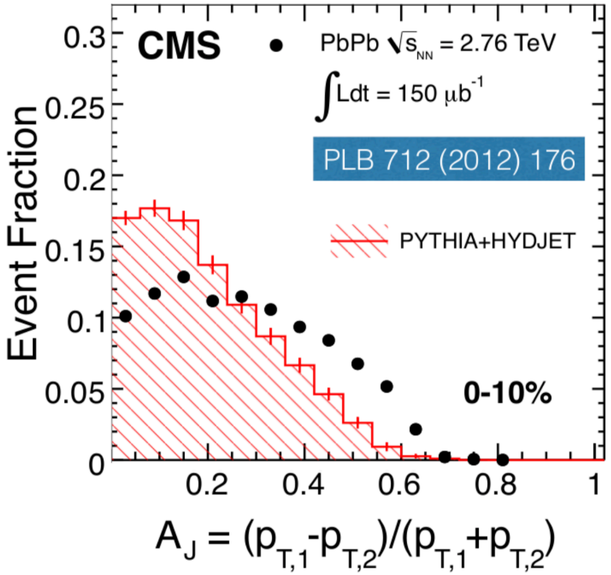
Studies of Quark and Gluon Contributions to Jets using Jet Charge Measurements in pp and PbPb Collisions

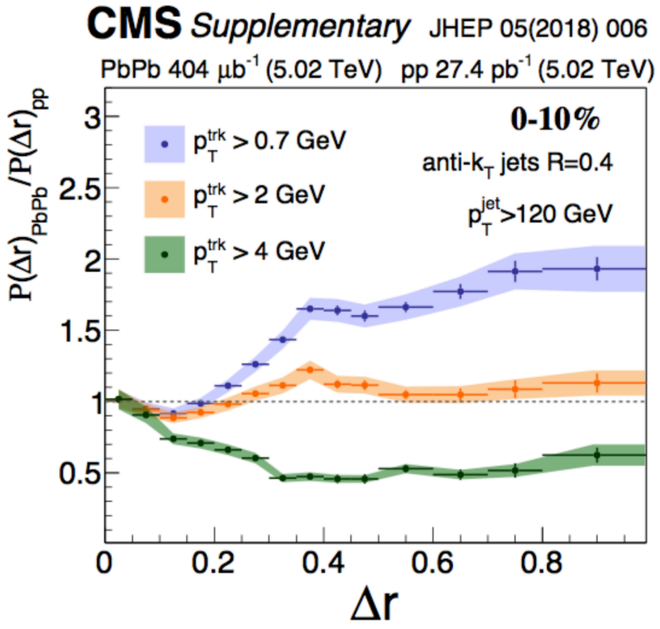
Dhanush Hangal, University of Illinois at Chicago
for the CMS Collaboration

Quark Matter 2019
Wuhan, China

Motivation

- Jets are important tomographic probes of QGP studies
- Jets are **quenched** and show significant **reshuffling of energy in and out of cone** in PbPb events compared to pp





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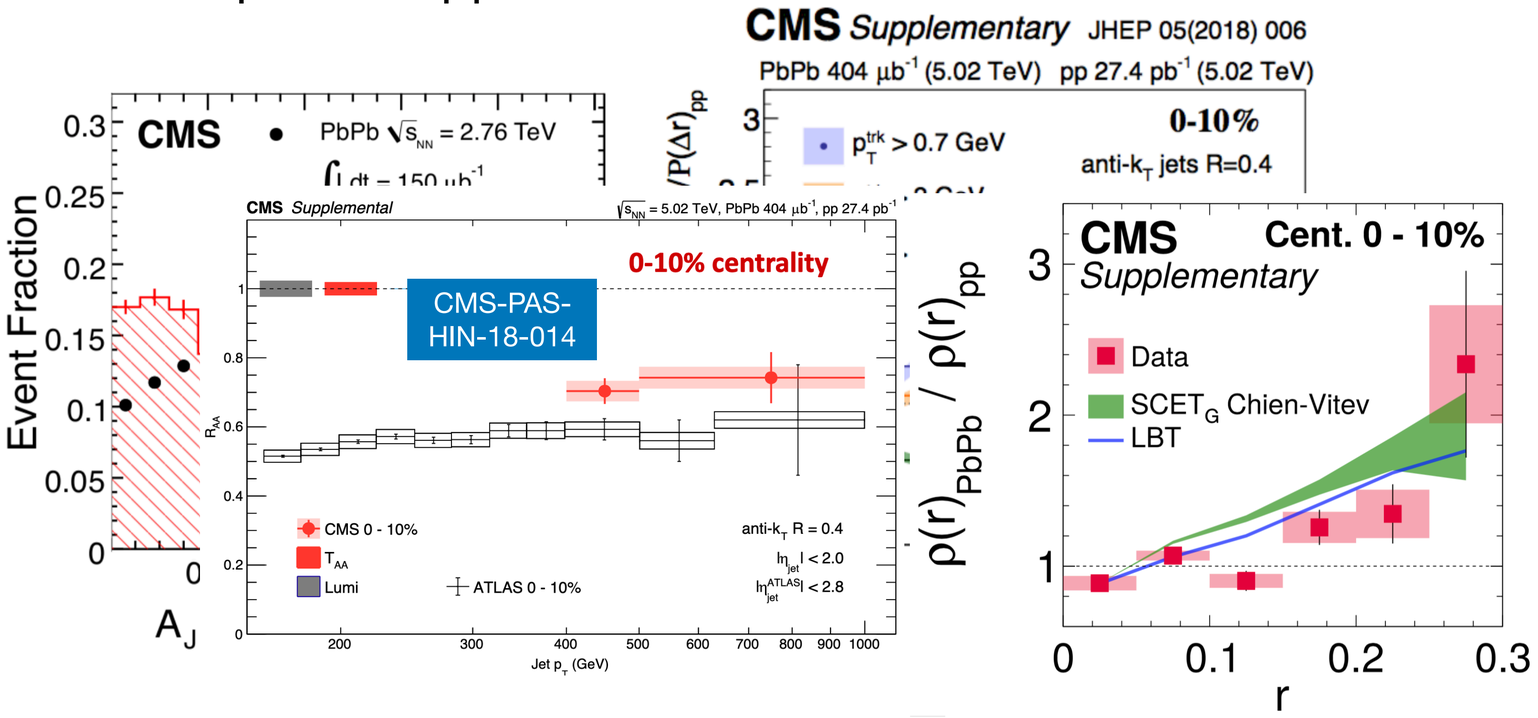

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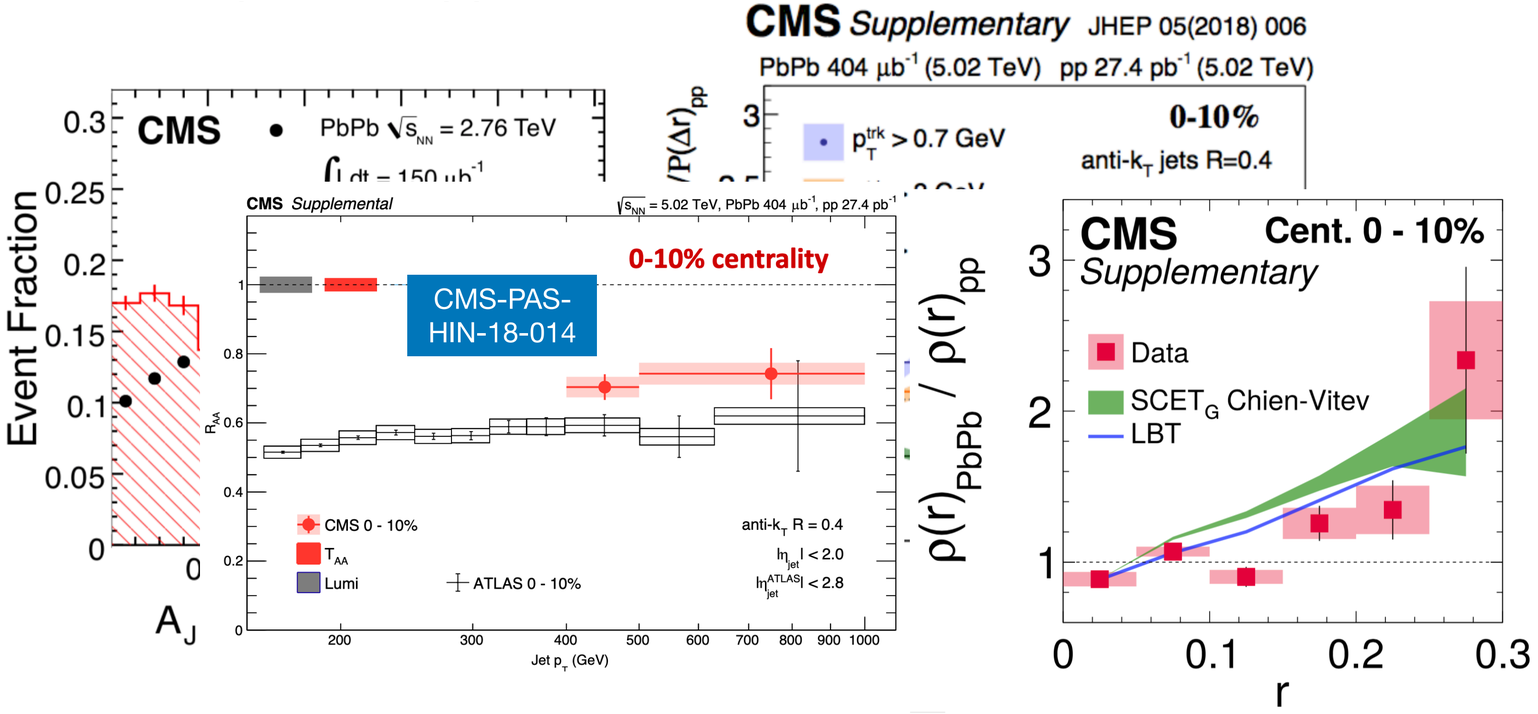
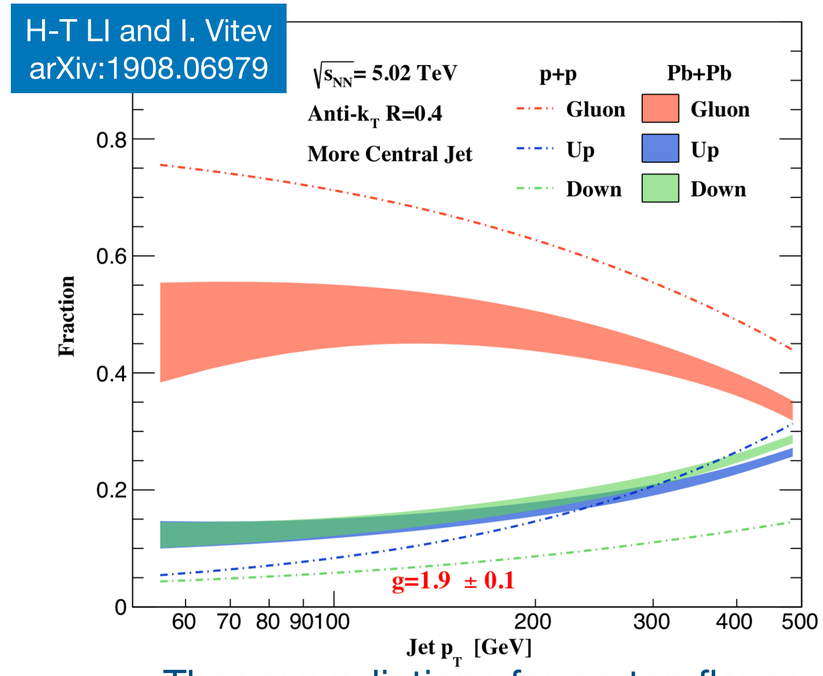


H-T LI and I. Vitev
arXiv:1908.06979



Theory predictions for parton flavor dependence of energy loss

- **What are the different energy loss mechanisms?**
- **What is the parton flavor dependence of the energy loss and shower modification?**

Jet Charge

Jet charge : Transverse momentum-weighted sum of the electric charges of the jet constituents

$$Q^{\kappa} = \frac{1}{(p_{\mathrm{T}}^{\mathrm{jet}})^{\kappa}} \sum_{i \in jet} q_i \, (p_{\mathrm{T}}^{i})^{\kappa}$$

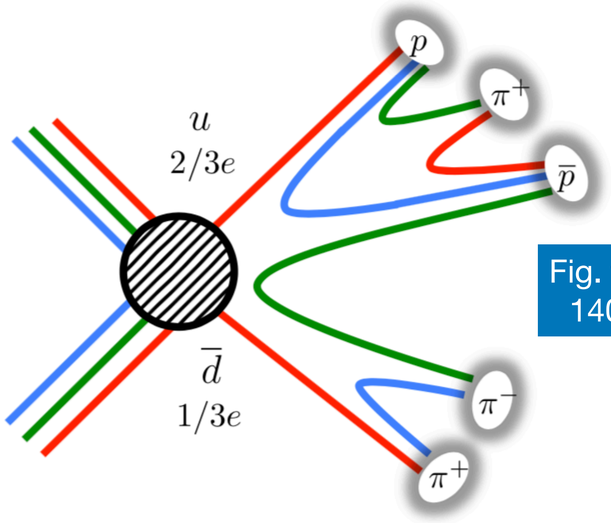


Fig. taken from: 1409.0318v1

Jet charge is sensitive to the electric charge of the initiating parton

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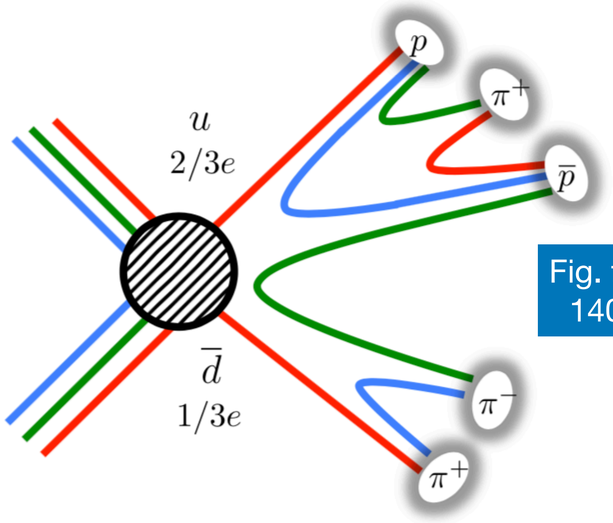
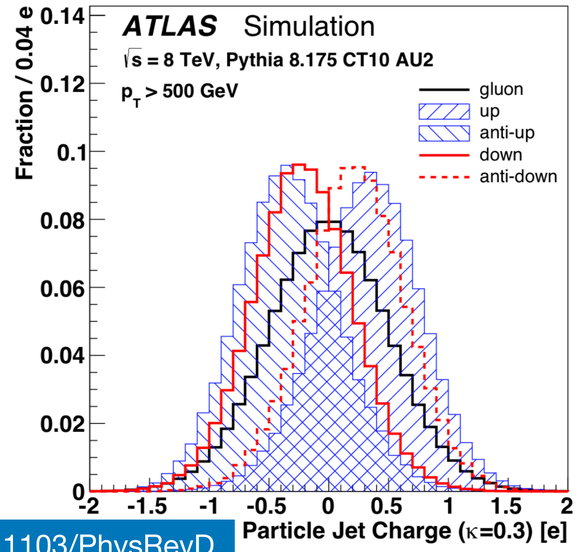


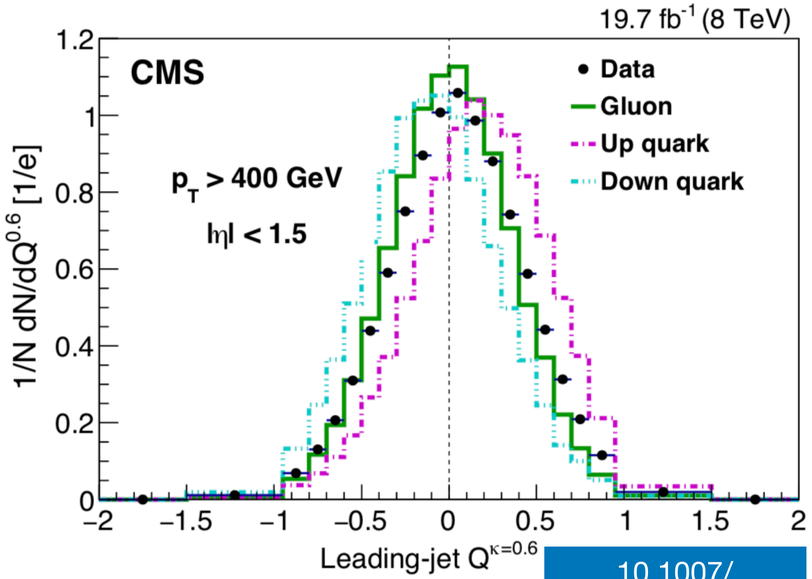
Fig. taken from: 1409.0318v1

Jet charge is sensitive to the electric charge of the initiating parton

- κ **parameter** controls the sensitivity of jet charge to low and high p_{T} particles
- Used to study **flavor dependent behavior of energy loss** mechanisms due to jet quenching



