To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY15 Q2

Report #10 April 17, 2015

Project Milestones

There was 1 Linac scheduled milestones level 3. See table 1 below for complete listing of PIP milestones for FY15.
Linac WBS Linac HLRF: *Prototype Klystron Final Assy Drawings Complete.* Milestone was completed.

LVL	WBS	Description	Date
3	1.02.03.01.02.05	Booster BPM System, Hdw. & Firmware Prototype Design Complete	5/1/15
2	1.02.03.02.01.14	Booster Long. Dampers Complete - boards installed & operational	5/15/15
3	1.01.02.03.03.20	Linac Notch (FA) Certify all three stages ready for installation	5/18/15
3	1.01.02.03.06.23	Linac Notch Beam shaping technology chosen	10/8/14
3	1.01.02.03.05.33	Linac Notch Final Optical Cavity Certified	10/22/14
3	1.02.01.01.03	Specifications for Anode Power Supply Documented	11/26/14
4	1.01.05.02.01.10	Linac LCW System Complete	12/30/14
3	1.01.05.02.02.16	Complete 55 LCW Spare Syst	12/18/14
4	1.01.05.02.01.09	Complete Installation of New Dual Temp System	12/30/14
3	1.01.01.01.02.02	Prototype Klystron Final Assembly Drawings Complete	3/2/15
3	1.02.03.02.01.09	Specifications document for Booster longitudinal dampers complete	3/18/15
2	1.02.02.04.07	Commissioning & Beam Studies - Booster Cogging System Complete	4/15/15
3	1.01.02.03.02.26	OPG module ready for installation	5/4/15
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install into OP	6/9/15
3	1.02.01.02.03.16	Finish program of gutting & assembling within Bias Supply enclosures	6/22/15
3	1.02.03.01.01.03	Booster BPM Specification Complete	7/2/15
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	7/22/15
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	7/21/15

Table 1 FY15 PIP Milestones

Booster also had 1 scheduled milestone this quarter and it was a level 3 as well. The specifications document for the Booster longitudinal dampers. This was also completed and entered into the laboratory's document database. The next quarter 4 level 3 milestones scheduled all of which look to be on schedule (one is already completed).

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 200MHz 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

The klystron prototype development continues to make good progress. As far Klystron design goes, the gun isolation tank and solenoid/frame assembly have been drawn and ordered. The SNS-style high voltage socked has been redrawn in CPI's format and submitted for purchasing. The design of the x-ray shielding is complete and detail drawings are being made at the end of the quarter. The customer interface panel has been designed and L2 manger worked close to CPI lead engineer to finalize styles of connectors for water lines, solenoid connections, ion pumps and RF input.

For klystron manufacturer status, most of the long lead items were delivered on time during this quarter except for the drift tubes and the domes. The majority of the seal-in parts have arrived at CPI and are going through the plate shop for cleaning. A major concern is the delay in getting the cavity parts to begin construction. The drift tubes and domes required rework by the suppliers and are thus delayed. The lead engineer worked close with the suppliers to resolve the issue and middle February the suppliers finally resolved their difficulties with manufacturing them and shipping the parts to CPI is now schedule for late April. Assembly has started on all components which are at company's site, such as input loop and circuit, output window and water cooling lines.

As stated, the delays of seal-in parts are the main risk to the schedule of the project. Several parts are now over a month delayed. However, the schedule was planned with additional time to accommodate delays, so the delivery date is still In October 2015.

Finally, in the last report was mentioned that FNAL, SLAC and CPI were close to an agreement to have the klystron tested at the company site. This was successful finalized this quarter. Since then, FNAL has been working with CPI to create a list of RF hardware and necessary instruments to create the acceptance test setup. This work continues at the end of the quarter.

WBS 1.1.1.2 Linac Modulator

AD/EE Support Design: Work is progressing well on developing a prototype modulator capable of replacing the present tube based design. During this quarter the all 7 control cards design was finalized. More manpower was added to the project to aid the assembly of the control cards to be used on the 28 cell version. High voltage testing on the cells were performed and results revealed important and necessary

modifications on the cell backplane structure and the bracket assembly. All these modification have already being incorporated into the design. See figure 1 below of new Linac modulator being assembled.

Procurement continues on purchasing parts necessary for the full size modulator, which is being developed in parallel with the half-size modulator.

An important activity initiated during this quarter, which is the completion of a test code for the feed forward learning for the Marx Modulator. The code mature enough that studies have been conducted in one of the Linac operational station to gain real-time experience with RF amplifier response during normal operational conditions, therefore subject to sparks, turn-on and regulation during flattop.

Also during this quarter, the control relay rack block diagram was complete and is waiting on the interlock information to interface with present interlocks. Test of this new system should occur during the next quarter in the Linac Test Station.

Figure 1 Linac Marx modulator being assembled

WBS 1.1.1.3 7835 Procurement

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

Linac Level-4 WBS completed (FY15-Q1).

