Jets in QCD Matter

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Outline

• jets in hot QCD matter with ALICE
• jets in cold QCD matter with ALICE
Relevant for this talk:
- Excellent tracking capabilities
- Low-material budget in front of calorimeter
Jet probes of quark-gluon plasma (QGP)

Control

Jet-QGP interactions

Source: APS
Jet spectra measurements

• Jets strongly suppressed in central Pb-Pb collisions
• Models that vary widely in the physics can all describe data within errors (☹️)
Jet mass in Pb-Pb

$$M_{Jet} = \sqrt{E_{Jet}^2 - p_{Jet}^2} \propto \text{Virtuality}$$


Models with energy loss miss data badly, PYTHIA (pp) describes it fairly well
Search for jet scattering off quark-gluon plasma

- Large-angle scattering off QGP not yet observed with current precision
- High-Luminosity LHC will provide percent-level precision arXiv:1812.06772
Deconstructing jets

“Shared Momentum Fraction” Zg
Found to converge to Altarelli-Parisi splitting functions
Shared-momentum fraction for well-separated sub-jets

\[ \Delta R > 0.1 \]

Significant modification for symmetric configurations
Shared-momentum fraction for collinear sub-jets

\[ \Delta R < 0.1 \]

No significant modification
“Color coherence”???

• Potentially yet another interesting QCD-in-matter effect (adding to color transparency, LPM, etc.)
Quark propagation in “QCD matter”

Source: EIC White paper
“QCD Matter” in diverse type of experiments

- eA
- pA
- pA and AA

Future: The Electron-Ion Collider

- CLAS12, SeaQuest, COMPASS, NA61 (fixed target)
- ALICE, ATLAS, CMS, LHCb and PHENIX, STAR (collider)
Theory of quark interactions with QCD matter has more than 20 years of development

Radiative energy loss and $p(T)$ broadening of high-energy partons in nuclei
R. Baier (Bielefeld U.), Yuri L. Dokshitzer (INFN, Milan), Alfred H. Mueller (Columbia U.), S. Peigne, D.
CU-TP-760, BI-TP-96-26, LPTHE-ORSAY-96-61
DOI: 10.1016/S0550-3213(96)00581-0
e-Print: hep-ph/9608322 | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvard | EndNote
ADS Abstract Service

Multiple collisions and induced gluon Bremsstrahlung in QCD
Published in Nucl.Phys. B420 (1994) 583-614
CU-TP-598, LBL-32682
DOI: 10.1016/0550-3213(94)90079-5
e-Print: nucl-th/9306003 | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvard | EndNote
KEK scanned document; ADS Abstract Service

Heavy quark colorimetry of QCD matter
Yuri L. Dokshitzer (Paris U., VI-VII & Orsay, LPT), D.E. Kha
LPT-ORSAY-01-58, BNL-NT-01-9
DOI: 10.1016/S0370-2693(01)01130-3
e-Print: hep-ph/0106202 | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvard
ADS Abstract Service

Detailed record - Cited by 1042 records
Detailed record - Cited by 698 records
Detailed record - Cited by 830 records

Theory applies to both:
EIC will be the fusion point of two distinct communities

“The realization of an EIC would unify the U.S. QCD community, which at present is two distinct research communities studying hadronic physics and heavy ion physics”

The National Academies of Sciences, An Assessment of U.S.-Based Electron-Ion Collider Science
Proton-lead collisions at the LHC → a gateway towards EIC Physics

- In 2013, the LHC delivered them at a center-of-mass energy of 5 TeV
- Our “probe” is in itself complicated, and we do not control kinematics. Electron beams would be better.
We constrain quark kinematics by measuring photon (mimicking electrons in DIS)
Hadrons spectra

Jet spectra

Integrated $\gamma$-Hadron Correlation: $2\pi/3 < \Delta\varphi < \pi, |\Delta\eta| < 0.6$

ALICE Preliminary

$pp \sqrt{s} = 5$ TeV
$p$-Pb $\sqrt{s_{NN}} = 5$ TeV

pp Systematic
p-Pb Systematic

Normalization $\pm 25\%$

$z_T = p_T^h/p_T^\gamma$

$1/N_\gamma dN/dz_T d\Delta\eta$

$1/N_\gamma dN/d\Delta\varphi$

arXiv:1812.04158

ALICE Preliminary

$p$-Pb $\sqrt{s_{NN}} = 5$ TeV
$pp \sqrt{s} = 5$ TeV

Syst. error

$20 < p_T^\gamma < 30$ GeV/$c$

$\Delta\varphi > \pi/2$, Anti-$k_T$ $R=0.4$

p-Pb data agree with pp collisions within errors
Photons measured with ALICE access a poorly explored region

\[
x \sim \frac{2p_T}{\sqrt{s}}
\]

\[
Q^2 \sim p_T^2
\]
EIC coverage with $\sqrt{s} = 100$ GeV
Jet mass in pA collisions


\[ M_{Jet} = \sqrt{E_{Jet}^2 - p_{Jet}^2} \propto Virtuality \]

No strong modifications observed with respect to reference (PYTHIA)
Constraints on jet quenching in p-Pb collisions

Coincidence hadron—jet measurements in p-Pb collisions are used to constrain possible energy loss in p-Pb collisions.

$\Delta E < 400 \text{ MeV at 90\% CL}$
Shared-momentum fraction in p-A collisions

- No strong modifications observed with respect to reference (PYTHIA)

ALI-PREL-120123
Summary

- Jets can be used to probe the Quark-Gluon Plasma. Exciting new tools are jet substructure (coming from HEP).
- No strong modification of jet production in p-A collisions within our precision.
- QCD matter physics bridges JLAB and RHIC/LHC communities.
- The physics of QCD matter can be studied precisely and in controlled way at the EIC. 20+ years of theory and all LHC jet physics developments.
Backup