Experimental EWK physics at the Tevatron'2004

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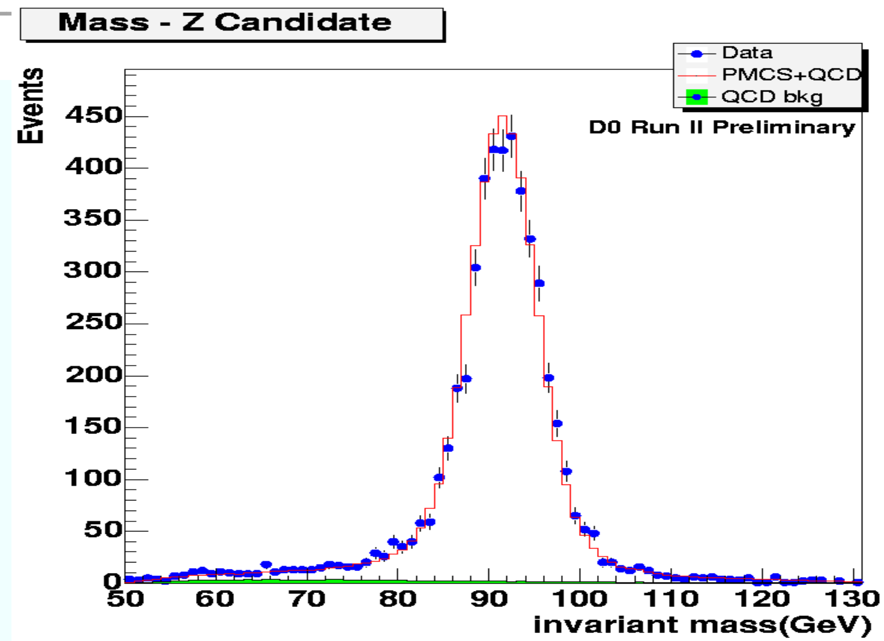
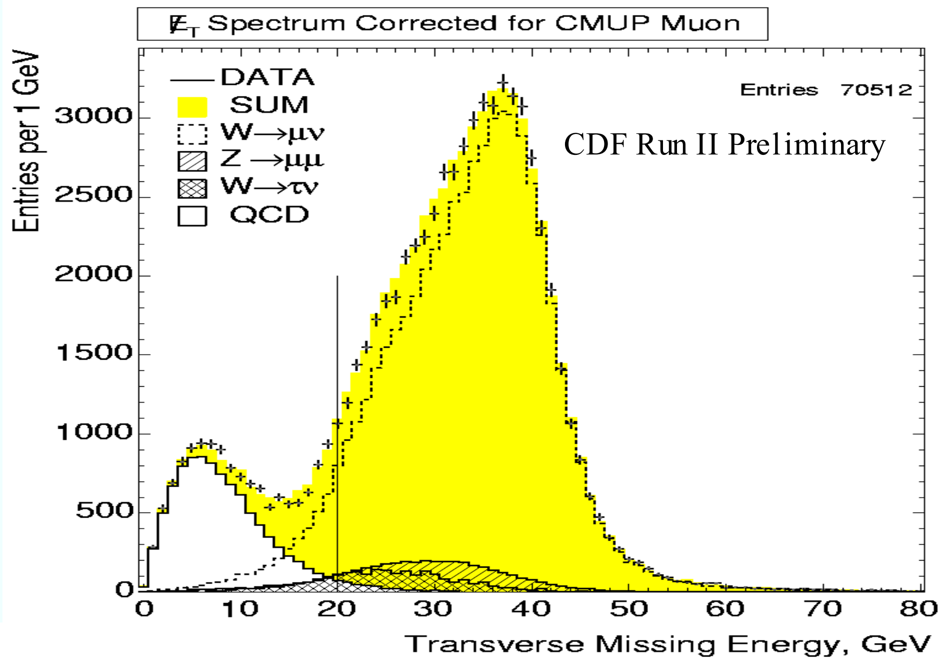
Overview:

- total of ~500pb^{-1} on tape, up to ~250 pb^{-1} analyzed
- What the Tevatron experiments have achieved in the area of electroweak physics
- Present challenges, what needs to be accomplished
- theoretical issues we need better understanding of
- What did we learn after 3 years of running?

SM vector bosons at the Tevatron: focus on W and Z

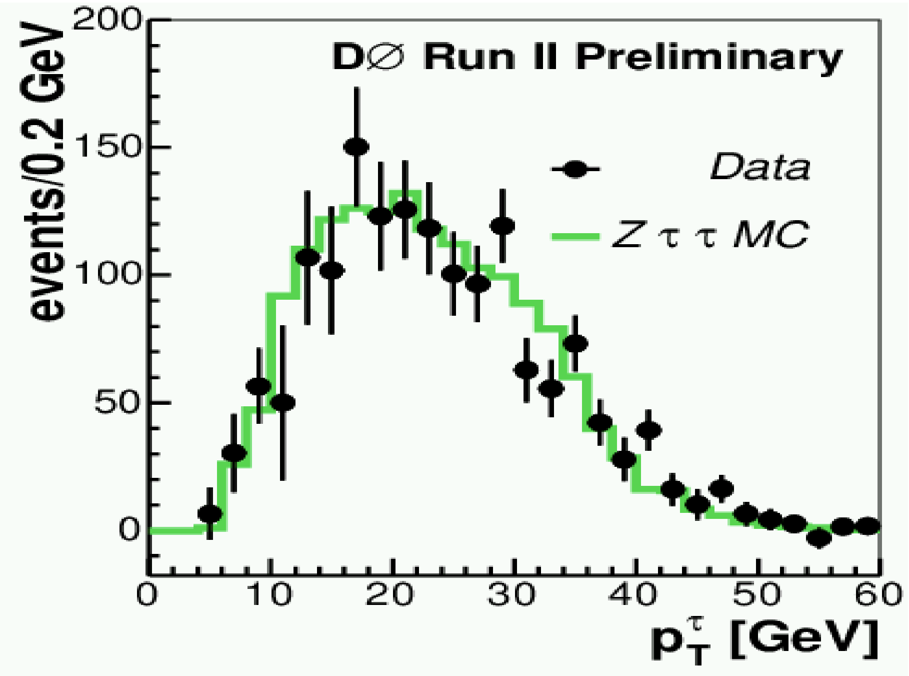
- Properties accurately predicted by the SM
- Production cross sections: reliable calculations in NLO and NNLO
- Large yields:
  - ~1 central (|eta|<1) W->enu event per 1nb^-1 : ~500K candidates per experiment
- clean experimental signatures - leptonic decays
- Good resolution: sigma(M_Z) ~ 3-5 GeV
- Experimental uncertainties small:
  - trigger/reconstruction/ID efficiencies ~ <1%
  - Acceptance calculation: ~2% (PDF)
  - Backgrounds (5-10% total) well controllable: mostly crosstalk between different W and Z decay channels
- All this makes W and Z bosons one of the best probes of the SM physics
- And even more: detector calibration, luminosity monitoring

