Effects of hadronic reinteraction on jet fragmentation from small to large systems

Quark Matter 2023

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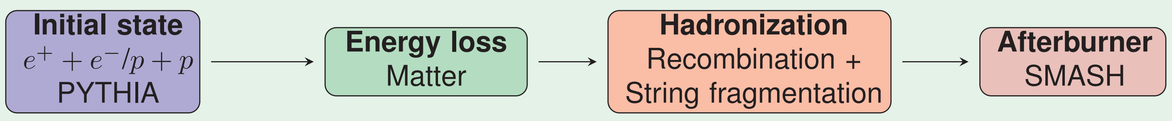
1. Introduction

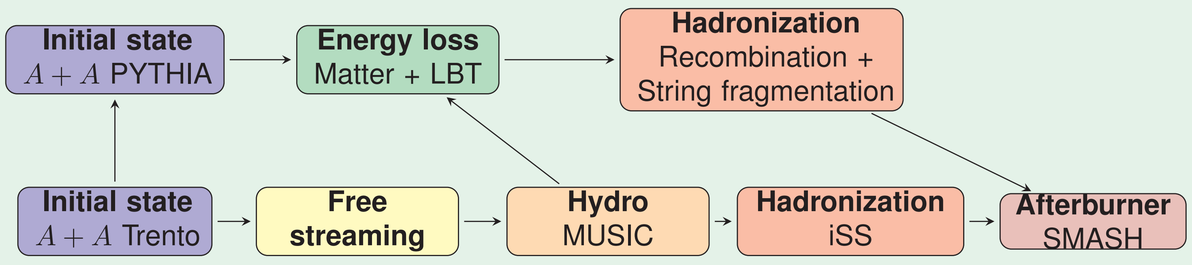
- Using the upcoming Jetscape 3.6 [1], we investigate the effect of the hadronic phase on jet quenching in nuclear collisions, which is largely an open question.
- With the new version of the framework we can feed hadrons from hadrd processes into the hadronic afterburner SMASH. With this we have the possibility to study the effects of hadronic rescatterings in $e^+ + e^-$, $p+p$ and $A+A$ systems quantitatively through simulations with and without rescatterings.

2. Simulation Setup

- Use upcoming JETSCAPE 3.6 framework for the study.
- Vacuum systems:



- Medium systems:



3. Hybrid Hadronization

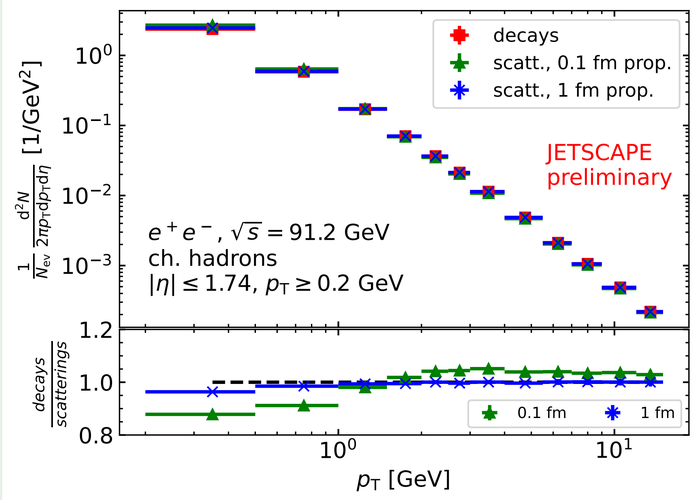
- Hybrid of string fragmentation and recombination [2].
- Smooth interpolation between two limits:
  - Dilute systems $\rightarrow$ String fragmentation dominates
  - Dense systems $\rightarrow$ Quark recombination dominates
- Workflow:
  - Input: Partons below virtuality cutoff with space-time information and color tags (in medium $\rightarrow$ bath of thermal partons).
  - Recombination: Decay gluons into $q\bar{q}$ and sample recombination probabilities for all $q\bar{q}$ and qqq bound states (in medium $\rightarrow$ with thermal partons).
  - Intermediate step: String system of recombined hadrons and remnant partons (in medium $\rightarrow$ thermal partons in remnant strings), only color singlets removed.
  - Fragmentation: Remnant partons tend to be further apart in phase space $\rightarrow$ Hadronize remnant string systems with PYTHIA.
- In medium: Process "negative partons" from processes like $q_{\text{shower}} + g_{\text{medium}} \rightarrow q_{\text{shower}} + g_{\text{shower}}$ separately for background subtraction.

