Preliminary Figures Request: Measurement of W^{+}/W^{-} cross ratio at RHIC

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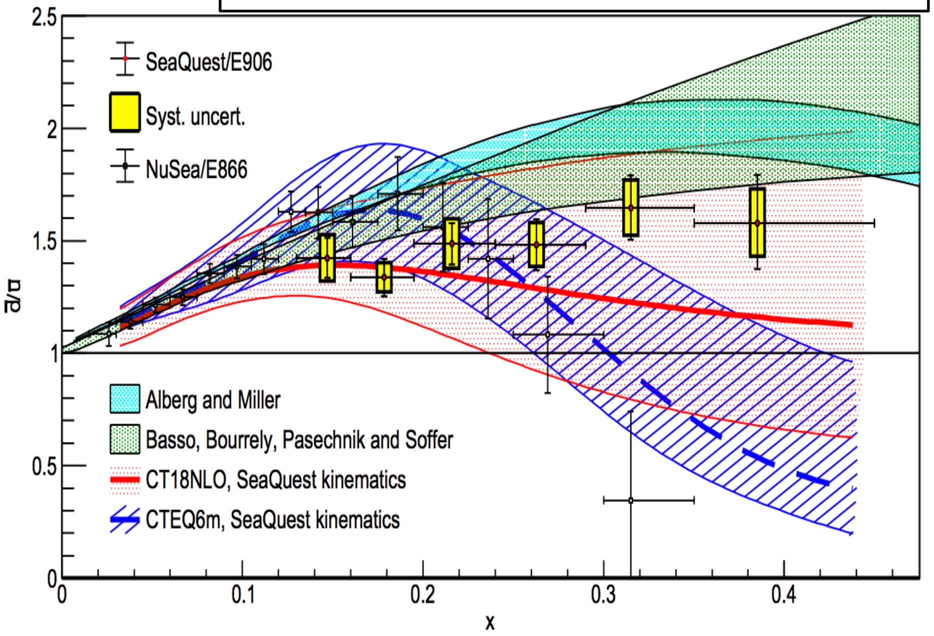
Measurements of $\bar{d}/\bar{u}$ asymmetry

SeaQuest, Nature 590 (2021) 7847, 561-565

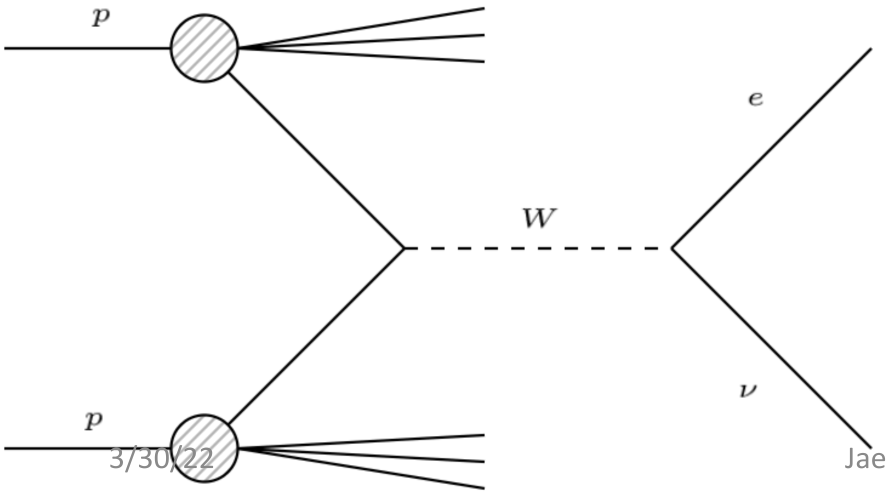


- The $\bar{d}/\bar{u}$ flavor asymmetry
  - Predominantly measured via Drell-Yan, such as NuSea/E866 and SeaQuest/E906.
  - Tension between measurements around the valence region.

- W production at STAR/RHIC
  - LO production sensitive to $\bar{d}$ (W^+) and $\bar{u}$ (W^-).
  - The cross-section ratio $\sigma_{W^+}/\sigma_{W^-}$ can be used to probe $\bar{d}/\bar{u}$;

$$R_W = \frac{\sigma_{W^+}}{\sigma_{W^-}} \approx \frac{u(x_1)\,\bar{d}(x_2) + u(x_2)\,\bar{d}(x_1)}{\bar{u}(x_1)\,d(x_2) + \bar{u}(x_2)\,d(x_1)}$$

  - Naturally provides a large momentum scale, $Q^2 \approx M_W^2$.
  - Sensitive to $\bar{d}/\bar{u}$ in the region $0.1 < x < 0.3$ in the STAR mid-rapidity ($|\eta| < 1$).
  - Kinematic reach further stretched to $0.06 < x < 0.4$ with Endcap EM Calorimeter (EEMC).
  - Characteristically produces final state ν.
  - Isolated high p_T electron.



Preliminary request

- Dataset
  - Dataset: st_W
  - Year: 2017 (P20ic)
  - Production tags: pp500_production_2017
  - Triggers used:
    - L2BW (570202)
    - L2EW (570206)
  - Embedding request id: 20201502

- Measurement
  - R_W $(= \sigma^{W^+ \to e\nu} / \sigma^{W^- \to e\nu})$ measurement in the endcap region $(1 < \eta < 1.5)$ by tagging the leptonic decay of $q\bar{q} \to W$.
  - In addition to the measurement in the barrel region.
    - https://drupal.star.bnl.gov/STAR/blog/jaenam/run-17-measurement-ww-cross-section-ratio-rhic-preliminary-request

Bad run list

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Event selection

- Based on the previous publication (Phys.Rev.D 103 (2021) 1, 012001)
  - Relaxed tracking requirements due to limited TPC acceptance region.
  - Additional constraints provided from ESMD.