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

Work continues with the development of the laser notch system. Following the successful in-situ test performed during last quarter, efforts resumed this quarter to re-focus on finalizing the design and implement the lessons-learned during the tests. The full assembly was disassembled and moved back to the laser lab. During this quarter the free space amplifier modules, controller, power supply and chiller have been delivered. In addition, a new fiber tray had to be made in order to hold the bare fiber up to the new seed source diode . The operation of the new seed source in the OPG was checked and the center wavelength and bandwidth look fine. However it was noticed that the new diode does have a photodiode responsivity larger than the previous diode which puts our nominal diode output current close to the limit for operating in a constant power mode without much head room. A fix to this feature has been given by the manufactured and it was implemented.

The modified PriTel amplifier was delivered and tested during this quarter. It very nicely produces 2W as designed. However, during the tests of the length of a gap in the pulse structure the pre-amp output on the photodiode and the power amp input monitor went to zero. Experts and the company worked closely together to diagnose the problem. The pump fiber output was checked and it was only a few mW (the nominal for the pump is 300-400 mW). This issue was cause by creating too large of a gap in the 450 kHz burst of laser pulses. This test revealed that the system is limited to about 3 -5 us gap in laser pulses. The company engineer verified that munch over 10 us gaps can cause the amplifier to create large pulses after the gap that can feedback to the pump. The rest of the quarter was devoted to alternatives on how to address this issue on several fronts to make sure that if the seed pulses disappear for longer than ~3 us, the keep alive will be un-clamped. Furthermore, additional protection to turn things off if either the seed pulses or keep alive disappear were discussed and a solution found. In addition experts asked for an isolator or band pass filter for pump protection.

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, water and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are three Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.1.5.2 LCW distribution

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.5.3 Vacuum System

Linac Level-4 WBS completed (FY14-Q4).

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.

For a while the scope of the New Cavity task (1.2.1.7) has been expanding to include a 2nd harmonic cavity, the rework of two additional cavities and the creation of three additional RF stations. During FY15Q2, these items were split into their own tasks: 1.2.1.9, 1.2.1.10 and 1.2.1.11.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

Parts for the anode supplies have been received. Sub-assemblies are being constructed and tested. Final assembly will occur in FY15Q3 with testing to follow. During the 2015 shutdown, the anode supplies will be installed.

Figure 2 The two Booster anodes (large grey boxes) and testing gear

WBS 1.2.1.2 Bias Supply

Six retrofit bias supplies have been tested and installed. The seventh retrofit is complete and awaits testing. Two more bias supplies are undergoing retrofits.

WBS 1.2.1.3 *Not Used*

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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

Three more cavity tuner sets were refurbished this quarter. The time it takes to refurbish and test each set has averaged over the last three sets is a little more than six weeks.

One previously refurbished cavity failed during operation. It appears that a vacuum problem with the cavity ceramic is a problem. The refurbished tuners from this cavity were removed and placed upon a recently refurbished cavity.

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. The tuner was installed on a re-furbished cavity; the cavity has been operation since FY14Q4. A purchase order for enough ferrite cores to build twenty tuners was placed. The first part of the order arrived at the end of FY15Q1. During FY15Q2, Technical Division has

started production of new tuners. During this quarter, the first two were built; a third tuner is being put together.

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. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); further measurements will be done during the next cavity tuner set certification.

WBS 1.2.1.8 Cavity 1013

The cavity was put into operation in FY14Q4 and was operational during FY15Q1. There have been no problems with this reworked cavity. This task is considered complete.

WBS 1.2.1.9 Second Harmonic Cavity

This has been separated out from 1.2.1.7. We are continuing to investigate possible benefits of using a higher order harmonic cavity; in particular, for beam capture and transition crossing. We have been investigating a perpendicular biased cavity. Work previously done at SSC and TRUIMF was our starting point. Modelling and simulations progress has led to improvement over the old designs. Garnet sample testing show that it is suitable for a perpendicular biased cavity. Parts are being orders and manufacture to build a partial mock-up which will be used for further testing for design and simulation validation.

WBS 1.2.1.10 Rework of Two Cavities

Although not new cavities, PIP has decided to reclaim two other cavities and rework them to be the 21st and 22nd Booster cavities (similar to the rework done for cavity 1013; WBS 1.2.1.8). Long lead time items are being procured. This work will commence after the refurbishment task (1.2.1.5) is complete. Tuners will be provided by work done by the New Tuner task (1.2.1.6).

WBS 1.2.1.11 Three New RF Stations

In addition, PIP will implement three additional RF stations to bring the total number of Booster RF stations to 22. This requires electrical work, water cooling work, assembly of power equipment and cable pulling. The 20th RF station is to be completed during the 2015 shutdown and the remaining two RF stations to be completed in the following shutdown. Detail planning for the 20th RF station is on-going. For the other two stations, an initial conceptual layout has been done.

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 few quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several physicists from the Accelerator Physics Center also involved. The control programs for adjusting the lattice and tunes have been combined. The resulting application can adjust either the lattice or tune without affecting the other. Testing of this application is on-going and has to not affect operations.

