

Measurement of $\sin^2\theta_W$ in $Z\mu\mu$ events at the D0 experiment

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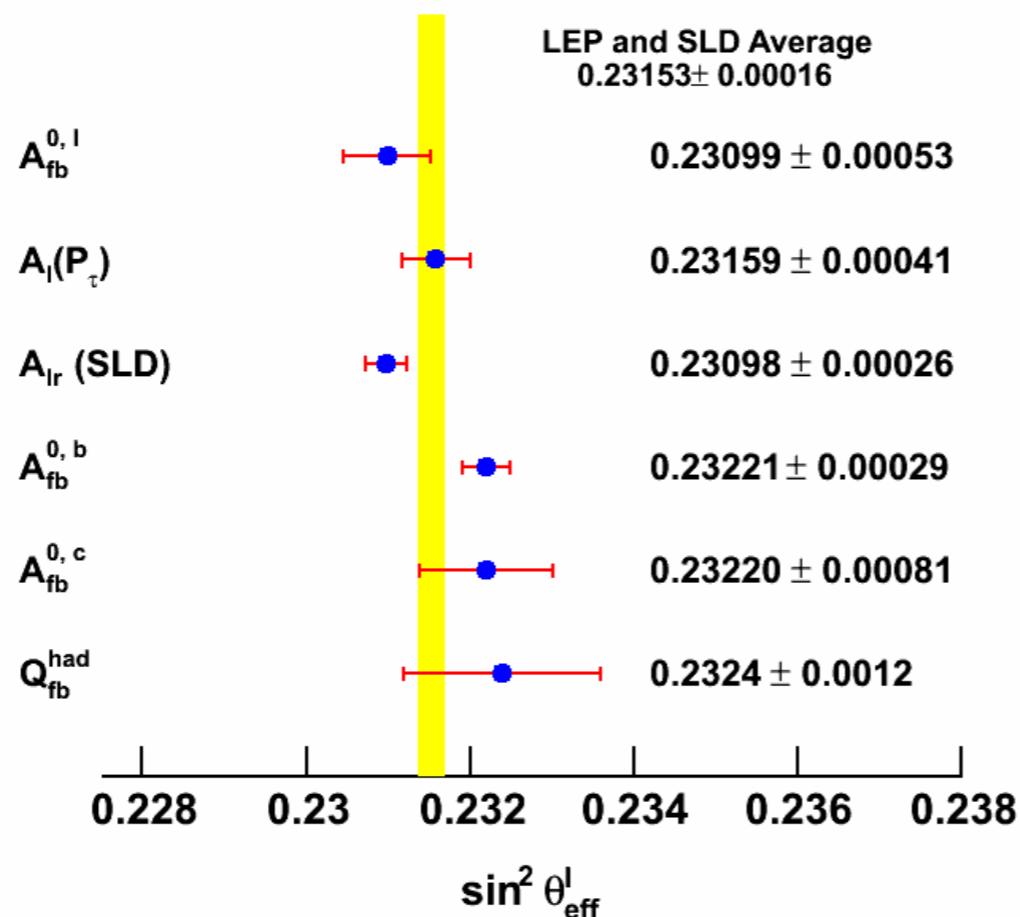
¹⁾ institution when research started

²⁾ current institution

Motivation (1)

The weak mixing angle ($\sin^2 \theta_w$) measurement

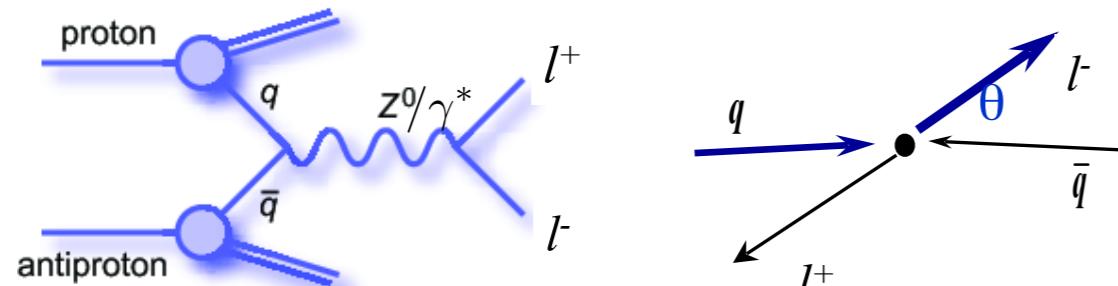
- fundamental parameter of Standard Model
- most precise results from LEP/SLD, differ by 3.2σ
- high precision measurements from hadron collider experiments are important



Motivation (2)

Drell-Yan process and the Forward-Backward Charge Asymmetry (A_{FB})

