The information content of jet quenching and machine learning assisted observable design

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in collaboration with

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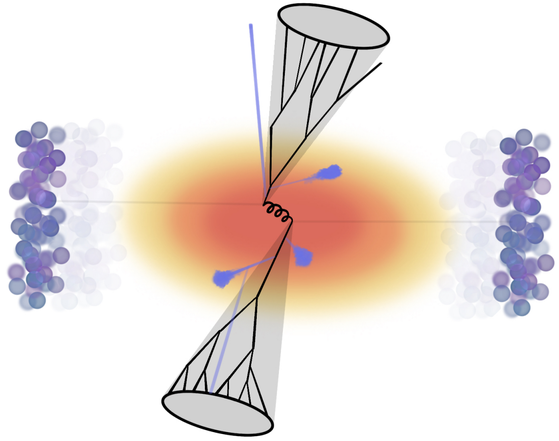
arXiv 2111.14589



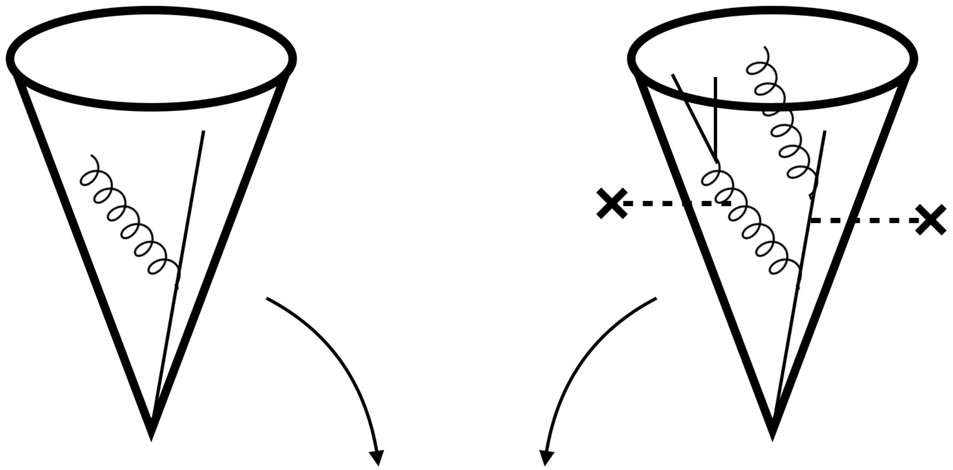
Quark Matter 2022
Poster Session
April 6, 2022

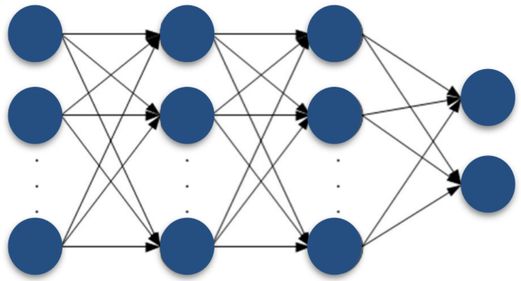
Berkeley
UNIVERSITY OF CALIFORNIA

Jet classification — pp vs. AA

We seek to understand how jets in heavy-ion collisions are different than jets in proton-proton collisions

→ Binary classification problem





pp vs. AA

Goal: Use ML to discriminate pp from AA jets in a way that is theoretically interpretable

