Project X Status Report

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http://www.fnal.gov/pub/projectx/







- Previous Project X presentation at HEPAP
 - S. Holmes, Nov 13, 2008
- Developments since Nov 2008
 - Evolution of initial configuration
 - Preliminary IC-1 and IC-2 estimates
 - 4th Project X Physics Workshop

http://www.fnal.gov/directorate/Longrange/Steering_Public/workshop-physics-4th.html

- Collaboration
- Technical and cost optimization
- Strategy
 - Cost range strategy



Concurrent

Project X missions



Long-Baseline

Neutrino Experiment:

2 MW at 60-120 GeV

- well understood beam requirements;
- it will be supported in any configuration we select.
- Rare Processes: ≥ several 100's kW at 2.x 8 GeV
 - well understood beam requirements for this mission.
 4th Project X Physics Workshop (Nov 2009)
- NF/MC Platform: upgradable to 4 MW at 5 15 GeV
 - MC beam requirements are (x~10) harder than NF;
 - High on our "radar screen" but is not a driver;
 - Do not need to have it on day 1 of initial program; need to demonstrate a plausible path.

Project X Initial Configuration -1 (IC-1)

- IC-1 has been based on ILC-technology with a pulsed, 325-MHz lowenergy and 1.3GHz high-energy SC linac (8 GeV)
- Objectives for the initial proposal (September, 2007)
 - ILC technology test (360 kW proton beam power at 8 GeV)
 - 2 MW at (60 -120 GeV) in the Main Injector for neutrinos
 - 100-200 kW at 8 GeV for rare processes (muons and kaons)
 - Replacement for a ~40 year-old Booster & Linac
- Final IC-1 (as of spring 2009)
 - 2 MW at (60 -120 GeV) in the MI for neutrinos (LBNE)
 - ~300 kW at 8 GeV for rare processes
 - 150 kW to Mu2e (Phase 2) upgraded (with a slow extraction)
 - Reduced coupling to ILC (500 kW proton beam power at 8 GeV)
 - Improved but still comparatively narrow physics program









Rare processes require a stream of bunches with a ~100% duty cycle.

		Train Frequency	Pulse Width
			(nanoseconds)
Examples:	Kaon experiments	20-30 MHz	< 0.2
	Muon conversion experiment	0.5-1.0 MHz	<100
	$\mu \rightarrow e\gamma \& \mu \rightarrow eee experiments$	80-300 MHz	< 0.2

- A pulsed beam from linac is not optimal; requires beam conditioning in rings and slow extraction.
- There is a fundamental limit to slow extraction: losses at the electrostatic septum
 - Also, space-charge for short bunches, single user for a given bunch format, non-uniform spill rates
 - World's best: AGS, 70 kW (2% loss), unbunched beam (25 GeV); similar beam power from Tevatron in the past
 - JPARC design: several 100 kW at 50 GeV, unbunched (undemonstrated)
- At the end, we understood that slow extraction is the bottleneck.



Initial Configuration - 2



• Mar. 2009: To improve the rare processes program we have focused on a cw proton linac.

Missions:

- 2 MW at 60-120 GeV in MI for LBNE
 - Same as in IC-1
- Diverse program with muon, kaon, and nuclear physics
 - Different experiments require different time structures
 - "unlimited" beam power on target
- 8 GeV program with a single turn extraction (≥100 kW)
 g-2, ...
- A path to MC/NF
- Experiments in other fields
- CEBAF is an example of such a machine with e-beam -



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- IC-2 concept (as of end of summer 2009)
 - 2.0 GeV CW linac
 - potentially "unlimited power"
 - RF separation + bunch-by-bunch chopping
 - Multiple experiments operating simultaneously
 - Independent bunch structure control
- "Pulsed" 2-to-8 GeV acceleration (10 Hz, 4.3 ms, 5% duty cycle) to support MI program
 - Both synchrotron and pulsed SC linac are a good choice



IC-2 Overview







IC-2 Operating Scenario





S. Nagaitsev, March 11, 2010



IC-2 Provisional Siting







Initial Configuration-2 Technology Map 2-GeV Super Conductive cw linac











- IC-1 point estimate completed March 2009, subject to Director's Review
 - Assessed to be conservative w/ caveats: escalation, scope, schedule
- IC-2 point estimate completed in October 2009
 - Same estimators and methodology as IC-1
 - Not yet reviewed
 - ~6% higher than IC-1 within range of error.

	IC-1 (\$M)	IC-2 (\$M)
Base Cost	\$743.5	\$798.4
Overhead	\$185.9	\$187.5
Escalation	\$135.7	\$144.0
Contingency (40%)	\$426.1	\$452.0
Total	\$1,491.2	\$1,581.9



• Identified optimum energies for various programs

	Proton Energy (kinetic)	Beam Power	Beam Timing
Rare Muon decays	2 – 3 GeV	> 500 kW	1 kHz – 160 MHz
Precision K ⁰ studies	2.6 – 3 GeV	> 200 kW	20 – 160 MHz (< 50 psec pings)
Rare Kaon decays	2.6 – 4 GeV	> 500 kW	20 – 160 MHz (< 50 psec pings)
(g-2) measurement	8 GeV	20 – 50 kW	30 - 100 Hz
Neutron and exotic nuclei EDMs	1.5 – 2.5 GeV	> 500 kW	> 100 Hz



IC-2 remaining issues



- Solved the IC-1 problems (slow extraction)
- But...
- two issues remained...
- 1. Low proton beam energy (2 GeV intead of 3)
- 2. Inefficient acceleration in the linac







• What problem are we trying to solve?



