# W Physics in PHENIX

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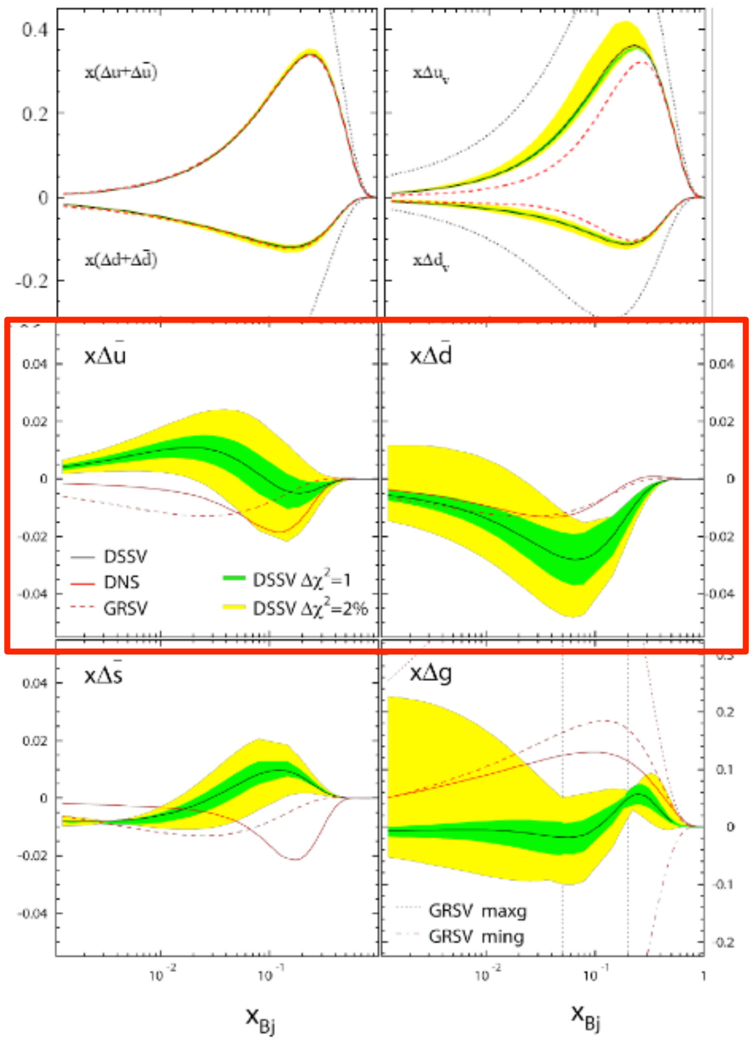
(RIKEN)

# Outline

- Introduction
  - Physics motivation
  - W measurement
- PHENIX Experiment
  - Data
  - Detector configuration
- Analysis
- Results
- Summary

# Motivation


De Florian et al. PRL 101, 072001 (2008)




$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$$

Quarks + **Anti-quarks**

Gluon contributions

Quark & gluon orbital angular momentum

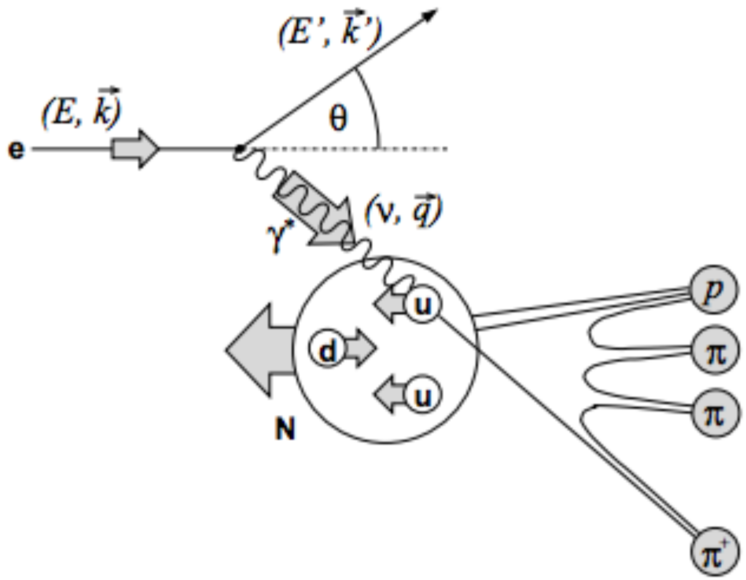
$$\Delta\Sigma = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) + (\Delta s + \Delta\bar{s})$$

- Well known combined quark PDFs by polarized DIS experiment.
- SIDIS sensitive to flavor separated quark and anti-quark PDFs
  - Limited by large uncertainties of fragmentation functions

# What and How to Measure?

- Single Spin Asymmetry: $$A(x,Q^2) = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

- Semi-Inclusive Deep Inelastic Scattering (SIDIS):



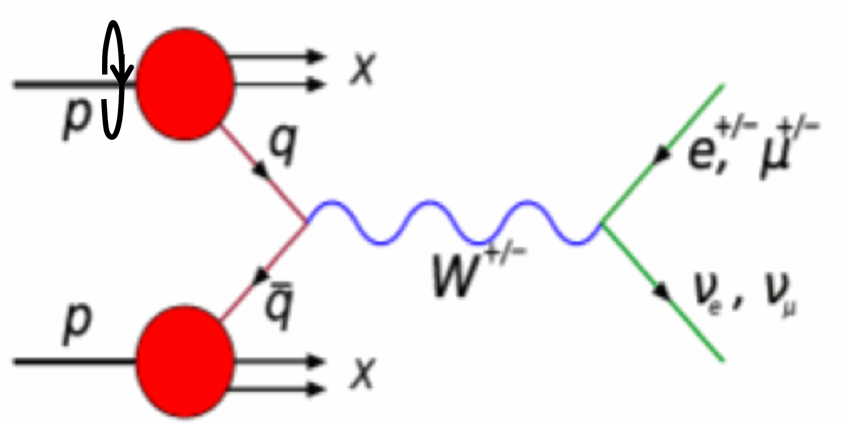

$$\mathrm{u}\bar{\mathrm{d}} \rightarrow \pi^+$$
$$\bar{\mathrm{u}}\mathrm{d} \rightarrow \pi^-$$
$$\mathrm{u}\bar{\mathrm{s}} \rightarrow \mathrm{K}^+$$
$$\vdots$$

Flavor tagging

$$A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2 \, \Delta q(x,Q^2) \, D_q^h(z,Q^2)}{\sum_{q'} e_{q'}^2 \, q'(x,Q^2) \, D_{q'}^h(z,Q^2)}.$$

Fragmentation Functions (FFs)

# W Measurement in polarized p+p collisions




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

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

- High scale set by W mass
- Maximum parity violation of weak interaction.

  → Fixed helicity of incoming quark and antiquark.

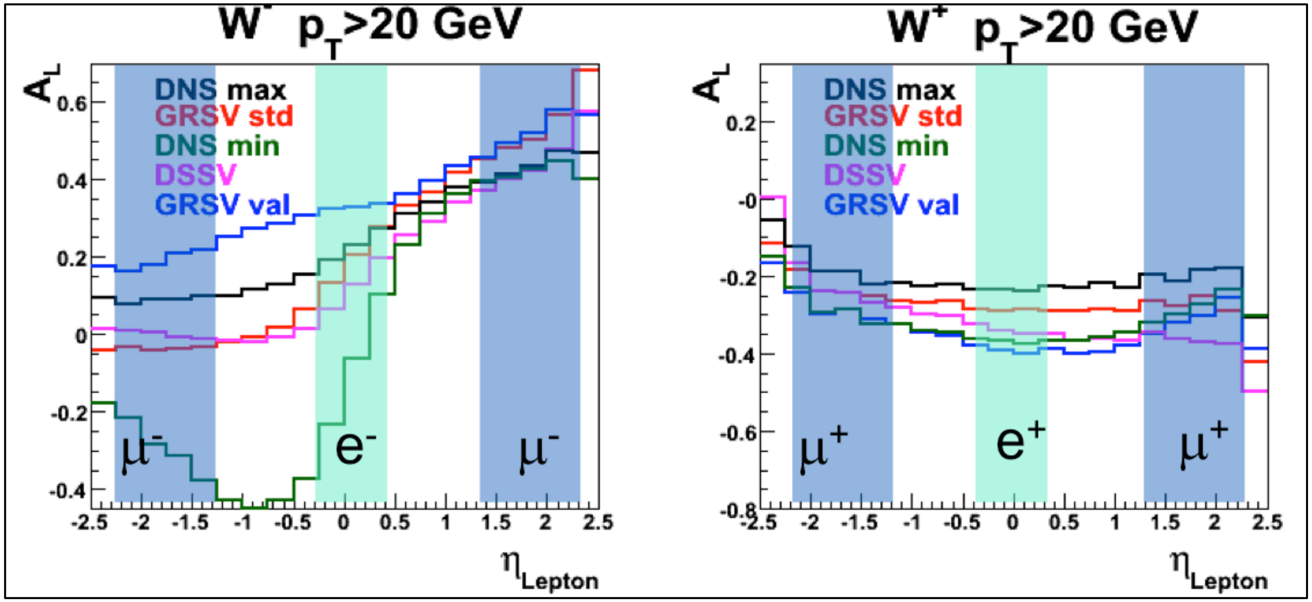
$$u_L \bar{d}_R \rightarrow W^+$$

$$d_L \bar{u}_R \rightarrow W^-$$

  → Independent from FFs

- Direct probe of the flavor-separated PDFs $\Delta u, \Delta\bar{u}, \Delta d, \Delta\bar{d}$

# W Measurement in polarized p+p collisions



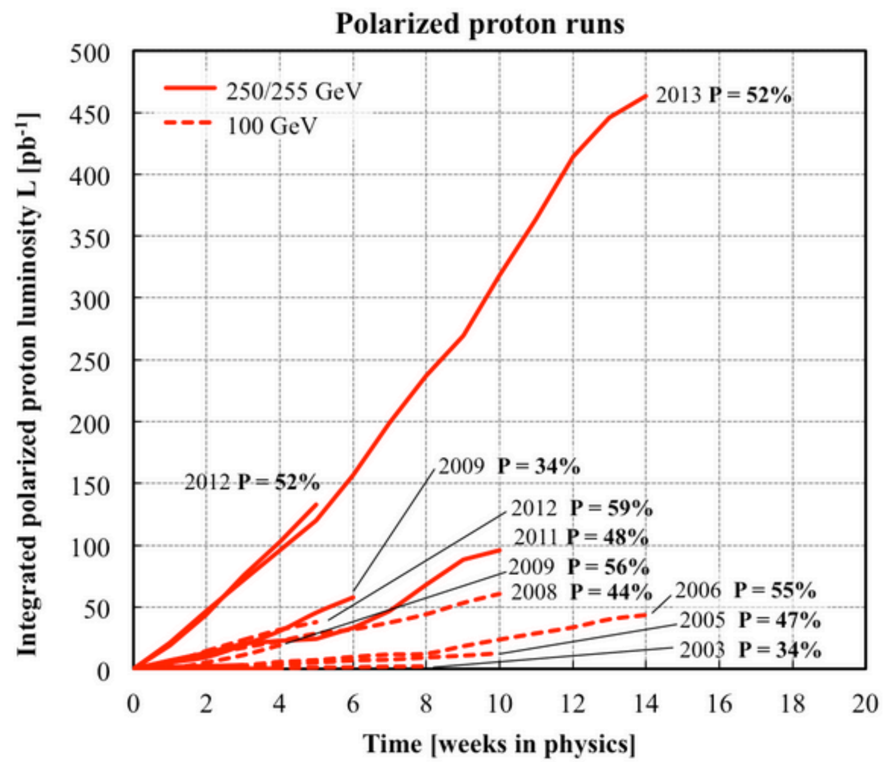

$$A_L^{W^-} \approx \frac{\Delta\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 - \Delta d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}{\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 + d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}$$

$$A_L^{W+} \approx \frac{\Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 - \Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}{\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 + u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}$$

- Quark flavor mixed at mid-rapidity
- Sensitive to anti-quark polarization at forward/backward measurement

# Polarized p+p data @ RHIC

- Longitudinally polarized p+p data taking 2009 - 2013 at √s = 510 (500) GeV.
- Accumulated data over 300pb$^{-1}$ (multiple collision corrected)

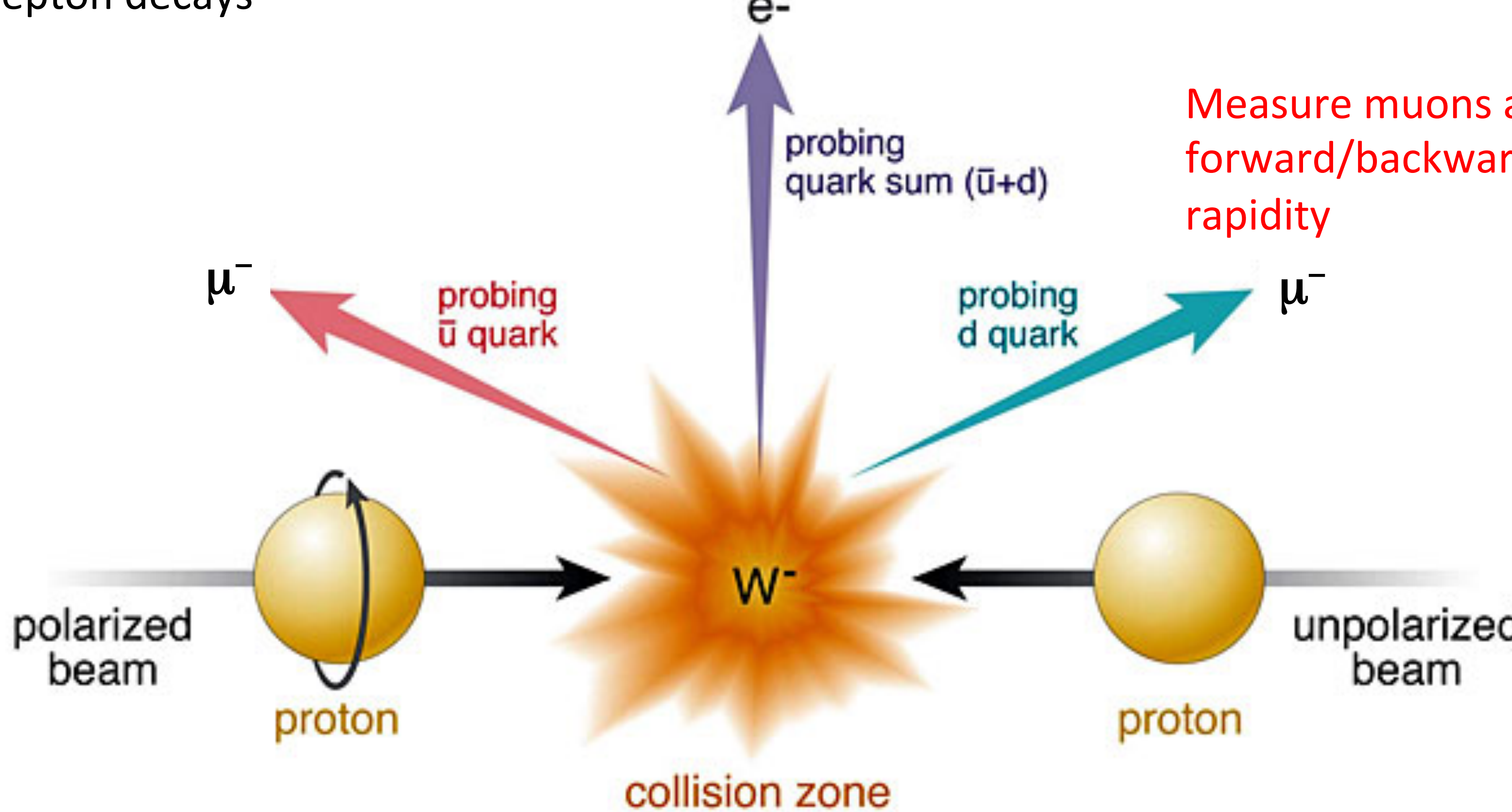


# W Measurement @ PHENIX

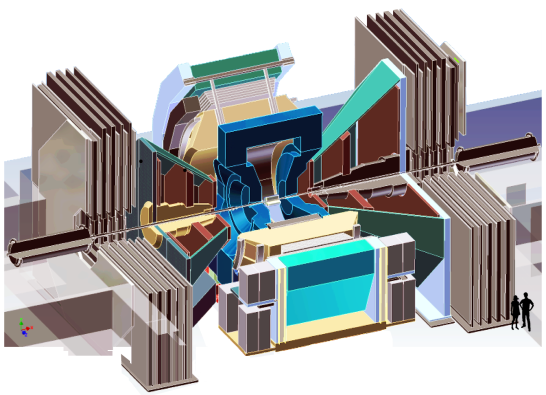
- W is massive (~ 80 GeV)
- Short lifetime; observed by its lepton decays

