Longitudinal Double-Spin Asymmetries for Dijet Production at Intermediate Pseudorapidity in Polarized Proton Proton Collisions at $\sqrt{s}$ = 200 GeV

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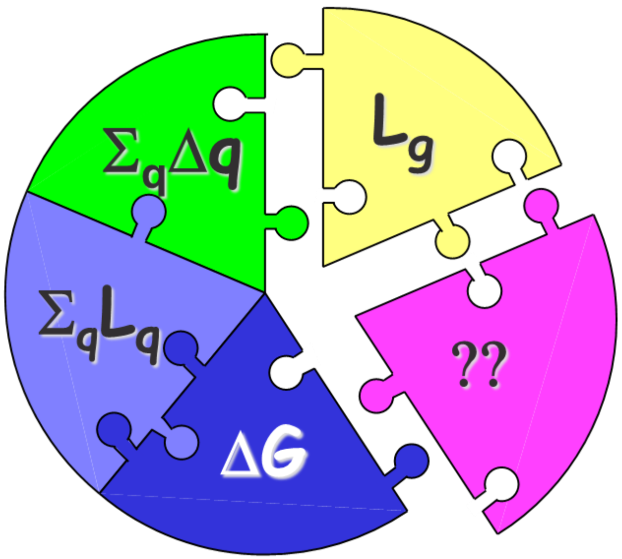
Texas A&M University

Introduction: Spin of the Proton



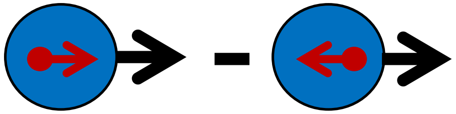
$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

- Simple picture of proton composed of three valence quarks superseded by complex interaction of quarks, antiquarks, and gluons
- The proton's spin must arise from combination of intrinsic and orbital angular momenta of these components

$$\Delta\Sigma = \int \left(\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s}\right)dx$$

$$\Delta G = \int \Delta g(x)dx$$

Helicity Distributions: Δq,Δg



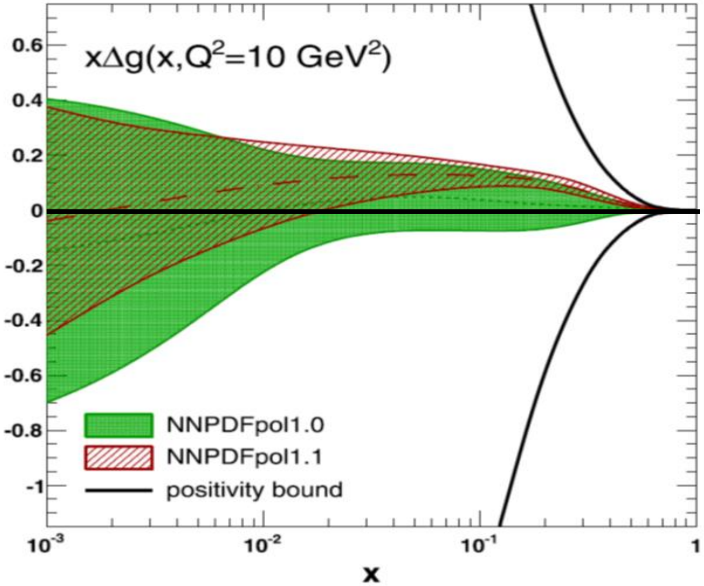
Motivation: Constraining ΔG

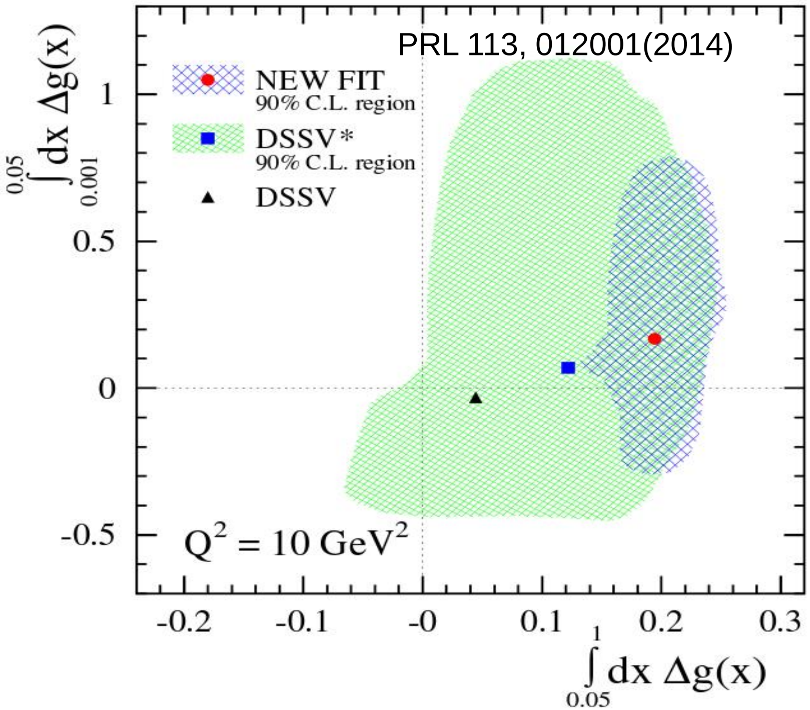
$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

Deep inelastic scattering measurements have found that the spin of the quarks (ΔΣ) account for ~30% of the total spin of the proton, the rest must come from gluon spin (ΔG) or orbital angular momentum (L) of the partons

RHIC data have been added to the DSSV and NNPDF global analyses. Including the STAR 2009 inclusive jet results (PRL 115.092002), these global analyses show, for the first time, a non-zero gluon polarization in our region of sensitivity

Nucl. Phys. B 887, 276 (2014)

