Dijet Production in Polarized Proton-Proton Collisions at 200 GeV at STAR

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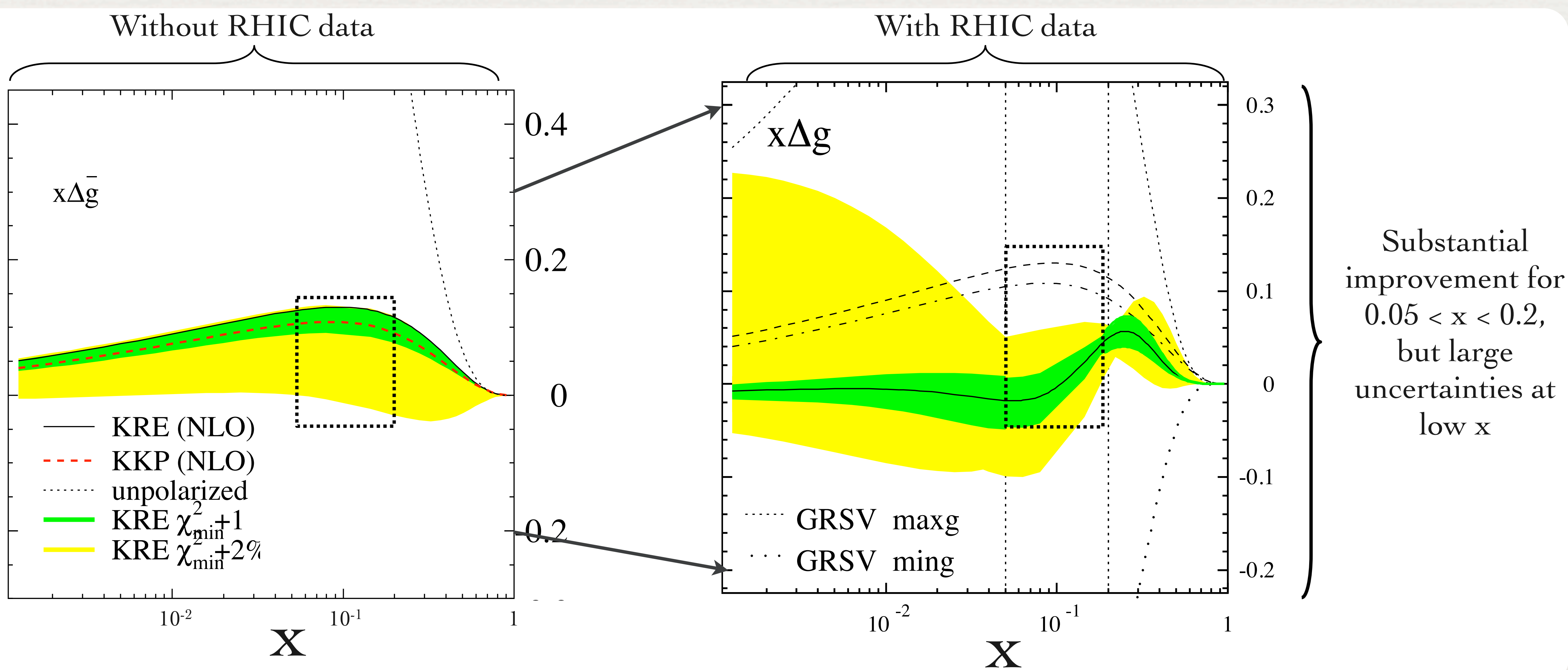
Outline

- Brief theoretical motivation
- Experimental Overview
- Cross Section Analysis
- Asymmetry Analysis
- Status of ongoing analysis

Theoretical Motivation

- Polarized DIS tells us that the spin contribution from quark spin is only ~30%.

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



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

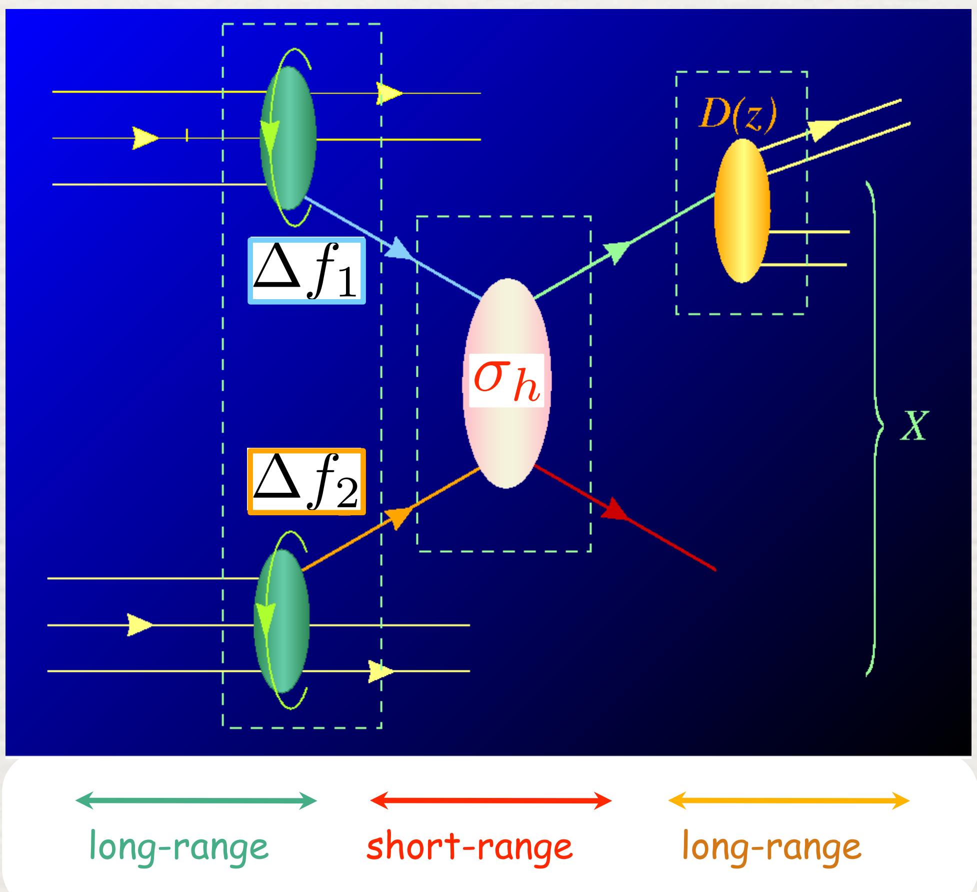
D. de Florian et al., Phys. Rev. Lett. 101 (2008) 072001

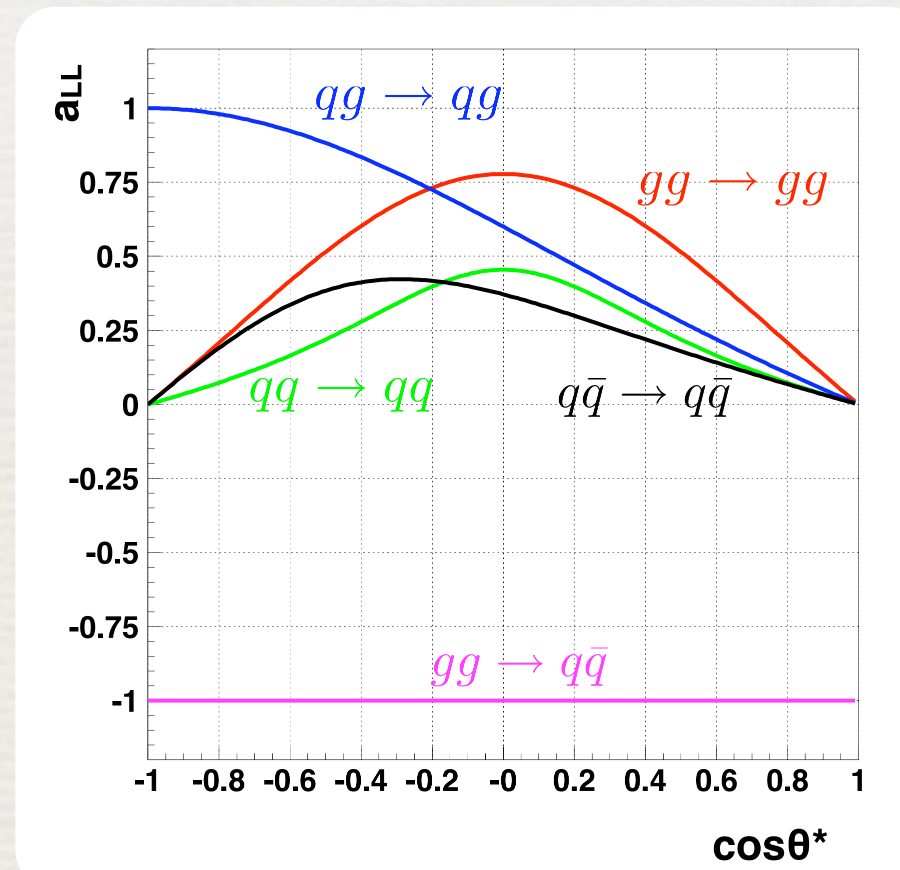
Theoretical Motivation

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

- Extracting gluon polarization

$$A_{LL} = \frac{d\Delta\sigma}{d\sigma} = \frac{\Delta f_1 \otimes \Delta f_2 \otimes \sigma_h \cdot a_{LL} \otimes D_f^h}{f_1 \otimes f_2 \otimes \sigma_h \otimes D_f^h}$$

