Investigating Radius-Dependent Jet Quenching Dynamics with the JETSCAPE Framework

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Outline

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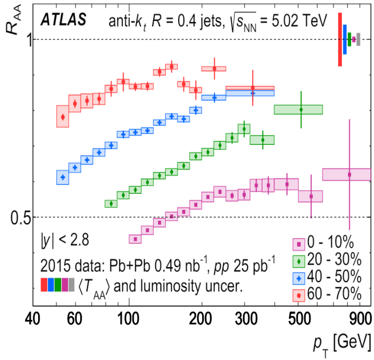

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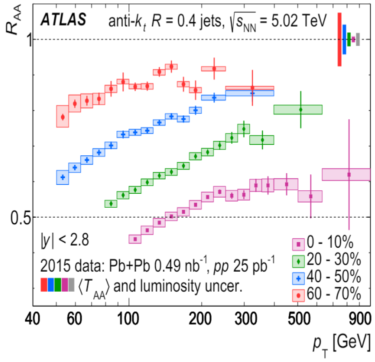
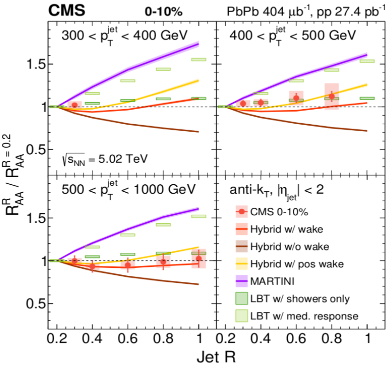


ATLAS [PLB 790, 108 (2019)]



CMS [JHEP 05, 284 (2021)]

- Explore how quenching effects vary with jet cone sizes (jet-R) and transverse momentum (jet-p_T) in the QGP medium.

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- Investigate jet-medium interactions in the QGP using modular approaches in the JETSCAPE framework with energy loss modules like MATTER, LBT, MARTINI, and AdS/CFT.
- Validate results against ATLAS and CMS experimental data, covering a broad p_T region ranging from 100 GeV – 1 TeV for ATLAS and 300 GeV – 1 TeV for CMS.
- Calculate and analyze the double ratio ($R_{\mathrm{AA}}^{\mathrm{R}} / R_{\mathrm{AA}}^{\mathrm{R=small}}$) as a function of jet-$R$ and jet-p_T, demonstrating consistency with JETSCAPE predictions.

Jet nuclear modification factor

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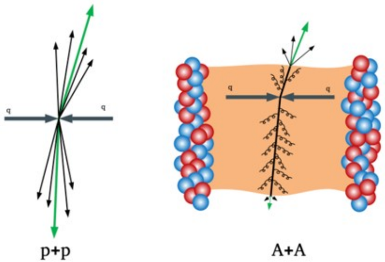
- Measures jet suppression in heavy-ion collisions (A+A) compared to proton-proton collisions.

$$R_{AA} = \frac{\frac{1}{N_{evt}} \frac{d^2 N_{jet}}{dy_{jet}\, dp_T^{jet}}\Big|_{AA}}{\langle T_{AA} \rangle \frac{d^2 \sigma_{jet}}{dy_{jet}\, dp_T^{jet}}\Big|_{pp}}$$



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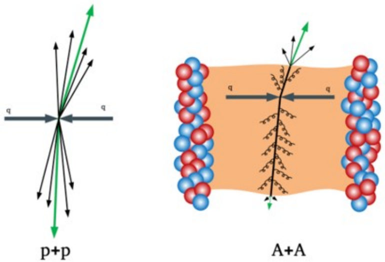

- In this study –
  - Pb-Pb collisions for the centrality (0-10%).
  - Dependence of jet-R_{AA} on
    1. Jet-R
    2. Jet-p_T

Simulation Tools

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- *MARTINI and AdS/CFT* – also explore the low virtuality phase.

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- Features of energy loss modules:
  - **LBT** models both collisional energy loss (via elastic scatterings with medium constituents) and medium-induced radiation.
  - **MARTINI** combines Monte Carlo techniques with pQCD to model gluon bremsstrahlung and parton energy dissipation.
  - **AdS/CFT** offers insights into strongly coupled plasma behavior.