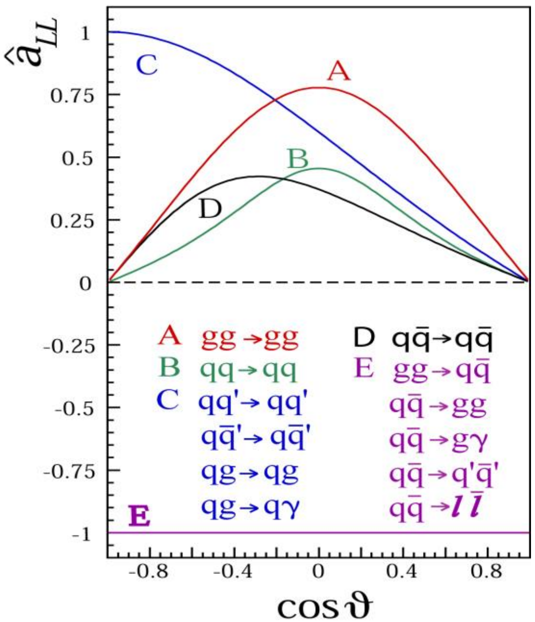


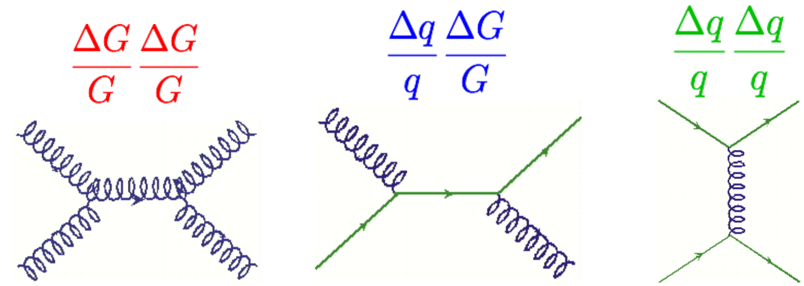


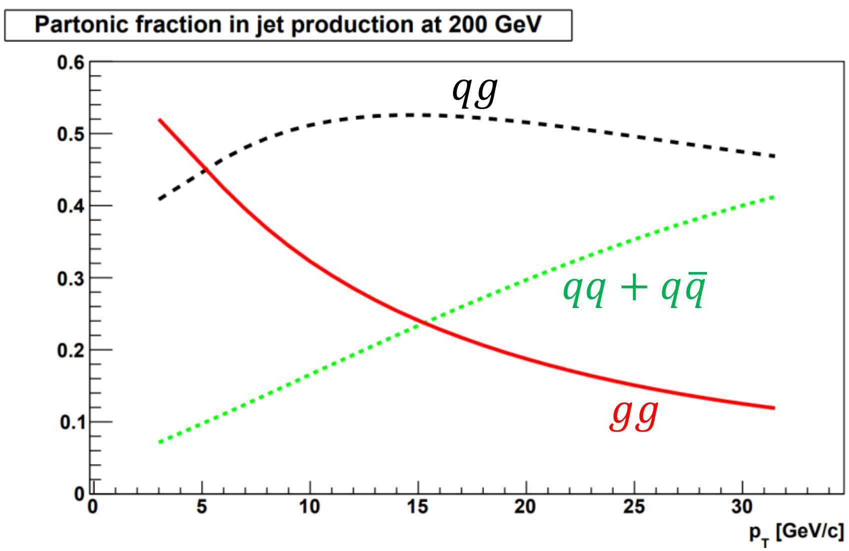
The low x behavior and shape of Δg(x) are still poorly constrained. Recent data will extend our reach in x using forward pion and jet results, and also using higher collision energies.

Exploring Gluon Polarization at RHIC

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

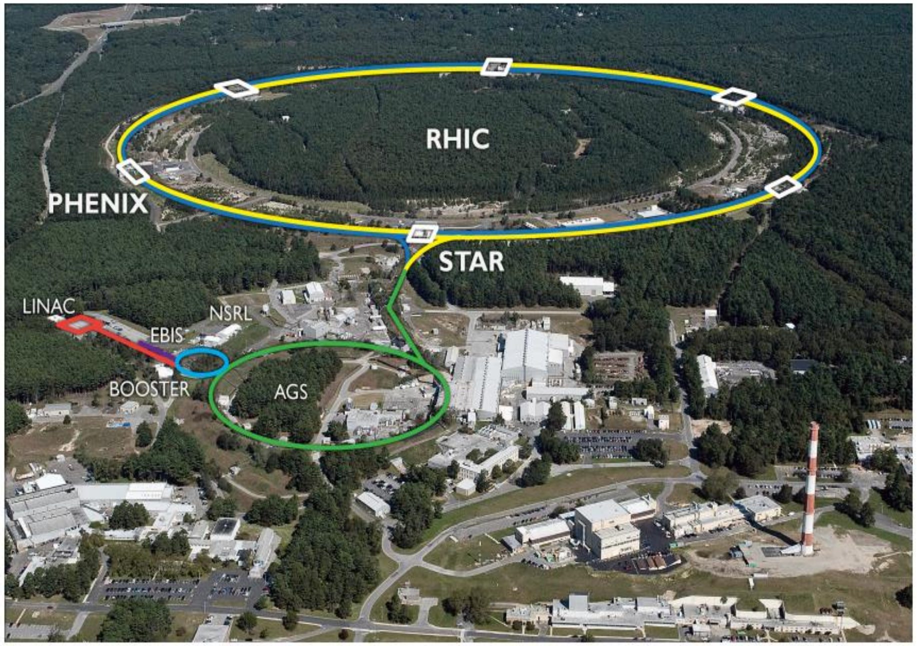






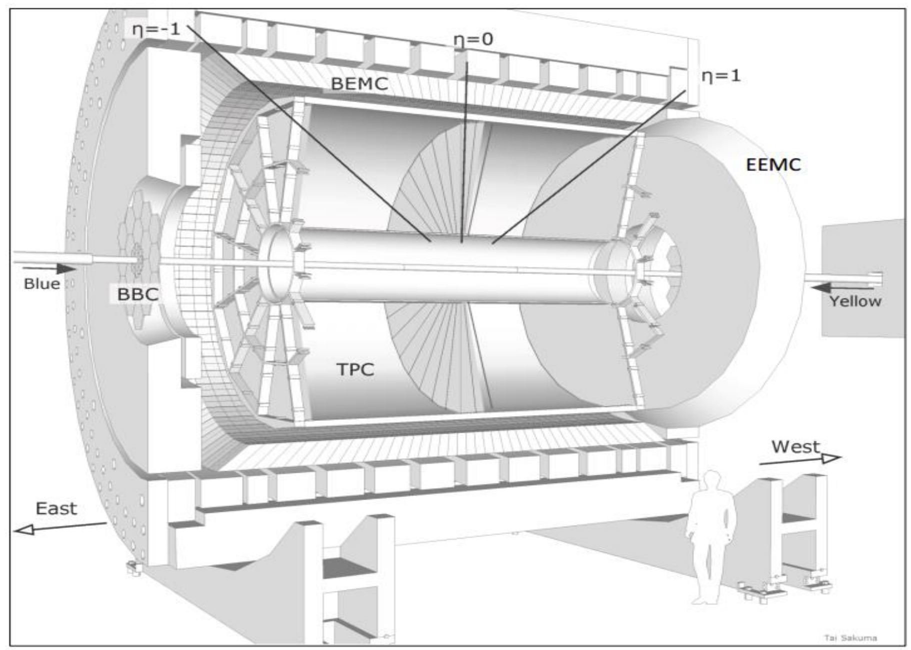
- At the parton level, helicity correlations are very large in leading-order QCD
- For most RHIC kinematics, gg and qg dominate, making A_{LL} for jets sensitive to gluon polarization.

Relativistic Heavy Ion Collider and STAR Detector



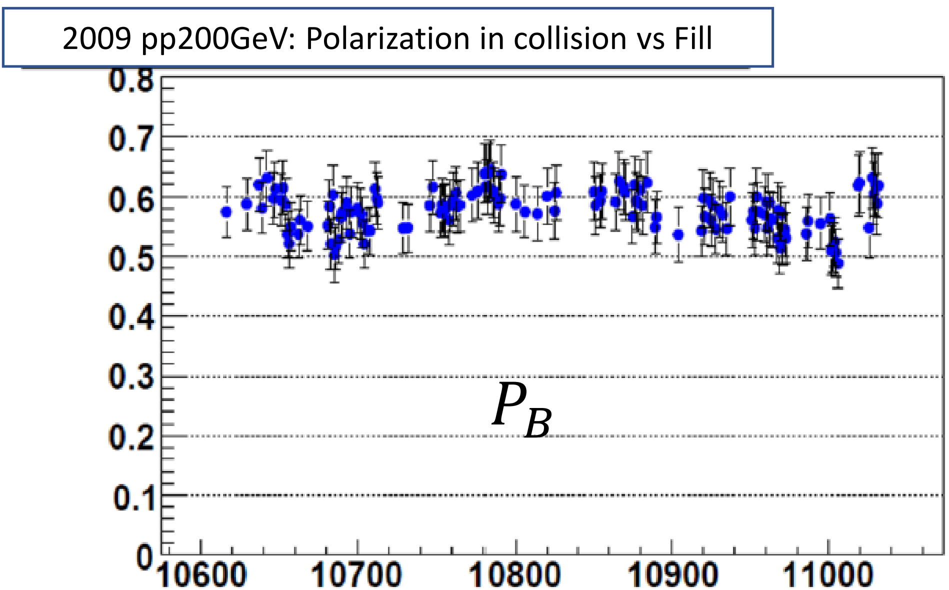
- The Relativistic Heavy Ion Collider(RHIC) is located at Brookhaven National Laboratory on Long Island
- Has the capability to accelerate many particle species to a wide range of energies
- World's first and only accelerator capable of colliding polarized protons

