The STAR W Physics Program at RHIC

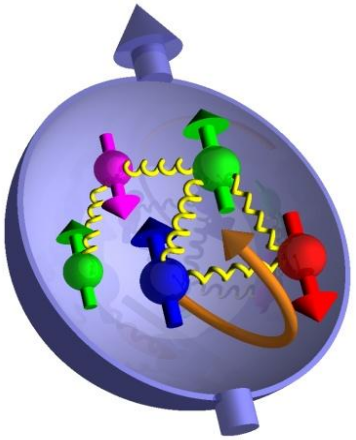
Justin Stevens

for the STAR Collaboration

RHIC/AGS Users' Meeting

June 20, 2011

Proton Spin Puzzle



The observed spin of the proton can be decomposed into contributions from the intrinsic quark and gluon spin and orbital angular momentum

$$\left\langle S_p \right\rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

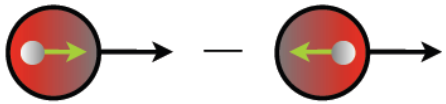
Being measured at RHIC (Jets, hadrons, etc.)

Integral of quark polarization is well measured in DIS to be only ~30%, but decomposition (especially sea) is not well understood

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

Polarized PDFs

$$\Delta f(x) =$$



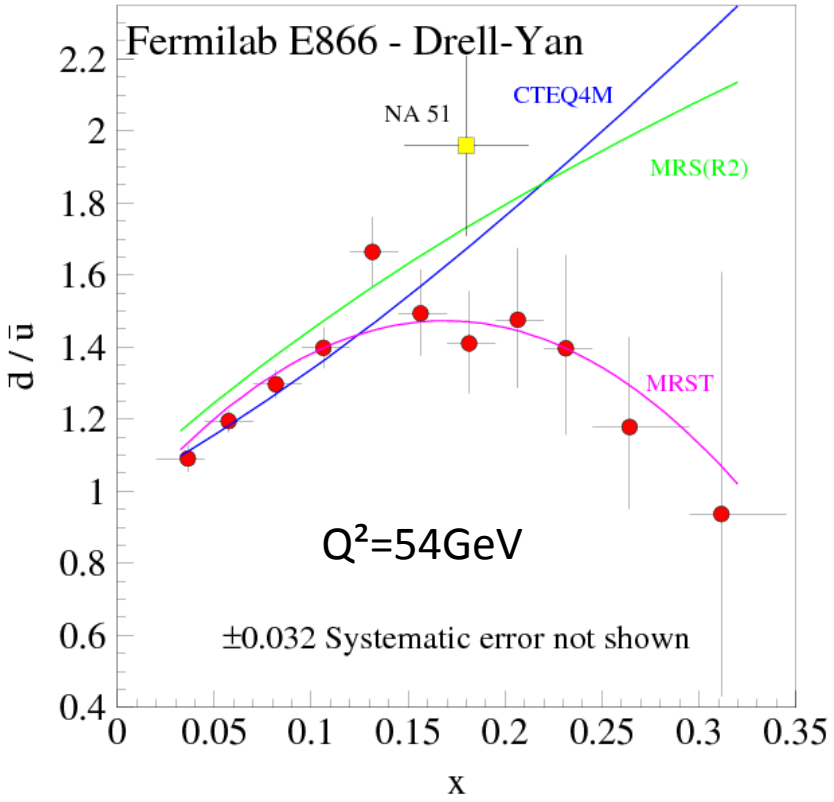
$$f^{+}(x) - f^{-}(x)$$

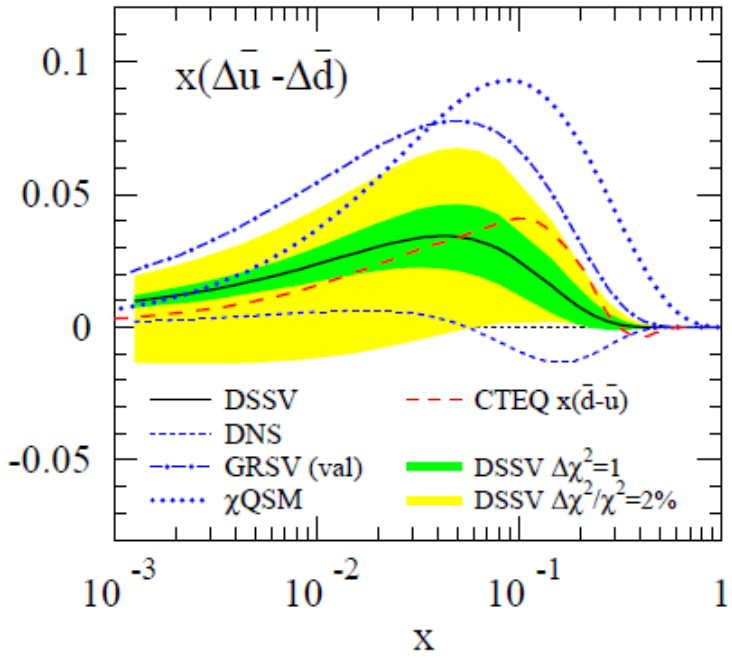
Flavor Asymmetry of the Sea

PRL **80,** 3715 (1998)

Upolarized Flavor asymmetry:

- Quantitative calculation of Pauli blocking does not explain $\bar{d}/\bar{u}$ ratio
- Non-perturbative processes may be needed in generating the sea
- E866 results are qualitatively consistent with pion cloud models, chiral quark soliton models, instanton models, etc.





Polarized flavor asymmetry:

- Valence u and d distributions are well determined
- Polarized flavor asymmetry $x(\Delta\bar{u} - \Delta\bar{d})$ could help differentiate models

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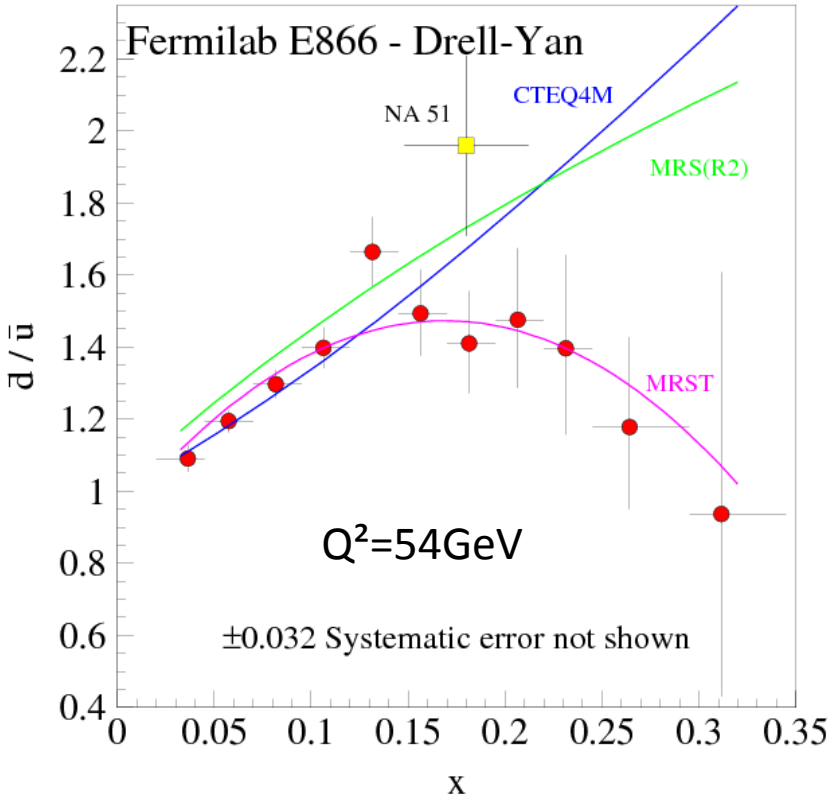

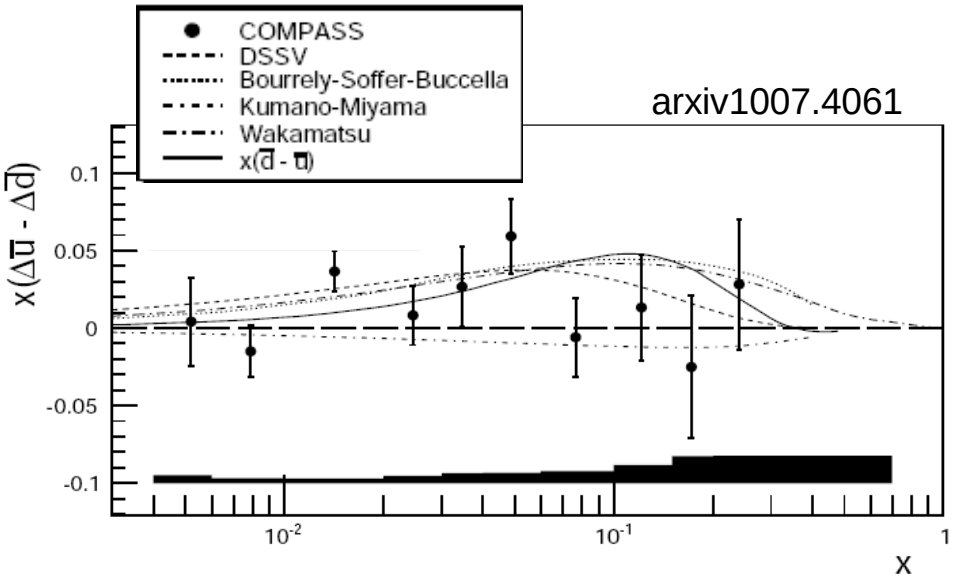

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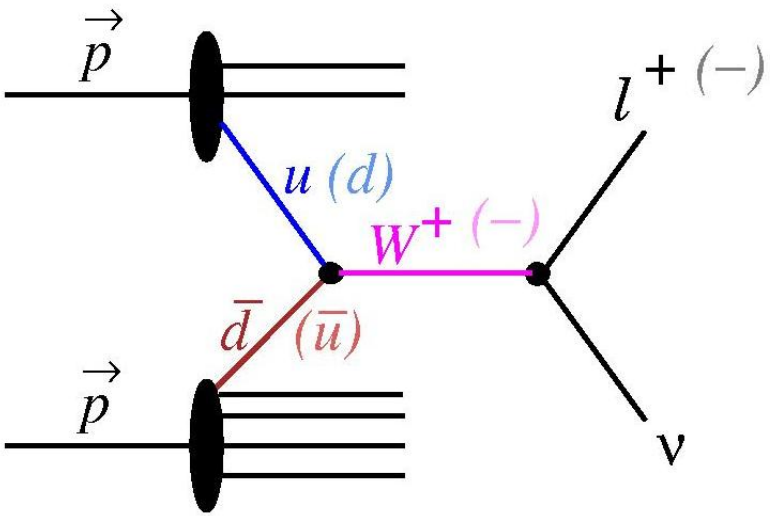
- Polarized flavor asymmetry $x(\Delta\bar{u}-\Delta\bar{d})$ could help differentiate models

Probing the Sea Through W Production



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

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

- Detect Ws through e^+/e^- decay channels
- V-A coupling leads to perfect spin separation
  - LH quarks and RH anti-quarks
- Neutrino helicity gives preferred direction in decay

