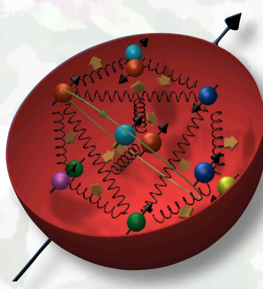
Recent STAR W production results of the high-energy polarized p-p program at RHIC at BNL

Bernd Surrow

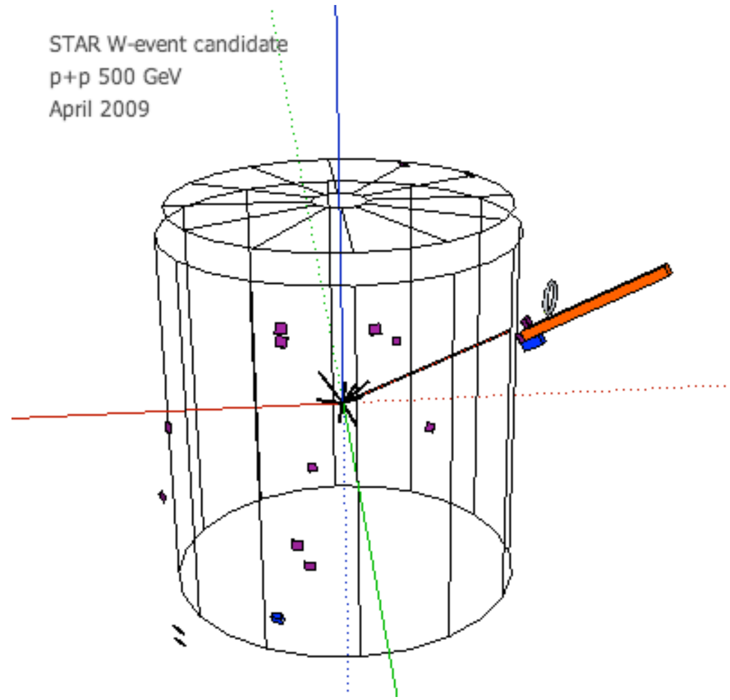
Massachusetts Institute of Technology

(On behalf of the STAR Collaboration)



ICHEP 2010
Paris, France, July 22-28, 2010

Outline

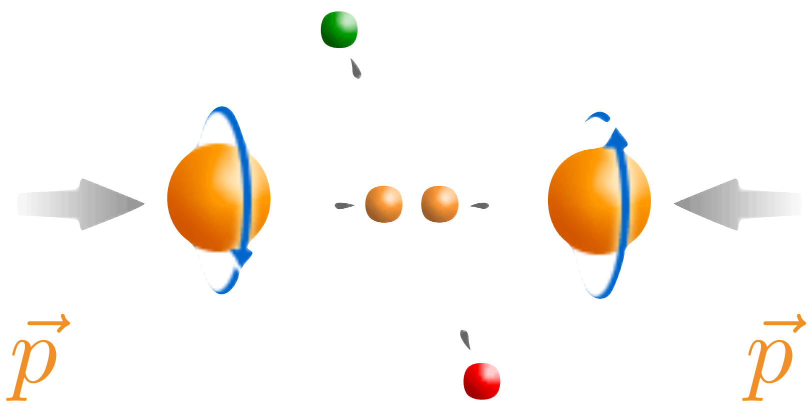


- W production - Recent Results

  First W^+/W^- Cross-section and A_L Measurement at STAR

- Experimental aspects: RHIC / STAR

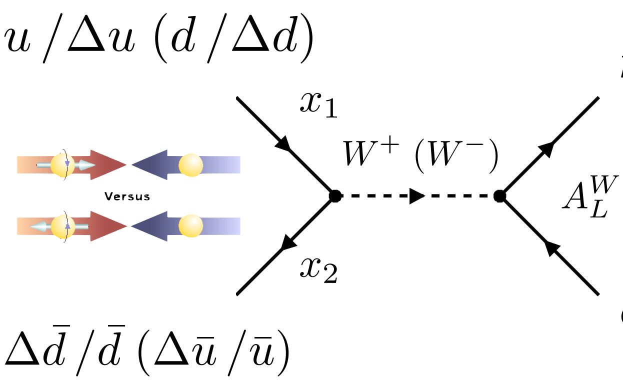
- Theoretical foundation



- Summary and Outlook

Theoretical foundation

- STAR W program in e-decay mode at mid-rapidity and forward/backward rapidity



$$A_L^W = \frac{1}{P}\frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}$$

$$y_l = y_W + \underbrace{\frac{1}{2}\ln\frac{1+\cos\theta^*}{1-\cos\theta^*}}_{y_l^*}$$

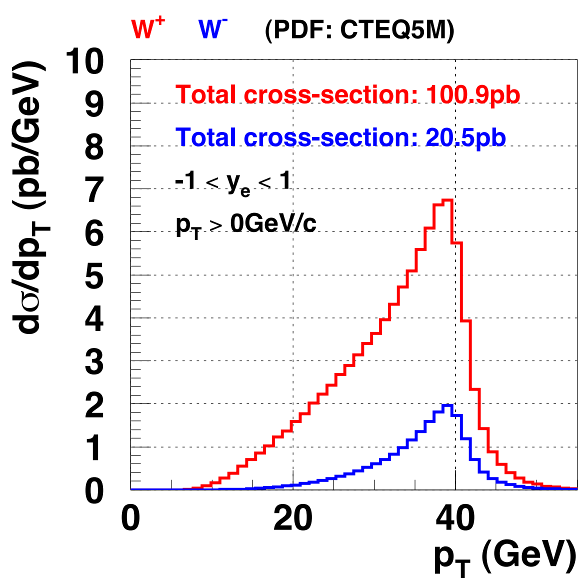
$$p_T = p_T^* = \frac{M_W}{2}\sin\theta^*$$

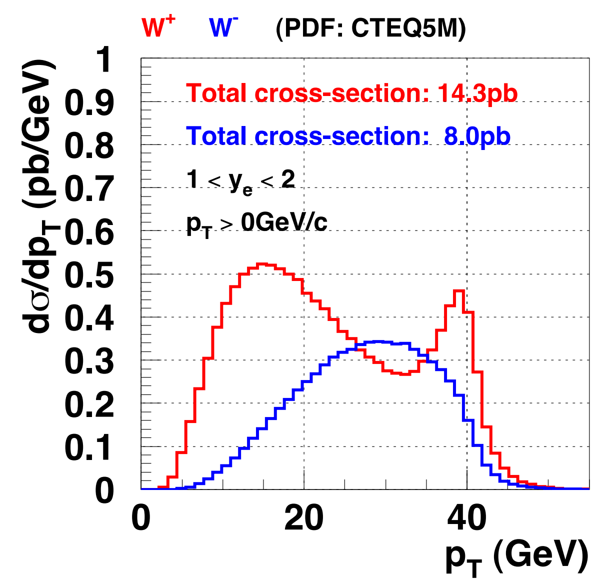
$$x_1 = \frac{M_W}{\sqrt{s}}e^{y_W}$$

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

$$\frac{M_W}{\sqrt{s}} = 0.16$$

- Key signature: High p_T lepton (e^-/e^+)(Max. $M_W/2$) - Selection of W^+/W^- : Charge sign discrimination of high p_T lepton
- Required: Lepton/Hadron discrimination



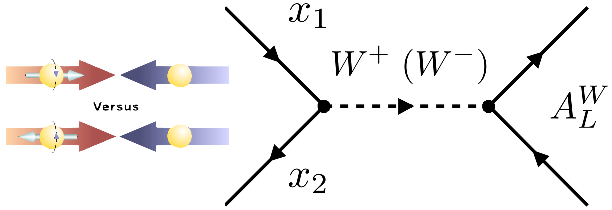


Total (√s=500GeV) $\sigma(W^+)$=135pb and $\sigma(W^-)$=42pb

Theoretical foundation

- STAR W program in e-decay mode at mid-rapidity and forward/backward rapidity

$u\,/\Delta u\;(d\,/\Delta d)$



$\Delta\bar{d}\,/\bar{d}\;(\Delta\bar{u}\,/\bar{u})$

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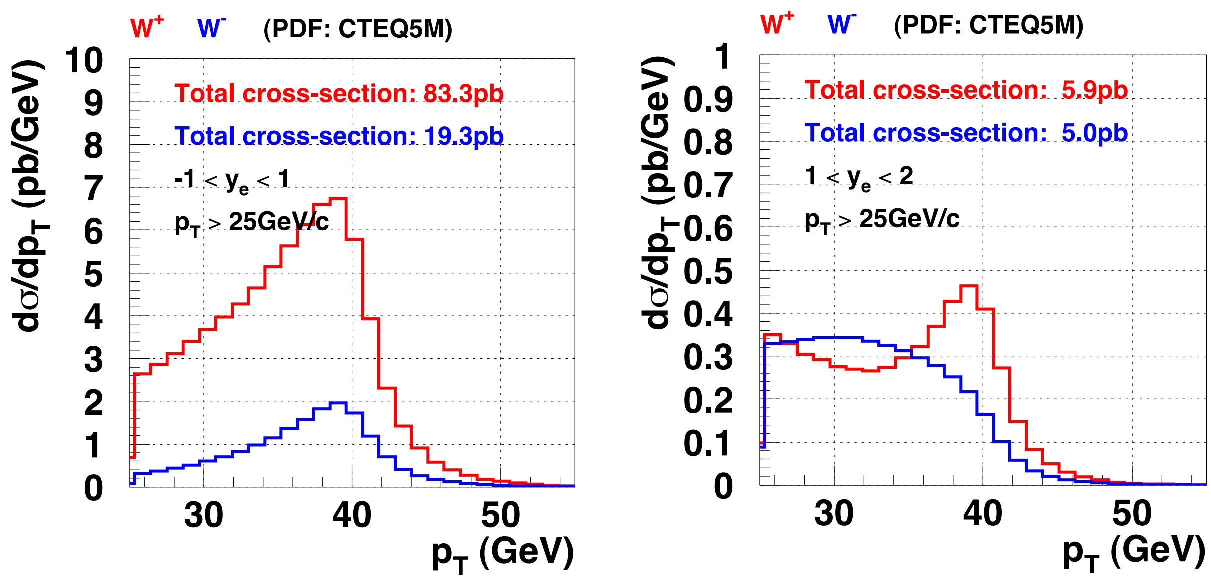

