Preliminary Request: W^+/W^- ratio analysis STAR Run 2017

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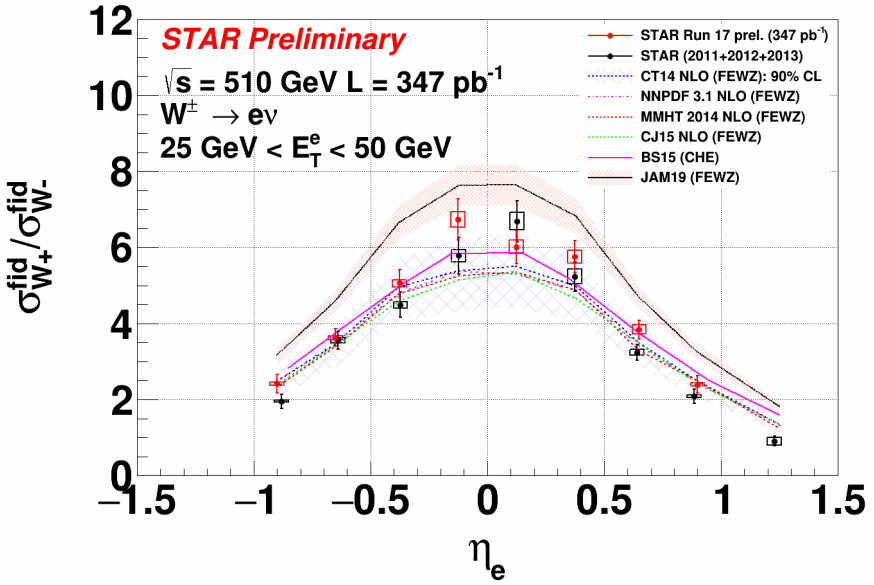
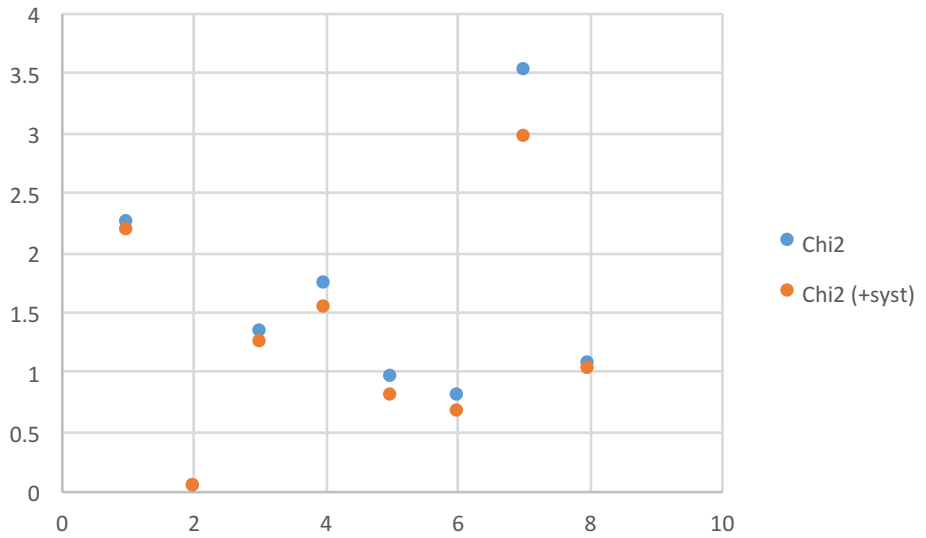
Overview

- Run 17 and 11-13 consistency check (efficiency & R_W)
- Systematic effect from BEMC gain correction
- Graphics on the final pictures

Consistency check (R_W)

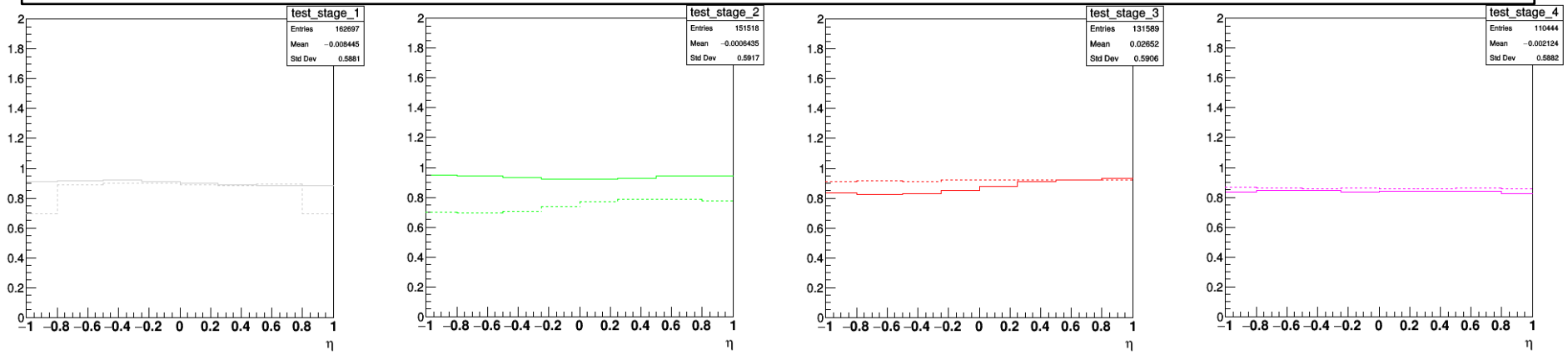




- Chi2 test shows that Run 17 and 11-13 are consistent
  - $X^2/N_{dof} = 11.67/7 = 1.67\ (p = 0.11)$
  - $X^2/N_{dof}\ (+syst) = 1.5$
- No significant trend in η has been found.

Consistency check (ϵ)

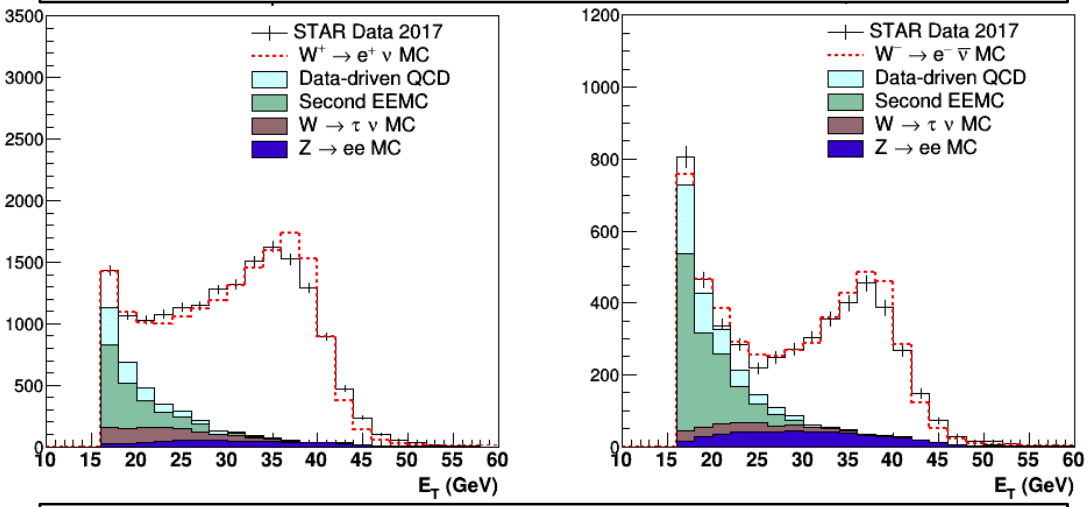
Efficiency comparisons (trigger, vertex, tracking, algorithm)



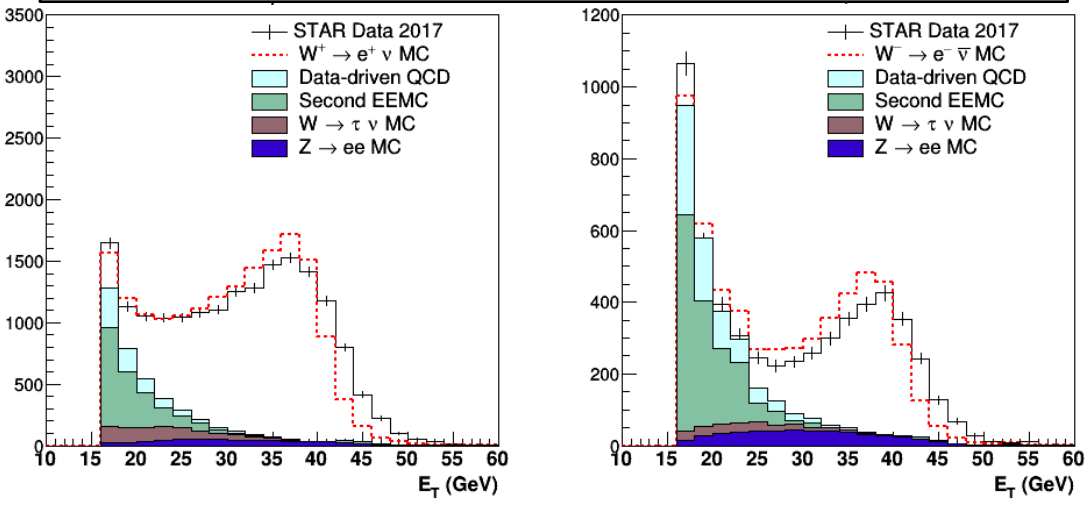
- The biggest difference is seen at the vertexing stage.
  - In Run 13, TPC 20 effect is seen at the vertexing stage, while this happens at tracking stage in Run 17.
    - Possibly due to change in truth→tagged matching scheme.
  - About ~15% improvement in vertex efficiency
    - No change has been made to the vertex selection.
      - $Rank > 0, \quad |z_{vtx}| < 100\ cm$
    - Improvements in vertex finder?
  - Discrepancy in Trigger efficiency is due to the change in kinematic limits put at $|\eta| < 1 \rightarrow 0.9$

BEMC gain correction

Nominal



w/o BEMC gain correction



BEMC gain correction

- δ_{BEMC} was obtained by comparing R_W before and after applying the gain correction.

η-bin	σ^+/σ^-	δ_{stat}	δ_{syst}	δ_{BEMC}	$\delta_{syst+BEMC}$
1	2.42	0.24	0.04	0.16	0.17
2	3.63	0.23	0.05	-0.13	0.14
3	5.06	0.36	0.10	0.13	0.17
4	6.73	0.54	0.20	0.30	0.36
5	6.01	0.43	0.18	0.24	0.30
6	5.75	0.43	0.17	-0.01	0.17
7	3.84	0.25	0.12	0.07	0.14
8	2.40	0.23	0.05	-0.03	0.05

- In many case, the newly-introduced δ_{BEMC} dominates all the other sources of systematic uncertainties.