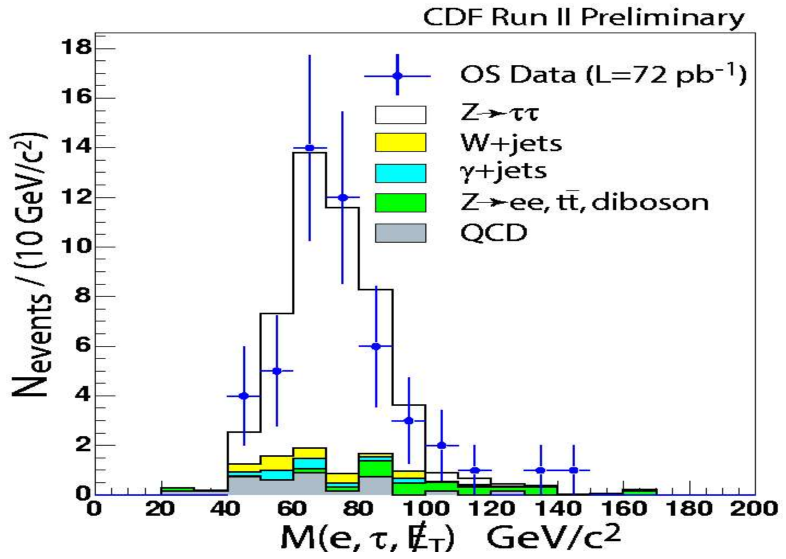




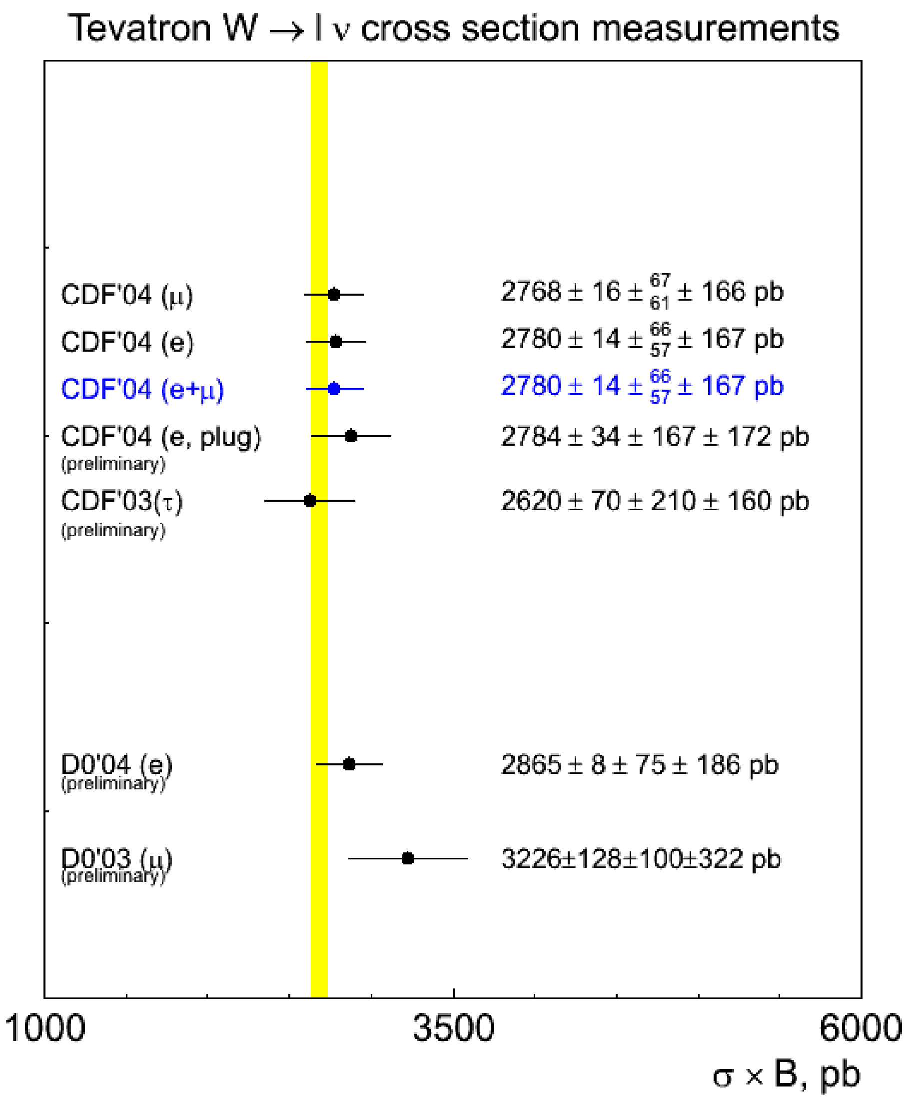
Z->tau tau cross section

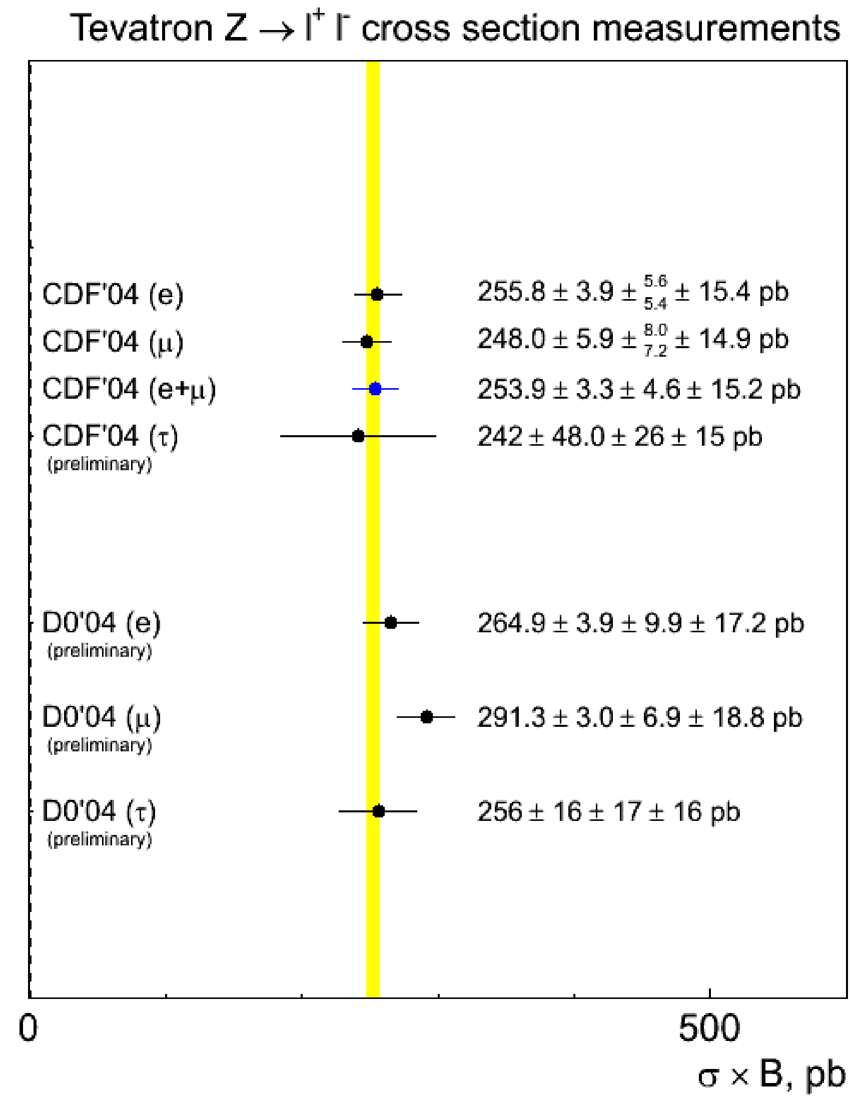
- Taus: realm of high tan(beta) SUSY
  - MSSM Higgs: A/H->tau tau
  - Sparticle cascade decays :multi-tau states
- Calibrate search techniques on SM process
- D0: ppbar->Z->tau(mu) tau(e/hadrons)
- NN-based approach, 1946 candidate events
  - ~45% signal = 875 Z->tau tau events
- CDF:
  - lower statistics,
  - significantly cleaner sample S/B = 3:1





Inclusive W/Z cross-section measurements: summary





- Overall good agreement with the NNLO calculations
- Experimental uncertainties (~6%) dominated by the luminosity measuremnts, correlated

e-mu-tau universality in W decays (CDF)

- Probe lepton couplings to the charged currents

  $BR(W\to\mu\nu)/BR(W\to e\nu) = g^2\mu/g^2e$

- large Q2

  $g\mu/ge = 0.998 \pm 0.004_{sta} \pm 0.011_{sys}$

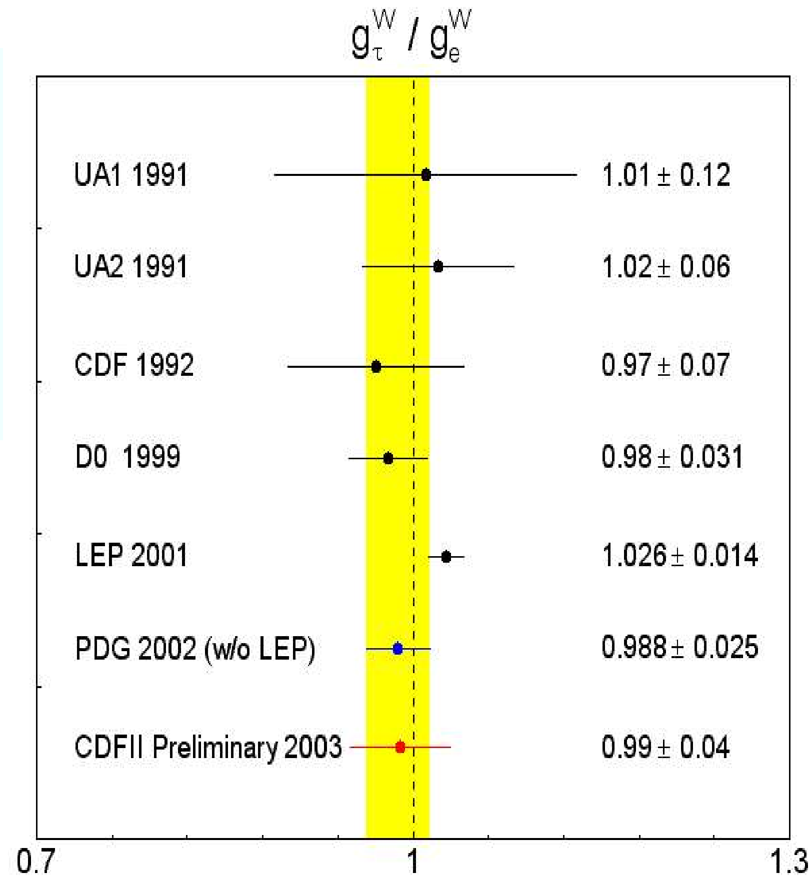
- <u>World Average'2004:</u>

  $g\mu/ge = 0.993 \pm 0.013$

<u>More than just test of couplings:</u>

are all the high Pt leptons accounted for by the SM sources?