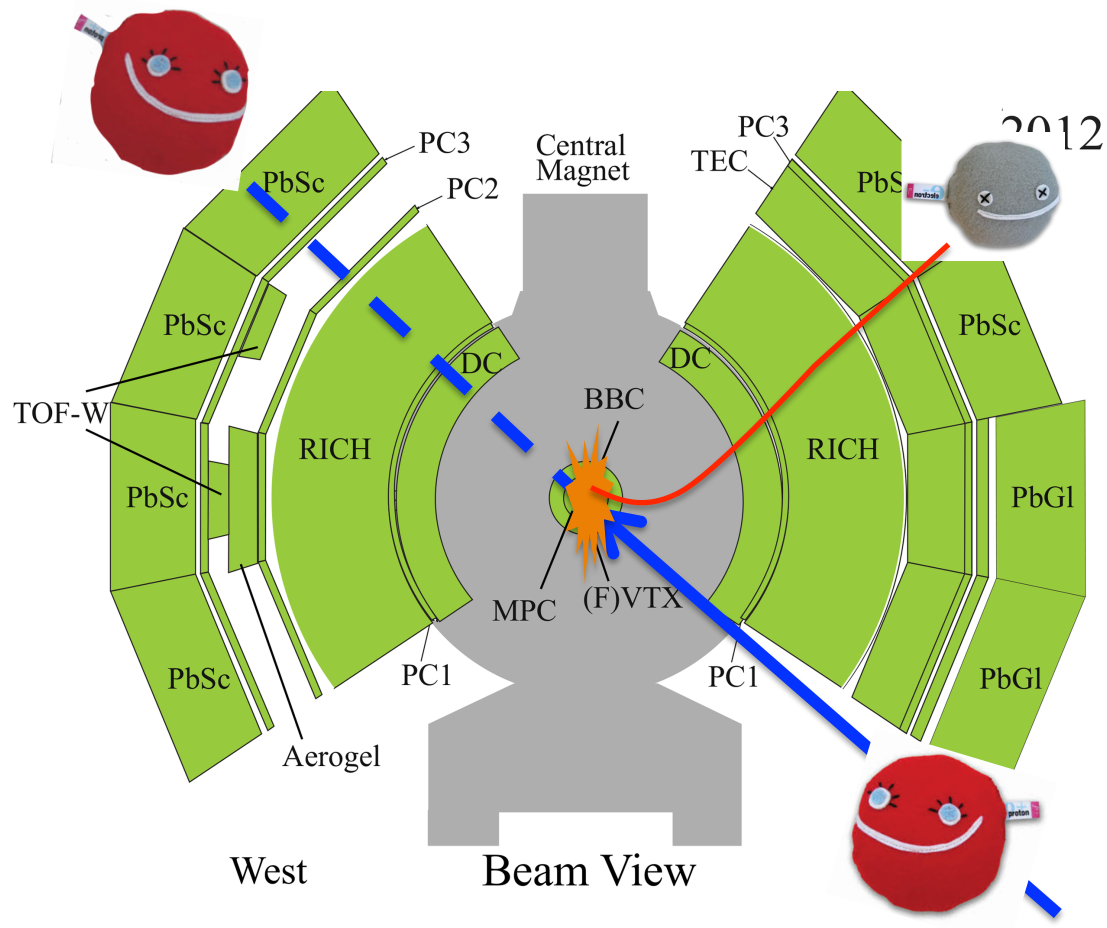
Measure electrons at mid-rapidity

Measure muons at forward/backward rapidity



# PHENIX Central Arm Detector

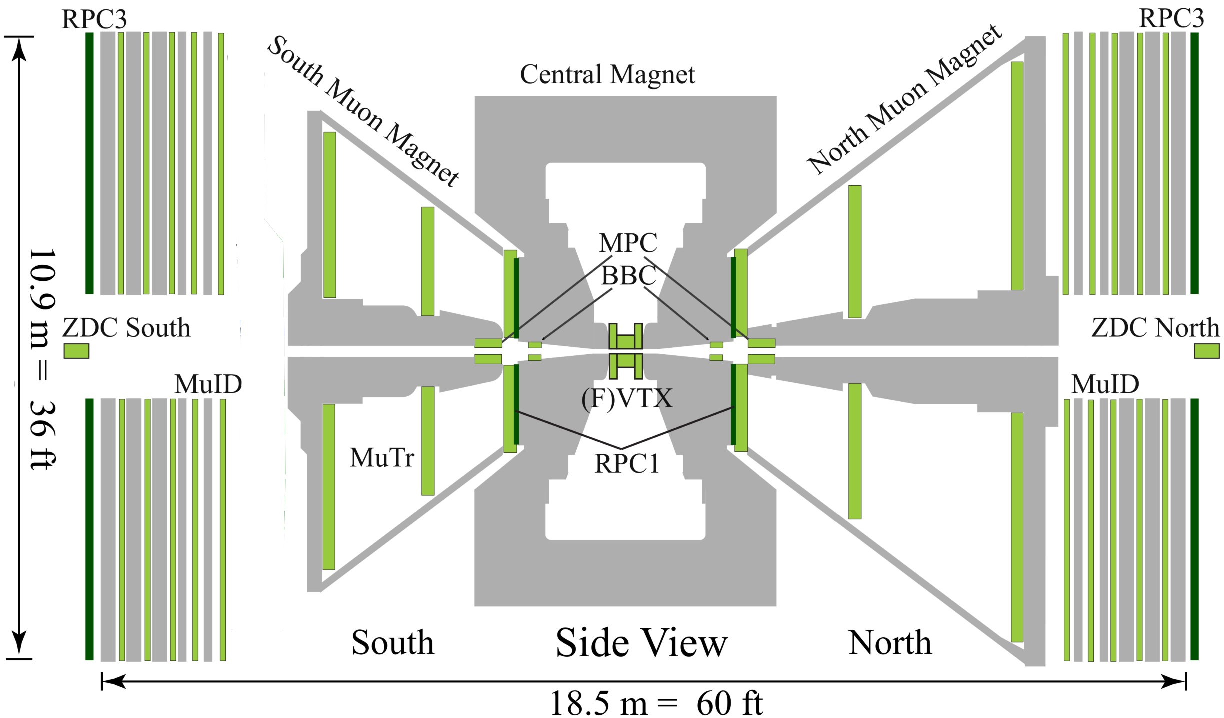


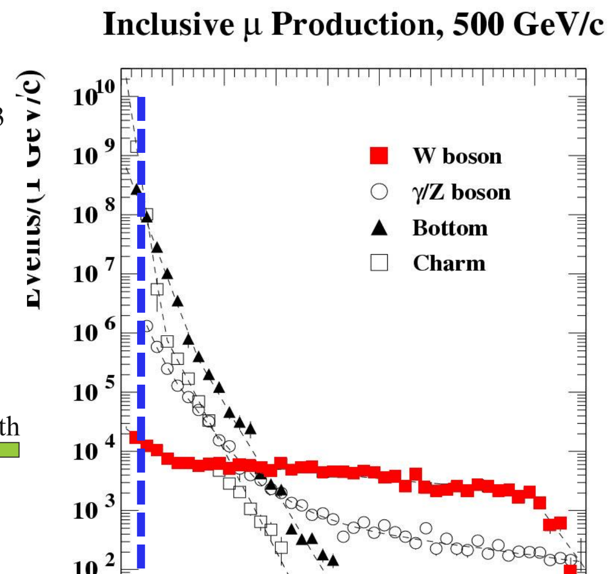



- Measure W → e
- $|\eta| < 0.35$
- $\Delta\phi = \pi$
- Electromagnetic Calorimeter
- DC and PC for tracking and charge separation

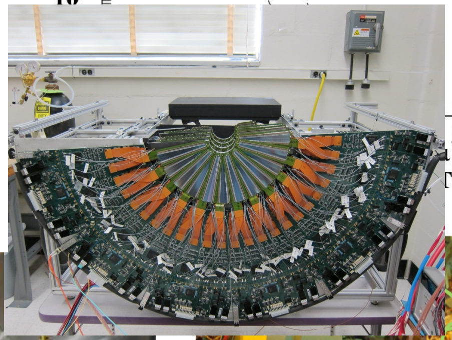
# PHENIX Forward Arm Detector

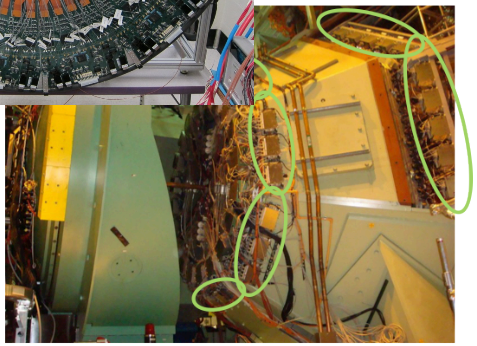
- Forward upgrade



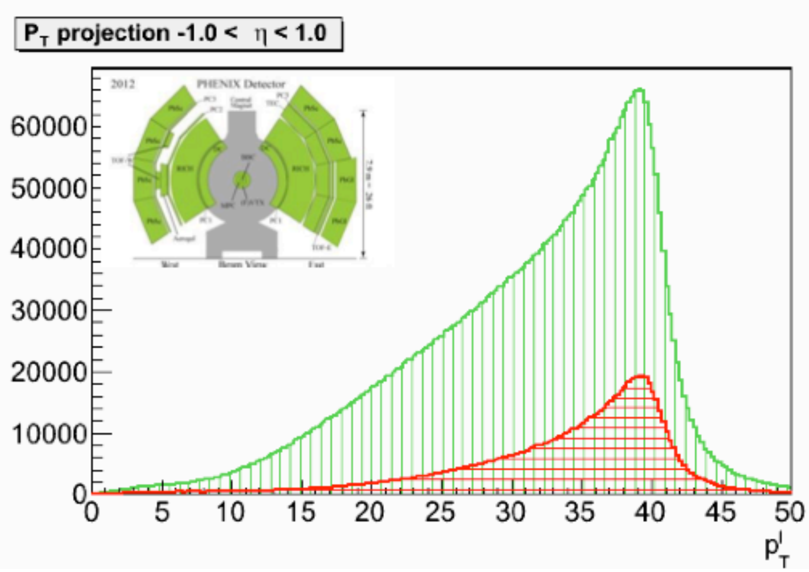



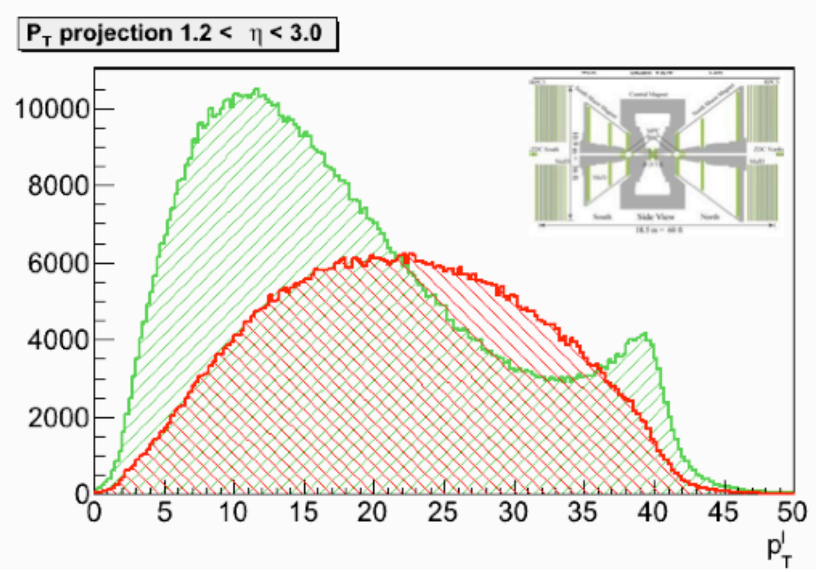

- $1.2 < |\eta| < 2.4$, $\Delta\phi = 2\pi$
- **Fully upgraded in 2012**
- **MuTr, MuID**
- **High-$p_T$ trigger:**
  **small bending in magnetic filed**
  **+ timing (BBC / RPC)**
- **RPCs, FVTX: Additional BG rejection**





# W Kinematics



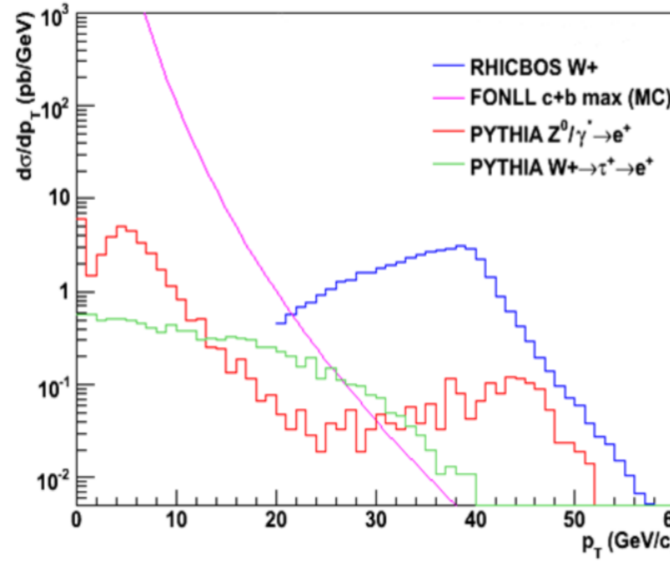

- Different kinematics at mid-rapidity and forward rapidity
- Jacobian peak is only visible at mid-rapidity
- Different analysis approach to identify W

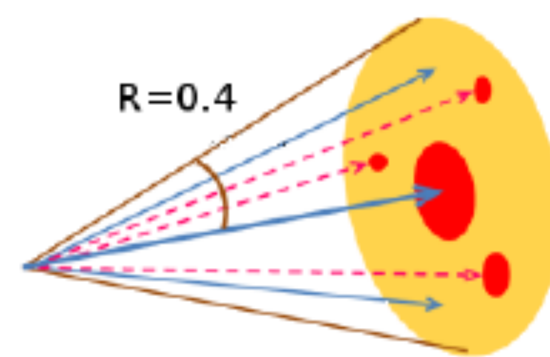
# Mid-rapidity Measurement

- Background:
  - Photons from neutral pion/eta decays followed by $e^{\pm}$ pair production
  - Cosmic rays
  - Beam related backgrounds
  - Z, charm and bottom, other W decays

