W and Z boson production (D0)

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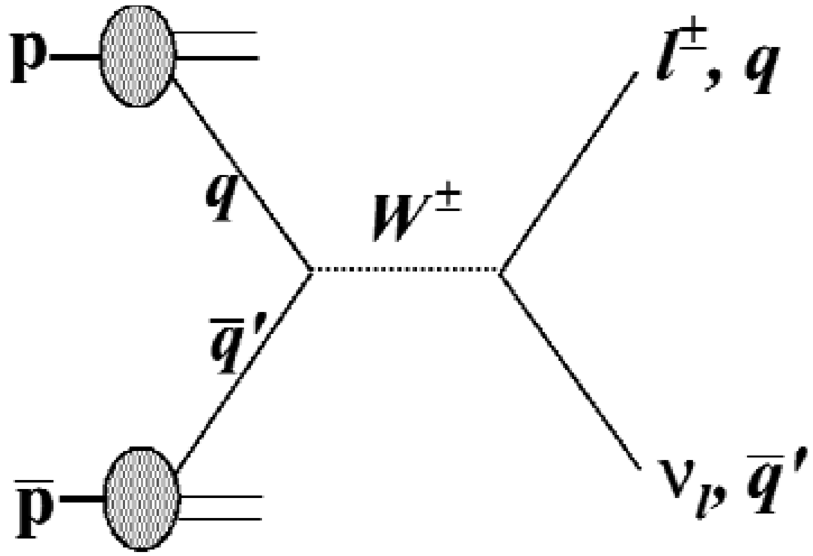
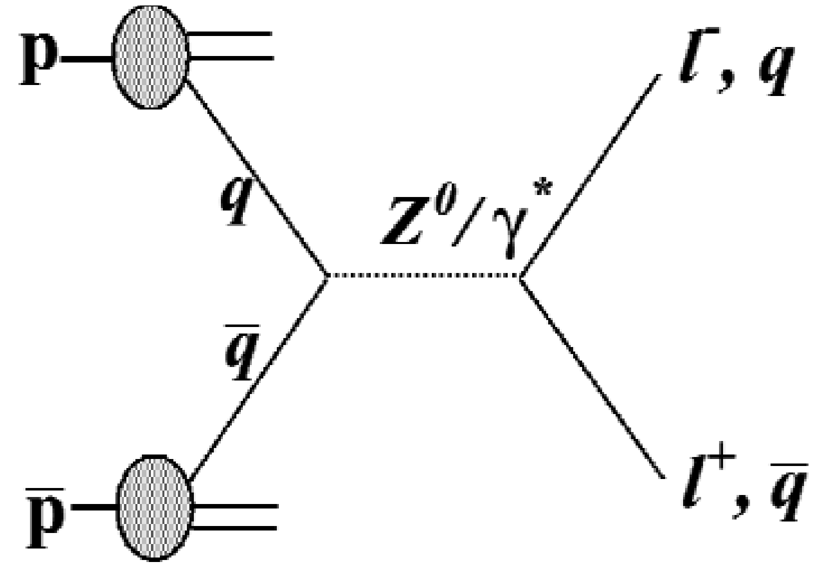
Outline

- Introduction
- Electron charge asymmetry $W \to e\nu$
- A study of the $Z \to ee$ and $Z \to \mu\mu$ events at low p_T using a novel technique
- Forward Backward asymmetry (A_{FB}) measurement

Introduction

- W and Z production at Tevatron

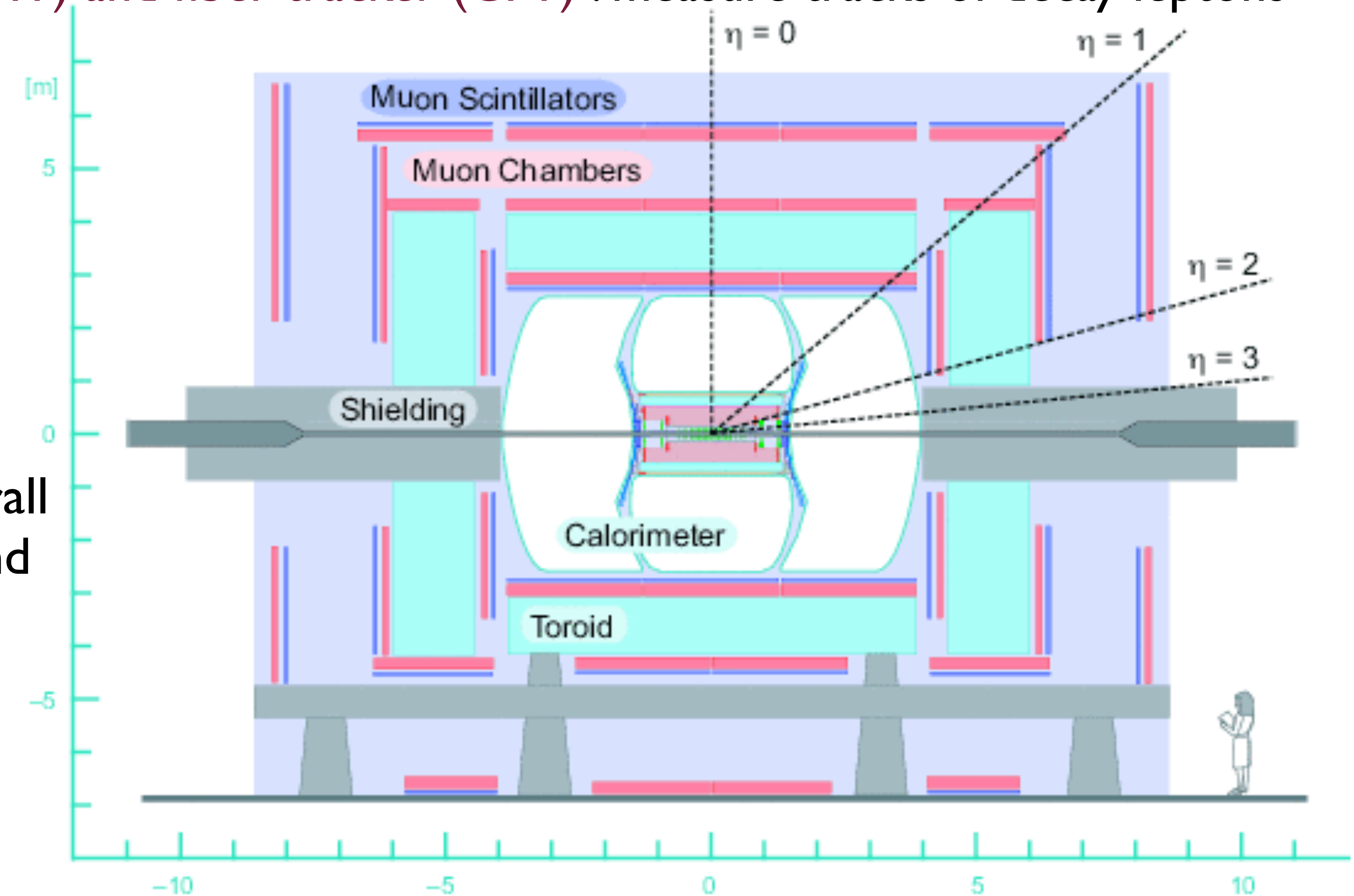




- Constrain Parton Distribution Functions (PDFs)
  - W charge asymmetry
- Test higher order QCD and QED corrections
  - Z boson A_{FB} measurement and Zpt measurement

