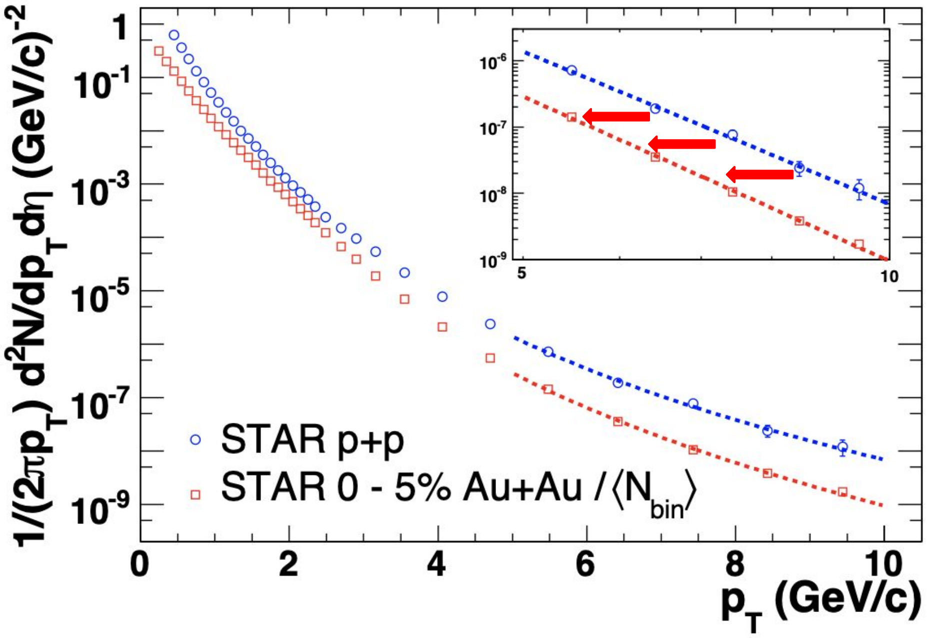
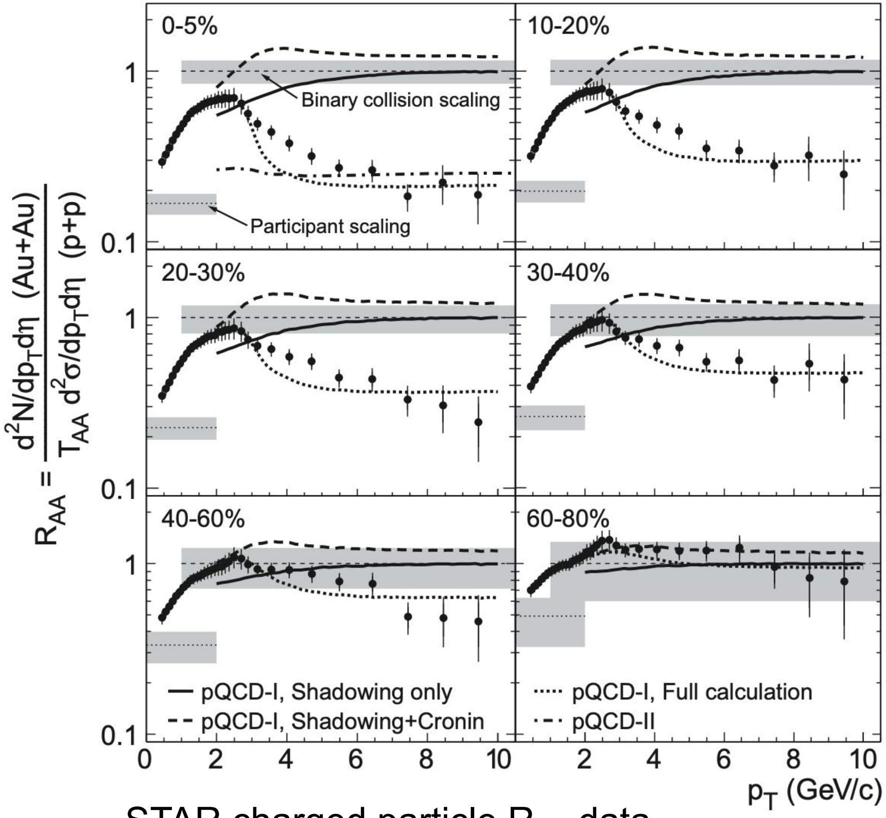
Empirical Constraints on Parton Energy Loss Dynamics

