SEARCH FOR RESONANT DOUBLE HIGGS PRODUCTION WITH bbZZ DECAYS IN THE $b\bar{b}\ell\ell\nu\bar{\nu}$ FINAL STATE IN pp COLLISIONS AT $\sqrt{s} = 13$ TeV

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Since the discovery of the Higgs boson in 2012 by the ATLAS and CMS experiments, most of the quantum mechanical properties that describe the long-awaited Higgs boson have been measured. Due to the outstanding work of the LHC, over a hundred of fb^{-1} of proton collisions data have been delivered to both experiments. Finally, it became sensible for analyses teams to start working with a very low cross section processes involving the Higgs boson, e.g., a recent success in observing ttH and VHbb processes. One of the main remaining untouched topics is a double Higgs boson production. However, an additional hundred of fb^{-1} per year from the HL-LHC will not necessarily help us much with the SM double Higgs physics, as the process may remain unseen even in the most optimistic scenarios. The solution is to work in parallel on new reconstruction and signal extraction methods as well as new analysis techniques to improve the sensitivity of measurements. This thesis is about both approaches: we have used the largest available dataset at the time the analysis has been performed and developed/used the most novel analysis methods. One such method is the new electron identification algorithm that we have developed in the CMS electron identification group, to which I have had a privilege to contribute during several years of my stay at CERN.

The majority of this thesis is devoted to techniques for the first search at the LHC for double Higgs boson production mediated by a heavy narrow-width resonance in

the $b\bar{b}ZZ$ channel: $X \to HH \to b\bar{b}ZZ^* \to b\bar{b}\ell\ell\nu\bar{\nu}$. The measurement searches for the resonant production of a Higgs boson pair in the range of masses of the resonant parent particle from 250 to 1000 GeV using 35.9 fb^{-1} of data taken in 2016 at 13 TeV. Two spin scenarios of the resonance are considered: spin 0 and spin 2. In the absence of the evidence of the resonant double Higgs boson production from the previous searches, we proceed with setting the upper confidence limits.

"Here will be a quote "

name, year.

ACKNOWLEDGMENTS

This will be a long list!

Table of Contents

List of Figures

List of Tables

Chapter *1*

Conclusions

In this dissertation, the search for double Higgs boson production (HH) mediated by a KK graviton or a radion is presented. The double Higgs system subsequently decays through the intermediate $bbZZ$ state - one of the Higgs bosons decays to two b quarks, while the other decays to a pair of Z bosons, which, in turn, decay to a pair of neutrinos and a pair of electrons or muons. The search is performed in data samples corresponding to an integrated luminosity of 35.9 fb^{-1} at $\sqrt{s} = 13$ TeV, recorded by the CMS experiment at the LHC in 2016.

This is the first search for a double Higgs boson production in the $bbZZ$ intermediate channel that was done at CERN. A measurement of the double Higgs production process is an important test of the standard model (SM) and can open doors to beyond the standard model physics. The HH process, observed in a resonant production mode, would mean new physics; while the HH process observed in a non-resonant mode at the SM predicted level allows one to study Higgs boson self-coupling.

No statistically significant deviations from the SM theory predictions for background processes were observed in this measurement, and 95% upper-level confidence limits are reported for production cross section of a KK graviton or a radion multiplied by the branching fraction of its subsequent decay into a di-Higgs system, and further to the $2b2\ell2\nu$ final state. The limits are derived for resonance masses in the

250 GeV to 1 TeV range.

This measurement has became public in November 2018. The measurement is part of an intensive program in the search for a di-Higgs production in CMS in a wide range of channels. Current projections suggest that the first observation of this process, if no new physics is found, is not expected in any individual HH channel in the near future. The CMS plan is to combine several HH channels. The first such combination was completed in early 2018, but did not include this measurement. The next step is to combine present CMS searches in $bbZZ$ channels with different final states, and then to add them to a combination of the CMS HH searches in other channels.

CERN guide, S'Cool Lab teacher, Finance Club admin, Boxing Club coach

It has been a great pleasure to stay at CERN for four years. From the bottom of my heart, I want to thank my adviser and my HEP group for this opportunity. I have exploited all the possible areas of science, outreach, fun, and joy available at CERN. Well, almost all, and I know it is ridiculous, but here, in Genève, I have not yet tried skiing...

I have been an official CERN guide, giving people tours to the Antimatter Decelerator, the ATLAS control room, the Low Energy Ion Ring complex, the Proton Synchrotron, the LHC control room, the Data Centre, the SM18 facility (a world-leading magnet test facility for testing magnets and instrumentation at low temperature and high currents), and the Alpha Magnetic Spectrometer control room. The audience ranged from middle school kids to emeritus professors of science.

Also, I have been a teacher at the S'Cool Lab, where high school students have a chance to come to CERN and build a real experimental setup at this "cool" scientific laboratory and then conduct an experiment on their own.

