Constraining Sea Quark Distributions Through W+/- Cross Section Ratios Measured at STAR

Matthew Posik
Temple University

for the **STAR** Collaboration

DIS 2015
Dallas, TX
April 27-May 1, 2015

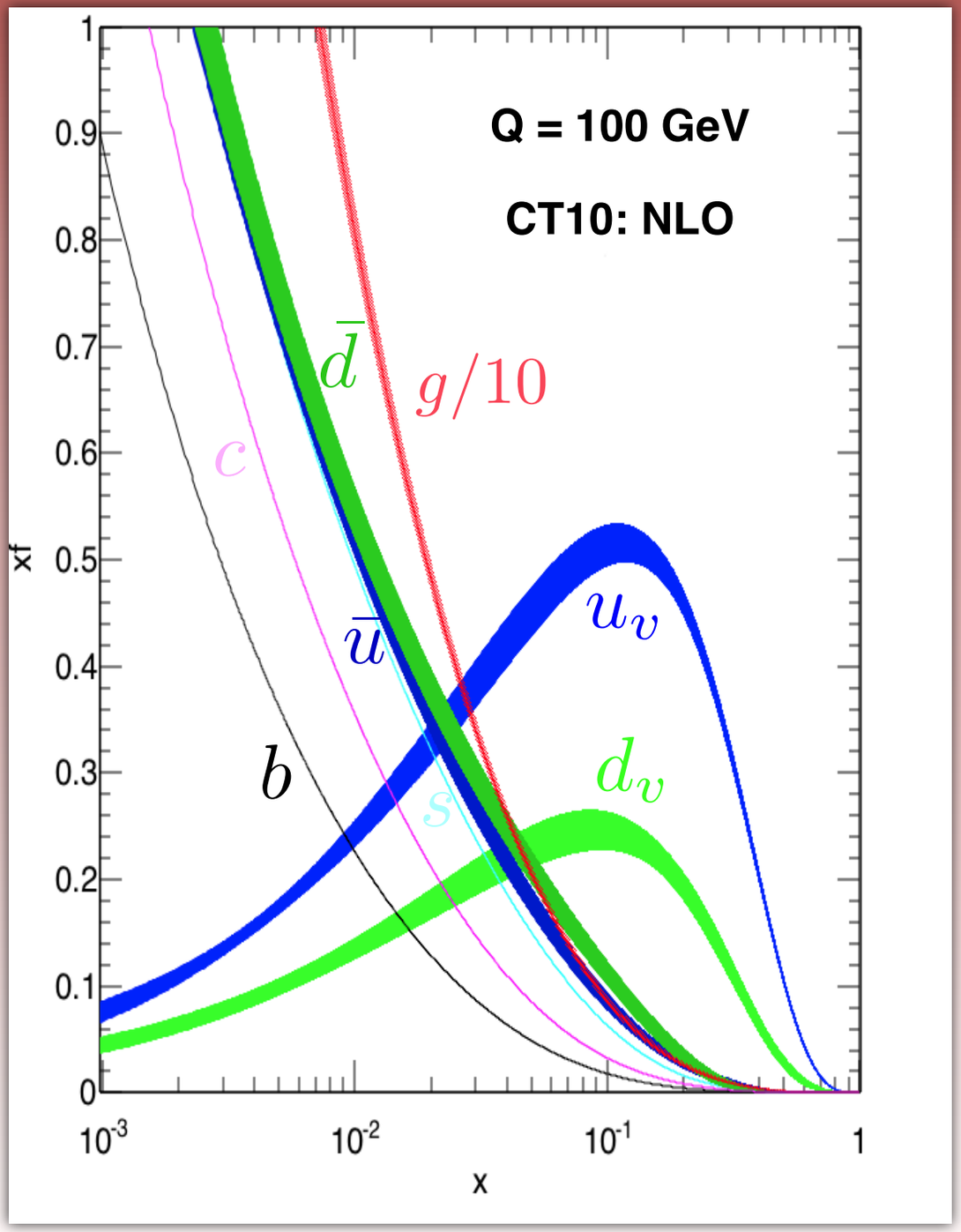
Outline

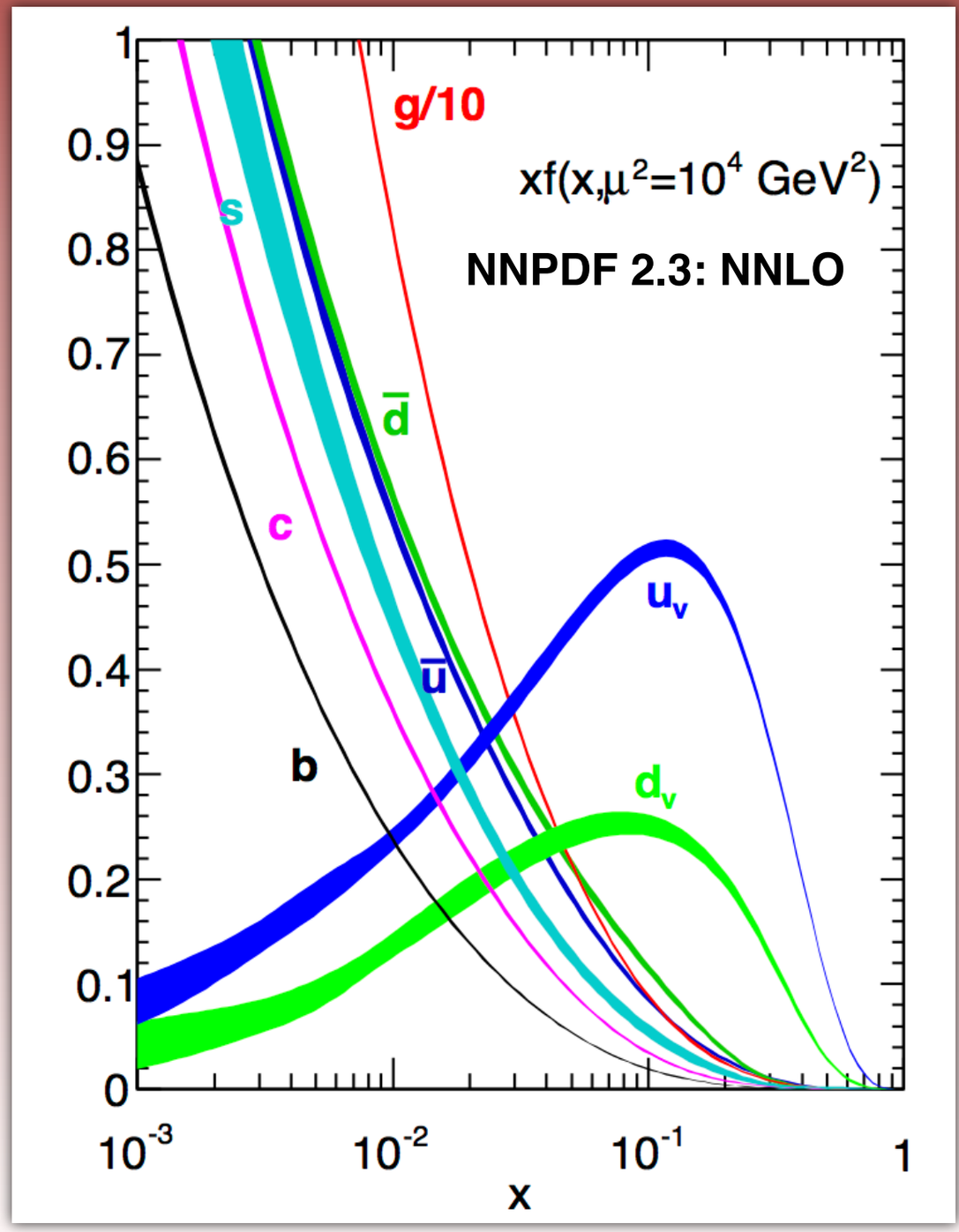
- Motivation
- Experimental Aspects
- Recent Preliminary Results

Outline

- **Motivation**
- **Experimental Aspects**
- **Recent Preliminary Results**

Current Unpolarized PDFs

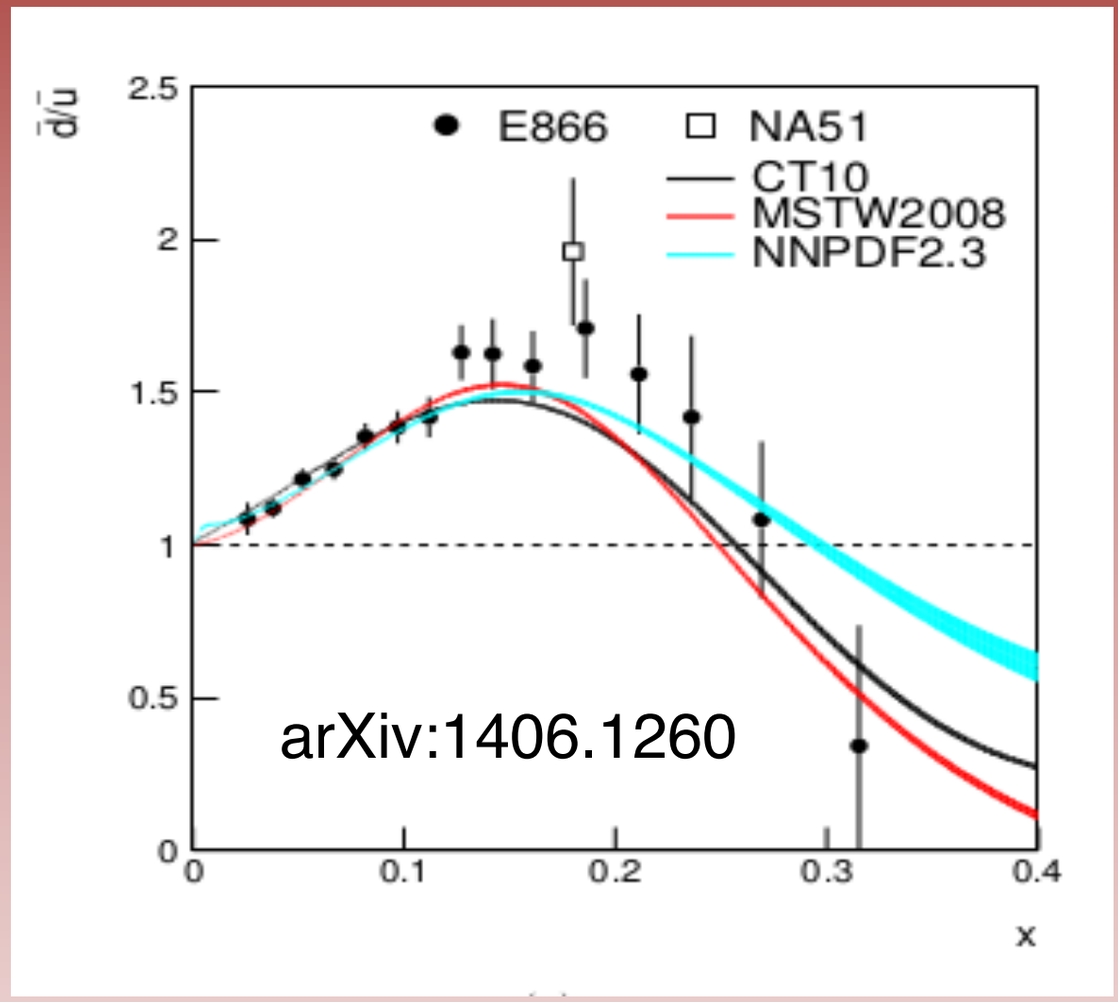




nnpdf.hepforge.org

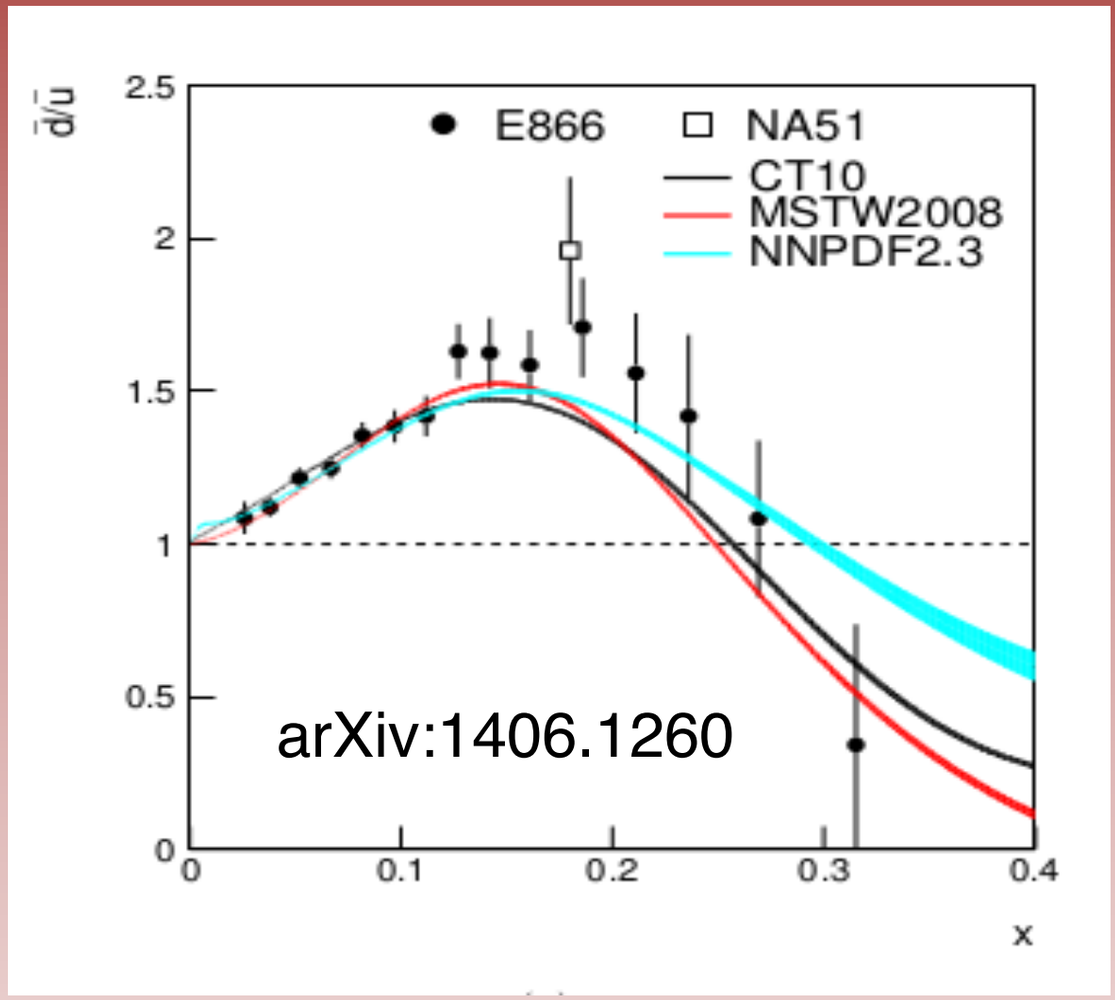
Unpolarized Sea Quark Distributions

- **Unpolarized** sea quarks currently have **large uncertainties** near the **valence region**.