Jet Spectra in *pp* collision

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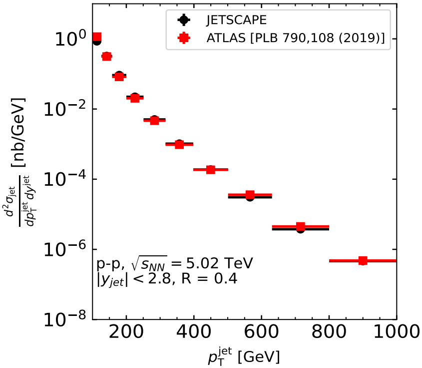

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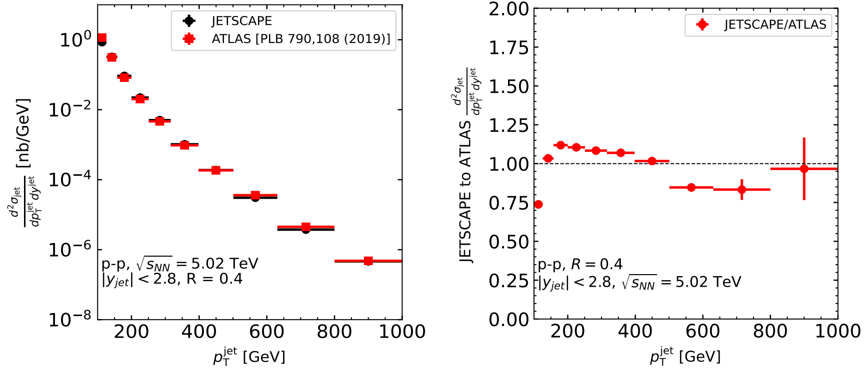

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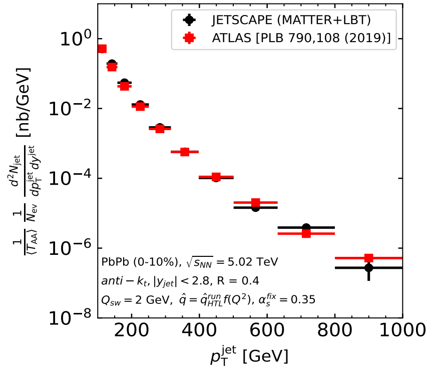

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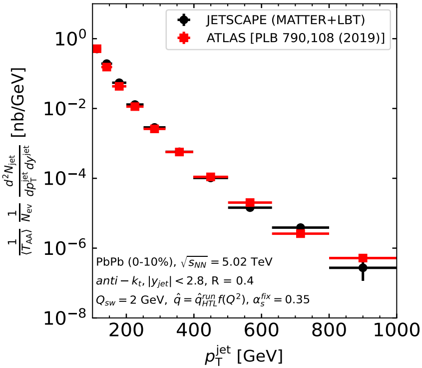

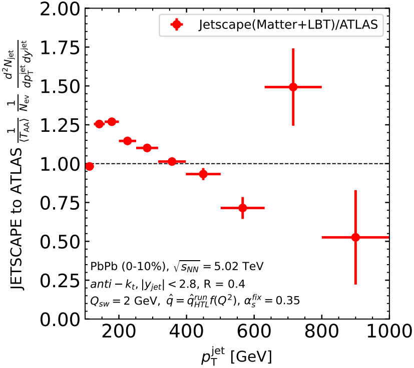

Jet-R_{AA} in Pb-Pb Collisions

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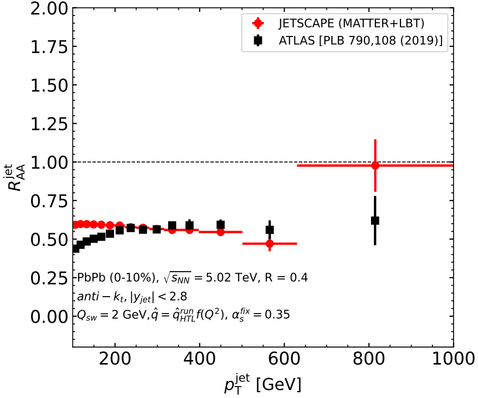

Jet-R_{AA} as a function of jet-p_T for the most central (0-10%) Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV for the jet cone radius R = 0.4.