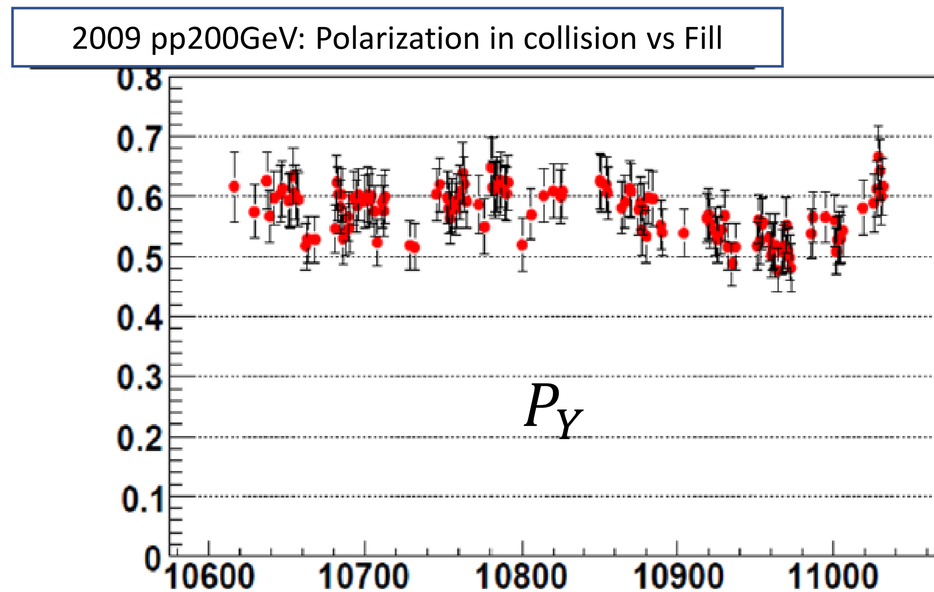
- The Solenoidal Tracker at RHIC (STAR) is a large solid angle detector with charged particle tracking and electromagnetic calorimetry
- Tracking is accomplished with a Time Projection Chamber (TPC) over $|\eta| < 1.3$
- Electromagnetic calorimetry provided by Barrel EMC & Endcap EMC and extends from $-1 < \eta < 2$



Exploring Gluon Polarization at RHIC

$$A_{LL} = \frac{1}{P_B P_Y} \frac{(N^{++} + N^{--}) - R(N^{+-} + N^{-+})}{(N^{++} + N^{--}) + R(N^{+-} + N^{-+})}$$





Pushing to Lower x: Dijets at Forward Rapidity

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

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

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

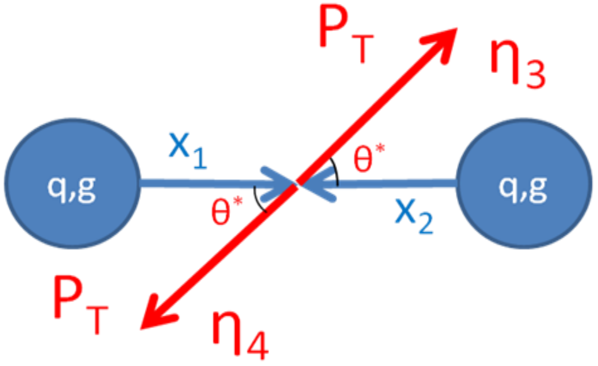
$$\eta_3 + \eta_4 = \ln\frac{x_1}{x_2}$$

$$\left|\cos\theta^*\right| = \tanh\left|\frac{\eta_3 - \eta_4}{2}\right|$$

- Correlation measurements such as dijets capture more information from the hard scattering and provide a more direct link to the initial parton-level kinematics than inclusive measurements

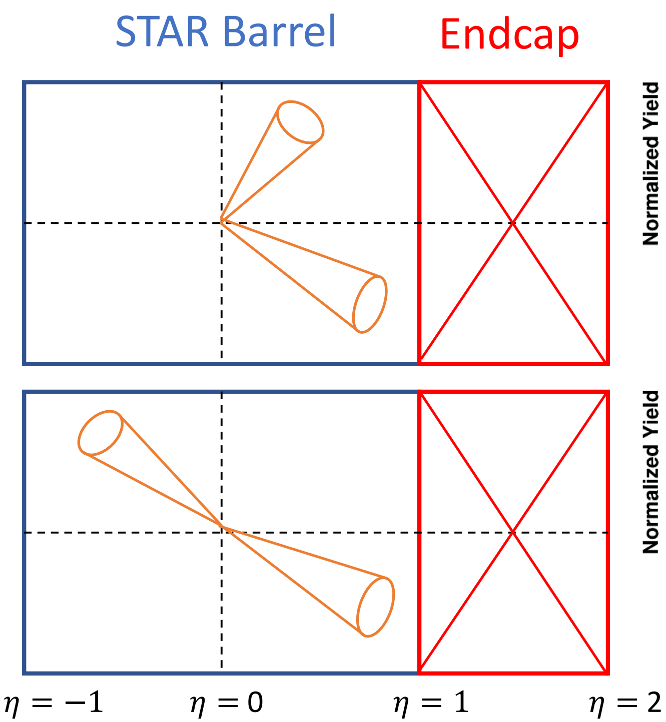
- Leading order expressions show how different jet configurations are sensitive to different kinematic values

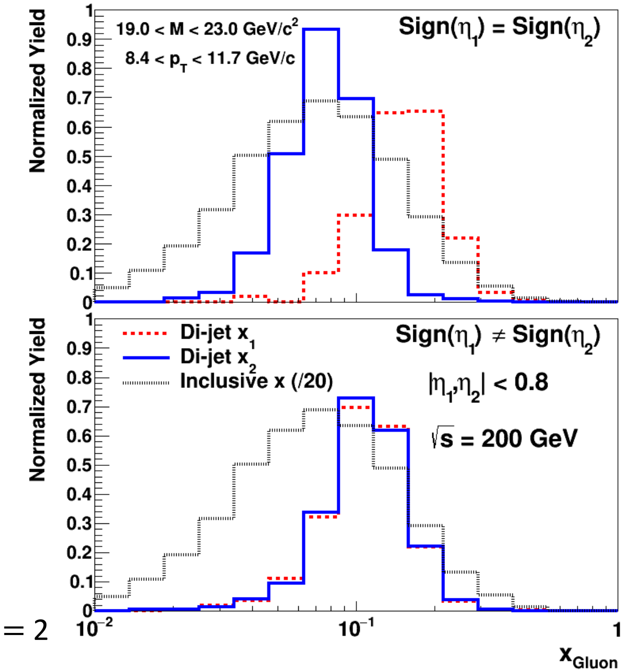
- Dijets may place better constraints on the functional form of $\Delta g(x,Q^2)$

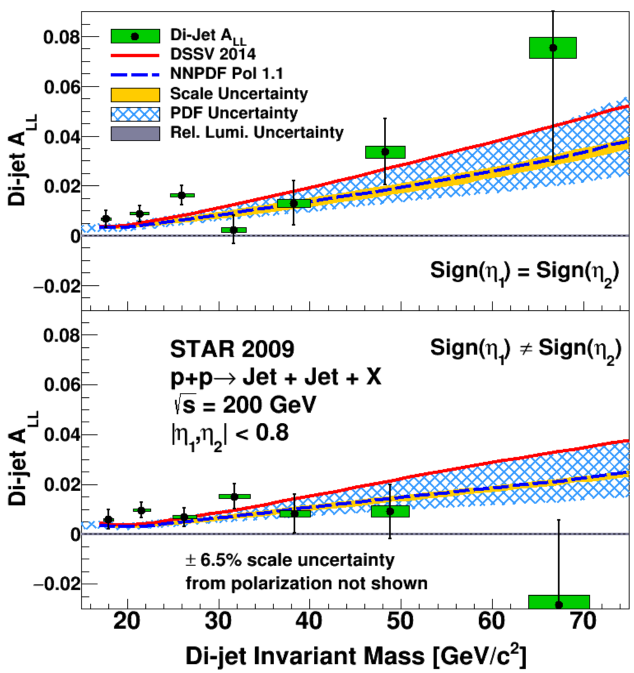


Mid-Rapidity dijet A_{LL}

Phys. Rev. D 95, 071103 (2017)







