# Measurements of parity violating spin asymmetries of the boson, $W^{\pm} \rightarrow e^{\pm}$, at mid-rapidity with the PHENIX Detector at RHIC


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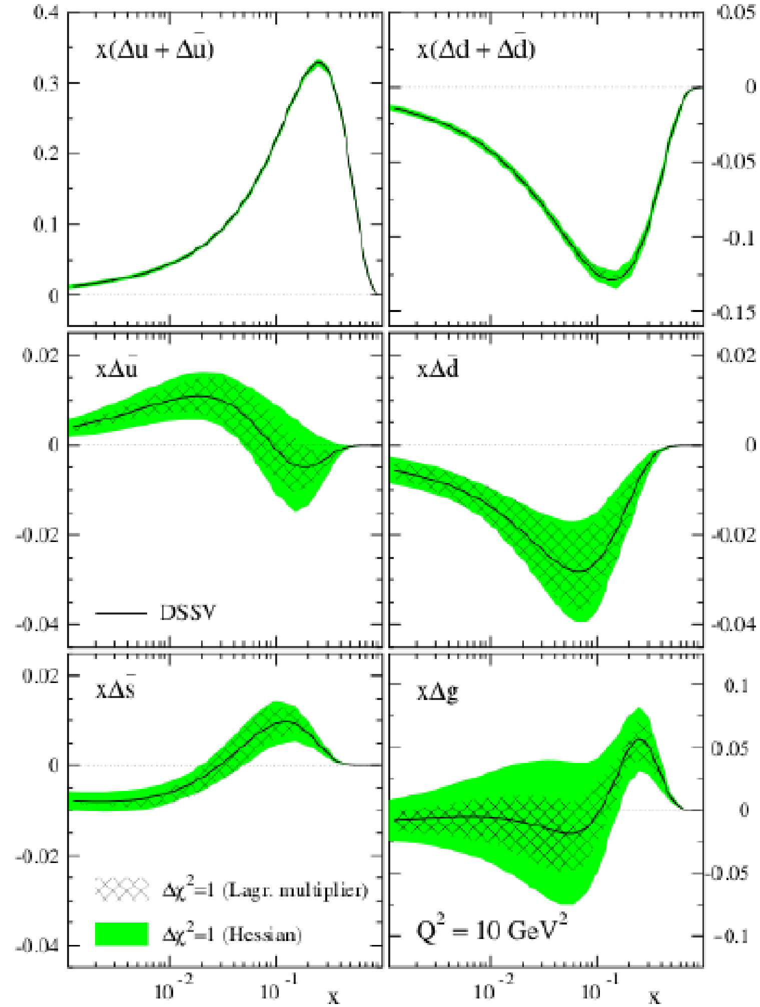
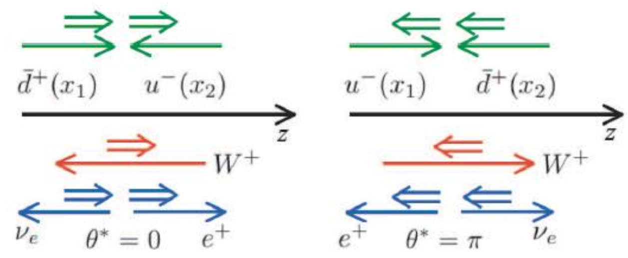
# Motivation

- (SI)DIS measurements have done an amazing job constraining quark polarized PDFS
- Significant uncertainties remain for anti-quark PDFs
- RHIC W program gives a clean measurement

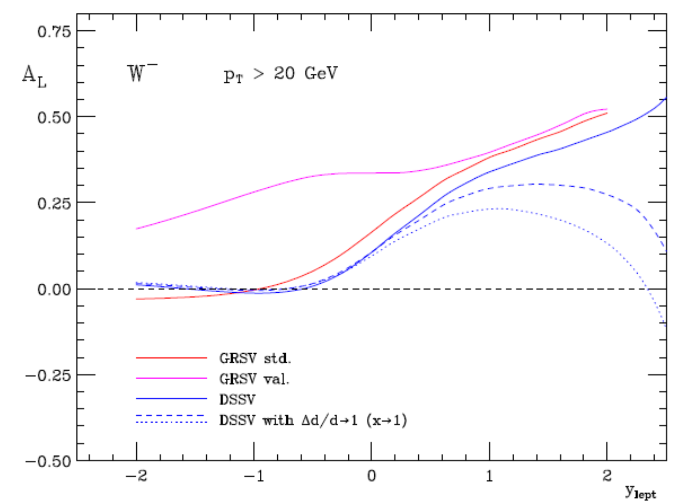


# Measurement

- Use parity violating coupling of Ws gives access to quark and antiquark polarized PDFs
- Measure the single spin asymmetry of decay leptons
- The theoretical predictions have a high degree of variation particularly at large lepton rapidities

