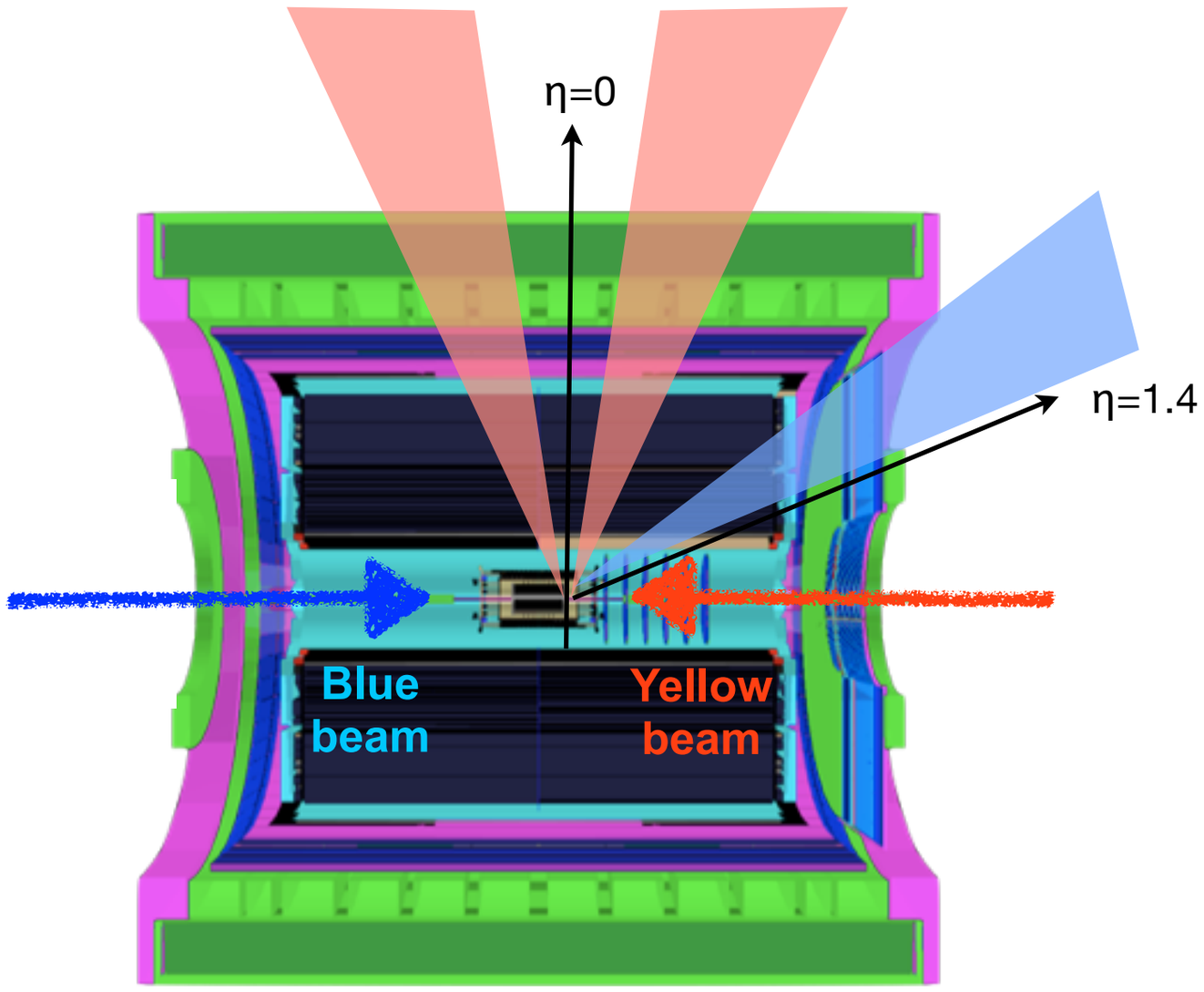
Recent STAR results on W (and Z) bosons production in polarized p+p collisions at √s=510 GeV

Jan Balewski (MIT)

for the STAR Collaboration

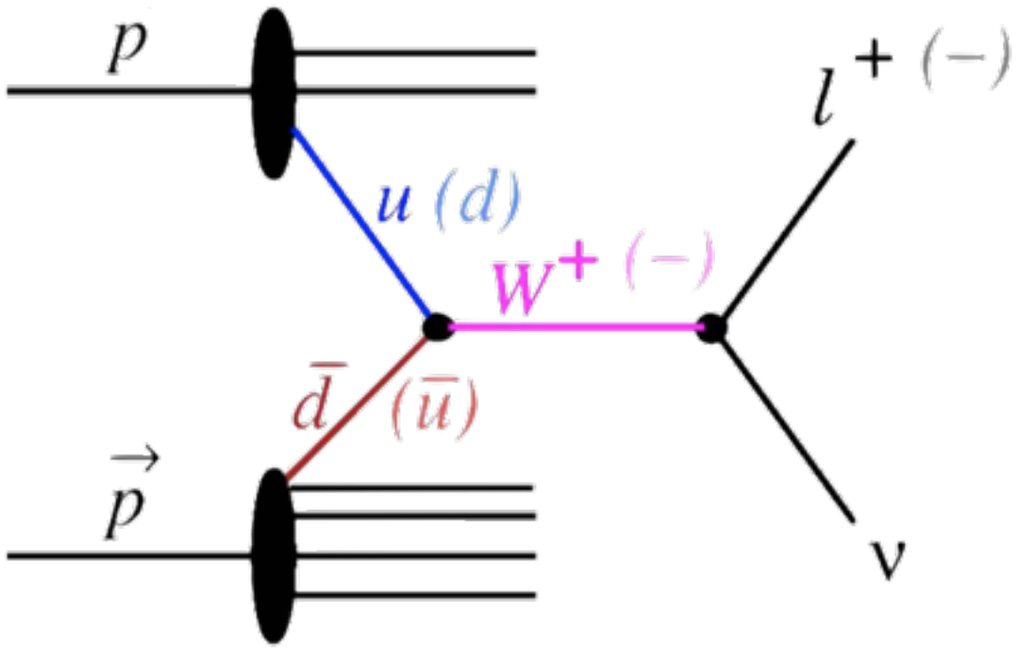


APS DNP Meeting 20102

October 25, 2012

Newport Beach, CA

STAR measures Ws via lepton channel



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

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

- Ws couple directly to the quarks and antiquarks of interest
- Detect Ws through e+/e- decay channels

Measure parity-violating single-spin asymmetry:

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

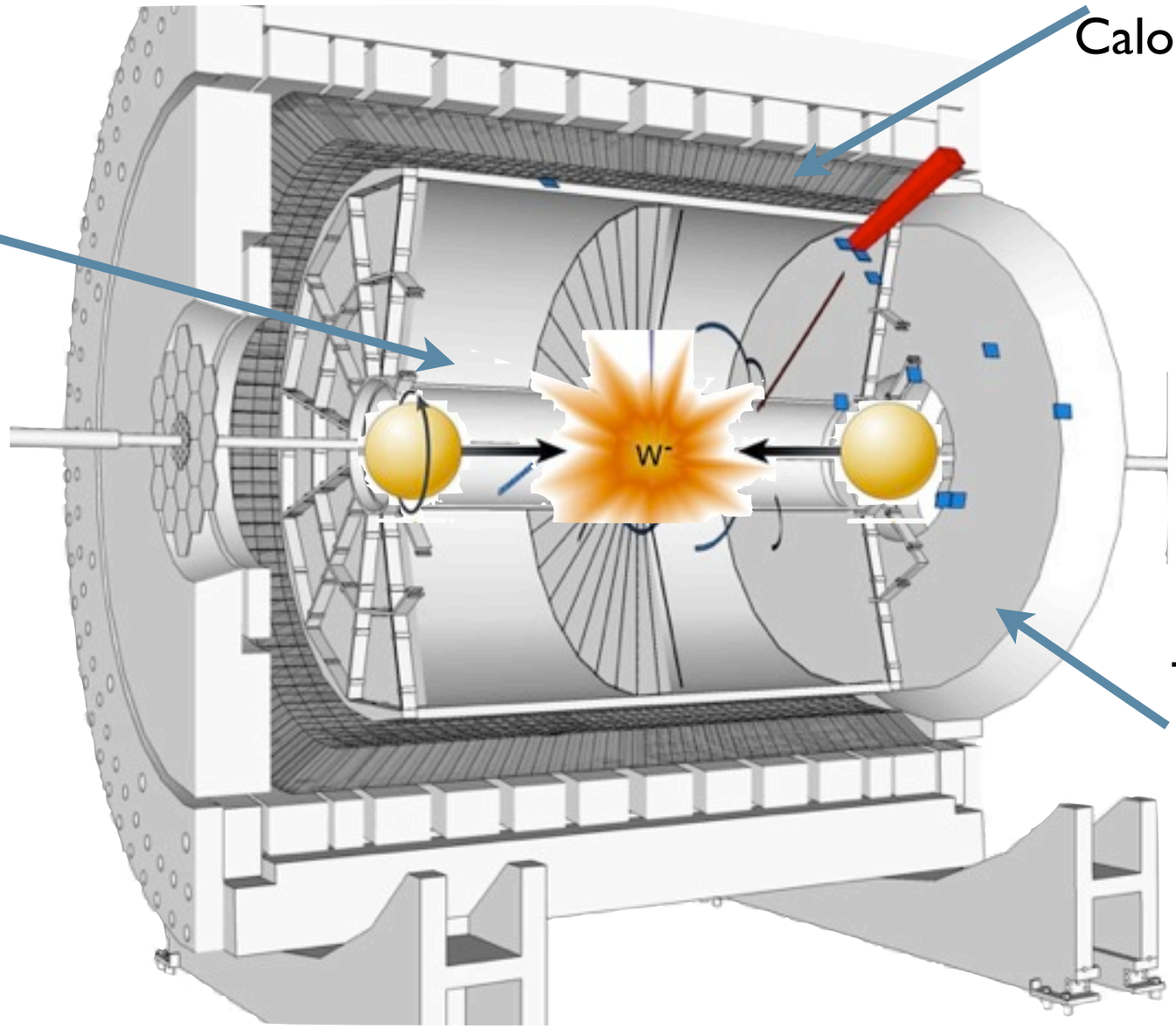
$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

STAR Detector Overview

0.5 T Solenoidal Magnet

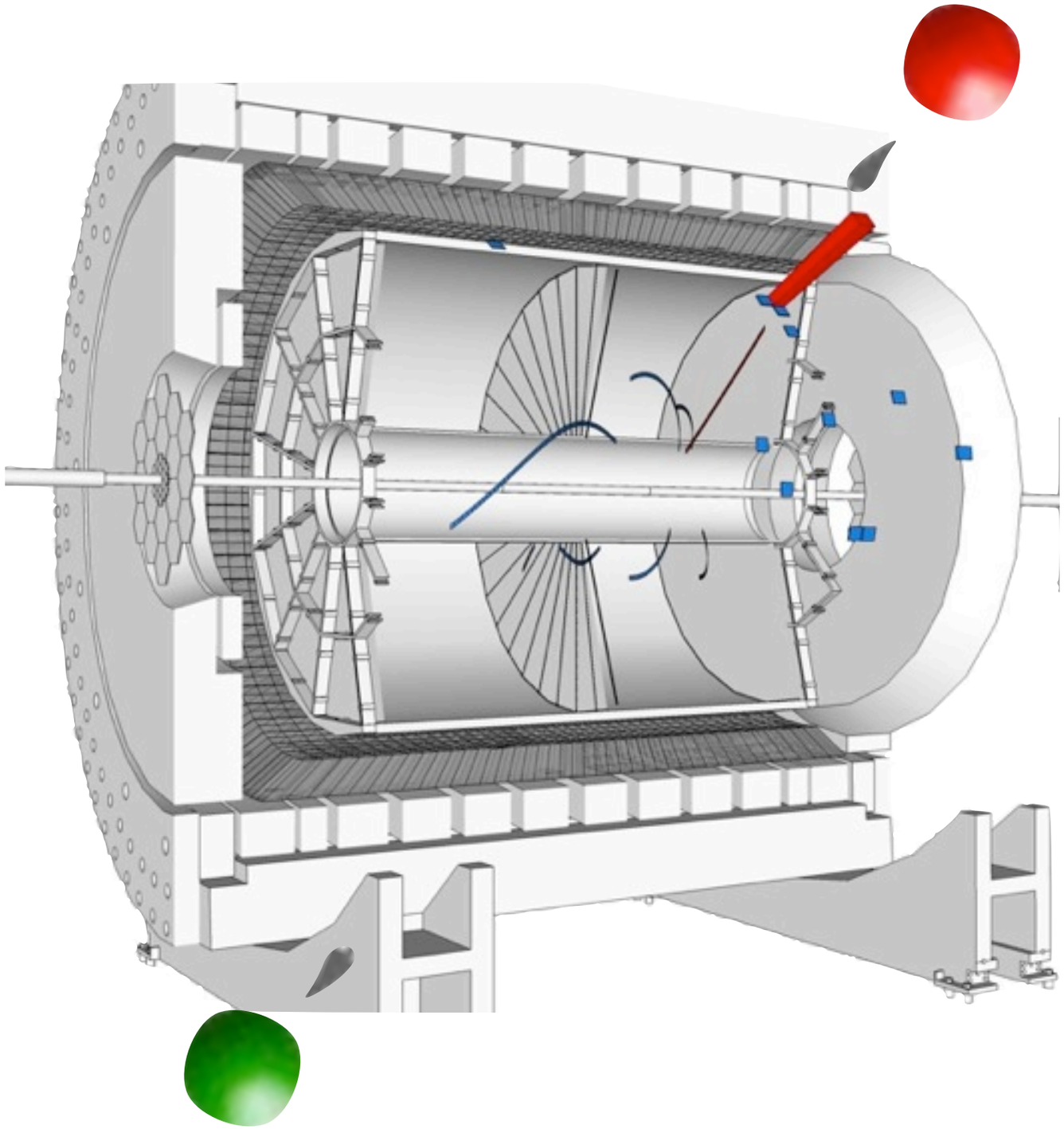
Triggering Barrel EM Calorimeter (BEMC): $|\eta|<1$