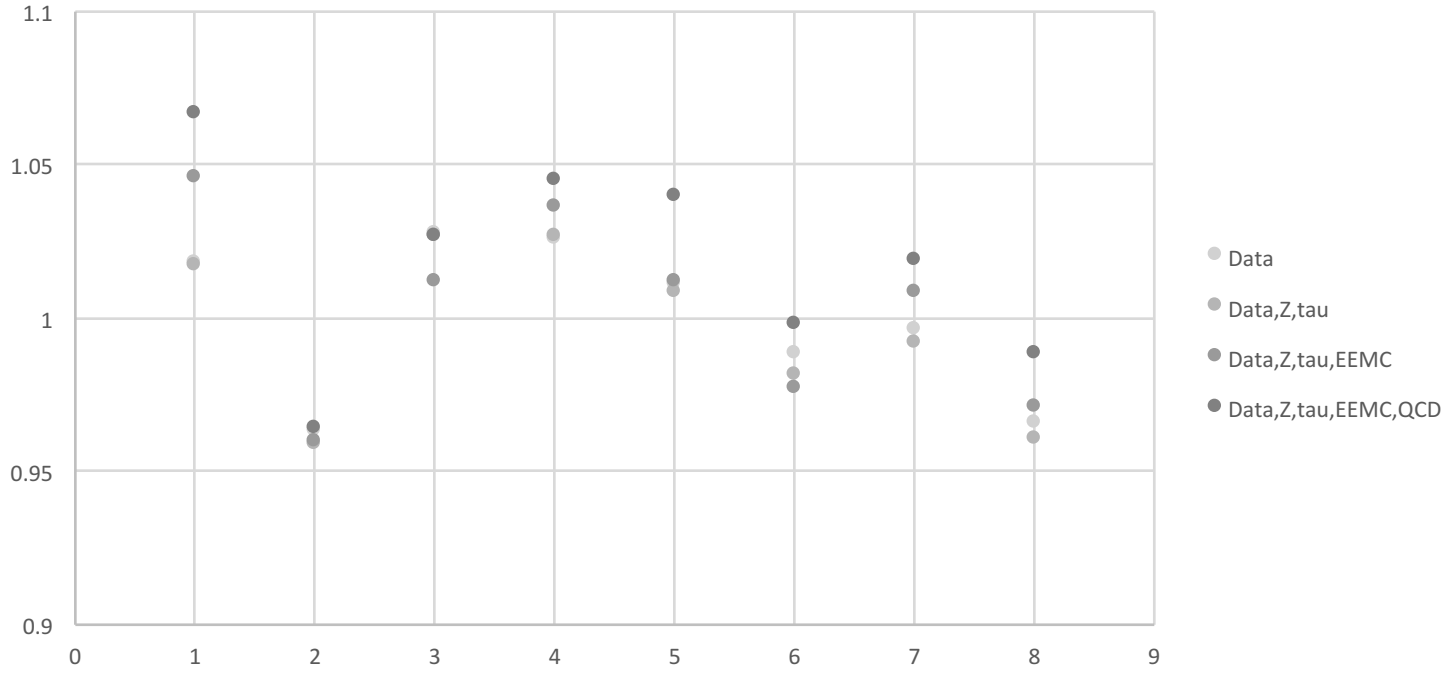
BEMC gain correction

W^-	N_{dat}	$N_{Z,\tau}$	N_{QCD}	N_{EEMC}	N_{BG}	$N_{W,dat}$
$\frac{N_{nocor}}{N_{nominal}}$	1.07	1.00	2.27	1.33	1.31	1.02
	1.06	1.00	1.47	1.25	1.12	1.05
	1.03	1.00	1.78	0.92	1.05	1.02
	1.01	1.00	1.11	1.15	1.05	1.00
	1.02	1.00	1.50	1.52	1.12	0.99
	1.05	1.00	1.51	0.85	1.07	1.04
	1.04	1.00	1.33	2.08	1.17	1.01
	1.10	1.00	2.21	1.91	1.41	1.04
W^+	N_{dat}	$N_{Z,\tau}$	N_{QCD}	N_{EEMC}	N_{BG}	$N_{W,dat}$
$\frac{N_{nocor}}{N_{nominal}}$	1.09	1.00	5.30	1.00	1.08	1.09
	1.02	1.00	1.01	1.41	1.15	1.01
	1.05	1.00	1.26	1.41	1.13	1.05
	1.04	1.00	0.82	1.11	0.99	1.04
	1.03	1.00	0.83	1.64	1.05	1.03
	1.03	1.00	0.92	1.12	1.00	1.03
	1.04	1.00	1.31	1.47	1.12	1.03
	1.06	1.00	1.90	1.38	1.25	1.03

	R_W
$\frac{N_{nocor}}{N_{nominal}}$	1.07
	0.96
	1.03
	1.04
	1.04
	1.00
	1.02
	0.99

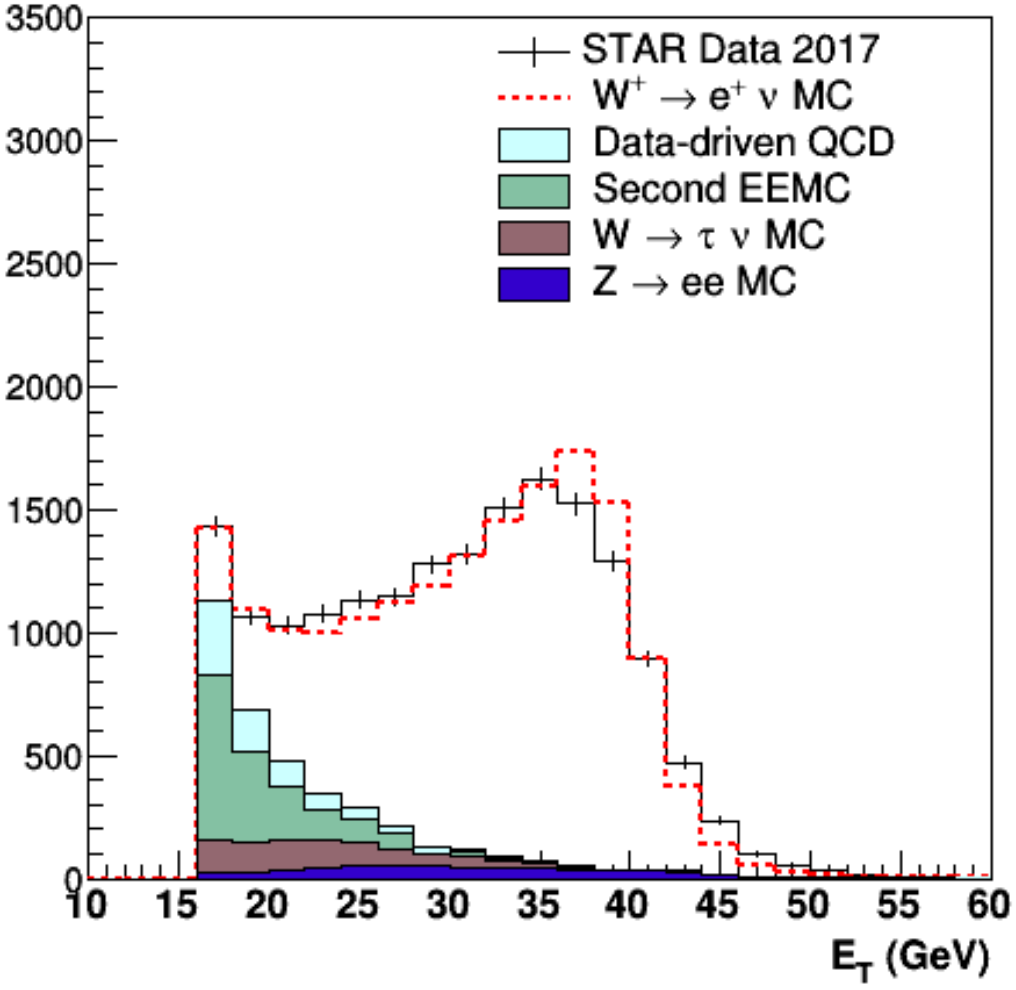
- We expect the number of W candidates from data increase when excluding the gain correction.
- No change in $Z \rightarrow ee$ and $W \rightarrow \tau\nu$ as expected.
- Change in QCD background is larger in W^- than in W^+.

