Measurement of the $W^{\pm}$ Boson Single-Spin Asymmetry in Transversely Polarized pp Collisions at STAR

Salvatore Fazio and Dmitri Smirnov
Brookhaven National Lab

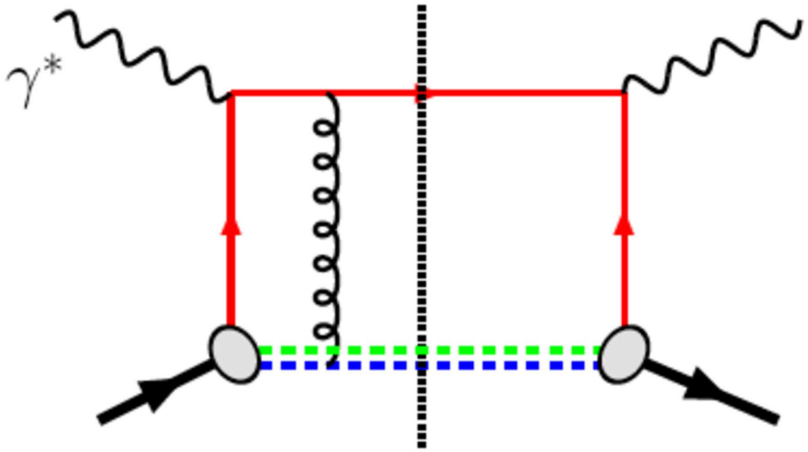
for the STAR Collaboration

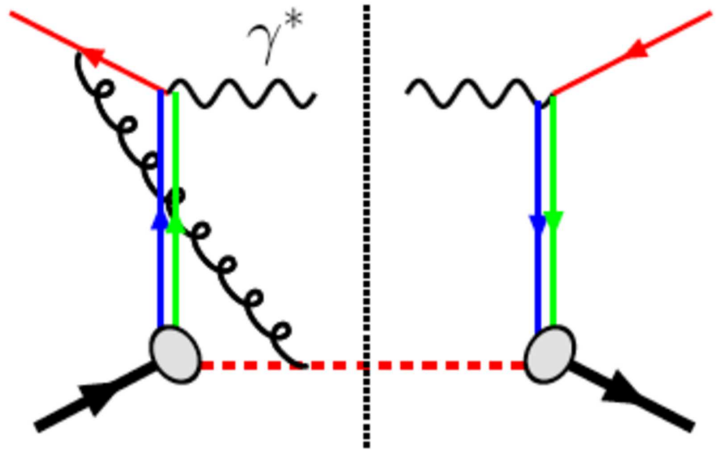
Oct 26, 2013

Motivation

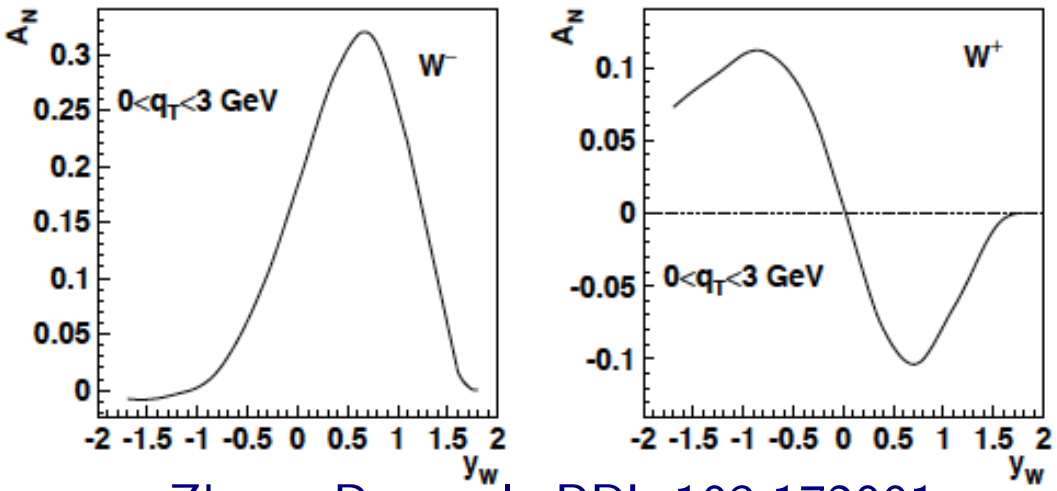
- $Z/\gamma^\star$ and W production can be used to measure the predicted sign change of the **Sivers function** as extracted from SIDIS measurements