Time Projection Chamber (TPC): Charged particle tracking $|\eta|<1.4$



Triggering Endcap EM Calorimeter (EEMC): $1.1<\eta<2$

STAR Detector Overview



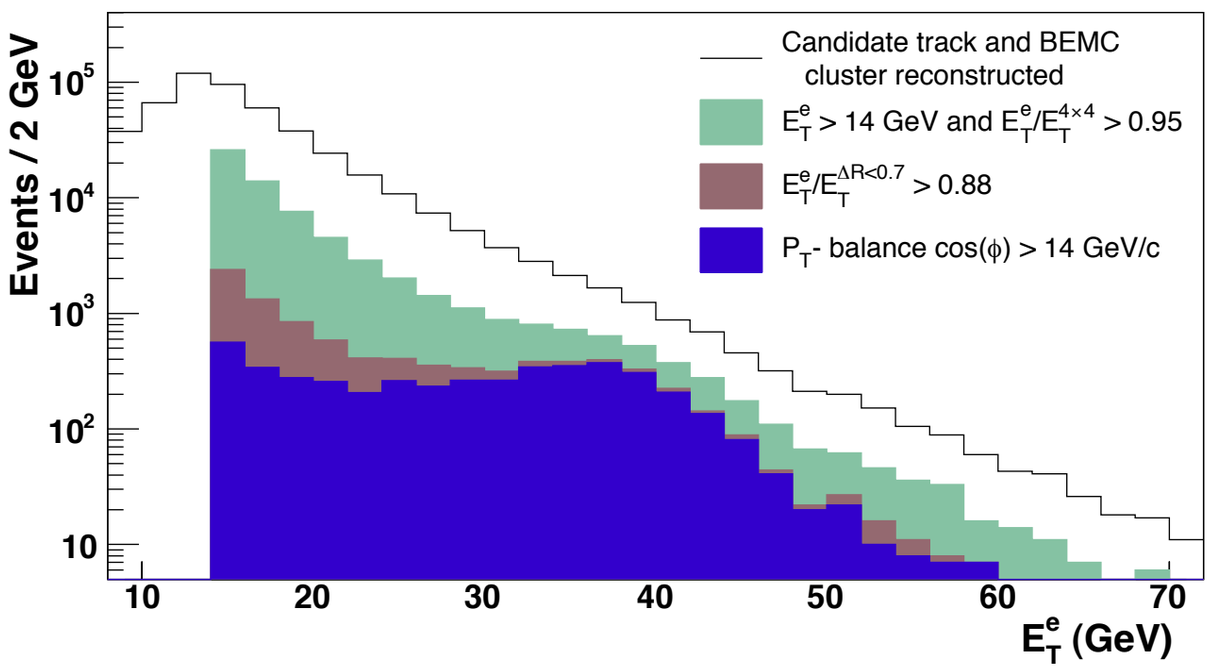
Finding Ws Barrel |η|<1

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

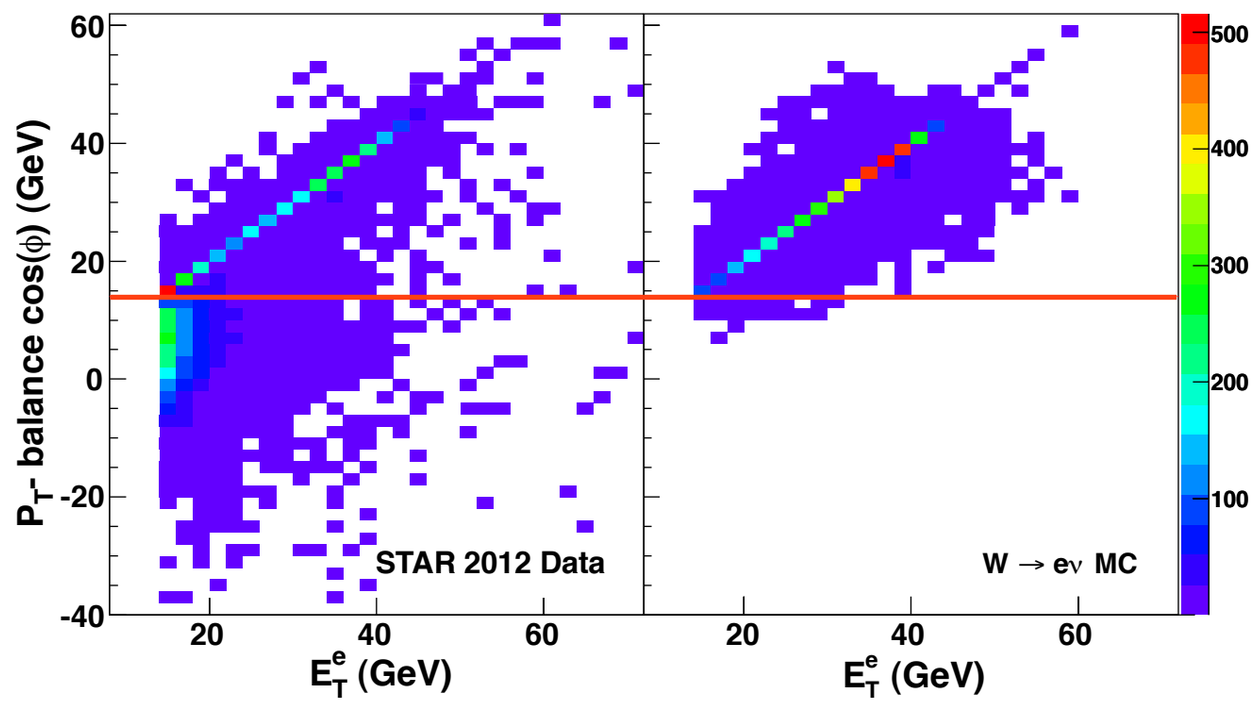
$$\vec{p_T}^{\,bal} = \vec{p_T}^{\,e} + \sum_{\Delta R>0.7} \vec{p_T}^{\,jets}$$

