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STAR

# Measurement of Energy Correlators Within Jets in *p+p* Collisions at $\sqrt{s} = 200\ \mathrm{GeV}$ in STAR

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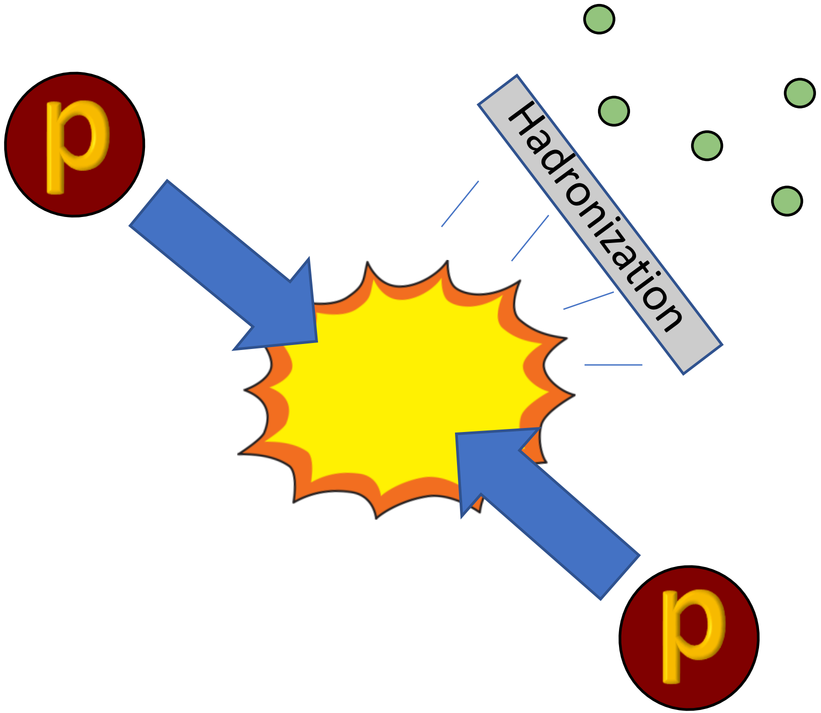
# Introduction and Experiment

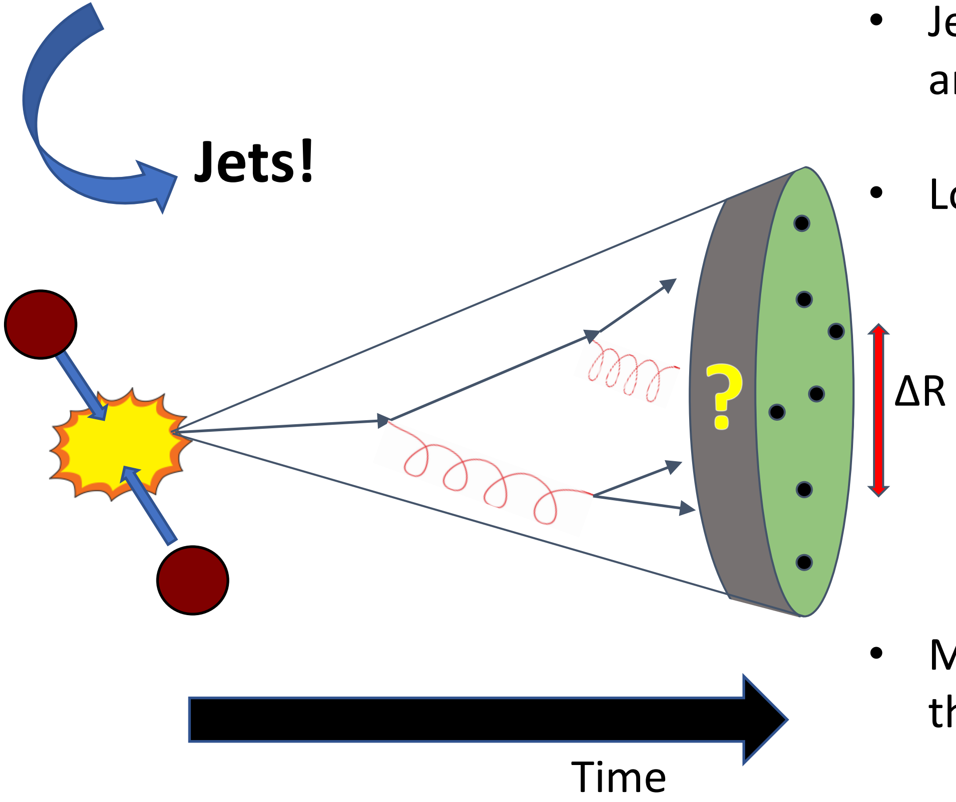



STAR Time Projection Chamber (TPC) provides excellent charged track reconstruction