<u>Especially important for the 3rd generation (tau)</u>



$Br(W\to\tau\nu)/Br(W\to e\nu) = 0.99 \pm 0.04 \pm 0.07$

$g\tau/ge = 0.99 \pm 0.02_{sta} \pm 0.04_{sys}$

Checking consistency in the EWK sector

Convert measured value of

$$R = \frac{\sigma(p\bar{p} \to W) \cdot B(W \to e\nu)}{\sigma(p\bar{p} \to Z) \cdot B(Z \to e^+e^-)}$$

into a measurement of the full W width:

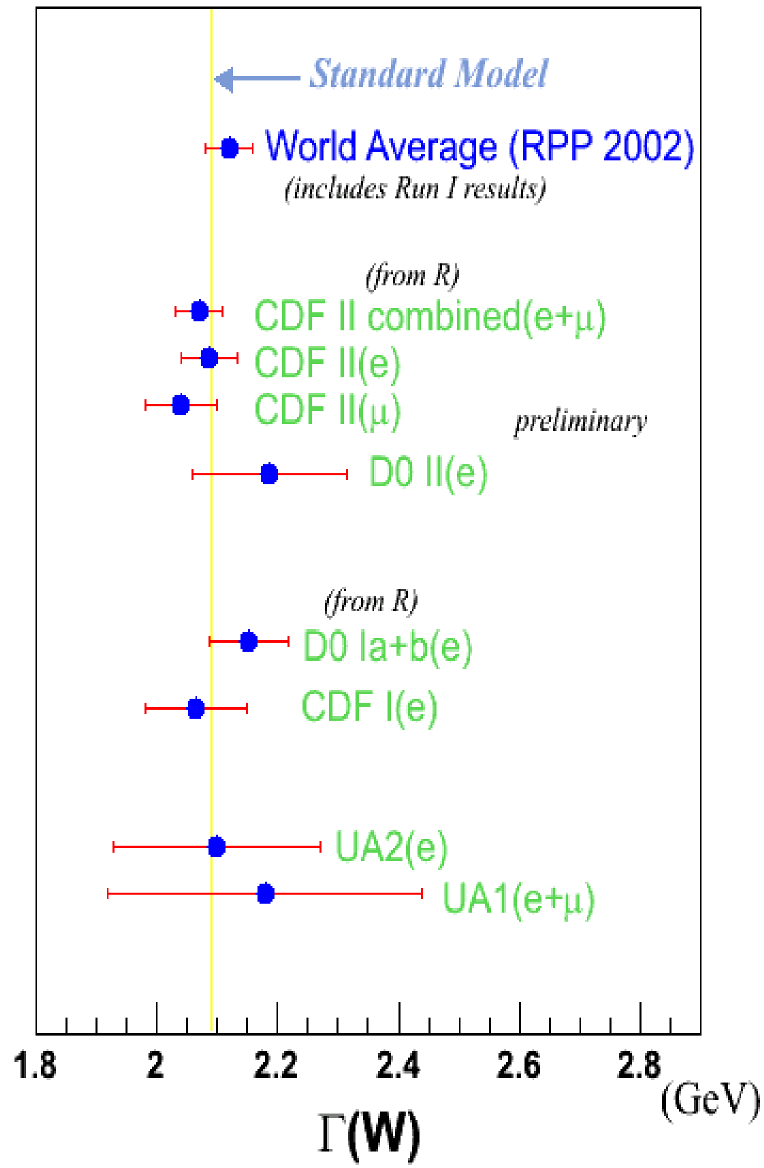
$$R = \frac{\sigma(p\bar{p} \to W)}{\sigma(p\bar{p} \to Z)} \cdot \frac{\Gamma(W \to e\nu)}{\Gamma_W} \cdot \frac{\Gamma_Z}{\Gamma(Z \to e^+e^-)}$$

calculated

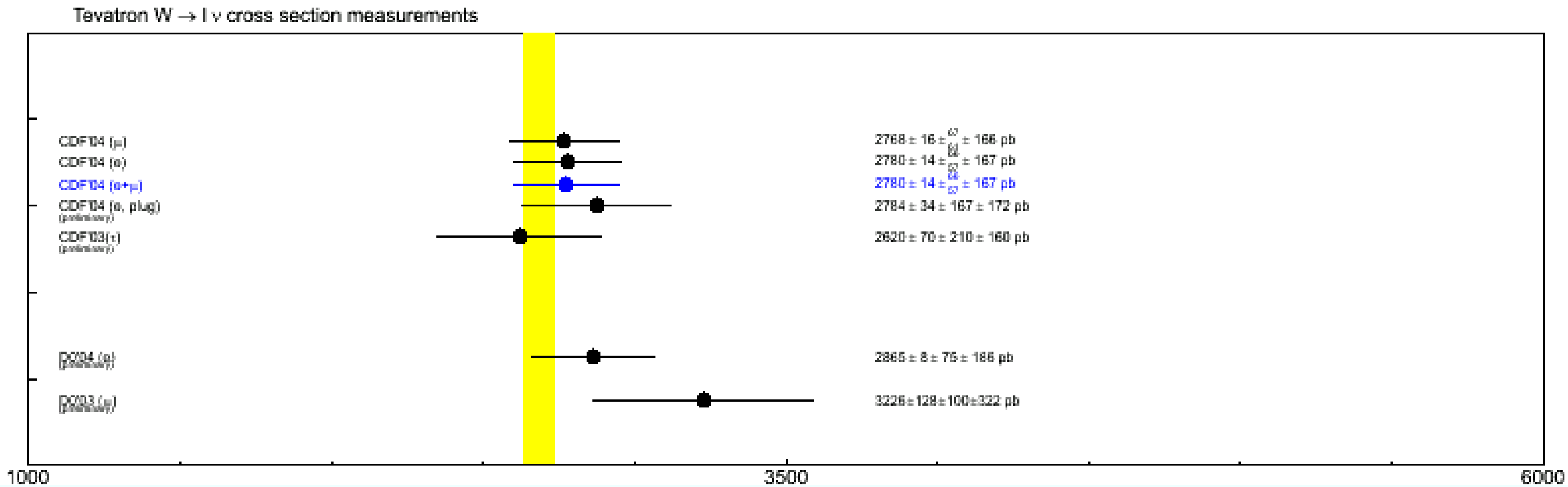
measured (LEP)

	CDF'2004	WA'2004	SM prediction
BR(W->lnu)	0.1089+/-0.0022	0.1068+/-0.0012	0.1082+/-0.0002
(W), MeV	2079+/-41	2118+/-42	2092.1+/-2.5
Vcs	0.967+/-0.030	0.996+/-0.013	

- Good consistency between the production cross sections, and full and partial widths of the SM vector bosons , calculated and measured



