The evolution of jets and high-p_T probes in small collision systems using a multi-stage approach

Ismail Soudi

Wayne State University

For the JETSCAPE Collaboration

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Outline

- Multi-Stage Approach In Heavy-ion Collisions
- Multi-Stage Approach to small Systems
- 3D MCGlauber
- iMatter: Initial State Radiation
- Preliminary Results
- Summary & Outlook

Multi-Stage Approach In Heavy-ion Collisions I

- Modular Framework for studying jets and bulk dynamics of HIC
- Latest version 3.5 available: github.com/JETSCAPE

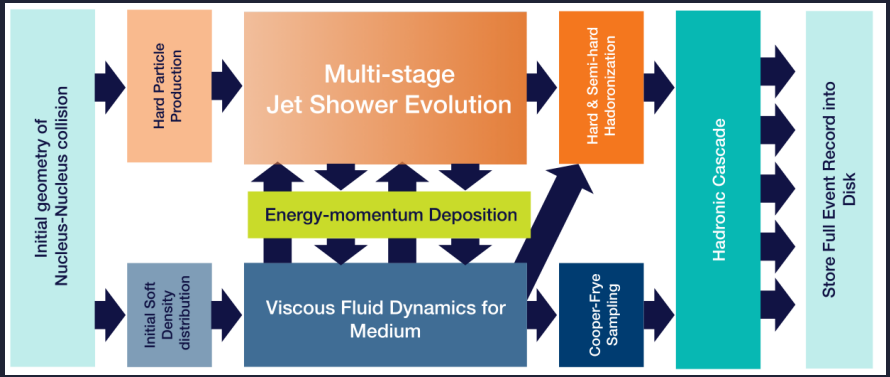

Diagram by Y. Tachibana

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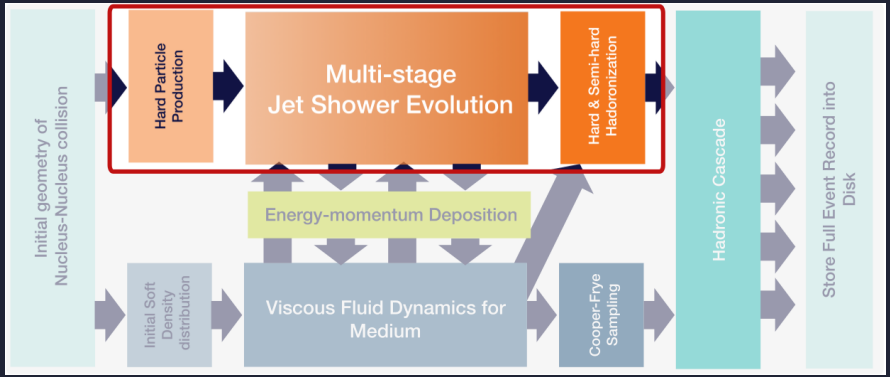