Energy gain/cavity in IC-2

- 1300 MHz section is not an efficient accelerator (for protons)
- Primary culprit is transit factor
 - also, number of cells per cavity
- Maximal gain at zero synchronous phase is 17 MeV (for β=1) but for a 2-GeV proton beam it is close to 15 MeV

Several 3-GeV linac schemes analyzed TSR SSR1 SSR2 #1 SSR0 $\beta = 0.8$ $\beta = 0.9$ 650 MHz, 0.47-3 GeV 325 MHz, 2.5-470 MeV SSR1 #2 SSR0 SSR2 TSR $\beta = 0.8$ ILC $\beta = 0.9$ 325 MHz, 2.5-470 MeV 650 MHz 1.3 GHz 0.47-2 GeV 2-3 GeV #3 SSR0 SSR1 SSR2 $\beta = 0.6$ $\beta = 0.9$ 325 MHz, 2.5-160 MeV 650 MHz, 0.16-3 GeV SSR1 SSR2 #4 SSR0 $\beta = 0.6$ ILC $\beta = 0.9$ 325 MHz, 2.5-160 MeV 650 MHz, 1.3 GHz 0.16-2 GeV 2-3 GeV







 Option 4: a 3-GeV CW linac with a 650 MHz intermediate system, based on 5-cell cavities.



Note: 650 MHz, β =0.9, 5-cell cavities are same physical length as 1300 MHz, β =1.0, 9-cell cavities







Energy gain/cavity in IC-2v2.0









Total number of cavities in each configuration:

IC-2v1.0:316 cavities(to 3 GeV)IC-2v2.0:250 cavities(less if β =0.95)

- Total linac length is reduced by ~20% (for 3 GeV)
 - Or, 3 GeV linac (option 4) is ~20% longer than the 2 GeV linac in IC-2v1.0
- Early analysis of cost trade-offs indicate that 1300 MHz cavity becomes more cost effective than 650 MHz somewhere in the range of 2 GeV
- Development of IC-2v2.0 (option 4) will allow us to explore issues related to introduction of a third frequency, and variations on the 1300 MHz cavity shape



Short Term Strategy (Next 6 months)



- Develop an estimate for a 3 GeV CW linac operating at 1.5-2 MW
 - Identify (cost) break points (with respect to beam power) on the rf system and cryogenics distribution system
 - Establish a better optimized (i.e. reduced cost) linac configuration: cavity types, cavity frequencies, and transition points
- Retain RCS within the estimate but limit work to critical issue(s)
 - Injection
- Investigate options for pairing a 3-8 GeV pulsed linac to CW front end
- Update RD&D Plan to cover CW linac
- Archive ICD-1 and associated cost estimate
- Proposed strategy for CD-0
 - Attempt to get cost of 3 GeV linac at or below \$1.0 B
 - Conduct a Director's Review to validate a cost range that extends below \$1.0 B



Short Term Plan (Next 6 months)



- Goals of the Director's Review:
 - Validate the cost estimate for IC-2
 - Validate a cost range proposed by the project
- Upper end of range = IC-2v1.0, with linac at 3.0 GeV/1.0 mA. RCS, Recycler, MI
 - Release ICD-2V1.0 as is (2.0 GeV) after final edit
 - Update the estimate with the incremental cost of adding 1 GeV of CW linac
- Lower end of range = IC-2v2.0, with linac at 3.0 GeV/0.5 mA, no RCS, Recycler, MI
 - Update to ICD-2V2.0 based on "Option 4" configuration
 - Update the cost estimate based on "Option 4" configuration



Collaboration plan



- A multi-institutional collaboration has been established to execute the Project X RD&D Program.
 - Organized as a "national project with international participation".
 - Fermilab as lead laboratory
 - International participation via in-kind contributions, established through bi-lateral MOUs. (First MOU with India in place)
 - Collaboration MOU for the RD&D phase outlines basic goals, and the means of organizing and executing the work. Signatories:

ORNL/SNS
MSU
TJNAF
SLAC
ILC/ART

 Collaborators to assume responsibility for components and sub-system design, development, cost estimating, and potentially construction.







- The configuration for Project X has evolved to maximize physics outcome since the initial proposal in 2007
 - At every step we have improved the performance
 - A new approach to high-duty factor beams and rare processes
 - Not another rendition of JPARC
 - x10 beam power of the IC-1 rare-process program, x7 goal of JPARC
 - Capture leadership in intensity frontier
- We now know what we want to build!
- We propose to build Project X based on a 3-GeV CW linac.
 - Could be constructed in a 5-year time period
 - Multi-user facility concurrent with LBNE
 - An rf splitter sends beam to 3 users (muon, kaon and nuclear physics), but technology is not limited to 3 users.



Backup: Potential cost reductions



- Extend cost range further downward by establishing a set of potential cost reductions that can be applied to either configuration
 - Reoptimization of linac configuration
 - Review of CM estimate to identify cost reduction opportunities
 - Identify rf infrastructure that is frequency independent vs dependent
 - Review of rf power and distribution system to identify breakpoints (with respect to beam current)
 - Review the cryo estimate to identify breakpoints with respect to segmentation, and complete G vs Q vs T
 - Identify potential in-kind contributions from international partners
 - Remove space offset budgets
 - Develop a reduced overhead model
 - Update R&D plan to configuration IC-2
 - \Rightarrow Consolidate all of the above into a cost opportunities spreadsheet



Backup: Project management



- We have assembled a senior management team (3 people part-time)
 - assempled a team of level-2 managers (all part-time)
- We are preparing an integrated SCRF plan
 - includes our commitments to the ILC program (1.3 GHz, pulsed)
- The FY2010 budget for Project X is \$10.3M. Of this \$1.6M is set aside for work at the collaborating institutions.



Integrated SRF Plan Cryomodules



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Integrated SRF Plan Infrastructure



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