



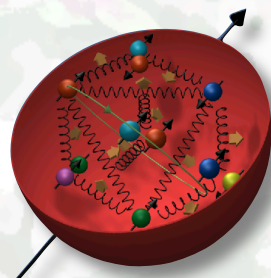
Recent STAR W production results of the high-energy polarized p-p program at RHIC at BNL

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Massachusetts
Institute of
Technology

(On behalf of the STAR Collaboration)



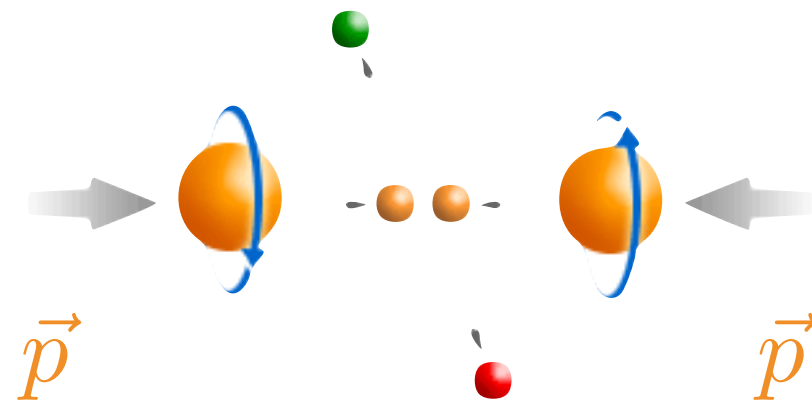
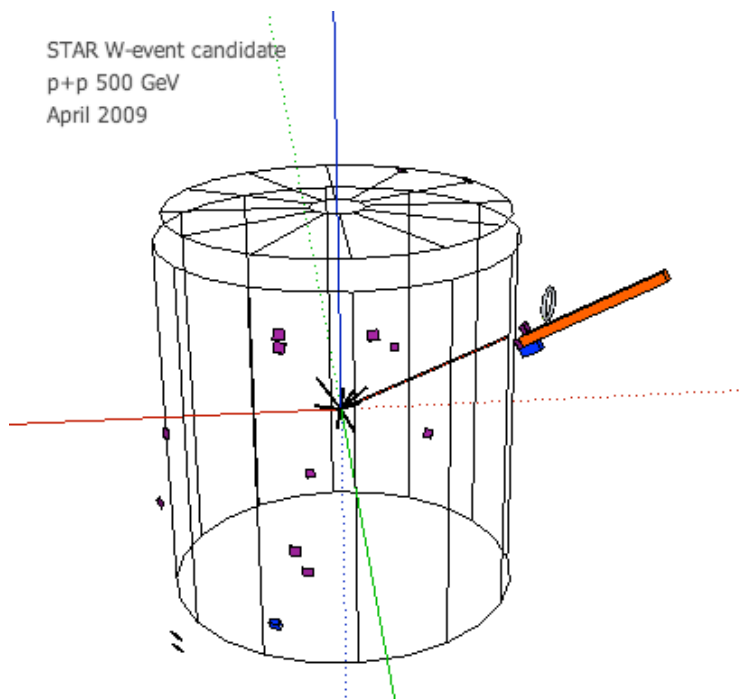
Outline

- W production - Recent Results

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

- Experimental
aspects:
RHIC / STAR

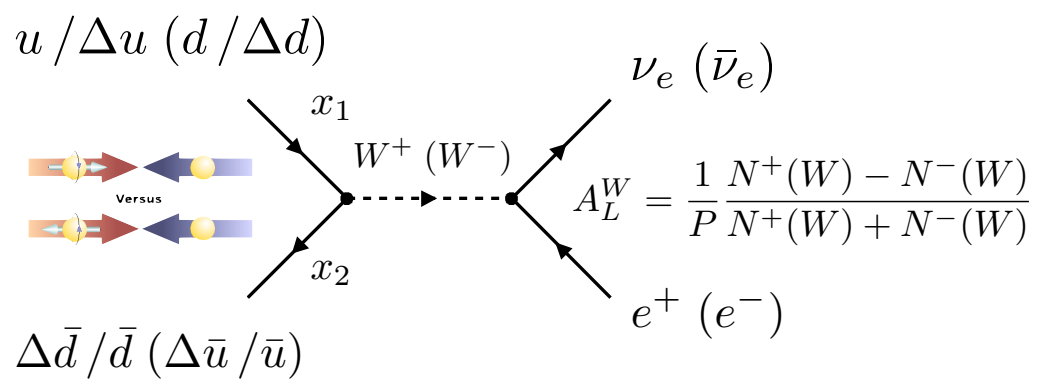
- Theoretical
foundation



- Summary
and
Outlook

Theoretical foundation

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



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

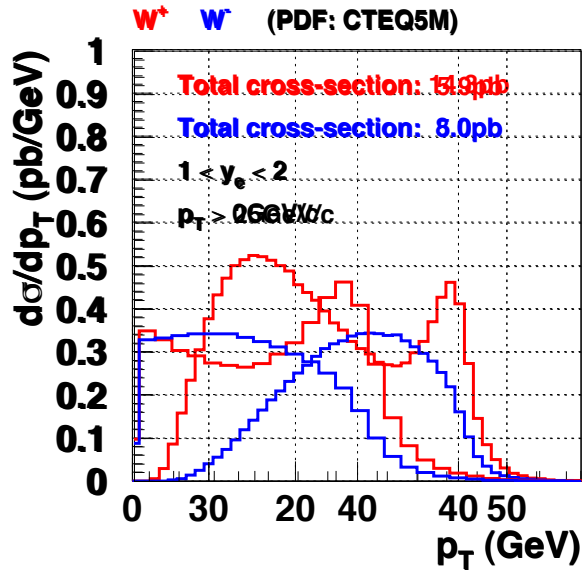
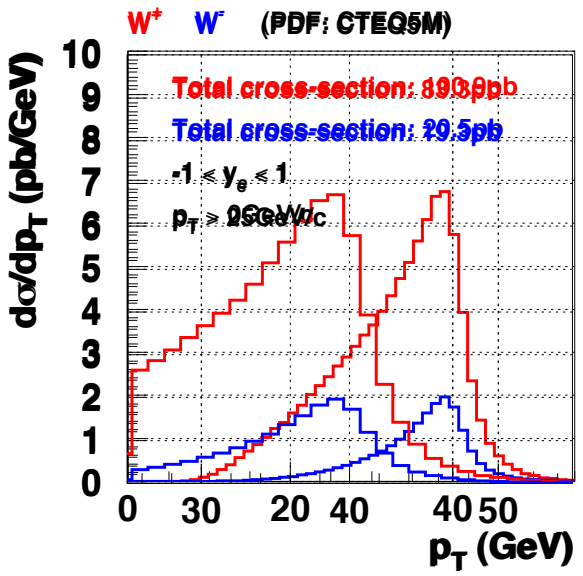
$$x_1 = \frac{M_W}{\sqrt{s}} e^{y_W}$$

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

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

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

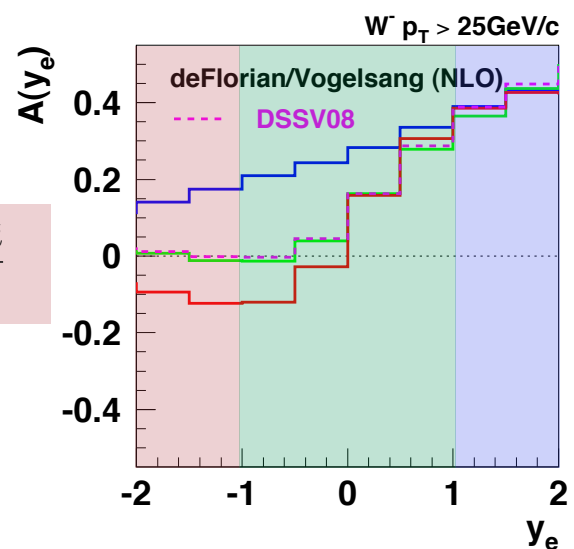
- Key signature: High p_T lepton (e^-/e^+)(Max. $M_W/2$) - Selection of W^+/W^- : Charge sign discrimination of high p_T lepton
- Required: Lepton/Hadron discrimination



