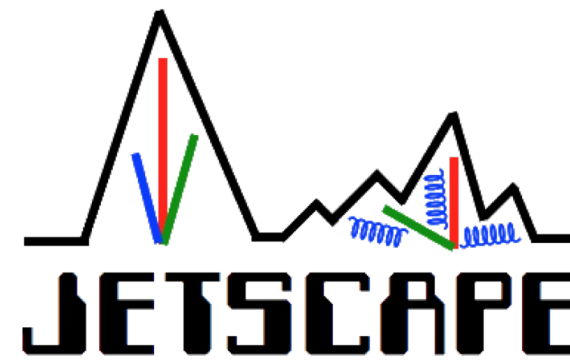




U.S. DEPARTMENT OF  
**ENERGY**

Office of Science



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

Abhijit Majumder

For the JETSCAPE collaboration

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...

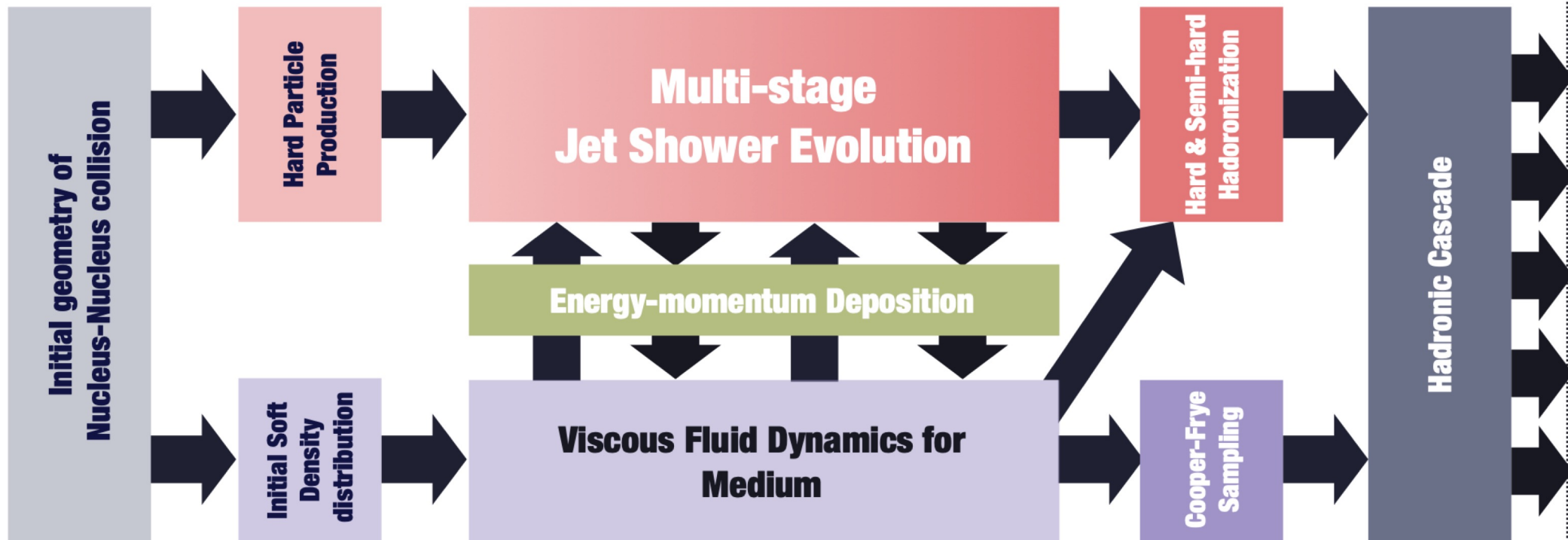
# Outline

- 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

## JETSCAPE Event Generator



Artwork by Y. Tachibana

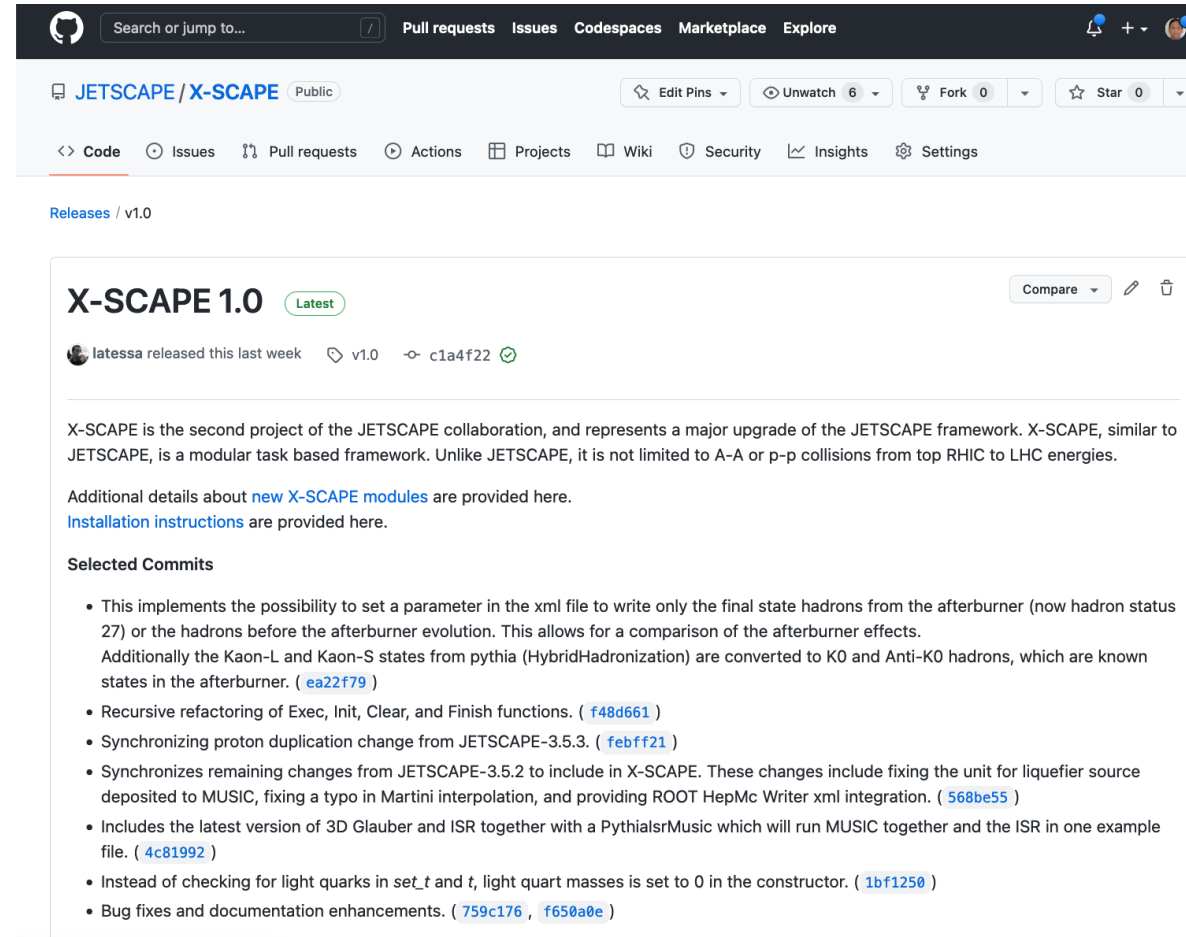
# JETSCAPE results (only hard sector)

- 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?



