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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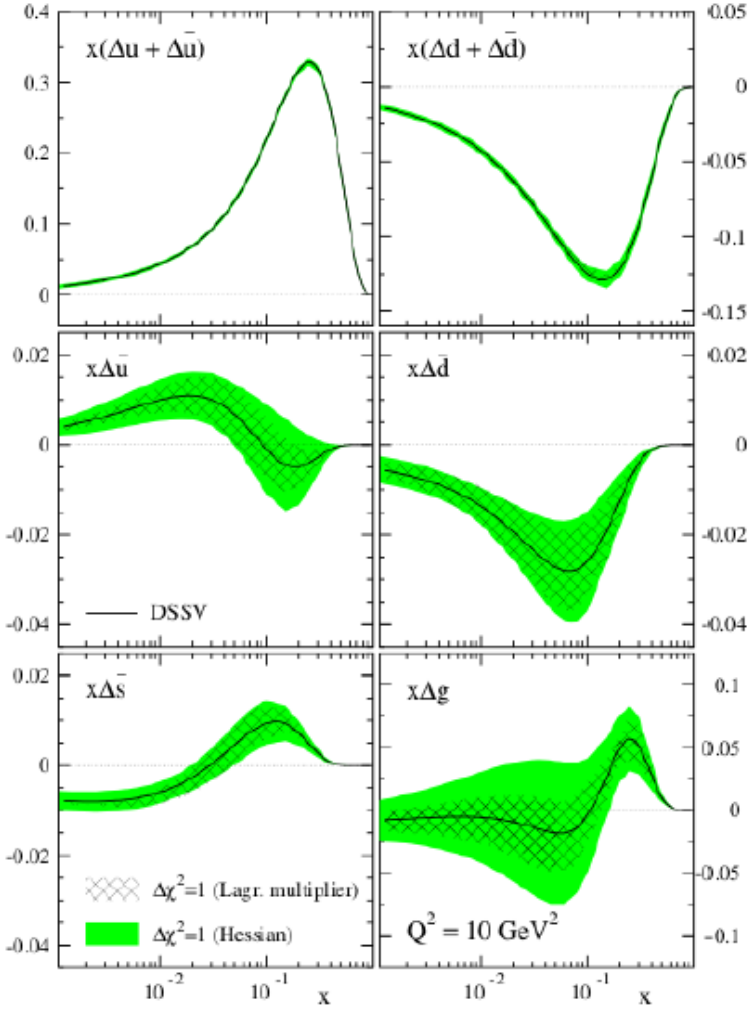
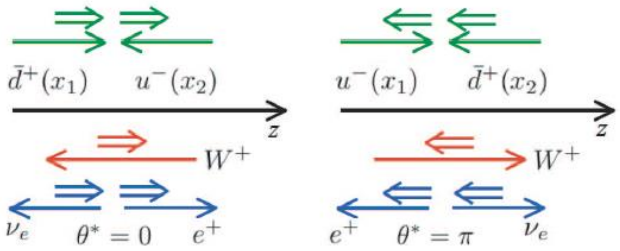
Motivation