Advanced jet algorithms allow for detailed study of jet substructure

Leverage these tools to learn about how partons are confined into hadrons

# How to Probe Hadronization




- Jets are found in this study using the anti-$k_T$ algorithm
- Look at time evolution of jet
  - Hadrons at larger angular distance ($\Delta R$) from each other are more likely to be related by splits earlier in time

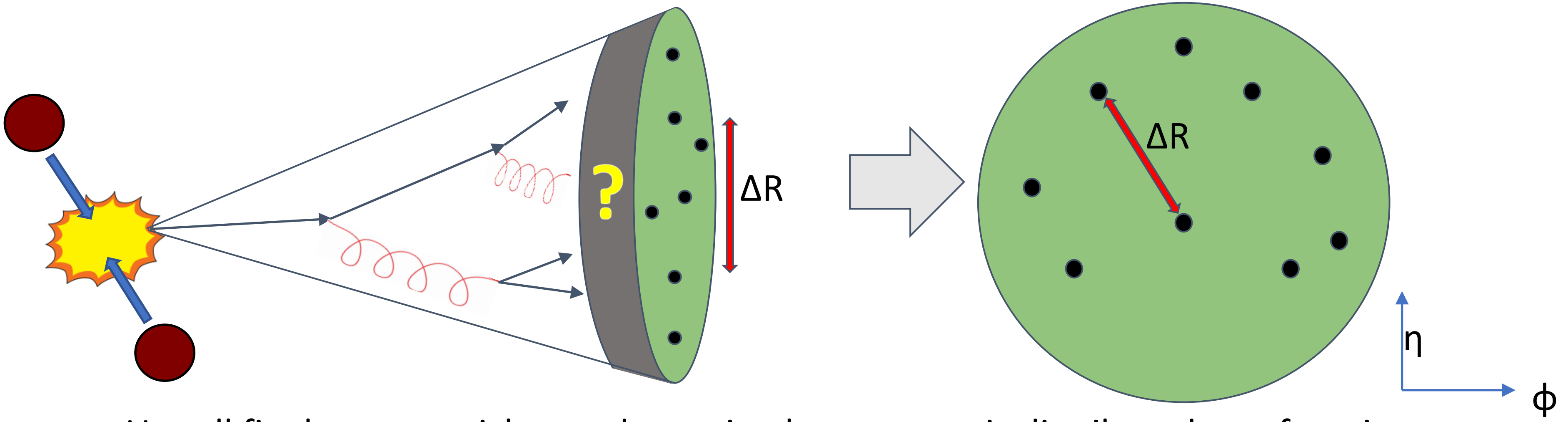
$$t_f \approx \frac{1}{\Delta R^2}$$

Apolinário, L., Cordeiro, A. & Zapp, K. *Eur. Phys. J. C* **81**, 561 (2021).

- Many other methods used to probe this rely on clustering algorithms
  - What if we want to use a method without additional algorithms?

# Energy Energy Correlators (EEC)

$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

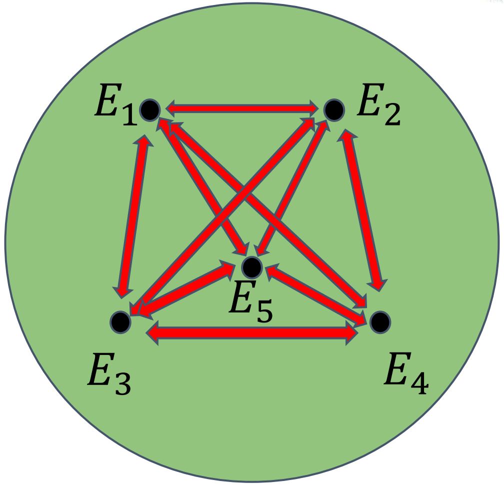



- Use all final state particles, and examine how energy is distributed as a function of their separation
- Allows for study of jet evolution using final state particles as they are, no additional clustering after jet-finding – Direct connection to theory
  - Can be described with perturbative calculations

Chen, Moult, Zhang and Zhu
Phys. Rev. D 102, 054012 (2020)