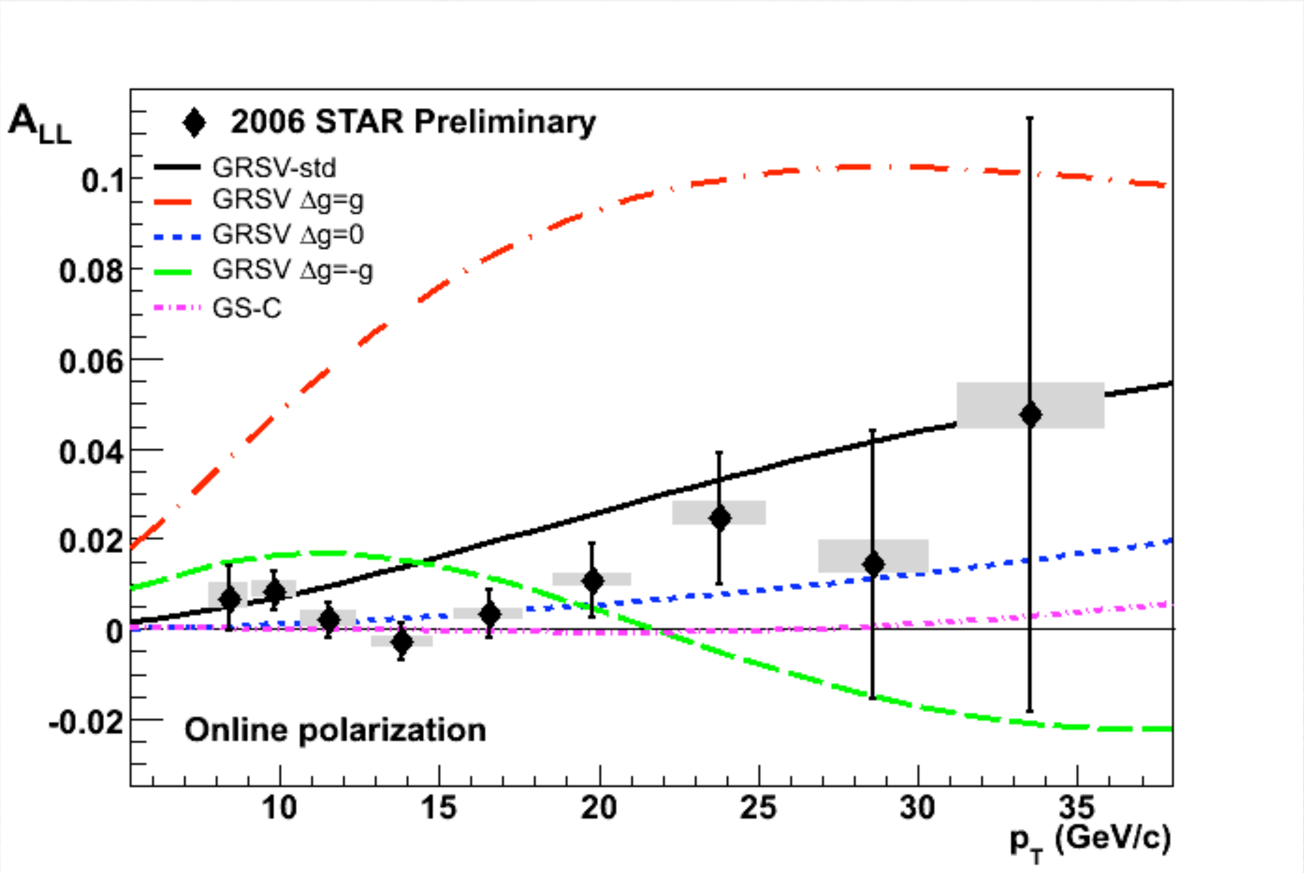


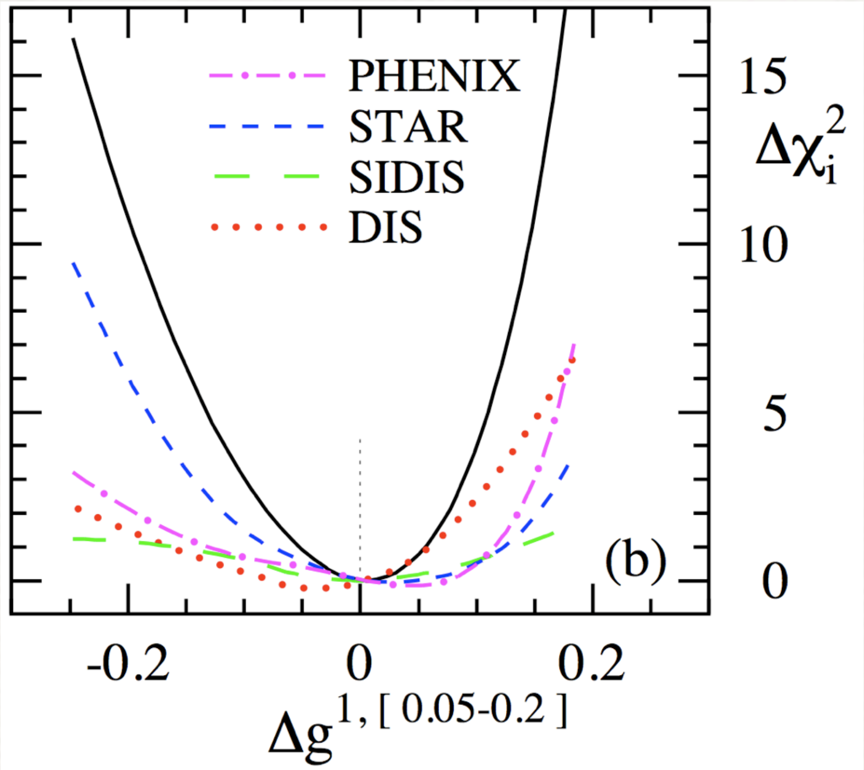


Extract Δg(x,Q²) using a global fit

$$\Delta G(Q^2) = \int_0^1 \Delta g(x, Q^2)dx$$

Inclusive jets





D. de Florian et al. PRL 101 (2008) 072001.

A_{LL} systematics	(x 10^{-3})
Reconstruction + Trigger Bias	[-1,+3] (p_T dep)
Non-longitudinal Polarization	~ 0.03 (p_T dep)
Relative Luminosity	0.94
Backgrounds	1st bin ~ 0.5 else ~ 0.1
p_T systematic	± 6.7%

- Run 6 results: GRSV-MAX/ GRSV-MIN ruled out, a gluon polarization between GRSV-std and GRSV-zero favored

See Pibero Djawotho's talk for more on inclusive jets from STAR

Correlation Measurements

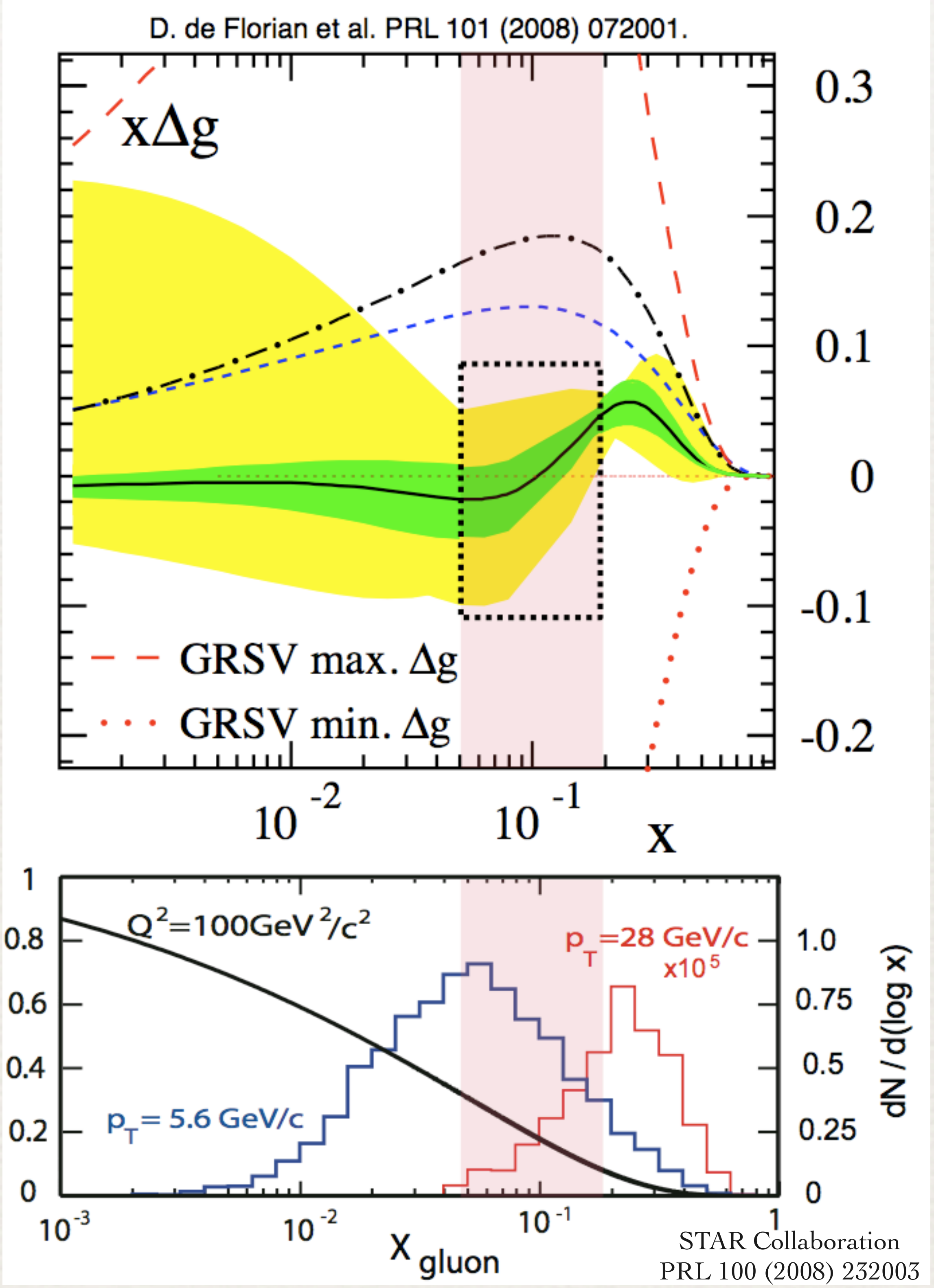
- Reconstructing multiple physics objects (di-jets, photon/jet) provides information about initial parton kinematics
- STAR well suited for correlation measurements with its large acceptance

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

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

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

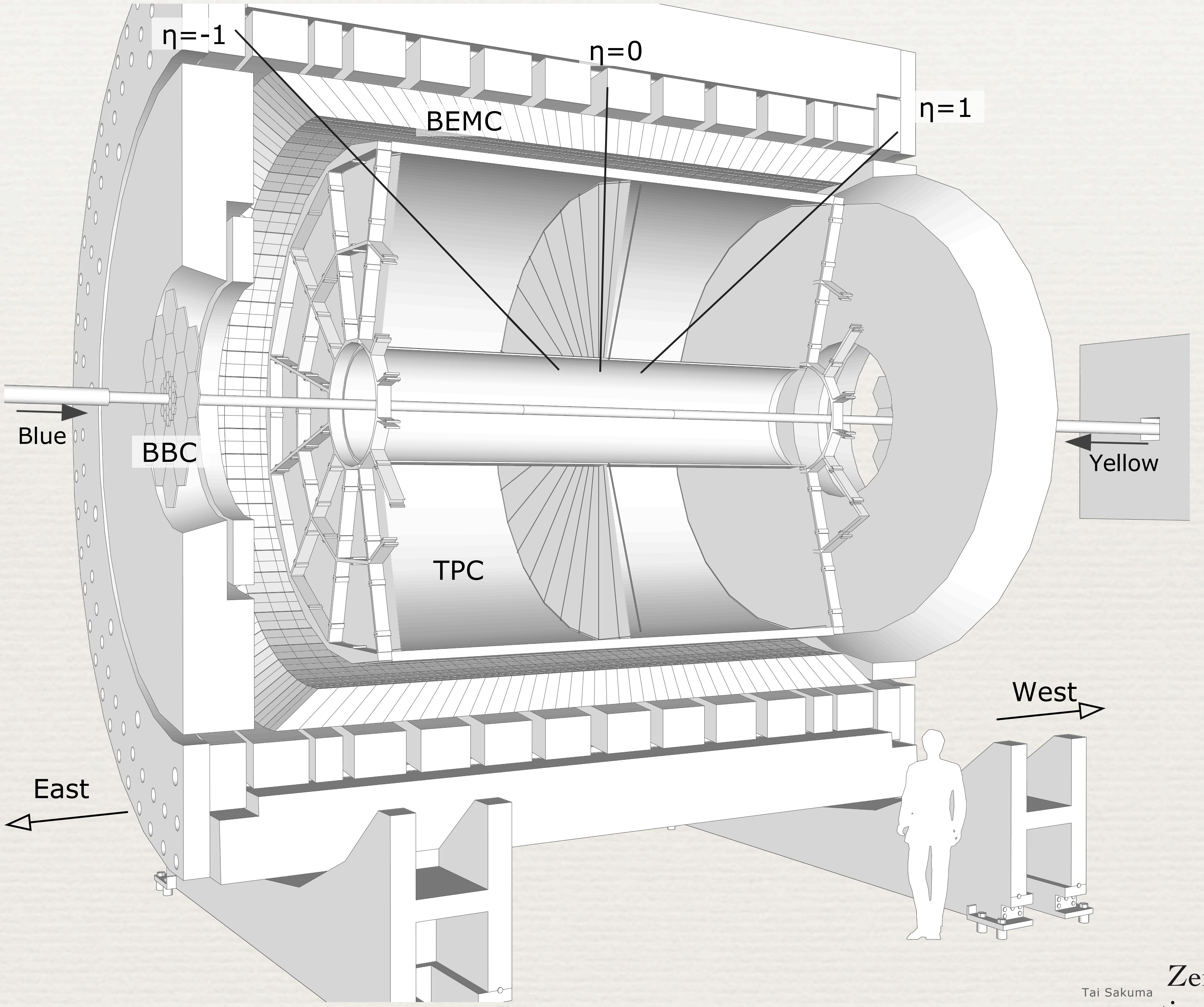
$$\eta_3 + \eta_4 = \ln \frac{x_1}{x_2}$$



