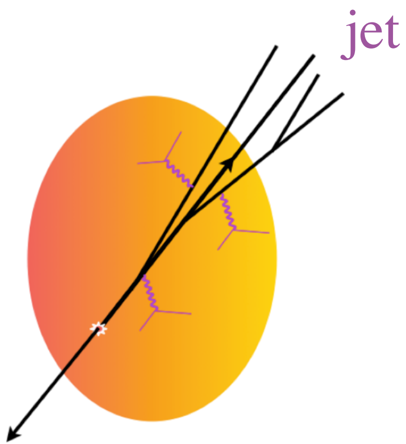
Sorting out energy loss for medium-modified jets

Jasmine Brewer

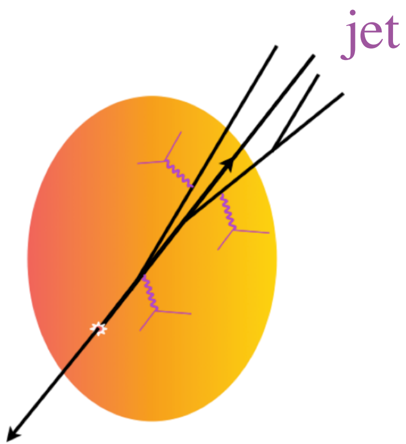
With Guilherme Milhano and Jesse Thaler

arXiv: 1812.05111

Jets: a multi-scale probe of the QGP



Jets: a multi-scale probe of the QGP



- How is a jet modified by the quark-gluon plasma?

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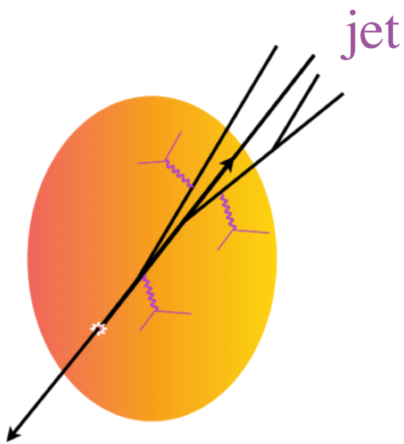

- How is a jet modified by the quark-gluon plasma?
- What can we learn about the medium on different length scales?

How can jet modification be quantified?

Ideally…

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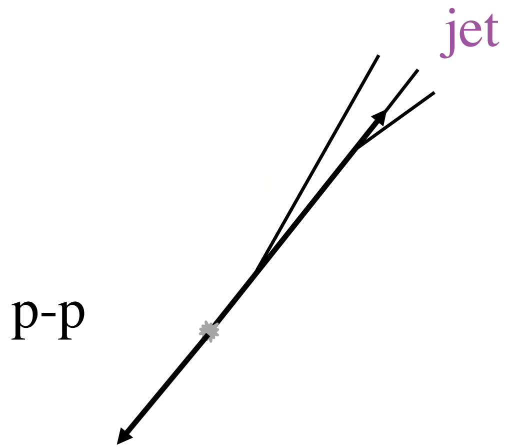

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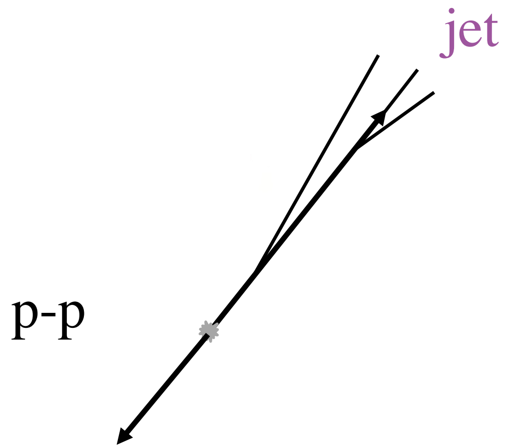

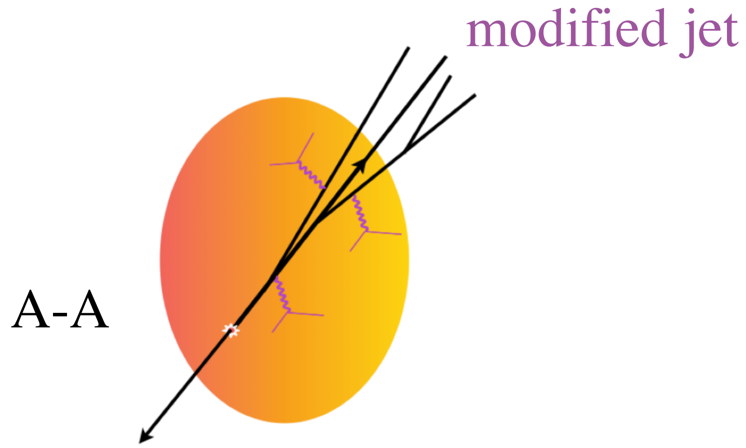

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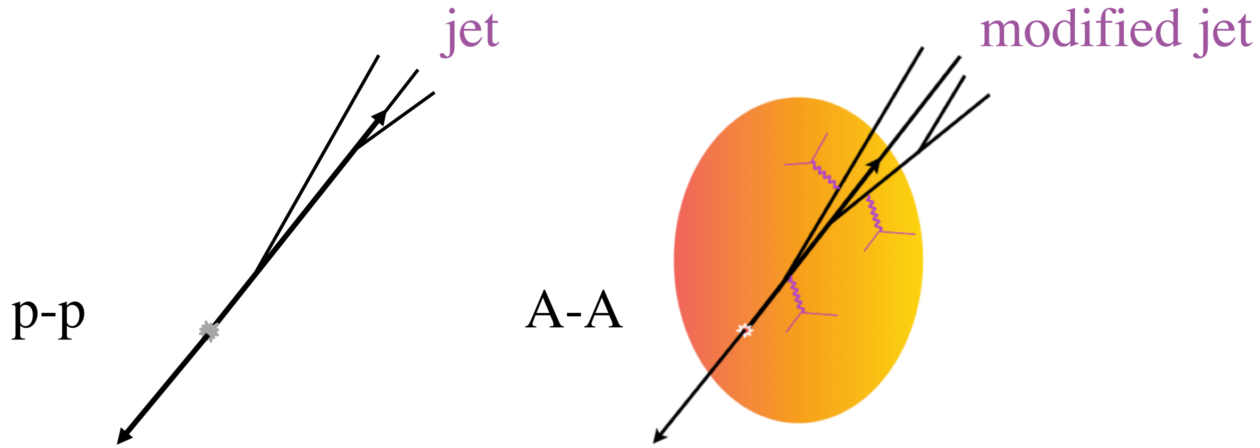
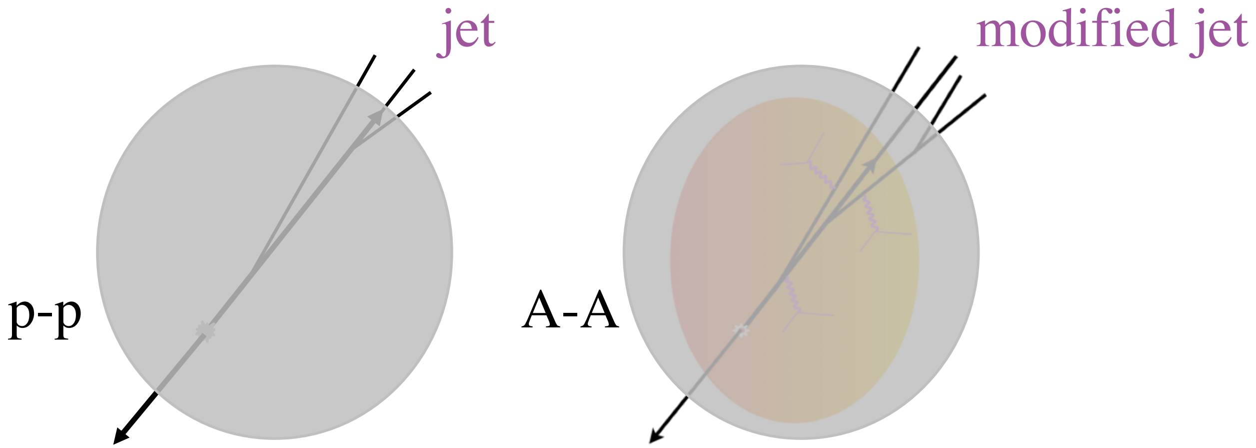


How do jets from an identical hard process differ in vacuum and in medium?

Features of hard process can generally not be observed

Reality…



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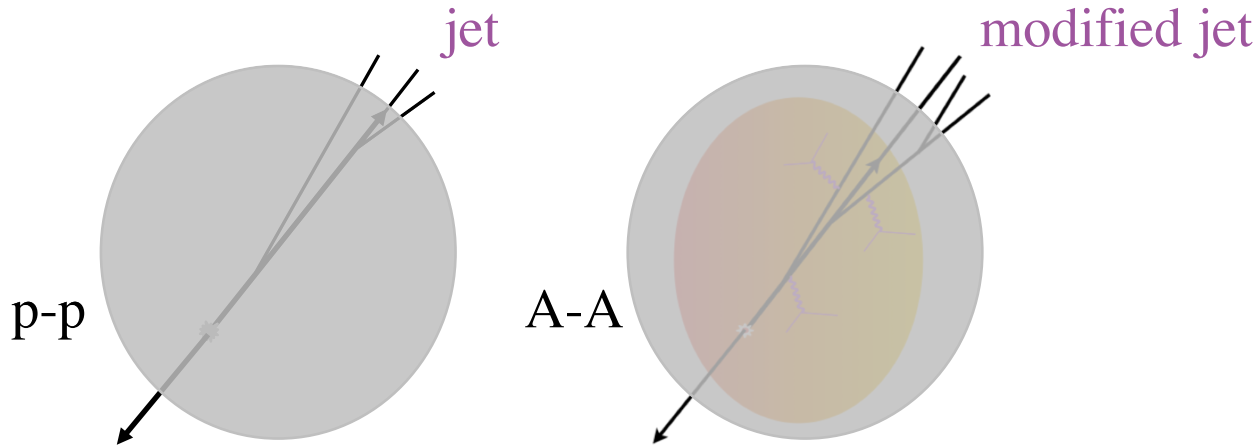

(Exception: rare processes where boson recoils a jet)

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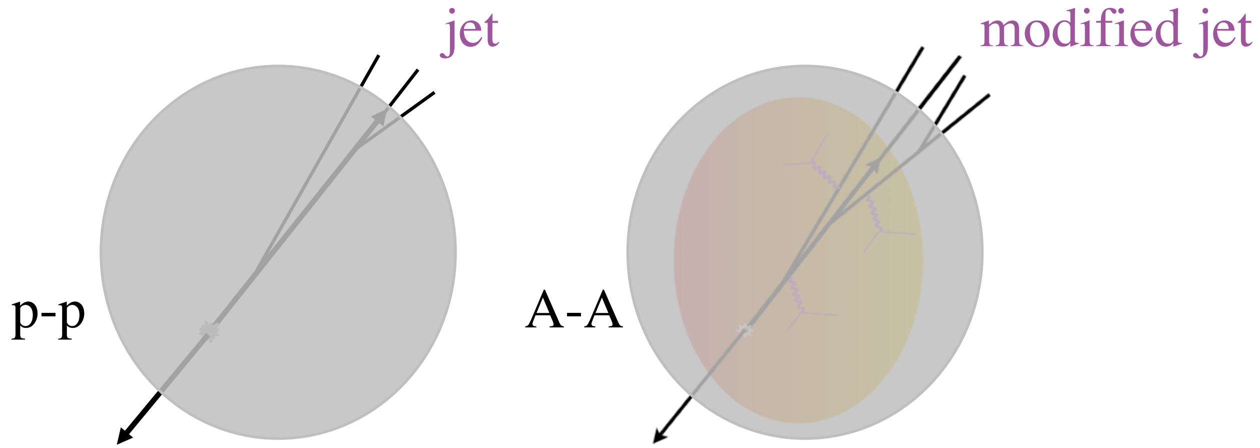
Reality…



Without knowing the properties of the initial hard process, standard is to compare p-p and A-A jets of the same final jet p_T

“Jet modification” observables: part modification and part bias

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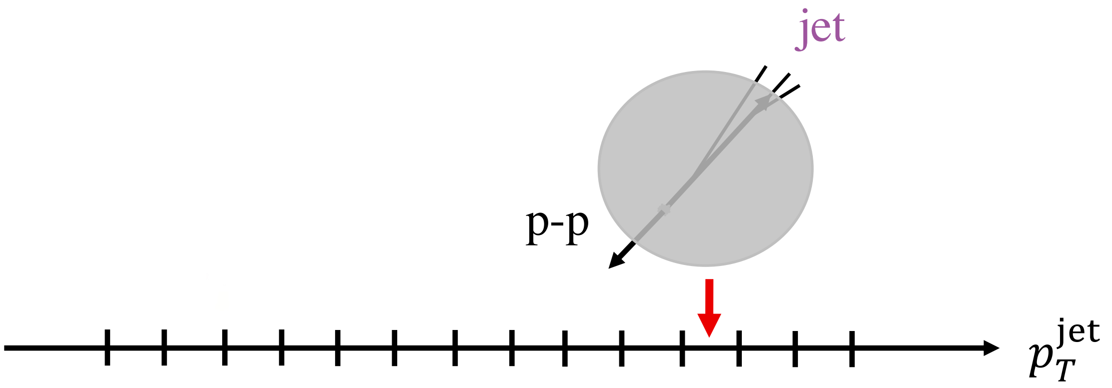

