The STAR W Physics Program

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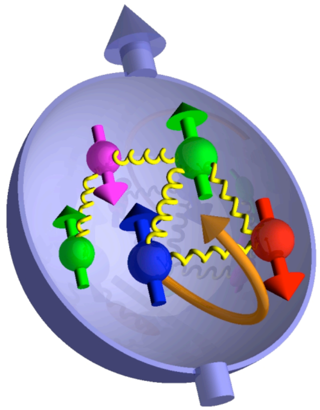
STAR Collaboration

2009 RHIC/AGS User's Meeting
Longitudinal Spin Workshop

The Spin Puzzle



The proton is viewed as being a “bag” of bound quarks and gluons interacting via QCD

Spins + orbital angular momentum need to give the observed spin 1/2 of proton

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

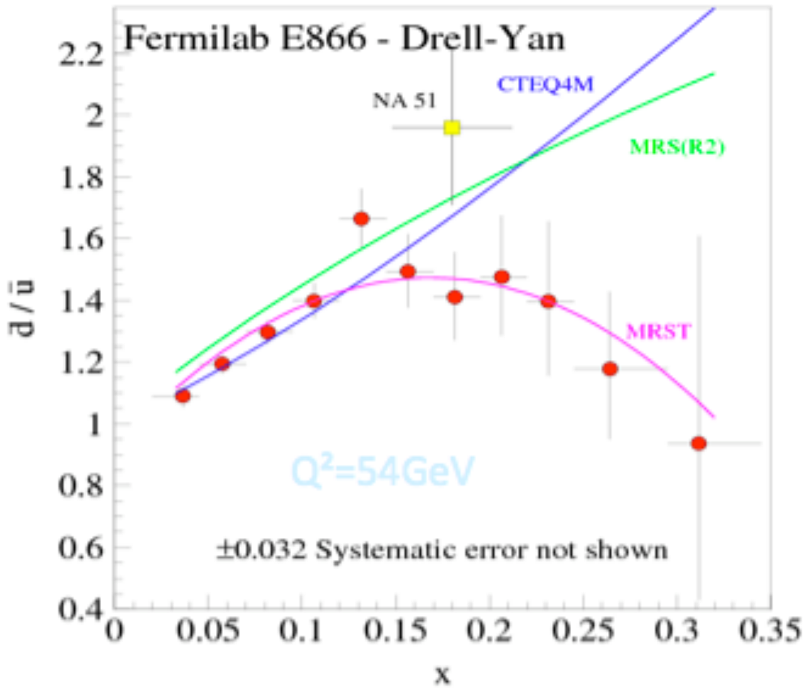
Being measured at RHIC (for STAR results see talk by D. Staszak)

Fairly well measured only ~30% of spin

Its decomposition is not well understood, especially the sea… needs data

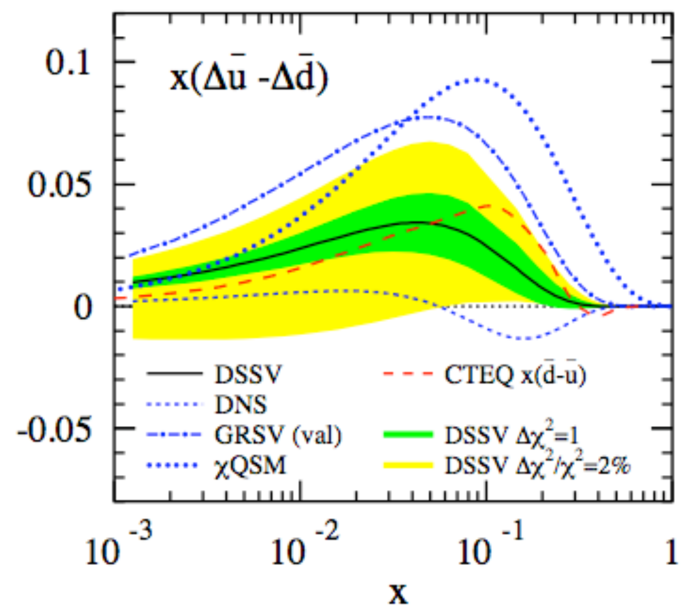
$$\Delta\Sigma = \int (\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s} + \cdots)dx$$

Flavor Asymmetry in the Sea



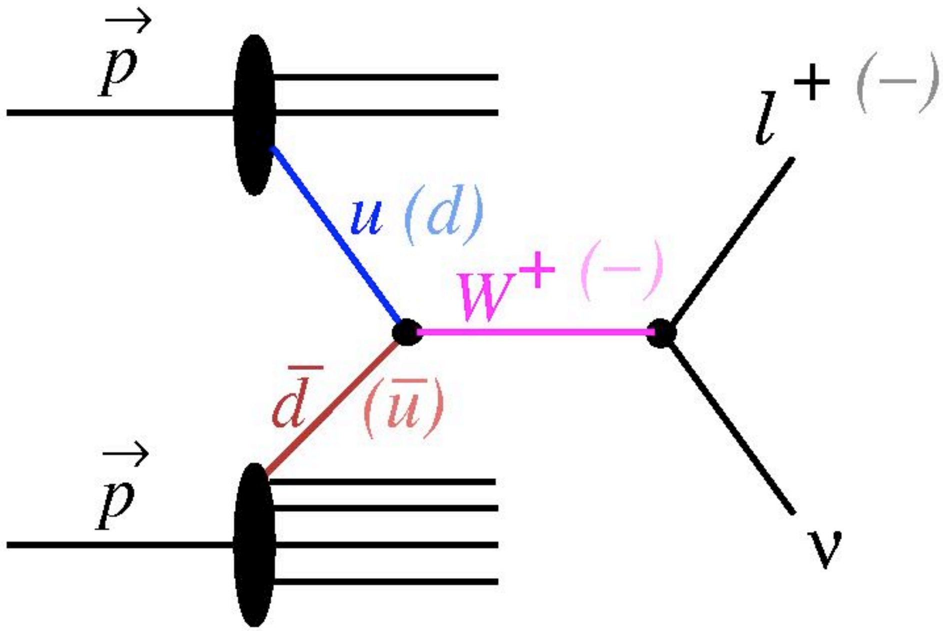
• Pauli blocking should contribute to the observed signal, but how much is currently debated
• Non-perturbative processes may be needed in generating the sea

