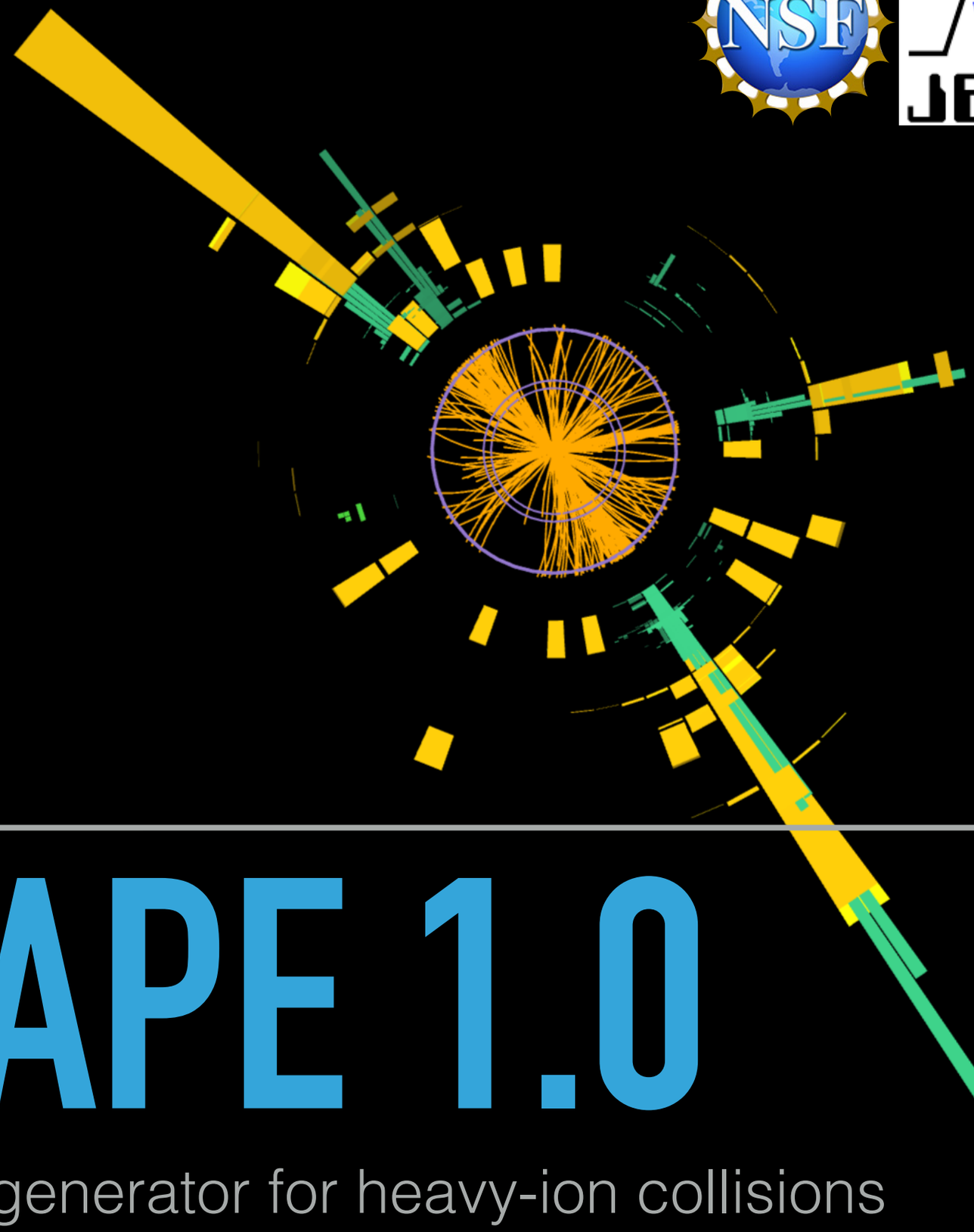
BROOKHAVEN NATIONAL LABORATORY



CHUN SHEN

JETSCAPE 1.0

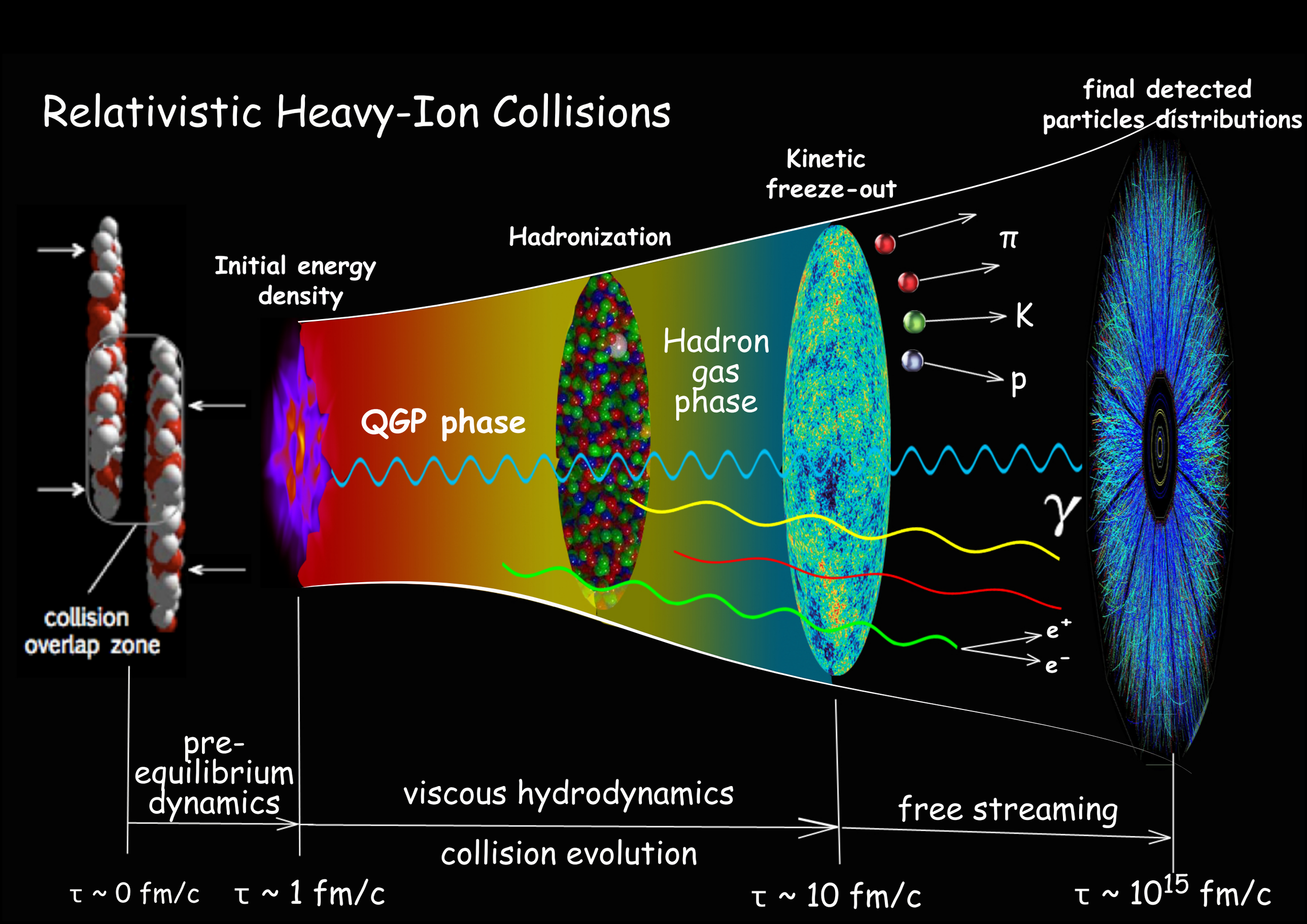
— an event generator for heavy-ion collisions

July 25, 2018

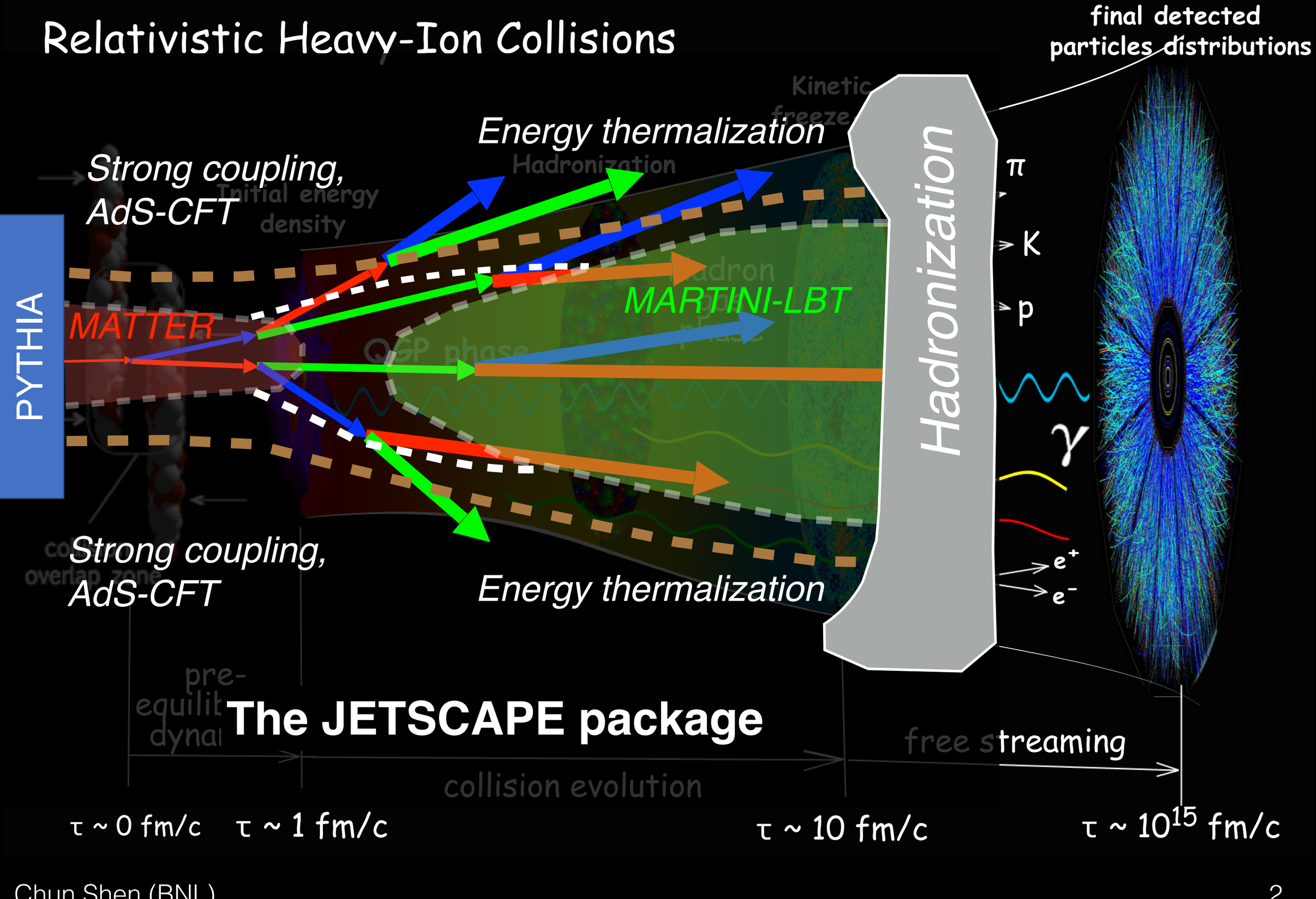
Workshop on Probing Quark-Gluon Matter with Jets

