Supported in part by:
U.S. DEPARTMENT OF ENERGY | Office of Science
STAR
WAYNE STATE UNIVERSITY

First Measurement of the Jet Charge in $\sqrt{s} = 200$ GeV pp Collisions at STAR

Grant McNamara
for the STAR Collaboration
grant.mcnamara@wayne.edu

DNP2022

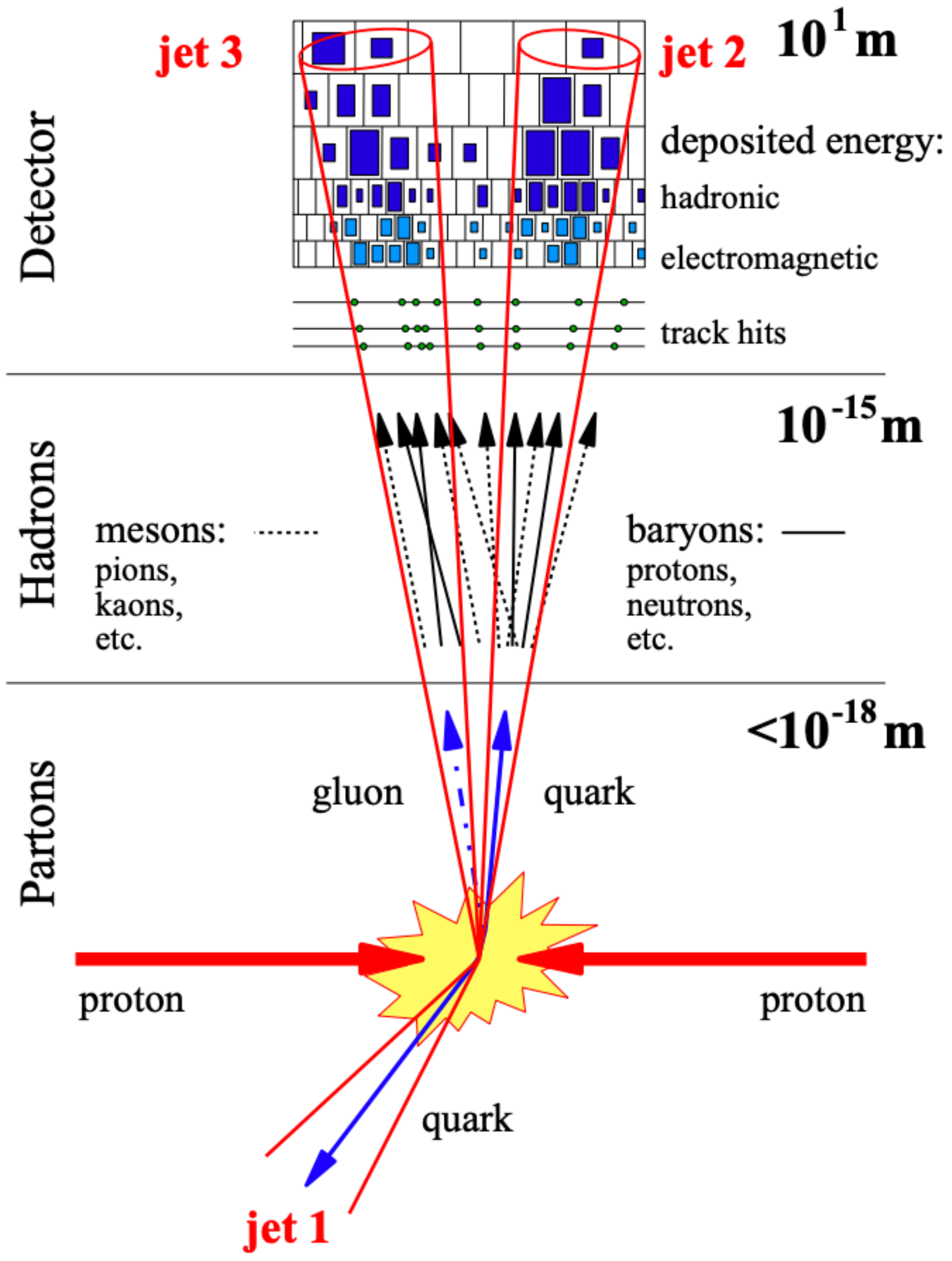
Fall Meeting of the Division of Nuclear Physics
of the American Physical Society
Oct. 27 – 30, 2022
Hyatt Regency Hotel, New Orleans, LA

APS physics

Introduction: Jets

- Jets are collimated sprays of hadrons produced from hard scatterings of partons (quarks and gluons)
- Goal is to study the initiating parton that participates in this hard scattering
- Electric charge is conserved
    - Different partons have different charges
    - Total electric charge of a jet contains information about the initiating parton

Rabbertz, K.
https://doi.org/10.1007/978-3-319-42115-5



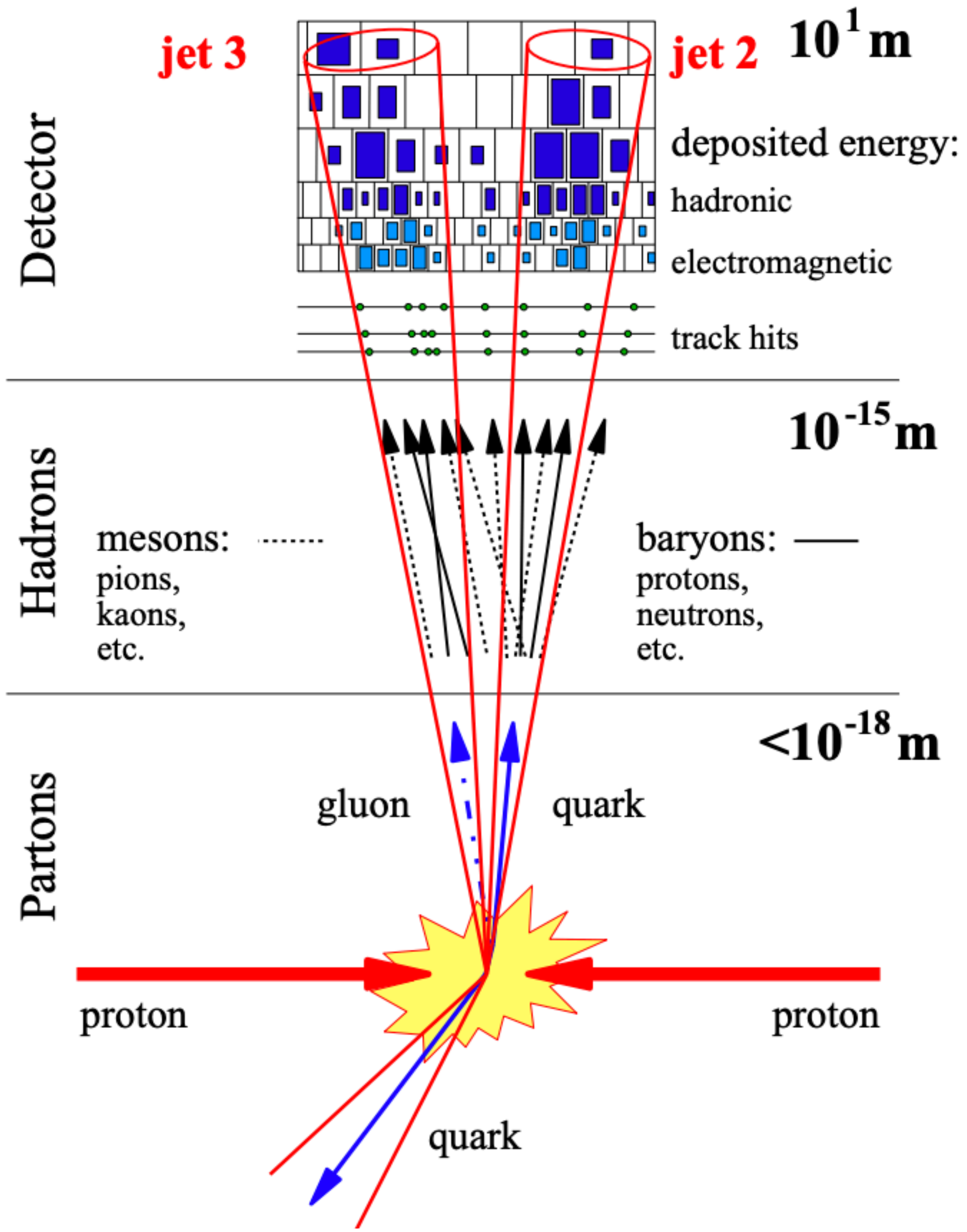
Introduction: Jet Finding

- Need to connect experiment to theory
- Theoretically and experimentally well-defined

