Photon-jet correlations in p-p and Pb-Pb collisions using JETSCAPE framework

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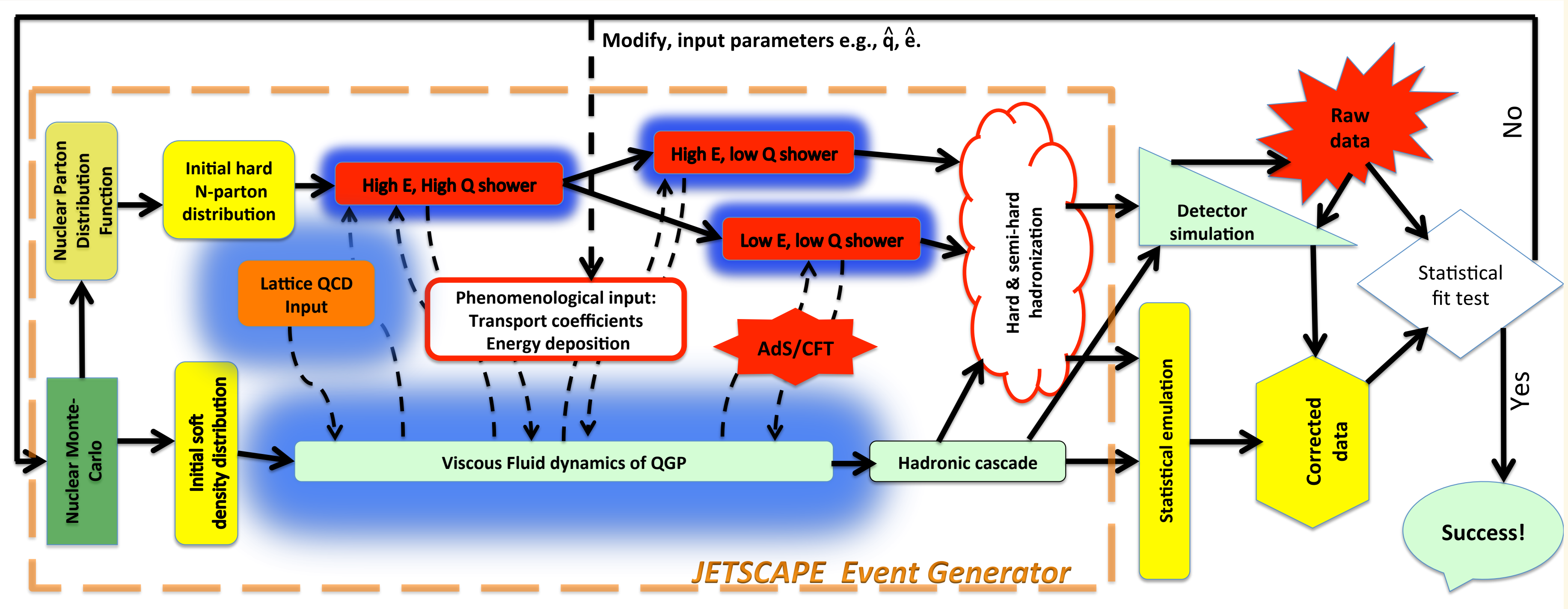
for the JETSCAPE Collaboration

Outline

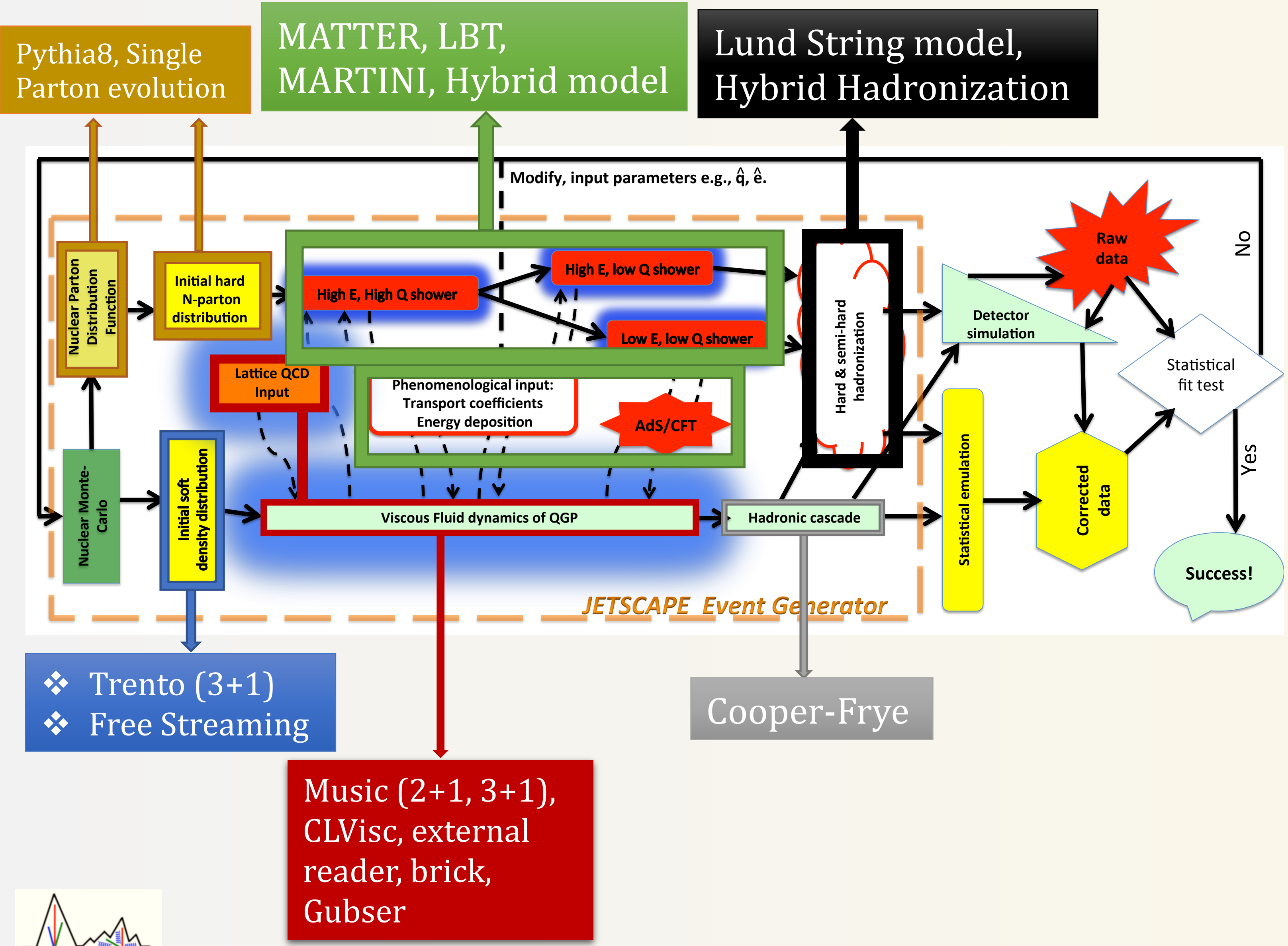
- JETSCAPE framework
- Simulating jet evolution with JETSCAPE framework
- Photon Simulation
- Photon Results
- Summary

