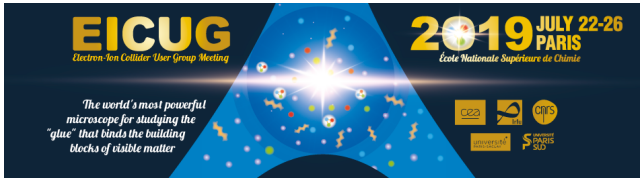
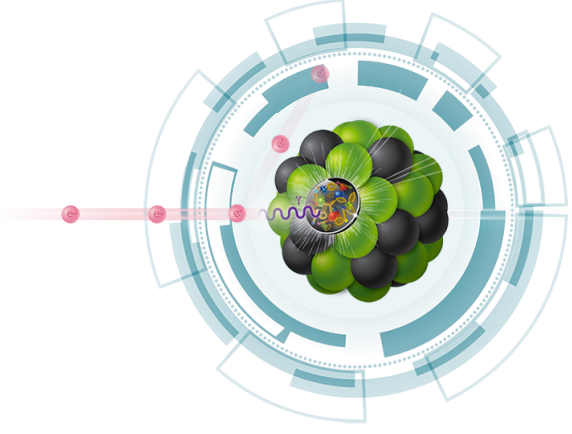


Using JETSCAPE to Simulate Jets at an EIC

Kolja Kauder

(not on behalf of)



JETSCAPE

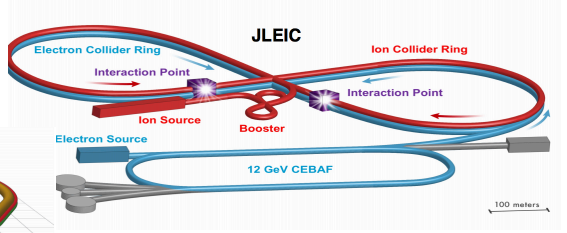
Center for Frontiers in Nuclear Science

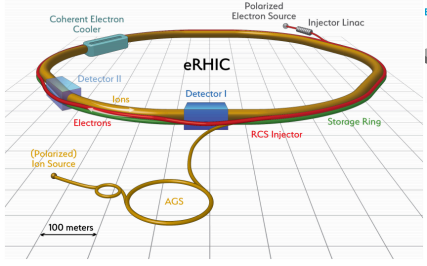
BROOKHAVEN NATIONAL LABORATORY

The eA MC Landscape

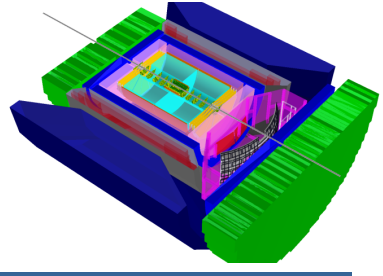
- BeAGLE not yet publicly released
- Omitting specialized MCs, there are more prospects but not many

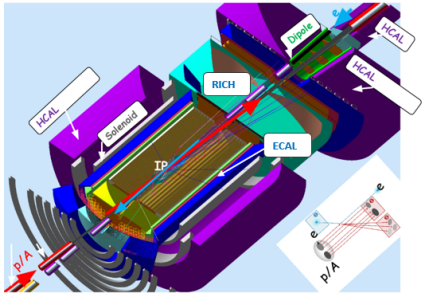
The Need for MC



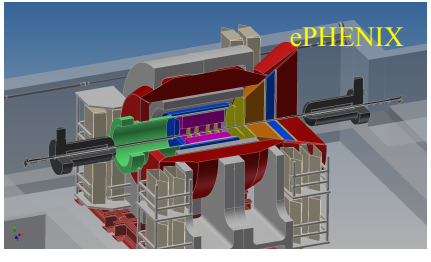


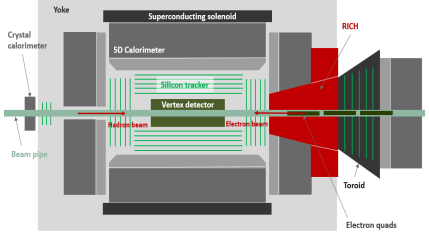
"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction"
2015 LRP





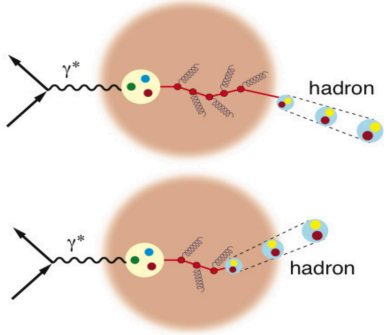
"To realize fully the scientific opportunities an EIC would enable, a theory program will be required to predict and interpret the experimental results within the context of QCD, and furthermore, to glean the fundamental insights into QCD that an EIC can reveal."
NAS Report

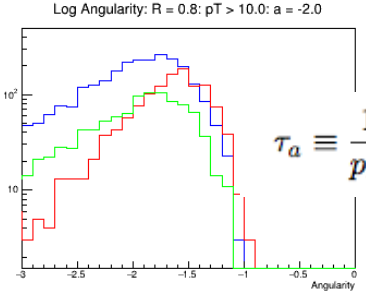




We need to know where to look

Jets beyond σ

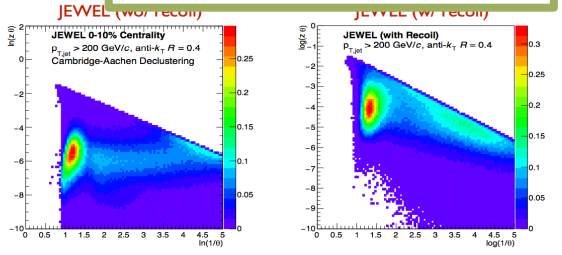


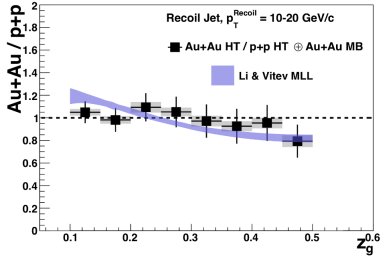


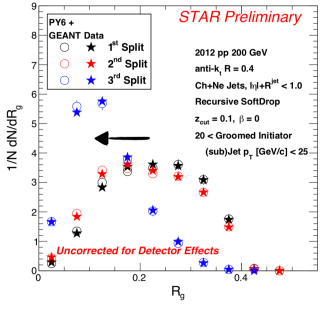
$$\tau_a \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i \left(\Delta \mathcal{R}_{iJ}\right)^{2-a}$$

