



# Sea Quark Longitudinal Spin: $W$ measurements at PHENIX

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For the PHENIX collaboration

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- ▶ Proton Longitudinal Spin Structure
- ▶  $W$  Boson Probe for  $\Delta\bar{q}$
- ▶ Polarized  $pp$  at RHIC
- ▶ PHENIX  $A_L$  Measurements:
  - ▶  $W \rightarrow e^-$
  - ▶  $W \rightarrow \mu^\pm$

# Proton Spin

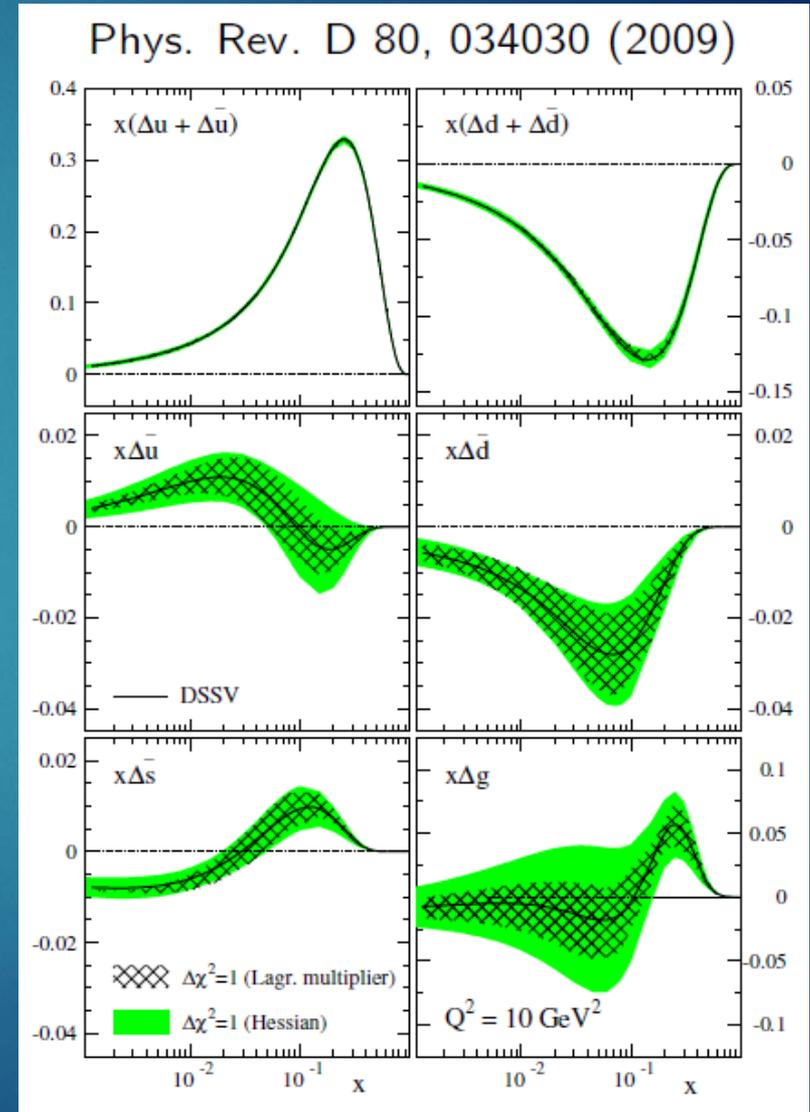
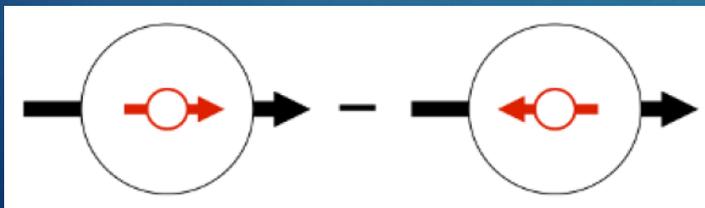
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## Spin Composition of the Proton:

- ▶  $S_p = \frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + L_q + L_g$ 
  - ▶  $\Delta\Sigma$  – Quark and anti quark spins
  - ▶  $\Delta G$  – Gluon spin
  - ▶  $L$  orbital angular momentum

## Current Understanding

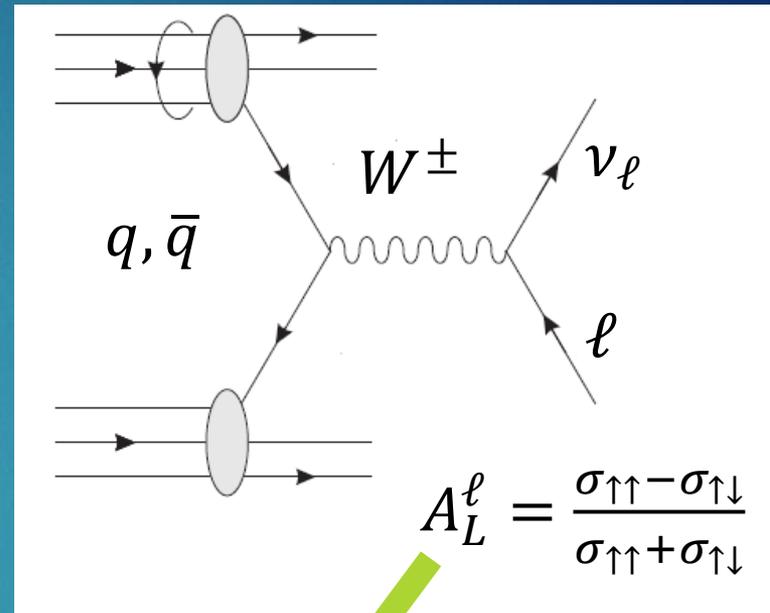
- ▶ DIS/SIDIS
  - ▶  $\Delta q + \Delta\bar{q}$
  - ▶ some  $q/\bar{q}$  flavor separation
- ▶ RHIC
  - ▶  $\Delta g$  and  $\Delta q, \Delta\bar{q}$  with separation



