W Boson Production in Polarized p+p Collisions at RHIC

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Moriond QCD and High Energy Interactions

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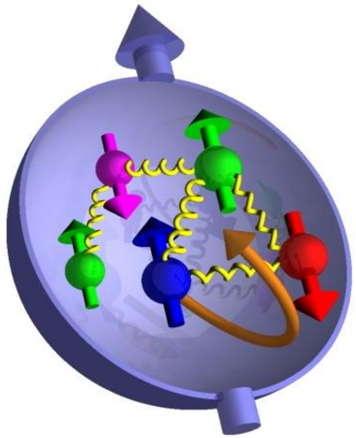
Proton Spin Puzzle



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

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

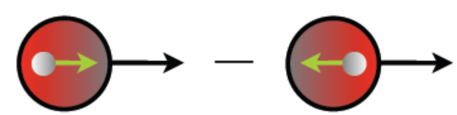
Being measured at RHIC (Jets, hadrons, etc.)

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

$\Delta f(x) =$

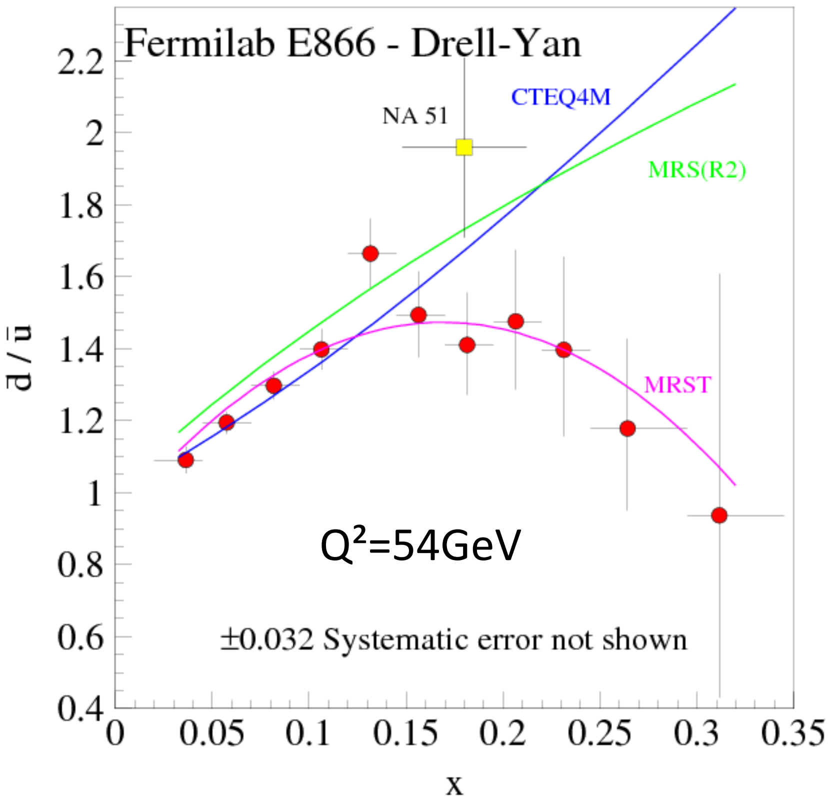


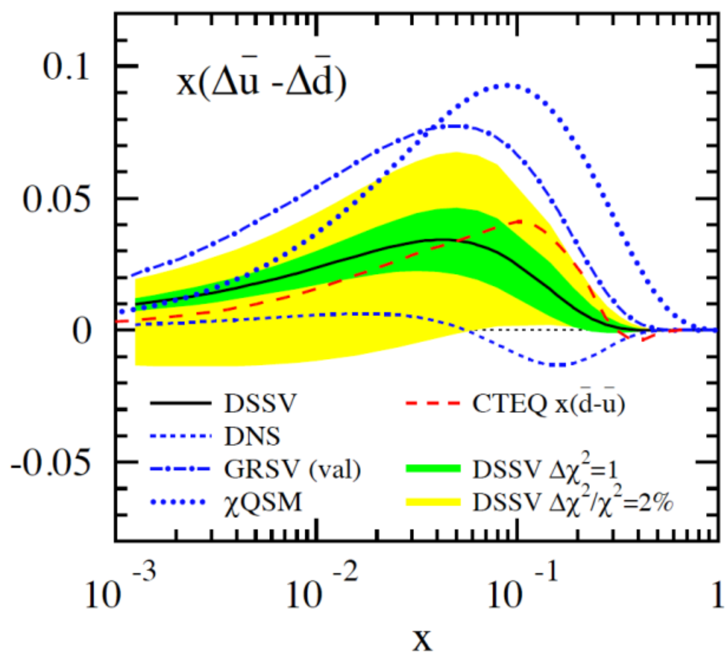
$f^+(x) - f^-(x)$

Flavor Asymmetry of the Sea

PRL **80,** 3715 (1998)

- 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.



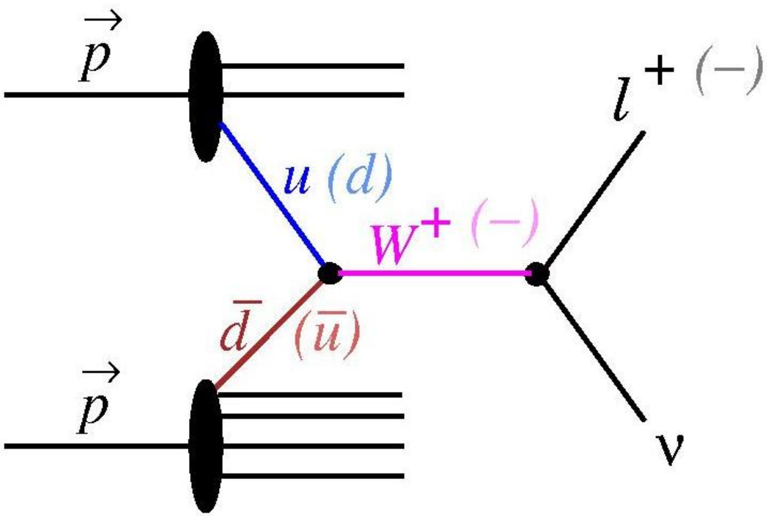


PRL **101,** 072001 (2008)

Polarized PDFs from recent global fits:

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

Probing the Sea Through W Production



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

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

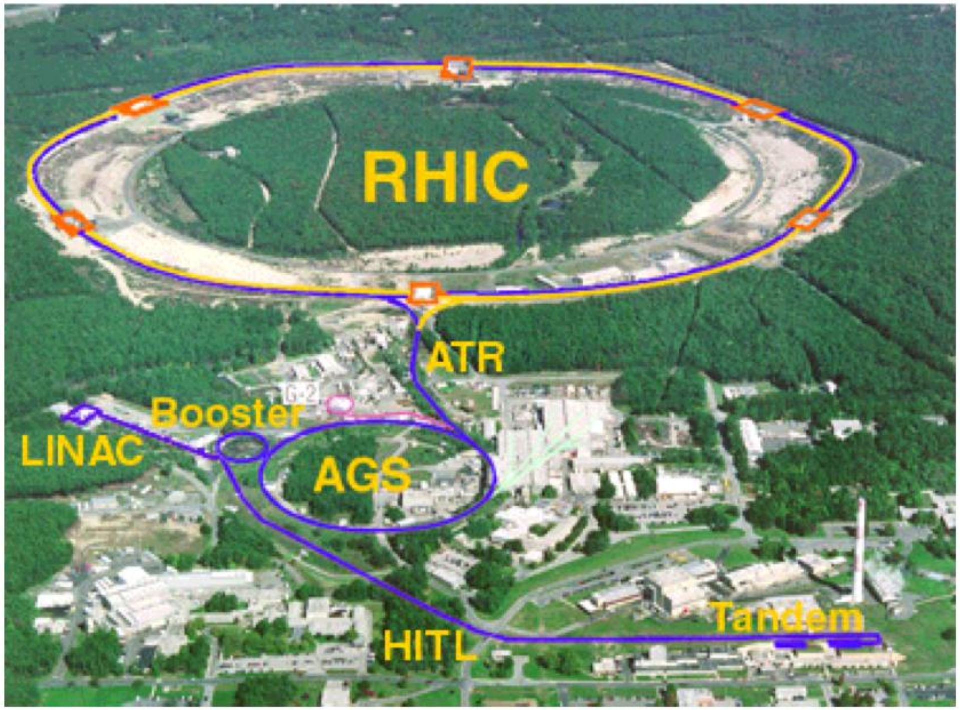
- Detect Ws through e^+/e^- decay channels
- V-A coupling leads to perfect spin separation
  - LH quarks and RH anti-quarks
- Neutrino helicity gives preferred direction in decay

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

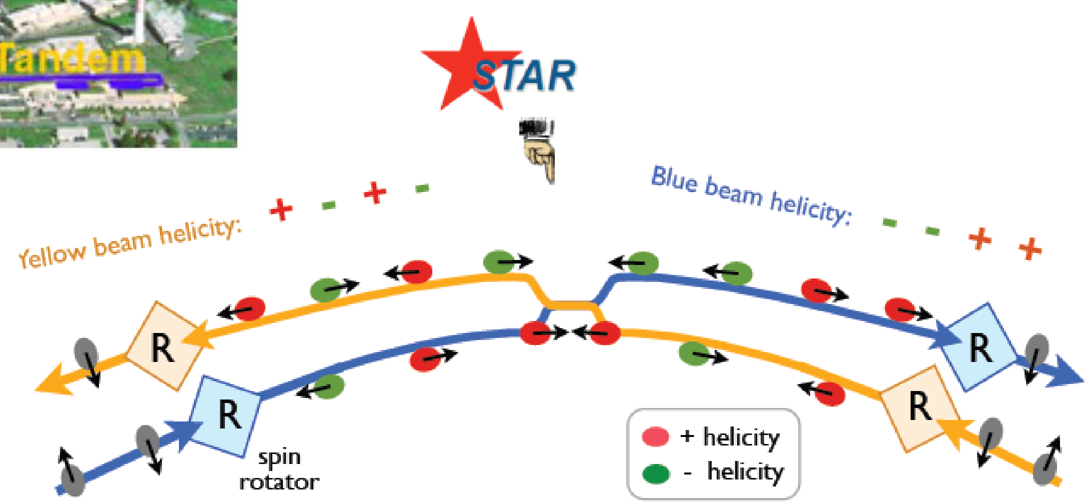
(Helicity flip in one beam while averaging over the other)

