

# Parity Violating Single Spin Asymmetry in W Production from Longitudinally Polarized p+p Collisions at 500 GeV

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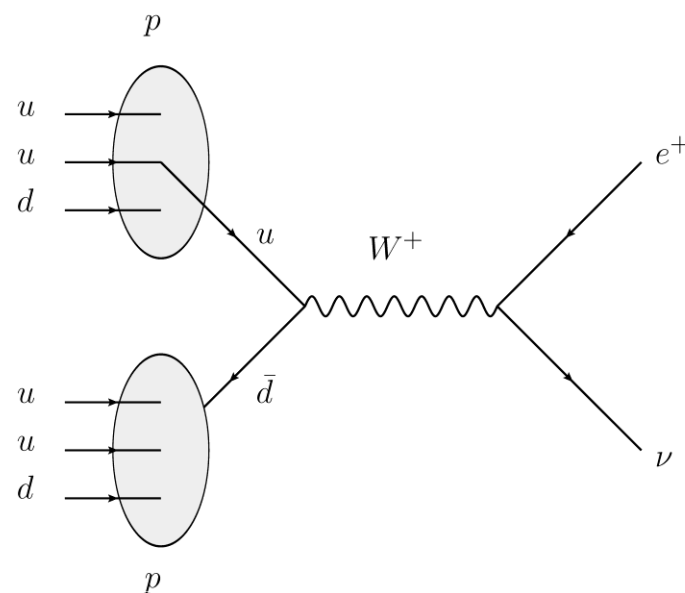
on behalf of the PHENIX Collaboration

# $W^\pm$ at RHIC

- First look at RHIC and PHENIX performance at  $\sqrt{s} = 500$  GeV in one month run in 2009
- First observation in p+p collisions
- First  $W$ 's produced with polarized beams
- $W$ 's at RHIC used to measure polarized PDF's through measurement of single spin asymmetry

# What can $W$ decays at RHIC tell us?

- The  $W^\pm$  probes the quark distribution in  $pp$ 
  - Different PDF sampled than in  $\bar{p}+p$
- Access to polarized PDF's through
  - Cross section
  - $W^+/W^-$  ratio
  - **Longitudinal spin asymmetry**



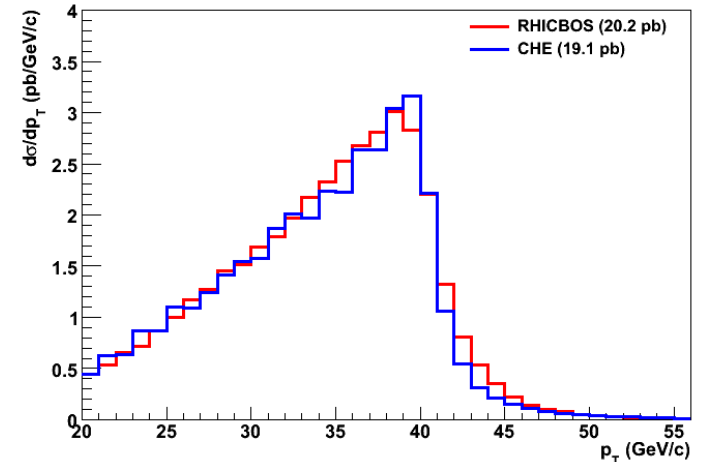
# Cross section predictions

- LO, NLO, and NNLO calculations
- RHICBOS Monte Carlo includes spin dependent PDF's, soft gluon resummation
- CHE NLO calculation