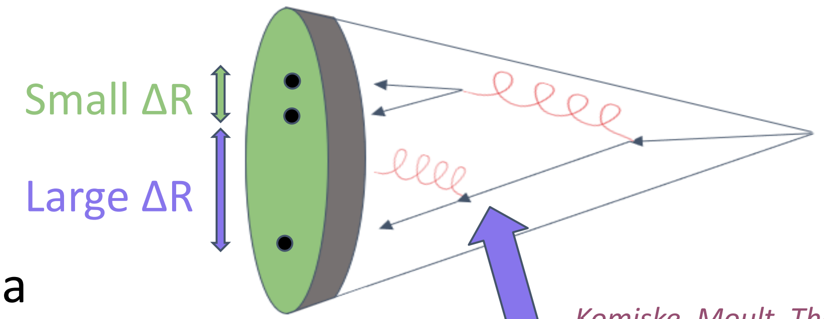
# Experimental Measure of EEC

- Create a multiplicity histogram of the ΔR between all combinations of charged track pairs
- Weight each entry by the energy product of the two constituents
  - Infrared and Collinear safe
- Normalize the distribution to unity in order to directly compare the shape




$$\text{Normalized EEC} = \frac{1}{\sum_{Jets} \sum_{i \neq j} \frac{E_i E_j}{(p_{T\,Jet})^2}} \frac{d\left(\sum_{Jets} \sum_{i \neq j} \frac{E_i E_j}{(p_{T\,Jet})^2}\right)}{d \ln(\Delta R)}$$

# Relate to Jet Evolution

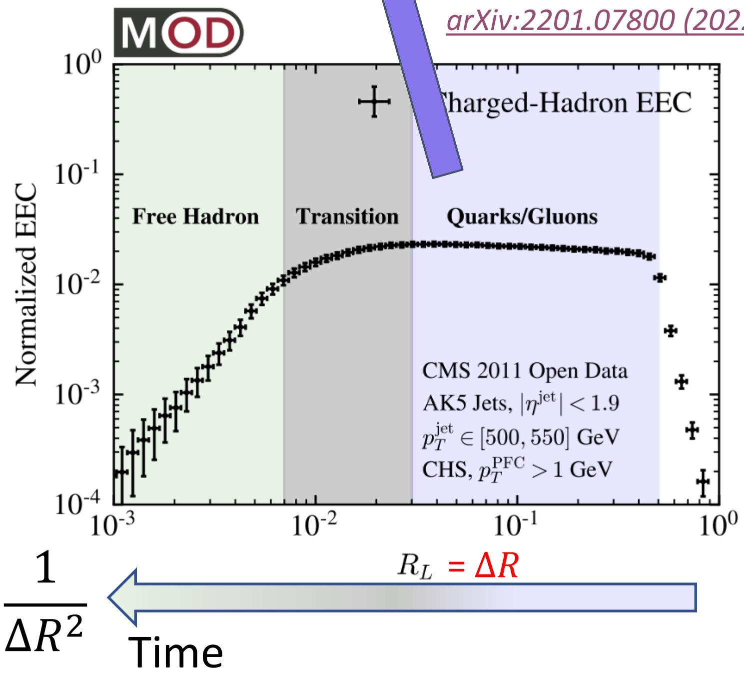



- Behavior at small $\Delta R$ corresponds to a random distribution of hadrons, while behavior at large $\Delta R$ is influenced by fragmentation – study **transition region**

- Each region is characterized by its scaling behavior

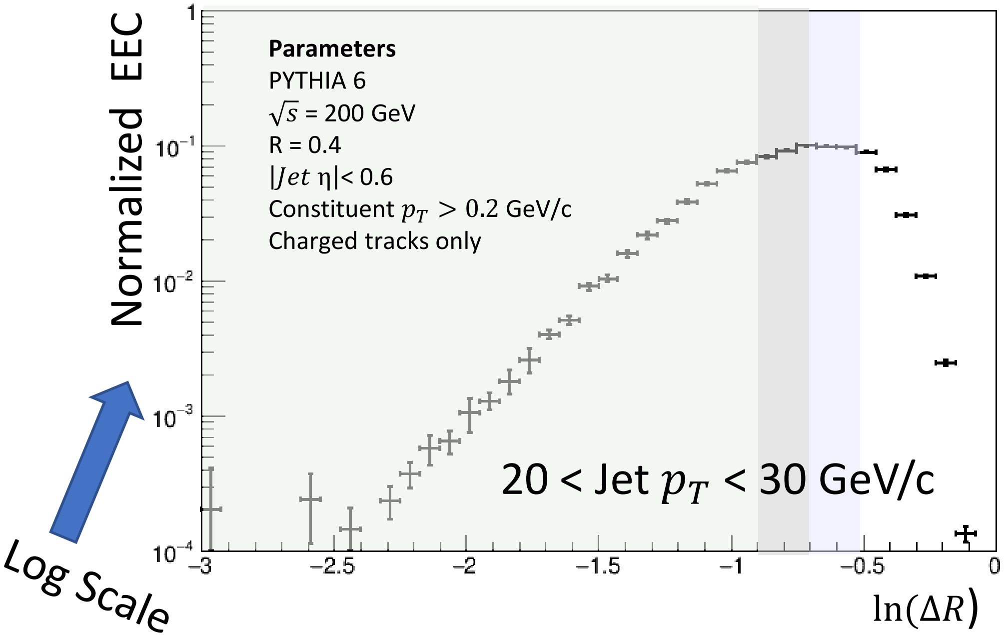
- Energy-Energy Correlators make a direct connection with theory!

