A multistage framework for studying the evolution of jets and high-p_T probes in small collisions systems

Abhijit Majumder

For the JETSCAPE collaboration

Hard Probes 2023, Aschaffenburg, Germany, March 27-31 2023

Most of the physics portion of this work is done by

- Ismail Soudi

Wenbin Zhao

(in collaboration with the COMP group at JETSCAPE)

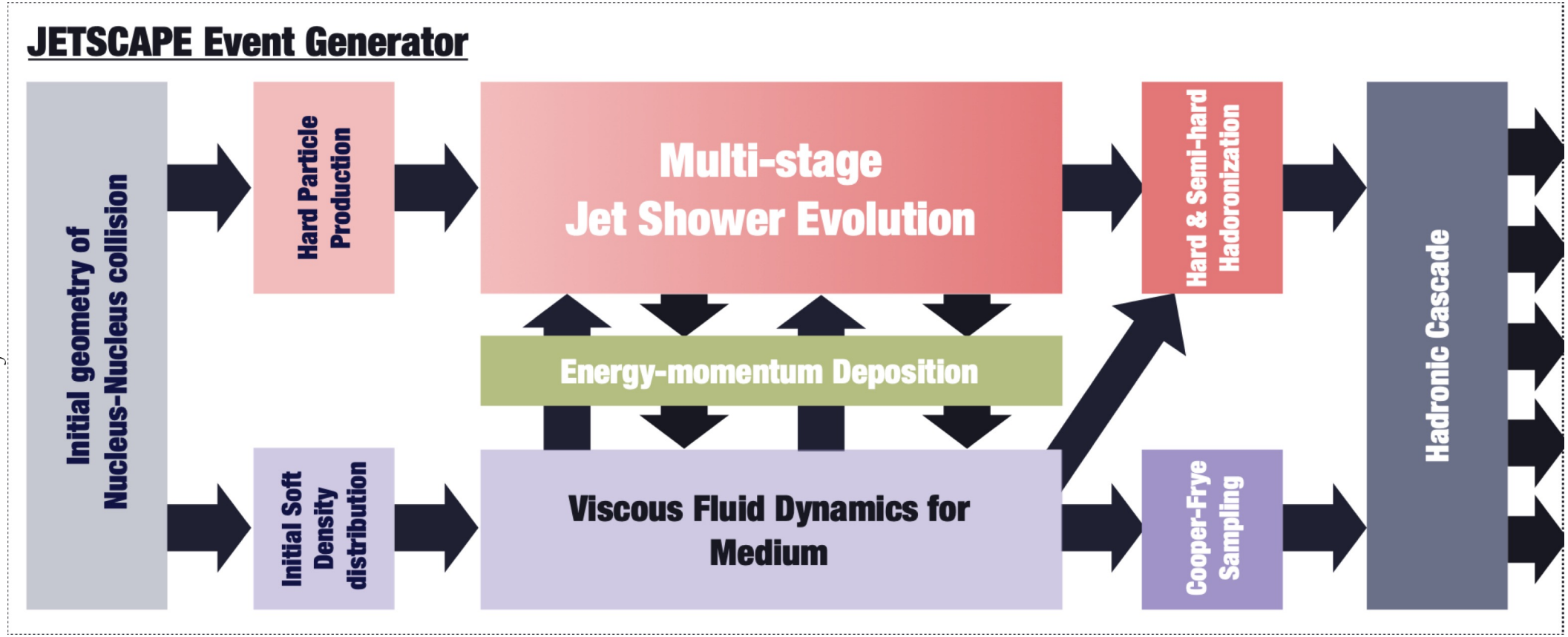
- Neither of them could get a visa for this conference…

Outline

- Transition from JETSCAPE to X-SCAPE
- Framework level advances
- Content/Module level advances
- A new working model for small systems in p-p and p-A
- Preliminary results

JETSCAPE: a p-p and A-A generator

- Framework controls order of modules and information flow
- Modules are user defined, replaceable, divisible
- Can be run in pure bulk, pure hard, or interactive modes



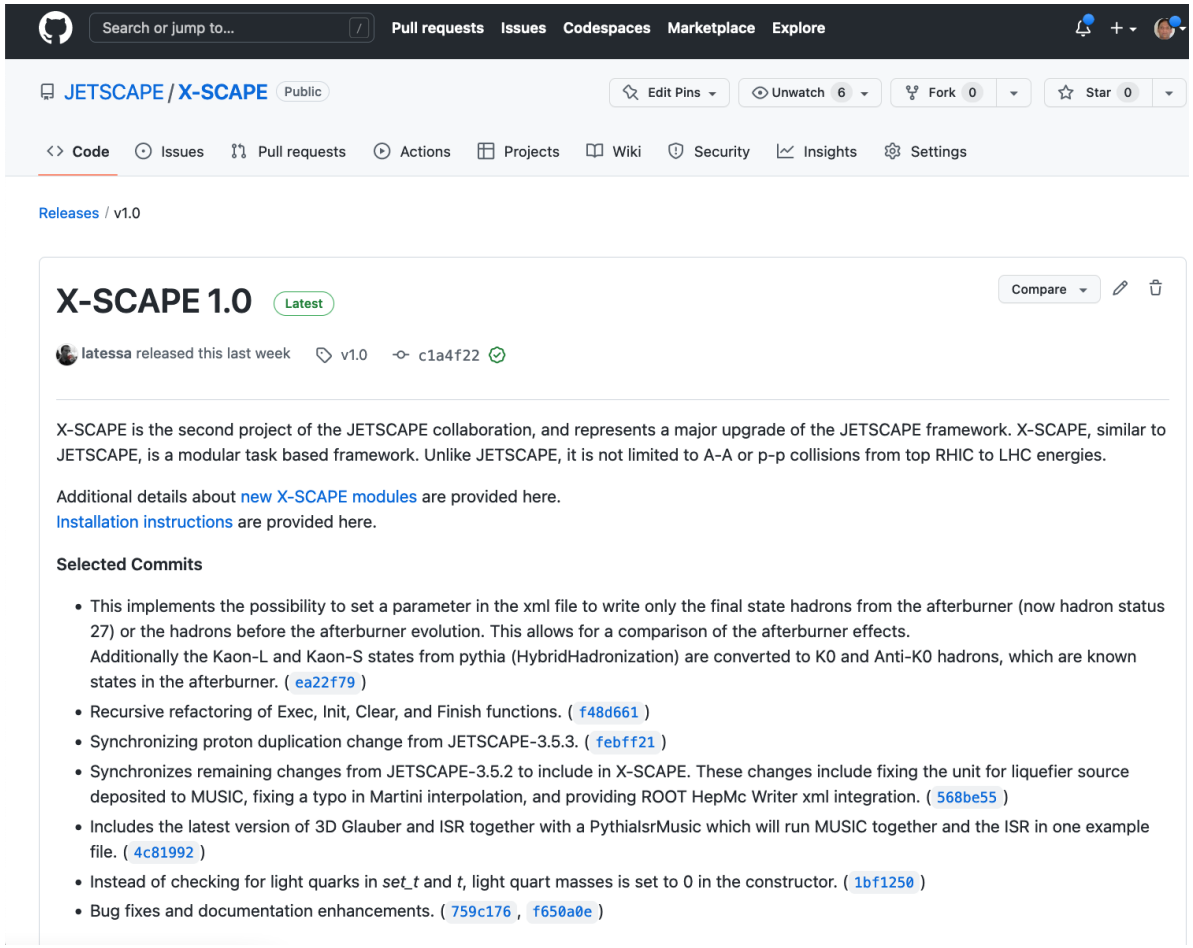
Artwork by Y. Tachibana

JETSCAPE results (only hard sector)

