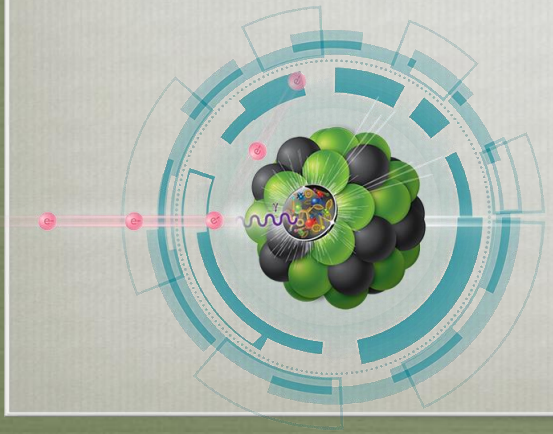
DIS 2019 TORINO 8-12 April

Using JETSCAPE to Simulate Jets at an EIC

Kolja Kauder

(not on behalf of)

JETSCAPE



U.S. DEPARTMENT OF ENERGY | Office of Science

Center for Frontiers in Nuclear Science

BROOKHAVEN NATIONAL LABORATORY

MCEGs in eP

Slide from Ilkka Helenius

Herwig
Traditional focus on showers, Qtilde and Dipoles shower, cluster hadronization model, NLO matching and merging.

Pythia
Sophisticated soft physics, pt-ordered, DIRE and Vincia shower, string hadronization, NLO merging using event files.

Sherpa
Focus on perturbative improvements, CS and DIRE shower, cluster or string hadronization, NLO matching and merging.

Slide from Simon Plätzer

DIS 2019 TORINO 8-12 April

SHERPA
- DIS with ME corrections and PS merging
- Good description of jet data at low Q^2 with $\gtrsim 3$ partons in the final state
- Automated NLO matching with POWHEG method, applicable for jets at high-Q^2

HERWIG
- Two shower options with spin correlations and NLO matching
- Good description for single-particle properties in DIS
- Also QED radiation for angular-ordered shower

PYTHIA
- Possible to generate DIS events with the new dipole shower implementation
- Higher-order corrections via DIRE plugin, soon part of PYTHIA core
- Photoproduction for hard and soft QCD processes, also hard diffraction

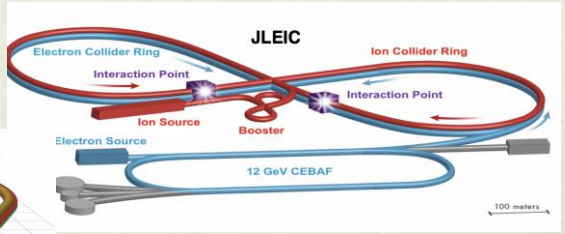
MCEGs for future ep and eA facilities

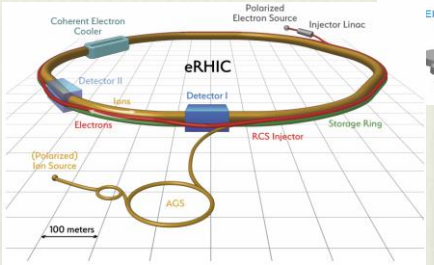
- "Multi-purpose event generators: tremendous development in recent years."
- Thriving community beyond the Big Three

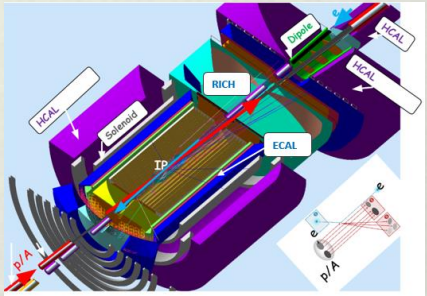
The eA Landscape

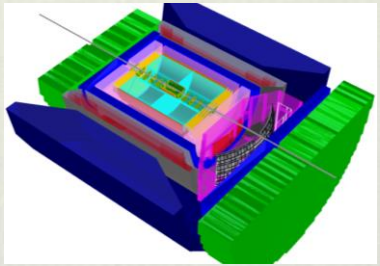
- BeAGLE not yet publicly released
- Omitting specialized MCs, there are more prospects but not many

The Need for MC



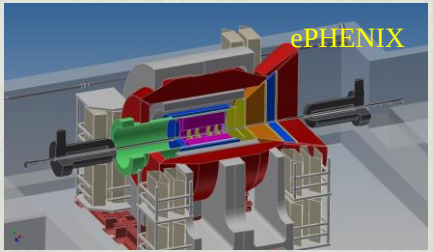


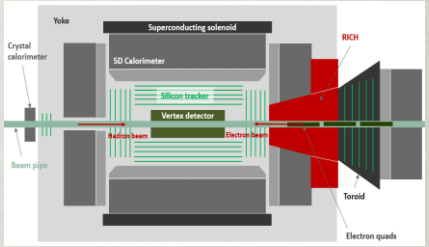




"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction"
2015 LRP

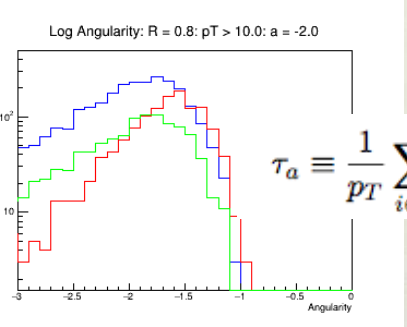
"To realize fully the scientific opportunities an EIC would enable, a theory program will be required to predict and interpret the experimental results within the context of QCD, and furthermore, to glean the fundamental insights into QCD that an EIC can reveal."
NAS Report





