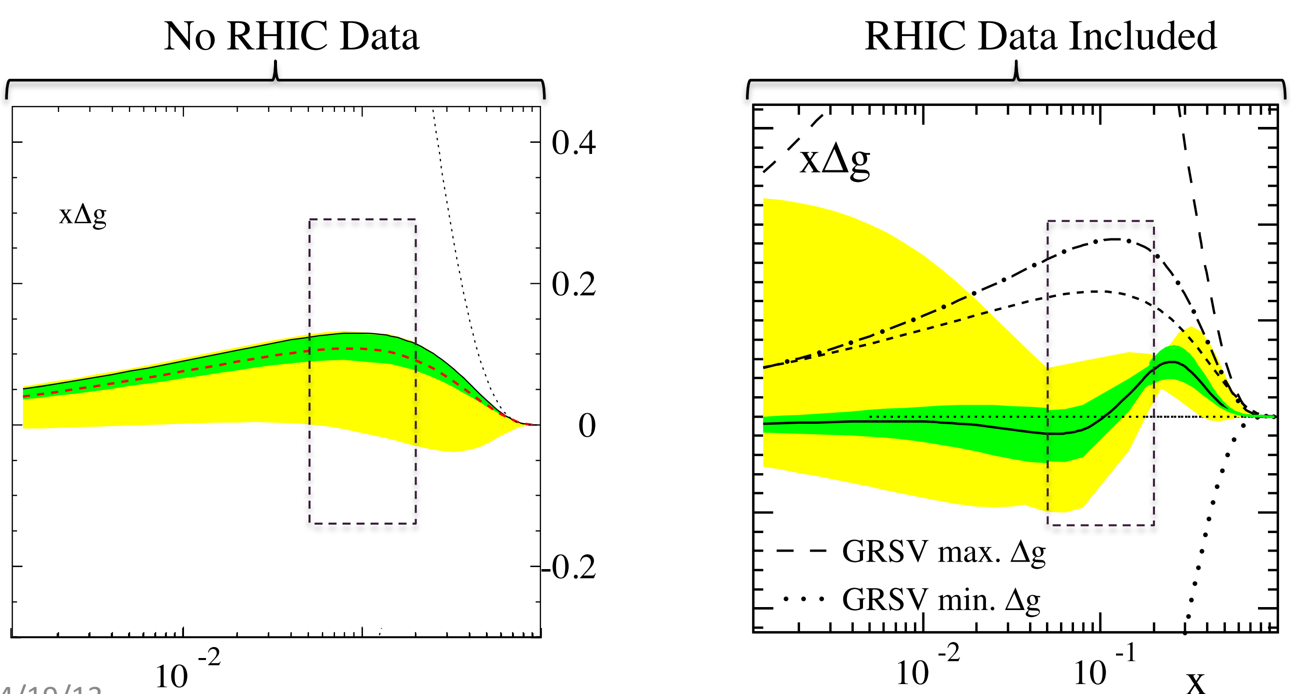
The Dijet Cross Section Measurement of Polarized Proton-Proton Collisions at $\sqrt{s}$ = 500 GeV at STAR

Grant Webb
For the STAR Collaboration
University of Kentucky
Apr. 23, 2013

Motivation: Proton Spin Puzzle

Polarized DIS experiments determined the quark contribution to the spin of the proton is ~30%.

$$\frac{1}{2}\Delta\Sigma + L_q + \Delta G + L_g = \frac{1}{2}$$



Inclusive jet and pion data from RHIC allowed for significant improvement but large uncertainties at low X remain

de Florian *et al.*, Phys. Rev. D71, 094018 (2005).

de Florian *et al.*, PRL **101** (2008) 072001

Polarized pp collisions at RHIC

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\Delta f_a \Delta f_b}{f_a f_b} \hat{a}_{LL}$$

Δf: polarized parton distribution functions

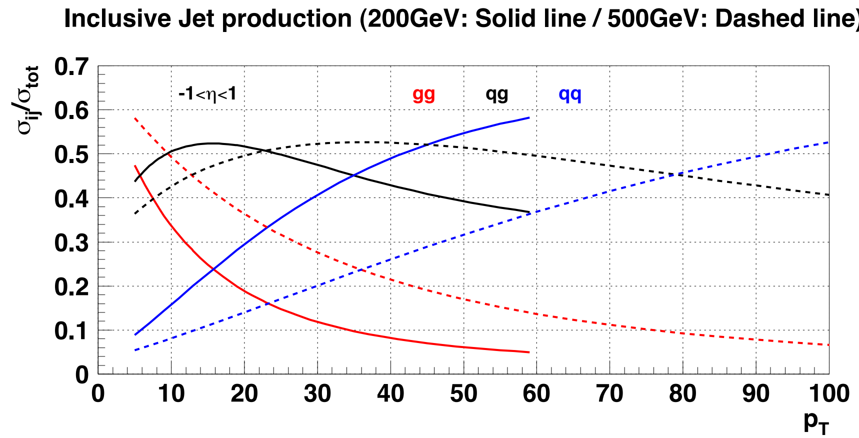
Reconstructing Di-jets provide access to the initial partonic kinematics at LO

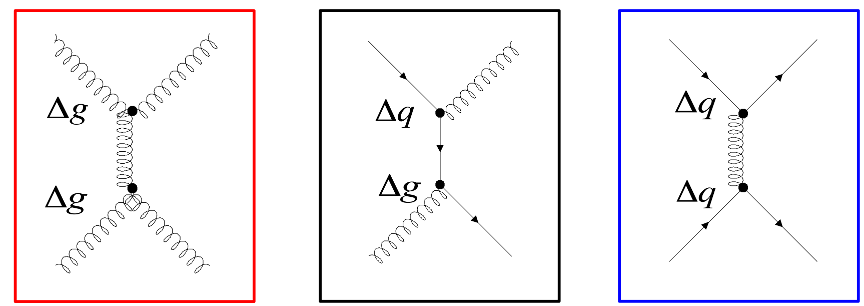
$$x_1 = \frac{1}{\sqrt{s}}\left(p_{T3}e^{\eta_3} + p_{T4}e^{\eta_4}\right)$$

