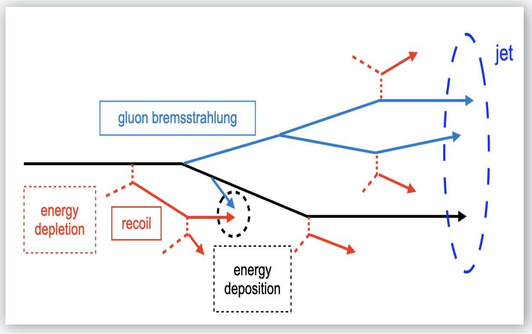
Deep learning on jet modification in the presence of the QGP background

Ran Li[1], Shanshan Cao[1], Yi-Lun Du[2]

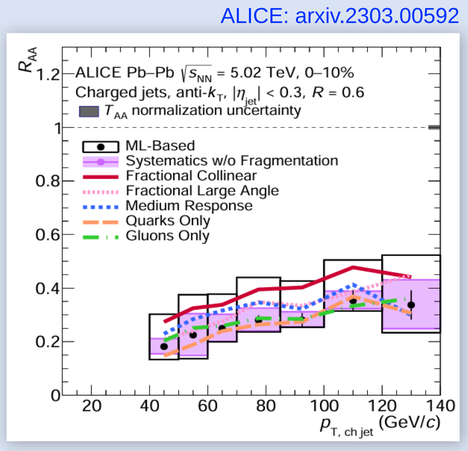
[1] Shandong University [2] Shandong Institute of Advanced Technology

Introduction



- Quark-gluon plasma (QGP) in heavy-ion collisions: deconfined phase, hot dense medium
- Jets are quenched in the medium via parton energy loss

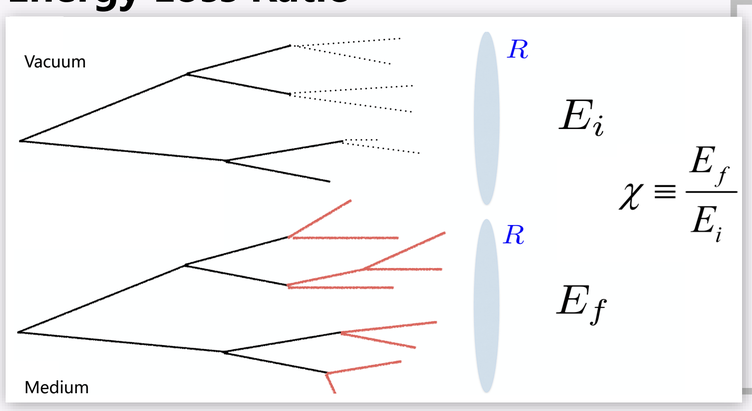
ALICE: arxiv.2303.00592



Machine learning method [1] has already been used in experiments for jets measurement [2].

Prediction of Jet Energy Loss

Energy Loss Ratio



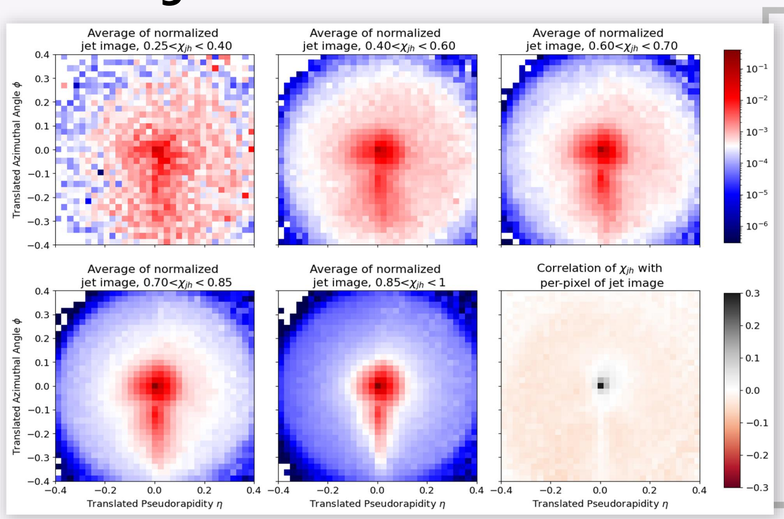
- E_f is the final energy of jet after medium modification
- E_i is the initial energy of jet without medium modification