- Big picture or base model (141 different data sets) vs. Fine structure

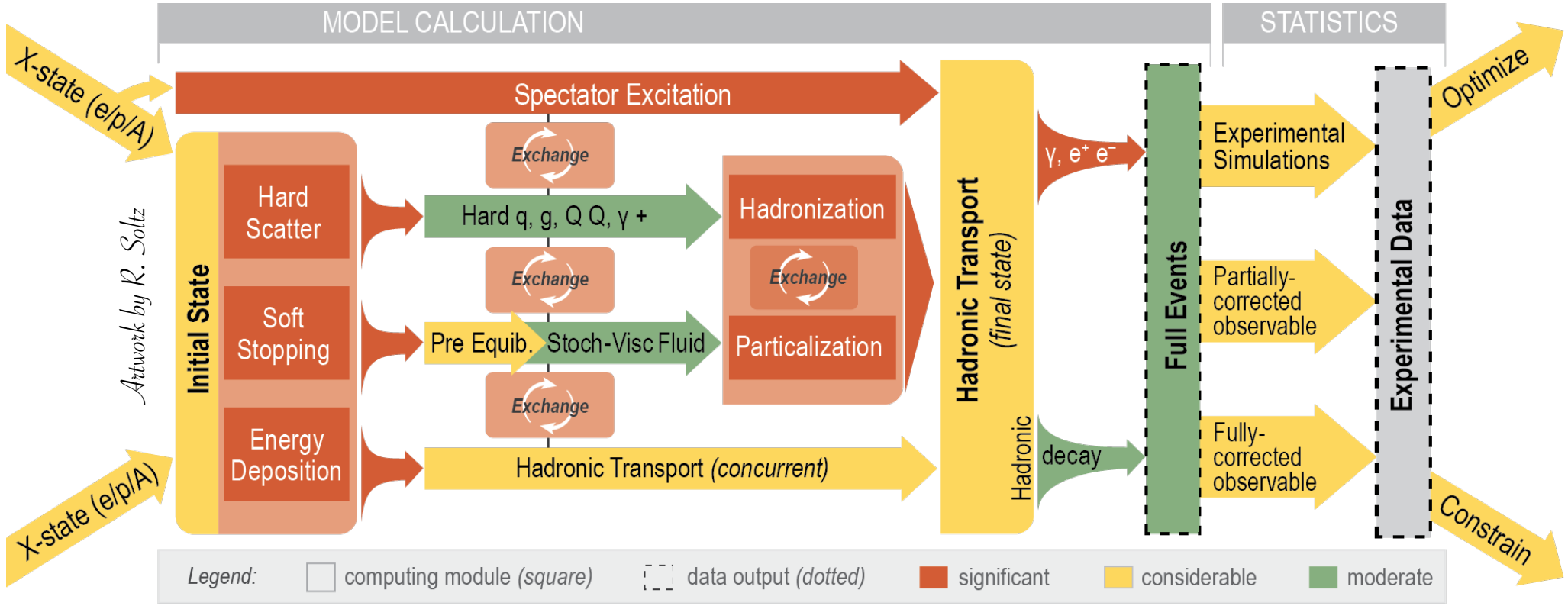
X-ion collisions with a Statistically and Computationally Advanced Program Envelop (X-SCAPE)

- Small systems in p-p, p-A etc.
  - Asymmetric systems such as d-A, A-A.
  - Require strong correlation between hard and soft sector
  - In both initial and final state.
- Lower energy A-A, for Beam Energy Scan
  - Require concurrent hydro + cascade
- Extension to e-A, for EIC.
  - Parton energy loss, CGC studies, TMD?



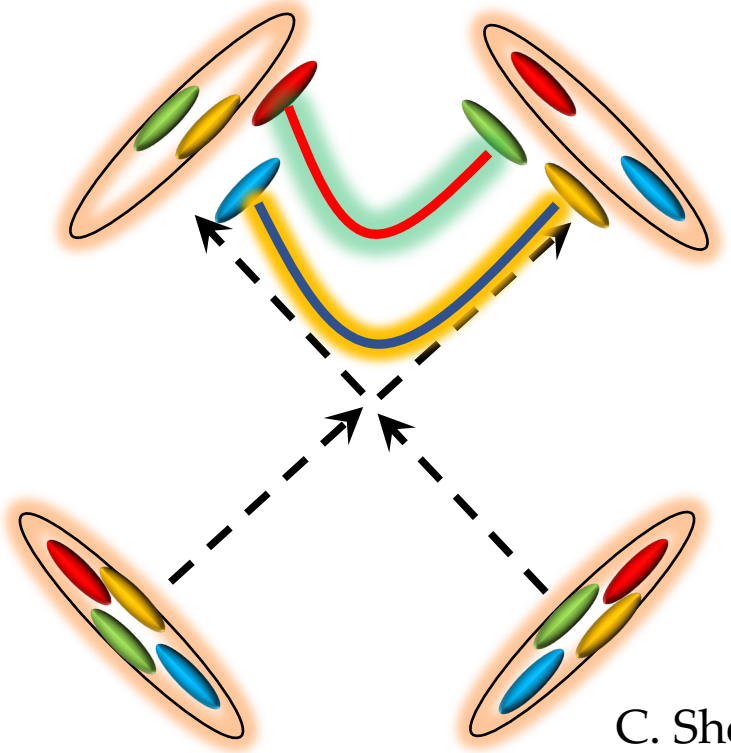
X-SCAPE framework

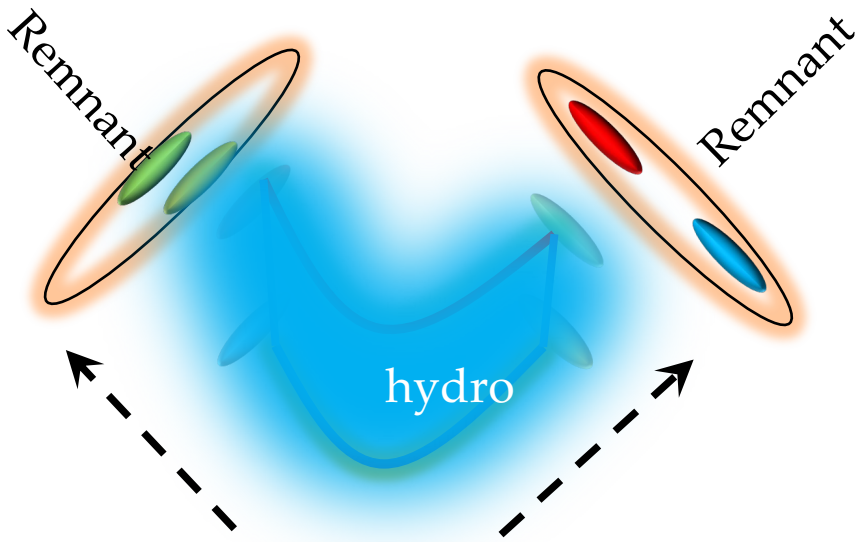
- A new framework that allows the user to determine the order of operations
- Time can go backwards and forwards !
- Backward evolution allows for natural implementation of ISR.
- Can be run with an arbitrary number of modules.



X-SCAPE module: 3D Glauber + MUSIC

- Nucleons have multiple hot spots within them.
- Strings connect pairs of hot spots
- String 4-momentum and baryon density seeds hydro simulation
- Hydro evolves producing particles
- Remnants go down beam line.