The Booster was operational most of this quarter. Work is on-going to smooth the orbit to an ideal orbit (see WBS 1.2.2.2), measure the optics and adjust optics throughout the ramp cycle.

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

This task would be considered complete with the exception of some modified components are more activated than expected. We continue studies to understand.

WBS 1.2.2.4 Booster Cogging

A new electronics board has been used to mimic the existing system. The further capabilities of this board are being implemented and tested. Code development associated with the new board is on-going. Beam tests of delivering cogged beam to a downstream accelerator have been done and generally the new cogging scheme is used the majority of the time during operations. There are still a few rare occurrence problems to be solved. This cogging board still needs to interface with the Linac laser notcher in FY16.

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. Simulation studies involve the effectiveness of the passive shielding, active detectors and radioactive source terms for penetrations are nearly complete.

A Total Loss Monitor (TLM) system of eight long detectors has been installed; each detector covers three Booster periods. The assembly, testing and installation of the needed electronics was completed during FY15Q2. Beam loss tests and measurements have continued. The TLM and radiation shielding assessment need to be concluded before much more proton flux can be attempted.

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. Final requirements are being checked.

WBS 1.2.4 *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 1.2.5 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 has been manufactured. The transformer is identical to the two transformers previously purchased by PIP. Plans for installation during the shutdown were postponed when it was determined that the connection of this transformer is different than other replacements. During FY15Q1, engineers designed a solution and parts are being manufactured. The installation is now scheduled for the 2015 shutdown.

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. During the shutdown, some vacuum work was done.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs and Obligations Updates (FY15 Q2)

The FY15 second quarter had no significant budget changes. PIP to PIP II alignment discussions are still ongoing with plans to complete a document describing the necessary work to be released in FY15.

PIP budget and labor through March of FY15 are provided below. A significant amount of the budget will be allocated for the new Linac modulators. The testing of the first modulator was required before completing the purchasing for the other 5 modulators.

FY15 PIP OBL BUDGET K$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	6,454.5	928.4	0.0	5,526.2
Labor	5,465.5	2,946.6		2,518.8
FY15 Sums	11,920.0	3,875.0	0.0	8,045.0

Table 2 PIP FY15 Q2 budget table

The labor for this past quarter as shown in figure 3 below shows that PIP has been close on most of the requested labor. The bump in mechanical from TD is due to the increased effort in building new Booster tuners. This will improve the refurbishment process and help improve uptime.

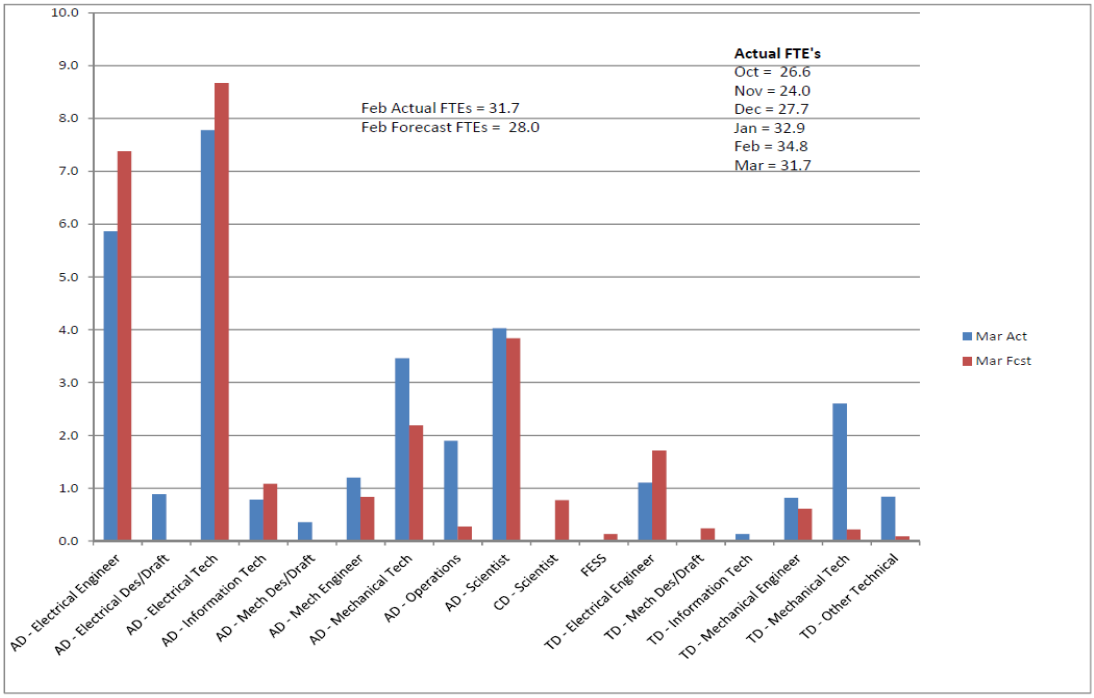

Table 3 PIP labor comparison - Forecast vs actual to date