CDF note 8119

Measurement of the $\sigma(p\bar{p} \to W) \times BF(W \to e\nu)$ in the region $1.2 < |\eta| < 2.8$

The CDF Collaboration
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We present a measurement of the $\sigma(p\overline{p} \to W)\times BF(W \to e\nu)$ at $\sqrt{s}$ 1.96 TeV in the rapidity region 1.2< $|\eta|$ <2.8, based on 223 pb^{-1} of data collected in CDF Run II. Using combined calorimetric and tracking information, we measure a cross section of 2.815 $\pm$0.013(stat)$^{+0.094}_{-0.089}$(syst) $\pm$ 0.169 (lum.) nb. The result is in agreement with previous CDF measurements in the central region and with theoretical estimates.

Preliminary Results for Winter 2006 Conferences

I. INTRODUCTION

We present a measurement of the W($\rightarrow e\nu$) cross section in the forward region, using combined calorimetric and tracking information. The W production cross section was measured by CDF in central region ($|\eta| < 1$) using both $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decays. The analysis presented here is a first step in studying W properties at large η.

Thanks to the new SVXII (5 layers of double sided silicon sensors) and to the ISL (two layers of double sided silicon sensors at $|\eta| >1$) CDF is able to reconstruct 3D tracks at large η. That new tool allows to extend to this rapidity range the same strategy used in the analysis of central leptons.

In this analysis we start from a calorimeter-based selection and then, to reject the large remaining background, we match electromagnetic calorimetric clusters to independently reconstructed 3D tracks. Clusters energy and position are measured by the *plug* calorimeters (rebuilt for Run II). Latter is obtained by using the shower maximum detectors embedded in the EM compartment of plug calorimeters. 3D tracks, pointing to the plug calorimeters, are matched to cluster candidate position. This requirement rejects most of the background, mainly coming from jets with large EM component in events with large missing transverse energy (MET).

The ingredients needed for this analysis are those contained in the basic equation: $\sigma = (N_{ev} - B)/(\epsilon \times L)$, where N_{ev} is the number of selected events, B is the remaining background, L is the integrated luminosity and ϵ is the product of kinematical, geometrical, trigger and reconstruction efficiencies.

II. DATA SAMPLE & EVENT SELECTION

The data set we use corresponds to runs, with working silicon detector, collected between March 2002 until February 2004 (run interval 149264–179056), corresponding to $\simeq 223$ pb^{-1}. For the measurement itself we use events collected by a calorimeter-based trigger which requires an EM cluster in the plug region in conjunction with missing transverse energy.

The following selection criteria are applied:

- at least one EM cluster belongs to PLUG in the region 1.2< $|\eta|$ <2.8;
- at least one calorimetric EM cluster with $E_T > 20$ GeV;
- EM fraction of the cluster > 0.95
- the EM cluster must be isolated (Relative Isolation < 0.1);
- Missing Transverse Energy (MET)> 25 GeV.

In order to clean up our data sample, we require events to have at least one 3D track with $P_T > 1$ GeV/c pointing to the EM cluster and extrapolating to the PES to better than 3 cm in the X and Y coordinates. This cut was optimized by using the $Z \rightarrow ee$ sample (see section below for a description of the sample). We require also the z_0 coordinate of the track matched to the EM cluster to be: $|z_0^{Track}| < 60$ cm.

Last criteria applied is an E/p matching. We require E/p<2. 48144 candidate events pass this final cut.

III. BACKGROUNDS

Background to our sample is composed of a component due to multijet (a.k.a "QCD") events where one jet fakes an electron and a component due to events coming from other EWK processes ($Z \rightarrow ee$, $W \rightarrow \tau\mu$) .

QCD background is computed studying the MET vs IsoRel plot. One defines four regions:

- region A: MET <10 GeV, IsoRel < 0.1;
- region B: MET <10 GeV, IsoRel > 0.2;
- region C: MET >25 GeV, IsoRel > 0.2;
- region D: MET >25 GeV, IsoRel < 0.1.

Signal region is D. The number of backgound events in this region is given by the following equation:

$$N_{bckg} = N_A \times \frac{N_C}{N_B}$$

Shape of background is provided by events in region C. Number of events in regions A, B and C is corrected for contributions -to the different regions- from signal itself, from $Z \to ee$ and $W \to \tau\nu$, which are computed separately. After applying all corrections, the final QCD background amounts to 877 events. In order to determine the systematic uncertainty on QCD background, we varied the IsoRel and MET cuts which define the four regions.