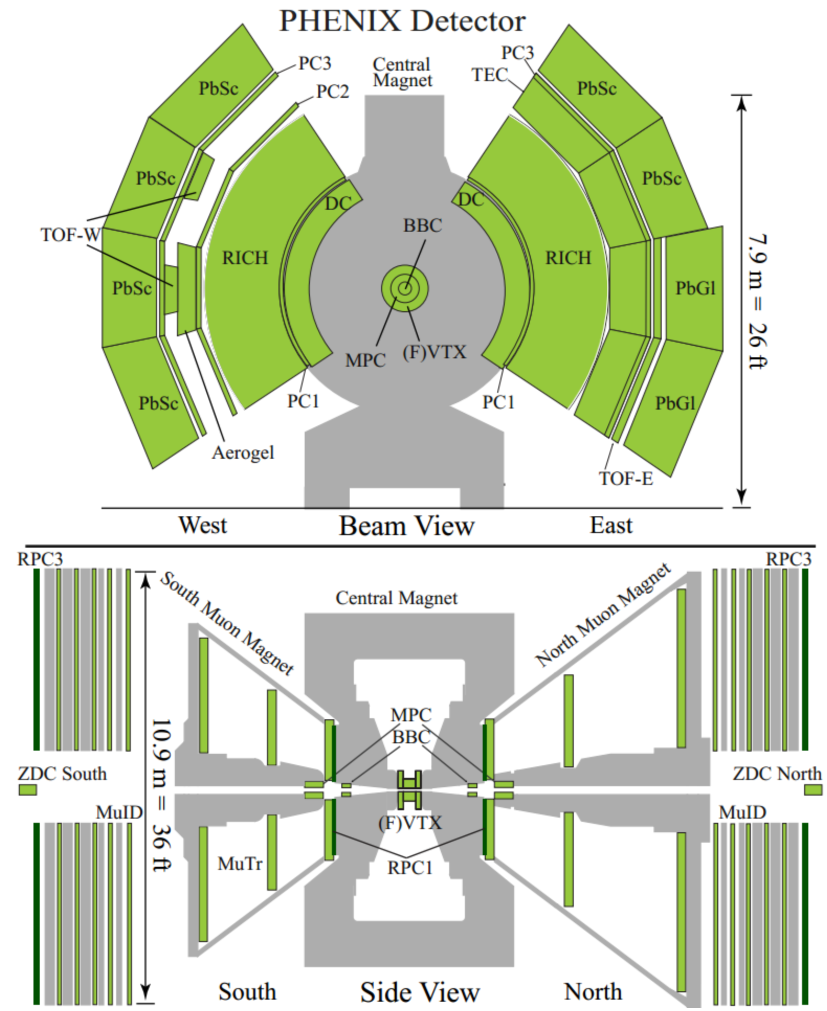



$$A_L^{W^+} = -\frac{\Delta u(x_1)\bar d(x_2) - \Delta \bar d(x_1) u(x_2)}{u(x_1)\bar d(x_2) + \bar d(x_1) u(x_2)}.$$



