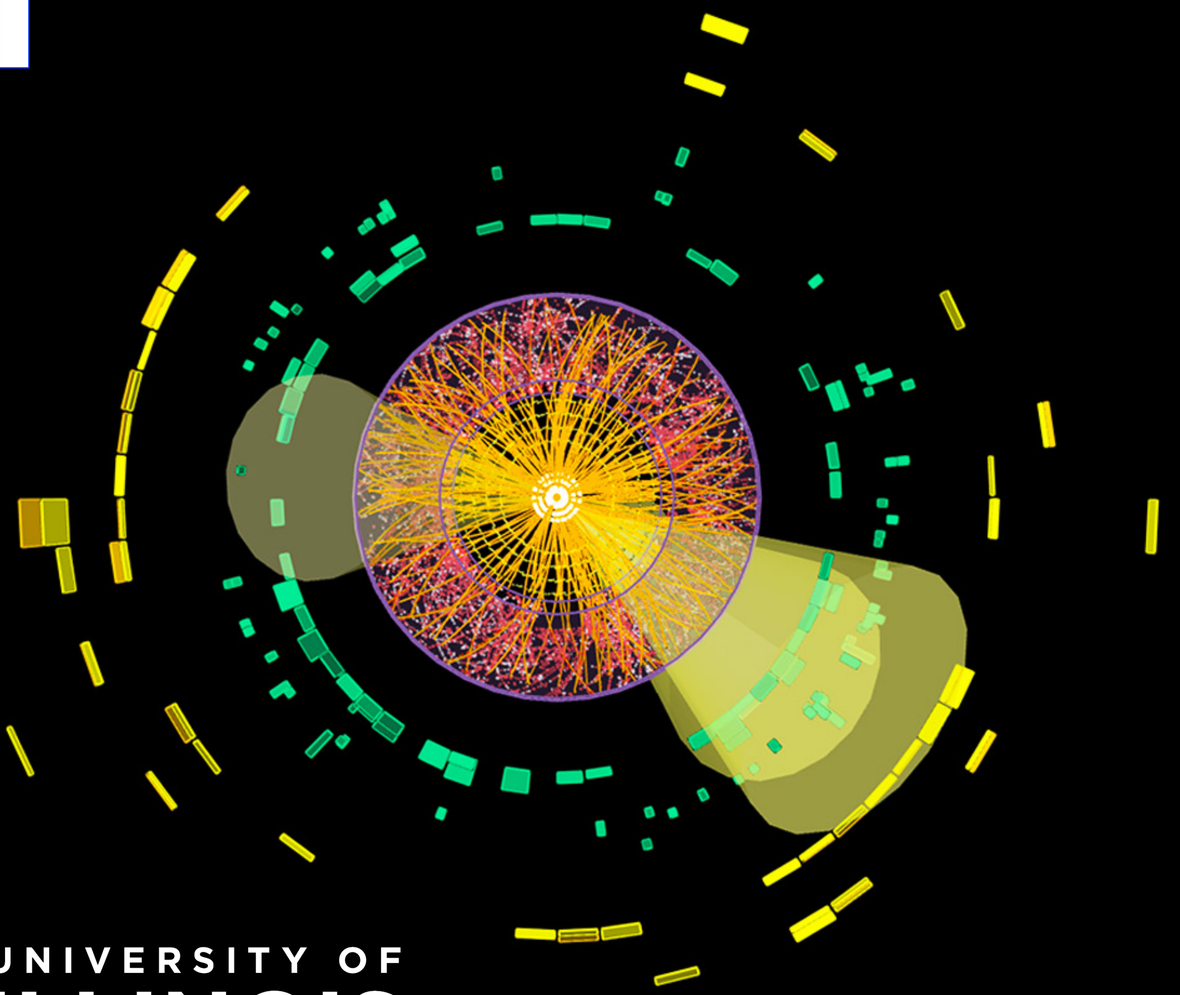
Looking for the Small Size Limit of Energy Loss at the LHC

Riccardo Longo, Anne Sickles, Sierra Cantway, Eliza Marlin

22 September 2026

EMMI Light Ion Workshop 2026 - Heidelberg (Ge)



MUR Ministero dell'Università e della Ricerca

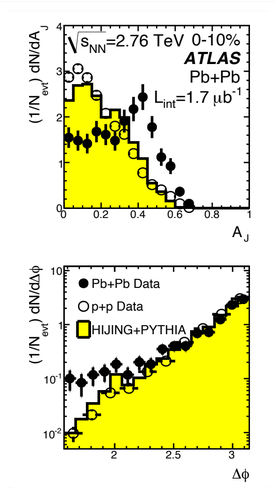
UNIVERSITÀ DI TORINO

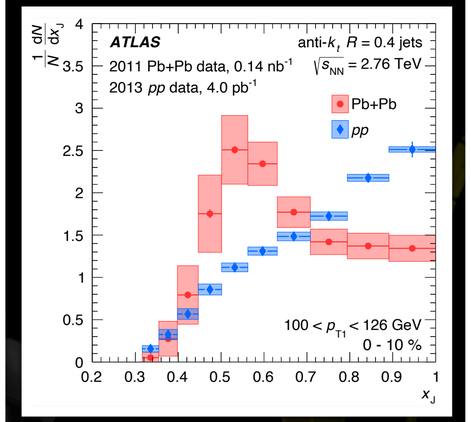
INFN TORINO

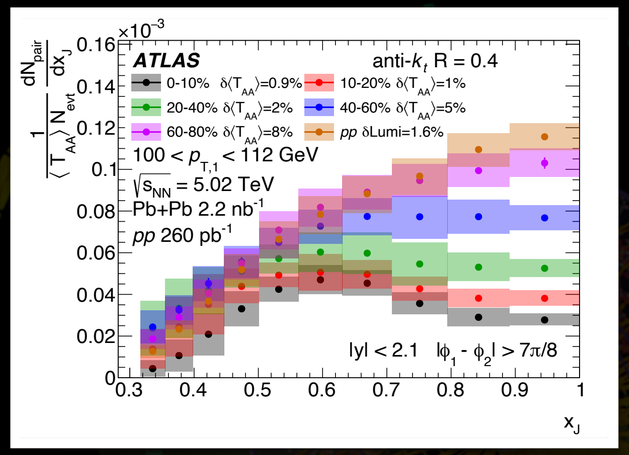
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

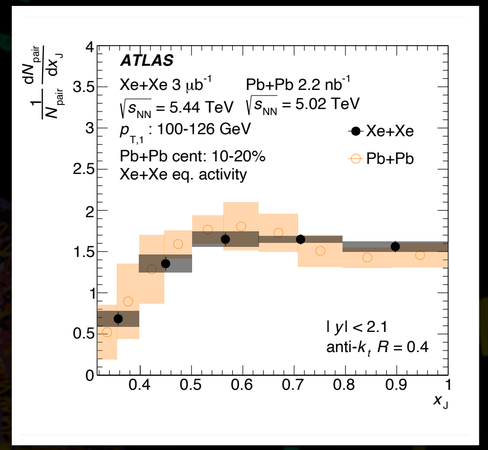
The outlook - pre LI run

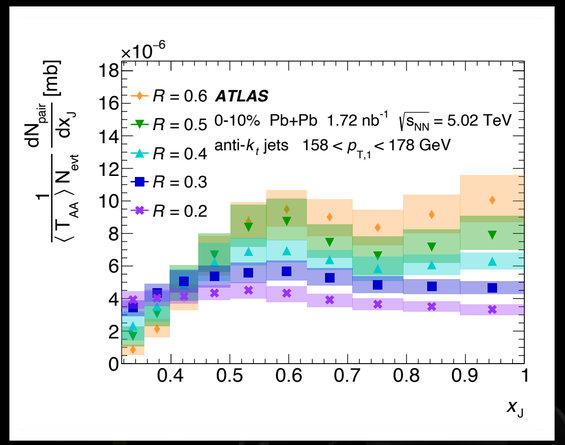
Well-established observation of **Jet quenching** in Pb + Pb











2012 — First Observation of Dijet Asymmetry in Pb+Pb — [Phys. Rev. Lett. 105 (2010) 252303]

2017 — First fully unfolded measurement of x_J — [Phys. Lett. B 774 (2017) 379]

2022 — First absolutely normalized measurement of x_J — [Phys. Rev. C 107 (2023) 054908]

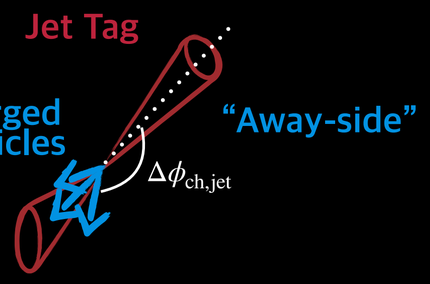
2023 — First measurement of x_J in another collision system — [Phys. Rev. C 108 (2023) 024906]

2024 — First measurement of x_J dependence on jet radius — [Phys. Rev. C 110 (2024) 054912]

Dijet asymmetry: powerful tool to investigate the **path-length dependence of Energy Loss**

The outlook - pre LI run

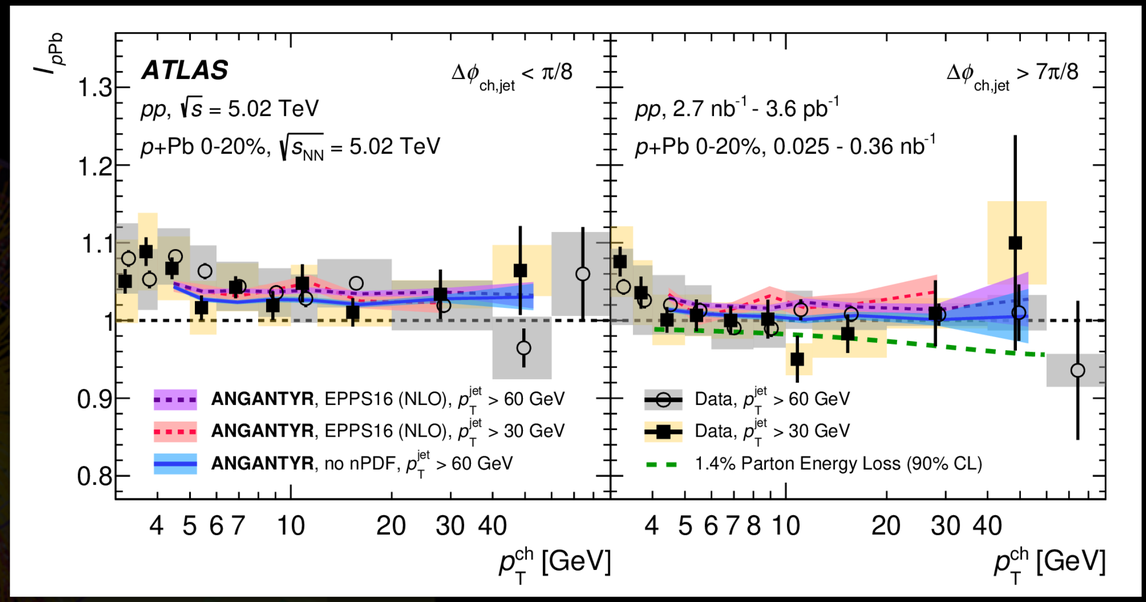


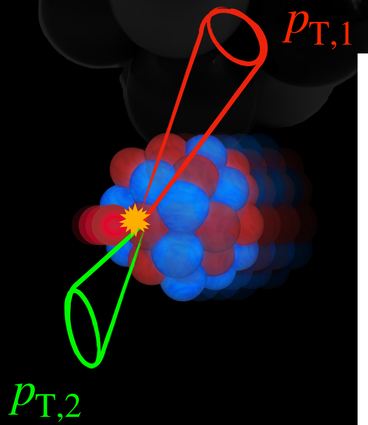


No evidence of Jet quenching in $p + \mathrm{Pb}$

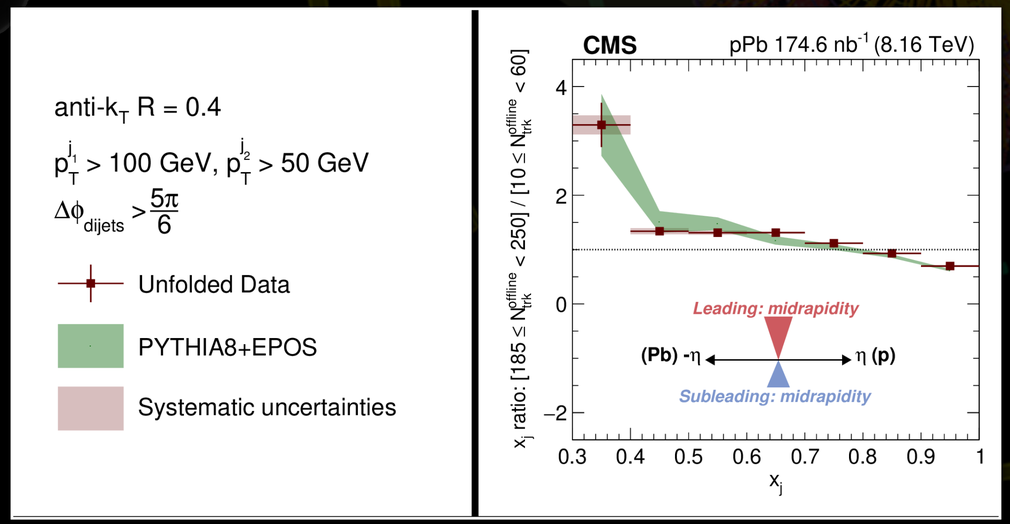
Strong parton energy loss constraints: 0.2 ± 0.5% and < 1.4% at 90% confidence level

