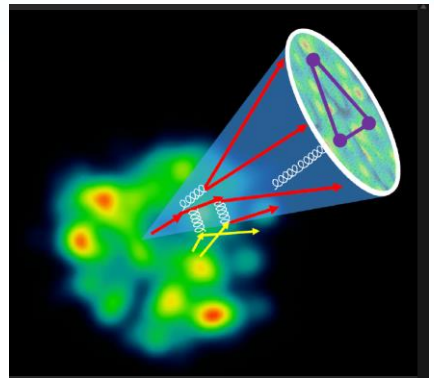
Energy-energy correlators of inclusive jets in heavy-ion collisions

Yayun He
For the JETSCAPE Collaboration



HP2024
NAGASAKI

Sep. 22-27, 2024

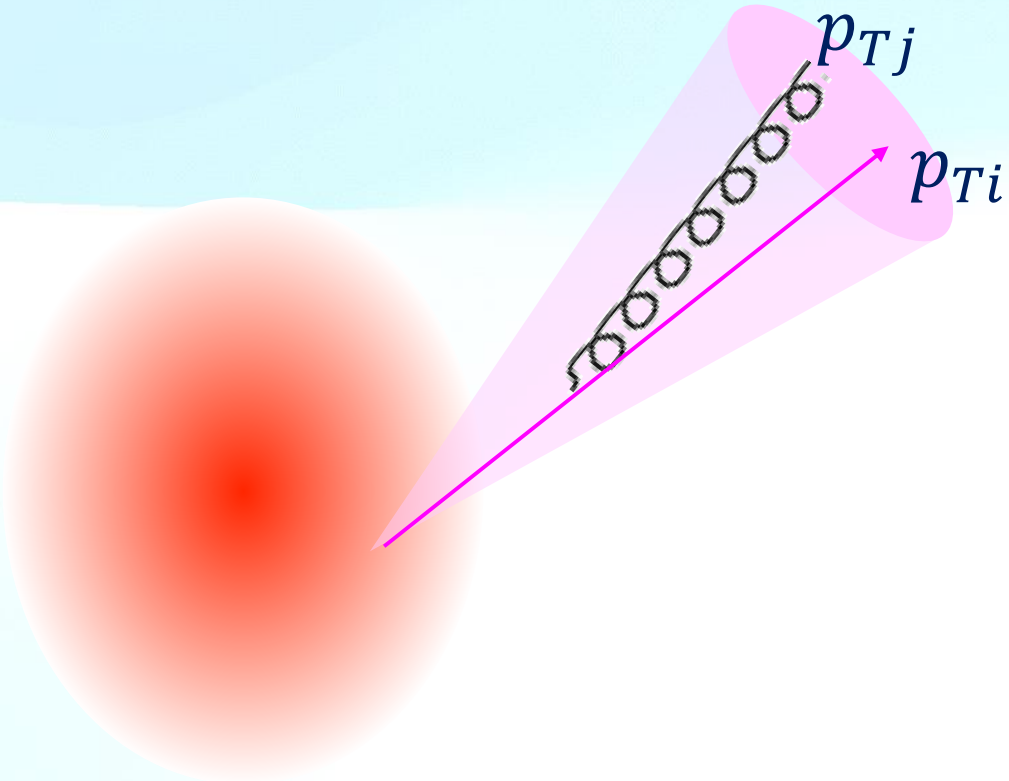
Outline

- Introduction
- The JETSCAPE framework
- Results: EECs of inclusive jets
- Summary and outlook

State-of-the-art: Energy Correlators

Jet energy-energy correlator

$$\frac{d\Sigma^{\mathrm{n}}}{dR_L} = \Sigma_{i,j} \int dR'_L \, \frac{d\sigma}{dR'_L} \frac{p_{T,\,i}^{n} \, p_{T,\,j}^{n}}{p_{T,jet}^{2n}} \delta(R'_L - R_L)$$



$$R_L = \sqrt{(\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2}$$

- ✓ pQCD calculable
- ✓ Background contribution suppressed ($n \geq 1$)

State-of-the-art: Energy Correlators

Jet energy-energy correlator

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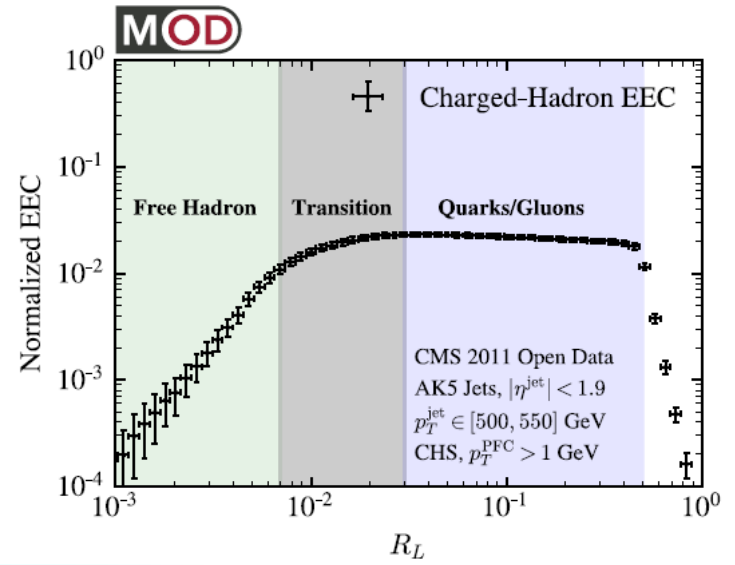
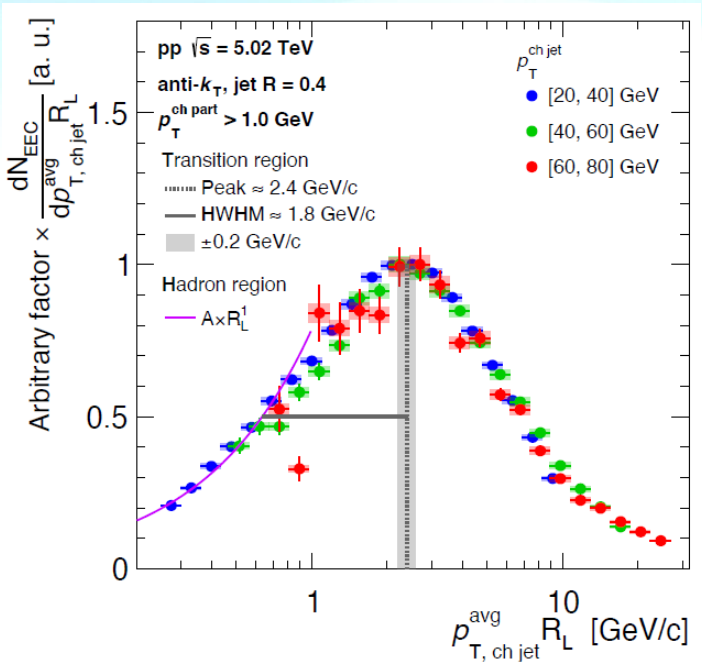
- Perturbative & NP regions in pp



Komiske, Moult, Thaler, and Zhu, PRL 130, 051901 (2023)

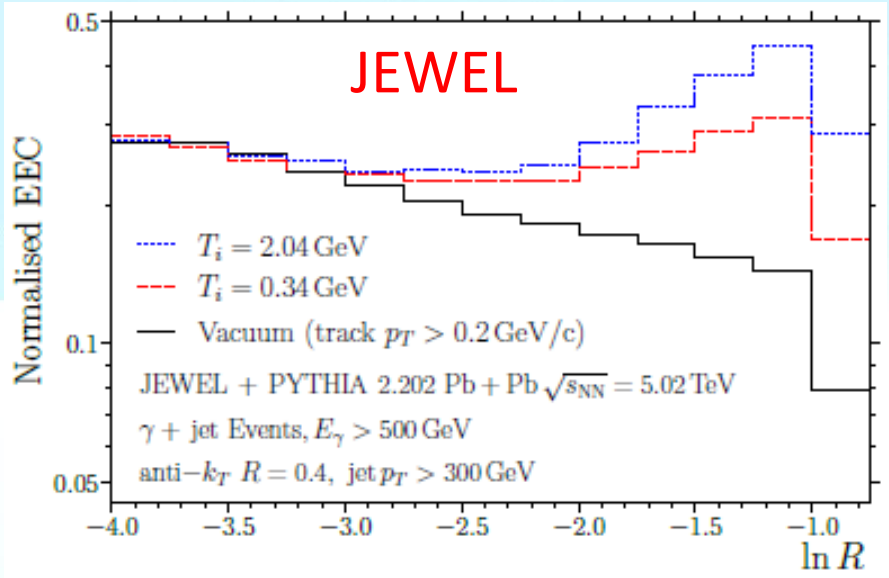


ALICE, arXiv:2409.12687

State-of-the-art: Energy Correlators

❖ Nuclear effects in AA (γ-triggered jet)

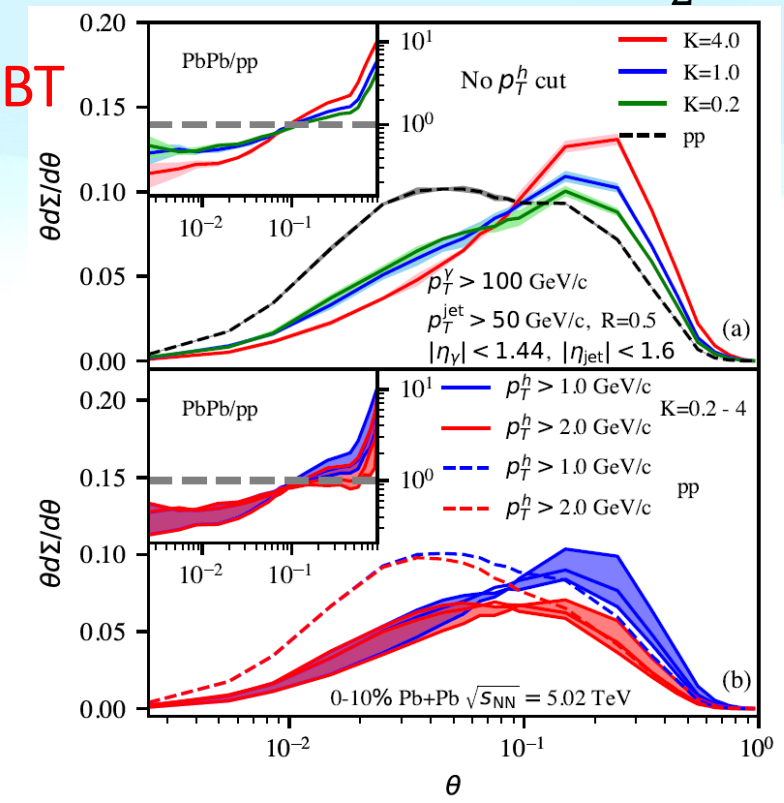
Color decoherent



Andres, Dominguez, Elayavalli, Holguin, Marquet, & Moult, PRL 130, 262301 (2023).

Medium response: $\mu_D^2 = \frac{3}{2} K g^2 T^2$

CoLBT



Yang, He, Moult & Wang, PRL 132, 011901 (2024)

State-of-the-art: Energy Correlators

❖ Nuclear effects in AA (γ-triggered jet)