# Accessing Sea Quark Spin

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- ▶ Advantages over DIS/SIDIS
  - ▶ No fragmentation functions
  - ▶ High  $Q^2$
- ▶ Constraints:
  - ▶ Weak parity violation
    - ▶  $W$ 's couple to left handed  $q$  and right handed  $\bar{q}$
  - ▶ Known  $q$  spin distributions
    - ▶  $u$  spin tends to be aligned with proton spin,  $d$  anti-aligned



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

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

# Flavor Sensitivity at Forward Rapidity

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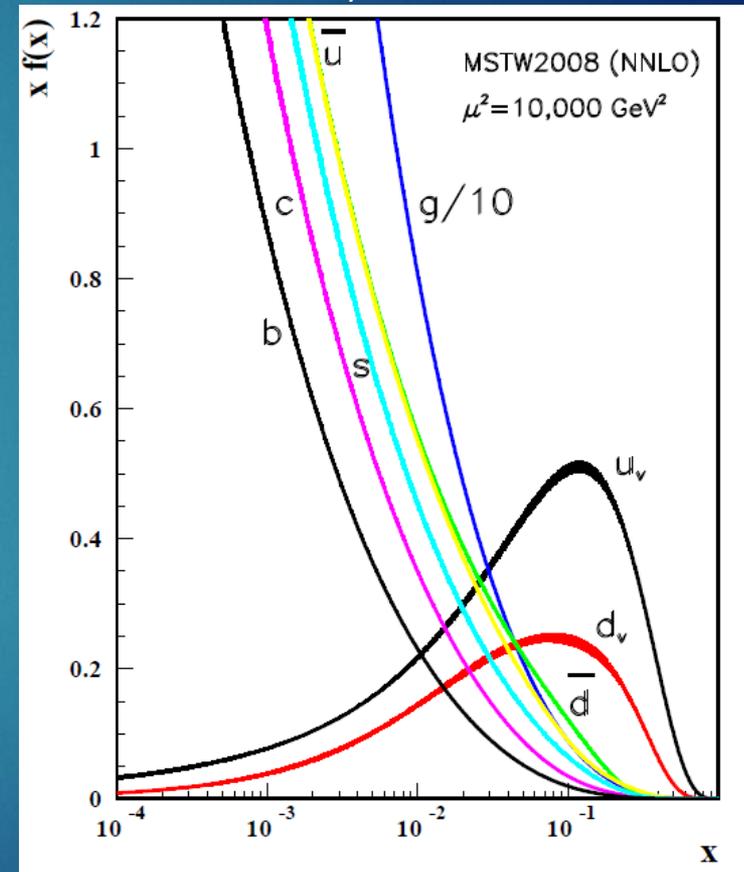
- ▶ A first order motivation:
  - ▶ At large rapidity  $x_1 \gg x_2$  or  $x_1 \ll x_2$
  - ▶  $A_L$  equations reduce:

$$A_L^{W^+} \approx \frac{\Delta \bar{d}(x_1)}{\bar{d}(x_1)} \text{ for } x_1 \gg x_2$$

$$A_L^{W^-} \approx \frac{\Delta \bar{u}(x_1)}{\bar{u}(x_1)} \text{ for } x_1 \gg x_2$$

- ▶ Actual observable:  $A_L^\ell$
- ▶ This and other higher order effects are accounted for in global fit

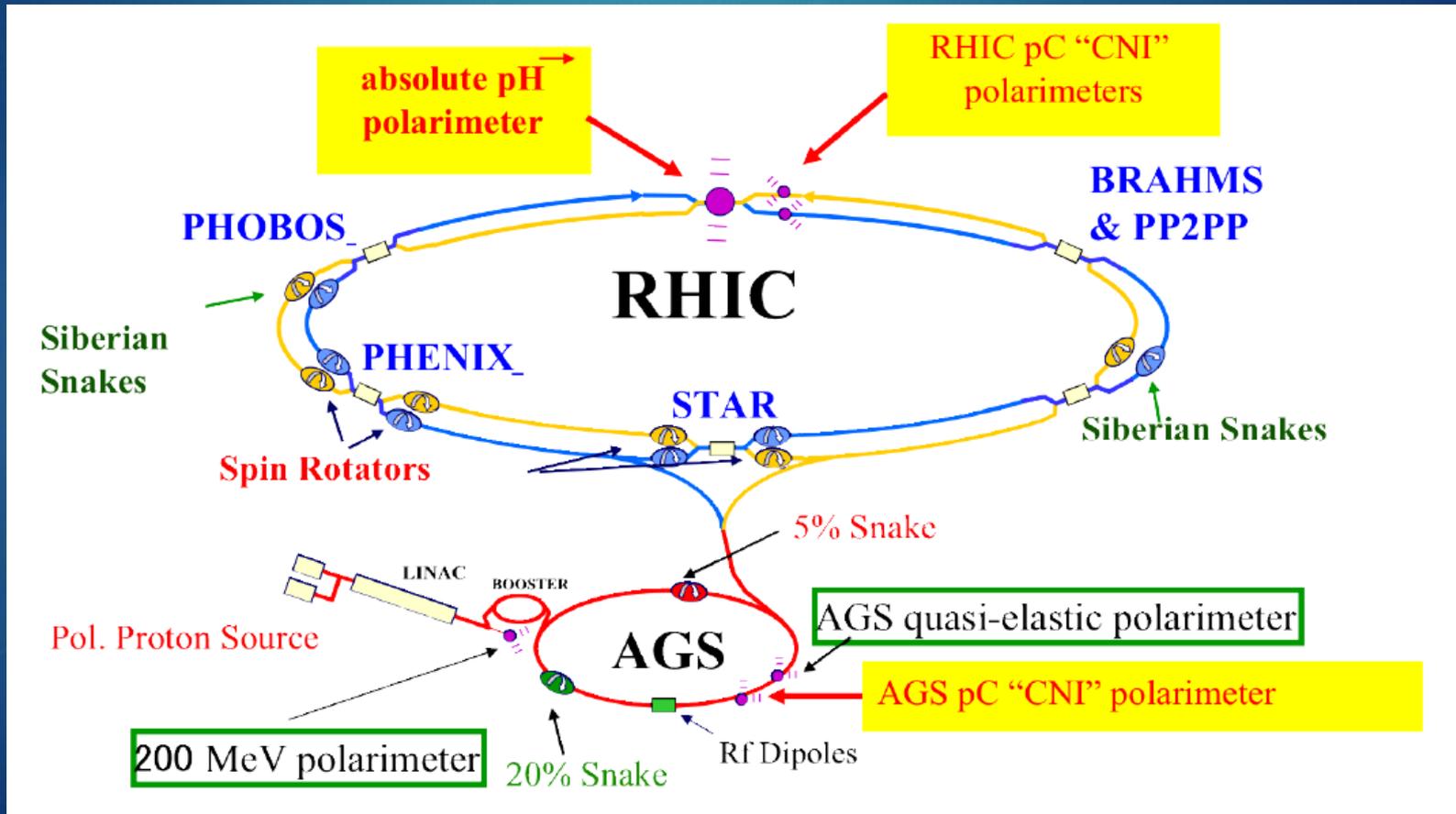
Proton Constituent Probability Distributions



