Pis'ma v ZhETF, vol. 98, iss. 5, pp. 283 – 284 

# The mass of the Higgs like boson in the four lepton decay channel at the LHC

*V. Roinishvili*[1)]

*Joint Institute of Nuclear Research, 141980 Dubna, Russia*

Submitted 24 June 2013

A very simple and transparent way for the mass definition of a new boson, probably Higgs ($H$), observed at LHC, decaying into 4 leptons, is presented. The obtained mass of $H$ is $125.5 \pm 0.4$ GeV with today statistics.

DOI: 10.7868/S0370274X13170013

**Introduction.** In the resent publication on $H \to \to 4\,leptons$ the ATLAS [1] and CMS [2] collaborations give the following values for the measured mass of $H$ in this decay channel:

$$\text{ATLAS} - 124.3 \pm 0.5(\text{st}) \pm 0.6(\text{syst})\,\text{GeV}, \quad (1)$$

$$\text{CMS} - 125.8 \pm 0.5(\text{st}) \pm 0.2(\text{syst})\,\text{GeV}. \quad (2)$$

Fig. 1 shows the distribution of the effective mass of 4 leptons-$M_{4l}$ for ATLAS and CMS extracted from the corresponding figures in [1] and [2]. The 4-lepton samples have the advantage that they contain two signals: one from $H$ under the study and another from the very well known $Z$ boson. The last can be used to obtain the experimental resolution and a possible systematic shift of the 4-lepton effective mass scale in the selected samples without MC simulations.

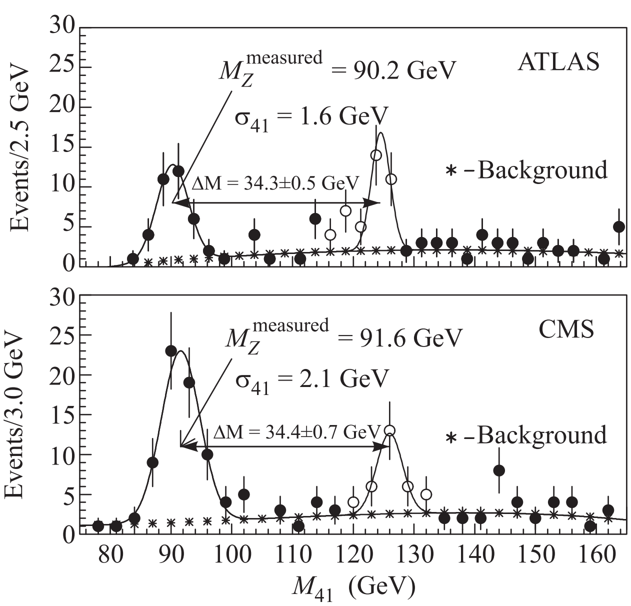


Fig. 1. The distribution of the four-lepton effective mass

The main idea of the present approach is to determine experimentally the mass difference between $H$ and $Z$ – $\Delta M$, and then to define the mass of $H$ as the sum of $\Delta M$ and the table value of the $Z$ mass – $M_Z^{\text{table}} = 91.19$ GeV. In this case the constant systematic shifts of the mass scale will be cancel. Such a definition of the mass leads to a surprisingly good coincidence between ATLAS and CMS as it will be shown below.

**Analysis and results.** The distributions on Fig. 1 were fitted (MINUIT) in the range of the effective mass 4 leptons $75 < M_{4l} < 165$ GeV without white points to define experimentally backgrounds – BKG and 4-leptons effective mass resolutions – $\sigma_{4l}$ by the sum of Gaussian - $G_Z$, describing the signal of $Z$ and the 3[nd] order polynomial describing the background:

$$G_Z + \text{BKG} = \frac{N_Z \text{bin}}{\sqrt{2\pi}\sigma_Z} \exp\left[-\frac{(M_{4l} - M_Z)^2}{2\sigma_Z^2}\right] + \text{BKG}, \quad (3)$$

where:

$$\sigma_Z = \frac{\Gamma_Z}{2 \cdot 1.177} + \sigma_{4l}; \quad (4)$$

$N_Z$ is the integrated number of $Z$ events, bin is the binning of the abscissa (2.5 GeV for ATLAS and 3 GeV for CMS), $\Gamma_Z = 2.5$ GeV is the table value of the full widths of $Z$ and $\sigma_{4l}$ is the experimental resolution of $M_{4l}$. Free parameters were $N_Z$, $M_Z$, $\sigma_{4l}$, and the coefficients of the polynomials. For the $M_Z$ and $\sigma_{4l}$ the following values were obtained:

$$\text{ATLAS} - M_Z^{\text{measured}} = 90.2\,\text{GeV}, \quad \sigma_{4l} = 1.6\,\text{GeV}, \quad (5)$$

$$\text{CMS} - M_Z^{\text{measured}} = 91.6\,\text{GeV}, \quad \sigma_{4l} = 2.1\,\text{GeV}. \quad (6)$$