Toward a standardization of jet definitions Research directions for the decade pp 134-136

- FastJet provides jet finding algorithms: anti-k_T
- Resolution parameter R = 0.4

Rabbertz, K.
https://doi.org/10.1007/978-3-319-42115-5

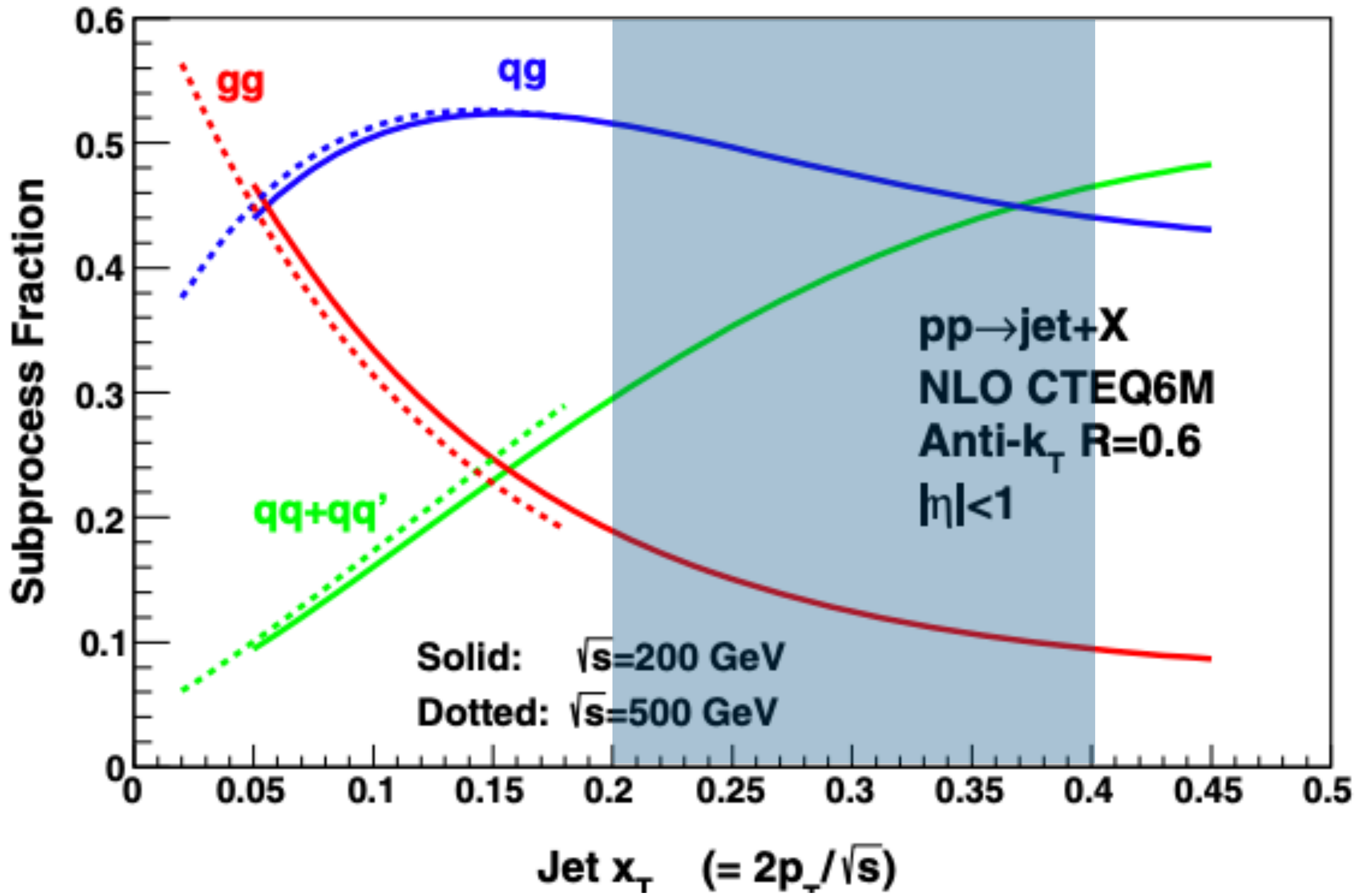


Cacciari, Salam, J. High Energ. Phys. 04 (2008) 063

Cacciari, Salam, Soyez, Eur.Phys.J. C 72 (2012) 1896

Motivation

- Measure quark vs gluon fraction of jets in pp collisions to constrain theory
- The energy loss in AuAu collisions depends on the flavor of parton
- Jet charge is sensitive to the quark vs gluon fraction