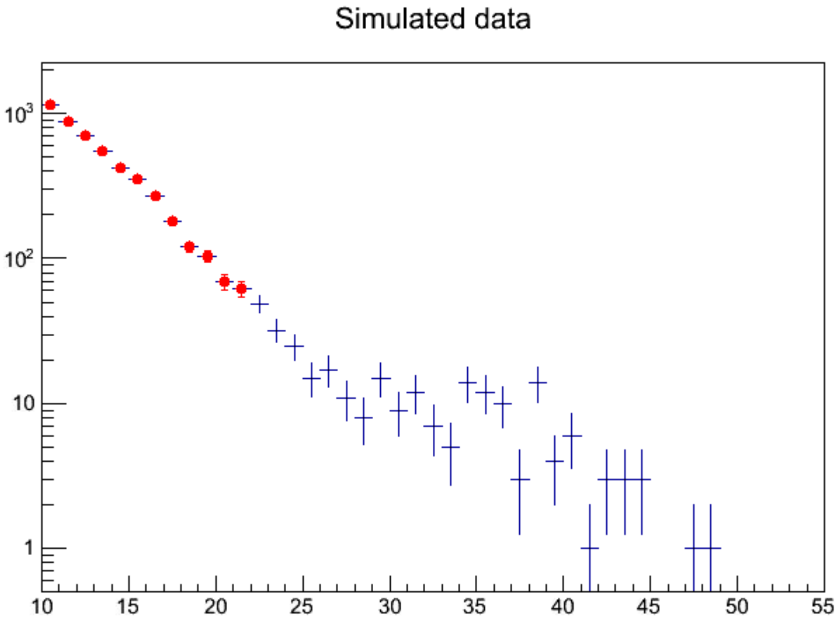
- Reduce background and estimate contribution between 30 and 50 GeV
  - Measure high pT electrons using EMCal
  - DC-EMCal matching ($\Delta\varphi < 0.01$ rad)

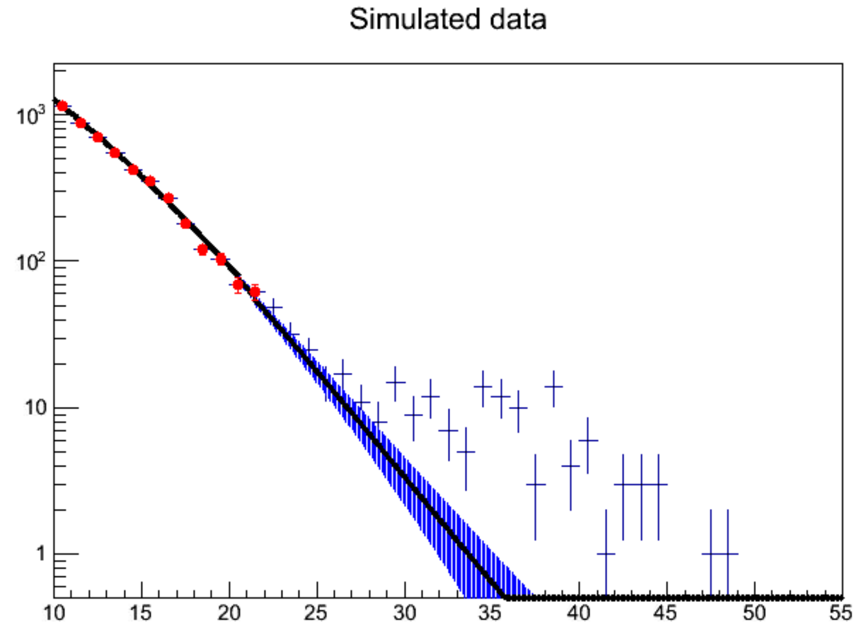
- Relative isolation cut:
  - Main background discriminator
  - Energy in a cone of R=0.4 divided by energy of the candidate
  - reduces background by a factor of 10



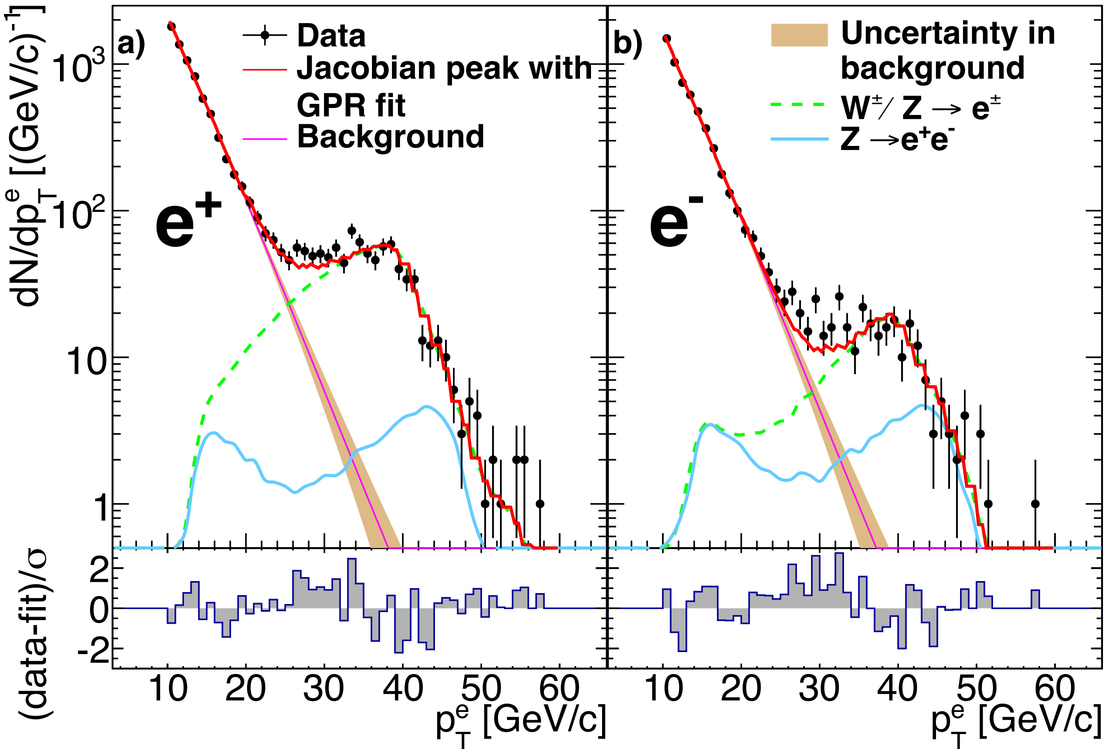
# Gaussian Process Regression




- Use background control region to extrapolate a shape in the 30 to 50 GeV region
- The GPR will give a background contribution and uncertainty
- Cross check with a classical functional form (modified power law) showed good agreement

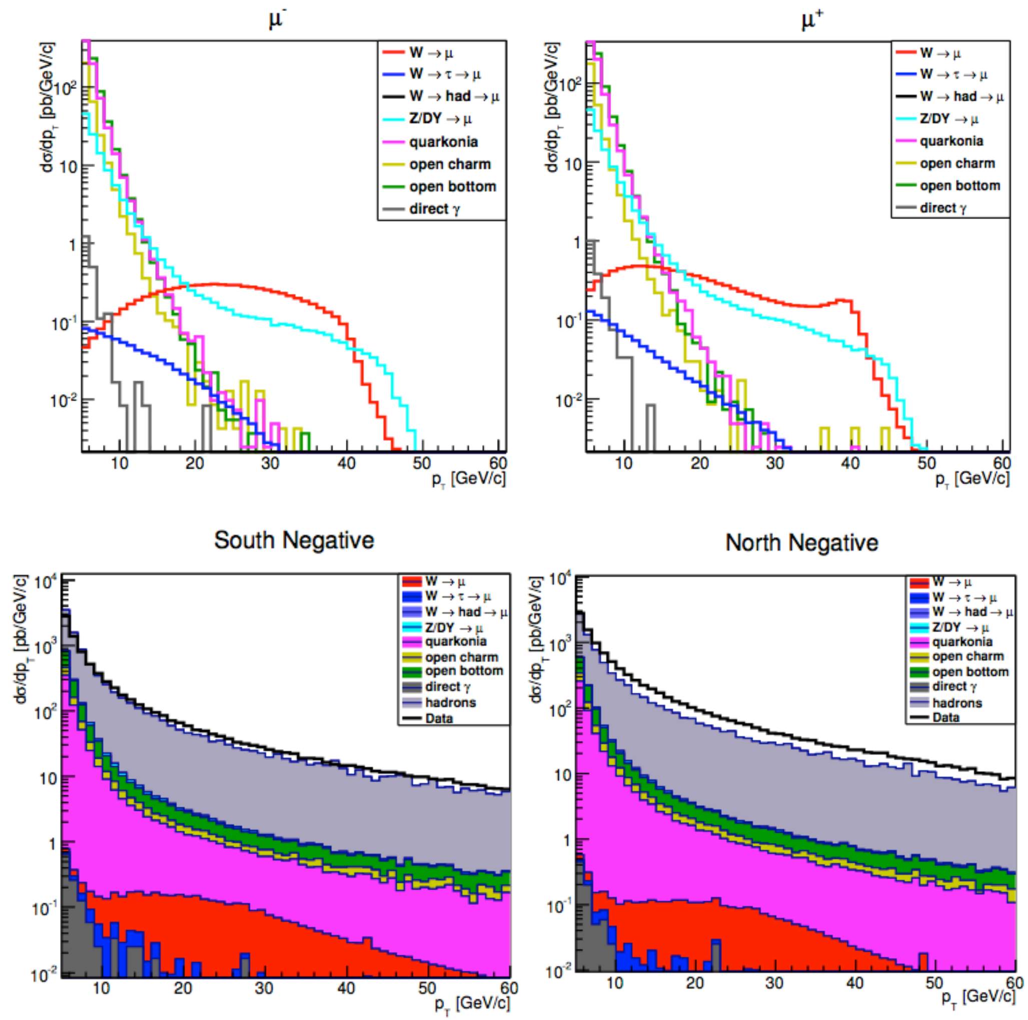
# $p_T$ Spectra




- Fitting with simulated Jacobian peak and GPR background shape
- Estimate the signal-to-background ratio in the signal region (30-50 GeV)
- 97% (94%) of positron signal remains for $e^+$ ($e^-$)

# Forward Rapidity Measurement

- Real muon background:
  - Open heavy flavor, quarkonium, DY/Z
  - Get smeared into high pT region
- Looking for W at pT > 16 GeV/c
- Large Hadron BG contamination: low pT charged kaons, pions.
- Careful signal identification required.

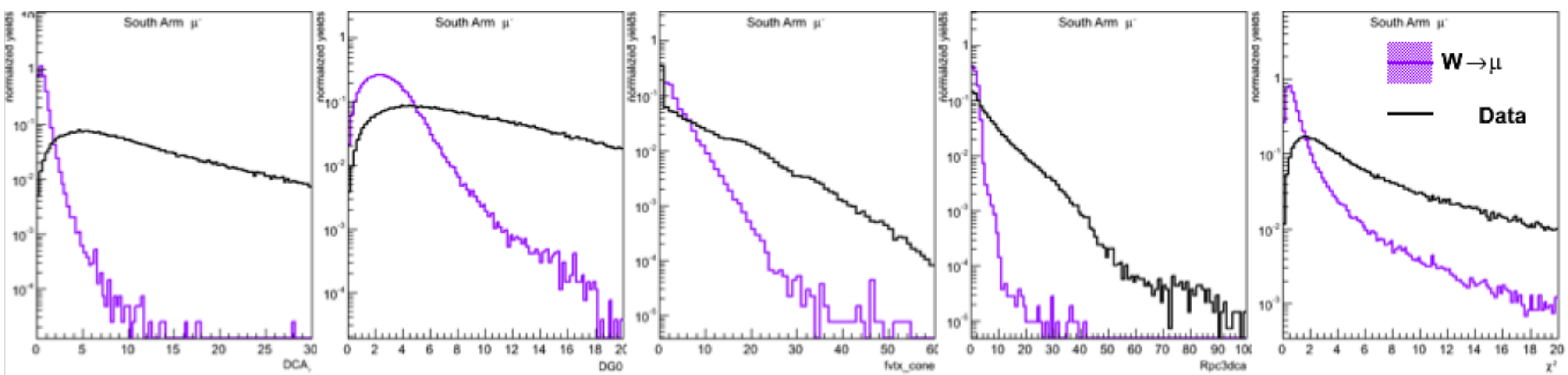


# Background reduction

- Multivariate analysis using likelihood approach
- Signal purity < 1%: use data as background shape at the initial stage
- Define likelihood ratio (Wness) based on signal (MC) and BG shapes (data):

$$\text{Wness} \equiv \frac{\lambda_{\text{sig}}(x)}{\lambda_{\text{sig}}(x) + \lambda_{\text{BGs}}(x)}$$

$$\lambda = p(\text{DG0}, \text{DDG0})\, p(\text{chi2}, \text{DCAr})\, p(\text{RPC\_DCA})\, p(\text{FVTX\_match})\, p(\text{FVTX\_cone})$$



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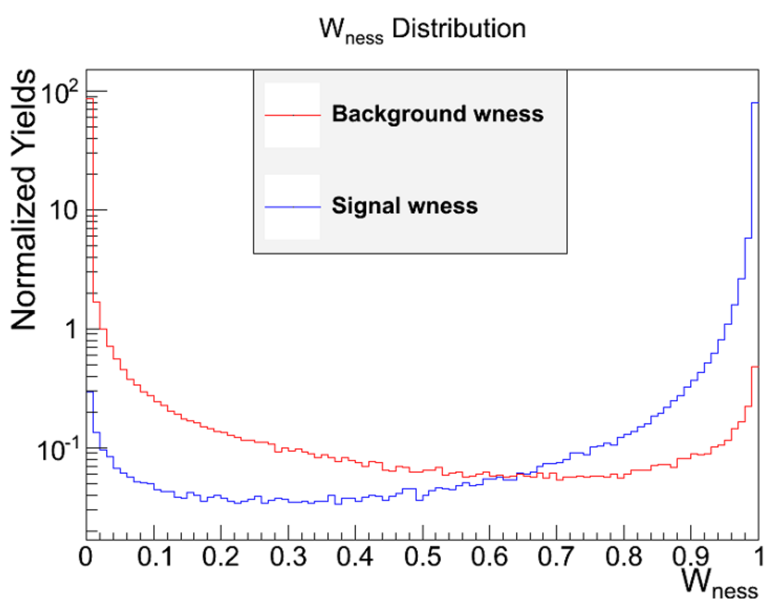
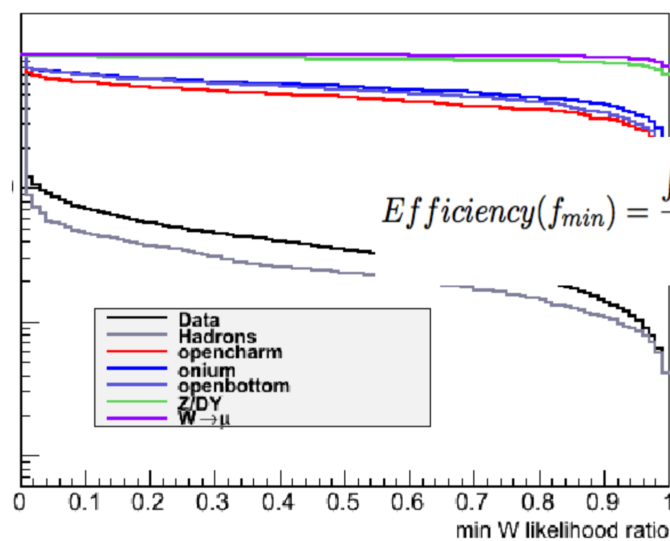
$$\text{Wness} \equiv \frac{\lambda_{\text{sig}}(\text{x})}{\lambda_{\text{sig}}(\text{x}) + \lambda_{\text{BGs}}(\text{x})}$$