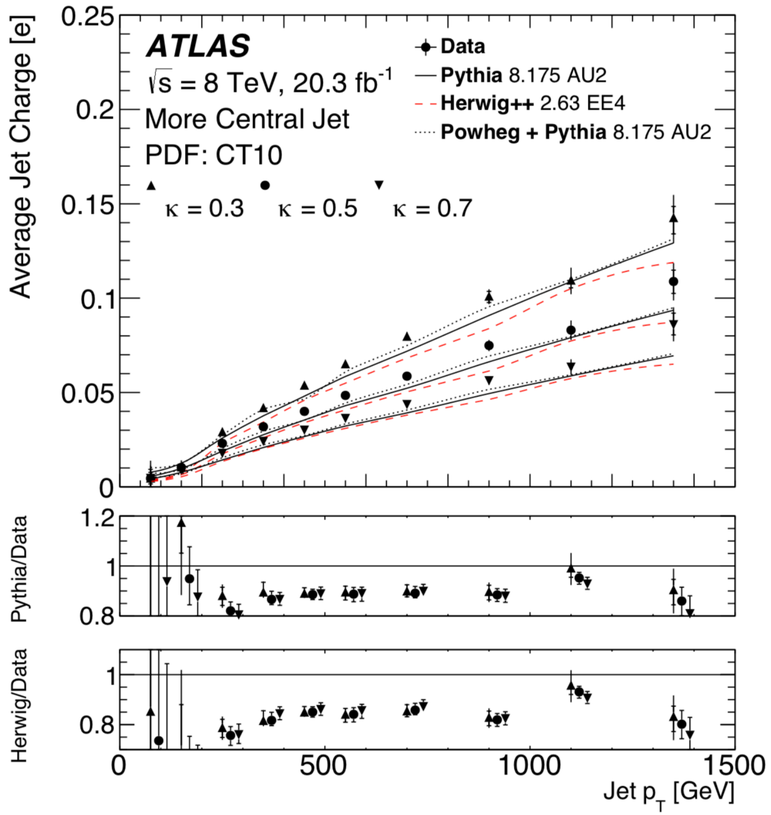
10.1103/PhysRevD.93.052003



10.1007/JHEP10(2017)131

Jet Charge in pp collisions

- Dependence of average and width (RMS) of jet charge on jet energy and size can be calculated **independently of MC fragmentation model**[1]
- **Average jet charge** observed to **increase with jet** p_{T} due to increase in valence quark initiated jet fraction



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[1]D.Krohn & M.D.Schwartz PRL 110, 212001 (2013)

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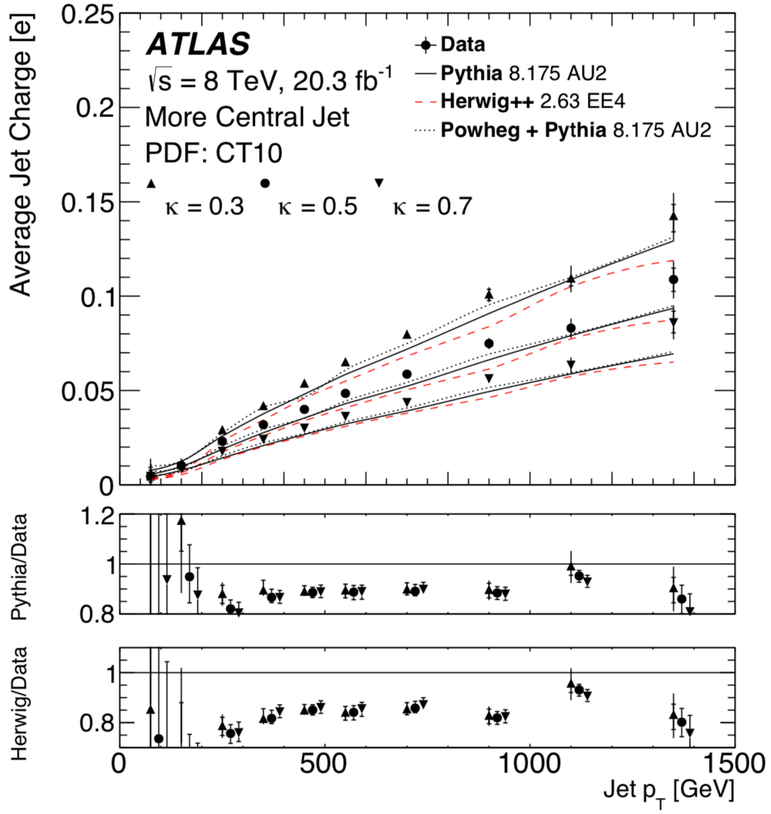
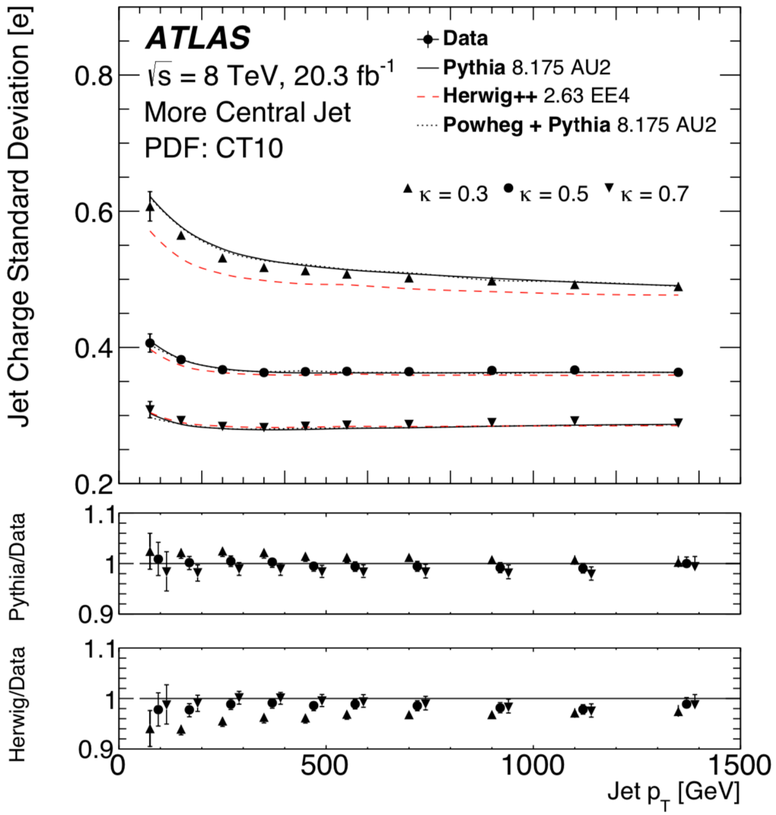
- **Width of jet charge** observed to **increase with decreasing** κ due to higher sensitivity to low p_{T} particles





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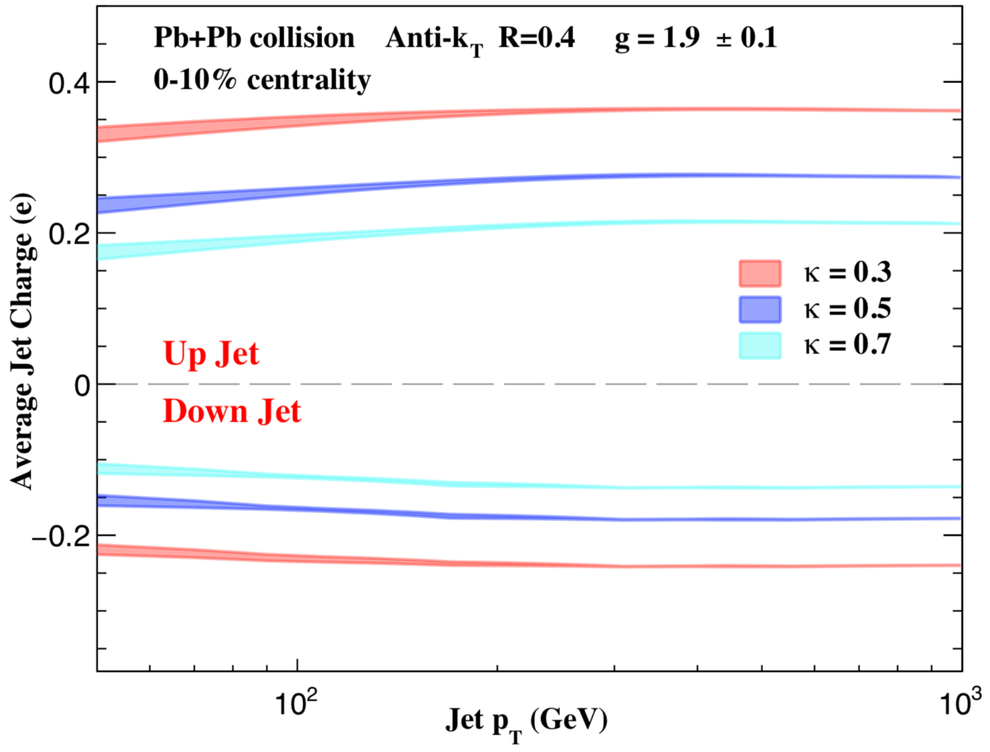
Theory Predictions : Quenching and Jet Charge

- Jet charge for various flavor jets remain distinct even in the heavy-ion environment



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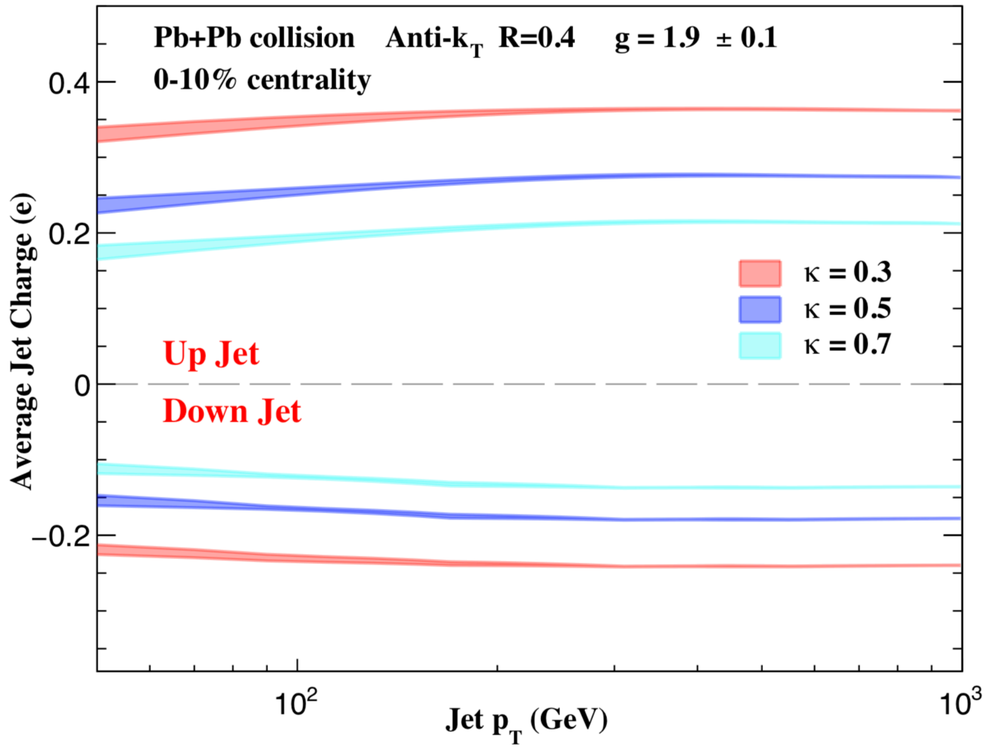
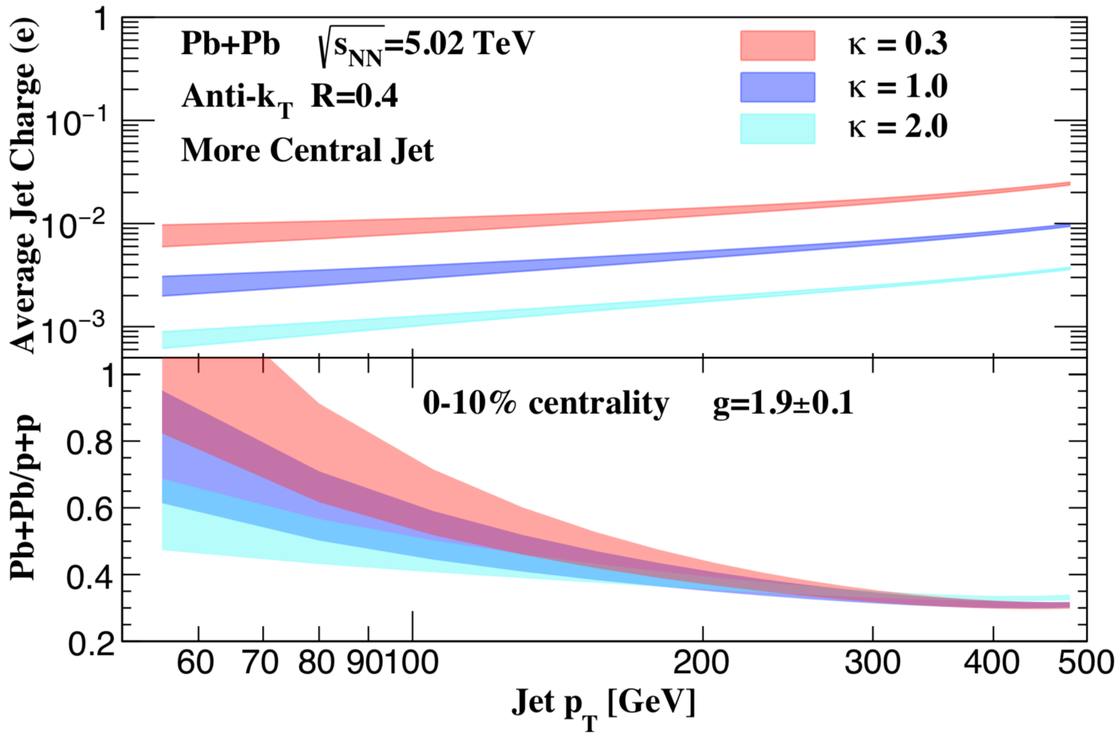
SCET Approach

Theory Predictions : Quenching and Jet Charge

- Jet charge for various flavor jets remain distinct even in the heavy-ion environment
- Up and down-quark jet fractions significantly modified in PbPb collisions compared to pp due to presence of **neutrons in the heavy nucleus**