JETSCAPE framework

- Jet Energy loss Tomography with a Statistically and Computationally Advanced Program Envelope
- General, modular and extensive framework
- JETSCAPE 3.0.1 publicly available at https://github.com/JETSCAPE
- Manual (arXiv:1903.07706), JETSCAPE PP19 tune (arXiv:1910.05481)

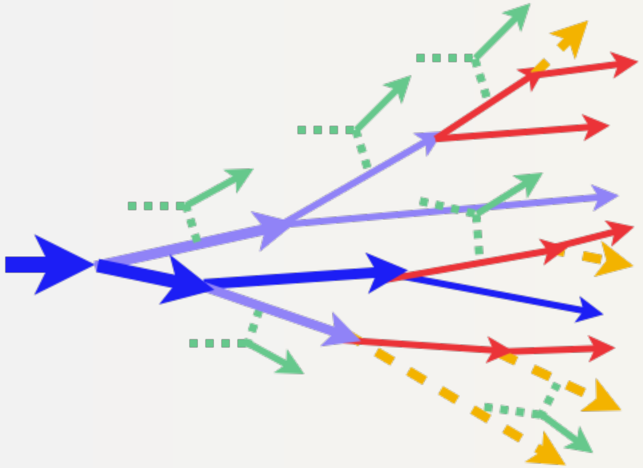


JETSCAPE framework



- Pythia8 - Hard scattering and MATTER, MARTINI, LBT, etc. – Intermediate shower
- Multi-stage jet evolution
- Different stages depending on the virtuality Q and energy E of the partons
- No single model can describe all stages of jet evolution simultaneously

JETSCAPE framework: Multi-stage evolution



Virtuality Separation Scale: Q_0

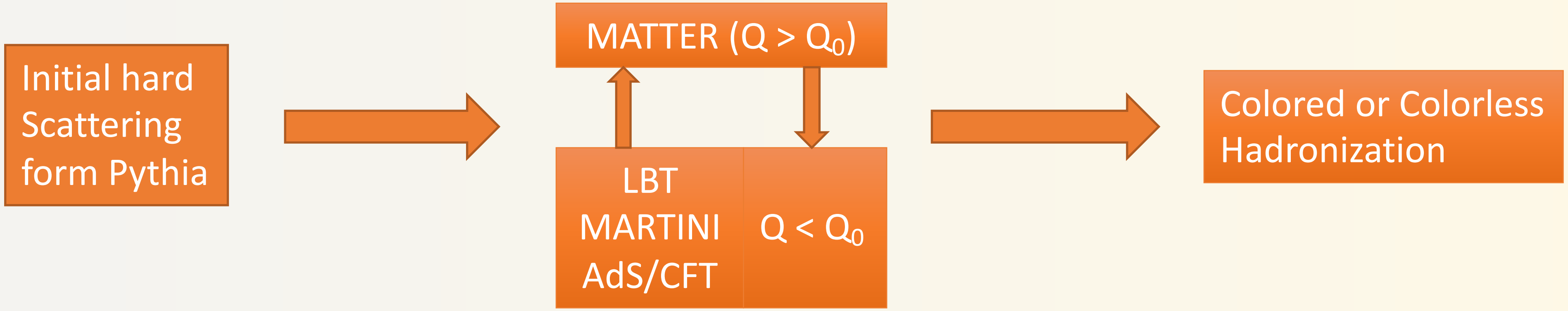
Switching between modules parton by parton depending on the virtuality and energy

Large Q: $Q > Q_0$
Small Q: $Q < Q_0$

- Large Q, Large E: Dominated by radiation with few scatterings (DGLAP, HT)
  - MATTER *(Majumder(13), Kordell, Majumder(17), Cao, Majumder(17))*
- Small Q, Large E: Scattering driven mostly by medium effects (Transport, AMY, HT)
  - LBT *(Wang, Zhu(13), Luo, et al.(15,18),Cao, et al.(16,17), He, et al.(18))*
  - MARTINI *(Schenke, Gale, Jeon(09), Park, Jeon, Gale(17, 18))*
- Small Q, Small E: Nearly thermal, strongly coupled approach (AdS/CFT)
  - AdS/CFT *(Chesler, Rajagopal(14, 15), Pablos, et al.(15, 16, 17), and others)*

Simulating jet evolution with JETSCAPE framework

- Settings used in our simulations
  - p-p baseline: Pythia for hard scattering and MATTER for shower
  - Common settings for Pb-Pb 2.76 TeV and 5.02 TeV
    - Virtuality separation scale, Q_0 = 2 GeV
    - Recoil ON in MATTER and LBT
    - Hadronization: Colored and Color randomized (Colorless) hadronization using Lund string model (Pythia8) Please see the talk by Michael Kordell for more details
  - Event averaged hydro is used for 2.76 TeV
  - Event by event hydro hydro is used for 5.02 TeV