Total ($\sqrt{s}=500\text{GeV}$) $\sigma(W^+)=135\text{pb}$ and $\sigma(W^-)=42\text{pb}$

Theoretical foundation

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



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

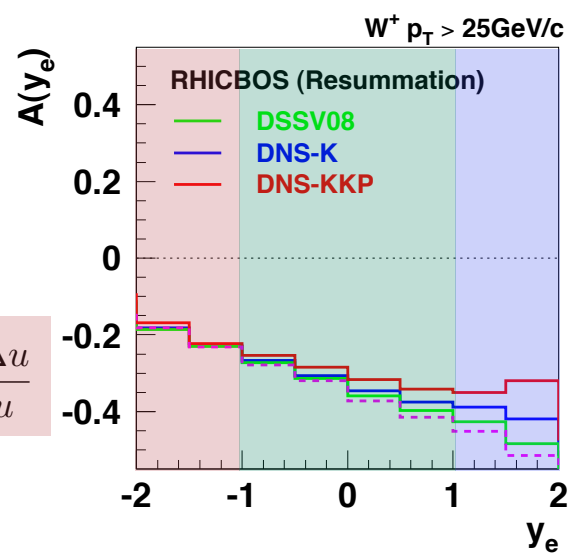
$x_1 \ll x_2$

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

$x_1 \gg x_2$

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

$x_1 = x_2$



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

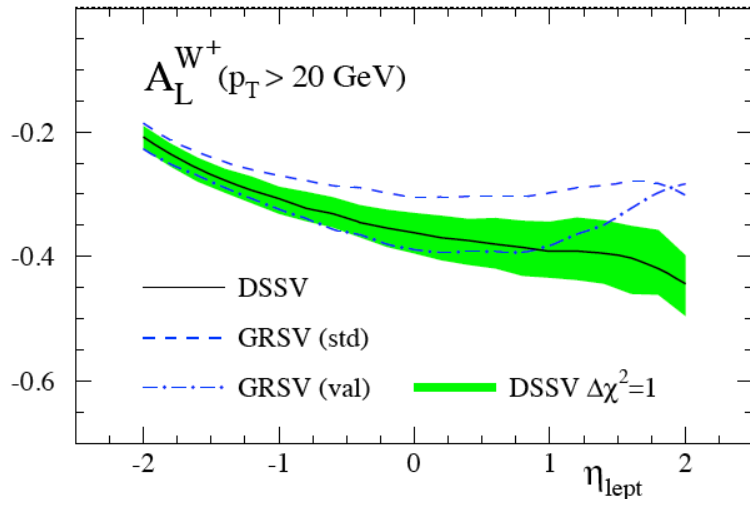
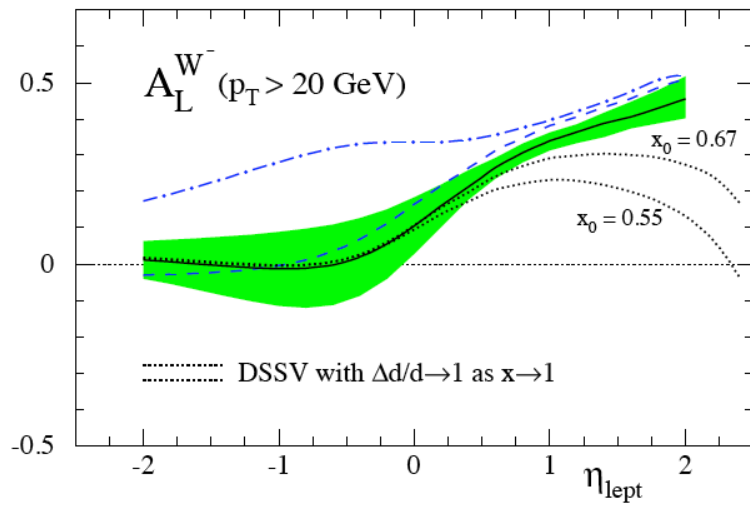
$x_1 \ll x_2$

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

$x_1 = x_2$

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

$x_1 \gg x_2$



Calculations:

- 1) RHICBOS: P.M. Nadolsky and C.-P. Yuan, Nucl. Phys. B666 (2003) 31.
- 2) deFlorian / Vogelsang: D. deFlorian, private communications.

The STAR Experiment at RHIC

□ Overview

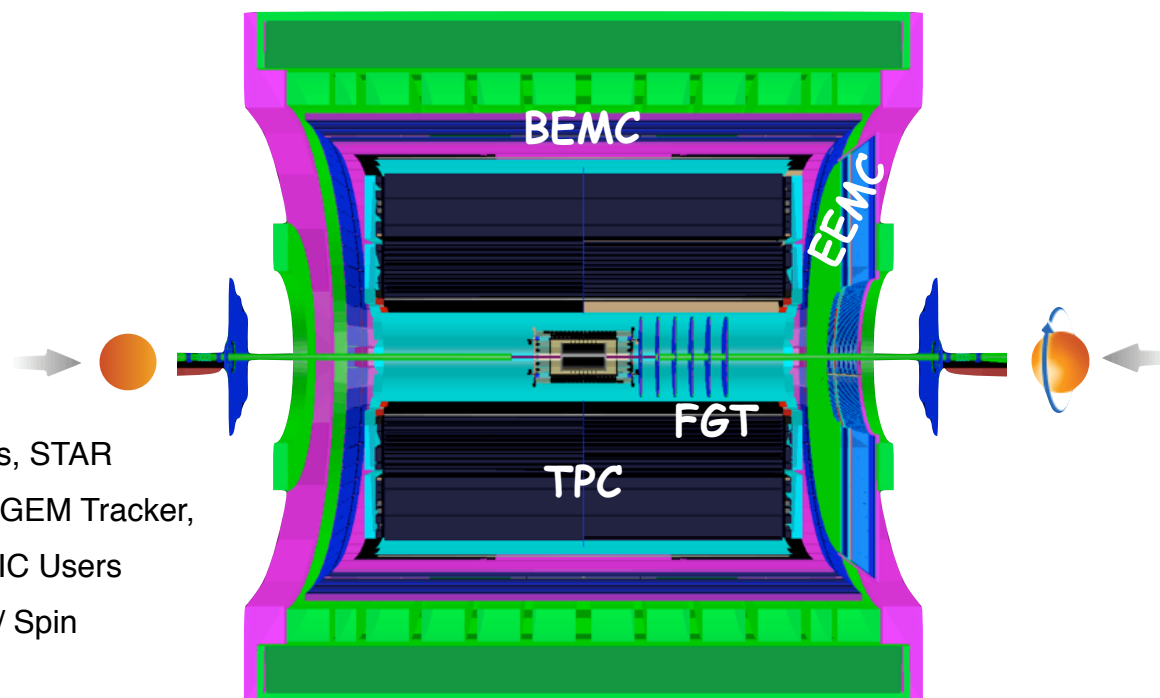
First collisions of polarized proton beams at STAR at $\sqrt{s} = 500\text{GeV}$: Run 9 ($P \sim 40\%$ / $L \sim 12\text{pb}^{-1}$)

- Calorimetry system with 2π coverage: BEMC ($-1 < \eta < 1$) and EEMC ($1 < \eta < 2$)