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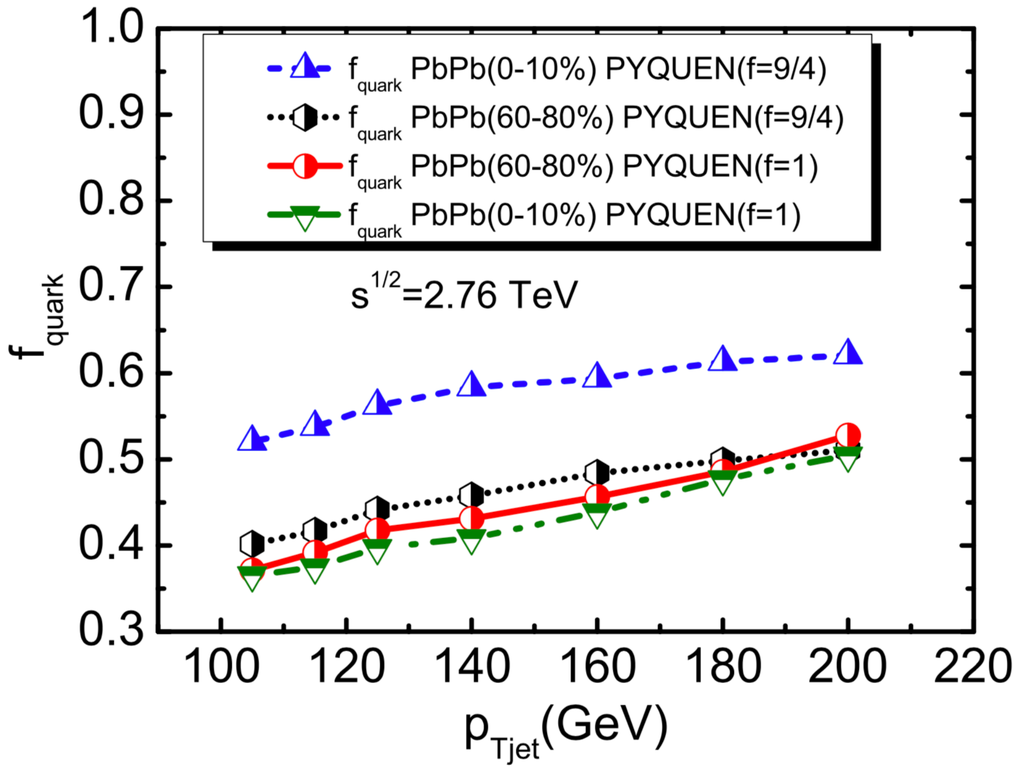

S-Y Chen, B-W Zhang & E Wang
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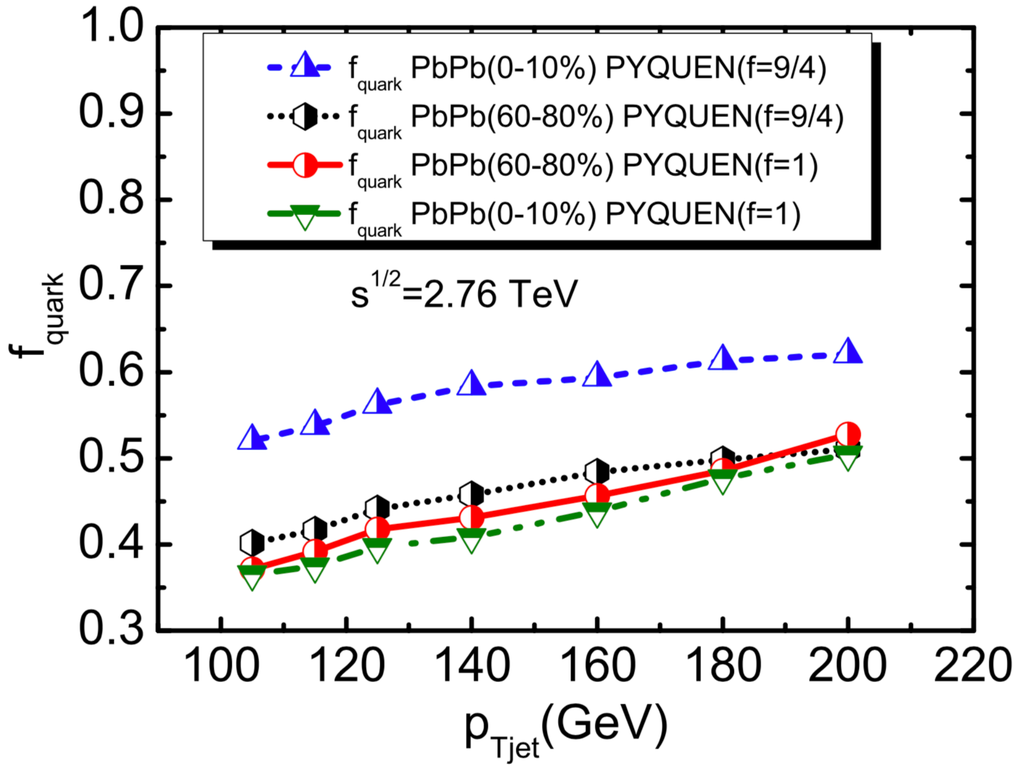
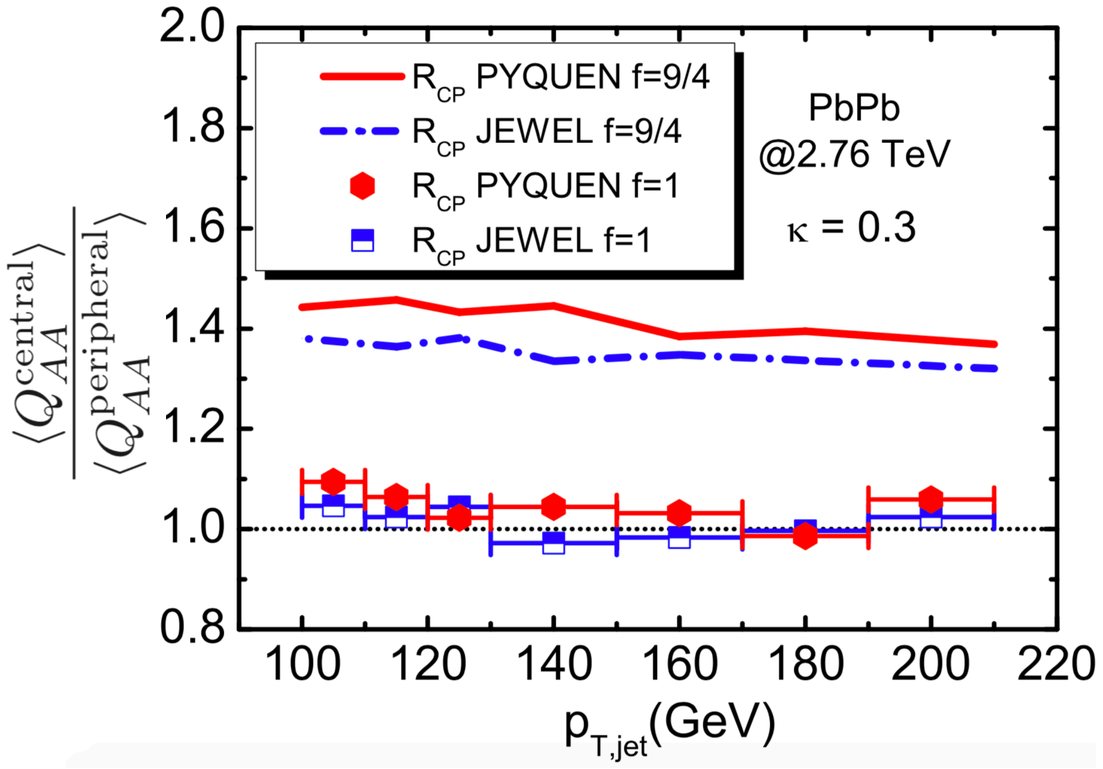
PYQUEN and JEWEL predictions

Theory Predictions : Quenching and Jet Charge

- Gluons expected to lose more energy than quarks from quenching due to their larger color charge
- **Larger average jet charge expected in central PbPb collisions compared to peripheral events**





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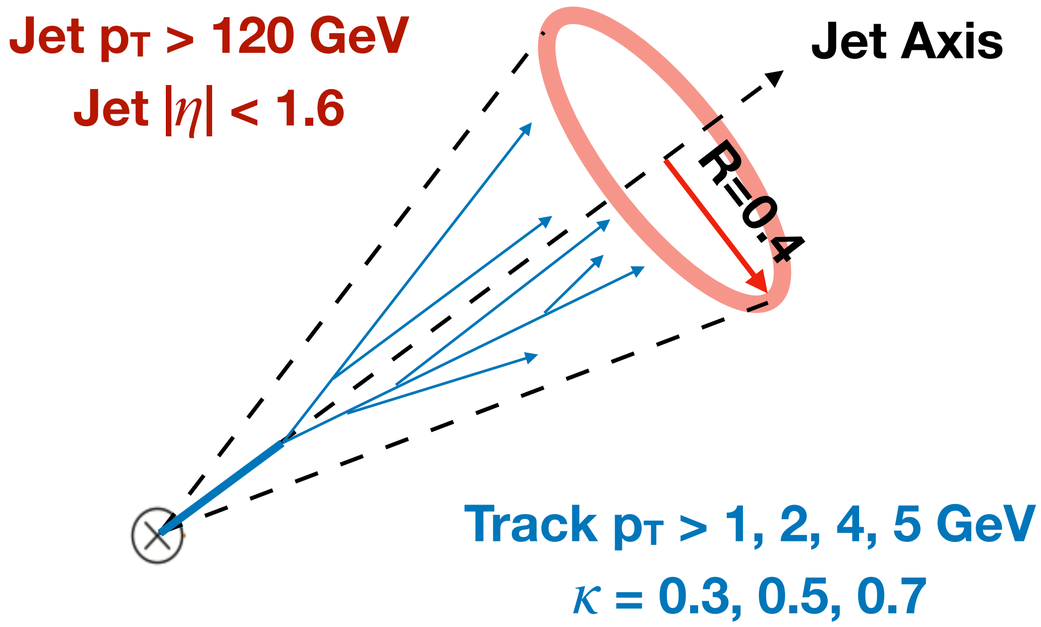
PYQUEN and JEWEL predictions

Data Analysis

Analysis Strategy

- Jet charge measured using reconstructed **jets and tracks within the jet cone ($\Delta r < 0.4$)**
- Measurements unfolded to account for **detector inefficiencies** using a D'Agostini's iteration method[1]

[1]Nucl. Instrum. Meth. A 362 (1995) 487



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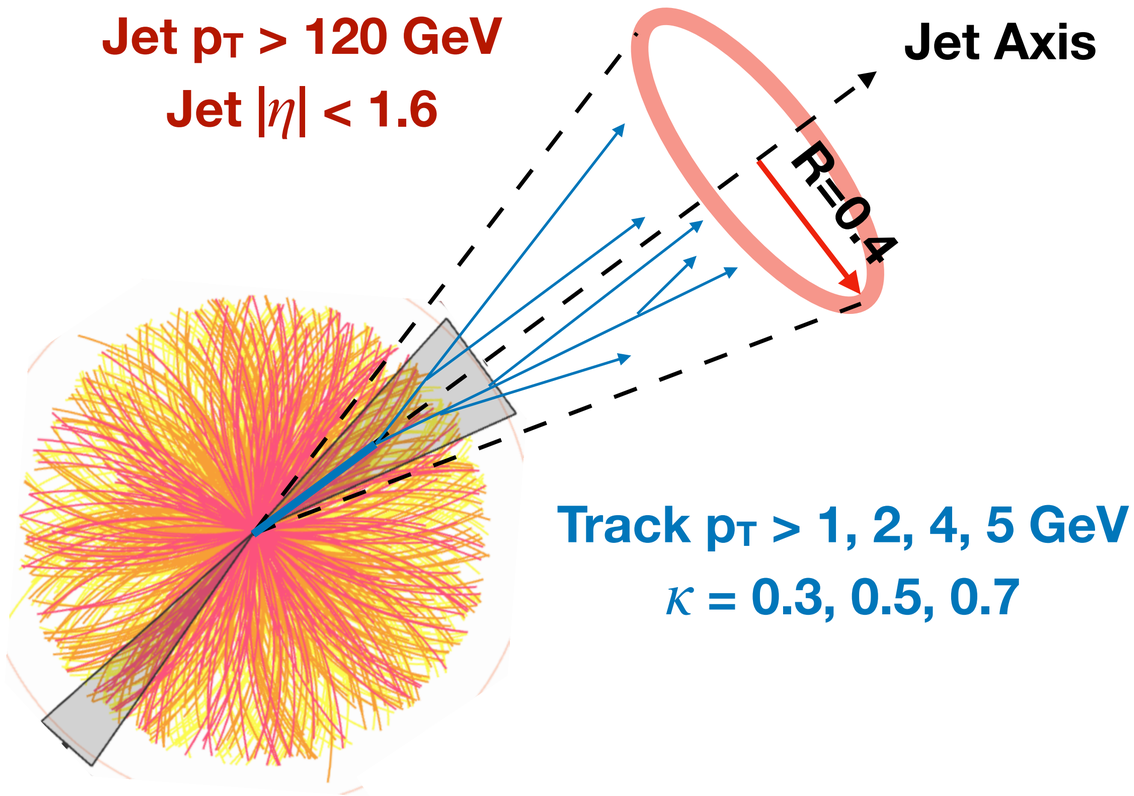
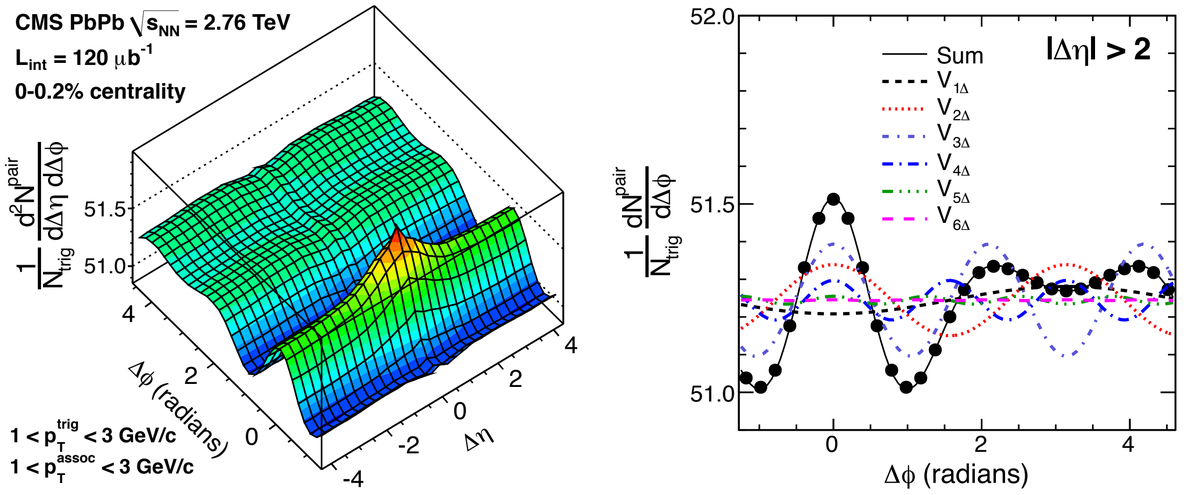


