Measurement of Asymmetry in W/Z production with D∅ detector at Fermilab

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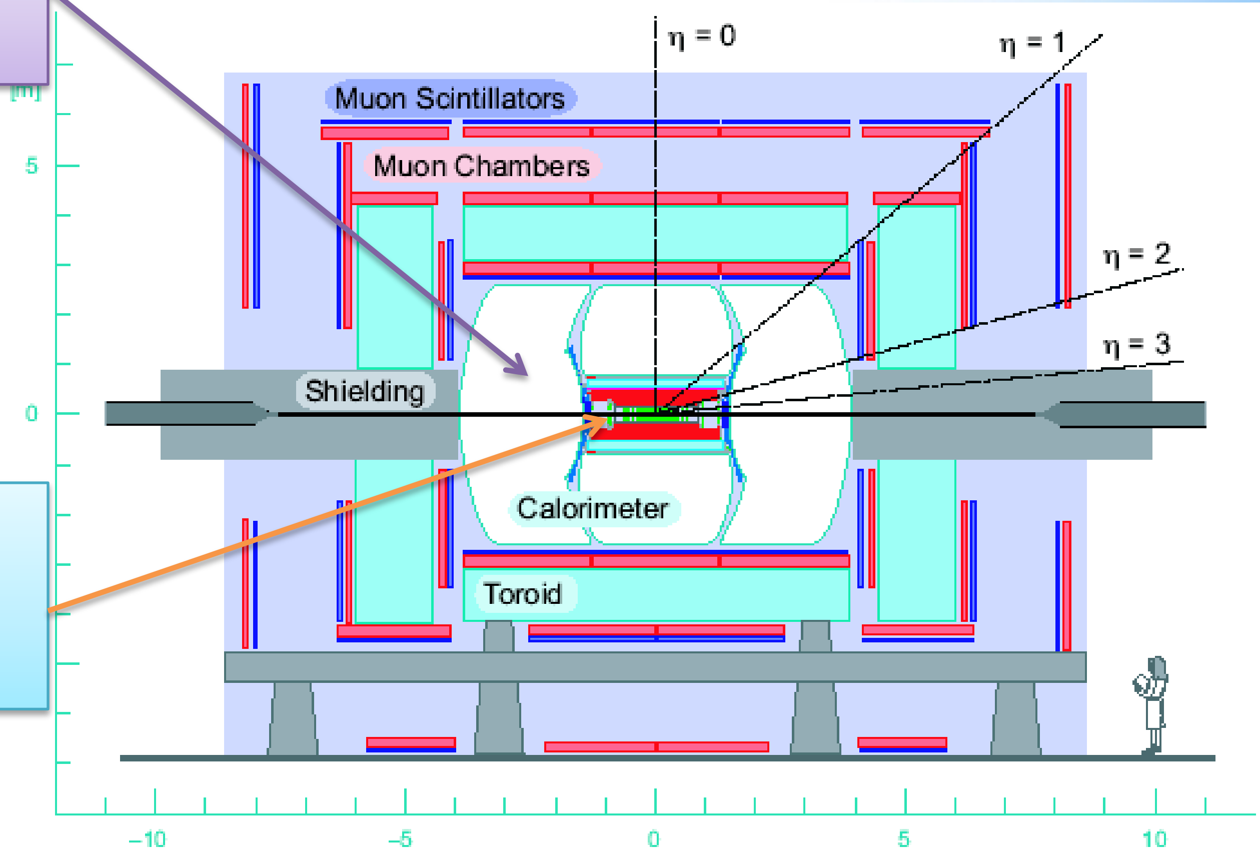
Outline

- Introduction
- Measurement of the electron charge asymmetry in ppbar $\rightarrow$ W + X $\rightarrow$ eν + X events
- Measurement of the forward-backward charge asymmetry in Z/γ^* $\rightarrow$ ee events
- Summary

Introduction

Liquid-argon calorimeter
- Central (CC) and end cap (EC)
- Coverage $|\eta| < 4.2$