Criteria	Relevant quantities	Selection cut
Trigger	Trigger	L2EW
Vertex	Vertex Rank	> 0
	Vertex z	$\|z\| < 100\ cm$
Track	N_{hits} = number of TPC hits	> 5
	N_{hits}/N_{pos}	≥ 0.51
	R_{IN} = inner most TPC radius	$< 120\ cm$
	R_{OUT}	$> 70\ cm$
	N_{ESMD} = number of ESMD strips signaled	> 20
	$r_{ESMD} = \frac{\Sigma_{i=-3}^{+3} E_i^U + E_i^V}{\Sigma_{i=-20}^{+20} E_i^U + E_i^V}$	> 0.6
Cluster	$E_T^{2\times2}$	$> 16\ GeV$
	$E_T^{2\times2}/E_T^{4\times4}$	> 0.97
	$R_{cluster-track}$	$< 10\ cm$
e^W tagging	$E_T^{2\times2}/E_T^{\Delta R<0.7}$	> 0.88
	$Q\times E_T/p_T$	$0.4 < \|Q\times E_T/p_T\| < 1.8$
	$sp_{T,bal}$	$> 20\ GeV$
	$E_T = E_T^{2\times2}$	$25\ GeV < E_T < 50\ GeV$

Procedure

- In the W cross section ratio measurement, the ratio reduces to:

$$\frac{\sigma_{W^+}}{\sigma_{W^-}} = \frac{r^-_{charge}}{r^+_{charge}} \cdot \frac{\epsilon^-}{\epsilon^+} \cdot \frac{N^+_{obs}}{N^-_{obs}} = \frac{r^-_{charge}}{r^+_{charge}} \cdot \frac{\epsilon^-}{\epsilon^+} \cdot \frac{N^+_{sig} - N^+_{bg}}{N^-_{sig} - N^-_{bg}}$$

- where ϵ represents the sum of the efficiencies of our selection process.

$$\epsilon = \epsilon_{trigger} \times \epsilon_{vertex} \times \epsilon_{tracking} \times \epsilon_{tagging}$$

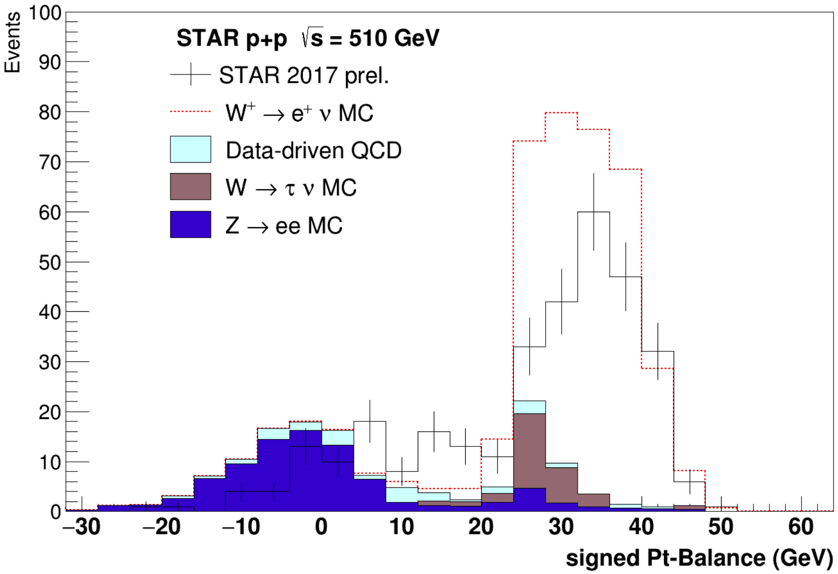
- N_{bg} represents the sum of all remaining background contributions.

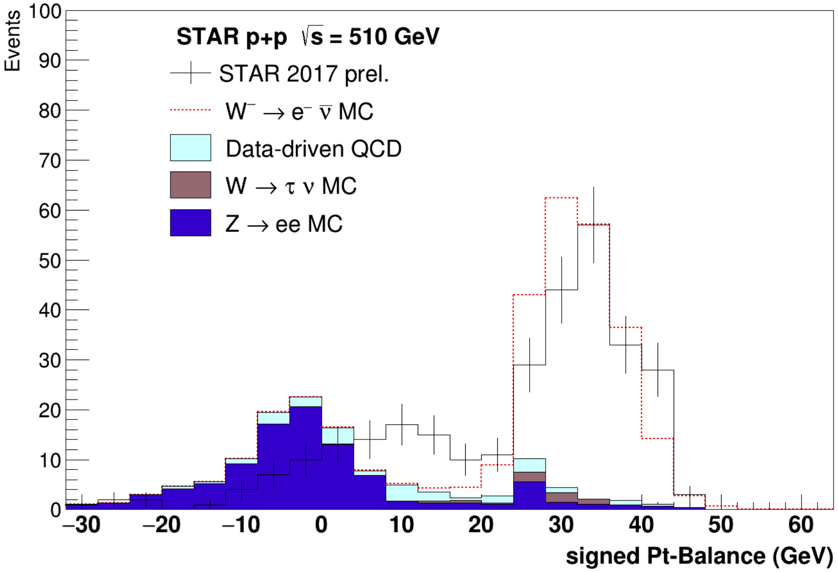
$N_{bg} = N_{W\to\tau\nu} + N_{Z\to ee} + N_{QCD} \cancel{+ N_{EEMC}}$ (second EEMC background only for barrel measurements)

- $N_{W\to\tau\nu}$ and $N_{Z\to ee}$ are entirely determined from events from the embedding samples that pass the selection cuts.
- N_{QCD} represents the QCD background events that pass the selection cuts. Its shape is estimated by looking at the distribution of events with **low** $\boldsymbol{r_{ESMD}}$ $\boldsymbol{(< 0.4)}$ and normalize to match the discrepancy between data and simulation in $sp_{T,bal}$ window $\boldsymbol{-8 < sp_{T,bal}/GeV < 14}$.
- Finally, a correction factor is determined from data and MC to obtain the fraction of correctly assigned electron charge.

$$\frac{r^-_{charge}}{r^+_{charge}} = \frac{N^-_{cor}/N^-_{obs}}{N^+_{cor}/N^+_{obs}}$$

Background description



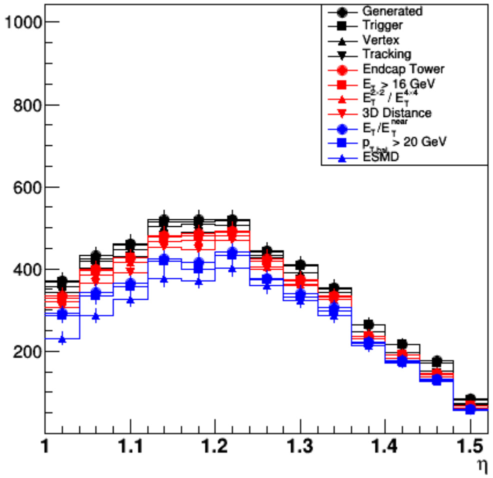


- Background contributions
  - EW contributions ($Z \to ee, W \to \tau\nu_\tau$) are estimated with the embedding scaled to data luminosity
  - Data-driven QCD distribution is first obtained from the distribution with $r_{ESMD} < 0.4$. This is then scaled to match the discrepancy between data and the other background contributions in the region of $-8\ GeV < sp_{T,bal} < 14\ GeV$.

