Disentangling Jet Modification

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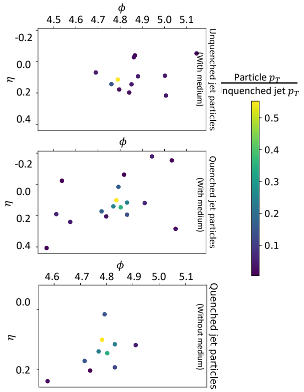
Introduction

Jet modification in heavy-ion (HI) collisions is an important probe to study the structure of the QGP produced in HI collisions. However, in experiment, one cannot know what a jet would have looked like without quenching, making it difficult to interpret measurements in terms of individual jet modification. The goal of this study is to gain insight into the modification of jet observables using the Monte Carlo-based hybrid model in which it is possible to study a jet as it would evolve in vacuum or in medium. We reproduce previous results in the hybrid model that the distribution of groomed ΔR appears to be unmodified, and we show that there is a substantial modification of the ΔR of individual jets, indicating that this apparent lack of modification is a bias effect.

Methods

Hybrid model: hybrid strong/weak coupling model of jet quenching

- Vacuum Pythia shower in evolving hydrodynamic medium (boost-invariant ideal hydrodynamic simulations)
  - Energy loss of partons in medium → formula inspired by strongly-coupled energy loss in holography
  - Turning energy loss off, one can look at unquenched version of any quenched jet in the model
- Hadronization effects and wake of jet propagating in medium
- Can distinguish between particles produced from Pythia shower and particles produced from medium response
- Jets reclustered with anti-kt ($R = 0.4$).

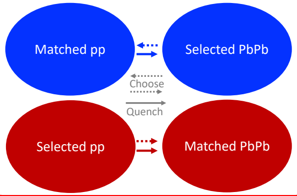


Matching procedure (**not possible in experiment**):

- Look at unquenched and quenched event and compare jets at the same location in the (η, ϕ) plane in one event (azimuthal angle ϕ, pseudorapidity η)
- Match jets by finding the jet in the quenched and unquenched samples that are the same (η, ϕ) location

We study 4 types of hybrid model samples:

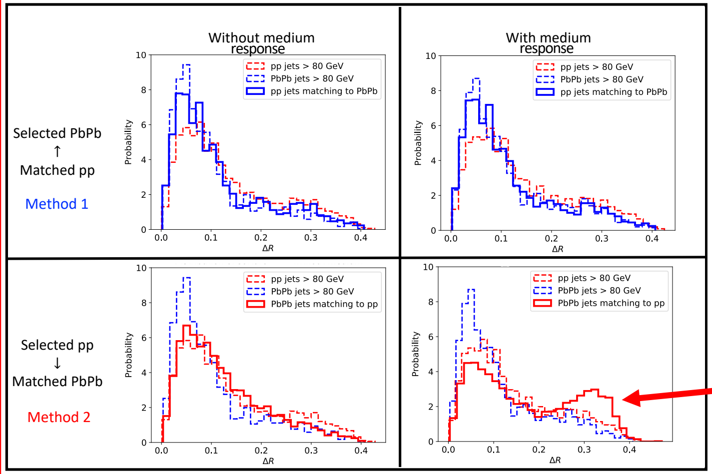
1. Select on pp jets with/without medium response. For each jet, find the PbPb jet that it becomes after quenching.
2. Select on PbPb jets with/without medium response. For each jet, find the pp jet that it came from before quenching.



Results

Method 1: Select PbPb jet with $p_T > 80$ GeV, find pp jet (of any p_T) which matches to it
Method 2: Select pp jet with $p_T > 80$ GeV, find PbPb jet (of $p_T > 30$ GeV) which matches to it

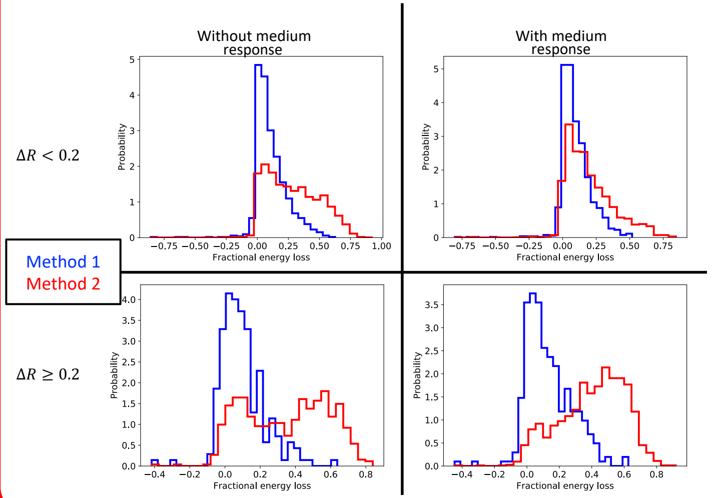
We groomed the jets with a z-cut of 0.10 and $\beta = 0$. The groomed ΔR distributions are shown below for these jets, both with and without medium respons.



Selection Bias in Methods:

- Selection bias in Method 1
  - Most heavy ion jets with $p_T > 80$ GeV don't lose much energy
  - Method 1 results similar to experiment conclude ΔR remains unmodified
- Method 2 does **NOT** have that selection bias
  - Select on pp sample → heavy ion jets of any p_T are allowed (if they match)
  - Remove selection bias - conclude ΔR is NOT unmodified

- Plot using Method 1 → ΔR distribution remains unmodified after quenching in hybrid model
- Plot using Method 2 → Modification of ΔR on **jet-by-jet basis**



In order to understand what jets are in the excess at large ΔR, we looked at two samples of jets which had $\Delta R < 0.2$ and ≥ 0.2. For these jets, plots of the fractional energy loss show that jets with large ΔR are those which lose most energy, and therefore are the jets that don't end up in distribution of Method 1 due to its selection bias (most heavy ion jets with $p_T > 80$ GeV don't lose much energy)

Discussion

- In the hybrid model, quenching modifies ΔR of jets substantially.
- The jets whose ΔR is substantially modified are those which lose a large fraction of their energy.
- Selecting a jet sample using a cut on the jet p_T in PbPb collisions creates bias towards jets that lose very little energy. These are the jets whose ΔR is not substantially modified.
- By selecting a jet sample using a cut on the jet p_T in pp collisions and looking at the quenched versions of these jets, we remove the bias toward less modified jets and see that the ΔR of individual jets is substantially modified in the hybrid model.
- Modification of ΔR distribution (see Results) is not seen if medium response is excluded. In the hybrid model, the structure of the parton shower is not modified by quenching except that energy can be redistributed among partons. This suggests that this effect does not substantially modify the ΔR distribution, but medium effects do.

References

[1] Casalderrey-Solana, Jorge et al. "A Hybrid Strong/weak Coupling Approach to Jet Quenching." Journal of High Energy Physics 2014.10 (2014): n. pag. Crossref. Web.
[2] Casalderrey-Solana, Jorge et al. "Jet substructure modification probes the QGP resolution length." arXiv 2002.09193 (2020).
[3] Larkoski, Andrew J. et al. "Soft Drop." Journal of High Energy Physics 2014.5 (2014): n. pag. Crossref. Web.
[4] Casalderrey-Solana, Jorge et al. "Angular Structure of Jet Quenching Within a Hybrid Strong/weak Coupling Model." Journal of High Energy Physics 2017.3 (2017): n. pag. Crossref. Web.