Picture from the ATLAS Collaboration

Relativistic Heavy-Ion Collisions

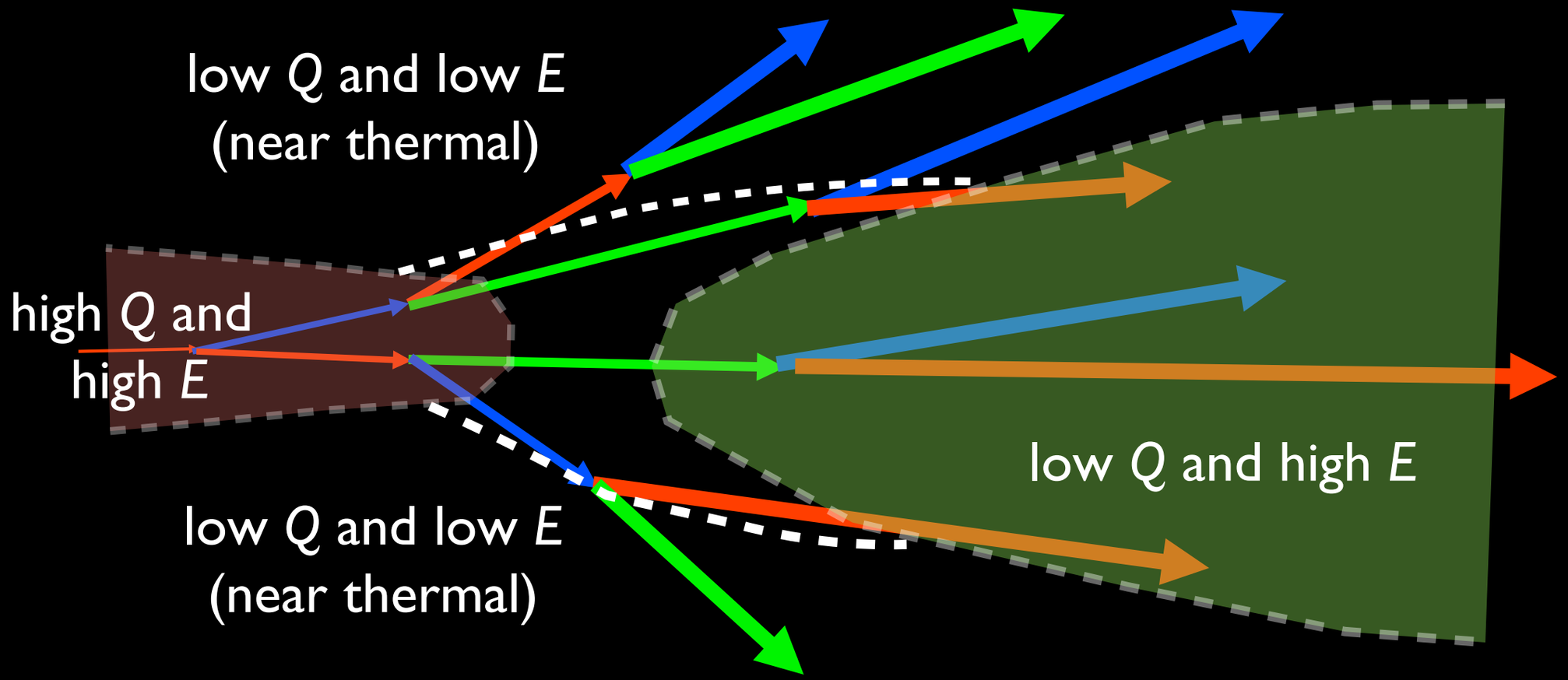


Relativistic Heavy-Ion Collisions



The JETSCAPE package

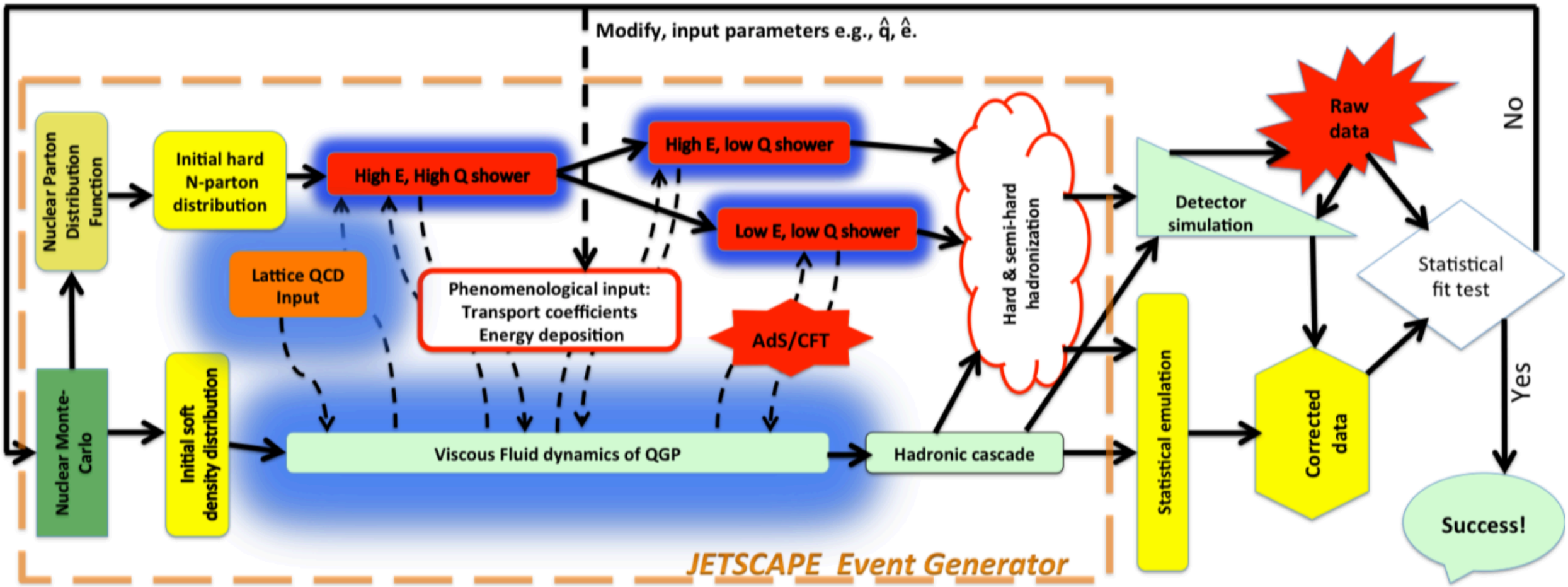
Multistage jet evolution in heavy-ion collisions



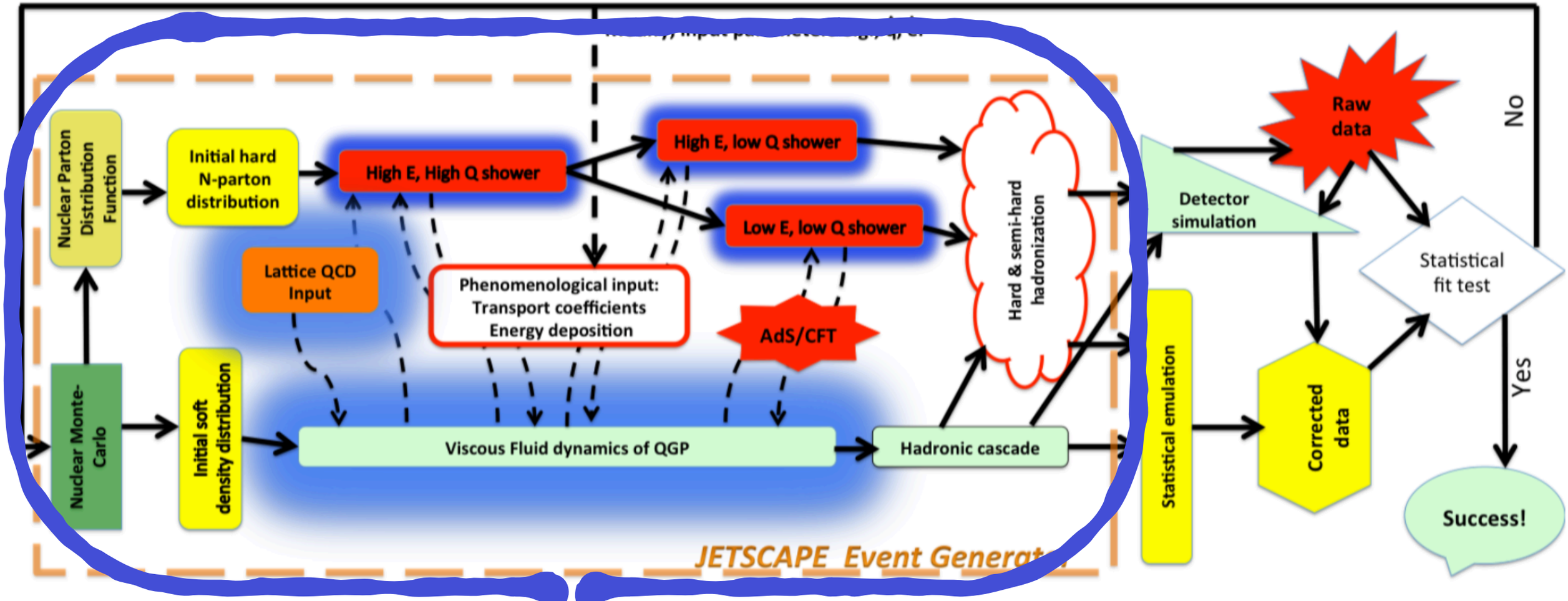
- Stage 1: High Q and high E (DGLAP, higher-twist); lose Q faster than E [Majumder and Putschke, PRC 93 (2016)]
- Stage 2: low Q and high E (Transport, higher-twist, AMY)
- Stage 3: low Q and low E (near thermal) (strongly coupled approach)

