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Measurements of single-spin asymmetries, A_L for $W^{\pm}$ boson production in longitudinally polarized proton-proton collisions at STAR

- Motivation
- Theoretical Aspect
- Experimental Aspect
- Analysis
- Results
- Summary

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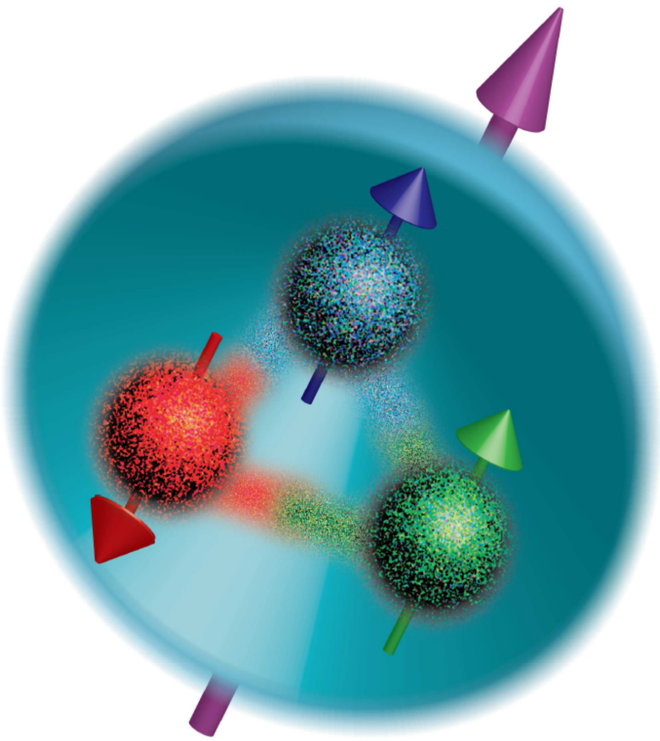
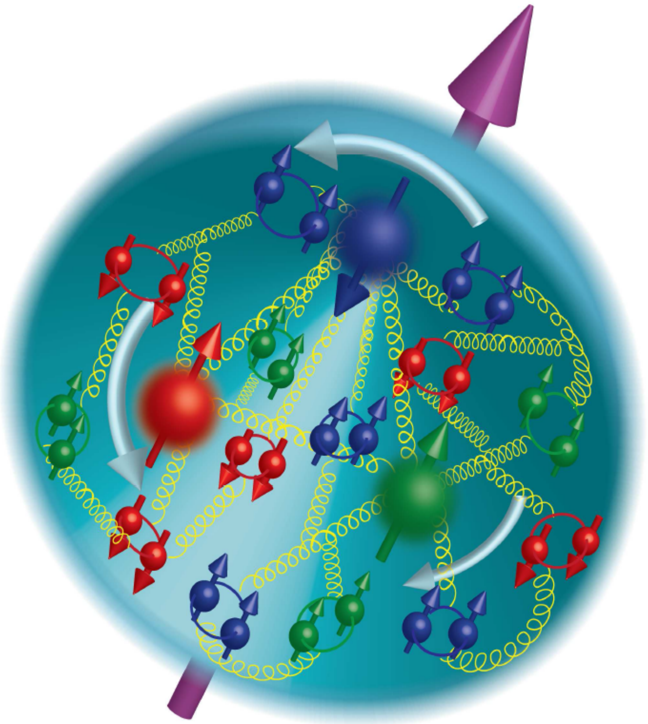
MOTIVATION : Proton Helicity Structure



1989 : EMC : DIS

$$\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14$$

"Spin Crisis"



Simple Quark Models

$$\frac{1}{2} = \frac{1}{2}(\Delta u_v + \Delta d_v)$$

Gluons , Sea quarks are polarized.

Parton orbital angular momentum.

Current Understanding

$$\langle S_z \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$$

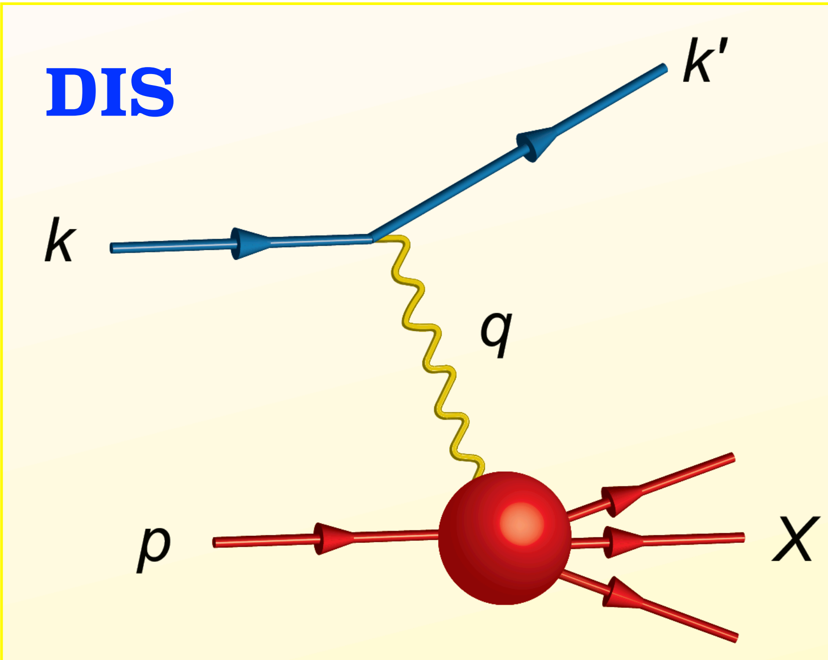
Nucl. Phys. B337, 509 (1990)

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

Helicity PDF

$$\Delta f(x,Q^2) \equiv f^+(x,Q^2) - f^-(x,Q^2)$$

MOTIVATION : Current Knowledge of PDFs



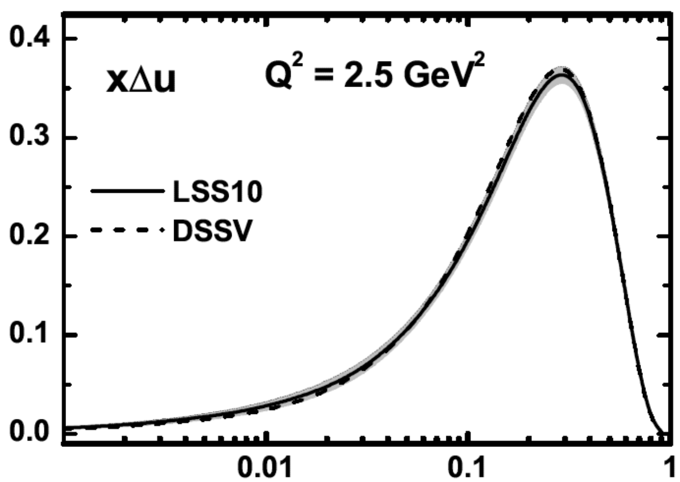
$$\Delta\Sigma = \int (\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s})dx$$

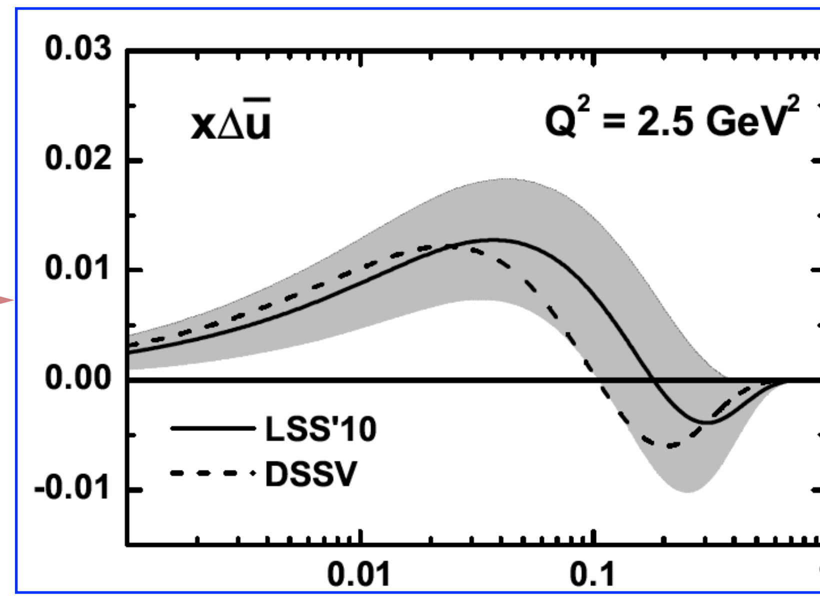
DIS

- Well measured!
- Not sensitive to flavor separation!

