Constraining the Sea Quark Distributions Through $W^{\pm}$ Cross Section Ratio Measurements at STAR

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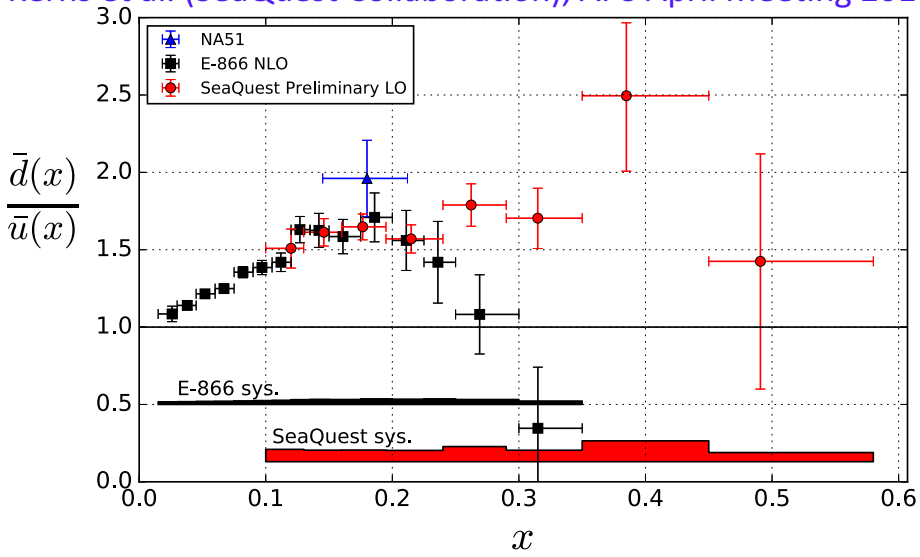
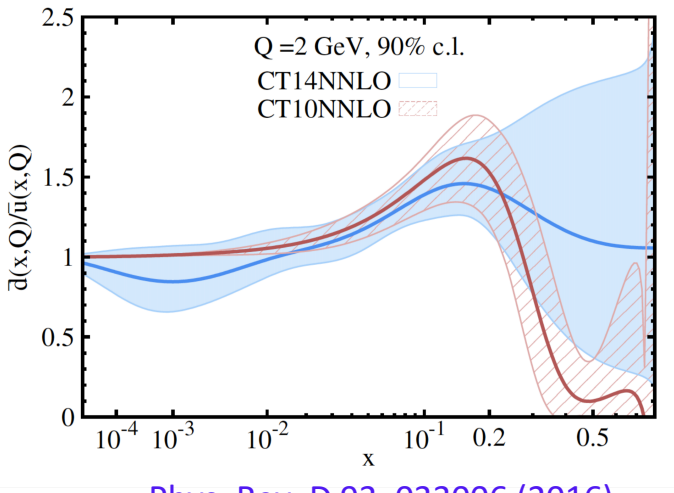
Theory

- Unpolarized **dbar/ubar** distribution can be probed via Drell-Yan scattering.
- **E-866** measured this ratio and found it to fall below one at **high x** (~0.3)
- **SeaQuest** recently extended the **dbar/ubar** measurement to **higher x**.
- **E-866** and **SeaQuest** appear to find different distributions.
- More direct and indirect data is needed at **high-x** to help **constrain** the distribution.

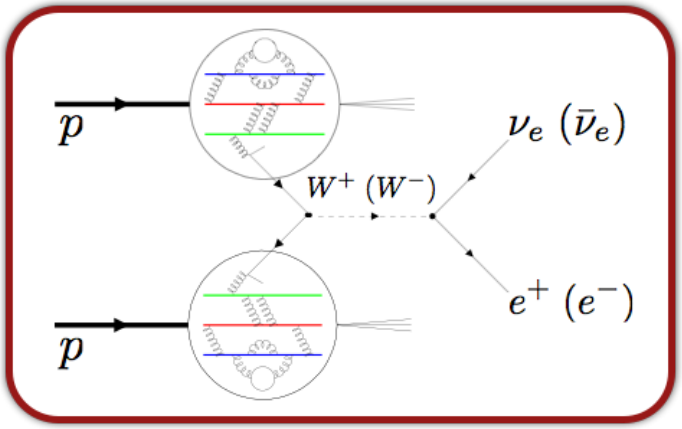
B. Kerns et al. (SeaQuest Collaboration), APS April Meeting 2016.





