Jet Tagging with Deep Sets of Subjets

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arXiv: 2211.XXXXX w/ Andrew J. Larkoski, James Mulligan, Mateusz Płoskoń, Felix Ringer

ML 4 Jets, Rutgers
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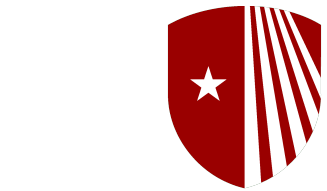

Stony Brook
University

Outline

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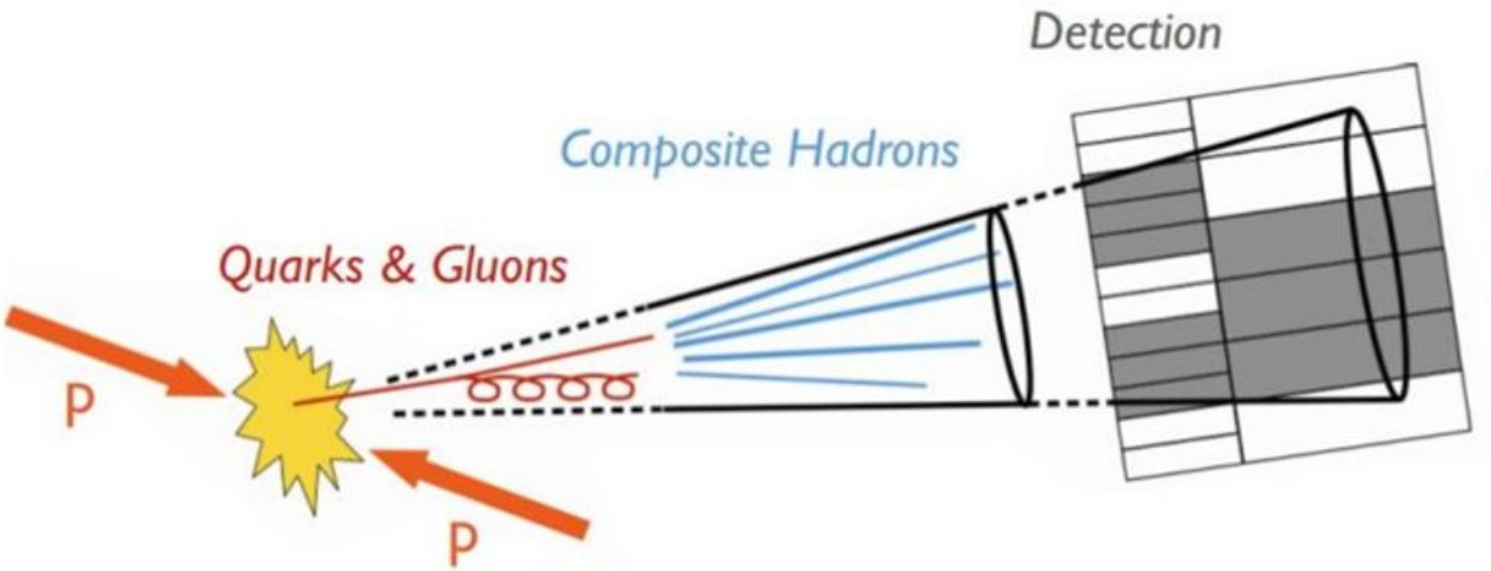
Jet Classification