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JETSCAPE / X-SCAPE Public

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Releases / v1.0

## X-SCAPE 1.0 Latest

latessa released this last week v1.0 c1a4f22

X-SCAPE is the second project of the JETSCAPE collaboration, and represents a major upgrade of the JETSCAPE framework. X-SCAPE, similar to JETSCAPE, is a modular task based framework. Unlike JETSCAPE, it is not limited to A-A or p-p collisions from top RHIC to LHC energies.

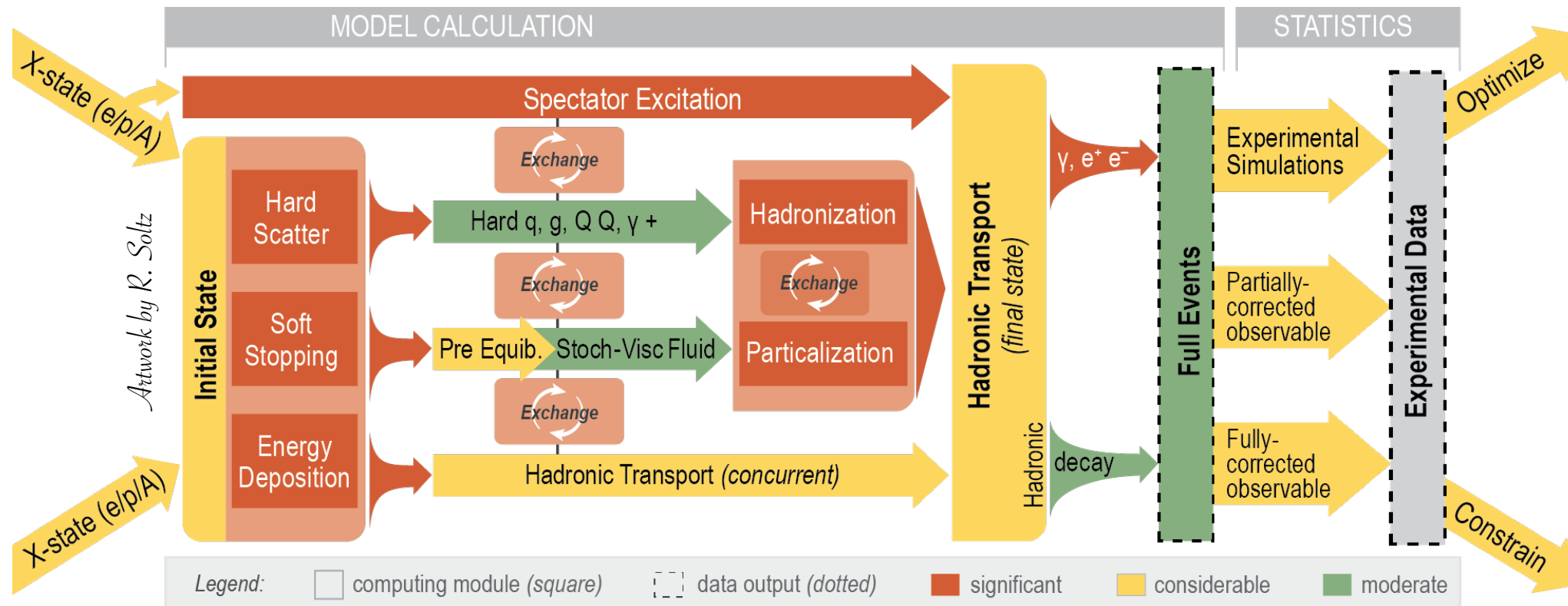
Additional details about [new X-SCAPE modules](#) are provided here.  
[Installation instructions](#) are provided here.

### Selected Commits

- This implements the possibility to set a parameter in the xml file to write only the final state hadrons from the afterburner (now hadron status 27) or the hadrons before the afterburner evolution. This allows for a comparison of the afterburner effects. Additionally the Kaon-L and Kaon-S states from pythia (HybridHadronization) are converted to K0 and Anti-K0 hadrons, which are known states in the afterburner. ( [ea22f79](#) )
- Recursive refactoring of Exec, Init, Clear, and Finish functions. ( [f48d661](#) )
- Synchronizing proton duplication change from JETSCAPE-3.5.3. ( [febff21](#) )
- Synchronizes remaining changes from JETSCAPE-3.5.2 to include in X-SCAPE. These changes include fixing the unit for liquefier source deposited to MUSIC, fixing a typo in Martini interpolation, and providing ROOT HepMc Writer xml integration. ( [568be55](#) )
- Includes the latest version of 3D Glauber and ISR together with a PythiaIrsMusic which will run MUSIC together and the ISR in one example file. ( [4c81992](#) )
- Instead of checking for light quarks in set\_t and t, light quark masses is set to 0 in the constructor. ( [1bf1250](#) )
- Bug fixes and documentation enhancements. ( [759c176](#) , [f650a0e](#) )