- Initial jet: Pythia8
- Jet interaction with QGP: linear Boltzmann transport (LBT) model[3]
- QGP background: a thermal model
- Background subtraction: Constituent subtraction method

Constituent subtraction[4]

- local subtraction of soft background
- Constituent-based subtraction is performed particle-by-particle
- Simultaneously correcting the 4-momentum of the jet and its substructure

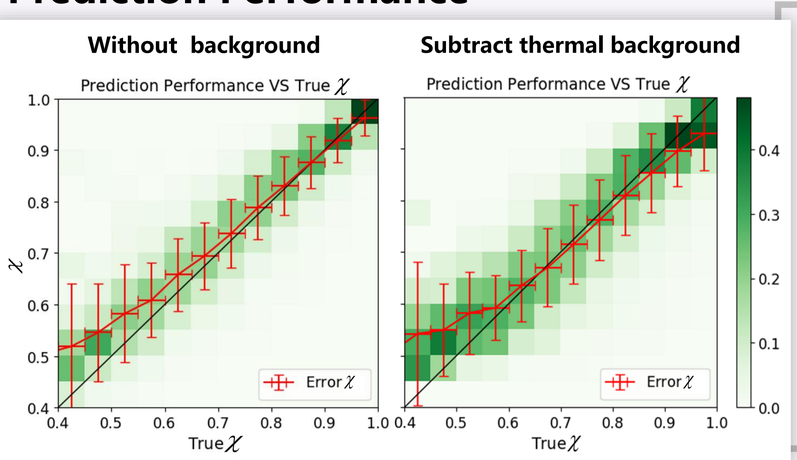
Jet Image



- With background subtraction, jet images basically return to the pattern without background
- Jet quenching increases the number of soft particles at large angles

- For jets images, convolutional neural network (CNN) is a natural choice
- Network architecture: three convolutional layers and one fully-connected layer[5]

Prediction Performance

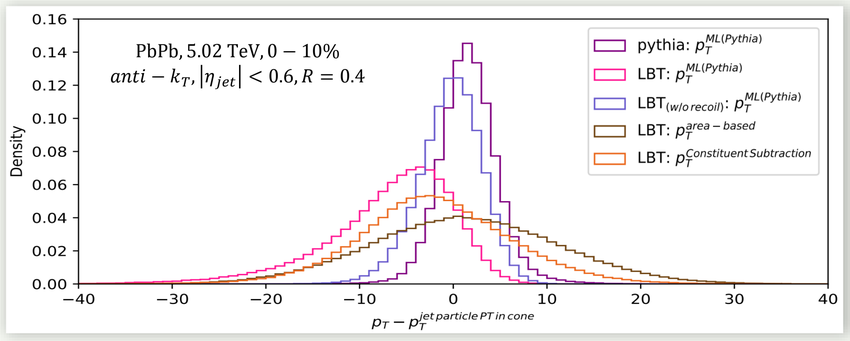


- Well predicted for a wide range of χ
- Exhibit a narrow distribution around the true value
- Slightly decreases when introducing background

Jet Momentum Reconstruction

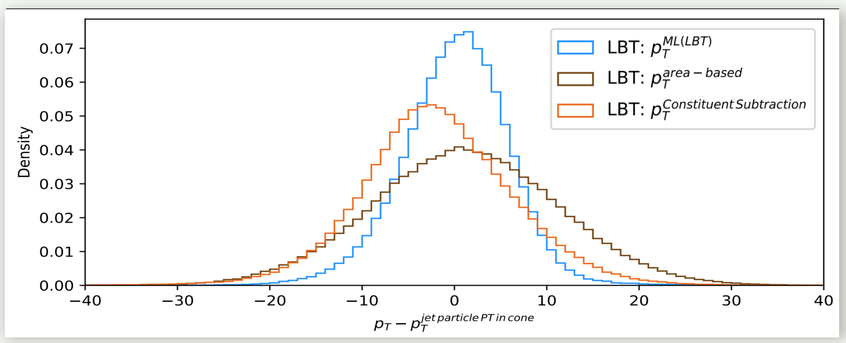
- Area-based method is a conventional background subtraction applied in ALICE, which reconstructs jets momentum with $p_T^{rec} = p_T^{raw} - \rho A$.
- Machine Learning method is used for jet momentum reconstruction by separate training with Pythia jets and their variants to avoid fragmentation bias [1,2] .