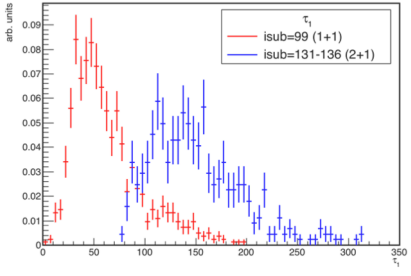
Angularity family (B. Page)

De-clustered (groomed) observables









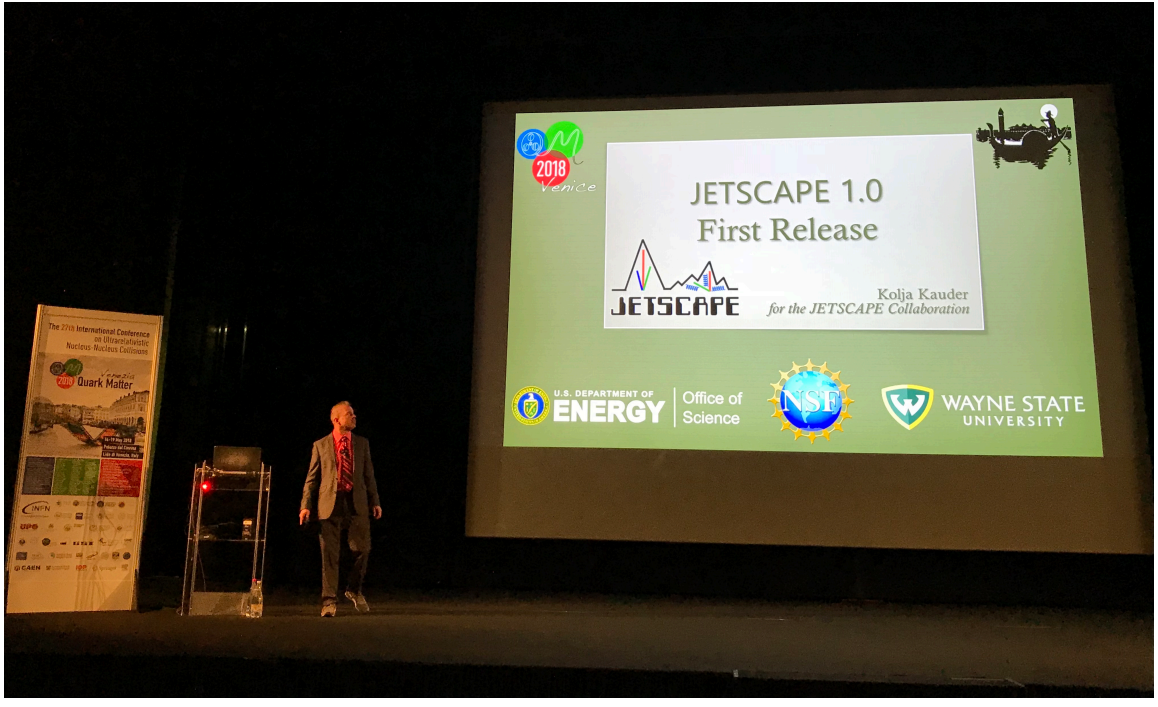
N-(Sub)jettiness

My own goal:

- Explore signatures of jet sub-structure modification in eA
  → need modification predictions