Other background contributions come from the $W \to \tau\nu$ (1073 events) and $Z \to ee$ (233 events) processes. Transverse mass shape for these two processes is obtained by MC.

Figures 1, 2, 3 show data overlayed to expected yield of events after taking into account background contributions.

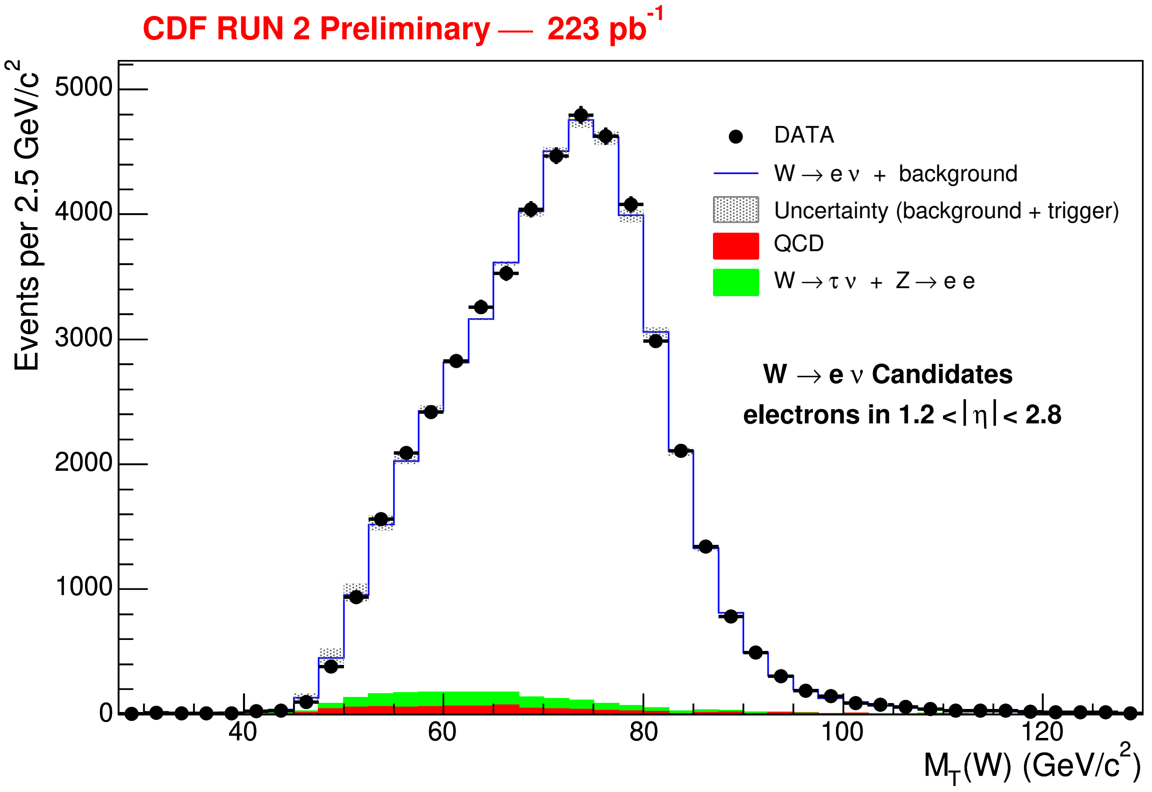

FIG. 1: *Transverse mass of W candidates compared to expected signal.*

IV. $Z \to ee$ SAMPLE

Z events with one of the two legs reconstructed in the *plug* calorimeters, constitute a useful sample. We select events with a *tight* central electron and a *loose* plug candidate, whose invariant mass falls within ± 10 GeV/c^2 about the mass peak of the Z.

This sample is used for several purposes, from tuning MC to data, to measure the efficiency of several requirements as well as the tracking efficiency for high P_T electrons.