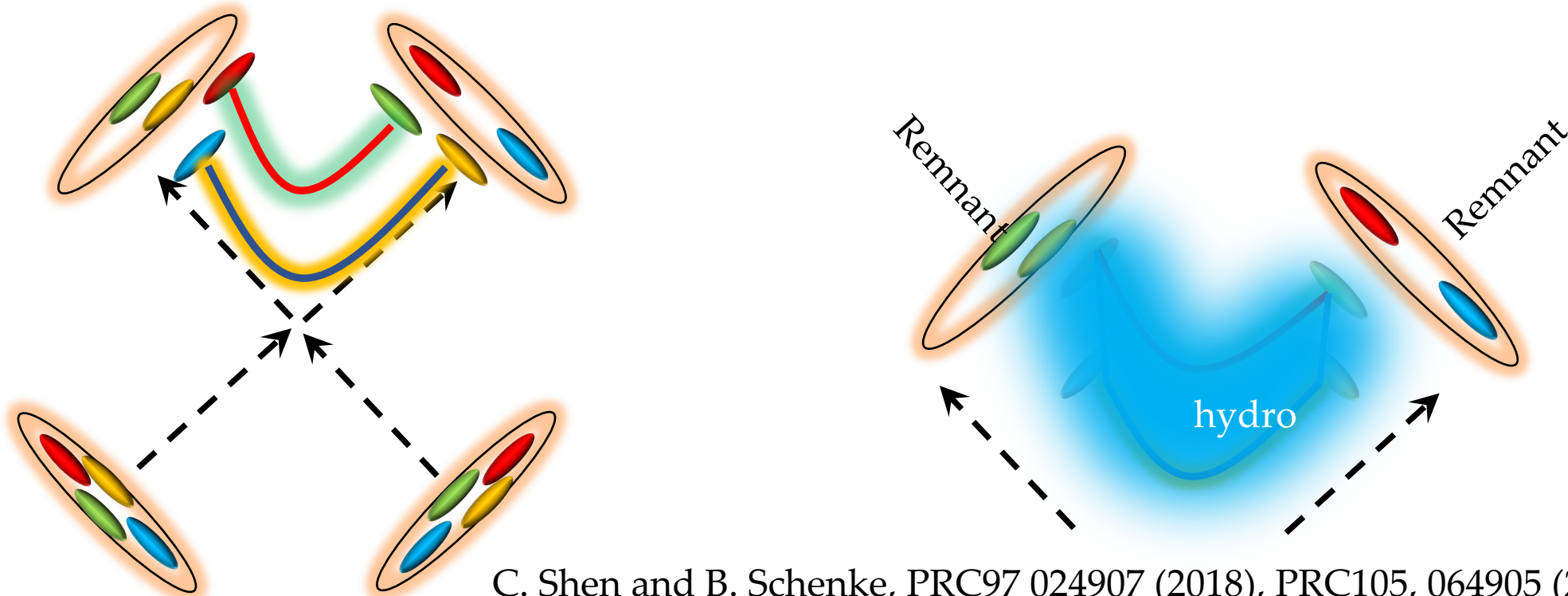
# X-SCAPE framework

- 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

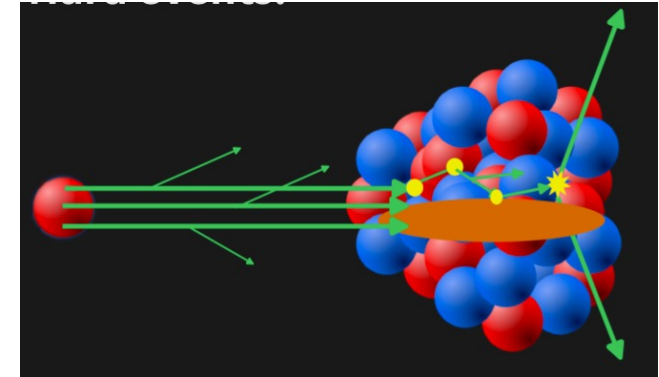
- Nucleons have multiple hot spots within them.
- Strings connect pairs of hot spots
- String 4-momentum and baryon density seeds hydro simulation
- Hydro evolves producing particles
- Remnants go down beam line.



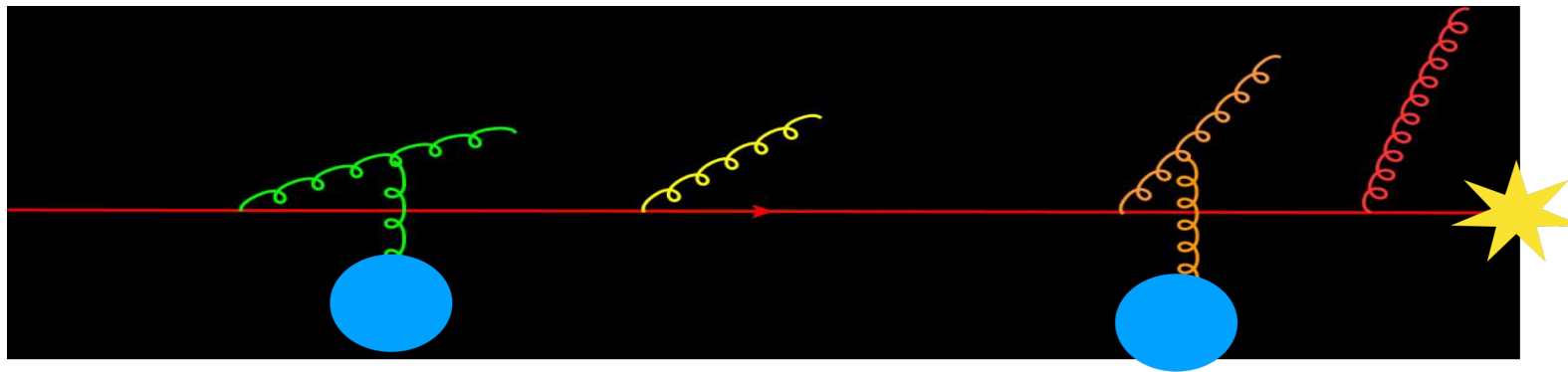


# X-SCAPE module: I-MATTER

- Call Pythia (ISR-FSR-OFF) generate MPI scatterings
- Start each parton at  $Q^2 = -p_T^2$  and evolve up to  $Q^2 = -1 \text{ GeV}^2$ .
- 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.



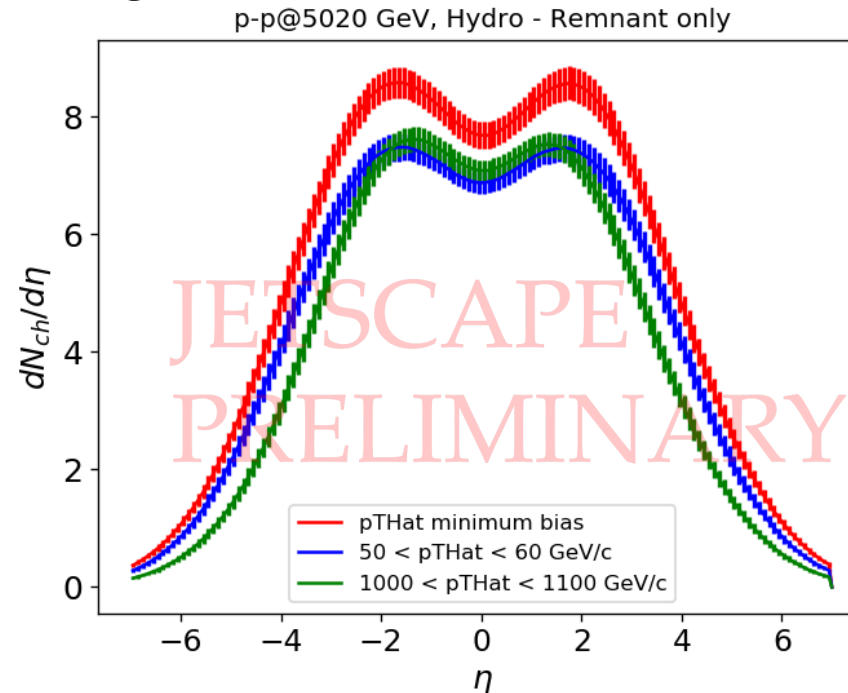
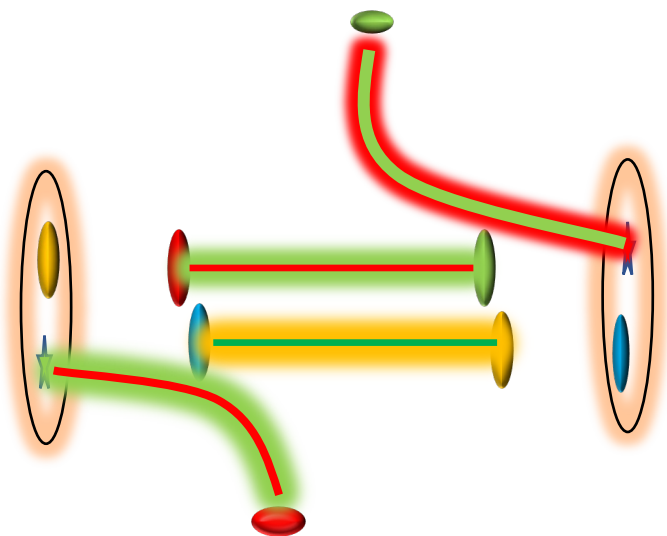
*Framework can handle Initial State-E-loss, current results only include Vacuum shower*



