Jet energy loss in relativistic heavy-ion collisions with realistic medium modeling

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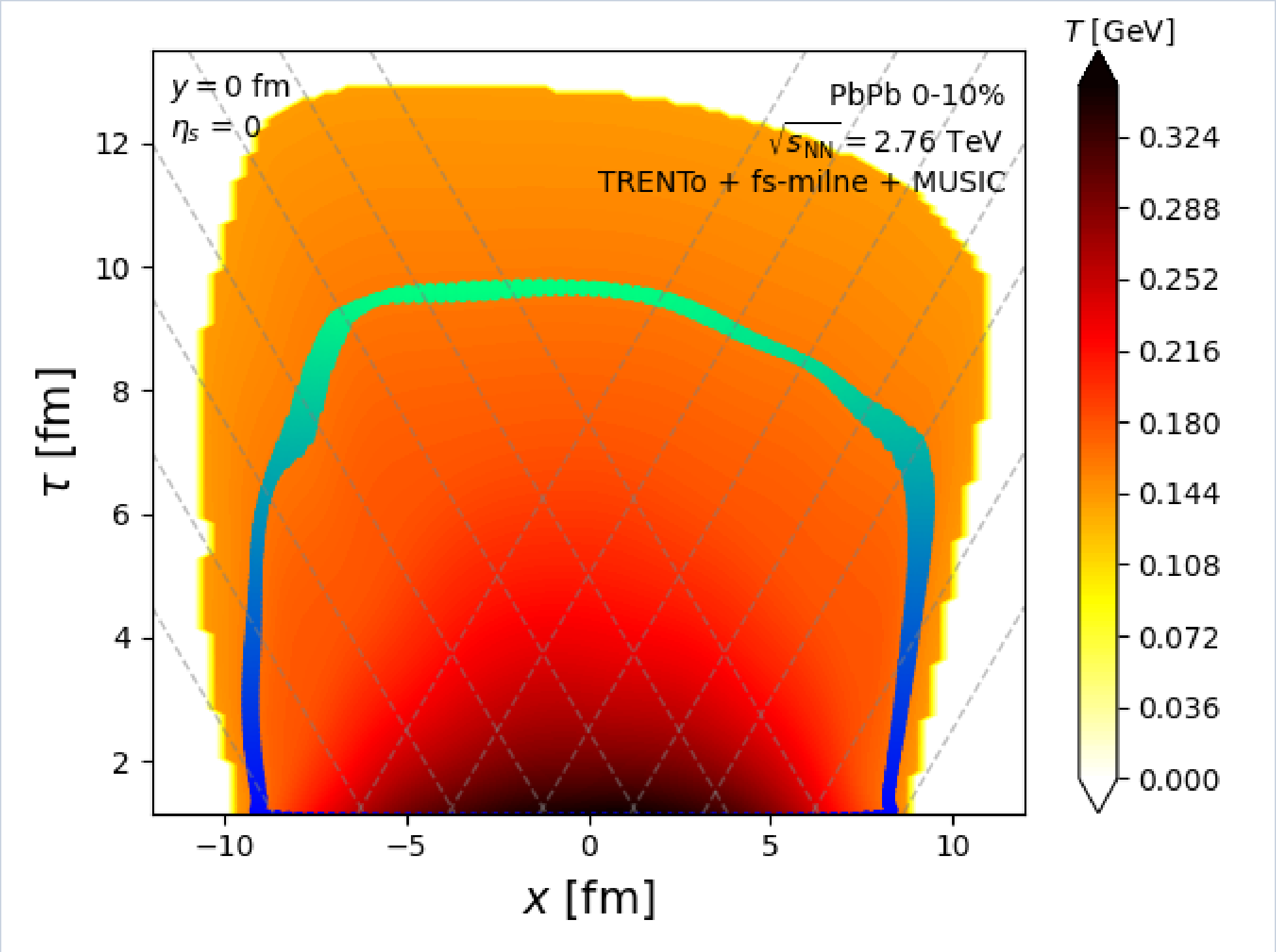
Abstract