Diagram by Y. Tachibana

Multi-Stage Approach In Heavy-ion Collisions II

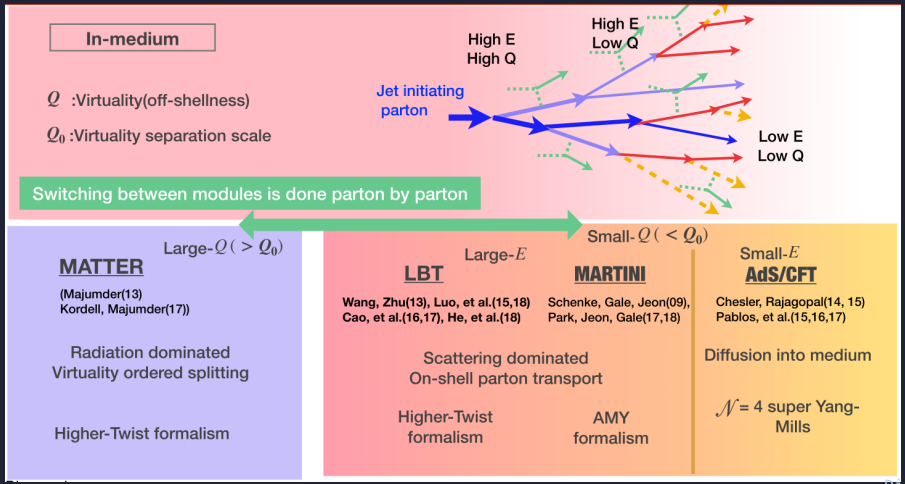


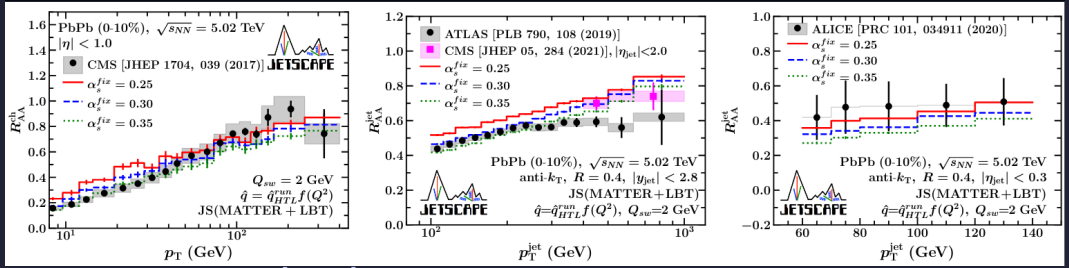
Diagram by
Y. Tachibana

⊙ Multi-Stage Approach In Heavy-ion Collisions III

Inclusive Jet and Hadron Suppression in a Multi-Stage Approach

JETSCAPE Collaboration • A. Kumar Show All(60)

Apr 3, 2022



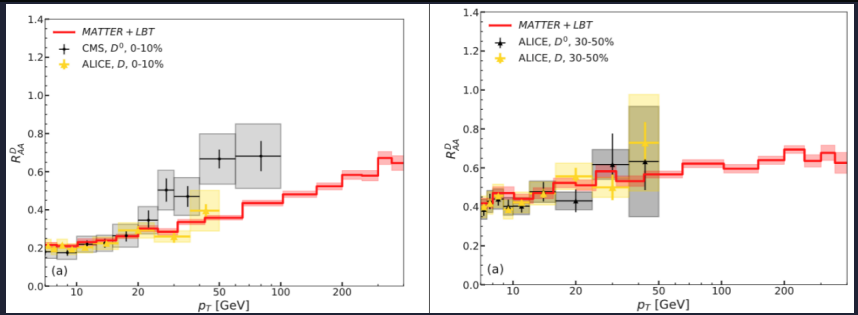
A. Kumar et al., 2204.01163 [hep-ph]

Multi-Stage Approach In Heavy-ion Collisions IV

Multi-scale evolution of charmed particles in a nuclear medium

JETSCAPE Collaboration • W. Fan Show All(59)

Aug 1, 2022



W. Fan, et al. e-Print: 2208.00983 [nucl-th] [hep-ph]

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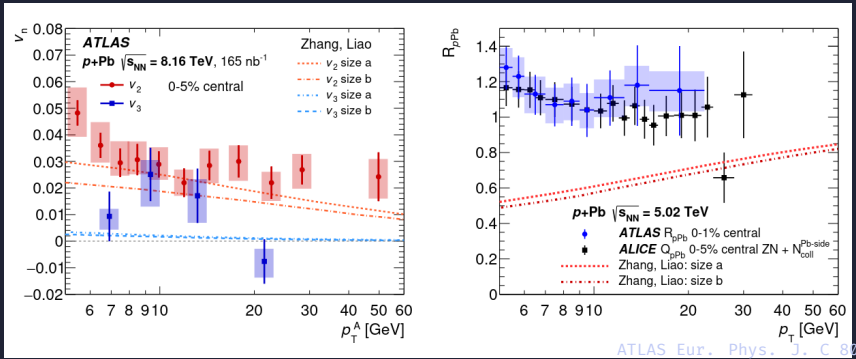
Jet quenching vs Flow

