Project-X Plans for Snowmass

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U.S. DEPARTMENT OF ENERGY

Fermilab

The Project-X Research Program

- ***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 underground laboratories.

- ***Kaon, muon, nuclei & nucleon precision experiments***

These could include world leading experiments searching for lepton flavor violation in muons, atomic, muon, nuclear and nucleon electron dipole moments (edms), precision measurement of neutron properties (e.g. n,nbar oscillations) and world-leading 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.

- ***Material Science and Nuclear Energy Applications***

Accelerator, spallation, target and transmutation technology demonstrations which could investigate and develop accelerator technologies important to the design of future nuclear waste transmutation systems and future thorium fuel-cycle power systems. Possible applications of muon Spin Resonance techniques (muSR). as a sensitive probes of the magnetic structure of materials .

Detailed discussion on Project X website

Example Research Program, definitive space of accelerator parameters on PXPS Indico site

Program:	Onset of NOvA operations in 2013	Stage-1: 1 GeV CW Linac driving Booster & Muon, n/edm programs	Stage-2: Upgrade to 3 GeV CW Linac	Stage-3: Project X RDR	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2450 kW	2450-4000 kW
8 GeV Neutrinos	15 kW +0-50kW**	0-42 kW* + 0-90 kW**	0-84 kW*	0-172 kW*	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	0-172 kW*	1000 kW
1-3 GeV Muon program, e.g. Mu2e-2	-----	80 kW	1000 kW	1000 kW	1000 kW
Kaon Program	0-30 kW** (<30% df from MI)	0-75 kW** (<45% df from MI)	1100 kW	1870 kW	1870 kW
Nuclear edm ISOL program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Ultra-cold neutron program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Nuclear technology applications	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
# Programs:	4	8	8	8	8
Total max power:	735 kW	2222 kW	4284 kW	6492 kW	11870kW

* Operating point in range depends on MI energy for neutrinos.

** Operating point in range depends on MI injector slow-spill duty factor (df) for kaon program.

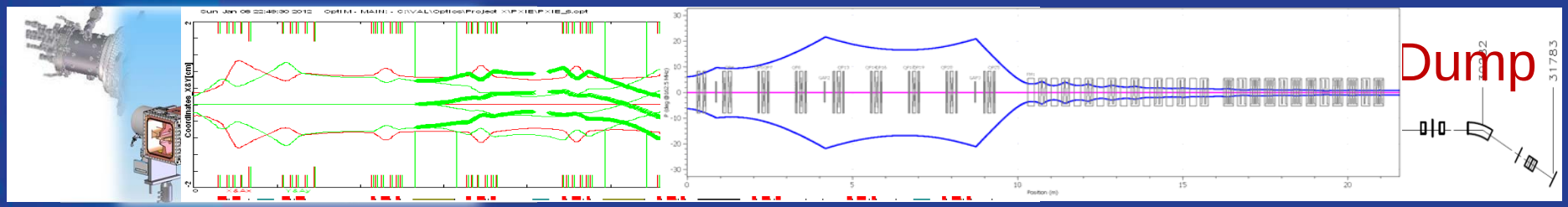
Stage-1 Accelerator Resources:

- Promotes the Main Injector (MI) to a Mega-Watt class machine for neutrinos, and increases the potential beam power for other medium power MI experiments (e.g. ORKA, nu-STORM).
- Unshackles the $\mu \rightarrow e$ (Mu2e) experiment from the Booster complex: Potentially increases sensitivity of Mu2e by x10 - x100 with 1-GeV CW drive beam.
- High power spallation target optimized for ultra-cold neutron and atomic-edm particle physics experiments and neutron$\Leftrightarrow$anti-neutron oscillation experiments.
- Capability to drive polarized protons to a proton-edm experiment.
- Increases the available integrated 8 GeV power for other experiments (e.g. short-baseline neutrinos) from the Booster complex by liberating Mu2e.

Project-X Injector Experiment "PXIE":

- PXIE is the centerpiece of the Project X R&D program
  - Integrated systems test for Project X front end components
    - Validate the concept for the Project X front end, thereby minimizing the primary technical risk element within the Reference Design.
    - Operate at full Project X design parameters
- Systems test goals
  - 1 mA average current with 80% chopping of beam delivered from RFQ
  - Efficient acceleration with minimal emittance dilution through ~30 MeV
  - Achieve in 2016
- PXIE should utilize components constructed to PX specifications wherever possible
  - Opportunity to re-utilize selected pieces of PXIE in PX/Stage 1
- Collaboration between Fermilab, ANL, LBNL, SLAC, India