- AFB from Z-II events is very sensitivity to the weak mixing angle



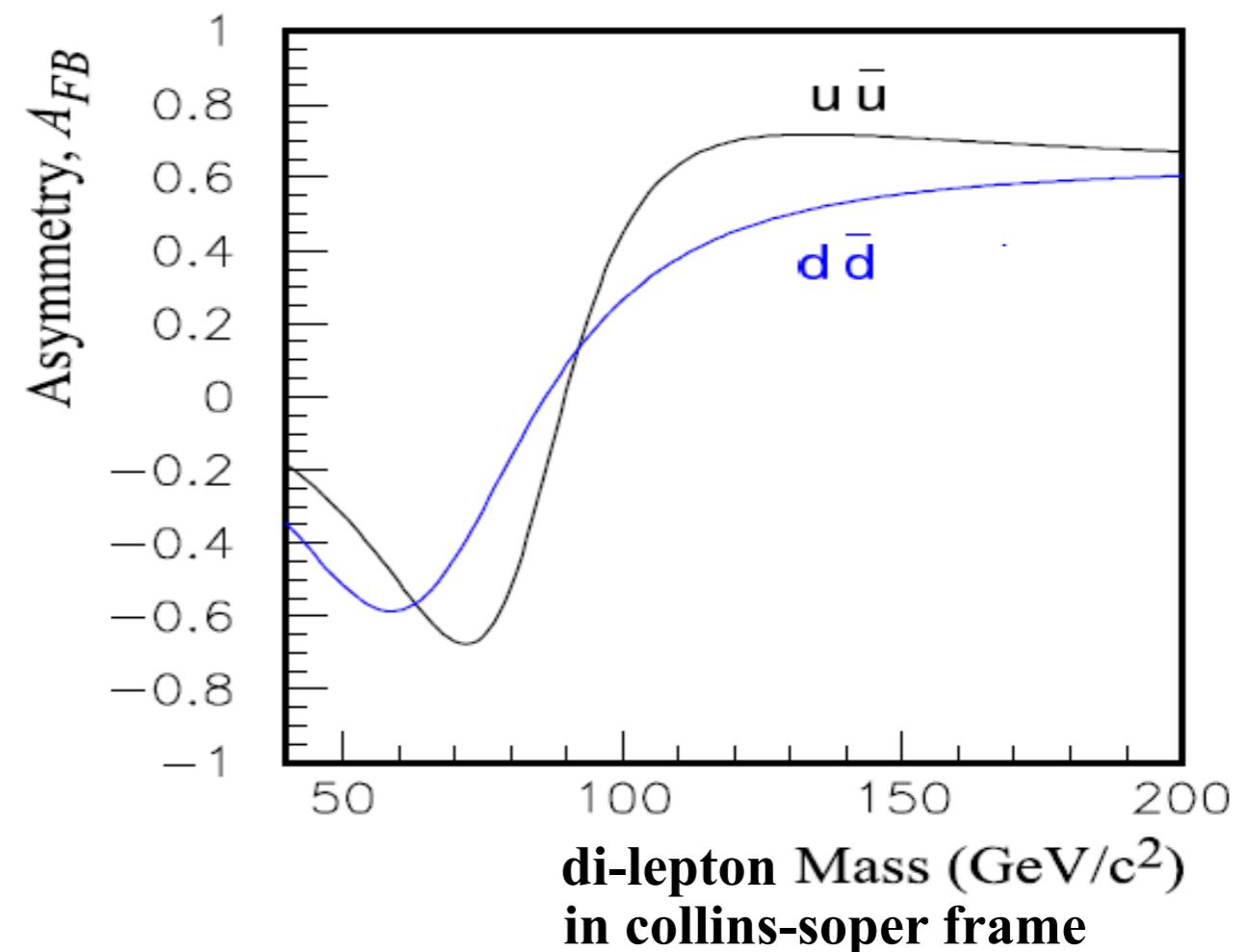
Z-quark coupling

$$g_V^i \equiv t_{3L}(i) - 2q_i \sin^2 \theta_W ,$$

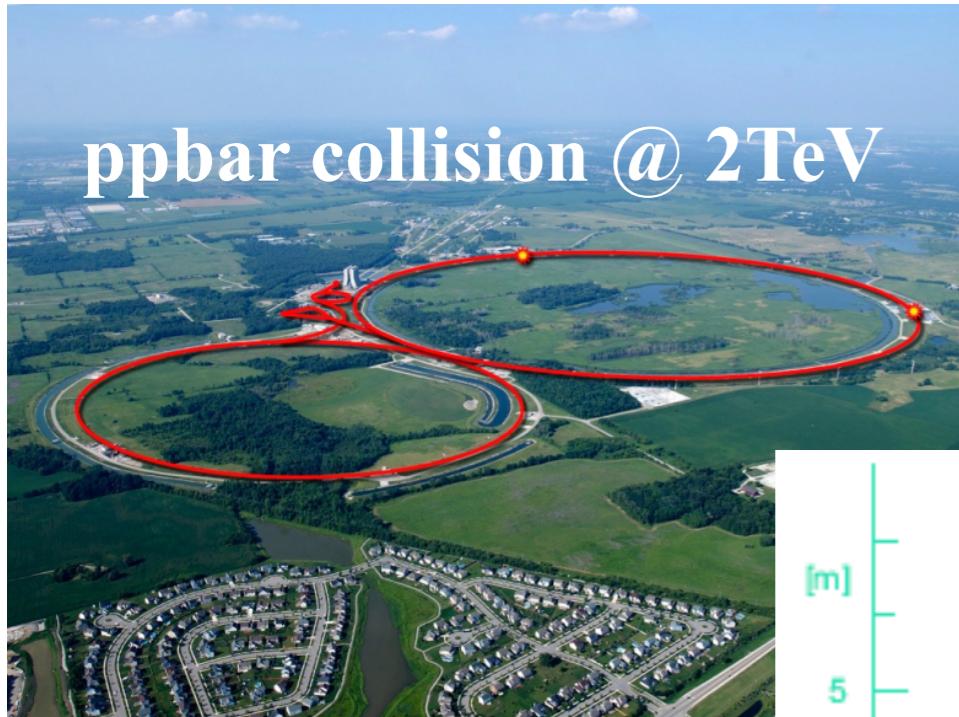
$$g_A^i \equiv t_{3L}(i) ,$$

$\cos\theta > 0$, forward