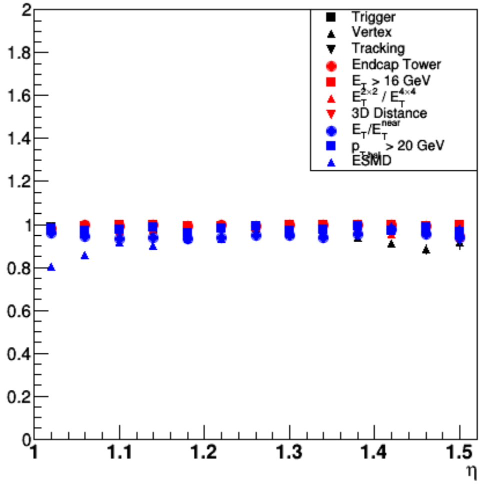
- Similar degree of agreement to Run 11+12+13 (backup)

Efficiency correction

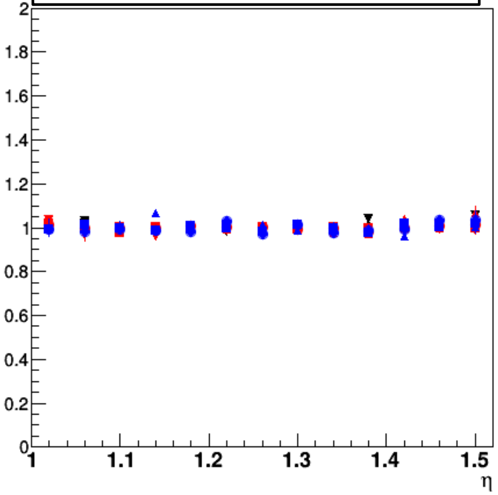
Yield (W^+)



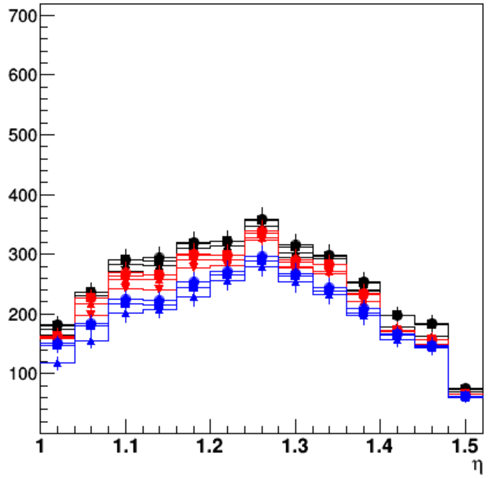
ϵ_i (W^+)



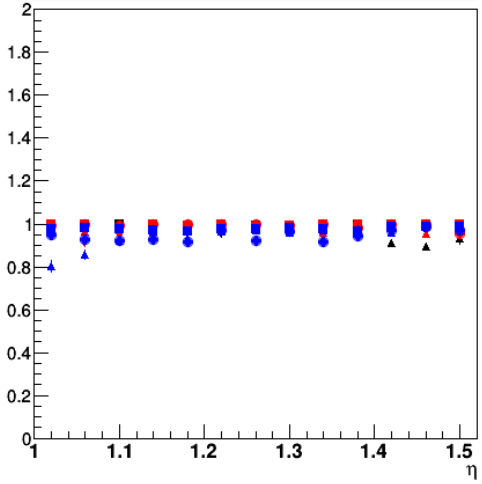
$\epsilon_i^- / \epsilon_i^+$



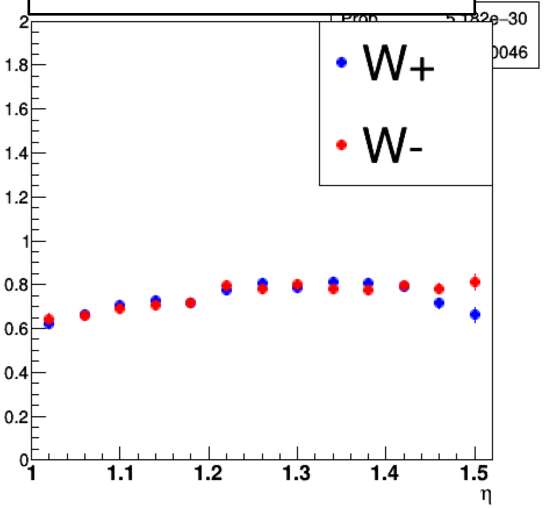
Yield (W^-)



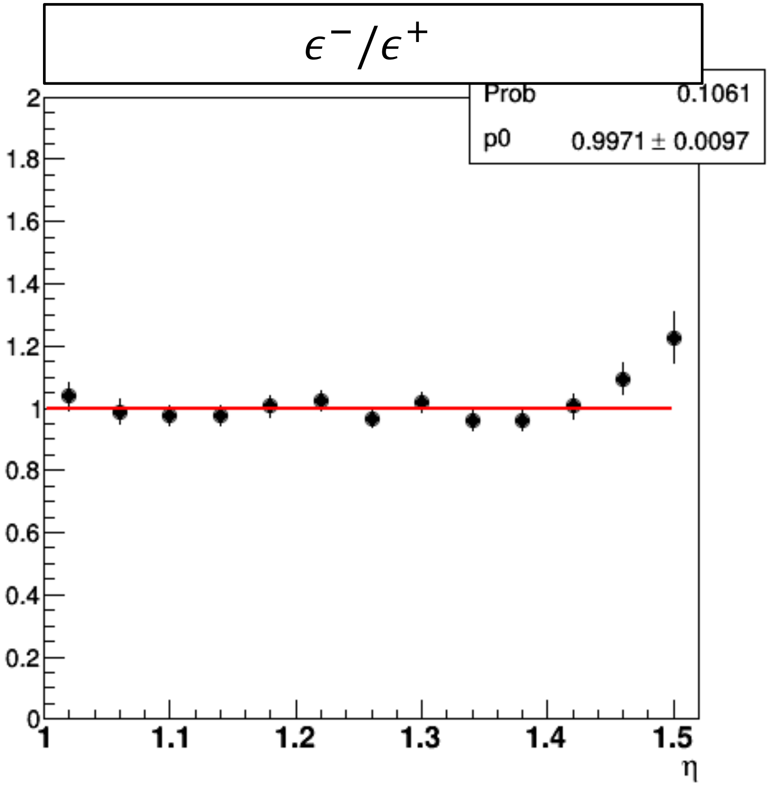
ϵ_i (W^-)