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

RHIC: Polarized p+p Collider

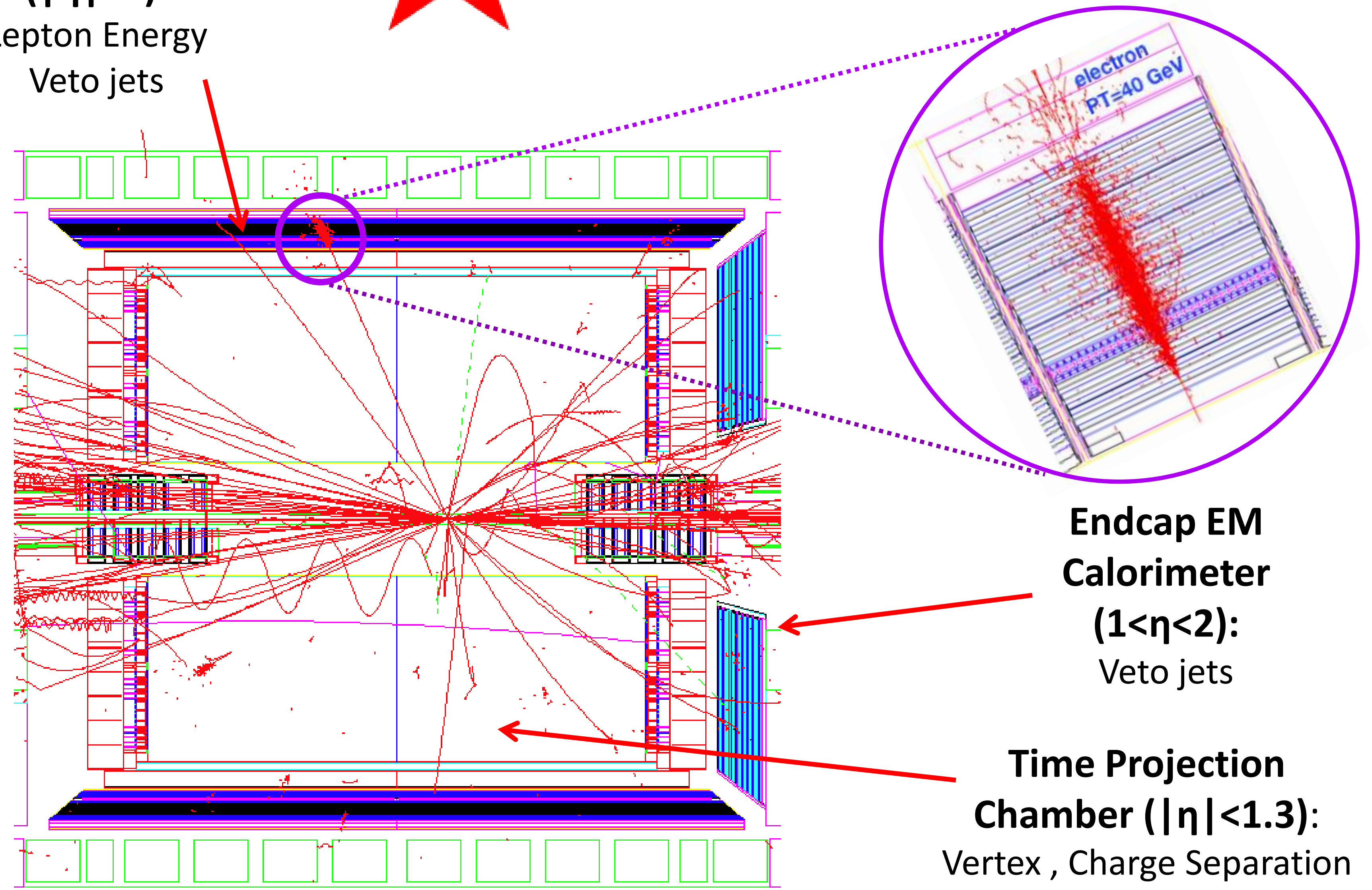


- First collisions at √s=500 GeV in 2009
- Beam polarization ~40%



STAR Detector

Barrel EM Calorimeter ($|\eta|<1$):
Lepton Energy
Veto jets



Endcap EM Calorimeter ($1<\eta<2$):
Veto jets

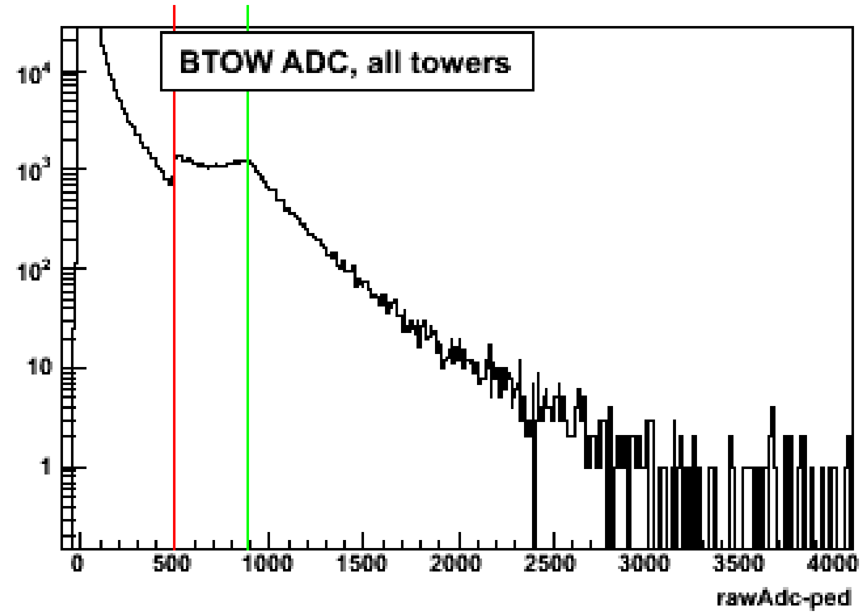
Time Projection Chamber ($|\eta|<1.3$):
Vertex , Charge Separation
Veto jets

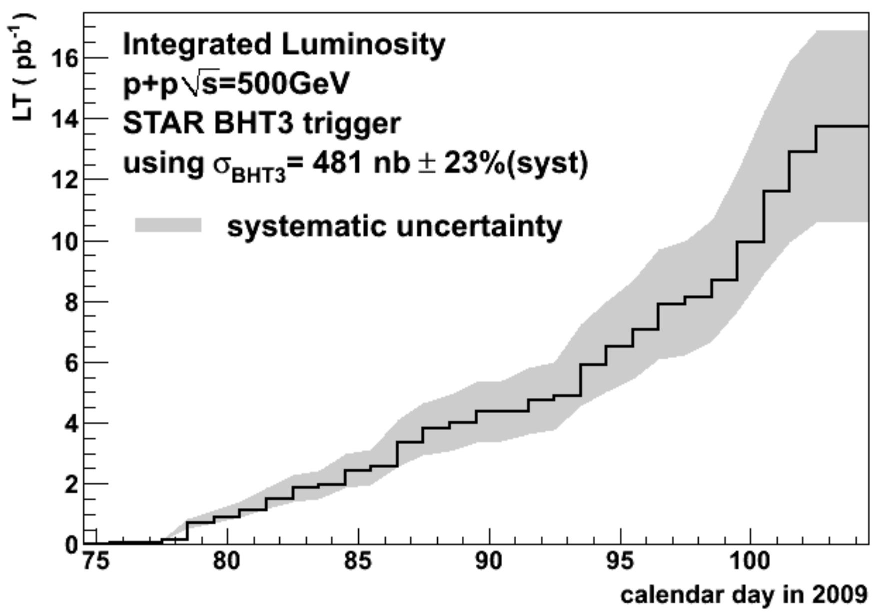
Pythia+Geant p+p→W→e+ν event @ 500 GeV

500 GeV Data Set from Run 9

W Trigger:

High Tower Hardware L0 Trigger
(E_T > 7.3 GeV)
High E_T 2x2 Cluster Software L2
(E_T > 13 GeV)





