Disentangling Jet Modification in Jet Simulations and in Z+Jet Data

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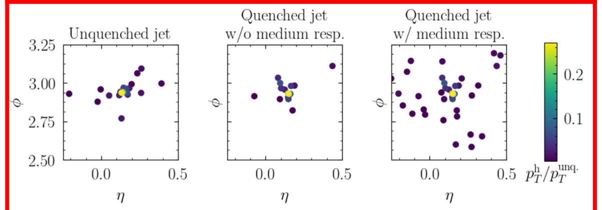
Introduction

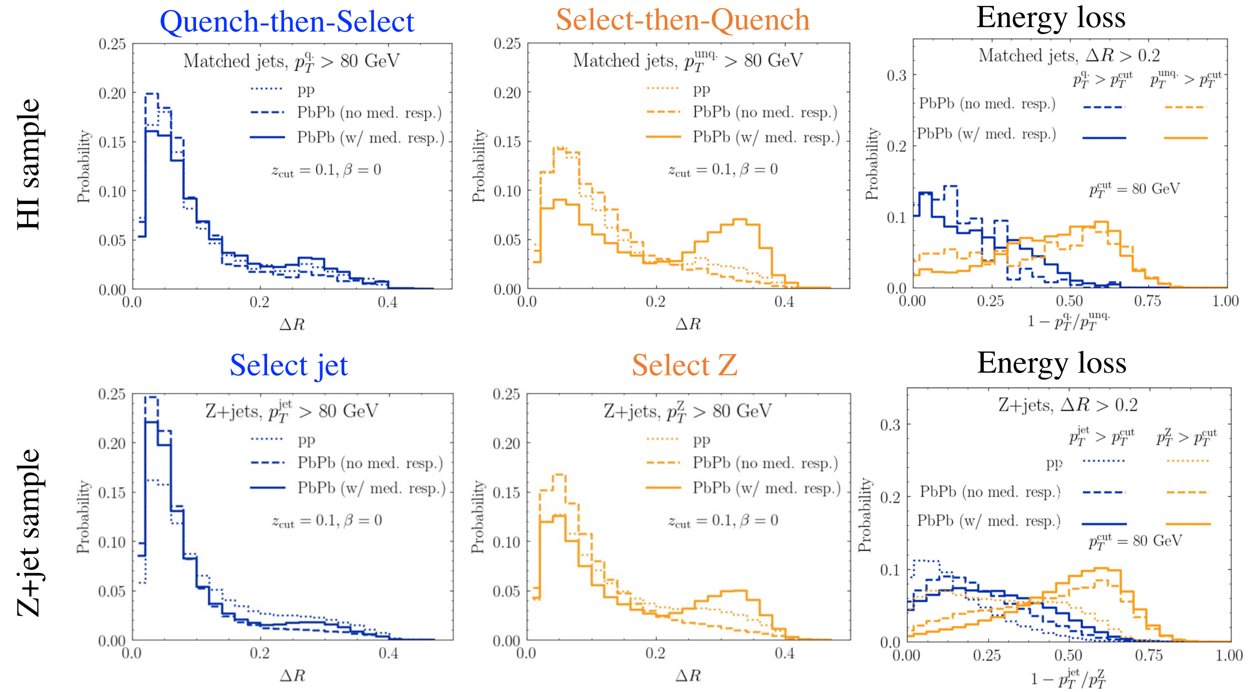
Jet modification in heavy-ion (HI) collisions is an important probe to study the structure of the QGP produced in HI collisions. However, in experiment, one cannot know what a jet would have looked like without quenching, making it difficult to interpret measurements in terms of individual jet modification. 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. To create an experimentally-verifiable analogy, we show the same analysis holds for Z+jet collisions.

Methods



- Hybrid model: hybrid strong/weak coupling model of jet quenching
- Matched jets = jets in quenched and unquenched samples at the same (η, ϕ) location
- For Z+jet samples, compare observables of Z boson with those of jet with highest recoiling p_T
- **Quench-then-Select/Select Jet**: in HI collisions, select on quenched p_T; in Z+jet collisions, select on p_T of highest-p_T recoiling jet
- **Select-then-Quench/Select Z**: in HI, select on unquenched p_T; in Z+jet, select on p_T^Z

Results



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

- Selection Bias in Methods:
  - Selection bias in Quench-then-Select/Select Jet
    - Most heavy ion jets with $p_T > 80$ GeV don't lose much energy
    - This method's results similar to experiment – conclude ΔR remains unmodified
  - Select-then-Quench/Select Z 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: modification of ΔR on jet-by-jet basis
- Effect is not dependent on grooming: can show similar distribution for C_1^1
- 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 Quench-then-Select/Select Jet 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.
- The methods outlined for the HI sample (particularly, Select-then-Quench) are not feasible in experiment. However, the analysis of Z+jet collisions is an analysis that can be performed on experimental data.