Phys. Rev. D 93, 033006 (2016)

W Boson Production Through p+p Collisions



- **W bosons** are **sensitive** to **quark/anti-quark** distributions. They can be accessed via the W leptonic decay channels in **proton + proton** collisions
  - $u + \bar{d} \rightarrow W^+ \rightarrow e^+ + \nu$
  - $d + \bar{u} \rightarrow W^- \rightarrow e^- + \bar{\nu}$

- The **charged W cross-section ratio**
  - is proportional (at LO) to the **dbar/ubar** ratio
  - can be used to **constrain** the **sea quark distributions**

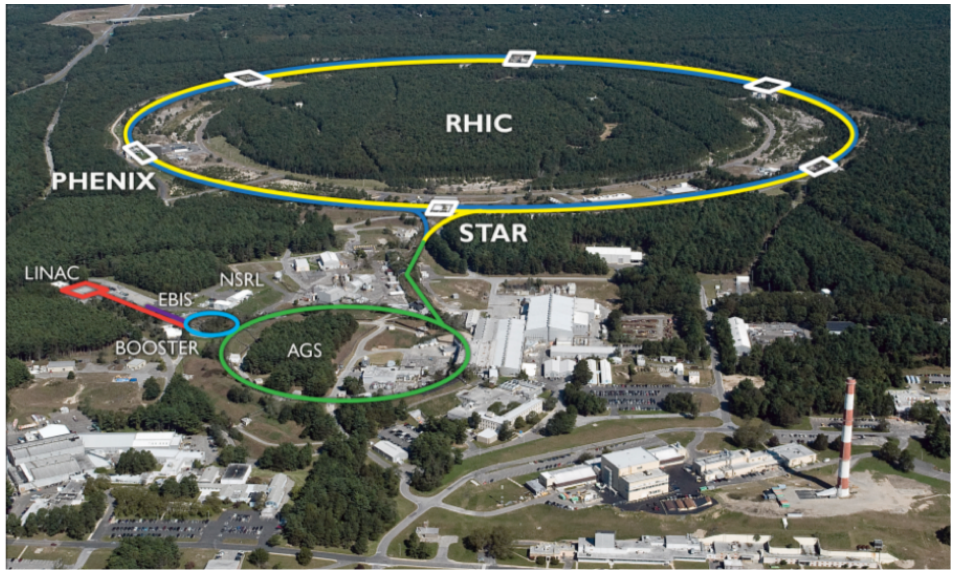
$$\frac{\sigma_{W^+}}{\sigma_{W^-}} \approx \frac{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}{\bar{u}(x_1)d(x_2) + \bar{d}(x_1)u(x_2)}$$

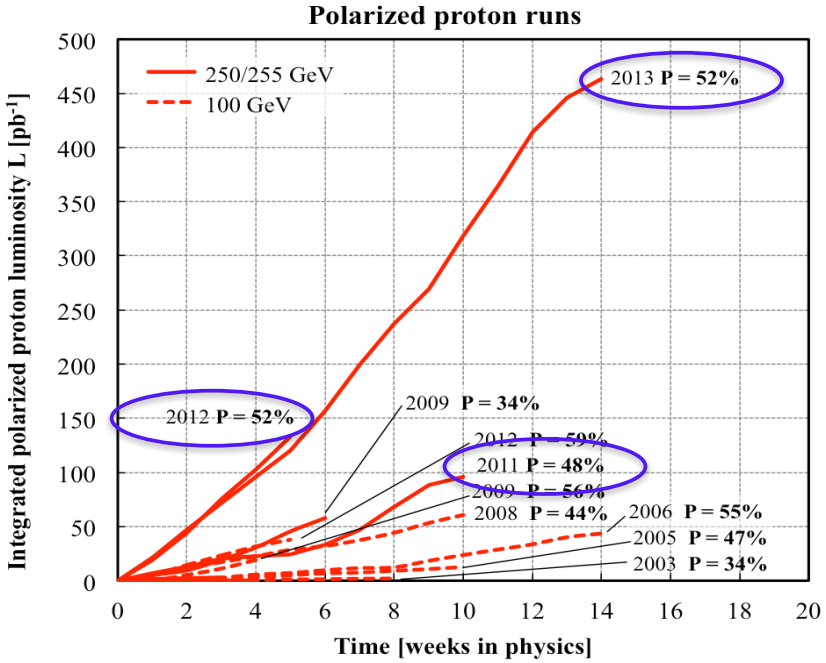
$$\frac{\sigma_{W^+}}{\sigma_{W^-}} = \left(\frac{N_O^+ - N_B^+}{N_O^- - N_B^-}\right)\left(\frac{\epsilon^-}{\epsilon^+}\right)$$

- +/- is positron/electron from W leptonic decay
- N_O is number of observed W events
- N_B is number of background events
- ε is the measured W efficiency

