Extracting W Single Spin Asymmetry in Longitudinally Polarized *pp* Collisions at PHENIX forward arms

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09 October 2014

The Fourth Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and The Physical Society of Japan
Hawaii 2014

U.S. DEPARTMENT OF ENERGY

PHENIX

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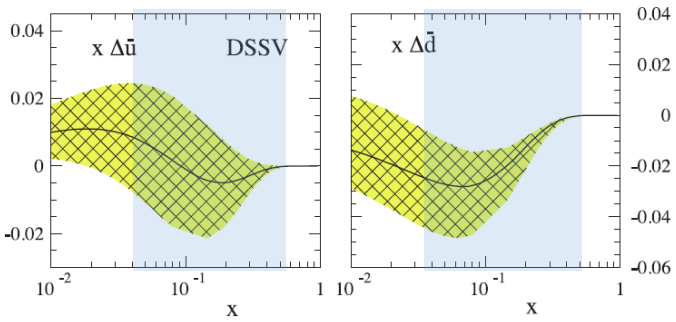
Motivation

Spin dependent quark distribution

➔By the QCD analysis of (SI)DIS data
Polarized Parton distribution function (pPDF)

- $\Delta q(x)$: well known,
- $\Delta\bar{q}(x)$: **large uncertainties from dealing with fragmentation functions**



Spin dependent PDF's for $\bar{u}$, $\bar{d}$ from DSSV global fit PHENIX rapidity sensitivity range

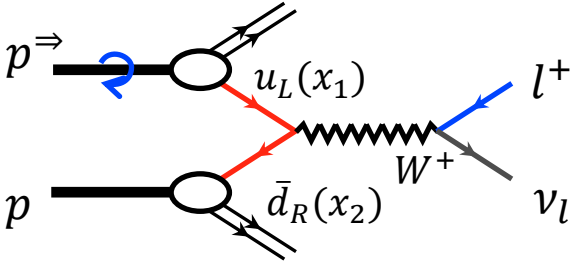
➔The Weak Interaction (flavor selection coupling) can be used to constrain sea quark distribution.

- No dependence on fragmentation functions
- High Q^2 (lower NLO contribution)
- W bosons couple to:Left Handed Particles and Right Handed Antiparticles
- In the forward arms and at high p_T, W decay is the dominant source of μ's

$$\boldsymbol{p + p^{\Rightarrow} \rightarrow W^{+} \rightarrow l^{+} + \nu_l}$$

Probing Sea Quark Polarization

Technique: by measuring Parity-violating longitudinal single spin asymmetries (A_L^W) :

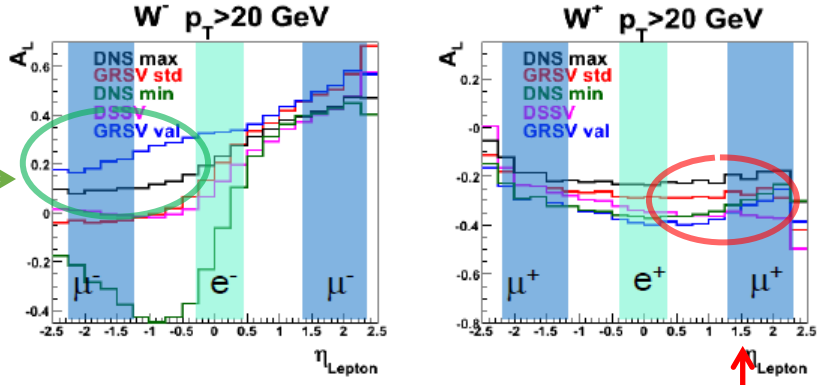


$$u\bar{d}\ (d\bar{u}) \rightarrow W^{+(-)} \rightarrow \mu^{+(-)}\nu_\mu$$

$$A_L^{W\rightarrow\mu} = \frac{d\sigma^{\Rightarrow} - d\sigma^{\Leftarrow}}{d\sigma^{\Rightarrow} + d\sigma^{\Leftarrow}}$$

$$A_L^{W^-\rightarrow\mu^-} \approx \frac{\Delta\bar{u}(x_1)}{\bar{u}(x_1)}, x_1 \ll x_2$$