$$x_2 = \frac{1}{\sqrt{s}}\left(p_{T3}e^{-\eta_3} + p_{T4}e^{-\eta_4}\right)$$

$$M = \sqrt{x_1 x_2 s}$$

$$\cos\theta^* = \tanh\left(\frac{\eta_3 + \eta_4}{2}\right)$$

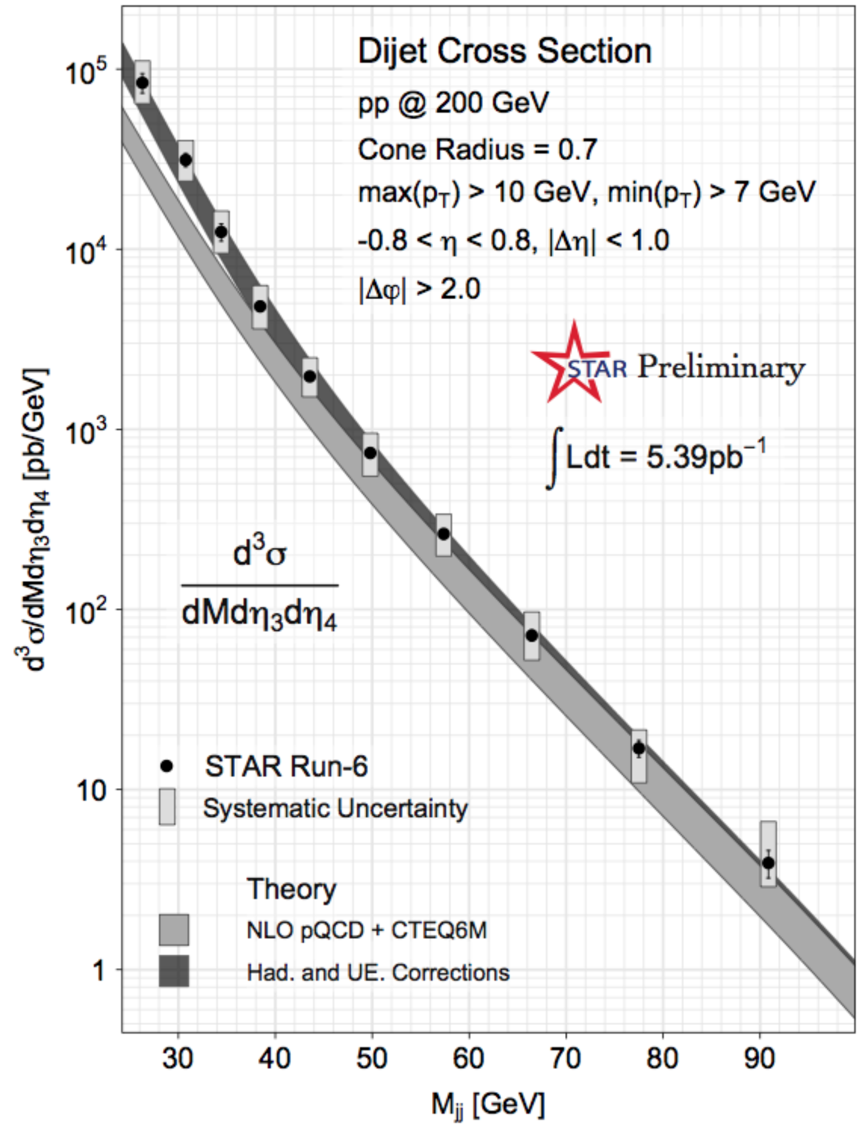


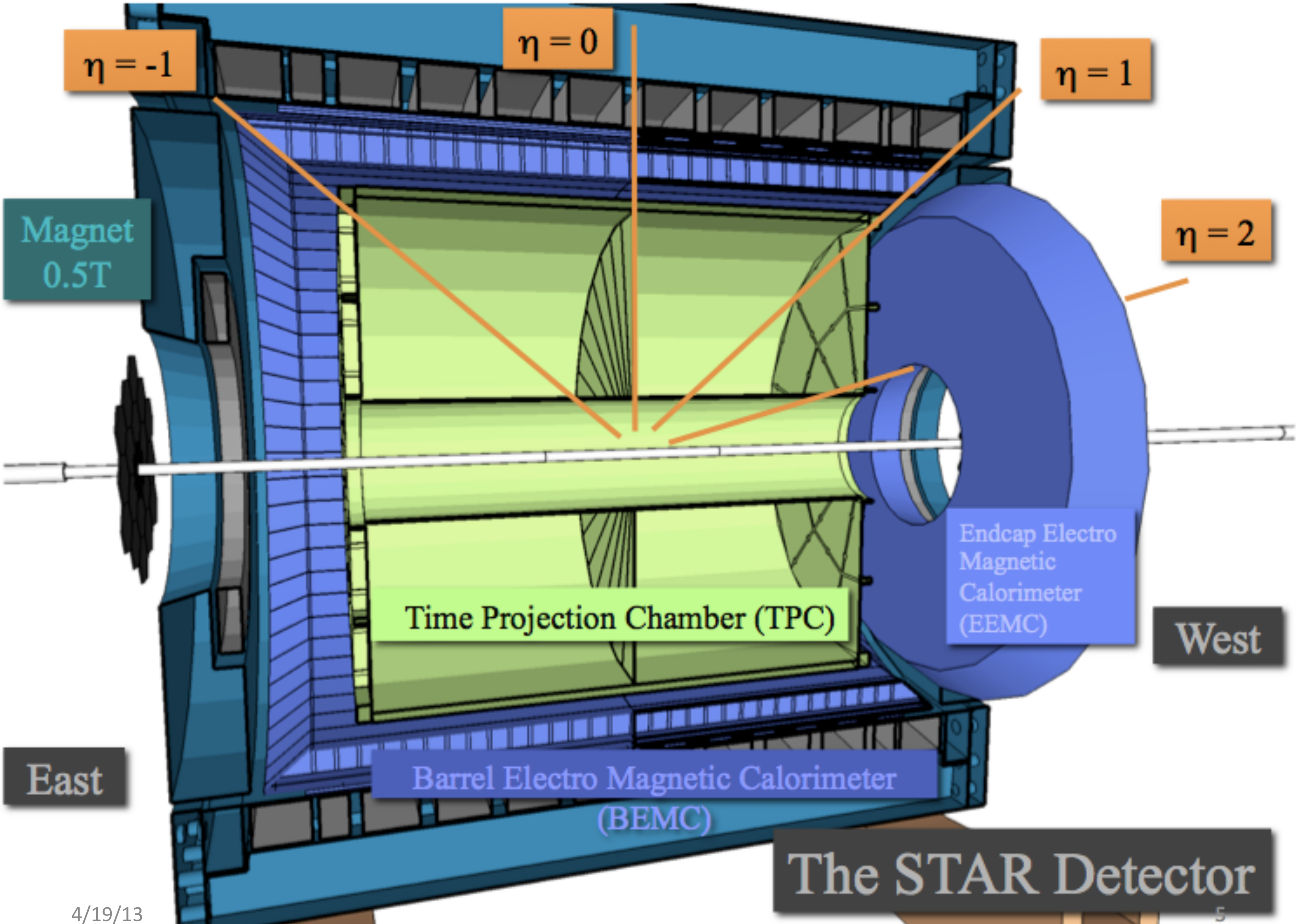


The Dijet A_{LL} at 500 GeV has the potential to sample lower x values than existing STAR measurements and therefore provides information on ΔG in a new kinematic regime