PXIE Program



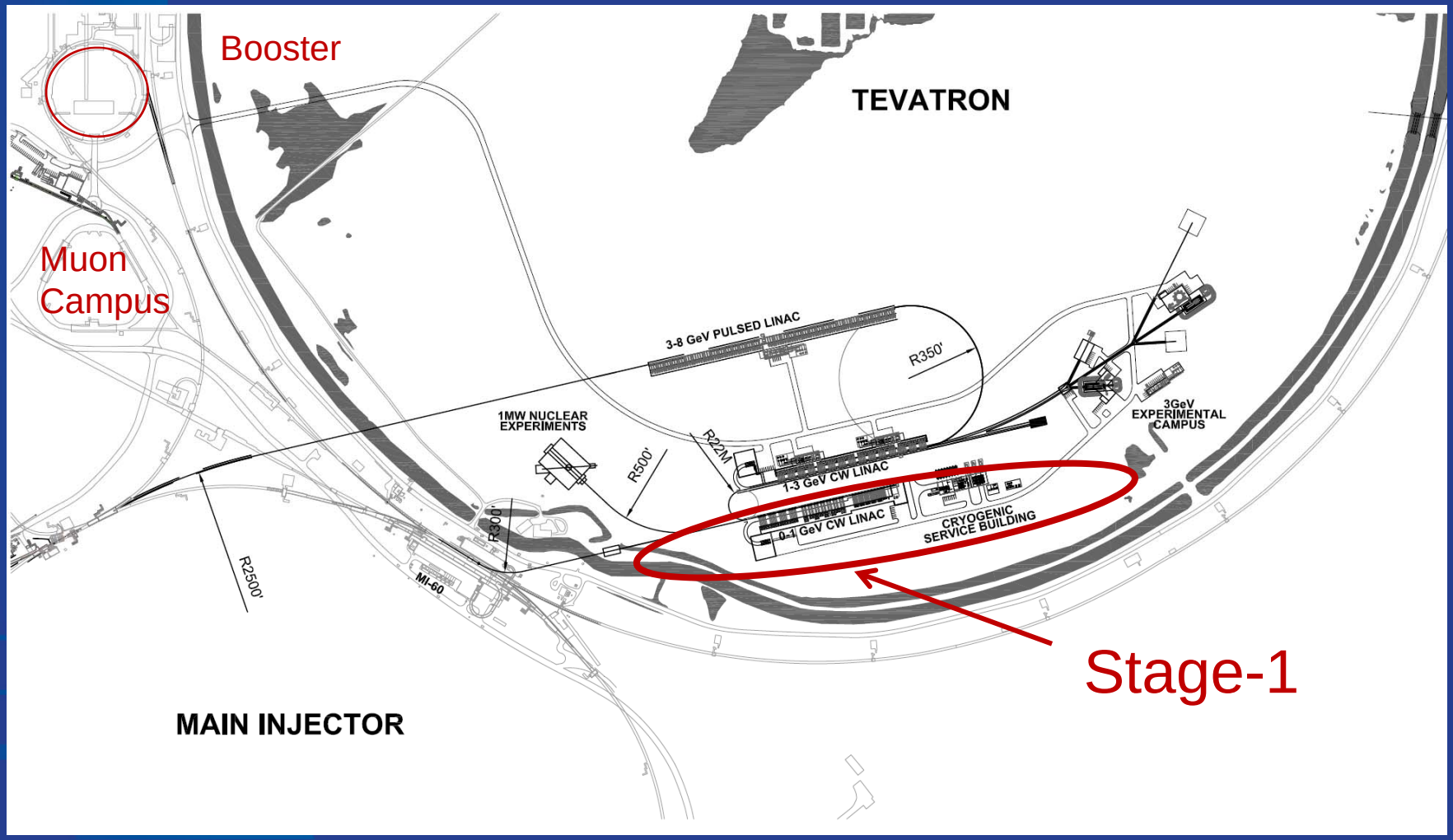
LBNL FNAL,SLAC ANL FNAL

32 m, 30 MeV

PXIE will address the address/measure the following:

- Ion source lifetime
- LEBT pre-chopping
- Vacuum management in the LEBT/RFQ region
- Validation of chopper performance
- Kicker extinction
- Effectiveness of MEBT beam absorber
- MEBT vacuum management
- Operation of HWR in close proximity to 10 kW absorber
- Operation of SSR with beam
- Emittance preservation and beam halo formation through the front end

Current Project-X Staging and Layout Plan



Recent Interaction with the Fermilab PAC*

Project X Charge:

"The PX Stage-1 physics case continues to be refined. We ask the PAC to comment on the plans for understanding and articulating the physics case in preparation for the "Snowmass 2013" meeting."

Associated Charges:

"The laboratory has also received two EOI's:

EOI: NNbarX (Kamyshkov)

EOI: Proton EDM (Semertzidis)

These initiatives are seeking support for R&D that will enable them to eventually prepare a full proposal. We ask the PAC to comment, for each EOI, on whether the science goals are compelling, and on the scope and appropriateness of the proposed R&D."