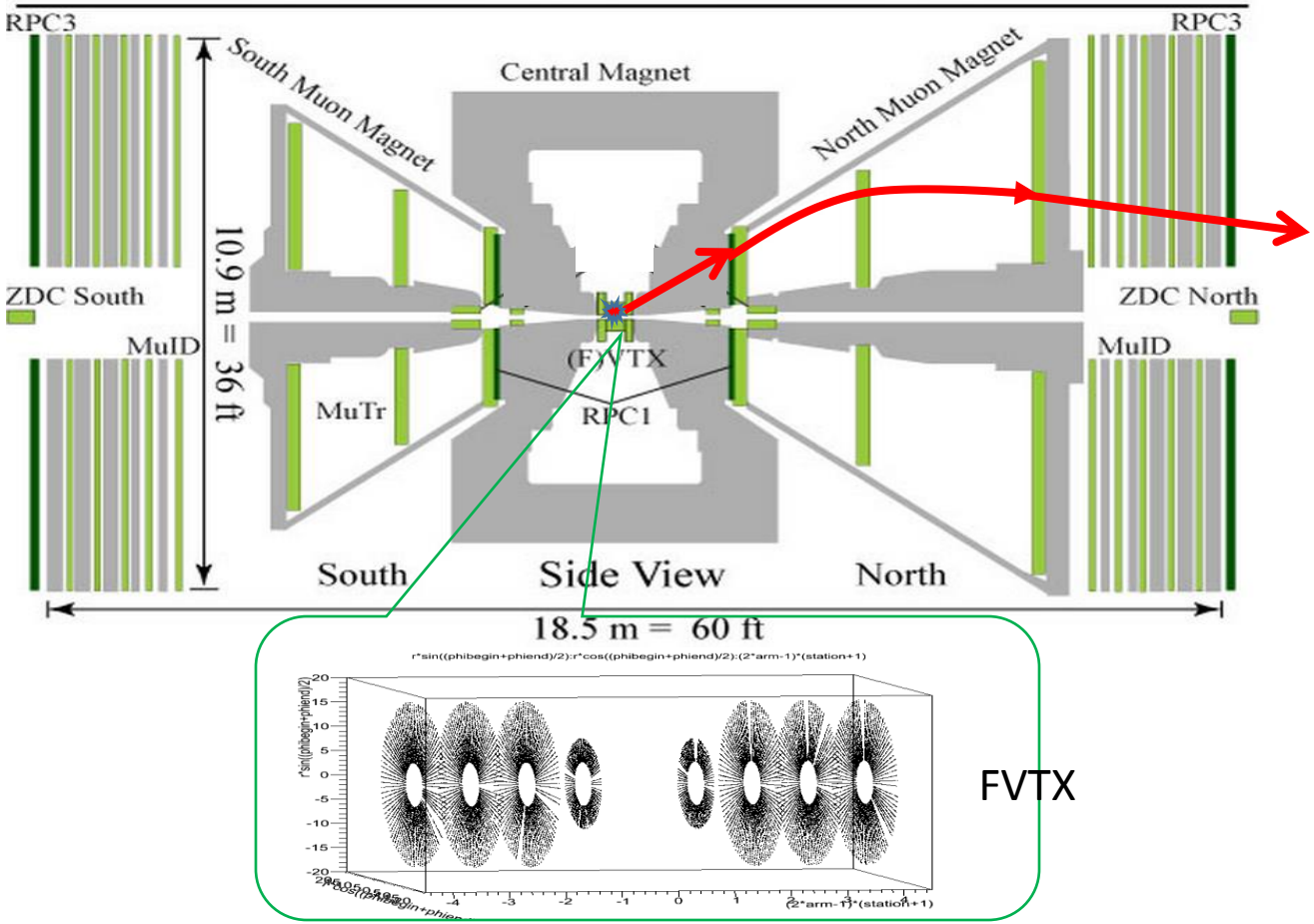
$$A_L^{W^+\rightarrow\mu^+} \approx \frac{\Delta\bar{d}(x_1)}{\bar{d}(x_1)}, x_1 \gg x_2$$



simulations

PHENIX Forward Muon Spectrometer

Pioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment at RHIC



Forward vertex detector (FVTX)

