

# Observation of forward rapidity $W$ -decay in 500 GeV p+p collisions

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for the PHENIX collaboration

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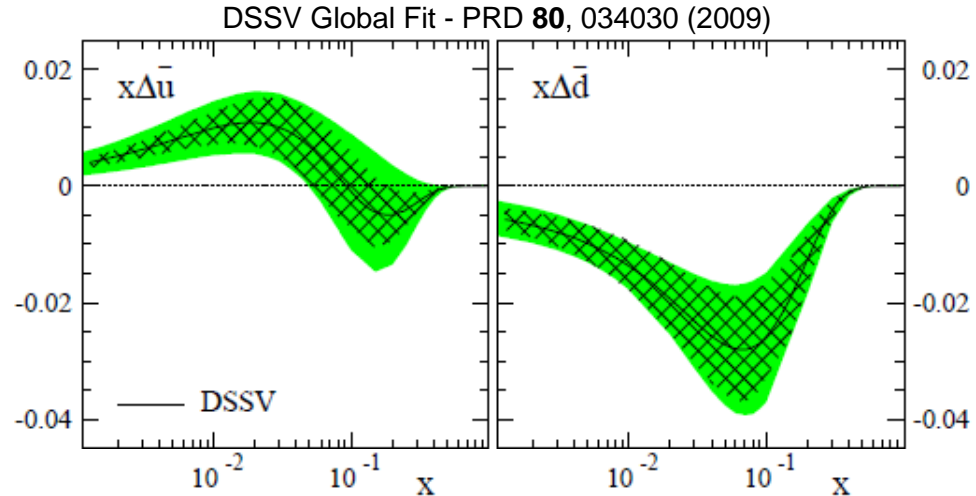
**APS April Meeting 2012**

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# Introduction

Over many years, worldwide program of form factor measurements, inclusive deep-inelastic and semi-inclusive deep-inelastic scattering has made possible a definitive measurement of the polarized PDFs of the u and d quarks.

However, the contribution of the sea quarks and gluons to the spin of the proton remains relatively unclear.



❖ Use completely independent probe:  
**Parity Violating  $W$  Production**

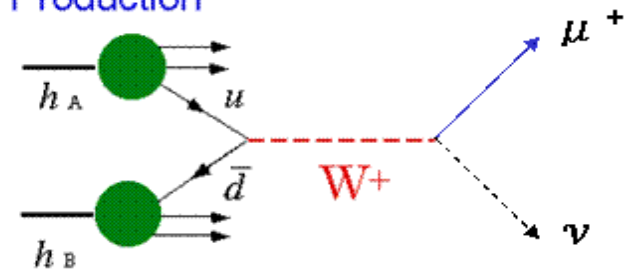
➤ Parity violation of the weak interaction and u- & d-quark polarizations in proton

⇒ control over helicity states of colliding partons

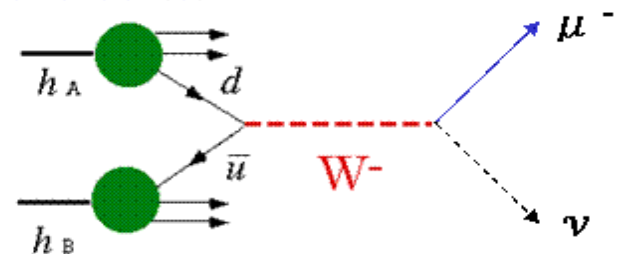
➤ Large scale ( $\sim m_W$ ) and independent of knowledge of fragmentation