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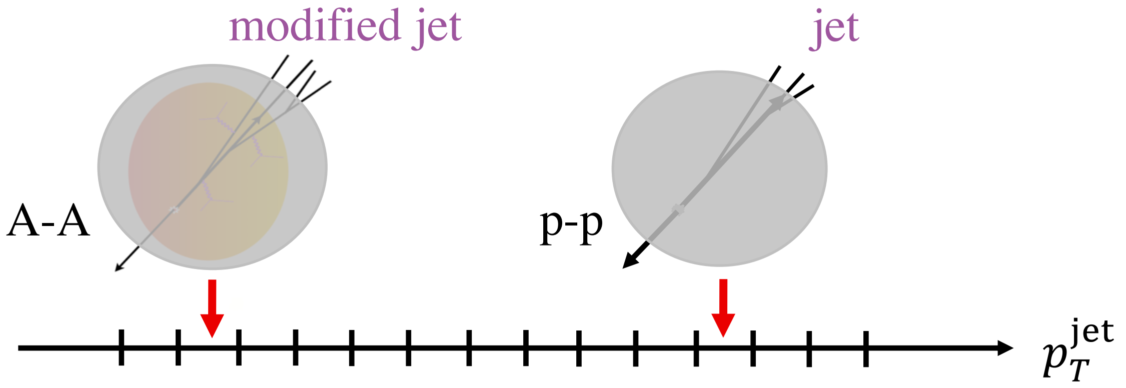

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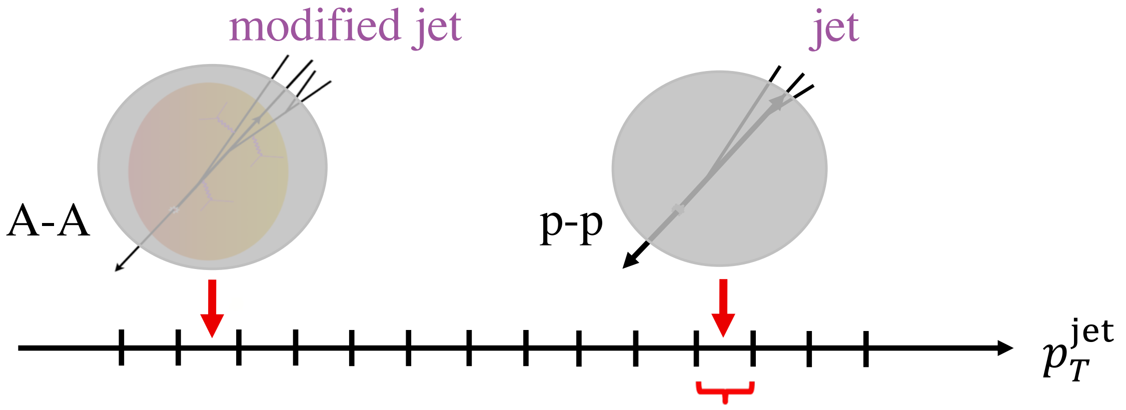

Compare features of p-p and A-A jets

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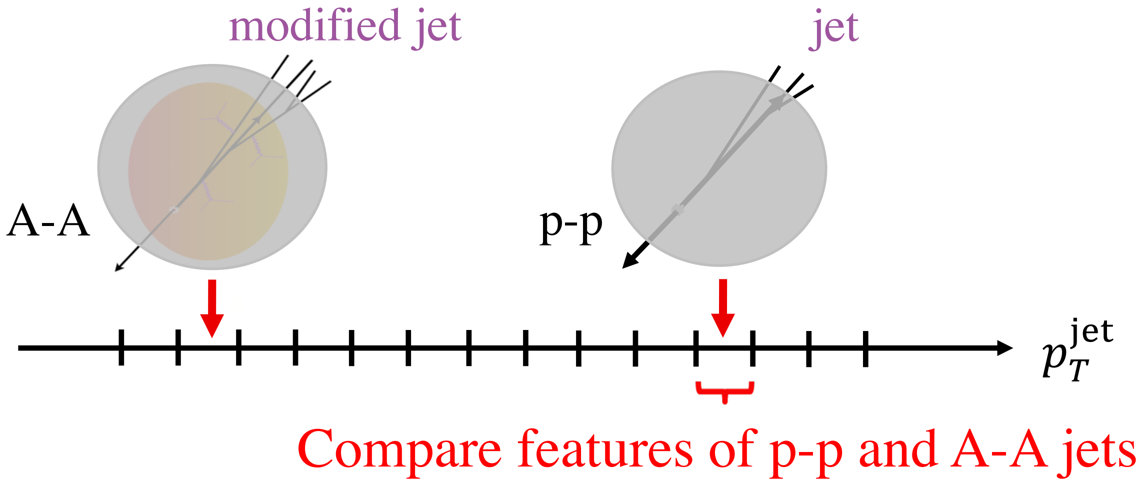

- Significant biases from migration of jets to lower energy

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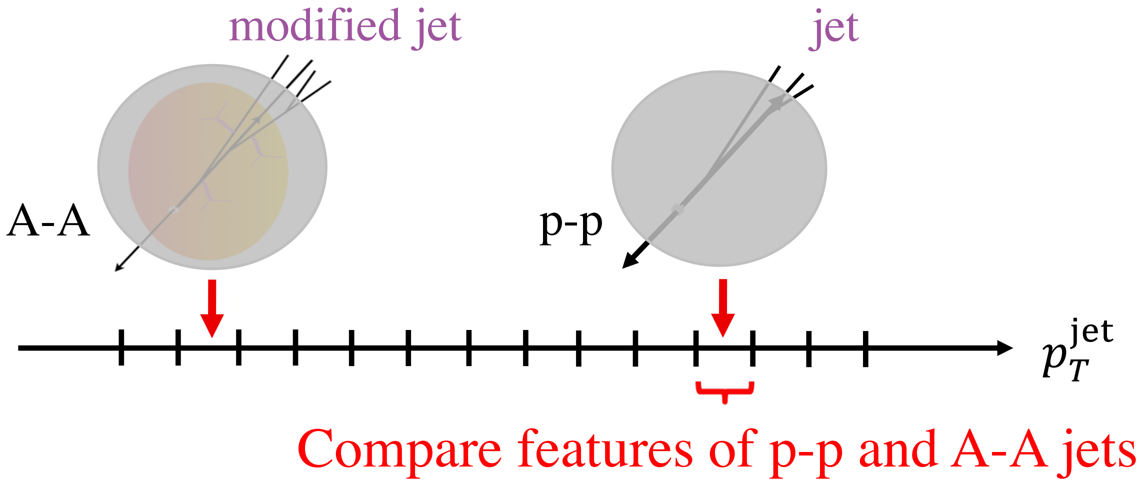

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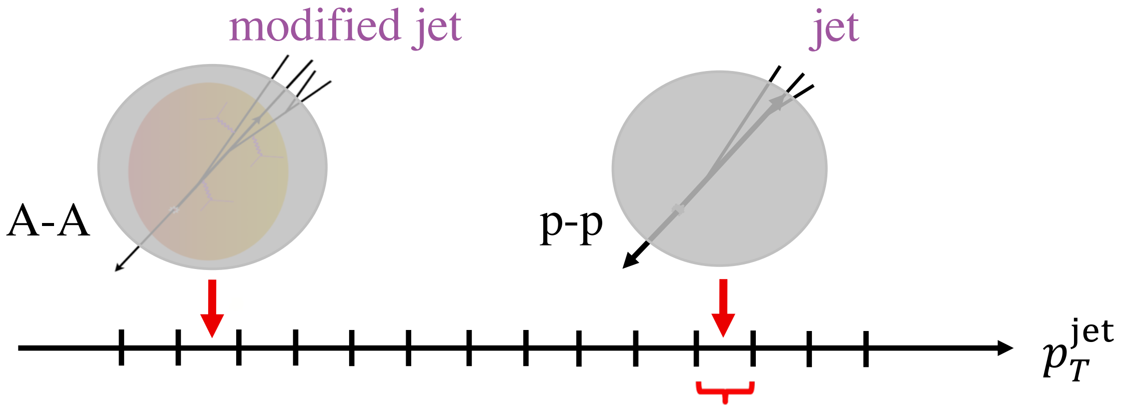
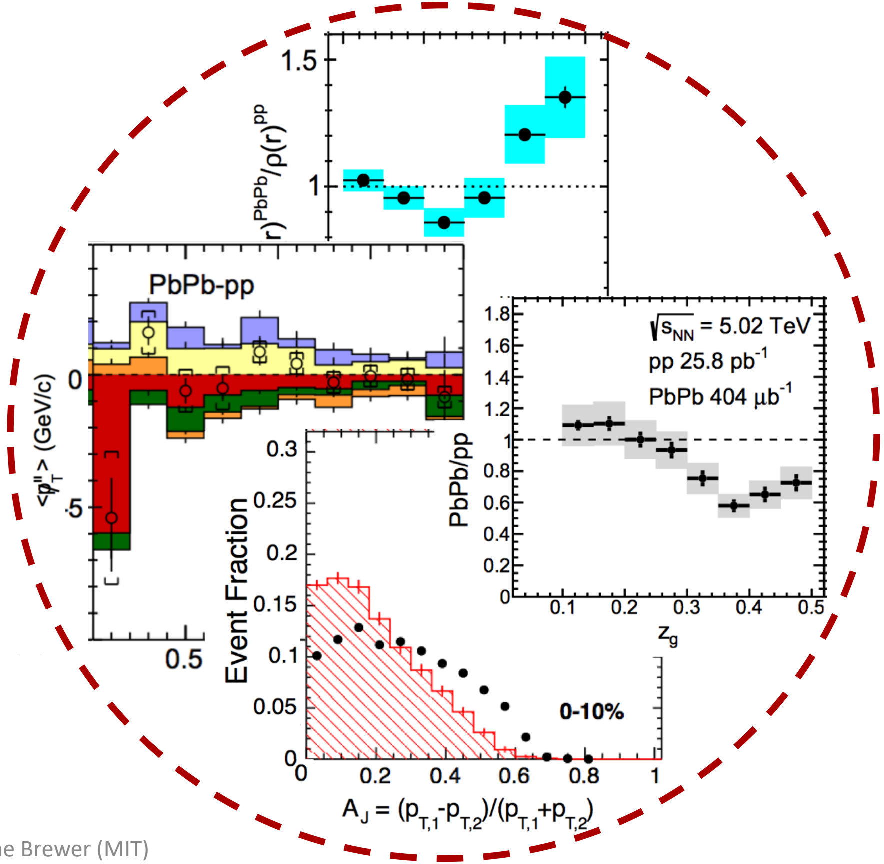


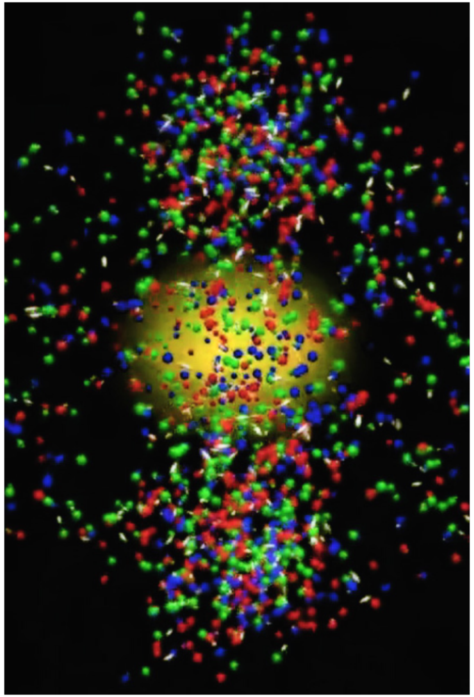
Compare features of p-p and A-A jets

- Significant biases from migration of jets to lower energy
- Strongly emphasizes jets which are modified least

Often requires significant theory input to interpret measurements

Goal: data-driven approach to interpreting jet modification





Roadmap

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- Demonstrate new strategy for matching p-p and A-A jets
- Discuss impact for interpretation of jet modification observables
- Demonstrate in Monte Carlo that it does a reasonable job of comparing p-p and A-A jets with the same hard process
- Advertisement: relevance for finding features that control jet quenching

Key question: compare A-A jets to which p-p jets?