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

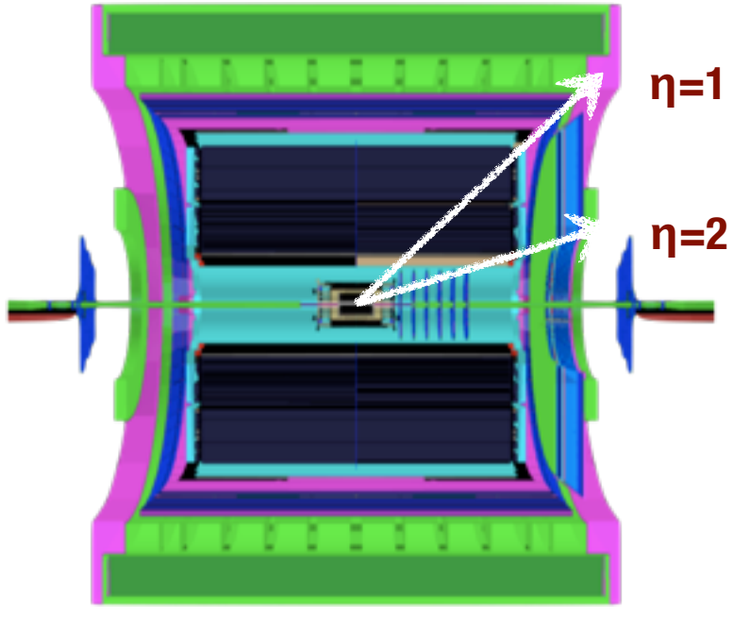
Transverse Plane View



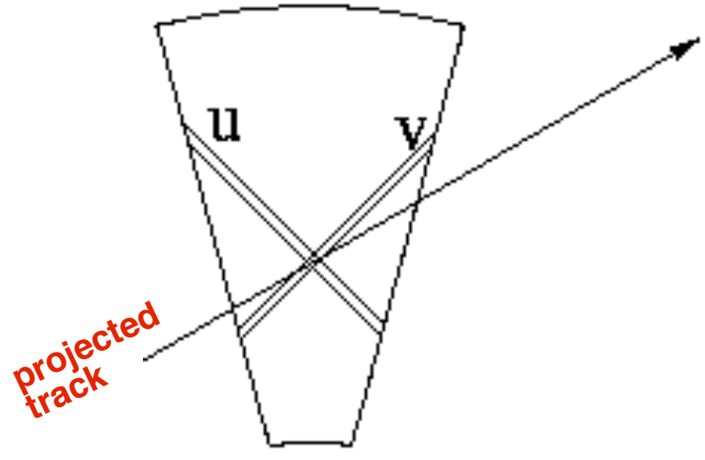
STAR 2012 data M-C Ws



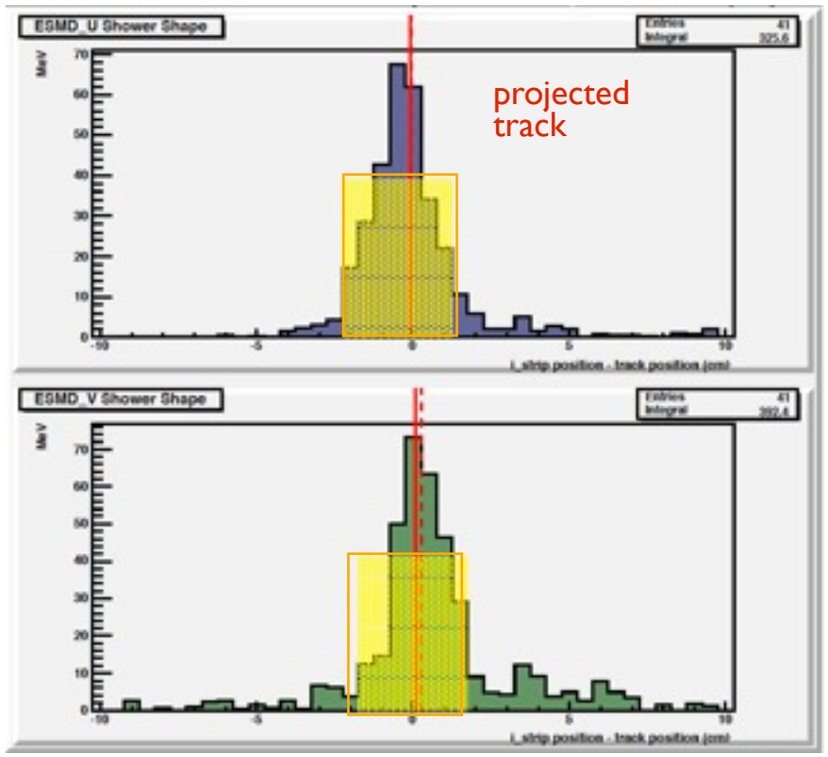
W algo extension for $|\eta|$>1



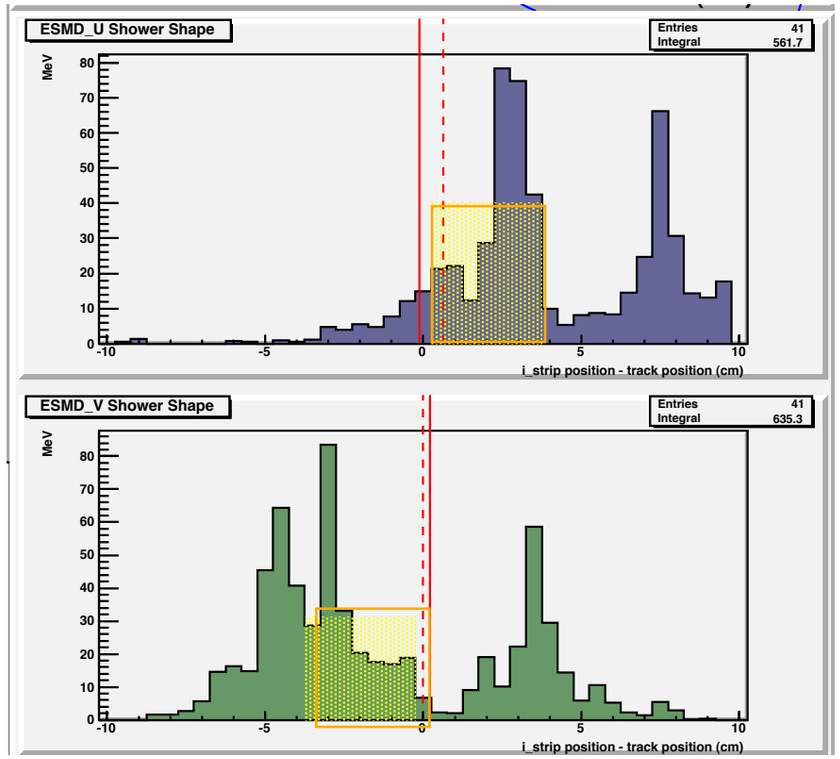
Endcap SMD



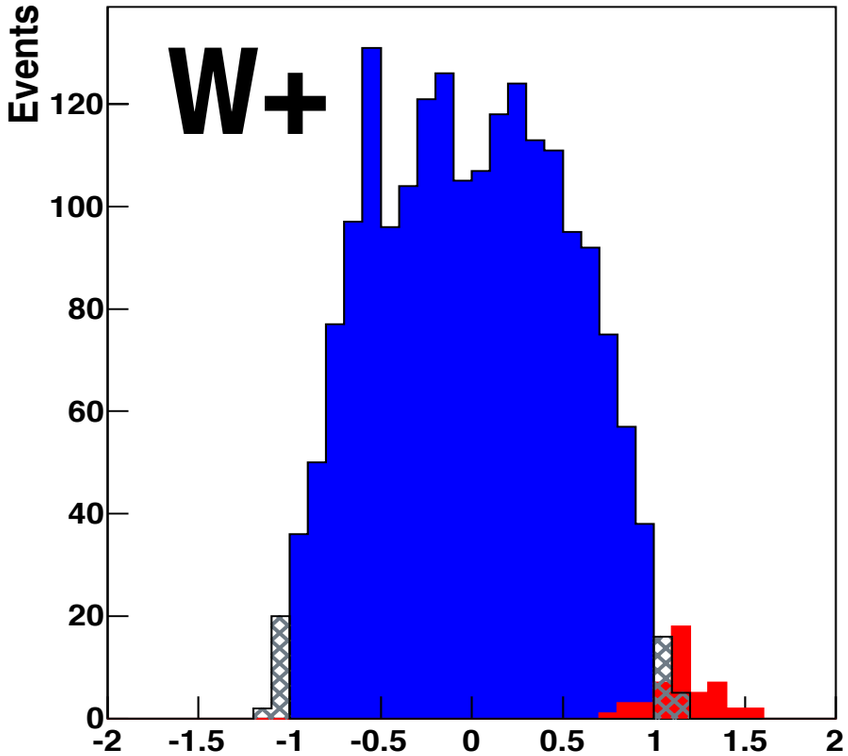
W candidate 2012 event

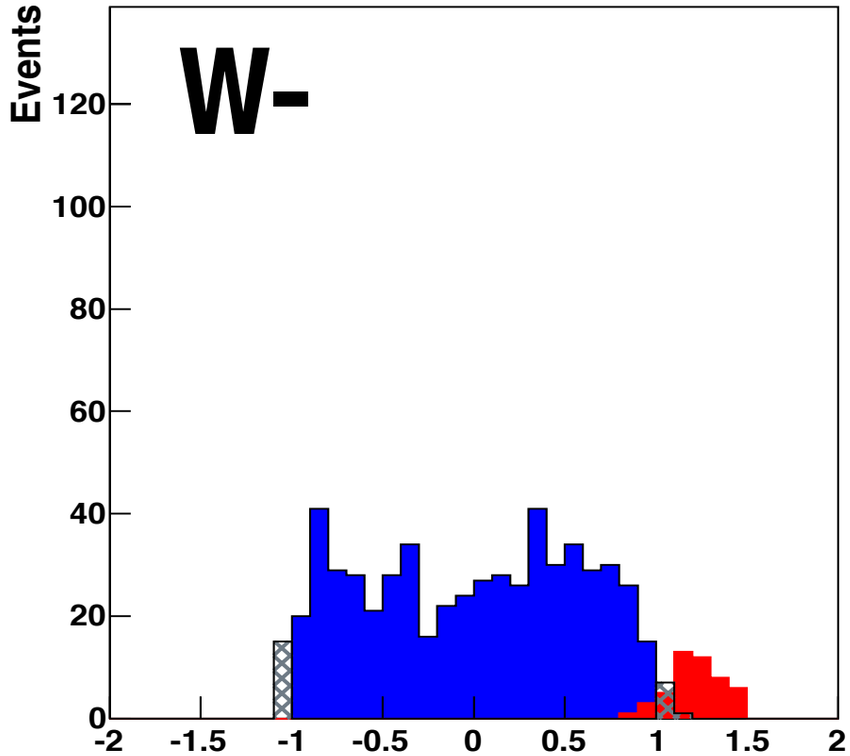


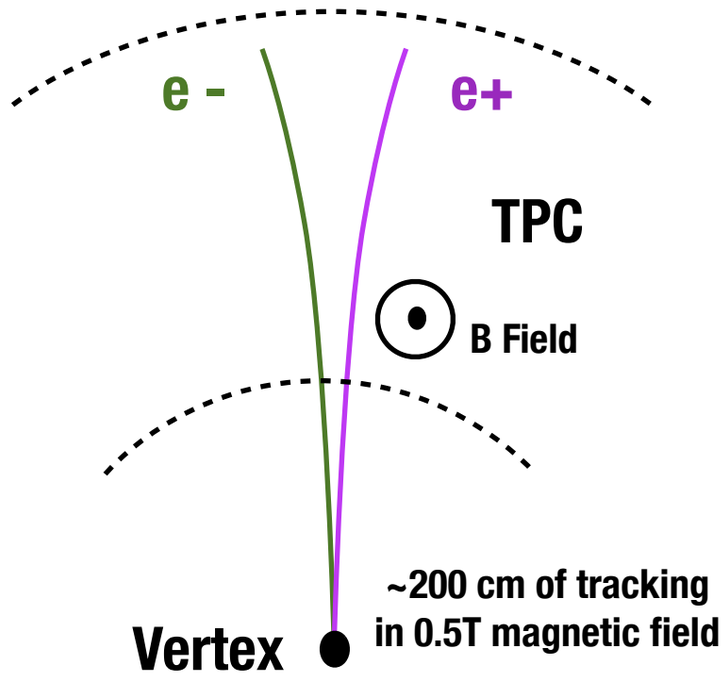
Likely **QCD** 2012 event (detected $\pi^0 \rightarrow \gamma\,\gamma \rightarrow e\,e$)

