Interpretable ML applied to jet background subtraction in heavy ion collisions

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1. Jet Multiplicity Method

Jet measurements in heavy ion collisions can provide constraints on the properties of the Quark Gluon Plasma (QGP) but the kinematic reach is limited by the presence of a fluctuating background of soft particles not due to hard scatterings. Studies of the background at the Large Hadron Collider (LHC) found that the fluctuations in background energy density of random cones are well described by a random background with correlations arising from hydrodynamical flow and Poissonian fluctuations,

$$\sigma_{\delta p_T} = \sqrt{N\sigma_{p_T}^2 + (N + 2N^2\sum_{n=1}^{\infty} v_n^2)\langle p_T\rangle^2}. \quad (1)$$

where $\delta p_T = p_{T,Cone} - p_{T,Cone}^{Truth}$ is the expected background from the area subtraction method [1, 2].
We propose a multiplicity method as an alternative to the area method,

$$p_{T,jet}^{Corr.N} = p_{T,jet}^{tot} - \rho_{Mult}(N_{tot} - N_{signal}). \quad (2)$$

This approach leverages the natural variable N which drives the width of the δp_T distribution.

2. Machine Learning Methods

Previous applications of machine learning (ML) to jet momentum resolution have demonstrated significant improvements, particularly at low jet momentum, compared to traditional methods of background subtraction [3]. The enhanced performance of ML methods suggests that there is valuable information accessible to machine learning algorithms, which contributes to this improvement. We apply interpretable machine learning techniques to extract analytic expressions from a neural network trained to predict corrected jet momentum.

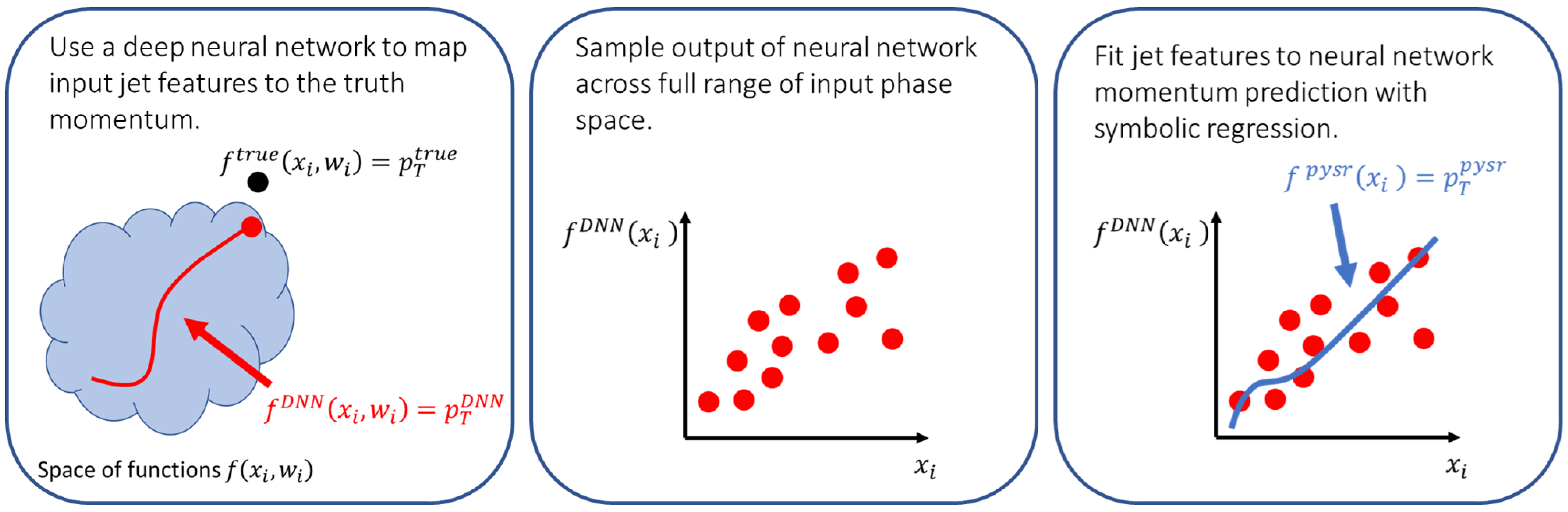

Figure 1. Procedure for extracting an analytical expression from the mapping between input jet features to the corrected jet momentum using a neural network and symbolic regression.