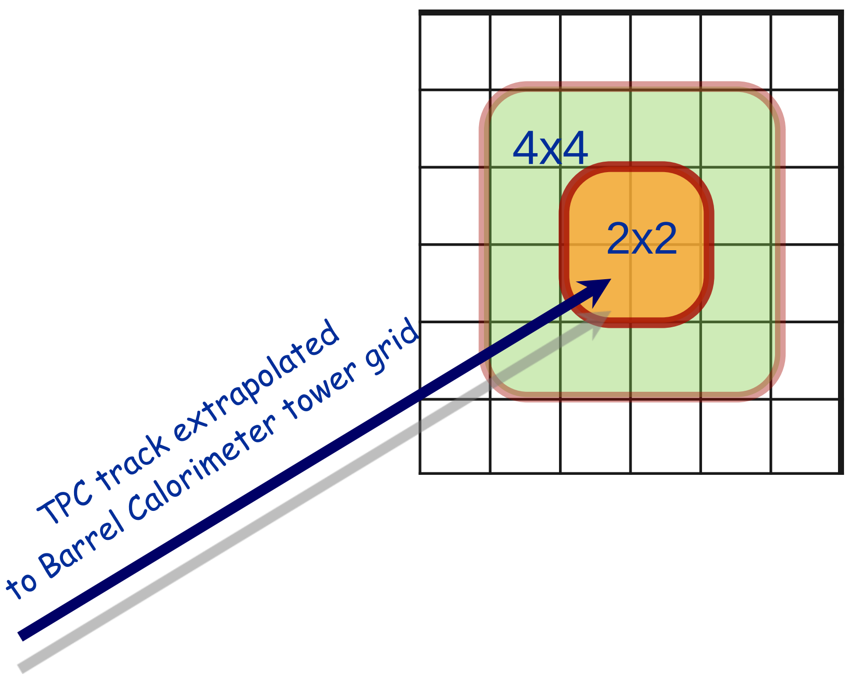
Integrated Luminosity @ 500 GeV:

•**Vernier Scan** technique used to measure cross section for high tower trigger

$$\sigma_{BHT3} = 481\,\mathrm{nb} \pm 10\,(\mathrm{stat.}) \pm 110\,(\mathrm{syst.})$$

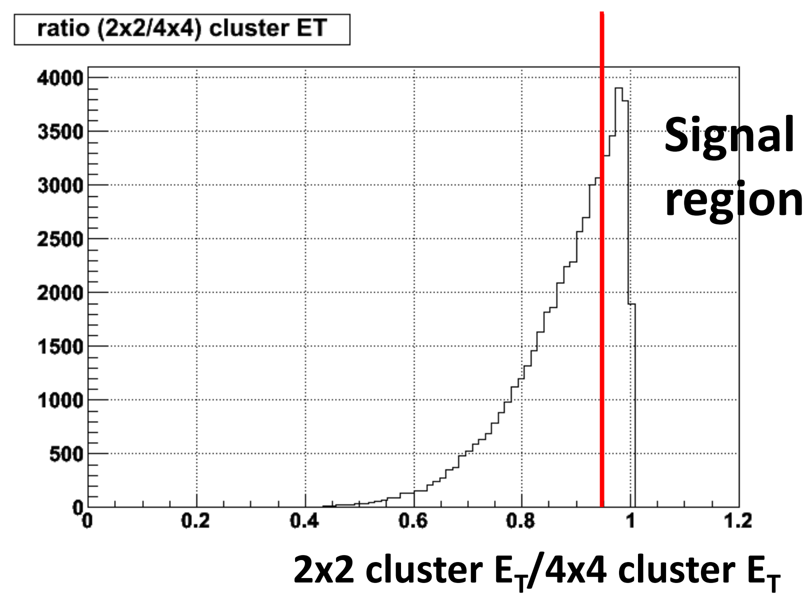
•Scaling the number of background-subtracted high tower triggers by $1/\sigma_{BHT3}$ yields the integrated luminosity of **L=13.7 pb^{-1}**

W Algorithm: Lepton Isolation

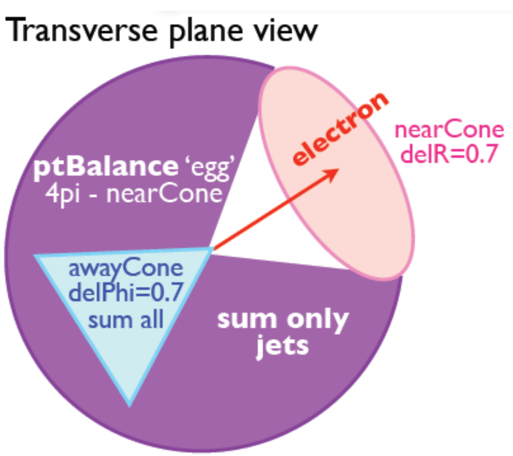


Lepton Isolation Cuts:

- 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

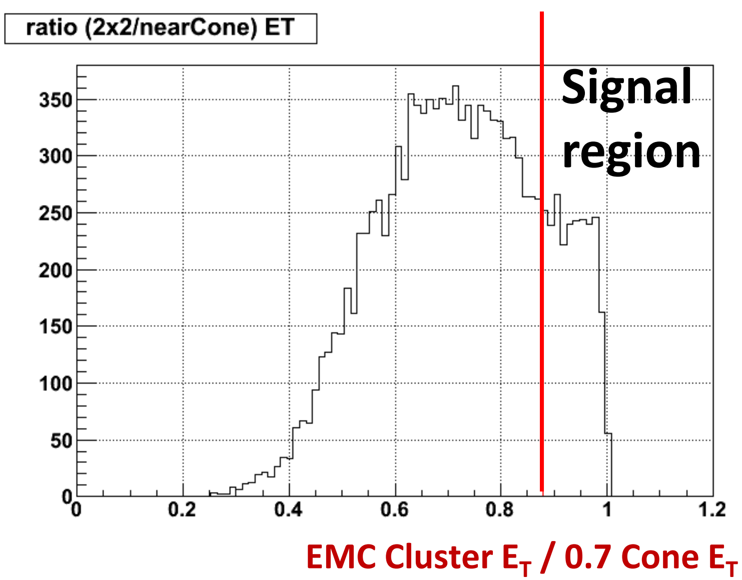


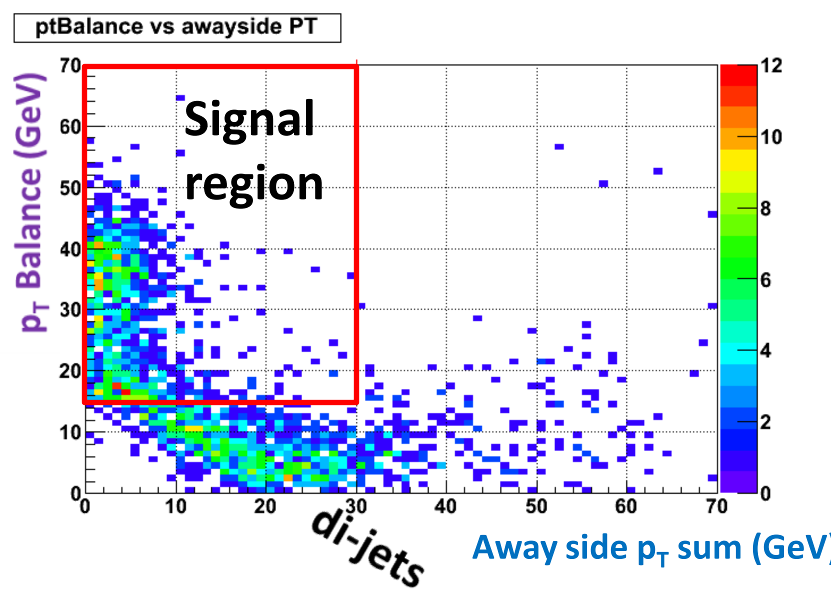
Suppress jets with leading hadron

- Near side jet-cone veto

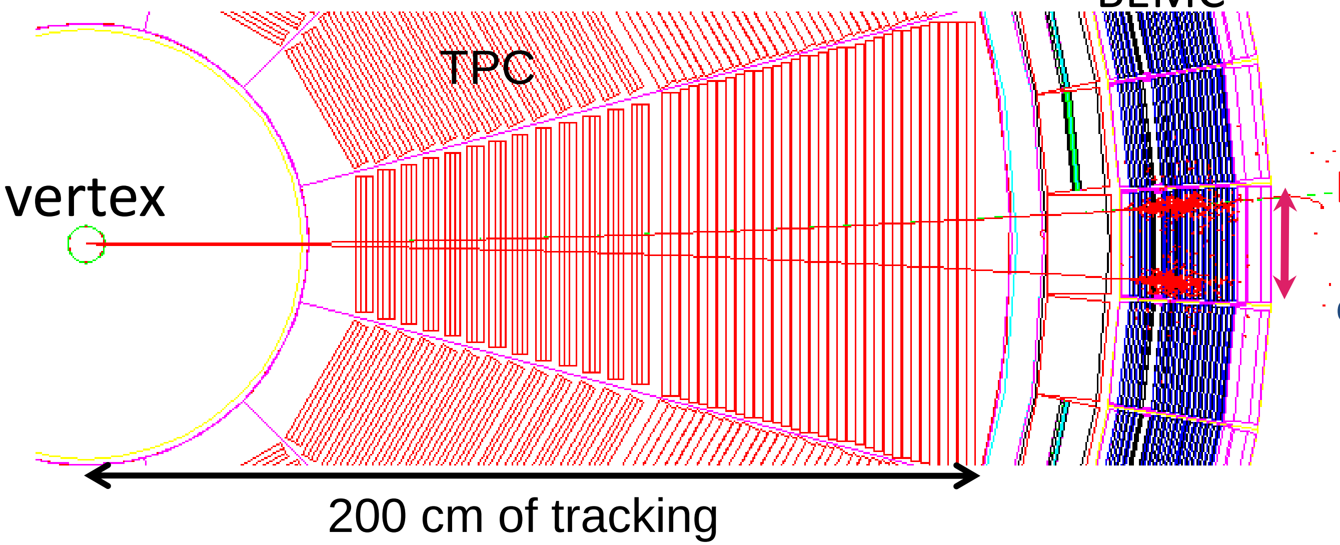
Suppress di-jets and multi-jet events

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





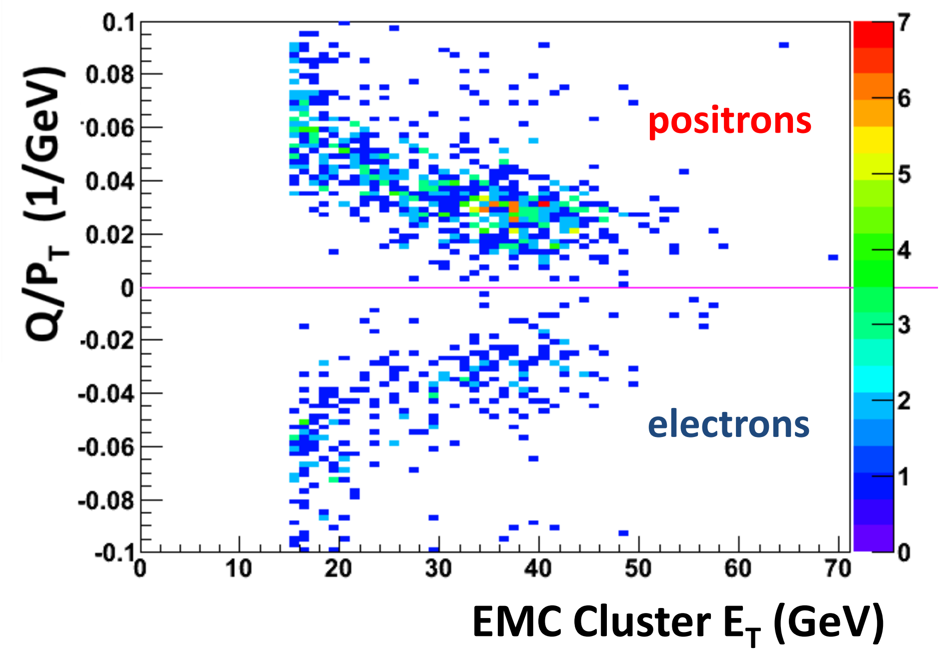
e^+/e^- Charge Separation at High P_T



+/- distance D ~ 1/P_T

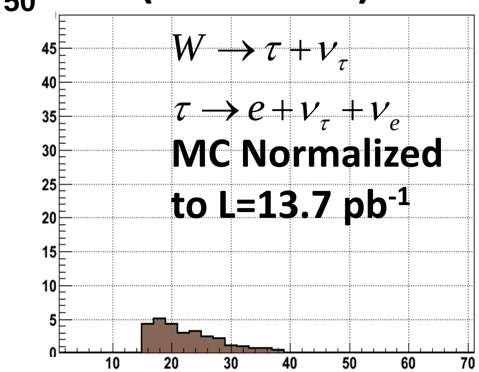