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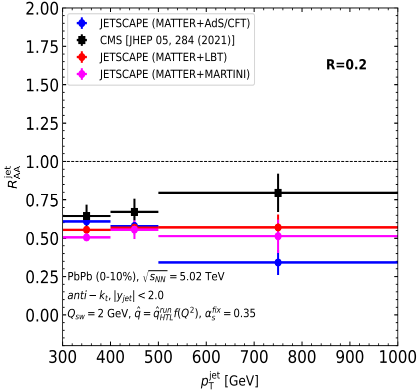

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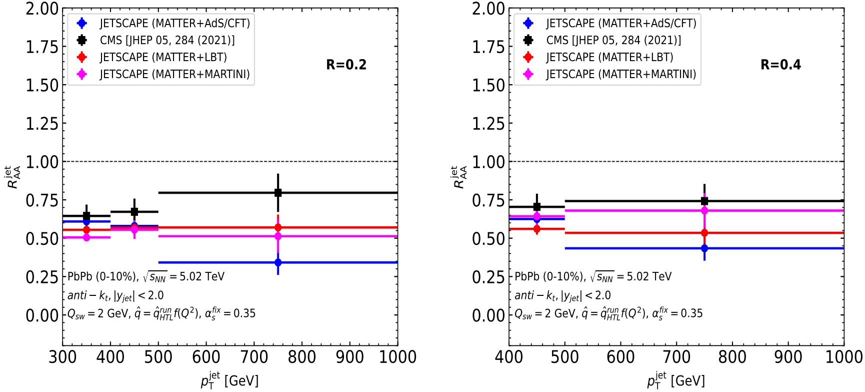

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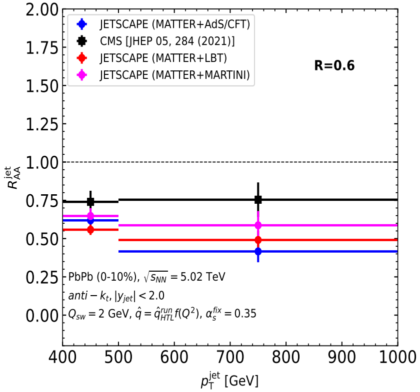

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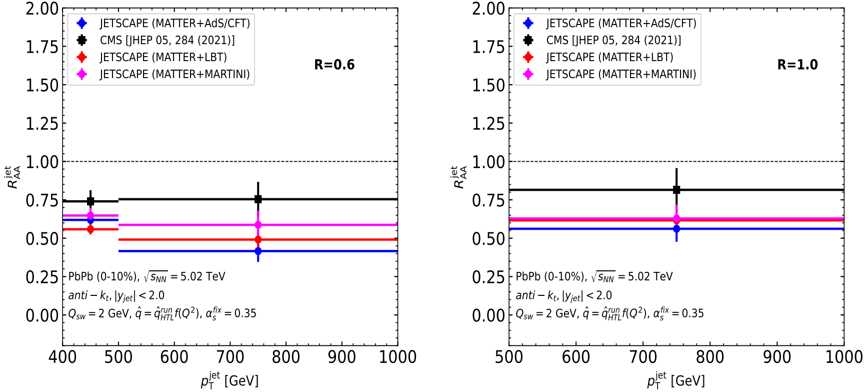

Jet-R_{AA} as a function of jet-p_T for the most central (0-10%) Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV for the jet cone radius R = 0.6 and 1.0.