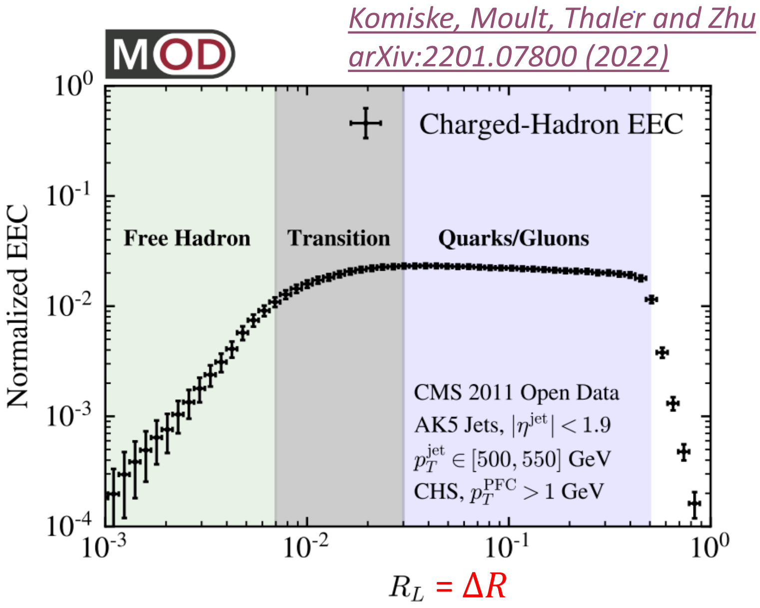
*Komiske, Moult, Thaler and Zhu arXiv:2201.07800 (2022)*




$$t_f \approx \frac{1}{\Delta R^2}$$

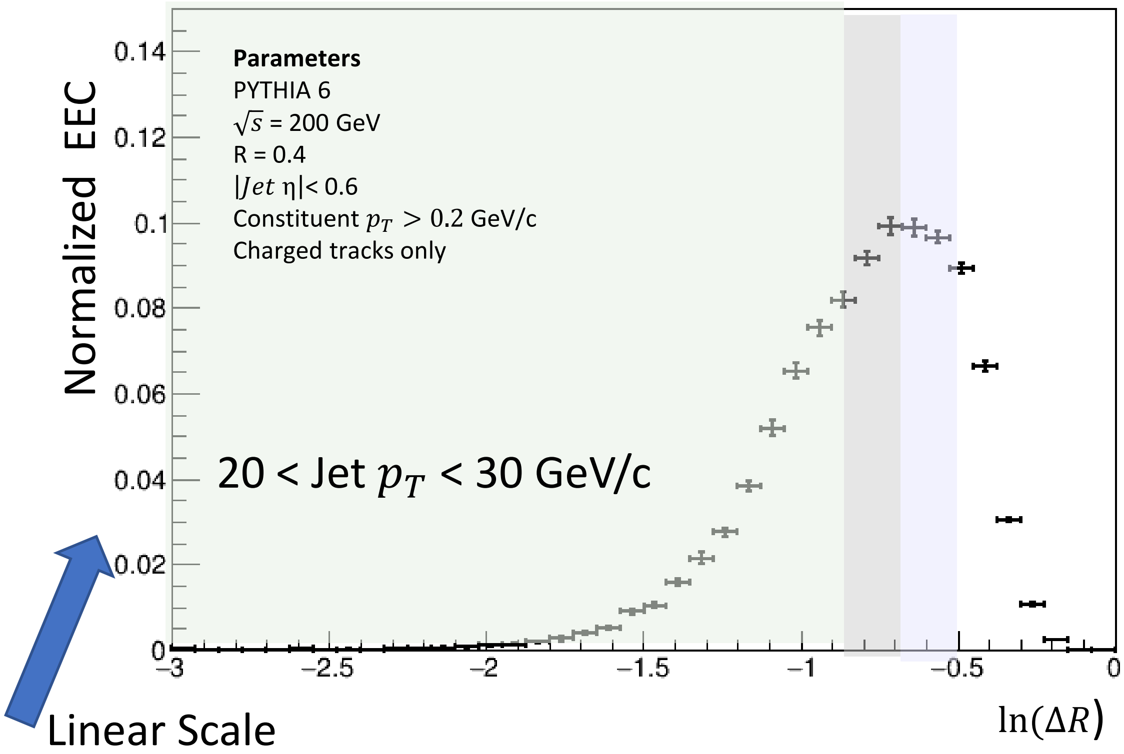
# Move to Lower Jet $p_T$ (at STAR)