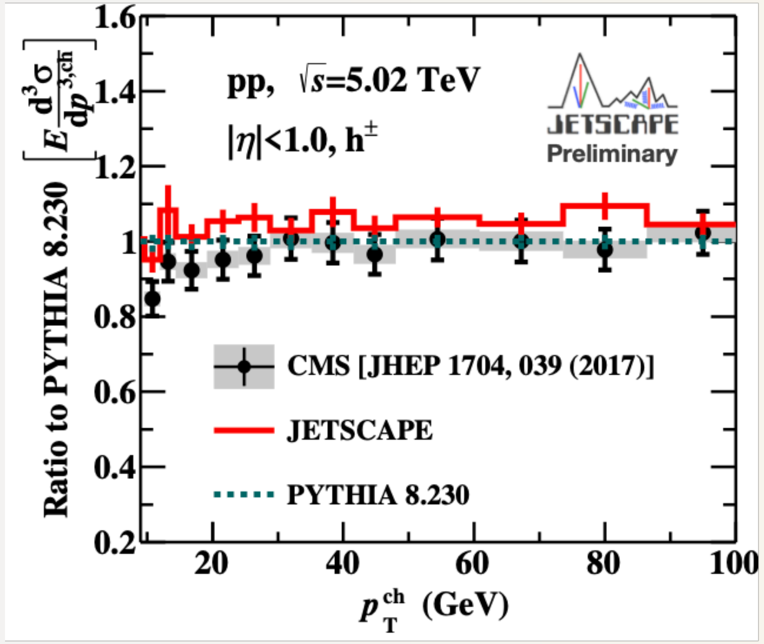
Leading hadrons and jets

- JETSCAPE 3.0

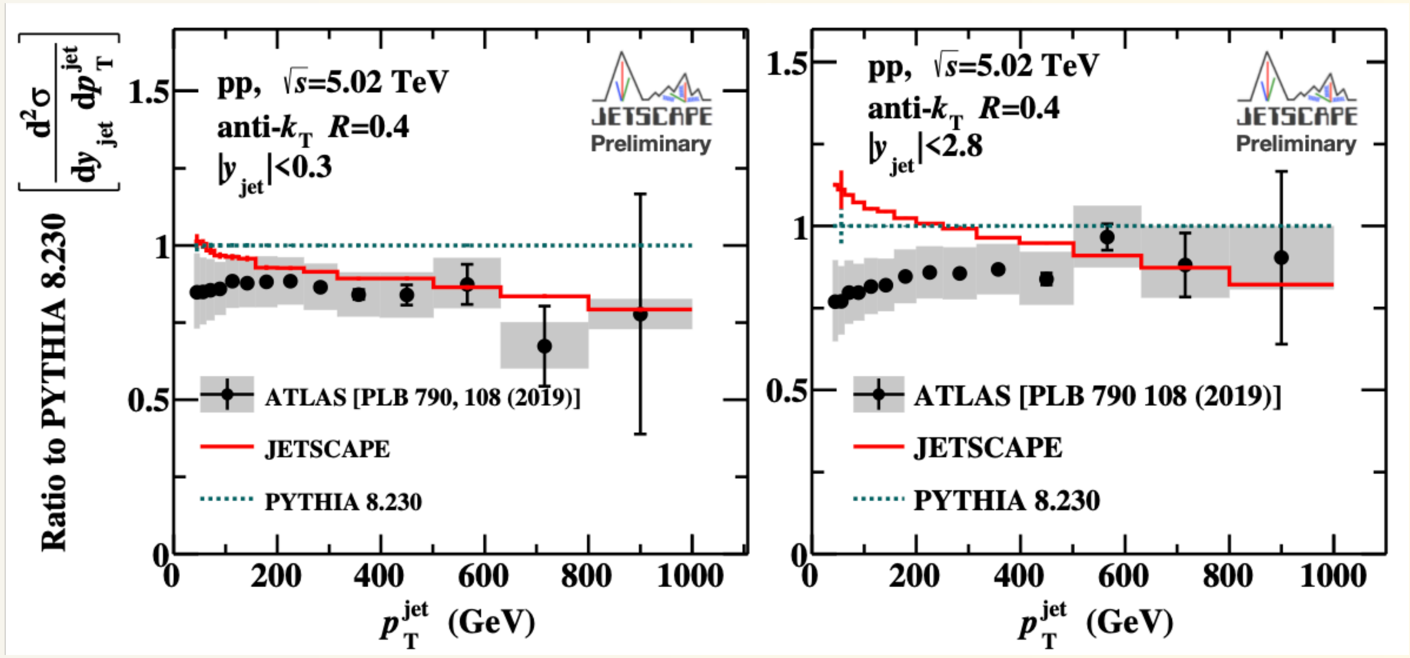
- MATTER – high virtuality partons
- LBT – low virtuality partons

