HEPAP FACILITIES SUBPANEL
Intensity Frontier Facilities

Mark Wise

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Main Science Goals of Intensity Frontier

- Develop a full understanding of the neutrino sector (neutrino physics is beyond the standard model (BSM).
- Search for BSM physics using high intensity beams to gain high precision and/or reach for rare processes. E.g. flavor changing neutral currents in the quark and lepton sectors, CP violation in the quark and lepton sectors, baryon number non-conservation.
- Complimentary to energy and cosmic frontier physics programs. Energy reach for new physics sometimes much higher than the LHC has.
- Scientific opportunities were surveyed at recent workshop in 2011.

LBNE

- Neutrino and anti-neutrino Beams from Fermilab to Homestake, liquid argon detector. Distance between 1350 km.
- Stage 1: 700kW beam to 10kt detector at surface, no near detector.

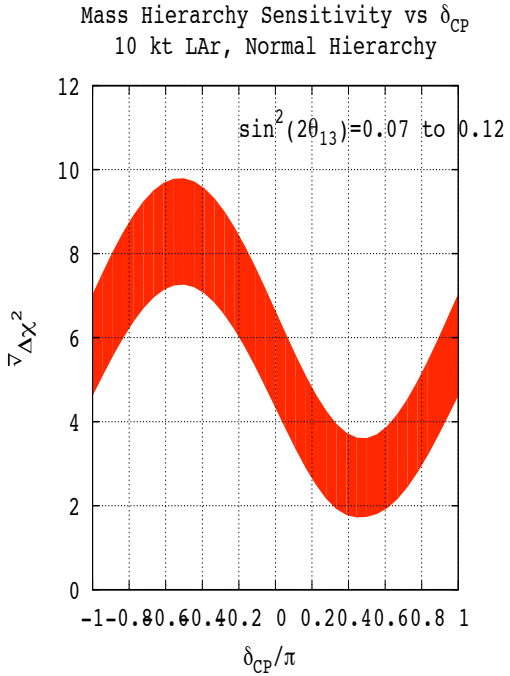
International collaboration is being sought to reach full vision

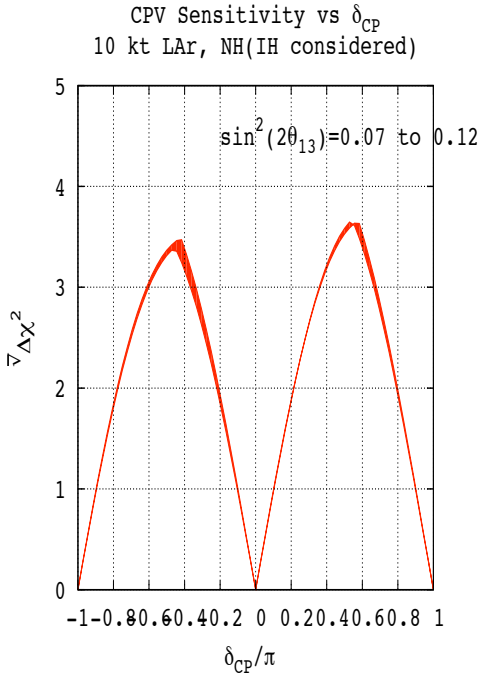
- Full Vision: 2.3MW beam power from project X to 35kt underground detector, near detector.
- Science Goals:
- What is the neutrino mass hierarchy, normal or inverted (sensitivity improves with baseline)
- Is there CP violation in the neutrino sector and if so what is the value of δ (long baseline helps resolve ambiguities between mass effects and CP violation)
- Search for nucleon decay (underground)
- Study supernova neutrinos (underground)
- Search for physics beyond standard three flavor neutrino mixing (BPMNS) (near detector)

LBNE (10kt,700kW)

Resolve using neutrino and antineutrino beams mass hierarchy at greater than 3 sigma CL for 75% of allowed values of δ (100% if results from other experiments are included). Establish CP violation at 99% CL for more than 50% of allowed values of delta.

CL (expressed as sigma) versus normalized CP parameter.





LBNE Full Vision

- Dramatically improved resolution for mass hierarchy . Detection of δ at high precision for almost all values.
- Sensitivity to kaon final states in proton decay. Reach greater than SuperK. Decay modes favored by Grand Unified supersymmetric theories. Discovery possible.
- Excellent capabilities for neutrino physics beyond standard three flavor neutrino mixing (BPMNS).
- Significant new addition to worlds supernova detection ability. Matter effect, different detection mode.
- Opportunity to achieve full vision earlier with additional foreign participation.