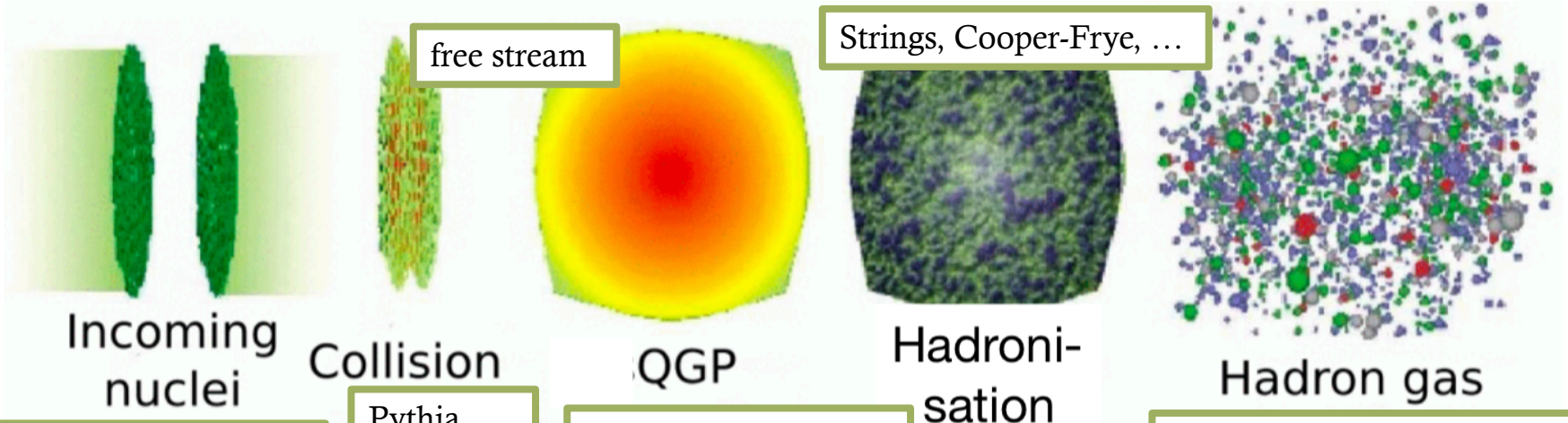
… and what to look for

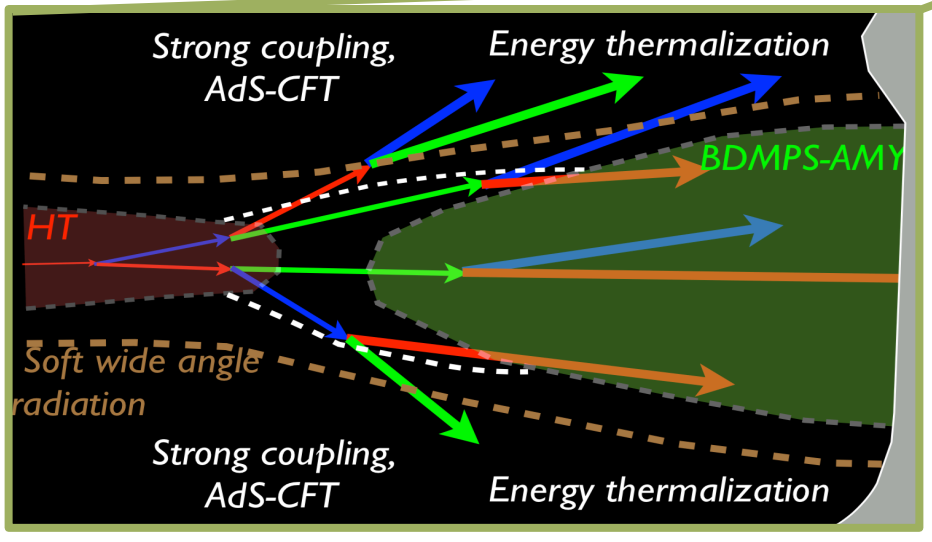
That is to say, I'm not a Theorist or MC Expert



But I play one on TV!

KK [nucl-th]
arXiv:1807.09615





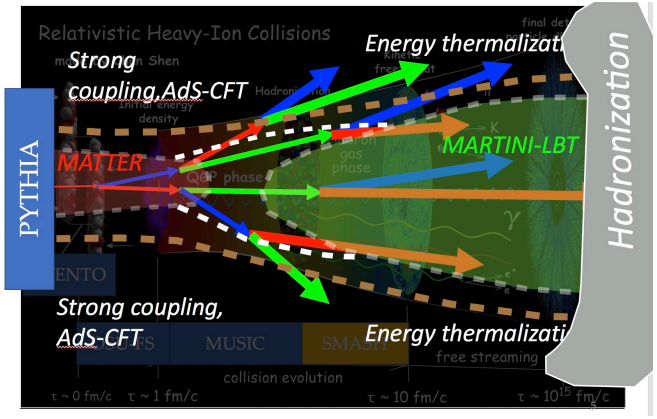
- Experts at every stage
- Multi-Stage Energy Loss
- … no one group can do it all