$$\text{Sivers(SIDIS)} = -\text{Sivers}(W^\pm/Z^0)$$

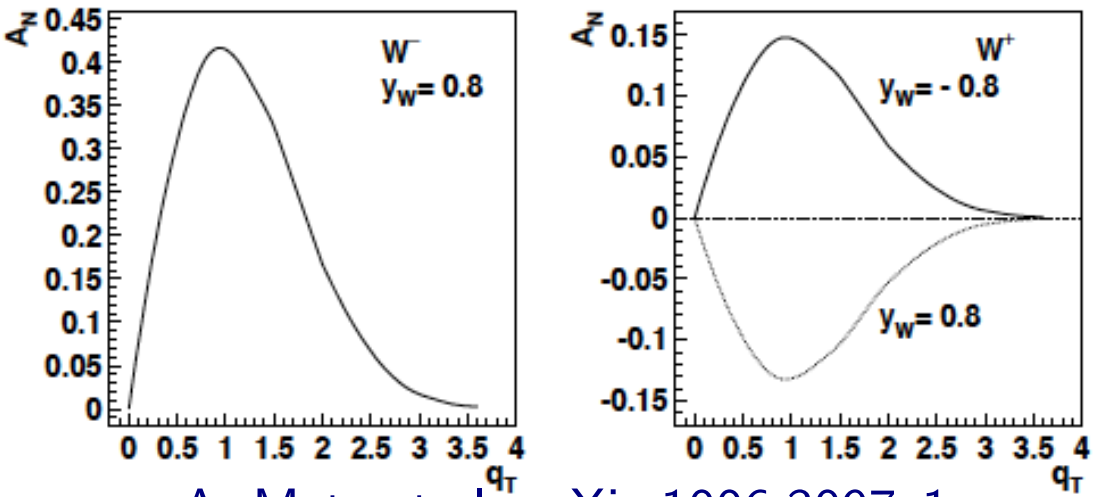




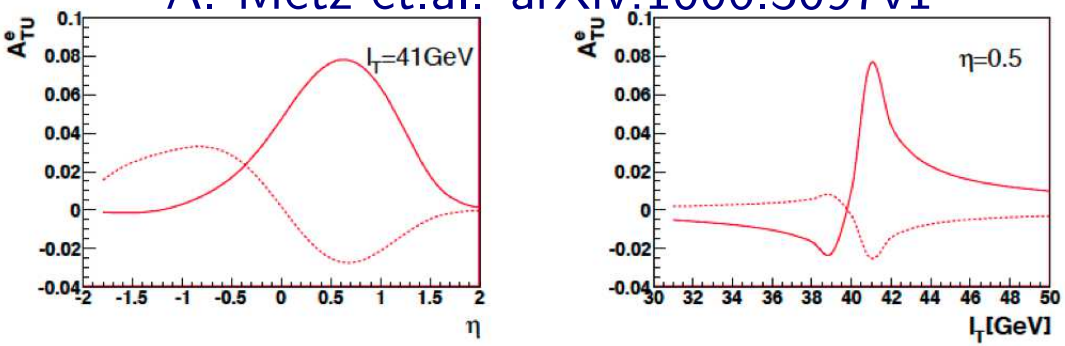
Motivation



Zhong-Bo et.al. PRL 103.172001



A. Metz et.al. arXiv:1006.3097v1



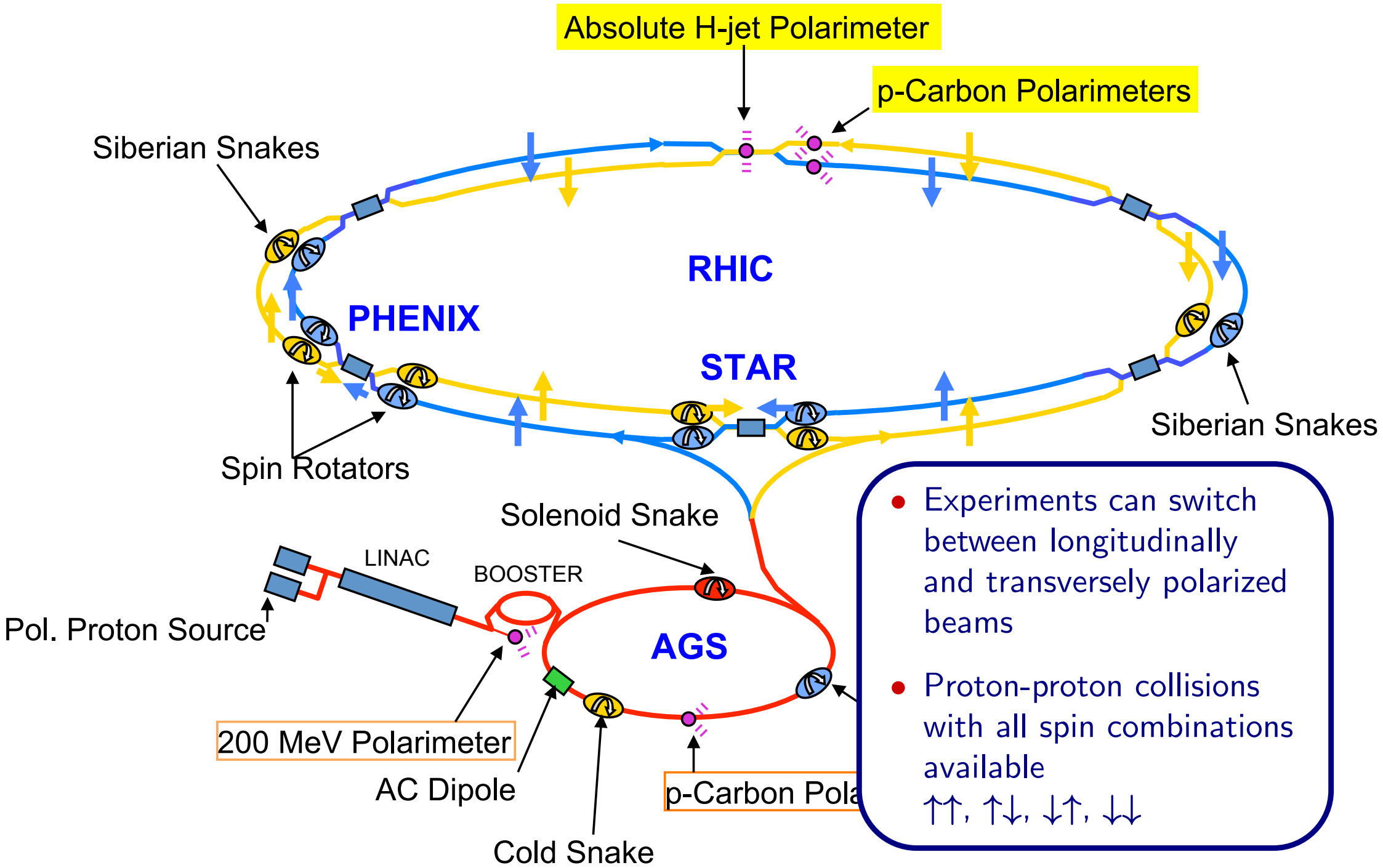
- $Z/\gamma^\star$ and W production can be used to measure the predicted sign change of the **Sivers function** as extracted from SIDIS measurements

$$\text{Sivers(SIDIS)} = -\text{Sivers}(W^\pm/Z^0)$$

- **Single-Spin Asymmetry** for vector bosons is expected to be larger than for leptons

- Current predictions do not account for TMD evolution
  - $\Rightarrow$ Doing so will reduce asymmetries
  - $\Rightarrow$ Lepton asymmetry too small to measure