* http://www.fnal.gov/directorate/program_planning/Oct2012Public/PAC%20Agenda%20October%202012.htm

Materials* submitted to the Fermilab PAC

Physics Opportunities with Stage 1 of Project X

Wolfgang Altmannshofer, Marcela Carena, Patrick Fox, Stuart Henderson, Stephen Holmes, Young-Kee Kim, Joachim Kopp, Andreas Kronfeld, Joseph Lykken, Chris Quigg, and Robert Tschirhart

August 2012

* http://www.fnal.gov/directorate/lbne_reconfiguration/

PAC Feedback* Regarding Project-X

"The PAC commends the proponents on the clear articulation of the physics case for Stage 1. The breadth of the program is impressive. The staged approach to Project X should provide the opportunity for the first stage to proceed in a timely manner. Coordination with the nuclear physics field is encouraged for the definition of the plan for physics topics that touch both particle and nuclear physics interests, such as those involving slow neutrons. A well focused R&D program is required for a number of the proposed experiments. The proponents are encouraged to submit detailed documentation of the physics case to the current Snowmass process."

*http://www.fnal.gov/directorate/program_planning/Oct2012Public/PAC-2012Oct-final.pdf

Recent interaction with the European Strategy for Particle Physics*

- "Opportunities for Collaboration at Fermilab: Input to the European Strategy for Particle Physics, 2012"
  Submitted by P. Oddone

- "Opportunities for Collaboration in the Design and Development of the Project-X Accelerator Complex and Research Program."
  Submitted by S. Holmes & R.T.

- "Americas: Vision, Status &Strategy"
  Presented by A. Lankford.

*(http://espp2012.ifj.edu.pl/)

Project X – Overview

Unique facility with a 3 MW at 3 GeV continuous-wave (CW) linac.

Principal characteristics:

- **Increases Fermilab low-energy proton flux by *x*100**
  with flexible timing patterns, ideal for rare decay experiments
- **Experiments run simultaneously at 3 GeV, 8 GeV, & 60-120 GeV at high power**
- **Delivers 2+ MW to LBNE**
- **Design consistent with serving as front end for neu factory or muon collider**

Capable of a rich physics menu
with neutrinos, kaons, muons, nuclei

Centerpiece of a world-leading Intensity Frontier program

R&D in progress

A. Lankford, ESPP Sept 2012

Project X – Phased approach

Project X can be broken down into 3 phases, each about 1/3 of the cost.

- **Phase 1: Up to 1 GeV**
  Retires old linac, increases neutrino flux *x*1.7, enhances existing Mu2e by *x*10, starts EDM, nuclear-physics and nuclear-materials studies
- **Phase 2: Up to 3 GeV**
  Starts powerful Intensity Frontier experiments with kaons and feeds short baseline neutrino programs
- **Phase 3: Up to 8 GeV**
  Multiplies power to LBNE by *x*3, multiplies power at 8 GeV several fold for short baseline neutrino program

First phase could be 2nd phase of LBNE.

Decision on when to start later in decade.

A. Lankford, ESPP Sept 2012

U.S. at the Intensity Frontier - Summary

Vision: Implement comprehensive program to understand **neutrino mixing.**
Deliver much improved limits (measurements?) of **charged lepton mixing** and **hidden sector phenomena**

Status:

Neutrinos

Broad, world-class neutrino program already in progress at Fermilab
New facilities are under construction for near term

Planned program of **major projects**:

long baseline neutrino experiment – **LBNE** (CD-1 planned by end 2012)
lepton number violation experiment – **Mu2e** (CD-1 approved July 2012)
muon anomalous magnet moment experiment – **g-2**

R&D for next generation multi-MW proton accelerator – **Project X**

Strategy:

Devote Fermilab accelerator complex to advantage of worldwide community
Develop LBNE to its full potential: underground, detector mass, flux
Construct Project X to feed rich, world-leading IF program w/ nu's, mu's, K's

Lankford, Krakow, September 13, 2012 46

A. Lankford, ESPP Sept 2012

SNOWMASS WORKING GROUPS

- Energy Frontier
- Intensity Frontier
- Cosmic Frontier
- Frontier Capabilities
- Instrumentation Frontier
- Computing Frontier
- Education and Outreach

Intensity Frontier group charge:

Conveners: JoAnne Hewett (SLAC),
Harry Weerts (Argonne)

The Intensity Frontier working group is charged with summarizing the current state of knowledge and identifying the most promising future opportunities at the intensity frontier. Topics are described under the working groups.

Frontier Capabilities Group

Conveners: William Barletta (MIT), Murdock Gilchriese (LBNL)

Frontier Facilities will assess the existing and proposed capabilities of two distinct classes of experimental capabilities for high energy physics broadly understood, namely, those provided by accelerator-based facilities and those provided by detector facilities distinct from accelerators. We expect the evaluations to be performed with two principal groups that will operate independently: Accelerator Facilities and Non-accelerator Facilities.

