Electroweak Physics at CDF

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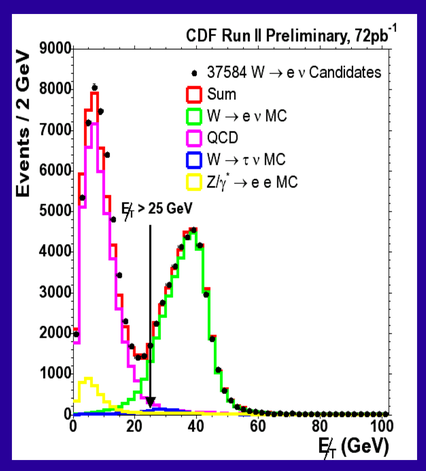
The discovery of the massive W and Z bosons at CERN in 1983 proved beyond doubt the unification of electromagnetism and the weak interaction. However, in terms of vigorously testing the predictions of electroweak theory it was really only the beginning. In the nineties the LEP collider at CERN did much work in this area, but the Tevatron is now in a position to not only improve on these results, but to probe deeper into the electroweak model and potentially the physics beyond it. Being the highest centre of mass collider in the world, W and Z bosons are produced with hitherto unseen abundance.

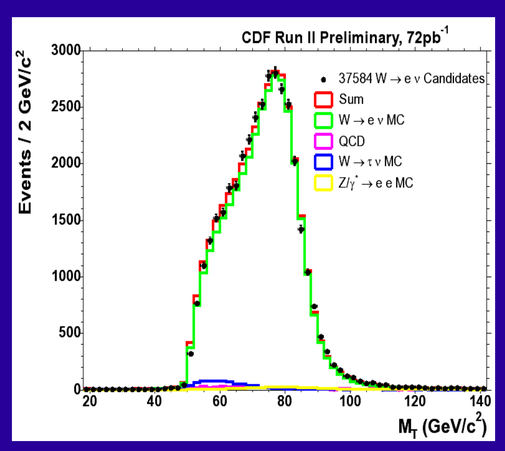
W Inclusive Cross-Section

$$\sigma \cdot Br(p\bar{p} \to W \to e\nu) = 2782 \pm 14_{(\mathrm{stat})}\ ^{+61}_{-56}{}_{(\mathrm{syst})} \pm 167_{(\mathrm{lum})}\ \mathrm{pb}$$
$$\sigma \cdot Br(p\bar{p} \to W \to \mu\nu) = 2772 \pm 16_{(\mathrm{stat})}\ ^{+64}_{-60}{}_{(\mathrm{syst})} \pm 166_{(\mathrm{lum})}\ \mathrm{pb}$$
$$\sigma \cdot Br(p\bar{p} \to W \to \ell\nu) = 2777 \pm 10_{(\mathrm{stat})} \pm 52_{(\mathrm{syst})} \pm 167_{(\mathrm{lum})}\ \mathrm{pb}$$

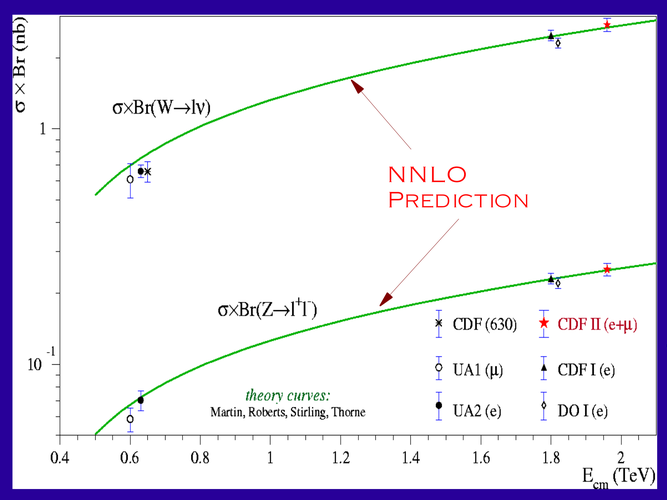
Missing Et distribution of events containing electrons. Excellent agreement between data and simulation signal + bkgd predictions.



Transverse mass distribution of W events. Note purity of W sample and the agreement with signal simulation.

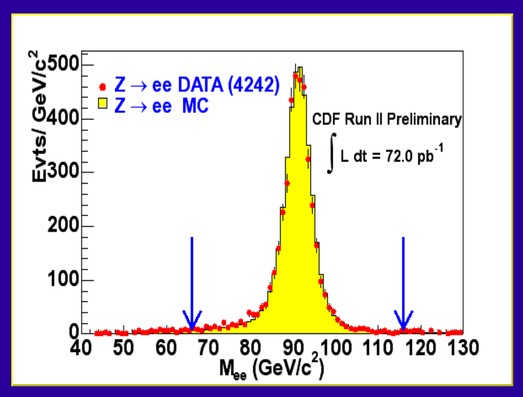


These measurements are of crucial importance. With their high event yields and relatively clean signatures, these signals not only provide a solid test of the Standard Model, but they are also extensively used in the calibration of the calorimeter. Currently they are systematics limited, and much recent work has been focused on understanding and reducing the sources of systematic error.