ATLAS Phys. Rev. Lett. 131 (2023) 072301





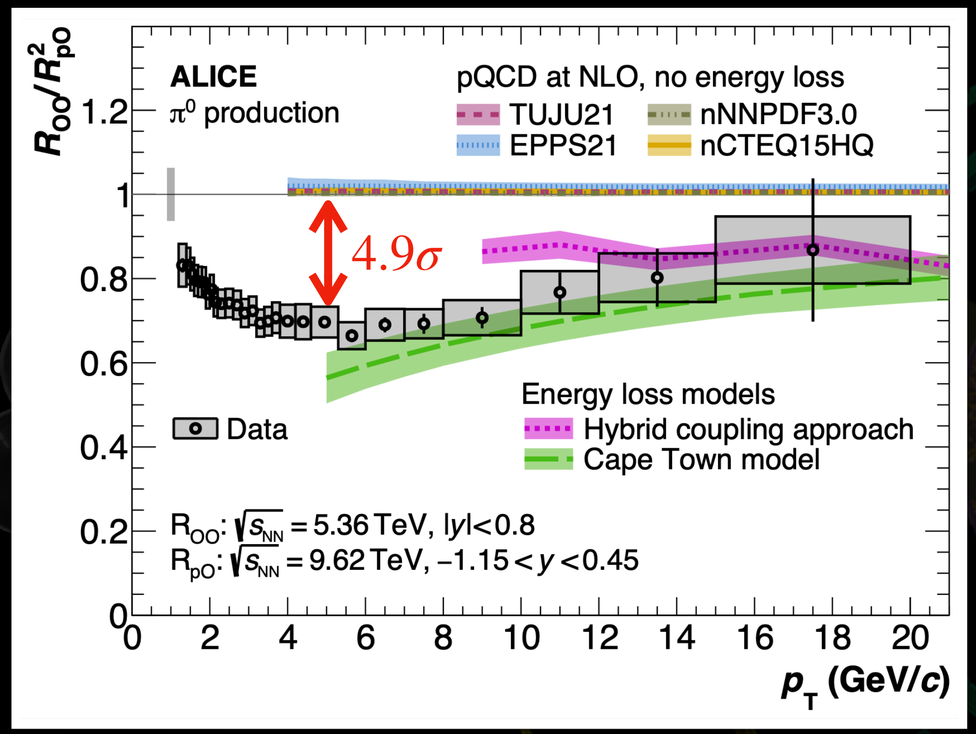
$$x_J = \frac{p_{T,2}}{p_{T,1}}$$



Upper-limit on medium-induced energy loss of the subleading jet of 1.26% of its transverse momentum at the 90% confidence level in high-multiplicity p+Pb events

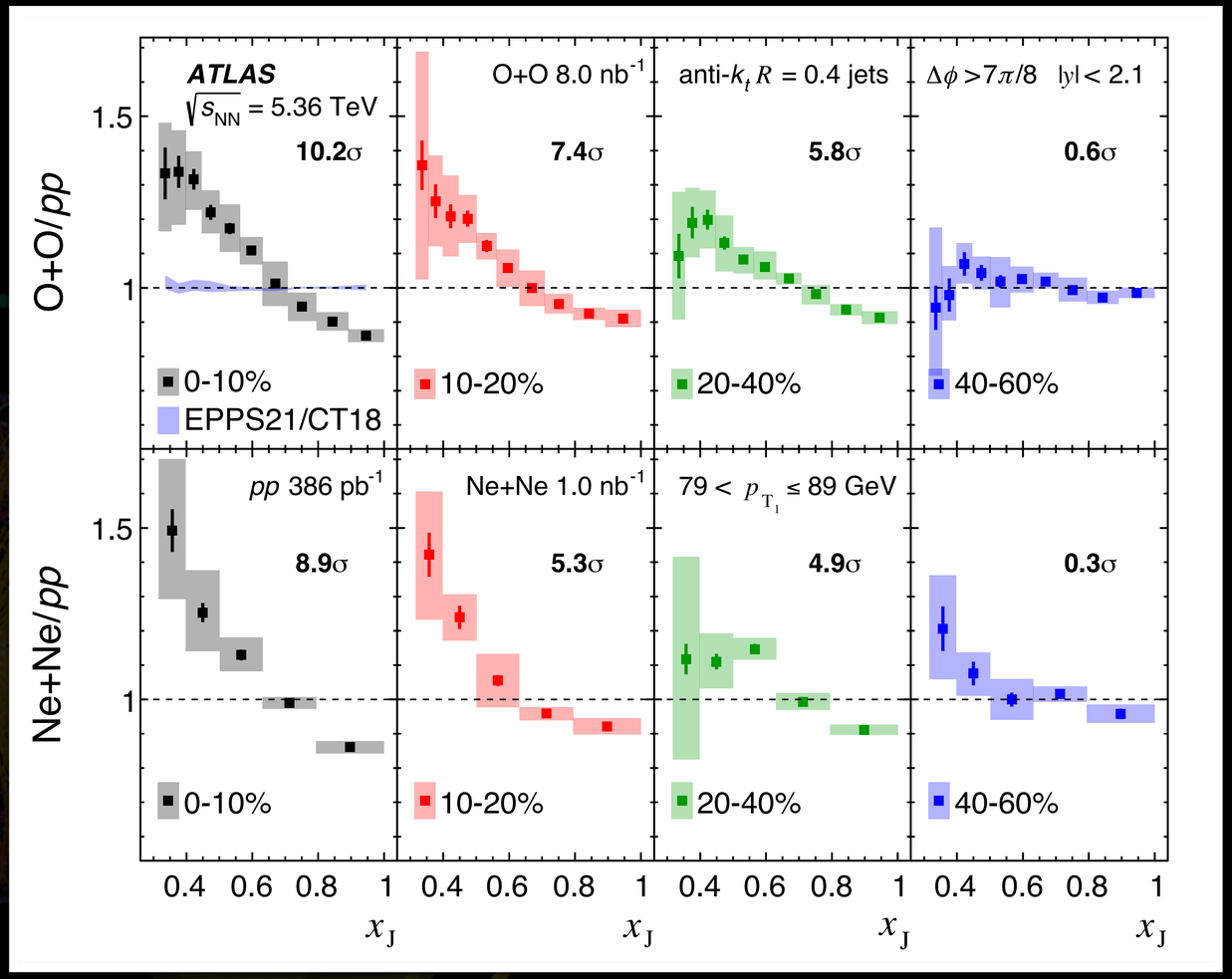
JHEP 07 (2025) 118

The LI input (as of today)



ALICE strong evidence from parton energy loss by canceling the majority of nPDF effects via R_{OO}/R_{pO}^2 (see *N.Strangmann's talk*)

arXiv:2606.19967

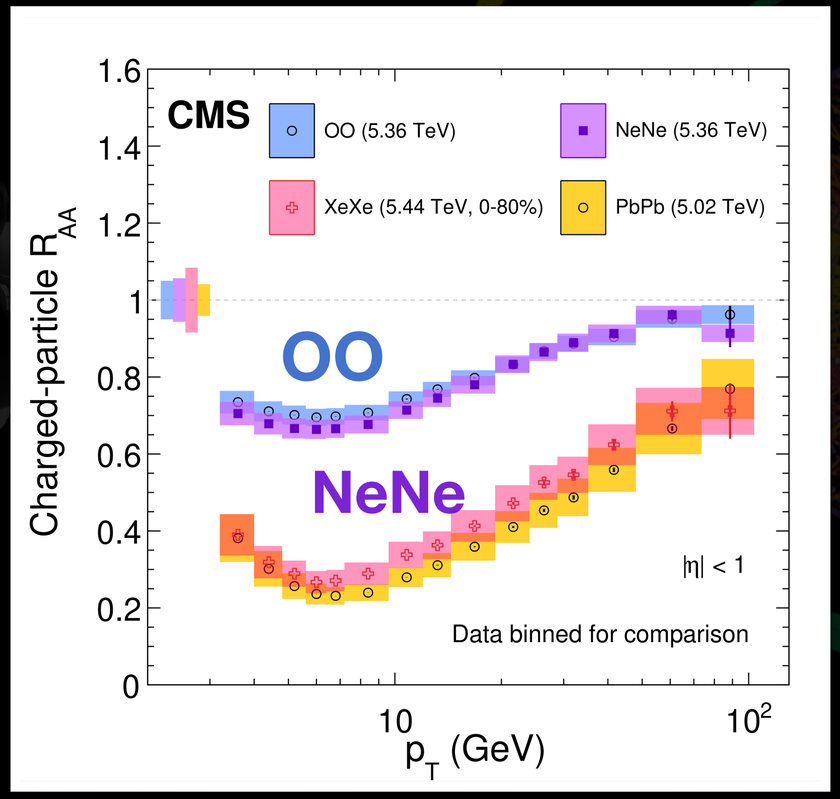


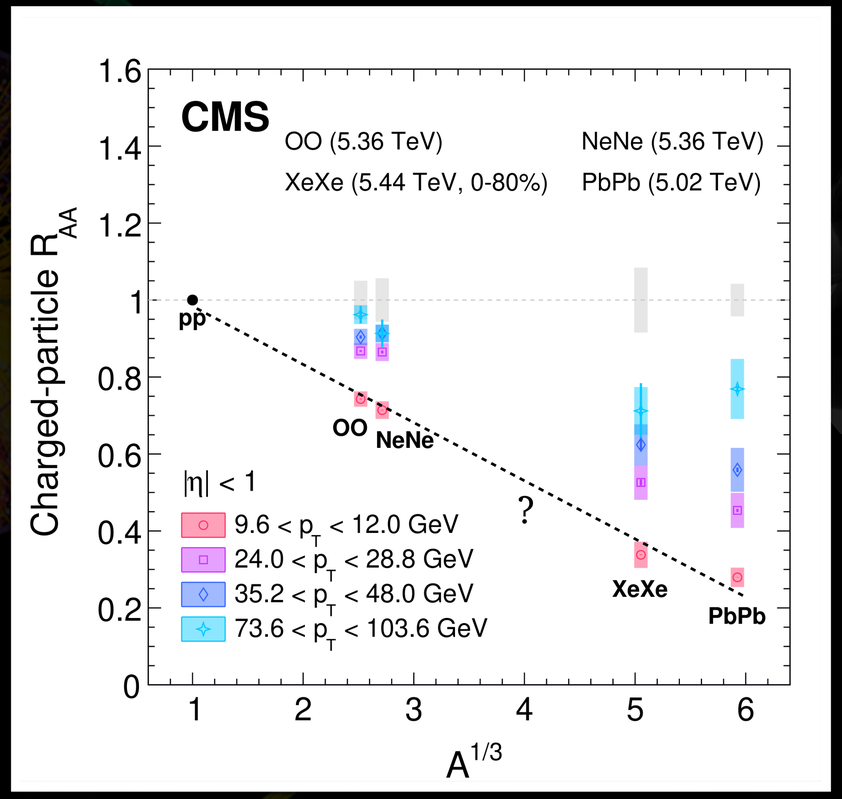
ATLAS dijet asymmetry: Jet quenching *observation* from central to mid-central O-O and Ne-Ne collisions (see *A. Sickles' talk*)

arXiv:2606.20463

The LI input (as of today)

Strong hints from CMS R_{OO} and R_{NeNe} (also very suggestive of a possible system-size dependence)

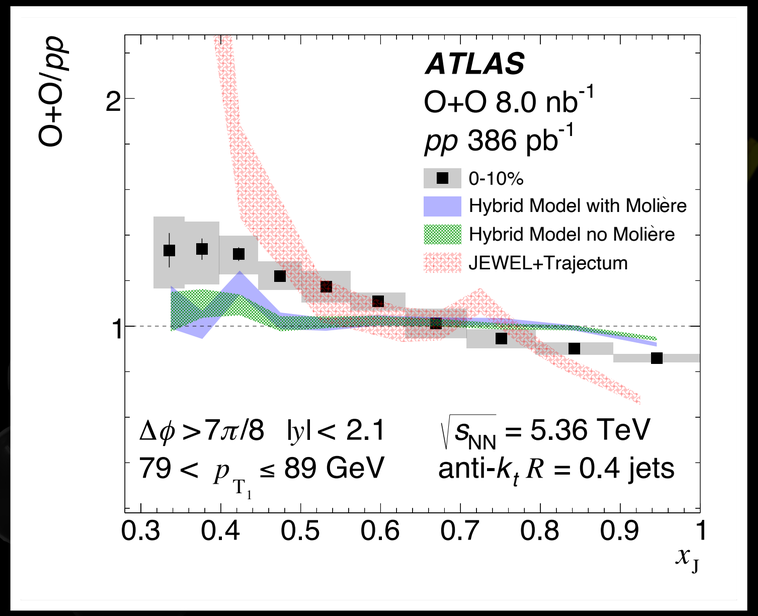


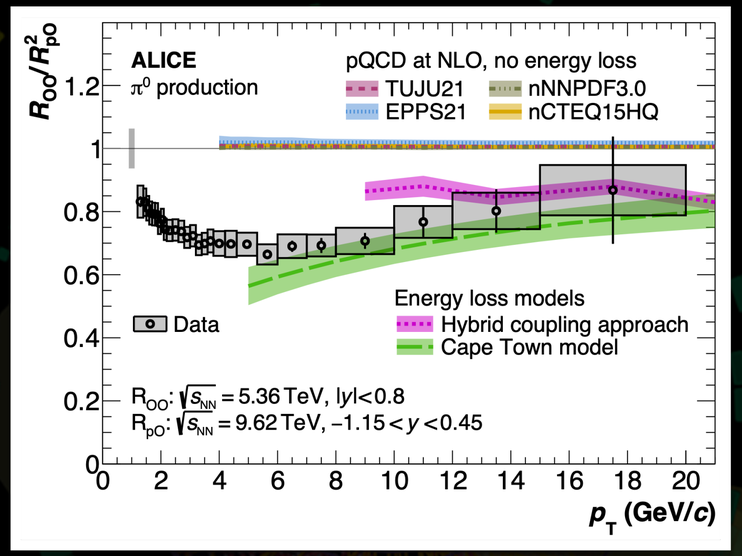


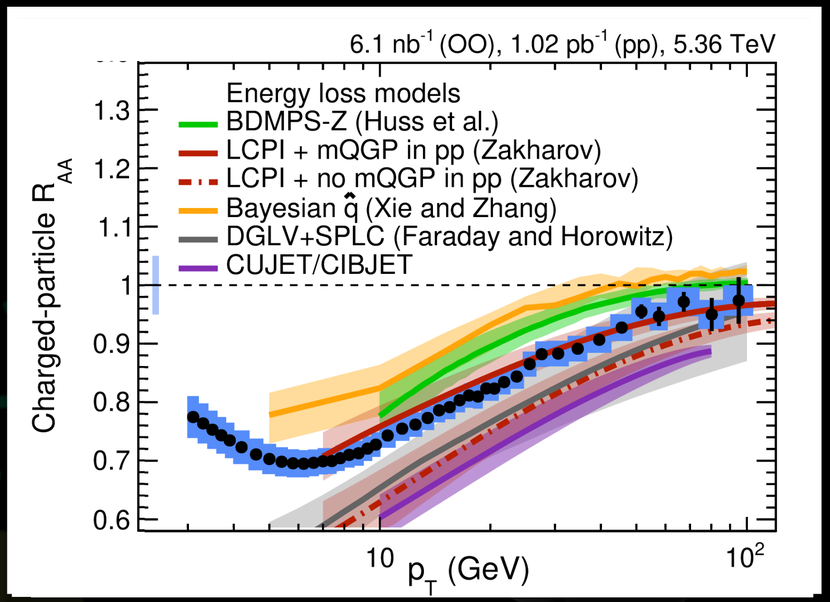
PRL 136 (2026) 162301
PLB 880 (2026) 140679

See also *A.Baty's talk*

A lot yet to understand from modeling...







