Measurement of $\sigma(p\bar{p} \to Z) \cdot \mathrm{Br}(Z \to \tau^+\tau^-)$ with the DØ Experiment

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The measurement of resonant production of tau lepton pairs at hadron colliders is important not only as a test of the standard model (SM), through its implications on lepton universality, but also as a seed in the search for new phenomena. For example, due to the large tau lepton mass, the detection of resonant tau lepton pairs is of particular importance in the search for particles with decay coupling proportional to mass, such as SM or supersymmetric Higgs bosons. A supersymmetric Higgs boson may first be observed in the tau lepton channel, as the production cross section of this particle is significantly enhanced in certain regions of parameter space compared to that of the SM Higgs boson. Since the detection of tau leptons is far more challenging than that of other charged leptons, a good understanding of the SM production processes, in particular the Z boson production decaying into tau leptons, is crucial.

The cross section times branching ratio $\sigma\cdot$ Br for the process $p\bar{p} \to Z \to \tau^+\tau^-$ was measured at $\sqrt{s} = 1.96$ GeV using 1.0 fb^{-1} of data collected by the DØ experiment. This measurement was performed in the channel in which one of the tau leptons decays to a muon and neutrinos, while the other decays either hadronically or to an electron and neutrinos. A set of 1511 events, of which about 20 % estimated background, passed all selection criteria. The trigger and muon reconstruction efficiencies, as well as the efficiency for track reconstruction were obtained from data using the "tag and probe" method on $Z \to \mu^+\mu^-$ events. The multijet background was estimated from the sample of events which passed all selection criteria but in which the muon and the tau candidate had the same charge. The $W \to \mu\nu$ + jets background was modeled by Monte Carlo simulations, but normalized to data. All the other backgrounds, as well as the efficiency for $Z \to \tau^+\tau^-$ events were estimated using simulated events normalized to the theoretical calculations of cross sections at next-to-leading order or next-to-next-to-leading order. The energy of the tau candidates was corrected for the estimated response of the charged pions in the calorimeter, which is of the order $50-80$ %. Since the charged pion response in data was not well reproduced by the default simulation of hadronic interactions (Geisha), a different simulation (gCALOR) was used to obtain an estimated charged pion response consistent with the one measured in data. This tau energy correction method makes use of the superior resolution of the track momentum measurement compared to the resolution of the tau candidate energy as measured by the calorimeter, which leads to a better data - simulation agreement and a descrease of 10 % in the resolution of the visible mass peak, which can be seen in Fig. 1 .

The result of this measurement is $\sigma(p\bar{p} \to Z) \cdot \mathrm{Br}(Z \to \tau^+\tau^-) = 240 \pm 8$ (stat) $\pm$ 12 (syst) $\pm$ 15 (lumi) pb, which is in good agreement with the SM prediction of $251.9^{+5.0}_{-11.8}$ pb [1,2] that results from the NNLO calculation using the MRST2004 PDFs, as well as with the $241.6^{+3.6}_{-3.2}$ pb [1,3] value obtained at NNLO using the CTEQ6.1M PDF parametrization. This result, published recently in [4], is the most precise measurement of $\sigma(p\bar{p} \to Z + X) \cdot \mathrm{Br}(Z \to \tau^+\tau^-)$ to date, in good agreement with previous measurements of the Z boson cross section times branching ratio to leptons at $\sqrt{s} = 1.96$ TeV, as seen in Fig. 2. The analysis demonstrates the ability of the DØ experiment to identify tau leptons decaying hadronically with good efficiency and high purity, a challenging task in $p\bar{p}$ collisions where the number of jets resembling tau leptons is very high. This achievement forms a solid basis for other analyses using hadronic tau lepton decays, such as the search for the Higgs boson decaying into tau-lepton pairs.

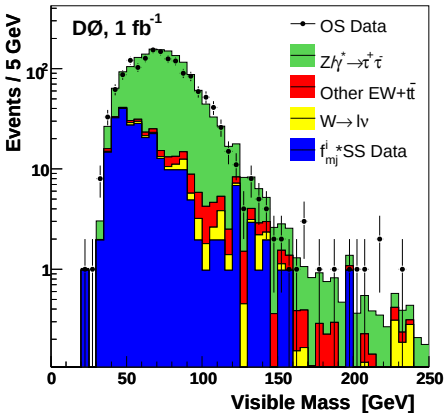

Fig. 1: Visible mass peak in the di-tau channel.

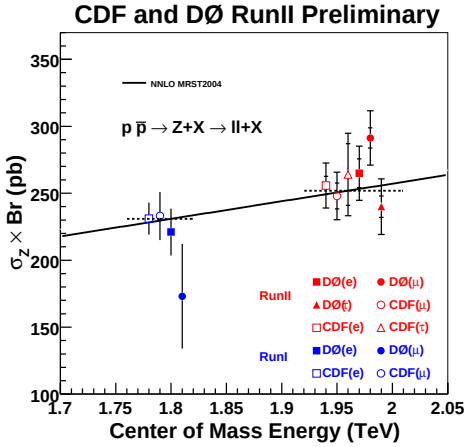

Fig. 2: Comparison of the available measured Z cross sections times branching ratios performed by DØ and CDF in all lepton channels.

References

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