3. Improved Momentum Resolution

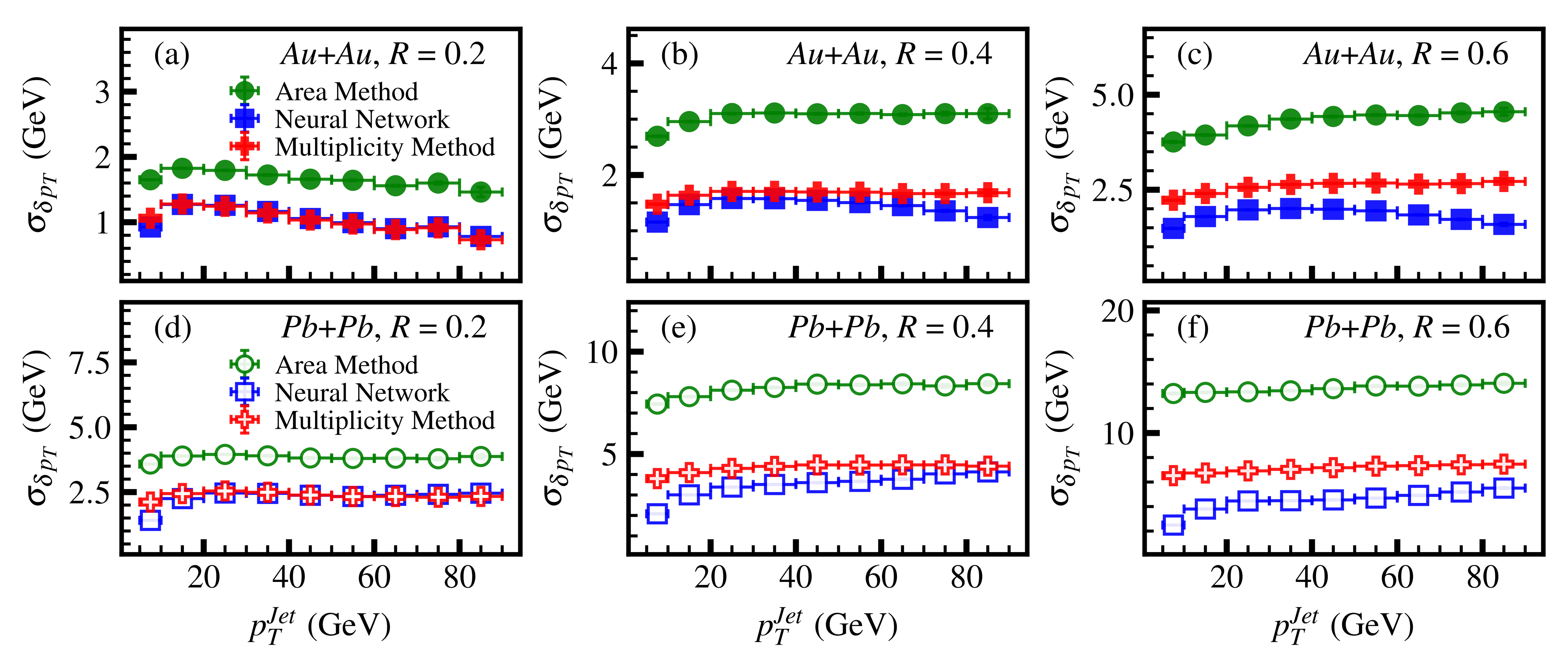

Figure 2. Comparisons of δp_T width vs p_T^{jet} for each background subtraction method for Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV and Pb+Pbcollisions at $\sqrt{s_{NN}}$= 2.76 TeV.

