

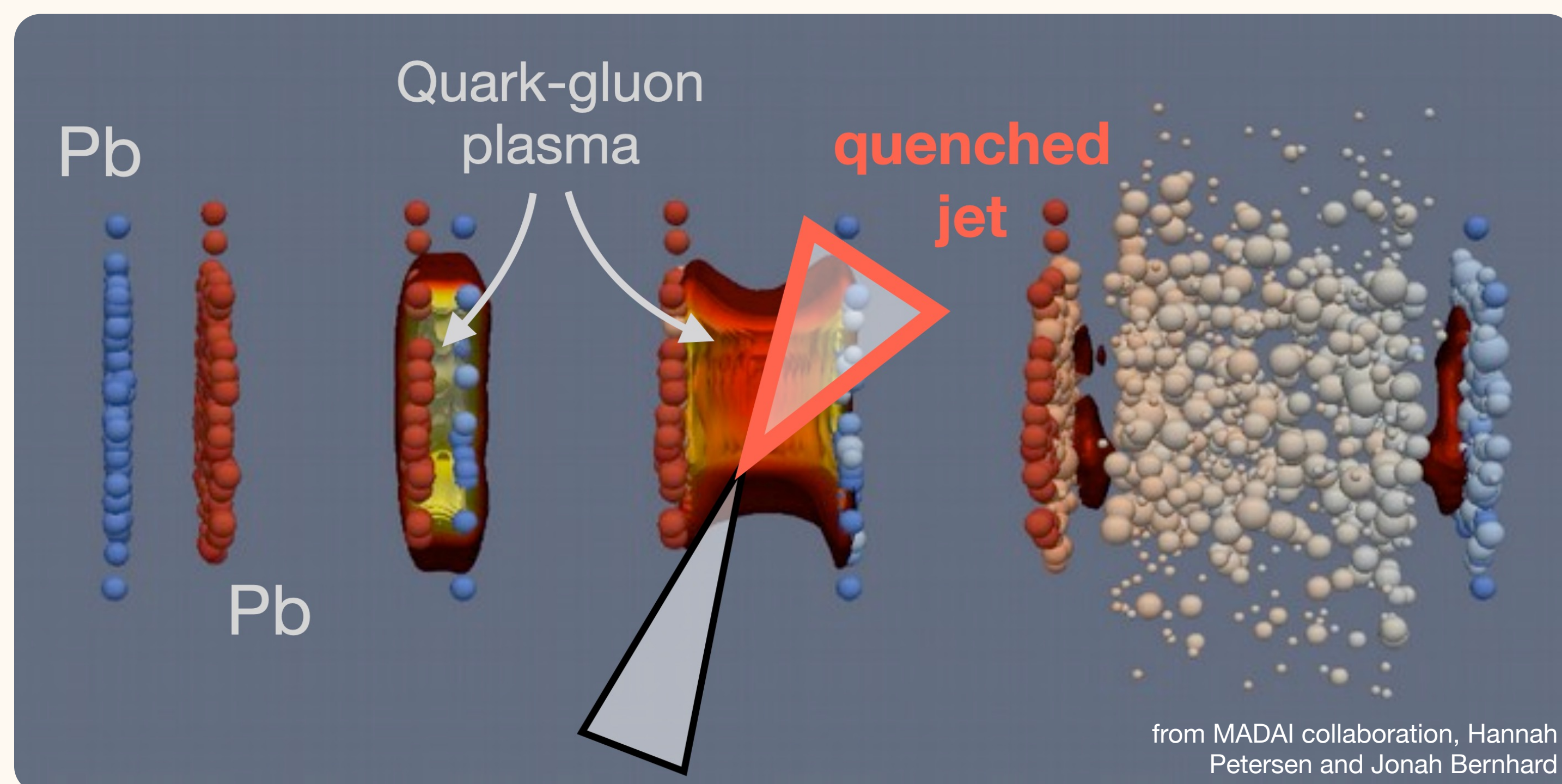
Universality of jet energy loss in quark-gluon plasma using Bayesian inference