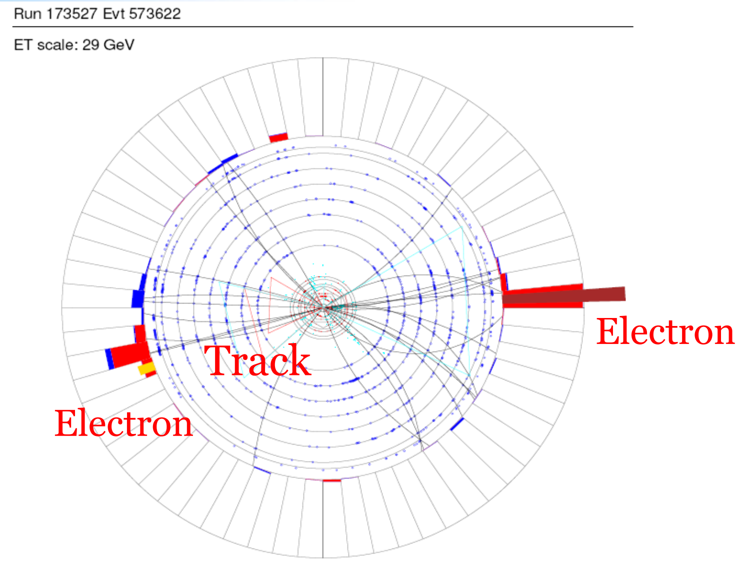


- Silicon Microstrip Tracker (SMT)
- Central Fiber Tracker
- 2T solenoid field

W and Z events

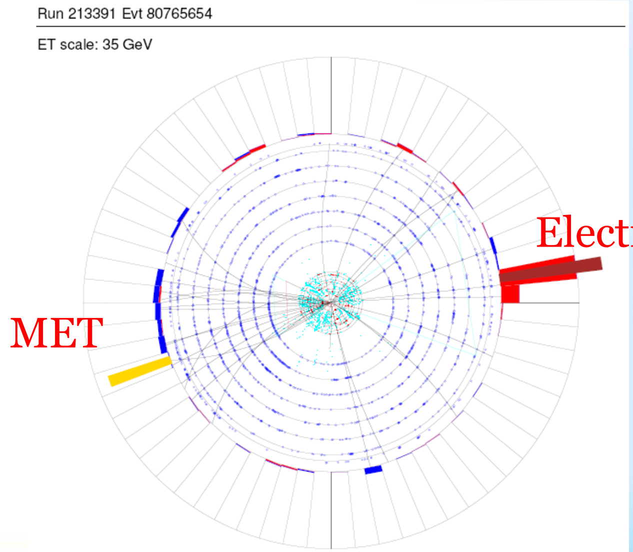
Z event

- Two high p_T electron
- Identify the charge, and measure the momentum of the electron using the trackers and calorimeter



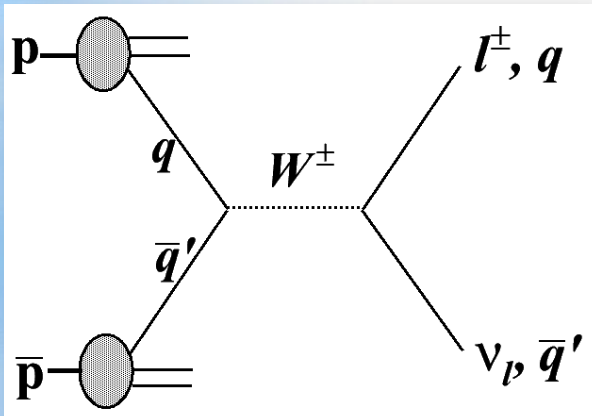
W event:

- One high p_T electron
- One high p_T neutrino
- Identify the charge, and measure the momentum of the electron
- Neutrino cannot be detected, $p_T(\nu)$ is inferred by the "missing E_T (MET)" in the detector

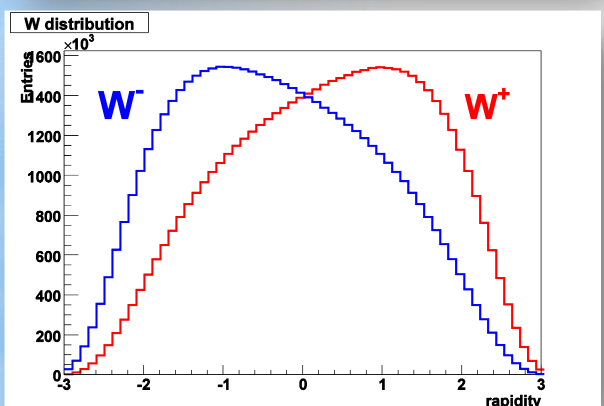


Measurement of the electron charge asymmetry in ppbar $\rightarrow W + X \rightarrow e\nu + X$ events