- TPC: Tracking and particle ID

- ZDC: Relative luminosity and local polarimetry

- BBC: Relative luminosity and Minimum bias trigger

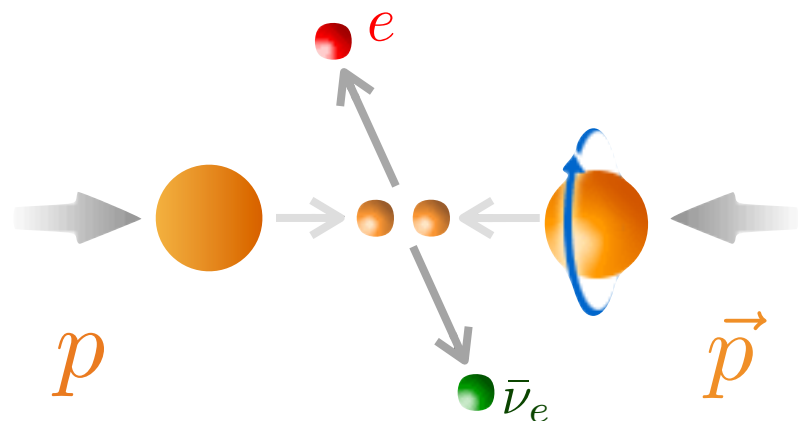


R. Corliss, STAR
Forward GEM Tracker,
AGS-RHIC Users
Meeting / Spin
Session

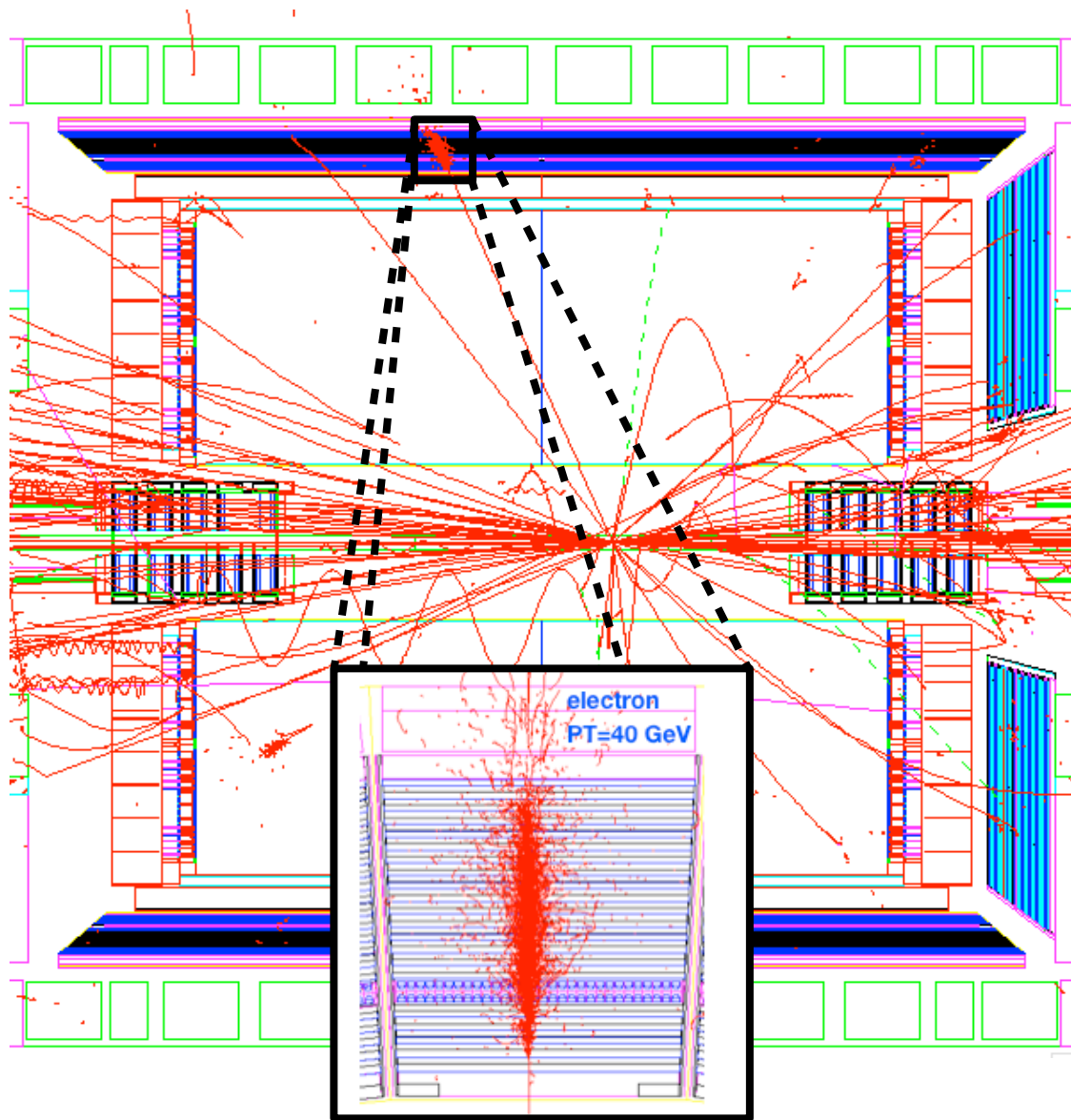
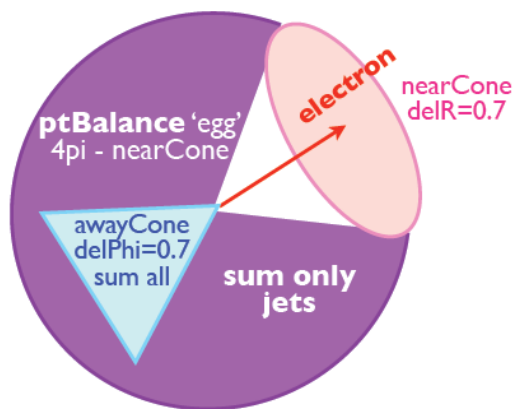
- STAR Mid-rapidity W program ($-1 < \eta < 1$): BEMC and TPC
- STAR Forward/Backward W program ($1 < \eta < 2$): EEMC and TPC / FGT (Installation in summer 2011)