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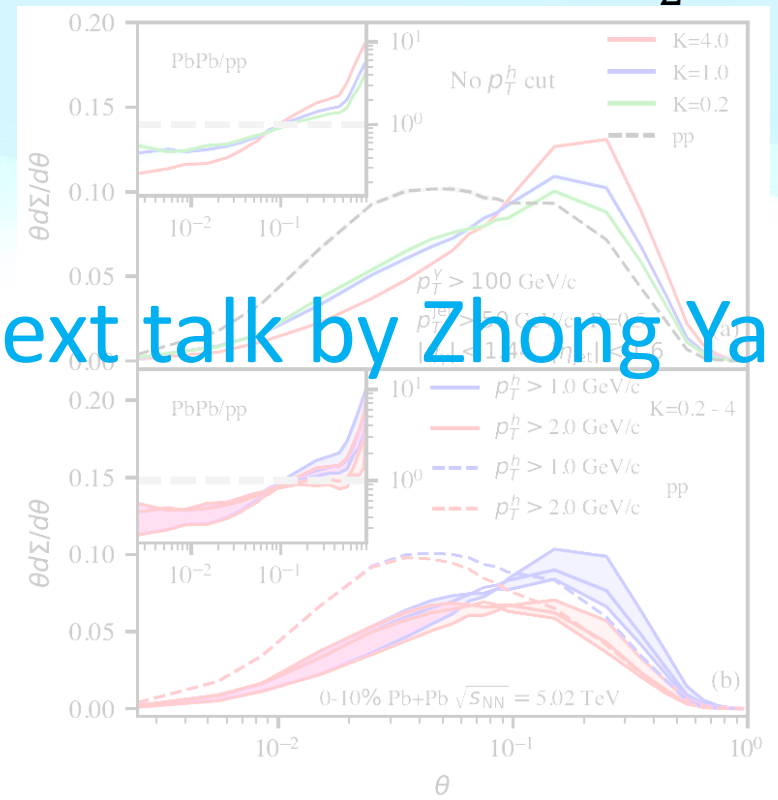
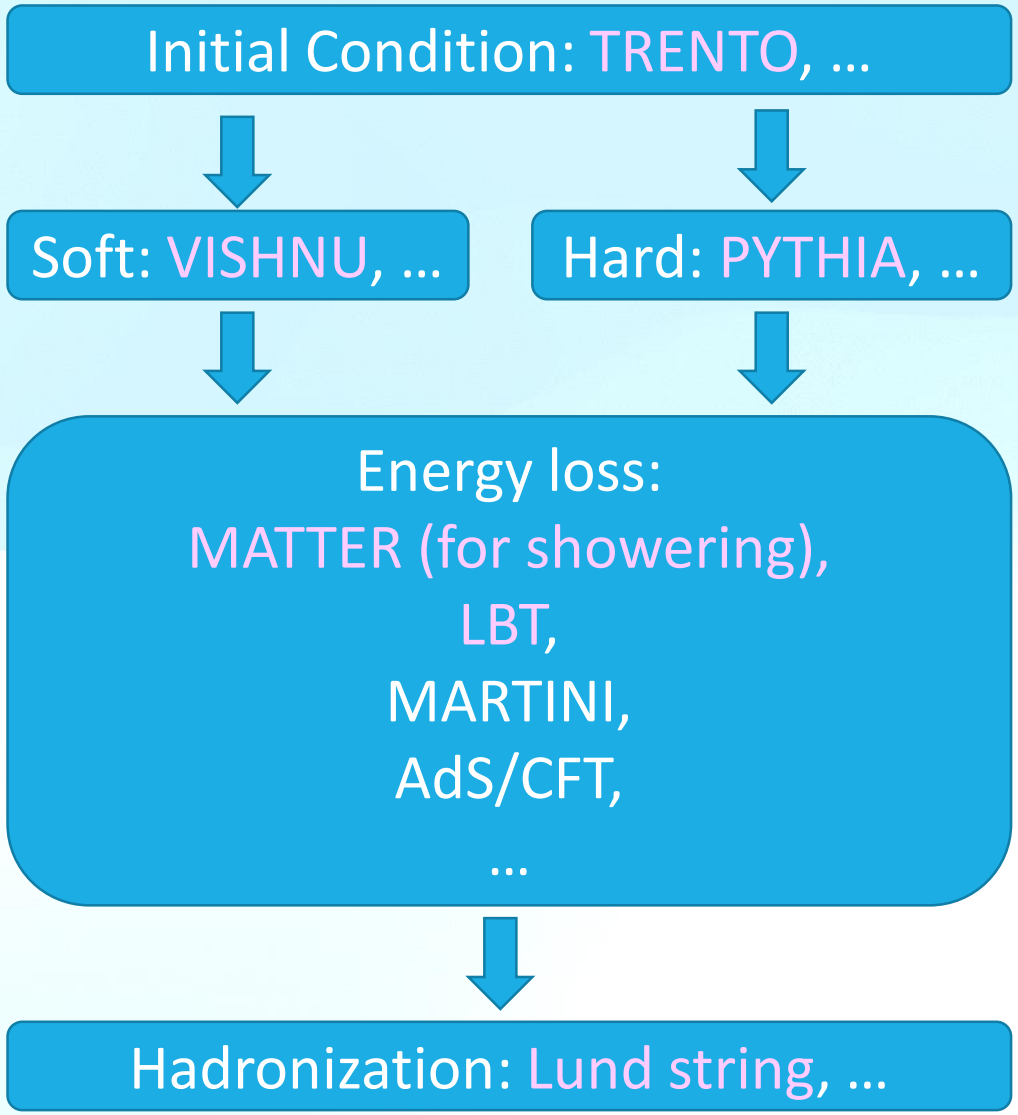


Next talk by Zhong Yang

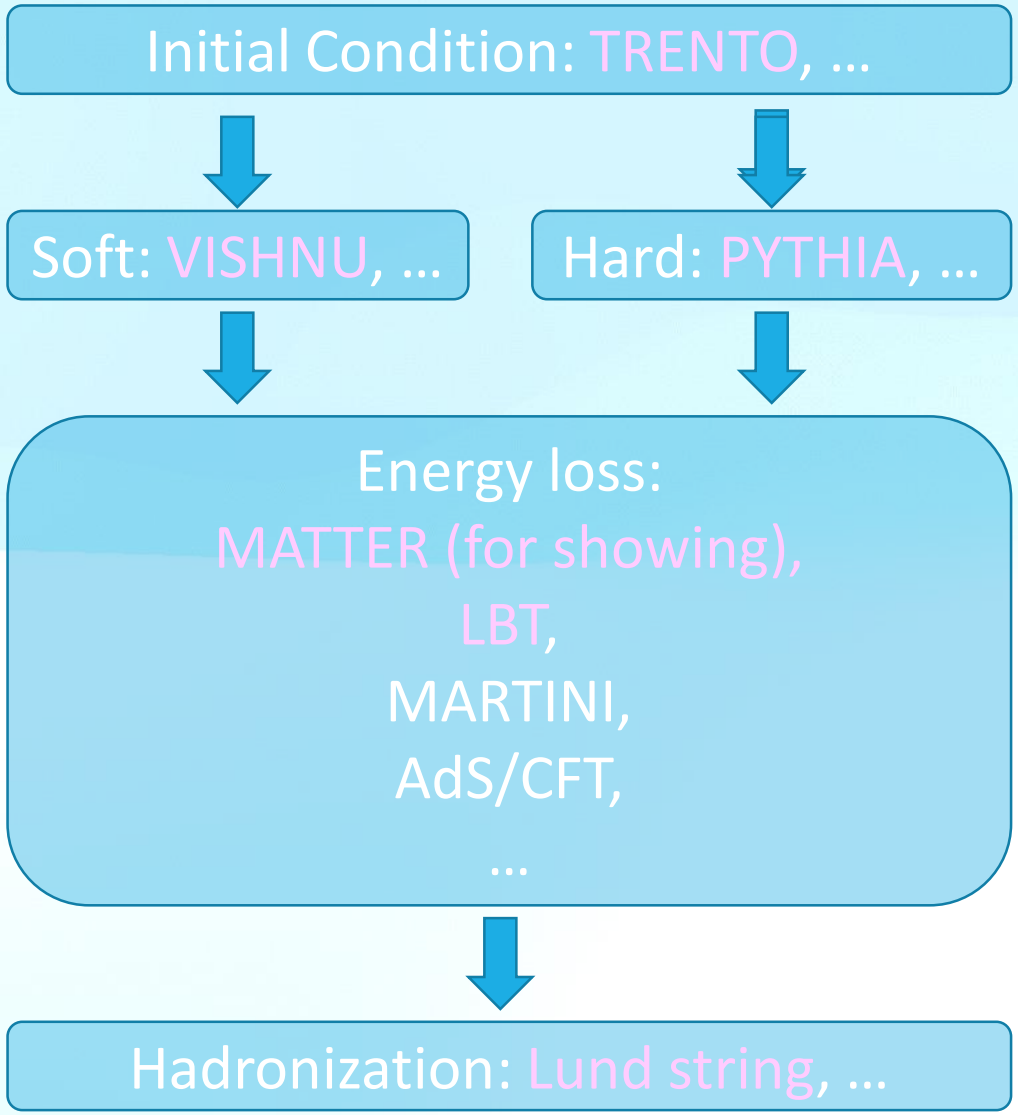
Yang, He, Moult & Wang, PRL 132, 011901 (2024)

The JETSCAPE Framework



- ✓ Modular: implement your favorate modules
- ✓ Multi-stage: jet evolution is controlled by the virtuality of the parton
- ✓ Output: ASCII, Gzip, HepMC format

The JETSCAPE Framework



- ✓ Modular: implement your favorate modules
- ✓ Multi-stage: jet evolution is controlled by the virtuality of the parton
- ✓ Output: ASCII, Gzip, HepMC format

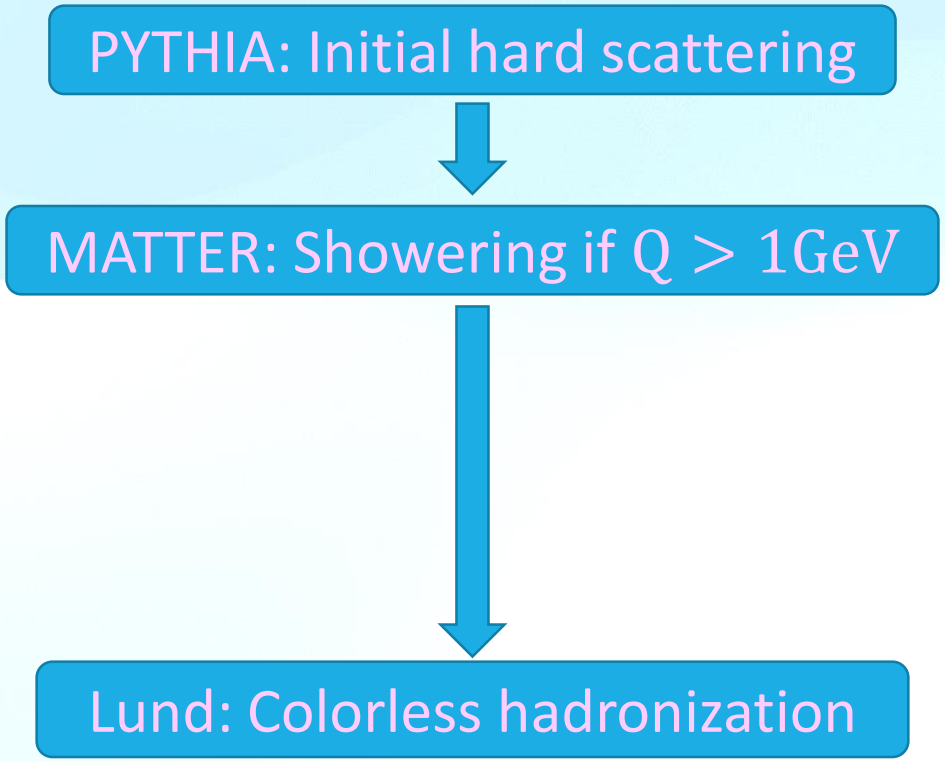
See the talks for more details:

