Gluon Polarization from Longitudinally Polarized Proton Collisions at STAR

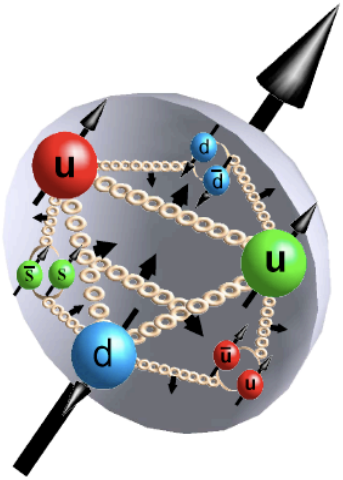
Suvarna Ramachandran

For the STAR Collaboration

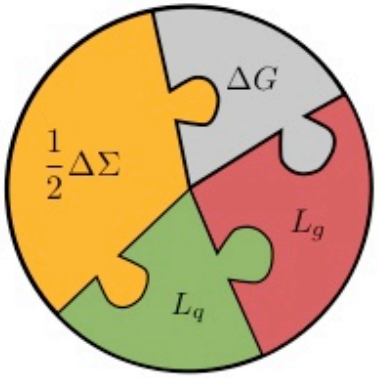
University of Kentucky

- Introduction and Motivation
- RHIC and STAR Detector
- A_{LL} Measurements at STAR
- Conclusion

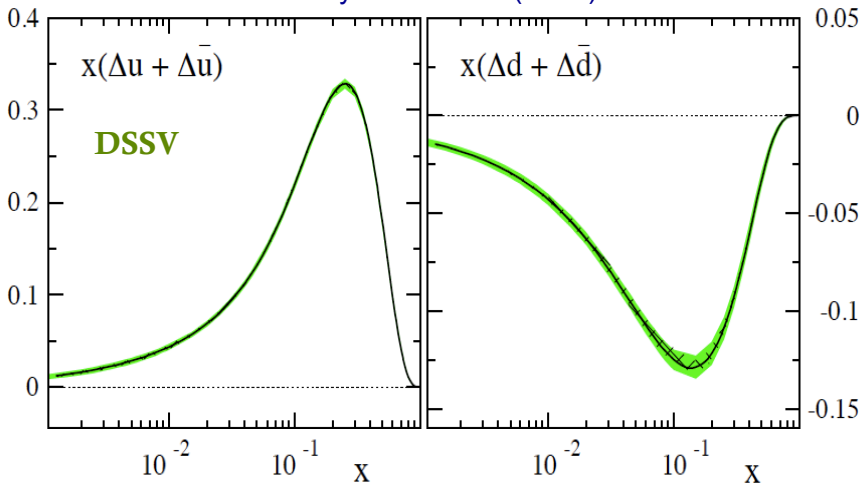
Spin of the Proton



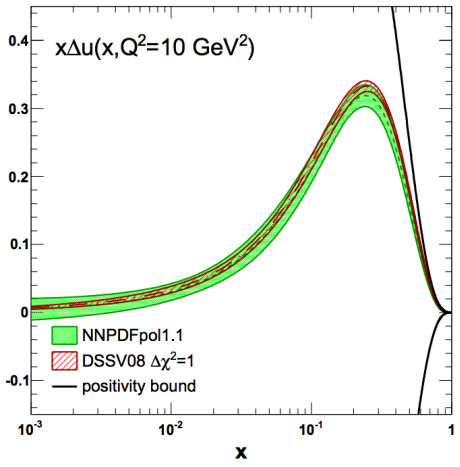
$$S_{PROTON} = \frac{\hbar}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

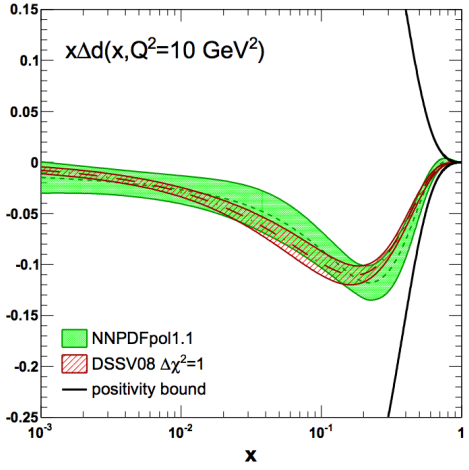


Phys. Rev. D80 (2009) 034030



Nucl. Phys. B887 (2014) 276-308





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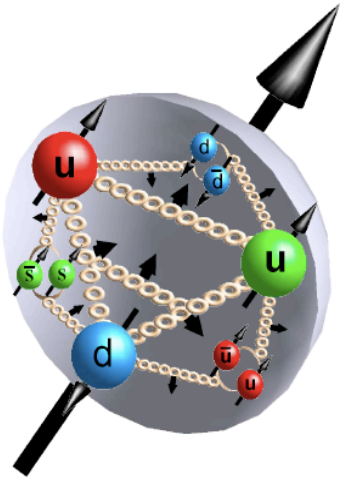

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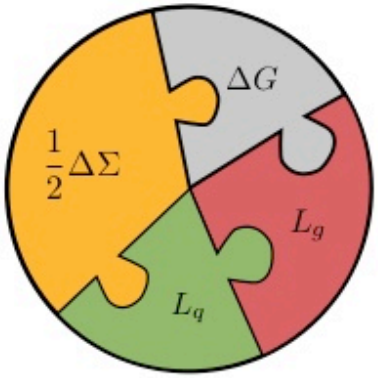
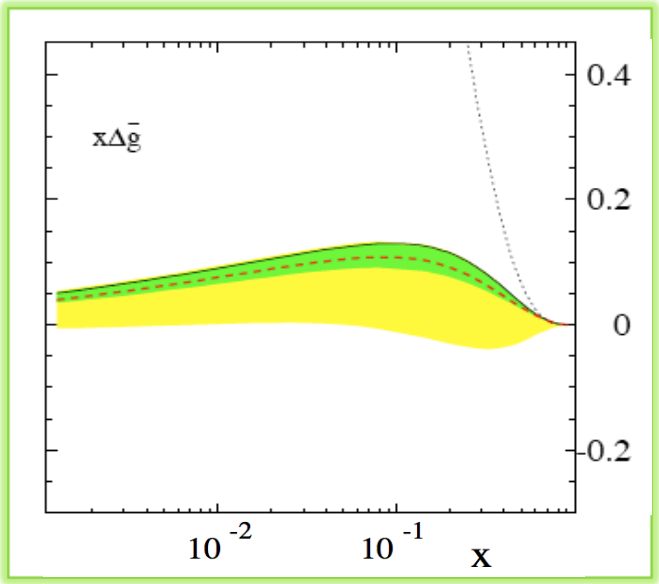
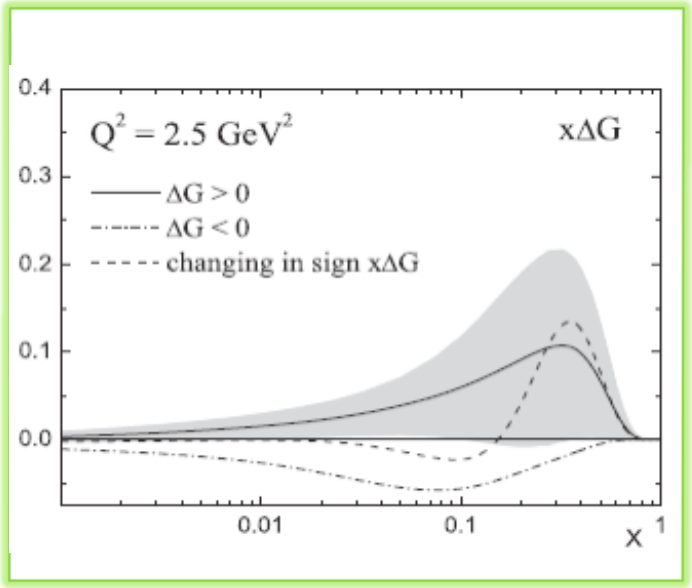


Phys. Rev. D71 094018 (2005)

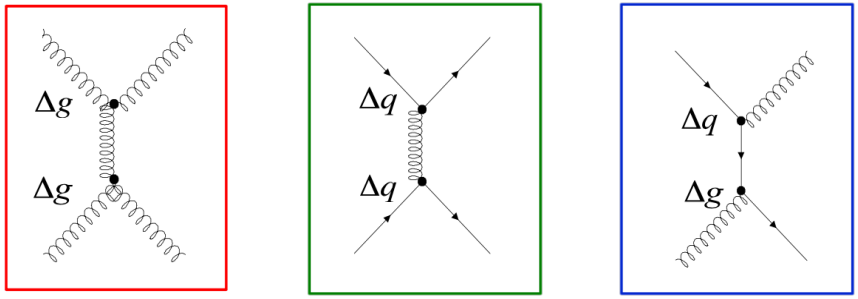


Phys. Rev. D75 074027 (2007)

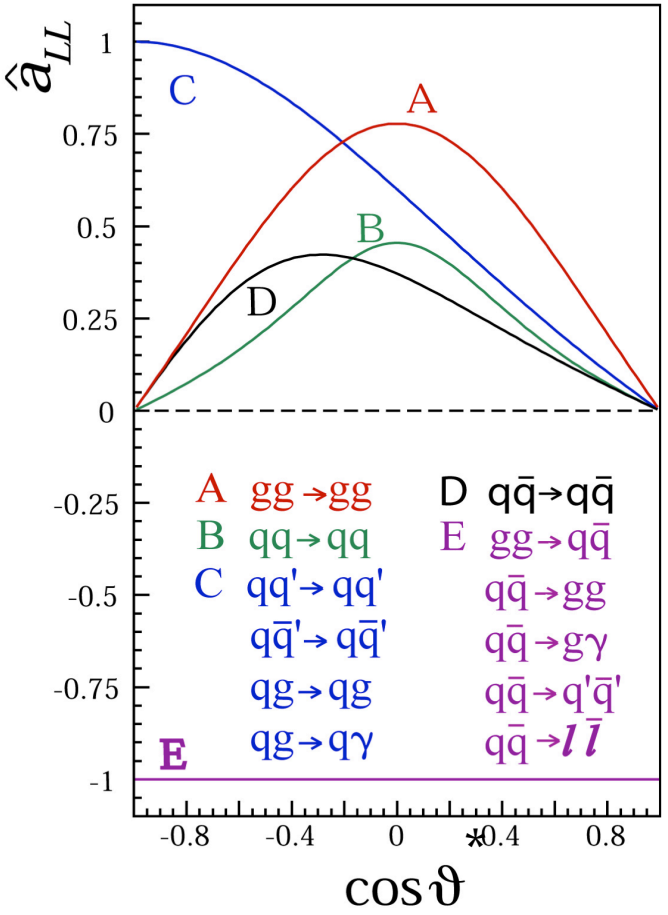


How do we access ΔG at a polarized proton collider?