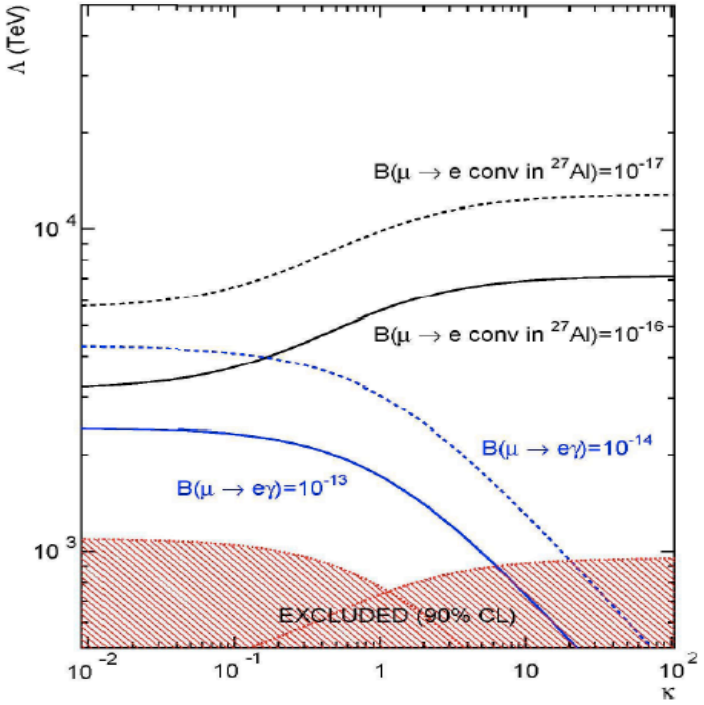
LBNE

- Stage 1 begins a world leading program in neutrino physics + (BPMNS neutrino oscillations, supernova neutrinos, proton decay) The 2008 P5 report strongly endorsed such a program.
- Interest worldwide in long baseline neutrino experiments, Asia and Europe.
- Collaboration: 360 scientists, 70 institutions including participation from India, Italy, Japan and United Kingdom.
- CD1 granted in Dec 2012. *Ready for construction,* planned start in 2016 and completed in 2023.
- Science reach of the First Stage of LBNE is *important* and it lays the groundwork for an *absolutely central facility*.

Mu2e

- Modify accelerator complex to transfer 8GeV protons with required time structure from Fermilab booster to Mu2e experiment.
- Scientific Goal: to study charged lepton flavor violation via Mu2e conversion in the field of a nucleus.
- Single event sensitivity of 2×10^{-17}
- 10^4 improvement in sensitivity, order of magnitude in mass scale of new physics.
- Occurs in many extensions of the standard model, Lepto-quarks with masses of several thousand TeV, supersymmetric unified models.
- Complementary to (MEG PSI Switzerland) $\mu \longrightarrow e\gamma$

Mu2e



$$L_{CLFV} = \frac{m_\mu}{(1+\kappa)\Lambda^2}\bar{\mu}_R \sigma_{\mu\nu} e_L F^{\mu\nu}$$

$$+\frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L\gamma_\mu e_L \left(\sum_{q=u,d}\bar{q}_L\gamma^\mu q_L\right)$$

- COMET experiment at JPARC potential competition for Mu2e. First phase approved which reaches sensitivity about order of magnitude less than Mu2e.
- Factor of 100 increase in sensitivity for Mu2e possible with Project X.
- Collaboration: 140 physicists from 26 institutions (5 from Italy and 2 from Russia)
- Strongly endorsed by 2008 P5
- CD1 approval, *ready for construction* starting 2014 completed 2018.
- *Absolutely Central Facility*.

Project X

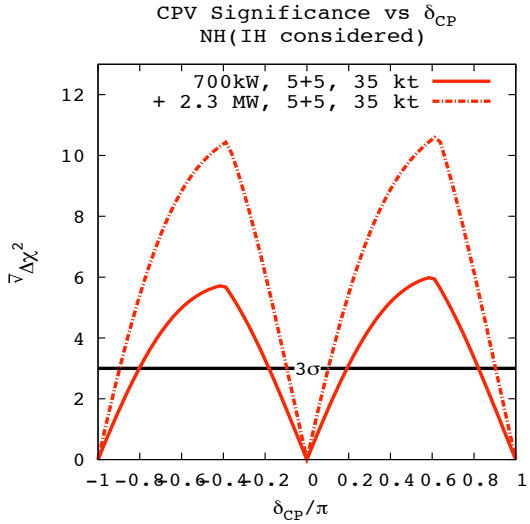
- Project X facility provides high intensity proton source at multiple energies to a suite of intensity frontier experiments that range from *important* to *absolutely central*. Planned in three stages.

Diverse Science Goals:

- Determination of neutrino properties, mass hierarchy and CP violation (LBNE).
- CP violation through electric dipole moments.
- BSM physics in the muon sector, Mu2e and other muon experiments, e.g. g-2, rare decays.
- New sterile neutrinos in the neutrino sector (MicroBooNE, nuSTORM+…)
- Search for baryon number violation; (LBNE) and n-anti n oscillations.
- Beyond the standard model physics including CP non conservation in the quark sector (ORKA)