BEMC gain correction

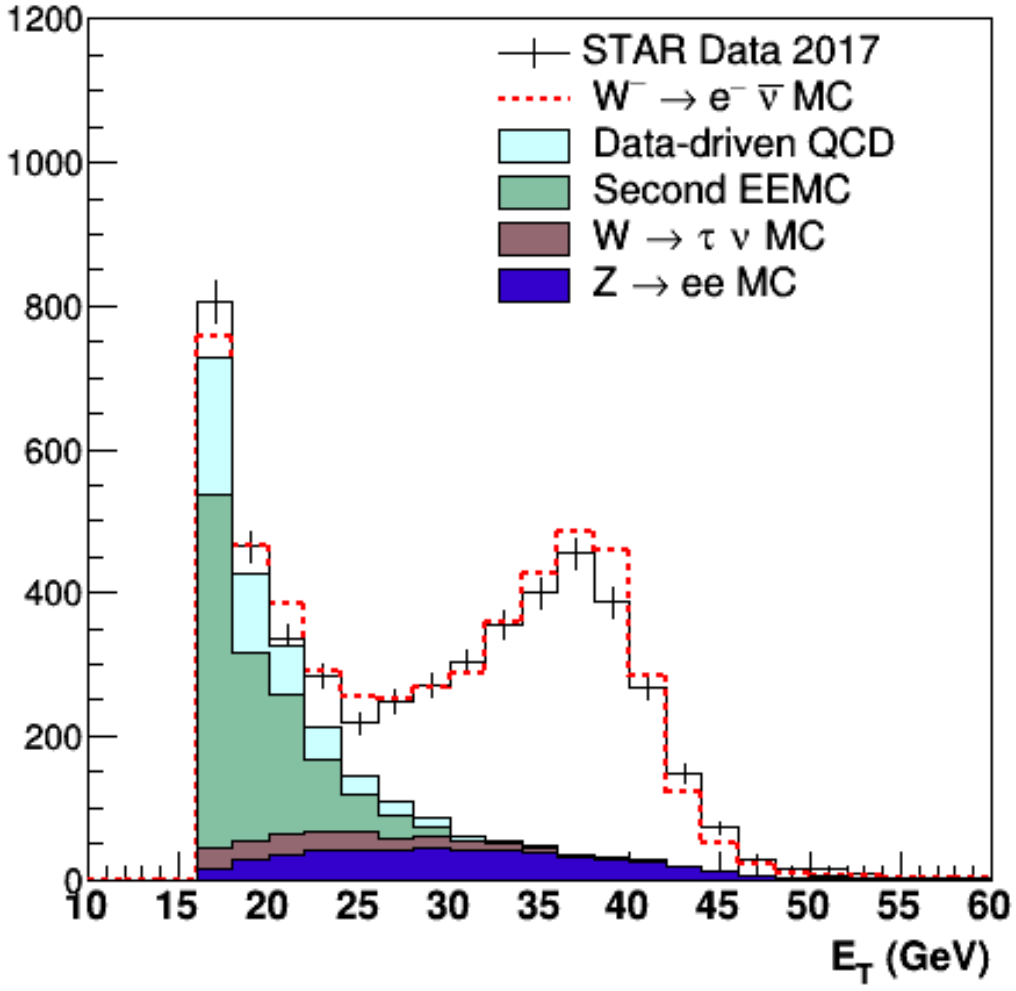


- Change in QCD background always increase the $R_W^{no\ gain}/R_W^{nominal}$.
  - W^+ is more resistant to the rightward shift in E_T from data than W^-.
- Change in EEMC background has ”random” effect.
- Overall,
  - Data only. : 0-3%
  - Data + Z,τ. : 1-4%
  - Data + Z,τ + EEMC : 1-5%
  - Data + Z, τ + EEMC + QCD : 0-7%