Thomas Marshall
UCLA
August 21, 2023

Motivation



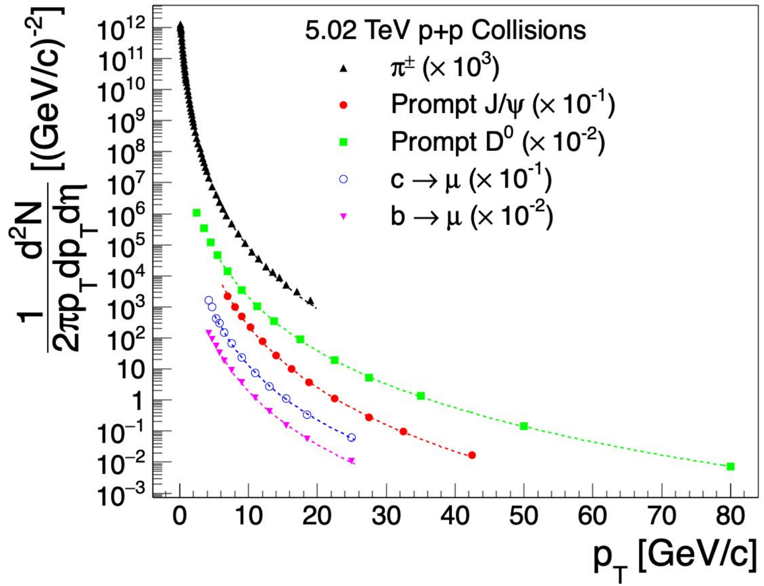
G. Wang and H. Z. Huang, Empirical constraints on parton energy loss in nucleus–nucleus collisions at rhic, Physics Letters B 672 (2009) 30–34.

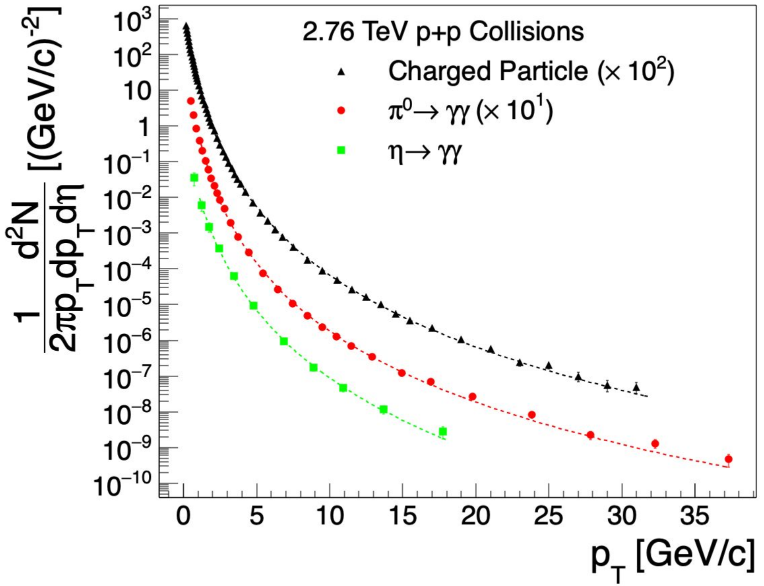


STAR charged particle R_{AA} data

Phys. Rev. Lett. 91 (2003) 172302

Tsallis Fits of Leading Particle pT Distributions





$$\frac{1}{2\pi p_T} d^2N/dp_T d\eta = A(1 + p_T/p_0)^{-n}$$

C.-Y. Wong and G. Wilk, Tsallis fits to pT spectra for p-p collisions at the lhc, Acta Physica Polonica B 43 (2012) 2047–2054

