LHC Accelerator Upgrades

Description: After the current shutdown, the LHC should reach at least 6.5 TeV per beam and achieve its design peak luminosity of $1x10^{34}$ $cm^{-2}s^{-1}$. After the LS2 shutdown in 2018, that peak luminosity should reach at least $2x10^{34}$ $cm^{-2}s^{-1}$. The improvements made during an extended, currently scheduled to begin in 2022, will enable a leveled luminosity of $5x10^{34}$ $cm^{-2}s^{-1}$, for an integrated luminosity of ~250 fb^{-1}/year.

The key to increasing the luminosity will be decreasing the β* at the interaction point from 55 cm to ~15 cm. Achieving this will require a gradient and aperture at the focusing quadrupoles which are beyond the capabilities of NbTi. LARP magnet R&D has focused on developing Nb_3Sn for this application, and as a result the US is the undisputed world leader in this area. The proposed US contribution is to complete R&D leading to a 150 mm aperture Nb_3Sn prototype, and then to produce half of the required cold masses for the upgrade, while transferring the technology to CERN, who will build the remaining cold masses, as well as all the cryostats.

Because the effect of the beams' crossing angle increases with transverse size, it will go from insignificant at the current β* to a major effect at the new value, requiring some sort of compensation. The baseline approach is to use crab cavities to introduce a position dependent lateral deflection into the bunches, such that they collide head-on, even though the beams are crossing. Again, LARP has been a leader in this area. We propose building cryostated prototypes for test in the SPS in 2016, and then producing all the required cavities and cryostats for the upgrade, with CERN providing the power couplers and all required infrastructure.

The final US contribution will be a high bandwidth feedback system to compensate for intensity and brightness effects in the SPS, and possibly other accelerators in the system. This work directly leverages US expertise that was applied to the low level RF system in the LHC.

Science: A robust physics program has been proposed to utilize up to 3000 fb^{-1} at ~14 TeV C.o.M. energy. These upgrades are required to reach this integrated luminosity in reasonable amount of time.

Collaboration and Funding: All three projects are tightly integrated with CERN, with both sides providing significant resources. In the case of the magnets, CERN will provide the other half of the cold masses and all cryostats and power supplies. For the crab cavities, CERN will provide the power couplers and infrastructure. For the feedback system, CERN will provide all vacuum components.
Cost: This project is being developed to fit into the ~$250M total cost range mandated by the DOE.

Science Classification and Readiness: The LHC luminosity upgrade is ***absolutely central*** to the goals of particle physics. The upgrades still require ***significant R&D and engineering.***