One of the biggest challenges of collider phenomenology is Jet Classification



Jet Classification

Machine Learning techniques far outperform theoretical observables

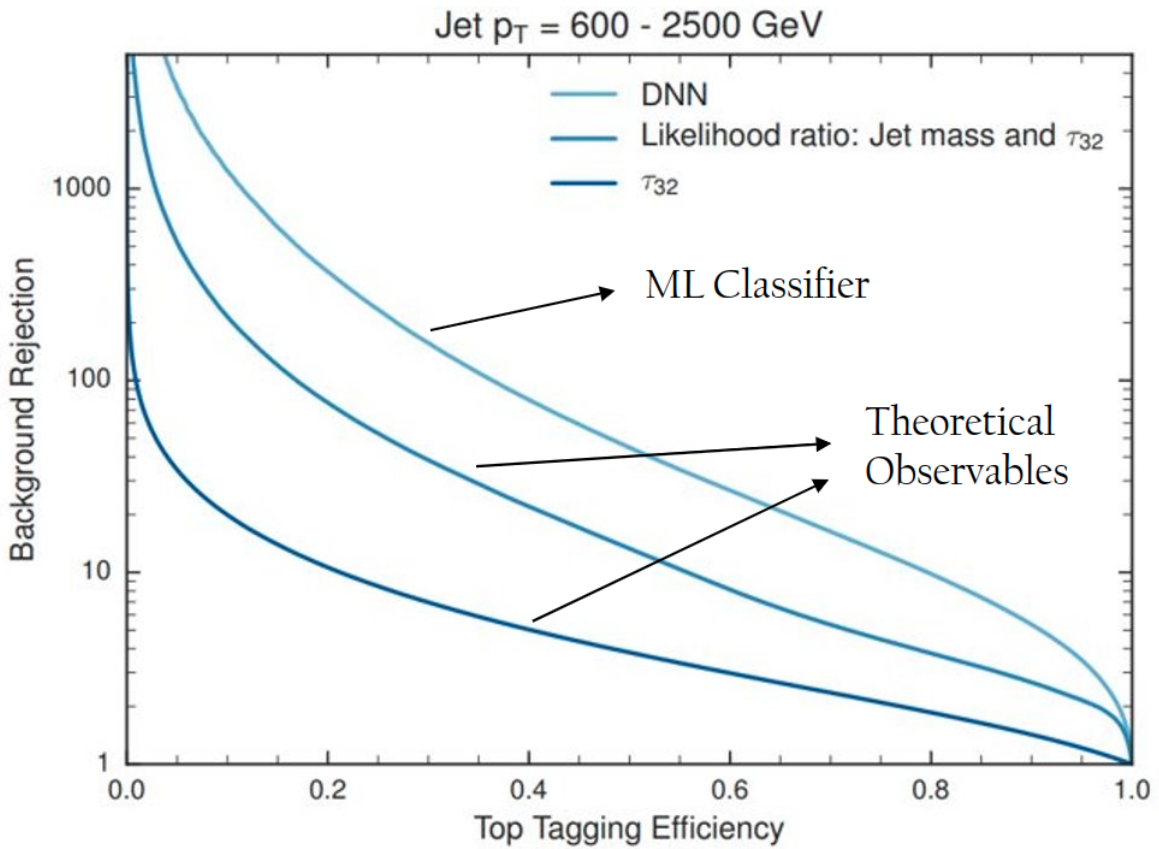


Figure: Taken from J. Pearkes et al 1704.02124

Jet Classification

There are many ways to represent a jet

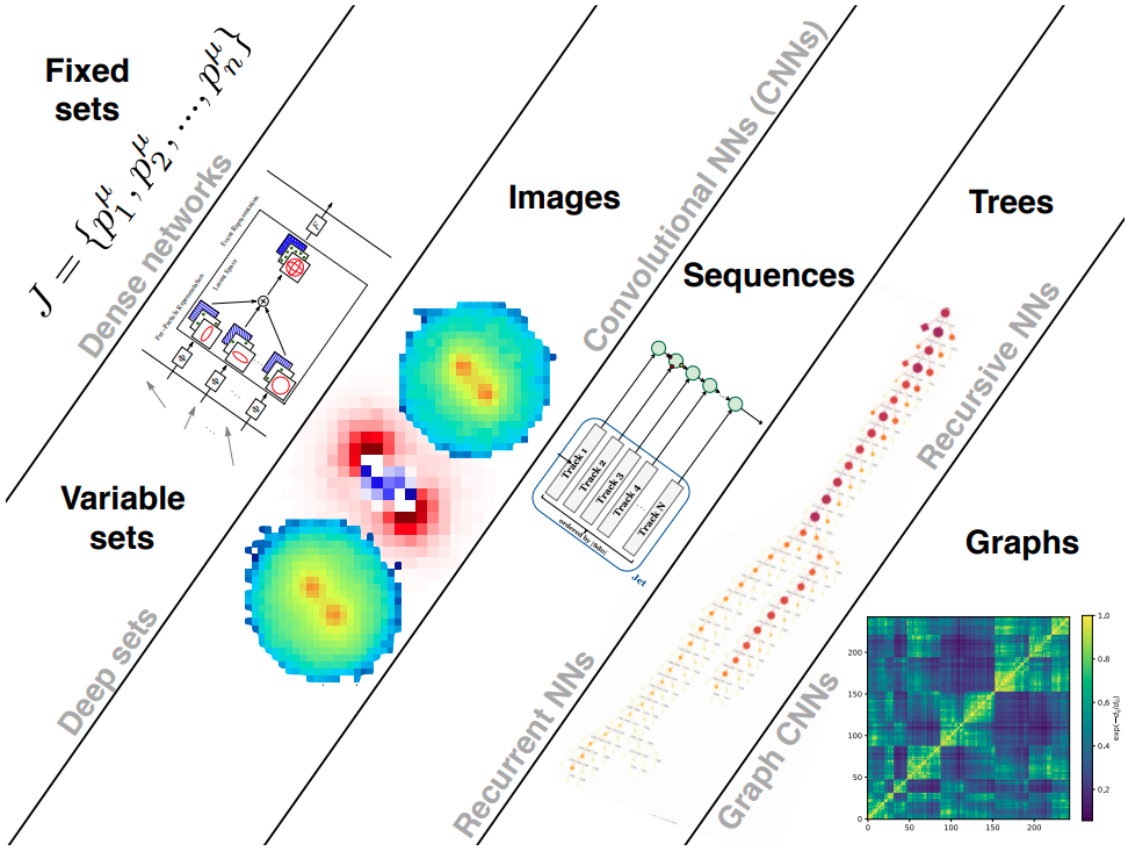


Figure: Taken from Larkoski et al 1709.04464

Jet Classification

Architectures that use IRC unsafe information (PFN, ParticleNet, CNN etc) perform better than IRC safe classifiers (EFN, EFP, Nsub)