# PHENIX

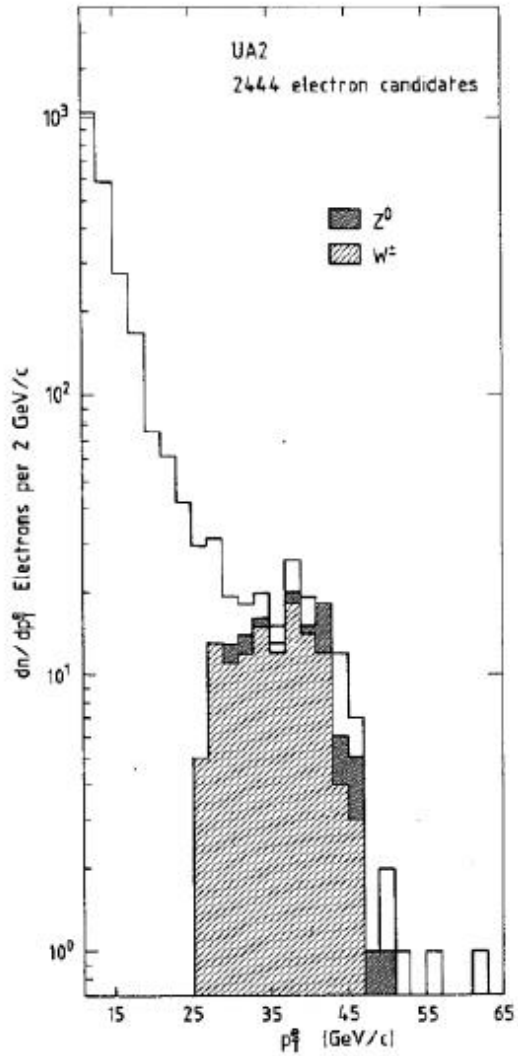
- Access through W→e decay in central arms and W→μ in forward arms
- Central arms:
  - $|\eta|<0.35$ and $\Delta\phi=\pi$
  - Electromagnetic Calorimeter (EMCal) $\Delta\phi \times \Delta\eta \approx 0.01 \times 0.01$
  - Drift and Pad Chambers tracking and charge separation



# Central Arm W->e

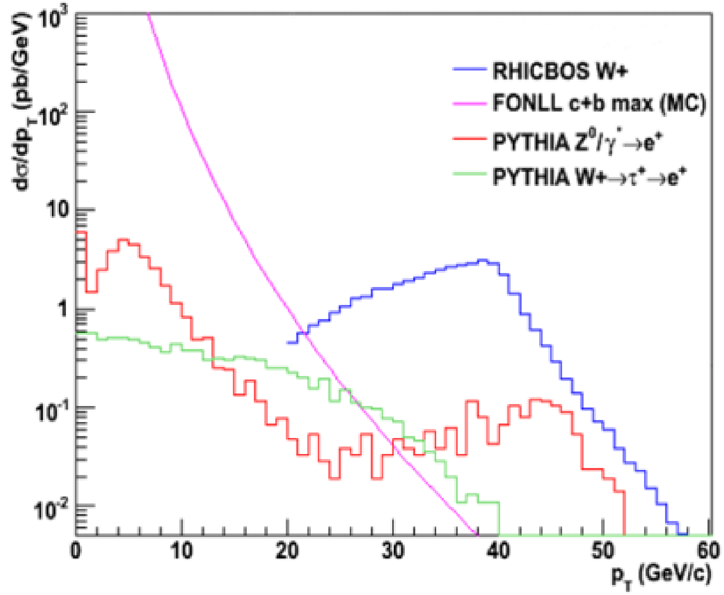
- Limited ϕ coverage can only determine decay electron
- Measure electron $p_T$ spectra
- Reduce background and estimate contribution between 30 and 50 GeV
- Use spin differentiated yields to measure asymmetry

$$A_L = \frac{1}{P}\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \qquad A_{L,f} = \frac{1}{\beta_\pm}A_{L,old}$$



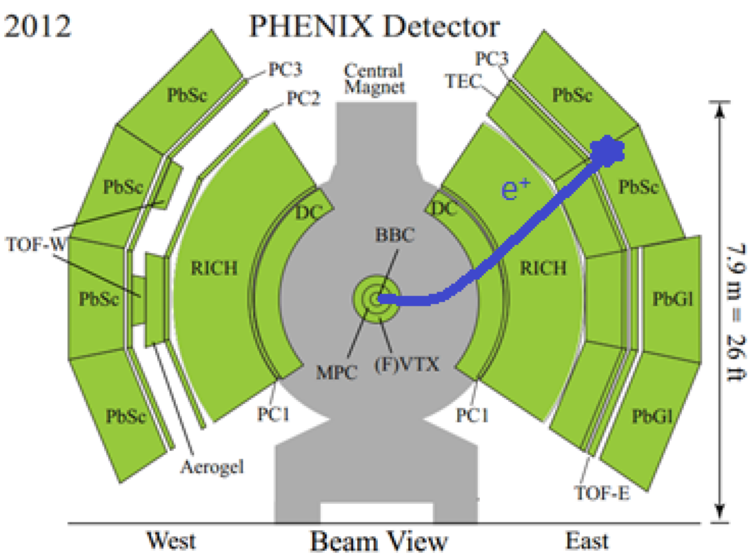
# Background

- Reducible Backgrounds:
  - Photons from neutral pion/eta decays followed by $e^{\pm}$ pair production
  - Cosmic rays
  - Beam related backgrounds
- Irreducible Backgrounds
  - Z decays
  - Charm, bottom decays
  - Other W decays