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

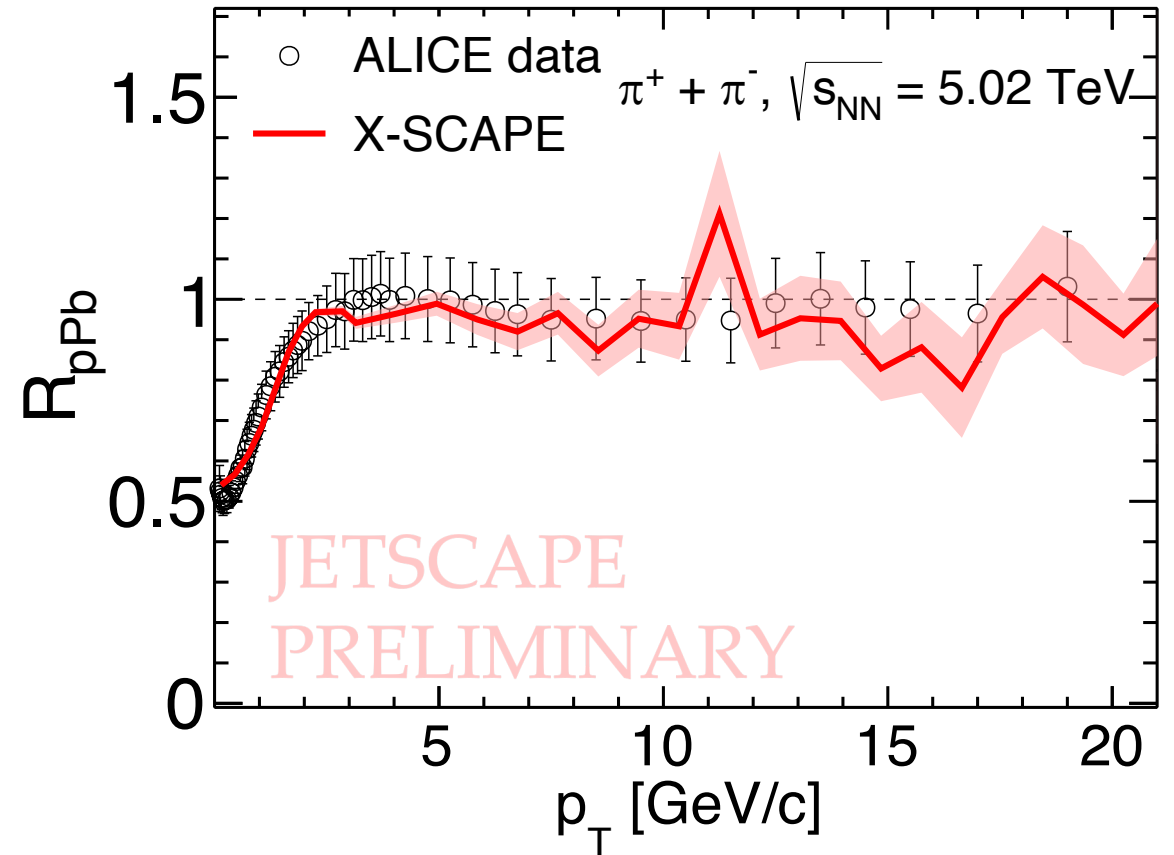
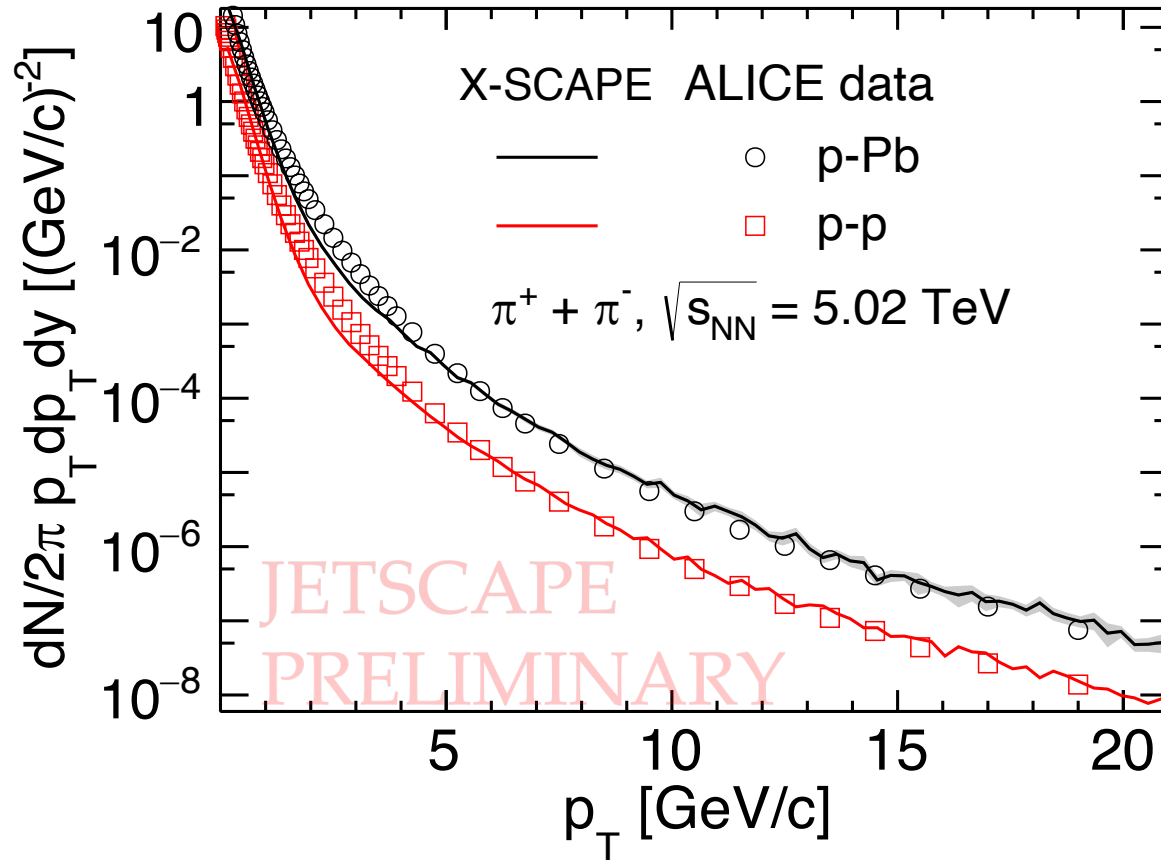
# Physical Model

- 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.