- **~ 1 million Si-strip**
- **high resolution ,** 75 µm radial, 3.75 ^{o} in ϕ

Muon Tracker (MuTr)

- **Tracking and**
- **Momentum**

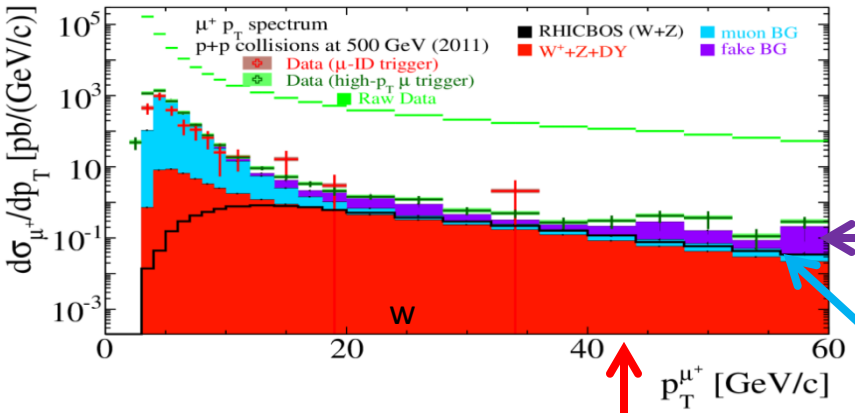
Muon Identifier (MuId) :

- **µ/hadron separation**

RPCs

- **background rejection**
- **timing improvements**

Forward Muon Backgrounds



Signal: In the forward arms and at high p_T, W decay is the dominant source of muons

Major Backgrounds

1) Hadronic backgrounds: decay inflight low p_T muons misreconstructed as high p_T.

2) Real muons from heavy flavor decays get smeared to higher transverse momenta.

Analysis Overview

Phase 1: Produce Kinematic Distribution PDF's

Variables Sensitive To W Signal vs. Background

- RpcDca(1|3)
- DG0 vs DDG0
- χ^2 vs DCA_r
- $fvtx$: $dr \times d\theta, d\phi$

Phase 2: Event Preselection with "Wness" Likelihood Ratio

Likelihood of event to be W based on Signal and Background kinematic P.D.F.'s

- Signal PDFs
- Background PDFs

Phase 3: Signal to Background Ratio

Extrapolate signal to background ratio with unbinned maximum likelihood fit

- Signal PDF
- Muon Background PDF
- Hadronic Background PDF

Phase 4: Calculate Asymmetry

$$A_{L_{corrected}} = A_{L_{measured}}\left(1 + \frac{BG}{SIG}\right)$$

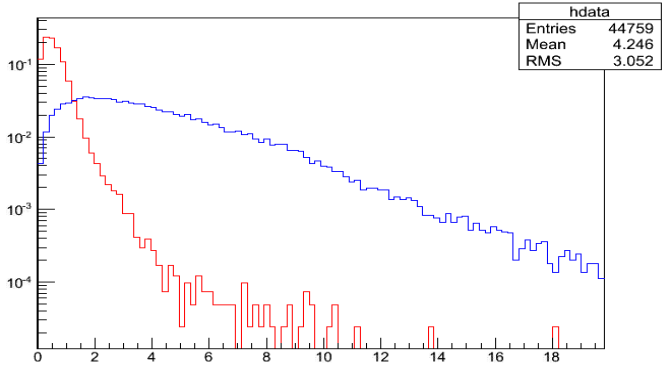
- DG0/DDG0 : distance/angle between the projected MuTr track and the MuID road at the gap 0 z position.
- χ^2 : chi-squared value from the track fitting + Kalman fitter during reconstruction
- RpcDca(1|3): Distance between extrapolated track at RPC 1 or 3 and the hit-cluster at RPC 1 or 3.