- (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

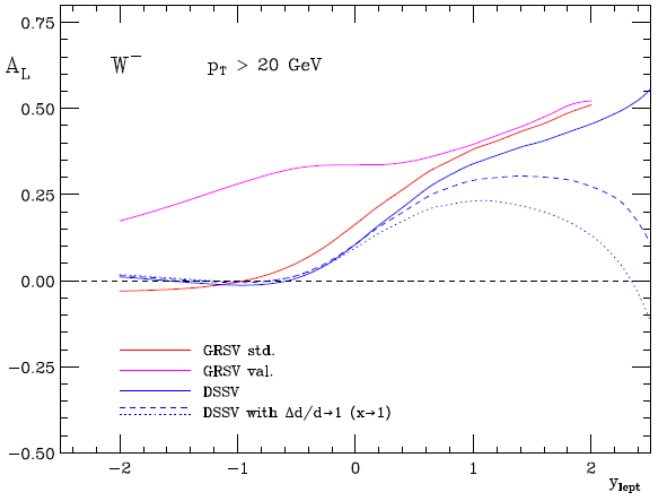


Measurement

- 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

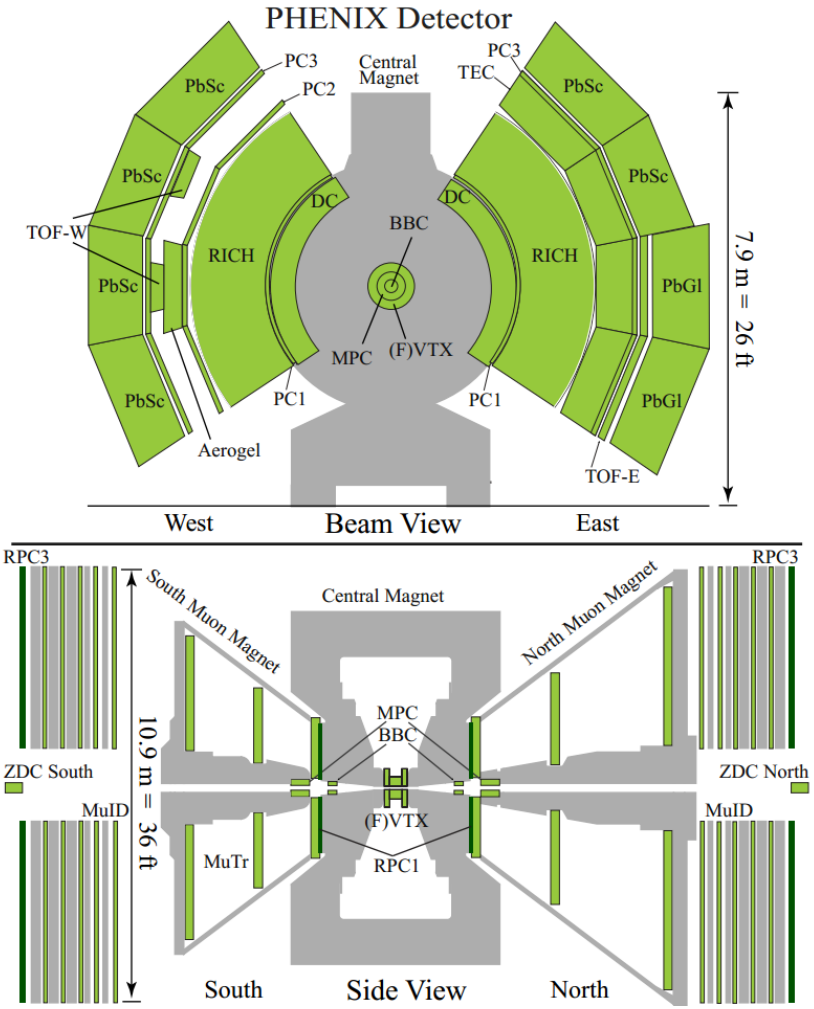


$$A_L^{W^+} = -\frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}.$$



PHENIX

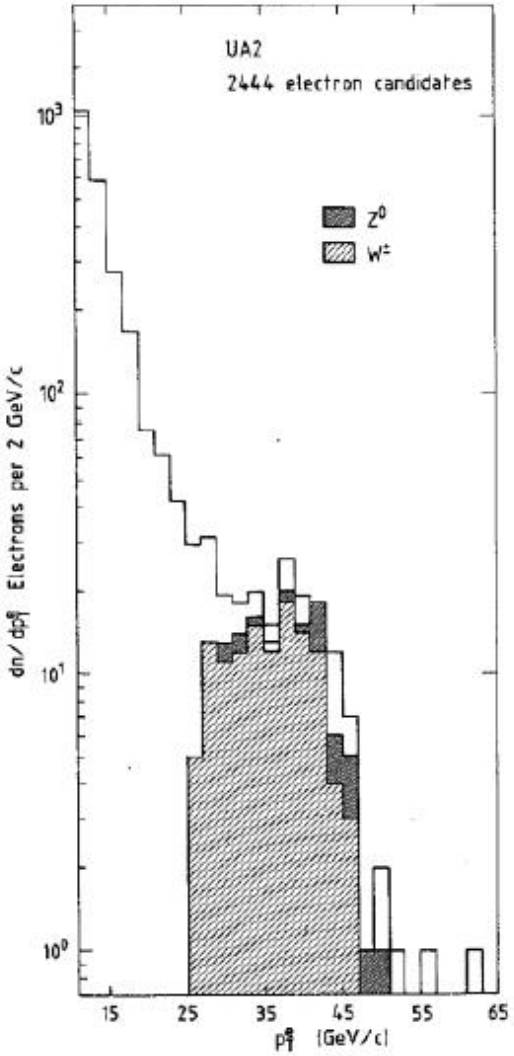
- Access through W→e decay in central arms and W→μ in forward arms
- Central arms:
  - $|\eta|<0.35$ and $\Delta\phi=\pi$
  - Electromagnetic Calorimeter (EMCal) $\Delta\phi x\Delta\eta \approx 0.01 \times 0.01$
  - Drift and Pad Chambers tracking and charge separation