- Longitudinal Double Spin Asymmetry



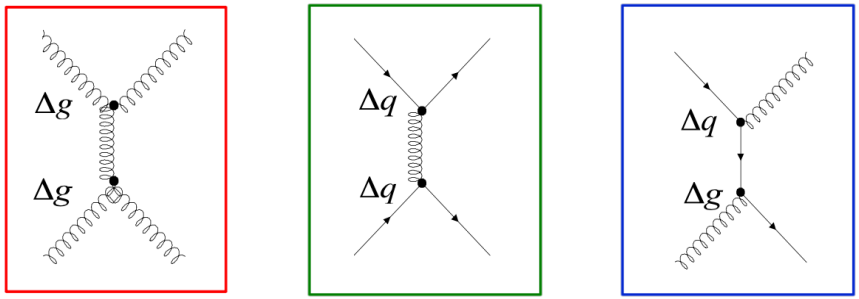
$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\sum_{abc} \Delta f_a \otimes \Delta f_b \otimes \Delta\hat{\sigma}_{ab->cx}}{\sum_{abc} f_a \otimes f_b \otimes \hat{\sigma}_{ab->cx}}$$



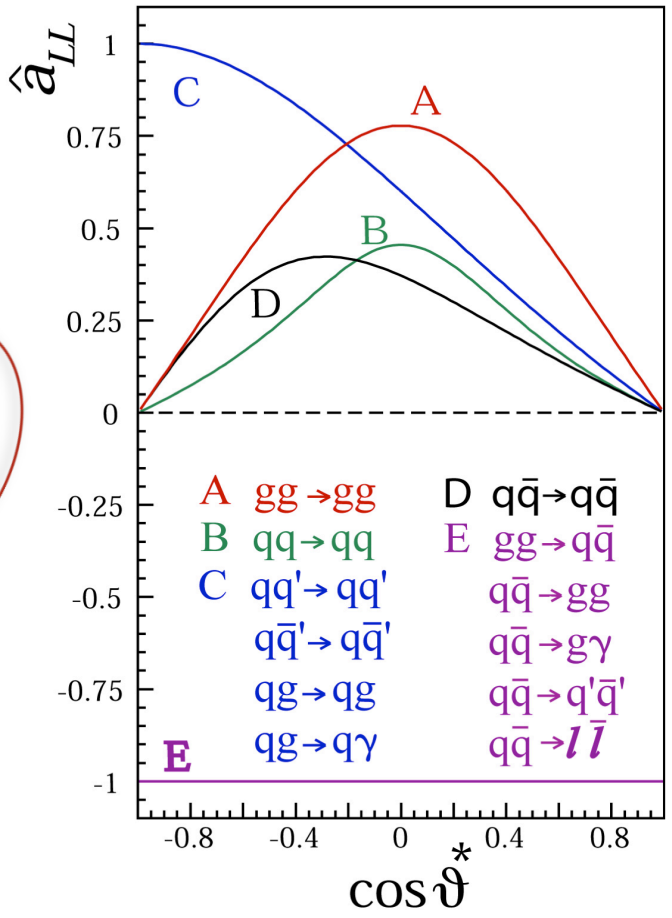
- Analyses based on final states
  - Inclusive Jets
  - Dijets

How do we access ΔG at a polarized proton collider?

- Longitudinal Double Spin Asymmetry

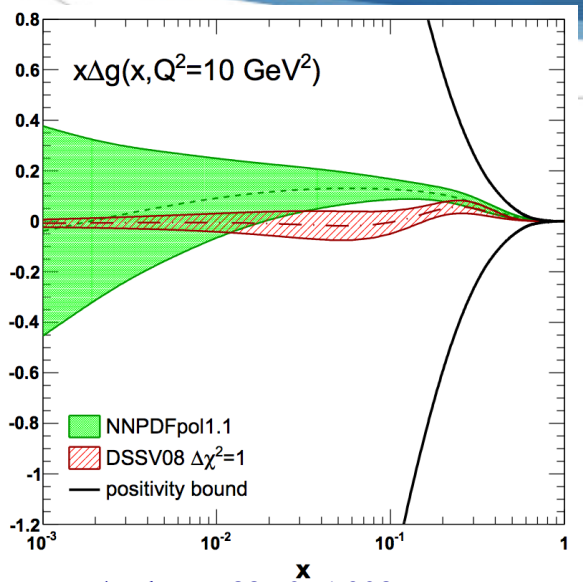


$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\sum_{abc} \Delta f_a \otimes \Delta f_b \otimes \Delta\hat{\sigma}_{ab->cx} \otimes D_c^{\pi^0}}{\sum_{abc} f_a \otimes f_b \otimes \hat{\sigma}_{ab->cx} \otimes D_c^{\pi^0}}$$

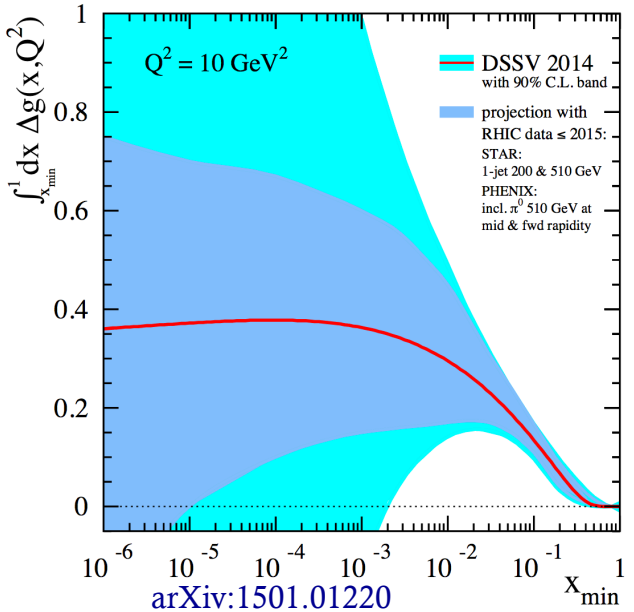


- Analyses based on final states
  - Inclusive Jets
  - Dijets
  - Pions

ΔG

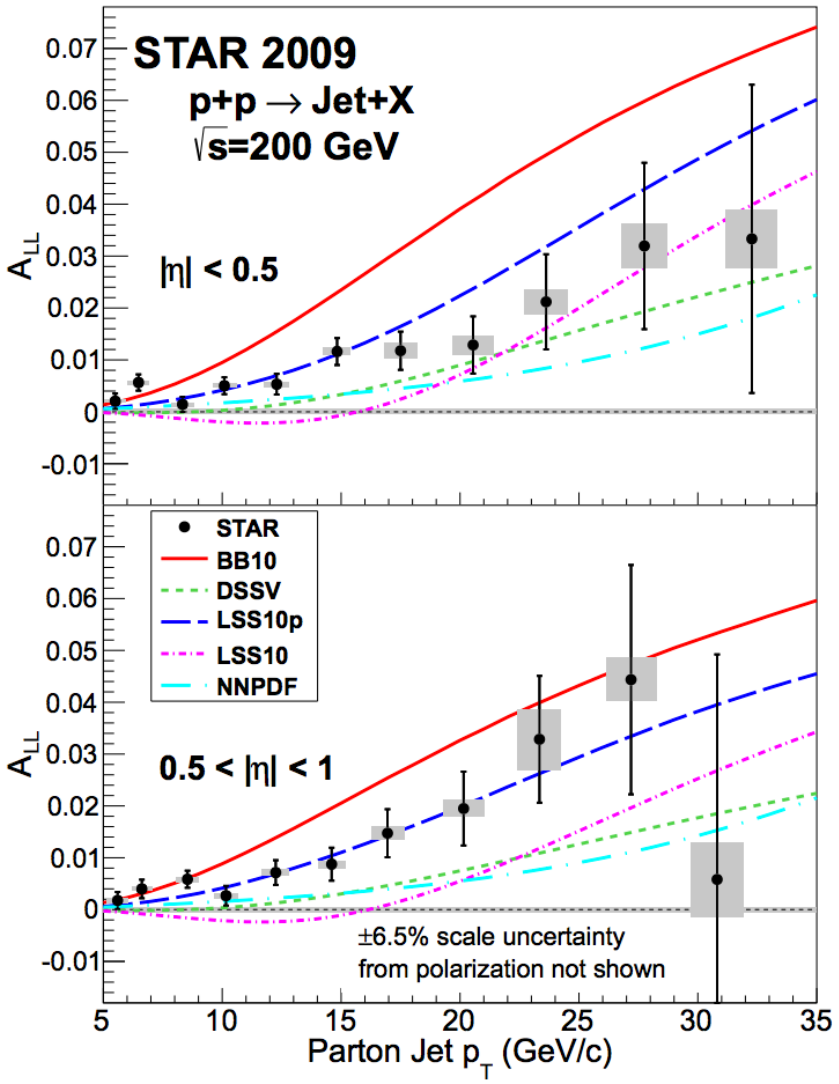


Nucl. Phys. B887 276-308

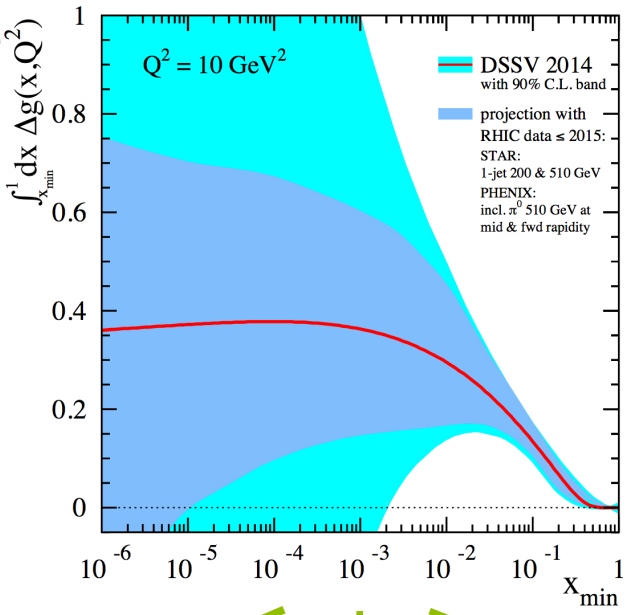


arXiv:1501.01220

Phys. Rev. Lett 115.092002



How do we reduce the errors on ΔG at low x?

