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Study of EEC discrimination power on quark and gluon quenching effects based on LHC heavy-ion detectors

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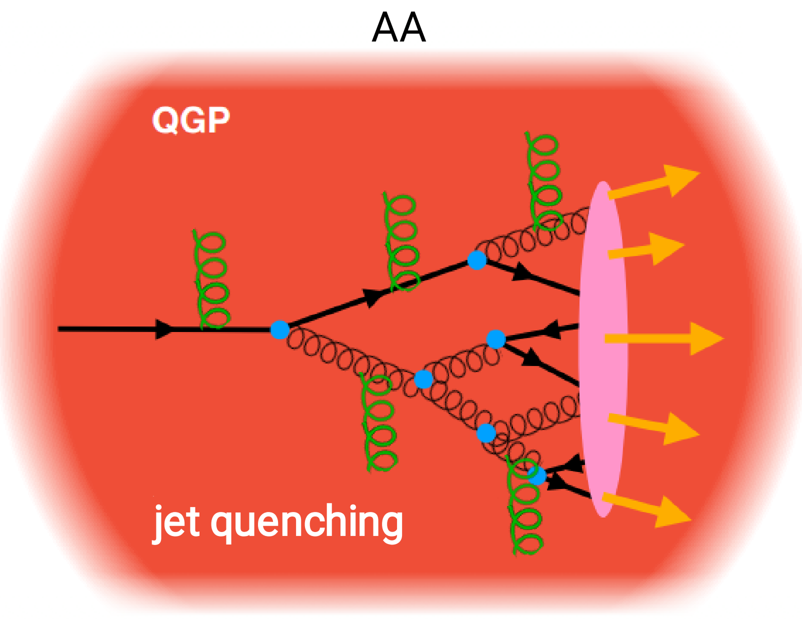
01 Background & Motivation



Quenching effects is flavor dependent!

Quark vs gluon?

1. Hadron chemistry

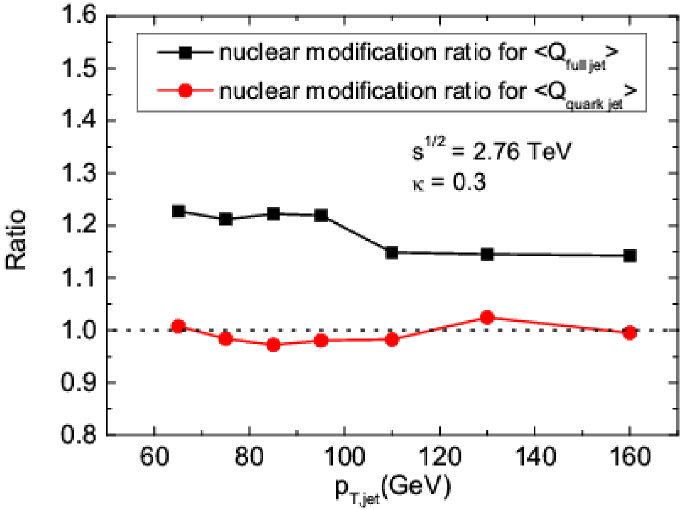
(e.g. η meson production, Wei Dai et al. [PLB (2015) 390-39)]

2. Jet observable

(e.g. Jet charge, Shi-Yong Chen et al. [Nucl.Part.Phys.Proc. (2017) 448-451])

$$Q^k = \sum_{i \in jet} z_h^k Q_i$$

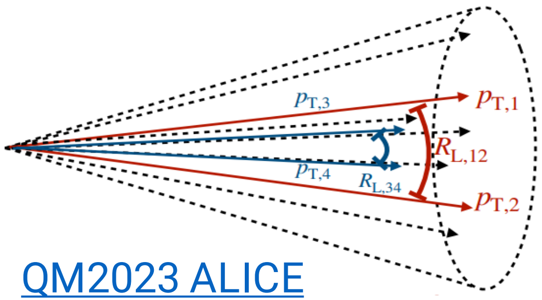
where $z_h^k = p_T^i / p_T^{jet}$



3. **Jet substructure!**

(e.g. EEC, Andrew J. et al. [JHEP06(2013)108])

Energy-energy correlators (EEC) are a jet substructure observable that measures statistical correlations of energy flux in jets.



