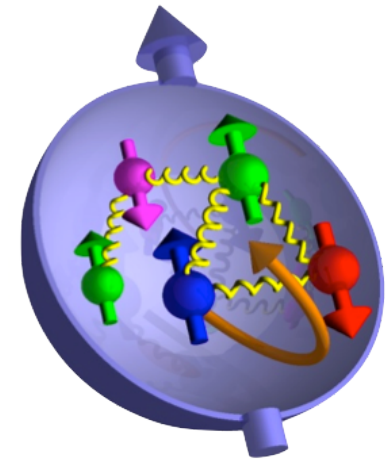
Recent Results on W Boson Production in Polarized Proton Collisions at STAR

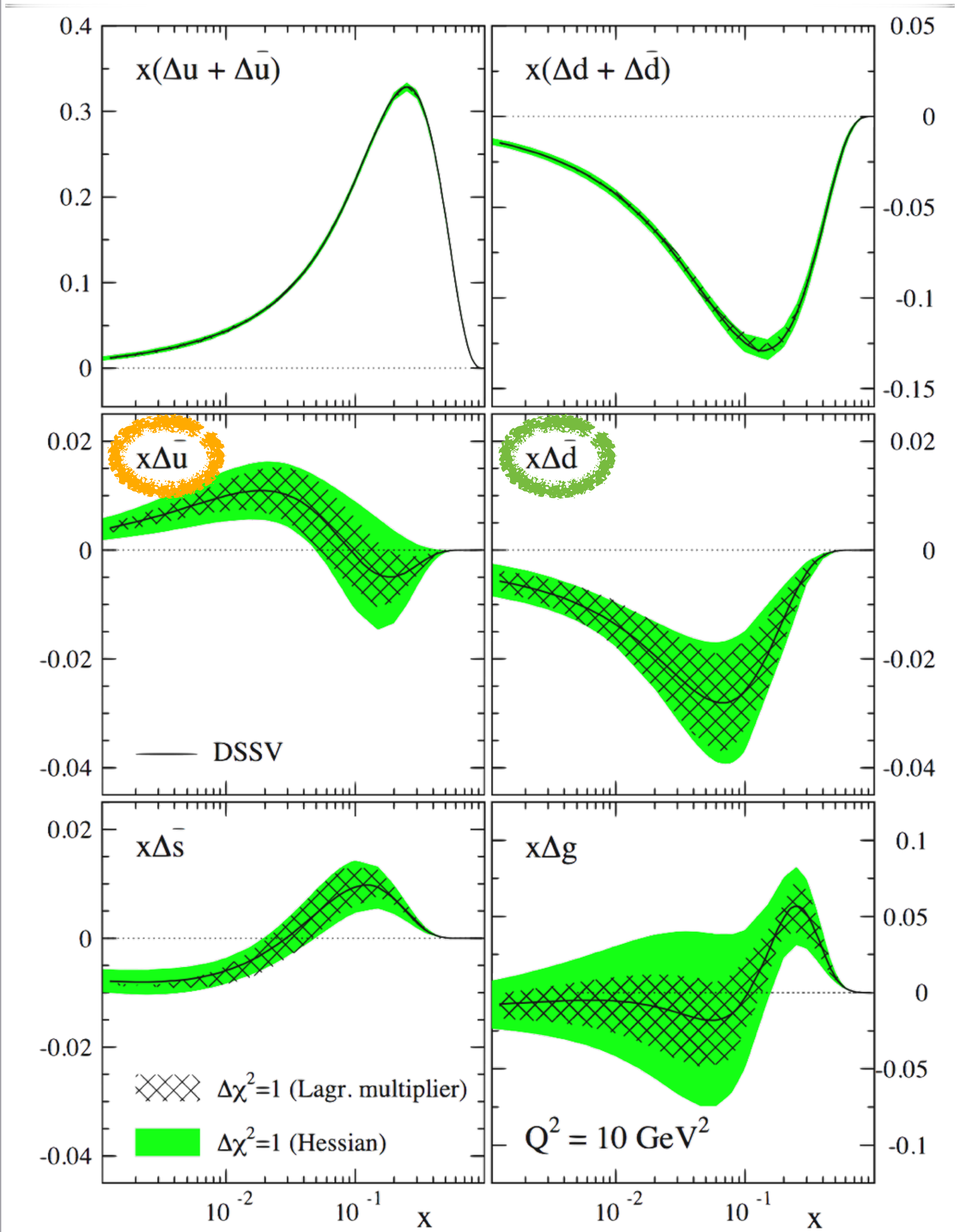
Justin Stevens for the STAR Collaboration

APS 2013

Proton Spin Puzzle



DSSV Global Analysis



PRD **80**, 034030 (2009)

$$\langle S_p \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

$$\Delta\Sigma = \int \left(\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s}\right) dx$$

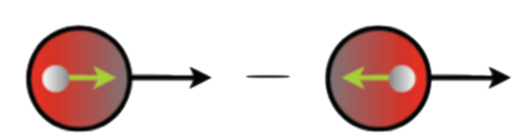
Integral of quark polarization is well measured in DIS to be ~30%, some info on decomposition from SIDIS but sea not well constrained

$$\Delta G = \int \Delta g\,(x)\,dx$$

First experimental evidence of non-zero Δg from 2009 RHIC data (previous talks)

Polarized PDF

$$\Delta f(x) =$$

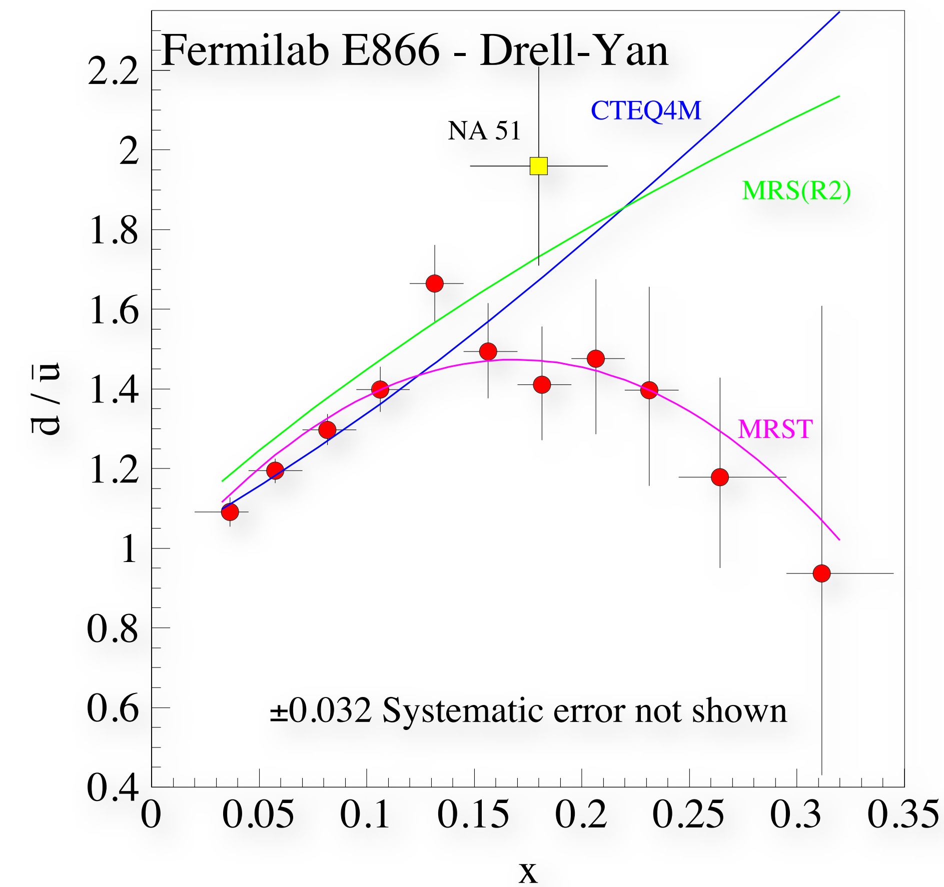


$$f^+(x) - f^-(x)$$

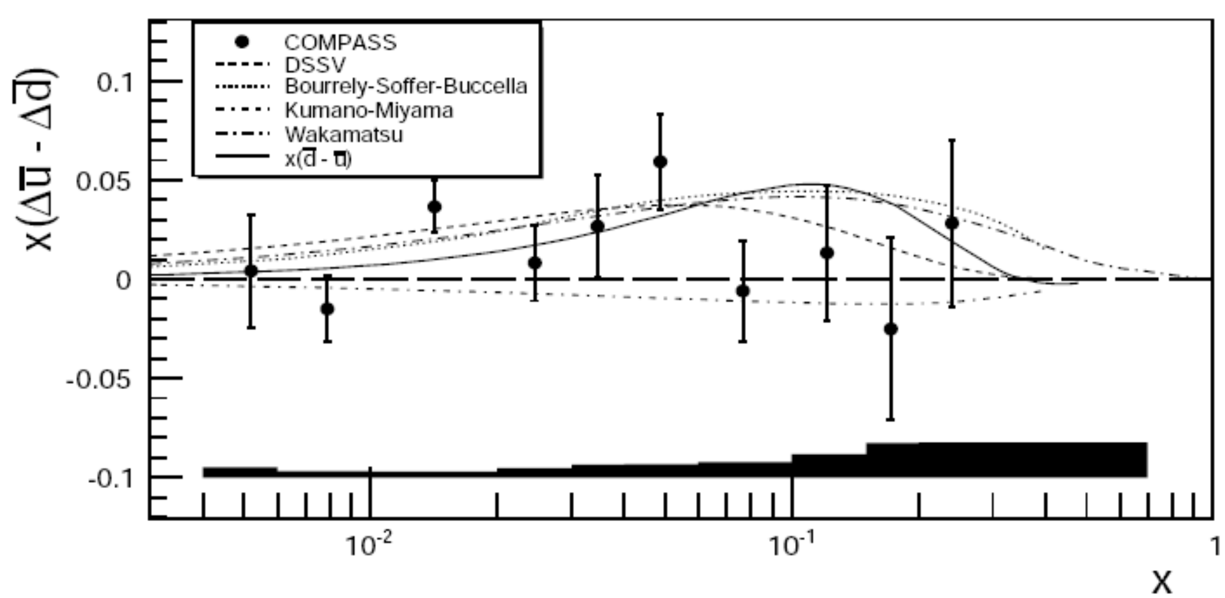
Flavor Asymmetry of the Sea

Unpolarized Flavor Asymmetry:

- Quantitative calculation of Pauli blocking does not explain $\bar{d}/\bar{u}$ ratio
- Non-perturbative processes may be needed in generating the sea
- E866 results are qualitatively consistent with pion cloud models, chiral quark soliton models, instanton models, etc.



PRD **64**, 052002 (2001)

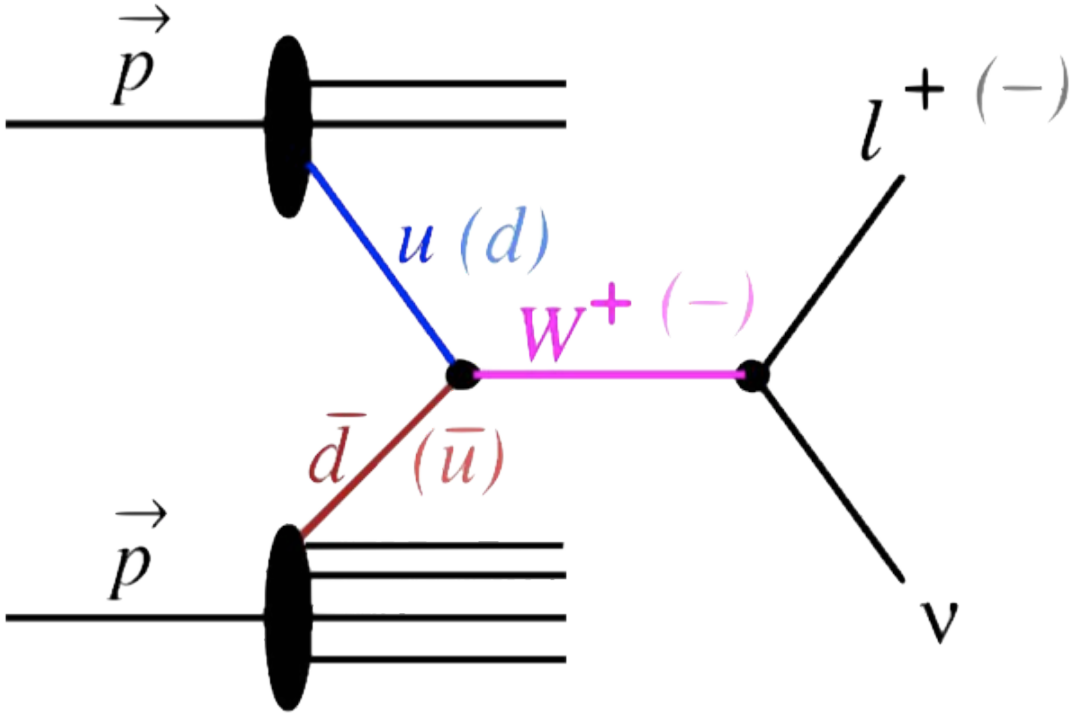


PLB **693**, 227 (2010)

Polarized Flavor Asymmetry:

- Valence u and d distributions are well determined from DIS
- Polarized flavor asymmetry $x(\Delta\bar{u} - \Delta\bar{d})$ could help differentiate models
- SIDIS results depend on FFs

Why Ws?



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

$$d + \bar{u} \rightarrow W^- \rightarrow e^- + \bar{\nu}$$

- Ws couple directly to the quarks and antiquarks of interest
- Detect Ws through e+/e- decay channels
- V-A coupling of the weak interaction leads to perfect spin separation

Measure parity-violating single-spin asymmetry:

(Helicity flip in one beam while averaging over the other)

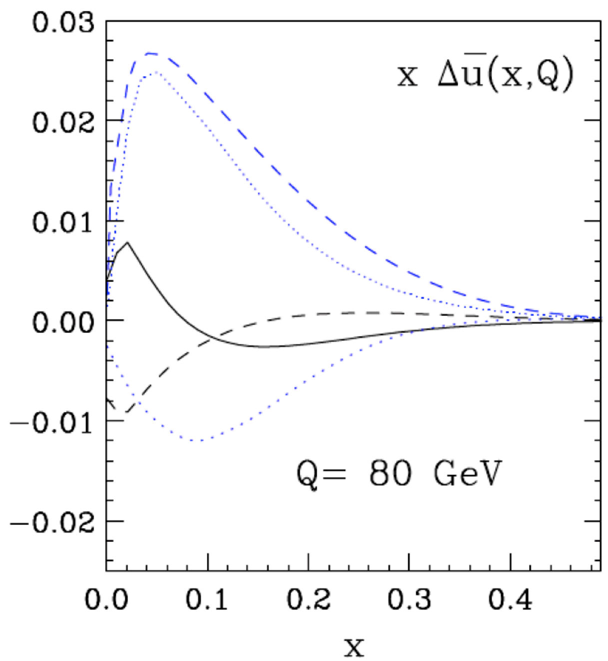
$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

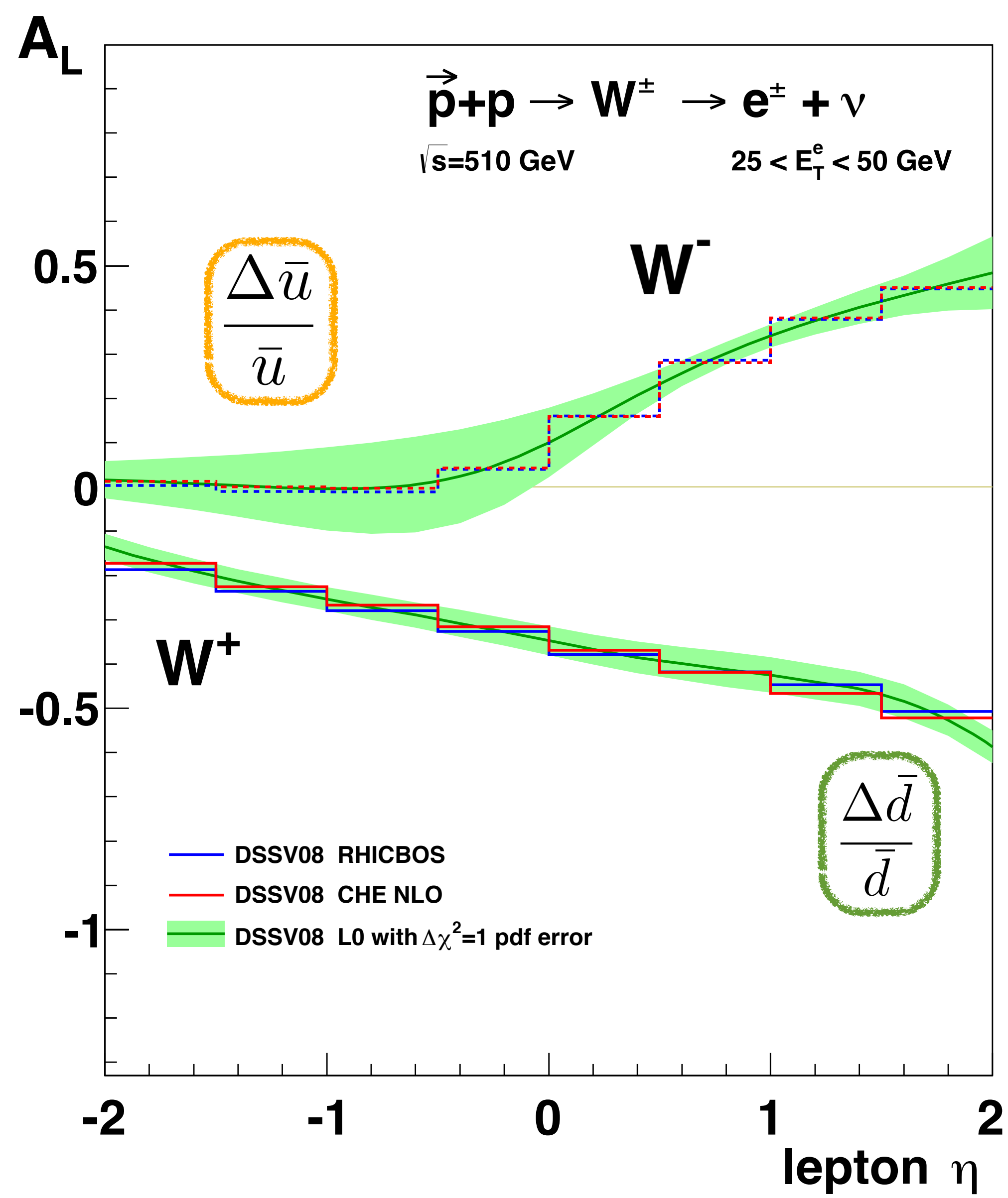
$$A_L^{W-} \propto \frac{-\Delta d(x_1)\bar{u}(x_2) + \Delta\bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)}$$

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

Expectations for W A_L

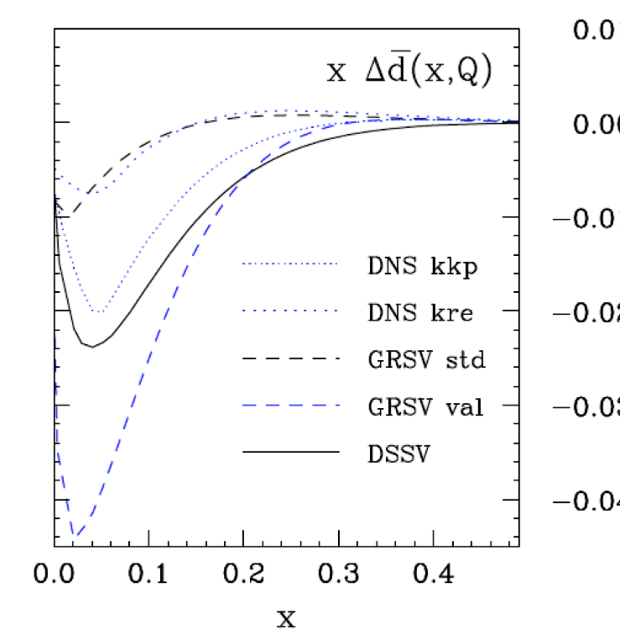
$$A_L^{W-} \propto \frac{-\Delta d(x_1)\bar{u}(x_2) + \Delta\bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)} \qquad A_L^{W+} \propto \frac{-\Delta u(x_1)\bar{d}(x_2) + \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$





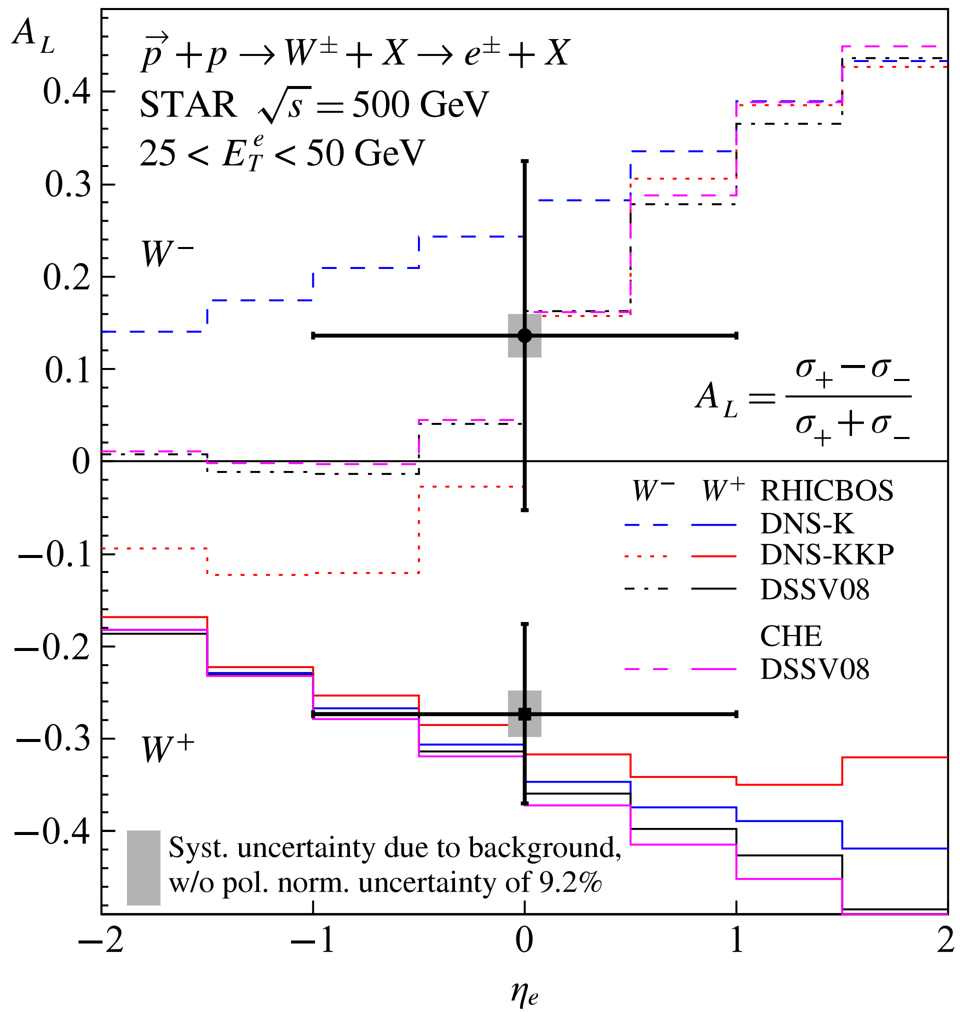
- Large parity-violating asymmetries expected
- Simplified interpretation at forward and backward rapidity

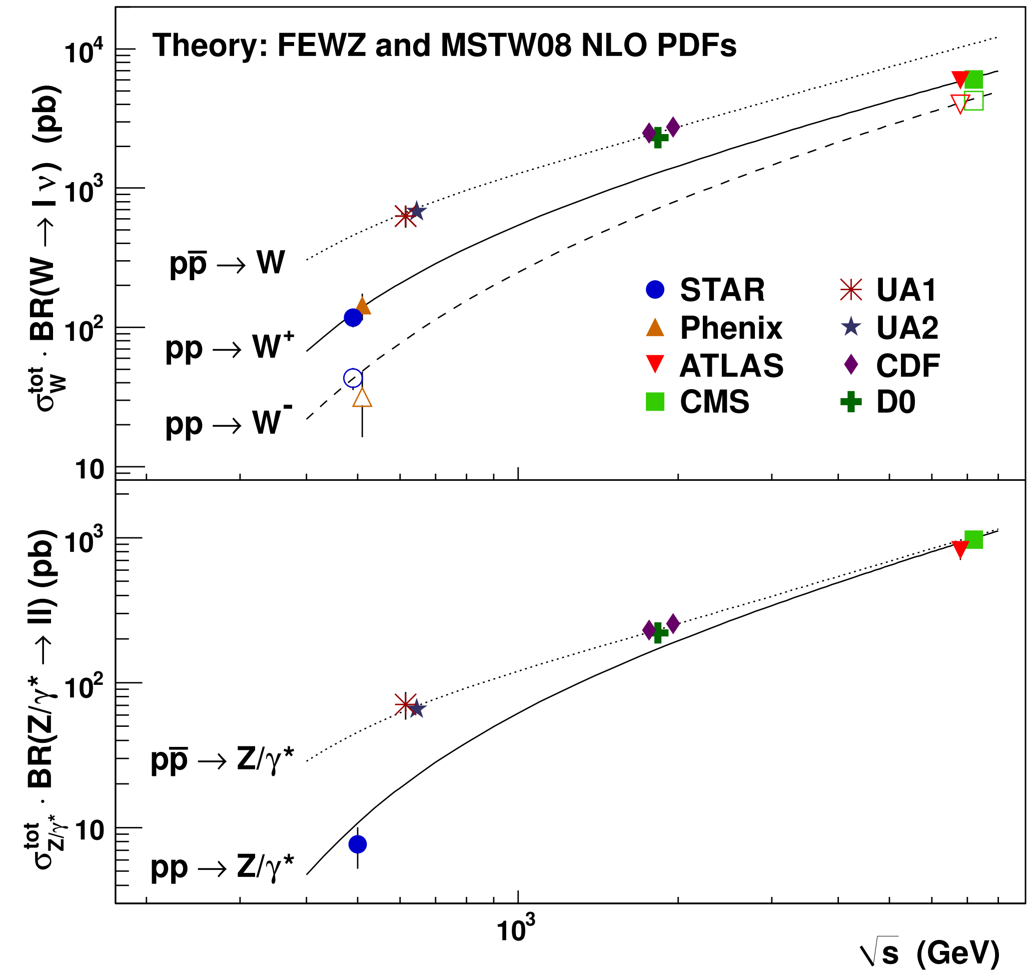
- DSSV $\Delta\chi^2 = 1$ band underestimates the theoretical uncertainty (and Lagrange multiplier estimates for a $\Delta\chi^2/\chi^2 = 2\%$ error are in progress)

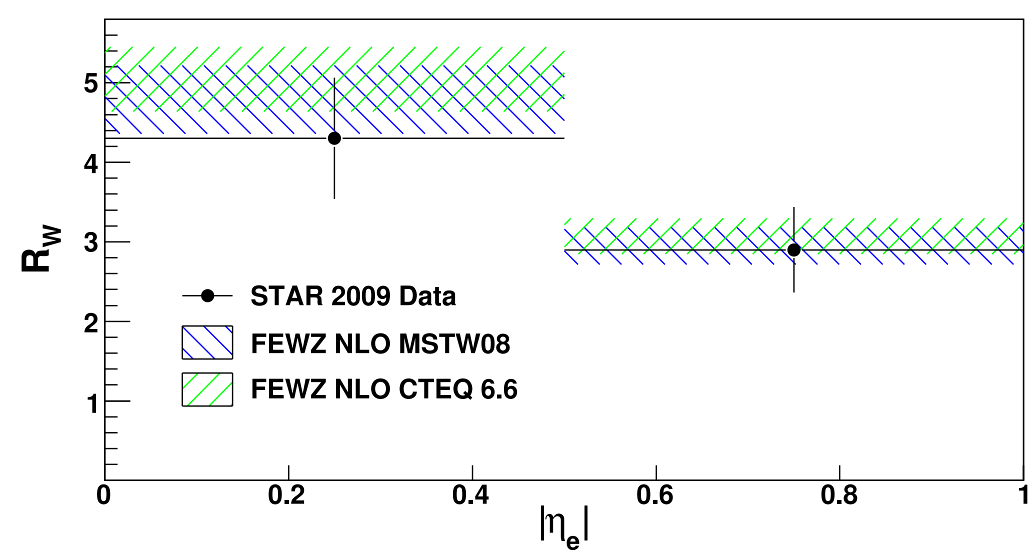


Previous STAR Measurements

PRL **106,** 062002 (2011)



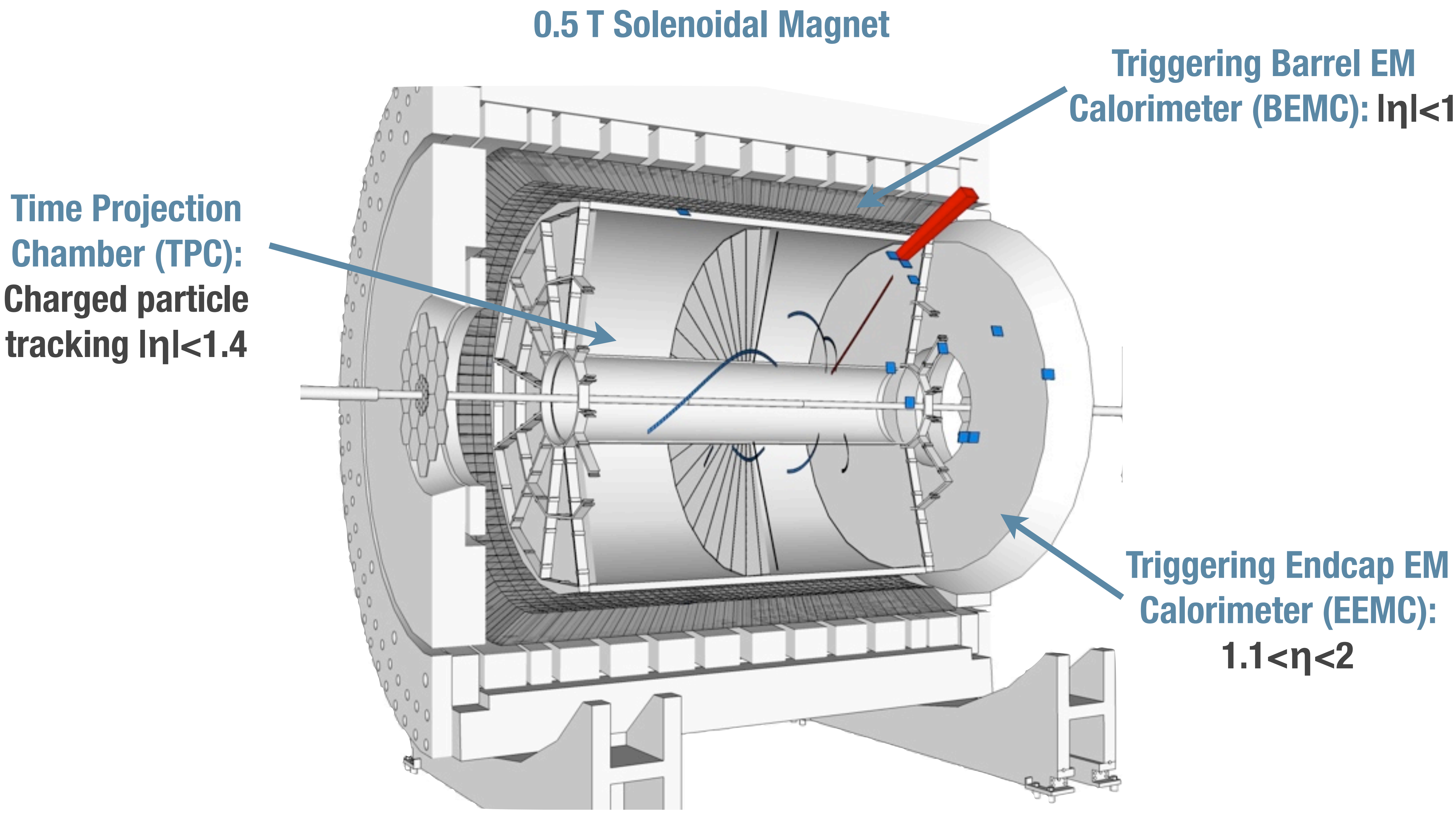




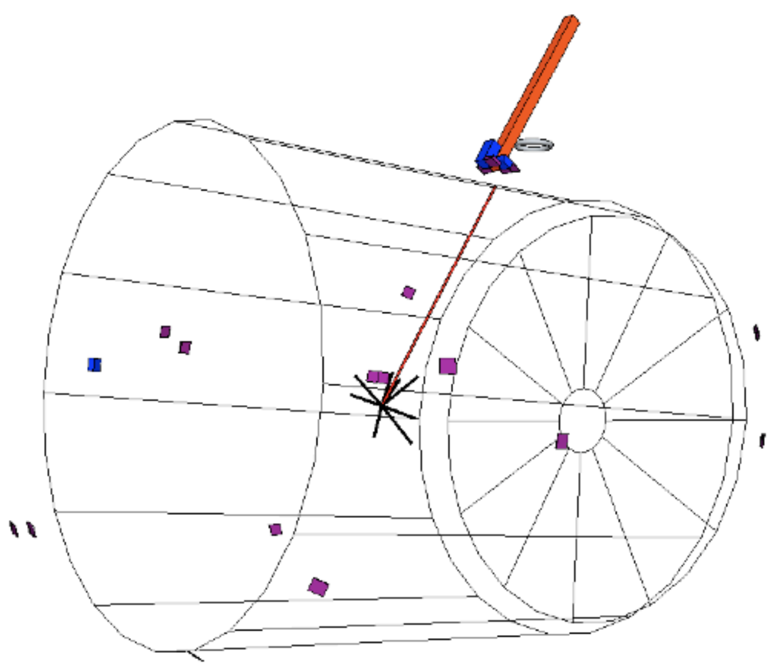
PRD **85,** 92010 (2012)

- 2009 was a very successful first 500 GeV physics run
- 2012 increase in FOM = P^2L of an order of magnitude!

STAR Detector Overview



What do W decays look like?