Relativistic Heavy Ion Collider

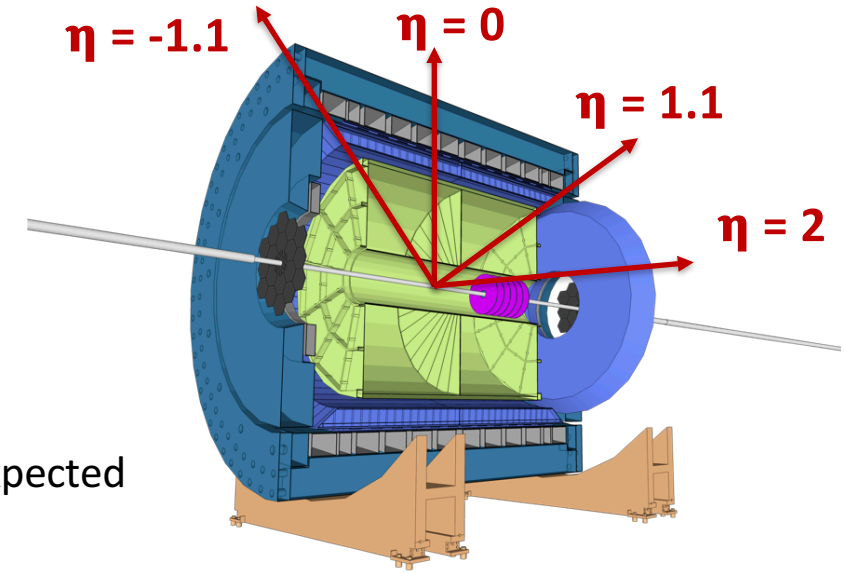
- **RHIC** is the world's first polarized hadron collider
- Over the past several years luminosity at **RHIC** has **steadily increased**





Solenoidal Tracker At RHIC

- **Calorimetry system** with 2π coverage
  - Barrel electromagnetic calorimeter (**BEMC**), $-1 < \eta < 1$
  - Endcap electromagnetic calorimeter (**EEMC**), $1.1 < \eta < 2$
- Time projection chamber (**TPC**), $|\eta| < 1.3$
- The **2017** (transverse p+p $\sqrt{s}$ = 510 GeV) run is expected to add ~**400 pb^{-1}** more data

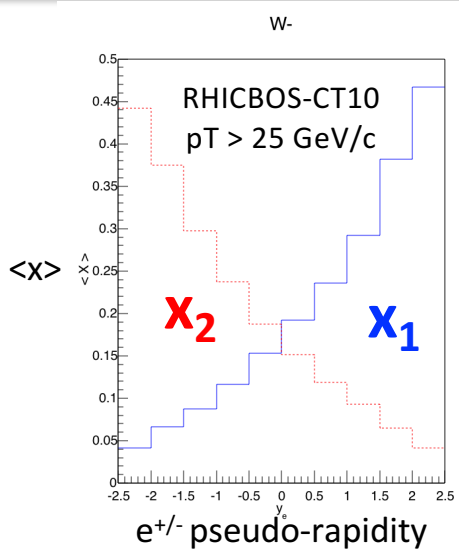


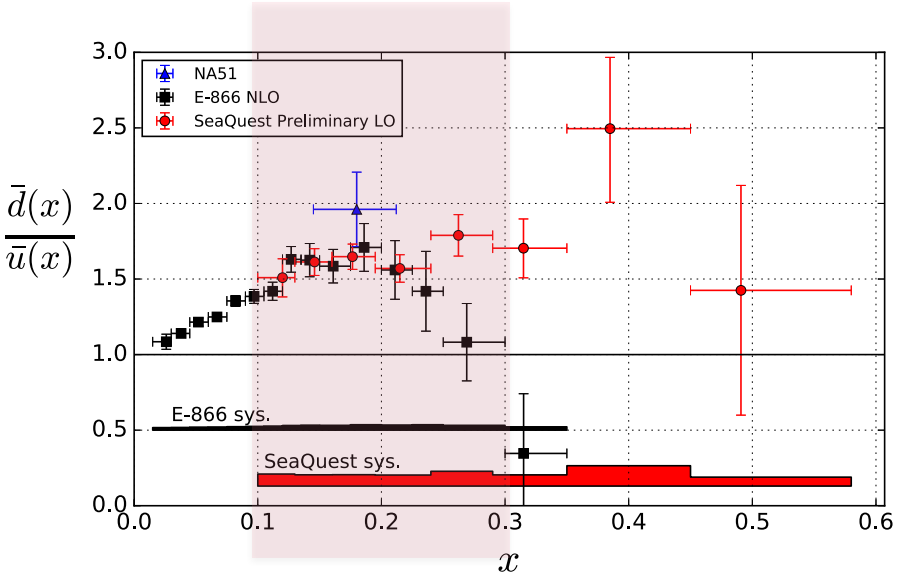
Production runs at **$\sqrt{s}$ = 500/510 GeV**

Year	~Luminosity (pb^{-1})
2011	25
2012	75
2013	250
2017	400 (expected)
Combined	**750**

STAR Kinematics

- Approximate kinematic range at STAR **mid-rapidity** (**TPC + BEMC**)
  - ➢ $0.1 < x < 0.3$ for $-1 < \eta < 1$
- For collision energies of $\sqrt{s}$ = 500 GeV and $\eta = 0$, ($x_1 \approx x_2$)
  - ➢ $x = M_W/\sqrt{s} = 0.16$