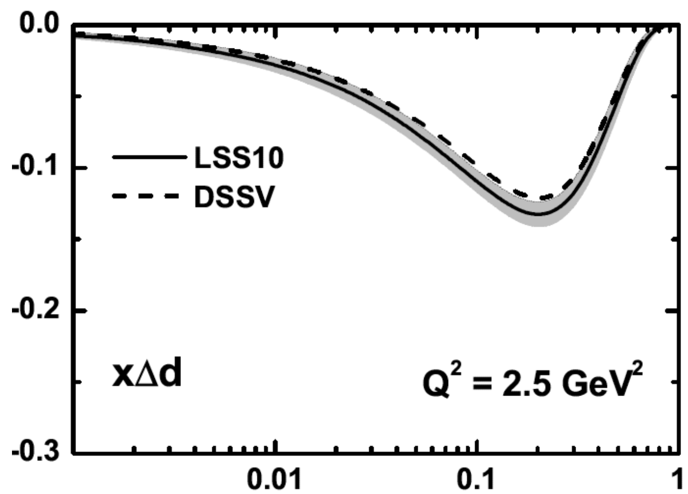
SIDIS

- FF's use to tag flavor!
- Flavor separation / quark, anti-quark separation!
- But large uncertainties in FFs.

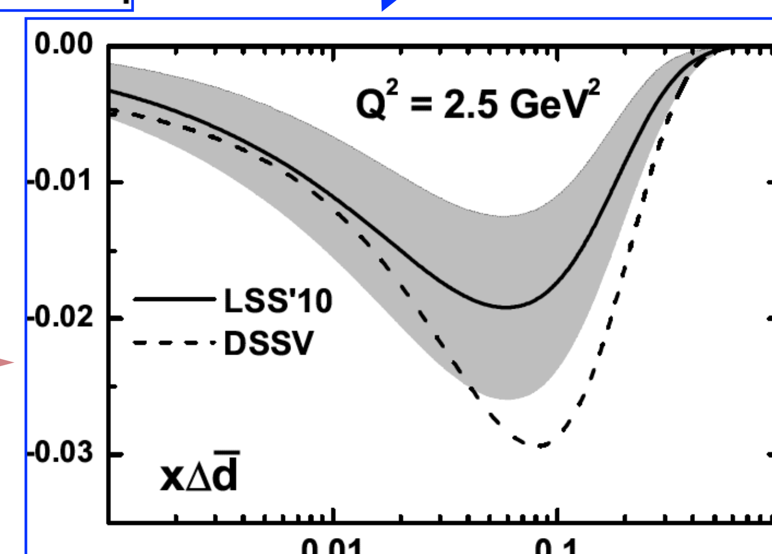




Large uncertainties w.r.t quark PDFs



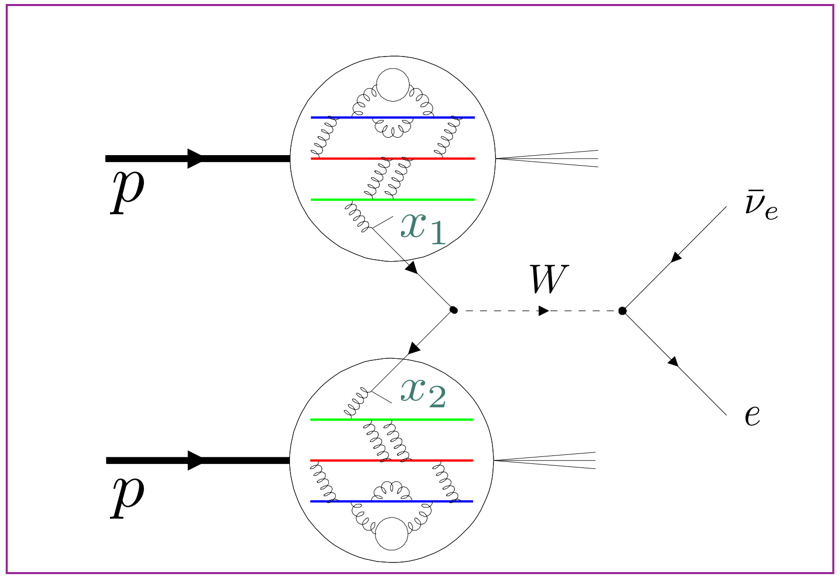
Phys. Rev. D 82, 114018 (2010)



Theoretical Aspects - W A_L

- Probing quark / anti-quark (sea) flavor structure using W boson production at RHIC