RHIC vs LHC

[G. Wang and H. Z. Huang, Empirical constraints on parton energy loss in nucleus–nucleus collisions at rhic, Physics Letters B 672 (2009) 30–34.]

$$R_{AA}(p_T) = \frac{(1 + p'_T/p_0)^{-n} p'_T}{(1 + p_T/p_0)^{-n} p_T} \left[1 + \frac{dS(p_T)}{dp_T} \right]$$

$$p'_T = p_T + S(p_T)$$

Flat R_{AA} at high p_T

$$S(p_T) = S_0 p_T$$

Modification for rising R_{AA} trend at LHC

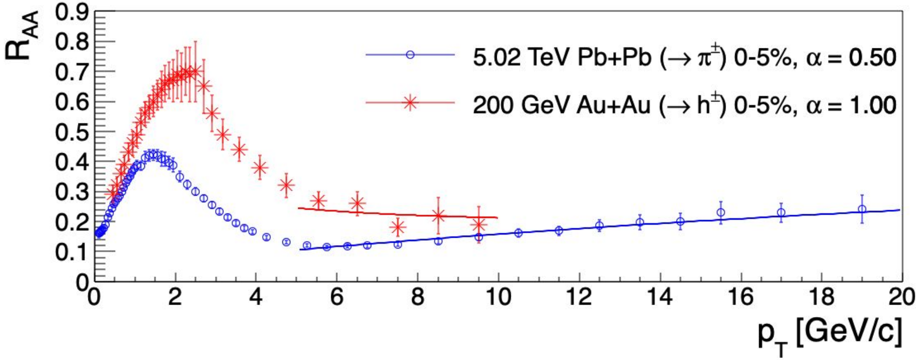
$$S(p_T) = S_0 {p_T}^{\alpha}$$

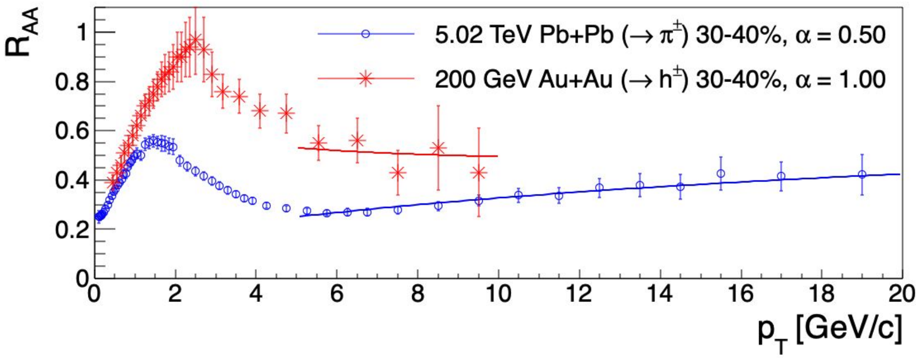
The value of α can then vary for RHIC or LHC conditions