Please see the talk by Chanwook Park for more details

Charged Hadron Yield

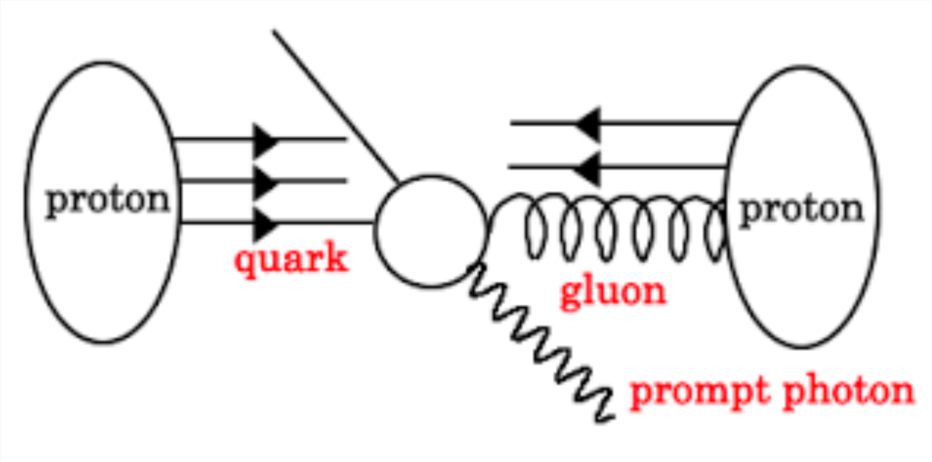


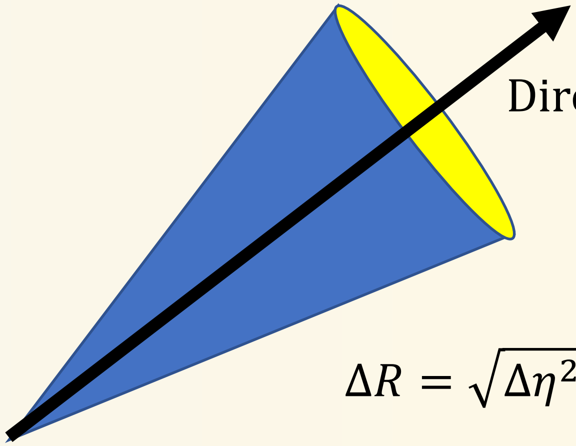
Jet Cross Section



Photons

- Same set of parameters tuned for leading hadron and jet analysis were used
- Prompt photons - produced directly in the hard sub-processes
- These prompt photons can be used to estimate the energy and the direction of jet initiating parton (before the energy loss) – Calibrated probe of the QGP
- Isolation criteria is necessary to identify the prompt photons
    - Same isolation criteria used in experimental analysis (CMS-HIN-13-006, CMS-HIN-16-002, PLB 789 (2019) 167)
- Isolated photons mainly consist of prompt photons

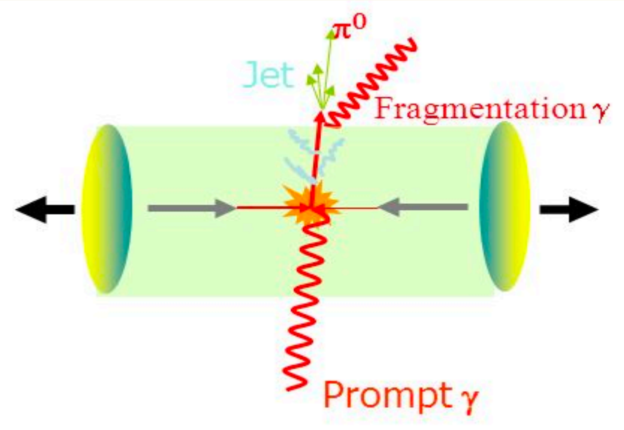




$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

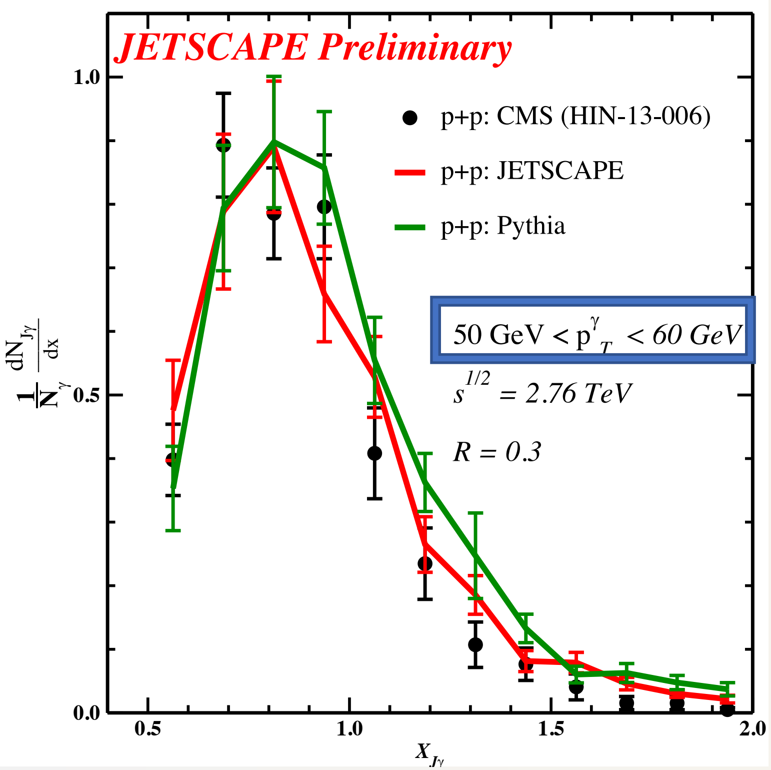
Photon Simulation

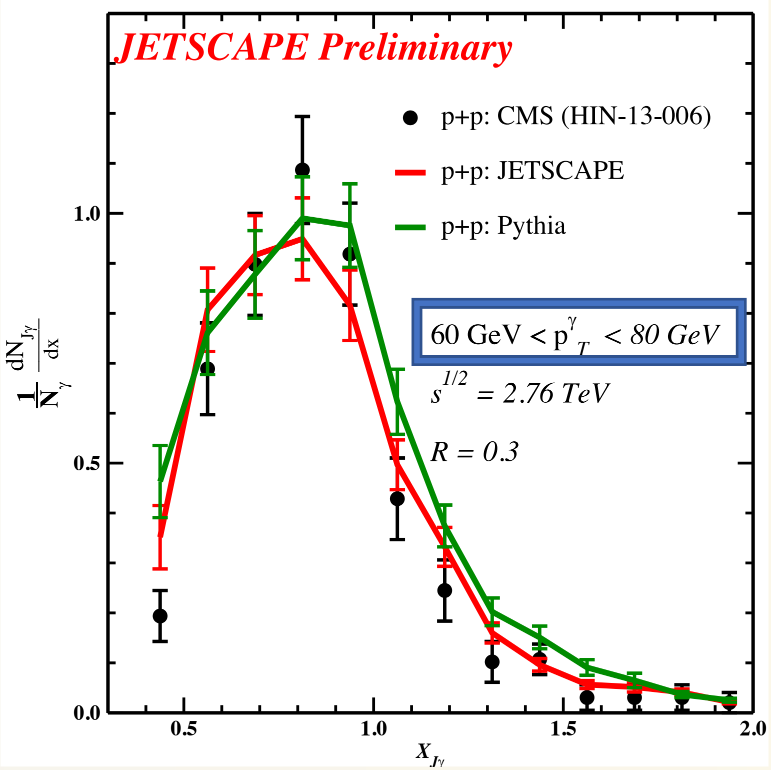
- An independent, parameter free verification of the multistage evolution
- Medium induced terms for energy loss – included
- Medium induced photon emission terms - not included
- Photons included in the analysis
  - Photons from initial hard scattering (prompt photons)
  - Photons radiated from intermediate shower
  - Photons radiated by hadrons in the process of hadronization