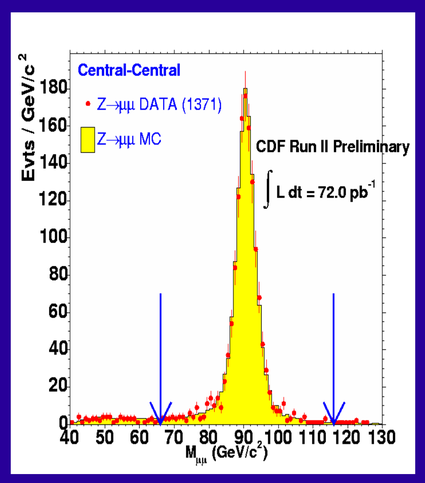
Z inclusive Cross-Section

$$\sigma \cdot Br(p\bar{p} \to \gamma^*/Z \to ee) = 255.2 \pm 3.9_{(\mathrm{stat})}\ ^{+5.5}_{-5.4}{}_{(\mathrm{syst})} \pm 15.3_{(\mathrm{lum})}\ \mathrm{pb}$$
$$\sigma \cdot Br(p\bar{p} \to \gamma^*/Z \to \mu\mu) = 248.9 \pm 5.9_{(\mathrm{stat})}\ ^{+7.0}_{-6.2}{}_{(\mathrm{syst})} \pm 14.9_{(\mathrm{lum})}\ \mathrm{pb}$$
$$\sigma \cdot Br(p\bar{p} \to \gamma^*/Z \to ll) = 254.3 \pm 3.3_{(\mathrm{stat})} \pm 4.3_{(\mathrm{syst})} \pm 15.3_{(\mathrm{lum})}\ \mathrm{pb}$$



Invariant mass of electrons in Z(ee) sample. Note absence of any backgrounds – these are estimated at less than one event per bin.

Invariant mass of muons in Z(μμ) sample. The Z(μμ) sample is completely free of backgrounds.



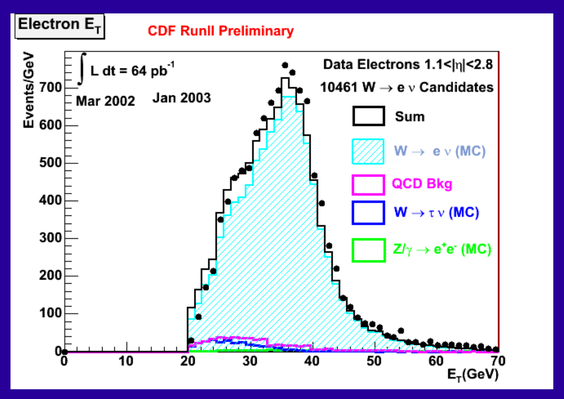
Comparison of CDF II cross-section measurements with those of other Hadron colliders.

W Cross-Section using Plug Electrons

$$2874 \pm 34(\mathrm{stat}) \pm 167(\mathrm{syst}) \pm 172(\mathrm{lum})\ \mathrm{pb}$$

For the standard measurement of W (eυ) cross-section only central electrons are used,. This measurement has recently been made using plug electrons in order to improve our understanding of this region of the detector. The plug is a forward calorimeter close to the beam pipe.

Et distribution of electrons in plug W events.



Derived Quantities

The ratio of the measured cross-sections. Correlations mean many systematics cancel.

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

$$R_e = 10.86 \pm 0.18_{(\mathrm{stat})} \pm 0.16_{(\mathrm{syst})}$$
$$R_\mu = 11.10 \pm 0.27_{(\mathrm{stat})} \pm 0.17_{(\mathrm{syst})}$$
$$R = 10.94 \pm 0.15_{(\mathrm{stat})} \pm 0.13_{(\mathrm{syst})}$$

Predicted by Theory

From LEP

$$Br(W \to \ell\nu) = 0.1093 \pm 0.0021$$

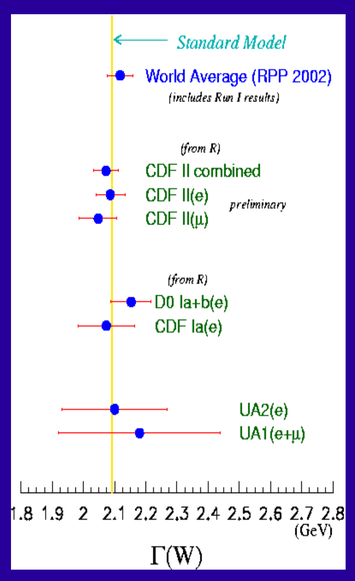
Using SM prediction for leptonic partial width

$$\Gamma_W = 2071.4 \pm 39.8\ \mathrm{MeV}$$

The ratio of ratios provides a stringent test of lepton universality.

$$U \equiv \frac{R_\mu}{R_e} = \frac{\Gamma_W(\mu\nu)}{\Gamma_W(e\nu)} = \frac{g^2_{W\mu}}{g^2_{We}}$$

$$\frac{R_\mu}{R_e} = 1.022 \pm 0.036 \qquad \frac{g_\mu}{g_e} = 1.011 \pm 0.018.$$



The CDF run II measurement of the W width compared to other hadron colliders.