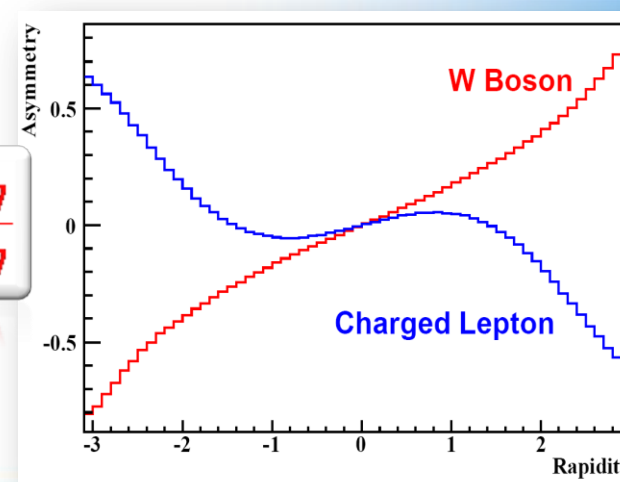
Electron charge asymmetry



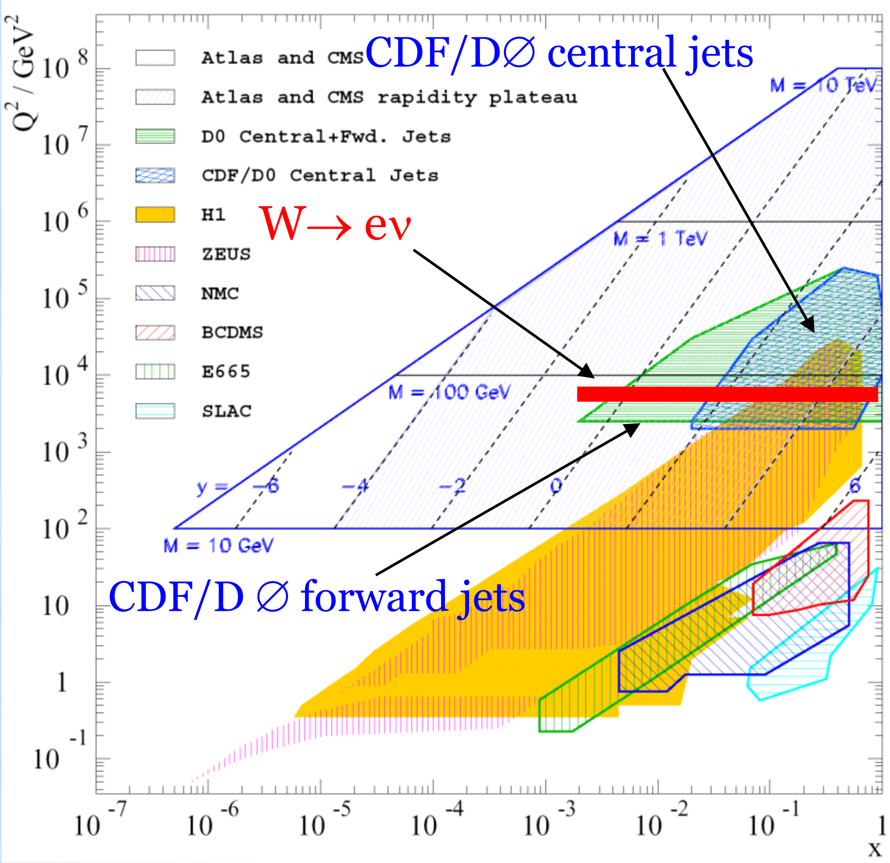
- The W^+ is boosted along the proton and W^- is boosted along the anti-proton because the *u* quarks carry more momentum than the *d* quarks in proton
- Cannot reconstruct the transverse momentum of the neutrino → difficult to measure the W rapidity
- W production asymmetry → electron charge asymmetry.
- Electron charge asymmetry A(y) ⊗ (V-A)



$$A(\eta_l) = \frac{d\sigma(l^+)/d\eta - d\sigma(l^-)/d\eta}{d\sigma(l^+)/d\eta + d\sigma(l^-)/d\eta}$$