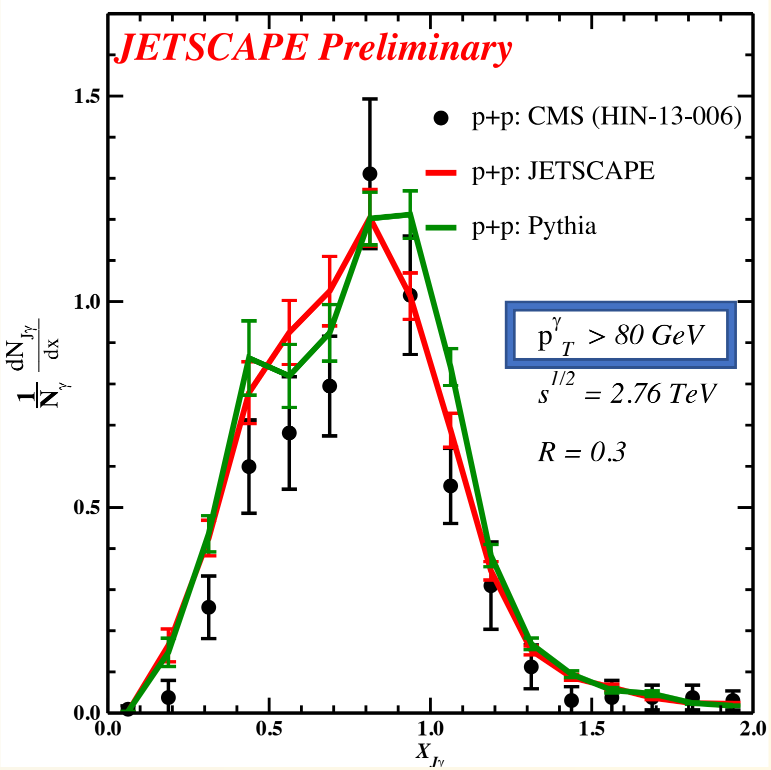


Photons: p-p 2.76 TeV

Gamma-Jet transverse momentum imbalance (Gamma-Jet Asymmetry)







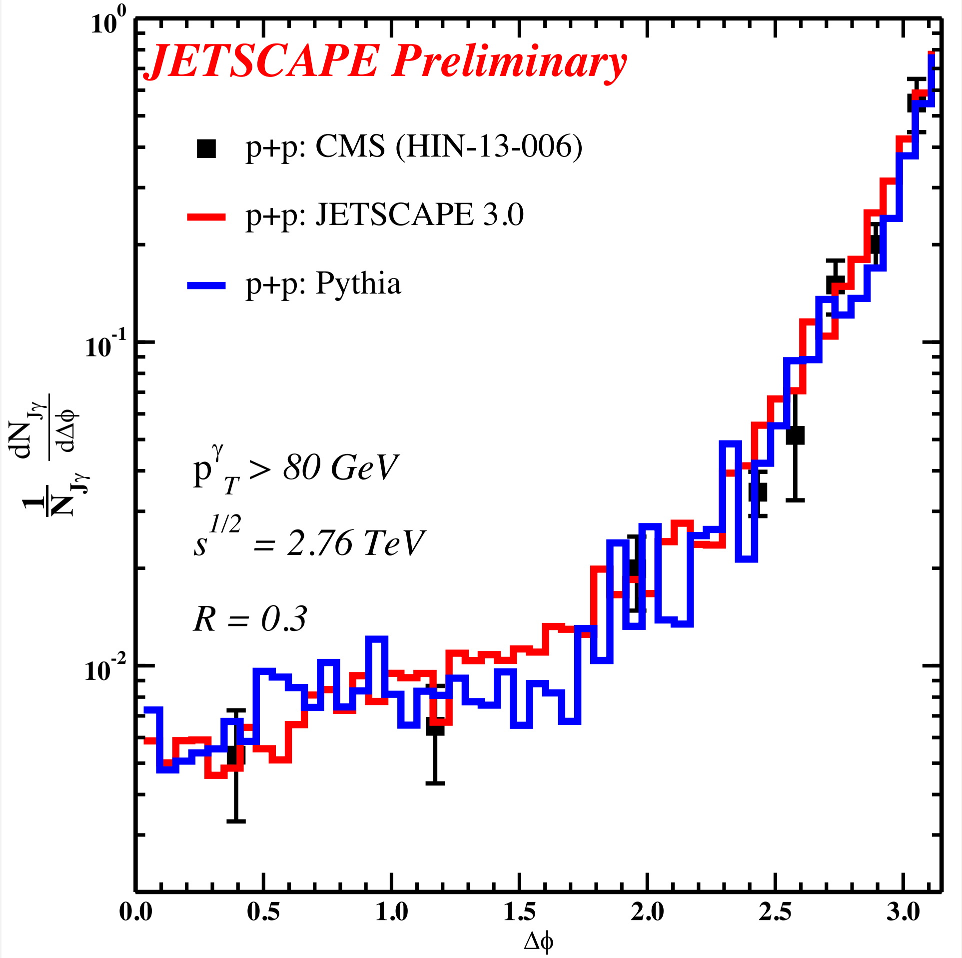
$X_{J\gamma} = \frac{p_T^{jet}}{p_T^{\gamma}},\ p_T^{jet} > 30\ GeV,\ |\eta_\gamma| < 1.44,\ |\eta_{jet}| < 1.6, |\Delta\phi| > \frac{7\pi}{8}$