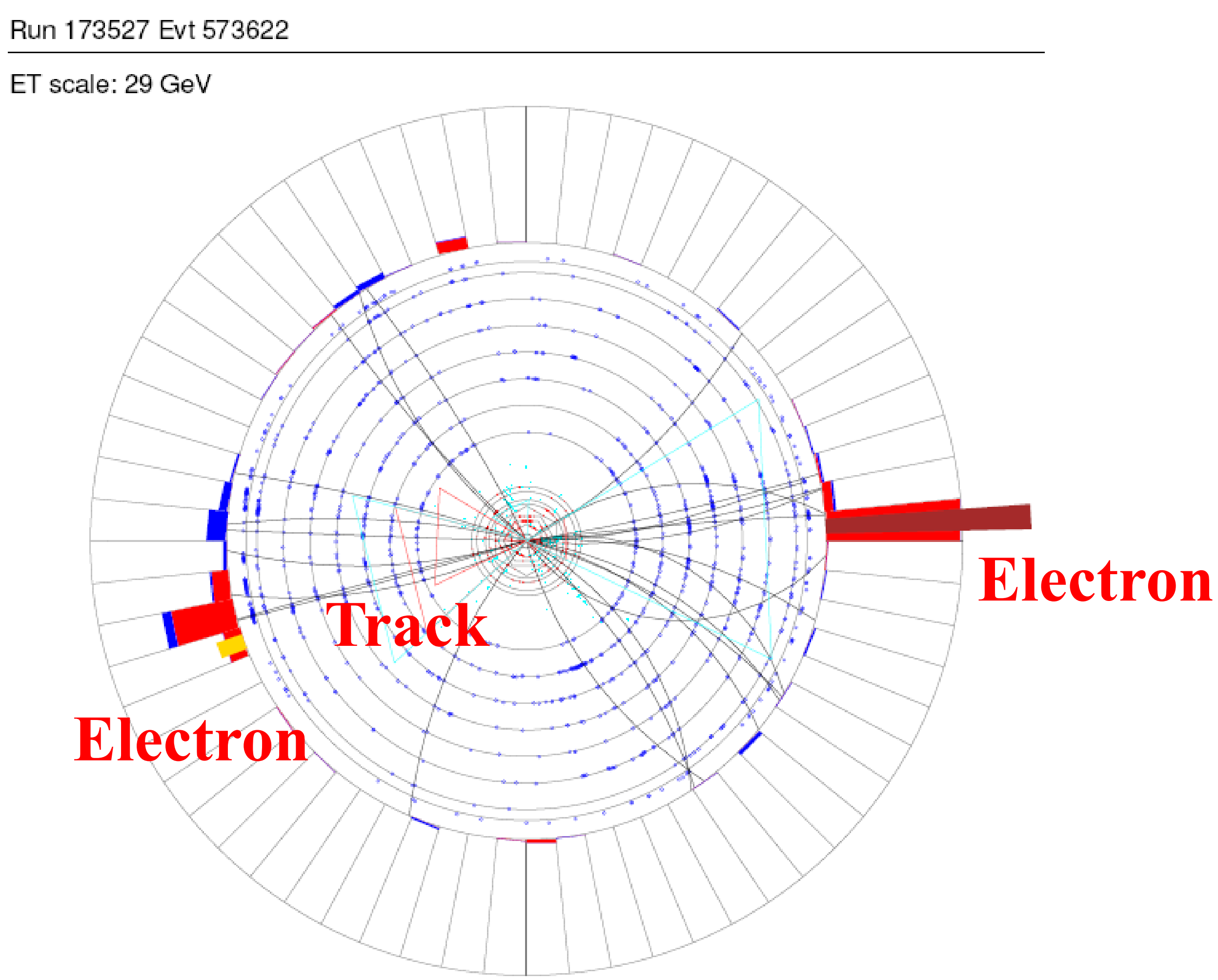
D0 detector

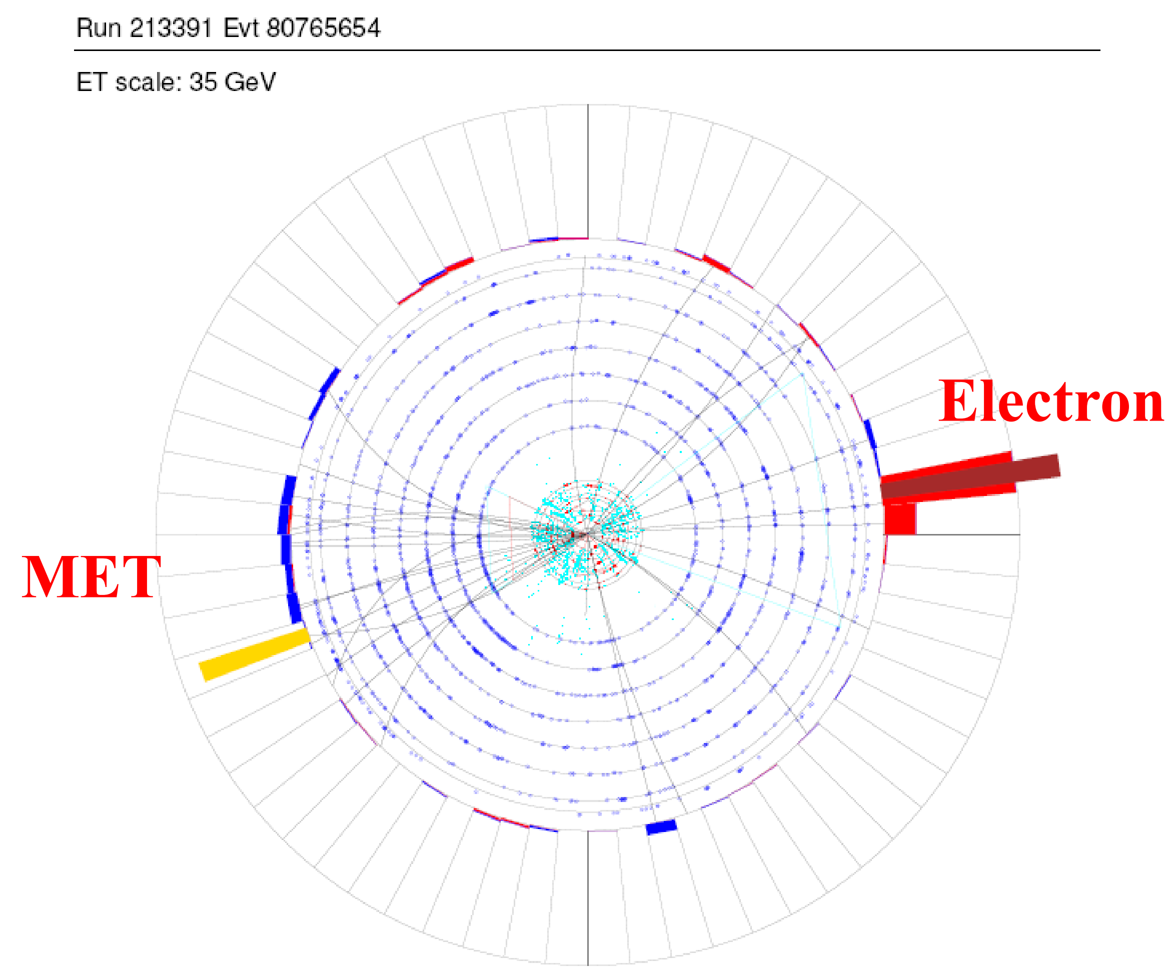
- Important components for these analyses
  - Silicon tracker (SMT) and fiber tracker (CFT) : measure tracks of decay leptons



- Calorimeter
  - Identify and measure E_T of electrons.
  - Measure the overall E_T of the event and calculate MET
- Muon system
  - Identify muons

