# Effective Theory for Precision Jet Physics in HIC Beyond the Energy Loss Approach

- **The most important recent advance (~5y) in the area of hard probes in HIC is the development of the theory of jet production and modification and the related experimental measurements**

  - Has provided first insights in to the transverse and longitudinal structure of in-medium parton showers
  - Has elucidated the relative significance of collisional and radiatve energy loss
  - Has helped constrain the coupling between the jets and the medium and provided insight into the nature of the QGP quasiparticles
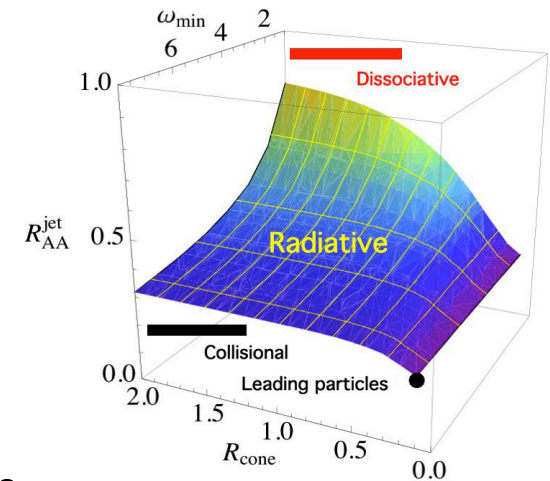
- **Within the energy loss framework, systematic improvements in the precision of the theory are very difficult or impossible**

  - Advances, however, are essential to guide the jet physics programs at RHIC and the LHC and interpret the results

Current Status

- Effective theory of jet propagation in matter – $SCET_G$ (soft-collinear effective theory with Glauber gluons)

  - SCET has been extremely successful in advancing jet physics, one of the areas (together with heavy flavor) where significant progress in QCD occurs
  - $SCET_G$ was developed to include the jet-medium interactions (G)
  - Was applied to the transverse momentum broadening of partons
  - Full set of medium-induced collinear splitting kernels beyond the soft gluon approximation obtained. Gauge-invariance and factorization established
  - Result for $O(\alpha_s^2)$ in-medium splitting function relevant to NNLO

- First application to inclusive particle production

  - Established the connection to the energy loss approaches
  - Allowed to reliably quantify the uncertainty (~5%) in the extraction of the jet medium coupling from inclusive observables
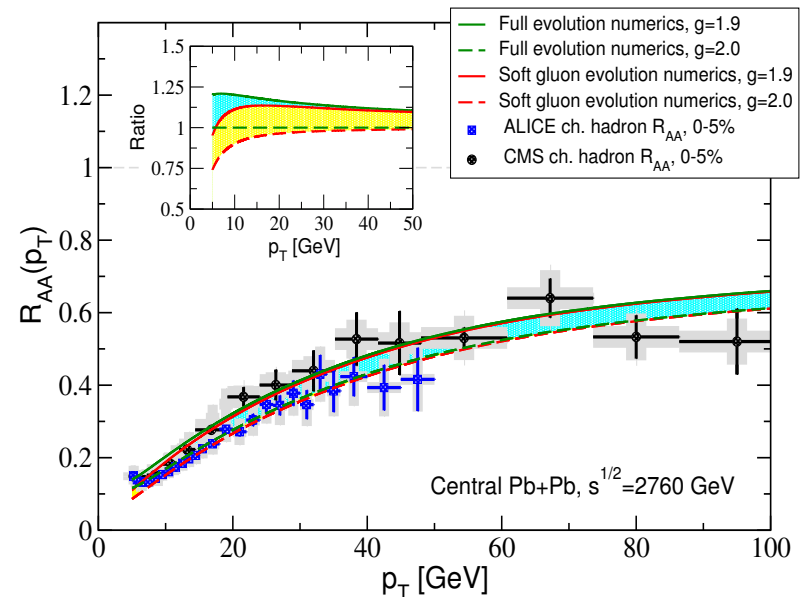
Future Prospects

- Unified treatment of "vacuum" and "in-medium" parton showers and a common vernacular for HEP, NP

  - Understand the soft-Glauber interactions and power corrections
  - Apply the unified parton shower picture to jet observables, including jet cross sections, jet shapes and fragmentation functions
  - Significant improvement expected for more exclusive observables, di-jets and photon-tagged jets. Heavy flavor observables

  - Achieve higher resummed accuracy for jet observables in heavy ion collisions, next-to-leading logarithmic accuracy (NLL) and combine with higher order calculations (NLO)
  - When combined with improved theory of CNM effects, fully characterize the in-medium parton shower and the properties of the QGP
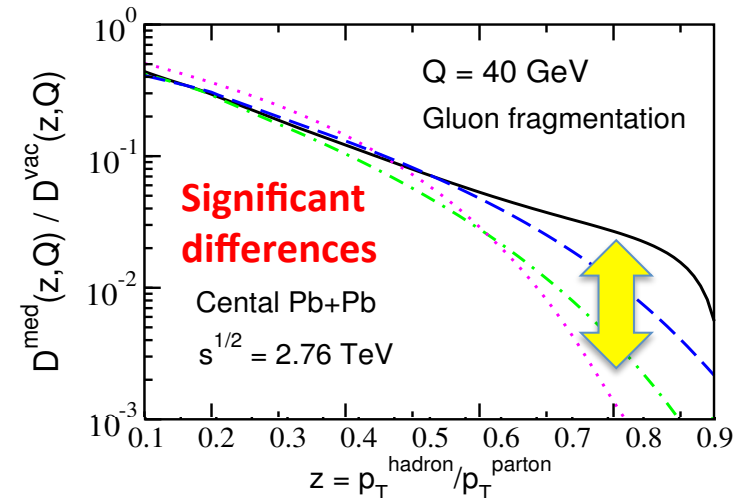
Advances in precision pQCD calculations of jet observables, including resummation and higher perturbative orders must be a top priority for theory and the field