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First observation of Z^0Z^0 in the four-lepton decay channel at CDF

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Summary. — In this paper we will present the measurement of the Z^0Z^0 production cross section through the four-charged-lepton decay channel.

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1. – Introduction

Z^0Z^0 events are produced at the Tevatron, in $p\bar{p}$ collisions at $\sqrt{s} = 1.96\,\text{TeV}$, with an expected cross section of $1.4 \pm 0.1\,\text{pb}$ at NLO calculation in the Standard Model (SM). The study of this process is an important test of the SM and can give hints of new physics beyond that. The measurement of the Z^0Z^0 production cross section is necessary to evaluate one of the main backgrounds to the search of the Higgs boson, which decays significantly to a Z^0 pair for $m_H \geq 140\,\text{GeV}$. Finally the Z^0Z^0 production cross section is sensitive to new physics through anomalous trilinear gauge couplings [1] and large extra-dimensions [2].

2. – Analysis techniques

Data used in this analysis has been collected by the CDF II experiment which uses a multi-purpose detector whose description can be found in [3].

The $Z^0Z^0 \to lll'l'$ candidates are selected using a high momentum muon and high energy electron triggers corresponding to an integrated luminosity of $4.8\,\text{fb}^{-1}$. The evaluation of the background contamination was performed using real data, collected with high energy jet triggers. A Monte Carlo (MC) simulation based on Pythia as generator and CDFSim as emulator of the detector response is used to determine signal efficiency and acceptance.

The Z^0Z^0 events selection is based on the reconstruction of both Z^0 bosons. In the final state, exactely four reconstructed leptons (e, μ) are required. One of them must be the lepton that triggered the event, with $p_T \geq 20\,\text{GeV}/c$, while the others are required to have $p_T \geq 10\,\text{GeV}/c$. We combine the four leptons to form two pairs of same flavour and opposite charge leptons, requiring one of the two pairs to have an

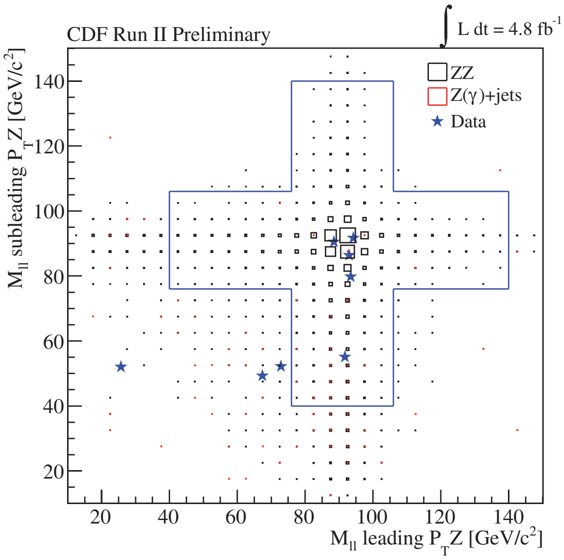

Fig. 1. – Invariant mass distribution of the two reconstructed Z^0.

invariant mass in the range 76–106 GeV/c^2. To increase the acceptance of the analysis, the second pair is allowed to have an invariant mass in a wider range, 40–140 GeV/c^2. Given a signal selection efficiency of $\sim 10\%$, the number of expected Z^0Z^0 events is $4.68 \pm 0.02(\text{stat.}) \pm 0.76(\text{syst.})$.

The background contribution to this analysis is low because there are no physical processes leading to a four-lepton final state. The main contribution is instead due to

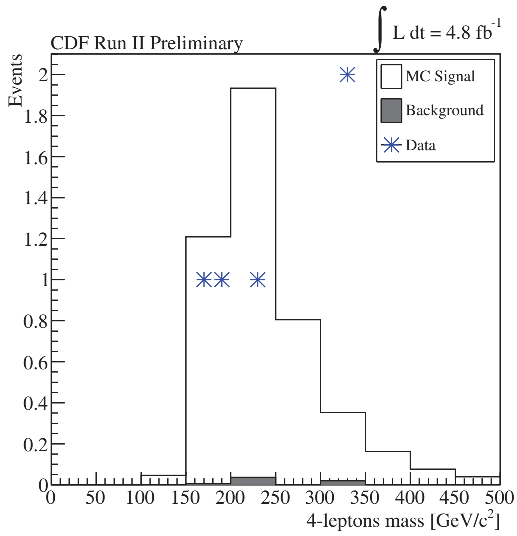

Fig. 2. – Four-lepton invariant mass distribution.

fake leptons, $Z^0 + \gamma$ events in which one or more jets are mis-identified as leptons. A data sample composed mainly of jets is used to evaluated the probability for a jet to be reconstructed as a lepton. This probability is used to weigh events containing one or two jets in the final state, that replace the real leptons. The background prediction obtained is 0.04 ± 0.02(stat.) $\pm\, 0.03$(syst.) events, where the systematic error is due to the uncertainties in the *fake rates* calculation and is the main systematics uncertainty in the calculation of the signal significance.

3. – Results

In $4.8\,\mathrm{fb}^{-1}$ of collected data we observe 5 events with a statistical significance of 5.7σ. This is the first observation of Z^0Z^0 production at CDF. Figure 1 shows the scatterplot of the two Z^0 invariant masses for the MC simulation, background expectations and data (stars). Solid lines represent the cuts applied. The four lepton invariant mass is displayed in fig. 2.

With the observed events we evaluate the production cross section $\sigma(p\bar{p} \to Z^0Z^0) = 1.56^{+0.80}_{-0.63}$(stat.) $\pm\, 0.25$(syst.) pb, that is in agreement with the previous measurements done by CDF [4] and DØ [5] and with the theoretical expectation at NLO, $\sigma_{ZZ} = 1.4 \pm 0.1$ pb.

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