P_T=5 GeV : D~15 cm

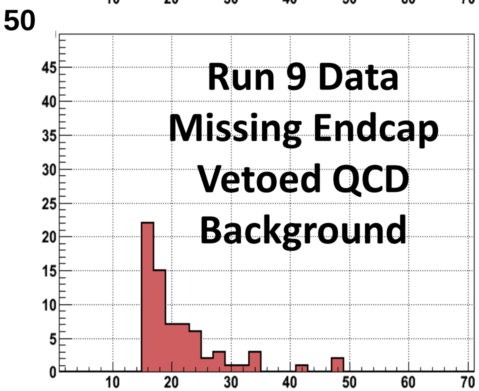
P_T=40 GeV : D ~2 cm

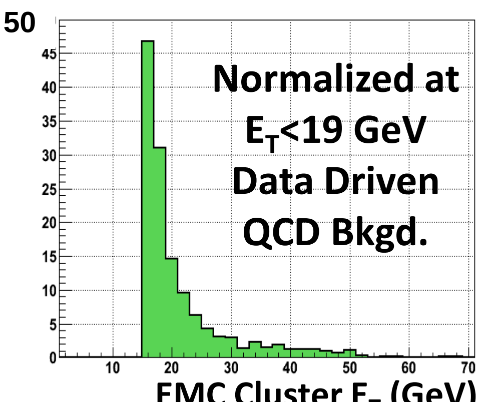


Background Subtraction

(W+ shown)

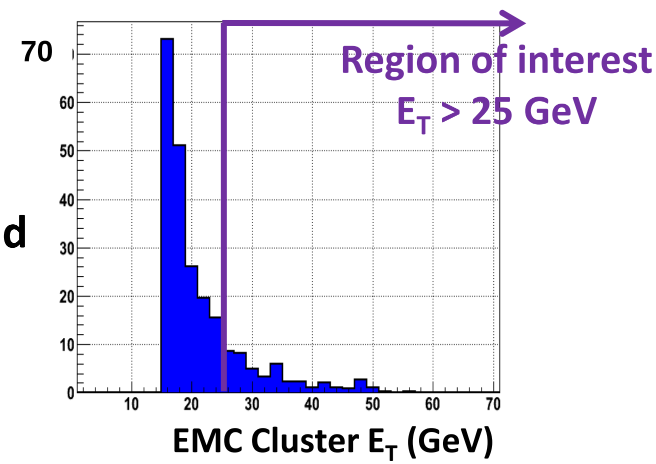


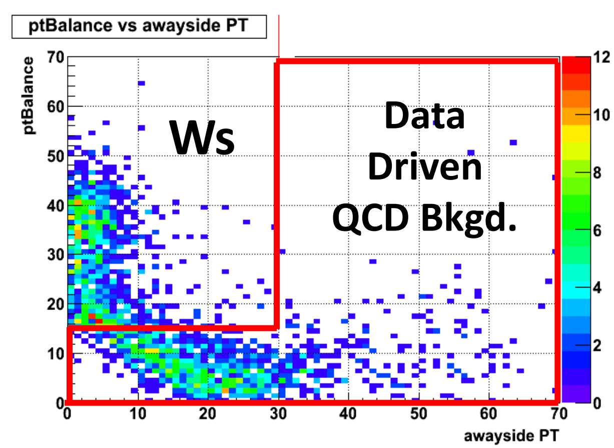




Background Events ($E_T > 25$ GeV)	$W^- \to e^- + \bar{\nu}_e$	$W^+ \to e^+ + \nu_e$
$W \to \tau + \nu_\tau$	2.7 ± 0.7	8.4 ± 2.2
Missing Endcap	14 ± 4	13 ± 4
Normalized QCD	$8.0\ ^{+20}_{-4}$	$25\ ^{+36}_{-9}$
Total	$25\ ^{+21}_{-7}$	$46\ ^{+36}_{-11}$