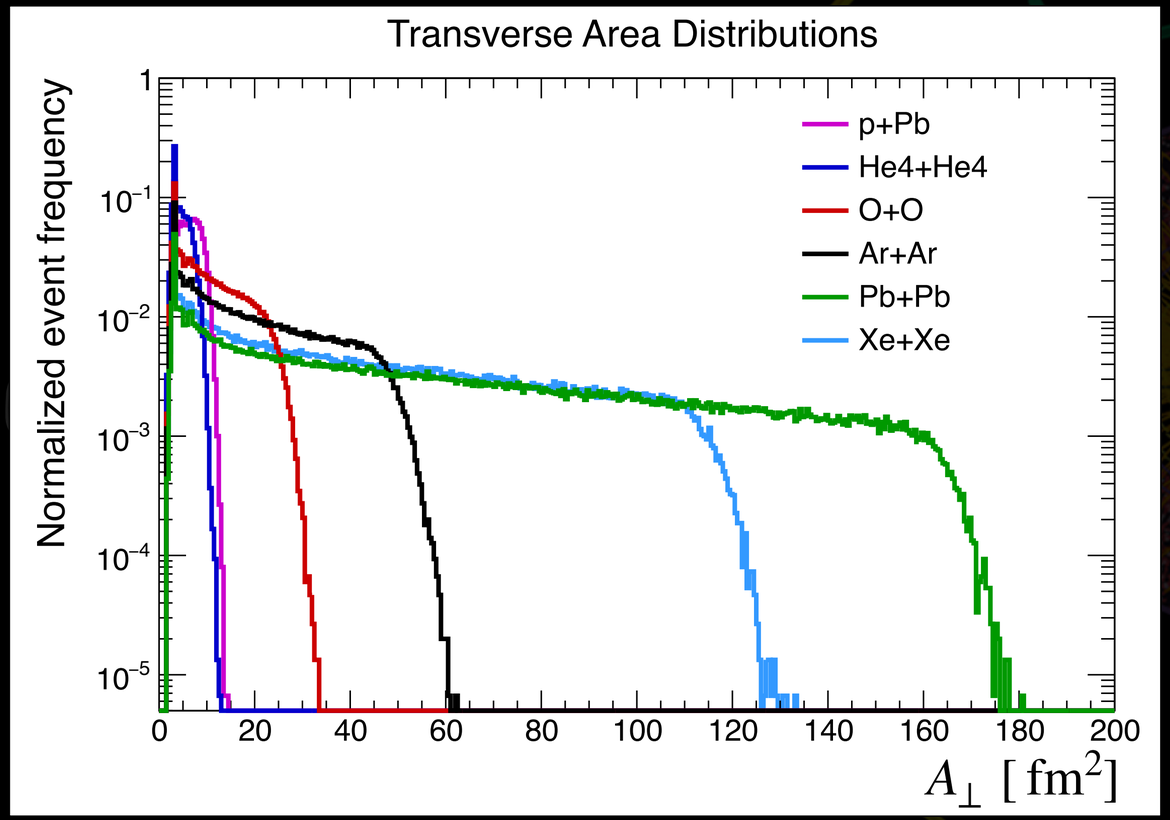
- Existing (and future) results are invaluable input to further constrain models
- More fundamental open questions still out there to be answered:
  - ➡ Between p+Pb and mid-central O-O/Ne-Ne collisions, ***where is the onset of energy loss effects?***
  - ➡ Between mid-central O-O and Ne-Ne collisions and heavy nuclei (Pb+Pb, Xe+Xe), ***how does the energy loss evolve with the system size?***

Goal of this talk

Use a simple approach to showcase how a diverse ion program at the HL-LHC can push foward the understanding of the path length dependence of energy loss and help in shedding light on its onset

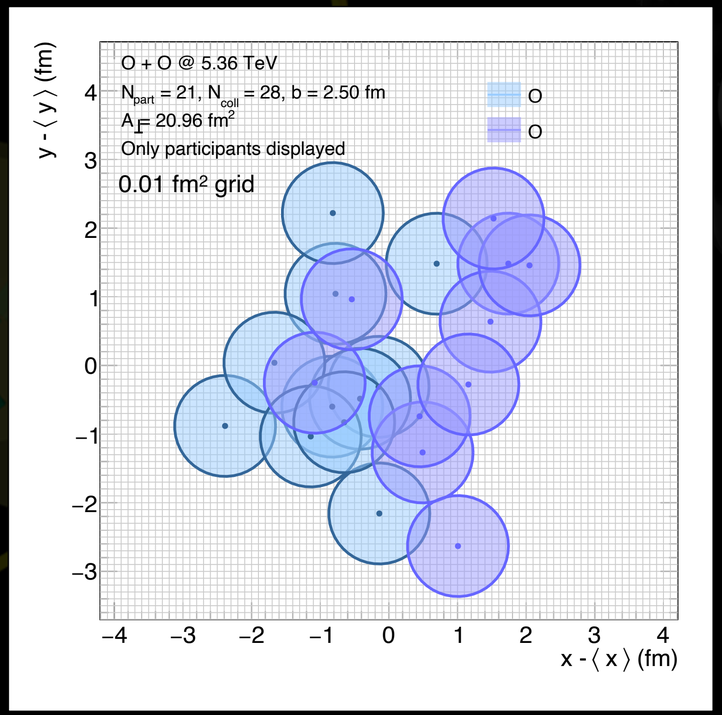
Focus on LHC and on one particular experimental tool: the dijet asymmetry

Transverse area of the collision



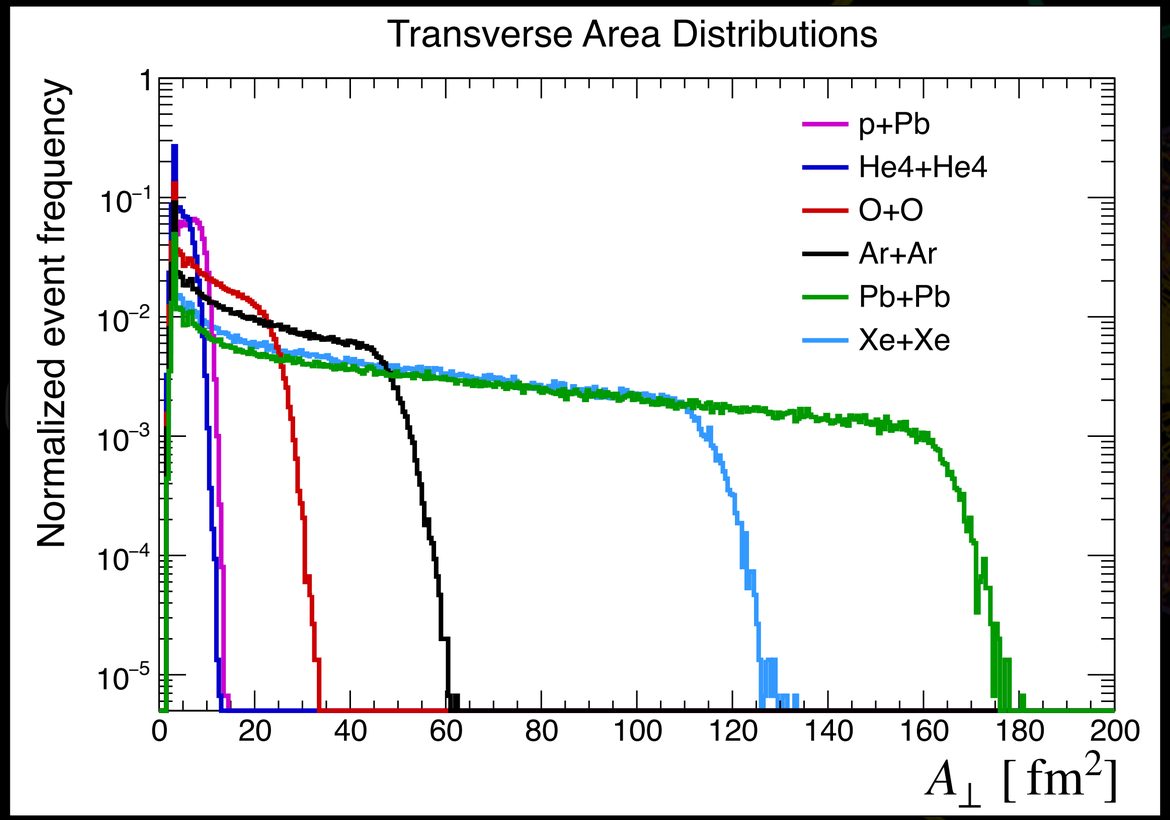
$A_\perp$ => ‘Grid-based’ area from Glauber.

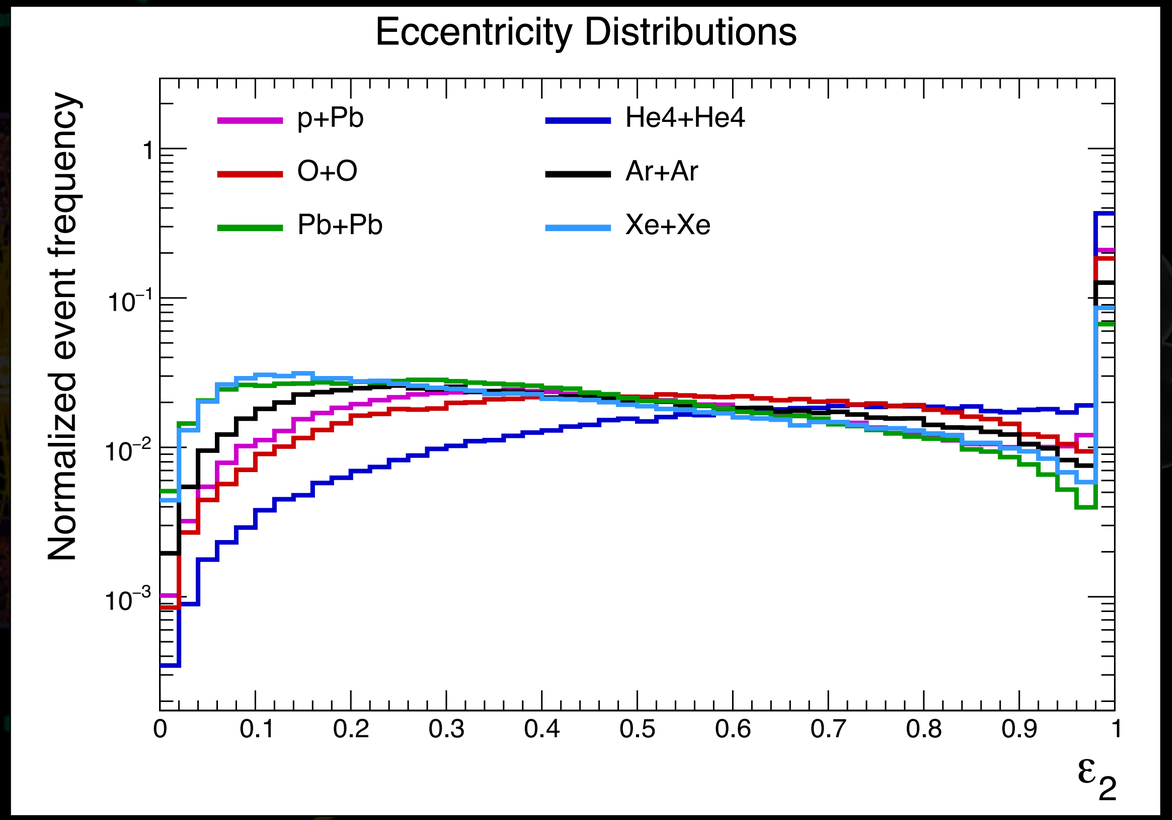
In this study, the **participant-footprint area.** Not a calculated QGP boundary, but a static geometric proxy.



Angantyr was also checked - w/ no major differences in terms of takeaways;