V. KINEMATICAL AND GEOMETRICAL ACCEPTANCES

To estimate kinematical and geometrical acceptances (A) we use Montecarlo samples. $W \to e\nu$ events are generated with Pythia 6.216 (CTEQ5L), passed through the full simulation of the CDF detector and reconstructed. Figure 4

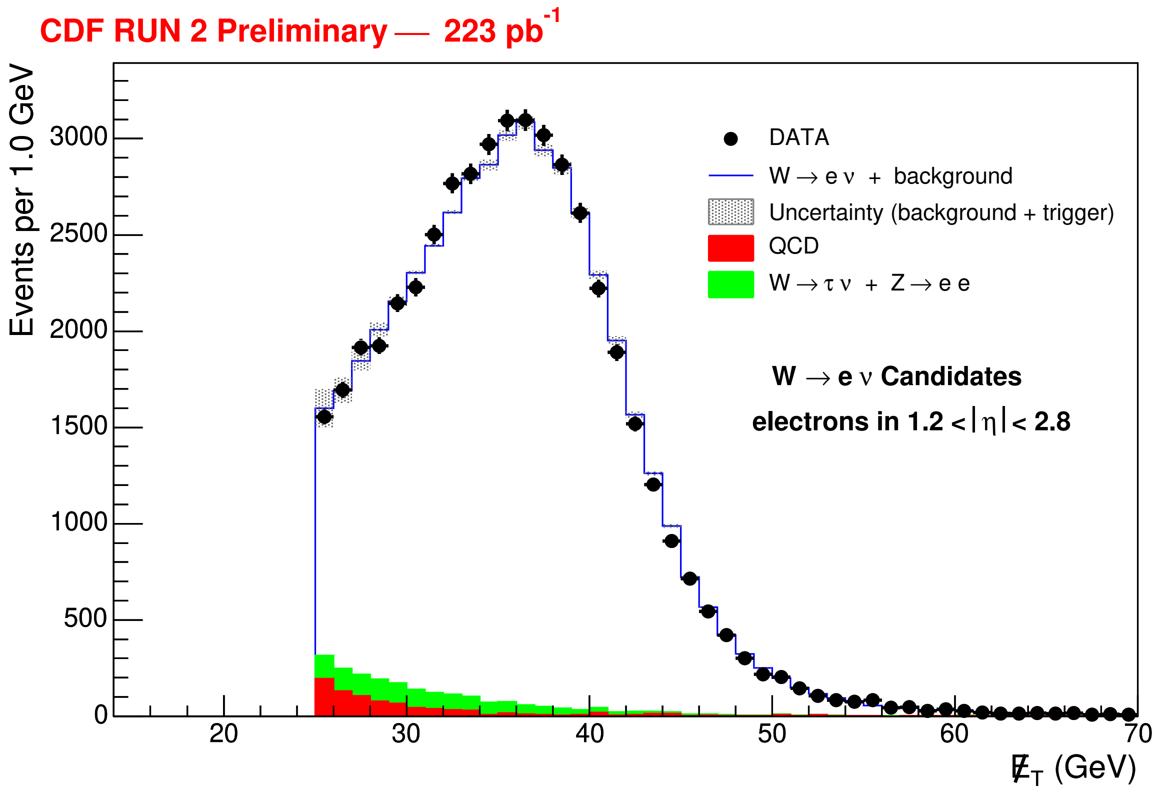

FIG. 2: *MET in W candidate events compared to expected signal.*

shows the $A(y)$ distribution after full detector simulation, where y is the W rapidity from Montecarlo parton–level information.

Several parameters in generator and simulation are tuned to reproduce features seen in data. Montecarlo is tuned to match with data in W boson p_T distribution and in E/p distribution, with an appropriate description of the material. E_T is tuned to data using a sample of $Z \to ee$ CP events. The model of energy deposition in calorimeter is tuned by matching data and MC for recoil energy $\vec{U}$, where $\vec{U}$ indicates the energy deposited in calorimeters not coming from the high P_T electron, i.e. $\vec{U} = -(M\vec{E}T + \vec{E}^e_T)$.

We obtain the central geometrical acceptance value embedding the $A(y)$ distribution obtained from Pythia into the NLO calculation of $d\sigma/dy$ with the default MRST01E PDF set. The result is $A = 0.2555 \pm 0.0002(stat.)$.

We calculated the systematic uncertainty on acceptance due to the following effects:

- Energy Scale and Resolution;
- P_T of W;
- Extra Material;
- Recoil Energy Modeling;
- PDF Uncertainty;
- Effect of primary vertex reconstruction in data and MC.