Experimental Setup

- RHIC produces polarized proton beams up to 250 GeV in energy
- Siberian snake magnets in the AGS and RHIC help protect beam from depolarized resonances

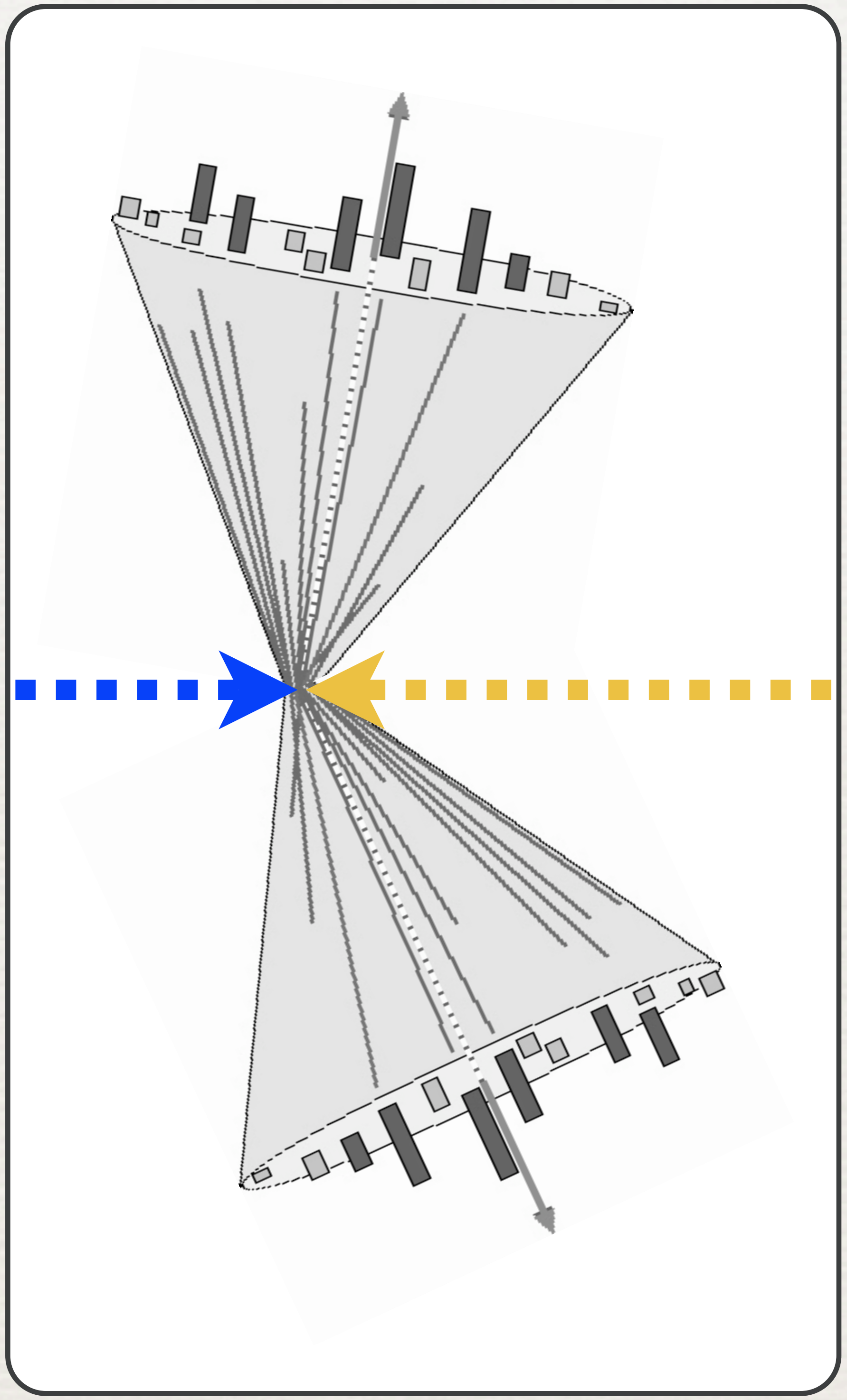
STAR Detector



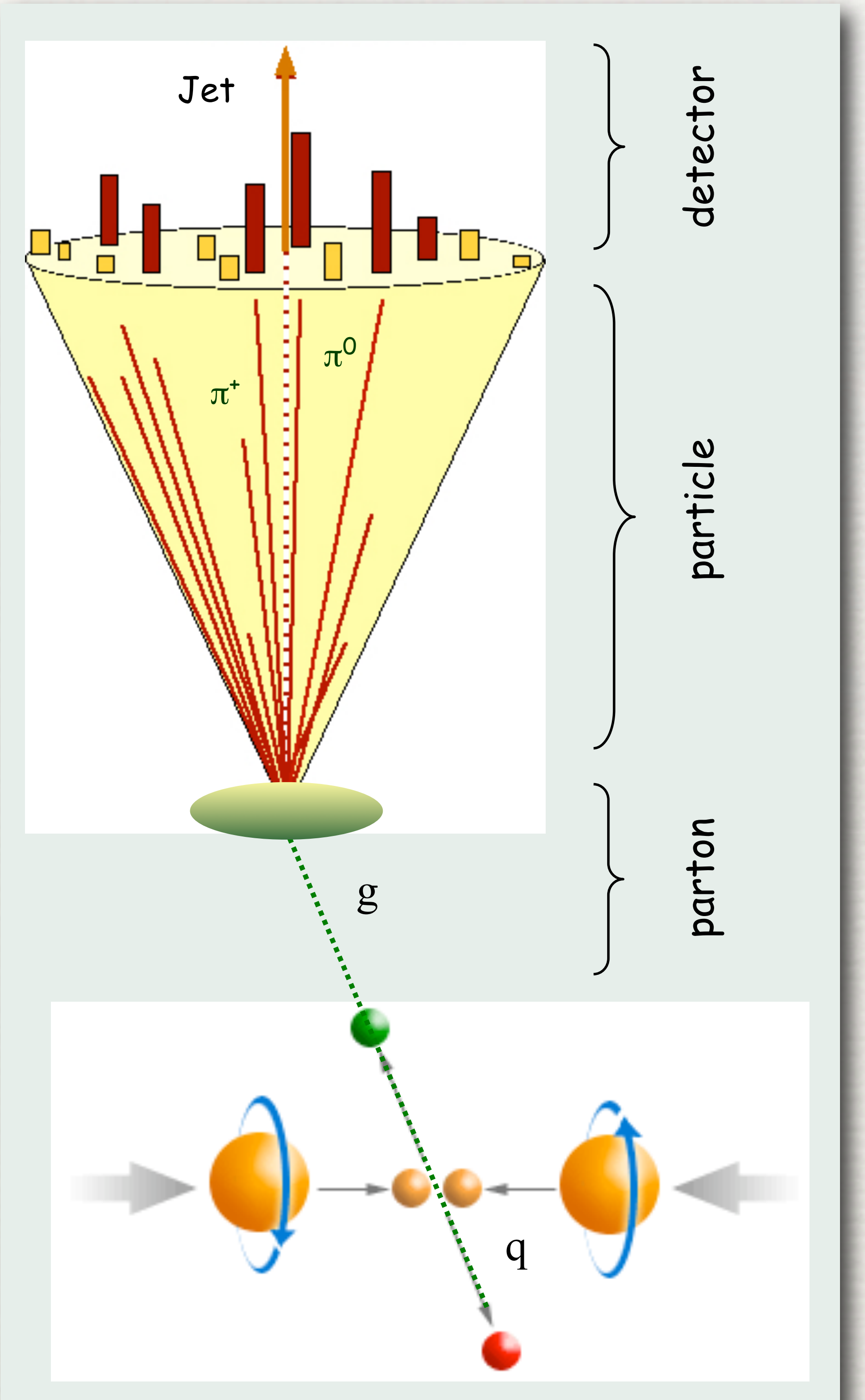
Not shown:
Zero-degree calorimeters,
time-of-flight, polarimeters

Jet Reconstruction

- Midpoint Cone Algorithm with Split-Merge
  - Cone Radius: 0.7
  - Seed 0.5 GeV
- Dijet Cuts
  - Asymmetric p_T cut
    - $\max(p_{T1},p_{T2}) > 10$
    - $\min(p_{T1},p_{T2}) > 7$
  - Back-to-back in ϕ