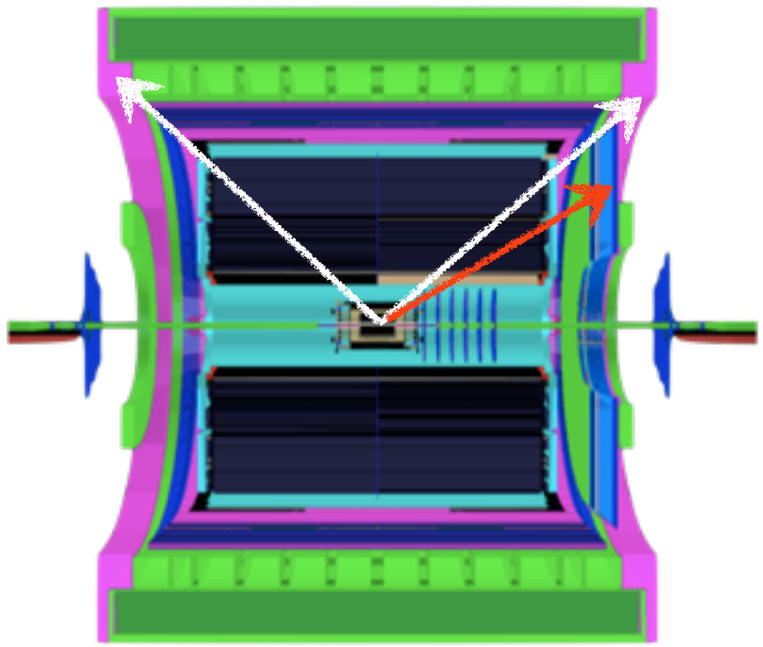


W yields & charge separation

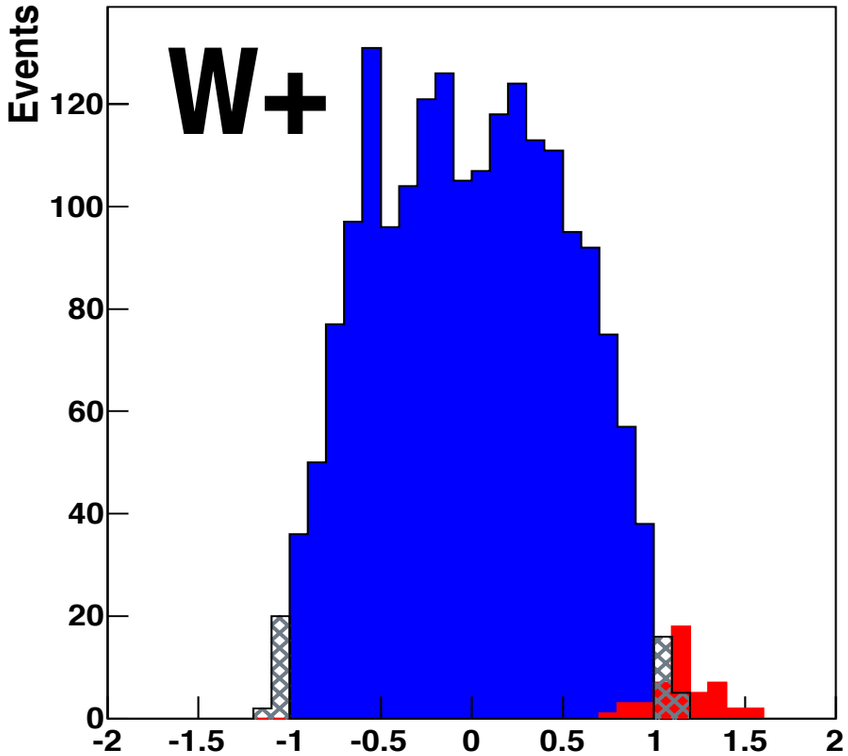


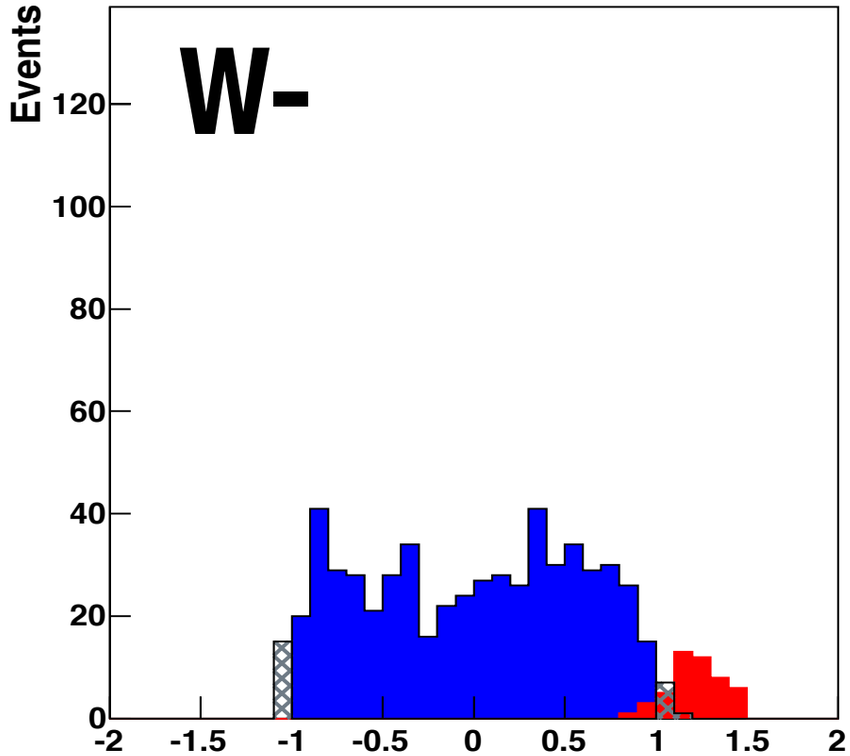


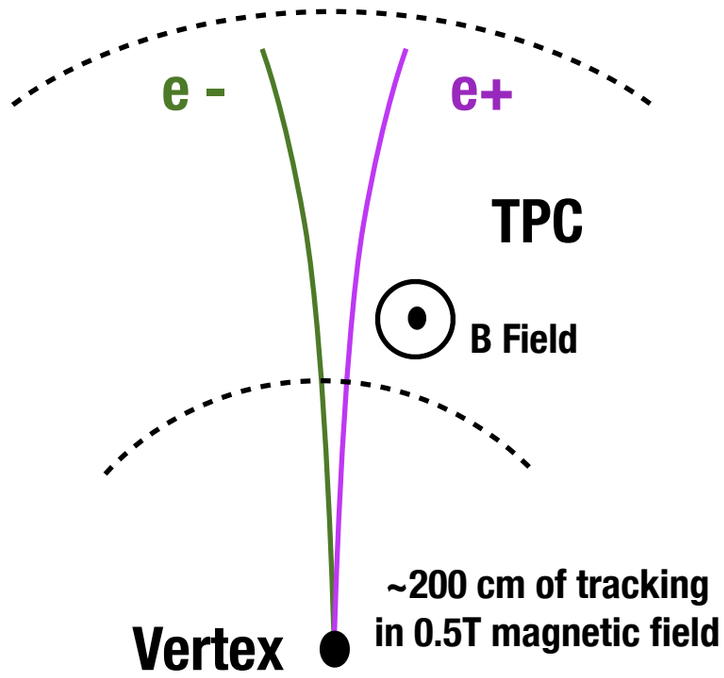




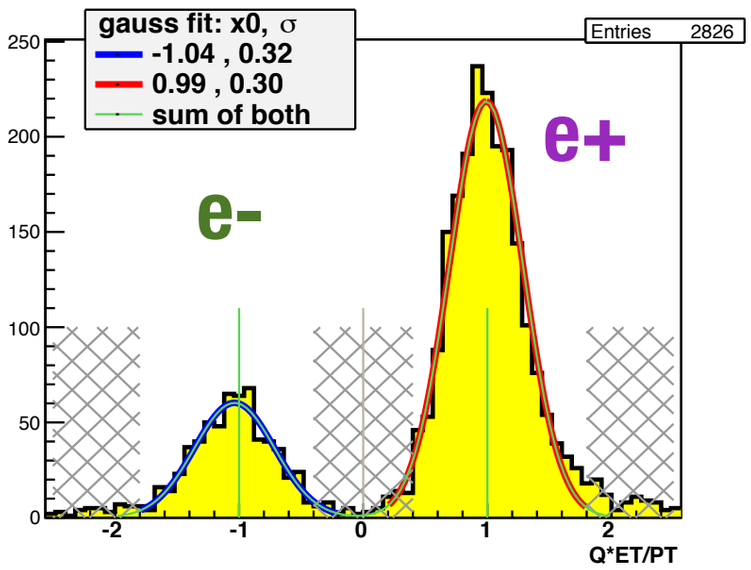
W yields & charge separation

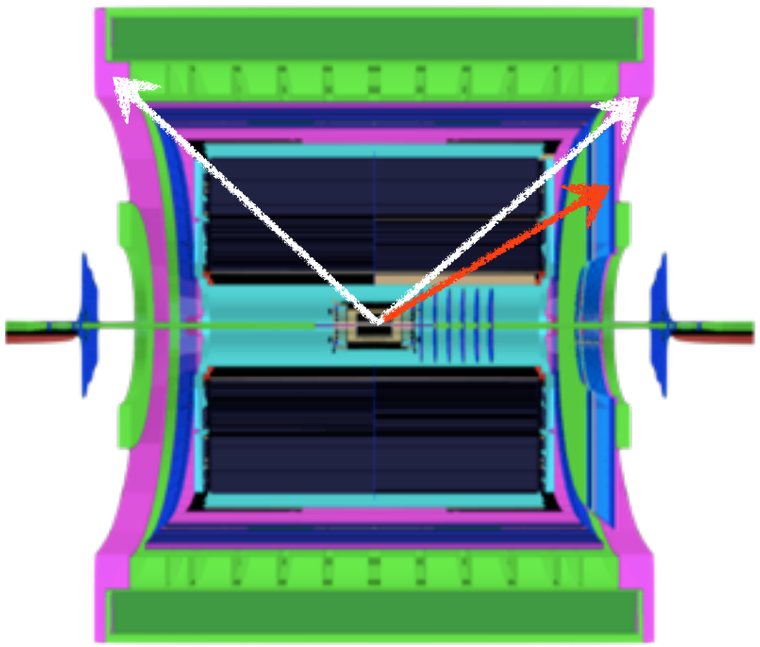




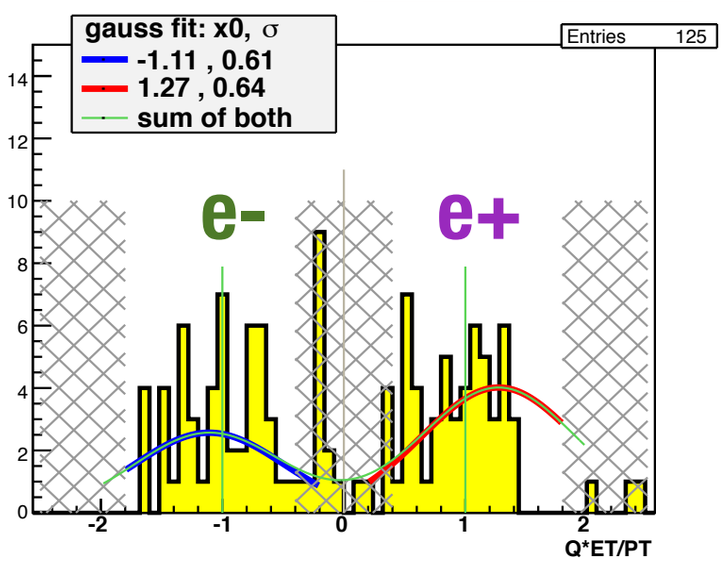


lepton **|η|<1**





lepton **|η|>1**



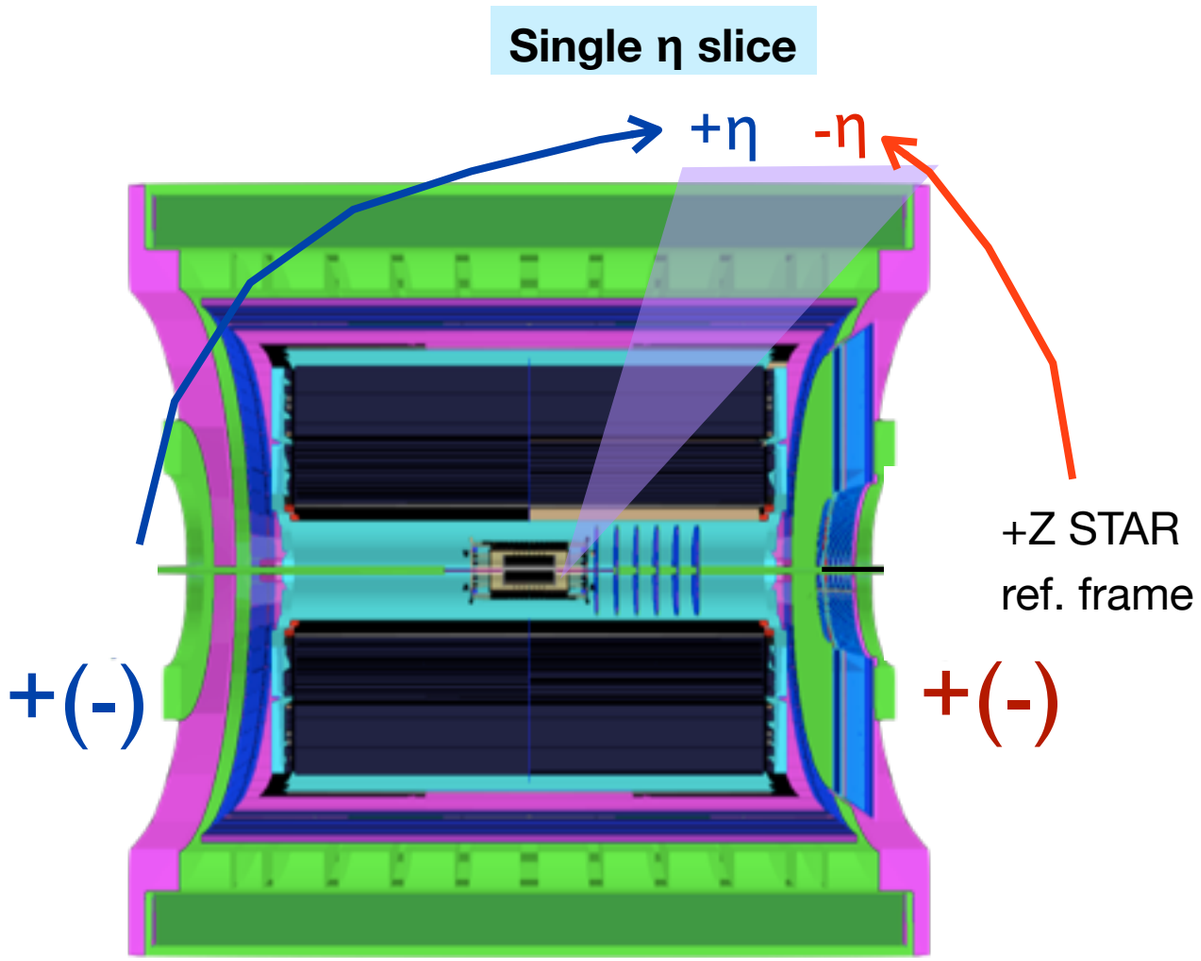
Single Asymmetric η Slice

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

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

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

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



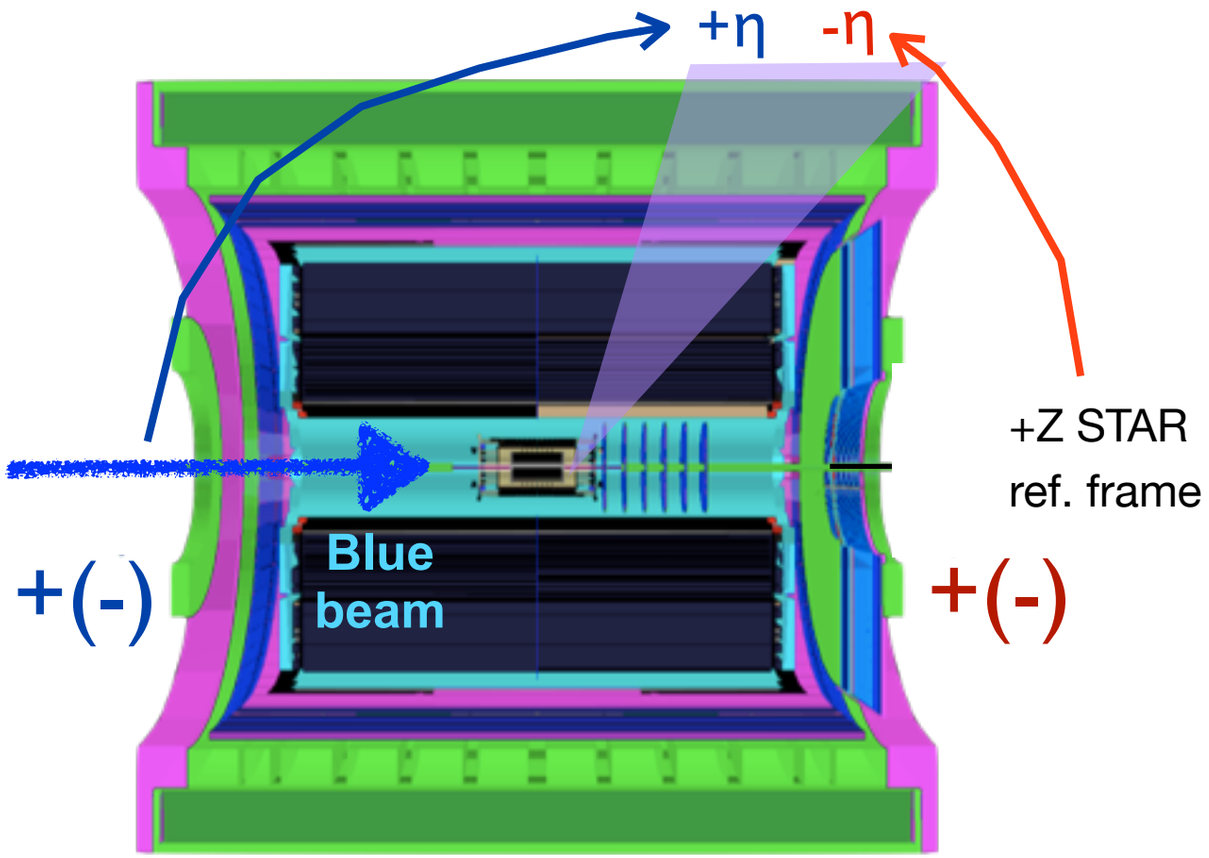
A_L for both beams measured from 4 spin dependent yields

