

# Discussion Materials for the PXPS Conveners Meeting

Thursday April 5<sup>th</sup> 2012

R. Tschirhart for the organizing committee:

S. Holmes, A. Kronfeld, S. Parke, E. Ramberg,  
R. Tschirhart

# Conveners for Experimental Concepts and Sensitivities

## **"Long Baseline Neutrinos" :**

P. Huber (Virginia Tech) , K. Nishikawa (KEK, FNAL), [Steve Geer (FNAL)]

## **"Short Baseline Neutrinos":**

A. de Gouvea (Northwestern University), G. Mills (LANL)

## **Muon Experiments:**

R. Bernstein (Fermilab), [co-convener theorist, TBA]

## **Kaon Experiments:**

K. Pitts (University of Illinois UC), V. Cirigliano (LANL)

## **EDMs:**

W. Haxton (Univ of California Berkeley), T. Chupp (Univ. of Michigan) , Zheng-Tian Lu (ANL)

## **n-nbar oscillations:**

C. Quigg (FNAL), A. Young (North Carolina State University)

# Enabling Technologies and Techniques Conveners

High rate Precision Photon Calorimetry:

D. Hitlin (Caltech), M. Diwan (BNL)

Very Low-Mass High-Rate Charged Particle Tracking:

R. Lipton (FNAL), J. Ritchie (University of Texas, Austin)

Time-of-Flight System Performance below 10 psec:

M. Albrow (FNAL), [co-convener TBA]

High Precision Measurement of Neutrino Interactions:

K. McFarland (Rochester), Jonghee Yoo (FNAL), , [co-convener TBA]

Large Area Cost Effective Detector Technologies:

M. Sanchez (Iowa State University), Y. Kamyshkov (University of Tennessee)

Lattice QCD:

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

# The Project-X Research Program

- ***Neutrino oscillation experiments***

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

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

- These could include world leading experiments searching for muon-to-electron conversion, nuclear and neutron electron dipole moments (edms), precision measurement of neutron properties 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.

- ***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.

Detailed Discussion: [Project X website](#)



**Working groups:** Heavy Quarks • Charged Leptons  
Neutrinos • Photons • Proton Decay • Nucleons, Nuclei & Atoms

This workshop is an opportunity for the scientific community to identify the physics potential of the Intensity Frontier. Starting in September, six working groups will study and document the full spectrum of Intensity Frontier physics and describe the necessary facilities to execute such a program. The working groups will be open to and solicit input from the broader particle and nuclear physics community, and will present their preliminary findings at the workshop.

More information is available at [www.intensityfrontier.org](http://www.intensityfrontier.org) or from the workshop chairs, JoAnne Hewett and Harry Weerts, at [intensity-frontier@slac.gov](mailto:intensity-frontier@slac.gov).



**FUNDAMENTAL PHYSICS AT THE  
INTENSITY FRONTIER**

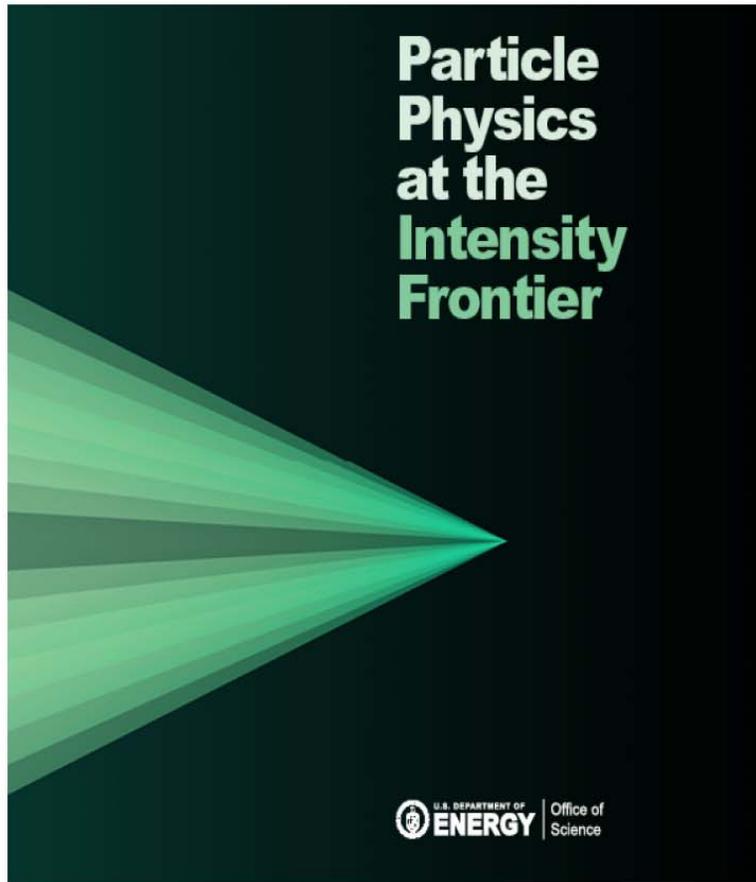
November 30–December 2, 2011  
Rockville, MD | [www.intensityfrontier.org](http://www.intensityfrontier.org)