*wness*
- wness → 1: signal-like event
- wness → 0: background-like event

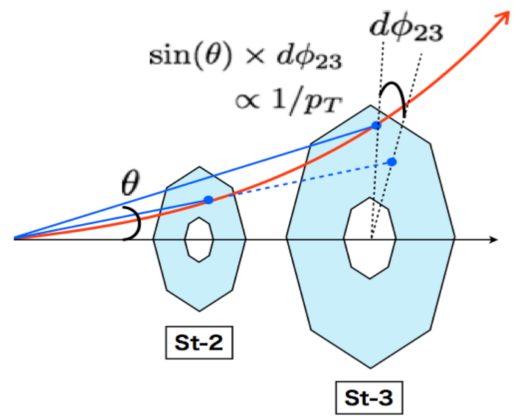


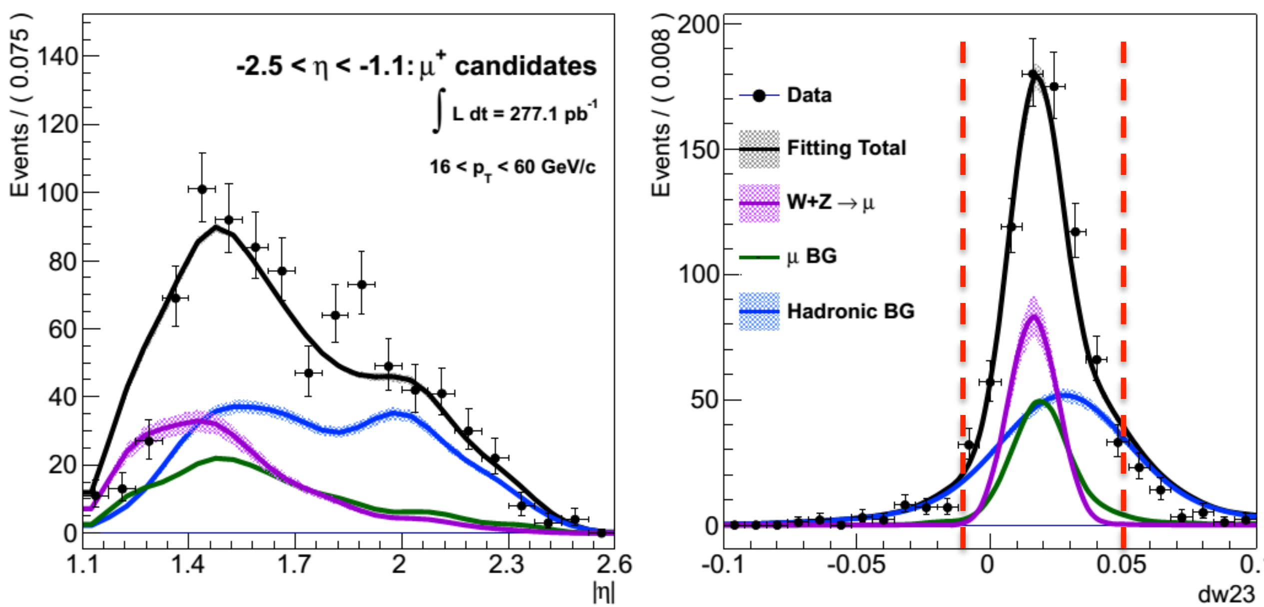

$$Efficiency(f_{min}) = \frac{\int_{f_{min}}^{1} f(wness)\, dwness}{\int_{0}^{1} f(wness)\, dwness}$$

# W Signal Fit

- After the pre-selection, perform 2D unbinned maximum likelihood fit in independent variables: rapidity, effective bending angle (dw23)



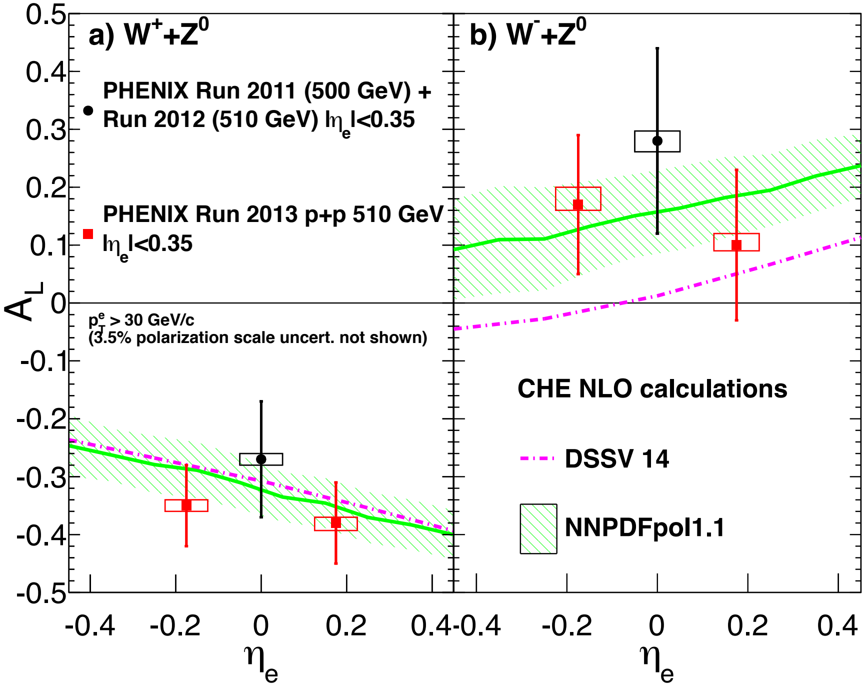

$$\mathrm{dw23} \equiv \mathrm{pT} \times \sin\theta \times \mathrm{d}\phi 23$$

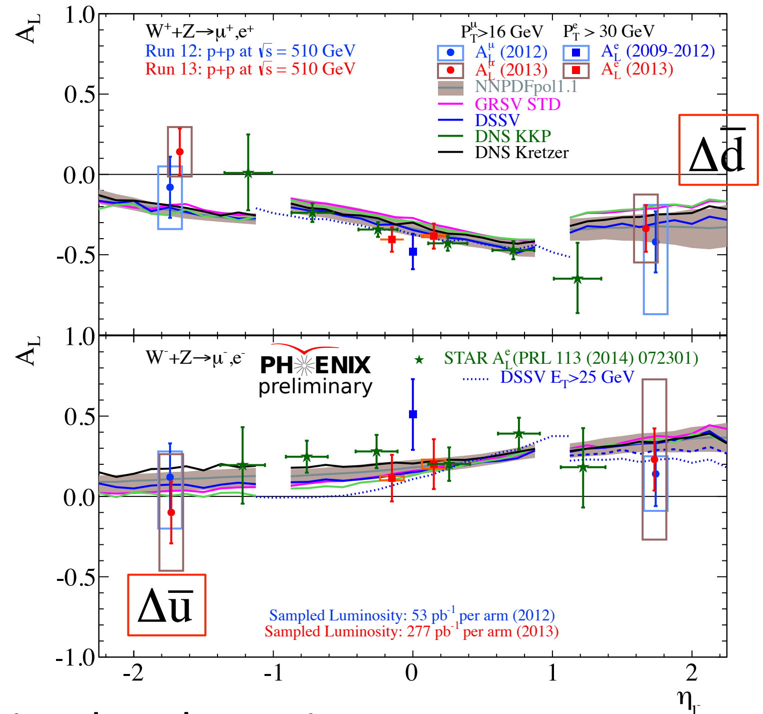



S/B ratio: ~30%-50% depending on the arm/charnge

# $A_L$ Results

arXiv:1504.07451v1 [hep-ex]

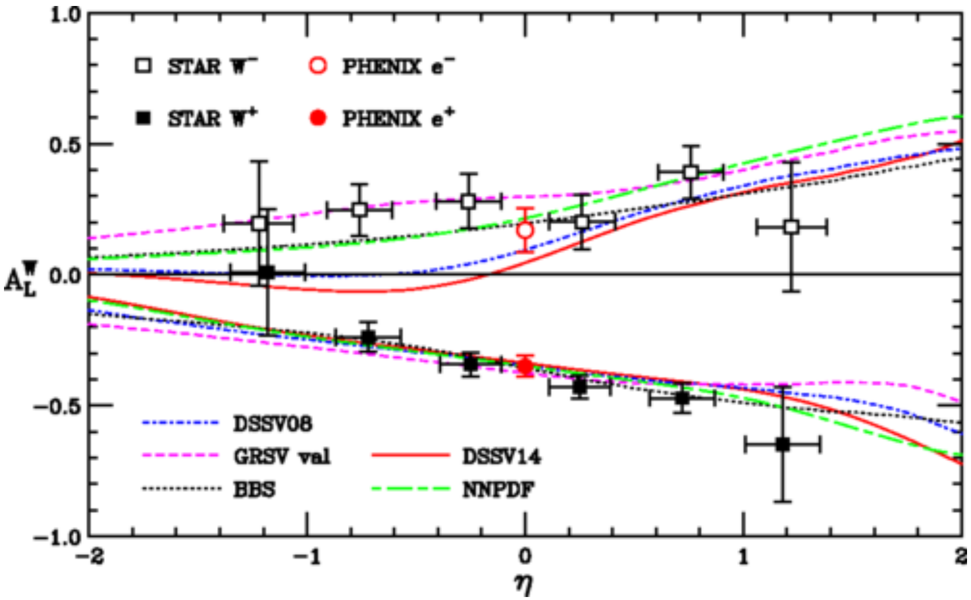


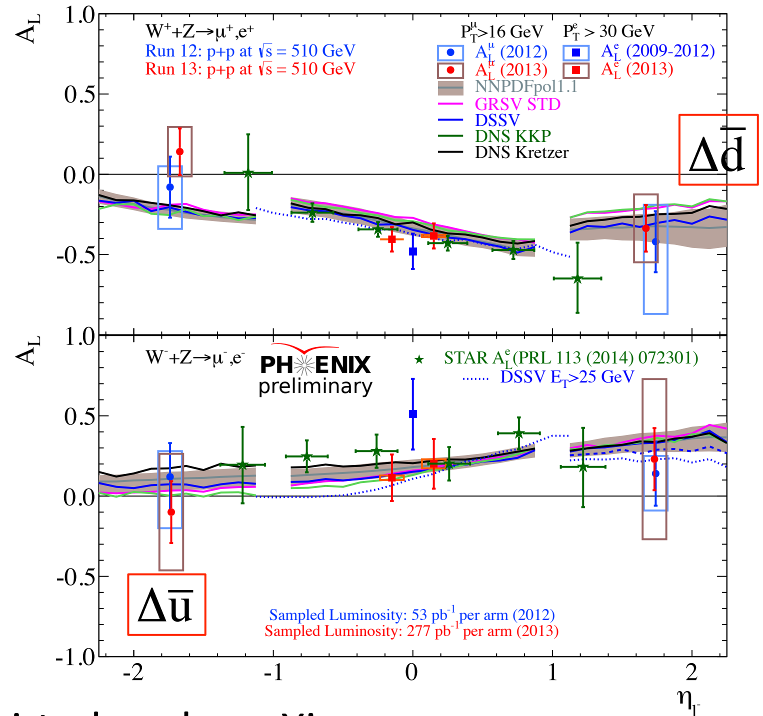




- Mid-rapidity results has been recently submitted to the arXiv
  - included in the recent global analysis
- Preliminary results at forward/backward rapidities
- Mid-rapidity and forward rapidity results show good agreement with theory predictions
- AL at backward rapidity tends to be smaller/positive

# $A_L$ Results

Phys. Rev. D 91, 094033 (2015)




- Mid-rapidity results has been recently submitted to the arXiv
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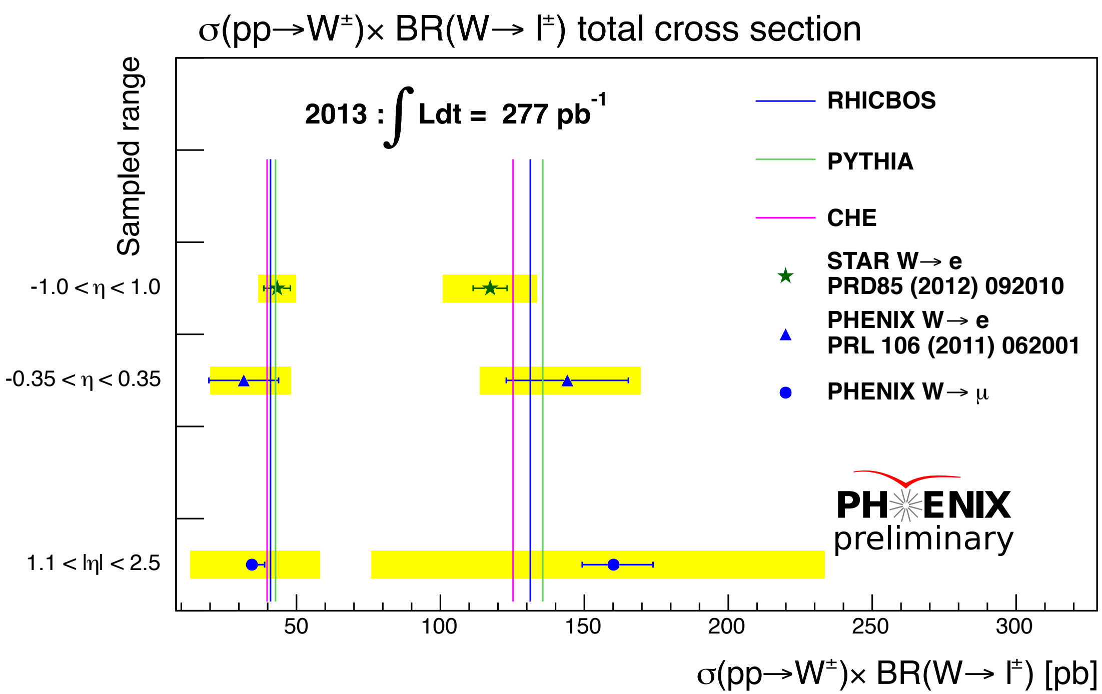
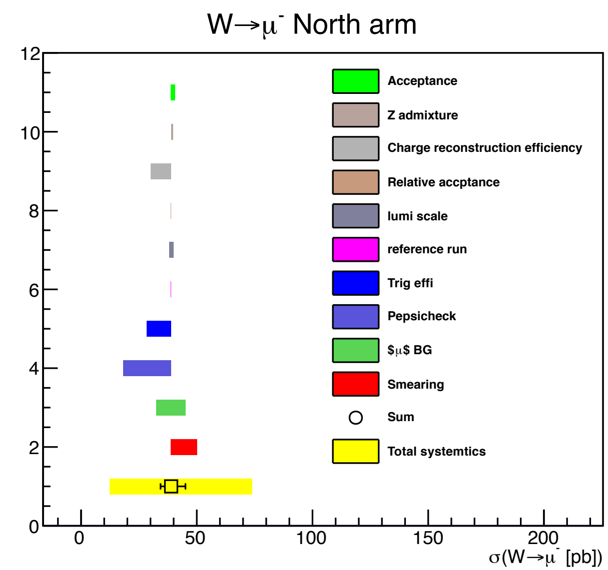
# Cross Section Results




Contributions to systematic uncertainty for W→μ

- Cross section for the W→e using 2009 data (Phys.Rev.Lett. 106:062001)
- Preliminary for the W→μ using 2013 data: consistent with prediction within large systematic uncertainty

# Summary

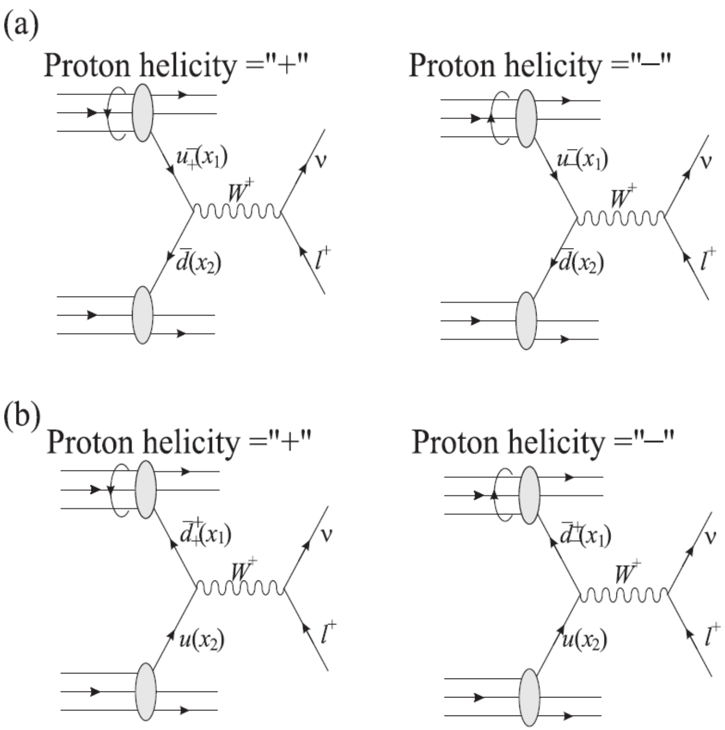
- W cross section, single spin asymmetry $A_L$ are measured using all available data collected at PHENIX