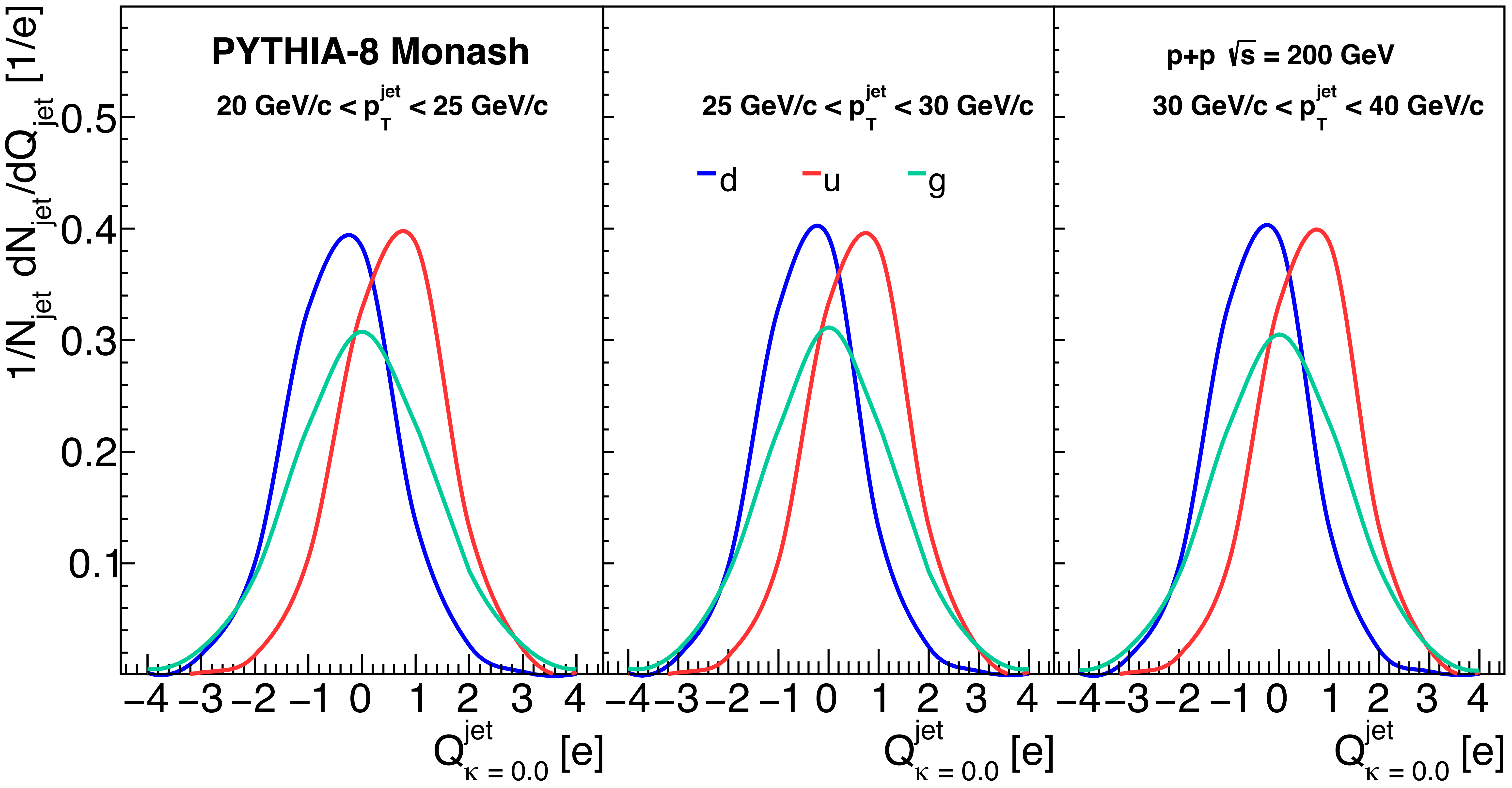


STAR Collaboration, Phys.Rev. D 100 (2019) no.5, 052005

(Weighted) Jet Charge

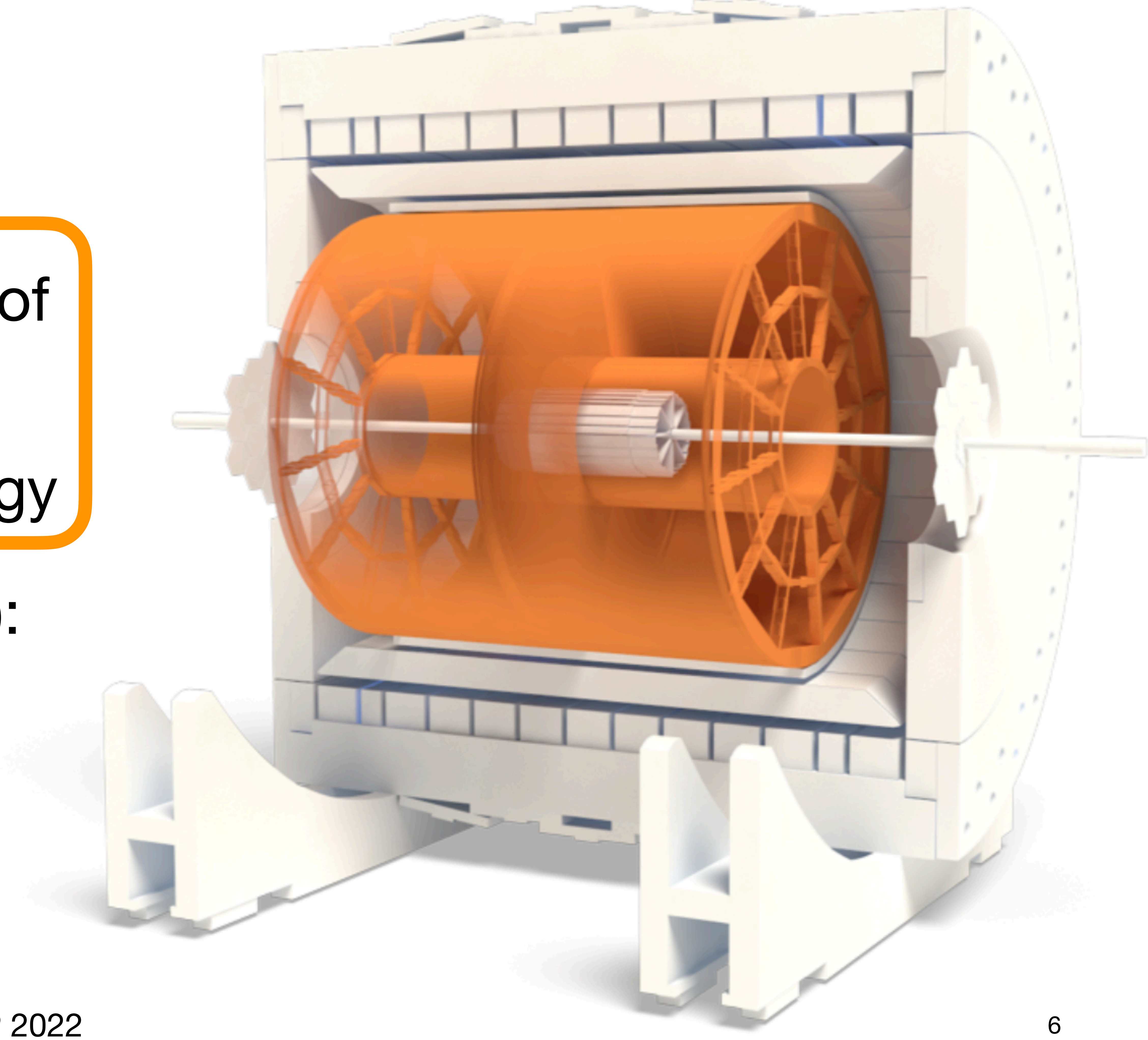
Charges
Up: +2/3
Down: -1/3
Gluon: 0

- $$Q^i_\kappa = \sum_{j \in jet} \left(\frac{p_T^j}{p_T^{jet}} \right)^\kappa Q_j$$
- Choice of $\kappa = 0.0$
  - $Q^{jet}_{\kappa=0.0}$
- Study change in quark vs gluon fraction as function of jet p_T



Solenoidal Tracker at RHIC (STAR)

- Relativistic Heavy Ion Collider (RHIC) collides *p*+*p* beams at $\sqrt{s} = 200$ GeV
- Time Projection Chamber (TPC): momenta of charged particles
  - Utilized in jet charge, included in jet energy
- Barrel Electromagnetic Calorimeter (BEMC): neutral energy deposits, provides online trigger (Jet Patch)
  - Included in jet energy