W production results: Algorithm

- W reconstruction - Algorithm : Idea



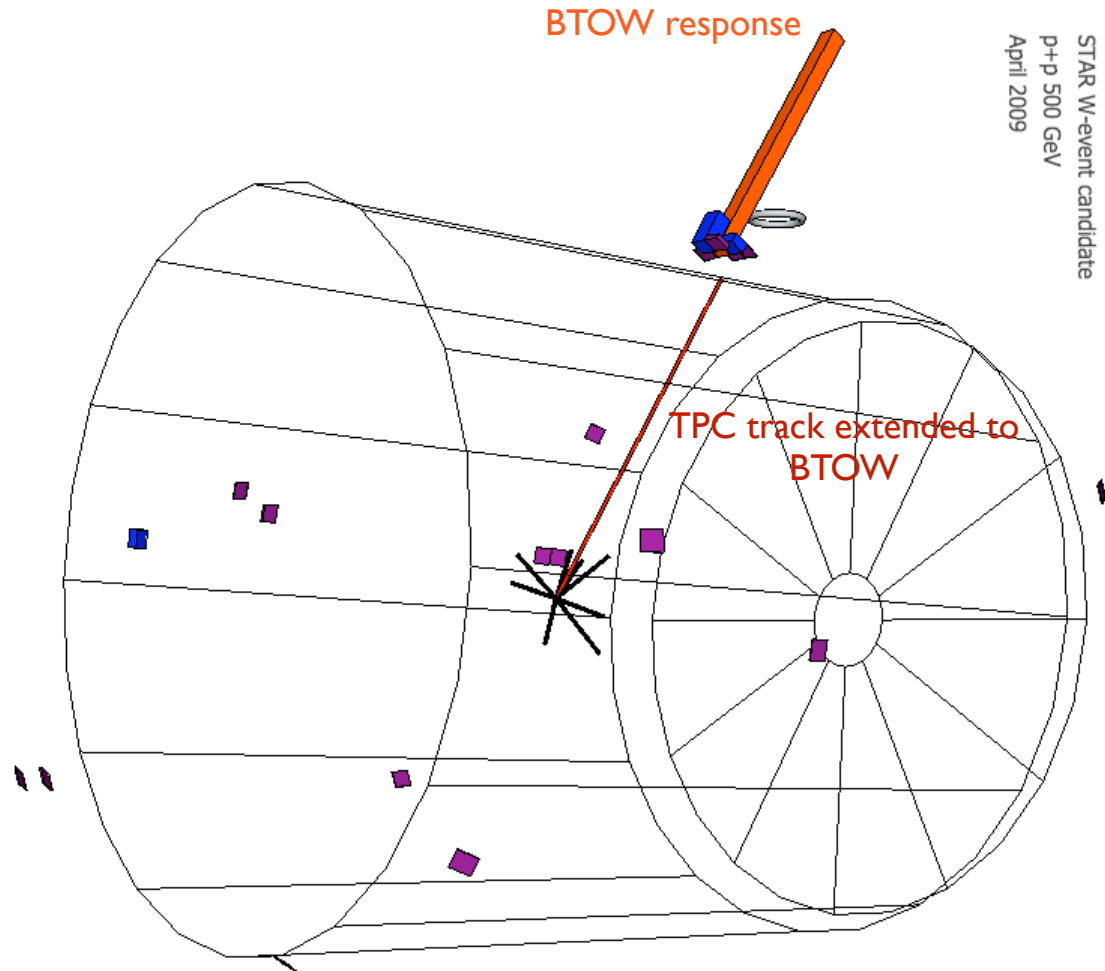
Transverse plane view





W production results: W event

- Event display (W event candidate) and detector signature

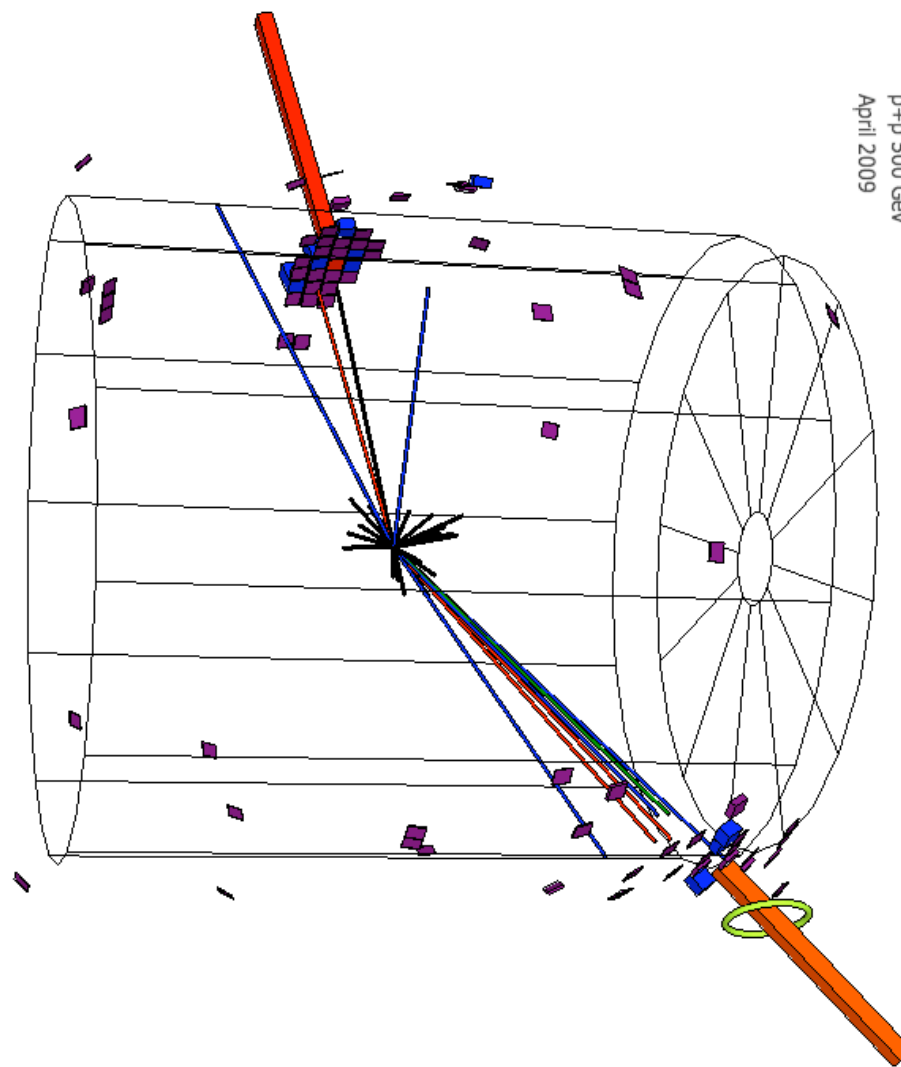


We found
~600 of those
kinds of
events!



W production results: QCD Background event

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

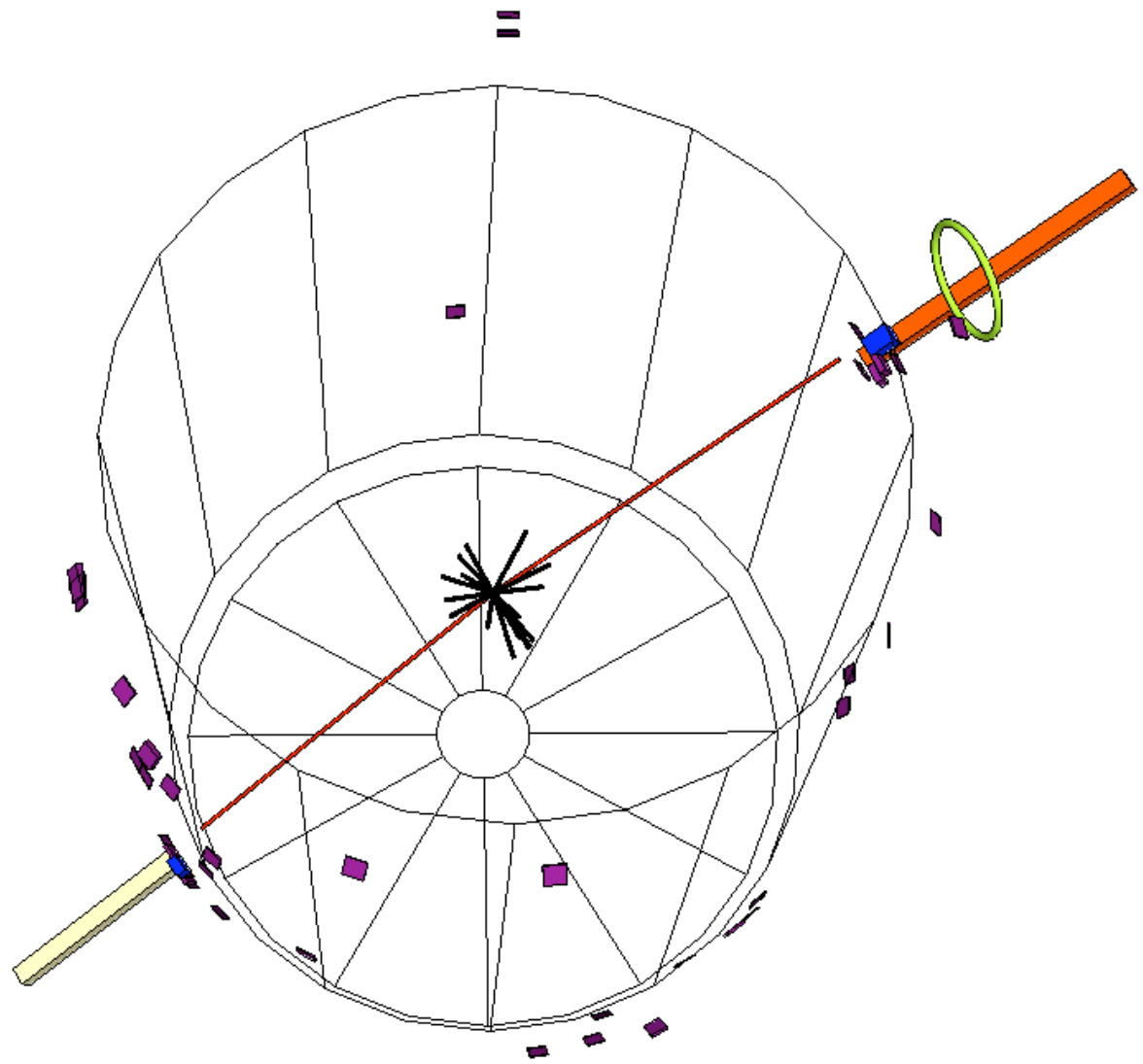


We recorded
and rejected
 $\sim 1.5\text{M}$ of those
kinds of events!

