

W Physics Result of PHENIX

XXI INTERNATIONAL WORKSHOP ON
DEEP-INELASTIC SCATTERING AND
RELATED SUBJECTS
Marseille Congress Centre April 22-26 2013



Sanghwa Park
(Seoul National University / RIKEN)
for the PHENIX collaboration

Outline

- Physics Motivation
- W Measurement
- PHENIX Detector System
- Analysis
 - $W \rightarrow e$
 - $W \rightarrow \mu$
- Result
- Summary and Prospects

Physics Motivation

- Proton spin structure
- To answer to the question “where does proton spin come from?”

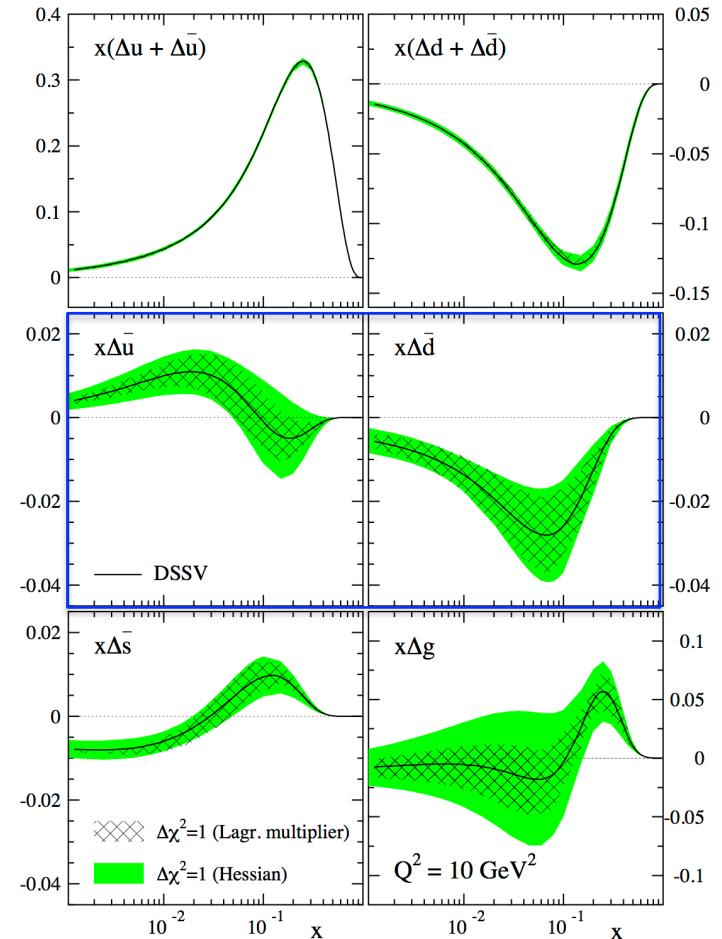
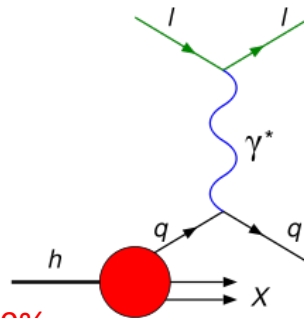
$$\frac{1}{2} = \frac{1}{2} \underbrace{\Delta\Sigma}_{\text{Quark}} + \Delta G_{\text{Gluon}} + L_{\text{Orbital angular momentum}}$$

Measured by DIS experiment:

Quark contribution to the proton spin: ~30%

$$\Delta\Sigma = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) + (\Delta s + \Delta\bar{s})$$

Large uncertainty

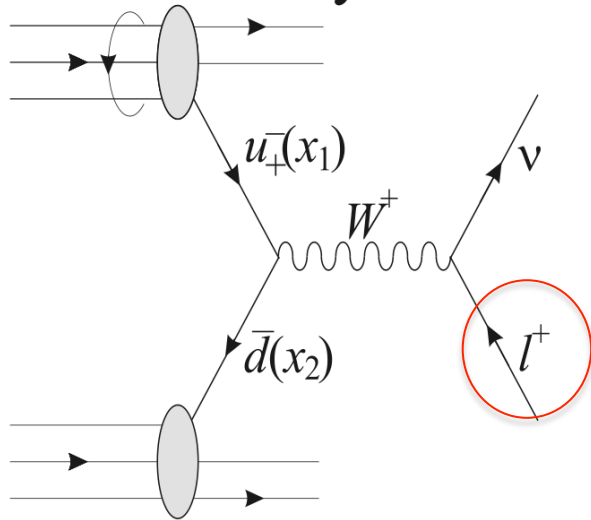


D. de Florian, R. Sassot, M. Stratmann, W. Vogelsang, Phys. Rev. D 80, 034030 (2009)

- Well known combined quark PDFs by polarized DIS experiment.
- Semi-Inclusive DIS (SIDIS) constrains separated PDFs. Limited by large uncertainties of fragmentation functions

W Physics in Polarized PP Collisions

Proton helicity = "+"



- W production in polarized pp collision
- Large Q^2
- Independent of the knowledge of fragmentation functions:
 - maximum parity violation;
 - left handed quark + right handed anti-quark
 - flavor is almost fixed:

$$u\bar{d} \rightarrow W^+$$

$$d\bar{u} \rightarrow W^-$$

- Single Spin Asymmetry:

$$A_L^{W^+} \equiv \frac{\sigma_- - \sigma_+}{\sigma_- + \sigma_+}$$

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

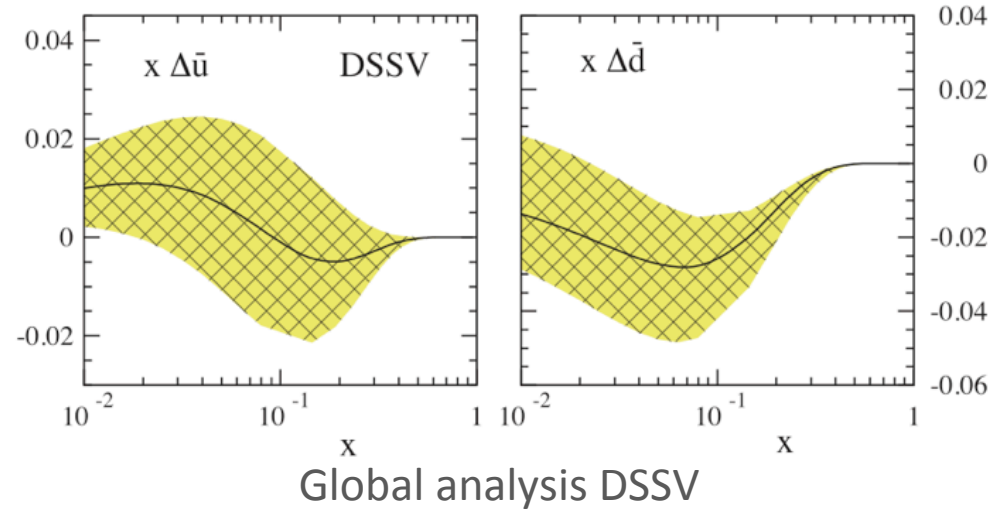
Relative rapidity of W to the proton, y_w