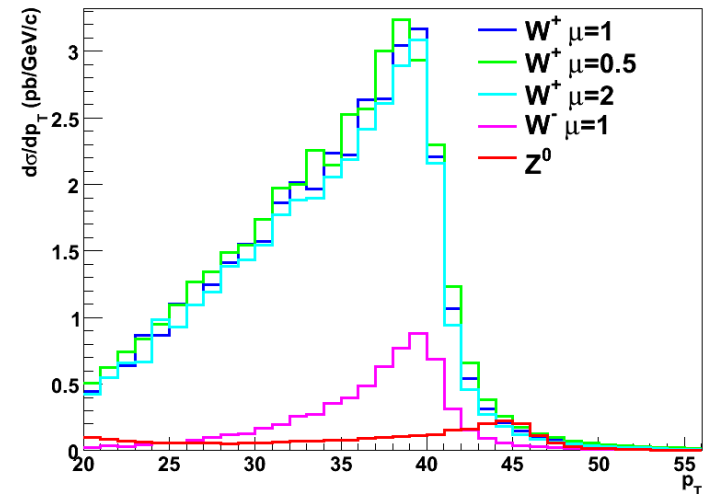
RHICBOS due to Nadolsky and Yuan, Nucl.Phys.B666:31-55 (2003)

CHE due to de Florian and Vogelsang, arXiv 1003.4533 (2010)

W<sup>+</sup> MRST2002



W and Z<sup>0</sup> MRST2002  $|y_e| < 0.35$



# Longitudinal spin asymmetry $A_L$

Parity violating longitudinal single spin asymmetry defined by

$$\epsilon_L = \frac{N^+ - R \cdot N^-}{N^+ + R \cdot N^-}$$

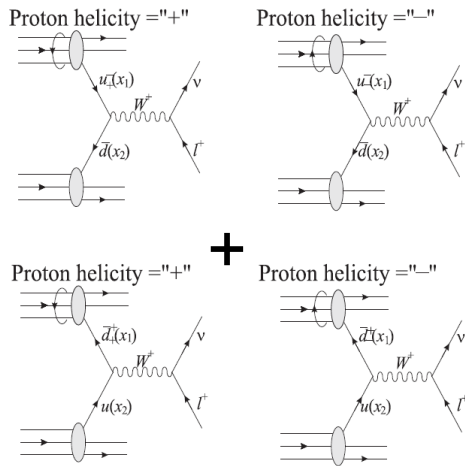
$$A_L = \frac{\epsilon_L \cdot D}{P}$$

- $N^+$  = right handed production of W
- $N^-$  = left handed production of W
- P = Polarization
- R = relative luminosities of the helicity states
- D = dilution by background and  $Z^0$

# Interpreting $A_L$

$A_L(y)$  probes sea and valence quark PDF's

Example at LO ignoring other quark contributions:

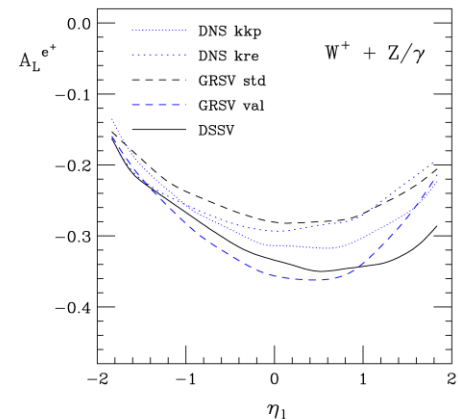


$$= A_L^{W^+} = -\frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$

Bunce et al., Ann.Rev.Nucl.Part.Sci.50:525-575,2000 (up to sign convention)