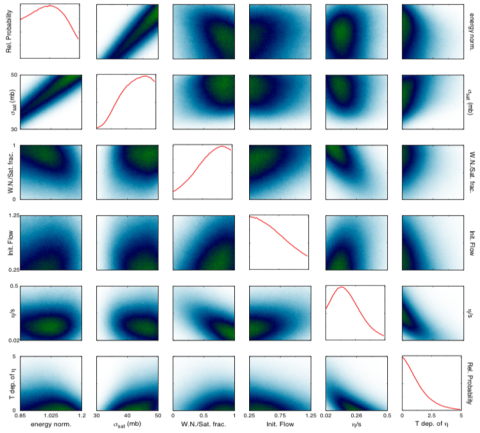
→ Unify in JETSCAPE

A. Majumder, Hard Probes '15

A. Majumder, JETSCAPE Users Meeting 2019

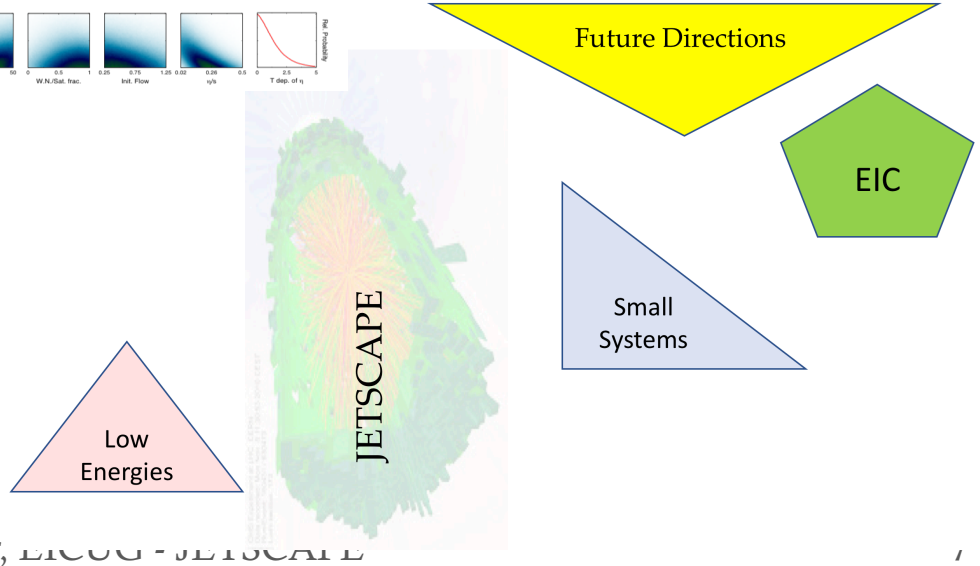
Status



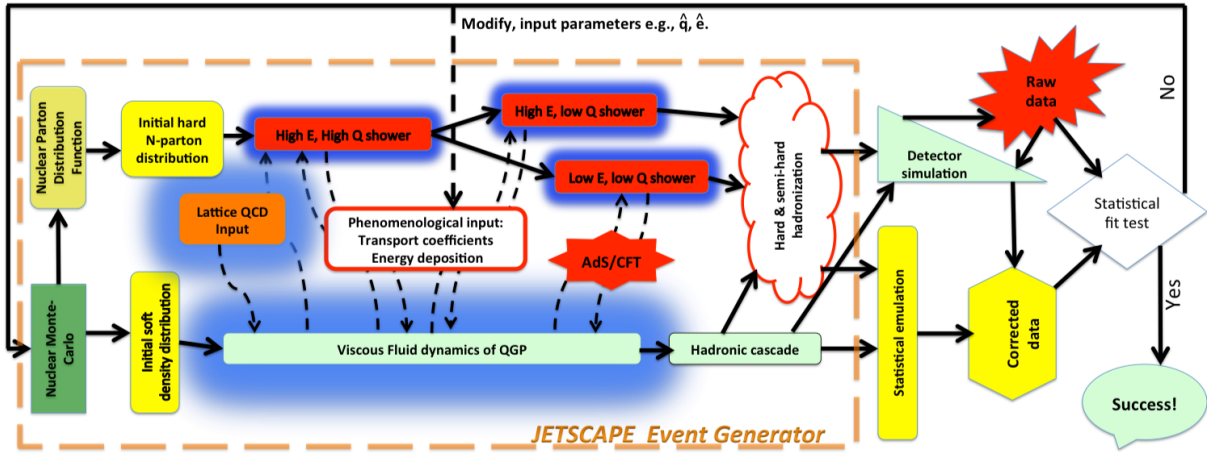


- Year 1: Refactor existing code in C++
  - hydro and e-loss codes applied separately.
  - Add LBT + AdS/CFT
  - *start designing framework,*
  - *start designing jet-STAT model*
- Year 2: E-loss codes applied in tandem.
  - Start combining MATTER+MARTINI + LBT + AdS/CFT
  - Port code to GPU, MIC Hard Heavy-Quarks
  - *Mid scale runs on XSEDE, tuning the framework carried out.*
  - *STAT analysis completed.* Hard Photons
  - *Code released*
- Year 3: Full physics incorporation
  - MATTER+MARTINI + LBT + AdS/CFT as default
  - Energy deposition included
  - Code available in CPU, MIC, GPU versions.
  - *Code released, STAT routines released,*

- v2.0 released June 28
- Collaboration interest in small systems and EIC for the next funding round

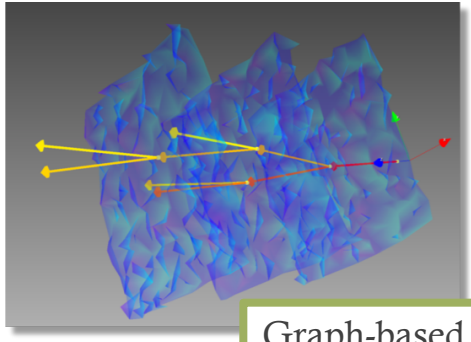


Scope



Large collaboration of ex and th physicists, computer scientists, statisticians.

Manual: J Putschke, KK, + 43
arXiv:1903:0771906

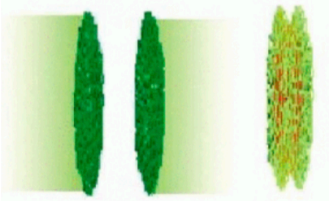


Graph-based internal shower format

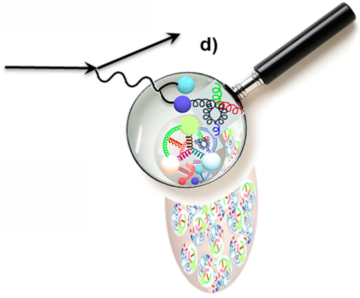
- Extensive, extensible event generator
  - Modular. Self-contained. State-of-the-art.
- Agnostic to "multi-stage", "energy loss"
- Task-based, Signals/Slots, C++11, …

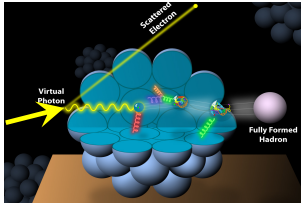
→ *Extend (and subtract) to e+A collisions*

Initial Stage

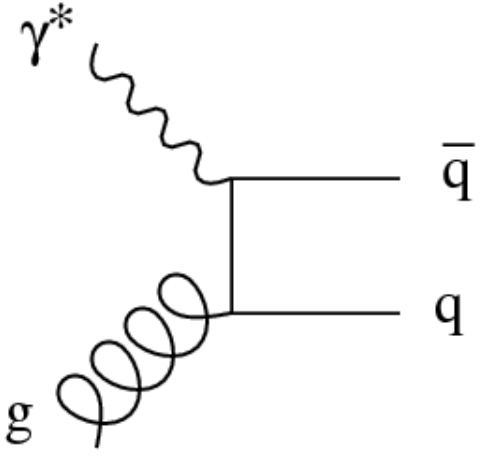


- Start with collision at origin
  - Future:
  - Nucleus model
  - Separate radiative correction?

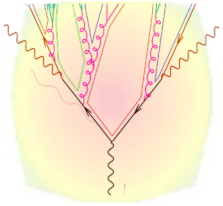




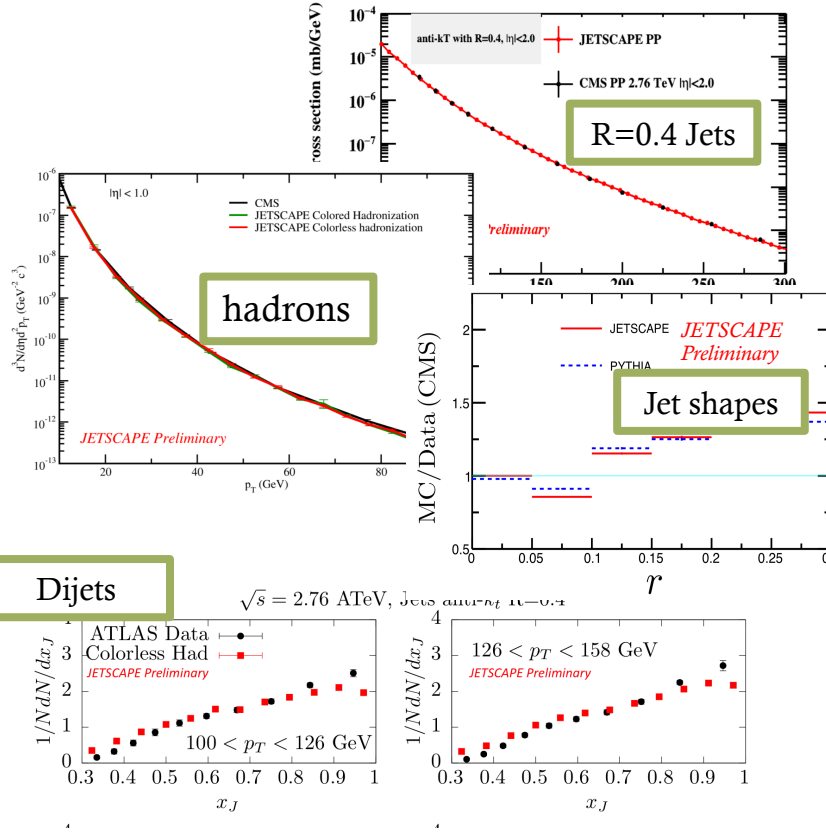
- Currently: hard scattering from tuned Pythia6
  - Can select PDF in generator
  - Future:
  - Full process list (currently just PGF etc.)
  - Herwig, Sherpa, …



