Subject: Proton Improvement Plan - PIP

Project Quarterly Summary FY14 Q1

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Project Milestones

There were no high level (0 or 1) PIP milestones for FYQ1. All the level 3 milestones were completed as scheduled. Progress this year can be attributed to the NoVA shutdown completion and labor becoming available. As mentioned in previous quarterly reports, an effort to update the RLS so as to bring it up to date with the present funding profile is nearly complete. The updated RLS will likely result in changes to the Q2 milestones but certainly outlying milestones will see changes.

Table 1 PIP Milestones for FY14Q1

Lev	WBS	Name	Baseline Date	Fcst Date	% Complete
3	1.02.03.02.01.06	MILESTONE: Booster Damper prototype board for transverse system complete	11/14/13	10/18/13	100%
3	1.01.02.03.03.12	MILESTONE: 1st two stages fiber complete	12/2/13	10/1/13	100%
3	1.01.02.03.05.09	MILESTONE: Linac Notch Prototype optical cavity certified (on bench)	12/26/13	12/4/13	100%
3	1.02.03.02.01.08	MILESTONE: Booster Damper prototype board testing complete	1/23/14	11/22/13	100%

PIP Highlights by WBS Section

WBS 1.1 Linac

The vulnerabilities associated with the LINAC are the 200 MHz accelerating system, including power amplifier tubes and other associated systems such as the modulator; utilities for power distribution and vacuum systems; better need for reliable instrumentation along the Linac to improve beam transport and realistic machine model supported by real beam measurements. There are four largest elements of WBS Level 2 in Linac which are further subdivided at Level 3.

WBS 1.1.1 200 MHz RF Power System

The 200 MHz RF Power System represents approximately 40% of the total scope of the PIP project. There are 3 level 4 elements which will be described below.

WBS 1.1.1.1 High Level RF

At the end of the previous quarter, the team was awaiting for the end of the bid process for a 200 MHz single beam klystron (SBK). Once again, Communications and Power Industries (CPI, CA) was the only company which bid. The technical team accepted the bid and initiated the contract process in collaboration with the business service at Fermilab. A series of meetings were held between CPI, PIP management and technical members, procurement experts and legal advisors. One of the main negotiation points was the assertion of allowing free communication among other DOE laboratories to share experiences and results on the performance and operation of such device without having to have CPI consent for such collaboration. This was granted. At the end of the quarter, the order was finalized and a purchase order generated and accepted. This marks an important step forward in this task. The team immediately turned the focus on the test setup at Fermilab. The SBK is expected to be received at the beginning of FY16.

WBS 1.1.1.2 Linac Modulator

AD/EE Support Marx Modulator Design

During the last quarter of 2013, the 3 cell testing finished. After resolving the issue of cell ringing when switching within 600 ns, which turned out to be an effect of the diode reverse turn off time of the main IGBT switch, the building of the 9 cell prototype commenced. An analog based control system has been built to test all of the 9 cells to create any desired wave shape. This waveform will consist of discrete voltage steps to create the desired pulse. To be able to resolve in more detail, any desired waveform without steps, a new pulse width modulation (PWM) board is being created to test the new 9 cell prototype. The 9 cells have been assembled and safety gates created for testing of the 9 cell version (see attached picture). Presently, the charging of all 9 cells has been problematic, and designers and technicians are presently investigating the problem. Once solved, the 9 cells will be fired both sequentially and all at once, to show both the slew rate and voltage regulation of the Marx modulator. From this data, final capabilities of this modulator with become better understood. Completing the 9 cell "stepped" waveform test is the goal of FY2014 Q2. Once the goal is completed, and the new PWM controller is designed, then some of the cells will be tested to create the interleave regulator version of the cells, which will be able to resolve the desired waveform without discrete steps. This work should start in FY2014 Q3. This will require a new filter circuit to be designed and procured, which will start after the 9 cell prototype is turned on to full power.

SLAC Marx Modulator Update

During the last quarter, the third stage of modulator development started. The goal of this stage is to incorporate the model of the Linac accelerating cavity and triode into the simulation in order to generate expected cavity gradient for Marx modulator design. This will include modeling the expected beam current to see the effect on the modulator waveform needed to keep gradient flat during beam.

To start this work, flow charts of the main and Vernier cells turn on and regulation logic where developed. During a visit by L3 manager (PIP Linac Modulator Lead engineer) to SLAC in Dec. 2014, these flow charts where revised to match the present modulator performance. A list of specific tasks to complete this work by the end of FY2014Q2 where defined. As part of this, a cavity and tube models are being created by Fermilab for use in the SLAC simulation. SLAC is presently working on developing different control techniques to create the desired modulator waveform overshoot required to keep accelerating gradient stable before beam enters the cavity, as well that the appropriate feed forward pulse to compensate for beam loading. Simulations will commence once the cavity and tube models are complete. This work is anticipated to be complete by April 2014 assuming availably of both Fermilab and SLAC personal.

WBS 1.1.1.3 7835 Procurement

A new order for a 7835 was placed in this quarter.