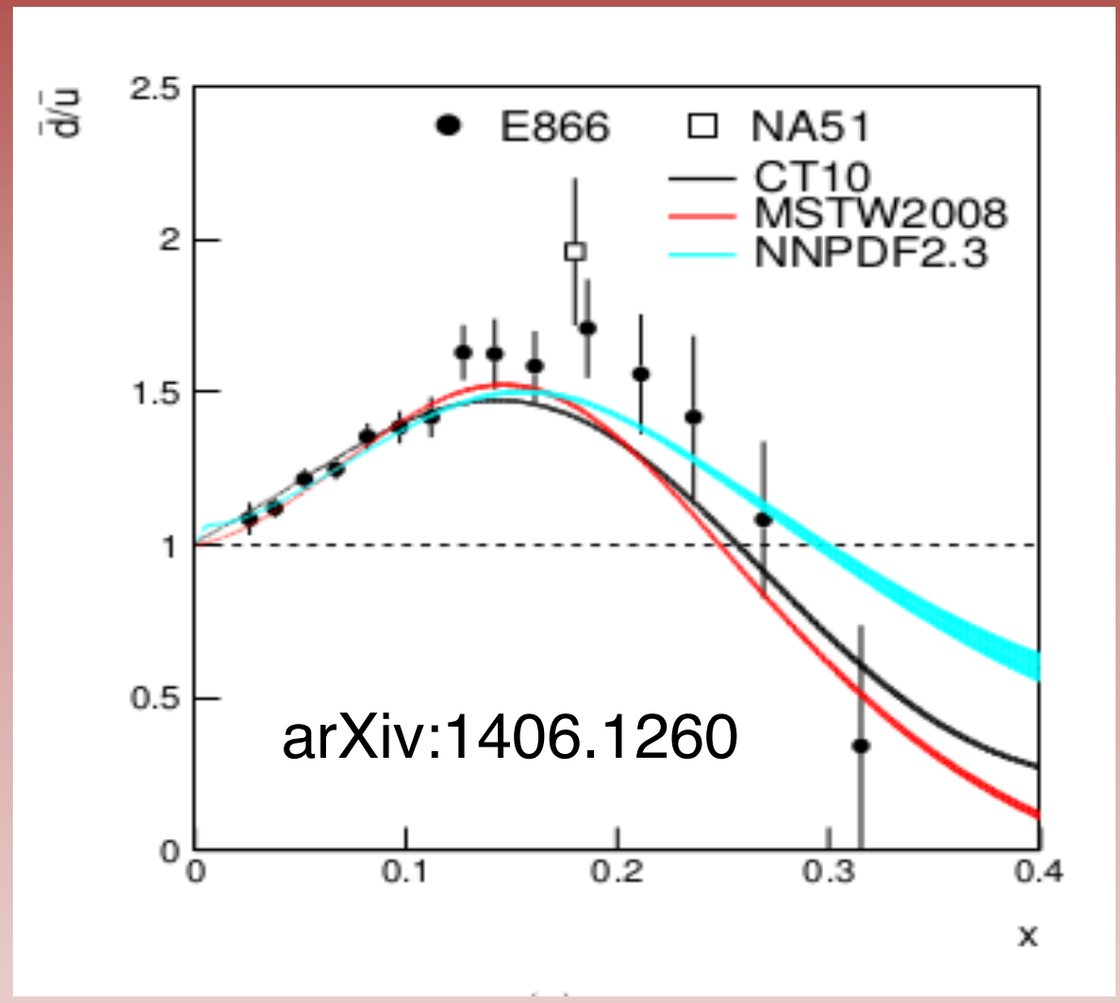
Unpolarized Sea Quark Distributions

- **Unpolarized** sea quarks currently have **large uncertainties** near the **valence region**.
- **E866** suggests $\bar{u} > \bar{d}$ at **large** x.

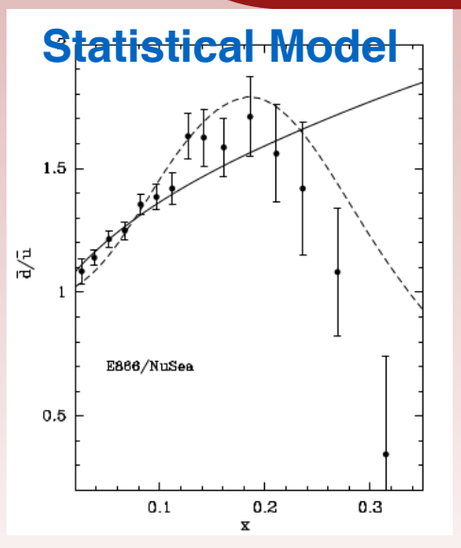


Unpolarized Sea Quark Distributions

- **Unpolarized** sea quarks currently have **large uncertainties** near the **valence region**.
- **E866** suggests $\bar{u} > \bar{d}$ at **large** x.
- **Many models** can predict the general $\bar{d} > \bar{u}$ behavior, but **fail to describe** the suggested behavior of $\bar{d}/\bar{u} < 1$

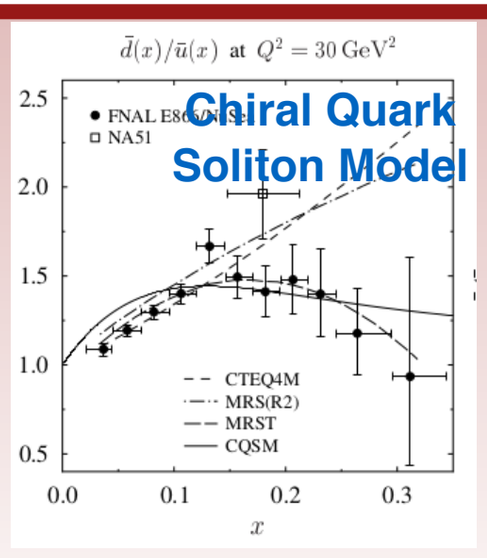


Statistical Model



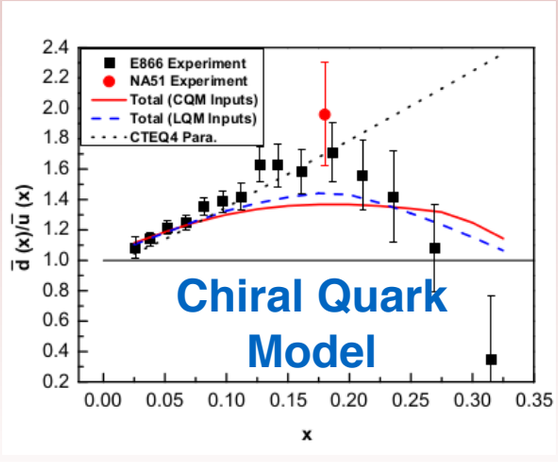
Phys. J. C **23** (2002) 487

Chiral Quark Soliton Model



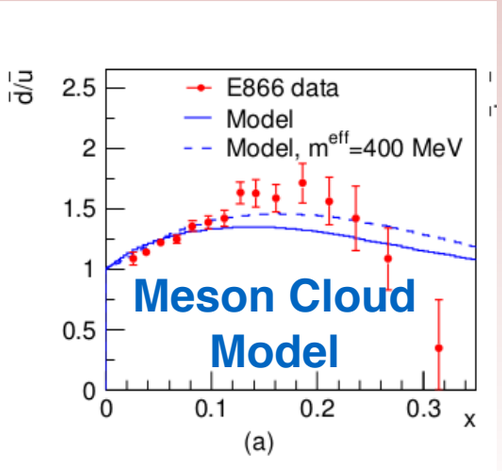
Phys. Rev. D **79** (2009) 094028

Chiral Quark Model



Eur. Phys. J. C **71** (2011) 1542

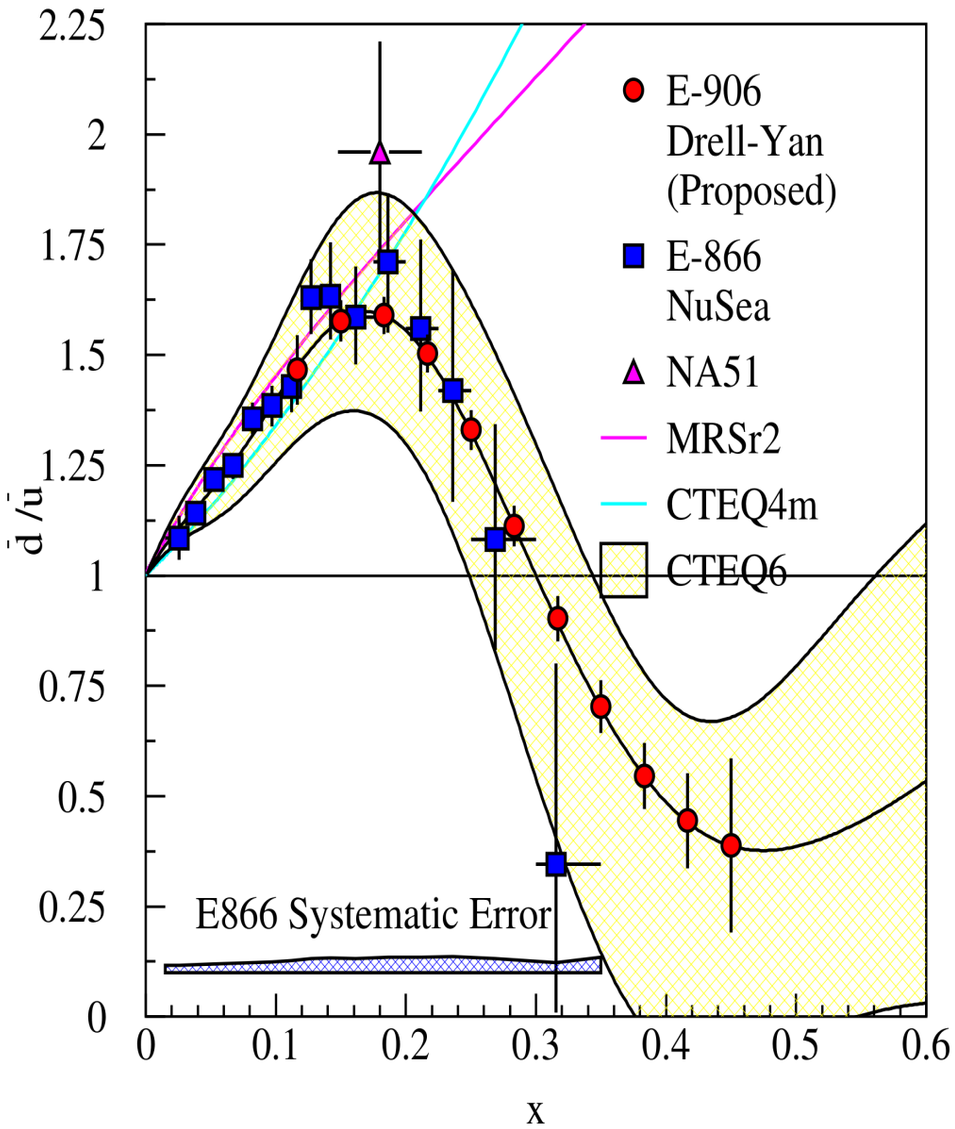
Meson Cloud Model



Phys. Rev. D **71** (2005) 094015

Unpolarized Sea Quark Distributions

- E906 (Sea Quest) will help to constrain the sea quark distribution.
- E906 will probe sea quark distribution at a lower Q^2 scale through **Drell-Yan** scattering.