Dijet Cross Section

- The di-jet cross section provides an essential check for the experiment.
- The Dijet cross-section was found to be in good agreement with NLO pQCD theory at $\sqrt{s} = 200$ GeV
- Measuring the cross-section at 500 GeV will allow STAR to:
  - Test the behavior of a new Jet Algorithm (anti-Kt versus midpoint cone)
  - Study the effects of increased backgrounds and pileup
  - Understand trigger inefficiencies
  - Study detector response and calibration
  - Verify that we understand our observables and can use them in asymmetry measurements





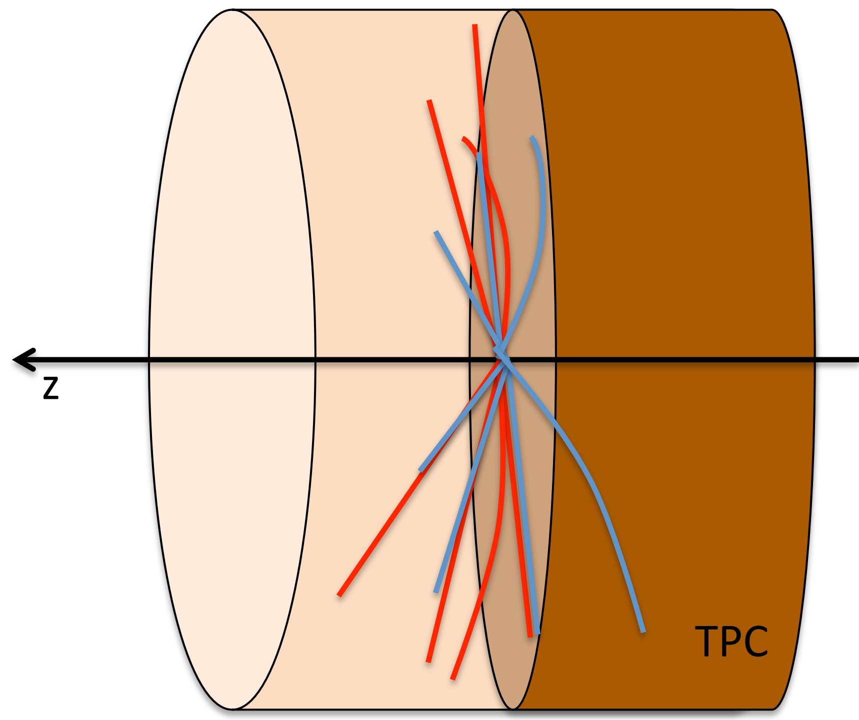
Tai Sakuma, Thesis, MIT (2010)

Run 9 pp500 MC Sample

- The goal of this MC sample is to properly account for
  - Inefficiencies
    - Trigger
    - Vertex
    - Fiducial
  - Resolutions

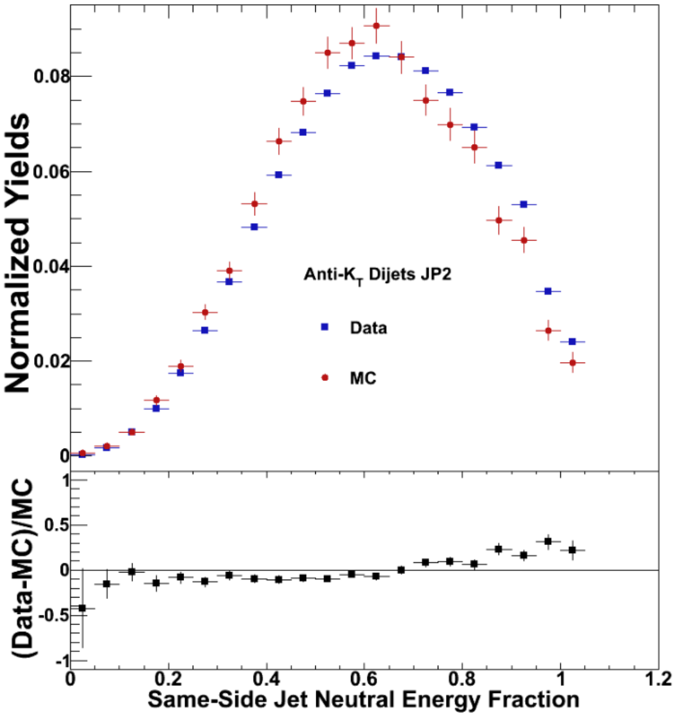
- An Embedding Simulation Sample of 83M thrown events
  - Embed Pythia* MC particles/tracks into zero bias triggered events from data
  - Detector backgrounds (pile-up) are properly included in simulation.
  - Perugia 0 TUNE 320

- Two Filters used:
  - Di-jet Pythia-level Filter
    - Improves signal extraction
  - Trigger Reconstruction level Filter
    - Reduced CPU time and disk space



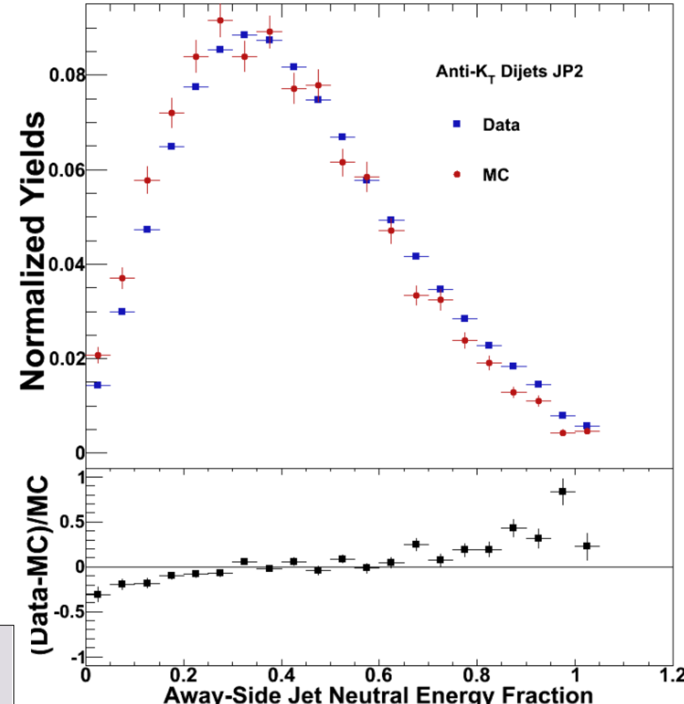
*T. Sjostrand, S.Mrenna, P.Skands PYTHIA 6.4 Physics and Manual, JHEP 0605:026, 2006 [arXiv:hep-ph/0603175]

