Jet Workshop Summary

Anthony Hodges

On Behalf of the Jet Workshop
RHIC/AGS Users’ Meeting
June 13\textsuperscript{th}, 2024
The Workshop at a Glance

- Two overview talks from theory and experimental perspective
- Talks focused on variety of physics topics
- All centered, of course, on jets!
Setting the Stage, What Are Jets?

• Textbook definition: “jets are collimated, high-energy spray of hadrons resultant from the fragmentation of a hard-scattered parton”
Setting the Stage, What Are Jets?

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- In theory:

\[
\frac{d\sigma}{dp_{T1} dp_{T2} d\tau} \equiv x f(x_1) x f(x_2) \otimes H(\mu^2) \otimes S \otimes J(p_1) J(p_2) \delta \left( \tau - \sum_{i \in \Omega} p_i \right)
\]

Theory Overview: Yacine Mehtar-Tani
Setting the Stage, What Are Jets?

• Textbook definition: “jets are collimated, high-energy spray of hadrons resultant from the fragmentation of a hard-scattered parton”

• In experiment:

Grouped together using jet clustering algorithms to form experimental jets with a $p_T$ and resolution parameter $R$

Experimental Overview: Laura Havener
Why Do We Study Jets?

- Jets serve as proxies for the partons that created them, which we are interested in studying.
- For theorists: Jets are perturbatively calculable objects.
- For experimentalists: Jets use high-resolution detector response regimes.

\[
\frac{d\sigma}{dp_T^1 dp_T^2} \equiv xf(x_1) xf(x_2) \otimes H(\mu^2) \otimes S \otimes J(p_T^1) J(p_T^2) \delta \left( \tau - \sum_{i=1} J(p_i) \right)
\]

Grouped together using jet clustering algorithms to form experimental jets with a $p_T$ and resolution parameter $R$. 

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Why Do We Study Jets?

- Jets are a critical probe of the QCD phase space!

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**Caveat: approximate ranges!**

Experimental Overview: Laura Havener
Why Do We Study Jets... In Heavy-Ion Collisions?

- Jet-Medium interactions important probe of Quark-Gluon Plasma formed in heavy-ion collisions

- Large underlying event offers challenges our understanding of particle correlations (positive spin!)

- Elucidate important QCD question, e.g. quark vs. gluon QCD interactions, mass dependence…

Experimental Overview: Laura Havener
Why Do We Study Jets…

At the LHC
Large Hadron Collider (LHC) at CERN

vs.

At RHIC?
Relativistic Heavy Ion Collider (RHIC) at BNL

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Different Jet Populations

- Jets at RHIC offer a more quark-rich sample
- Jets at LHC offer interesting physics opportunities to study inclusive vs. quark-rich samples
- Additionally, jets at RHIC exist closer to the medium scale
The Power Of Multiple Machines…

- Generally one wants multiple experiments (2-3)
  - To serve as cross-checks on collider results
  - Also to complement varying strengths
- Cross-checks across colliders now possible as well, thanks to LHC-detector sPHENIX’s development at RHIC

RHIC and LHC Synergies: Virginia Bailey
What Do Jets See in Heavy-Ion Collisions?

• How finely can jets resolve the medium?
• Strong, system-independent, centrality dependent $R_{AA}$ hints that jets can resolve differential path-lengths

$$R_{AA} = \frac{1}{N^{AA}} \frac{d^2 N^{AA}/d\eta dp_T}{T_{AA}d^2\sigma^{NN}/d\eta dp_T}$$

$$T_{AA} = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$$

Path-length-dependent Energy Loss: Megan Connors
Clear Path-Length Dependence

• Not only non-zero $v_2$ for high $p_T$ jets, but non-zero $v_3$ measured at LHC!
• Jets are sensitive not only to differences in pathlength, but fluctuations of the pathlength as well
How Finely Can We Resolve Jets?

• Jet grooming can be used to study the hard splittings within jets

• Gives experimental access to the hadronization/fragmentation process

Jet Substructure: Dhanush Hangal
How Finely Can the Medium Resolve Jets?

- ATLAS result hints that at high $p_T$, medium modification is more sensitive to coherence effects.
- Large $r_g \rightarrow$ medium sees two colored objects $\rightarrow$ more energy loss.
- Small $r_g \rightarrow$ medium sees one colored object $\rightarrow$ less energy loss.
Energy-Energy Correlators!

- Energy N-point Correlators becoming increasingly popular
- Possible to delineate regions of perturbative and non-perturbative physics related to free-hadrons and partons, respectively

In pp collisions

Looking Towards the Future: Jets at the EIC

• Aim of Electron-Ion collider is to probe the spin structure of nuclear matter with unprecedented precision

• Jets still an important part of the EIC physics mission!

Arratia, Jacak, FR, Song `19
see also Aschenauer et al.
Looking Towards the Future: Jets at the EIC

• Aim of Electron-Ion collider is to probe the spin structure of nuclear matter with unprecedented precision

• Electron-jet imbalance at the EIC

\[ \vec{q}_T = \vec{p}_T^e + \vec{p}_T^{\text{jet}} \]

• Sensitivity to TMD PDFs but no TMD FF

• TMD factorization

\[ F_{UU} = \sigma_0 H_q(Q, \mu) \sum_q e_q^2 J_q(p_T^{\text{jet}}, R, \mu) \]

\[ \times \int \frac{d^2 \vec{b}_T}{(2\pi)^2} e^{i\vec{q}_T \cdot \vec{b}_T} f_q^{\text{TMD}}(x, \vec{b}_T, \mu) S_q(\vec{b}_T, y_{\text{jet}}, R, \mu) \]

• Sensitivity to the Sivers function

Jets At the EIC: Felix Ringer
A Framework For Theory and Experiment

- JET/XSCAPE modular framework allows for the simultaneous usage of many theory models and event generators

Anthony Hodges, NSF Ascend Fellow, UIUC
XSCAPE in Asymmetric Systems

- A theory/experiment framework for xA systems
- Shows good agreement with LHC data already
- Improves ease of model discrimination with unified framework
Some Concluding Remarks

• Jets a multifaceted way to make precision measurements of QCD phenomenon
• The field is rapidly approaching a transition from the familiar “Golden Age” of Heavy-Ion physics to the new frontier of EIC physics
• Proper accounting of what we’ve learned in the past 20 years of RHIC and LHC jet physics is a necessity
• The successful conclusion of the sPHENIX, STAR, and RHIC science missions are a necessity
• The development of models that can simultaneously describe multiple aspects of jet physics are necessary more than ever to begin approaching a more unified understanding of hot and cold QCD physics