- ❑ *Y. Tachibana, Mon. 5:50 pm*
- ❑ *C. Sirimanna, Wed. 9:40 am*

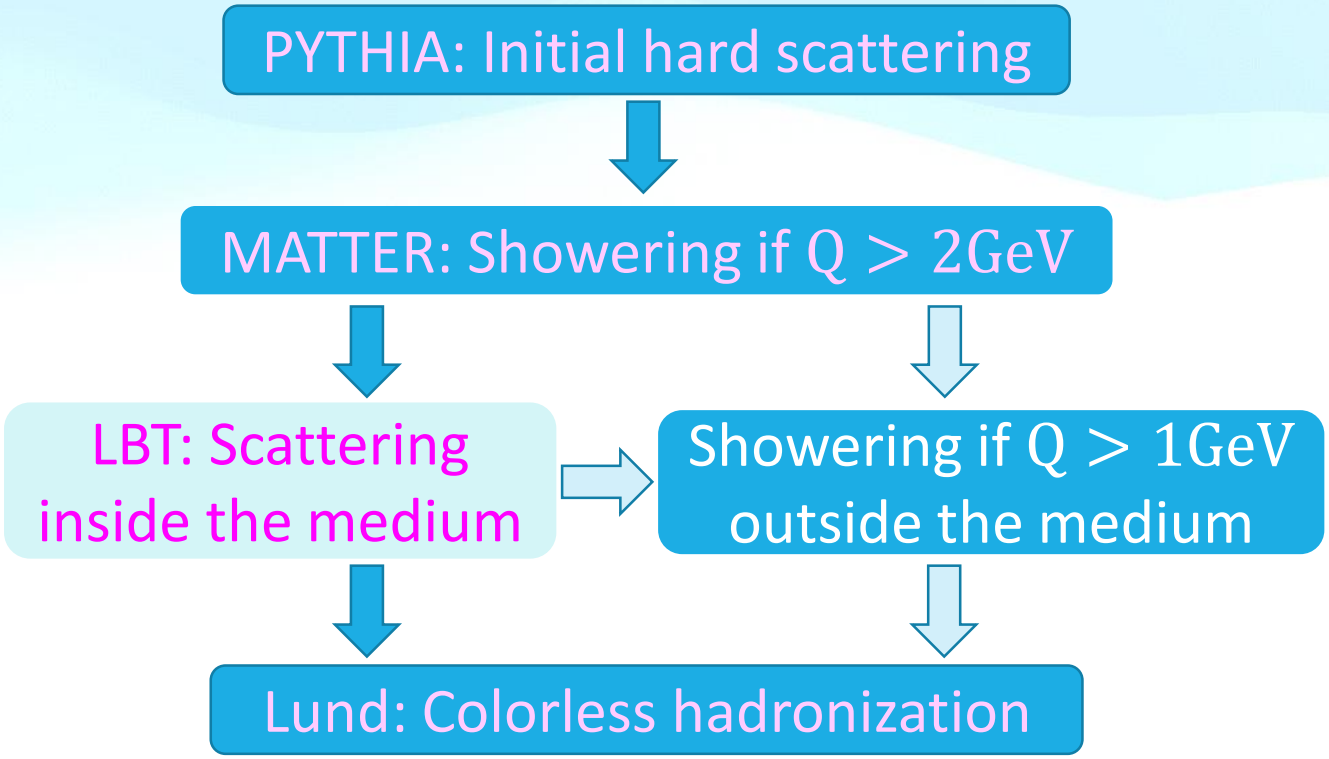
The JETSCAPE Framework

✓ Multi-stage: jet evolution is controlled by the virtuality of the parton

❑ pp tune: *JETSCAPE, PRC 102, 054906 (2020)*



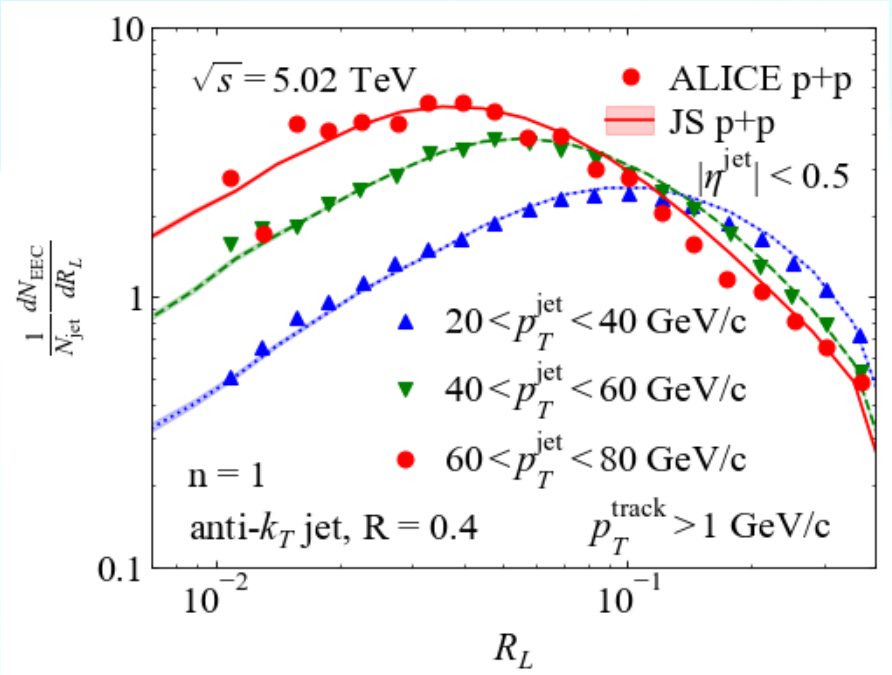
❑ AA tune: *JETSCAPE, PRC 107, 034911 (2023)*



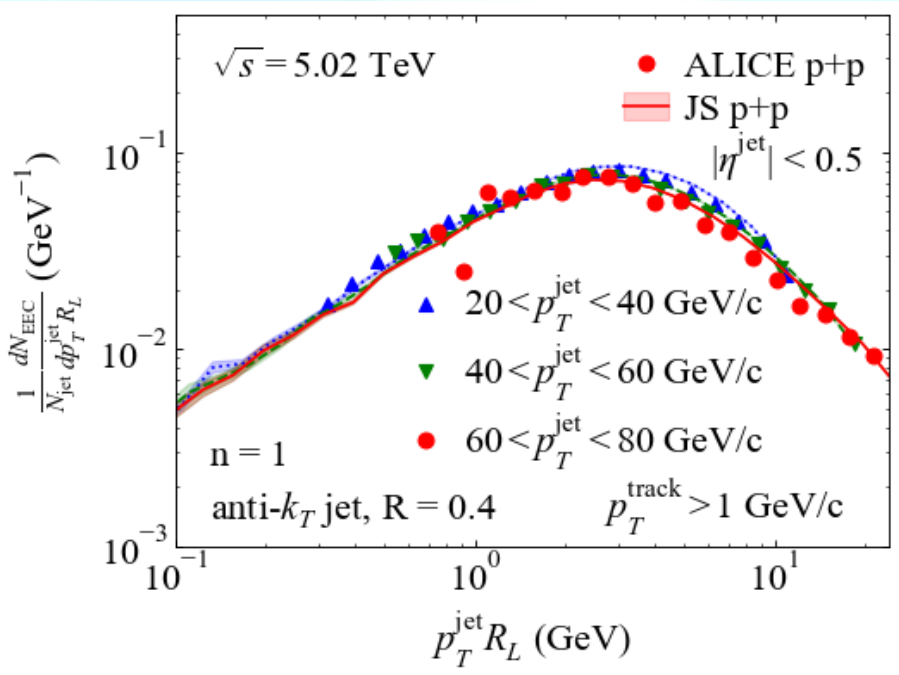
EECs of Inclusive Jets

ALICE $\frac{d\Sigma^{\mathrm{n}}}{dR_L} = \Sigma_{i,j} \int dR'_L \frac{d\sigma}{dR'_L} \frac{p_{T,i}^n p_{T,j}^n}{p_{T,jet}^{2n}} \delta(R'_L - R_L)$

p+p



p+p, scaling, $\propto \Lambda_{QCD}$



ALICE, arXiv:2409.12687

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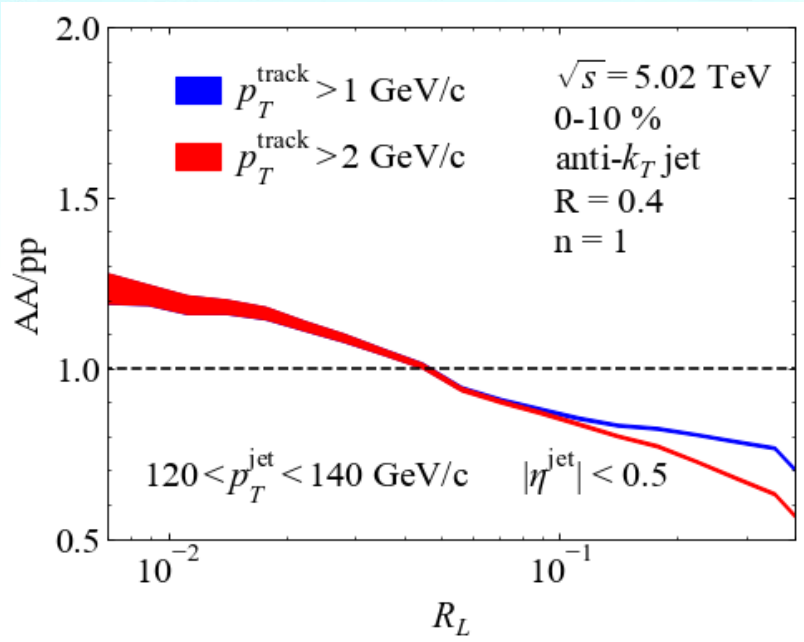
Nuclear effect, n=1