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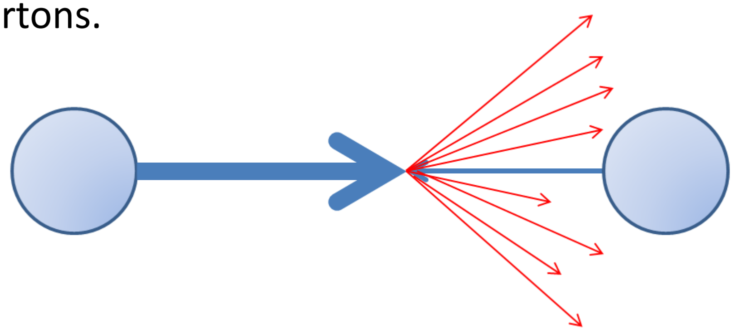
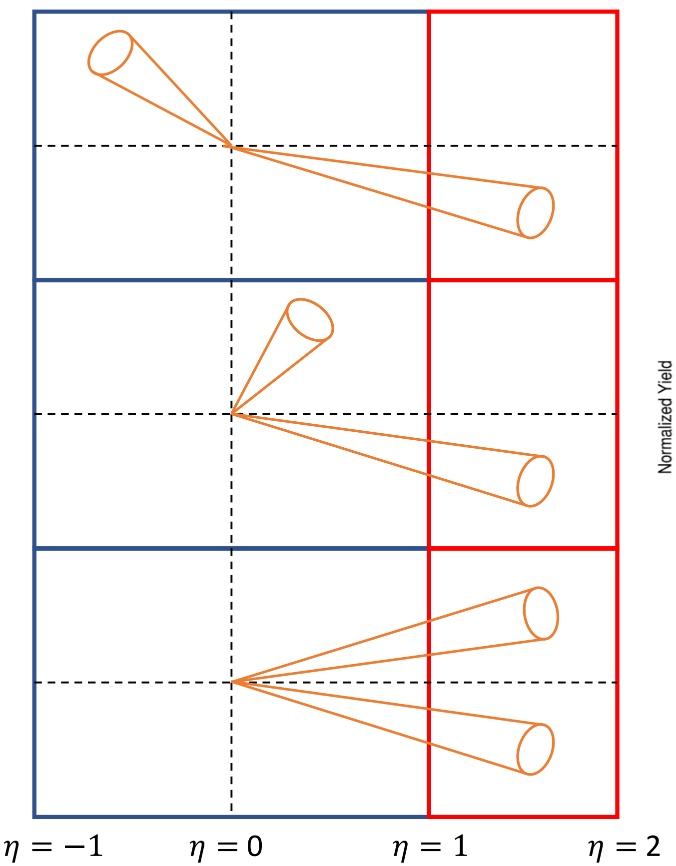
- Correlation measurements such as dijets capture more information from the hard scattering and provide a more direct link to the initial kinematics than inclusive probes
- Leading order expressions show how different jet configurations are sensitive to different kinematic values
- Dijets may place better constraints on the functional form of $\Delta g(x,Q^2)$
- More forward jets are indicative of more asymmetric collisions which will contain lower x partons.



Forward Rapidity dijet Topology



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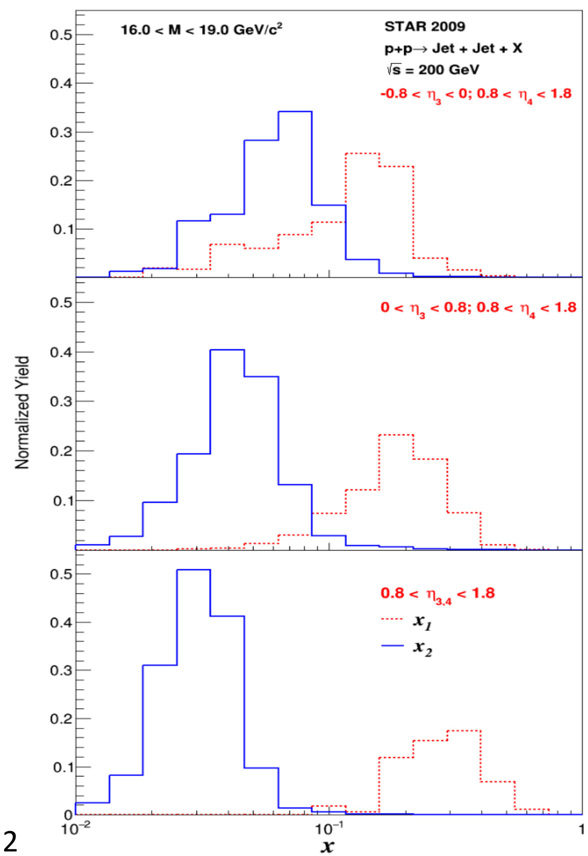

- Adding the Endcap opens up several new dijet topologies
- Forward jets probe lower values of gluon momentum fraction while selecting more asymmetric collisions
- The large imbalance in momentum fractions, coupled with the unpolarized PDF's, suggests that x_2 is dominated by gluons, while x_1 are most often valence quarks

Data-Simulation Comparison

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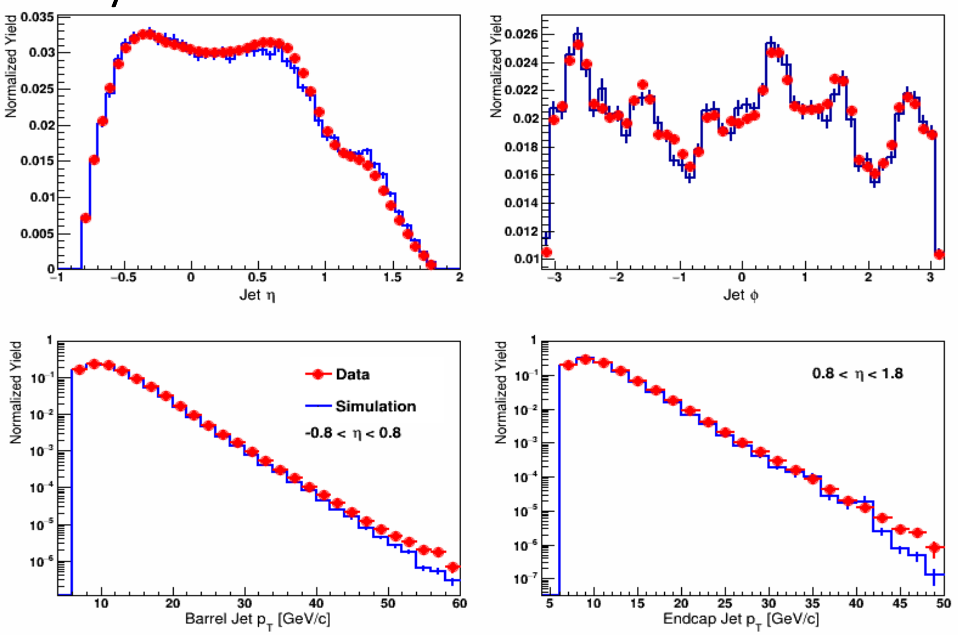
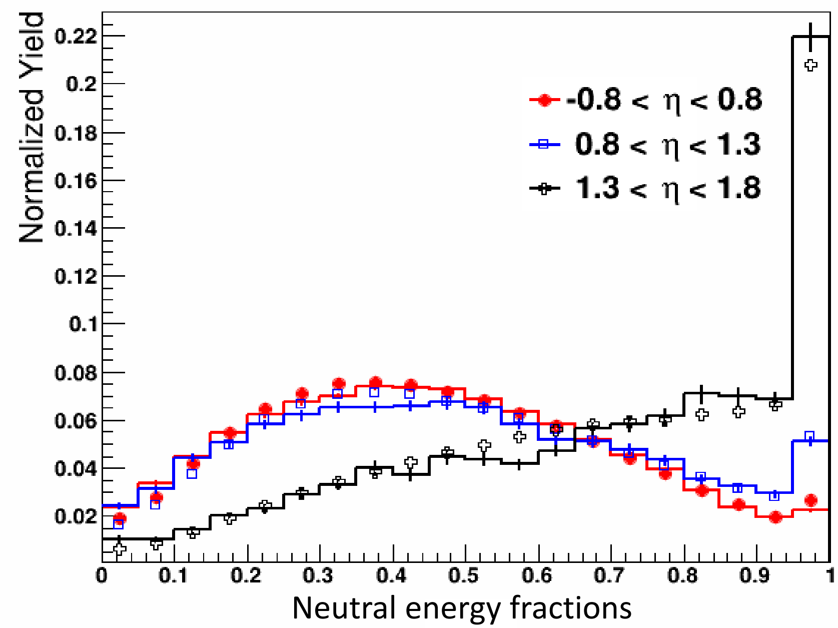