We need to know where to look

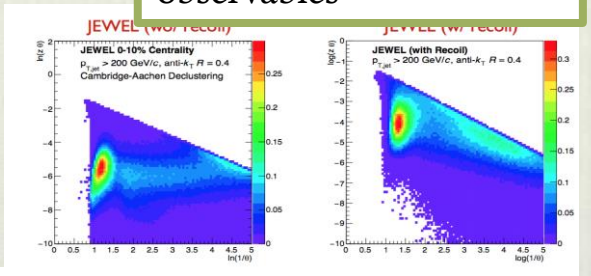
Jets beyond σ

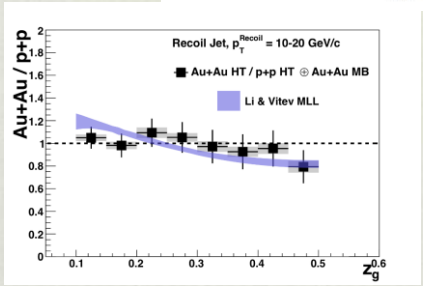


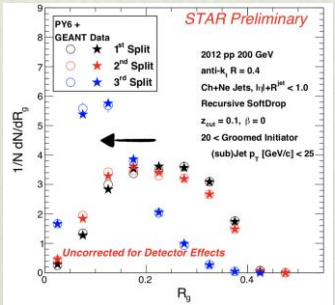
$$\tau_a \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i \left(\Delta \mathcal{R}_{iJ}\right)^{2-a}$$

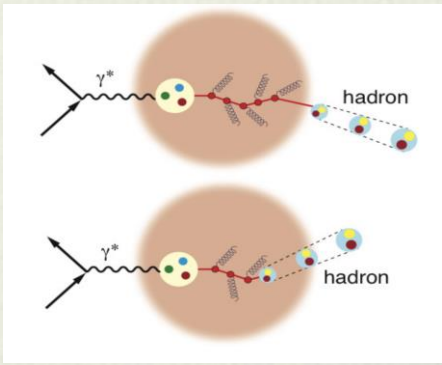
Angularity family (B. Page)

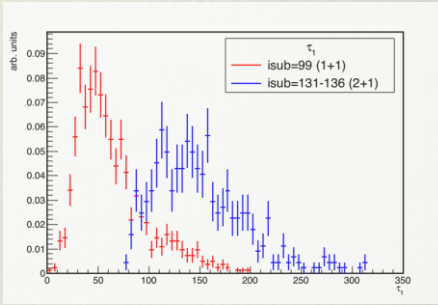
De-clustered (groomed) observables











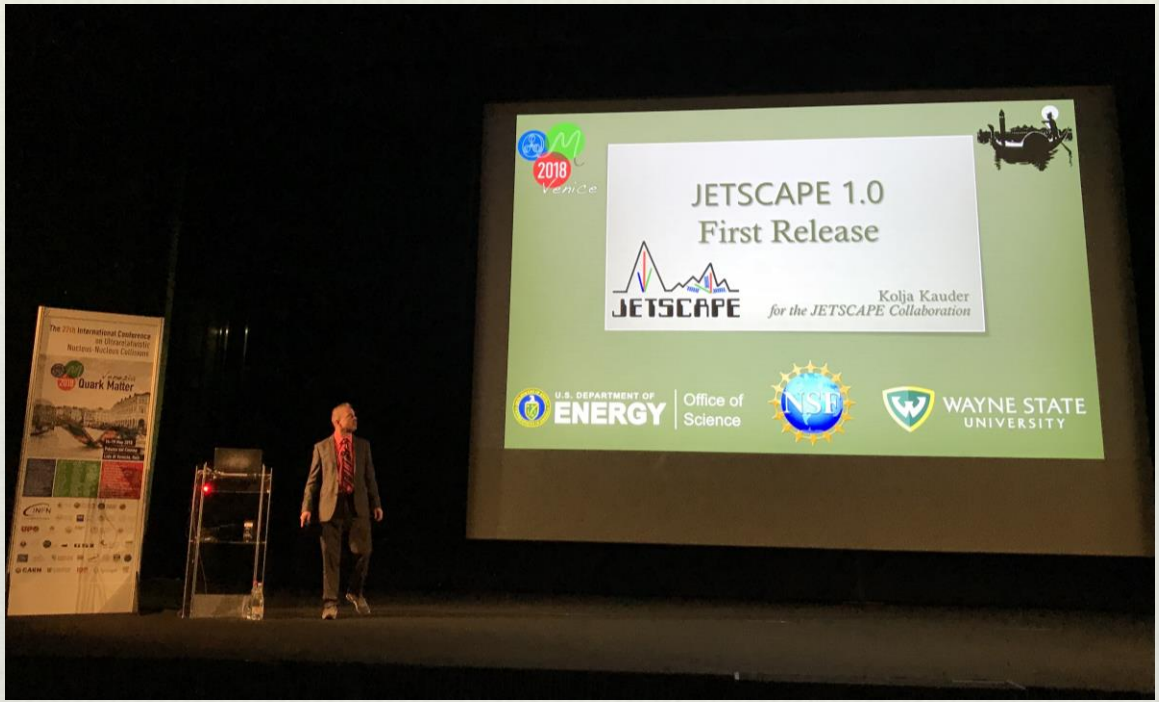
N-(Sub)jettiness

My own goal:

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

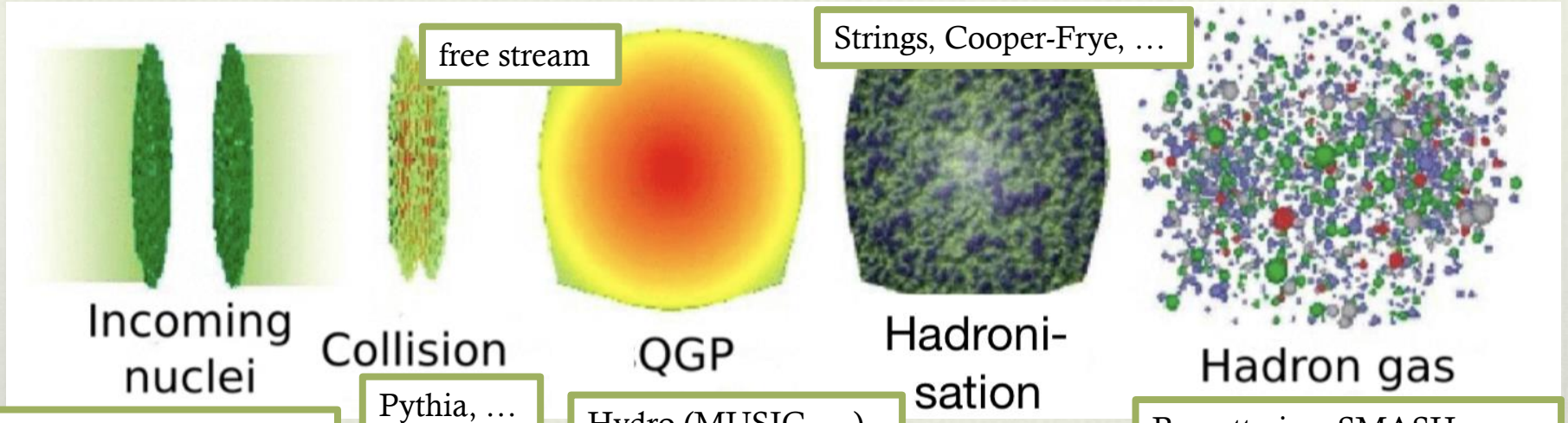
… and what to look for

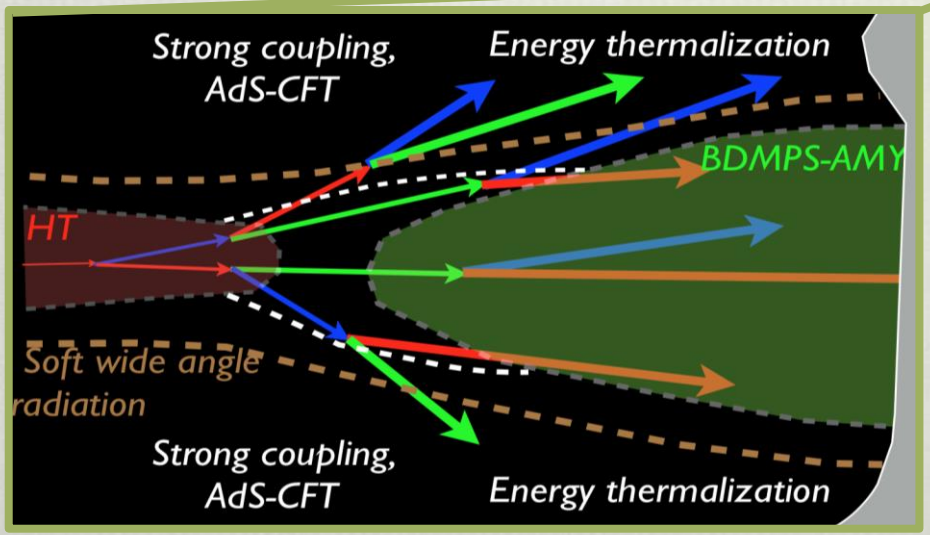
That is to say, I'm not a Theorist or MC Expert



But I play one on TV!

KK [nucl-th]
arXiv:1807.09615



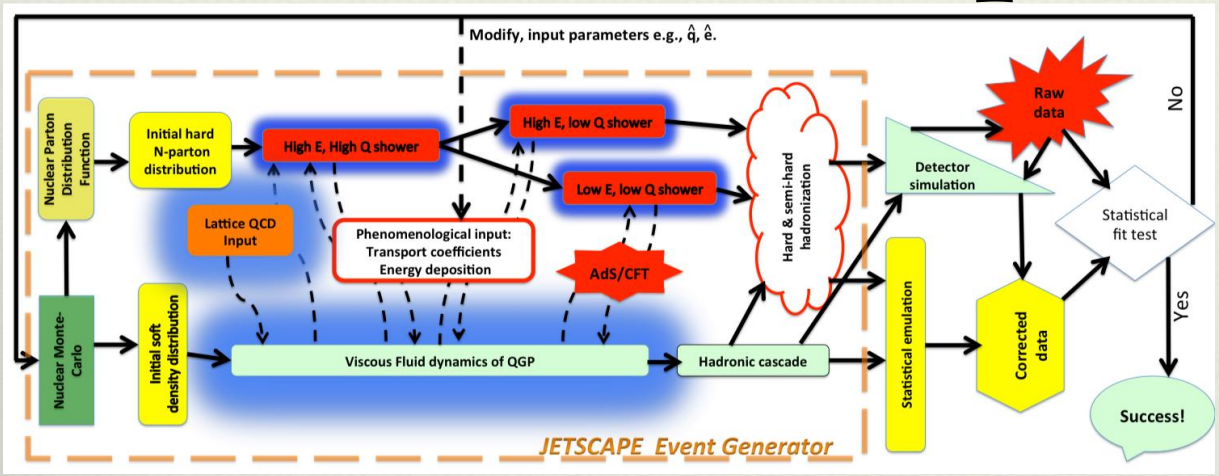


- Experts at every stage
- Multi-Stage Energy Loss
- … no one group can do it all