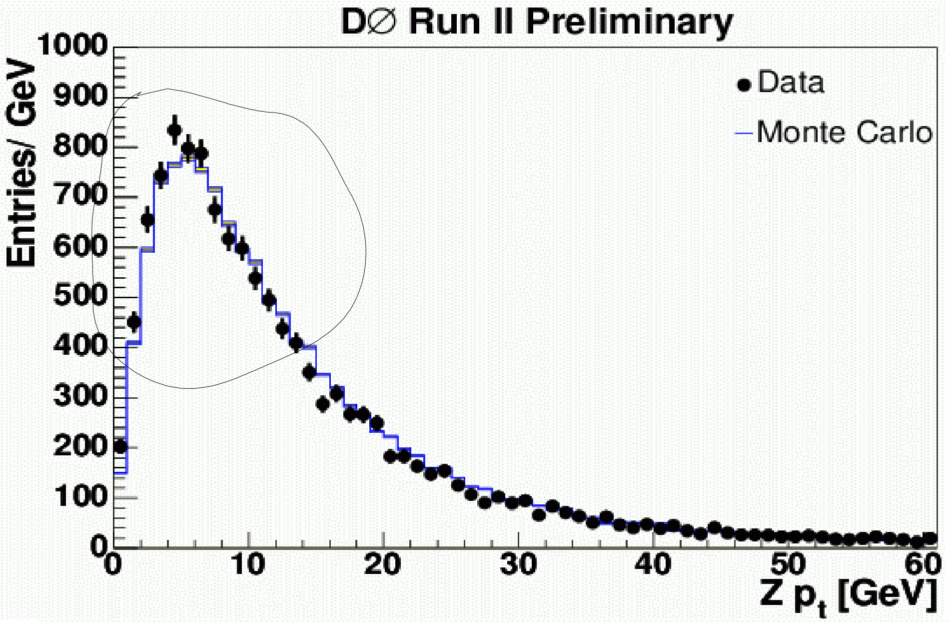
W->l nu : a luminosity monitor

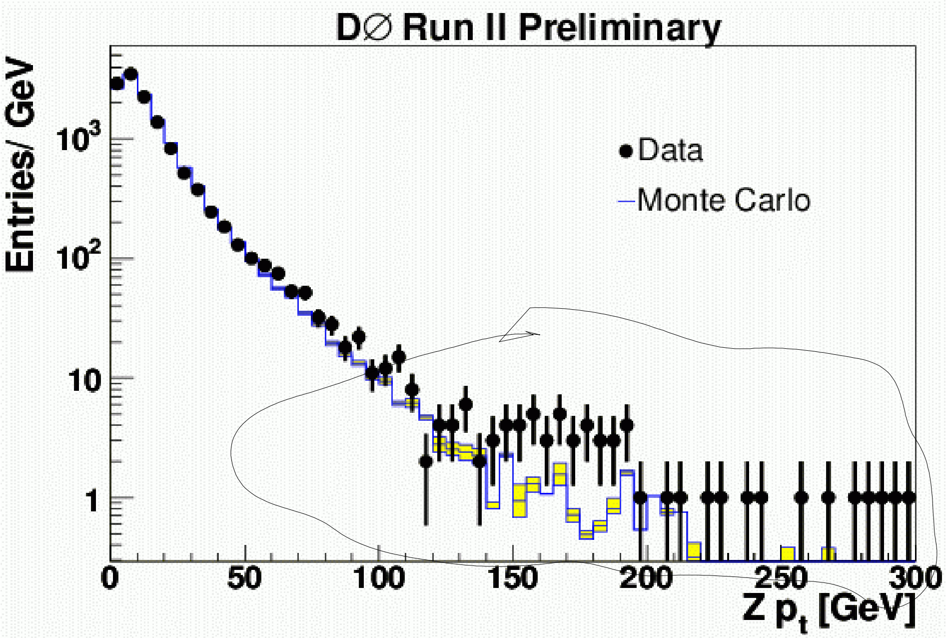


- measure luminosity with an accuracy better than 5% ?
- Standard way: not much room for improvement σ_{inel}(ppbar)= 61.7±2.4 mb @ 1.96 TeV (4%)
- M.Dittmar et al, hep/ex-9705004: use [measured] σ(W->lv) cross section to normalize to
- Experimental uncertainties ~ 2%, dominated by the acceptance/PDF
- Use NLO MC to calculate acceptance (Mangano, Frixione, hep-ph/0405130)
  - Overall accuracy of the MC@NLO calculations also ~2%
  - Scale dependence ~ 1%, parton distributions (~ 1%)
- NNLO calculation of the total W/Z cross sections: uncertainty ~ 2%
  - No spin correlations, currently "NNLO acceptance" doesn't have NNLO accuracy
- could benefit from normalizing the cross sections to the W->lv now ?

Run II differential W/Z cross sections – still to come

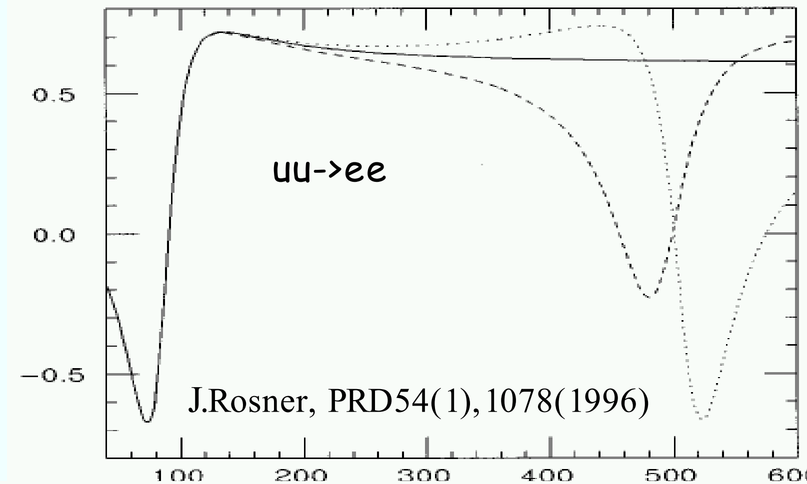
- **d σ(ppbar->W/Z)/d p_T**
- Low Pt end: one of the important inputs for W mass and width measurement
- Experiment: understanding of the resolution
- Theory: understanding of the soft gluon resummation
- High-Pt end: any hints of new physics?
- **d(sigma ppbar->Z)/d(rapidity)**
- Another source of information about the parton momentum distributions: u*ubar+d*dbar
- Experimental challenge:
  - |eta| < 2.5: need to combine information from several subdetectors (in absolute scale)
  - for ~1-2% measurement they need to be cross calibrated at the same level of accuracy