Central Arm W→e

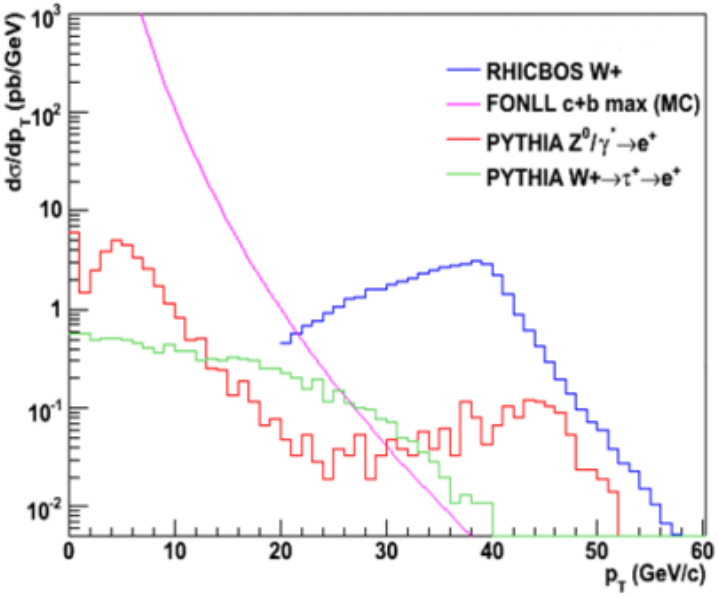
- Limited ϕ coverage can only determine decay electron
- Measure electron p_T spectra
- Reduce background and estimate contribution between 30 and 50 GeV
- Use spin differentiated yields to measure asymmetry