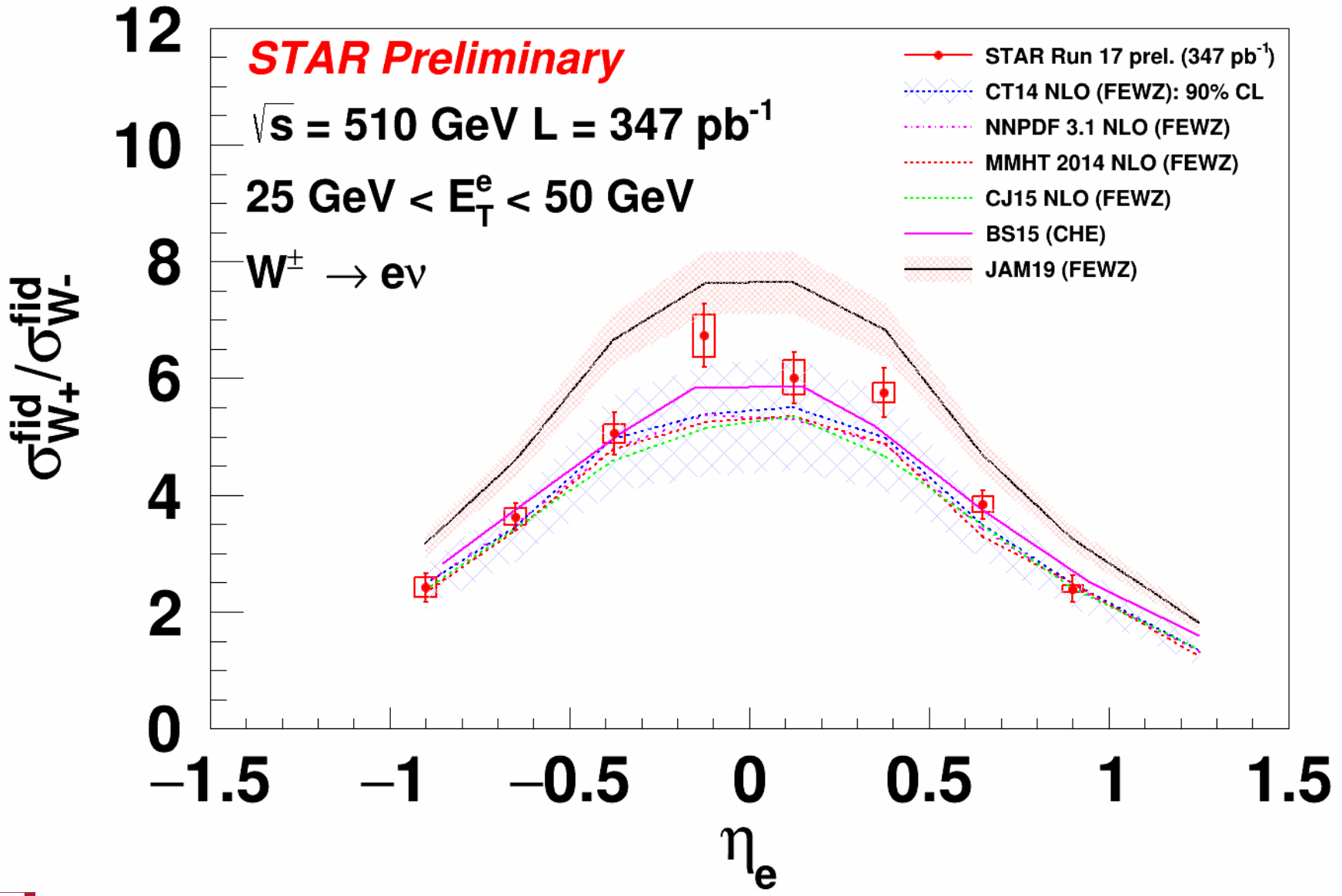
Preliminary request 1



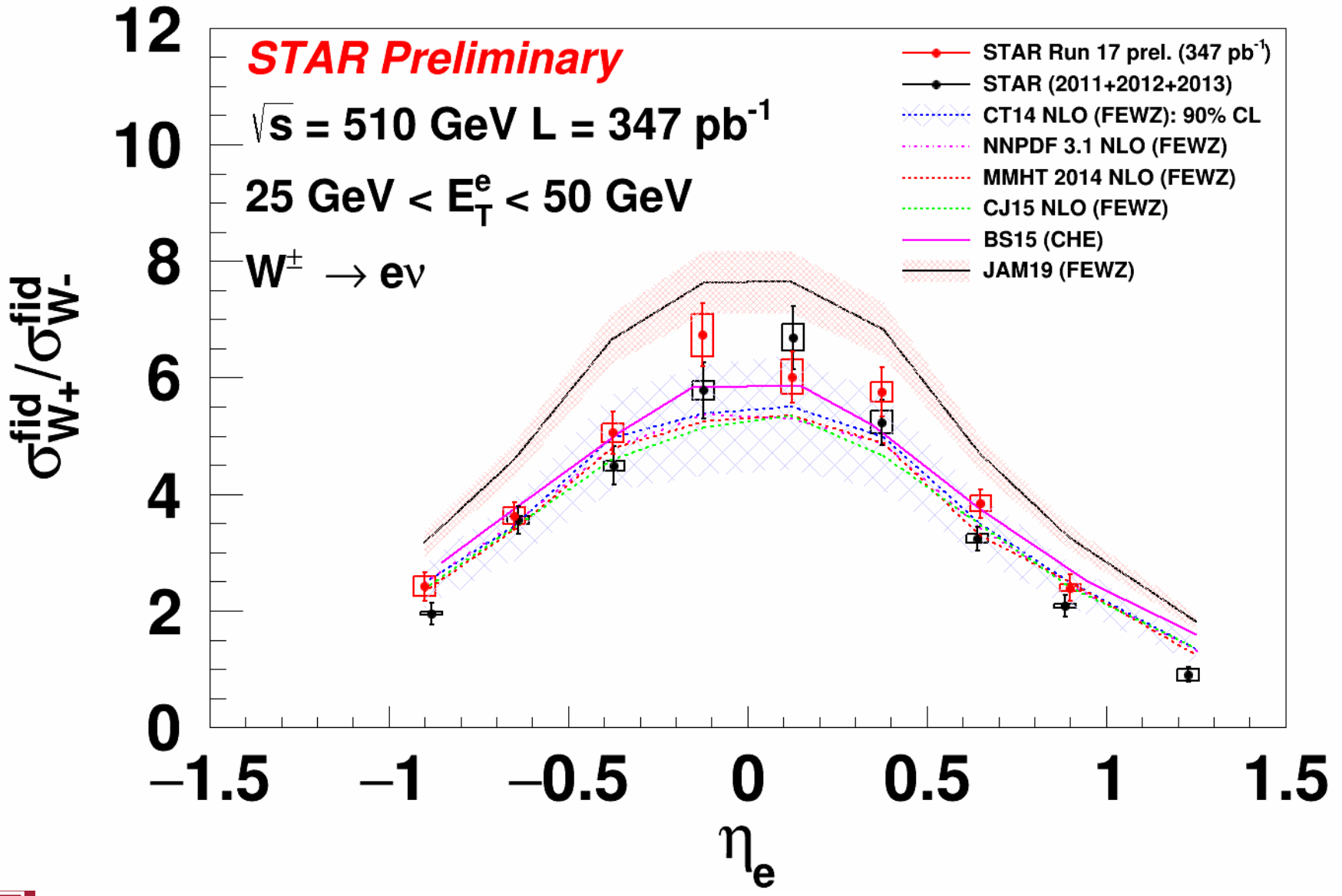
Preliminary request 2



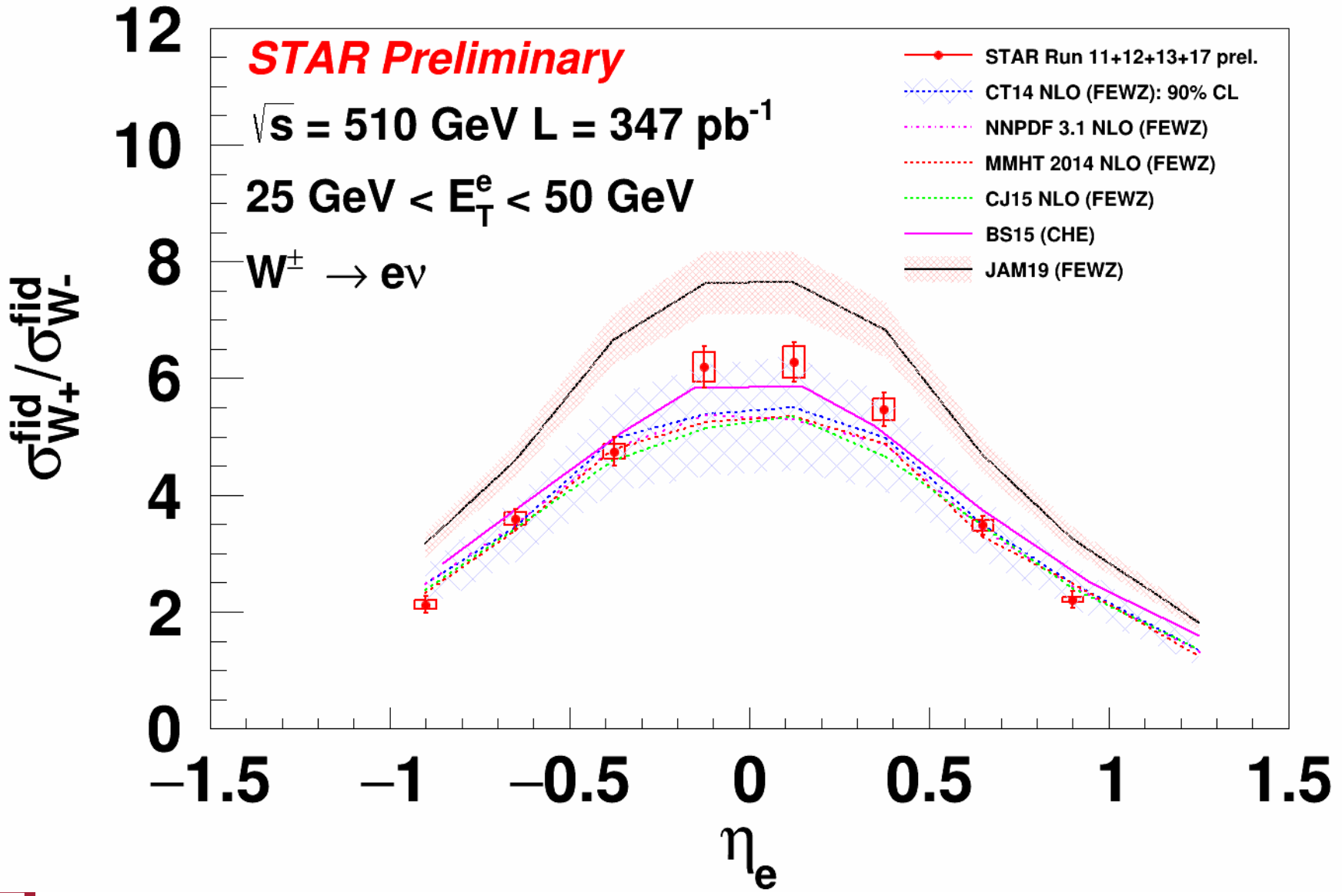
Preliminary request 3.a



Preliminary request 3.b

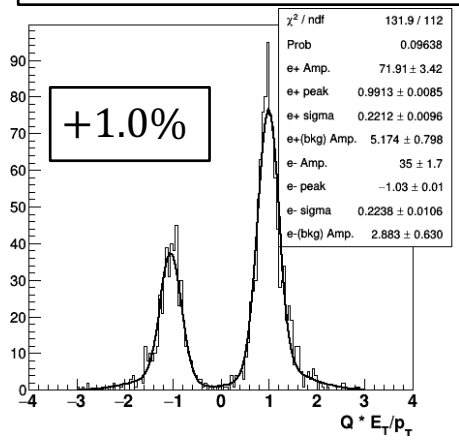


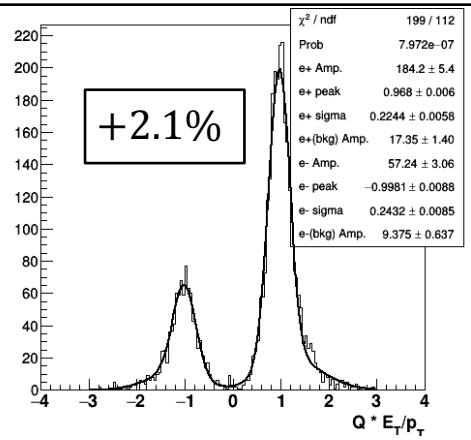
Preliminary request 3.c

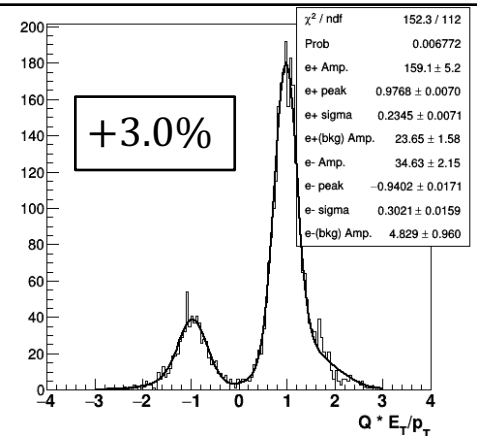


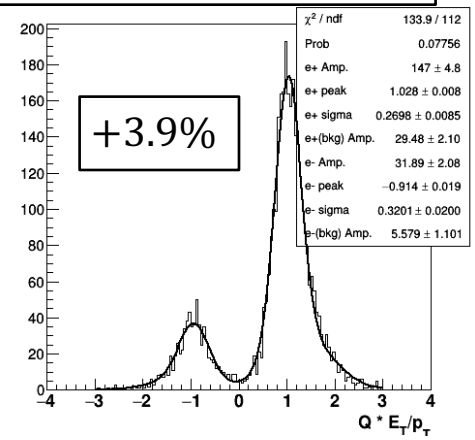
Charge separation

$-1 < \eta < 0$

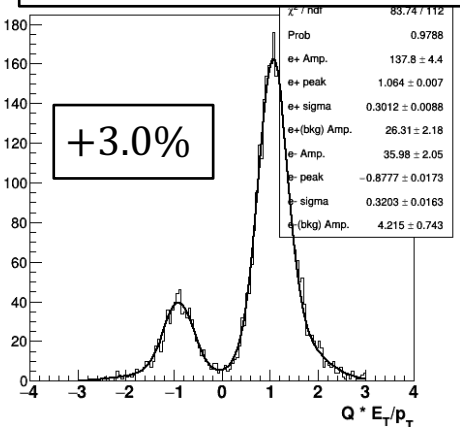


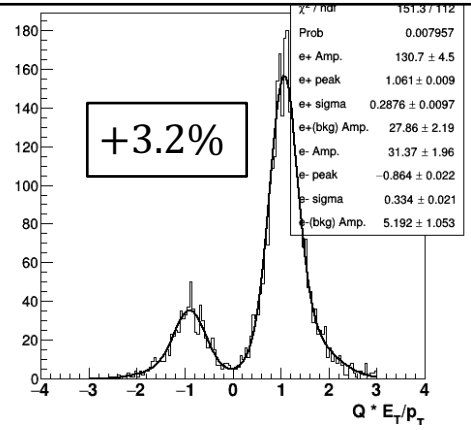


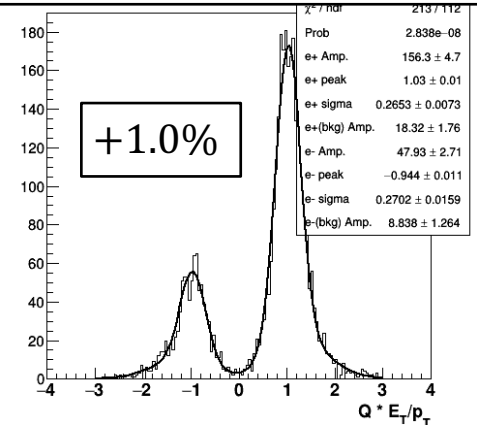


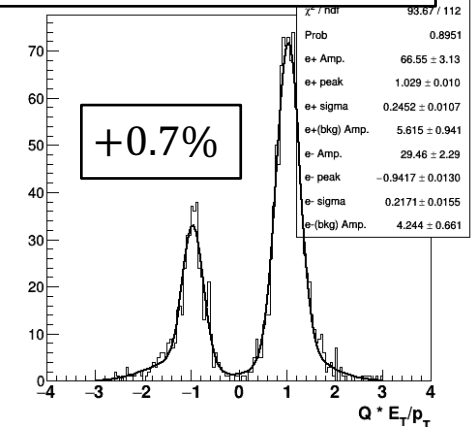


$0 < \eta < 1$

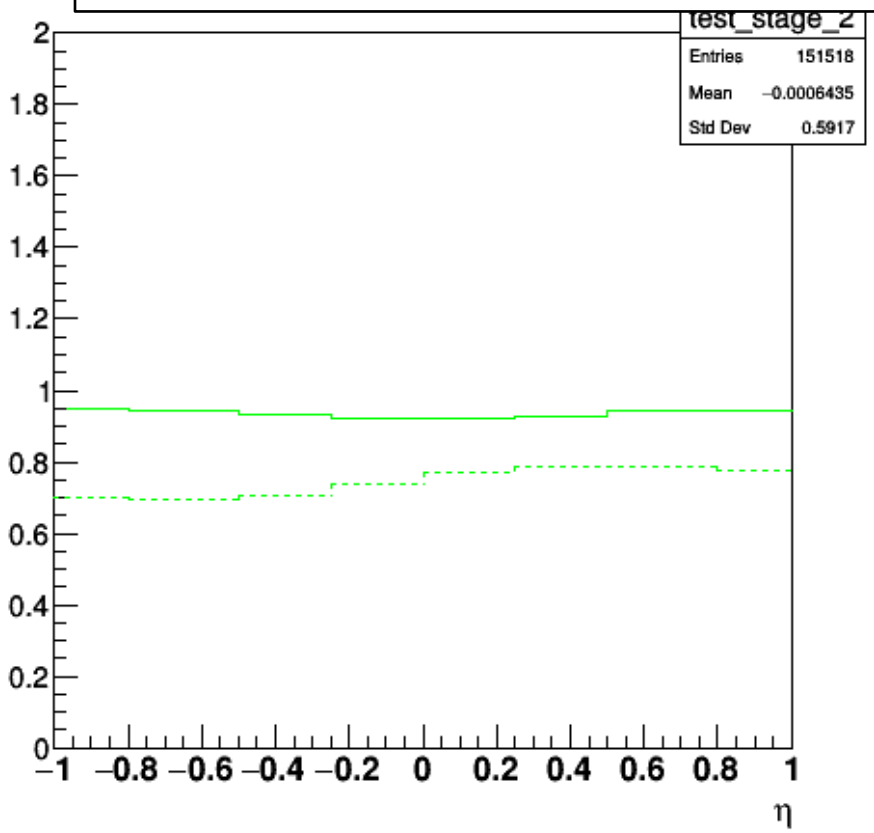


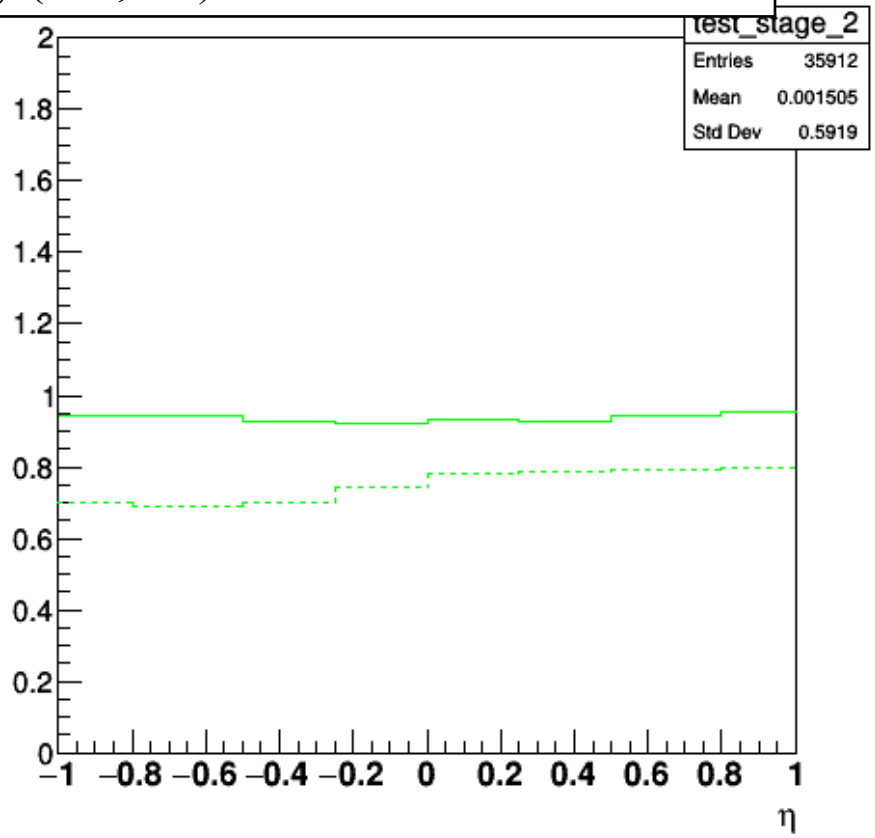




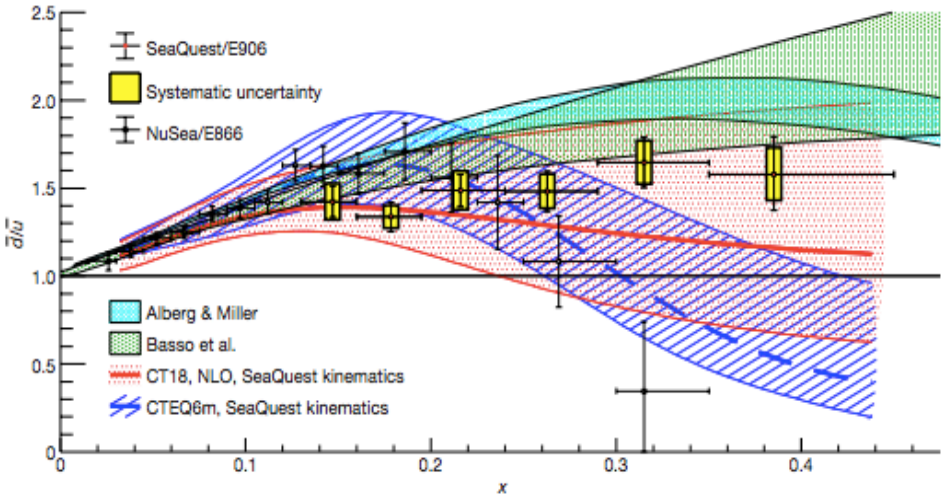


Vertex Efficiency (W+, W-)

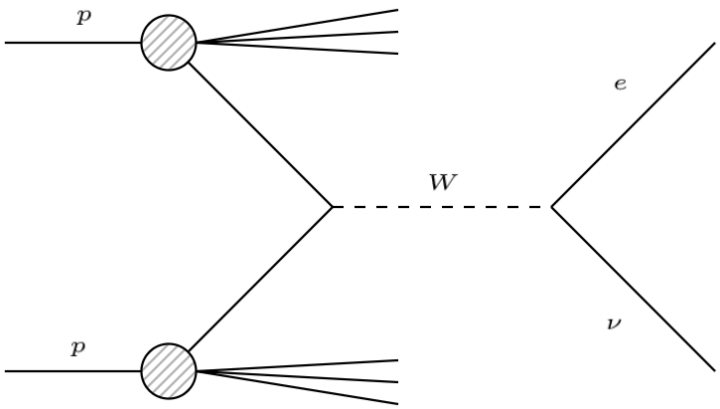




Motivation



- The unpolarized sea quark ratio $\bar{d}/\bar{u}$
  - Traditionally measured via Drell-Yan
  - Conflict between measurements around the valence region.