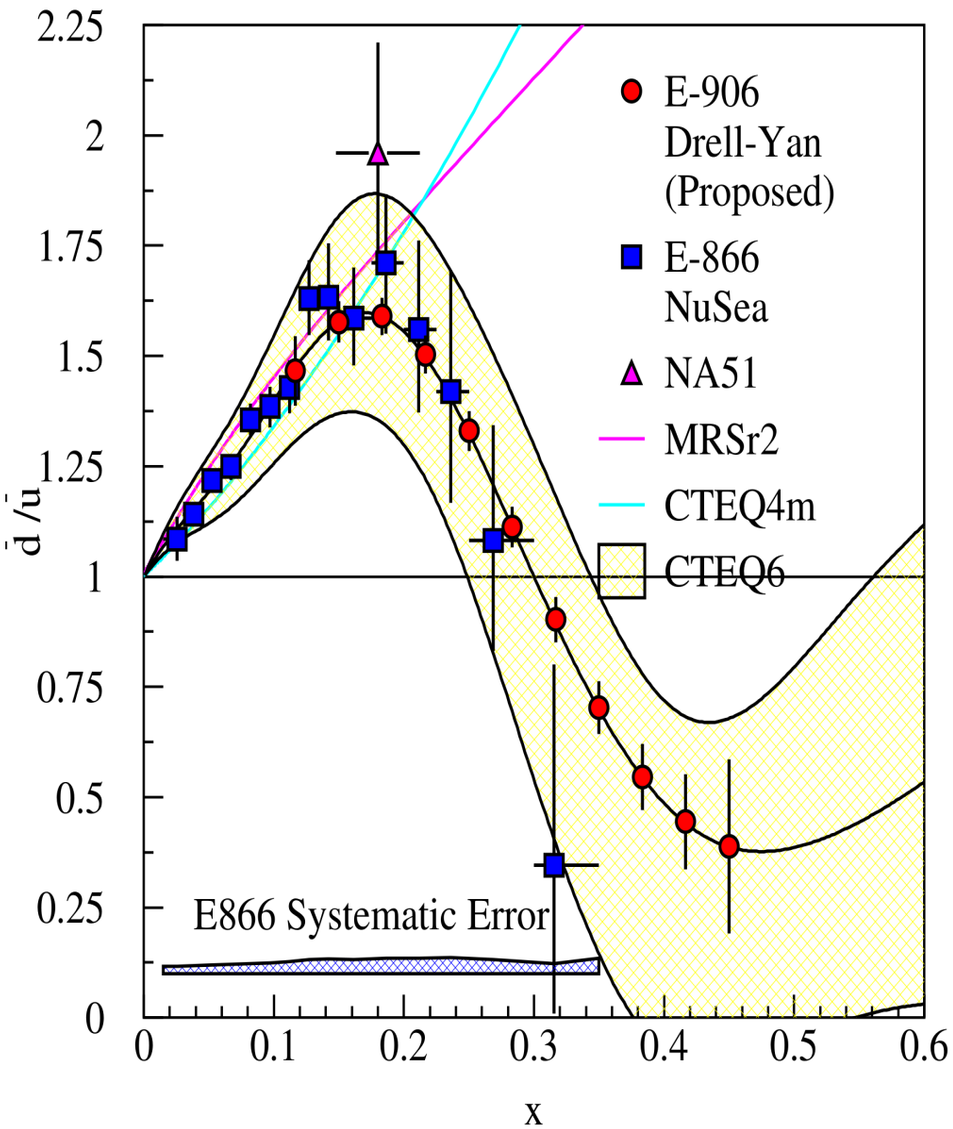


J. Phys. Conf. Ser. **295** (2011) 012163

Unpolarized Sea Quark Distributions

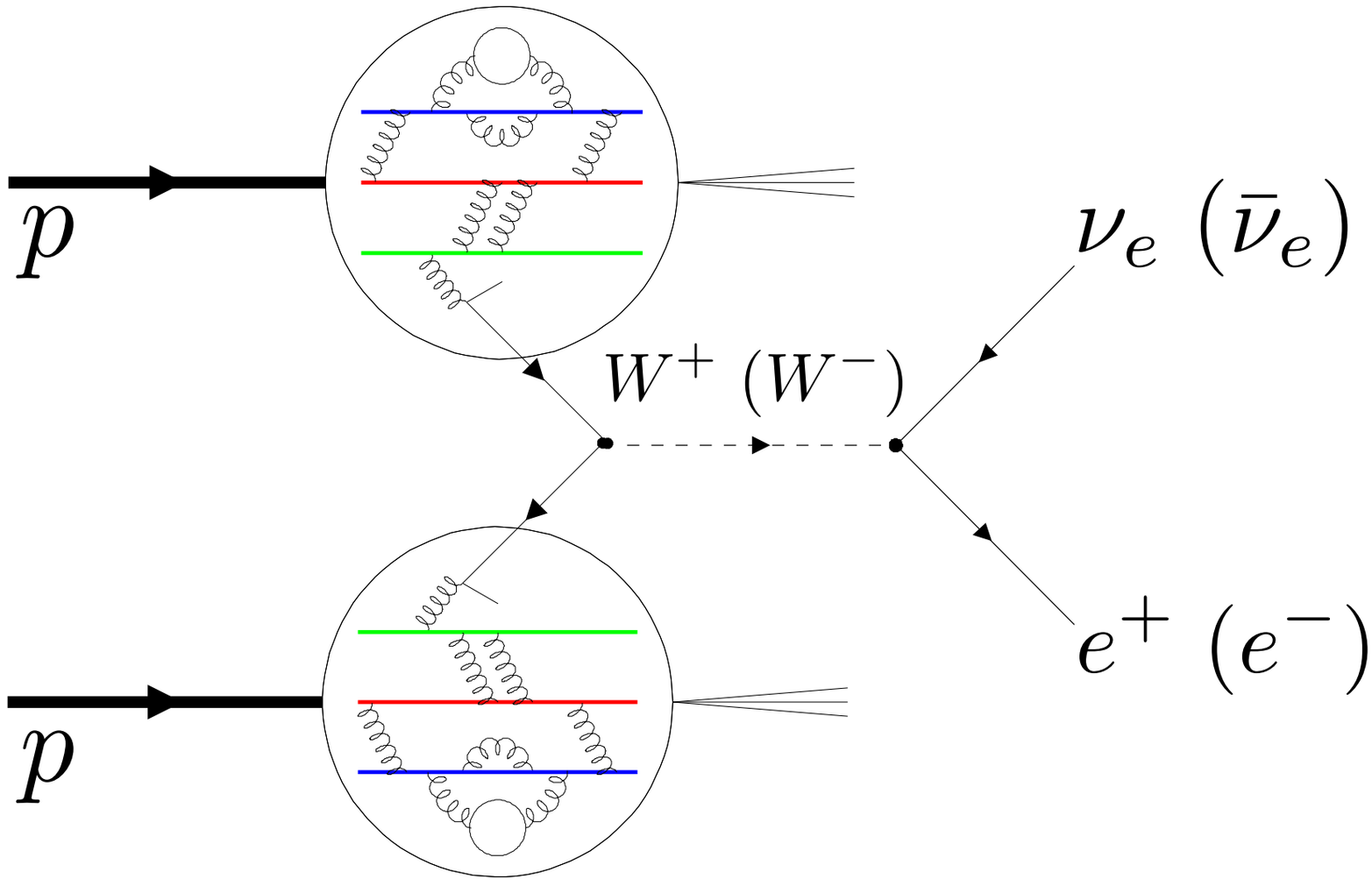
- E906 (Sea Quest) will help to constrain the sea quark distribution.
- E906 will probe sea quark distribution at a lower Q^2 scale through **Drell-Yan** scattering.

- Ideally to better constrain pdf fits, data over a **range of** Q^2 and **scattering processes** is desired.
- In general this will help **minimize** any **process dependent assumptions** and more importantly serve as an independent **cross check** of our understanding of the physics.

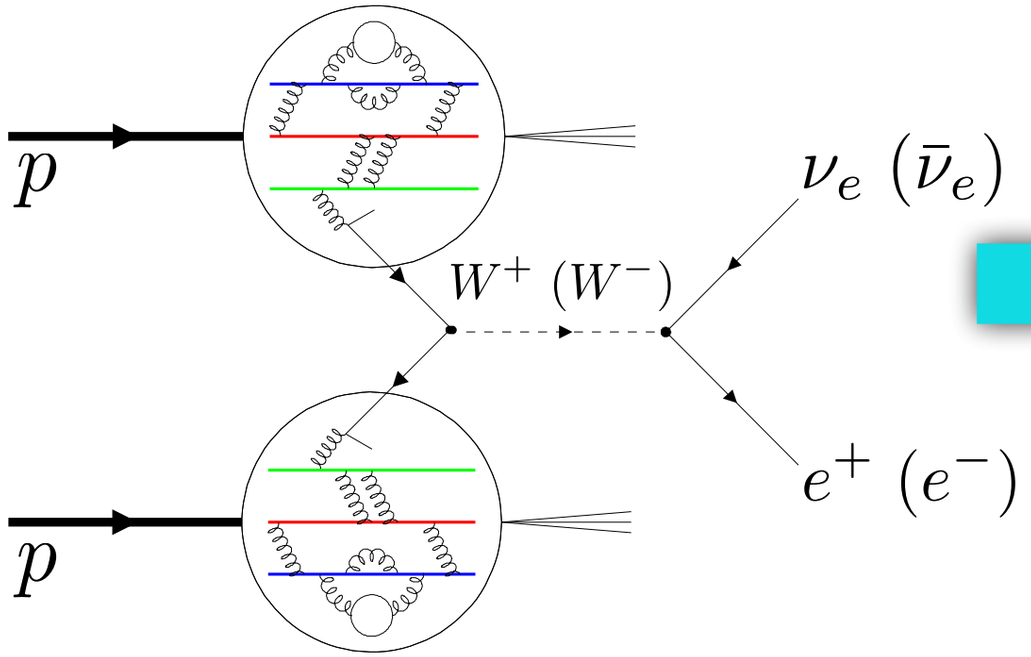


J. Phys. Conf. Ser. **295** (2011) 012163

W Boson Production Through Proton-Proton Collisions



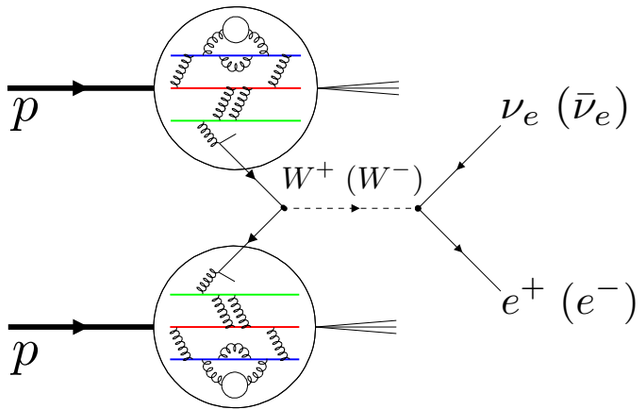
W Boson Production Through Proton-Proton Collisions



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

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

W Boson Production Through Proton-Proton Collisions



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

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

$$y_l = y_W + \underbrace{\frac{1}{2}\ln\frac{1+\cos\theta^*}{1-\cos\theta^*}}_{y_l^*} \qquad x_1 = \frac{M_W}{\sqrt{s}}e^{y_W}$$

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

$$p_T = p_T^* = \frac{M_W}{2}\sin\theta^* \qquad \sqrt{x_1 x_2} = \frac{M_W}{\sqrt{s}}$$

- W Boson's are **directly sensitive** to quark/anti-quark distributions (**no fragmentation functions needed!**).
- They can be detected through its l**eptonic decay channels** in **proton-proton** collisions.
- **Key signature**: high p_T lepton near $M_W/2$
- Selection of W+/W- made through **charge sign discrimination** of high p_T lepton

W Cross Section Ratio

$$R\left(x_F\right) \equiv \frac{\sigma_W^+}{\sigma_W^-} = \frac{u\left(x_1\right)\bar{d}\left(x_2\right) + \bar{d}\left(x_1\right)u\left(x_2\right)}{\bar{u}\left(x_1\right)d\left(x_2\right) + d\left(x_1\right)\bar{u}\left(x_2\right)}$$

$$+NLO + NNLO + ...$$

W Cross Section Ratio

$$R\left(x_F\right) \equiv \frac{\sigma_W^+}{\sigma_W^-} = \frac{u\left(x_1\right)\bar{d}\left(x_2\right) + \bar{d}\left(x_1\right)u\left(x_2\right)}{\bar{u}\left(x_1\right)d\left(x_2\right) + d\left(x_1\right)\bar{u}\left(x_2\right)}$$

$$+NLO + NNLO + ...$$

$$R = \frac{N_O^+ - N_B^+}{N_O^- - N_B^-} \cdot \frac{\epsilon^-}{\epsilon^+}$$

W Cross Section Ratio

$$R(x_F) \equiv \frac{\sigma_W^+}{\sigma_W^-} = \frac{u(x_1)\,\bar{d}(x_2) + \bar{d}(x_1)\,u(x_2)}{\bar{u}(x_1)\,d(x_2) + d(x_1)\,\bar{u}(x_2)} + NLO + NNLO + \ldots$$