• E866 results are qualitatively consistent with pion cloud models, instanton models, chiral quark soliton models, etc.



arXiv:0904.3821

Probing the Sea through Ws



$$u + \bar{d} \rightarrow W^{+} \rightarrow e^{+} + \nu$$

$$\bar{u} + d \rightarrow W^{-} \rightarrow e^{-} + \bar{\nu}$$

- Detect Ws through e^{+} and e^{-} decay channels
- V-A coupling leads to perfect spin separation
- Neutrino helicity gives preferred direction in decay

Measure parity violating single helicity asymmetry A_L

(Helicity flip in one beam while averaging over the other)

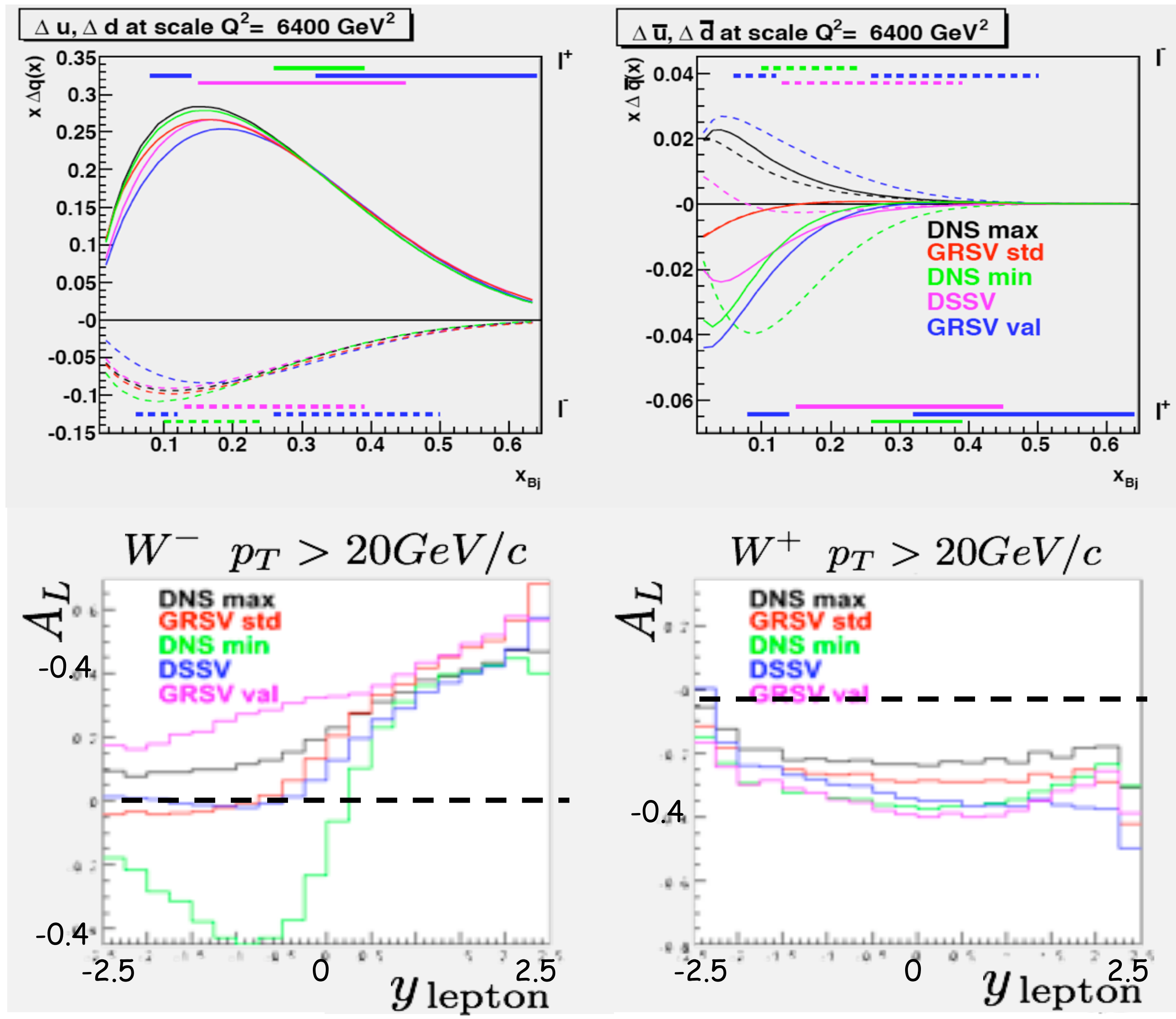
$$A_L^{W-} \propto \Delta d(x_1)\bar{u}(x_2) - \Delta\bar{u}(x_1)d(x_2) \qquad A_L^{W^+} \propto \Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)$$