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

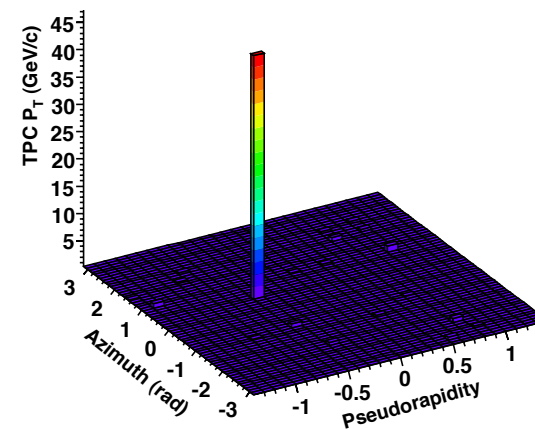
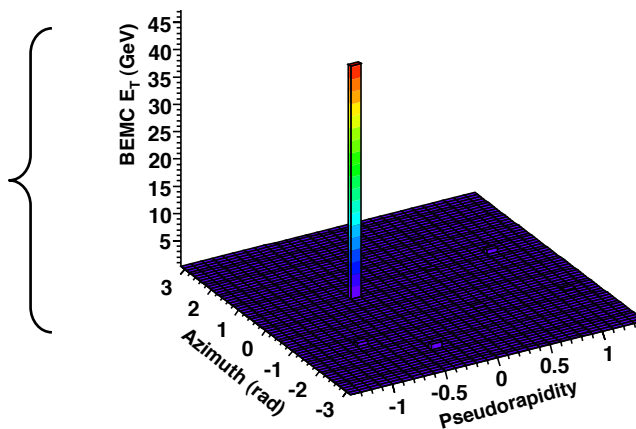
□ Lego plots - STAR BEMC/TPC

W event

BEMC E_T Distribution (GeV)

TPC p_T Distribution (GeV/c)

Run 9 STAR Data ($\sqrt{s}=500\text{GeV}$)

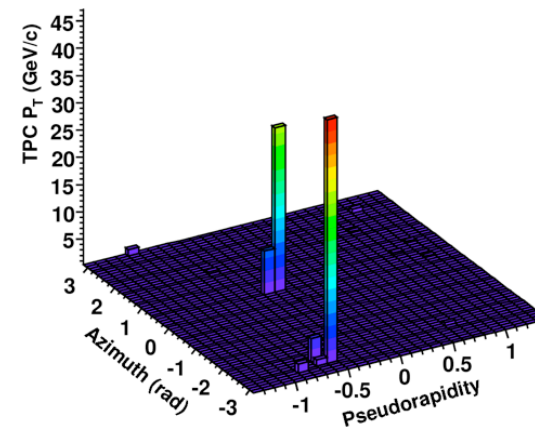
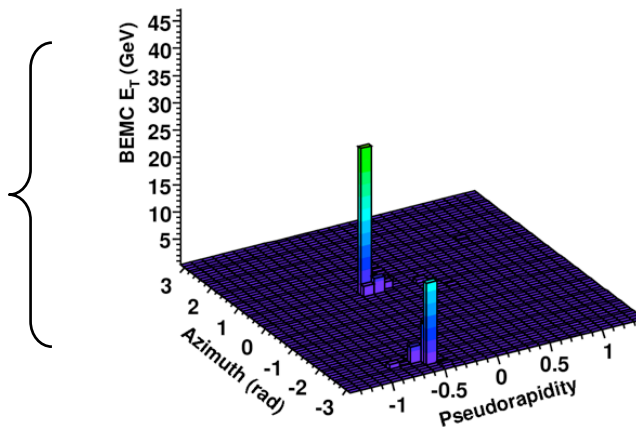


Di-Jet event

BEMC E_T Distribution (GeV)

TPC p_T Distribution (GeV/c)

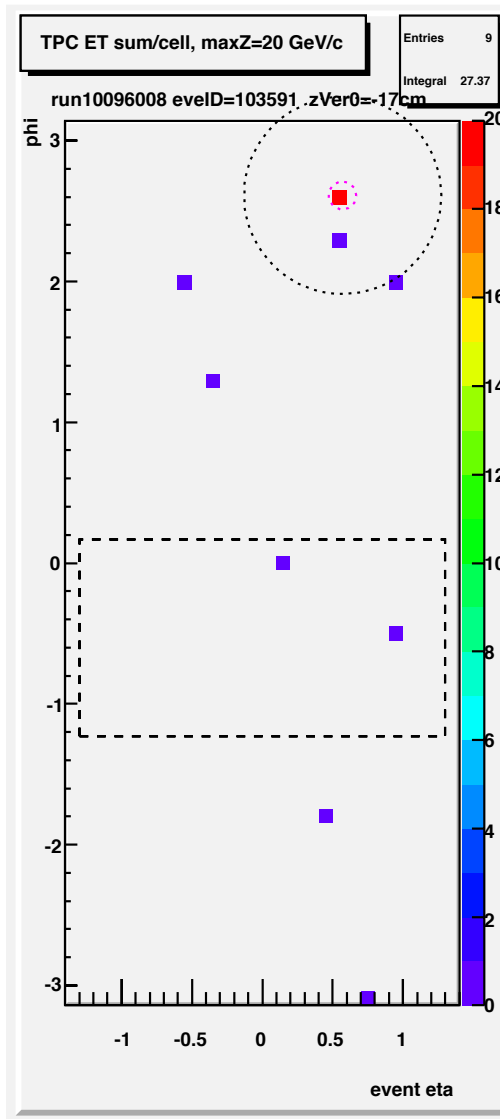
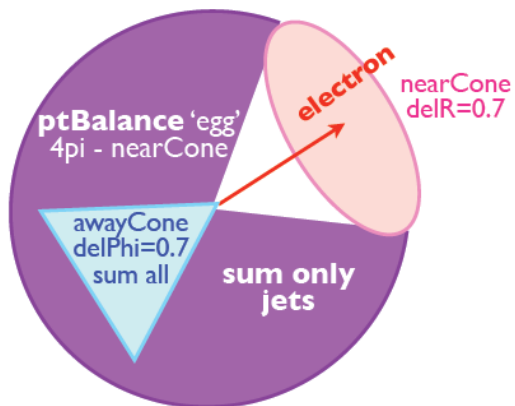
Run 9 STAR Data ($\sqrt{s}=500\text{GeV}$)



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 2×2 tower cluster E_T , require E_T sum > 15 GeV
- Require the excess E_T in 4×4 tower patch over 2×2 patch to be below 5%
- Require distance of 2×2 cluster vs. TPC track below 7 cm

Near-cone veto:

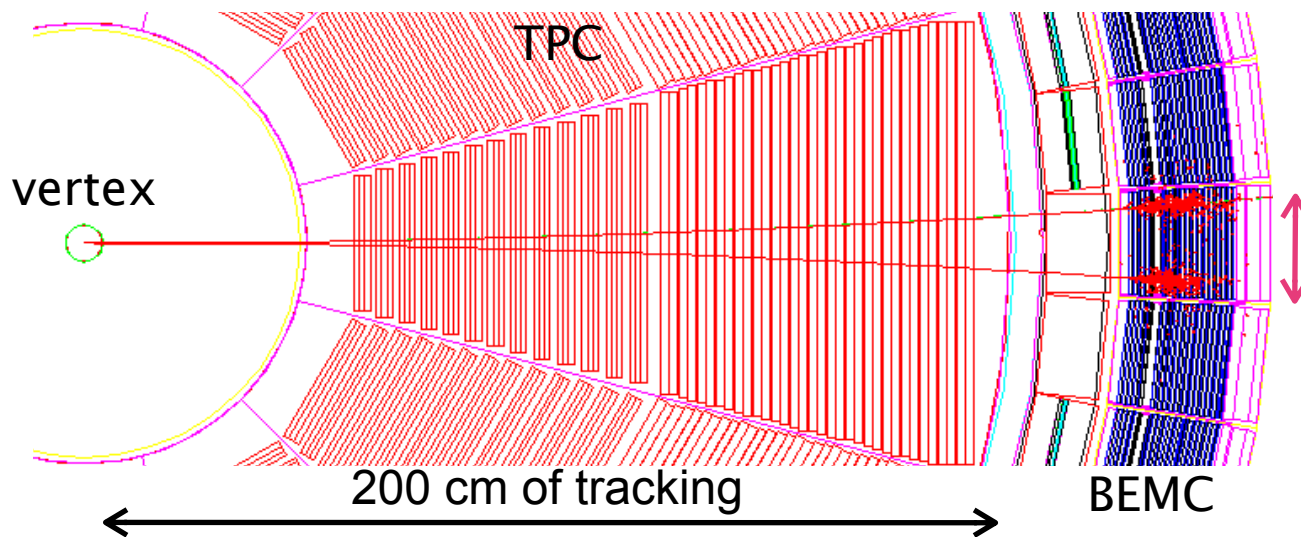
- Compute near-cone E_T sum of BEMC+TPC over $\Delta R = 0.7$ in η - ϕ space
- Require near-cone excess E_T below 12%