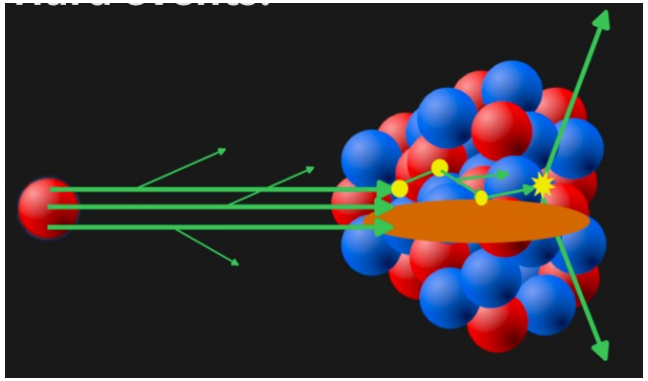




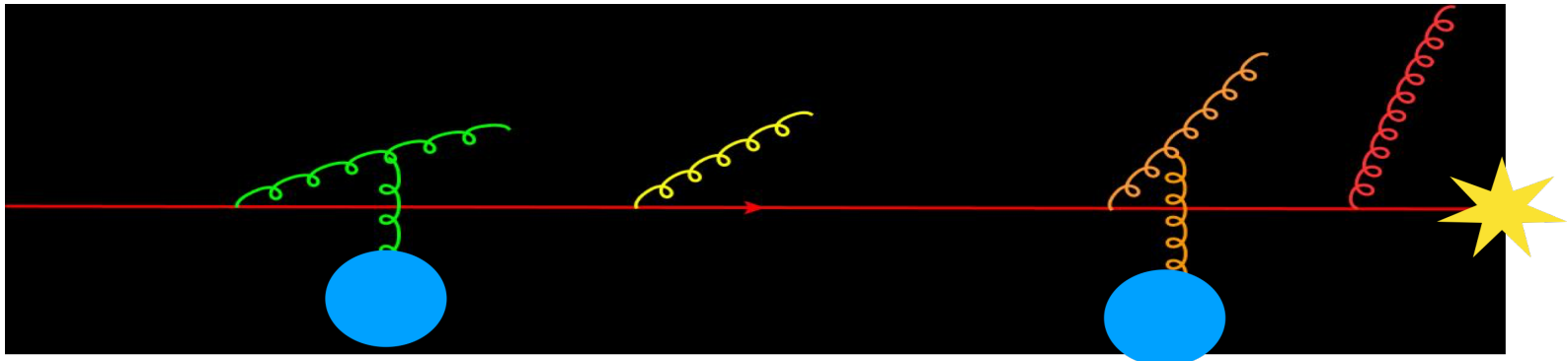
C. Shen and B. Schenke, PRC97 024907 (2018), PRC105, 064905 (2022)

X-SCAPE module: I-MATTER

- Call Pythia (ISR-FSR-OFF) generate MPI scatterings
- Start each parton at $Q^2 = -p_T^2$ and evolve up to $Q^2 = -1$ GeV^2.
- A well-established method of generating ISR*
- Run Matter backwards in time with i-MATTER.
- Parton energy increases with splits, keep track of position
- Final parton at most negative time is the parent.



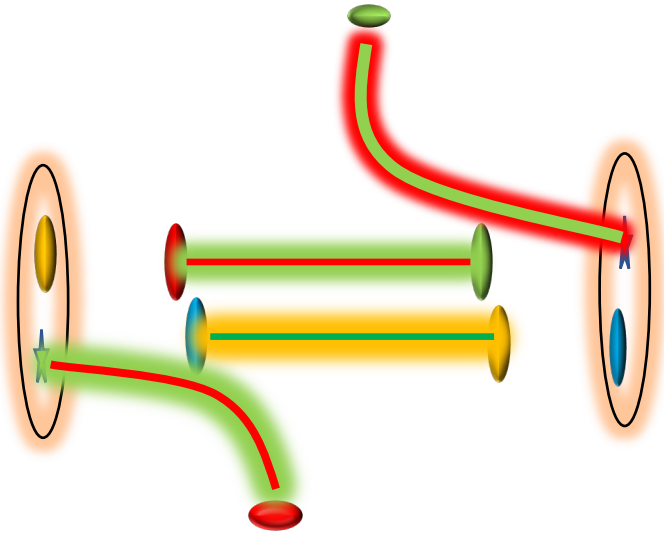
Framework can handle Initial State-E-loss, current results only include Vacuum shower

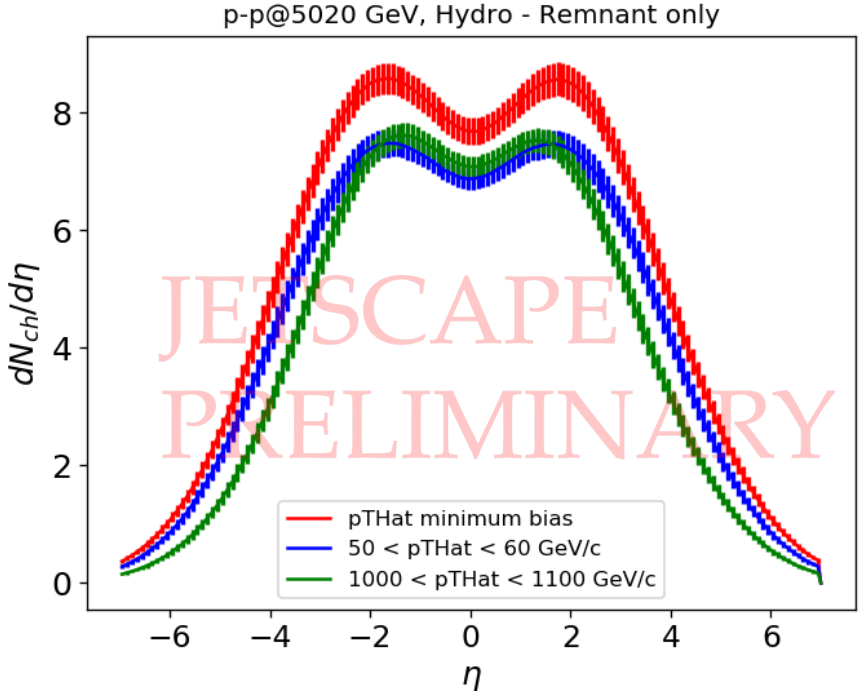


*T. Sjostrand
Phys.Lett.B 157 (1985) 321.