Expected Asymmetries

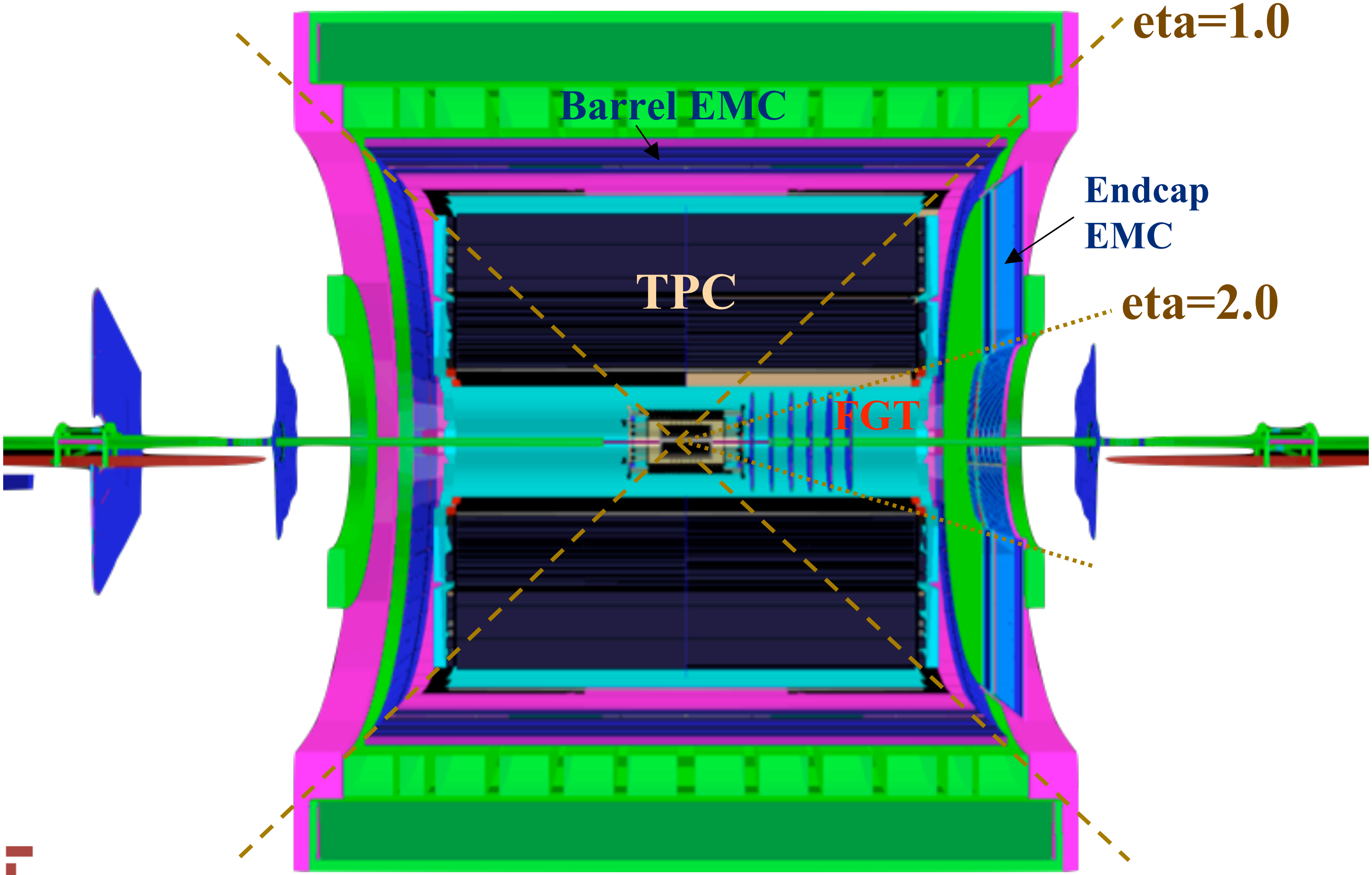
Valence quark pdfs are well constrained by DIS data

Uncertainty in sea quark pdfs leads to a wide range of predictions for single helicity asymmetries

Will be a strong test of pdf evolution ($Q^2 \sim M_W{}^2 \sim 6400$)



STAR (ca 2012)



Two Regions for Ws - I

There are two different kinematical regimes in which STAR can detect the decay electrons/positrons from the W

Forward/Backward Rapidity

At forward or backward rapidity (defined by polarized proton), the formulas for the single helicity asymmetries simplify to

$$A_L^{W^+}(y_W >> 0) \approx \frac{\Delta u(x)}{u(x)} \qquad A_L^{W^-}(y_W >> 0) \approx \frac{\Delta d(x)}{d(x)}$$

$$A_L^{W^+}(y_W << 0) \approx -\frac{\Delta \bar{d}(x)}{\bar{d}(x)} \qquad A_L^{W^-}(y_W << 0) \approx -\frac{\Delta \bar{u}(x)}{\bar{u}(x)}$$

Mid Rapidity

At mid-rapidity, the simple interpretation is not applicable because of large q_T dependent resummation effects, but framework for inclusion into global fits exists

$$A_L^{W^+} \approx \frac{\Delta u(x_1)\bar{d}(x_2) - \Delta \bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$

$$A_L^{W-} \approx \frac{\Delta d(x_1)\bar{u}(x_2) - \Delta \bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)}$$

W Kinematics

$$x_1 = \frac{M_W}{\sqrt{s}} e^{y_W} \qquad x_2 = \frac{M_W}{\sqrt{s}} e^{-y_W}$$

$$y_{lep}^{lab} = y_{lep}^{*} + y_W$$

$\longrightarrow$ if q_T is small

$$y_{lep}^{*} = \frac{1}{2}\ln\frac{1+\cos\theta^{*}}{1-\cos\theta^{*}} \qquad p'_{T,l} = \frac{M_W}{2}\sin\theta^{*}$$