 $\cos\theta < 0$, backward

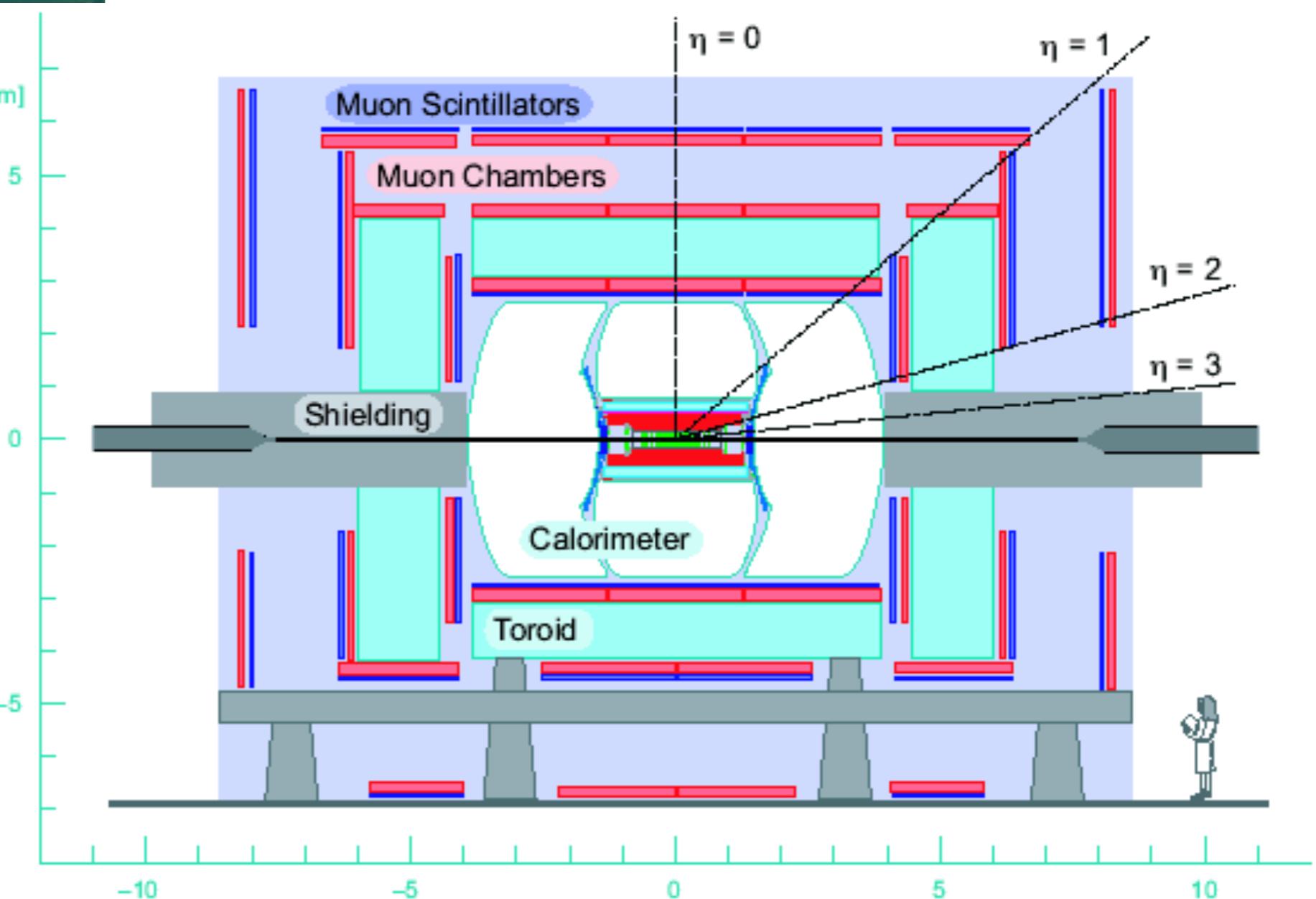
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$



Tevatron and the D0 detector



The D0 detector



- tracking:
 - scintillating fiber + silicon microstrip trackers
 - 2T solenoid
- muon system: $\eta < 2.0$