CPM 2012 Feedback

- There will be discussion regarding facilities.
- What the “Capabilities” group wants:

Particle	Energy	Rate	Timing	Purity	Spatial…
Kaons					
Muons					
Neutrinos					
Neutrons ….					

CSS 2013 Engagement Plan: Accelerator Reference Design Report*

- Accelerator Reference Design Report (RDR) will be prepared for distribution to the community in at the Fermilab Users Meeting June 12th 2013. The RDR will include:

  -Staging plan, capability of each stage.

  -Some information on cost drivers and scaling.

*Editor: S. Holmes

CSS 2013 Engagement Plan: Research Program Report*

- Research program opportunities report will be prepared for distribution be prepared for distribution to the community at the Fermilab Users Meeting June 12th 2013. This report will include:

  - Experimental concepts and physics reach opportunities of each stage.

  - Evolution of existing white papers, work at the Project X Physics Study, a URA funded theory study group (C. Quigg P.I.) and PX/CSS Intensity Frontier meetings in late April 2013.

*Editors: A. Kronfeld, R.T.

PX Physics Study Conveners for Experimental Concepts and Sensitivities

Neutrinos:

Andre de Gouvea (Northwestern University), Patrick Huber (Virginia Tech) , Geoff Mills (LANL)
Ko Nishikawa (University of Chicago/FNAL), Steve Geer (FNAL)

Muon Experiments:

Bob Bernstein (Fermilab), Graham Kribs, (University of Oregon)

Kaon Experiments:

Kevin Pitts (University of Illinois UC), Vincenzo Cirigliano (LANL)

EDMs:

Tim Chupp (University of Michigan) , Susan Gardner (University of Kentucky), Zheng-Tian Lu (ANL)

n-nbar oscillations:

Chris Quigg (FNAL), Albert Young (North Carolina State University)

Hadron physics:

Stephen Godfrey (Carleton University), Paul Reimer (ANL)

CSS 2013 Engagement Plan: Necessary Detector R&D Report*

- A report on Detector R&D required to develop the research program opportunities will be prepared for distribution to the community at the Fermilab Users Meeting June 12th 2013. This report will include:

  - R&D necessary for each stage.

  - Coordination with the DPF Coordination Panel for Advanced Detectors (CPAD) and connections to other scientific and technical disciplines. Meetings at ANL in January, Boulder Co. in the spring.

*Editors: E. Ramberg, R.T.

PX Physics Study Conveners for Enabling Technologies and Techniques

High rate Precision Photon Calorimetry:

David Hitlin (Caltech), Milind Diwan (BNL)

Very Low-Mass High-Rate Charged Particle Tracking:

Ron Lipton (FNAL), Jack Ritchie (University of Texas, Austin)

Time-of-Flight System Performance below 10 psec:

Mike Albrow (FNAL), Bob Wagner (ANL)

High Precision Measurement of Neutrino Interactions:

Kevin McFarland (Rochester University), Jonghee Yoo (FNAL), Rex Tayloe (University of Indiana)

Large Area Cost Effective (LACE) Detector Technologies:

Mayly Sanchez (Iowa State University), Yury Kamyshkov (University of Tennessee)

Lattice QCD:

Ruth Van de Water (BNL), Tom Blum (University of Connecticut)

CSS 2013 Engagement Plan: Broader Impacts Report*

- A report on the broader impacts of Project-X will be prepared for distribution to the community at the Fermilab Users Meeting June 12th 2013. This report will include:

  - Energy and material irradiation applications working closely with our DOE NE colleagues at ANL, LANL and PNNL and our Indian collaborators.

  - muon Spin Rotation applications.

*Editors: D. Asner, S. Henderson, S. Holmes

Schedule in advance of CSS 2013

- December 2012: Provide table of particle beam requirements to Bill Barletta (CSS2013 capabilities group).
- Broader applications forums and workshops Oct 2012 (muSR), January 2013 (Energy & Materials).
- EDM theory study session at Fermilab associated with colloquium from Klaus Kirch (PSI), February 13th-15th 2013.
- Late April 2013: Meeting at Fermilab to review Project X draft materials for Snowmass. This meeting will be coordinated with an Intensity Frontier CSS 2013 preparatory meeting at ANL.
- Late May 2013: Project-X Boot-Camp for liaisons.
- June 2013: Post and distribute Project X Snowmass materials at Fermilab Users Meeting June 11th-12th.

Opportunities for Contribution and Leadership

- Continued development of PX/LBNE case.
- Continued development of Stage-1 experimental concepts, particularly the n-nbar and proton-edm initiatives. Active participation on writing teams.
- Developing Detector R&D required for all stages.
- Project X liaison team, participate in the outreach Boot-Camp.