Rice Informal Seminar
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Data-Driven Approaches to Jet Quenching

Jesse Thaler

ongoing work with Jasmine Brewer, Guilherme Milhano, Andrew Turner, Patrick Komiske, and Eric Metodiev

References: 1812.05111 1802.00008 1809.01140

I am a particle theorist, not a nuclear theorist, but I've started to get interested in jet quenching from the perspective of LHC data analysis

Of course, revolution in understanding substructure of jets in proton-proton collisions. Exciting progress in jet studies in lead-lead collisions as well.

But interpreting jet quenching results is right now limited by theoretical understanding. Therefore want ways of probing jet quenching using data-driven approaches.

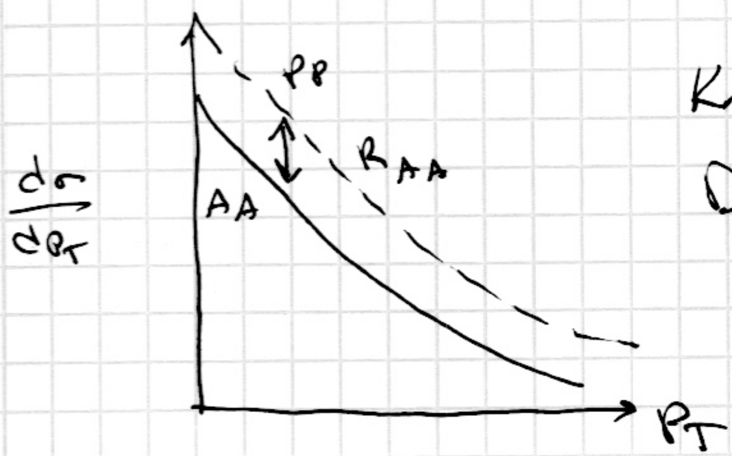
Ultimate goal: Transfer function.

$$\{p_T, \text{mass}, \text{color}, \ldots\}_{\text{perturbative jet in vacuum}}$$

$$\Rightarrow \{p_T, \text{mass}, \ldots\}_{\text{measured jet after passage through medium}}$$

Can't access "perturbative" jet, but we have pp baseline.

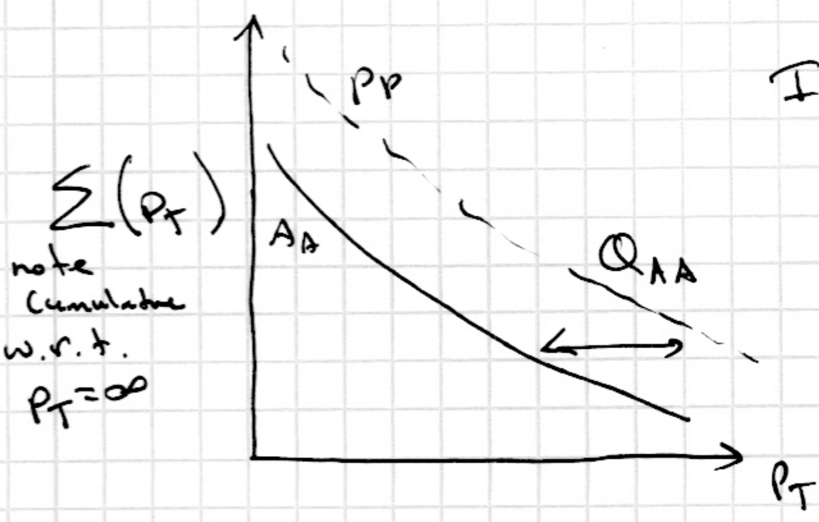
Standard method: R_{AA}



Known bias effects!

Dominated by jets that were least modified, because of steeply falling p_T spectrum.

Quantile method.



If energy loss is monotonic, tells you fractional energy loss for jet that started at given p_T.

(see yesterday's colloquium for why this is optimal transport problem.)

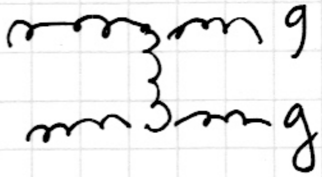
But we really want to know what controls jet energy loss. Mass? Color charge? Something else?

How do you control for these variables when they themselves can get modified?

Today: only partial answer.

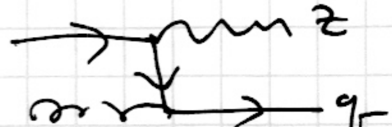
Related question in pp: what is mass spectrum of quark jets?