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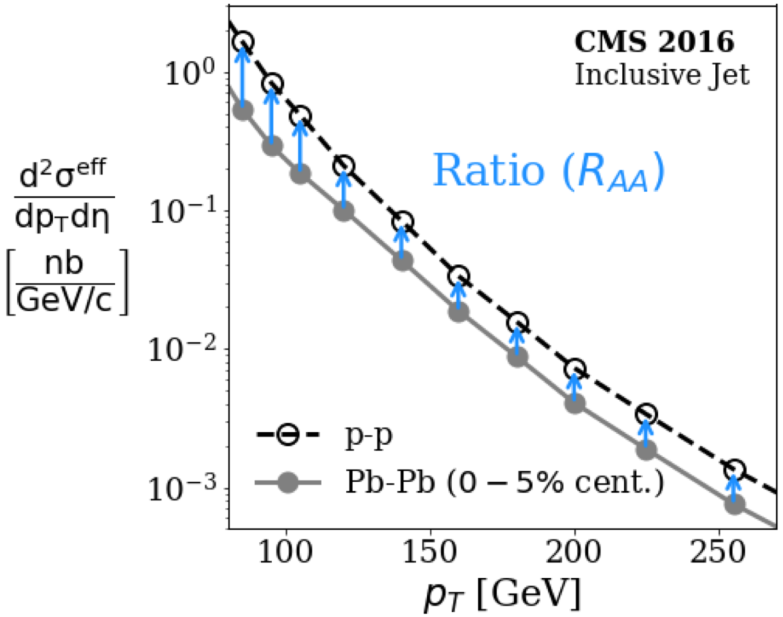
- Standard answer: match final (reconstructed) p_T



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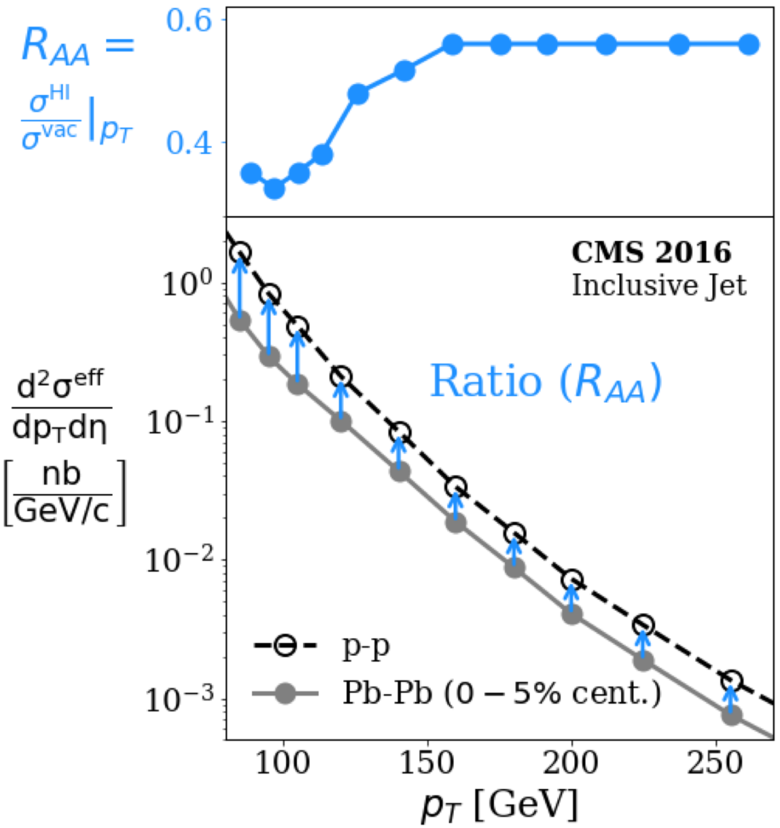

Is m/p_T modified or not?

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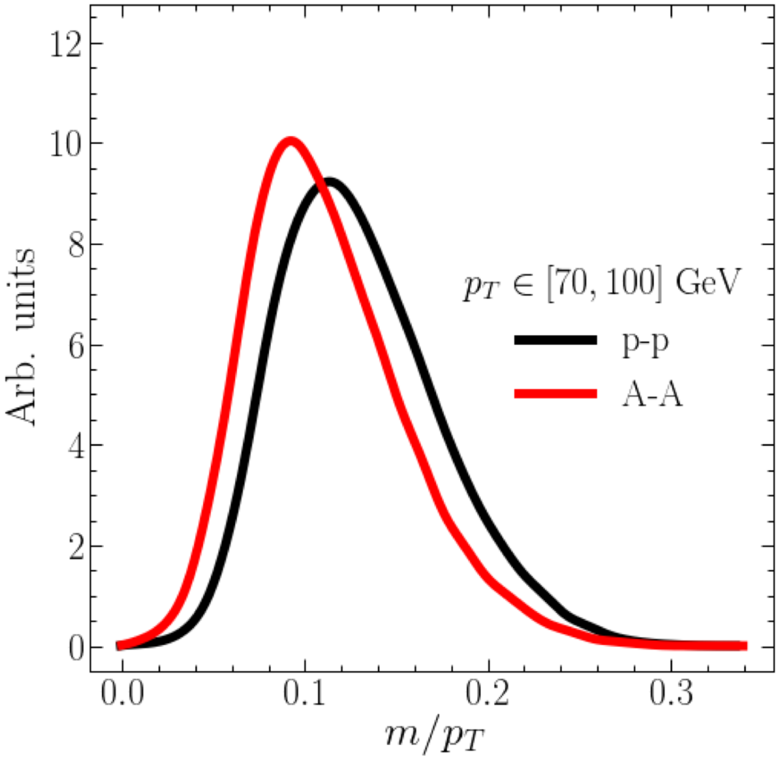

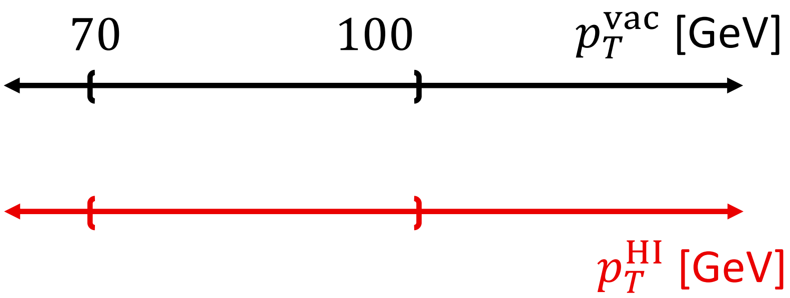

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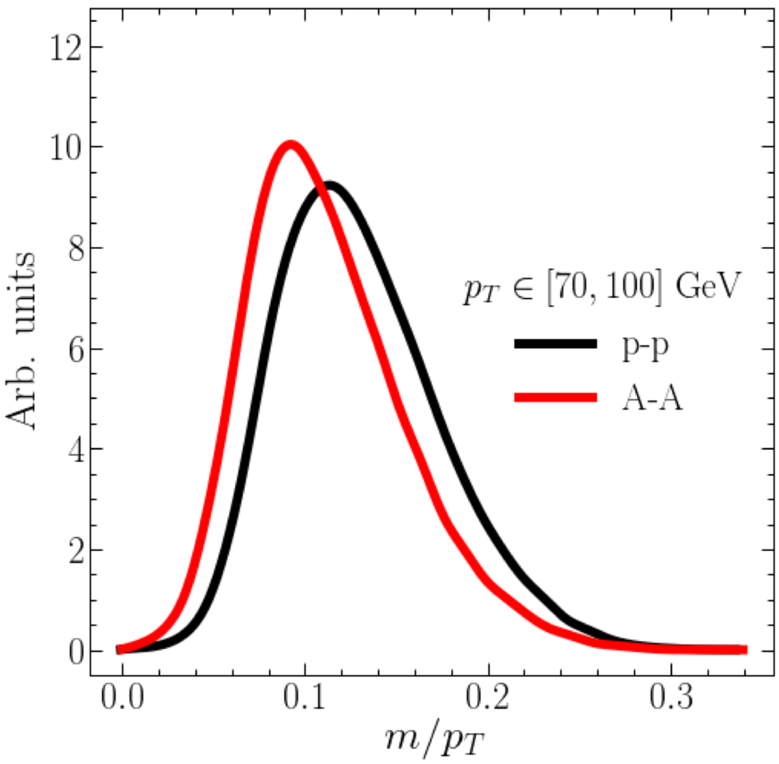

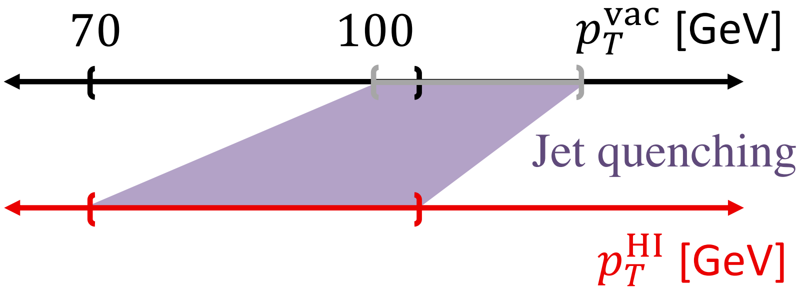

A-A jets were higher p_T when they were produced

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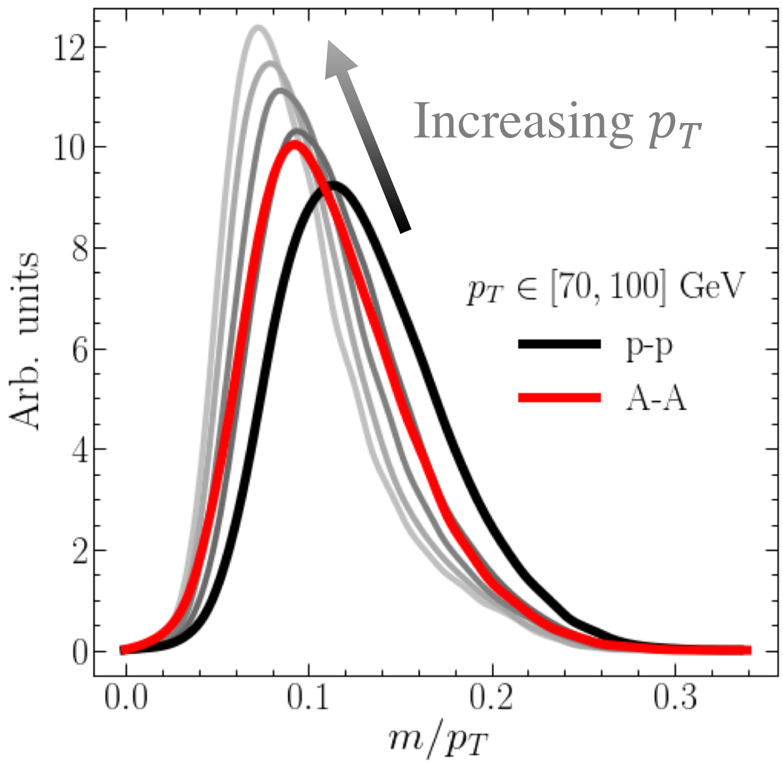

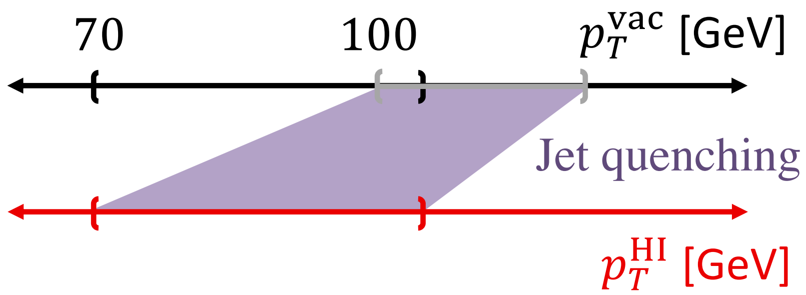

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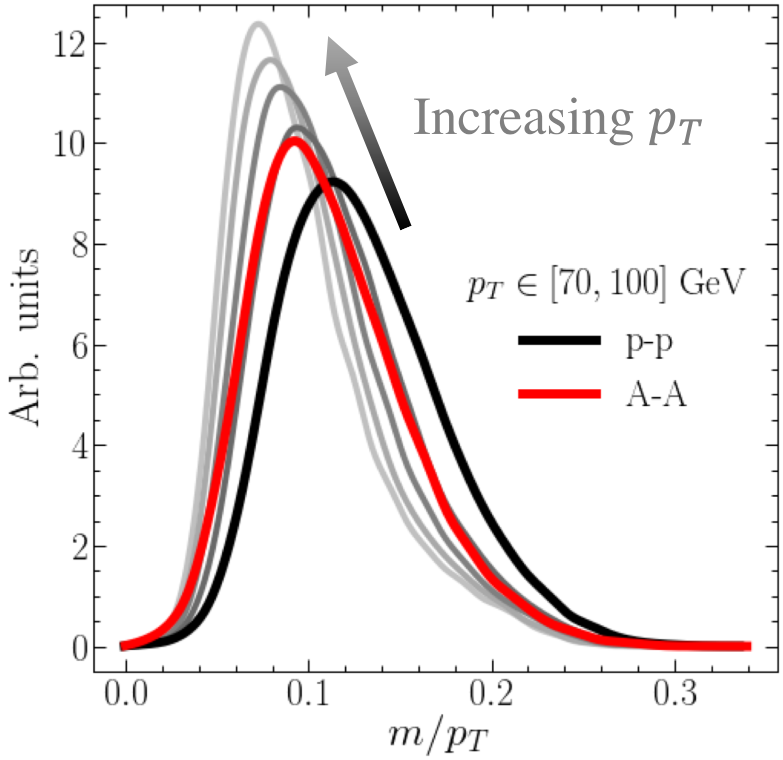
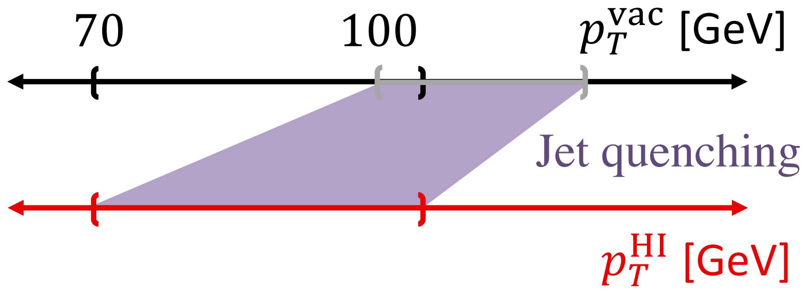




A-A jets were higher p_T when they were produced

- How to isolate jet samples with the same initial parton p_T?