QM2023 ALICE

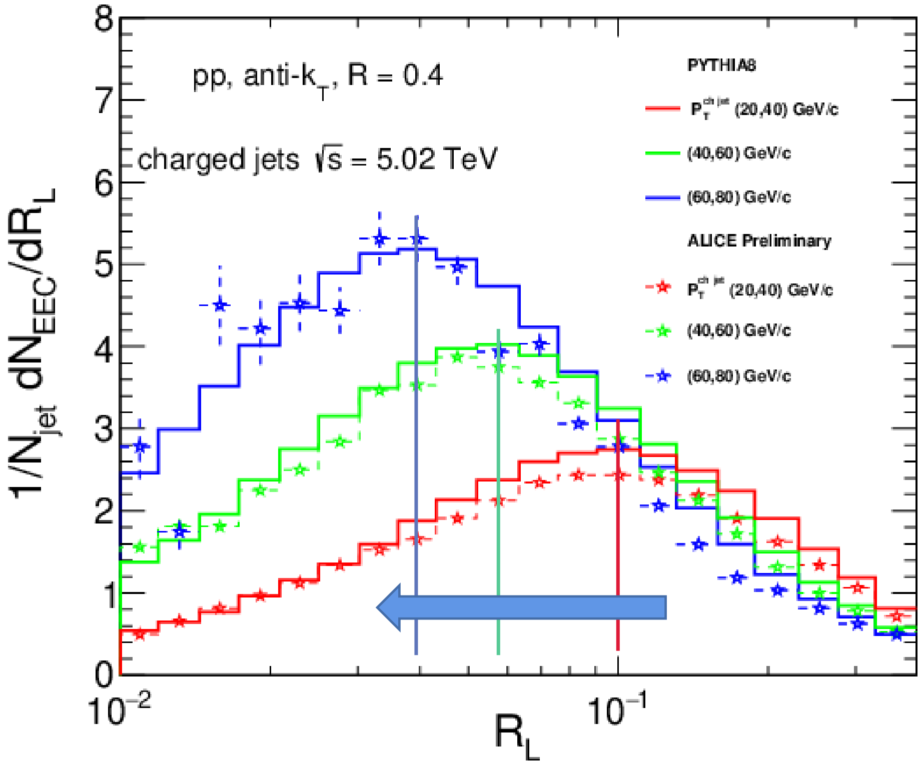
$$\frac{d\sigma_{EEC}}{dR_L} = \sum_{i,j} \frac{\int d\sigma(R_L') p_{T,i} p_{T,j}}{p_{T,jet}^2} \delta(R_L' - R_L) \quad (1)$$

where $R_L = \sqrt{\Delta\phi_{i,j}^2 + \Delta\eta_{i,j}^2}$

How is the EEC discrimination power on quark and gluon quenching effects ?

02 EEC distributions in pp

- PYTHIA v8.309[1] with Monash 2013 tune[2] →simulate pp collisions
- FASTJET v3.4.0[3] with R=0.4 → reconstruct inclusive charged jets
- Counting number of energy weighted particles pairs as functions of R_L.



ALICE data (arXiv:2409.12687 [hep-ex])

Nice agreements !

The EEC distributions are shifted to lower R_L region with the increasing jet p_T .

↓

Higher $P_{T,jet}$,lower R_L distributions !

I. PYTHIA8 → initial showered partons and Glauber model[4] → initial positions

II. Simulating Heavy quark Energy Loss with Langevin equations (SHELL) model[5]

1. Energy Loss from medium-induced gluon radiation:

$$P_{rad}(t,\Delta t) = 1 - e^{-\langle N(t,\Delta t)\rangle} \quad (2)$$

where $N(t,\Delta t)$ is from Higher−Twist method[6]:

$$\frac{dN}{dx dk_\perp^2 dt} = \frac{2\alpha_s C_s P(x)\hat{q}}{\pi k_\perp^4}\sin^2\left(\frac{t-t_i}{2\tau_f}\right)\left(\frac{k_\perp^2}{k_\perp^2+x^2M^2}\right)^4 \quad (3)$$

sample:

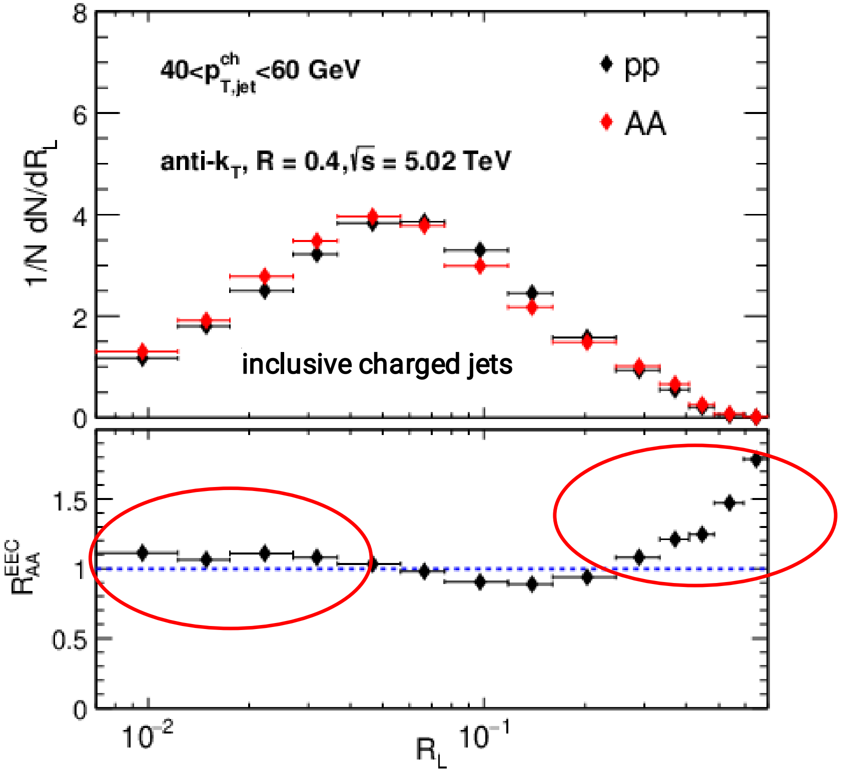
$$P(n_g,t,\Delta t) = \frac{\langle N(t,\Delta t)\rangle^{n_g}}{n_g!}e^{-\langle N(t,\Delta t)\rangle} \quad (4)$$

2. Energy Loss from elastic collision :

$$\text{Hard Thermal Loop[7]: } \frac{dE^{coll}}{dt} = \frac{\alpha_S C_S \mu_D^2}{2}\ln\frac{\sqrt{ET}}{\mu_D} \quad (5)$$

III. PYTHIA Lund string method (with colorless string[8]) **→ Hadronization and hadron decays**

03 EEC distributions in AA



There are clear enhancement at R_L > 0.2 and R_L < 0.05

For R_L > 0.2 :

Energy loss → particle pair angular wider

→ EEC shift to larger R_L

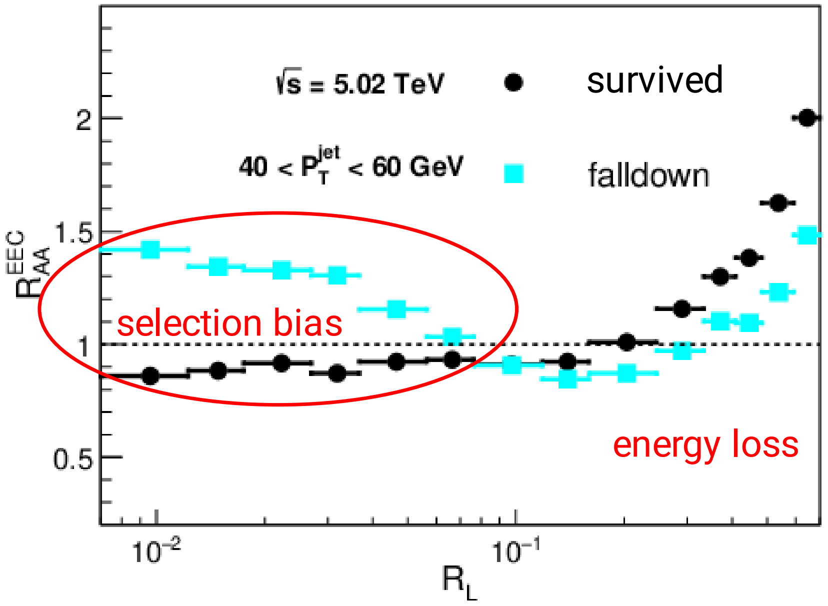
But why EEC also shift to small R_L?