Physical Model

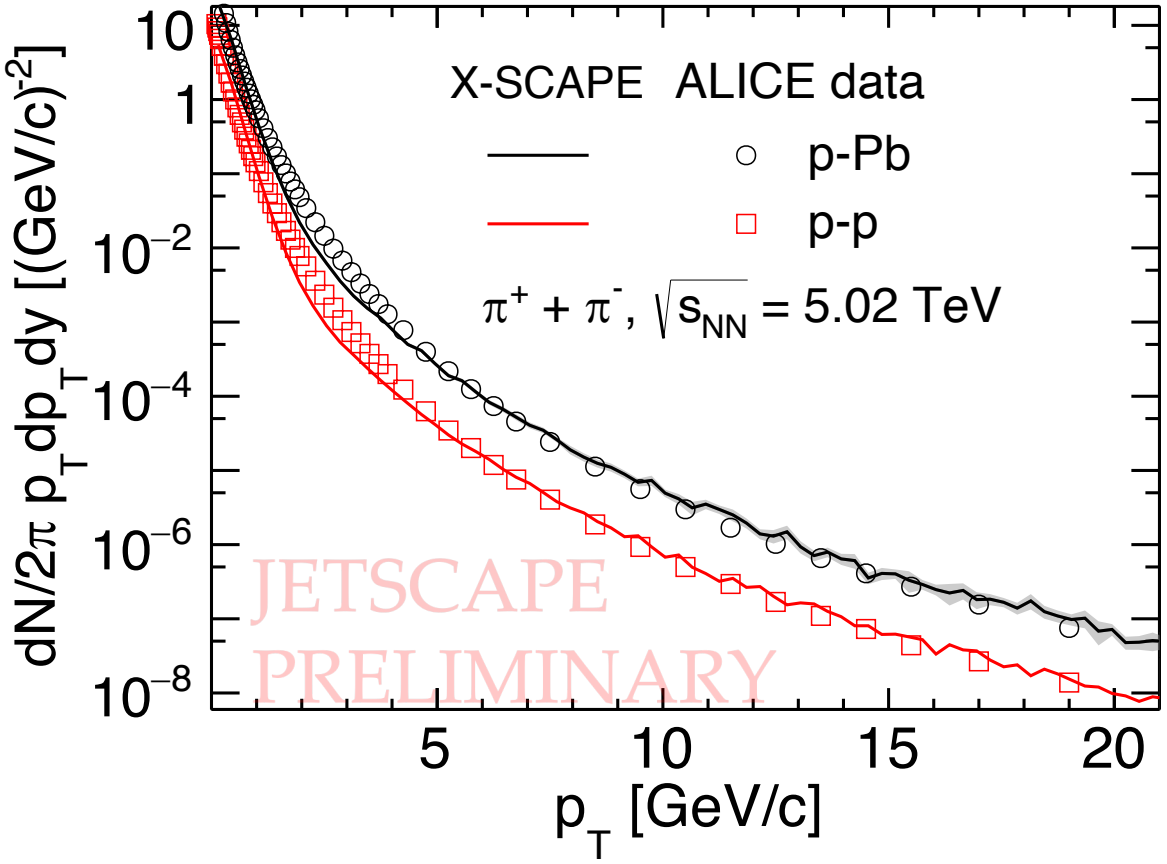
- Hard initial state partons are included in a hot spot
- Hard partons scatter with ISR and FSR.
- ***Hard energy removed from nucleons, not available for hydro evolution***
- Some strings get pulled out by hard processes, fragmented by string breaking
- Strings that don't get pulled out are liquified into a fluid
- Fluid evolves and produces particles
- Larger jet energy implies more fragmentation hadrons, and less hydro (Cooper-Frye) hadrons

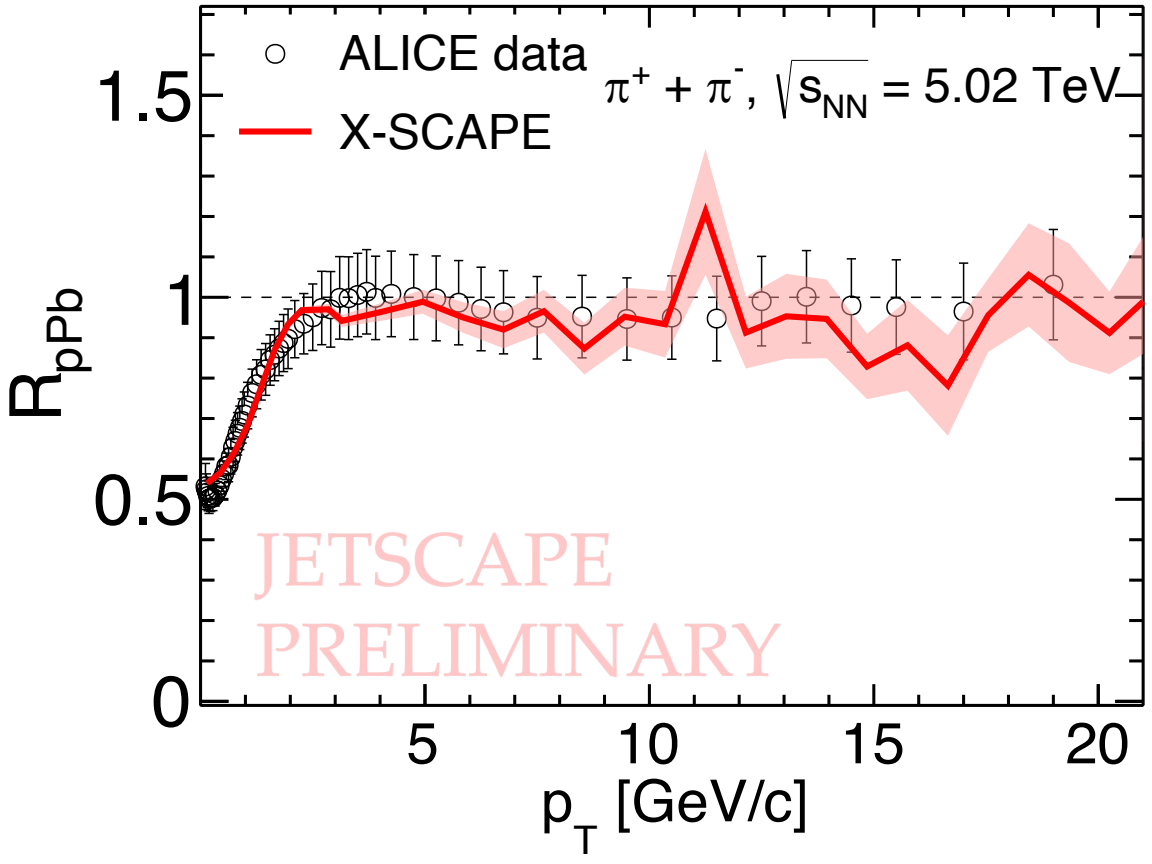




Preliminary results

Set min p_T hat in Pythia = 8 GeV, softer phenomena modelled by hydro.
Hadron spectra in p-p and p-A.

