Towards a Yoctosecond Imaging Tool for the Quark-Gluon Plasma

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> 7th IDPASC/LIP Students Workshop Coimbra, July 2022



1. PhD Work Plan

Where and why would one study the Quark-Gluon Plasma?

- In ultra-relativistic heavy-ion collisions, e.g., Pb-Pb or Au-Au, conducted at the LHC and at RHIC, which aim to explore and characterize the QGP.
- Signaled by an **abrupt increase** in energy and particle densities about ~1 fm/c (10⁻²⁴ s) after the collision.
- Collective properties are lost on a timescale of ~10 fm/c due to fast fluid-like expansion.
- The QGP is believed to have existed during the first microseconds of our Universe's lifetime.





Wit Busza et al. "Heavy Ion Collisions: The Big Picture and the Big Questions"

How does one study the Quark-Gluon Plasma?

- QGP time evolution is rapid need for a probe that can identify different timescales during the collision's first 10 fm/c.
- Hadronic jets (fragmentation of energetic quarks and gluons) are produced concurrently with the QGP, through which they have to propagate and interact with - imprinted modifications tell a story (jet quenching).
- Jet evolution spans a wide range of scales sensitivity to the QGP at different timescales!



M. van Leeuwen. Results of the ALICE experiment. 54 Int. Winter Meet. on Nuc. Phys., 2016.

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PhD research aim: To endow jets produced in heavy-ion collisions with the ability to serve as yoctosecond-resolution probes of the QGP.

Jet evolution and jet observables

Vacuum jet evolution (**proton-proton** collisions) is well established via probabilistic implementation of the DGLAP equations (momentum space).

- Need for a space-time description of in-medium jet evolution (heavy ion collisions).
- Need for observables that can tap into the relation between the medium-induced modifications of jets

and the time evolution of the QGP.





Recent work: L. Apolinário., A. Cordeiro, K. Zapp, Time reclustering for jet quenching studies, Eur.Phys.J.C 81 (2021) 6,

2. Current ongoing work

Jet quenching studies

- Experimentally, heavy ion jets appear to suffer modifications when they travel through the QGP:
 - transverse momentum loss
 - orientation
 - composition
 - 0 ...

Compare **heavy ion jets** with a well established proton-proton baseline (**vacuum jets**)



Nuclear modification factor - RAA



Bin migration effects in RAA - a toy model

$$p_T \to (1 - \epsilon) p_T$$



Bin migration effects in RAA - a toy model



Same energy loss but different RAA!

QAA - a proxy for jet energy loss



"1-QAA is a proxy for the average fractional jet energy loss"

RAA vs QAA for different event types



all reconstructed jets with pT > 50 GeV

 $\sqrt{s_{NN}} = 5.02 ~{
m TeV}$ 13

QAA as a function of jet radius



Work on possible parametrizations of the QAA as a function of transverse momentum and jet radius;

Explore possible correlations between the QAA and the formation times calculated in Apolinário et al., "Time reclustering for jet quenching studies" (2021);

Thank you!

Back-up slides



subleading without recoils

Absolute energy loss



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Separable parametrization of average energy loss