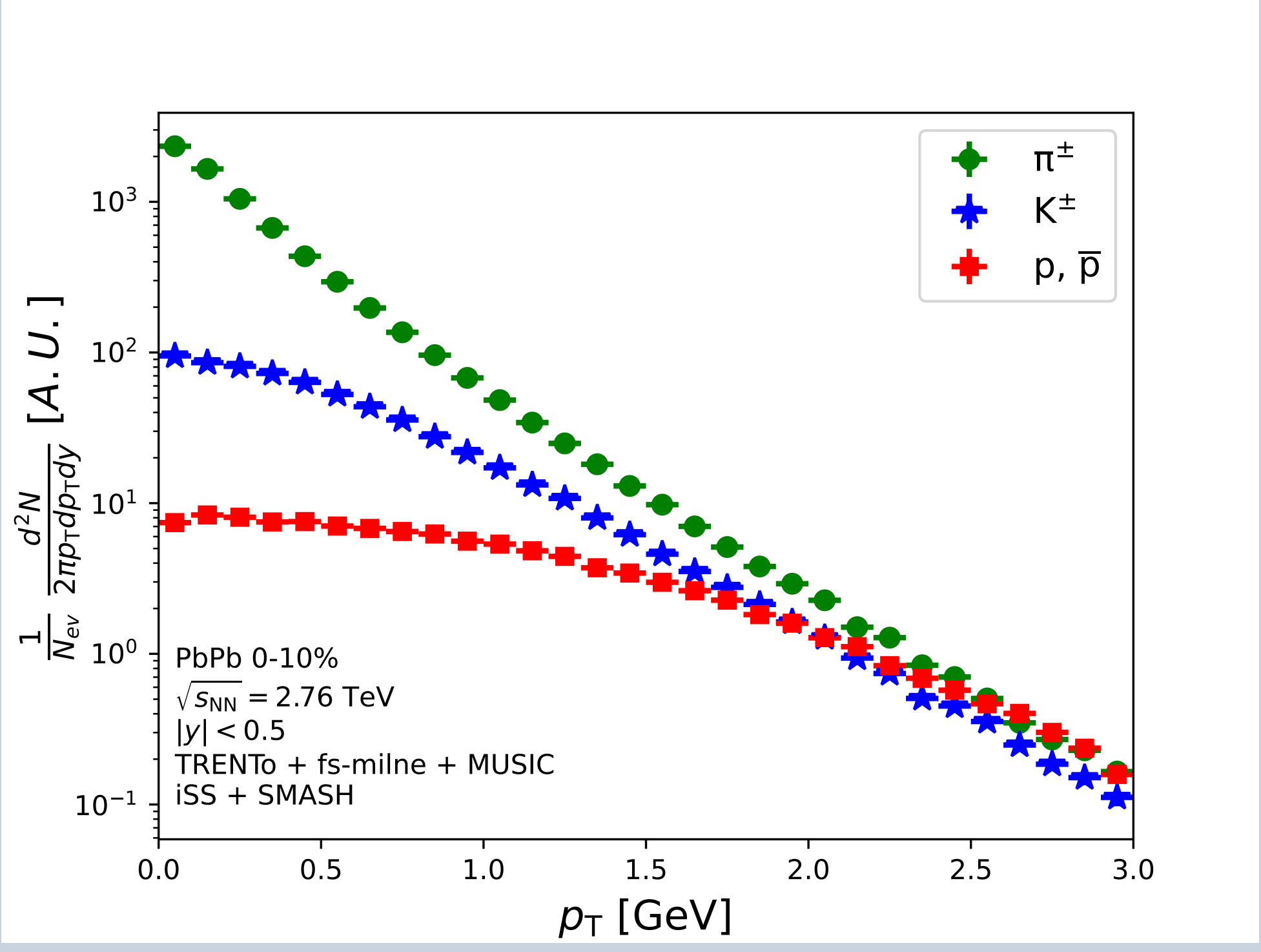
It was established that the state of matter called quark-gluon plasma (QGP) was created in heavy-ion collisions (HIC) at $\sqrt{s_{\mathrm{NN}}} \gtrsim 10^2$ GeV. It was also discovered that QGP has a collective behavior. Thus, relativistic hydrodynamics has been employed, and its development showed that it is a powerful tool for describing measured observables such as hadronic p_T spectra or azimuthal harmonic coefficients. Nowadays, relativistic hydrodynamics is essential to our current understanding of the soft sector observables that come from the bulk properties of the QGP. Another part of high-energy physics is the hard sector. Hard processes come from high-momentum-transfer interaction at the beginning of the collision. One of the observables is high transverse momentum p_{T} colimated showers of hadrons called jets. Initial hard parton fragments to more partons, which lose energy inside the strongly interacting medium and then hadronizes. With the help of the **JETSCAPE** framework we can simulate the energy loss inside the realistic medium and compare it with the jet energy loss in an equivalent sized simplified (brick) medium.