WBS 1.1.2 Accelerator Physics

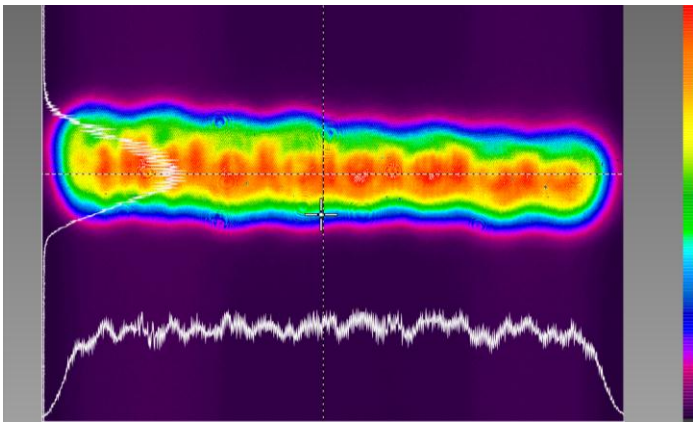
WBS 1.1.2.1 Simulations and Studies

Little progress was achieved during this quarter for the Linac lattice due to shift of priorities during this quarter by the L3 manager.

WBS 1.1.2.2 *Not Used*

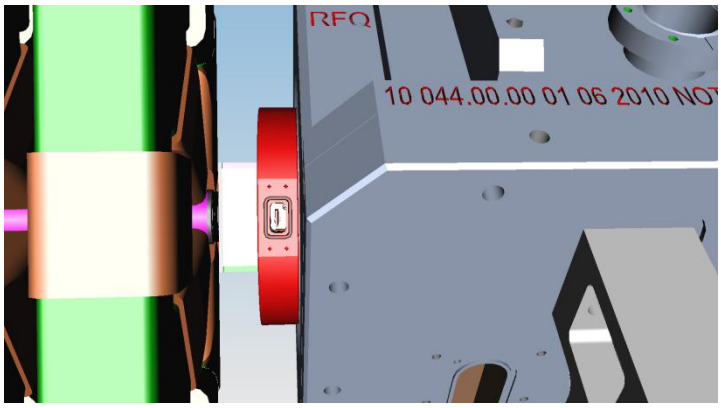
Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.2.3 Linac Notch Creation



After proving proof of principle for generating the laser pulse pattern required for creating 50-60 ns notches at the Booster revolution frequency within each linac pulse, the team started to design the 19” rack mount Optical Pattern Generator to be used in the final system. During this quarter the required components were purchased and the lay out of the chassis commenced. This module is expected to be complete by the end of January. One of the requirements of the laser system is to provide spatially uniform roof-top beam profile (uniform photon fluence) to all ions in the H- bunch regardless of their amplitude. A novel scheme for the production of this spatial profile was proposed and tested. This technique looks quite promising. A camera snapshot of the obtained profile is shown below. Here, one can see a Gaussian profile in one dimension with the profile 7mm x 1mm.

In addition to the above advances progress continue on the 3D model of the vacuum chamber/optical cavity design working out fine detail and eliminating internal component interferences. The cavity is shown attached to the RFQ in the MEBT beam line in the next figure.



WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

First Linac Level-3 WBS completed (FY13-Q2).

WBS 1.1.4 *Not Used*

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WBS 1.1.5 Utilities

The Linac Utilities, such as power distribution and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are two Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

Little progress was done during this quarter on the programming of the Motor Control Center PROFIBUS/SCADA system which was initiated. The reason is simply due to manpower restriction.

WBS 1.1.5.2 *Not Used*

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WBS 1.1.5.3 Vacuum System

Experts are currently, waiting for summer shutdown to finish installation of the last rougher pump in the Linac tunnel. All the prep work has been completed upstairs.

WBS 1.2 Booster

Part of the PIP effort for the Booster Accelerator is to address the increase proton beam flux that will be demanded by the Fermilab program in the upcoming years. The increased flux will be achieved by providing beam on more/all of the Booster cycles; certain equipment will increase from an average 7.5 Hz to 15Hz. Overheating of old components is a major concern; several Booster PIP tasks are to upgrade/refurbish equipment to run at 15 Hz.

The aging original equipment and infrastructure of the Booster are vulnerable due to obsolescence and increase wear due to the increase of flux. Some of the PIP effort is to replace these possible reliability problems.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

The specifications for the anode supplies were completed. Design work has continued through the quarter. The anode supply transformers (ordered at the end of FY13) are in the process of being manufactured.

WBS 1.2.1.2 Bias Supply

The retrofit of the first bias supply has begun. The retrofit is being documented as a procedure for the remaining bias supplies. There are many pieces (cables and cooling pipes) which are being specified as the retrofit proceeds. Heat sink work continues.