JETSCAPE unifies multiple theories under one framework

Program Envelope

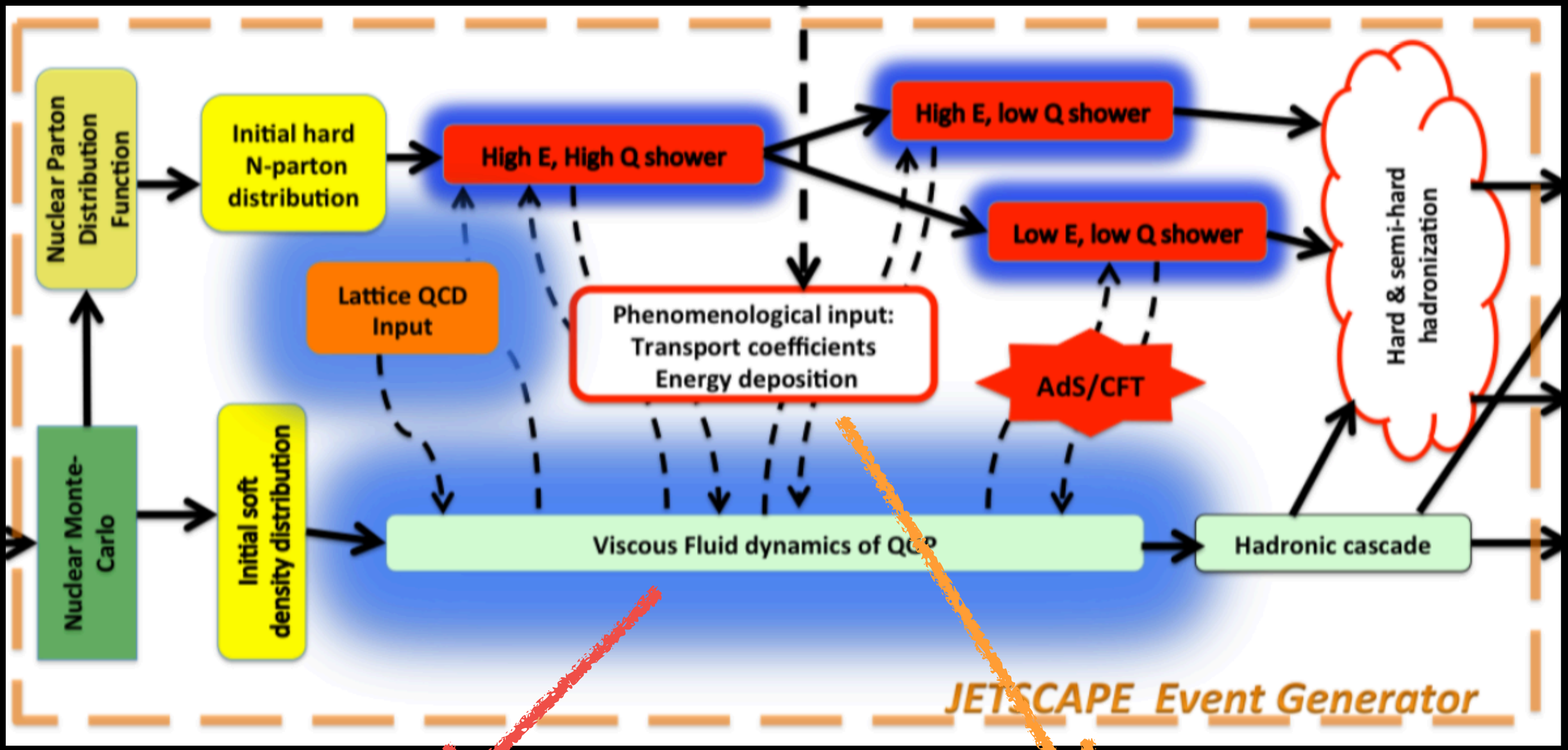


Program Envelope



EVENT GENERATOR

Program Envelope

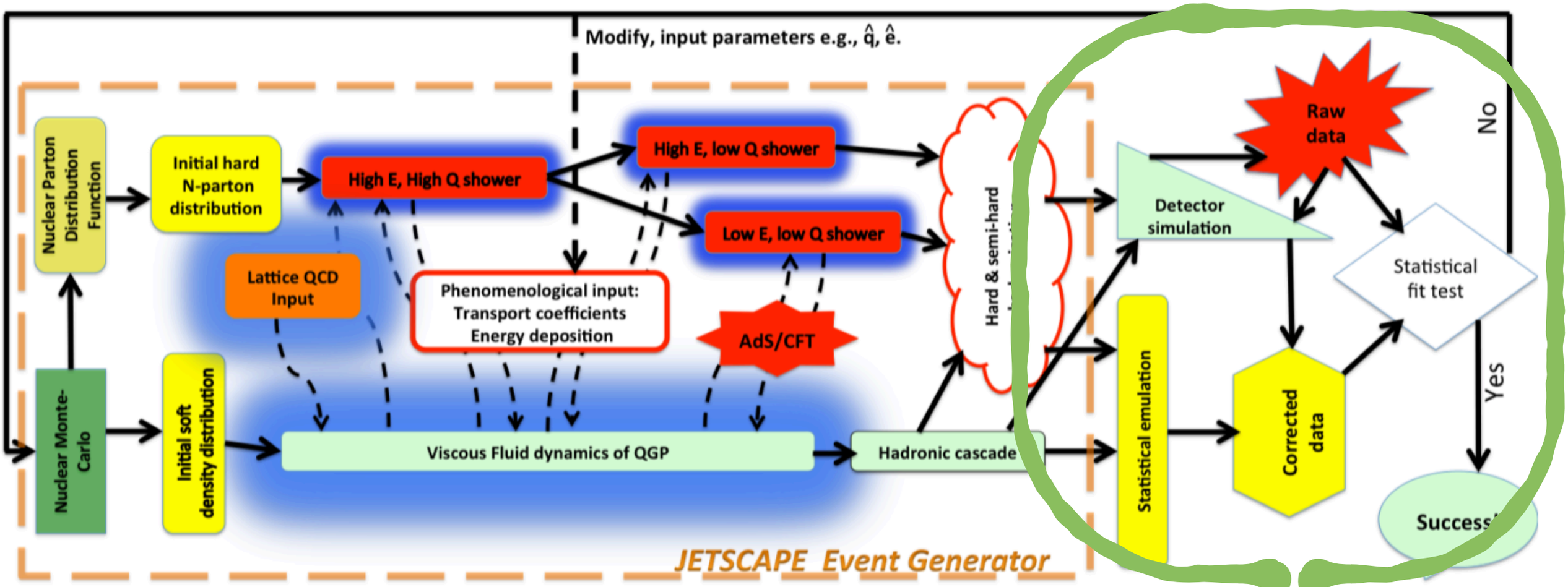


Tasks: User defined modules

Communication: Signal/Slots

C++11 standard

Program Envelope



Computational Advance

- Utilize large-scale distributed storage and computation resources



- Massive parallelization and GPU optimization under development



CLVisc



GPU-VH



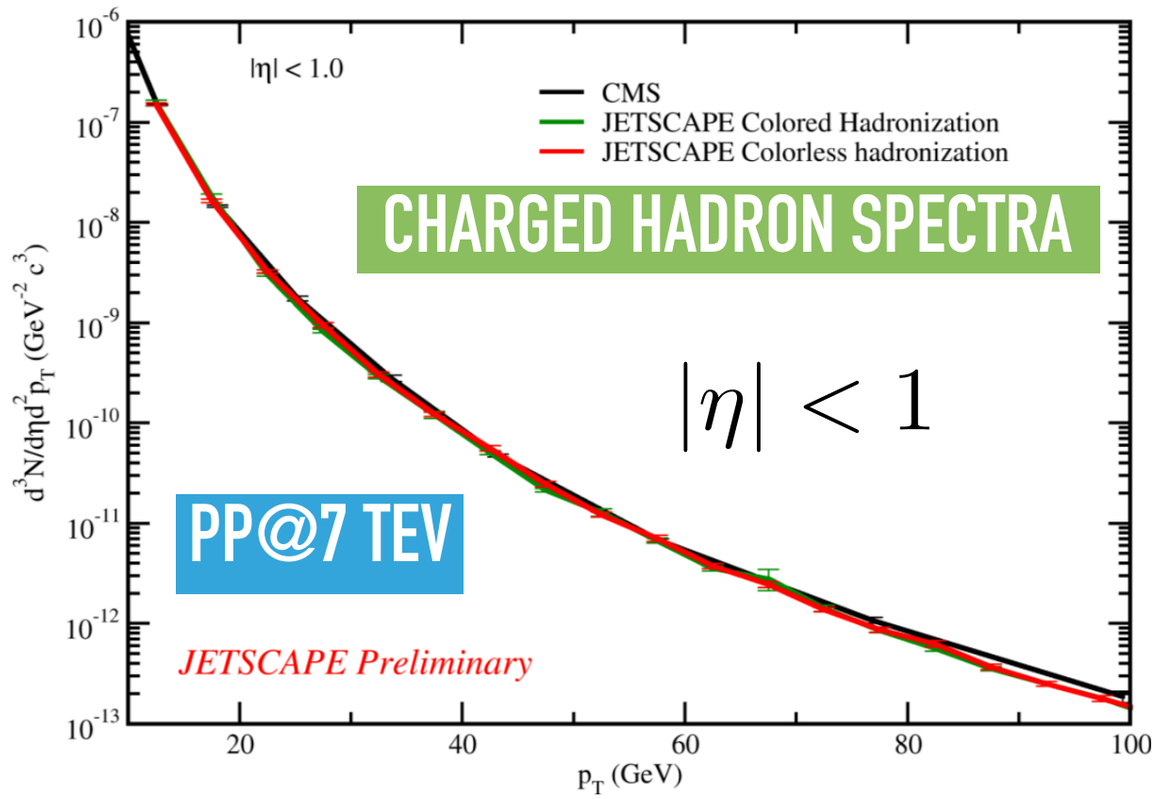
baseline validation in p+p collisions

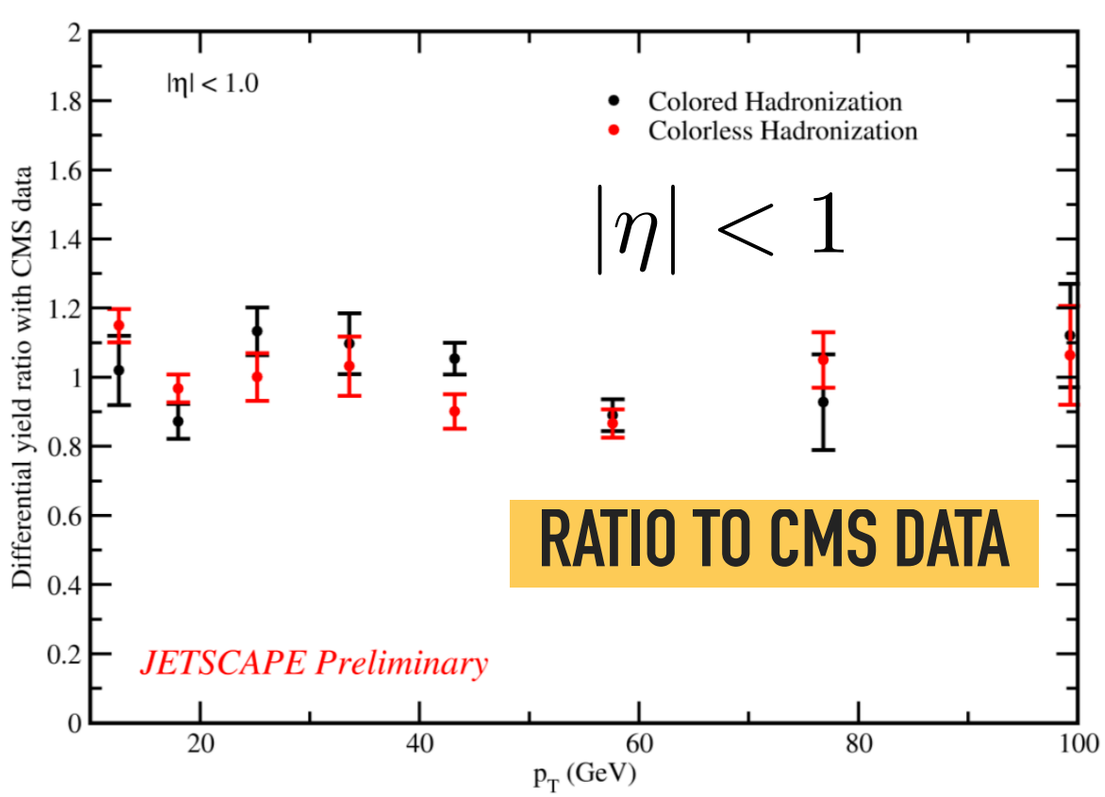
Jet observables in p-p collisions

Pythia hard scattering (FSR off) + MATTER vacuum showers

Parameter tuning

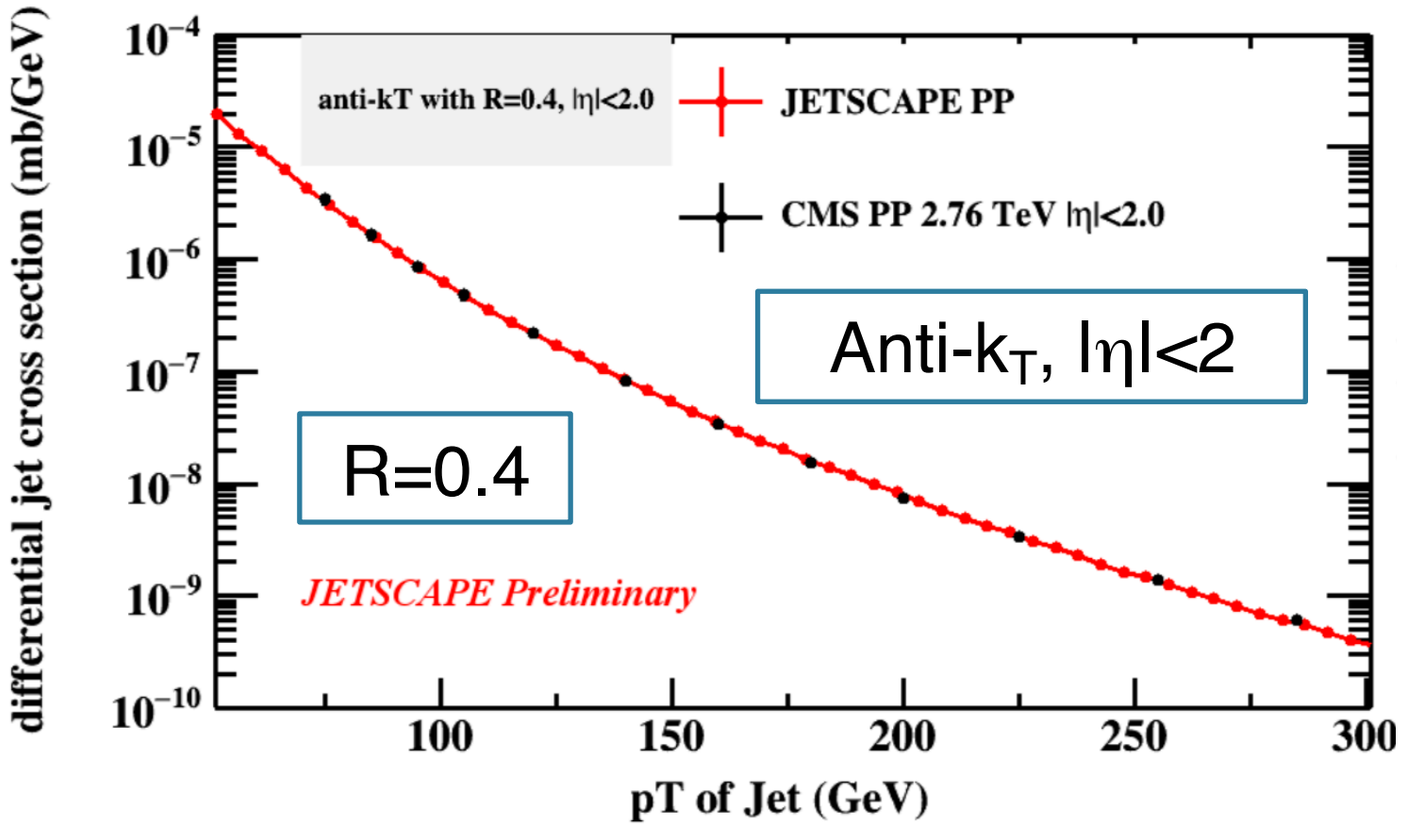
- Maximum possible virtuality: $Q^2_{\max} = p_T^2/4$
- Scale parameter in the running coupling: $\Lambda_{\rm QCD} = 0.2\,{\rm GeV}$

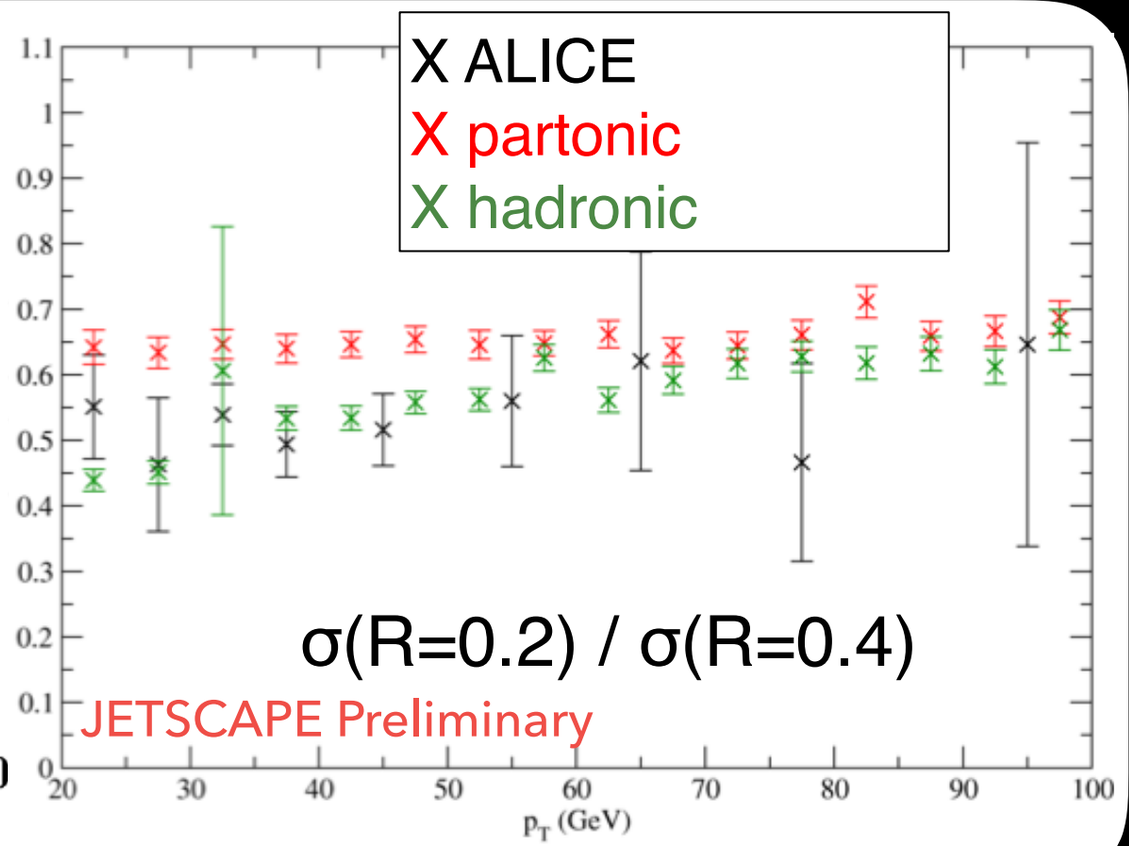




- Good agreement with data [EPJ C72,1945 (2012)]
- No significant differences between hadronization specifies

Single inclusive jet spectra

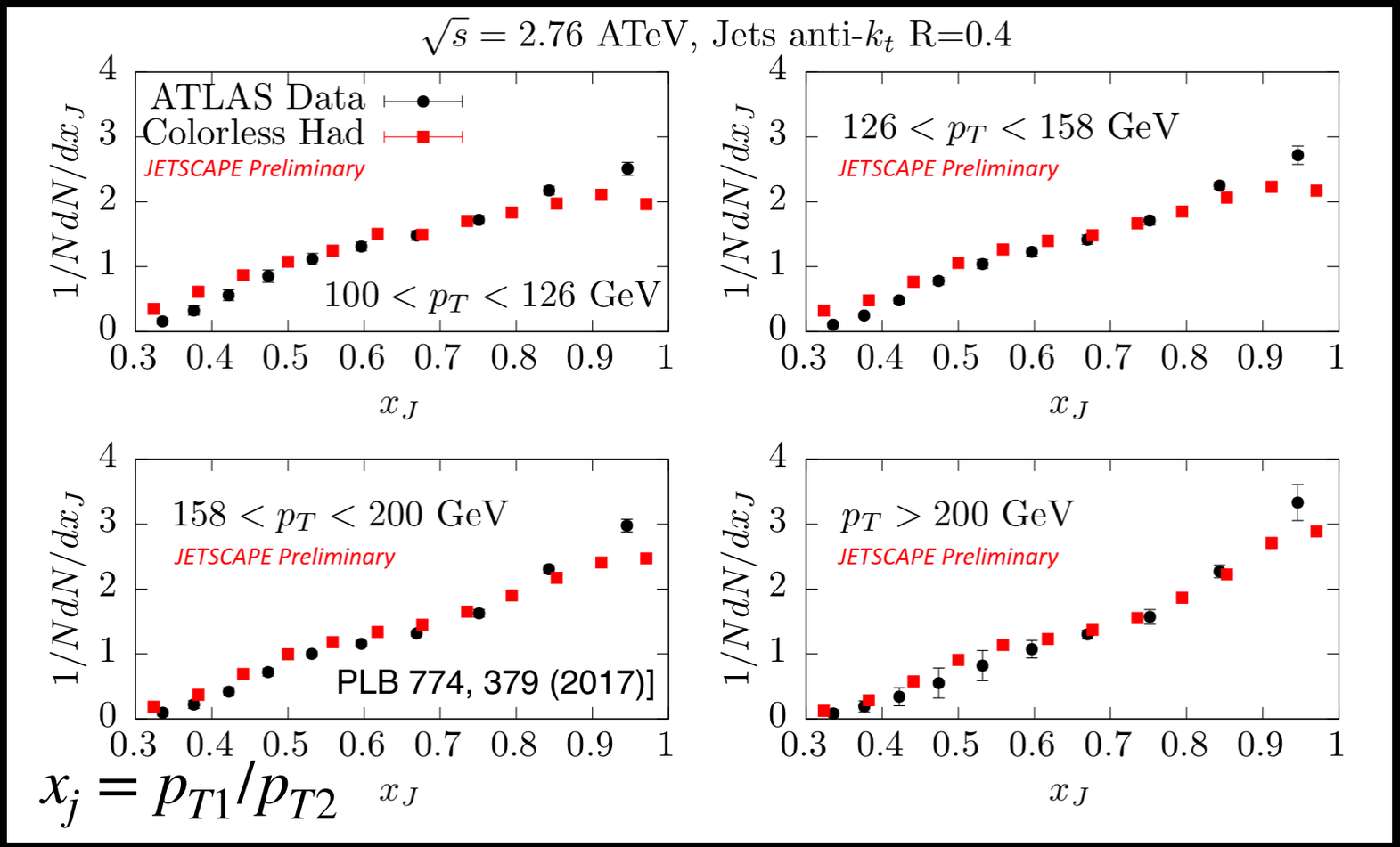




- Good agreement with data [PRC 96, 015202 (2017)]
- Necessary to include proper hadronization scheme for the cone size dependence