ϵ comparison



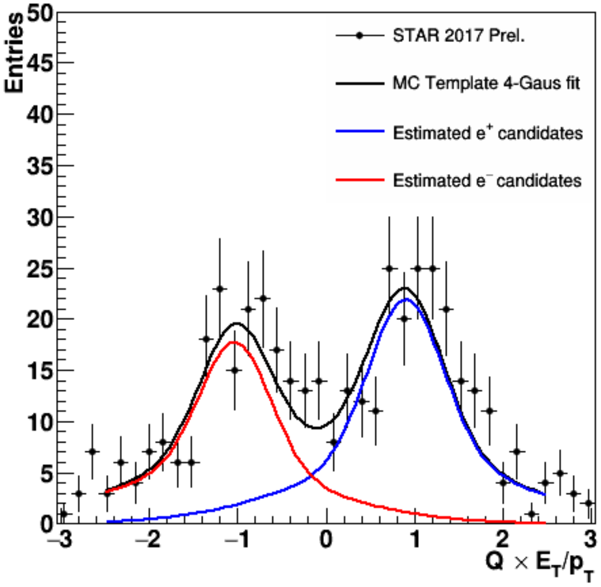
Efficiency correction (continued)

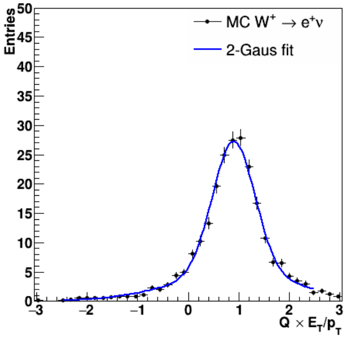


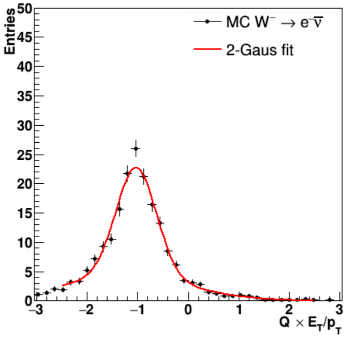
- The efficiency of W tagging in the endcap is evaluated within the region
    - $25\ GeV < E_T < 50\ GeV$
    - $1 < \eta < 1.5$
- No strong charge dependence has been found.
- The efficiency correction factor (ϵ^-/ϵ^+) has been found to be

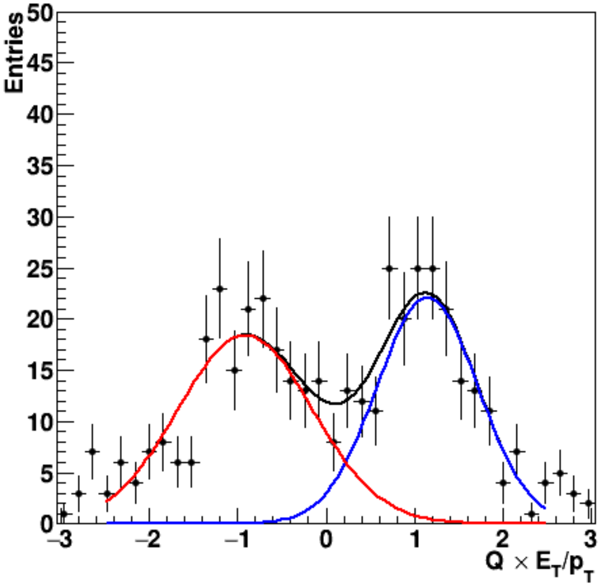
$$\frac{\epsilon^-}{\epsilon^+} = \frac{N_{sig}^-/N_{gen}^-}{N_{sig}^+/N_{gen}^+} = \frac{0.74}{0.75} = 1.01$$

Charge correction









- Two different calculations have been tested for charge correction estimate.

- MC template (4-Gaus)
  - $Q \times E_T/p_T$ distributions from the W^- and W^+ embedding samples are fitted to 2-Gaus function
  - The widths and means of these Gaus's are used as template for the 4-Gaus fit to the data.

- Log-likelihood (2-Gaus)
  - The charge distribution from data is directly fit to 2-Gaus function.

- Charge correction factor

$$\left(\frac{r^-}{r^+}\right)_{4Gaus} = \frac{N^-_{cor}/N^-}{N^+_{cor}/N^+} = \frac{145.9/205}{180.2/214} = 0.96$$

$$\left(\frac{r^-}{r^+}\right)_{2Gaus} = \frac{N^-_{cor}/N^-}{N^+_{cor}/N^+} = \frac{189.2/205}{190.9/214} = 1.06$$

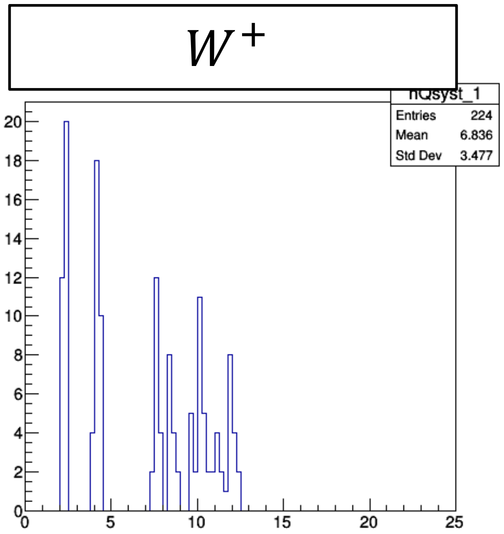
Systematic uncertainties

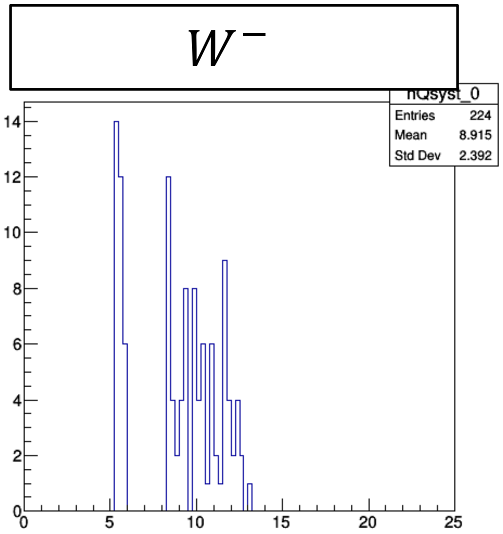
- Charge correction method
  - Evaluated at the difference in C_{charge} between 4-Gaus and 2-Gaus methods ($\delta = 10.4\%$).
- Charge selection
  - The lower and upper bounds of charge selection cut ($0.4 < |Q \times E_T/p_T| < 1.8$) was varied by ± 0.3.
  - The systematic uncertainty was taken from the largest deviation from the nominal value.