Jet Terminology



Tracks, Energy Depositions

Detector Effects

Hadrons, Leptons

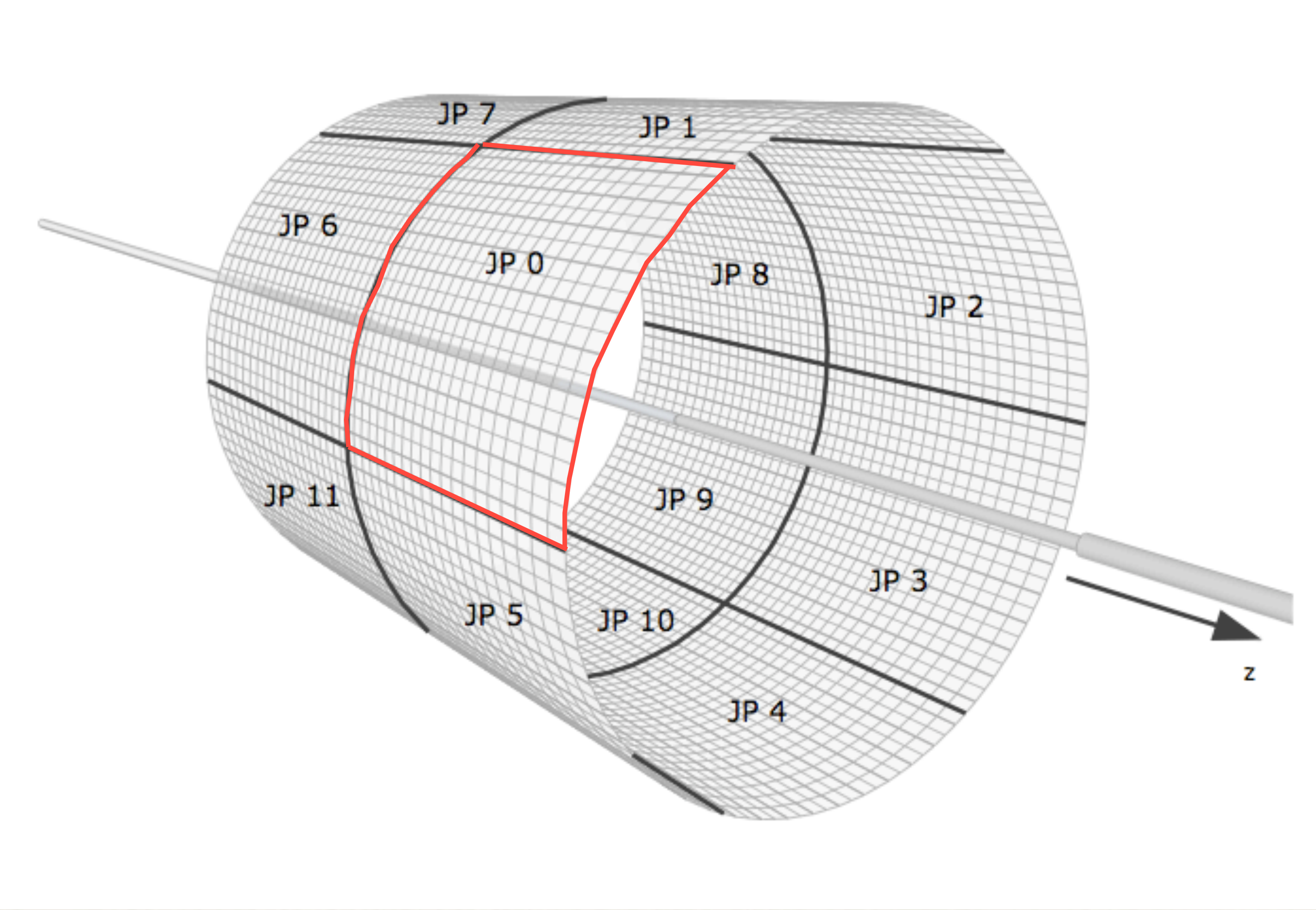
Parton Branching, Hadronization, Underlying Event

Partons

Data

- 2006 Data: 5.39 pb^{-1} taken during RHIC Run 6
- 2009 Data: ~8 pb^{-1} taken during RHIC Run 9

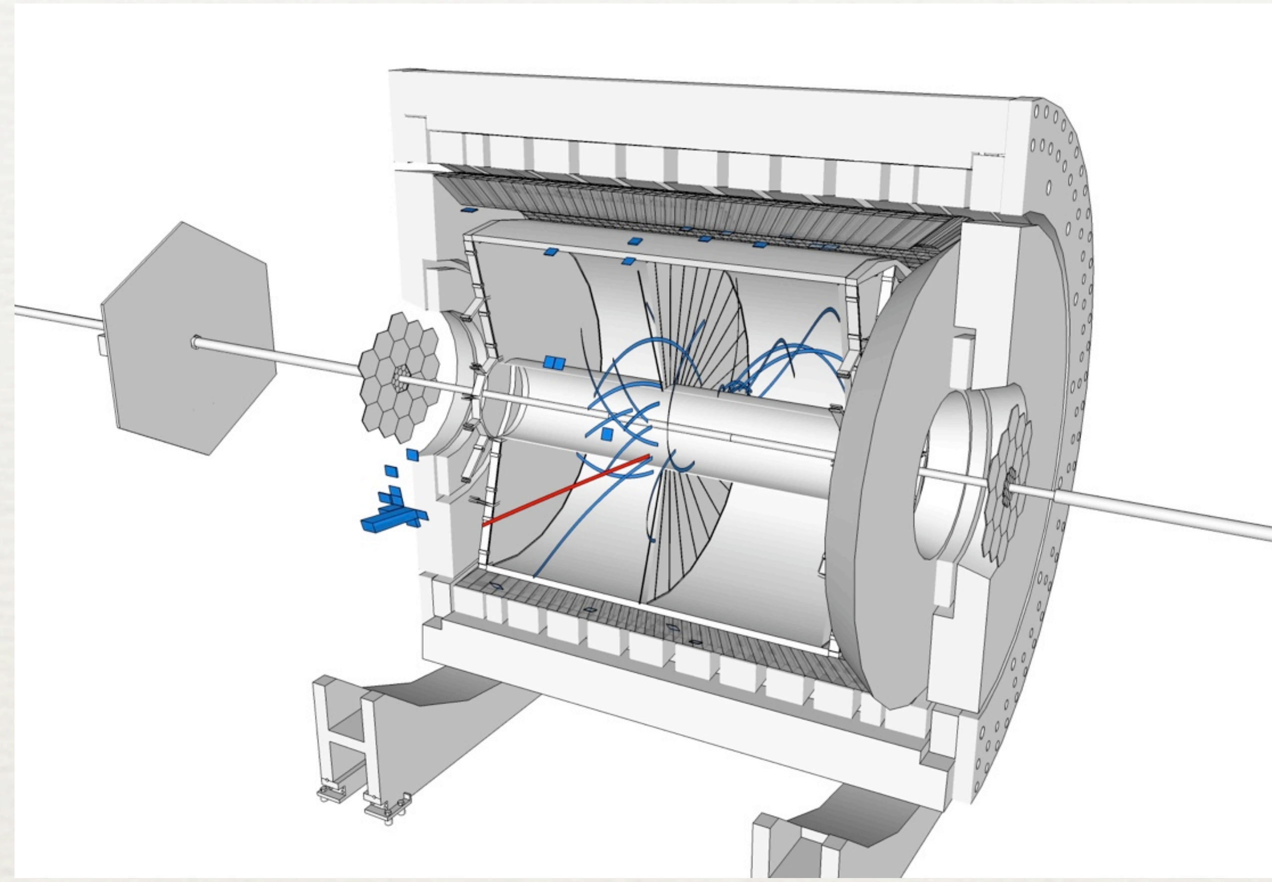
- Jet Patch Trigger:
  - 1x1 in ϕxη patch of towers in the BEMC (400 towers)



2006 Cross Section

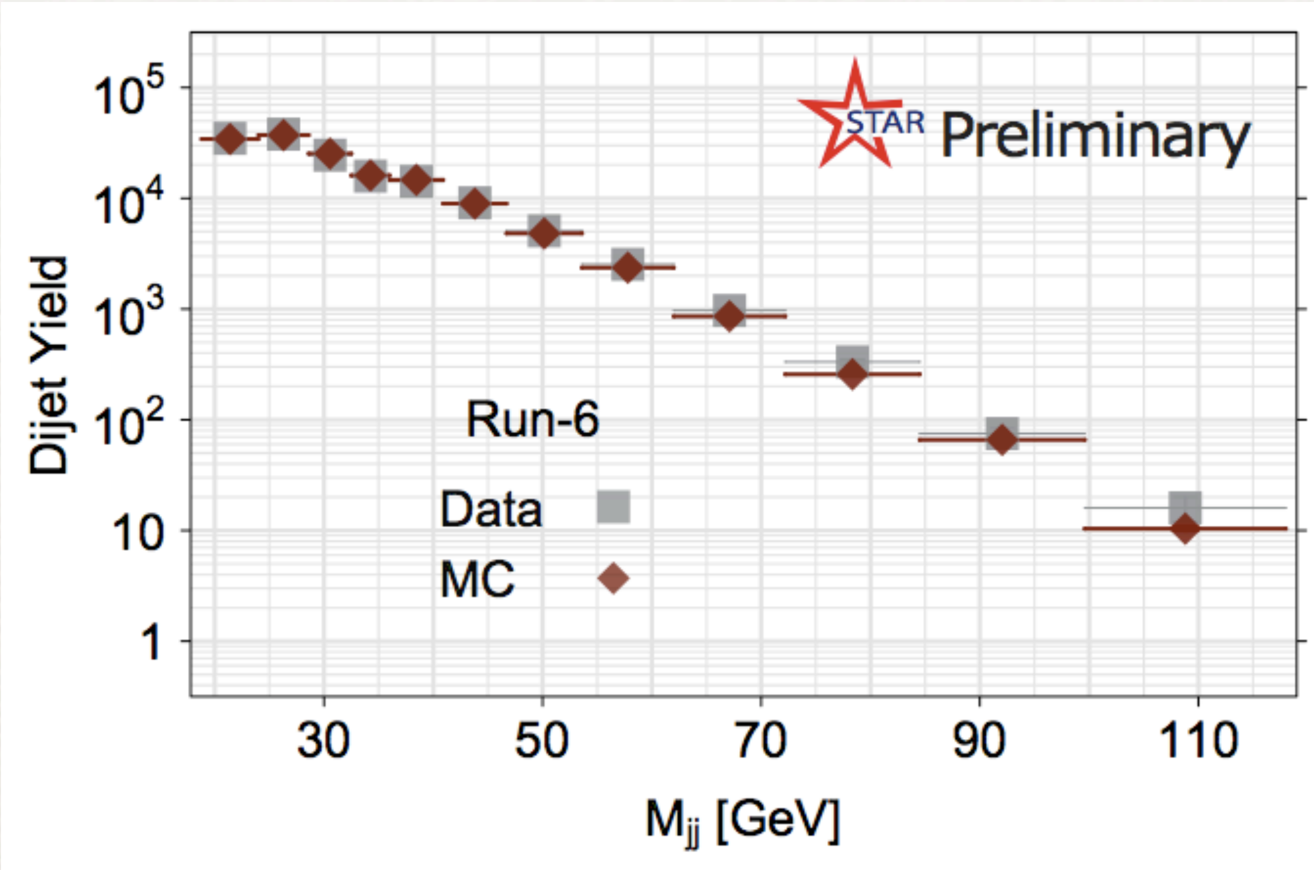
$$\frac{d^3\sigma}{dM_{jj}d\eta_3 d\eta_4} = \frac{1}{\int \mathcal{L}dt} \cdot \frac{1}{\Delta M_{jj}\Delta\eta_3\Delta\eta_4} \cdot \frac{1}{\mathcal{C}} \cdot Y$$

- Y: Detector-level dijet yields
- $\mathcal{C}$: Correction factors
- $\Delta M_{jj}\Delta\eta_3\Delta\eta_4$: Phase space volume
- $\int \mathcal{L}dt$: Luminosity