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Theoretical foundation

- A_L behavior for STAR mid-rapidity and forward/backward rapidity region

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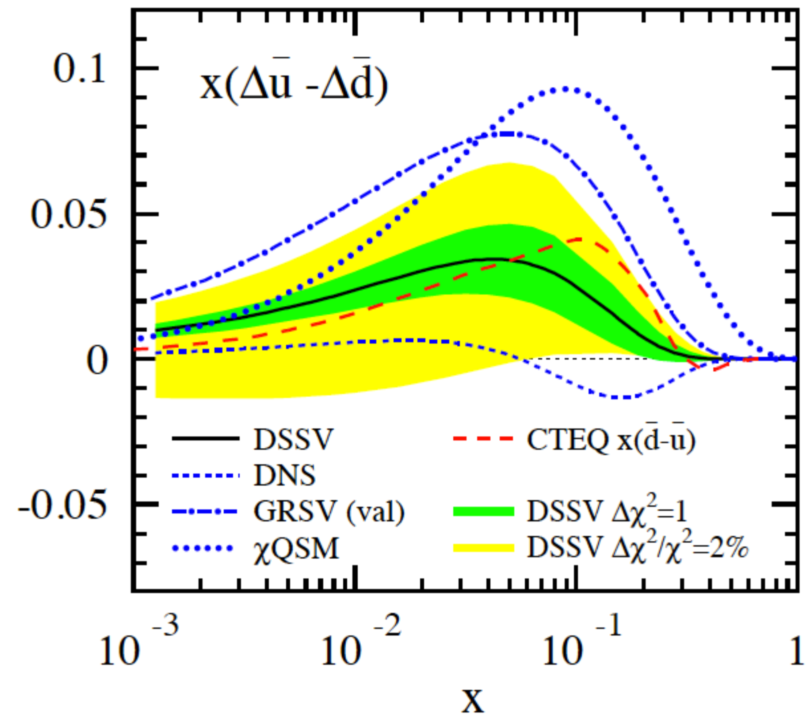

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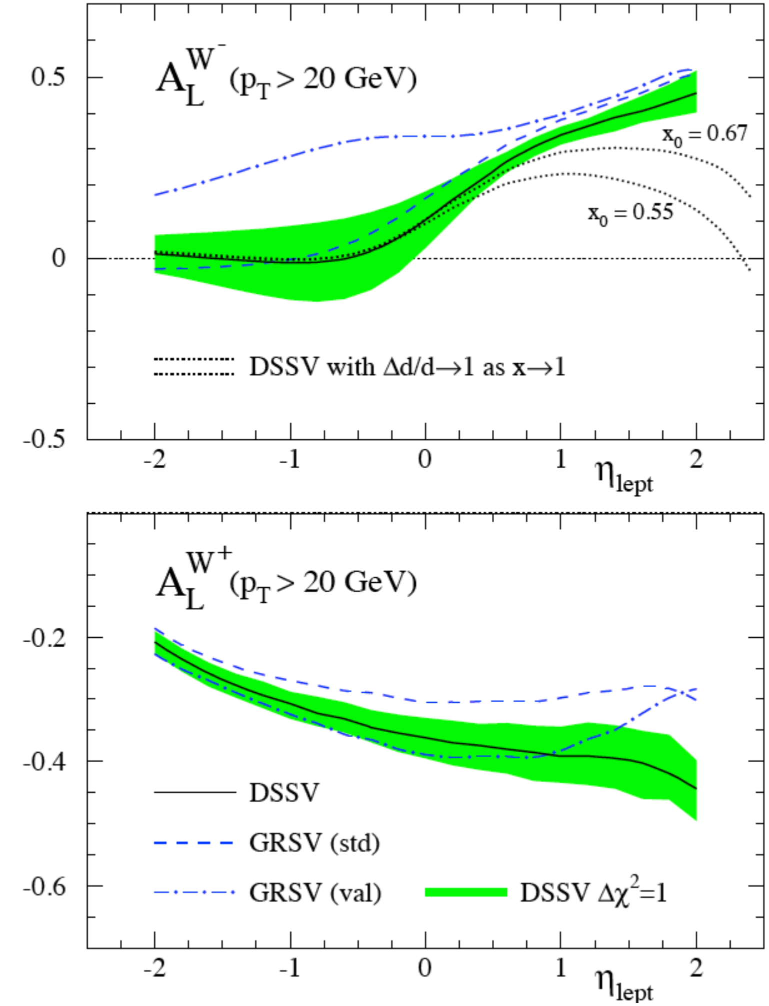

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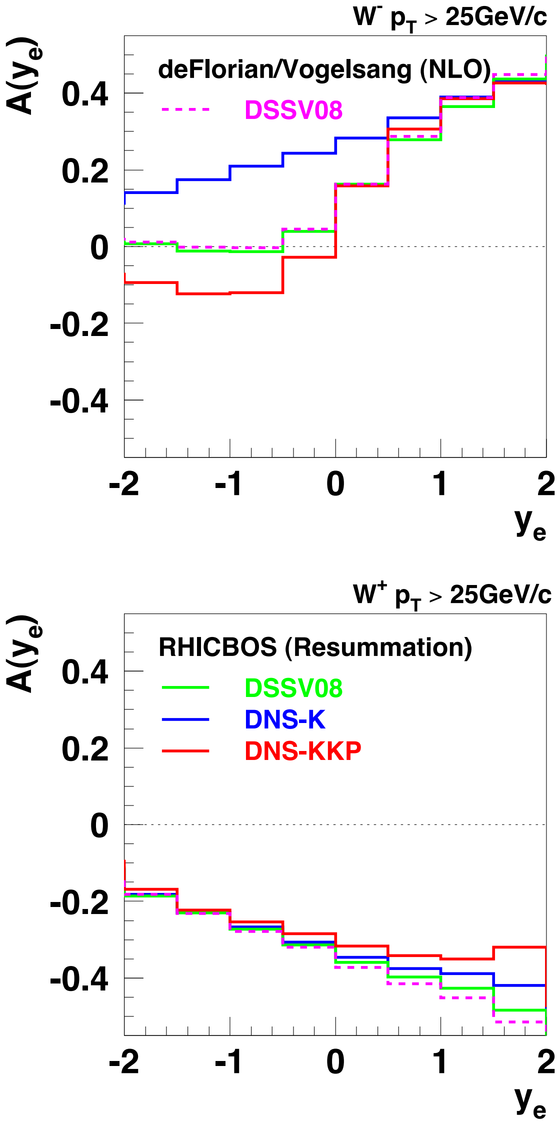

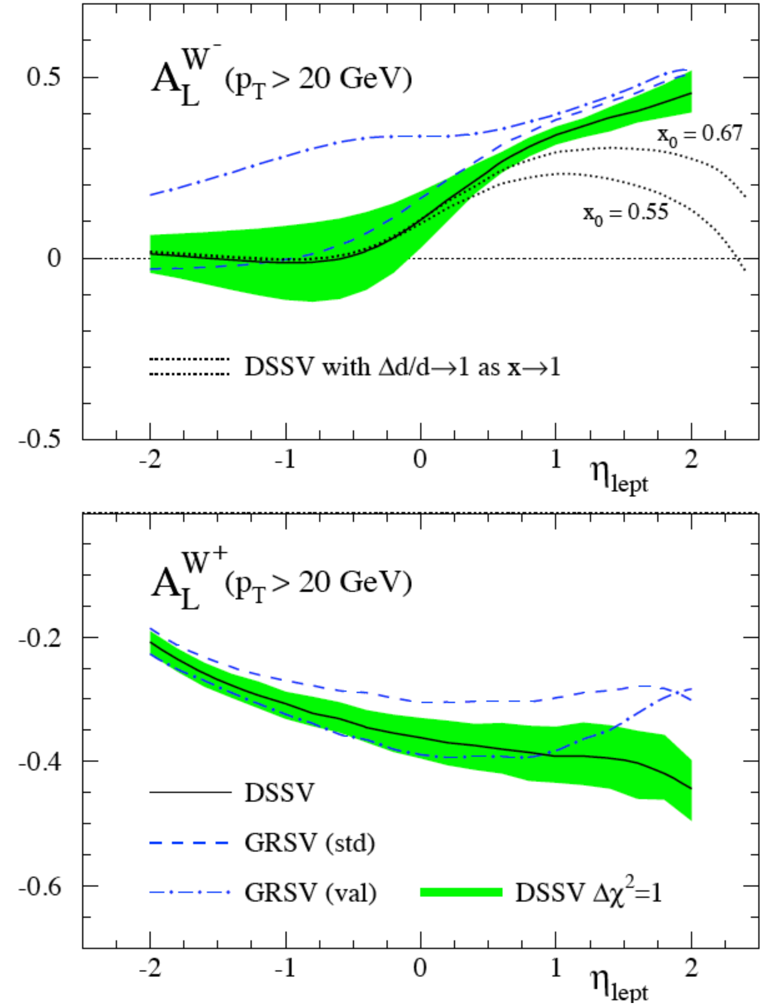

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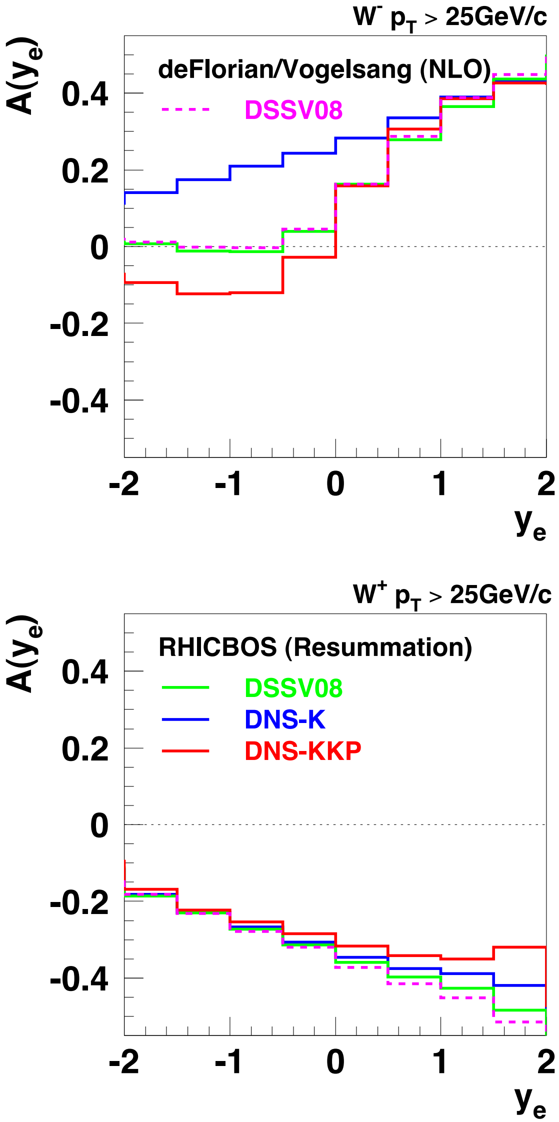