4. Unfolding to lower $p_{T,jet}$

The improvement in jet momentum resolution extends the kinematic range of the unfolded spectra to lower jet momenta.

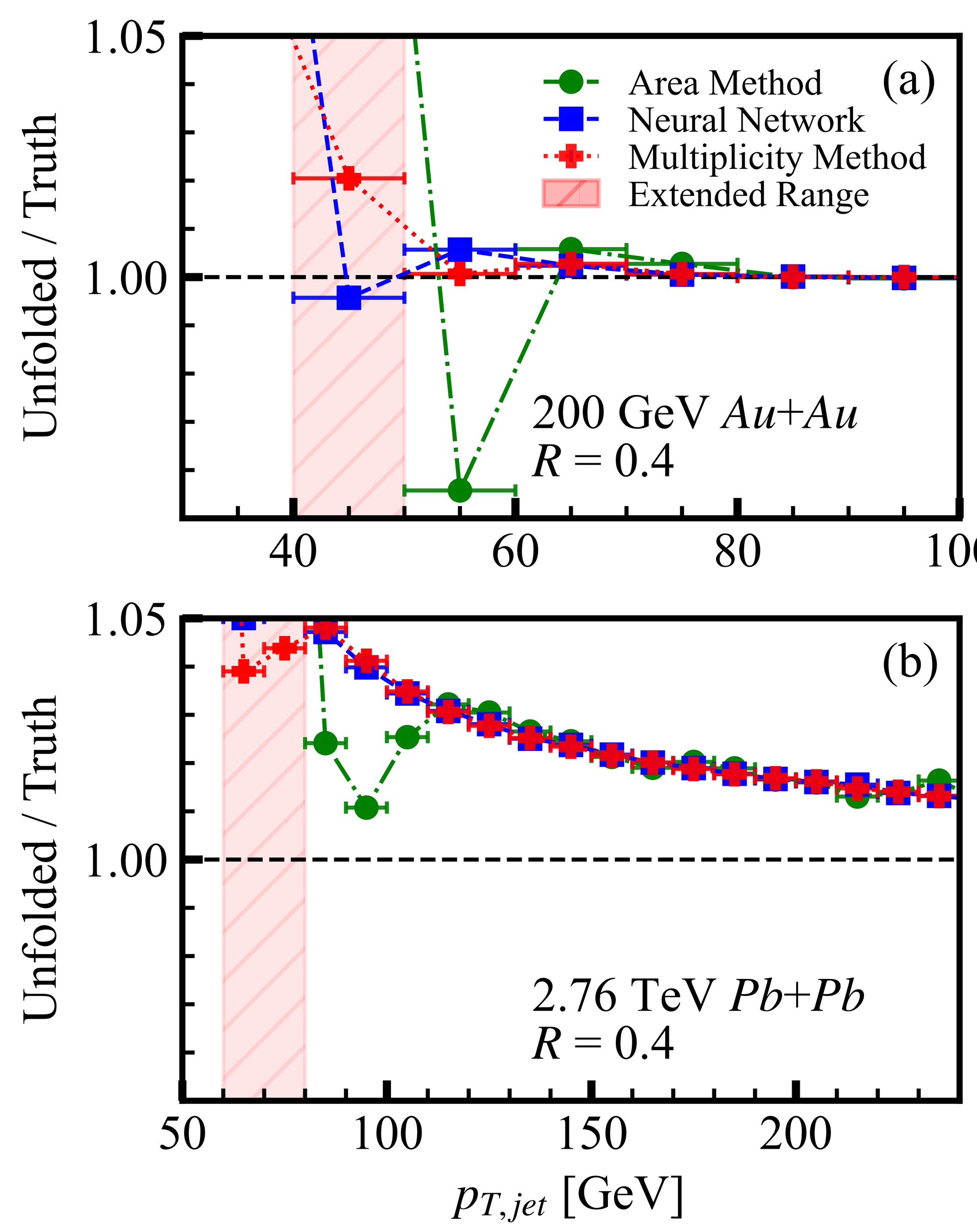

Figure 3. Ratio of unfolded jet spectrum over truth spectrum for (a) Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV and (b) Pb+Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV.