Away-'cone' cuts: p_T balance requirement

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

W production results: Charge separation

Mid-rapidity high p_T e^\pm charge separation



positron $p_T = 5 \text{ GeV}$

electron $p_T = 5 \text{ GeV}$

+/- distance $D: \sim 1/P_T$

$p_T = 5 \text{ GeV} : D \sim 15 \text{ cm}$

$p_T = 40 \text{ GeV} : D \sim 2 \text{ cm}$

Assign:

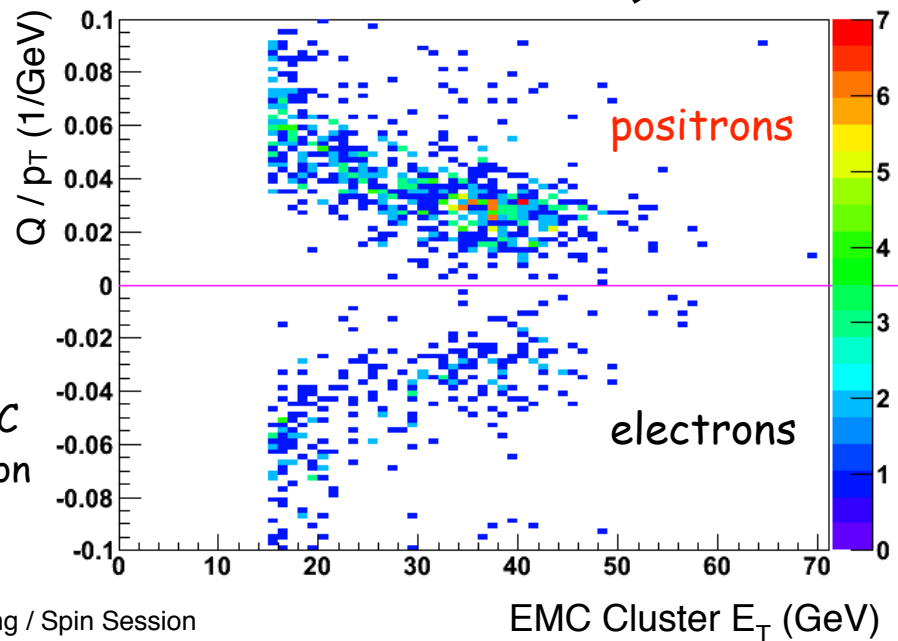
$Q/p_T > 0$ positrons

$Q/p_T < 0$ to be electrons

Successful separation of
different charge states!

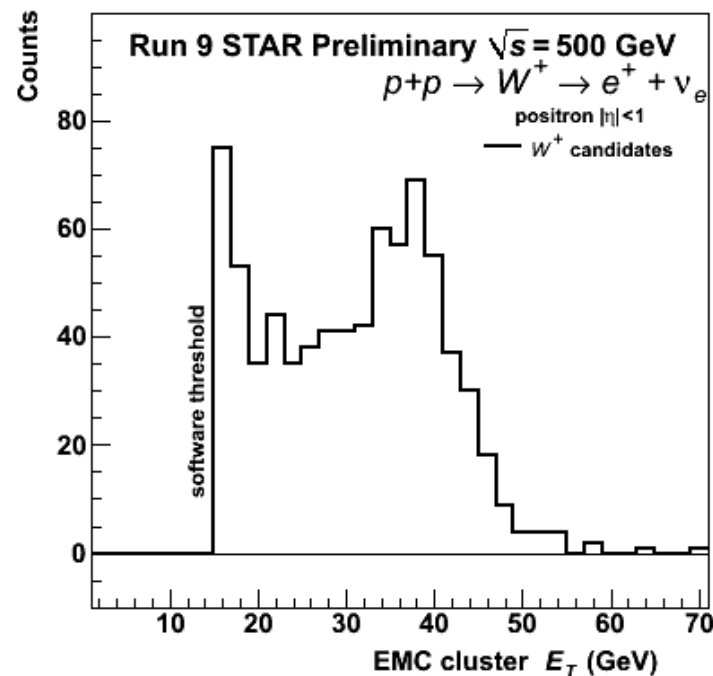
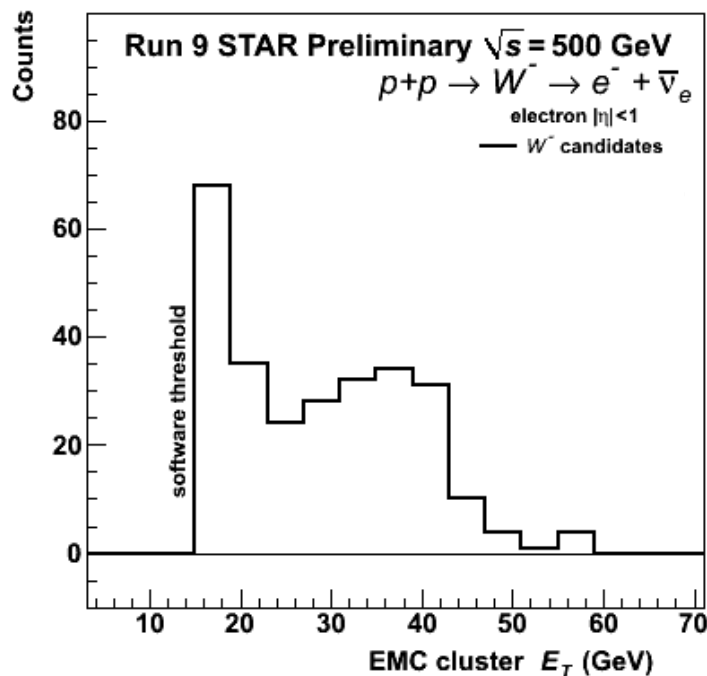
Q: Charge-sign
of
reconstructed
track

Final TPC
calibration



W production results: Charged-separated Yields

- Charge separated raw Signal / Jacobian Peak Distributions



- Charged separated W^+/W^- candidate distributions of the BEMC cluster transverse energy E_T (GeV)
- Cuts: All previously discussed cuts!

W production results: Background

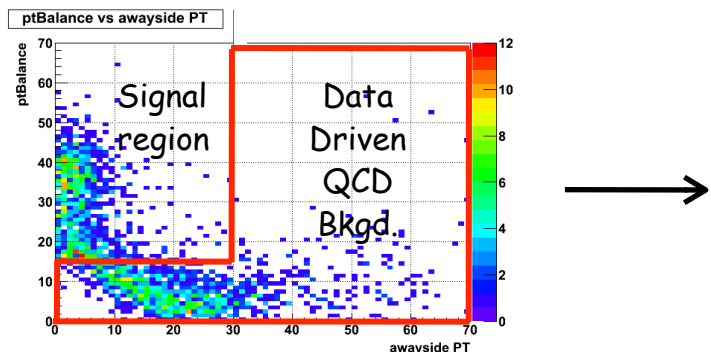
□ Background treatment

PYTHIA+GEANT MC →

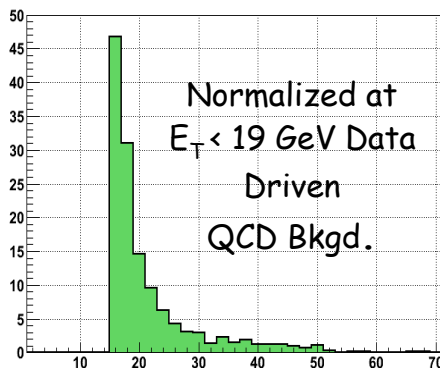
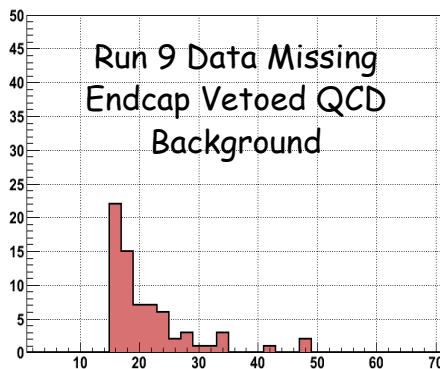
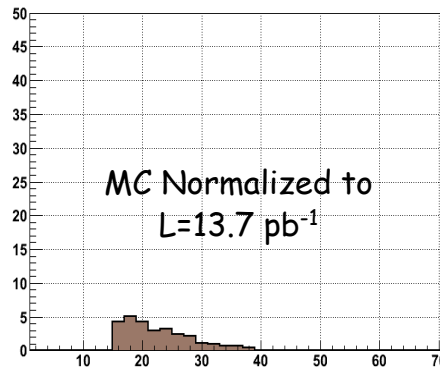
$$W \rightarrow \tau + \nu_\tau$$