Single Asymmetric η Slice

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

Blue beam polarized → $A_L(+\eta)$

Single η slice



A_L for both beams measured from 4 spin dependent yields

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

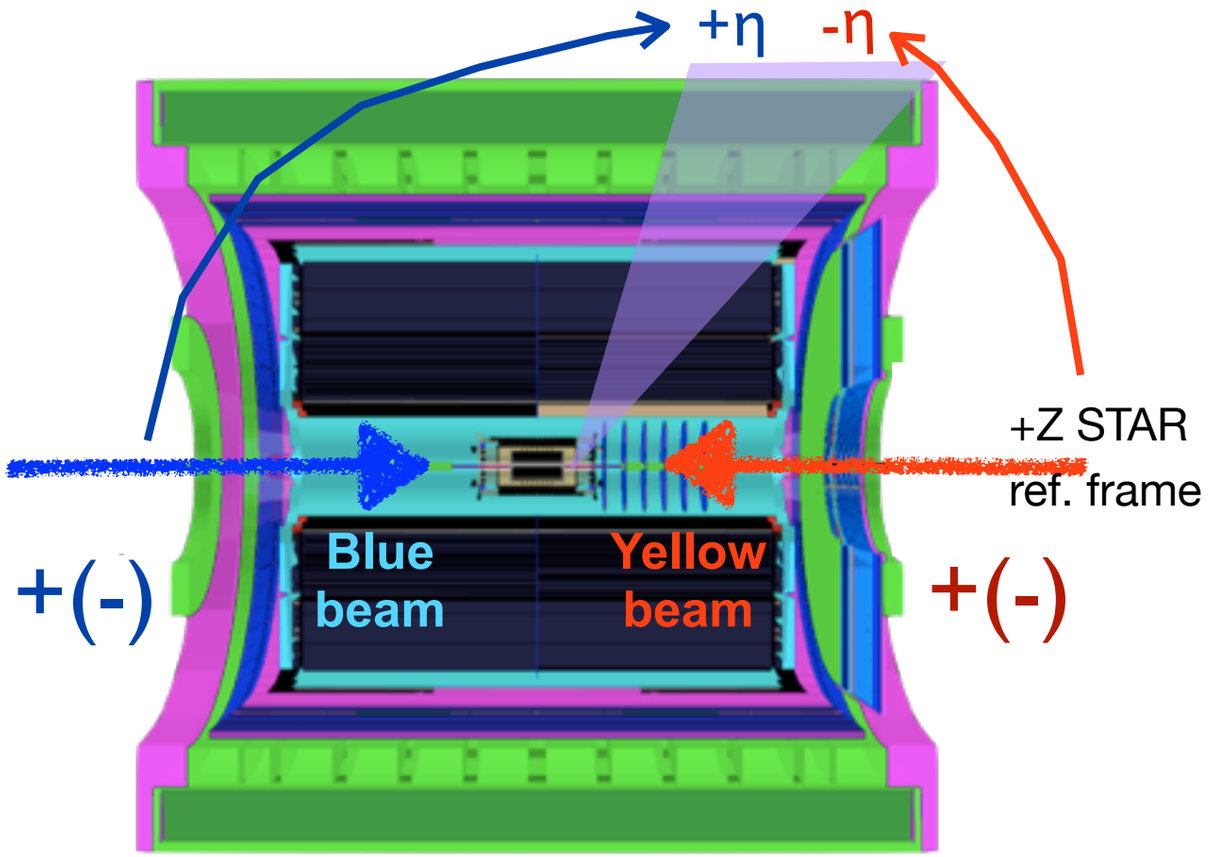
Single Asymmetric η Slice

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

Blue beam polarized → $A_L(+\eta)$

Yellow beam polarized → $A_L(-\eta)$

Single η slice

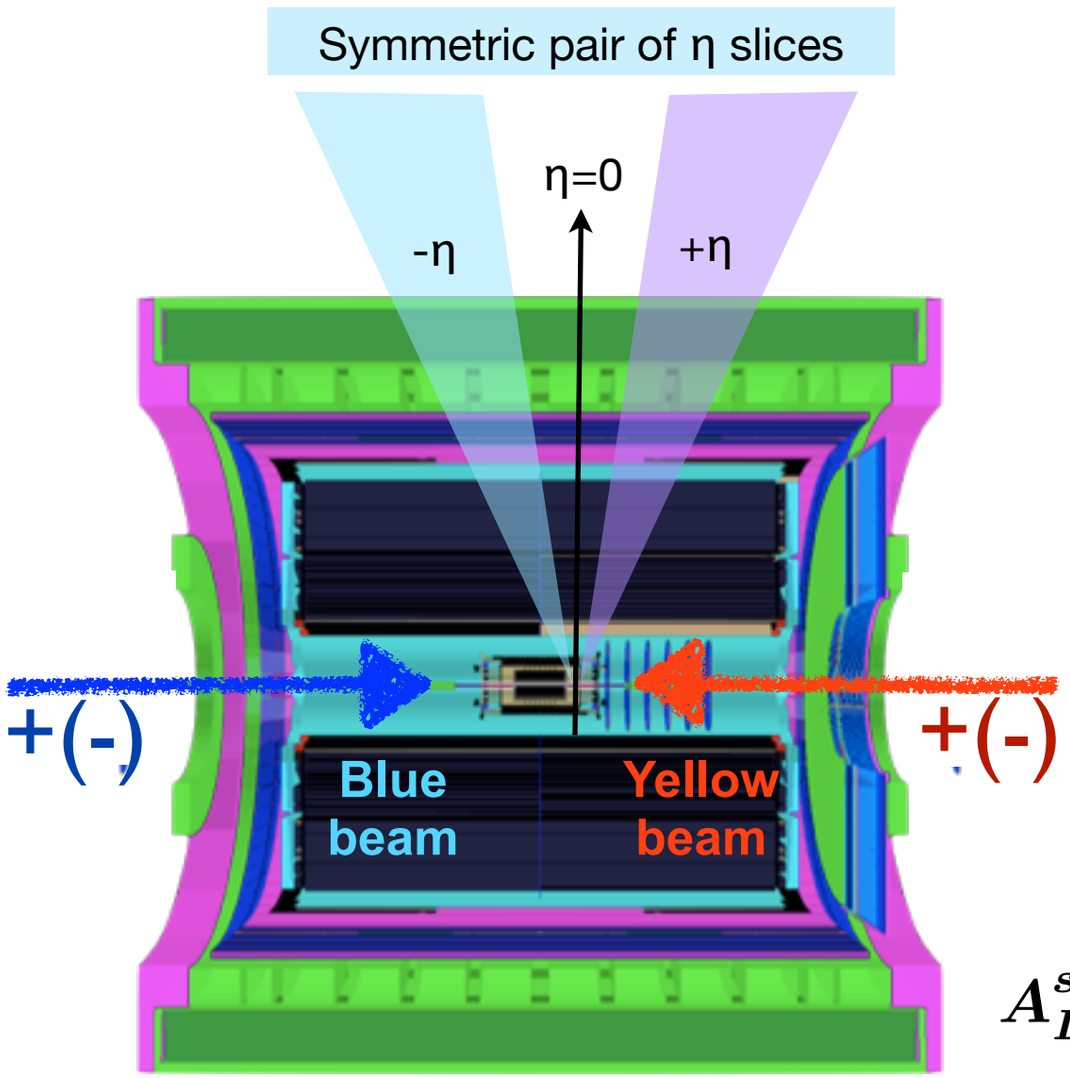


A_L for both beams measured from 4 spin dependent yields

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

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

Symmetric Pair of η Slices



8 yields from a symmetric "pair of detectors"

$$
\begin{aligned}
N^{++}_{\eta^{STAR}}/\mathcal{L}^{++} &= \mathcal{C}_{\eta^{STAR}}\,[\,1 + A_L(\eta)P_1^L + A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#1\\
N^{+-}_{\eta^{STAR}}/\mathcal{L}^{+-} &= \mathcal{C}_{\eta^{STAR}}\,[\,1 + A_L(\eta)P_1^L - A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#2\\
N^{-+}_{\eta^{STAR}}/\mathcal{L}^{-+} &= \mathcal{C}_{\eta^{STAR}}\,[\,1 - A_L(\eta)P_1^L + A_L(-\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#3\\
N^{--}_{\eta^{STAR}}/\mathcal{L}^{--} &= \mathcal{C}_{\eta^{STAR}}\,[\,1 - A_L(\eta)P_1^L - A_L(-\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#4\\
N^{++}_{-\eta^{STAR}}/\mathcal{L}^{++} &= \mathcal{C}_{-\eta^{STAR}}\,[\,1 + A_L(-\eta)P_1^L + A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#5\\
N^{+-}_{-\eta^{STAR}}/\mathcal{L}^{+-} &= \mathcal{C}_{-\eta^{STAR}}\,[\,1 + A_L(-\eta)P_1^L - A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#6\\
N^{-+}_{-\eta^{STAR}}/\mathcal{L}^{-+} &= \mathcal{C}_{-\eta^{STAR}}\,[\,1 - A_L(-\eta)P_1^L + A_L(\eta)P_2^L - A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#7\\
N^{--}_{-\eta^{STAR}}/\mathcal{L}^{--} &= \mathcal{C}_{-\eta^{STAR}}\,[\,1 - A_L(-\eta)P_1^L - A_L(\eta)P_2^L + A_{LL}(|\eta|)P_1^L P_2^L\,] \quad \#8
\end{aligned}
$$