Dijets and γ-jets

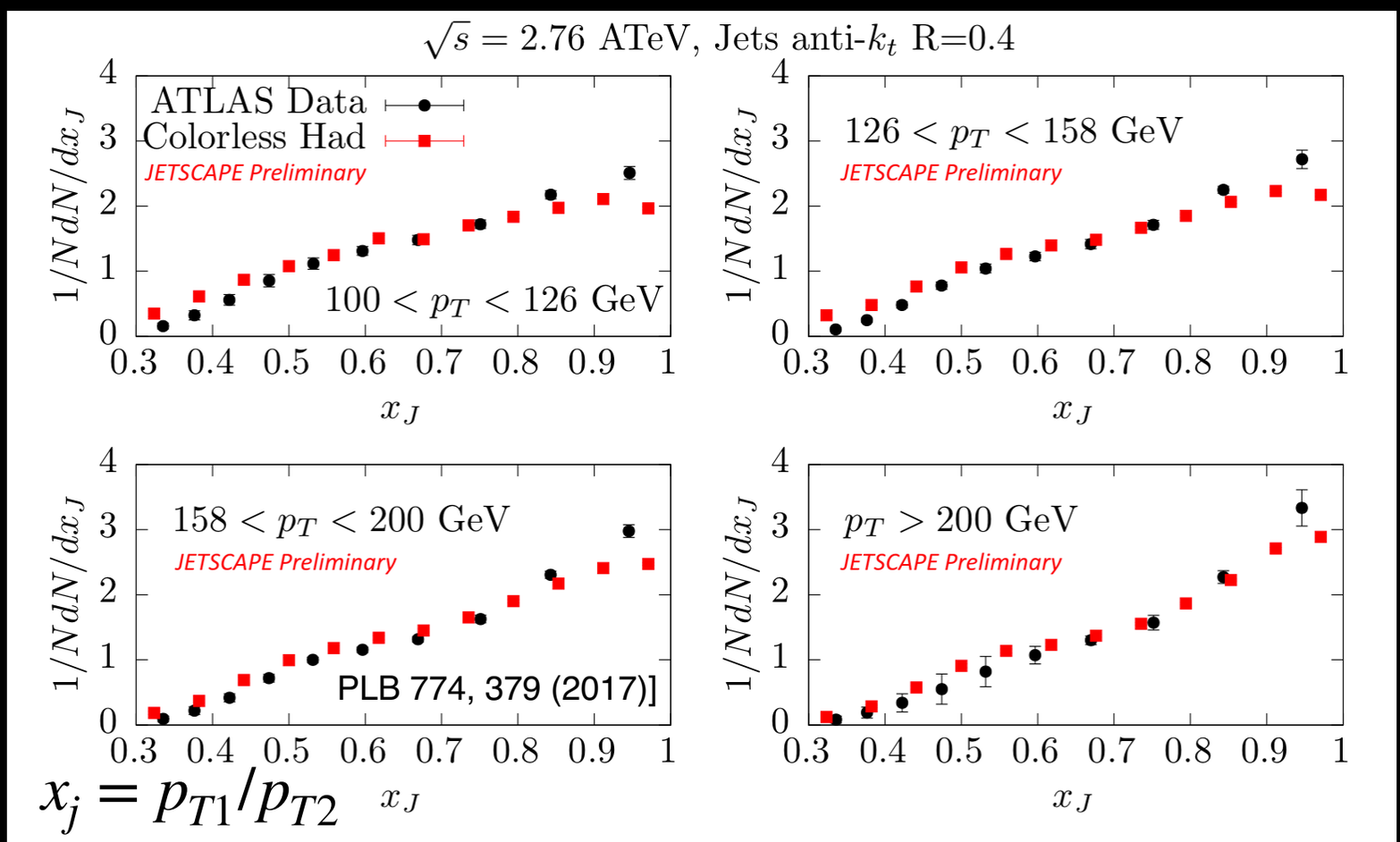
DI-JET ASYMMETRY



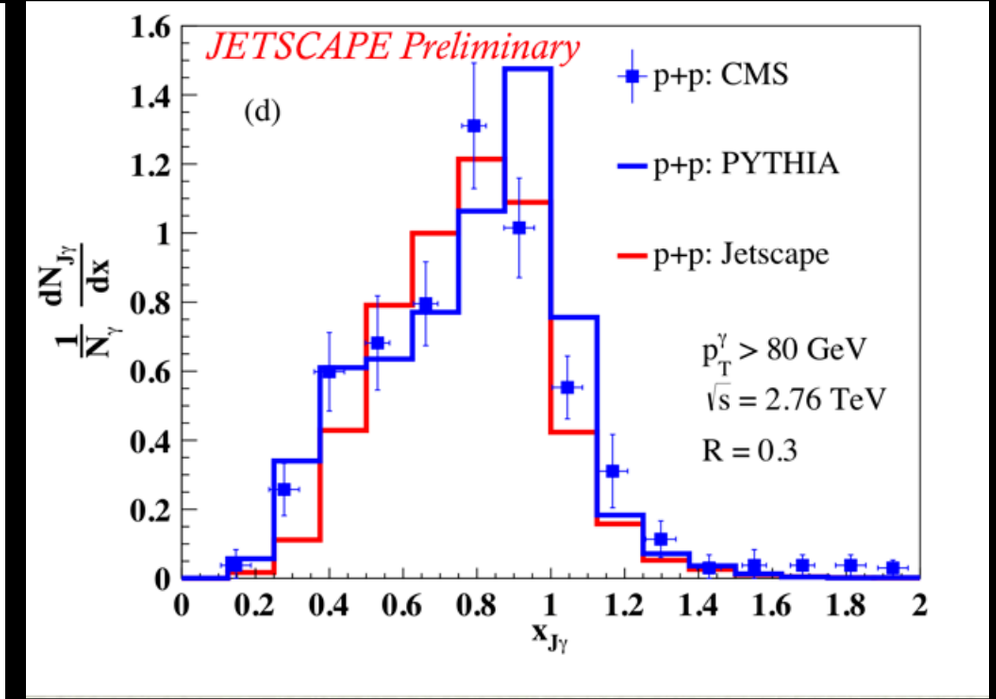
- Di-jet asymmetry in good agreement with data

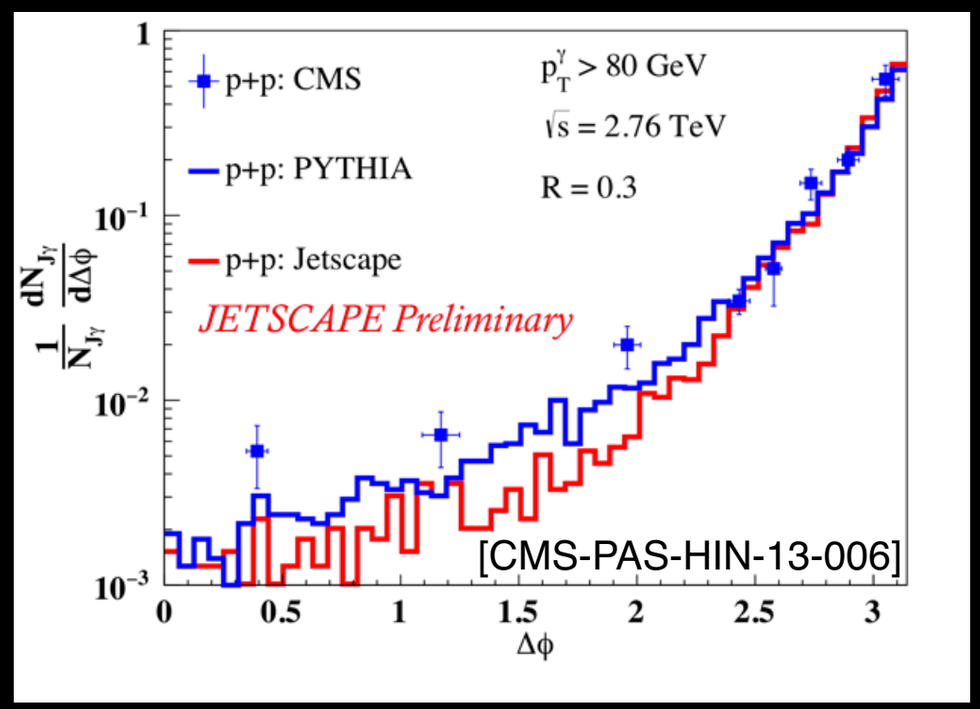
Dijets and γ-jets

DI-JET ASYMMETRY



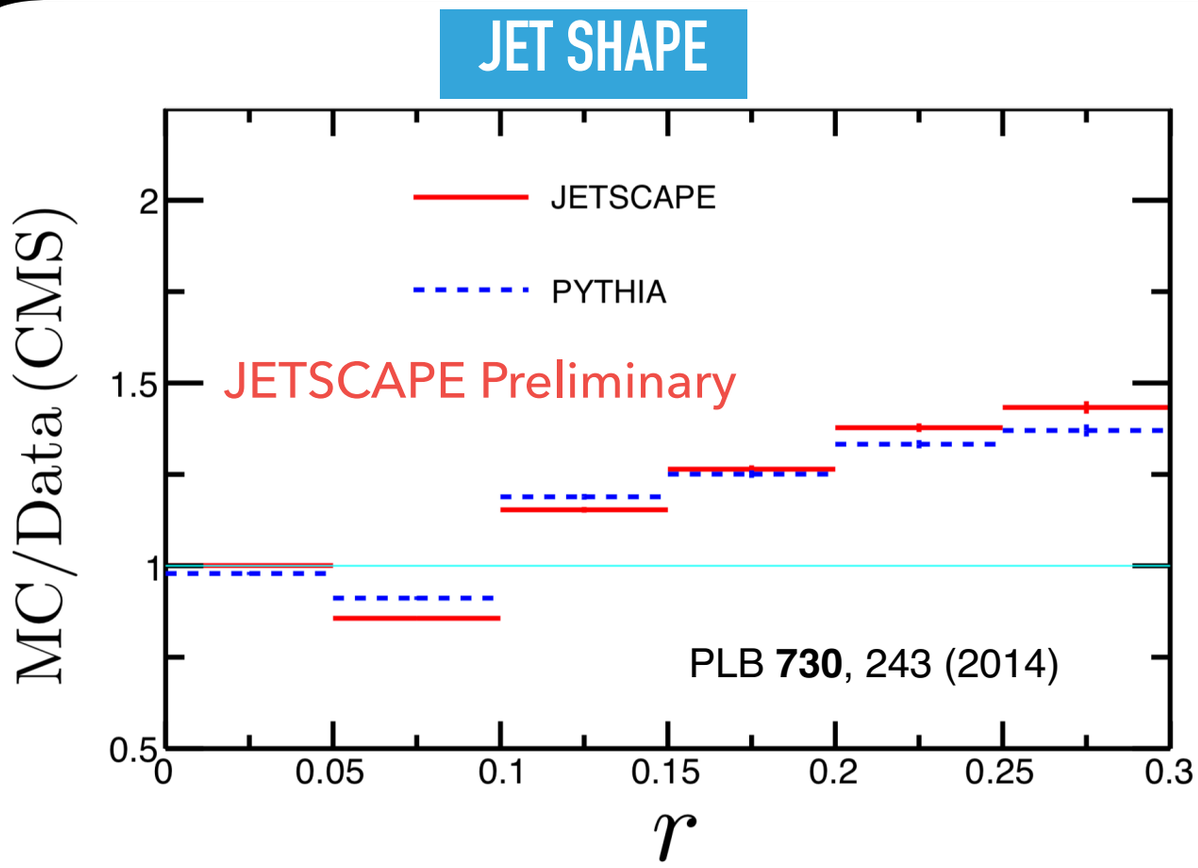
γ-JET ASYMMETRY

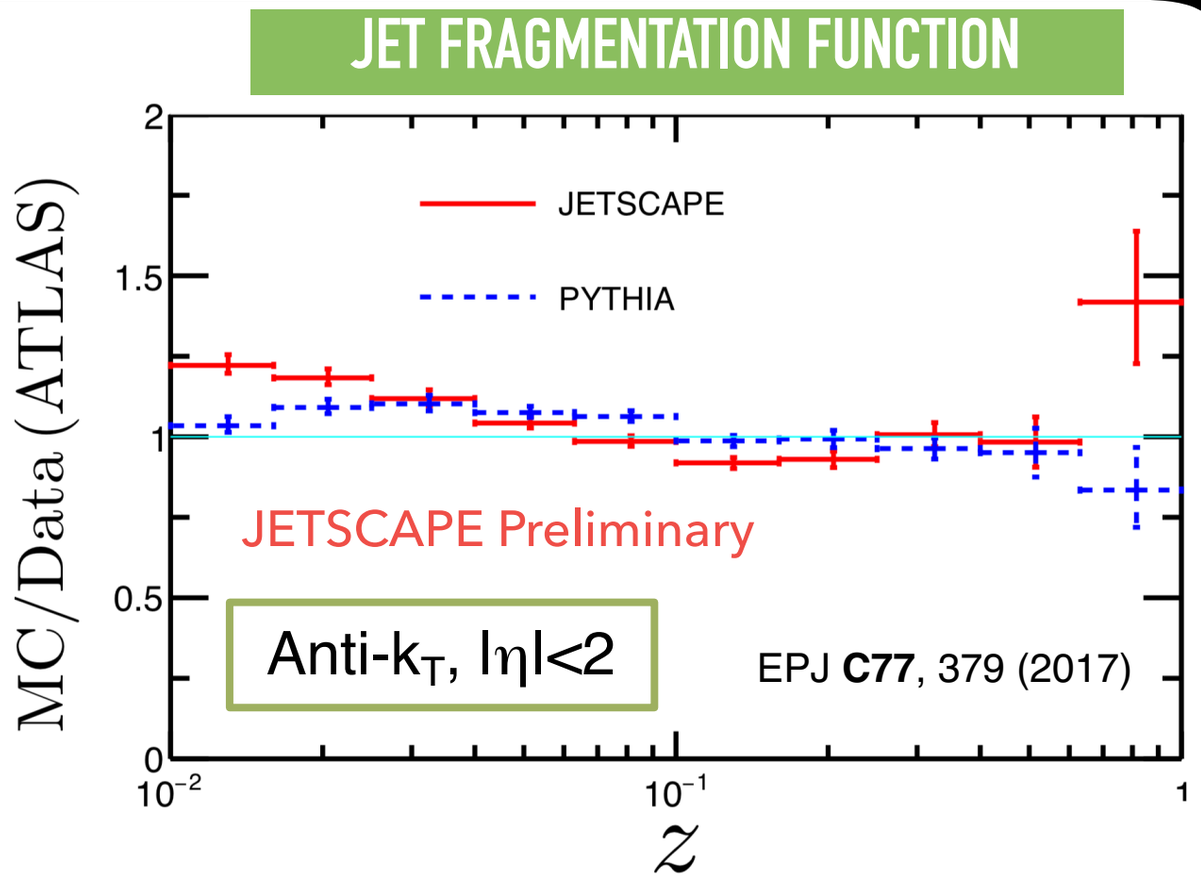




- Di-jet asymmetry in good agreement with data
- γ-jet asymmetry consistent with Pythia (smearing to be added to compare to data)