- Simulation events created using PYTHIA run through a STAR detector response model based on GEANT 3, and then embedded into Zero-Bias data



- In general, we see good agreement between 2009 data and simulation for single jet kinematic quantities

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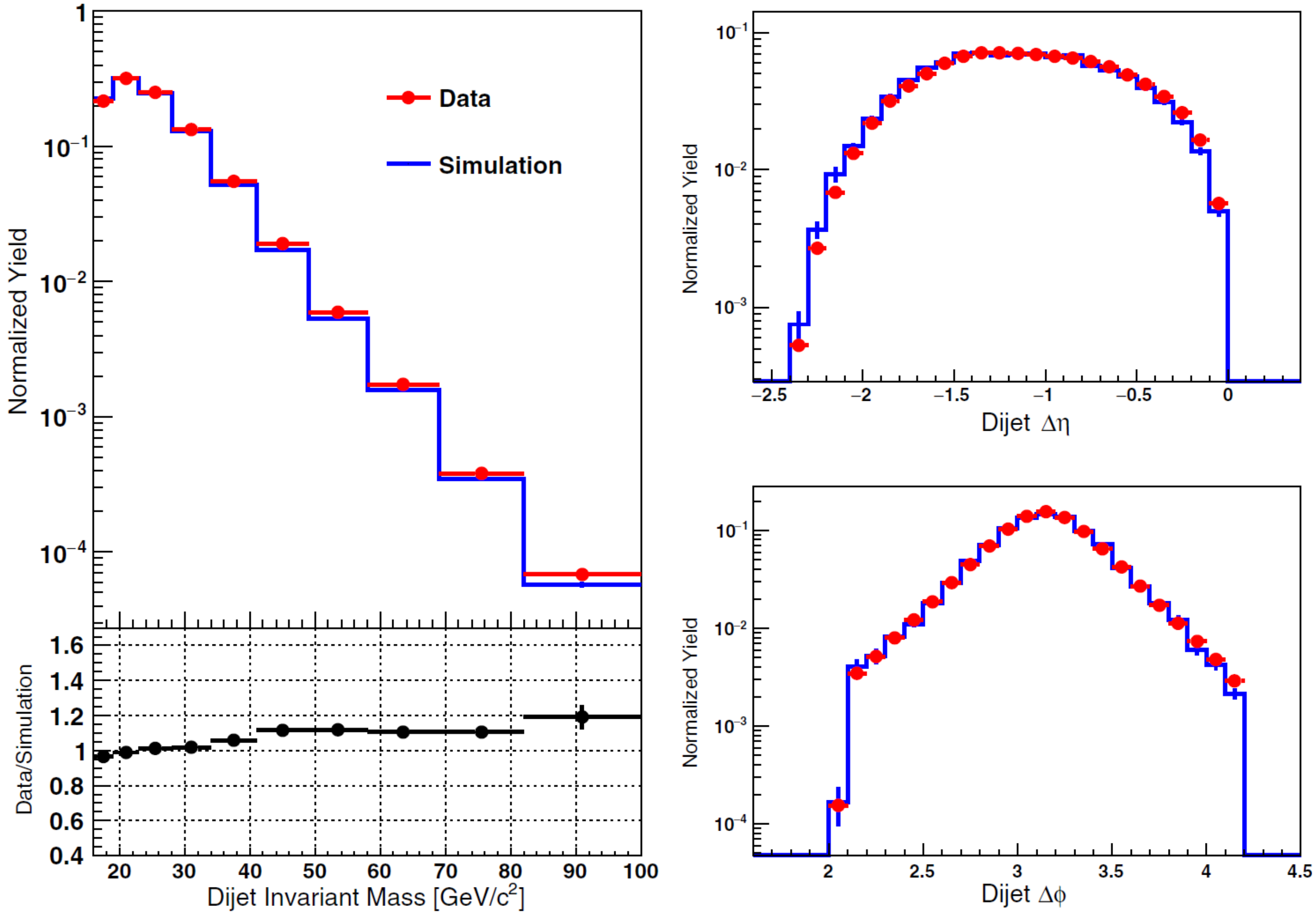
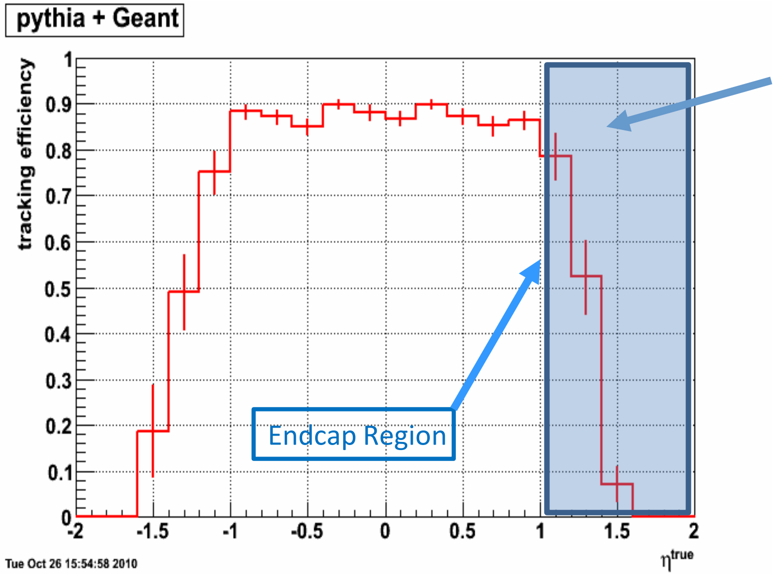


- Good agreement between 2009 data and simulation for dijet kinematic quantities.

Challenges and Methods



- TPC efficiency decreases in forward region
- Fewer tracks means reconstructed jets will have lower p_T and jet mass on average
- Inaccurate p_T reconstruction skews extraction of partonic momenta

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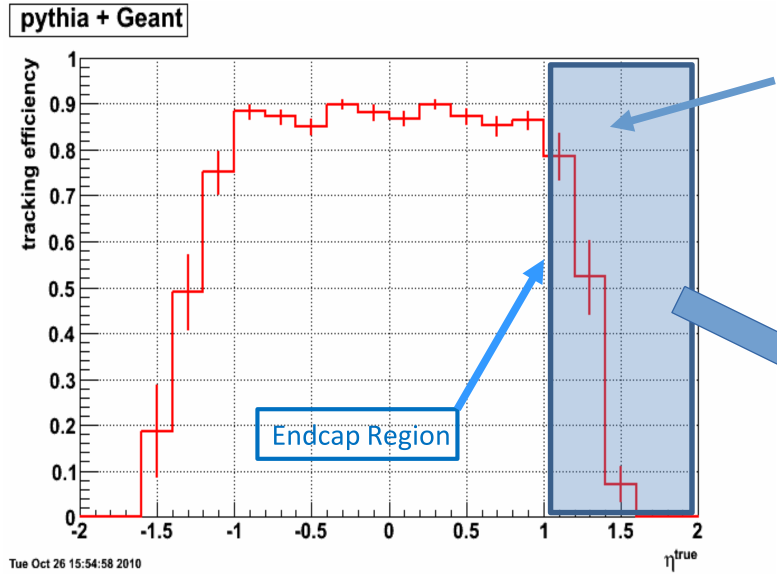