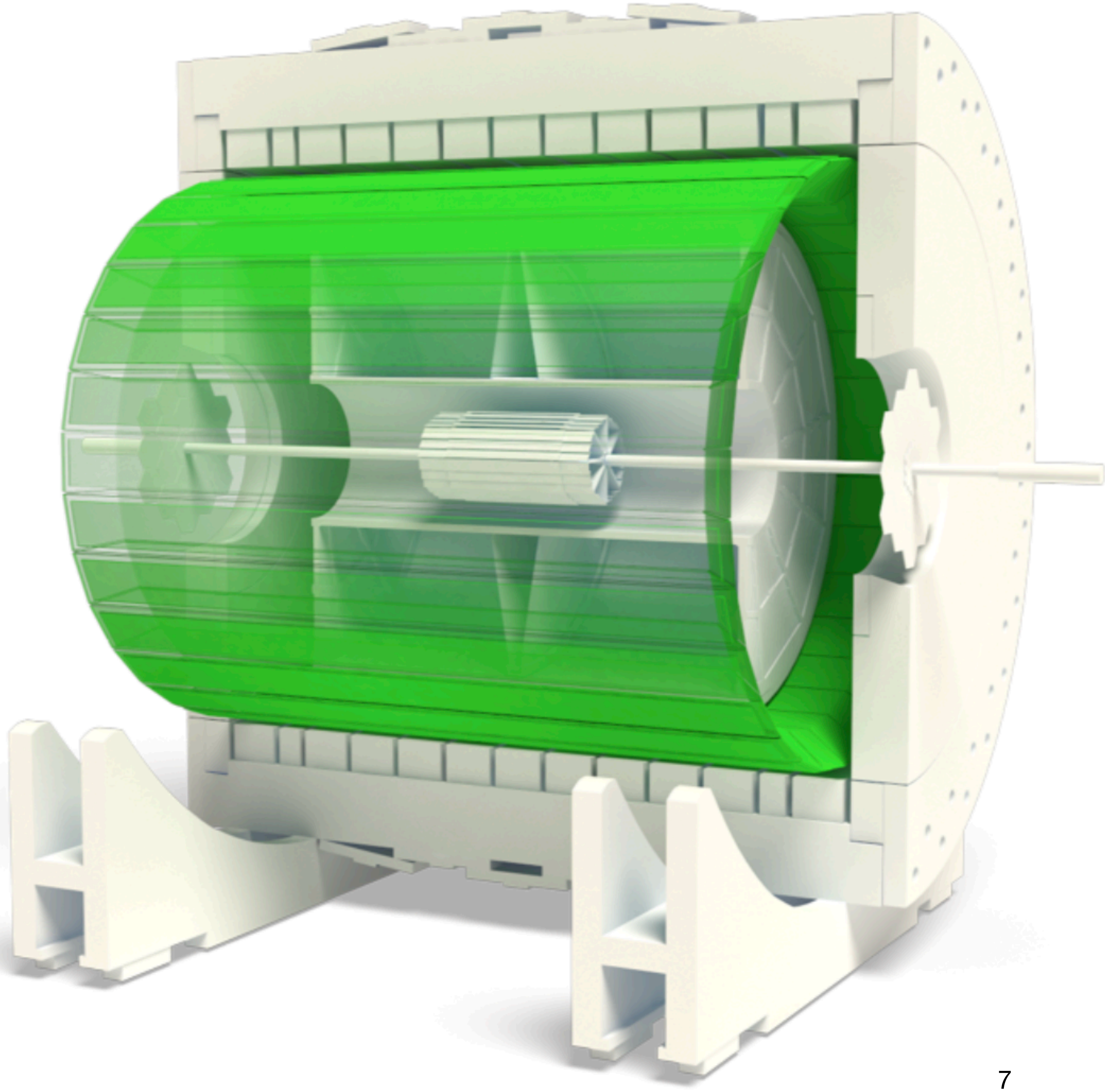


Solenoidal Tracker at RHIC (STAR)

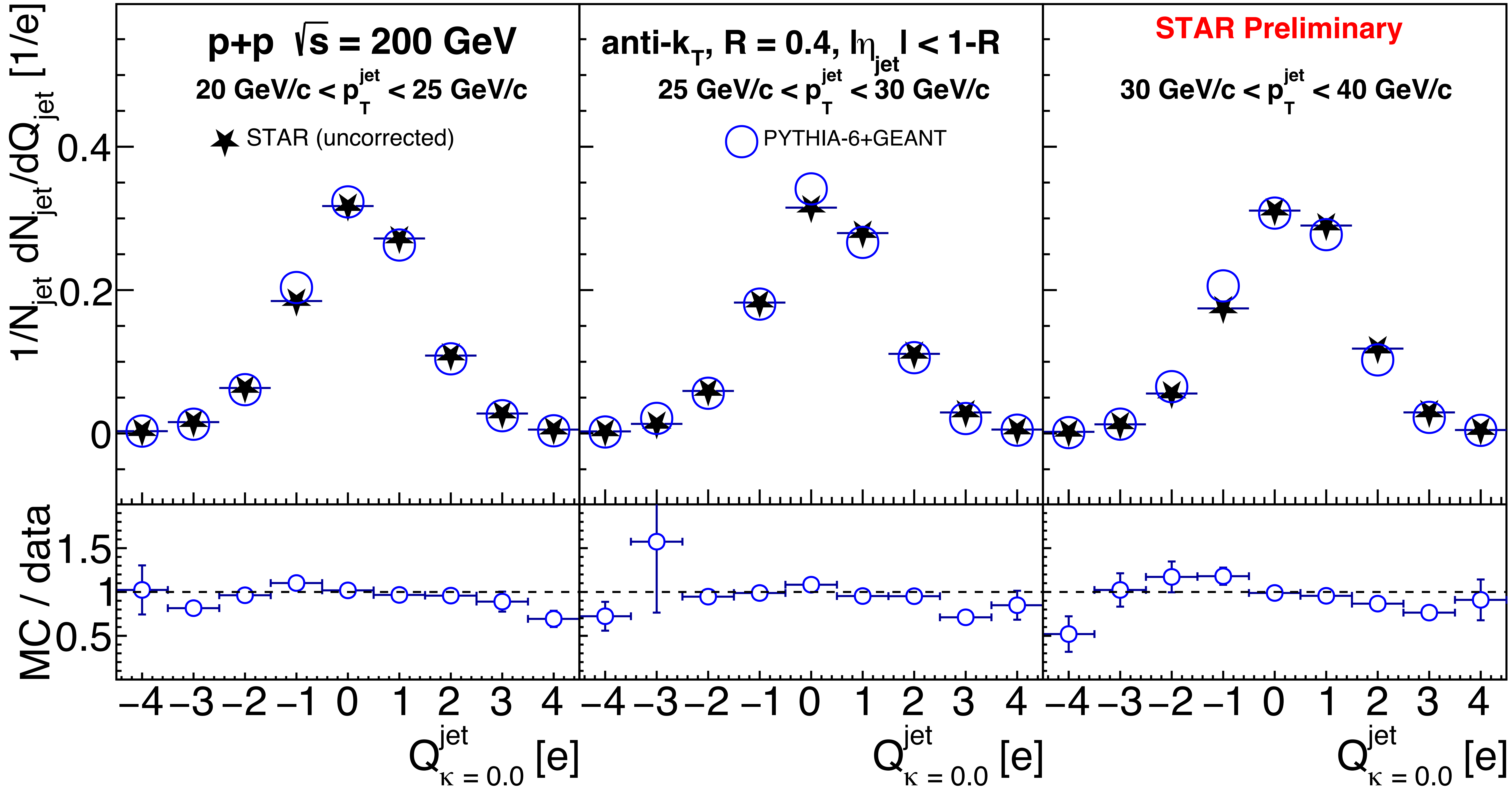
- Relativistic Heavy Ion Collider (RHIC) collides p+p beams at $\sqrt{s} = 200$ GeV

- Time Projection Chamber (TPC): momenta of charged particles
    - Utilized in jet charge, included in jet energy

- Barrel Electromagnetic Calorimeter (BEMC): neutral energy deposits, provides online trigger (Jet Patch)
    - Included in jet energy