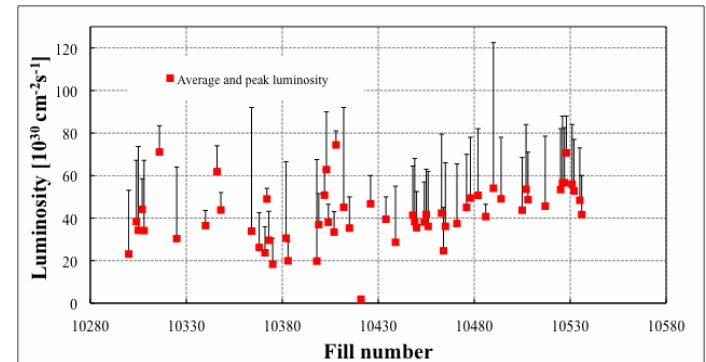
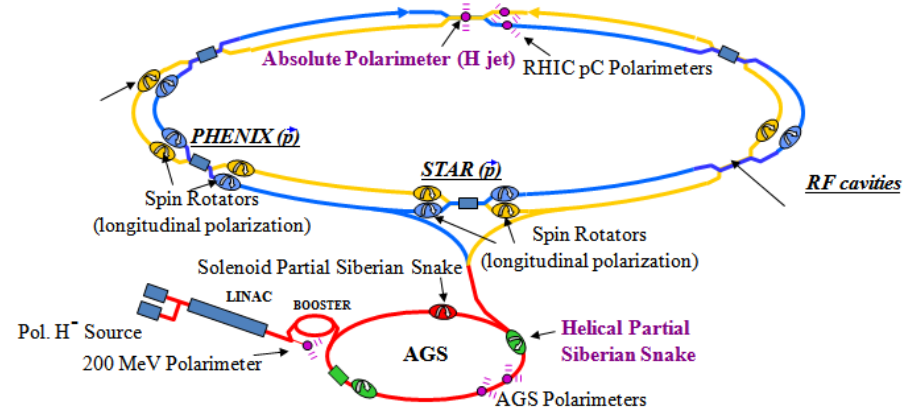
NLO calculations of  $A_L$  can be added to PDF fits

de Florian and Vogelsang, arXiv 1003.4533 (2010)



# RHIC

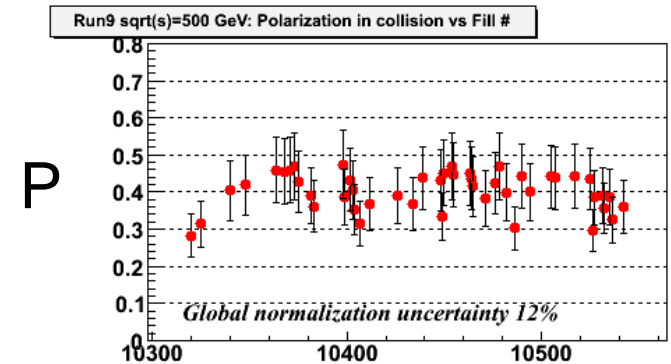
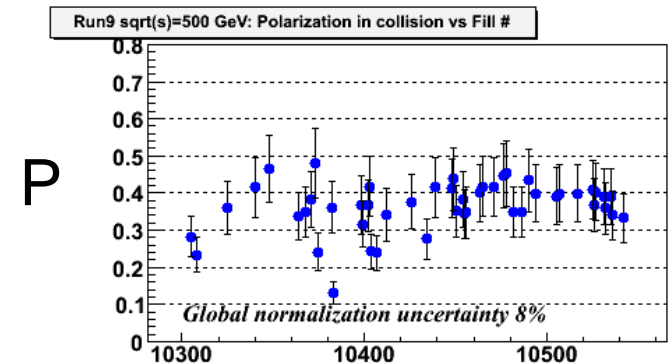
- Longitudinally polarized collisions at PHENIX and STAR
- Up to 111 bunch crossings with varied spin orientations for control of systematic errors
- Luminosity typically  $\approx 4 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1}$



W. Fischer

# Polarization

- Measured with two polarimeters
  - CNI polarimeter measurements available during run
  - H jet polarimeter provides absolute polarization
  - Measured residual polarization in real time after rotation at PHENIX