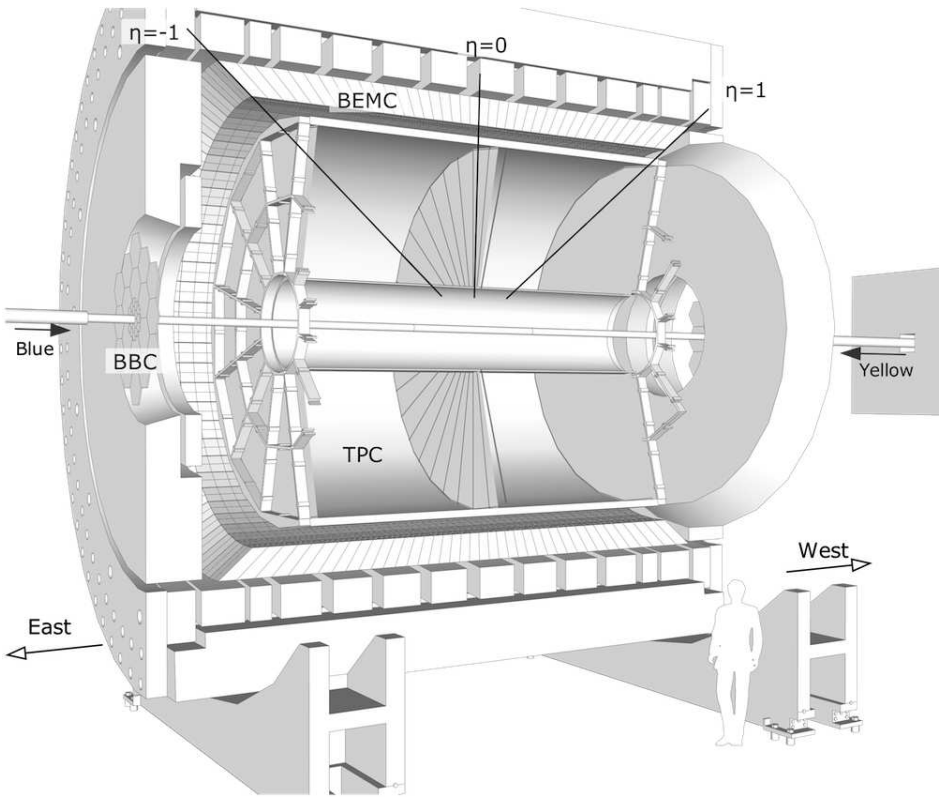
Accelerator Complex

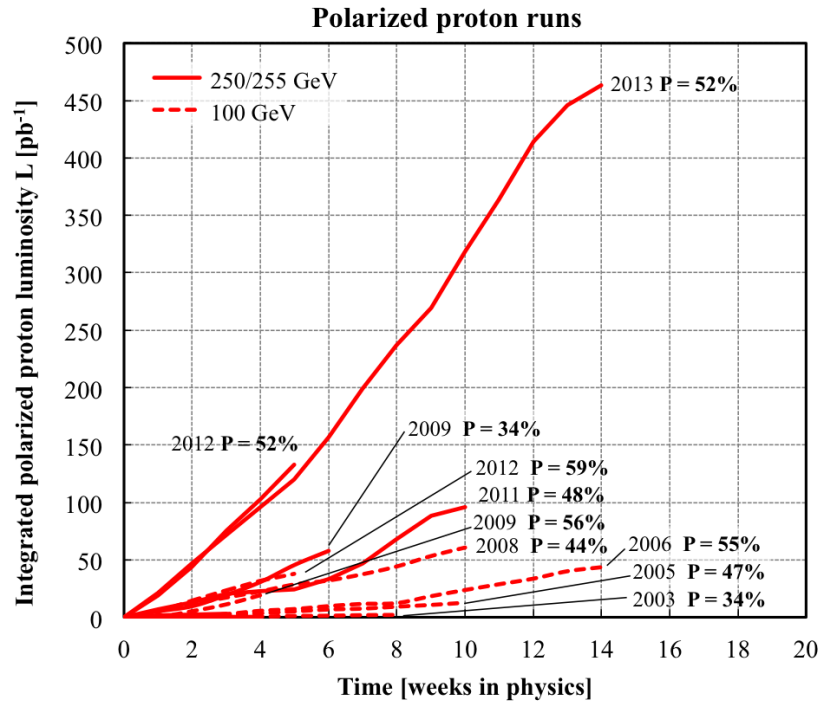


- Experiments can switch between longitudinally and transversely polarized beams
- Proton-proton collisions with all spin combinations available
  ↑↑, ↑↓, ↓↑, ↓↓

STAR Detector

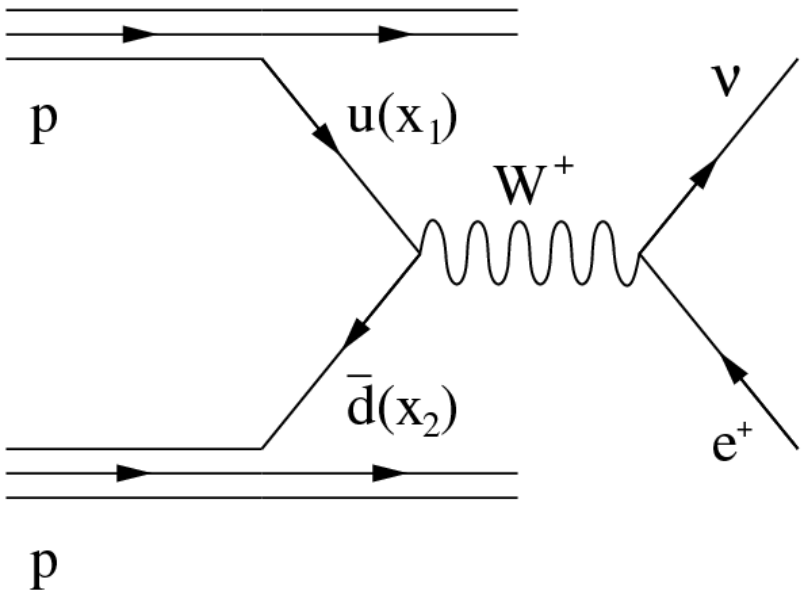
- STAR EM calorimetry has almost complete azimuthal coverage for $-1 < \eta < 4$:
  - **Barrel Electro-Magnetic Calorimeter,** $-1 < \eta < 1$
  - **Endcap Electro-Magnetic Calorimeter,** $1 < \eta < 2$
  - Forward Meson Spectrometer, $2.5 < \eta < 4$
- STAR tracking exploits magnetic field of 0.5 T
  - **Time Projection Chamber,** $-1.3 < \eta < 1.3$





- In 2011 STAR collected $L \approx 25$ pb^{-1} from transversely polarized pp-collisions at $\sqrt{s} = 500$ GeV

Analysis Strategy



- Select events with the signature of the W decay
  - High $P_T > 25$ GeV isolated electron
  - High $P_T > 18$ GeV neutrino
- Neutrino's transverse momentum is reconstructed from the missing energy in the event:

$$\vec{P}_{T,\nu} \approx \vec{\not{E}}_T = -\sum_{i \in \substack{\text{tracks,}\\ \text{clusters}}} \vec{P}_{T,i}$$

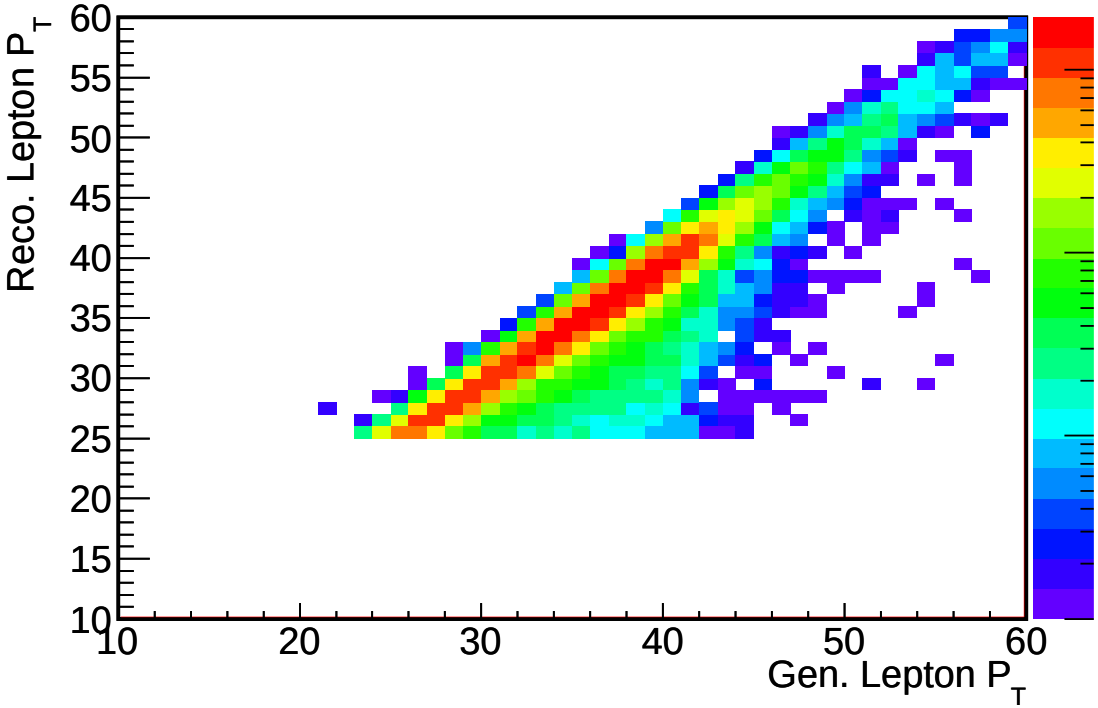
- Neutrino's longitudinal momentum is reconstructed from the decay kinematics with an assumed W mass

