

Referee Report
on the JINR CMS Project
“Upgrade of the CMS Detector” for 2022-2026, Topic 02-0-1083-2009/2022

The goal of the presented Project is JINR's participation in the creation of High Granularity Calorimeter (HGCAL) and in the modernization of the ME1/1 front muon station of cathode strip chambers (CSC) of the endcap muon system in the Compact Muon Solenoid – (CMS) at the Large Hadron Collider (LHC) CERN. This activity is entrusted to JINR according to the Addendums to the Memorandum of Understanding for Collaboration in the Construction of the CMS Detector. For more than 25 years, JINR physicists have been participating in the CMS project, starting from the design of the experiment and ending with the processing and analysis of the experimental data. JINR participates in the CMS Project within the framework of Russia and Dubna Member states CMS Collaboration (RDMS). JINR's responsibility since the very beginning is creation and maintenance of the Endcap Hadron Calorimeter and the First Forward muon Station. CMS is one of the world's largest general-purpose experiment to explore physics at the TeV-energy scale. The project annotation highlights the fundamental physics problems studied at this experiment, among those are the study of the Higgs boson, verification of the predictions of the Standard model, the study of the properties of Quantum Chromodynamics, and many others.

The increase in the energy of colliding $p-p$ beams to the nominal one and the increase in luminosity up to $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ planned to begin in 2027 necessitate an adaptation of CMS detectors to work with significantly increased radiation loads, an increased number of "superimposed events", high multiplicity of interactions in one intersection of beams. Existing equipment is not designed to operate efficiently in the future conditions, has suffered significant radiation damage during previous operations, and therefore must be replaced. The authors of the project motivate very well the emerging difficulties, formulate requests, and offer adequate ways to solve them.

In the presented project, it is proposed to create a calorimeter with high transverse granularity and longitudinal segmentation HGCAL, with a high precision time resolution, which will provide an effective events reconstruction, down to individual particles in jets.

Well-motivated and thorough, to the last smallest details, study of the project, which includes the usage of world expertise, computer modeling, measurements at stands and test beams, the choice of materials, an original design and technological solutions, a detailed procedure for the manufacture and control of the components and the assembly of the detector, prototyping, cost estimation, time schedule is striking. HGCAL consists of electromagnetic and hadronic parts, silicon sensors are used in the most loaded areas, and scintillators with SiPM as photodetector are used in the least loaded part. The

reduction of electronic noise is achieved by cooling the calorimeter to -30°C . Such scale cooling system is rather complicated technical task.

Another important task of the project is the modernization of the end muon system. This includes the modernization of the electronics of the cathode strip chambers (CSC), the refurbishment of the CSC, the continuation of the development and testing of the track segment reconstruction algorithm for muon trigger improvement, the study of the aging mechanisms of the chambers and the study of methods for restoring their parameters, the study of new gas mixtures. The development of the overlapping signal separation algorithm is impressive. As in the case of HGCal, attention is drawn to a fundamental comprehensive approach to the analysis of emerging problems and the development of methods for their solution.

Qualifications and experience of the project participants inspire confidence in its successful implementation. The proposed methods, the estimation of the requested resources and the work schedule appear to reflect the real situation correctly. Project cost is estimated at the total contribution of 2.2 MCHF for HGCal detector and an upgrade of the CSC muon system with the total contribution of 76 kCHF.

In this brief report, it is difficult to highlight all advantages of the project which I found to be excellent. As an optional request that may be considered by the proponents, I would suggest to add the main generalized characteristics of the equipment being created: the number of channels, thickness in terms of radiation and nuclear length, weight, resolution, etc.

I recommend approving the project “Upgrade of the CMS Detector” with the first priority.