Dijet studies at the LHC

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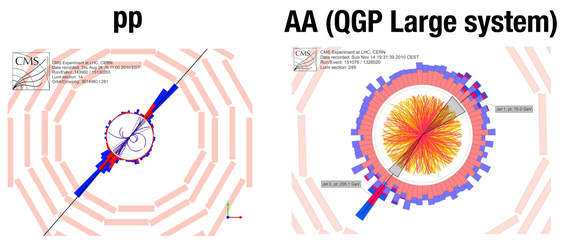
Introduction



High-energy partons generated in collisions create collimated showers of particles, which are called jets. Jets are widely used in heavy ion collisions to study the medium properties of the quark-gluon plasma (QGP). Previous studies from RHIC and LHC indicate that dijet-invariant mass can be sensitive to modifications caused by the QGP medium. In this study we present a model study of dijet mass distributions in Pb–Pb collisions at center-of-mass energy of 5.02 TeV and latest studies of ALICE and ATLAS as a preparation before measuring the dijet invariant mass in LHC RUN3.

Dijet Invariant Mass M_{jj}

A dijet is a system of two most energetic jets in a collision. They are called leading and subleading jet p_1, p_2. Dijet invariant mass is a good tool to probe new physics (BSM) in pp collision. In Pb-Pb collision, it can be complementary to see dijet asymmetry. Also, dijet invariant mass can be detected easier than momentum due to about 2 times larger kinematic region. [1] Dijet invariant mass is defined 4-vector equation as:

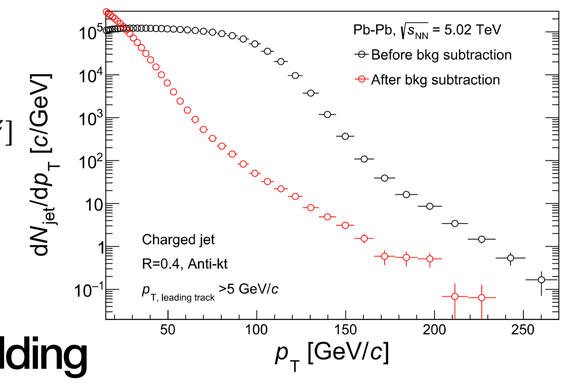
$$\begin{aligned} M_{jj}^2 &= (p_1 + p_2)^2 \\ &= m_1^2 + m_2^2 + 2\big(m_{T,1}m_{T,2}\cosh(\Delta y) - p_{T,1}p_{T,2}\cos(\Delta\phi)\big) \\ &\approx 2p_{T,1}p_{T,2}(\cosh(\Delta\eta) - \cos(\Delta\phi)) \end{aligned}$$

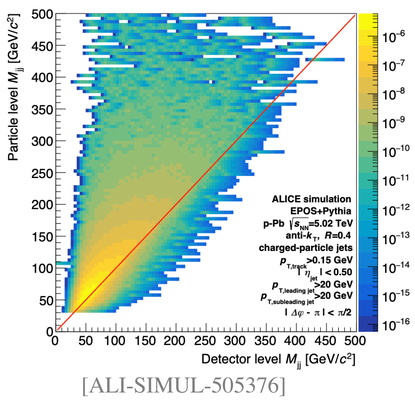
Corrections

Background Subtraction

$$p_{corr}^{\mu} = p^{\mu} - [(\rho + \rho_m)A^E, \rho A^x, \rho A^y, (\rho + \rho_m)A^z]$$

A : *area of a pad*
p_{corr} : *corrected* $4-$*vector momentum*
ρ : *median of detected* p_t *of* A
ρ_m : *median of detected mass of* A





[ALI-SIMUL-505376]

(f) p–Pb combined response matrix

Unfolding

- Full detector simulation for detector effects.
- Include background fluctuations with

$$U_{tot} = U_{bg-fluct} \times U_{det}$$

- Unfold with Bayesian iterative method.
- Figure: BG fluctuations and detector effects combined for p–Pb response.