W and Z events



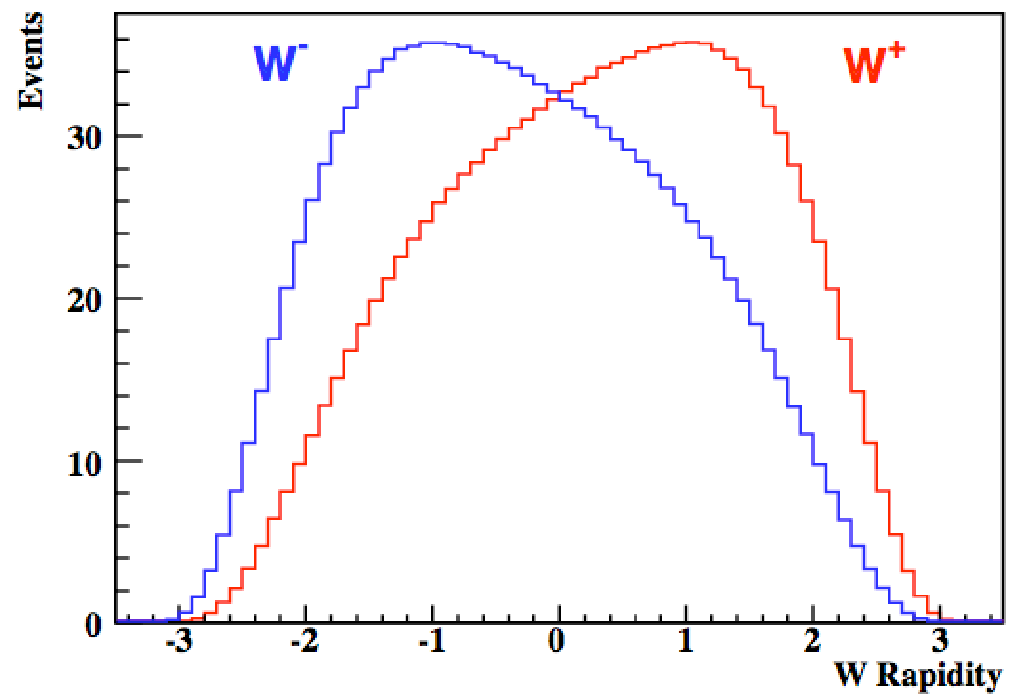


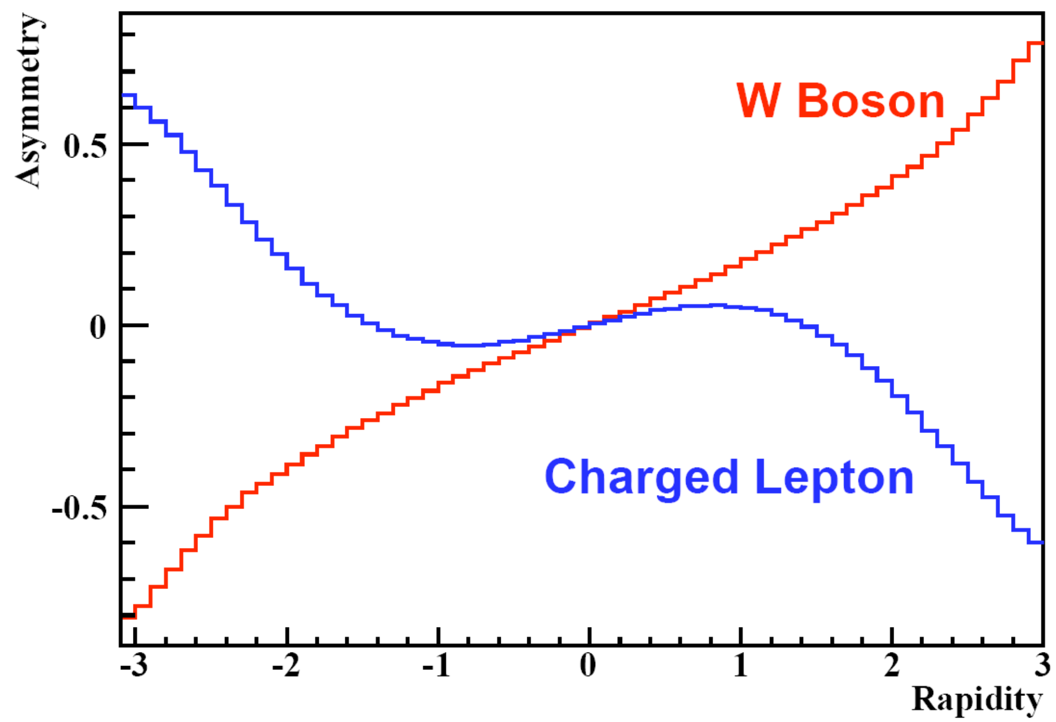
- Z: two high P_T charged lepton
- W: one high P_T charged lepton and one high P_T neutrino
- Neutrino can not be detected: Missing E_T used to estimate P_T^{ν}

W asymmetry

- On average u quark carries more momentum than d quark, which causes asymmetry in W^+ and W^- distributions.
  - Rapidity $\eta=-\ln[\tan(\theta/2)]$, θ is azimuthal angle.
- Use Ws to probe proton structure.
- $W \rightarrow e\nu \Rightarrow$ W asymmetry hard to

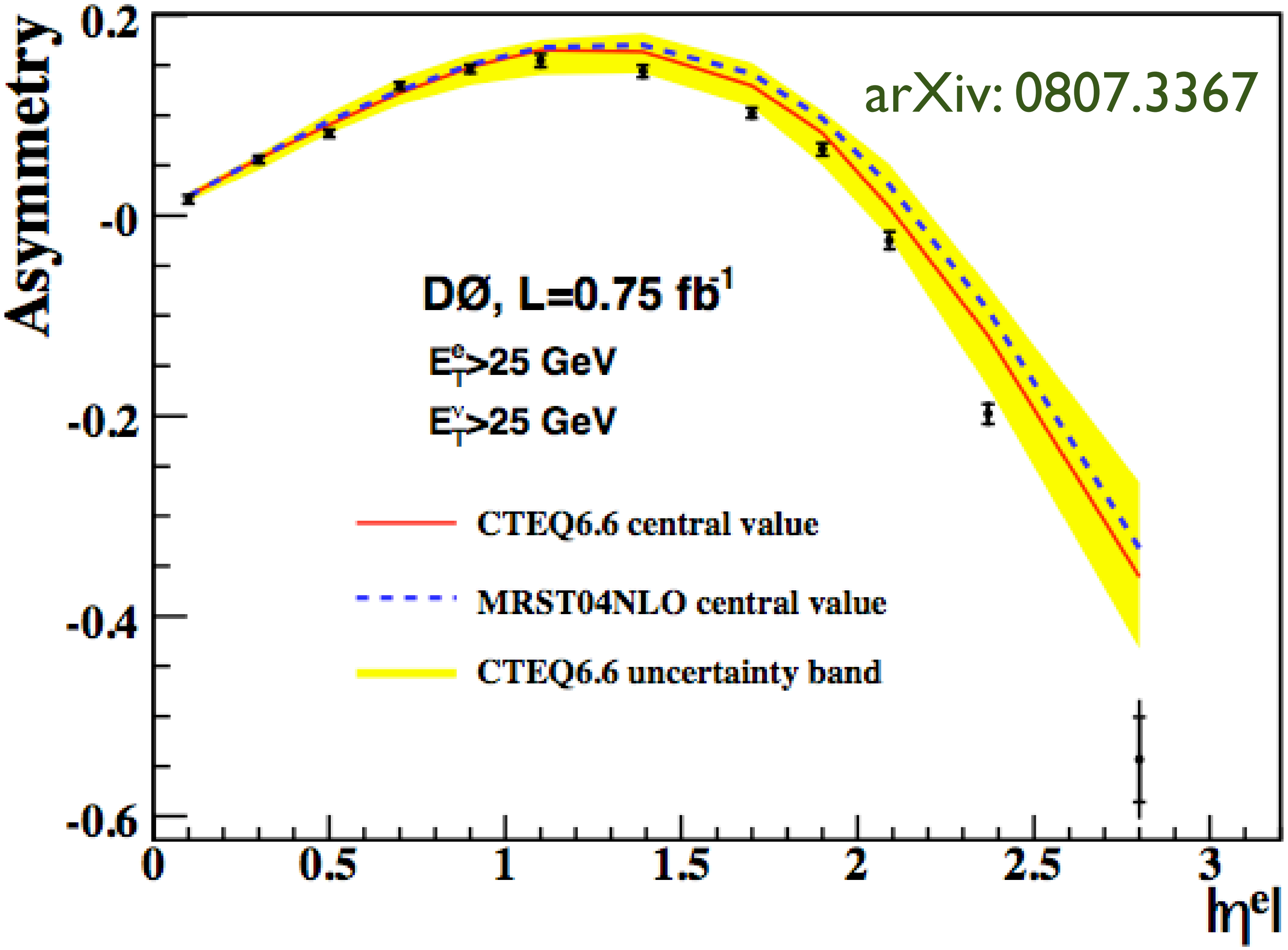
  measure as we don't know longitudinal momentum of neutrino.
- W asymmetry → electron asymmetry.
- Electron asymmetry: $A(y) \otimes (V\text{-}A)$