  - STAR kinematics at the mid-rapidity ($|\eta| < 1$) is sensitive to the region $0.1 < x < 0.3$.
  - Can be further stretched to $0.06 < x < 0.4$ with EEMC.

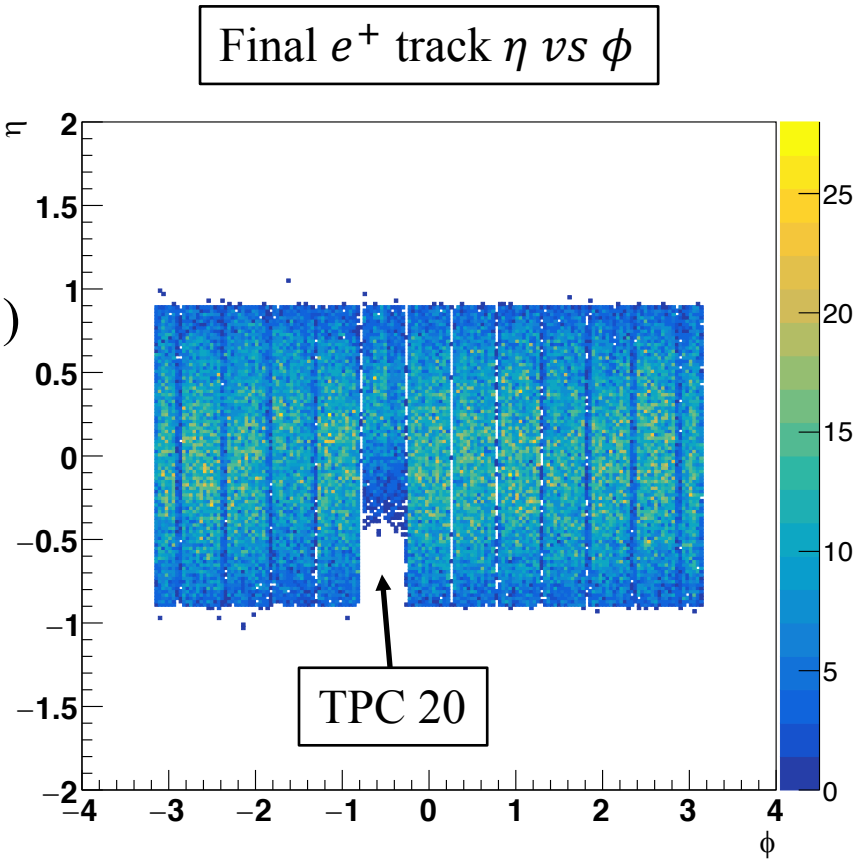


- W production at STAR
  - Sensitive to $u\bar{d}$ (W^+) and $\bar{u}d$ (W^-) at leading order;
  - The cross section ratio $\sigma_{W^+}/\sigma_{W^-}$ can be used to probed $\bar{d}/\bar{u}$;

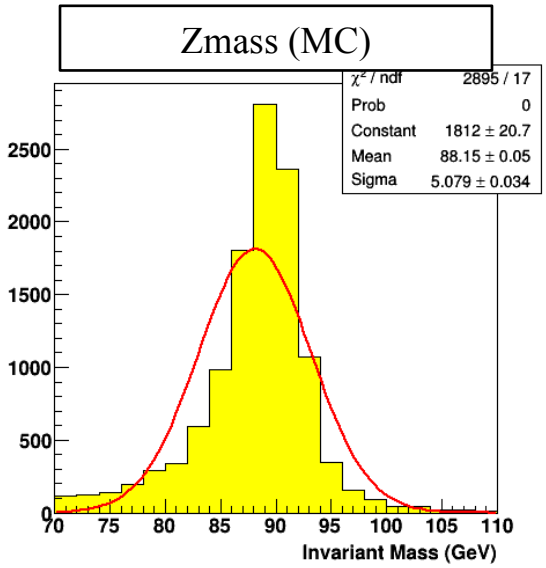
$$\sigma_{W^+}/\sigma_{W^-} \approx \frac{u(x_1)\,\bar{d}(x_2) + u(x_2)\,\bar{d}(x_1)}{\bar{u}(x_1)\,d(x_2) + \bar{u}(x_2)\,d(x_1)}$$

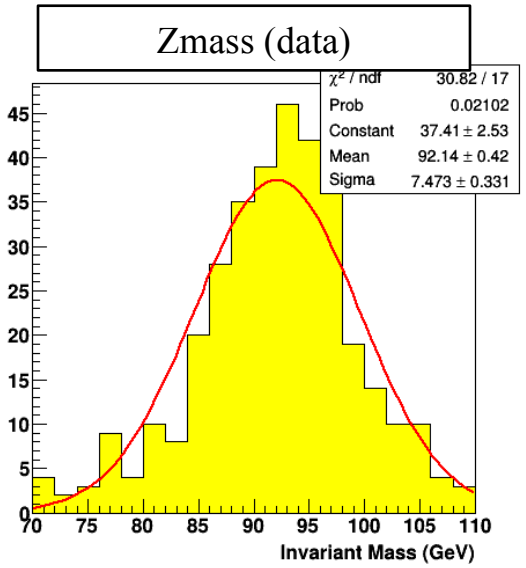
Data and MC

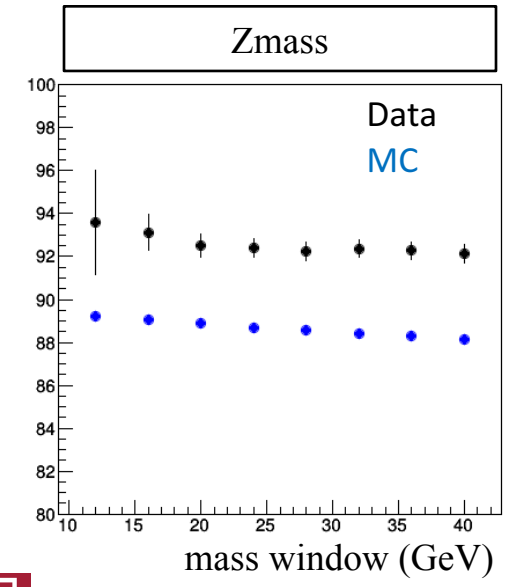
- Data
  - P20ic (w/ final BEMC calibration)
  - $\int L\,dt = 347\,pb^{-1}$ (2604 runs)
- MC
  - Official samples: ($W \to e\nu$, $Z \to ee$)
  - Private sample: ($W \to \tau\nu$)
- Detector space
  - TPC sector 20 has been masked out for both MC and data.
  - The current measurement focuses on the barrel region ($|\eta| < 1$).