J. High Energy Phys. 02 (2014) 088



Azimuthal dihadron correlations in ultra-central PbPb collisions

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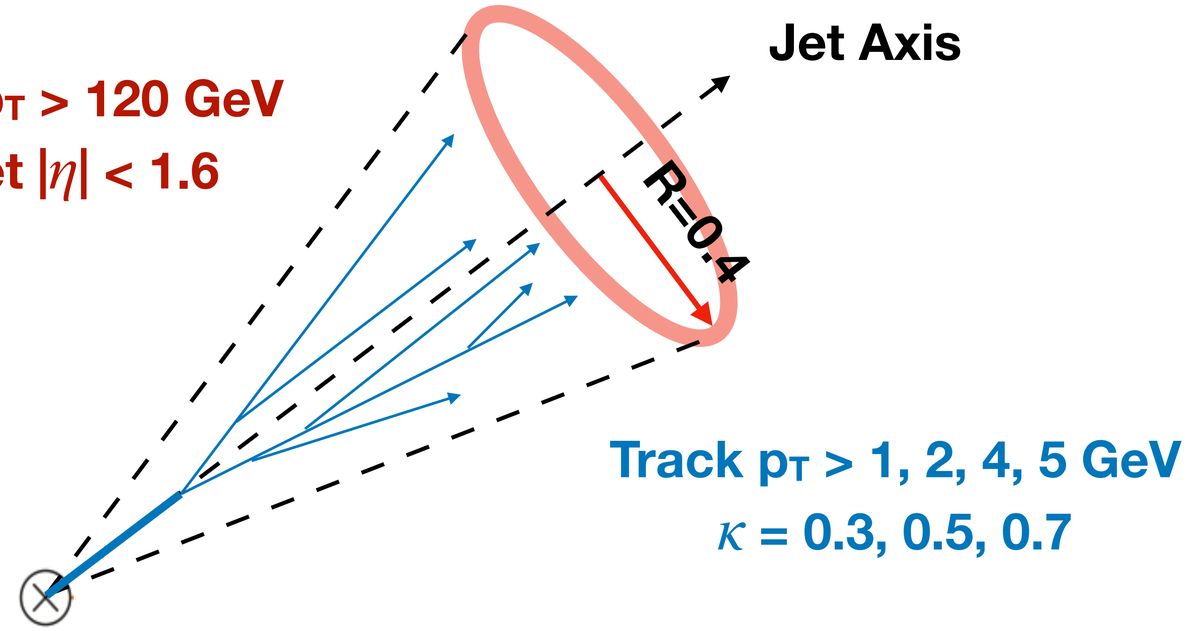
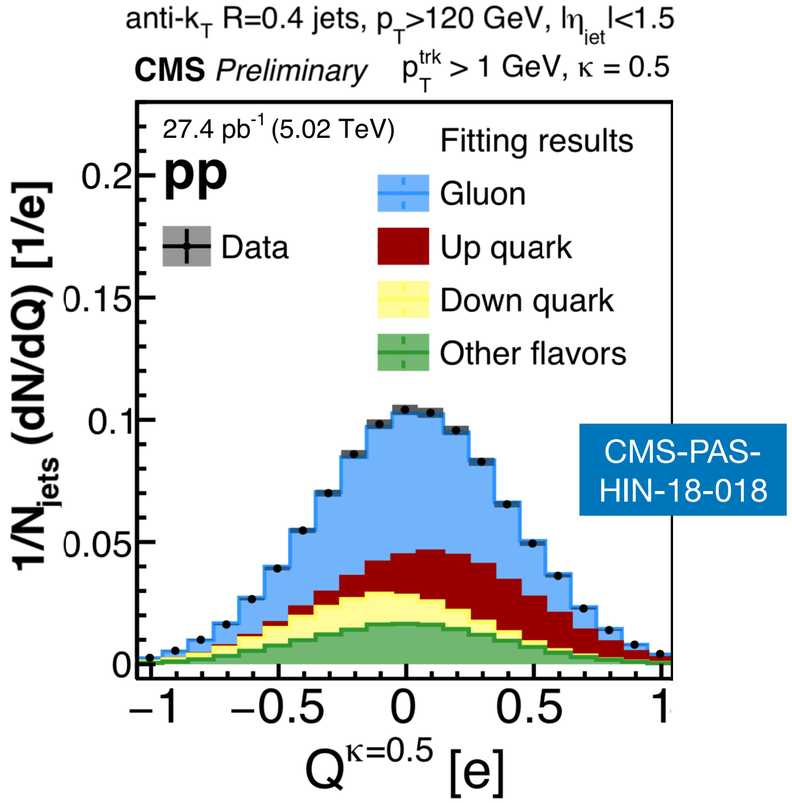
- Measurements unfolded to account for detector inefficiencies using a D'Agostini's iteration method[1]
- Additionally unfolded for contribution from UE and long-range correlations in PbPb collisions
- **Unfolded data jet charge measurements are fit with templates from MC simulations to extract the quark- and gluon-like jet fractions**
- Results presented in bins of centrality, track p_T and κ





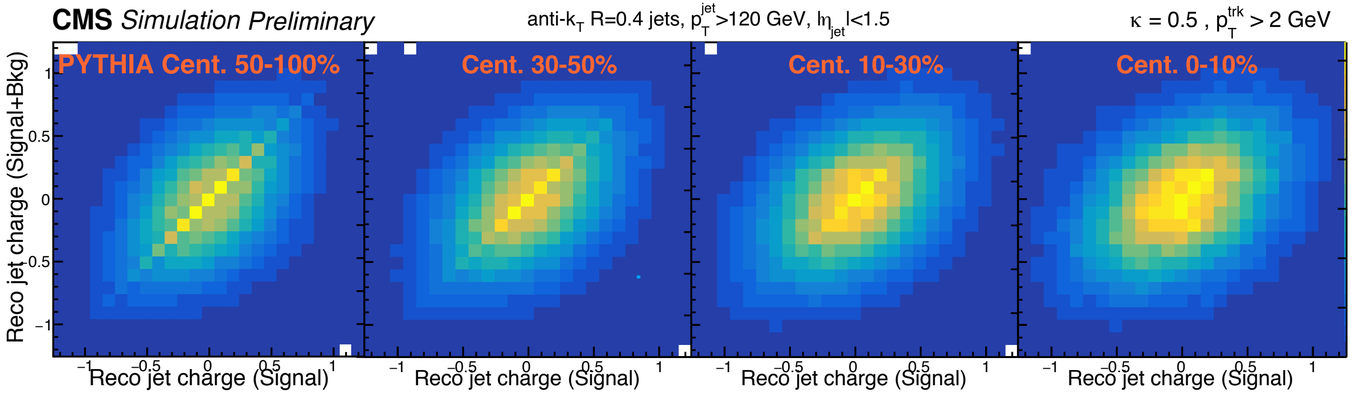
Unfolding Procedure and Corrections

Raw Jet Charge Measurements

Data-driven bkg correction

Corrected for Background Fluctuations

Prior Matrices for Background Unfolding



MC Samples:

- **pp** - PYTHIA6 (tune Z2)
- **PbPb** - PYTHIA6 embedded in HYDJET

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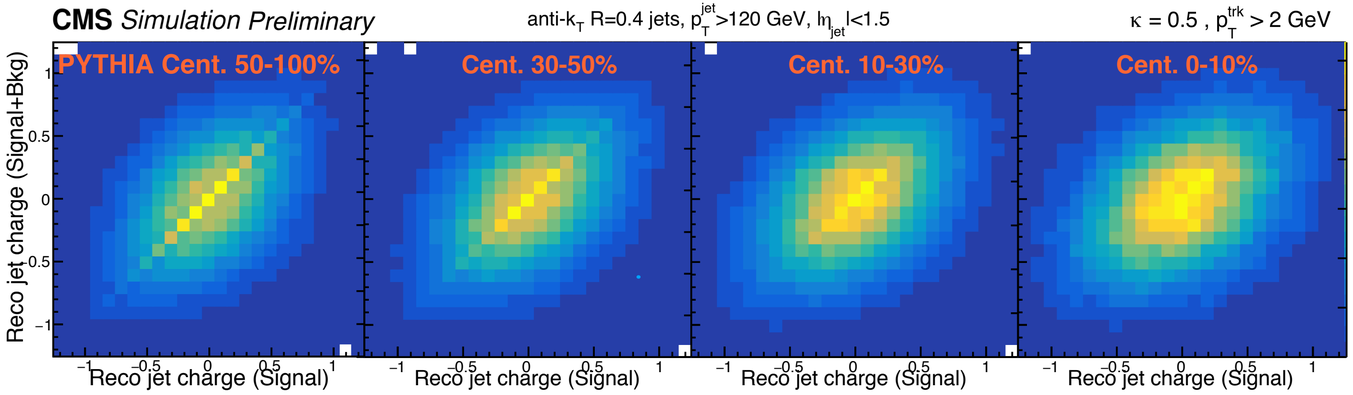

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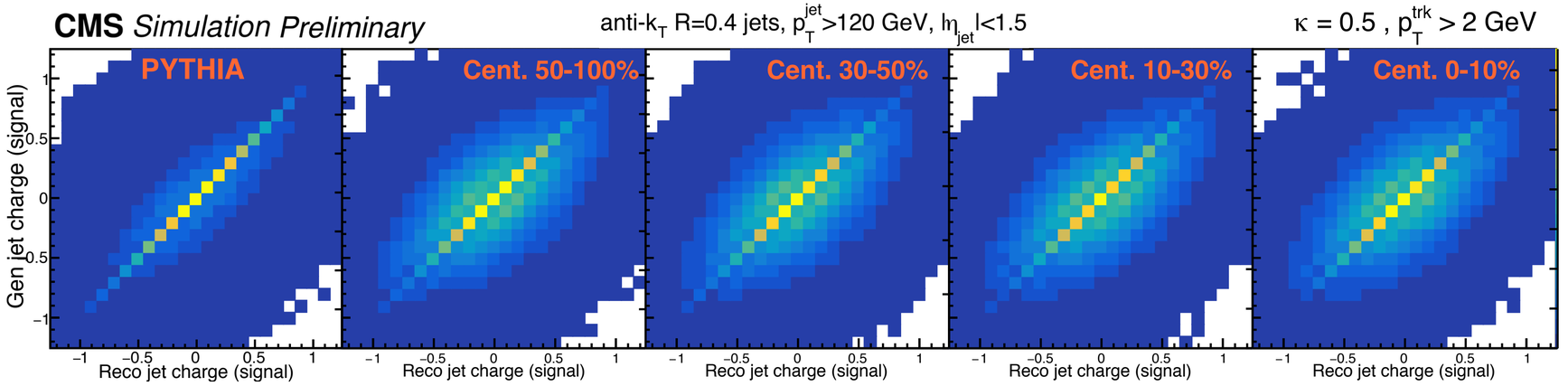

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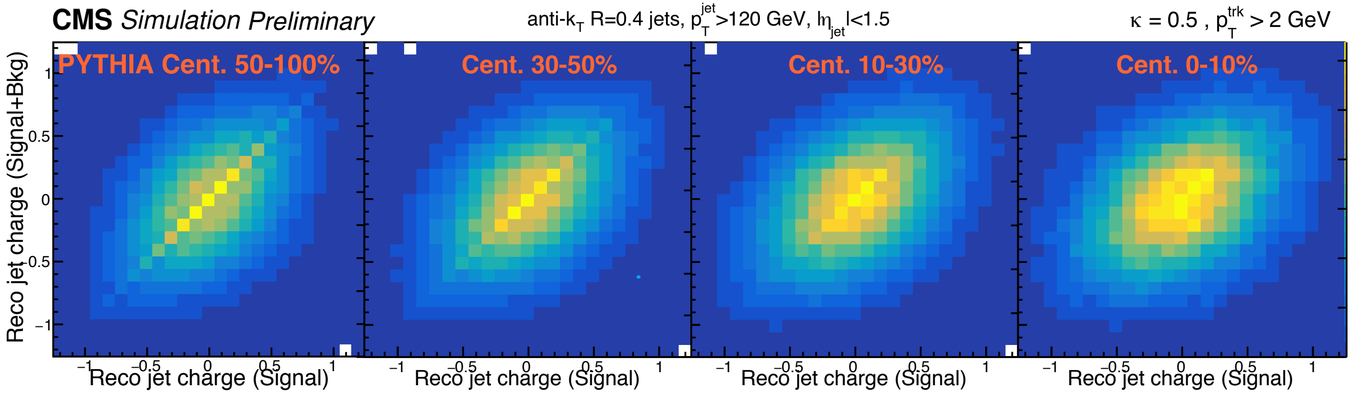

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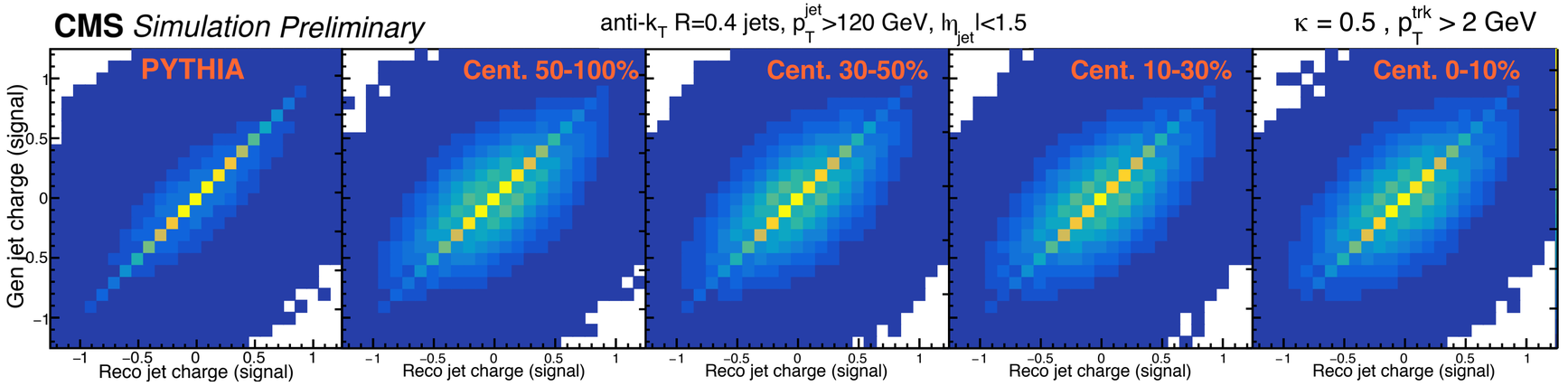
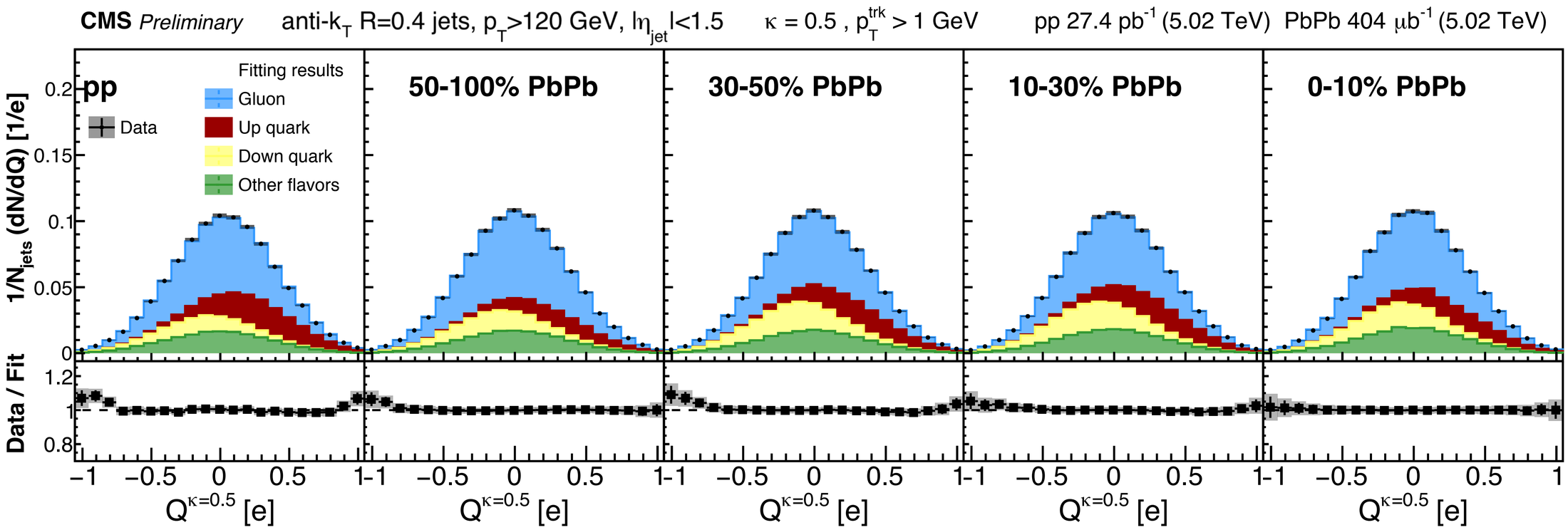


- Measurements in PYTHIA+HYDJET **rescaled to match up and down quark fractions** in PbPb
- Corrections applied to account for jets with no reconstructed tracks above the p_T threshold and the jet energy scale