Realistic Medium Simulation

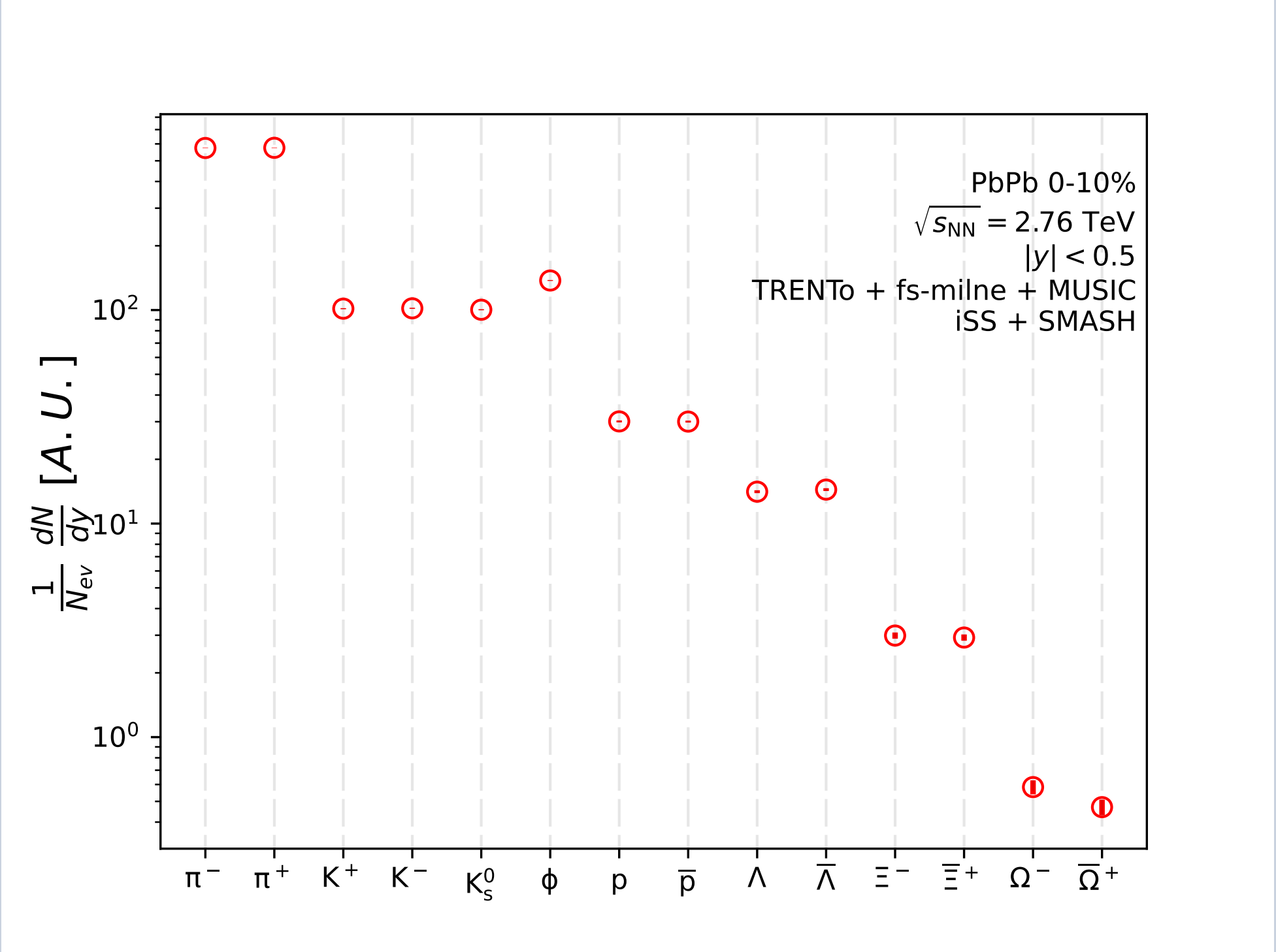
Simulation of the medium is segmented into five stages. The first two simulate the initial state of the collision that is plugged into the hydrodynamic code. The last two segments simulate the hadron cascade from the freezout hypersurface.