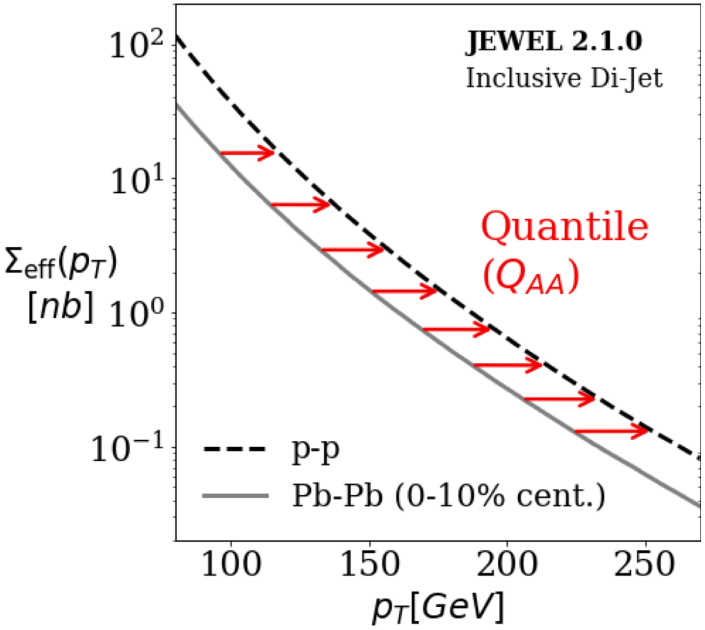
Key question: compare A-A jets to which p-p jets?

- Another answer: match in (effective) cumulative jet cross-section

$$\sigma^{\text{eff}} = \sigma^{\text{pp}}, \sigma^{\text{HI}}/\langle T_{AA}\rangle$$

$$\Sigma^{\text{eff}}(p_T) = \int_{p_T}^{\infty} dp_T \frac{d\sigma^{\text{eff}}}{dp_T}$$

- “Quantile” matching



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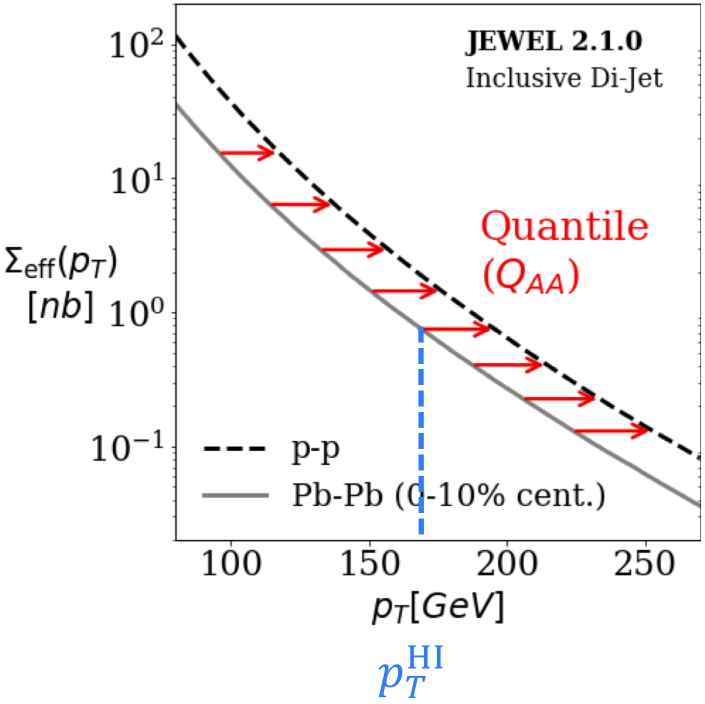

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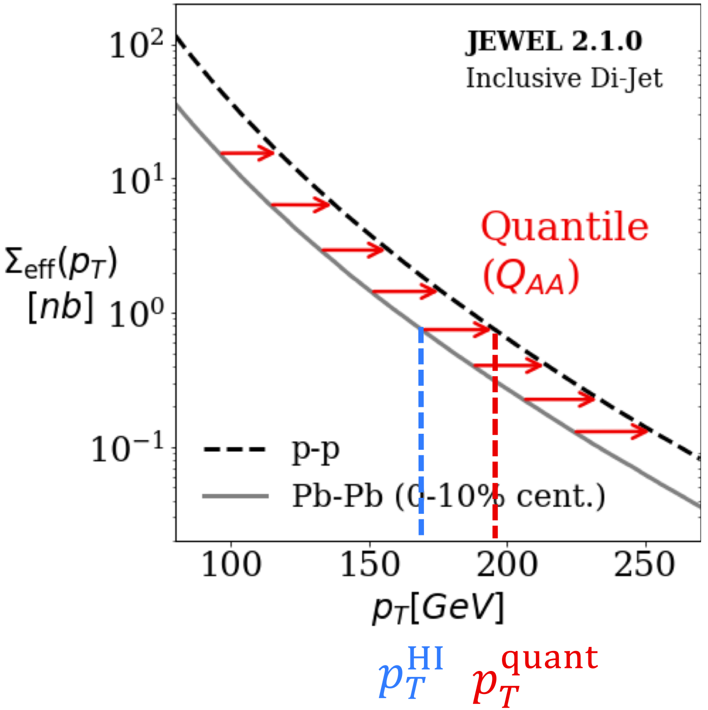

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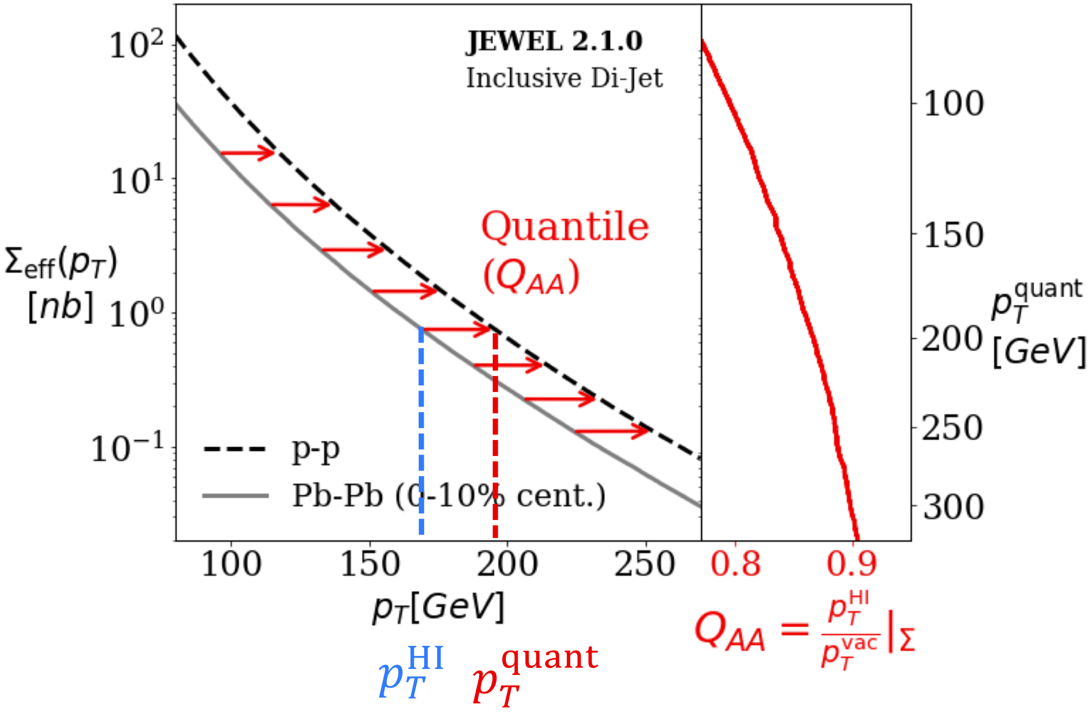
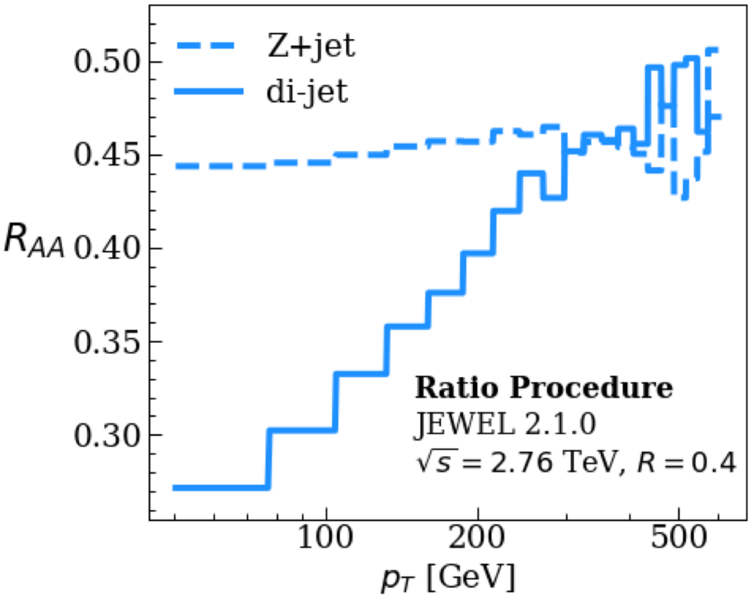
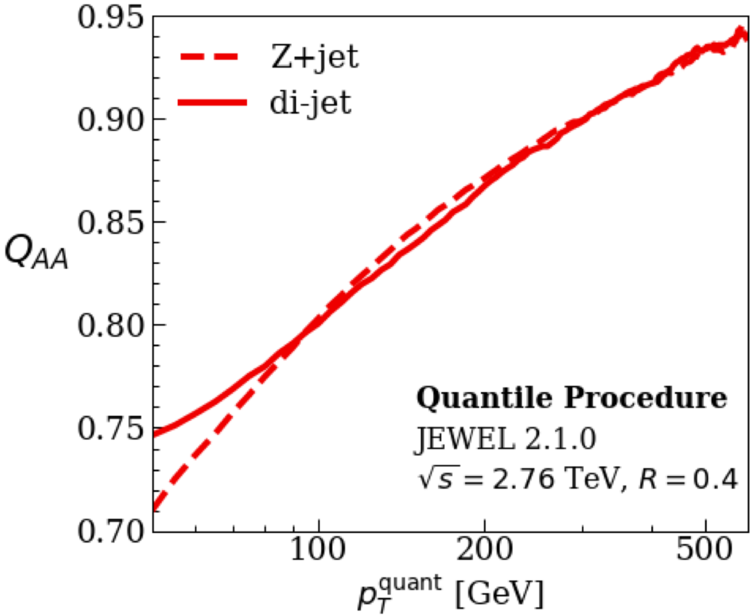


Interpretation of R_{AA} and Q_{AA} is significantly different…

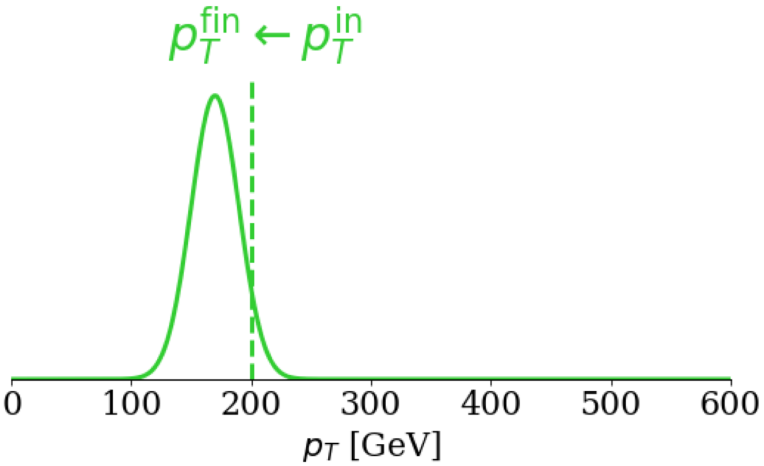




Average jet loss per p_T

Average p_T loss per jet

Sorting out energy loss: quantile matching



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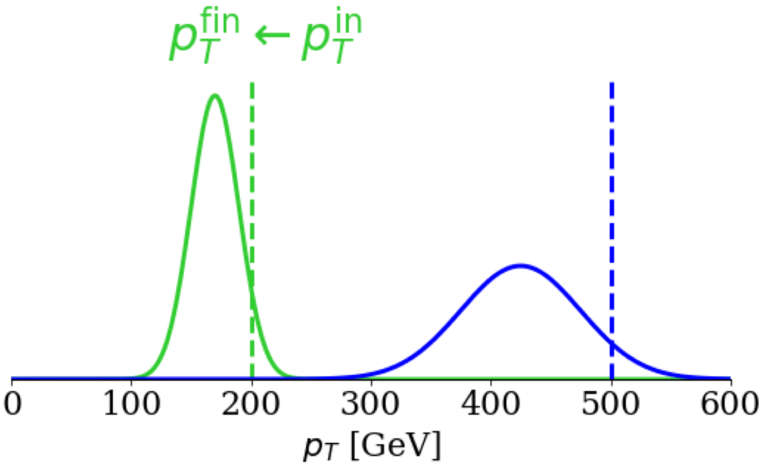
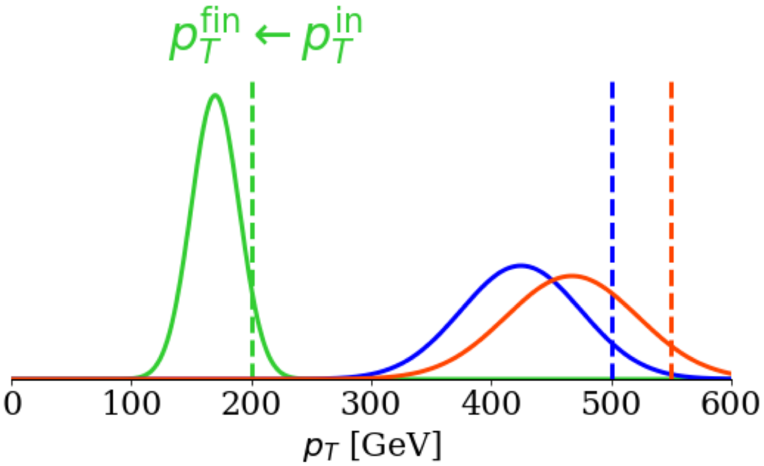