Jet fragmentation and Jet shape





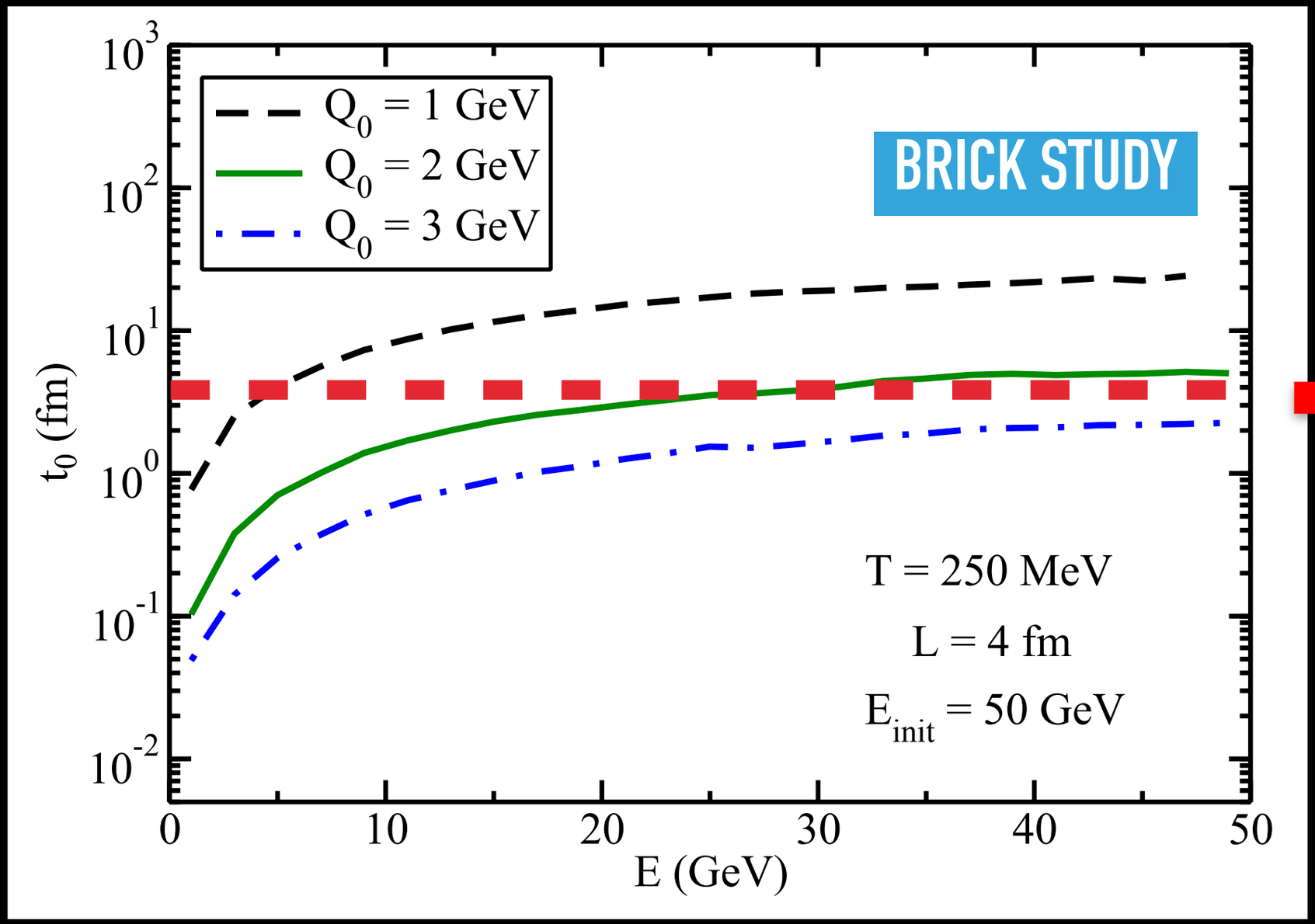
- Similar level of description compared to Pythia
- Further parameters tuning is needed to describe experimental measurements

Jet Energy Tomography in medium

Necessity of a multi-stage approach

S. Cao et al. [JETSCAPE Collaboration], Phys. Rev. C 96, 024909 (2017)

t_0: time for a parton to hit Q_0 after multiple splittings in MATTER

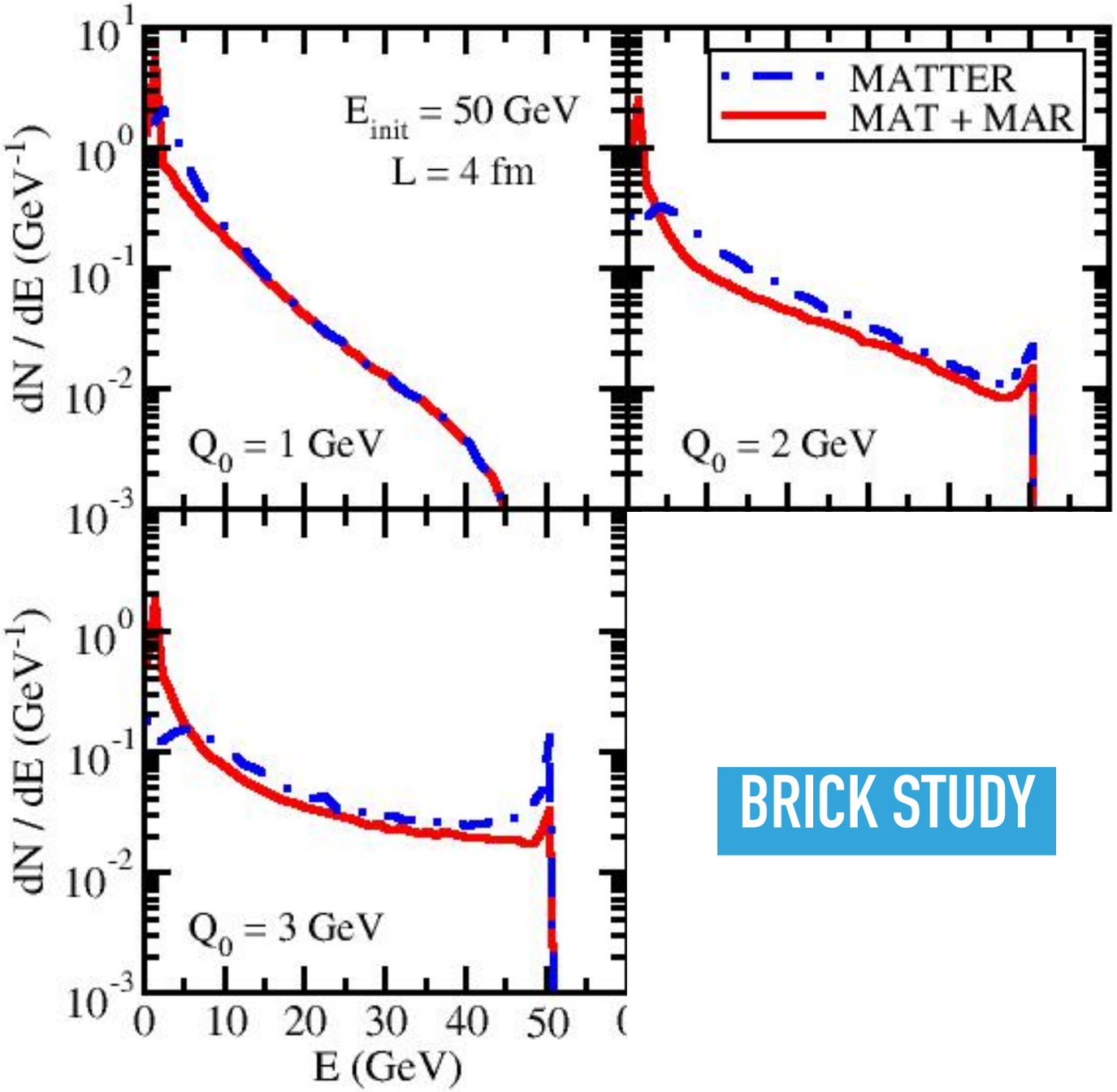


→ medium length (4 fm)

the switching time between MATTER and LBT/MARTINI varies with E and Q_0

MATTER + MARTINI/LBT hybrid approach

S. Cao et al. [JETSCAPE Collaboration], Phys. Rev. C 96, 024909 (2017)



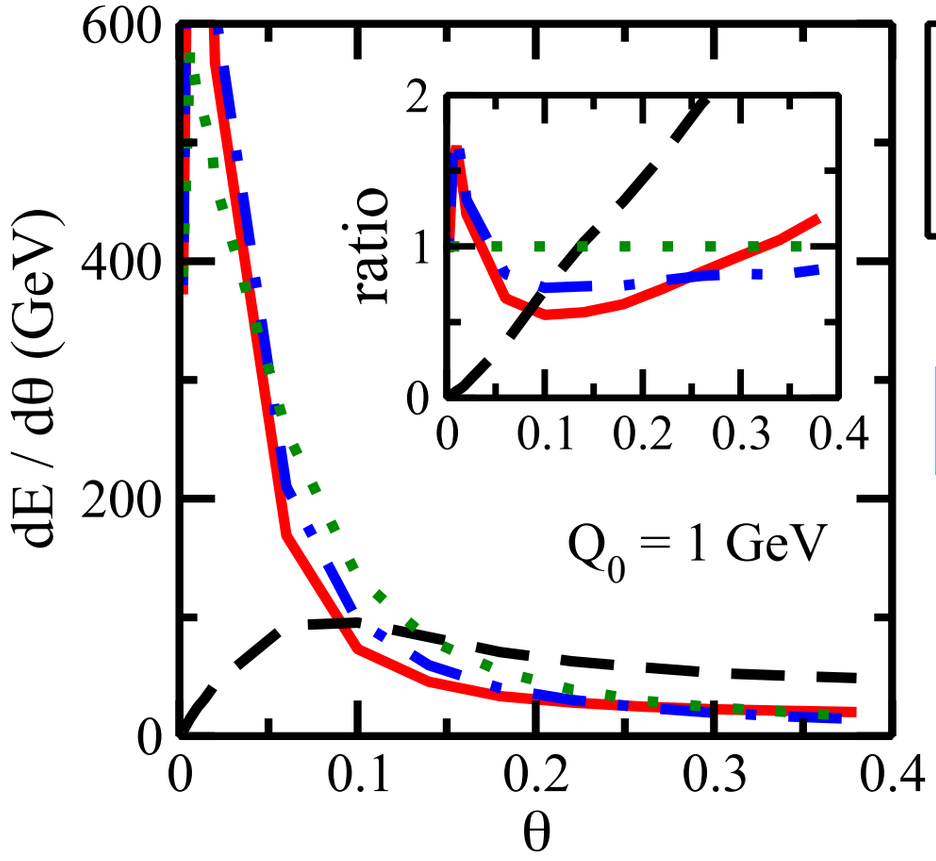
BRICK STUDY

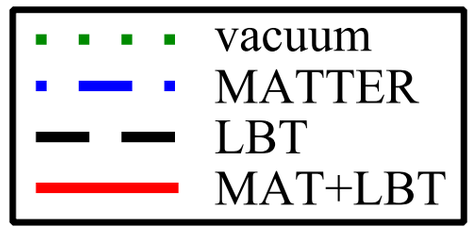
- It takes longer time for partons to hit lower Q_0 in MATTER and leaves shorter time for the subsequent MARTINI

- Energy loss from MARTINI/LBT is weak for high E partons, but becomes stronger for low E ones.

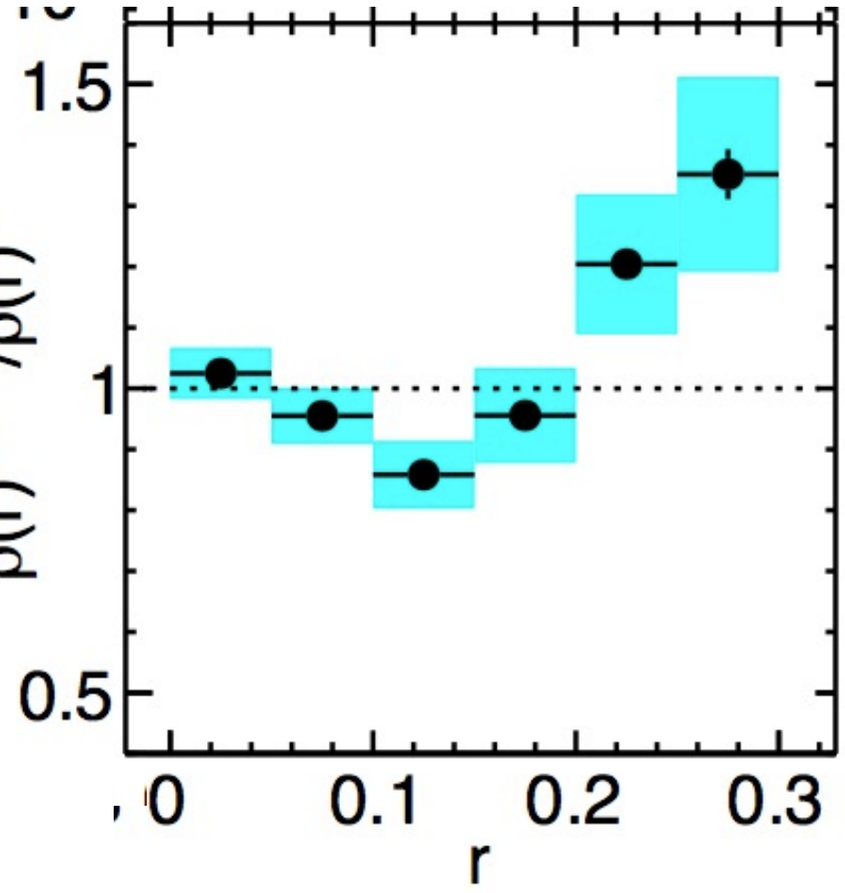
dE/dθ of daughter partons (jet shape)