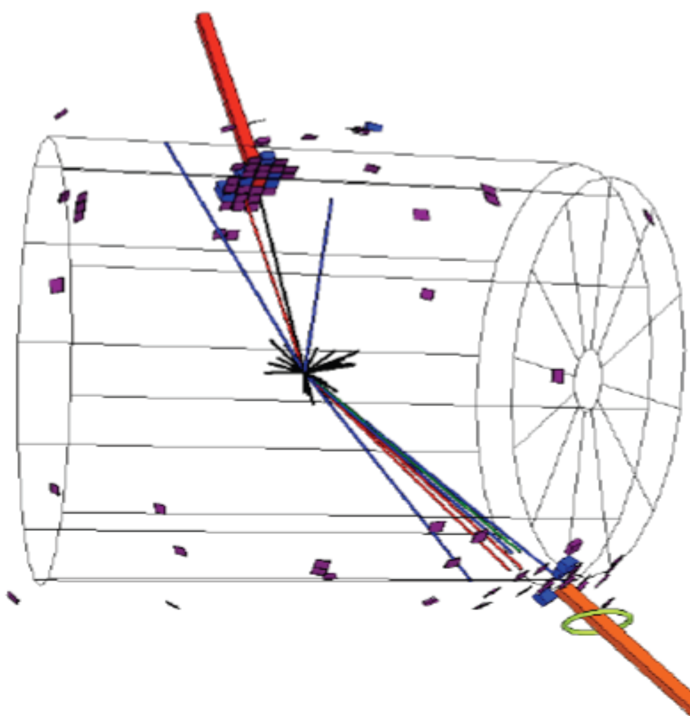


$W \rightarrow e + \nu$ Candidate Event

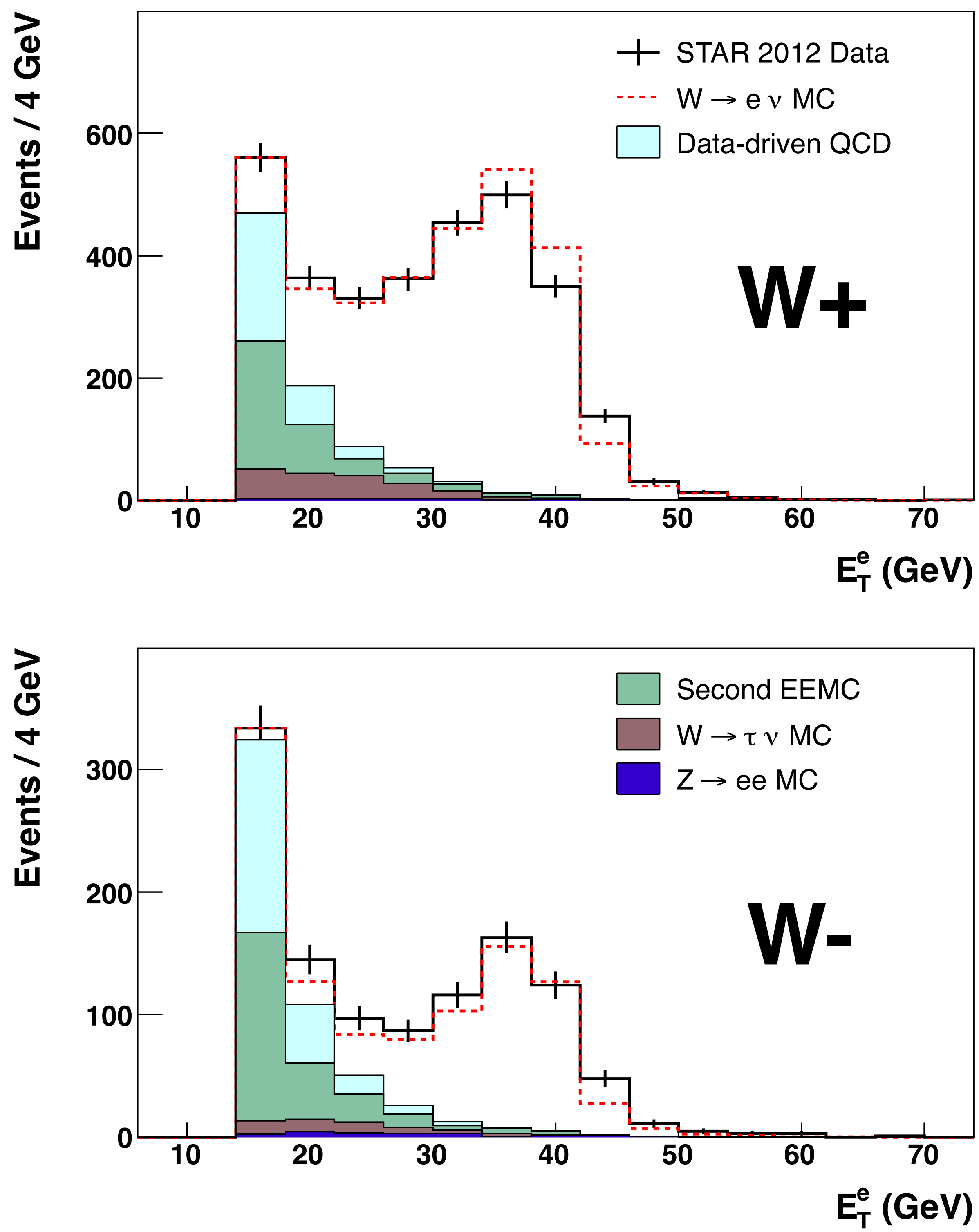
- Isolated track pointed to isolated EM cluster in calorimeter
- Large "missing energy" opposite the electron candidate

Di-jet Background Event

- Several tracks pointing to EM energy deposit in several towers
- Vector p_T sum is balanced by opposite jet, "missing energy" is small



Mid-rapidity Background Estimation



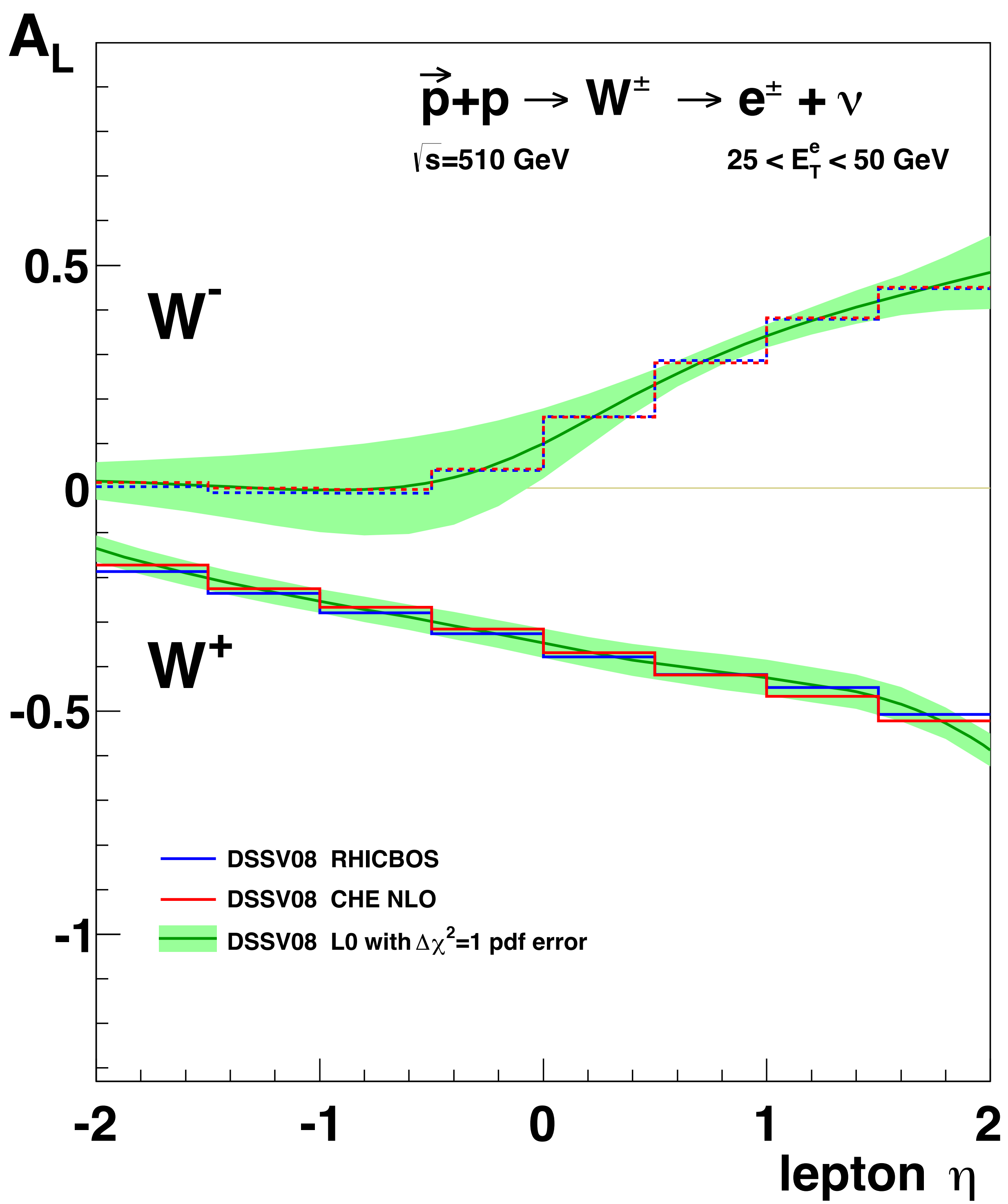
W Signal

- "Jacobian Peak"

Background Estimation

- Electroweak
  - Z → ee MC
  - W → τν MC
- Second EEMC
- Data-driven QCD

STAR 2012 W $A_L(\eta)$



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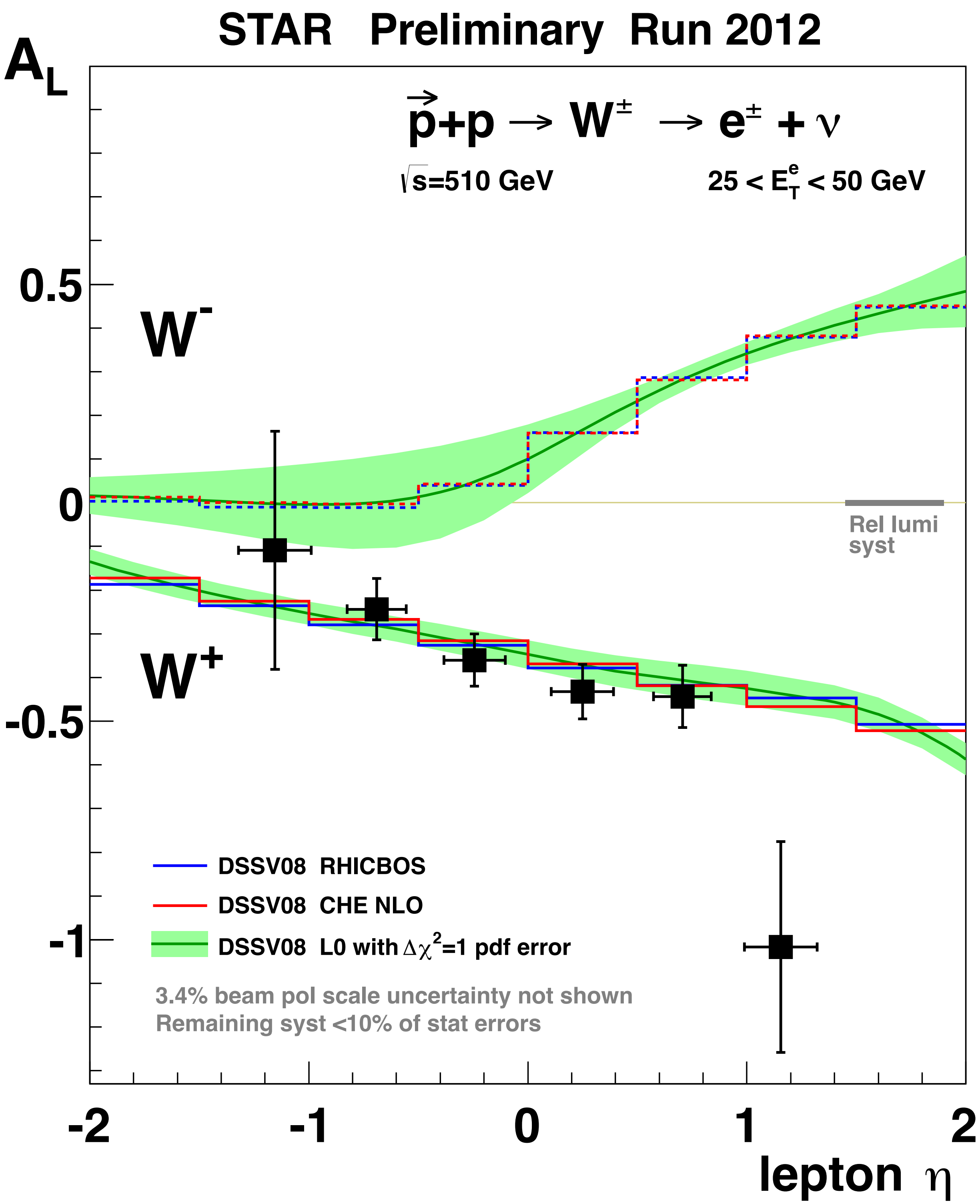

- $A_L(W+)$ is consistent with theoretical predictions using the DSSV polarized PDFs

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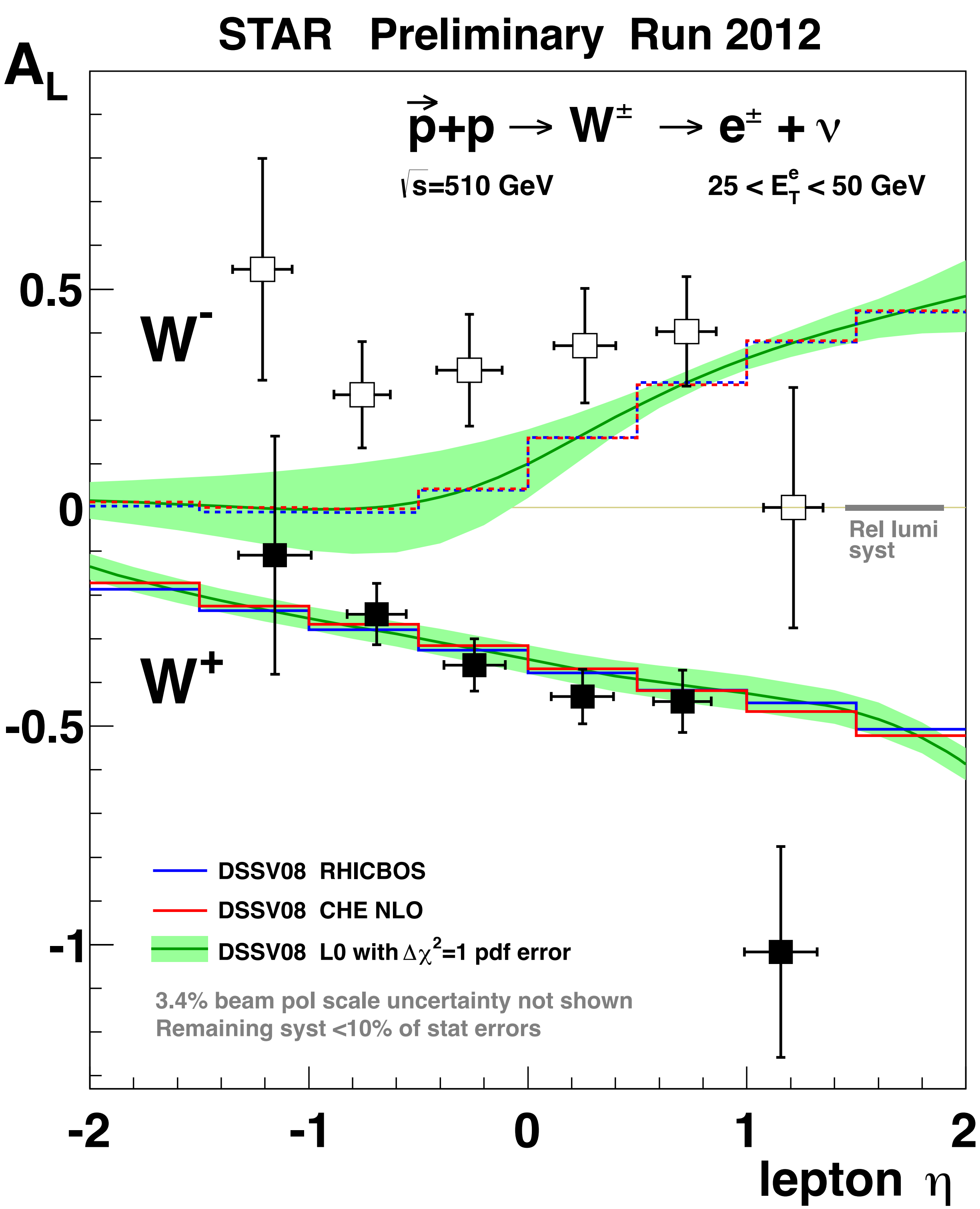
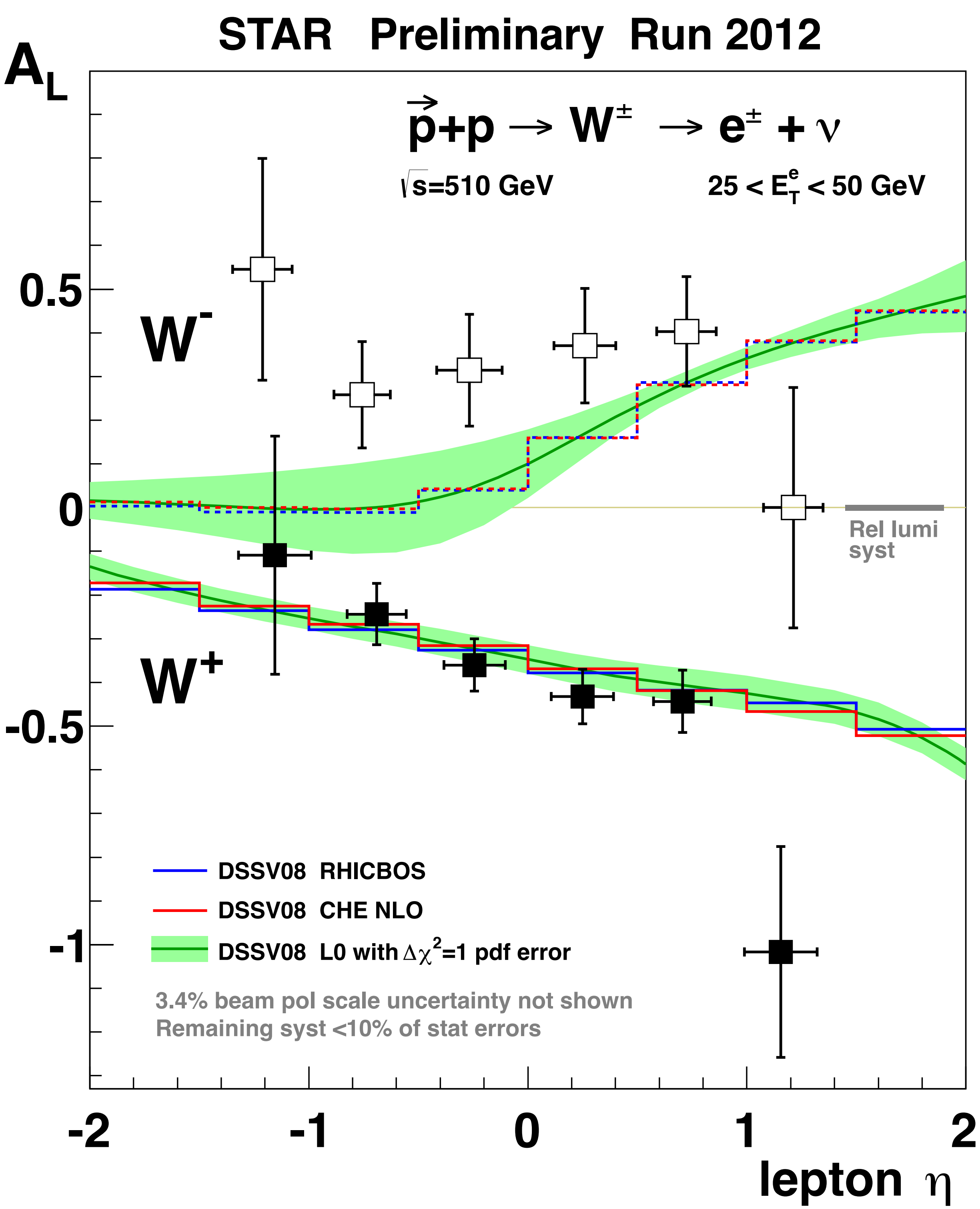


- $A_L(W-)$ is systematically larger than the DSSV predictions
  - The enhancement at $\eta_e<0$, in particular, is sensitive to the $\Delta\bar{u}$ polarized antiquark distribution
- $A_L(W+)$ is consistent with theoretical predictions using the DSSV polarized PDFs

STAR 2012 W $A_L(\eta)$

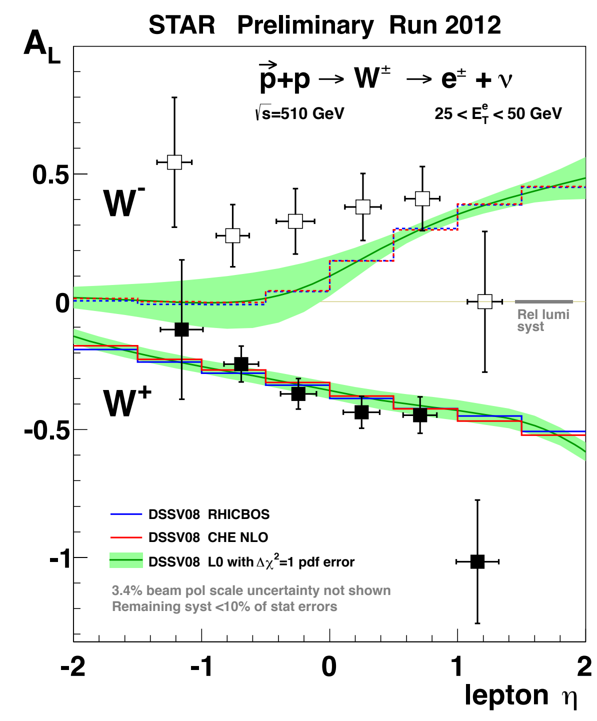


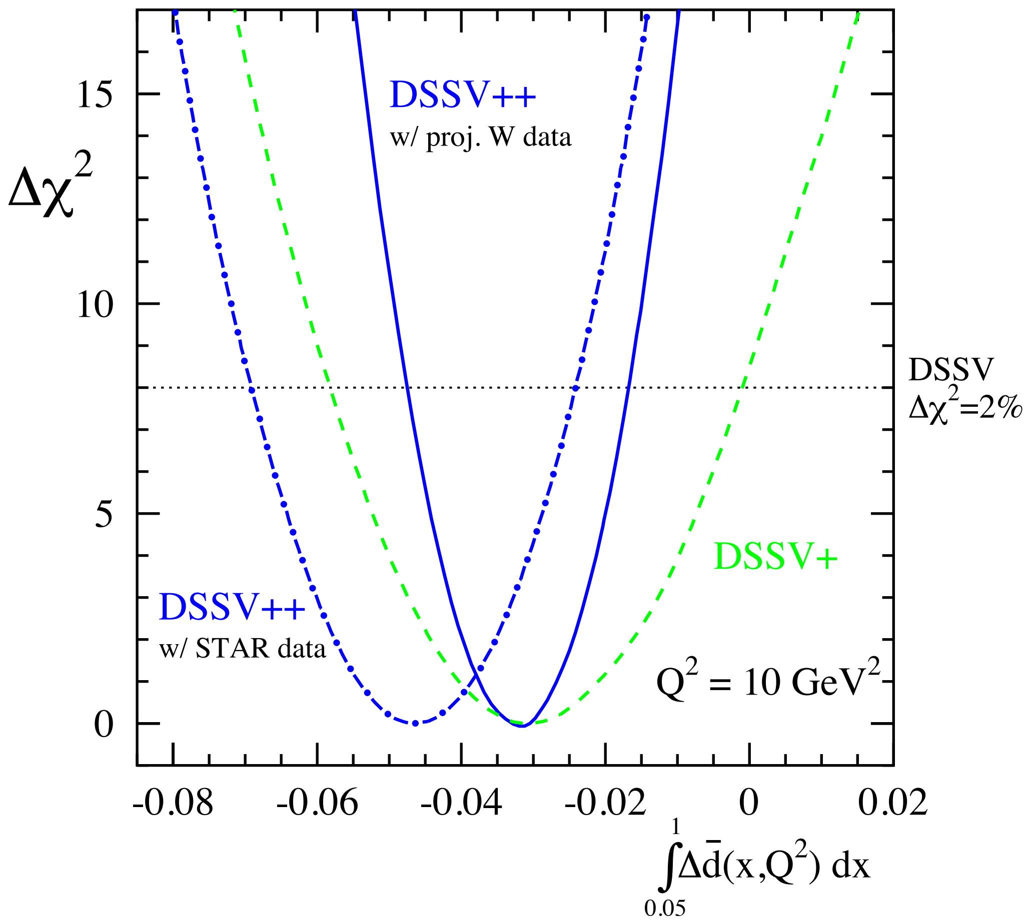
- $A_L(W-)$ is systematically larger than the DSSV predictions
  - The enhancement at $\eta_e<0$, in particular, is sensitive to the $\Delta\bar{u}$ polarized antiquark distribution
- $A_L(W+)$ is consistent with theoretical predictions using the DSSV polarized PDFs
- The systematic uncertainties for A_L are well under control for $|\eta_e| < 1.4$

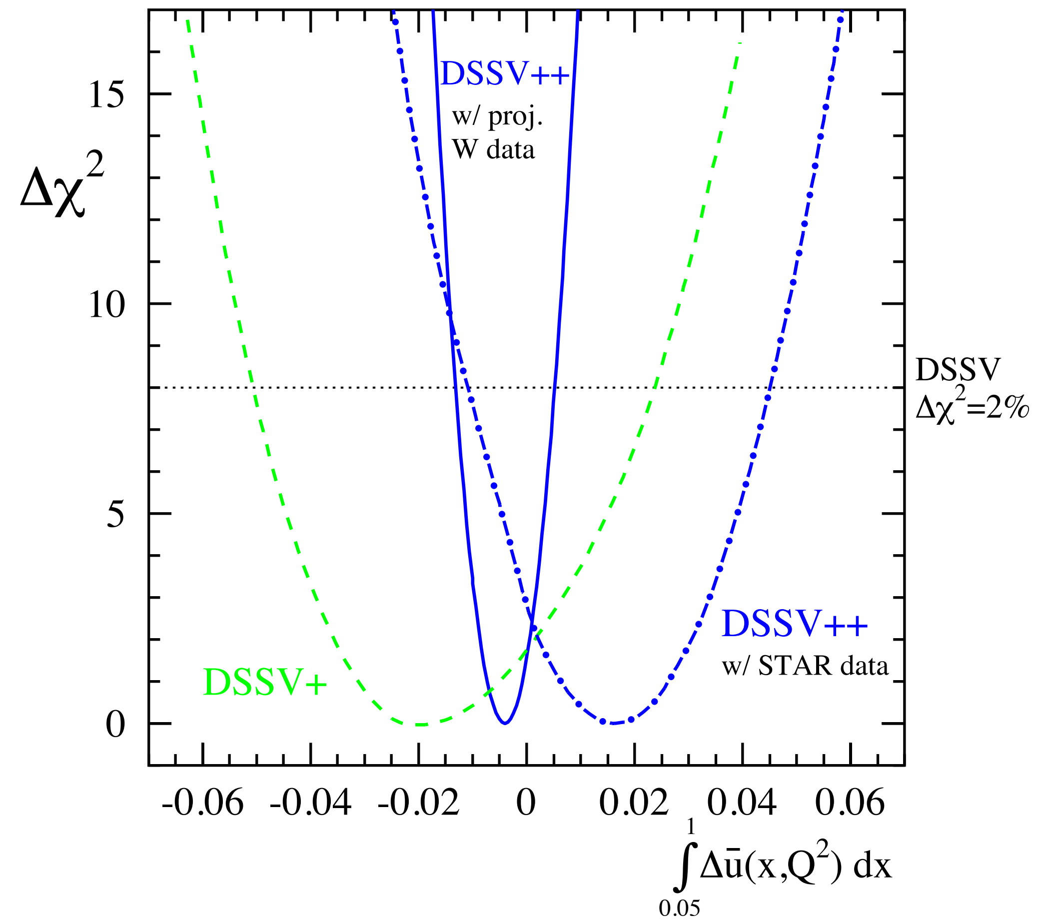
DSSV++ Global Analysis

- DSSV++ is a new preliminary global analysis from the DSSV group that includes RHIC 2009 A_{LL} data and STAR 2012 W A_L data

- Significant shift in $\Delta\bar{u}$ due to A_L W-

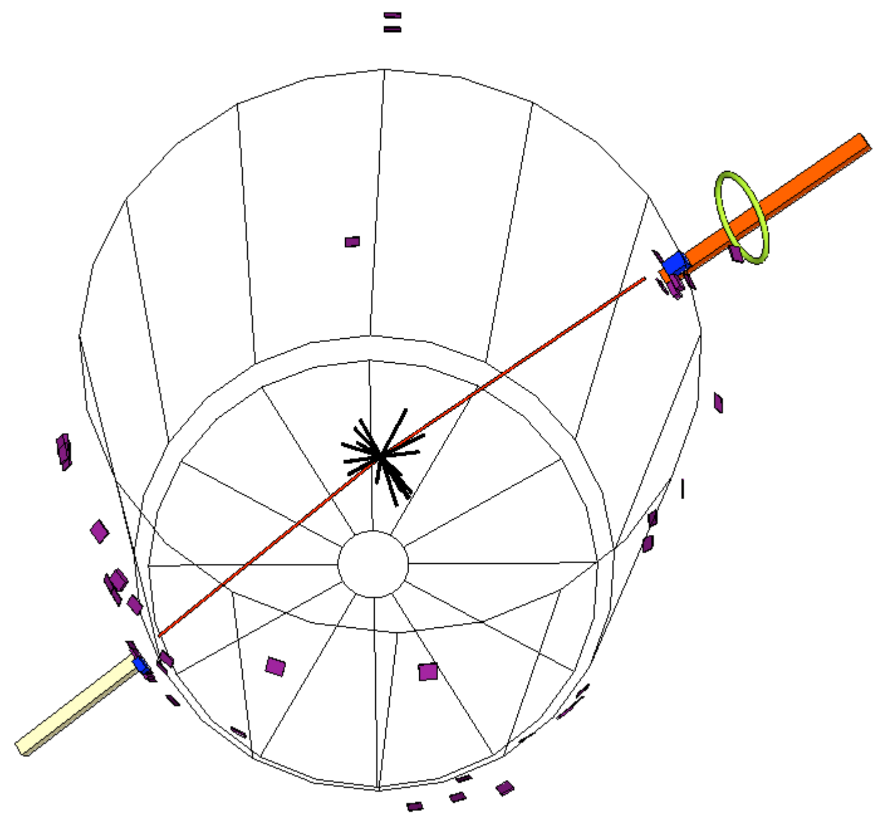






STAR 2012 Z A_L

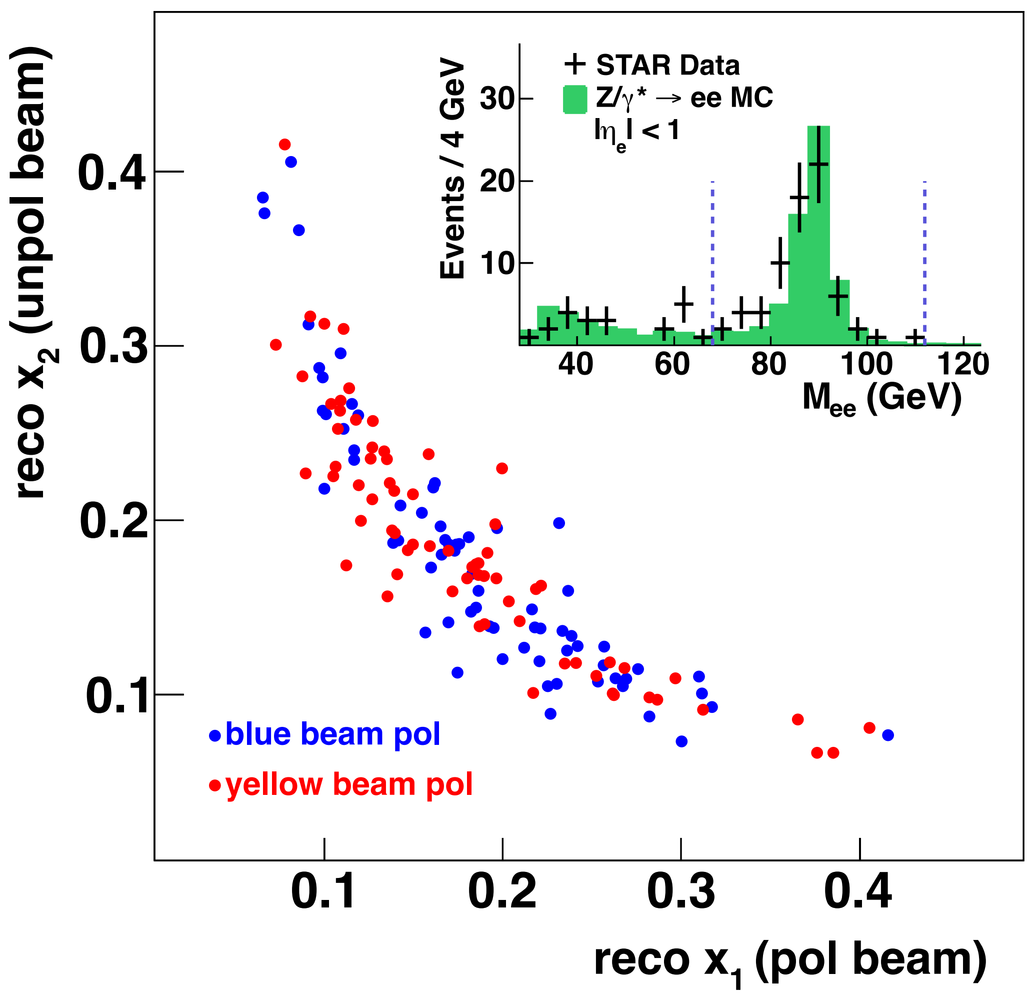
$Z \rightarrow e^+e^-$ Candidate



Reconstruct initial state kinematics at leading order:

$$x_{1(2)} = \frac{M_{ee}}{\sqrt{s}} e^{\pm y_Z}$$

STAR 2012 Z A_L



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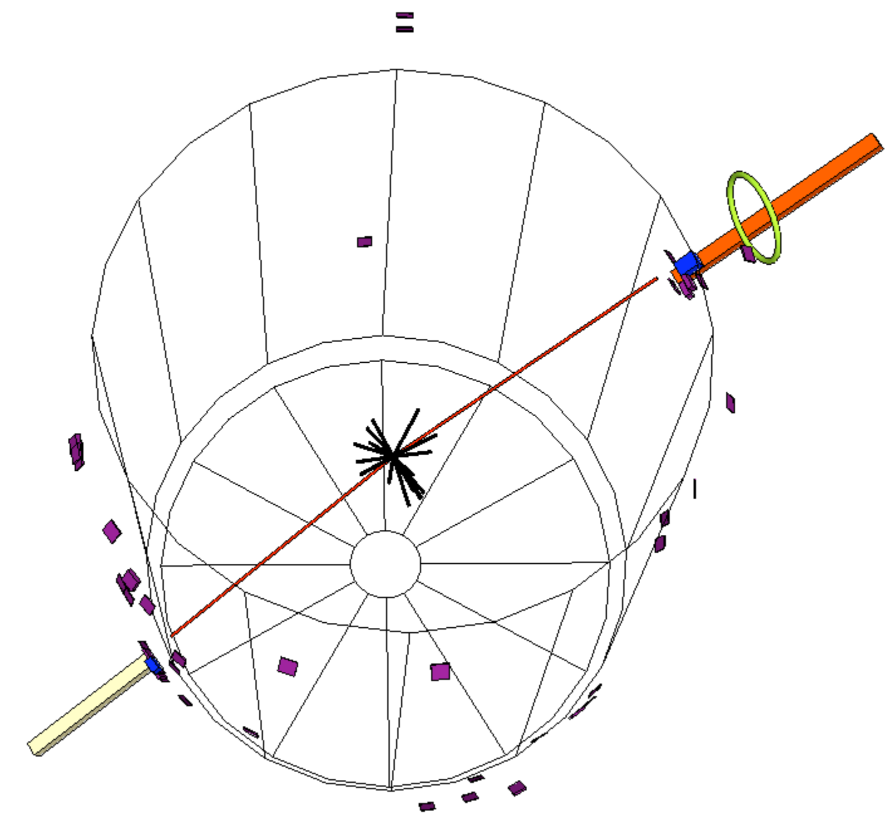