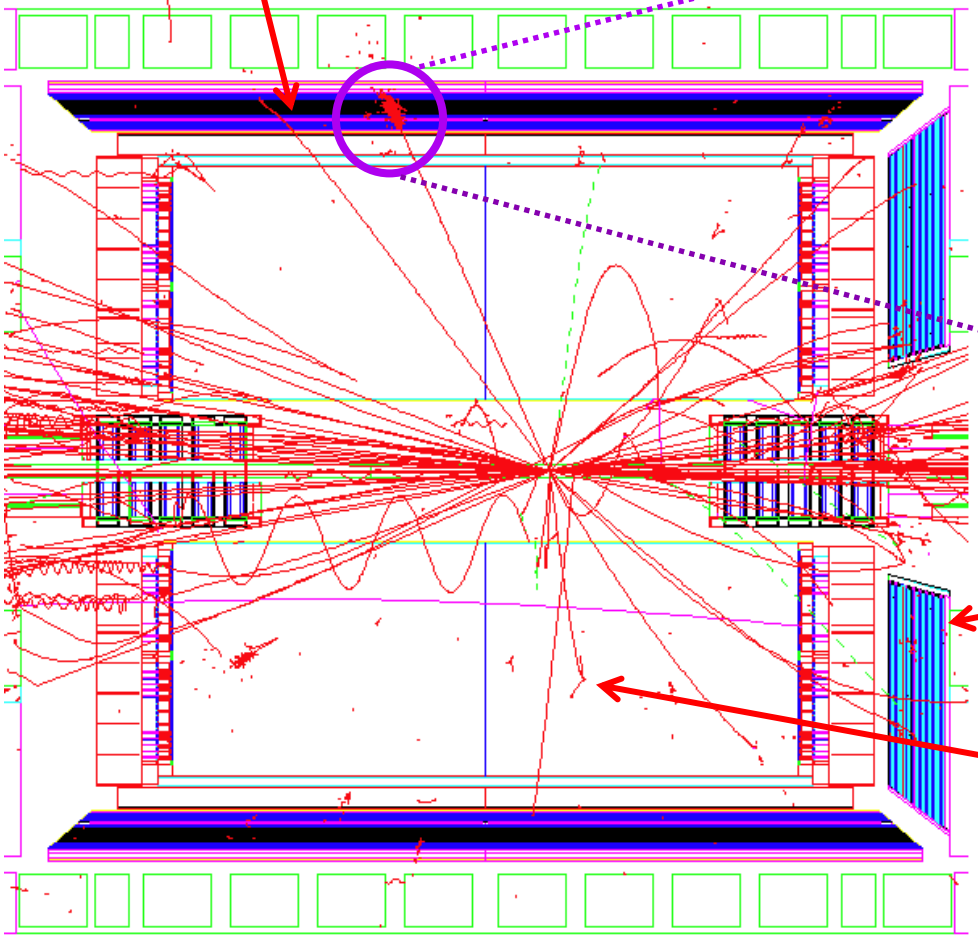
Measure parity-violating single-spin asymmetry: $A_L = \dfrac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

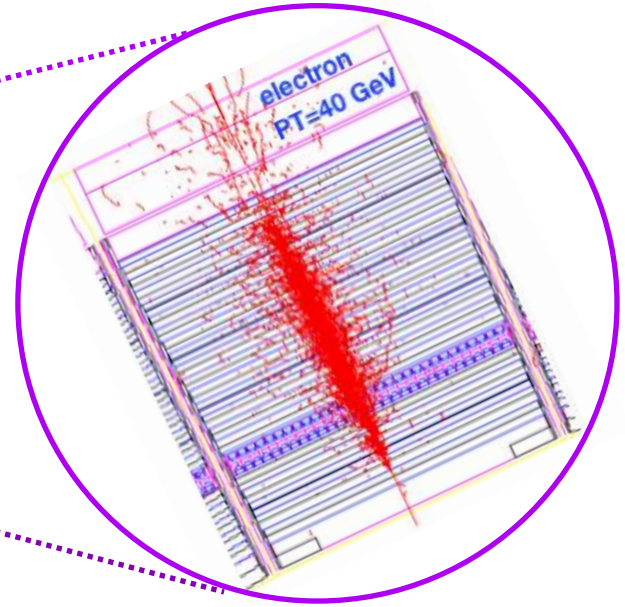
(Helicity flip in one beam while averaging over the other)

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

STAR Detector

Barrel EM Calorimeter:
Lepton Energy
Veto jets

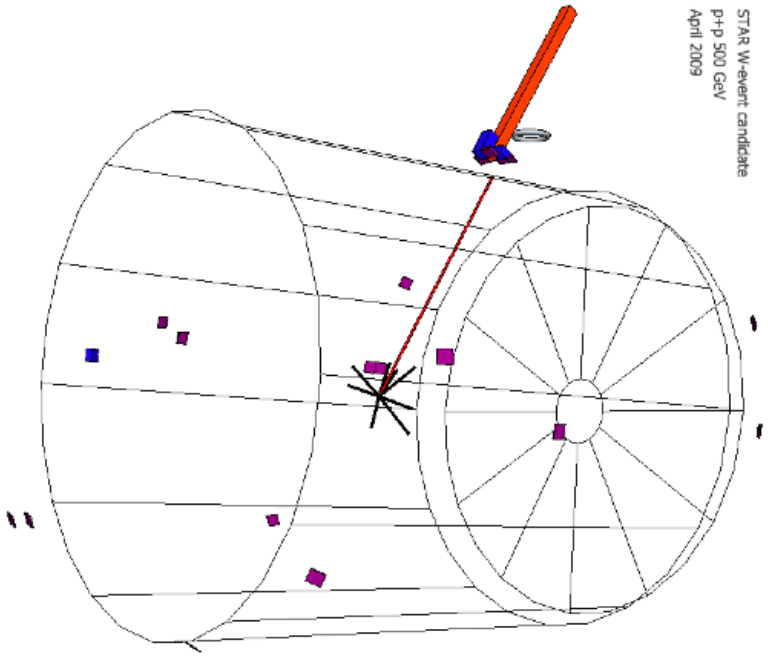




Endcap EM Calorimeter:
Veto jets

Time Projection Chamber (TPC):
Vertex
Charge Separation
Veto jets

Pythia+Geant p+p→W→e+ν event @ 500 GeV

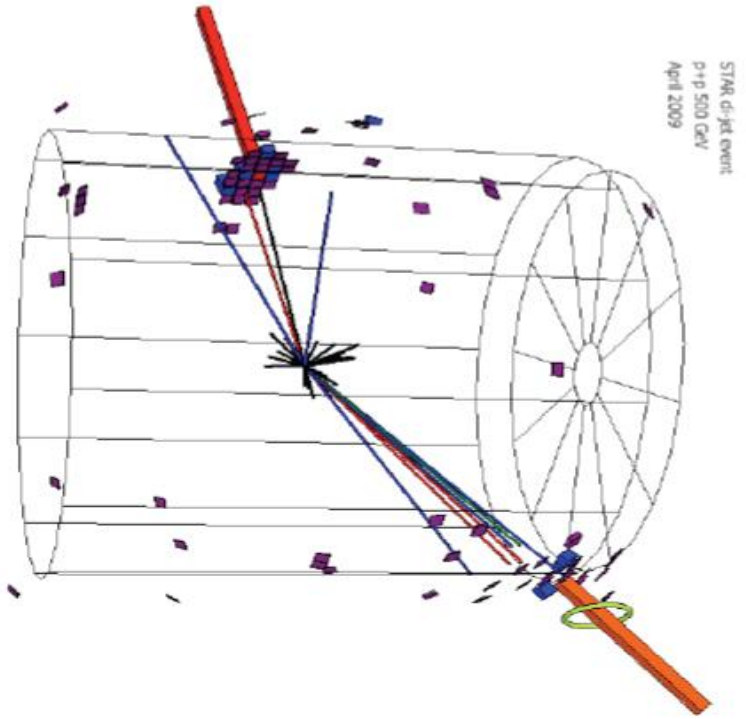


W -> e + ν Candidate Event

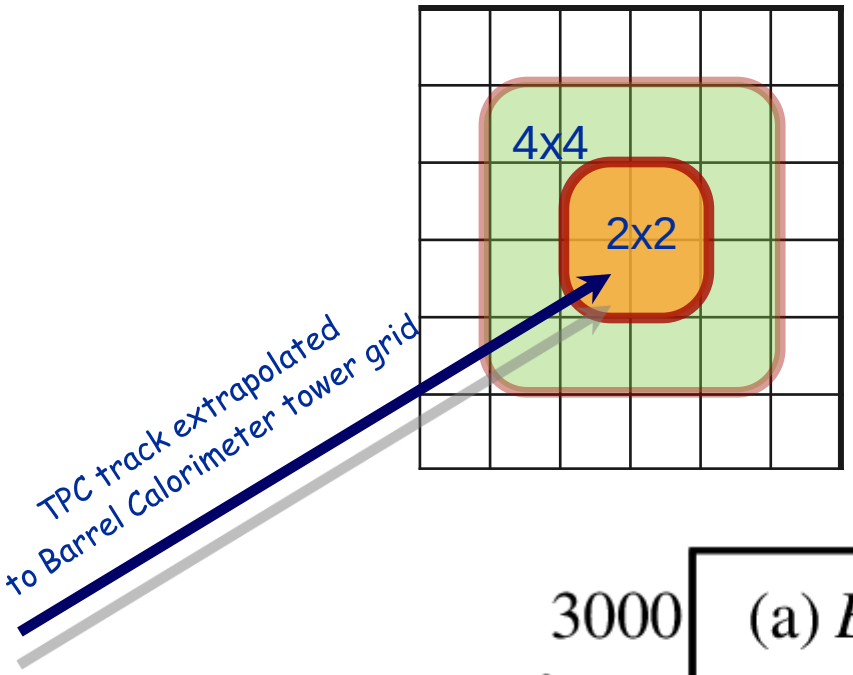
- Isolated track pointing to isolated EM deposit in calorimeter
- Large “missing energy” opposite electron candidate

Di-jet Background Event

- Several tracks pointing to EM deposit in calorimeter spread over a few towers
- Vector pt sum is balanced by opposite jet, “missing energy” is small