# Spin at RHIC

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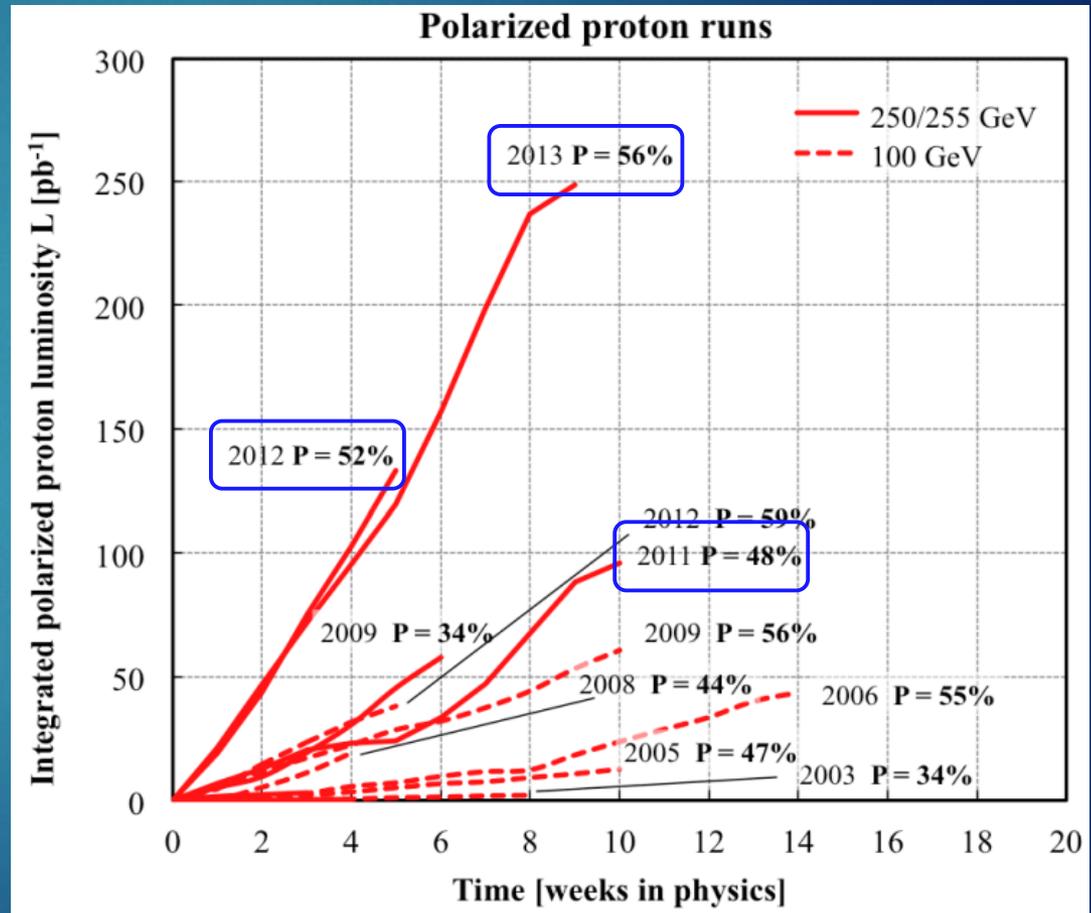
- ▶  $\sqrt{s} = 510 \text{ GeV}$  at up to 60% polarization
- ▶ “Siberian Snake” Spin Flippers