Project X

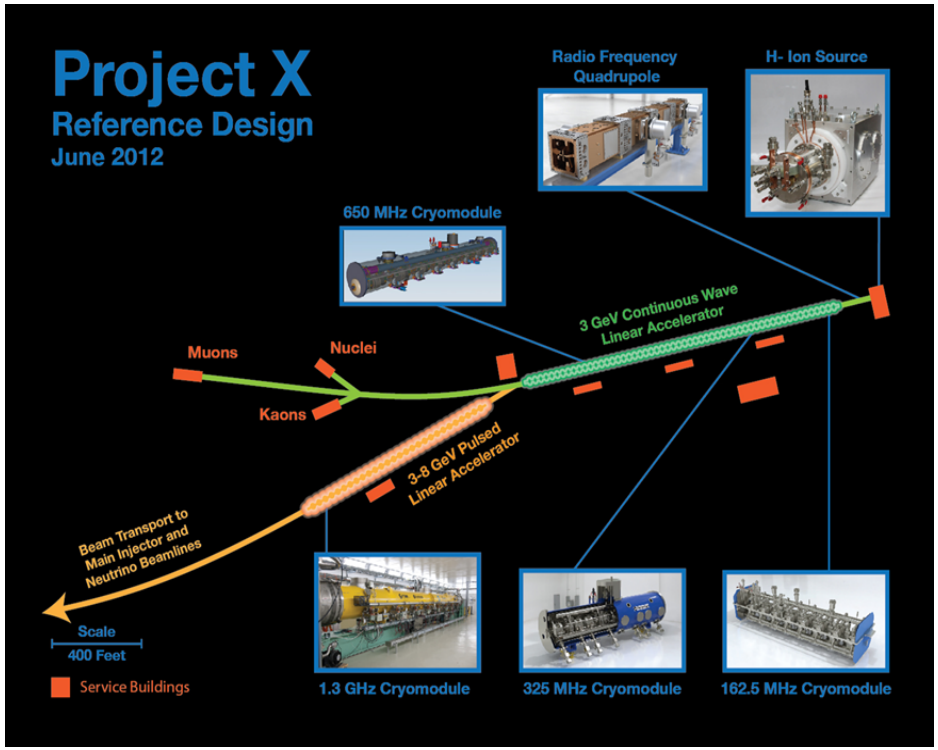
- Stage 1 increases power to short baseline neutrino program by a factor of 4 and again in stage 3 by another factor of 4.
- Stage 1 electric dipole moments at $10^{-29} ecm$ (uses spallation target).
- Stage one more than doubles power to charged kaon mode and at stage 2 the power increases by a factor of 10. Unique detailed study of neutral mode possible at stage 2 . Theory in SM very clean $K^+ \to \pi^+ \nu\bar{\nu}$ $K_L \to \pi^0 \nu\bar{\nu}$
- Dramatically improves reach of LBNE



- Limit on neutron anti neutron oscillation transition time improved by about at factor of 50 at stage 1 (uses spallation target)
- Increases power by factor of 10 to muon experiments in stage 1 and again in stage 2.
- Stage 1 different targets for Mu2e to determine effective Lagrangian.

Project X

- Unique world leading facility at Fermilab for intensity frontier physics with unmatched ability to deliver very high beam power at multiple energies simultaneously to multiple users.



- Project X accelerator R&D is a collaboration of 12 national labs and universities as well as four Indian laboratories.
- Applications to materials science (Oct 2012 workshop on muon spin rotation), and nuclear energy (Jan 2013 workshop on irradiation facilities applications).
- Project X is an *absolutely central* facility and although it is pre CD0 it is *ready for construction*.

nuSTORM

- Muon storage ring that would provide neutrino beams with well defined flavor composition and energy structure.
- Motivated by anomalies from LSND, MiniBooNE+… . Search for Large Δm^2 neutrino oscillations that go beyond PMNS (sterile neutrinos). If discovered would be of great scientific importance. nuStORM is not unique in being able to detect such oscillations at the LSND level but if confirmed a unique facility to study them with.
- Determine neutrino nucleon cross sections that are likely to be sources of systematic uncertainty for future long baseline experiments. This is valuable science but not essential at this time.
- Serve as a platform for developing technologies for future muon storage rings.
- While committee is not aware of any major technical challenges to realizing nuSTORM, the performance requirements *are not yet fully defined*.
- While nuSTORM has great potential, we *don't yet know enough* to asses its role in world leading science.

Conclusions

- LBNE: Stage 1 begins a world leading program in neutrino physics +… . Science reach of Stage 1 is *important* and it lays the groundwork for an *absolutely central* facility. *Ready for construction,* planned start in 2016 and completed in 2023.
- MU2E: Will search for muon to electron conversion in the field of a nucleus with unparalleled sensitivity. It is *absolutely central. Ready for construction* starting in 2014, completed in 2018.
- PROJECT X: Unique world leading facility at Fermilab for intensity frontier physics. It is *absolutely central* and although it is pre CD0 it is *ready for construction*.
- nuSTORM: Muon storage ring that would provide neutrino beams with well defined flavor composition and spectrum. While the committee is not aware of major technical challenges in realizing nuSTORM, its performance *requirements are not yet fully defined*. While nuSTORM has great potential we *don't know enough* yet to assess nuSTORM's role in US world-leading science.