Jet-R dependent Jet-R_{AA}

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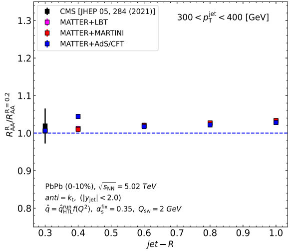

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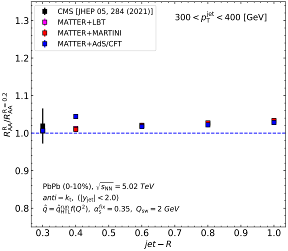

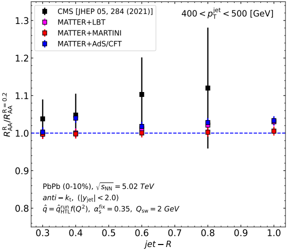

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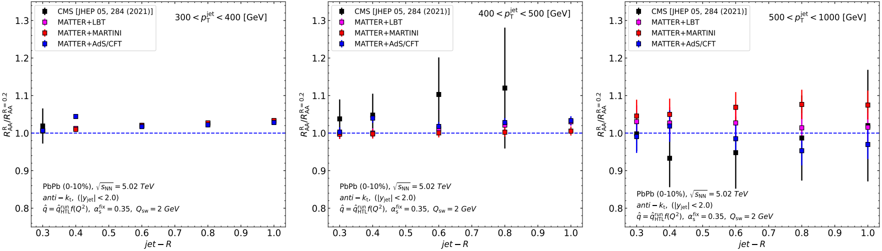

Double ratio ($R^{\mathrm{R}}_{\mathrm{AA}}/R^{\mathrm{R=small}}_{\mathrm{AA}}$) as a function of jet-$R$ in the most central (0-10%) Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with different energy modules.

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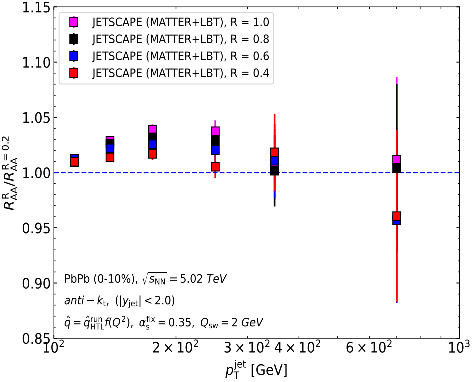

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- Jets with larger radii ($R > 0.4$) increasingly recover more energy, indicating that medium-induced radiations are better captured within broader jet cones as they propagate through the QGP.

Thank you!

Questions?


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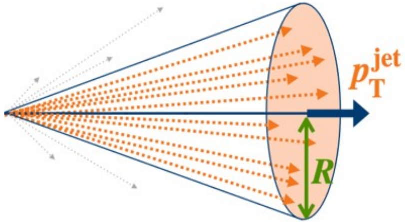
Back up slides

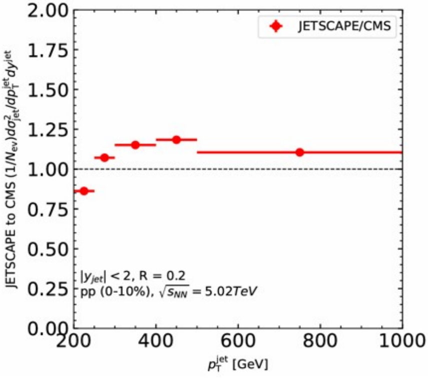
Jet Spectrum

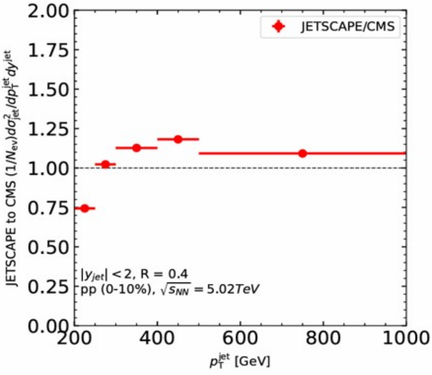
- The jet spectrum refers to the distribution of the transverse momentum (p_T) of the jets produced in the collision.



- It is represented as a function showing the number of jets as a function of their energy, which can be calculated as $\frac{d^2\sigma_{\text{jet}}}{dy_{\text{jet}}\, dp_T^{\text{jet}}}$.

