# First Measurement of W Bosons and their Spin Asymmetry $A_L$ in 500 GeV polarized p+p collisions at PHENIX

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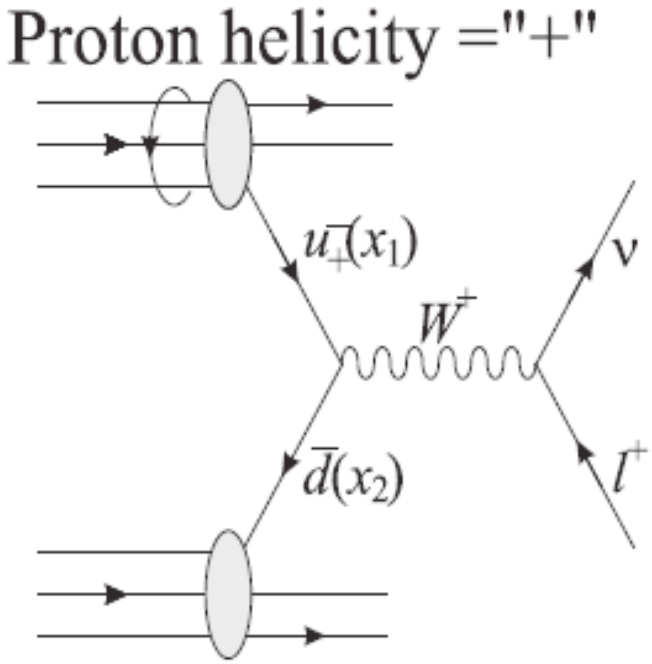
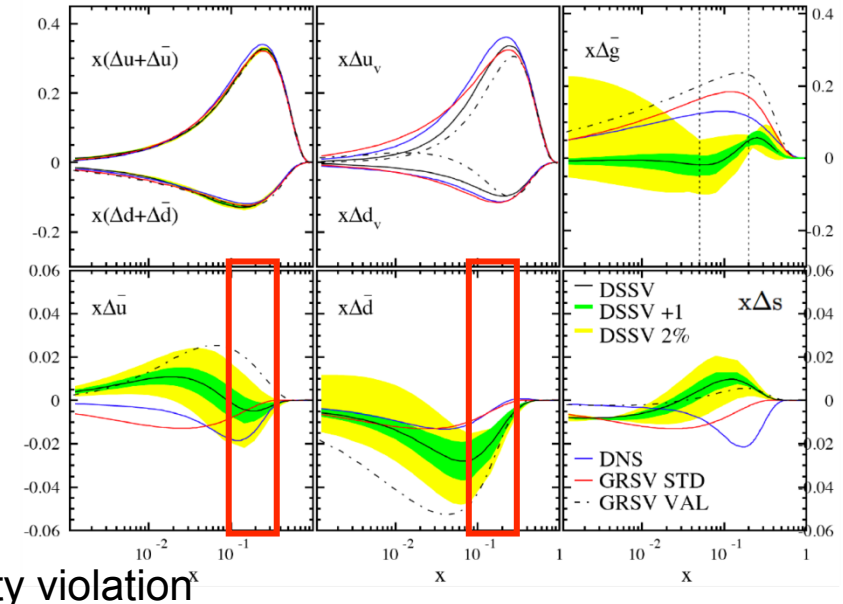
# W Bosons in Polarized Proton Collisions




$$|y_W - y_l| \approx \ln\left[\frac{M_W}{2E_T} + \sqrt{\left(\frac{M_W}{2E_T}\right)^2 - 1}\right] \qquad \langle x_{1,2} \rangle \approx \frac{M_W}{\sqrt{s}} e^{\pm\frac{y_l}{2}}$$

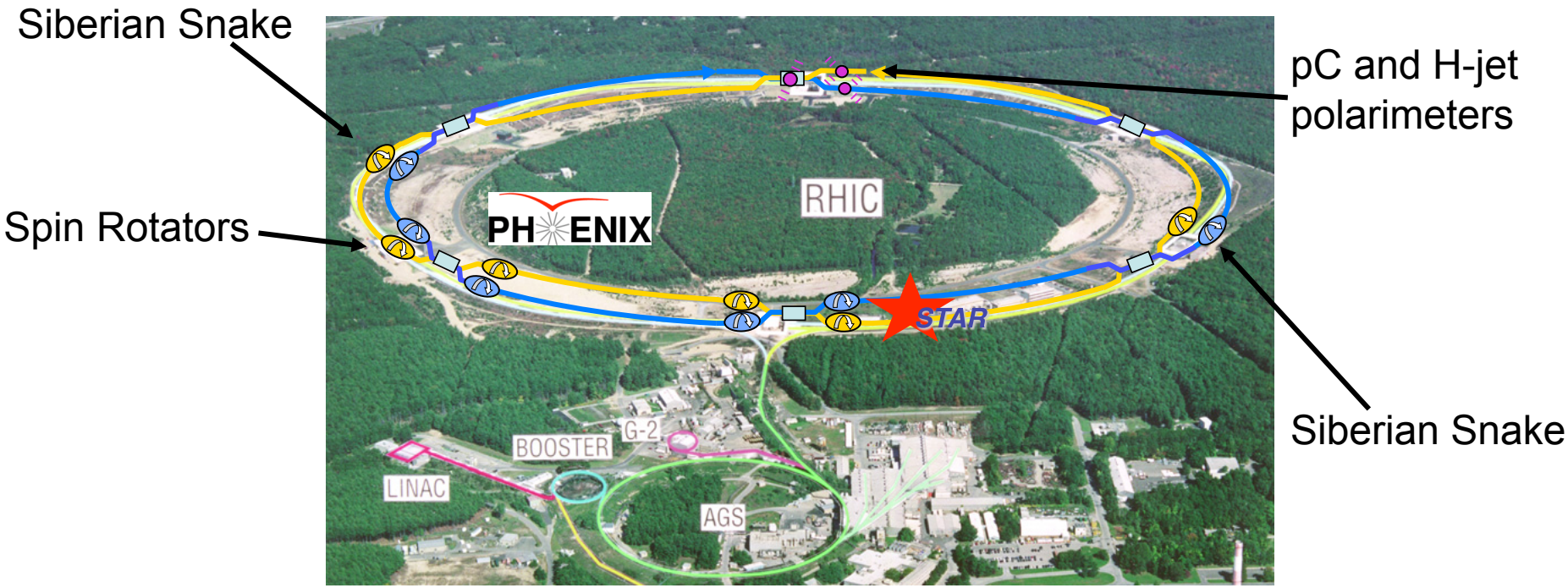
D. De Florian et al. arXiv:0804.0422 NLO @ $Q^2$=10 GeV$^2$