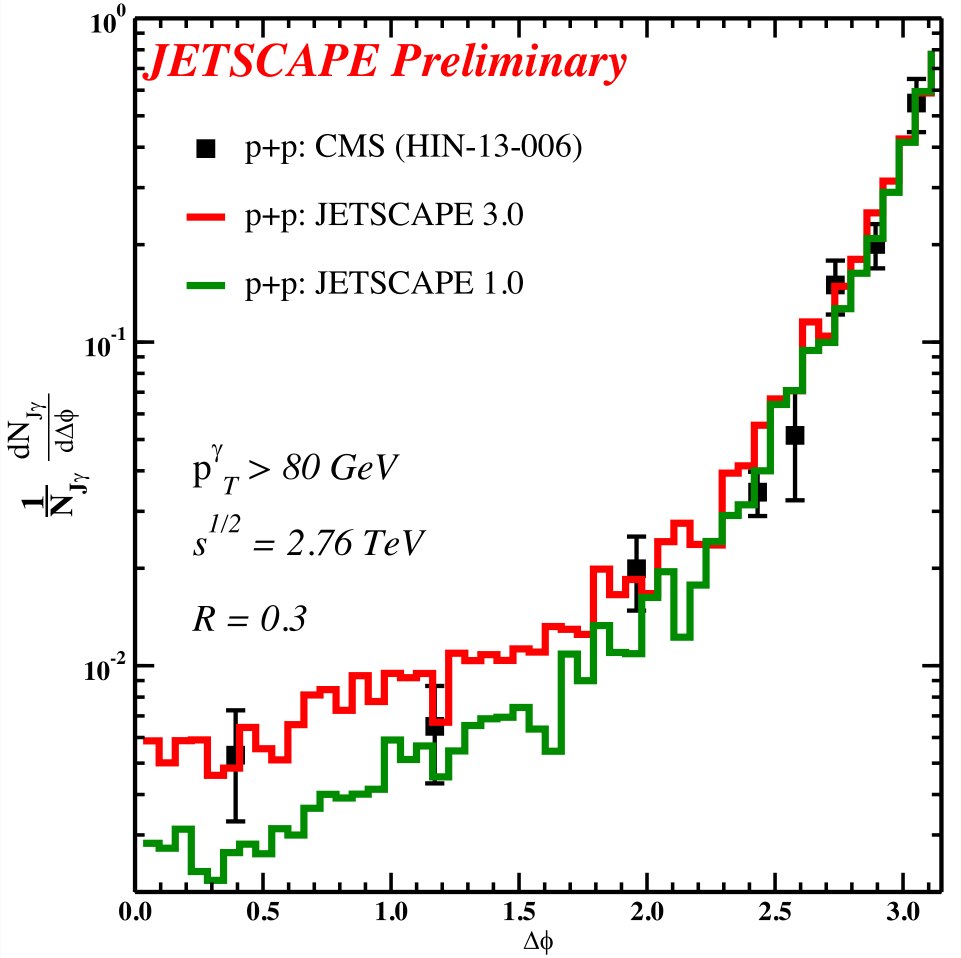
Isolation cut (E < 5 GeV) $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$

JETSCAPE 3.0

Photons: p-p 2.76 TeV

Gamma-Jet Azimuthal correlation





JETSCAPE 3.0

$\Delta\phi = |\phi^{jet} - \phi^{\gamma}|$

$p_T^{jet} > 30\ GeV$

$|\eta_\gamma| < 1.44$

$|\eta_{jet}| < 1.6$

Isolation cut (E < 5 GeV)

$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$

Photons: p-p 5.02 TeV

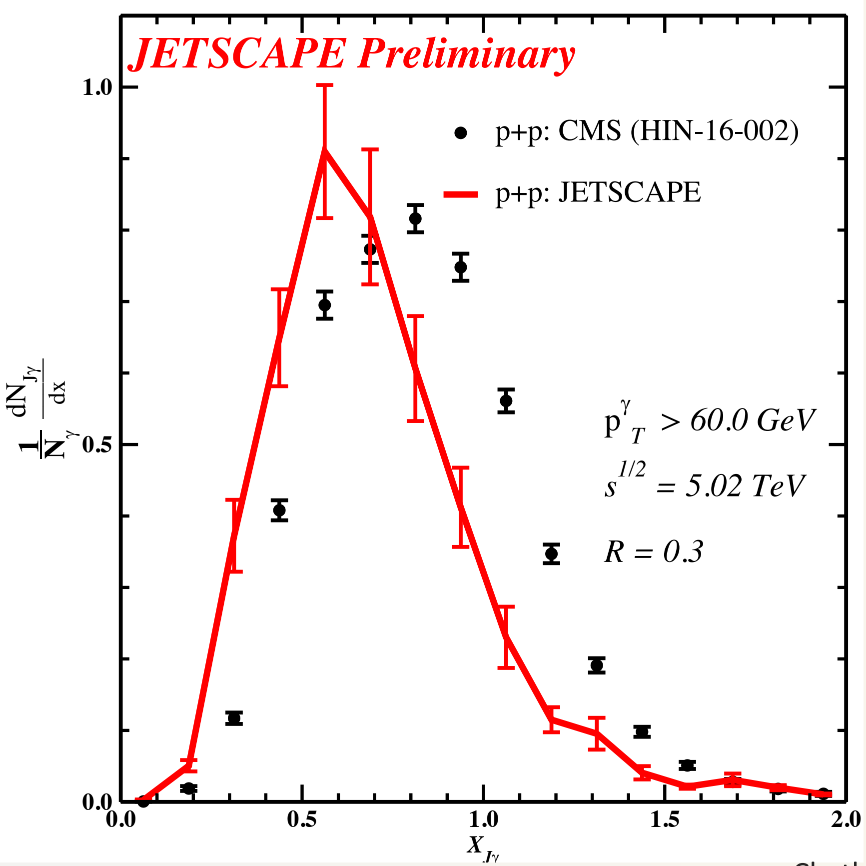
Gamma-Jet transverse momentum imbalance (Gamma-Jet Asymmetry)