Results

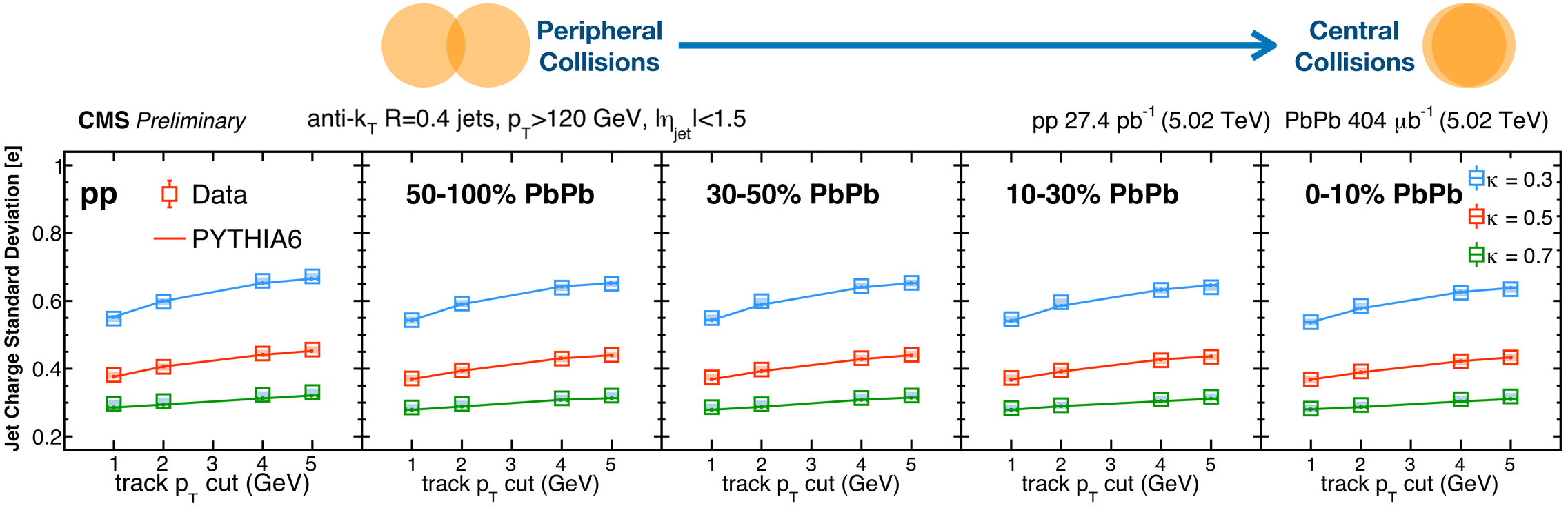
Jet Charge Measurements

- Jet charge measurements presented with template fitting results
- Measurements are unfolded for background fluctuations and tracking inefficiencies
- MC generally describes data well



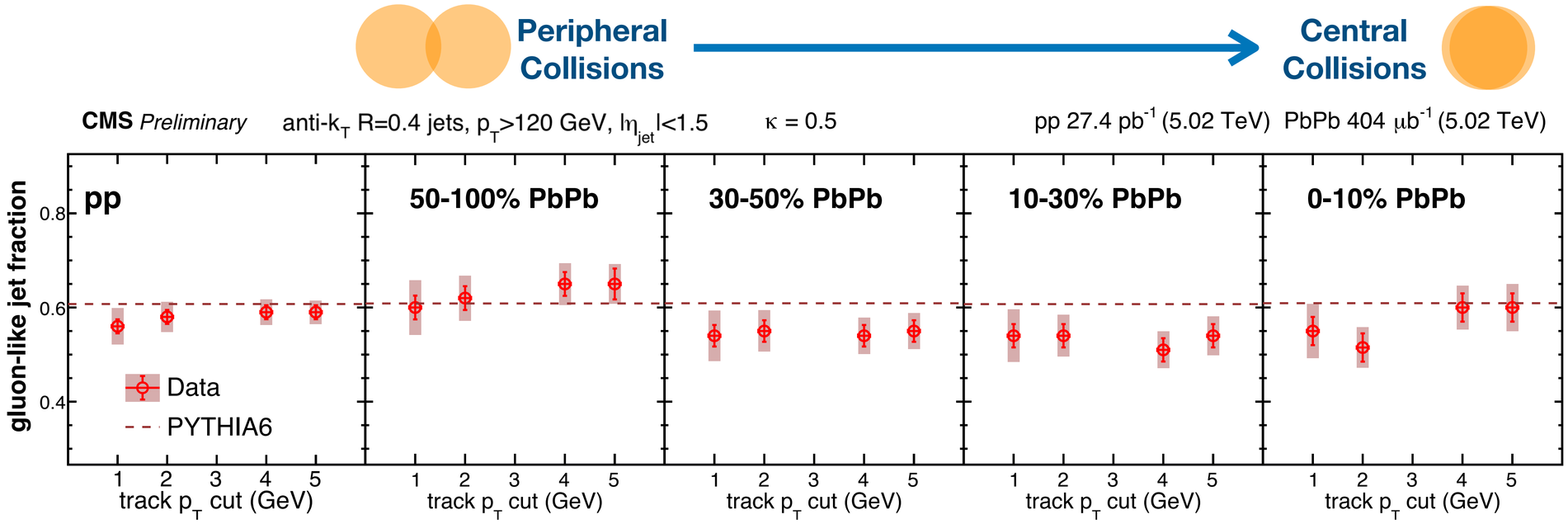
Jet Charge Width

- Width of the jet charge measurements well described by PYTHIA
- No significant centrality dependence is observed



Gluon-like Jet Fractions

$\kappa = 0.5$



- No significant modification observed in the extracted fractions of gluon-like jet fractions in different centrality bins

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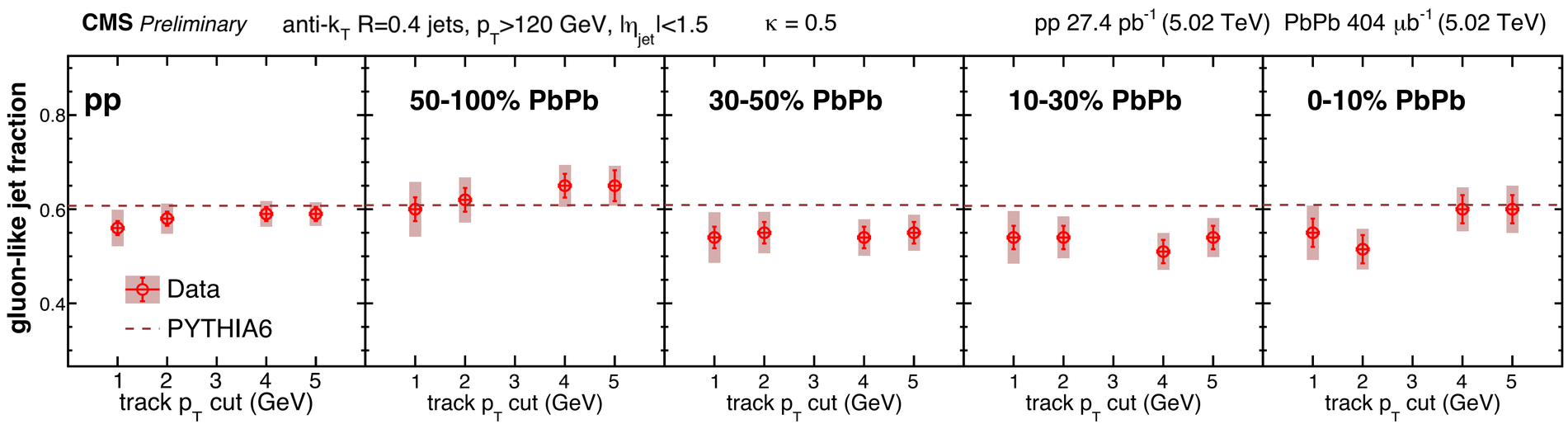
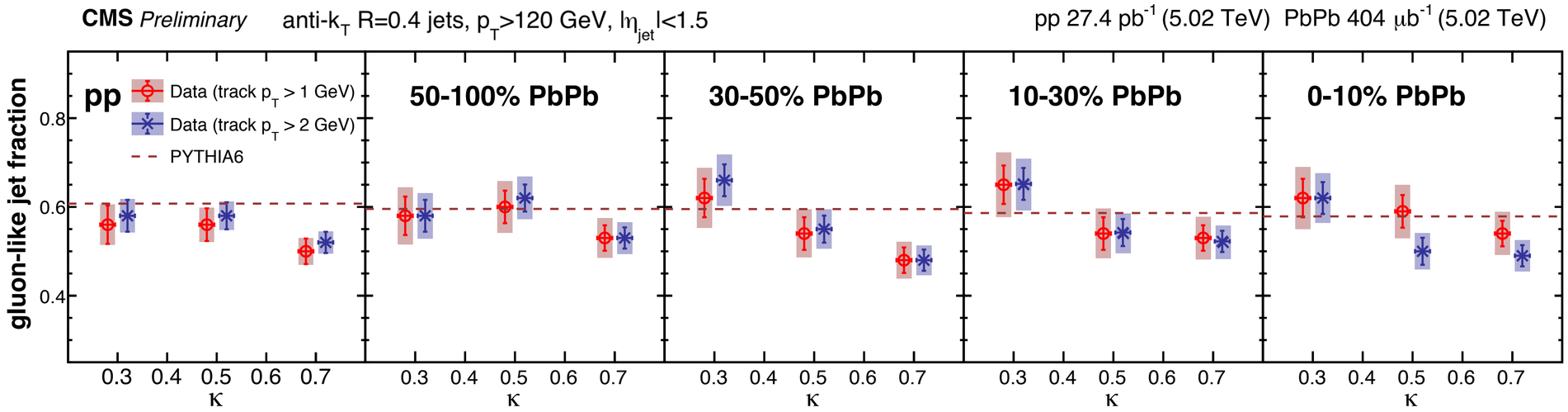
Track p_T > 1 GeV

Track p_T > 2 GeV





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Comparison with PYQUEN

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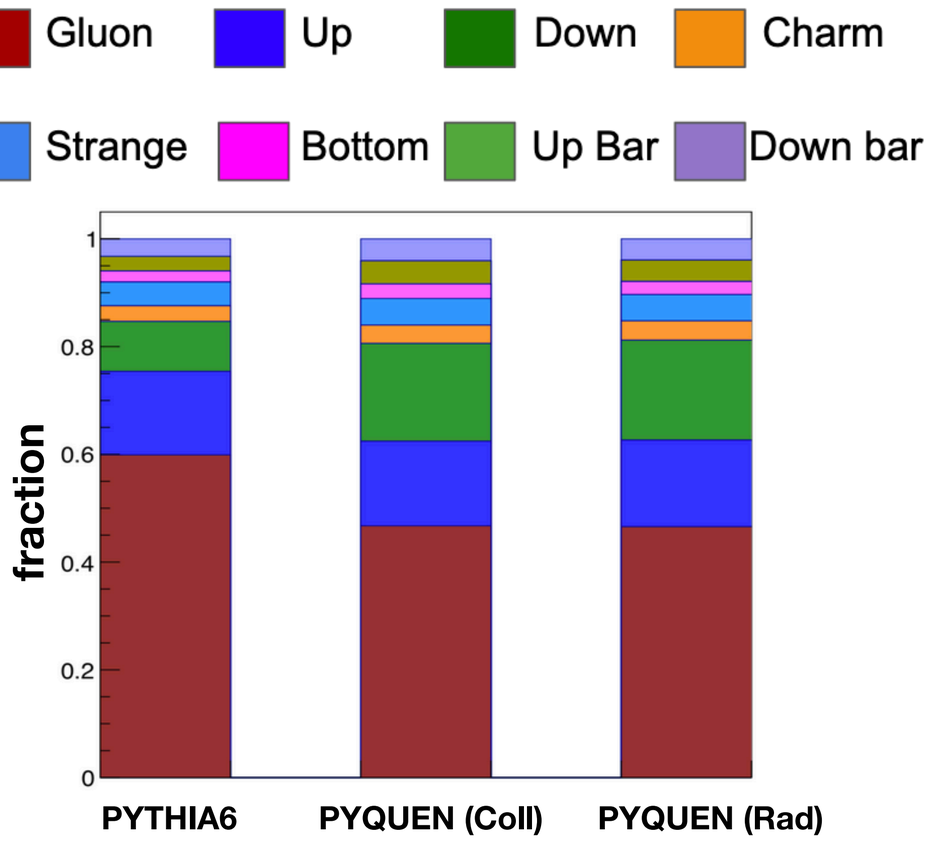
- Accounts for rescattering and optionally for both **collisional and radiative energy loss** for hard partons



[1] : 10.1140/epjc/s10052-011-1650-1

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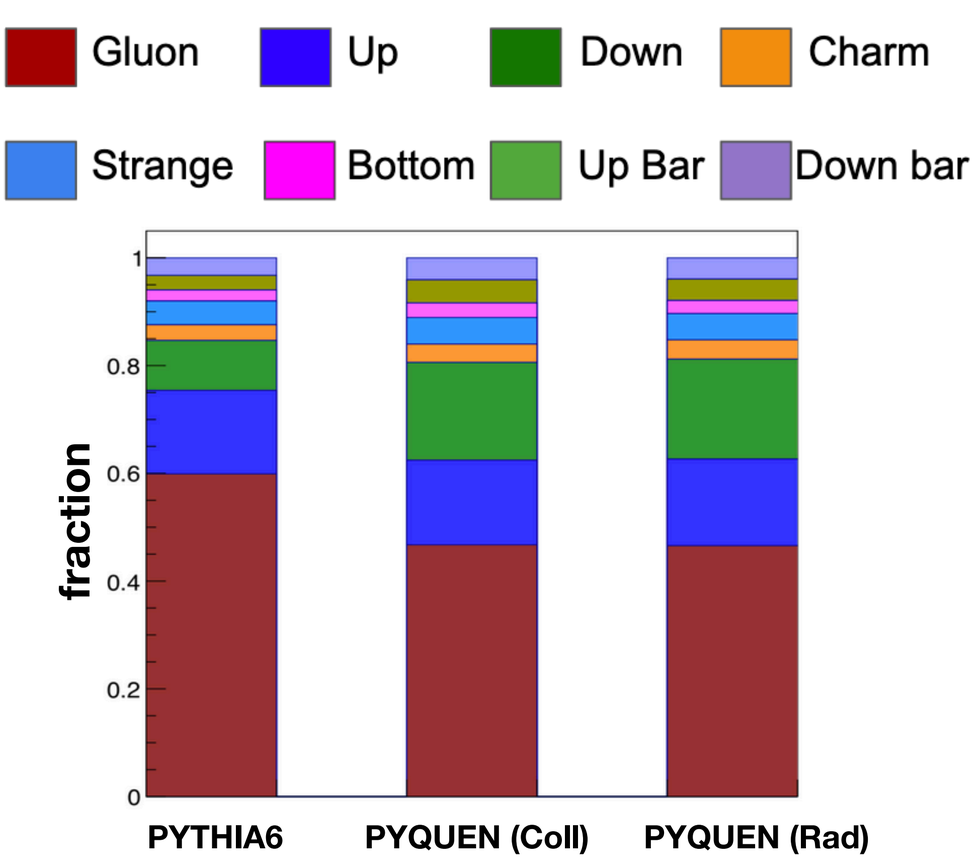
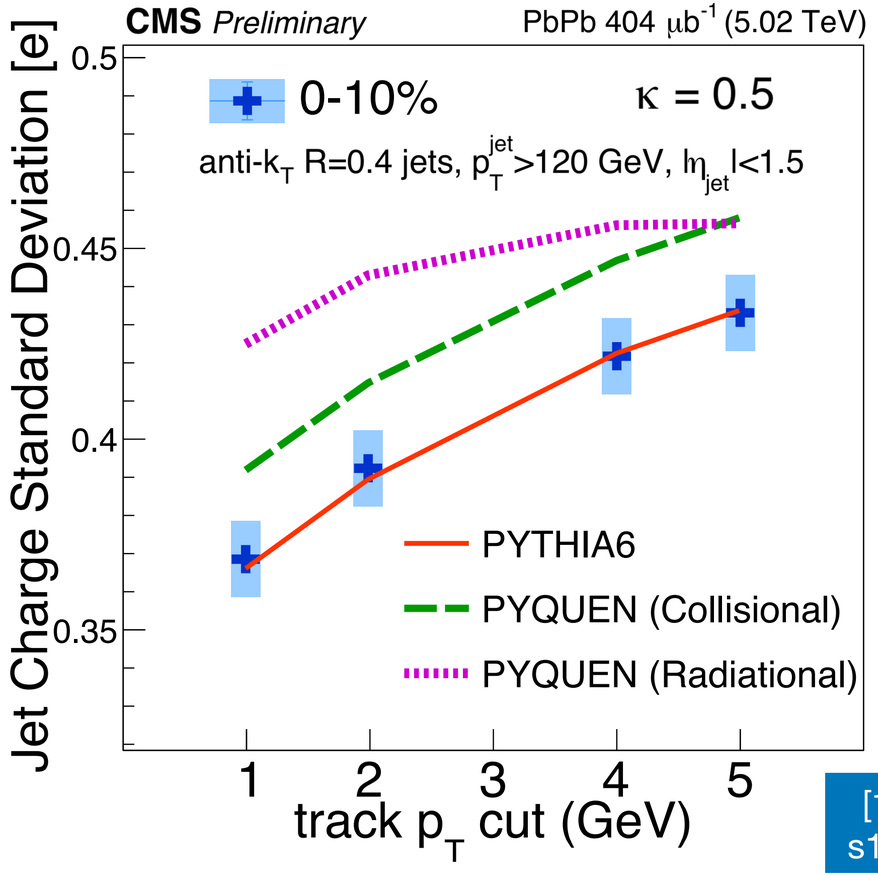
- Both the settings predict an **increase in the jet charge width, not observed in data**