- 500+ Attendees
- Six very active working groups:
  - Charged leptons
  - Heavy Quarks
  - Hidden Sector
  - Neutrinos
  - Nucleons/Nuclei/Atoms
  - Proton Decay
- DOE OHEP listened...

(<http://www.intensityfrontier.org/>)

# Vision for Program Development



**Dr. Jim Siegrist, Associate Director  
Office of High Energy Physics  
Office of Science, U.S. Department of Energy**

- Our domestic program is the world leader in 'Intensity Frontier' area, and we need to increase investments there, while keeping a balance with the other frontiers
- Community is engaged on further developing the science case on all 3 frontiers – we need a healthy portfolio of construction ideas supported by compelling science drivers at achievable budget levels
  - Will need more help from the community here; see also talks tomorrow
- Our program will deliver science now, in the near term, and in the long term on all 3 frontiers

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Presentation to the High Energy Physics Advisory Panel, March 12<sup>th</sup> 2012

## HEP Priorities for the Next 12 Months

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- Develop Mission Need statement for US participation in LHC detector upgrades
- Make critical decisions on Long Baseline Neutrino Experiment
- Issue solicitation for R&D leading to Next Generation Dark Matter Experiments and make selections
- Develop strategic plans for Intensity Frontier and Accelerator R&D programs



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# Community Assistance in Program Development

- **We need to continue to develop the science case and planned program on all 3 frontiers. We need more projects in the pipeline than we have budget to be certain the funding directed out of the program onto construction will not be lost.**
- **Plan for ‘Snowmass’ in summer 2013 to assess our program (neutrino and LHC results available for guidance)**
- **We need active participation of our community in the development of the science case, with lab leadership in the background. DOE and NSF agree on this approach.**
  - This is an inversion of the “traditional” HEP modus operandi
  - The HEP community needs to own the science case, and sell the science case
- **For the intensity frontier, DOE/NSF plan to work with DPF to continue the development of the science case started at the December workshop.**
  - FNAL will lead work on research infrastructure improvements to support that science case.
- **For the energy frontier, DPF could do the same, or the LHC users organization.**
  - Less time-critical than the intensity frontier, but discoveries at LHC could change this rapidly. Your thoughts are welcome.
- **For the cosmic frontier, HEP is less clear how to proceed.**
  - Solicitations for 2<sup>nd</sup> Generation Direct Dark Matter detection in place
  - Work is needed to further develop other parts of the program, especially in dark energy.



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

HEP 4

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# Intensity Frontier Issues

- **Science case development – see IF workshop talks yesterday**
  - Continued community engagement a must
  - Theorists need to engage in development of the program here
- **Generally, need more protons on target at FNAL to support the intensity frontier program.**
  - FNAL looking at options here
- **Program internationalization**
  - International contributions to our intensity frontier efforts will help stabilize our program

# Project-X Accelerator Functional Requirements\*

## CW Linac

Particle Type	H <sup>-</sup>	
Beam Kinetic Energy	1.0-3.0	GeV
Average Beam Current	1	mA
Linac pulse rate	CW	
Beam Power @ 3 GeV	3000	kW
Beam Power to 3 GeV program	2870	kW

## RCS/Pulsed Linac

Particle Type	protons/H <sup>-</sup>	
Beam Kinetic Energy	8.0	GeV
Pulse rate	10	Hz
Pulse Width	0.002/4.3	msec
Cycles to MI	6	
Particles per cycle to Recycler	$2.6 \times 10^{13}$	
Beam Power to 8 GeV program	190	kW

## Main Injector/Recycler

Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.3	sec
Particles per cycle	$1.6 \times 10^{14}$	
Beam Power at 120 GeV	2200	kW

simultaneous

\* <http://projectx-docdb.fnal.gov/cgi-bin/ShowDocument?docid=658>

# Power Staging for the Research Program



← Project X Campaign →

Program:	Stage-0: Proton Improvement Plan	Stage-1: 1 GeV CW Linac driving Booster & Muon, EDM programs	Stage-2: Upgrade to 3 GeV CW Linac (MI>70 GeV)	Stage-3: Project X RDR (MI>60GeV)	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2300 kW	2300-4000 kW
8 GeV Neutrinos	15 kW + 0-50 kW**	0-40 kW* + 0-90 kW**	0-40 kW*	85 kW	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	85 kW	1000 kW
1-3 GeV Muon program	-----	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	1100 kW	1100 kW
Nuclear edm ISOL program	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
Ultra-cold neutron program	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
Nuclear technology applications	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
# Programs:	4	8	8	8	8
Total* power (mean):	660 kW	1950 kW	4230 kW	5490 kW	11300kW