Training data: Pythia Output: Jet Particle p_T in cone



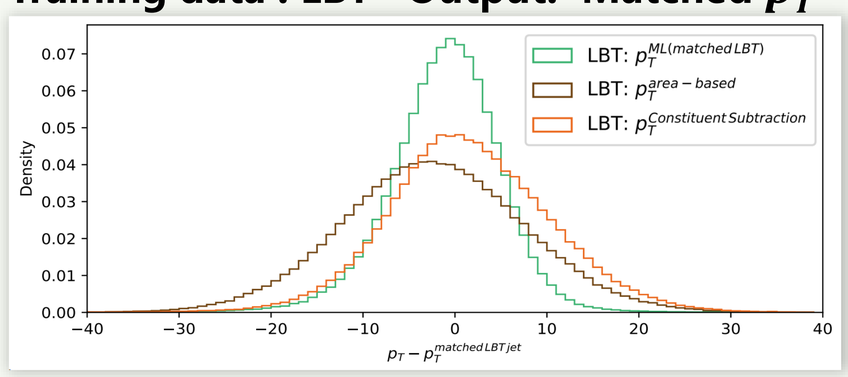
- When training on Pythia data, a bias occurs for prediction on LBT data.
- ML may consider the recoil particles as background.

Training data: LBT Output: Jet Particle p_T in cone



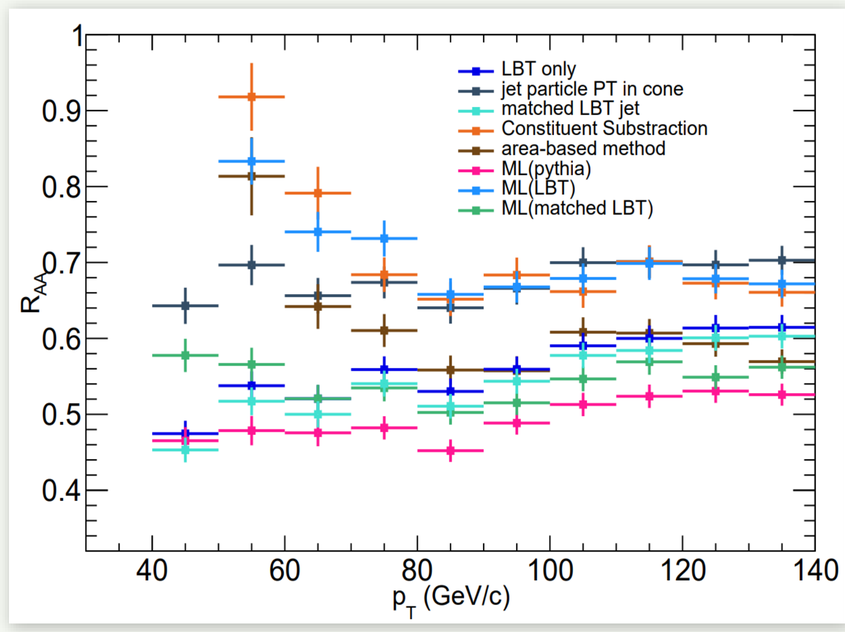
- Less bias when the ML model is trained by LBT data.

Training data : LBT Output: Matched p_T



- Matched p_T: p_T of LBT jet in the absence of background within $\Delta\theta < 0.4$

R_{AA}



- R_{AA} with ML(LBT) is closer to that of "jet particle PT in cone" than ML(Pythia).
- ML(matched LBT) is closest to "LBT only" above 40 GeV.
- To obtain R_{AA} with LBT only, it is helpful to remove fake jets during training.

Conclusion

- CNN can extract energy loss ratio jet-by-jet from jet image with good performance.
- Machine learning is appliable to more realistic environment.
- Machine learning method provides a more precise estimate for the jet momentum by training with the quenched jets.
- By removing the fake jets in the training, we can obtain RAA more accurately.

Reference

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[3] Cao S, Luo T, Qin G Y, et al. Physical Review C, 2016, 94(1): 014909.
[4] Berta P, Spousta M, Miller D W, et al. Journal of High Energy Physics, 2014, 2014(6): 1-16.
[5] Y.-L. Du, D. Pablos and K. Tywoniuk, JHEP03 (2021) 206.