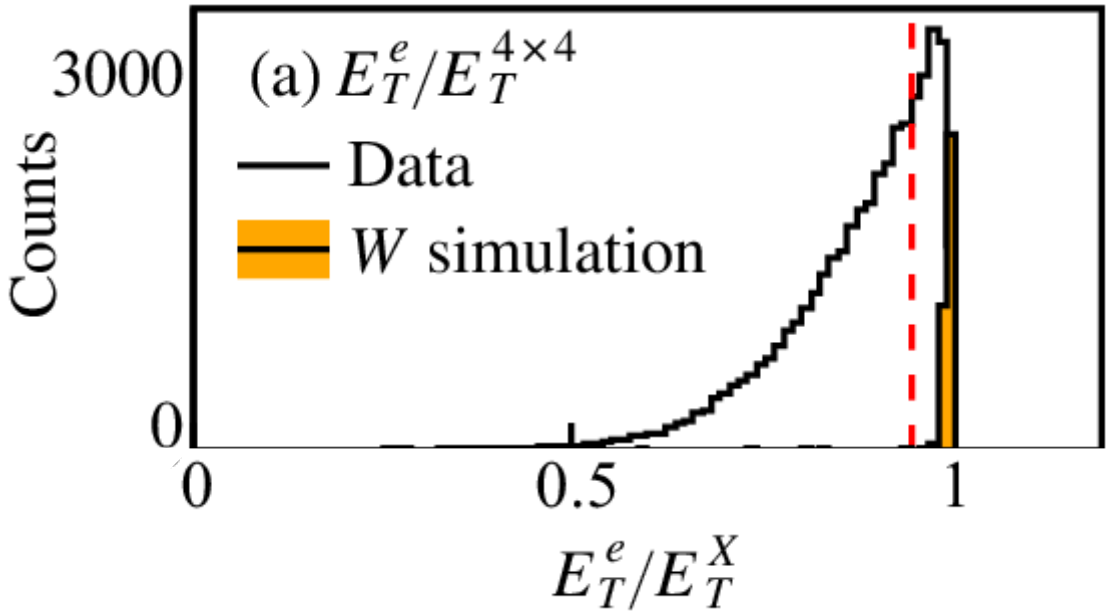


W Algorithm: Lepton Isolation

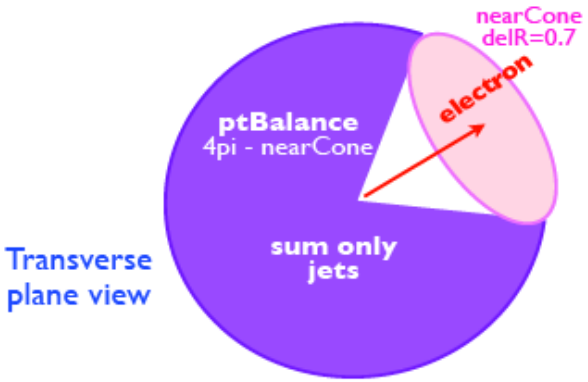


Lepton Isolation Cuts:

- Require TPC track with $p_T > 10$ GeV
- Extrapolate track to Barrel Calorimeter
- Require highest 2x2 cluster around pointed tower sum $E_T > 15$ GeV
- Require excess E_T in 4x4 cluster < 5%
- Match track to 2x2 cluster position



W Algorithm: Suppress QCD Background

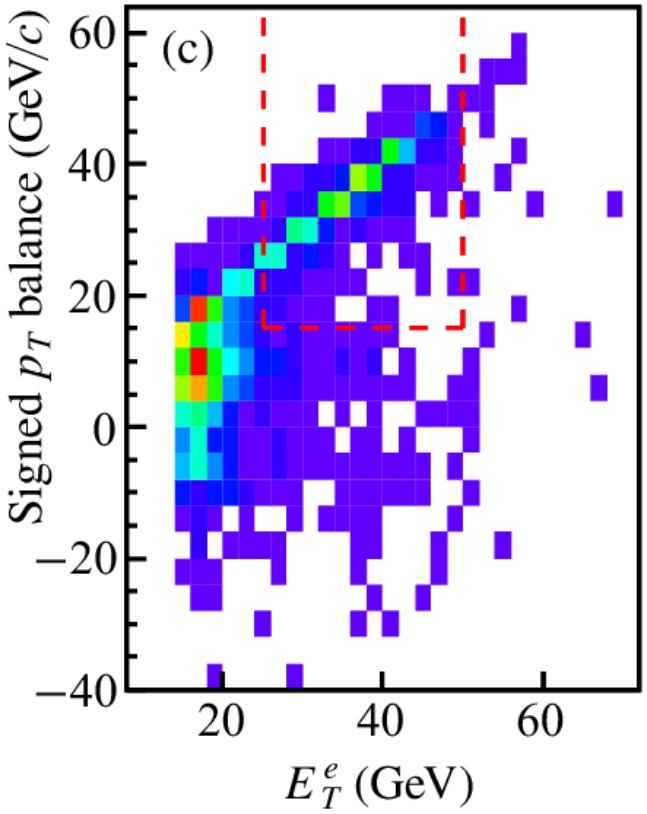


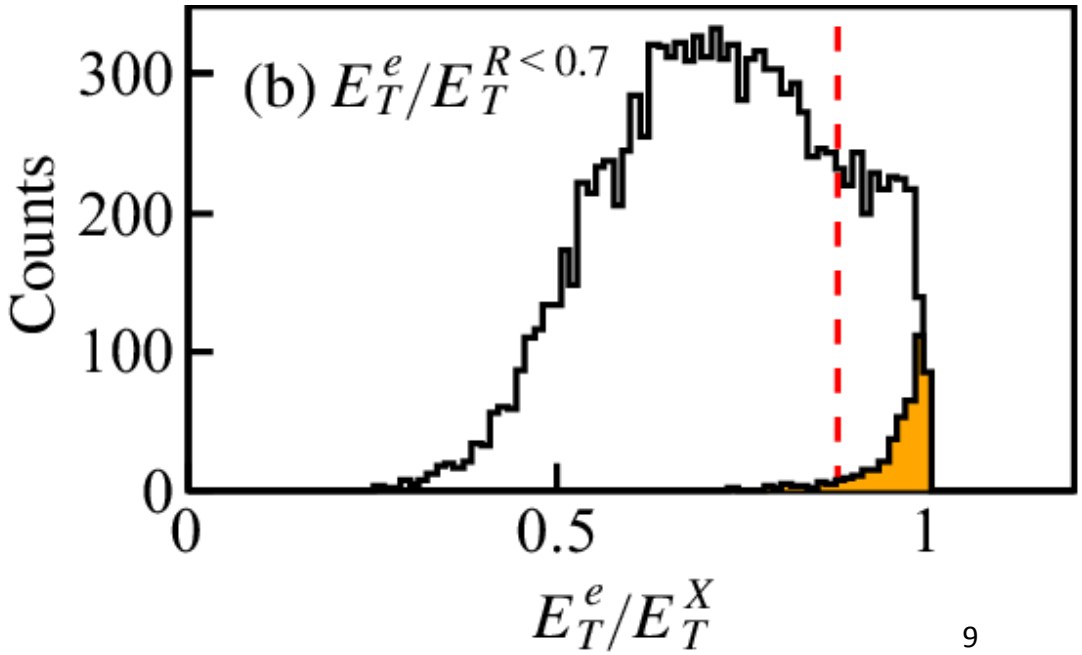
Suppress jets with leading hadron

- Near side jet-cone veto

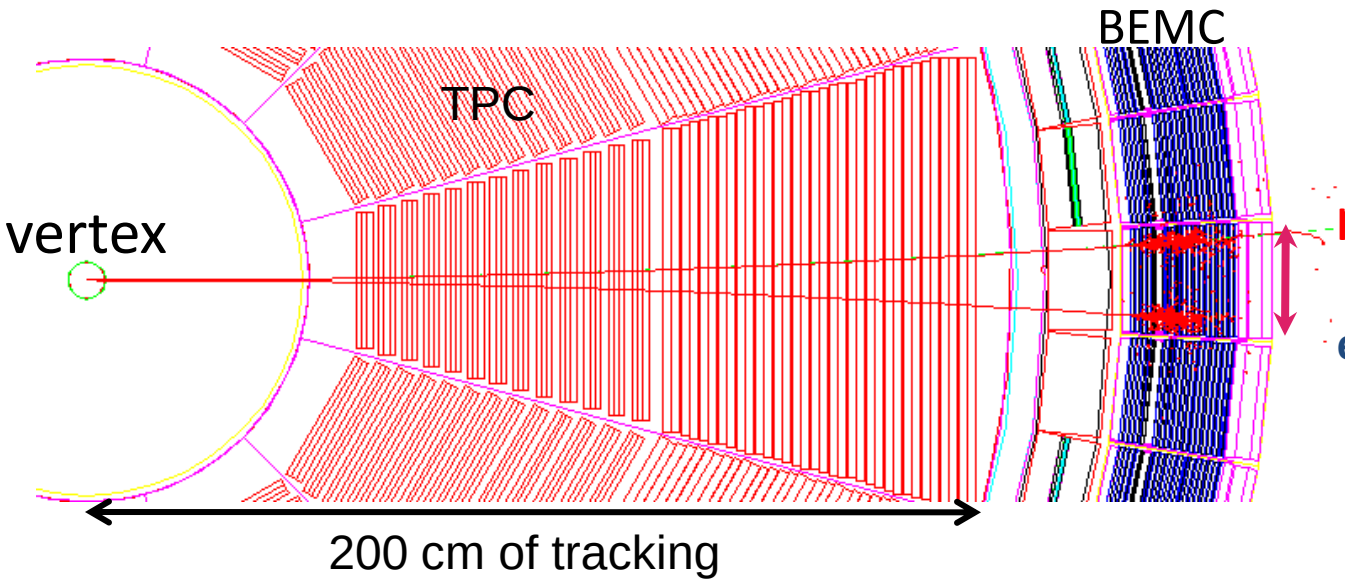
Suppress di-jets and multi-jet events

- Require an imbalance in p_T of the lepton cluster and any jets reconstructed outside the near side jet cone