RAA Trends at the LHC and RHIC

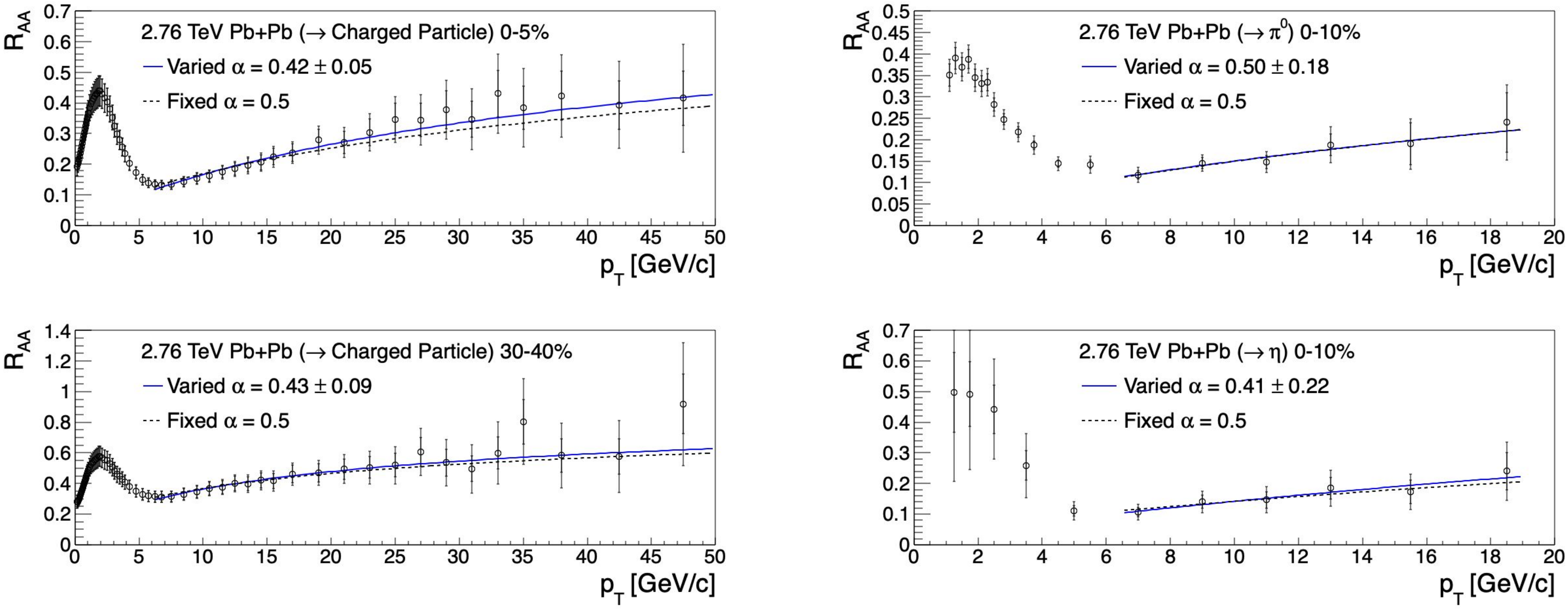
$$S(p_T) = S_0 {p_T}^{\alpha}$$

- In general, leading particle R_{AA} at high p_T appears to flatten at RHIC energies and steadily increase at LHC energies
- Could be explained by differing dependencies on collisional and radiative energy loss induced by the medium



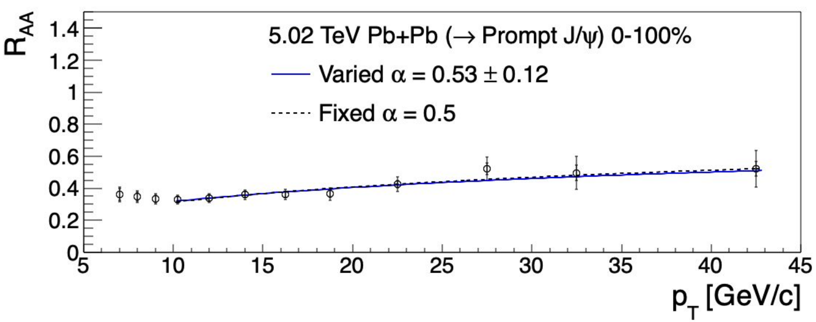


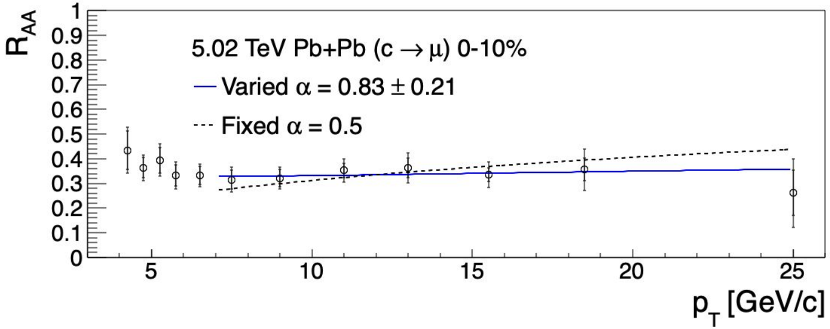
Other Leading Particle Species at the LHC