Total Background

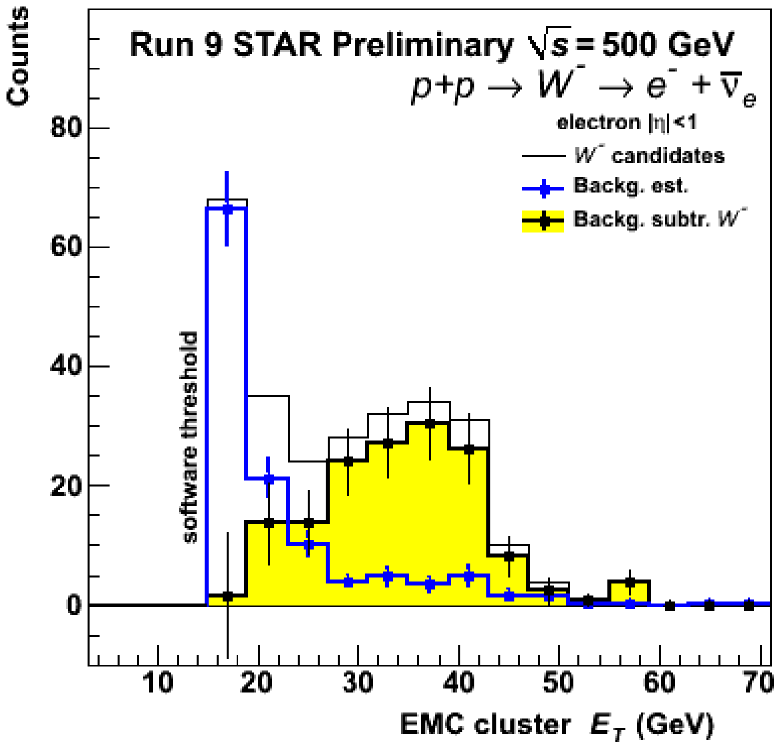


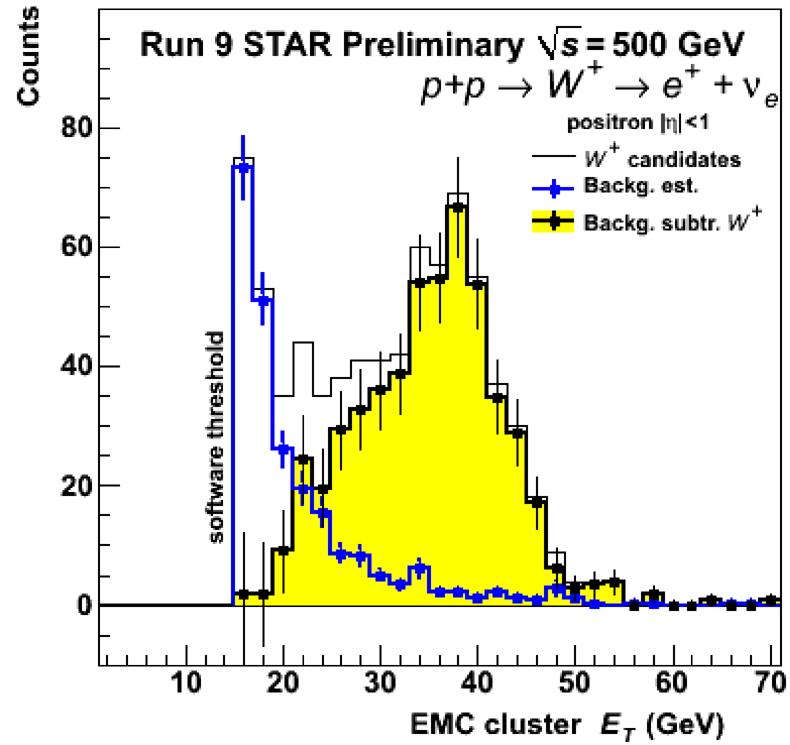


Background Systematic

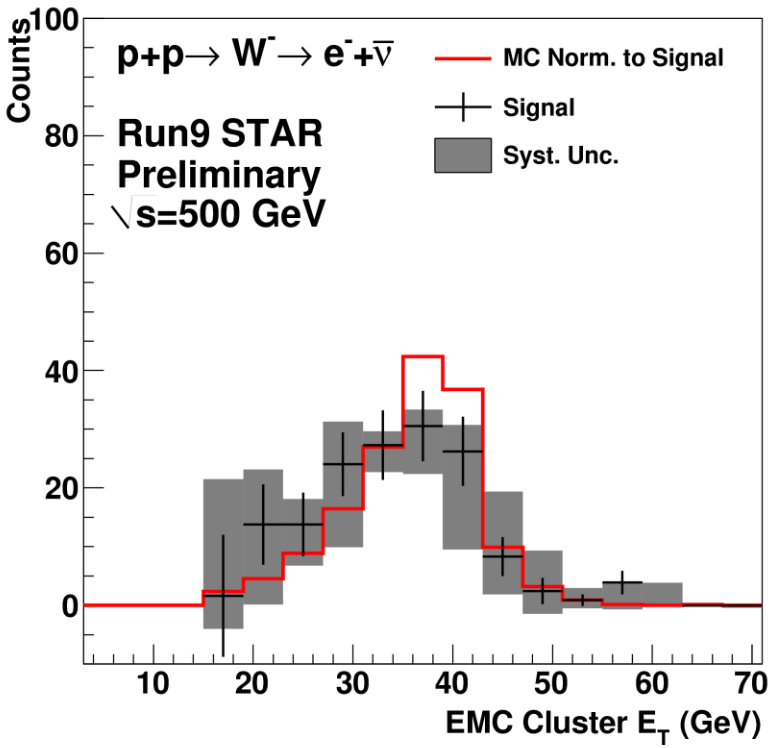
- Calculate different data driven QCD background shapes by varying p_T Balance and away side p_T cuts
- Vary normalization region (E_T < 17 and E_T < 21 GeV)
- The largest deviation in each bin gives an estimate of the systematic uncertainty