$$R = \frac{N_O^+ - N_B^+}{N_O^- - N_B^-} \cdot \frac{\epsilon^-}{\epsilon^+}$$

+ = positron from W decay

- = electron from W decay

N_O = measured lepton decay events

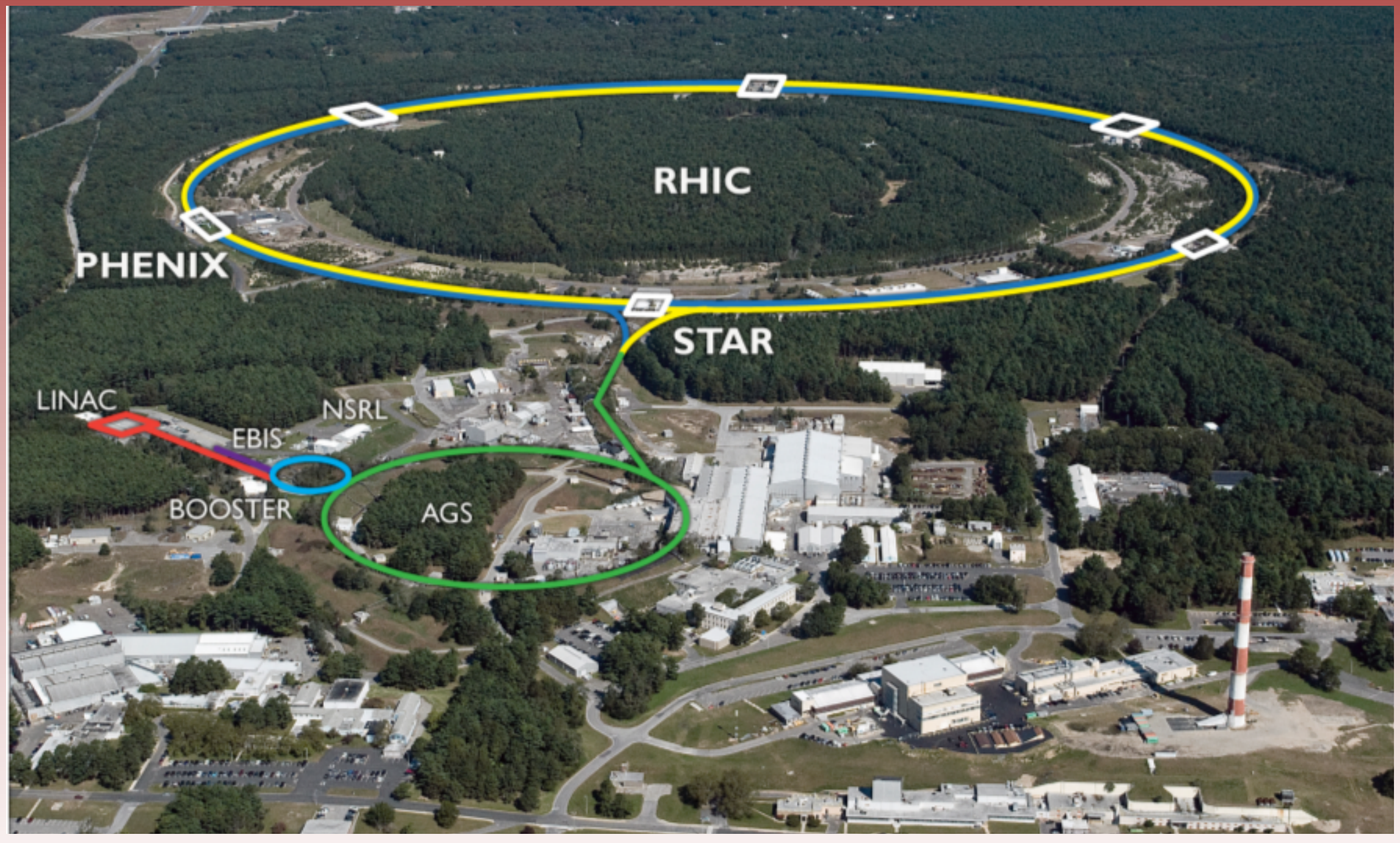
N_B = background events

ϵ = lepton detection efficiency

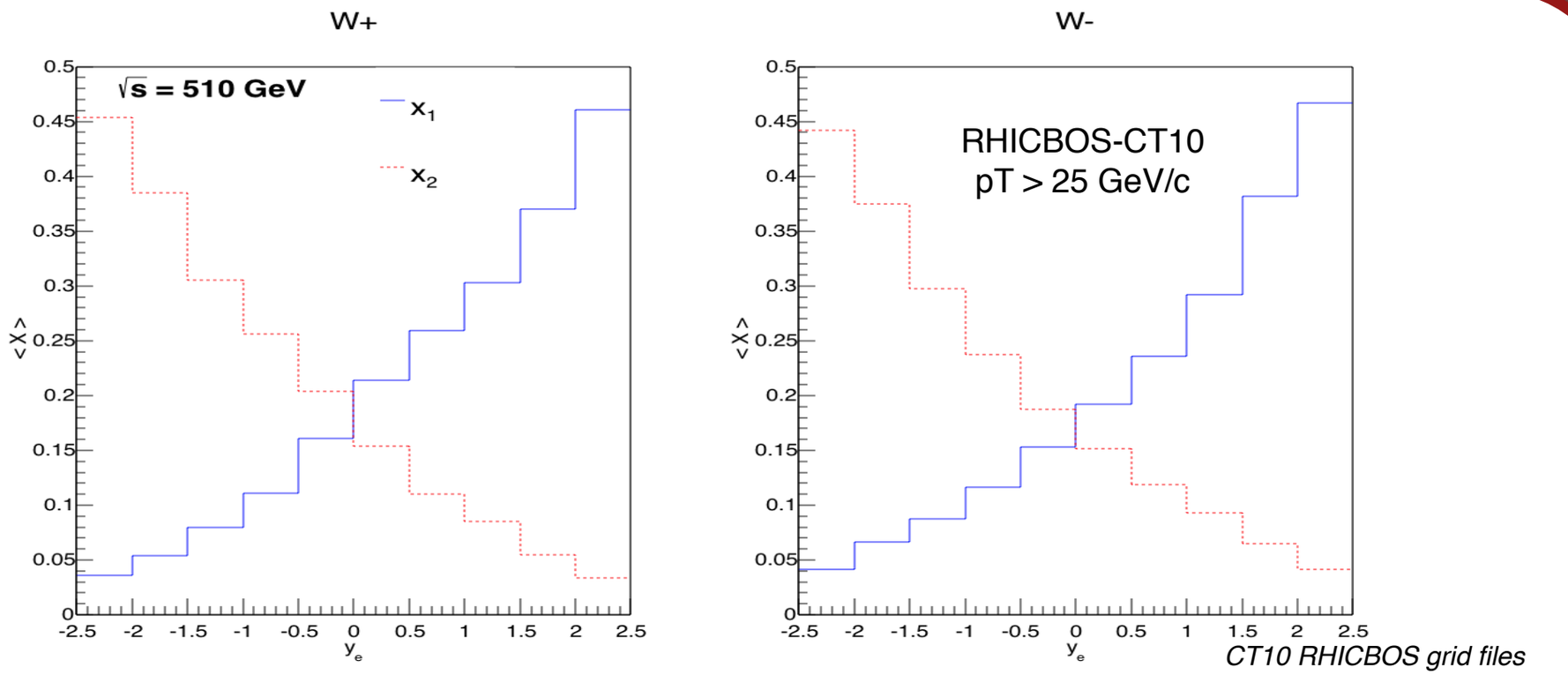
Outline

- Motivation
- Experimental Aspects
- Recent Preliminary Results

Relativistic Heavy Ion Collider



Kinematic Reach at RHIC



CT10 RHICBOS grid files produced by Pavel Nadolsky

- Approximate kinematic range at RHIC:

$$0.06 < x < 0.4 \quad \text{for} \quad -2 < \eta < 2$$

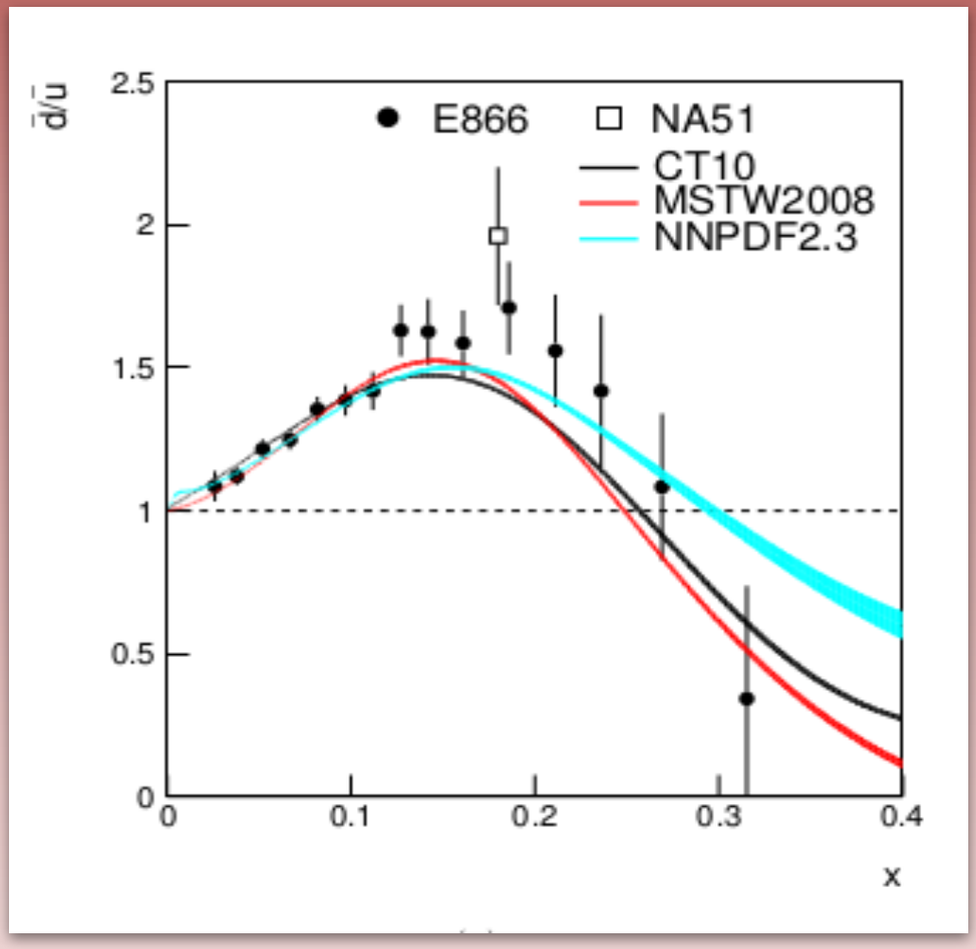
- Probes distributions at high Q^2 :

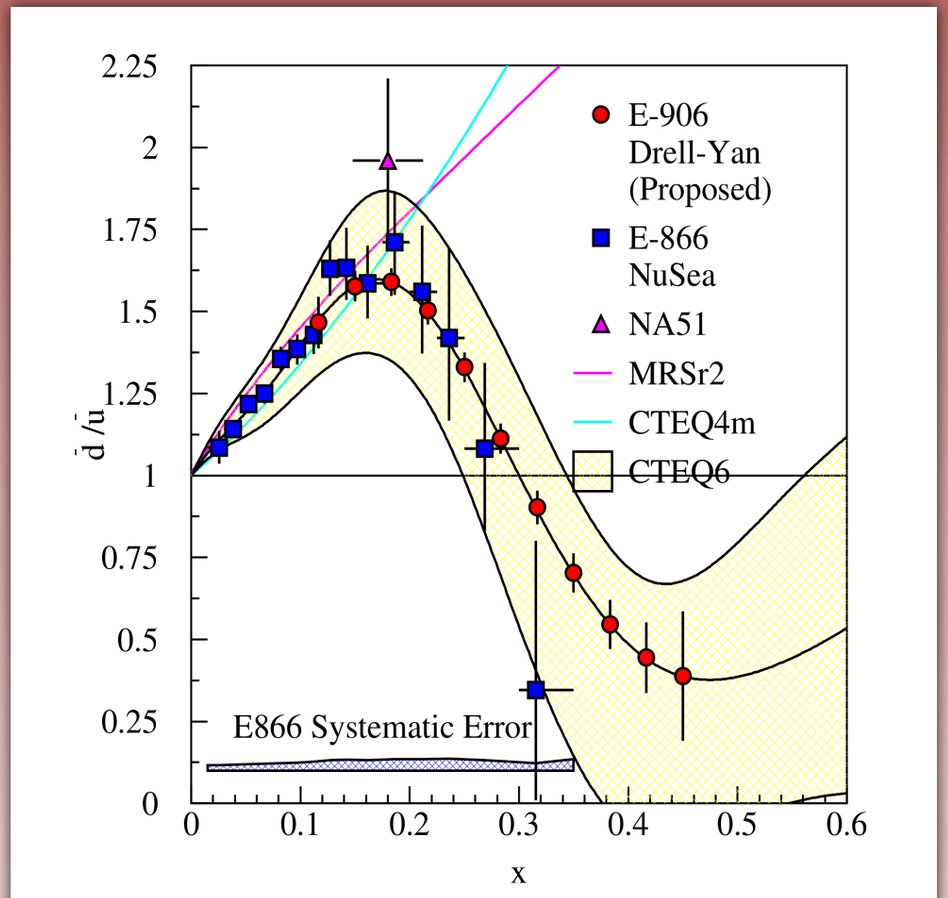
$$Q^2 = M_W^2$$

- For collision energies of $\sqrt{s} = 500\ GeV$ and $\eta = 0\ (x_1 \approx x_2)$