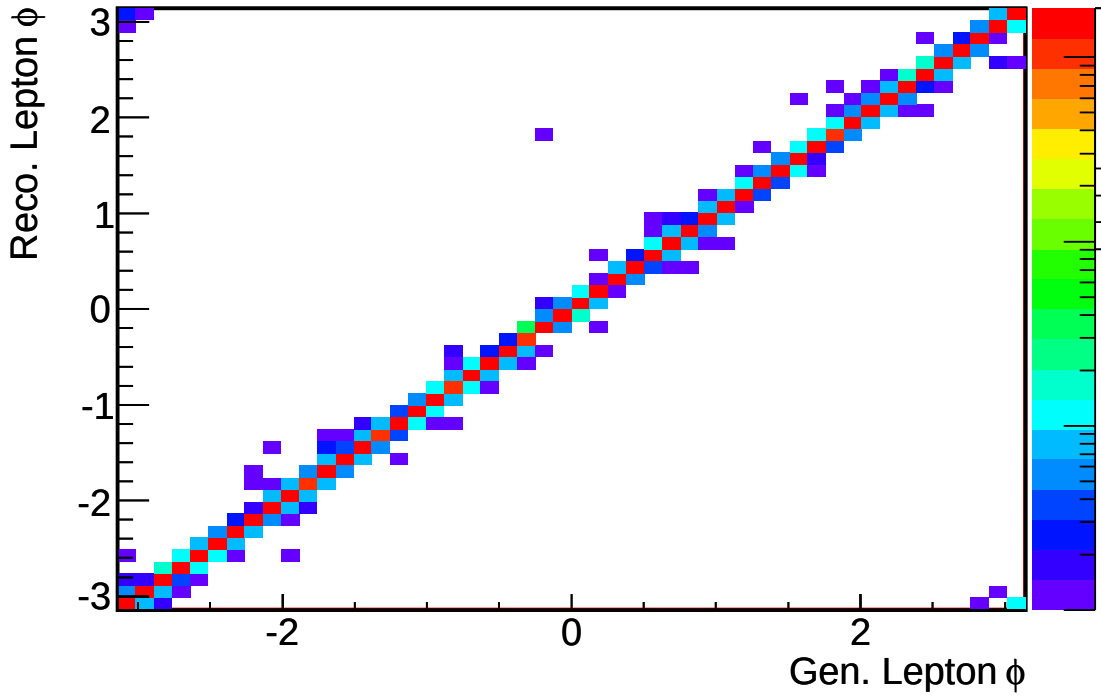
$$M_W^2 = (E_l + E_\nu)^2 - (\vec{P}_l + \vec{P}_\nu)^2$$

- Finally, the **Single-Spin Asymmetry** can be calculated as a function of W kinematics

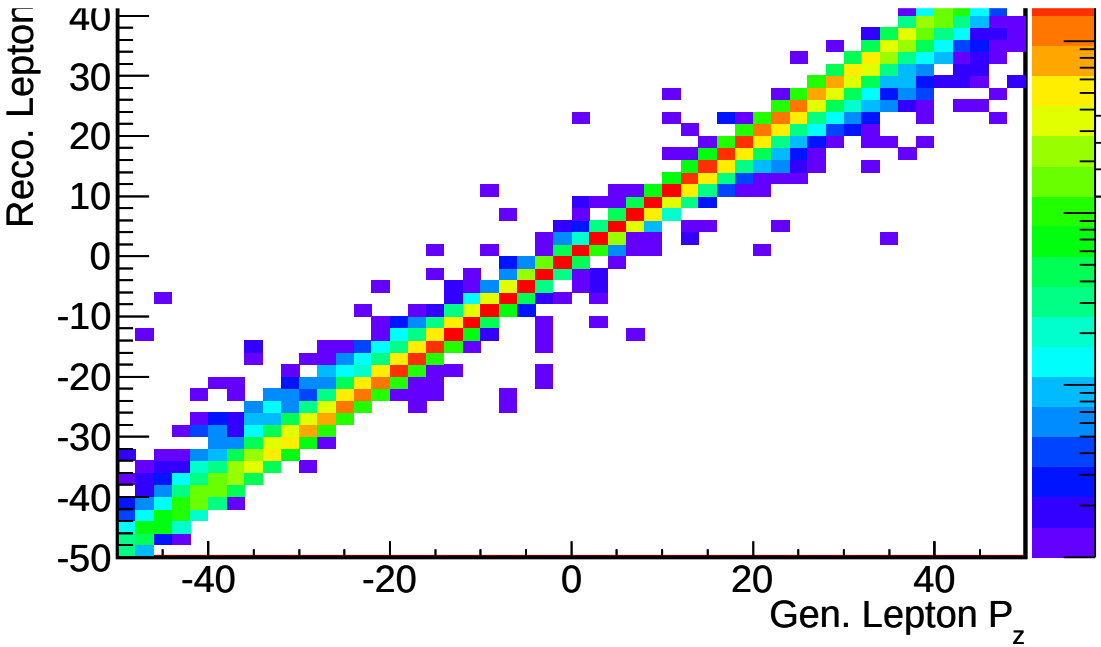
$$A_N = \frac{1}{P} \frac{\sqrt{N^\uparrow(\phi) N^\downarrow(\phi - \pi)} - \sqrt{N^\uparrow(\phi - \pi) N^\downarrow(\phi)}}{\sqrt{N^\uparrow(\phi) N^\downarrow(\phi - \pi)} + \sqrt{N^\uparrow(\phi - \pi) N^\downarrow(\phi)}}$$

W Monte-Carlo Test for Event Selection: Electron





- To test our selection we use Monte-Carlo generated signal $W \to e\nu$
- Good agreement observed in kinematic distributions between the selected lepton and the electron from the W decay



Monte-Carlo Based Correction

- We define the W recoil as a vector sum over all detected particles except the high P_T electron:

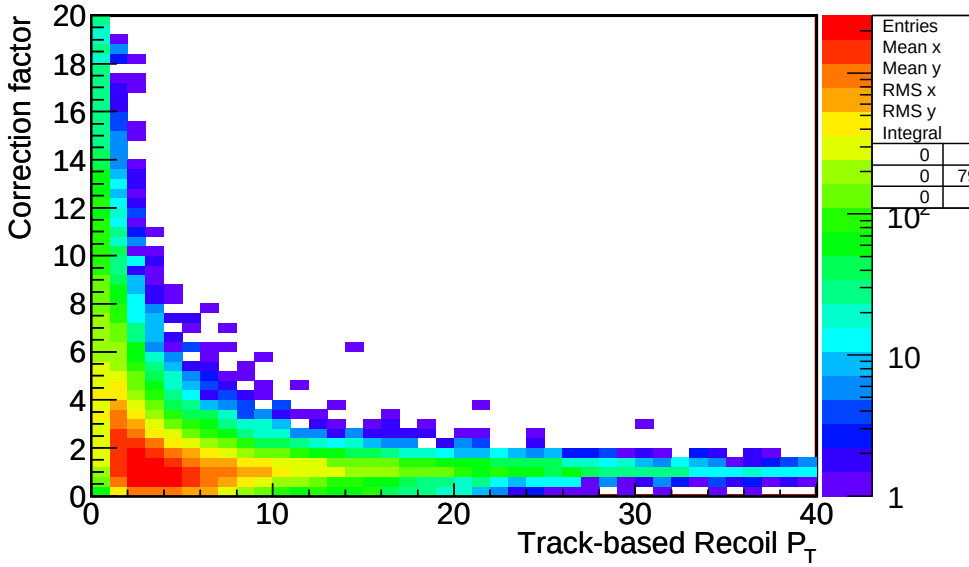
$$\vec{P}_{T,W} = \vec{P}_{T,l} + \vec{P}_{T,\nu} = -\vec{P}_{T,\text{recoil}}$$

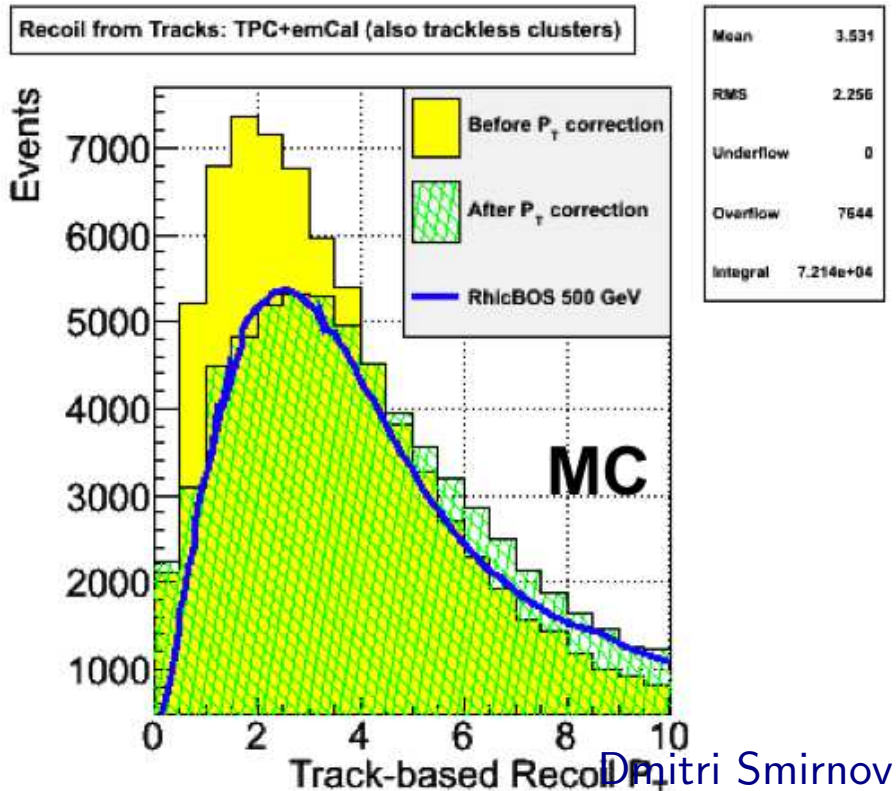
- Part of the recoil is missing due to limited STAR acceptance in $\eta \Rightarrow$ Apply MC correction

$$P_{T,W} = k \times P_{T,\text{recoil}}$$

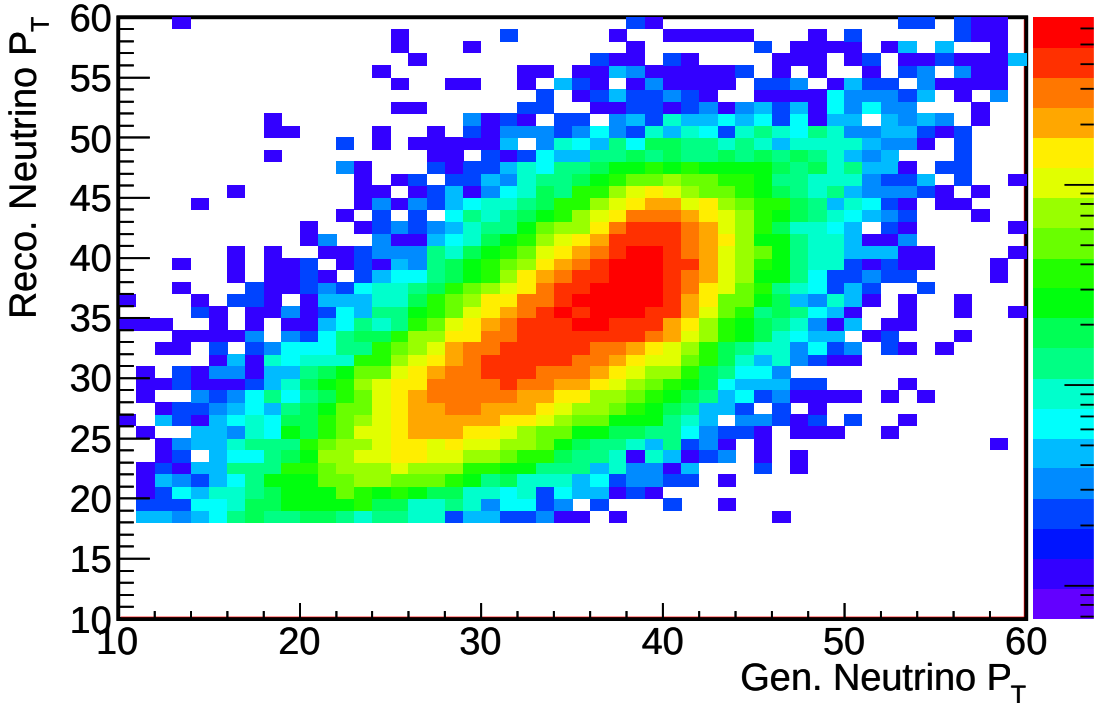
$$k = (P_{T,W}/P_{T,\text{recoil}})_{MC}$$