$$\tau \rightarrow e + \nu_e + \nu_\tau$$

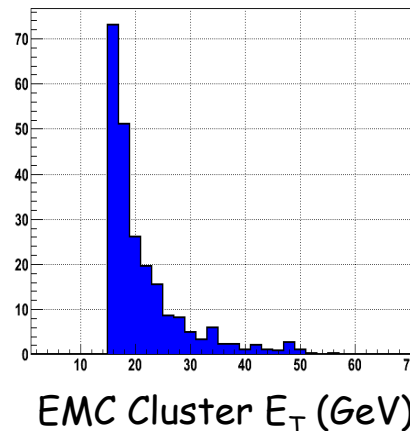
1. Run analysis **with** EEMC in veto cuts
2. Run analysis **without** EEMC in veto cuts
3. Subtract two raw signals



W⁺ distributions



Total Background

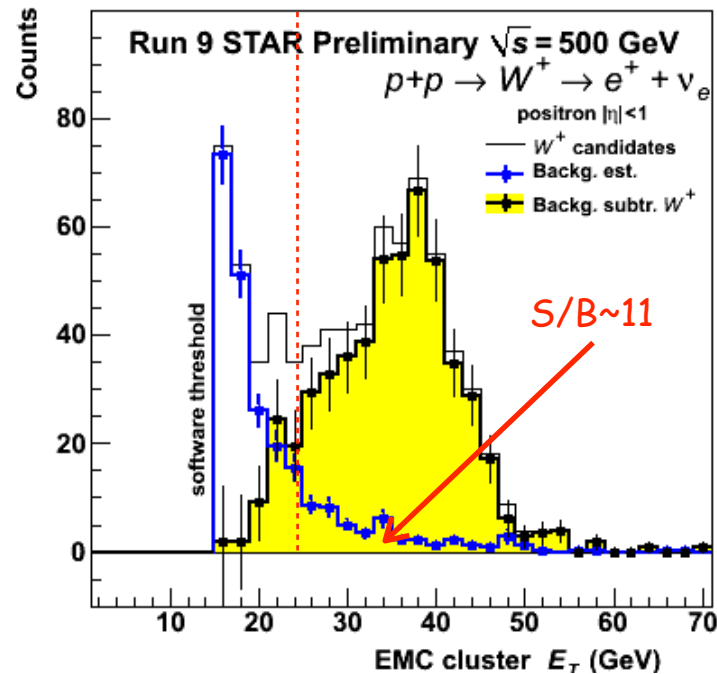
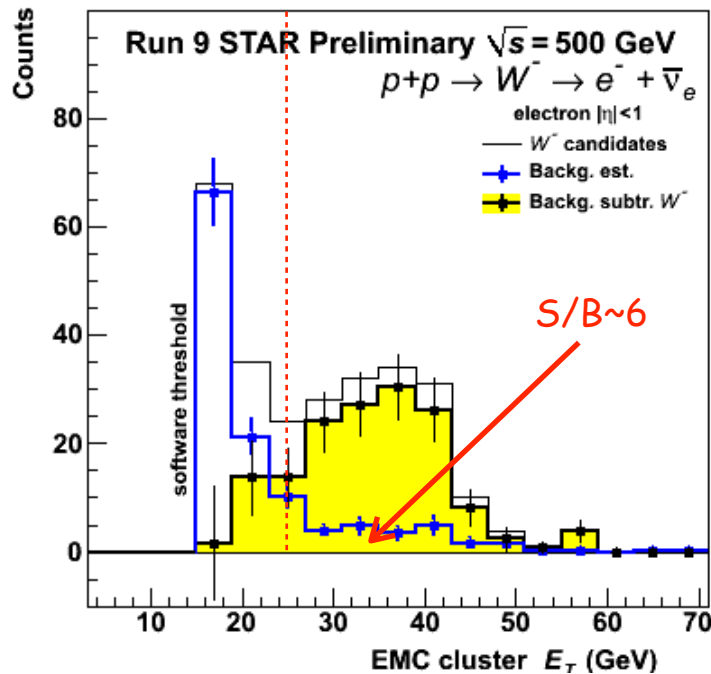


Background systematics:

- Calculate different data driven QCD background shapes by varying p_T balance and away-side p_T cuts
- Vary normalization region ($E_T < 17 - 21$ GeV)
- The largest deviation in each bin used for sys. error estimate

W production results: Background

□ Background subtraction



- Background distribution and background-subtracted signal distribution

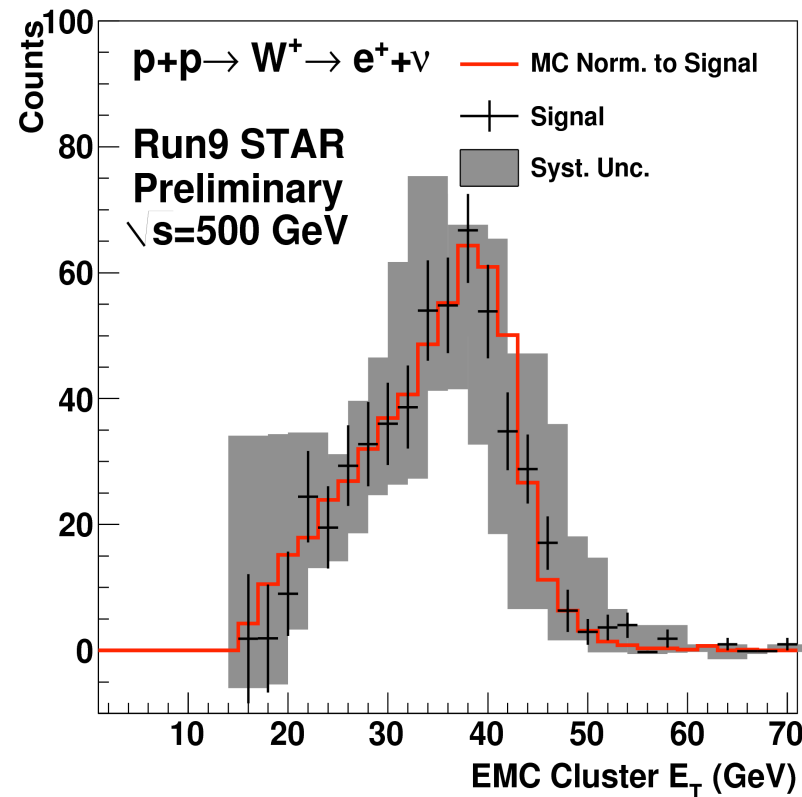
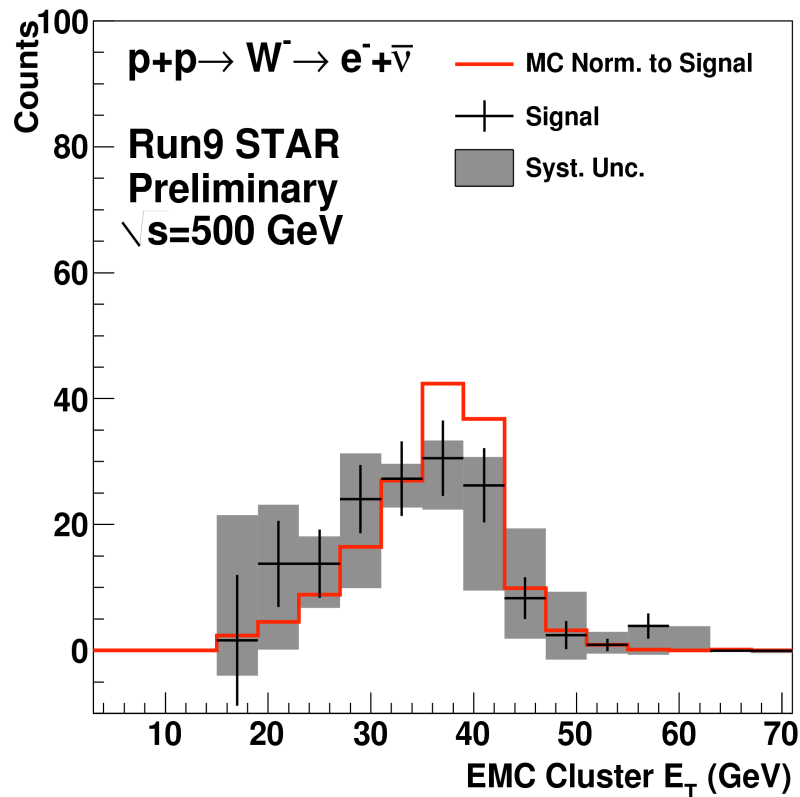
○ $B/(S+B)$ ($E_T > 25\text{GeV}$) W^- : 16%