References

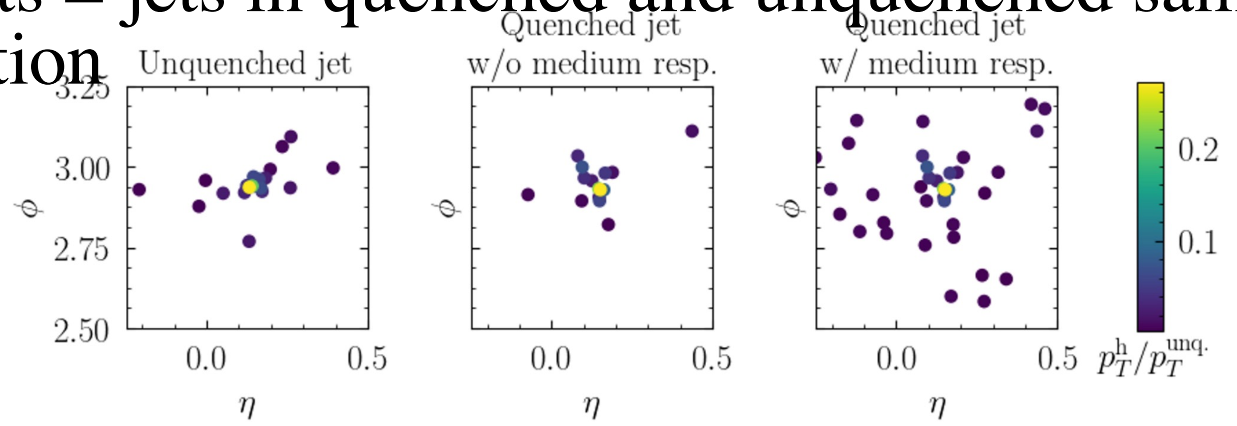
Brewer, J., Brodsky, Q. & Rajagopal, K. Disentangling jet modification in jet simulations and in Z+jet data. J. High Energ. Phys. 2022, 175 (2022). https://doi.org/10.1007/JHEP02(2022)175

Introduction

- In experiment, one cannot know what an individual jet would have looked like without quenching
  - How to best to study jet modification, given that selection biases also modify observed distributions?
- Monte Carlo-based hybrid model: possible to study a jet as it would evolve in vacuum or in medium.
- Reproduce previous results in the hybrid model that the distribution of groomed ΔR appears to be unmodified
- Substantial modification of the ΔR of individual jets → apparent lack of modification is a bias effect.
- Analogous experimentally-realizable approach: Z+jet collisions