Jet Spectra in p-p collision for CMS comparison





Ratio of jet spectra obtained from JETSCAPE to the CMS data for R=0.2, 0.4

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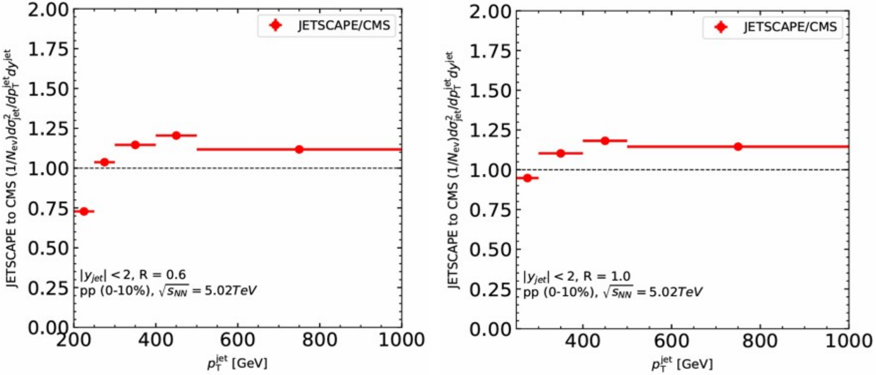
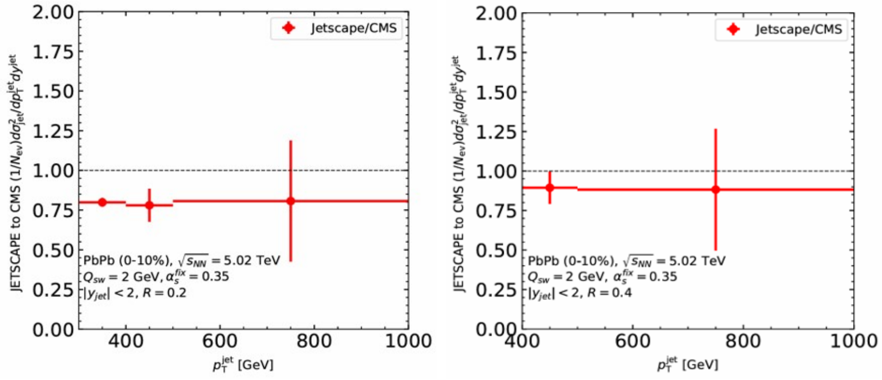


Ratio of jet spectra obtained from JETSCAPE to the CMS data for R=0.6, 1.0



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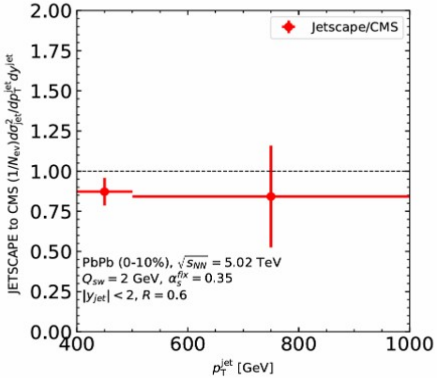