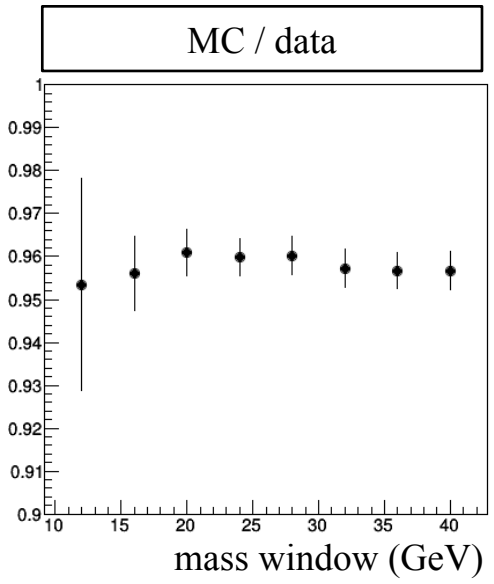


BEMC gain correction









- EMC calibration gains are corrected at the analysis stage based on Z mass mean.
  - For Run 17, a correction of -4.2% has been applied to BEMC gain for data.
  - Larger than the uncertainty of the BEMC calibration (~3%).

- It was found that this different is resistant to the mass window of the fit.
  - Immediate solution for this analysis may be to observe the difference in the cross section ratio measurement with and without the gain correction.

W candidate selection

- Kinematic selection
  - $25 < E_{T,cl}/GeV < 50$
  - $|\eta| < 1$
  - $p_{T,trk} > 10\ GeV$
- Event selection
  - Large imbalance in p_T due to final state neutrino.
  - $\vec{p}_{T,bal} = -\sum \vec{p}_T$
  - $sp_{T,bal} = \vec{p}_{T,bal} \cdot \frac{\vec{p}_{T,cl}}{E_{T,cl}}$
- Electron isolation
  - Energy confined in a small space.
  - $E_{T,cl} = E_T^{2\times2}$
  - $E_T^{near} = E_{T,jet}^{\Delta R<0.7}$

Vertex	Rank > 0
	$\|z\| < 100\ cm$
Track	$p_T > 10\ GeV$
	$N_{hits} > 15$
	$N_{hits}/N_{pos} > 0.51$
Electron	$E_T^{2\times2}/E_T^{near} > 0.82$
	$E_T^{2\times2}/E_T^{4\times4} > 0.96$
W	$\left\|Q\times\frac{E_T}{p_T}\right\| < 3.0$
	$sp_{T,bal} > 16\ GeV$
	$25 < E_{T,cl} < 50\ GeV$
	$E_{T,away} < 11\ GeV$

Cross section ratio

- Cross section of a process is often expressed as:

$$\sigma = \frac{N}{\int L\, dt} = \frac{N_{obs}}{\epsilon \int L\, dt}$$

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

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

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

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

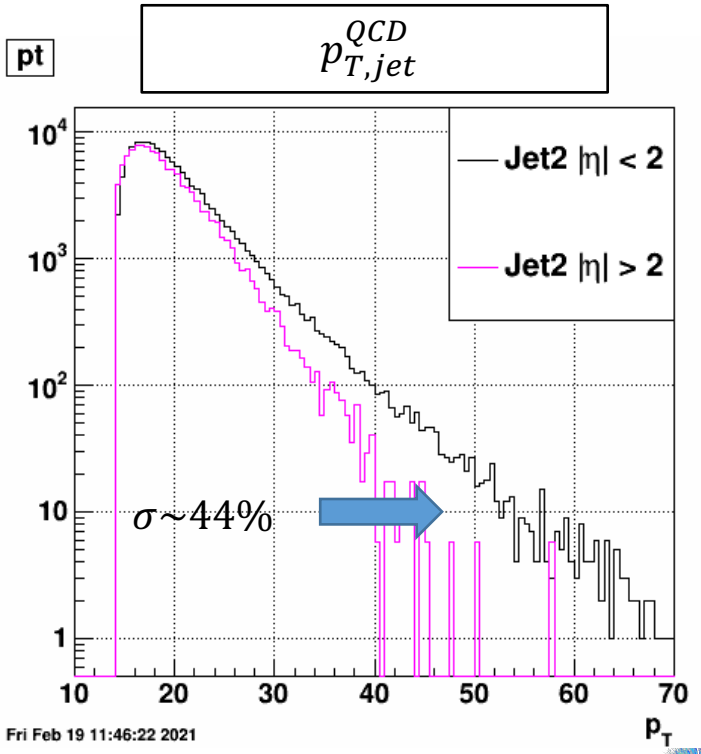
- N_{bg} represents the sum of all remaining background contributions.

$$N_{bg} = N_{W\to\tau\nu} + N_{Z\to ee} + N_{QCD} + N_{EEMC}$$

QCD Background

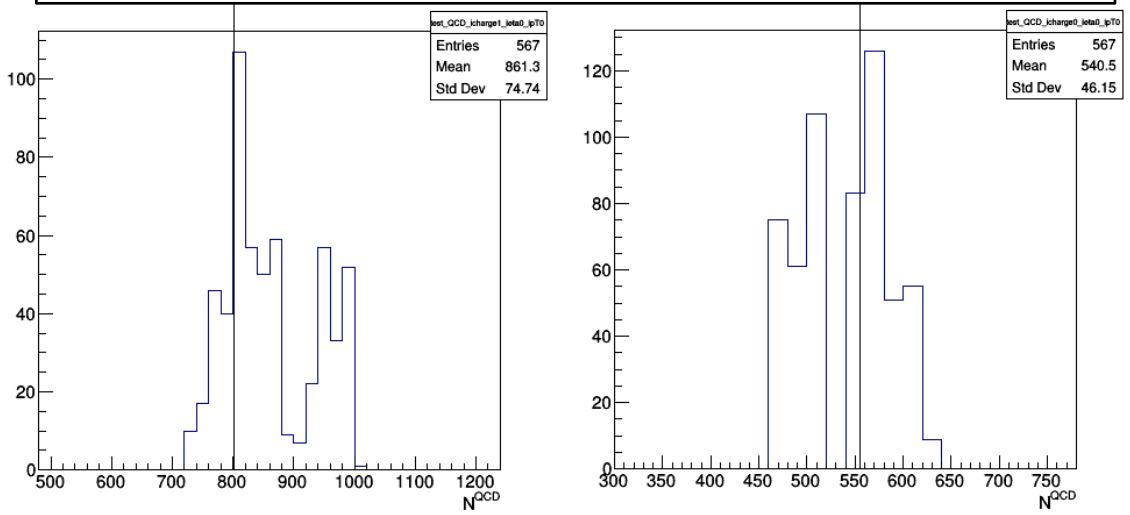
- QCD background has been estimated by;
  - Shape: W candidates that fail $sp_{T,bal}$ cut
  - Normalization: Discrepancy between data and MC (incl. BG) within a window $16 < E_{T,cl} < 21$.

- Systematics
  - Background description δ_{QCD}^{bg}:
    - The uncertainty associated with the QCD background description in terms of its shape and normalization has been tested by varying $sp_{T,bal}$ cut from 5 GeV to 25 GeV (nominal = 16 GeV) and the upper limit of $E_{T,cl}$ window from 18 GeV to 25 GeV.
  - Missing dijet δ_{QCD}^{dijet}:
    - Dijet events are neglected when one of the two jets is outside the detector acceptance region.
    - A Pythia study was done to estimate the effect.

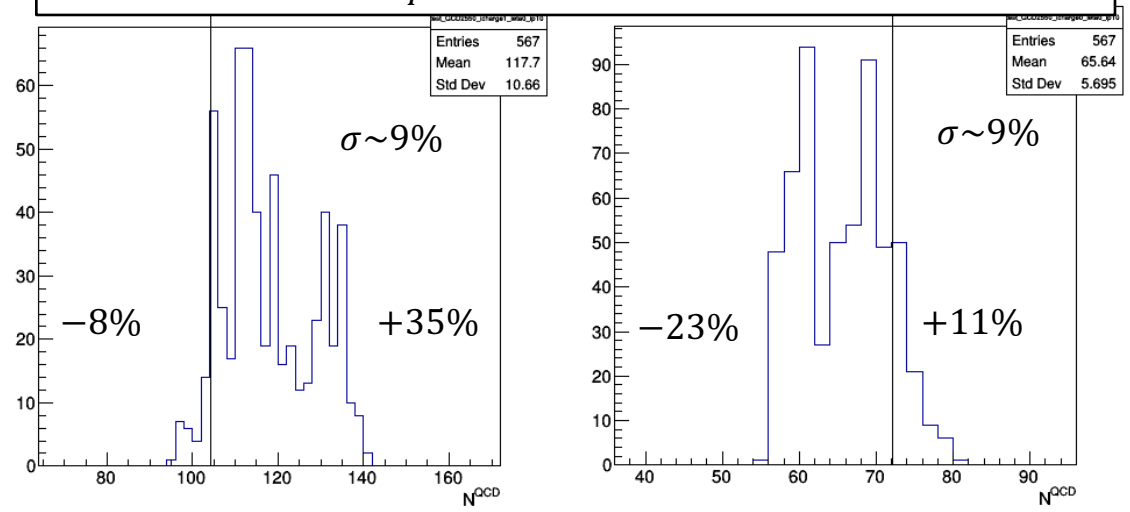


Systematics (QCD Background)