4. SMASH

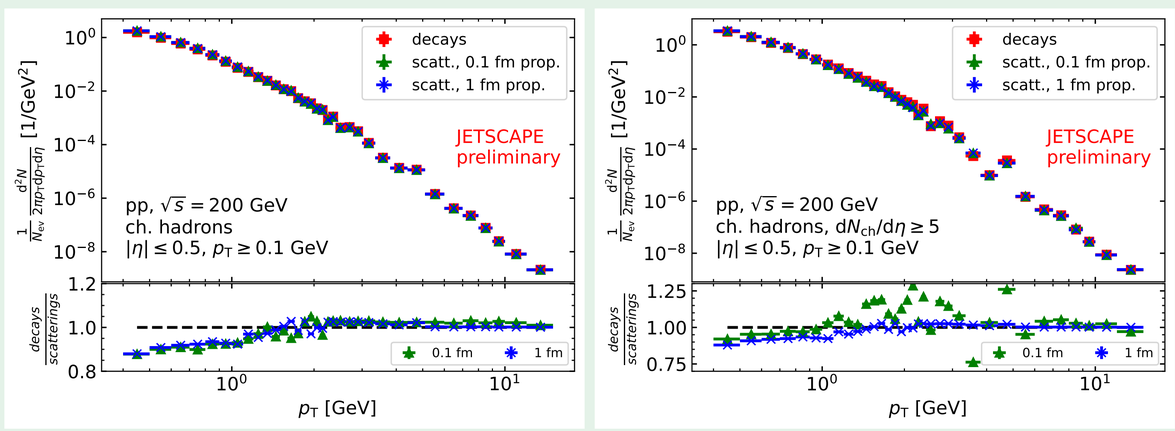
- Use the hadronic transport approach SMASH 3.0 as afterburner [3].
- Provide effective solution to the relativistic Boltzmann equation: $p^\mu \partial_\mu f_i(t,\vec{x},\vec{p}) + m_i F^\alpha \partial^p_\alpha f_i(t,\vec{x},\vec{p}) = \mathcal{C}_i^{\text{coll}}[f_i(t,\vec{x},\vec{p})]$
- Includes all mesons and baryons up to ≈ 2 GeV.
- Geometric collision criterion: $d_{\text{trans}} < d_{\text{int}} = \sqrt{\sigma_{\text{tot}}/\pi}$.
- Inelastic collisions via resonance/string excitation and decay.

5. $e^+ + e^-$

Assuming that hadronization takes 1 fm in the hadron rest frame, then there is a small effect ($\approx 4\%$) at small p_{T} on the charged hadron spectrum. When the duration is decreased to 0.1 fm, then there are effects at small and large p_{T} up to $\approx 12\%$.

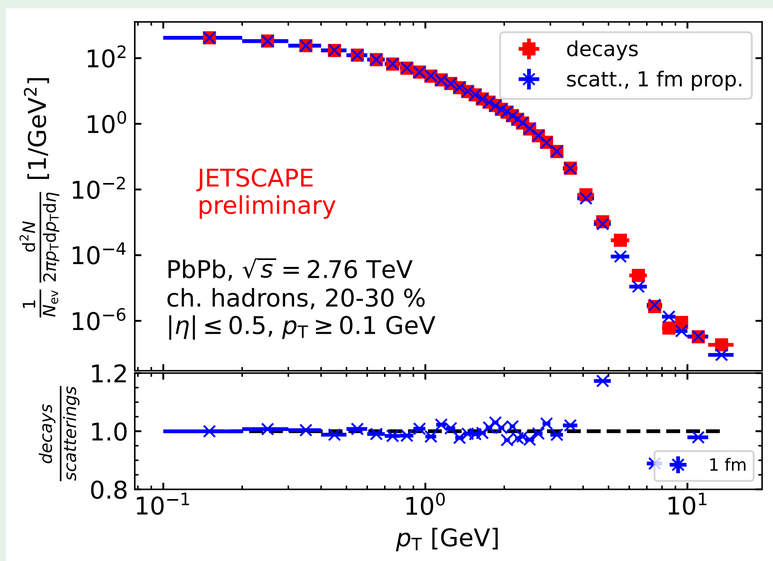


6. $p + p$



We find a $\approx 10\%$ effect at low p_{T} for both hadronization times. With a high multiplicity cut there is a visible difference between the two hadronization times, but more statistics is needed to draw a final conclusion.

7. $\text{Pb} + \text{Pb}$



In heavy-ion collisions the low p_{T} region is not modified because it is dominated by soft hadrons. We find a larger modification in the high p_{T} region here. However, there is not enough statistics to draw a final conclusion yet.

8. Conclusion & Outlook

- Conclusion:
  - Even in small systems the effect of hadronic reinteractions is visible in the p_{T} spectra and even sizable, if a very short time span is assumed for the hadronization. The effects on spectra are reminiszent of collective flow. In $p+p$ the effect is visible for both hadronization time spans.
  - For the $Pb+Pb$ system more statistics is needed. There is a hint of additional suppression above $p_{\text{T}} \approx 5$ GeV.
- Outlook:
  - Investigate effects of hadronic scatterings on jet observables.
  - Look at collective effects in high multiplicity $e^+ + e^-$ and $p+p$ collisions.
  - More statistics and comparison to experimental data.

References & Acknowledgements

[1] JETSCAPE Collaboration. JETSCAPE 3.6. https://github.com/JETSCAPE/JETSCAPE, 2023.
[2] K. C. Han, R. J. Fries, and C. M. Ko. Jet Fragmentation via Recombination of Parton Showers. *Phys. Rev. C*, 93(4):045207, 2016.
[3] SMASH Collaboration. SMASH 3.0. https://github.com/smash-transport/smash, 2023.

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