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

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

# Project X Research Program Milestones...

The poster features a blue background with a flock of birds flying upwards. At the bottom, there is a photograph of the Fermilab Main Building. Text is arranged in columns on the left and right sides of the poster.

**2012 Project X Physics Study**

June 14 - 23, 2012 • Fermilab • Batavia, Illinois

The Project X Physics Study will engage theorists, experimenters, and accelerator scientists in establishing and documenting a comprehensive vision of the physics opportunities at Project X, and integrating these opportunities within a coherent plan for development of detector capabilities and the accelerator complex.

**Working Groups**  
Long-Baseline Neutrinos  
Short-Baseline Neutrinos  
Muon Experiments  
Kaon Experiments  
Electric Dipole Moments  
Neutron-Antineutron Oscillations  
Lattice QCD  
High Rate Precision Photon Calorimetry  
Very Low-Mass High-Rate Charged Particle Tracking  
Time-of-Flight System Performance Below 10 psoc  
High-Precision Measurement of Neutrino Interactions  
Large-Area Cost Effective Detector Technologies

**Organizing Committee**  
Steve Holmes, Andreas Kronfeld  
Stephan Pöhl, Erik Frankberg  
Cynthia Szamoa, Boba Tschirhart  
Suzanne Weber

**For Further Information**  
Cynthia Szamoa (cszamoa@fnal.gov)  
Fermilab Conference Office  
PO, Box 500, Batavia, IL 60510-0500

[indico.fnal.gov/event/projectxps12](http://indico.fnal.gov/event/projectxps12)

Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science | Fermilab Research Accelerator

- June 2012 Physics Study.

- Summer 2012 through Spring 2013:

Continue to evolve existing white papers into a comprehensive program.

- October 11<sup>th</sup>-13<sup>th</sup> 2012:

US particle physics town meeting at Fermilab preparing for "Snowmass", summer 2013.

- Snowmass, summer 2013:

Event to develop US strategies.

# Project X Physics Study Deliverables

- **Conveners for Experimental Concepts and Sensitivities:**

Update white papers with a particular focus on quantitative physics sensitivities for each stage of Project X, and a road-map of studies up to Snowmass 2013.

- **Enabling Technologies and Techniques Conveners:**

Develop a roadmap of enabling technologies and as appropriate draft Field Work Proposals to the DOE OHEP for critical generic detector R&D.

# Resources

- [Intensity Frontier documentation and participants](#)
- [Project X physics workshops](#)
- [Project X white papers](#)
- [Detector R&D: Glen Crawford \(DOE OHEP\)](#)
- [Detector R&D at Fermilab](#) : Erik Ramberg.

# Resources for PXPS

- \$12K from FRA for conference support and \$25K from the URA visiting scholars program to support travel for critical URA institution researchers.
- Some travel support for critical non-URA institution researchers.
- Indico site, conveners will all have pages and management access of these pages.
- The Short Baseline Neutrino Study Focus Group.
- Associated collaborations, LBNE staging study activity.
- Fermilab conference office. C. Sazama, S. Weber.
- Local Organizers.

# Structure of Study

- Not a monolithic tiling of presentations over nine days. Not an attendance jamboree.

Suggestion of:

- 1 day of fully plenary: Thursday June 14<sup>th</sup>.
- 2 days of integrated parallel sessions between the enabling technology teams and the concept and sensitivities teams.
- Saturday June 16<sup>th</sup> PM BBQ, Sunday June 17<sup>th</sup> off.
- 3-4 days of focused working group activity with ala carte cross-term interaction with other groups.
- Dinner at Chez Leon (Thursday PM or Friday PM) followed by 1 day of closing plenaries.
- Embedded accelerator expert in each concept team.