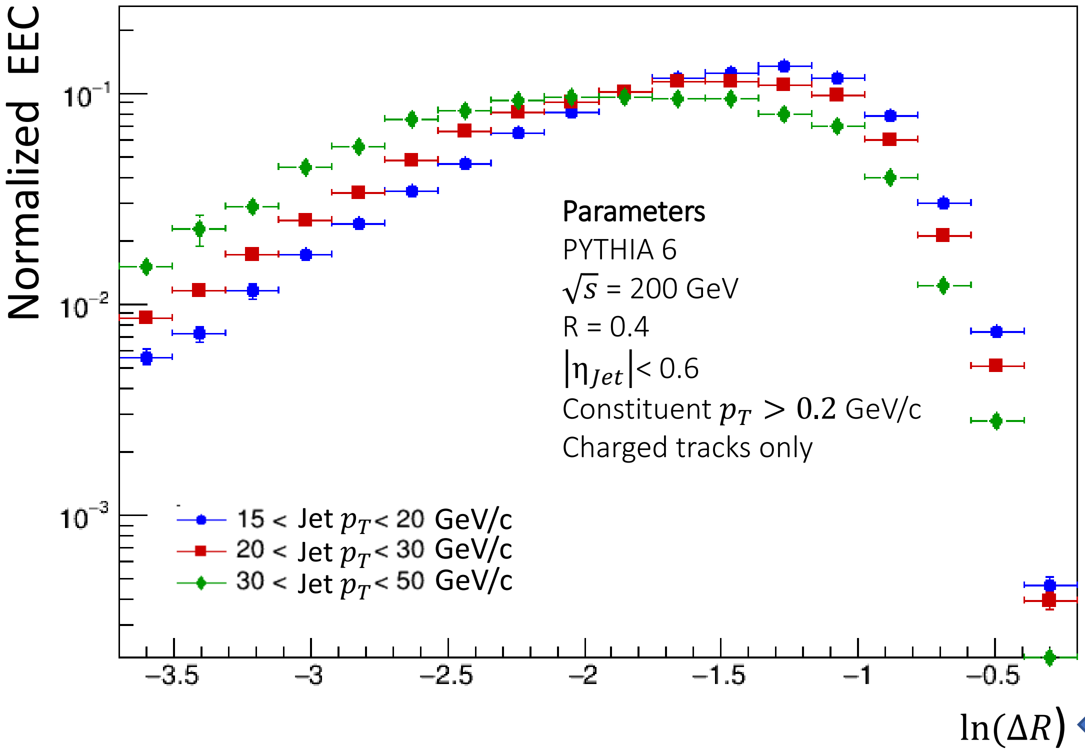

- Lower jet $p_T$ causes transition region to occur at larger angles
- Less time spent traveling before hadronization

# Move to Lower Jet $p_T$ (at STAR)




- Quarks/Gluons region is less pronounced at lower jet $p_T$ typically examined at STAR
- Less “time” is being spent there during jet evolution
- Two different scales on y axis highlight different properties of EEC