<u>Ideal probe for polarized PDFs</u>

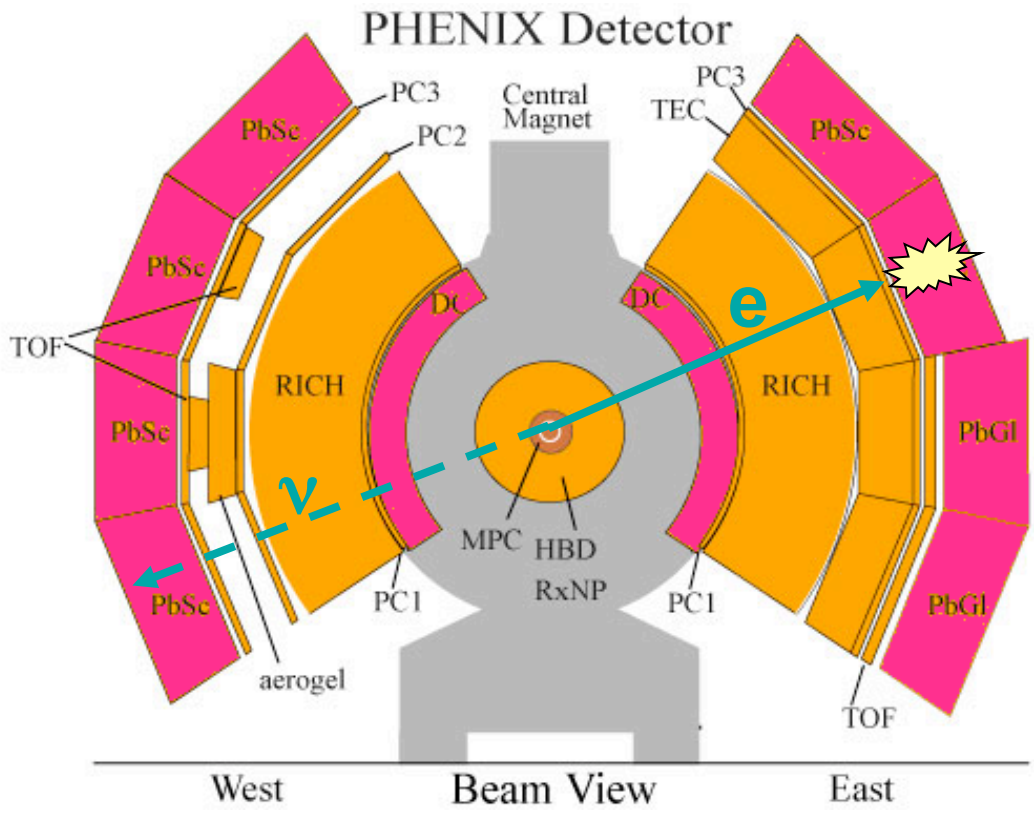
- Couples to only one helicity: Maximal parity violation
- Can get large asymmetries, almost can read off polarized pdfs from asymmetry $A_L$
- W mass produces hard scale – "easily" calculable
  - Theory Uncertainties Fairly Small O(1%): Resummed or straight NLO?
  - PDF uncertainties O(10%)
- No uncertainties from fragmentation in W's leptonic decay channel
  - SIDIS extractions of identified polarized pdf's require models of the quark fragmentation
- Also possible to probe ubar/dbar ratio

# RHIC-PHENIX 2009 run



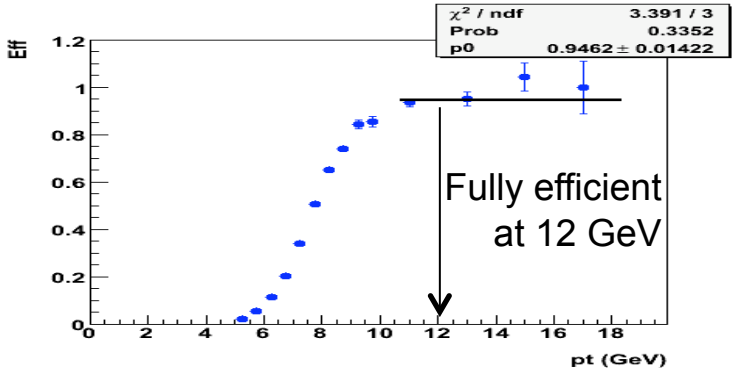

- Run 09: First 500 GeV Run, March 17-April 13, 2009
- Machine development in parallel with physics running to increase luminosity, polarization
- Integrated luminosity (with vertex cut) is $\int Ldt=8.57/pb$
- Polarization is $\langle P \rangle = 0.39 \pm 0.04$ (scale uncertainty)