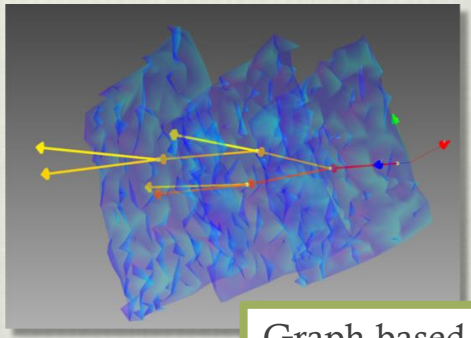
→ Unify in JETSCAPE

A. Majumder, Hard Probes '15

Scope



Theoretical and experimental physicists, computer scientists, statisticians.
Manual: J Putschke, KK, + 43 arXiv:1903:0771906

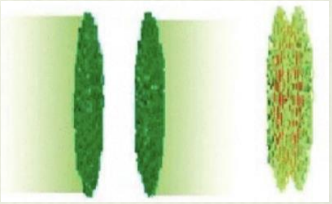


Graph-based internal shower format

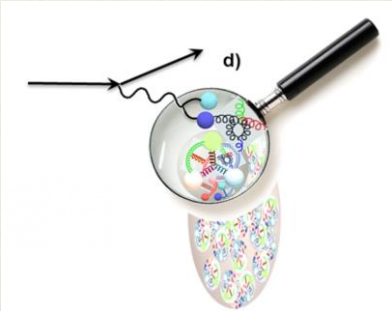
- Extensive, extensible event generator
  - Modular. Self-contained. State-of-the-art.
- Agnostic to "multi-stage", "energy loss"
- Task-based, Signals/Slots, C++11, …

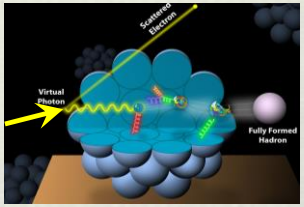
→ *Extend (and subtract) to e+A collisions*

Initial Stage

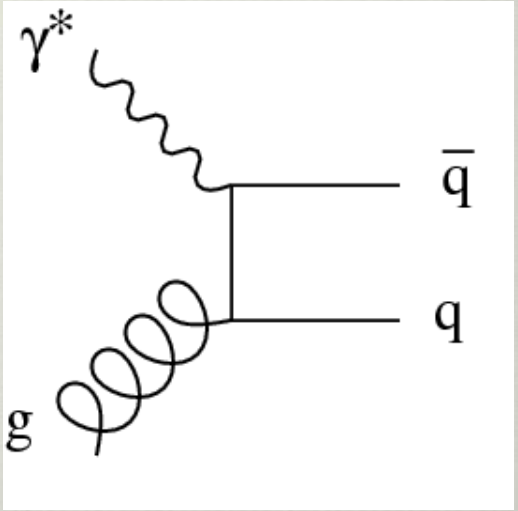


- Start with collision at origin
  - Future:
  - Nucleus model
  - Separate radiative correction?

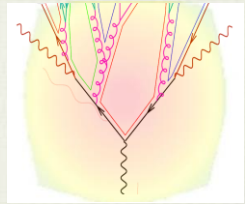




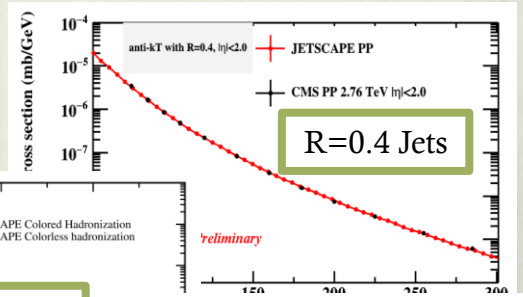
- Currently: hard scattering from tuned Pythia6
  - Can select PDF in generator
  - Future:
  - Full process list (currently just PGF etc.)
  - Herwig, Sherpa, …

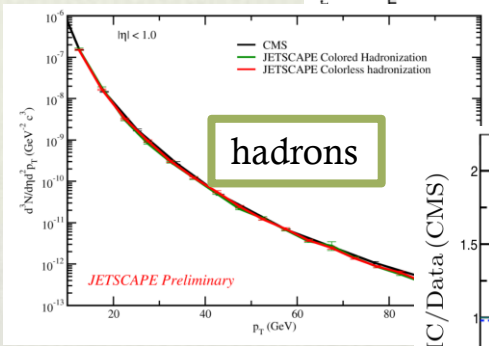


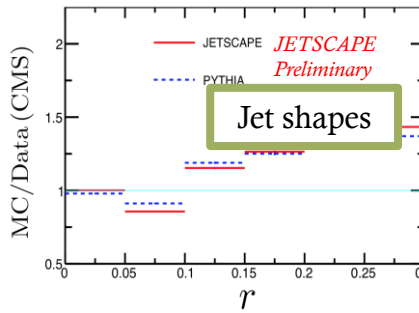
Shower



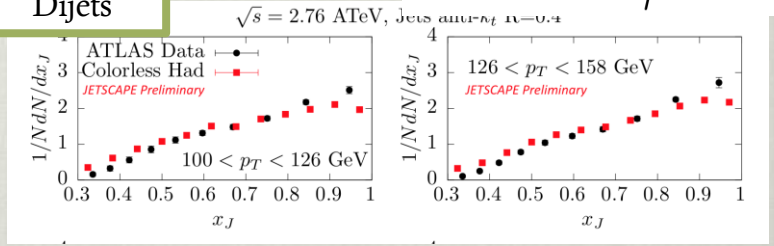
- Vacuum fragmentation with MATTER and `qhat = 0`
  - Based on Pythia6
  - Individual showers are generated for all "hard" partons and underlying event hadrons
  - Virtuality regenerated before shower
- Tuned to mid-η at LHC energies, demonstrated excellent agreement
- E-loss options: MATTER, AdS/CFT,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