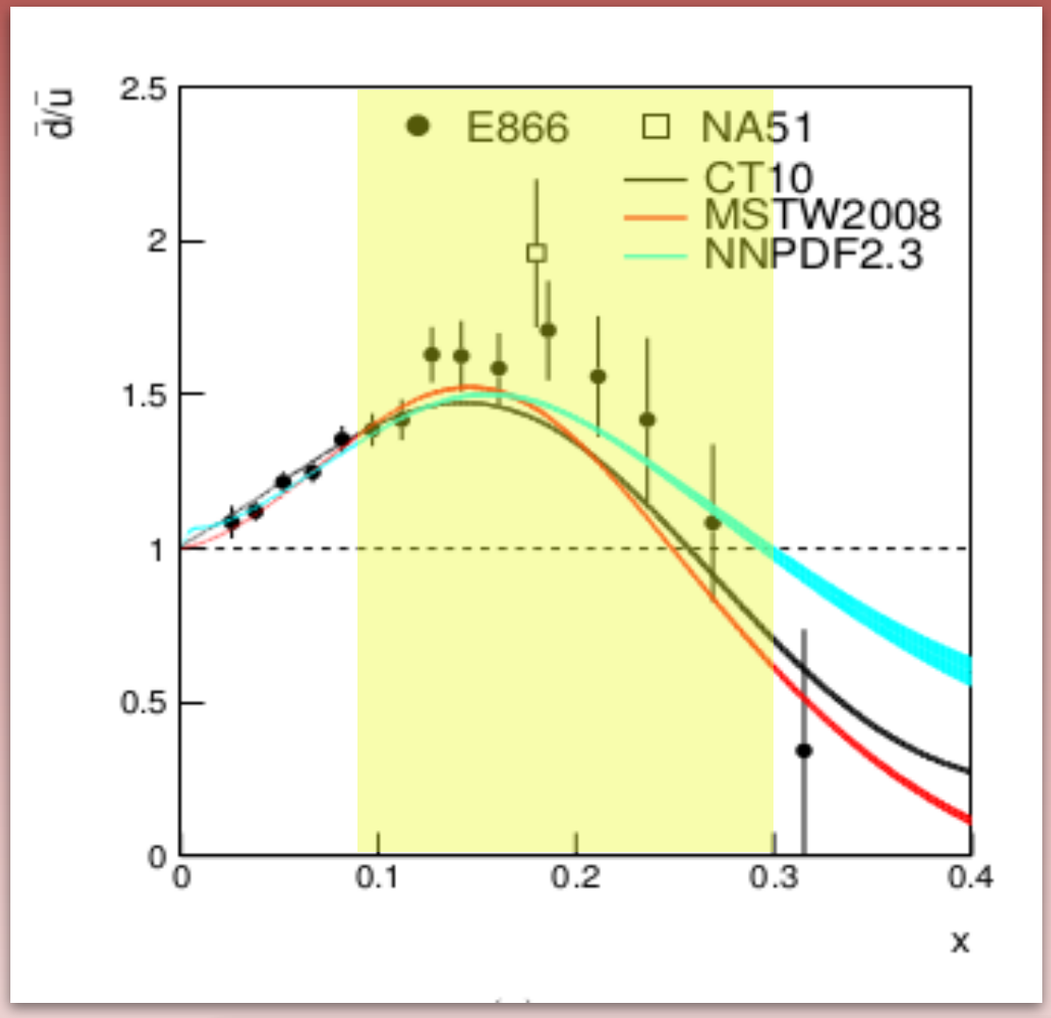
$$x = \frac{M_W}{\sqrt{s}} = 0.16$$

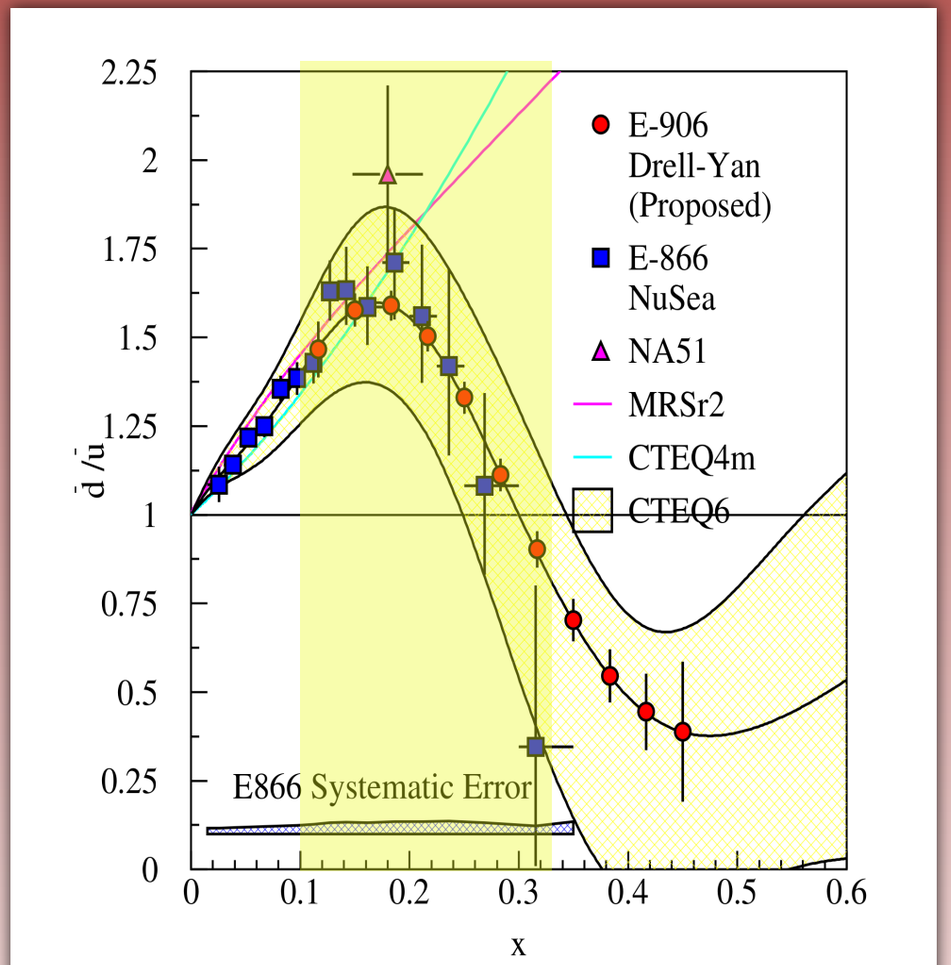
Sea Quark Distribution





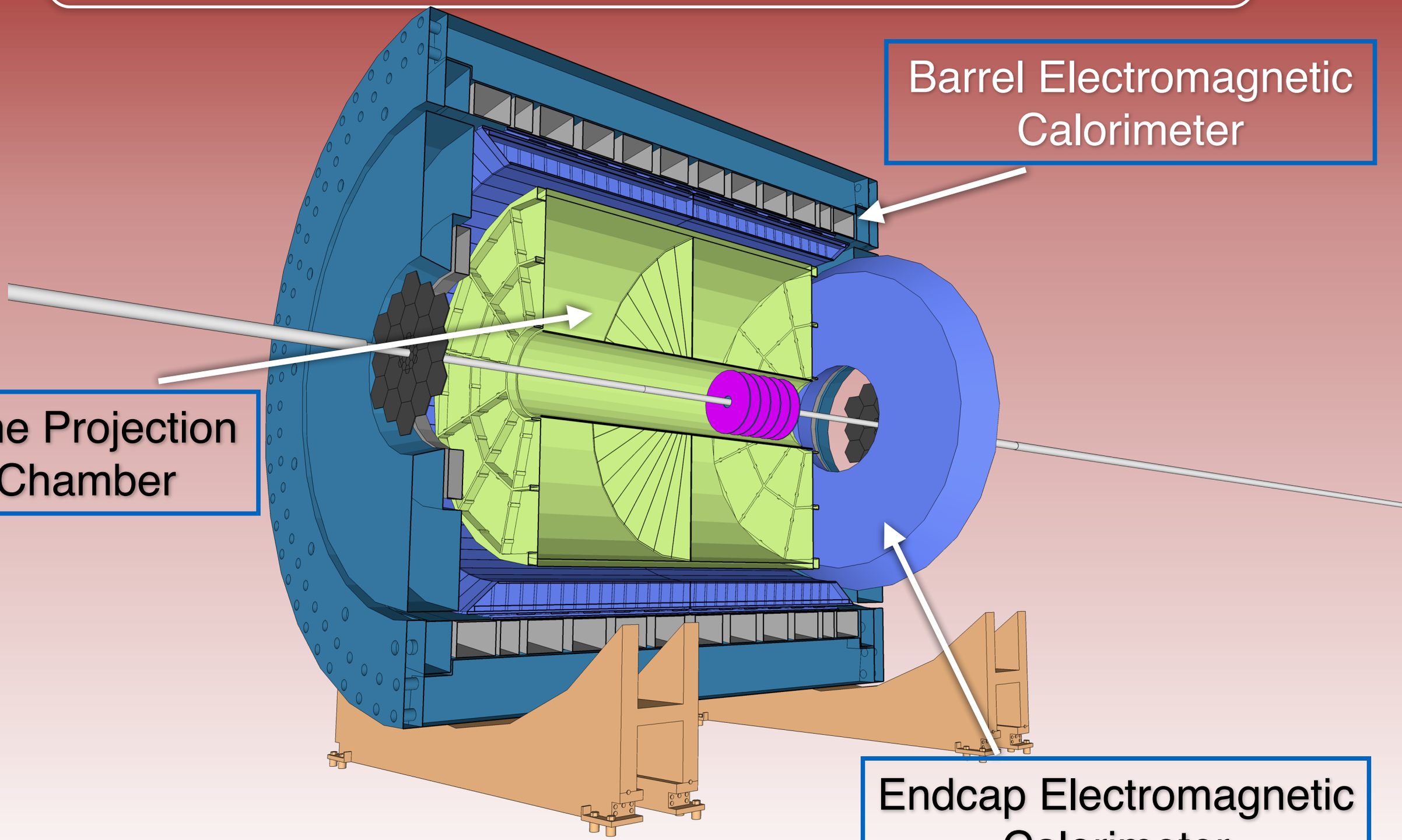
Sea Quark Distribution: RHIC Reach



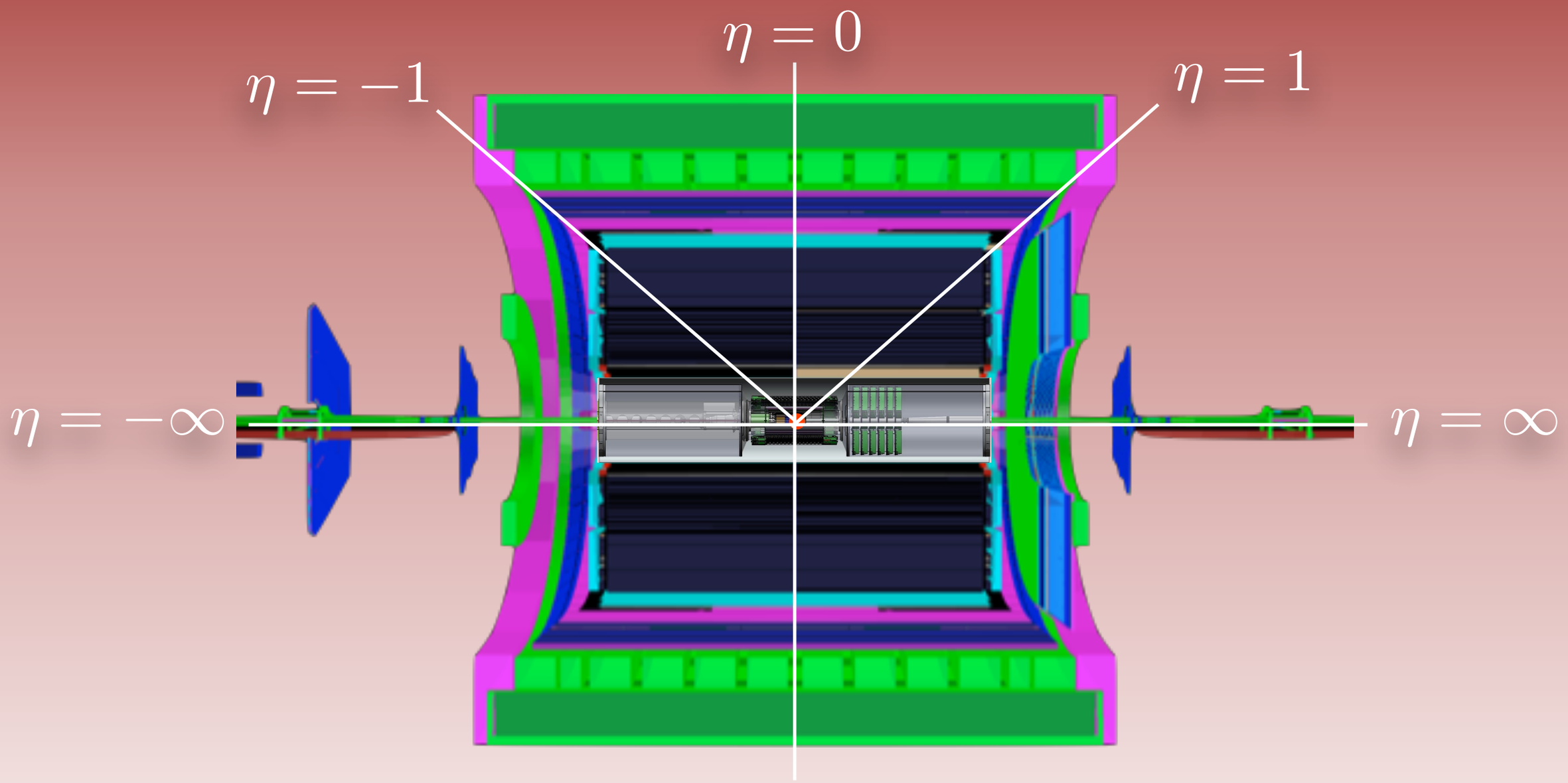


- STAR at mid-rapitity $|\eta| < 1$ covers approximately $0.1 < x < 0.3$
- Will be able to provide **constraints** on global **PDF fitting** for **anti-u** and **anti-d quarks** through W production at **higher** Q^2 than E906.
- Serves as an **independent check** of the Drell-Yan data which assumes a charge symmetry to relate p/n to $\bar{d}/\bar{u}$ asymmetries.