W production in p+p,

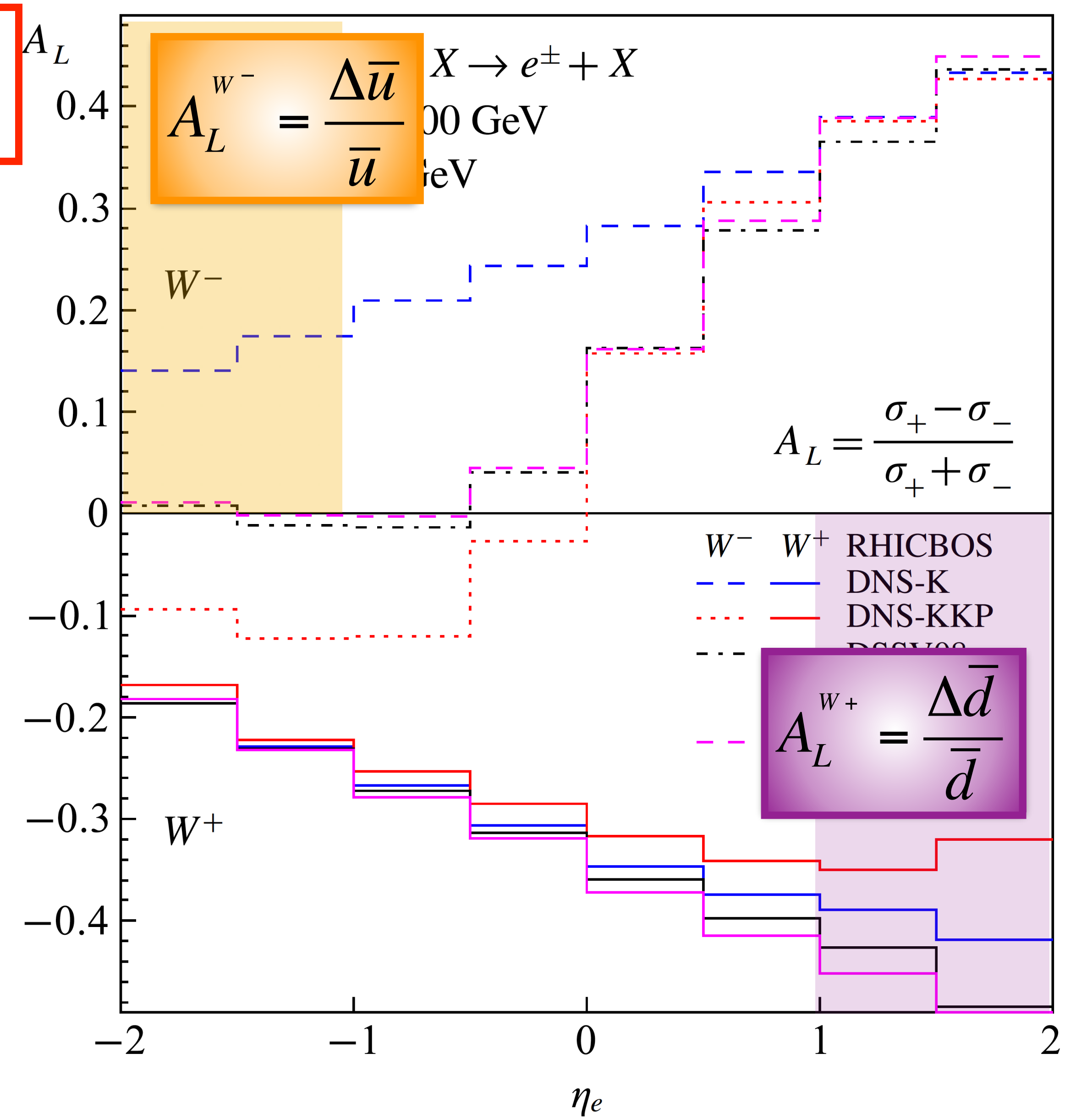


$$A_L = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

$$A_L^{e^-} \approx \frac{\int_{\otimes(x_1,x_2)} [\Delta\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 - \Delta d(x_1)\bar{u}(x_2)(1+\cos\theta)^2]}{\int_{\otimes(x_1,x_2)} [\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 + d(x_1)\bar{u}(x_2)(1+\cos\theta)^2]}$$

$$< x_{1,2} > \sim \frac{M_W}{\sqrt{s}} e^{\pm\eta_e/2}$$

$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$



In comparison to SIDIS,

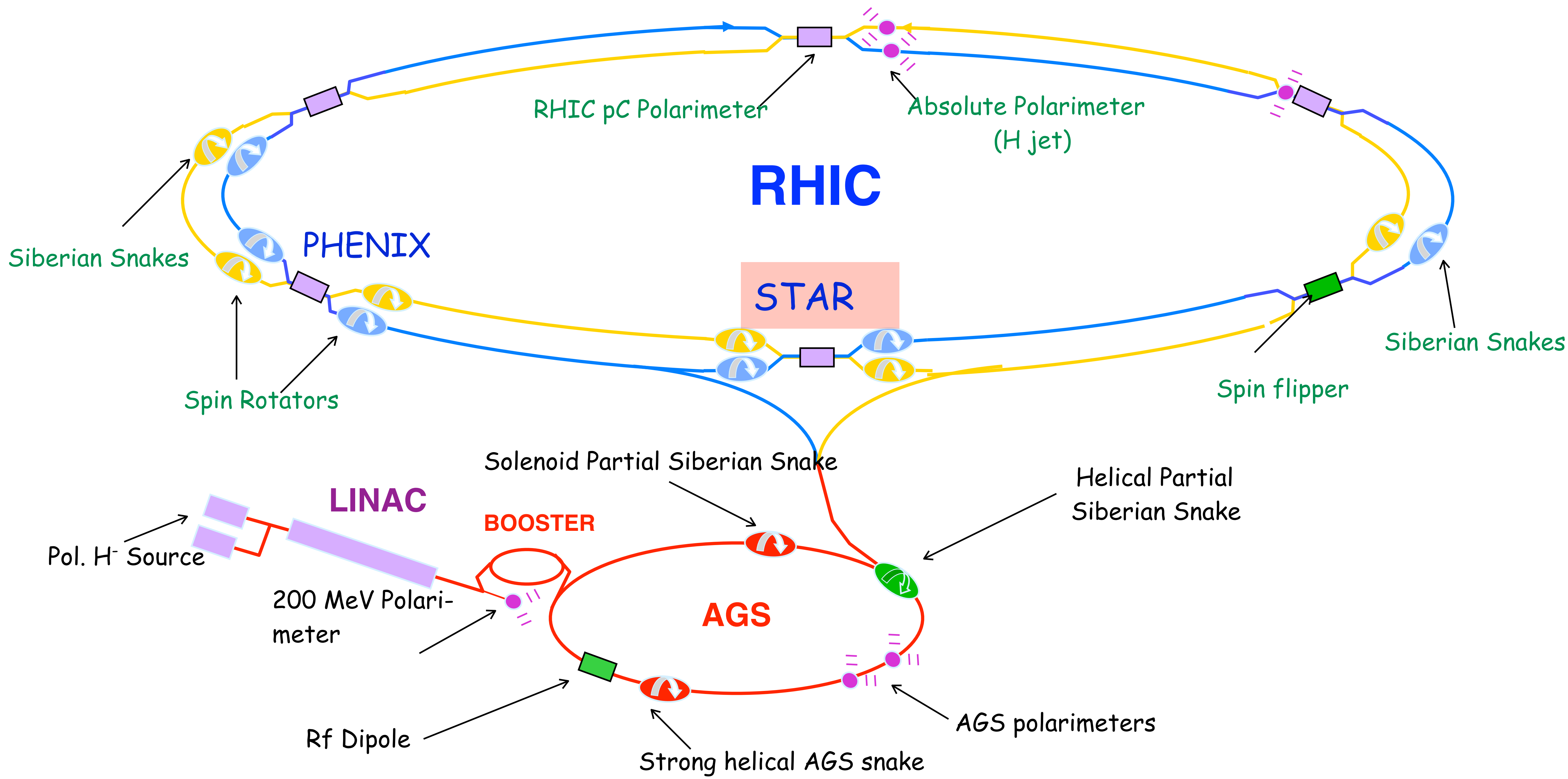
- Direct sensitivity to ū, đ.
- Large Q^2 defined by W mass (more reliable perturbative calculation / higher twist effects unimportant!).
- Parity violating coupling gives rise to single-spin asymmetry which is directly related to anti-quark helicity PDFs.
- Free of FFs.
- Easy detection via decay leptons.

EXPERIMENTAL ASPECT - RHIC

- **RHIC : Relativistic Heavy Ion Collider**

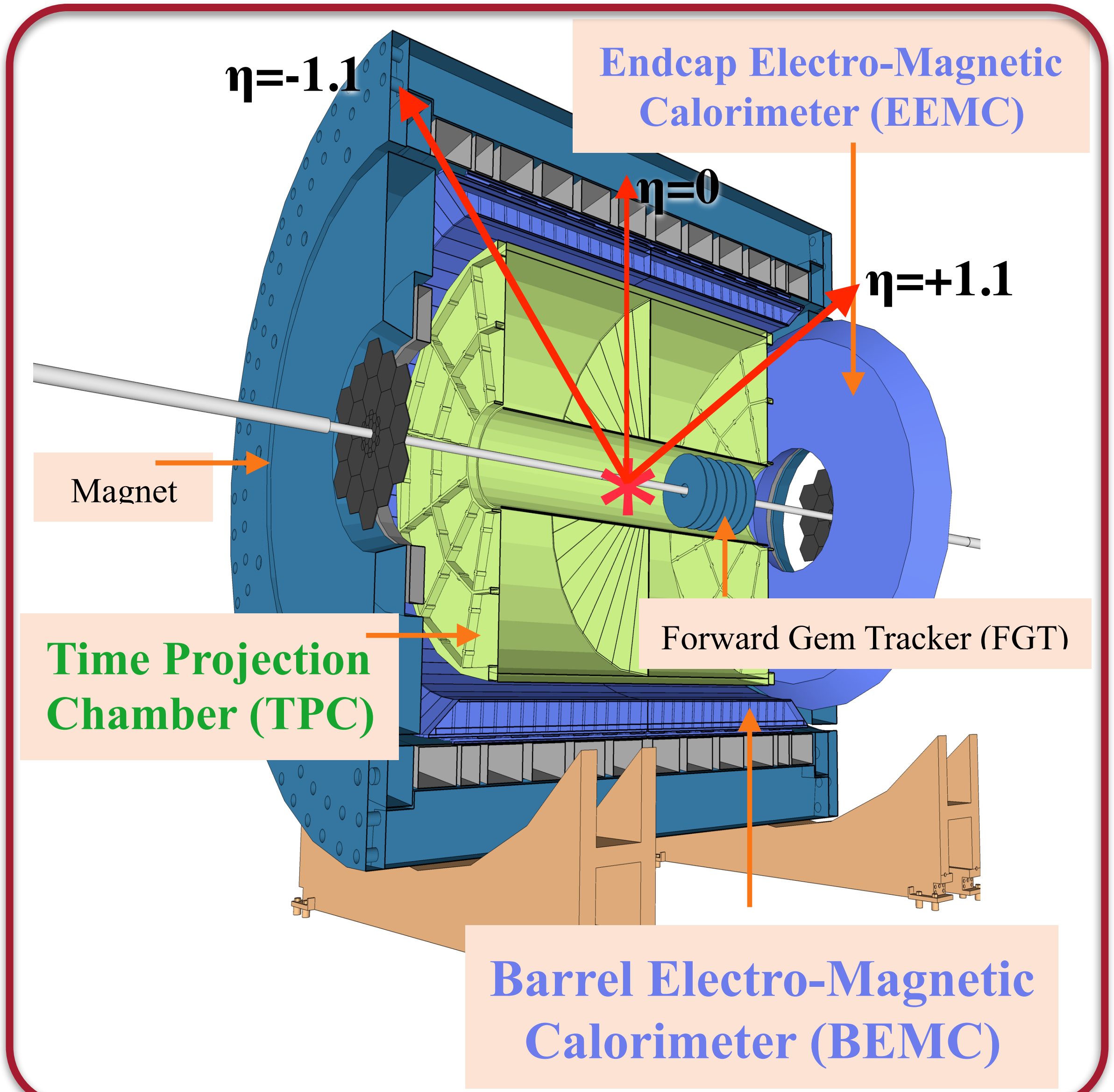
The World's first polarized hadron collider!