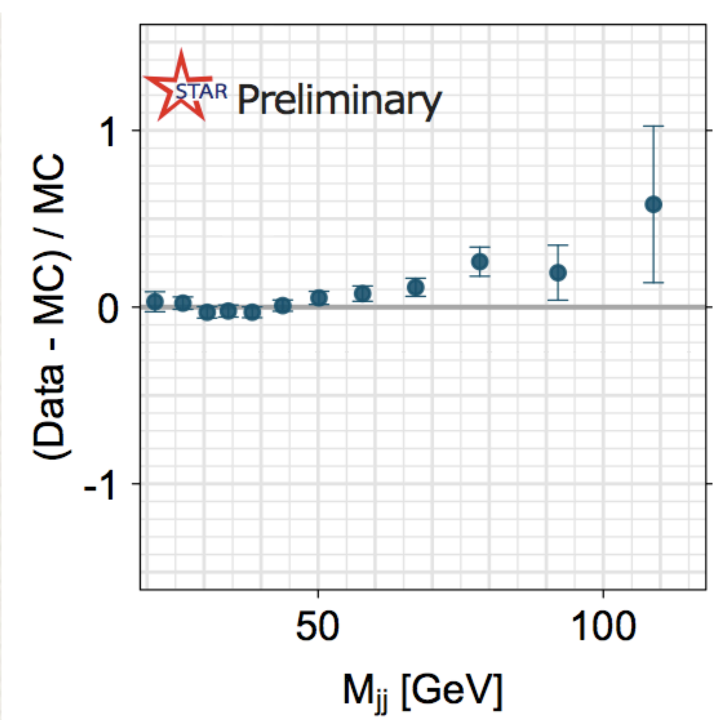


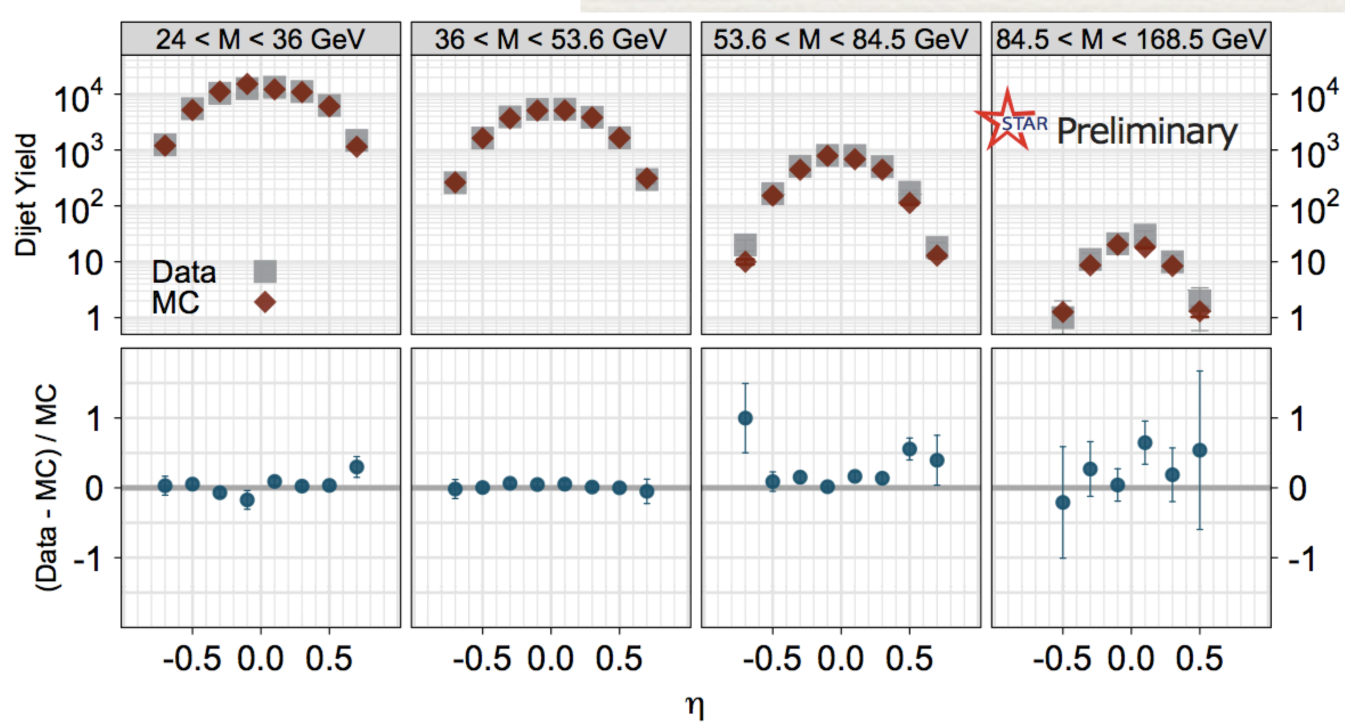
- Correction factors:
  - $C = C_{vert}\, C_{det}$
  - C_{vert}: Acceptance correction for vertex cut
  - C_{det}: Correction for detector effects, calculated as the ratio of events reconstructed at the particle level and at the detector level in the simulation for each bin

Data/Simulation Run 6



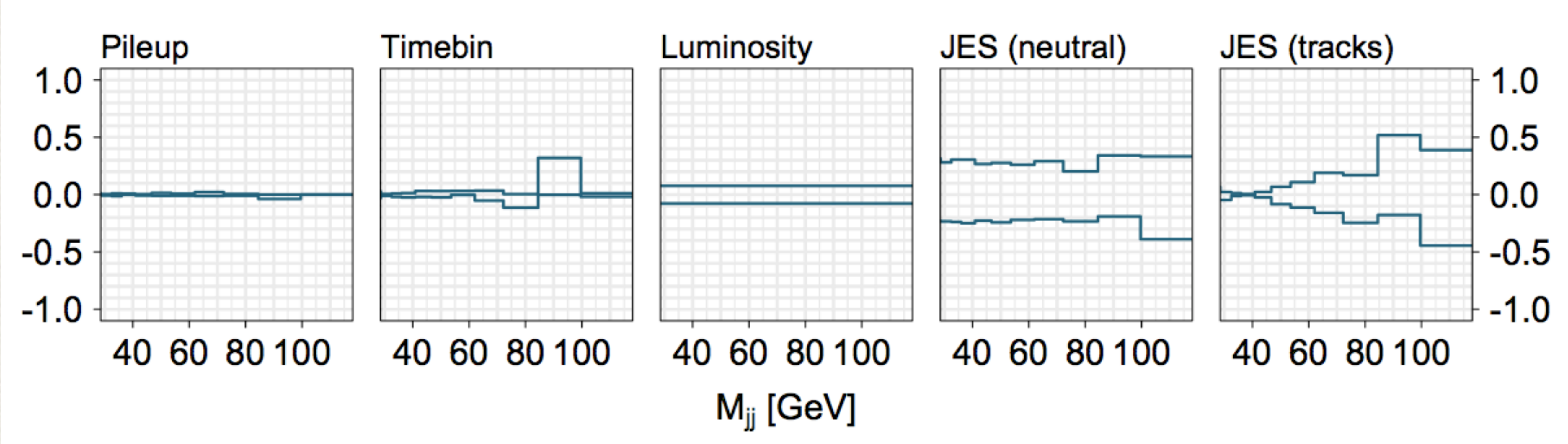
- 2006 Simulation:
  - 11 STAR MC productions producing 4M events with partonic pT between 3 GeV and 65 GeV
  - PYTHIA 6.410, CDF Tune A
- Run 6 data and simulation agreement is good



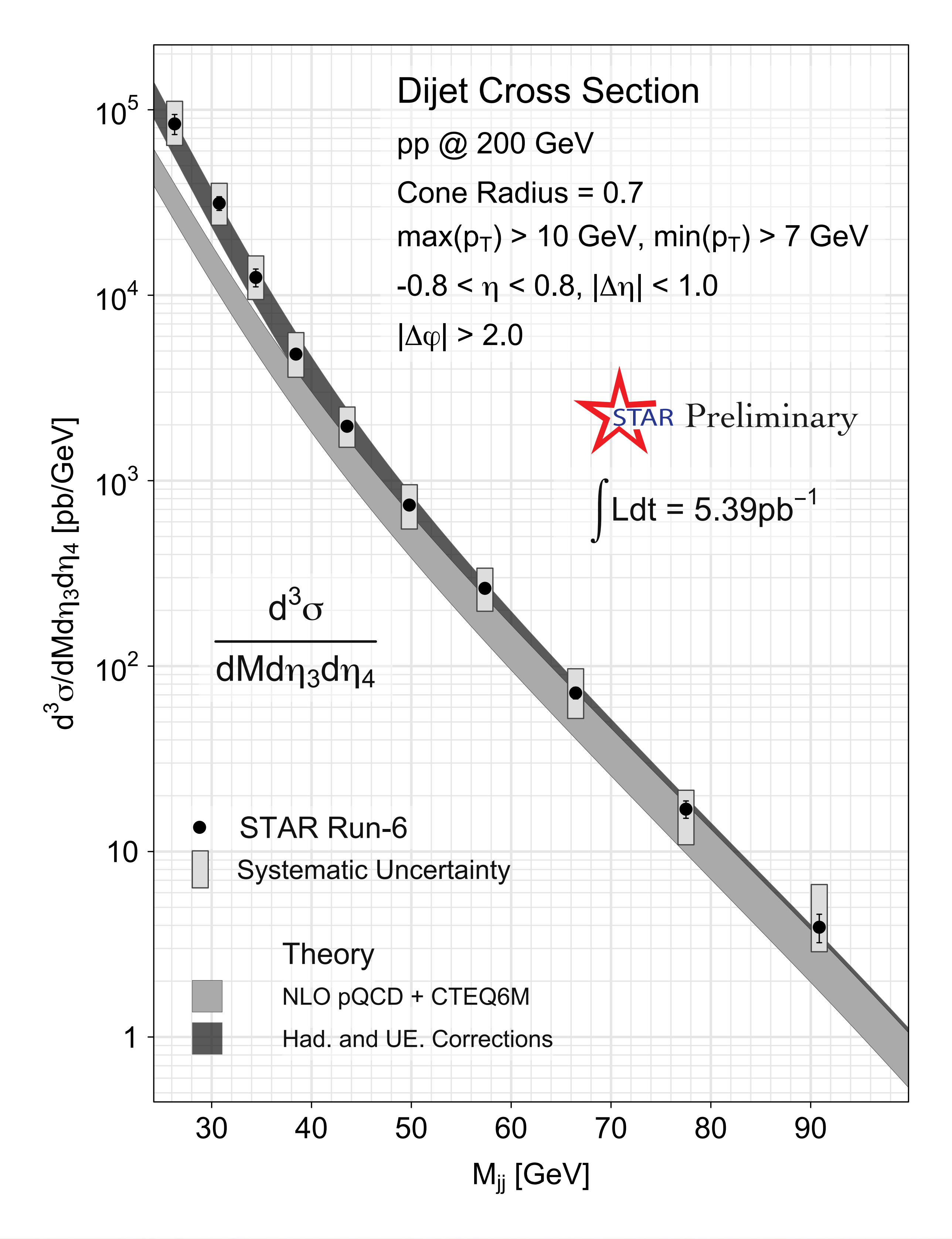


2006 Cross Section

- Systematic Uncertainties:
  - Luminosity: 7.6 % normalization uncertainty
  - Jet Energy Scale: 20-50%
  - Pile-up: 1%
  - Timebin acceptance: 3%