x_{low}	0.4	0.1	0.7	0.4	0.4	Largest Difference
x_{high}	1.8	1.8	1.8	1.5	2.1	
4-Gaus	0.96	0.88	1.12	0.89	0.97	0.16
2-Gaus	1.06	1.09	1.06	1.04	1.04	0.03

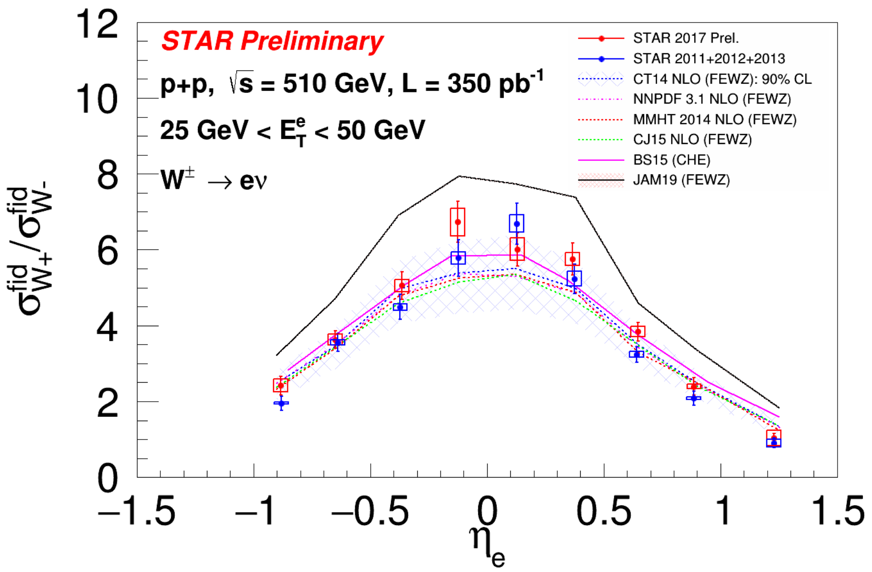
Nominal

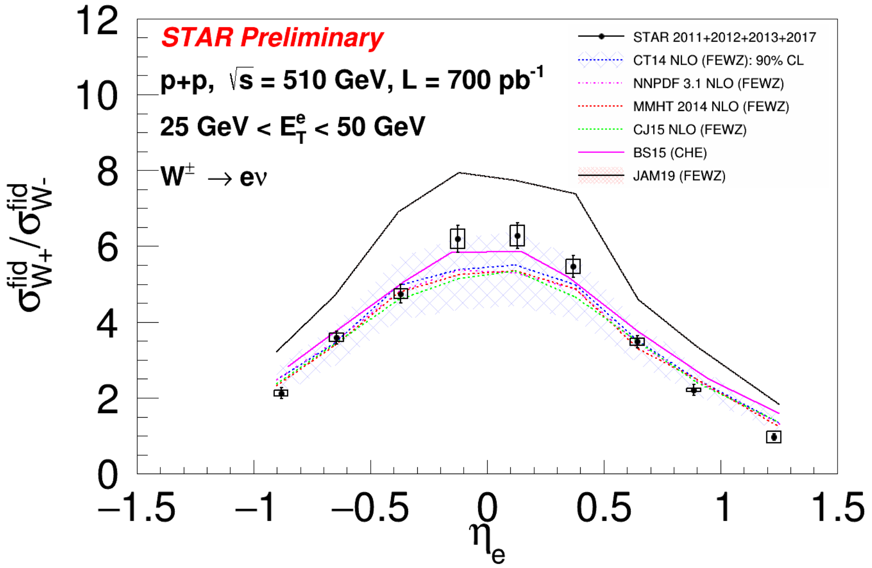
- QCD background description
  - Systematic uncertainty estimated by varying the upper r_{ESMD} limit for QCD background from 0.4 to 0.55 in steps of 0.01 (shape) and $sp_{T,bal}$ upper limit from $-4\ GeV$ to 22 GeV in steps of 2 GeV (normalization).
  - The value was taken from the RMS of QCD contribution.