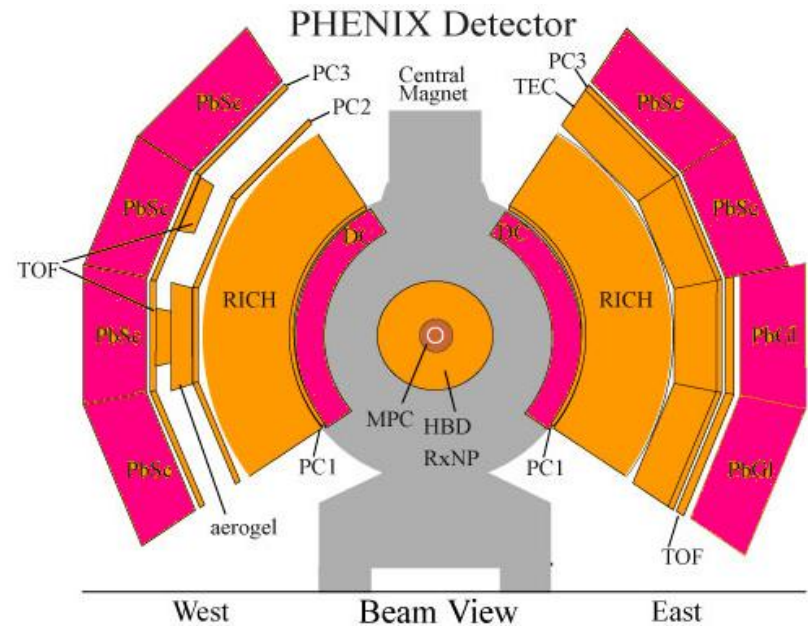
Polarization measured by CNI polarimeters fill-by-fill



# PHENIX

## Central arm spectrometer

- $|\eta| < 0.35$
- EM calorimeter  
( $\Delta\phi \times \Delta\eta \approx 0.01 \times 0.01$ )
- trigger fully efficient  
above  $\approx 12$  GeV

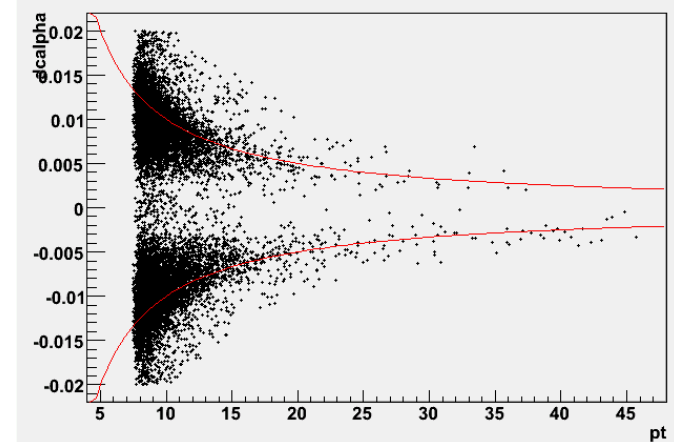
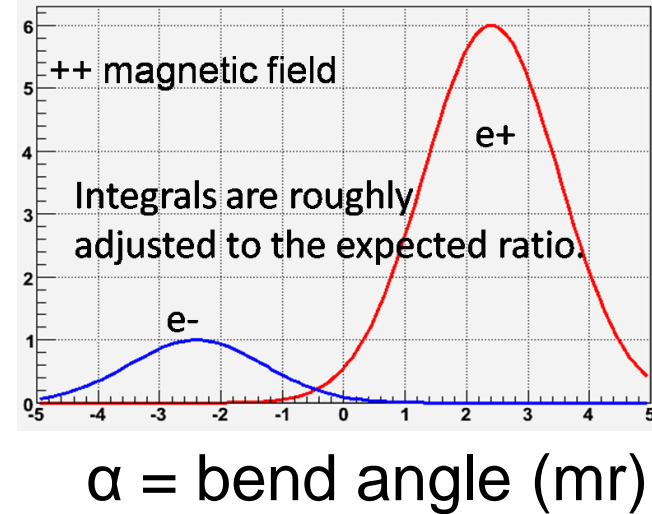


# Run 9 500 GeV pp data

- First 500 GeV in RHIC Run 9: March 17-April 13, 2009
- Machine development in parallel with physics running to increase luminosity, polarization, reduce backgrounds
- Detector challenged by high rates, sometimes high backgrounds
- Forward muon arms running only with prototype trigger electronics, RPC's, and shielding (no forward muon physics reported )