Q^2, x limit



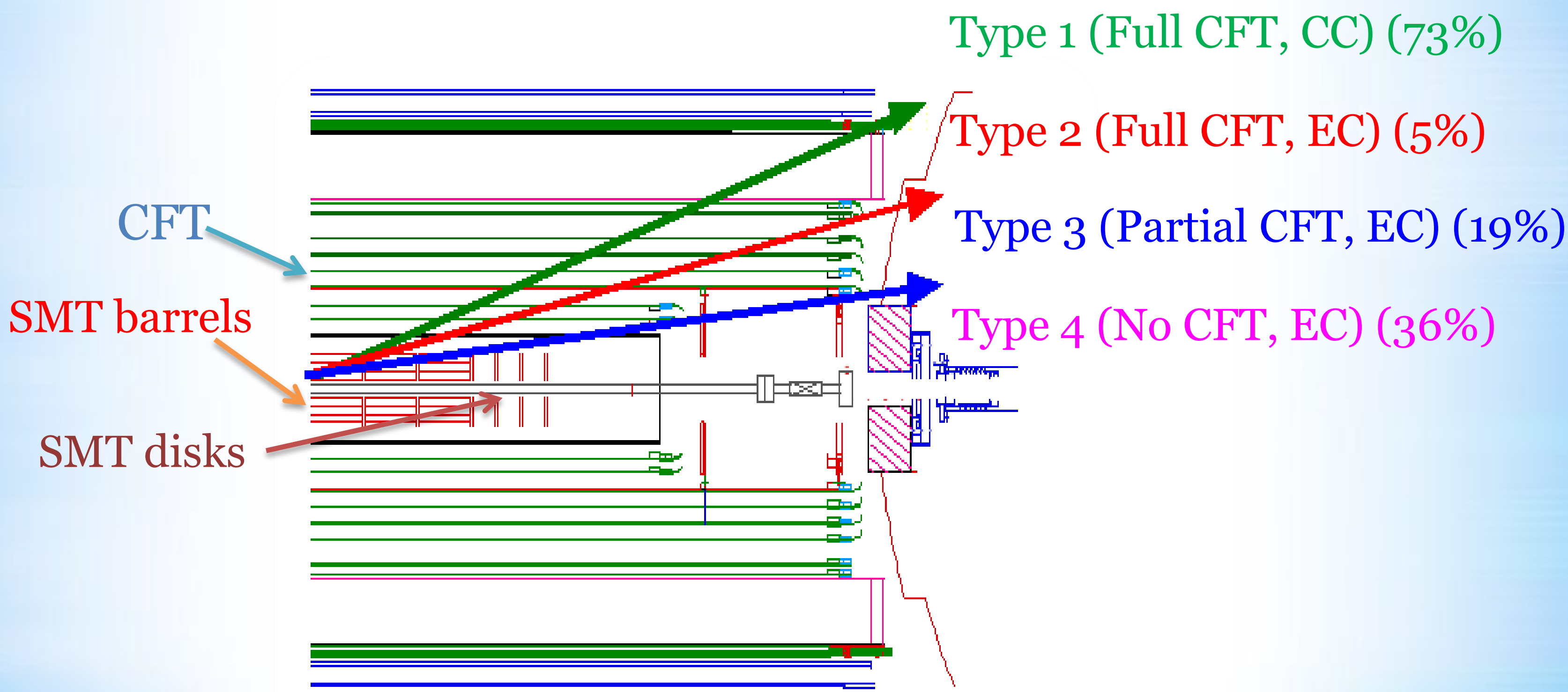
W asymmetry measurement constraints

$$Q^2 \approx M_W^2, x = \frac{M_W}{\sqrt{s}} e^{\pm y_W}$$

$|y_W| < 3.2 \Rightarrow 0.002 < x < 1.0$

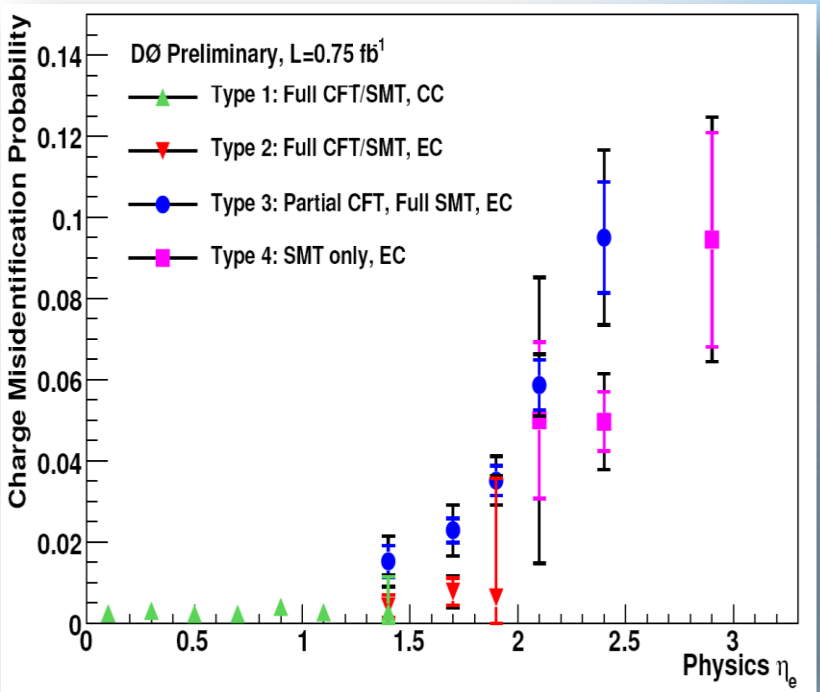
Electron selection

- Luminosity ~ 0 .75 fb^{-1}
- Four electron types depending on the position of EM cluster, incident angle and the primary vertex
- Different track quality cuts applied for different electron types