S. Cao et al. [JETSCAPE Collaboration], Phys. Rev. C 96, 024909 (2017)





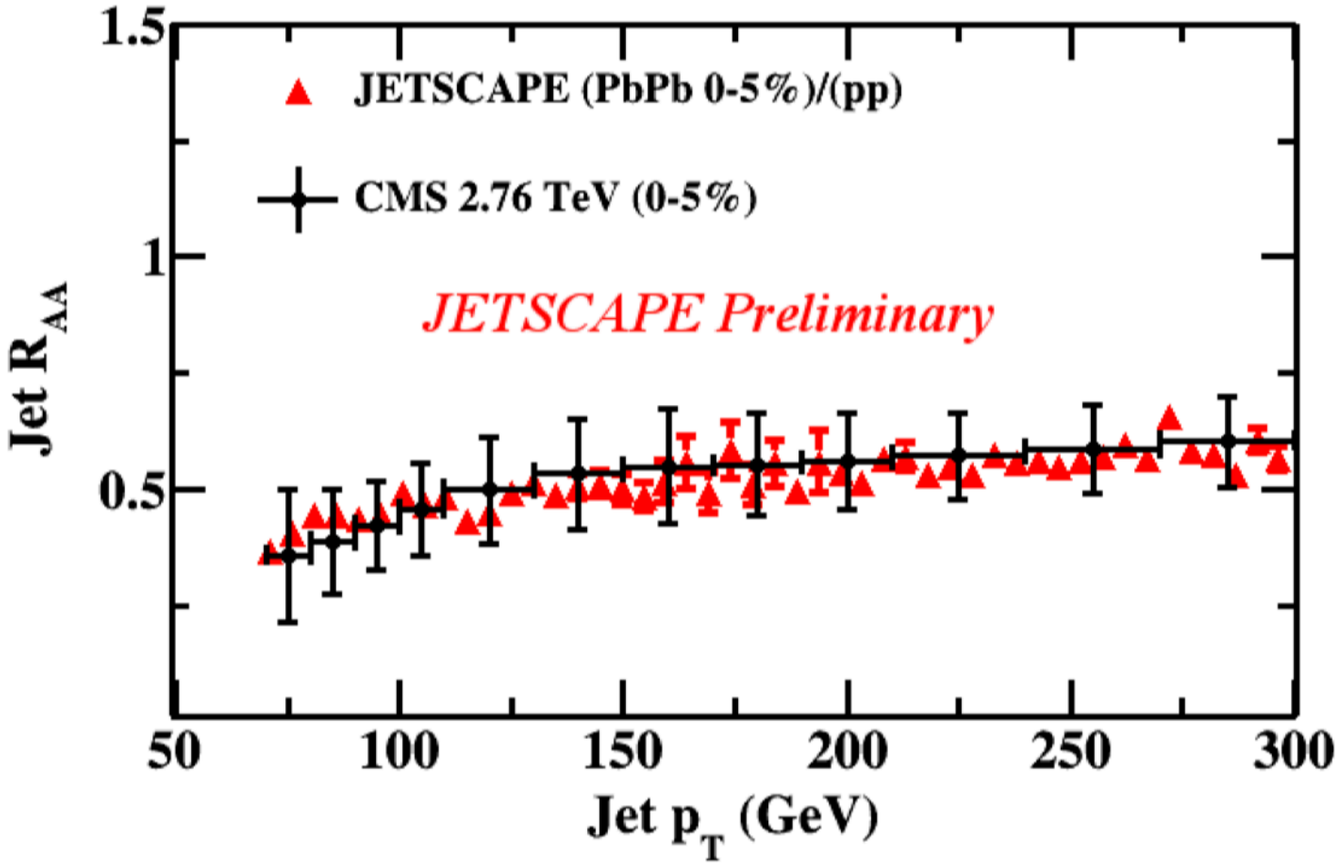
BRICK STUDY



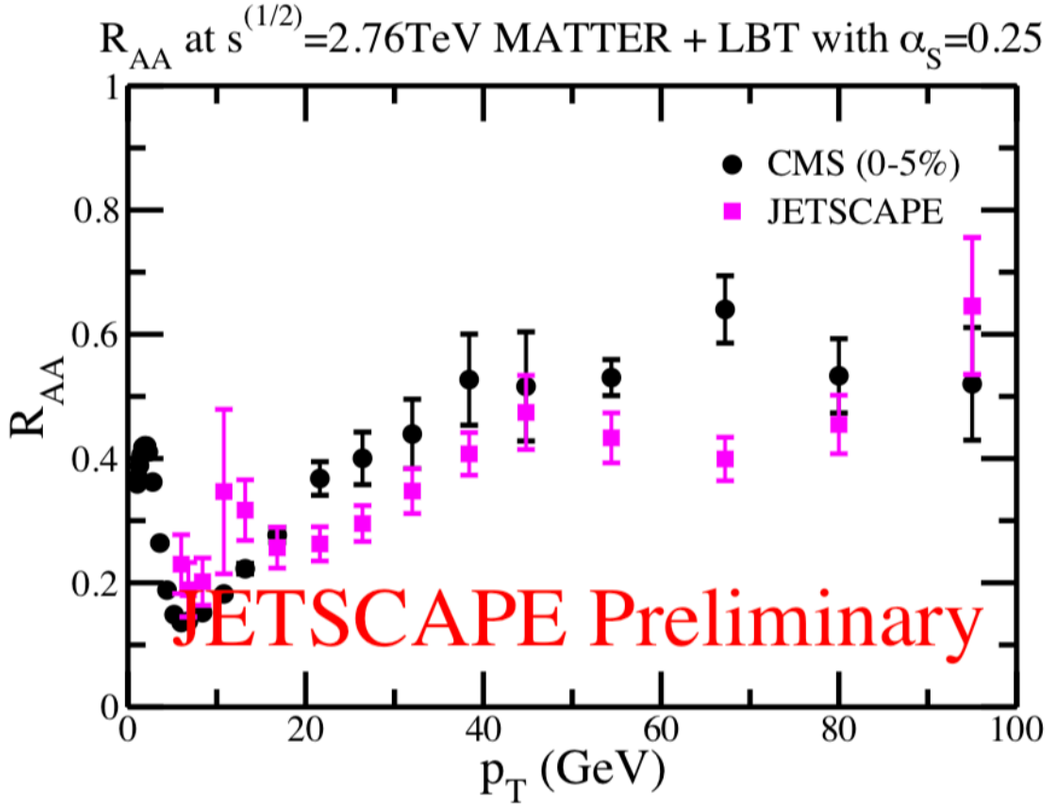
- Elastic scatterings in LBT is more effective than MATTER in shifting energy distribution into larger angle
- Enhanced Sudakov type splitting at very small r in MATTER and elastic scatterings at large r from LBT

Nuclear modification of jets in A+A collisions

SINGLE INCLUSIVE JET



CHARGED HADRON

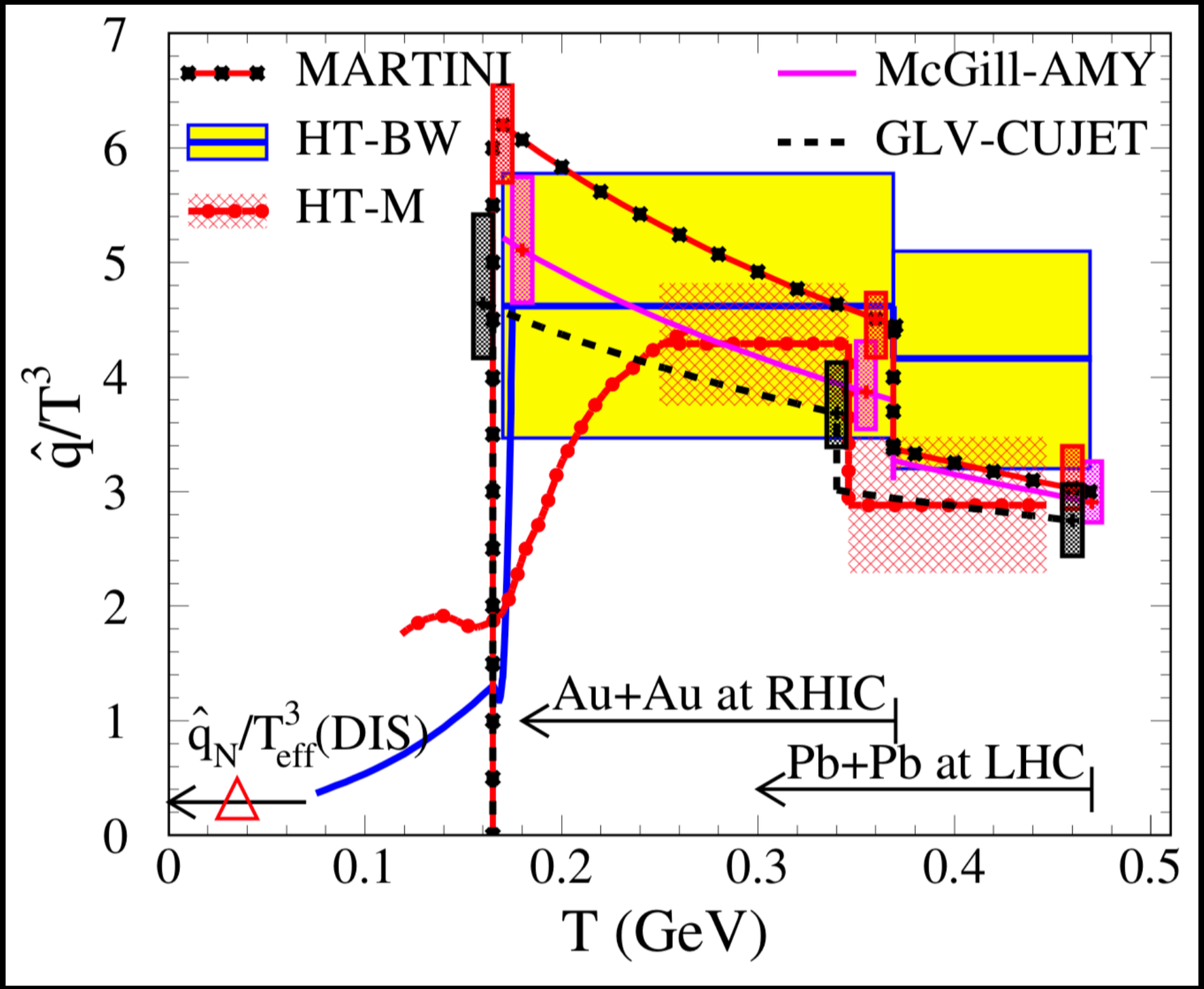


- MATTER+LBT within JETSCAPE 1.0, Q_0 = 2 GeV, α_s = 0.25
- Reasonable descriptions of both jet and charged hadron R_{AA}

Extensive study will come soon

Extract jet transport coefficient $\hat{q}$

K. M. Burke et al. [JET Collaboration], Phys. Rev. C 90, 014909 (2014)



Bayesian extraction of $\hat{q}$

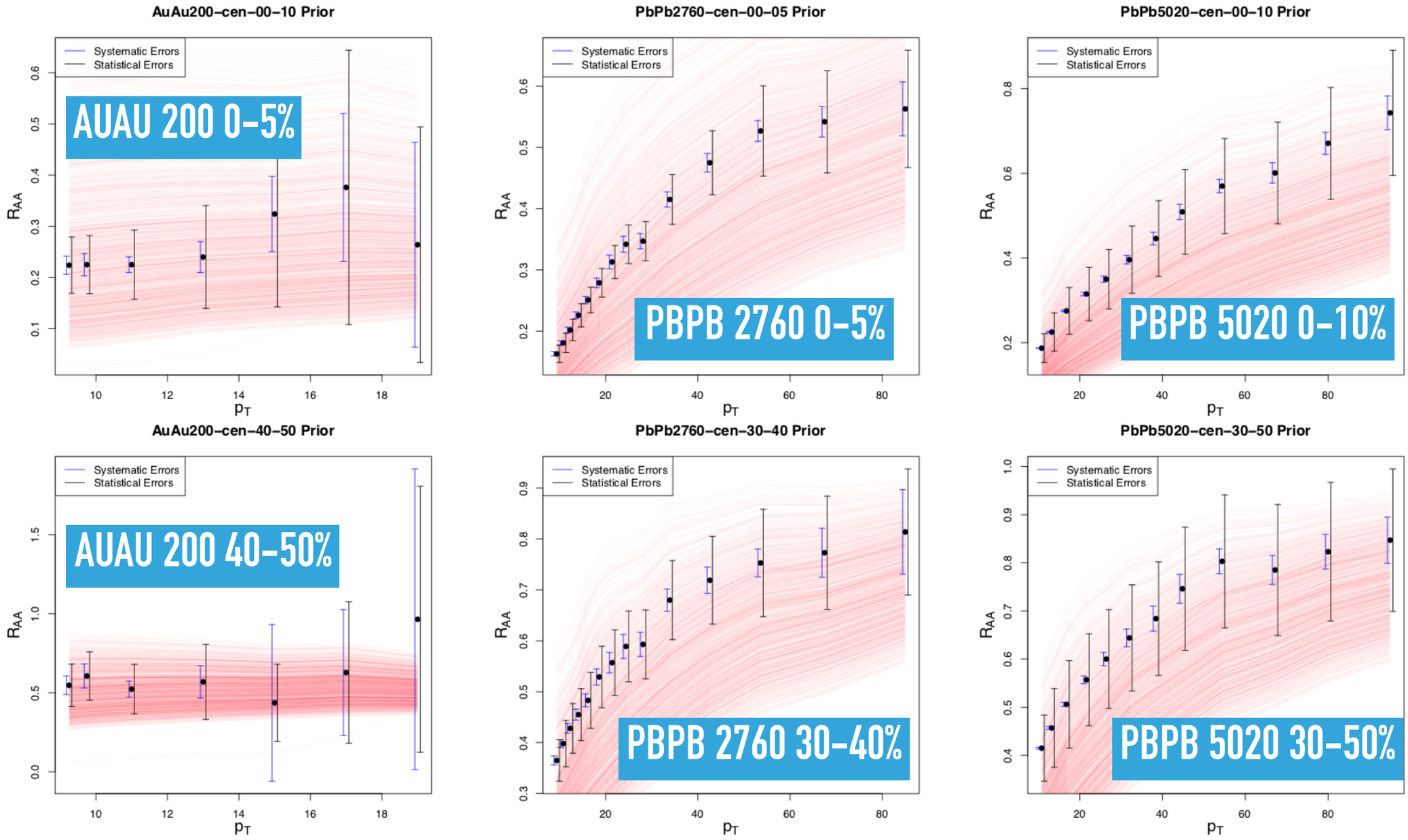
$$\frac{\hat{q}}{T^3} = 42 C_R \frac{\zeta(3)}{\pi} \left(\frac{4\pi}{9}\right)^2 \left[\frac{A(\ln\frac{E}{\Lambda} - \ln B)}{(\ln\frac{E}{\Lambda})^2} + \frac{C(\ln\frac{E}{T} - \ln D)}{(\ln\frac{ET}{\Lambda^2})^2} \right]$$