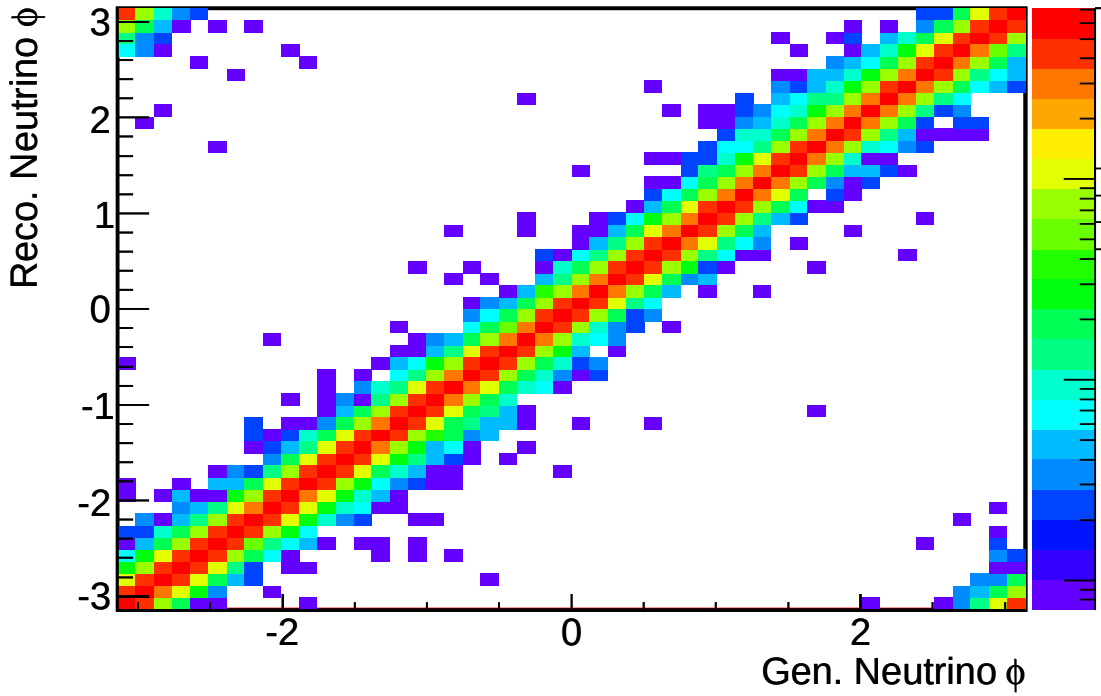
- Correction k is applied in measured recoil P_T bins on event-by-event basis using randomized distributions
- After correction a good agreement with expected W P_T is observed