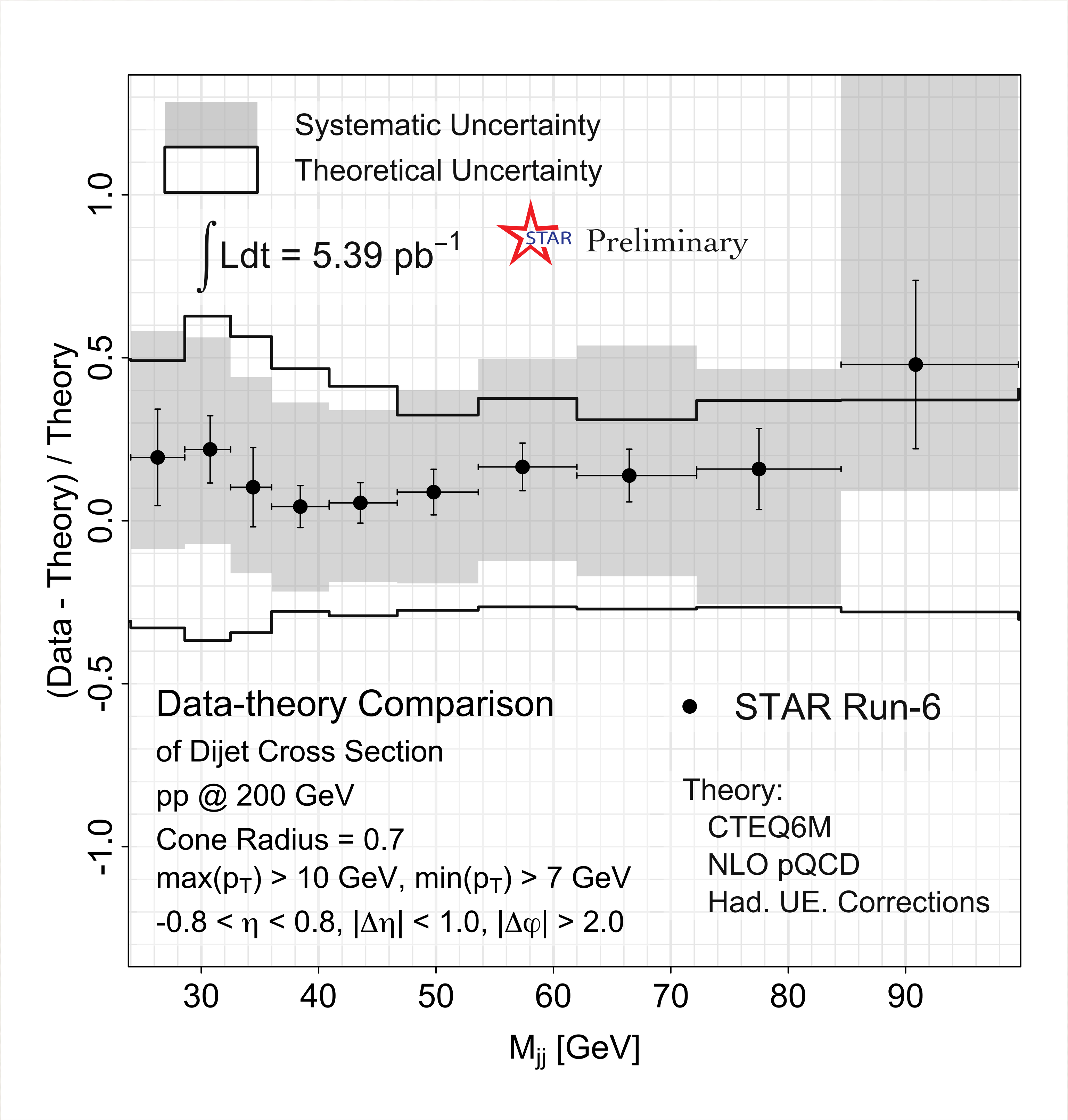


2006 Cross Section



- Unpolarized differential cross section between 24 and 100 (GeV/c^2)
- NLO theory predictions using CTEQ6M provided by de Florian with and without corrections for hadronization and underlying event from PYTHIA
- Statistical Uncertainties as lines, systematics as rectangles

2006 Cross Section



- Comparison to theory (including hadronization and underlying event correction) shows good agreement within systematic uncertainties

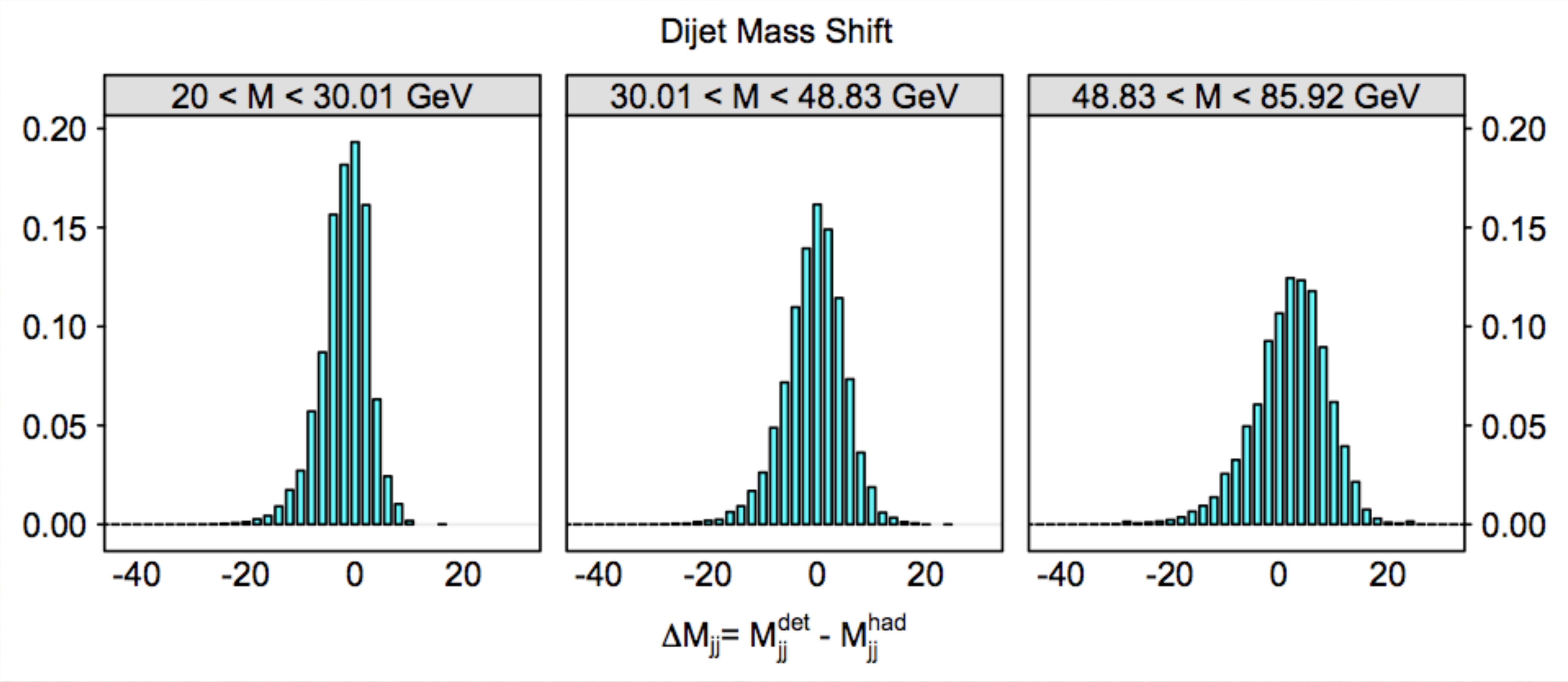
2006 Asymmetry

$$A_{LL} = \frac{1}{P_B P_Y} \frac{N^{++} - RN^{+-}}{N^{++} + RN^{+-}}$$

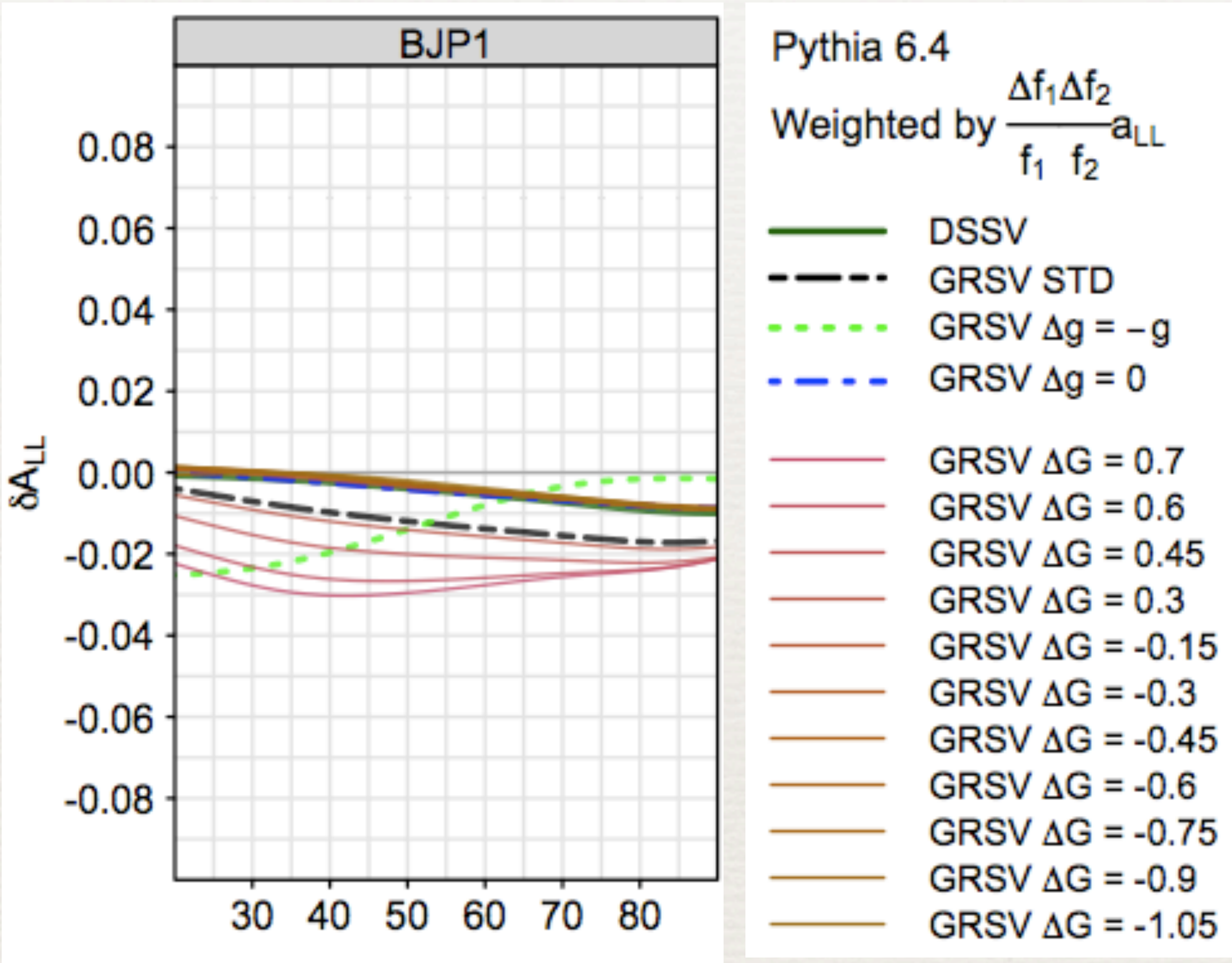
- Asymmetry formula:
  - N^{++}: like sign yields
  - N^{+-}: unlike sign yields
  - R: relative luminosity
  - P: polarization

