IL NUOVO CIMENTO Vol. 36 C, N. 1 Gennaio-Febbraio 2013
DOI 10.1393/ncc/i2013-11457-x

Colloquia: IFAE 2012

Search for the Standard Model Higgs boson in the 4-lepton channel at CMS

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ricevuto il 31 Agosto 2012

Summary. — A search for a Standard Model (SM) Higgs boson in the four-lepton (4l) decay channel H→ZZ, with each Z boson decaying to an electron or muon pair, is reported. The analysis uses data corresponding to an integrated luminosity of 4.7 fb^{-1} recorded by the CMS detector in proton-proton (pp) collisions at $\sqrt{s} = 7$ TeV from the LHC. A non-significant excesses of events are observed, and upper limits are calculated.

PACS 14.80.Bn – Standard-model Higgs bosons.

The inclusive Higgs boson production, in gluon fusion or vector boson fusion process, followed by the decay H→ZZ is expected to be one of the main discovery channels at the pp LHC in the mass range $110 < m_H < 600\,\mathrm{GeV}/c^2$.

The characteristic topology of the signal is two pairs of opposite-charge same flavour isolated leptons. Collision events are selected by the trigger system, requiring the presence of electron (or muon) pair with transverse energy (transverse momenta) above 17 GeV for the first lepton and above 8 GeV for the second one. To reconstruct Z bosons, one or both off-shell, the leptons must satisfy criteria on p_T, η, isolation, and impact parameter significance at the off-line level. Two selections are defined: the *baseline*, requiring $m_{Z_1} > 50\,\mathrm{GeV}/c^2$ and $m_{Z_2} > 12\,\mathrm{GeV}/c^2$, used to search for the Higgs boson; and the *high-mass*, requiring both the $m_Z > 60\,\mathrm{GeV}/c^2$, used to measure the ZZ cross section. The efficiencies are measured in data, using a tag-and-probe technique [1].

The main background sources include: 4l from direct ZZ production via qq annihilation and gg fusion; $\mathrm{Zb\bar{b}}$ and $\mathrm{t\bar{t}}$ events, with two isolated leptons and two b jets producing secondary leptons in the final states; and Z + jets events where jets are misidentified as leptons.

The number of events expected from the ZZ background is evaluated on MC as explained in ref. [1], with a systematic uncertainty of 8%. The reducible ($\mathrm{Zb\bar{b}}$, $\mathrm{t\bar{t}}$) and instrumental (Z + light jets) backgrounds are estimated from data, by defining a control

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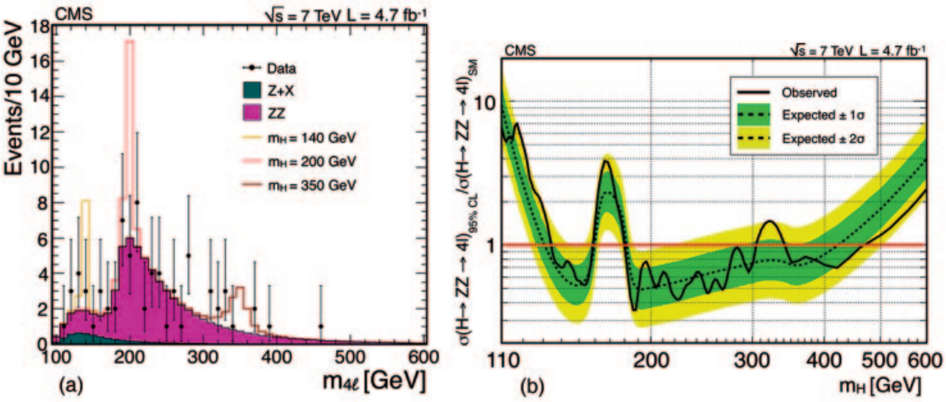

Fig. 1. – (a) Distribution of the 4l reconstructed mass for the sum of the 4e, 4μ and $2e2\mu$ channels, compared to the expected background. (b) Exclusion limit at 95% CL for $\sigma(\mathrm{pp} \to \mathrm{H} + \mathrm{X}) \times B(\mathrm{ZZ} \to 4\mathrm{l})$ normalized to σ_{SM}.

region. The result is found to be compatible with the MC expectation in the signal region within a 20% systematic uncertainty, and is independent on the uncertainty on the integrated luminosity. This uncertainty (4.5%) enters in the evaluation of the ZZ background. The systematic uncertainties for trigger efficiency (1.5%), lepton reconstruction and identification (2–3%), and isolation efficiencies (2%) are evaluated from data, while those on the Higgs boson cross section (20%) and branching fraction (2%) are taken from ref. [2]. The systematics on the energy calibration (0.5%), and resolution are accounted by introducing a 30% uncertainty on the width of the signal mass peak.

Seventy-two events (2 in 4e, 23 in 4μ, and 37 in $2e2\mu$) are observed with an invariant mass of the four leptons $m_{4\mathrm{l}} > 100\,\mathrm{GeV}/c^2$ (with 13 below $160\,\mathrm{GeV}/c^2$), while 67.1 ± 6.0 (9.5 ± 1.3) events are expected from background. The reconstructed 4l invariant mass distribution is shown in fig. 1a. The shapes are fit using a convolution of a Breit-Wigner probability density function to describe the theoretical resonance line shape and a Crystal Ball function to account for detector effects. For each mass hypothesis we perform an unbinned likelihood fit using the statistical approach discussed in ref. [3].

Limits, shown in fig. 1b, are calculated relative to the expected SM Higgs boson cross section values σ_{SM}, using the modified frequentist method CLs [4]. The SM Higgs boson is excluded at 95% CL in the m_{H} ranges [134,158] GeV/c^2, [180,305] GeV/c^2 and [340,465] GeV/c^2. Small excesses of events are observed around masses of 119, 126, and $320\,\mathrm{GeV}/c^2$.

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