Event Selection

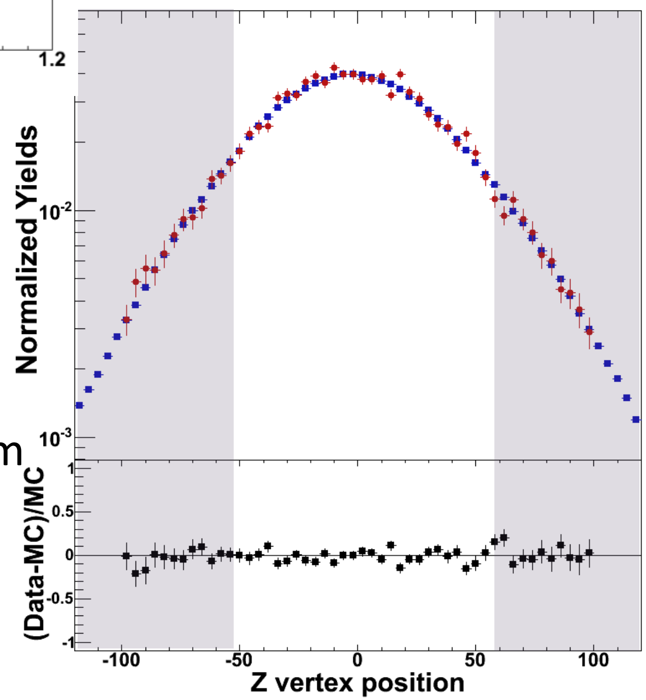


2009 Data collect ~10pb^{-1} with an average polarization of ~40%

Jet Patch (JP): Division of the BEMC into 18 regions (1x1 in ηxφ space) each containing 400 towers



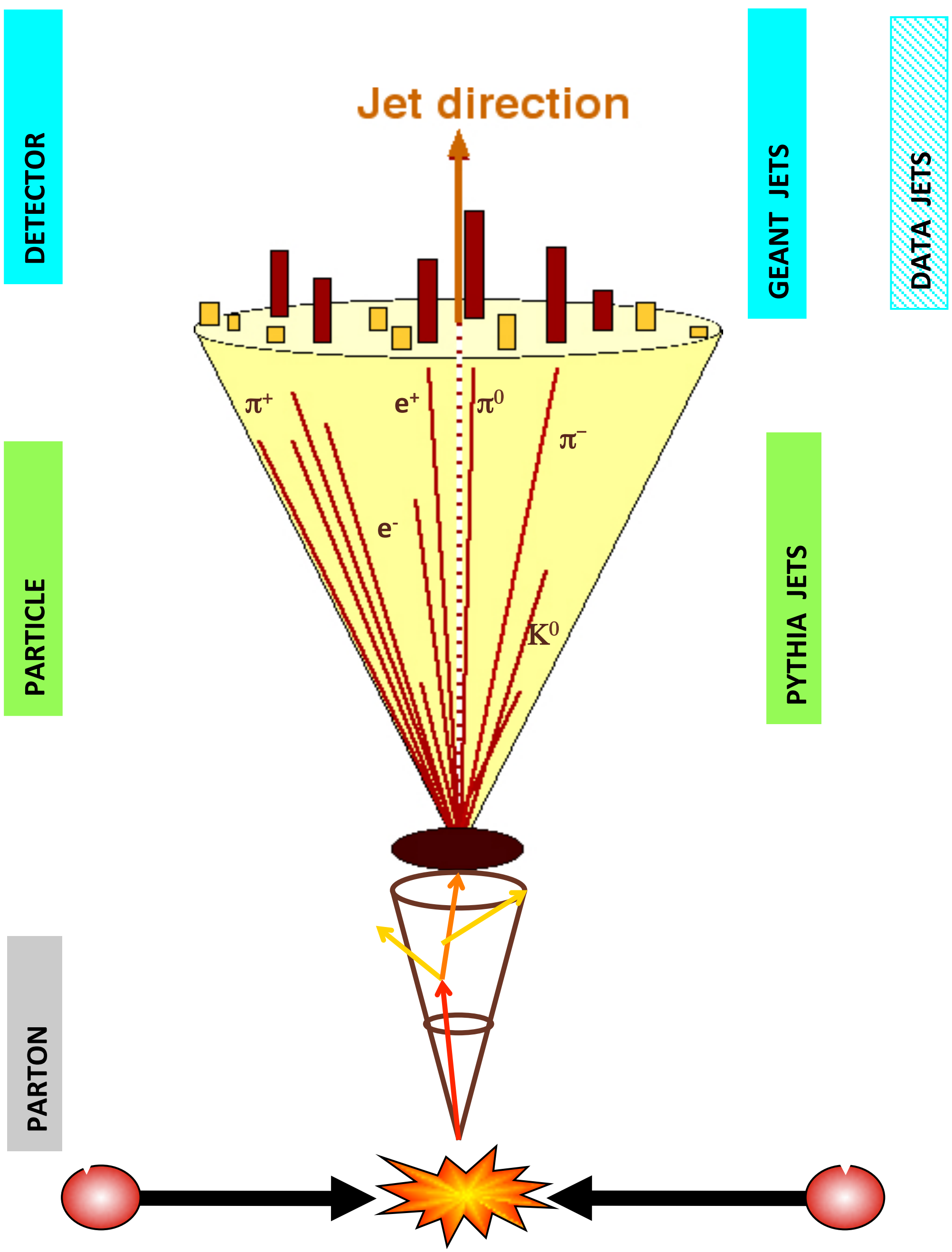
- Same side jet demonstrates trigger bias
- Require # jets ≥ 2
- Require | Z vertex | ≤ 50 cm



- JP2 Trigger: $E_T \geq$ ~13.0GeV
- Geometric Trigger:
  - Requiring a jet to point at a JP

STAR Jets @ 500GeV

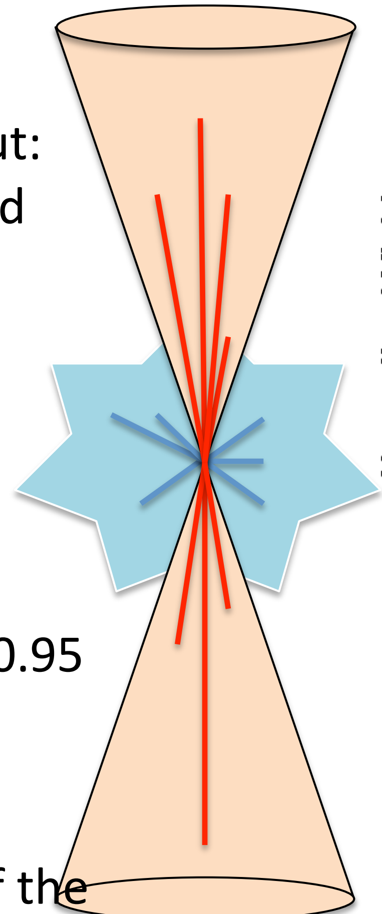
*M. Cacciari, et.al. FastJet User Manual, Eur.Phys.J. C72 (2012) 1896, [arXiv:1111.6097].