For more than a year I have been an administrative managing officer at the CERN Finance Club. I was responsible for inviting top professionals from finance and FinTech companies to give talks at our club. I started the "quant group" and was the first to optimize our portfolio of stocks using Monte Carlo methods and minimization techniques. Needless to say, that would not have been possible if I had not learned those tools first in High Energy Physics!

Last but not least, thank you to my friends from the CERN Powerlifting Club who introduced me to the Boxing Club. There is where I met most of my CMS and ATLAS friends. I have been training people with the goal to improve their health. As a side effect, some picked up self-defense, others had fun and found themselves truly addicted to this combination of hard work and laughter. A few people journeyed into the world of intelligent boxing, which is not about power, but about strategy and outworking the opponent 1.1.

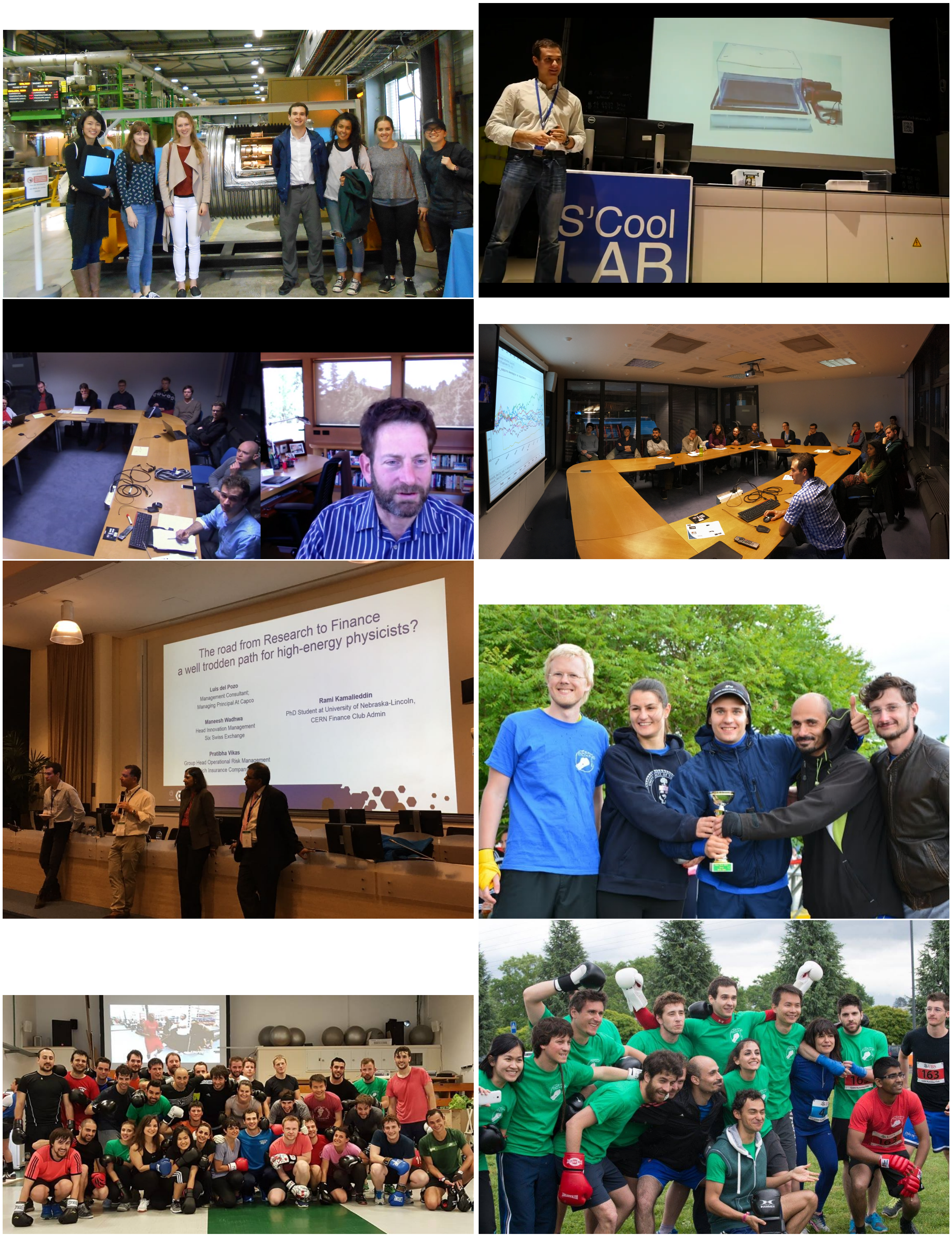

Figure 1.1: Top row: visit at SM18 and S'Cool lab. Second row: invited talks at the Finance Club. Third row: moderator at the CERN Alumni Collisions and CERN Relay Race trophy. Bottom row: Boxing Club.

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