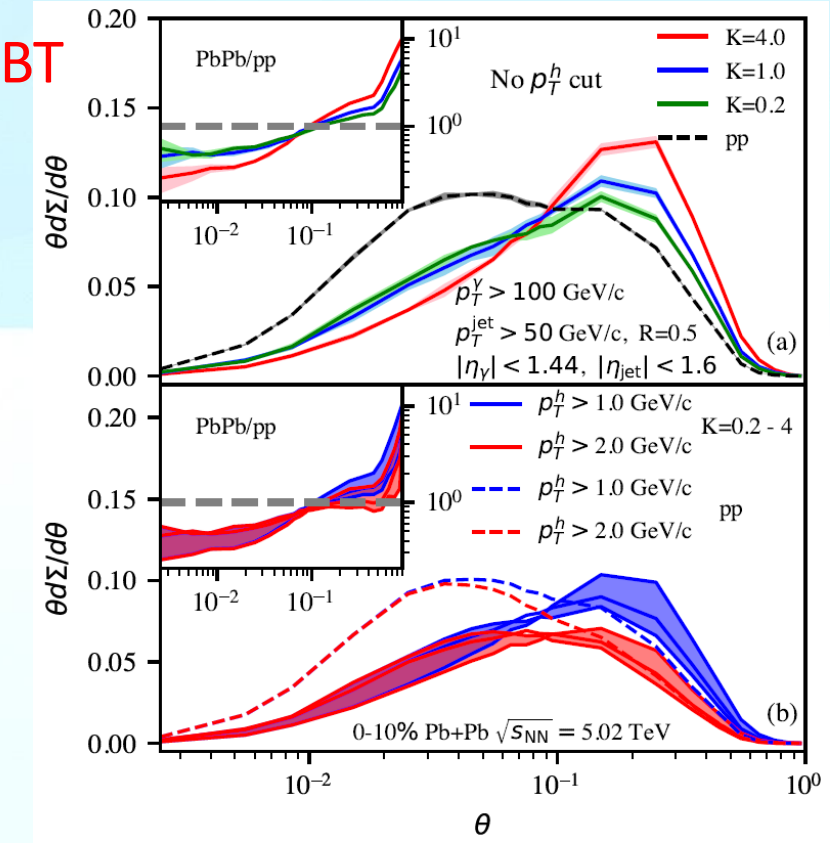


Try to explain …

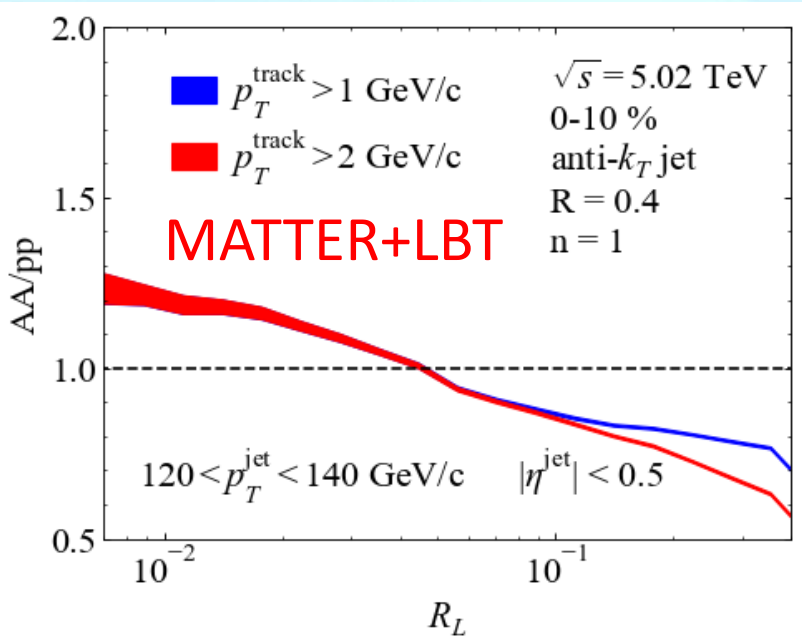
- Nuclear effects in AA

γ-triggered jet

CoLBT



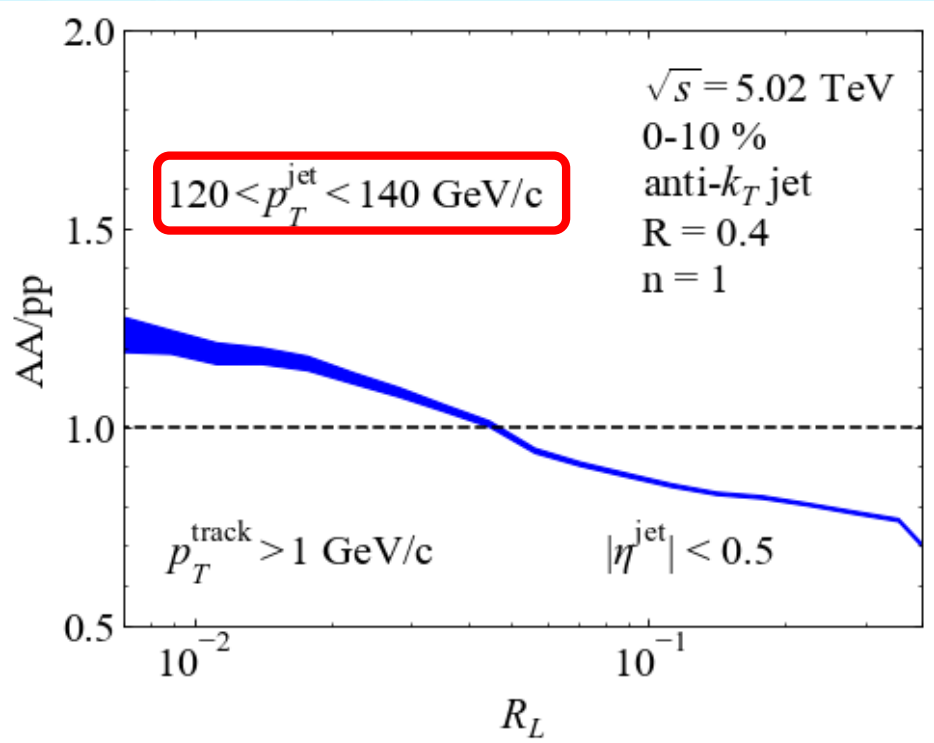
Inclusive jet



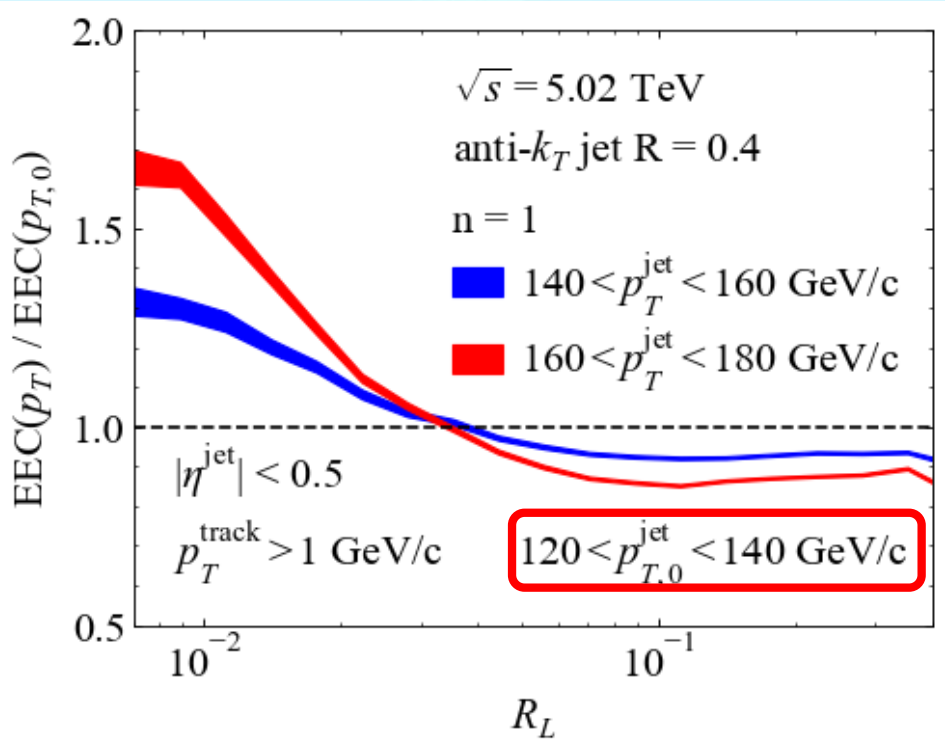
Try to explain …

- Nuclear effects in AA

MATTER+LBT



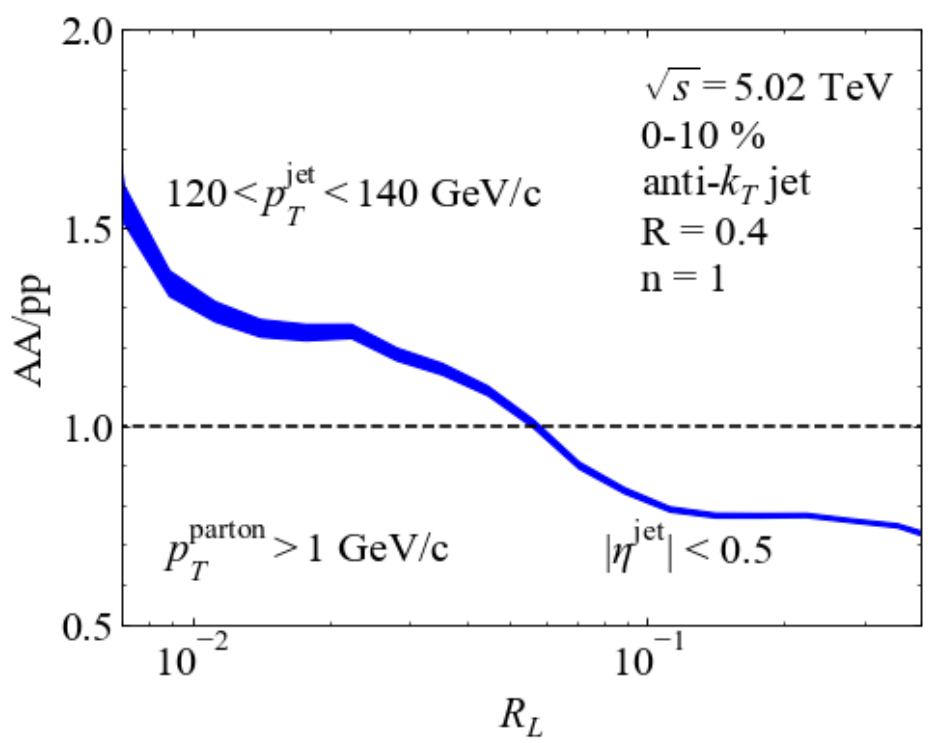
pp, jet p_T shifting



Try to explain …

- Nuclear effects in AA

partonic
w. showering outside of the medium



partonic
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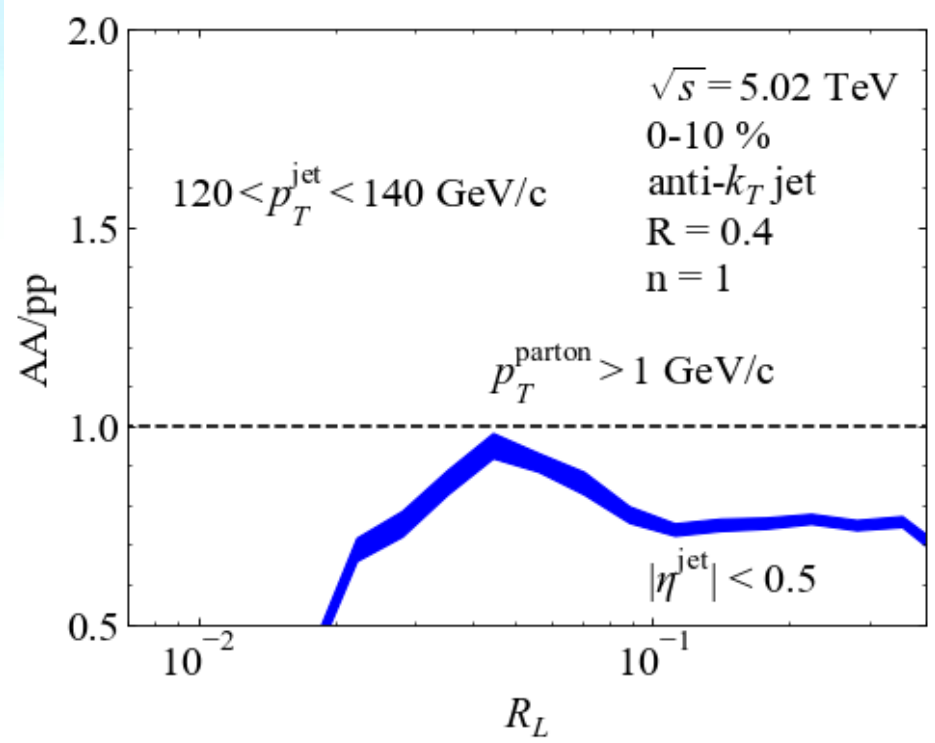
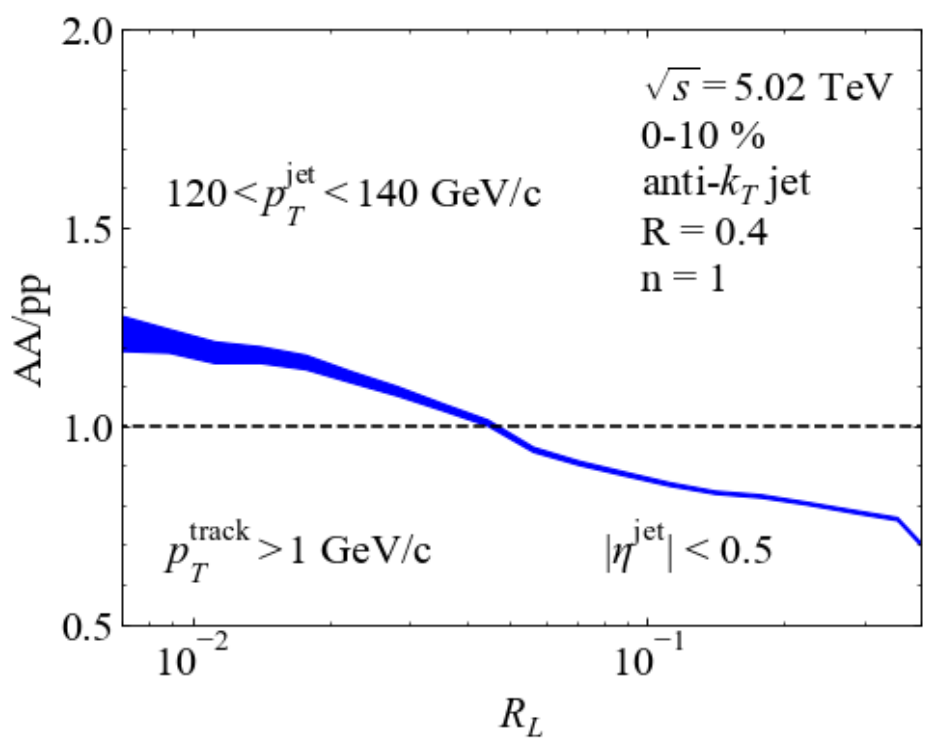


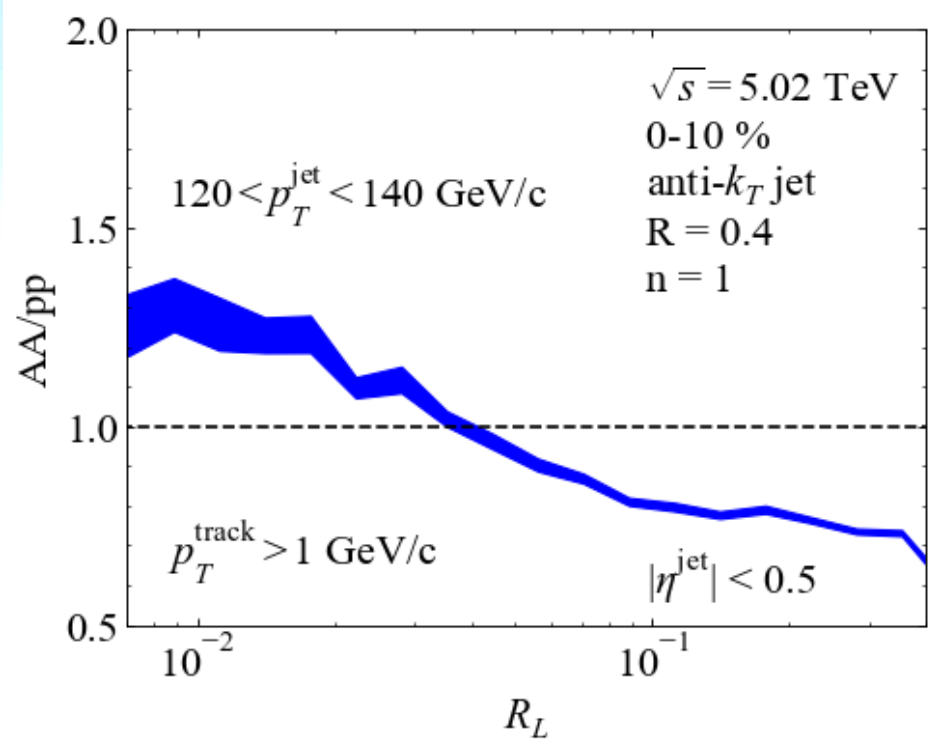
Try to explain …

- Nuclear effects in AA

charged
w. showering outside of the medium



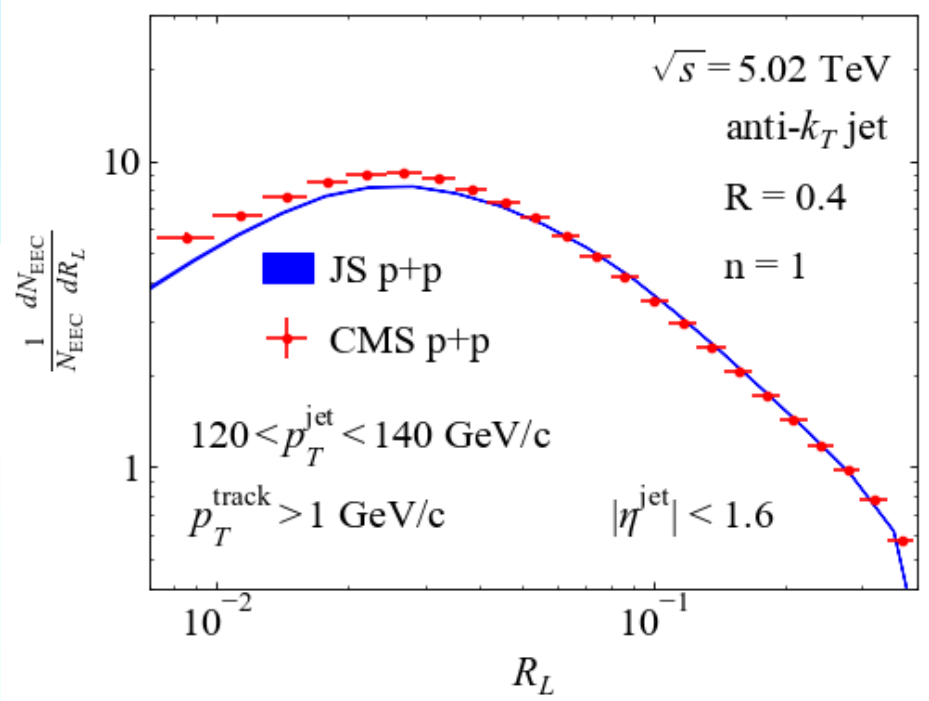
charged
w/o showering outside of the medium