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



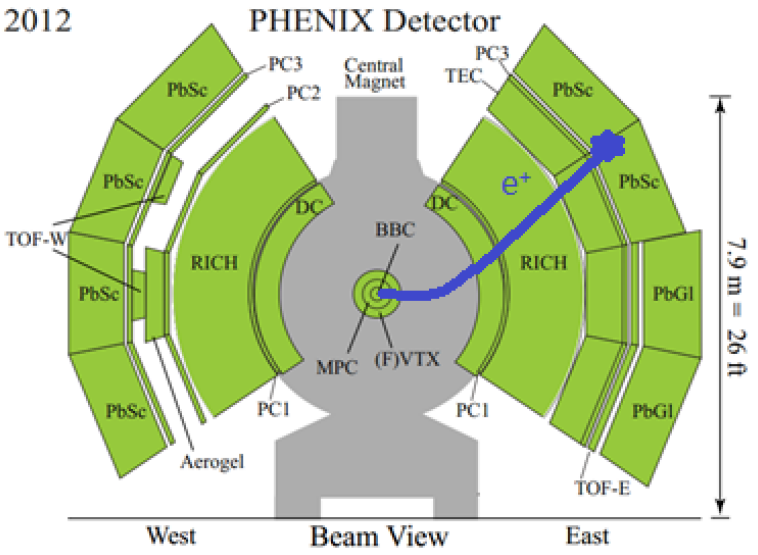
Background

- 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

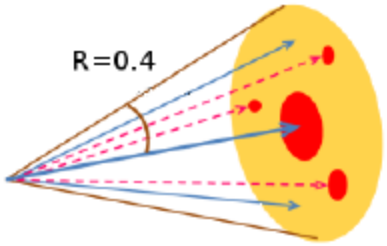
	2009	2011	2012	2013
√s (GeV/c)	500	500	510	510
∫Ldt (pb^{-1})	8.6	16	23.7	114
Pol. (%)	39	48	55	55
P^2∫Ldt (pb^{-1})	1.3	3.7	7.2	33

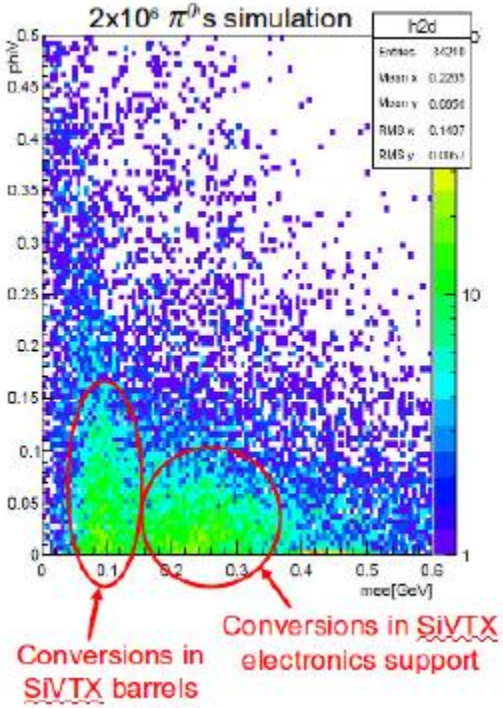


- High energy trigger with the EMCal
- Matching between EMCal and DC tracks
- Track disambiguation by removing candidates with high probability to produce false charge information