$$\text{At } y_w \gg 0, A_L^{W^+} \approx - \Delta u / u$$

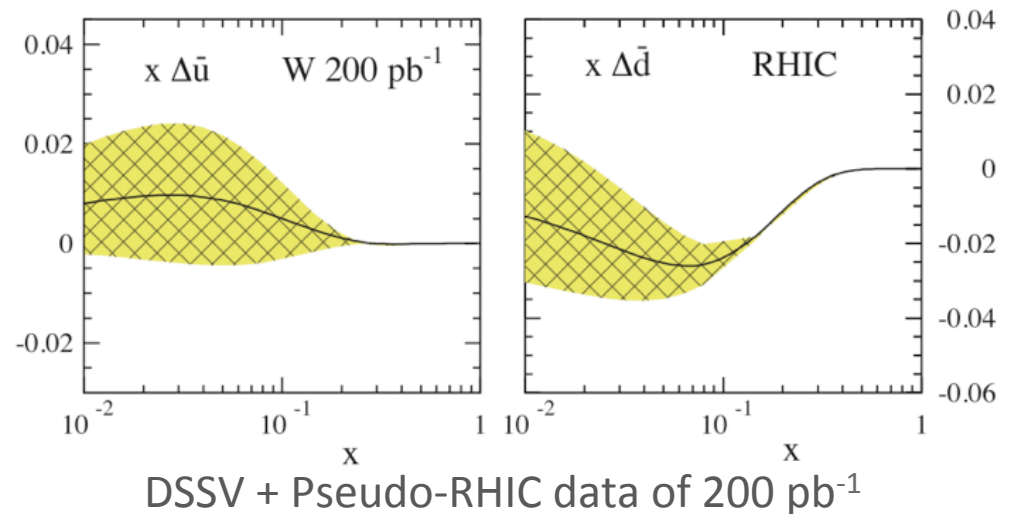
$$\text{At } y_w \ll 0, A_L^{W^+} \approx \Delta\bar{d} / \bar{d}$$

Physics Impact of A_L

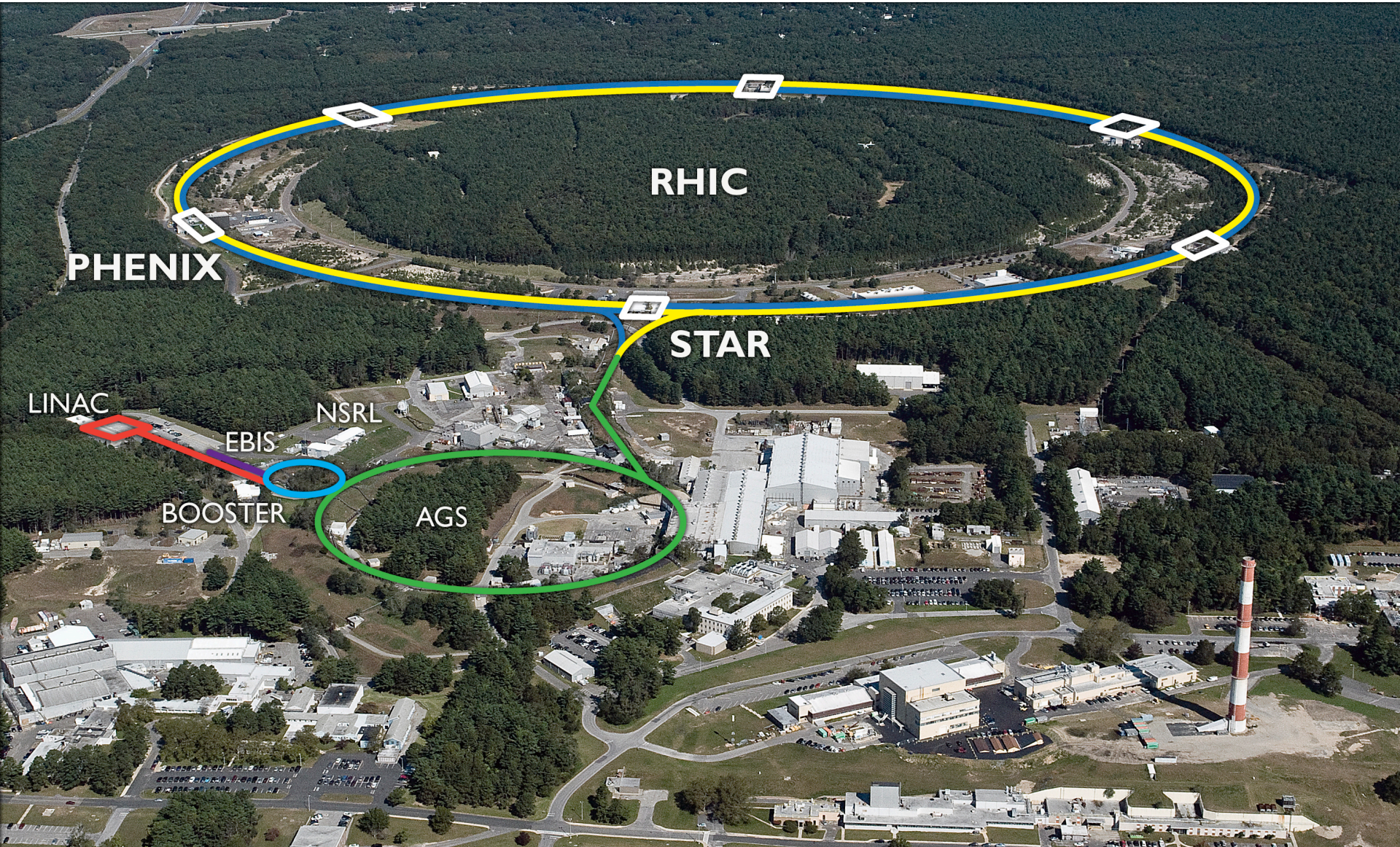
- Global analysis DSSV (top) and Pseudo-experiment data of 200 pb^{-1} (bottom)