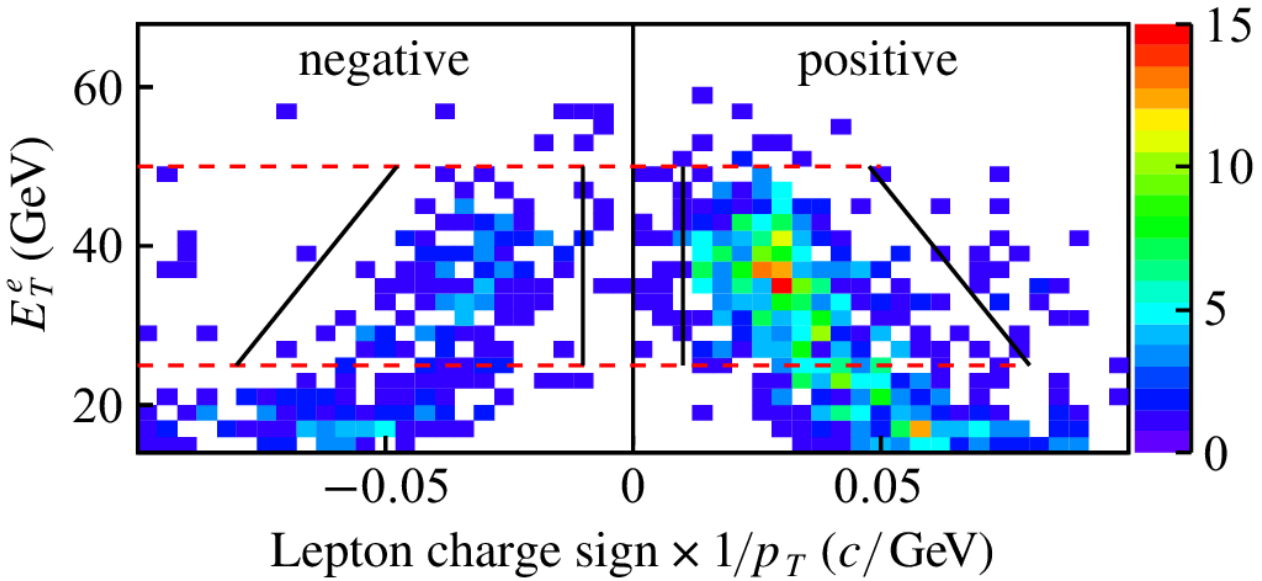
e^+/e^- Charge Separation at High P_T



+/- distance D ~ $1/P_T$

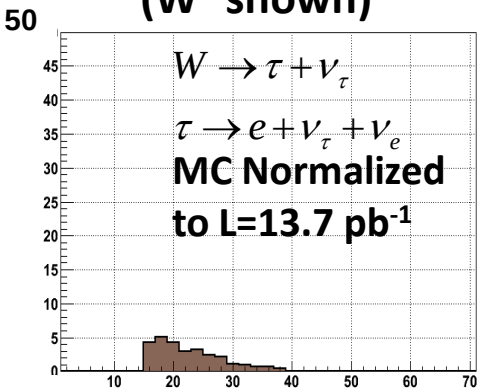
P_T=5 GeV : D~15 cm

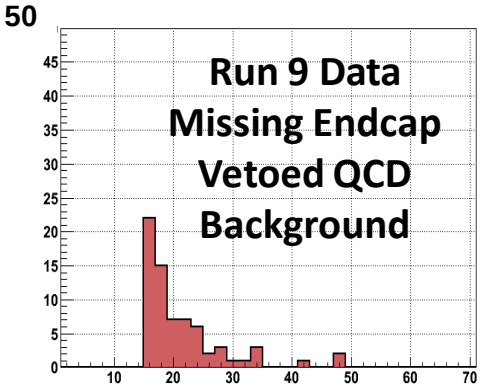
P_T=40 GeV : D ~2 cm

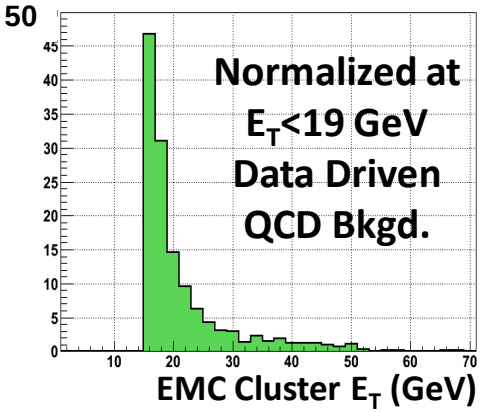


Background Subtraction

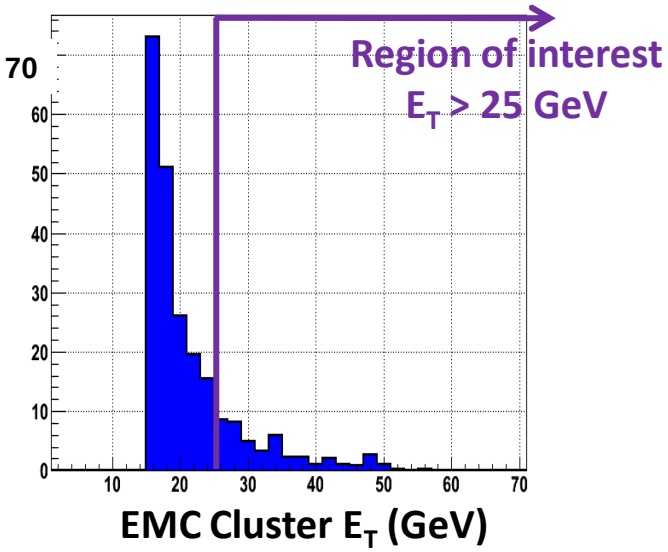
(W+ shown)

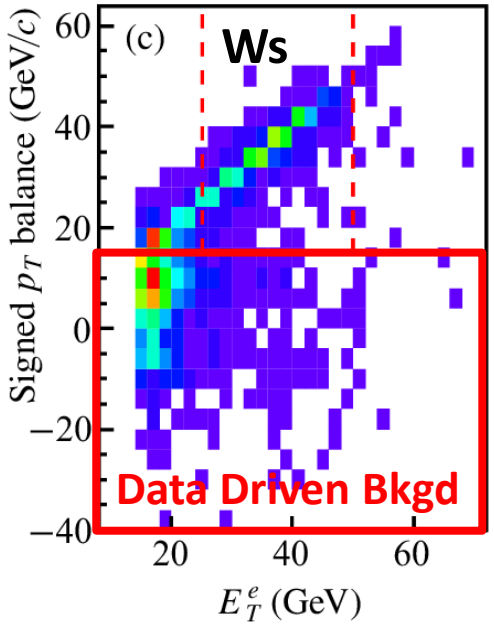




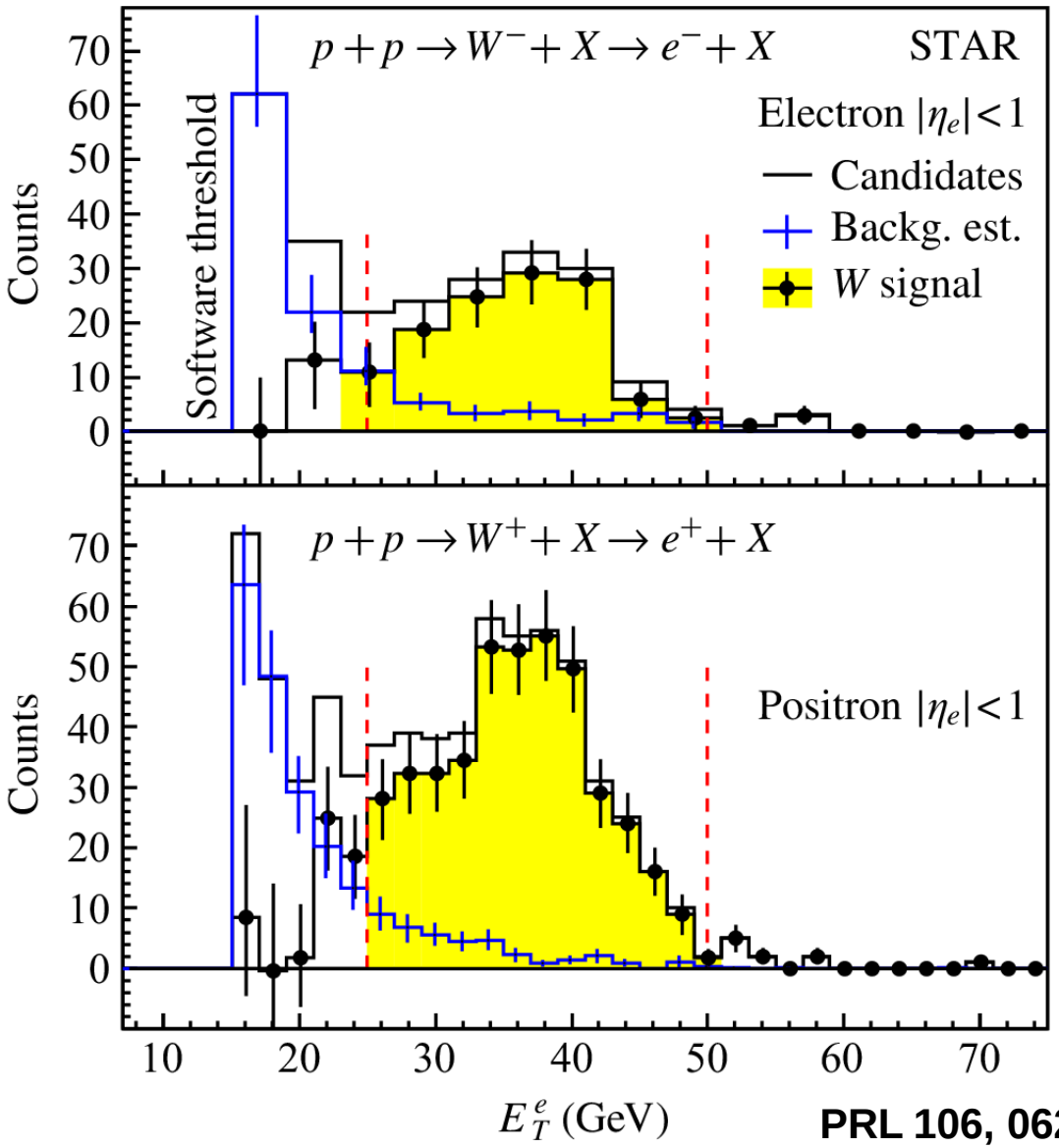


Total Background





STAR Ws from Run 9



PRL 106, 062002

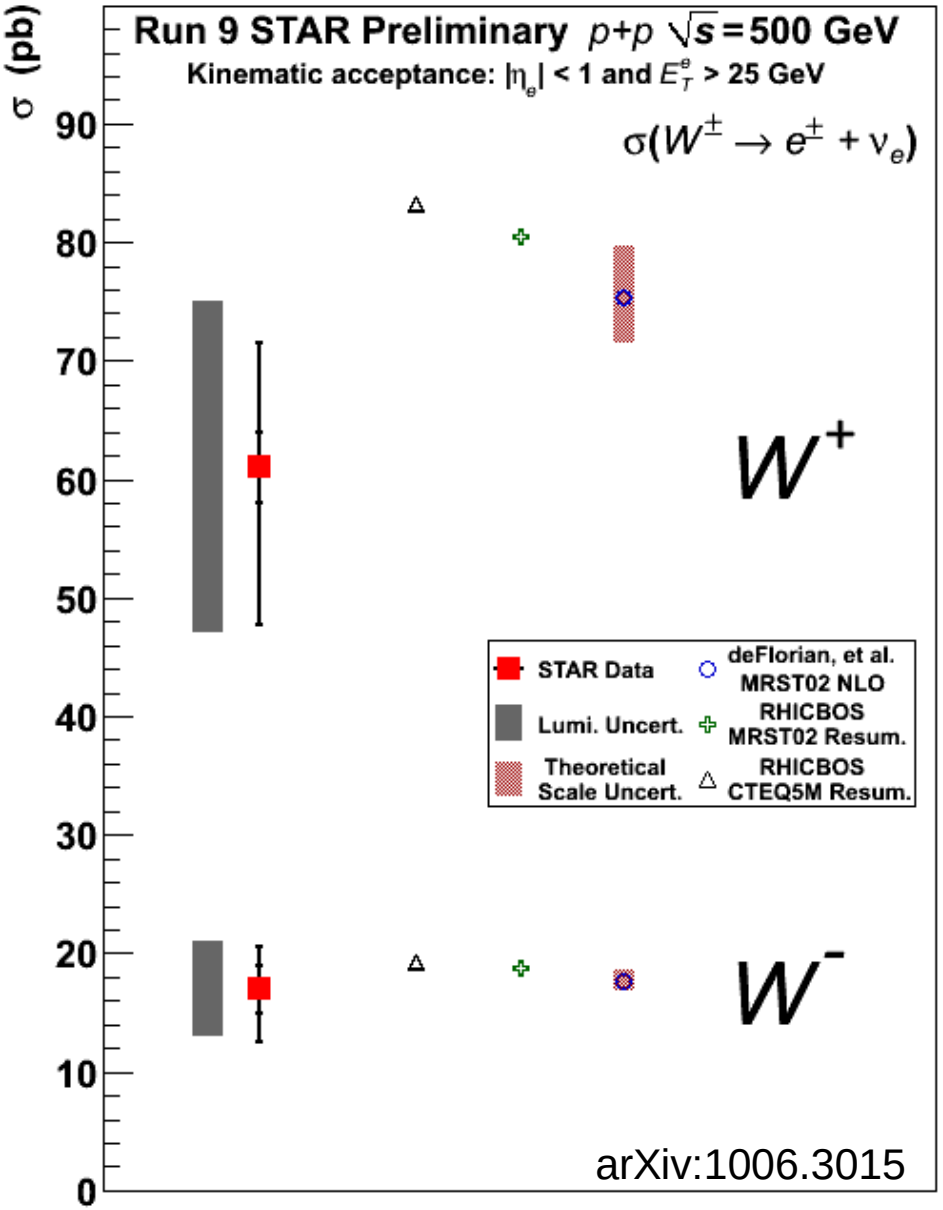
W Signal

- "Jacobian Peak"