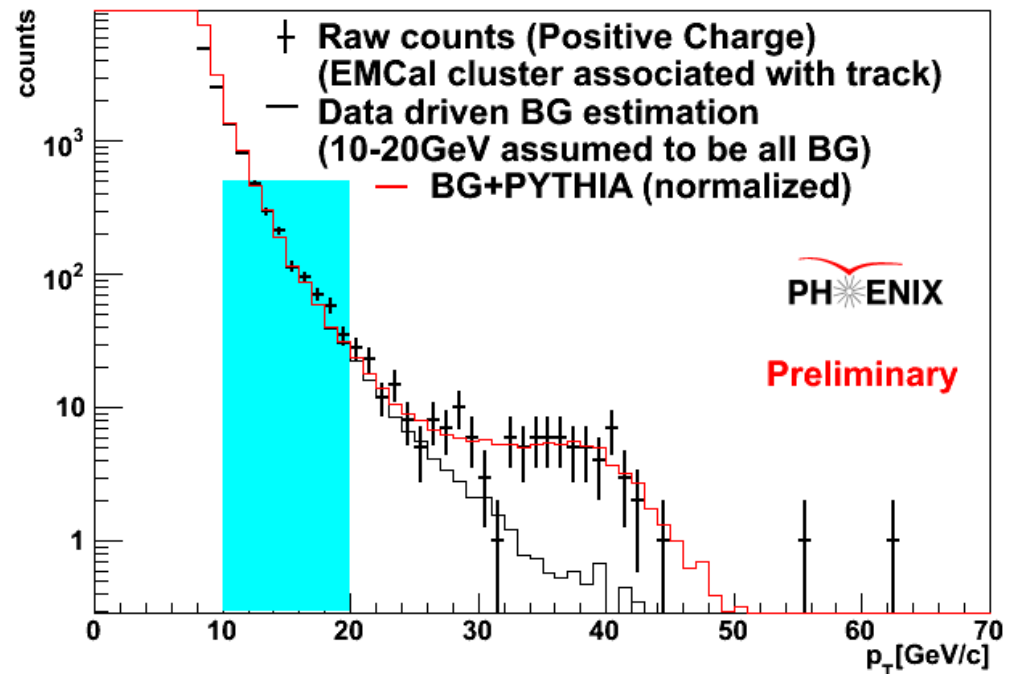
# Event selection

- $\pm 30$  cm vertex cut
- High energy EM Calorimeter clusters matched to charged track
- Loose timing cut eliminates cosmic rays
- Momentum resolution allows only loose  $E/p$  cut
- Charge sign discrimination by measuring bend angle in drift chamber