# Data

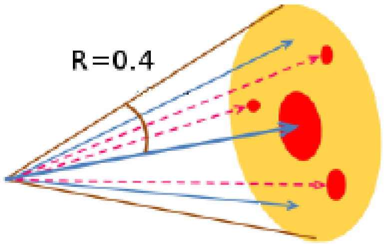
| | 2009 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| $\sqrt{s}$ (GeV/c) | 500 | 500 | 510 | 510 |
| $\int Ldt$ ($pb^{-1}$) | 8.6 | 16 | 23.7 | 114 |
| Pol. (%) | 39 | 48 | 55 | 55 |
| $P^2\int Ldt$ ($pb^{-1}$) | 1.3 | 3.7 | 7.2 | 33 |

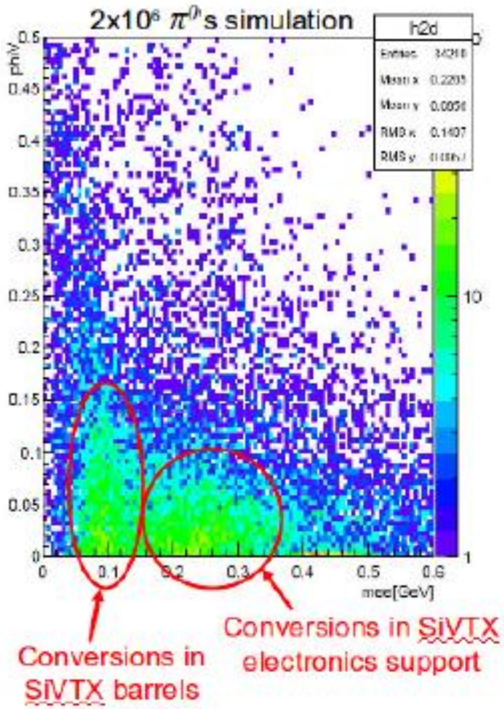



- High energy trigger with the EMCal
- Matching between EMCal and DC tracks
- Track disambiguation by removing candidates with high probability to produce false charge information