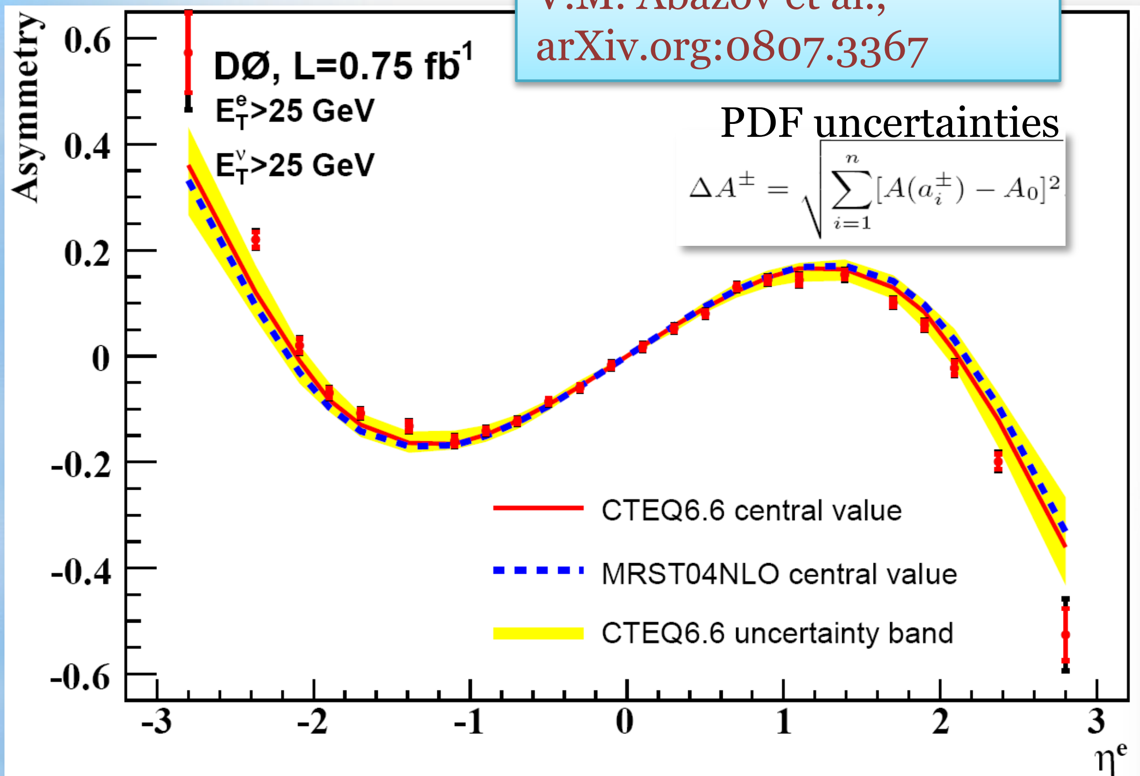
Charge misidentification and bias

- Charge misidentification (misID) dilutes the asymmetry.
- Using Z→ee sample to estimate the misID probability.
- Tighten the requirement for one electron, check the charge of the other electron.
- $|\eta| < 1$, misID ~ 0.3%
- $2.8 < |\eta| < 3.2$, misID ~ 9%
- The solenoid polarity are flipped frequently in D∅. No significant difference in asymmetry for the forward and backward polarity is found.
- The selection efficiencies are similar for the positive and negative electrons.



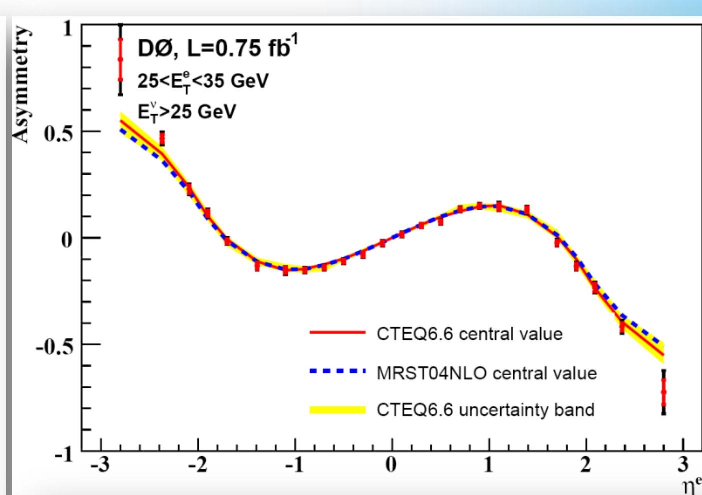
Electron charge asymmetry

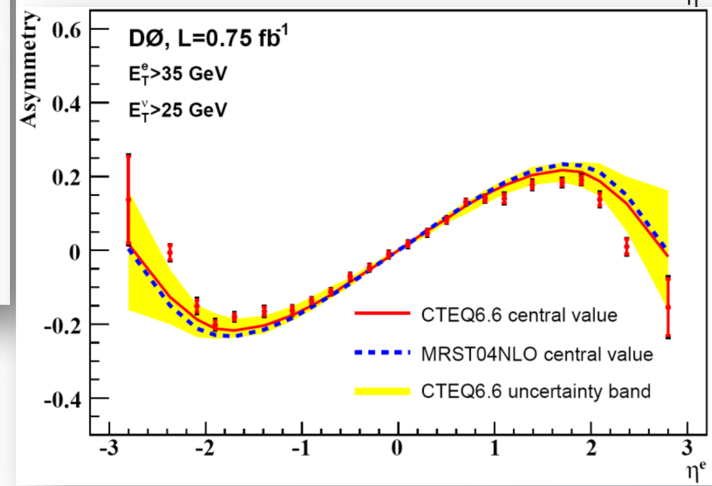
V.M. Abazov et al., arXiv.org:0807.3367



PDF uncertainties

$$\Delta A^{\pm} = \sqrt{\sum_{i=1}^{n} [A(a_i^{\pm}) - A_0]^2}$$

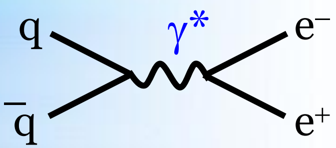




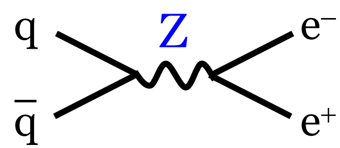
- Latest CTEQ6.6 NLO PDFs with 44 uncertainty PDF sets (P. Nadolsky *et al.*, arXiv: 0802.0007v3)

Measurement of the forward-backward charge asymmetry in $Z/\gamma^* \to ee$ events