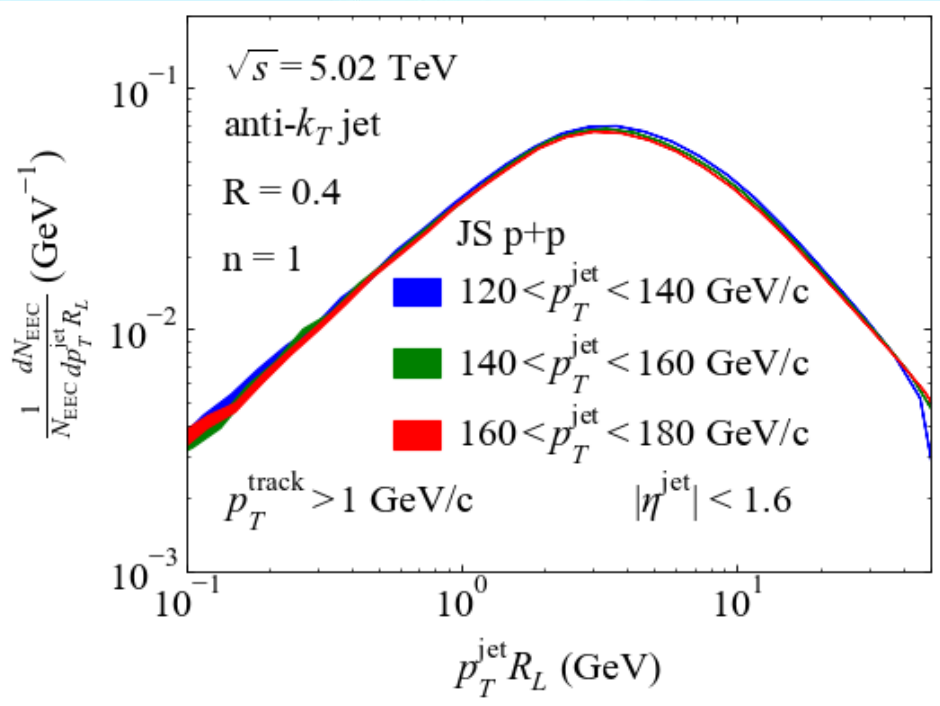
EECs of Inclusive Jets

CMS $\frac{d\Sigma^{n}}{dR_L} = \Sigma_{i,j} \int dR'_L \frac{d\sigma}{dR'_L} p^{n}_{T,i}\, p^{n}_{T,j}\, \delta(R'_L - R_L)$ (normalized to unity)

p+p, 1 GeV cut, n=1



scaling, $\propto \Lambda_{QCD}$



J. Viinikainen, MITP, CMS-PAS-HIN-23-004

EECs of Inclusive Jets

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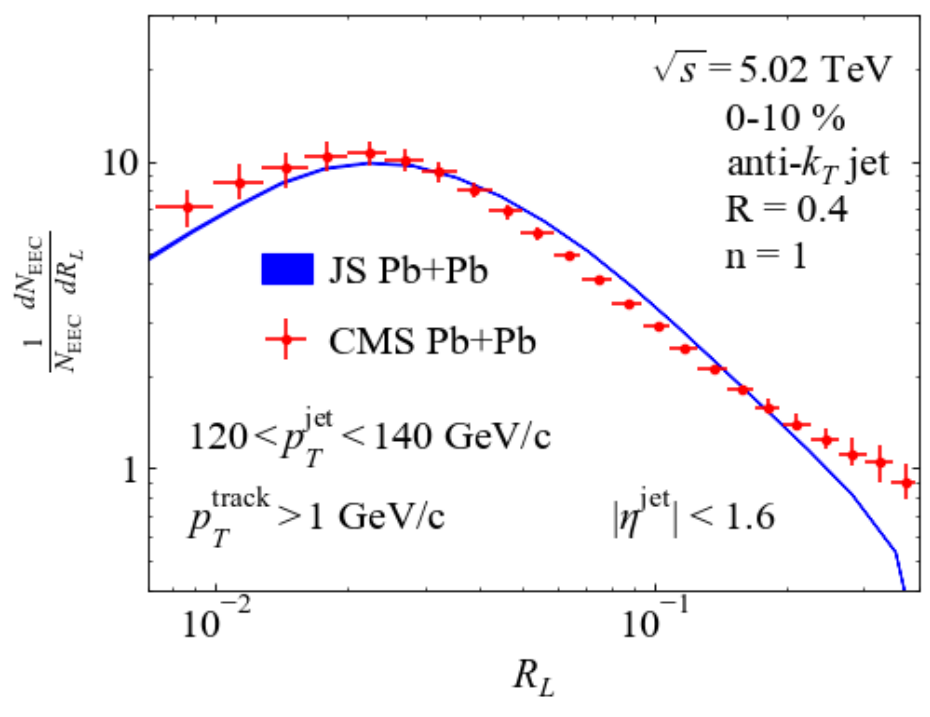
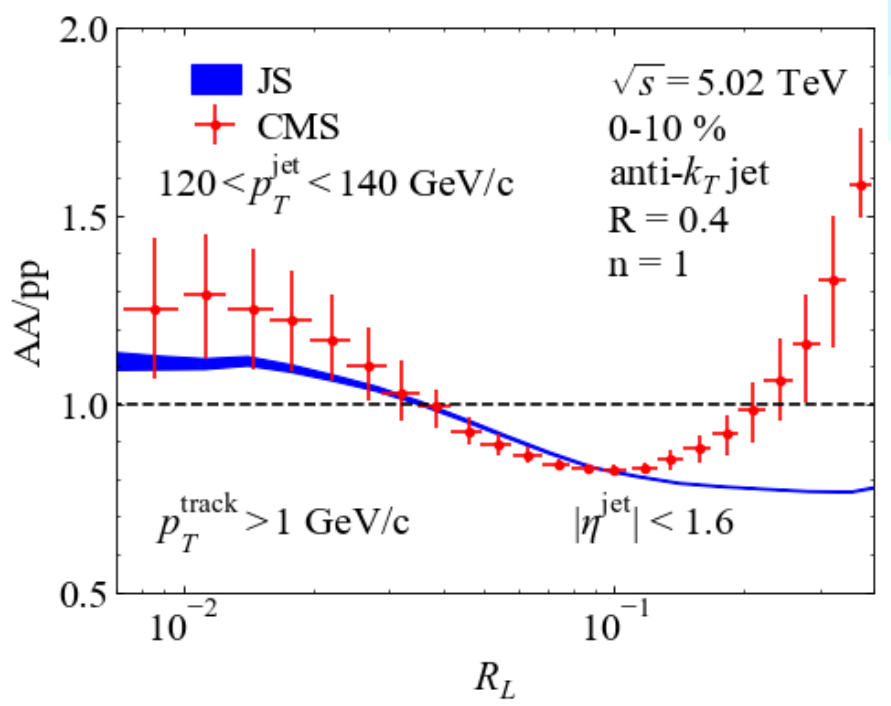
Pb+Pb, 1 GeV cut, n=1



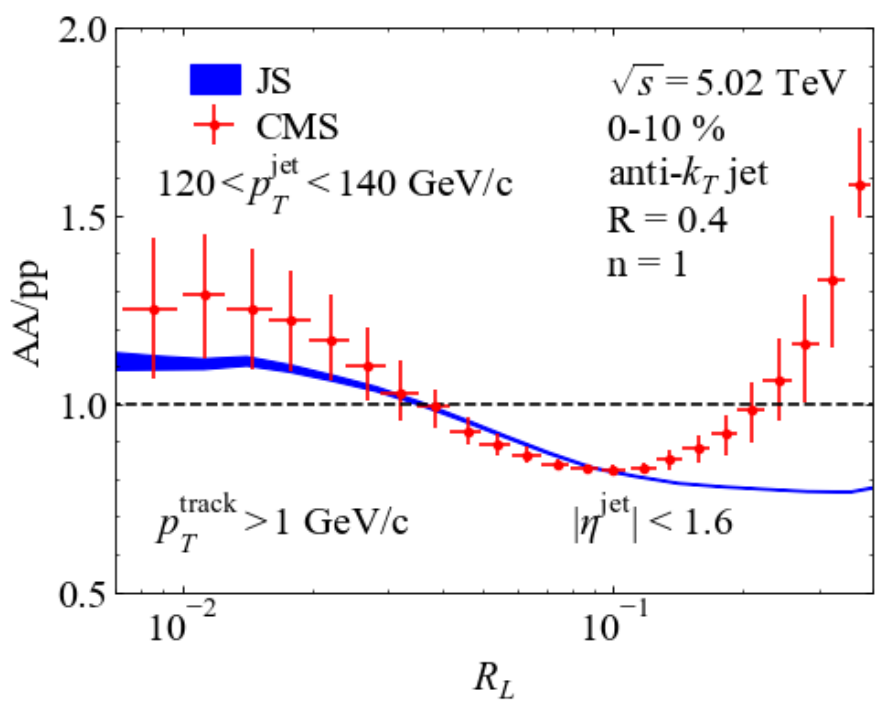
Nuclear effect



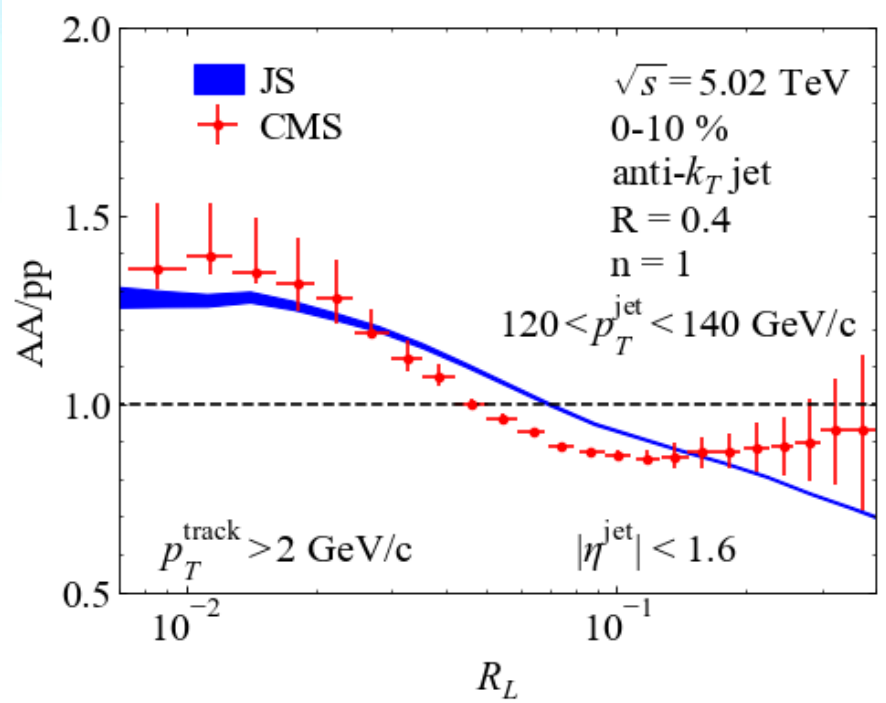
Medium Response ?

CMS $\frac{d\Sigma^{n}}{dR_L} = \Sigma_{i,j} \int dR'_L \frac{d\sigma}{dR'_L} p^{n}_{T,i}\, p^{n}_{T,j}\, \delta(R'_L - R_L)$ (normalized to unity)

Nuclear effect, 1 GeV cut, n=1



Nuclear effect, 2 GeV cut, n=1



Medium Response ?

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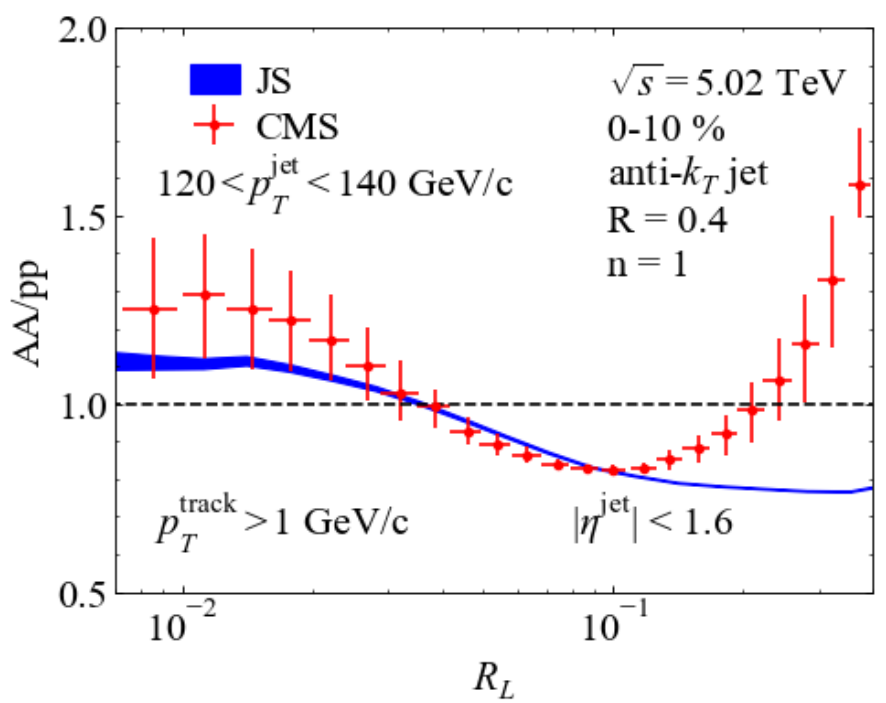
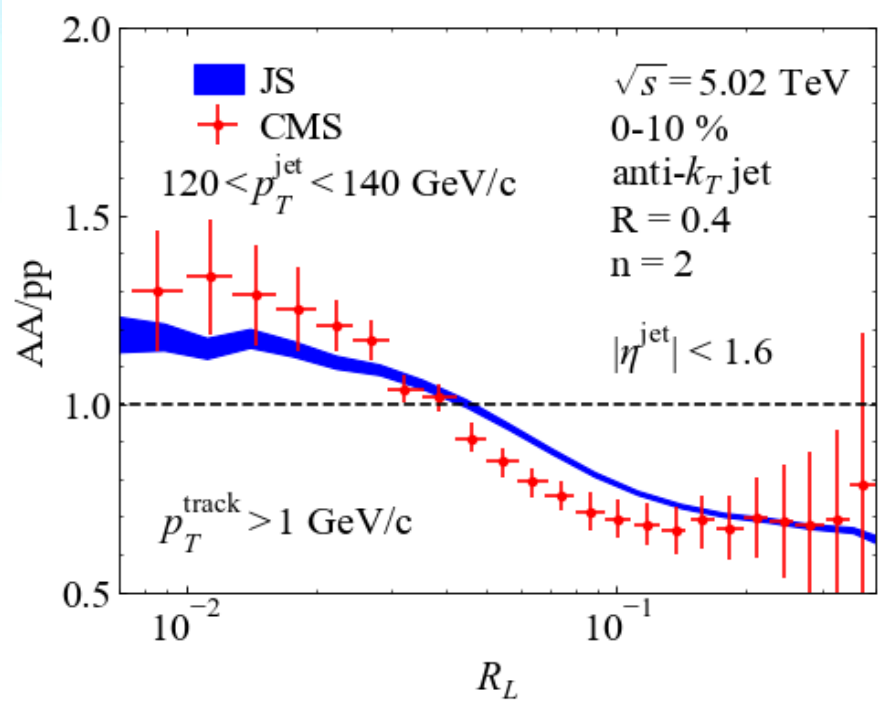
Nuclear effect, 1 GeV cut, n=1



Nuclear effect, 1 GeV cut, n=2



Medium Response ?