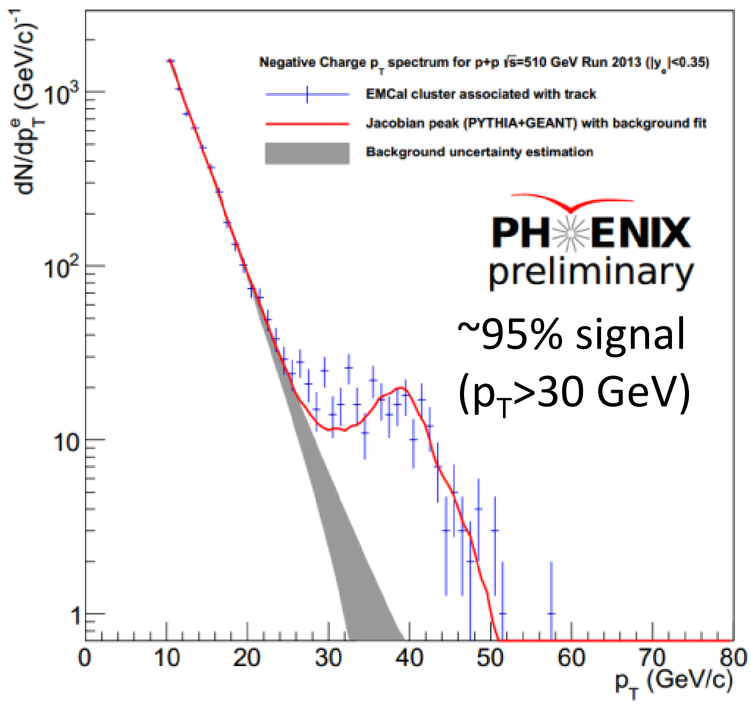
# Relative isolation cut

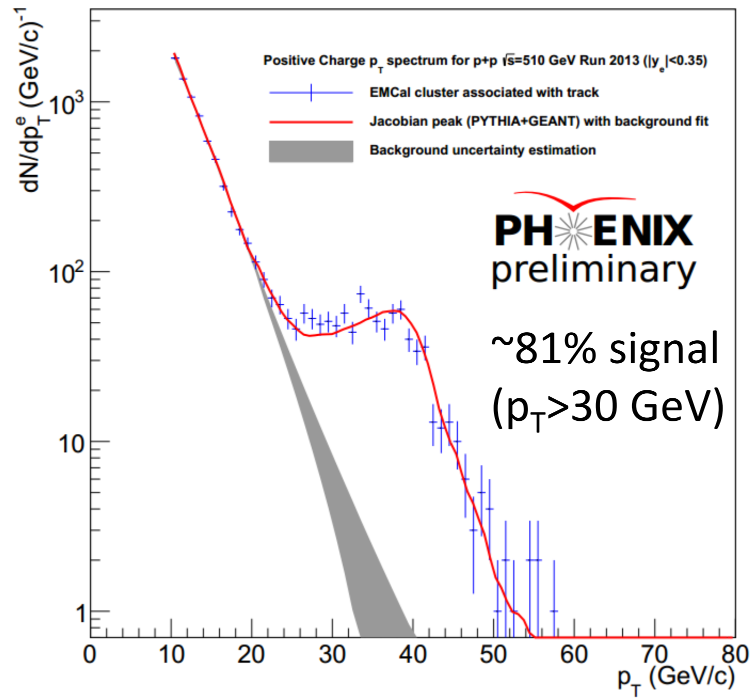
- Main background discriminator
- Energy in a cone of R=0.4 divided by energy of the candidate
- Removes most (>99%) of identified conversions
- Reduces background by a factor of 10 while leaving the signal region relatively untouched



# Spectra




- After applying all the cuts we are left with a clear signal
- Fitting with a simulated Jacobian peak and Gaussian Process Regression background shape

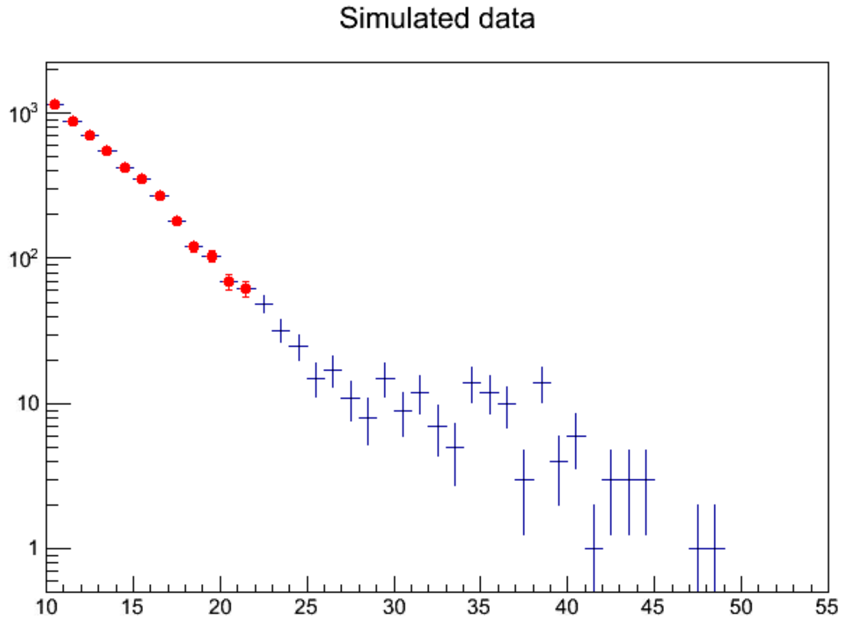
# Gaussian Process Regression

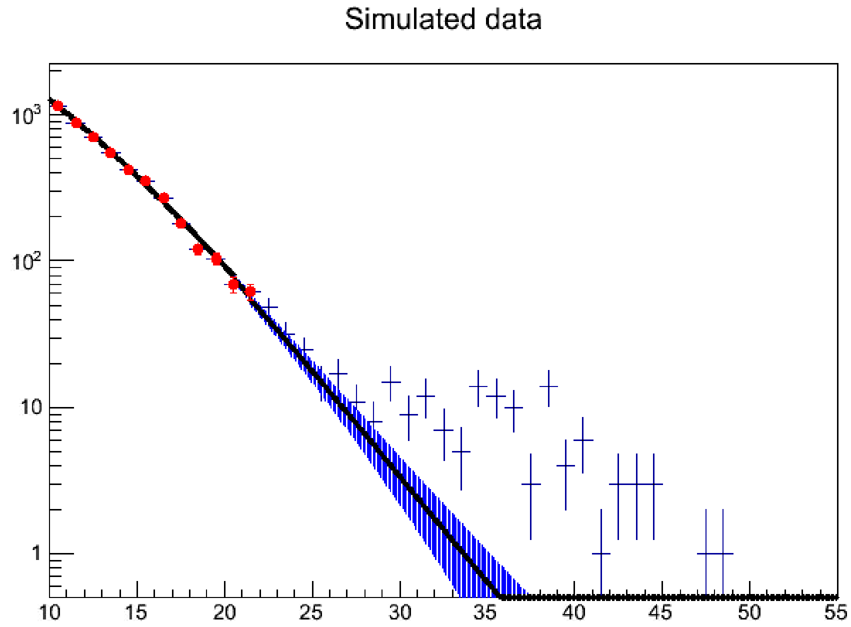
- Functional form is not known apriori
- Shift focus from prior knowledge over parameters to prior over functions

