Referee report

on the project "CMS detectors upgrade"

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JINR group participates in the CMS experiment at the Large Hadron Collider (LHC) from the very beginning. Letter of intent of collaboration was published by 1 October 1992. Scientific relations with CMS were established through collaboration of Russian and Dubna member states institutes (RDMS collaboration). The RDMS collaboration has been responsible for the design, construction, maintenance and operation of the endcap hadron calorimeter (HCAL) and the forward muon station (ME1/1) for over 10 years.

JINR physicists make a significant contribution to the upgrade program of the CMS experiment, aimed at preparing the experimental setup for reliable and efficient work in the high luminosity conditions of the LHC. The first stage of the upgrade program, Phase1, which includes 3 periods of data taking Run1, Run2 and Run 3 and two periods of the LHC long shutdowns LS1 and LS2, aims to modify the detector and readout systems for stable and effective work at luminosity level up to $2x10^{34}$ $cm^{-2}s^{-1}$. The Phase1 period will continue till the end of Run3 in 2023, and by that time the integrated luminosity will be increased to ~ 350 fb^{-1}.

Starting from 2027, the LHC will operate with energy $\sqrt{s}$=14 TeV at an increased luminosity up to $5x10^{34}$ cm^{-2} s^{-1} (HL–LHC), which will increase the statistics by an order of magnitude (~ 3000 fb^{-1}). To implement the planned research program at the HL – LHC, the detector systems of the experimental facilities must be significantly upgraded during the Phase 2 modernization program.

The main physical goals of the project are: study of muon pair production in the Drell – Yan process for testing the Standard Model (SM) predictions in a new energy range, measuring the angular coefficients, and checking distributions of structure functions of quarks and gluons (PDF); study of the Higgs boson properties and search for new scalar bosons beyond the SM in the decay channels to leptons; search for signals of extended gauge models in a channel with two muons in the final state, and somewhat exotic problems of searching for signals of models with gravity on the TeV scale (models with extra dimensions) in a channel with two muons in the final state and studying the processes of inclusive and multiple jet production to search for microscopic black holes and other signals beyond the Standard Model.

Special interest in the search for new physics are processes in which the production of new particles with a transverse momentum much greater than their mass (enlarged objects) is expected. As a consequence, their decay products are spatially close, in particular, they give very narrow intersecting (merged) jets. To separate such events, a good spatial resolution of the calorimeters is required.

According to the Memorandum of Understanding (MoU) on the CMS detector construction between CERN and JINR, the corresponding addendums and the Memorandum of Understanding on JINR's participation in the HGCal CMS project, JINR's obligations include participation in the design and construction of high granularity calorimeter HGCal and upgrade of the forward muon station ME1/1.

A calorimeter with high longitudinal and transverse segmentation facilitates the particle flow energy measurement, when information from all subsystems is optimally combined. Design of the CMS HGCal is taking in to account that particle-flow will be the main reconstruction algorithm, i. e. energy flows of particles will be reconstructed. Therefore, the accuracy of the spatial reconstruction is of primary importance. In particular, the transverse segmentation should be less than the Moliere radius in both the electromagnetic and hadronic parts. This allows good separation of the double jets, especially in high density HL–LHC environments. The potential of CMS HGCAL is to be able to identify individual particles within jets.

The Endcap Muon System upgrade is focusing on the modernization of the detector electronics of the innermost ring cathode strip chambers (CSC) of all four Muon stations, ME1/1, ME2/1, ME3/1 and ME4/1. The HL-LHC conditions with increasing of the luminosity to $5x10^{34}$ cm^{-2} s^{-1} at an integrated luminosity of $3000fb^{-1}$ will lead to increase of pileup by a factor 5, an increasing the trigger rate by a factor 7.5 and increase bandwidth of the muon system DAQ by a factor 10, what requires of modernization of some readout and trigger electronics. In conditions of high luminosity of the LHC collider, the radiation impact on detectors and electronics, leading to the effects of "ageing" of CSC construction elements and to radiation damage of electronic components, increases substantially. The JINR CMS group carries out comprehensive R&D to study the detector and readout electronics ageing. The JINR group continues to work on the development and implementation of algorithms for reconstruction of track-segments in CSC in the CMS software.

The project under consideration is a continuation of the many years of very effective work of the JINR group in the CMS experiment aimed at obtaining new experimental data with an integrated luminosity of up to 3000 fb^{-1}. The robust and effective operation of the HGCal and forward muon station ME1/1will play a substantial role in fulfillment of the CMS physics program at HL–LHC conditions.

The composition of the project team is well balanced in all areas of responsibility of the JINR group. However, considering the LHC work plans for at least the next 15 years, it is strongly recommended that more young physicists be involved in this project.

The requested resources are generally adequate to the tasks set in the Project. In view of the aforesaid and taking into account the significant contribution already made to the CMS experiment by the JINR group, I recommend accepting the Project “CMS detectors upgrade” for 2022-26 with the first priority.

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