Initial state is governed by **TRENTo** that gives the distribution of the entropy density in the transverse plane according to the reduced thickness function T_{R}. This is given to **freestream-milne** and according to the collisionless Boltzmann equation, the initial state evolves at the proper time $\tau \in [\tau_0, \tau_s]$ to the energy-momentum tensor $T^{\mu\nu}$.



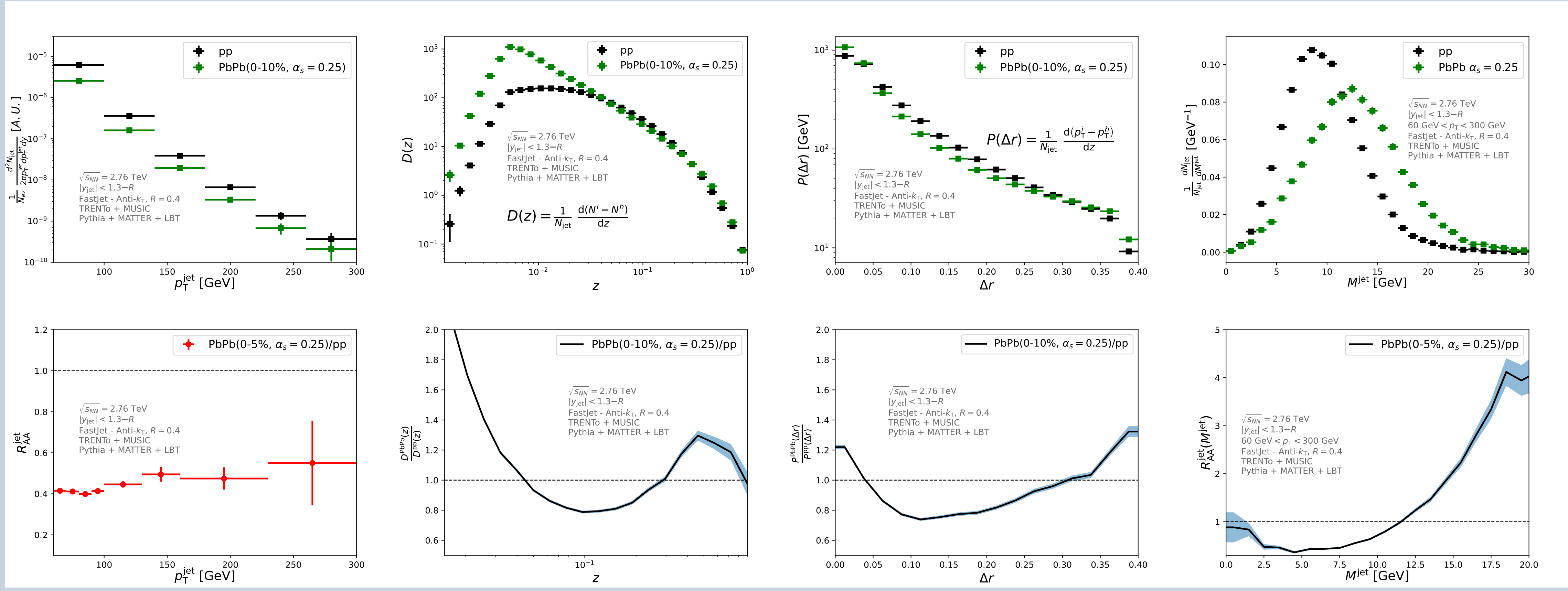
Relativistic hydrodynamic code **MUSIC** simulates medium evolution according to the Israel-Steward equations (2nd order relativistic hydrodynamics), the equation of state and transport coefficients such as $\frac{\eta}{s}(T)$ and $\frac{\zeta}{s}(T)$. The freezeout hypersurface at T_{c} is then obtained.