D0 muon channel measurement

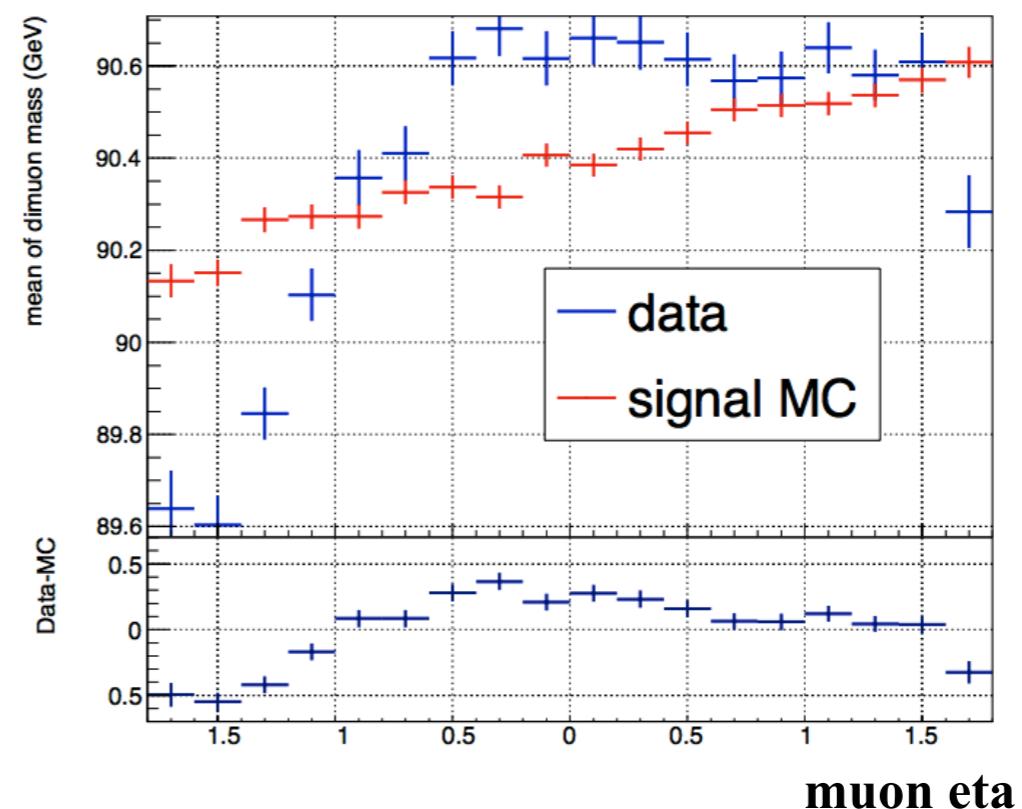
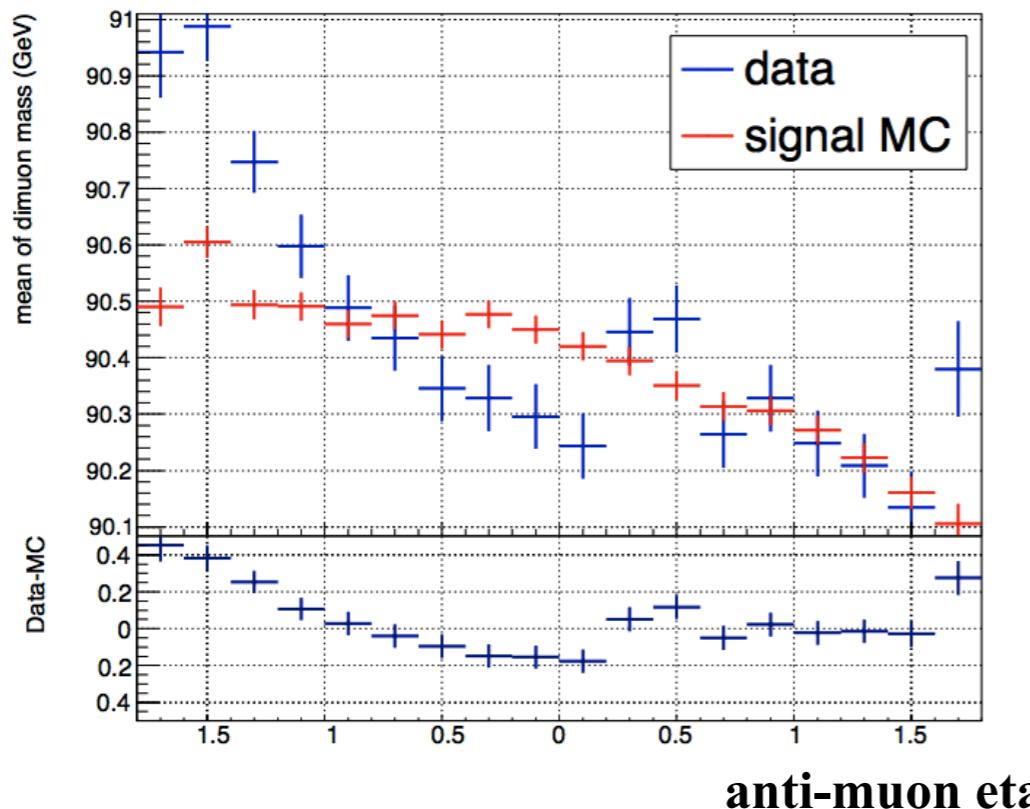
- D0 ee: unc. = 0.00047 (2015)
- CDF ee+ $\mu\mu$: unc. = 0.00046 (2016)

Last channel from Tevatron, but first time measurement!