==========

- dr_fvtx/ dtheta_fvtx/ dphi_fvtx: radius/theta/phi residual btw. MuTr and FVTX track
- FVTX Cluster cone: Number of FVTX clusters inside a cone around the track

Background Extraction

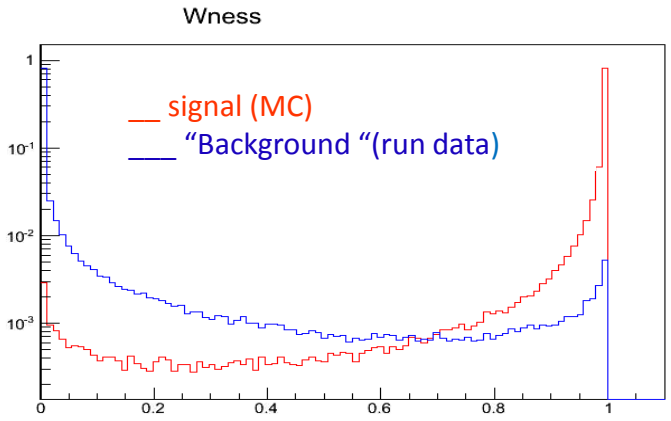
Determine "likelihood", λ, of an event to be signal as defined by the product of the normalized PDF's of the kinematic distributions



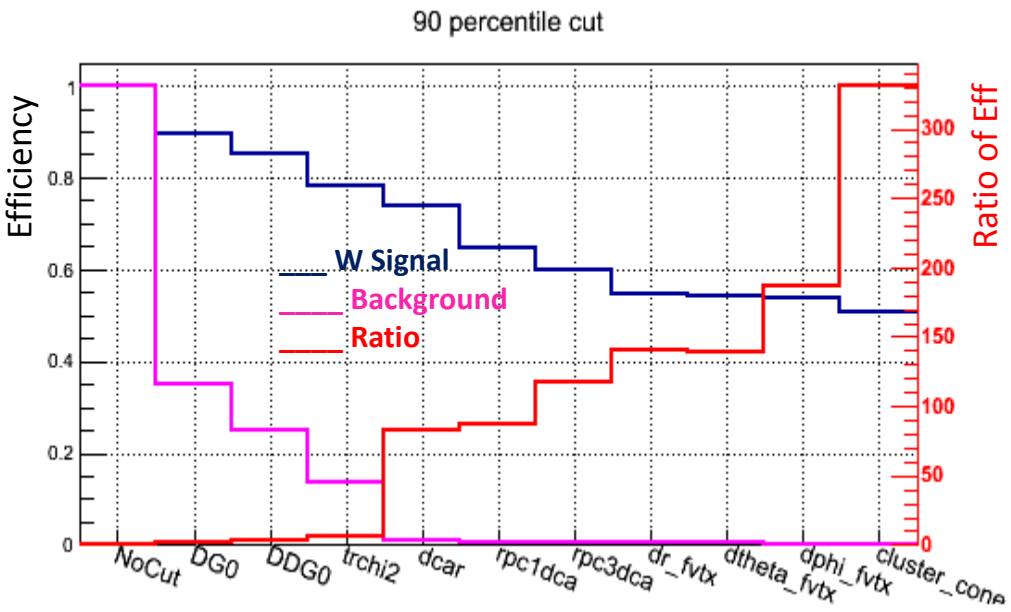
$$\lambda = p(DG0, DDG0)p(chi2)p(DCA_r)p(Rpc1/3dca)p(dr_{fvtx} * d\theta_{fvtx})p(d\phi_{fvtx})$$

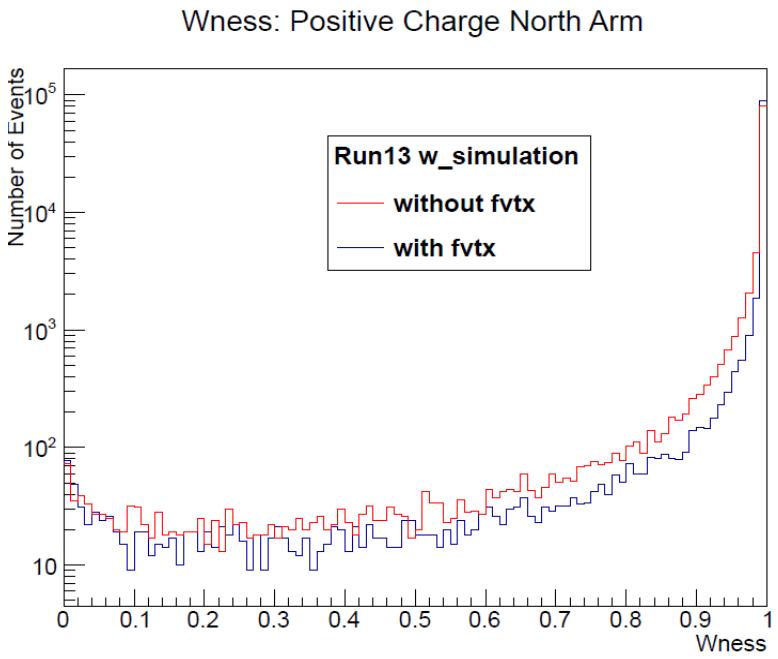
Calculate "Wness" as the ratio of signal likelihood, λ_{sig}, and signal and background likelihood, $\lambda_{sig} + \lambda_{bkg}$:

$$Wness_{signal} = \frac{\lambda_{sig}}{\lambda_{sig} + \lambda_{bkg}}$$



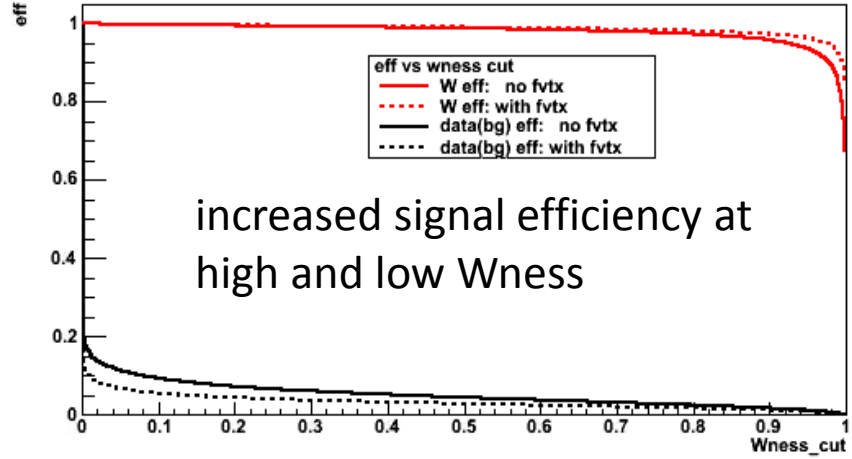
FVTX: Successive cut and likelihood ratio