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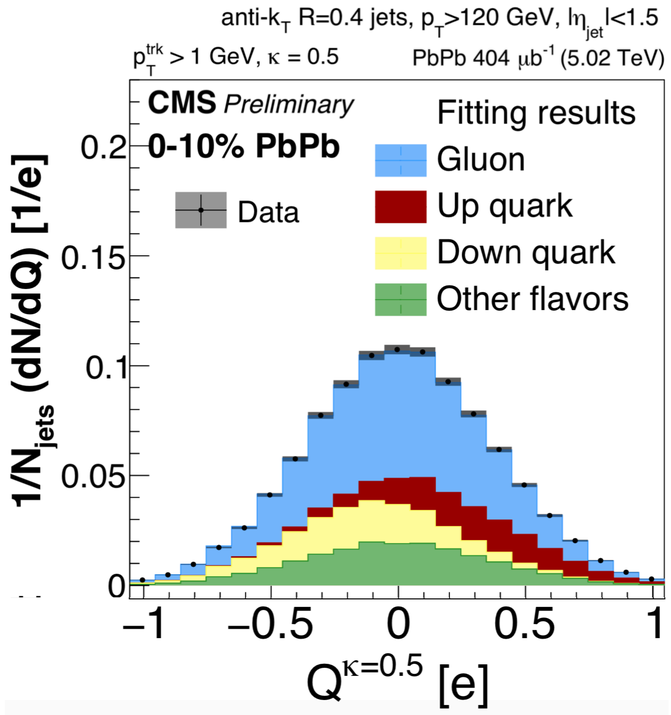

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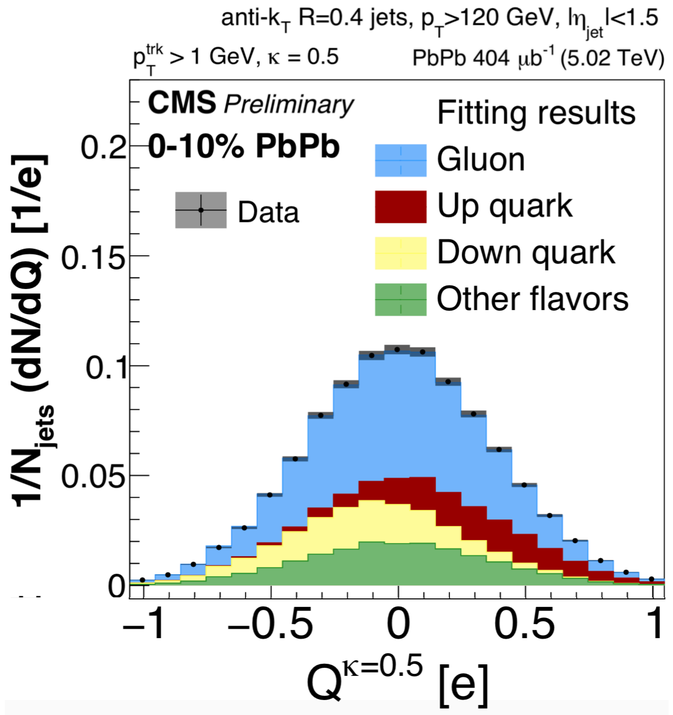

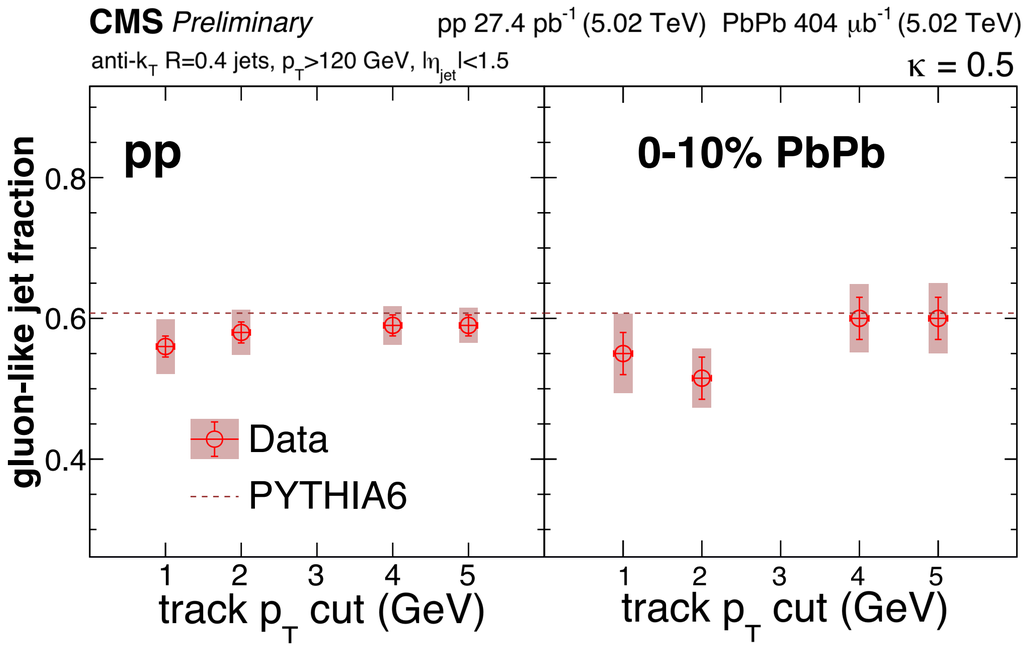

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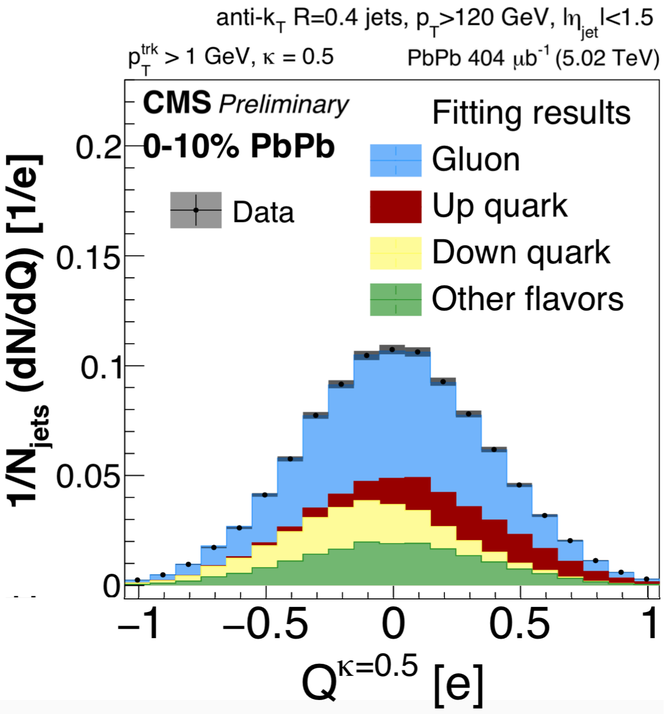
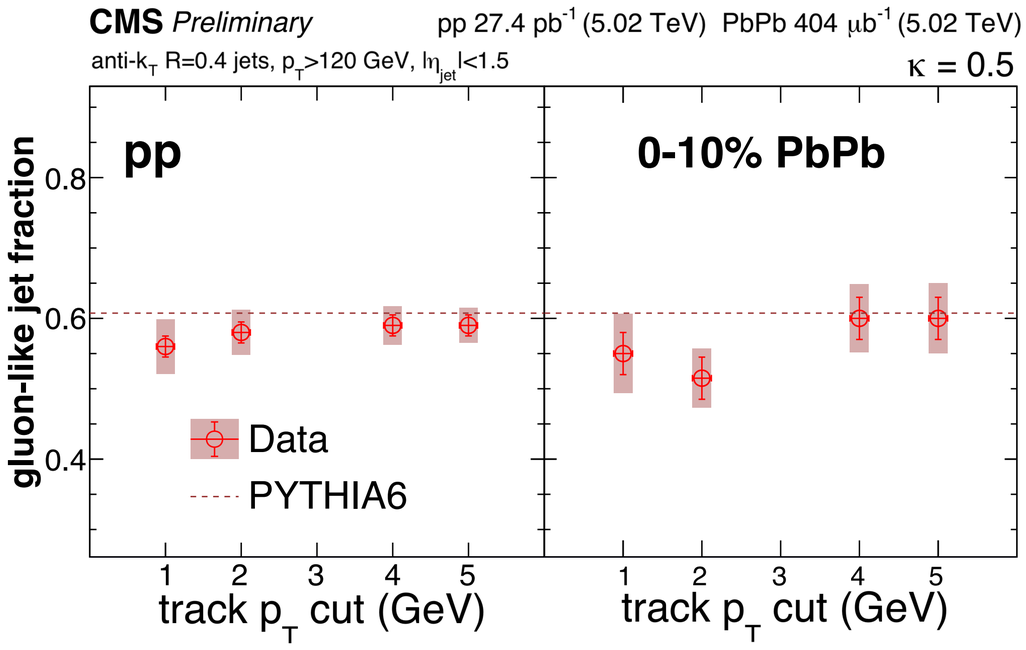
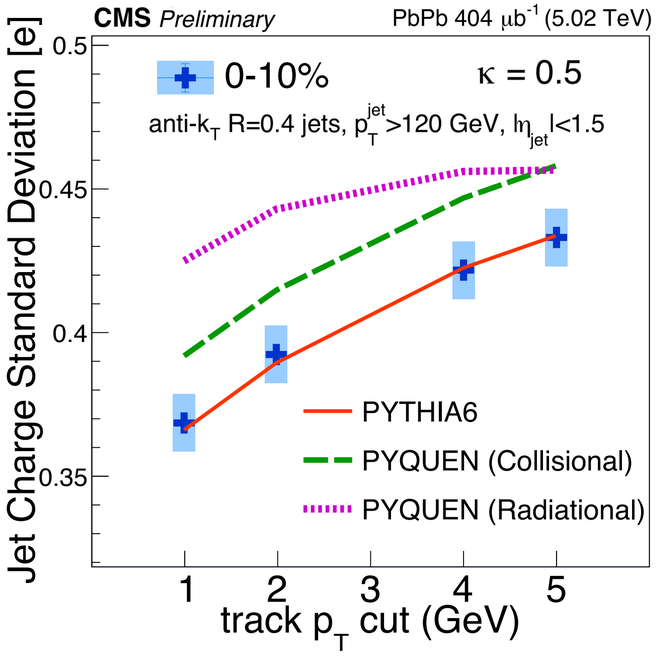
- Contrary to theory expectations, quark- and gluon-like jet fractions from template fitting are **relatively unmodified in various centrality bins**
- PYQUEN predicts an increase in the jet charge width in central PbPb collisions, **not observed in data**





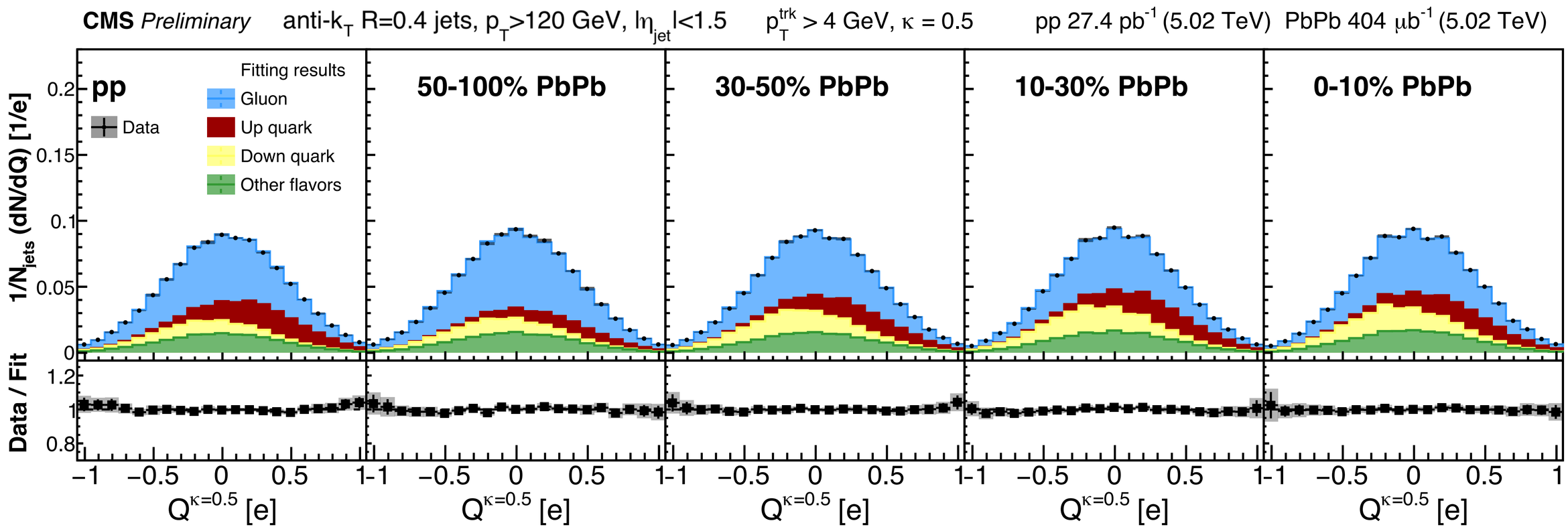


Thank you

This work is supported by the grant DE-FG02-94ER40865 from the US Department of Energy.

Jet Charge Measurements

- Jet charge measurements presented with template fitting results
- Measurements are unfolded for background fluctuations and tracking inefficiencies



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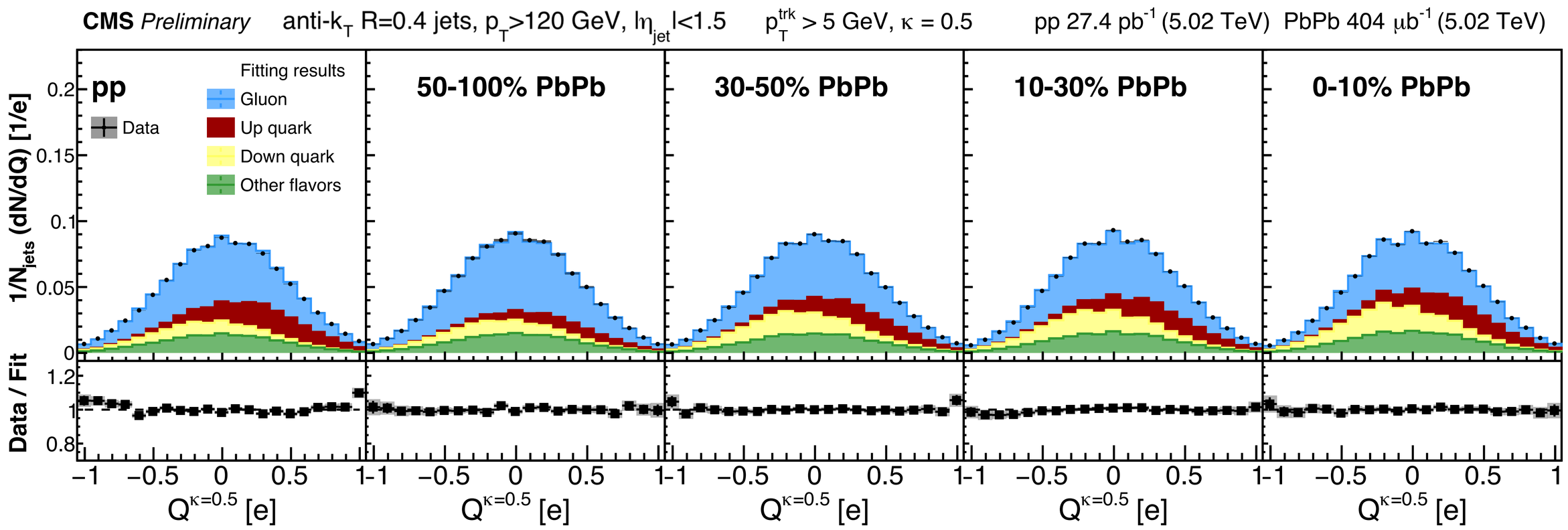