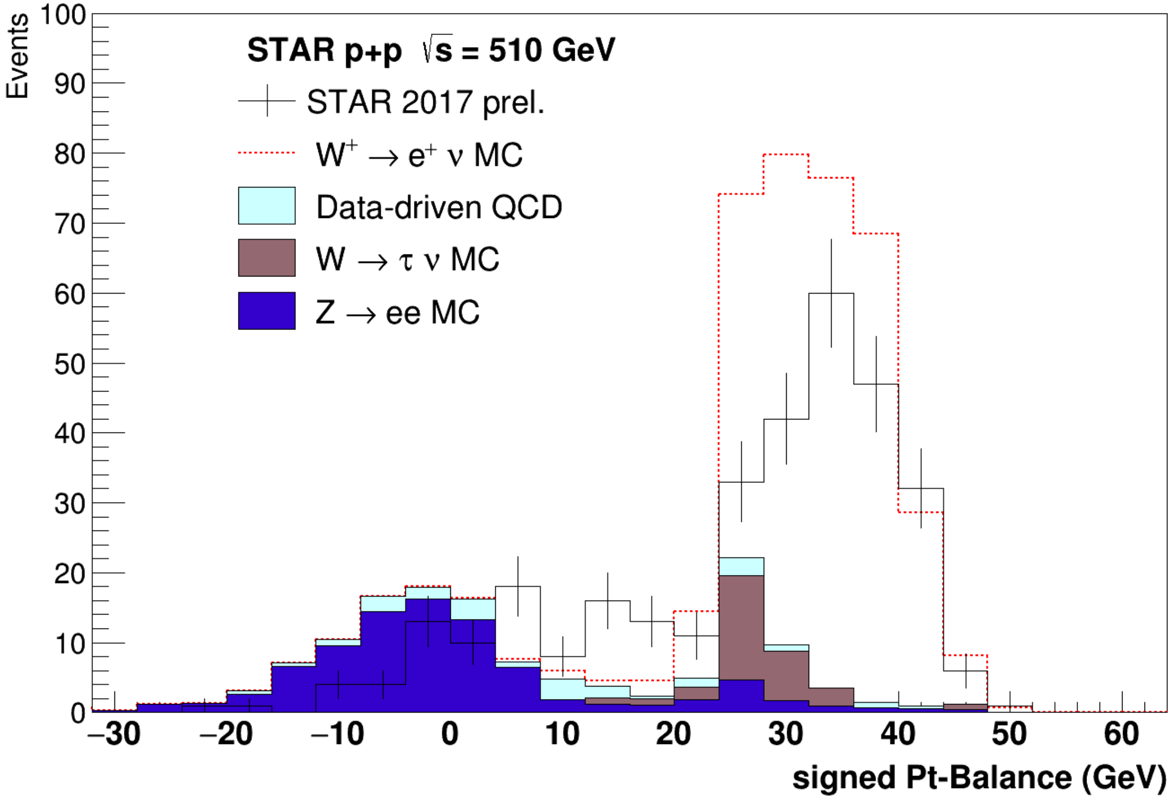
Results & Summary





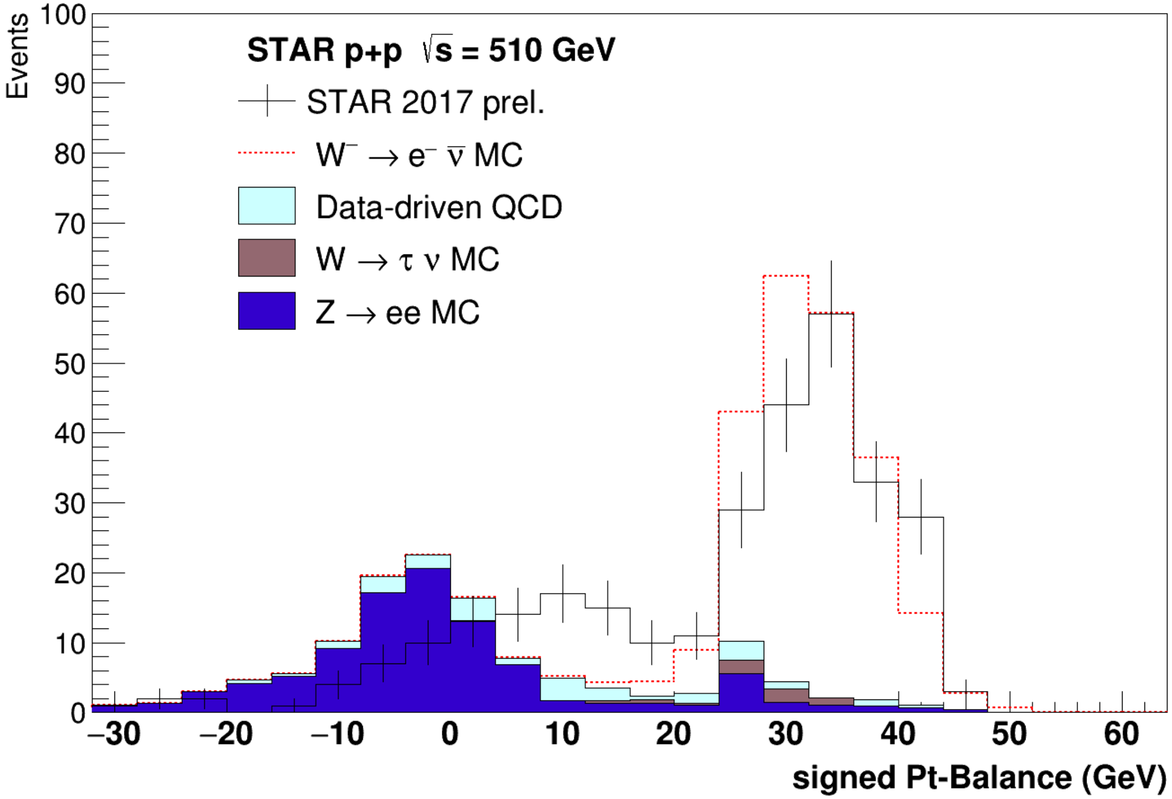
- R_W in the endcap region with STAR Run 2017 dataset has been measured.
    - Evaluated at $25 \text{ GeV} < E_T < 50\ GeV$ and $1 < \eta < 1.5$
    - Efficiency correction factor $\frac{\epsilon^-}{\epsilon^+} = 1.01$ was used.
    - Charge correction factor was calculated with the MC template method ($\frac{r^-}{r^+} = 0.96$).
- Assigned systematics evaluates:
    - The difference between the two charge correction estimates (MC template vs. Log-likelihood)
    - The lower and upper limits of charge selection cut.
    - Description of the QCD background.
- Preliminary request for DIS2022

Preliminary request 1



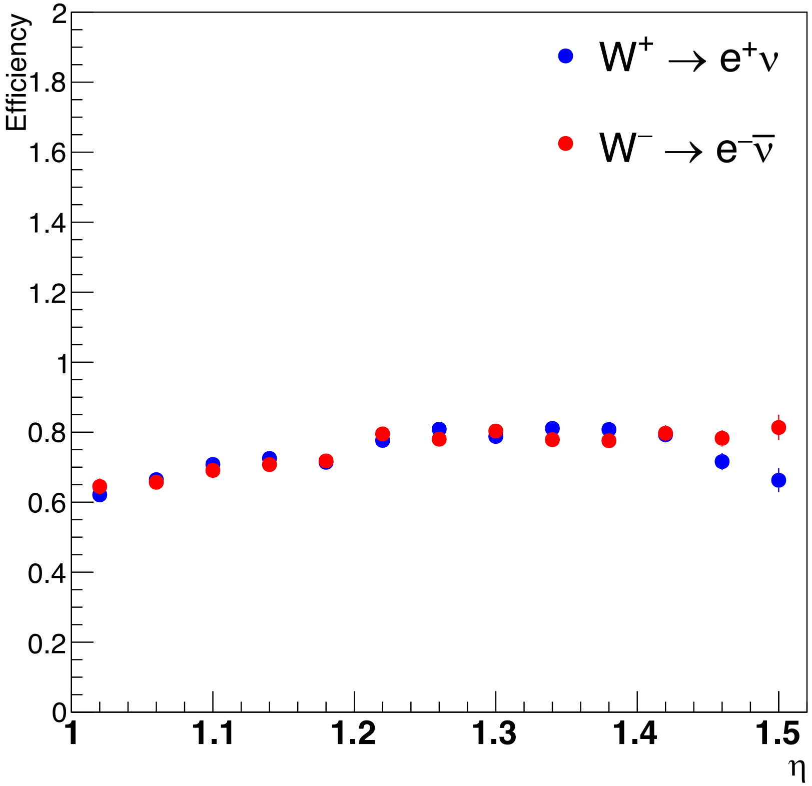
- Caption: Signal and background signed-$p_{T,bal}$ distributions for positron candidates in the EEMC.