- Mid-rapidity measurement (W→e):
  - Final $A_L$ result has been submitted to the arXiv
  - Work in progress on the cross section measurement using 2013 data

- Forward rapidity measurement (W→$\mu$):
  - Preliminary results
  - Ongoing analysis efforts to reduce systematics

# Backup

# W measurement

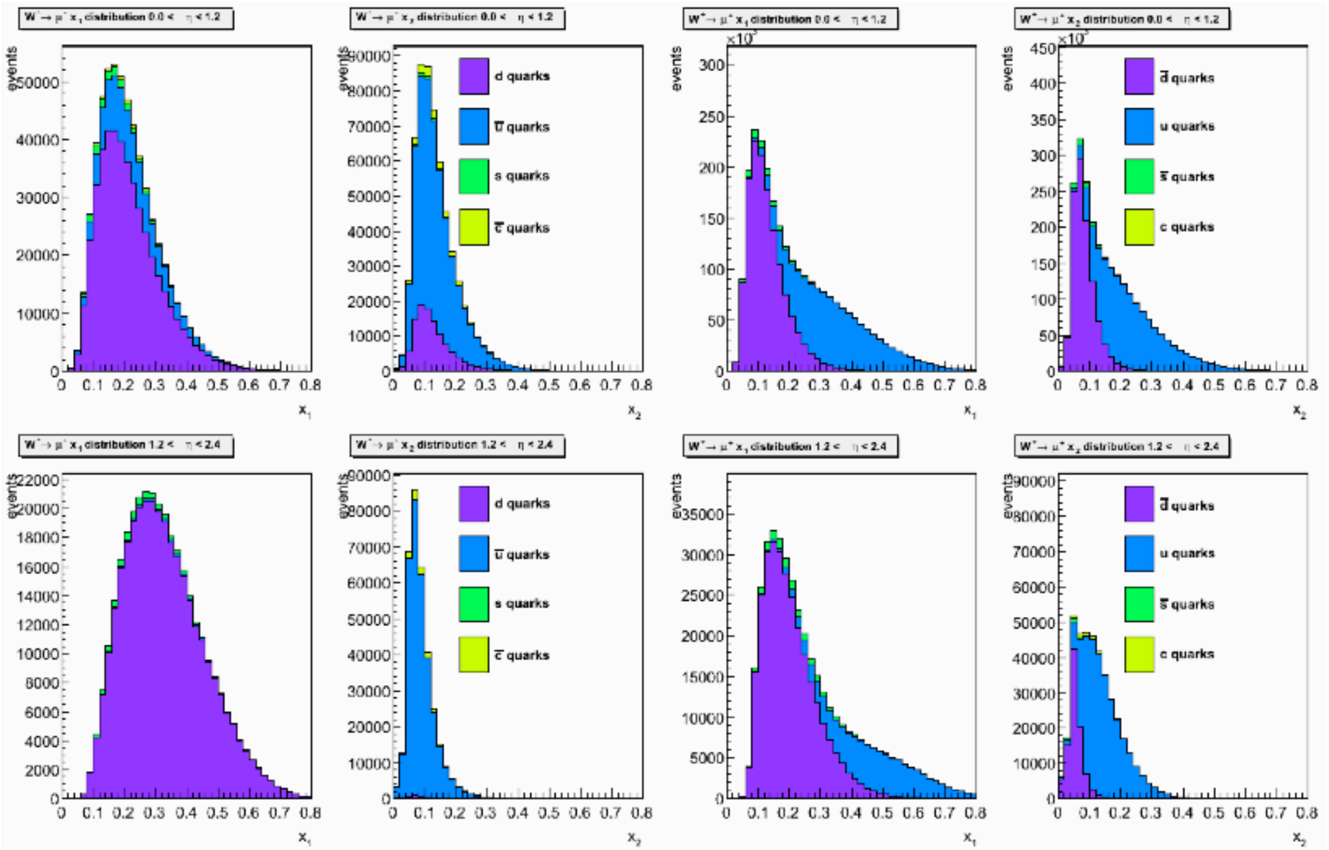



$$A_L^{W^+}(y) = \frac{-u^+(x_1)\bar{d}(x_2) - (-u^-(x_1))\bar{d}(x_2)}{u^+(x_1)\bar{d}(x_2) + u^-(x_1)\bar{d}(x_2)}$$

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

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

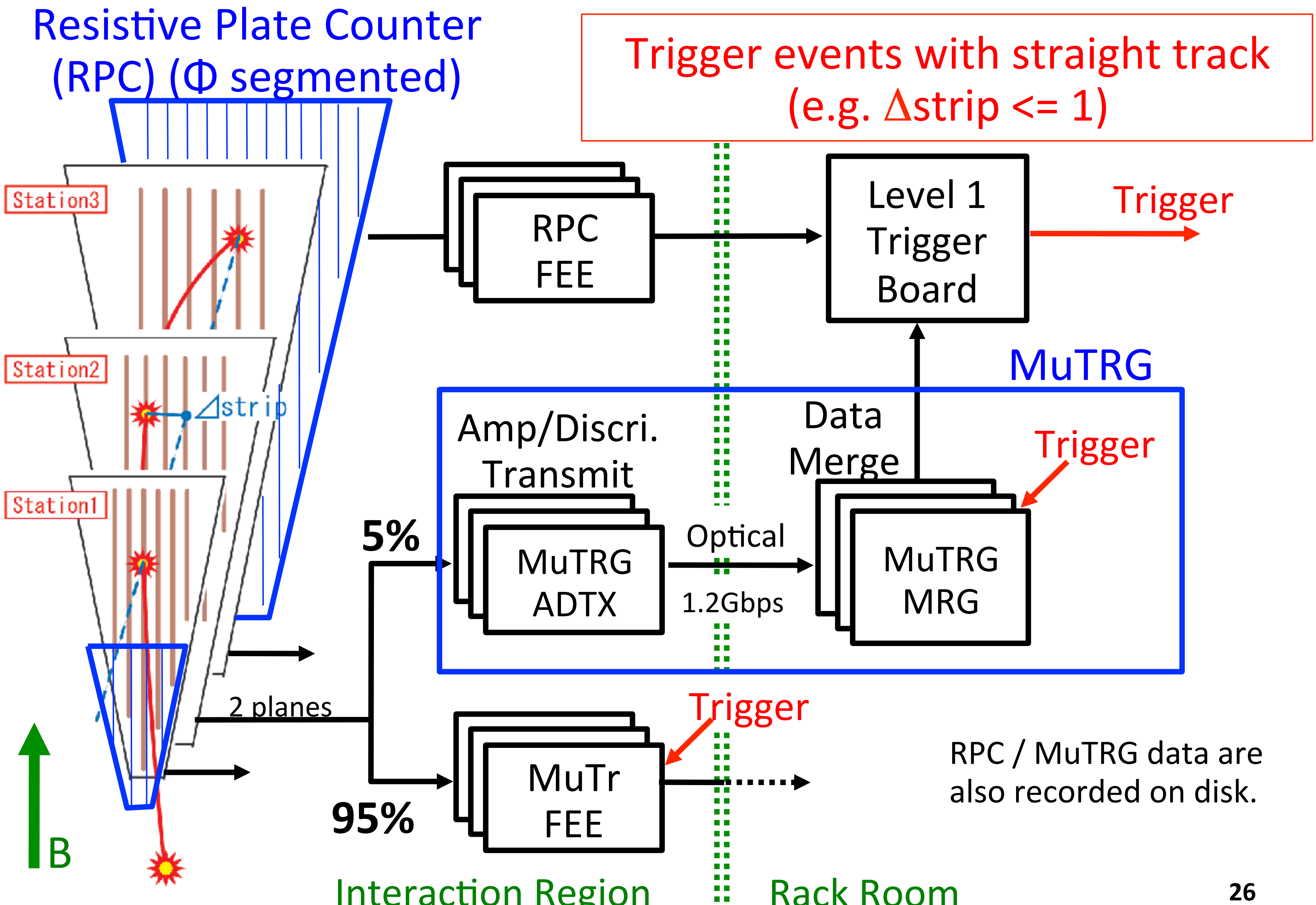
# PYTHIA: x1, x2




$$A_L^{e^+} = \frac{\Delta\bar{d}(x_1)u(x_2)(1+\cos\theta_l)^2 - \Delta u(x_1)\bar{d}(x_2)(1-\cos\theta_l)^2}{\bar{d}(x_1)u(x_2)(1+\cos\theta_l)^2 + u(x_1)\bar{d}(x_2)(1-\cos\theta_l)^2}$$

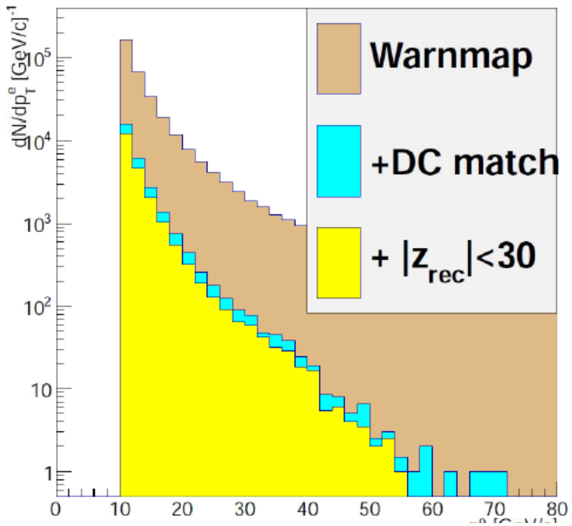
$$A_L^{e^-} = \frac{\Delta\bar{u}(x_1)d(x_2)(1-\cos\theta_l)^2 - \Delta d(x_1)\bar{u}(x_2)(1+\cos\theta_l)^2}{\bar{u}(x_1)d(x_2)(1-\cos\theta_l)^2 + d(x_1)\bar{u}(x_2)(1+\cos\theta_l)^2}.$$

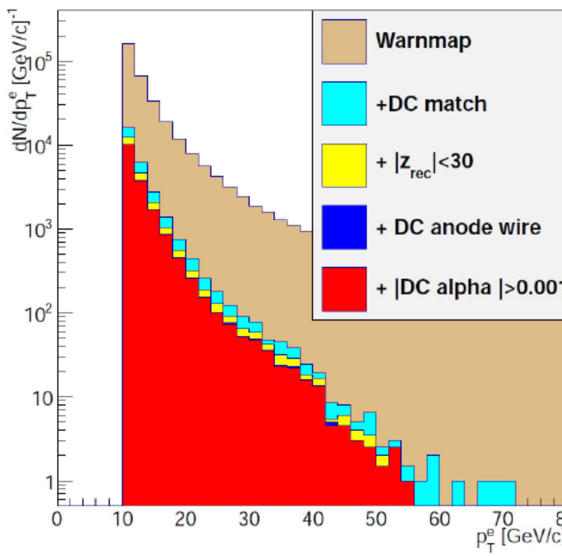
# W Trigger System



# Event selection and basic cuts

- Select high EMCal clusters
- Match to DC tracks
- Reconstruct the z vertex position
- Remove problem areas in the DC
- Remove tracks that have a very small bending angle to increase purity



# Gaussian Process Regression

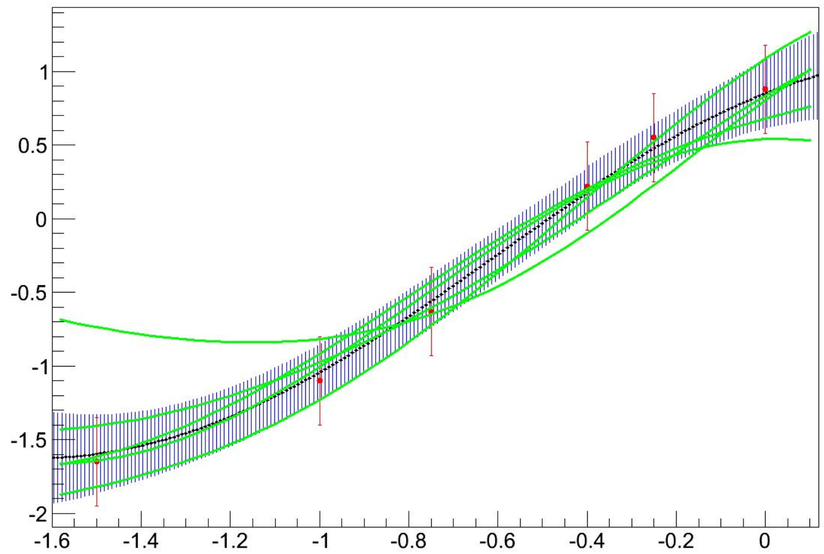
- When functional form is not known apriori
- Shift focus from prior knowledge over parameters to prior over functions (with some minimal constraints)

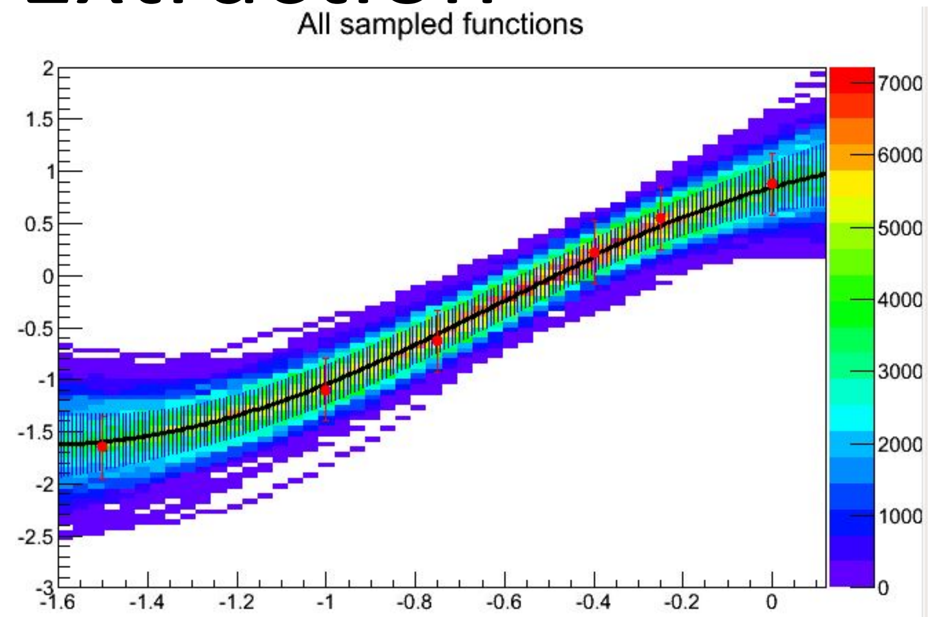
$$k(x, x') = \sigma_f^2 \exp\left[\frac{-(x - x')^2}{2l^2}\right] + \sigma_n^2 \delta(x, x')$$

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

# Function Extraction



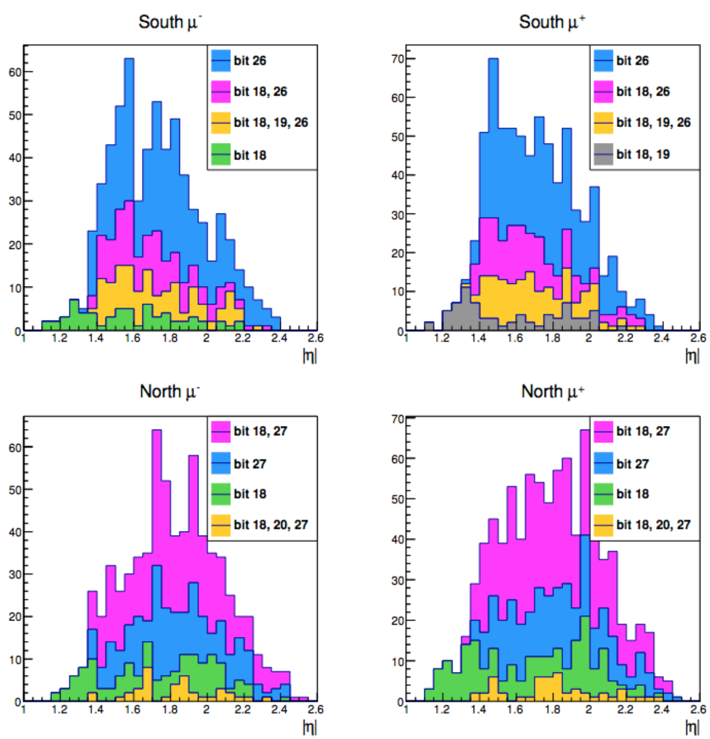



- Sampling over these functions and filling a 2D histogram (as on the right) will give a Gaussian distribution for each prediction point
- The mean of the Gaussian distribution is the prediction and the sigma is the uncertainty
- *The GPR we use does this mathematically through the equations I presented 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*