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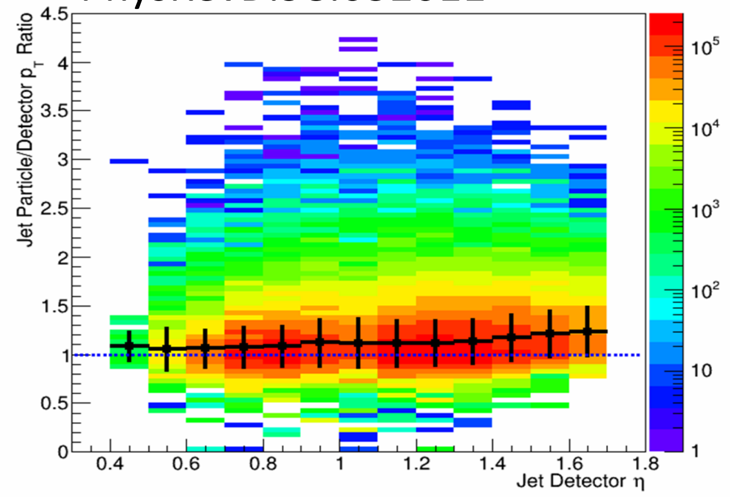

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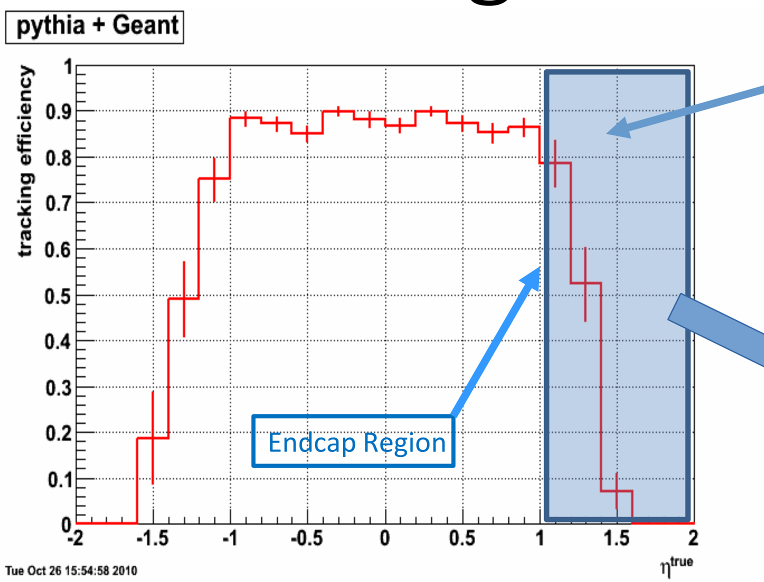

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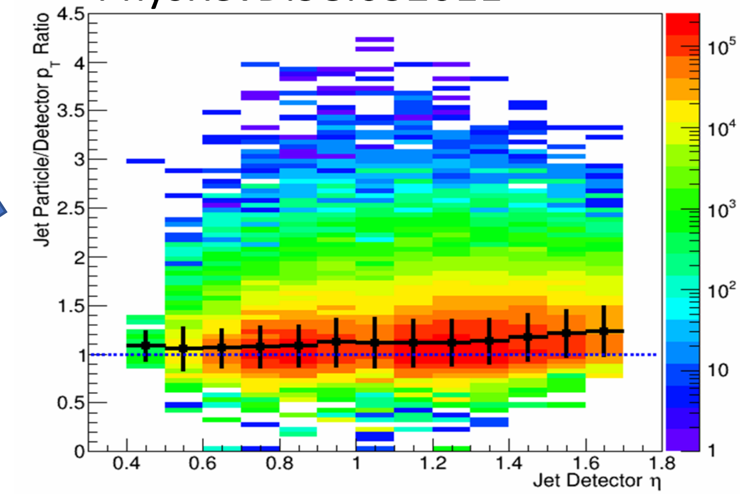
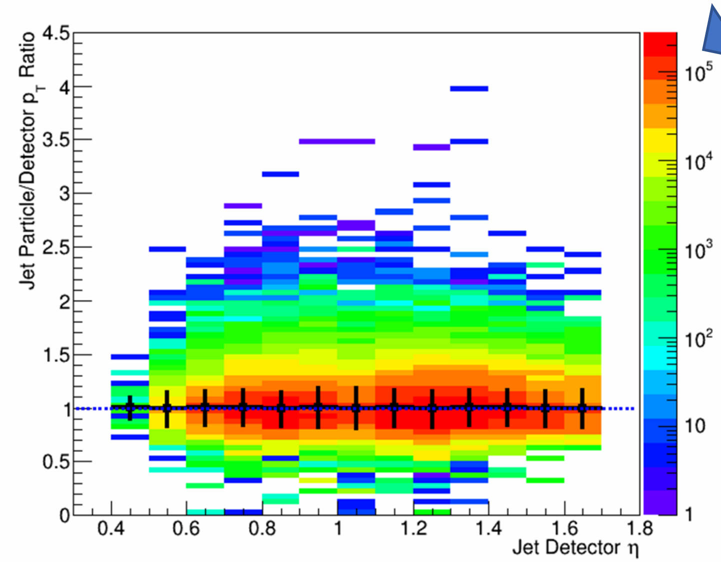
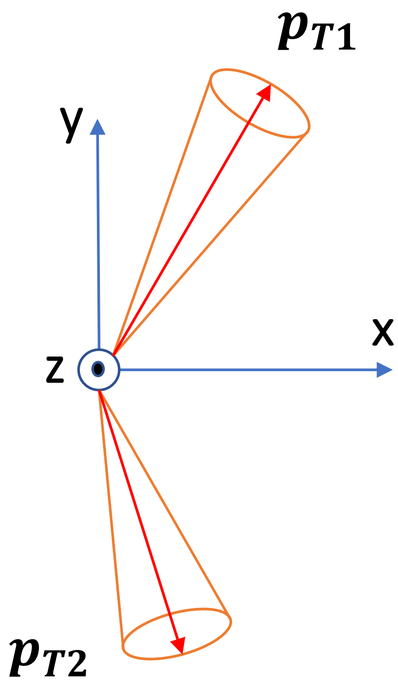




Machine Learning: Multilayer Perceptron(MLP)
Variables: Endcap jet detector level p_T , detector eta, neutral energy fraction; Barrel jet p_T
Target: particle level jet p_T

Challenges and Methods



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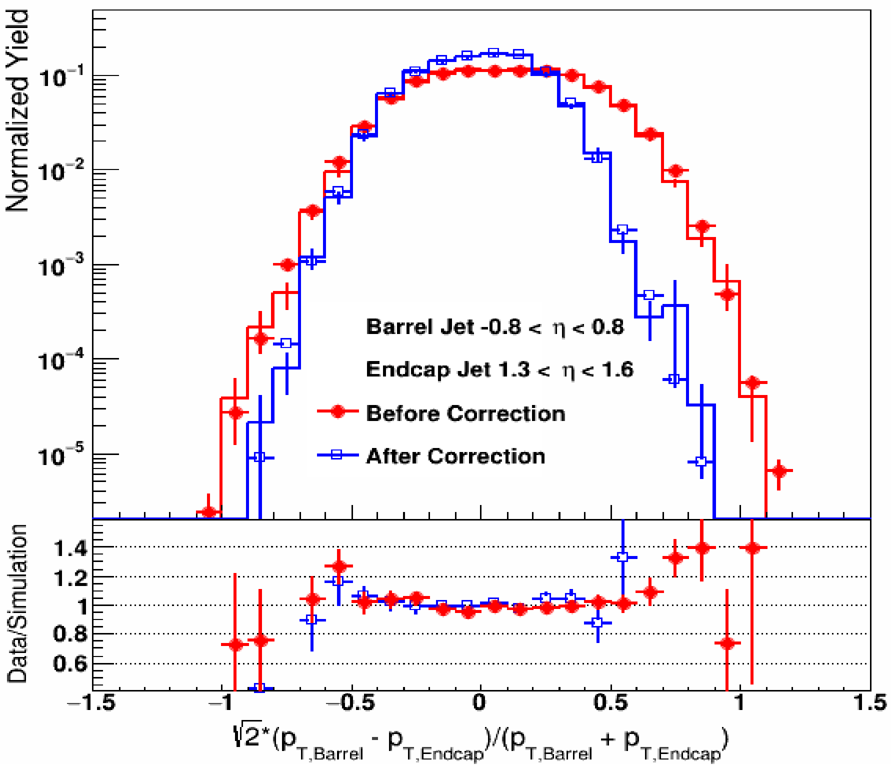