At forward rapidity q_T is small and x_1 and x_2 are calculable

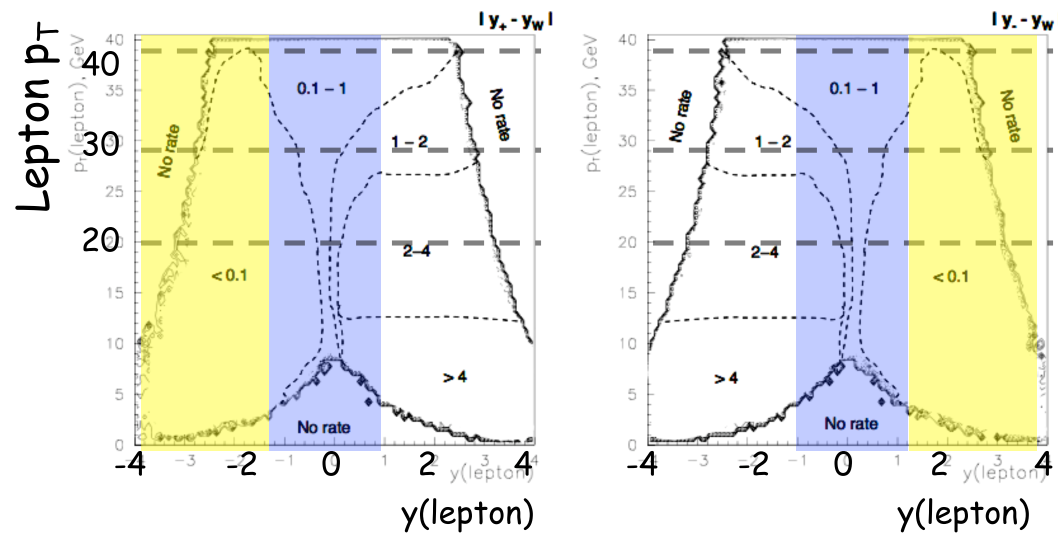
But Born approximation does not work well at mid-rapidity
-> cannot calculate x_1 and x_2 with lepton kinematics

How badly does it do?

