Measurement of Z-quark, Z-electron Couplings and $\sin^2\theta_W$ at CDF

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Leading Order Calculation

- Amplitude $(f_i\bar{f} \to e^+e^-_j)$, i,j = spin of the fermions, L or R.

$$A_{ij} = -Q_f Q_e e^2 + \Lambda(\hat{s}) C_i^Z(f) C_j^Z(e),$$

$$\Lambda(\hat{s}) \equiv \frac{\hat{s}}{\hat{s} - M_Z^2 + iM_Z\Gamma_Z},$$

$Q_{f,e}$: electric charge of fermions,

$C^Z_{i,i}(f,e)$: Z-fermion coupling constants

- Cross Section

$$\frac{d\hat{\sigma}}{d\cos\theta^*} = \frac{\pi\alpha^2}{8\hat{s}}\Big[(|A_{LL}|^2 + |A_{RR}|^2)(1+\cos\theta^*)^2 \leftarrow \text{forward}$$
$$+(|A_{LR}|^2 + |A_{RL}|^2)(1-\cos\theta^*)^2\Big], \leftarrow \text{backward}$$

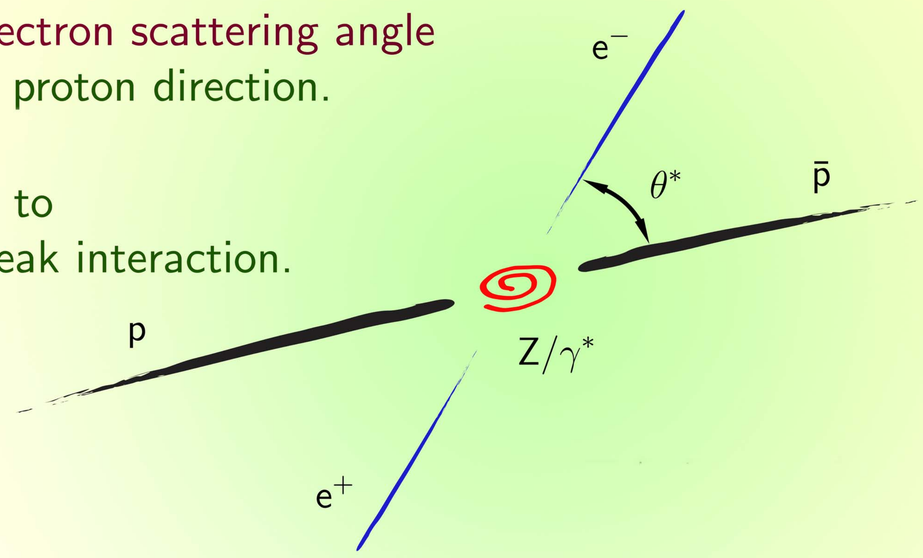
$$|A_{ij}|^2 = (Q_f Q_e e^2)^2 \leftarrow \gamma^*$$
$$+2Q_f Q_e e^2 C_i^Z(f) C_j^Z(e)\Lambda(\hat{s}) \leftarrow Z/\gamma^* \text{interference}$$
$$+(C_i^Z(f) C_j^Z(e)\Lambda(\hat{s}))^2 \leftarrow Z$$

- Forward-Backward Asymmetry

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{\int_0^1 \frac{d\hat{\sigma}}{d\cos\theta^*} - \int_{-1}^0 \frac{d\hat{\sigma}}{d\cos\theta^*}}{\int_0^1 \frac{d\hat{\sigma}}{d\cos\theta^*} + \int_{-1}^0 \frac{d\hat{\sigma}}{d\cos\theta^*}}$$

θ^* : electron scattering angle off the proton direction.

θ^* is not symmetric due to parity violation in the weak interaction.

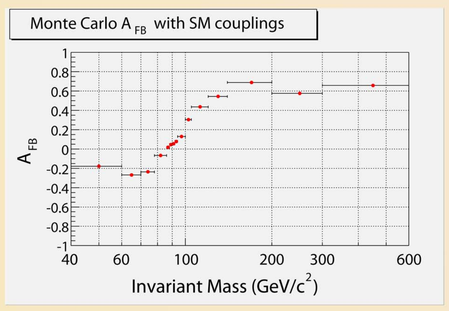


$$p\bar{p} \to Z/\gamma^* \to e^+e^-$$

Monte Carlo

- ZGRAD : Calculates Drell-Yan Cross Section
- Electroweak correction up to full order of α

- Varying the parameters in the generator,
- Minimize χ^2 against the Data.
- Fit variables can be one of the following
  - Z-quark couplings (u_L, u_R, d_L, d_R)
  - Z-electron couplings (e_V, e_A)
  - $\sin^2\theta_W$
- The other parameters are fixed to SM values.
- Fit variables are highly correlated.