# Trigger Efficiency

1. Scanned contributions of each trigger combination within the muon data



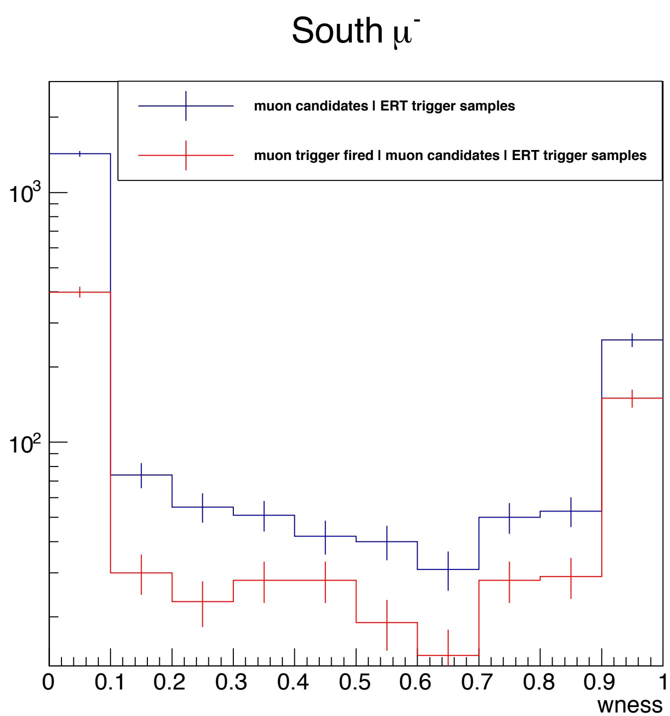

< PHENIX physics triggers >

| Trigger bit | Name |
|---|---|
| 0 | BBCLL1(> 0 tubes) |
| 1 | BBCLL1(> 0 tubes) novertex |
| 2 | ZDCLL1wide |
| 3 | BBCLL1(noVtx)&(ZDCN‖ZDCS) |
| 4 | BBCLL1(> 0 tubes) narrowvtx |
| 5 | ZDCNS |
| 6 | ERTLL1_4×4b |
| 7 | [illegible] |
| 8 | [illegible] |
| 9 | [illegible] |
| 10 | [illegible] |
| 11 | [illegible] |
| 12 | [illegible] |
| 13 | [illegible] |
| 14 | MPC_C&ERT_2×2 |
| 15 | (MPCS_C & MPCS_C & MPCN_C) |
| 16 | ((MUIDLL1_N2D‖S2D)‖(N1D&N2D))&BBCLL1(noVtx) |
| 17 | (MUIDLL1_N1D‖S1D)&BBCLL1(noVtx) |
| 18 | (MUON_S_SG1&MUIDLL1_S1D)‖ (MUON_N_SG1&MUIDLL1_N1D)&BBCLL1(noVtx) |
| 19 | MUON_S_SG3&MUIDLL1_S1D&BBCLL1(noVtx) |
| 20 | MUON_N_SG3&MUIDLL1_N1D&BBCLL1(noVtx) |
| 21 | (MUON_N_SG3&MUIDLL1_N1H)‖ (MUON_S_SG3&MUIDLL1_S1H)&BBCLL1(noVtx) |
| 22 | MUON_S_SG3&BBCLL1(noVtx) |
| 23 | MUON_N_SG3&BBCLL1(noVtx) |
| 24 | MUON_S_SG1&BBCLL1(noVtx) |
| 25 | MUON_N_SG1&BBCLL1(noVtx) |
| 26 | MUON_S_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |
| 27 | MUON_N_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |

Used all muon arm triggers to maximize statistics

# Trigger Efficiency

2. Measure the trigger efficiencies for each trigger combination using electron trigger samples



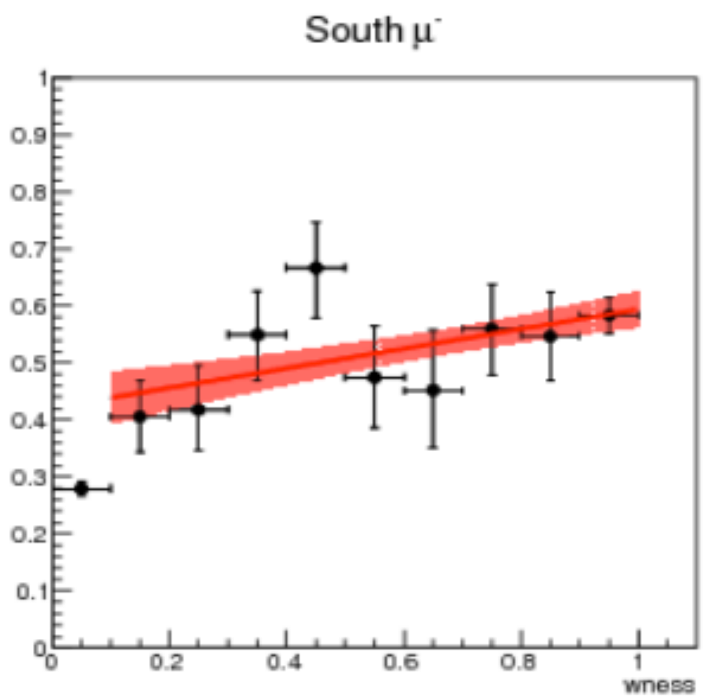

< PHENIX physics triggers >

Electron / photon triggers

| Trigger bit | Name |
|---|---|
| 0 | BBCLL1(> 0 tubes) |
| 1 | BBCLL1(> 0 tubes) novertex |
| 2 | [illegible] |
| 3 | [illegible] |
| 4 | [illegible] |
| 5 | ZDCNS |
| 6 | ERTLL1_4×4b |
| 7 | ERTLL1_4×4a&BBCLL1 |
| 8 | ERTLL1_4×4c&BBCLL1(narrow) |
| 9 | ERTLL1_E |
| 10 | ERTLL1_E&BBCLL1(narrow) |
| 11 | CLOCK |
| 12 | MPC_B |
| 13 | MPC_A |
| 14 | MPC_C&ERT_2×2 |
| 15 | (MPCS_C & MPCS_C & MPCN_C) |
| 16 | ((MUIDLL1_N2D‖S2D)‖(N1D&N2D))&BBCLL1(noVtx) |
| 17 | (MUIDLL1_N1D‖S1D)&BBCLL1(noVtx) |
| 18 | (MUON_S_SG1&MUIDLL1_S1D)‖ (MUON_N_SG1&MUIDLL1_N1D)&BBCLL1(noVtx) |
| 19 | MUON_S_SG3&MUIDLL1_S1D&BBCLL1(noVtx) |
| 20 | MUON_N_SG3&MUIDLL1_N1D&BBCLL1(noVtx) |
| 21 | (MUON_N_SG3&MUIDLL1_N1H)‖ (MUON_S_SG3&MUIDLL1_S1H)&BBCLL1(noVtx) |
| 22 | MUON_S_SG3&BBCLL1(noVtx) |
| 23 | MUON_N_SG3&BBCLL1(noVtx) |
| 24 | MUON_S_SG1&BBCLL1(noVtx) |
| 25 | MUON_N_SG1&BBCLL1(noVtx) |
| 26 | MUON_S_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |
| 27 | MUON_N_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |

# Trigger Efficiency

2. Measure the trigger efficiencies for each trigger combination using electron trigger samples




< PHENIX physics triggers >

Electron / photon triggers

| Trigger bit | Name |
|---|---|
| 0 | BBCLL1(> 0 tubes) |
| 1 | BBCLL1(> 0 tubes) novertex |
| 2 | [illegible] |
| 3 | [illegible] |
| 4 | [illegible] |
| 5 | ZDCNS |
| 6 | ERTLL1_4×4b |
| 7 | ERTLL1_4×4a&BBCLL1 |
| 8 | ERTLL1_4×4c&BBCLL1(narrow) |
| 9 | ERTLL1_E |
| 10 | ERTLL1_E&BBCLL1(narrow) |
| 11 | CLOCK |
| 12 | MPC_B |
| 13 | MPC_A |
| 14 | MPC_C&ERT_2×2 |
| 15 | (MPCS_C & MPCS_C & MPCN_C) |
| 16 | ((MUIDLL1_N2D‖S2D)‖(N1D&N2D))&BBCLL1(noVtx) |
| 17 | (MUIDLL1_N1D‖S1D)&BBCLL1(noVtx) |
| 18 | (MUON_S_SG1&MUIDLL1_S1D)‖ (MUON_N_SG1&MUIDLL1_N1D)&BBCLL1(noVtx) |
| 19 | MUON_S_SG3&MUIDLL1_S1D&BBCLL1(noVtx) |
| 20 | MUON_N_SG3&MUIDLL1_N1D&BBCLL1(noVtx) |
| 21 | (MUON_N_SG3&MUIDLL1_N1H)‖ (MUON_S_SG3&MUIDLL1_S1H)&BBCLL1(noVtx) |
| 22 | MUON_S_SG3&BBCLL1(noVtx) |
| 23 | MUON_N_SG3&BBCLL1(noVtx) |
| 24 | MUON_S_SG1&BBCLL1(noVtx) |
| 25 | MUON_N_SG1&BBCLL1(noVtx) |
| 26 | MUON_S_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |
| 27 | MUON_N_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |

# Trigger Efficiency

3. Calculate the total trigger efficiency for all trigger combinations

$$\epsilon_{total} = \sum_{trigger} \epsilon_{trigger} \times f_{trigger}$$

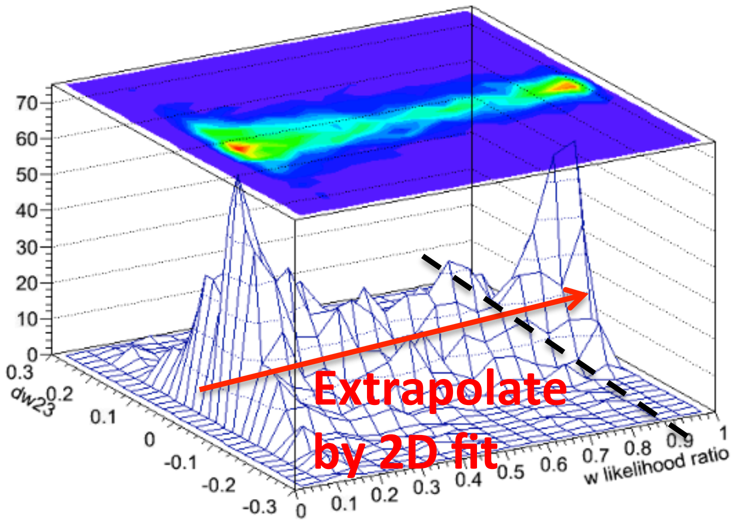
| Arm | Charge | $\epsilon_{total}$ |
|---|---|---|
| South | Negative | $0.450 \pm 0.016$ |
| South | Positive | $0.463 \pm 0.015$ |
| North | Negative | $0.573 \pm 0.019$ |
| North | Positive | $0.557 \pm 0.016$ |

< PHENIX physics triggers >

| Trigger bit | Name |
|---|---|
| 0 | BBCLL1(> 0 tubes) |
| 1 | BBCLL1(> 0 tubes) novertex |
| 2 | [illegible] |
| 3 | [illegible] |
| 4 | [illegible] |
| 5 | ZDCNS |
| 6 | ERTLL1_4×4b |
| 7 | ERTLL1_4×4a&BBCLL1 |
| 8 | ERTLL1_4×4c&BBCLL1(narrow) |
| 9 | ERTLL1_E |
| 10 | ERTLL1_E&BBCLL1(narrow) |
| 11 | CLOCK |
| 12 | MPC_B |
| 13 | MPC_A |
| 14 | MPC_C&ERT_2×2 |
| 15 | (MPCS_C & MPCS_C & MPCN_C) |
| 16 | ((MUIDLL1_N2D‖S2D)‖(N1D&N2D))&BBCLL1(noVtx) |
| 17 | (MUIDLL1_N1D‖S1D)&BBCLL1(noVtx) |
| 18 | (MUON_S_SG1&MUIDLL1_S1D)‖ (MUON_N_SG1&MUIDLL1_N1D)&BBCLL1(noVtx) |
| 19 | MUON_S_SG3&MUIDLL1_S1D&BBCLL1(noVtx) |
| 20 | MUON_N_SG3&MUIDLL1_N1D&BBCLL1(noVtx) |
| 21 | (MUON_N_SG3&MUIDLL1_N1H)‖ (MUON_S_SG3&MUIDLL1_S1H)&BBCLL1(noVtx) |
| 22 | MUON_S_SG3&BBCLL1(noVtx) |
| 23 | MUON_N_SG3&BBCLL1(noVtx) |
| 24 | MUON_S_SG1&BBCLL1(noVtx) |
| 25 | MUON_N_SG1&BBCLL1(noVtx) |
| 26 | MUON_S_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |
| 27 | MUON_N_SG1_RPC3_1_A‖B‖C&BBCLL1(noVtx) |

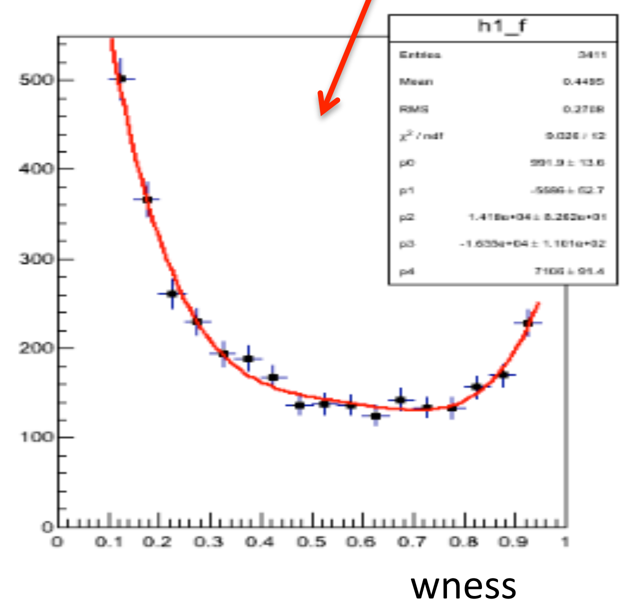
Electron / photon triggers

# dw23 for Hadron Background

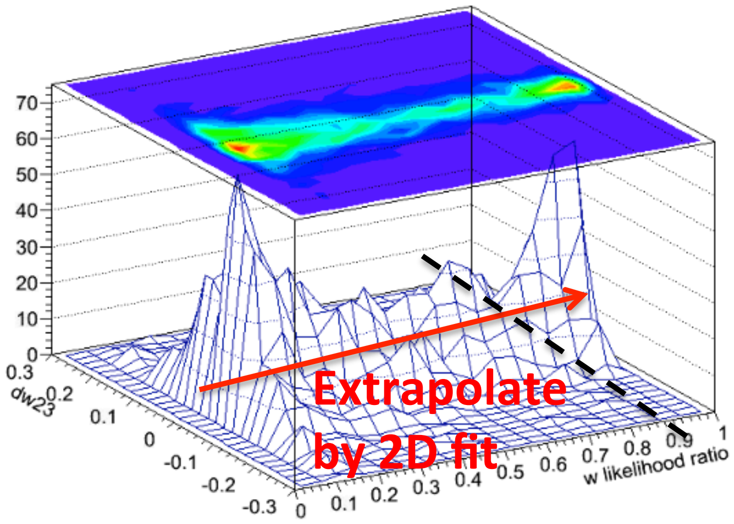



## 2D model of dw23-wness

$$p(\text{wness}, \text{dw23}) = p(\text{wness}) \cdot p(\text{dw23} \mid \text{wness})$$