Pure dependence on the scale of jet

Perturbative scattering with quasi-particles from a thermal medium

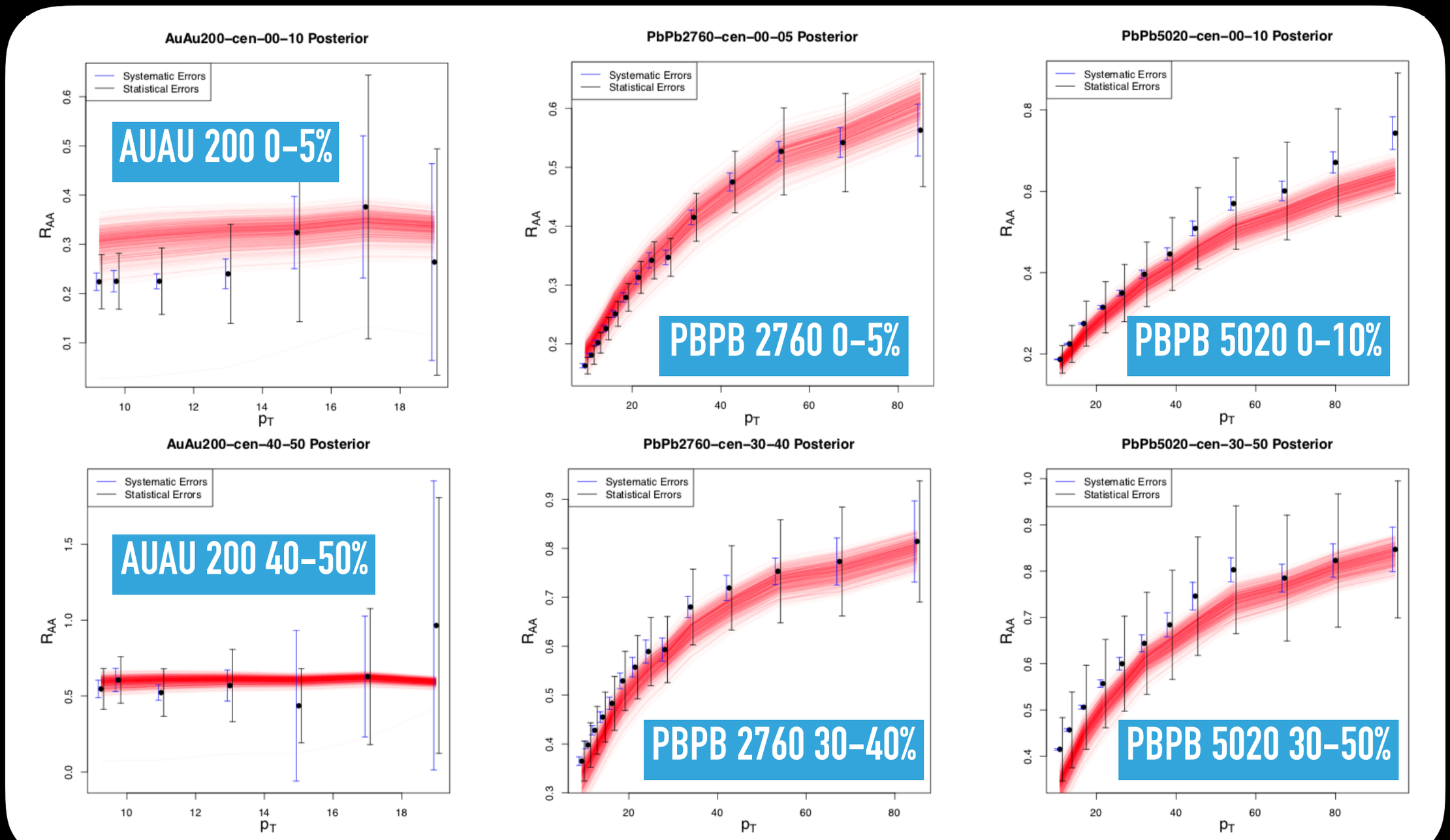
Bayesian extraction of $\hat{q}$

$$\frac{\hat{q}}{T^3} = 42 C_R \frac{\zeta(3)}{\pi} \left(\frac{4\pi}{9}\right)^2 \left[\frac{A(\ln\frac{E}{\Lambda} - \ln B)}{(\ln\frac{E}{\Lambda})^2} + \frac{C(\ln\frac{E}{T} - \ln D)}{(\ln\frac{ET}{\Lambda^2})^2}\right]$$

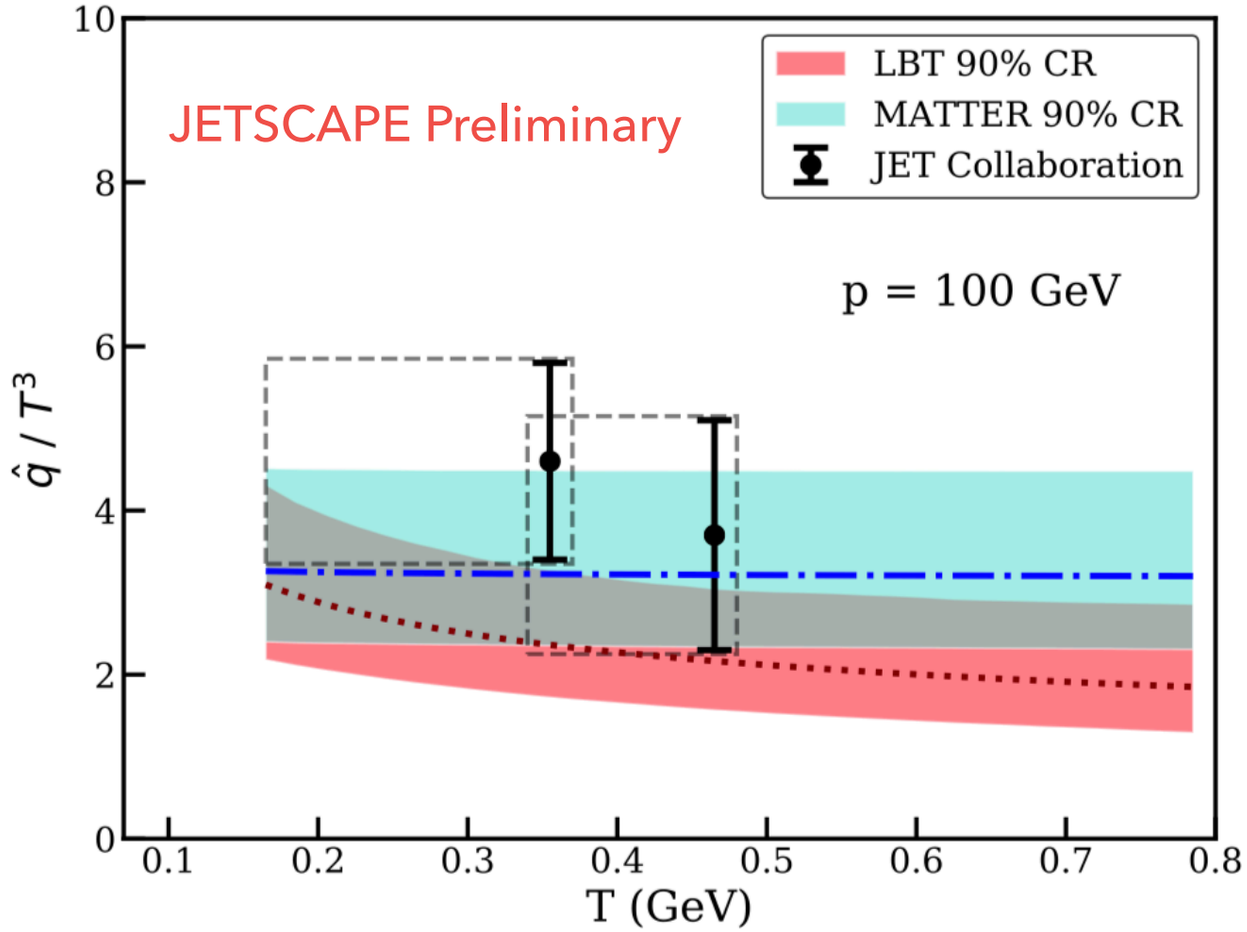


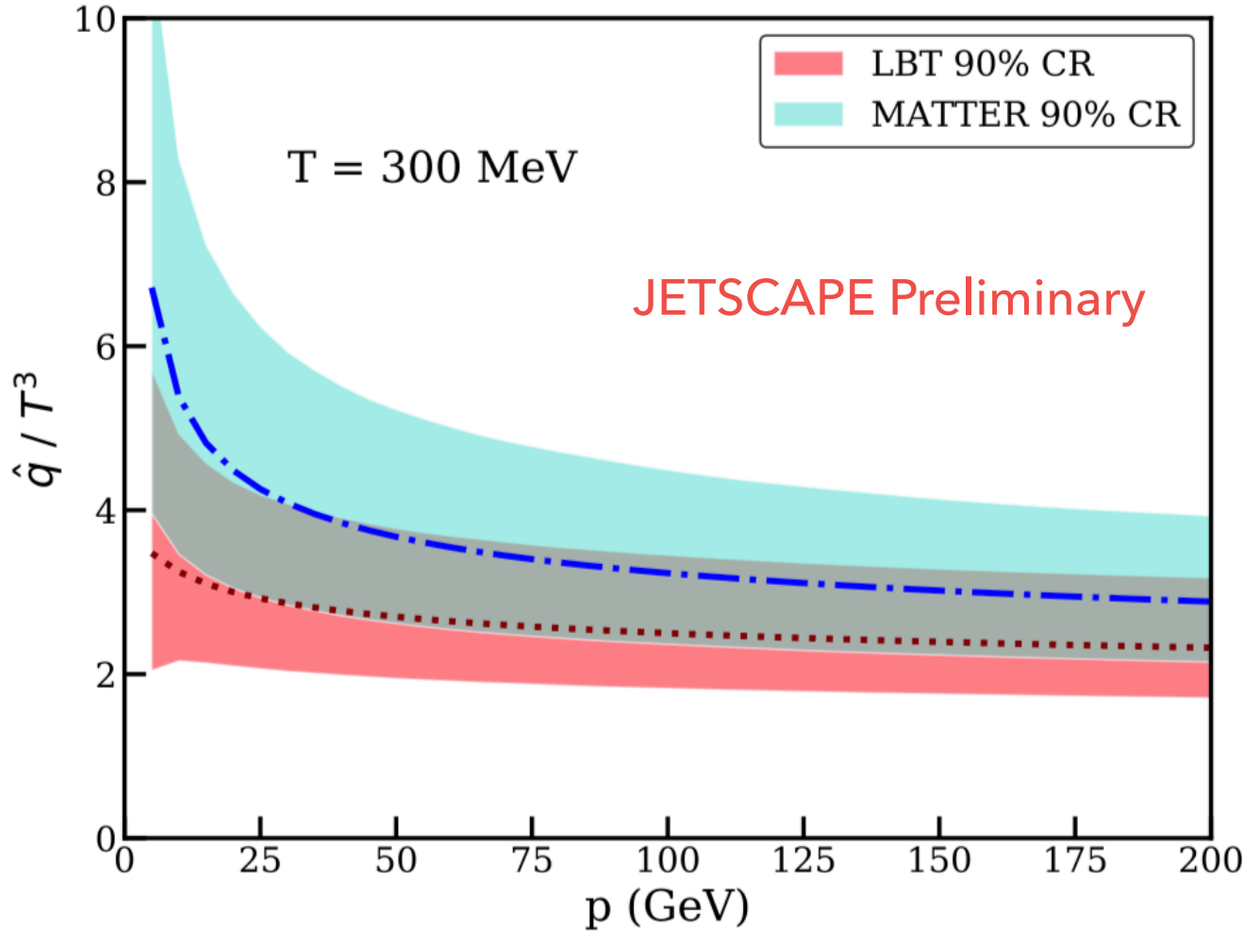
Bayesian extraction of $\hat{q}$

$$\frac{\hat{q}}{T^3} = 42 C_R \frac{\zeta(3)}{\pi} \left(\frac{4\pi}{9}\right)^2 \left[\frac{A(\ln\frac{E}{\Lambda} - \ln B)}{(\ln\frac{E}{\Lambda})^2} + \frac{C(\ln\frac{E}{T} - \ln D)}{(\ln\frac{ET}{\Lambda^2})^2}\right]$$



Bayesian extraction of $\hat{q}$





- Smooth functions of q

  mean value + 90% confidence interval

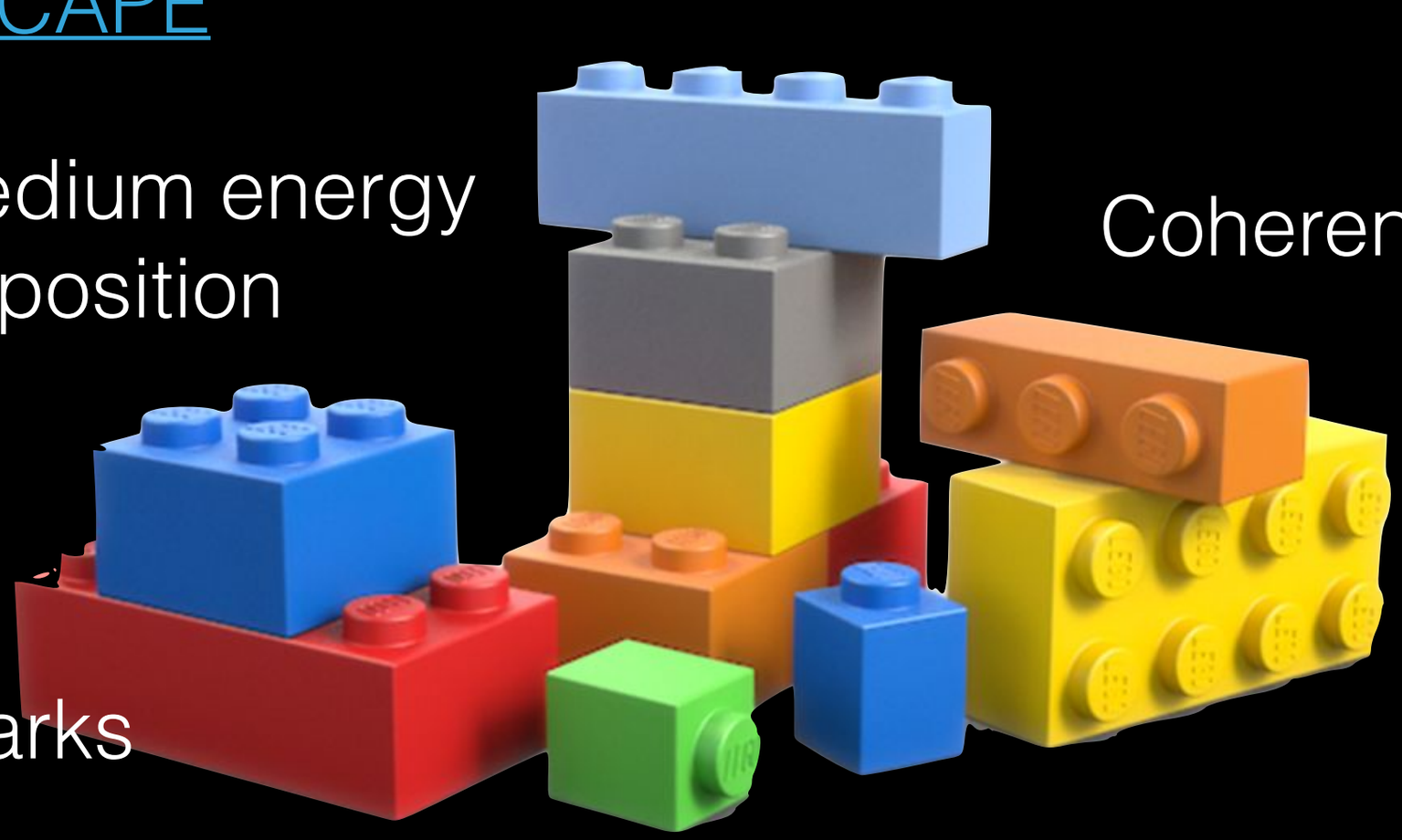
- Larger value with a weaker T dependence extracted from MATTER than from LBT