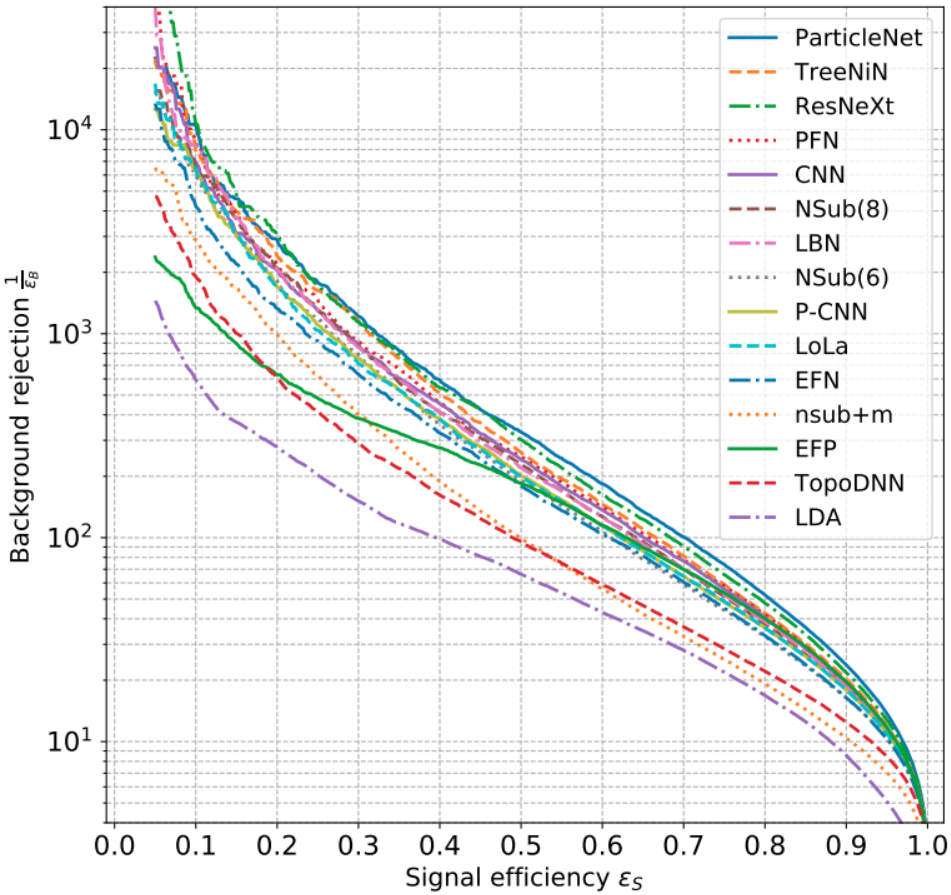


Figure: Taken from Kasieczka et al 1902.09914

Jet Classification

Lets focus on the Deeps Sets' architectures

Permutation-invariant neural networks based on deep sets

Zaheer et al. 1703.06114
Wagstaff et al. 1901.09006
Bloem-Reddy, Teh JMLR 21 90 (2020)

Unordered, variable-length sets of particles as input

Komiske, Metodiev, Thaler JHEP 01 (2019) 121

Particle Flow Network (PFN)