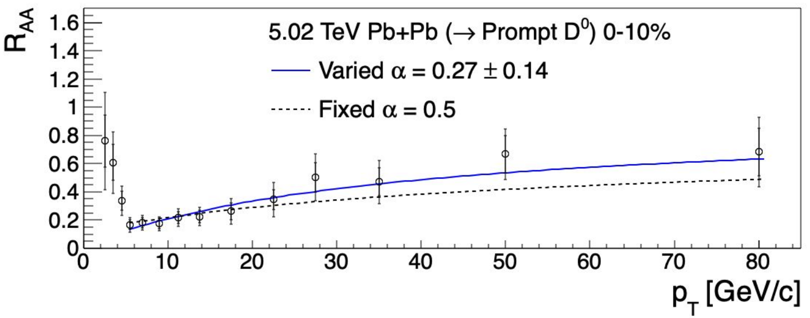


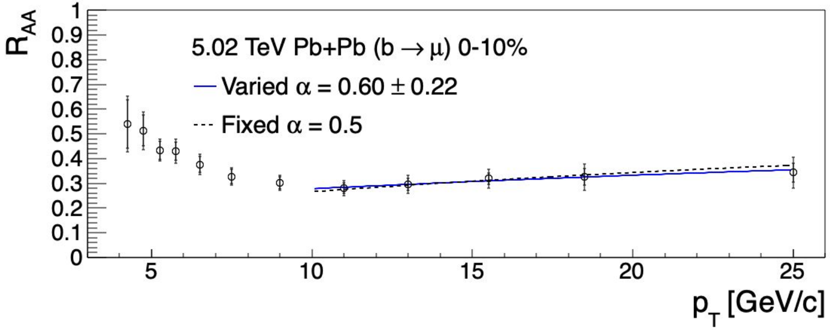
Most fits seem to be in good agreement with an α value of 0.5 at LHC energies