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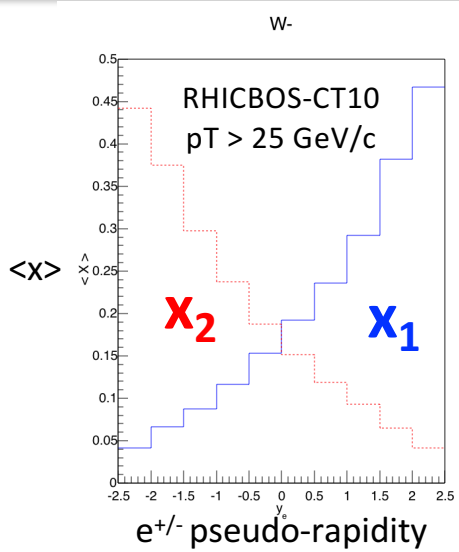
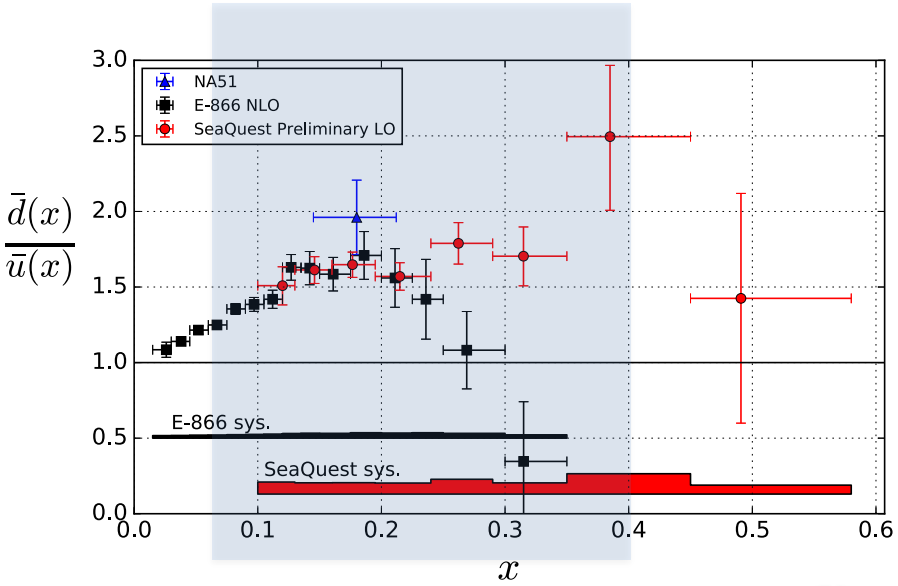
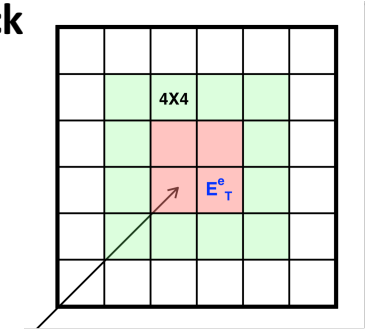
  - ➢ $x = M_W/\sqrt{s} = 0.16$
- In STAR the **EEMC** could be used to obtain a more forward eta-bin (**$1.1 < \eta < 2$**) which would extend the x reach of STAR
  - ➢ $0.06 < x < 0.4$ for $-2 < \eta < 2$
- Analysis of this **forward EEMC** eta-bin is currently underway