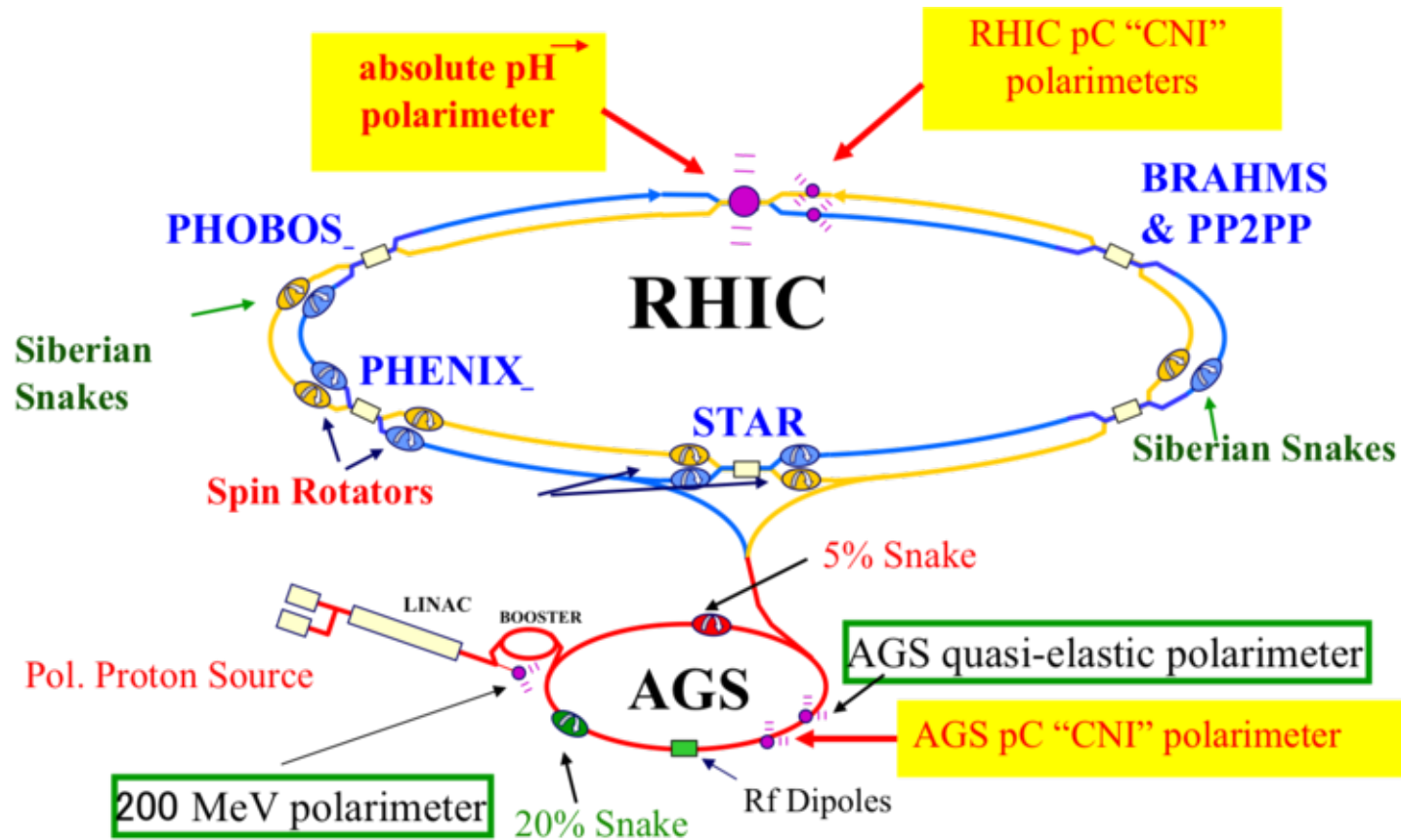
- Significant impact for reducing uncertainties



W Program of PHENIX at RHIC



W Program of PHENIX at RHIC



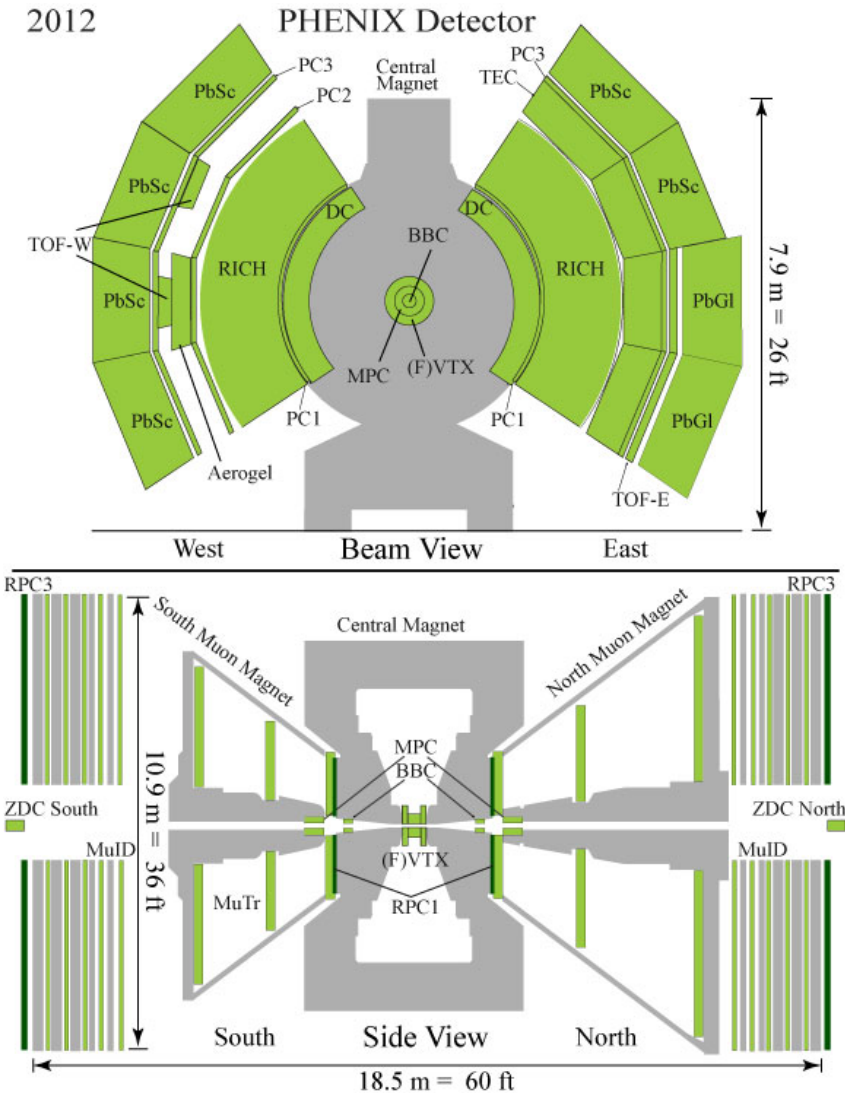
In 2012:

- Center of mass energy $\sqrt{s}=510$ GeV
- Average polarization: 55% / 57%



PHENIX Detector System

2012



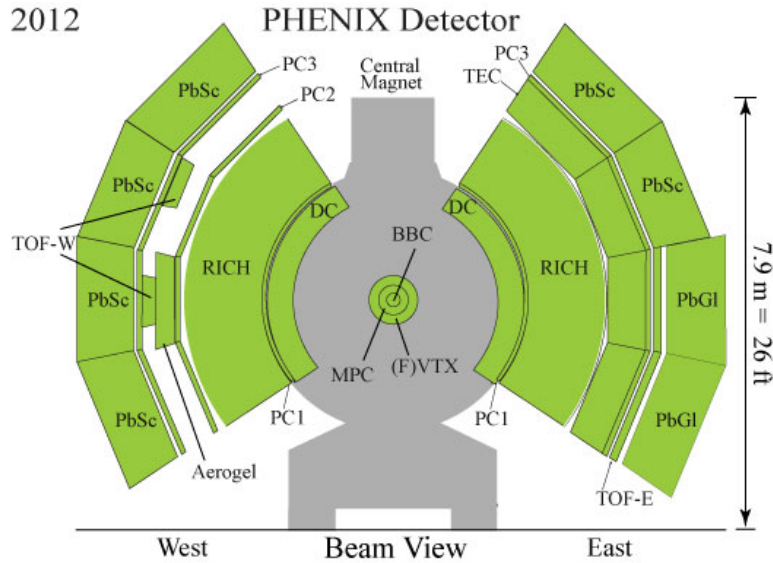
Central Arm ($W \rightarrow e$):

- **Acceptance:**
 - $|\eta| < 0.35$
 - $\Delta\phi = 2 \times \pi/2$
- **Subsystems:**
 - Drift chamber (DC), Pad chamber (PC) : tracking
 - Electromagnetic Calorimeter (EMCal): PbSG, PbGI, calorimeter, triggering

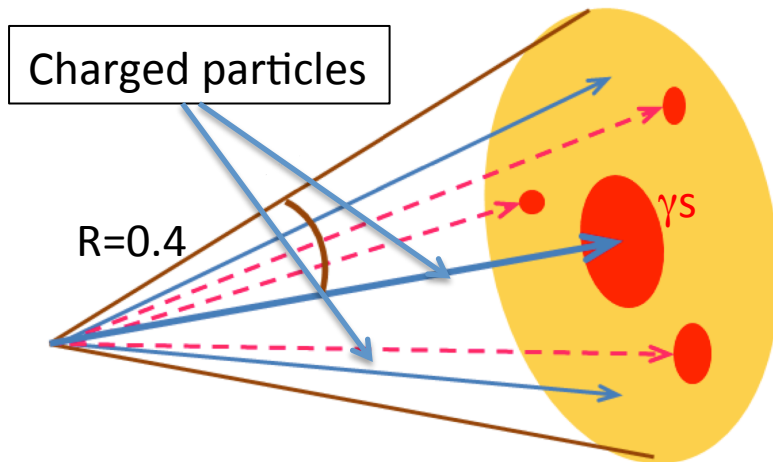
Muon Arm ($W \rightarrow \mu$):

- **Acceptance:**
 - $1.2 < |\eta| < 2.4$, North
 - $1.2 < |\eta| < 2.2$, South
 - $\Delta\Phi = 2\pi$
- **Subsystems:**
 - Muon Tracker (MuTr): tracking, triggering
 - Muon Identifier (MuID): particle ID, triggering
 - Resistive Plate Chamber (RPC): particle ID, triggering
 - Forward Silicon Vertex Detector (FVTX)

Central Arm Measurement

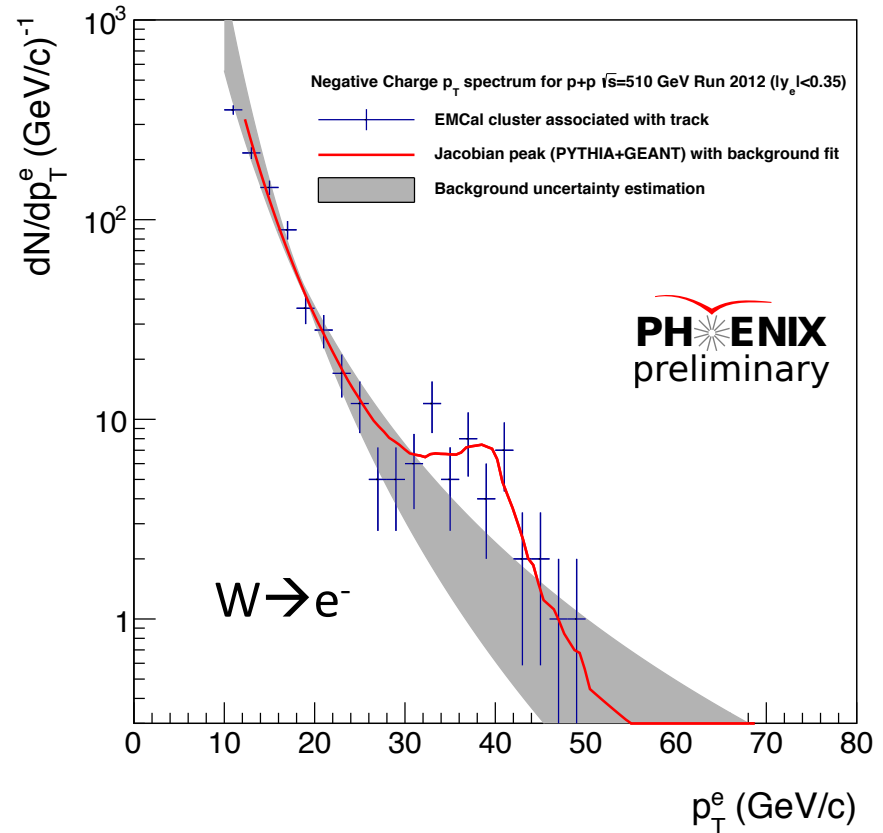
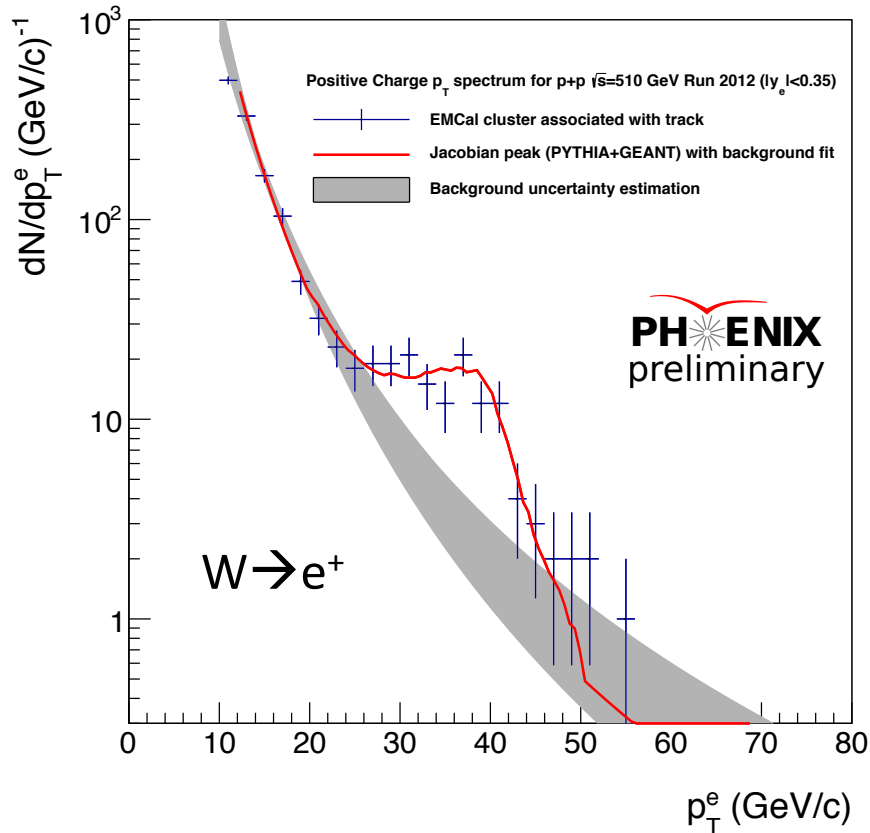