Preliminary request 2



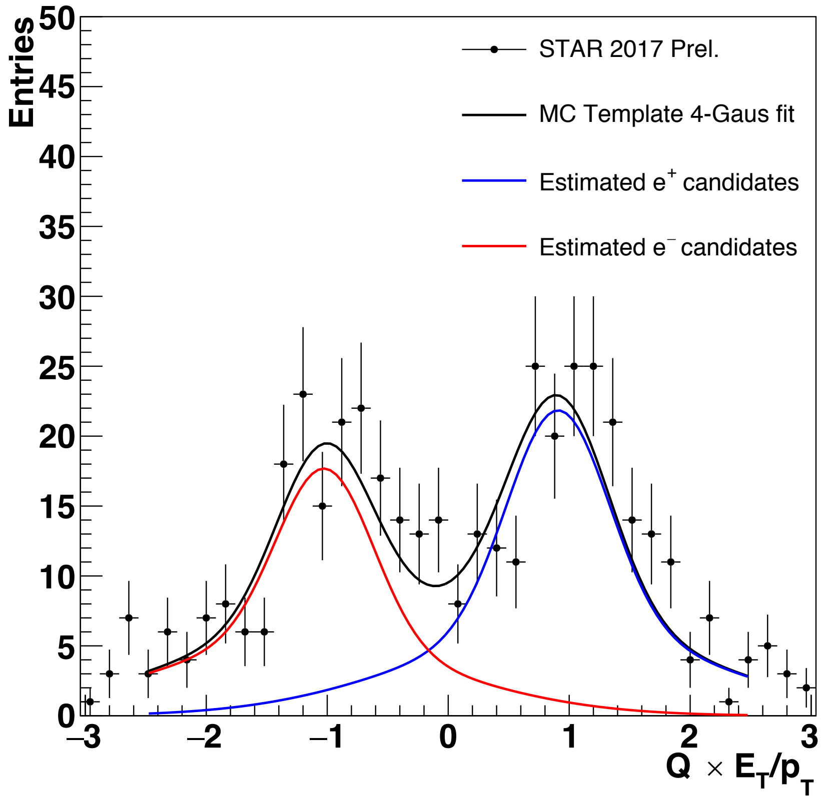
- Caption: Signal and background signed-$p_{T,bal}$ distributions for electron candidates in the EEMC.

Preliminary request 3



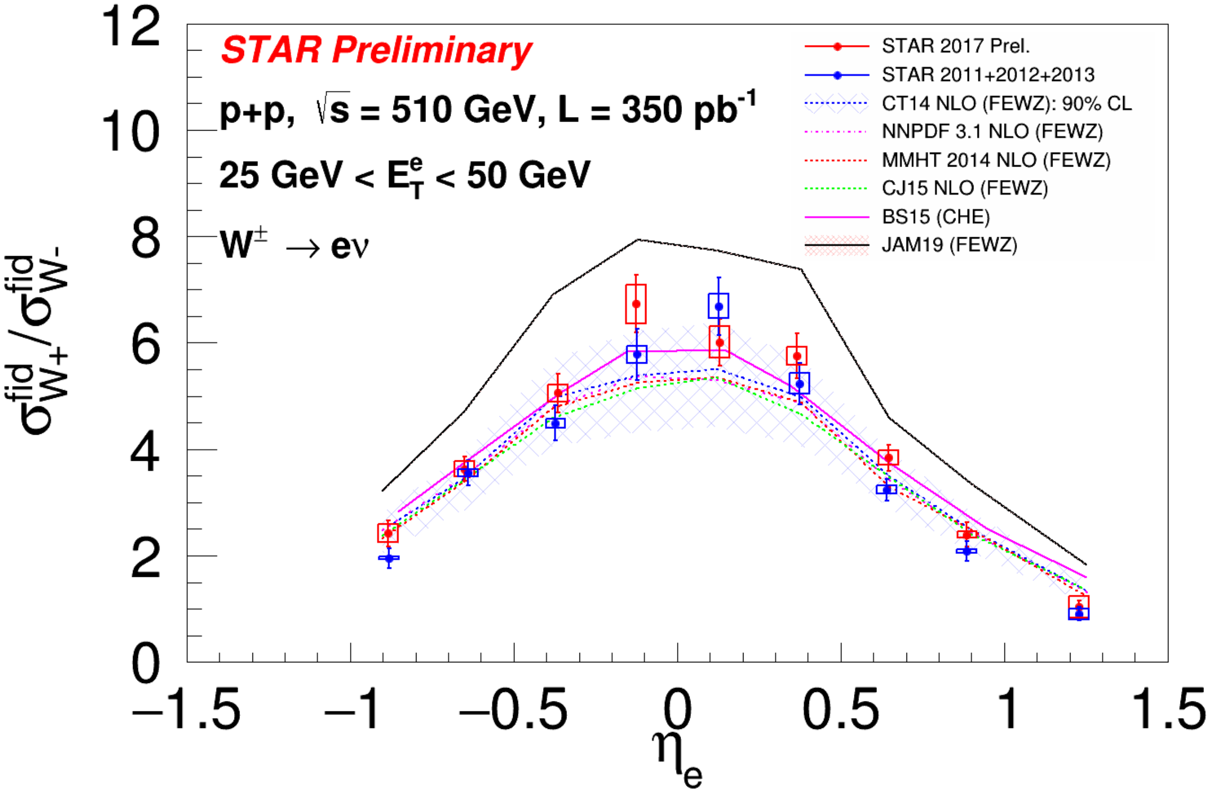
- Caption: Total efficiencies of electroweak positrons and electrons plotted as a function of the leptonic pseudorapidity.