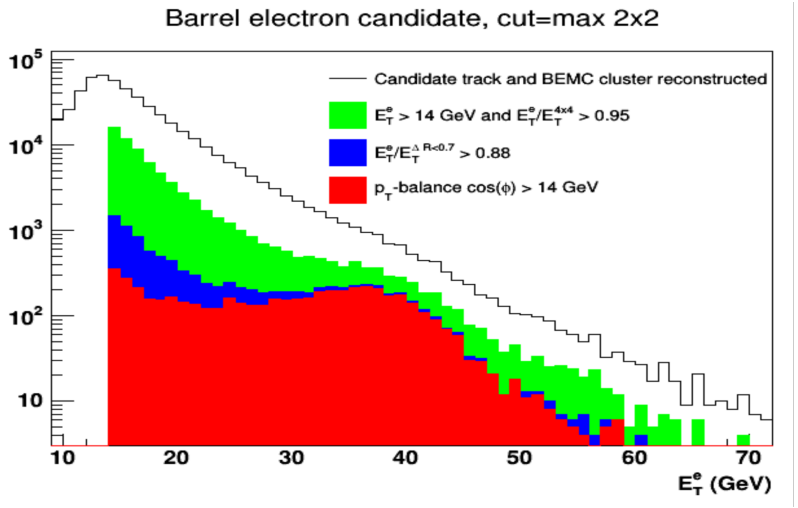


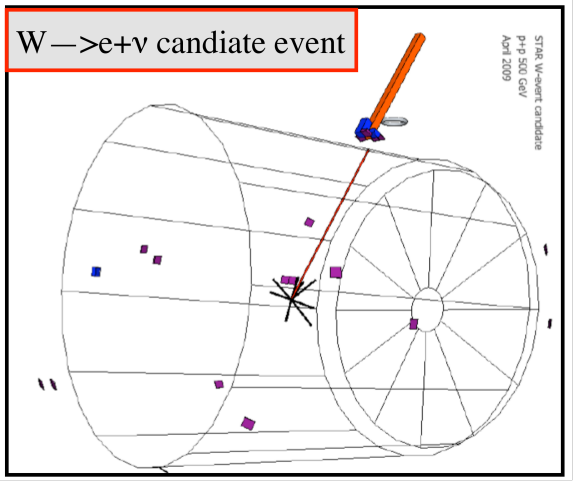
Selecting W Candidates

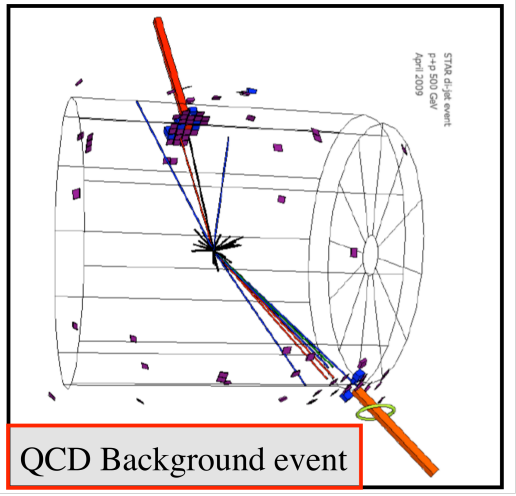
- Mid-rapidity STAR W selection criteria
  - **Match p_T > 10 GeV/c track to BEMC cluster**
  - **Isolation ratio 1 / Isolation ratio 2**
  - **p_T-balance cut**
  - **Leads to good charge discrimination**