Quenched and initial p_T have same ordering

Sorting out energy loss: quantile matching

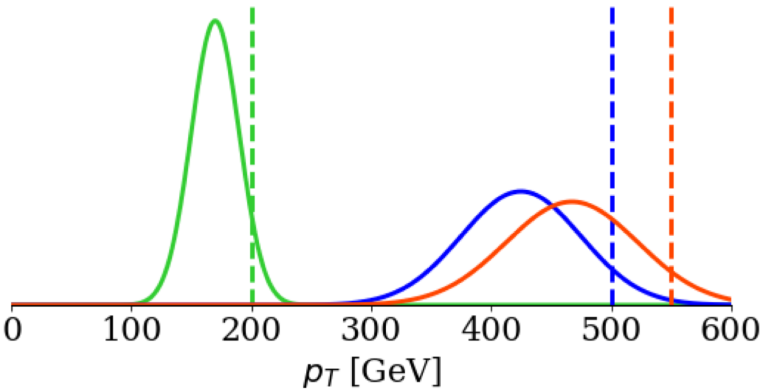


Quenched and initial p_T ^may have same ordering

Sorting out energy loss: quantile matching

Energy loss is...

on average monotonic in p_T



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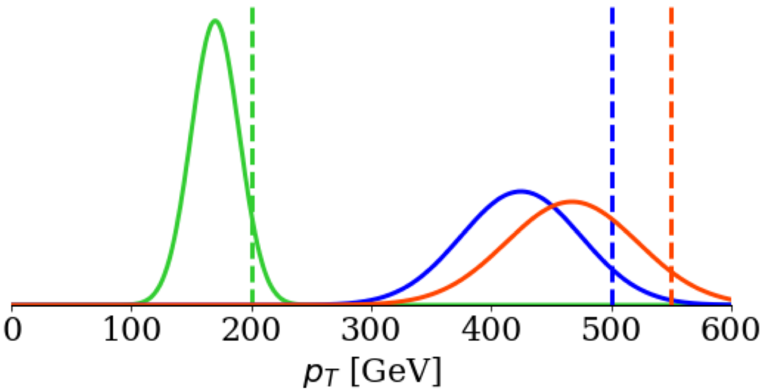

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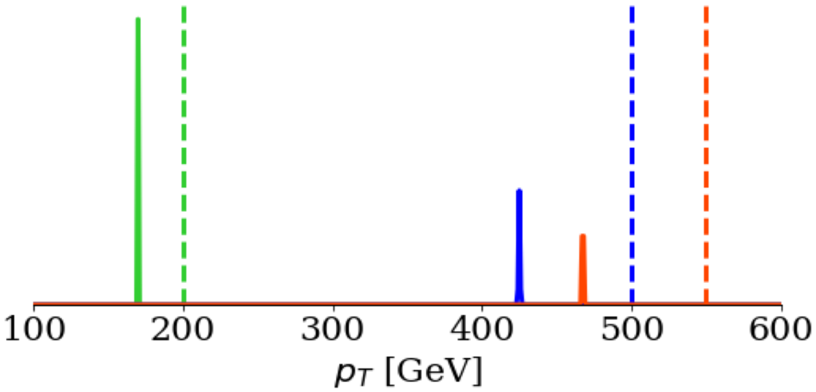

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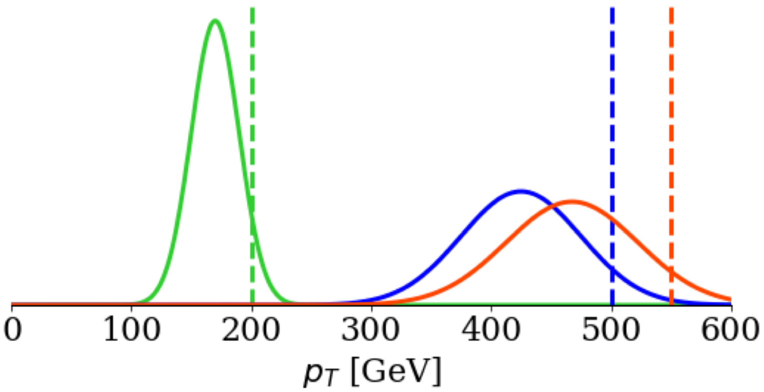

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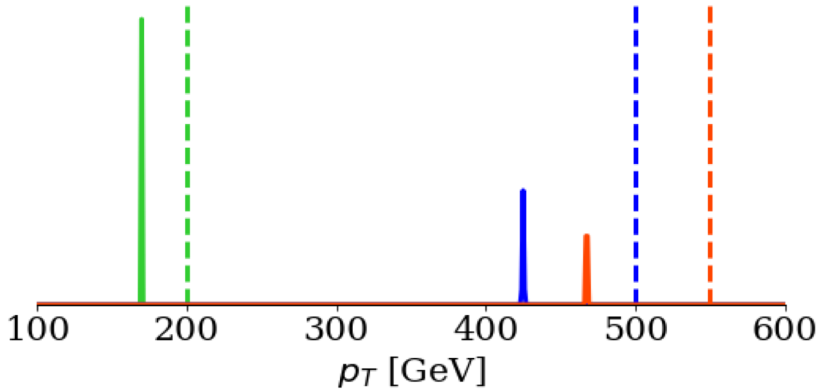
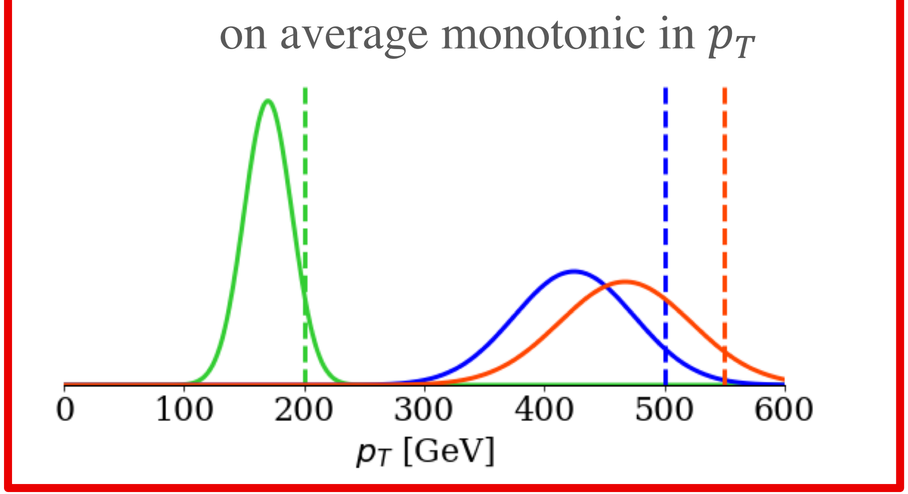
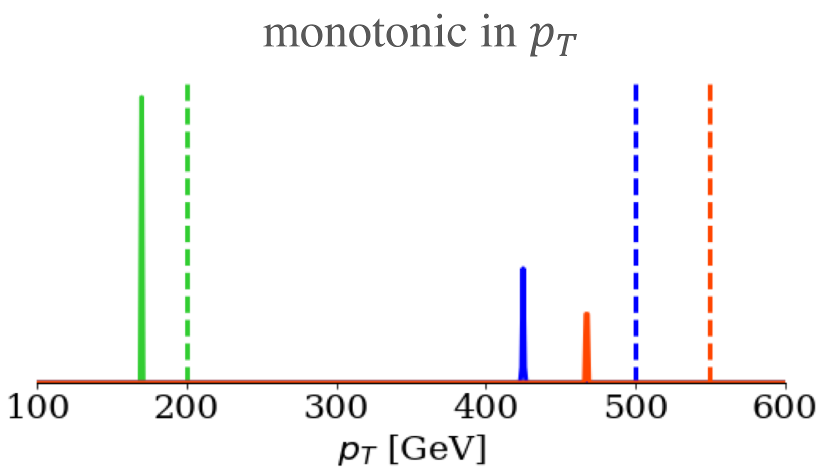


In this limit, quantile matching gives equivalent jets in p-p and A-A

Sorting out energy loss: quantile matching

Energy loss is…





How does quantile matching work in the more realistic case?

How to quantify that?

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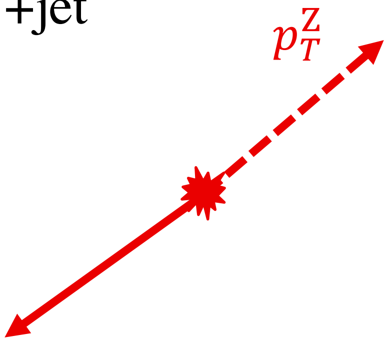
Z+jet



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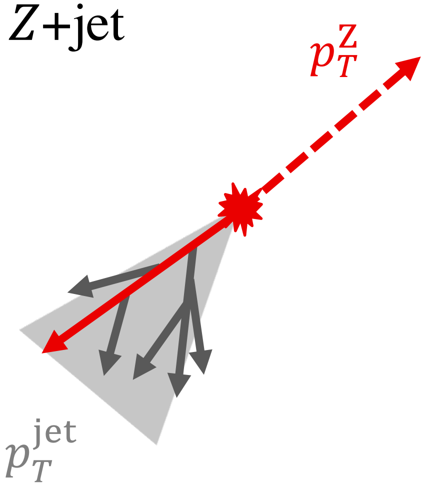

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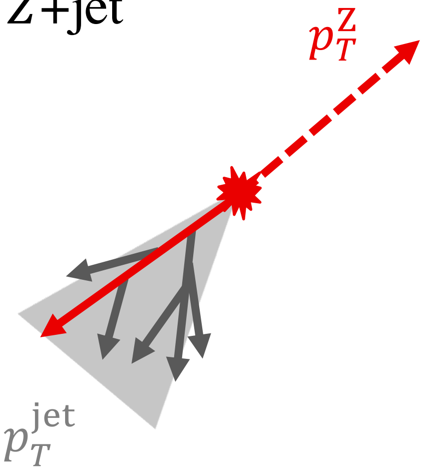
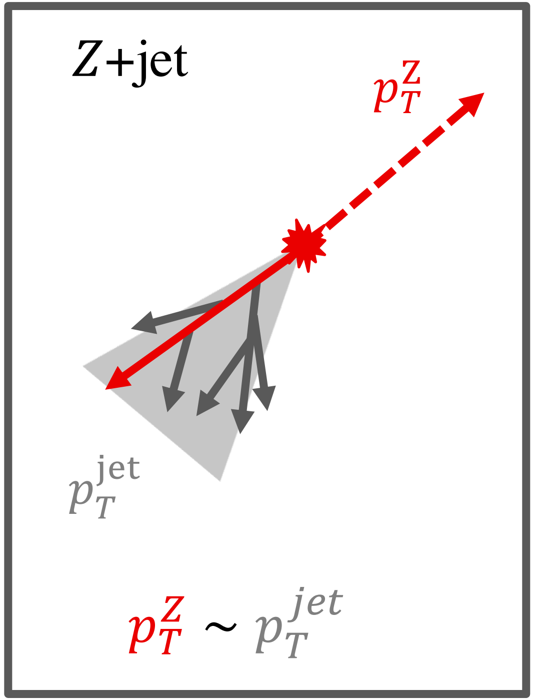


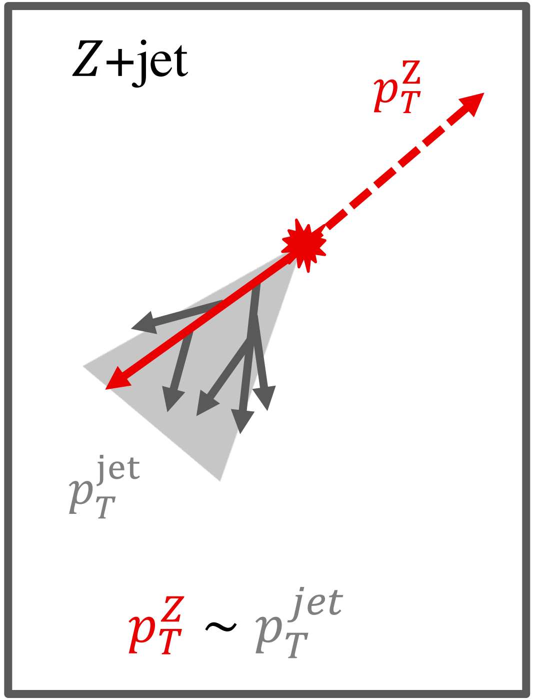
$$p_T^Z \sim p_T^{jet}$$

How to quantify that?



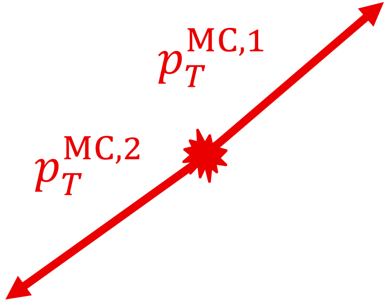
Probe of p_T^{jet} in data

How to quantify that?