# PHENIX Central arm: W→e±



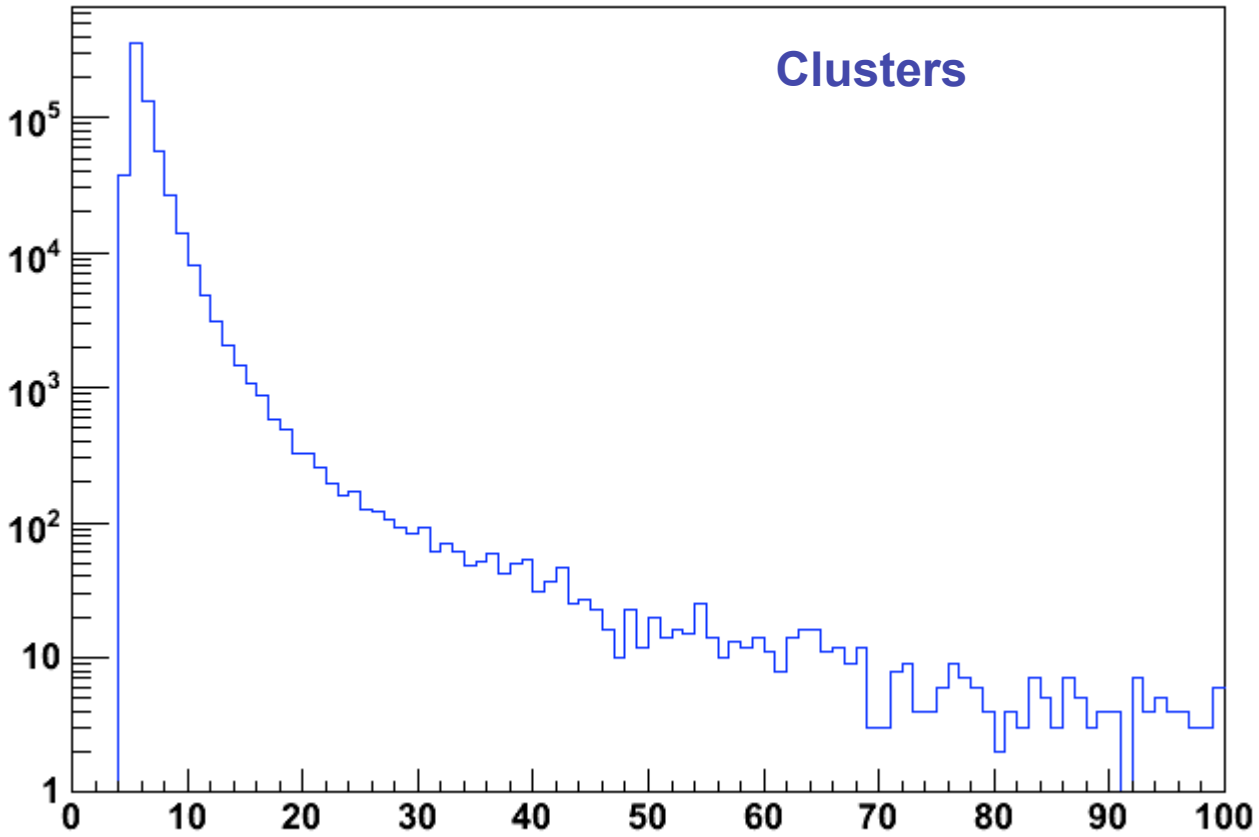

Central Arm Acceptance :
$|\eta|<0.35$ in rapidity
2 arms covering $\Delta\phi = \pi$

- EMC 4x4 Tower Sum Trigger



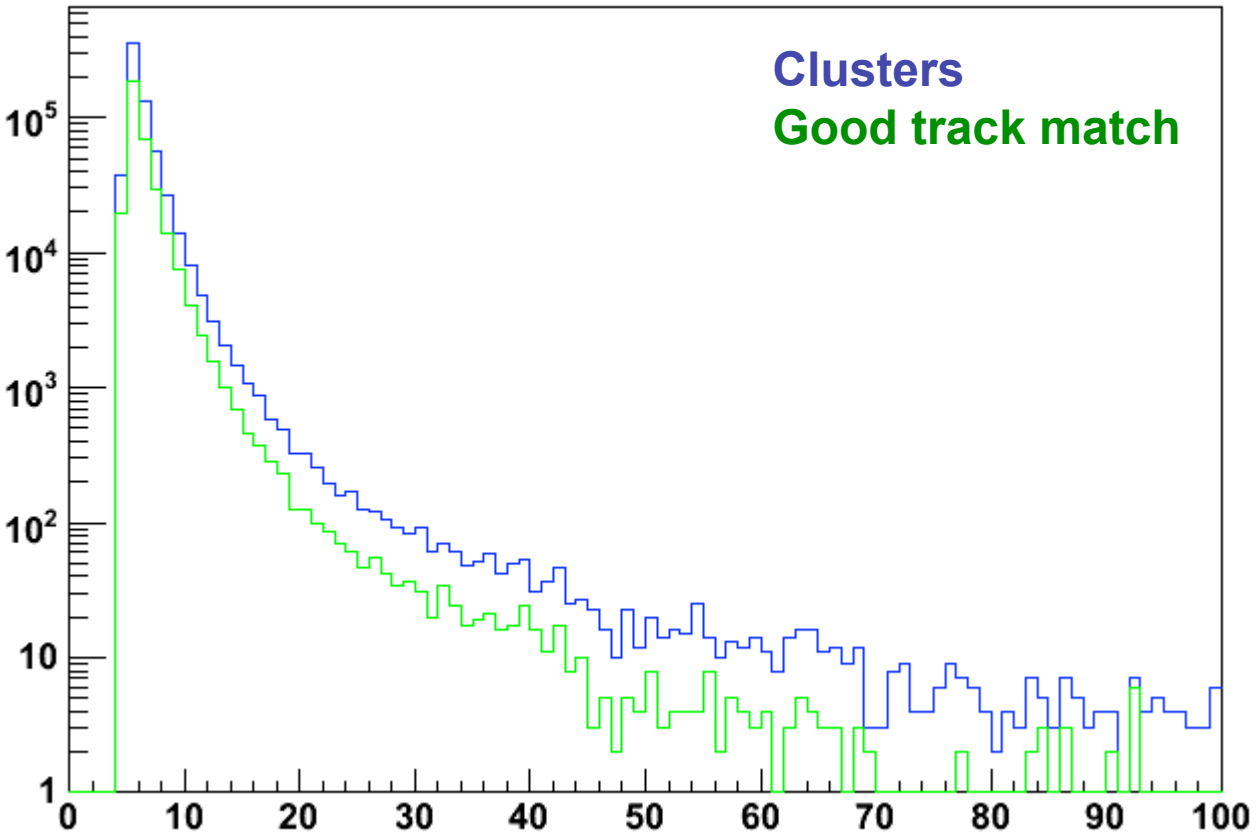

- ±30 cm vertex cut
- High energy EM Calorimeter clusters matched to charged track
- Loose timing cut to reduce cosmic ray bkg
- Loose E/p cut