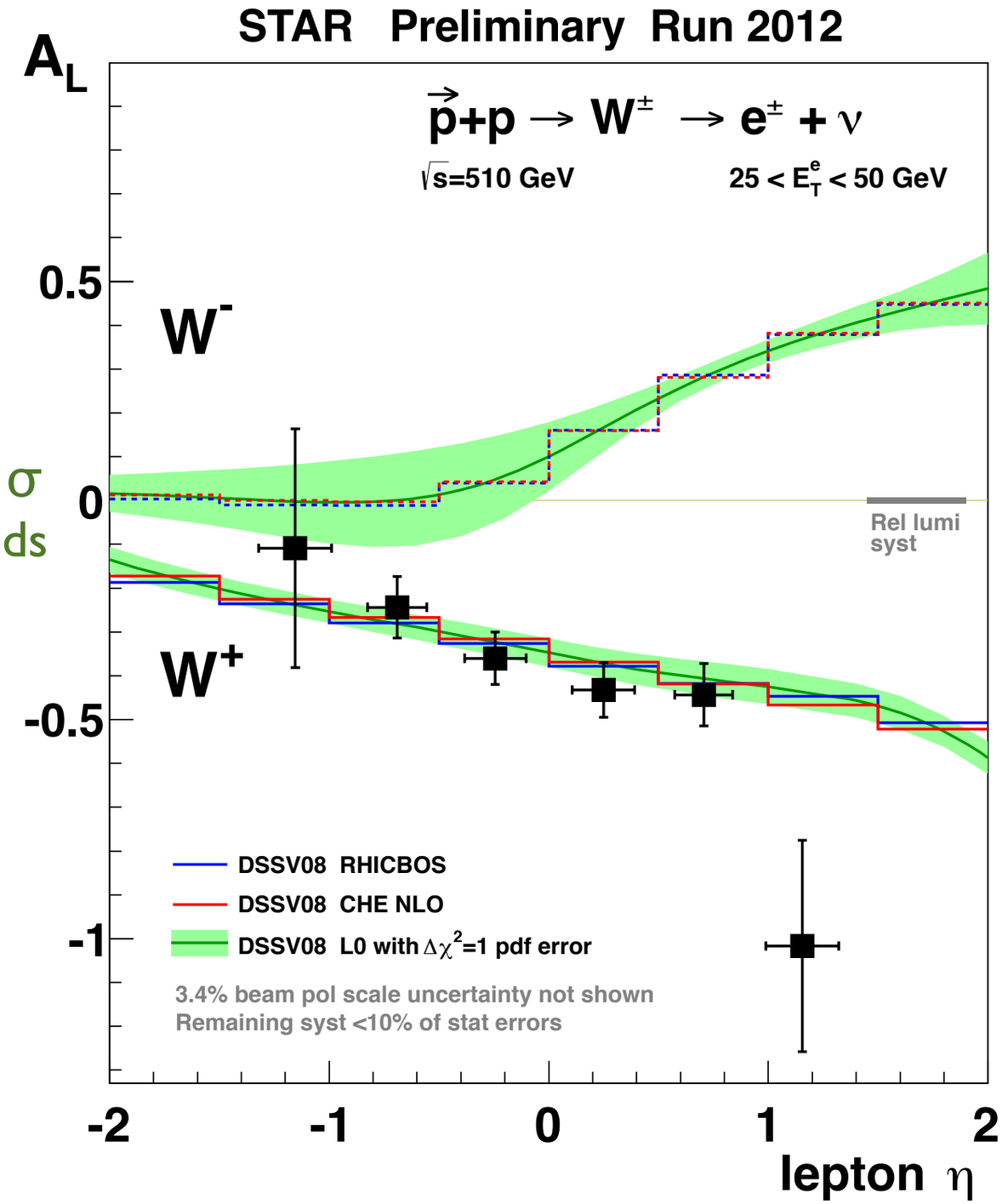
Extract two A_L values from 8 spin dependent yields using 2 polarized beams

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

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

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

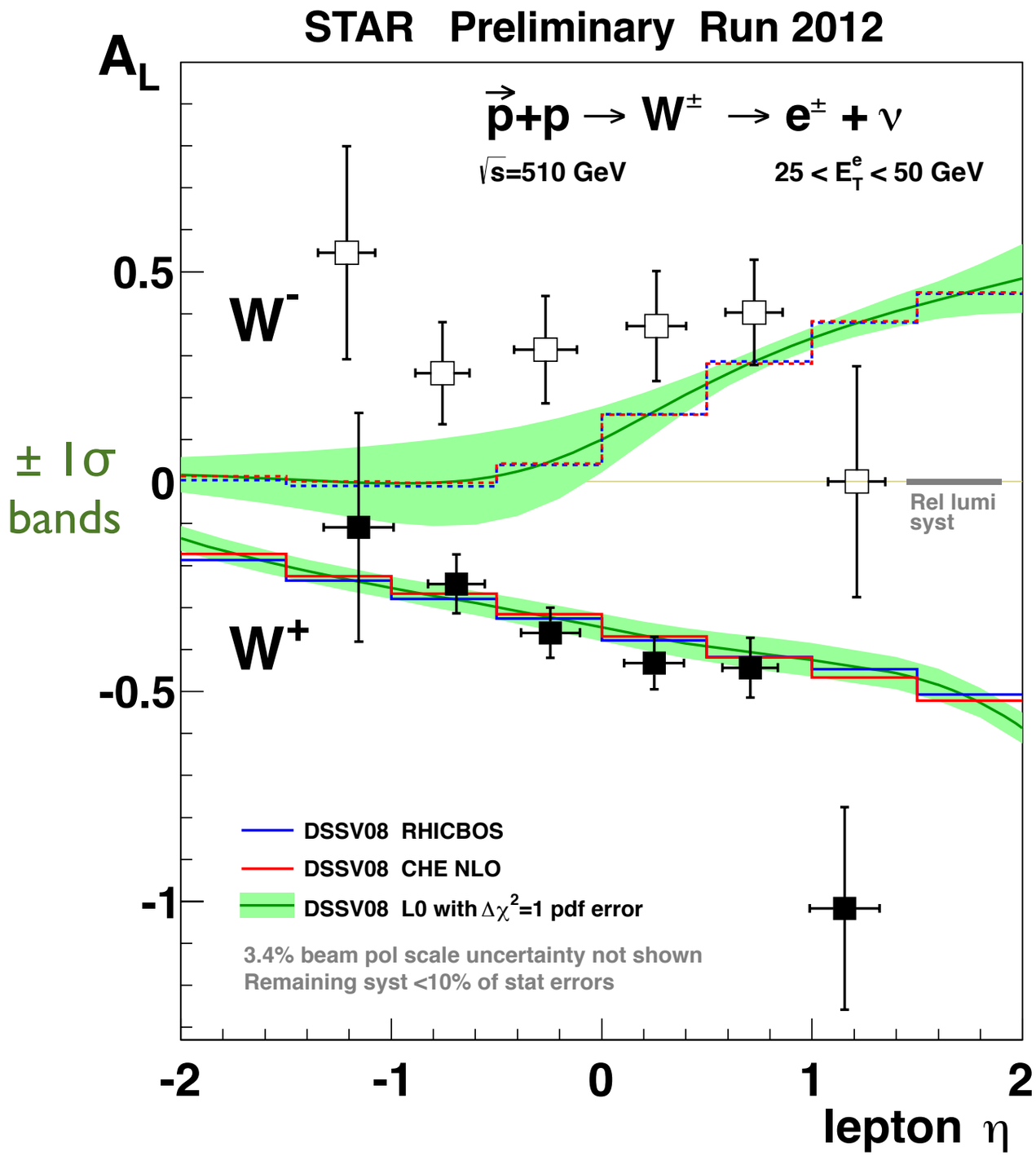
2012 A_L for $W \rightarrow e\,\nu$



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

- The **systematic** uncertainties for A_L are well **under control** for $|\eta_e| < 1.4$

2012 A_L for $W \rightarrow e\,\nu$

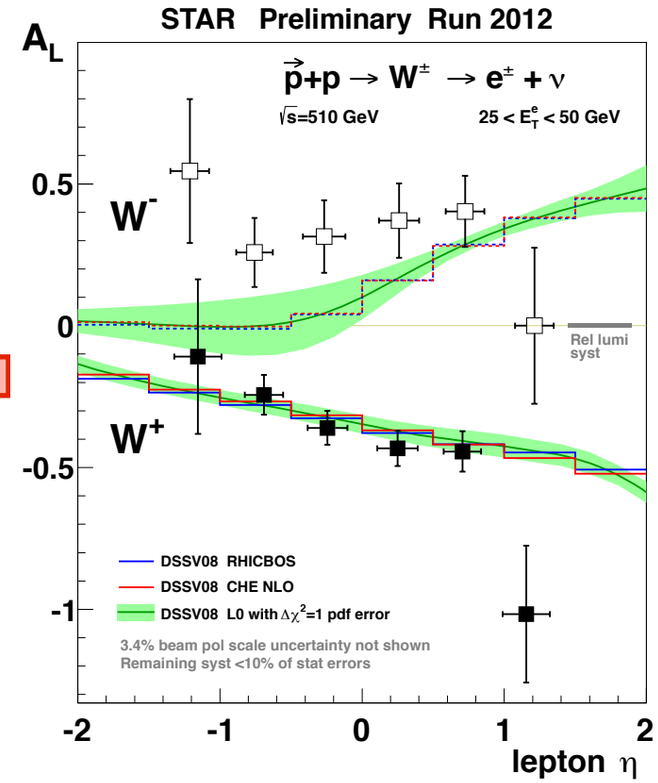


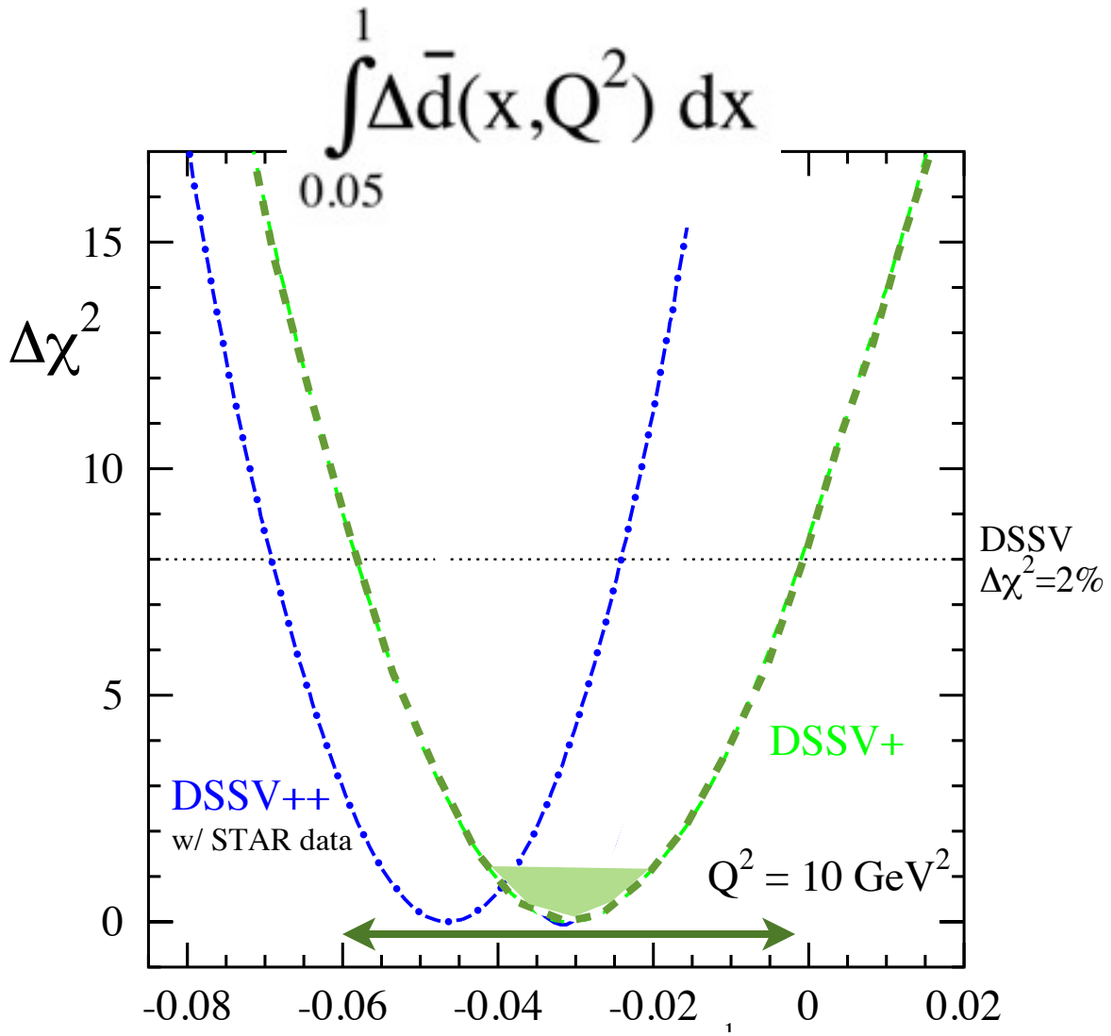
- **A_L(W-)** is systematically larger than the DSSV predictions
- The **enhancement at η_e<0**, in particular, is sensitive to the **Δu polarized antiquark** distribution
- **A_L(W+)** is consistent with theoretical predictions using the DSSV polarized PDFs
- The **systematic** uncertainties for A_L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