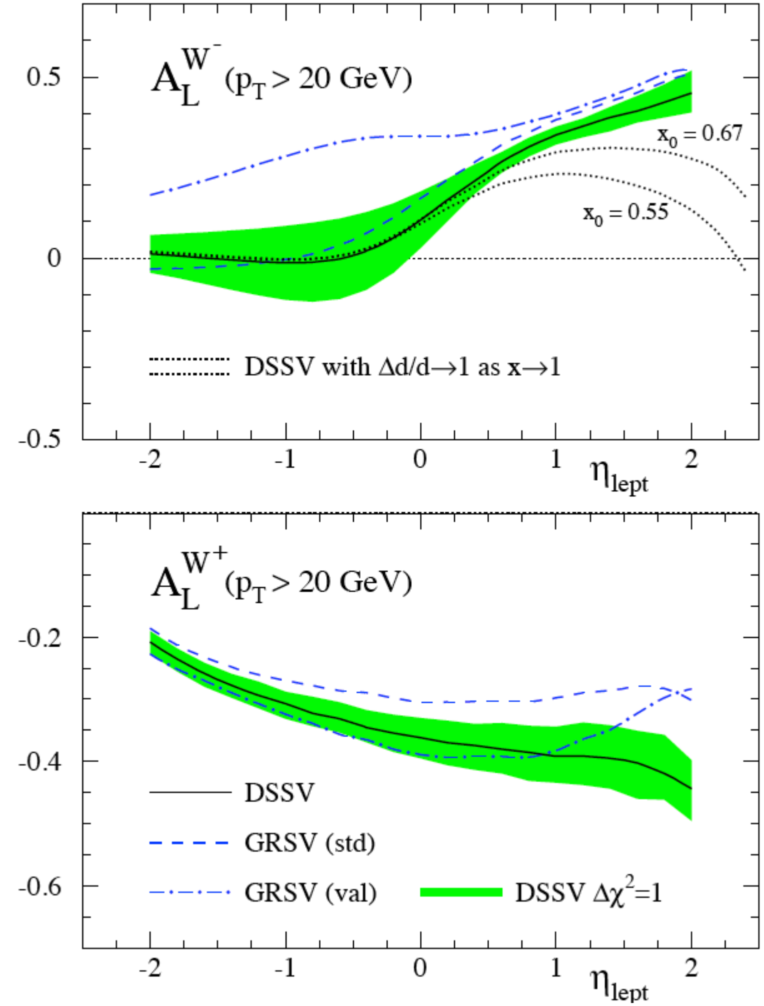

Calculations:

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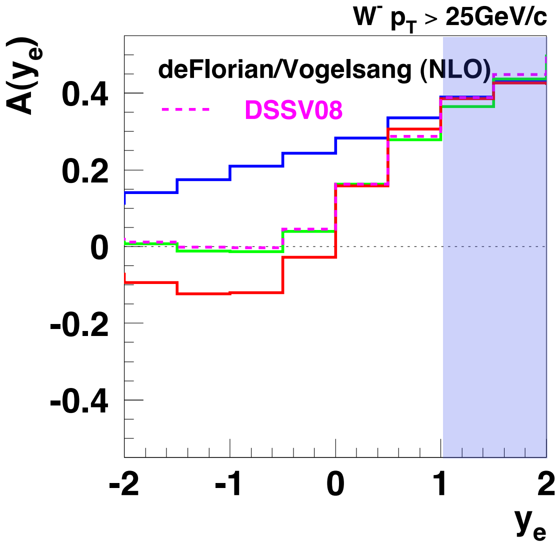
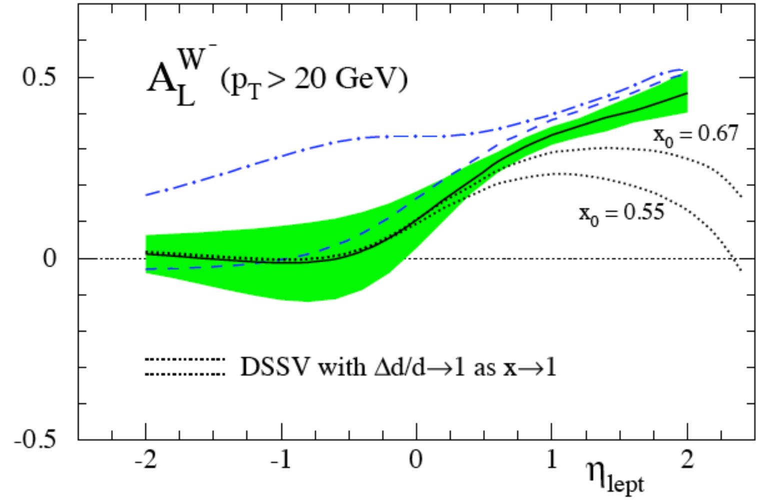
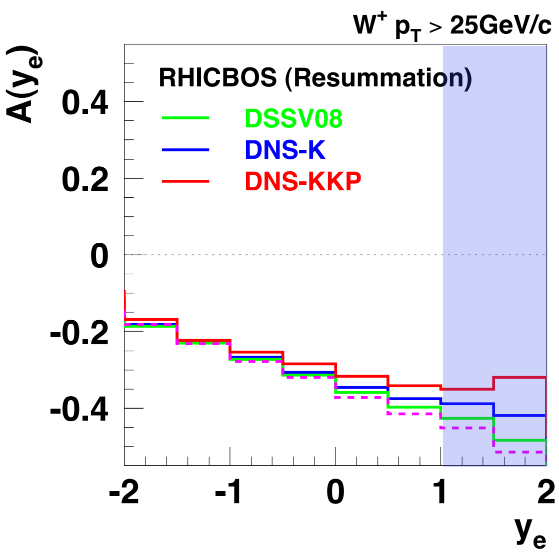


$$A_L^{W^-} = -\frac{\Delta d}{d}$$

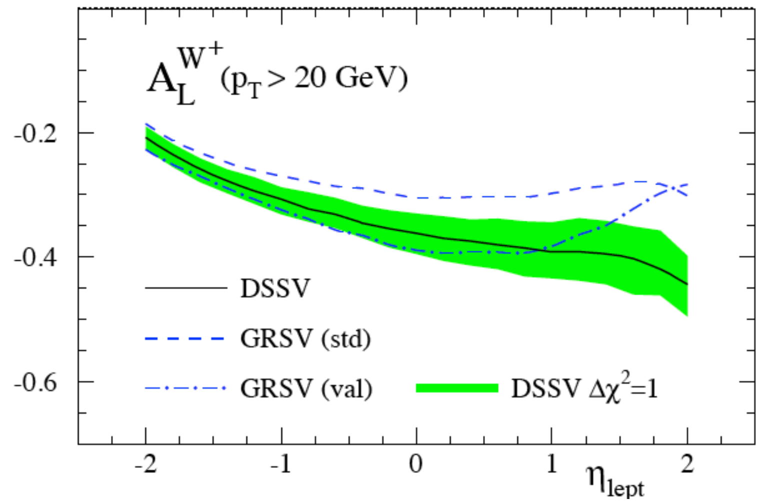
$$x_1 \gg x_2$$





$$A_L^{W^+} = \frac{\Delta \bar{d}}{\bar{d}}$$

$$x_1 \gg x_2$$



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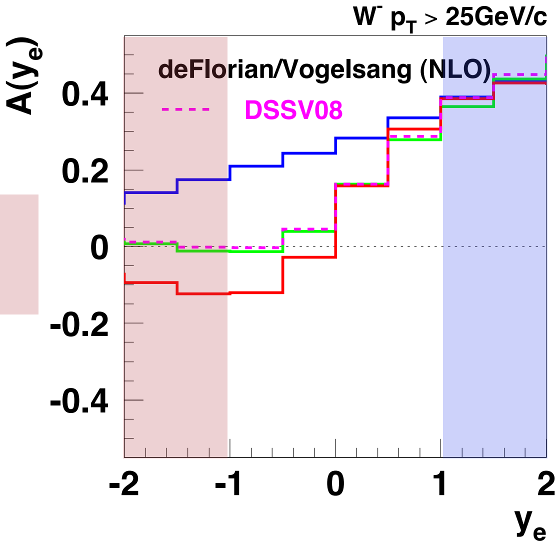
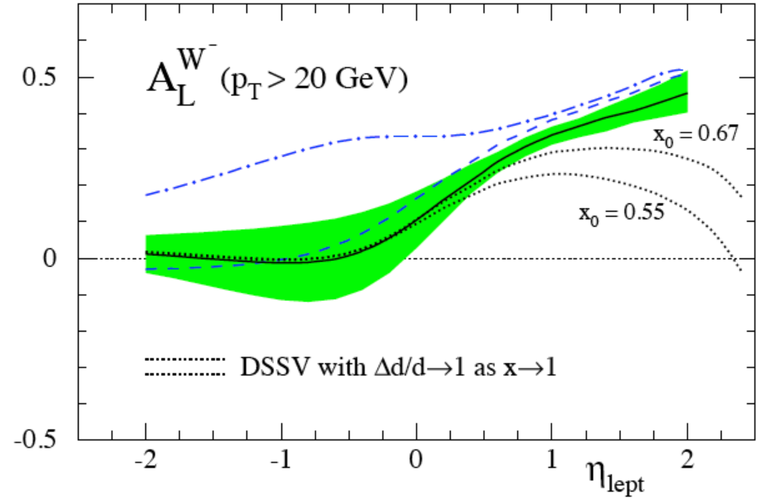


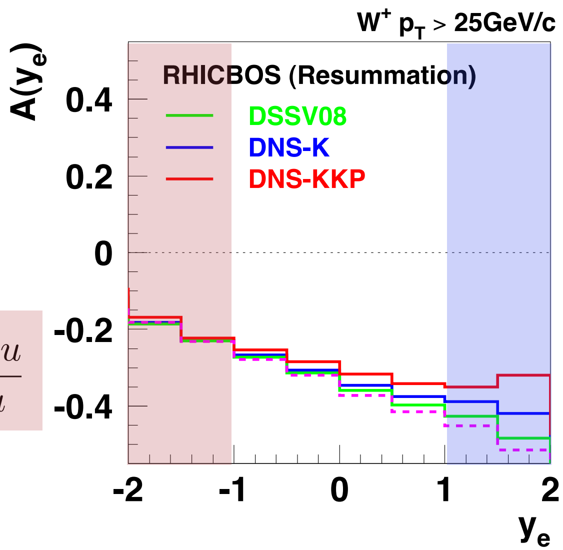
$$A_L^{W^-} = \frac{\Delta\bar{u}}{\bar{u}}$$