# Effect of Cuts



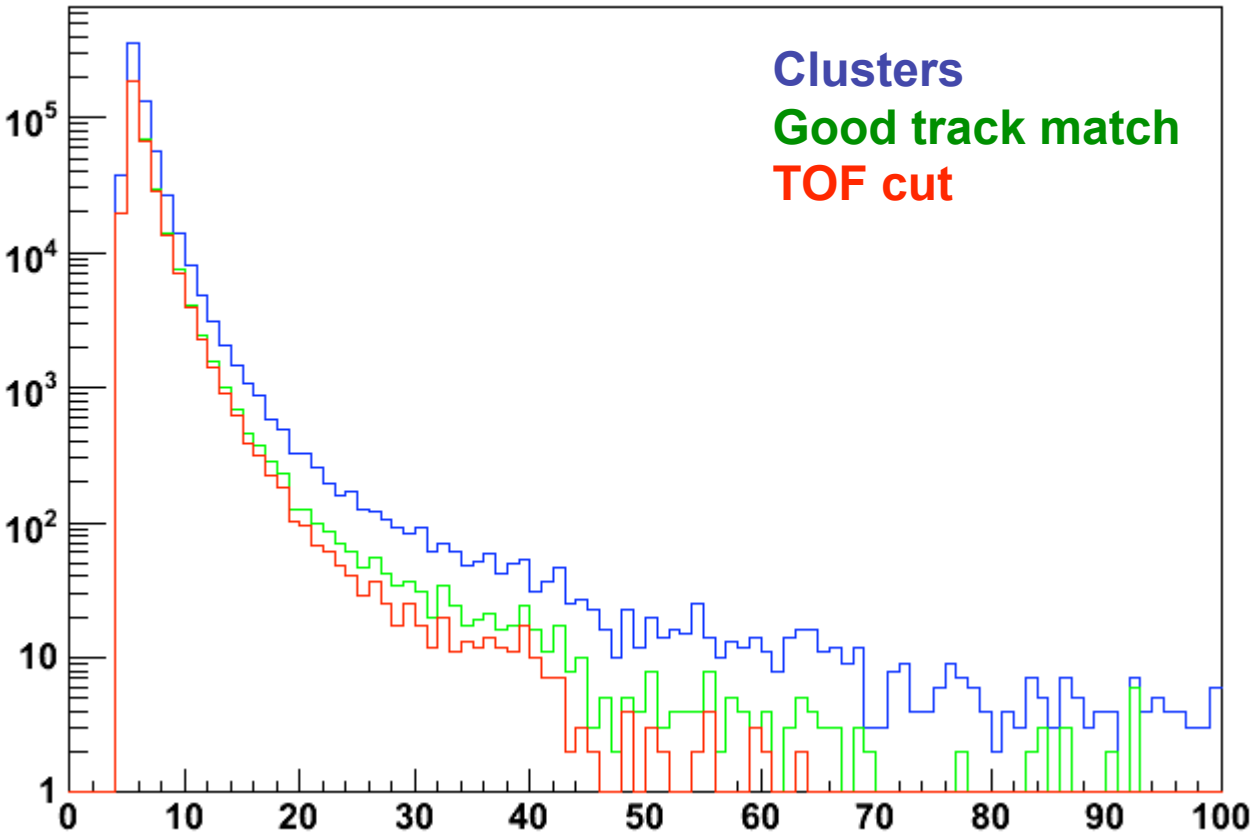

•Smooth spectrum of EMC clusters after removing bad towers

# Effect of Cuts



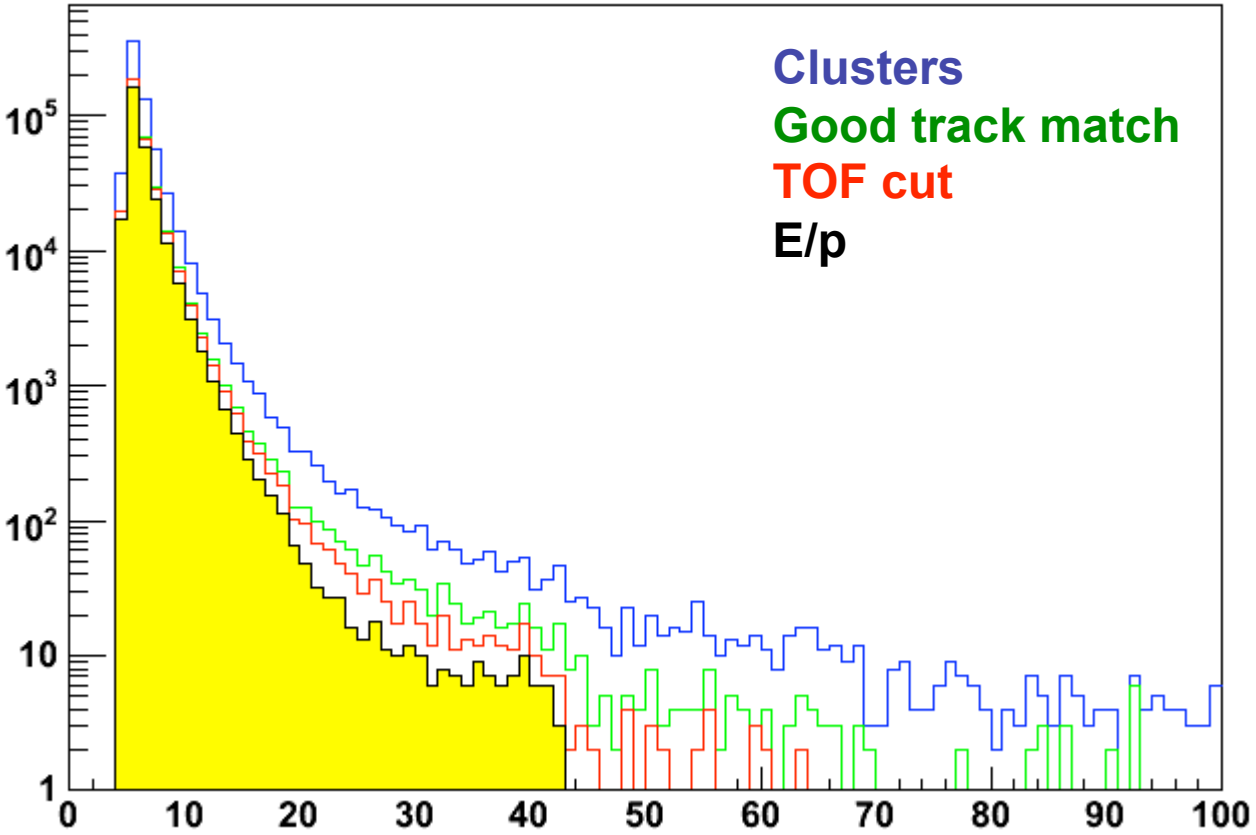

- Smooth spectrum of EMC clusters after removing bad towers
- Have a good track pointing to an EMC cluster