Transverse area & eccentricity of the collision

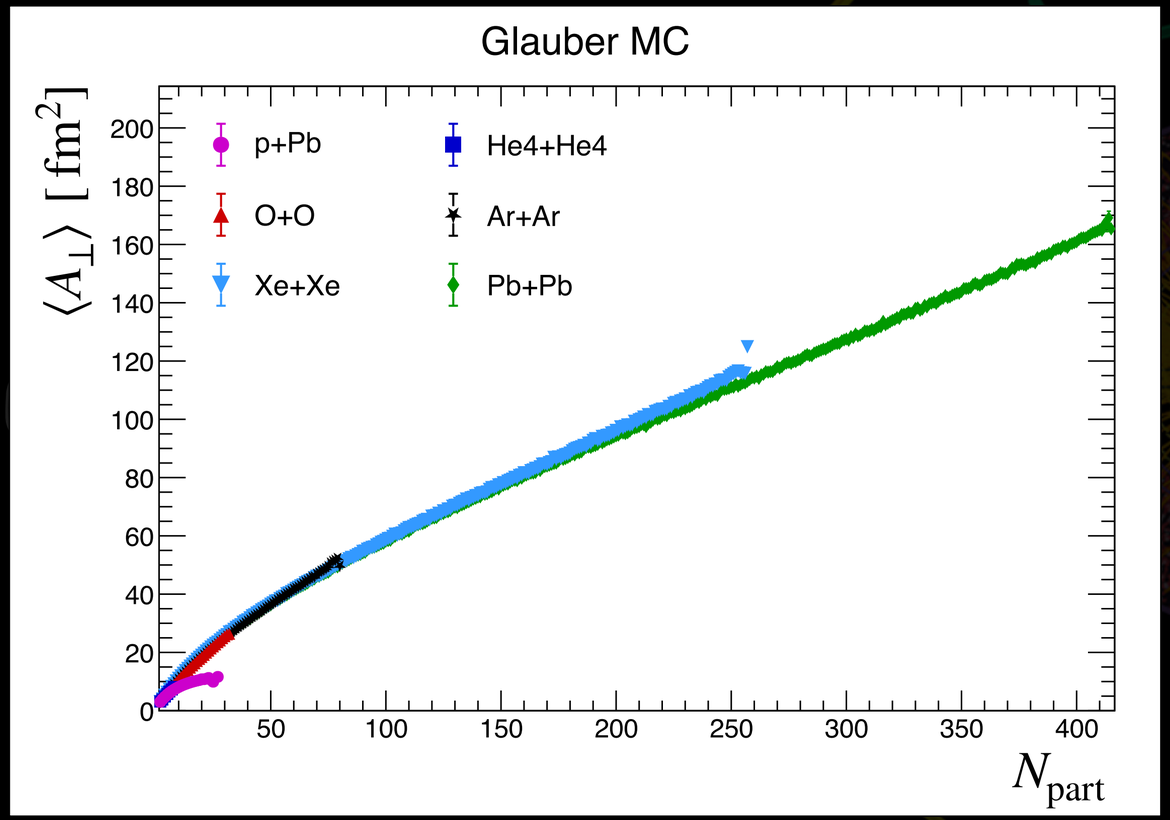


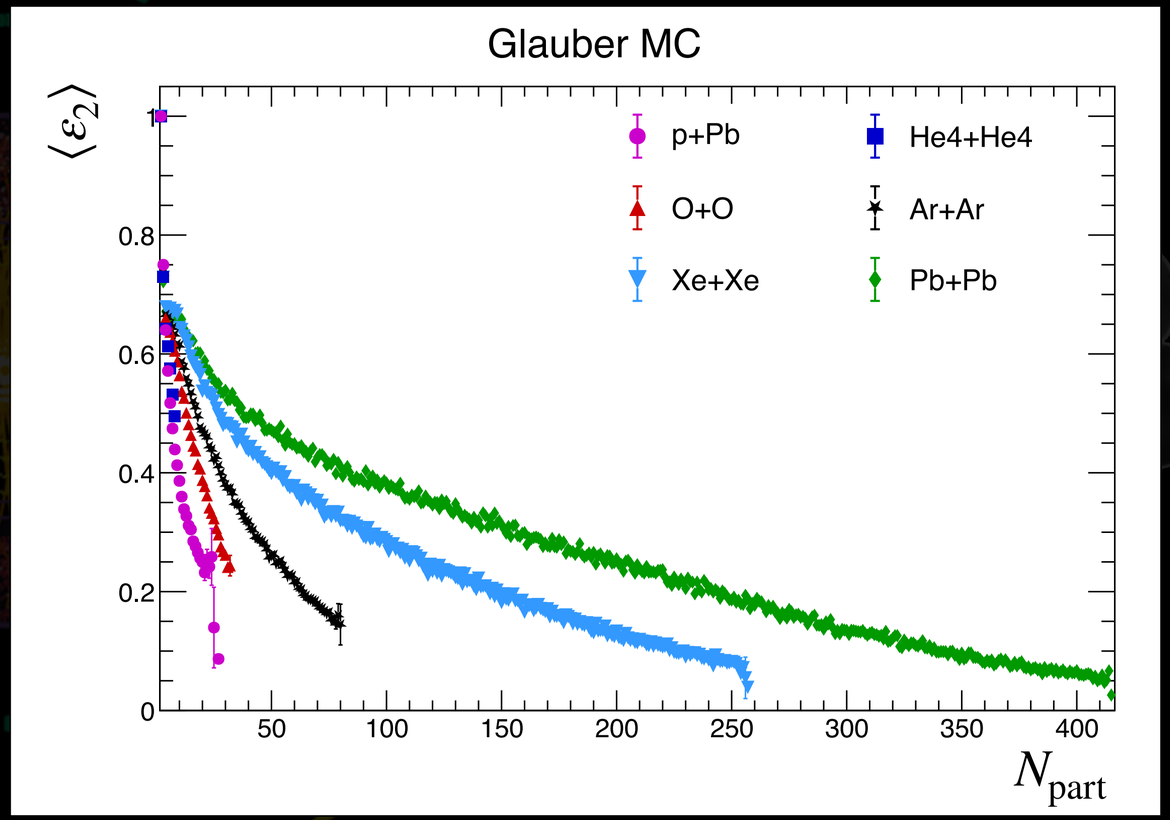


How does this map on event geometry?

Transverse area & eccentricity of the collision

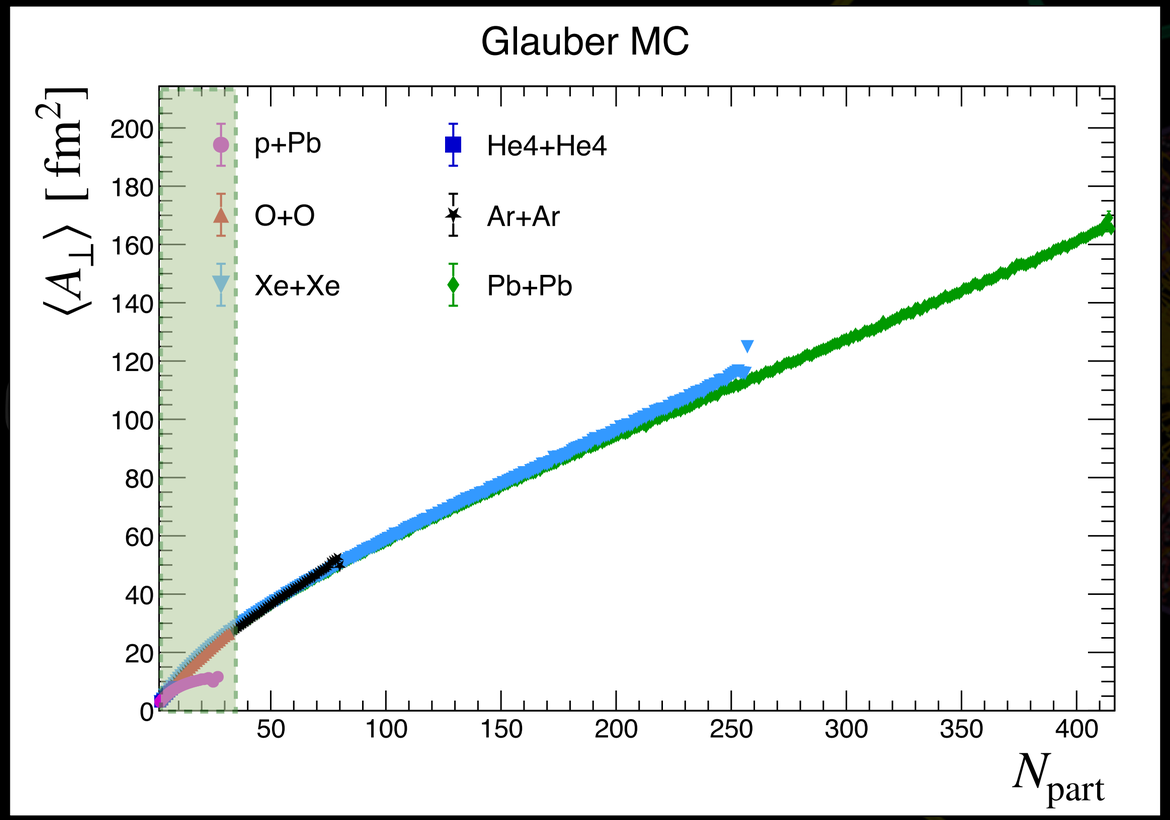
Now correlate area and eccentricity with the number of participants in the collision

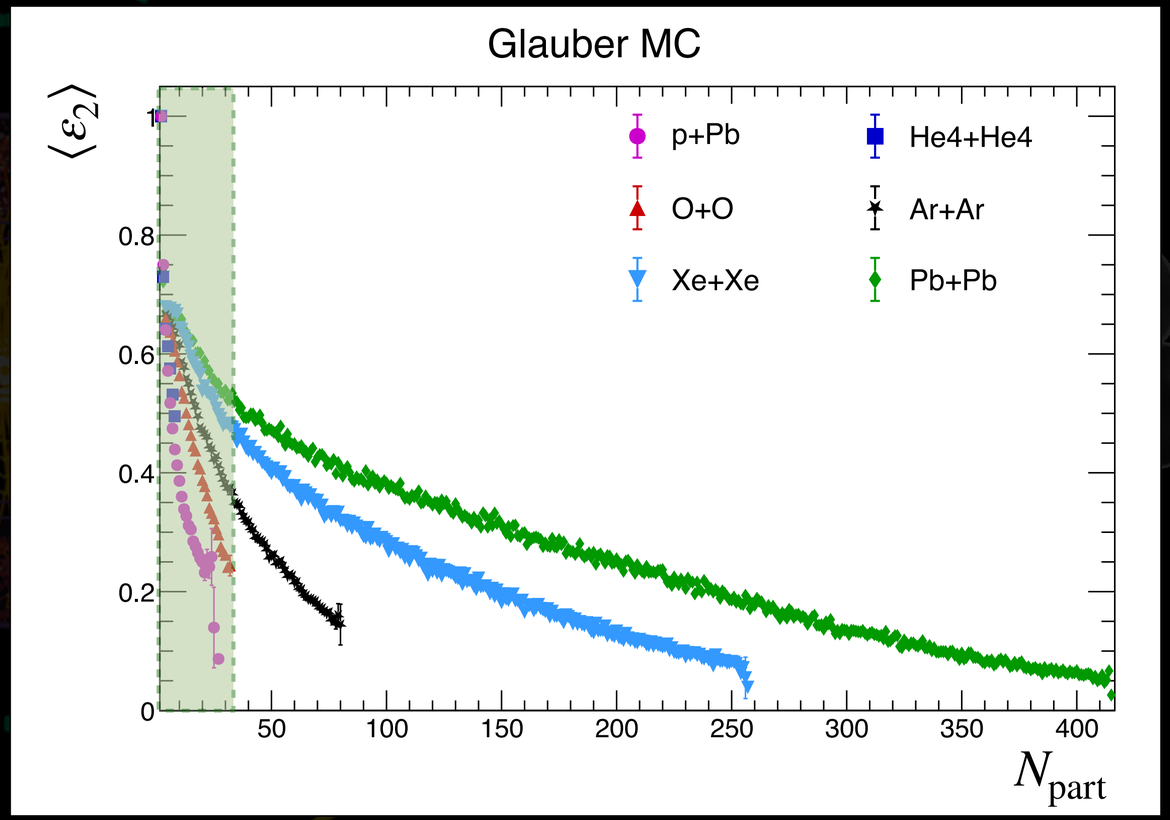




Transverse area & eccentricity of the collision

Now correlate area and eccentricity with the number of participants in the collision

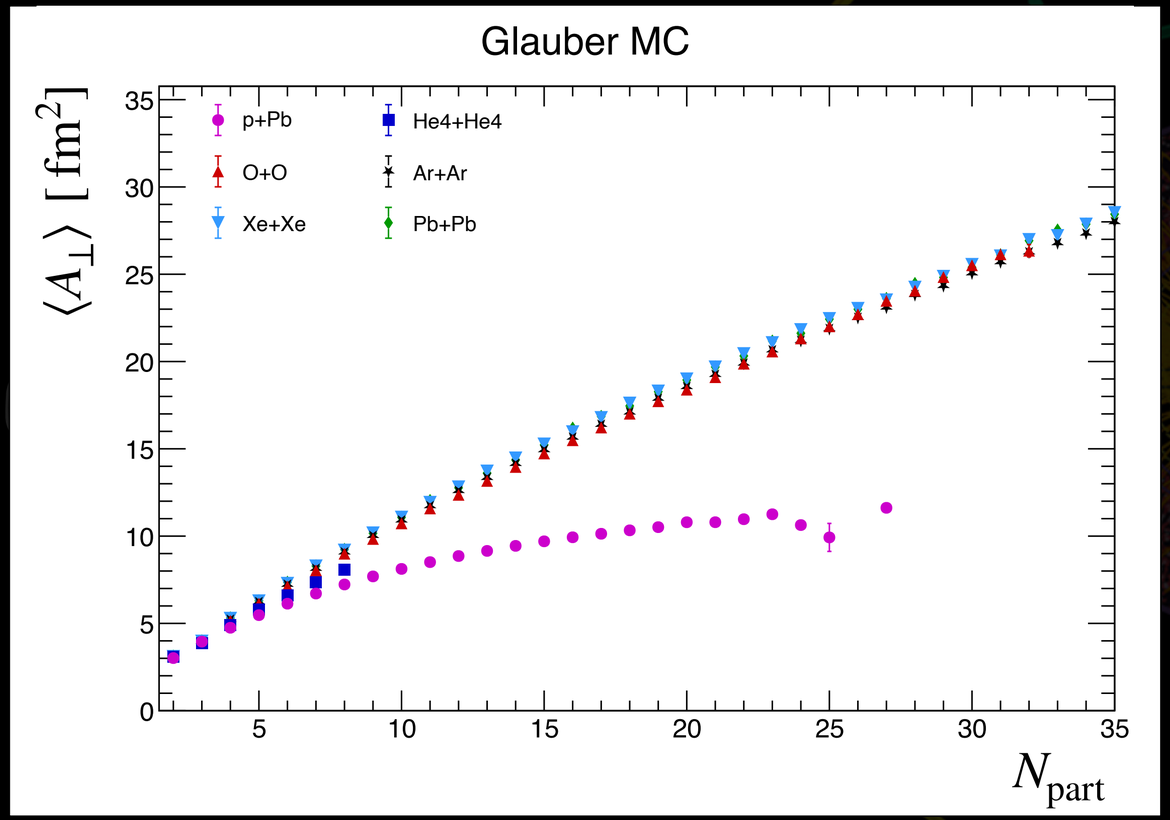




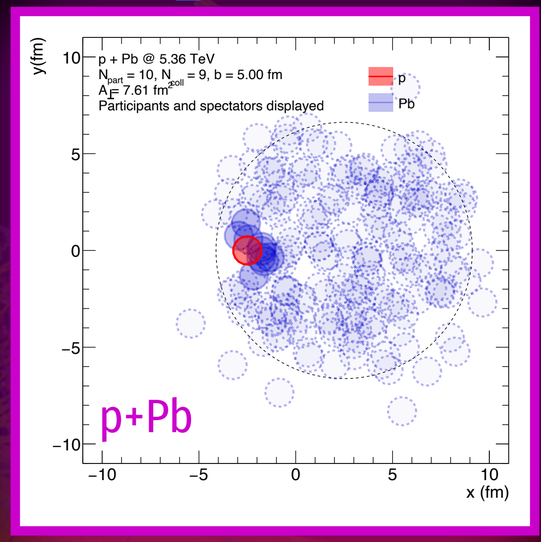
And focus on light-ion range (N_{part} < 35)

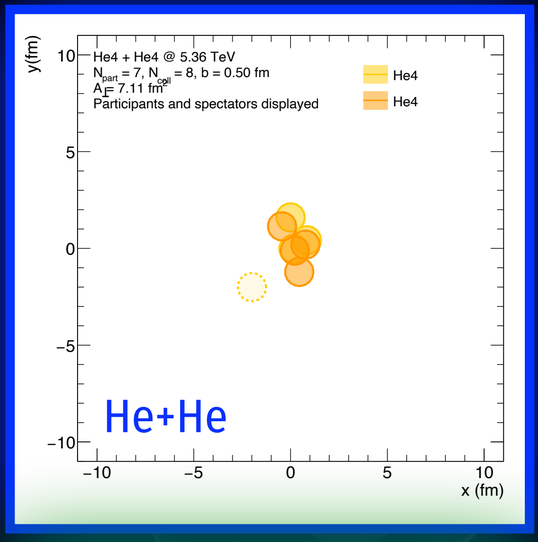
Transverse area & eccentricity of the collision