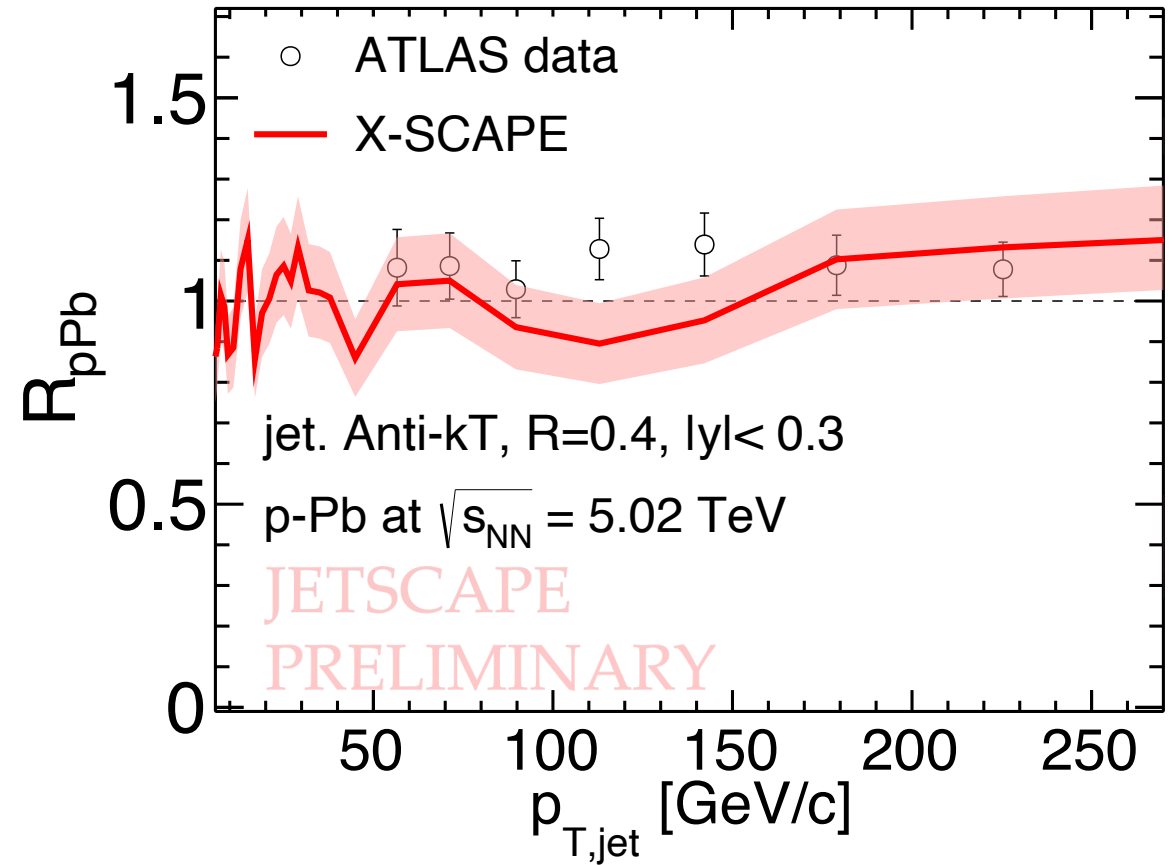
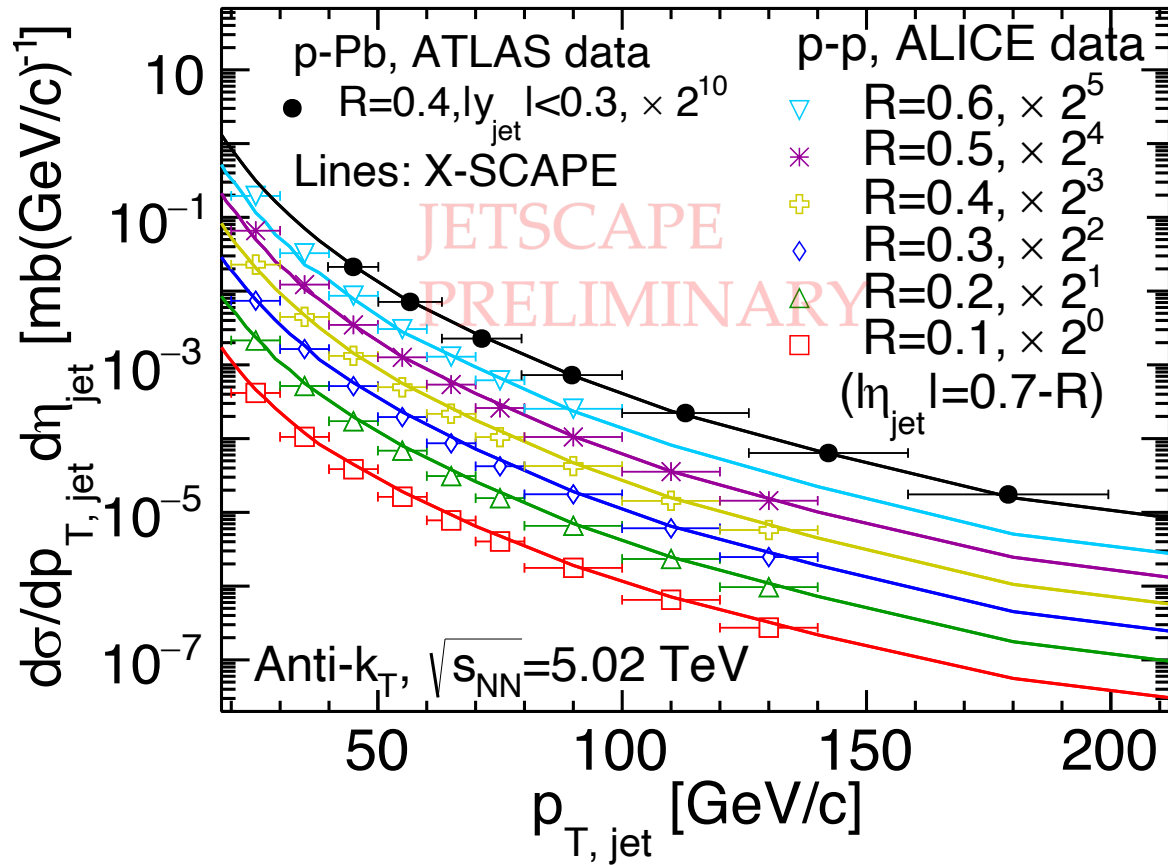