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

Classifier

DNNs

latent space $d = 256$

Includes IRC-unsafe information

Energy Flow 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

Includes only IRC-safe information

Jet Classification

PFN performs amazingly well and almost matches the state of the art performance

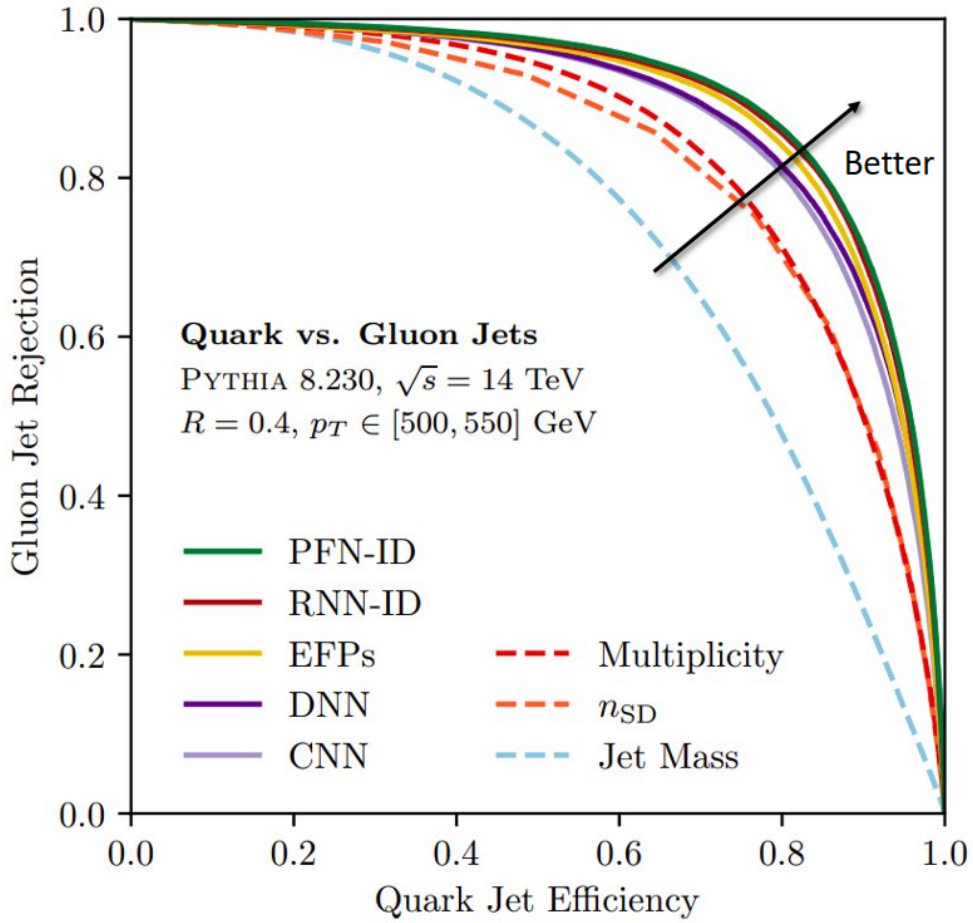


Figure: Taken from Thaler et al 1810.05165

Jet Classification

Interpretability

PFN is IRC unsafe, sensitive to non perturbative physics and it has 3N variables where N is the number of hadrons

→

Increase interpretability by connecting it to Sudakov/IRC safe observables and by cutting down the input's size

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JFN

Jet Flow Network (JFN)

Instead of hadrons, we work with subjets

For a non-zero subjet radius r the classifier is Sudakov safe

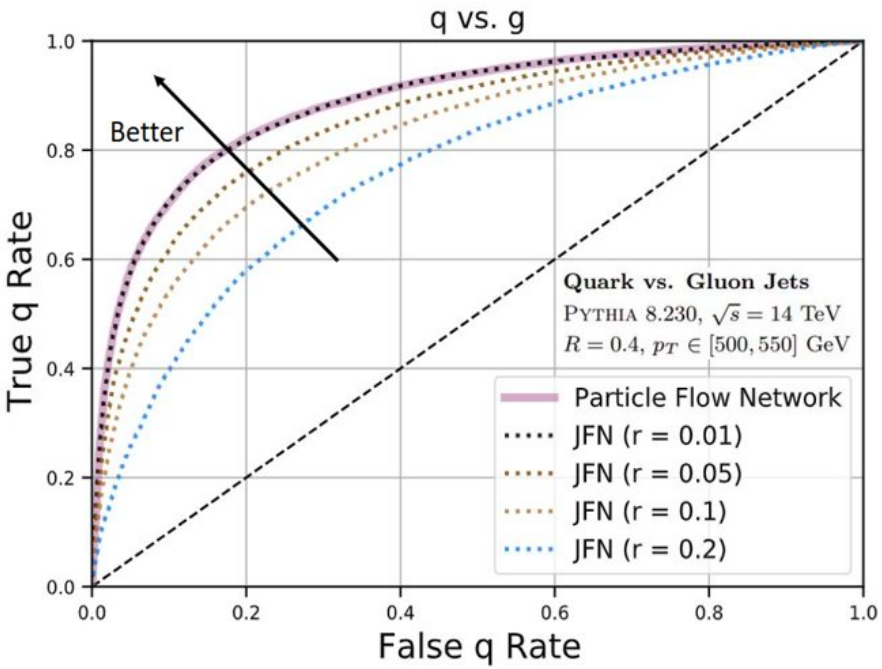
As we lower r, we smoothly transition to the non-perturbative regime