Systematics related to energy scale and resolution was obtained by varying those parameters by $\pm$ 1 σ and recomputing the acceptances. $d\sigma/dp_T$ distribution is tuned to Run I data by changing the relevant parameters in Pythia. Change of acceptance due to a ± 3 σ variation of those parameters was taken as systematics. Effect of extra material on acceptance was calculated using 2 special MC samples generated with $\pm$ 1/3 X_0 of extra material (copper) in front of the plug calorimeters. The largest difference in acceptance is taken as the corresponding systematics.

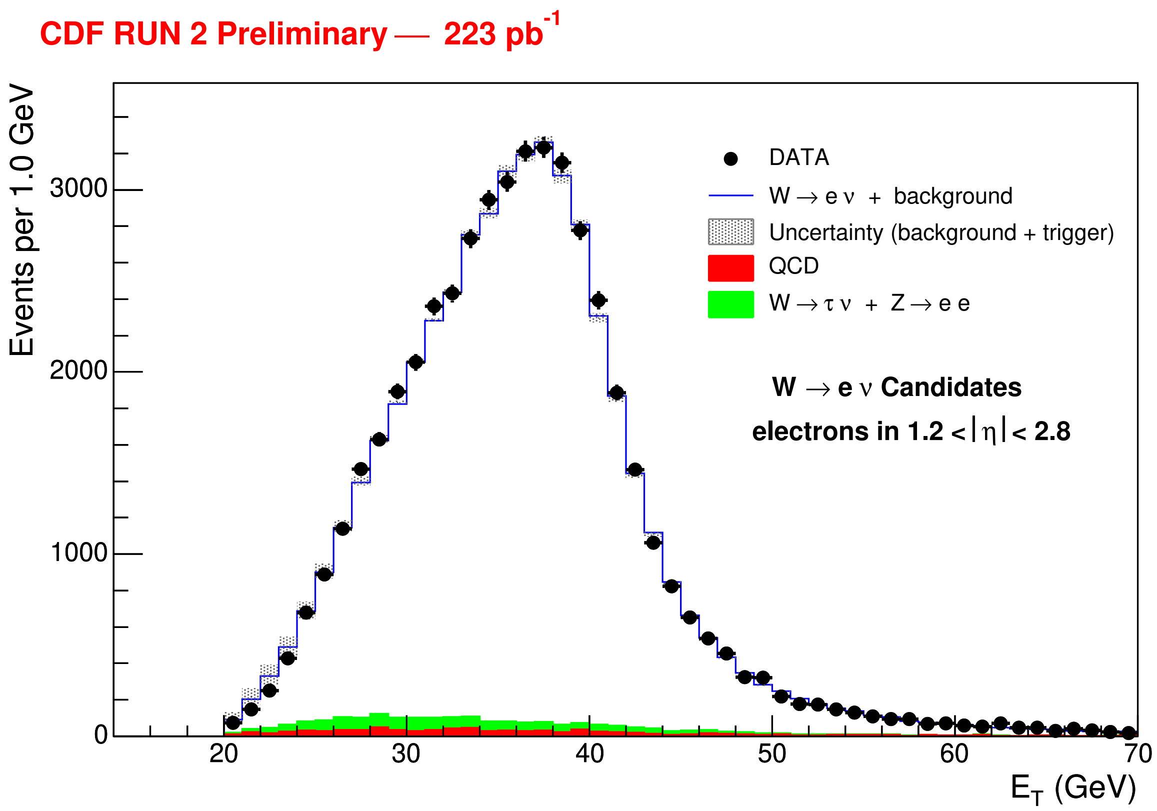

FIG. 3: *E_T distribution for plug electron of W candidates compared to expected signal.*

Energy recoiling against the W ($\vec{U} = -M\vec{E}T - \vec{E}_T^e$) was studied in data and MC. The effect of a possible mis-modeling of $\vec{U}$ on the acceptance calculation was estimated taking the $\pm 3\sigma$ variation of the paramters needed to reproduce in MC the behaviour seen in data.

The effect of the choice of Parton Distribution Functions (PDFs) in the MC was studied by using CTEQ6.1 PDF, described by 20 parameters. Changing by $\pm 1\sigma$ each parameter one obtains a total of 40 error PDF sets. We perform the NLO $d\sigma/dy$ cross section calculation for each error PDF set and check how much the acceptance values based on each calculation deviate from the value obtained using the central PDF set.