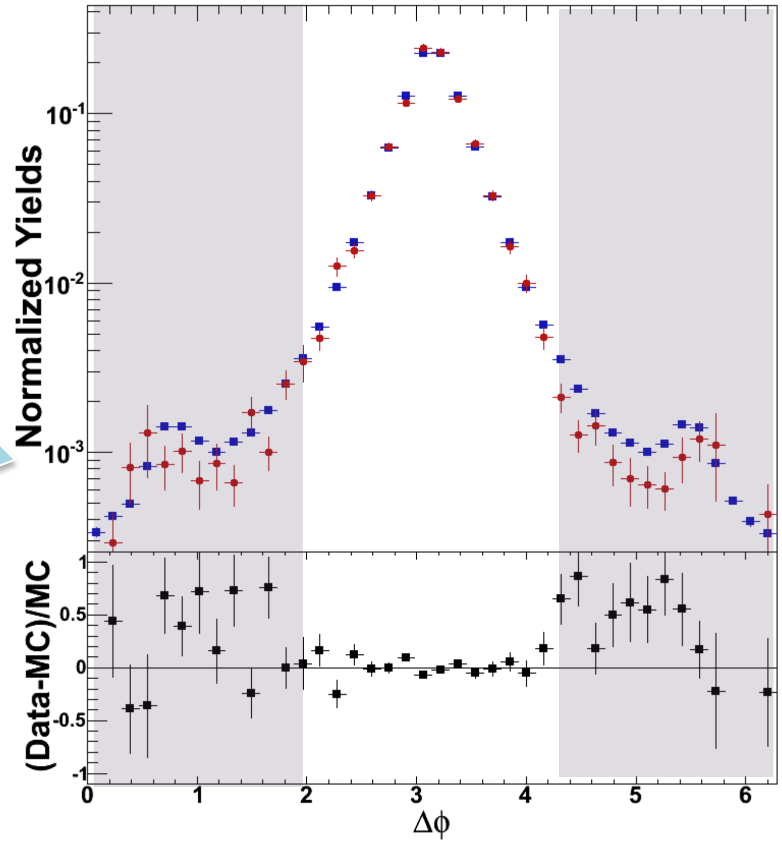


- Previously used the mid-point cone with radius 0.4 and 0.7.
- Moved to Anti-kT with R= 0.6 implemented by FastJet*.
- TPC tracks and Calorimeters towers are used as 4-vectors
- This is used for jet reconstruction at the parton, particle and detector level.
- We do not use FastJet for UE evaluation at this time

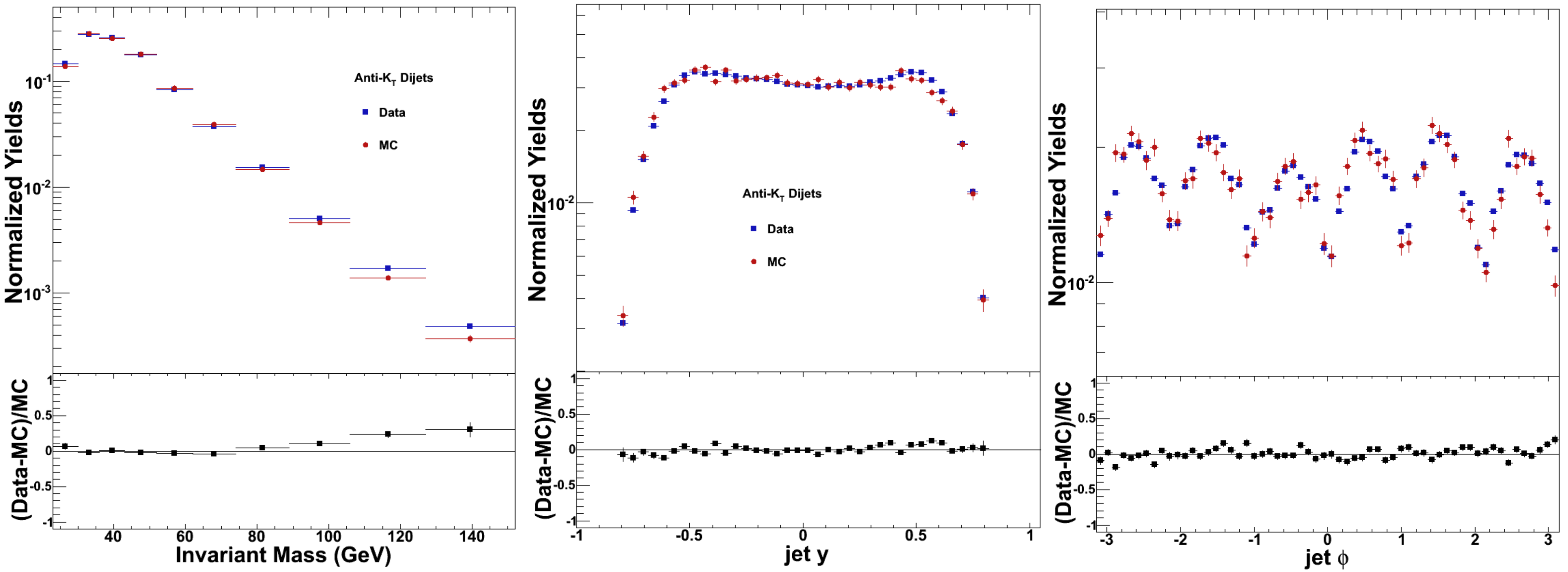
Selecting Di-jet Events

- Select the highest two pT jets
- Apply the asymmetric jet pT cut: max(pT1, pT2) > 13 (GeV/c) and min(pT1, pT2) > 10 (GeV/c)
- Require |jet η| < 0.8
- Require |det jet η| < 0.7
- Require one jet to have NEF < 0.95
- Δφ ≥ 2.0 for back to back jets
- Calculate the invariant mass of the two jets