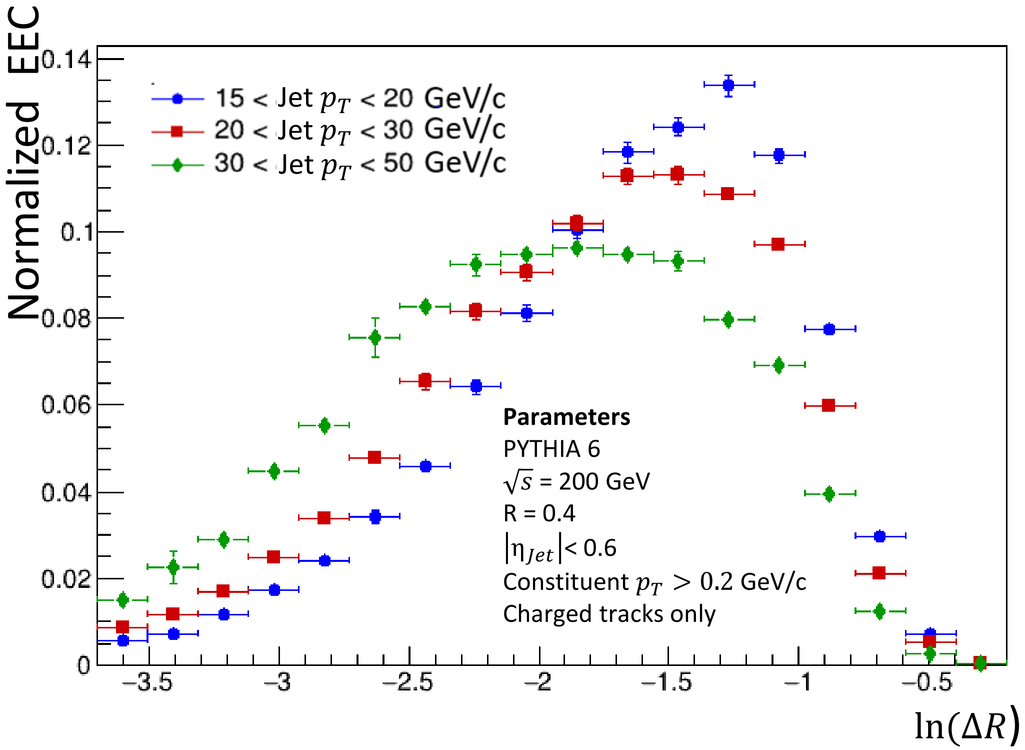
# PYTHIA Simulations of Jet $p_T$ Dependence




- The flat "Quark and Gluon region" grows wider with increasing $p_T$
- Transition region moves to smaller opening angle with higher jet $p_T$