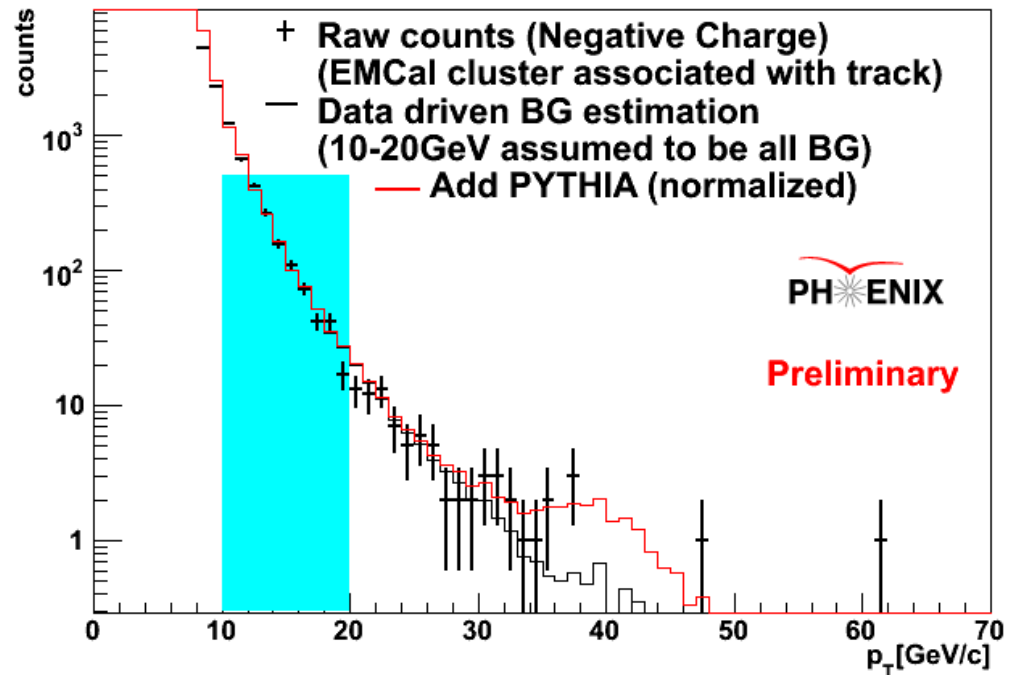
# Positive

- Positive charged tracks matched with EM Calorimeter cluster
- Background estimated using 10-20 GeV/c region



# Negative

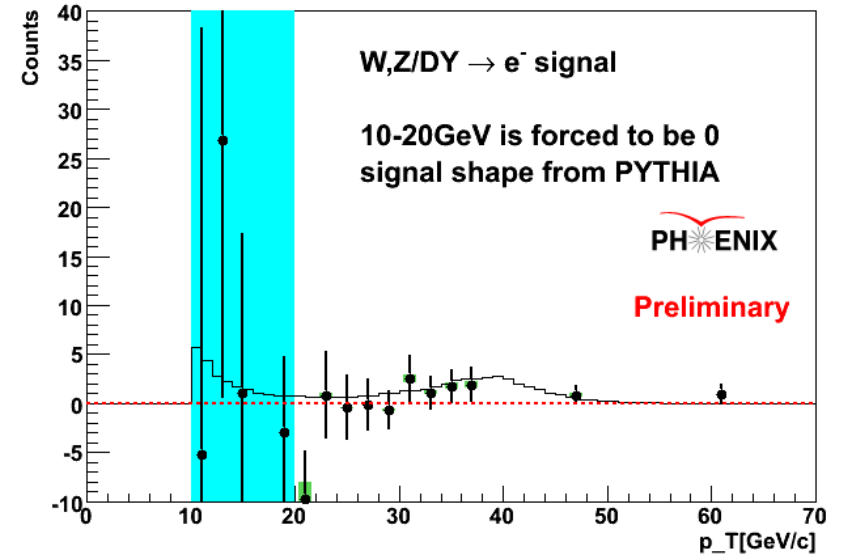
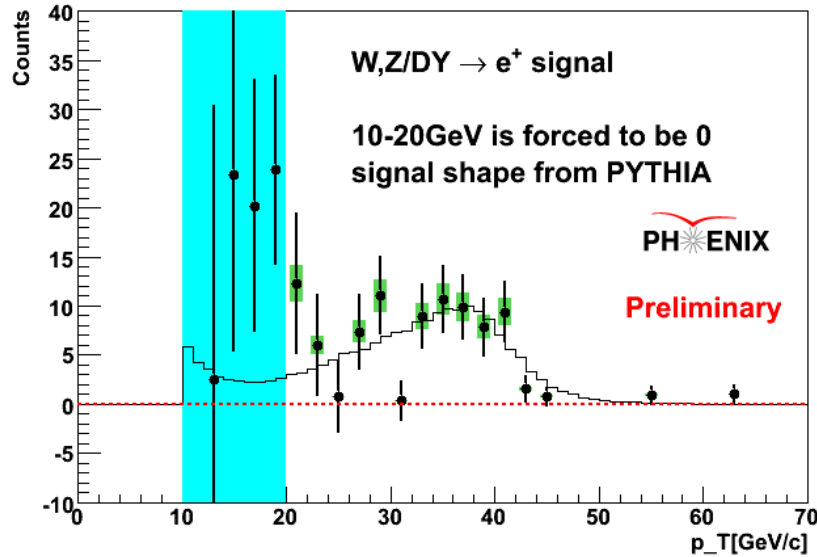
- Estimated 25% contamination from  $Z^0$  (larger fraction because lower  $W^-$  statistics)