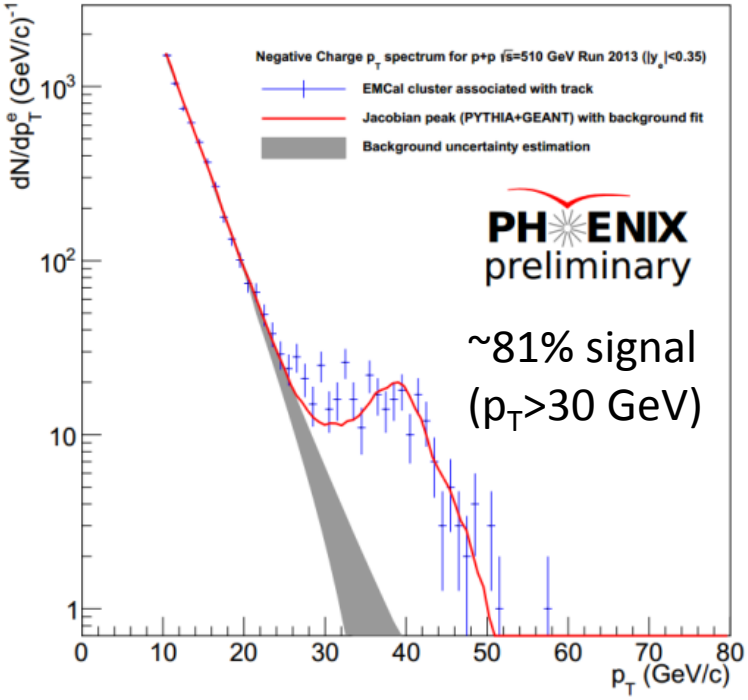
Relative isolation cut

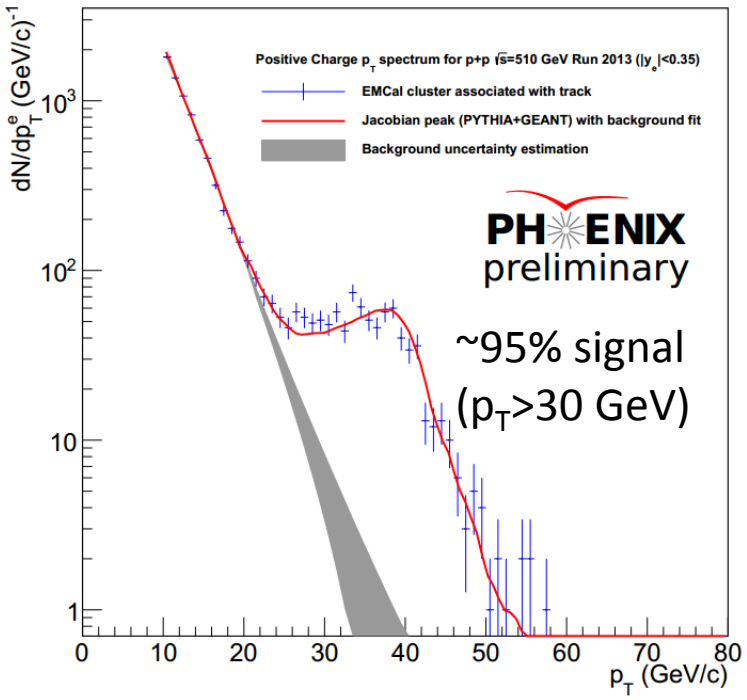
- Main background discriminator
- Energy in a cone of R=0.4 divided by energy of the candidate
- Removes most (>99%) of identified conversions
- Reduces background by a factor of 10 while leaving the signal region relatively untouched