ABSTRACT

Experimental data on a wide range of jet observables measured in heavy ion collisions provide a rich picture of the modification of jets as perturbative probes and of the properties of the quark-gluon plasma that is formed in these collisions. However, their interpretation is often limited by the assumptions of specific quenching models, and it remains a challenge to establish model-independent statements about the universality of different jet quenching observables. In this work, we address this issue by proposing a treatment that is agnostic to the details of the jet-medium interactions, and that relies only on the universality of quark and gluon jet quenching in different jet observables. We use Bayesian inference to constrain the parameterization of the energy loss of quark- and gluon-initiated jets in a data-driven manner. We fit the model using the inclusive jet p_T spectrum, which we can then use to predict di-jet and boson-jet measurements, providing evidence for the universality of quenching effects in heavy ion collisions, free from the assumptions of specific models.

Jet quenching and energy loss

In heavy-ion collisions, quark-gluon plasma is formed. Meanwhile, jets are created from hard scatterings. Contrary to what happens in proton-proton collisions, these jets evolve while interacting with the hot medium via strong force, which changes the jet structure, and makes it lose energy via medium-induced radiation that might end up outside the jet cone. This is known as jet quenching.



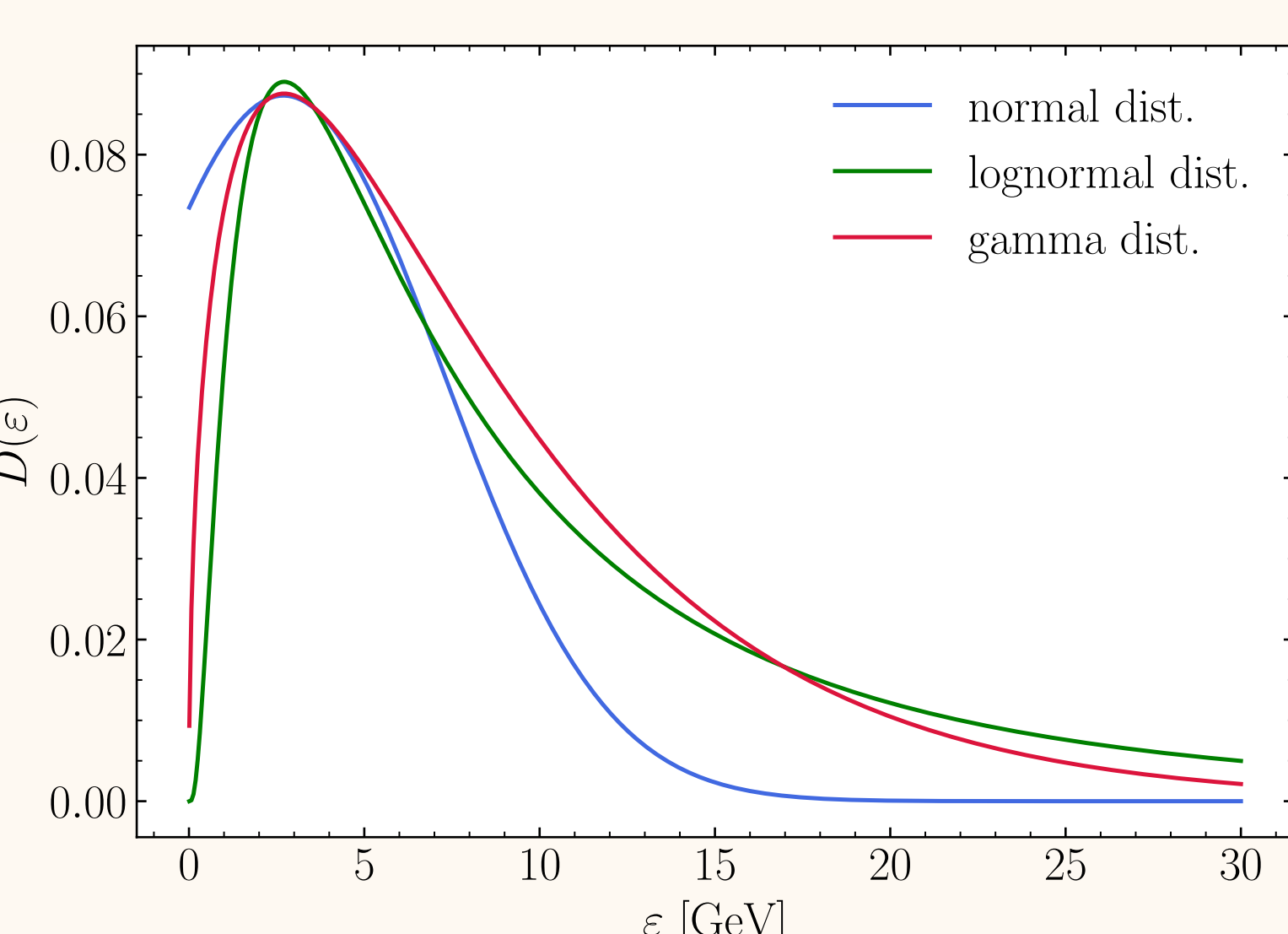
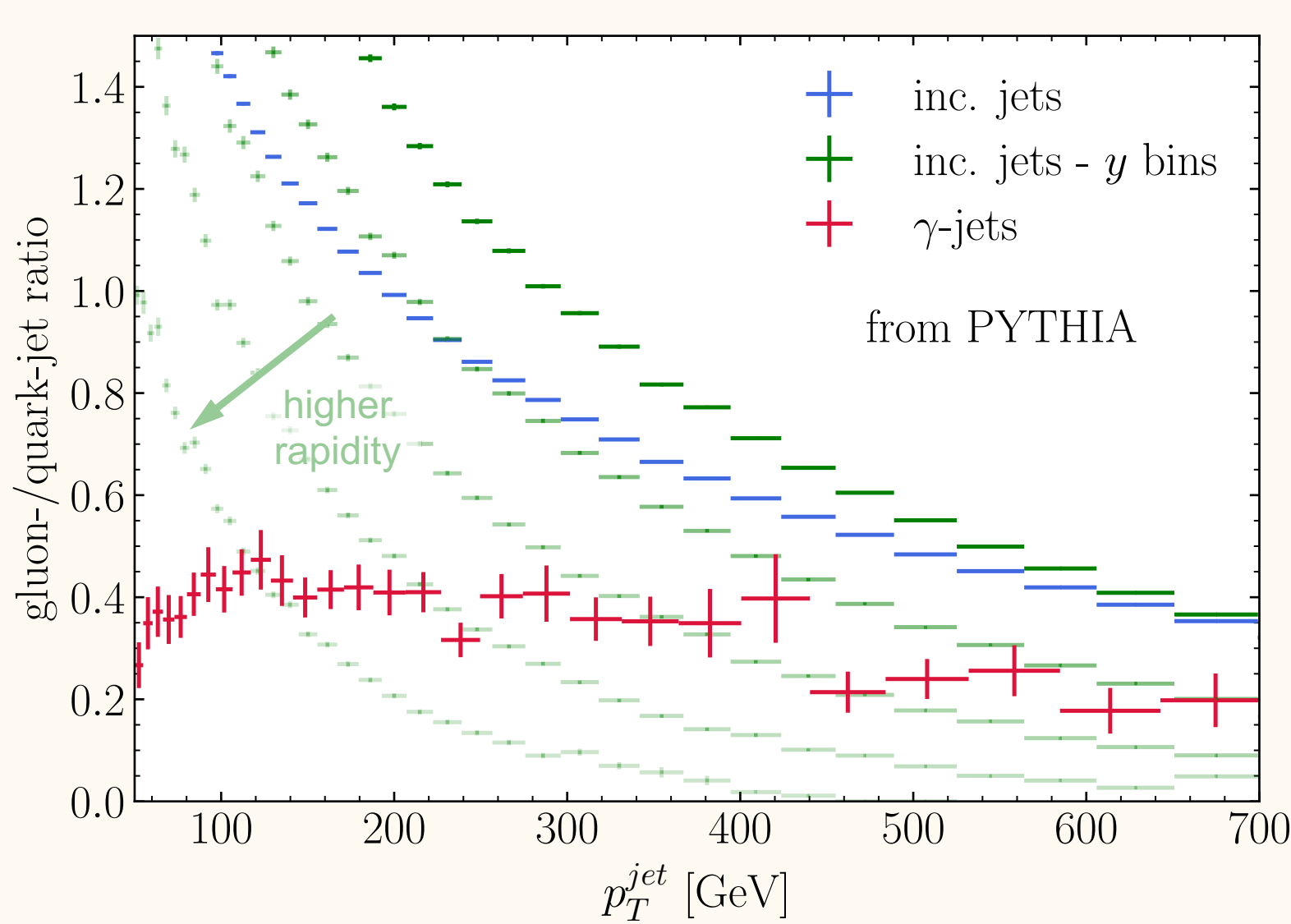
Modeling the jet energy-loss