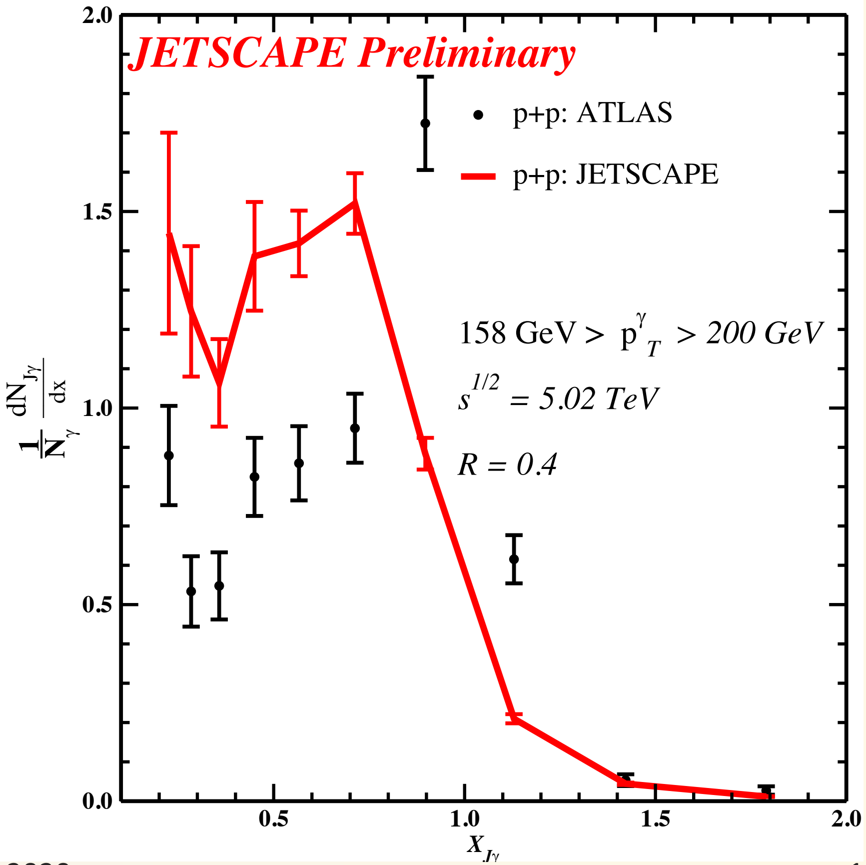
$p_T^{jet} > 30\ GeV,\ |\eta_\gamma| < 1.44,\ |\eta_{jet}| < 1.6, |\Delta\phi| > \frac{7\pi}{8}$

Isolation cut (E < 5 GeV) $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$

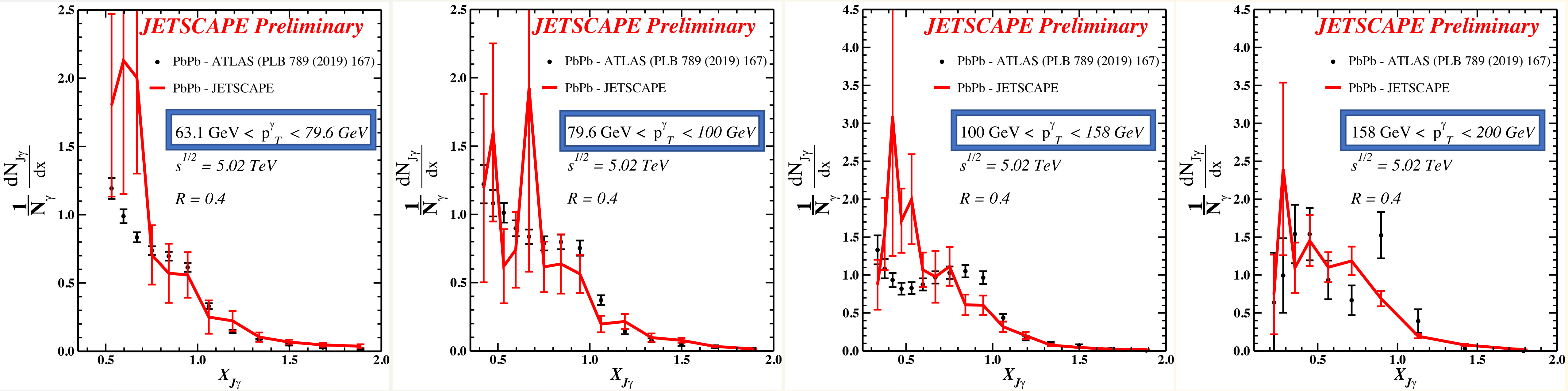
$p_T^{jet} > 31.6\ GeV;\ \ |\eta_\gamma| < 2.37$ (excluding the region $1.37 < |\eta_\gamma| < 1.52$); $|\eta_{Jet}| < 2.8, |\Delta\phi| > \frac{7\pi}{8}$

Isolation cut (E < 3 GeV) $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.3$





Photons: Pb-Pb 5.02 TeV



Gamma-Jet transverse momentum imbalance (Gamma-Jet Asymmetry)

$p_T^{jet} > 31.6\ GeV;\quad |\eta_\gamma| < 2.37$ (excluding the region $1.37 < |\eta_\gamma| < 1.52$); $\quad |\eta_{Jet}| < 2.8, |\Delta\phi| > \frac{7\pi}{8}$

Isolation cut (E < 8 GeV) $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.3$