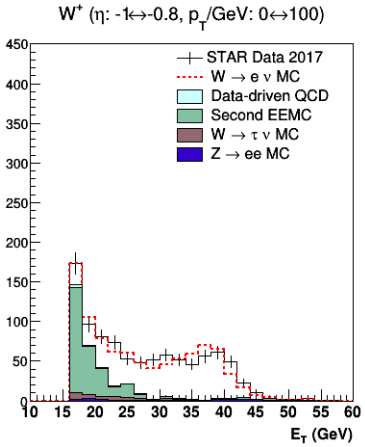
N^{QCD} (left: W^+ right:W^-)

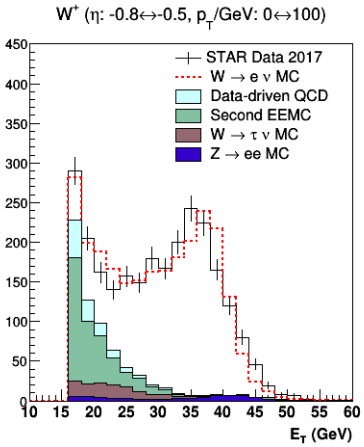


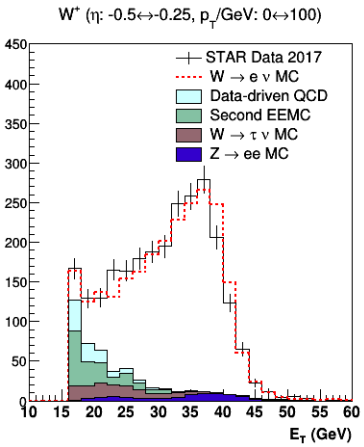
$N^{QCD}_{25<E_T<50}$ (left: W^+ right:W^-)

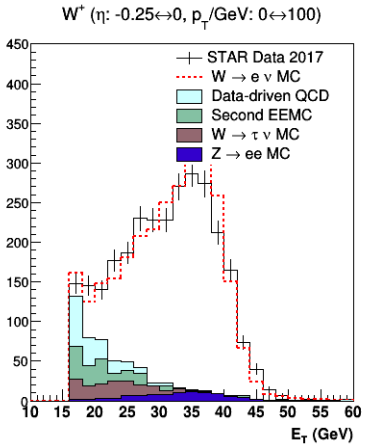


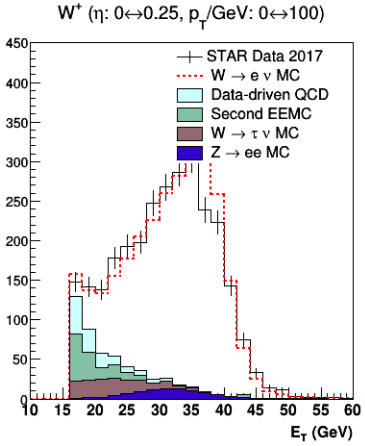
W+

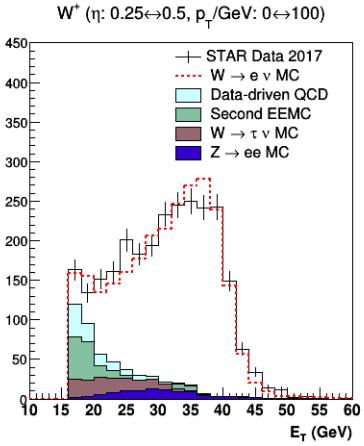

W+ (η: -1↔-0.8, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

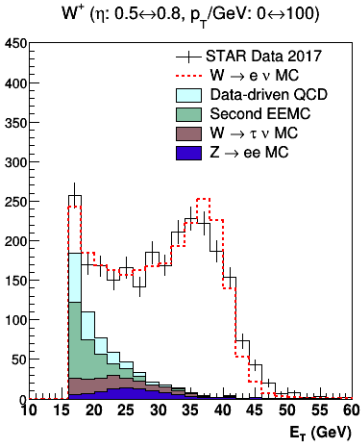

W+ (η: -0.8↔-0.5, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

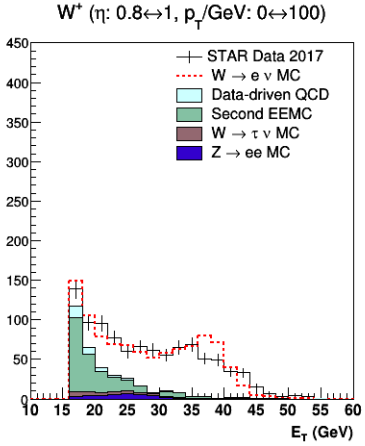

W+ (η: -0.5↔-0.25, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)


W+ (η: -0.25↔0, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

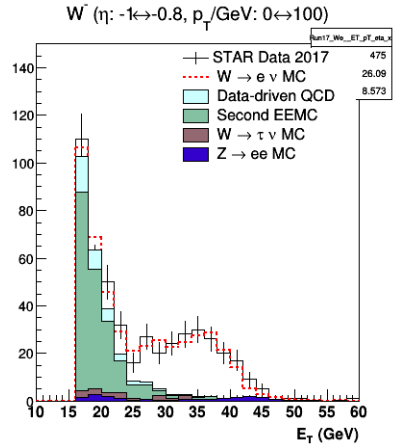

W+ (η: 0↔0.25, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

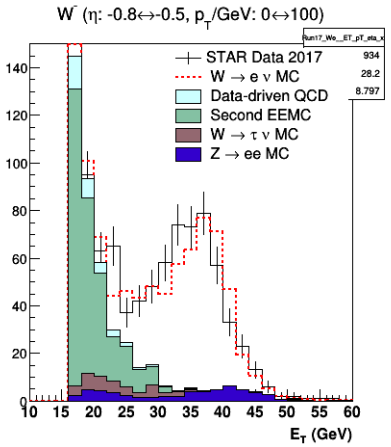

W+ (η: 0.25↔0.5, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

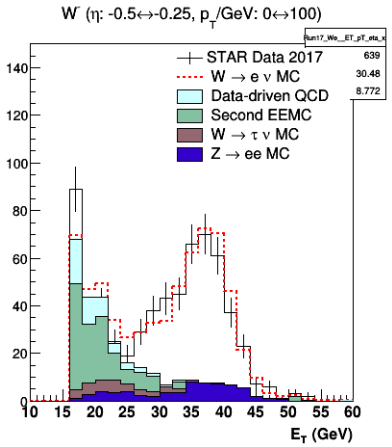

W+ (η: 0.5↔0.8, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

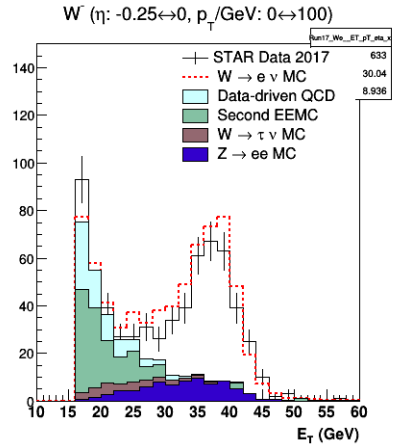

W+ (η: 0.8↔1, pT/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
ET (GeV)

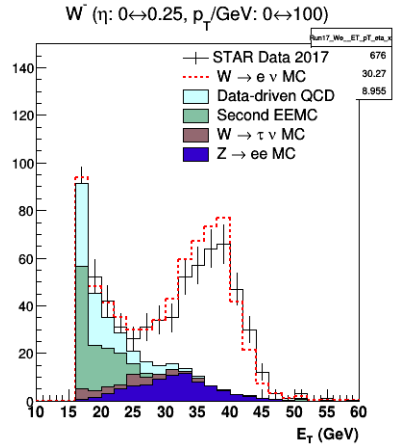
W-

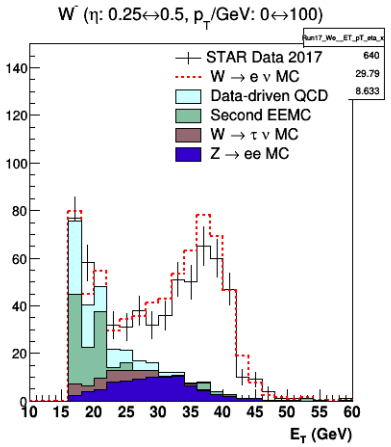

W⁻ (η: -1↔-0.8, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

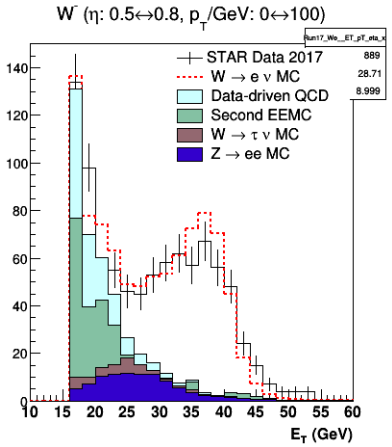

W⁻ (η: -0.8↔-0.5, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

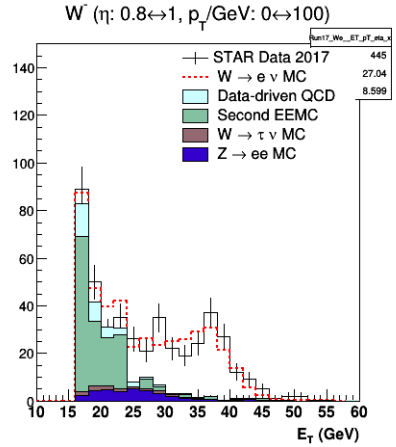

W⁻ (η: -0.5↔-0.25, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)