Solenoidal Tracker At RHIC



Solenoidal Tracker At RHIC



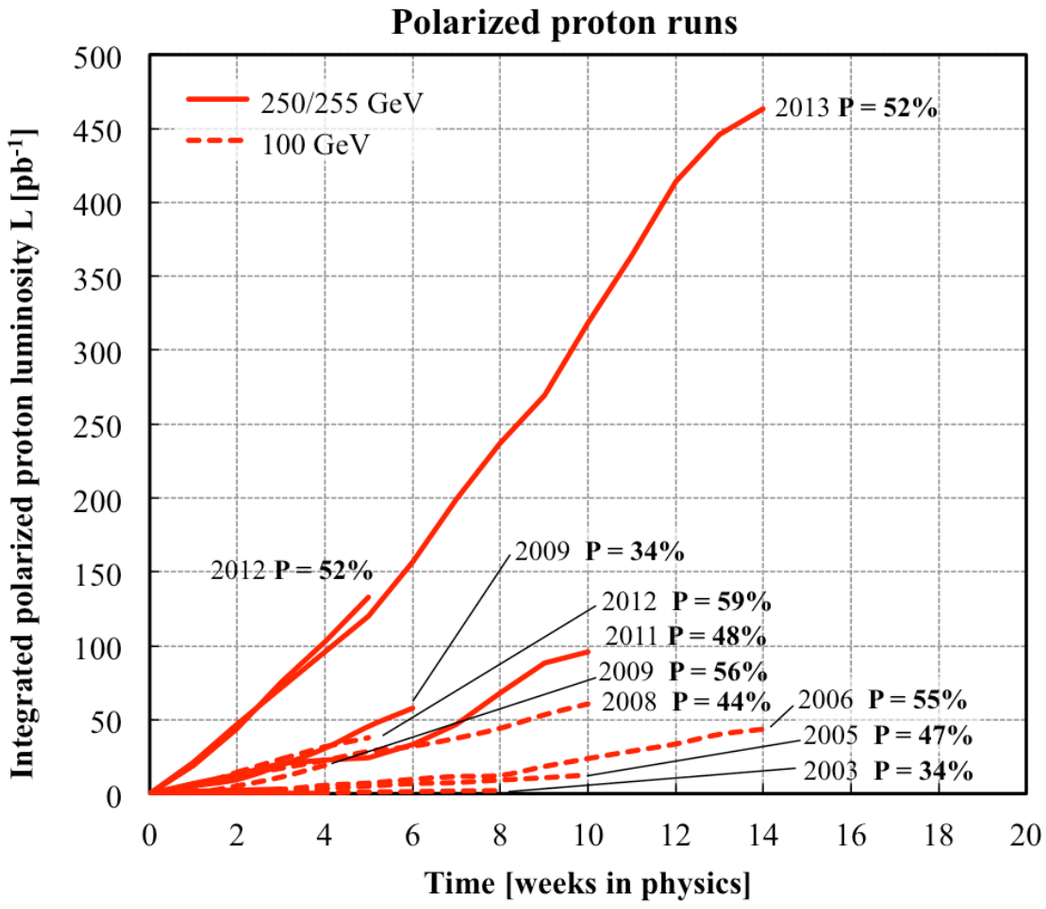
$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

Outline

- Motivation
- Experimental Aspects
- Recent Preliminary Results

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:



STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb
  - 2012 Integrated luminosity: 77 1/pb

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb
  - 2012 Integrated luminosity: 77 1/pb
  - 2013 Integrated luminosity: 250 1/pb

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb
  - 2012 Integrated luminosity: 77 1/pb
  - 2013 Integrated luminosity: 250 1/pb
- **~350 1/pb** of W production data was collected over those 3 years!

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb
  - 2012 Integrated luminosity: 77 1/pb
  - 2013 Integrated luminosity: 250 1/pb
- **~350 1/pb** of W production data was collected over those 3 years!

Currently still under analysis, but will **improve** the precision of the W cross section ratio measurements

STAR W Data Collection

- Over the past several years **luminosity** at **STAR** has steadily **increased**:
  - 2011 Integrated luminosity: 25 1/pb
  - 2012 Integrated luminosity: 77 1/pb
  - 2013 Integrated luminosity: 250 1/pb
- **~350 1/pb** of W production data was collected over those 3 years!

Preliminary result of **combined 2011** and **2012** data set (~100 1/pb) just released

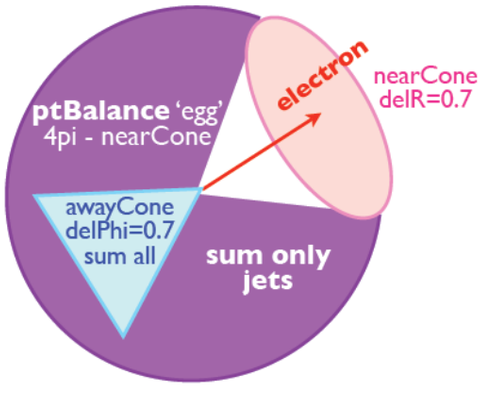
W Selection

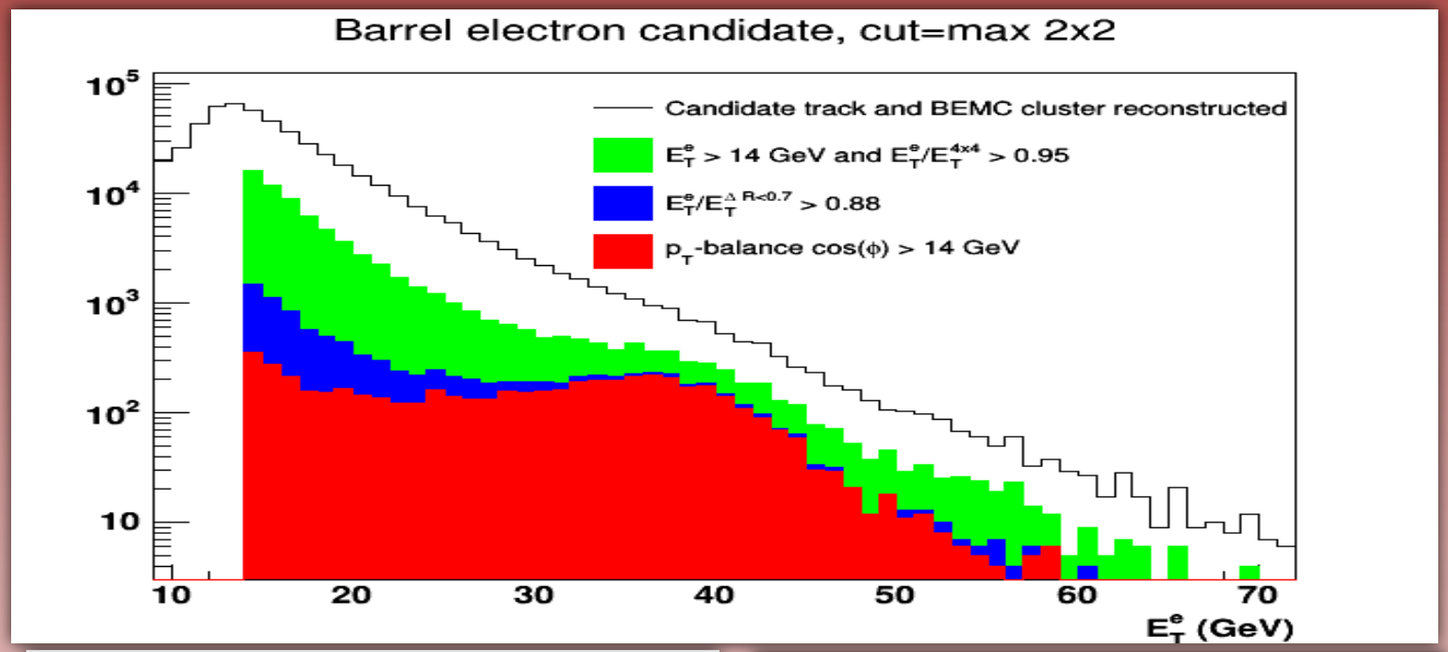
Mid-rapidity Selection Criteria

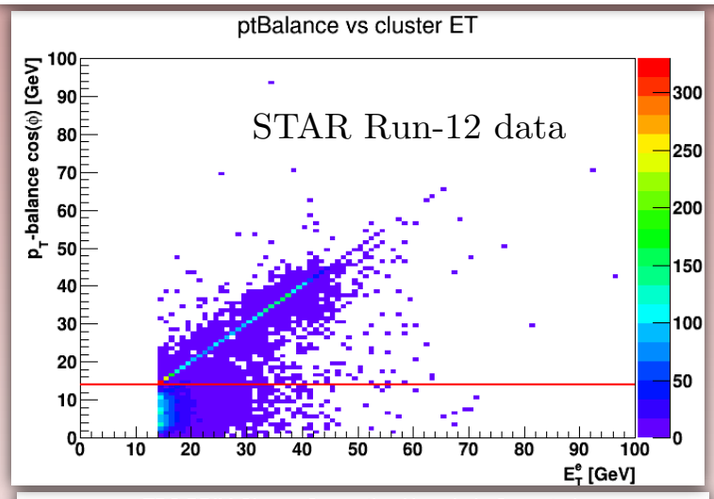
- Match pT > 10 GeV track to BEMC cluster
- Isolation Cuts
- pT-balance cut

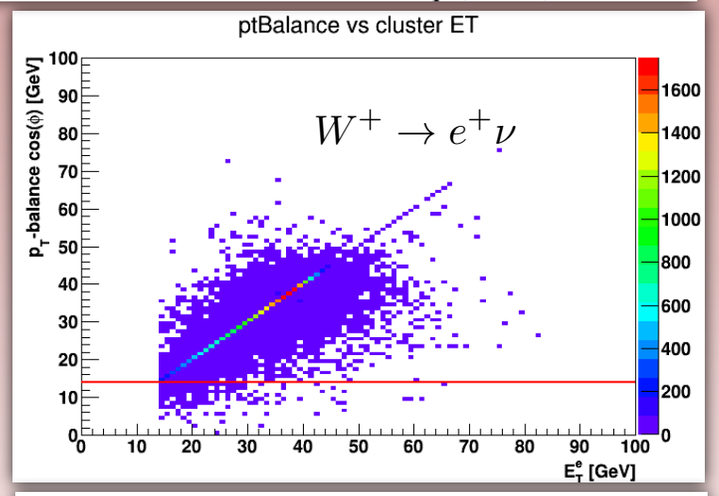
$$\vec{p_T}^{\,bal} = \vec{p_T}^{\,e} + \sum_{\Delta R>0.7} \vec{p_T}^{\,jets}$$

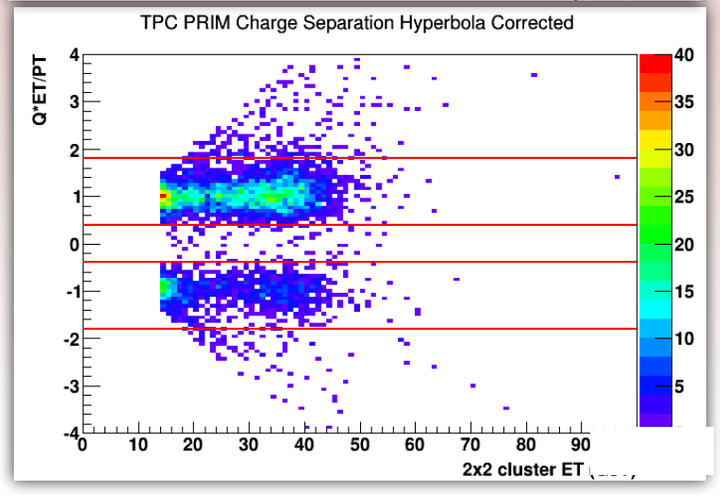
$$P_T\text{-balance}\cos(\phi) = \frac{\vec{p_T}^{\,e} \cdot \vec{p_T}^{\,bal}}{|\vec{p_T}^{\,e}|}$$