The difference in energy scales of the plasma and the hard scattering, and consequent jet evolution, allows for the following factorization of the jet spectrum in heavy-ion collisions,

$$\left. \frac{d\sigma^{AA}}{dp_T} \right|_{p_T} = \int_0^\infty d\varepsilon \sum_{i=q,g} D_i(\varepsilon) \left. \frac{d\sigma_i^{vac}}{dp_T} \right|_{p_T+\varepsilon}.$$

The medium spectrum $d\sigma^{AA}/dp_T$ is given by the equivalent vacuum spectrum $d\sigma^{vac}/dp_T$ convoluted with an energy-loss distribution $D(\varepsilon)$.

This factorization picture leads to the non-dependence of the energy loss on the process that created the jet, but only on how the jet interacts with the medium. This means a universality of the jet energy loss across different observables and kinematic cuts.



Quark- vs. gluon-initiated jets

The ratio between quark- and gluon-initiated jets varies for different processes, and for different kinematical cuts. Depending on the initiating parton, the jet interacts and evolves in a distinct way inside the medium.

Energy-loss loss distribution

We consider three parameterizations for the energy-loss distribution $D(\varepsilon)$:

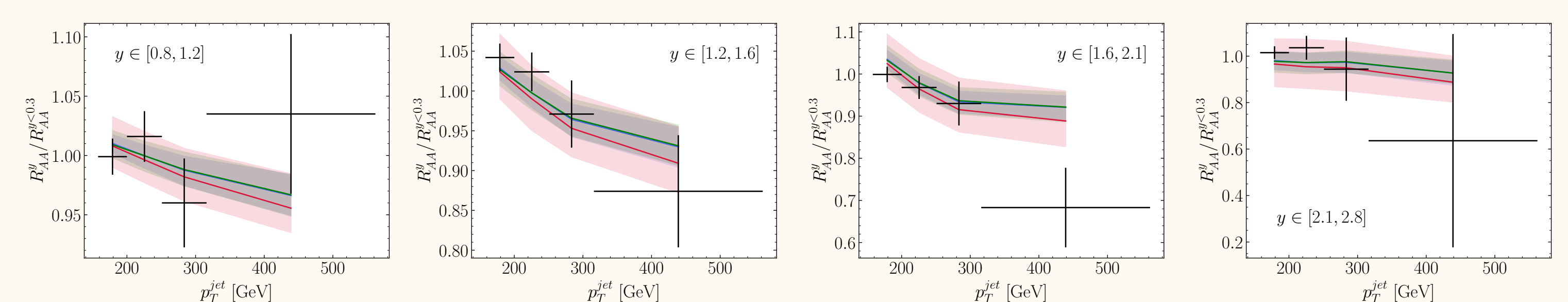
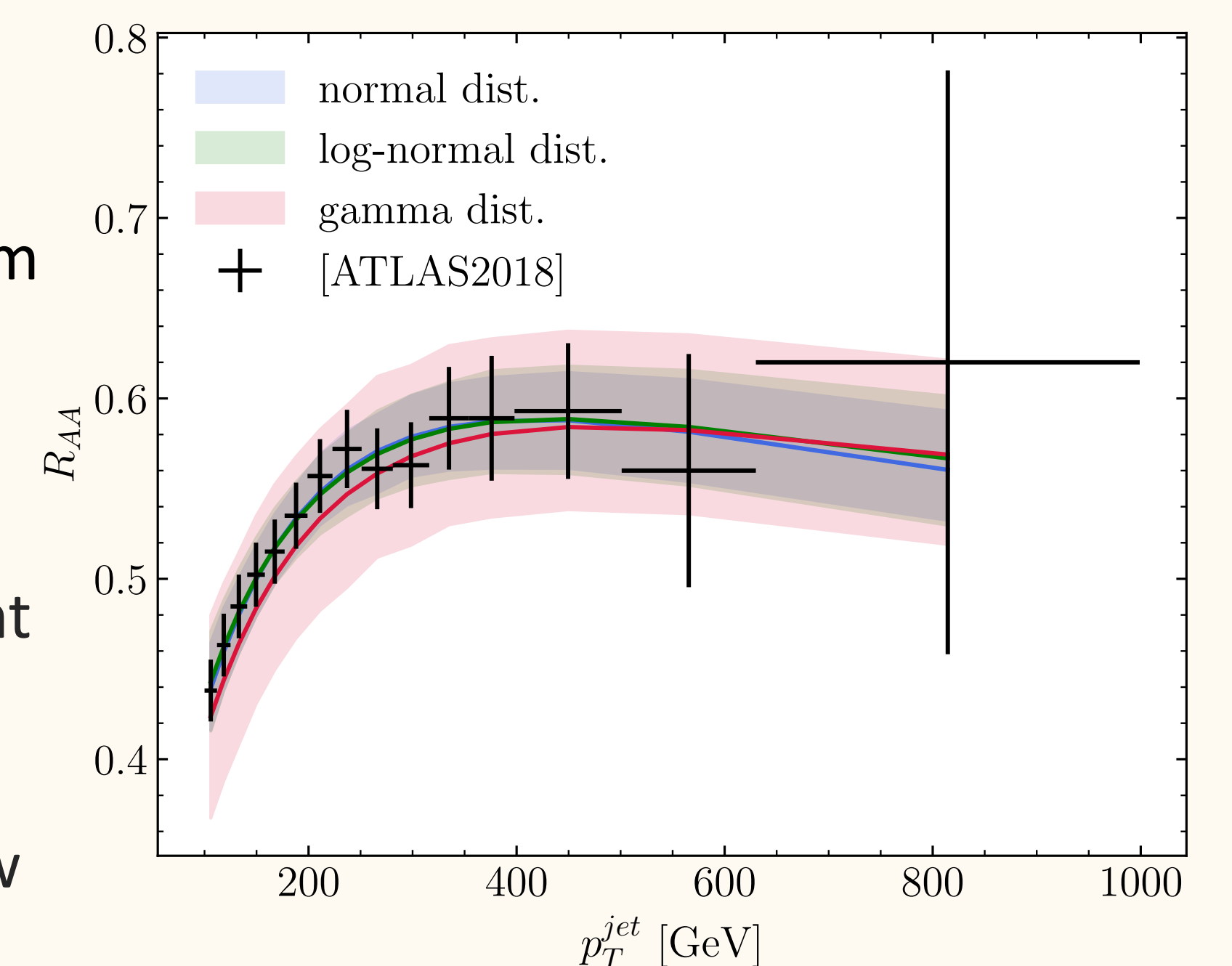
- a normal distribution;
- a lognormal distribution;
- a gamma distribution,

the main difference being the probability of losing a higher amount of energy.