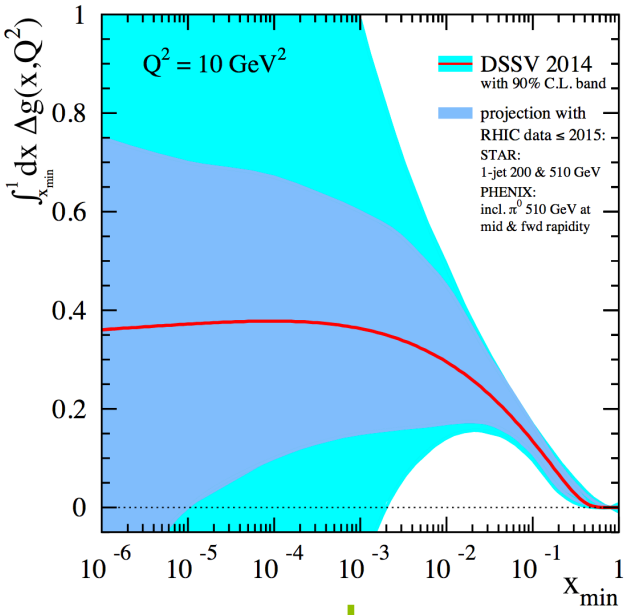


Look at higher √s
2012 Inclusive jet results

Constrain the functional form
200 GeV Dijet Results
510 GeV Dijet Results

Look at forward rapidity
EEMC π^0 Results
FMS π^0 Results

How do we reduce the errors on ΔG at low x?



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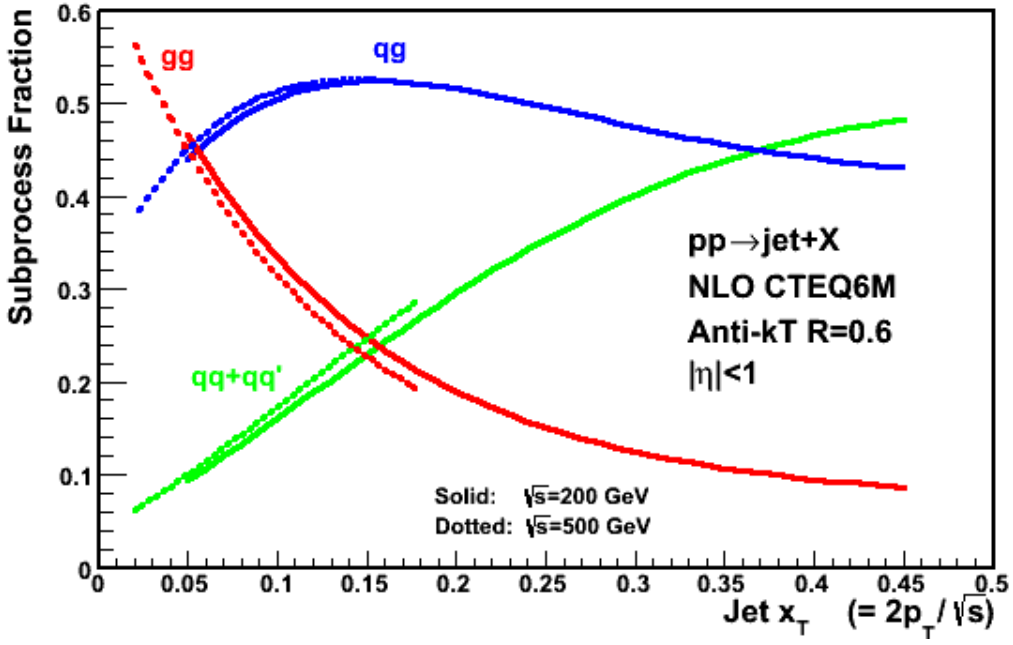
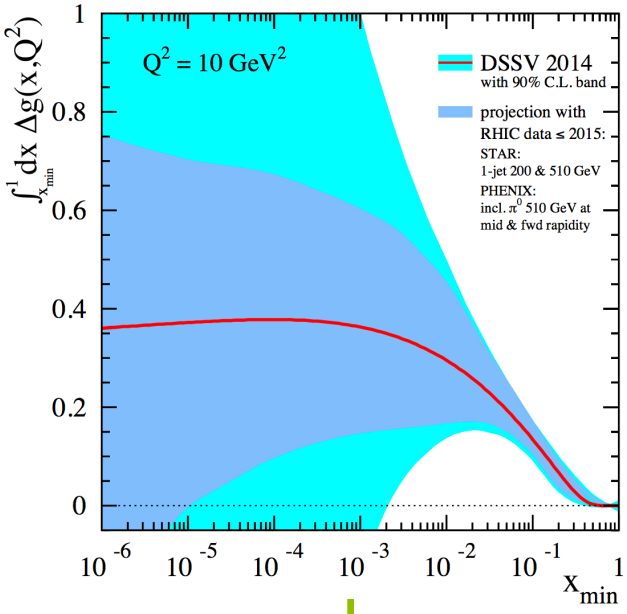
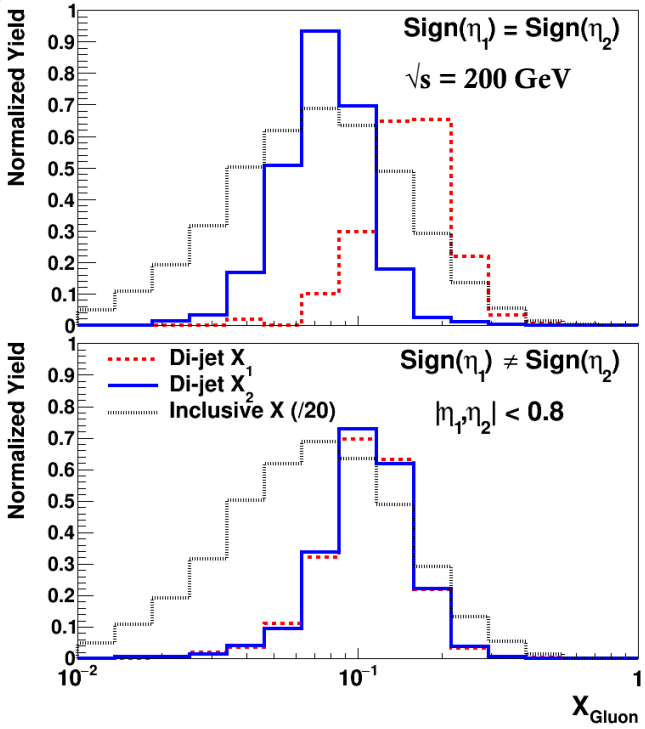


Note: No experimental access to x in inclusive observables in pp collisions!

At mid-rapidity x_T is related to x as:
$x_1 \sim x_T\ (2- x_T)$ and $x_2 \sim x_1 x_T/(2x_1 - x_T)$

How do we reduce the errors on ΔG at low x?





Constrain the functional form

200 GeV Dijet Results

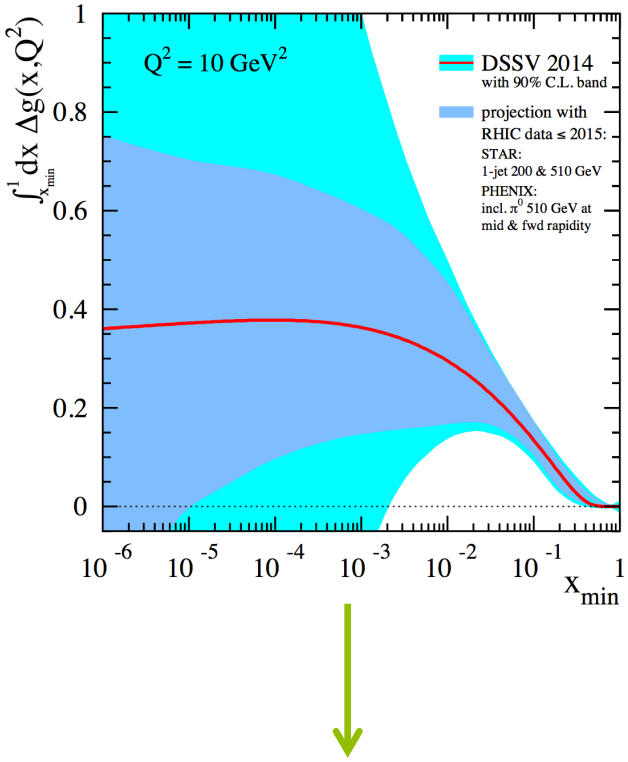
510 GeV Dijet Results

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

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

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

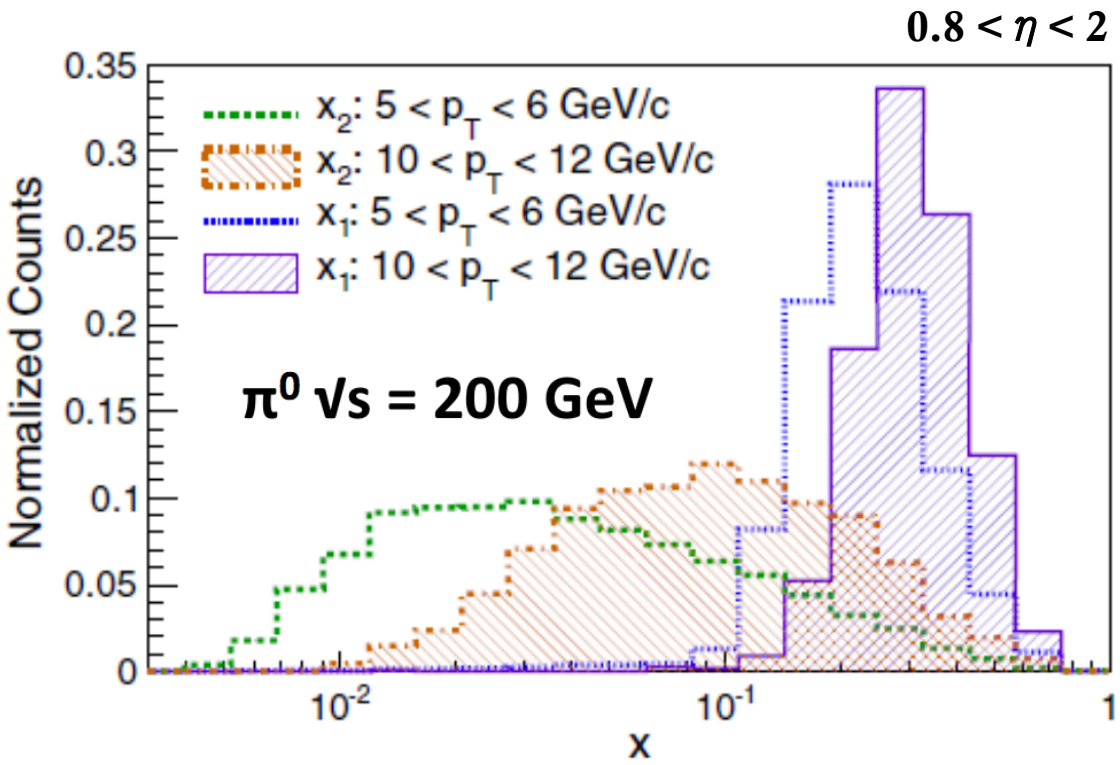
How do we reduce the errors on ΔG at low x?