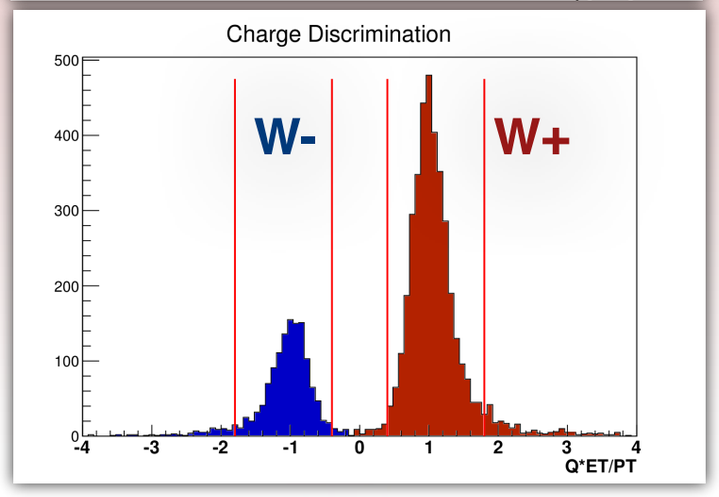










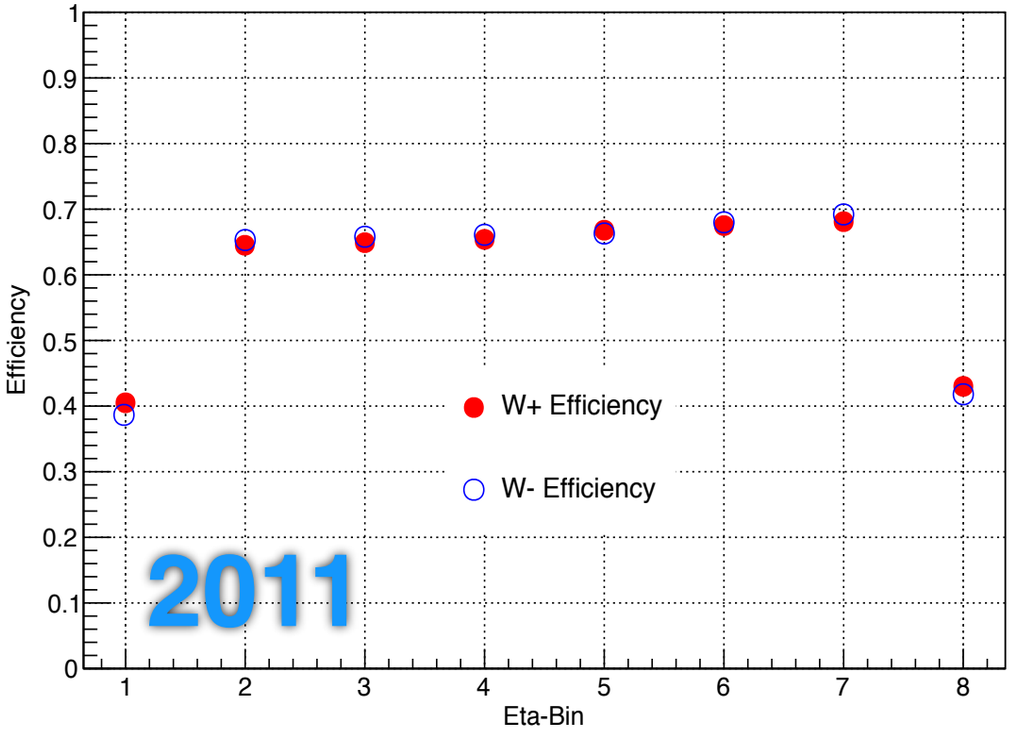


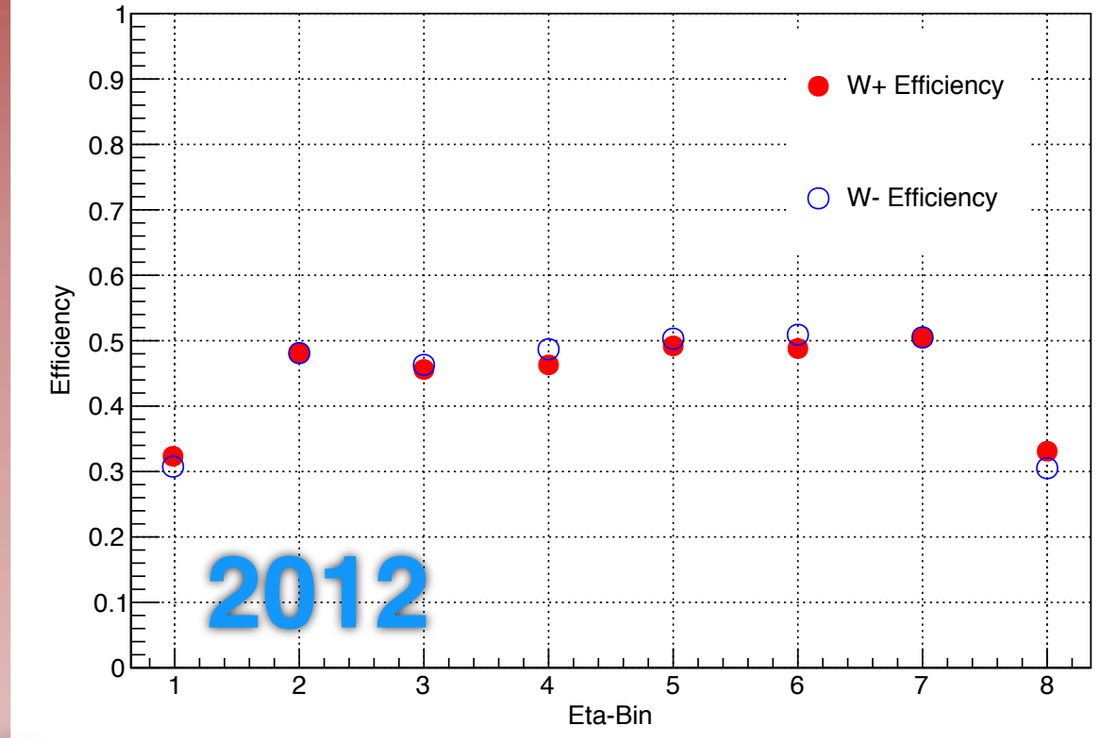
Matthew Posik
DIS 2015: April 27 - May 1, 2015

W+/W- Efficiencies

- **Efficiency = (# events reconstructed) / (# events generated)**
- Covers of contributions from:
  - **Trigger efficiency**
  - **Vertex efficiency**
  - **Tracking efficiency**
  - **W Algorithm efficiency**
  - **Charge efficiency**

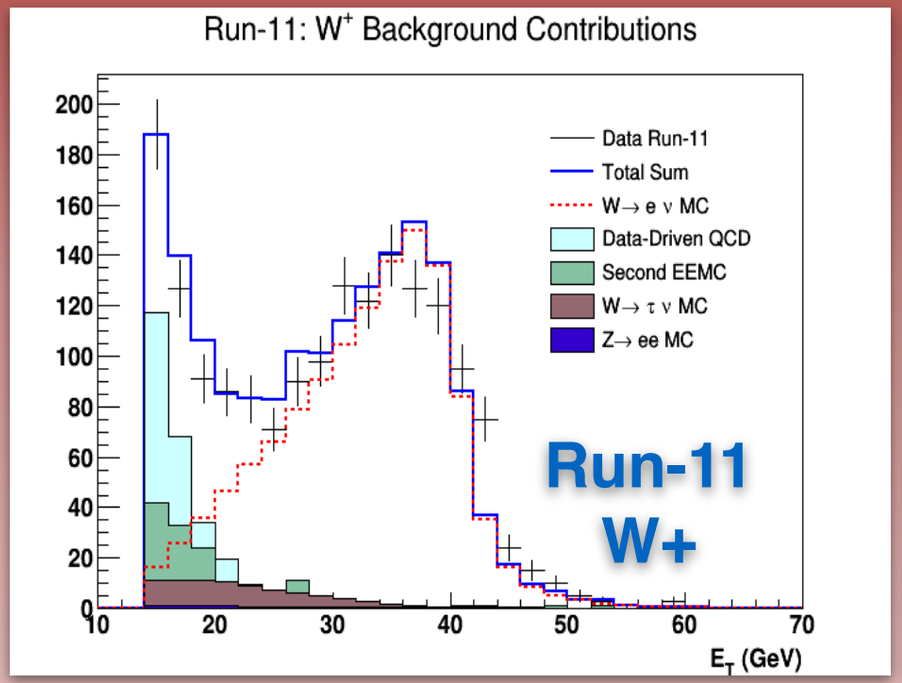
W+/- Efficiencies

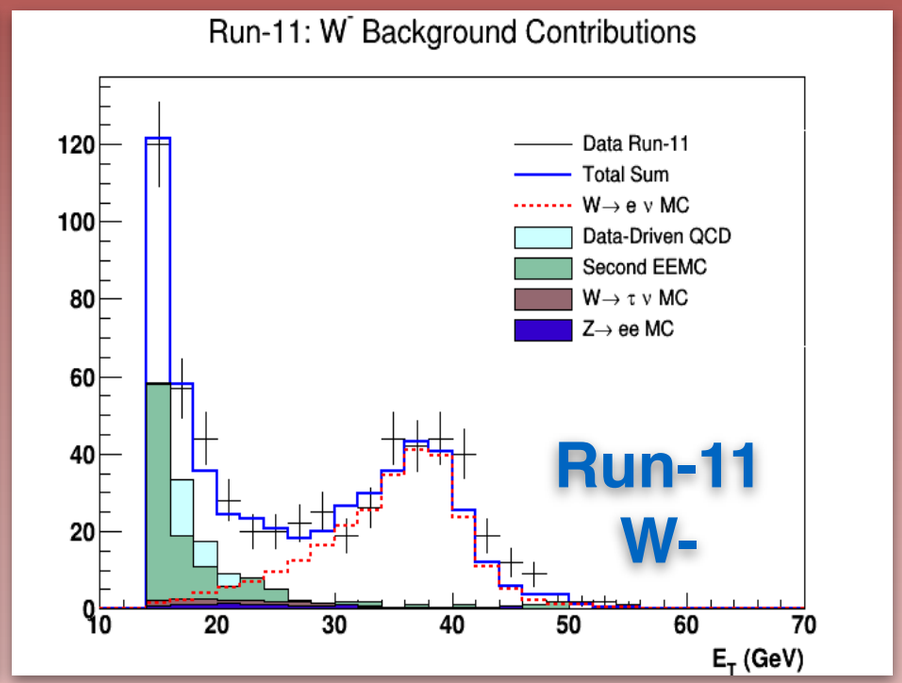


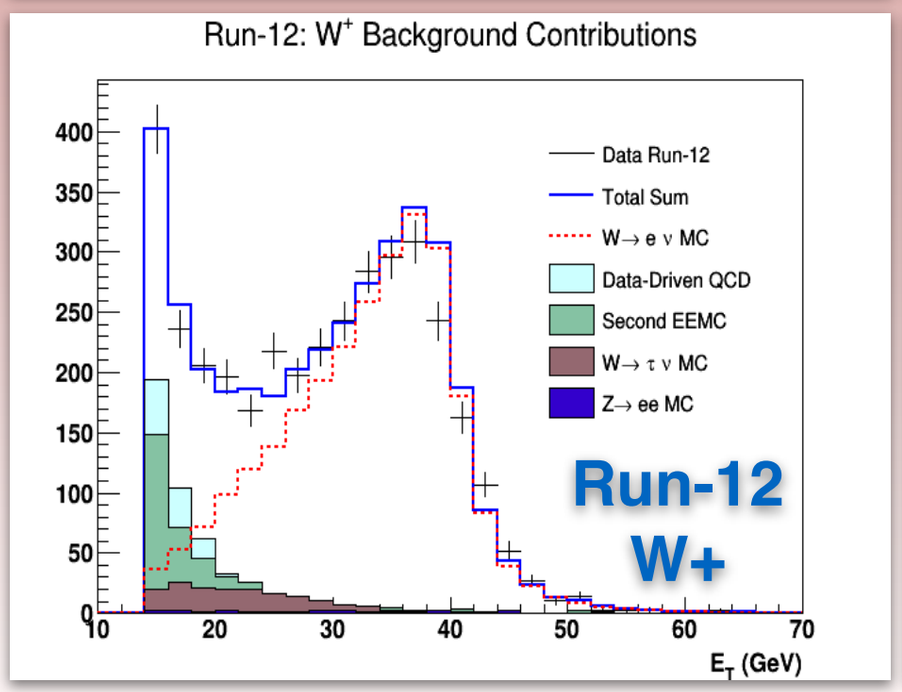


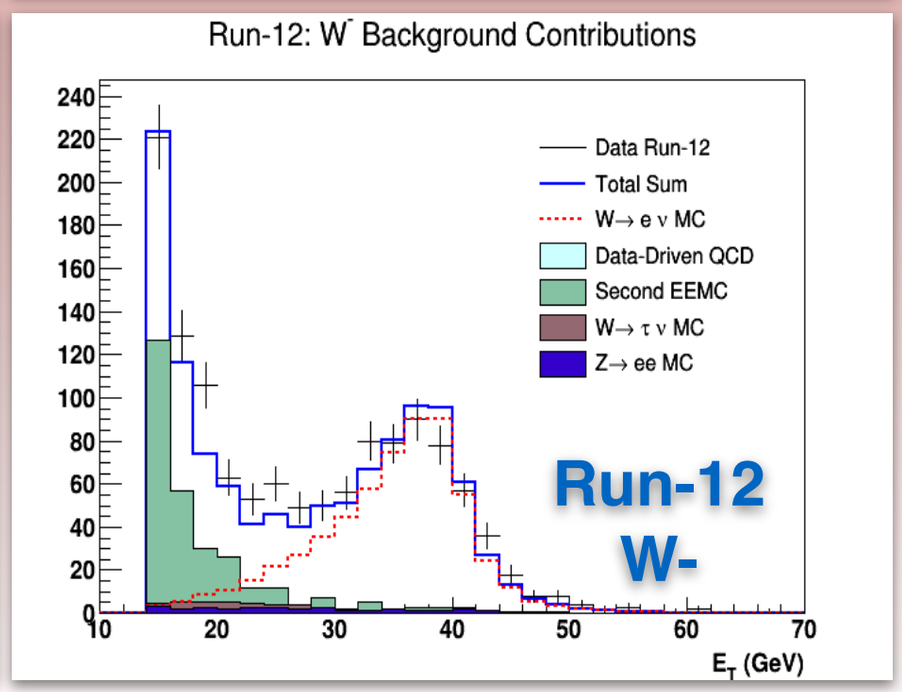
- 2012 running had lower W+/- efficiencies due to running at higher luminosity rates.
- This lead to more pile up in the **TPC** which resulted in less efficient track reconstruction.
- **Minimal** charge dependance leads to **small** contribution to W cross section ratio measurement.