- D0 $\mu\mu$: expected <0.00070

Challenge: charge-dependence

- AFB vs. mass is extremely sensitive to charge-dependence in muon momentum



Z mass mean vs. charge and muon η .
Data/MC difference ~ 0.5 GeV

Charge-eta-solenoid dependent calibration

General idea

- data/MC separately calibrated to generator level
- dependence with muon charge, eta and solenoid polarities

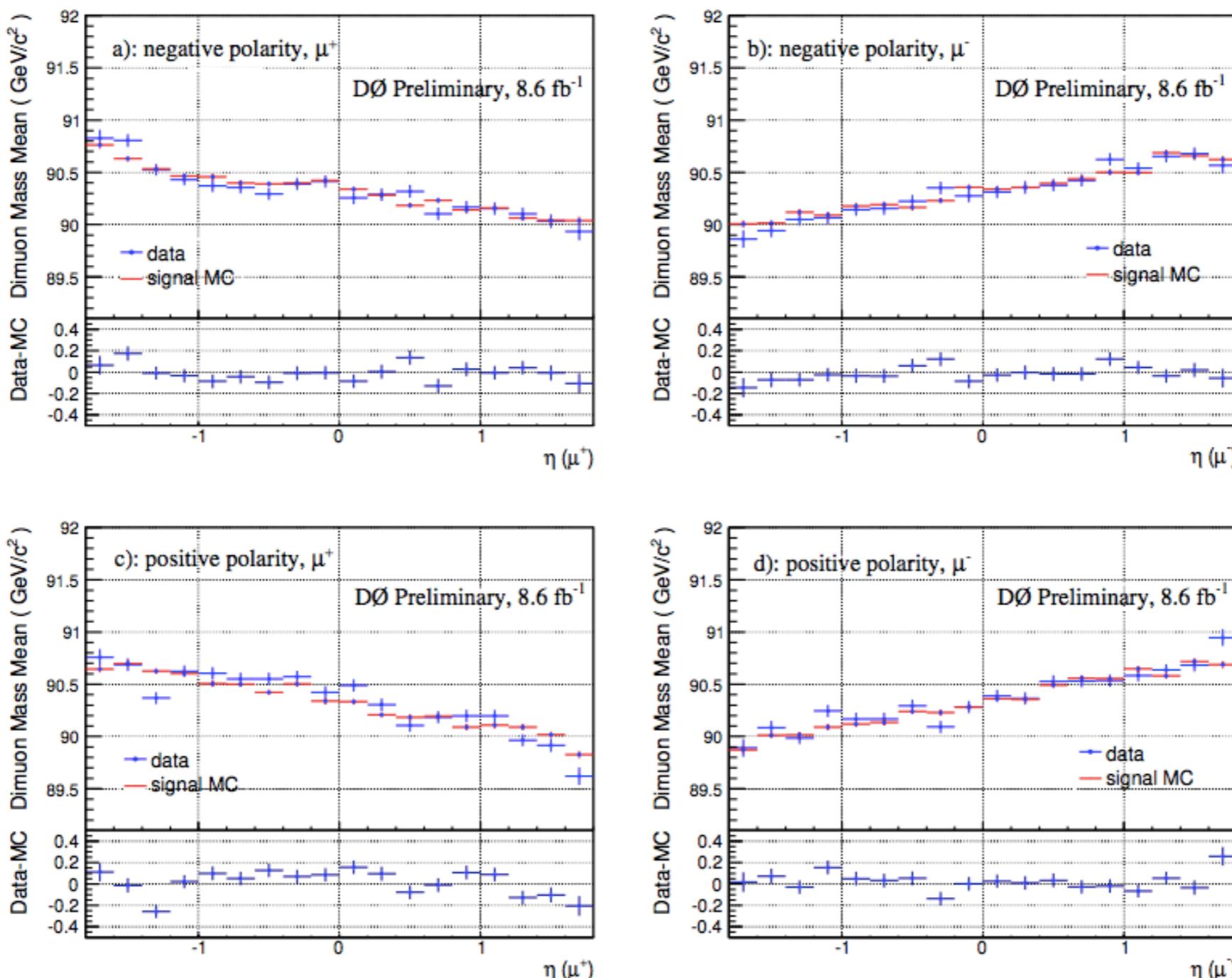
$$P_{\text{corr}} = \alpha(\eta, q, S) \cdot P_{\text{obs}}$$

- calibration parameter determined by requiring consistent Z mass mean in each charge-eta-solenoid category

Charge-eta-solenoid dependent calibration

After calibration

- data/MC comparison consistent within statistical uncertainty
- residual difference considered as systematic (relative unc. ~ 0.0001)