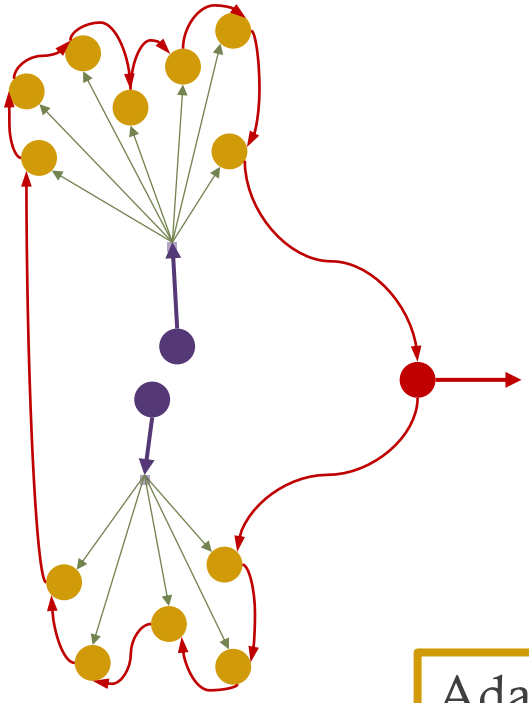
Shower



- Vacuum fragmentation with MATTER and `qhat = 0`
  - Based on Pythia6
  - Individual showers are generated for all "hard" partons and underlying event hadrons
  - Virtuality regenerated before shower
- Tuned to mid-η at LHC energies, demonstrated excellent agreement
- E-loss options: MATTER, AdS/CFT, MARTINI, LBT



Hadronization Options



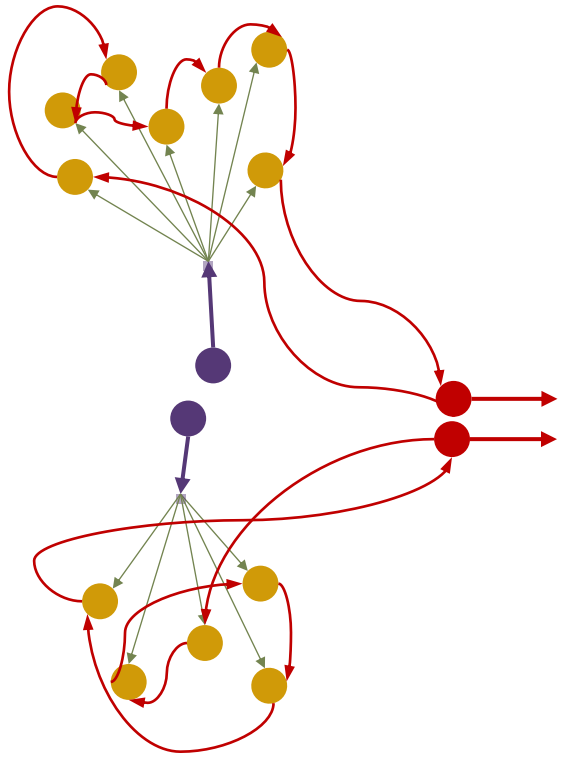
“Colorless”:

- All showers hadronize together
- Intended for situations where color information is not maintained in E-loss module
- One parton down the beam pipe closes the loop
- Then hand off to Pythia8

Adaptions:

- Use true remnant kinematics

Hadronization Options



“Colored”:

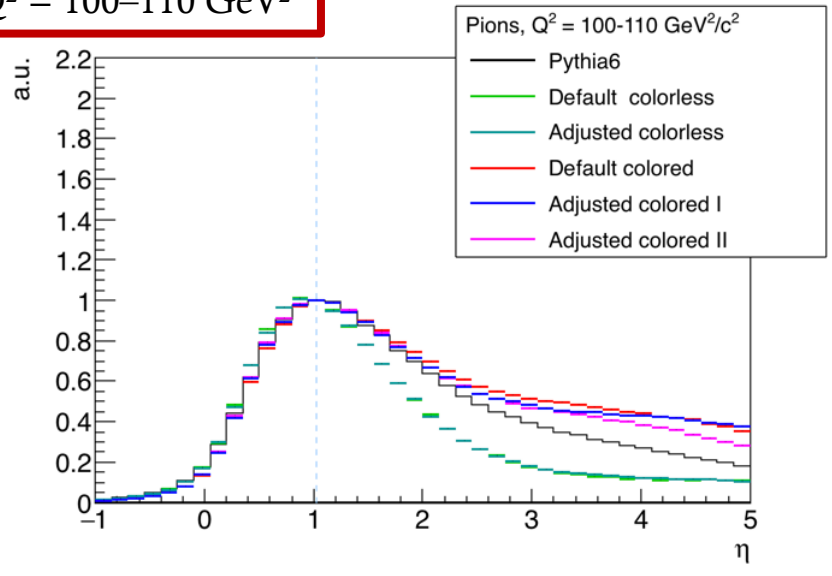
- Showers hadronize individually
- One beam parton closes each loop
- +/- η assigned interchangingly
- Then hand off to Pythia8