2006 Asymmetry

- Mass point shift
  - Invariant mass location corrected for shift due to difference in detector mass and particle mass distributions in simulation



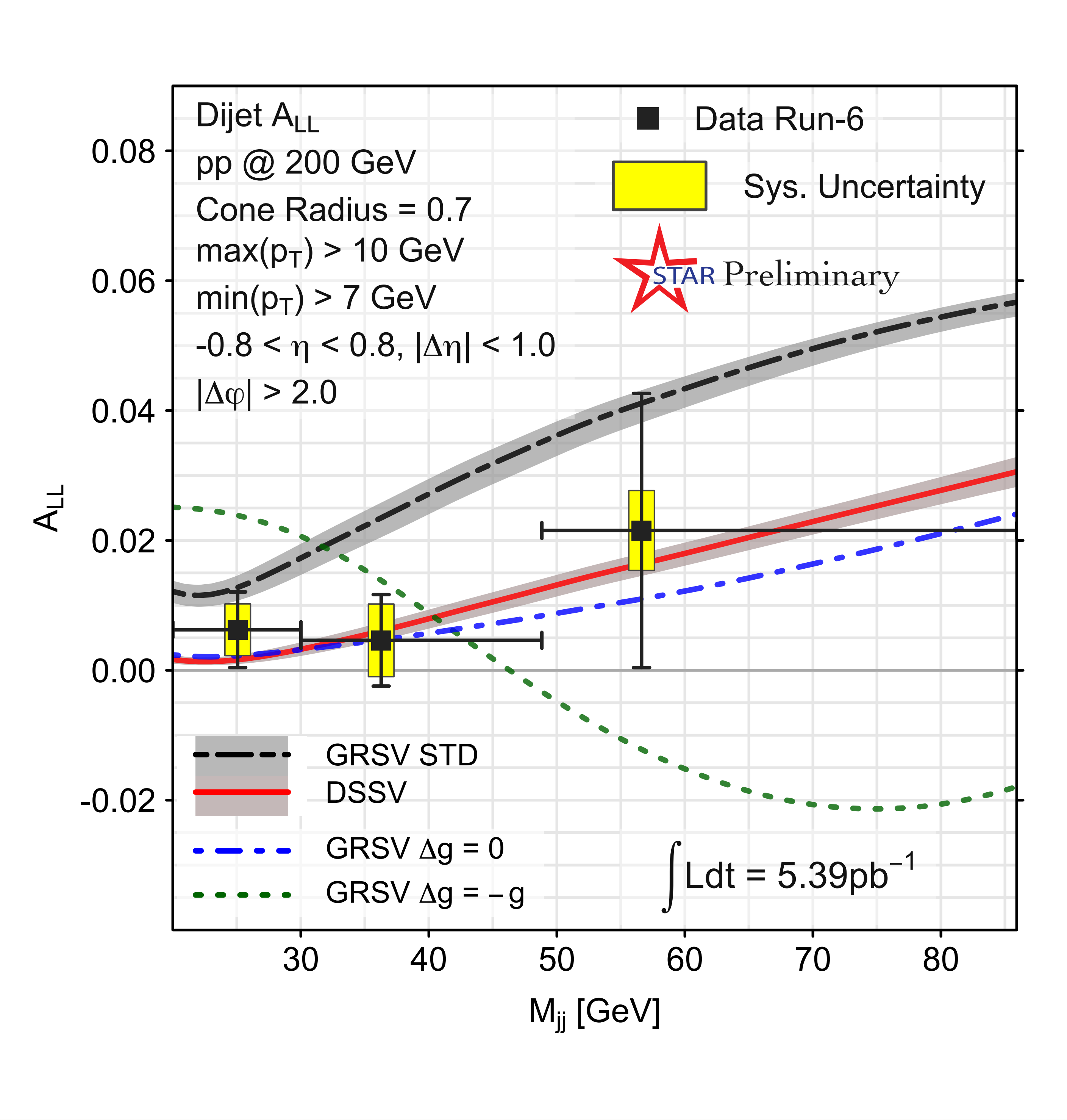
2006 Asymmetry



- Trigger efficiency uncertainty
  - Trigger efficiency can vary with polarized cross section
  - Compare A_{LL} at particle level with detector level

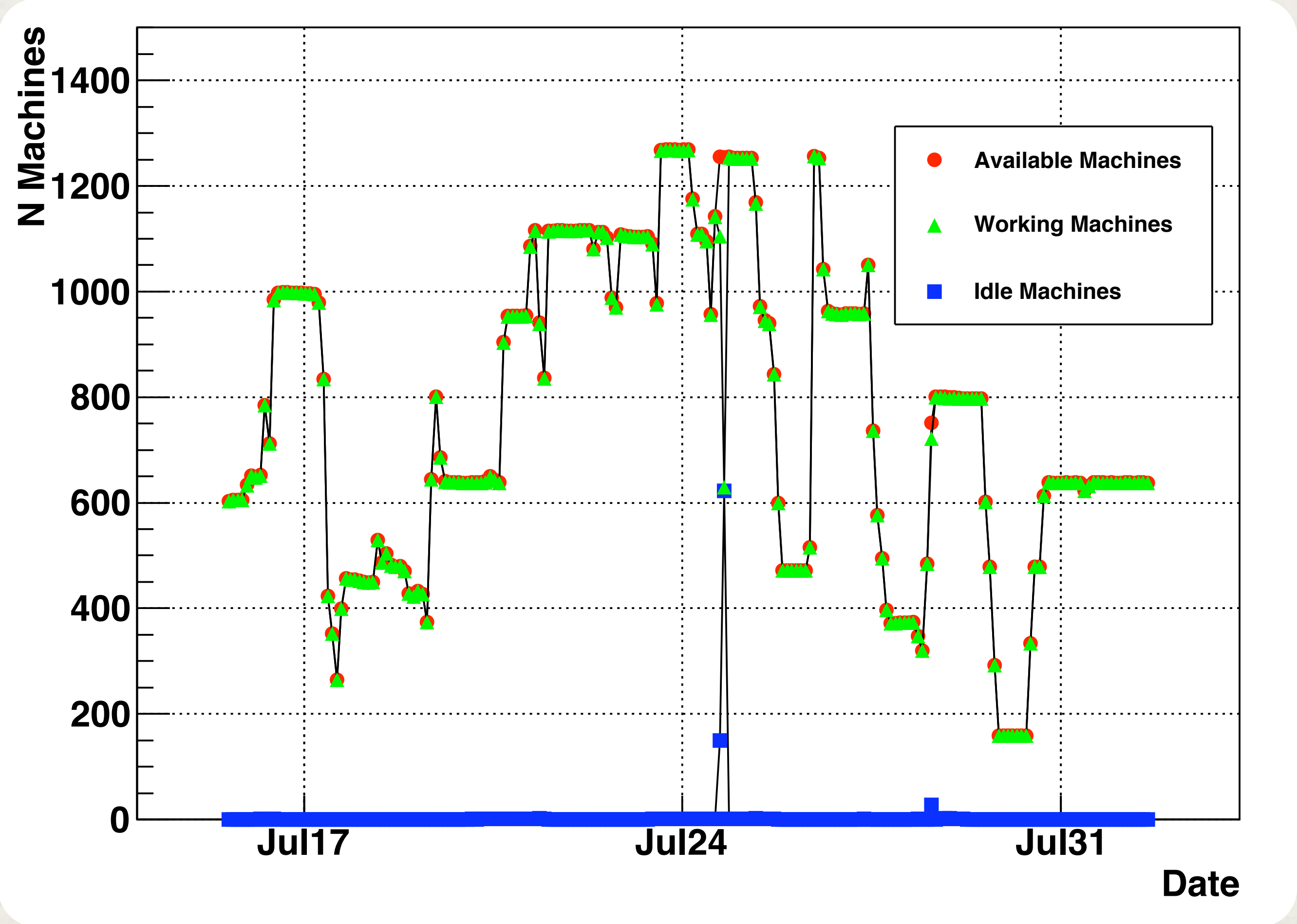
2006 Asymmetry

- Run 6 Longitudinal double helicity asymmetry
- Systematic uncertainties show effects on trigger efficiency from different theory scenarios
- Scale uncertainty (8.3%) from polarization uncertainty not shown



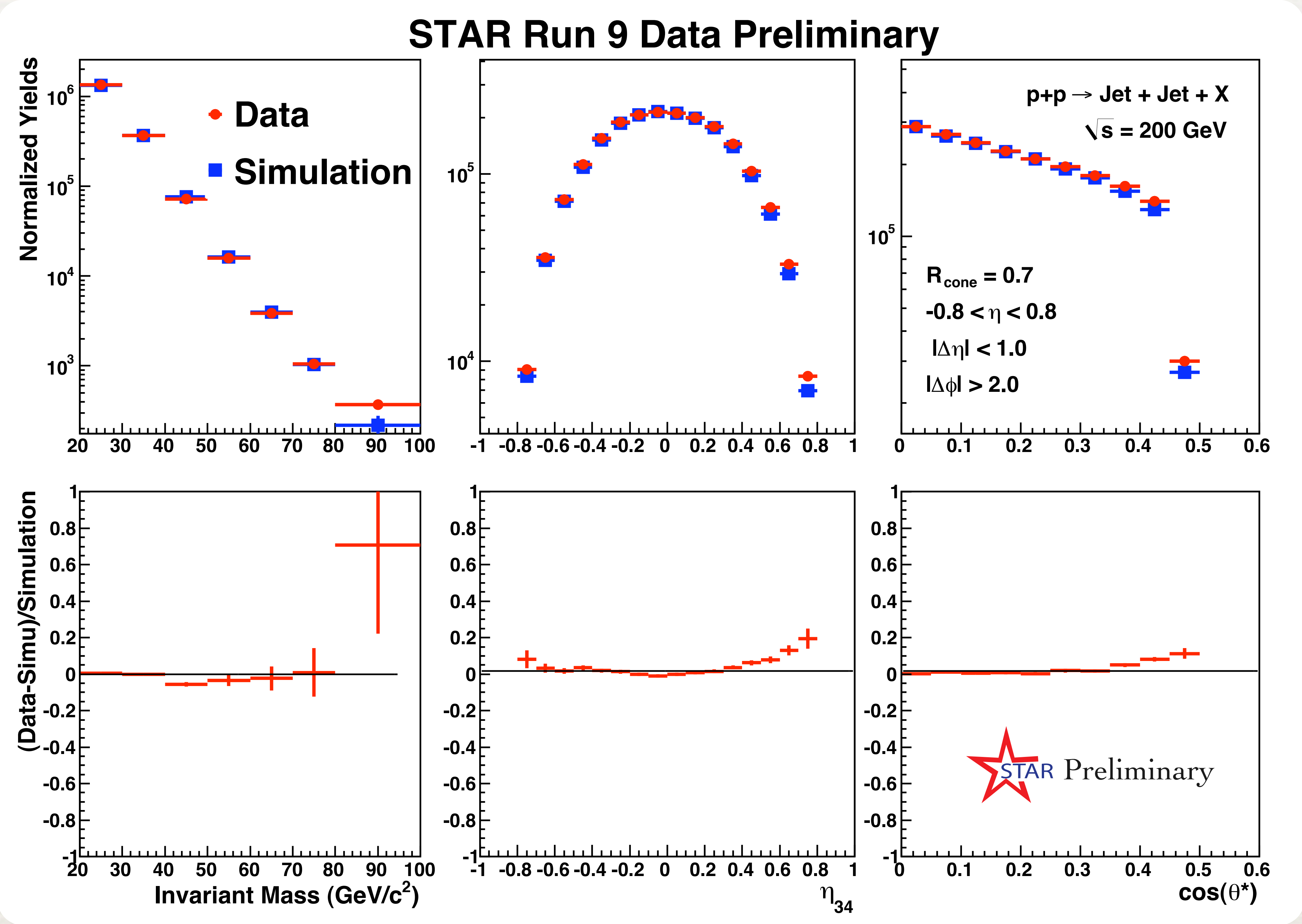
2009 Simulation

- Different detector, different trigger, updated geometry
- 9 STAR MC productions with partonic $p_T > 2$ GeV
- PYTHIA 6.4.23, proPt0 (PYTUNE 329)
- Virtual Machine prepared with STAR software stack and deployed to over 1000 machines
- Run using cloud computing resources at Clemson University in South Carolina (Ranked #85 best supercomputer)
- Over 12 billion events generated by PYTHIA, filtered to allow only 36 million to undergo detector simulation (GEANT3), and 10 million through full reconstruction
- Took over 400,000 CPU hours and generated 7 TB of files transferred to BNL (2.7 hours on JUGENE with memory)
- Largest physics simulation on cloud, largest STAR simulation