Strategy and other systematics

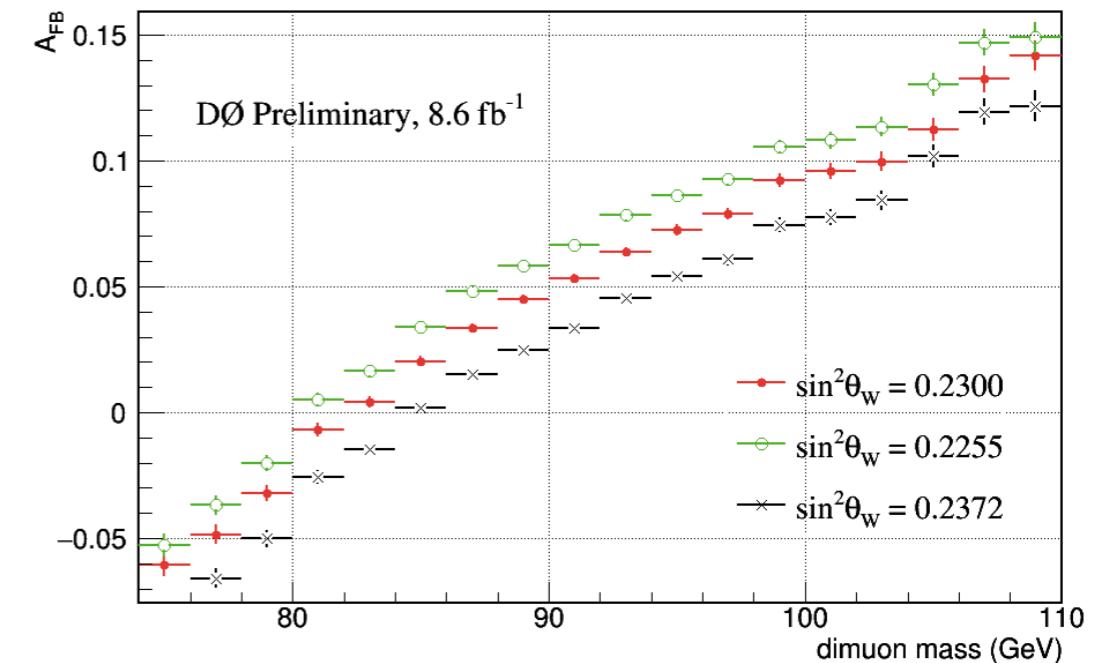
Selected data

- 2 high pT muons ($pT > 15 \text{ GeV}$), within $|\eta| < 1.8$
- events with both muon $|\eta| > 1.6$ excluded, same charge sign events excluded
- 8.6 fb^{-1} ($\sim 48\text{K}$ events) of D0 data
- di-muon mass range $74 - 110 \text{ GeV}$

Systematics

- muon momentum calibration
- efficiency measurement for muon ID and trigger
- background estimation ($< 1\%$)
 - multi-jet (data driven)
 - $W + \text{jet}$, $t\bar{t}$, $Z\tau\tau$ and di-boson process (MC)

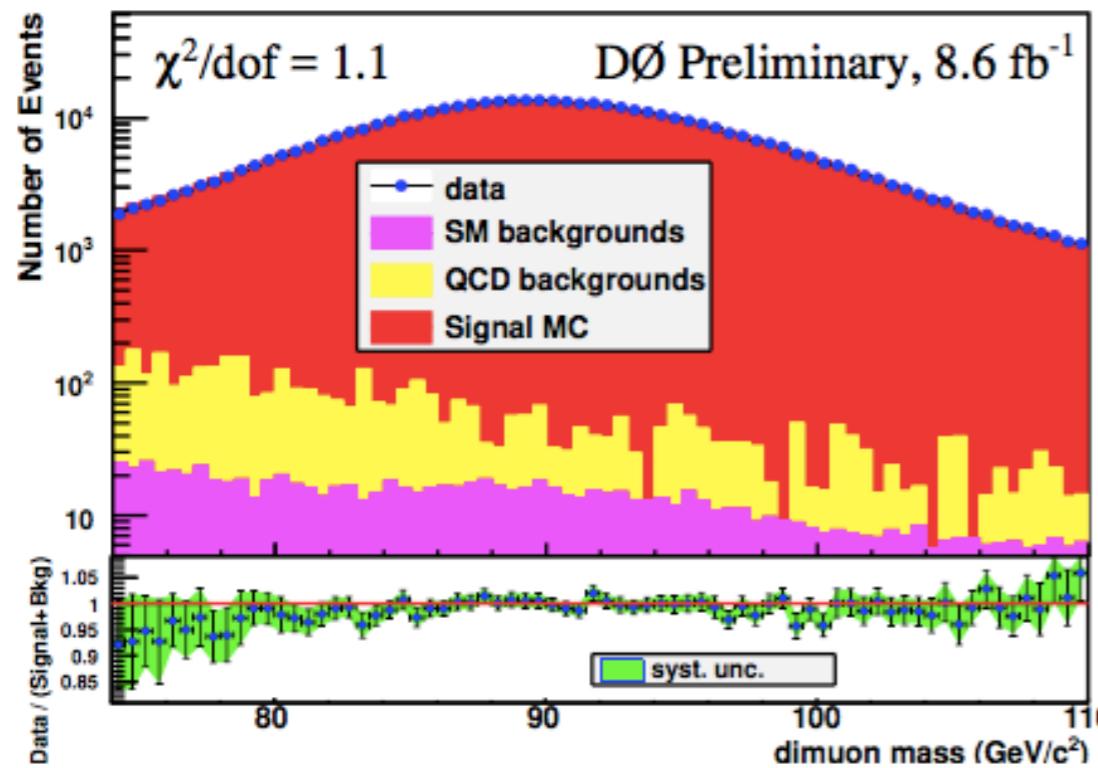
signal MC templates with different weak mixing angle values as Pythia inputs