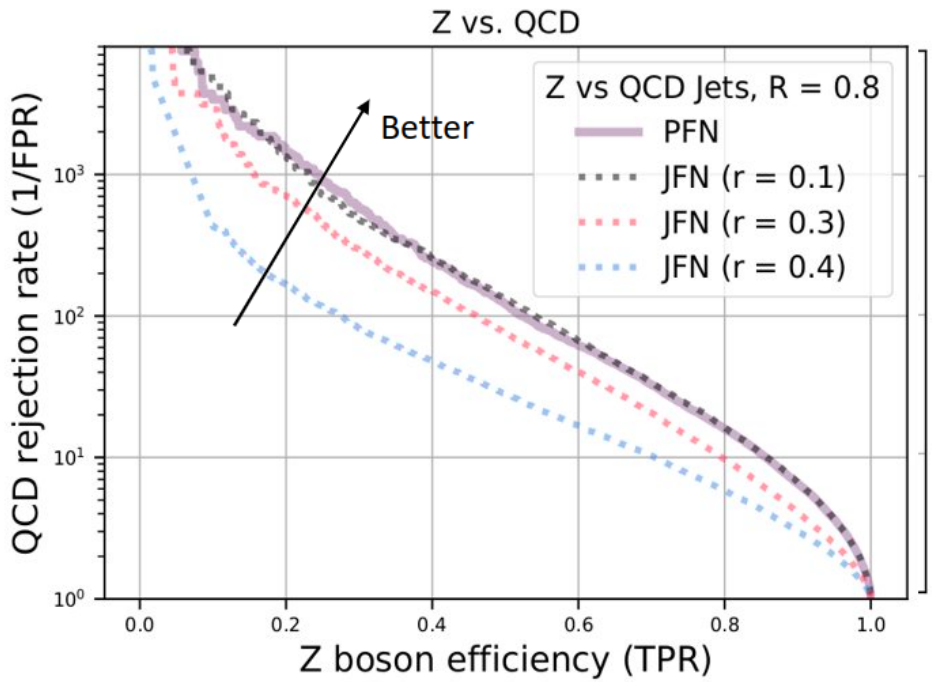
Properties of **inclusive** and exclusive subjets are **known to NLL** *(L. Dai et al 1606.07411, F.Ringer et al 1705.05375, 2103.16573, A. Larkoski et al* 2205.01117*)*

	PFN	JFN	EFN
Input	particle 4-momenta	subjet 4-momenta	particle 4-momenta