Look at forward rapidity

EEMC π^0 Results

FMS π^0 Results



Looking at the **$2.5 < \eta < 4$** region pushes the access down to x ~ 10^{-3} regime for $\sqrt{s}$ = 510 GeV

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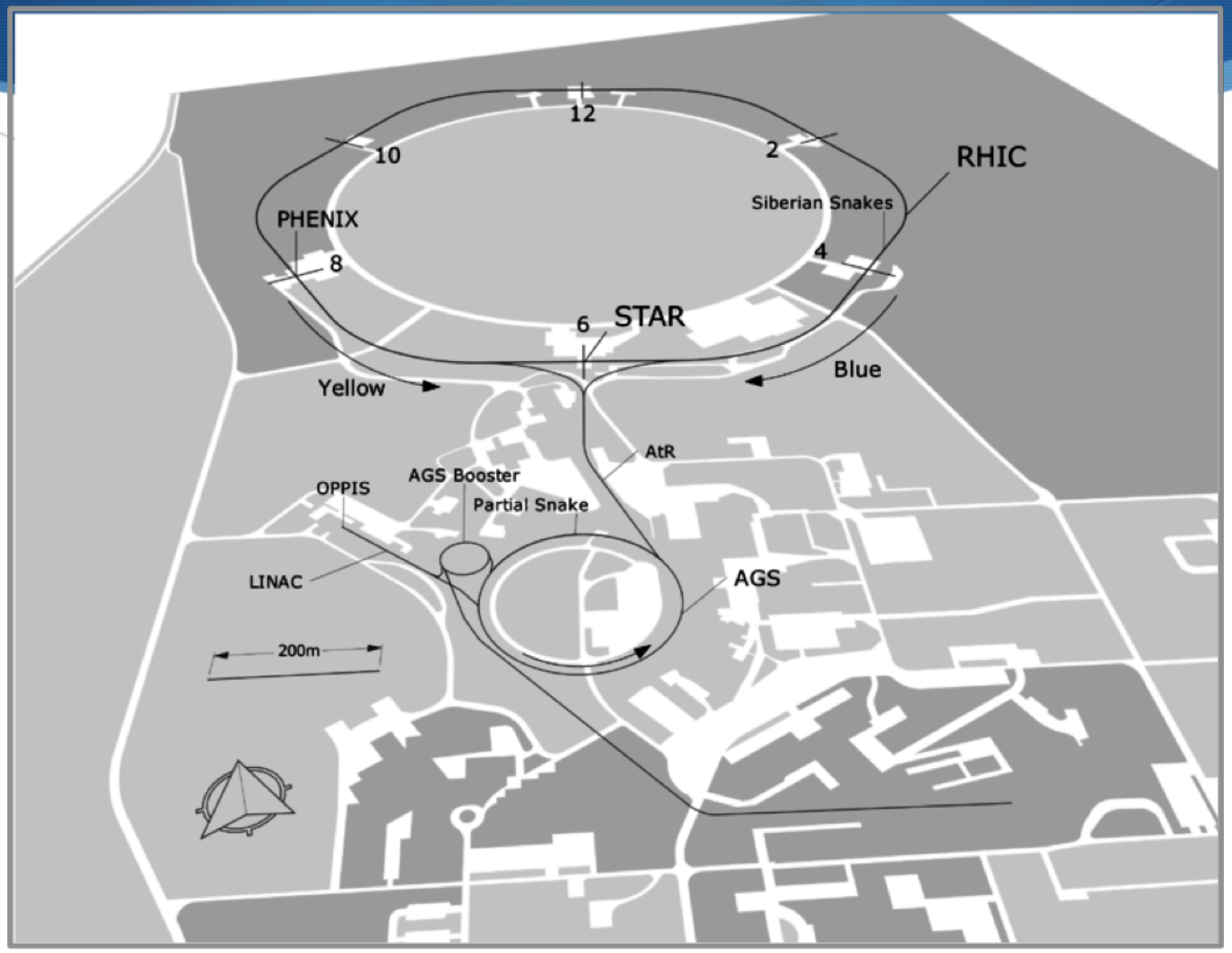
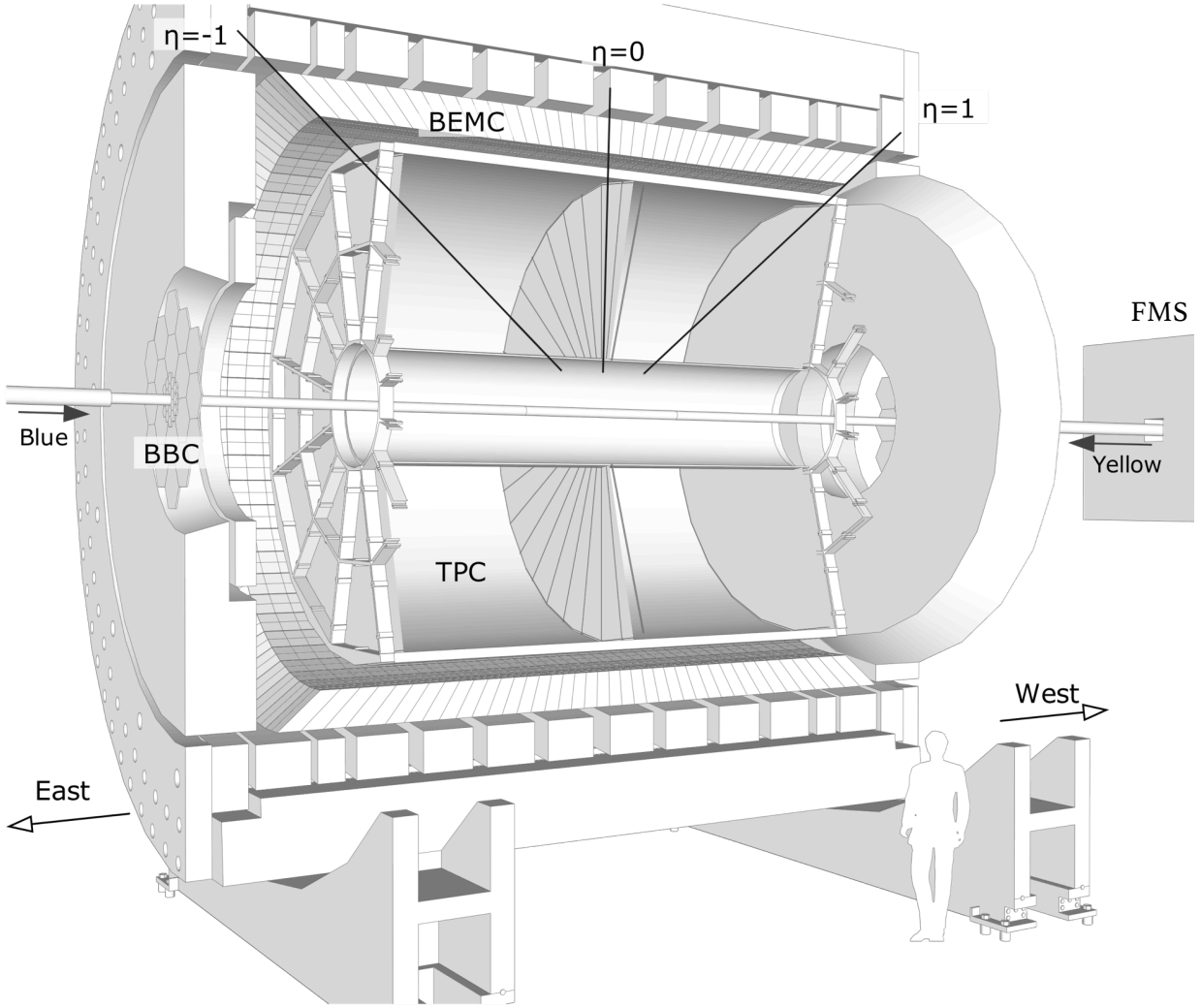
Relativistic Heavy Ion Collider