$$A(y_e) = \frac{N_{e^+}(y) - N_{e^-}(y)}{N_{e^+}(y) + N_{e^-}(y)}$$

Asymmetry

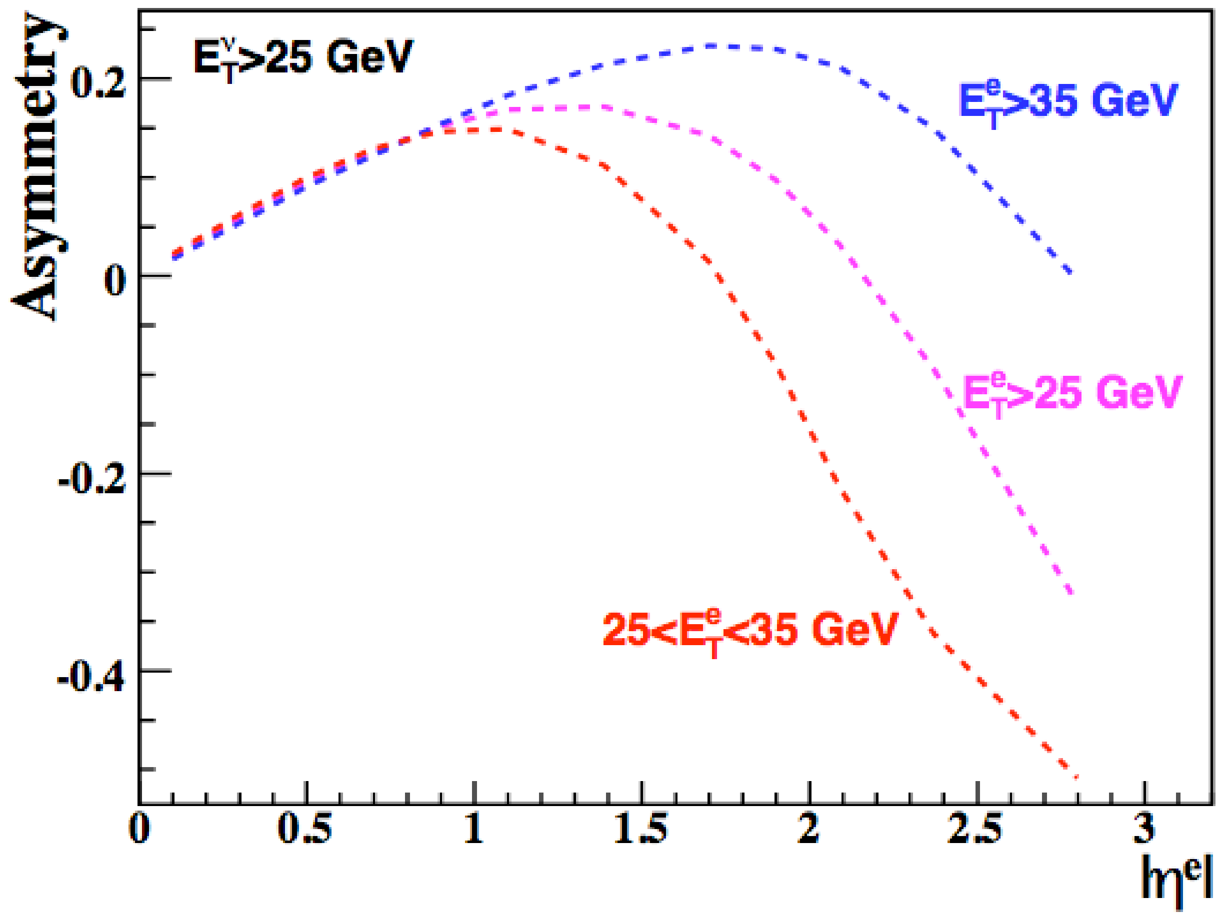


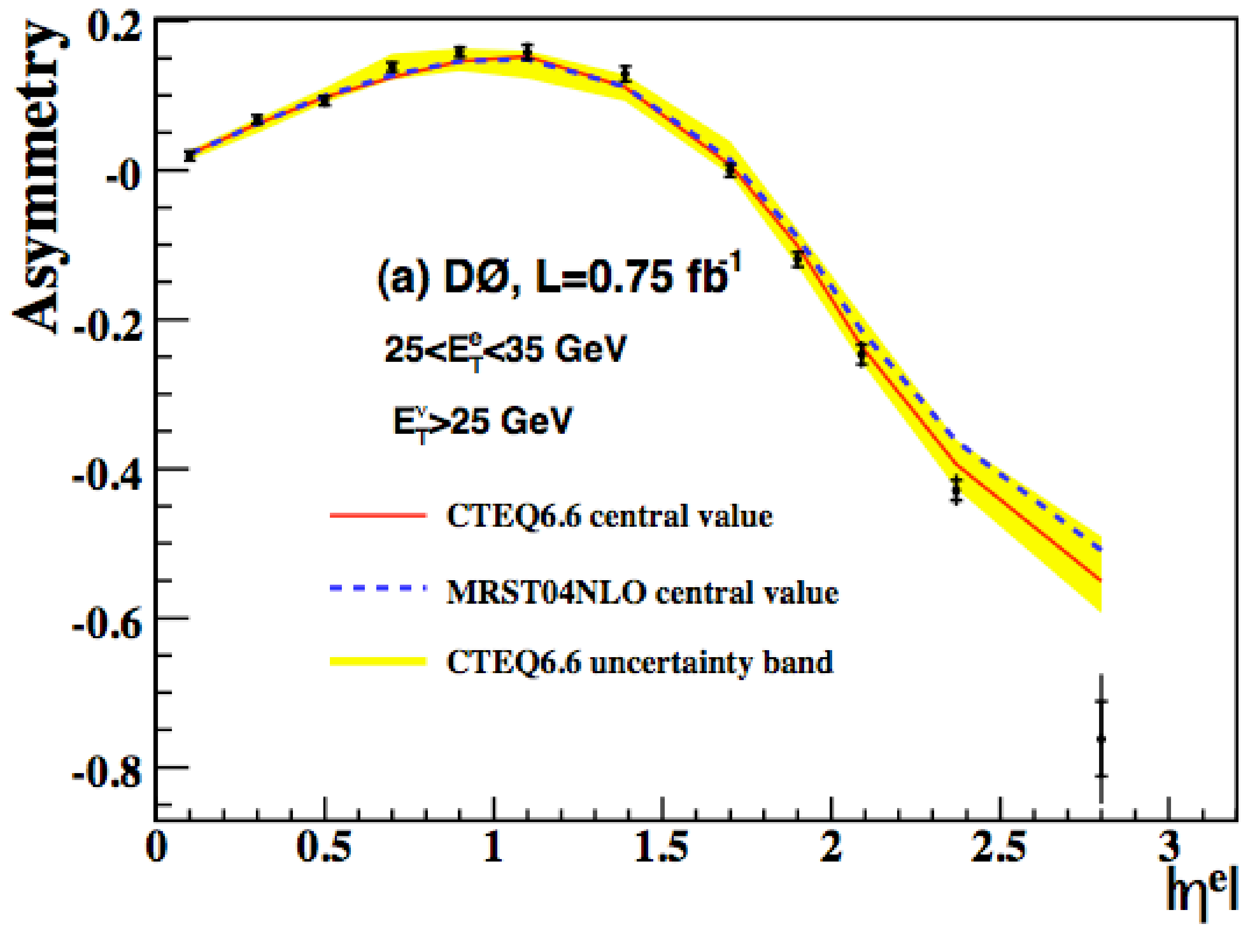
- Major collaborations that use experimental data to derive PDFs are **CTEQ** and **MRST**
- CTEQ 6.6 NLO PDFs
  - P.M.Nadolsky et. al. Phys. Rev. D78 013004 (2008)
- MRST2004
  - A.D.Martin, R.G.Roberts, W.J.Stirling, R.S.Thorne Phys. Lett. B604, 61 (2004)