Classifier	IRC unsafe	Sudakov safe	IRC safe

JFN

As we lower r_{subjet} JFN converges to PFN





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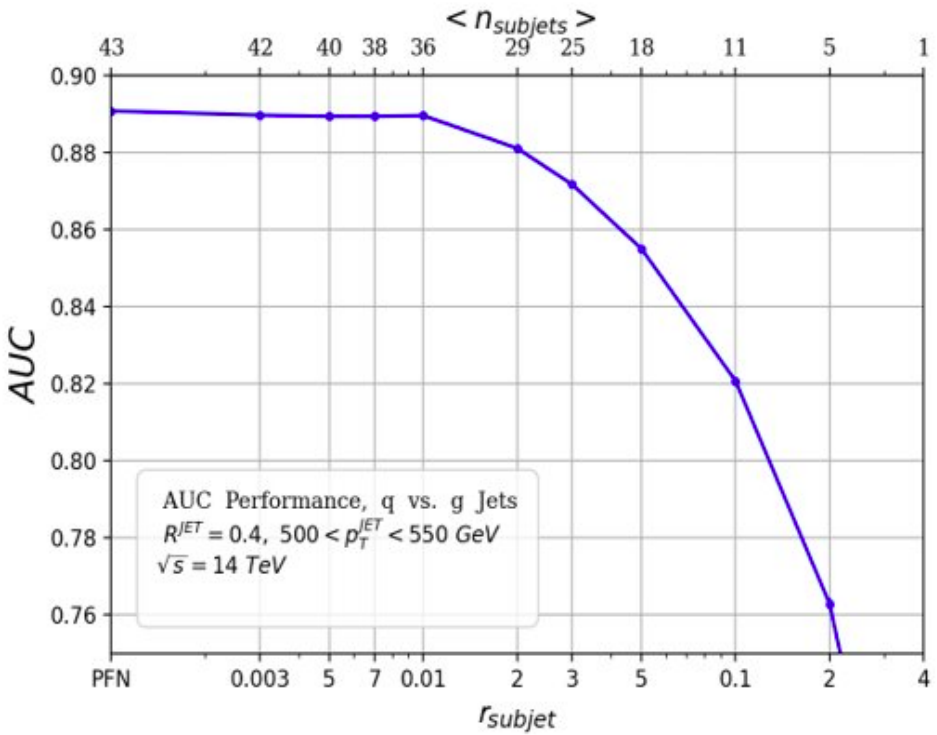
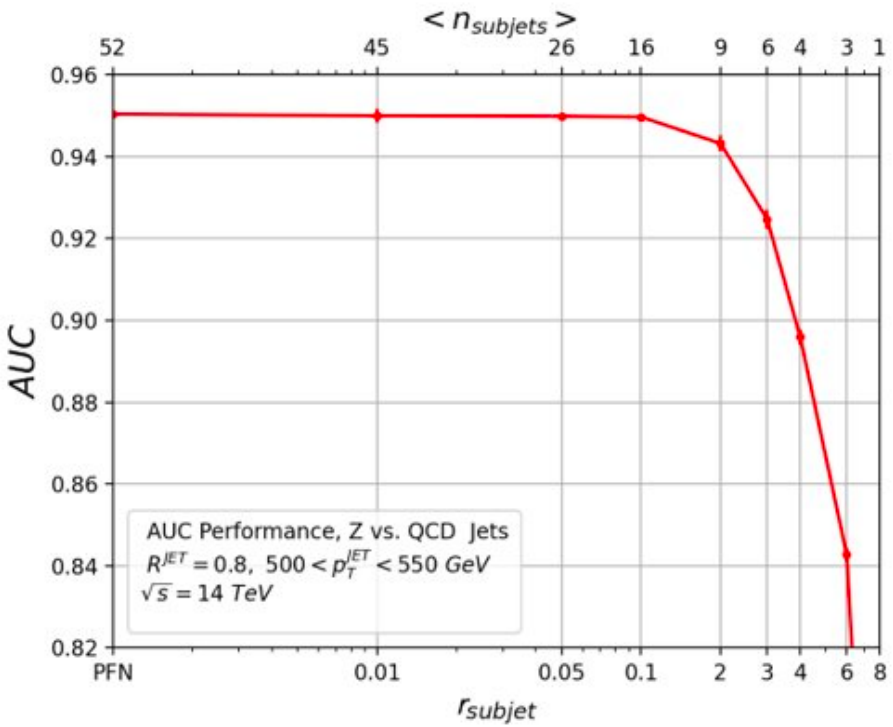
Physical Scales