# Effect of Cuts



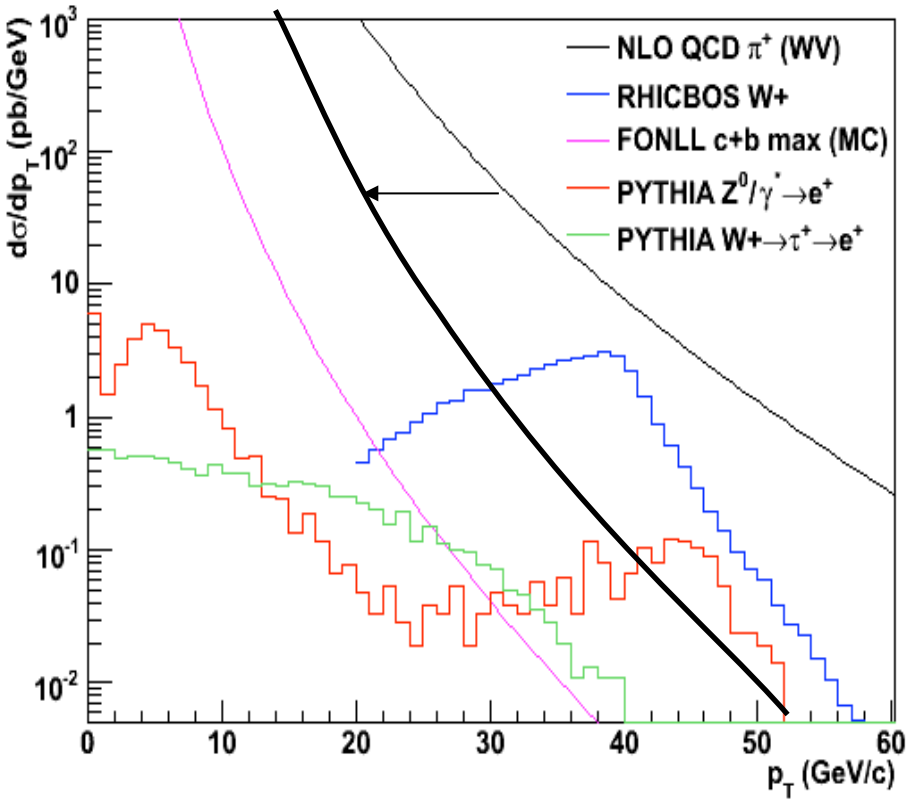

- Smooth spectrum of EMC clusters after removing bad towers
- Have a good track pointing to an EMC cluster
- Timing within start time of collision
  - Reduces out of time backgrounds (cosmics) by ~80%

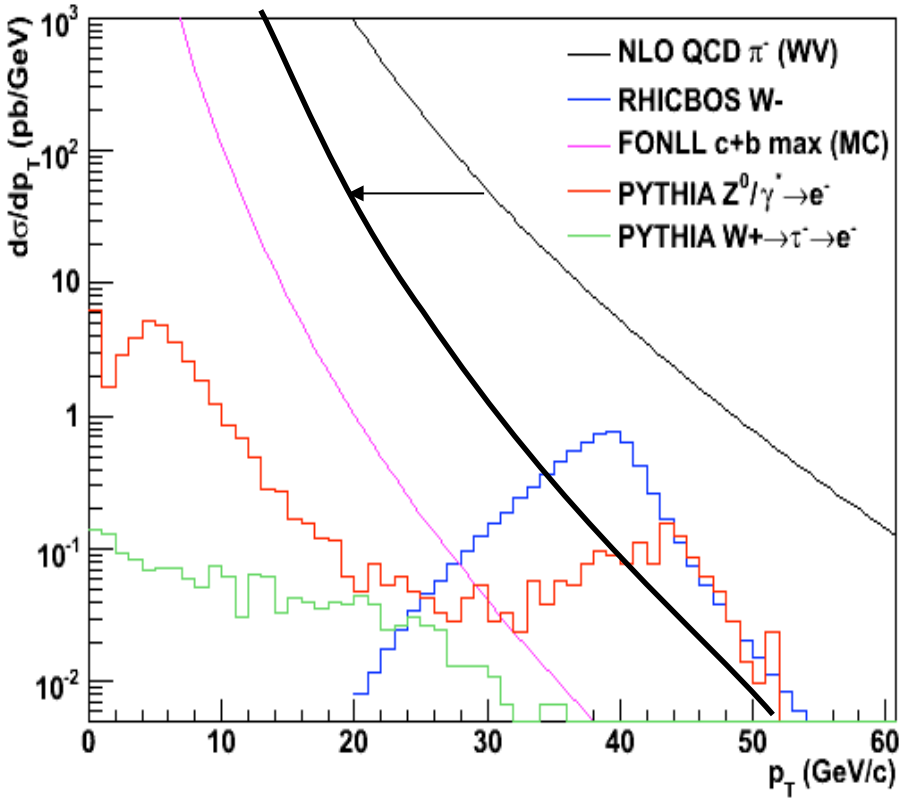
# Effect of Cuts




- Smooth spectrum of EMC clusters after removing bad towers
- Have a good track pointing to an EMC cluster
- Timing within start time of collision
  - Reduces out of time backgrounds (cosmics) by ~80%
- E/P cut

# Expected W->e decay signal




- QCD provides the most obvious background (W. Vogelsang)
- Not shown here but very important
  - Cosmics and photons (from meson decays and direct), which can have accidental matches to tracks or conversions
- c/b relatively small above 30 GeV, calculated at FONLL (Matteo Carciari)
- Z/γ* background is estimated from PYTHIA (~1 count is expected in Run09).
- W→τ→e is also small