# Spin at RHIC

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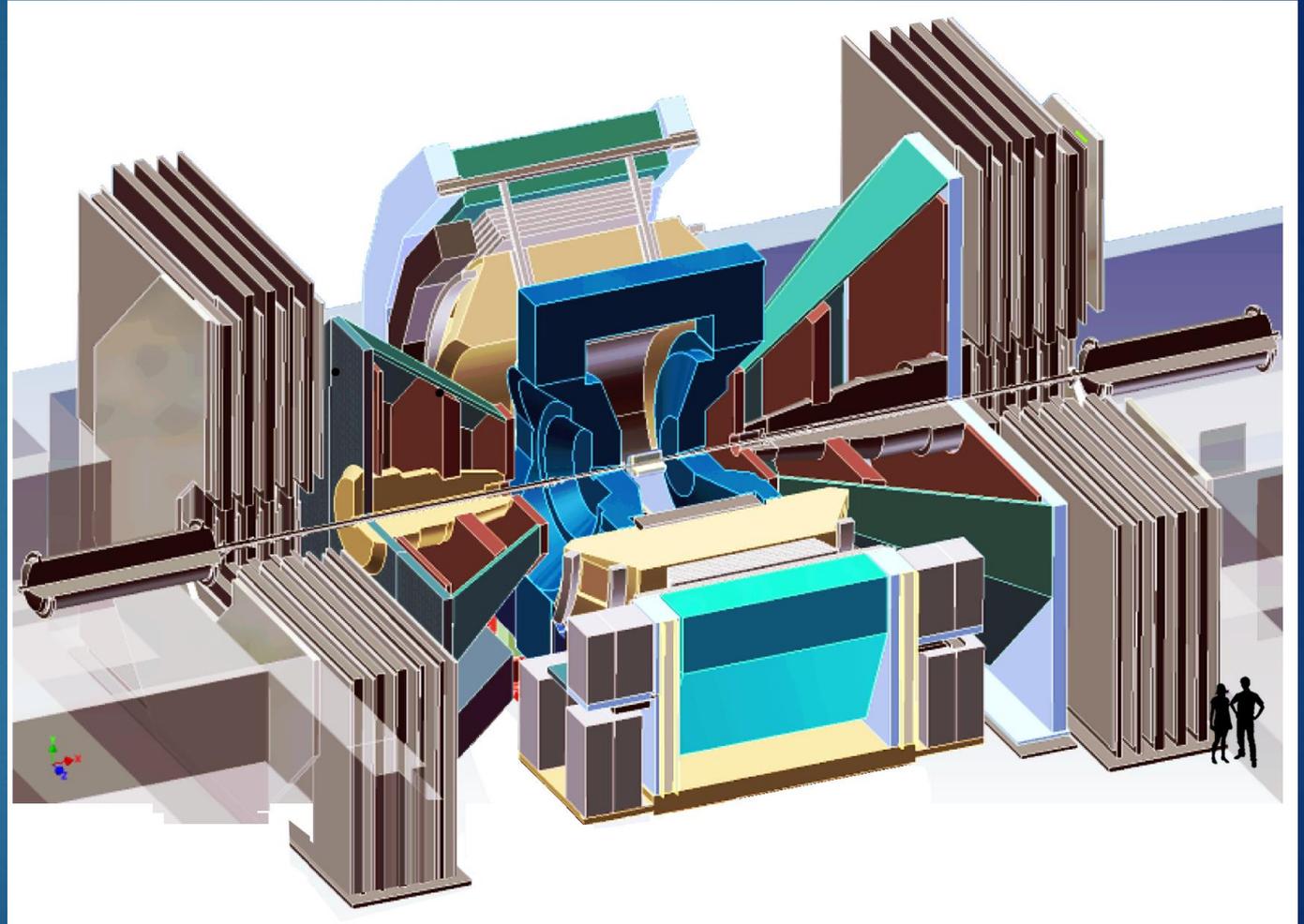
- ▶ Runs 2011-2013
  - ▶ 2013 offers highest luminosity
- ▶ High polarization is important for figure of merit
  - ▶  $A_L FOM \propto LP^2$



# PHENIX W Measurements

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- ▶ Central  
 $W \rightarrow e\nu_e$ 
  - ▶  $|\eta| < 0.35$
- ▶ Forward  
 $W \rightarrow \mu\nu_\mu$ 
  - ▶  $1.2 < |\eta| < 2.4$