Dijet:



mostly gluons, but not 100%

Z+jet:



mostly quarks, but not 100%

Want: $P_q(\text{mass})$ $P_g(\text{mass})$

Have: Mixed samples of f_q^A, f_q^B

quark jet fractions

This is already a well studied problem in natural language processing! ("Topic modelling")

RHIC papers } $\Longrightarrow$ pure particle physics words ?

LHC papers } pure nuclear physics words.

If there are "anchor words"...

"RS graviton" $\longrightarrow$ particle

"hydrodynamics" $\longrightarrow$ nuclear.

... you can disentangle mixed distributions!

$$p_{dijet}(\text{mass}) = f_q^{dijet}\, p_q(\text{mass}) + (1 - f_q^{dijet})\, p_g(\text{mass})$$

$$p_{Z+jet}(\text{mass}) = f_q^{Z+jet}\, p_q(\text{mass}) + (1 - f_q^{Z+jet})\, p_g(\text{mass})$$

If there are "anchor bins" in mass, you can solve for f_q^{dijet}, f_q^{Z+jet} $p_q(\text{mass})$ $p_g(\text{mass})$!

[Turns out that mass doesn't work, but multiplicity does.]

Existence of anchor bins $\Rightarrow$ "mutually irreducible"

Trick to extract distributions

$$p_{\text{topic }1}(x) = \frac{p_A(x) - \kappa_{A|B}\, p_B(x)}{1 - \kappa_{A|B}}$$

make as large as possible such that $p_{\text{topic}}(x)$ stays <u>positive</u>.

$$p_{\text{topic }2}(x) = \frac{p_B(x) - \kappa_{B|A}\, p_A(x)}{1 - \kappa_{B|A}}$$

$$f^A_{\text{topic }1} = \left(1 - f^A_{\text{topic }2}\right) = \frac{1 - \kappa_{A|B}}{1 - \kappa_{A|B}\,\kappa_{B|A}}$$

$$f^B_{\text{topic }1} = \left(1 - f^B_{\text{topic }2}\right) = f^A_{\text{topic }1} \cdot \kappa_{B|A}$$

Key assumption: "Sample independence"

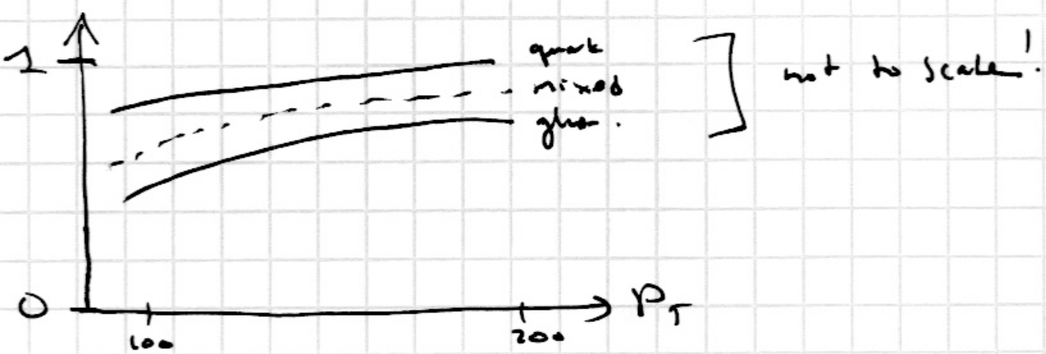
"quark" in one region of phase space same as in any other. Approximately true for well-separated jets in high-energy QCD.

Our Current strategy: Slice pp and AA data by p_T.

Use dijet and Z+jet in jet topics algorithm (using groomed multiplicity as observable) to get out "quark" and "gluon" fractions. (in pp/AA separately)

With this, we can define separate quark/gluon cross sections in pp and AA. Therefore, we can make separate Q_{AA} distributions for "quark" and "gluon" jets.

Ultra-preliminary. (in Jewel)



Will be interesting to see if.

$$\frac{1-Q_{AA}^{quark}}{1-Q_{AA}^{gluon}} \approx \frac{C_F}{C_A} = \frac{4/3}{3} \quad \text{(Casimir Scaling)}$$

Preliminary results suggest not.

More broadly: data-driven, model agnostic analyses with both intuitive qualitative and rigorous quantitative interpretation.