Summary and Future directions

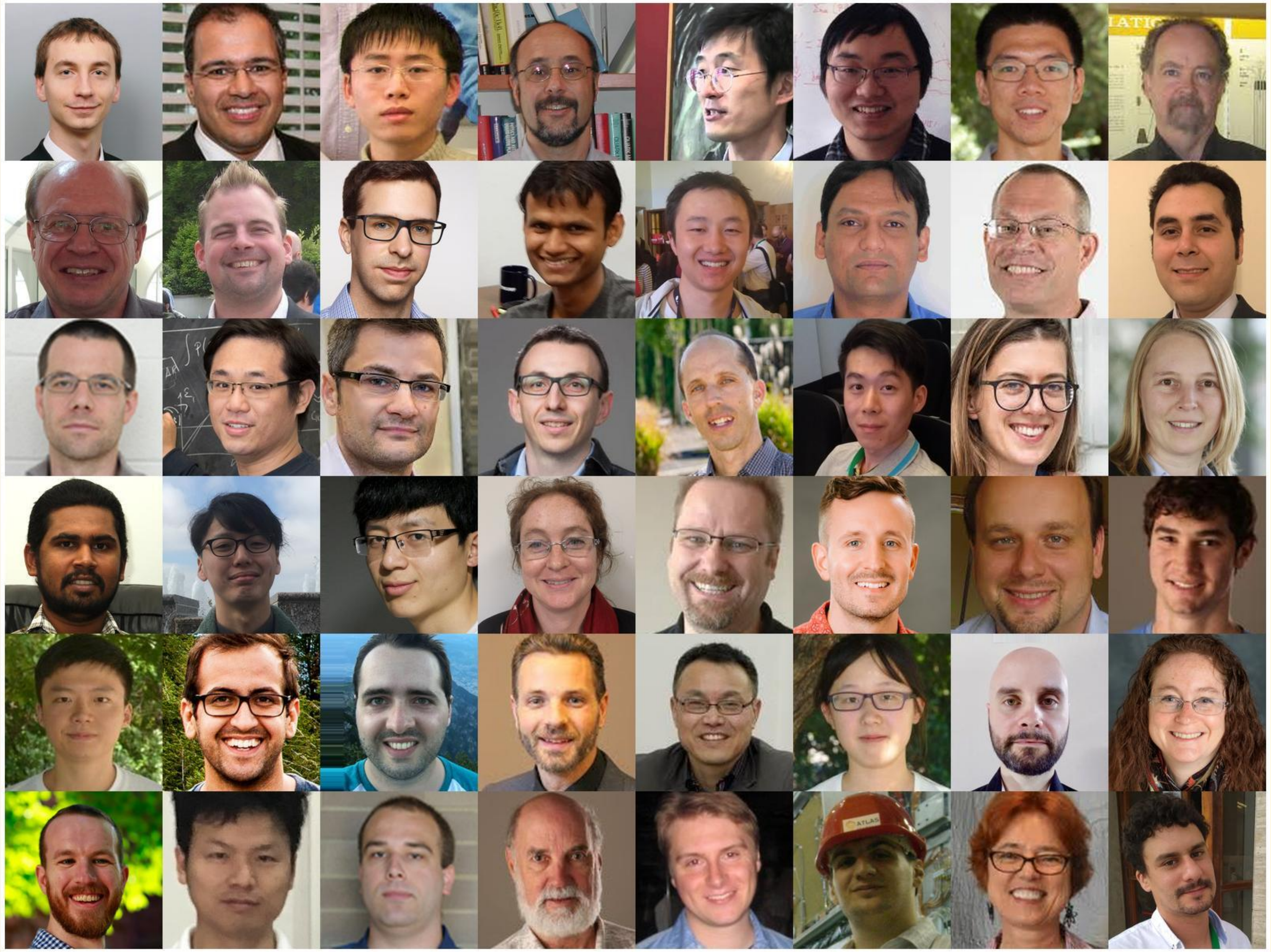
- JETSCAPE is a general, modular and extensive framework that can be used to simulate heavy ion collisions
- Multi-stage evolution can describe all the stages of jet evolution significantly better than single module evolution
- JETSCAPE can describe most of the observables by using the same set of parameters for different center of mass energy
- Photon observables - an independent, parameter free verification of the multistage evolution

- Further examination on pp results at 5.02TeV
- Pb-Pb analysis with higher statistics (5.02 TeV and 2.76 TeV) using JETSCAPE 3.0
- Include more physics in our simulations
- More photon observables to better understand the limits of these module combinations

The JETSCAPE Collaboration

Presentations from JETSCAPE collaboration

- Chanwook Park: Constraints on jet quenching from a multi-stage energy-loss approach (ID #163, in track "Jets and High Momentum Hadrons", Wednesday)
- Michael Cordell: First Results from Hybrid Hadronization in Small and Large Systems (ID #161, in track "Jets and High Momentum Hadrons", Thursday)
- Wenkai Fan: Probing the multi-scale dynamical interaction between heavy quarks and the QGP using JETSCAPE (ID #160, in track "Heavy Flavor and Quarkonia", Tuesday)

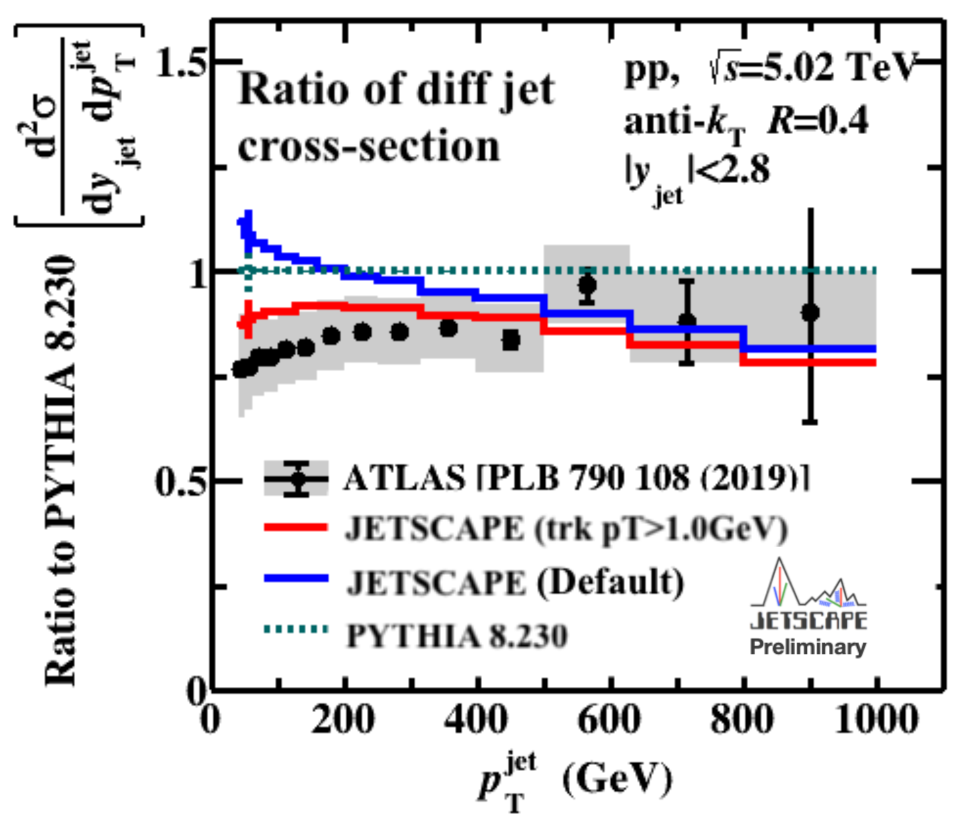


Thank You

JETSCAPE

Backup

Soft background contribution to jet spectrum



- All inclusive jets – Discrepancy at lower p_T region
- Still working on to resolve this issue
- After removing soft hadrons – Good agreement with experimental results