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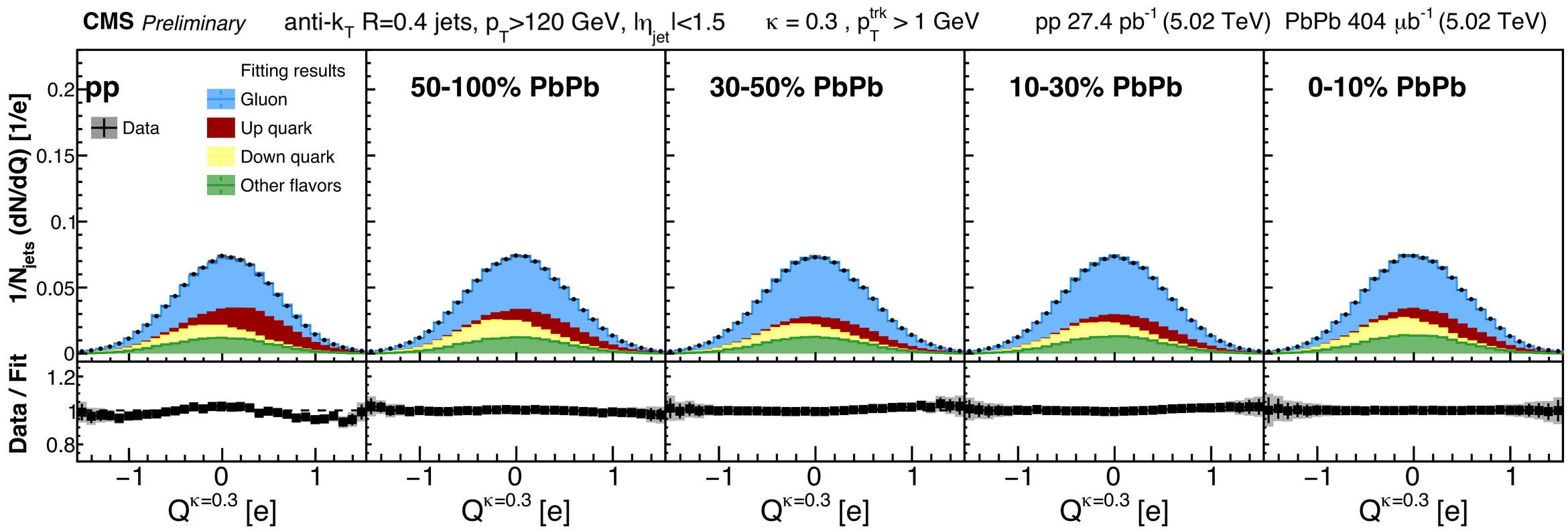

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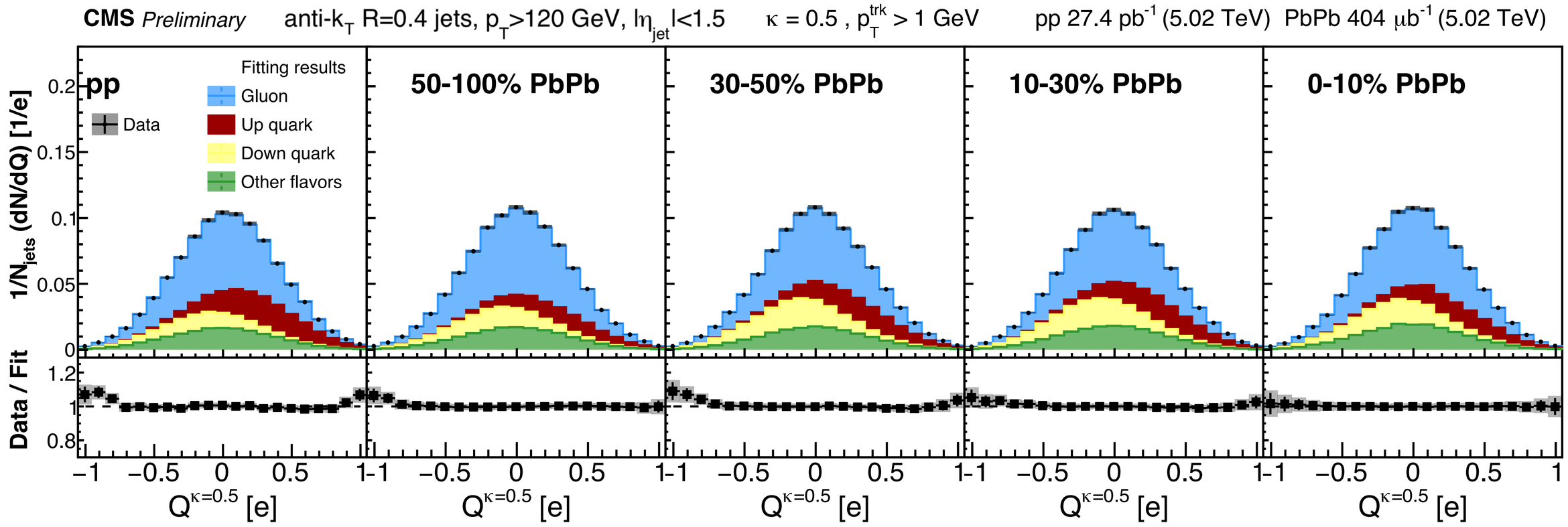

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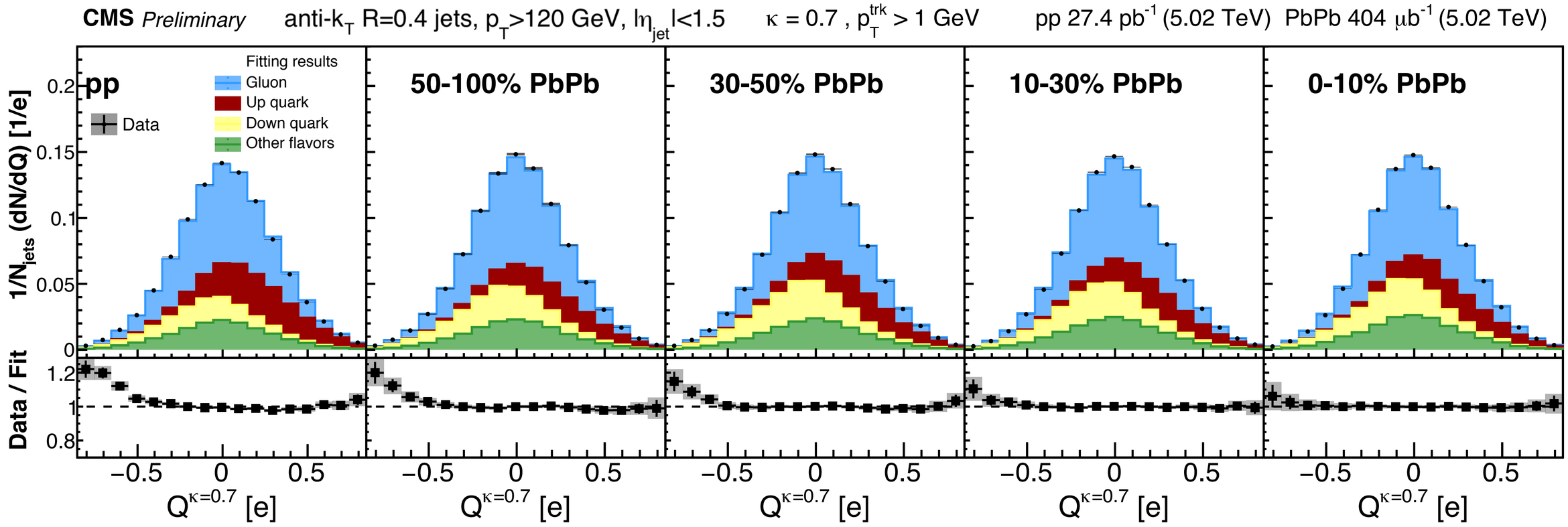

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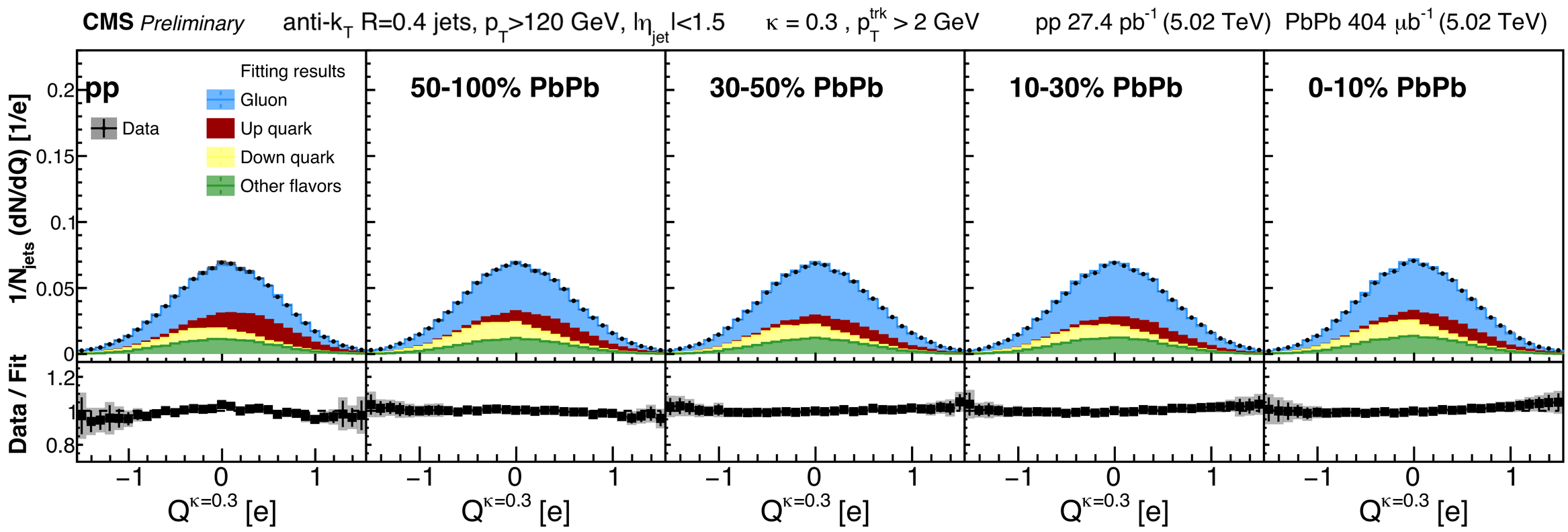

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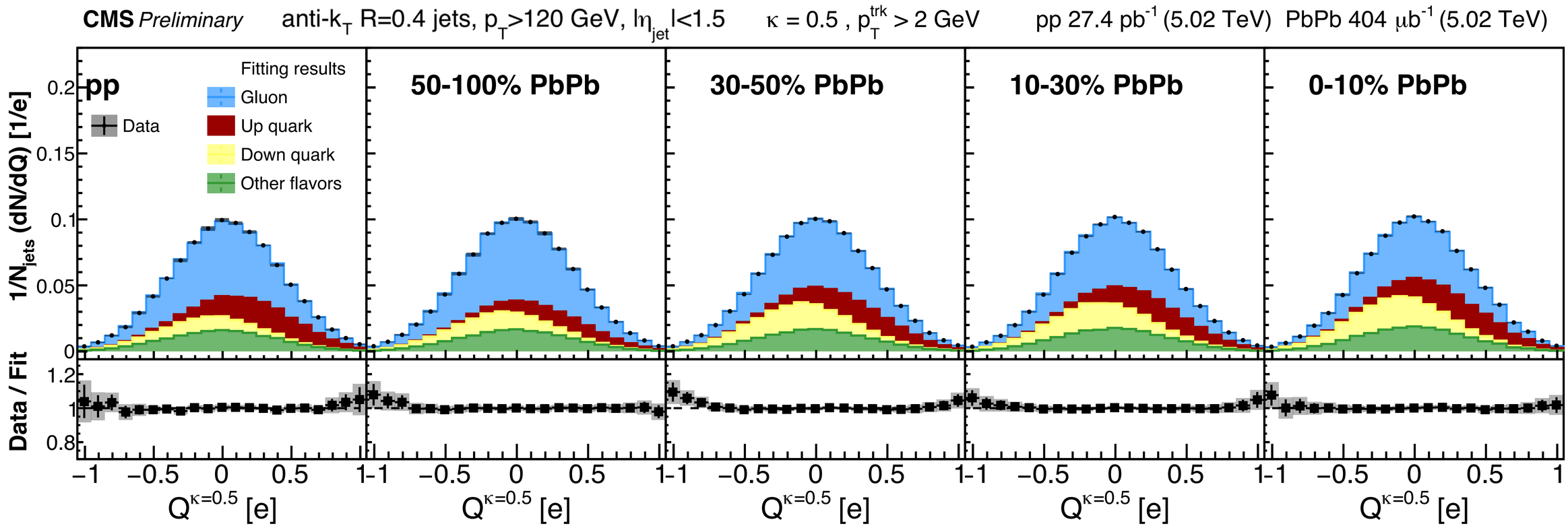

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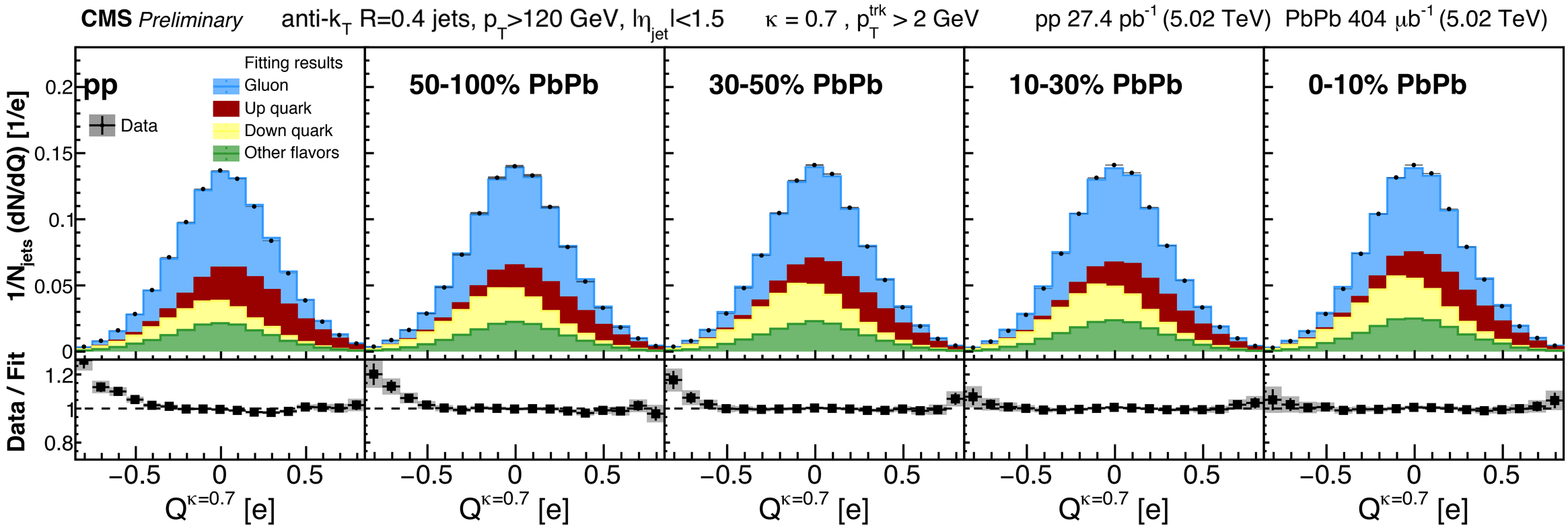
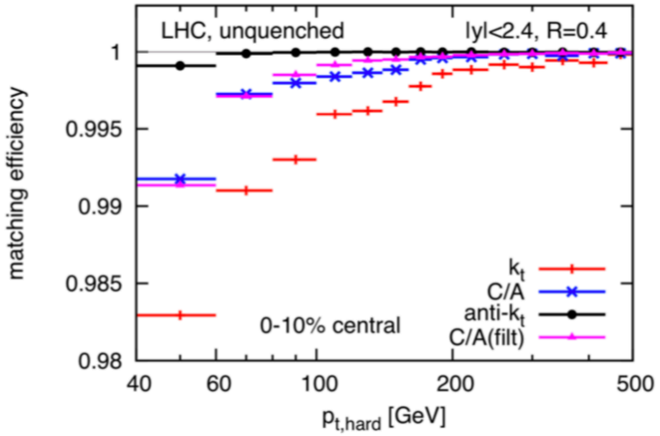
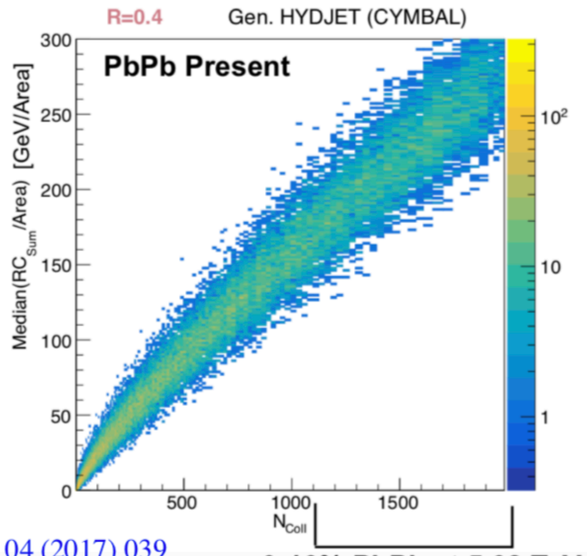