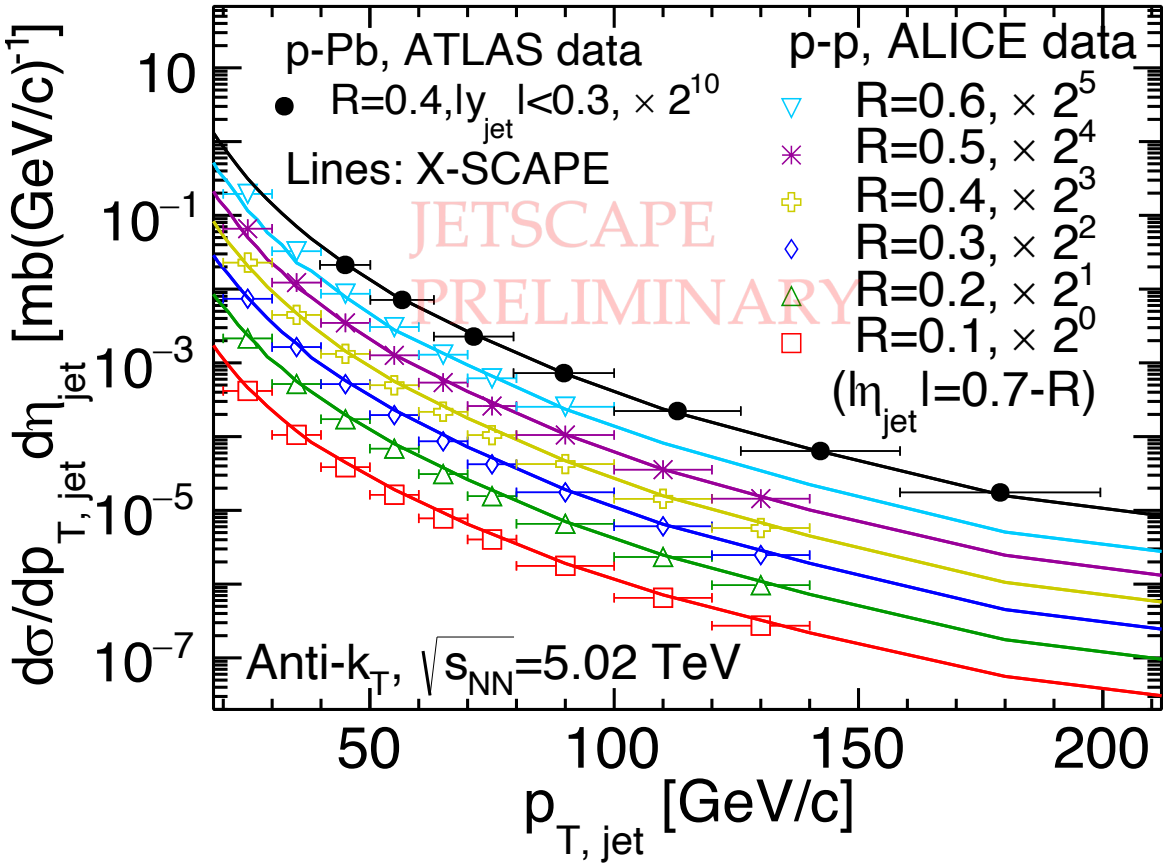


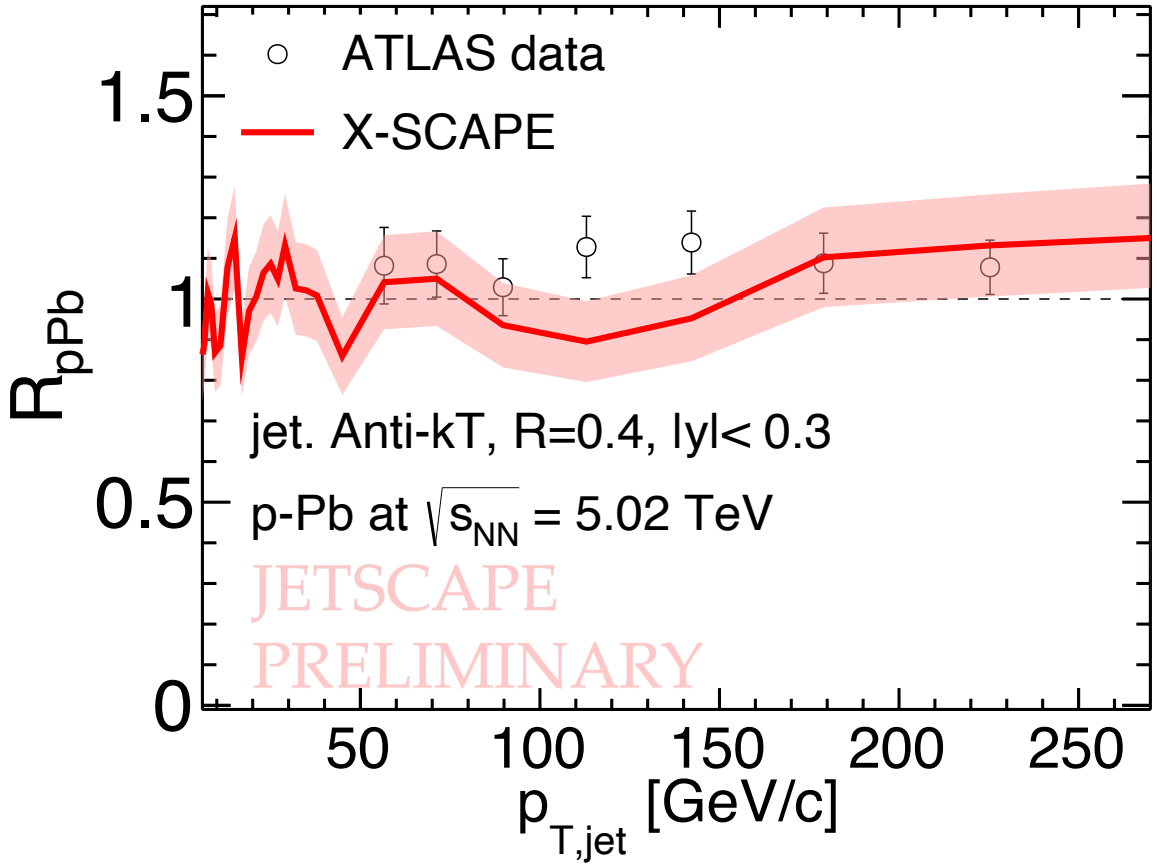


Preliminary Results

- Jets in p-p and p-A

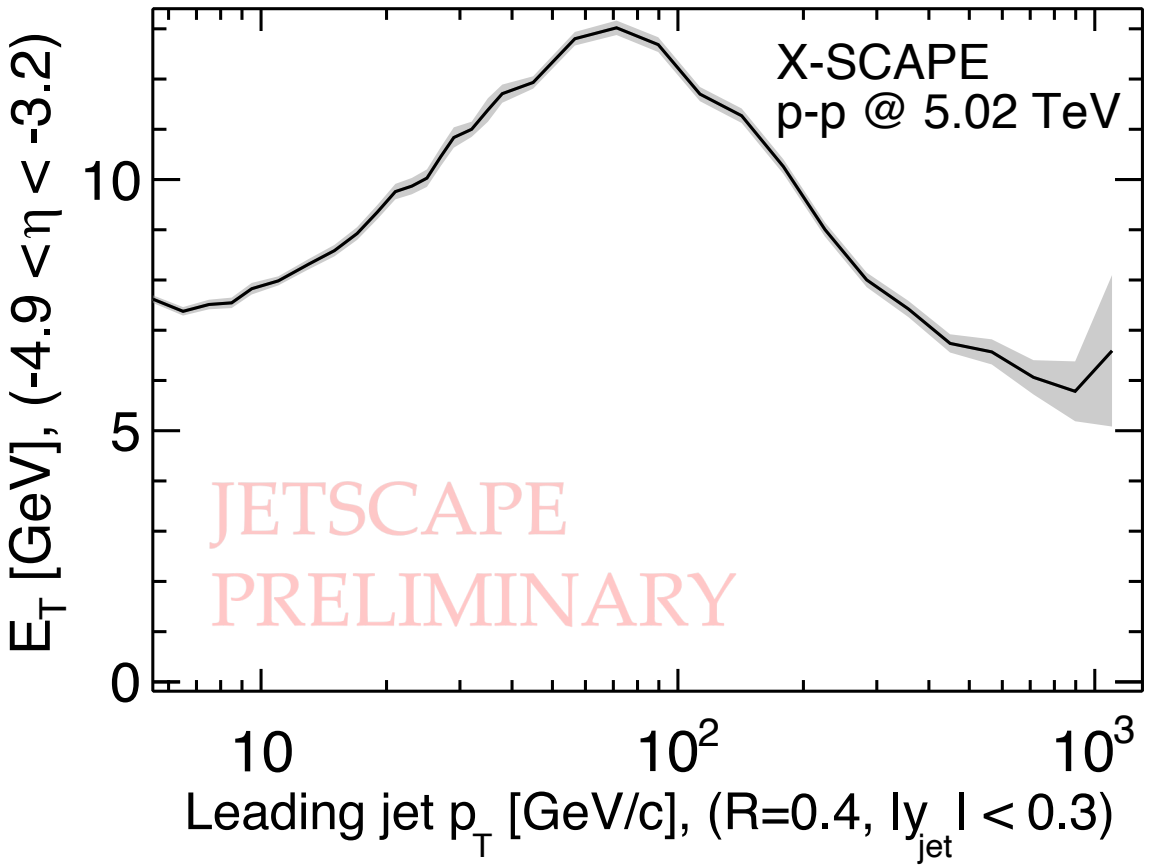
- Simple background subtraction: only use fragmentation hadrons in jet clustering