03 EEC distributions in AA

$$\frac{AA}{pp} \rightarrow \frac{AA_{\text{survived}}}{pp} + \frac{AA_{\text{fall-down}}}{pp}$$

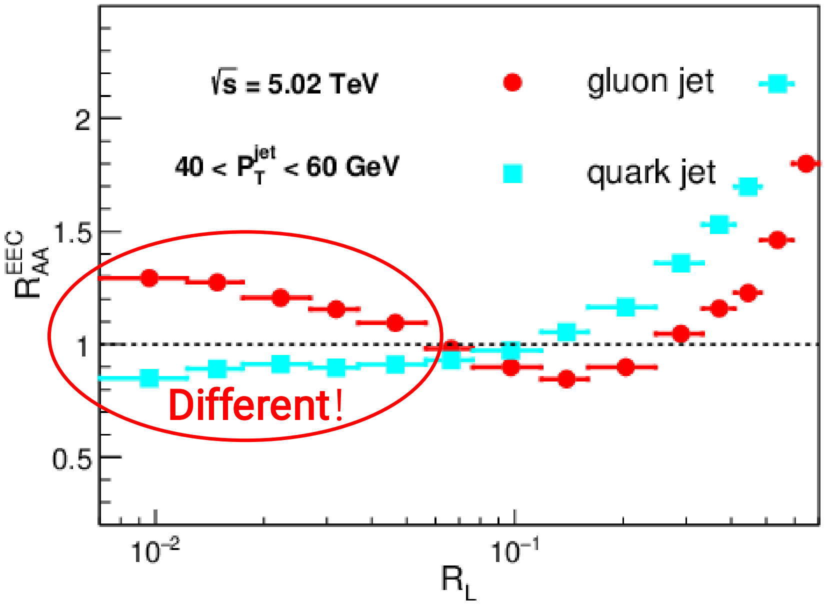
survived: 40 < $p_{T,jet}$ < 60 GeV in pp

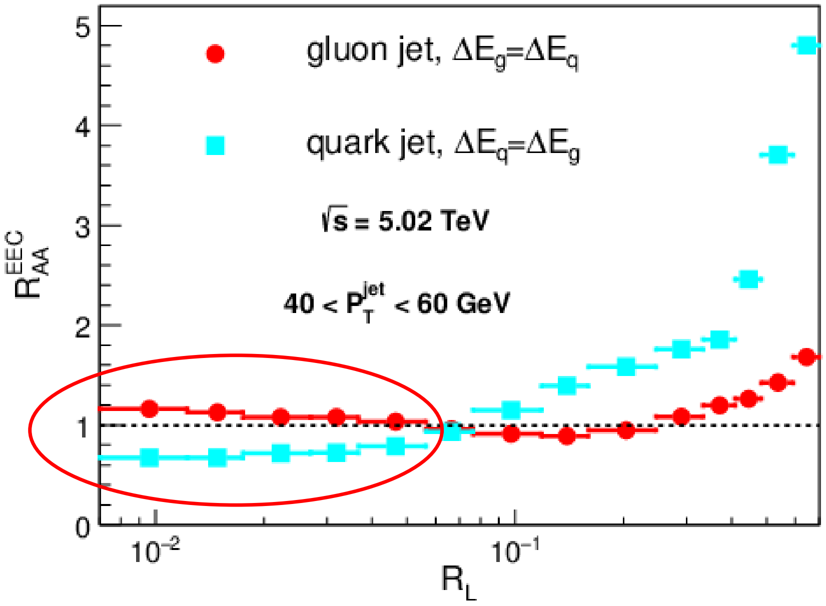
fall-down: $p_{T,jet}$ > 60 GeV in pp



selection bias effects → EEC shifting to smaller R_L : **Higher $P_{T,jet}$,lower R_L distributions !**

04 quark/gluon discrimination





energy loss: $\Delta E_g > \Delta E_q$

Is the difference caused by energy loss?