$$k(x,x') = \sigma_f^2 \exp\left[\frac{-(x-x')^2}{2l^2}\right] + \sigma_n^2 \delta(x,x')$$

- Correlation function encodes how much each data point influences the neighboring points
- Hyperparameters are determined through minimization over data

# Gaussian Process Regression

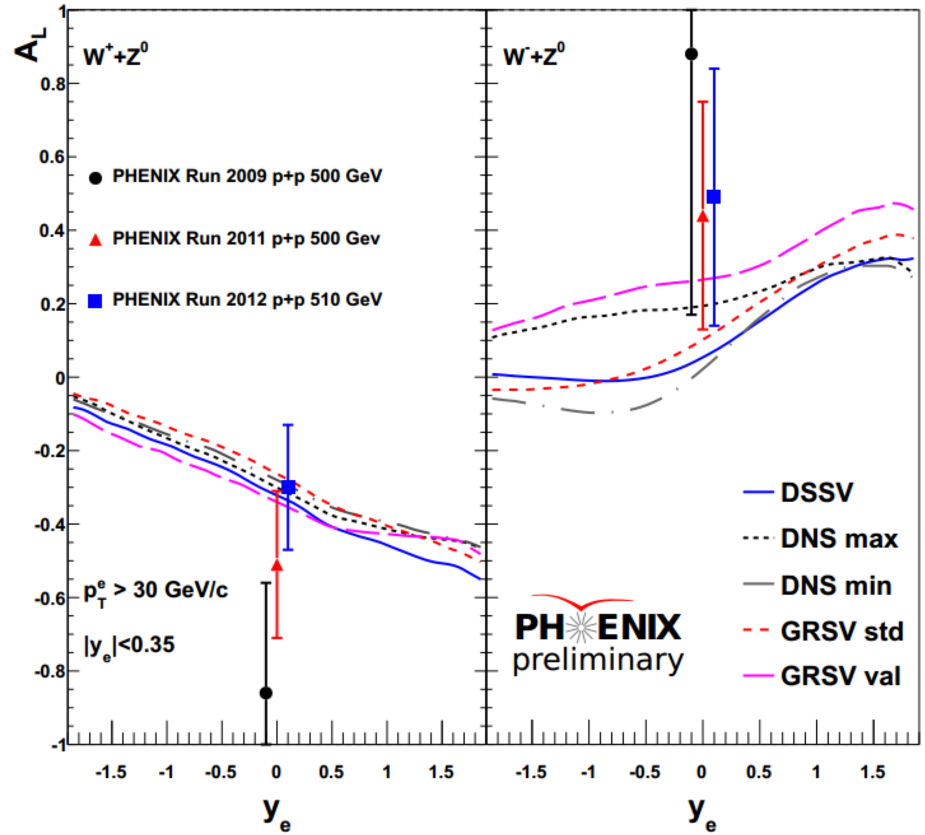



- Use background control region to get a shape
- The GPR will give a background contribution and uncertainty
- A cross check of the method has been performed with a classic functional form showing good agreement