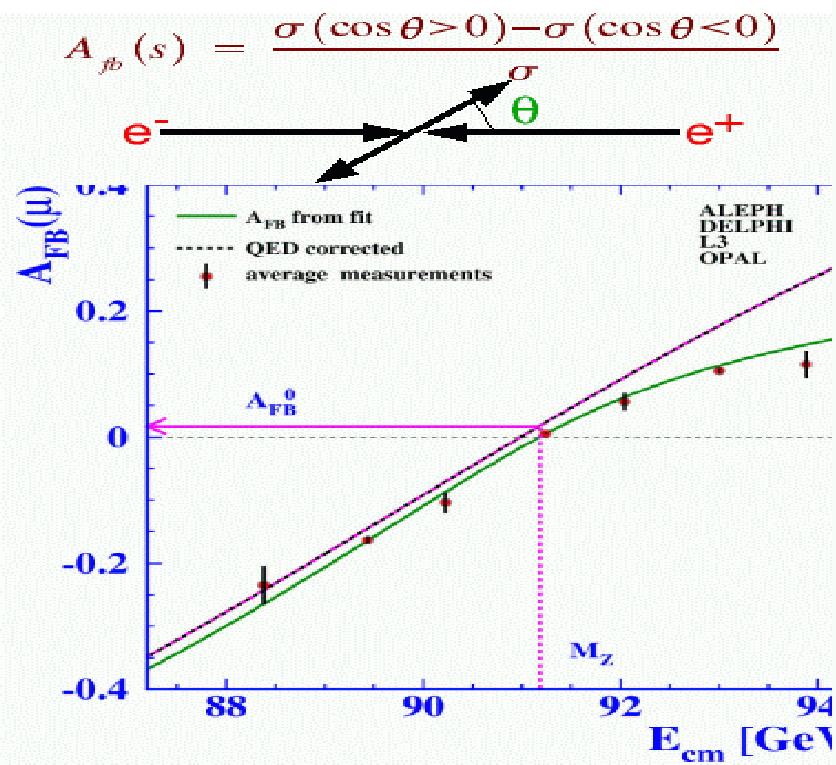


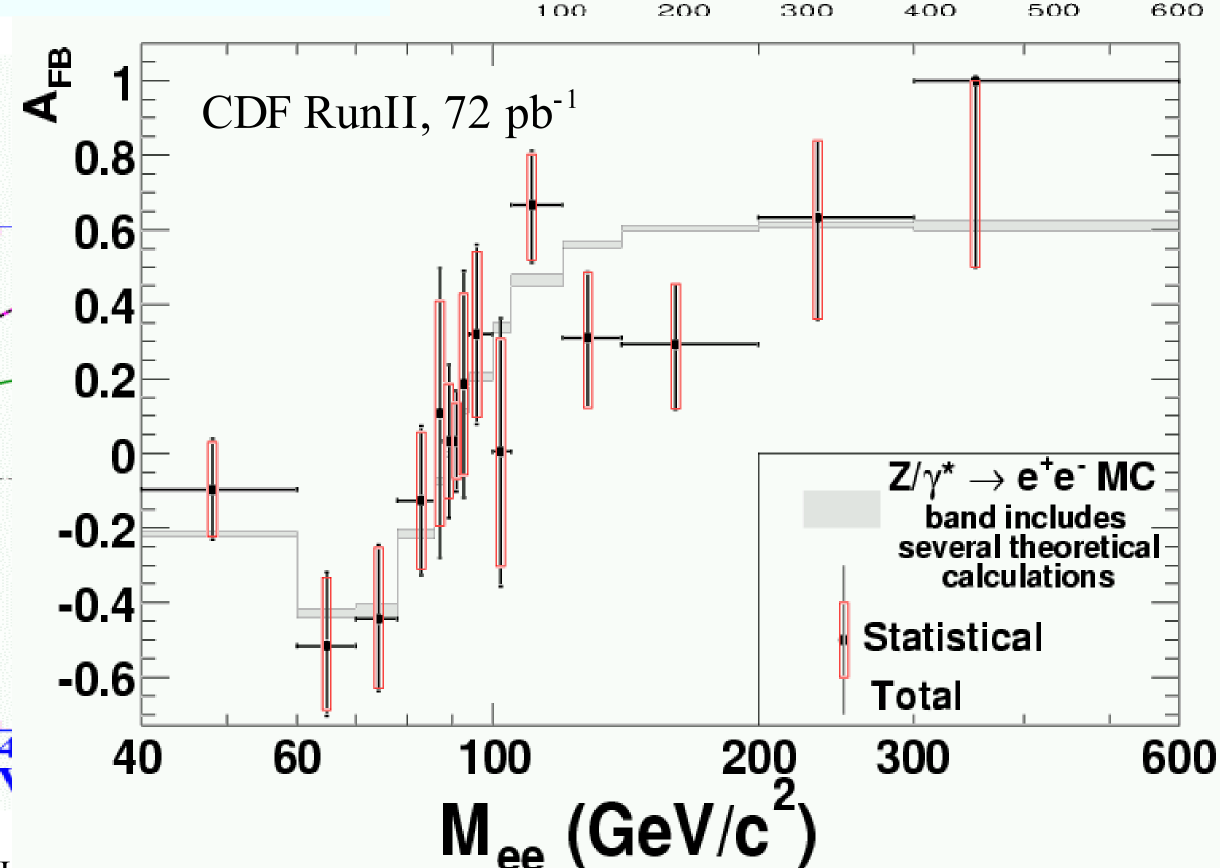


EWK asymmetries: AFB beyond the Z pole

- Forward-Backward asymmetry in Drell-Yan pair production studied carefully around Z pole at LEP
- probes non-SM couplings of quarks and leptons, interference (Q-I_{weak}) different for different quarks
- Linear in α_{new}, need >1 event in a given mass bin
- CDF measurement consistent with SM







W-charge asymmetry

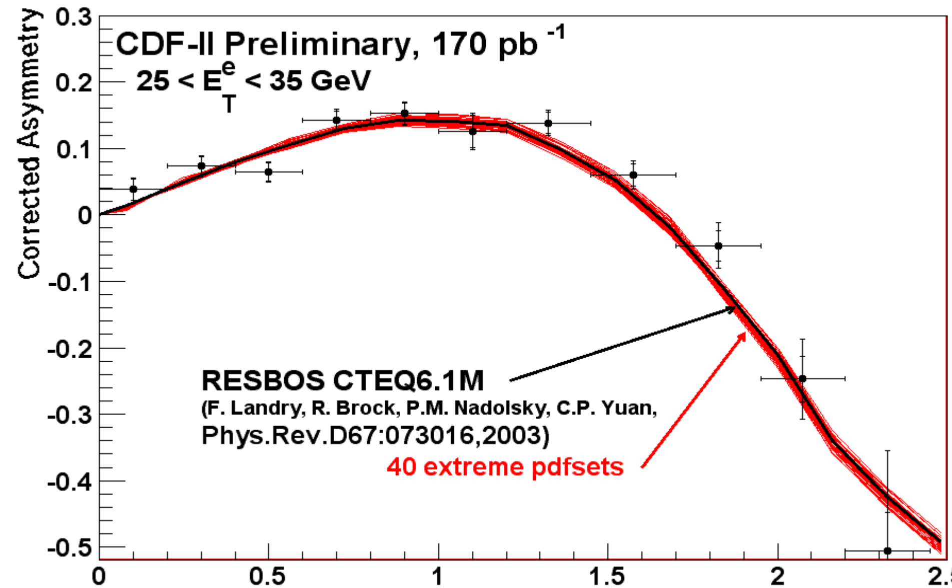
W production asymmetry in ppbar collisions sensitive to U/D

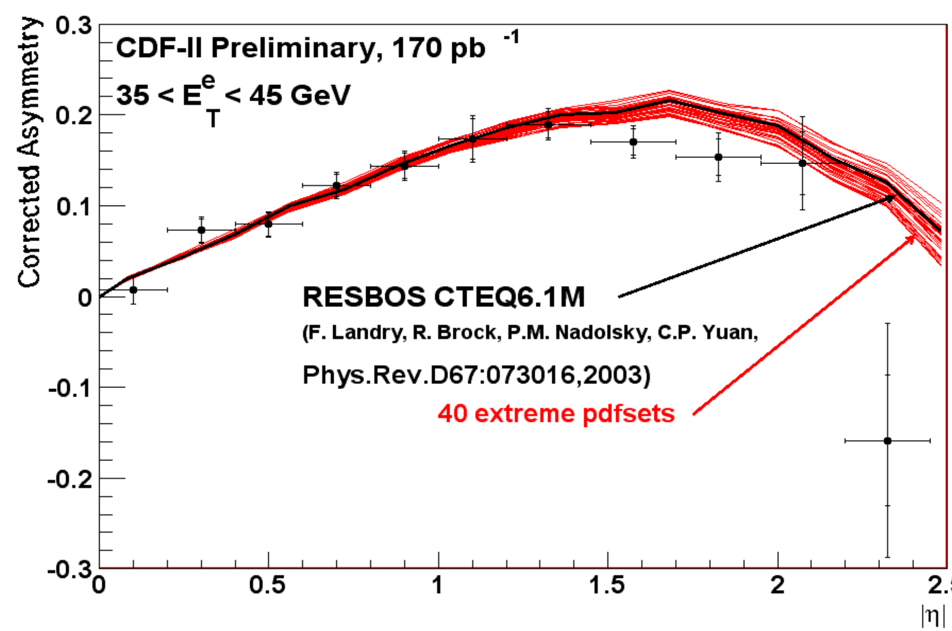
$$A(y_W) = \frac{d\sigma(W^+)/dy - d\sigma(W^-)/dy}{d\sigma(W^+)/dy + d\sigma(W^-)/dy}$$

Measured asymmetry: production asymmetry + V-A decay

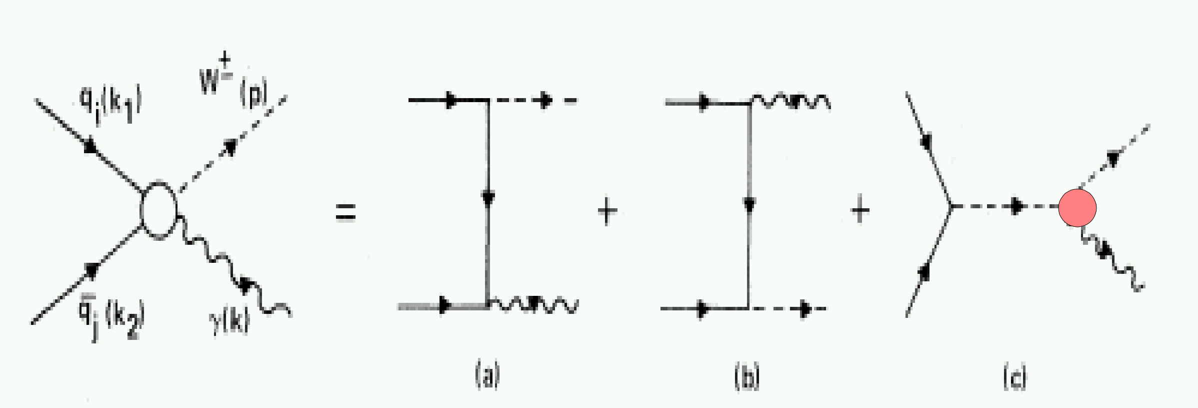
$$A(\eta_l) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta}$$