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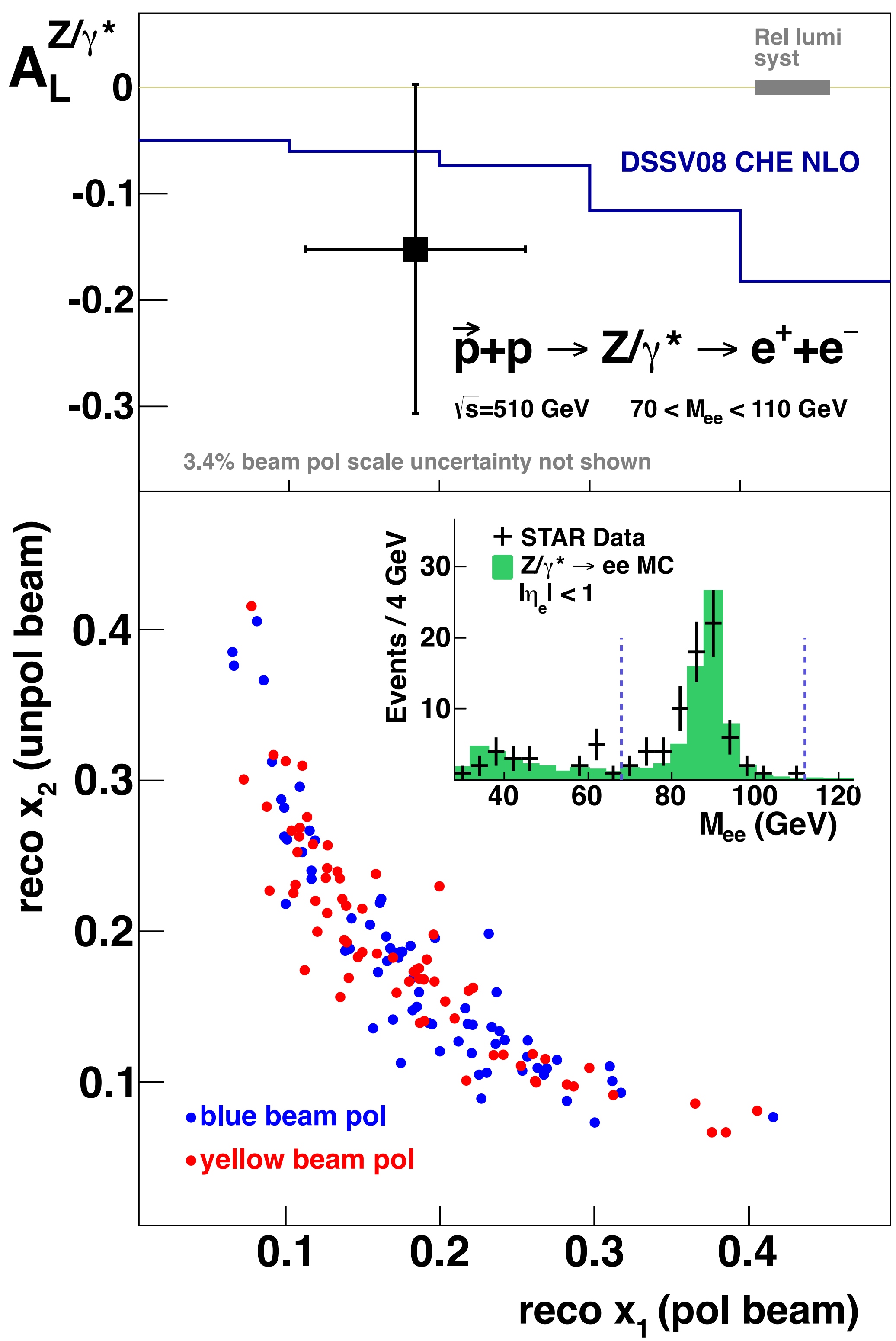
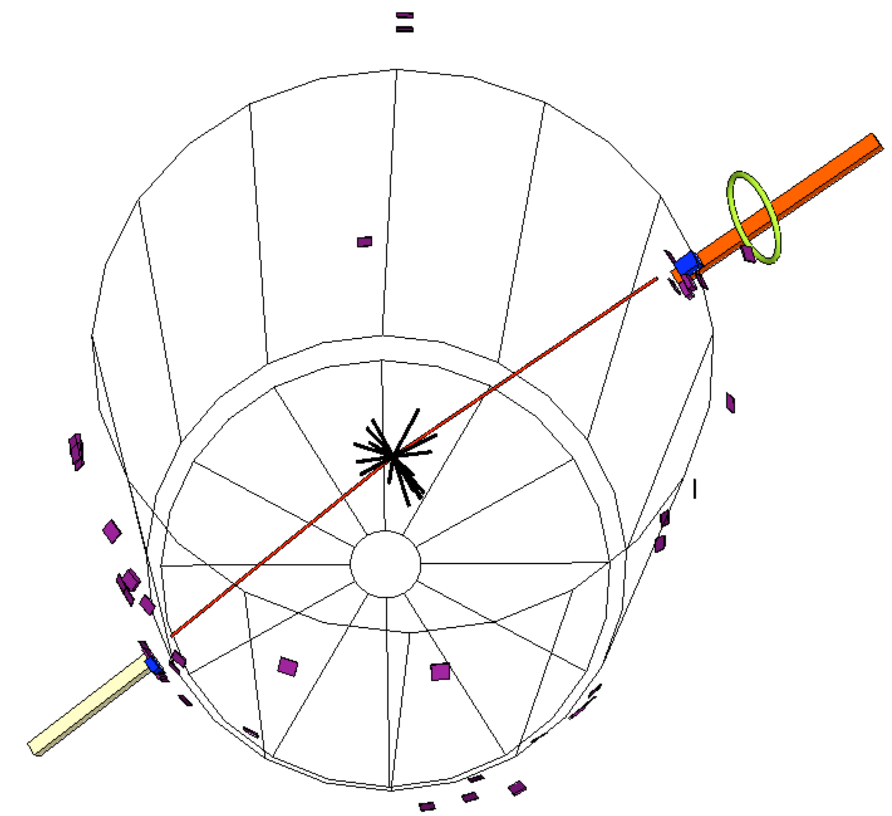


Z → e⁺e⁻ Candidate



Reconstruct initial state kinematics at leading order:

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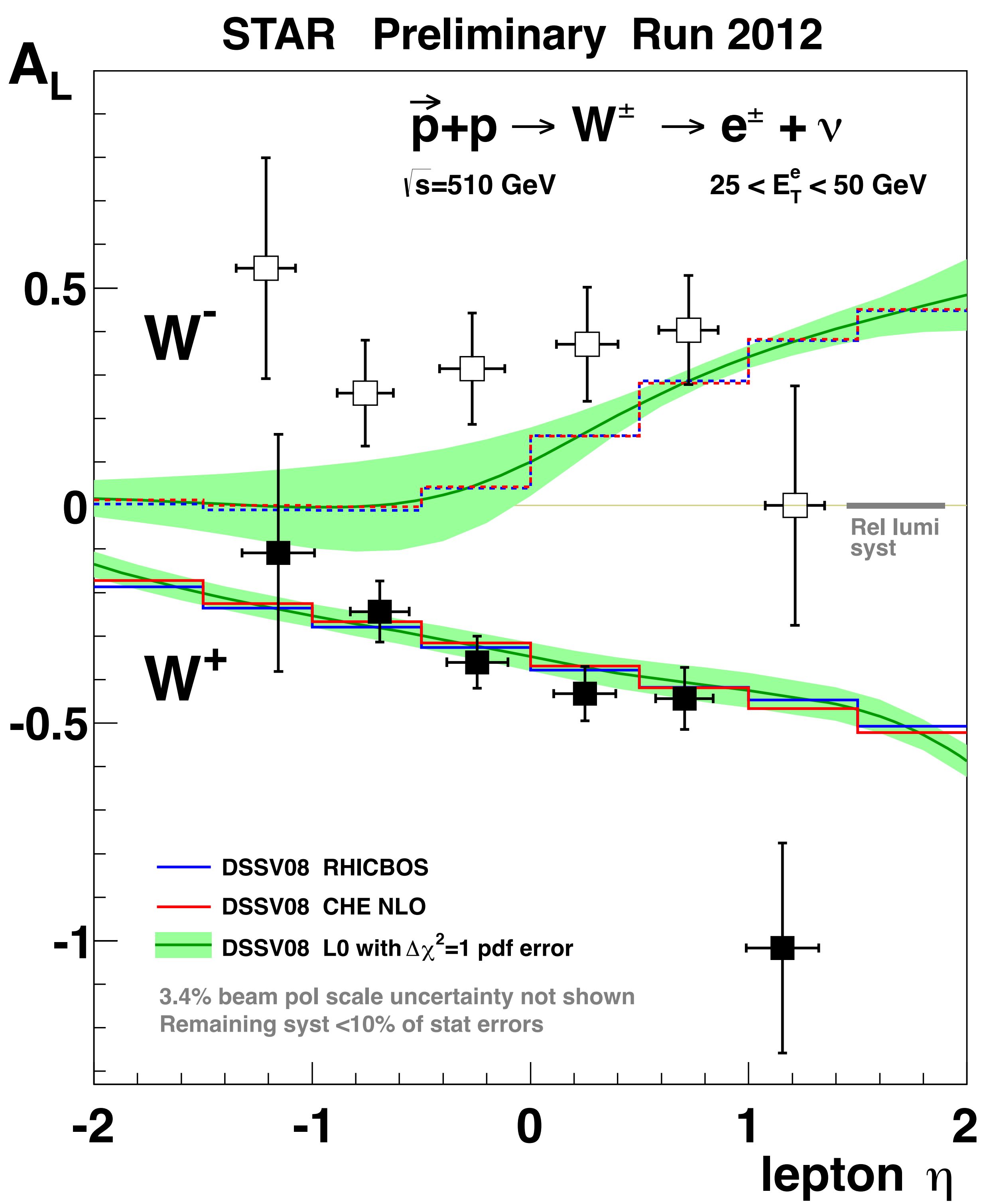
Summary



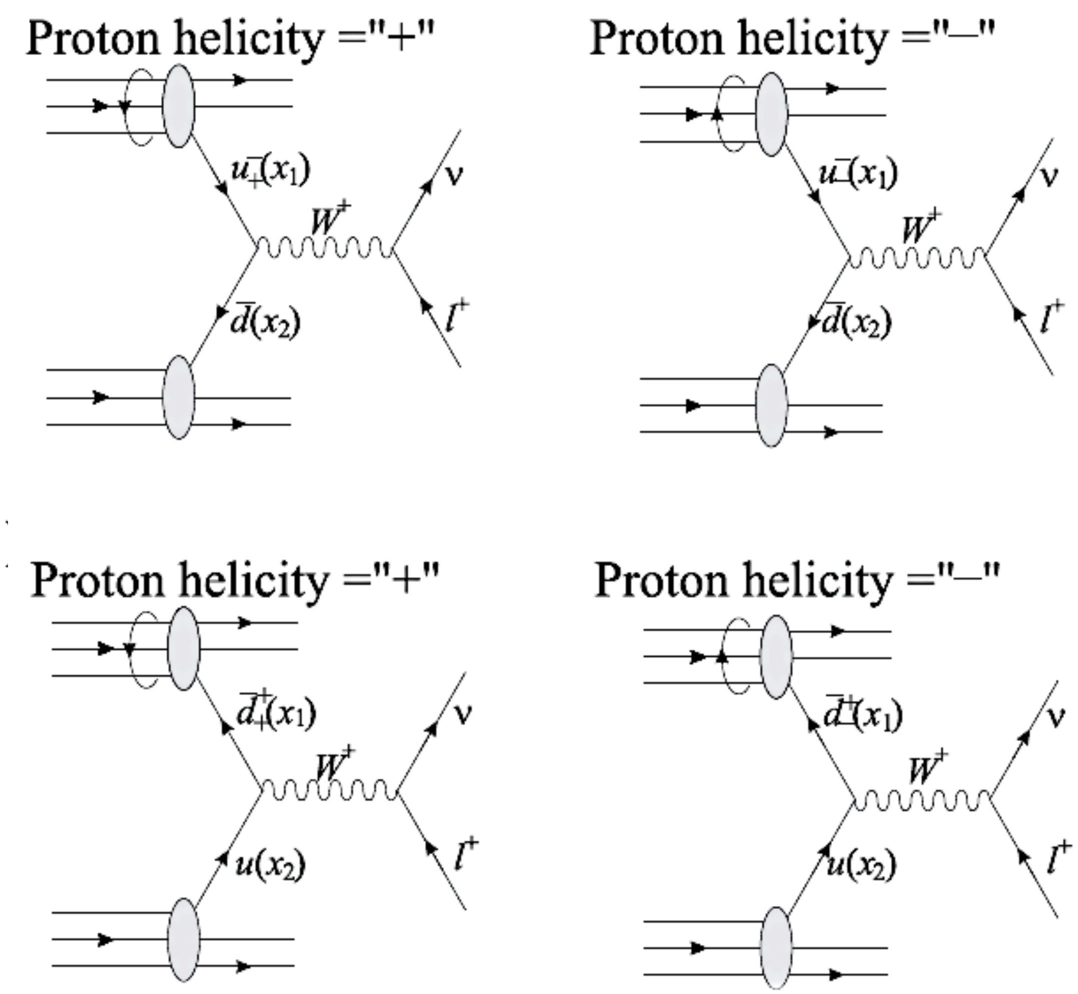
- The production of W bosons in polarized p+p collisions provides a new means of studying the spin and flavor asymmetries of the proton sea quark distributions
- STAR has measured the parity-violating single-spin asymmetry A_L for $|\eta_e| < 1.4$ from 2012 data, providing the first detailed look at the asymmetry's η_e dependence
- A_L for Z/γ^* production was also measured, and is consistent with the theoretical predictions

Backup

Parity-Violating Asymmetry: A_L

$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

- V-A coupling of the weak interaction leads to perfect spin separation
- Only LH quarks and RH anti-quarks



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

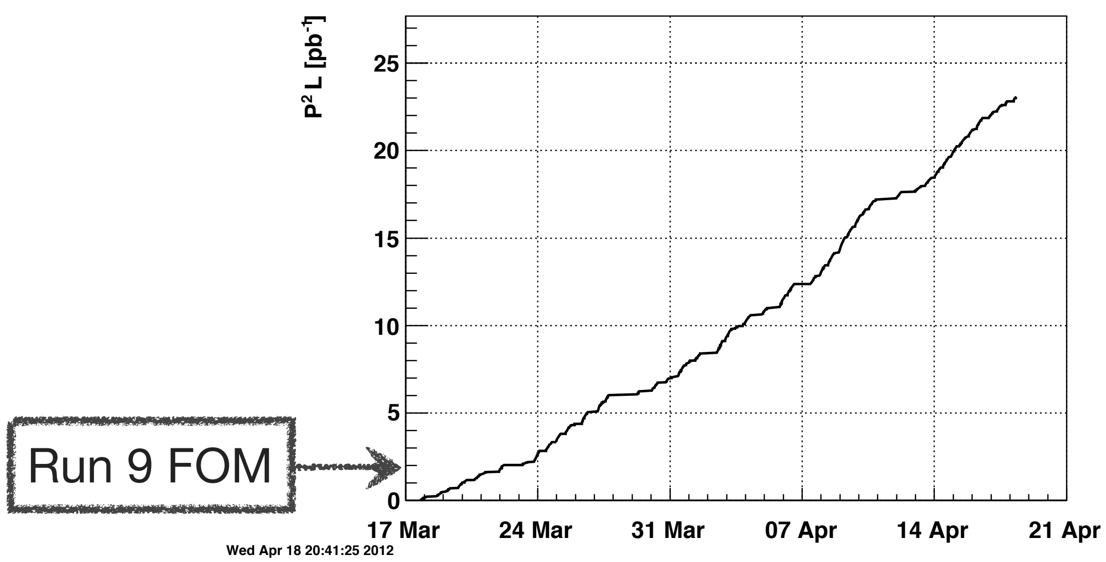
+

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

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

2012 STAR Dataset

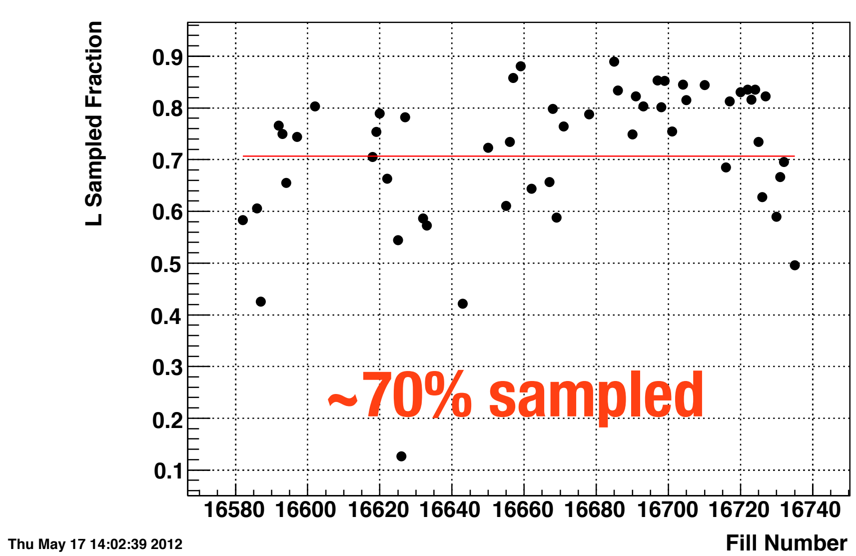
W Trigger FOM = P^2L

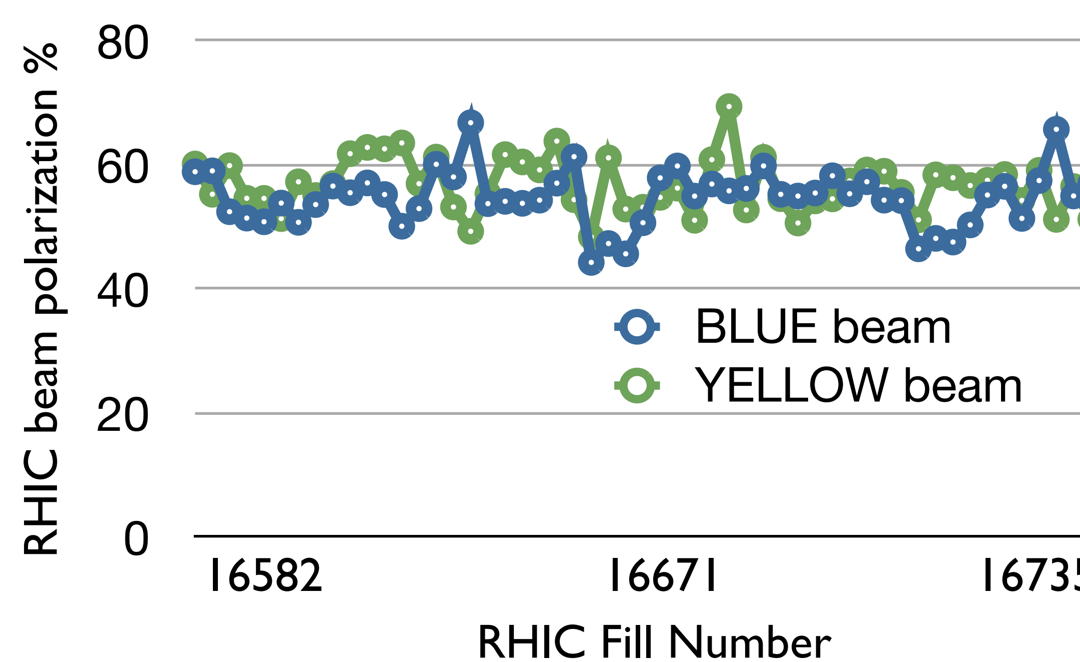


	L (pb^{-1})	P	P^2L (pb^{-1})
Run 9	12	0.40	1.9
Run 12	72	0.56	22.6

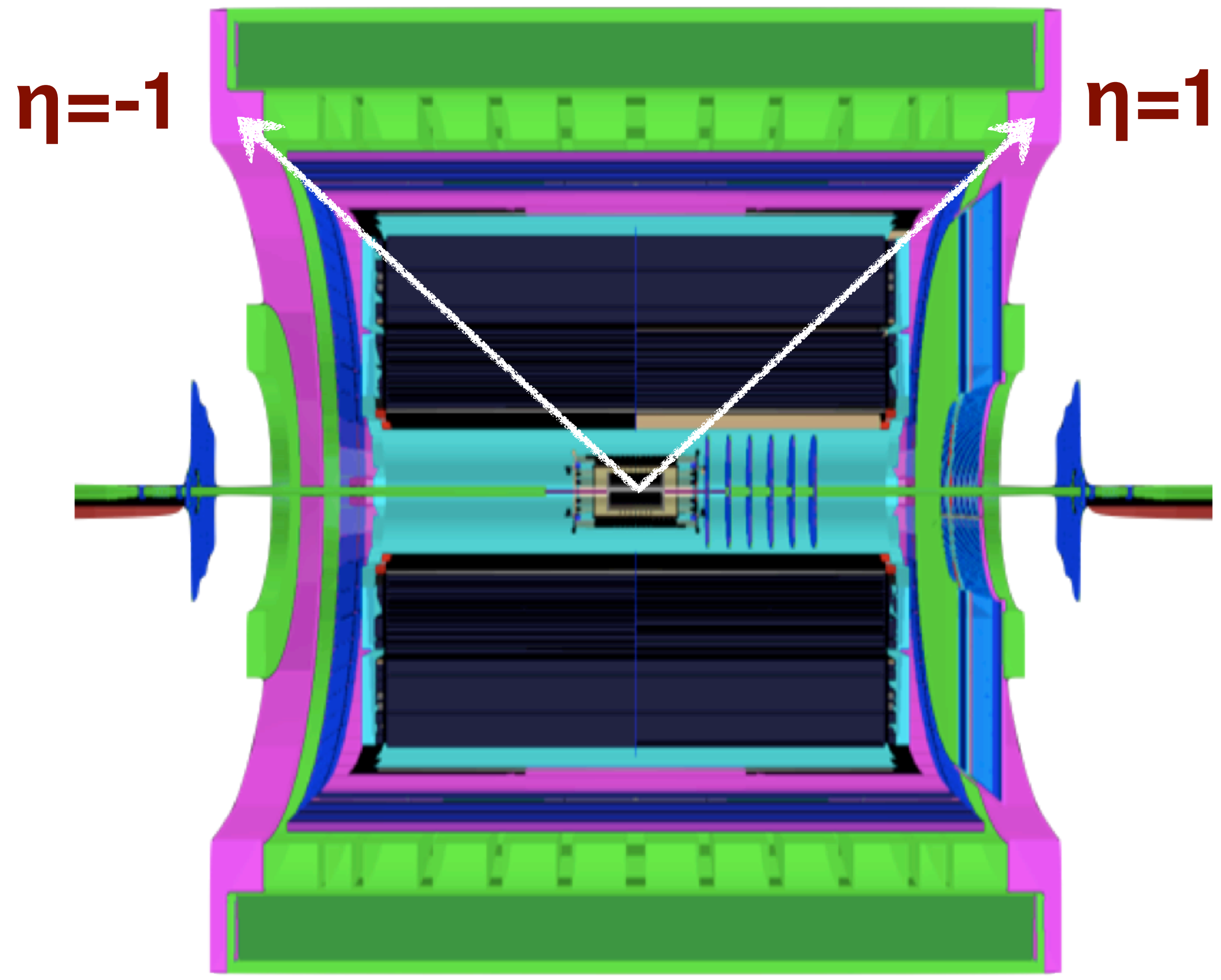
Note: For Run 12 expect ~10% more statistics with final calibrations

Lumi Sampled Fraction



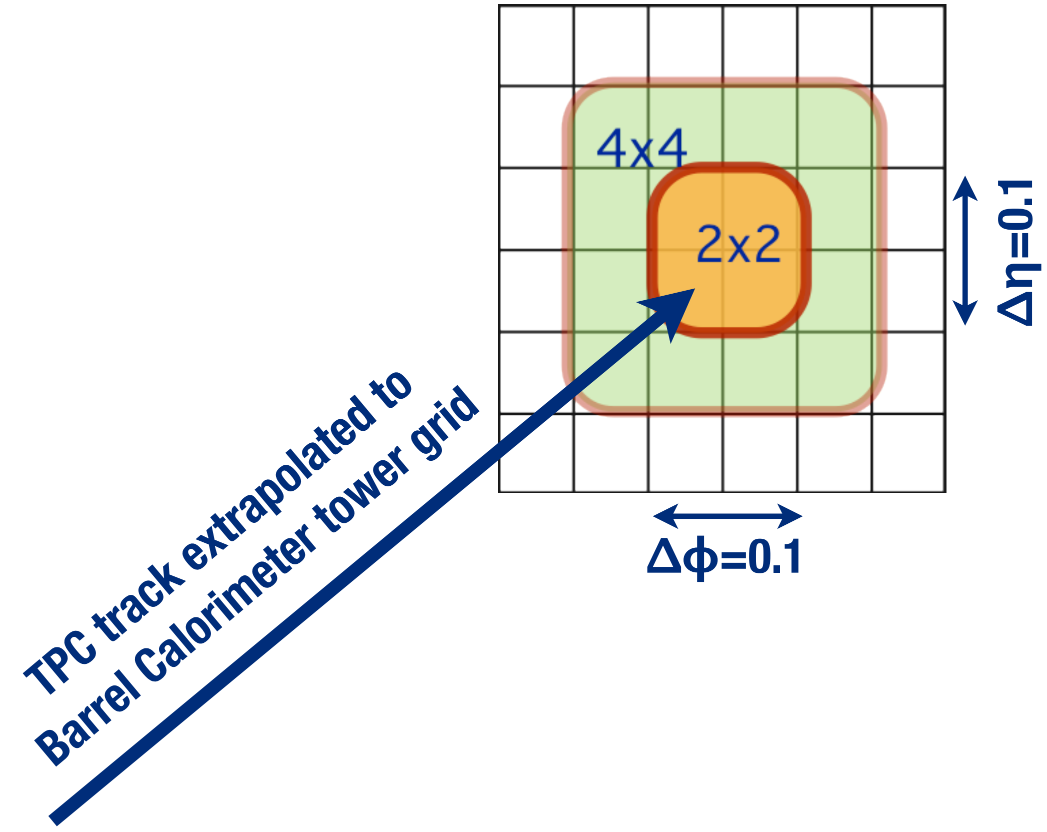


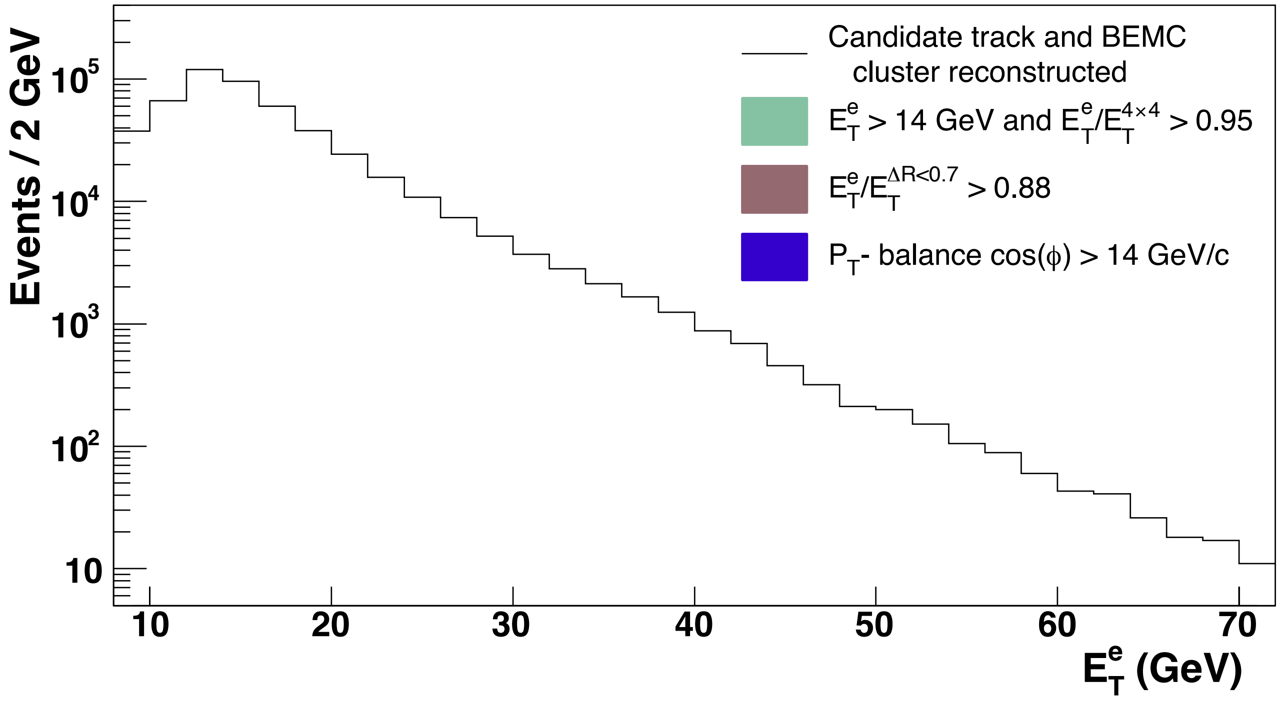
Mid-Rapidity Ws at STAR



How do we find Ws?

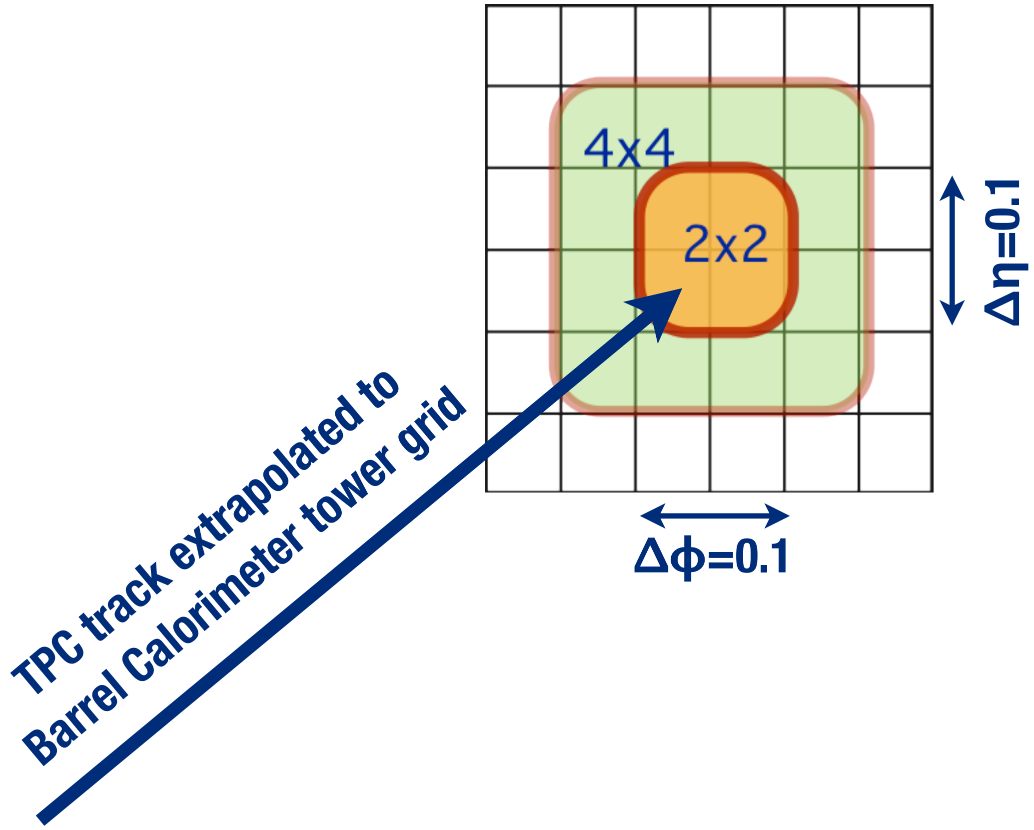
- Match $p_T > 10$ GeV track to BEMC cluster

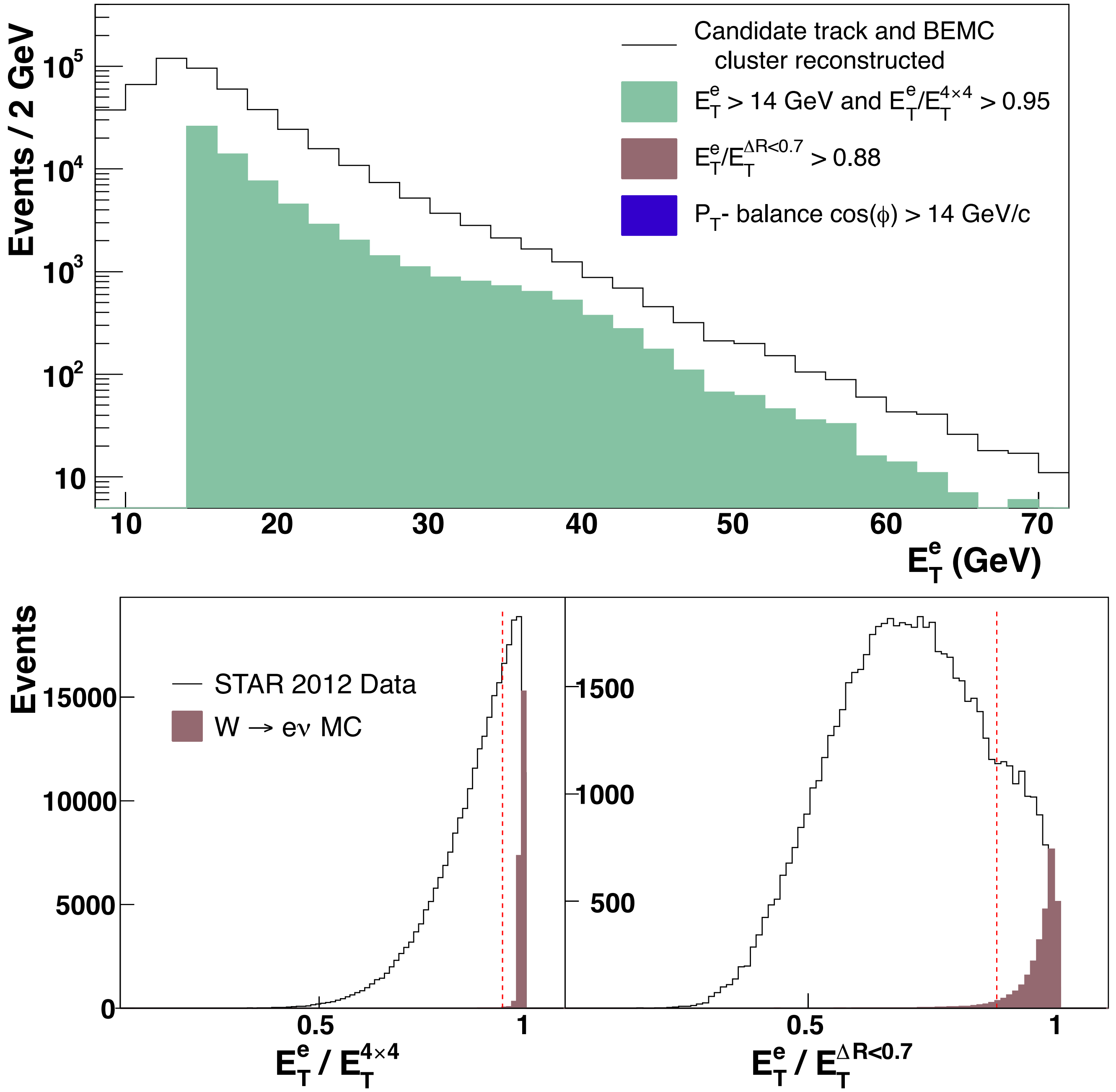




How do we find Ws?