$$|\, y_{lep}^{lab} - y_{lep}^{*} - y_W \,| \longrightarrow$$

mid-rapidity

for./back. rapidity

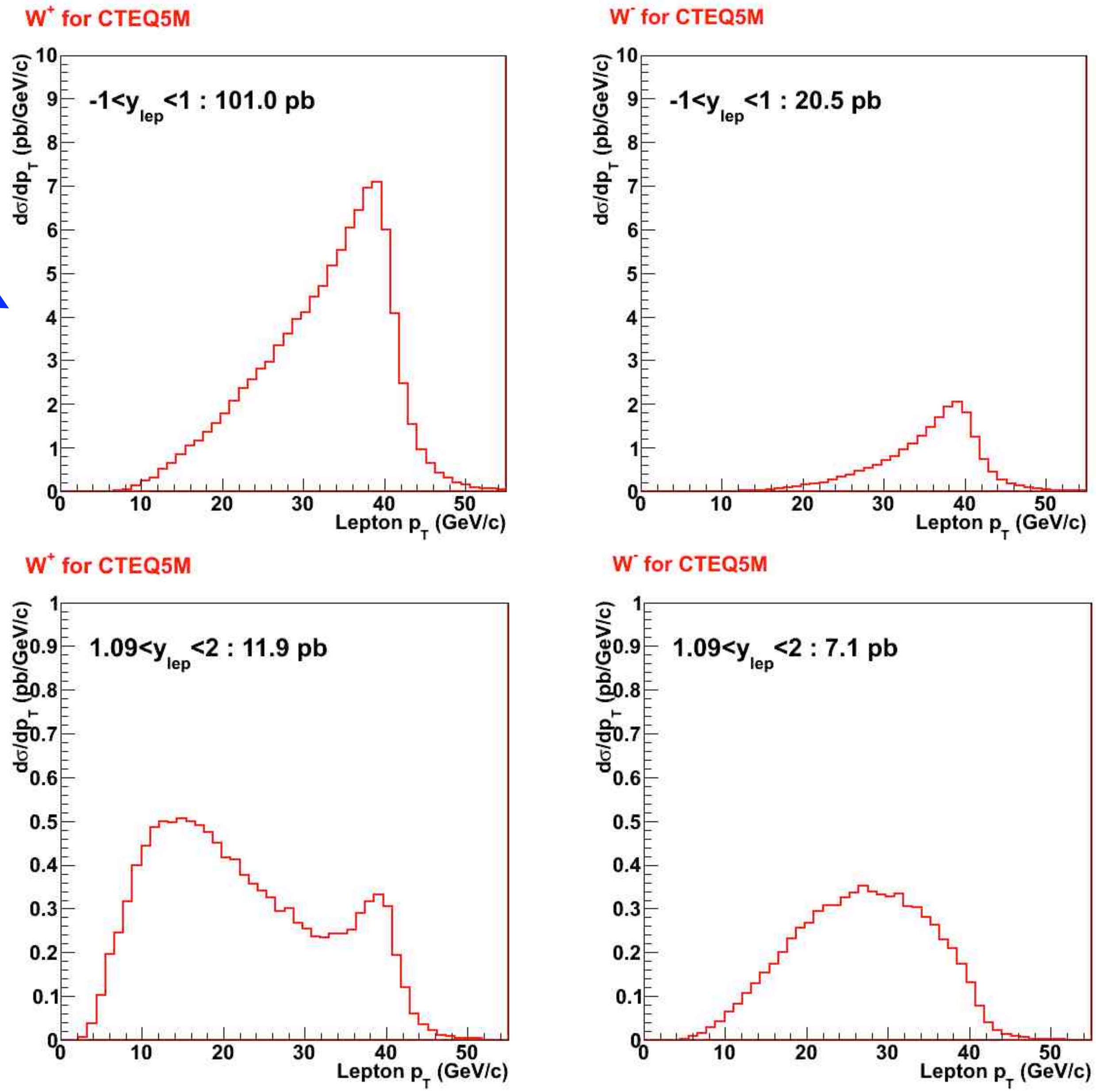


Two Regions for Ws - II

Cross section for mid-rapidity W production

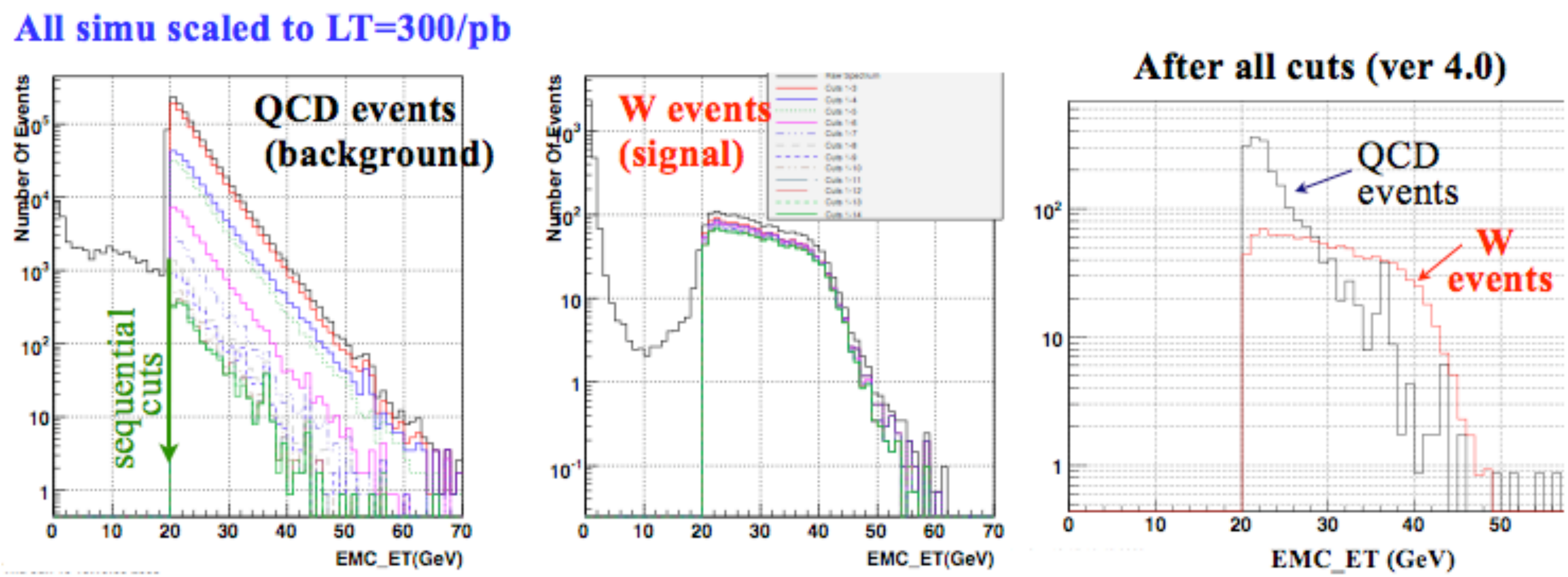
Cross section for forward-rapidity W production

The $W^{+/-}$ cross section at mid-rapidity is ~9x/3x larger than at forward rapidity