Polarization direction varies from bunch to bunch. Spin pattern changes from fill to fill. Spin rotators provide choice of spin orientation.



EXPERIMENTAL ASPECT - STAR

- **STAR : Solenoidal Tracker At RHIC**

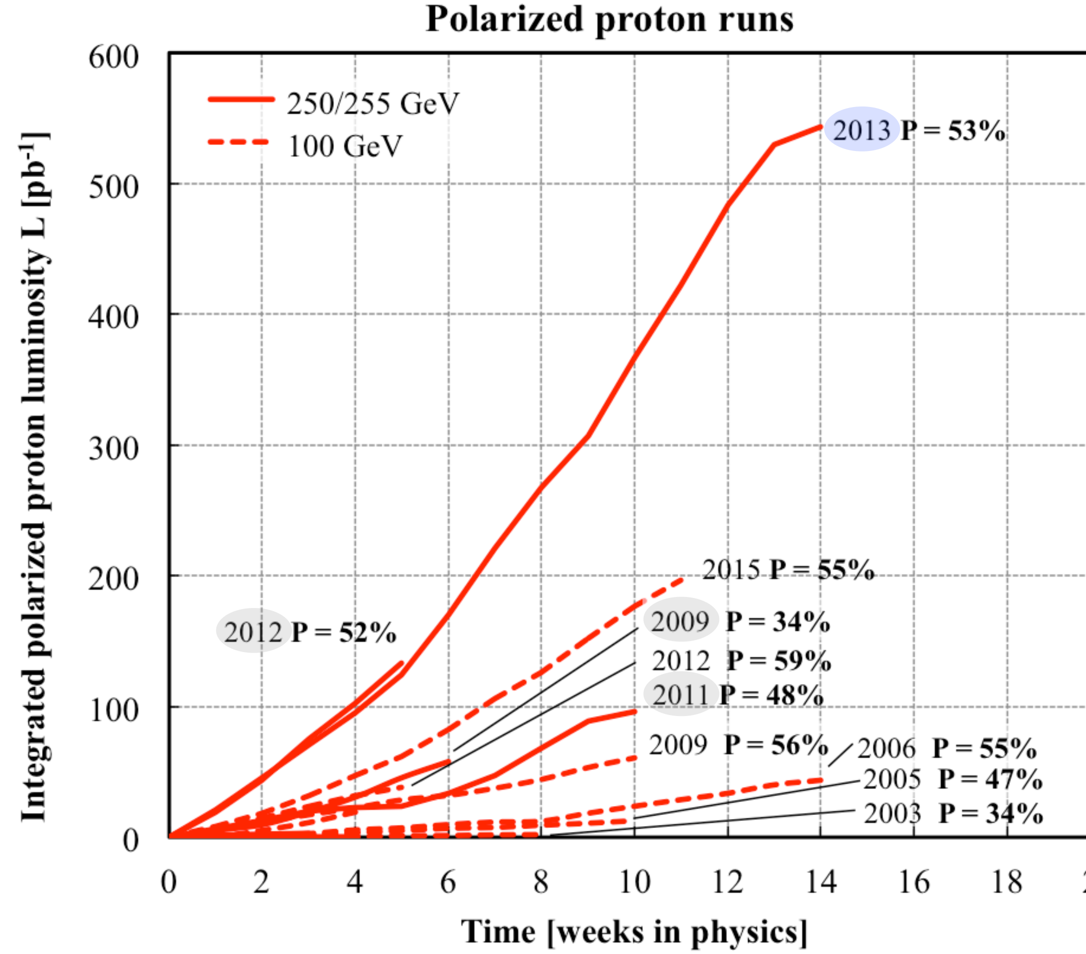


TPC	: $-1.3 < \eta < +1.3$
BEMC	: $-1.0 < \eta < +1.0$
EEMC	: $+1.1 < \eta < +2.0$
FGT	: $+1.0 < \eta < +2.0$

TPC: Charged particle tracking

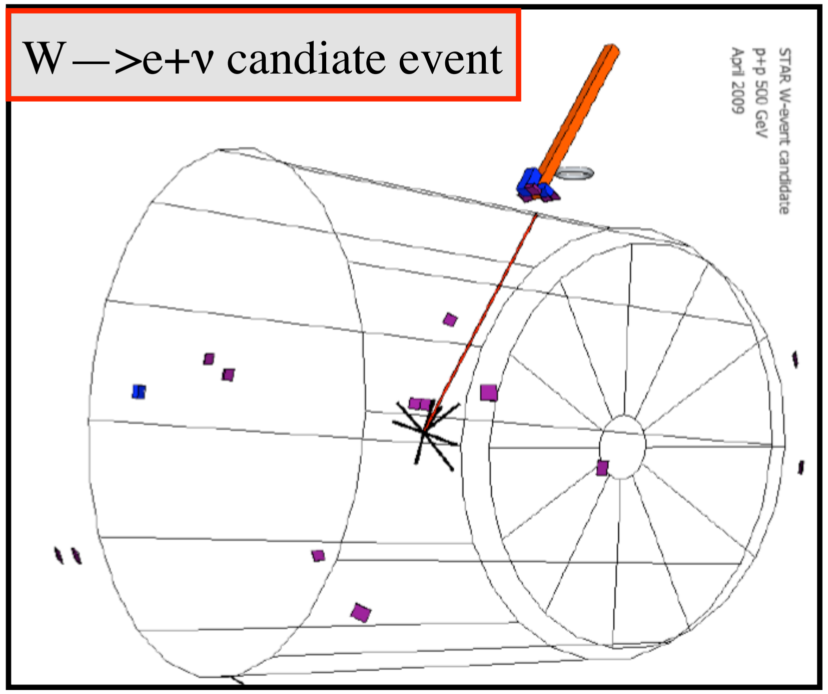
BEMC, EEMC: EM Calorimetry

RHIC p+p runs : Luminosity



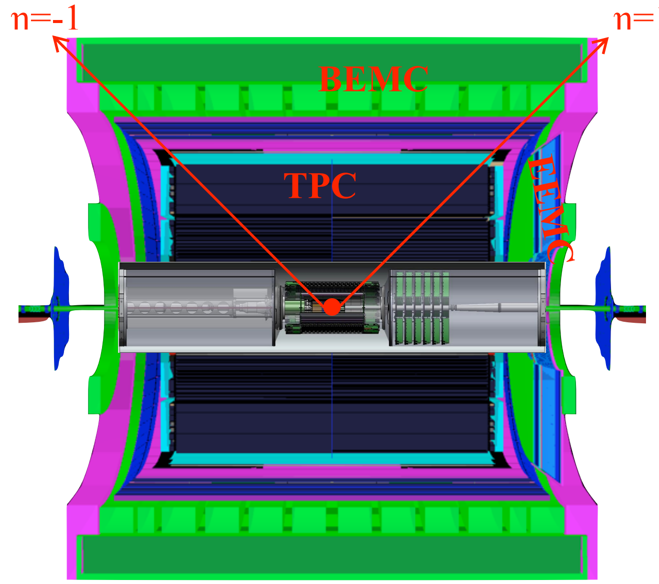
Run	L (pb^{-1})	P (%)	FOM (P^2L) (pb^{-1})
2009	12	0.38	1.7
2011	9.4	0.49	2.3
2012	77	0.56	24
2013	246.2	0.56	77.2