Background Estimation

- Electroweak
- QCD :
  - Data-driven

Run 9 STAR W Cross Section



	$W^- \to e^- + \bar{\nu}_e$	$W^+ \to e^+ + \nu_e$
N_W^{obs}	156	513
N_{back}	$25\ ^{+21}_{-7}$	$46\ ^{+36}_{-11}$
ϵ_{total}	$0.56\ ^{+0.11}_{-0.09}$	$0.56\ ^{+0.12}_{-0.09}$
$\int Ldt\ (\mathrm{pb}^{-1})$	13.7 ± 3.2	13.7 ± 3.2

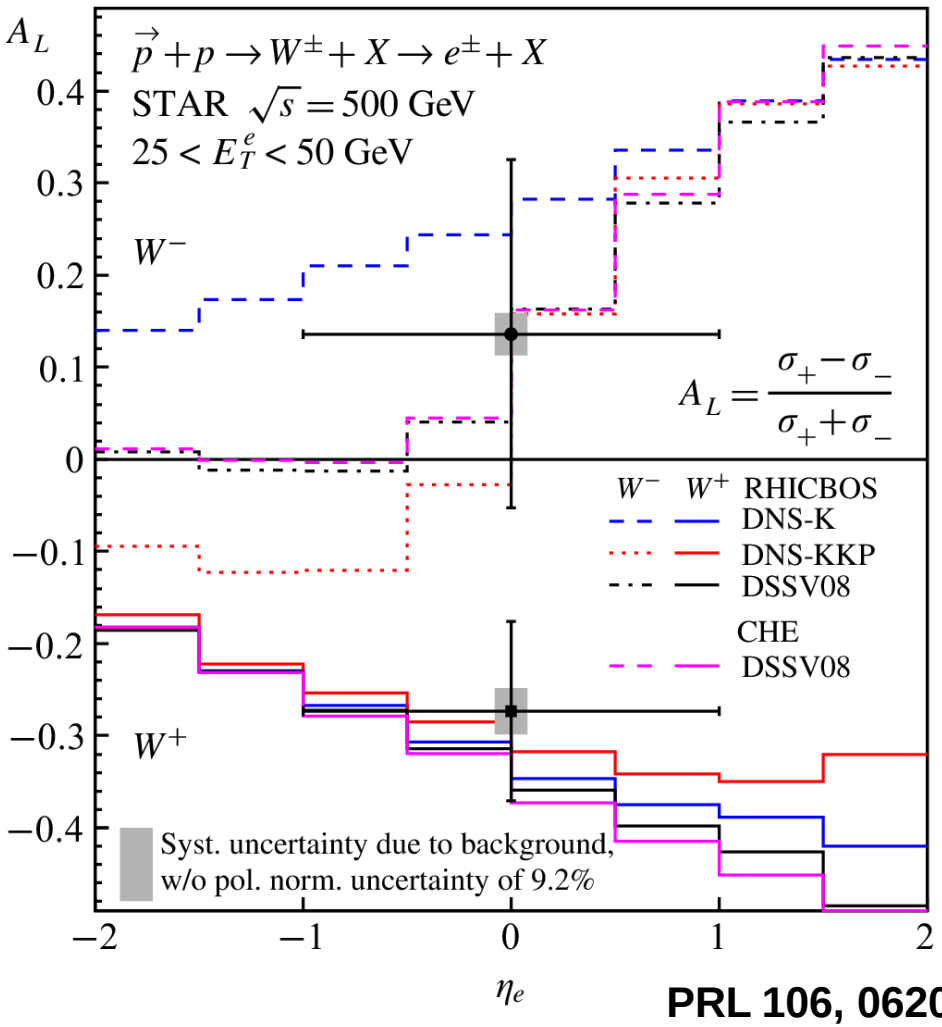
Run 9 STAR Preliminary (p+p 500 GeV)

$$\sigma_{W^+ \to e^+ + \nu} = 61 \pm 3\,(\mathrm{stat.})\ ^{+10}_{-13}\,(\mathrm{syst.}) \pm 14\,(\mathrm{lumi.})\ \mathrm{pb}$$

$$\sigma_{W^- \to e^- + \bar{\nu}} = 17 \pm 2\,(\mathrm{stat.})\ ^{+3}_{-4}\,(\mathrm{syst.}) \pm 4\,(\mathrm{lumi.})\ \mathrm{pb}$$

There is reasonable agreement between the measured and expected cross sections.

Run 9 STAR W A_L



PRL 106, 062002

$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

STAR Run 9 Result

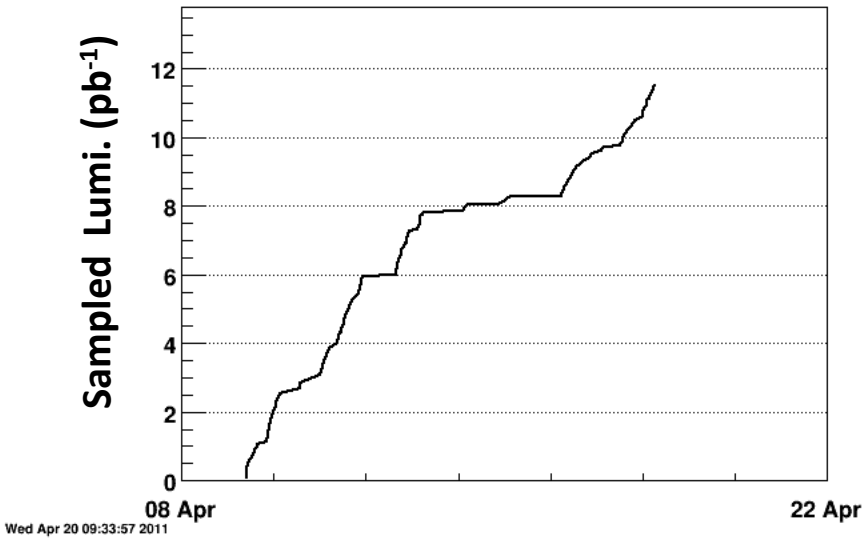
$$A_L(W^+) = -0.27 \pm 0.10(stat) \pm 0.02(syst)$$

$$A_L(W^-) = 0.14 \pm 0.19(stat) \pm 0.02(syst)$$

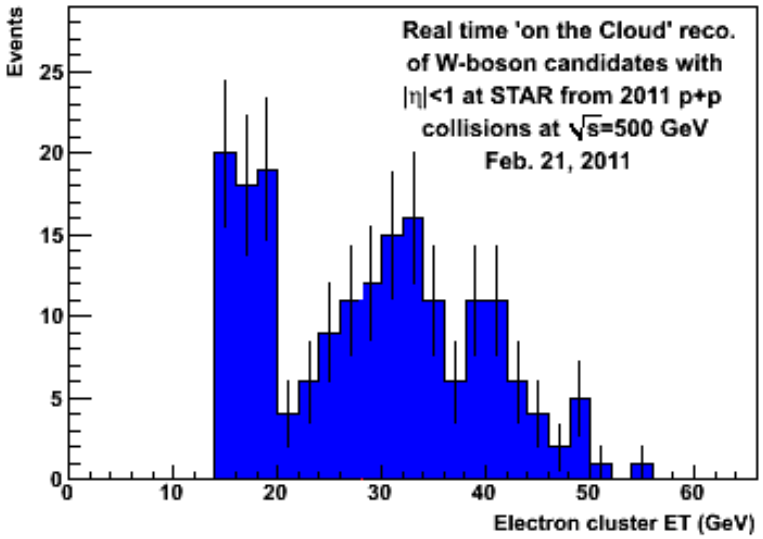
Run 11 Dataset

- Transverse Dataset (8 weeks of data taking):
  - W Trigger Sampled: L ~ 25 pb^{-1}, P ~ 40-50% (online)
  - Possible feasibility studies for W A_N?
- Longitudinal Dataset (9 days of data taking):
  - W Trigger Integrated: L ~ 12 pb^{-1}, <P> ~ 43% (online)
  - Similar to Run 9 dataset with slight increase in polarization

Run 11 Longitudinal W Trigger

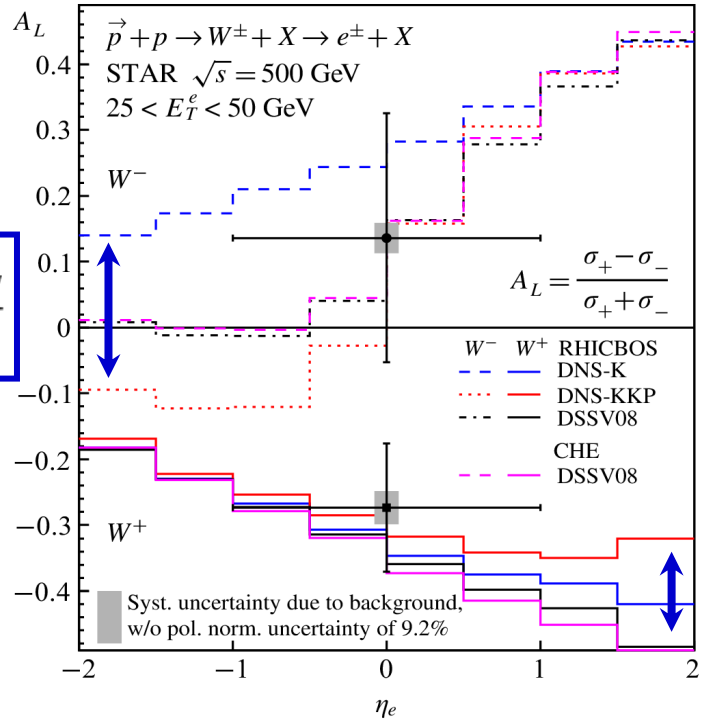


Run 11 "Online"Analysis: L~3.5 pb^{-1}



What About Forward Rapidity?