Weak mixing angle extraction

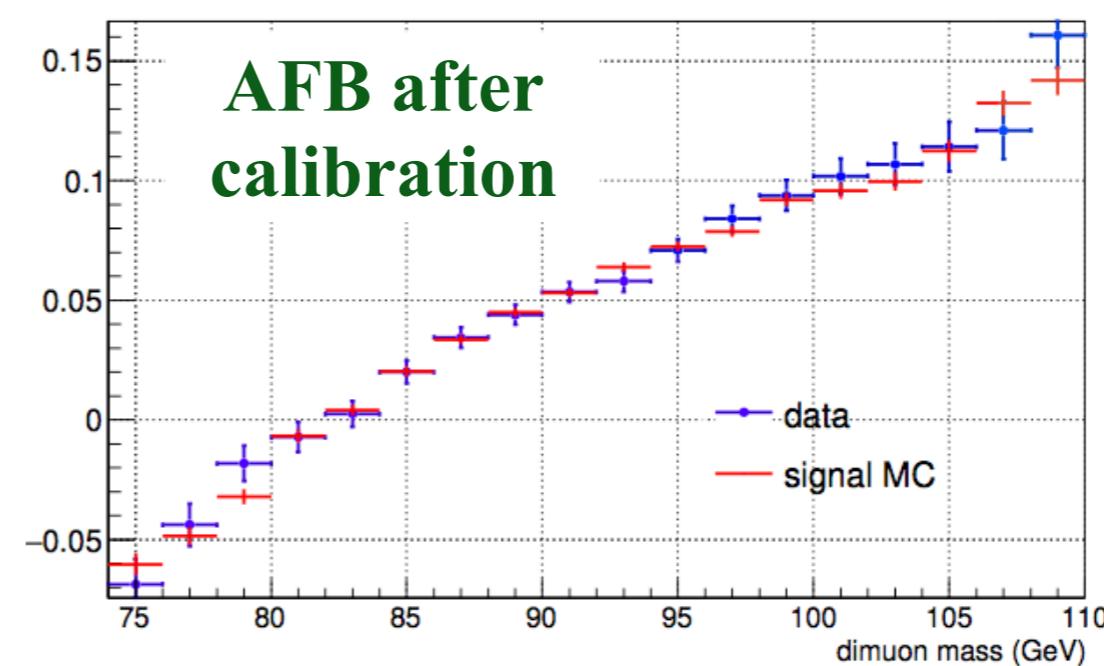
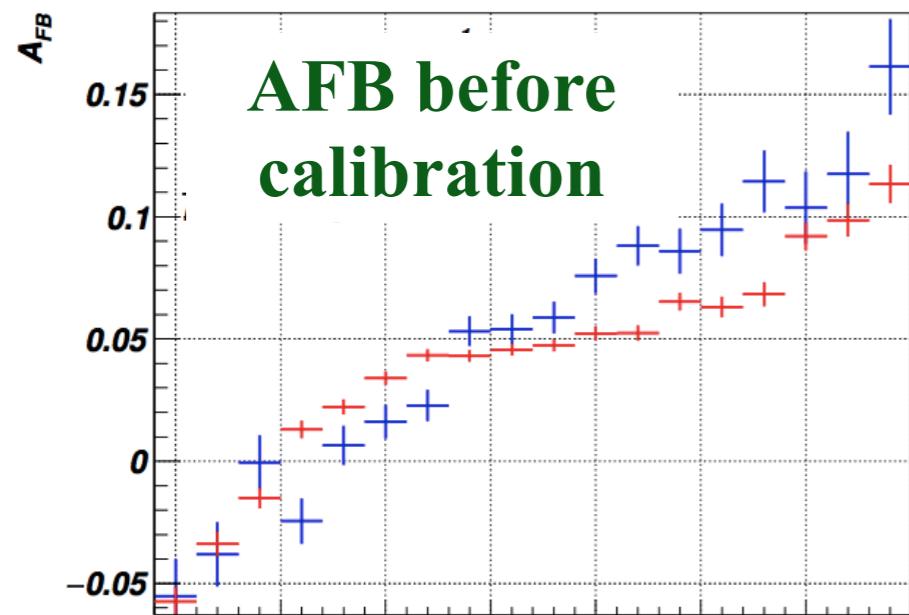
- observe A_{FB} vs. mass distribution in data
- extract the weak mixing angle from A_{FB}