- Sensitivity increases at large lepton Pt's
- New techniques may become possible witht the increased statistics
- <u>To which extent Run II Tevatron data (EWK, QCD) can reduce uncertainties in parton disrtibutions?</u>





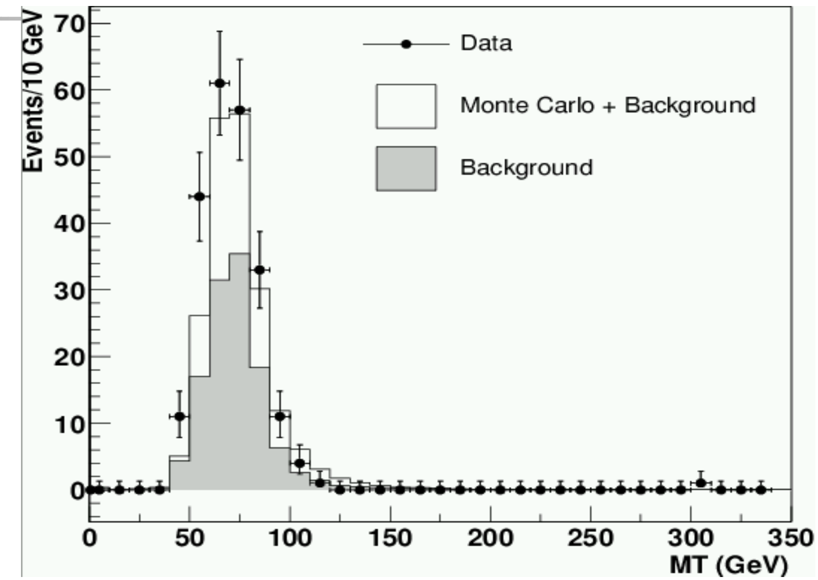
Diboson production: W/Z + gamma

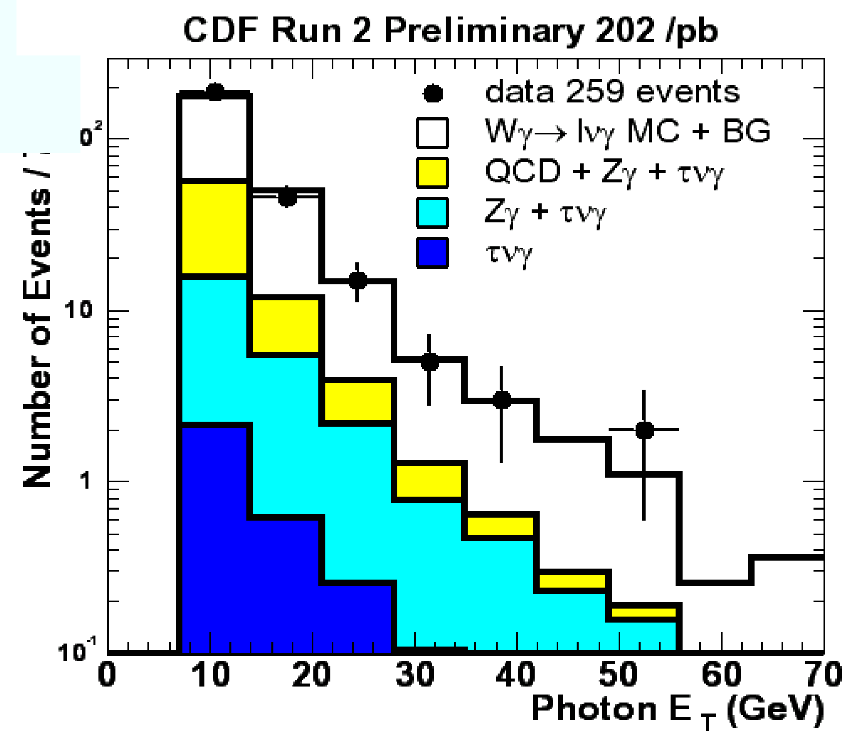


- Probe tri-boson (WWγ) couplings , SM ZZγ coupling = 0
- Experimant: photon identification important

	sigma(ppbar->Wg->lnug), pb	Sigma(ppbar->Z ->ll), pb
D0	19.3±6.7±1.2(lum)	3.86±0.86 ± 0.25(lum)
SM exp	16.4± 0.4	4.3

	s(ppbar->Wg->lnug), pb	S(ppbar->Z ->ll), pb
CDF	19.7 ± 1.7 ± 2.0± 1.1 (lum.)	5.3 ± 0.6 ± 0.3 ± 0.3 (lum.)
SM exp	19.3 ± 1.4	5.4 ± 0.3





Interference effects in W-gamma production

- Very elegant SM interference effect: “radiation amplitude zero”: (u and dbar quarks involved)

$$d\sigma(pp\to WgX)/d\cos(\Theta_{cm}) = 0 \quad \text{at } \cos\Theta_{cm} = -(1+2Q_d)$$

- More difficult to measure at LHC (qqbar involves the sea quarks)

- Sensitivity to anomalous couplings comparable to LEP at ~ 2fb^-1

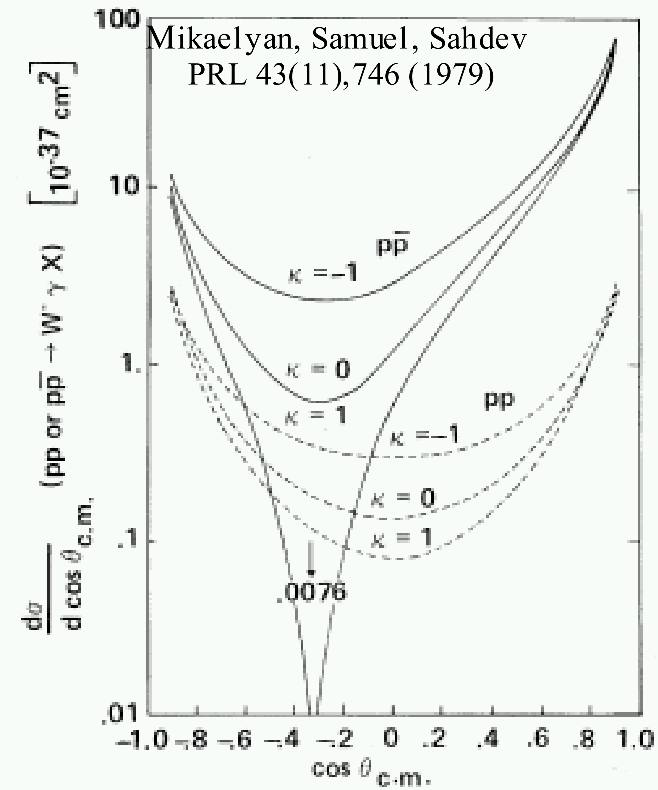
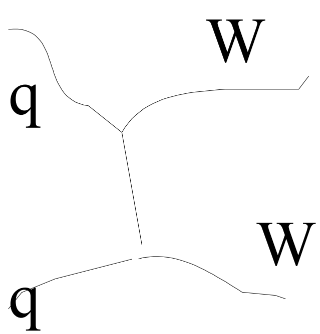
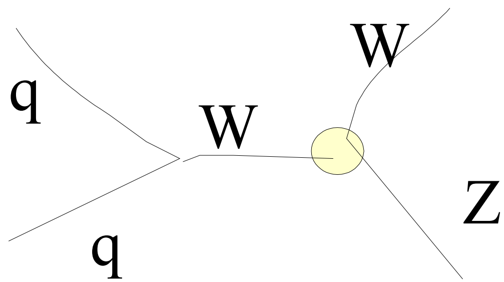
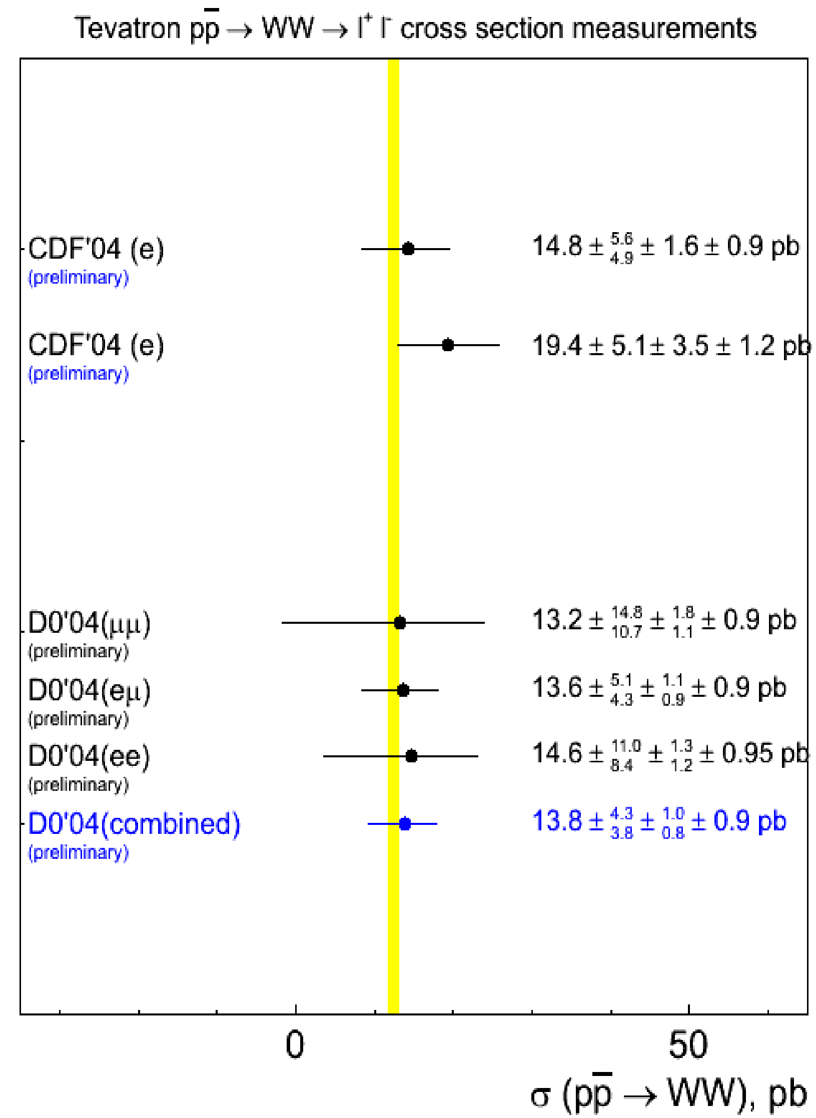