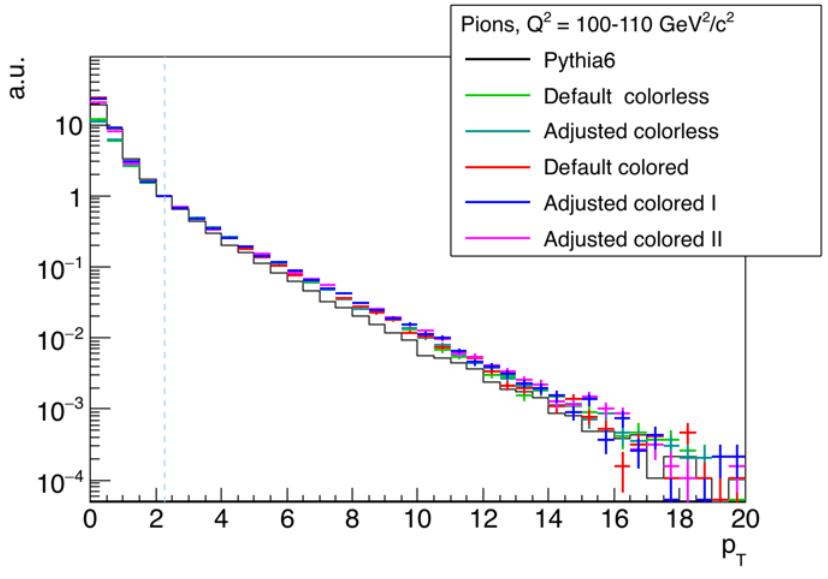
Adaptions:

- Ensure forward remnant
- Use true remnant kinematics
- Re-distribute remnant momentum among showers

Pions after Hadronization

Q^2 = 100–110 GeV^2



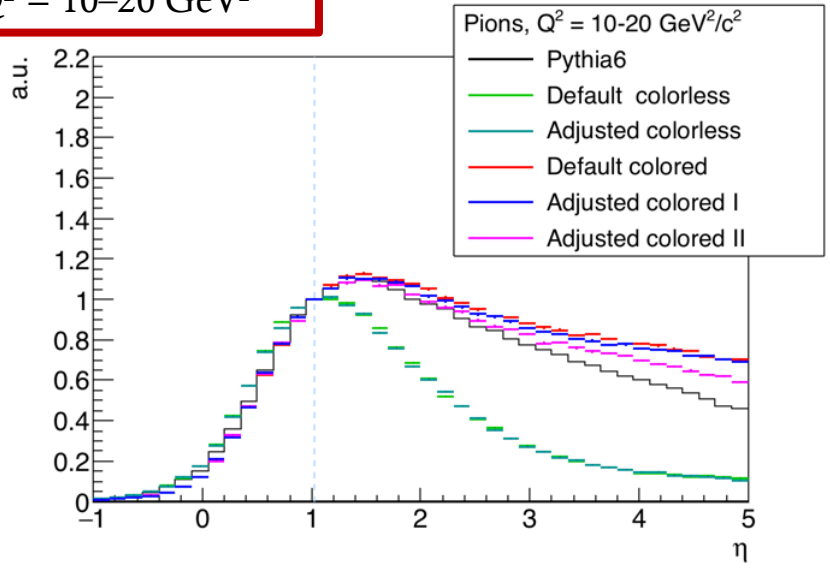


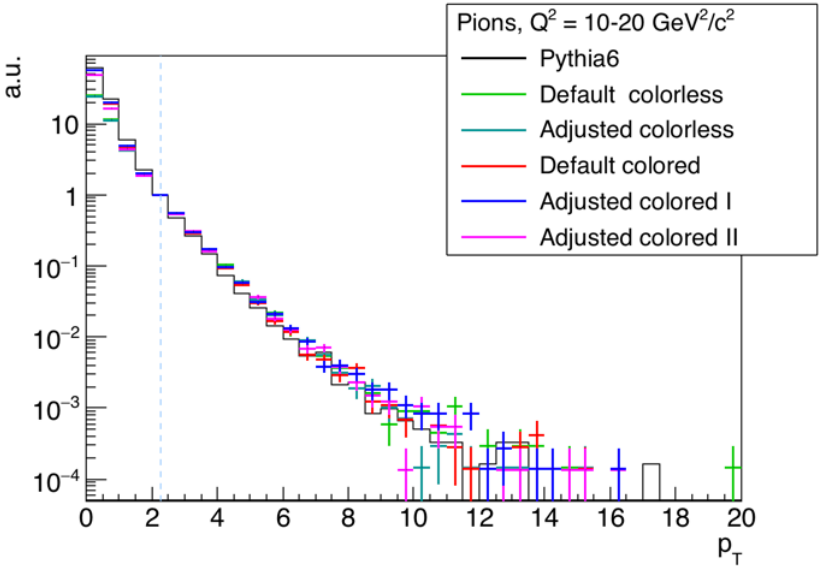
- Colorless: Forward and low-p_T discrepancies, irrespective of remnant adjustments
- Colored: Overshoots forward production, improved by better kinematics
- Similar above 2 GeV/c, harder than Pythia around 10 GeV/c

20 on 250 GeV e+P
Breit Frame

Pions after Hadronization

Q^2 = 10–20 GeV^2





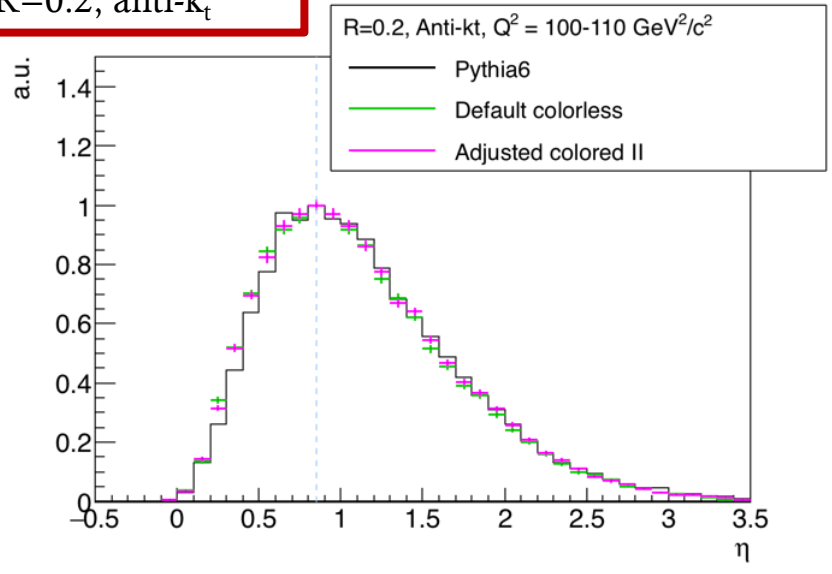
Lower Q^2:

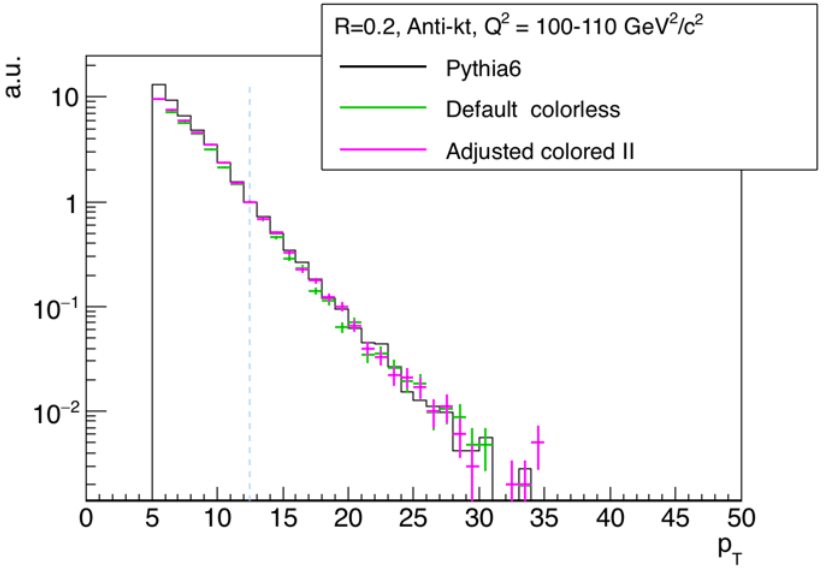
- Same trends, but colorless farther and colored closer
- Both harder than Pythia around 5 GeV/c

20 on 250 GeV e+P
Breit Frame

Small Jets

R=0.2, anti-k_t

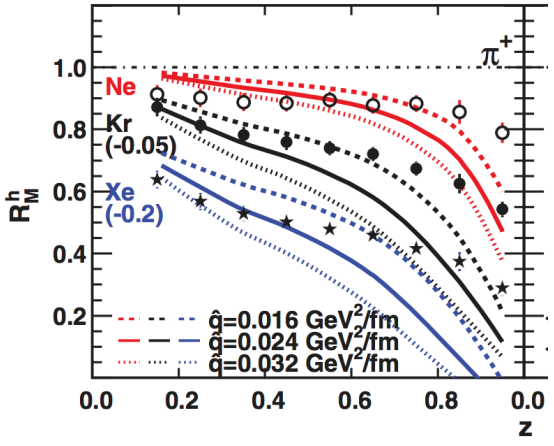


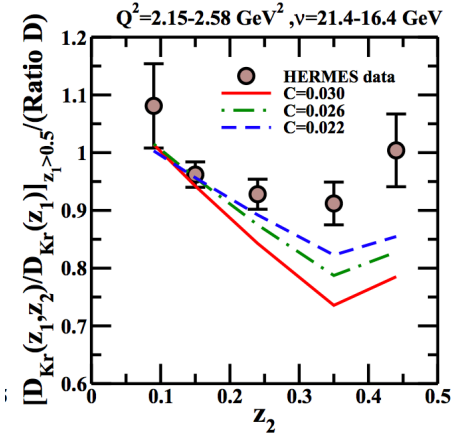


- Good agreement even for rather small jets
- Hint at pion fraction difference in hadronization?

20 on 250 GeV e+P
Breit Frame
Q^2 = 100–110 GeV^2

Near Future



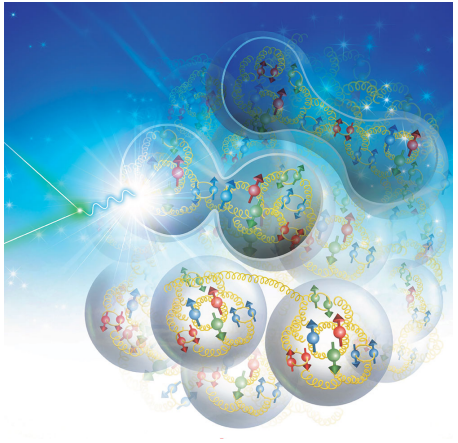


- Recreate existing qhat calculations for HERMES data
- More tuning

Deng, Wang - PRC 81, 024902 (2010)
Majumder, Wang - arXiv:0806.2653

Medium and modification

- Have Glauber nucleon distribution
- Soliciting nuclear medium specifications and model proposals



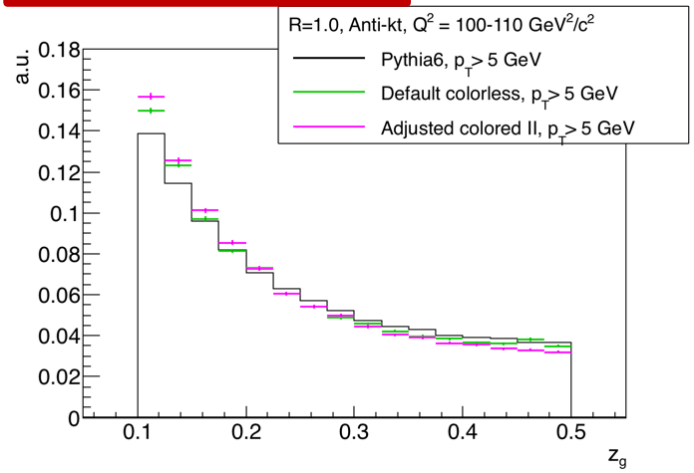
Summary and Outlook

- JETSCAPE: candidate for general e+A MC with unique strengths
- e+P baseline:
  - Hadronization done → further improvements out of scope
  - Hard process generation → include all processes
  - Infrastructure mostly done → some fine polish needed (e.g., $\mathbb{P}$)
  - Next: Include into official distribution, fine-tune & validate
- e+A
  - Switch to E-loss modules in principle trivial, works
  - Next: tuning (e.g., HERMES) and attract users!