⇒ clean interpretation of the results in hard scattering QCD framework

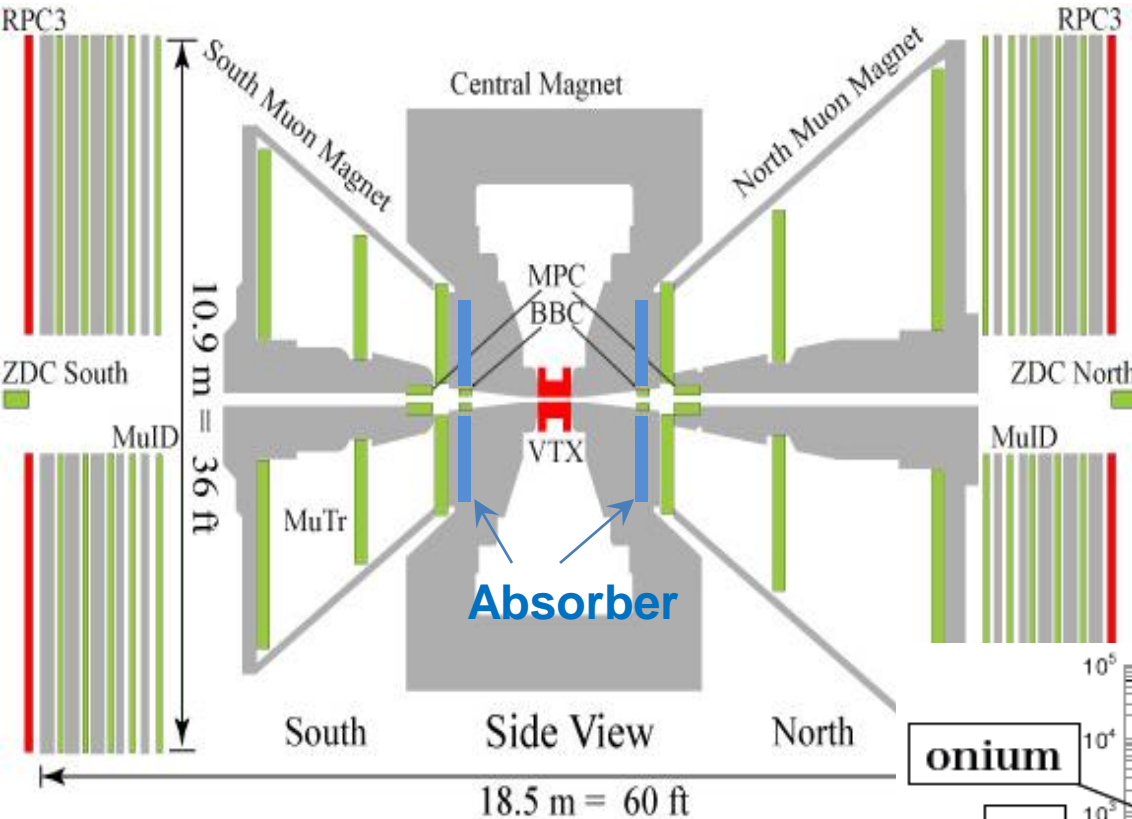
$W^+$  Production



$W^-$  Production



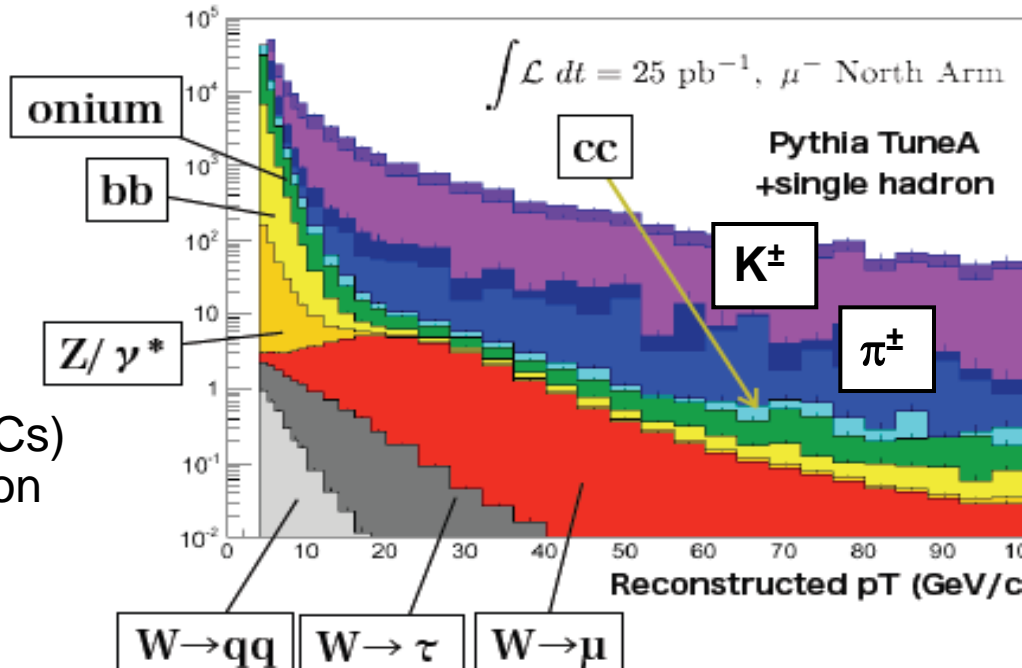
# PHENIX Run-11 Forward Experimental Setup



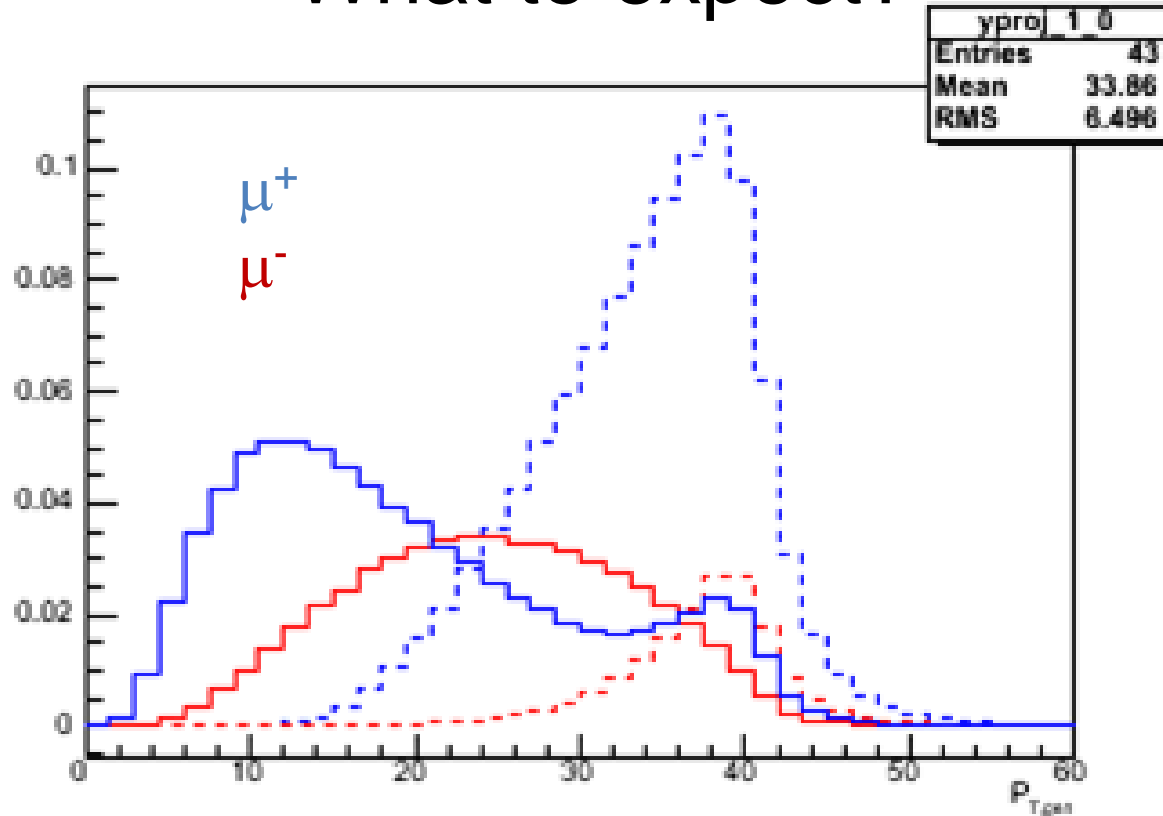
- Hadronic decays dominate muon rates ( $k^\pm$  and  $\pi^\pm$ )
- $W$  dominate muon backgrounds only above 20 GeV/c
- Muon trigger before upgrade was momentum “blind”  $\Rightarrow$  *Need for a momentum sensitive muon trigger*
- DAQ cannot take full rate @ 500 GeV