# Background subtracted

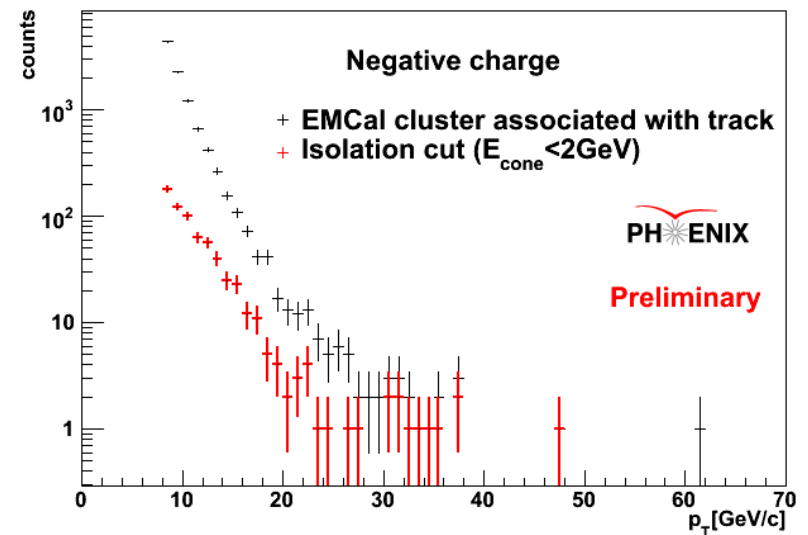
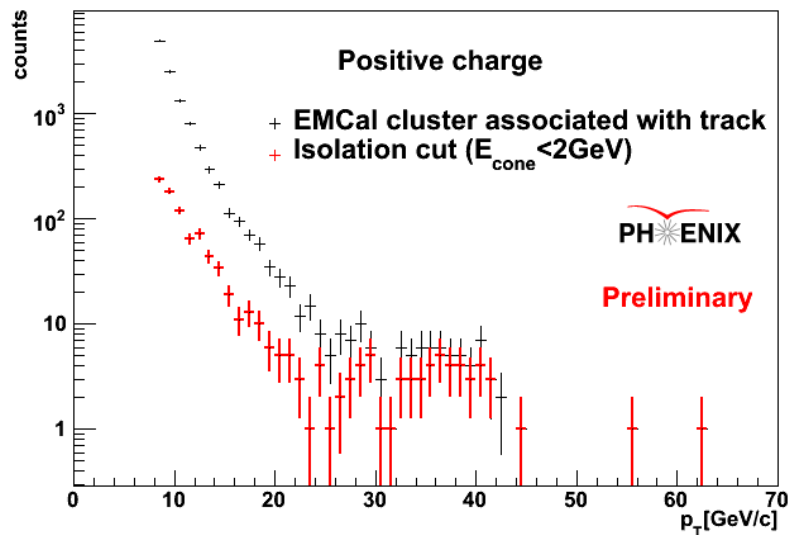
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# Isolation cut

Lepton side isolation cut used to increase signal/background for asymmetry measurement



# Event sample $30 < p_T < 50$ GeV/c

PHENIX Preliminary from  $9.28 \text{ pb}^{-1}$  of data

Sample	Raw counts	Background counts	Background subtracted	Isolation cut counts
Positive	60	11.1	48.9	39
Negative	16	10.6	5.4	11
Total	76	21.7	54.3	50



# Acceptance

- Acceptance calculation in progress
- Account for acceptance variation during run
- Acceptance factors:
  - Solid angle
  - $\pm 30$  cm vertex cut
  - Trigger efficiency
  - Calorimeter hot/dead towers
  - Tracking efficiency
- Cross section agrees within errors of expectation making us confident that we have understood the signal and backgrounds