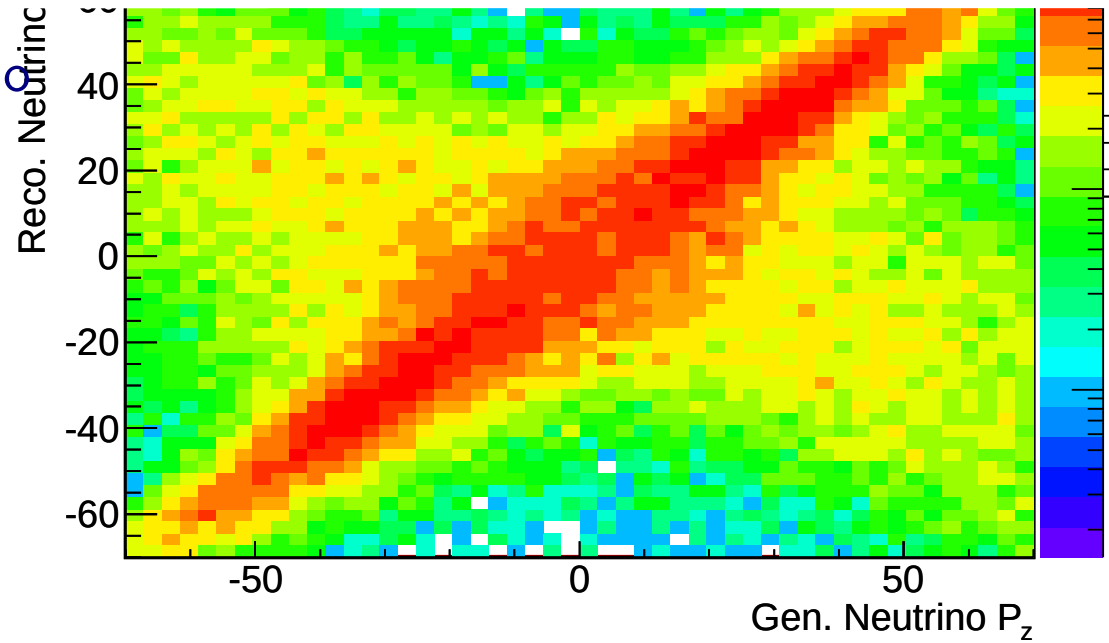


Monte-Carlo Test for Reconstructed Neutrino ν

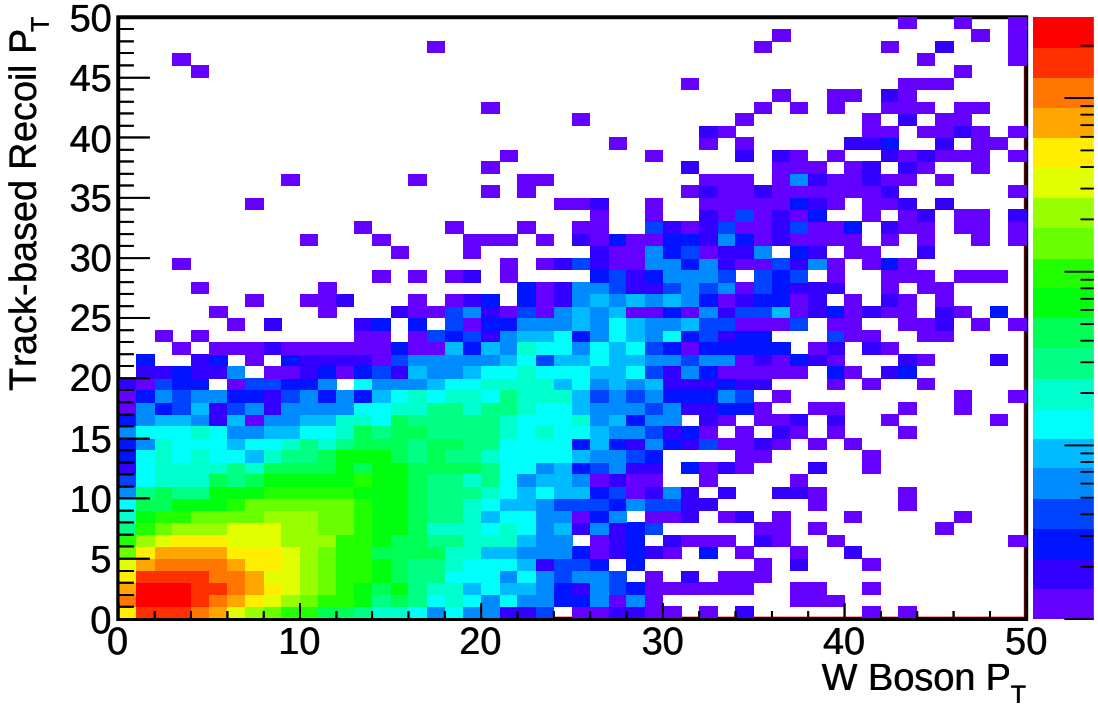


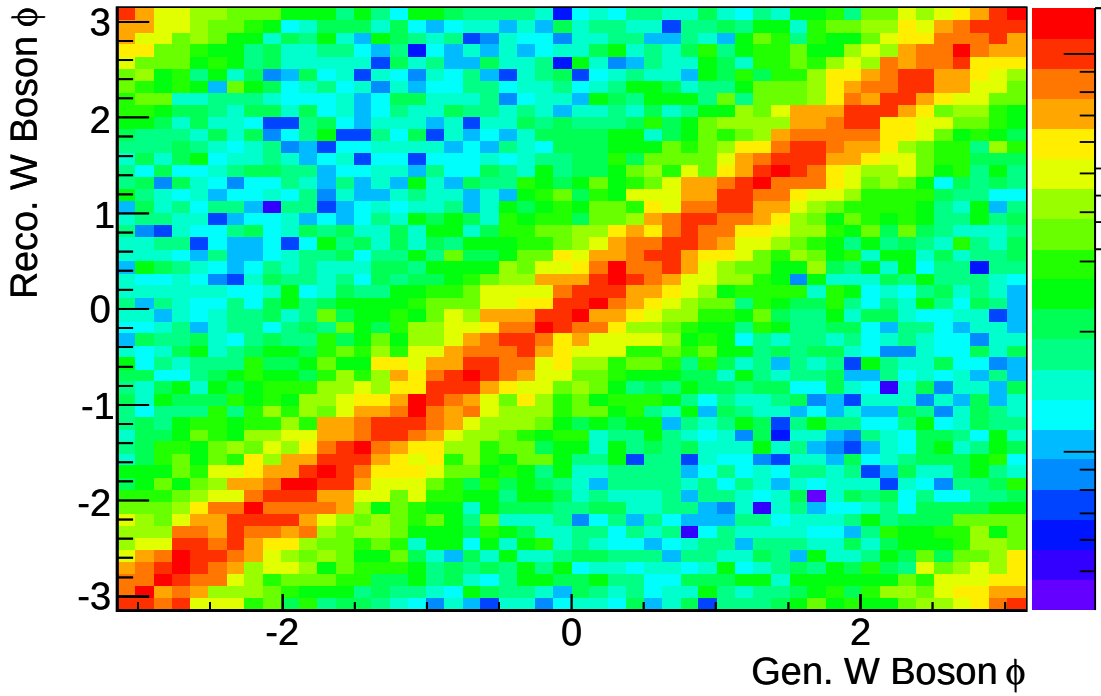


- To test reconstruction of ν we use Monte-Carlo generated $W \to e\nu$ events
- Reasonable agreement observed in kinematic variables between the reconstructed and generated neutrino
- For longitudinal momentum reconstruction we select the smallest absolute solution



Monte-Carlo Test for Reconstructed W

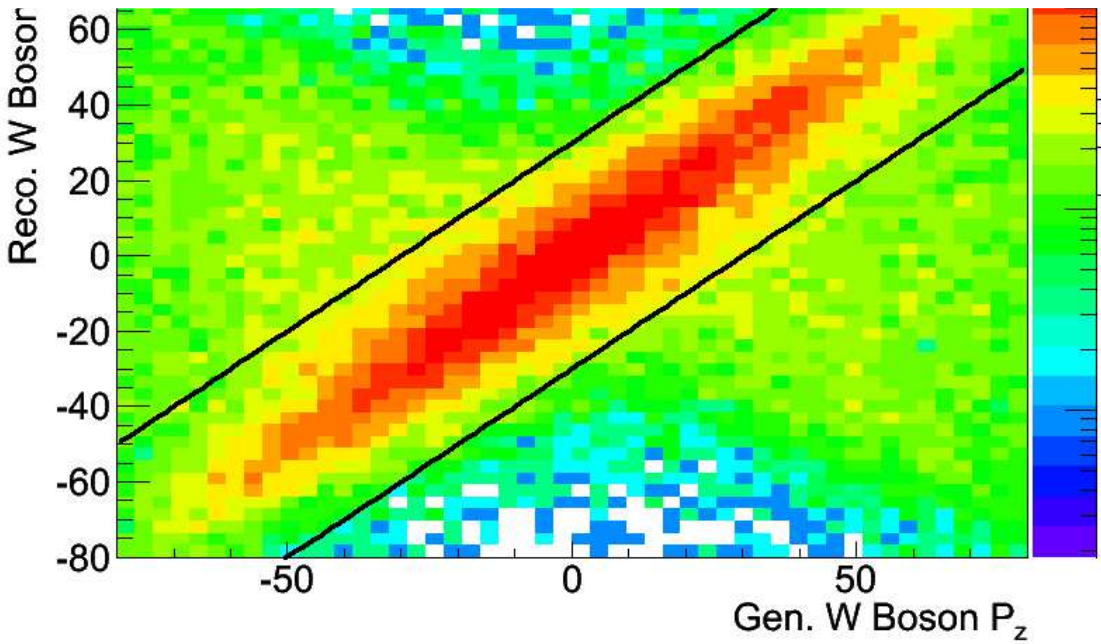




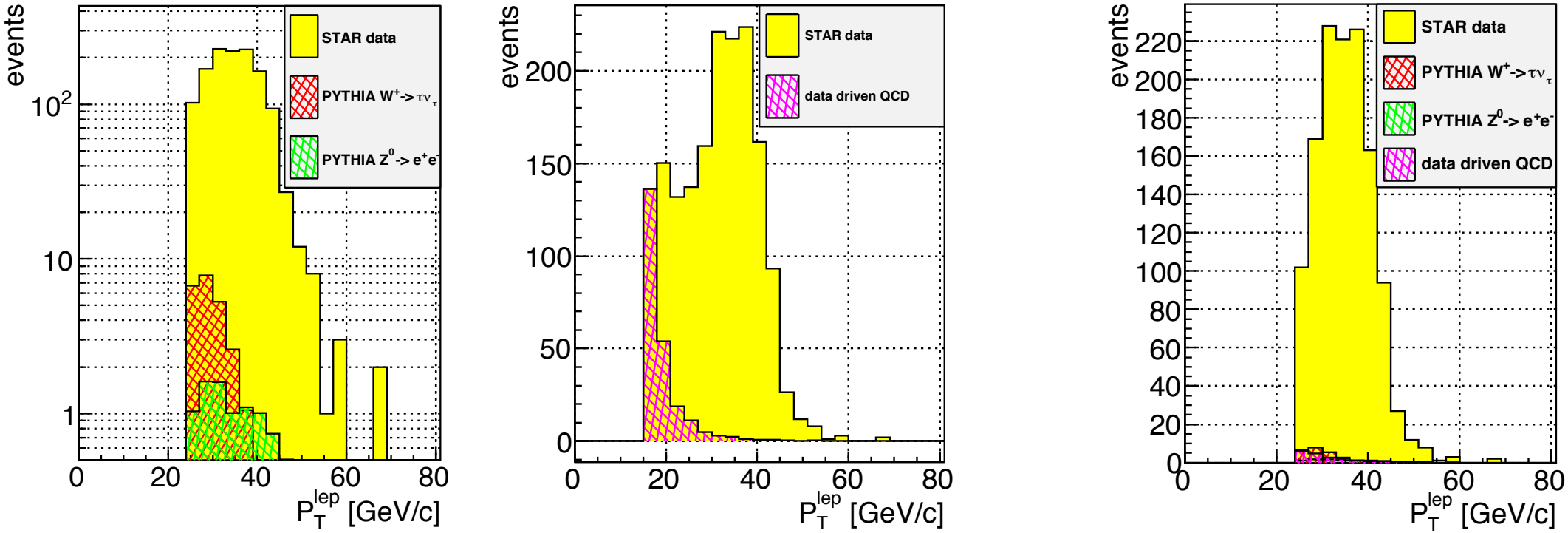
- We test the W reconstruction with the same MC sample

$$\vec{P}_{T,W} = \vec{P}_{T,e} + \vec{P}_{T,\nu}$$

- About 70% of selected solutions is in agreement with the generated kinematics
- The other 30% contaminate the final sample and have to be accounted for