Uncorrected Jet Charge



PYTHIA-6+GEANT agrees well

→ Can be used to simulate and correct for detector effects

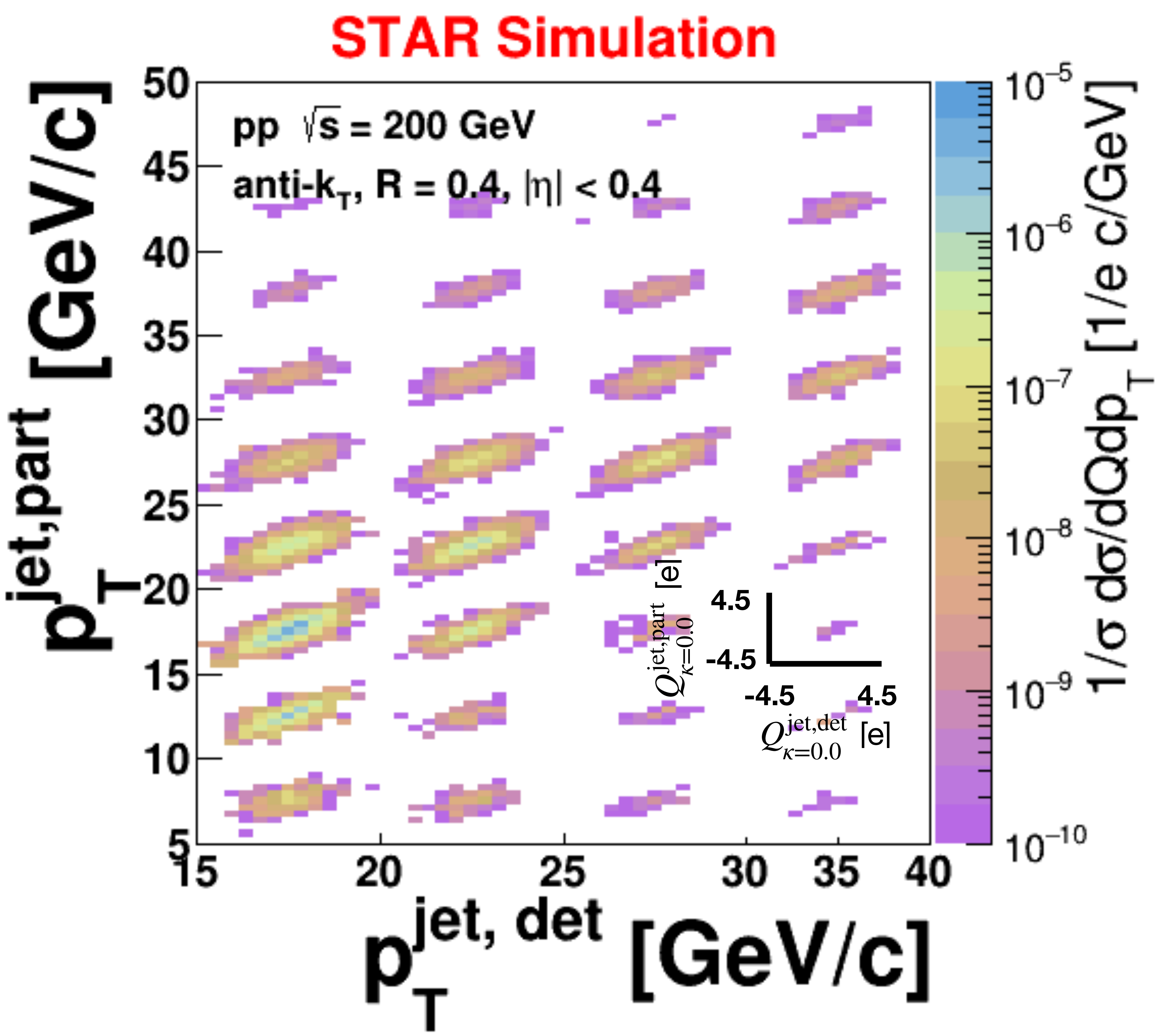
Unfolding

- Correct for detector effects by using a response matrix R
  - $D = RP$ where D is detector-level, P is particle-level
  - Invert matrix R to obtain P
- Iterative Bayesian procedure from RooUnfold

Proceedings of the PHYSTAT 2011 Workshop, CERN, Geneva, Switzerland, January 2011, CERN-2011-006, pp 313-318

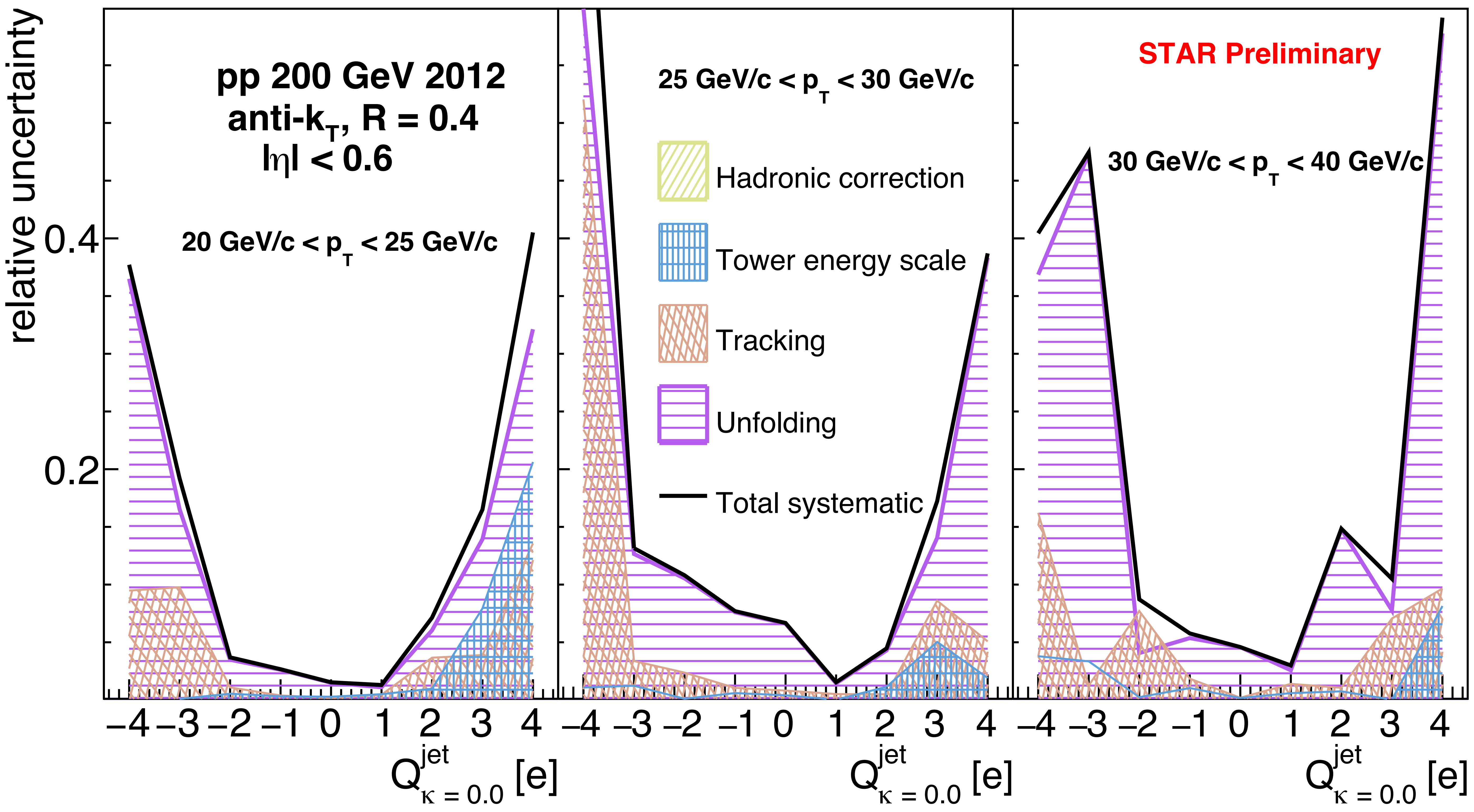
- Q depends on jet p_{T}
  - Requires 4D response for 2D unfolding