- All methods shown here can be applied directly on experimental data

IRC-safe vs. IRC-unsafe physics

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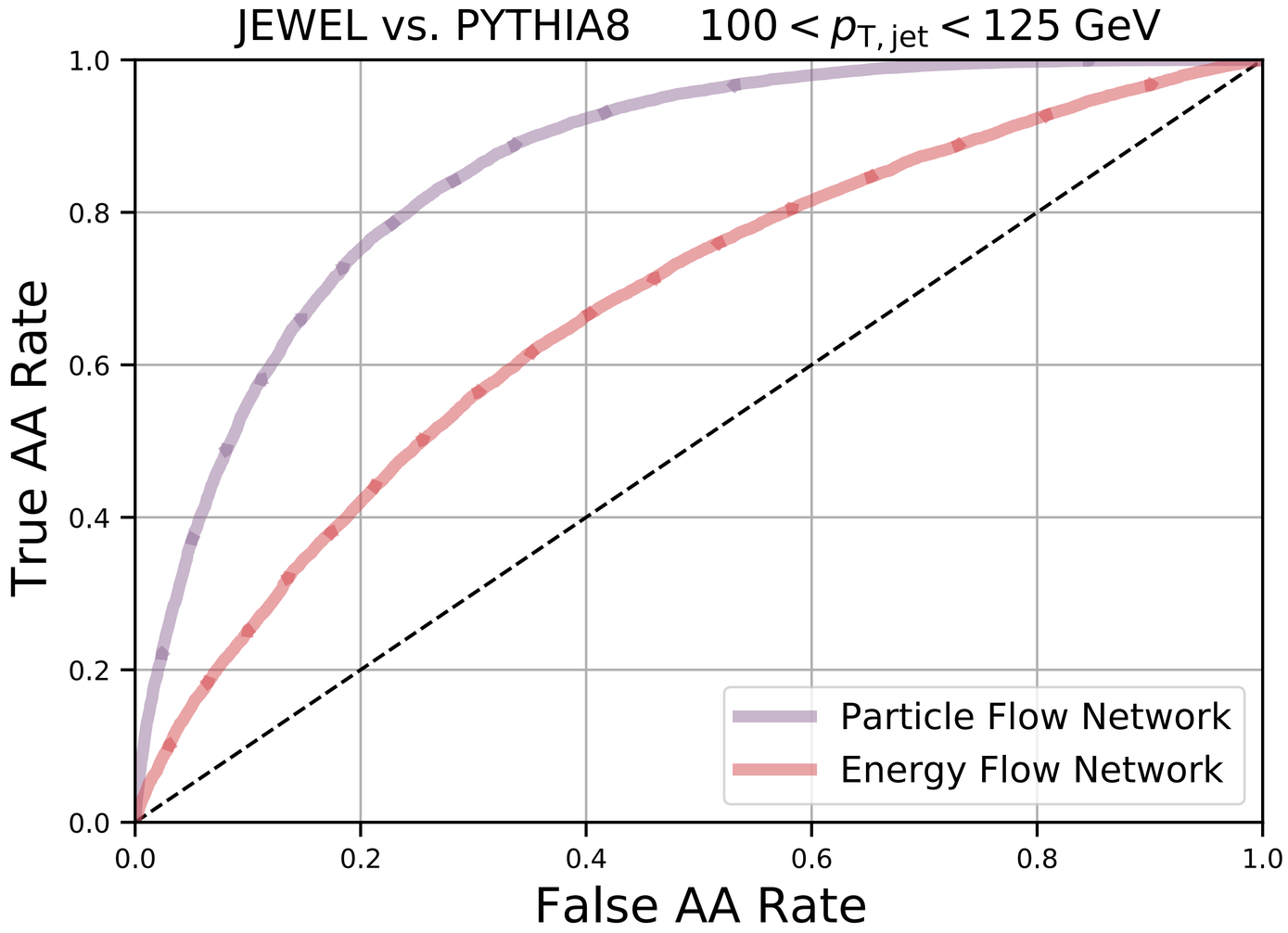

We compare the IRC-unsafe network (PFN) to an IRC-safe network (EFN)

$$f(p_1, \ldots, p_M) = F\left(\sum_{i=1}^{M} z_i \Phi\left(\hat{p}_i\right)\right)$$