Data-MC Fit

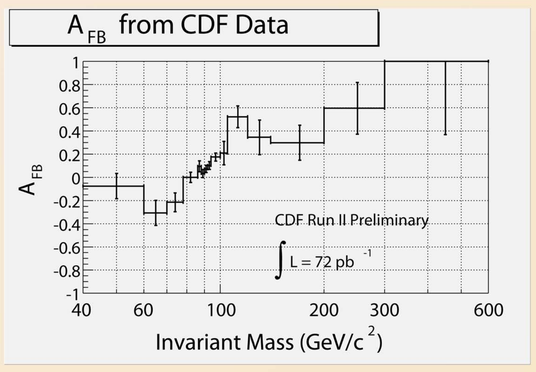
CDF Data

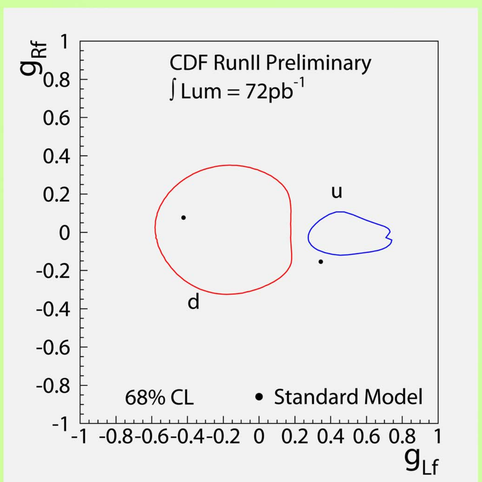
- Luminosity : 72 pb^{-1} from Run II
- Require one good electron candidate with $|\eta| < 1$
- Require one loose electron candidate with $|\eta| < 3$
- Count the number of events

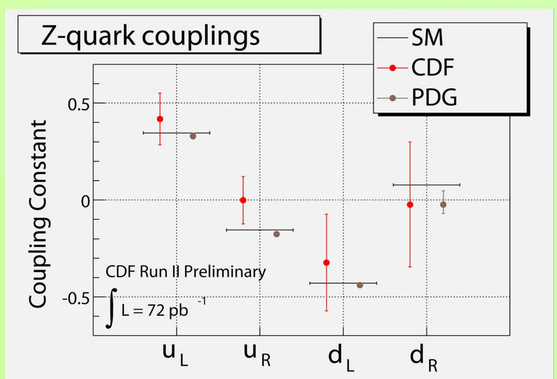
with $\cos\theta^* > 0$ (forward) $\to N_F$

$\cos\theta^* < 0$ (backward) $\to N_B$

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$





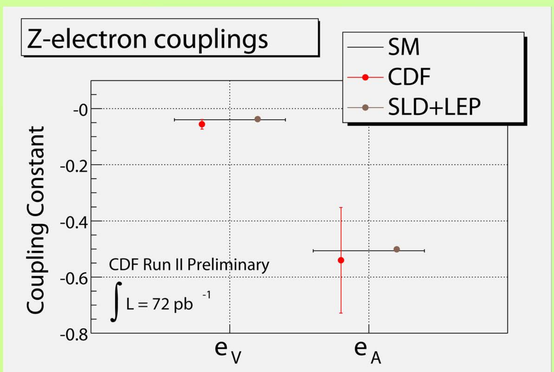


Z-quark couplings

(left) **Z-quark couplings** compared with SM prediction and other experiments.

(far left) **Z-quark couplings** compared with 68% confidence level from SM prediction.

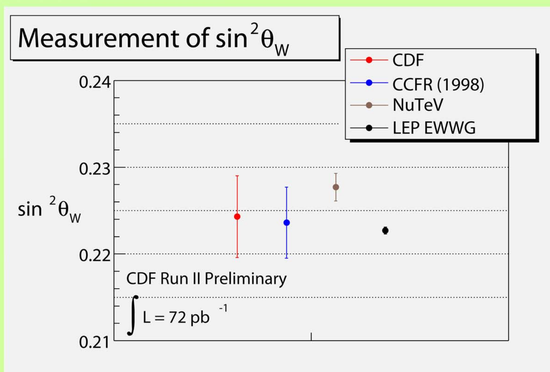
	CDF	PDG	SM prediction
u_L	0.418 ± 0.133	0.330 ± 0.016	0.3459 ± 0.0002
u_R	-0.001 ± 0.122	$-0.176\ ^{+0.011}_{-0.006}$	-0.1550 ± 0.0001
d_L	-0.323 ± 0.249	-0.439 ± 0.011	-0.4291 ± 0.0002
d_R	-0.023 ± 0.322	$-0.023\ ^{+0.070}_{-0.047}$	0.0776



Z-electron couplings

Electron couplings measured from the fit. Compared with SM prediction and other experiments.

	CDF	SLD+LEP	SM prediction
e_V	-0.056 ± 0.017	-0.03816 ± 0.00047	-0.0397 ± 0.0003
e_A	-0.540 ± 0.188	-0.50111 ± 0.00035	-0.5064 ± 0.0001



$\sin^2\theta_W$ (on-shell)

Measurement of $\sin^2\theta_W$. Compared with other experiments.

	CDF	CCFR	NuTeV	LEP EWWG
$\sin^2\theta_W$	0.2243 ± 0.0047	0.2236 ± 0.0041	0.2277 ± 0.0016	0.2227 ± 0.0004