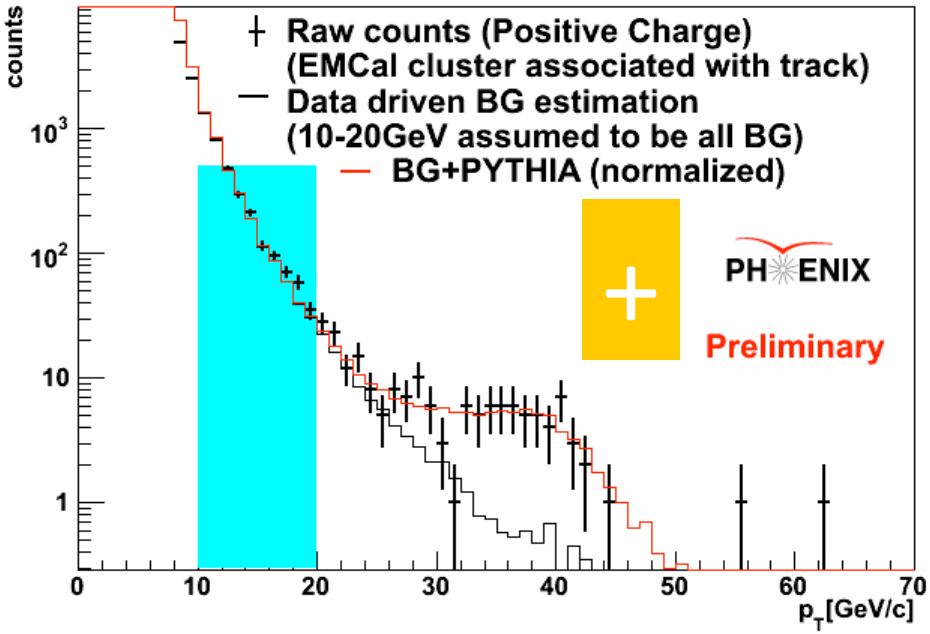
# Comparison To Measured spectra

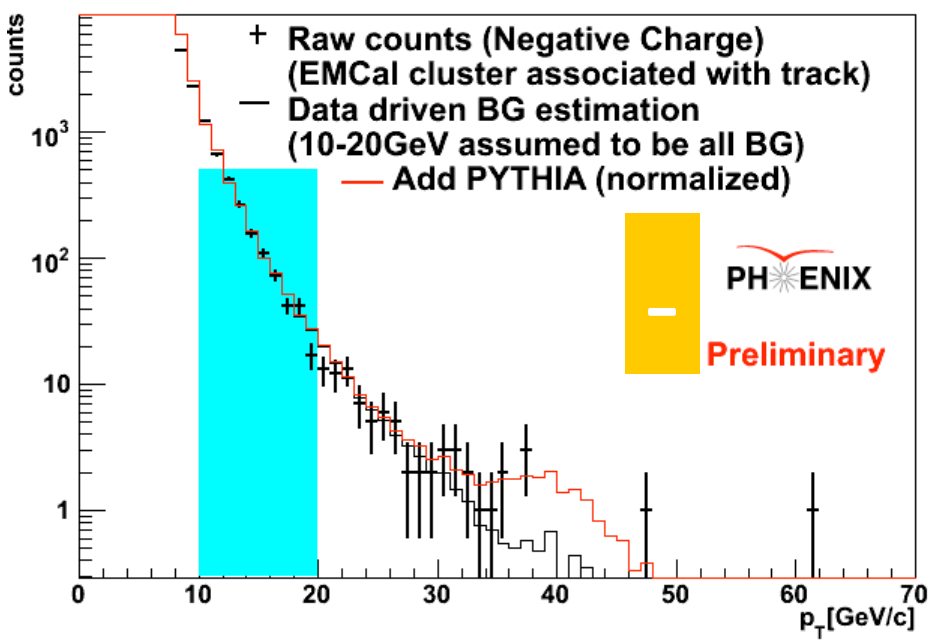
Data and MC driven BG estimation:

EMCal cluster distribution after subtracting cosmic background
× (Conversion + Accidental)
× Tracking Acceptance

**+**

(NLO Hadrons thru Geant + FONLL c/b)
× Normalization from fit to 10-20 GeV

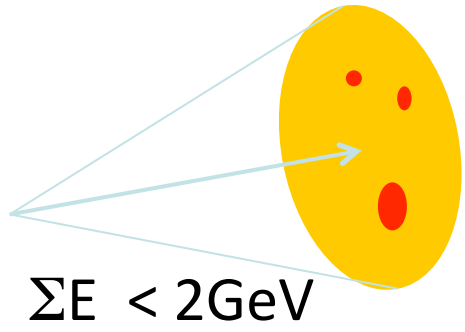


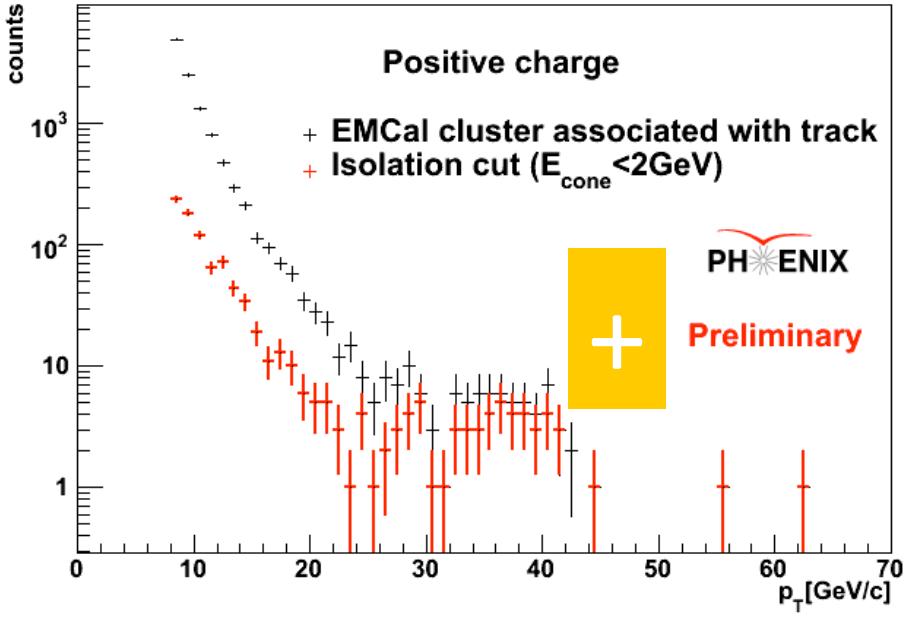



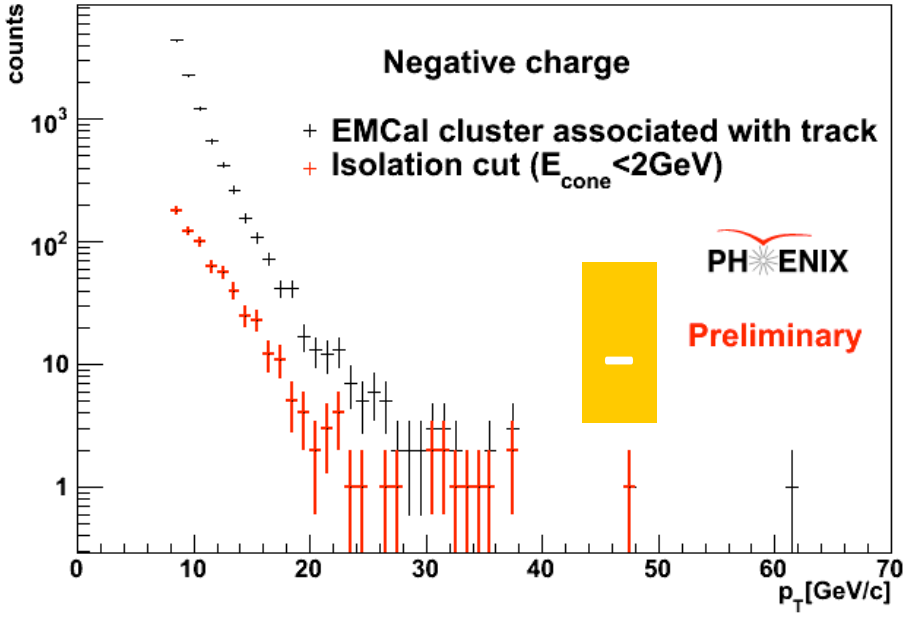

- The same scale factor for PYTHIA was used for W/Z shape.
- $W^- \rightarrow e^-$ signal has fewer counts than $W^+ \rightarrow e^+$ signal as expected

# Isolation cut

- Signature of a W event is that it is isolated
- Sum up energy in a cone around electron and in cone on opposite hemisphere




- 90+% of signal is kept (red histograms)
- Factor ~5 reduction in jet dominated region

# Parity Violating Single Spin Asymmetry

- Spin Asymmetry is calculated from isolated leptons
  - Reduced background
  - Doesn't introduce a bias
- The data are sorted by their spin states (++,+-,-+,--) calculate the asymmetry