JETSCAPE  
PRELIMINARY

JETSCAPE  
PRELIMINARY

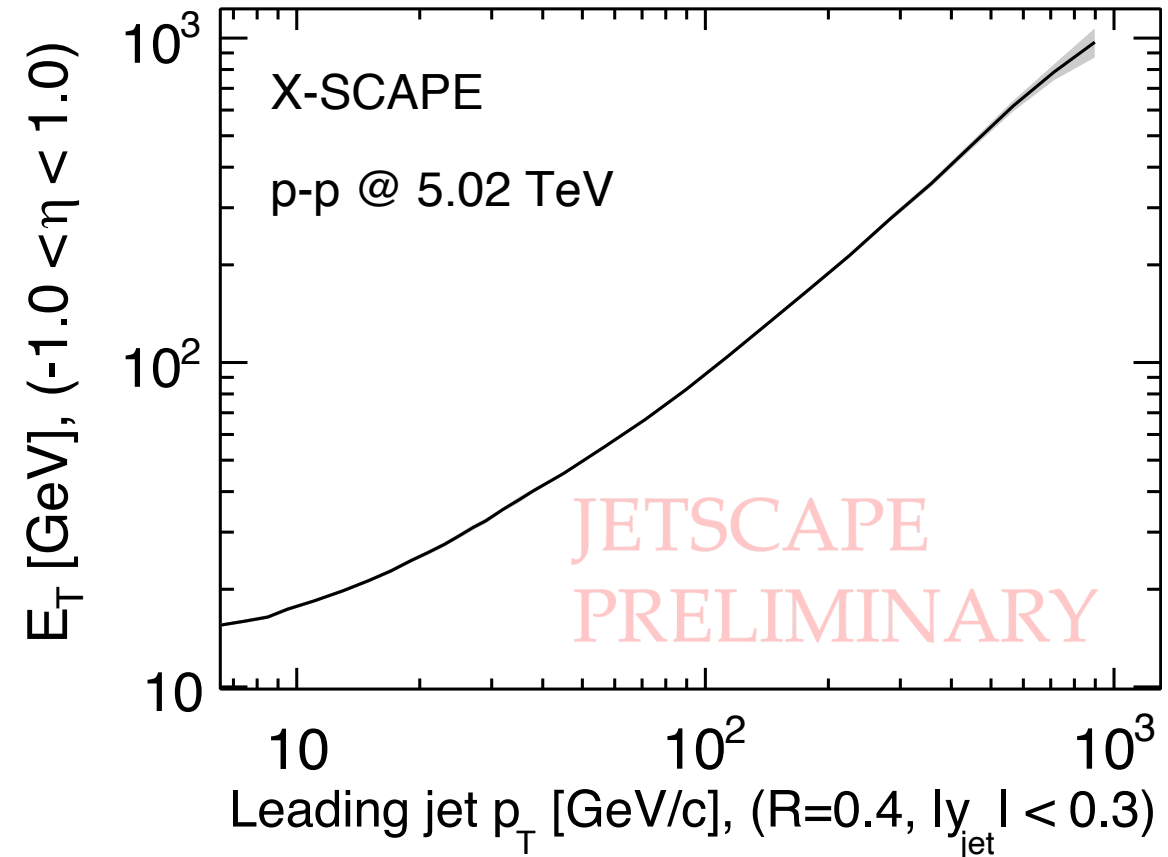
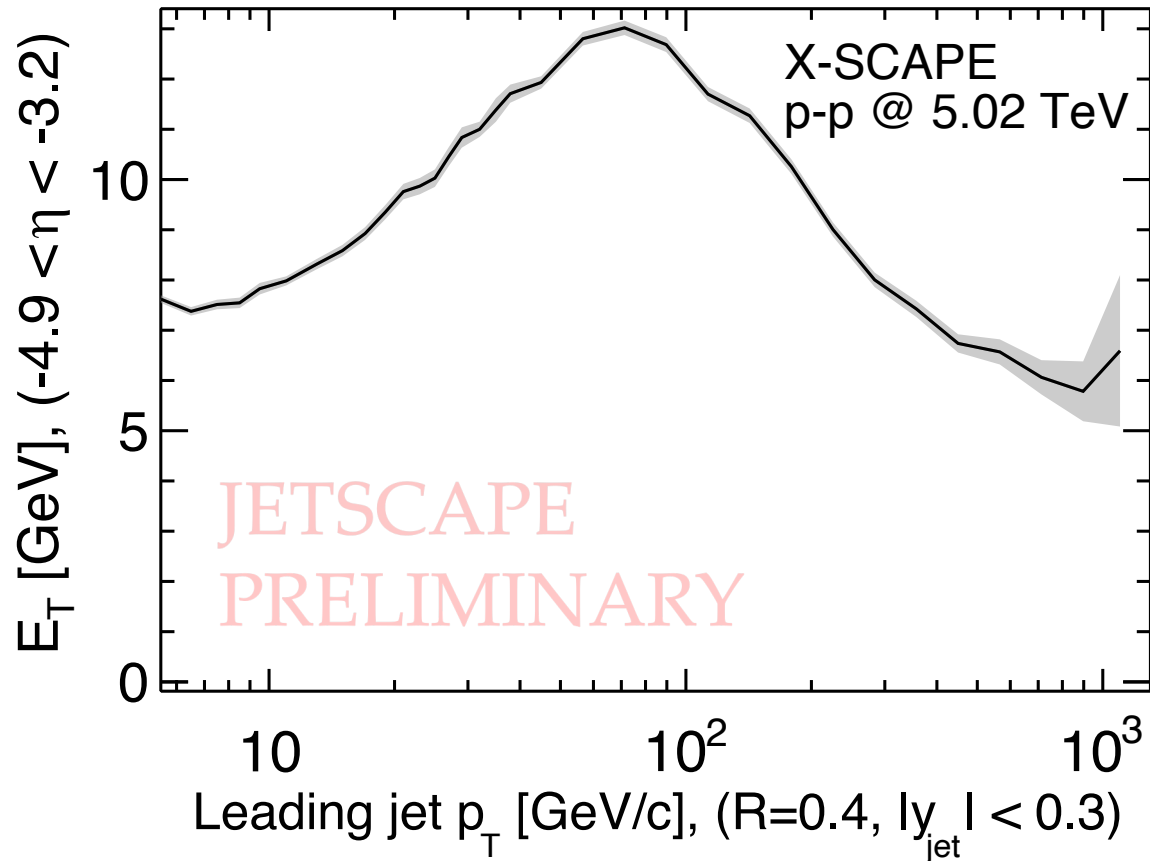
# Preliminary Results