- Models of flow for high-p_T particles can lead to large supressions
- R_{pPb} vs v_2 puzzle

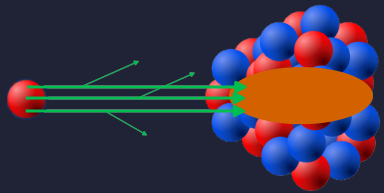


ATLAS Eur. Phys. J. C 80 (2020) 73
X. Zhang and J. Liao, arXiv: 1311.5463 [nucl-th]

Jets In Small Systems

- For Small systems:
  - » Soft interactions may lead to thermalization of the medium

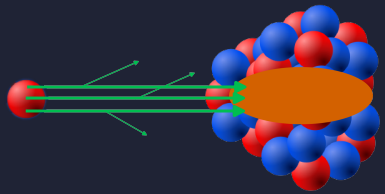
- Soft:



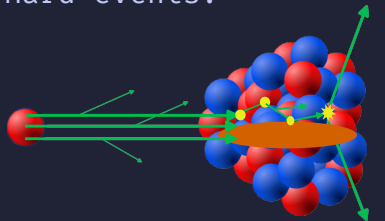
Jets In Small Systems

- For Small systems:
  - » Soft interactions may lead to thermalization of the medium
  - » Hard partons can interact with the nucleons before the hard scattering

- Soft:



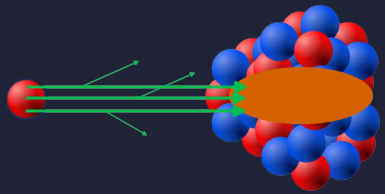
- Hard events:



Jets In Small Systems

- For Small systems:
  - » Soft interactions may lead to thermalization of the medium
  - » Hard partons can interact with the nucleons before the hard scattering
  - » May lead to modification of the initial state radiation

- Soft:



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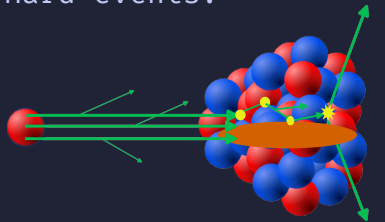
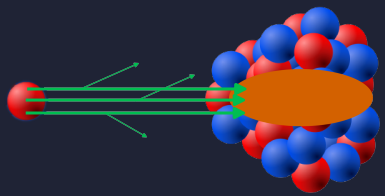


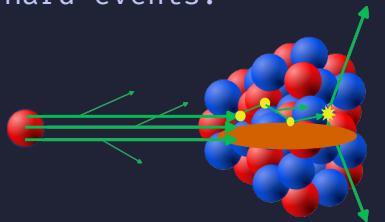
Jets In Small Systems

- For Small systems:
  - » Soft interactions may lead to thermalization of the medium
  - » Hard partons can interact with the nucleons before the hard scattering
  - » May lead to modification of the initial state radiation
  - » Correlation of Soft/Hard particle production, i.e. More hard scatterings $\Rightarrow$ less energy for soft-partons

- Soft:



- Hard events:



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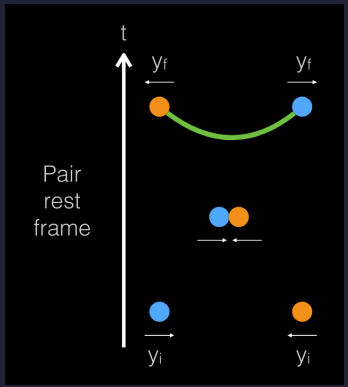
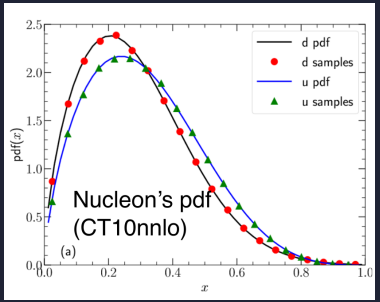
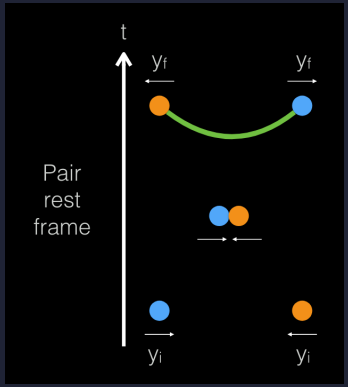
3D MCGlauber: W. Zhao, C. Shen & B. Schenke