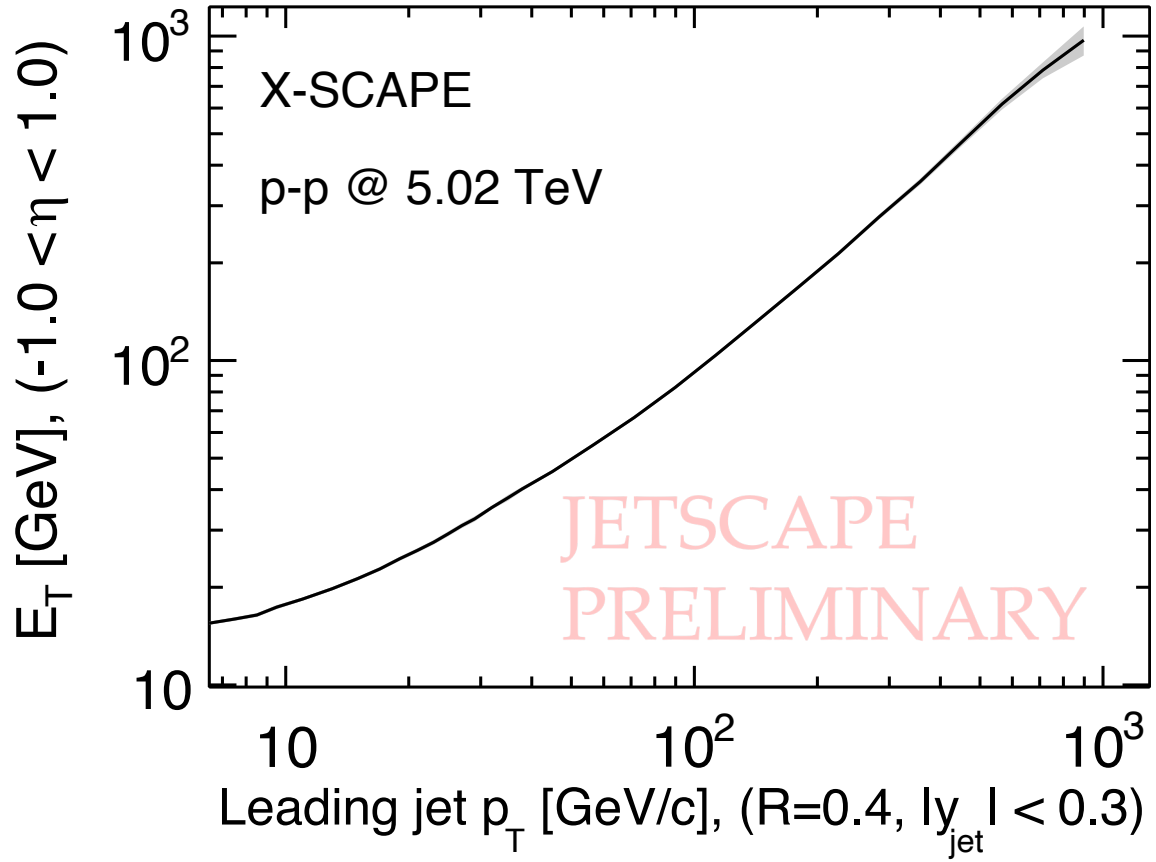




Preliminary Results

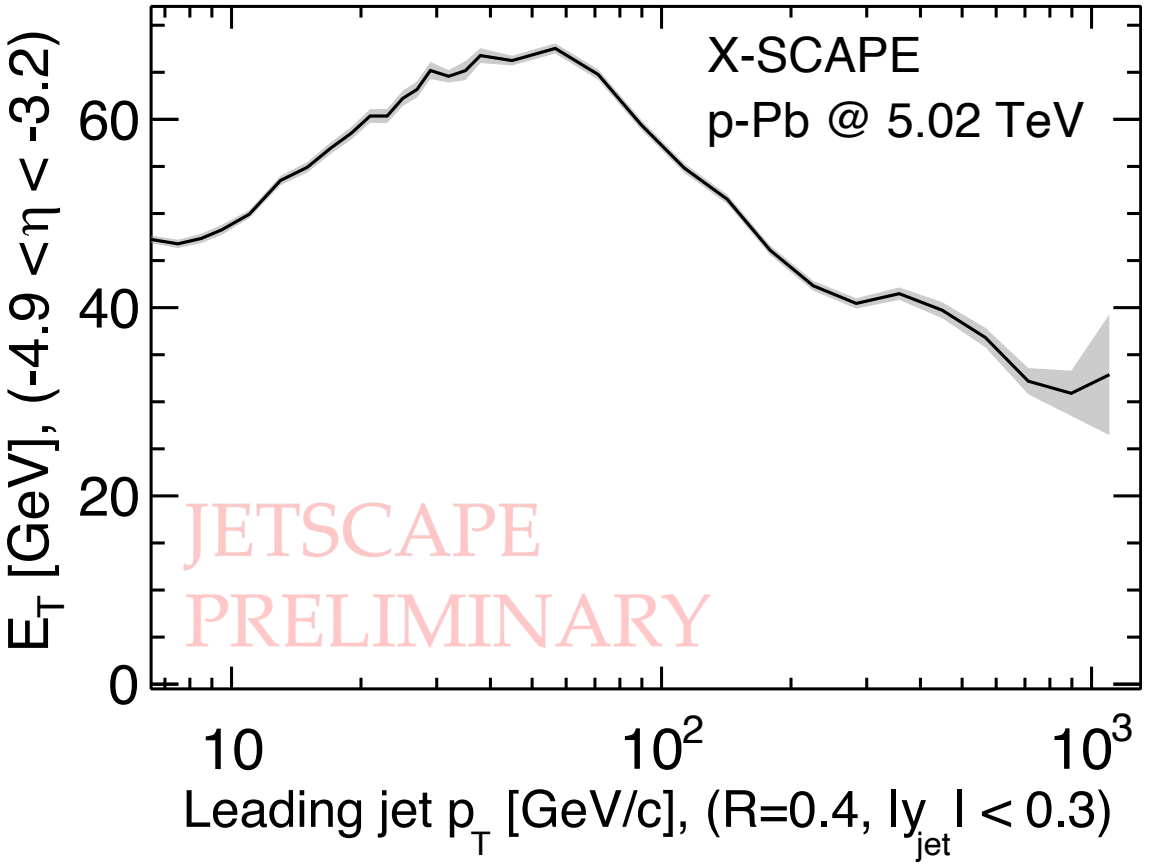
- Event activity modification in p-p with jet momentum
- We calculate the E_T from both Cooper-Frye hadrons and fragmentation hadrons