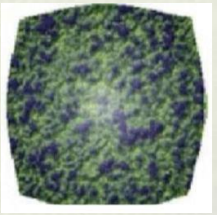


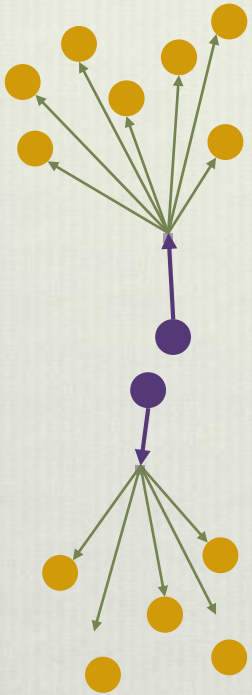


Dijets

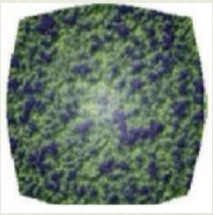


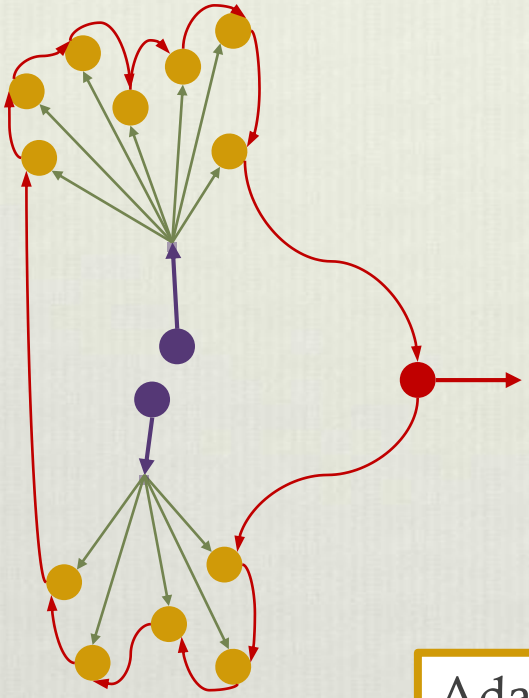
Hadronization Options





Hadronization Options





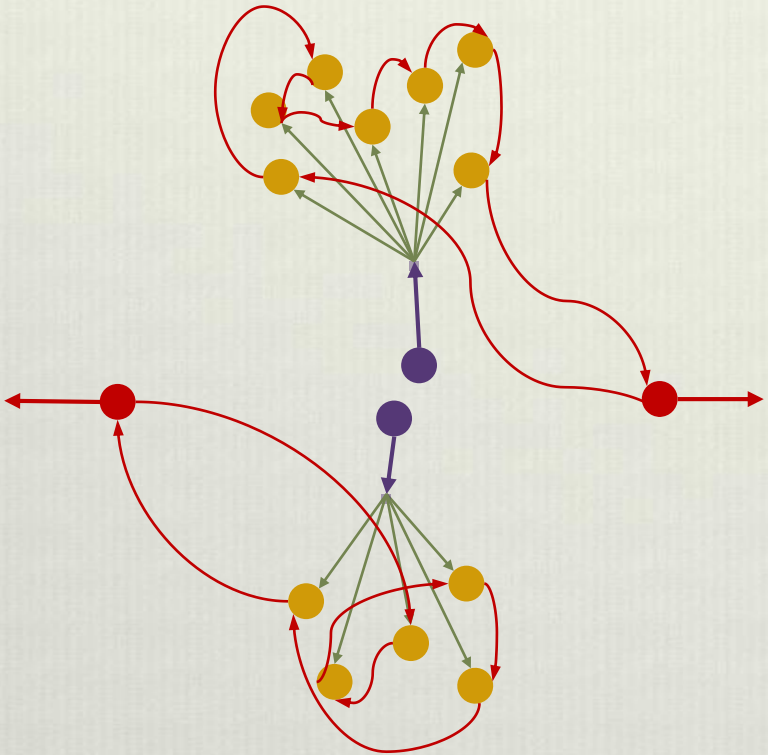
“Colorless”:

- 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

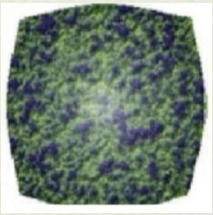
Hadronization Options

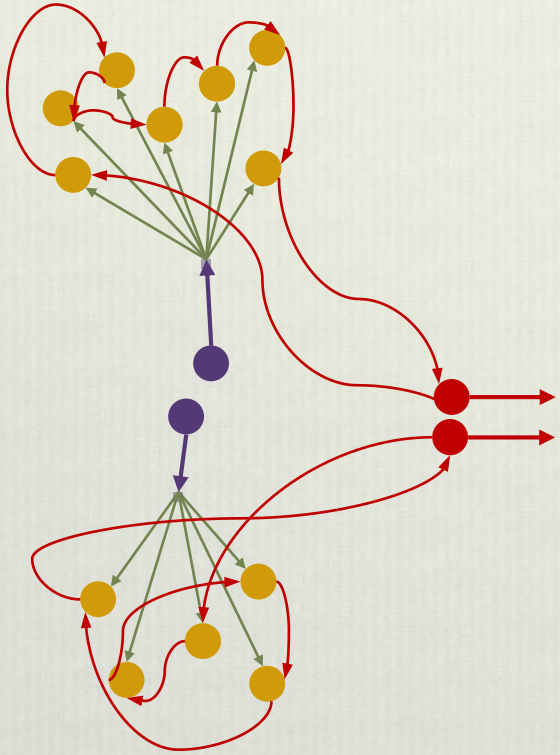


“Colored”:

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

Hadronization Options





“Colored”:

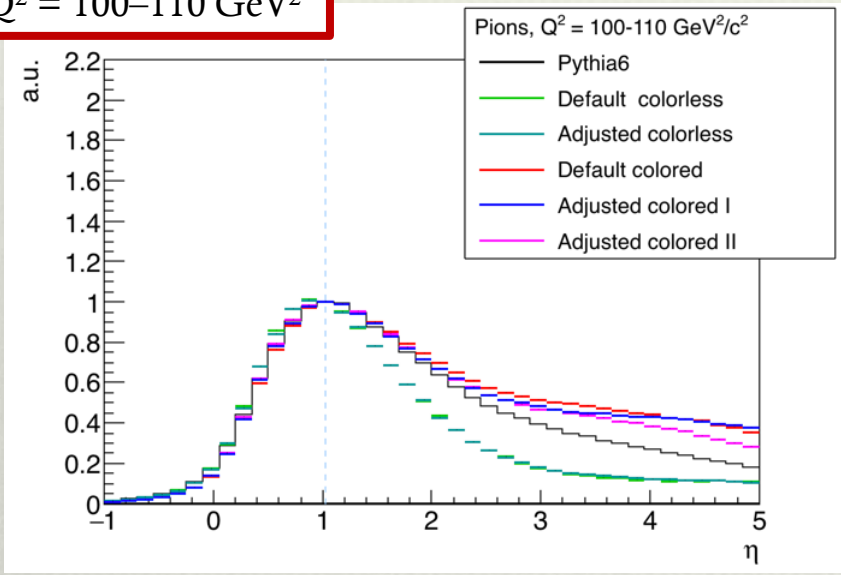
- Showers hadronize individually
- One beam parton closes each loop
- +/- η assigned interchangingly
- Then hand off to Pythia8

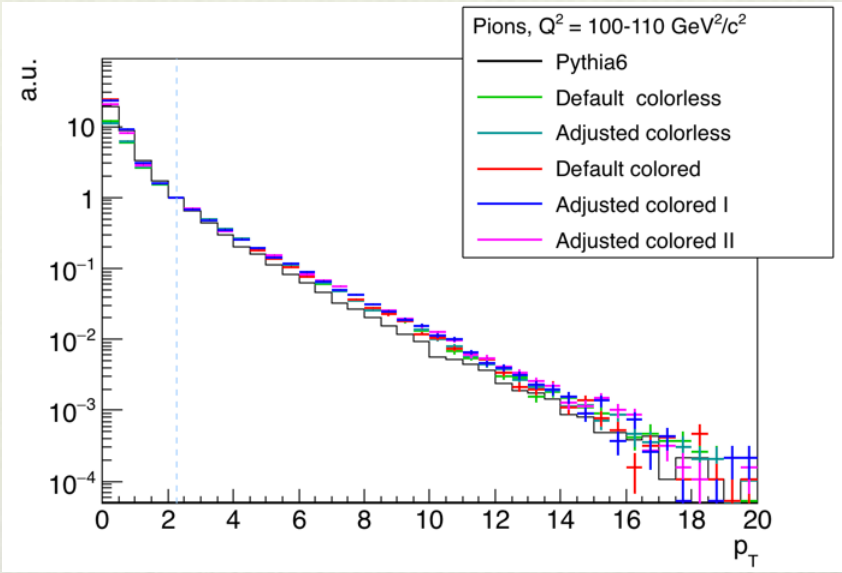
Adaptions:

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

Pions after Hadronization

Q^2 = 100–110 GeV^2



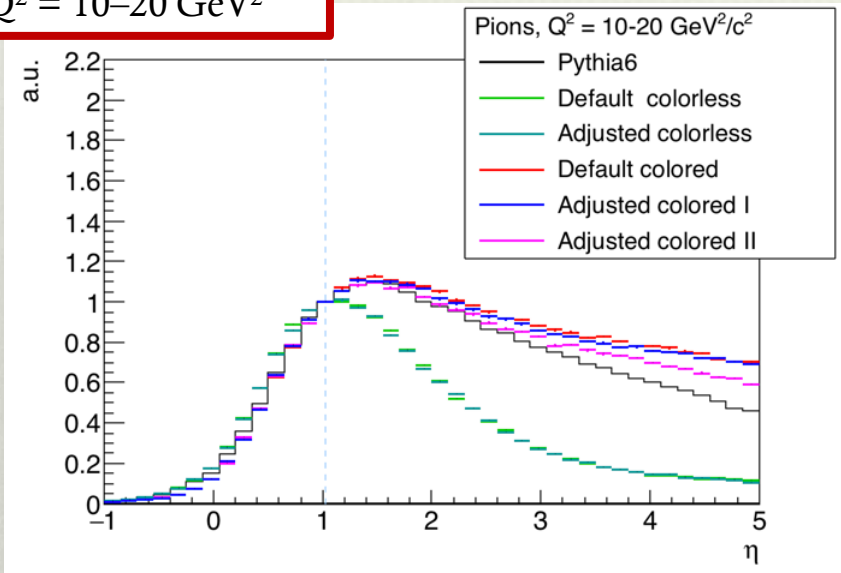


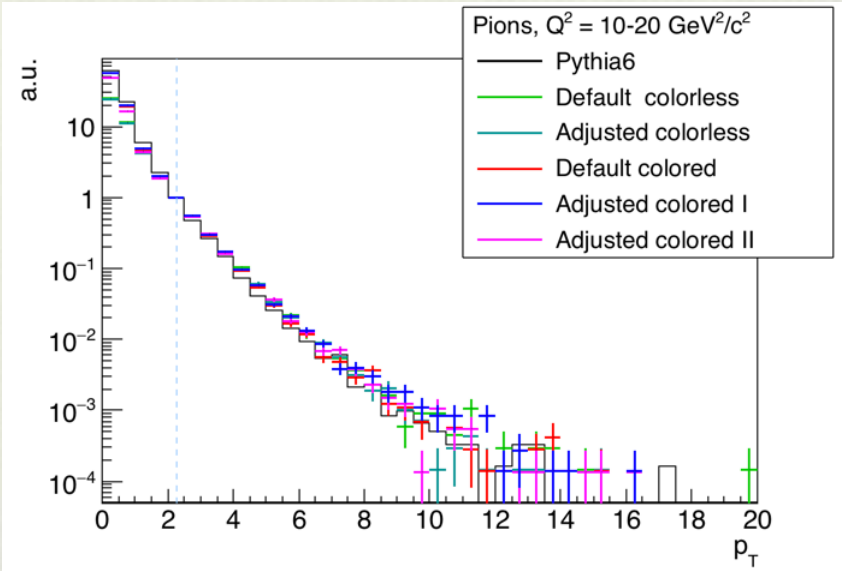
- Colorless: Forward and low-p_T discrepancies, irrespective of remnant adjustments
- Colored: Overshoots forward production, improved by better kinematics
- Similar above 2 GeV/*c*, harder than Pythia around 10 GeV/*c*