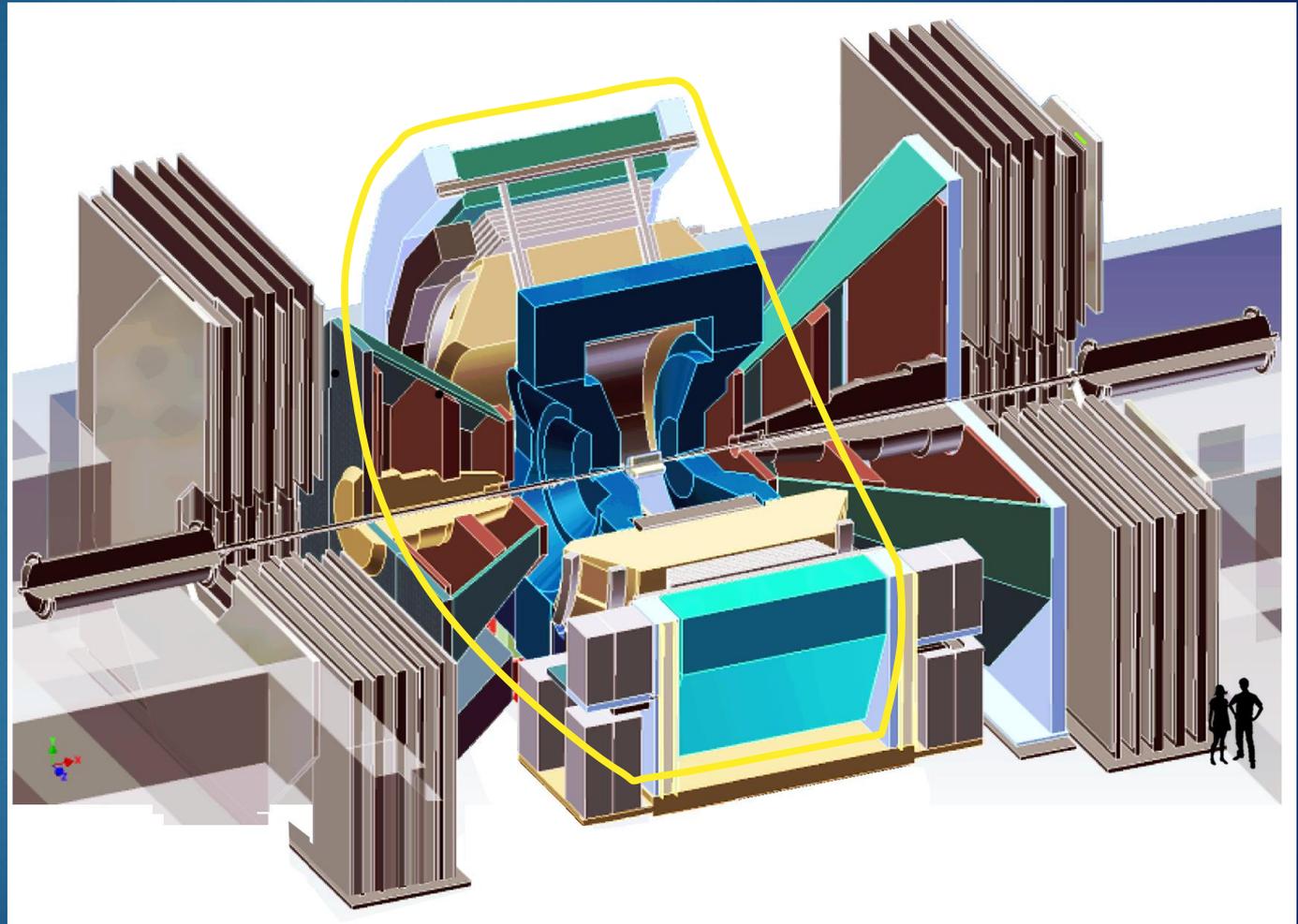


# PHENIX W Measurements

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Daniel Jumper - PHENIX W Physics  
5/23/2015

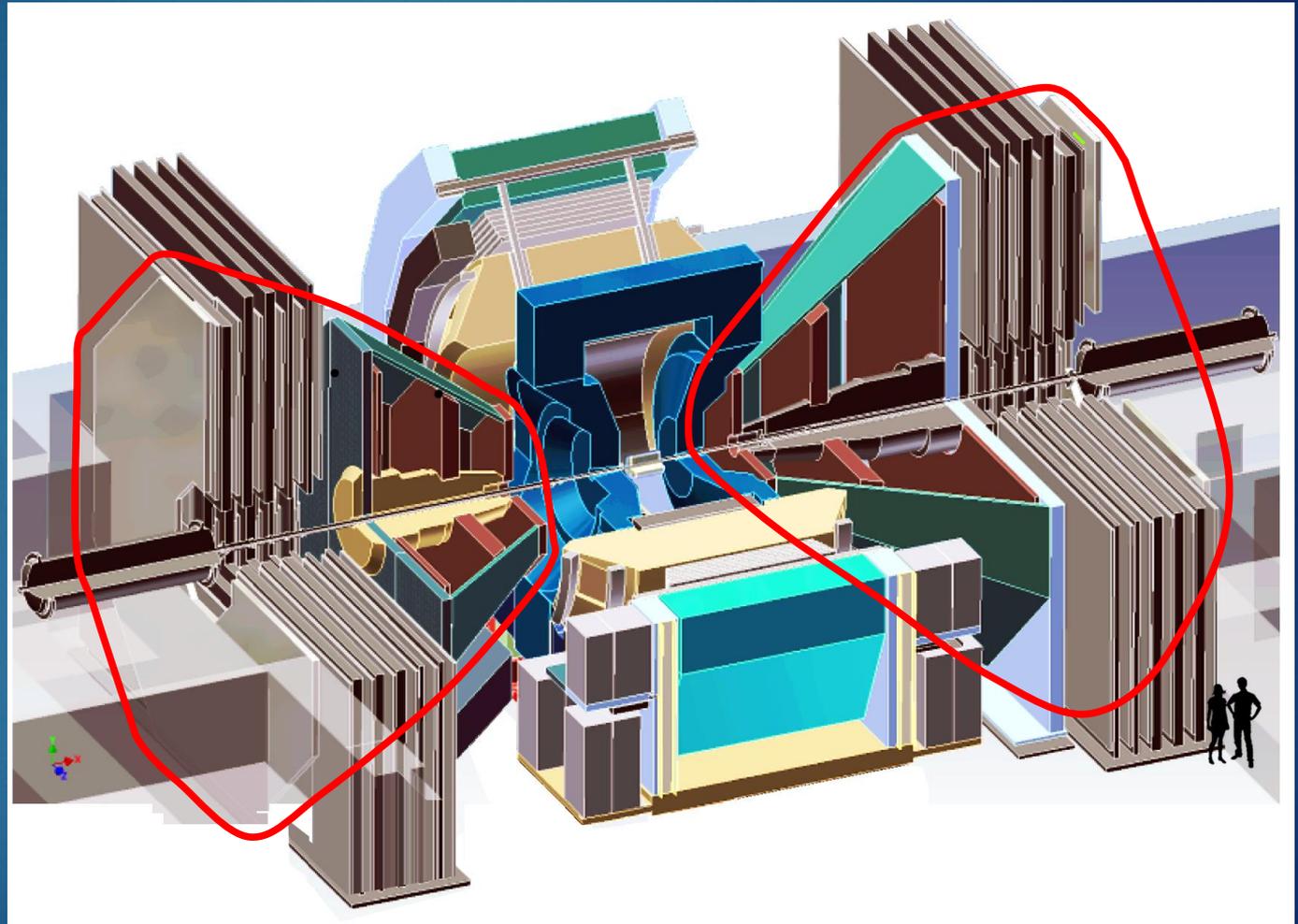
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# PHENIX W Measurements

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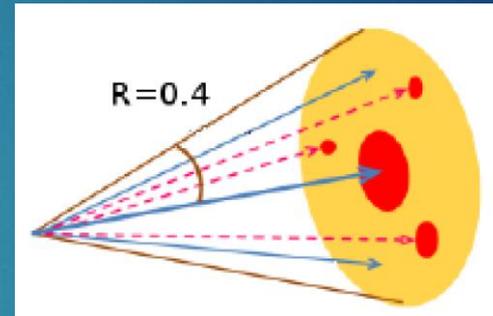


# Central $W \rightarrow e\nu_e$

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## Analysis Strategy:

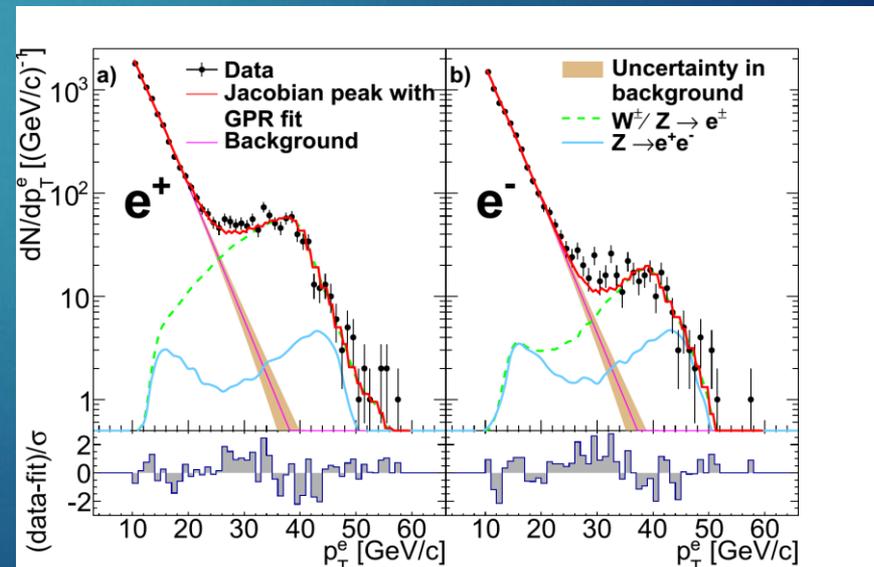
- ▶ Reduce Background with **Relative Isolation Cut**
  - ▶ Energy ratio between candidate and all hits in a cone
  - ▶ Factor of 10 reduction in Bkg



## ▶ Fit Jacobian Peak

- ▶ Extrapolate background with Gaussian Process Regression technique
- ▶ Fit signal + bkg model to data to extract signal yield

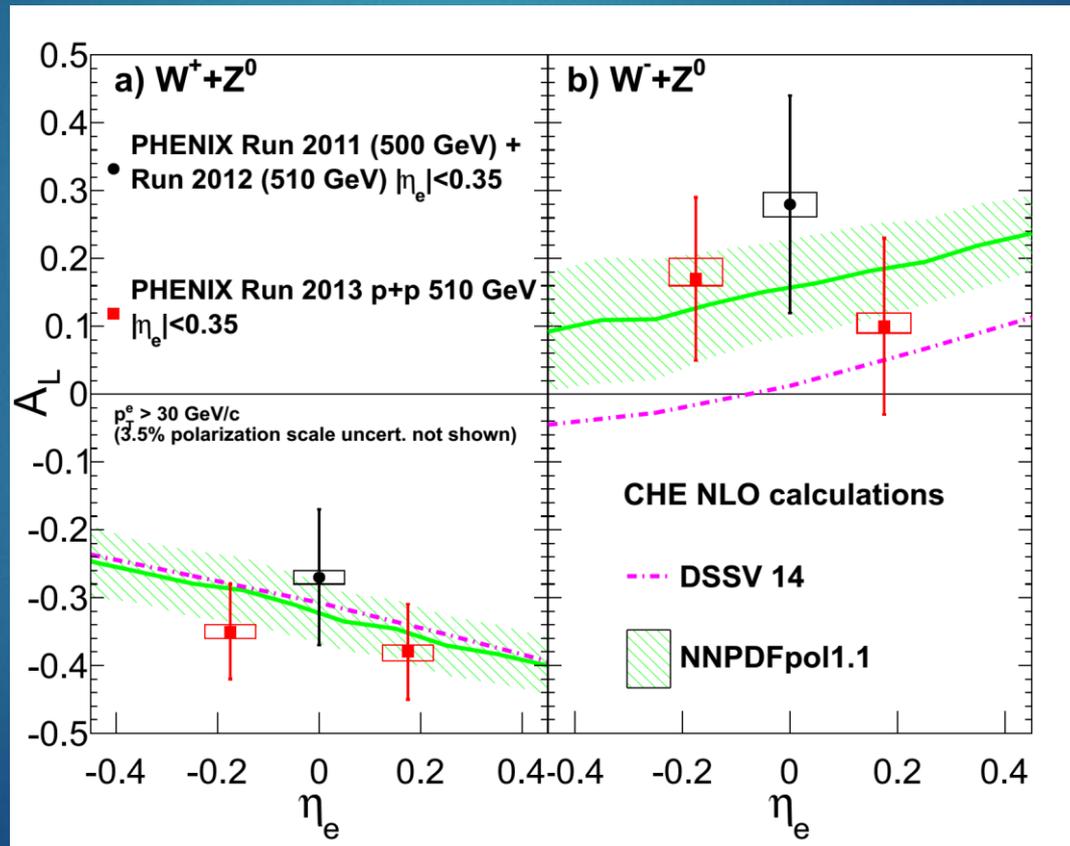
## ▶ Calculate Asymmetry $A_L$



# Central $W \rightarrow e\nu_e$

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- ▶ Run 13 final result just released!
- ▶ Now available on arXiv:
  - ▶ <http://arxiv.org/pdf/1504.07451v1.pdf>



Forward  $W \rightarrow \mu \nu_\mu$

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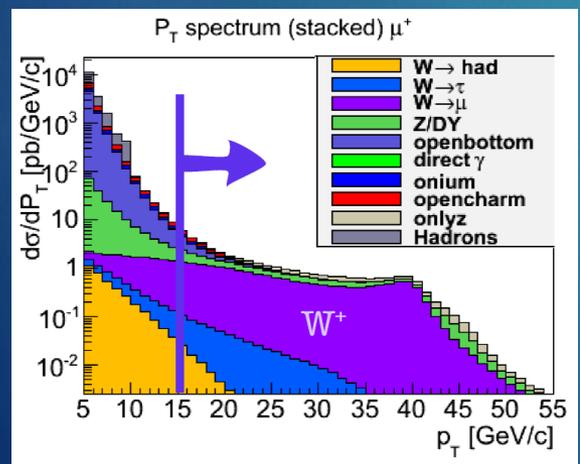
Challenge: Low signal with dominant background