Other Leading Particle Species at the LHC



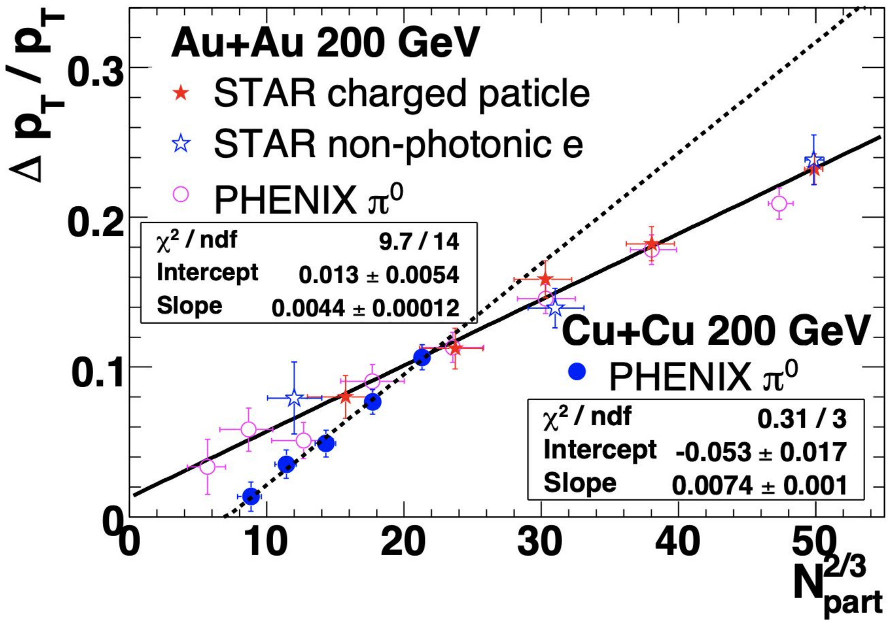


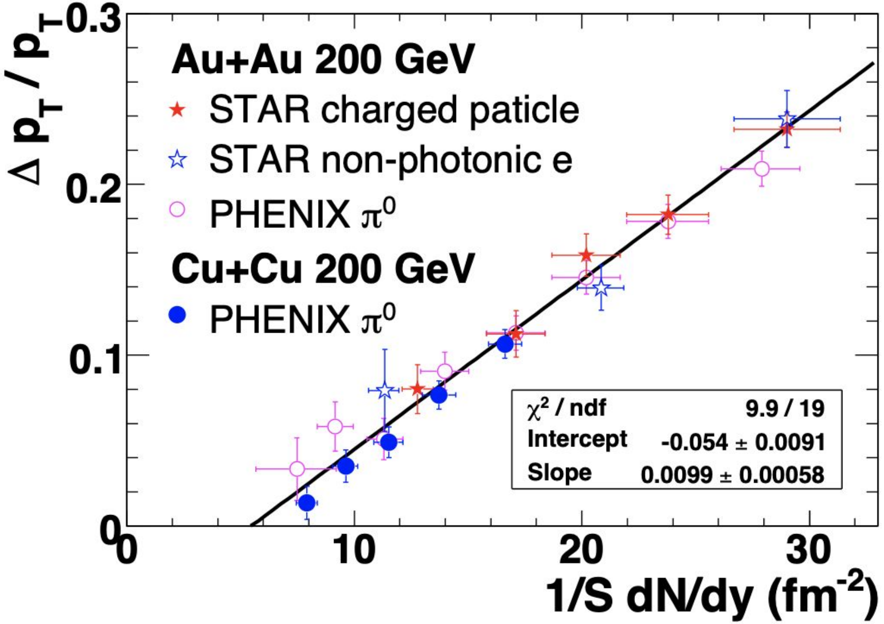




Some disagreement with heavy quarks, possible differences in energy loss mechanism

Path Length Dependence of Energy Loss

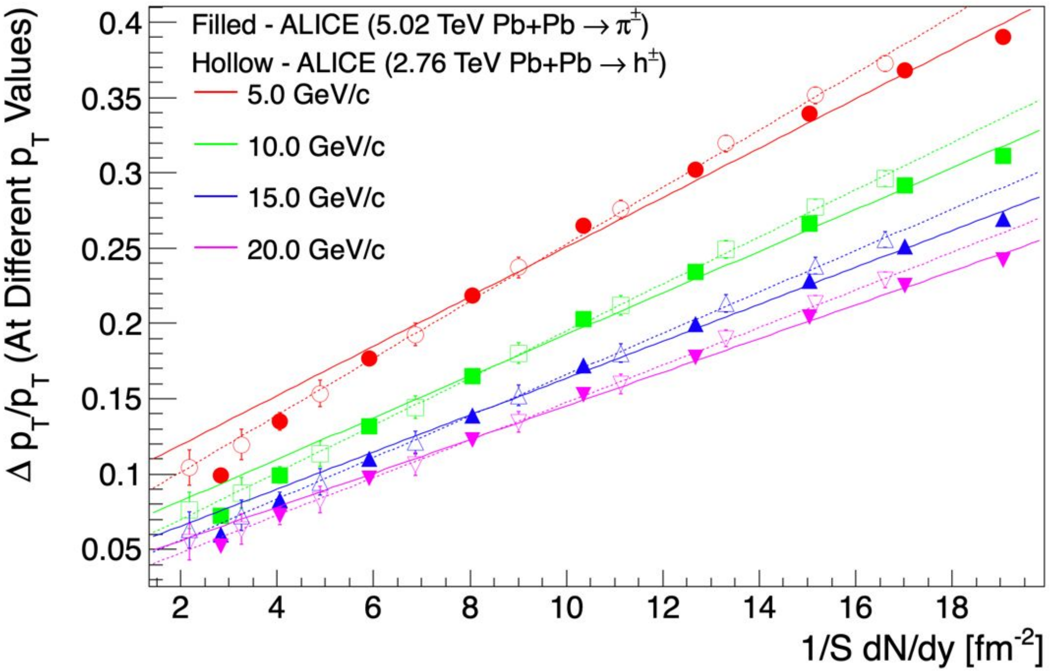




G. Wang and H. Z. Huang, Empirical constraints on parton energy loss in nucleus–nucleus collisions at rhic, Physics Letters B 672 (2009) 30–34.