Solenoidal Tracker At RHIC



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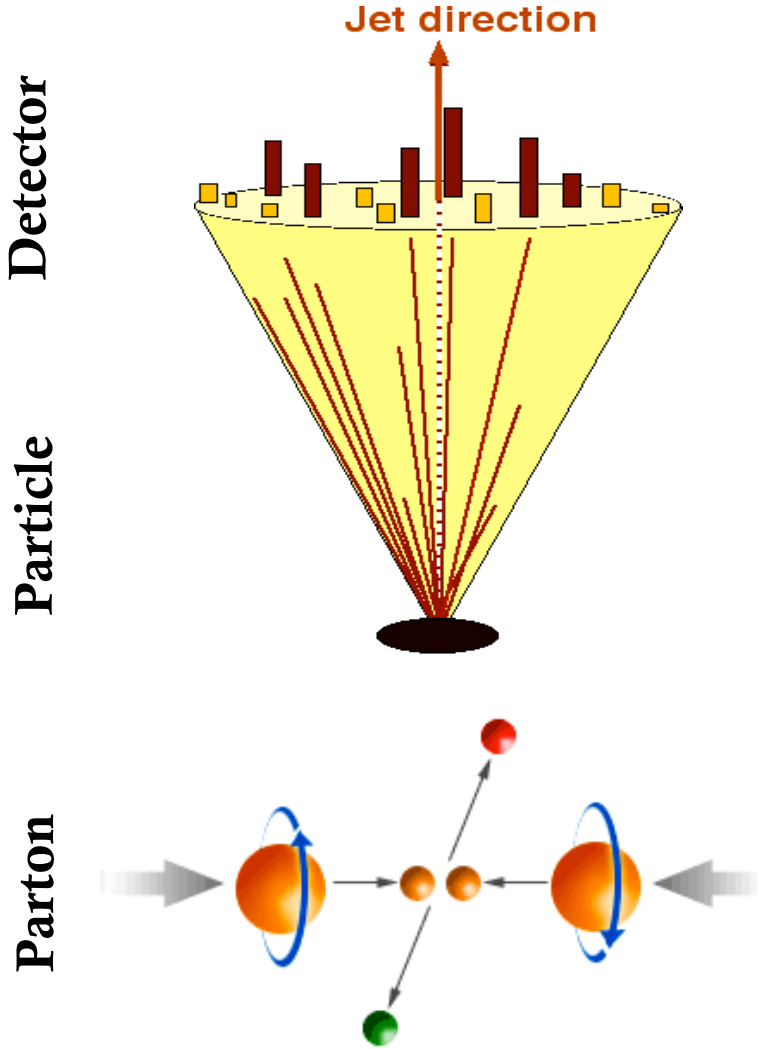
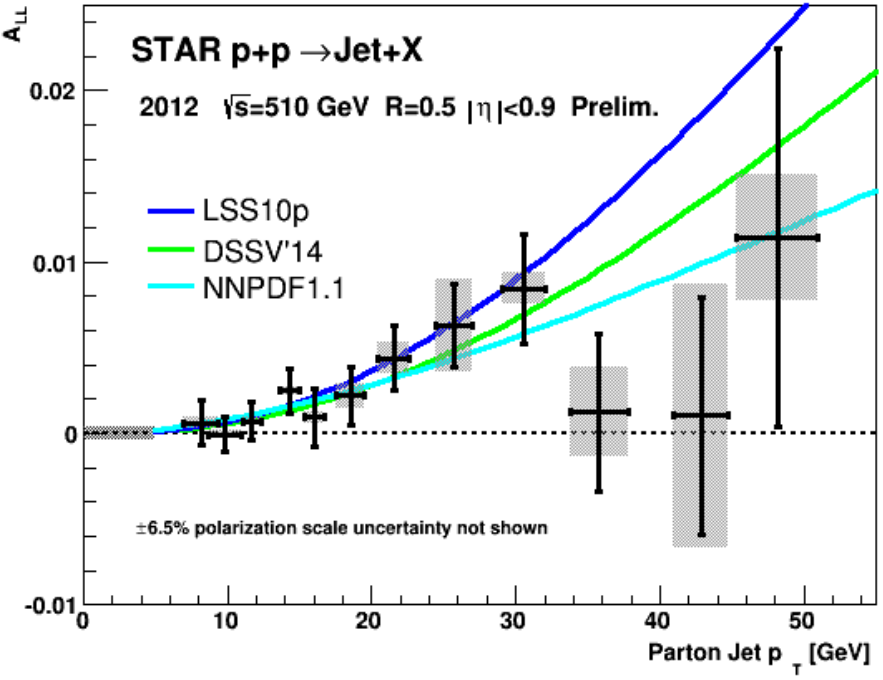
Jet Reconstruction at STAR

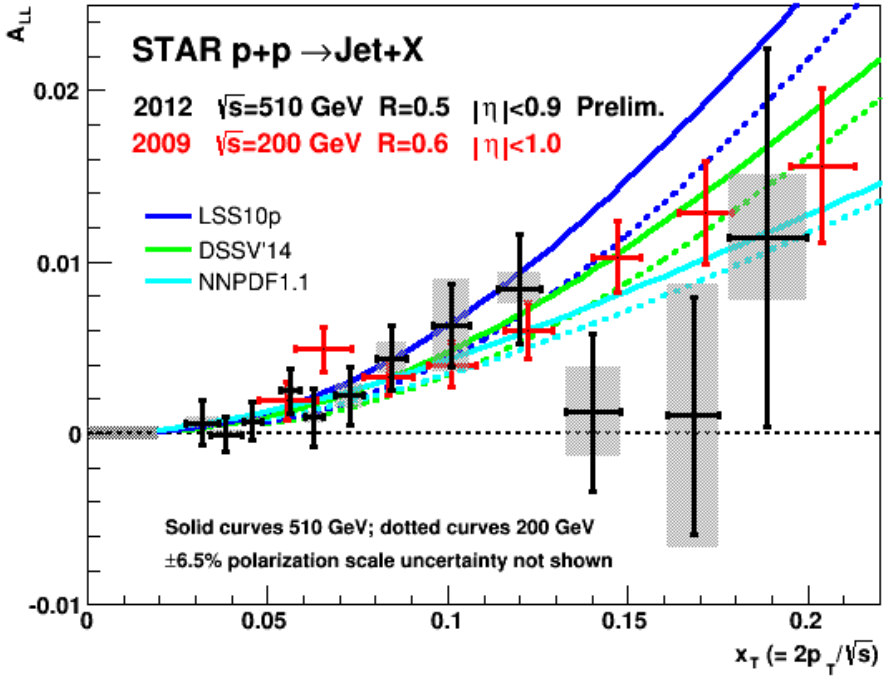


- Anti k_T algorithm *JHEP 0804 (2008) 063*
  - Sequential clustering algorithm
  - Infrared and collinear safe by design
- Jet and Dijet analyses
  - Anti k_T algorithm
  - R = 0.5 – 0.6
- Triggers used:
  - Jet Patch Triggers: JP0, JP1, JP2

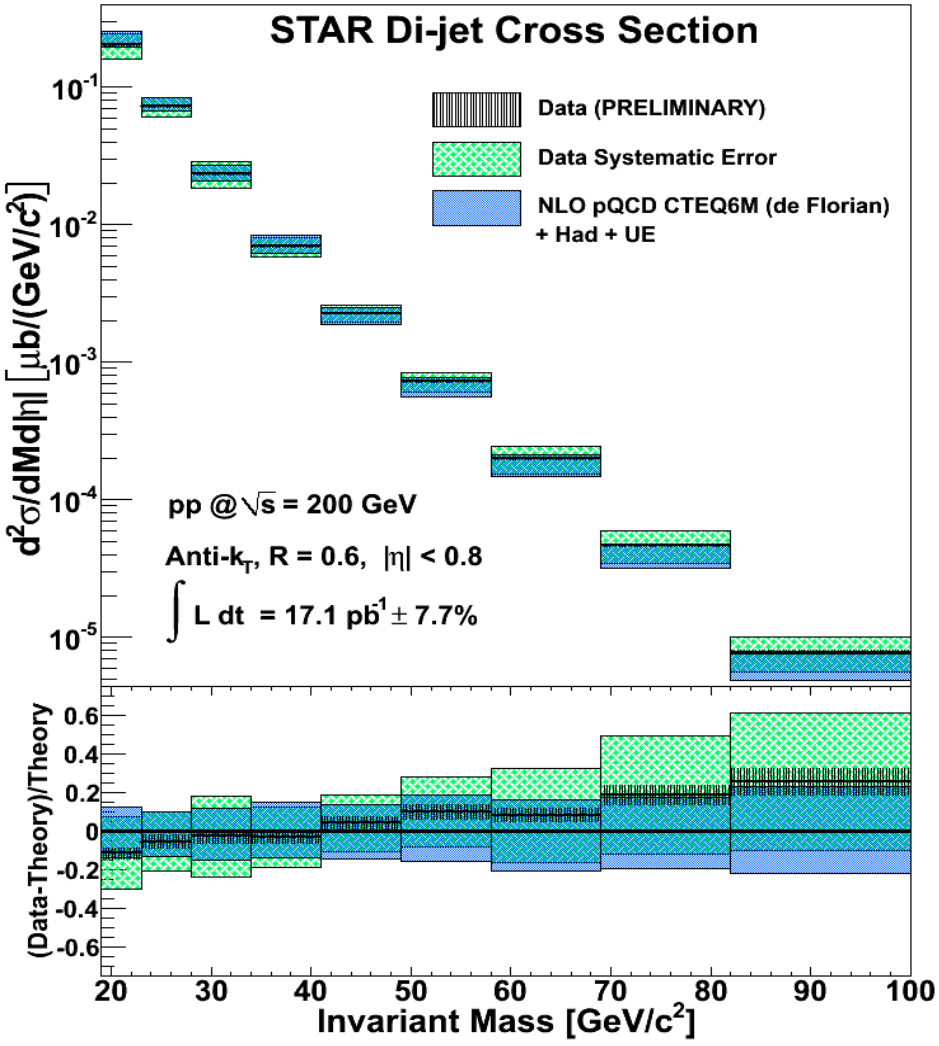
Inclusive Jet Results

arXiv:1512.05400





Dijet Results

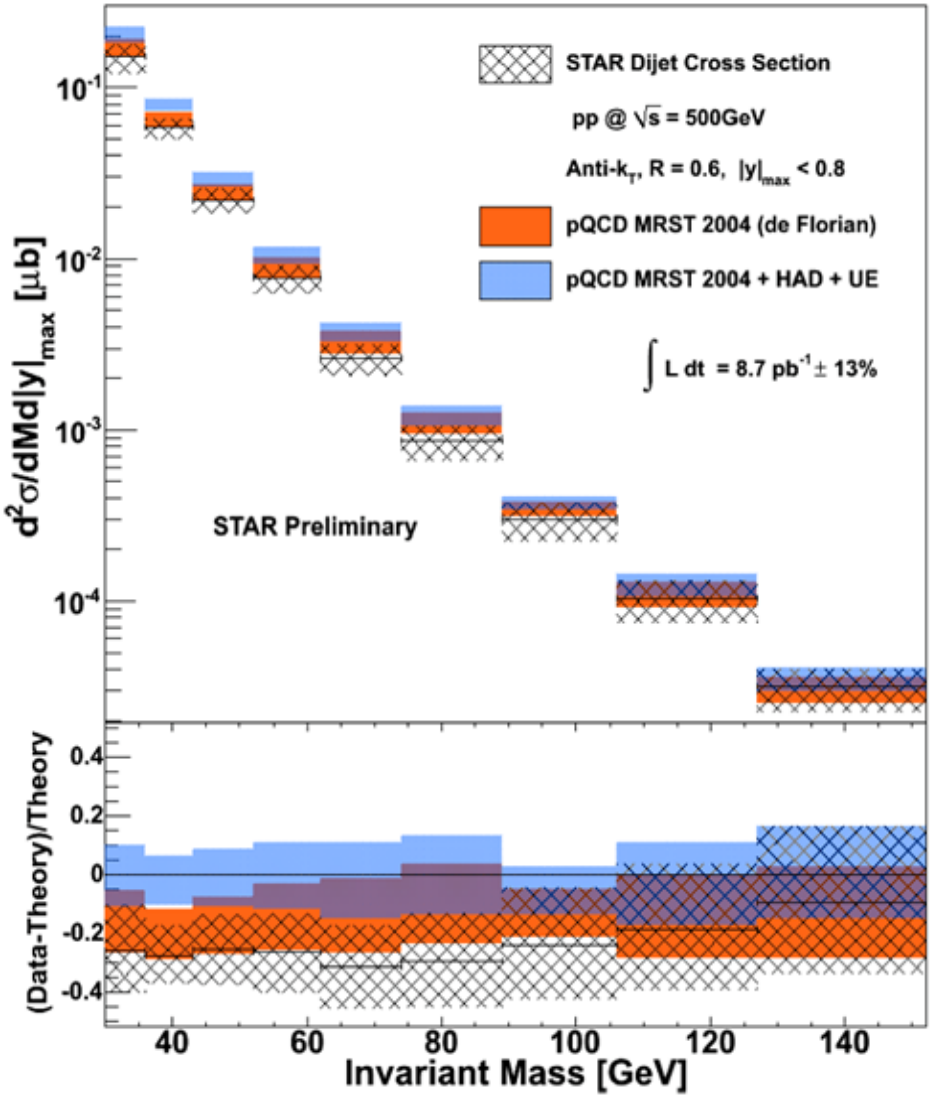


Dijet Analysis cuts

- Asymmetric p_T cut (8,6 GeV)
- Back-to-back cut
- Require one jet of the pair to point to a trigger jet patch
- $-0.8 < \eta_{\text{Physics}} < 0.8$
- Contribution from the calorimeters towards the total jet energy required to be less that 95%