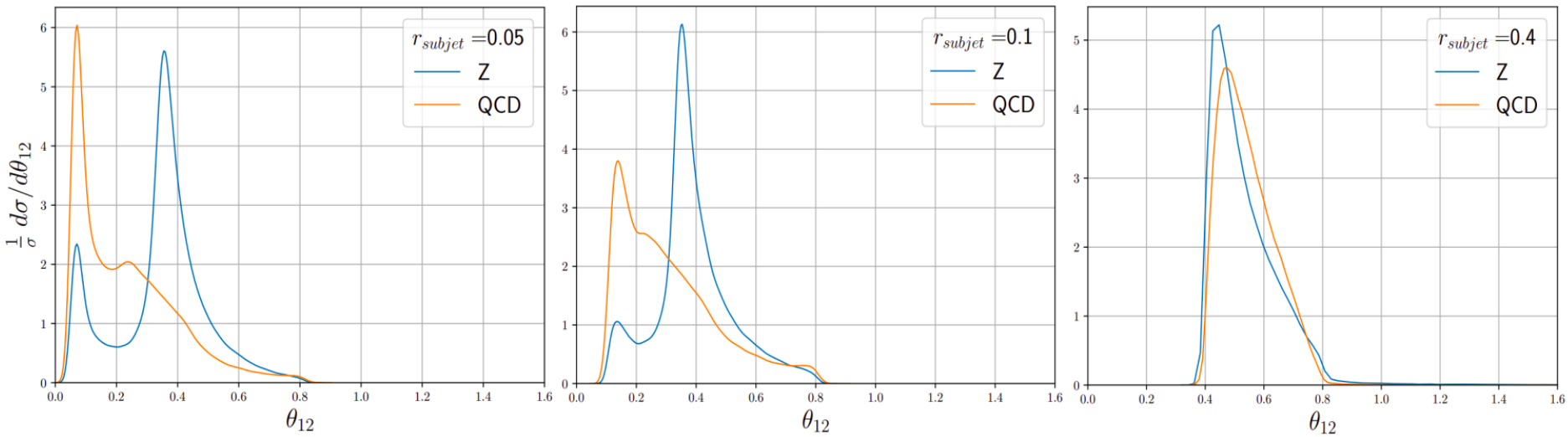
At what r_{subjet} do we expect a decrease in performance ?