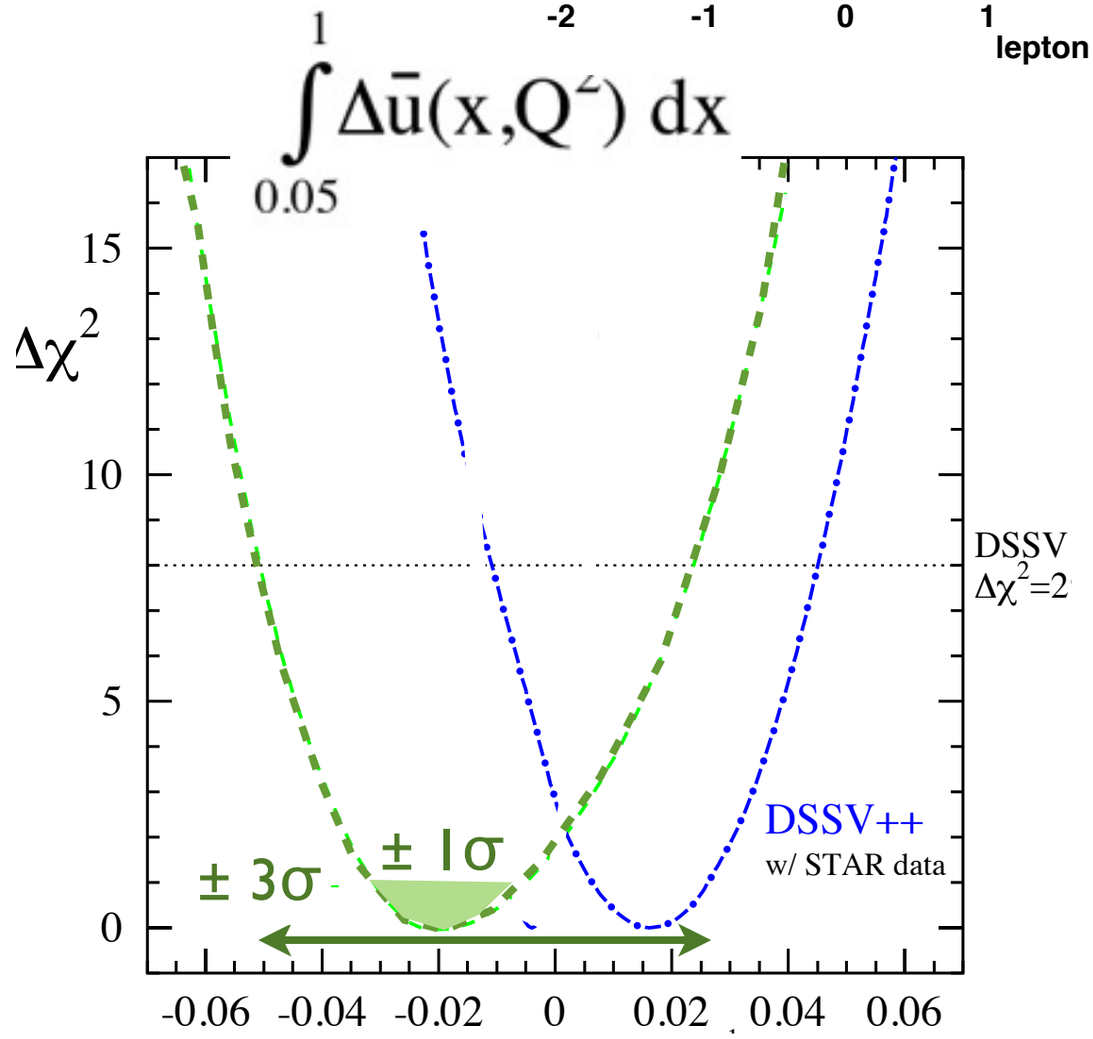
DSSV++ global analysis

DSSV+ as for DG plot publication plus all Compass data (green dashed)

DSSV++ w/ STAR data: this is DSSV+ + the run-09 pi0 and jet data **including the STAR run 12 W data** (blue dashed-dotted



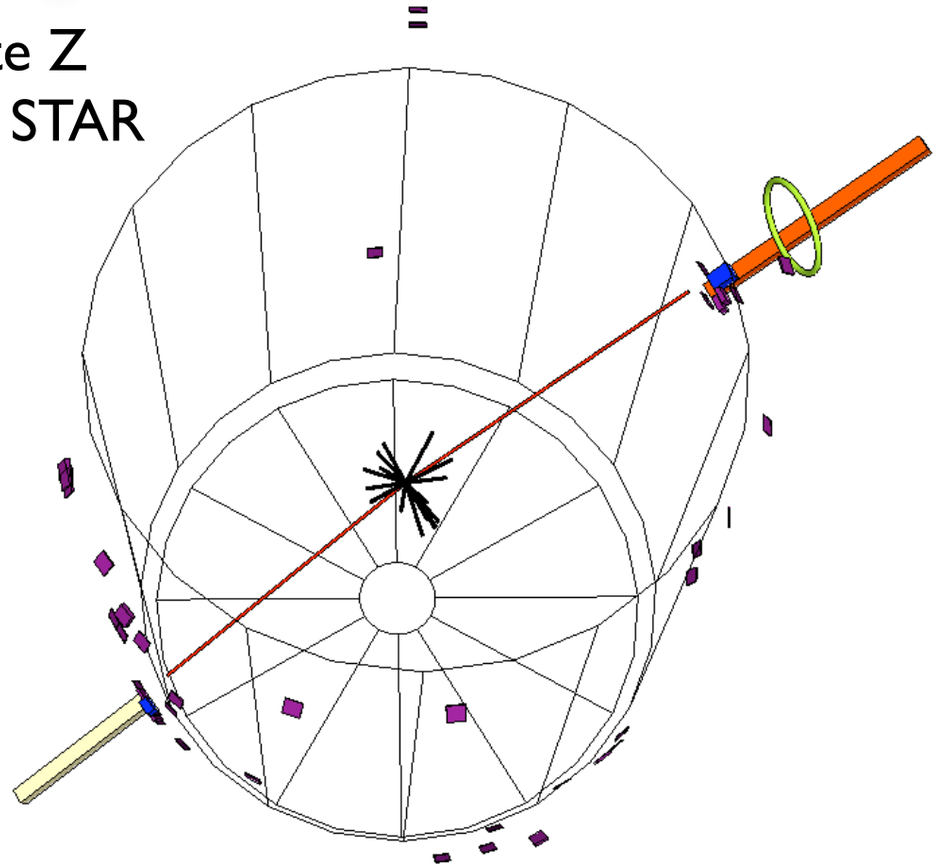




Special thanks to DSSV group !

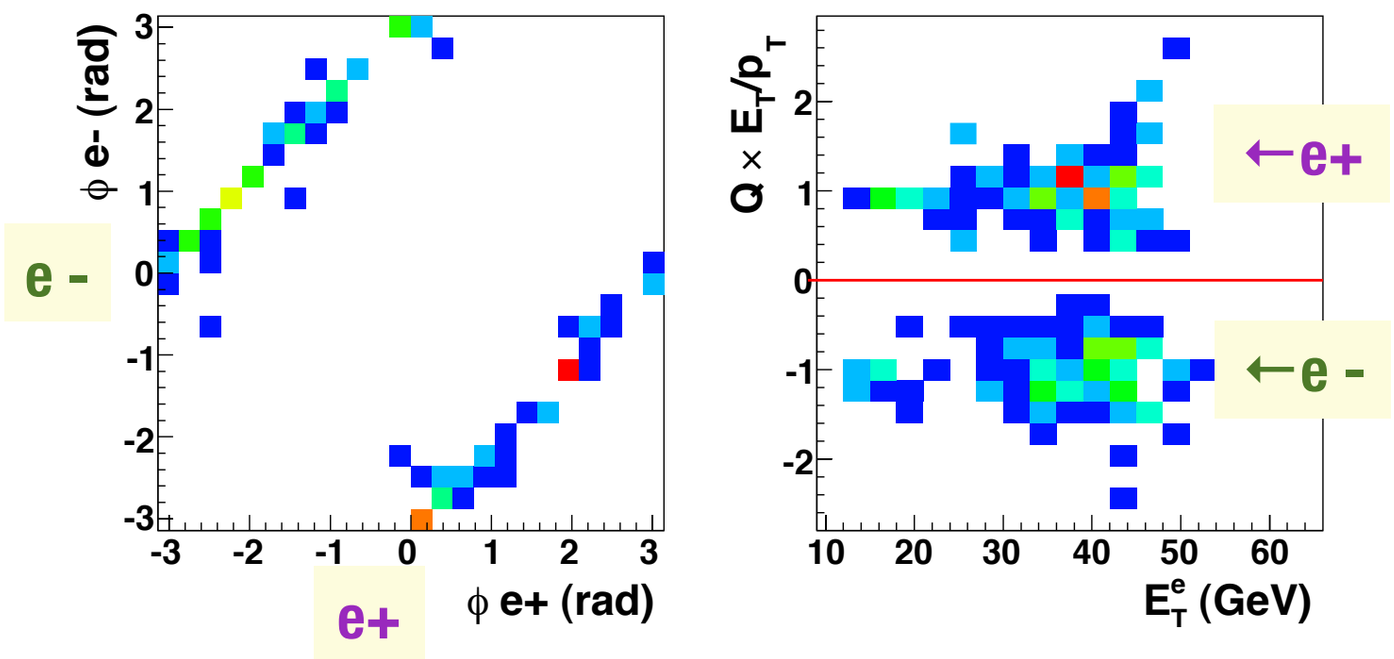
2012 A_L for $Z \rightarrow e^+e^-$

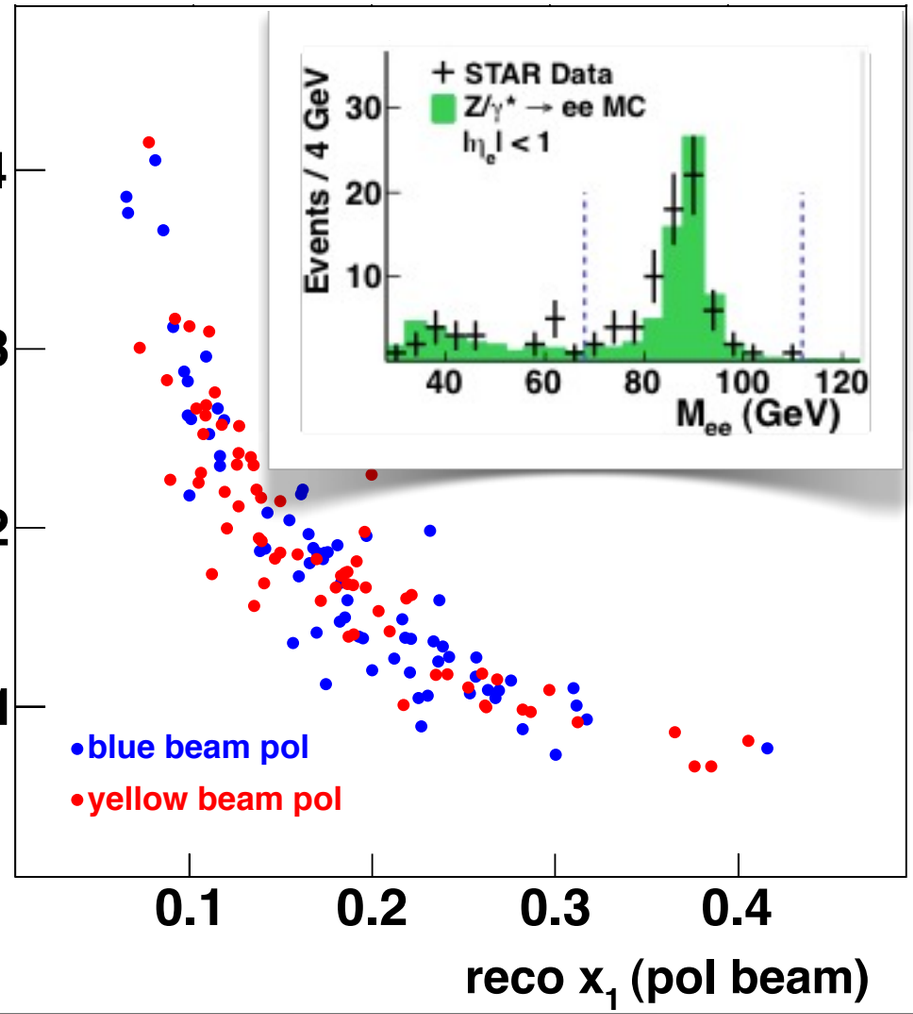
Candidate Z event @ STAR



Reconstruct initial state kinematics at leading order:

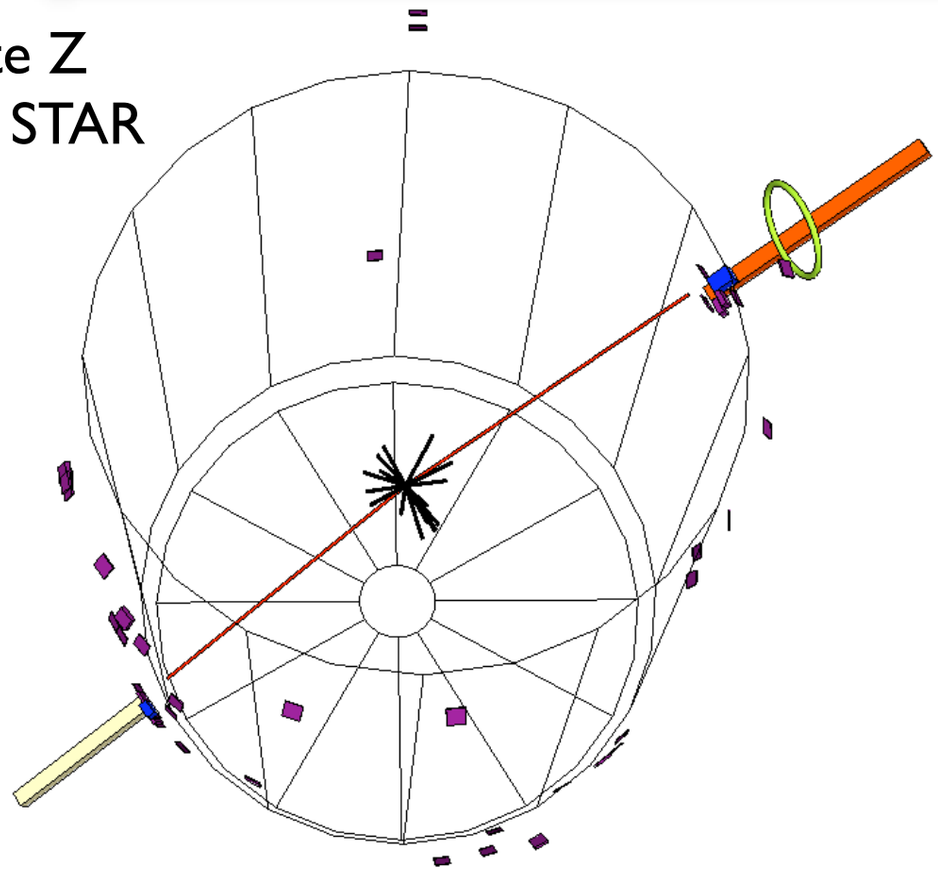
$$x_{1(2)} = \frac{M_{ee}}{\sqrt{s}} e^{\pm y_Z}$$

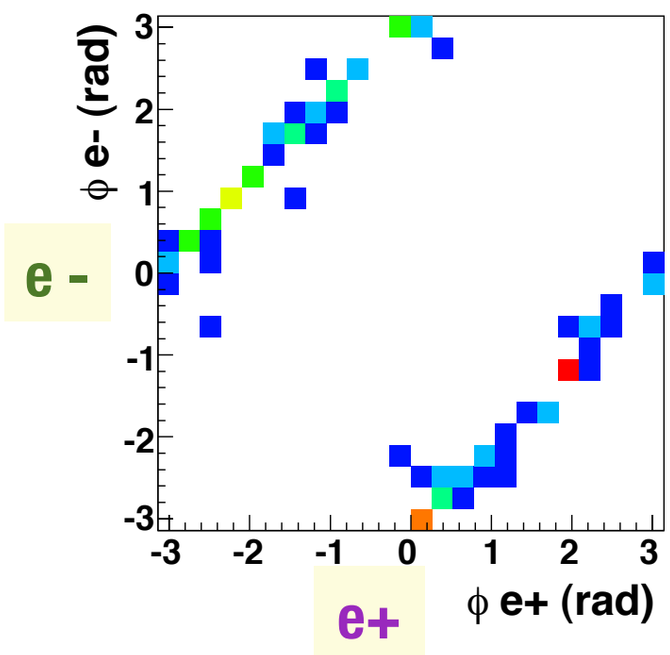


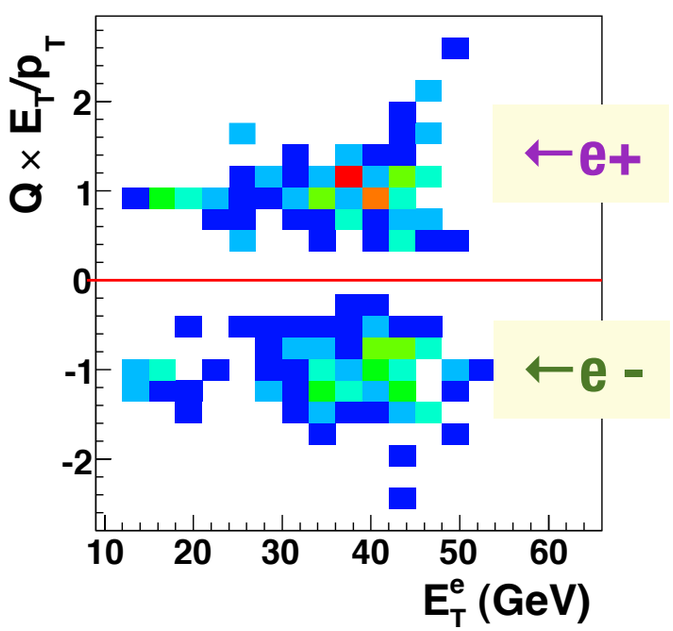


2012 A_L for $Z \rightarrow e^+e^-$

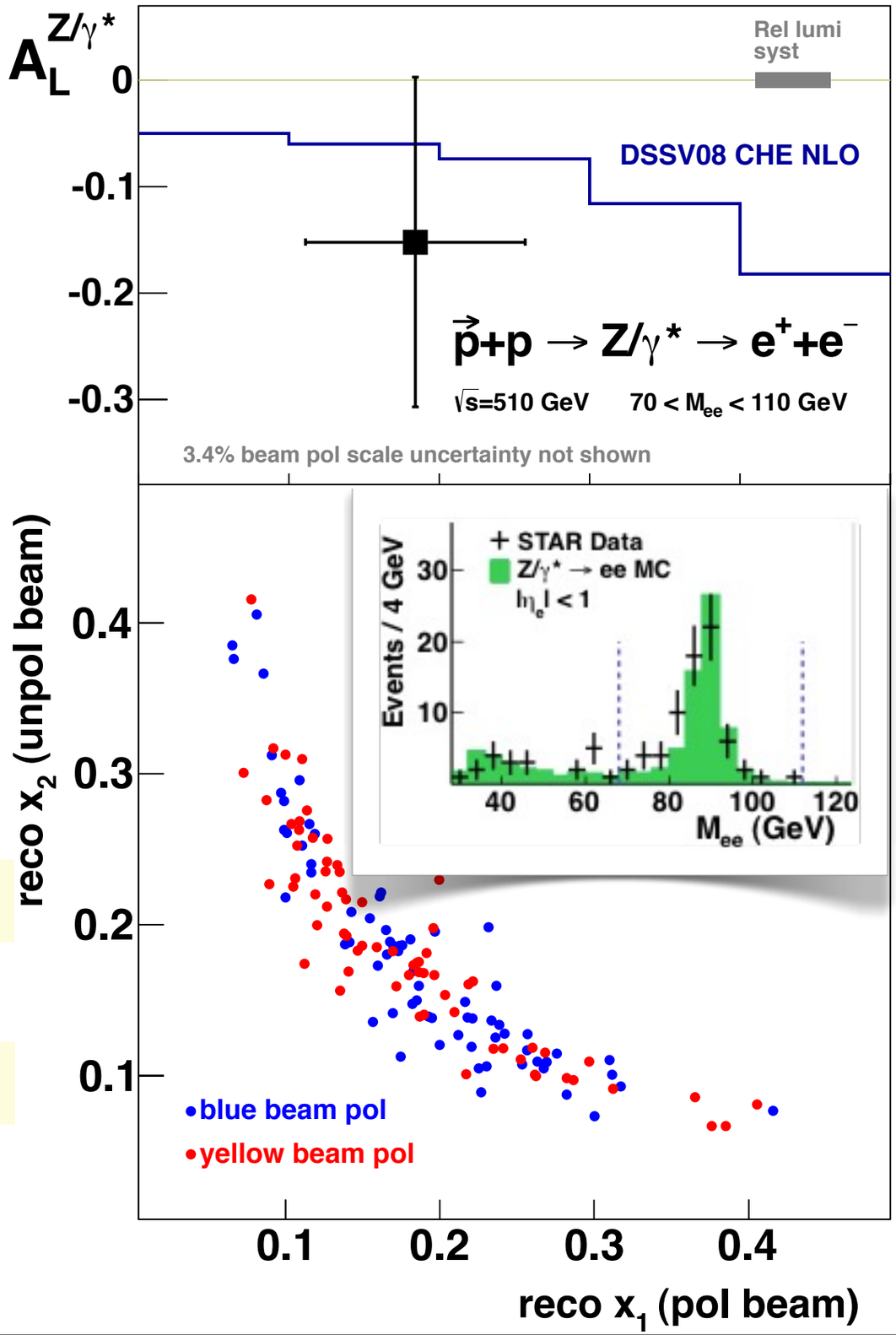
Candidate Z event @ STAR



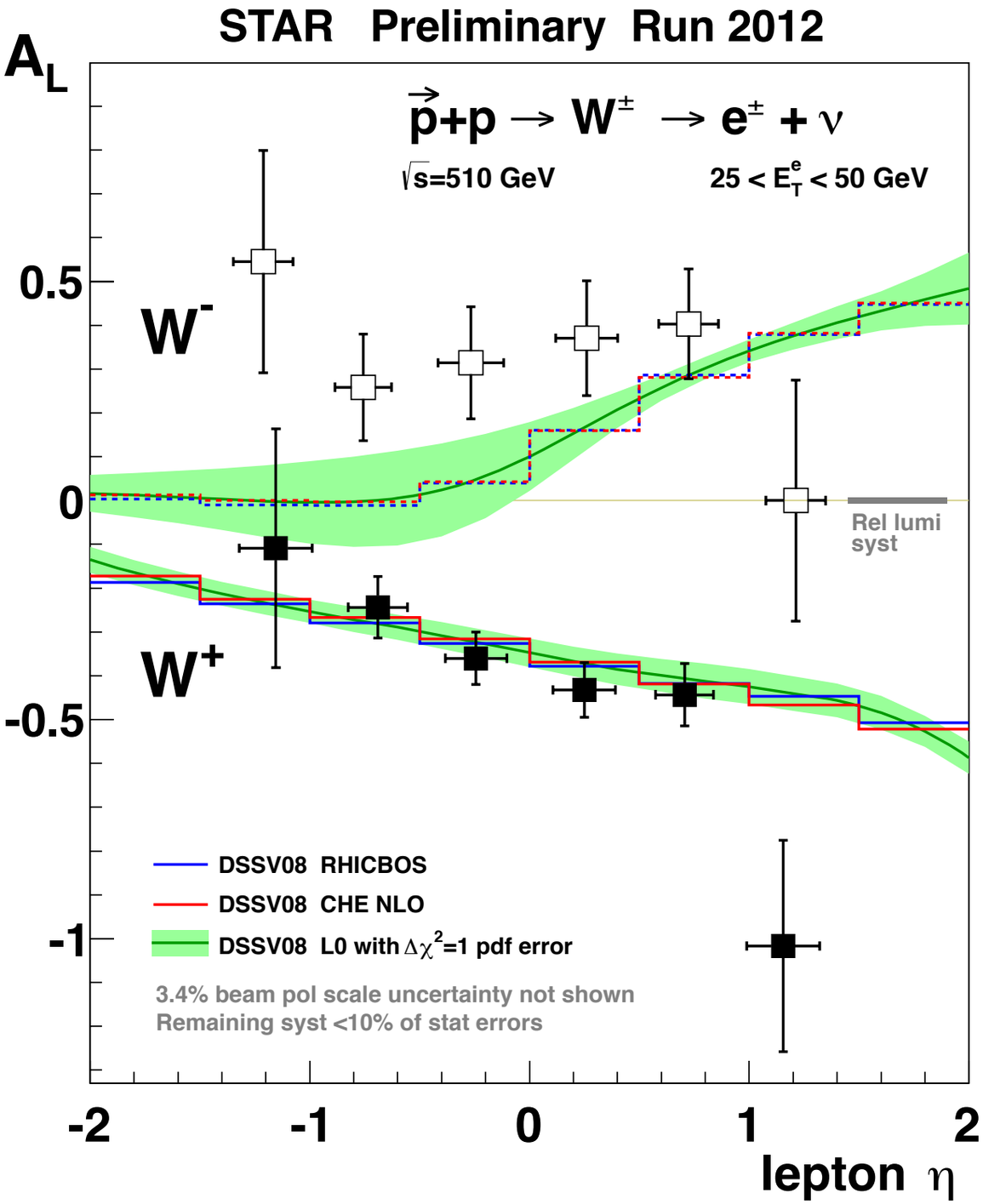




STAR Preliminary Run 2012



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 Run 12 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