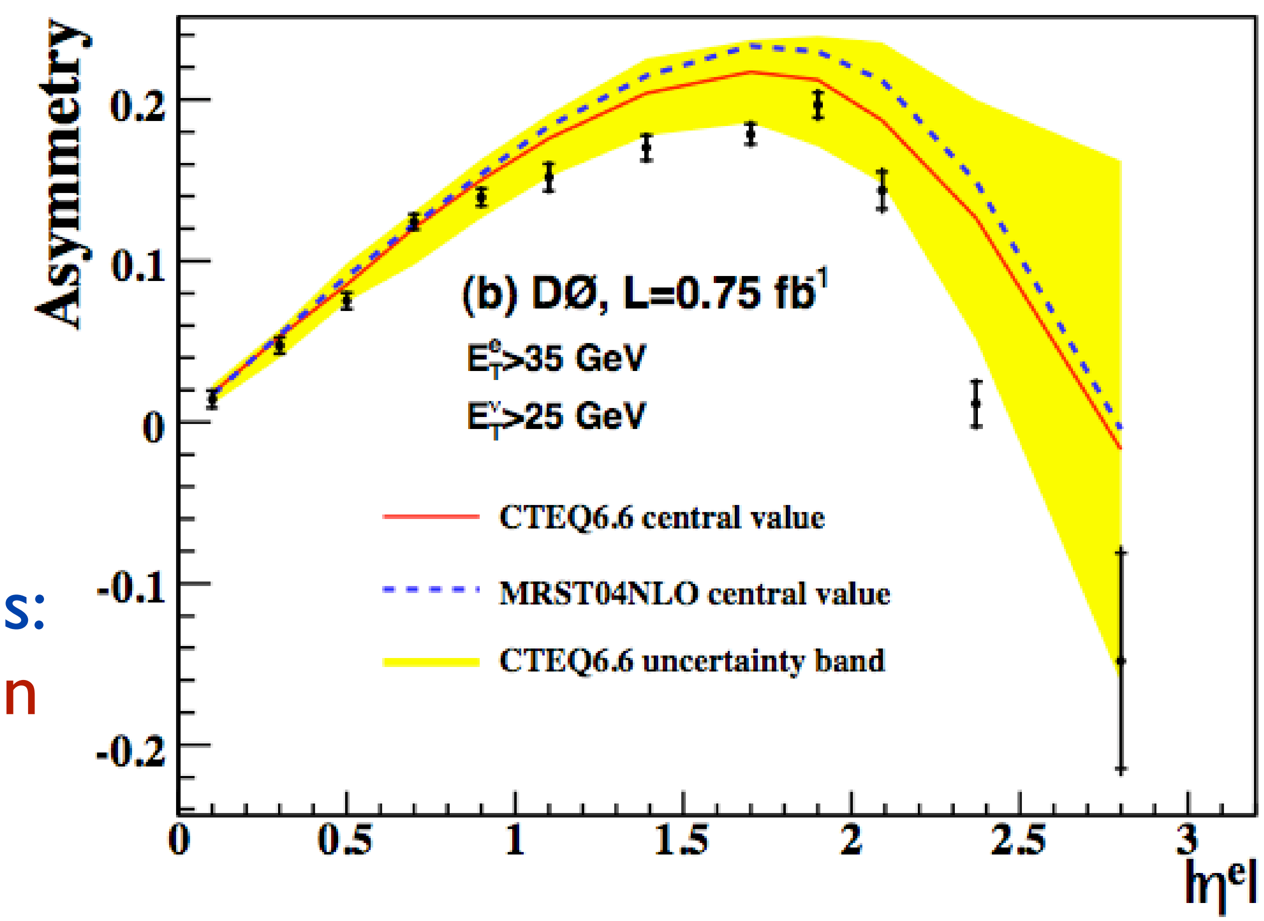
- The result corrected for the detector smearing effects
- Due to CP invariance, A(y)=-A(-y). The asymmetry “folded” to increase statistics.

E_T bins

- Splitting analysis in E_T bins allows finer probe of PDFs
- Plot below - MC simulation.







Uncertainties smaller than PDF uncertainties:
Inclusion of our results will further constrain future PDF fits and improve predictions

Low Z P_T analysis using novel method

- The Z P_T distribution is interesting
  - Test QCD
  - Understand the production of inclusive vector bosons.
- Perturbative QCD insufficient.
- NP effects absorbed into universal form factor, e.g. BLNY.
- At the tevatron the Z P_T is very sensitive to the g2 parameter.

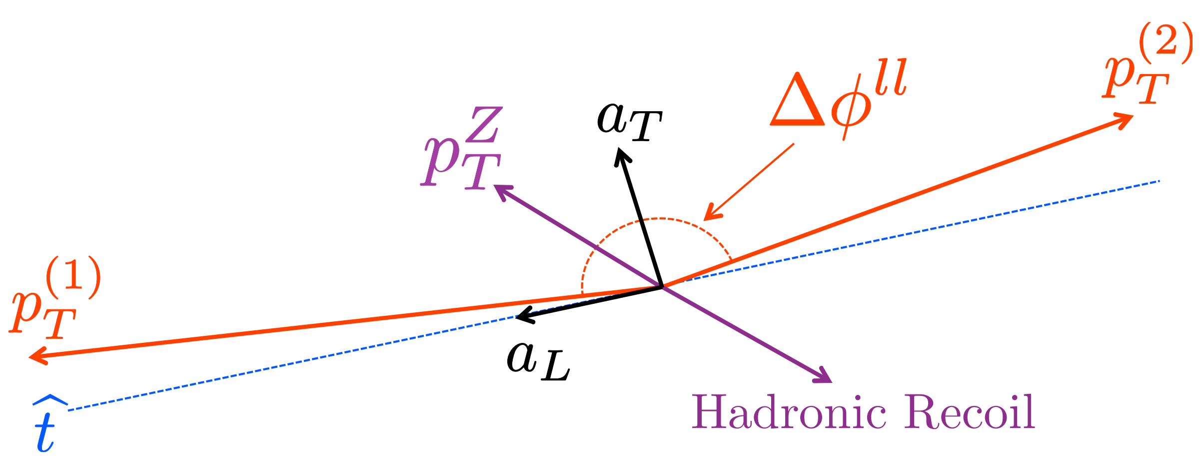
$$\frac{d\sigma}{dy\,dq_T^2} = \frac{\sigma_0}{S}\int \frac{d^2b}{(2\pi)^2} e^{-i\vec{q_T}\cdot\vec{b}}\tilde{W}^{\mathrm{PERT}} e^{-S^{\mathrm{NP}}b^2} + Y$$

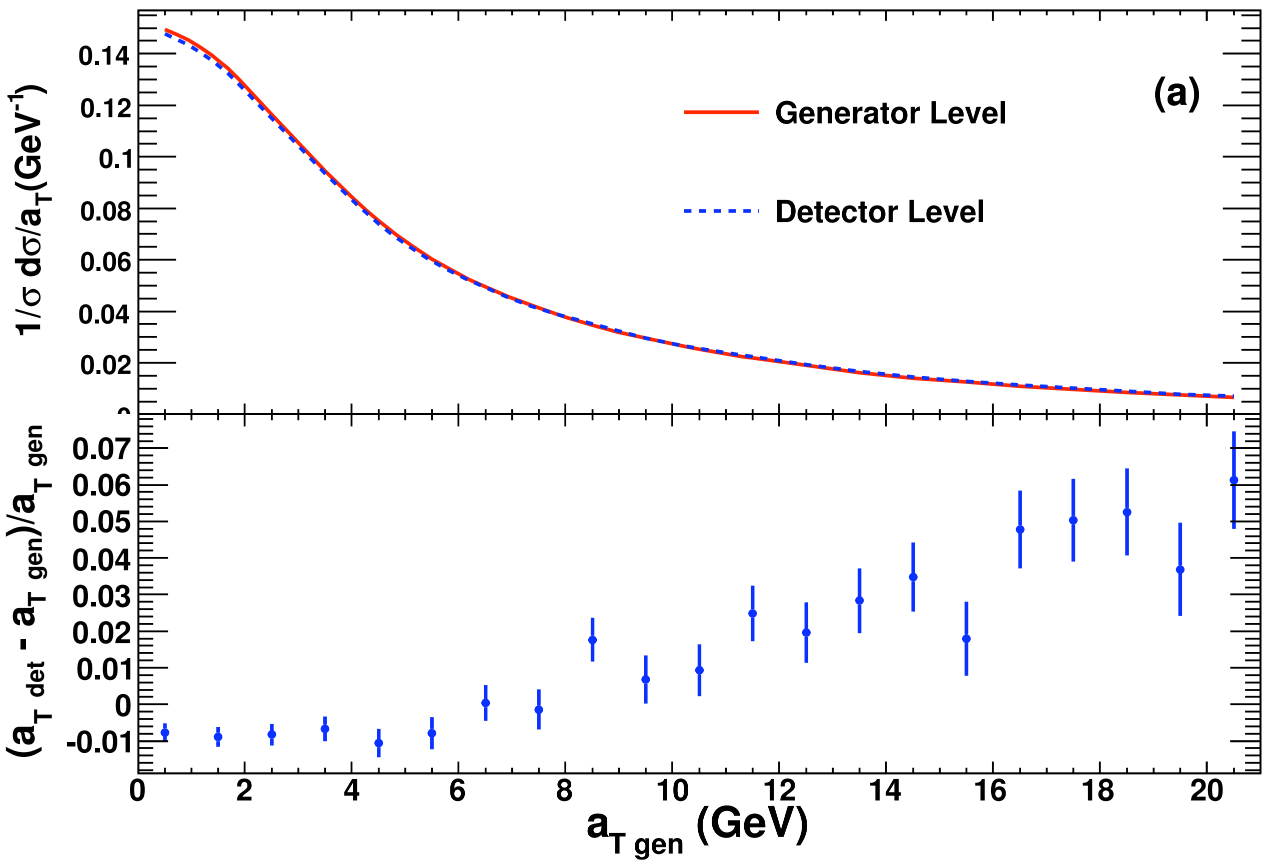
$$S^{\mathrm{NP}}_{\mathrm{BLNY}}(b,Q^2) = -g_1 - g_2\ln(\frac{Q^2}{Q_0}) - g_1 g_3 \ln(100 x_A x_B)$$