20 on 250 GeV e+P
Breit Frame

Pions after Hadronization

Q^2 = 10–20 GeV^2





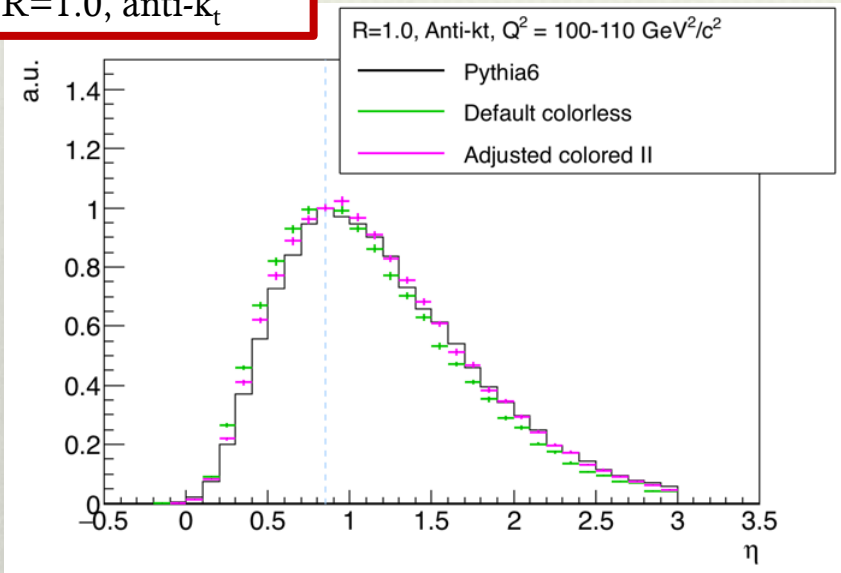
Lower Q^2:

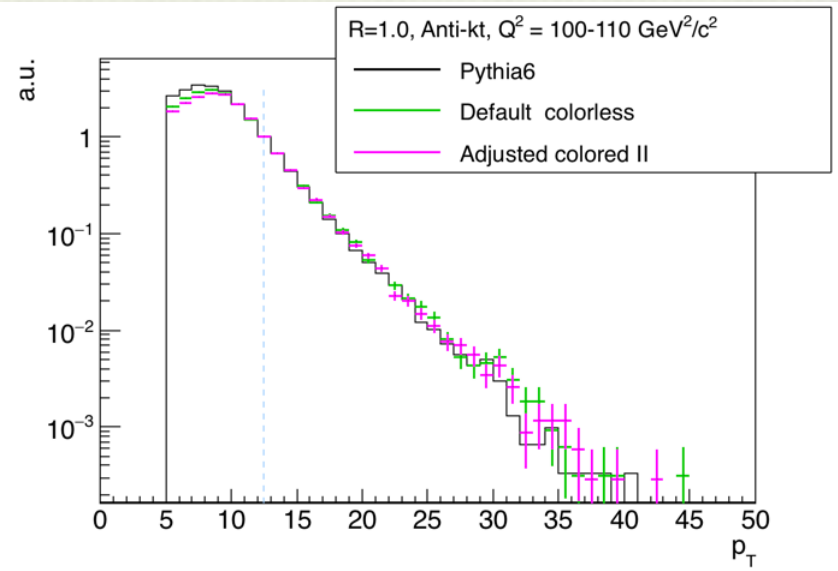
- Same trends, but colorless farther and colored closer
- Both harder than Pythia around 5 GeV/c