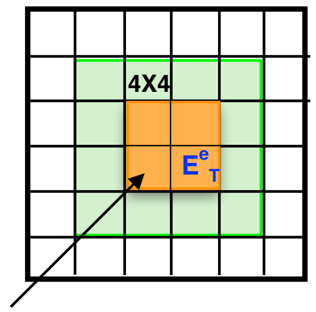
ANALYSIS -Mid rapidity STAR W selection criteria



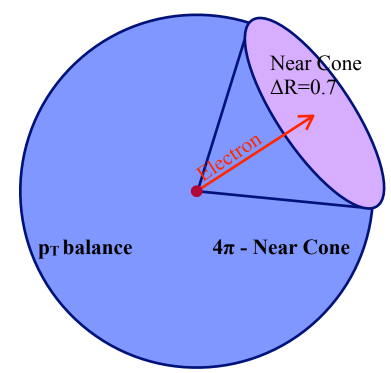
W—>e+ν candiate event

- Isolated high P_T track pointing to isolated EMC cluster.
- Large Imbalance in the reconstructed vector P_T sum in 4π due to undetected neutrino.

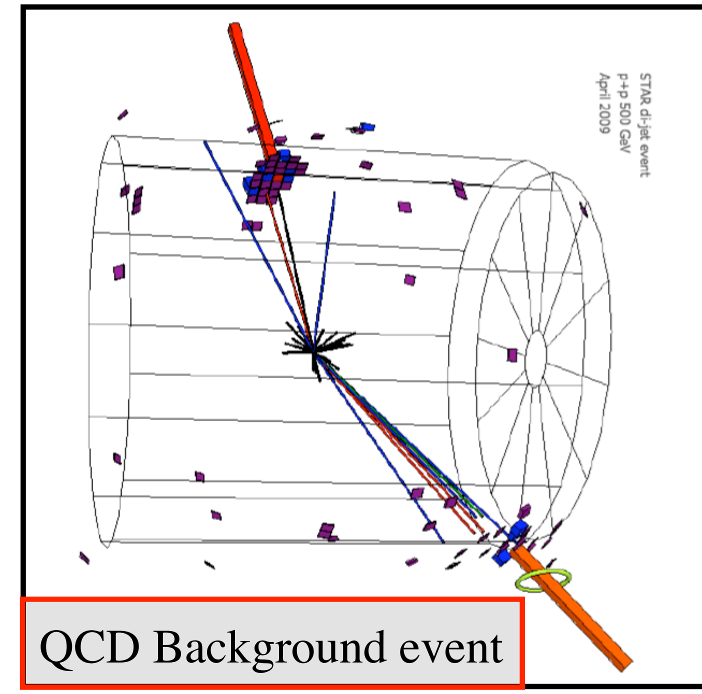




TPC track extrapolated
to Barrel colorimeter tower grid



Transverse plane view



QCD Background event

- Several tracks pointing to several EMC clusters.
- Vector P_T sum is balanced by the Jet opposite in azimuth.

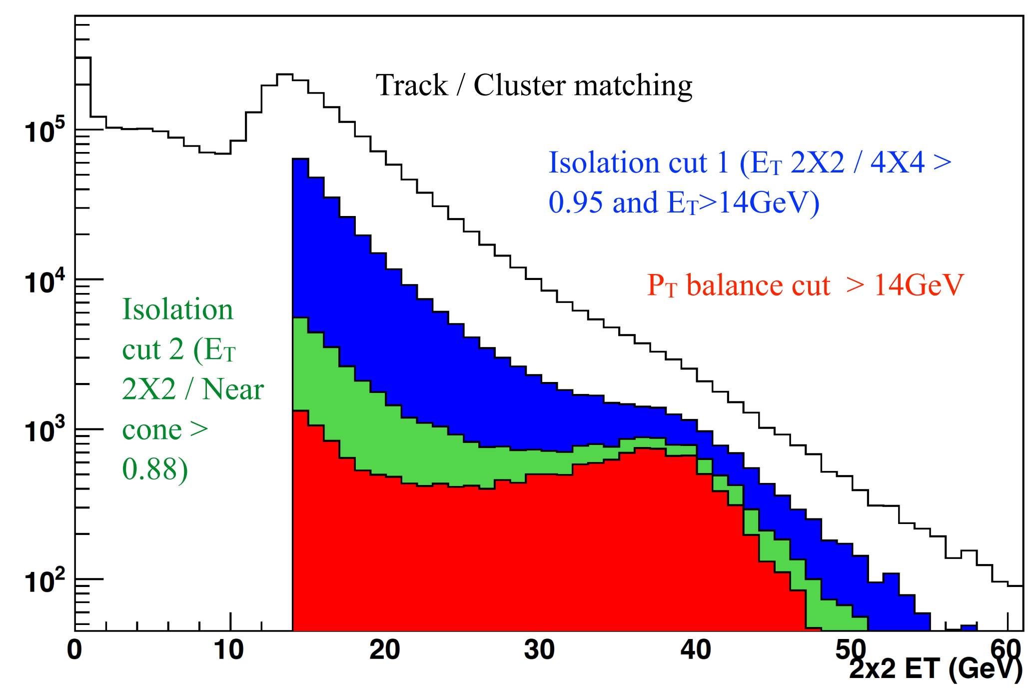
- Mid-rapidity STAR W selection criteria
  - Match P_T > 10 GeV track to BEMC cluster
  - Isolation ratio 1 / Isolation ratio 2
  - P_T-balance cut