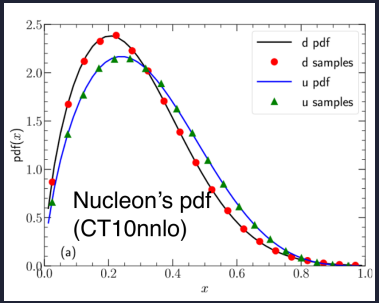




- Collision geometry is determined by MC-Glauber model

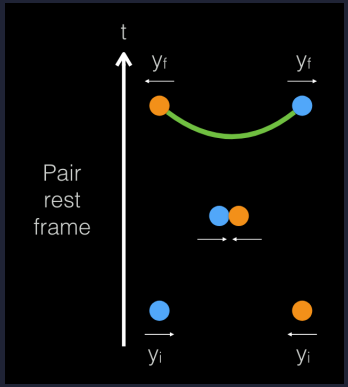
3D MCGlauber: W. Zhao, C. Shen & B. Schenke

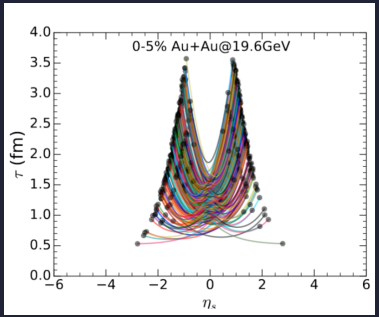




- Collision geometry is determined by MC-Glauber model
- 3 valence quarks sampled from PDF

3D MCGlauber: W. Zhao, C. Shen & B. Schenke

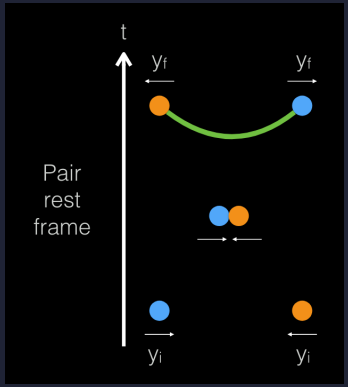


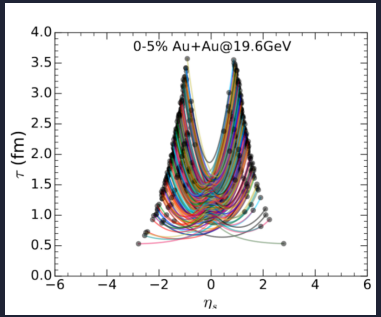


- Incoming quarks decelerated w/ string tension.

$$\frac{dE}{dz} = -\sigma\,, \qquad \frac{dp_z}{dt} = -\sigma \quad (1)$$

3D MCGlauber: W. Zhao, C. Shen & B. Schenke





- Incoming quarks decelerated w/ string tension.

$$\frac{dE}{dz} = -\sigma\,, \qquad \frac{dp_z}{dt} = -\sigma \quad (1)$$

- Conservations of energy, momentum, net baryon density

3D MCGlauber: W. Zhao, C. Shen & B. Schenke

- Energy-momentum current and net baryon density are fed into hydrodynamic simulations

$$\partial_\mu \mathrm{T}^{\mu\nu} = \mathrm{J}^\nu_{\mathrm{Source}}\,, \qquad (2)$$

$$\partial_\mu \mathrm{J}^\mu = \rho_{\mathrm{Source}} \qquad (3)$$

3D MCGlauber: W. Zhao, C. Shen & B. Schenke

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- Parameters callibrated with p+p at LHC