After that the distributions on Fig. 1 were fitted including the points of $H$ (white points) by the sum $G_Z + G_H + \text{BKG}$, where:

$$G_H = \frac{N_H \text{bin}}{\sqrt{2\pi}\sigma_H} \exp\left[-\frac{(M_{4l} - M_Z - \Delta M)^2}{2\sigma_H^2}\right], \quad (7)$$

1) e-mail: vladimir.roinishvili@mail.ihep.ru

$$\sigma_H \equiv \sigma_{4l} \quad (8)$$

with fixed $G_Z$ and BKG and free $N_H$ and $\Delta M$. The obtained values of $\Delta M$ are:

$$\text{ATLAS} - \Delta M = 34.3 \pm 0.5\,\text{GeV}, \quad (9)$$

$$\text{CMS} - \Delta M = 34.4 \pm 0.7\,\text{GeV} \quad (10)$$

giving the following values for the mass of $H$ defined as $M_H = M_Z^{\text{table}} + \Delta M$:

$$\text{ATLAS} - M_H = 125.5 \pm 0.5\,\text{GeV}, \quad (11)$$

$$\text{CMS} - M_H = 125.6 \pm 0.7\,\text{GeV}, \quad (12)$$

which are much more close to each other than the published results (1), (2). The weighted mean from the two experiments is now:

$$M_H = 125.5 \pm 0.4\,\text{GeV}. \quad (13)$$

**Discussion**. It is obvious that one day the data from ATLAS and CMS will be combined for analysis. But even now it can be done by:

a) choosing the appropriate abscissa for both experiments in the form of:

$$M_{4l}^{\text{corrected}} = M_{4l}^{\text{measured}} + M_Z^{\text{table}} - M_Z^{\text{measured}} \quad (14)$$

in order to take into account the systematic constant shift of measured mass of 4 leptons in the used samples, and

b) choosing as an ordinate the ratio of signal to the background:

$$R = \frac{\text{Signal}}{\text{Bakground}} = \frac{\text{Nevents}}{\text{BKG}} - 1 \quad (15)$$

in order to take into account the difference of the ATLAS and CMS acceptances. Such a plot is presented on Fig. 2. The curve is the result of the fit of $R$ with 3 free parameters – weights of the $Z$ and $H$ signals and the mass of $H$. The background and resolution were fixed to the ones of ATLAS and CMS correspondently. The coincidence between the two experiments is so good that one can consider the result as a result of a common LHC experiment with the total luminosity about twice more than accepted by ATLAS and CMS separately and which gives for the mass of $H \to 4$ leptons the value of $125.5 \pm 0.4\,\text{GeV}$.

**Conclusion.** The measured difference $\Delta M$ between the masses of $H$ and $Z$ is almost free from the systematic constant shift of the mass scale which, of course, could be different for ATLAS and CMS. This allows to get a rather good coincidence between the two experiments if one will use the definition of the mass of $H$ as the sum of the table value of the $Z$ mass and $\Delta M$. Obtained in this way the mass of the new boson discovered by ATLAS and CMS in the 4-lepton decay channel equals $125.5 \pm 0.4\,\text{GeV}$ with today statistics at the LHC.

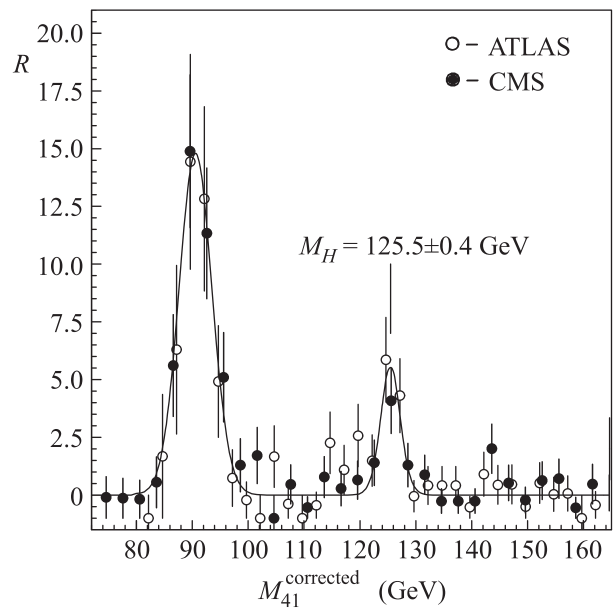


Fig. 2. The combined Atlas and CMS ratio of signals to the backgrounds as a function of the corrected four-lepton effective mass

Author wishes to thank I. Mandjavidze from IRFU, CEA Saclay for useful discussions and help.

1. The ATLAS Collaboration, *Measurements of the properties of the Higgs-like boson in the four lepton decay channel with the ATLAS detector using* $25 fb^{-1}$ *of proton-proton collision data*, ATLAS-CONF-2013-013, March 6, 2013, http://cds.cern.ch/record/1523699.
2. The CMS Collaboration, *Properties of the Higgs-like boson in the decay H to ZZ to 4l in pp collisions at* $\sqrt{s} = 7$ *and* $8\,TeV$, CMS-PAS-HIG-13-002, March 7, 2013, http://cds.cern.ch/record/1523767.