# Forward $W \rightarrow \mu\nu_\mu$

Challenge: Low signal with dominant background

- Signal  $W \rightarrow \mu$  events dominated by other processes at low  $p_T$

Process cross sections vs  $p_T$  from simulations

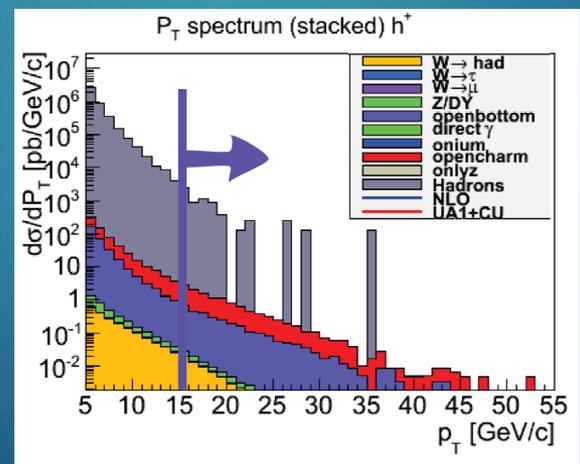
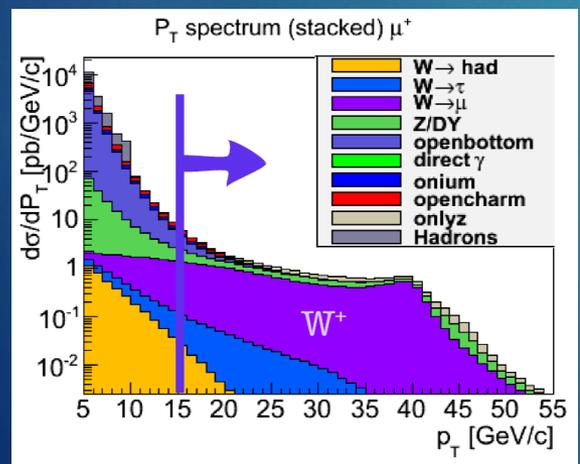


# Forward $W \rightarrow \mu \nu_\mu$

Challenge: Low signal with dominant background

- ▶ Signal  $W \rightarrow \mu$  events dominated by other processes at low  $p_T$
- ▶ Limited  $p_T$  resolution smears dominant low  $p_T$  background

Process cross sections vs  $p_T$  from simulations

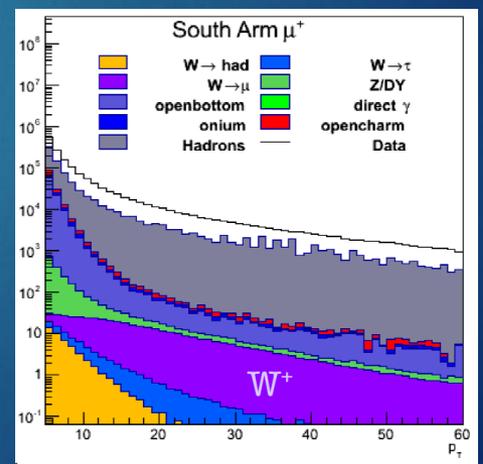
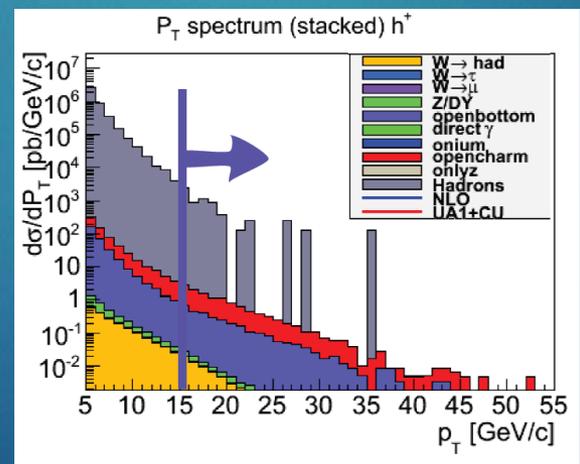
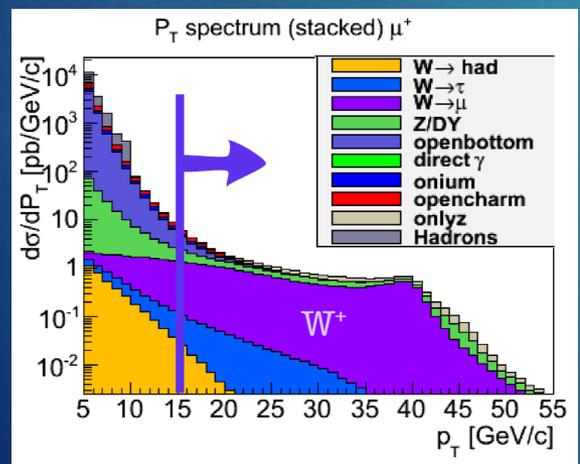


# Forward $W \rightarrow \mu \nu_\mu$

Challenge: Low signal with dominant background

- ▶ Signal  $W \rightarrow \mu$  events dominated by other processes at low  $p_T$
- ▶ Limited  $p_T$  resolution smears dominant low  $p_T$  background
- ▶ Additional “fake muons” result from multiple scattering hadrons