○ $B/(S+B)$ ($E_T > 25\text{GeV}$) W^+ : 8%

Background Events ($E_T > 25\text{ GeV}$)	$W^- \rightarrow e^- + \bar{\nu}_e$	$W^+ \rightarrow e^+ + \nu_e$
$W \rightarrow \tau + \nu_\tau$	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

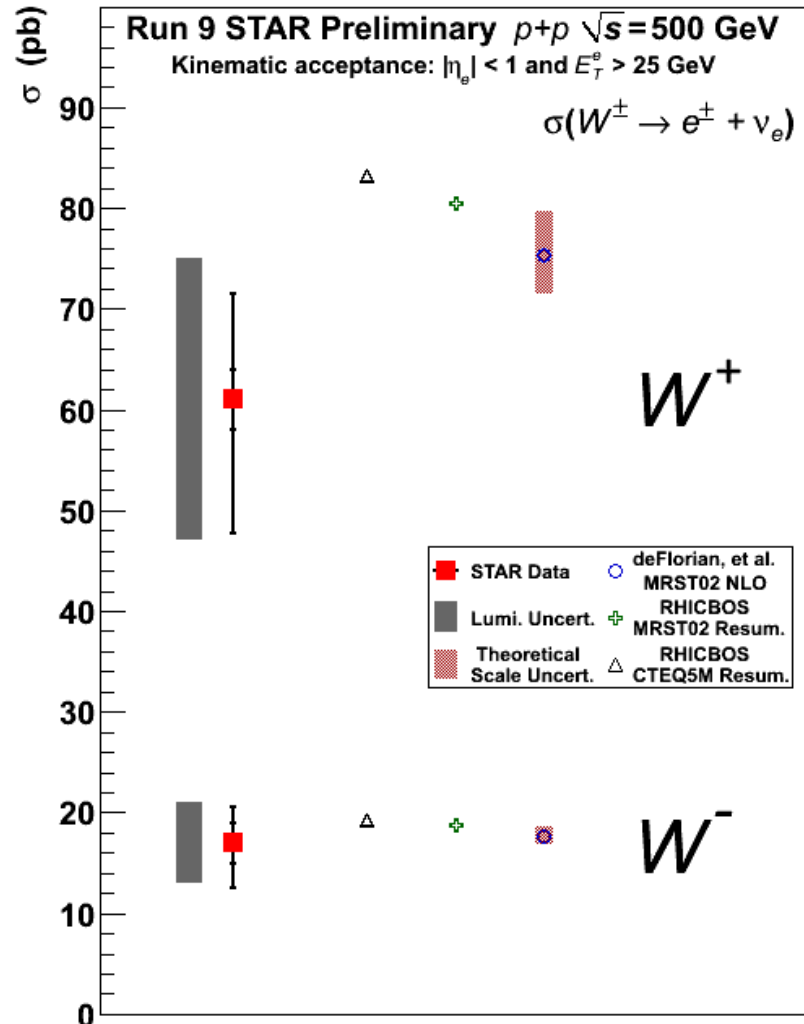
□ Data/MC Comparison of charge-separated Jacobian peak distributions



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

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}	$0.56^{+0.11}_{-0.09}$	$0.56^{+0.12}_{-0.09}$
$\int L dt$ (pb^{-1})	13.7 ± 3.2	13.7 ± 3.2

STAR Preliminary Run 9 ($p+p \sqrt{s}=500$ GeV)

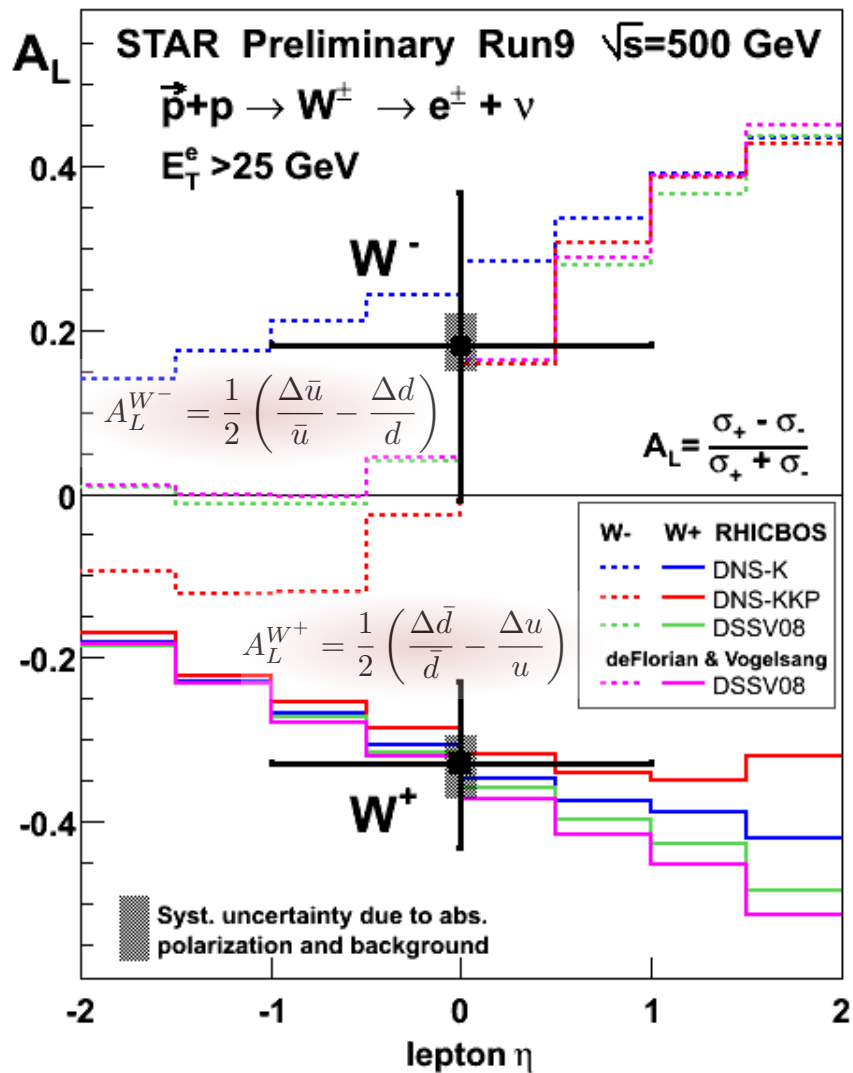
$$\sigma_{W^+ \rightarrow e^+ + \nu} = 61 \pm 3 \text{ (stat.) }^{+10}_{-13} \text{ (syst.) } \pm 14 \text{ (lumi.) pb}$$

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

- 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 $\sqrt{s}=500$ GeV)

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

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

- $A_L(W^+)$ **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 $p_T \sim 50$ GeV
- 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 $\sqrt{s} = 500\text{GeV}$ ($P \sim 40\%$ / $L \sim 12\text{pb}^{-1}$)
 - 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