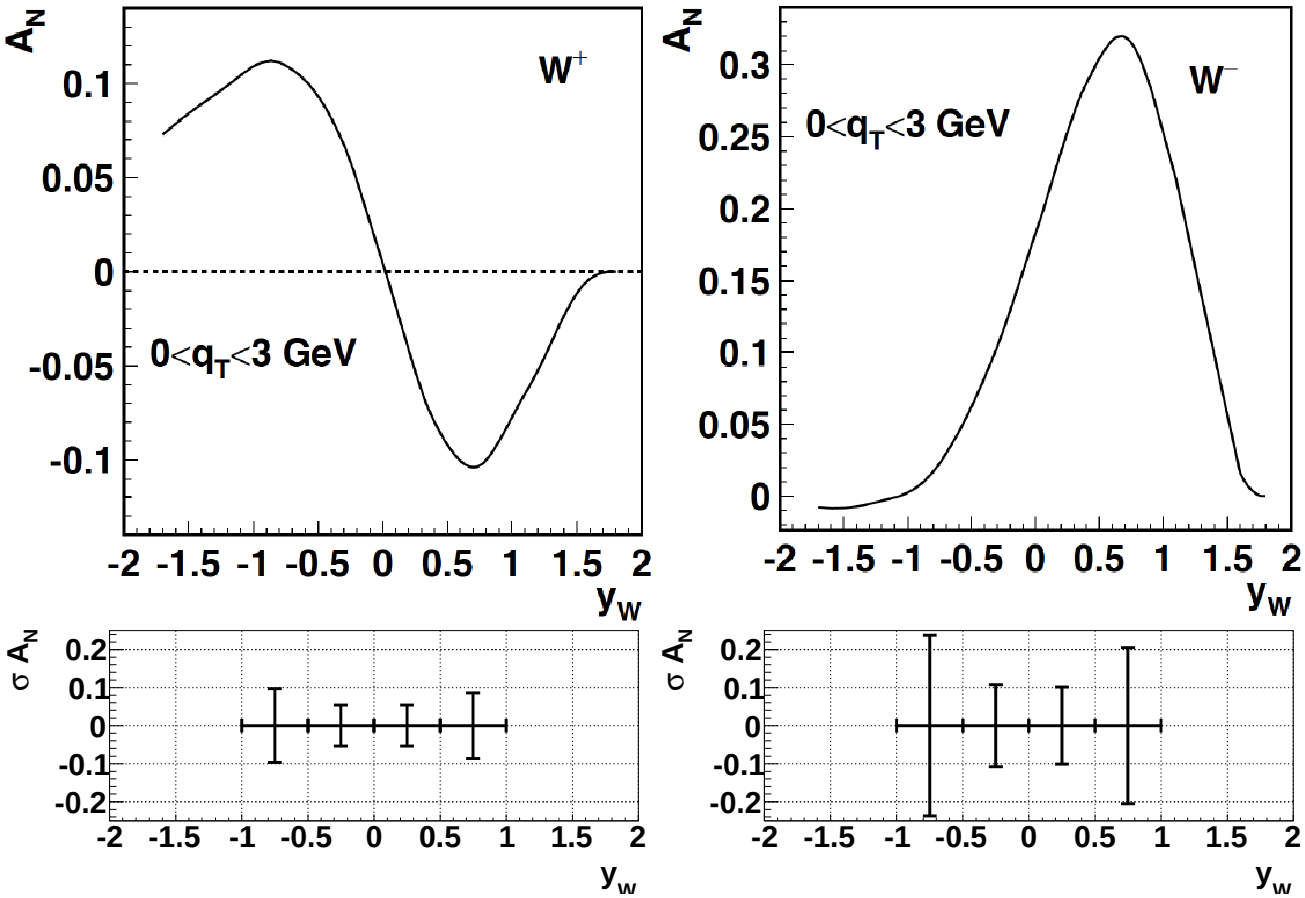


Background Contributions



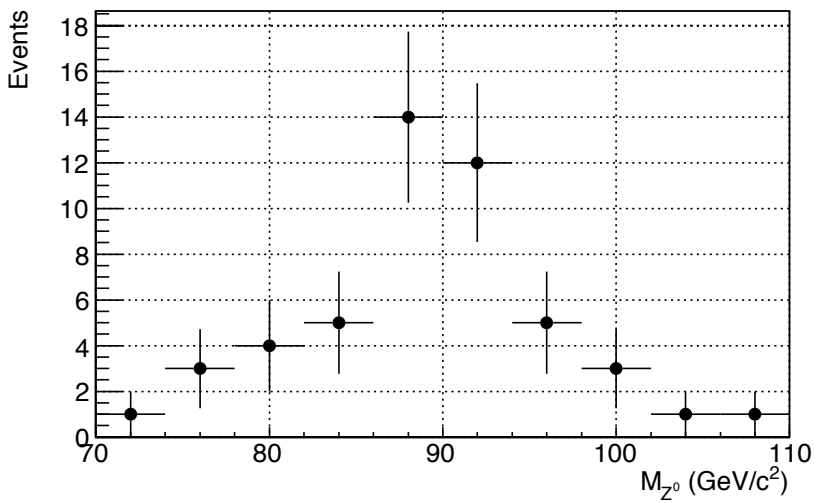
- In the data we select ≈ 1250 and ≈ 350 events with positron and electron in the final state respectively
- Contributions from Monte-Carlo modeled backgrounds are:
  - $W \to \tau\nu_\tau \to e\nu_e\nu_\tau$, $\lesssim 2\%$
  - $Z \to ee$, $\lesssim 2\%$
- QCD background shape is obtained by reversing the cut on the neutrino momentum
  - QCD fraction $\lesssim 3\%$ is estimated by normalizing to the leftmost bin of Jacobian peak ($P_{T,l} > 15$ GeV)

Statistical Sensitivity



- With ≈ 1600 selected $W^{\pm}$ events we estimate statistical sensitivity for A_N
  - ≈ 25 pb^{-1} of STAR data collected from transversely polarized ($P \approx 50\%$) pp-collisions at $\sqrt{s} = 500$ GeV
- Systematic errors are not included

- To select Z^0 event we require two high $P_T > 25$ GeV leptons with opposite charge
- Within $\pm 20\%$ window around the nominal Z^0 mass we select 49 events
- We expect minimal contamination from backgrounds in this sample



Summary

- Full reconstruction of W bosons kinematics fully underway and under control
  $\Rightarrow A_N$ will be released soon
- Statistical sensitivity on the order of the expected asymmetries

Outlook

- Estimate systematic uncertainties due to Monte-Carlo based corrections
- Optimize reconstruction of ν longitudinal momentum and improve selection of the "correct" solution
- Measure contribution to the asymmetry for events with the "wrong" solution