The overall fractional systematic uncertainty on the acceptance is +1.89, –1.54 %.

VI. EFFICIENCIES

The efficiency of the requirements on electromagnetic fraction of the energy, calorimetric isolation and E/p are evaluated using the (unbiased) *plug* leg of the $Z \to ee$ (CP) sample previously described.

Trigger efficiency is also evaluated on data, using independent triggers. The CDF trigger is composed of three different levels. The first two are based on hardware selection, while the third essentially runs a fast version of the offline recontruction code on a farm of parallel processors. Our data is selected by a trigger path requiring a missing transverse energy in excess of 15 GeV and an EM cluster in the plug region with E_T in excess of 20 GeV.

Tracking efficiency is measured on data, using the plug leg of the $Z \to ee$ (CP) sample, and corrected -using MC- to account for the small differences of the electrons from Z with respect to the ones from W decays. Tracking efficiency is defined as the probability to associate a track to an EM cluster passing all selection criteria and to extrapolate to a PES cluster with a ΔX, ΔY (PES–extrapolated track) to better than 3 cm.

The overall acceptance × efficiency is: $\epsilon_{overall} = 0.0732 \pm 0.0011$ (stat) $^{+0.0021}_{-0.0019}$ (syst).

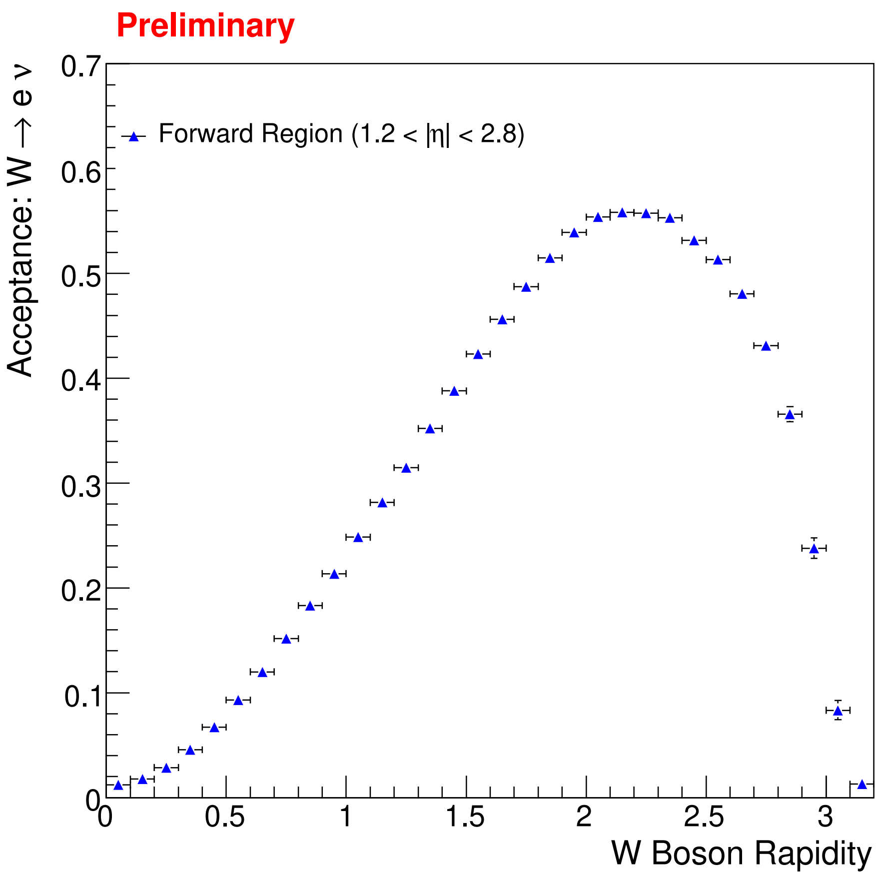

FIG. 4: *Acceptance obtained from Pythia + full detector simulation as a function of "hepg" W boson rapidity.*

VII. RESULTS

Table I is a summary of what is used for the cross section measurement.

N.candidate events	48144	
N.background QCD events	877 ± 59 (stat)	± 438 (sys)
N.background Z events	223 ± 3 (stat)	
N.background $W \to \tau\nu$ events	1073 ± 12 (stat)	
Lumin.(pb^{-1})	223	± 13 (sys)
ϵ	0.0732 ± 0.0011 (stat)	$^{+0.0021}_{-0.0019}$ (sys)

TABLE I: Quantities used for cross section measurement.