$x_1 \ll x_2$

$$A_L^{W^-} = -\frac{\Delta d}{d}$$

$x_1 \gg x_2$





$$A_L^{W^+} = -\frac{\Delta u}{u}$$

$x_1 \ll x_2$

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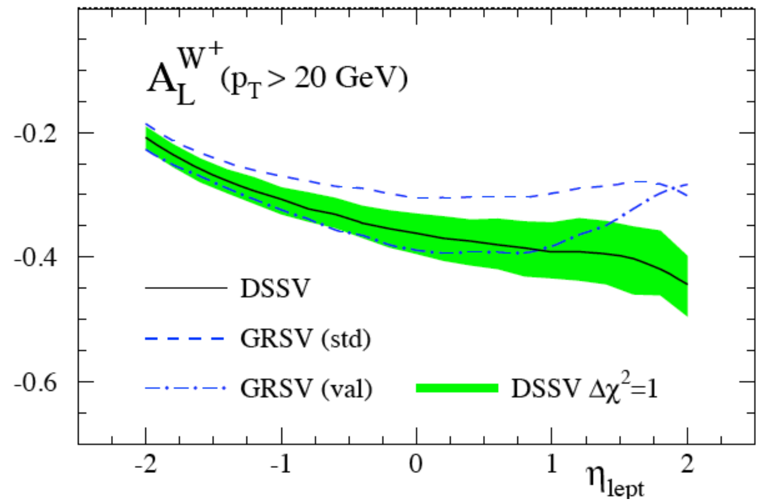

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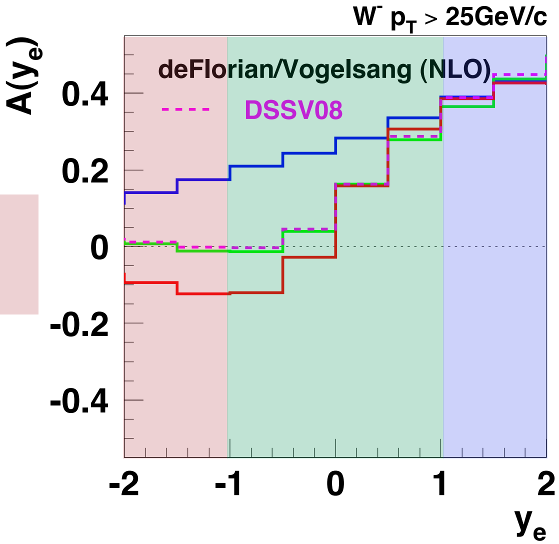


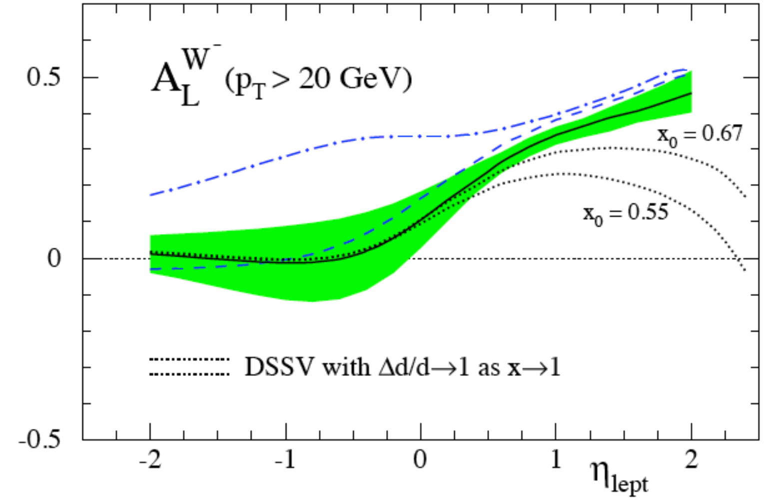
$$A_L^{W^-} = -\frac{\Delta d}{d}$$

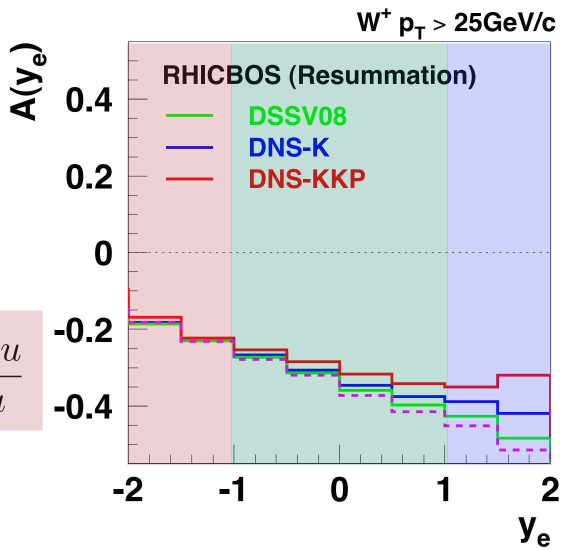
$x_1 \gg x_2$

$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta \bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right)$$

$x_1 = x_2$

$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta \bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$





$$A_L^{W^+} = -\frac{\Delta u}{u}$$

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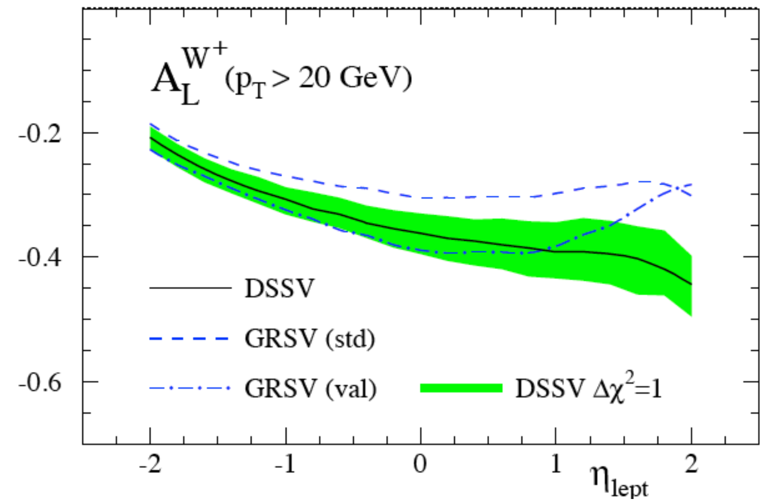

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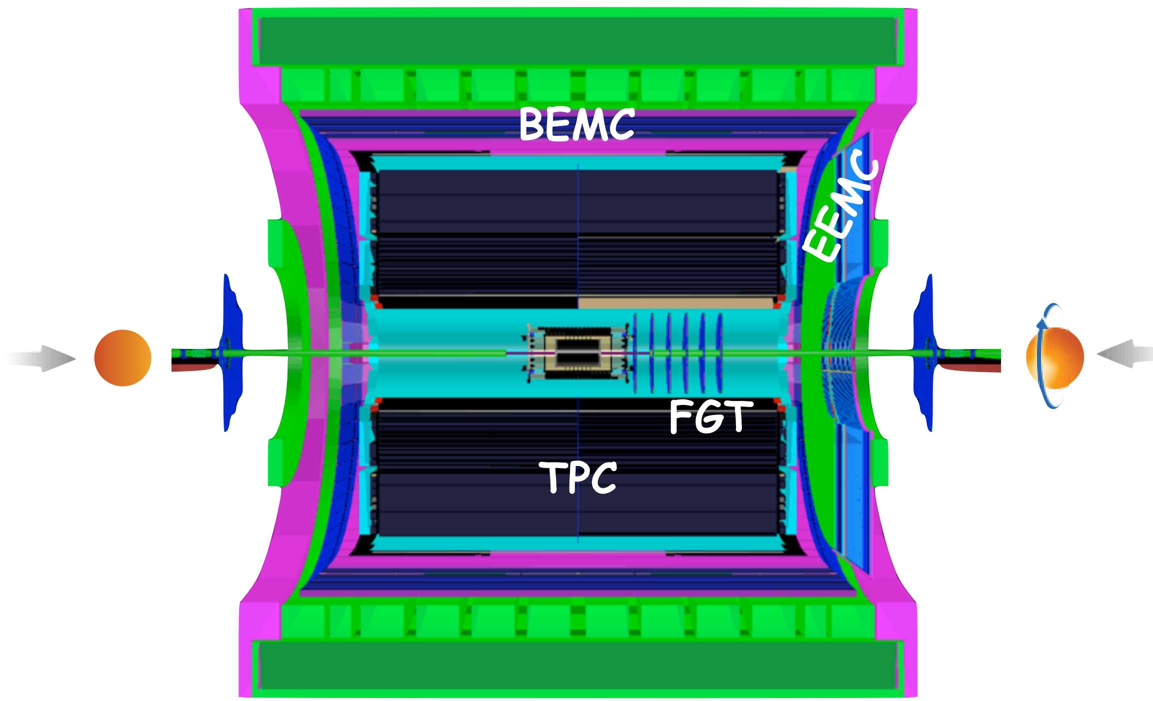
The STAR Experiment at RHIC

- Overview
  - Calorimetry system with 2π coverage: BEMC (-1<η<1) and EEMC (1<η<2)
  - TPC: Tracking and particle ID
  - ZDC: Relative luminosity and local polarimetry
  - BBC: Relative luminosity and Minimum bias trigger

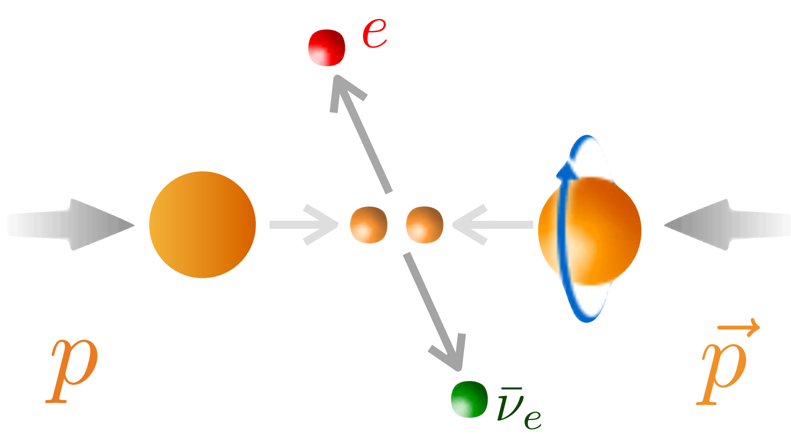
First collisions of polarized proton beams at STAR at $\sqrt{s}$ = 500GeV: Run 9 (P~40% / L~12pb^{-1})