**Huge backgrounds, Limited space, and Associated cost  $\Rightarrow$**

- Add absorber
- Add Resistive Plate Chambers (RPCs)
- Add fast readout electronics for Muon tracker



# What to expect?



RHICBOS simulation

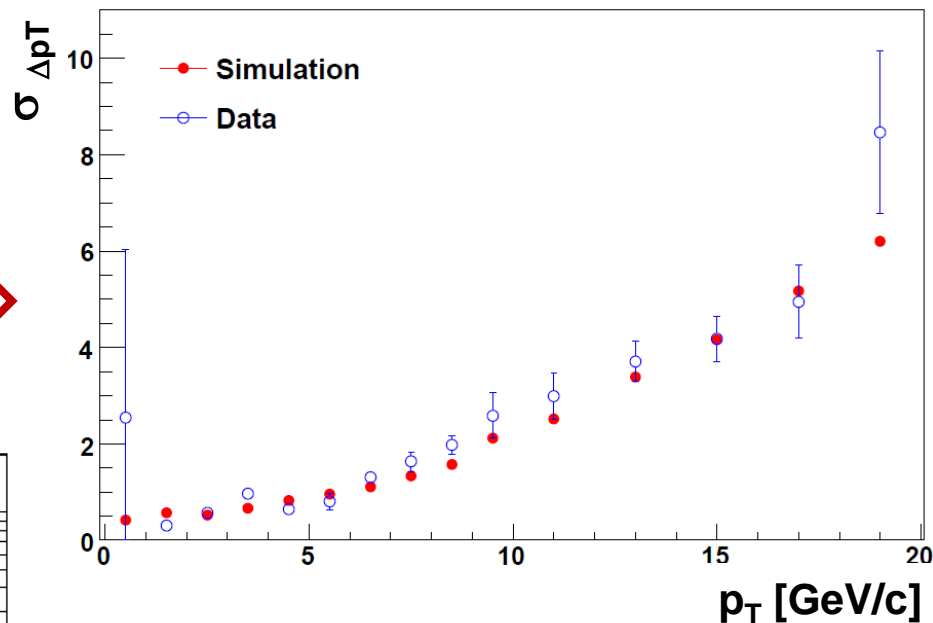
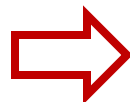
- Dashed lines for central arm ( $|\eta| < 0.35$ )
  - Clear Jacobian peaks
- Full lines for muon arm [ $\times 10$ ] ( $1.2 < |\eta| < 2.4$ )
  - No Jacobian peak for  $W^-$  && Small bump for  $W^+$