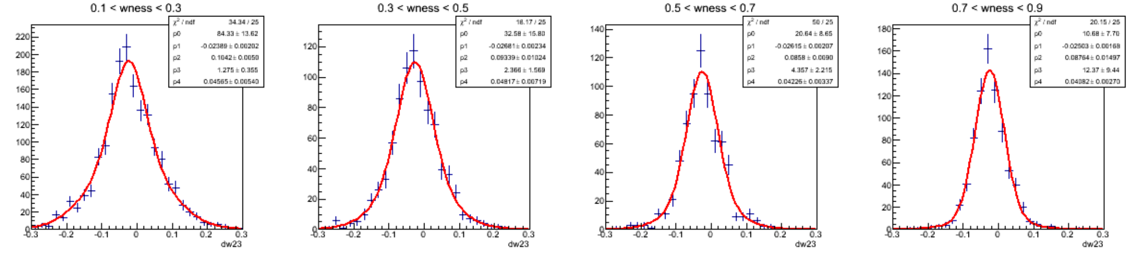
# dw23 for Hadron Background




## 2D model of dw23-wness

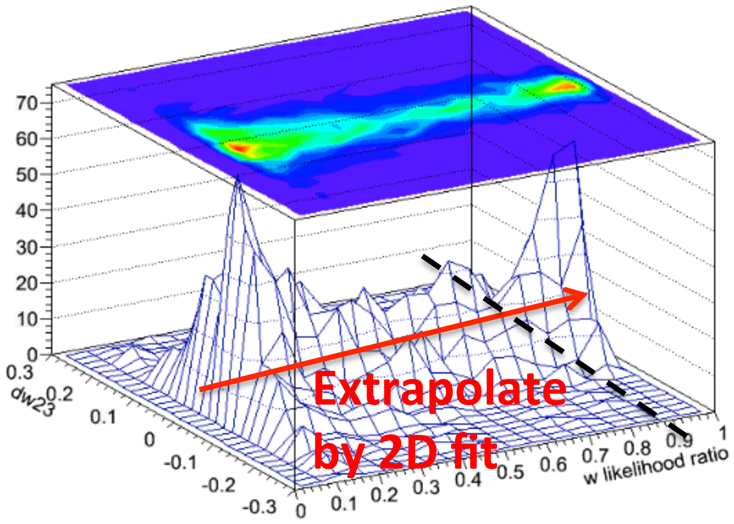
$$p(\text{wness}, \text{dw23}) = p(\text{wness}) \cdot p(\text{dw23} \mid \text{wness})$$

- Fit model: Coaxial double gaussian
- Vary parameters linearly




Slice of dw23 distributions

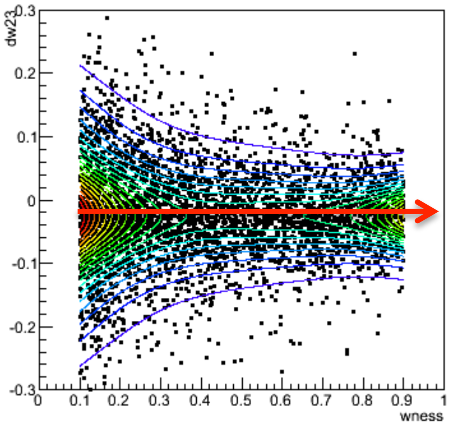
# dw23 for Hadron Background



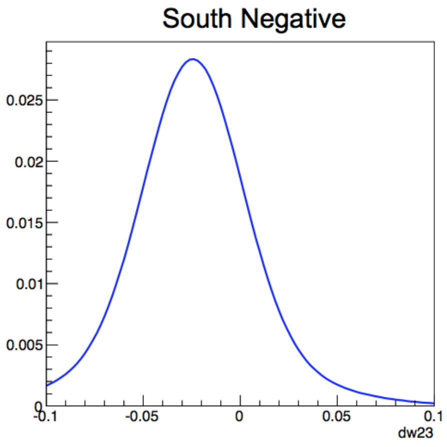

## 2D model of dw23-wness

$$p(\text{wness}, \text{dw23}) = p(\text{wness}) \cdot p(\text{dw23} \mid \text{wness})$$

2D fit result



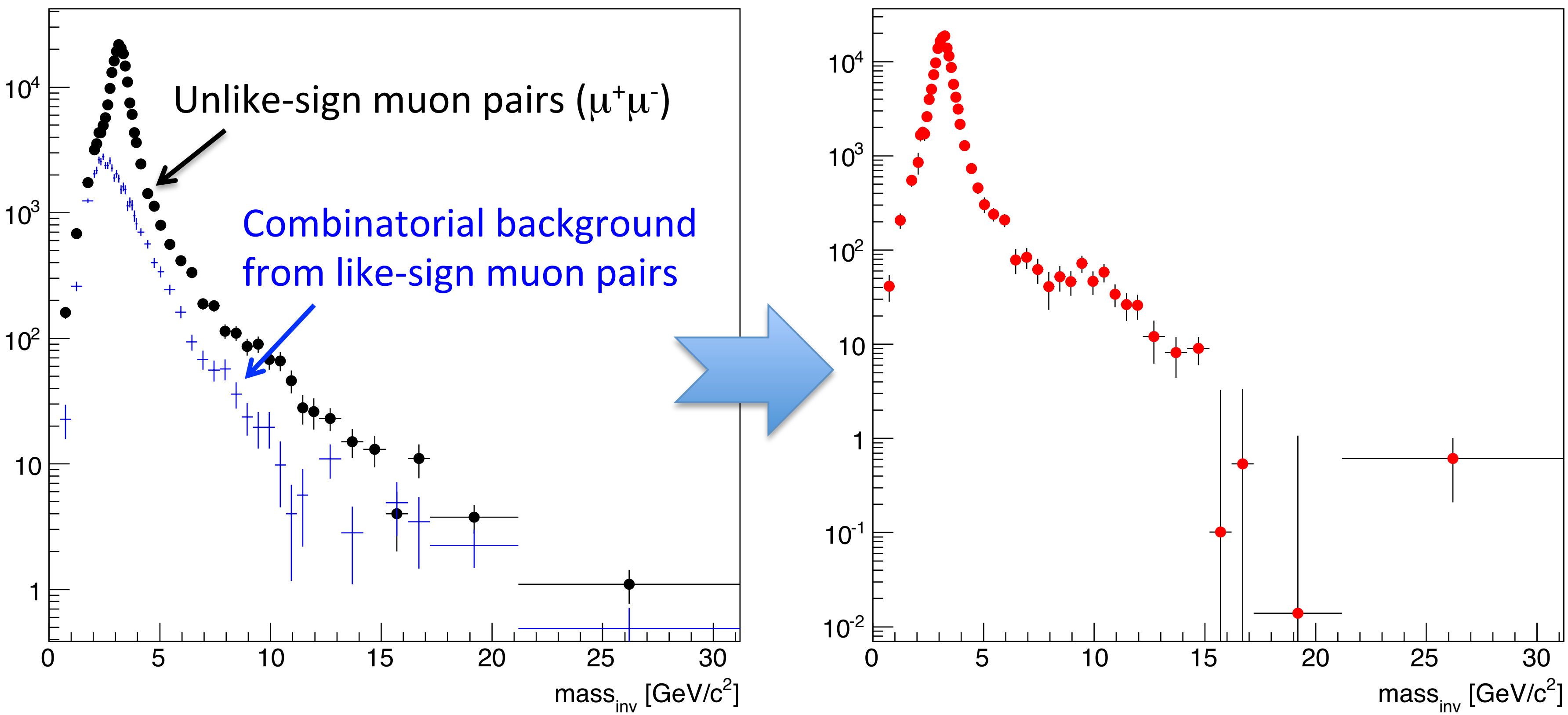

Extrapolate the fit function to the target wness region.



# Muon Background Estimation

- Real muon background is fixed in the signal fit
- Muon background is estimated by di-muon events

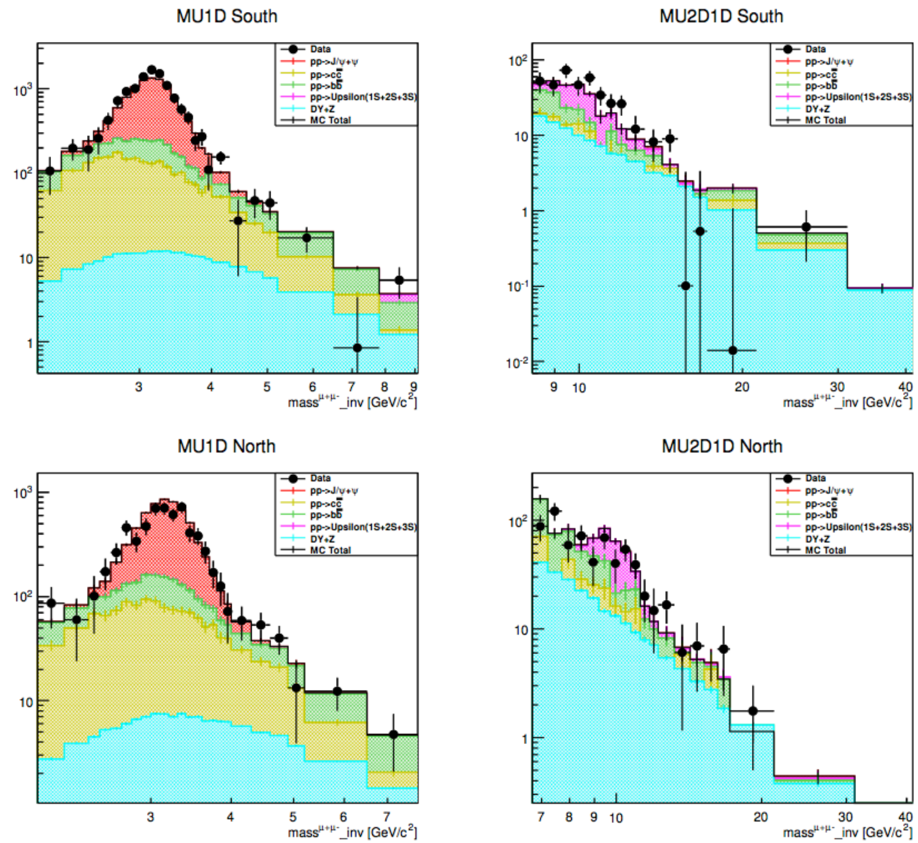
Invariant mass (real collision data)



# Muon Background Estimation

- Muon background: Open heavy flavor, quarkonia, Drell-Yan/Z
- Various muon background processes are combined together before constructing probability density functions.
- Relative contributions → scale factors.

| Process | Scale factors |
|---|---|
| $J/\Psi + \Psi$ | $0.317 \pm 0.016$ |
| Open charm | $2.605 \pm 0.817$ |
| Open bottom | $1.983 \pm 0.934$ |
| $\Upsilon(1S + 2S + 3S)$ | $0.437 \pm 0.093$ |
| Drell-Yan/Z | $1.112 \pm 0.446$ |



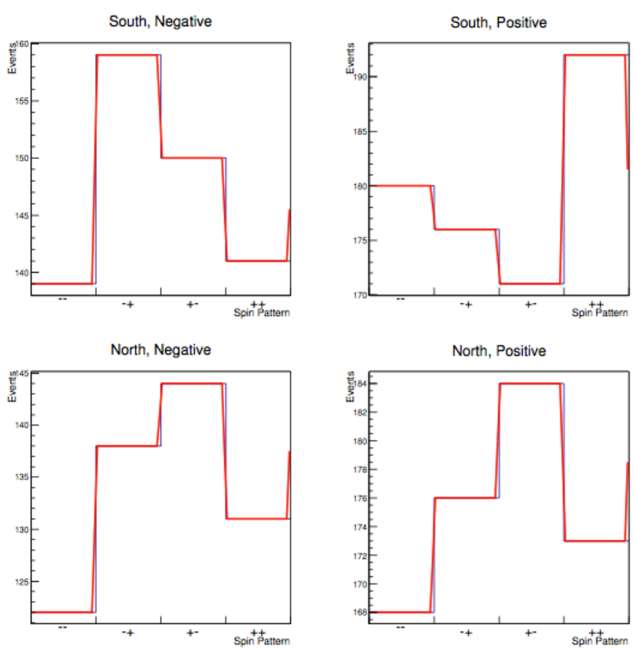
# Single Spin Asymmetry

- Corrected Single Spin Asymmetry:

$$A_L = \frac{1}{P}\frac{N^+ - N^-}{N^+ + N^-} \times \left(1.0 + \frac{BG}{SIG}\right)$$

Background does not have asymmetry, but dilute the signal asymmetry

- Both beams are polarized → measure independently and combined




$$N_{++} = \sigma_0 L_{++}\left(1 + A_L^{Blue}P_B + A_L^{Yellow}P_Y + A_{LL}P_1P_2\right)$$
$$N_{+-} = \sigma_0 L_{+-}\left(1 + A_L^{Blue}P_B - A_L^{Yellow}P_Y - A_{LL}P_1P_2\right)$$
$$N_{-+} = \sigma_0 L_{-+}\left(1 - A_L^{Blue}P_B + A_L^{Yellow}P_Y - A_{LL}P_1P_2\right)$$
$$N_{--} = \sigma_0 L_{--}\left(1 - A_L^{Blue}P_B - A_L^{Yellow}P_Y + A_{LL}P_1P_2\right)$$

$$N_{\alpha,\beta} = \sigma_0 + \alpha\sigma_L^{Blue} + \beta\sigma_L^{Yellow} + \alpha\beta\sigma_{LL}$$

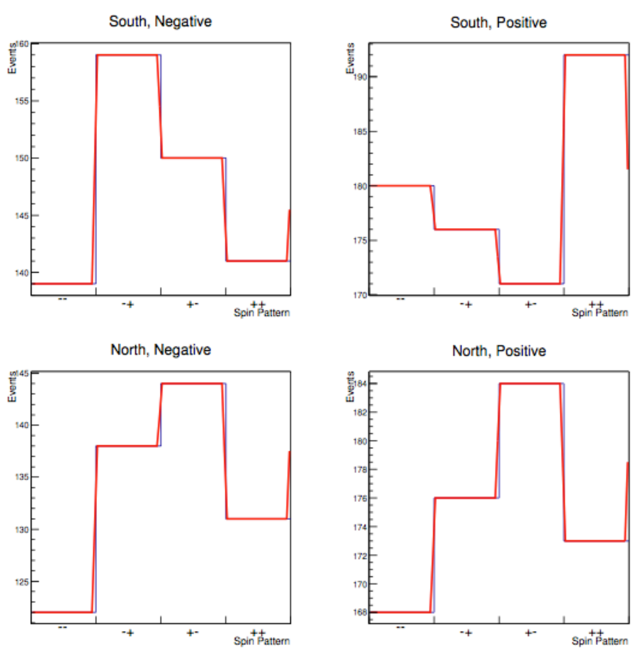
# Single Spin Asymmetry

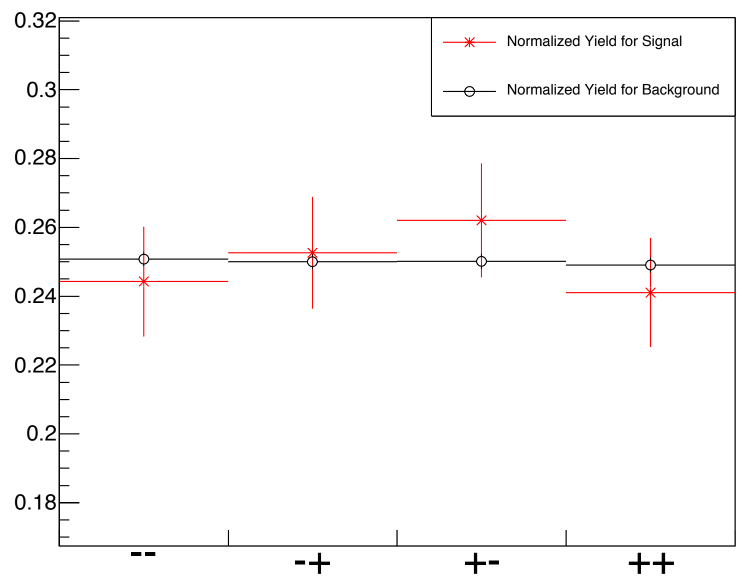
- Corrected Single Spin Asymmetry:

$$A_L = \frac{1}{P}\frac{N^+ - N^-}{N^+ + N^-} \times \left(1.0 + \frac{BG}{SIG}\right)$$