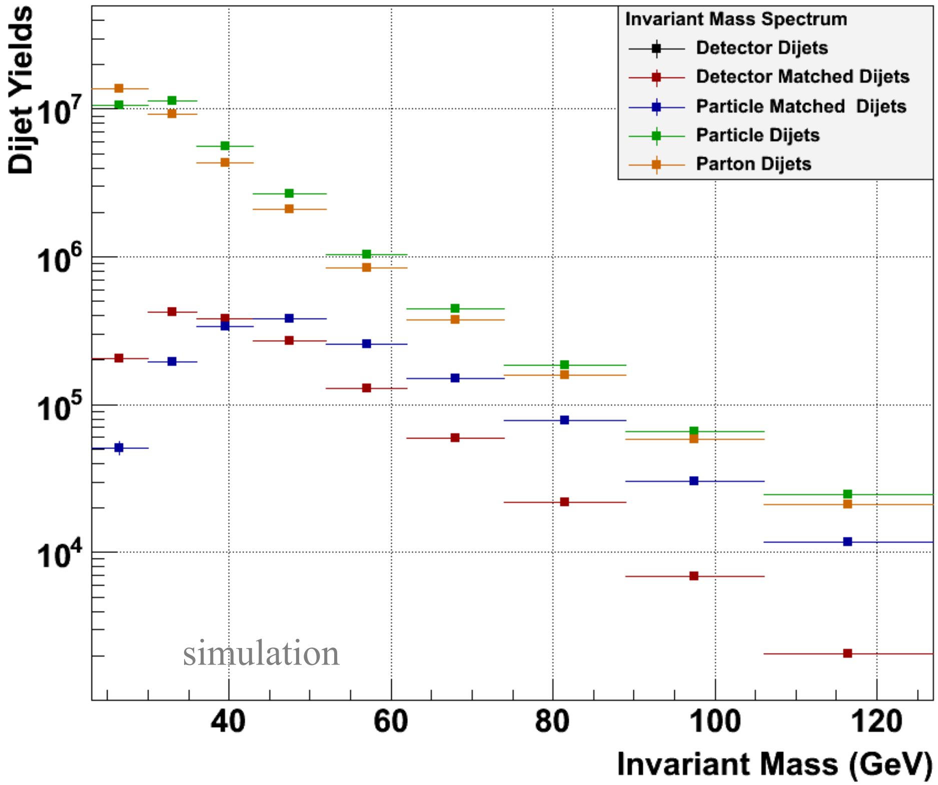
Run 9 500GeV Jet Data/Simulation Comparison

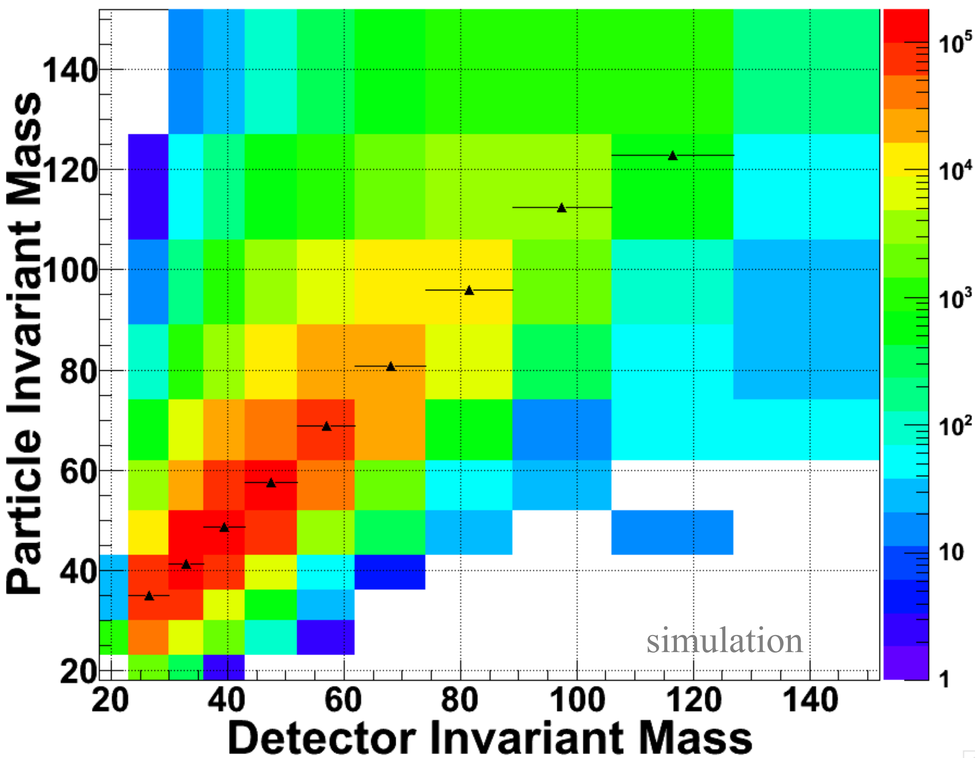


$$M_{inv} = \sqrt{2 p_{T3} p_{T4} \left(\cosh(\Delta y) - \cos(\Delta \phi) \right)}$$