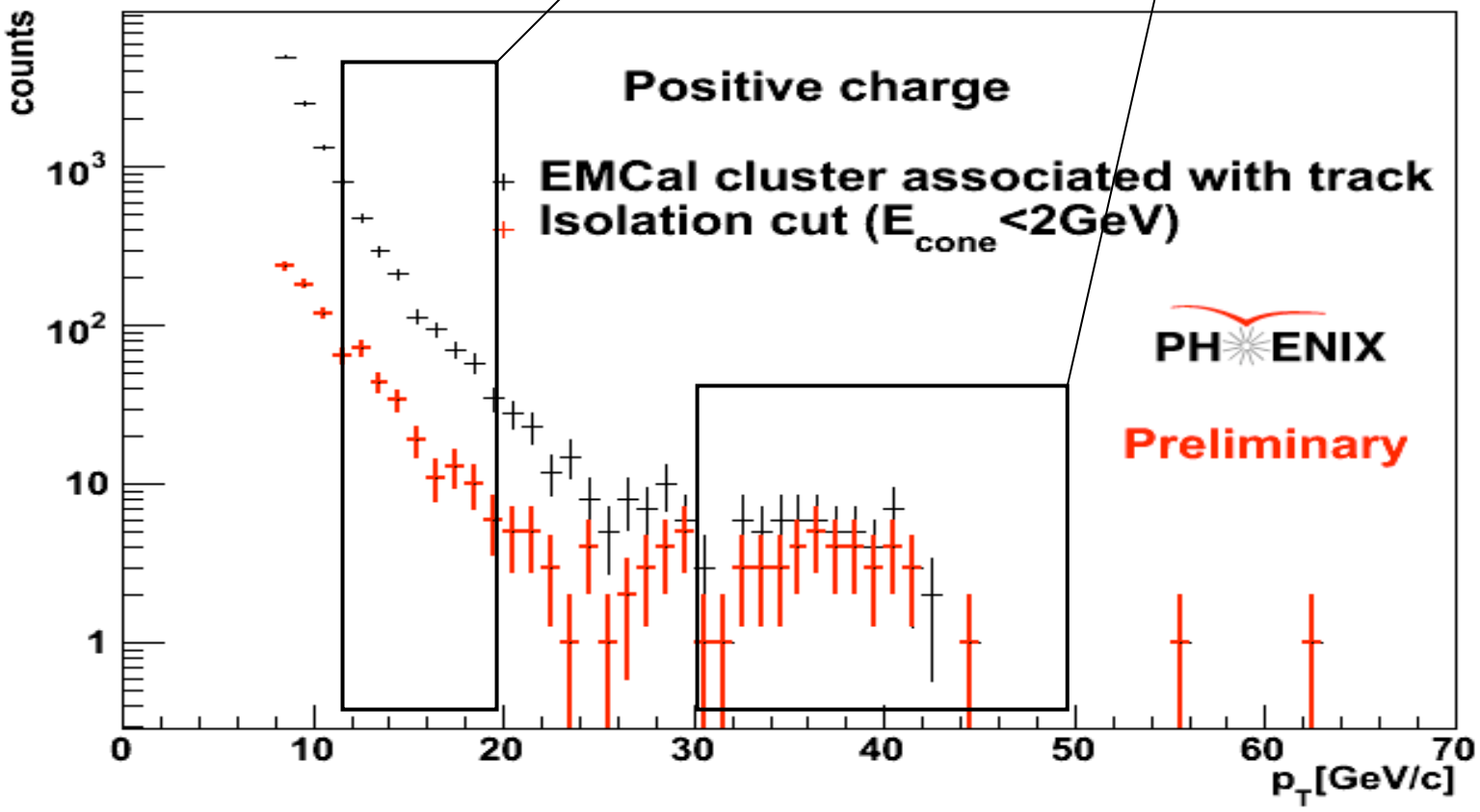
$$A_L^W = \frac{1}{P} \times \underbrace{\frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}}_{\text{Raw asymmetry}}$$

$N^+$ : helicity +
$N^-$ : helicity –
normalized by $\int L$

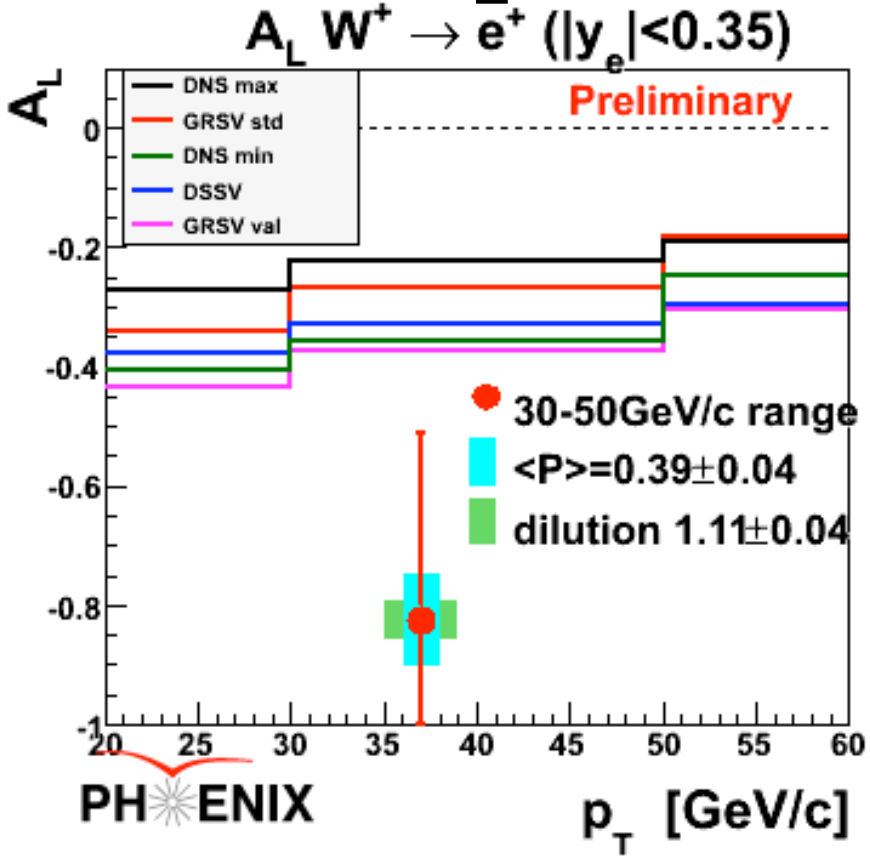
- Polarization is averaged by luminosity over run
- Get a factor of two from using both beams.