4D jet charge response matrix

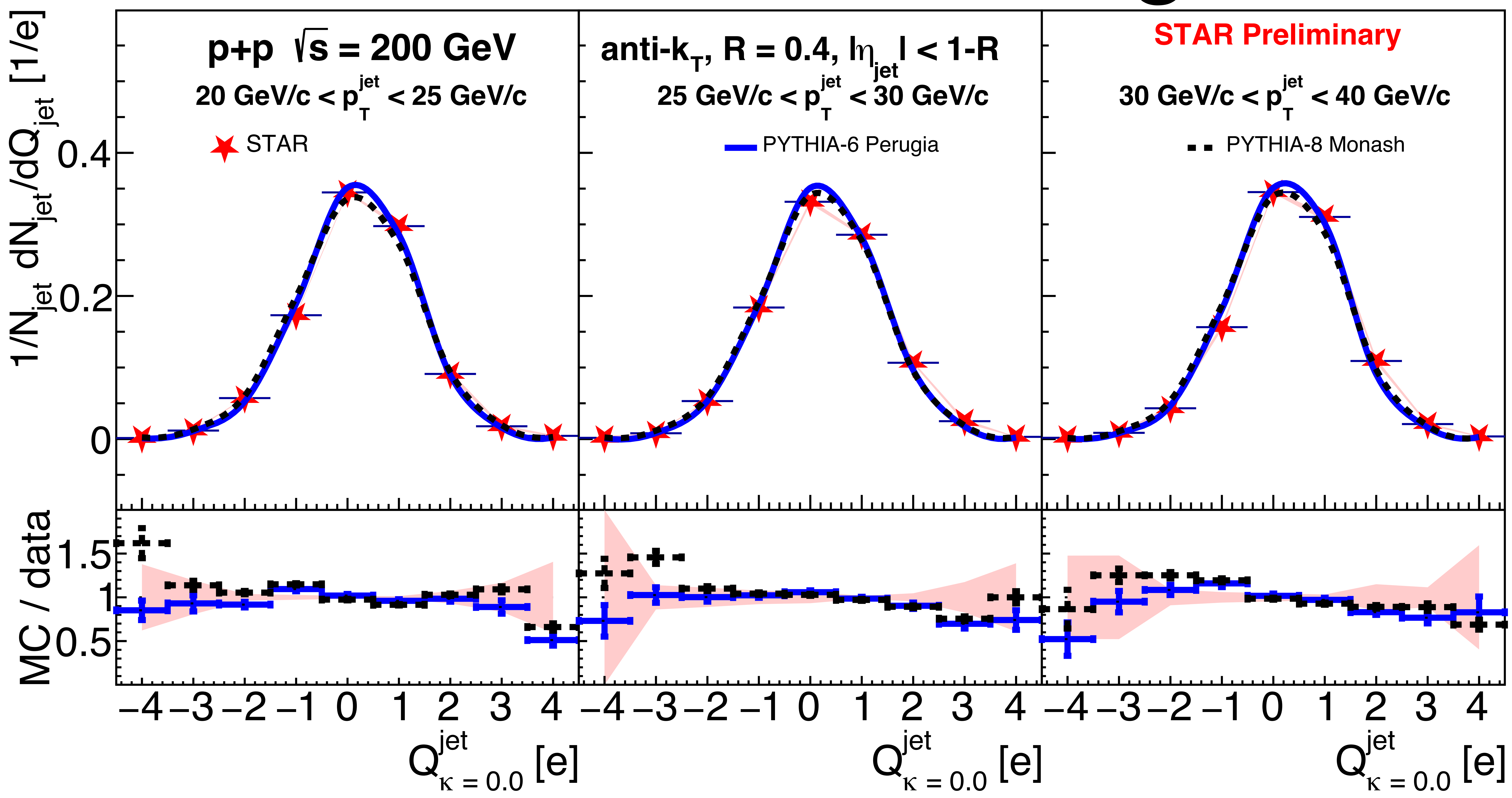


Systematic Uncertainties

- **Unfolding**: maximum envelope of the following systematic sources
  - Unfolding iteration parameter variation: nominal 4 iterations changed to 2, 6
  - Prior variation: p_{T}, Q spectra varied independently
- **Tower Energy Scale Uncertainty**
  - +3.8%: scale tower energy uniformly by 3.8%
- **Tracking Uncertainty**
  - -4%: randomly remove 4% of tracks
- **Hadronic Correction**
  - Variation: from nominal 100% to 50%