- **Observable: electron/positron**
from $W^{-/+} \rightarrow e^{-/+} + \nu_e$
- $(\Delta \bar{d} + \Delta u)$ from W^+ , $(\Delta \bar{u} + \Delta d)$ from W^-
- **Backgrounds:**
 - Reducible:
Cosmic, $\gamma \rightarrow e^+e^-$ conversion from $\pi/\eta \rightarrow \gamma\gamma$, direct photon, Beam related BGs
 - Irreducible:
 $Z \rightarrow e^+ + e^-$, Leptonic decay of charm, bottom to e^\pm



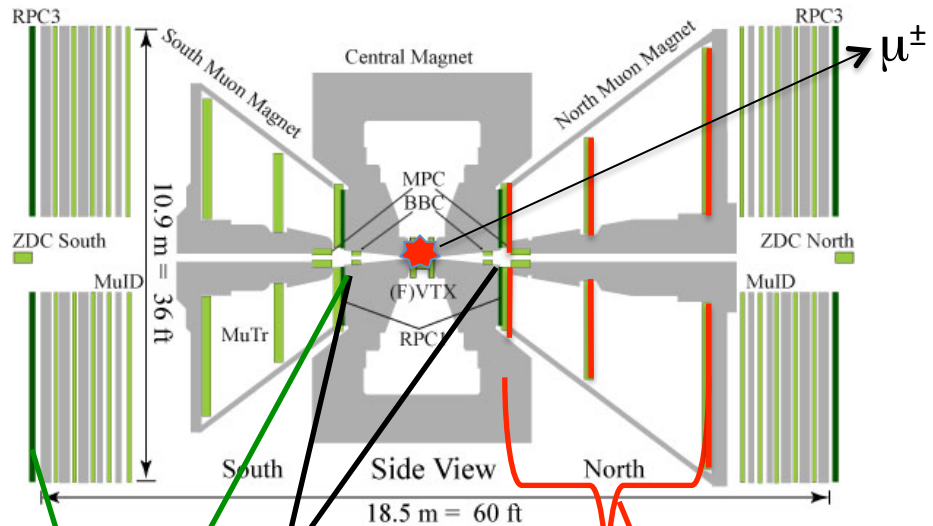
- **W event identification**
 - Jacobian peak at $p_T = M_W/2$ in p_T spectrum
 - Measure high p_T electrons using EMCal
 - DC-EMCal matching ($\Delta\phi < 0.01$ rad)
 - Relative isolation cut $< 10\%$

Run12 W^\pm/Z Spectra



- Background dominated: 10 to 30 GeV / signal region: $30 < p_T < 50$ GeV
- Background estimation:
 - Fit p_T region 10 to 69 GeV with a power law
 - Fit p_T region 20 to 50 GeV with a power law + Jacobian peak (simulation)

Forward Arm Measurement

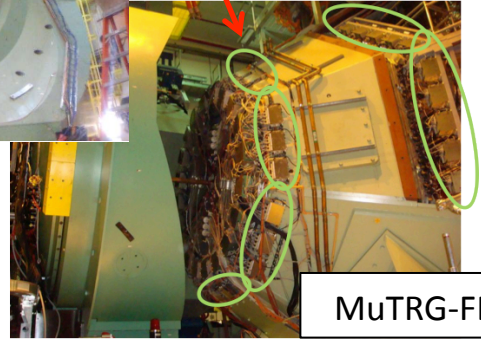
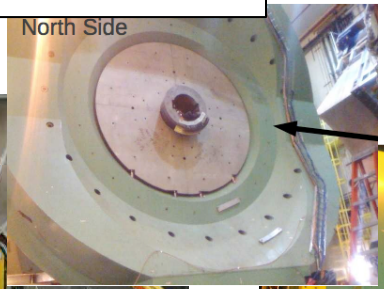


- Observable: muons
from $W^{-/+} \rightarrow \mu^{-/+} + \nu_{\mu}$

- Fully upgraded in 2012.
- High- p_T trigger including RPC:
small bending in magnetic field
+ timing (BBC / RPC)

- W dominant at $p_T > 15$ GeV
- Backgrounds:
 - Muon BGs: open heavy flavor, quarkonia, Drell-Yan, direct photon, $W \rightarrow \tau/\text{hadron} \rightarrow \mu$ decay.
 - Hadronic BGs