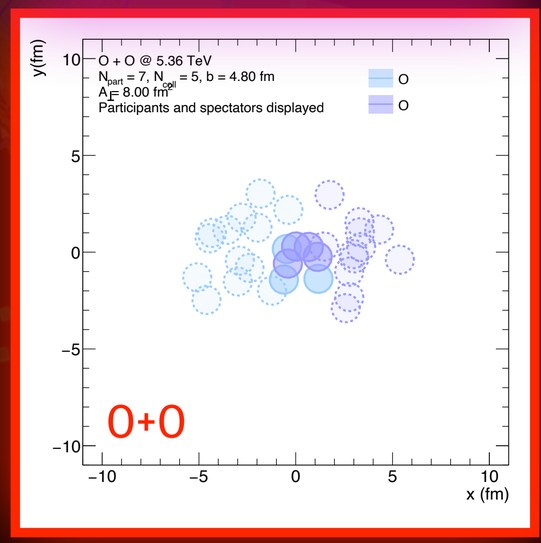
Similar areas for different AA at same N_{part}

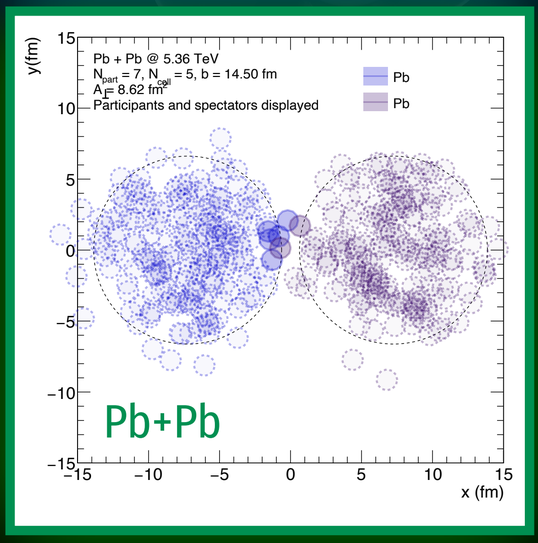


Checking similar areas and N_{part} in Glauber



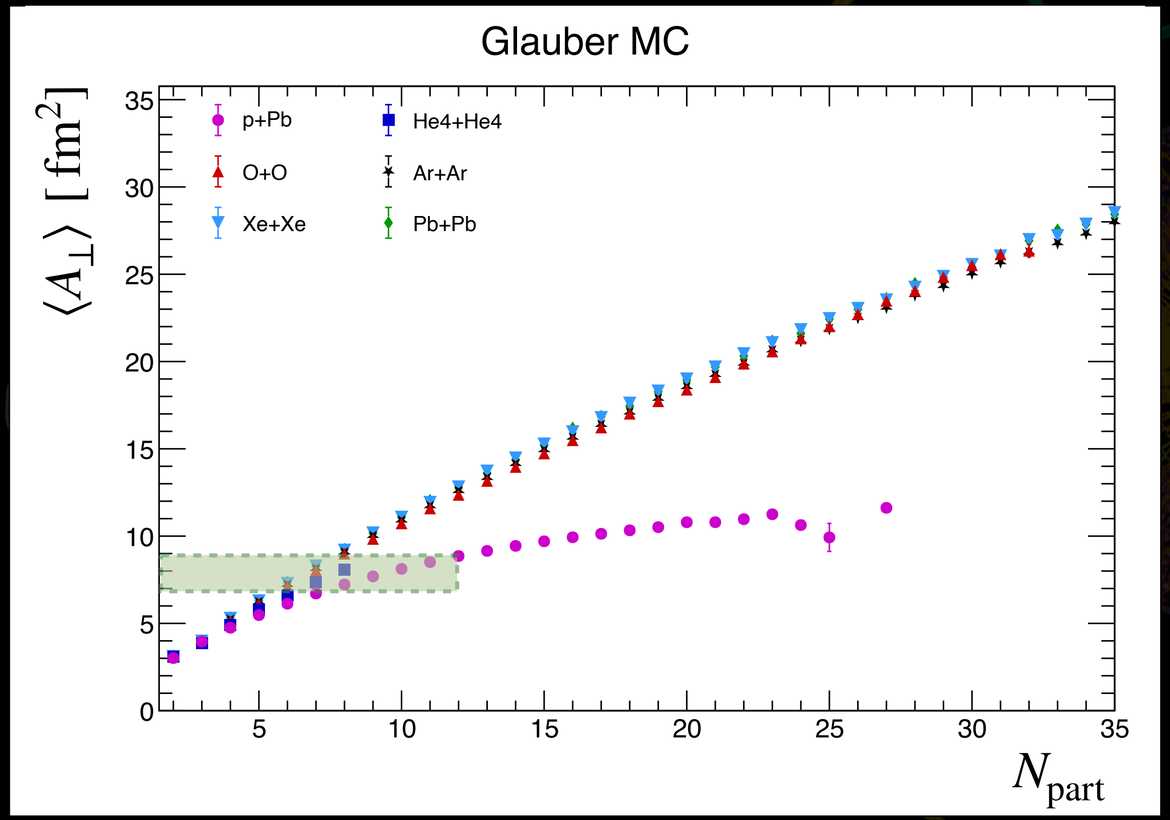




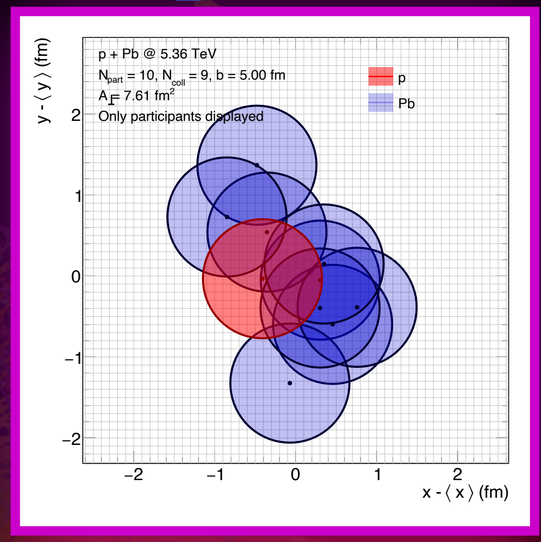


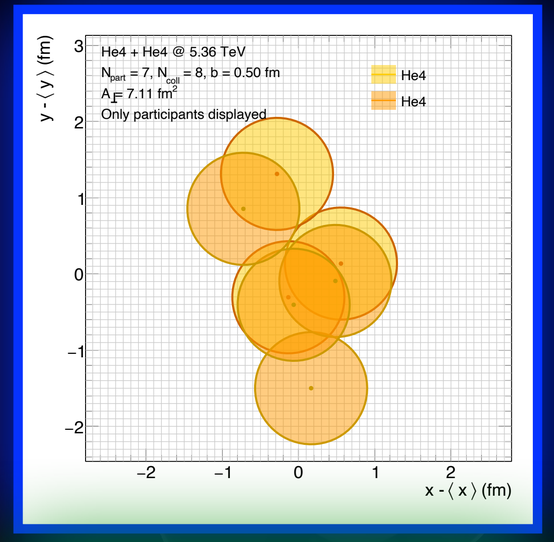
Transverse area & eccentricity of the collision

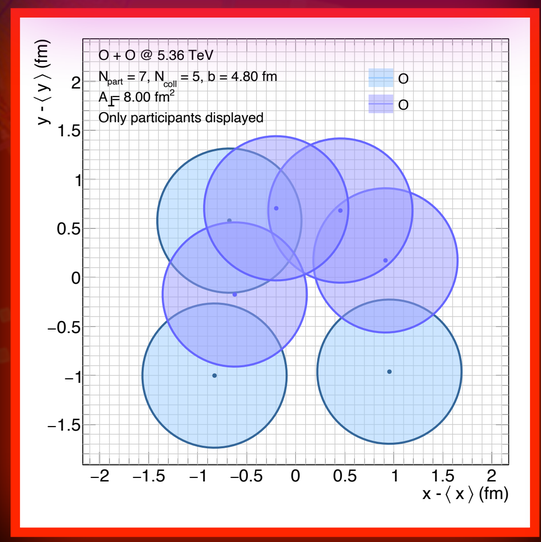
Similar areas for different AA at same N_{part}

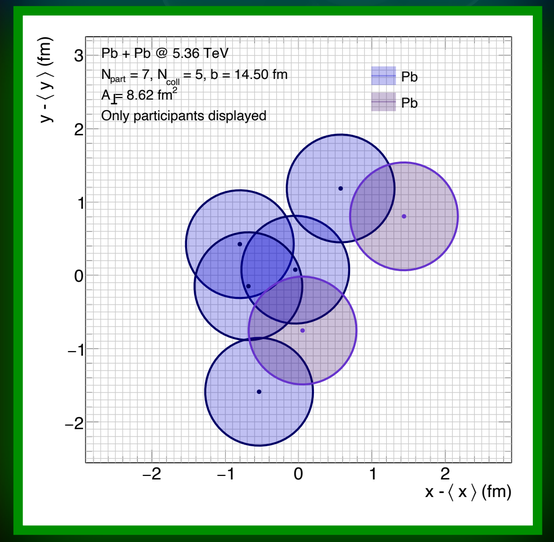


Now focusing on the participants' region

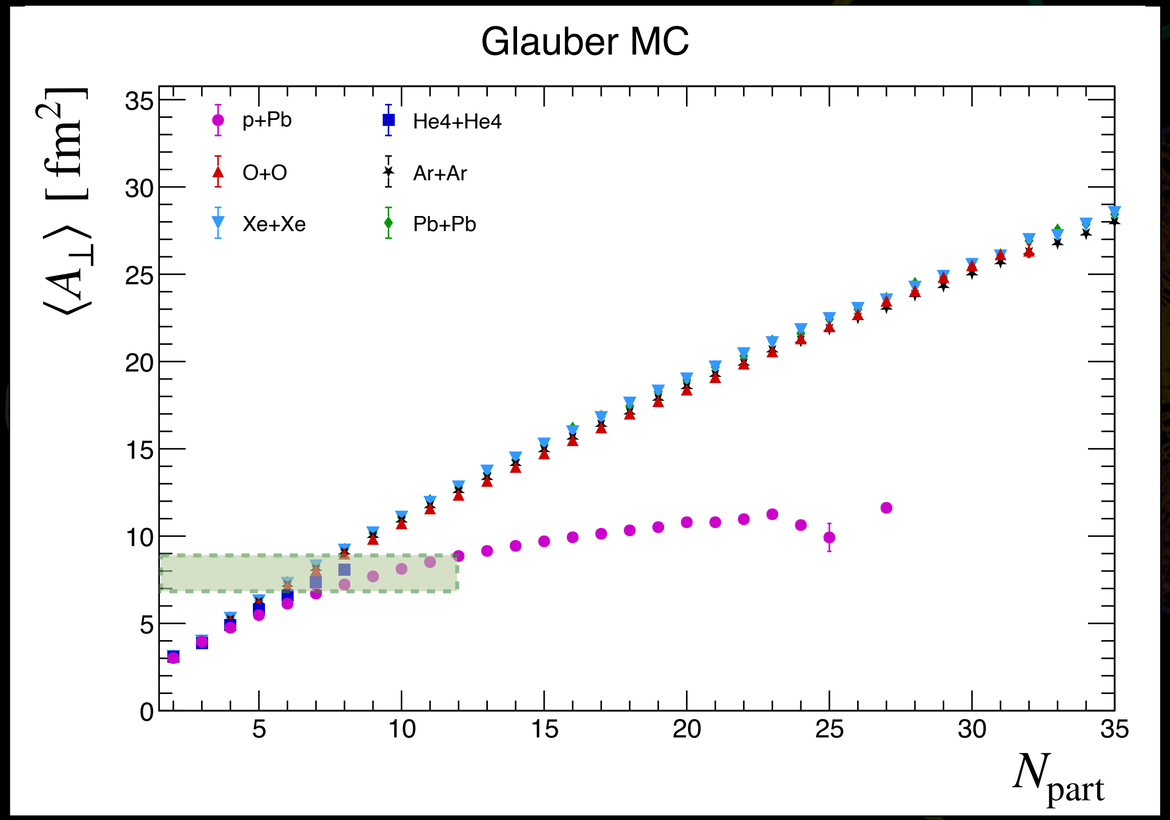




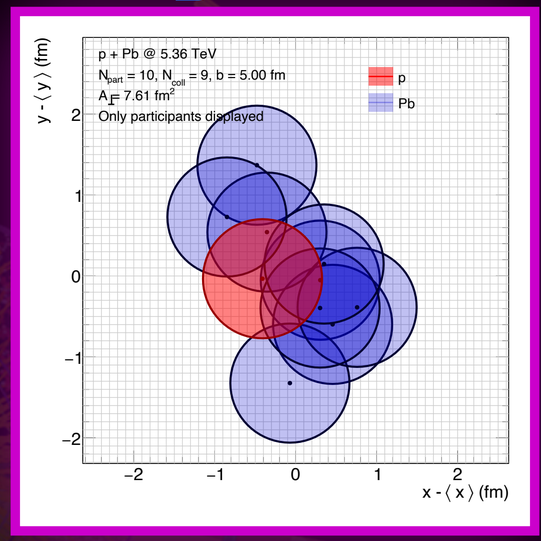


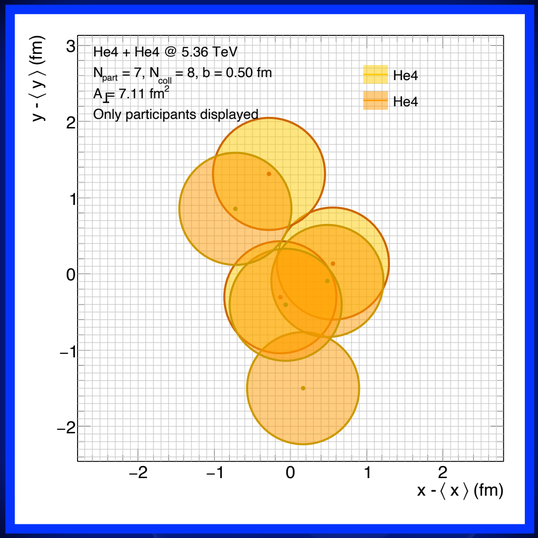


Transverse area & eccentricity of the collision



Additional reminder: protons in p+Pb are not always ‘average’-sized protons;
See Phys. Rev. D 98, 071502(R) (2018), ATLAS Phys. Rev. Lett. 132, 102301 ++