Jet Reconstruction in Heavy Ions

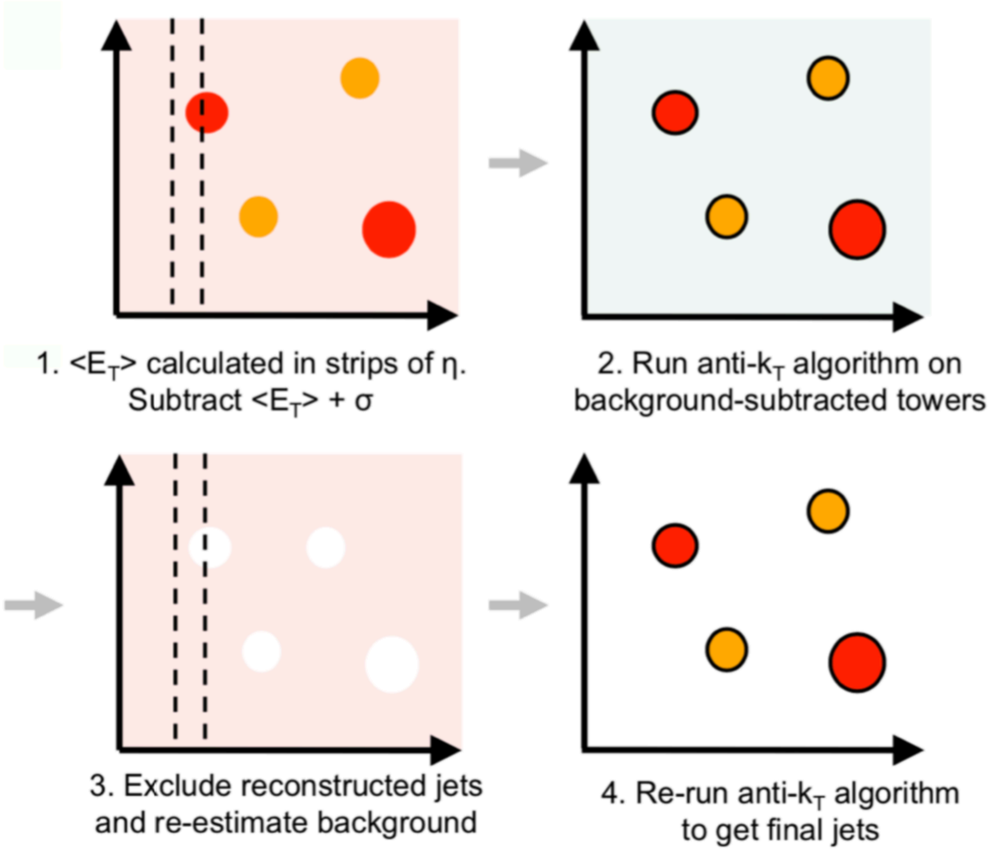
- **anti-kT** jet clustering algorithm used with calorimeter information with radius R=0.4
- Underlying event subtraction performed using **iterative pedestal** subtraction method





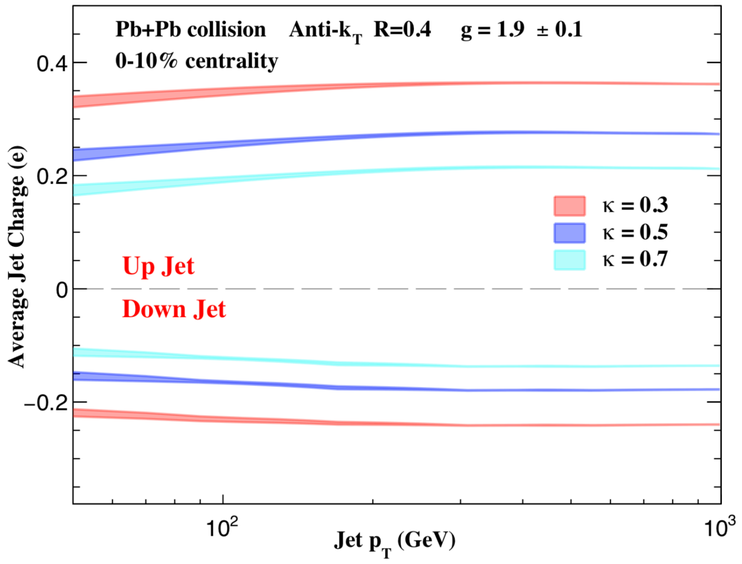
JHEP 04 (2017) 039

Iterative pedestal subtraction method

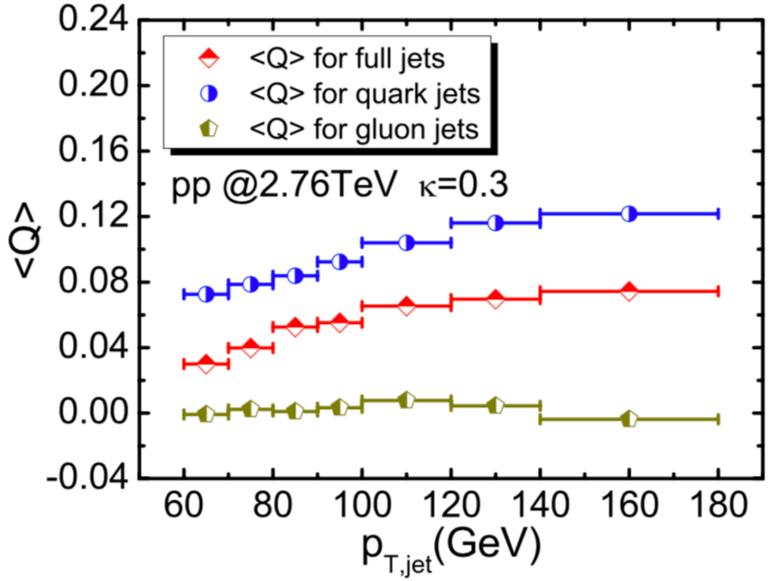


Theory : Jet Charge and Quenching

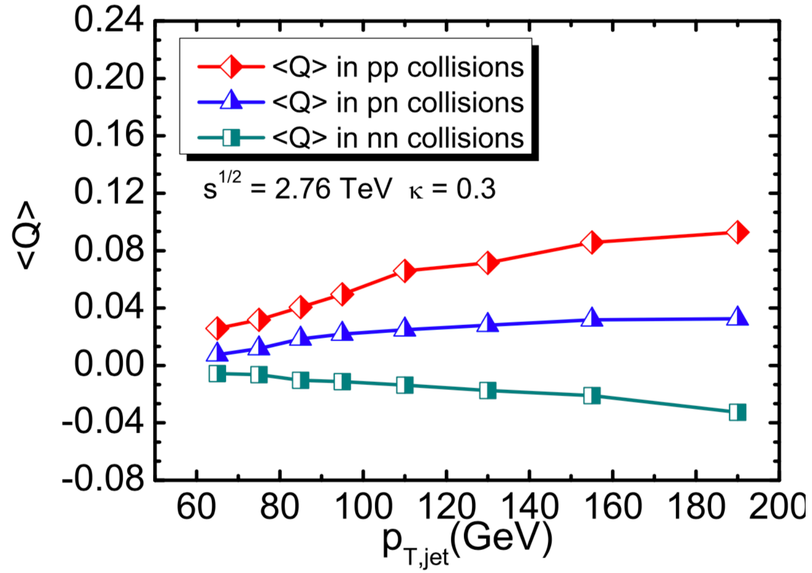
- Average jet charge for gluon-, up quark- and down quark- initiated jets have little p_T dependence
- Average jet charge in PbPb collisions without the final-state jet quenching effects also shown below



H-T LI and I. Vitev
arXiv:1908.06979

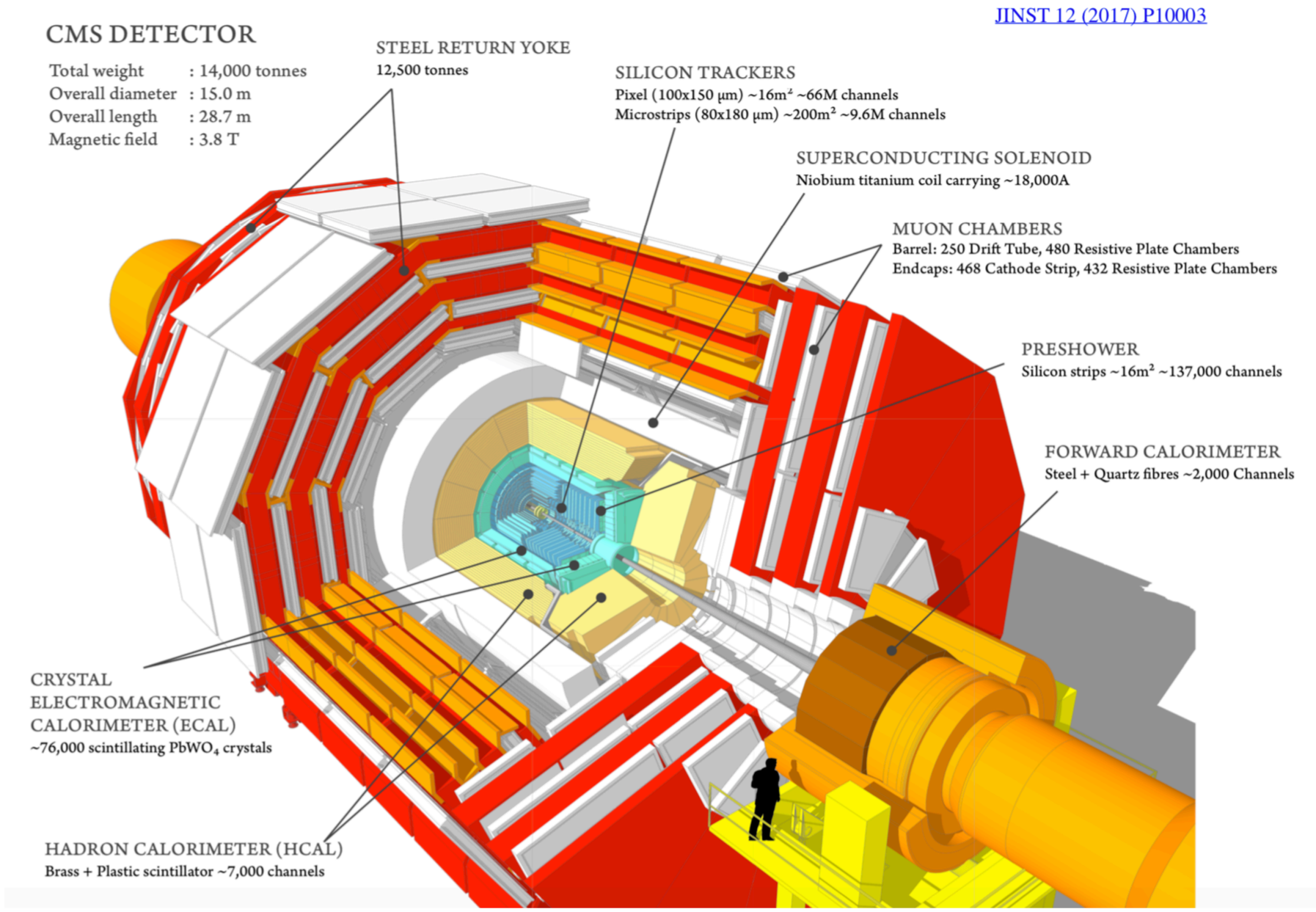


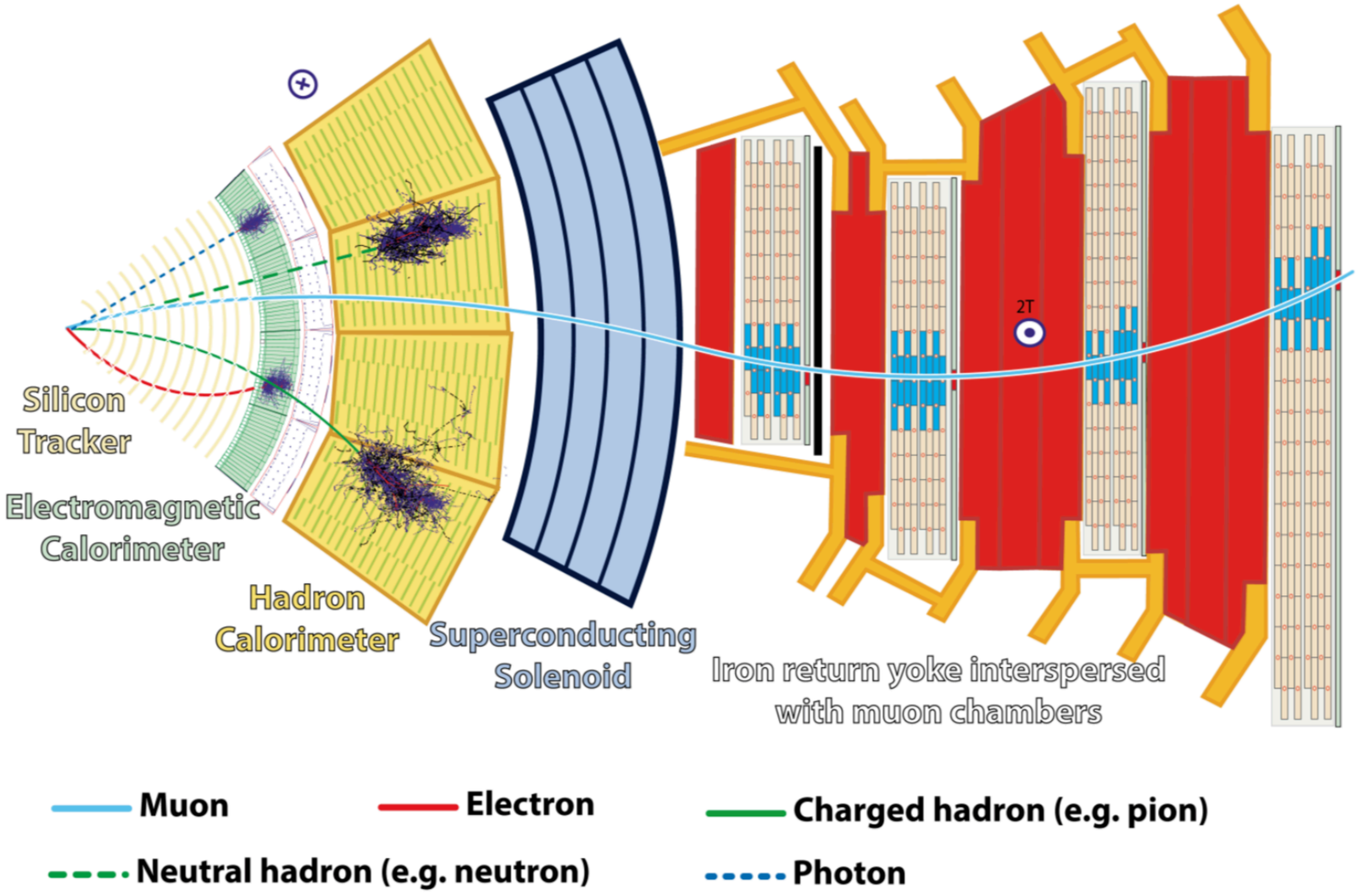
S-Y Chen, B-W Zhang & E Wang
arXiv:1908.01518v1



S-Y Chen, B-W Zhang & E Wang
arXiv:1908.01518v1

CMS Detector



CMS Detector Cross Section

JINST 12 (2017) P10003