WBS 1.2.1.3 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.1.4 Cavity Test Stand

The cavity test stand task will not be done since there will be no benefit to PIP.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

The refurbishment of the ninth cavity tuner set was completed this quarter. The time it takes to refurbish and test each set has averaged over the last three sets is a little more than nine weeks. Last quarter, the first cavity-tuner set that had been removed previously was reworked, retested and reinstalled. During the quarter, another previously refurbished cavity developed an RF leak; it has been removed from operations and will be reworked and tested during FY14Q2. Additional manpower has

been identified but is being shared with operations. Discussions continue on how to increase the labor to this critical task.

WBS 1.2.1.6 New Tuners

Previously, a high power test stand for ferrite cores showed that one of four different core sets (two different permeabilities from two vendors) was acceptable. The acceptable core samples have been implemented into a tuner and been certified. A purchase order for one set of ferrite cores was done; delivery and testing of these cores are complete. We have been working with the vendor as they establish the correct recipe and process to manufacture ferrite cores with a high permeability. A small order of five cores was delivered and tested. These did barely satisfy the permeability specification but were slightly the wrong physical dimensions. The vendor believes it can raise the permeability and will deliver another set of test ferrite cores in FY14Q2.

WBS 1.2.1.7 New Cavities

Comparison of a model developed for the current Booster RF cavities and the temperature measurements taken as part of the refurbishment task continues. Further tests of cooling rates will be done to be compared with the simulation. A preliminary look into making small improvements to the cavity-tuner design is being done. In addition, we are starting to investigate possible benefits of using a higher order harmonic cavity; in particular, for beam capture and initial acceleration.

WBS 1.2.1.8 Cavity 1013

The cavity was put under vacuum and is leak tight. The next step is to attach tuners. The existing extra four tuners are being used in the refurbishment task (WBS 1.2.1.5); cavity 1013 will have to wait for new tuners (WBS 1.2.1.6) to be built. This task requires the same manpower as the refurbishment task.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

The people assign to the task of organizing, performing and analyzing beam studies has been consistent for the last two quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several from the Accelerator Physics Center also involved. They are in email contact with the original person while they resurrect the codes, procedures and analyses.

The Booster was operational the entire quarter. Work is on-going to smooth the orbit to an ideal orbit (see WBS 1.2.2.2) and measure the optics.

WBS 1.2.2.2 Alignment and Aperture

Currently, no further magnets are scheduled to be moved. There are a few candidate magnets, but current simulation and beam studies (WBS 1.2.2.1) do not suggest that there will be noticeable

improvement. The centers of the apertures have been designated as the ideal orbit (see WBS 1.2.2.1). We may return to this task in the future.

WBS 1.2.2.3 Booster Notcher

Assembly of the upgraded power systems has been the main focus this quarter. A completed short kicker magnet is to be tested in the near future with the upgraded power system. Further assembly of kicker magnets will follow the successful testing of the short kicker magnets.

WBS 1.2.2.4 Booster Cogging

A new electronics board has been used to mimic the existing system. The further capabilities of the this prototype board are being implemented and tested. Code development associated with the new board is on-going.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems.

WBS 1.2.2.6 Radiation Shielding

Beam studies concerning the beam loss profile and measurements of beam loss radiation through penetrations have been done. Additional measurements are being planned. There are on-going discussions of the results of the studies and simulations with experts and ES&H.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

The specifications for the beam position monitor system are nearly complete and initial design work has started.

WBS 1.2.3.2 Dampers

Studies to verify damper design choices continue.

WBS 1.2.4 *Not Used*

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WBS 1.2.5 Utilities

WBS 1.2.5.1 Low Conductivity Water System

The task is done.

WBS 1.2.5.2 Power Distribution

The last power transformer is being manufactured; it was ordered at the end of FY13. The transformer will be identical to the two transformers previously purchased by PIP.

WBS 1.2.5.3 Vacuum System

The aged components will be replaced as opportunities present themselves with downtime of the Booster. Previously purchased vacuum equipment awaits opportunities for installation.

WBS 1.2.7 Solid State Upgrade

The task is done.

PIP Budget – Costs and Obligations Updates (FY14 Q1)

This first quarter in FY14 has had no significant budget or labor variances. Completion on the long NoVA and PS shutdown and ramp up of operations has gone smoothly. Significant progress has been made in several tasks as labor became available (for example, Linac Modulators and the Pulsed Notcher Power Supply System.) However, shortages of labor still impact some tasks such as the critical Booster cavity refurbishment effort. Discussions with lab management look to add some additional labor in FY14 Q2. Restrictions on M&S spending due to the federal budget impasse were resolved during the quarter and did not hamper PIP planning.

Table 2 Q1 FY14 PIP OBL Budget

FY14 PIP OBL BUDGET K$	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	8,625.2	230.5	2336.9	6,057.8
Labor	5,804.2	858.3		4,945.9
FY14 Sums	14,429.4	1,088.8	2,336.9	11,003.7

The M&S profile as mentioned above was slightly impacted by federal budget issues but will become more aligned with the RLS in Q2. Labor has picked up the shutdown and again after the start of the new year (holidays) and is expected to show further improvement in Q2.