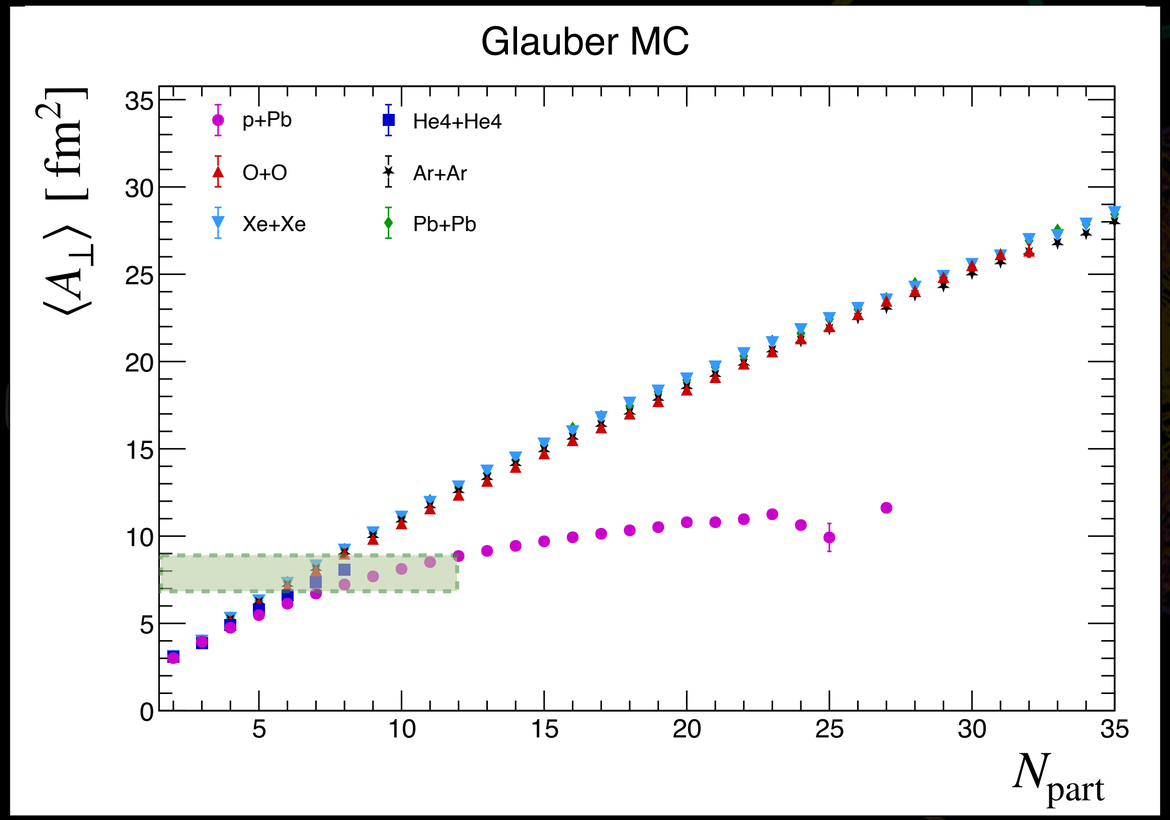


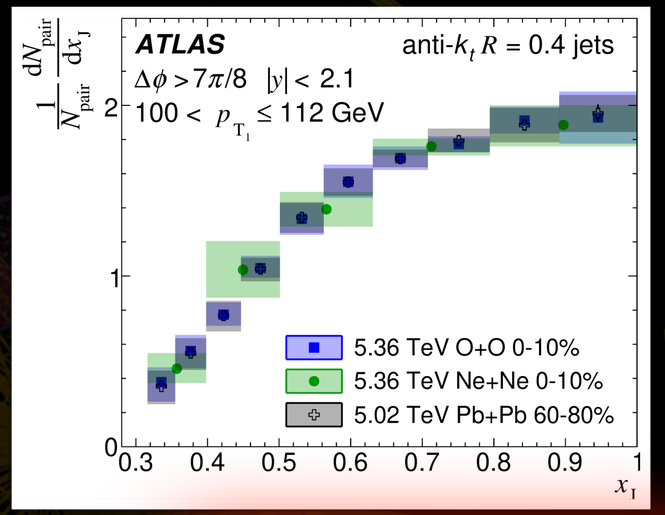


“Central” p+Pb vs head-on He+He
Similar transverse area and number of binary collisions - but very different geometry!

➡ Is there tangible energy loss in He+He?

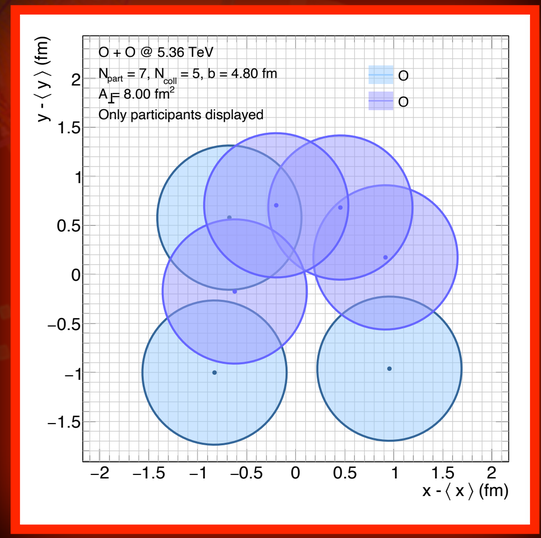
Transverse area & eccentricity of the collision

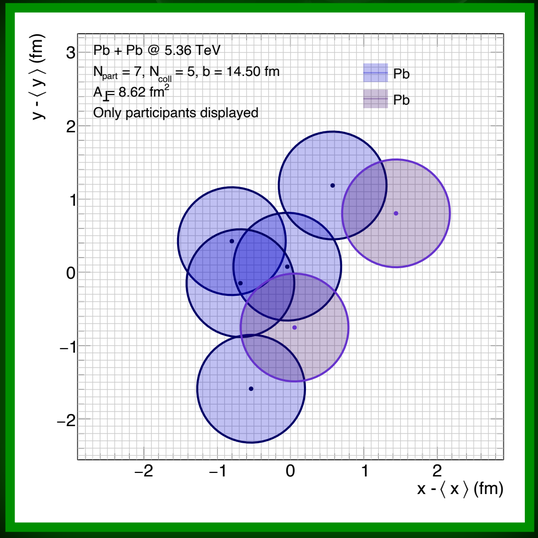




Suggestive agreement for dijet asymmetry between central OO and NeNe, and event-activity matched peripheral PbPb

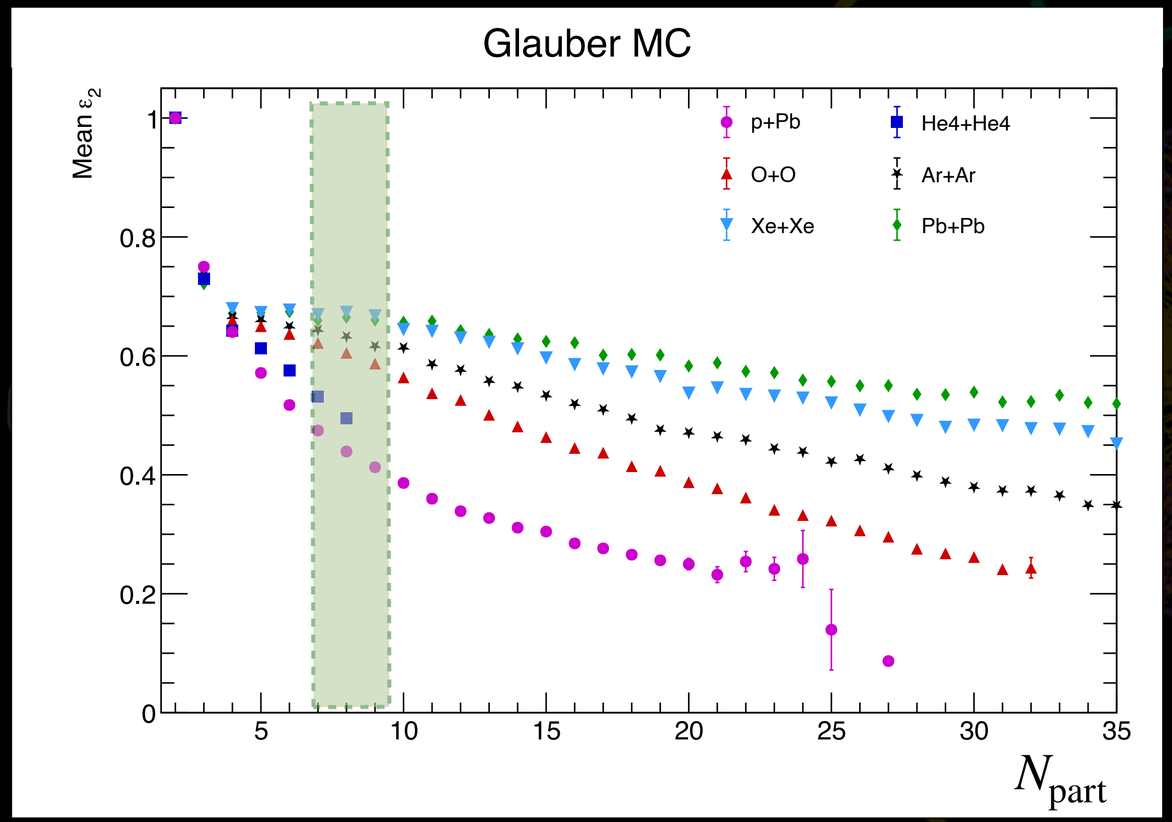
➡ We can now study better peripheral PbPb with Run 3 statistics





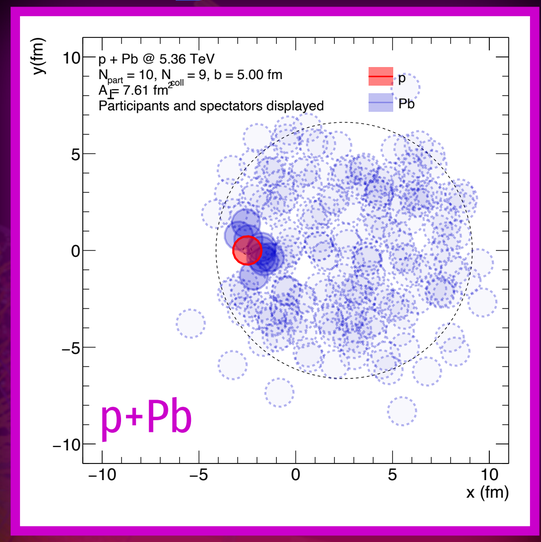
Transverse area & eccentricity of the collision

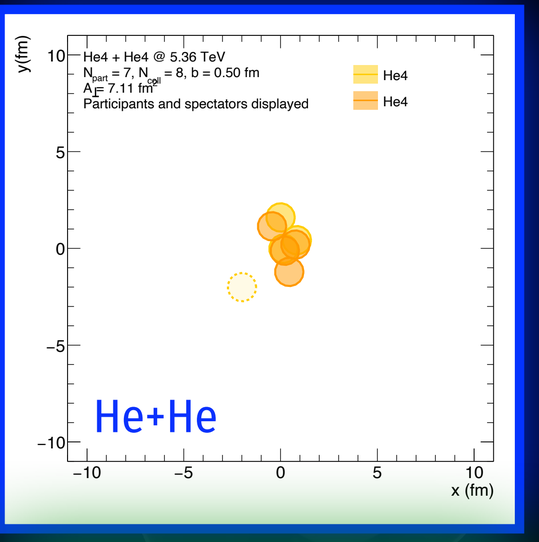
Very different eccentricity (geometry)