Bayesian inference

The parameterization of the energy-loss is constrained by training the model with data from inclusive jet observables.

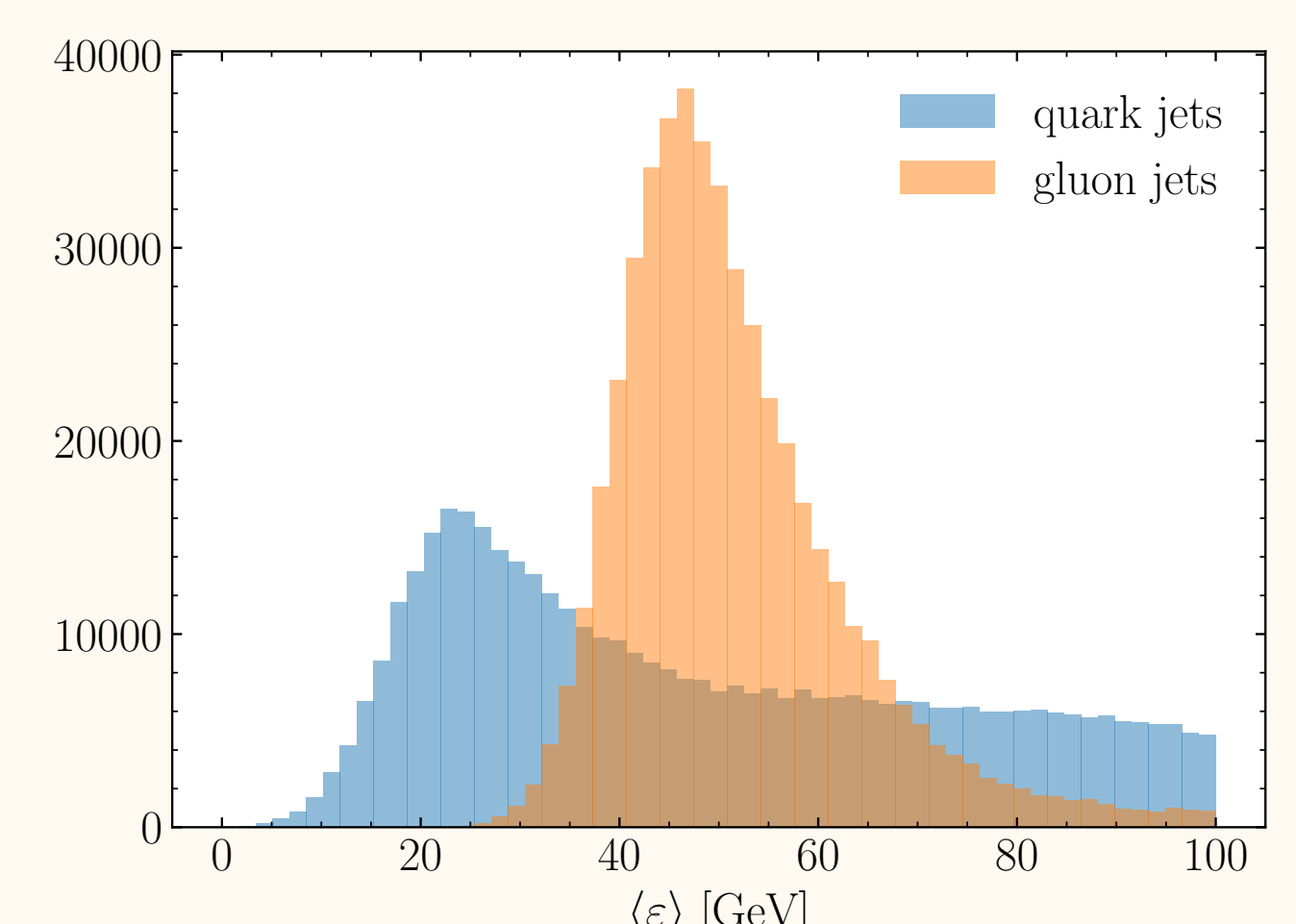
A successful global fit is achieved for the different observables, which have different gluon-/quark-jet fractions. This indicates the validity of the factorization, given that we know the jet initiating parton.