- Jets in p-p and p-A
- Simple background subtraction: only use fragmentation hadrons in jet clustering



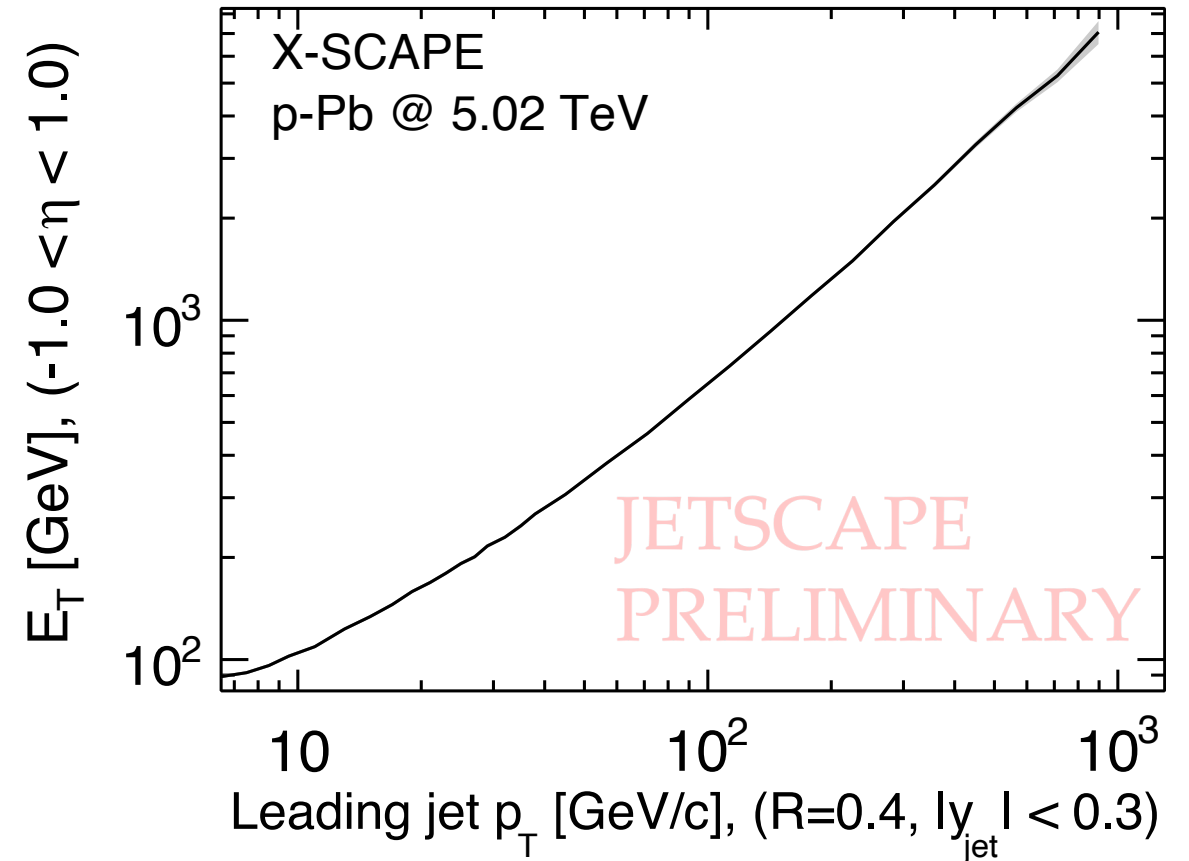
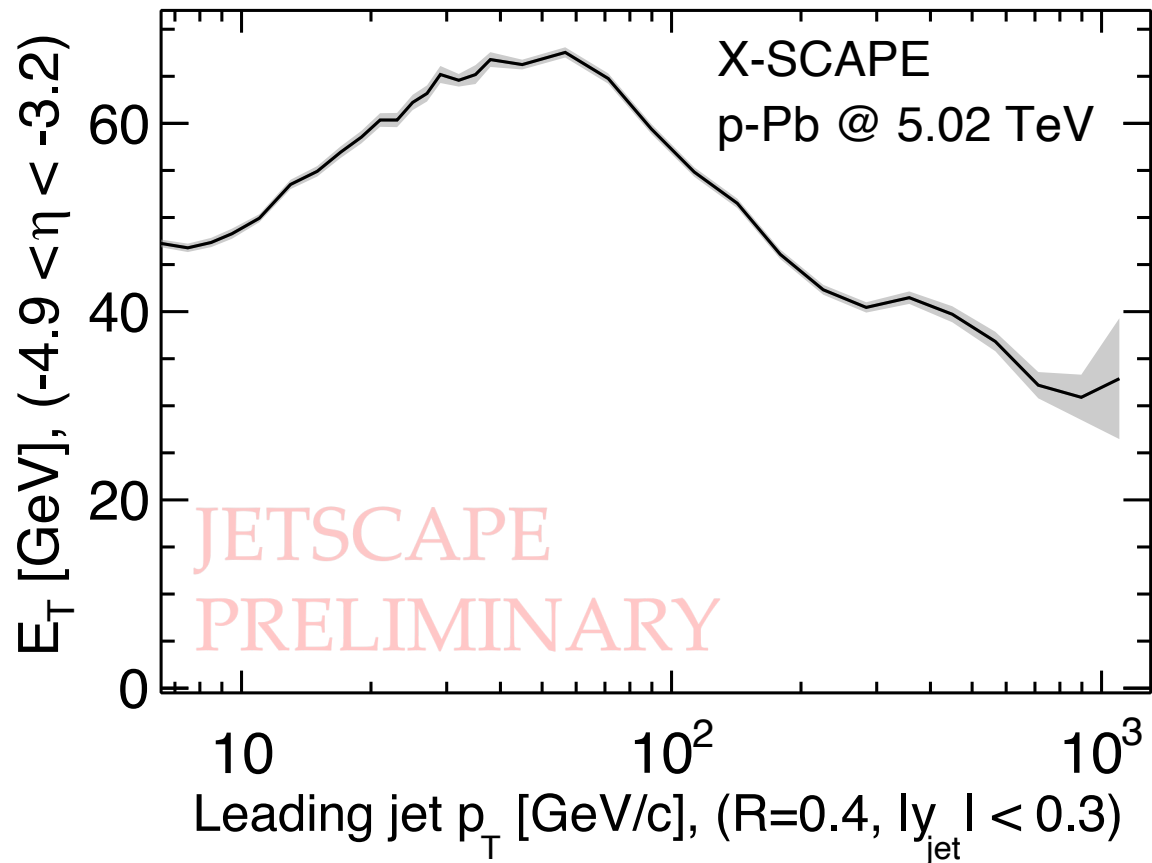
# Preliminary Results