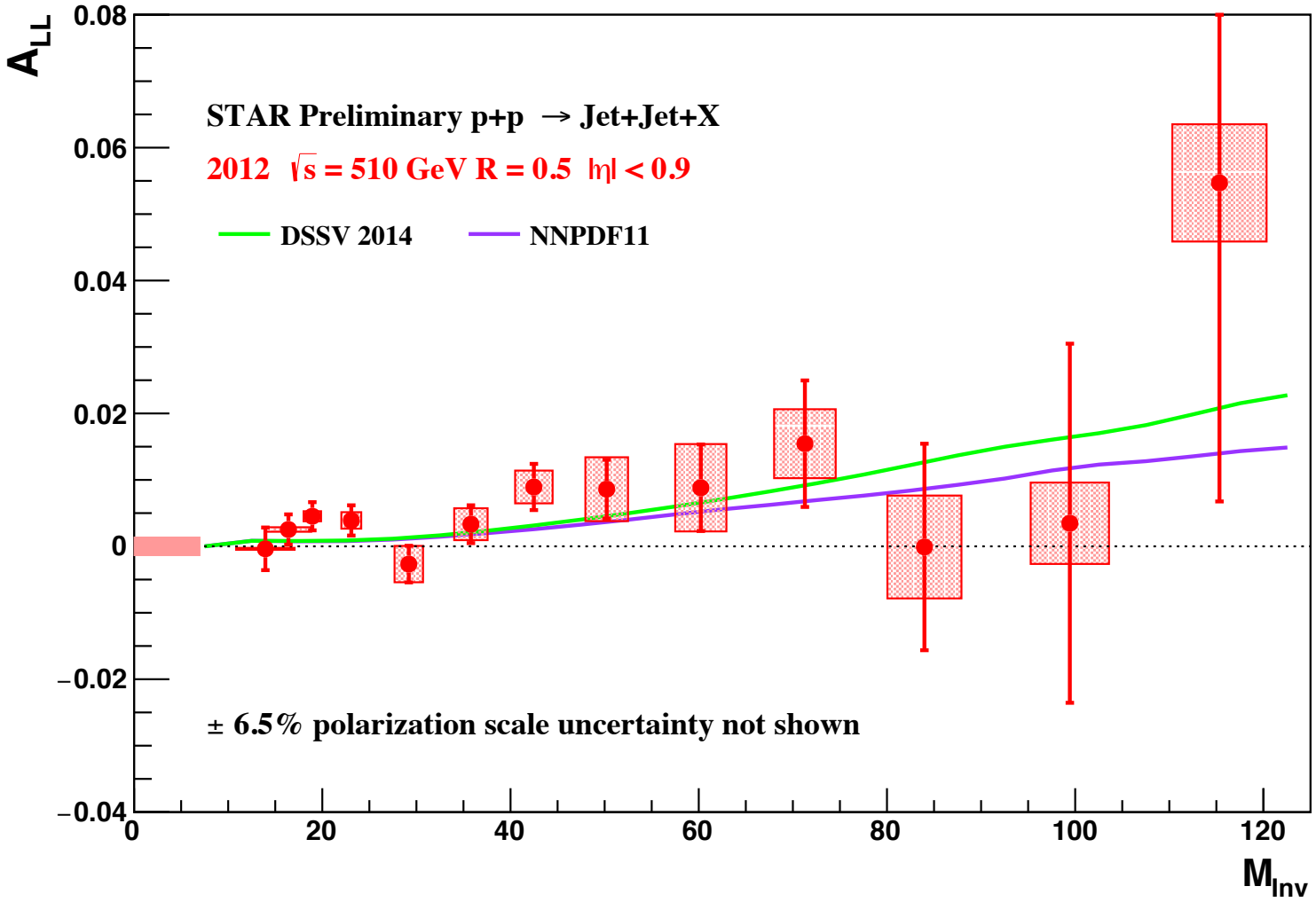
Dijets at 510 GeV

PoS (DIS 2013) 215



Dijet A_{LL} at 510 GeV

arXiv:1608.01332



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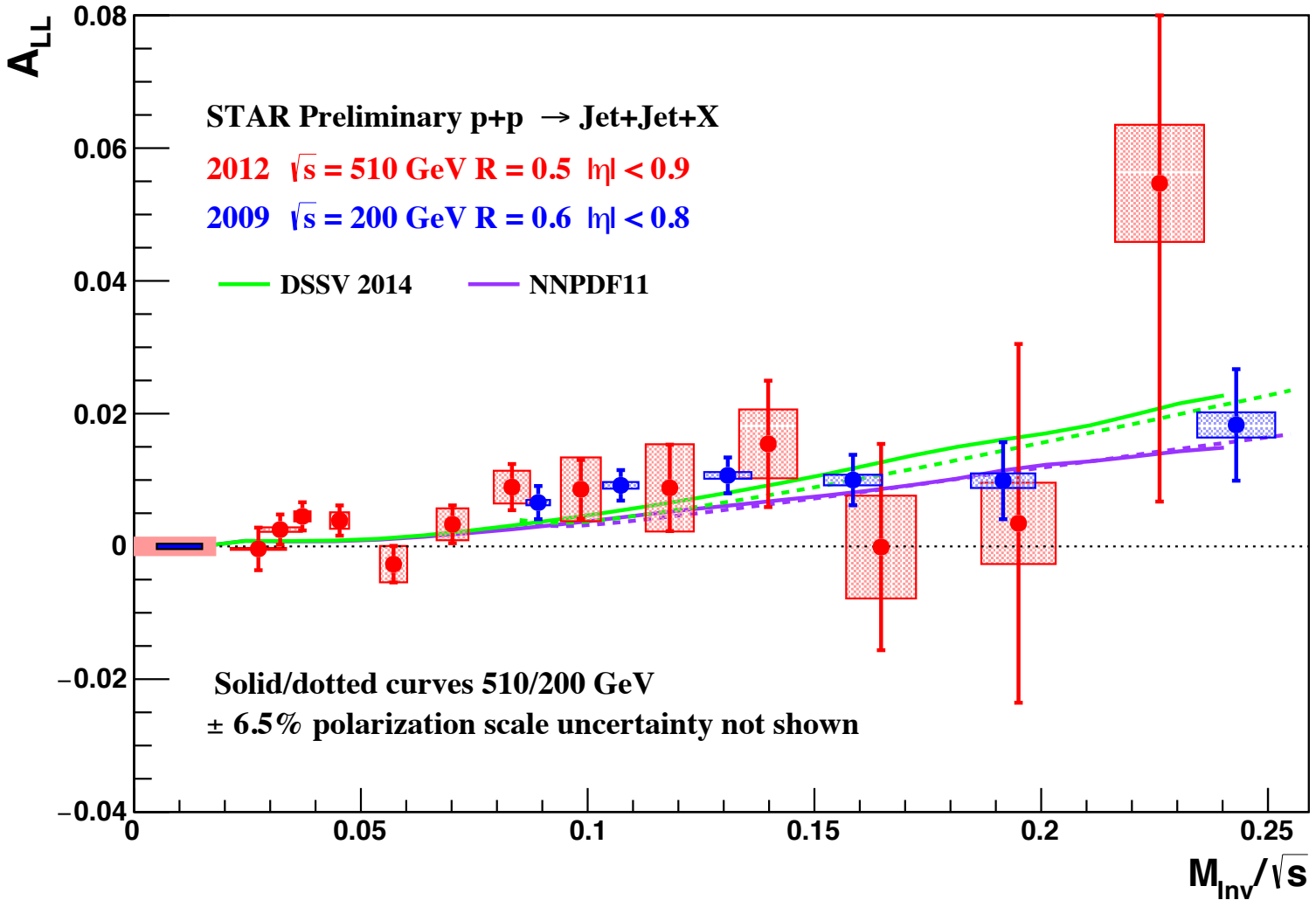
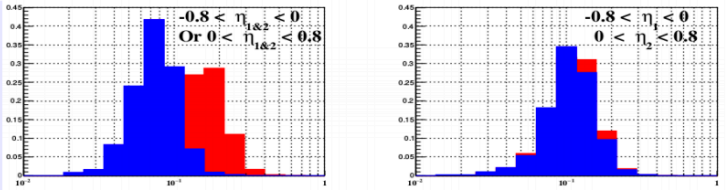
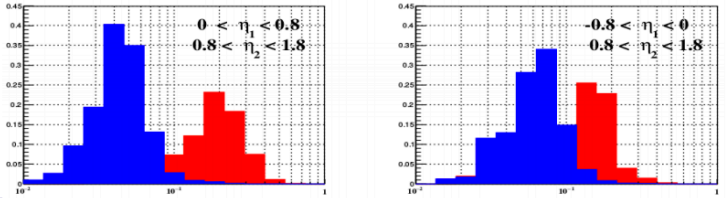
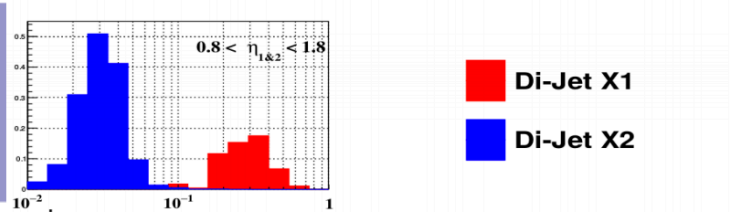