Data/Simulation Run 9

- Run 9 data simulation agreement is good

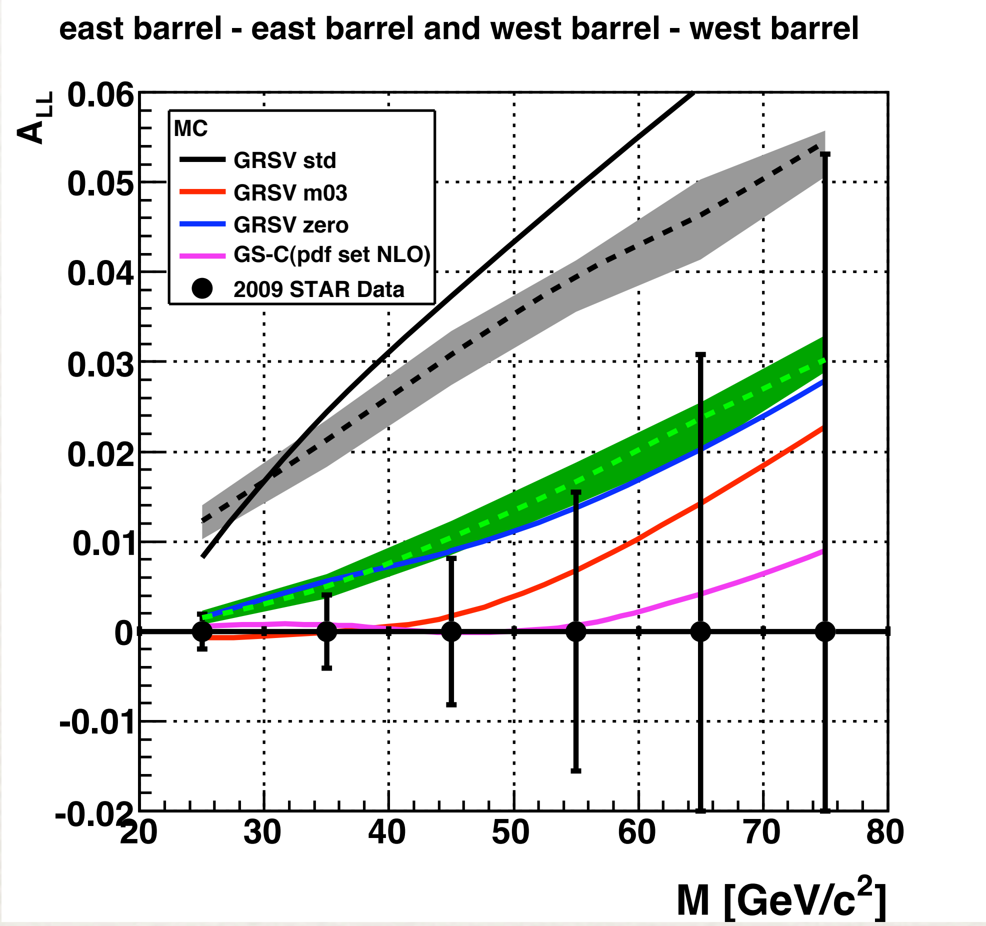


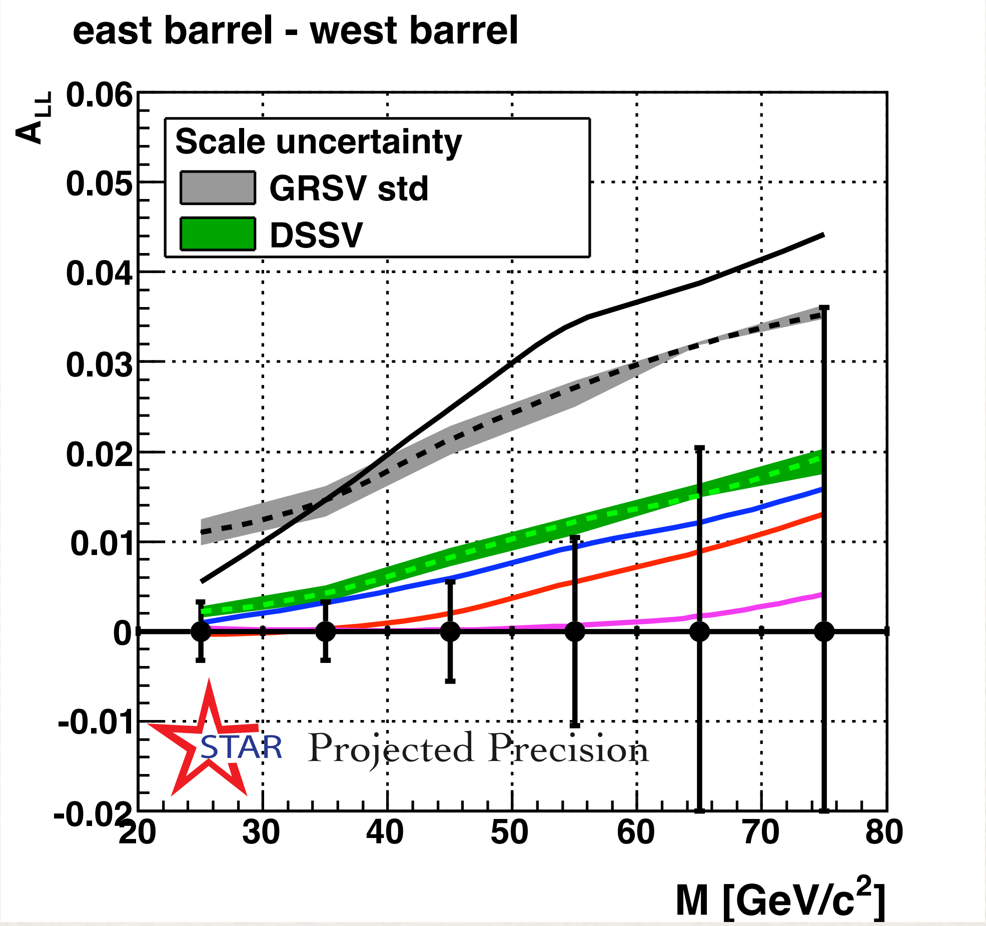
2009 Asymmetry

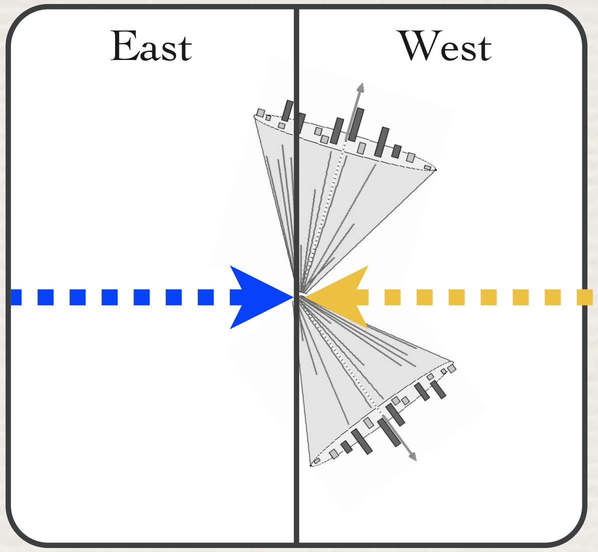
$$A_{LL,j} = \frac{\sum_k \alpha_{jk}(\sum_i P_{B,i}P_{Y,i}(N_{5,i,k} + N_{10,i,k}) - P_{B,i}P_{Y,i}R_i(N_{6,i,k} + N_{9,i,k}))}{\sum_k \alpha_{jk}(\sum_i P^2_{B,i}P^2_{Y,i}(N_{5,i,k} + N_{10,i,k}) + P^2_{B,i,j}P^2_{Y,i,j}R_i(N_{6,i,k} + N_{9,i,k}))}$$

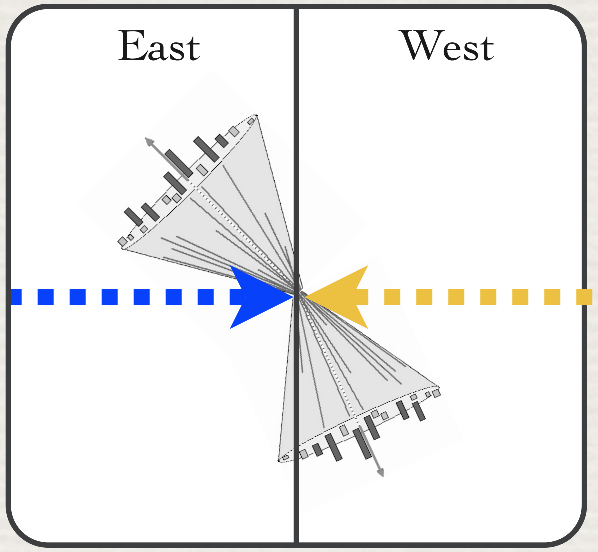
- The value of A_{LL} in a bin j is given by the above formula
  - α_{jk} are the matrix elements for the unfolding
- Changing the jet energy scale results in different unfolding matrices
- The calculation is repeated for the different matrices to get the uncertainty on A_{LL} due to the jet energy scale

2009 Projections









Summary

- Correlations measurements provide constraints on parton kinematics, which helps constrain the shape of $\Delta g(x)$
- 2006 Dijet cross section (5.39 pb^{-1}) shows good agreement with NLO calculations
- First Dijet double-spin asymmetry (FOM = 0.59 pb^{-1}) from 2006 data suggests preference away from GRSV-std scenario
- 2009 Dijet asymmetry analysis underway with FOM = 0.96 pb^{-1} analyzed to date, and more to come