❖ *Depend on simulations for background studies (signal/background)*

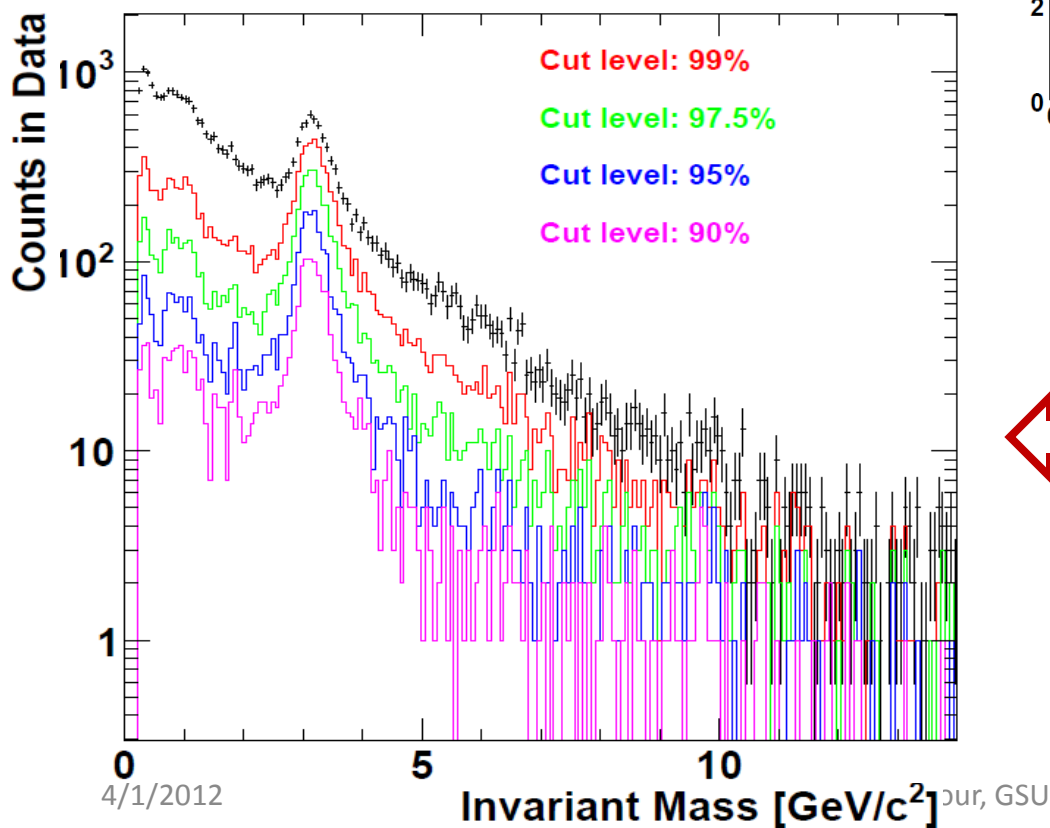
# PHENIX Muon Arm Analysis

Depend on simulation for signal/background  $\Rightarrow$  need cross checks

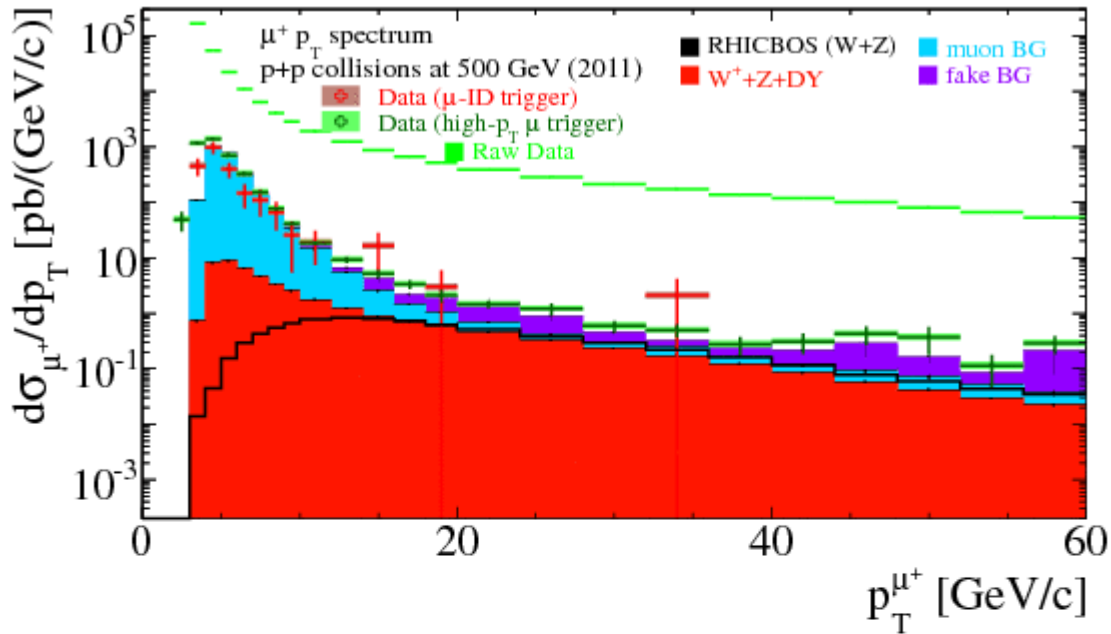
➤ Momentum smearing comparison between cosmics and simulation



➤ Test the efficiency of the cuts extracted from simulations over dimuon spectra from data to see the impact on  $J/\psi$  and associated background.