Probe of p_T^{jet} in data

Di-jets



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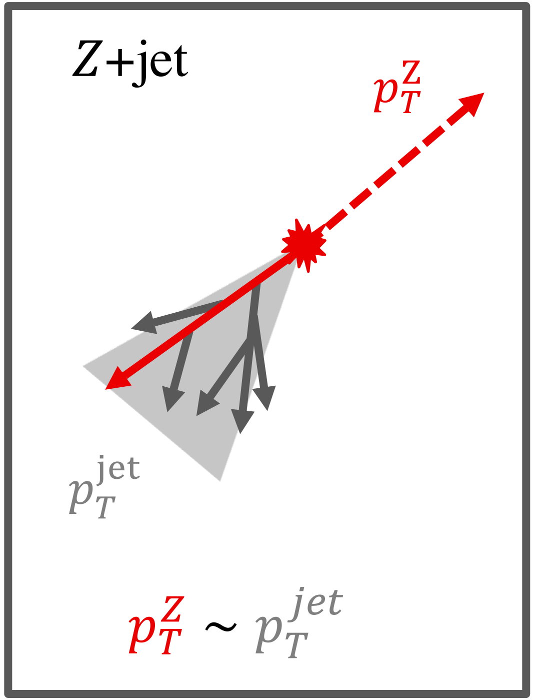

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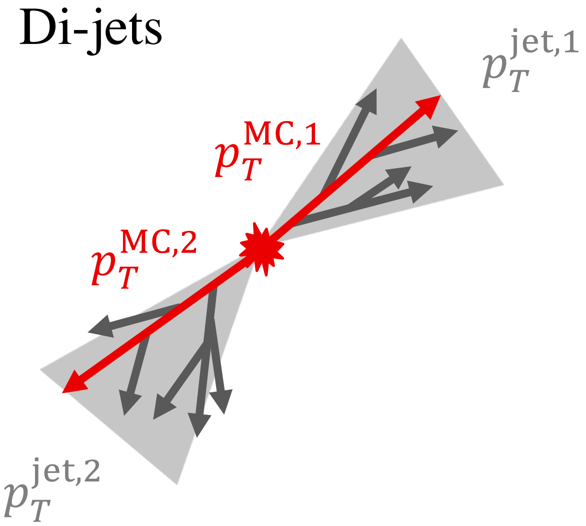

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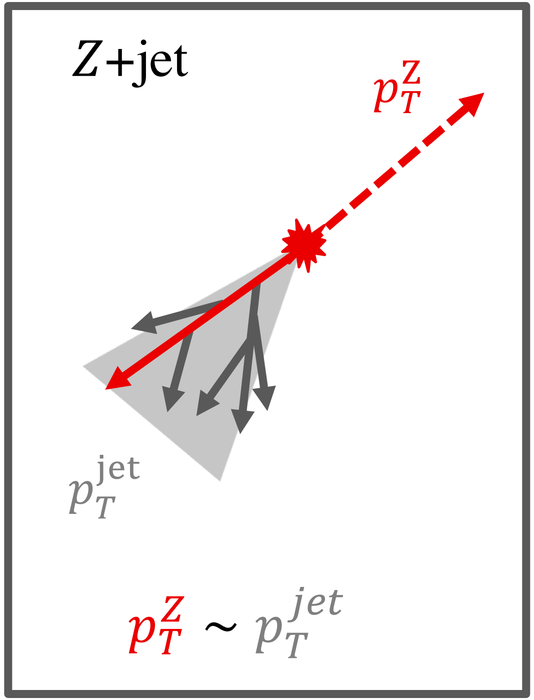

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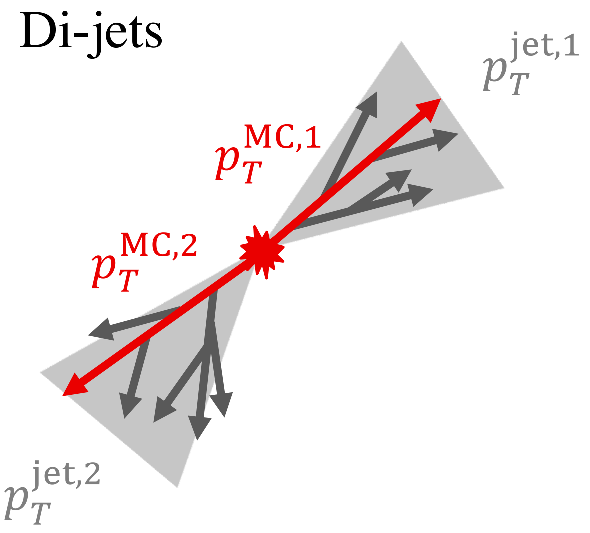
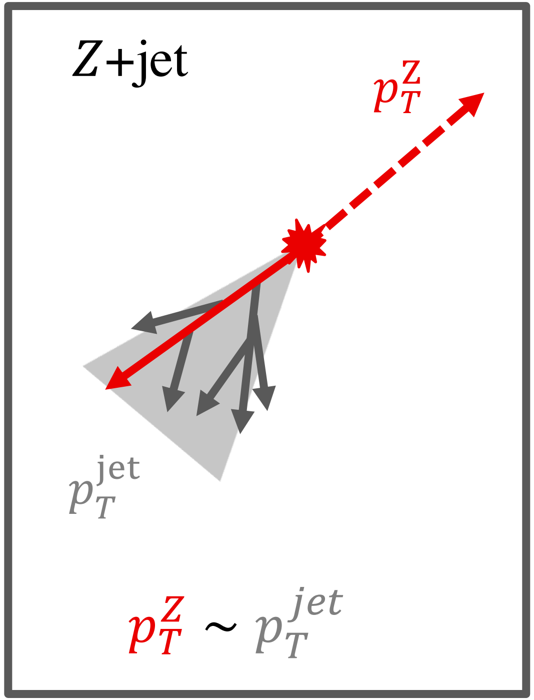


Unphysical $p_T^{MC} \sim p_T^{jet}$

How to quantify that?



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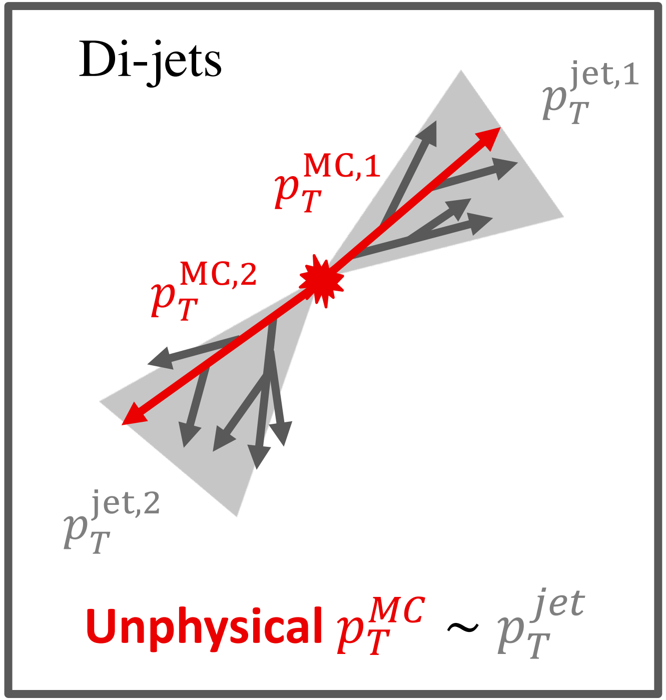
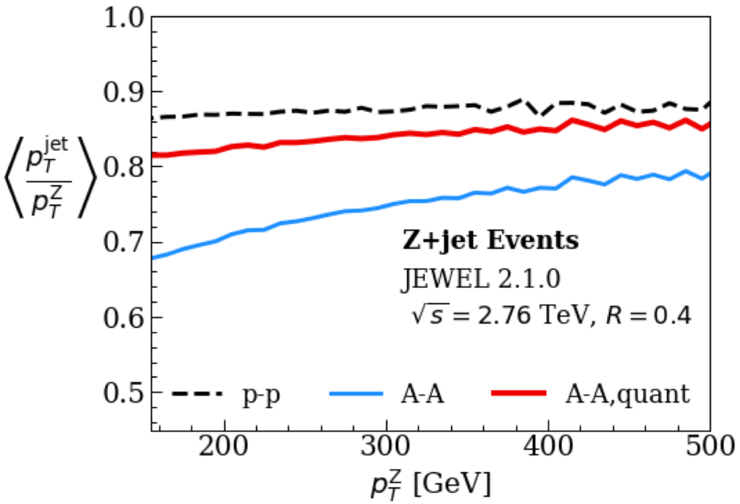


Probe of p_T^{jet} in Monte Carlo

Quantile matching approximates initial p_T of A-A jets

Z+jet



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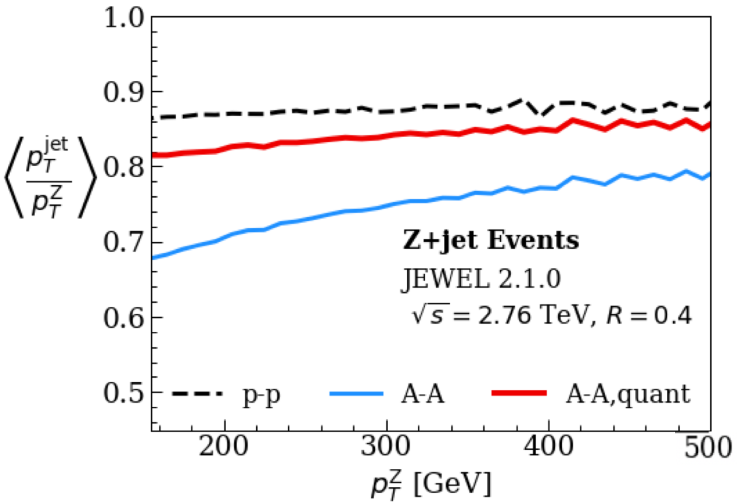

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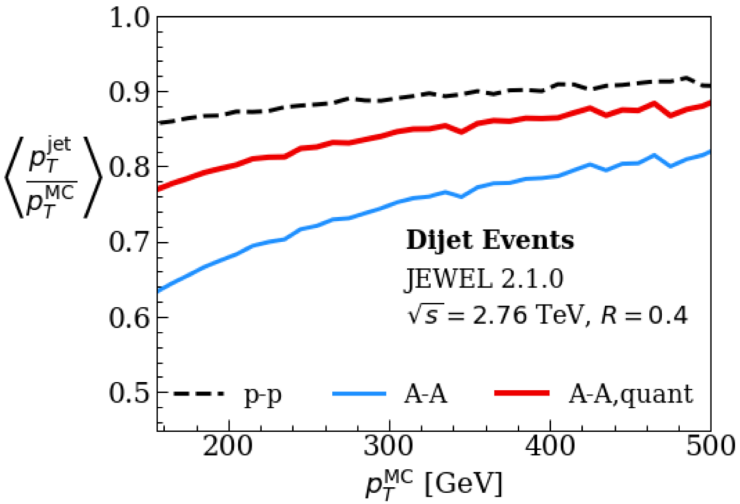

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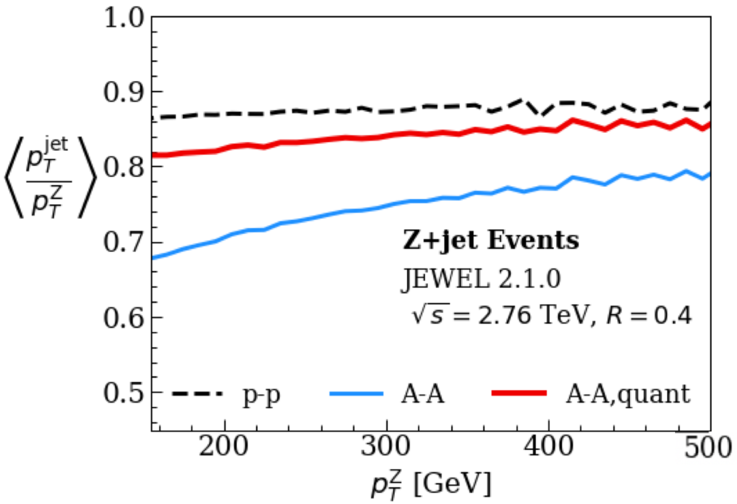
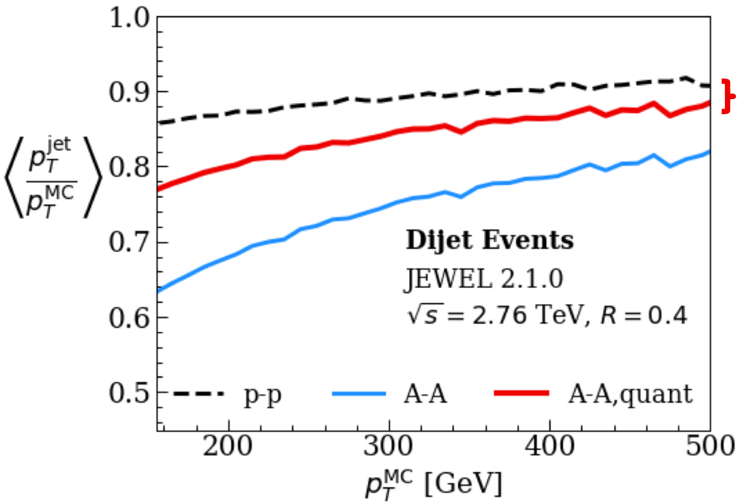