- Match $p_T > 10$ GeV track to BEMC cluster
- Isolation Ratios





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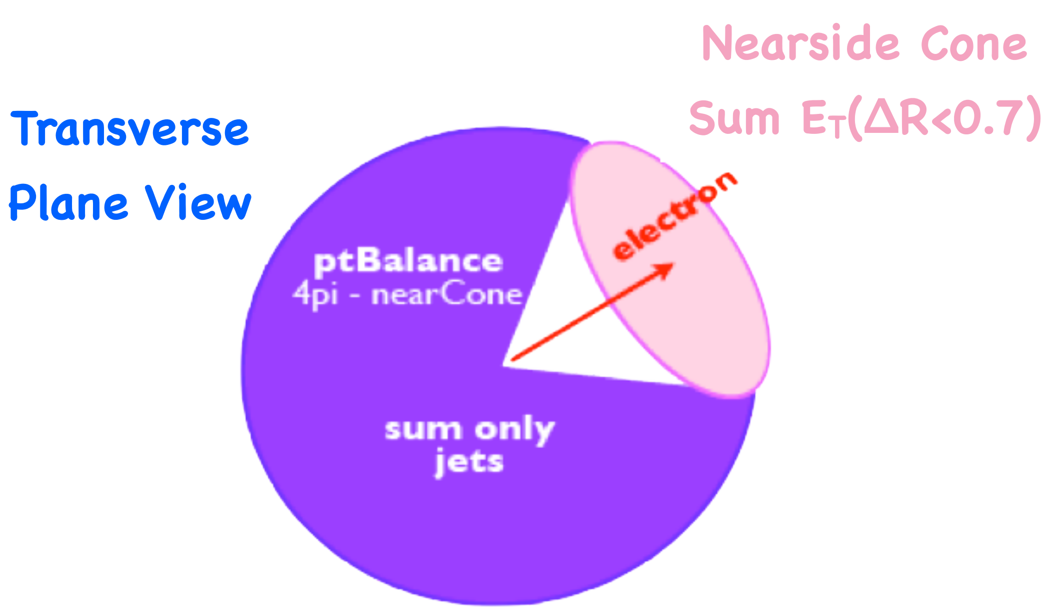
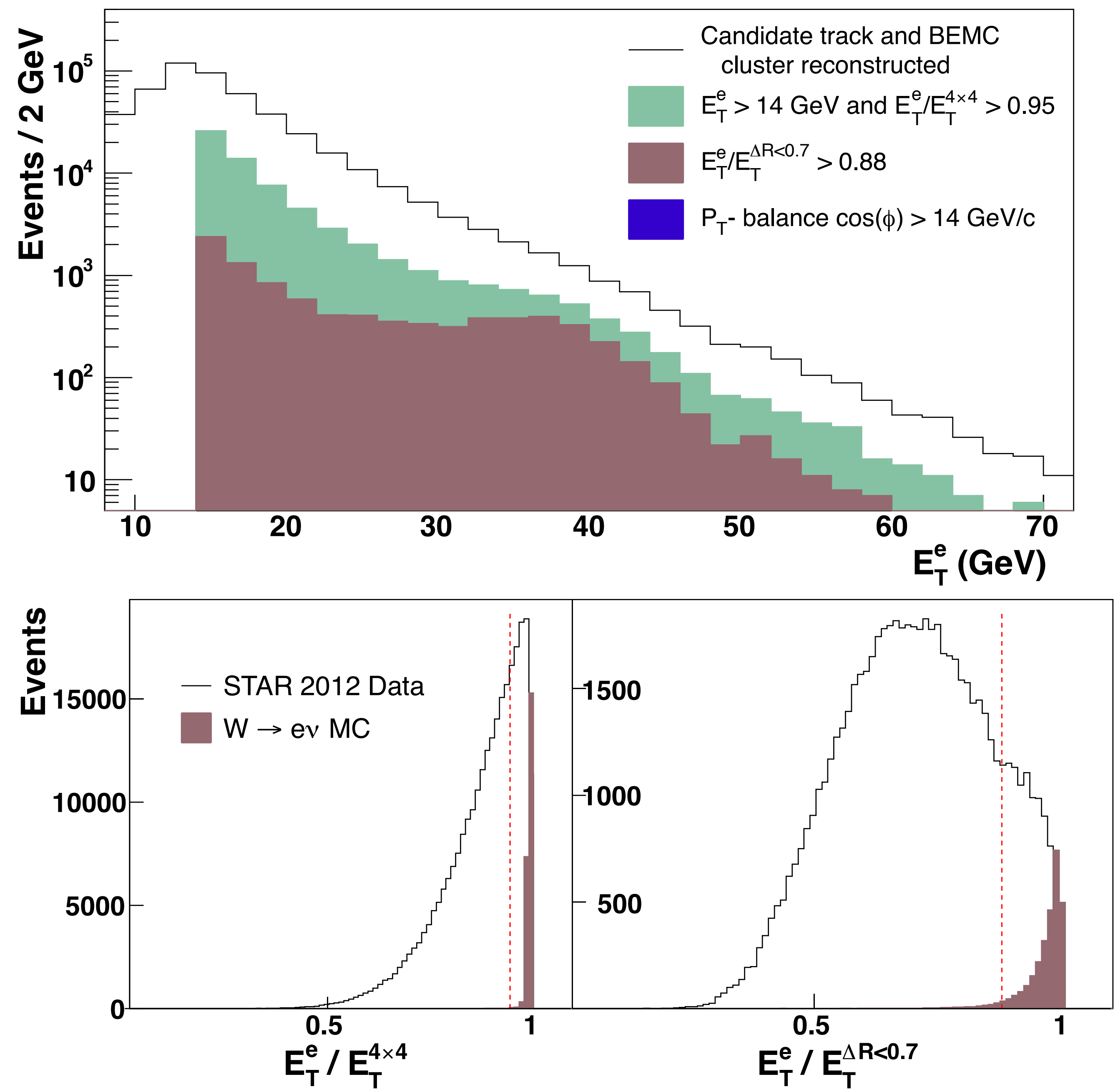




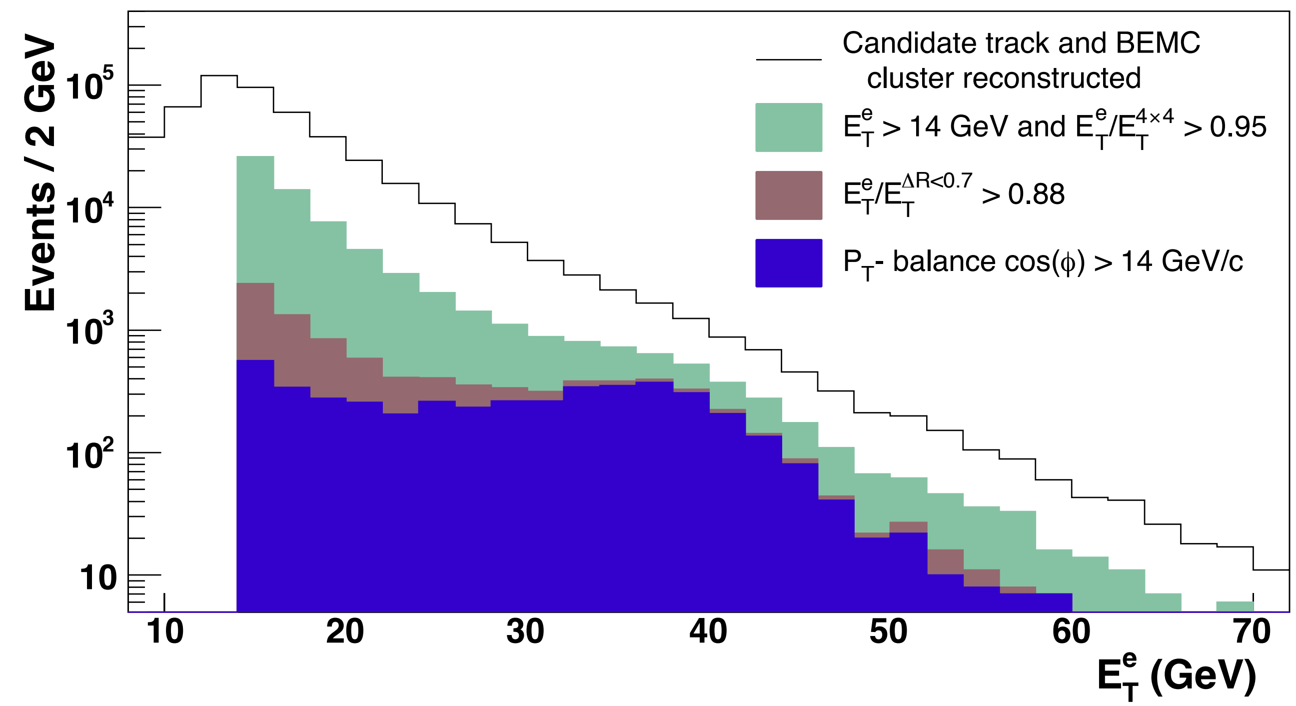
How do we find Ws?

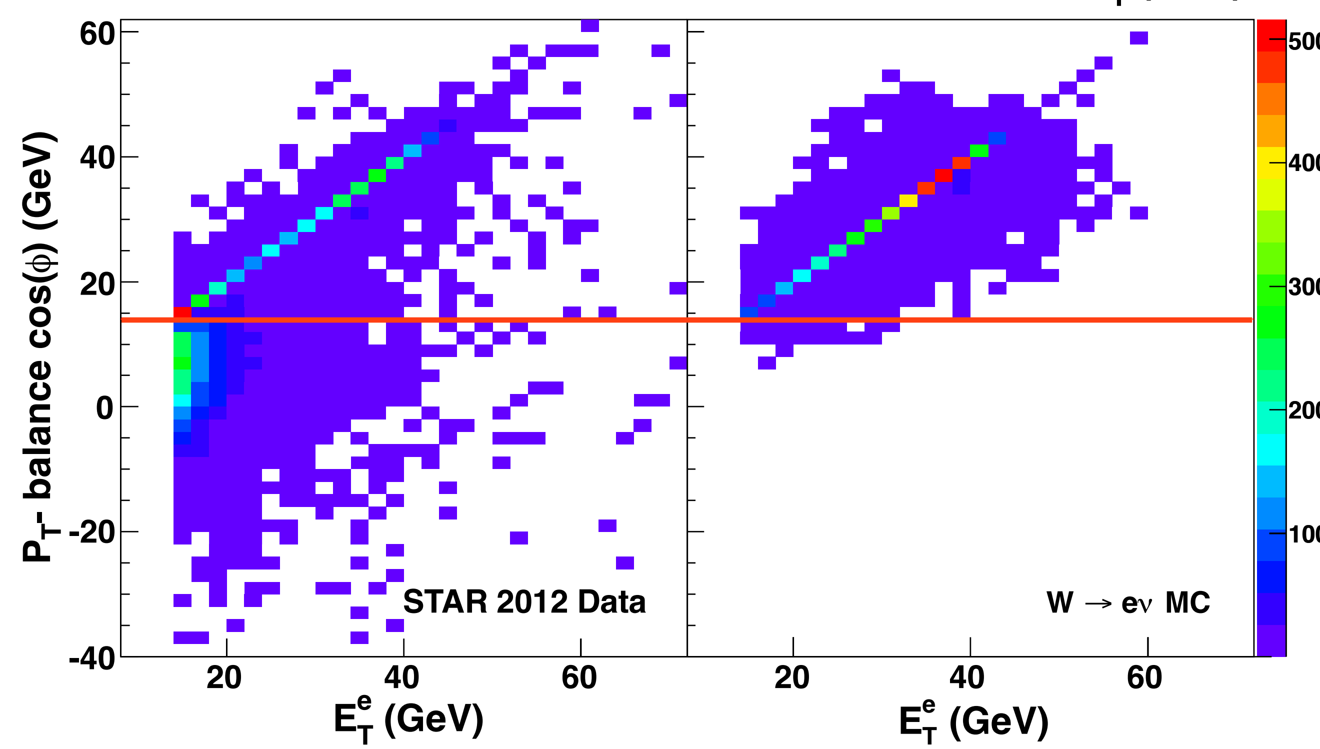
- Match $p_T > 10$ GeV track to BEMC cluster
- Isolation Ratios
- P_T-balance

$$\vec{p_T}^{\,bal} = \vec{p_T}^{\,e} + \sum_{\Delta R > 0.7} \vec{p_T}^{\,jets}$$

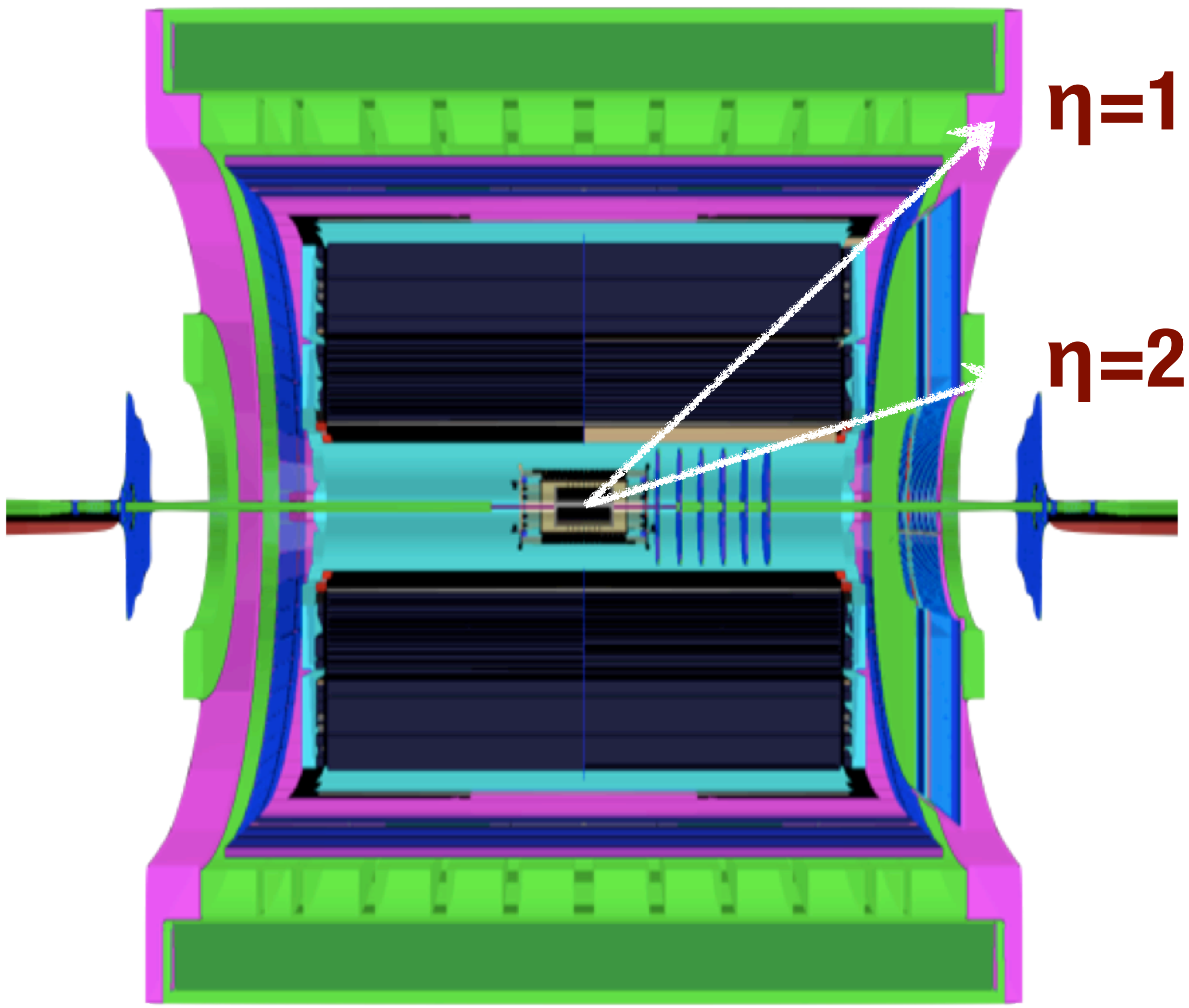
$$P_T\text{-balance}\cos(\phi) = \frac{\vec{p_T}^{\,e} \cdot \vec{p_T}^{\,bal}}{|\vec{p_T}^{\,e}|}$$

Transverse Plane View



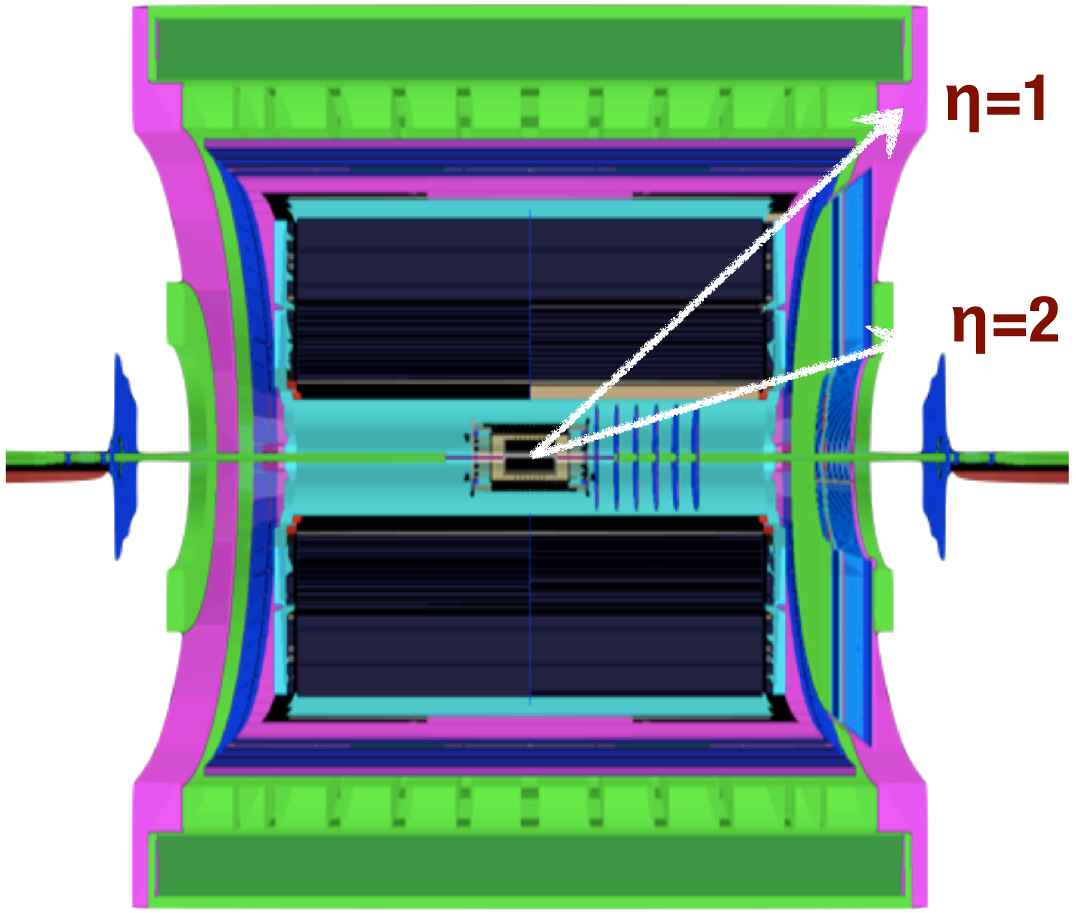


Forward Rapidity Ws at STAR

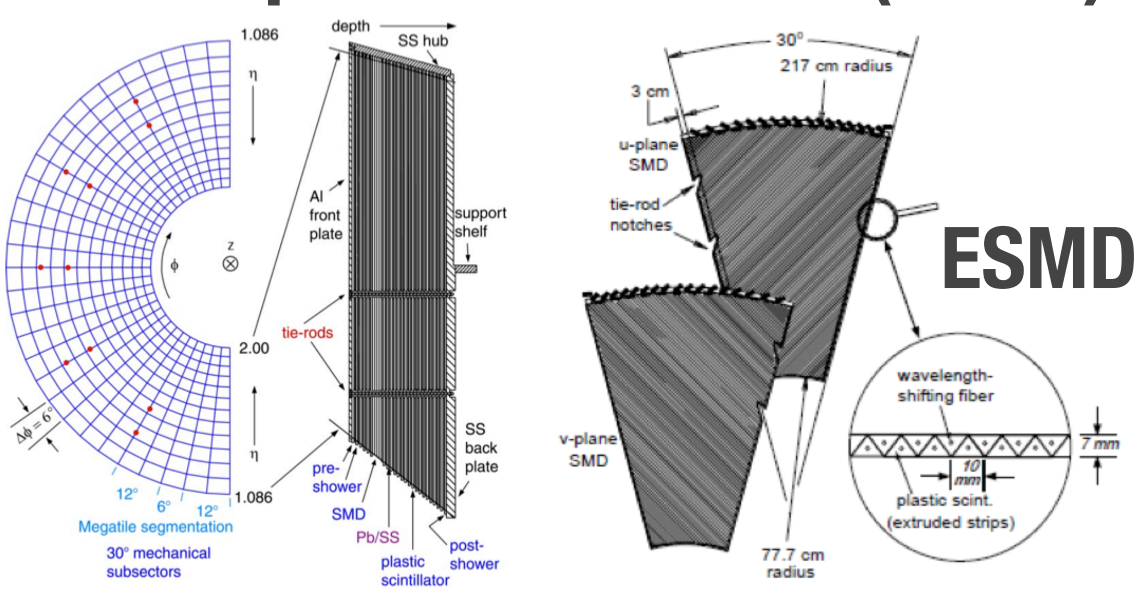


Forward Rapidity Analysis

- Similar concept as mid-rapidity:
  - Utilize TPC which extends to η ~1.4 to reconstruct high p_T TPC track
  - Use isolation ratios and vector p_T imbalance to reduced QCD background
- Improve background rejection by using the Endcap Shower Maximum Detector



Endcap EM Calorimeter (EEMC)



Forward Rapidity Analysis

- Similar concept as mid-rapidity:
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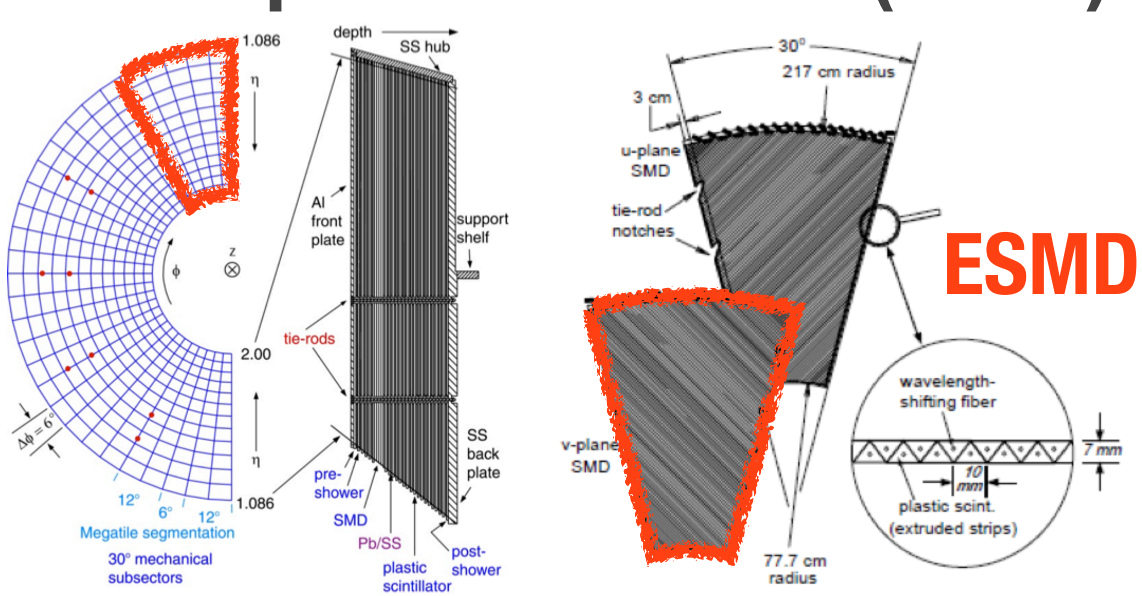
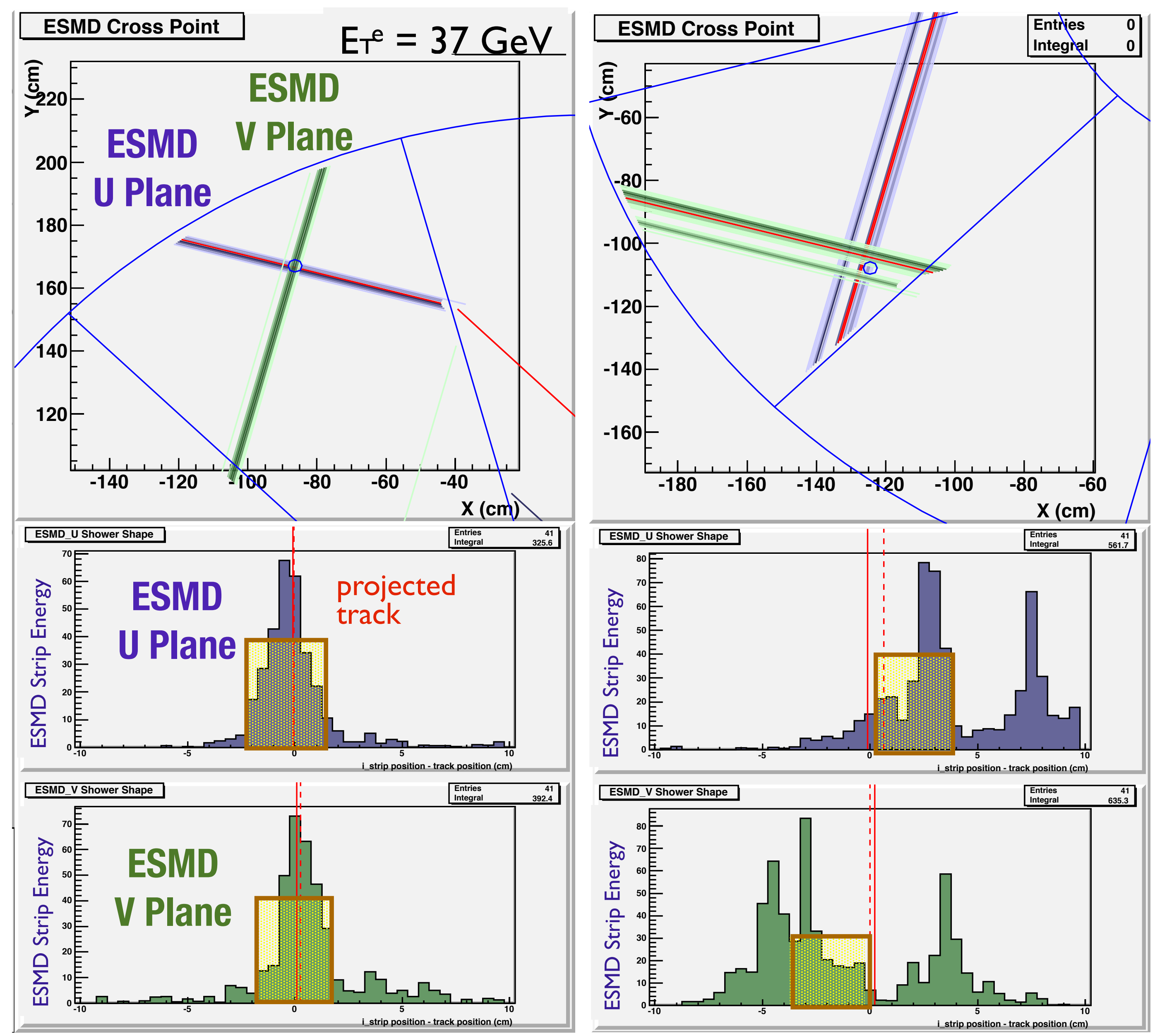
Endcap EM Calorimeter (EEMC)



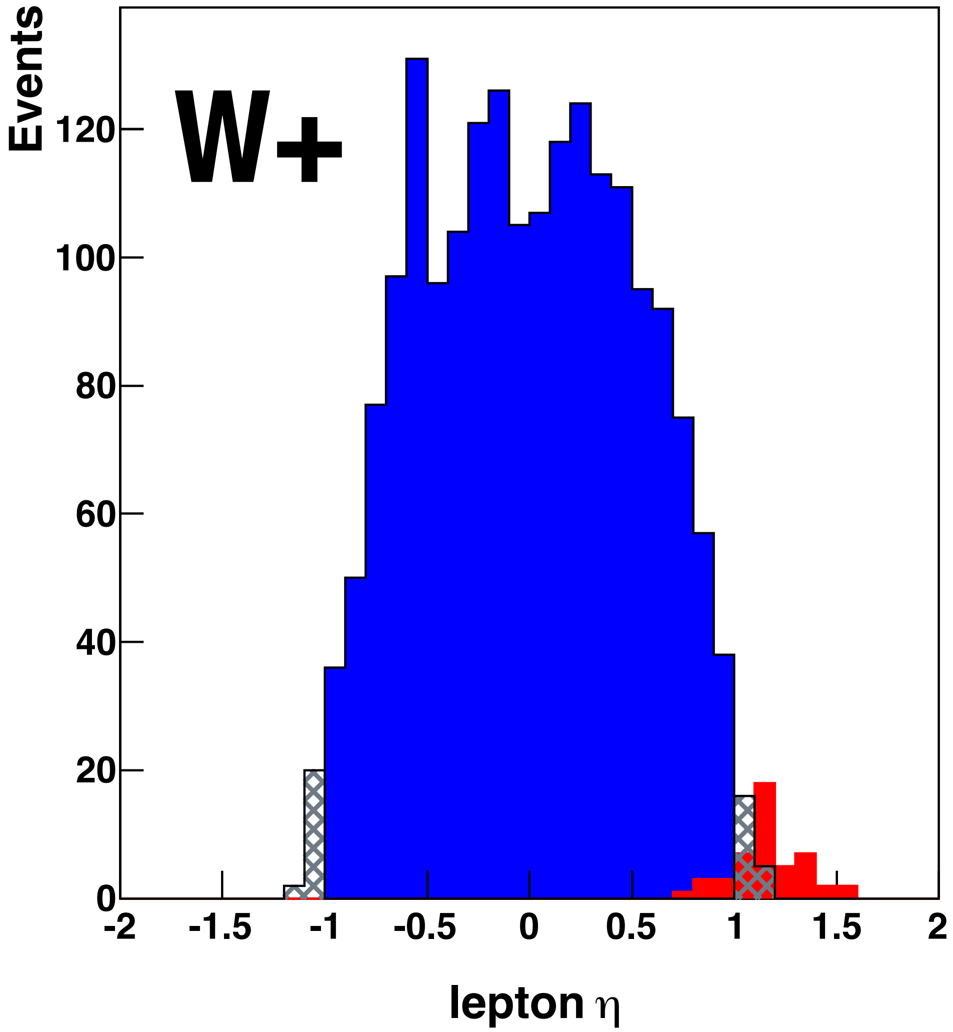
2012 data events which satisfy all previous cuts

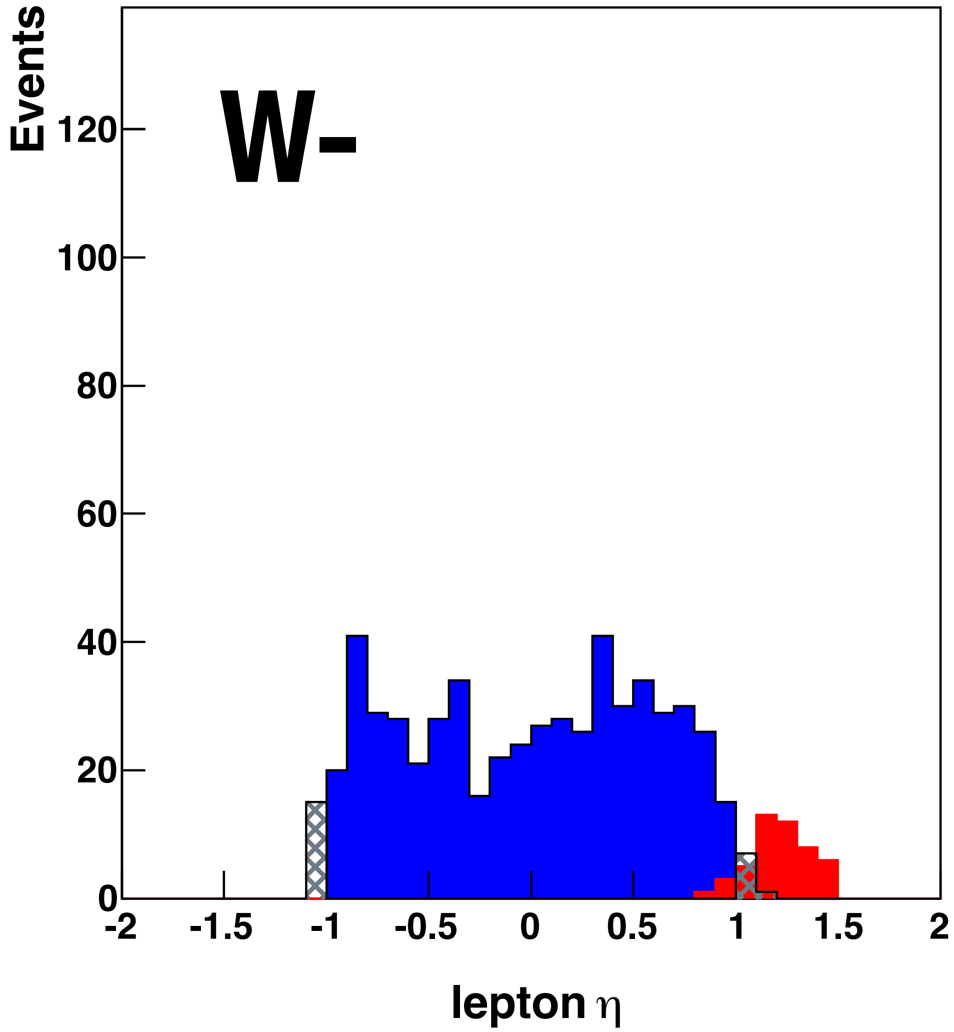
Signal Example | **Background Example**



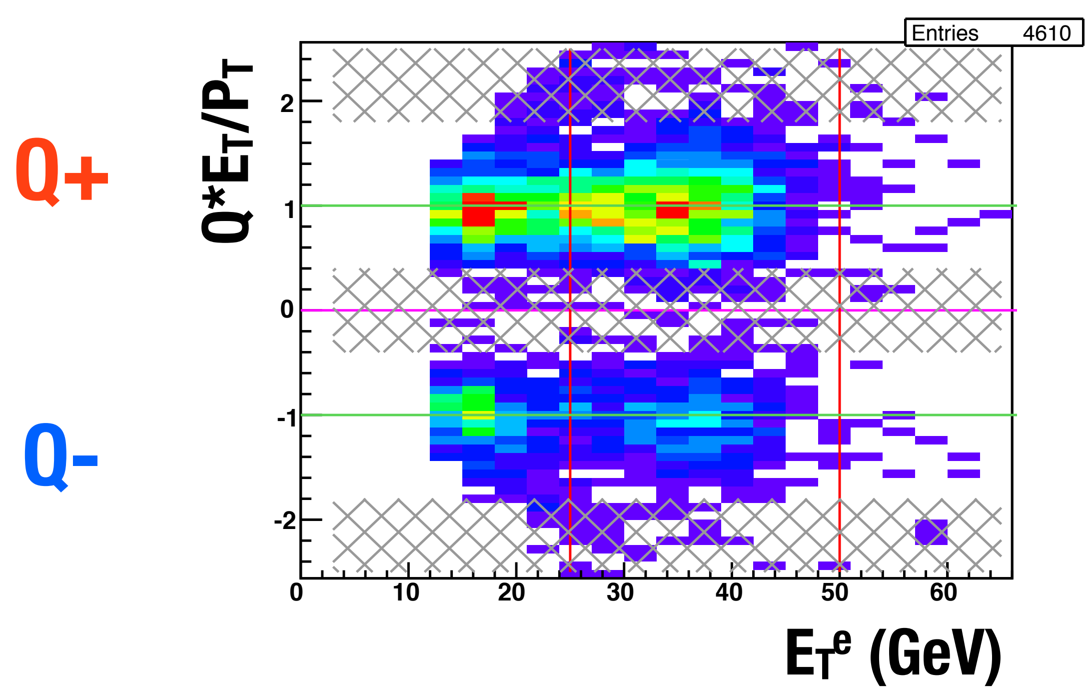
2012 STAR W Candidate Yields vs η

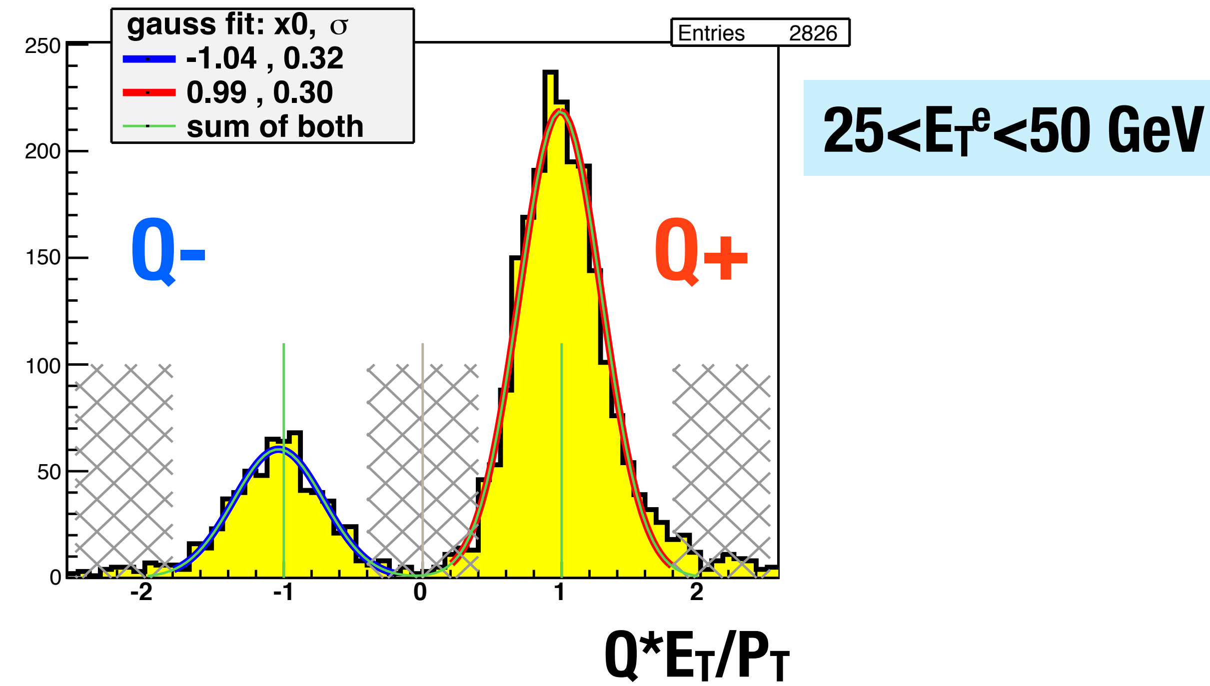
Mid-rapidity (Barrel) Ws
Forward rapidity (Endcap) Ws