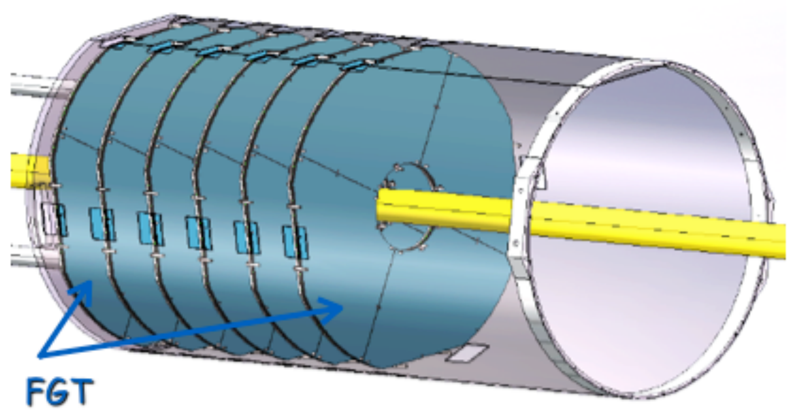
Ws at forward rapidity - I

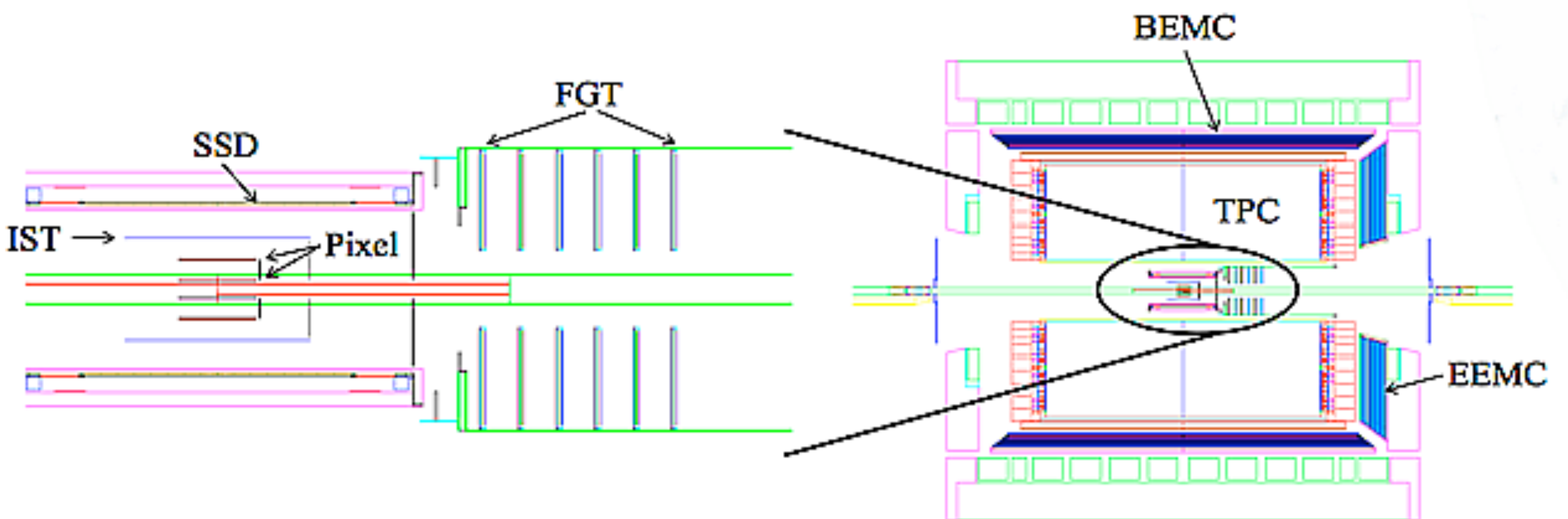
- Generated 10e10 pythia QCD events with full detector response
- e/h separation based on isolation style, missing E_T, and EEMC specific PID cuts
- With current algorithm S/B>1 for E_T > 30 GeV
- Assumes good tracking at forward rapidity



Forward Triple GEM Tracker

An upgrade is in preparation at STAR at forward rapidity that will be able to handle the rates/number of tracks at sqrt(s)=500 GeV

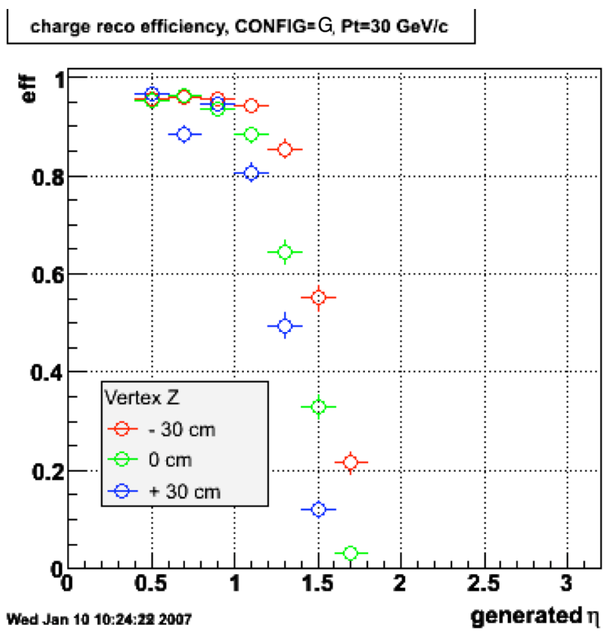




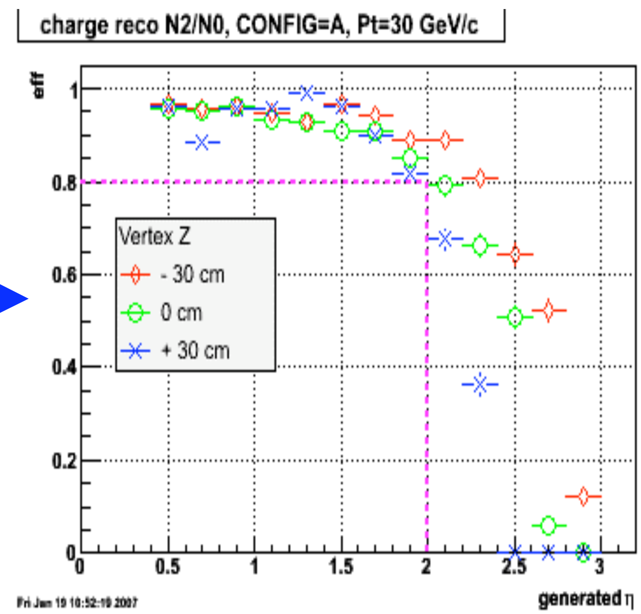
See poster by B. Surrow

Charge Separation at forward rapidity

- Charge separation in the forward region is essential
- TPC tracking degrades in forward direction
- Adding the FGT allows >80% c.s. separation out to limit of acceptance to the EEMC