Recent Studies

Model Study

Simulation model	Collision system	Center of mass energy $\sqrt{s_{NN}}$
AMPT*	Pb-Pb	5.02 TeV

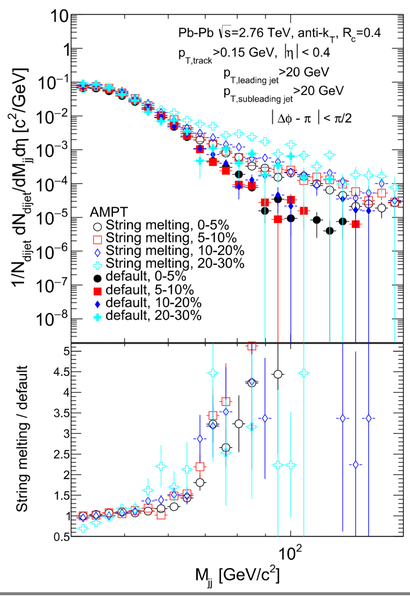
Kt jet	Anti-kt jet	Jet	Jet p_T
$\lvert\eta\rvert > 2$	$R > 0.5$	$\lvert\eta\rvert < 0.4$	$p_T > 20$ GeV

A Multiphase Transport model (AMPT) [2][3]

AMPT is a Monte Carlo simulation model for heavy ion collisions at relativistic energies. The AMPT model has String melting (AMPT-SM) version :

String melting: Initial state expected to have a parton degrees of freedom

In AMPT-SM, the colored strings are melted to form low momentum partons [2]. Dijet invariant mass distribution seems broader and larger in SM than default version in high mass area. The gap might indicate more QGP makes more dijet invariant mass. The sensitive modification in SM expected to be caused of larger radiations of jets in QGP.

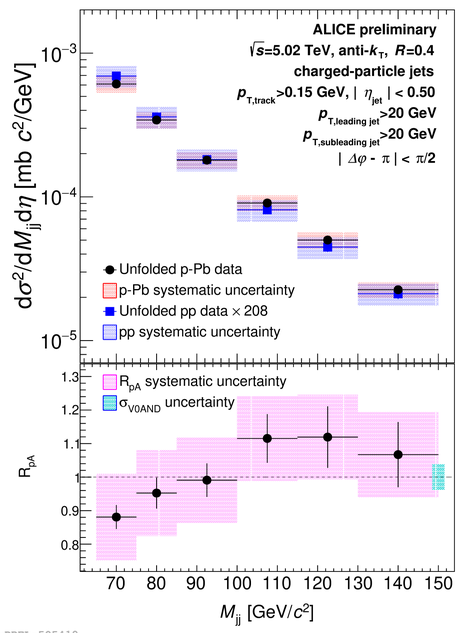


ALICE

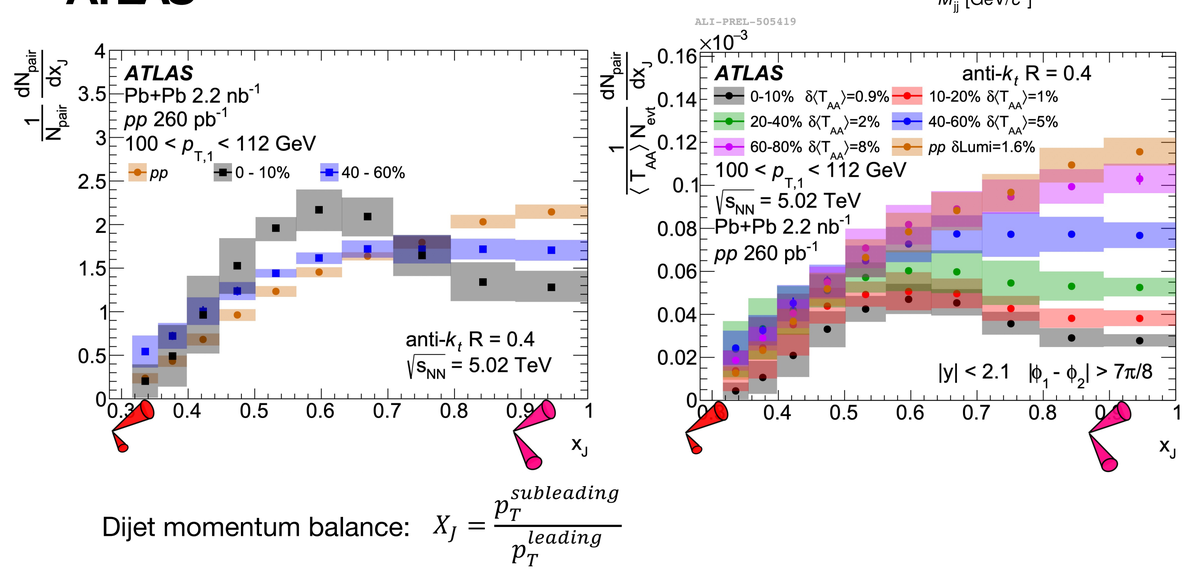
- Result in pp measured in 2017 and p-Pb in 2016.
- Top: Dijet invariant mass in pp and p-Pb.
- Bottom: Nuclear modification factor R_{pA}.
- No significant deviation from $R_{pA} = 1$.