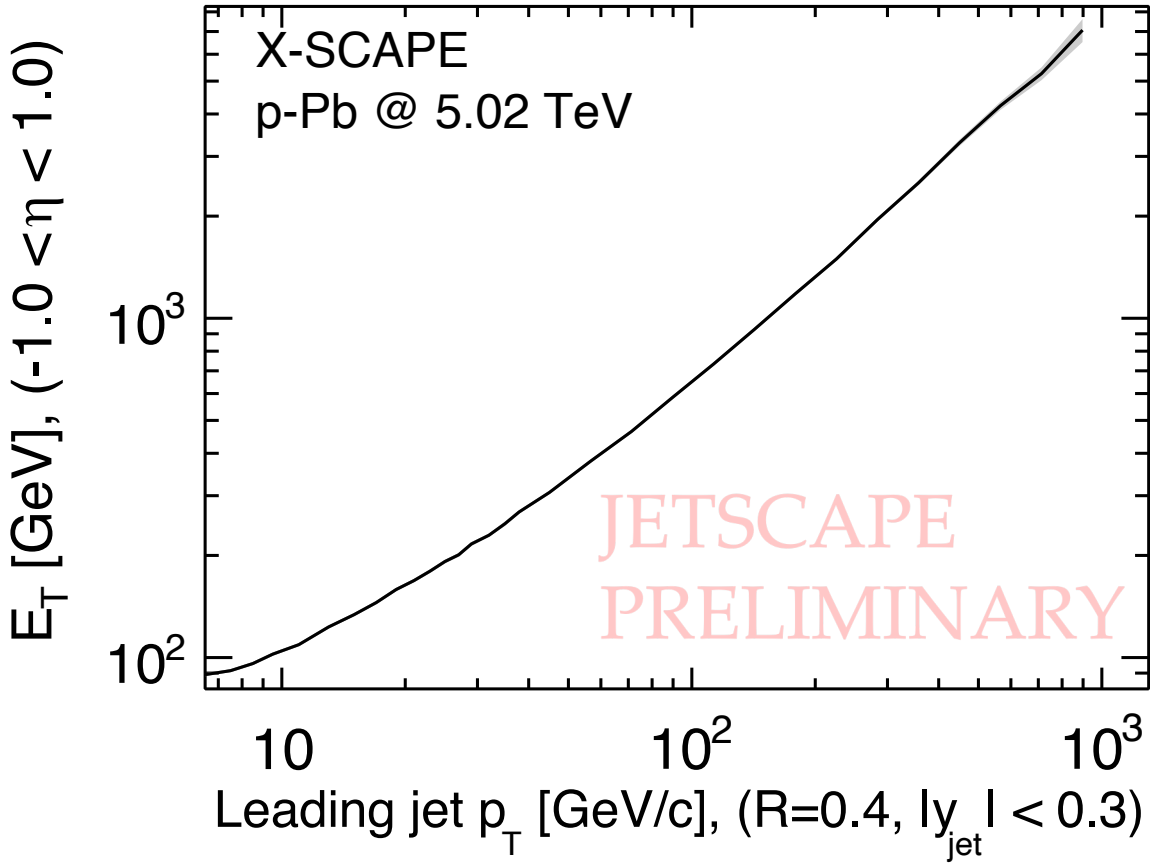




Preliminary Results

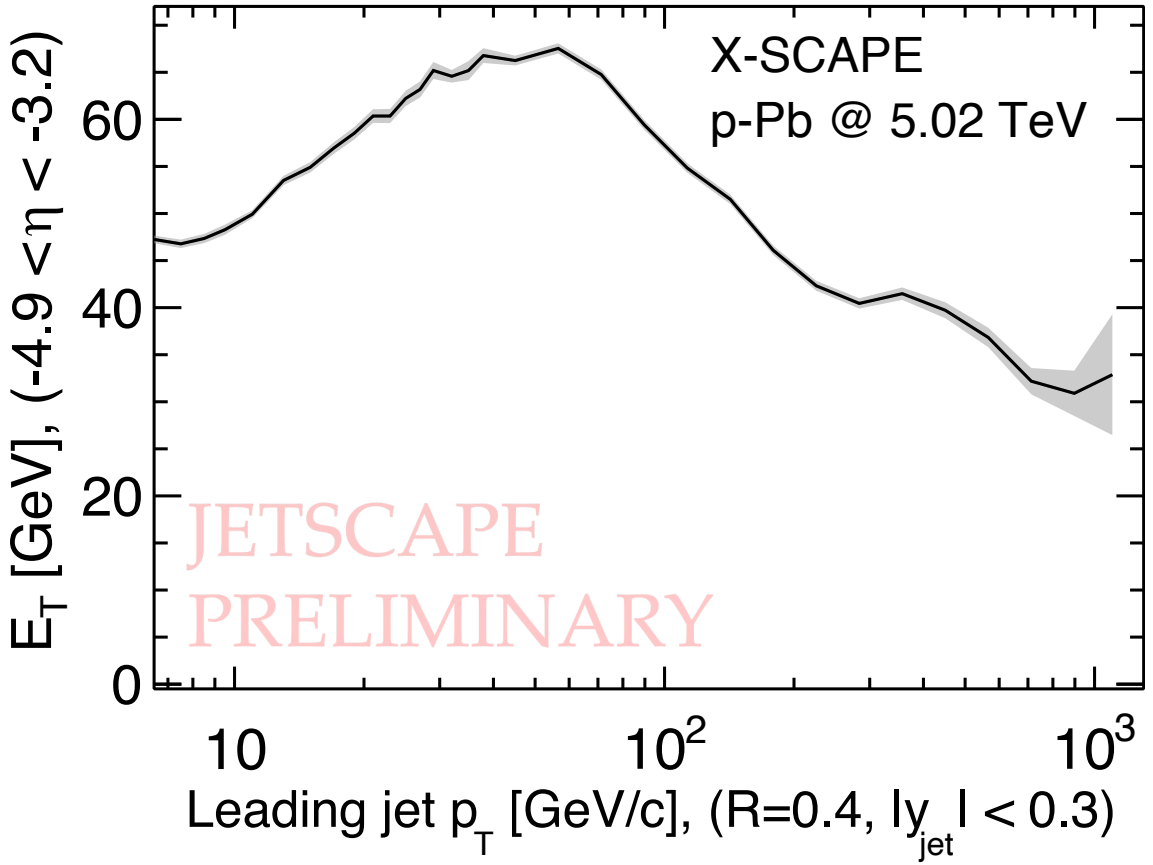
- Event activity modification in p-A with jet momentum
- Note the bump around 100 GeV!