Summary and Outlook

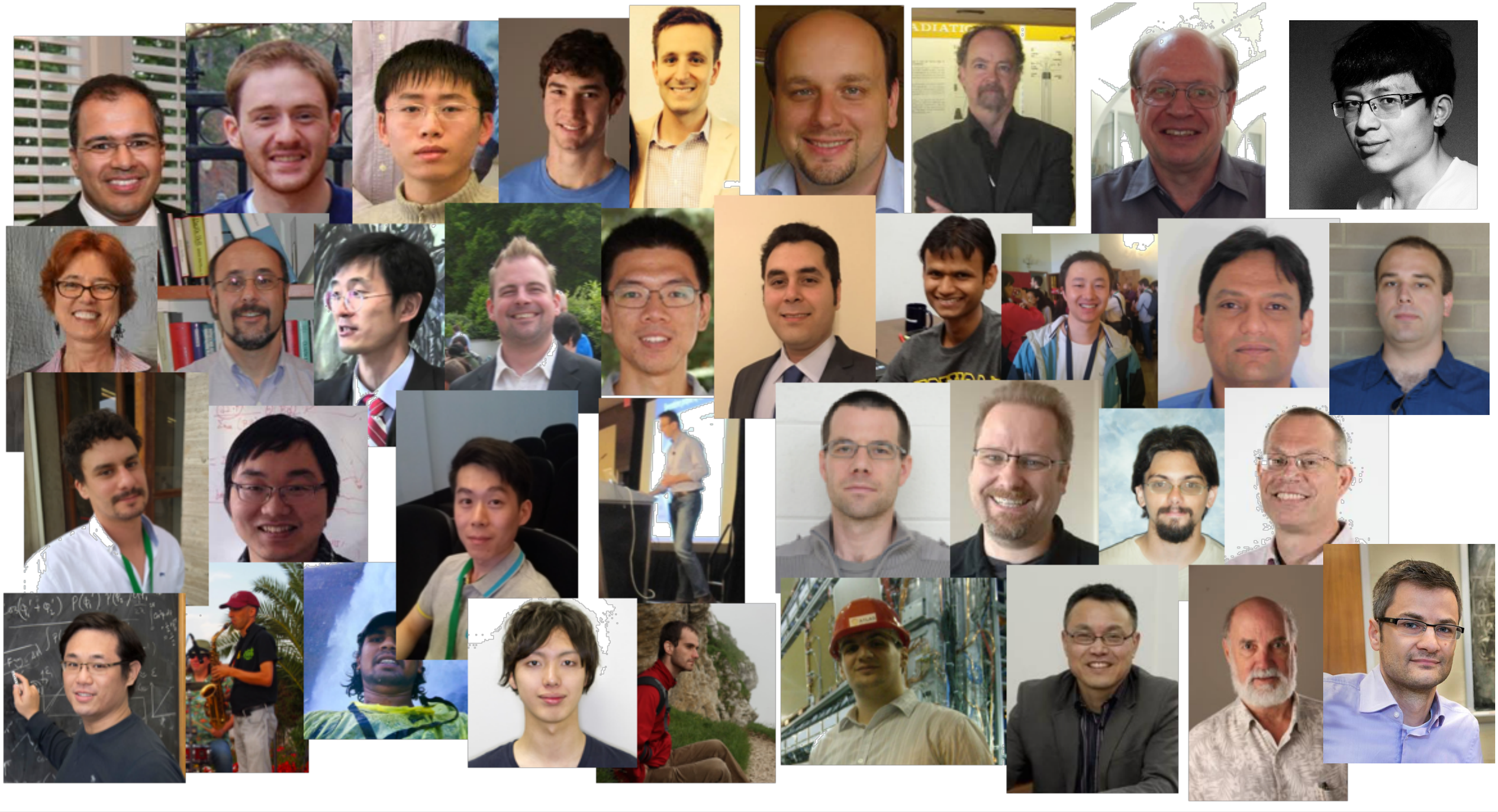
- JETSCAPE is an event generator for relativistic heavy-ion collisions

  Integrate multiple theories to describe different aspects of jet evolution inside medium

  publicly available in www.github.com/JETSCAPE/JETSCAPE

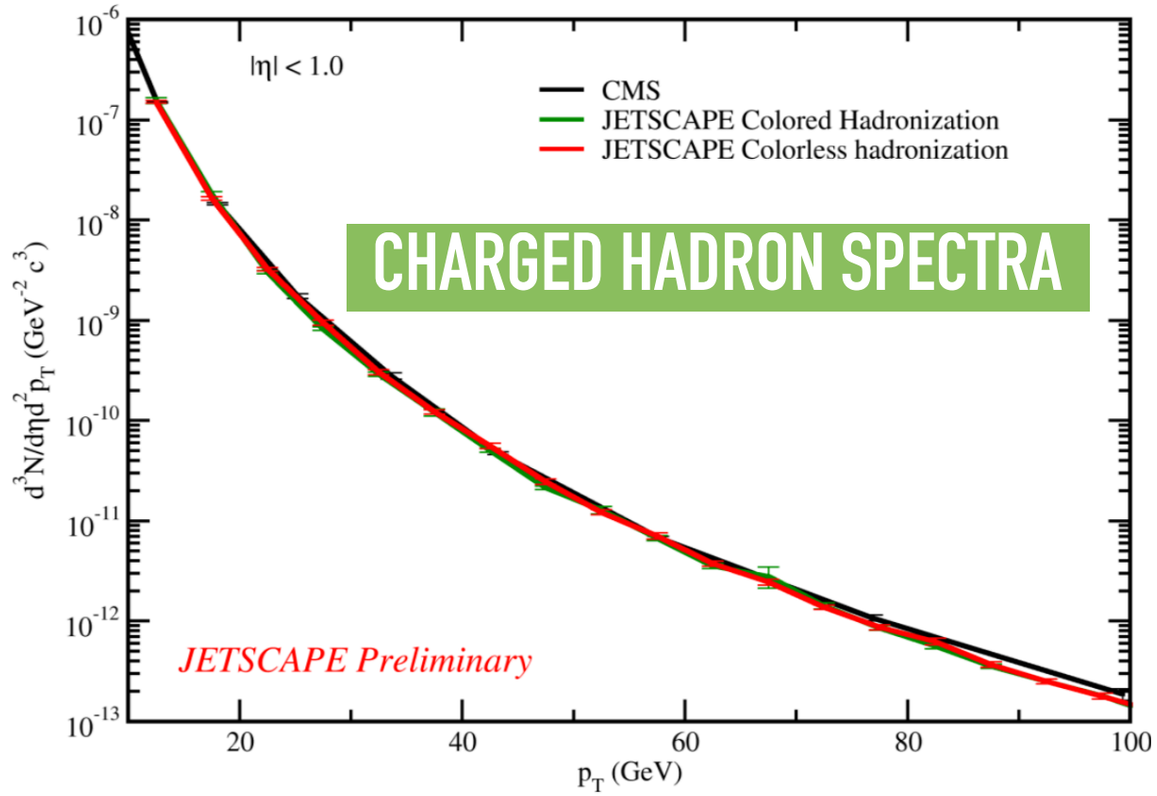


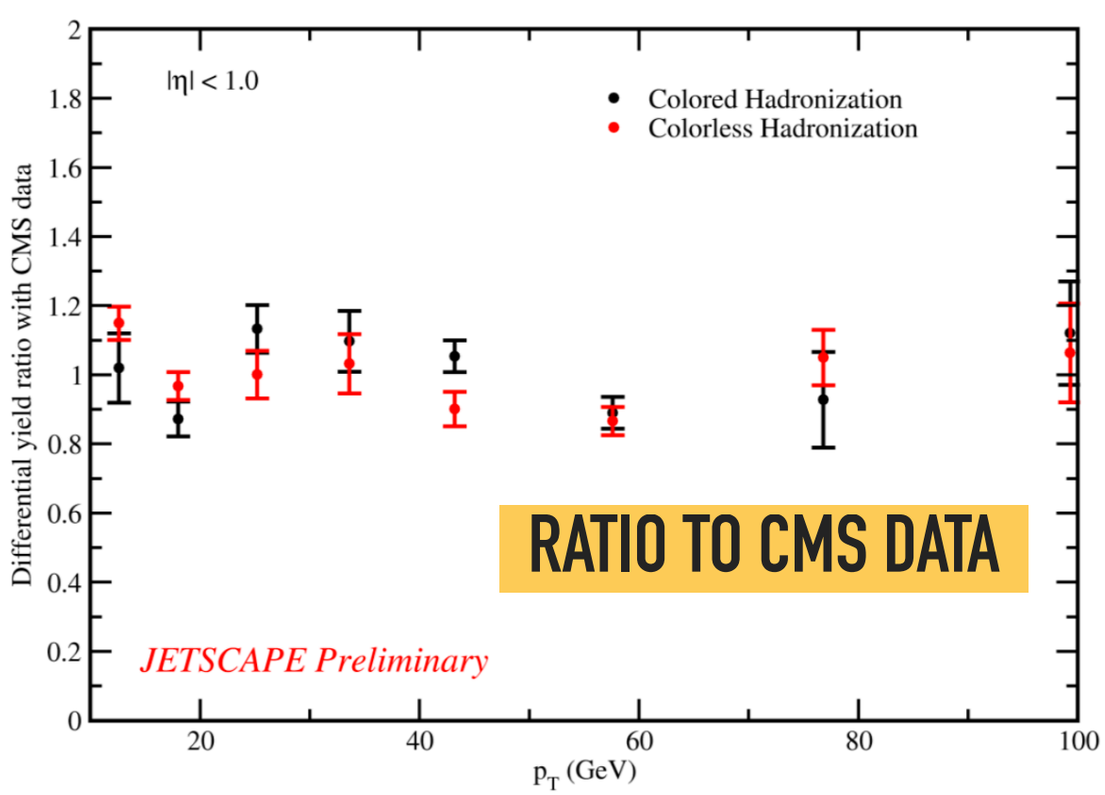
The JETSCAPE Collaboration



Hadronization in the JETSCAPE

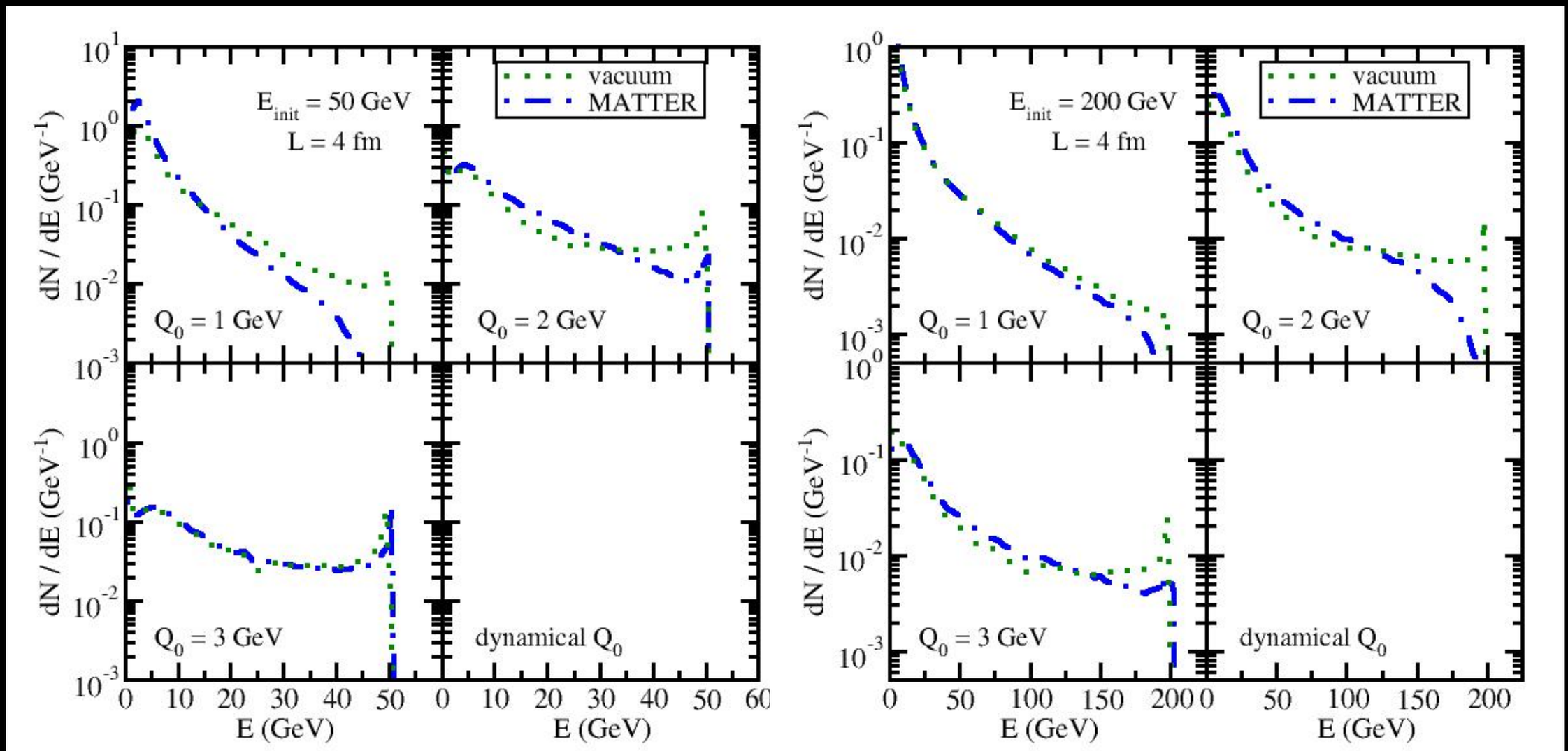
- Colored hadronization: track color information during parton showers and construct string for Pythia fragmentation in the end
- Colorless hadornization: assign colors to final state partons based on their phase space configuration (more flexible for A-A collisions)





MATTER vs vacuum shower

S. Cao et al. [JETSCAPE Collaboration], Phys. Rev. C 96, 024909 (2017)



- Energy loss in MATTER is stronger when Q_0 is smaller
- Energy loss in MATTER disappears when $Q_0^2 > \hat{q}\tau_f$
- $\hat{q}\tau_f$ increases with the jet energy; MATTER evolution is more important to high energy partons than to low energy ones