# Raw Asymmetries ($e^+$)

| | Background | Signal |
|---|---|---|
| $p_T$ Range (GeV/c) | 12-20 | 30-50 |
| Raw Asymmetry | 0.035±0.047 | -0.29±0.11 |



# PHENIX $A_L(W^+ \rightarrow e^+)$



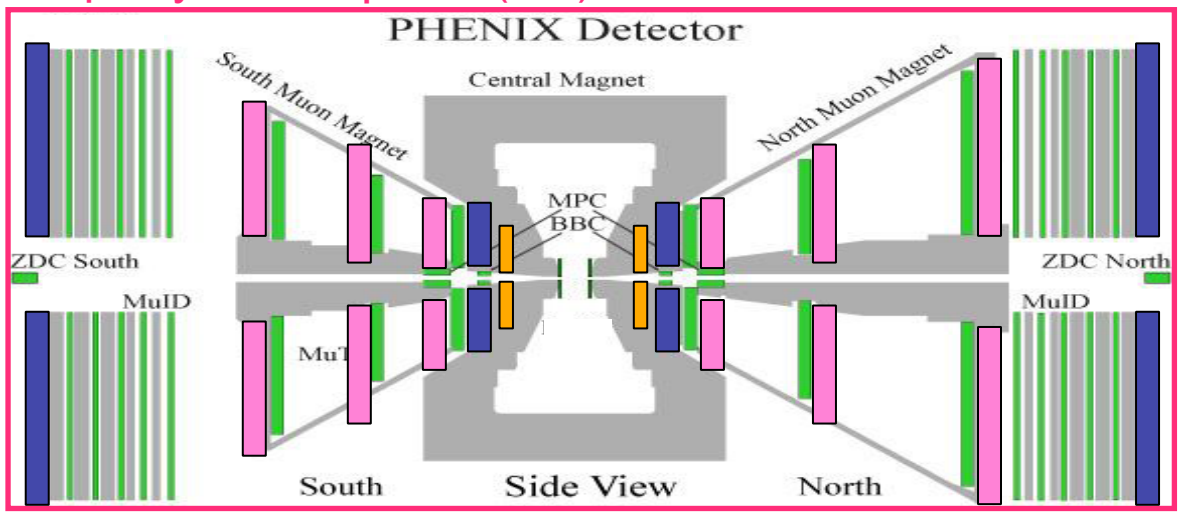

- Using average polarization 0.39±0.04, we get

$$A_L^{W^+} = -0.83 \pm 0.31$$

- Asymmetry is corrected for dilution by Z and QCD backgrounds

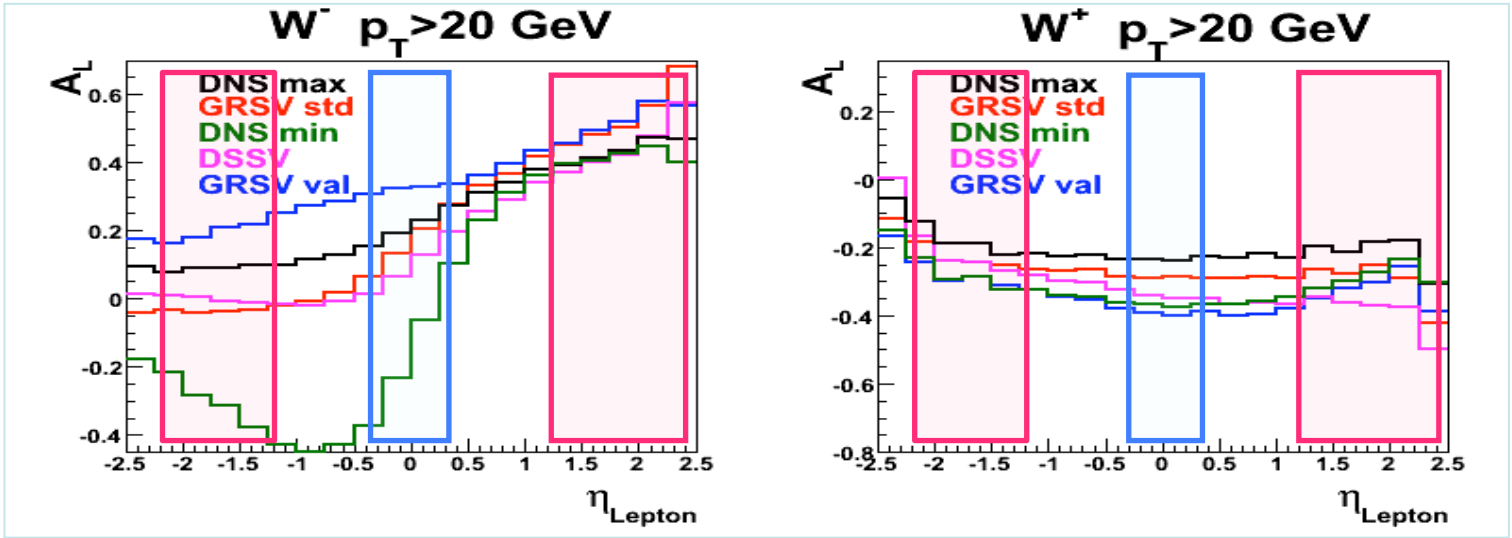
# PHENIX Muon Arm Upgrade

Rapidity: $1.2 < \eta < 2.2$ (2.4)




**Muon Trigger Upgrade**

- **MuTr FEE Upgrade (MuTRG)**
- **RPC's (Resistive Plate Chamber)**
- **Install additional Absorber**




- Big increase in acceptance makes PHENIX a significantly better W experiment
- Upgraded Muon Arms will be ready to measure $W \rightarrow \mu$ in the coming run

*see talk by A. Vossen

# Conclusions

- PHENIX observed W→ e decay in the mid-rapidity region
- First attempt to measure single spin asymmetry has detected a parity violating asymmetry leading to a preliminary value of $A_L$
- $A_L(W+ \rightarrow e+)$ at $|y_e|<0.35$ has been measured to be

$$A_L(W^+ \rightarrow e^+) = -0.83 \pm 0.31$$

  Within errors, it is consistent with the predictions.
- While the data sample is small, we got a first significant result
  - Gained experience on the backgrounds to the W in the PHENIX central arm
  - Learned how to handle multiple collisions from high luminosity
  - Learned how to handle very high momentum particles
  - Working on finalizing cross-sections, $A_L(W^+)$, and $A_L(W^-)$
- Goal of the RHIC W program is 300 $pb^{-1}$ and 70% polarization
  - Order of magnitude improvement in the error bars
  - Forward muon measurements in PHENIX will contribute significantly starting next year