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

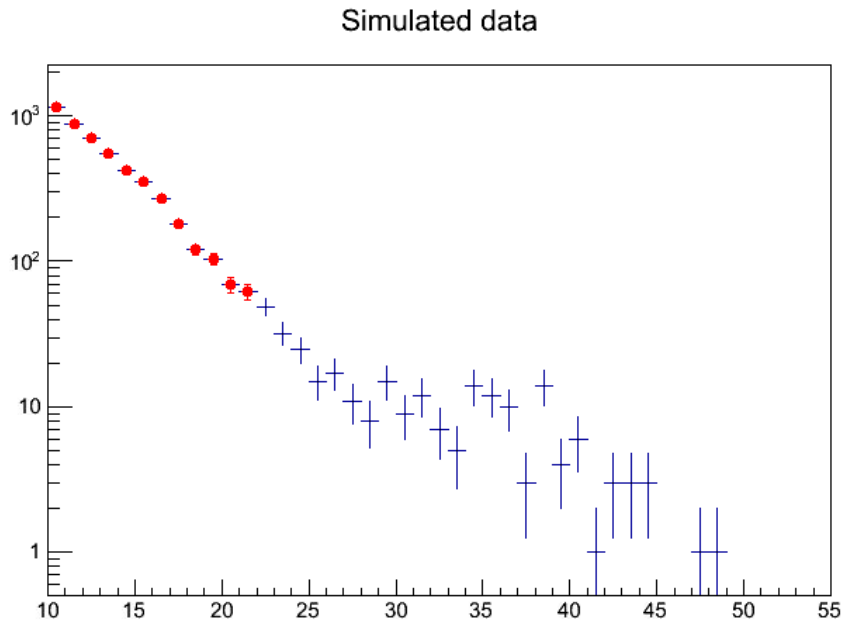
Gaussian Process Regression

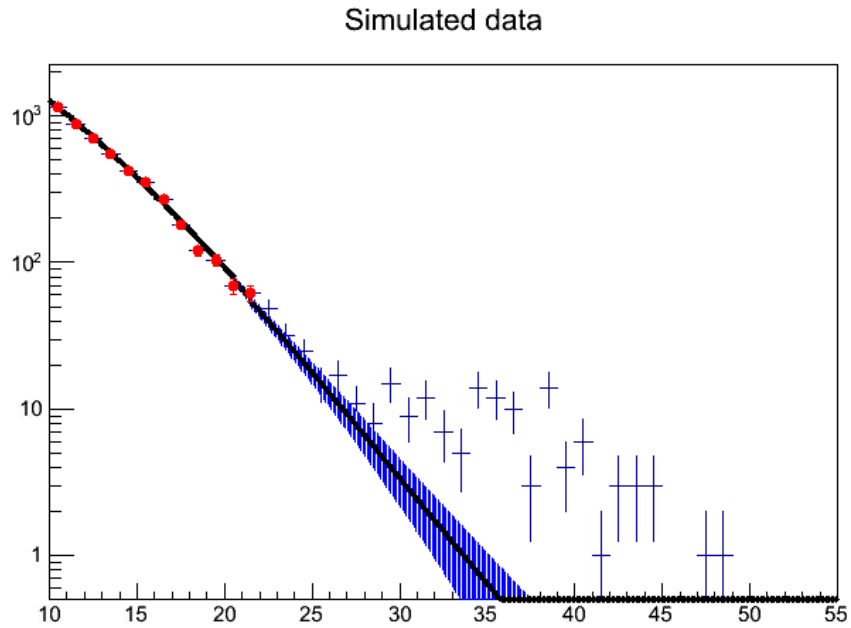
- Functional form is not known apriori
- Shift focus from prior knowledge over parameters to prior over functions

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

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

Gaussian Process Regression

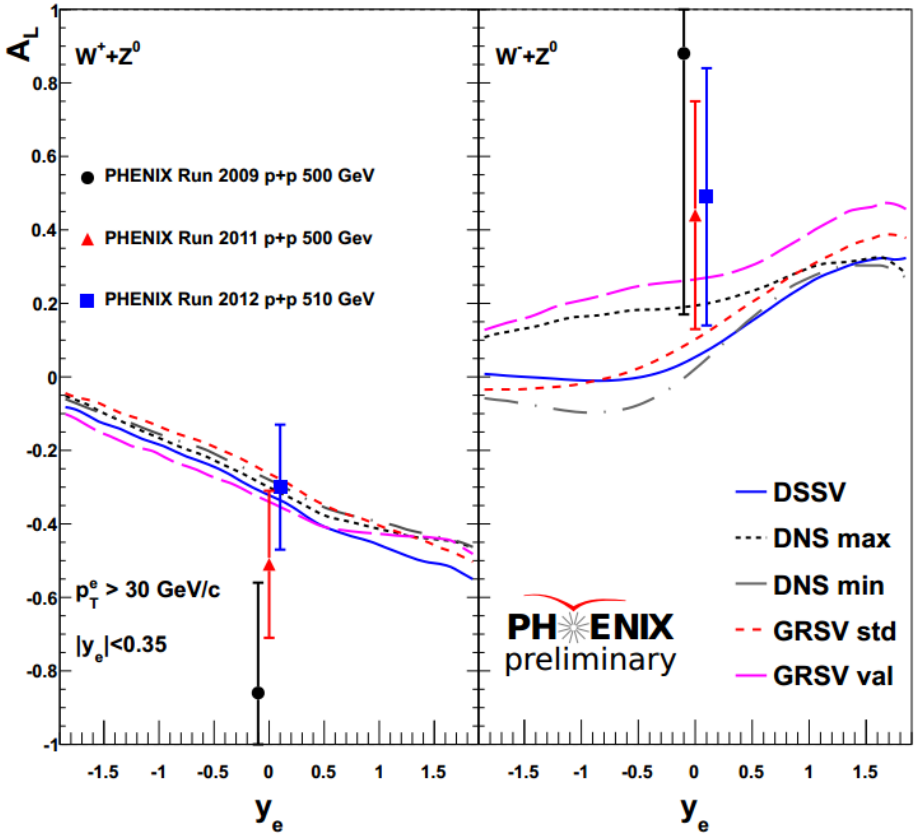




- Use background control region to get a shape
- The GPR will give a background contribution and uncertainty
- A cross check of the method has been performed with a classic functional form showing good agreement