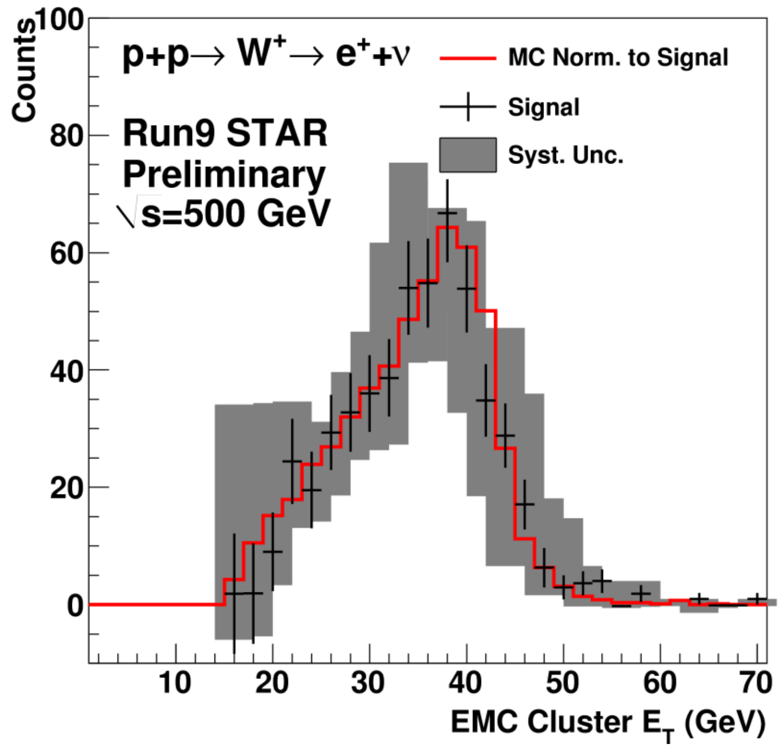
STAR Ws from Run 9





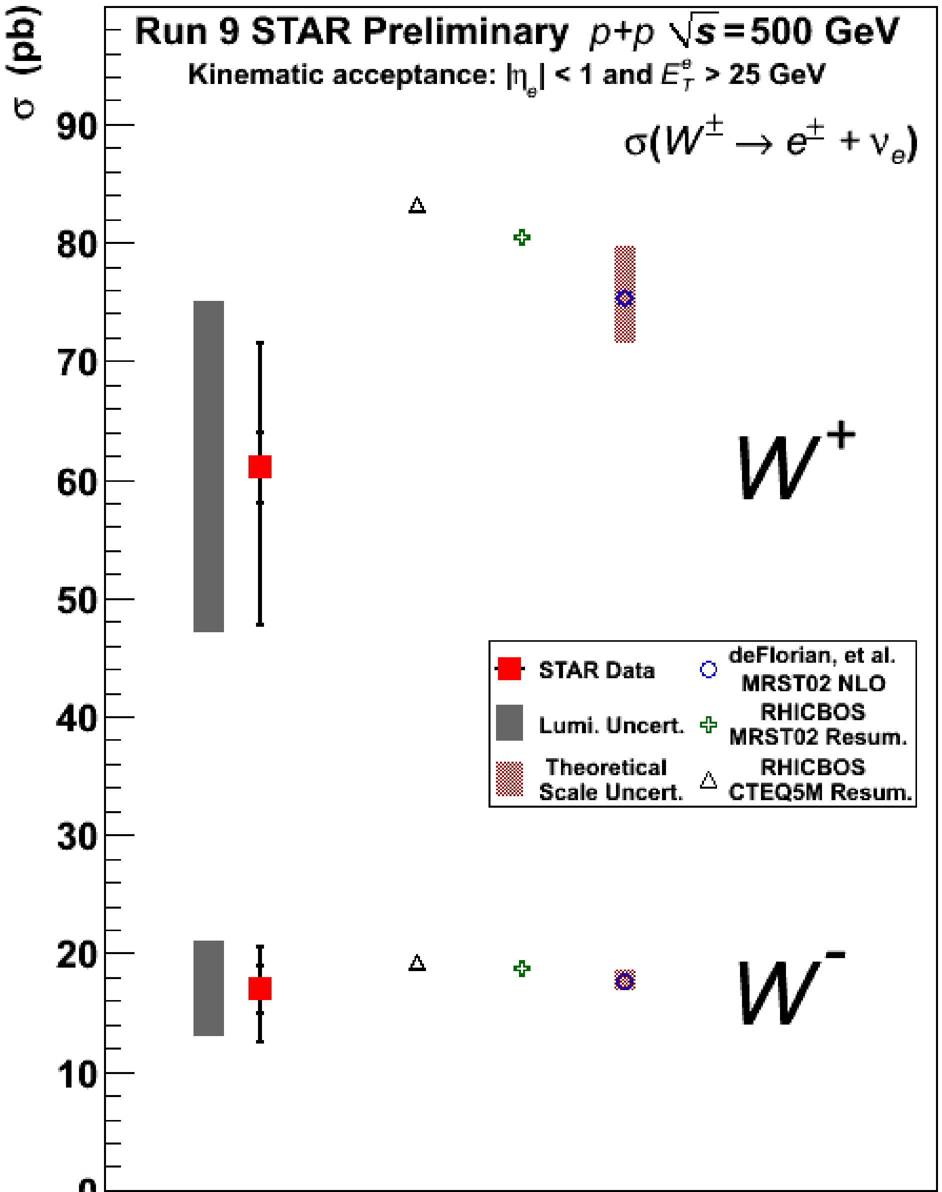
Data/MC Shape Comparison





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

W Production Cross Section at STAR



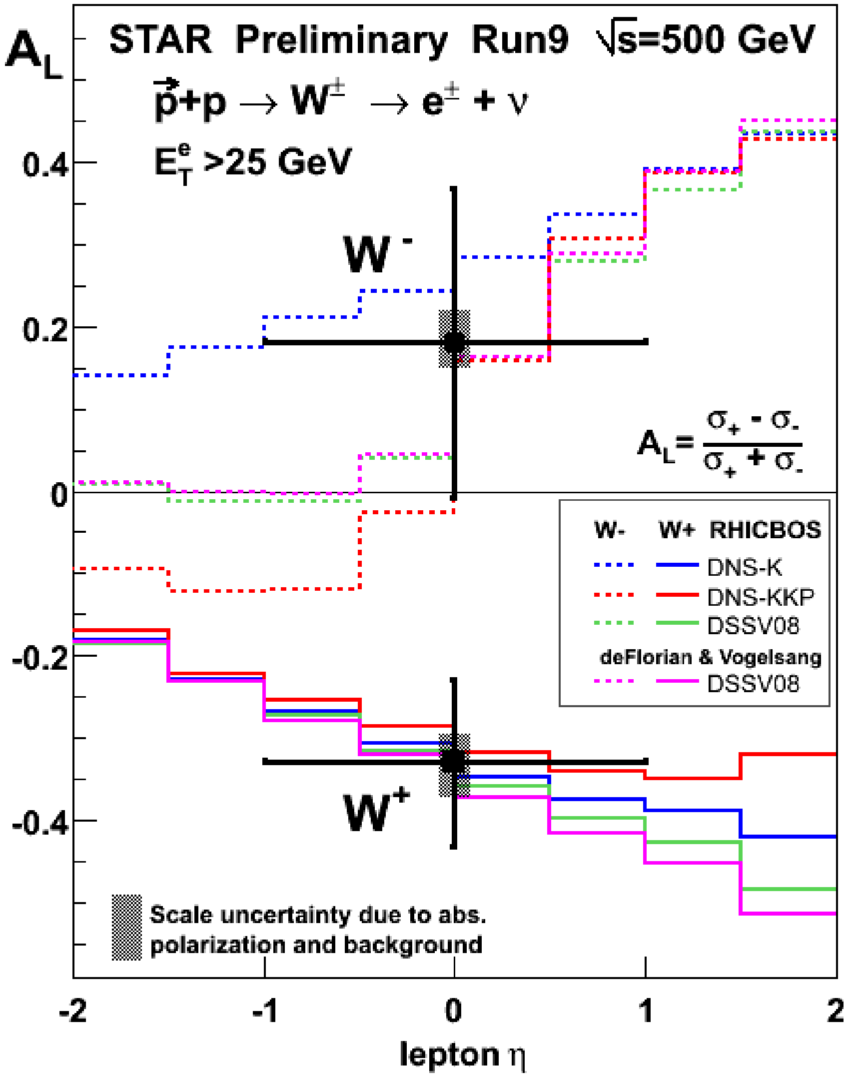
	$W^- \to e^- + \bar{\nu}_e$	$W^+ \to e^+ + \nu_e$
N_W^{obs}	156	513
N_{back}	$25\ ^{+21}_{-7}$	$46\ ^{+36}_{-11}$
ϵ_{total}	$0.56\ ^{+0.11}_{-0.09}$	$0.56\ ^{+0.12}_{-0.09}$
$\int Ldt\ (\mathrm{pb}^{-1})$	13.7 ± 3.2	13.7 ± 3.2

Run 9 STAR Preliminary (p+p 500 GeV)

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

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

A_L for Ws at STAR



After spin sorting the yields, calculate longitudinal parity-violating spin asymmetry A_L :

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

STAR Preliminary Run 9

$$A_L(W^+) = -0.33 \pm 0.10(\text{stat.}) \ \pm 0.04(\text{syst.})$$

$$A_L(W^-) = \ 0.18 \pm 0.19(\text{stat.}) \ {}^{+0.04}_{-0.03}(\text{syst.})$$

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 also 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