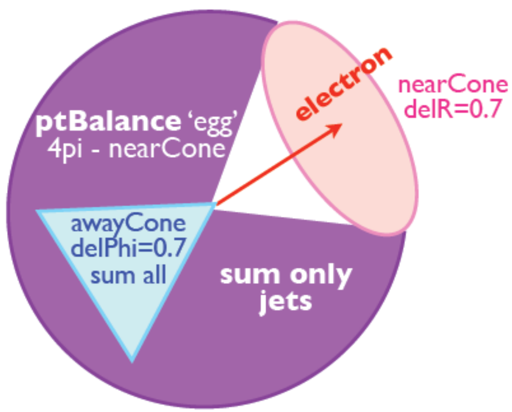
- STAR Mid-rapidity W program (-1<η<1): BEMC and TPC
- STAR Forward/Backward W program (1<η<2): EEMC and TPC / FGT (Installation in summer 2011)

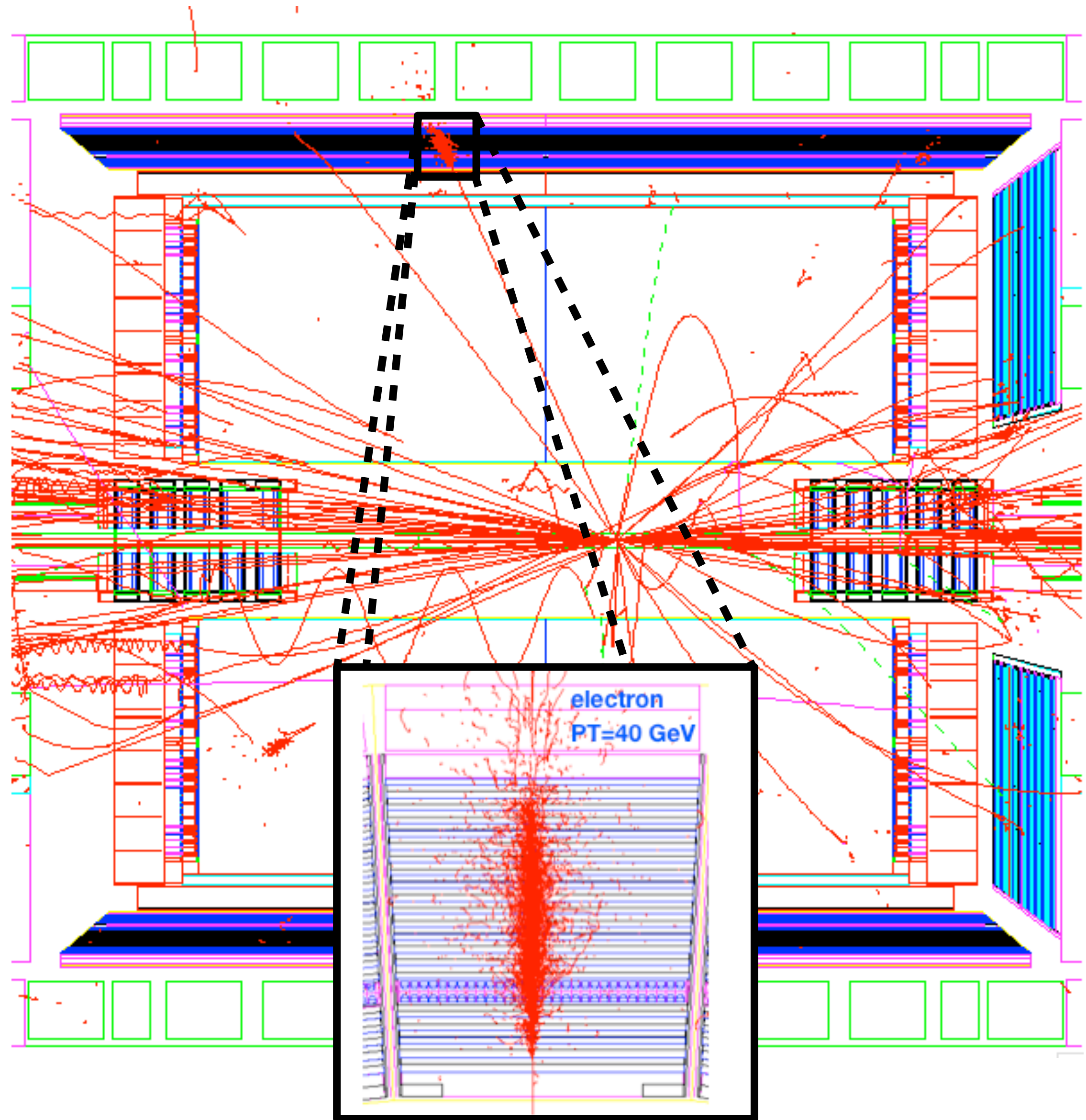
W production results: Algorithm

- W reconstruction - Algorithm : Idea



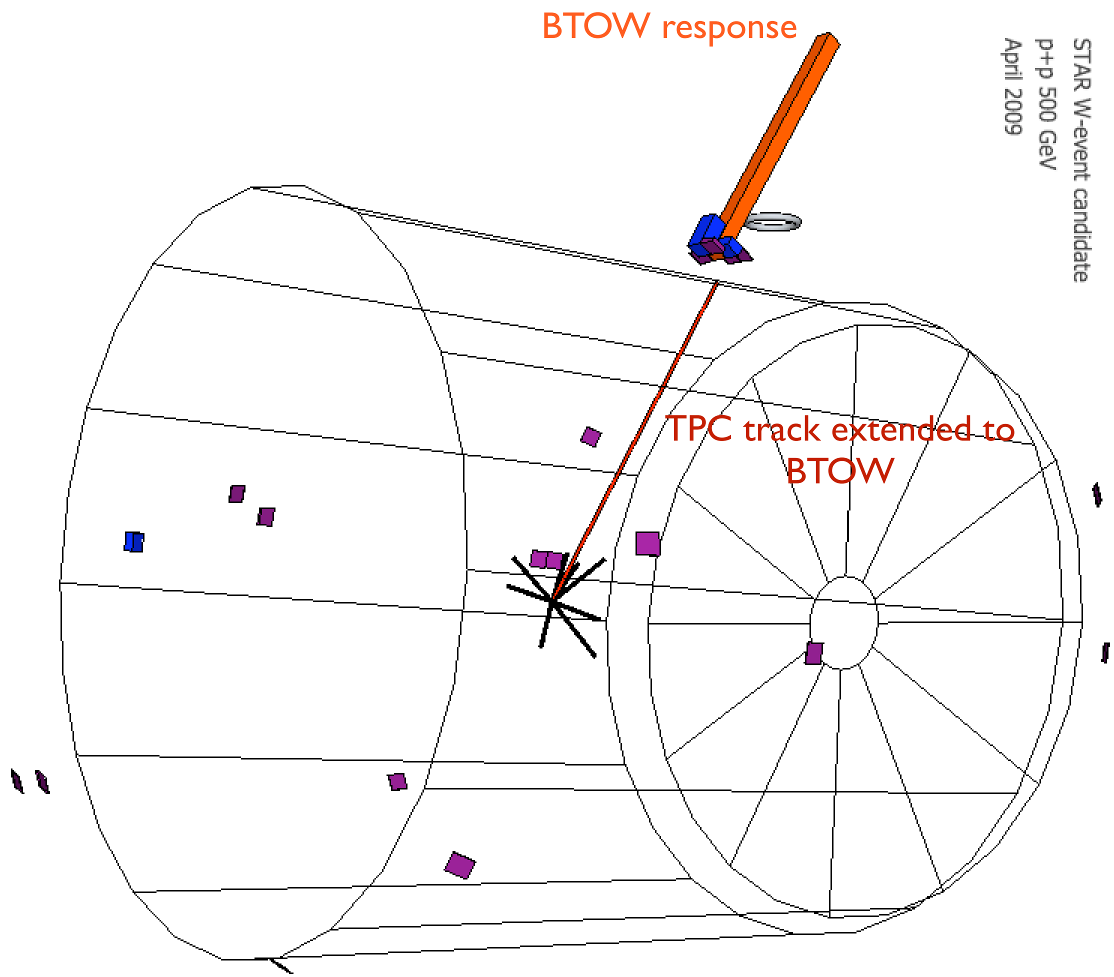
Transverse plane view





W production results: W event

- Event display (W event candidate) and detector signature

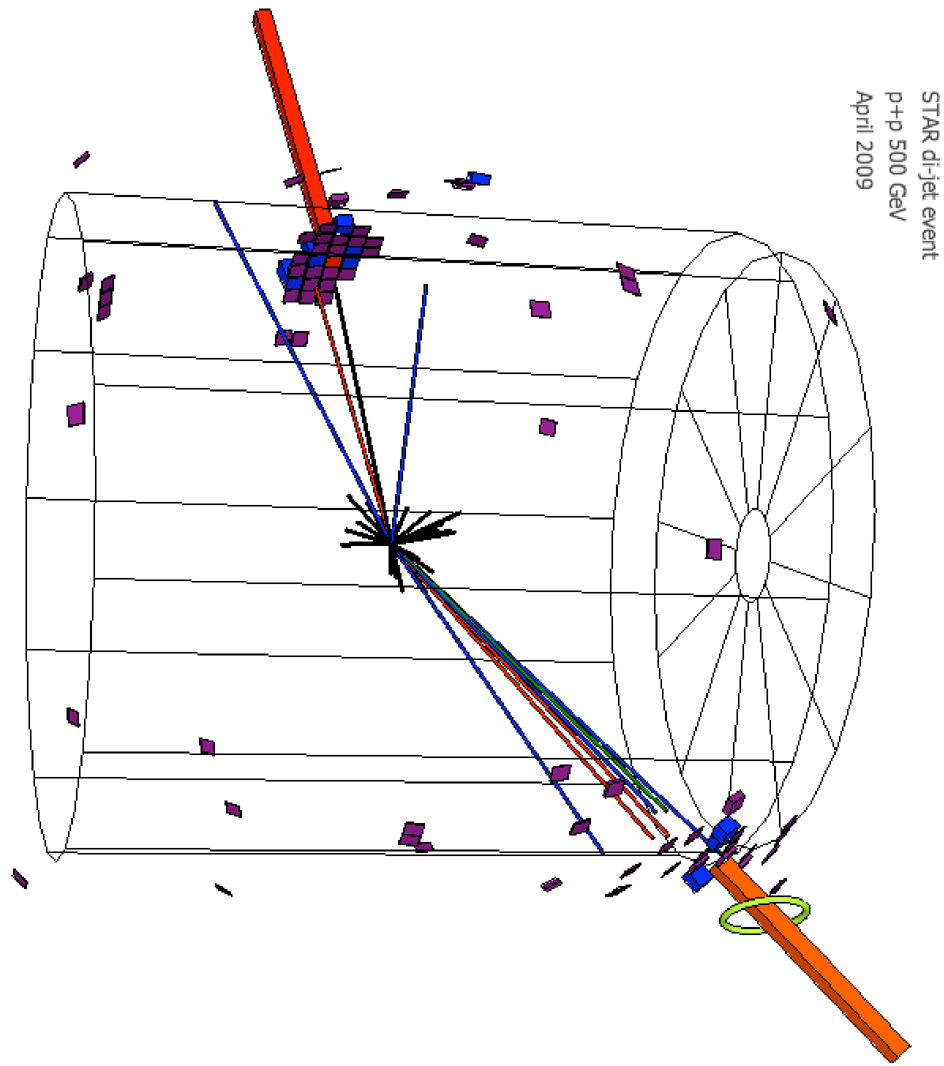


We found
~600 of those
kinds of
events!