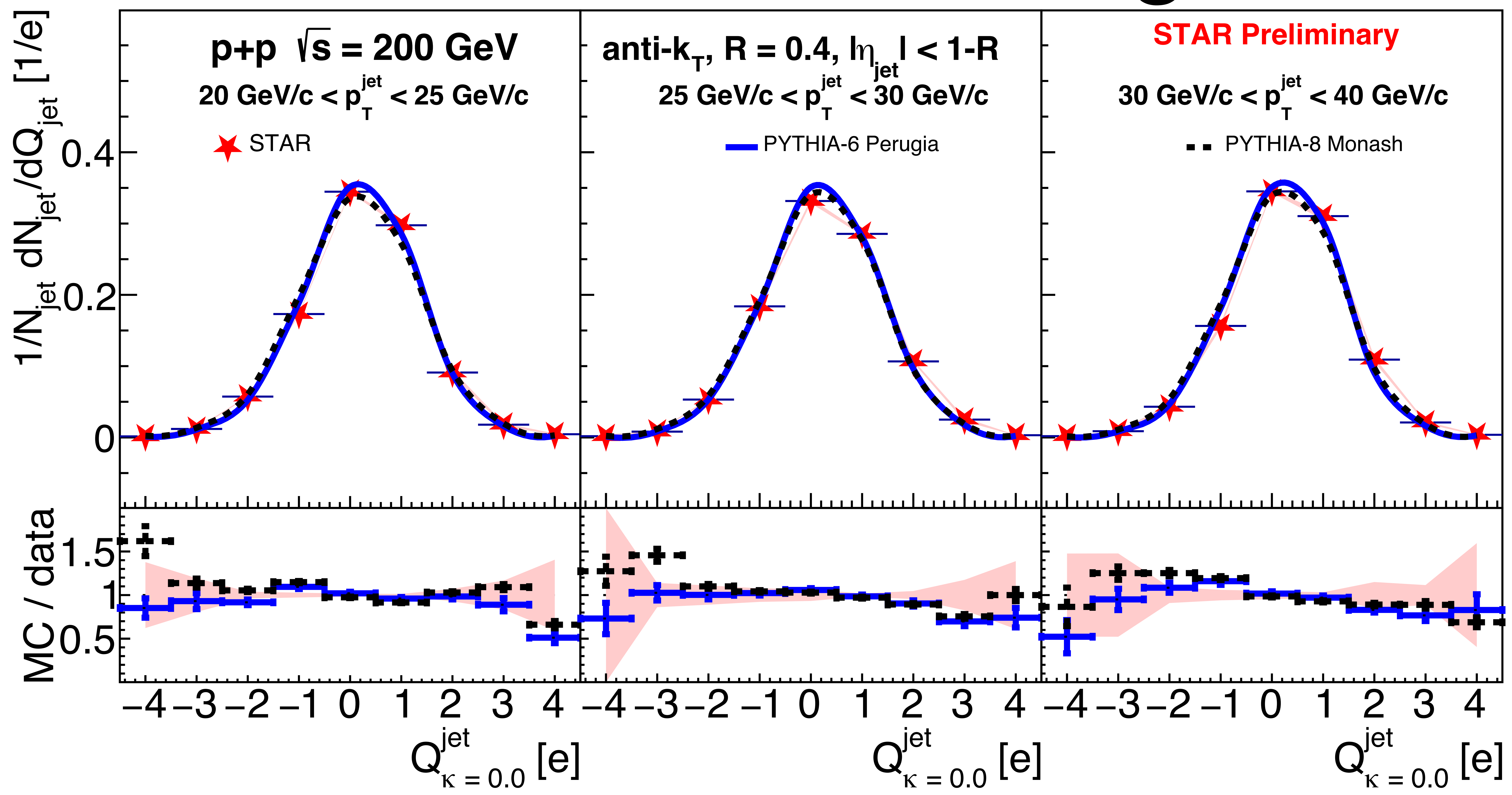


Corrected Jet Charge



Good agreement with PYTHIA-6 and PYTHIA-8

Corrected Jet Charge



Mean shifts from ~0.22 to ~0.33 with increasing jet p_{T}

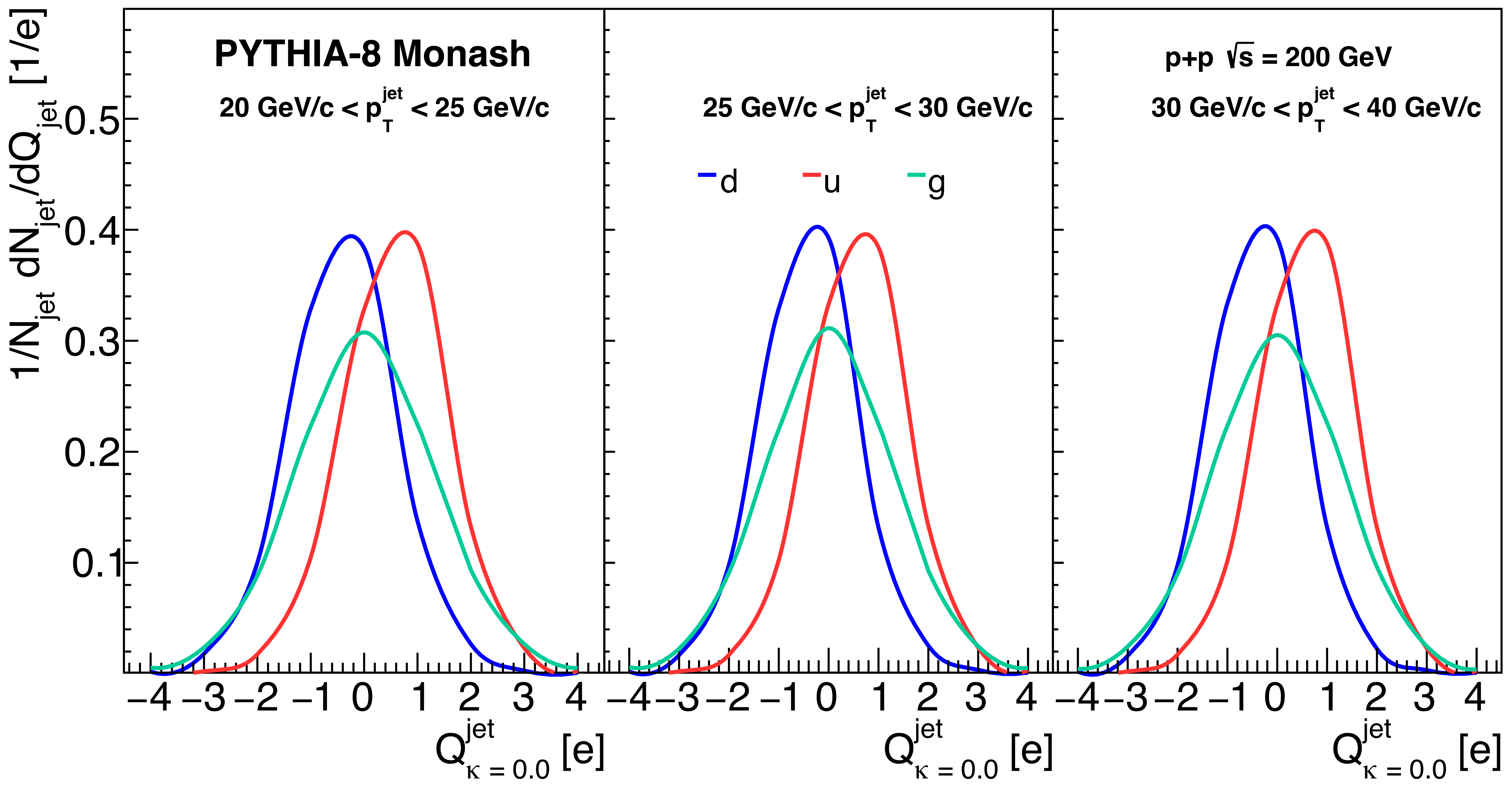
→ Consistent with more quark initiated jets

Future: Extracting Parton Information

Normalized Templates per jet

- Template fitting to extract quark vs gluon fraction in data

The CMS collaboration., Sirunyan, A.M., Tumasyan, A. et al. Measurement of quark- and gluon-like jet fractions using jet charge in PbPb and pp collisions at 5.02 TeV. J. High Energ. Phys. 2020, 115 (2020)



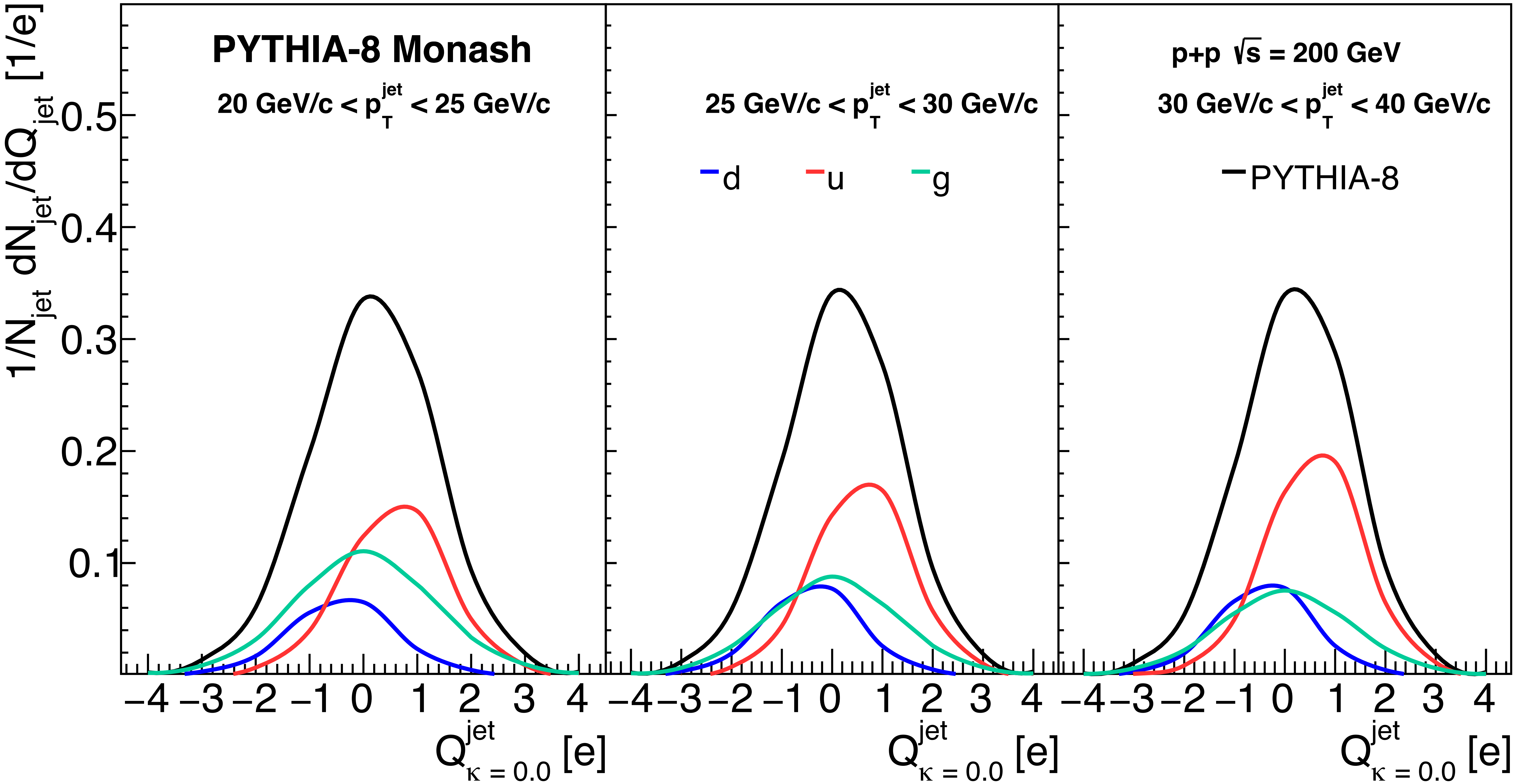
Future: Extracting Parton Information

Proof of Principle: Fit Result to PYTHIA-8

- Template fitting to extract quark vs gluon fraction in data

The CMS collaboration., Sirunyan, A.M., Tumasyan, A. et al. Measurement of quark- and gluon-like jet fractions using jet charge in PbPb and pp collisions at 5.02 TeV. J. High Energ. Phys. 2020, 115 (2020)

- Observe the change in quark vs gluon fraction as a function of p_T^{jet}
  - PYTHIA-8 Monash: Gluon initiated jet fraction shifts from ~36% to ~25%



Conclusion and Outlook

Mean shifts towards positive Q as jet p_{T} increases in jets in STAR $\sqrt{s}$ = 200 GeV p+p collisions

⟶ Indicates more quark dominated jets as jet p_{T} increases

- Use Monte Carlo templates to extract quark vs gluon fraction from data
- Extend analysis to other jet resolution parameter R values
- Extend analysis to additional values of κ to repeat the analysis to study flavor discrimination as function of κ