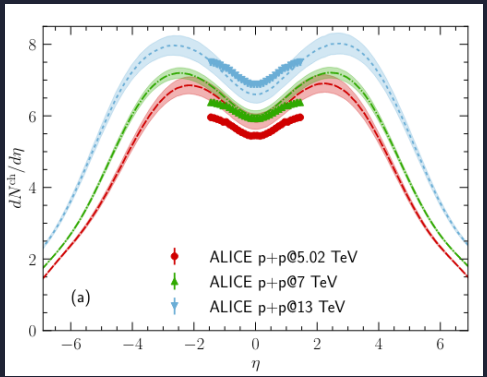

Figure: Charged hadron pseudo-rapidity distributions in p+p, experimental data from the ALICE Collaboration

3D MCGlauber: W. Zhao, C. Shen & B. Schenke

- Energy-momentum current and net baryon density are fed into hydrodynamic simulations

$$\partial_\mu T^{\mu\nu} = J^\nu_{\text{Source}}\,, \qquad (2)$$

$$\partial_\mu J^\mu = \rho_{\text{Source}} \qquad (3)$$

- Parameters callibrated with p+p at LHC
- Good description of charged hadron distributions at Au+Au at RHIC after retuning of parameters

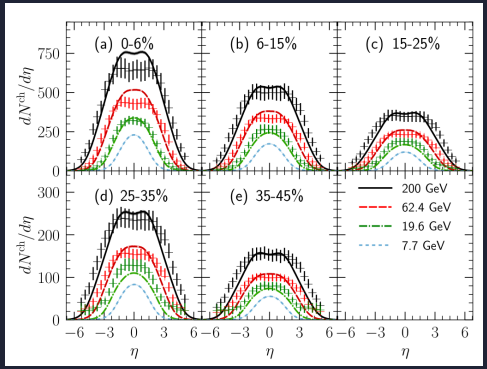

Figure: Centrality dependence of charged hadron pseudo-rapidity distributions in Au+Au, experimental data from the PHOBOS Collaboration

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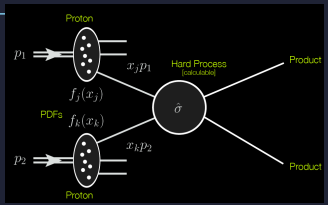
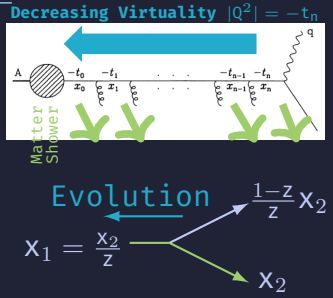
iMatter: Initial State Radiation

- One firsts generates the hard $2 \leftrightarrow 2$ scatterings using PYTHIA



iMatter: Initial State Radiation

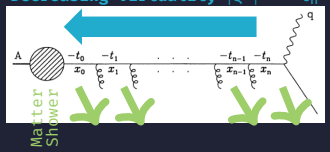
- One firsts generates the hard $2 \leftrightarrow 2$ scatterings using PYTHIA
- The initial state radiation generated in backward shower, starting from 2 scattering partons



T. Sjostrand, Phys. Lett. B157 (1985) 321.
G. Marchesini and B.R. Webber, Nucl Phys. B310 (1988) 461.
Ellis, R., Stirling, W., & Webber, B. (1996).

iMatter: Initial State Radiation

- One firsts generates the hard $2 \leftrightarrow 2$ scatterings using PYTHIA
- The initial state radiation generated in backward shower, starting from 2 scattering partons
- The Sudakov is dependent on the PDF $\Rightarrow$ limits the energy of earlier partons



Backward Sudakov

$$\Pi(t_1, t_2; x) = \frac{f(x,t_1)\Delta(t_2)}{f(x,t_2)\Delta(t_1)},$$

PDFs Sudakov

T. Sjostrand, Phys. Lett. B157 (1985) 321.
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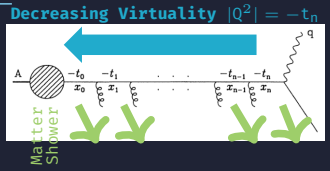
iMatter: Initial State Radiation