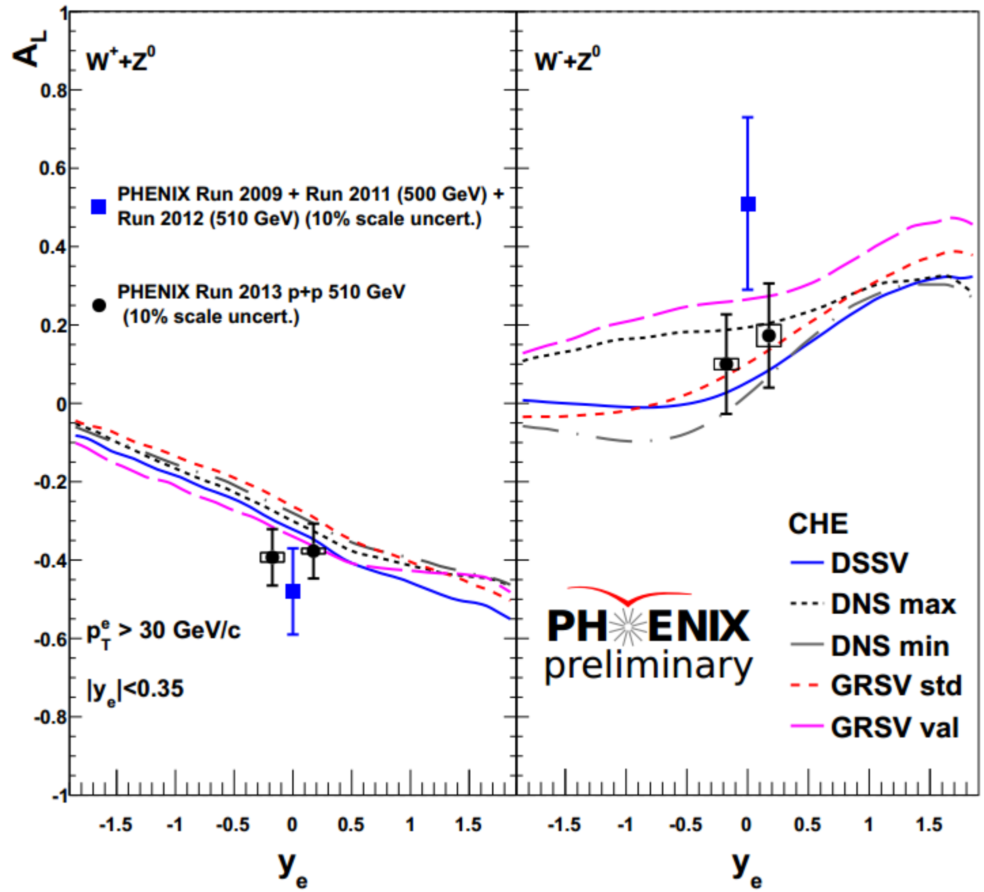
# Asymmetries '09/'11/'12

- Asymmetry values more consistent with theoretical predictions after 2009 data
- $W^-$ asymmetry seems to indicate a larger than predicted asymmetry



# Asymmetries all data

- Run 13 results were separated into two eta bins
- Run 09/11/12 data all combined into one single measurement
- Overall consistency with the theoretical predictions

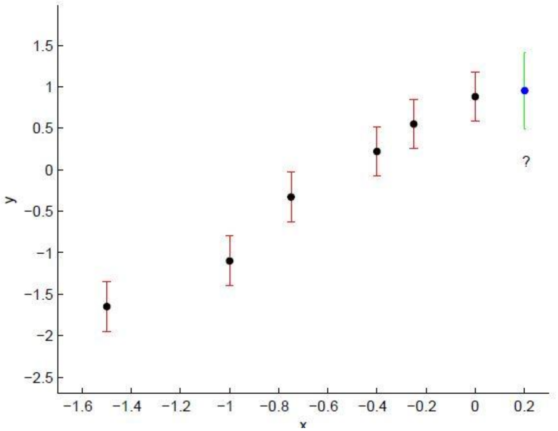


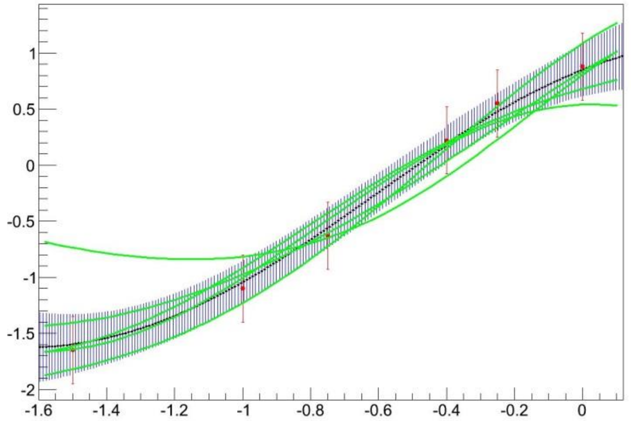
# Summary

- All of the data PHENIX has collected for the W→e measurement has been analyzed
- Using a Gaussian Process for Regression method the background has been estimated
- Asymmetries show good agreement with theoretical predictions
- Analysis nearing completion with publication on the horizon