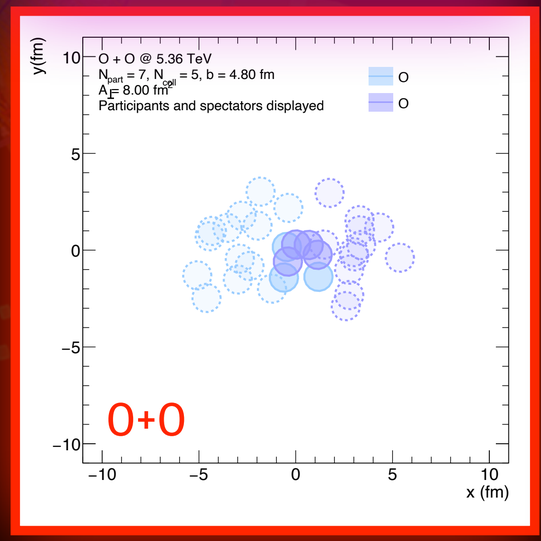


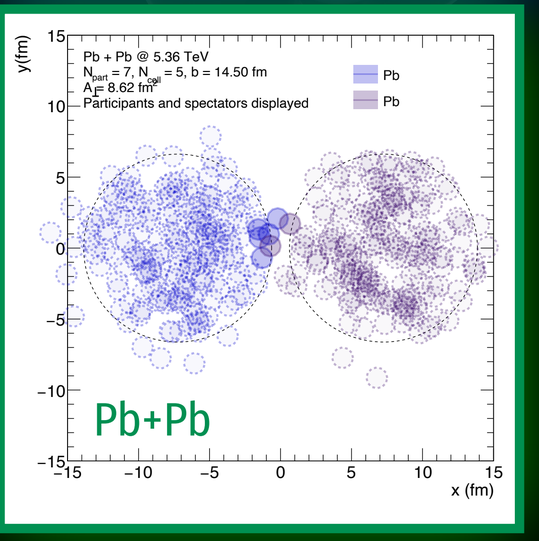
and constraining power for it

➡ Different path-length phase space to explore

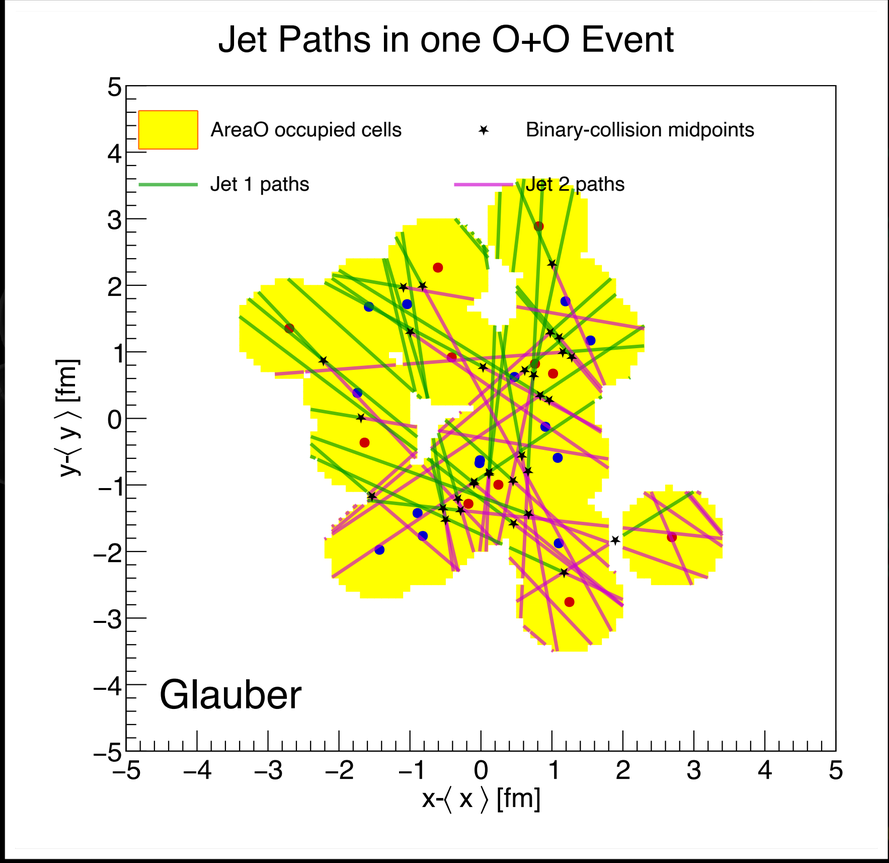








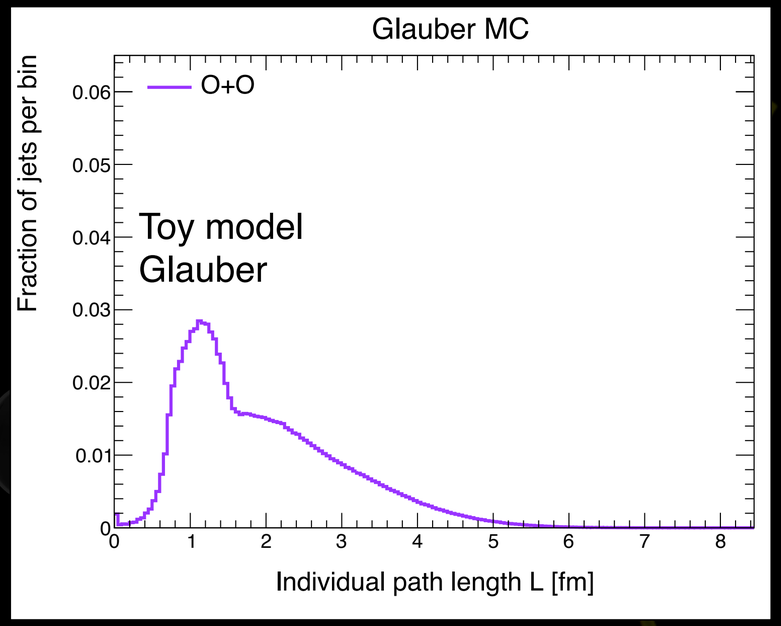
A simple model for path-length

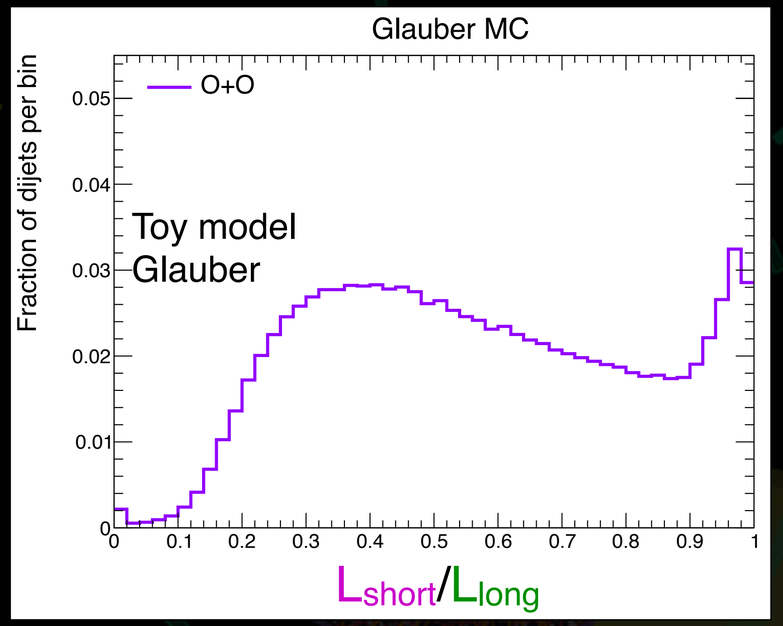


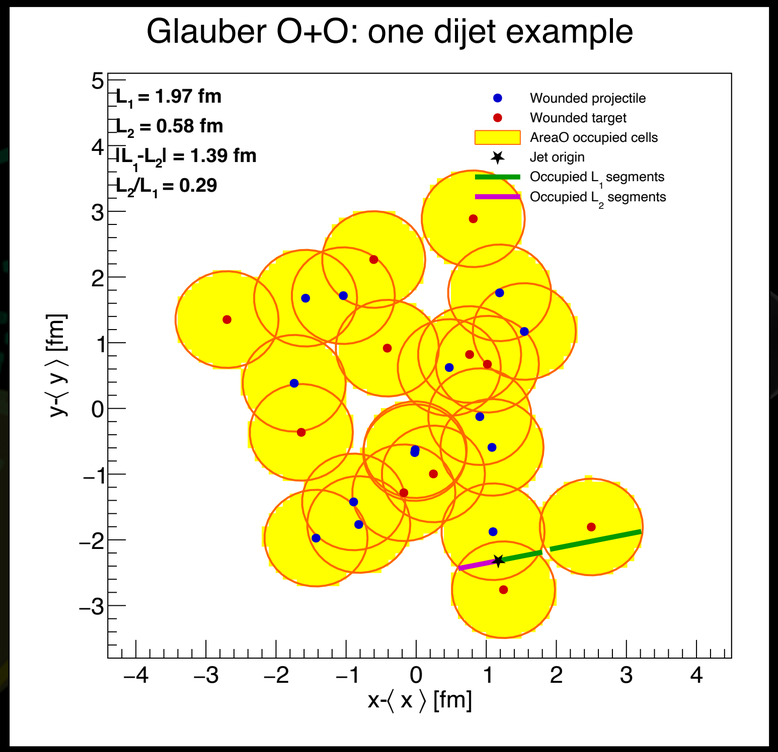
Simple toy model starting from Glauber (or Angantyr) collision geometry:

- Consider a binary collision midpoint as the origin of the (back-to-back) dijet pair
- Randomize the direction for the back-to-back emission
- Compute the path length through the transverse area
- Repeat it for all the possible binary collisions (i.e. nucleons that overlap) in the configuration

A simple model for path-length: O-O example



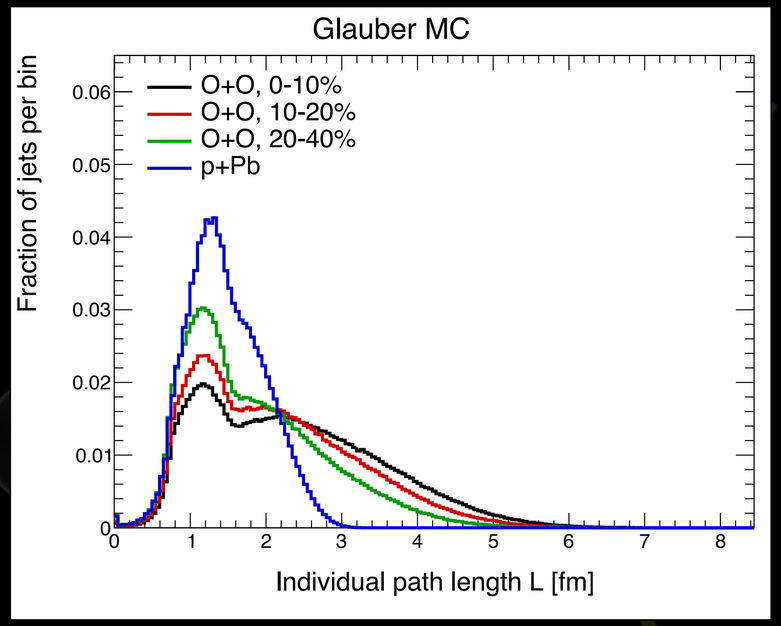


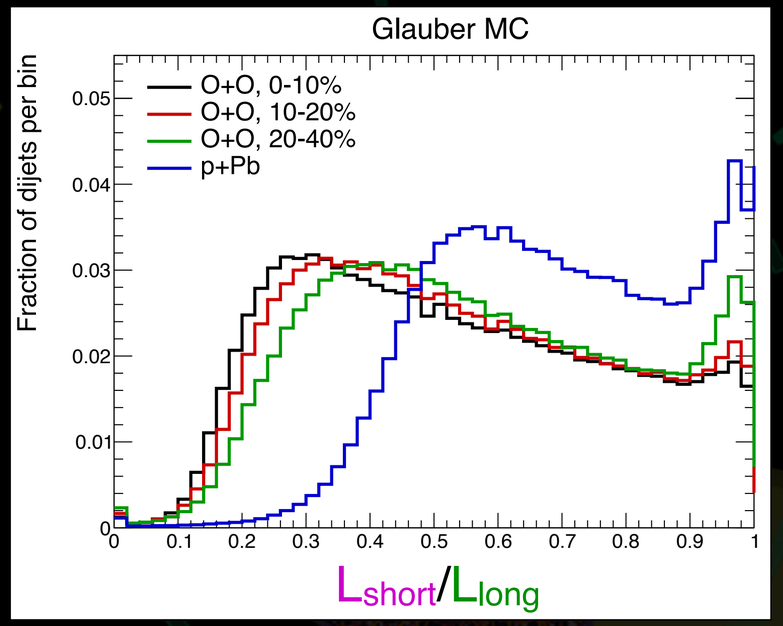


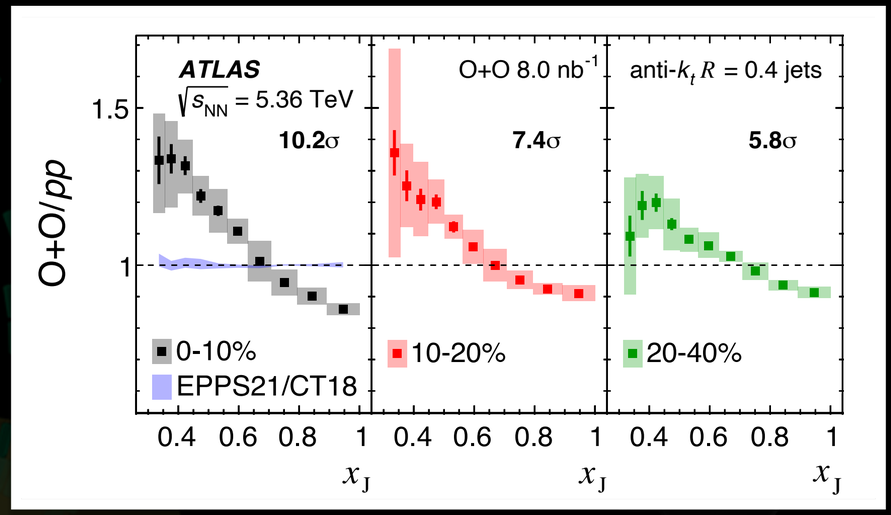
- Structures observed are mainly related to collisions with N_{Part} = 2, convoluted with different geometries of the collision;

- How does this look in different centrality selections?

Scanning through geometries

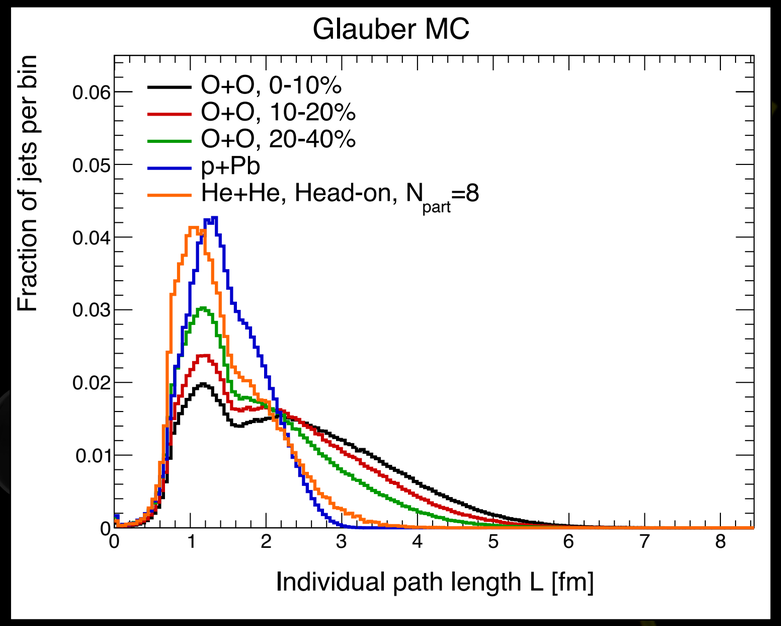


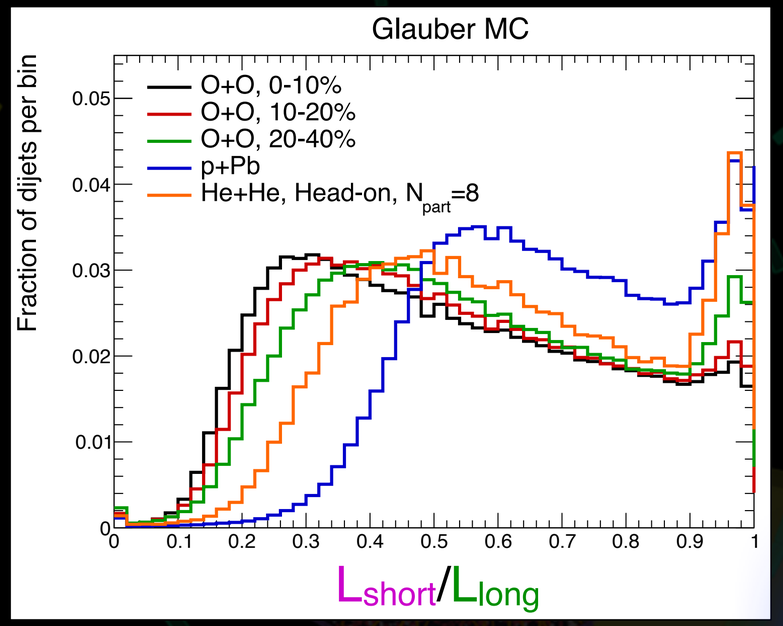




- Centrality classification in MC based on N_{Coll} - same classes as ATLAS observation of energy loss w/ dijets
- Path lengths significantly different from p+Pb (no quenching)
- Can we learn something by adding He+He collisions?