High density interval of the posterior distribution for the training data: inclusive R_{AA} (top right); and ratio of R_{AA} 's for four different rapidity bins of inclusive jets (bottom).

Analyzing the posterior

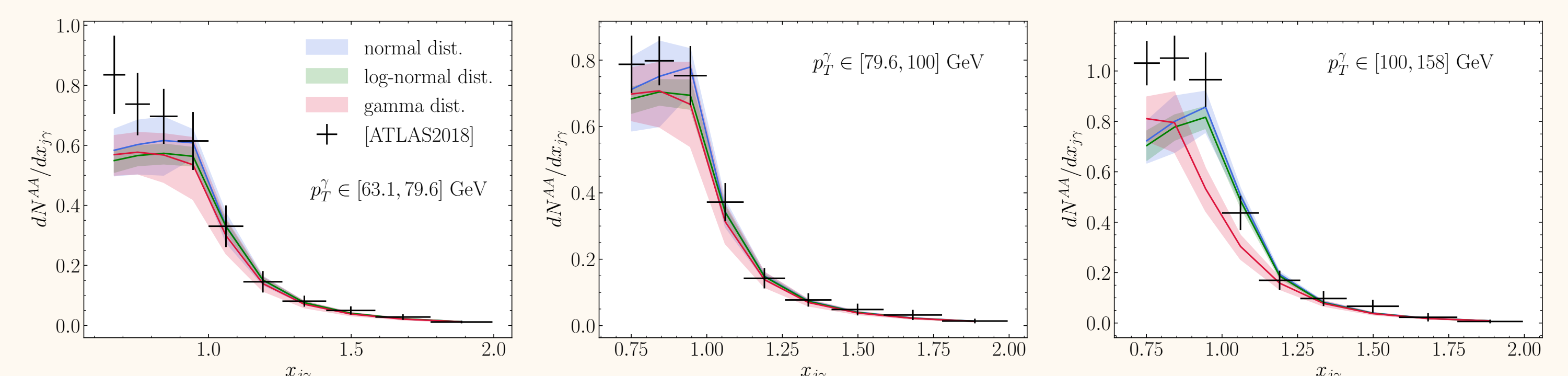
From the posterior distributions, we can access the mean energy loss of the jets. The method is able to distinguish between the energy loss of quark- and gluon-initiated jets, with the jets initiated by gluons being more probable to lose more energy than the ones initiated by quarks (as expected from theory).



Posterior distribution of the mean energy loss of quark- and gluon-initiated jets, when a gamma distribution is used.

Making predictions

Assuming the validity of the factorization, measurements from different hard processes can be predicted. This is done by integrating over the obtained posterior, accessing the marginal distribution at each data point.



High density interval of the posterior distribution for unseen data: prediction for photon-tagged jet spectra for three different photon p_T bins.

Conclusion

With the information about the jet initiating parton, and after being fitted to inclusive jet observables, the model successfully predicts the experimental data for different processes, for the three energy loss parameterizations. This validates the factorization picture in a minimal theory-dependent model and data-driven way, hinting for the universality of jet energy loss in quark-gluon plasma across different processes.

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