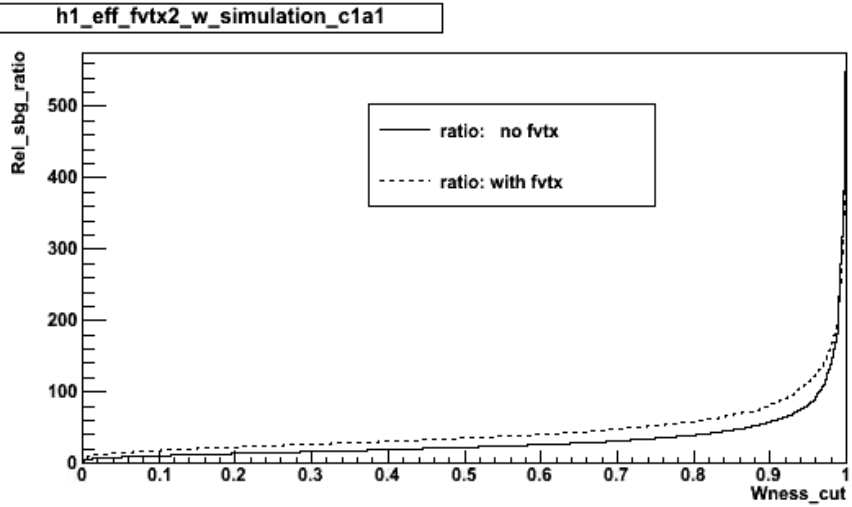


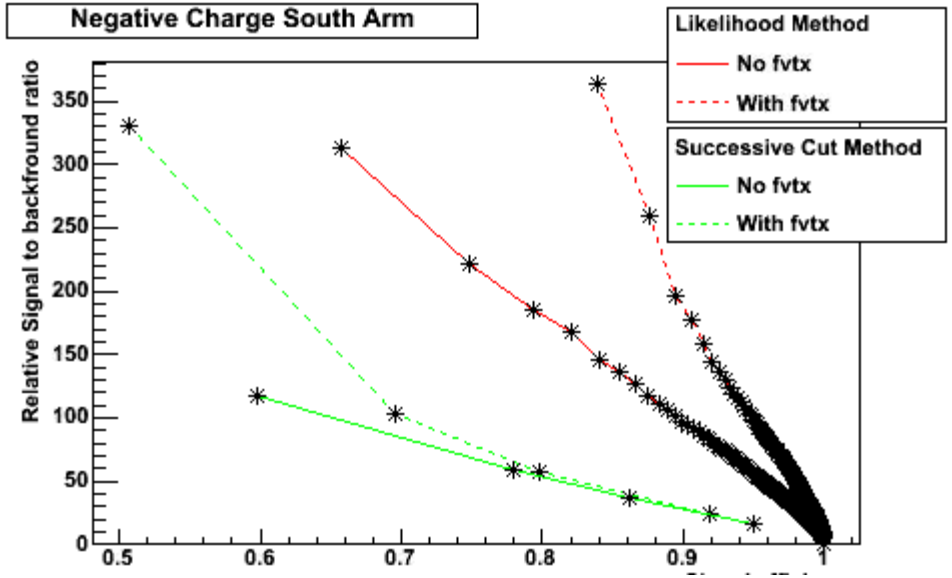
Shown: Only for events with valid FVTX variables ~ 25 % of data

dr_fvtx, dtheta_fvtx, dphi_fvtx + with cone



increased signal efficiency at high and low Wness





W eff

Successive cut and likelihood ratio

Shown: Only for events with valid FVTX variables

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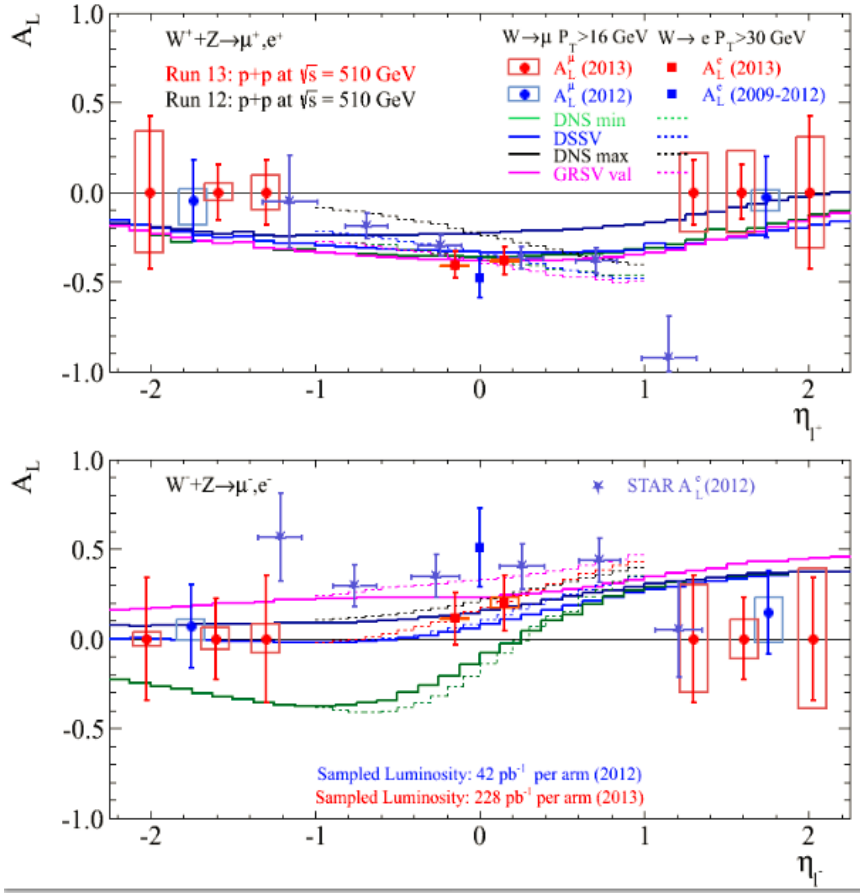
Asymmetry- PHENIX forward arms

- Run 2011, 2012 510 GeV preliminary
  - 25 pb^{-1} Integrated Luminosity, ~45% Polarization (2011)
  - 53.1pb^{-1} Integrated Luminosity ~50% Polarization (2012)

- Run13 510 GeV Asymmetry- in progress
  - 277 pb^{-1} Integrated Luminosity ~52% Polarization
  - Run dedicated to Polarized pp run.
  - FVTX matching variables included
  - Expect to release results soon.