Finally, **iSS** samples the information from the freezeout hypersurface in the Cooper-Frye formula, and the transition from fluid to hadrons is made. As a last step, **SMASH** provides hadron decays and rescatterings.

Jet Evolution and Energy Loss Inside the Realistic Medium

Jets originate from parton scatterings with high momentum transfer q at the beggining of the collision. This initial state of hard partons is obtained by **Pythia**. Before the medium forms (during the free streaming time $\tau \leq \tau_s$), there is a vacuum evolution according to the Sudakov form factor. After the medium is formed, the partons with large virtuality Q_0 evolve according to the Sudakov form factor with medium modifications. Both stages of evolution are carried out by **MATTER**. Parton splitting reduces its virtuality and after given treshold ($Q_0 < 2$ GeV) parton evolution switches to low virtuality treatment according to the linear Boltzmann equation by **LBT**.



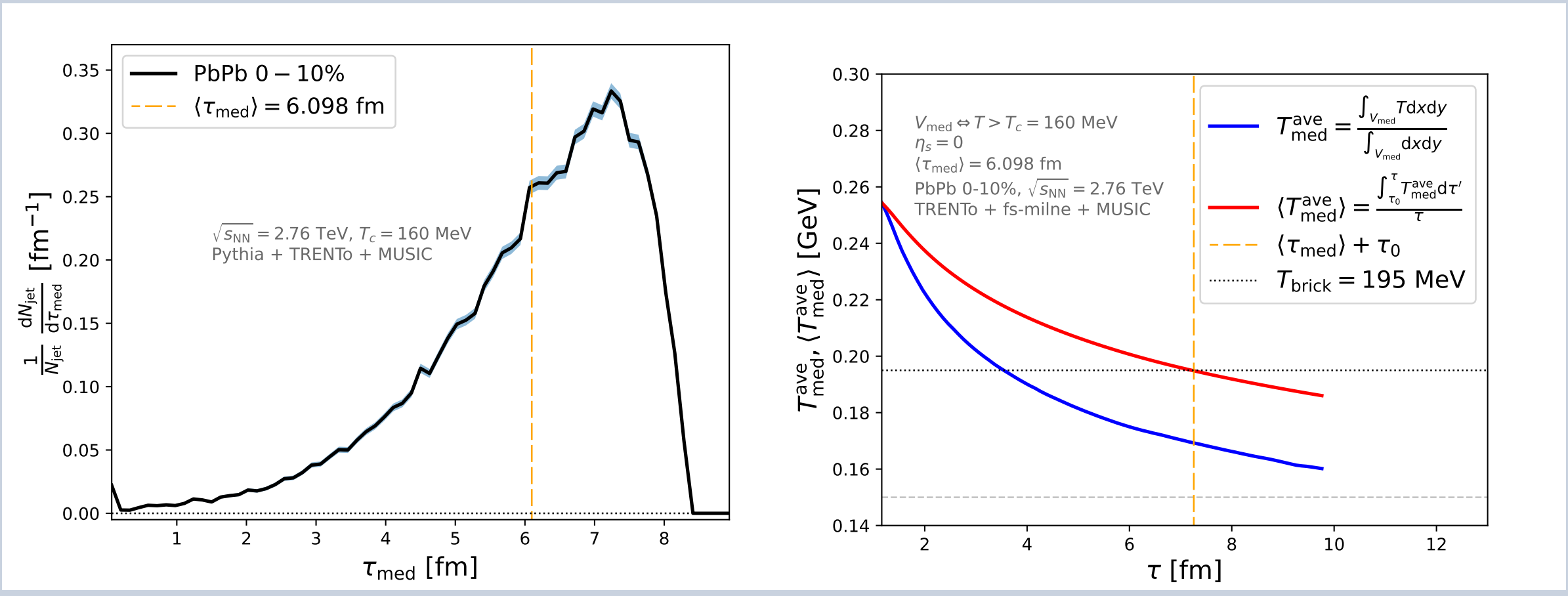
First column: Jet p_{T} spectra for pp and PbPb 0-10% (upper), nuclear modification factor R_{AA} (lower).
Second column: Jet fragmentation functions $D(z)$ for pp and PbPb 0-10% (upper), and their ratio (lower).
Third column: Jet shapes $P(\Delta r)$ for pp and PbPb 0-10% (upper), and their ratio (lower).
Fourth column: Jet mass spectra for pp and PbPb 0-10% (upper), and their ratio (lower).