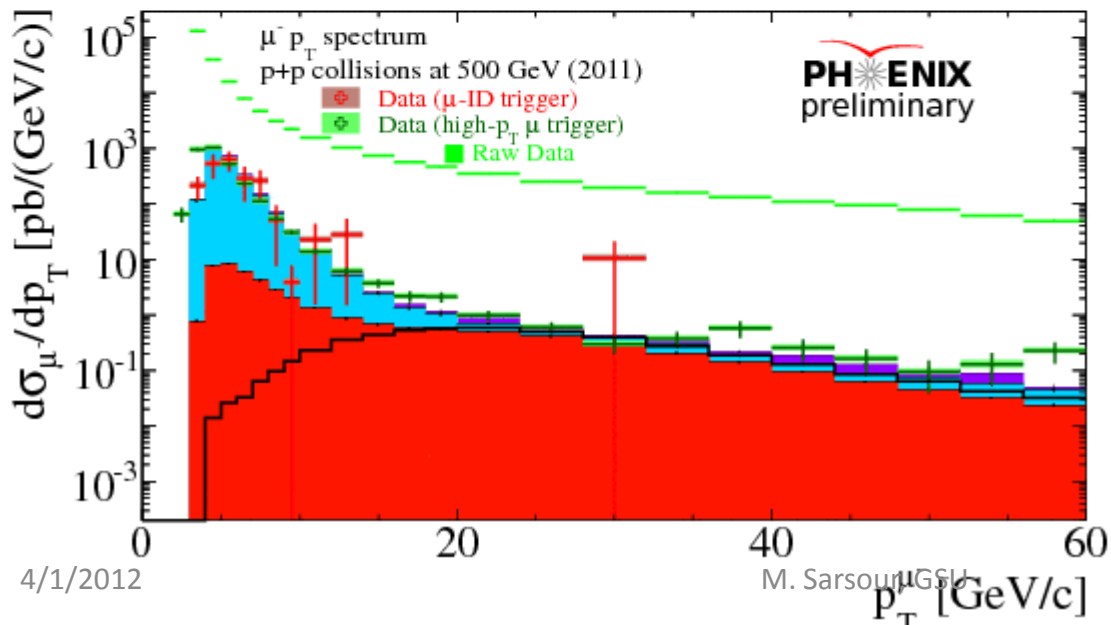


# Muon Candidate Cross Section



The stacked MC simulations separated into three categories: fakes, muon BGs, and W+Z/DY.

Shape of the MC simulation describes the data very well.



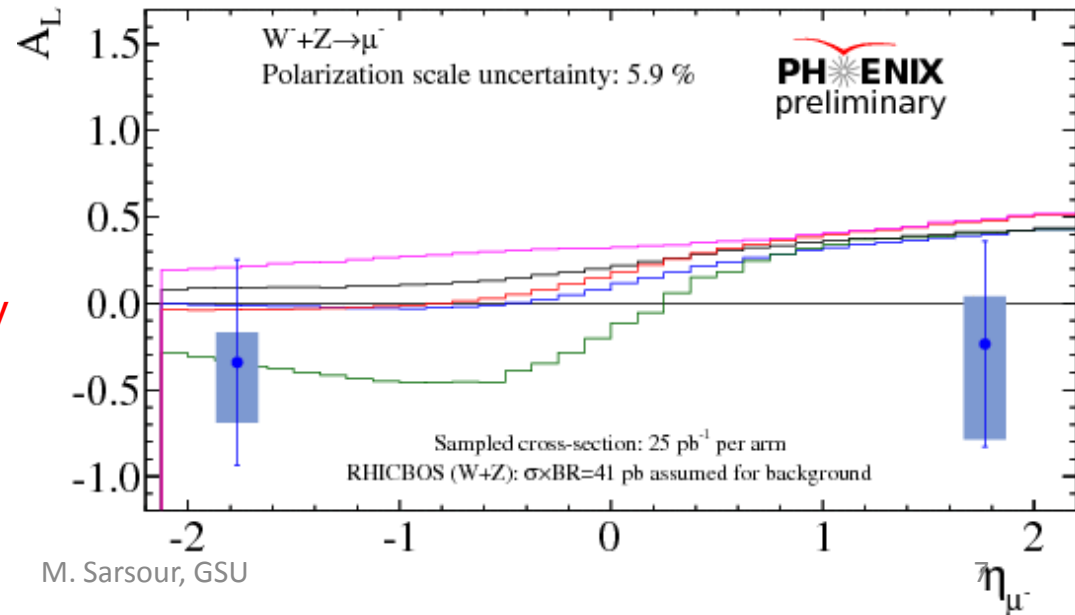
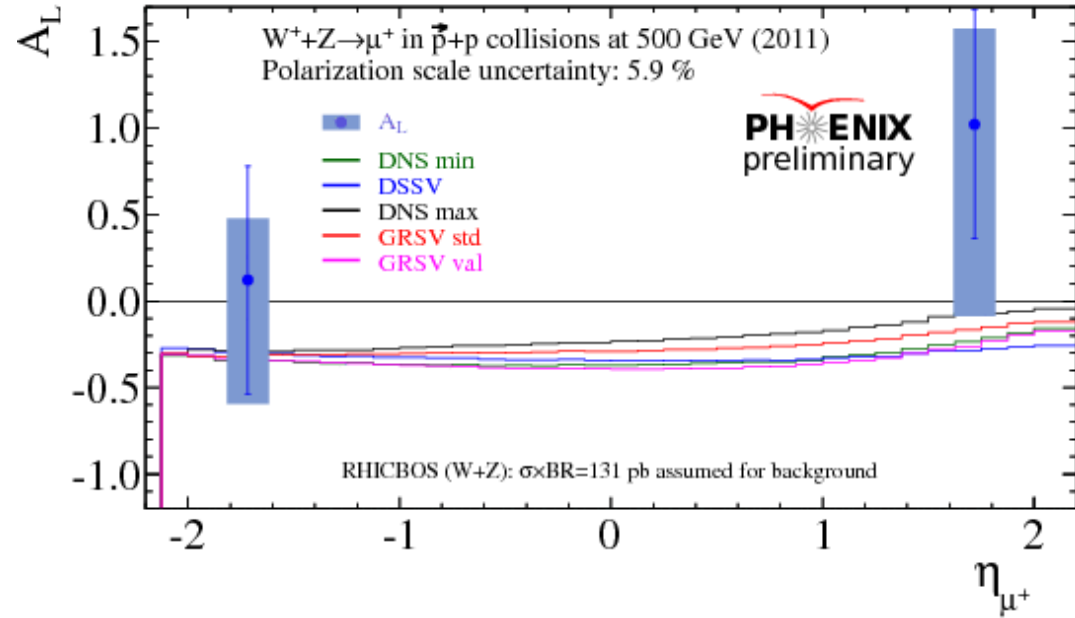
- RHICBOS over Data was taken to calculate the signal/BG ratio used to correct the asymmetries.