The value of the cross section is: $\sigma \times BR(W \to e\nu) = 2.815 \pm 0.013(stat)^{+0.094}_{-0.089}(syst) \pm 0.169(lum)$ nb, consistent with CDF result presented in Winter 2004 in the same pseudorapidity region and CDF results obtained in the central region. In figure 5 we summarize twenty years of W and Z cross section measurements at hadron colliders.

VIII. CONCLUSION

We presented a measurement of the cross section times branching fraction for $W \to e\nu$ in CDF, where the electron is identified in the plug region by combining calorimetric and tracking information. Tracking and calorimeter information

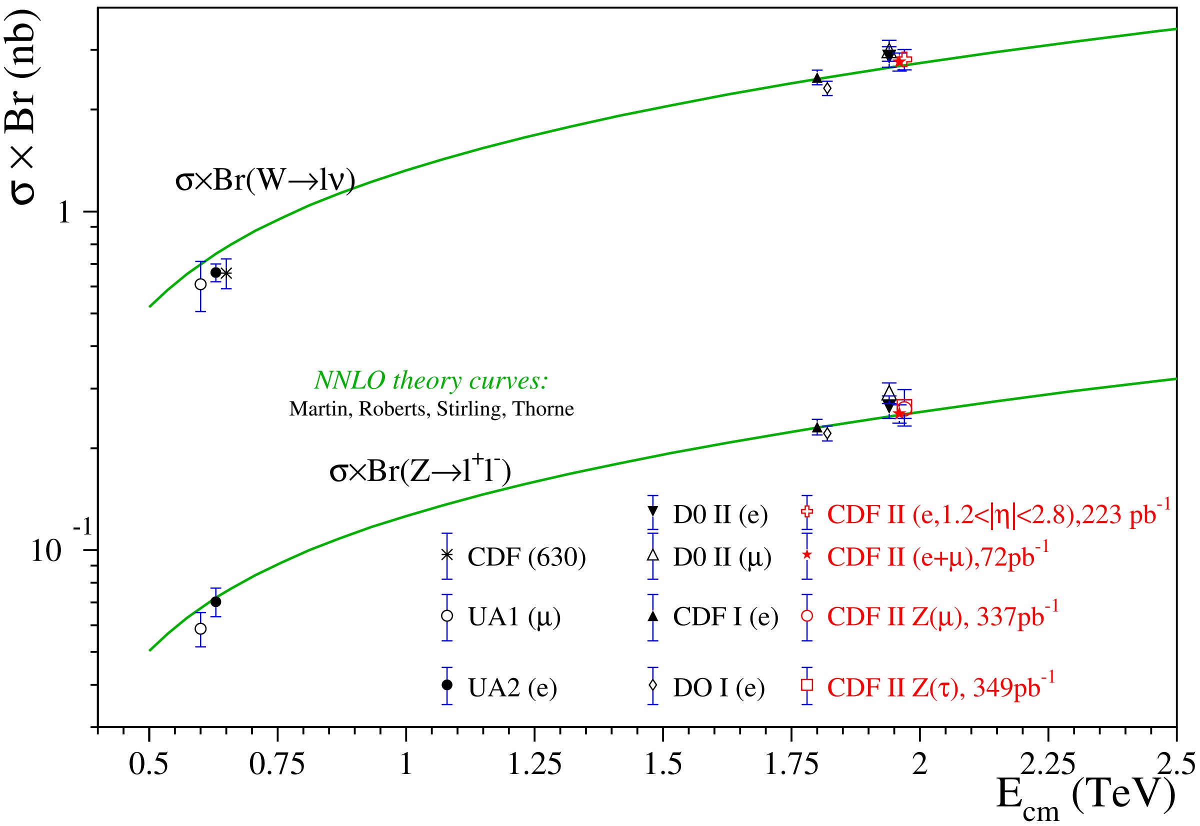

FIG. 5: *W and Z cross sections at hadron colliders.*

were treated separately as in the central region. A cross section of 2.815 ± 0.194 nb is measured using 223 pb^{-1}, consistent with other Run II CDF results.

Acknowledgments

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