FIG. 3. The differential cross section for $pp \to W^-\gamma X$ and $p\bar{p} \to W^-\gamma X$, with a photon energy cut $E_\gamma > 30$ GeV. $\theta_{c.m.}$ is the angle between the W^- and the proton direction in the $W^-\gamma$ c.m. frame. $\sqrt{S} = 540$ GeV and $M_W = 85$ GeV/c^2.

Heavy diboson production: WW/WZ/ZZ







- Probe self-interaction of W and Z bosons
- ppbar->WW: background to ppbar-> H->WW

  Spin correlations important, need them in NLO MC
- Production cross section small:~ 2x ttbar
- both experiments consistent with SM

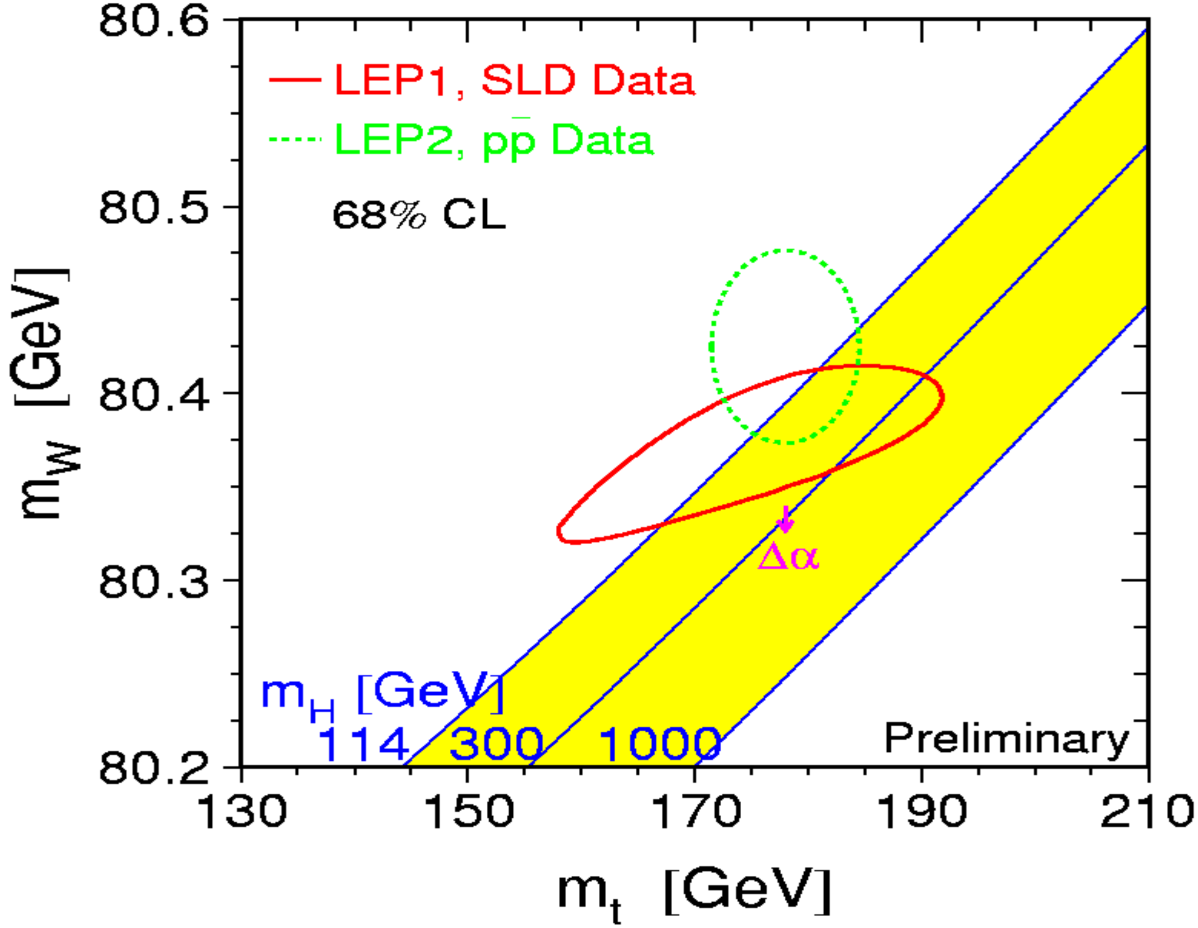
- limits on WZ/ZZ production:

CDF: σ(WZ+ZZ) < 13.9 pb @ 95%CL (SM: 5.4 pb)