Methods

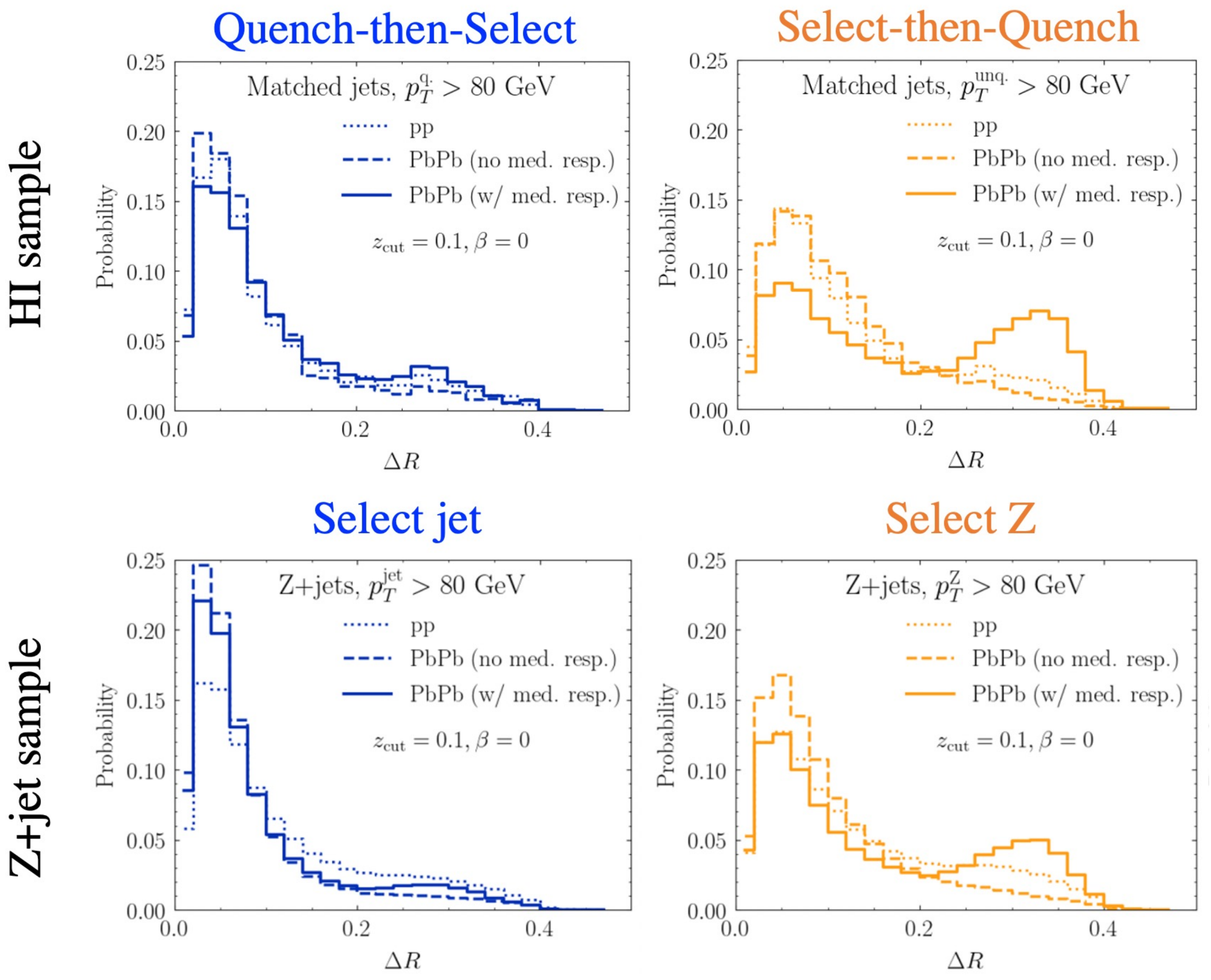
- Hybrid model: hybrid strong/weak coupling model of jet quenching
- Matched jets = jets in quenched and unquenched samples at the same (η, ϕ) location



- **Quench-then-Select/Select Jet**: in HI collisions, select on quenched p_T; in Z+jet collisions, select on p_T of highest-p_T recoiling jet
- **Select-then-Quench/Select Z**: in HI, select on unquenched p_T; in Z+jet, select on p_T^Z