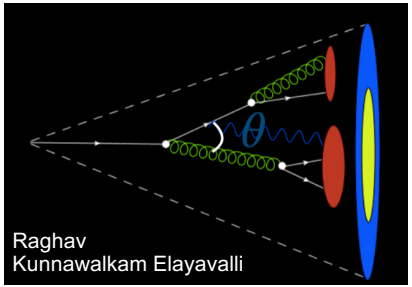
Backup

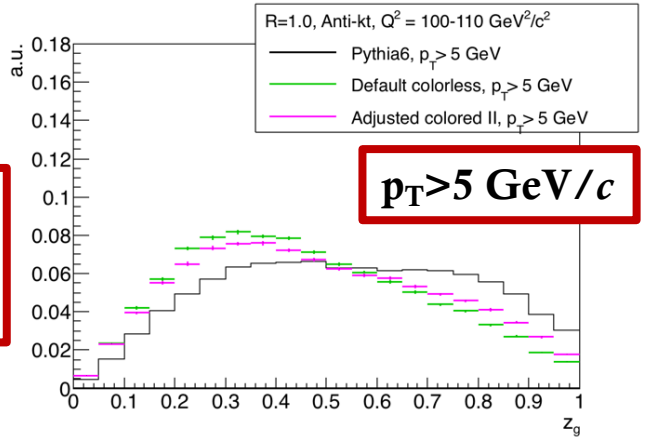
Substructure

z_g ~ "Hardest Split"
p_T>5 GeV/c
Good shape!

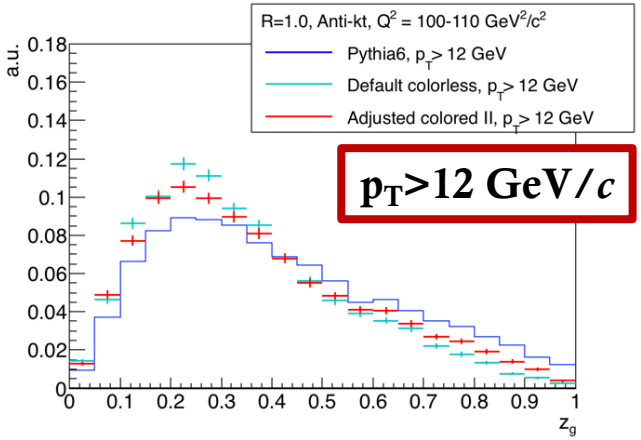


R_g ~ "Angle between hard prongs"
good p_T dependence





p_T>5 GeV/c



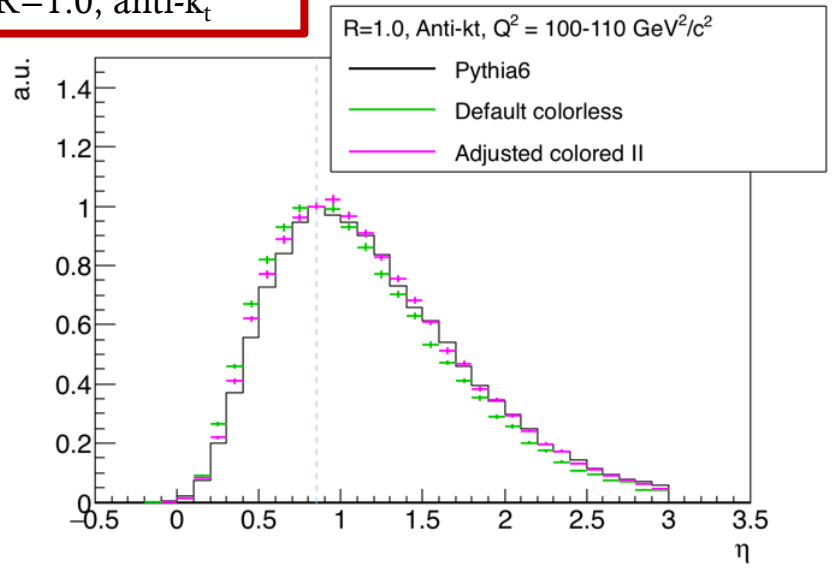
p_T>12 GeV/c

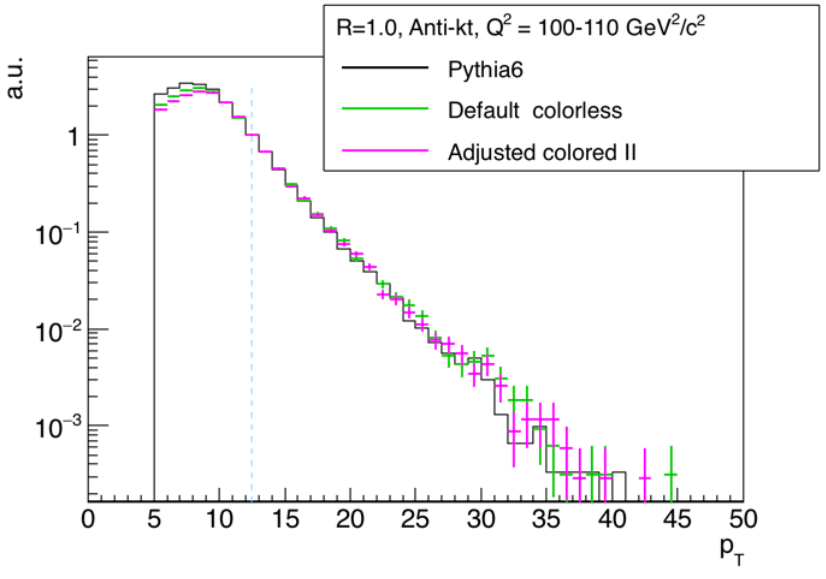
- More pronounced deviation from Pythia6
- Small sensitivity to hadronization details
- Promising first look at very low jet p_T

20 on 250 GeV e+P
Breit Frame
Q^2 = 100–110 GeV^2
R=1.0, anti-k_t

Jets

R=1.0, anti-k_t





- Pions tell the story – but differences are mitigated by large *R* and η cuts
- Note: Constituent cuts in Breit frame – not realistic but helpful for testing

20 on 250 GeV e+P
Breit Frame
Q^2 = 100–110 GeV²