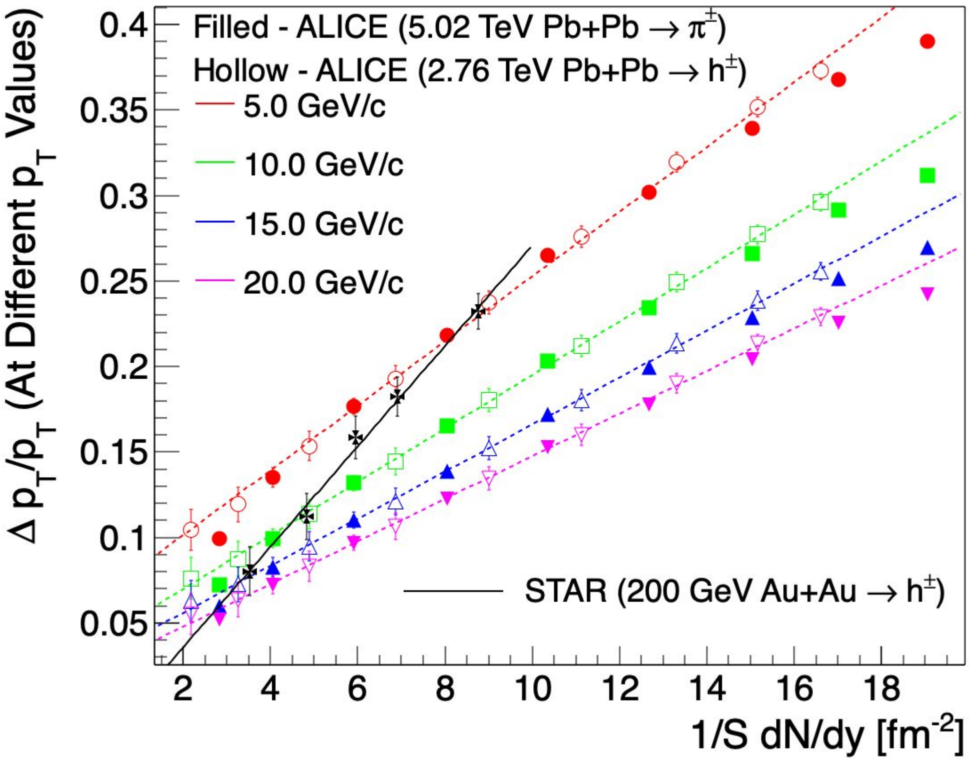
Path Length Dependence of Energy Loss

- Less rapid increase in fractional energy loss as a function of initial density at higher p_T
- Rapid expansion of the medium in the first couple Fermi
- Density reduces quickly, parton won’t have enough time to experience the full path length



Path Length Dependence of Energy Loss

- Larger slope with RHIC data
- Increased dependence on collisional energy loss → medium density matters more (more things to collide with)
- Vice versa for LHC increased dependence on radiative energy loss



Conclusions

- RHIC - $\Delta p_T \propto p_T$, LHC - $\Delta p_T \propto$ sqrt(p_T)
- Increase in radiative-collisional energy loss ratio at LHC energies
- Possible differences in energy loss mechanism in heavy quarks
  - Dead cone effect, etc
- Stronger dependence on initial collision density in RHIC energy loss
- No strong energy loss dependence on path length found
  - Rapid expansion of the medium in first few Fermi → not enough time for parton to traverse full path length
- Extension to cold QCD studies of energy loss with the EIC