Summary

- Real W boson production provides clean access to sea quark helicities.
- Major increase in integrated luminosity in 2013 (~ 277 pb^{-1})
- Analysis technique including FVTX established and progress has been made on analysis of Run 13 data.
- Anticipated preliminary release in the near future.

Session DF: Spin Structure and Parton Distributions

9:00 AM–12:15 PM, Thursday, October 9, 2014
Room: King's 2

Chair: Jen-Chieh Peng, University of Illinois at Urbana-Champaign

Abstract: DF.00012 : Extracting W Single Spin Asymmetry in Longitudinally Polarized pp Collisions at PHENIX forward arms

11:45 AM–12:00 PM

Preview Abstract *MathJax* ***On*** | *Off* _ *Abstract* _

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The parity-violating longitudinal single spin asymmetry AL in the production of W bosons in p+p collisions at s√ = 510 GeV is sensitive to the polarization of light quarks and anti-quarks in the proton. However, identifying the muons from the decay of the W is challenging due to a great background of hadronic processes and other muon producing processes. In the forward and backward hemispheres of PHENIX at RHIC, the muon spectrometers have been recently upgraded in order to provide additional trigger and tracking information to suppress those backgrounds. One of those upgrades is the Forward Vertex (FVTX) detector, a silicon-strip tracker. In 2013, PHENIX collected approximately 240 pb−1 of polarized p+p collisions at s√ = 510 GeV with a beam polarization of 56%. The ability of the FVTX to improve the W signal will be reviewed, over view of the analysis techniques used to extract the signal from the data in RHIC 2013 run will be discussed.

Signal to Background Extraction

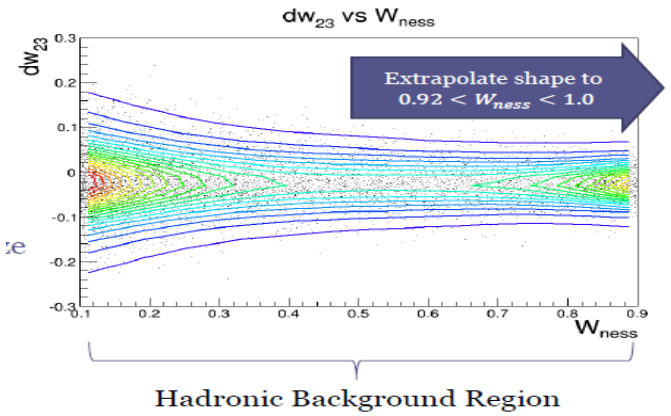
- Hadronic background dominates at low $Wness$
- Preform 2D (dw23 / η vs Wness) fit to characterize the change.

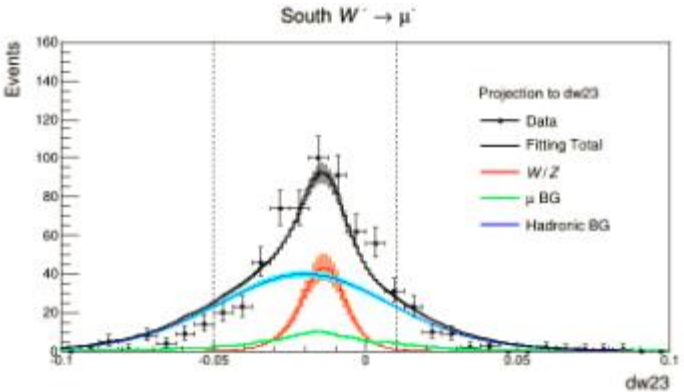
1) Hadronic background
    - Extrapolate the dw23 to high wness to estimate the hadronic background
    - η from low wness region

2) muonic backgrounds at high wness from simulation.

3) W signal at high wness from simulation.