20 on 250 GeV e+P
Breit Frame

Jets

R=1.0, anti-k_t



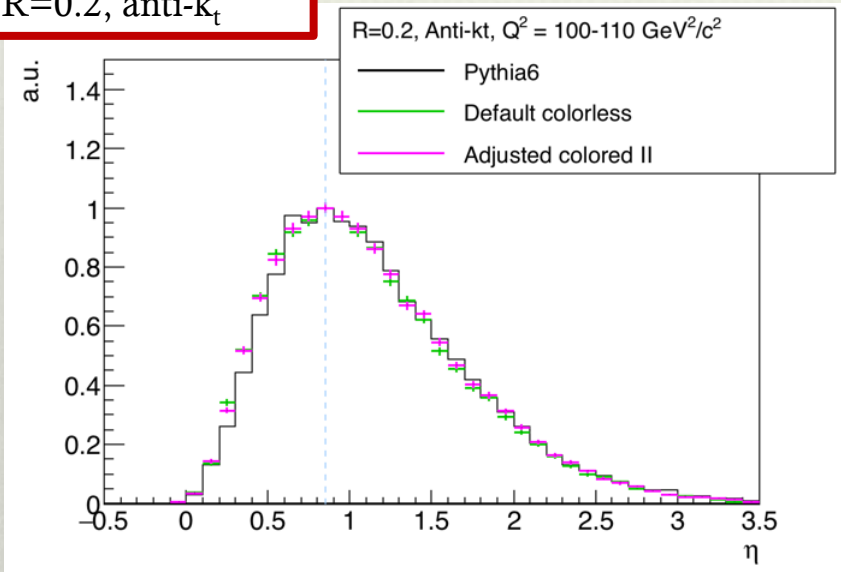


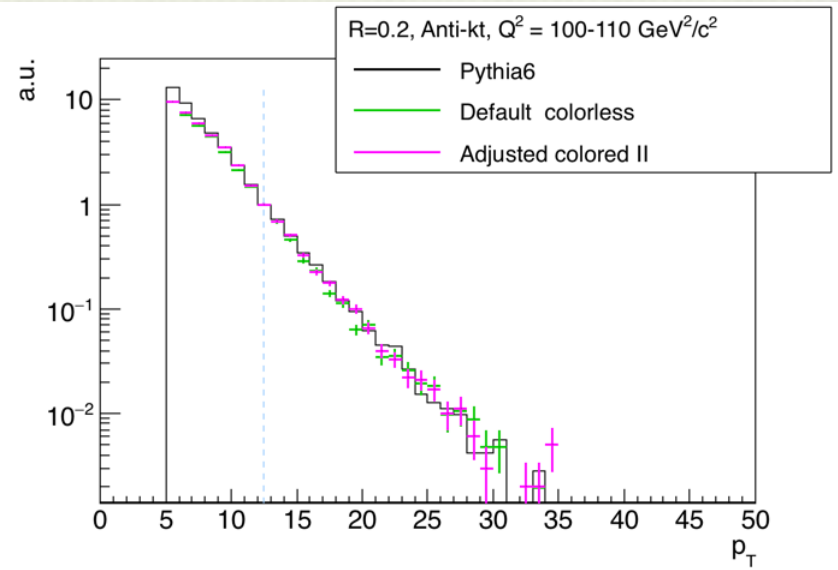
- Pions tell the story – but differences are mitigated by large *R* and η cuts
- Note: Constituent cuts in Breit frame – not realistic but helpful for testing

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

Small Jets

R=0.2, anti-k_t



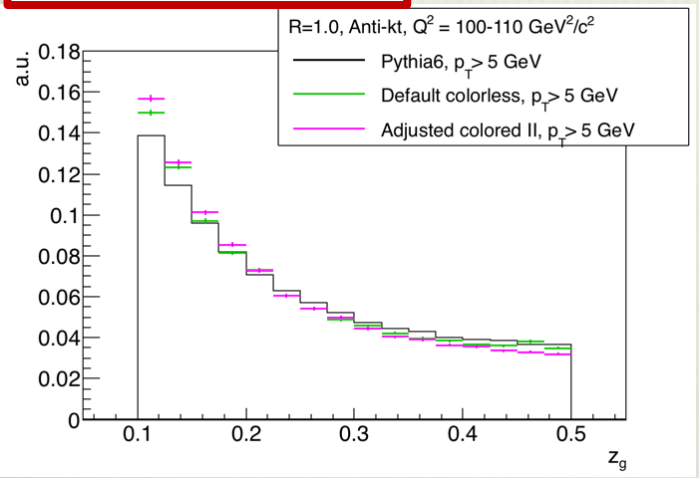


- Good agreement even for rather small jets
- Hint at pion fraction difference in hadronization?

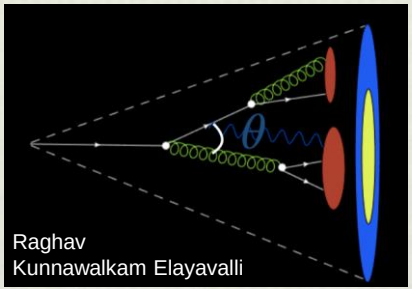
20 on 250 GeV e+P
Breit Frame
Q^2 = 100–110 GeV^2

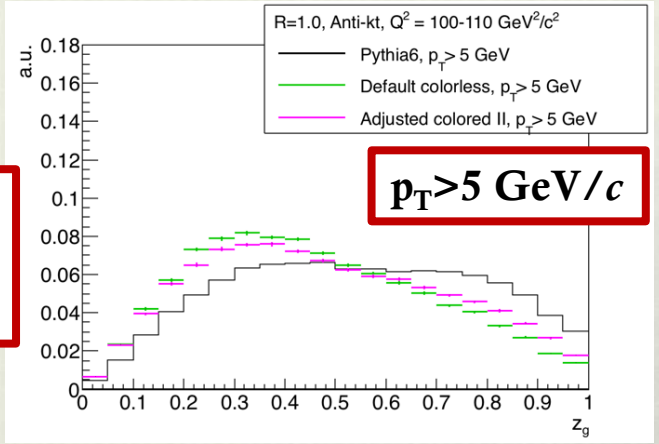
Substructure

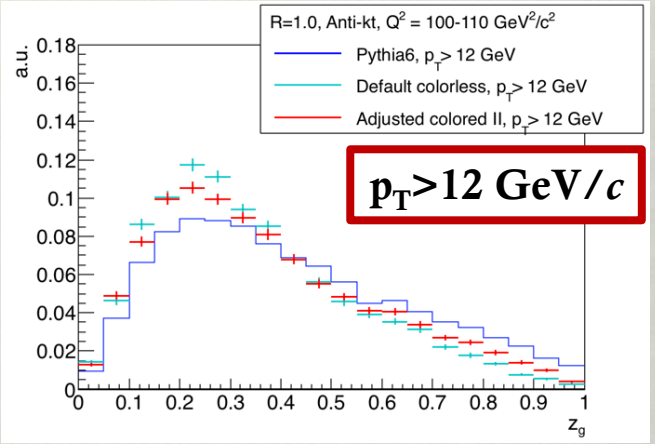
z_g ~ "Hardest Split"
p_T>5 GeV/c
Good shape!



R_g ~ "Angle between hard prongs"
good p_T dependence







- 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

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., $\mathbb{P}$)
  - Promising substructure outlook
  - 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