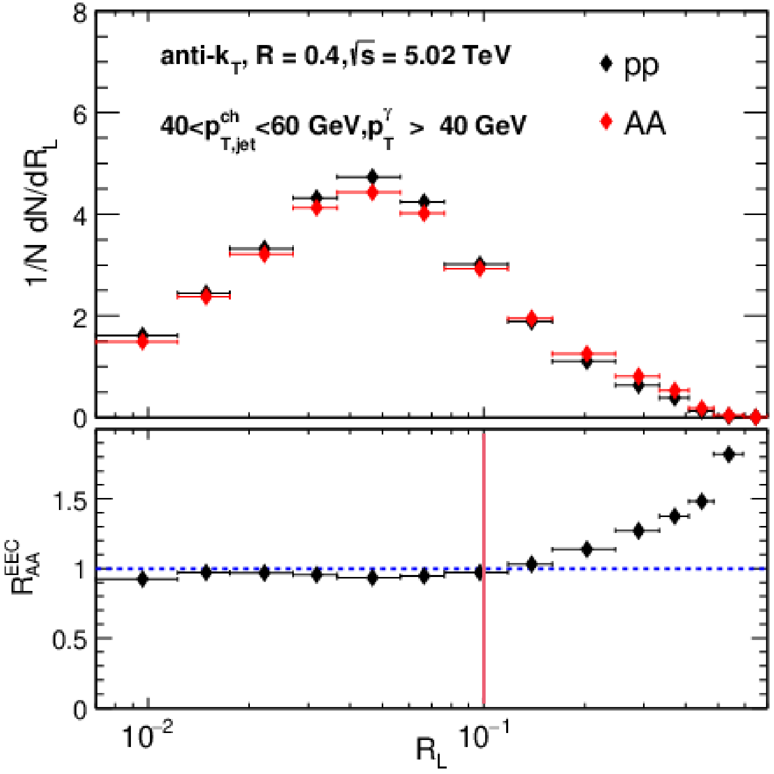
No! It is caused by the difference of EEC distribution in pp!

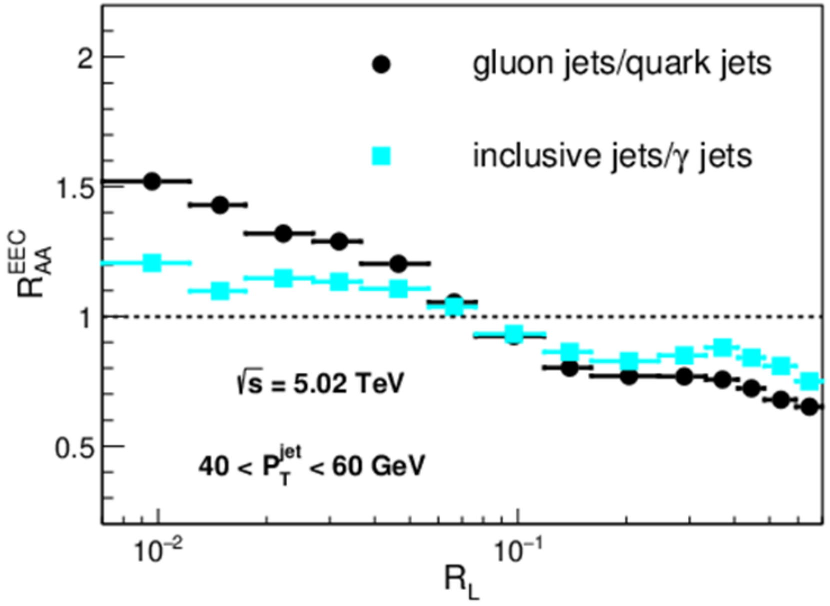
04 quark/gluon discrimination

No pure quark jet or pure gluon jet in the experiment.

Gluon jets constitute the major component of inclusive jets → γ tagged jets

inclusive jets → gluon jets
γ tagged jets → quark jets





05 Conclusions

1.EEC R_{AA}^{EEC} of inclusive jets has a clear enhancement at R_L > 0.2 (selection bias effects), and R_L < 0.05(Energy loss)

2. R_{AA}^{EEC} of quark jets and the gluon jets is different, and is not affected much by the energy loss differences between quark and gluon;

The jet quenching patterns (A+A/p+p) of the quark jets and the gluon jets can be separated by EEC!

We can verify this by measuring the R_{AA}^{EEC} of inclusive jets/γ jets.

Thanks

References

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[7] R. B. Neufeld. Thermal field theory derivation of the source term induced by a fast parton from the quark energy-momentum tensor. Phys.Rev. D, 83:065012, 2011.

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Back up

$$\frac{d\sigma_{EEC}}{dR_L} = \frac{dN_{pair}/dR_L}{N_{jet}} \frac{\sum_{i,j} p_{T,i} p_{T,j}}{(dN_{pair}/dR_L) * p_{T,jet}^2 dR_L} = \frac{N_{pair}}{N_{jet}} \frac{dN_{pair}}{N_{pair} dR_L}(R_L) * weight(R_L)$$