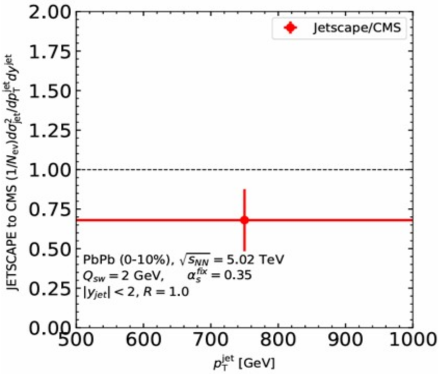

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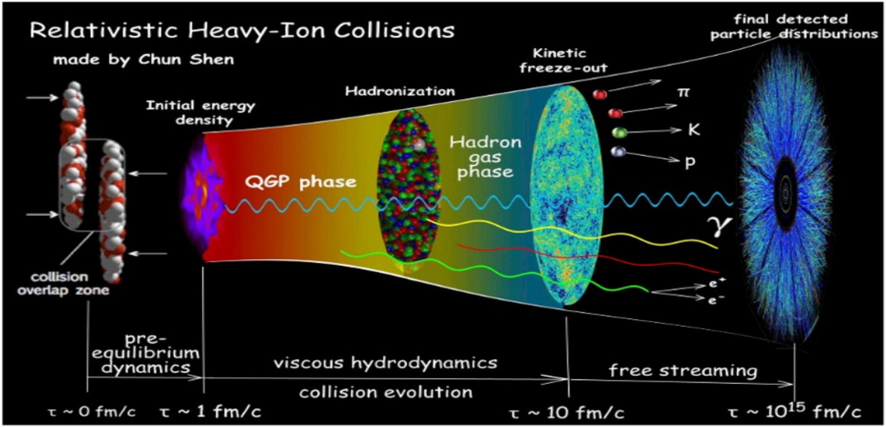
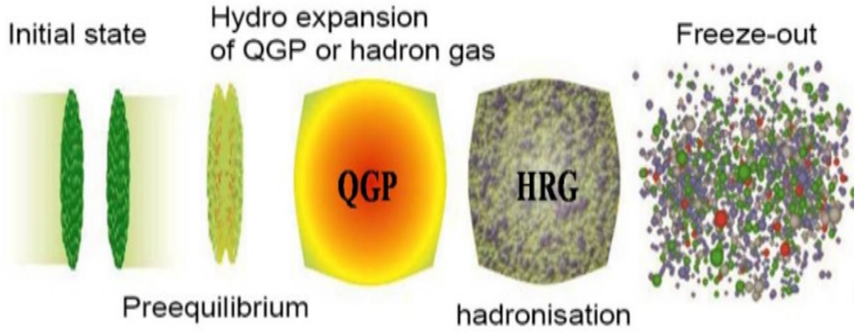
Relativistic Heavy-ion Collision



Application of hydrodynamics in QGP

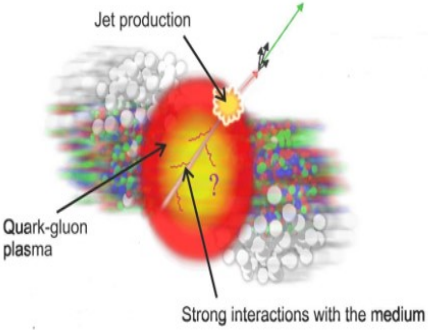
- A standard multi-stage approach is needed to model these collisions !!

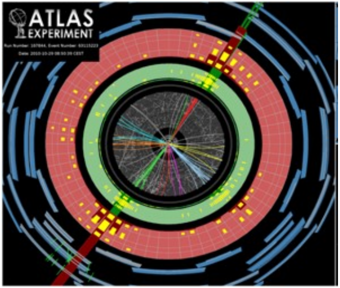


- To connect the physics of QGP, we need phenomenological models, where the theory of hydrodynamics becomes useful.

Jet quenching

- Jet quenching refers to the energy loss of high-p_T partons as they traverse the Quark-Gluon Plasma medium, leading to suppressed jet yields in heavy-ion collisions.

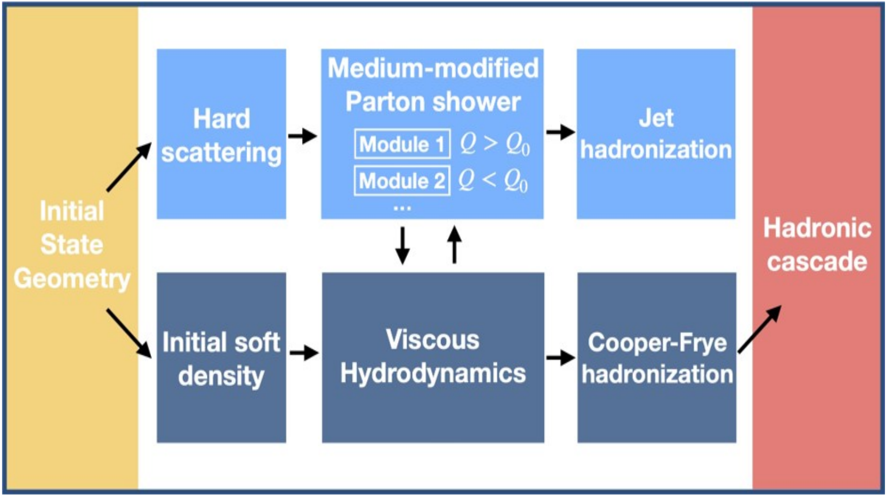




ATLAS [PLB 790, 108 (2019)]

- **Significance:** Serves as a probe of QGP properties, revealing its density, temperature, and transport coefficients.