Systematics well controlled



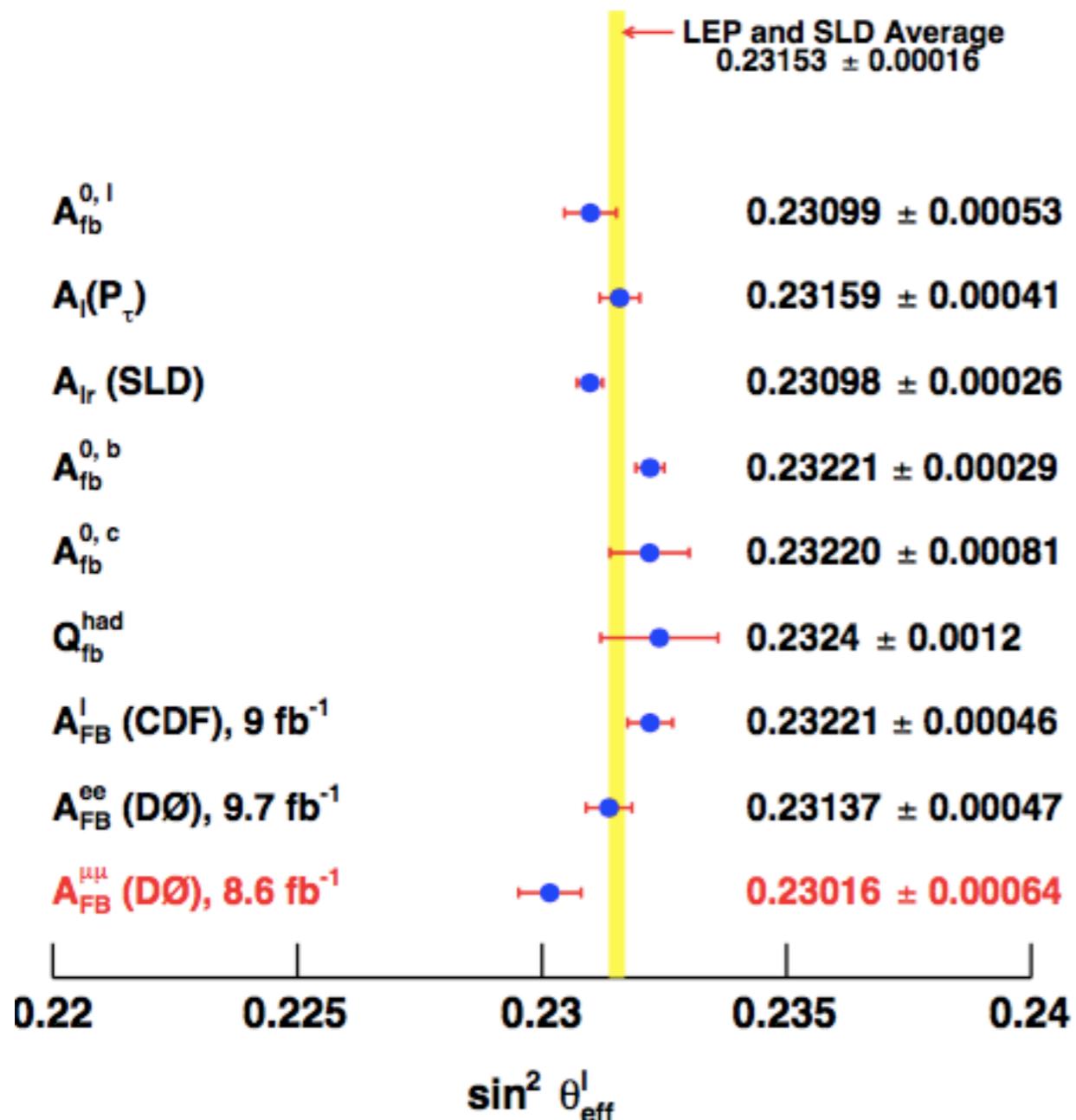
Statistical uncertainty	0.00059
Systematic uncertainties	
Momentum calibration	0.00002
Momentum resolution	0.00004
Background	0.00003
Efficiencies	0.00001
Total systematic	0.00005
PDF (NNPDF3.0)*	0.00024
Total	0.00064

*PDF uncertainty estimated according to the recipe from the NNPDF group



Final results

$$\begin{aligned}\sin^2 \theta_{\text{eff}}^l &= 0.22994 + 0.00022(\text{HO}) \\ &\quad \pm 0.00059(\text{stat.}) \pm 0.00006(\text{syst.}) \pm 0.00024(\text{PDF}) \\ &= 0.23016 \pm 0.00064\end{aligned}$$



Further combined with
D0 electron channel:

$$\begin{aligned}\sin^2 \theta_{\text{eff}}^l &= 0.23095 \pm 0.00035(\text{stat.}) \\ &\quad \pm 0.00007(\text{syst.}) \\ &\quad \pm 0.00019(\text{PDF})\end{aligned}$$