- Barrel and Endcap jets are separately corrected in p_T and mass using similar methods
- Dijet invariant masses are calculated using the corrected jet transverse momentum and mass from machine learning

Dijet Double Spin Asymmetry

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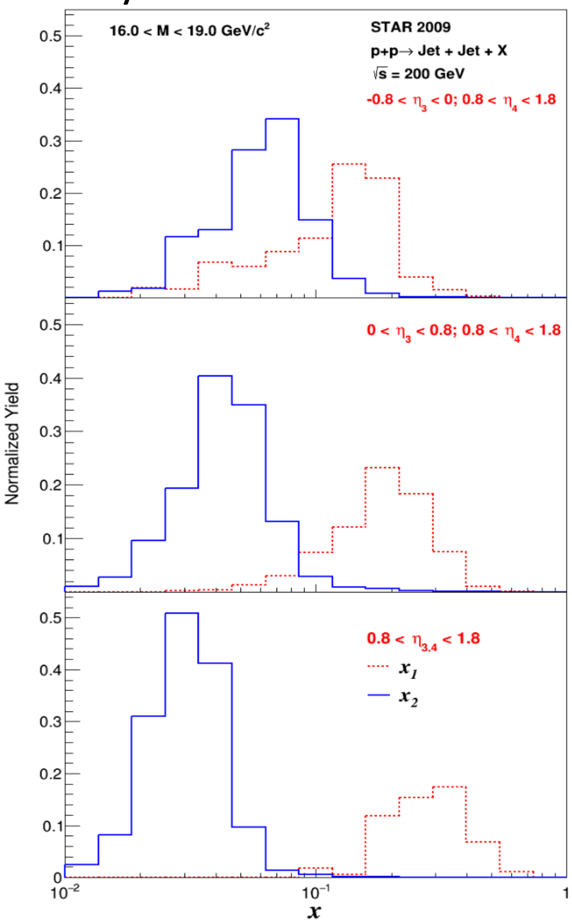

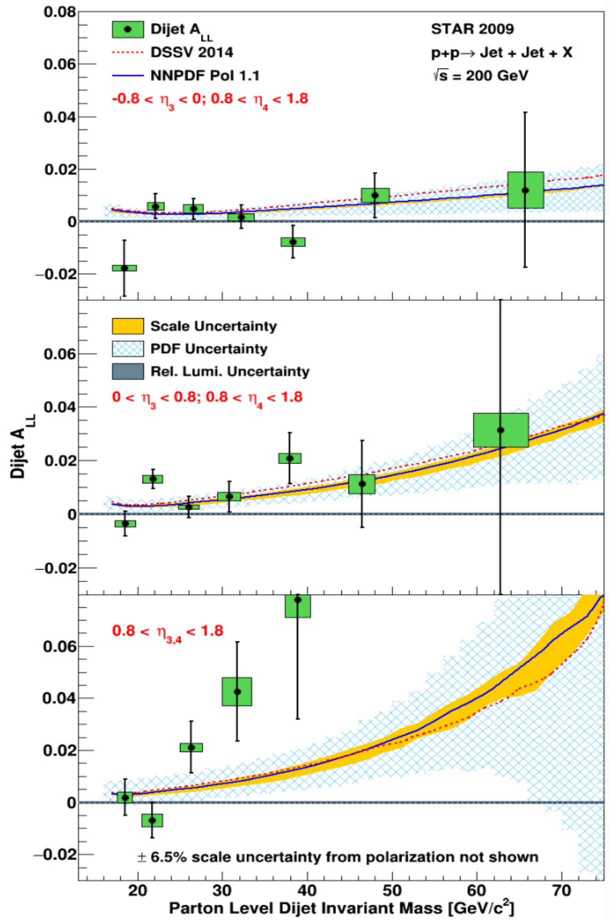

- Dijet A_{LL} with three different topologies
- New results are compared to DSSV14 and NNPDFpol1.1 expectations
- The forward dijet data will more tightly constrain gluon spin at lower momentum fraction

Forward-Forward Dijet A_{LL}

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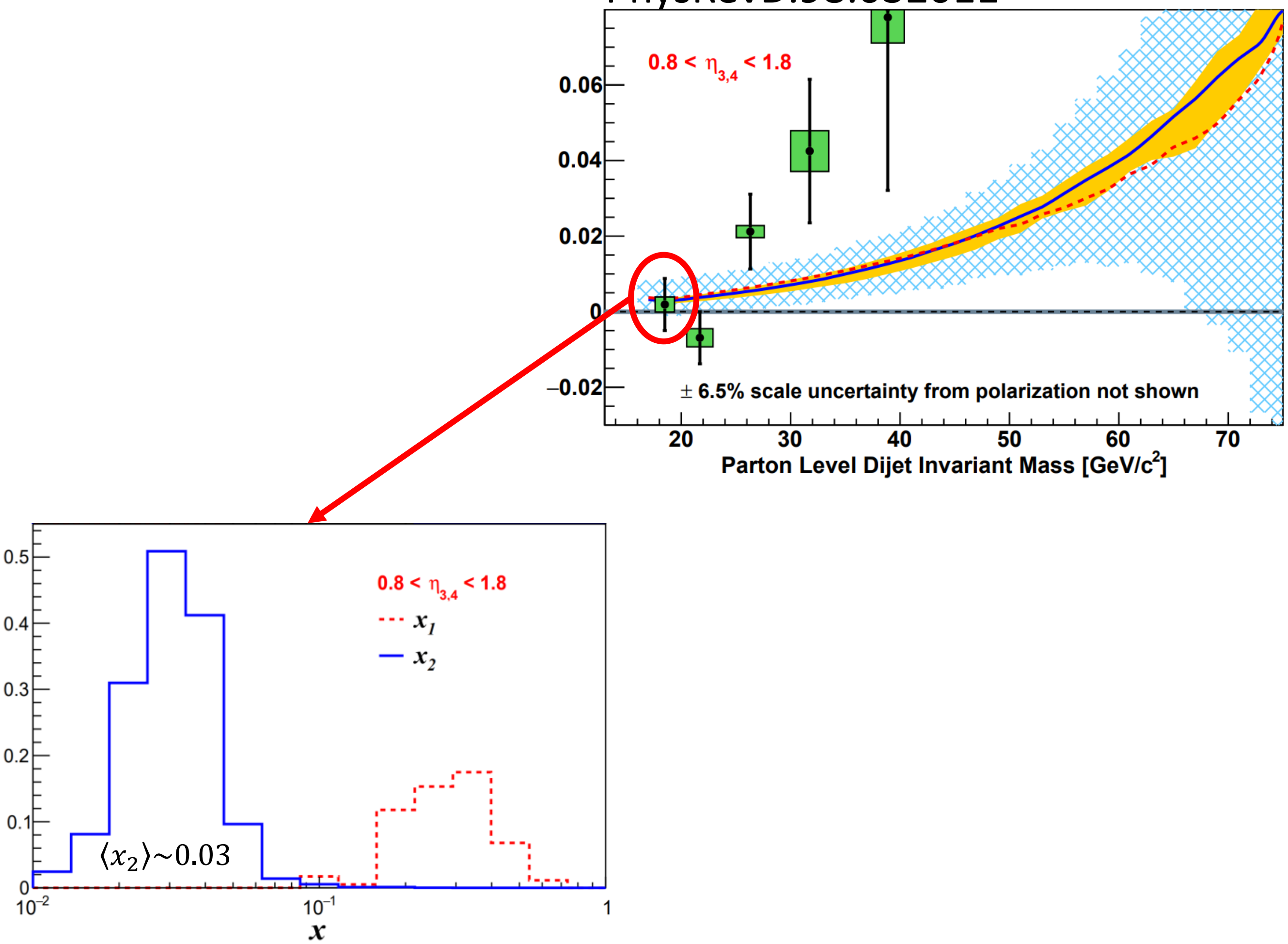