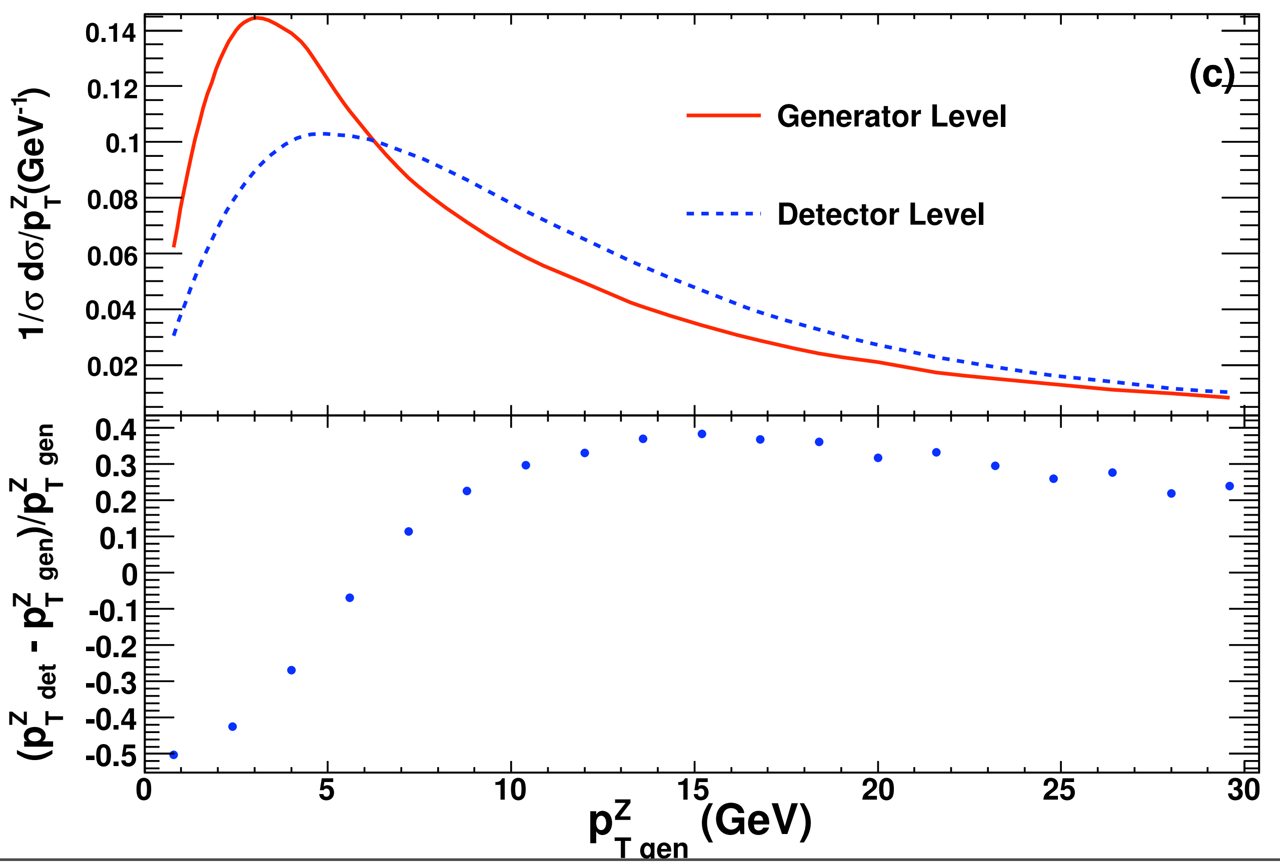
G.A.Ladinsky, C.P.Yuan, Phys. Rev. 50 4239 (1994);
C.Balazs, C.P.Yuan, Phys.Rev.A56: 5558-5583, 1997

a_t and a_L

- Previous measurement of the $d\sigma/dp_T$ have been dominated by systematics
  - "unfolding" for the lepton p_T resolution
  - Correcting for the Z p_T dependence of the event selection efficiency
- Decomposing Z p_T into a_t and a_L largely fixes the problem.

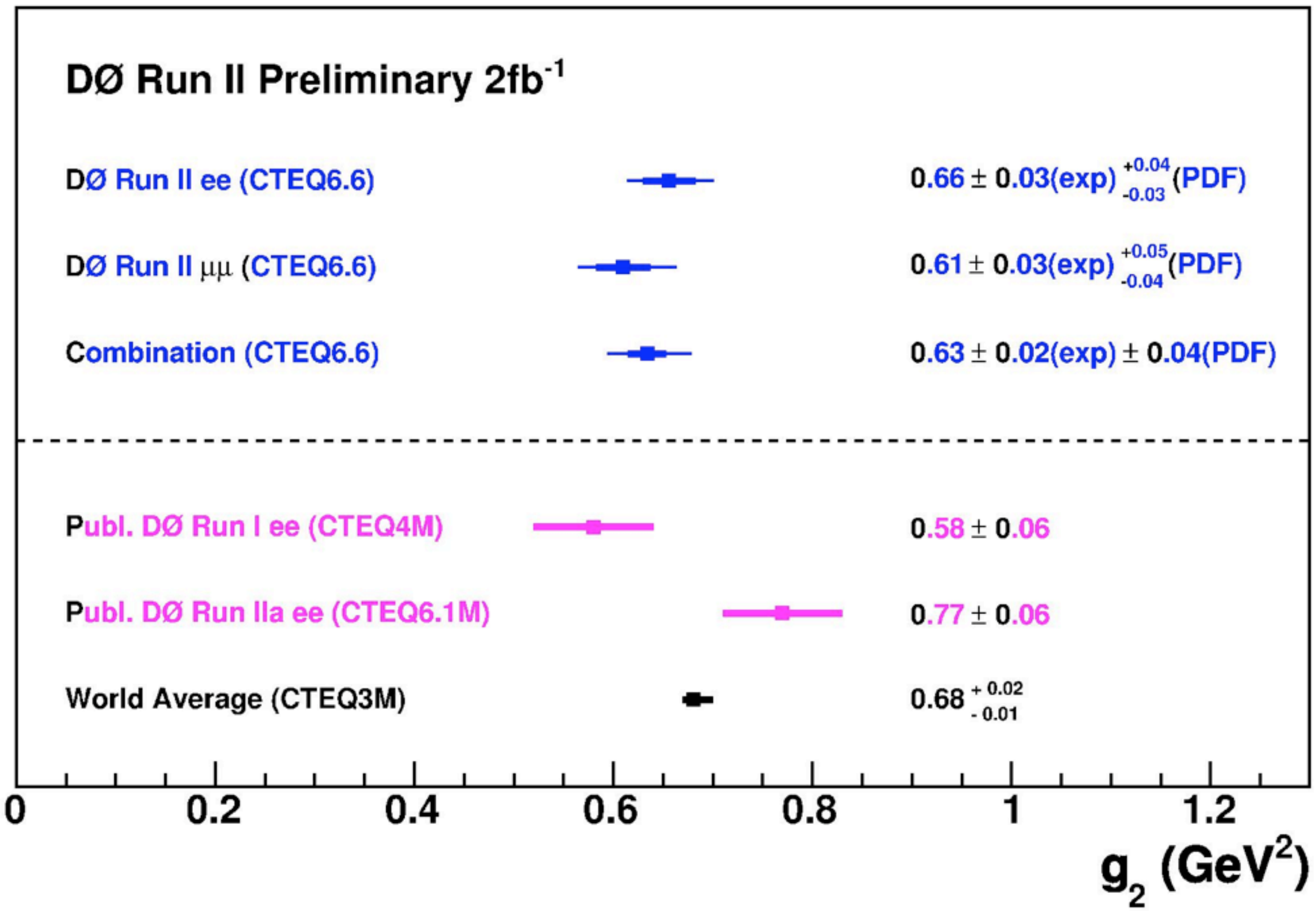






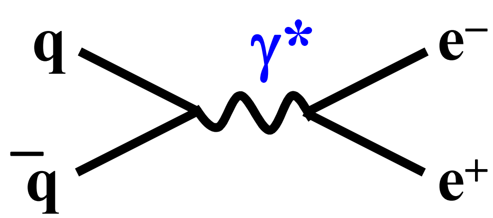
Results

- Consistent measurement in di-muon and di-electron channels.
- Experimental uncertainty comparable to the world average.
- Theoretical PDF uncertainty is dominant.