# Group Issues

- High Precision Measurement of Neutrino Interactions:  
K. McFarland (Rochester), Jonghee Yoo (FNAL), ), [co-convener TBA]

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# Group Issues

- Lattice QCD:  
Ruth Van de Water (BNL), Tom Blum (University of Connecticut)

# Common Issues

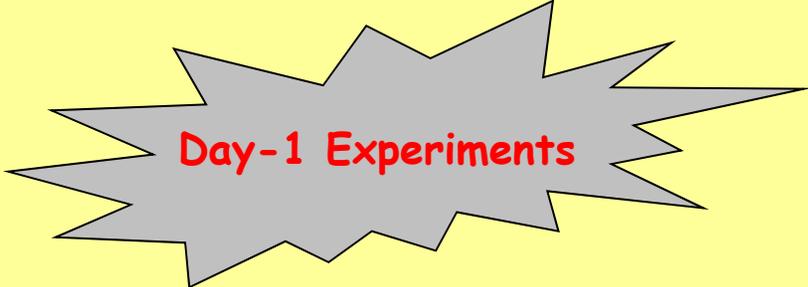
- Group conveners will meet separately and bi-laterally as necessary to develop agendas and assignments.
- Conveners are invited to give status reports at the four bi-weekly organizer meetings between now and June 14<sup>th</sup>.
- Final convener meeting will be June 4<sup>th</sup>-6<sup>th</sup>. Doodle pending.
- Indico site.
- Requests for travel support will be subject to convener recommendation.

# Spare Slides

# An Incomplete Menu of World Class Research Targets Enabled by Project-X

## Neutrino Physics:

- **Mass Hierarchy**
- **CP violation**
- **Precision measurement of the  $\theta_{23}$  (atmospheric mixing). Maximal??**
- Anomalous interactions, e.g.  $\nu_{\mu} \rightarrow \nu_{\tau}$  probed with target emulsions (Madrid Neutrino NSI Workshop, Dec 2009)
- Search for sterile neutrinos, CP & CPT violating effects in next generation  $\nu_e, \bar{\nu}_e \rightarrow X$  experiments....x3 beam power @ 120 GeV, x10-x20 power @ 8 GeV.
- Next generation precision cross section measurements.



**Day-1 Experiments**

# An Incomplete Menu of World Class Research Targets Enabled by Project-X

## Muon Physics:

Day-1 Experiment

- Next generation muon-to-electron conversion experiment, new techniques for higher sensitivity and/or other nuclei.
- Next generation  $(g-2)_\mu$  if motivated by next round, theory, LHC. New techniques proposed to JPARC that are beam-power hungry...
- $\mu$  edm
- $\mu \rightarrow 3e$
- $\mu^+ e^- \rightarrow \mu^- e^+$
- $\mu^- A \rightarrow \mu^+ A'$  ;  $\mu^- A \rightarrow e^+ A'$  ;  $\mu^- e^-(A) \rightarrow e^- e^-(A)$
- Systematic study of radiative muon capture on nuclei.

# An Incomplete Menu of World Class Research Targets Enabled by Project-X

## Kaon Physics:

Possible Day-1 Experiments

- $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ : >1000 events, Precision rate and form factor.
- $K_L \rightarrow \pi^0 \nu \bar{\nu}$ : 1000 events, enabled by high flux & precision TOF.
- $K^+ \rightarrow \pi^0 \mu^+ \nu$ : Measurement of T-violating muon polarization.
- $K^+ \rightarrow (\pi, \mu)^+ \nu_\chi$ : Search for anomalous heavy neutrinos.
- $K^0 \rightarrow \pi^0 e^+ e^-$ : <10% measurement of CP violating amplitude.
- $K^0 \rightarrow \pi^0 \mu^+ \mu^-$ : <10% measurement of CP violating amplitude.
- $K^0 \rightarrow X$ : Precision study of a pure  $K^0$  interferometer:  
Reaching out to the Plank scale ( $\Delta m_K / m_K \sim 1/m_P$ )
- $K^0, K^+ \rightarrow$ LFV: Next generation Lepton Flavor Violation experiments  
...and more

# An Incomplete Menu of World Class Research Targets Enabled by Project-X

Possible Day-1 Experiment

## Nuclear Enabled Particle Physics:

- Production of Ra, Rn, Fr isotopes for nuclear edm experiments that are uniquely sensitive to Quark-Chromo and electron EDM's. Production of Very-cold and Ultra-cold neutrons for EDM and n-nbar.

## Baryon Physics:

- $pp \rightarrow \bar{\Sigma}^+ K^0 p^+$ ;  $\Sigma^+ \rightarrow p^+ \mu^+ \mu^-$  (HyperCP anomaly, and other rare  $\Sigma^+$  decays)
- $pp \rightarrow K^+ \Lambda^0 p^+$ ;  $\Lambda^0$  ultra rare decays
- neutron - antineutron oscillations
- $\Lambda^0 \leftrightarrow \bar{\Lambda}^0$  oscillations (Project-X operates below anti-baryon threshold)
- neutron EDMs