Classifier

DNNs

IRC-unsafe information contains significant discriminating power

Hard vs. soft physics

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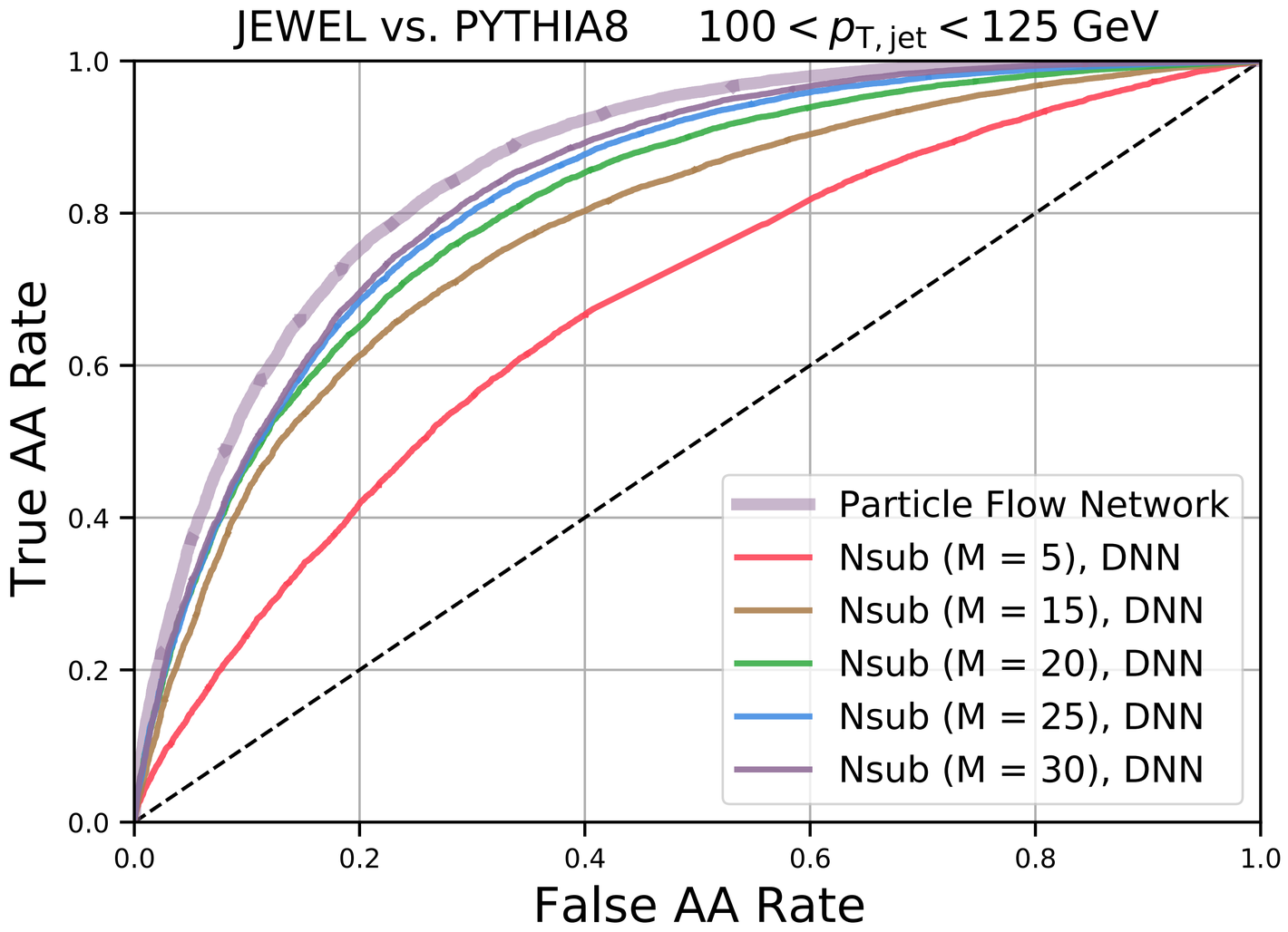

How many observables does one need to measure to saturate information?

DNN with $3M - 4$ *N*-subjettiness basis observables as input:

$$\left\{\tau_1^{(0.5)}, \tau_1^{(1)}, \tau_1^{(2)}, \tau_2^{(0.5)}, \tau_2^{(1)}, \tau_2^{(2)}, \ldots, \tau_{M-2}^{(0.5)}, \tau_{M-2}^{(1)}, \tau_{M-2}^{(2)}, \tau_{M-1}^{(0.5)}, \tau_{M-1}^{(1)}\right\}$$

