CMS Upgrade to Operate at the HL-LHC

Description: The HL-LHC will operate at 14 TeV center of mass energy with a peak luminosity of $5x10^{34}cm^{-2}s^{-1}$ and luminosity leveling. To exploit the very high interaction rate and integrated luminosity, reaching 3000 fb^{-1}, major upgrades to CMS are necessary. The goal is to achieve a physics efficiency at this higher luminosity (and pileup) that is at least as good as that achieved in the current detector at $10^{34}cm^{-2}s^{-1}$. The tracking system must be completely replaced with one with much higher granularity (hundreds of millions channels). The upgraded tracker, in addition to providing improved tracking capability in a very high density environment and presenting less material, will provide a Level 1 (L1) tracking trigger that reconstructs charged particles with $P_T > 2.5$ GeV and thereby substantially improves the overall L1 trigger. We are also examining a possible upgrade to the detector front end electronics, data acquisition and high-level trigger system to allow 1MHz L1 readout and 10 kHz event storage rate.

Studies are underway to ensure that precision electromagnetic calorimetry and robust jet and missing transverse energy reconstruction are maintained at the HL-LHC. A major upgrade or replacement of the endcap and forward calorimeters is needed, as well as increased tracking coverage to extend particle flow reconstruction up to a pseudorapidity of 4. We are also exploring a possible electromagnetic preshower system, to provide pointing information for the reconstruction of $H \rightarrow \gamma\gamma$ events and excellent time-of-flight resolution for pileup mitigation.

Science: The higher luminosity of the HL-LHC will extend the mass reach and vastly increase the sensitivity of searches for subtle signatures for new physics. Following the discovery of a Higgs boson candidate with a mass of 125 GeV, precision measurements of the properties of this new particle, in particular its mass and tree-level couplings to fermions, W and Z bosons, as well as self-coupling, will be central to the physics program. The goal is to either prove that we have observed the SM Higgs boson or, if not, to uncover the true nature of this particle. The search for new physics beyond the SM will continue, including searches for SUSY with massive squarks and gluinos and for new heavy resonances predicted in many extensions of the SM. New discoveries will broaden the scope of the program to include studies of new particles and their interactions. If SUSY is found, we will determine whether it is responsible for EWSB, can resolve the hierarchy problem, and/or account for dark matter.

Collaboration and Funding: The CMS experiment is a global effort. U.S. physicists, numbering about 750 Ph.Ds and graduate students from 50 institutions, comprise approximately 33% of CMS. The U.S., supported by the DOE and the NSF, has constructed significant parts of the detector, provides a large fraction of the computing, and has led key physics analysis efforts.

Cost: The work on the detector upgrades for HL-LHC are in the R&D stage and reliable cost estimates are difficult to make. However, based on the cost of the current CMS detector, and the initial conceptual designs, we estimate the U.S. share of the detector upgrades to be $200-300M.

Science Classification and Readiness: The science enabled by the “CMS Upgrade to Operate at the HL-LHC” is *absolutely central* to U.S. and world HEP . An extensive R&D program is ongoing to resolve the *significant scientific/engineering challenges before initiating construction*.