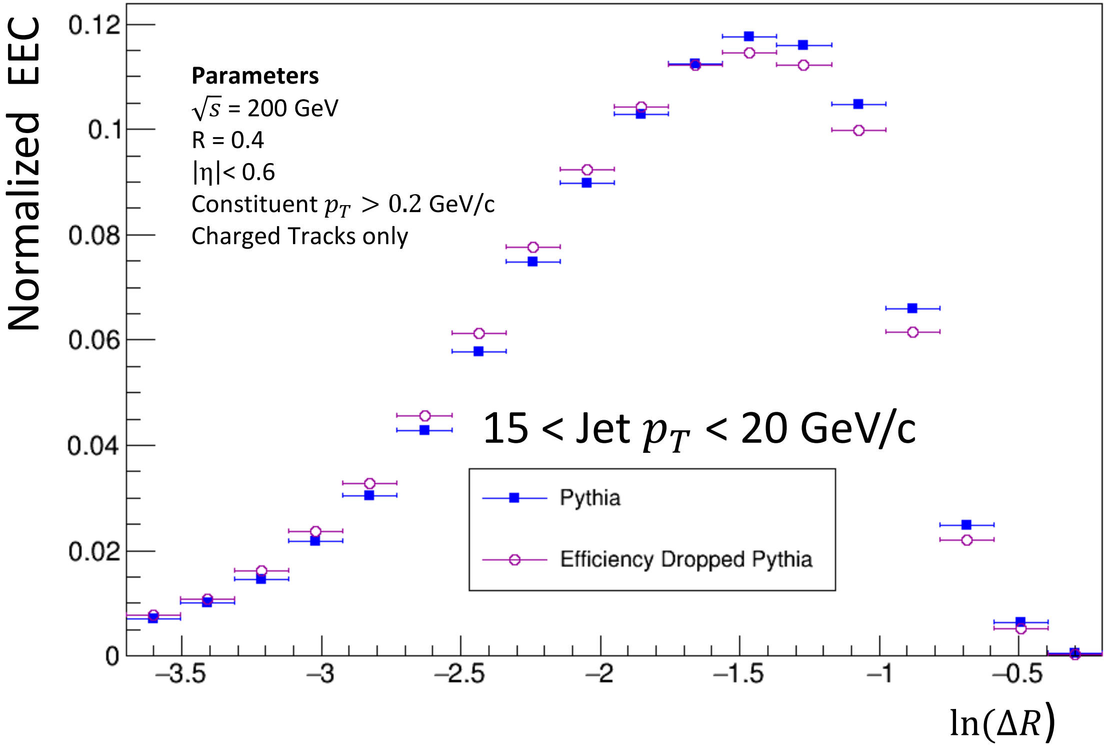
Base e from here on out

# PYTHIA Simulations of Jet $p_T$ Dependence



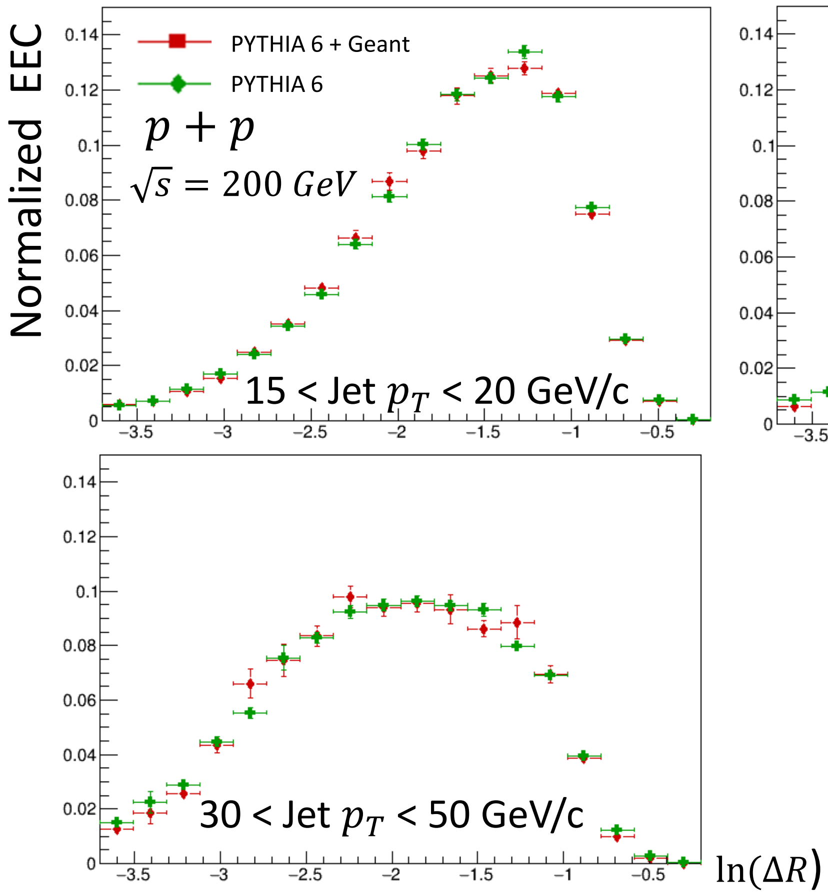

- The flat "Quark and Gluon region" grows wider with higher jet $p_T$
- Transition region (area around peak of curve) moves to smaller opening angle with higher jet $p_T$

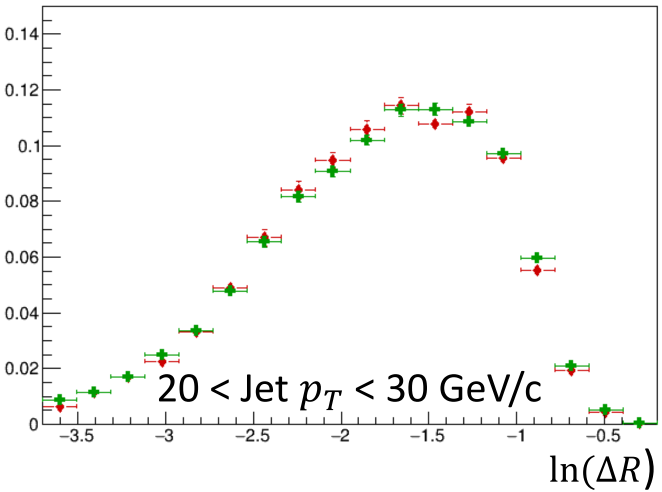
# Tracking Efficiency Effects




- As a test to detector effects, assume 80% tracking efficiency for charged particles
- Shape of EEC has minimal change with $p_T$ -**independent** tracking efficiency
- Do $p_T$-dependent efficiency and shift in jet $p_T$ make a difference?