- One firsts generates the hard $2 \leftrightarrow 2$ scatterings using PYTHIA
- The initial state radiation generated in backward shower, starting from 2 scattering partons
- The Sudakov is dependent on the PDF $\Rightarrow$ limits the energy of earlier partons
- Splitting probability also $\propto$ PDF



Backward Sudakov

$$\Pi(t_1, t_2; x) = \frac{f(x,t_1)\Delta(t_2)}{f(x,t_2)\Delta(t_1)},$$

PDFs Sudakov

$$\Gamma(z) = \frac{\alpha_s}{2\pi} \frac{P(z)}{z} f(x_1 = x_2/z, t_1),$$

T. Sjostrand, Phys. Lett. B157 (1985) 321.
G. Marchesini and B.R. Webber, Nucl Phys. B310 (1988) 461.
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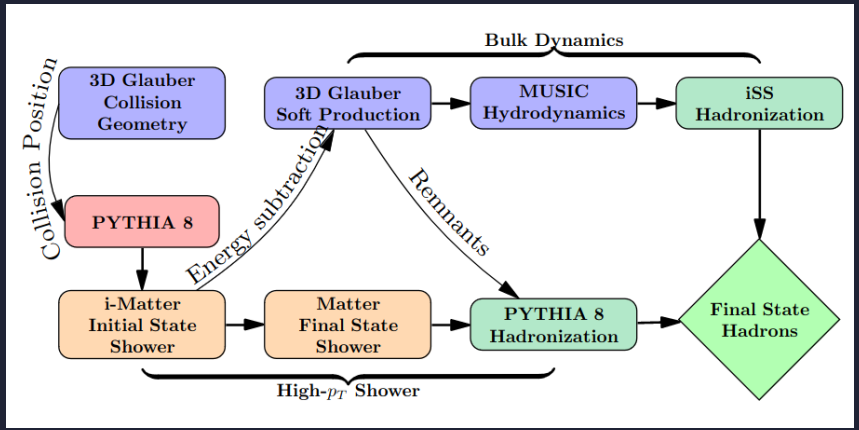
Multi-Stage Approach To Small Systems

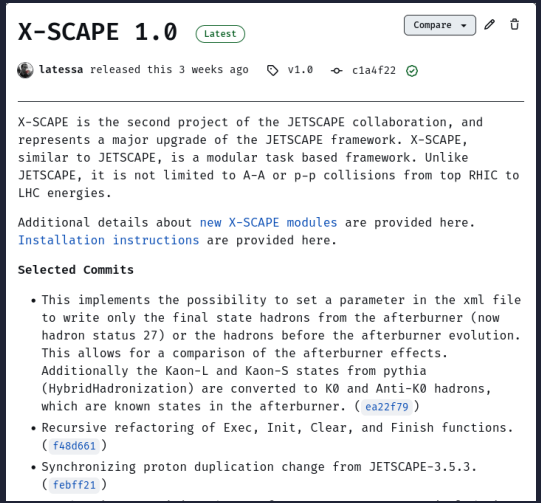
- Energy available for the hard shower is subtracted from the soft sector (3D-MCGlauber)



X-SCAPE

X-ion collisions with a Statistically and Computationally Advanced Program Envelop

- Small systems ⇒ p-p, p-A
  → Correlation between hard and soft sector
- Lower energy A-A ⇒ Beam energy scan
- Extension to e-A ⇒ EIC
- X-SCAPE v1.0 Release



X-SCAPE 1.0 Latest

Compare

latessa released this 3 weeks ago v1.0 c1a4f22

X-SCAPE is the second project of the JETSCAPE collaboration, and represents a major upgrade of the JETSCAPE framework. X-SCAPE, similar to JETSCAPE, is a modular task based framework. Unlike JETSCAPE, it is not limited to A-A or p-p collisions from top RHIC to LHC energies.

Additional details about new X-SCAPE modules are provided here. Installation instructions are provided here.