Significant information in quenched jets up to $M \approx 25$

Observable design

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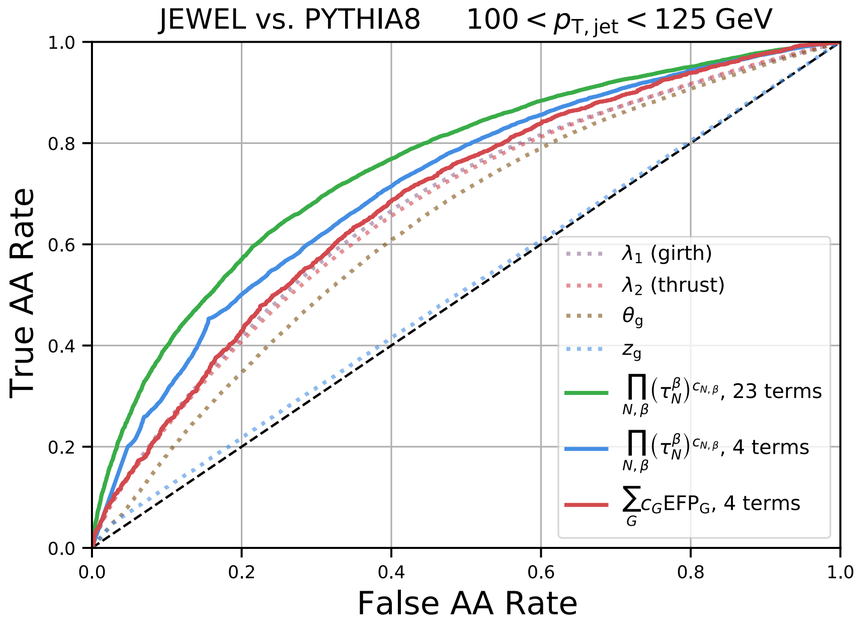
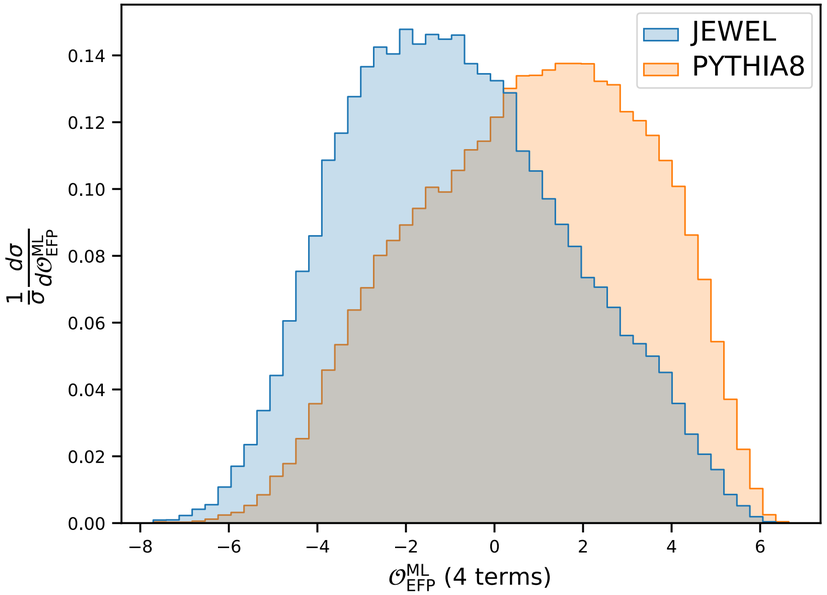
By balancing the tradeoff of discriminating power and complexity, we can design the *most strongly modified* calculable observable



Approximate classifier with small number of features

"Symbolic regression" using Lasso



ML-assisted observable design provides guidance to experiments and theory — can then measure and calculate designed observables using traditional methods