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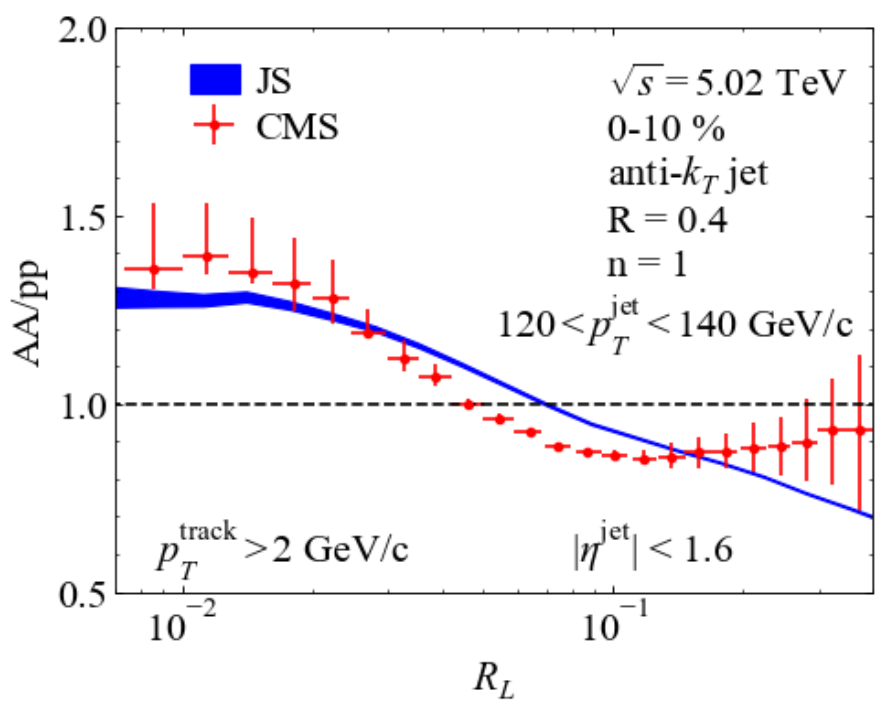
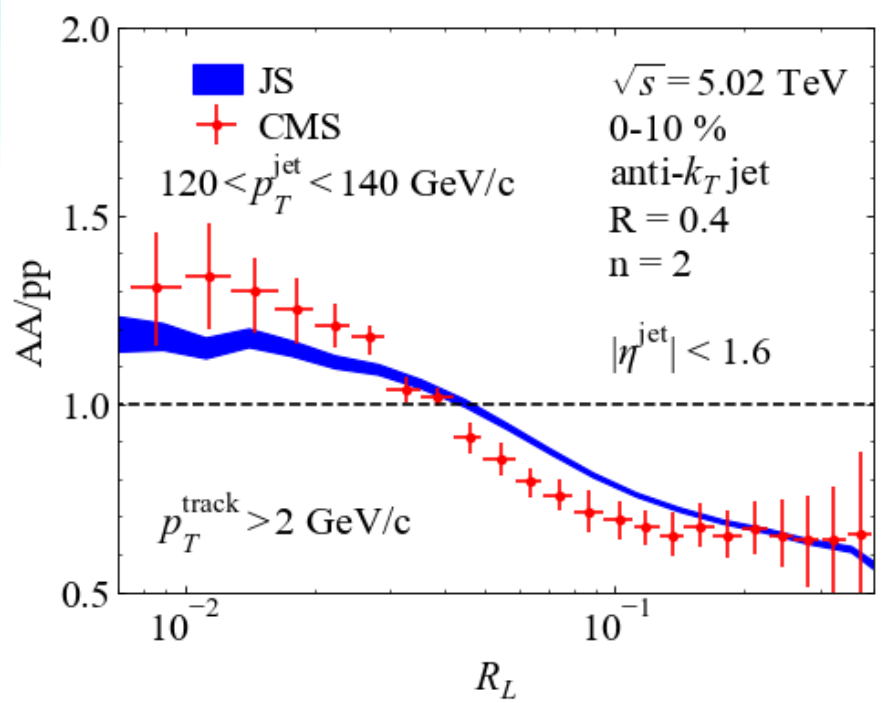
Nuclear effect, 2 GeV cut, n=1



Nuclear effect, 2 GeV cut, n=2



Summary

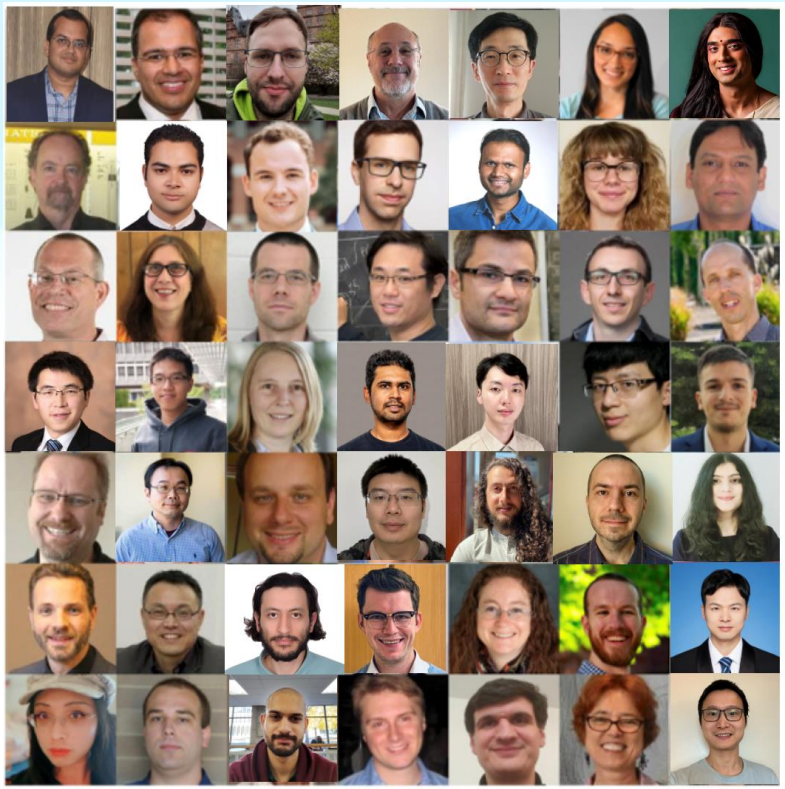
- ✓ Jets are powerful probes to reveal QGP properties.
- ✓ EEC distributions are dominated by selection bias and hadronization in the small angle region, and could be enhanced by medium response in the large angle region.

Outlook

- ➢ Further Investigating the effects of hadronization and medium response on EECs.
- ➢ Three-point energy correlators.

JETSCAPE @ HP2024

- Peter Jacobs, *Multi-Observable Analysis of Jet Quenching Using Bayesian Inference* (Parallel 4: high pt in small systems, Monday 3:40 pm)
- Yasuki Tachibana, *Extraction of jet-medium interaction details through jet substructure for inclusive and gamma-tagged jets* (Parallel 5: jet substructure, Monday 5:50 pm)
- Hendrik Roch, *Effects of hadronic reinteraction on jet fragmentation from small to large systems* (Parallel 5: jet substructure, Monday 6:10 pm)
- Yayun He, *Energy-energy correlators of inclusive jets in heavy-ion collisions* (Parallel 9: jet EEC, Tuesday 9:40 am)
- Abhijit Majumder, *Correlations between hard probes and bulk dynamics in small systems* (Parallel 21: jets in small systems, Tuesday 4:15 pm)
- Chathuranga Sirimanna, *Interplay of prompt and non-prompt photons in photon-triggered jet observables* (Parallel 28: hard EM, Wednesday 9:40 am)
- Rainer Fries, *X-SCAPE as a universal Event Generator for e+p, e+e- and pp collisions* (Poster, Tuesday 4:35 pm)

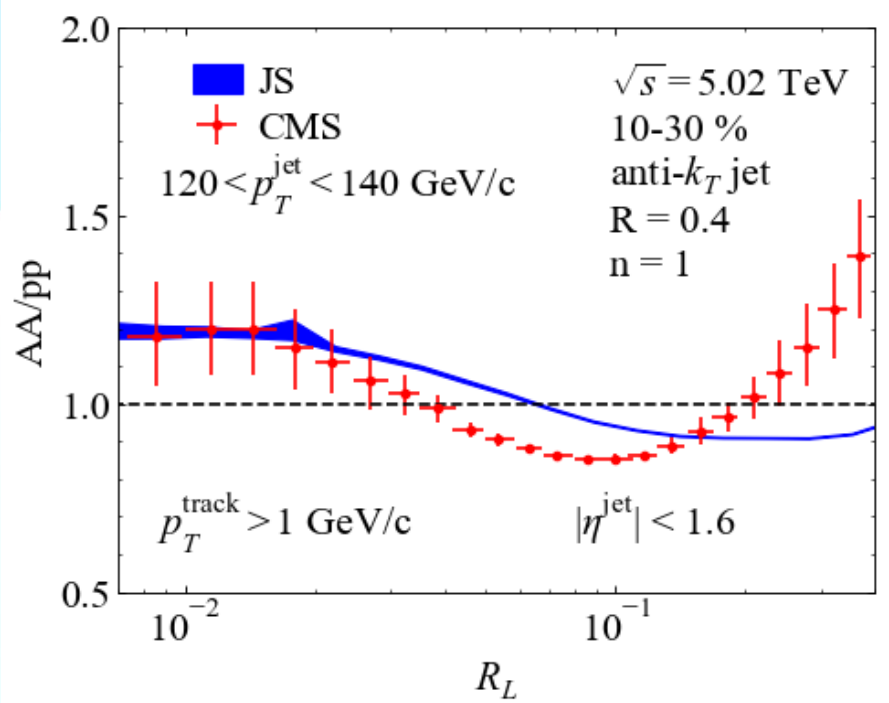


Thanks for your attention!

