THESIS PROPOSAL: PRECISION CALCULATIONS OF GROOMED JET MASS

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Preference: 1

In the collision of two high-energy particles (e.g. electron-positron or proton-proton), the emission of a quark or a gluon leads to the production of a collimated, structured spray of particles called a jet. This is a direct result of the self-coupling of the strong force, described by the theory of quantum chromodynamics (QCD) [1]. Since these jets are such a 'purely' QCD phenomenon, they provide an excellent laboratory in which to study the theory directly. One would like, for example, to use jet substructure to measure the strong coupling α_s, a fundamental quantity of QCD (if not *the* fundamental quantity).

Yet in order to measure quantities using jet substructure, we must have a clear theoretical understanding against which to compare experimental data. This is difficult due to the nature of QCD. A precise theoretical treatment of jets must contend with a breakdown of perturbation techniques (since $\alpha_s \sim 1$) and significant nonlinear corrections due to hadronization effects (since particles that have a charge under the strong force become 'confined' together). Moreover, in an experimental context, one must account for radiation introduced to a jet from other events in the collider.

We must, therefore, study jet observables that are robust to these problems. One such observable is the 'groomed jet mass' — the total mass/energy of all the particles in the jet, corrected to remove the low-energy and very off-axis particles typical of background radiation. This observable was recently calculated for the first time to high enough precision ($N^2LO + N^3LL$, for the *cognoscenti*) [2, 3] for comparison to data to be feasible[1]. However, this calculation is only valid at low and high values of groomed jet mass (relative to the center-of-mass energy of the collided particles); intermediate values fall outside the regions of validity. Yet interesting physics occurs here, as evidenced by the significant cusp in Fig. 4 of Ref. [2], and so understanding this region is crucial to the ultimate goal of computing α_s.

For this thesis, I would perform calculations to understand the physics of this intermediate-mass region, with the goal of pushing the calculation to the precision achieved for the tails of the distribution. If this proceeded swiftly, I would then attempt a (very rough) determination of α_s. This project would provide an excellent opportunity to learn about QCD, jet phenomenology, and the techniques of modern theoretical high-energy physics.

REFERENCES

[1] Andrew J. Larkoski. *Elementary Particle Physics: An Intuitive Introduction*. Cambridge University Press, Cambridge, United Kingdom ; New York, NY, 2019.

[2] Adam Kardos, Andrew J. Larkoski, and Zoltán Trócsányi. Groomed jet mass at high precision. *Physics Letters B*, 809:135704, October 2020.

[3] Adam Kardos, Andrew J. Larkoski, and Zoltán Trócsányi. Two- and three-loop data for the groomed jet mass. *Phys. Rev. D*, 101(11):114034, June 2020.

[4] ATLAS Collaboration. Measurement of soft-drop jet observables in *pp* collisions with the ATLAS detector at $\sqrt{s} =$ 13 tev. *Phys. Rev. D*, 101(5):052007, March 2020.

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[1] This is very timely, as the ATLAS collaboration recently produced a new measurement of groomed jet mass [4]