Z/γ* Forward-backward asymmetry

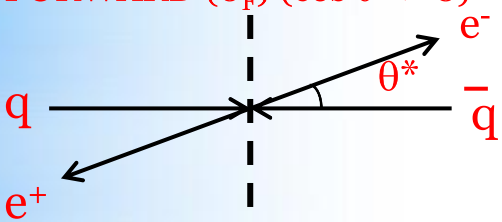


Vector coupling

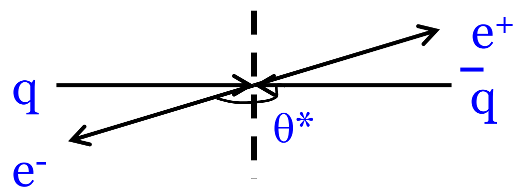


Vector & axial-vector coupling

FORWARD (σ_F) ($\cos\theta^* > 0$)



BACKWARD (σ_B) ($\cos\theta^* < 0$)

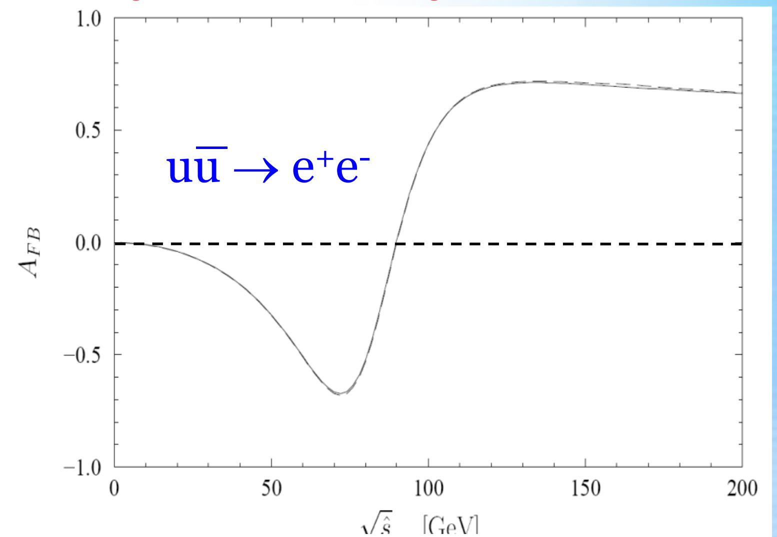


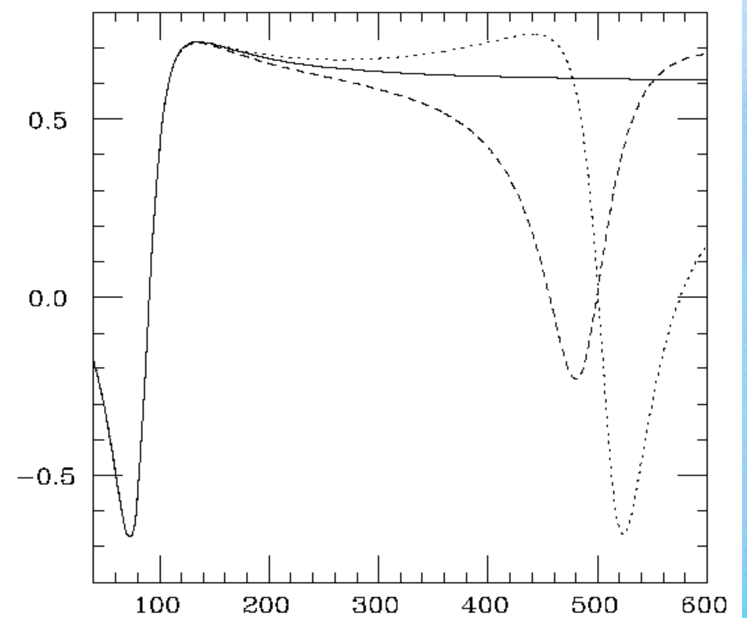
θ^* defined in Collins-Soper frame (Z/γ* rest frame)

$$\frac{d\sigma}{d\cos\theta^*} = A \times (1 + \cos^2\theta^*) + B \times \cos\theta^*$$

$$A_{FB} = \frac{(\sigma_F - \sigma_B)}{(\sigma_F + \sigma_B)}$$

New resonance (Z', LED etc) can interfere with Z and γ* . A_{FB} measurement complementary to bump search