Hadron Absorber



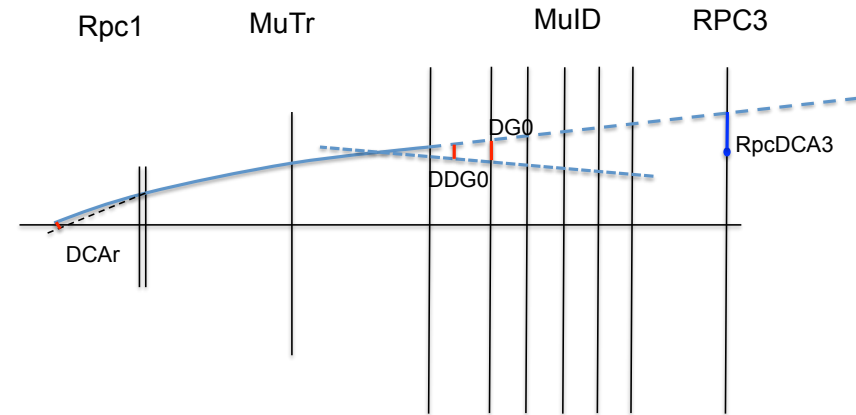
MuTRG-FEE

Signal Extraction in Forward Arm Analysis

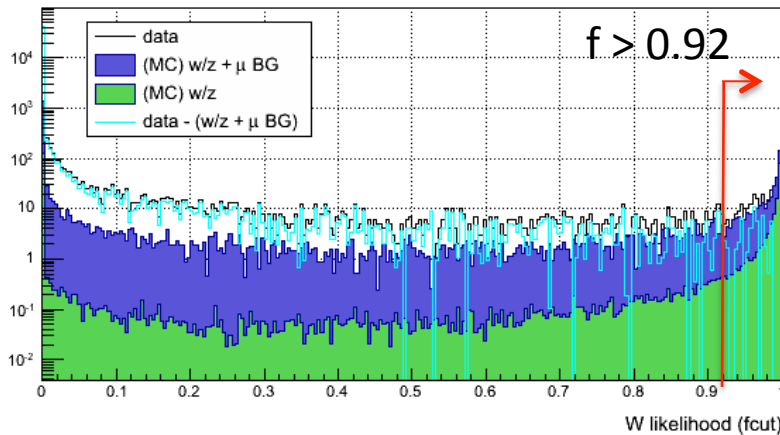
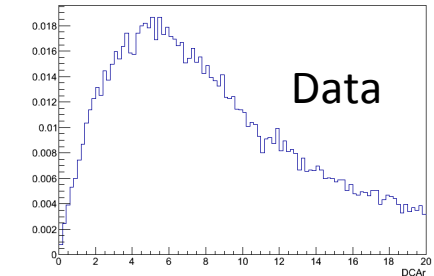
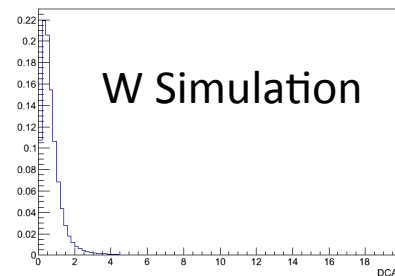
- Likelihood-based signal selection
 - Pre-selection: multivariate cut using likelihood ratio
 - S/B ratio extraction: unbinned maximum likelihood fitting (next page)
- Multivariate cut for pre-selection

$$f \equiv \frac{\lambda_{\text{sig}}}{\lambda_{\text{sig}} + \lambda_{\text{BGs}}}$$

$$\lambda = [p(\text{DG0}, \text{DDG0}) \cdot p(\chi^2) \cdot p(\text{DCAr}) \cdot p(\text{RpcDCA})]$$



DCAr distribution ($16 < p_T < 60$ GeV)

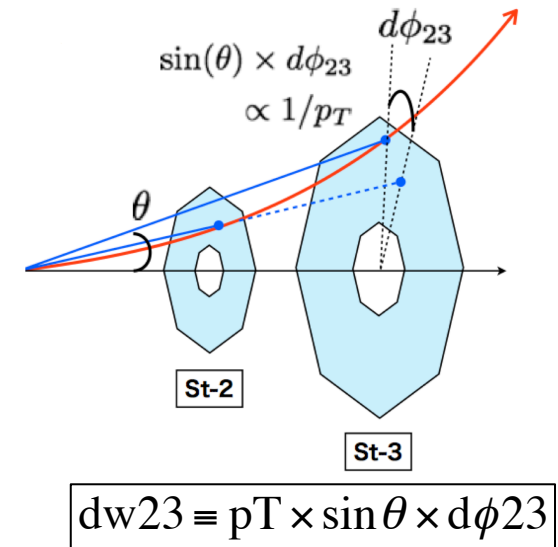


Signal Extraction in Forward Arm Analysis

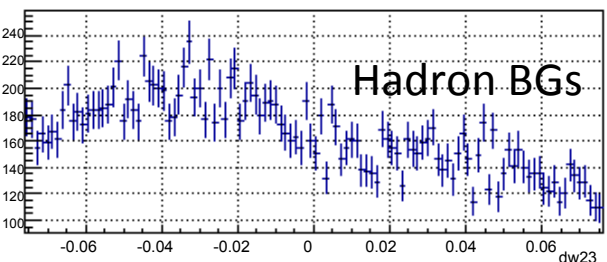
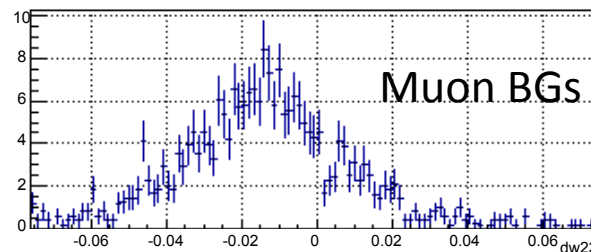
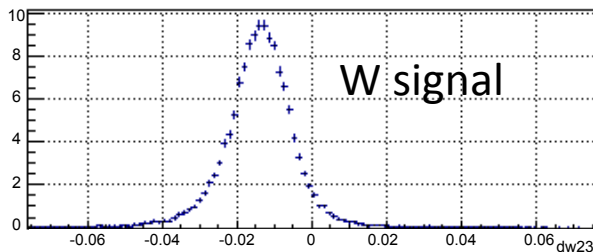
- Extended unbinned maximum likelihood fitting

$$\mathcal{L}(\theta|X) \equiv \frac{n^N e^{-n}}{N!} \prod_{x_i \in X} \left[\sum_c \frac{n_c}{n} p_c(x_i) \right], \quad n = \sum_c n_c$$

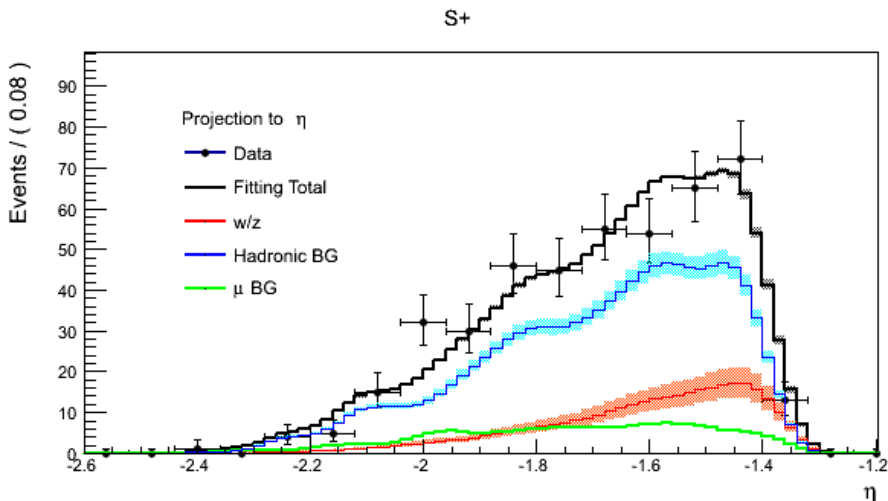
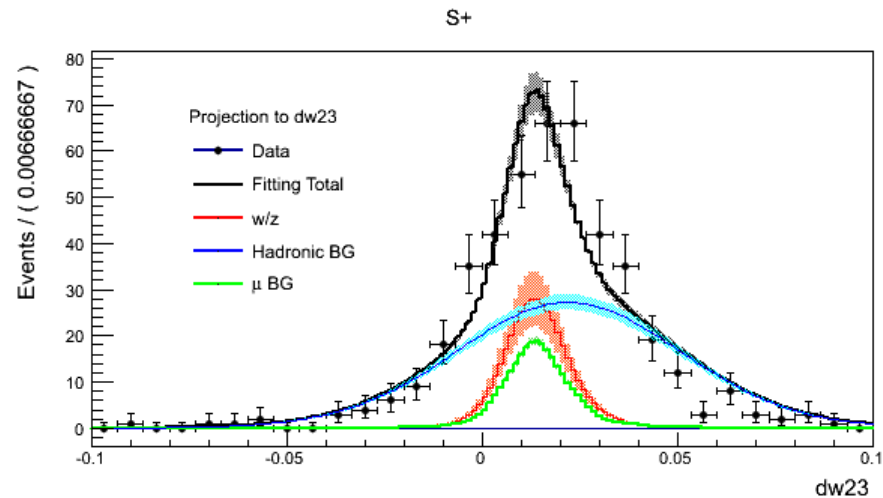
- Probability distribution functions extracted from simulation (W signal, muon BGs) and data (hadron BGs) using eta, dw23 (reduced azimuthal bending).