# Full Detector Effects




**Parameters**
PYTHIA 6
$\sqrt{s}$ = 200 GeV
R = 0.4
$|\eta_{Jet}|$< 0.6
Constituent $p_T > 0.2$ GeV/c
Charged Tracks only
p+p Run 12 Official Embedding

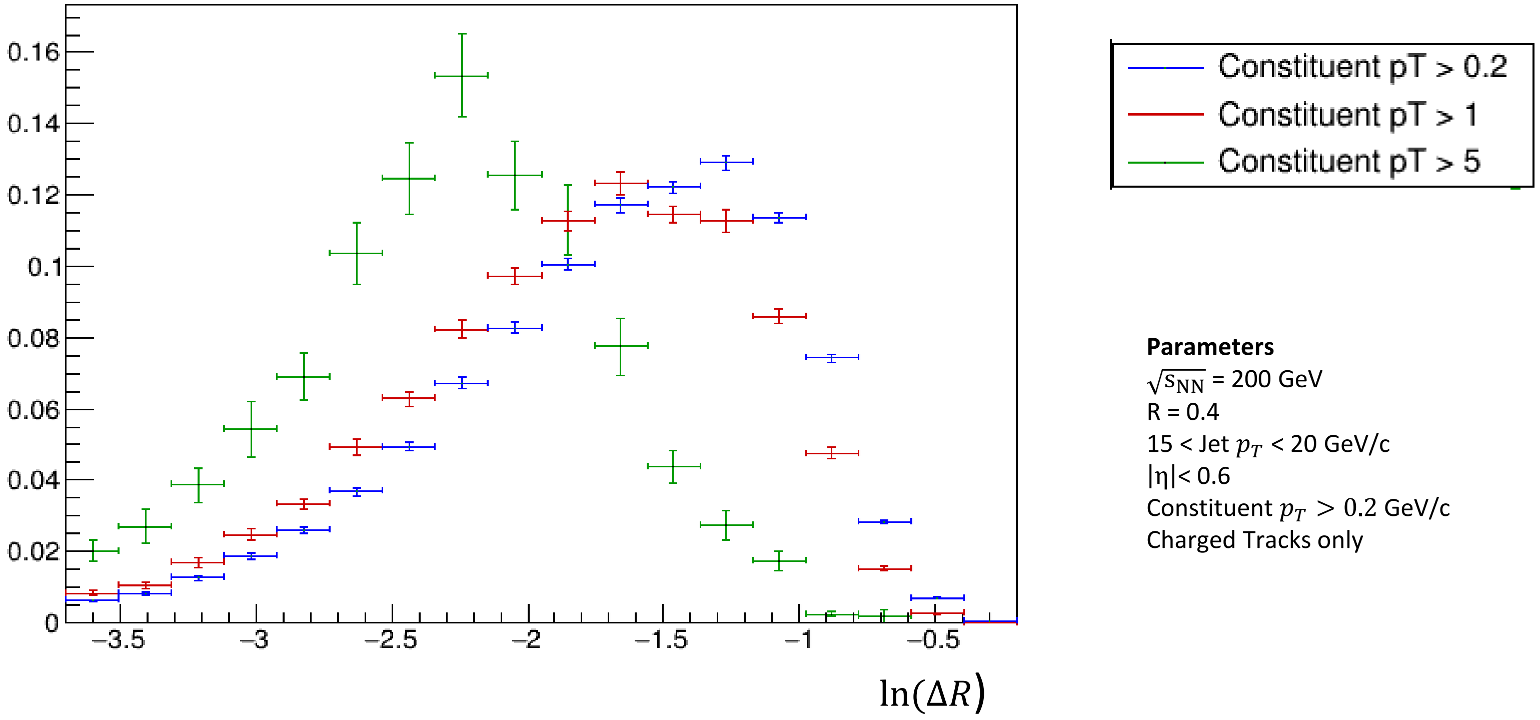
- No significant change in shape before and after passing through Geant (official simulation of full detector effects)
- Unfolding effect will be small
- Raw distribution from data has been obtained, will update when corrections are done!

# Conclusions

- EEC is an exciting observable with growing interest
- Examines jet substructure and probes behavior of jet during both fragmentation and hadronization
- PYTHIA 6 simulation shows a dependence on jet $p_T$
- Detector effects do not have large effect on measurement
- First measurement in *p+p* $\sqrt{s} = 200 \text{ GeV}$ in progress in STAR

# Backup

# Jet Constituent Behavior




**Parameters**
$\sqrt{s_{NN}}$ = 200 GeV
R = 0.4
15 < Jet $p_T$ < 20 GeV/c
|η|< 0.6
Constituent $p_T > 0.2$ GeV/c
Charged Tracks only