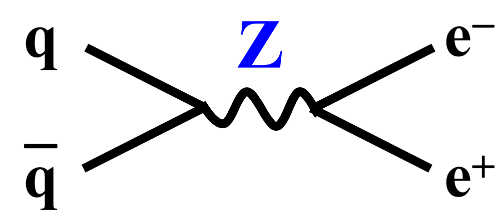


Z/γ* Forward-Backward asymmetry

- $p\bar{p} \rightarrow l^+l^-$: mediated by γ^*, Z, Z/γ^*

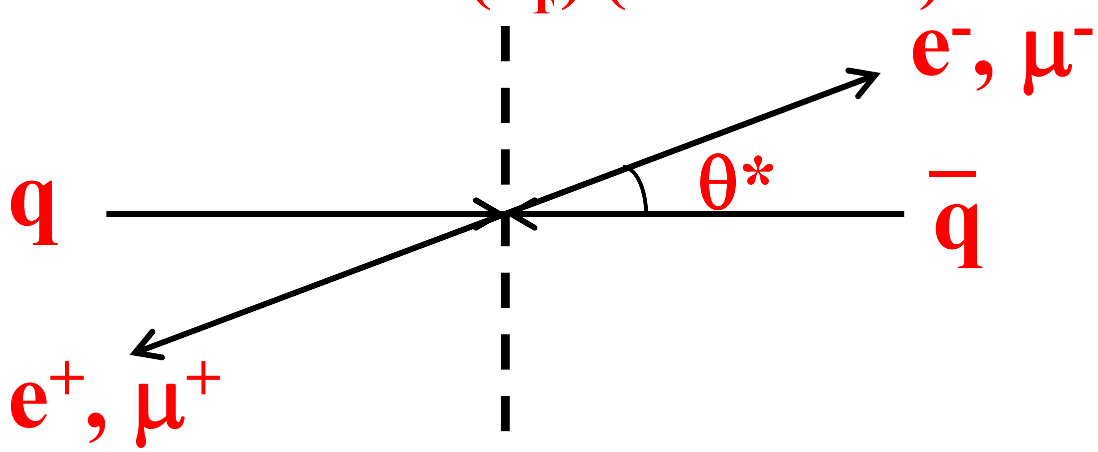


Vector coupling

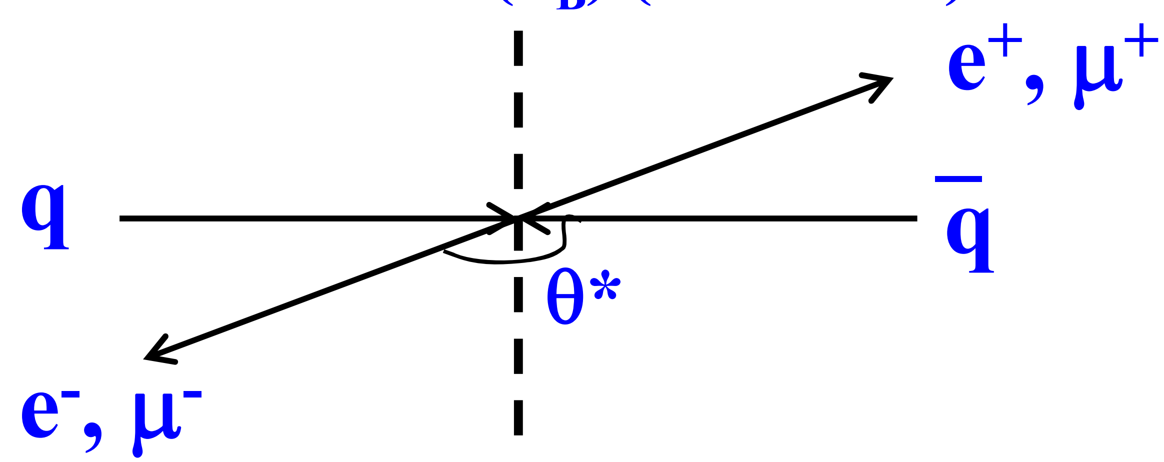


Vector & axial-vector coupling

FORWARD (σ_F) ($\cos\theta^* > 0$)



BACKWARD (σ_B) ($\cos\theta^* < 0$)

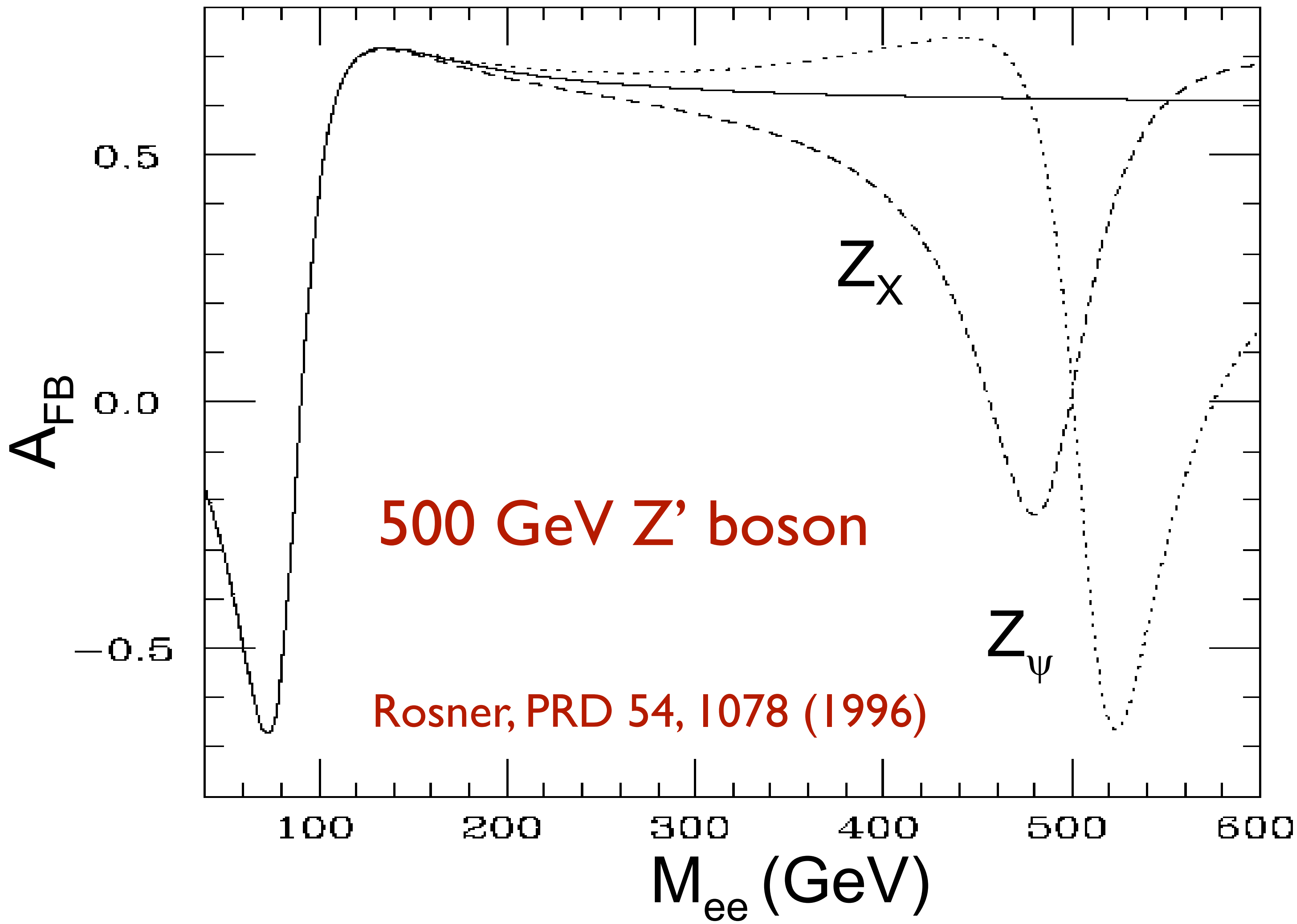


θ^* defined in Collins-Soper frame (Z/γ^* rest frame)