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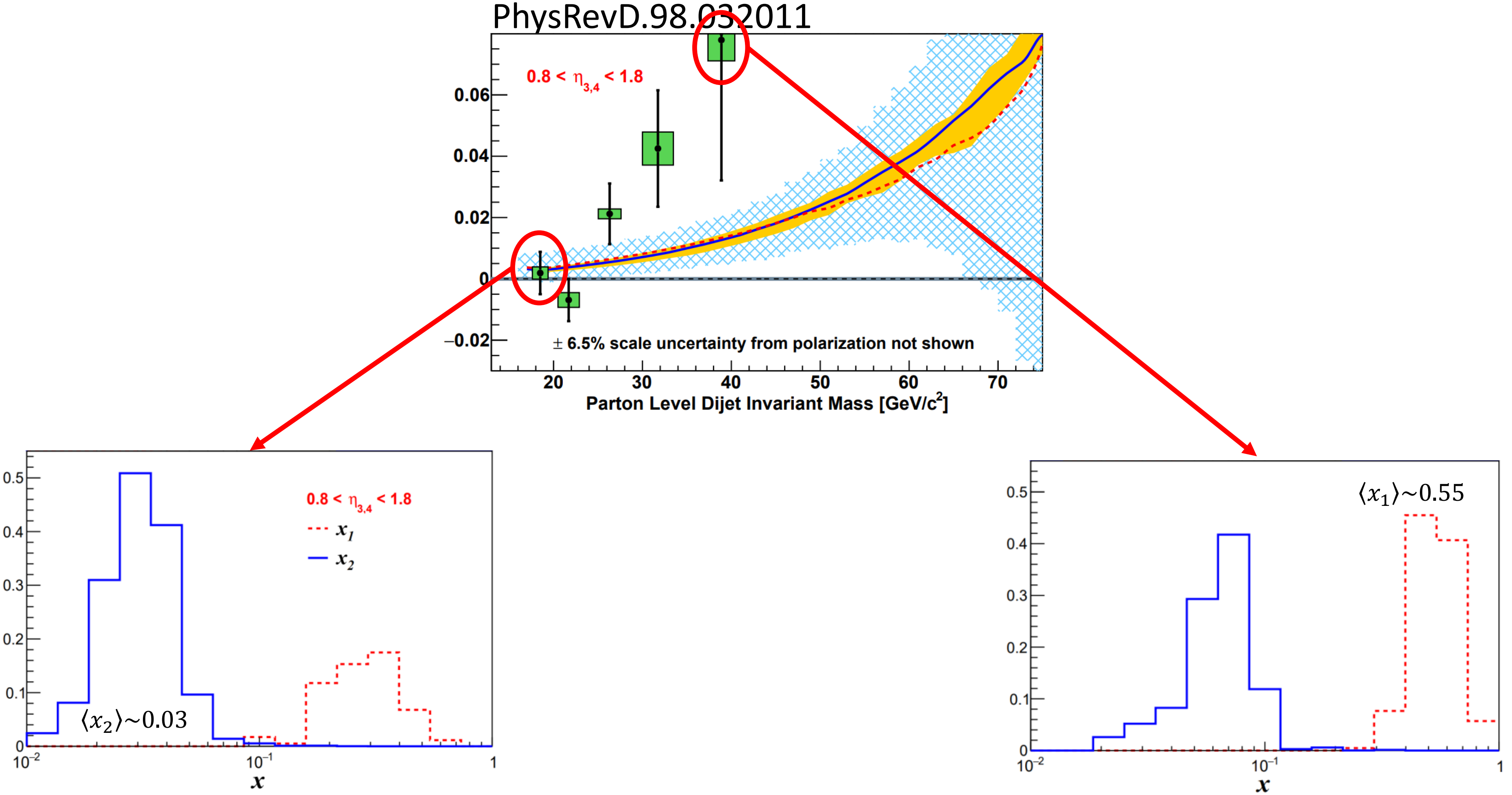

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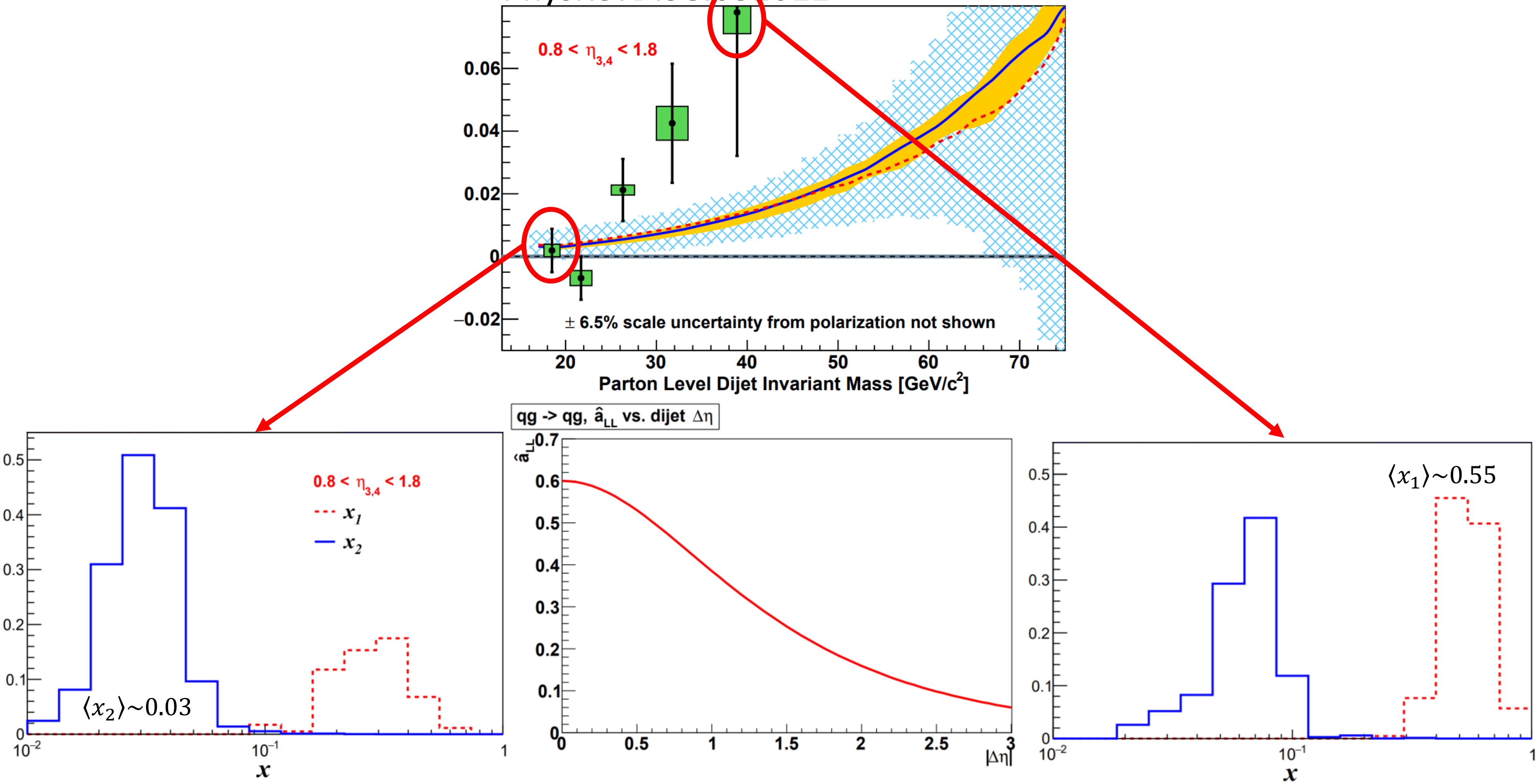

- Kinematic region maximizes the partonic asymmetry
- Future STAR pp200 data will improve the measurements at both low and high x range.

Conclusions

- The first measurement of the A_{LL} for dijets at intermediate pseudorapidity (0.8 < η < 1.8) is presented;
- The results are in good agreement with recent theory predictions and should help to significantly reduce the global analysis uncertainties at lower x;
- Many important related analyses in progress by STAR, as presented in Christopher Dilks's overview talk;
- With the increased statistics from 2012, 2013 and 2015, new STAR data will help to further constrain the value and shape of Δg(x).