It is possible that jet partons can scatter off thermal medium partons. This intraction leaves scttered jet parton, recoiled parton, and a hole parton that propagates freely. This kind of interaction is possible in both **MATTER** and **LBT**. Finally, jet partons and recoiled partons are hadronized separately from hole partons. Hadronization is performed using the Lund string model by **Pythia**.

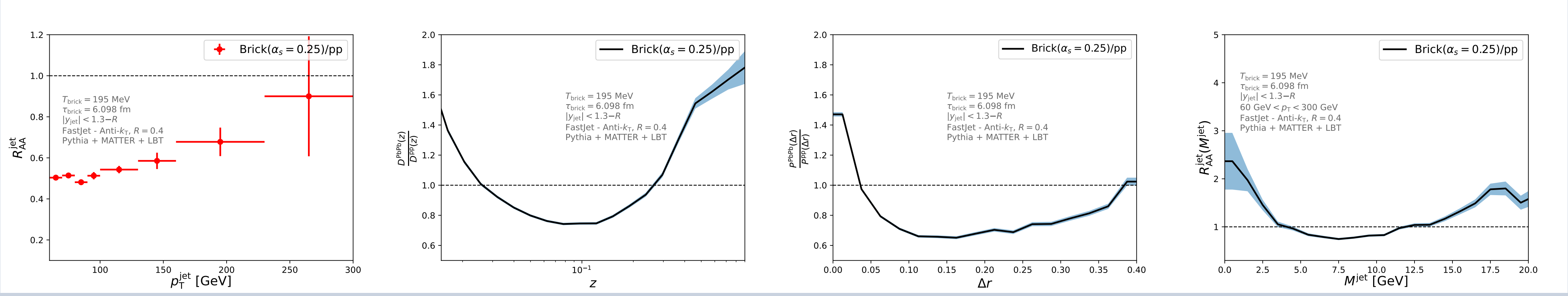
Reconstruction of the jets is done using the anti-k_{T} algorithm implemented in the **FastJet** package. Jet partons and recoiled partons are used for reconstrauction, and then the holes that fall into the jet cone contribute to the jet with negative weight.

Brick Medium Simulations

Due to the different production point and angle, every jet travels a different distance inside the hot medium. This can be determined with the distribution of hard processes obtained from **Pythia** and medium formation, medium evolution, and freezeout hypersurface from **TRENTo**, **freestream-milne**, and **MUSIC**. After that, it is possible to calculate the average temperature that the jet experiences during this time.



With the averege time and temperature that jet experience, one can swap the realistic medium simulation with the so-called brick medium. The brick medium is the medium with constant temperature and fixed jet path length.



Acknowlagements

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