Future plans

- Model comparisons to R_{pA}
- Later extend the analysis to Pb-Pb.

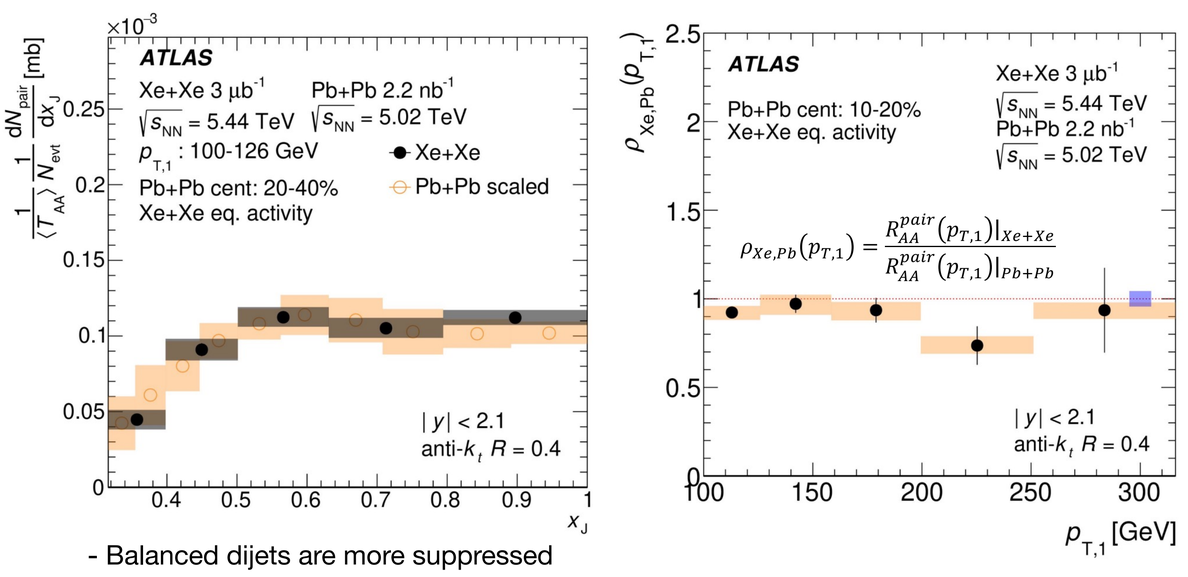


ATLAS [4]



Dijet momentum balance: $X_J = \frac{p_T^{subleading}}{p_T^{leading}}$

- Peak-like structure may falsely suggest the enhancement of production of imbalanced jets
- Absolutely normalized X_J show that balanced dijets are more suppressed compared to imbalanced ones
- Smooth centrality evolution
- Development of a peak at $X_J \approx 0.6$?



- Balanced dijets are more suppressed
- Imbalanced dijets are more probable configuration than balanced ones in Pb-Pb, Xe-Xe
- Dijet yields are consistent with each other when compared in the same activity intervals and after correcting for the difference in the $\sqrt{s_{NN}}$ between Pb-Pb and Xe-Xe

Conclusion

We present the dijet invariant mass distribution with AMPT in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The dijet mass shows a modification between the string melting and default model in high mass area. Also, the latest studies at ALICE shows that nuclear modification factor has no significant deviation in p-Pb collsions. ATLAS shows that balanced dijets of Pb-Pb collision are more suppressed and it does in Xe-Xe as well.

References

[1] Pachal, Katherine. Search for new physics in the dijet invariant mass spectrum at 8 TeV. Diss. Simon Fraser U., 2015.

[2] Singh, Randhir. "Centrality and Transverse Spherocity dependent study of charged-particle production in Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV using PYTHIA8 Angantyr and AMPT models." *arXiv preprint arXiv:2208.05212* (2022).

[3] Liuyao Zhang. "Implication of two-baryon azimuthal correlations in pp collisions at LHC energies on the QGP", Physics Letters B, Volume 829, 2022, 137063, ISSN 0370-2693, https://doi.org/10.1016/j.physletb.2022.137063.

[4] arXiv: 2302.03967.

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