Selected Commits

- This implements the possibility to set a parameter in the xml file to write only the final state hadrons from the afterburner (now hadron status 27) or the hadrons before the afterburner evolution. This allows for a comparison of the afterburner effects. Additionally the Kaon-L and Kaon-S states from pythia (HybridHadronization) are converted to K0 and Anti-K0 hadrons, which are known states in the afterburner. (ea22f79)
- Recursive refactoring of Exec, Init, Clear, and Finish functions. (f48d661)
- Synchronizing proton duplication change from JETSCAPE-3.5.3. (febff21)

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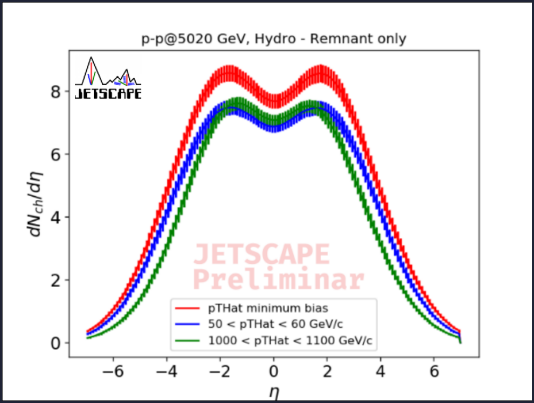
⊙ Preliminary Results