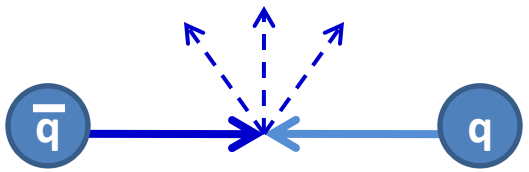
- Run 9 and Run 11 results are limited to mid-rapidity (|η| < 1), where A_L is a mixture of quark and anti-quark polarization
- At forward/backward rapidity a simplified interpretation emerges as the lepton rapidity can be used to help determine whether the polarized proton provided the quark or anti-quark

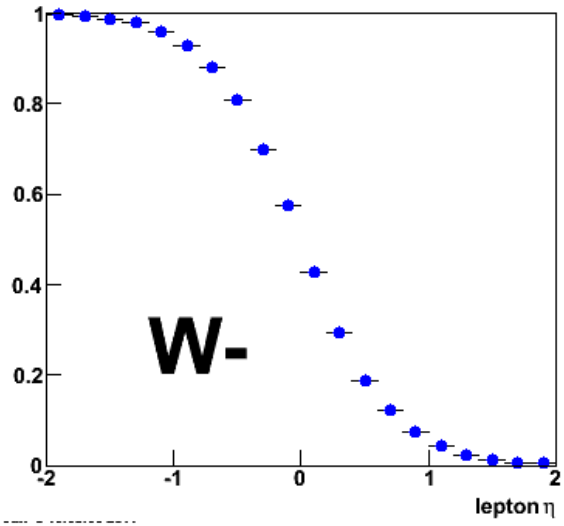


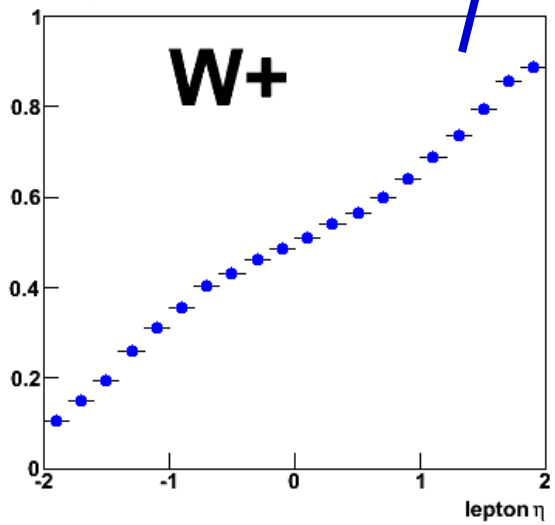
$\frac{\Delta\bar{u}}{\bar{u}}$

$\frac{\Delta\bar{d}}{\bar{d}}$

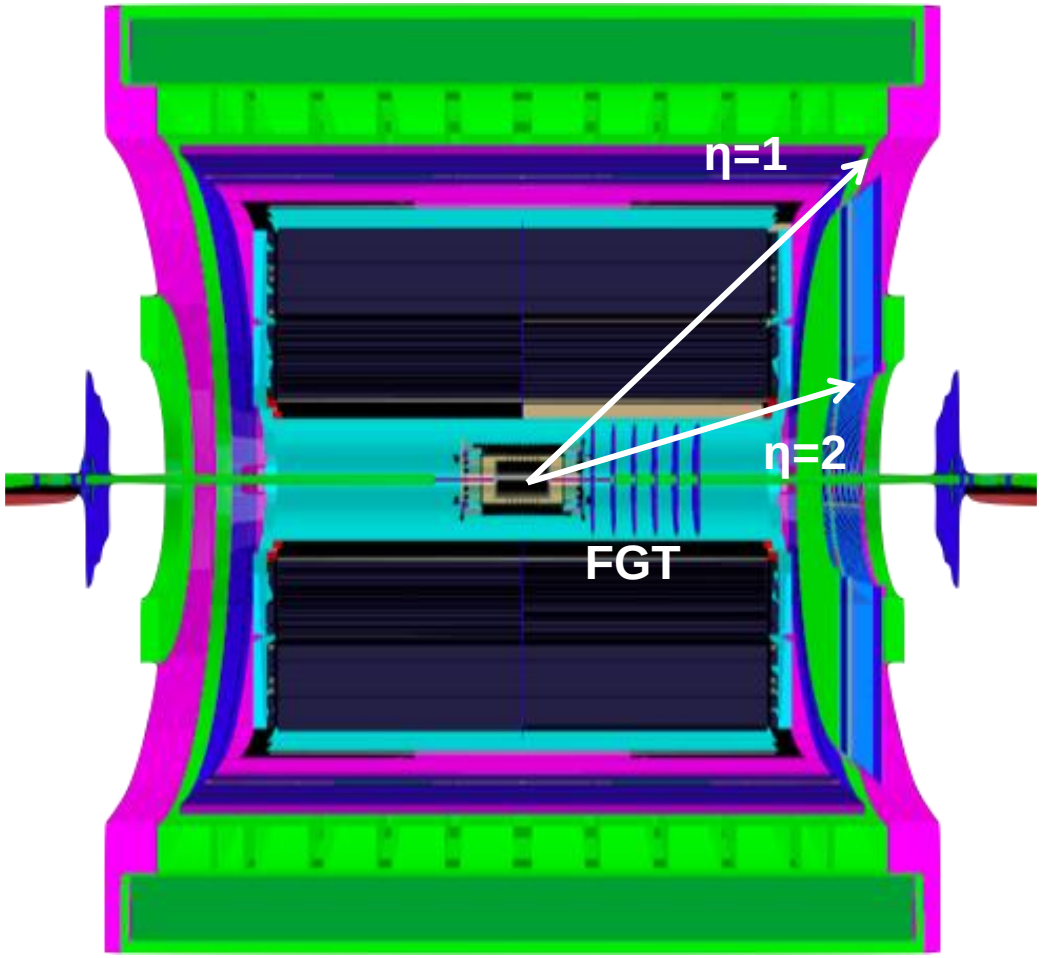
Fraction of events where polarized proton provides the anti-quark



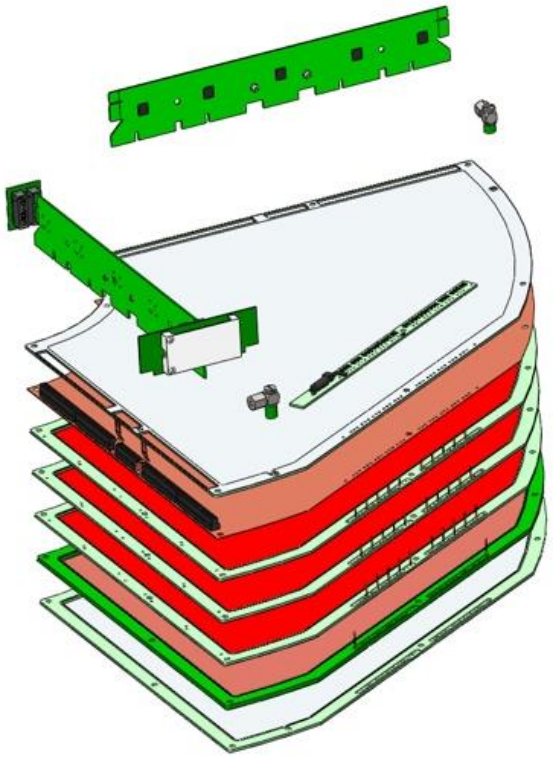




Forward Tracking: FGT Upgrade



Quarter Section Layout



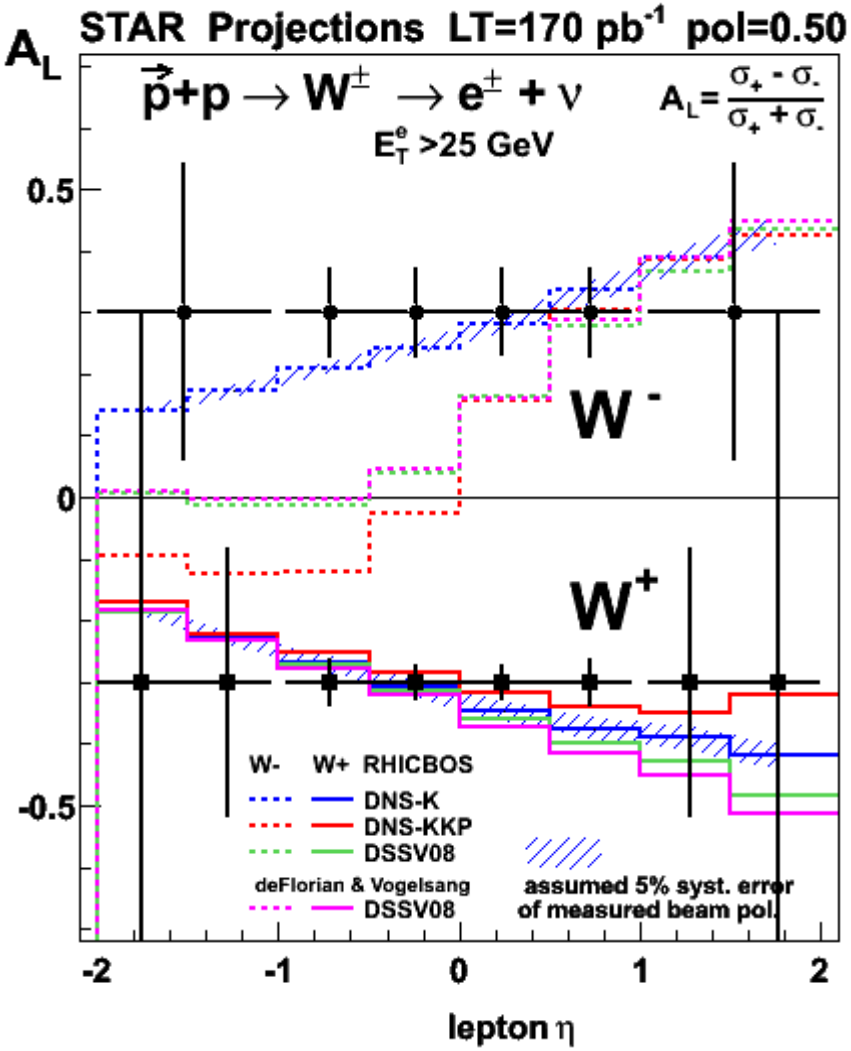
- FGT: 6 light-weight triple-GEM disks using industrially produced GEM foils (Tech-Etch Inc.)