5. More than a Coincidence

For all jet resolution parameters and collision energies the symbolic regression found that the best description of the neural network has the functional form

$$p_{T,Jet}^{Corr.PySR} = p_{T,Jet}^{tot} - C_1(N_{tot} - C_2). \quad (3)$$

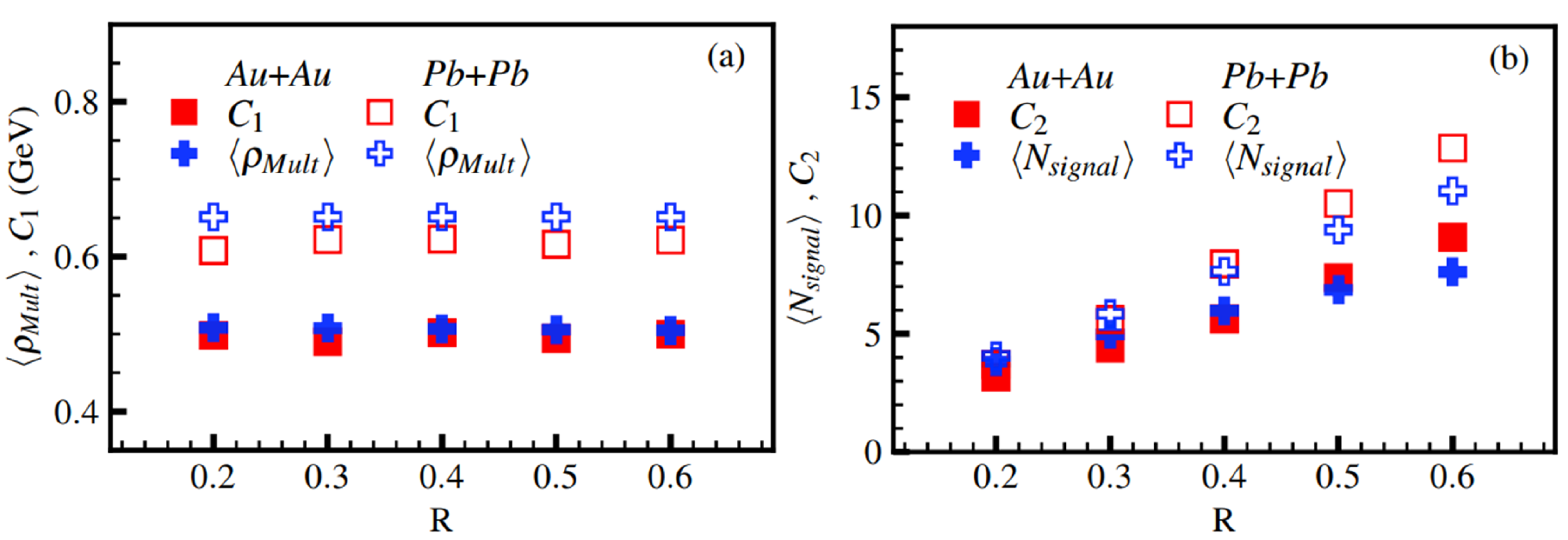

Figure 4. PySR optimization constants compared to average value of multiplicity method parameters versus jet resolution parameter for Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV and Pb+Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV.

6.Conclusions

1.The multiplicity method achieves similar performance without the model dependence of the neural network.

2. Applying machine learning to measurements requires ML methods that are interpretable.

Full details of this study are published here: *Interpretable Machine Learning Methods Applied to Jet Background Subtraction in Heavy Ion Collisions.* [4]

PhysRevC.108.L021901

References

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