Information loss due to background

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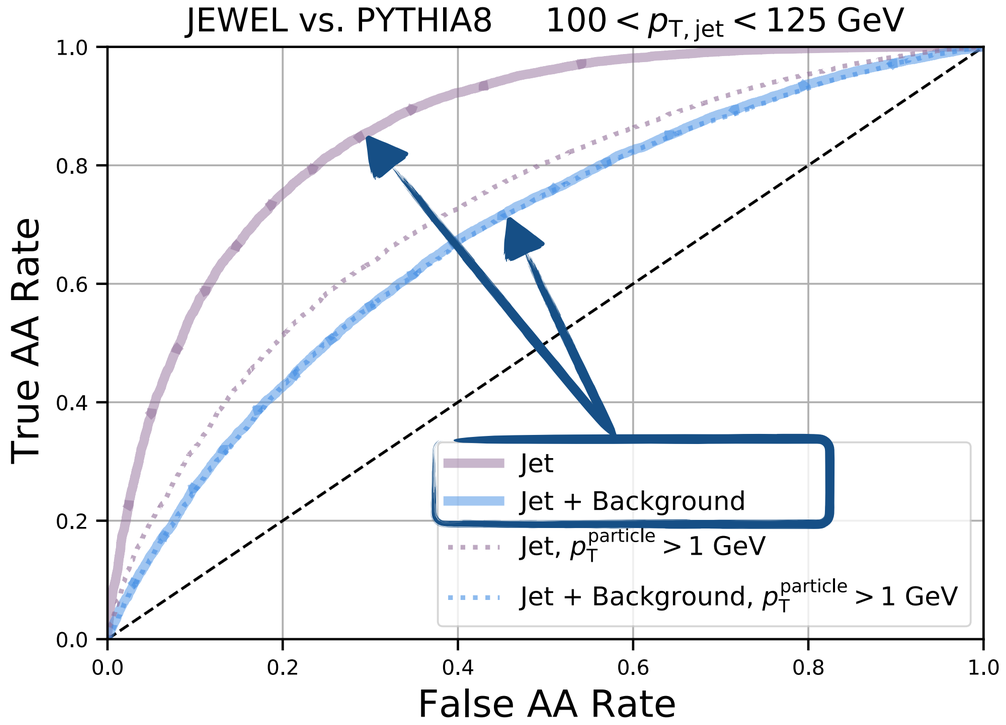
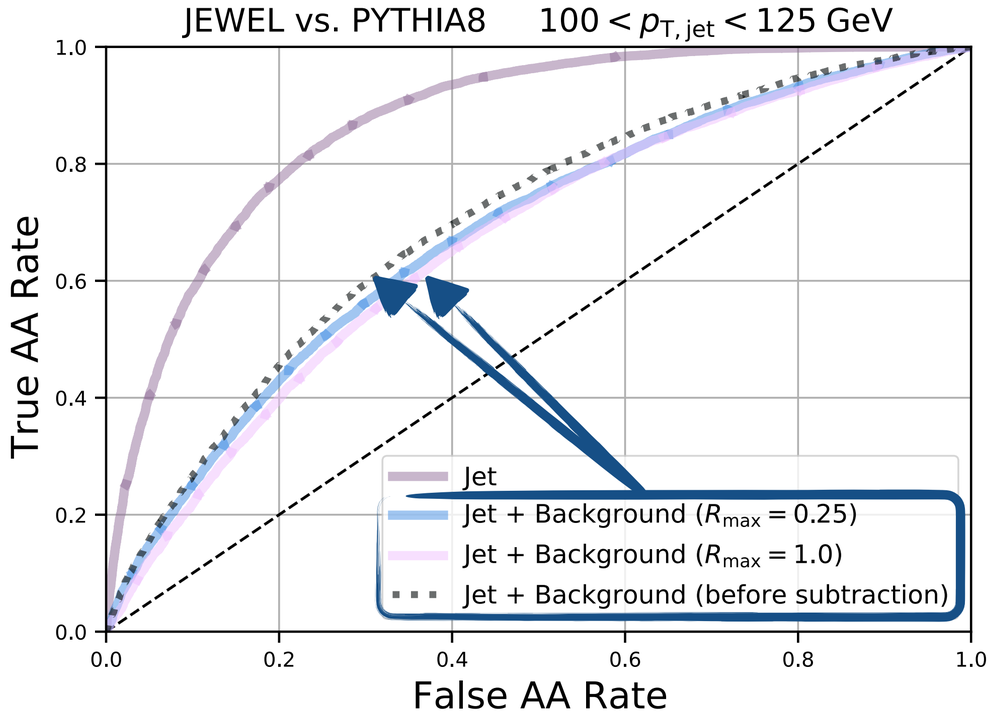
Discriminating power is highly reduced by the fluctuating underlying event



Delicate challenge: soft information crucial, yet background prevents from being accessed

Background subtraction algorithms remove small but significant information



New metric to assess background subtraction algorithms