dw23 distributions ($16 < p_T < 60$ GeV)

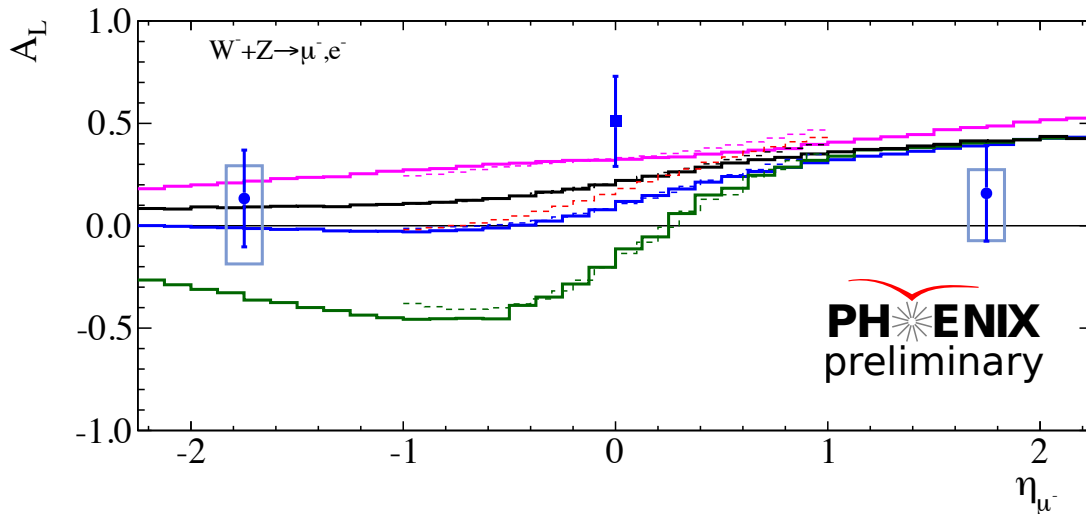
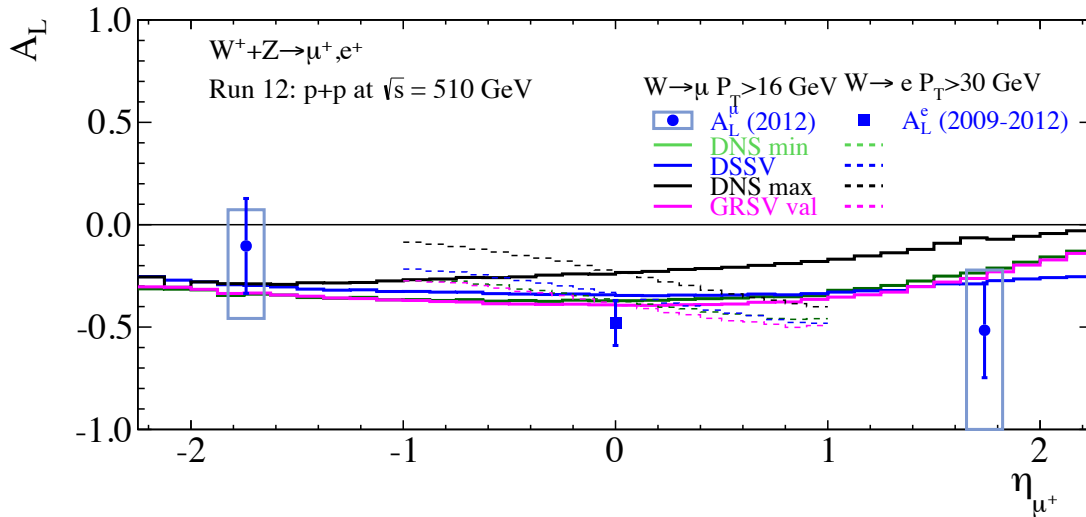


S/B Ratio in Forward Arm



- 1D projections of the 2D unbinned maximum likelihood fit onto dw23 (top), rapidity η (bottom)
- $16 < p_T < 60$ GeV, $f > 0.92$
- S/B ratio: $0.21 \sim 0.40$ (depending on arm, charge)