FGT Status and Schedule

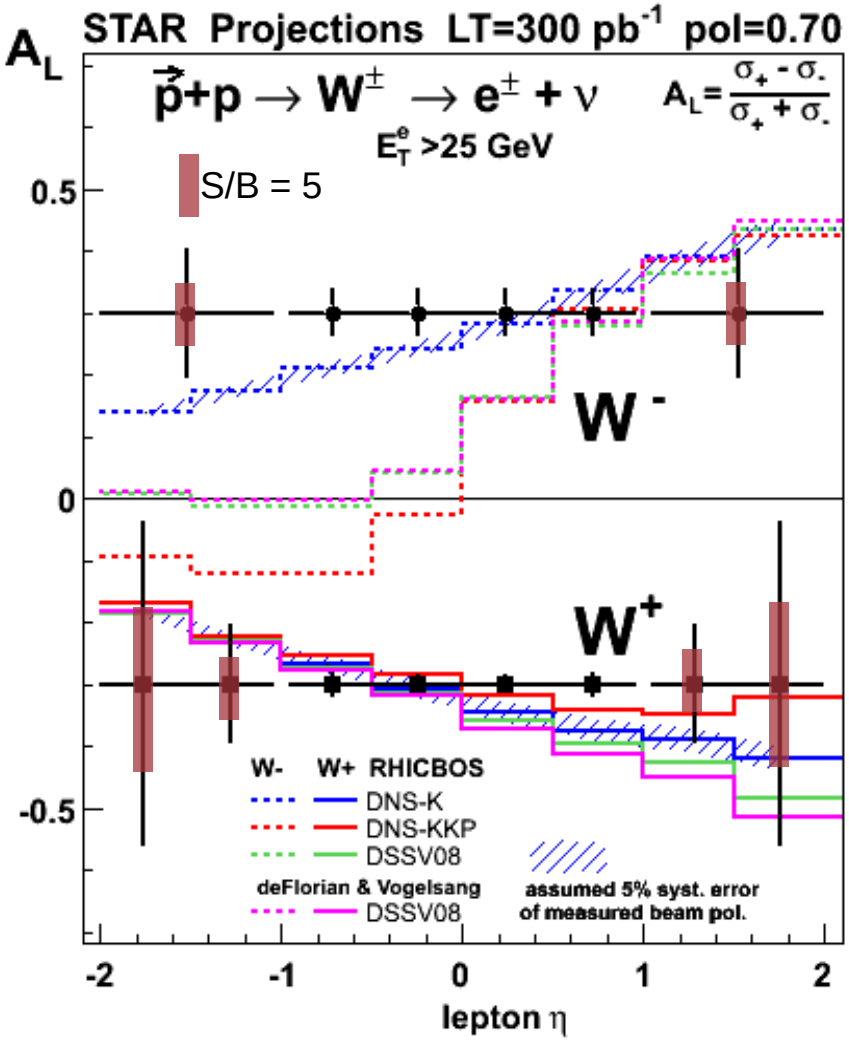
- Minimal configuration
  - Full FGT: 24 quarter sections / 6 disks (4 quarter sections per disk)
  - Minimal configuration to be installed prior to Run 12: 4 disks with 3 quarter sections each, i.e. 50% of full FGT system (24 quarter sections)
  - 4 disks, i.e. 4 space points are required for proper charge-sign discrimination
  - 6 disks eventually required to allow for full vertex acceptance : Acceptance loss taken into account in A_L projections for Run 12
- Schedule overview
  - June-September 2011: Cosmic-ray System test at STAR using STAR DAQ system
  - July-September 2011: Quarter section assembly and testing
  - September 2011: Disk assembly and WSC integration
  - October 2011: Integration of ESC / WSC / Beam pipe
  - November 2011: Installation in STAR

Future STAR W A_L

Run 12



Multi-year Program

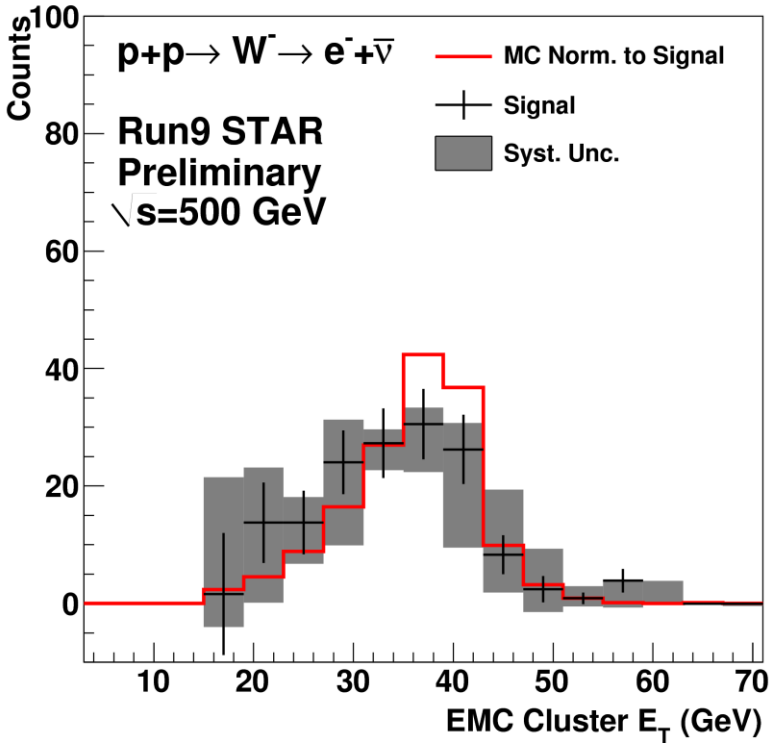


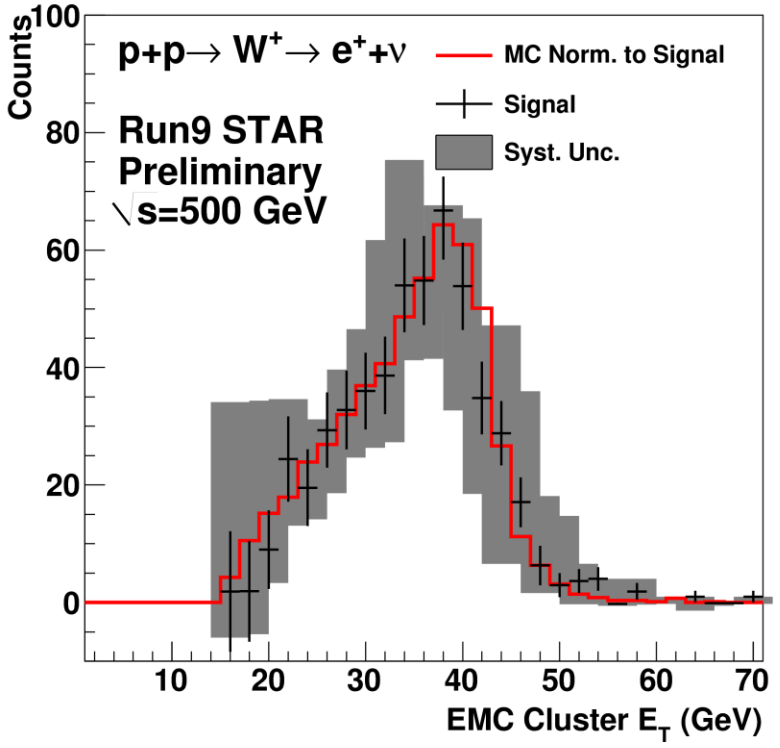
Conclusions

- W boson production in polarized p+p collisions provides a new means of studying the spin-flavor asymmetries of the proton sea quark distributions
- The cross sections for W^+ and W^- measured at STAR are consistent with theoretical expectations
- The parity-violating asymmetries, A_L, were observed and agree with theoretical predictions
- Future planned STAR measurements at mid-rapidity and forward rapidity with increased luminosity and beam polarization will provide significant constraints on the polarized sea

Backup

Data/MC Shape Comparison





Monte-Carlo is full PYTHIA+GEANT simulation of W→e+ν events at 500 GeV

Cross Section

$$\sigma_W = \int dE_T^e \int d\eta^e \frac{d^2\sigma_{W\to ev}}{d\eta^e dE_T^e} = \frac{1}{L}\frac{1}{\varepsilon_{trig}}\frac{1}{\varepsilon_{vertex}}\frac{1}{\varepsilon_{reco}}\left(N_W^{obs} - N_{back}\right)$$

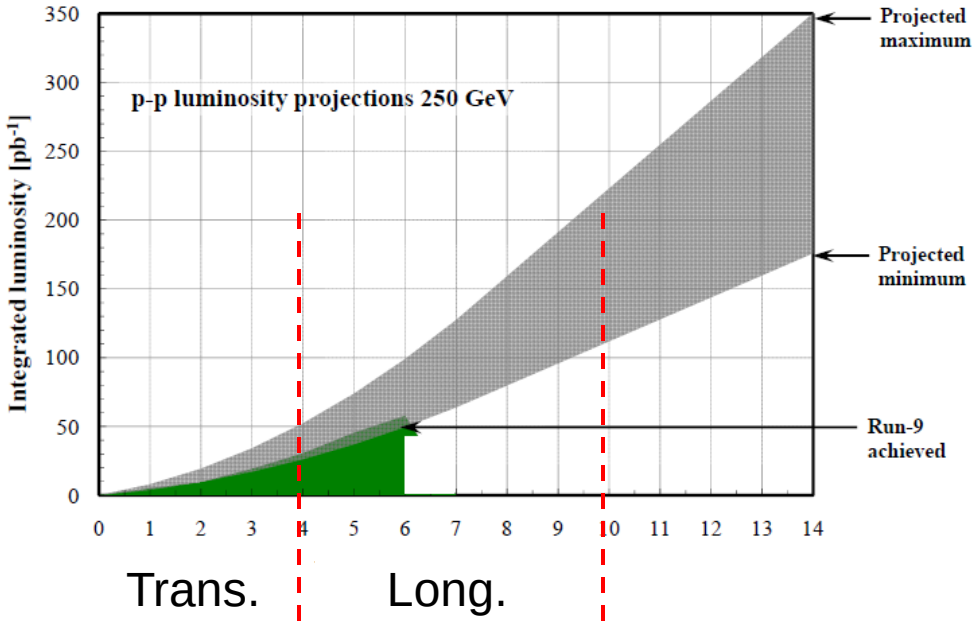
Kinematic acceptance : $|\eta_e| < 1$ and $E_T^e > 25\,GeV$

Efficiencies Calculated from full PYTHIA + GEANT simulations

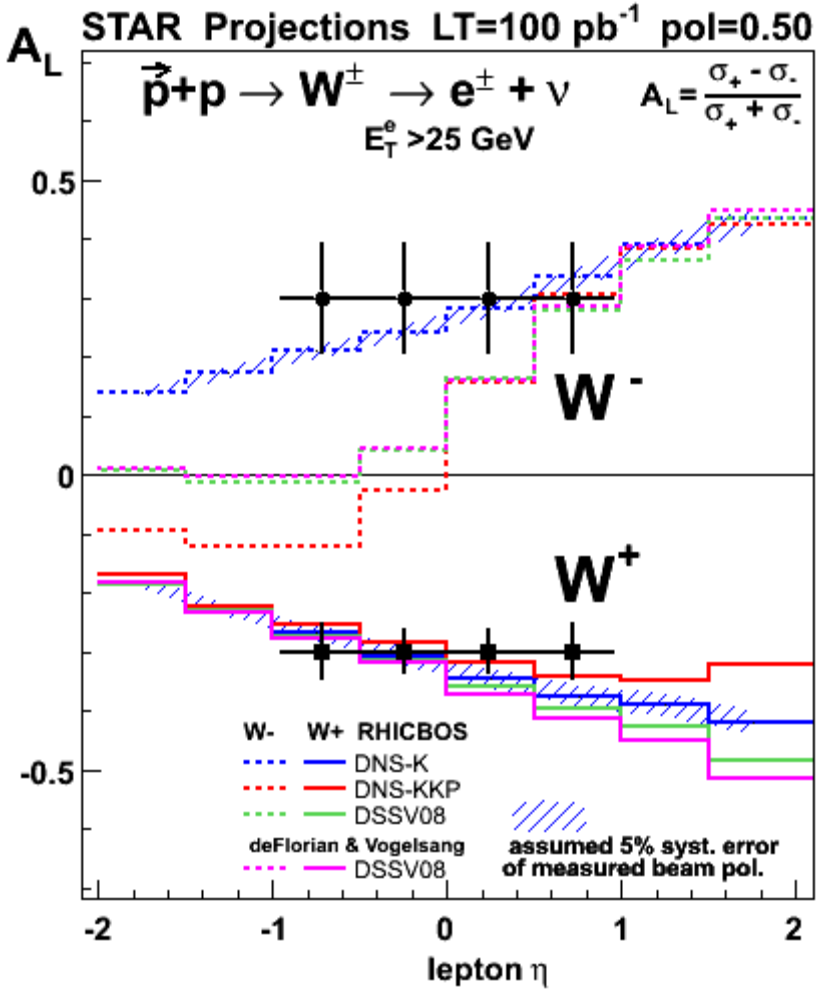
Efficiency Component	$W^- \to e^- + \bar{\nu}_e$	$W^+ \to e^+ + \nu_e$
Trigger: ϵ_{trig}	0.86 ± 0.04	0.88 ± 0.04
Vertex: ϵ_{vertex}	0.91 ± 0.03	0.91 ± 0.03
Reconstruction: ϵ_{reco}	$0.72\ ^{+0.13}_{-0.11}$	$0.71\ ^{+0.14}_{-0.11}$
Total: ϵ_{total}	$0.56\ ^{+0.11}_{-0.09}$	$0.56\ ^{+0.12}_{-0.09}$