W production results: QCD Background event

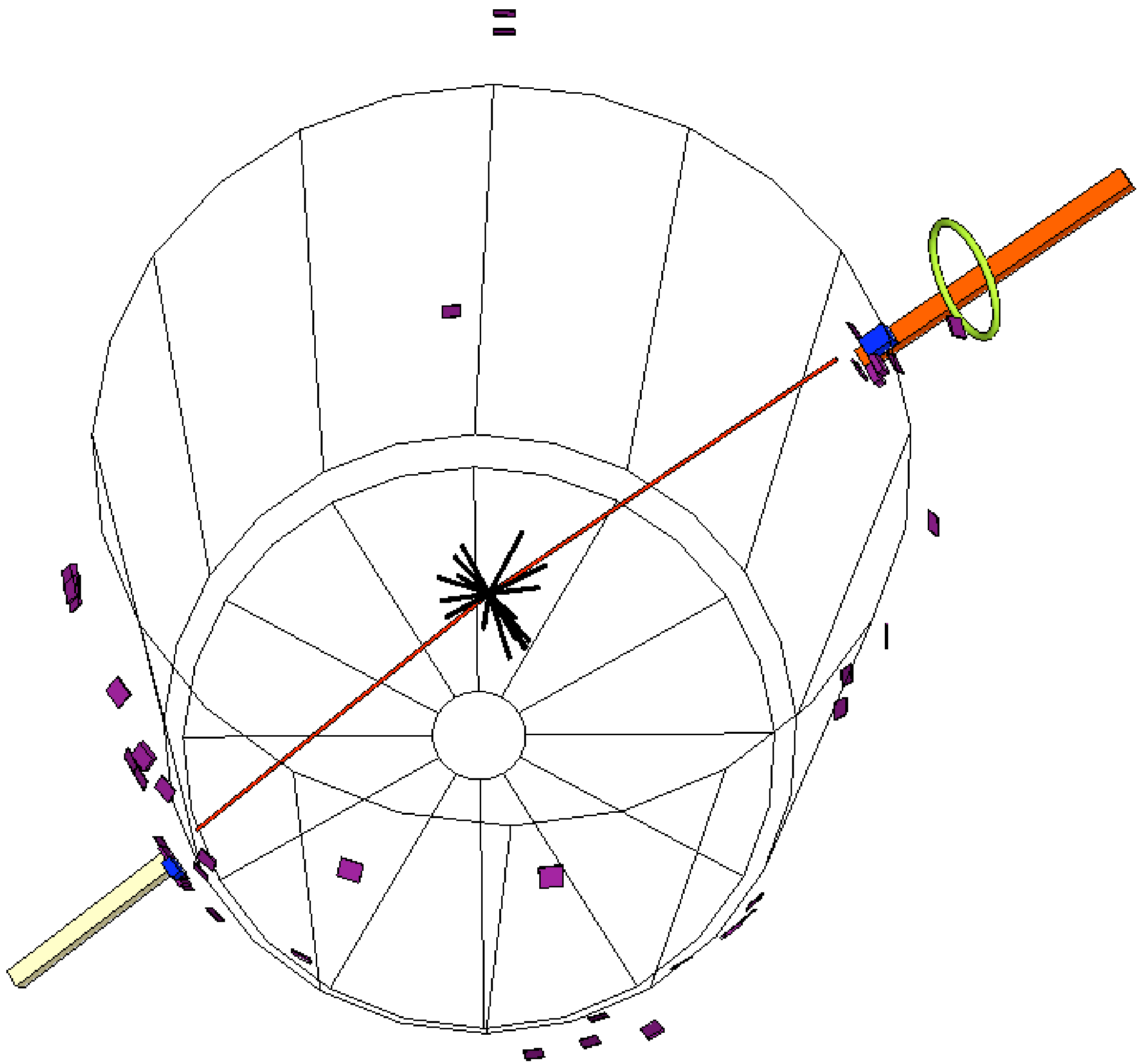
- Event display (Di-Jet event candidate) and detector signature

We recorded and rejected ~1.5M of those kinds of events!



W production results: Z^0 event

- Event display (Z event candidate) and detector signature

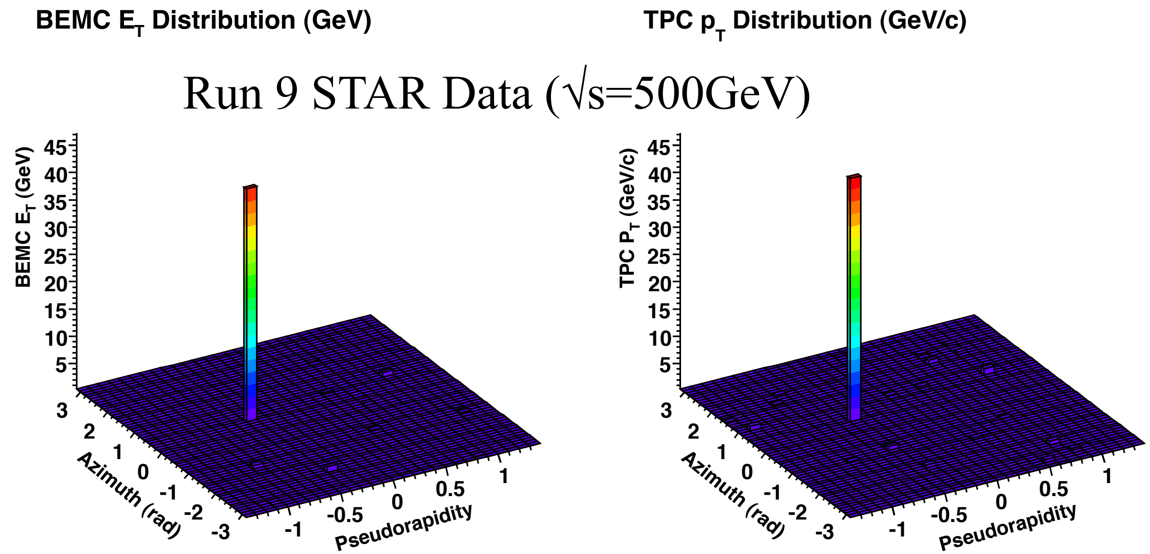


We found a handful of those kinds of events!

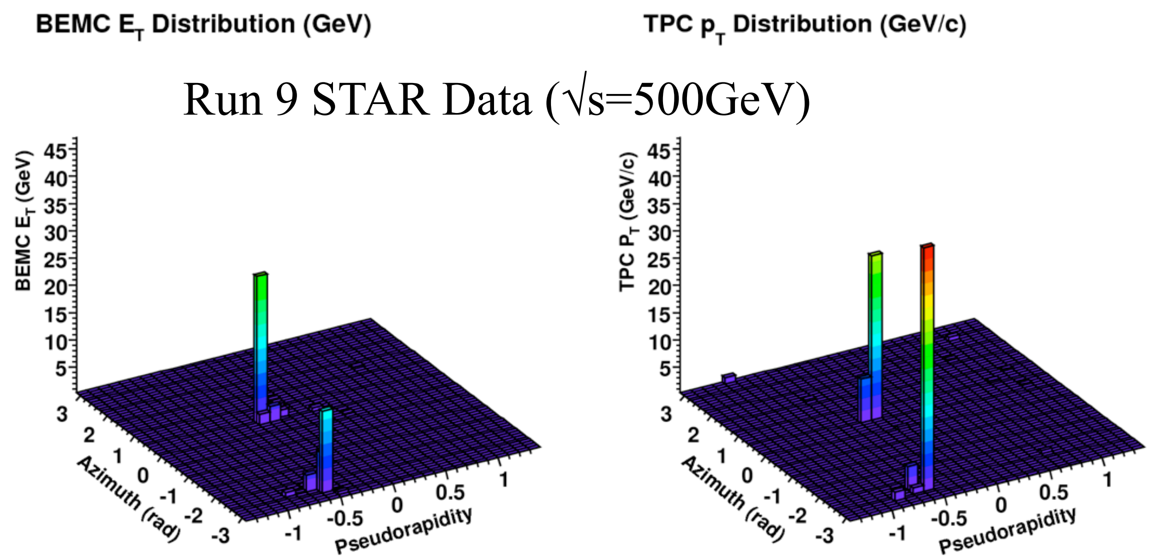
W production results: Lego plots

- Lego plots - STAR BEMC/TPC

W event



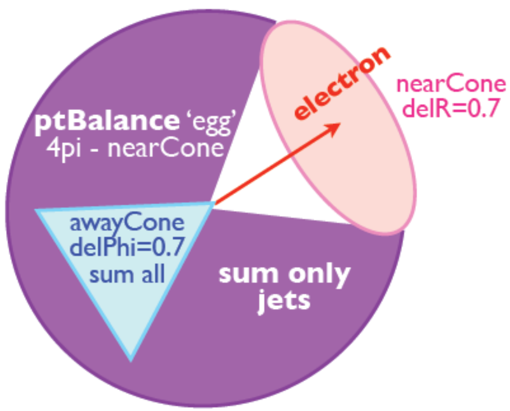
Di-Jet event

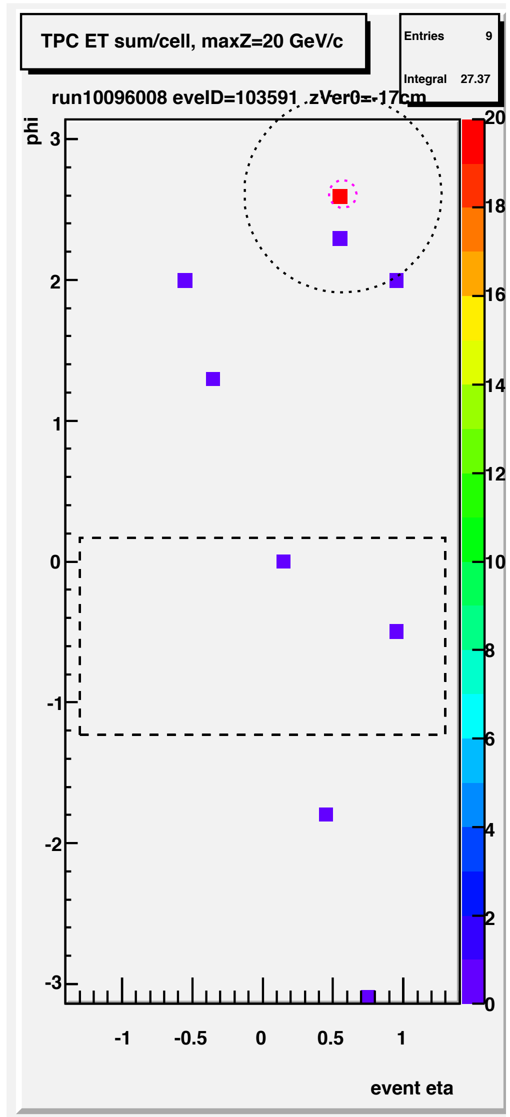


W production results: Algorithm Details

W reconstruction - Algorithm : Details

Transverse plane view





General:

- Select L2W-E_T triggered events
- Select vertices with |Z|<100 cm

Electron isolation cuts:

- Electron candidate is any primary TPC track with global P_T >10 GeV/c
- Extrapolate TPC track to BTOW tower
- Compute 2x2 tower cluster E_T, require E_T sum > 15 GeV
- Require the excess E_T in 4x4 tower patch over 2x2 patch to be below 5%
- Require distance of 2x2 cluster vs. TPC track below 7 cm

Near-cone veto:

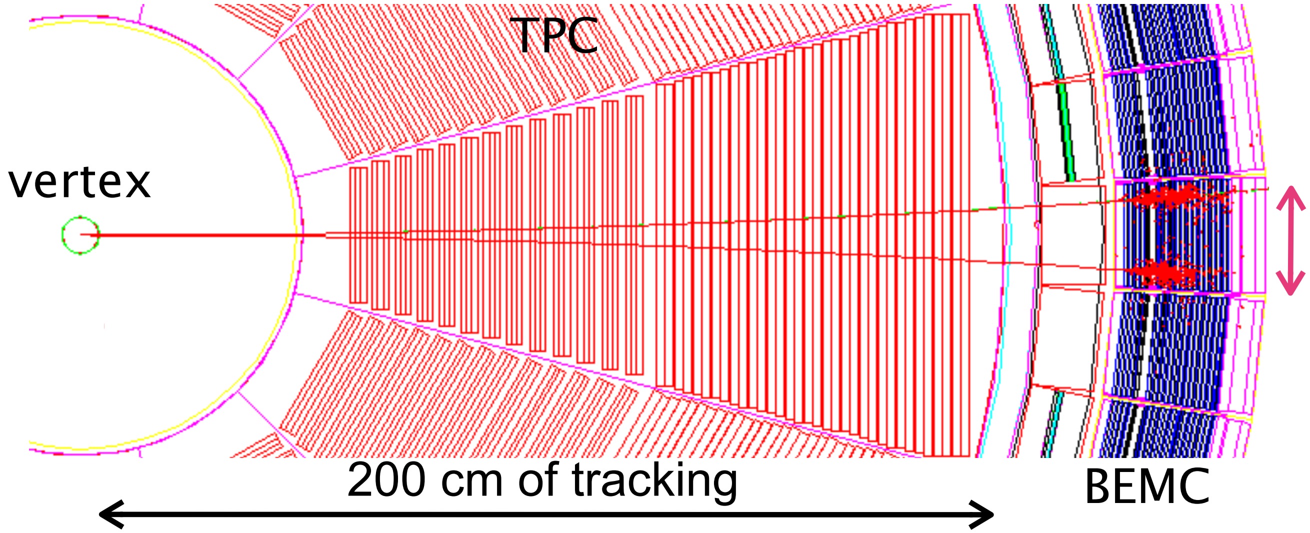
- Compute near-cone E_T sum of BEMC+TPC over ΔR=0.7 in eta-phi space
- Require near-cone excess E_T below 12%

Away-'cone' cuts: p_T balance requirement

- Vector sum > 15GeV/c of: 2X2 tower cluster p_T and p_T of any number of jets outside near-cone
- E_T of jet > 3.5GeV

W production results: Charge separation

- Mid-rapidity high p_T $e^{\pm}$ charge separation



positron p_T = 5 GeV

electron p_T = 5 GeV

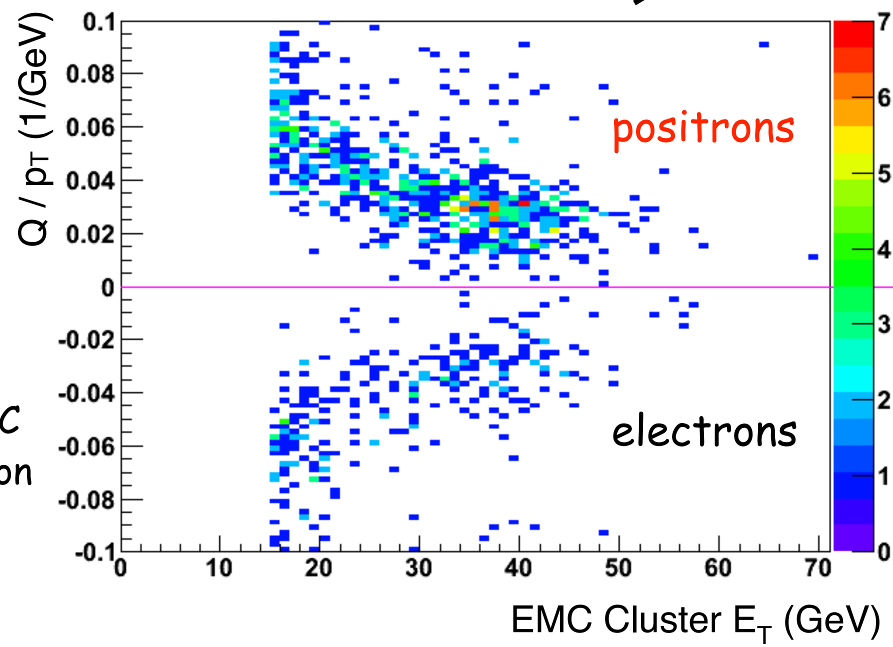
+/- distance D: ~1/P_T

p_T = 5 GeV : D ~15 cm

p_T = 40 GeV : D ~2 cm

Q: Charge-sign of reconstructed track

Final TPC calibration



Assign:

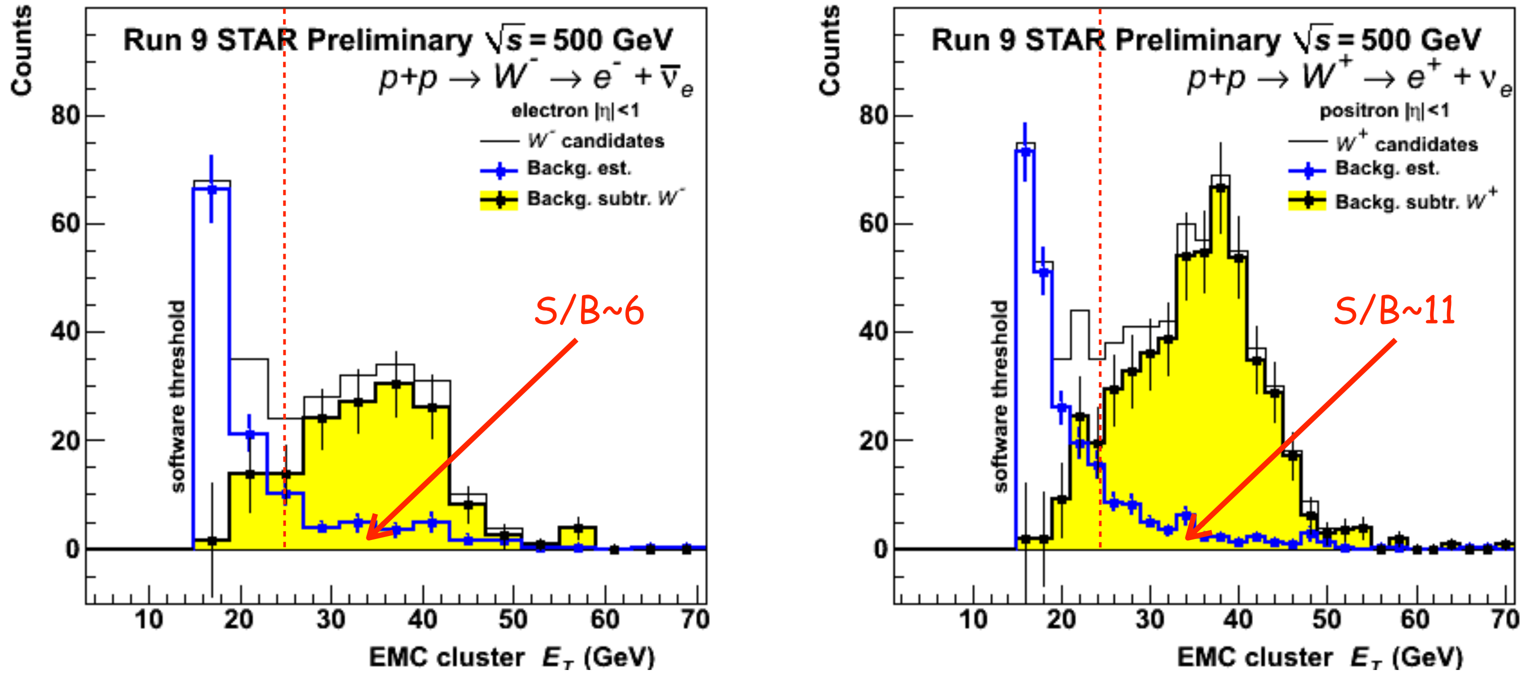
Q/p_T > 0 positrons

Q/p_T < 0 to be electrons

Successful separation of different charge states!