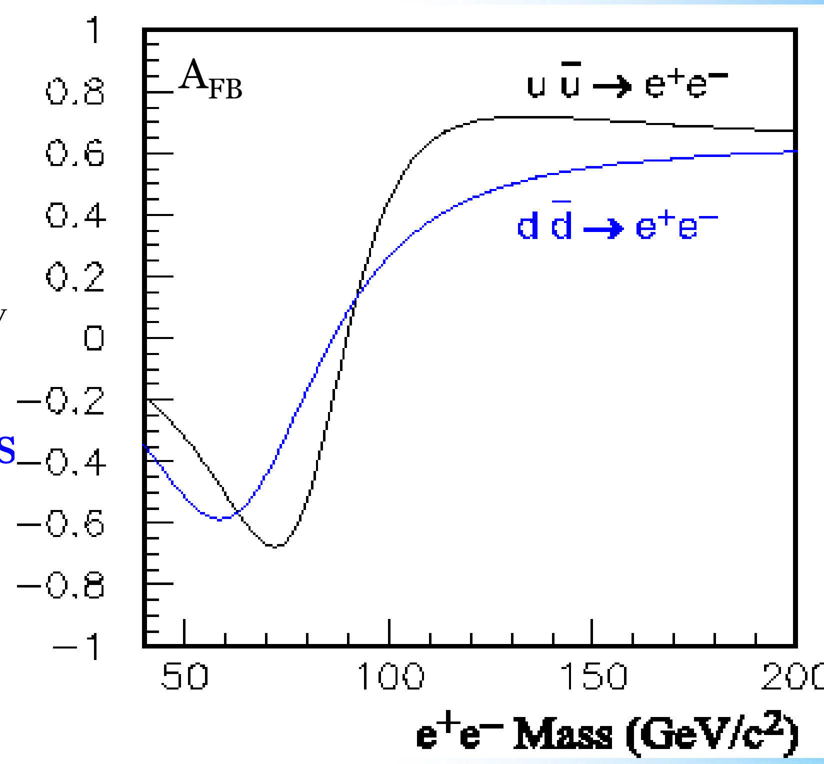




Weak mixing angle $\sin^2\theta_W$

$$u\bar{u}(d\bar{d}) \rightarrow Z/\gamma^* \rightarrow e^+e^-$$

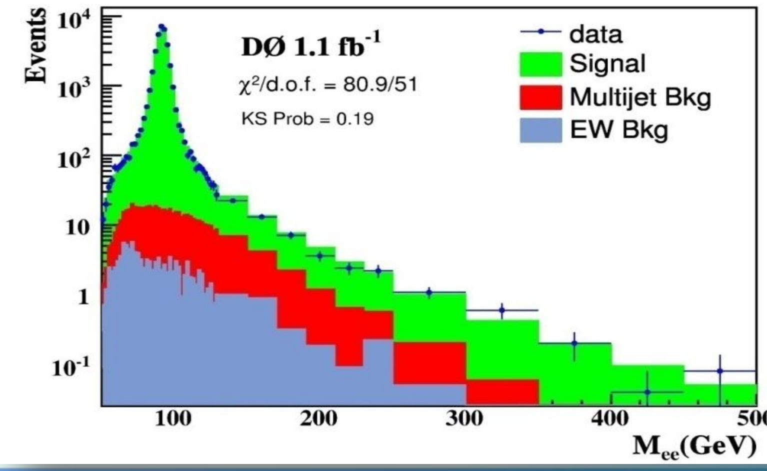
- SM couplings of fermions to Z boson:
  - Axial-vector coupling: $g_A = I_f^3$
  - Vector coupling: $g_V = I_f^3 - 2Q_f \sin^2\theta_W$
  - With $\sin^2\theta_W = 0.232$
- A_{FB} is sensitive to $\sin^2\theta_W$ ($\sin^2\theta_W^{eff}$ includes higher order corrections)



Event selection

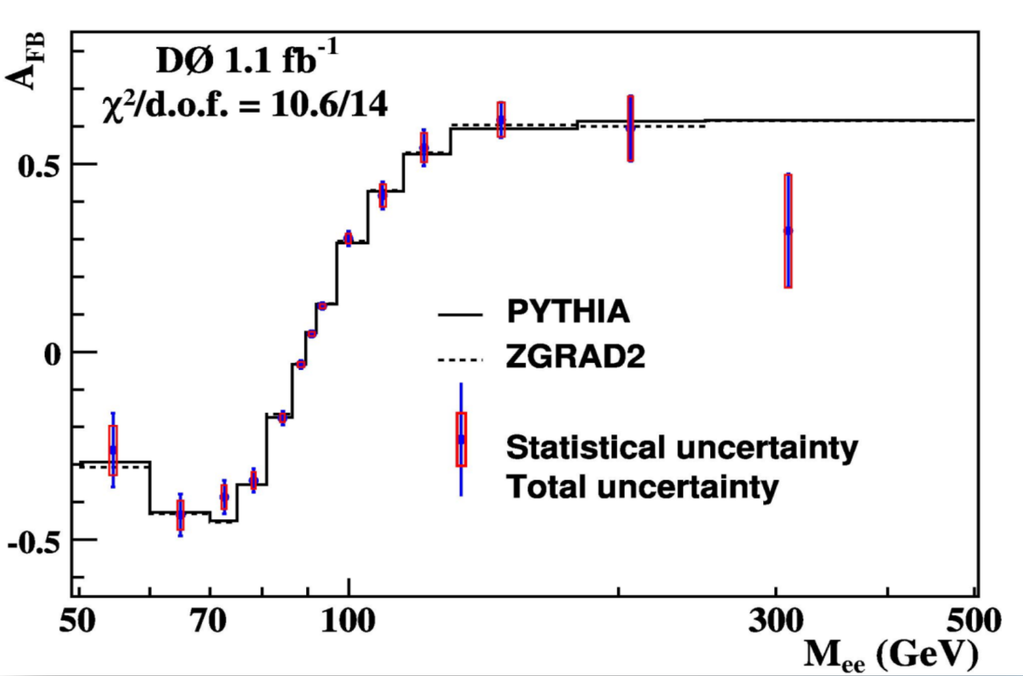
- Integrated luminosity ~ 1 fb^{-1}
- Two electrons:
  - $p_T > 25$ GeV
  - Isolated with large EM fraction
  - Shower shape consistent with that of an electron
- $50 < M_{ee} < 500$ GeV
- A_{FB} measured in 14 mass bins
- Bin size chosen by detector resolution and available statistics
- Electroweak backgrounds ~ 0.4% $Z/\gamma^* \to \tau\tau$, W+X, WW, WZ, ttbar
- QCD background ~ 0.9%