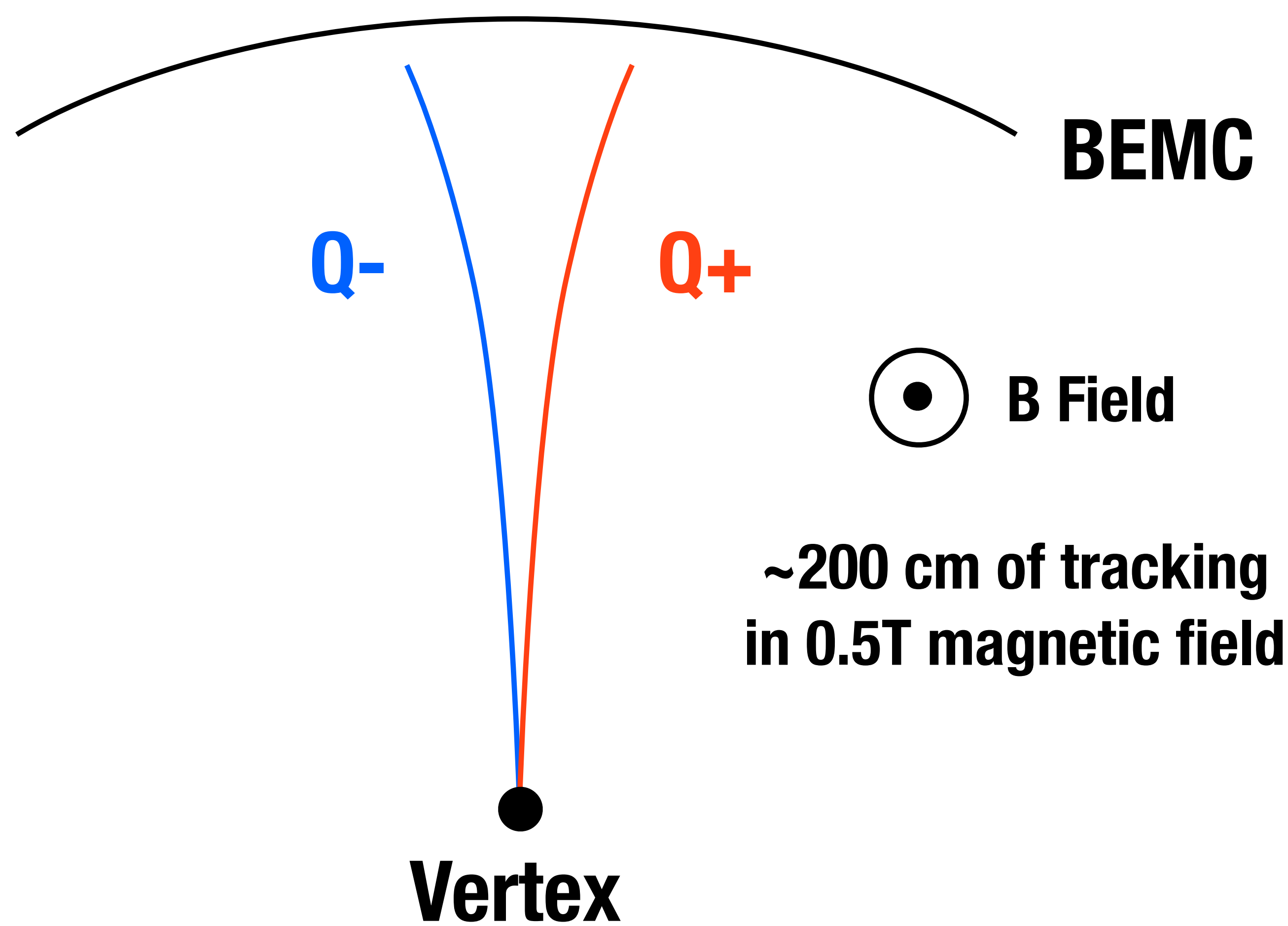


Mid-rapidity Charge Separation





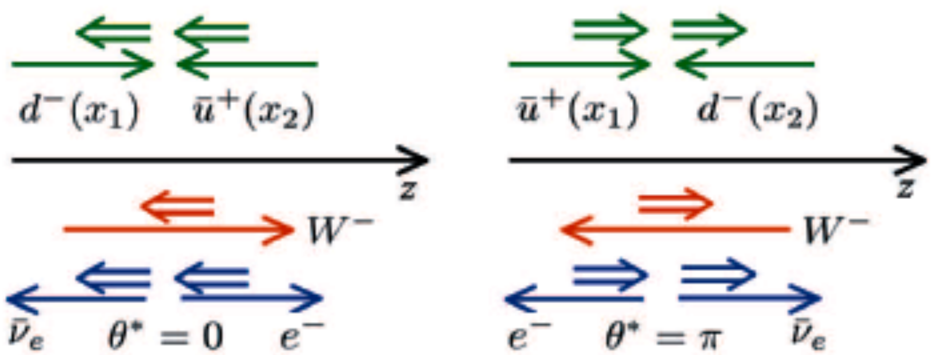
- E_T/P_T (EMC/TPC) distribution for each charge sign
- Estimate wrong sign contamination with a Gaussian fit
- Q+ and Q- peaks are separated by ~6σ
- Exclude tails (hatched region) to remove possible contamination



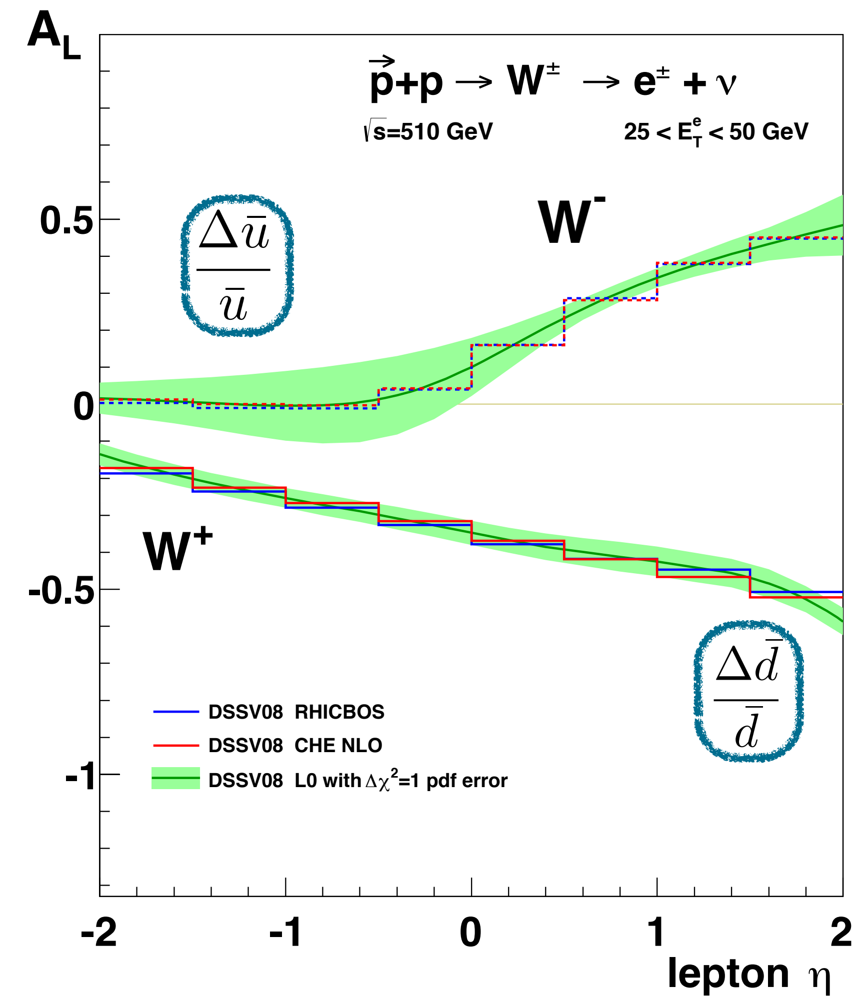
W Production at Forward Rapidity

$$x_1 = \frac{M_W}{\sqrt{s}} e^{y_W} \quad x_2 = \frac{M_W}{\sqrt{s}} e^{-y_W}$$

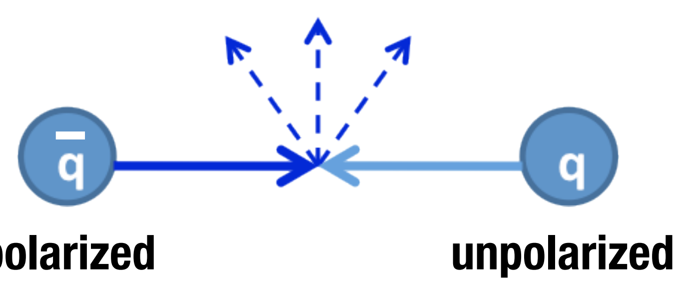
Use lepton rapidity as a surrogate for W rapidity based on W decay kinematics

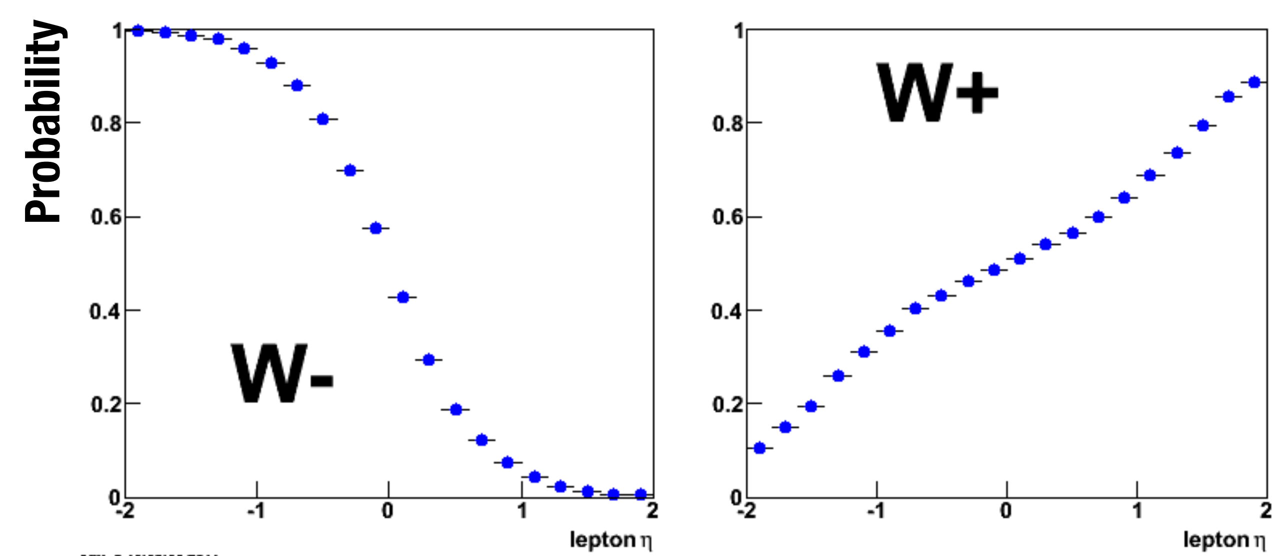


$e^{-(+)}$ are emitted along (opposite) the $W^{-(+)}$ direction



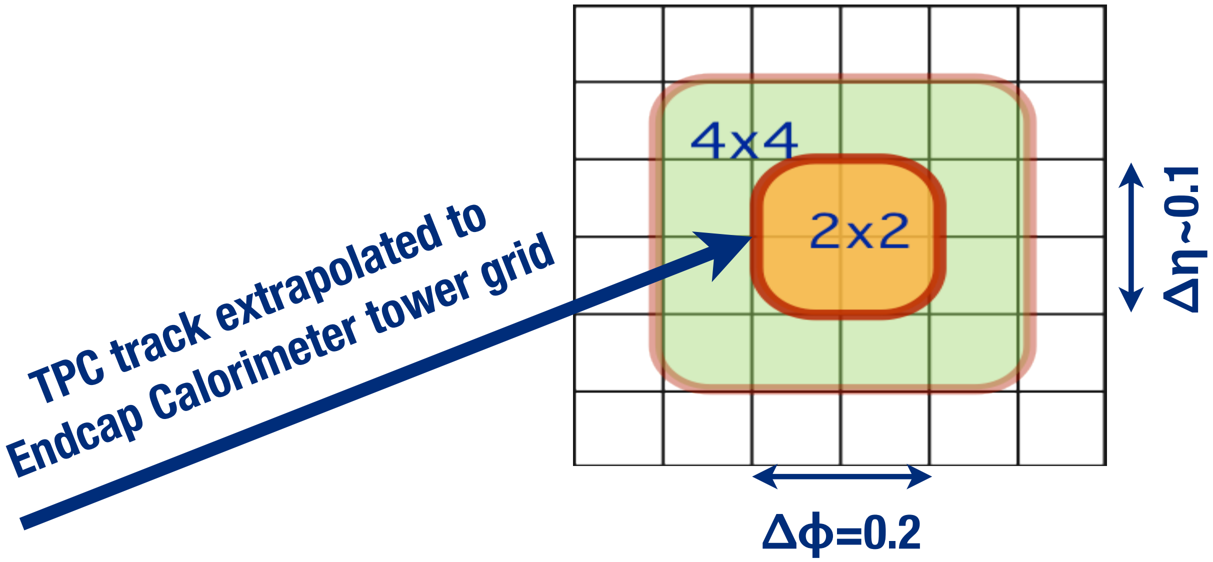
Probability that polarized proton provides the antiquark

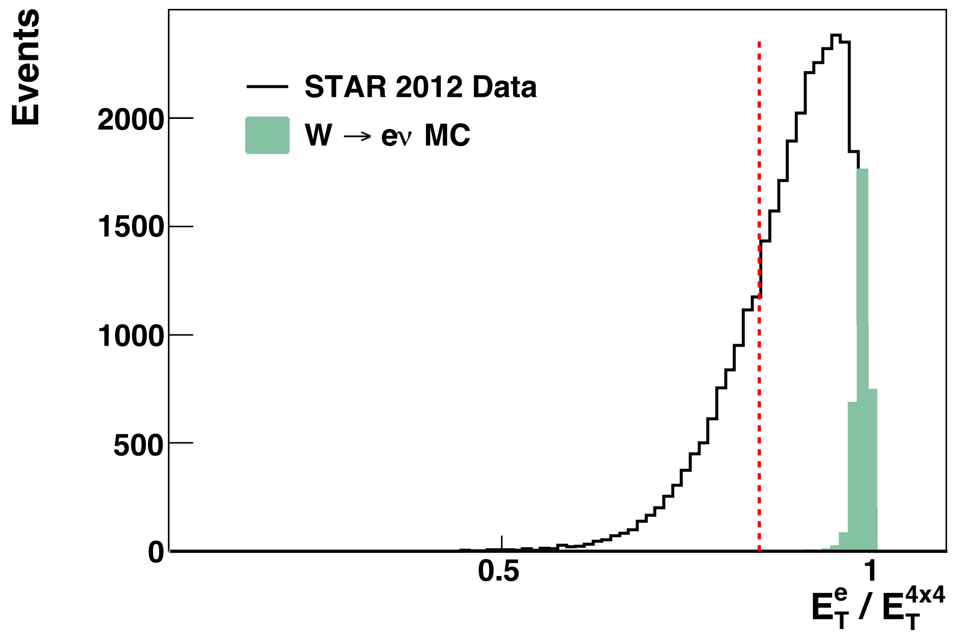


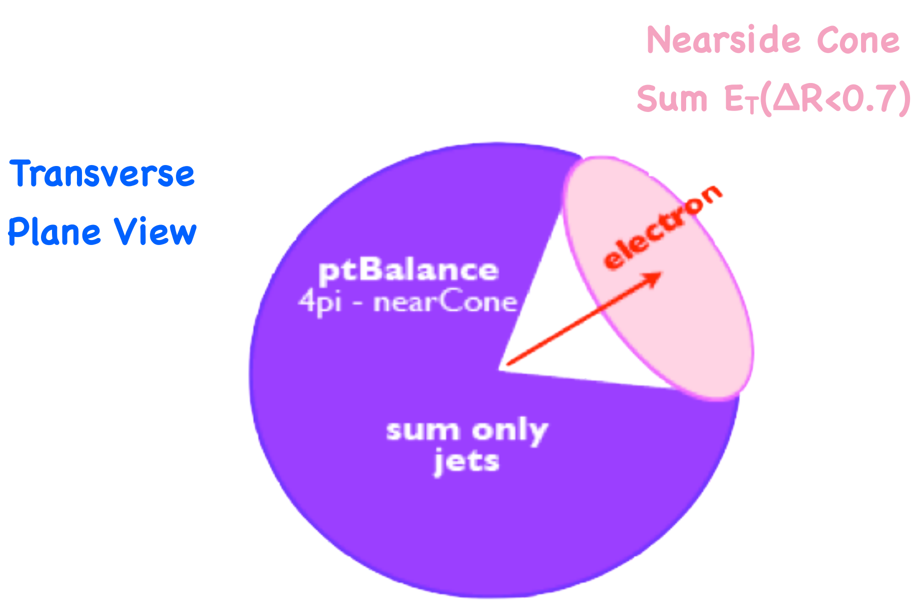


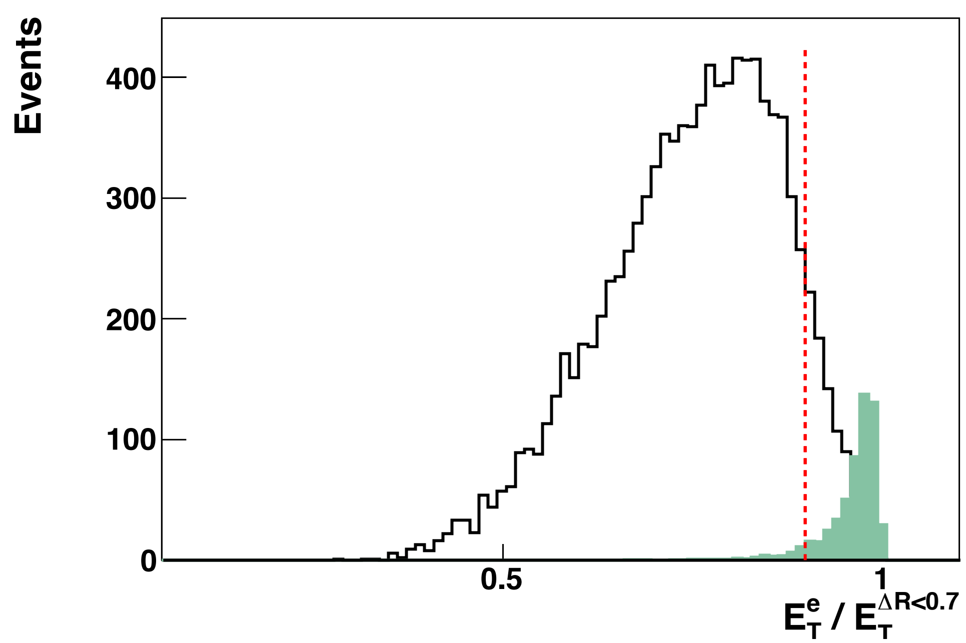
Forward Rapidity W Selection

- Similar to mid-rapidity analysis:
  - Use high-p_T TPC track as candidate seed
  - Isolation ratios





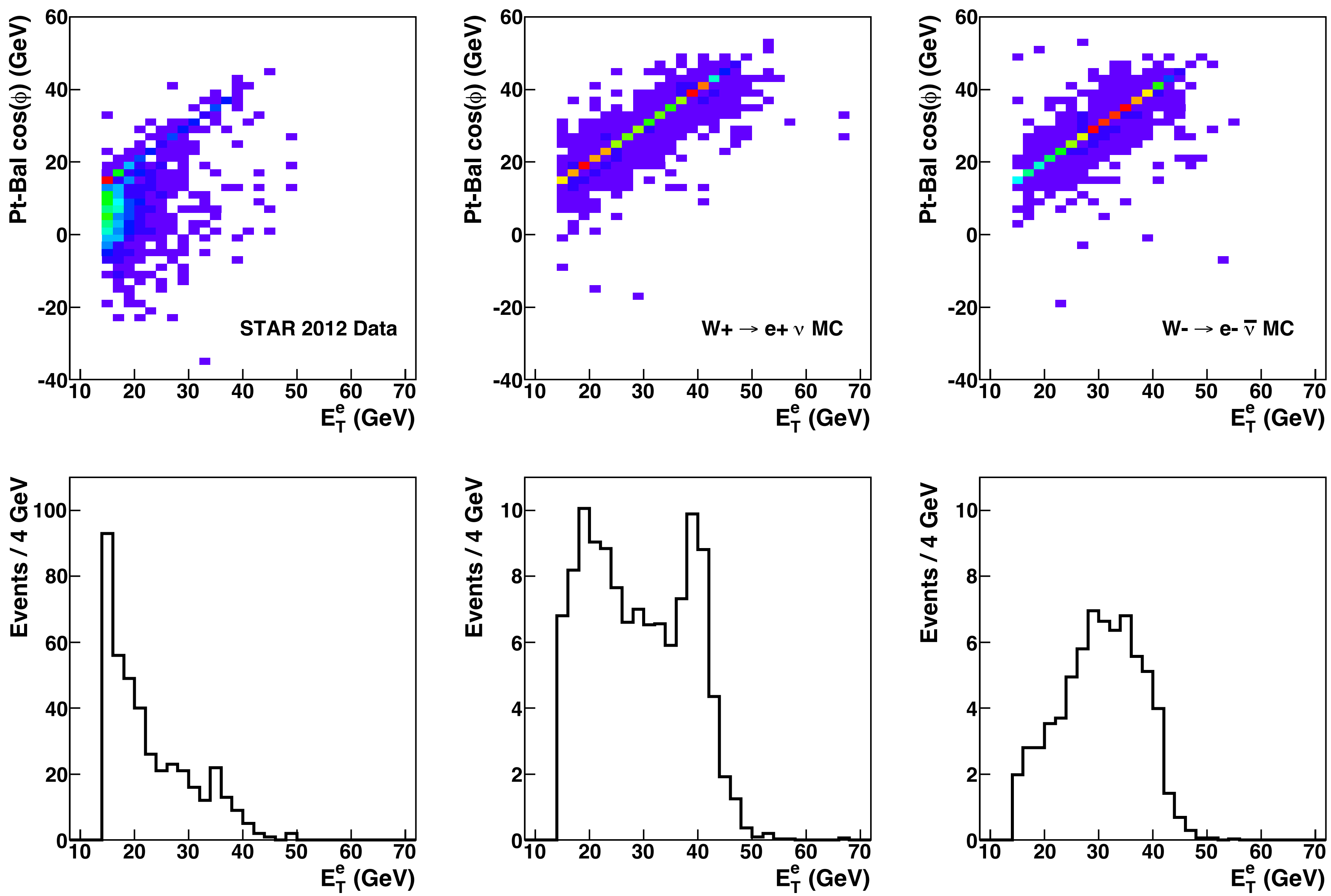




Forward Rapidity W Selection

- Jacobian peak less pronounced than at mid-rapidity
- Different background estimation than mid-rapidity, based on P_T-Balance
    - Select candidates with $25 < E_T < 50$ GeV

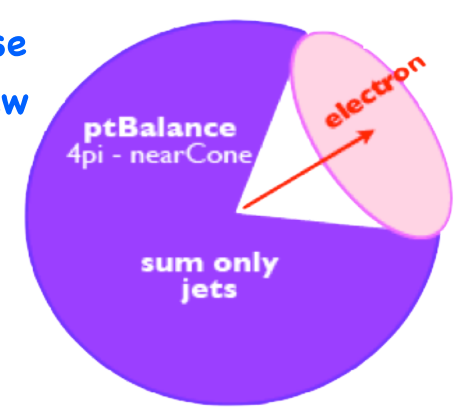
Run 12 Data | **W+ MC** | **W- MC**



$$\vec{p_T}^{bal} = \vec{p_T}^{e} + \sum_{\Delta R > 0.7} \vec{p_T}^{jets}$$

$$P_T\text{-balance}\cos(\phi) = \frac{\vec{p_T}^{e} \cdot \vec{p_T}^{bal}}{|\vec{p_T}^{e}|}$$

Transverse Plane View



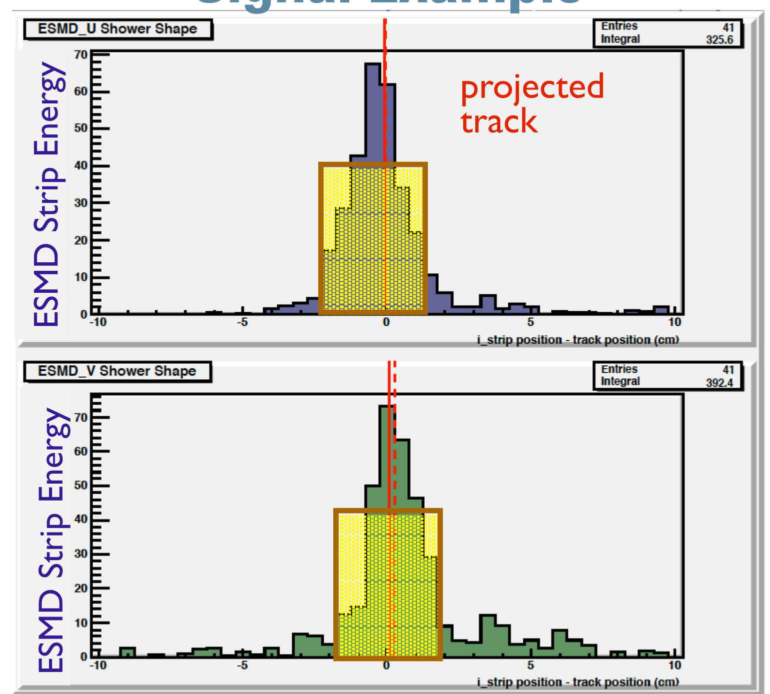
Forward Rapidity Algorithm Extension

Define Endcap SMD ratio R_{ESMD}:

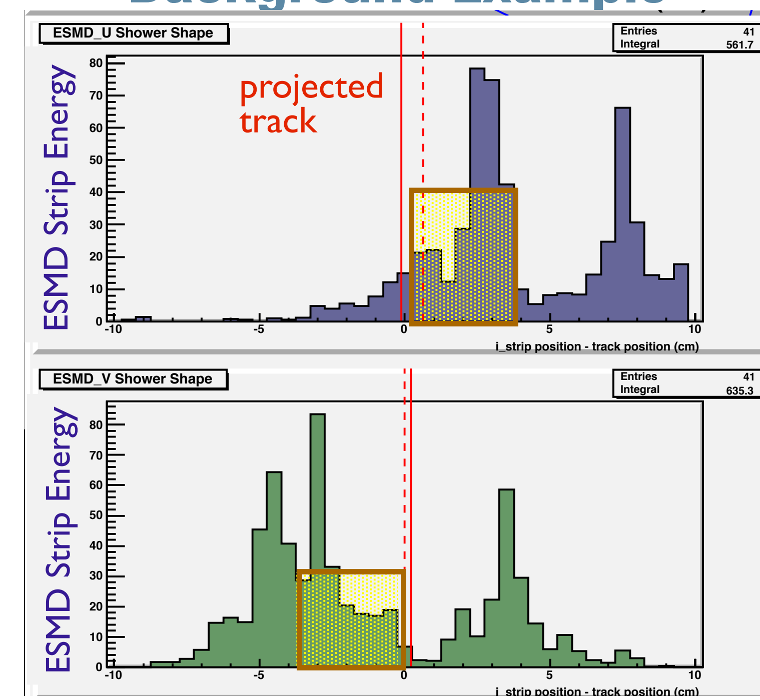
$$R_{ESMD} = \frac{\sum_{i=-3}^{3} E_i^U + E_i^V}{\sum_{i=-20}^{20} E_i^U + E_i^V} > 0.6$$

Run 12 data events which satisfy all previous cuts

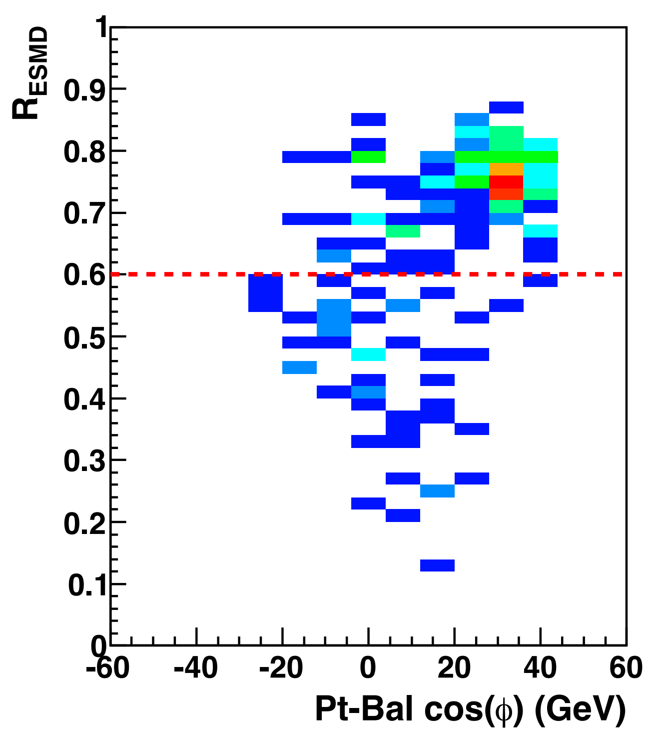
Signal Example



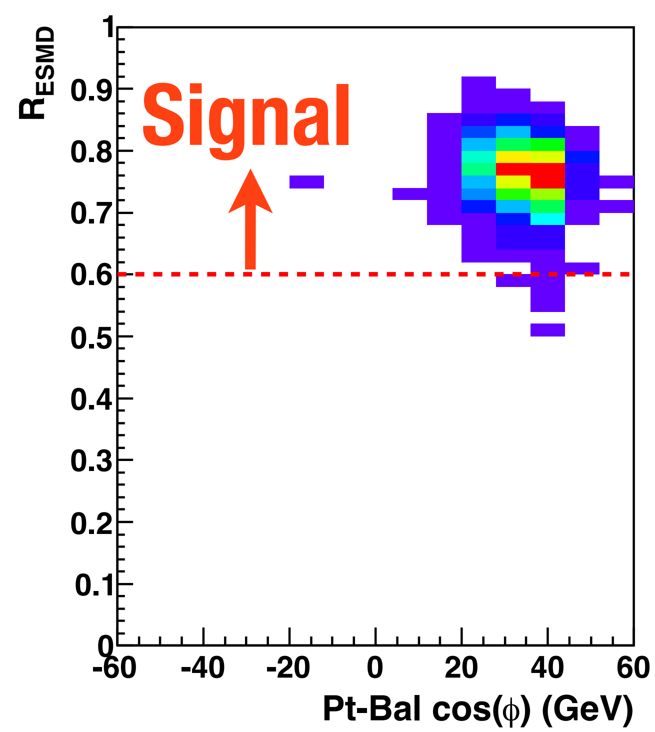
Background Example



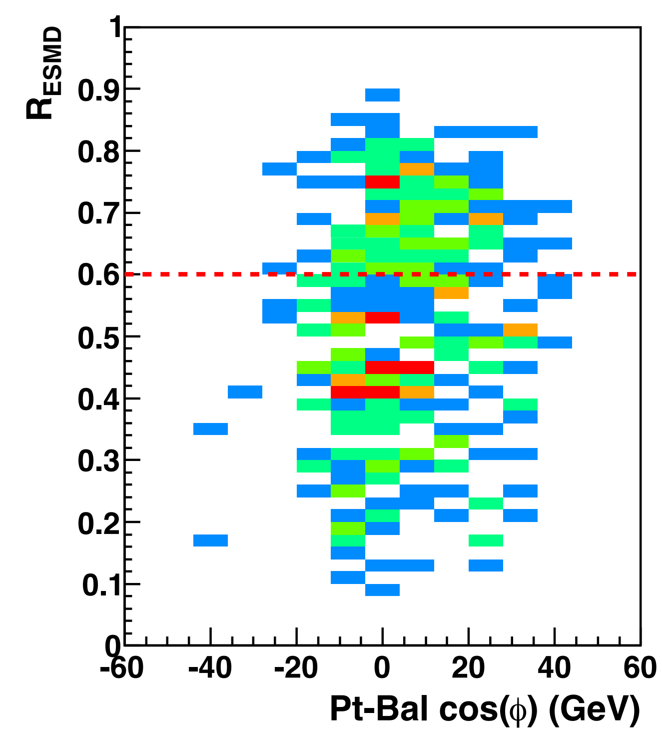
Run 12 Data



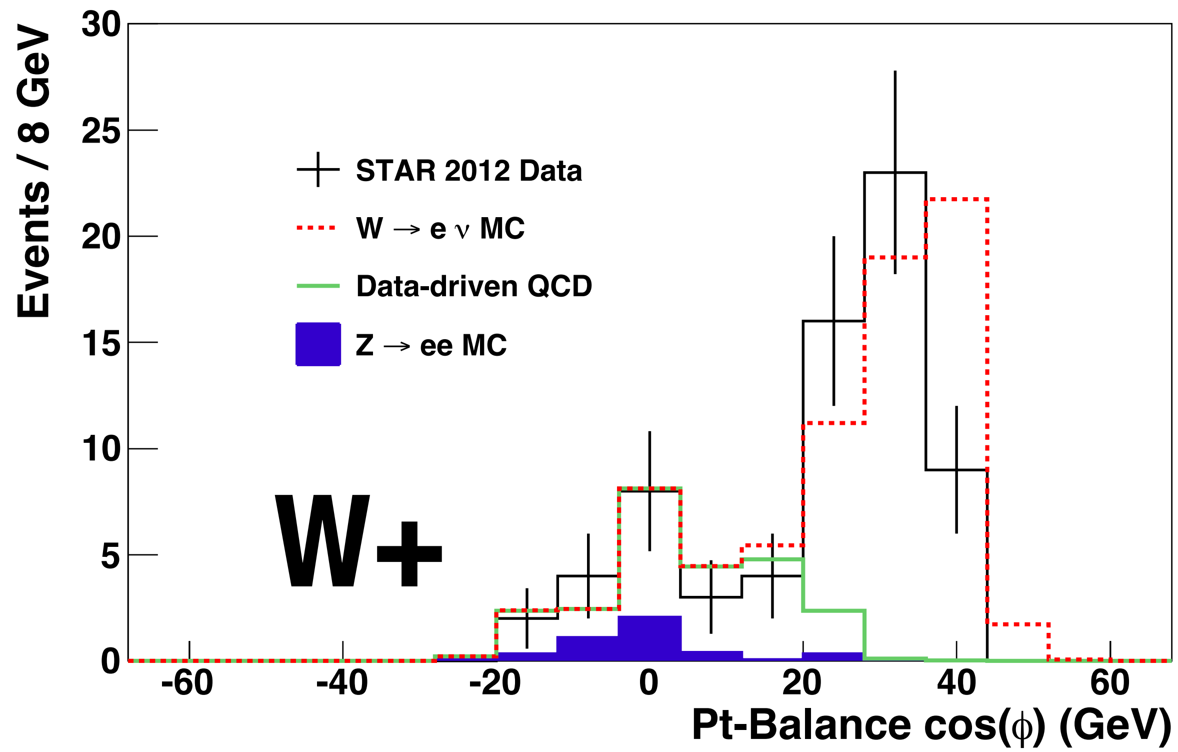
W+ MC

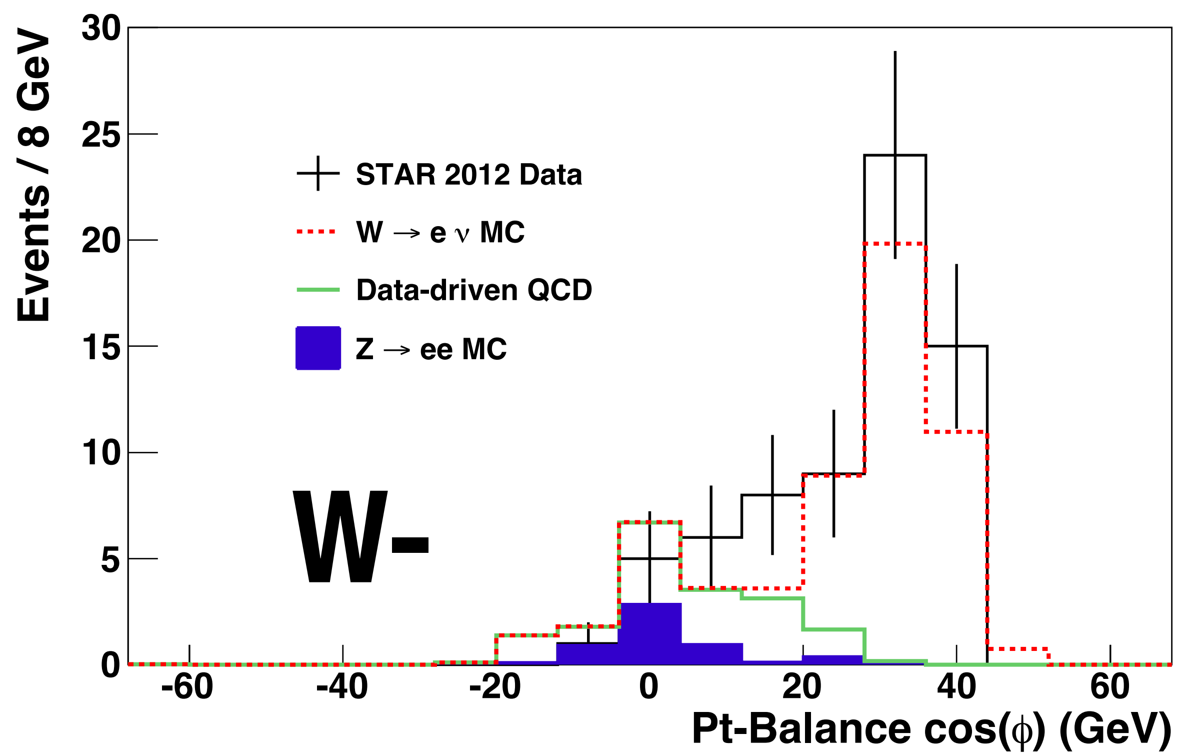


QCD MC



Forward Rapidity Background Estimation



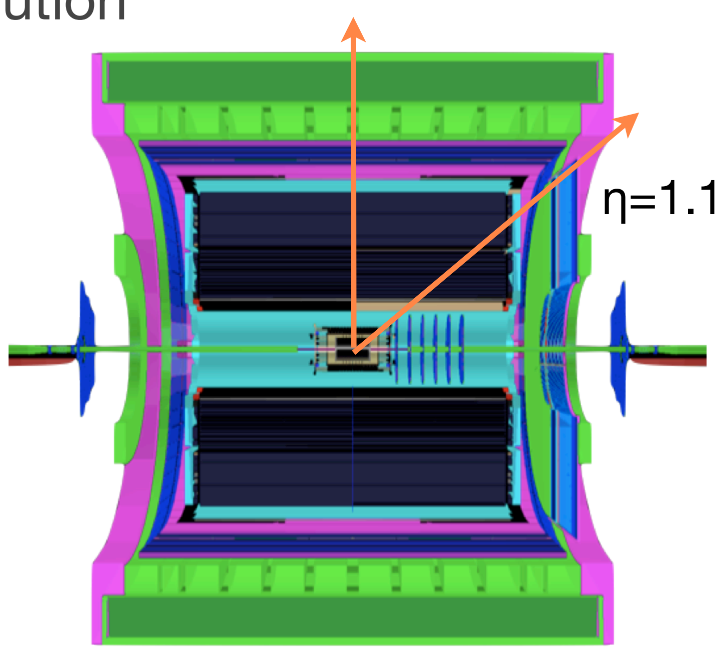


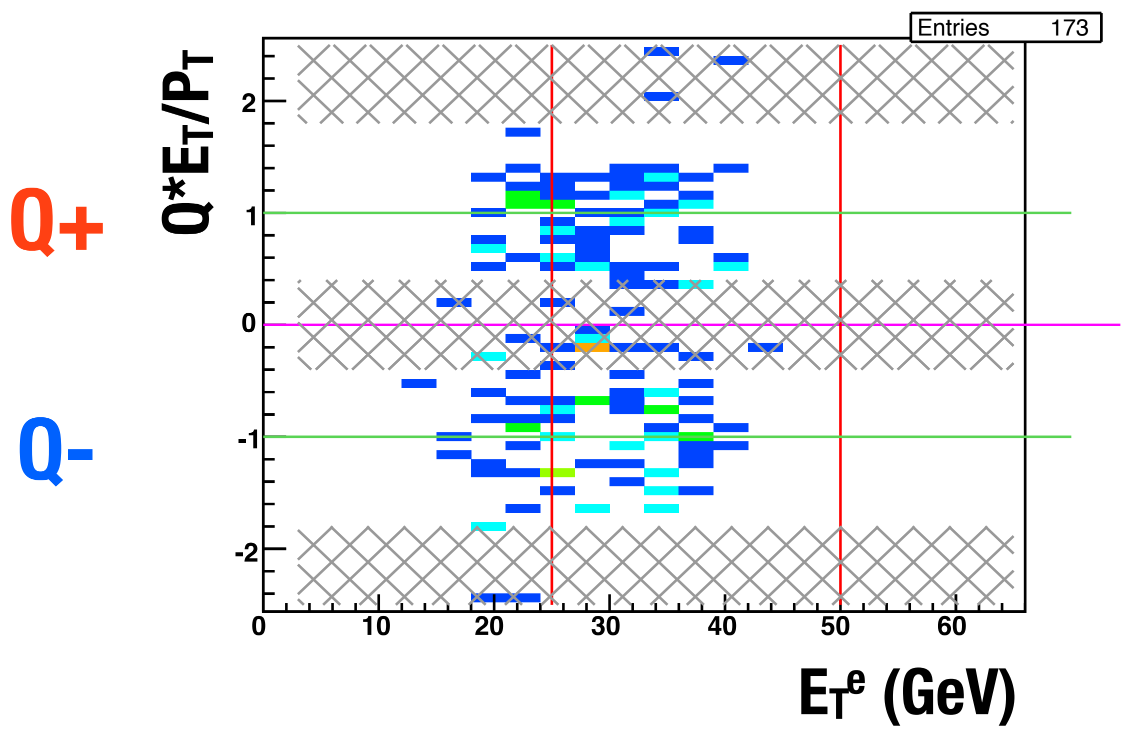
- Final signal selected by P_T-Balance > 20 GeV
- Raw Signal Yields:
  - W+ : 48
  - W- : 48
- Background Estimation:

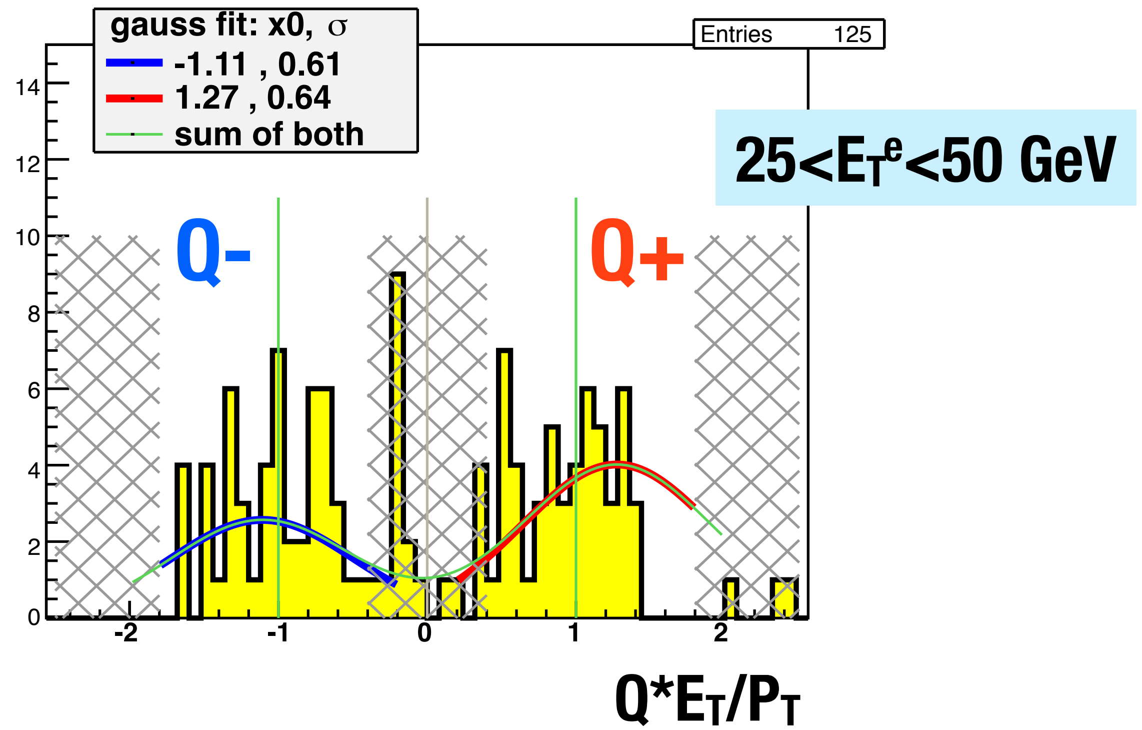
	Z→ee	QCD
W+	0.5 ± 0.1	2.0 ± 1.2
W-	0.5 ± 0.1	1.3 ± 0.7

Forward Rapidity Charge Separation

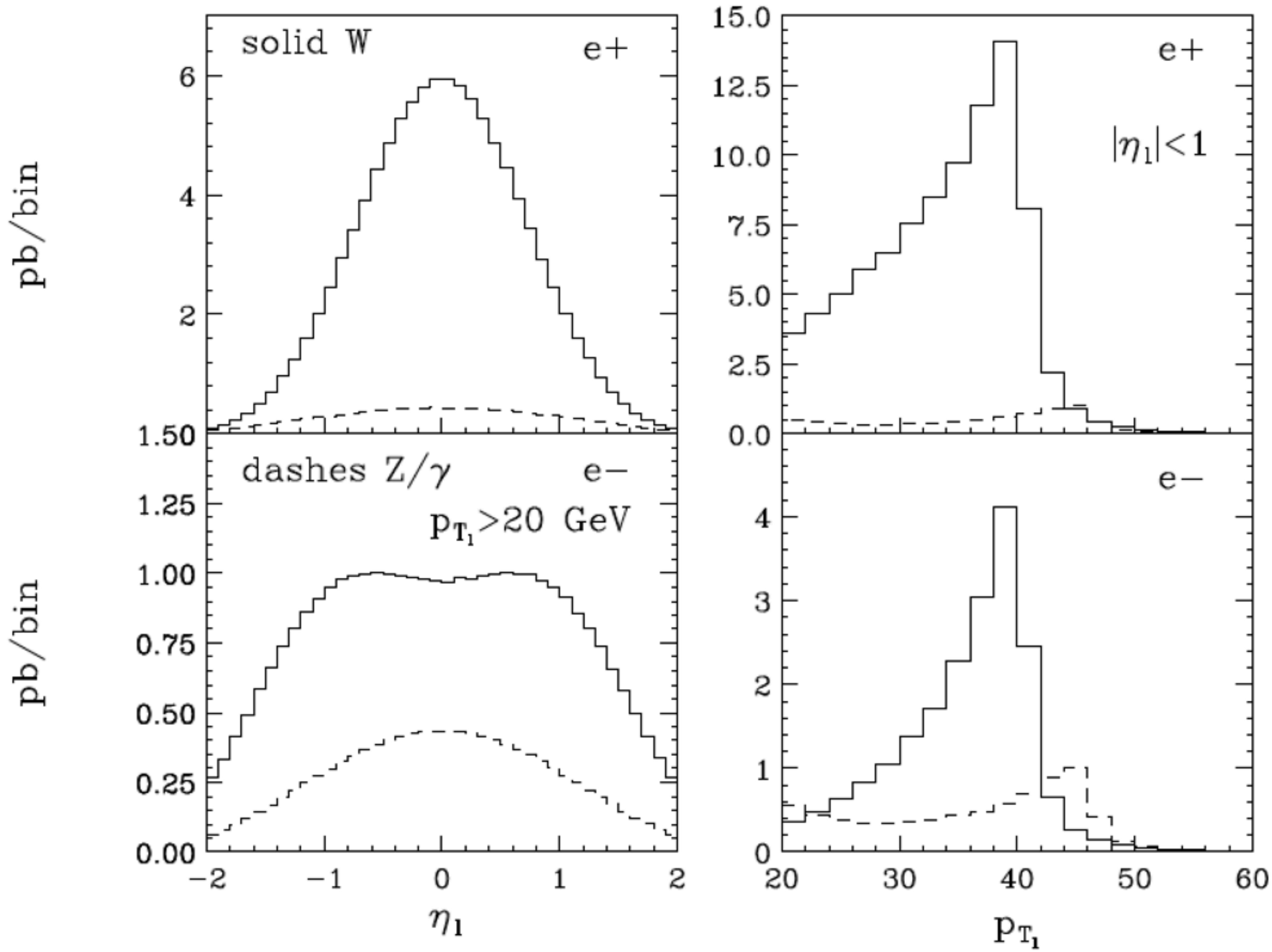
- Fewer TPC fit points at forward rapidity leads to worsened P_T resolution
  - Expect factor ~2 worse resolution than mid-rapidity
- Similar procedure as mid-rapidity
  - E_T/P_T (ie. EMC/TPC) distribution for each charge sign
  - Estimate wrong sign contamination with Gaussian fit
- Q+ and Q- peaks are separated by ~3σ
- After excluding tails, opposite charge sign contamination is less than 1%





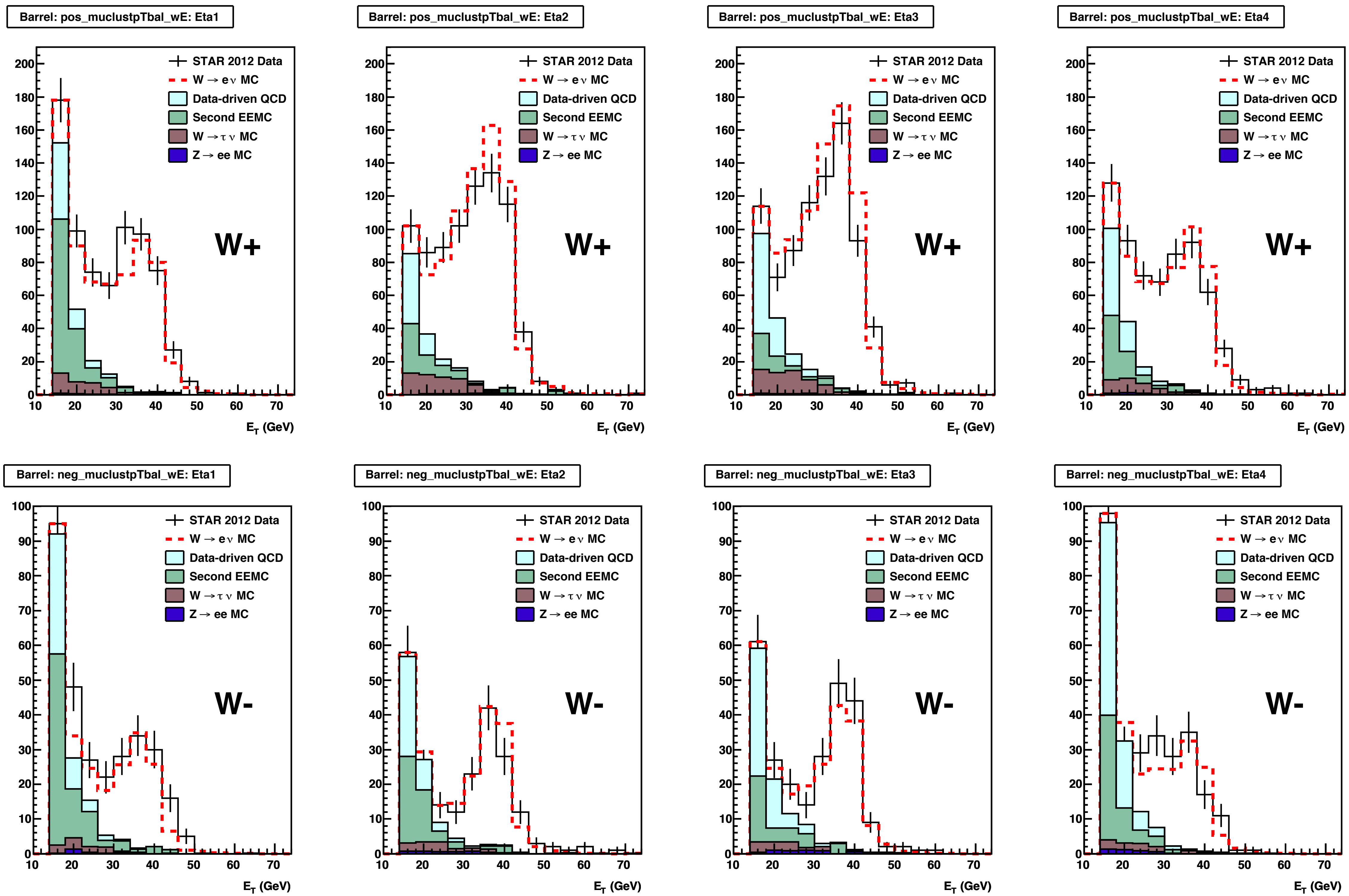


NLO CHE Cross Sections

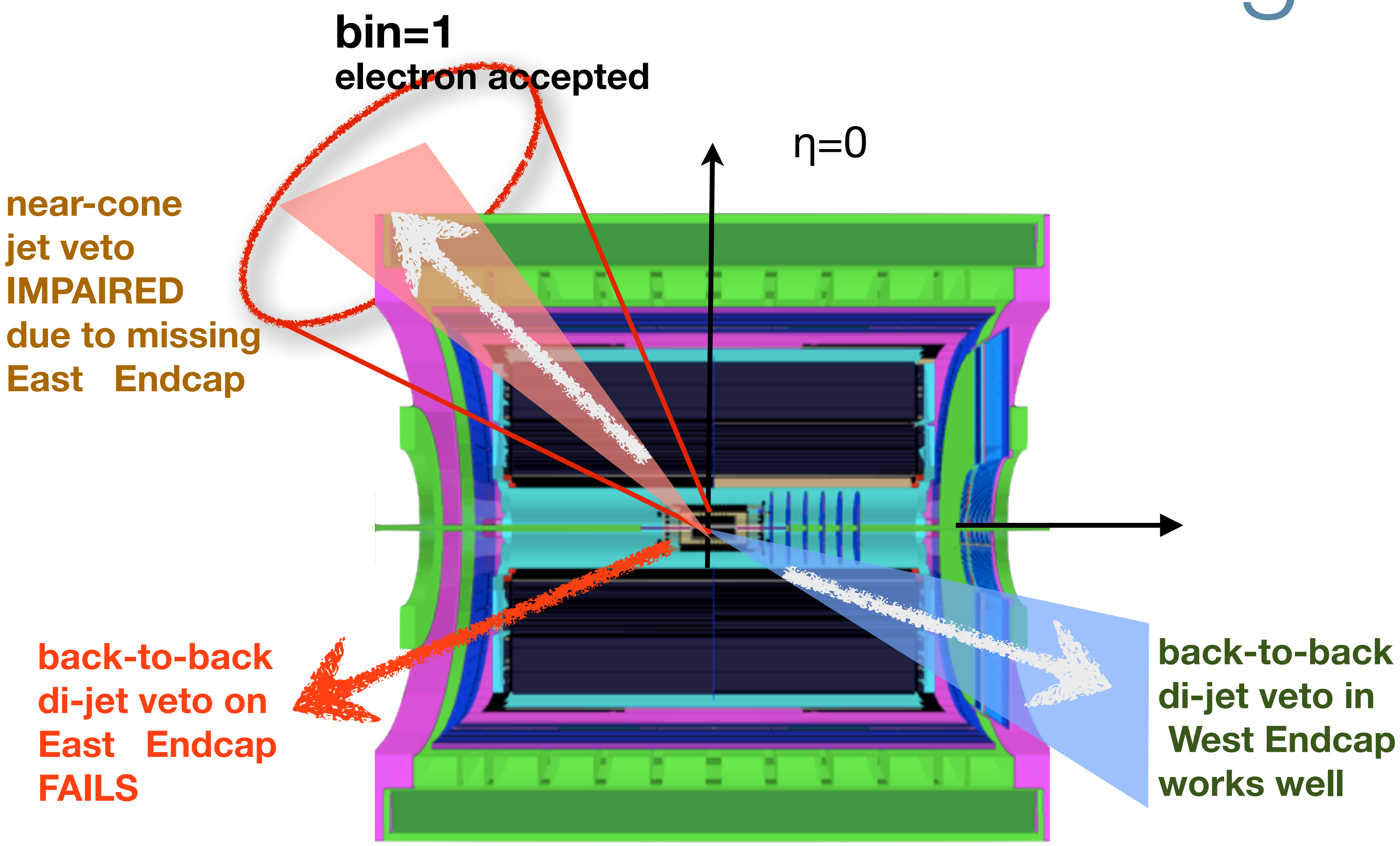


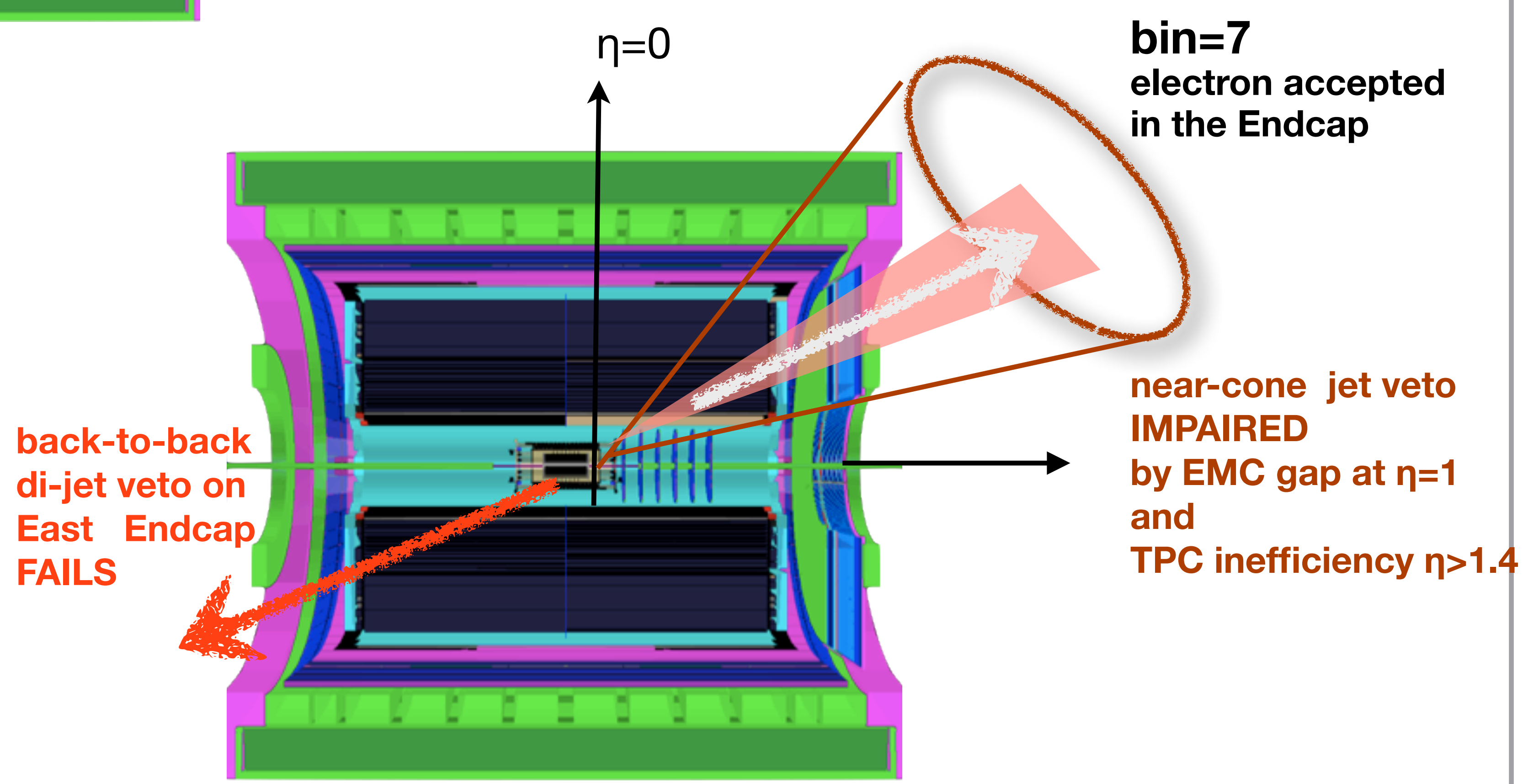
Mid-rapidity Background η Dependence

-1< η < -0.5 | -0.5 < η < 0 | 0 < η < 0.5 | 0.5 < η < 1

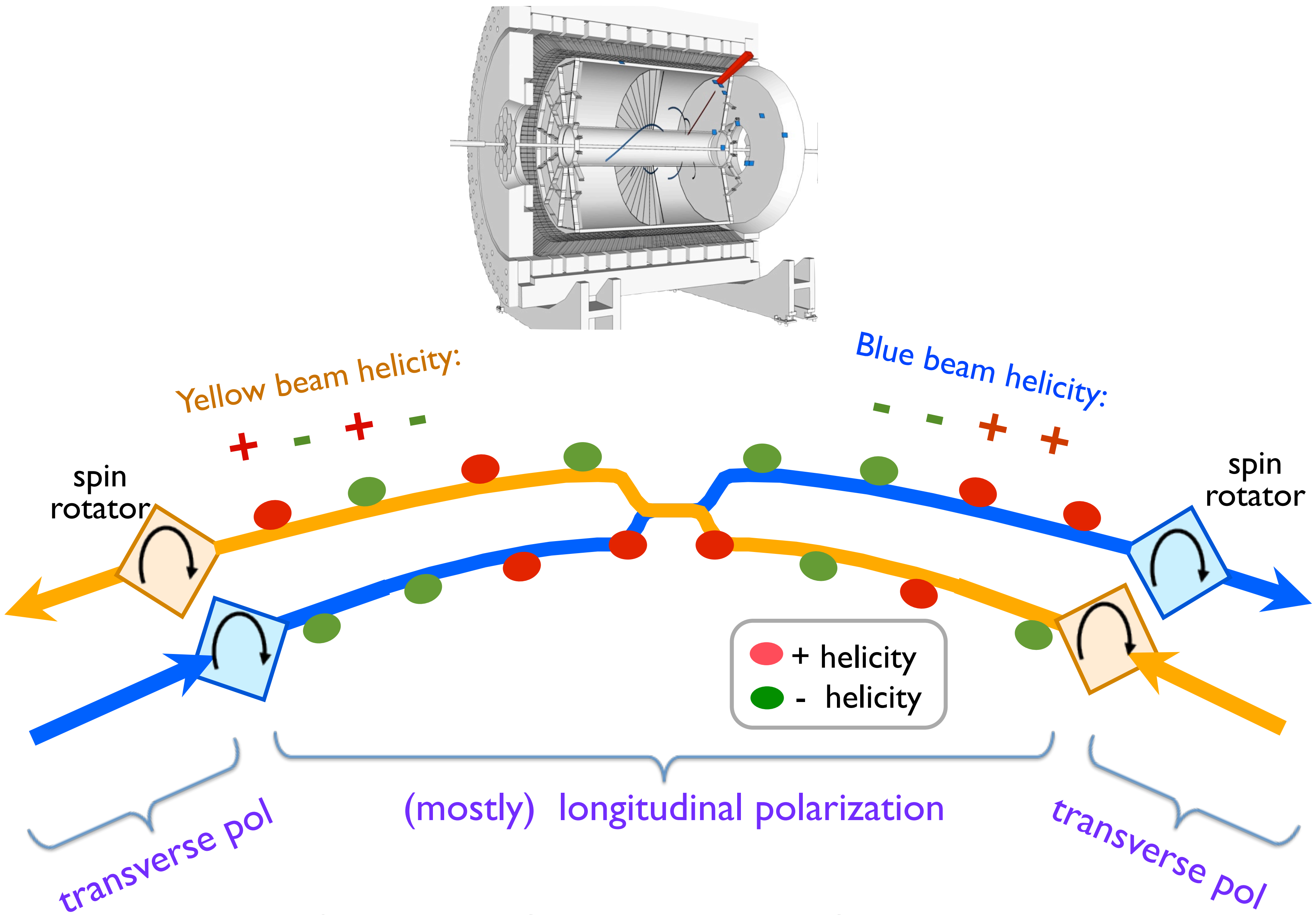


Second EEMC Background



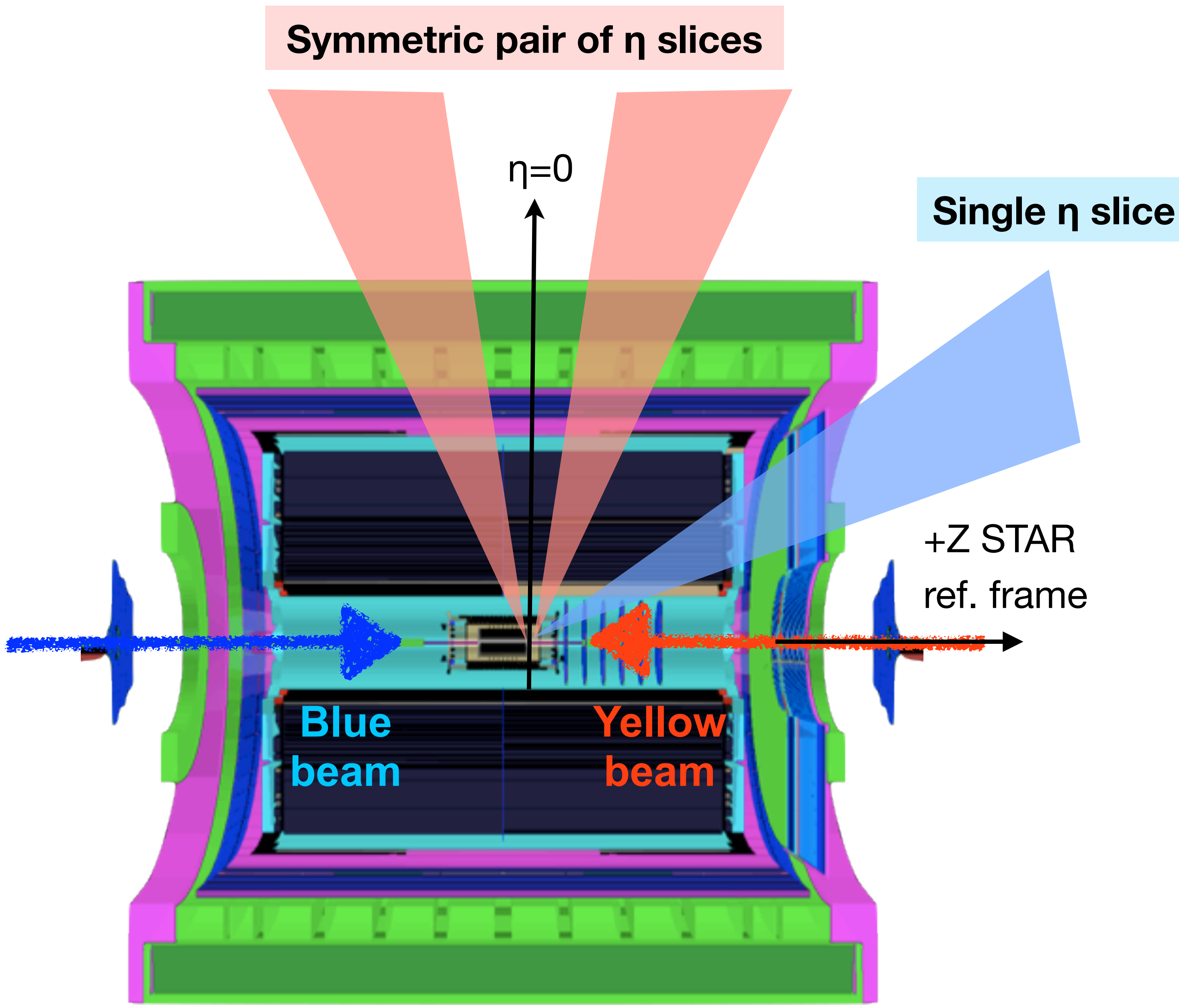


Spin Asymmetry: $A_L(\eta_e)$



STAR sees four helicity configurations

η Dependent Spin Sorting



$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{1}{P}\frac{N_+/\mathcal{L}_+ - N_-/\mathcal{L}_-}{N_+/\mathcal{L}_+ + N_-/\mathcal{L}_-}$$

Single Asymmetric η Slice

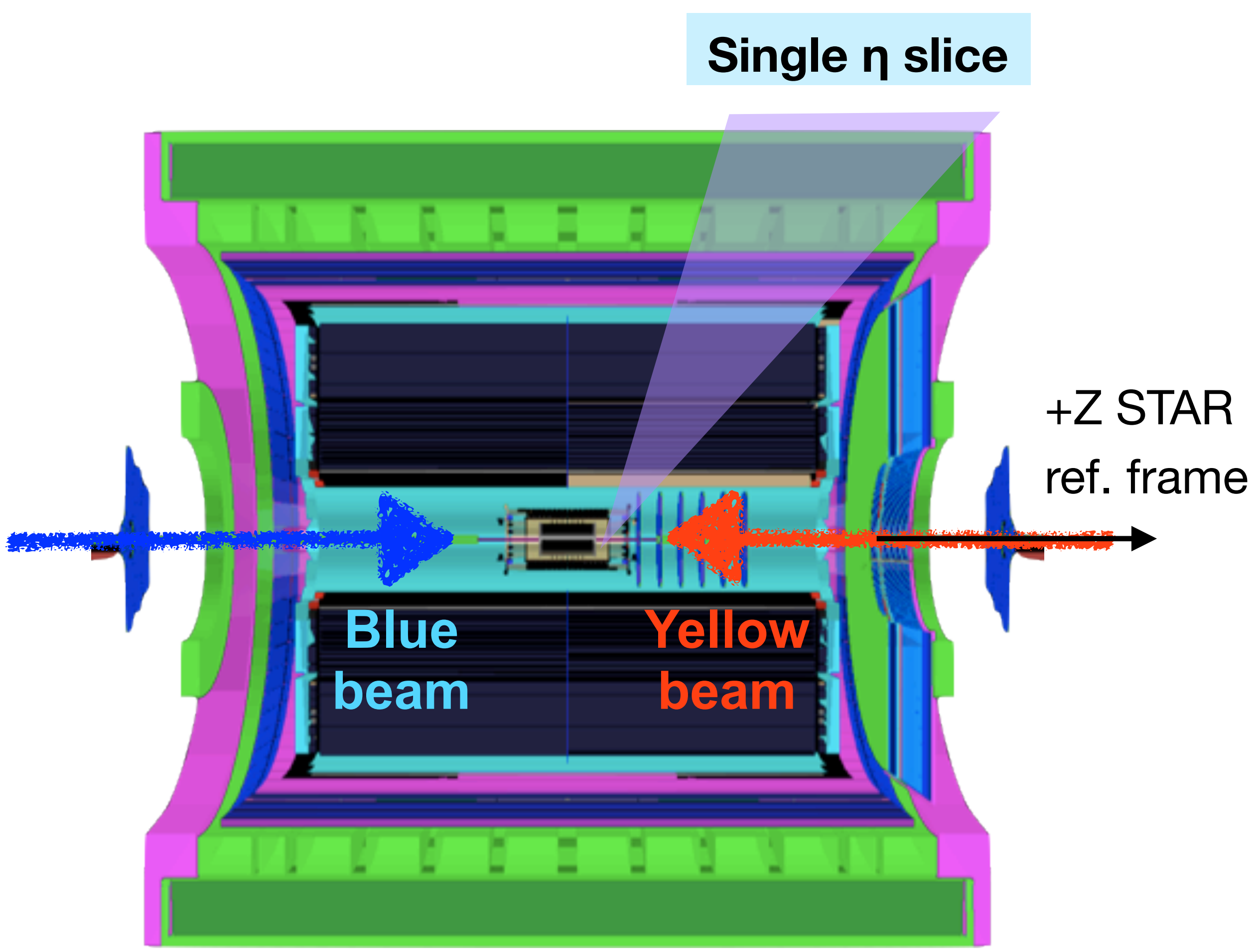
$$
\begin{aligned}
N^{++}_{\eta STAR}/\mathcal{L}^{++} &= \mathcal{C}_{\eta STAR}\,[\,1 + A_L(\eta)P^L_1 + A_L(-\eta)P^L_2 + A_{LL}(|\eta|)P^L_1P^L_2\,] \quad \#1\\
N^{+-}_{\eta STAR}/\mathcal{L}^{+-} &= \mathcal{C}_{\eta STAR}\,[\,1 + A_L(\eta)P^L_1 - A_L(-\eta)P^L_2 - A_{LL}(|\eta|)P^L_1P^L_2\,] \quad \#2\\
N^{-+}_{\eta STAR}/\mathcal{L}^{-+} &= \mathcal{C}_{\eta STAR}\,[\,1 - A_L(\eta)P^L_1 + A_L(-\eta)P^L_2 - A_{LL}(|\eta|)P^L_1P^L_2\,] \quad \#3\\
N^{--}_{\eta STAR}/\mathcal{L}^{--} &= \mathcal{C}_{\eta STAR}\,[\,1 - A_L(\eta)P^L_1 - A_L(-\eta)P^L_2 + A_{LL}(|\eta|)P^L_1P^L_2\,] \quad \#4
\end{aligned}
$$

$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{1}{P}\frac{N_+/\mathcal{L}_+ - N_-/\mathcal{L}_-}{N_+/\mathcal{L}_+ + N_-/\mathcal{L}_-}$$