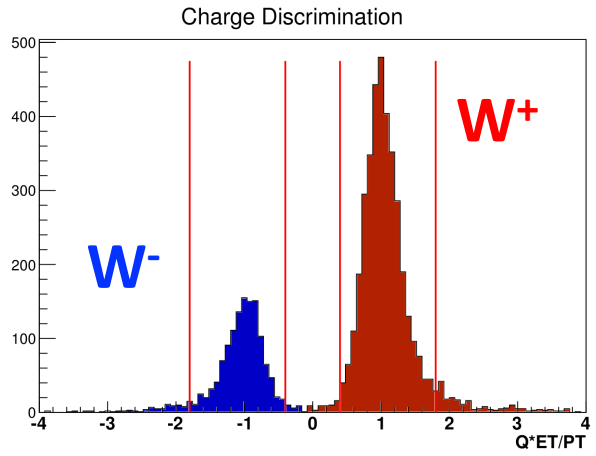


TPC track extrapolated to BEMC tower grid

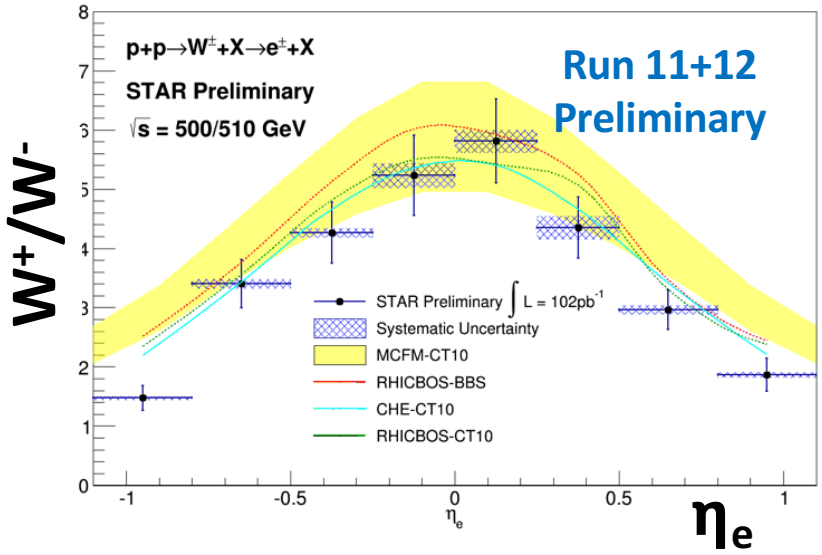


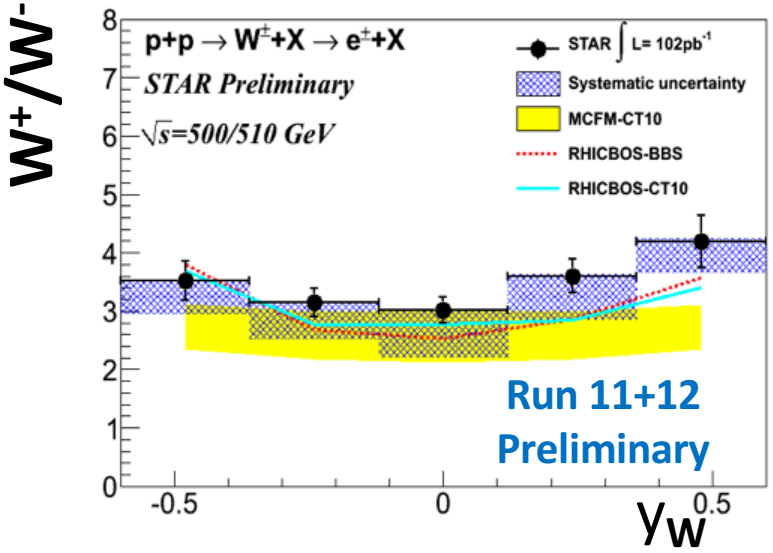






Charged W Cross Section Ratios

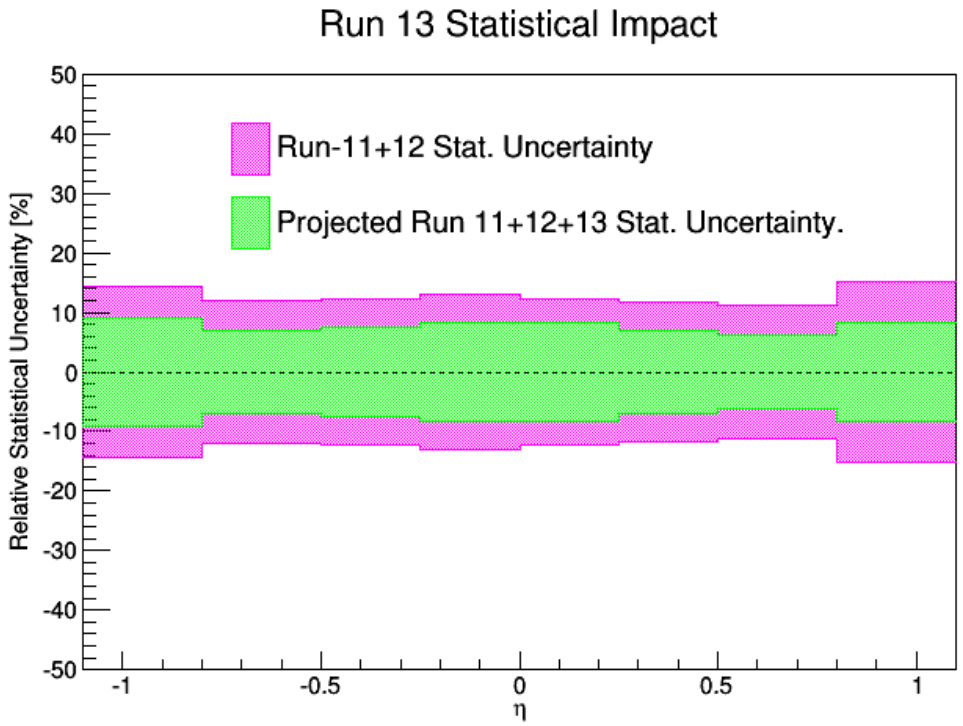




- **Run 11 + 12 preliminary result (~100 pb^{-1})**
- **Run 13** will add **~ 250 pb^{-1}**
- STAR **Run 17** is expected to add **~ 400 pb^{-1}** more data
- **Charge W cross-section ratio** vs. **lepton pseudo-rapidity** precision is dominated by statistics.
- The **W boson rapidity** can now also be reconstructed at STAR via its recoil. (Needed for run 11 transverse single-spin asymmetry measurement, **Phys.Rev.Lett. 116 (2016)**)
- Work is ongoing to improve the systematic uncertainty associated with the reconstructed **W boson rapidity**.

STAR Run 13 Statistical Impact

- **Run 13** will **significantly improve** the statistical precision of the STAR measured **W+/W- cross section ratio**.

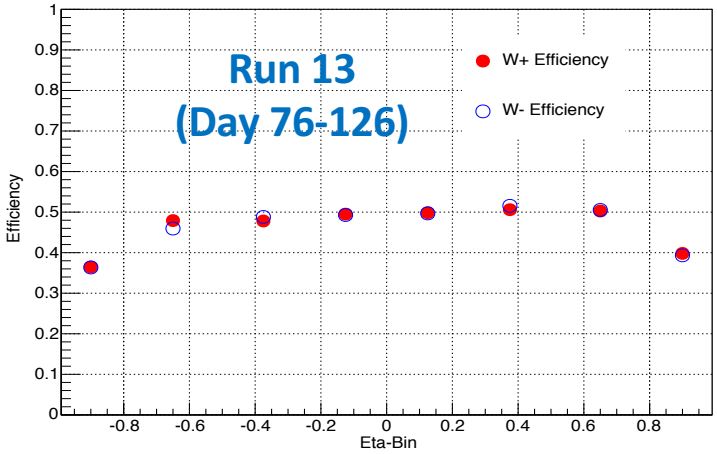


- Further improvement is expected from **Run 17** p+p 510 GeV data, with **~ 400 pb^{-1}** expected.