E^e_T / E_T^{4X4} > 95%

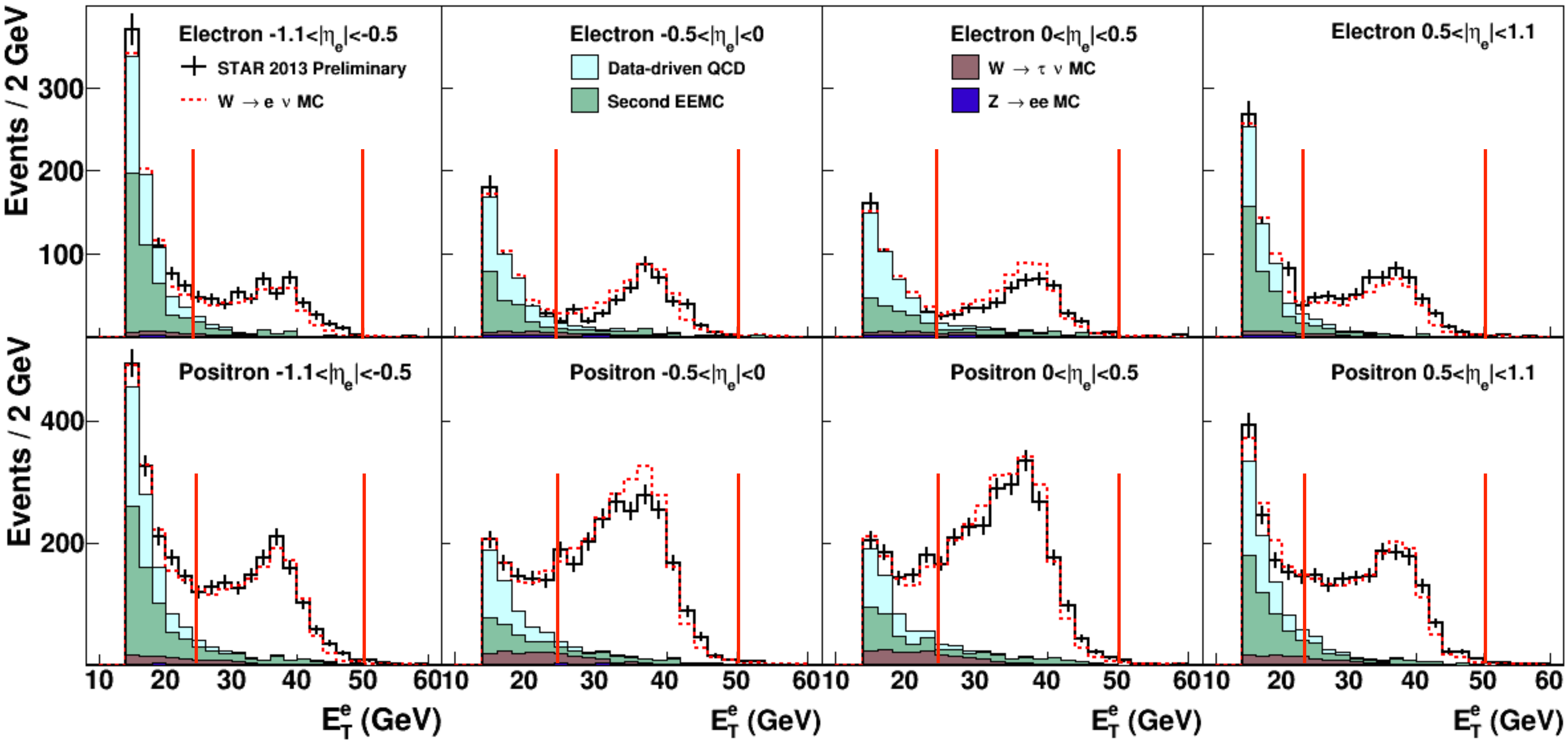
E^e_T / $E_T^{\Delta R<0.7}$ > 88%

$$\vec{p_T}^{bal} = \vec{p_T}^{e} + \sum_{\Delta R > 0.7} \vec{p_T}^{jets}$$

$$P_T\text{-balance}\cos(\phi) = \frac{\vec{p_T}^{e} \cdot \vec{p_T}^{bal}}{|\vec{p_T}^{e}|}$$



ANALYSIS -Mid rapidity STAR W BG Estimation



Primary Background

- Data-driven QCD : BG Events which satisfy $e^{+/-}$ candidate isolation cuts due to "jet" escape detection outside STAR acceptance , |η|>2.

- Second EEMC : due to "jet" escape detection at "non-existent" East EEMC, estimate based on "real" West EEMC

ElectroWeak Background

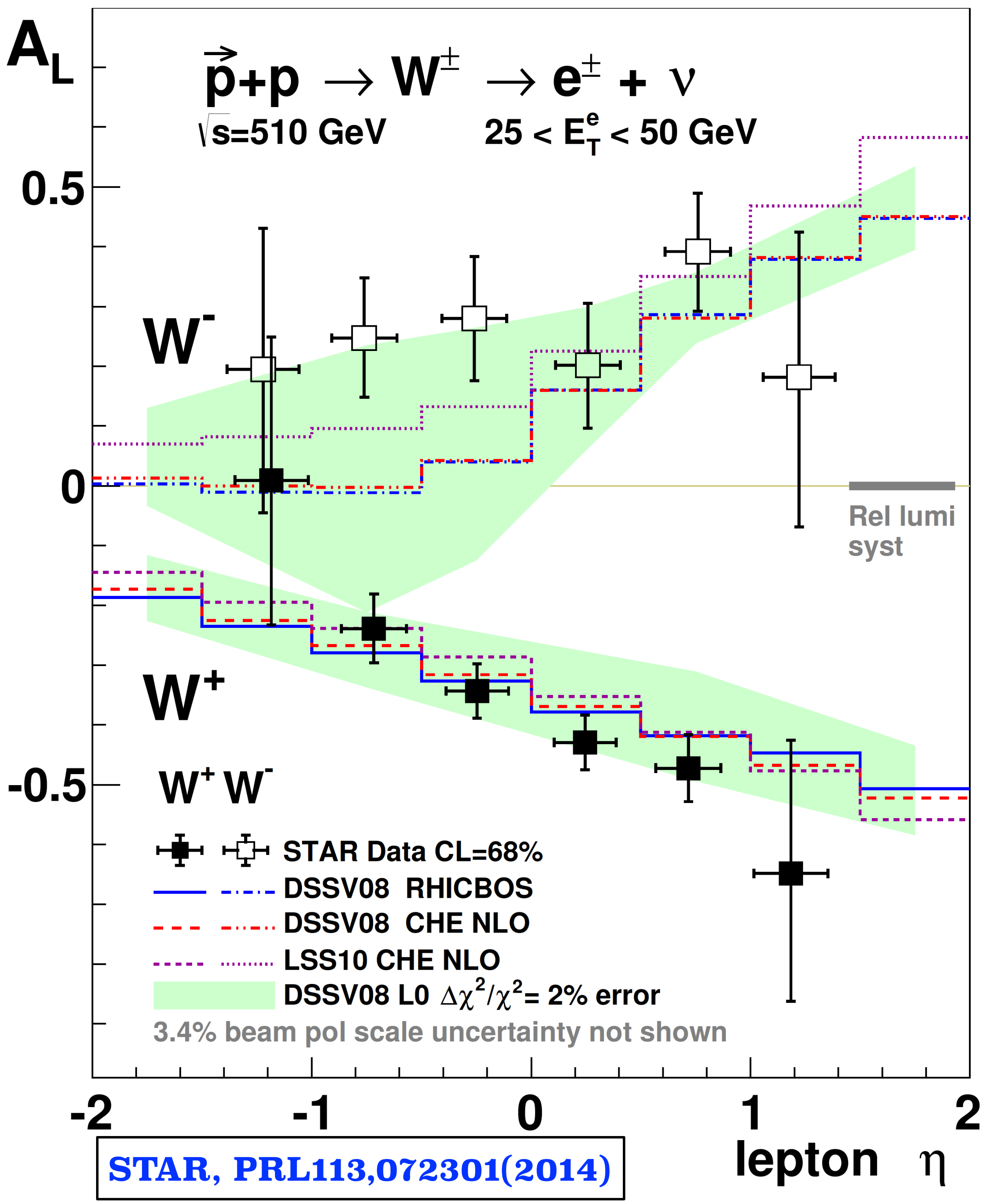
- Determine from MC simulation

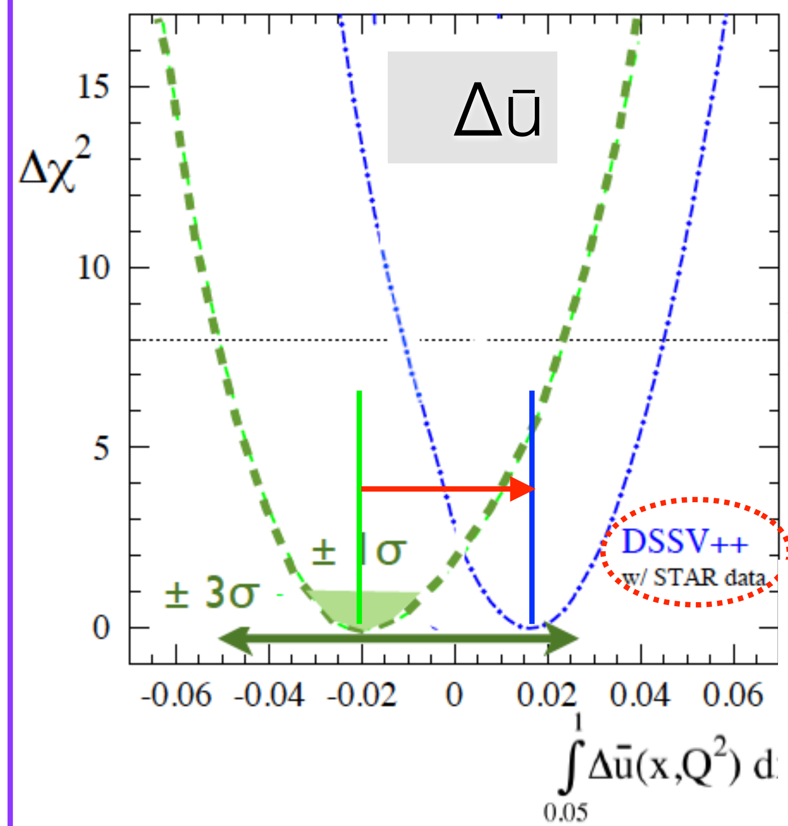
Z——> $e^+ + e^-$

W——> τ + v

RESULTS - W A_L - STAR 2011+2012 (published)