## Process cross sections vs $p_T$ from simulations

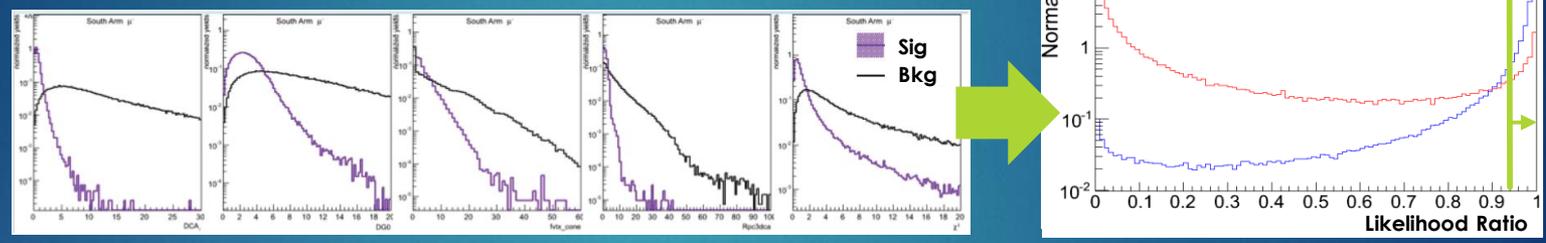


# Forward $W \rightarrow \mu\nu_\mu$

## Analysis Strategy:

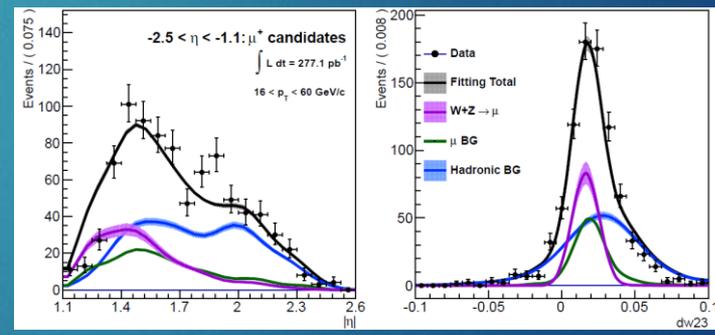
### ▶ Select High-Signal Data Subset

#### ▶ Multivariate Likelihood Ratio Calculation



### ▶ Characterize Remaining Data

- ▶ Signal to Background Ratio Fit
- ▶ Use simulations to estimate distributions for components



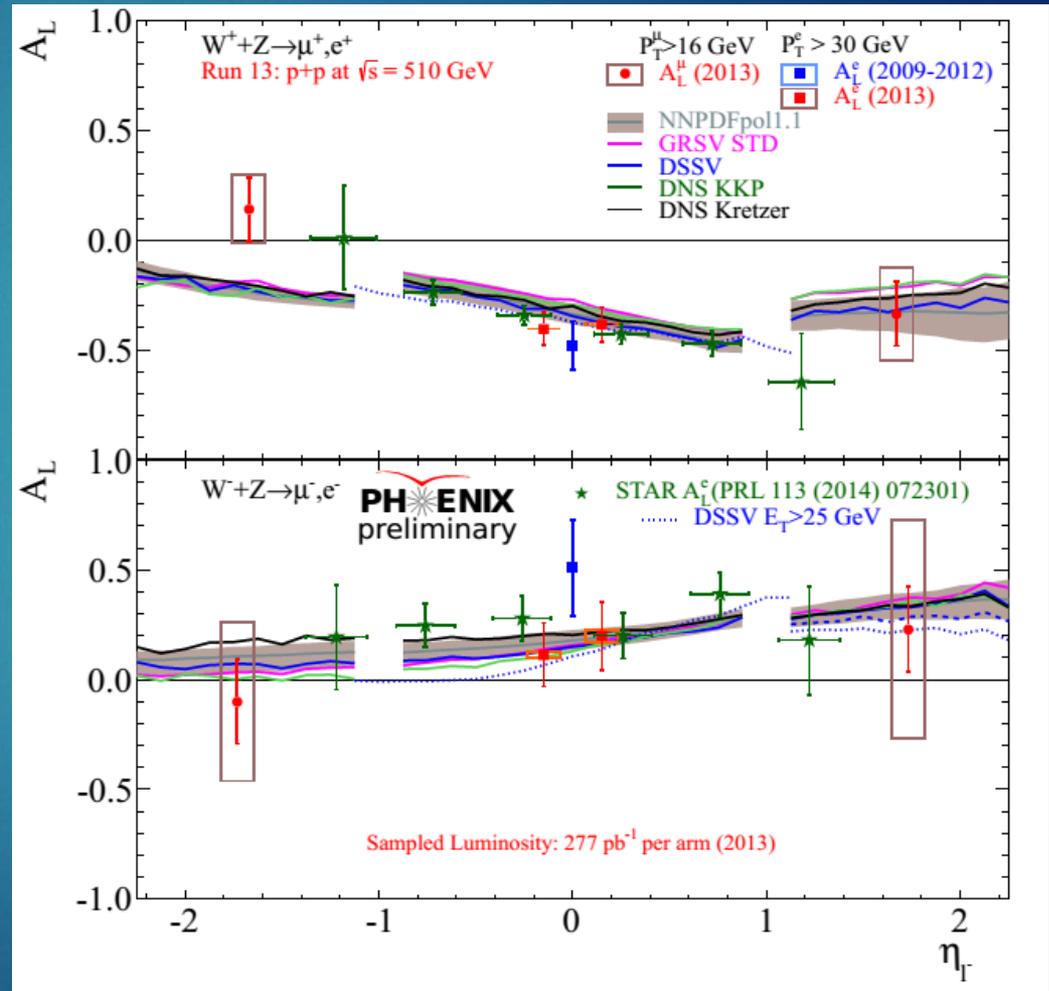
### ▶ Calculate & Correct Asymmetry

- ▶ Count yields for each helicity
- ▶ Apply correction factors (Sig/Bkg ratio, efficiencies, ...)

# Forward $W \rightarrow \mu\nu_\mu$

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- ▶ Preliminary Result
- ▶ Currently moving toward a finalized result and publication



# Summary

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- ▶ Proton spin structure remains poorly constrained
- ▶  $W$ 's as a weak probe, offer unique insight to  $\Delta\bar{u}$ ,  $\Delta\bar{d}$
- ▶ Forthcoming PHENIX results contribute to significantly improved constraints on these distributions
  - ▶ Central  $W \rightarrow e$  results just released
  - ▶ Forward  $W \rightarrow \mu$  preliminary result available

# Backup