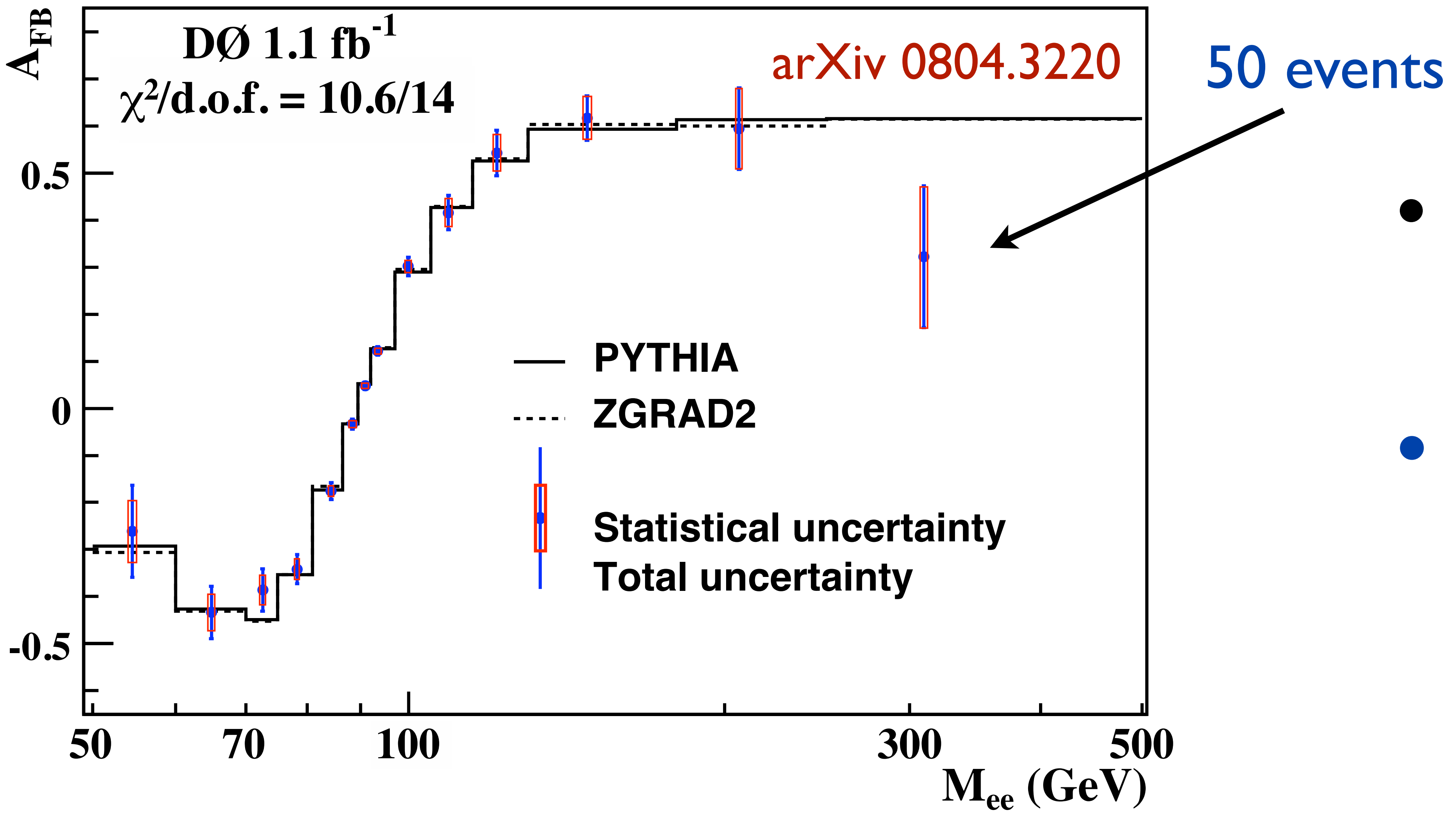
$$A_{FB} = (\sigma_F - \sigma_B) / (\sigma_F + \sigma_B) = (N_F - N_B) / (N_F + N_B)$$

Motivation

- New resonance can interfere with Z and γ^*
- A_{FB} is sensitive to $\sin^2\theta_W$



Results



- A_{FB} result agrees with the SM prediction.
- $\sin^2\theta_W$ result agrees with the global EW fit

- Result corrected for the detector smearing effects.
- $\sin^2\theta_W = 0.2327 \pm 0.0018(stat) \pm 0.0006(syst)$

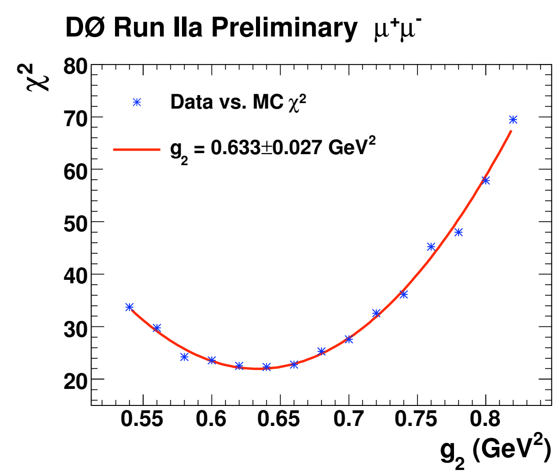
Conclusions

- Many exciting W and Z results at D0
- Many in the pipeline
- W charge asymmetry - 0.75 fb^{-1}, A_{FB} -1 fb^{-1}, Z pT analysis - 2 fb^{-1}. Now more than 6 fb^{-1} data recorded

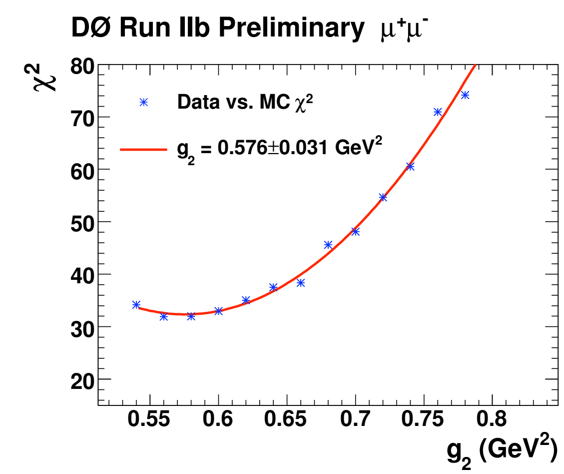
Thank you!

g2 measurement

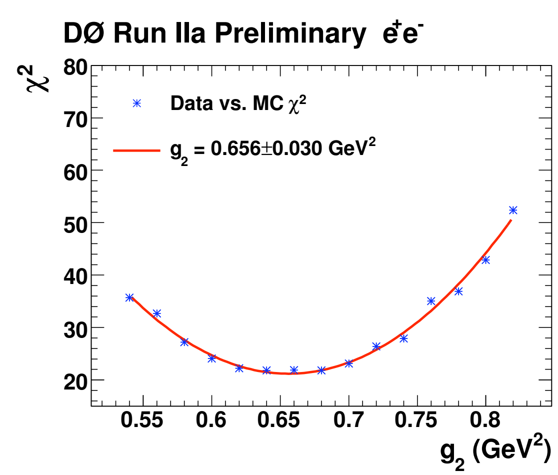
- Start with 15 MC samples for different values of g2.
- Data vs MC χ^2 is calculated for each of the 15.
- 2^{nd} order polinomial is fitted to the results.



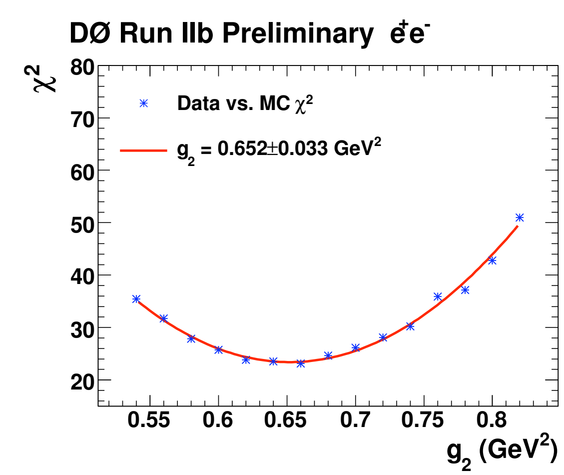
(a) Run IIa di-muon



(b) Run IIb di-muon



(c) Run IIa di-electron



(d) Run IIb di-electron

Asymmetry calculation

- Remove SM background using Monte Carlo simulated data.
- Calculate charge misidentification rate (g) and correct for it.
- Estimate QCD background using samples that pass loose and tight shower shape conditions.
  - $N_L = N_e + N_{QCD}$
  - $N_T = \varepsilon N_e + f N_{QCD}$
    - ε probability for real electron to pass tight cut, given it passed loose cut.
    - f same thing for fake electron.
- Calculate ε, f and g first and then calculate asymmetry.