Without FGT



With FGT

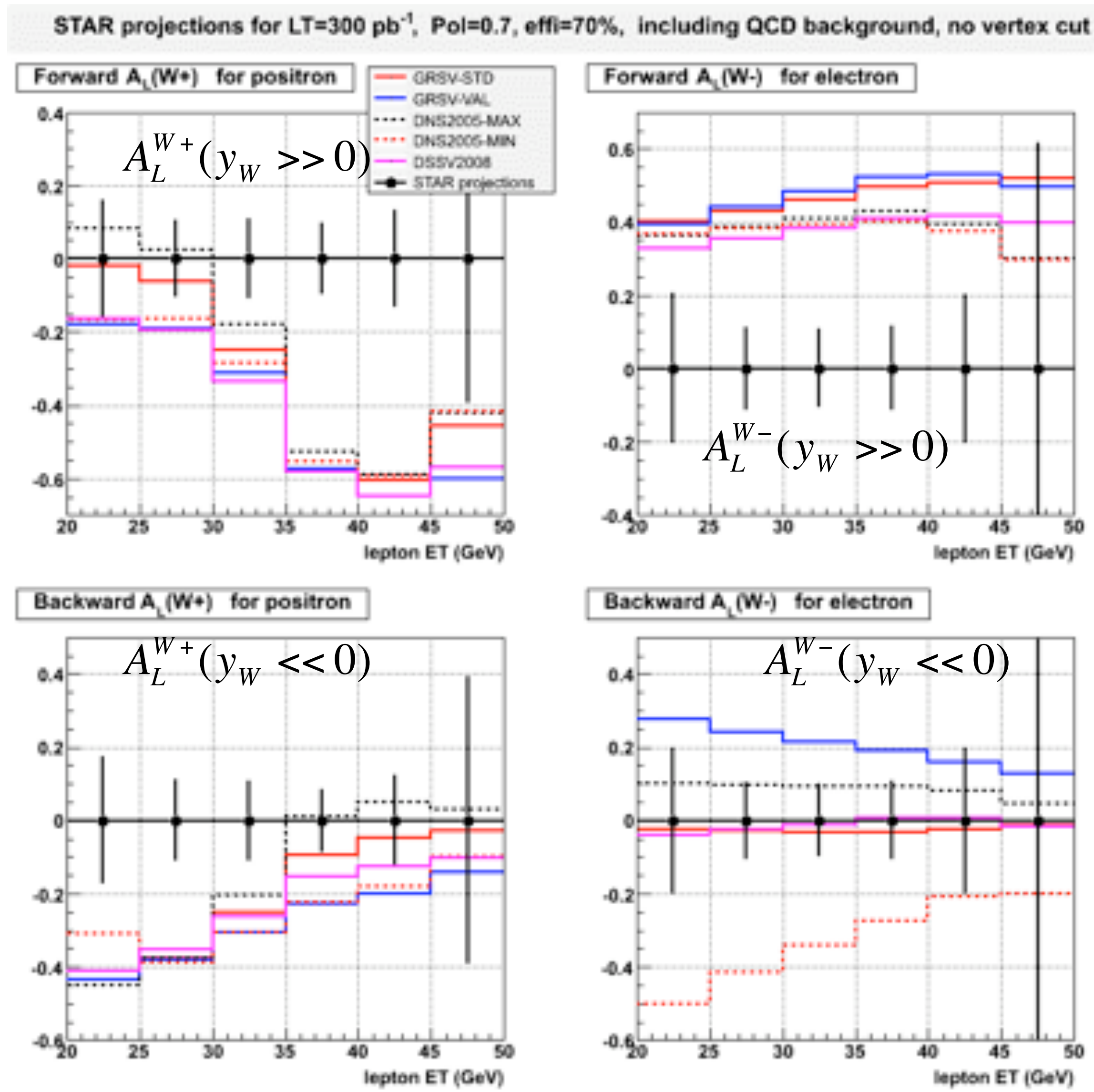
Ws at forward rapidity - II

The 500 GeV Program at RHIC should take about 300pb^{-1} of data.

The expected uncertainties as a function of the decay lepton E_T is shown to the right for endcap acceptance

$$1 < \eta < 2$$

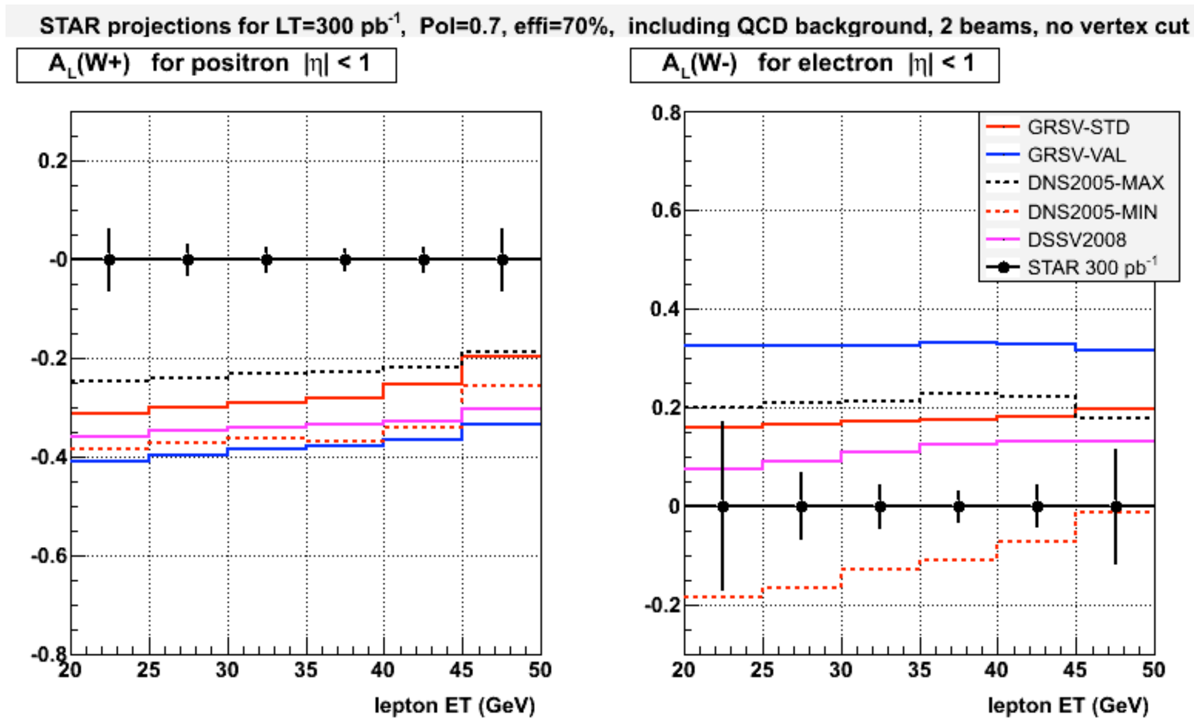
Assumes the sensitivities from the simulations and an installed FGT



Ws at mid-rapidity - I

The cross section for mid-rapidity $W^{+/-}$ production is ~9x/3x larger than at forward rapidity

STAR has the capabilities in place to detect the W at mid-rapidity.