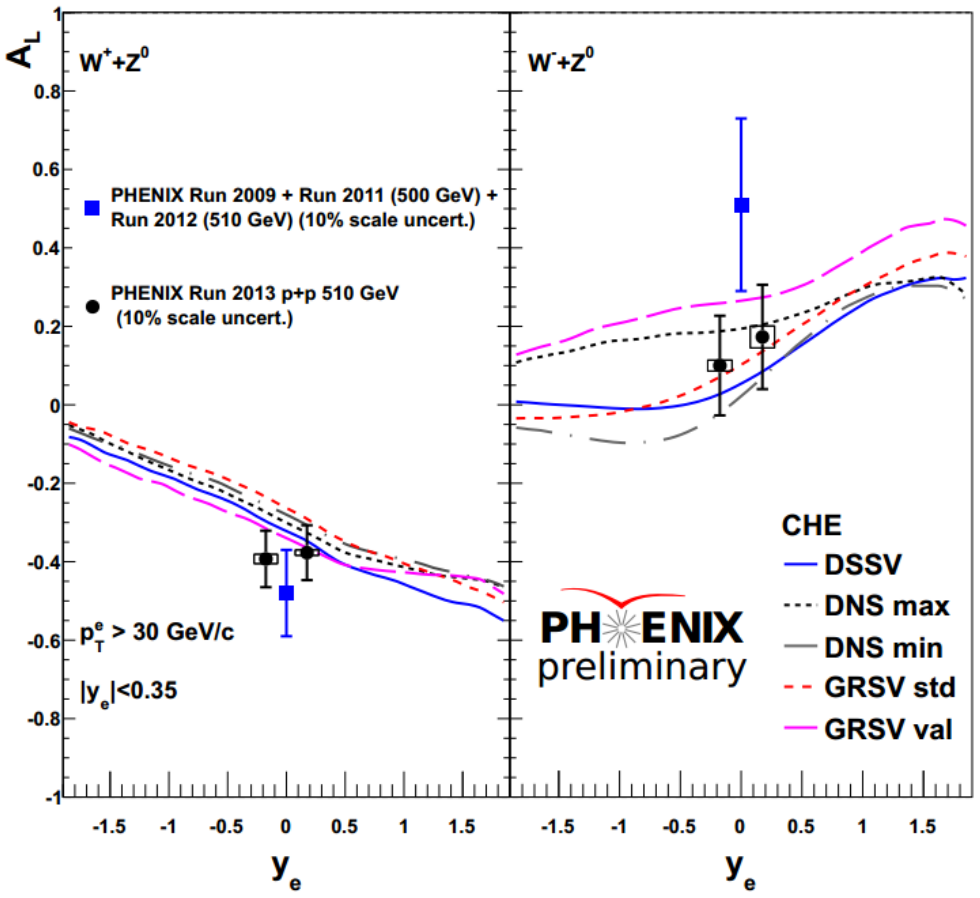
Asymmetries '09/'11/'12

- 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

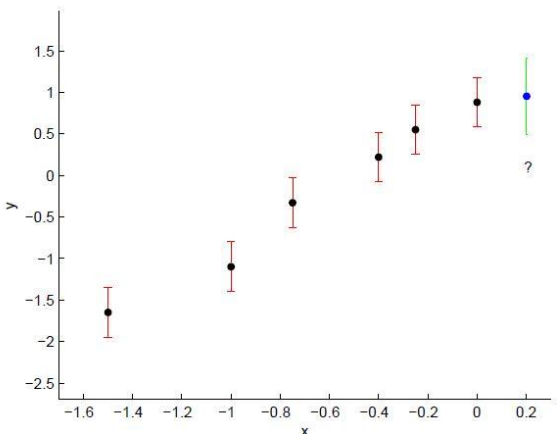


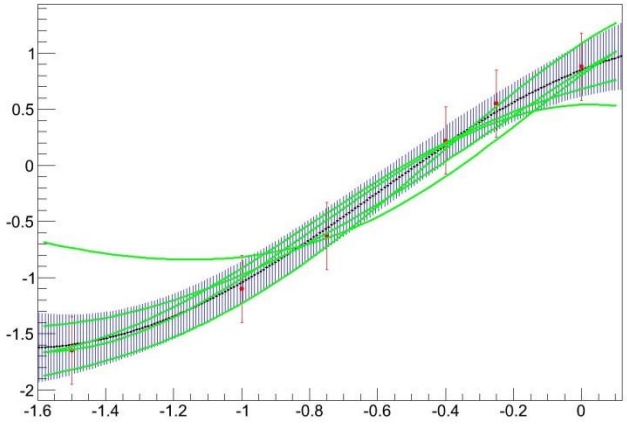
Summary

- 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