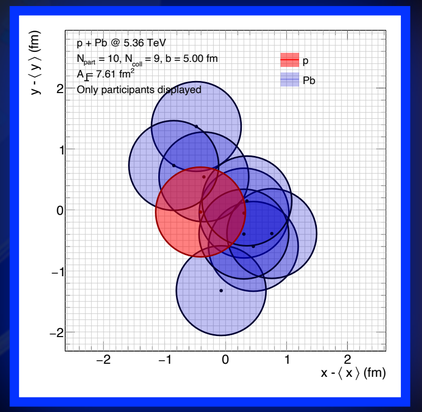
Adding head-on He+He to the picture

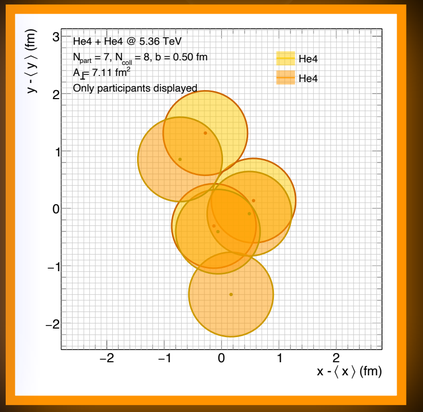




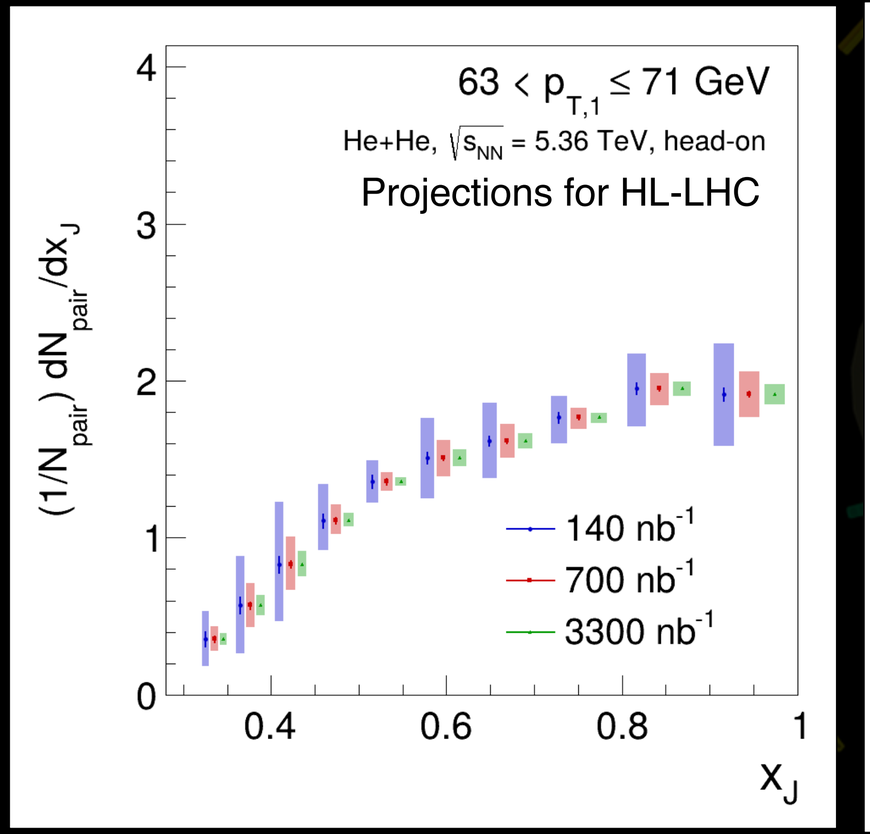
- Caveat: the smaller the system, the harder it is to define centrality
  - I.e., likely a no-go for He, but selections on head-on collisions could be studied

- Comparison between p+Pb and head-on He+He is going to be *extremely interesting*
  - Similar path lengths, but very different collision system geometry (i.e. more symmetric - not driven by the proton size)

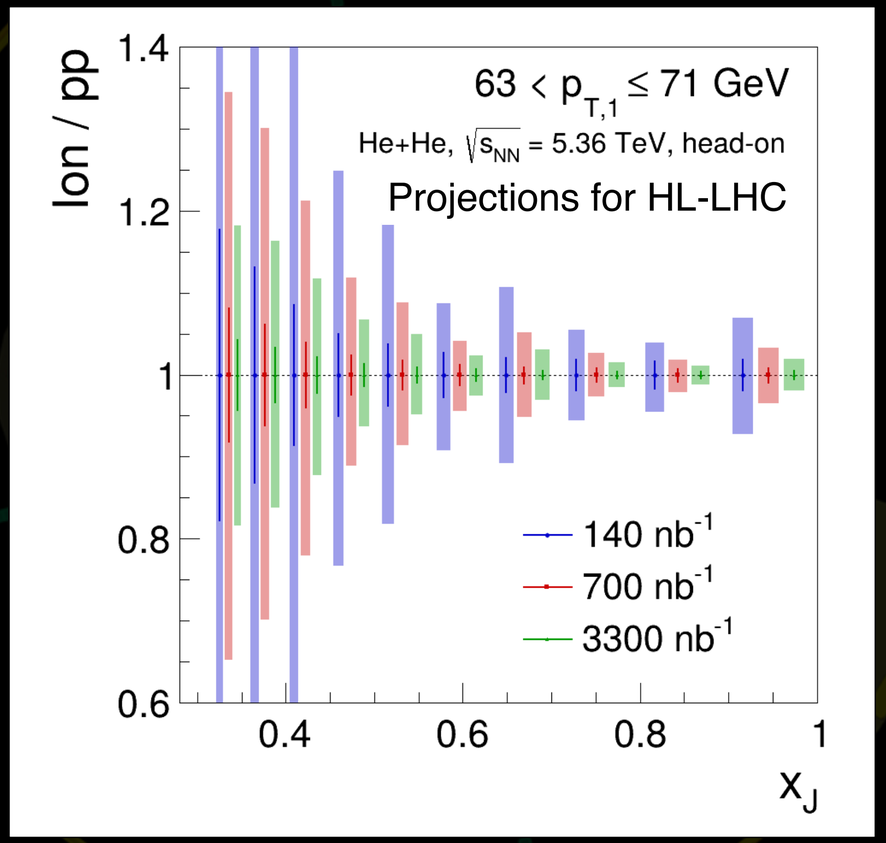




Projections for HL-LHC



x_J distribution
(pp data used to position the points)



Ratio He+He head-on / pp

- WIP. Here focus on He+He head-on collisions;
- Example of the lowest leading-jet p_T bin (same kinematic selections as for the ATLAS dijet results);
- Conservatively assuming the same level of syst/stat ratio;
- Three scenarios (w/ hypothetical luminosities):
  - **~1 day**
  - **~1 week**
  - **~4 weeks**

Summary

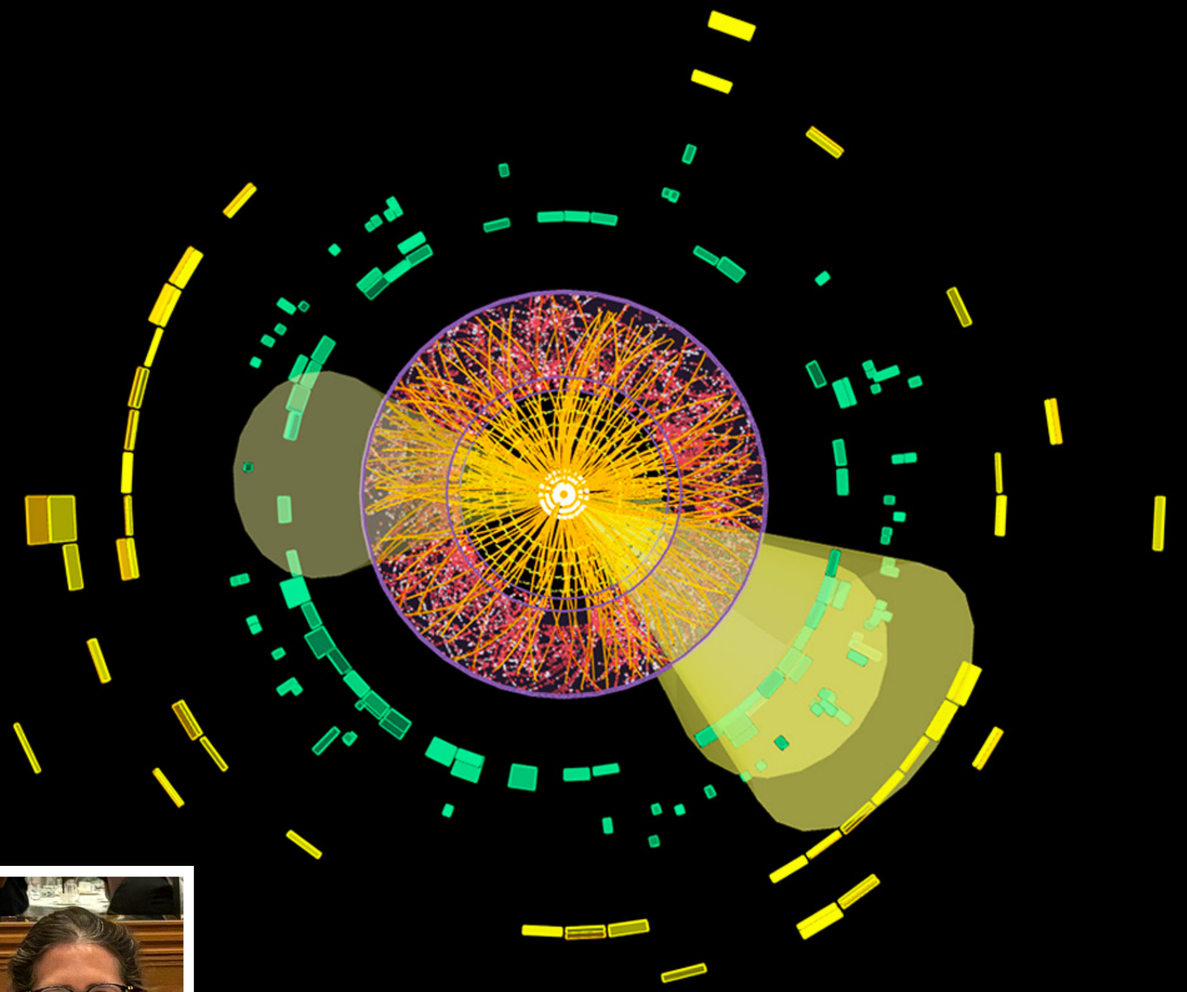
- The 2025 Light Ion run is providing unique input to advance our understanding of partonic energy loss - and we can expect much more in the coming year(s)

- A basic exercise with dijets and Glauber shows that many questions remain.
  ➡They will likely not be answered with the existing LI datasets alone.

- We have a unique opportunity to plan data-takings that enable answering these questions and then unlock a deeper understanding of partonic energy loss
  ➡See also *talk by M.Dunford* (Friday - 10:15 AM)

- To be kept in mind: if we miss this train, the next one will be in 30+ years (at the FCC hh - assuming it will be built)

Thank you for your attention!



Credits:



Eliza Marlin

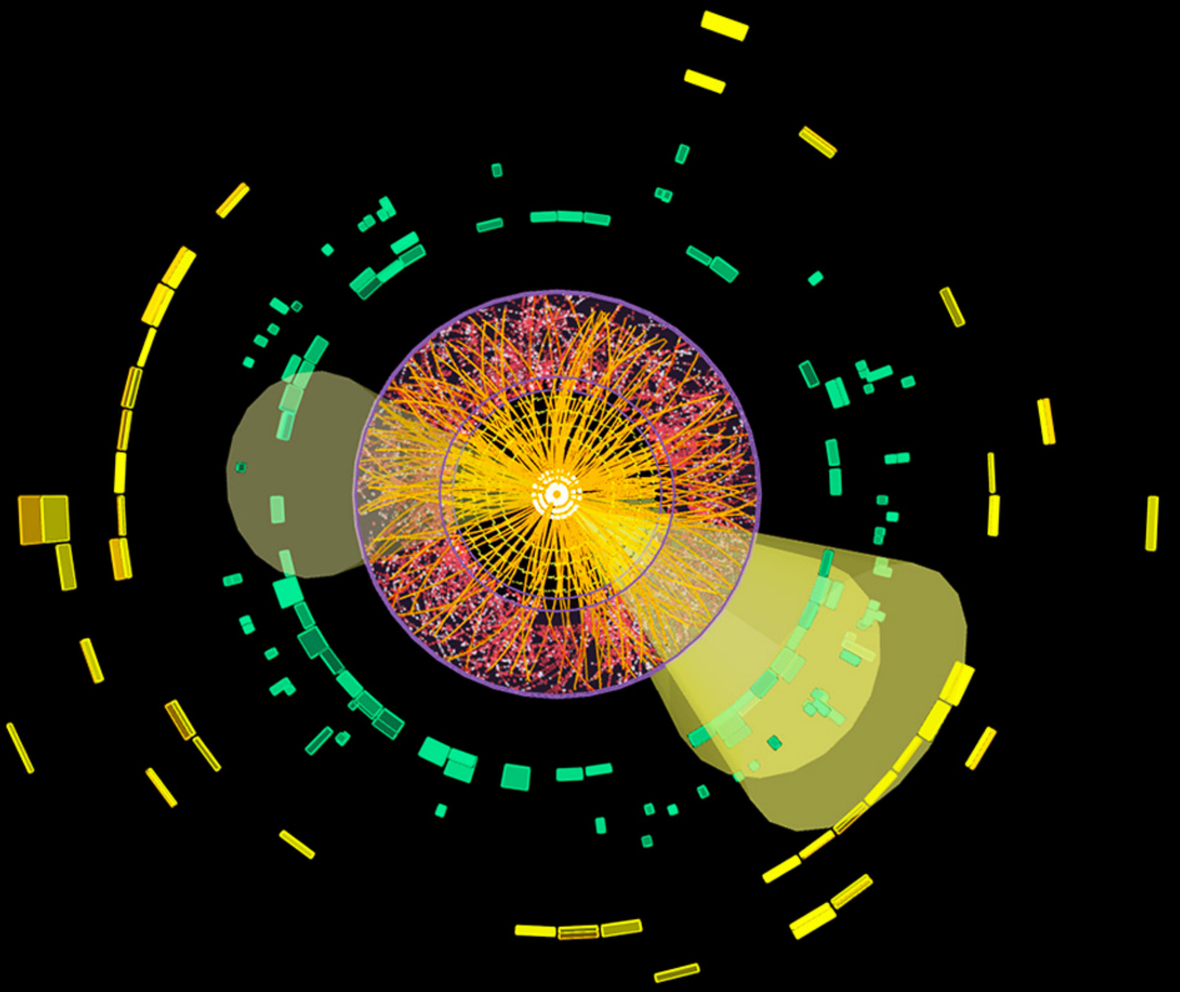


Sierra Cantway



Anne Sickles

Backup Slides



Scanning through geometries and systems: some remarks

- Minimum bias observables are interesting as a first approach, but will bring us only so far and do not carry great constraining power for path-length dependence
- Defining centrality clearly adds to the understanding of different contributions to the path-length dependence across systems
- So far, our path-length studies have focused on OO and smaller systems to probe the onset of jet quenching
  - Clearly, bridging the gap between O/Ne and Xe would also be extremely interesting
- Still a lot to learn from peripheral Pb+Pb (and starting from Run 3 the integrated luminosity allows us to study it in detail) and its comparison to lighter ions