D0: σ(WZ) < 15.1 pb @ 95%CL

- higher sensitivity to anomalous triple-gauge couplings in WW->ev jj channel

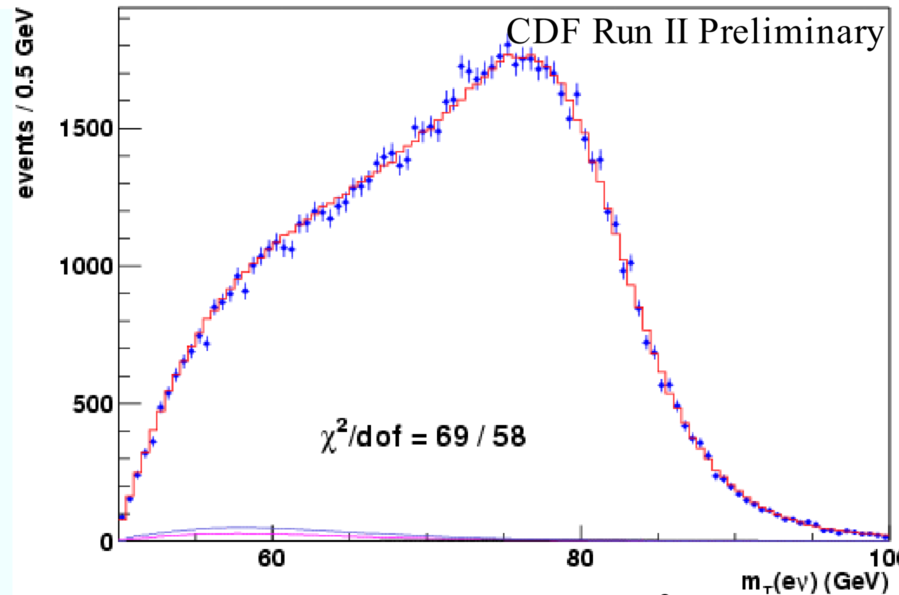
W mass: constraints on the Higgs mass



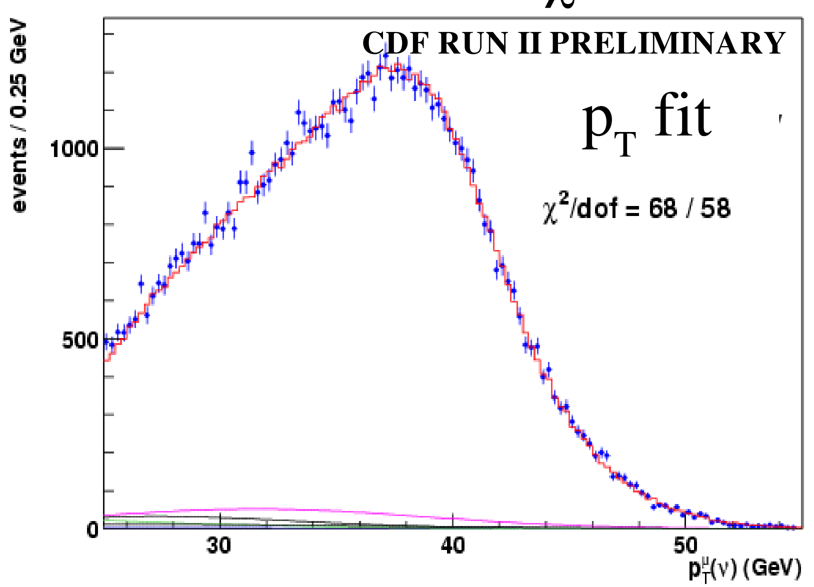
Direct measurements: evolution of the green ellipse for the next several years will be determined by the Tevatron experiments

W mass measurement at the Tevatron

- Required accuracy better than 10^-3
- Most sensitive technique at the Tevatron:
  - fit distribution for $M_T(W)$
- Theoretical/phenomenological inputs:
  - QED radiation
  - QCD : Pt spectrum of the W's
    - Parton momentum distributions
- Corresponding uncertainties on W mass :
  - Mt fit : ~30 MeV
  - Lepton Pt fit: ~ 40 MeV
- CDF ICHEP'2004:
  - 200pb^-1: total uncertainty(e+mu) = 76 MeV
  - 2fb^-1: other sources ~ 30MeV
- L > 1fb^-1: theoretical uncertainties [if not improved] will become important

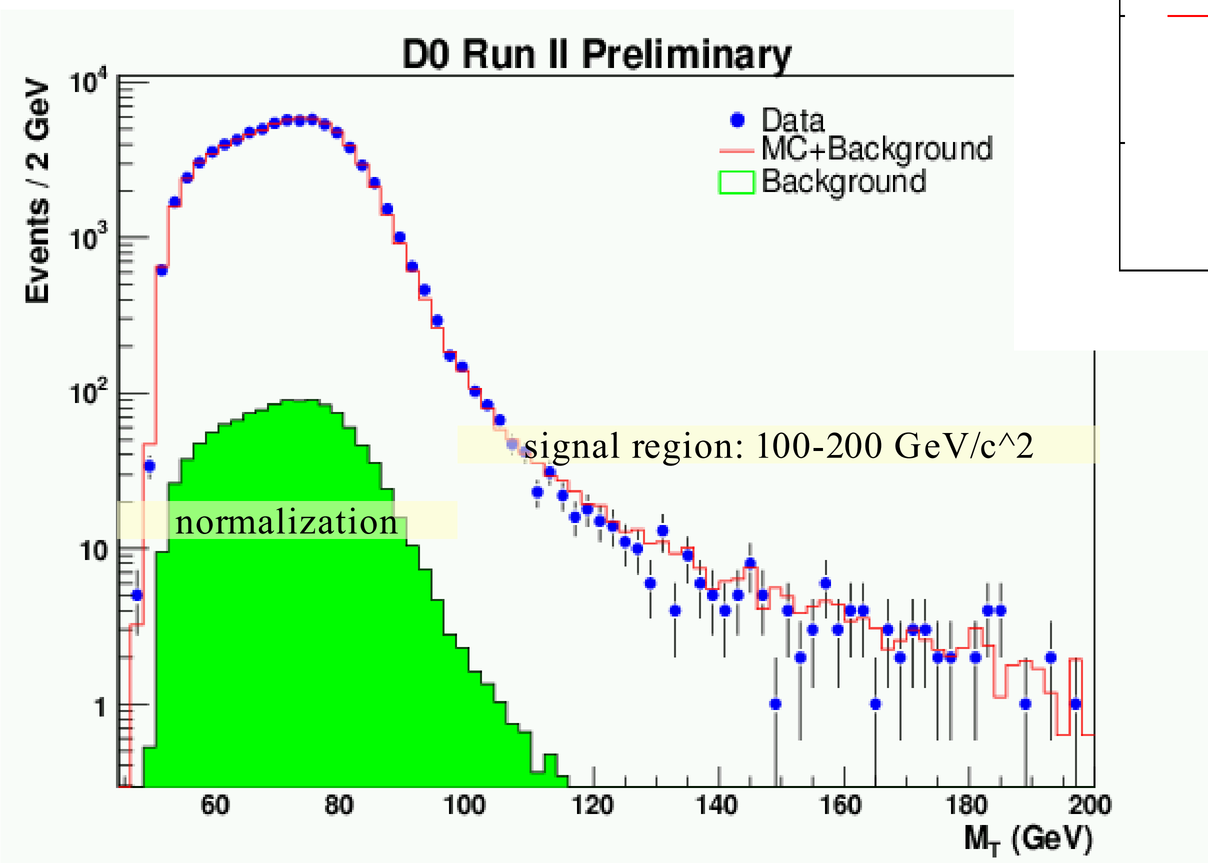


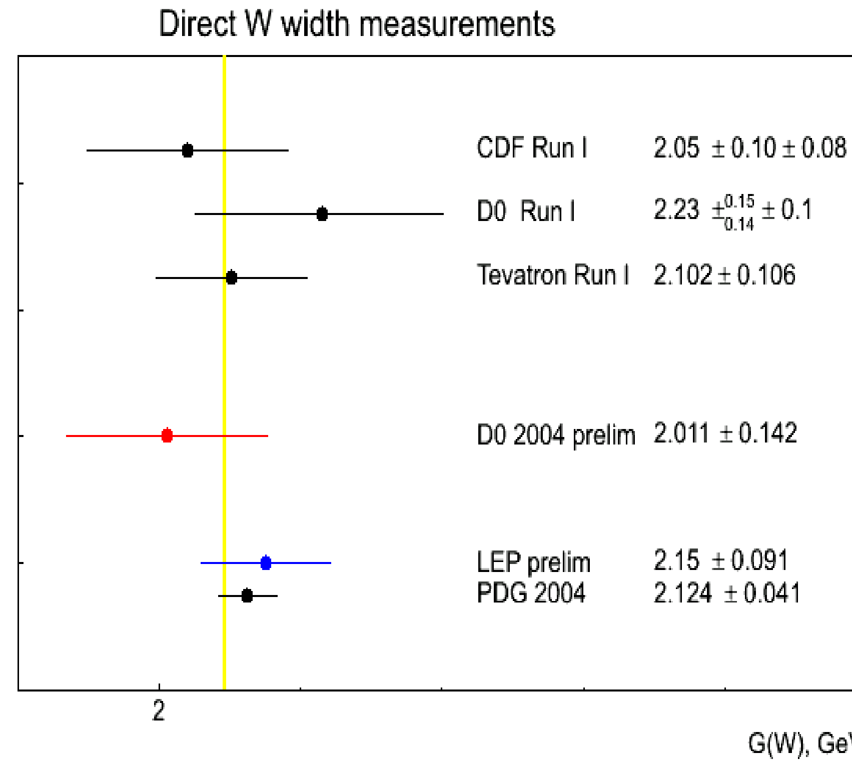
Good fit χ^2



W width: direct measurements (D0)

- D0 summer 2004:
- 75K W->enu candidates
- Normalization: 50 < MT < 100 GeV/c^2
- 625 events 100< MT <200 GeV/c^2





Summary

- First round of EWK measurements at the Tevatron successfully accomplished
- Production cross sections vary by 4 orders magnitude, all consistent with the SM
- Measurements of the EWK asymmeries done
- Direct measurement of W width
- Measurement of the W mass expected soon
- Also to come:
  - Measuremtnts of the diffferential cross sections
  - limits on the anomalous couplings
- Time to start using W->lnu to normalize the cross sections ?
- With 500pb^{-1} on tape – and N(Z@Tevatron) ~ N(W@LEP) Tevatron experiments are entering new phase of the Run II analyses