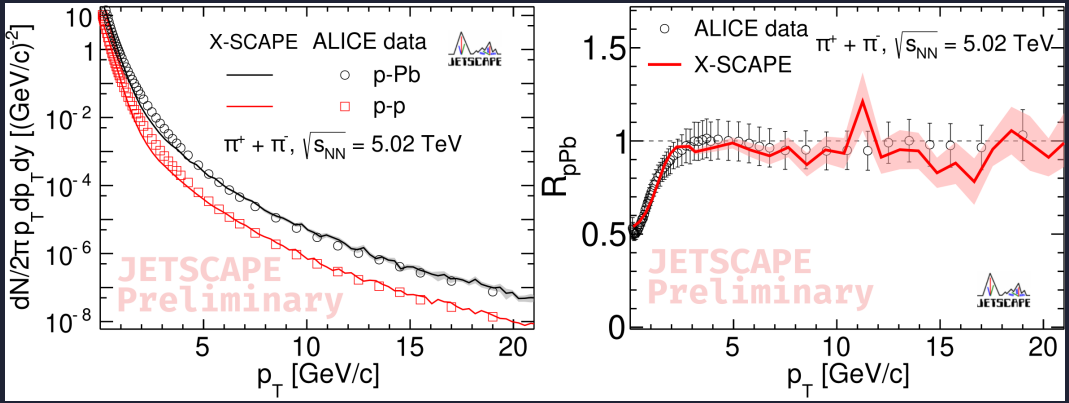
» Soft Hard Correlations



- Increase in the hard sector p_T leads to a depletion of the soft sector

⊙ Preliminary Results

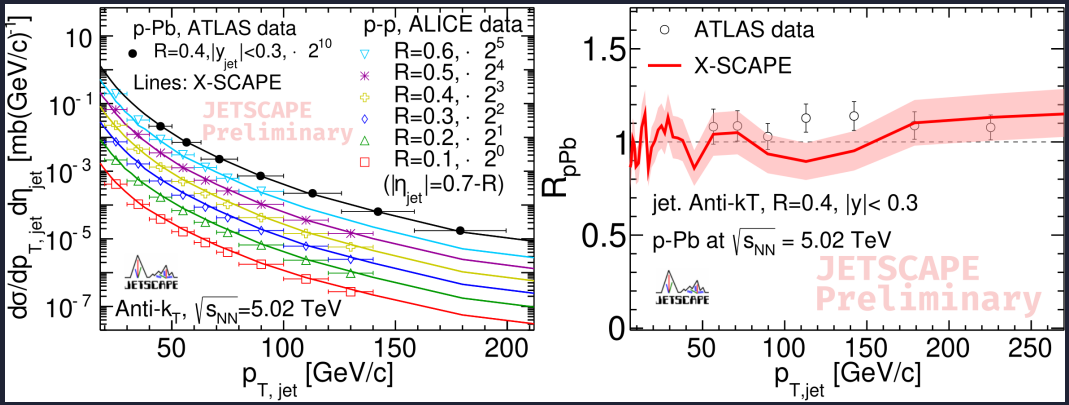
» Hadron Spectra



- Soft modeled by Hydro
- Hard modeled by PYTHIA + i-Matter + Matter

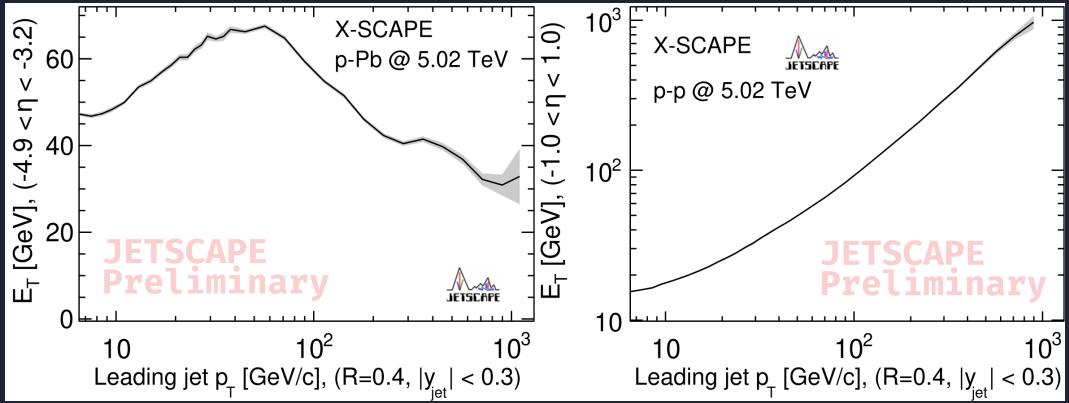
⊙ Preliminary Results

» Jet Spectra (Background subtraction ⇒ Only fragmentation of hard partons)



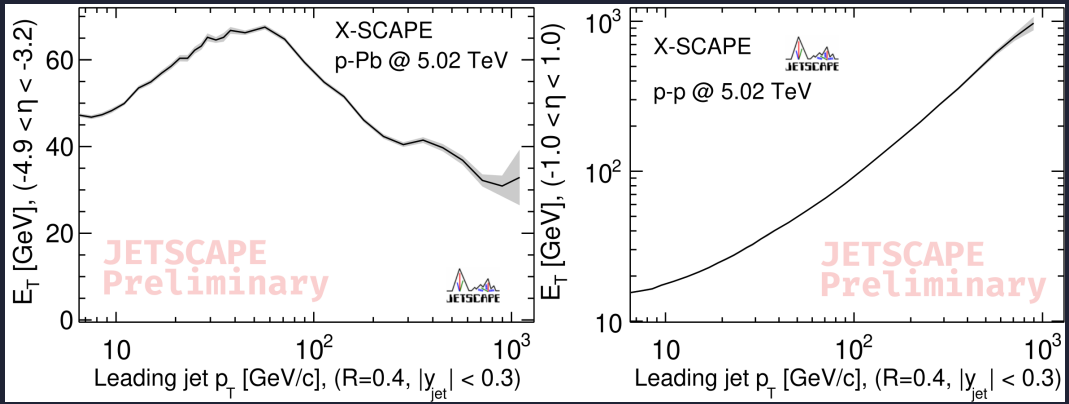
Preliminary Results

- Event activity modification in p-p as a function of jet p_T
- E_T from Cooper-Frye + fragmentation hadrons



Preliminary Results

- $p_T \lesssim 100$ GeV $\Rightarrow$ increase in activity
- $p_T > 100$ GeV $\Rightarrow$ decrease in activity



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Summary & Outlook

- New Multi-Stage event generator for small systems
  $\Rightarrow$ p-p, p-A
- Introducing correlation between hard and soft sector
- Good description of hadron and jet spectra
- Understanding correlation between soft and hard particle production
  $\Rightarrow$ crucial to understanding collectivity and jet modifications
- I. Soudi acknowledges financial support from The Gordon and Betty Moore Foundation and the American Physical Society to present this work at the GHP 2023 workshop.

And thanks to all collaborators !