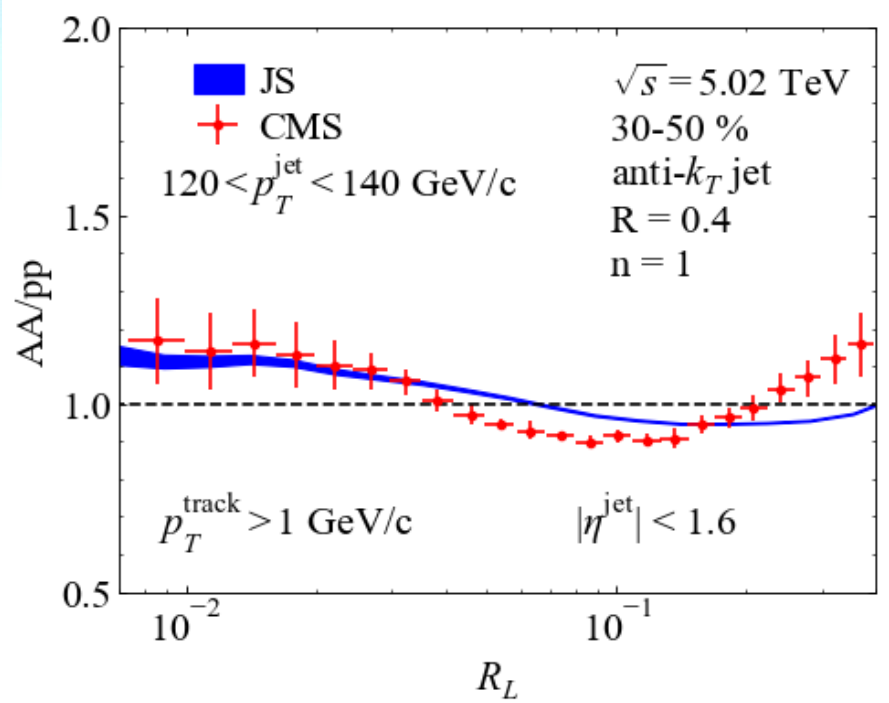
Centrality Dependence

CMS $\frac{d\Sigma^{n}}{dR_L} = \Sigma_{i,j} \int dR'_L \frac{d\sigma}{dR'_L} p_{T,i}^{n} p_{T,j}^{n} \delta(R'_L - R_L)$ (normalized to unity)

10-30%, 1 GeV cut, n=1

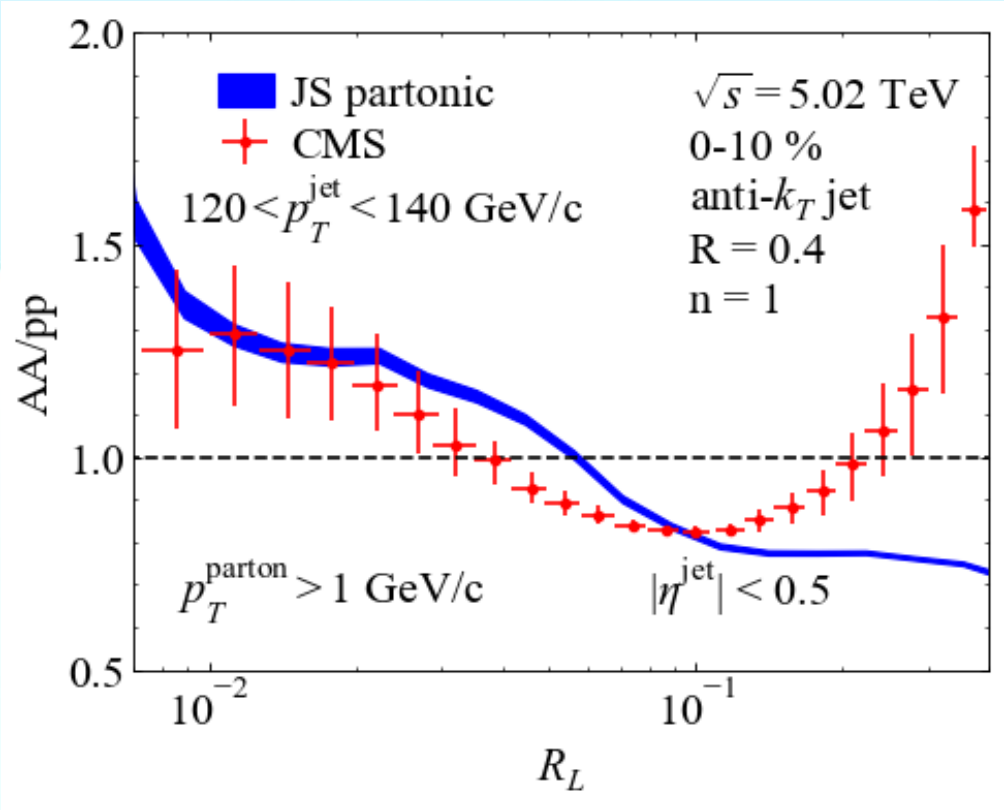


30-50%, 1 GeV cut, n=1



Try to explain …

Partonic
w. showering outside of the medium



Partonic
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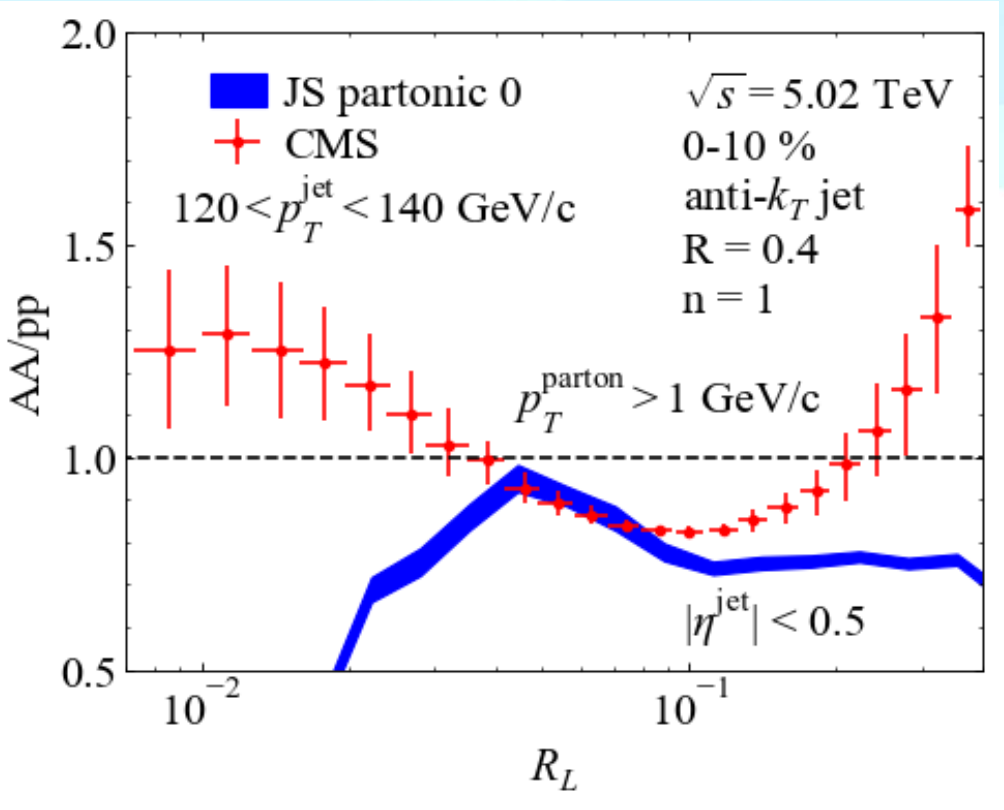
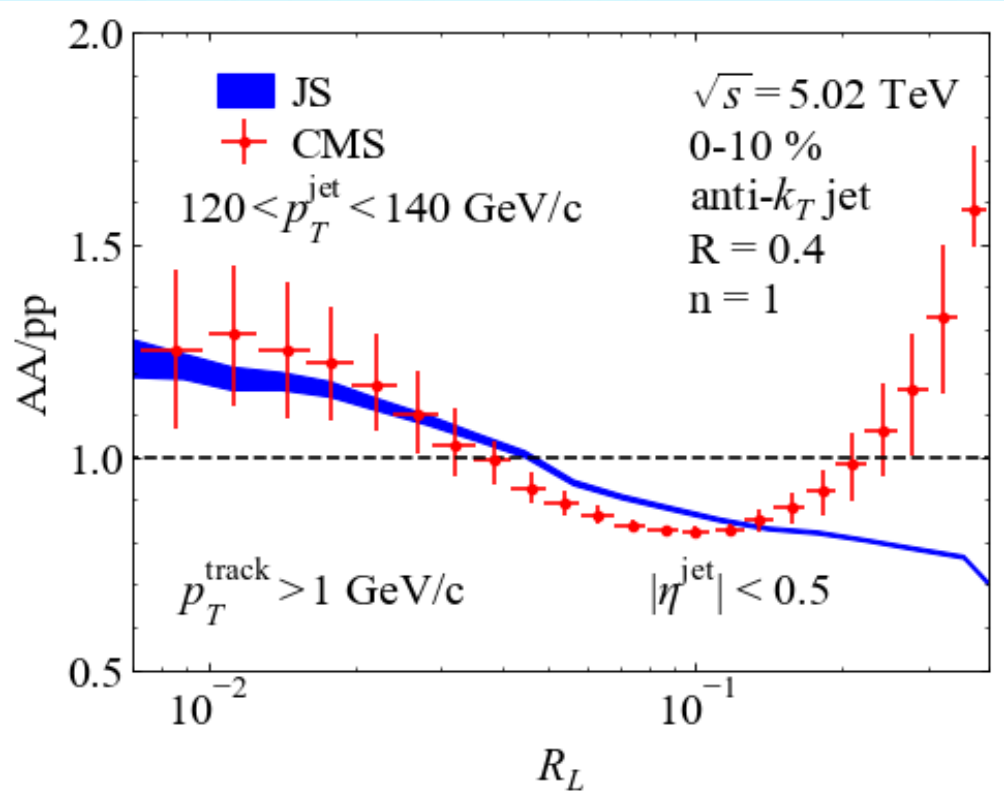


Try to explain …

Charged hadrons,
w. showering outside of the medium



Charged hadrons,
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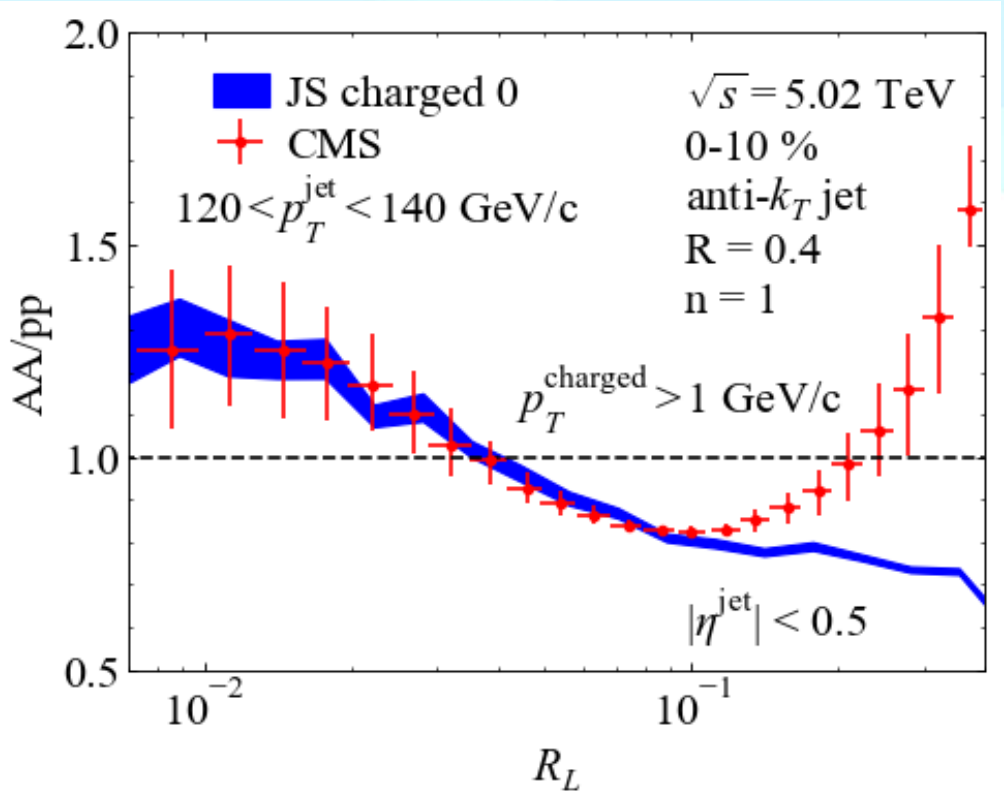
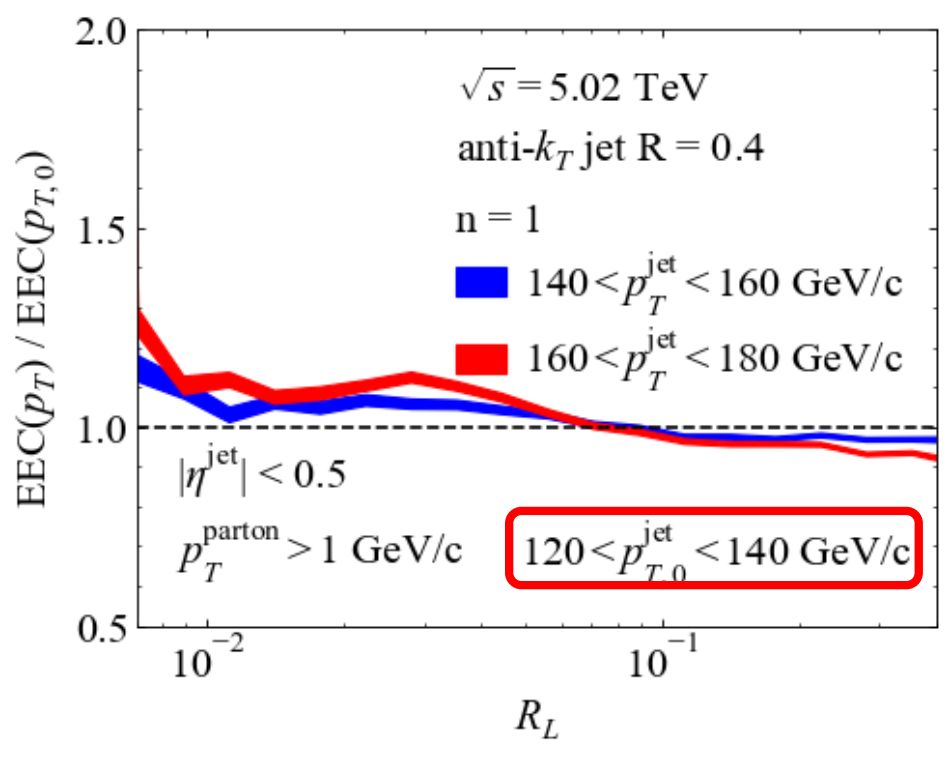
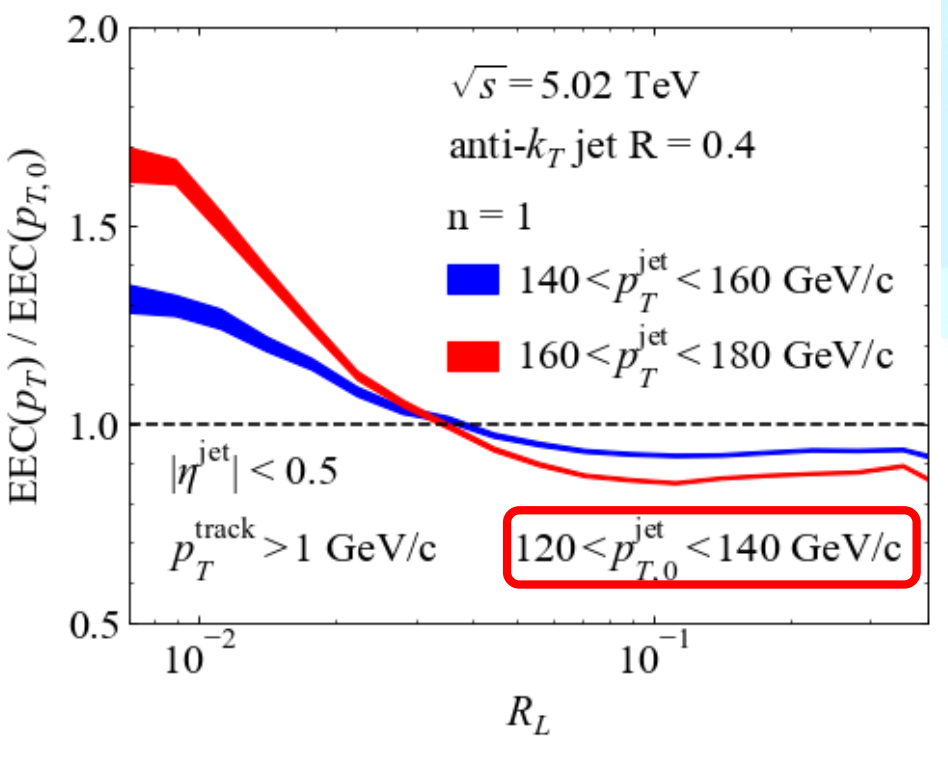


