Medium modification of averaged jet charge in heavy-ion collisions

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Outline:

- Motivation
- Averaged jet charge in pp and heavy-ion collisions
- Results and discussion
- Summary and outlook
Motivation:

A new form of matter: Quark Gluon Plasma (QGP)

Jet quenching -- parton in medium energy loss.

not only high $p_T$ hadrons, but also full jet observables

Xin - Nian Wang, M. Gyulassy, PRL68(1992)1480
Motivation: medium modification of full jet observables

Inclusive Jet suppression
I. Vitev, S. Wicks and B. W. Zhang, JHEP (2008)
I. Vitev and B. W. Zhang, PRL (2010)

Di-jet momentum asymmetry
Y. He, I. Vitev and B. W. Zhang, PLB (2011)
Guang-You Qin, Berndt Muller PRL106 (2011) 162302

Bosons tagged jet imbalance
R. B. Neufeld and I. Vitev, PRL 108, 242001 (2012)
W. Dai, I. Vitev and B. W. Zhang, PRL (2013)

Jet shape modified
I. Vitev, S. Wicks and B. W. Zhang, JHEP (2008)
Yang-Ting Chien, Ivan Vitev, JHEP 1605 (2016) 023
Guo-Liang Ma, PRC 88 (2013) no.2, 021902
Motivation: medium modification of full jet observables

Inclusive Jet suppression

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Guo-Liang Ma, PRC 88 (2013) no.2, 021902

Field and R. Feynman, Nucl. Phys. B136, 1 (1978).
averaged jet charge in pp collisions: baseline

definition of momentum weighted jet charge:

\[ Q_j = \frac{1}{(p_{Tj})^\kappa} \sum_{i \in \text{Tr}} q_i \times (p_{T}^i)^\kappa \]

- \( q_i \): electric charge of hadron inside jet cone
- \( p_{Ti} \): \( p_T \) of hadron inside jet cone
- \( p_{Tj} \): \( p_T \) of full jet
- \( k \): free parameter

David Krohn et al... Phys. Rev. Lett. 110 (2013) 212001
Waalewijn, Wouter J. Phys.Rev. D86 (2012) 094030

here we chose MC method for pp baseline
averaged jet charge in pp collisions: baseline

pythia6 Perugia 2012 tunes + FastJet

MC results fit experimental data well

the charge of quark and gluon jet is quite different

ATLAS Collaboration Phys.Rev. D93 (2016) no.5, 052003
Matteo Cacciari, Gavin P. Salam, Gregory Soyez Eur.Phys.J. C72 (2012) 1896
Peter Zeiler Skands Phys.Rev.D82:074018,2010
Nuclear effects: cold(initial) + hot(final)

Cold nuclear matter effects: nuclear shadowing

Parton distributions in free proton --> in nuclei

\[ f_i^A(x, Q) = R_i^A f_i^{CTEQ6}(x, Q) \]

K. J. Eskola, H. Paukkunen, C. A. Salgado JHEP 0904:065,2009

modifications from CNM effects:

\[ \text{ratio} = \langle Q \rangle_{pp}^{\text{CNM}} / \langle Q \rangle_{pp} \]

CNM effects slightly modify averaged jet charge

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parton energy loss in PYQUEN:

Collisional energy loss

high-momentum scattering

Radiative energy loss

BDMPSZ-Energy loss of partons

\[ \frac{dE^{\text{total}}}{dl} = \frac{dE^{\text{col}}}{dl} + \frac{dE^{\text{rad}}}{dl} \]

PYQUEN

R. Baier, Yu. L. Dokshitzer, A.H. Mueller, D. Schiff, Phys. Rev. C 60, 064902 (1999)
I.P. Lokhtin, A.M. Snigirev, Eur. Phys. J. C 16, 527 (2000)
I.P. Lokhtin, A.M. Snigirev Eur.Phys.J. C45 (2006)
Jet quenching results from PYQUEN:

high $p_T$ hadrons

1+1D Bjorken expansion: $T_0=1.0\text{GeV}$, $\tau_0 = 0.1\text{fm}$ @PbPb 2.76TeV

wide-angle radiation

$$\frac{dN_g}{d\theta} \propto \frac{1}{\theta}$$

1+1D Bjorken expansion: $T_0=1.0\text{GeV}$, $\tau_0 = 0.1\text{fm}$ @PbPb 2.76TeV
3+1D event-by-event Ideal Hydrodynamic:

L. Pang, Q. Wang and X. N. Wang, Phys. Rev. C 86, 024911 (2012)

PYQUEN+(3+1D) Ideal Hydro

Initial condition: $T_0 = 0.43\, GeV$, $\tau_0 = 0.6\, fm$ @PbPb 2.76TeV
first result of averaged jet charge in PbPb collisions:

**PYQUEN + (3+1D) Ideal Hydro**

\[ Q_j = \frac{1}{(p_T^j)_{\kappa}} \sum_{i \in T_r} q_i \times (p_T^i)^{\kappa} \quad R = \frac{\langle Q_j \rangle_{PbPb}}{\langle Q_j \rangle_{pp}} \]

- averaged jet charge is significantly modified
- expected medium modification of jet charge

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Shi-Yong Chen, Ben-Wei Zhang and En-Ke Wang, in preparation
first result of averaged jet charge in PbPb collisions:

PYQUEN + (3+1D) Ideal Hydro

momentum weighted jet charge:

- why ratio > 1 at small k, but ratio < 1 at large k?
averaged jet charge as a probe for flavour dependence of Eloss:
flavour dependence of pp baseline and nuclear modifications

• no contribution from CNM
• no contribution from modifications for quark jets

who did this significant modification?

\[ \frac{C_A}{C_F} = \frac{9}{4} \]
\[ \frac{\Delta E_g}{\Delta E_q} = \frac{9}{4} \]
averaged jet charge as a probe for flavour dependence of $E_{\text{loss}}$

- $p/\pi$ puzzle
  - $\Delta E_g/\Delta E_q = 9/4$ leads to stronger suppression
  - $\Delta E_g/\Delta E_q = 1$ closer to experimental data
  - $\Delta E_g/\Delta E_q = ?$ still an open question

Jet charge is an excellent candidate observable

- no contributions from CNM
- no contributions from modifications for quark jets

Nuclear modifications mainly from the changed portion of quark and gluon jets

Xiaofang Chen, Hanzhong Zhang, Ben-Wei Zhang, Enke Wang J. Phys. 37 (2010) 015004

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averaged jet charge as a probe for flavour dependence of Eloss:

- the medium modification of averaged jet charge is due to the changing portion of quarks and gluons
- precisely measurement of averaged jet charge in heavy-ion collisions in the future will highlight the flavour dependence of parton energy loss
Summy and outlook

• averaged jet charge is significantly modified due to hot nuclear matter effect

• cone size dependence of medium modification is consistent with other jet observables

• medium modification of averaged jet charge is sensitive to the portion of quarks and gluons, providing opportunity to study flavour dependence of parton energy loss

• analytical study of jet charge in heavy-ion collisions could be done by using medium modified fragmentation functions
Thank you for your attention!