Run 11 BUR Goals

- Transverse Goal:
  - L = 25 pb^{-1}, P = 40%
  - Driven by FMS goals (Some details in talk by T. Burton)
- Longitudinal Goal:
  - L = 80 pb^{-1}, P = 50%

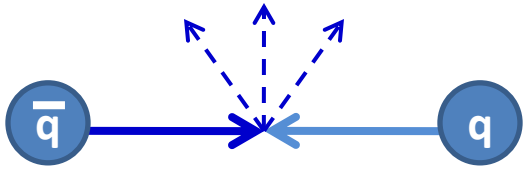


Run 11 Projections from BUR

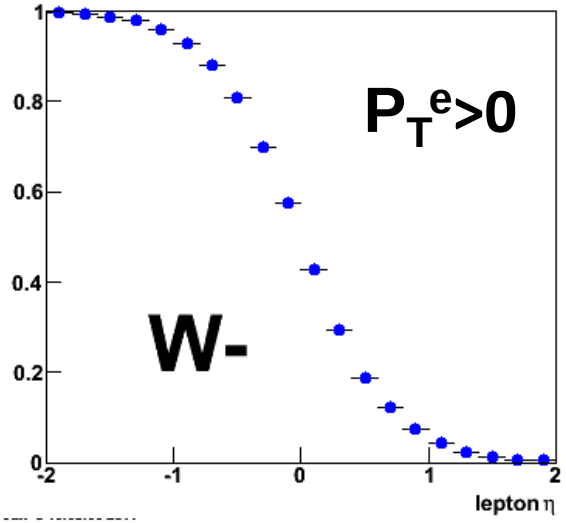


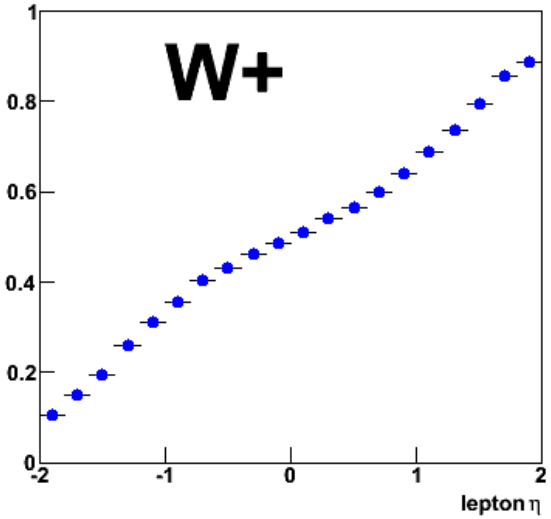
More About Forward Rapidity

Fraction of events where polarized proton provides the anti-quark



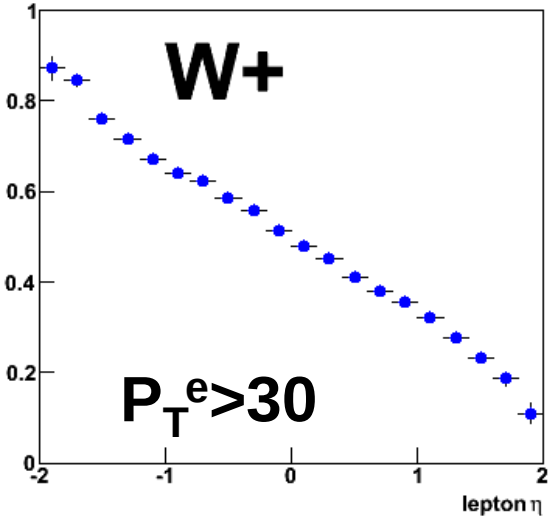
polarized **unpolarized**

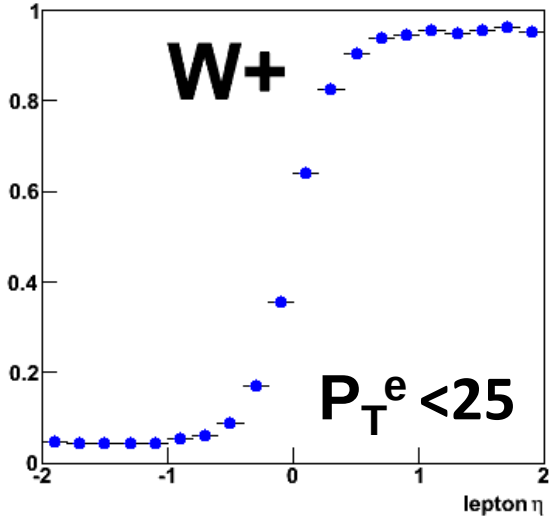




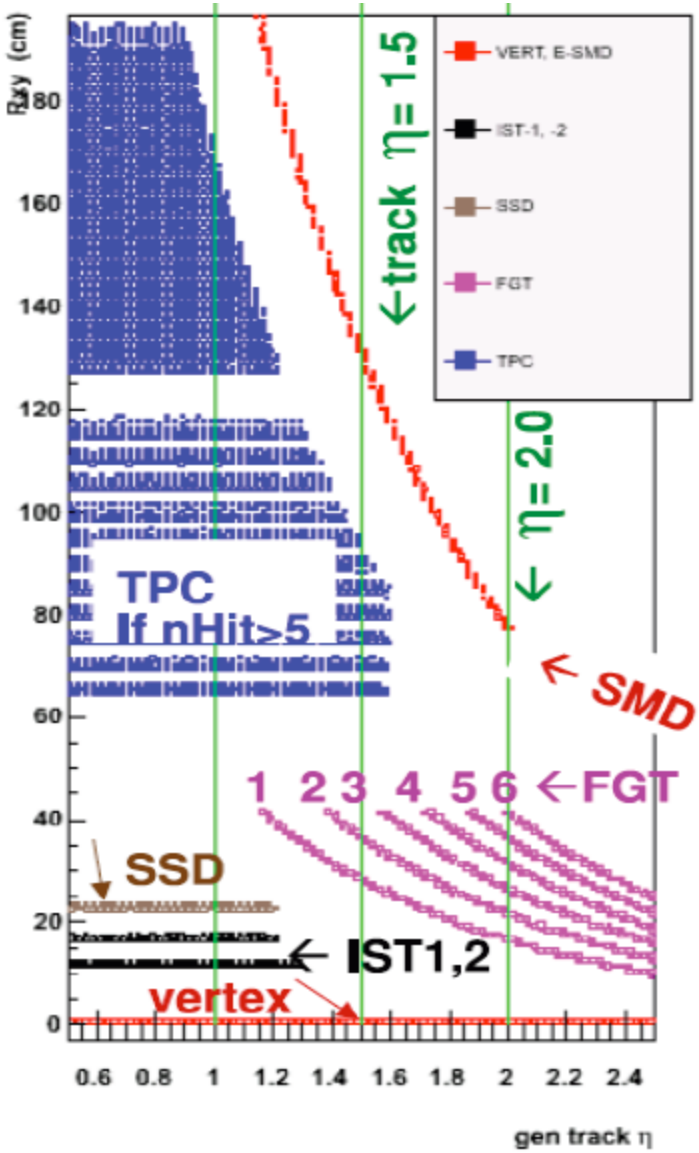
W decay kinematics

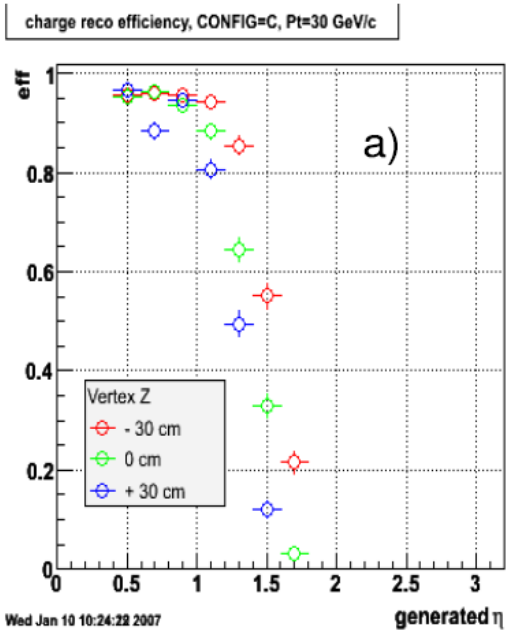
- W momentum in the direction of the higher x parton (usually the quark)
- W is left handed, so neutrino helicity gives preferred direction for $e^{\pm}$
- e- is focused parallel to W- direction for all P_T
- e+ has a strong dependence on P_T

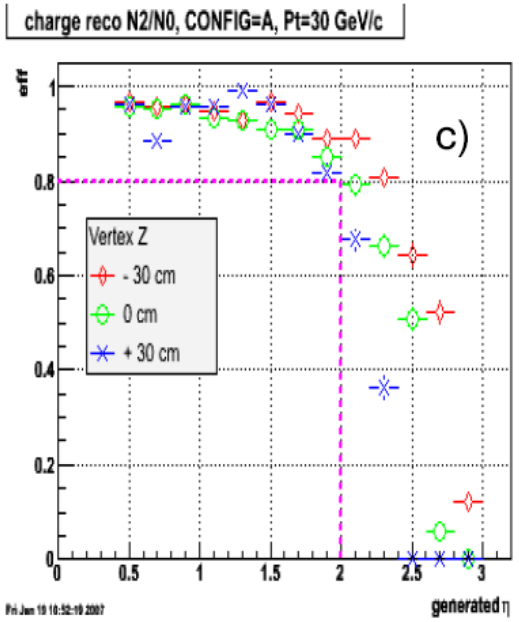




Forward Tracking: FGT Upgrade







The FGT provides charge sign identification at forward rapidity over the EEMC acceptance (η = 2)