2009 Forward Dijet A_{LL}

Pushing dijets forward into the endcap allows us to probe lower x range

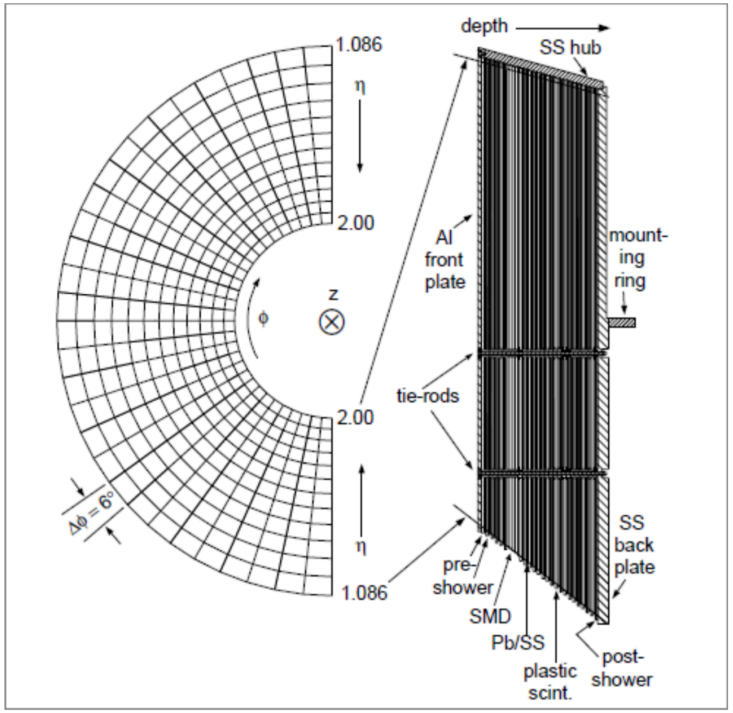
Dijet Configuration	Minimum X1/X2 ($\sqrt{s}$ = 200 GeV)
Barrel-Barrel	
Barrel-Endcap	
Endcap-Endcap	

Note: Ting Lin will show the first fully reconstructed dijet A_{LL} in the forward region with the endcap detector - see Thursday poster session!

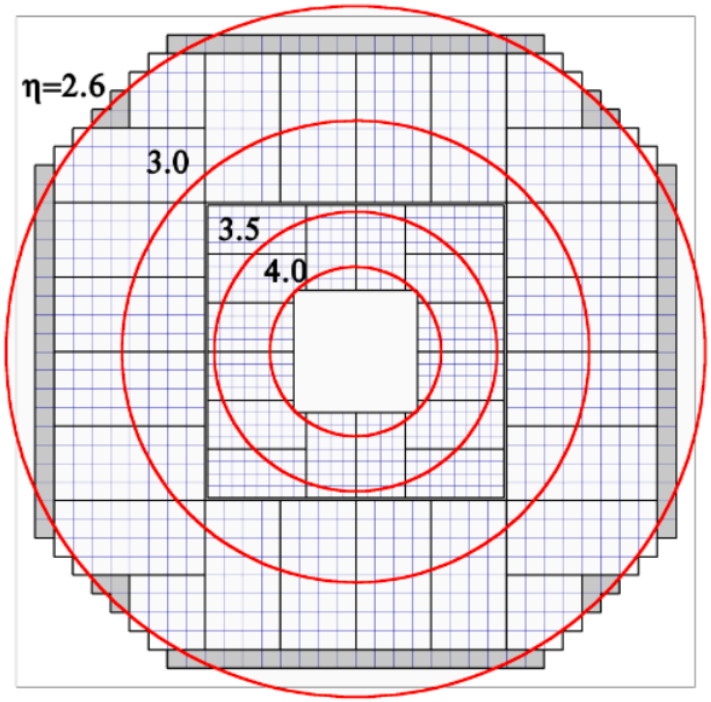
Pions at STAR

- Looking at Jets
  - Tracking only extends to $\eta \sim 1.4$
  - Challenge to look at jets in the forward region
  - Alternative → looking at pions

EEMC

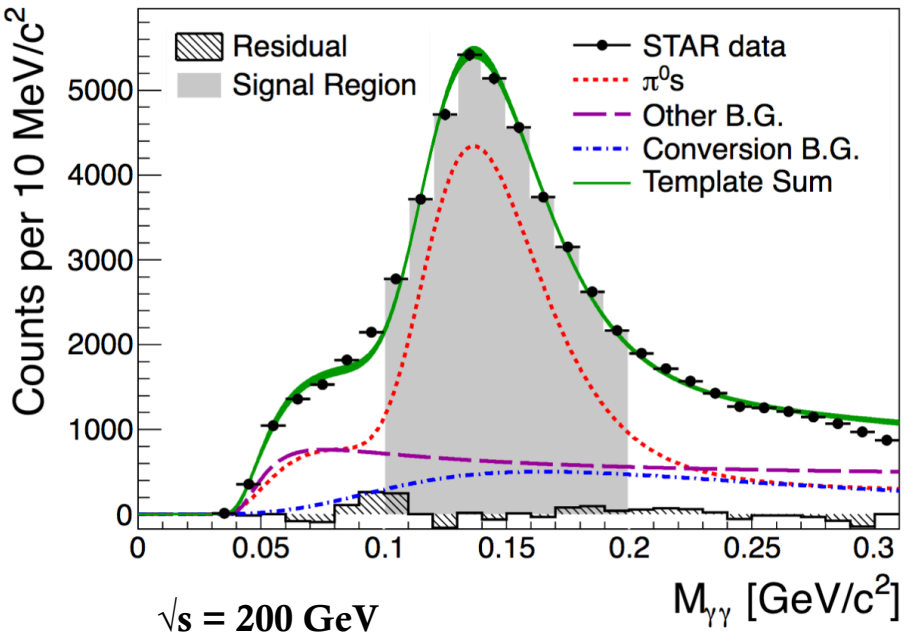


FMS



π^0 at STAR

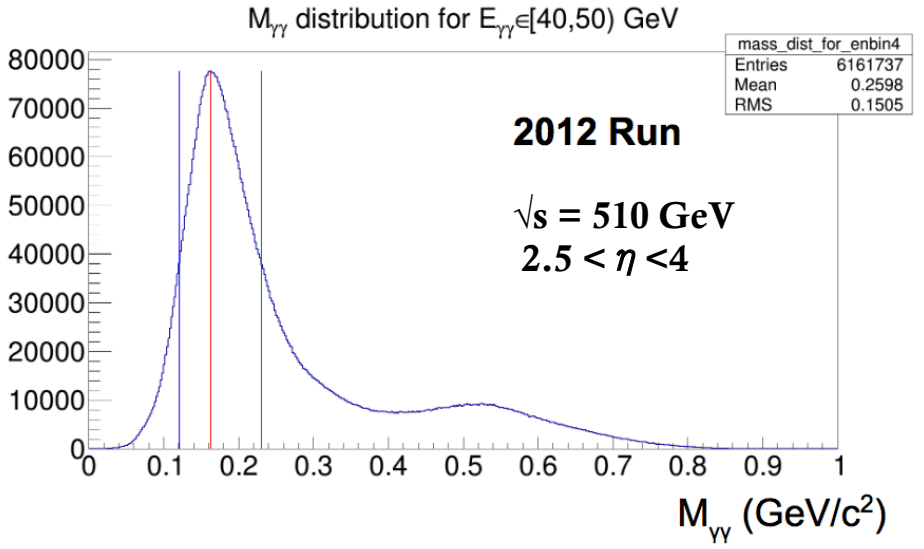
EEMC

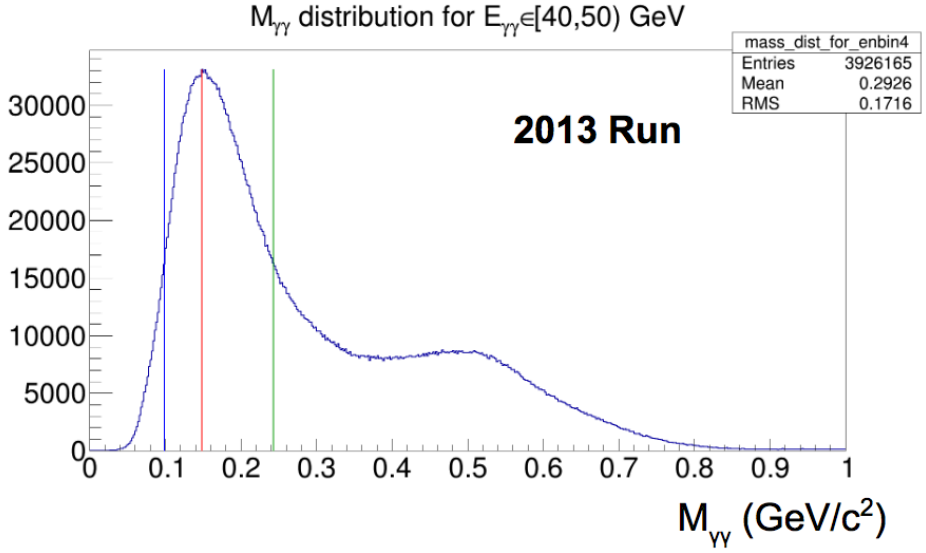


$\sqrt{s}$ = 200 GeV
$0.8 < \eta < 2$

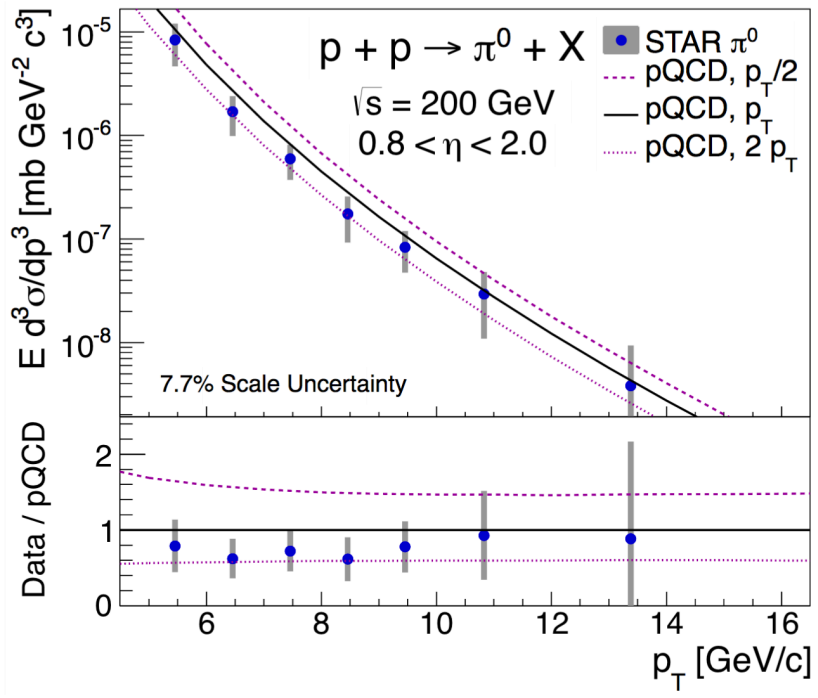
Phys. Rev. D 89, 012001 (2014)