# $A_L$ measurement

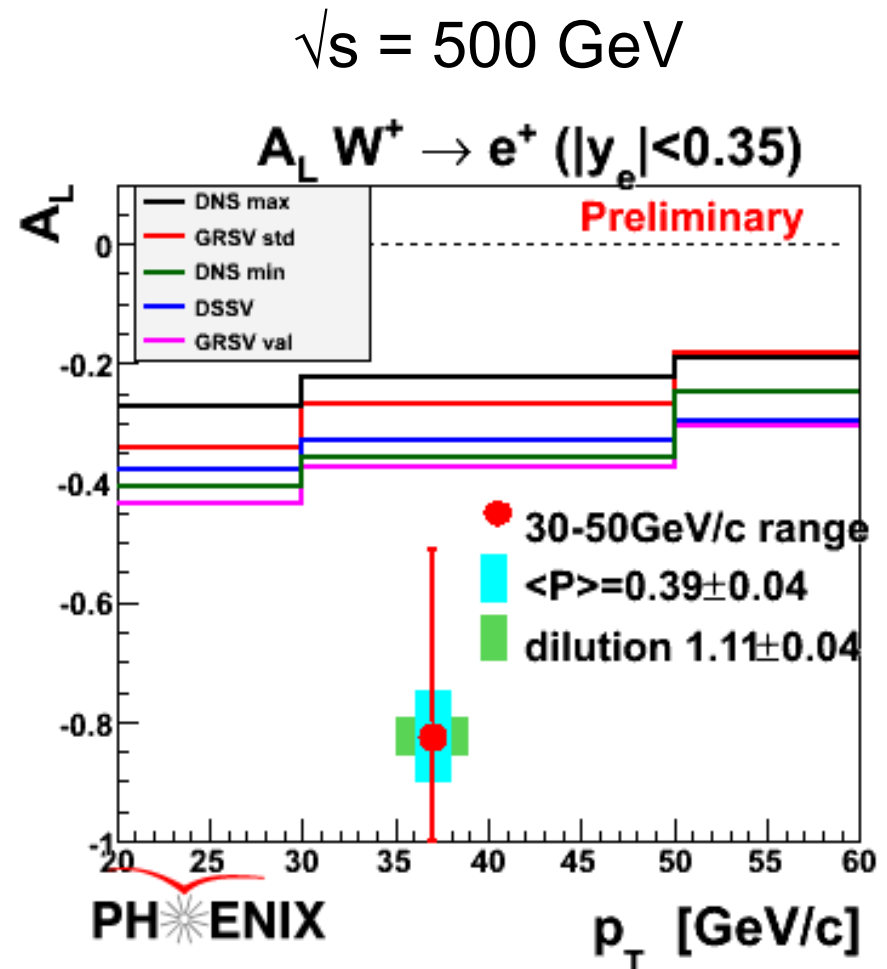
- First measurement with  $W^+$  sample
- Raw asymmetry  $\varepsilon_L$  measured in background region small and error estimation consistent; by a fitting method, 12-20 GeV, where we expect no asymmetry, we measure:

$$\varepsilon_L = +0.035 \pm 0.047$$

# $A_L$ for $W^+$ sample

- Average polarization  $0.39 \pm 0.04$
- Correct polarization for dilution by Z and QCD backgrounds
- Raw asymmetry  $-0.29 \pm 0.11$  leads to

$$A_L^{W^+} = -0.83 \pm 0.31$$



# Conclusion

- PHENIX has seen its first central arm W's
- Acceptance calculation and background estimates in progress
- First attempt to measure single spin asymmetry has detected a parity violating asymmetry leading to a preliminary value of

$$A_L^{W^+} = -0.83 \pm 0.31$$

# The future

- In a short exploratory run we have measured  $A_L$  in our  $W^+$  sample to be  $0.83 \pm 0.31$
- Future RHIC running at 500 GeV is expected to have higher polarization and longer running time
- The PHENIX detector is undergoing considerable upgrades to enable a program of measurements of  $W^\pm$  in the forward direction as well