Run 13 Analysis Update

1) **Run 13** recently switched over to a new **tracking algorithm** which resulted in

- Higher track reconstruction efficiency at large luminosity
- W+ and W- efficiencies for **run 13** show **similar behavior** as those measured in run 12
- Average efficiency ~ 50%



2) The **BEMC** was calibrated using **run 13 p+p 510 GeV** data and is now applied to the ongoing **run 13** analysis (used in STAR 2013 W A_L Prelim. Results shown at INPC and SPIN 2016).

- Comparison of the Z mass between the data and MC show good agreement

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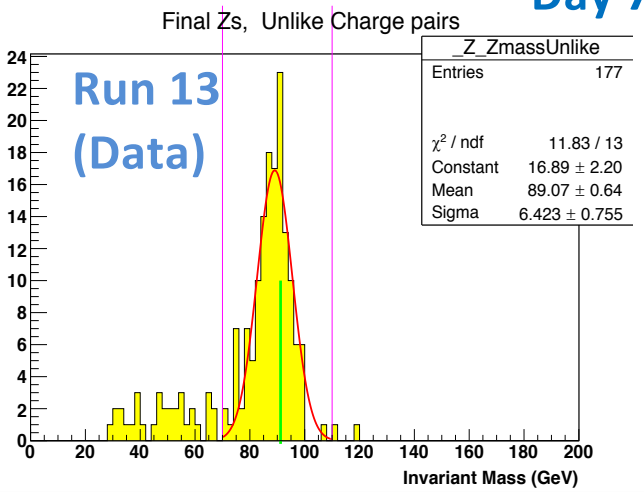
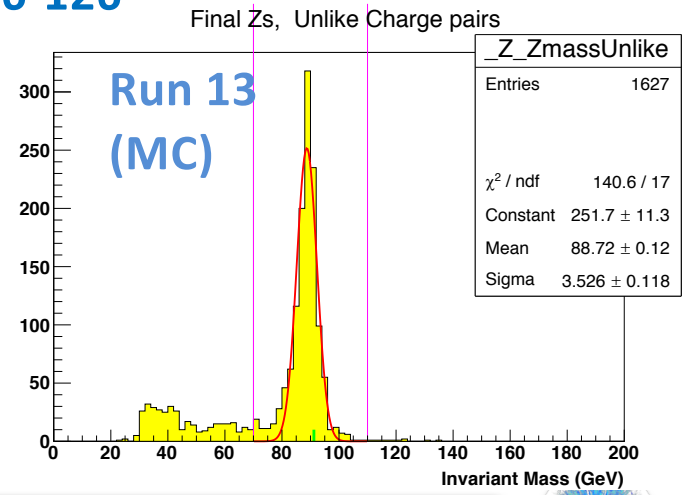