- Systematic uncertainty bands were added to the asymmetry plot to account for a variation of the S/BG by a factor of 2.

# $W^\pm \rightarrow \mu^\pm$ Single Spin Asymmetry

## at Forward Rapidities

- ❖ First measured single spin asymmetries at forward rapidities ( $W^\pm \rightarrow \mu^\pm$ ) at  $\sqrt{s} = 500$  GeV.
  - ❖ Beam averaged experimental results with an average polarization  $\sim 50\%$  and integrated luminosity  $\sim 25.5$  pb $^{-1}$
  - ❖ Different curves are expectation from RHICBOS calculation ( $p_T > 15$  GeV/c) with different parameterizations of the parton helicities.
- Allows to narrow down the currently existing uncertainties on the light sea quark polarizations, especially for the u quarks.

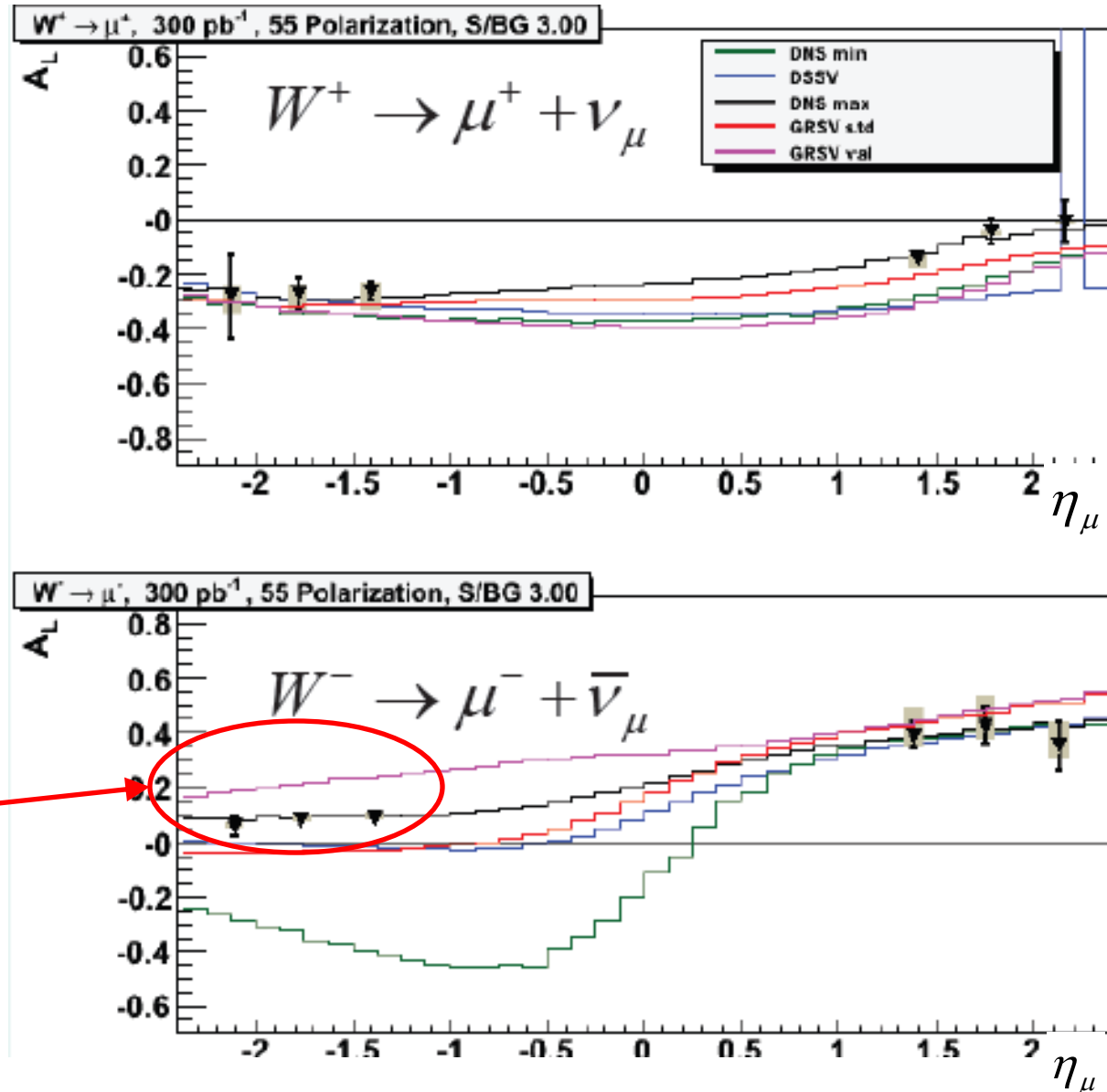


# Expectation for forward W Measurement

Expectation for uncertainties in parity-violating asymmetries in high- $p_T$  muon production

Assuming  $300 \text{ pb}^{-1}$  @ 55% polarization with  $S/B = 3.0$ . Expect to accumulate over the next several years

Powerful measurement of  $\Delta\bar{u}/\bar{u}$





# Summary and Outlook

- New upgrades delivered largely improved data.
- First preliminary result of  $W \rightarrow \mu$  single spin asymmetry in forward/backward rapidities.
- PHENIX forward upgrade for  $W$  measurement was completed in time for run 2012
- Need  $300 \text{ pb}^{-1}$  integrated luminosity at 60% polarization to meet the  $W$  measurement goals of the spin program