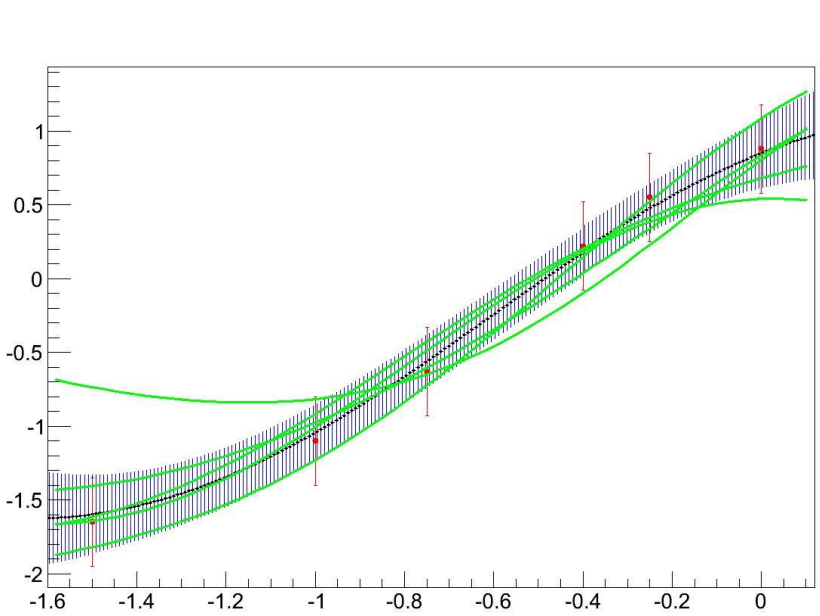


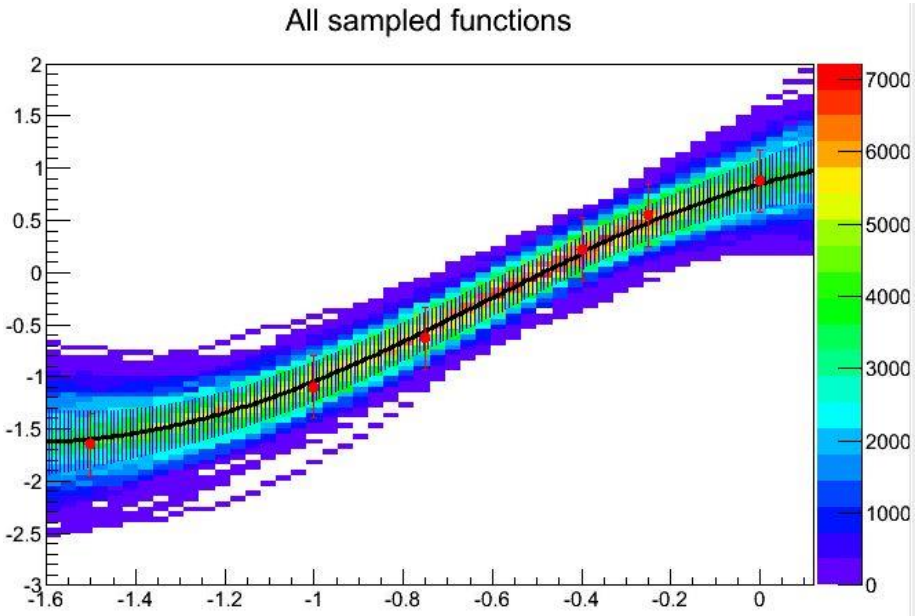


***Normal regression**: prior knowledge about parameters*
***GP Regression**: prior knowledge about functions*

- 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*