W production results: Jacobian peak distributions

- Charged separated Jacobian peak distributions

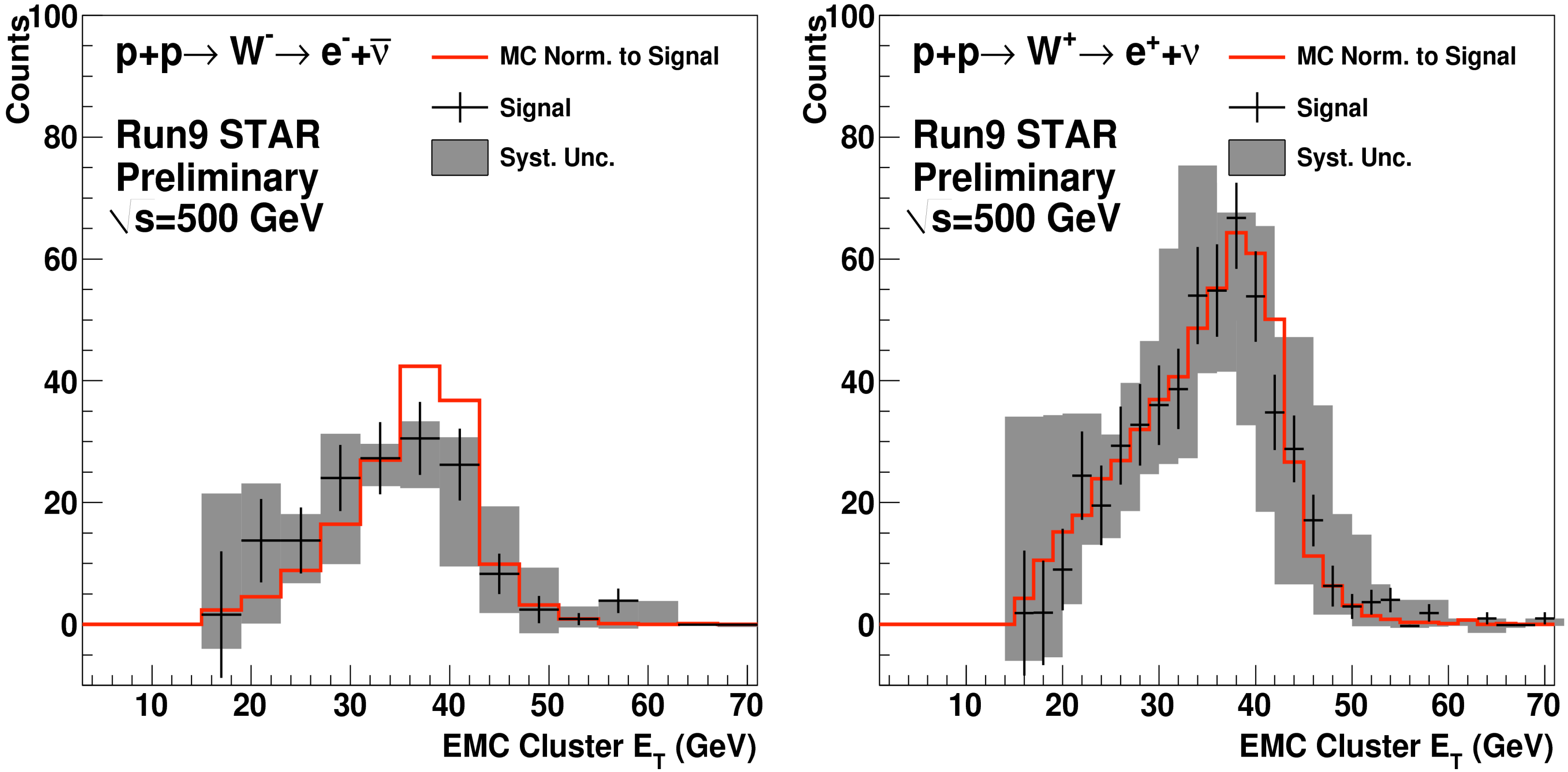


- Background distribution and background-subtracted signal distribution
- B/(S+B) (E_T > 25GeV) W^-: 16%
- B/(S+B) (E_T > 25GeV) W^+: 8%

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

W production results: Data/MC comparison

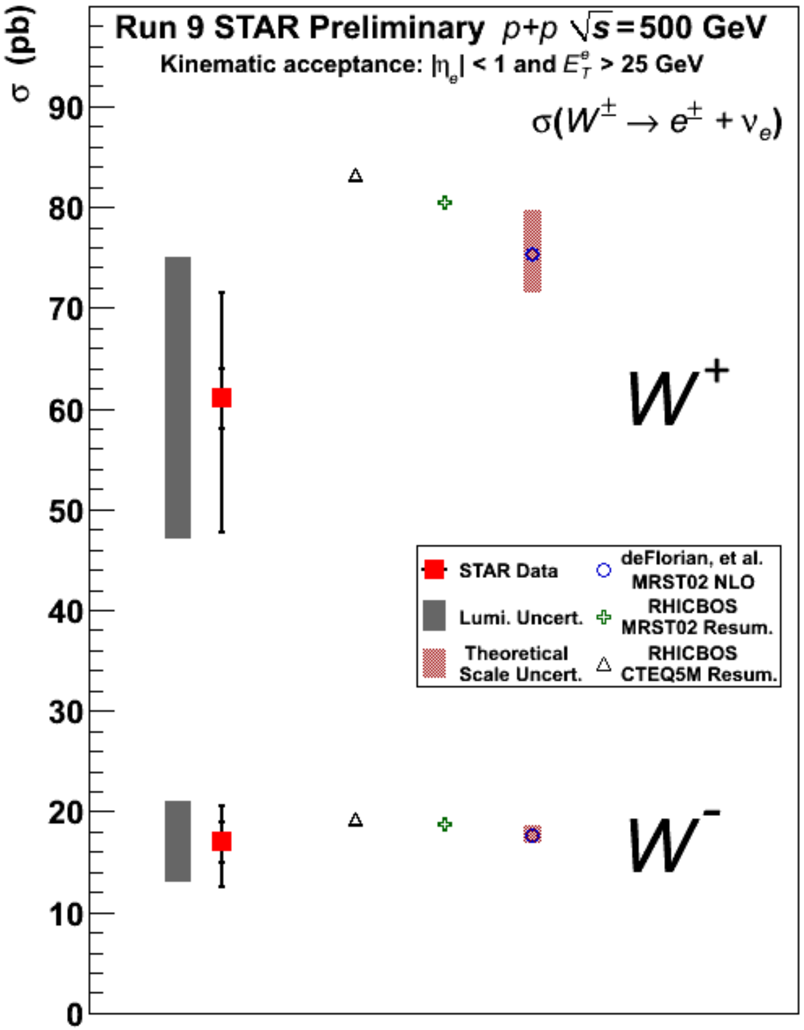
- Data/MC Comparison of charge-separated Jacobian peak distributions



- Comparison of data and PYTHIA+GEANT simulations for W signal events at √s=500GeV
- Systematic uncertainties were estimated by varying cuts and normalization regions for QCD background and by varying BEMC energy scale uncertainty (±7.5%)

W production results: Cross-Section

- Total W^+/W^- Cross-section results



	$W^- \rightarrow e^- + \bar{\nu}_e$	$W^+ \rightarrow e^+ + \nu_e$
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

STAR Preliminary Run 9 (p+p √s=500 GeV)

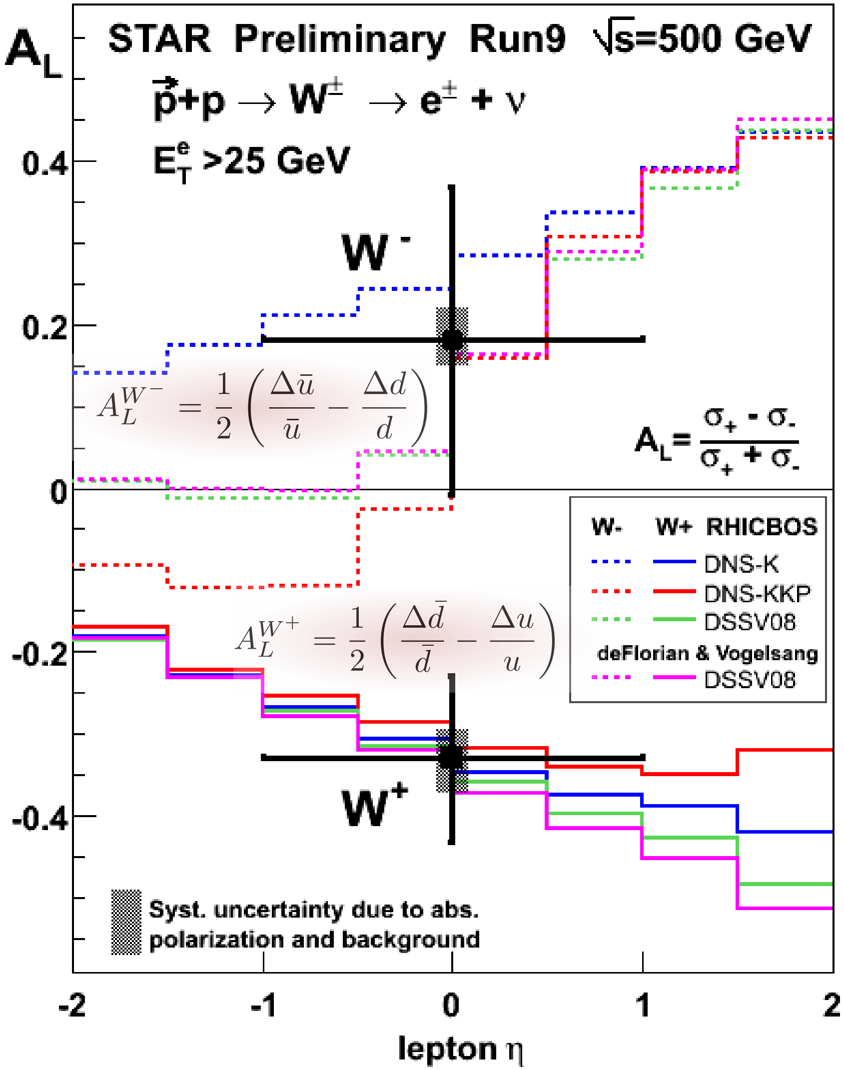
$$\sigma_{W^+ \rightarrow e^+ + \nu} = 61 \pm 3\ (\mathrm{stat.})\ ^{+10}_{-13}\ (\mathrm{syst.}) \pm 14\ (\mathrm{lumi.})\ \mathrm{pb}$$

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

- Reasonable agreement between measured and theory evaluated cross-sections within uncertainties!

W production results: Asymmetry result

- Parity-violating single-spin asymmetry W^+/W^- A_L results



STAR Preliminary Run 9 (p+p √s=500 GeV)

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

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

- $A_L(W^+)$ negative with a significance of 3.3σ
- $A_L(W^-)$ central value positive
- Systematic errors of A_L under control
- TPC charge separation works up to p_T ~ 50GeV
- Measured asymmetries are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data

  ⇒ Universality of helicity distribution functions!

Summary and Outlook

- Run 9: First observation of W production at STAR
  - First collision of polarized proton beams at $\sqrt{s}$ = 500GeV (P~40% / L~12pb^{-1})
  - $W^{\pm}$ Cross-section and Parity violating single-spin asymmetry measurement
- Critical analysis aspects:
  - Charge-sign discrimination at high p_T
  - Rejection and treatment of background
- STAR W program at forward/backward rapidity:
  - Installation of STAR Forward GEM Tracker ($1<\eta<2$) (FGT): Summer 2011