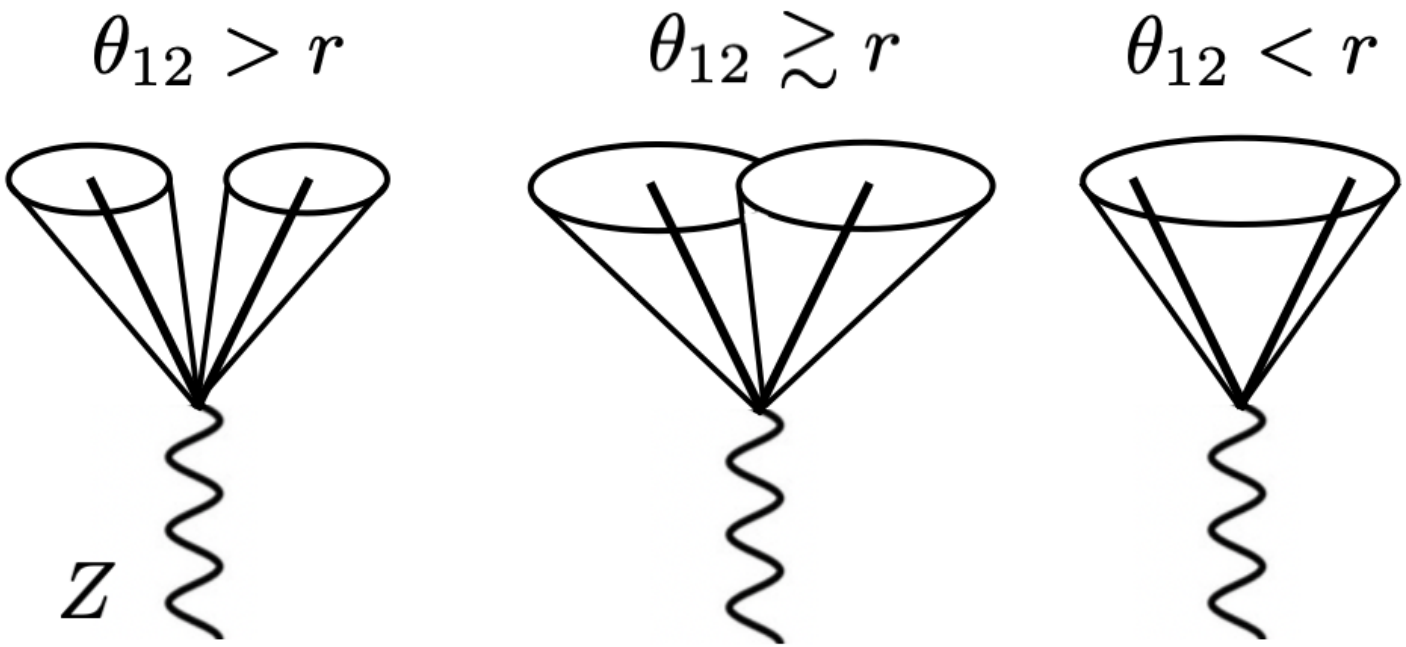
Physical Scales

What happens at this critical r_{subjet} ?



Physical Scales

We do not lose classification power as long as we still resolve the two leading subjets that originate from the Z splitting since $\theta_{12} \approx \frac{2M_Z}{p_T} \approx 0.35$



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- Why is there a performance saturation? Is it computational limitations or is there a physical reason?

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- Increased interpretability (less variables, connections to pQCD)
- Smaller dependency to Monte Carlo Hadronization Models (improved robustness?)
- Why is there a performance saturation? Is it computational limitations or is there a physical reason?
- Paper on arXiv soon

Thank you!