# Backup

# Intro to GPR

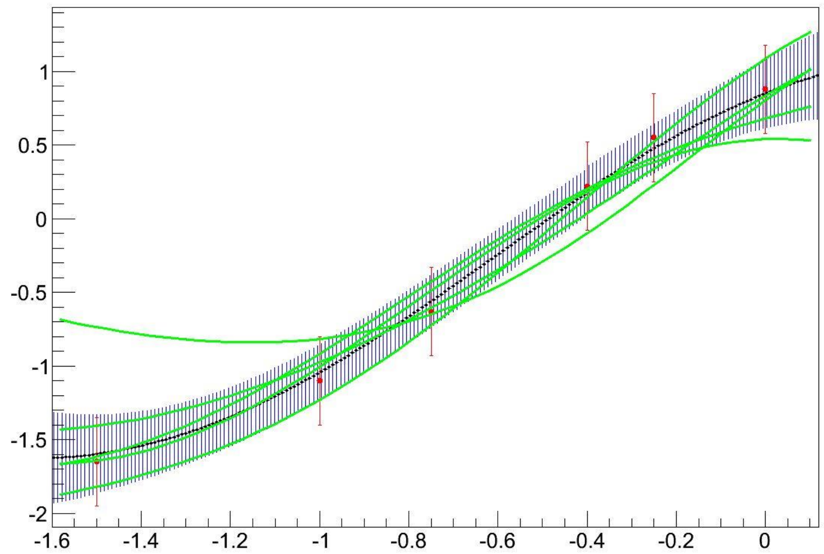


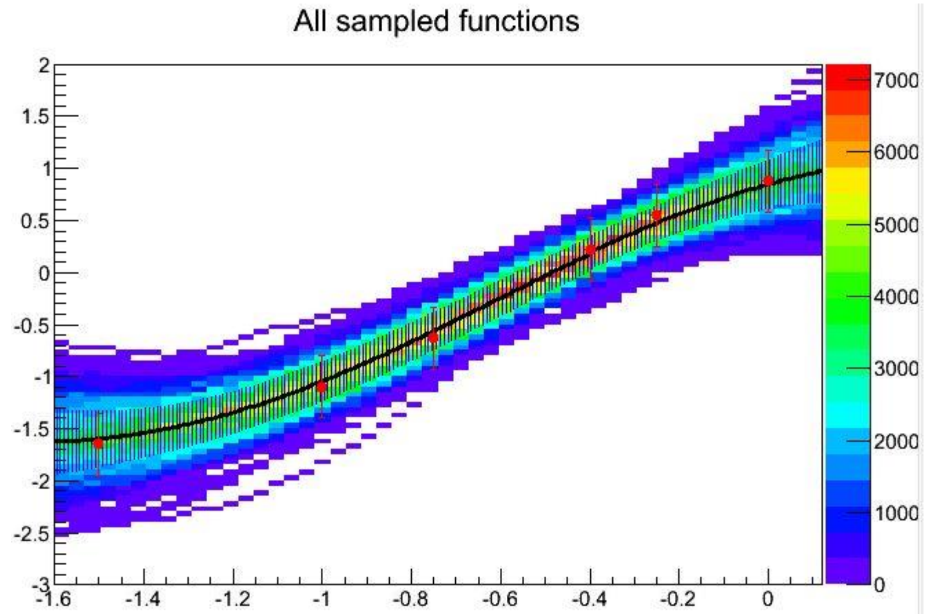




***Normal regression****: prior knowledge about parameters*
***GP Regression****: prior knowledge about functions*

- Through the use of a covariance function determined from the data the GPR can make predictions for data sufficiently close to the input set (see figure 1)
- It basically samples over a whole class of functional forms and returns predictions that are consistent with the data (see figure 2)
  - The class is determined by the covariance function

# Function Extraction




- Sampling over these functions and filling a 2D histogram (as on the right) will give a Gaussian distribution for each prediction point
- The mean of the Gaussian distribution is the prediction and the sigma is the uncertainty
- *The GPR we use does this mathematically through the equations I presented in the PWG and in the Group meeting but basically this is the only way I can think of to present this information in a couple of slides*