W+/- Background Contributions





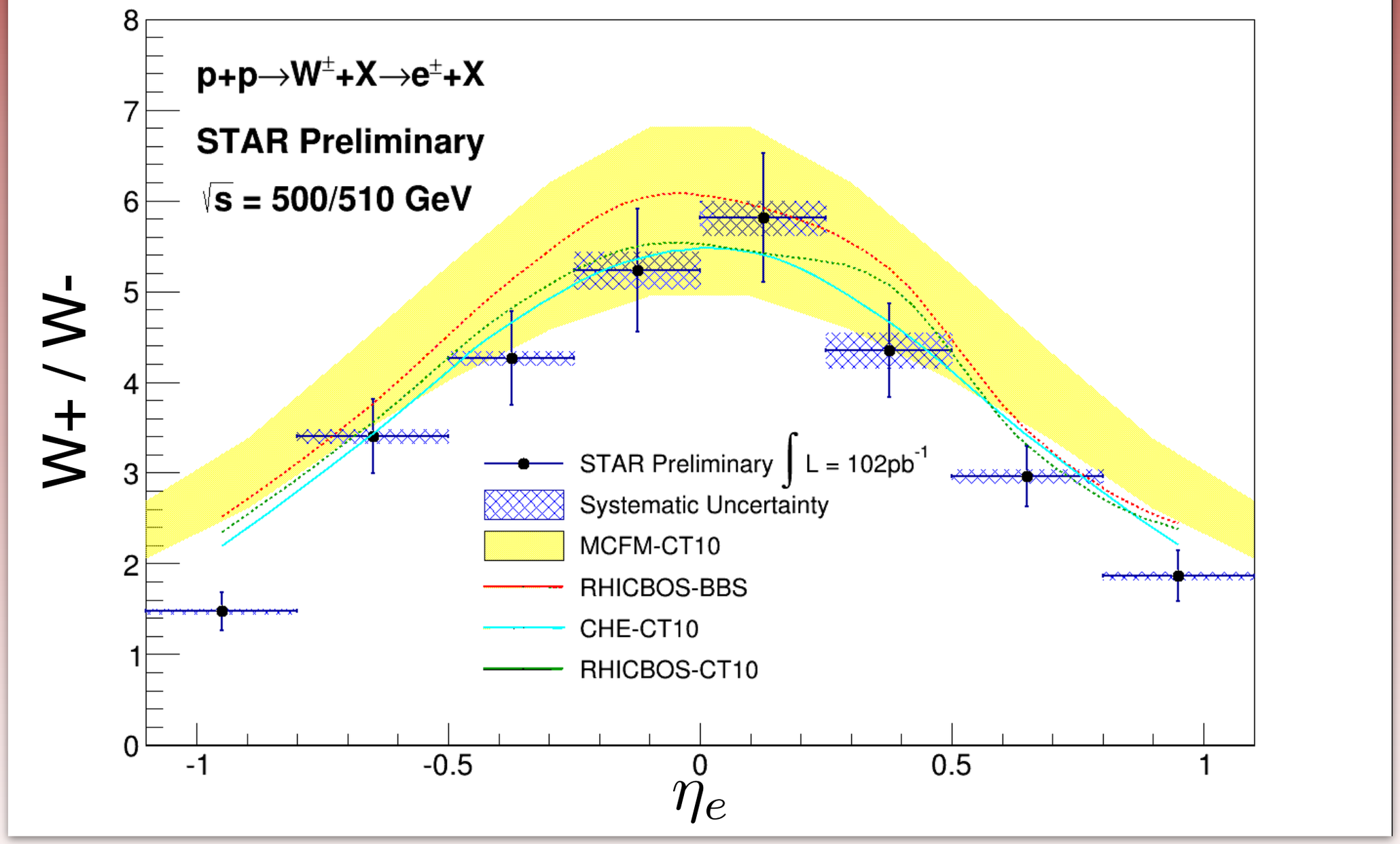




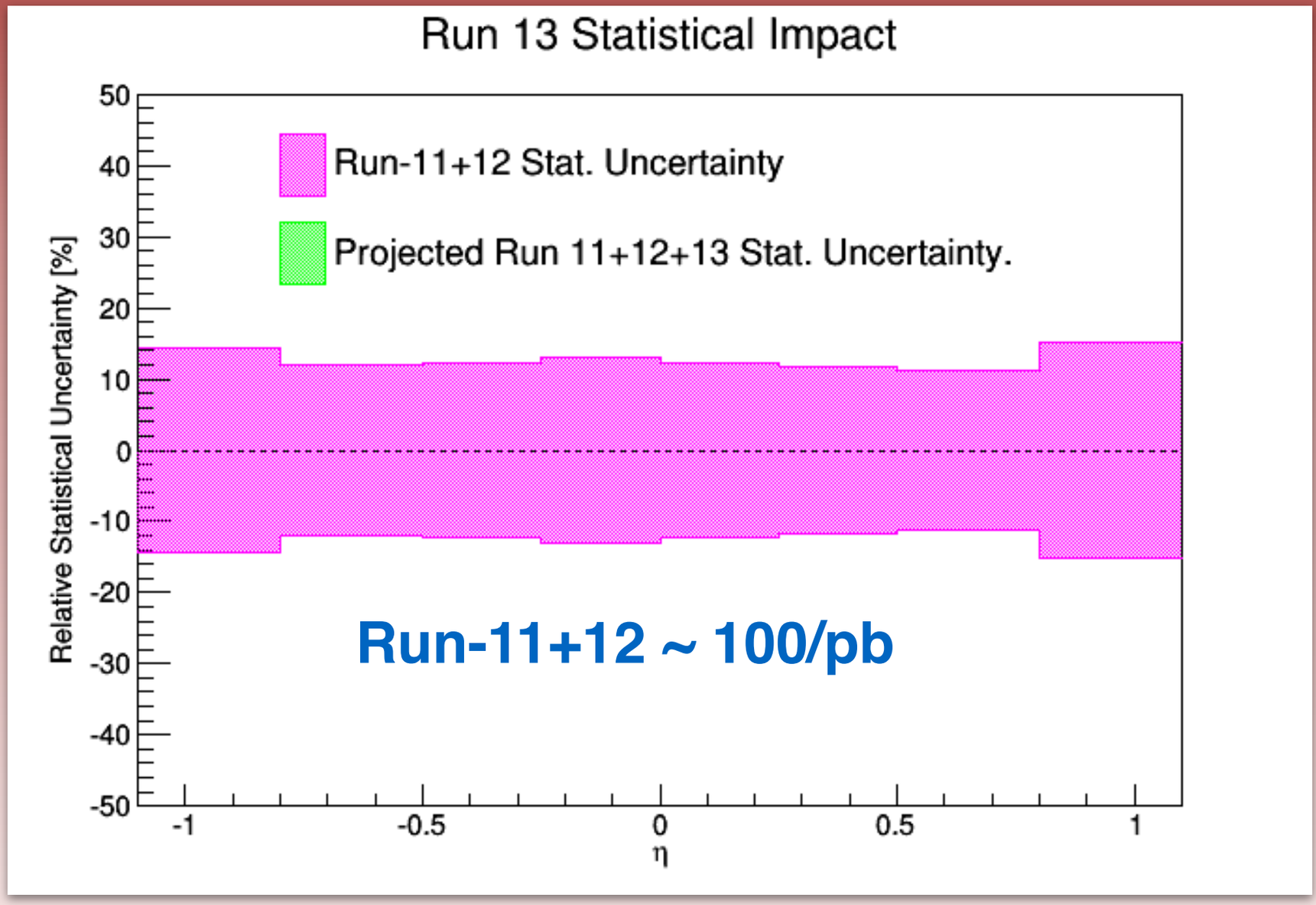
Small background contributions from:

- W boson induced tau decays.
- Z boson decays.

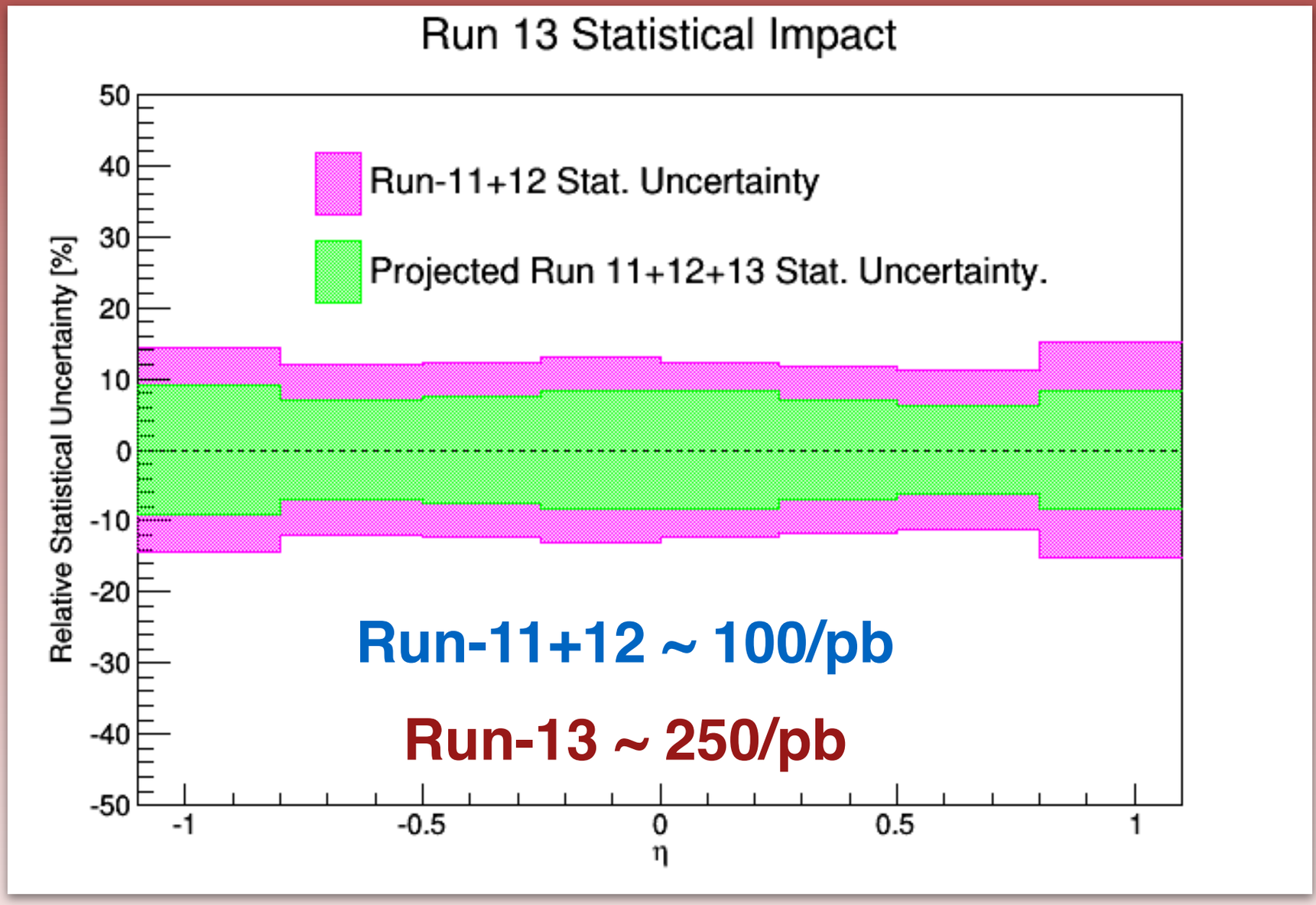
STAR 2011+2012 Preliminary Result



Projected STAR Run-13 Statistical Impact



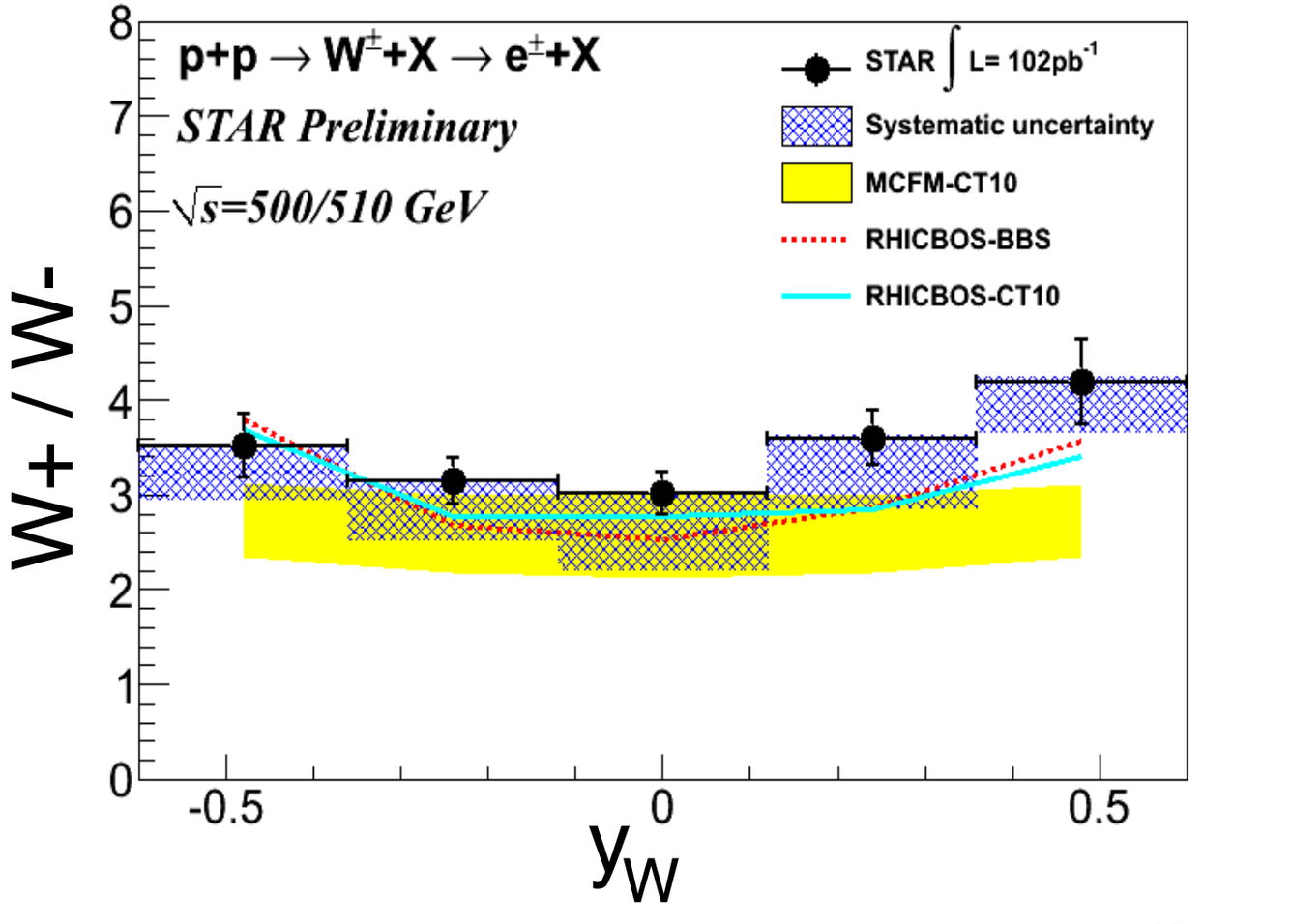
Projected STAR Run-13 Statistical Impact



Inclusion of **Run-13** data will **improve** precision of the cross section ratios

W+/W- vs Boson Rapidity

- **W boson rapidity** can be determined by reconstructing the W kinematics via its **recoil**
- Recently through the combination of **data and MC simulations**, a procedure for reconstructing the **W boson rapidity** has **been established** at **STAR**.
- This procedure has been applied to the **2011 + 2012 combined data set**.



See talk by **Salvatore Fazio** for more details

Summary

- **Preliminary W cross section ratio** results as a function of **W boson and lepton rapidities** form **STAR** W production data taken during **2011** and **2012** running have been analyzed.
- **2011 + 2012** W production reached an **integrated luminosity** of about ~ **100 1/pb**.
- **Preliminary results** will help to **constrain** pdf global fits to the **unpolarized sea quarks** in the range of x ~ 0.1 to 0.3
- **STAR 2013** W production reached an even **higher integrated luminosity** near **250 1/pb**.
- Integration of the **2013 data set** into the **combined 2011 and 2012 data set** will even further **constrain** global pdf fits of the **unpolarized sea quarks**.