Background does not have asymmetry, but dilute the signal asymmetry

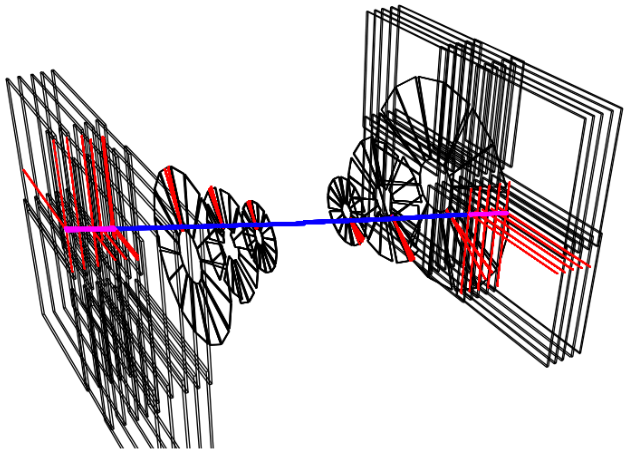
- Both beams are polarized → measure independently and combined

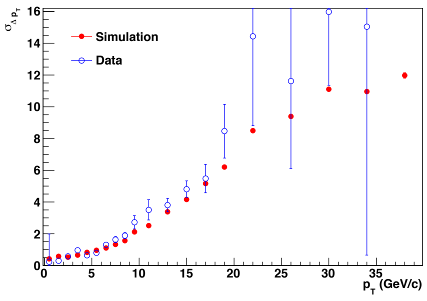


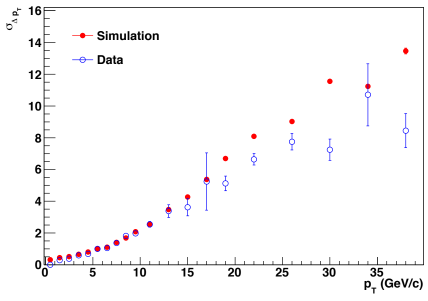



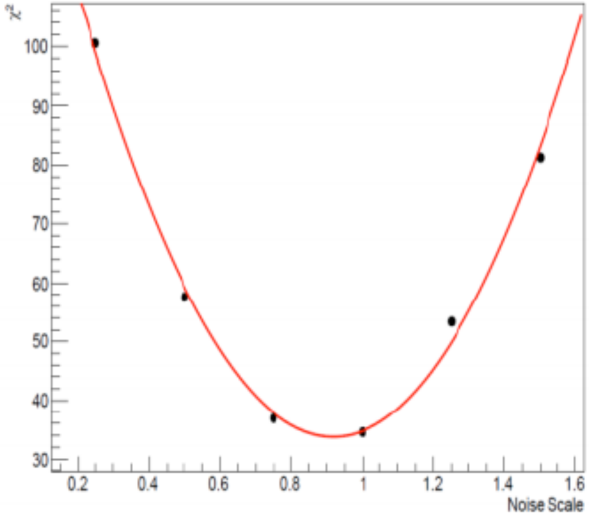
# MuTr position resolution

- Using the cosmic data
  - Measure momentum for incoming and outgoing tracks
  - Compare data with MC
  - Noise RMS to be tuned



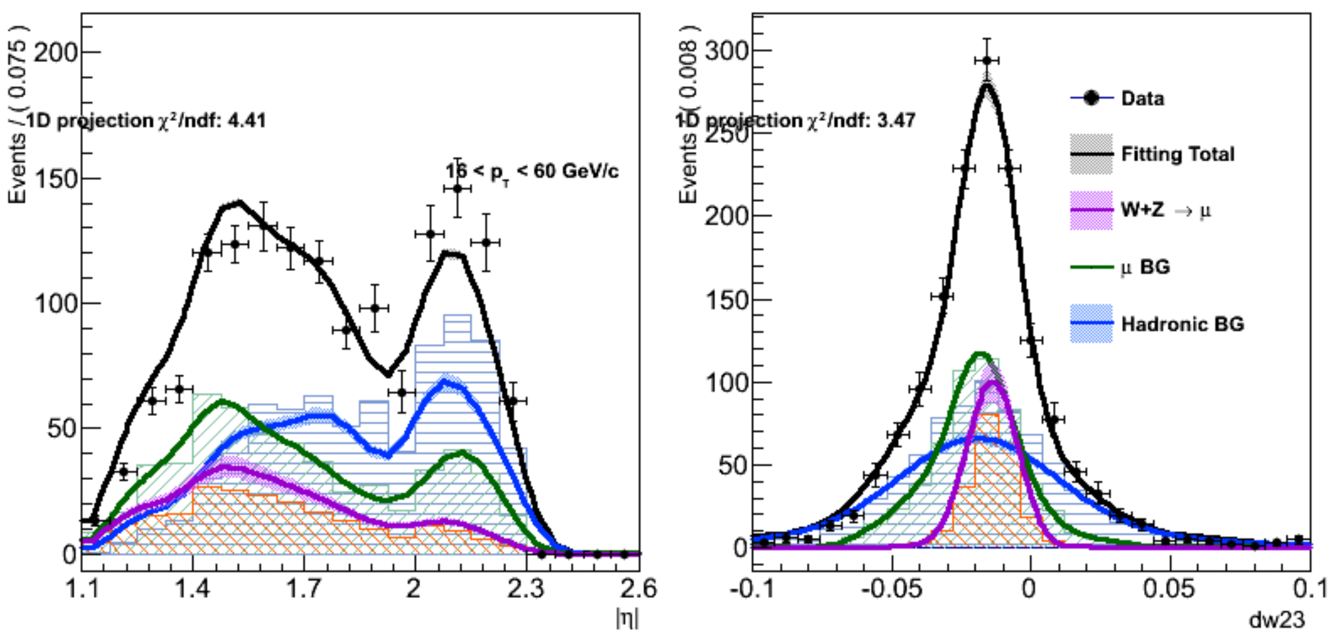


# Cross Check of the Fit

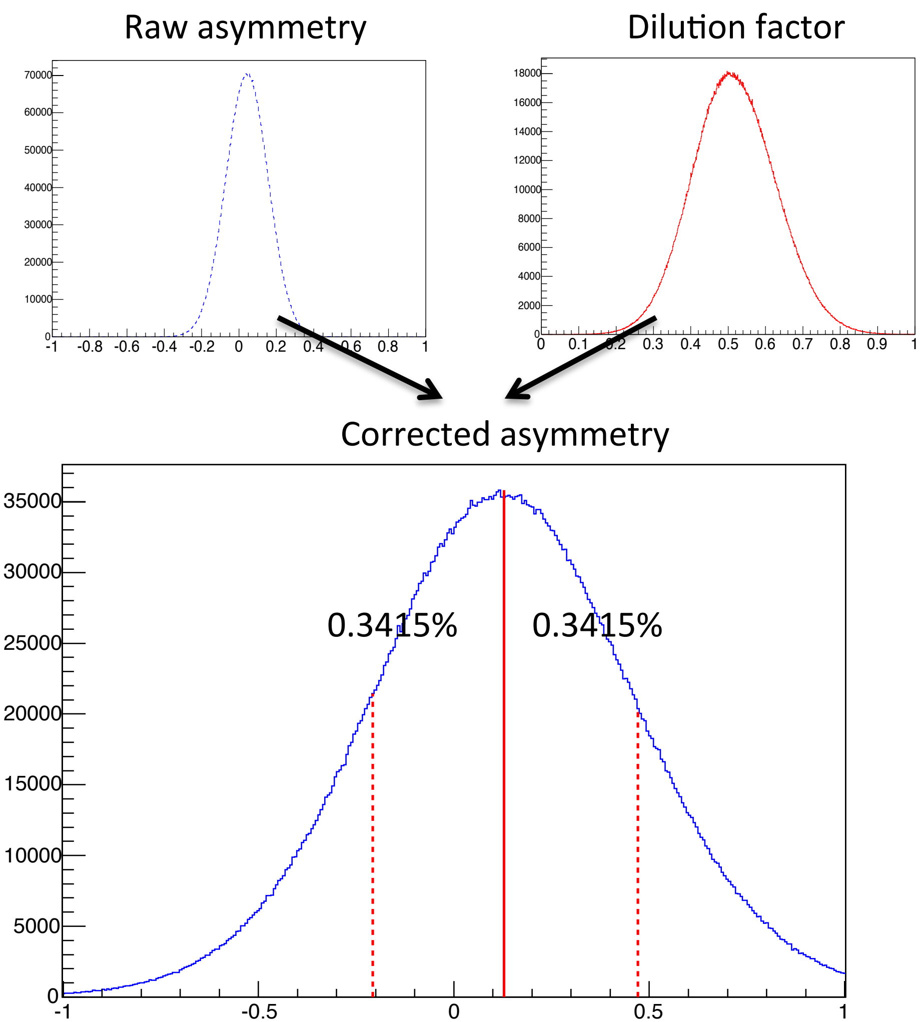
- Create a trial data set entirely of simulation.
- Signal, background contributions are known prior.
- Estimate the efficiency of the method used
  → predict possible over/under estimation
  → take the relative difference as systematic uncertainty



# Systematic Uncertainty

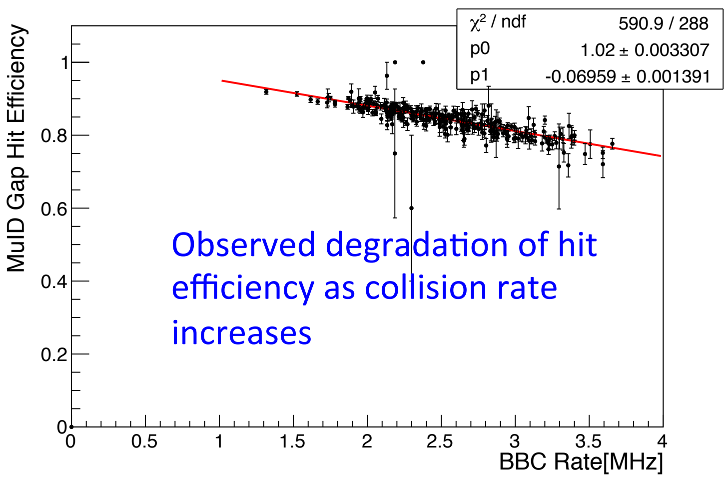
$$A_L = \frac{1}{P}\frac{N^+ - N^-}{N^+ + N^-} \times \left(1.0 + \frac{BG}{SIG}\right)$$

- Systematic uncertainty sources:
  - S/BG Fit
  - Trigger efficiency correction
  - Muon background
  - MuTr position resolution

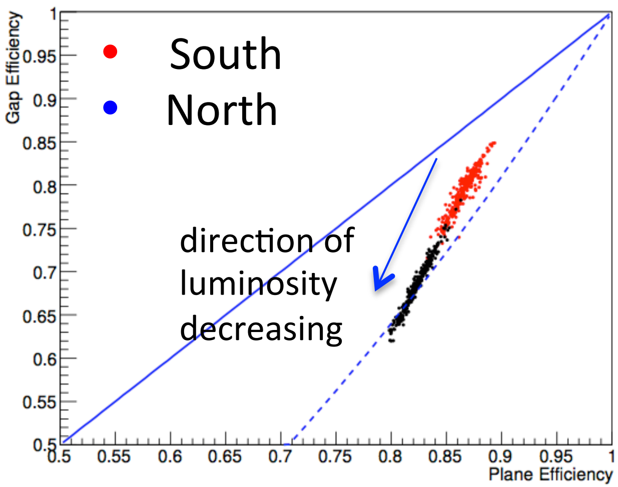


# Simulation Tuning

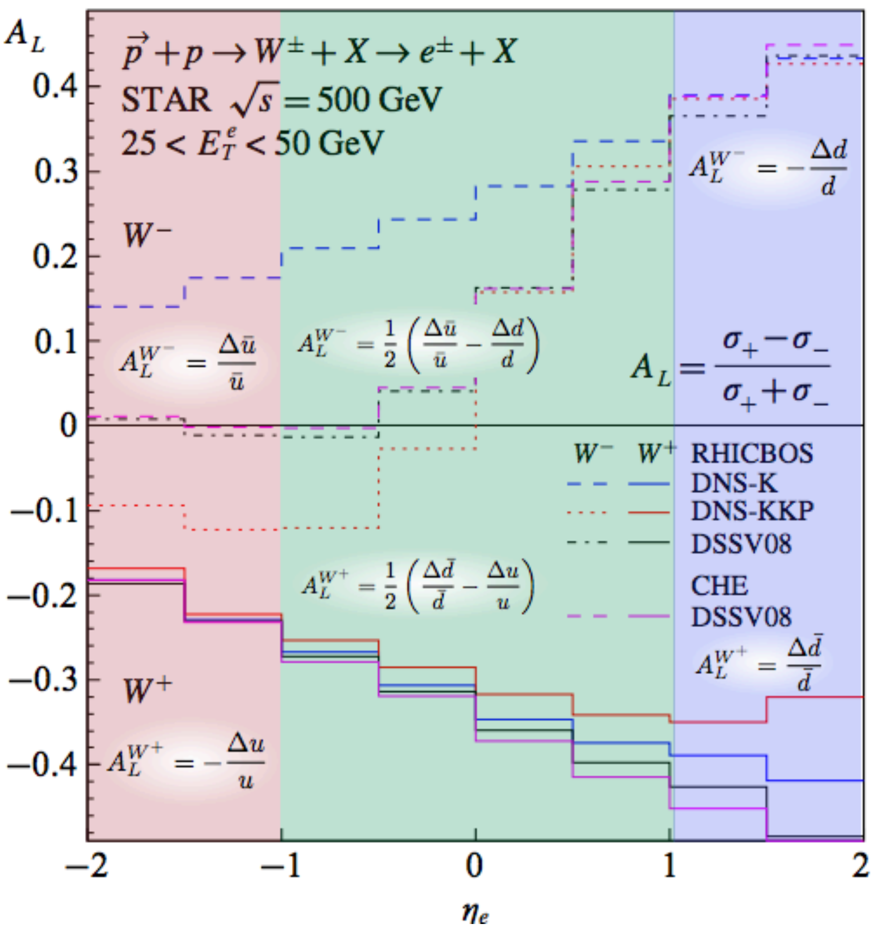
- Produced W/Z signal and various background MC simulations to support the analysis (PYTHIA +GEANT3)
- Rate dependence of detector performance:




MuID detector hit efficiency




MuTr detector hit efficiency



$A_L$
$\vec{p}+p \to W^{\pm}+X \to e^{\pm}+X$
STAR $\sqrt{s}=500$ GeV
$25 < E_T^e < 50$ GeV
$W^-$
$W^+$
$A_L^{W^-} = \frac{\Delta\bar{u}}{\bar{u}}$
$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta\bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right)$
$A_L^{W^-} = -\frac{\Delta d}{d}$
$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$
$A_L^{W^+} = -\frac{\Delta u}{u}$
$A_L^{W^+} = \frac{\Delta\bar{d}}{\bar{d}}$
$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$
$W^-$ $W^+$ RHICBOS
DNS-K
DNS-KKP
DSSV08
CHE
DSSV08
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−2
−1
0
1
2
$\eta_e$