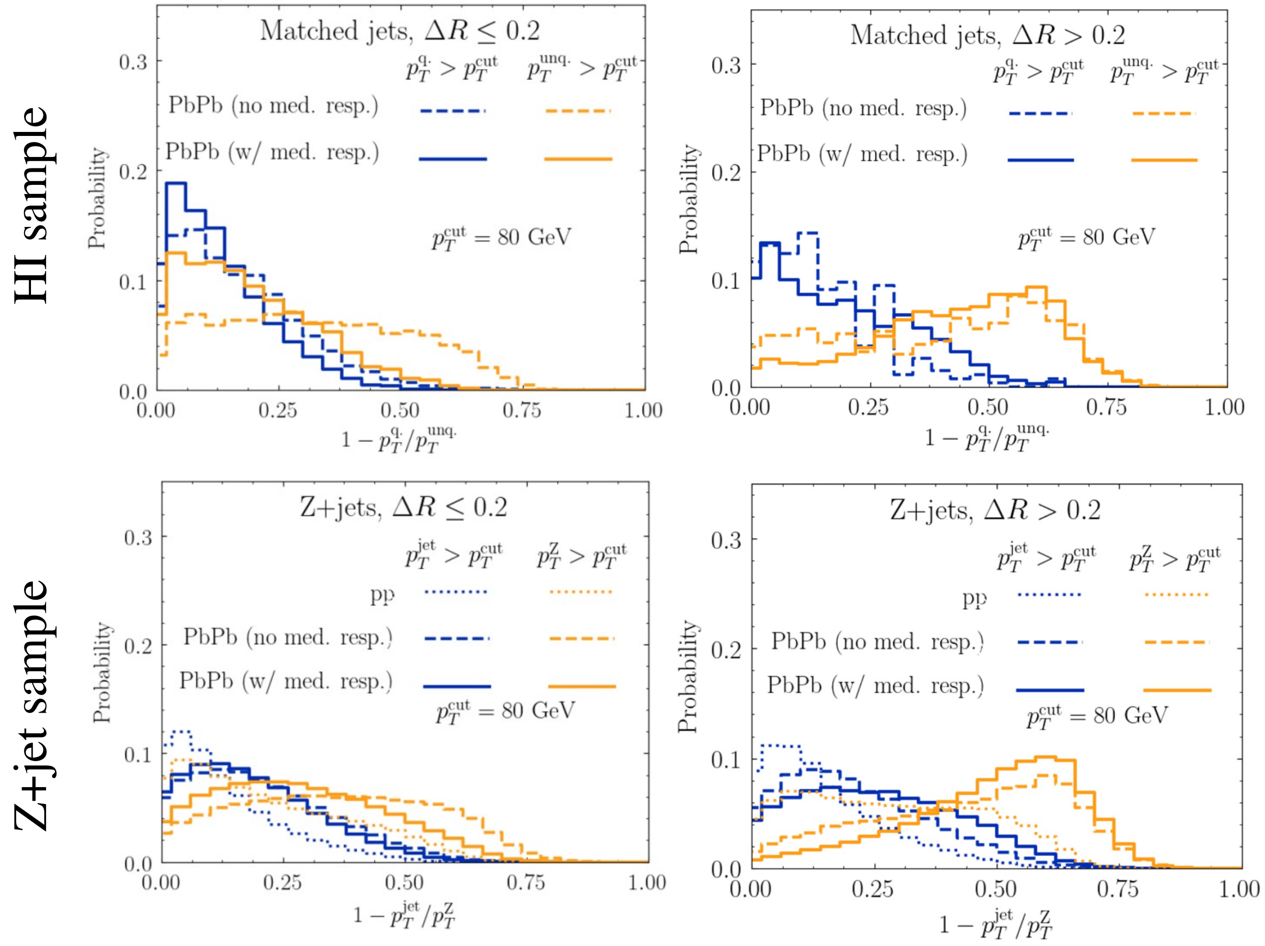
Results

- z-cut = 0.10 and $\beta = 0$, with and without medium response
- Selection bias in Quench-then-Select/Select Jet
  - Most heavy ion jets with $p_T > 80$ GeV didn't lose much energy
  - Similar to experiment – conclude ΔR distribution remains unmodified
- Select-then-Quench/Select Z does NOT have that selection bias
  - Select on pp sample → heavy ion jets of any p_T are are included (if they match to a pp jet with $p_T > 80$ GeV)
  - Conclude ΔR distribution is NOT unmodified: modification of ΔR on jet-by-jet basis
- Effect is not dependent on grooming: can show similar distribution for C_1^1



Results

- What jets are in the excess at large ΔR? Study jets with $\Delta R < 0.2$ and ≥ 0.2.
- Jets with large ΔR are those which lose most energy → don't end up in distribution of Quench-then-Select/Select Jet due to its selection bias
  - Most heavy ion jets with $p_T > 80$ GeV didn't lose much energy
- Modification of ΔR only seen when including medium response



Discussion

- Quenching modifies ΔR of jets in the hybrid model
- 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
  - Jets whose ΔR is not substantially modified
  - In Monte Carlo study, select jet sample by placing cut on jet p_T in pp collisions → study quenched versions of these jets → remove bias toward less modified jets. 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.
  - Hybrid model: structure of the parton shower is not modified by quenching except that partons in the shower lose energy.
  - This hardly changes ΔR distribution. Soft partons from medium response (i.e. the "lost" energy") does.
- The Select-then-Quench method outlined for the HI sample is not feasible in experiment.
- The Select Z method is one that experimentalists can employ in analyzing Z+jet events

References

- Brewer, J., Brodsky, Q. & Rajagopal, K. Disentangling jet modification in jet simulations and in Z+jet data. J. High Energ. Phys. 2022, 175 (2022). https://doi.org/10.1007/JHEP02(2022)175
- [other references found in the above paper]