# Thank You

# Backup

## Session L11: Spin Structure of the Nucleon

3:30 PM–5:18 PM, Sunday, April 1, 2012

Room: Embassy F

Sponsoring Unit: GHP

Chair: Ernst Sichtermann, Lawrence Berkeley National Laboratory

### **Abstract: L11.00008 : $W^\pm$ Production at Forward Rapidity in 500 GeV p+p Collisions at PHENIX**

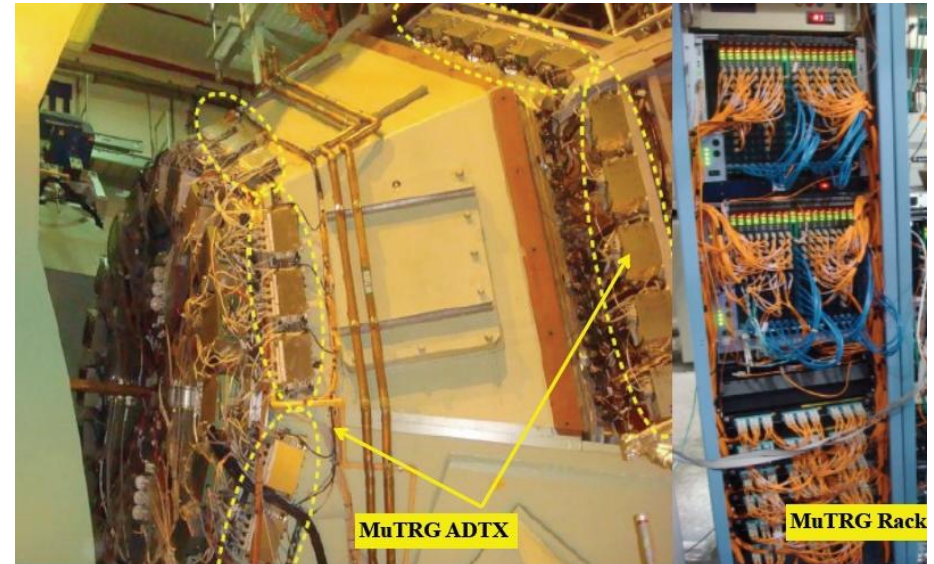
4:54 PM–5:06 PM

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A major emphasis of the RHIC spin program at BNL is to study the spin-flavor structure of the proton based on the production of  $W^\pm$  bosons.  $W^\pm$  bosons are produced at leading order in  $\bar{u}d, (\bar{d}u)$  collisions and detected at RHIC through their leptonic decays,  $l+\bar{\nu}_l, (\bar{l}+\nu_l)$ , where only the respective charged lepton is measured. At forward rapidity, PHENIX completed the needed upgrades of the muon spectrometers to observe muons from  $W^\pm$  decays and is ready for polarized p+p collisions at  $\sqrt{s}=500$  GeV in 2012. The upgrades included new electronics transferring information from the muon tracking systems to the level 1 trigger processors and new fast Resistive Plate Chamber (RPC) tracking stations up and down stream of the PHENIX muon spectrometers. In 2011, the up stream RPC tracking stations were not yet installed, PHENIX collected approximately  $17 \text{ pb}^{-1}$  of polarized p+p collisions at  $\sqrt{s}=500$  GeV with the forward muon detectors. The status of the data analysis towards  $W^\pm$  cross sections for the  $\mu^\pm$  channels, at forward rapidity, will be presented. The proton beams had a longitudinal polarization of approximately 46%, and progress on extracting  $W^\pm$ -decay muon single spin asymmetry will be reported.

# Muon Arms Upgrades



- ✓ Fast readout electronics for Muon tracker installed in 2009
- ✓ RPC-3 installed at RHIC Run-11 & RPC-1 installed at Run-12
- ✓ 35 cm SS310 (2\* $\lambda$ I thickness) absorber: reduce the lower momentum hadron punch through by a factor 5

Main Selection Variables:

- Track  $\chi^2$
- DG0
- DDG0
- DG4
- DCA(z,r)
- $\Delta\Phi_{1,2}$  &  $\Delta\Phi_{2,3}$
- RpcDCA,time
- multiplicity