JETSCAPE Framework



[https://github.com/JETSCAPE/JETSCAPE JETSCAPE Manual: arXiv:1903.07706]

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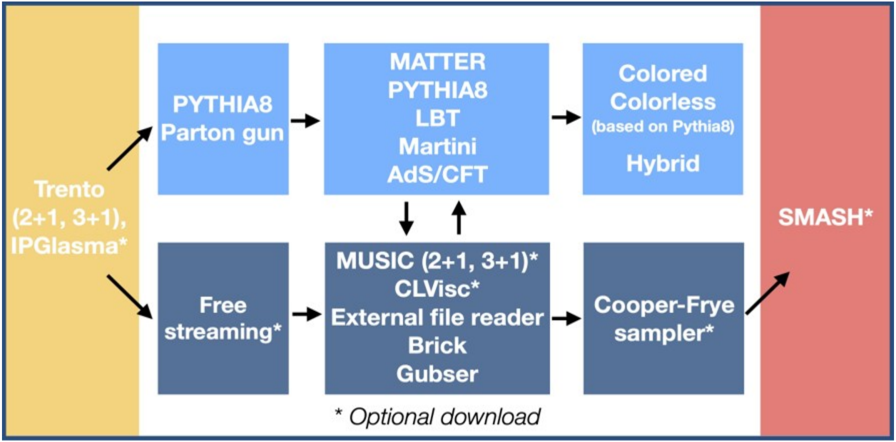

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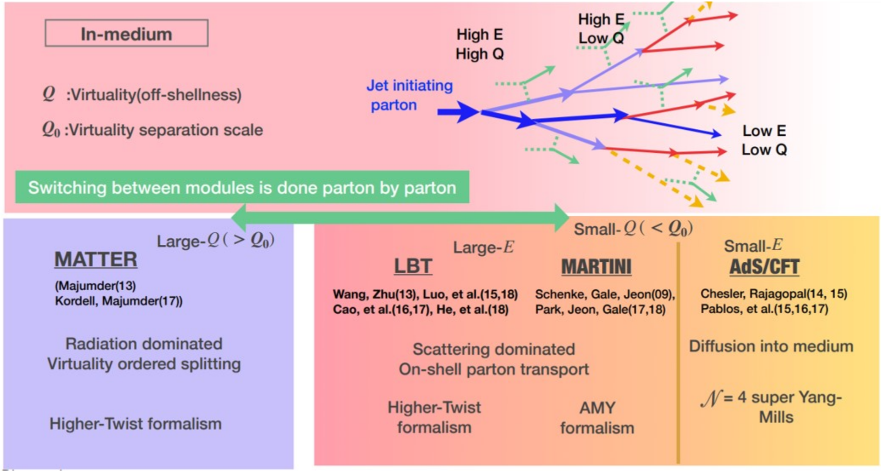
Energy loss modules in JETSCAPE



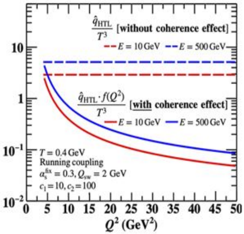
Coherence Effect

The coherence effects are represented by the effective jet quenching strength $\widehat{q}$ which is defined as:

$$\widehat{q} = \widehat{q}_{HTL} f(Q^2)$$

where f(Q^2) is virtuality dependent modulation factor and is given by:

$$f(Q^2) = \begin{cases} \frac{1+10(ln(Q^2_{SW}))^2+100(ln(Q^2_{SW}))^4}{1+10(ln(Q^2))^2+100((ln(Q^2))^4} & \text{if } Q > Q_{SW} \\ 1 & \text{if } Q < Q_{SW} \end{cases}$$



and $\widehat{q}_{HTL}$ is the jet quenching parameter for on-shell partons calculated by Hard Thermal Loop (HTL) effective theory.