- STAR 2011 + 2012 W AL Published Results

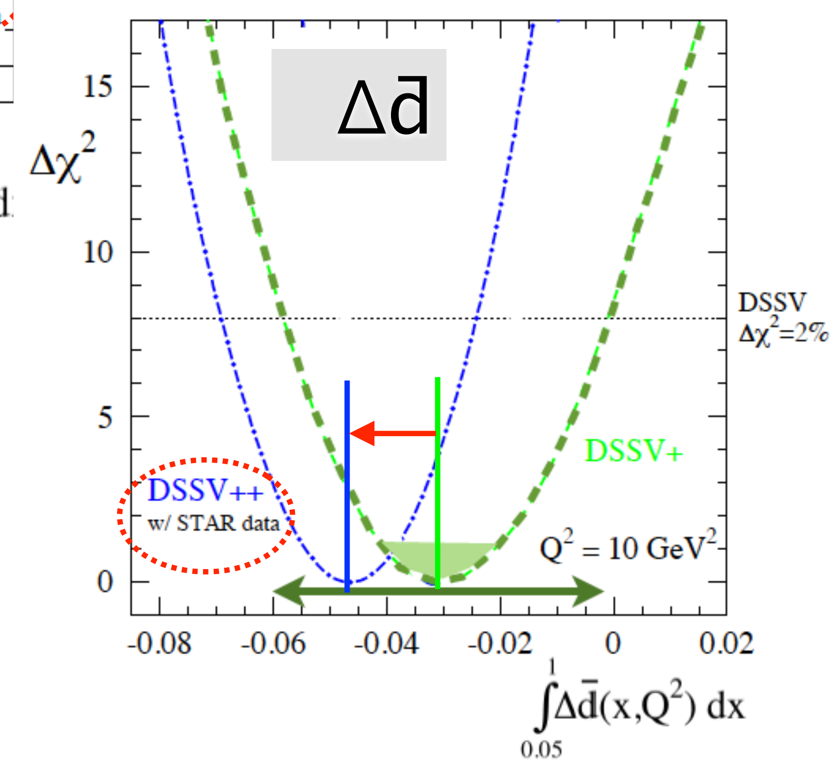




Impact on PDFs : DSSV

- Only DIS + SIDIS data
- DIS + SIDIS + STAR W A_L data

E.Aschenauer, et.al. arXiv:1304.0079



Significant shift of Δū central value from STAR W A_L data.

- A_L for W^+ is **consistent with theoretical predictions** constrained by polarized SIDIS data.
- A_L for W^- is larger than the prediction for $\eta_e < 0$,which suggest large Δū.
- Indication of positive Δū at 0.05<x<0.2.

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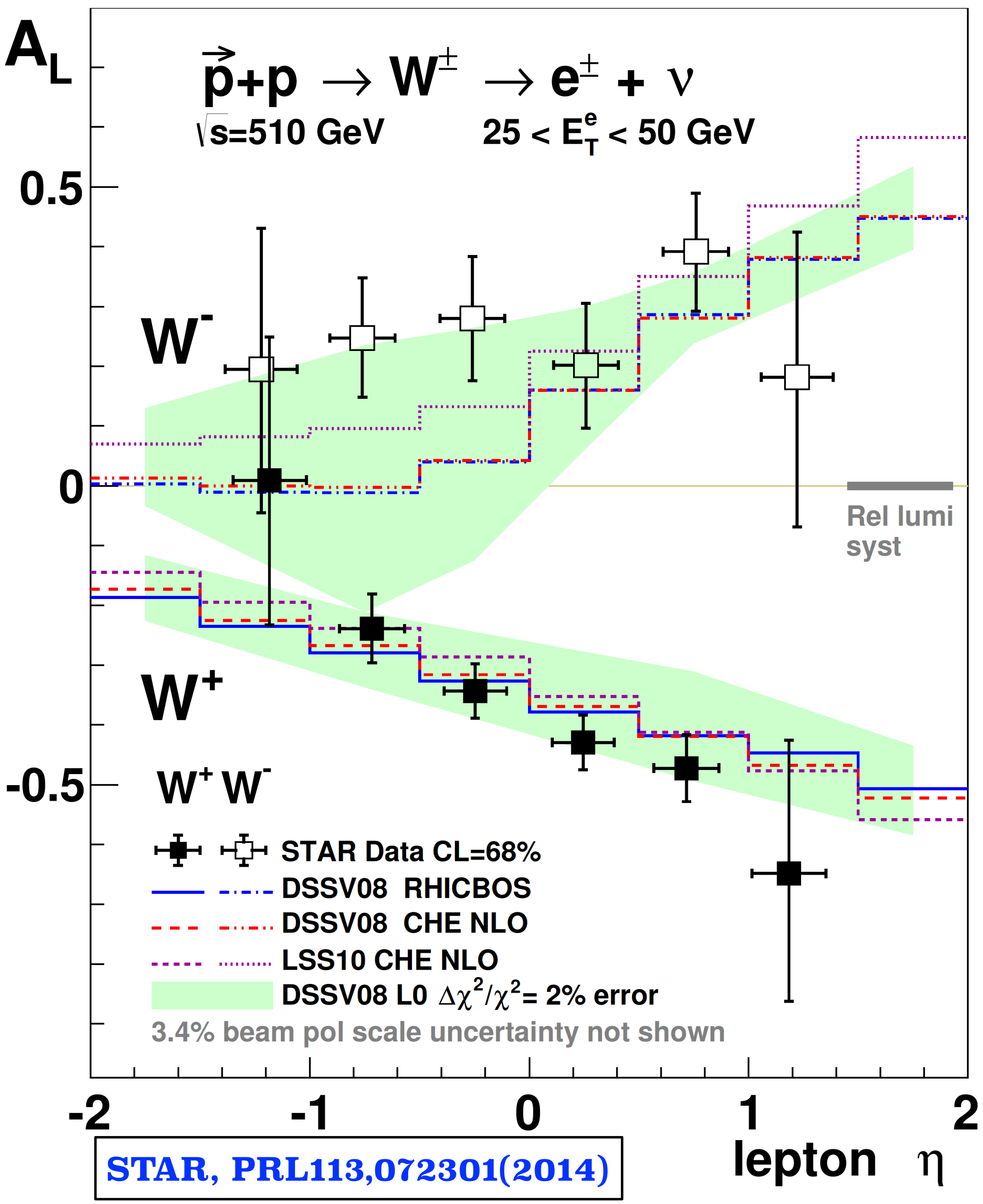