Blue beam pol: $A_L(+\eta)$

Yellow beam pol: $A_L(-\eta)$

A_{LL} |η|

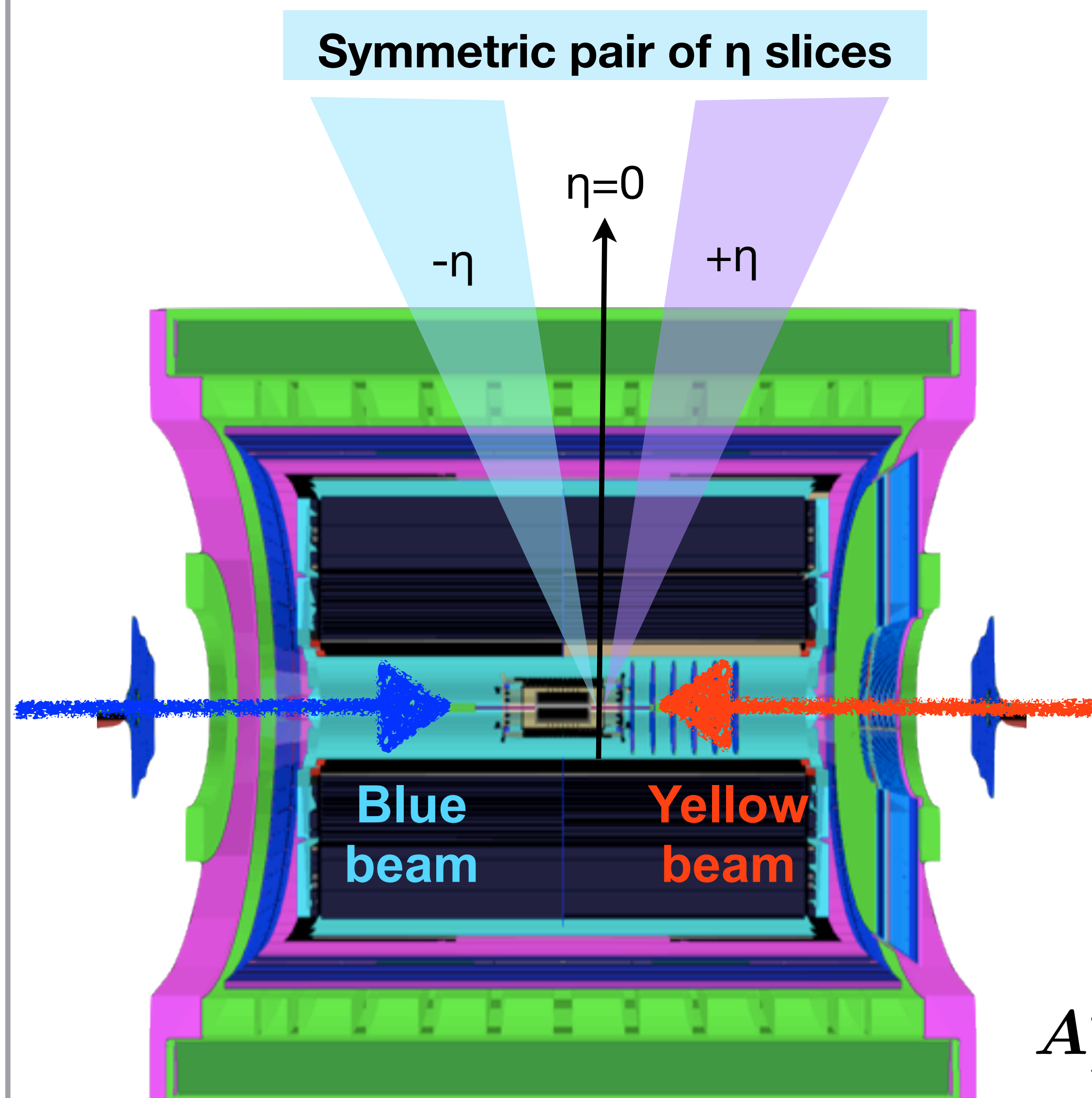


A_L for both beams measured from 4 spin dependent yields

$$A_L^{sig}(+\eta) = \frac{1+2-3-4}{P_1^L \cdot \Sigma 1\ldots 4}$$

$$A_L^{sig}(-\eta) = \frac{1-2+3-4}{P_2^L \cdot \Sigma 1\ldots 4}$$

Symmetric Pair of η Slices



8 yields from a symmetric “pair of detectors”

$$
\begin{aligned}
N^{++}_{\eta STAR}/\mathcal{L}^{++} &= \mathcal{C}_{\eta STAR}\,[\,1 + A_L(\eta)P_1^L + A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] && \#1\\
N^{+-}_{\eta STAR}/\mathcal{L}^{+-} &= \mathcal{C}_{\eta STAR}\,[\,1 + A_L(\eta)P_1^L - A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] && \#2\\
N^{-+}_{\eta STAR}/\mathcal{L}^{-+} &= \mathcal{C}_{\eta STAR}\,[\,1 - A_L(\eta)P_1^L + A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] && \#3\\
N^{--}_{\eta STAR}/\mathcal{L}^{--} &= \mathcal{C}_{\eta STAR}\,[\,1 - A_L(\eta)P_1^L - A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] && \#4
\end{aligned}
$$

$$
\begin{aligned}
N^{++}_{-\eta STAR}/\mathcal{L}^{++} &= \mathcal{C}_{-\eta STAR}\,[\,1 + A_L(-\eta)P_1^L + A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] && \#5\\
N^{+-}_{-\eta STAR}/\mathcal{L}^{+-} &= \mathcal{C}_{-\eta STAR}\,[\,1 + A_L(-\eta)P_1^L - A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] && \#6\\
N^{-+}_{-\eta STAR}/\mathcal{L}^{-+} &= \mathcal{C}_{-\eta STAR}\,[\,1 - A_L(-\eta)P_1^L + A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] && \#7\\
N^{--}_{-\eta STAR}/\mathcal{L}^{--} &= \mathcal{C}_{-\eta STAR}\,[\,1 - A_L(-\eta)P_1^L - A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] && \#8
\end{aligned}
$$

Extract two A_L values from 8 spin dependent yields using 2 polarized beams

$$A_L^{sig}(+\eta) = \frac{1}{2}\left(\frac{1+2-3-4}{P_1^L \cdot \Sigma 1\ldots 4} + \frac{5-6+7-8}{P_2^L \cdot \Sigma 5\ldots 8}\right)$$

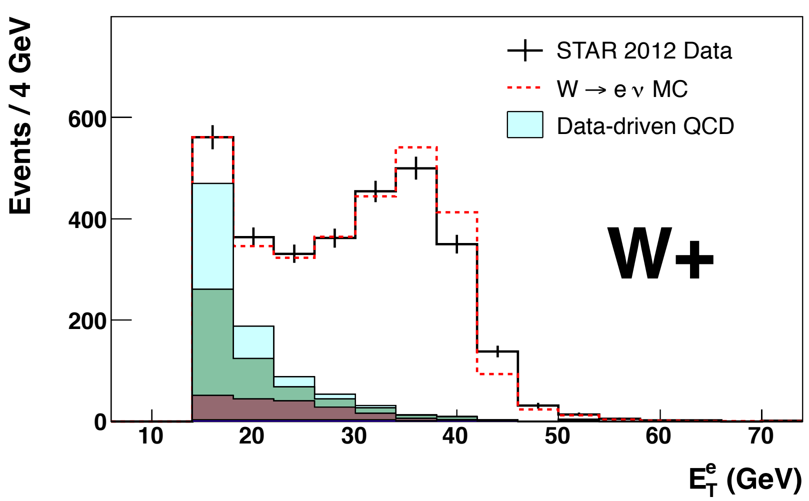
$$A_L^{sig}(-\eta) = \frac{1}{2}\left(\frac{1-2+3-4}{P_2^L \cdot \Sigma 1\ldots 4} + \frac{5+6-7-8}{P_1^L \cdot \Sigma 5\ldots 8}\right)$$

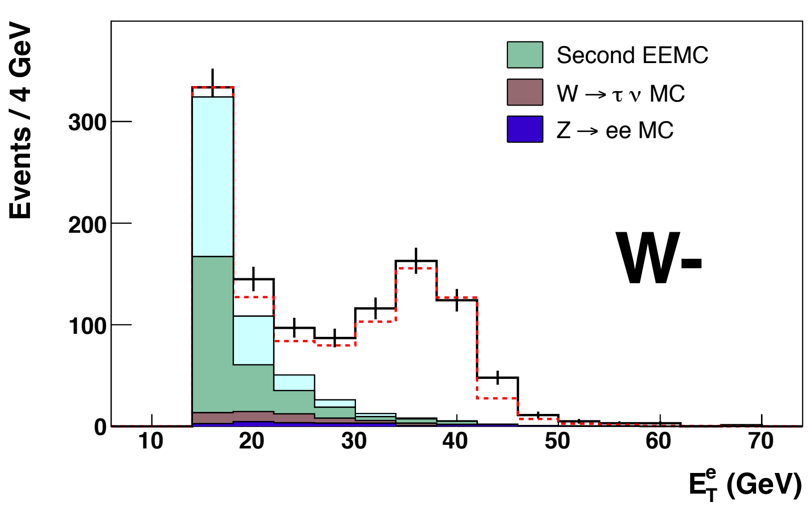
Note: There is a statistical correlation between symmetric η points with a correlation coefficient -5% for $|\eta| < 1$ and -10% for $|\eta| > 1$

Background Contributions to A_L

$$A_L^{sig}(\eta) = f_W(\eta)A_L^W(\eta) + \sum f_{Bkgd}(\eta)A_L^{Bkgd}(\eta)$$

$$A_L^W = \frac{A_L^{sig} - \left(f_{EEMC}A_L^{EEMC} + f_Z A_L^Z + f_{QCD}A_L^{QCD}\right)}{1 - f_{EEMC} - f_Z - f_{QCD}} = \boxed{\frac{A_L^{sig} - \alpha}{\beta}}$$



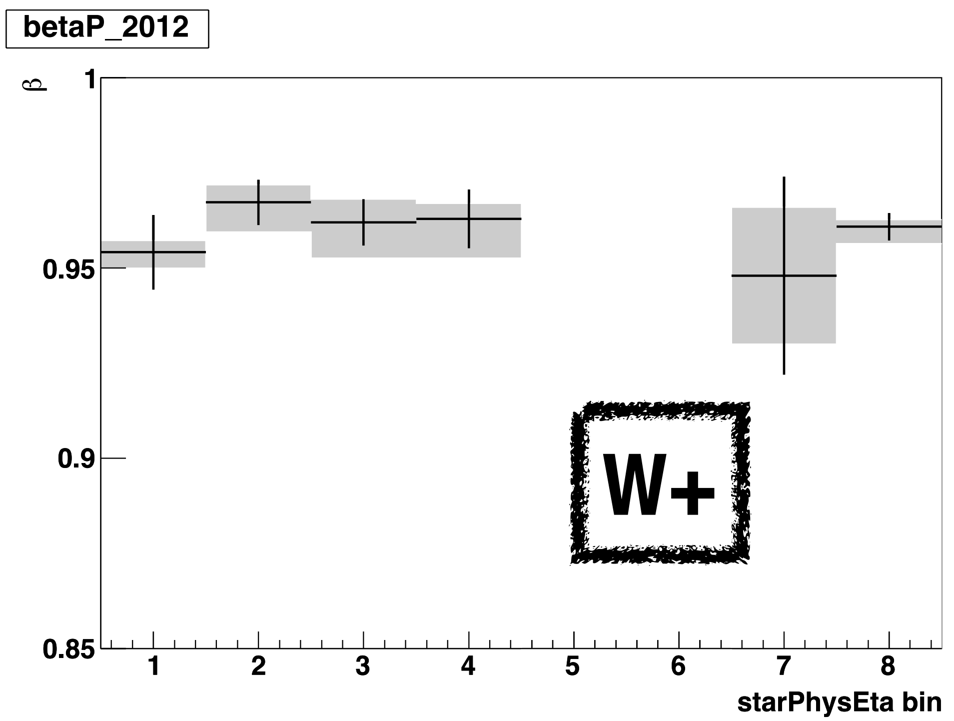


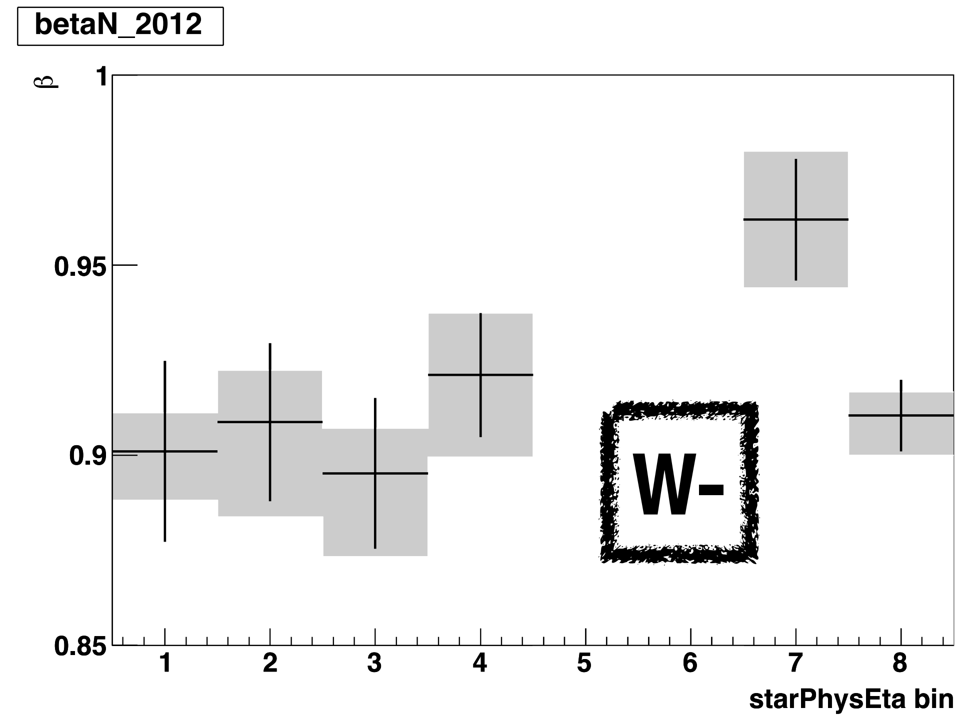
- The unpolarized background contribution β effectively dilutes the beam polarization

	$\|\eta_e\| < 1$	$1 < \eta_e < 1.4$
W+ β	~0.95	~0.95
W- β	~0.9	~0.95

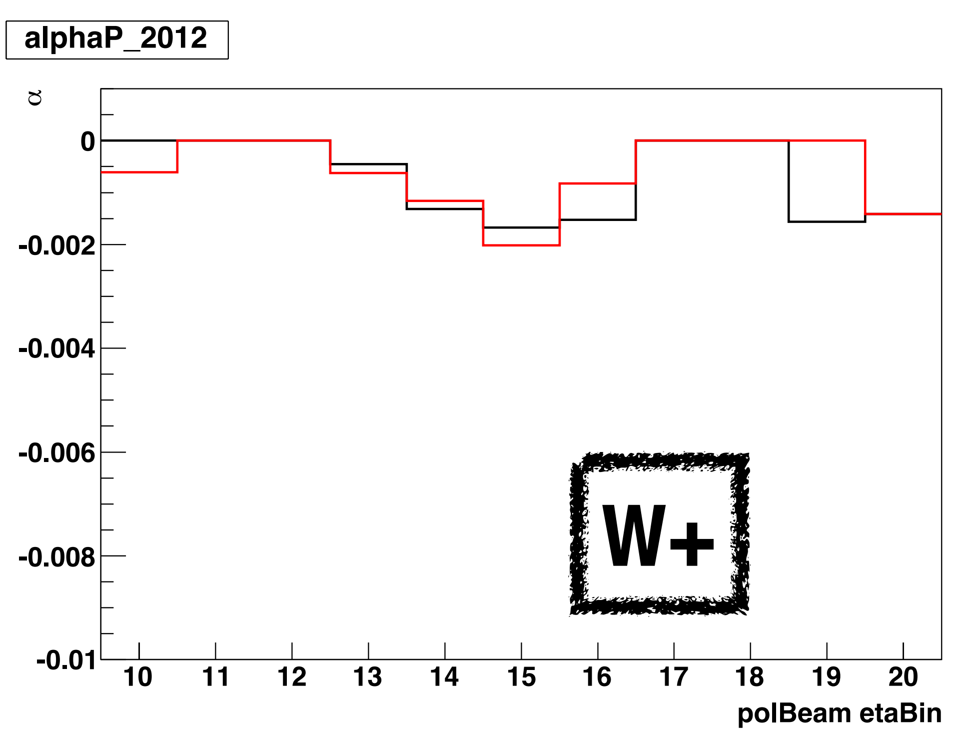
- The polarized background contribution ***α*** is estimated using the CHE NLO prediction for A_L^Z from DSSV
    - These are small corrections to the measured asymmetry with typical values of $|\alpha| < 0.005$

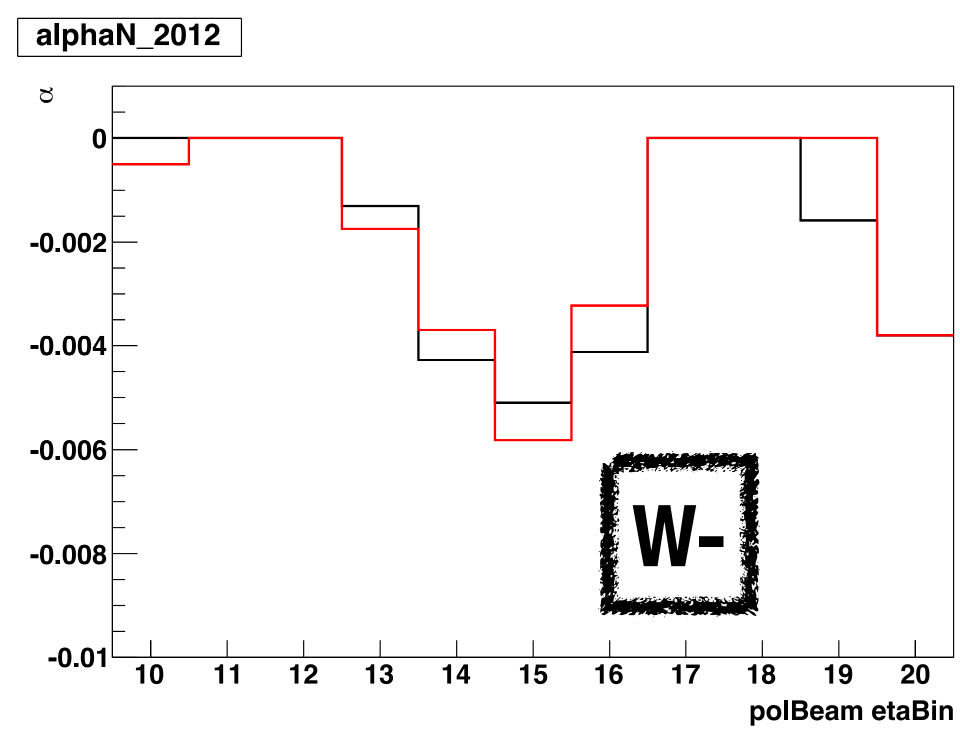
Background Details: α and β



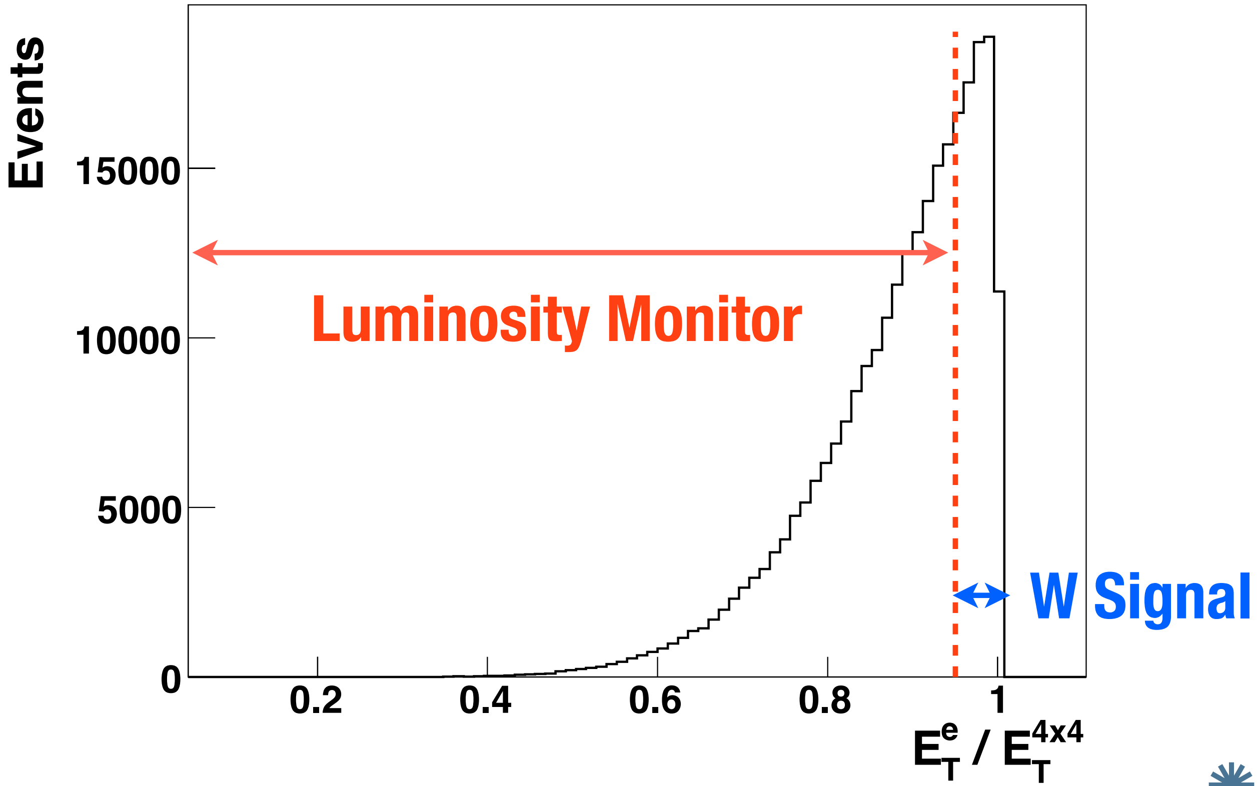


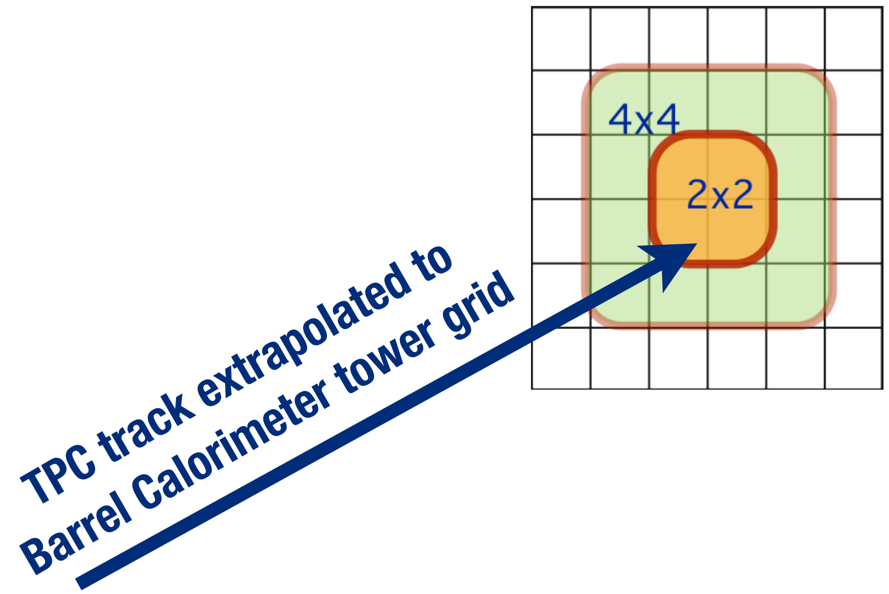
- Compute A_L using upper and lower systematic error bound on β and take largest difference from nominal A_L as systematic error due to β

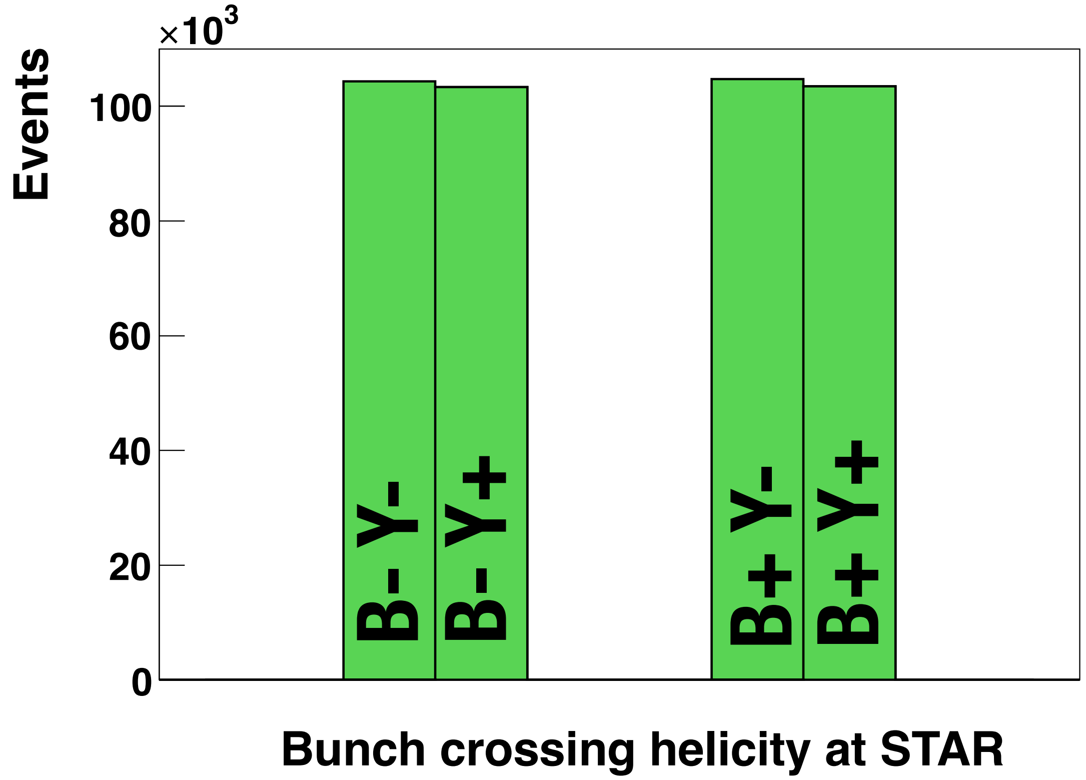




Relative Luminosity for Spin States





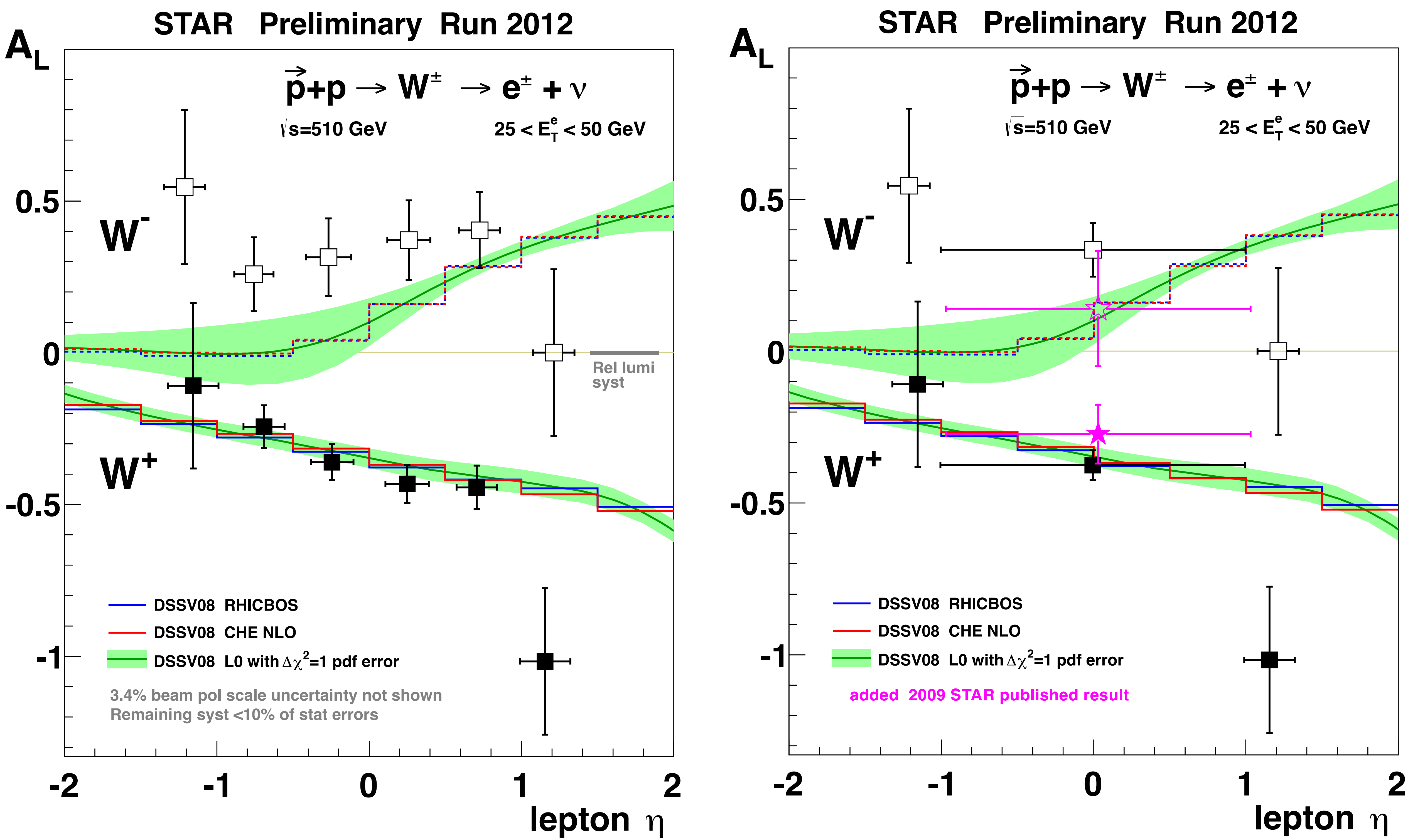


- Independent sample of QCD events, which fail E_T^e/E_T^{4x4} isolation cut with $E_T^e < 20$ GeV
- Spin dependent luminosity of four spin states measured to ~1%
- Luminosity monitor for $|\eta|<1$ used for A_L in all η bins

Systematic Uncertainties

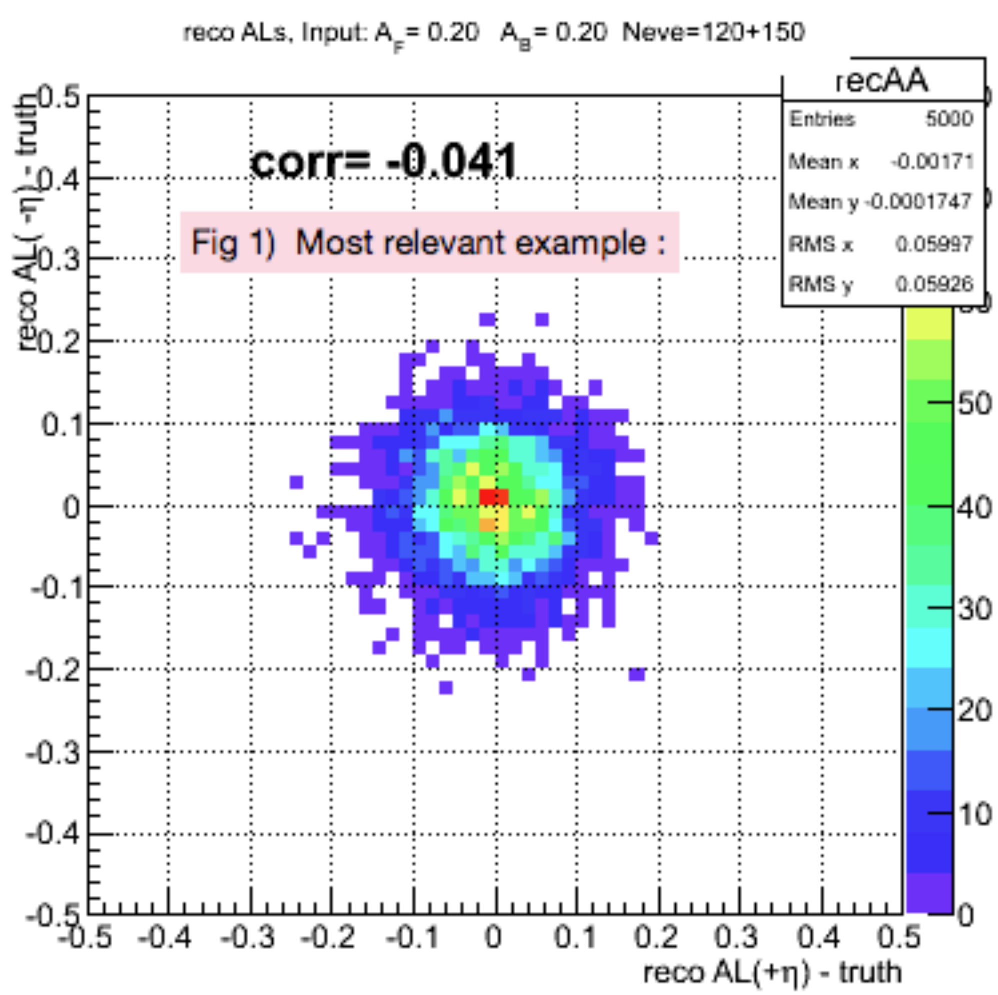
- **Beam polarization uncertainty: correlated scale 3.4%**
- **Relative luminosity uncertainty: correlated offset $\Delta A_L = 0.007$**
  - Accounts for possible parity-violating asymmetry in QCD events used for luminosity monitor
  - A_L is consistent with zero for a sample of high-p_T QCD events (invert isolation ratio and P_T-Balance requirements)
  - Systematic uncertainty estimated as half the statistical error on A_L for this high-p_T QCD sample
- **Background estimation: less than 10% of statistical error**
  - Uncertainty on unpolarized background contribution β: uncorrelated between points less than 10% of statistical error
  - Uncertainty on polarized background contribution α: negligible