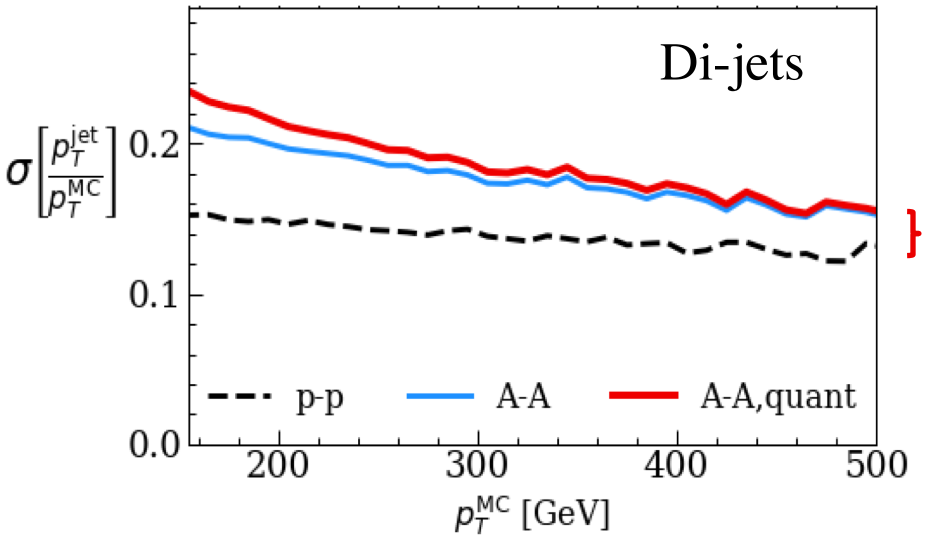
Di-jets



} mean more similar

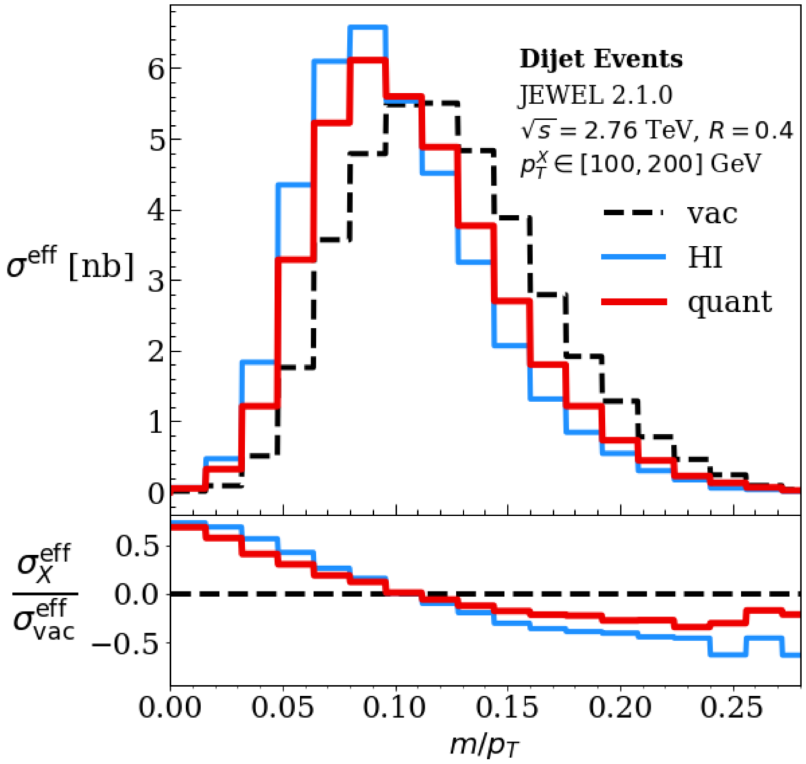
Compared to reconstructed p_T in A-A…

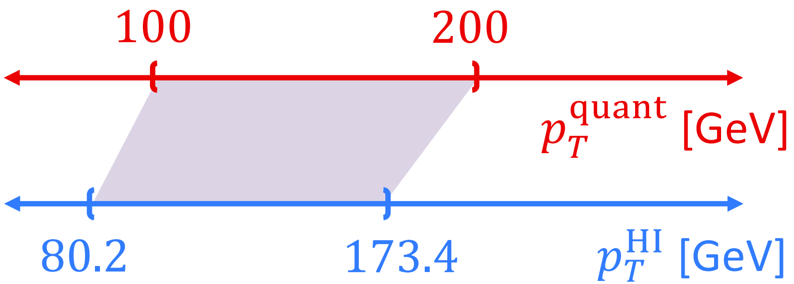
Quantile procedure does not undo energy loss fluctuations



larger standard deviation

Is m/p_T modified or not?





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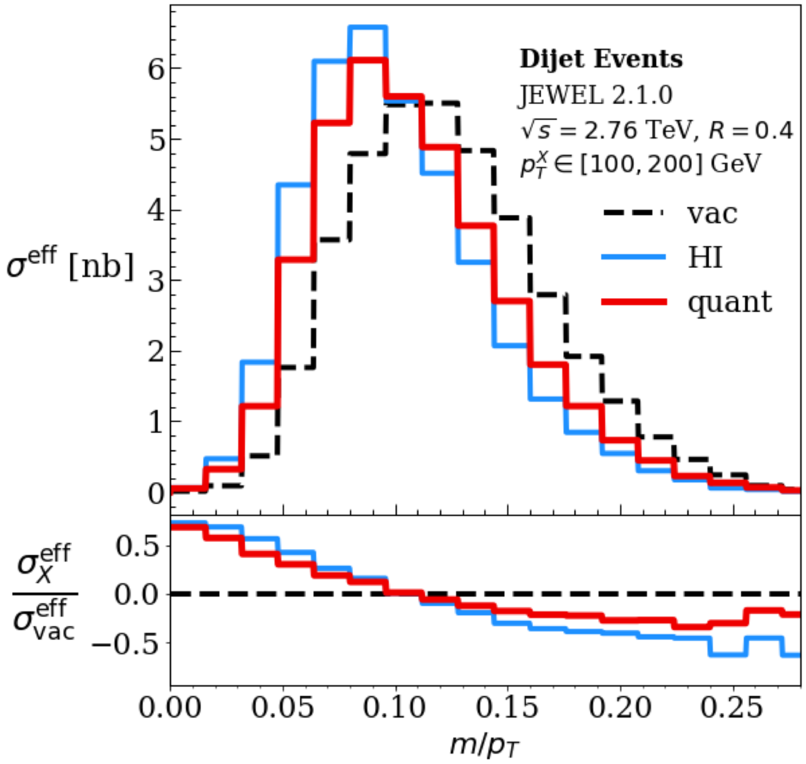

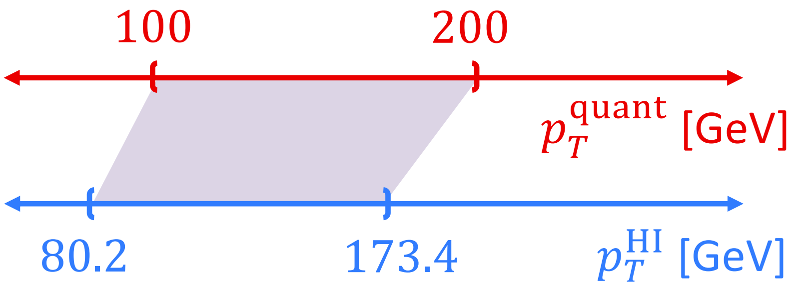

- Sensitivity to matching indicates significant jet p_T migration effects

Ongoing work

What features F control fractional energy loss of a jet?

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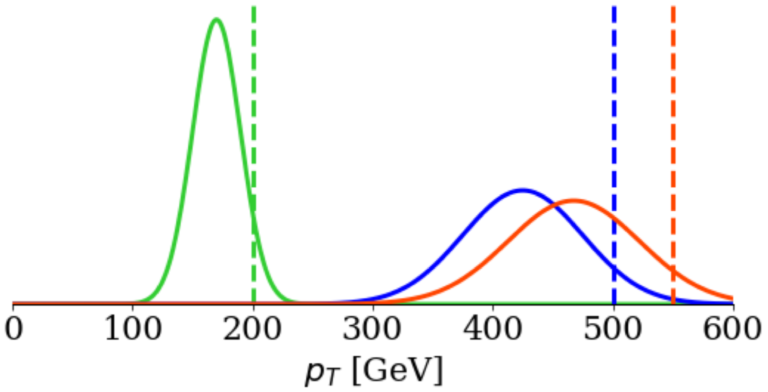
all jets; $p(p_T^{\text{fin}}|p_T^{\text{in}})$



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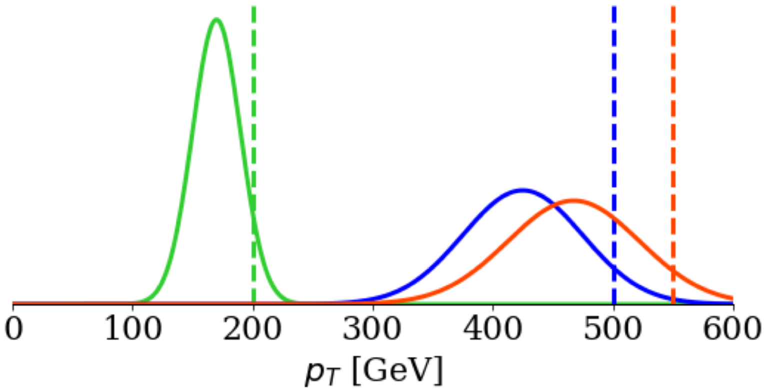

averaging over other features F gives wide range of fractional energy loss for jets with the same initial p_T

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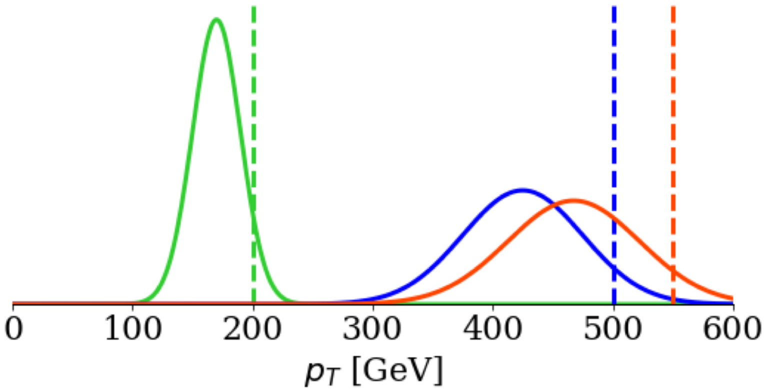
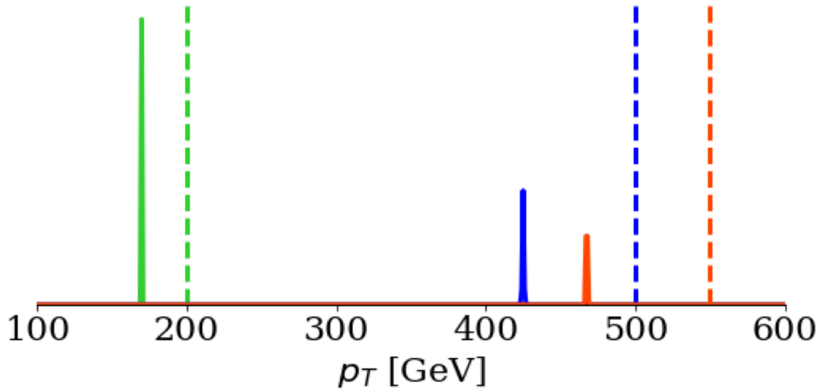


subset of jets with same features F

$p(p_T^{\rm fin}|p_T^{\rm in}, \{F_i\})$



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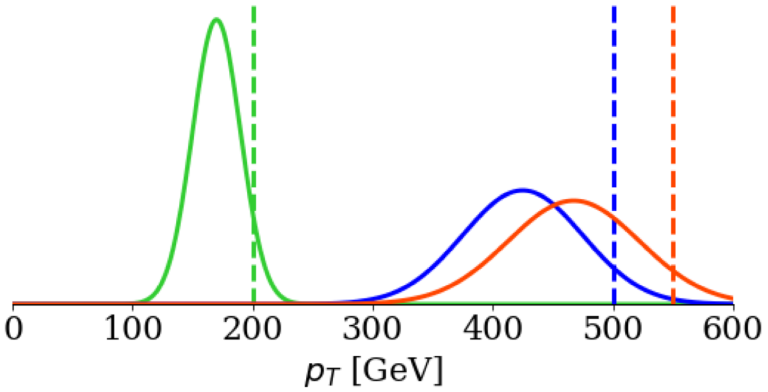

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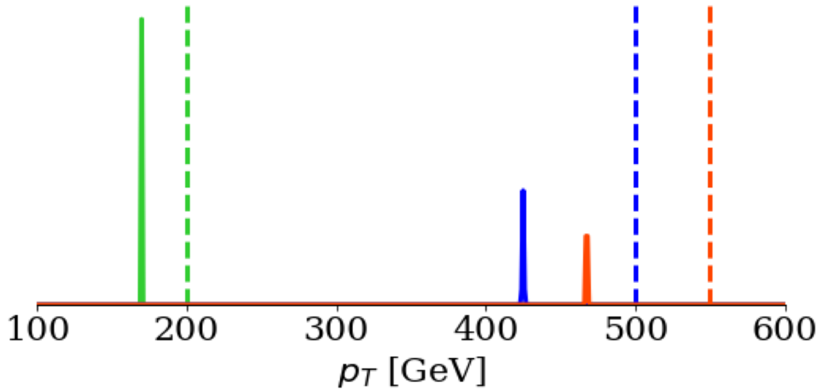

By definition, have same fractional energy loss

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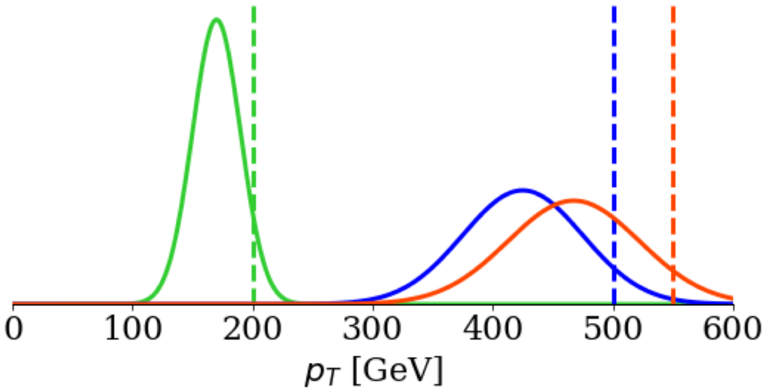

