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 $W$s 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.
• Access through $W \rightarrow e$ decay in central arms and $W \rightarrow \mu$ 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 $W \rightarrow e$

- Limited $\phi$ 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

\[
A_L = \frac{1}{P} \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \quad A_{L,f} = \frac{1}{\beta^\pm} A_{L,old}
\]
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

- 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

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>√s (GeV/c)</td>
<td>500</td>
<td>500</td>
<td>510</td>
<td>510</td>
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<tr>
<td>∫Ldt (pb⁻¹)</td>
<td>8.6</td>
<td>16</td>
<td>23.7</td>
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<td>Pol. (%)</td>
<td>39</td>
<td>48</td>
<td>55</td>
<td>55</td>
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<tr>
<td>P²∫Ldt (pb⁻¹)</td>
<td>1.3</td>
<td>3.7</td>
<td>7.2</td>
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</tbody>
</table>
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
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 $W\rightarrow e$ 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

- 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

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