W⁻ (η: -0.25↔0, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

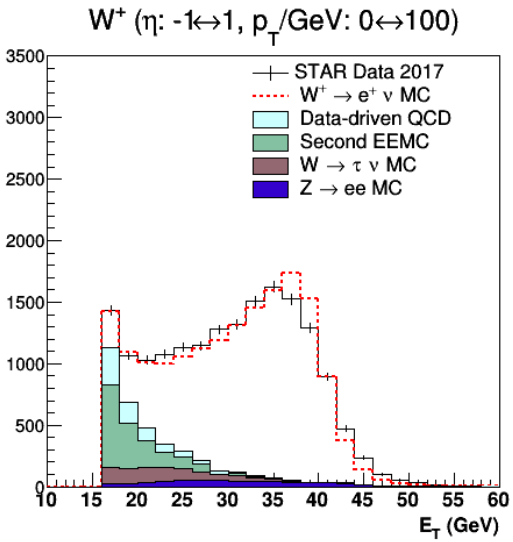

W⁻ (η: 0↔0.25, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

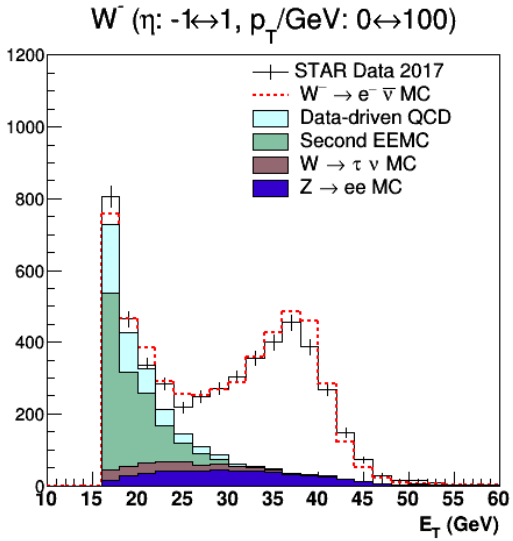

W⁻ (η: 0.25↔0.5, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

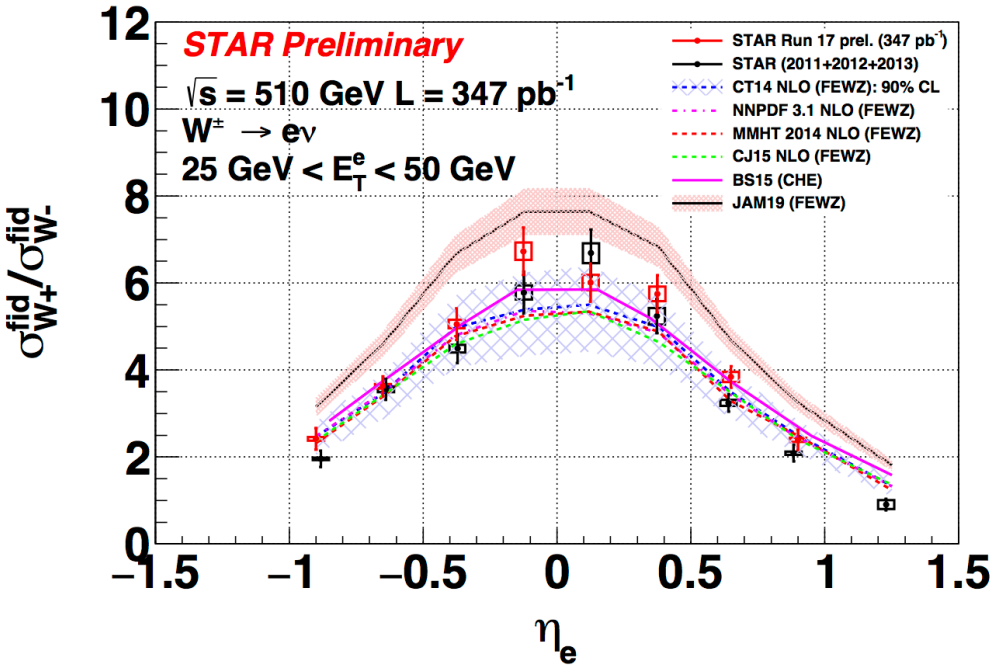

W⁻ (η: 0.5↔0.8, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)


W⁻ (η: 0.8↔1, p_T/GeV: 0↔100)
STAR Data 2017
W → e ν MC
Data-driven QCD
Second EEMC
W → τ ν MC
Z → ee MC
E_T (GeV)

Results







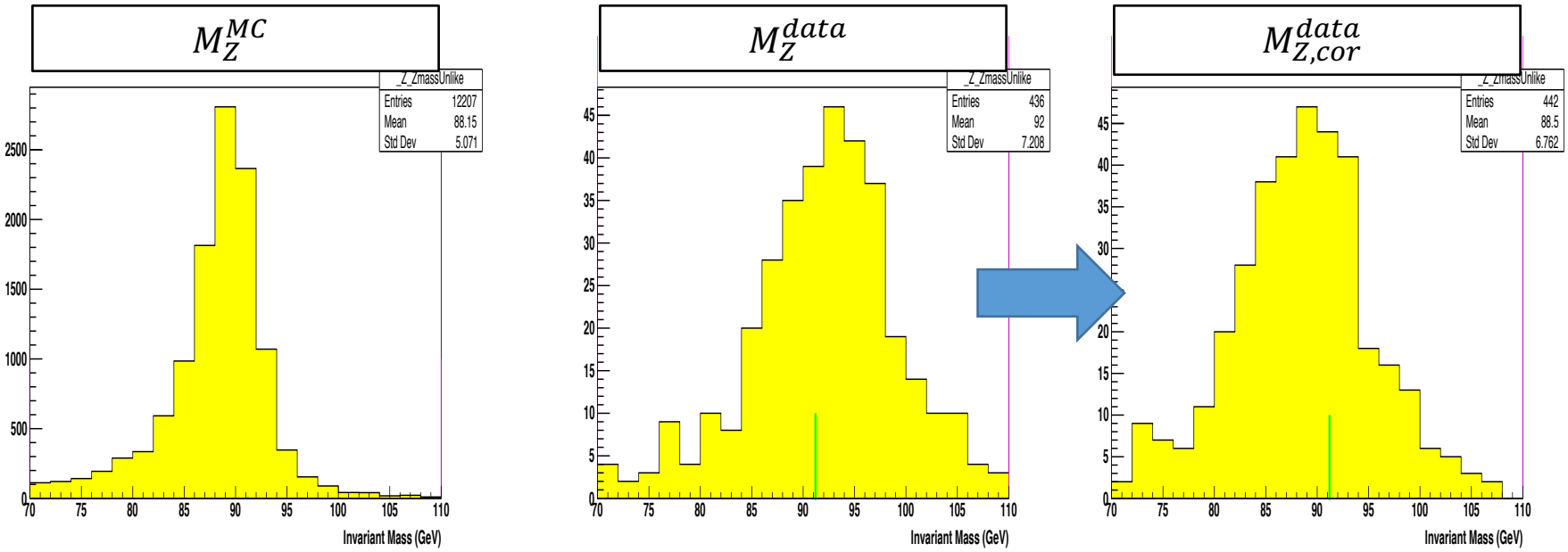
η-bin	σ^+/σ^-	δ_{stat}	δ_{syst}
$-1.0 < \eta < -0.8$	2.42	0.24	0.04
$-0.8 < \eta < -0.5$	3.63	0.23	0.05
$-0.5 < \eta < -0.25$	5.06	0.36	0.10
$-0.25 < \eta < -0.0$	6.73	0.54	0.20
$0 < \eta < 0.25$	6.01	0.43	0.18
$0.25 < \eta < 0.5$	5.75	0.43	0.17
$0.5 < \eta < 0.8$	3.84	0.25	0.12
$0.8 < \eta < 1.0$	2.40	0.23	0.05

Systematic uncertainties

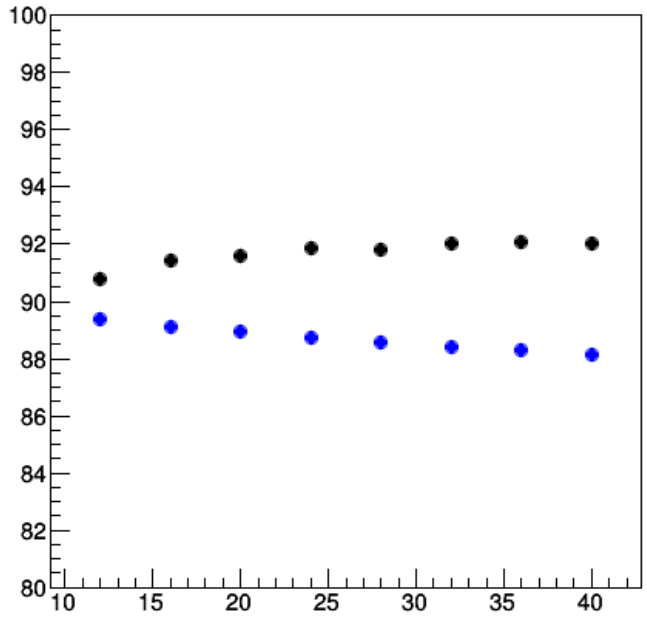
η bin	1	2	3	4	5	6	7	8
$\delta_{\Delta\epsilon}(\%)$	0.3	1.0	0.5	1.0	1.0	0.4	0.7	0.4
δ_{BEMC}^{high} (%)	0.2	0.0	0.0	0.0	-0.1	0.0	-0.4	0.3
δ_{BEMC}^{low} (%)	0.2	0.3	-0.3	-0.2	-0.2	-0.3	0.0	0.5
δ_{QCD}^{bg} (%)	0.3	0.3	0.6	0.7	0.5	0.6	0.6	0.5
δ_{QCD}^{dijet}	44% of N_{bg}^{QCD}							

⇐ 1% was used

BEMC gain correction



- EMC calibration gains are corrected at the analysis stage based on Z mass mean.
  - For Run 17, a correction of -4.2% has been applied to BEMC gain for data.


100
98
96
94
92
90
88
86
84
82
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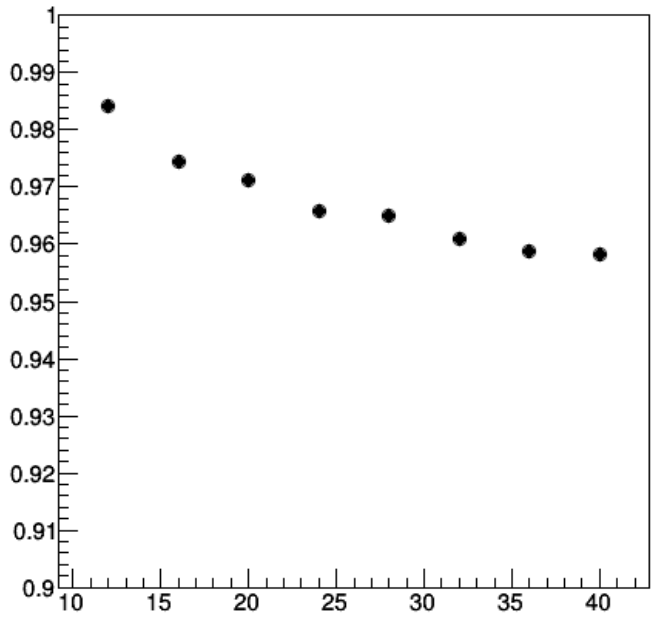
40


1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
10
15
20
25
30
35
40