Nice agreement between data and simulation in Run 9

Corrected Dijet Yields



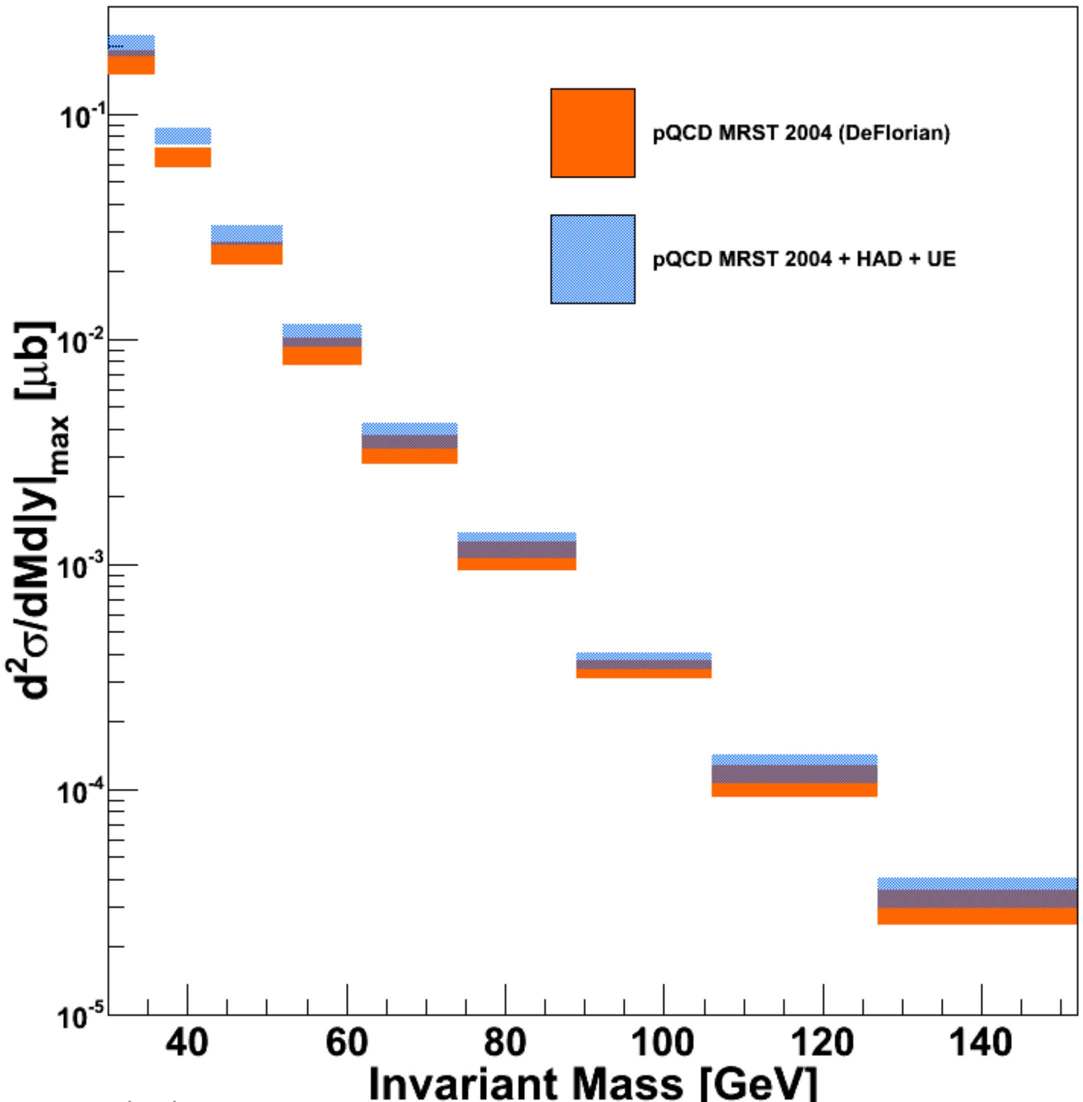


$$J_i = R_{2i} \sum_j M_{ij} \left[R_{1j} * A_j \right]$$

- Singular Value Decomposition SVD Method
  - Regularization parameter defines the level at which values are deemed to be due to statistical fluctuations and are cut out
  - Rescaling of the Response matrix

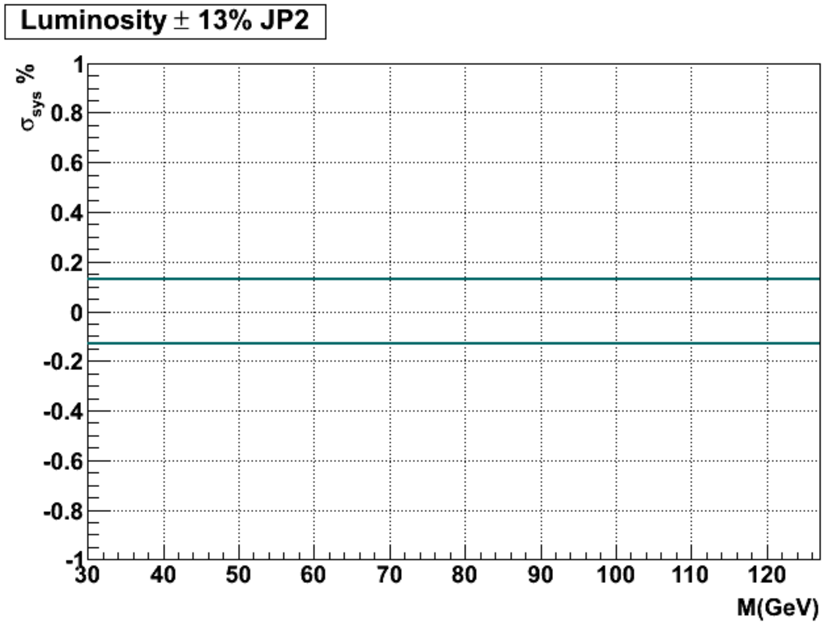
T. Adye. Unfolding algorithms and tests using RooUnfold CERN-2011-006, pp 313-318 arXiv:1105.1160