FMS





EEMC π^0 Results



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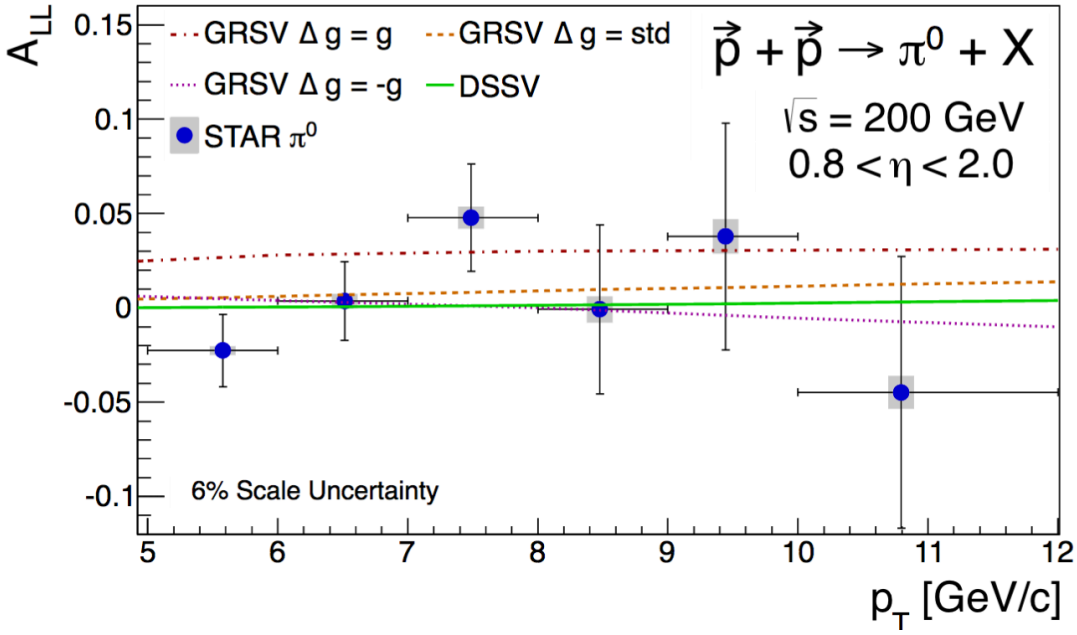
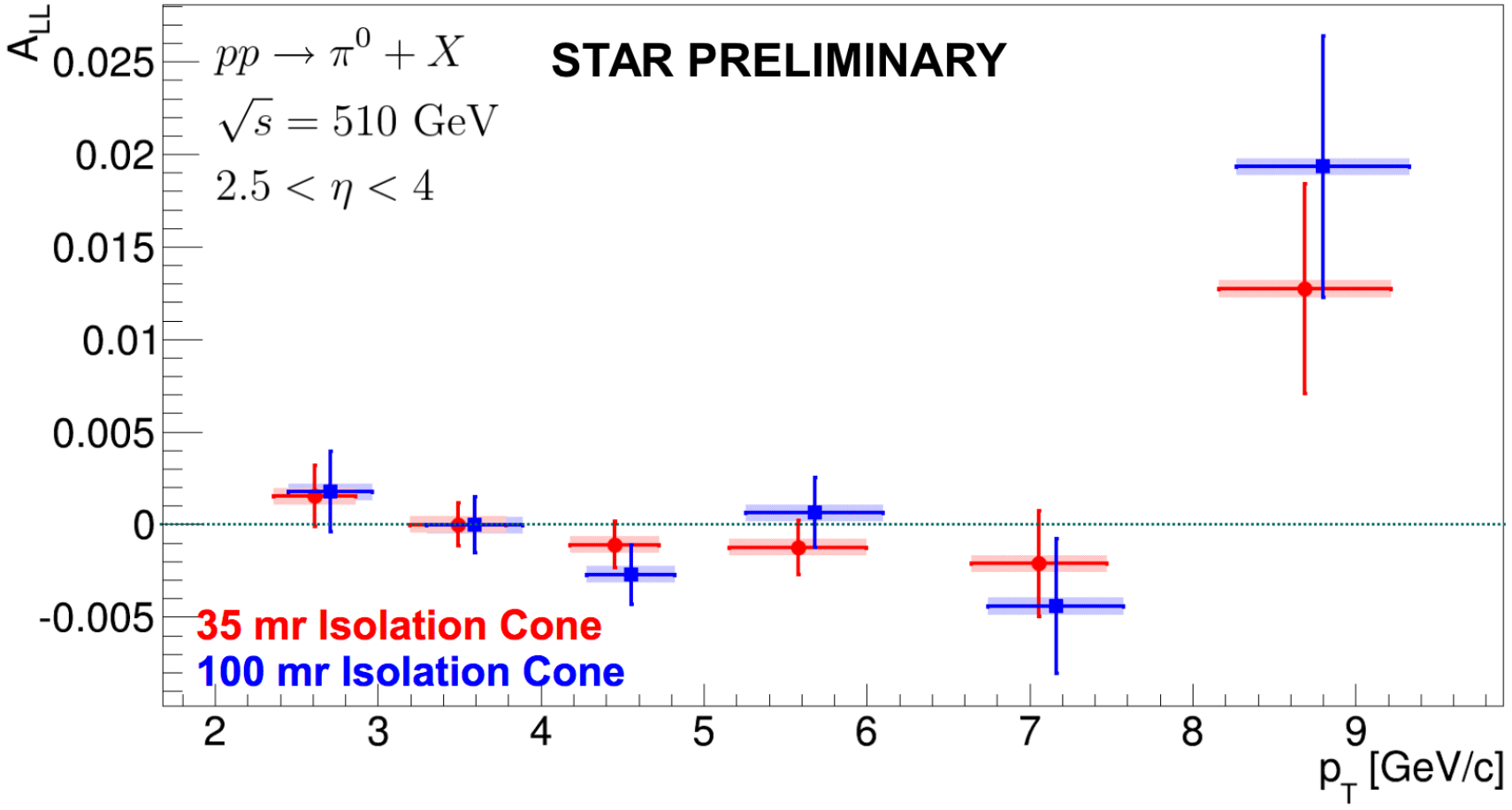


FMS π^0 Results

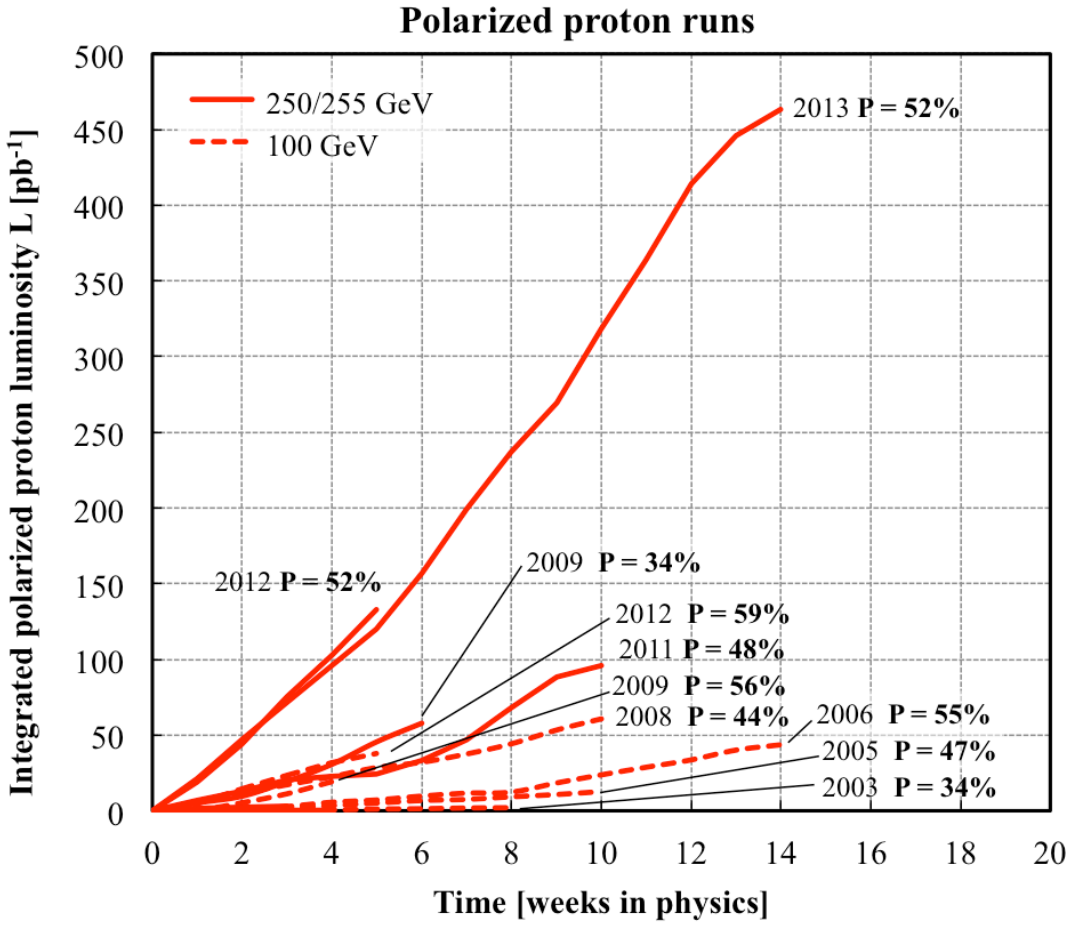
Int.J.Mod.Phys.Conf.Ser. 40 (2016) 1660024



Conclusion

- RHIC's highly polarized proton beams have facilitated a robust spin program at STAR. STAR utilizes its wide acceptance at mid-rapidity for jet reconstruction and dedicated calorimeters at forward rapidities for pion reconstruction.
- STAR inclusive jet measurements at $\sqrt{s}$ = 200 GeV have provided the first evidence of a significant polarized gluon distribution for $x > 0.05$.
- By extending these measurements to higher $\sqrt{s}$ and more forward regions it is possible to constrain the $x < 0.05$ region. Dijet observables allow for reconstruction of the partonic kinematics at leading order.
- In 2013 STAR collected 3 times more data, of longitudinally polarized proton collisions at $\sqrt{s}$ = 510 GeV.

Stay Tuned!



Thank You