Preliminary request 4



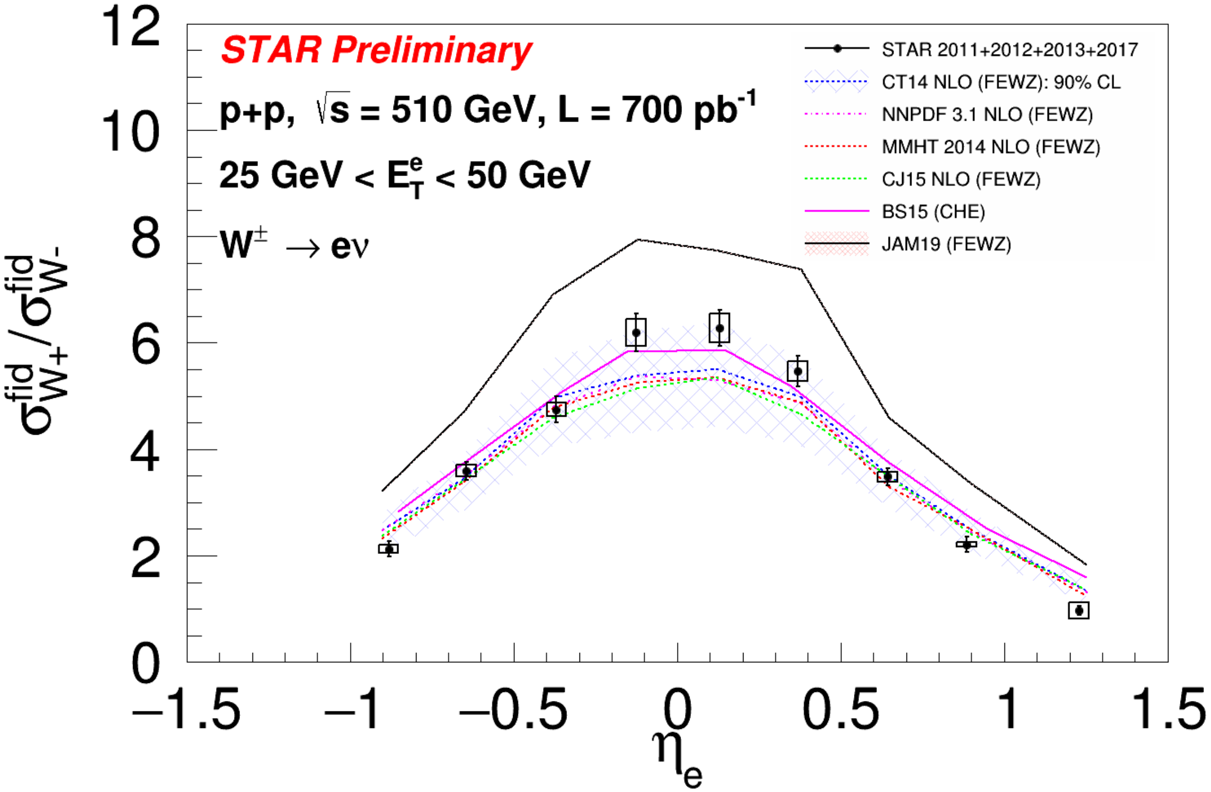
- Caption: $Q{\times}E_T/p_T$ distributions from the STAR 2017 dataset. The black curve represents the 4-Gaus fit using the 2-Gaus fit parameters from the MC samples. The blue and red curves represent the estimated charge distributions for positron and electron candidates, respectively.

Preliminary request 5



- Caption: R_W for STAR 2017 dataset against leptonic pseudorapidity in comparison to the published measurement using STAR 2011, 2012, and 2013 datasets. The central values correspond to the mean value of η_e for that bin. The vertical bars represent the statistical uncertainty, whereas the height of the rectangles represents the systematic uncertainty for the respective data point. The measurement is compared to various theory frameworks with several PDF inputs.

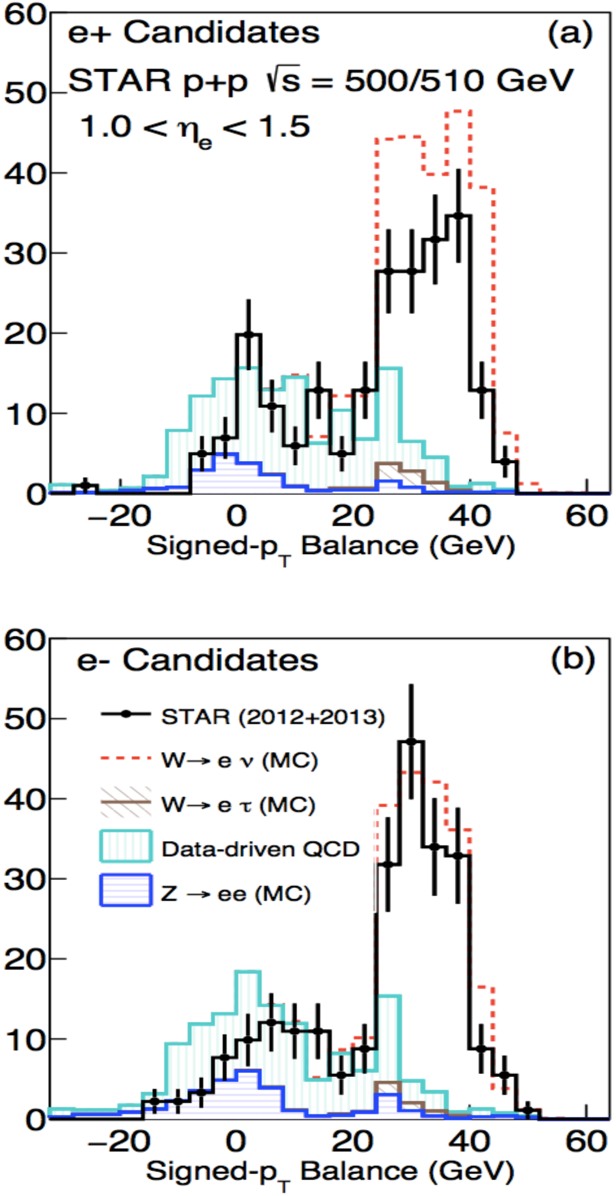
Preliminary request 6



- Caption: R_W for combined STAR 2011, 2012, 2013 and 2017 datasets against leptonic pseudorapidity. The central values correspond to the mean value of η_e for that bin. The vertical bars represent the statistical uncertainty, whereas the height of the rectangles represents the systematic uncertainty for the respective data point. The measurement is compared to various theory frameworks with several PDF inputs.

Back up

Run 12+13 (top:W+, bottom: W-)



Run 17 (top:W+, bottom: W-)