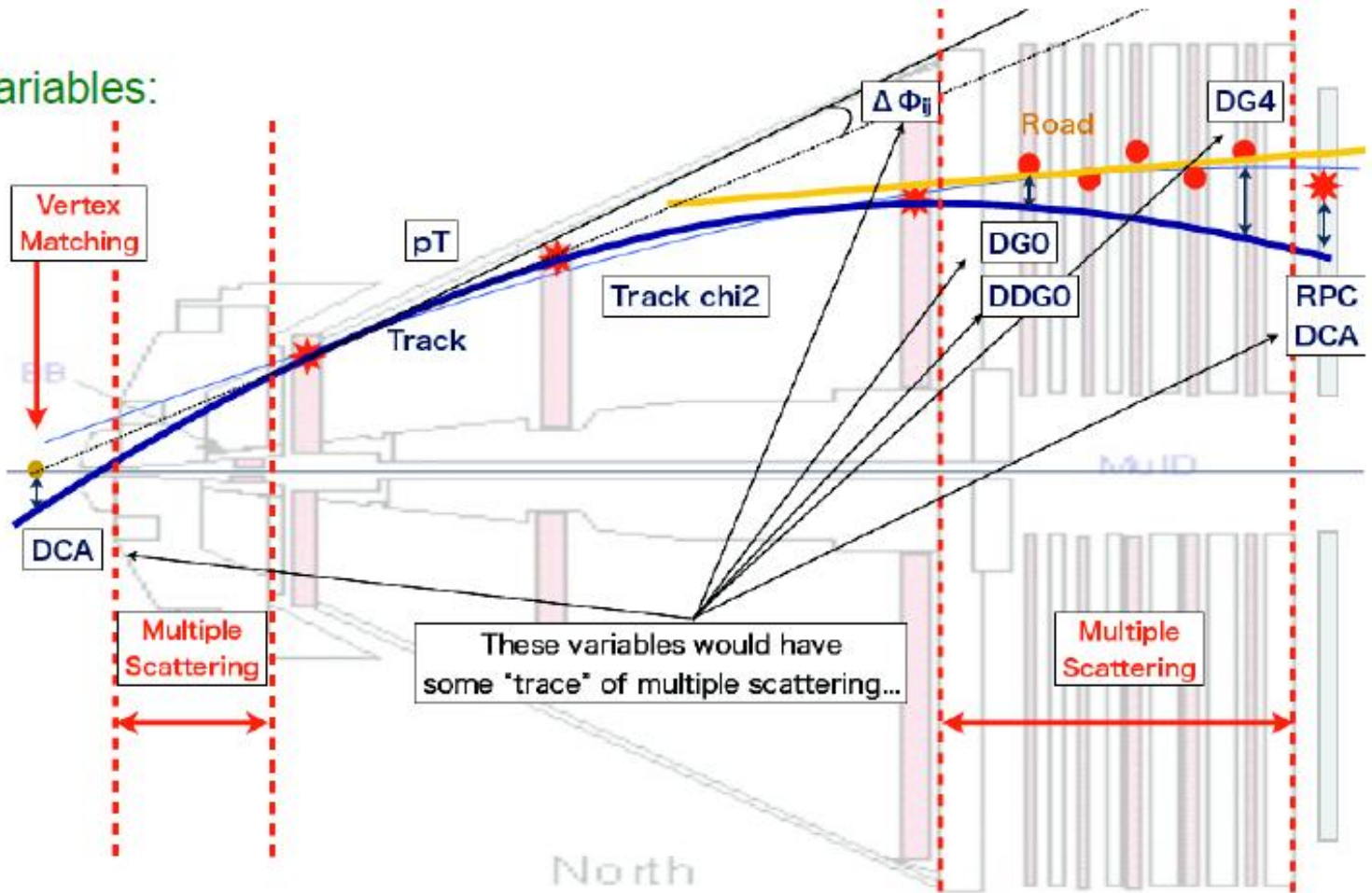




Table 2: Optimal selection criteria for the 99.5, 97, 95, and 90% percentile distributions evaluated for single muons at a reconstructed transverse momentum of 10 GeV/ $c$ . Positively and negatively charged muons are similar and therefore only positive charges are tabulated.

| Arm       | Charge   | Variable | 99.5%  | 97 %   | 95%    | 90 %   |
|-----------|----------|----------|--------|--------|--------|--------|
| North arm | pos chrg | dg0      | 6      | 4.8    | 4.4    | 4      |
| North arm | pos chrg | ddg0     | 1.1    | 0.9    | 0.8    | 0.7    |
| North arm | pos chrg | dg4      | 6      | 4.8    | 4.5    | 3.9    |
| North arm | pos chrg | chi      | 12.98  | 7.92   | 6.38   | 4.4    |
| North arm | pos chrg | dcar     | 3.85   | 2.75   | 2.2    | 1.65   |
| North arm | pos chrg | dcaz     | 12.6   | 6.6    | 5.4    | 4.2    |
| North arm | pos chrg | dphi12   | 0.018  | 0.012  | 0.0108 | 0.0084 |
| North arm | pos chrg | dphi23   | 0.0132 | 0.0108 | 0.0096 | 0.0096 |
| North arm | pos chrg | RpcDCA   | 11.5   | 9      | 8      | 7      |
| North arm | pos chrg | mult     | 4      | 3      | 2      | 1      |
| North arm | pos chrg | RpcTime  | 4      | 3      | 3      | 3      |
| South arm | pos chrg | dg0      | 6.8    | 5      | 4.6    | 4.2    |
| South arm | pos chrg | ddg0     | 1      | 0.8    | 0.8    | 0.7    |
| South arm | pos chrg | dg4      | 6.9    | 5.1    | 4.8    | 4.2    |
| South arm | pos chrg | chi      | 10.34  | 5.28   | 4.18   | 2.86   |
| South arm | pos chrg | dcar     | 3.85   | 2.75   | 2.2    | 1.65   |
| South arm | pos chrg | dcaz     | 9      | 6      | 4.8    | 4.2    |
| South arm | pos chrg | dphi12   | 0.0144 | 0.0096 | 0.0084 | 0.0072 |
| South arm | pos chrg | dphi23   | 0.0108 | 0.0084 | 0.0084 | 0.0072 |
| South arm | pos chrg | RpcDCA   | 14     | 9.5    | 8.5    | 7      |
| South arm | pos chrg | mult     | 4      | 3      | 2      | 1      |
| South arm | pos chrg | RpcTime  | 4      | 4      | 3      | 3      |