Use η and dw23 fits to count and calculate S/B.





HAWAII 2014

FOURTH JOINT MEETING OF THE NUCLEAR PHYSICS DIVISIONS OF THE American Physical Society and The Physical Society of Japan

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合同核物理
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Outline

- Spin, weak decay (1slide)
- RHIC/PHENIX (0slide)
- FVTX detector (1slide)
- FVTX matching variables and clusters in a cone: signal sensitivity (2 slides)
- Signal Extraction, likelihood method (2slides)
- Successive cut, likelihood methods, , FVTX contribution and limitation (2slides)
- Previous results (1slide)

Discriminating Kinematic Variables

Variable	Definition
$DG0, DDG0$	Roads are generated through MUID + MuTr planes. These roads are compared to tracks fit through the same hits. DG0 is the distance between the first gap's road and track. DDG0 is the opening angle between the road and track
$RpcDca\ 1,3$	Distance between extrapolated track at RPC 1 or 3 and the hit-cluster at RPC 1 or 3.
$fvtx_d\phi$, $fvtx_d\theta$, $fvtx_dr$	Fvtx residuals for phi, theta and radius. The FVTX has a separate tracking system from the Muon Tracker, so these residuals are the result of matching.
χ^2_{track}	This variable is the chi-squared value from the track fitting + Kalman fitter during reconstruction
DCA_r, DCA_z	Distance of closest approach between the track and beam axis (DCA_r). DCA_z is the distance between the track's intersection with the z axis, and the event vertex.
dw_{23}	Reduced azimuthal bending – the magnitude of this variable corresponds to the bending of the particle in the azimuthal direction. $dw_{23} = p_T \sin(\theta)(\phi_2 - \phi_3)$
η	Pseudorapidity – we use this variable to perform secondary likelihood cuts

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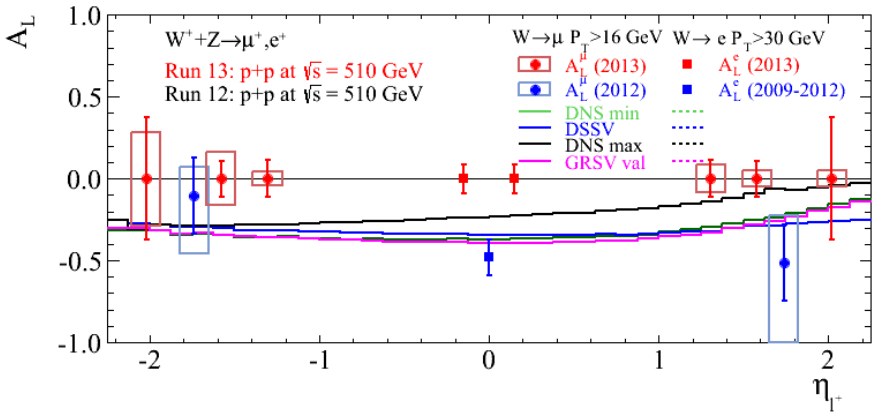
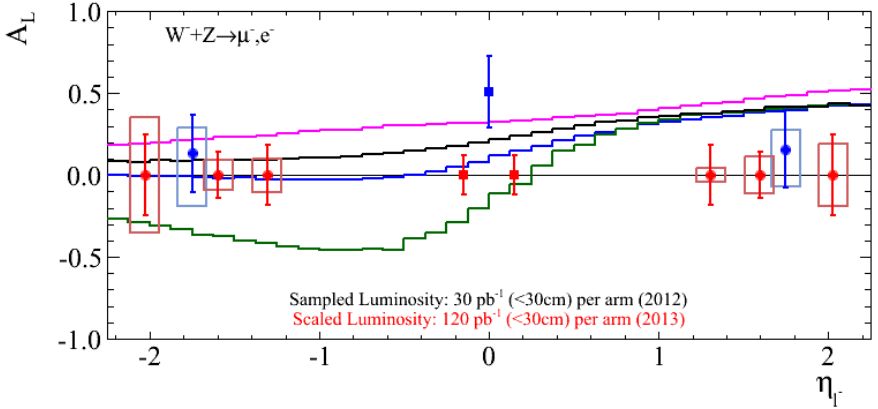
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