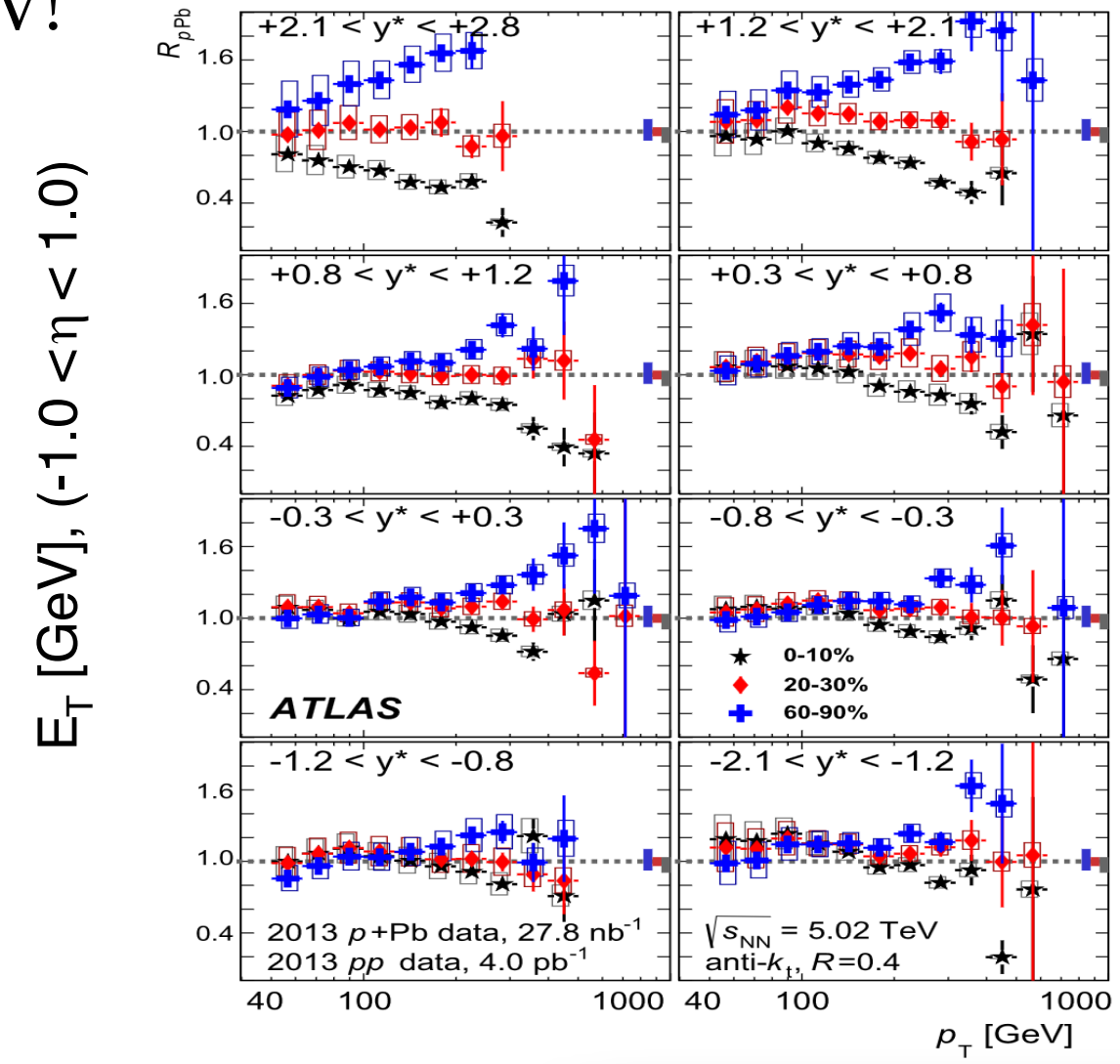




Preliminary Results

- Event activity modification in p-A with jet momentum
- Note the bump around 100 GeV!



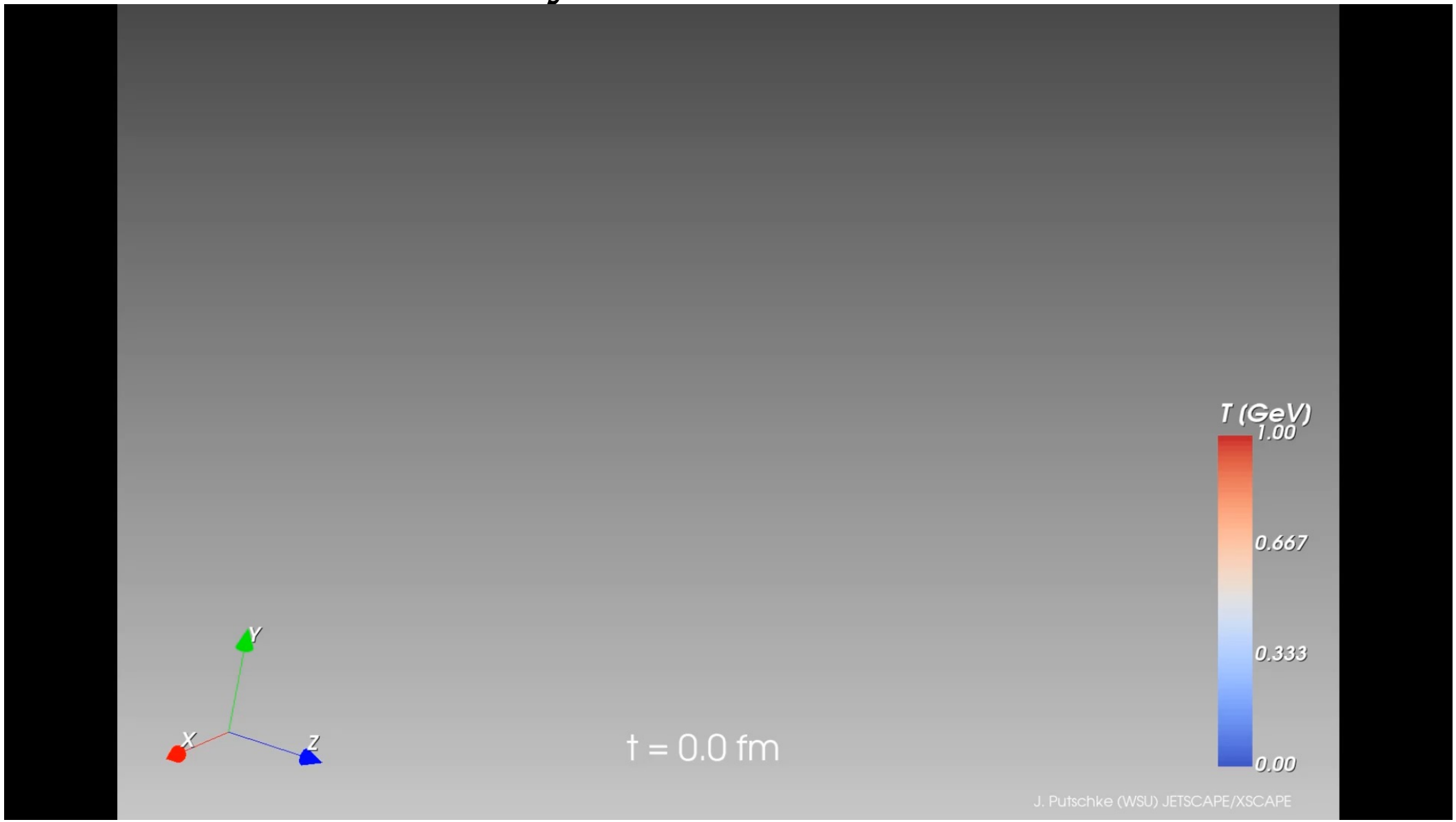


Summary and upcoming results

- Transition from JETSCAPE to X-SCAPE
- Constructed a new multi-stage hard soft event generator for p-p and p-A collisions.
- For any multiplicity!
- 3 D Glauber generates multiple hot spots in a nucleon
- MPI interactions in Pythia generates hard scatterings
- ISR done with i-MATTER, FSR done with MATTER
- Energy of incoming parent partons subtracted from hot spots
- Hadrons from depleted hydro and from hard fragmentation
- Very good description of data on particle and jet spectra.
- Appearance of energy correlation at jet energy of E>100GeV.

Thanks to all my collaborators

More analysis tools in JETSCAPE



Animations by J. Putschke