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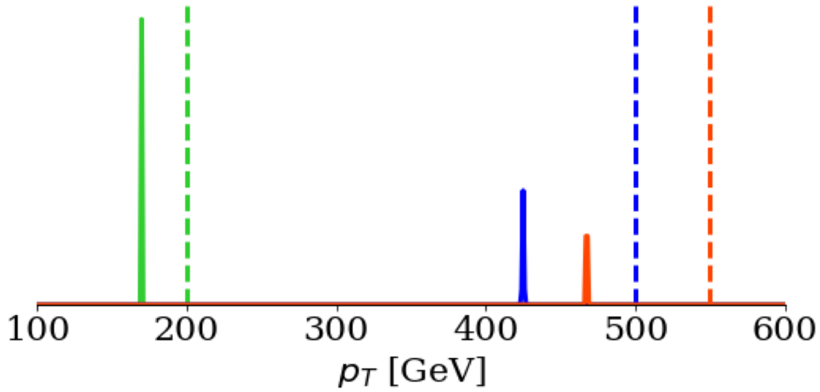

By definition, have same fractional energy loss

Quantile procedure gives exact result in this case

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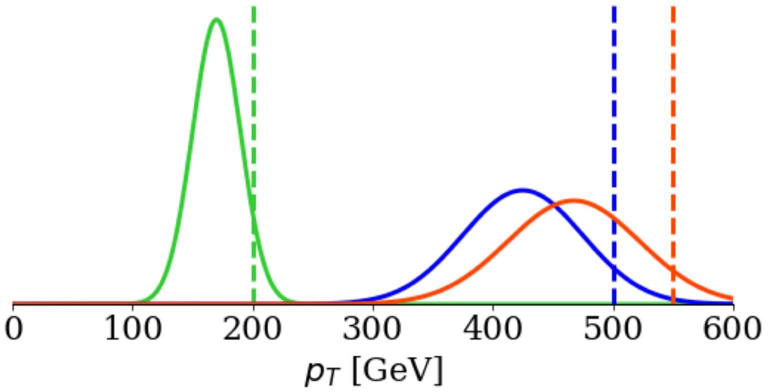

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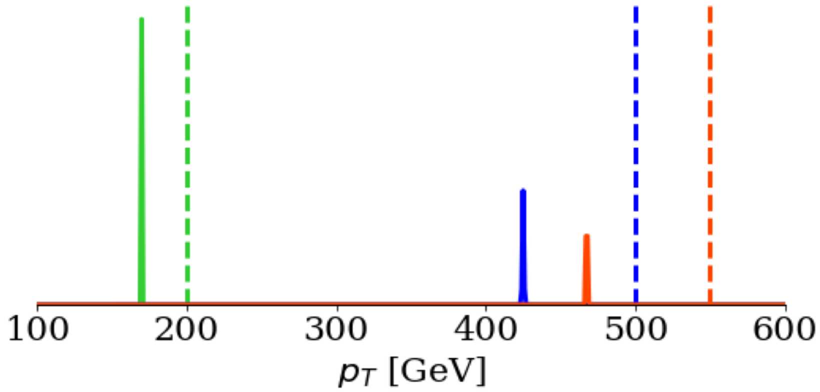

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- HOWEVER: features in F may be unobservable (e.g. path length)

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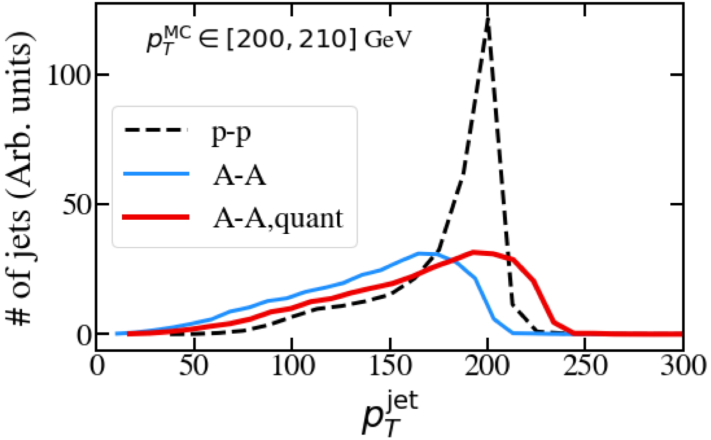

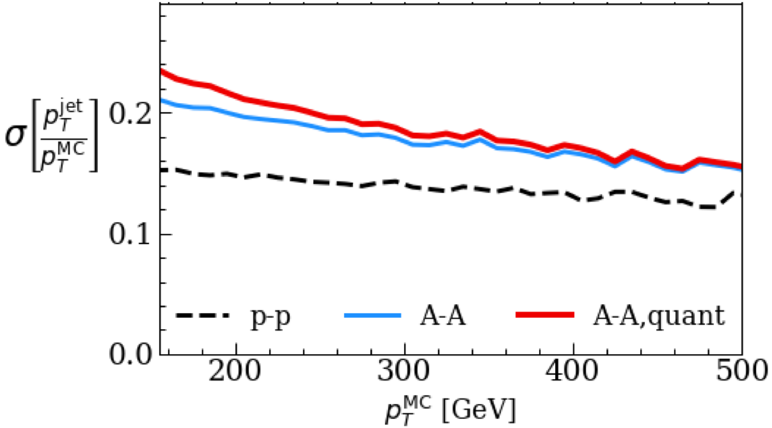

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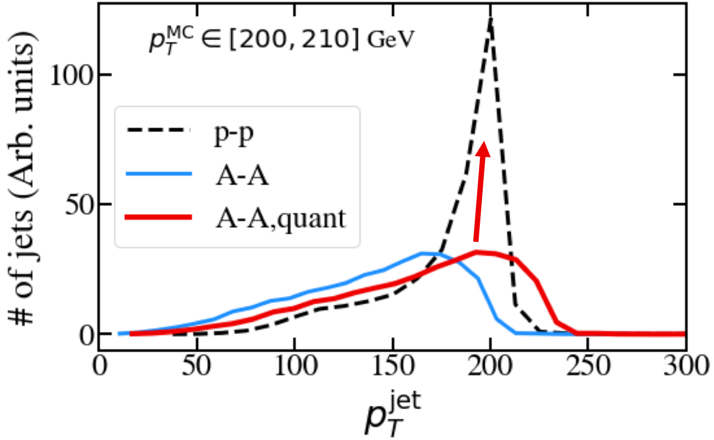

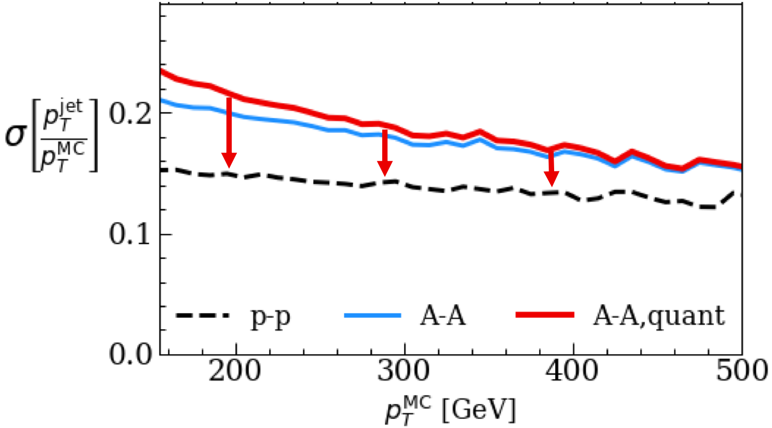

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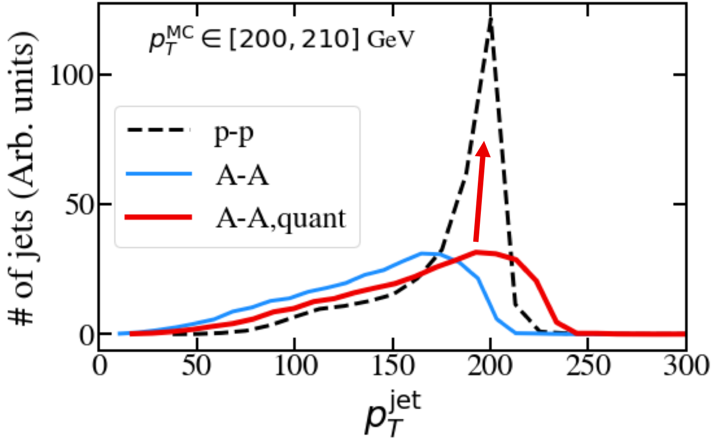

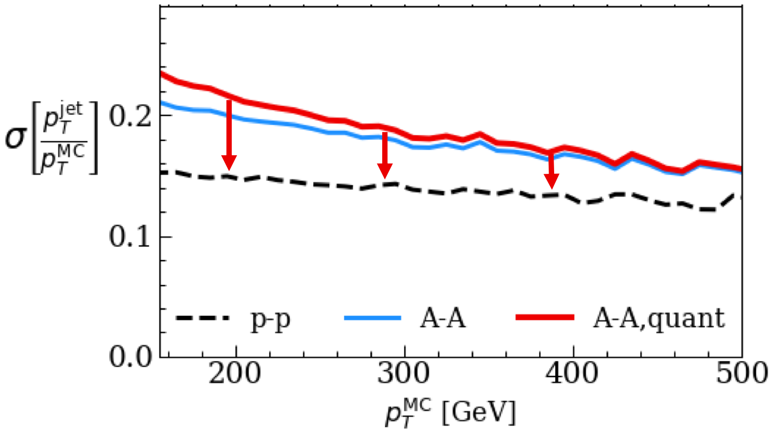

Expectation: performance of the quantile procedure provides quantitative test of extent to which a feature controls jet energy loss

Summary

Going beyond matching p-p and A-A jets in reconstructed p_T

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Going forward: finding jet features that control quenching?

For more on all that…

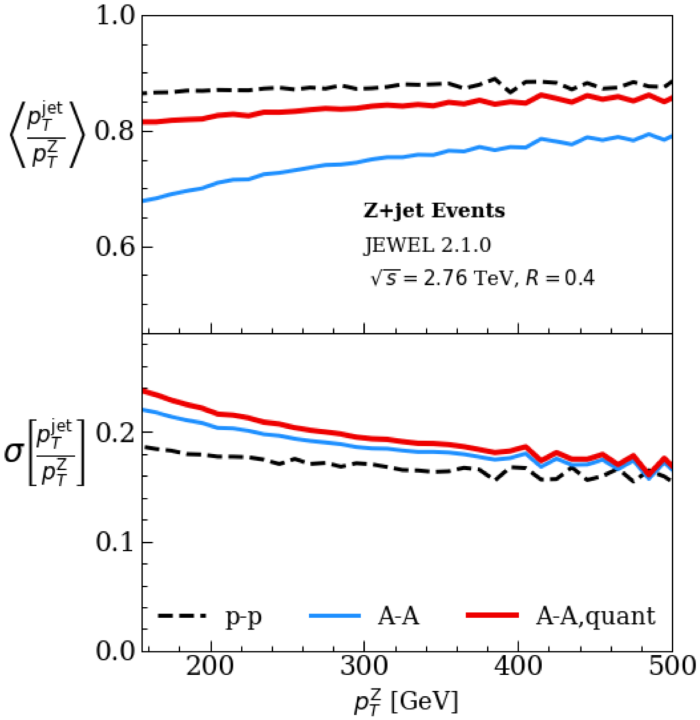
Comments on the definition of the quantile matching

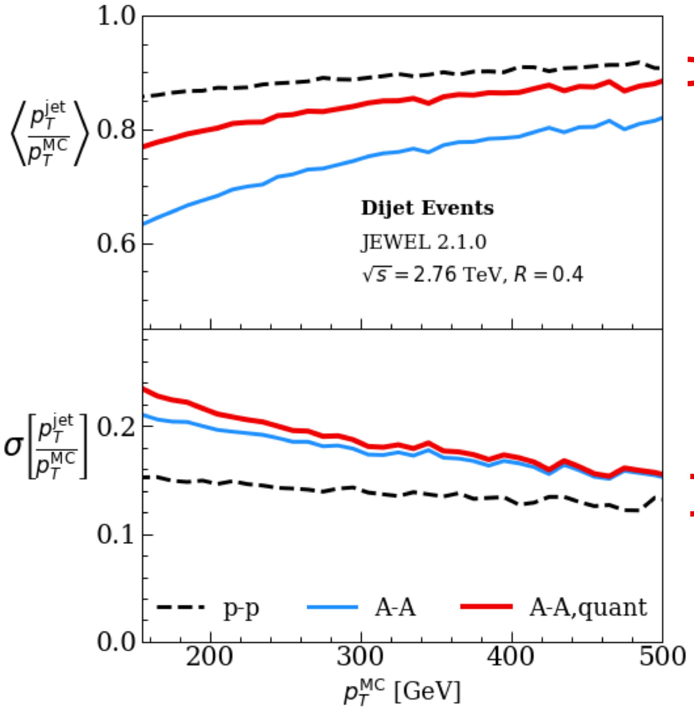
To match the *cumulative* jet cross-section, the formal definition of p_T^{quant} is

$$\int_{p_T^{\text{HI}}}^{\infty} dp_T \left(\frac{d\sigma_{\text{HI}}^{\text{eff}}}{dp_T} \right) = \int_{p_T^{\text{quant}}}^{\infty} dp_T \left(\frac{d\sigma_{\text{pp}}^{\text{eff}}}{dp_T} \right)$$

However, for steeply-falling spectra this is identical (to ~1% level corrections) to simply matching jets in the same cross-section

$$\sigma_{\text{HI}}^{\text{eff}} \left(p_T^{\text{HI}} \right) = \sigma_{\text{pp}}^{\text{eff}} \left(p_T^{\text{quant}} \right)$$





} mean more similar

} standard deviation larger

Compared to reconstructed p_T in A-A…

m/p_T for Z+jet and di-jet events