A_L Result

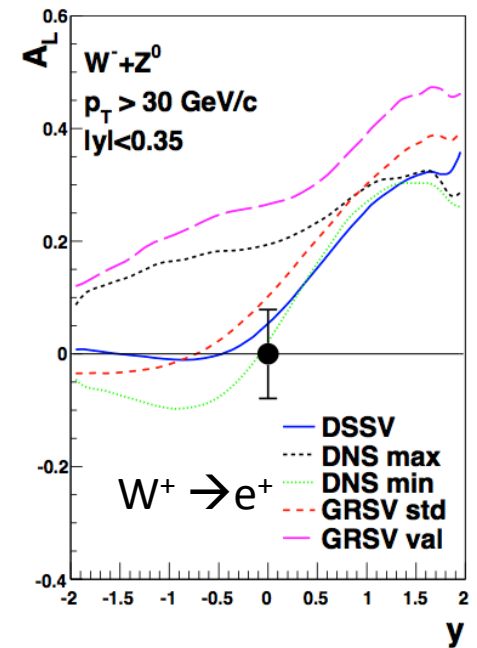
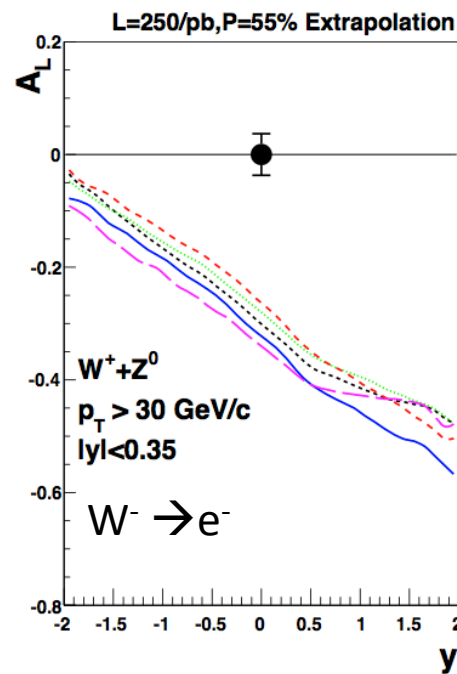
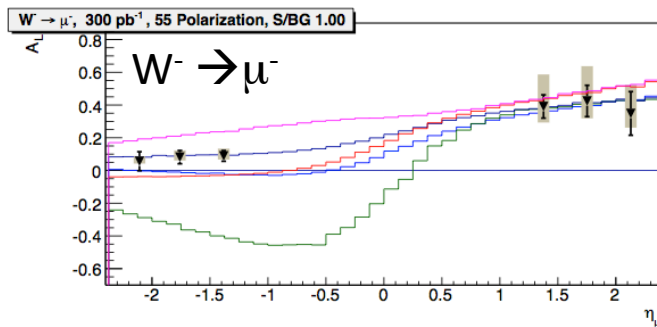
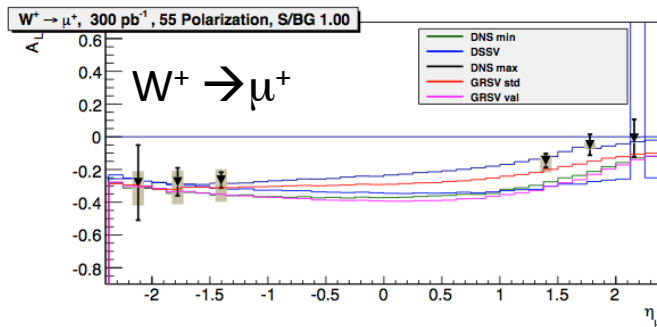


- Run12 preliminary
- Beam combined asymmetries for mid-rapidity and forward rapidity with respect to mean pseudorapidity
- Different energy cut for mid-rapidity and forward rapidity
- Agreement with theoretic curves

Expectation of PHENIX W Program

- assumed beam polarization of $P=55\%$
- sampled integrated luminosity of 300 pb^{-1}
- $S/B=1$ assumed for $W \rightarrow \mu$

• Projected plots in beam-use proposal



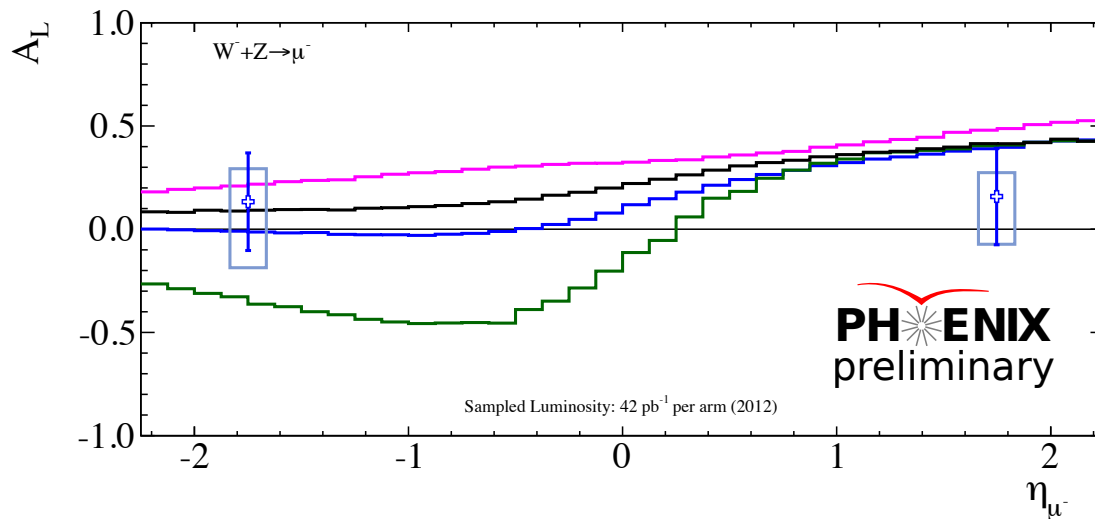
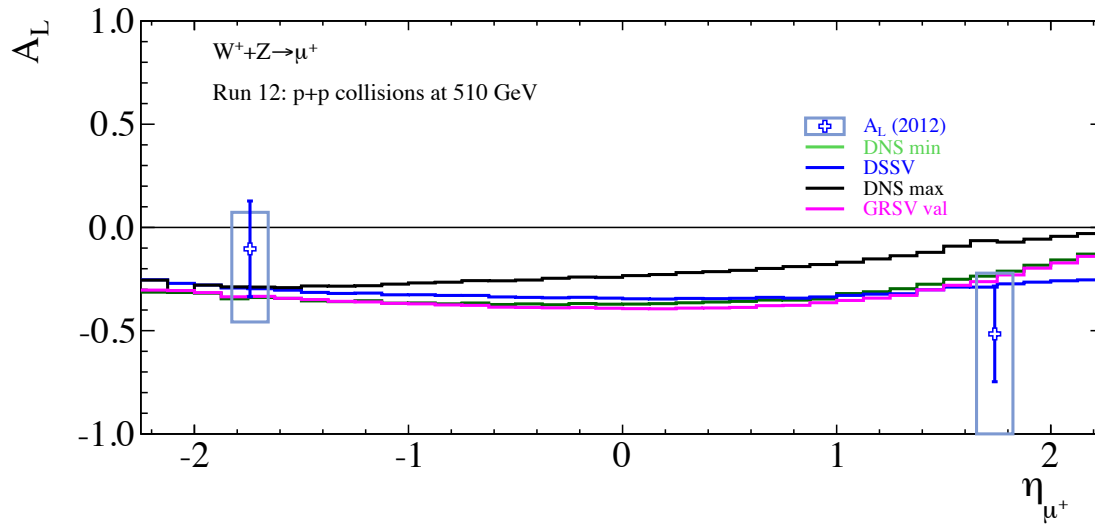
Summary and Prospects

- RHIC Run12:
 - PHENIX collected data of 30 pb^{-1} (with 30cm vertex cut) in 2012
 - Forward arm upgrade is completed
 - PHENIX Run12 Preliminary results are presented:
 - W^\pm spectra for $W^\pm/Z \rightarrow e^\pm$
 - Single spin asymmetries for $W^\pm/Z \rightarrow e^\pm$ and $W^\pm/Z \rightarrow \mu^\pm$
 - Agreement with theoretic predictions
 - Analysis is ongoing.
 - Improvement of S/B with FVTX is under development.
- RHIC Run13:
 - High statistics Run13 data taking is ongoing.
 - Integrated luminosity goal of 250 pb^{-1}

Thank you!

Backup

$A_L^{W \rightarrow \mu}$ Results



$A_L^{W \rightarrow \mu}$ Results (Beam separated)