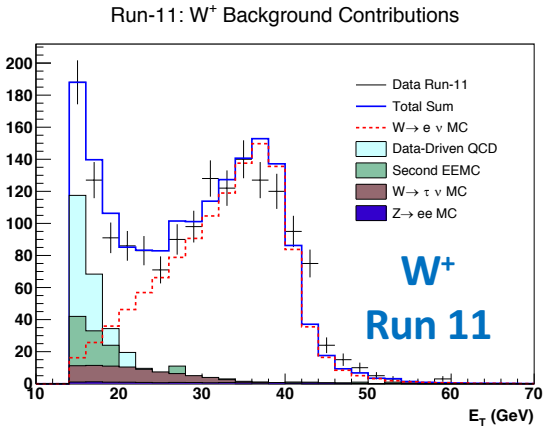


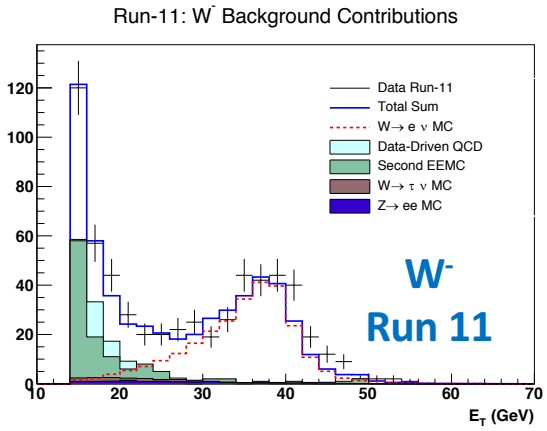
Summary

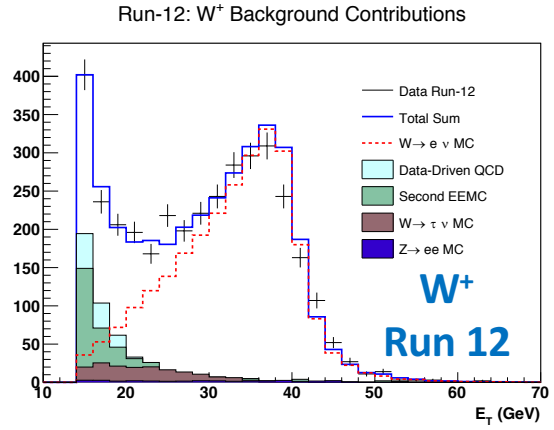
- **STAR** measured **cross-section ratio** using W production
  - A **complimentary** measurement to **SeaQuest** and **E-866**
  - Should help further **constrain** the **sea quark PDFs**
- **Preliminary results** of measured cross-section ratios using **Run 11 and 12** data sets have been released as a function of **lepton pseudo-rapidity** and **W boson rapidity**
- **Run 13** analysis now takes advantage of recently implemented
  - Barrel electromagnetic calorimeter calibration
  - Tracking algorithm
- **Run 13** data set **(~250 pb^{-1}**)to be included into the cross-section ratio measurement soon
- More **forward eta-bin (1.1 – 2.0)** looking to be added to the cross section ratio via the electromagnetic endcap
- Long 510 GeV **run in 2017** at transverse spin polarization of about **400 pb^{-1}** should further **improve** the charged W cross-section ratio precision.

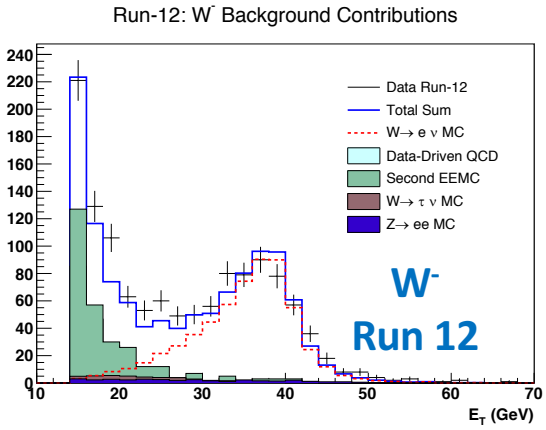
Mid-Rapidity $W^{+/-}$ Backgrounds

- **Data-driven QCD** backgrounds satisfy $e^{+/-}$ isolation cuts
- **Second EEMC backgrounds** result from backward ("Jet") at non-existing calorimeter coverage for $-2 < \eta < -1.1$
- **Second EEMC backgrounds** are estimated from EEMC located at $1.1 < \eta < 2$
- **Electro-weak background** from Z decay is done with PYTHIA/MC simulations.
- Small background contribution from Z decay.

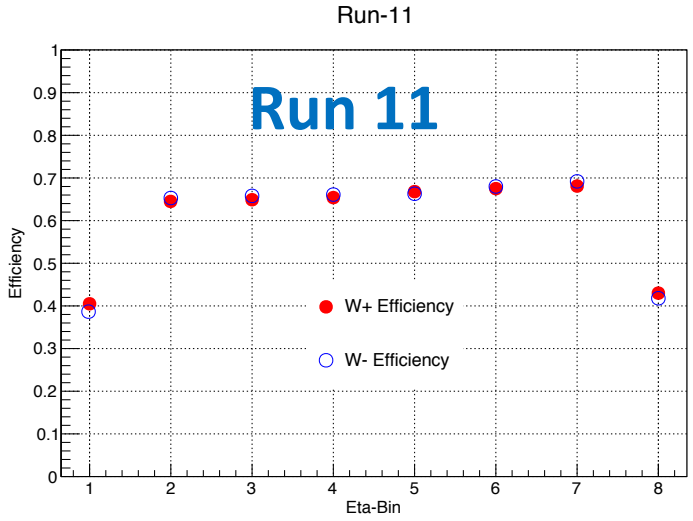


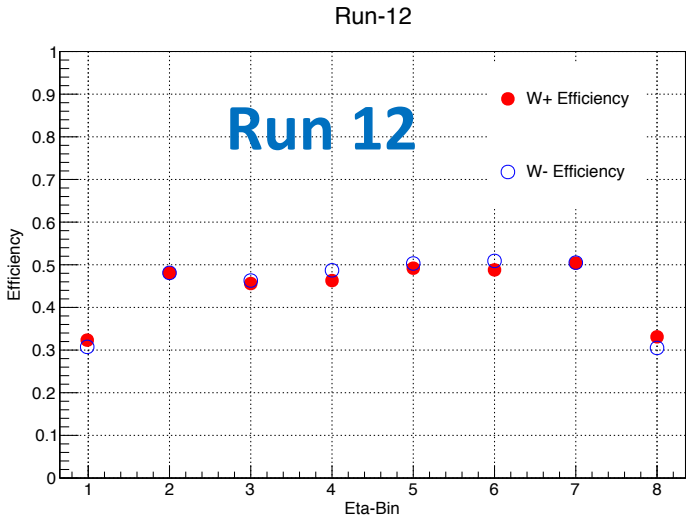






$W^{+/-}$ Efficiencies (Runs 11 and 12)





- **2012** running had lower $W^{+/-}$ efficiencies due to **higher luminosity** running.
- This lead to **more pile-up** in the TPC, which resulted in **less efficient** track reconstruction.
- **Minimal charge dependence** leads to small contribution to the charged W cross-section ratio