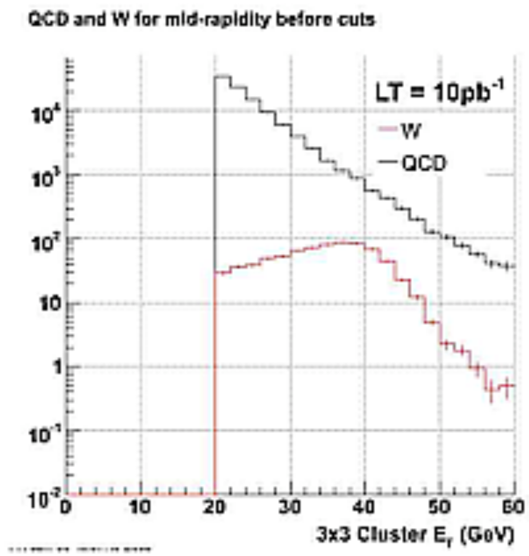


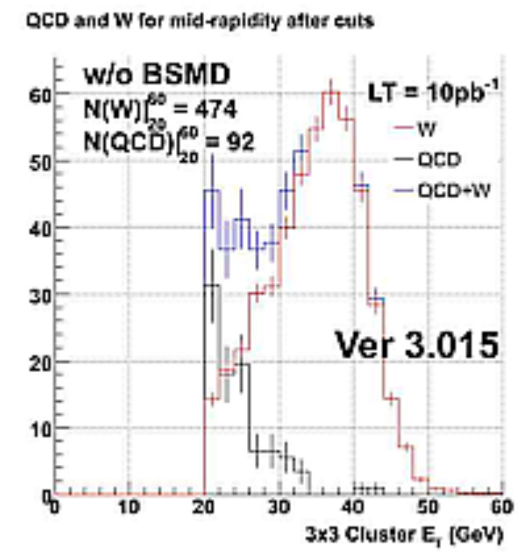
With the expected 300pb^{-1} STAR will provide strong constraints on the polarized sea pdfs using the mid-rapidity data

Ws at mid-rapidity - II

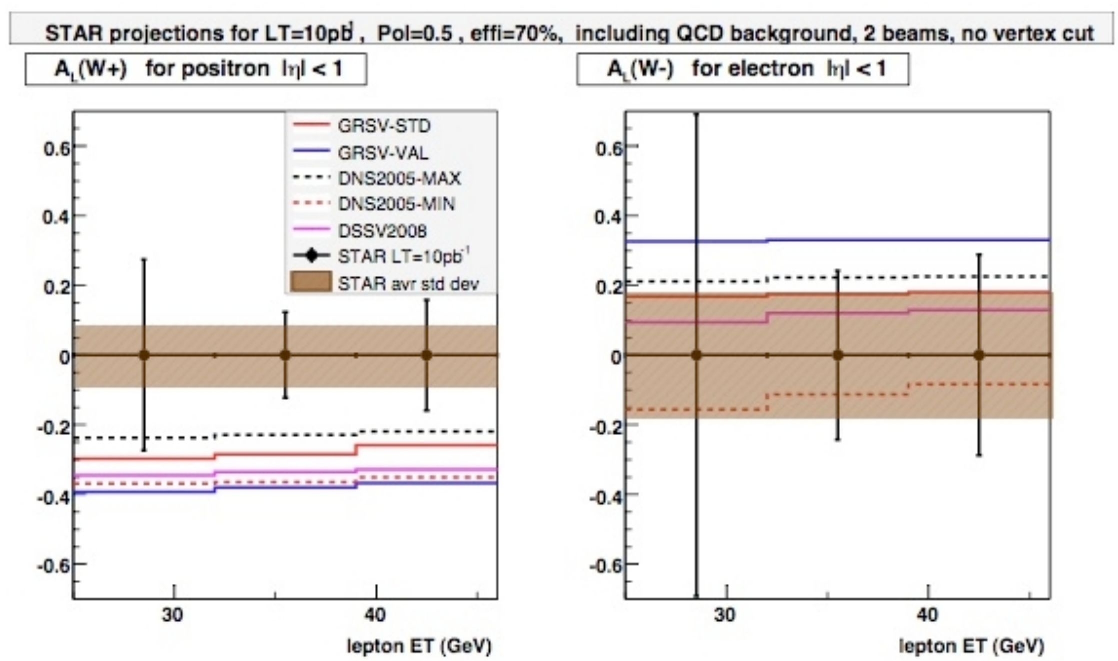
RHIC just completed its first sqrt(s) = 500 GeV running period

During this running STAR collected $10pb^{-1}$ with an average polarization of ~35%





STAR expects to detect ~400 electrons and positrons from W decays



A goal is a first measurement of A_L for W production

See poster by R. Corliss

Conclusions

- W production in polarized proton-proton collisions at RHIC will constrain polarized ubar/dbar distributions in the proton
- Construction and installation of the FGT will allow tracking and charge sign discrimination at forward rapidity.
- STAR has collected its first data sample at sqrt(s)=500 GeV (~10pb^{-1}) and is working to extract its first W signal.