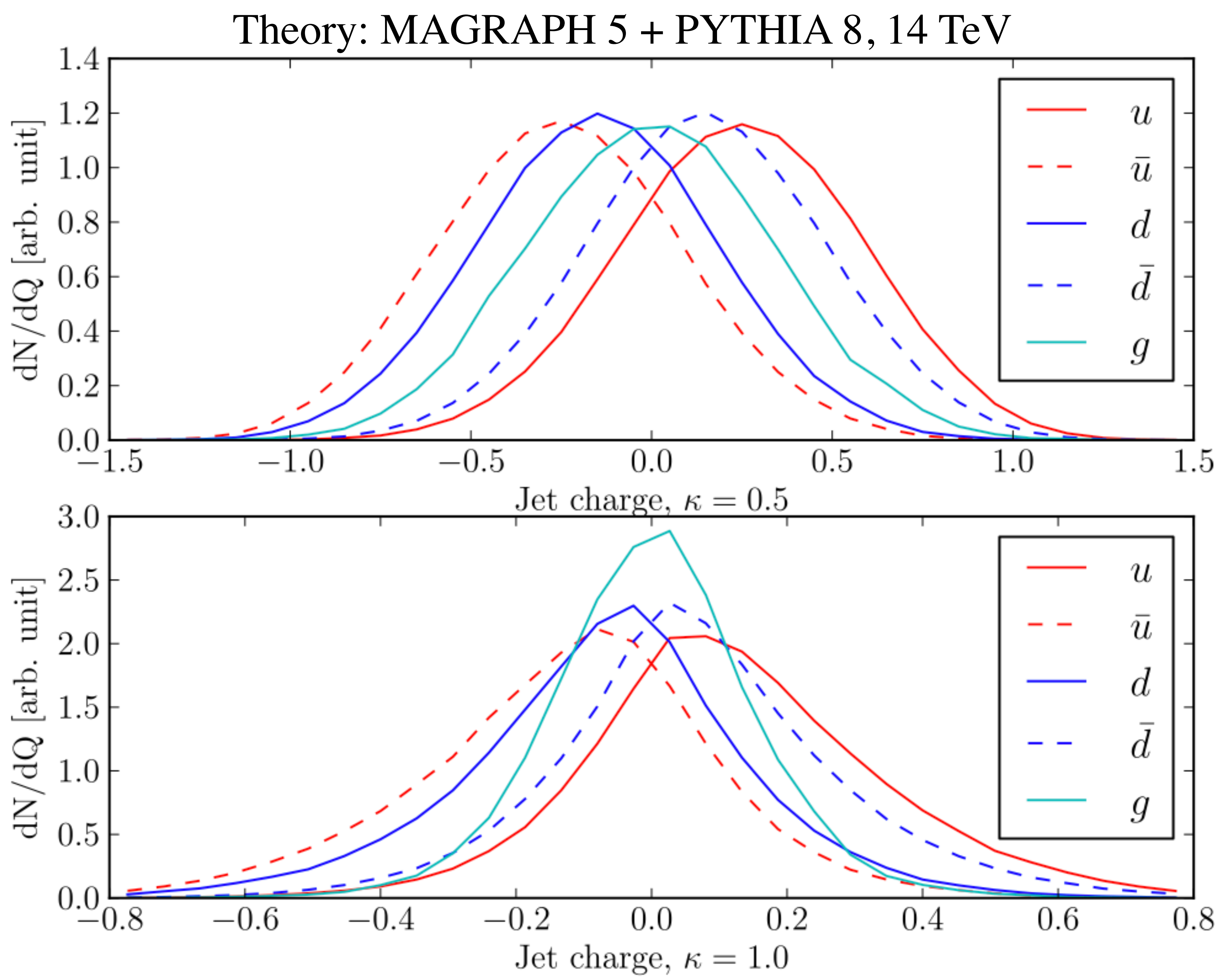
Backup

Jet Charge

- $$Q_\kappa^i = \sum_{j \in jet} \left(\frac{p_T^j}{p_T^{jet}} \right)^\kappa Q_j$$

- Discriminating power between flavors as a function of κ

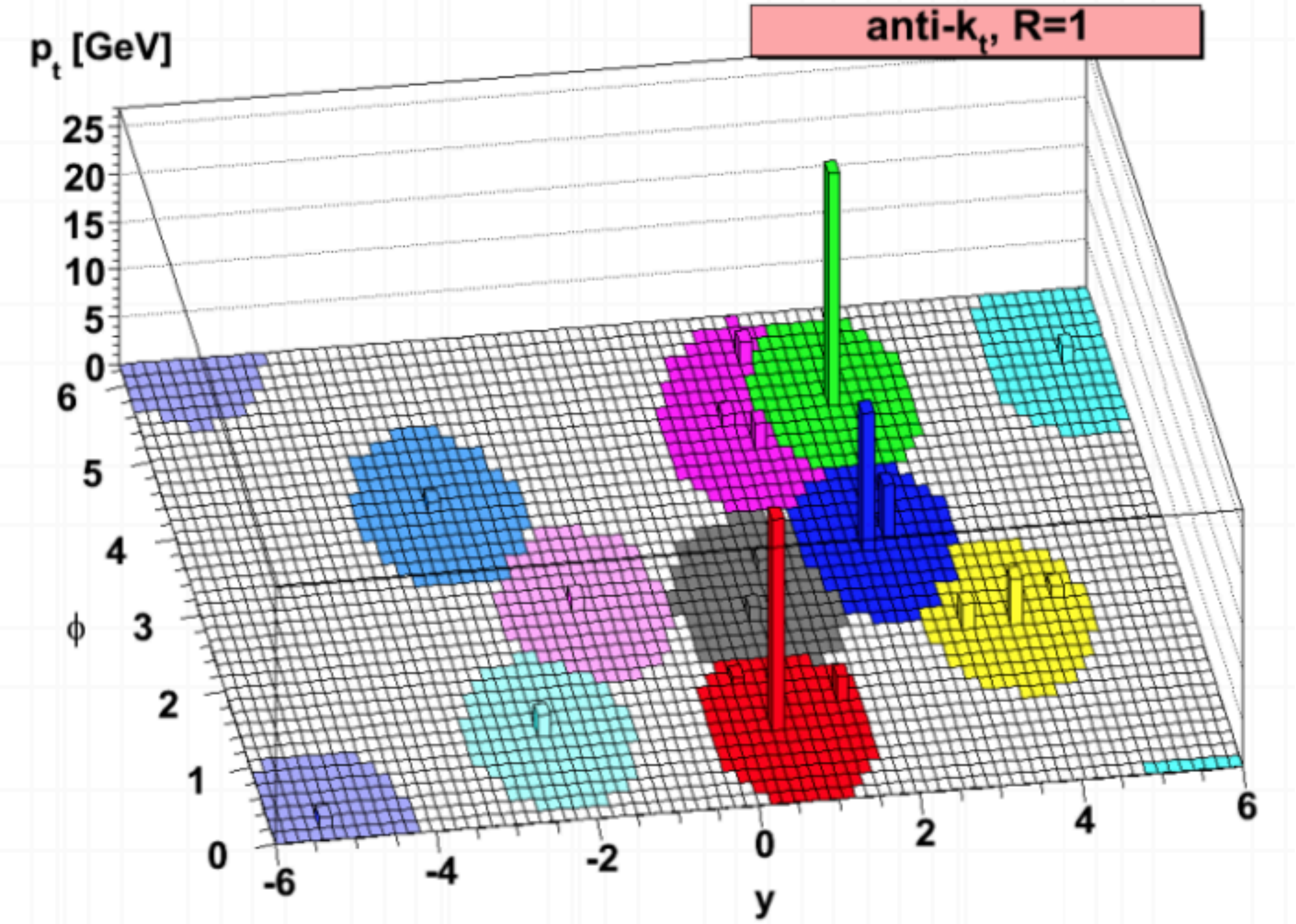
- To extract the quark vs gluon fraction as a function of jet p_T



https://arxiv.org/pdf/1209.2421.pdf

Introduction: Jet Finding

- Need to connect experiment to theory
- Infrared and collinear safe
- FastJet provides jet finding algorithms: anti-k_T
- Resolution parameter R = 0.4



https://doi.org/10.1140/epjc/s10052-012-1896-2

Cacciari, Salam, J. High Energ. Phys. 04 (2008) 063

Cacciari, Salam, Soyez, Eur.Phys.J. C 72 (2012) 1896