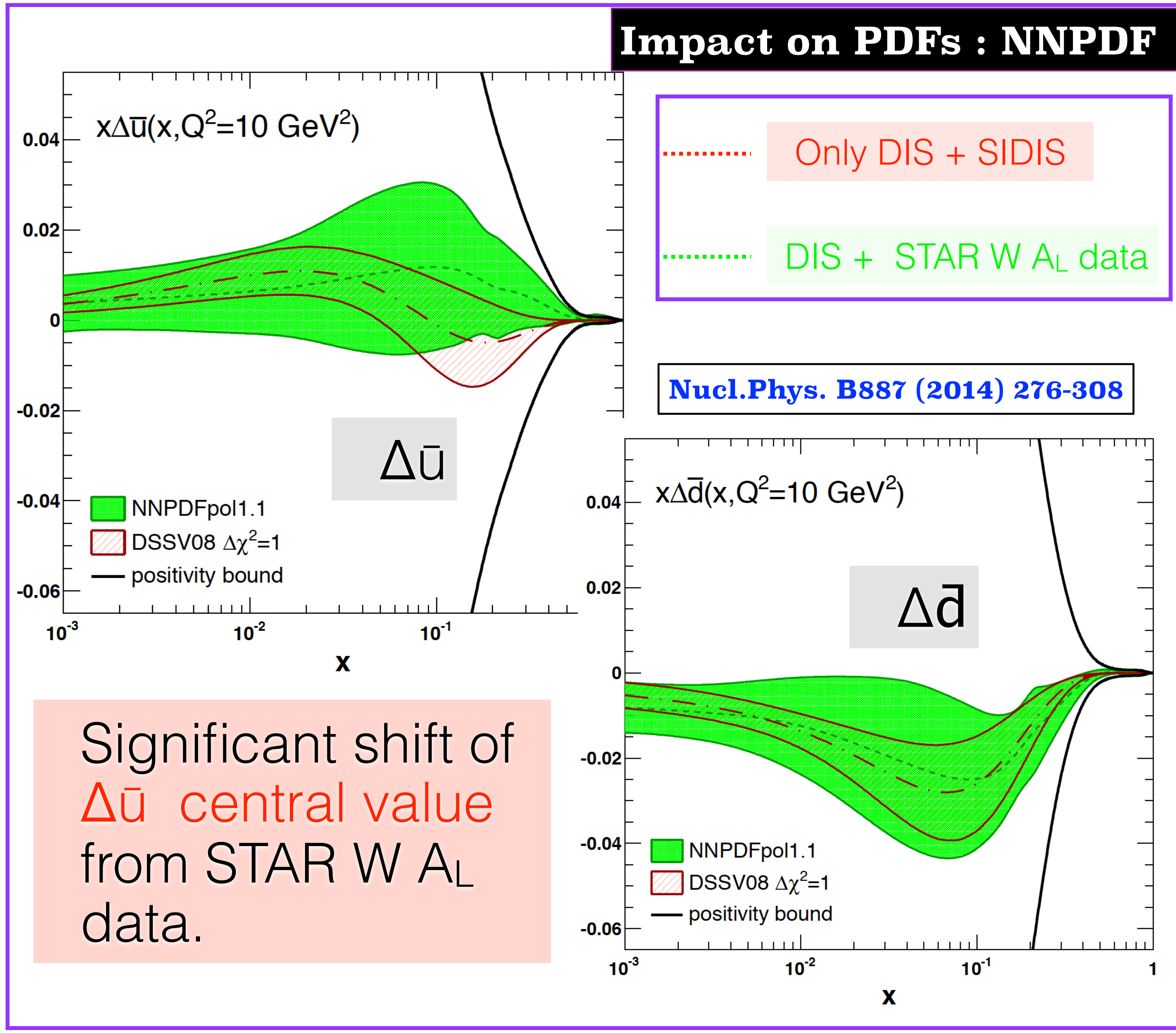

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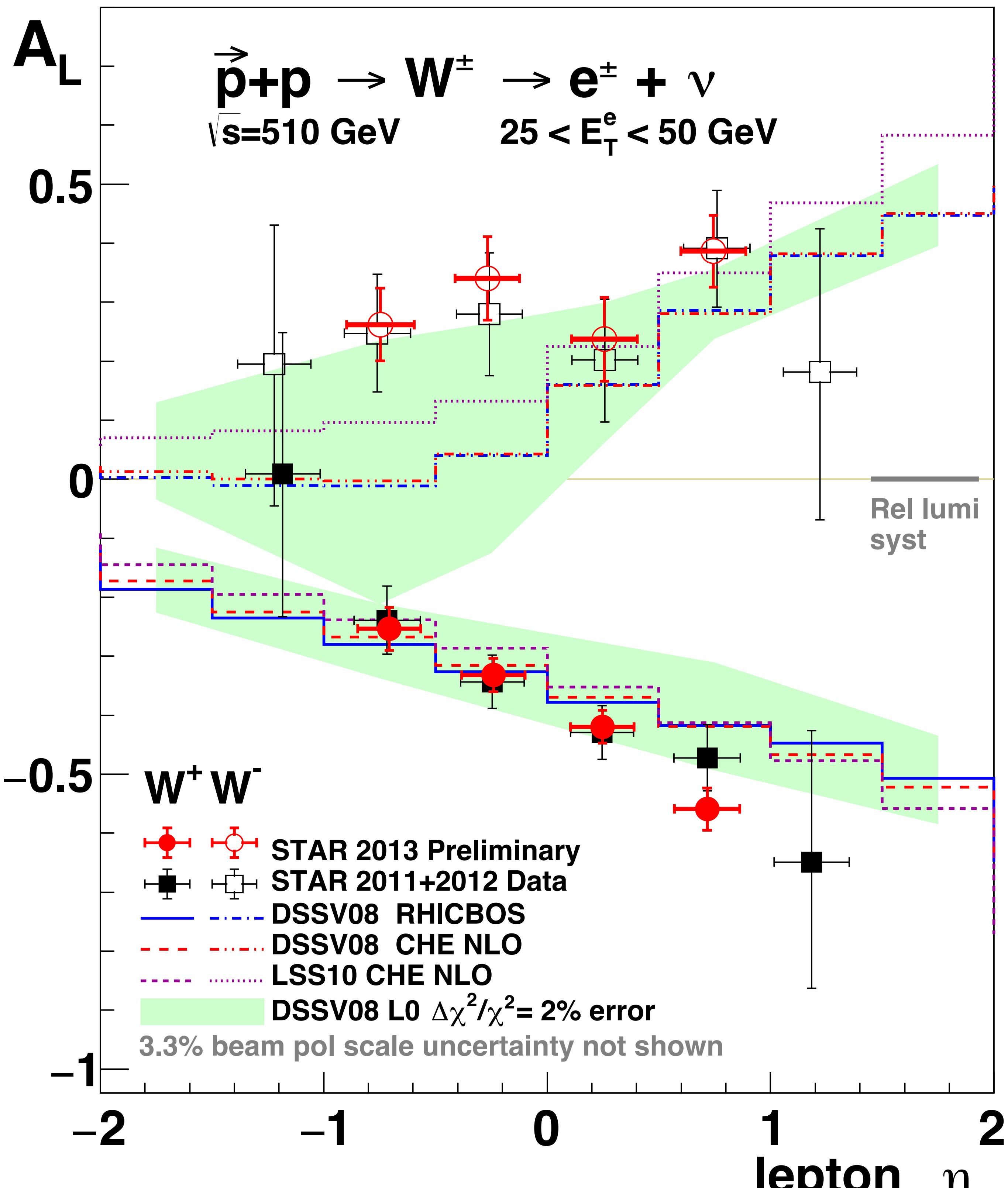
RESULTS - W A_L - STAR 2013 Preliminary vs Published

- STAR 2013 W A_L Preliminary Results in comparison to STAR 2011+2012 published results



- STAR 2013 W A_L Preliminary results is the Most Precise measurements of W A_L up to date!
- STAR 2013 preliminary W AL results consist with published 2011 + 2012 results.
- Uncertainties were reduced by 40 %.
- Forward rapidity analysis: refer : Amani Kraishan's talk

SUMMARY

- W boson production in longitudinally polarized p+p collisions at RHIC is a unique tool to probe quark antiquark helicity PDFs of the nucleon.
- Mid-rapidity (Run 11/12): Published W longitudinal single spin asymmetry results suggest large anti-u quark polarization along with broken QCD sea.
- New prelim. result of STAR 2013 W A_L is the most precious measurement up to date. These results will help to further constrain antiquark helicity distributions.
- New STAR 2013 W AL prelim. results consistent with published STAR 2011+2012 results.