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



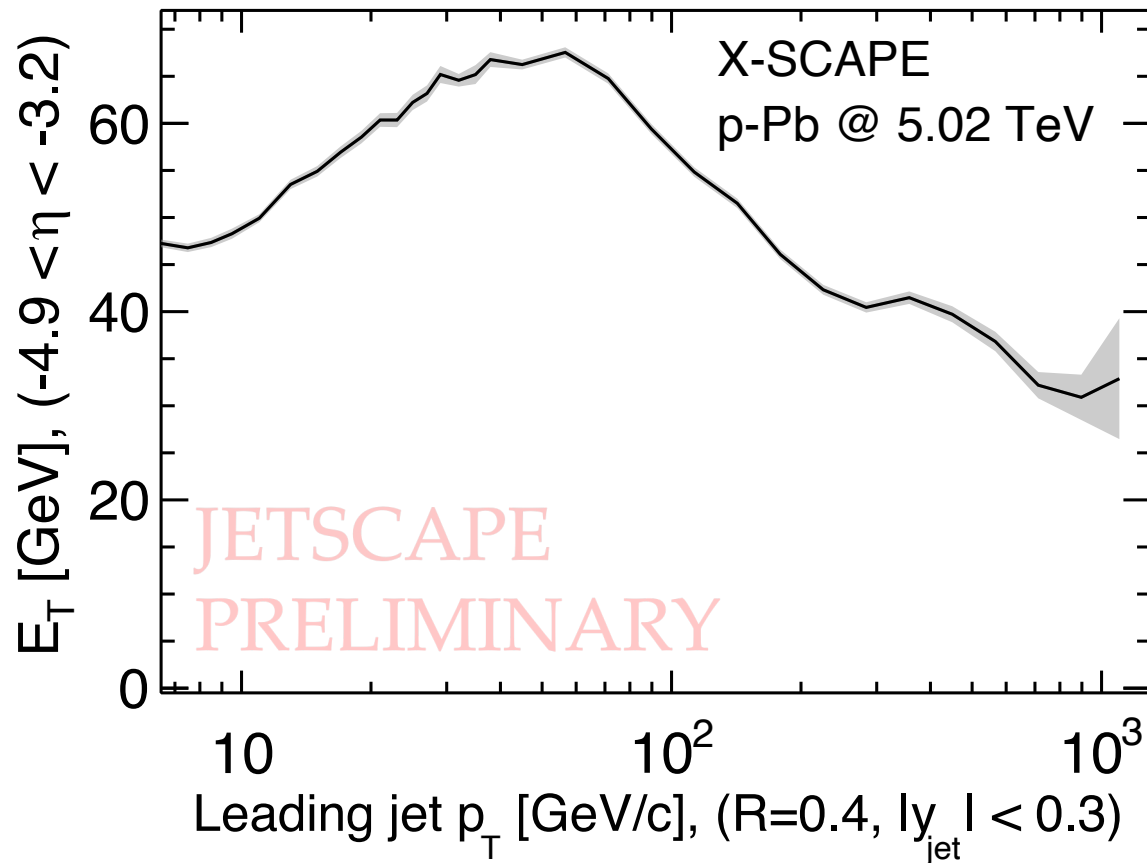
# Preliminary Results

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

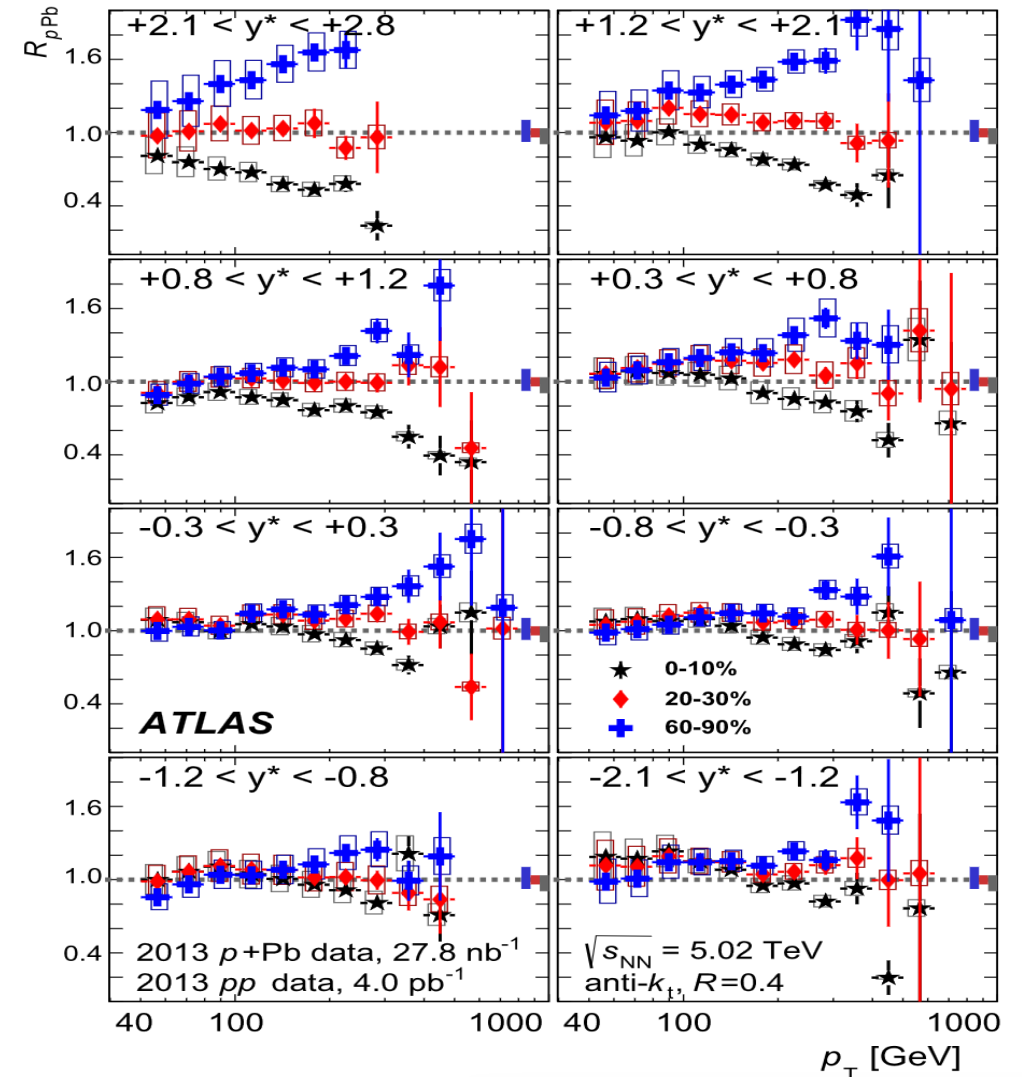


# Preliminary Results

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



$E_T$  [GeV],  $(-1.0 < \eta < 1.0)$



# 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  $E > 100 \text{ GeV}$ .



# Thanks to all my collaborators



# More analysis tools in JETSCAPE

*Animations by J. Putschke*

