Opportunities to Advance Fundamental Symmetries Research with Project X

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Project-X is a staged evolution of the Fermilab accelerator complex realized by the dramatic advances in super-conducting RF technology [1] of the past decade and it is central to Fermilab's strategic plan for the coming decades [2]. Research and development toward next-generation high-power accelerators that can drive particle physics forward was a leading recommendation of the 2008 Particle Physics Projects Prioritization Panel (P5) report [3] that was endorsed by the High Energy Physics Advisory Panel (HEPAP) and accepted by the US DOE Office of High Energy Physics (OHEP). The 2008 P5 report identified three interdependent domains of particle physics: the "Cosmic Frontier", the "Energy Frontier" and the "Intensity Frontier" which has proven to be an effective rubric to both organize and promote the opportunities and reach of particle physics. The scope of the Intensity Frontier research program was surveyed in December 2011 with a large-scale Intensity Frontier workshop sponsored by the OHEP [4] which included research goals identified in the 2007 NSAC long-range plan. The Project-X research program, broadly discussed at the Intensity Frontier Workshop [4] and in detail at the recent June 2012 Project X Physics Study [5], is summarized here:

Neutrino experiments:
A high-power proton source with proton energies between 1 and 120 GeV would produce intense neutrino sources and beams illuminating near detectors on the Fermilab site and massive detectors at distant laboratories.

Kaon, muon, nuclei & neutron precision experiments:
These could include world leading experiments searching for ultra-rare muon decays, atomic, nuclear, nucleon, and muon electron dipole moments (EDMs), nucleon instability, and precision measurements of ultra-rare kaon decays.

Platform for evolution to a Neutrino Factory and Muon Collider:
Neutrino Factory and Muon-Collider concepts depend critically on developing high intensity proton source technologies.

Nuclear Energy Applications:
Accelerator, spallation, target and transmutation technology demonstration which could investigate and develop accelerator technologies important to the design of future nuclear waste transmutation systems and future thorium fuel-cycle power systems.

Enabling technology for Project-X has advanced to a point where staged construction could commence later this decade with Stage-1 operational early in the next decade. The heart of Project-X Stage-1 is a new super-conducting 1000 MeV linac that replaces the aging 400 MeV conventional linac in the Fermilab accelerator complex. The accelerator parameters and physics reach of Project-X for each stage are described at the Project-X Physics Study site [5]. In short, Stage-1 will increase the Main Injector beam power for long-baseline neutrinos from 700 kW to

1200 kW, the 8 GeV Booster beam power available to short-baseline neutrino experiments from ~10 kW to 40 kW and serve as a powerful innovative proton driver for an upgrade of the Fermilab Muon Campus [6]. This upgrade can be realized with the new linac operating at 100 kW with a 10% duty factor. The core super-conducting technology of the new linac can support a very high beam duty factor (CW, Continuous Wave) and much higher beam power, 1 Mega-Watt at 1000 MeV, which could be realized with a marginal (15%) increase in cost associated with higher RF power and cryogenics. A Mega-Watt CW linac would open the door to an even broader research program for US particle physics. In particular, a Mega-Watt CW linac could support a deeply incisive program of electron, muon, nucleon, nuclear, and atomic EDM research and a neutron-antineutron oscillation experiment which is a unique probe of nucleon stability. With the addition of a compressor ring to optimize proton pulse timing the Mega-Watt linac could also drive a world-class decay-at-rest neutrino source for next generation short-baseline experiments. The new Mega-Watt linac can also support an important program of materials research and R&D for high reliability proton drivers and targetry necessary for energy applications based on accelerator driven systems.

Germane to the EDM goals of the 2007 NSAC long-range plan, high-power operation of the Project-X Stage-1 1000-MeV CW linac could provide world-leading yields of francium, radium, and radon isotopes for EDM research [5]. Further, an ultra-cold neutron source at Stage-1 optimized for particle physics is an opportunity to drive a next generation US-based neutron-EDM experiment, as well as a neutron-antineutron oscillation experiment [5]. Stage-1 of Project-X could also host world-leading proton-EDM [5] and next generation muon-EDM experiments [7], rounding out an opportunity to comprehensively advance US-based EDM research in the 2020s.

The Nuclear Physics community has a demonstrated history of US agencies working together toward common research goals. The Fermilab strategic plan for discovery [2] includes key participation from the many members of the Nuclear Physics community with leadership roles now in the Fermilab SeaQuest experiment and the Fermilab Muon Campus [6] research program. Project-X presents an opportunity for this partnership to continue and flourish in pursuit of particle physics goals common to the Fermilab and Nuclear Physics communities.

[1] Project-X website: http://projectx.fnal.gov/

[2] Fermilab plan for discovery: https://www.fnal.gov/directorate/plan_for_discovery/

[3] P5 report: http://science.energy.gov/~/media/hep/pdf/files/pdfs/p5_report_06022008.pdf

[4] Intensity Frontier Workshop: http://www.intensityfrontier.org/

[5] Project X Physics Study: https://indico.fnal.gov/conferenceDisplay.py?confId=5276

[6] Fermilab Muon Campus: g-2: http://gm2.fnal.gov/ ; Mu2e: http://mu2e.fnal.gov/ .

[7] Muon EDM frozen-spin technique: F.J.M. Farley, et al., Phys. Rev. Lett. 93, 052001 (2004) JPARC LOI: (J. Miller et al): http://www-ps.kek.jp/jhf-np/LOIlist/pdf/L22.pdf PSI study: Adelmann, Kirch, Onderwater, Schietinger, J. Phys. G37 (2010) 085001.