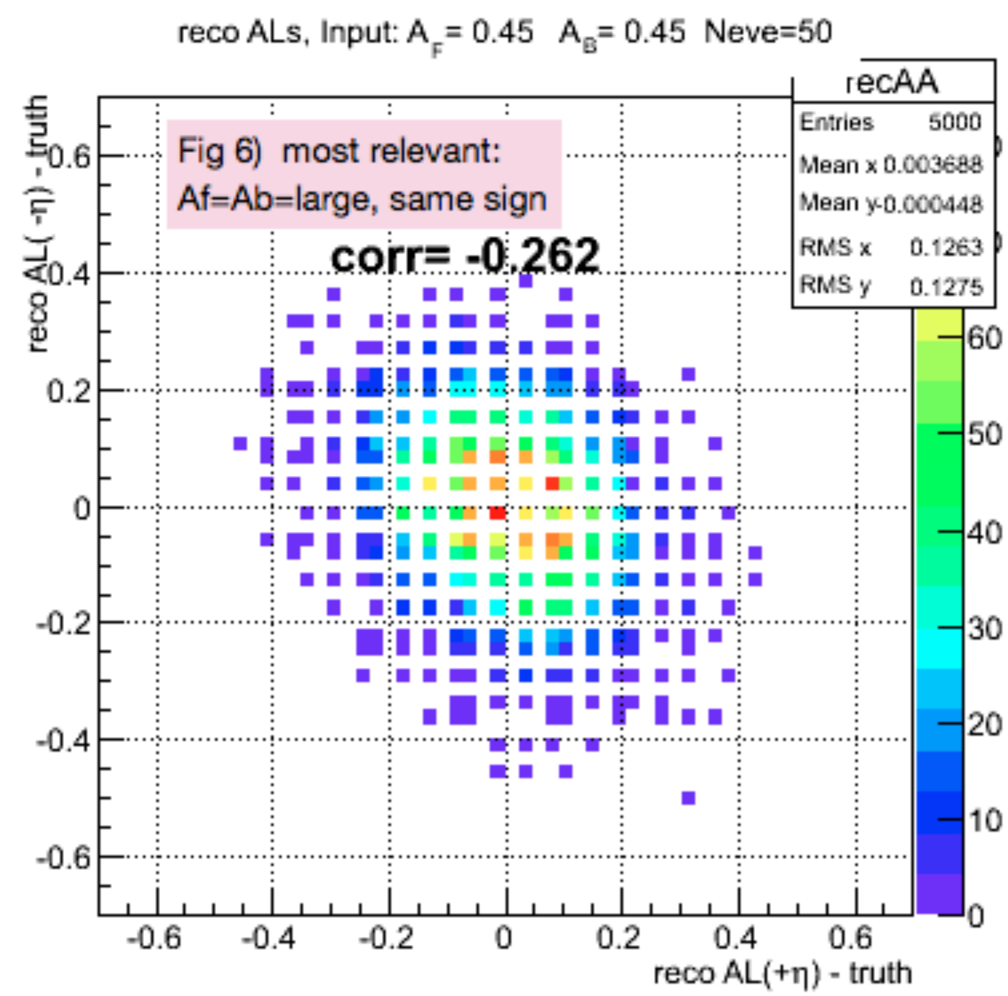
Comparison to 2009 Result



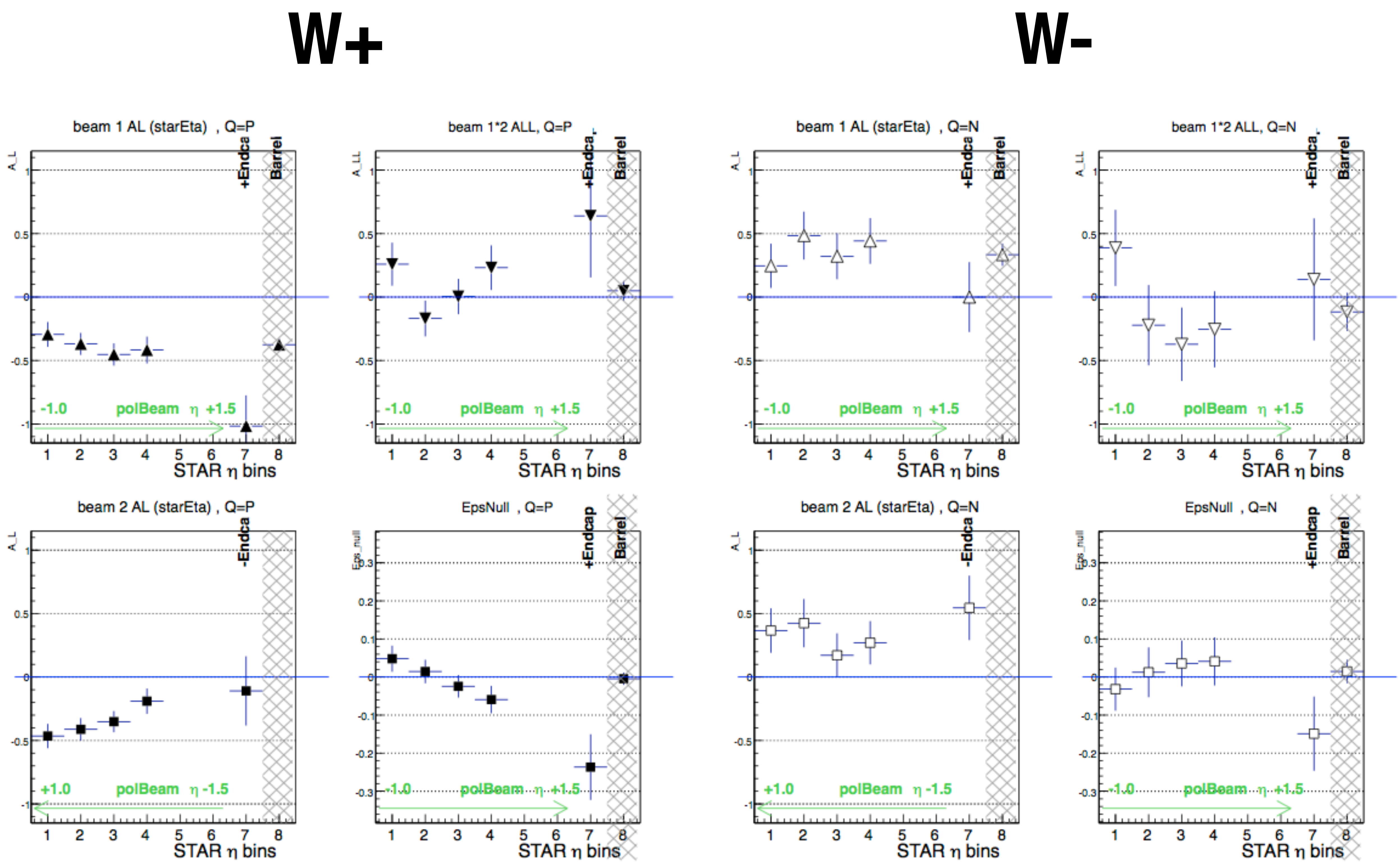
Correlations in $A_L(\eta)$

- The same 8 spin dependent yields are used to compute $A_L(\eta+)$ and $A_L(\eta-)$ leading to a correlation between pairs of η-symmetric points
- Correlation coefficient calculated with toy MC to be for various possible input asymmetries
- Find corr = -1.3 * A_L * A_L * P * P
  - Correlation coefficient ~ -5% for mid-rapidity and -11% for forward rapidity





Asymmetries Separated by Beam



More Equations

$$\frac{dN(\theta_e,\phi_e)}{d\theta_e\, d\phi_e} = \mathcal{L}\,\sigma_0(\theta_e)\,\varepsilon(\theta_e,\phi_e)\,[\,1 \;\; +A_1^L(\theta_e)P_1^L + A_1^N(\theta_e)\left(-P_{1x}^T\sin(\phi_e) + P_{1y}^T\cos(\phi_e)\right)$$
$$+A_2^L(\pi-\theta_e)P_2^L - A_2^N(\pi-\theta_e)\left(-P_{2x}^T\sin(\phi_e) + P_{2y}^T\cos(\phi_e)\right)$$
$$+A_{LL}(\theta_e)P_1^L P_2^L + o(\vec{P_1^T}\cdot\vec{P_1^T}) + o(\vec{P_1^T}\cdot\vec{P_1^T})\cos(2\phi_e)]$$

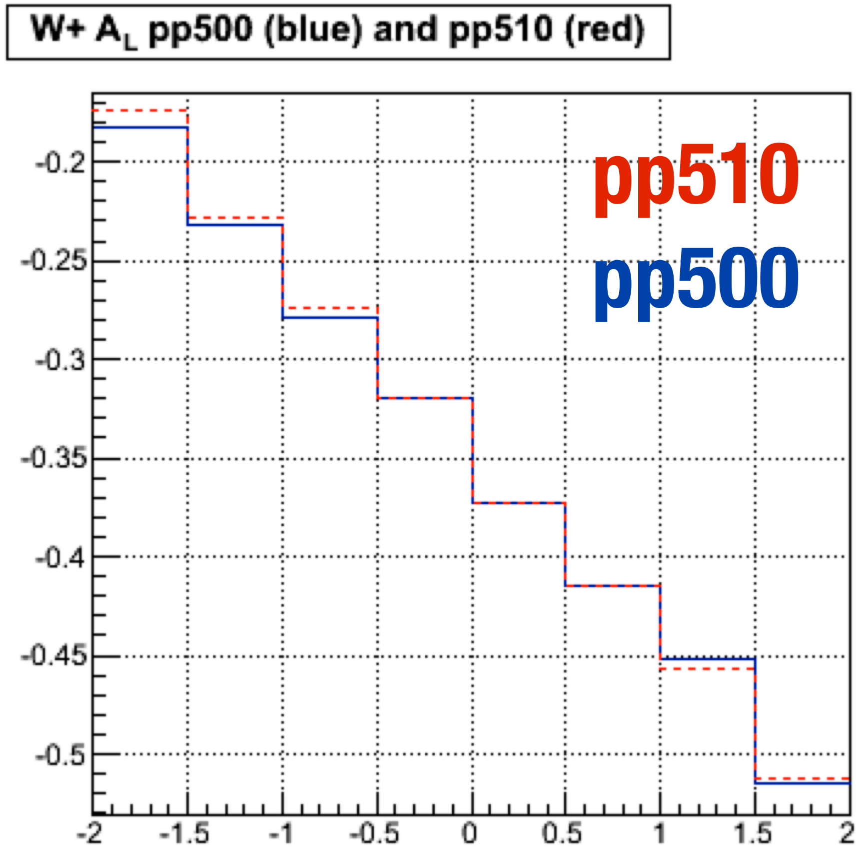
$$\frac{dN^{\pm\pm}}{d\eta^{STAR}} = \mathcal{L}^{\pm\pm}\mathcal{C}_{\eta^{STAR}}[\,1 \pm A_L(\eta)P_1^L \pm A_L(-\eta)P_2^L \pm A_{LL}(|\eta|)P_1^L P_2^L + \mathrm{BG}_{unpol} + \mathrm{BG}_{pol}\,]$$

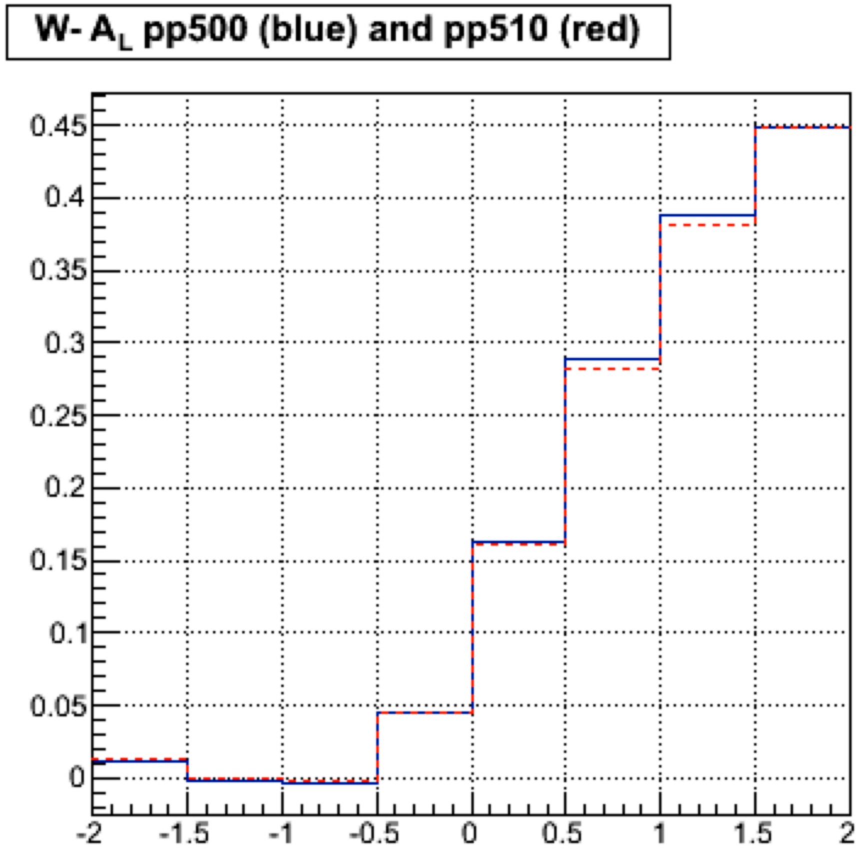
$$N_{\eta^{STAR}}^{++}/\mathcal{L}^{++} = \mathcal{C}_{\eta^{STAR}}\,[\,1 + A_L(\eta)P_1^L + A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#1$$
$$N_{\eta^{STAR}}^{+-}/\mathcal{L}^{+-} = \mathcal{C}_{\eta^{STAR}}\,[\,1 + A_L(\eta)P_1^L - A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#2$$
$$N_{\eta^{STAR}}^{-+}/\mathcal{L}^{-+} = \mathcal{C}_{\eta^{STAR}}\,[\,1 - A_L(\eta)P_1^L + A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#3$$
$$N_{\eta^{STAR}}^{--}/\mathcal{L}^{--} = \mathcal{C}_{\eta^{STAR}}\,[\,1 - A_L(\eta)P_1^L - A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#4$$

$$N_{-\eta^{STAR}}^{++}/\mathcal{L}^{++} = \mathcal{C}_{-\eta^{STAR}}\,[\,1 + A_L(-\eta)P_1^L + A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#5$$
$$N_{-\eta^{STAR}}^{+-}/\mathcal{L}^{+-} = \mathcal{C}_{-\eta^{STAR}}\,[\,1 + A_L(-\eta)P_1^L - A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#6$$
$$N_{-\eta^{STAR}}^{-+}/\mathcal{L}^{-+} = \mathcal{C}_{-\eta^{STAR}}\,[\,1 - A_L(-\eta)P_1^L + A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#7$$
$$N_{-\eta^{STAR}}^{--}/\mathcal{L}^{--} = \mathcal{C}_{-\eta^{STAR}}\,[\,1 - A_L(-\eta)P_1^L - A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#8$$

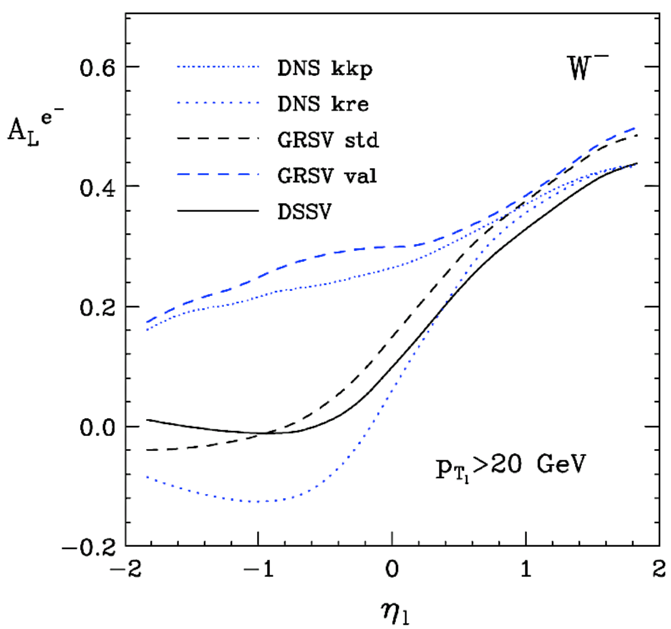
p+p 500 vs 510

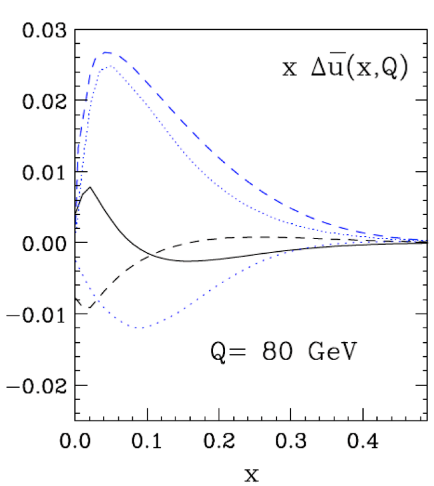
- Expect negligible difference in A_L from change in $\sqrt{s}$
- CHE (NLO) curves with DSSV confirm this expectation

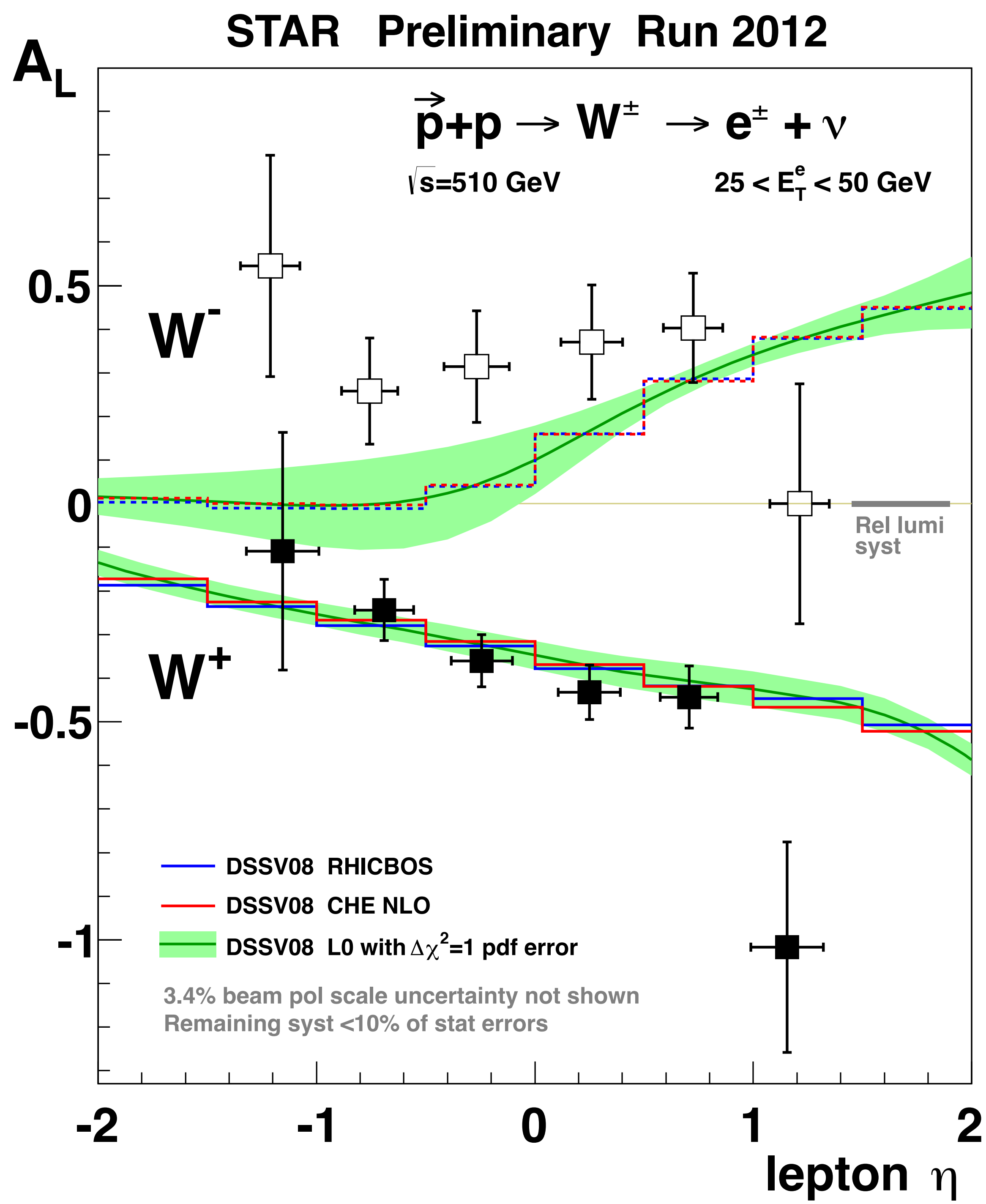


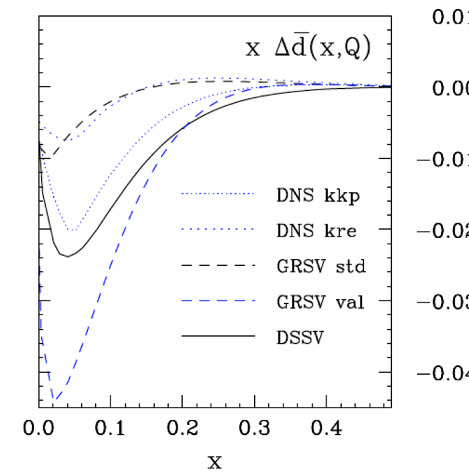


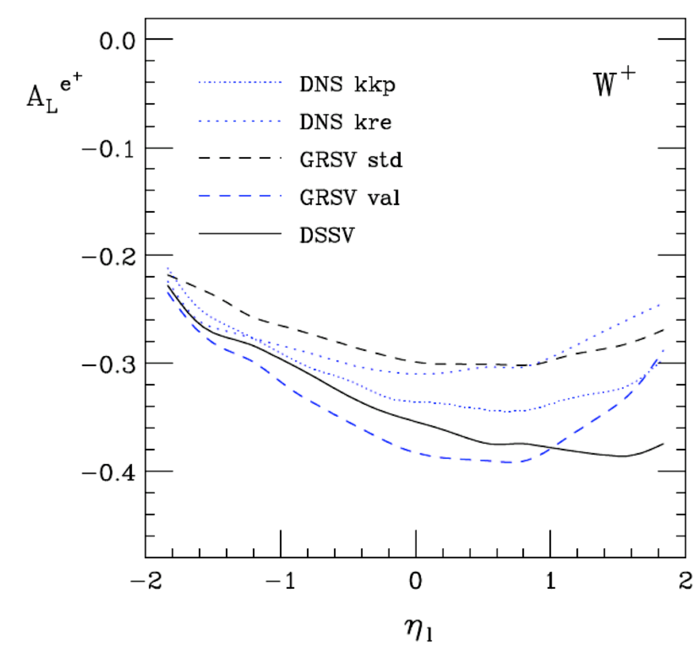
Other Theory Input



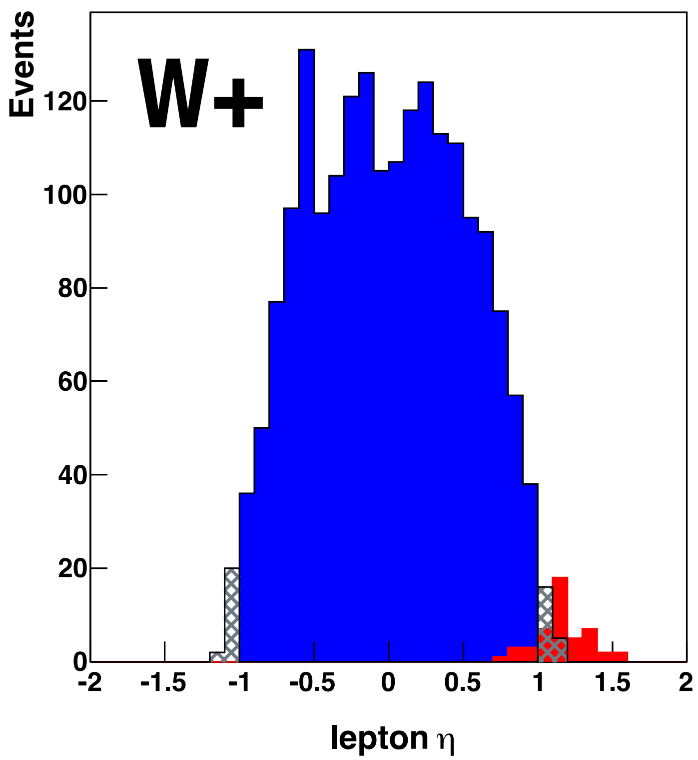


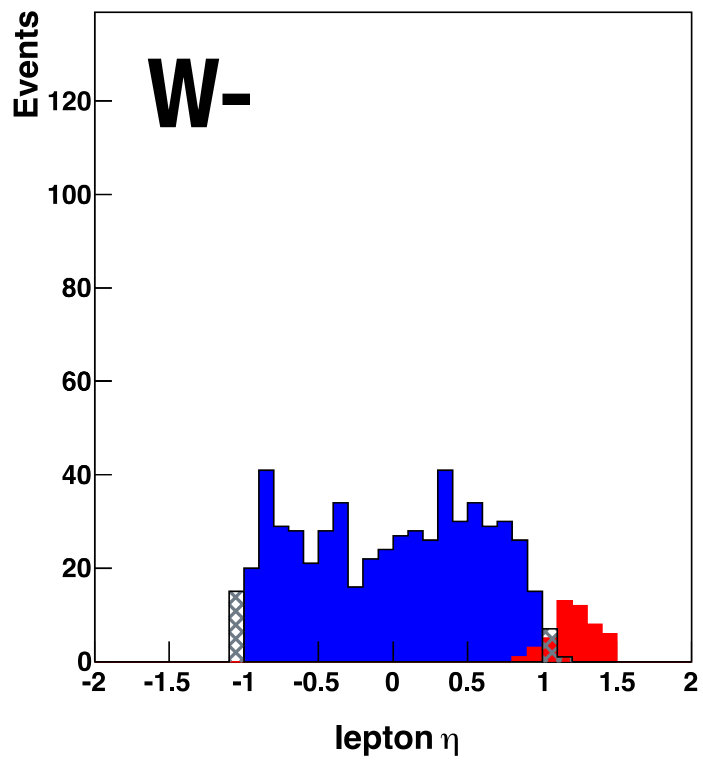


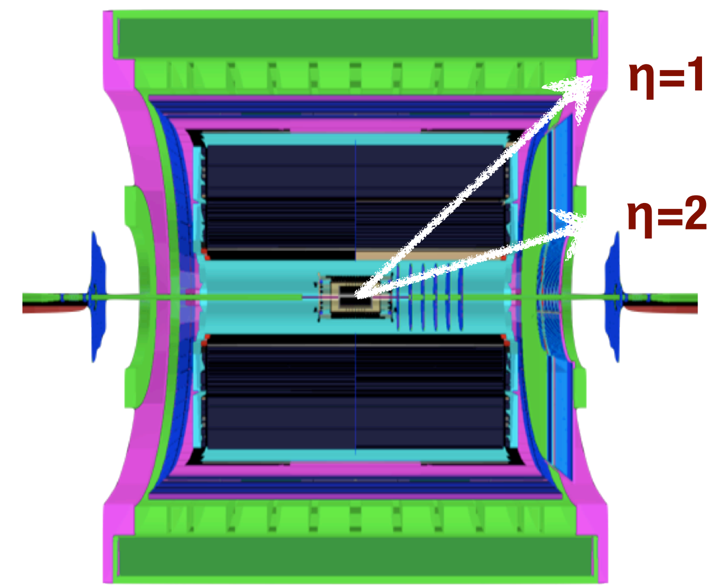


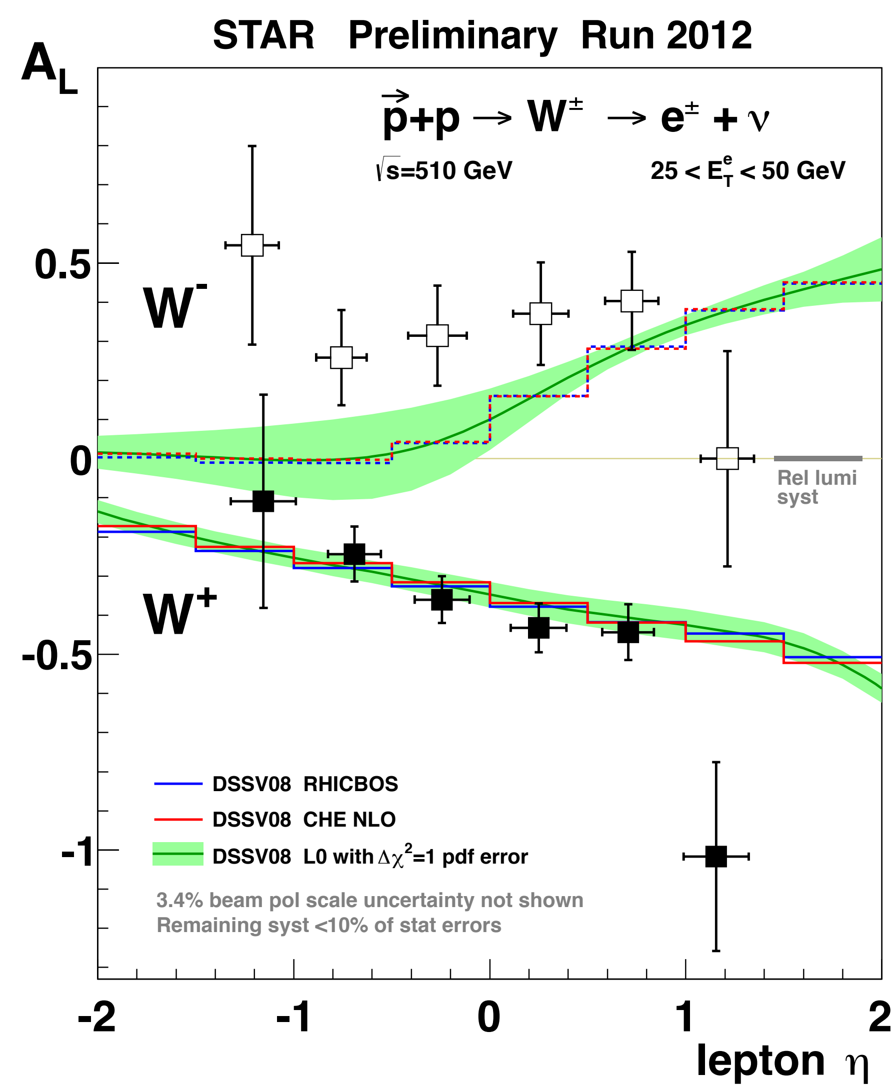


Forward Rapidity: FGT



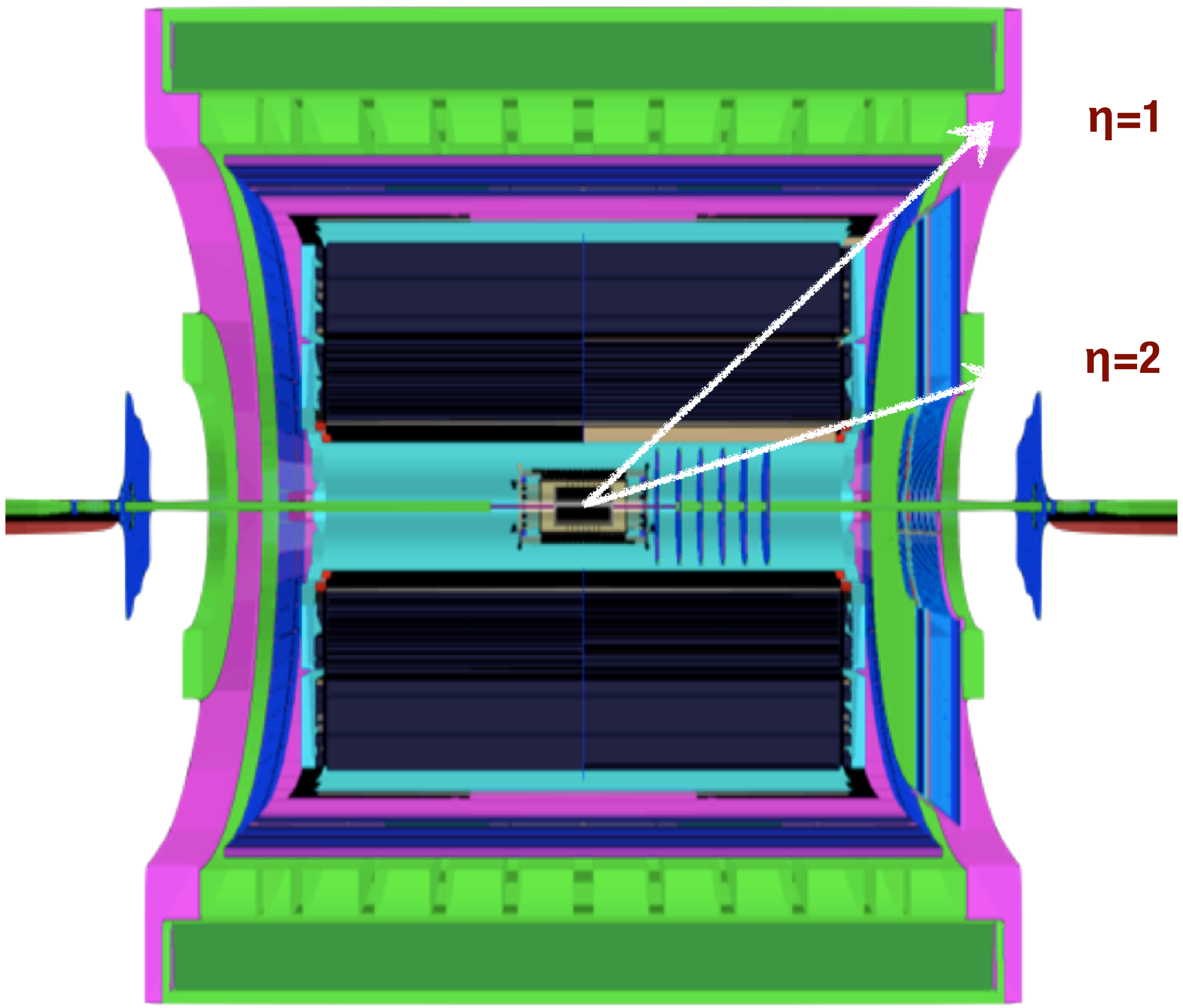


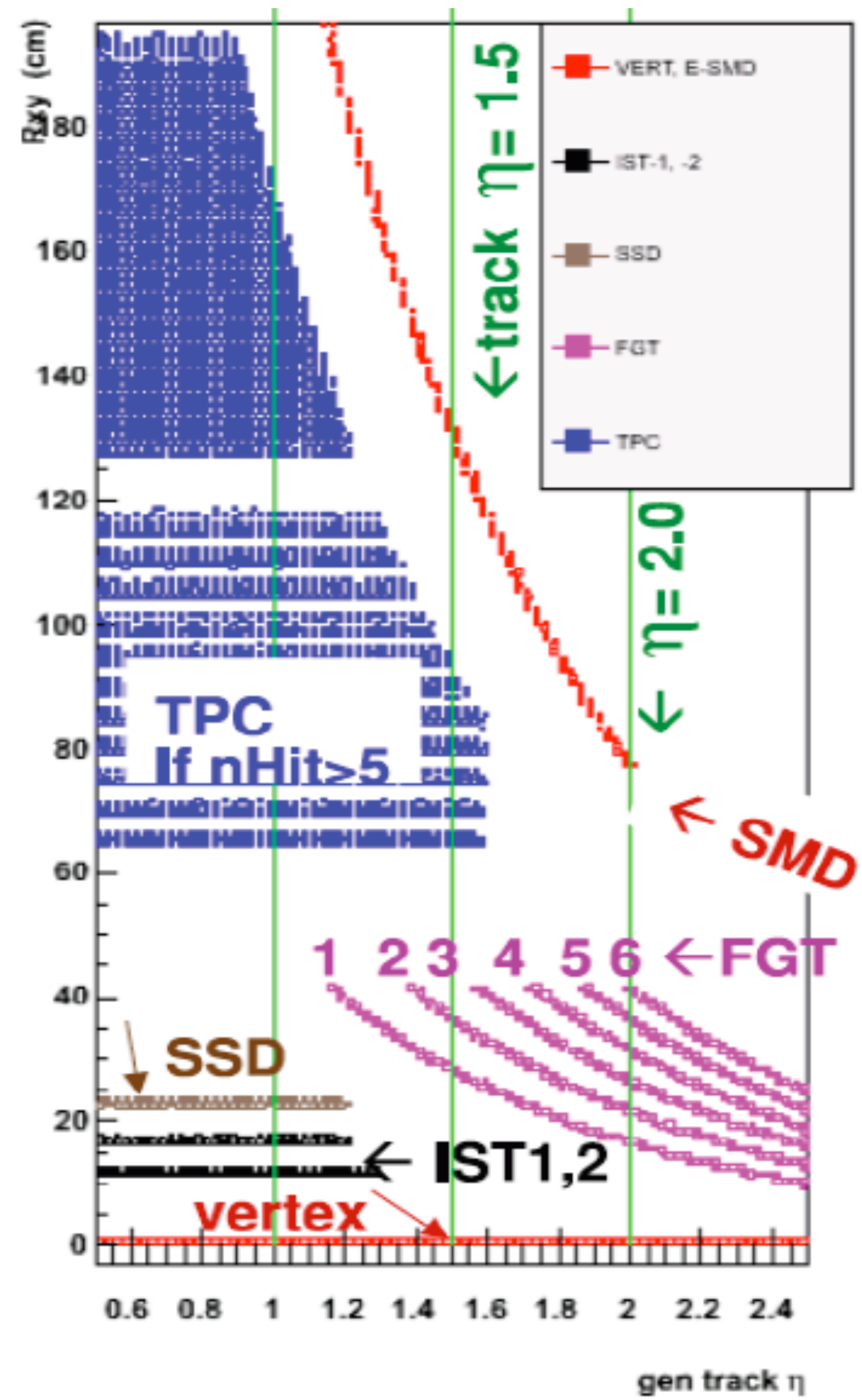




- Extend e+/e- track reconstruction to η = 2
  - This region has enhanced sensitivity to the antiquark polarized distributions
- Combined FGT+TPC tracks at forward rapidity will enhance reconstruction efficiency relative TPC only shown here

Forward Rapidity: FGT





STAR Run 13 Projections

PAC Recommendation

For Run 13 the PAC recommends the following (*in order of priority*):

1. Running with polarized proton collisions at 500 GeV to provide an integrated luminosity of 750 pb^{-1} at an average polarization of 55%.
2. Depending on the amount of running time remaining after priority #1
    a. If less than 3 weeks remain, a week of 200 GeV Au+Au collisions.
    b. If at least 3 weeks of running time remain, 3 weeks of 15 GeV Au+Au collisions.
3. 8 days of 62 GeV p+p collisions.
4. At the discretion of the ALD, 4 days of low-luminosity running to accomplish the pp2pp goals.

FGT fully installed for Run 13