Mass range (GeV)	CC Forward	CC Backward	CE Forward	CE Backward
50 – 60	69	78	15	16
60 – 70	104	158	51	91
70 – 75	96	117	64	93
75 – 81	191	235	172	293
81 – 86.5	749	763	843	970
86.5 – 89.5	1388	1357	1860	1694
89.5 – 92	2013	1918	2543	2214
92 – 97	2914	2764	3132	2582
97 – 105	686	549	867	470
105 – 115	153	97	243	88
115 – 130	101	39	167	61
130 – 180	91	33	202	69
180 – 250	31	13	53	16
250 – 500	14	15	17	4



Unfolded A_{FB} result

- Raw A_{FB} → Unfolded A_{FB}
  - Detector resolution:
    - Events migrate from one mass bin to the other
    - Especially important for mass bins near Z pole
  - Acceptance and efficiencies
- The SM prediction is consistent with the unfolded A_{FB}

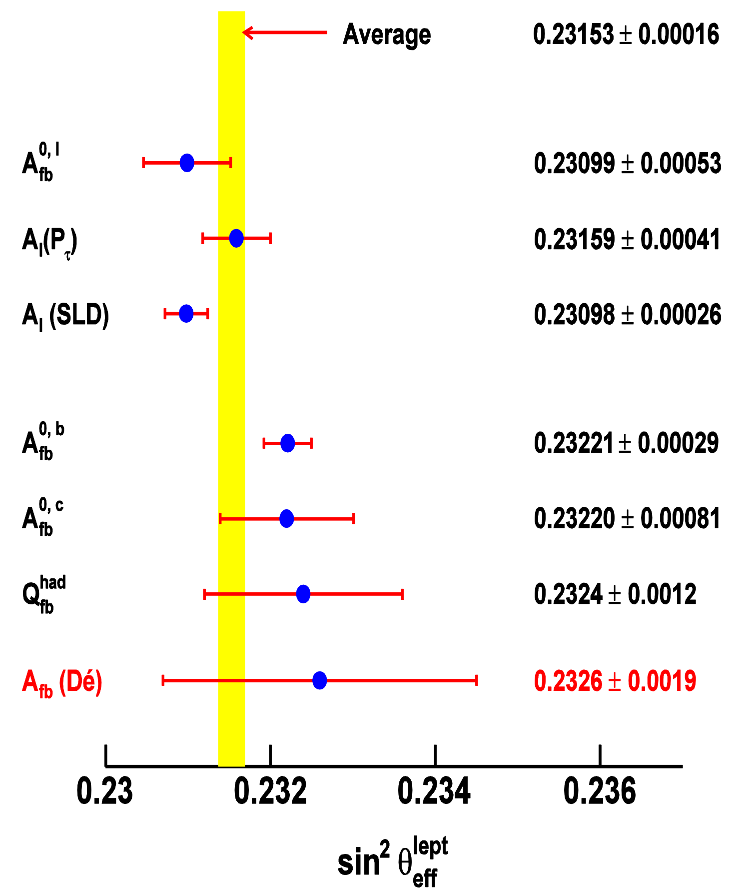


$\sin^2\theta_W^{eff}$ result

- Extraction of $\sin^2\theta_W^{eff}$ using PYTHIA:
  - Obtained from backgrounds-subtracted A_{FB} distribution
  - Compared with A_{FB} templates according to different values of $\sin^2\theta_W^{eff}$ generated with PYTHIA and GEANT-based MC simulation
- Higher-order QCD and EW corrections: using ResBos and ZGRAD2
- Fitted results (for $70 < M_{ee} < 130$ GeV):

$$\sin^2\theta_W^{eff} = 0.2326 \pm 0.0018\ (\text{stat.}) \pm 0.0006\ (\text{syst.})$$

- ❖ $\sin^2\theta_W^{eff}$ result agrees with the global EW fit
- ❖ Uncertainty comparable with the uncertainties from light quark asymmetries
  - ❖ Combined Q^{had}_{FB} from four LEP experiments (0.0012)
  - ❖ NuTeV measurement (0.0016)



Summary

- Electron charge asymmetry
  - Measured in three different electron E_T bins
  - Experimental uncertainties smaller than PDF uncertainties for most $\eta(e)$ bins
- A_{FB} measurement and extraction of $\sin^2\theta^{eff}_W$ ($Z \rightarrow ee$)
  - The SM prediction is consistent with the unfolded A_{FB} distribution
  - $\sin^2\theta_W^{eff} = 0.2326 \pm 0.0018$ (stat.) ± 0.0006 (syst.)
- More data collected and more high precision EW and QCD measurements expected