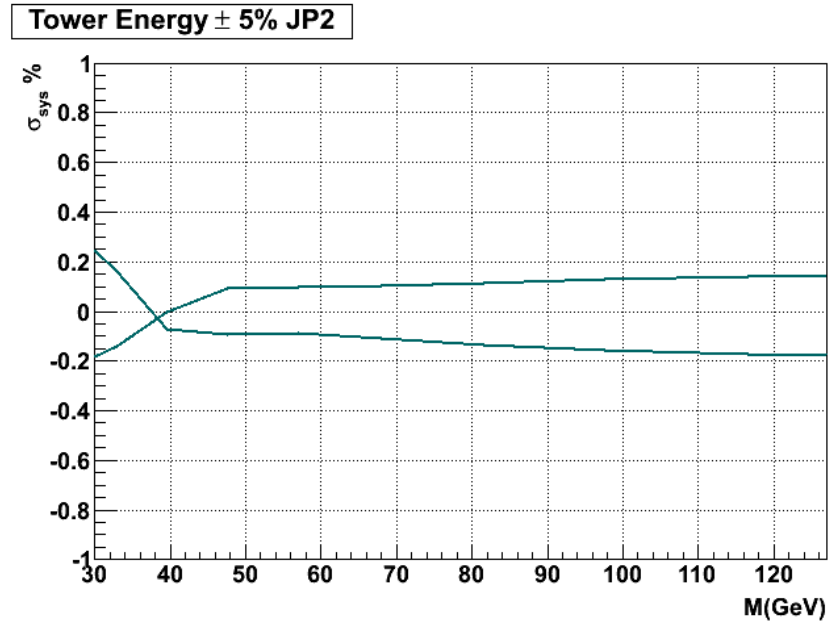
Hadronization and Underlying Event

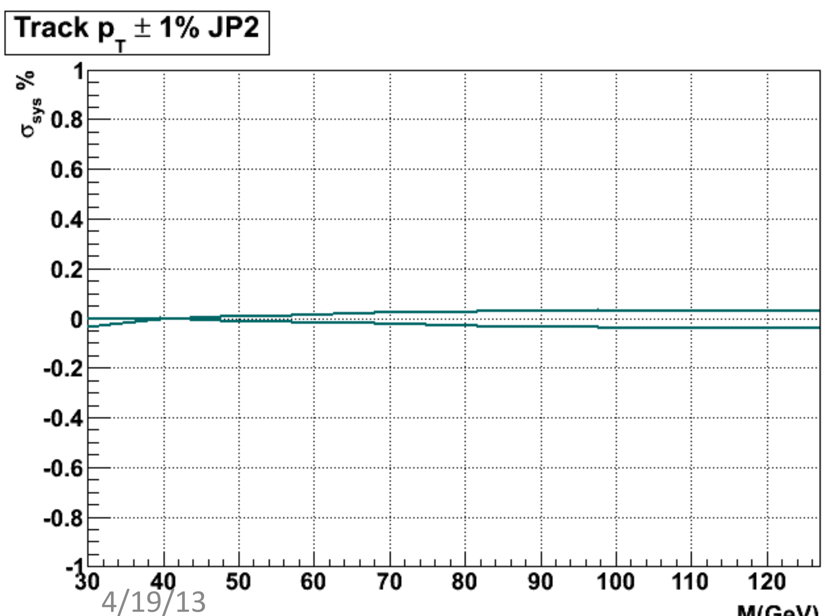


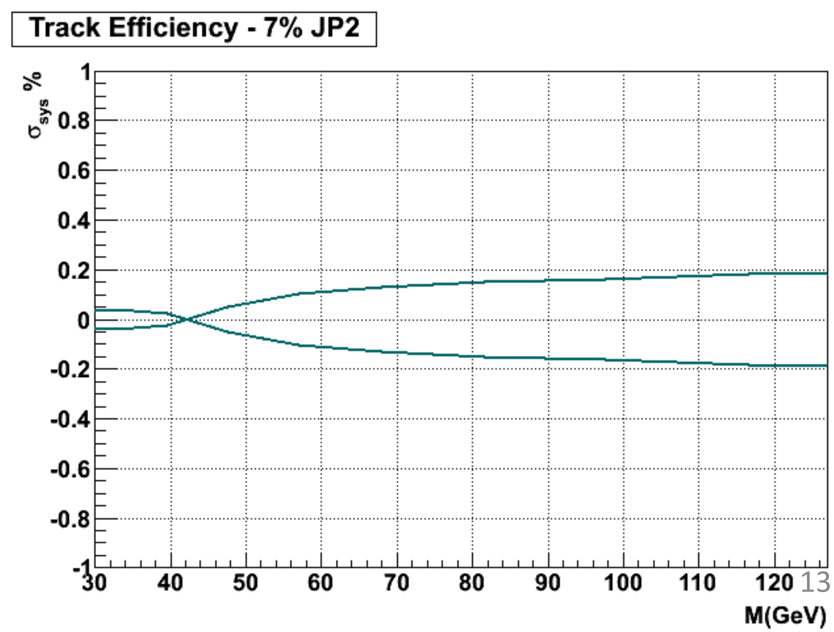
- Hadronization and the Underlying Event are not calculated by theory
- Determine the cross-section at parton and particle levels.
- Take the difference between these distributions
- Add this difference to the theoretically predicted values

The 4 Systematics

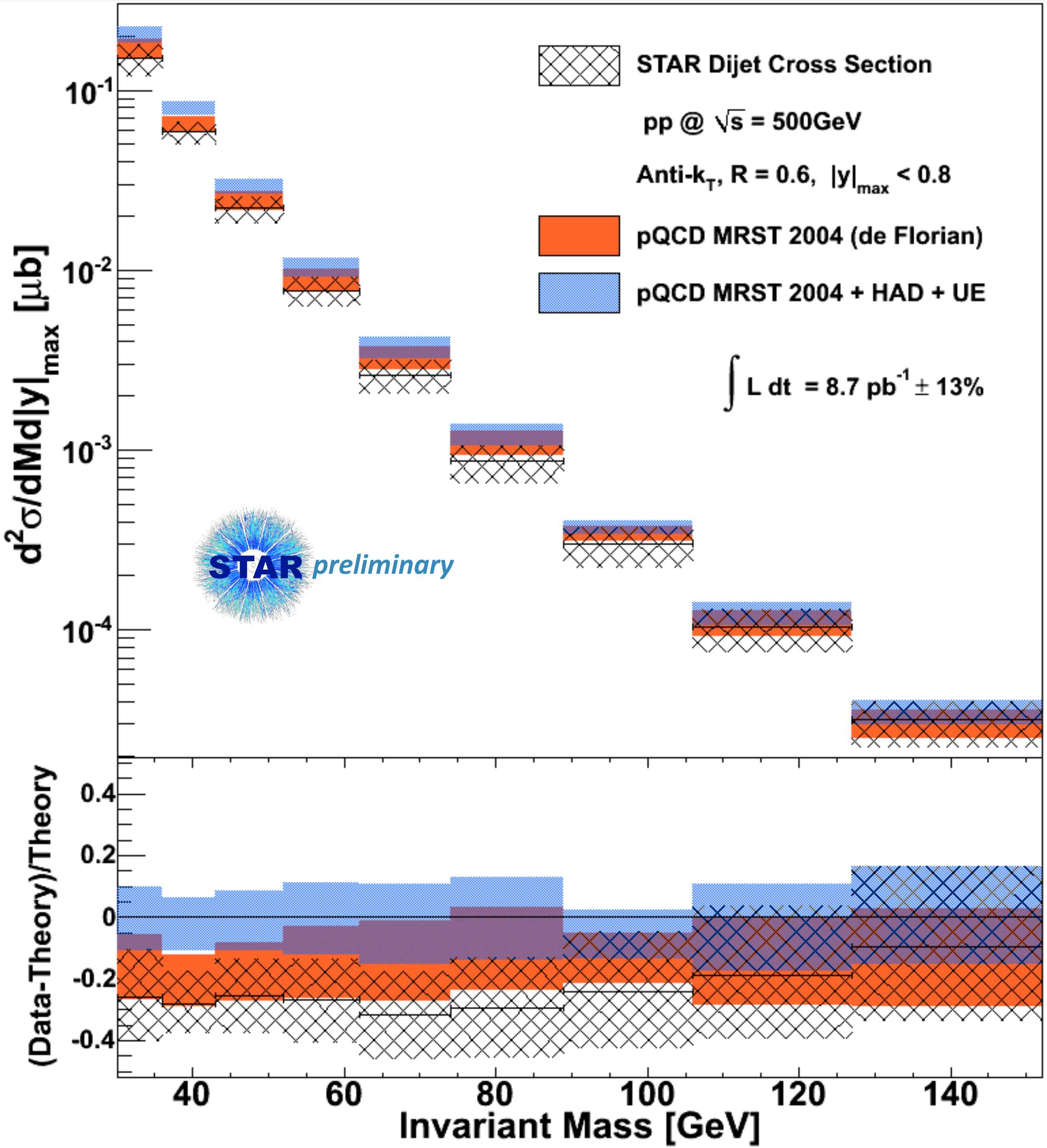








$$\frac{d^2\sigma}{dMd|y|_{\max}} = \frac{J}{\Delta M \Delta |y|_{\max}} \frac{\langle prescale \rangle}{\mathcal{L}}$$



Conclusion

- STAR has measured the proton-proton dijet cross section at 500 GeV using the anti-k_T algorithm
- Experimental measurement is systematically lower than theoretical predictions, but show good agreement within systematic errors
- This measurement sets the stage for future dijet asymmetry measurements using the anti-k_T algorithm at 500 GeV