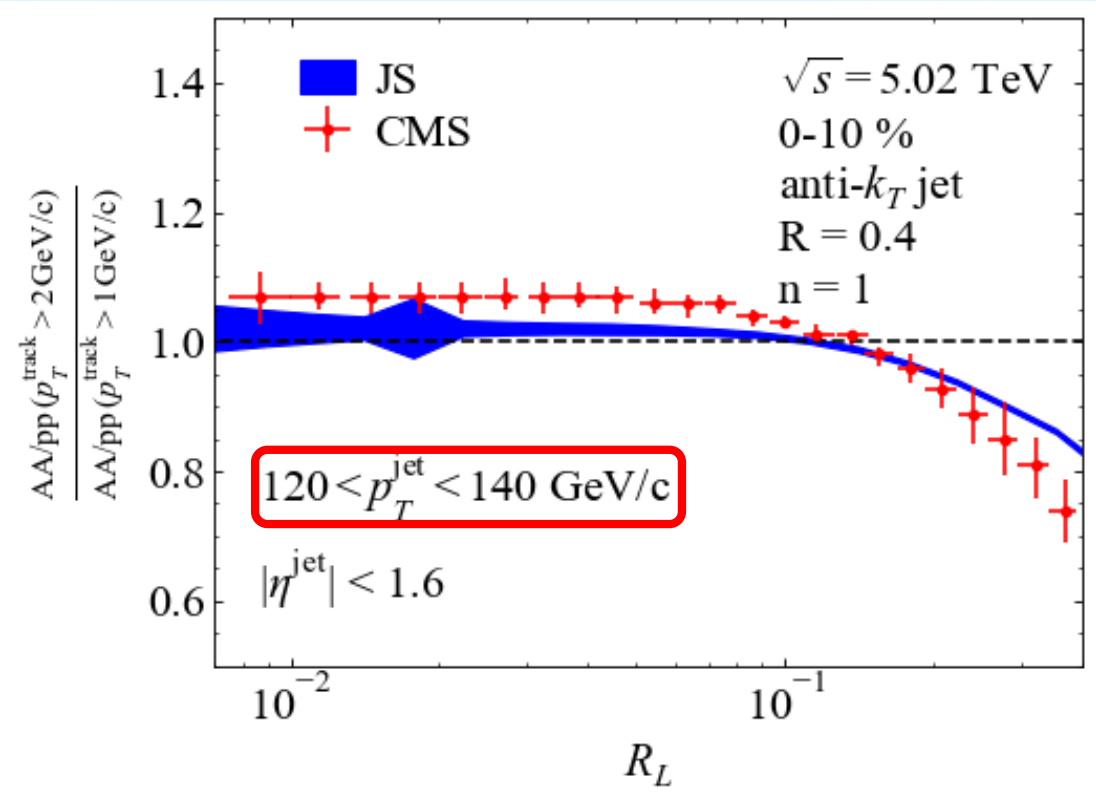
pp partonic, jet p_T shifting



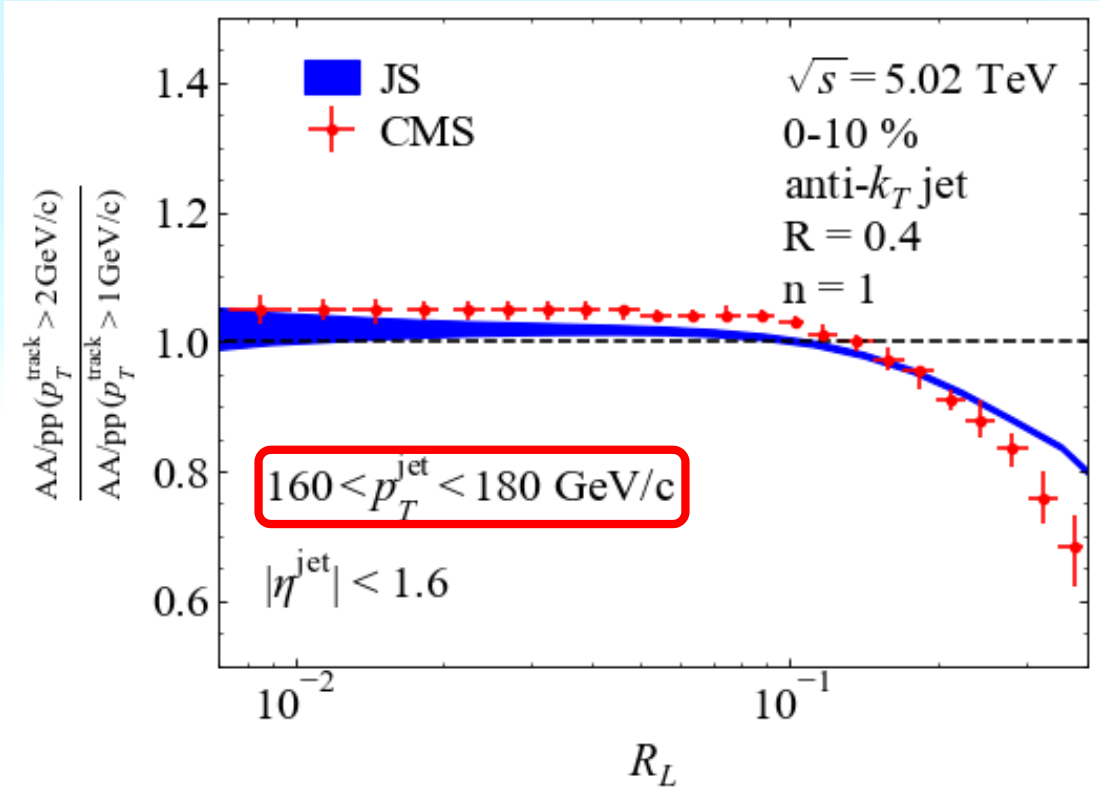
pp charged, jet p_T shifting



Double ratio

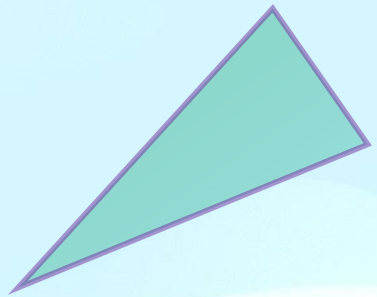


Double ratio



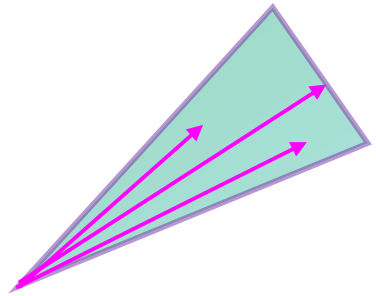
Jet Observables

- Jet as a whole
  - Jet nuclear modification factor
  - Jet anisotropic flow



(p_T, η, ϕ)

- Jet substructure
  - Jet shape
  - Jet fragmentation function
  - Groomed jet splitting function



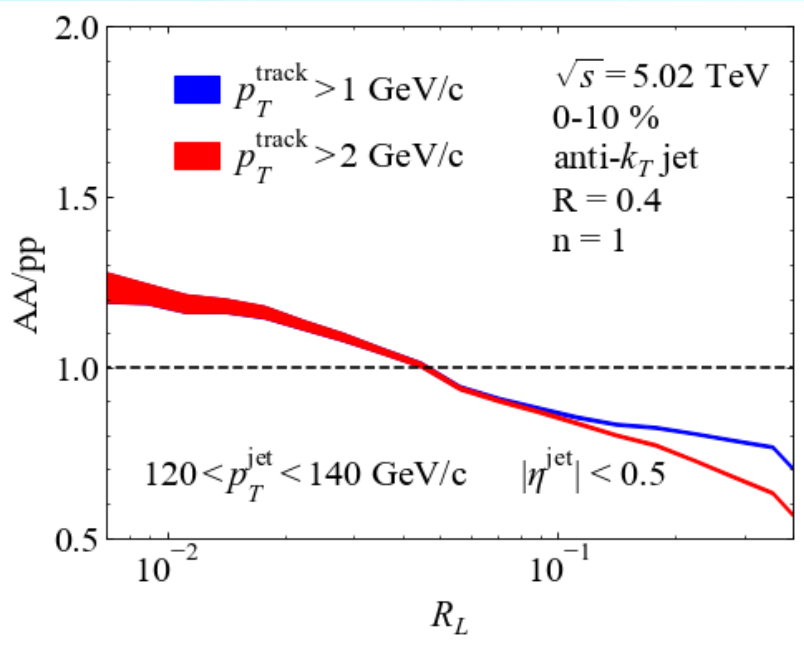
(p_T, η, ϕ)

(p_{Ti}, η_i, ϕ_i)

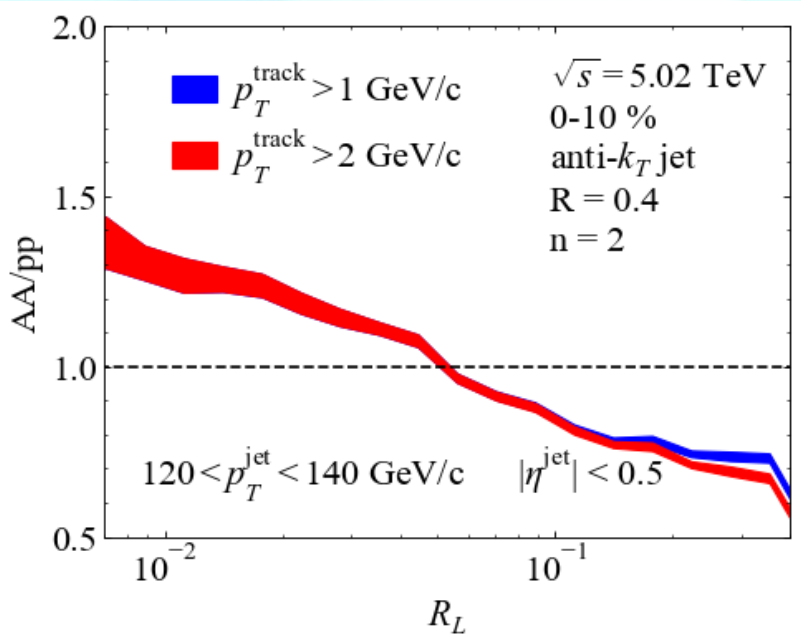
EECs of Inclusive Jets

ALICE $$\frac{d\Sigma^{n}}{dR_L} = \Sigma_{i,j} \int dR'_L \frac{d\sigma}{dR'_L} \frac{p_{T,i}^{n} p_{T,j}^{n}}{p_{T,jet}^{2n}} \delta(R'_L - R_L)$$

Nuclear effect, n=1



Nuclear effect, n=2



State-of-the-art: Energy Correlators

❖ Nuclear effects in AA (γ-triggered jet)

From γ-triggered jets to inclusive jets

☺ More jet events for experiments

☹ Selection biased