To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY16 Q2

Report #14 April 1st, 2016

Project Milestones

Project Milestones

There was 1 Linac scheduled milestones level 3 and 4 this quarter. The level 4 was the *Completion of Final acceptance test*. This milestone was close to completion at the end of the quarter. A detailed explanation is given below within WBS 1.1.1.1 High Level RF report. The level 3 milestone, *CPS System tested & Qualified*, came in about a month late due to vendor issues. One Level 4 delayed from the previous quarter, *Notch Beam Shaping*, is progressing and should meet the forecasted finish date. Booster had no milestones in the FY16 Q2 but has a level 3 from previous quarter that has not been met. Labor for the *Booster BPM Production Procure/Assembly Complete* was delayed to removal of labor from PIP to work on a critical Recycler instrumentation issue.

Table 1 PIP milestones

L	WBS	Description	Baseline	Fcst Fin
3	1.02.01.02.03.16	Finish program of gutting & assembling Bias Supply enclosures	4/15/15	11/11/16
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	4/21/15	4/21/16
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install	4/23/15	9/28/15
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	5/15/15	3/1/16
3	1.02.01.11.05	RF Station 20 Commissioned	7/6/15	10/6/15
4	1.01.02.03.06.33	Linac Notch Beam Shaping, Diag., Dump ready for installation	9/21/15	3/16/16
3	1.02.01.02.03.16	Finish program of gutting & assembling within Bias supply enclosures	10/19/15	11/11/15
2	1.02.01.01.13	Anode Power Supply Operational	10/21/15	10/14/15
2	1.02.01.01.14	All Anode Supply Documentation Complete	10/21/15	1/21/16
3	1.02.01.02.04.12	Complete Bias Supply testing	10/26/15	11/18/15
2	1.02.01.02.05.12	Complete Bias Supply installation (upgrade ends)	11/2/15	11/25/15
2	1.02.01.05.03.20	Booster RF Cavity Refurbishment Complete	12/3/15	12/8/15
4	1.01.01.01.02.01.02	Completion of Final Acceptance Test (at CPI)	1/5/16	12/14/15
3	1.01.01.02.10.03.41	CPS System Tested & Qualified	1/26/16	4/6/16
2	1.02.01.09.02.02.09	PA Amp Testing Complete	5/13/16	9/16/16
2	1.02.01.07.02.04	Booster Cavity Initial Design Complete	6/2/16	9/2/16
2	1.02.01.11.09	RF stations 21 & 22 Commissioned	9/2/16	9/2/17

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

During this quarter the final drafting of the linac gallery floorplan layout was completed. The final document report of this task is almost complete. Nevertheless, PIP management concede the approval to have this task code complete closed at the end of this quarter. The request was submitted to the AD Financial office and they are currently working on this.

WBS 1.1.1.2 Linac Modulator

Work is progressing well on developing a prototype modulator capable of replacing the present tube based design.

Commissioning work continued with the 28 cell prototype Marx Modulator during this quarter. The learning system was implemented and commissioned. Additional trip response states were added to the control system so that RF related trips would inhibit the modulator rather than tripping it off. Preliminary ACNET controls for the modulator have been implemented. In early March, LRF1 was switched to the new modulator and sustained operations for an entire day shift with HEP beam. On March 21st LRF1 was again switched to the Marx Modulator for long term testing, and has been running on the Marx since to gain experience of long term operation conditions.

For the 54 cell prototype, cell construction continued as parts were drafted and fabricated, and is nearly complete. The support structures for the cells inside the Marx Cabinet were fabricated and installed [Fig. 2]. Last quarter was reported that a purchase order for 24 power supplies unit were put in place. This quarter all the 24 charging supplies were received and are currently being tested. Two thirds of the supplies have been tested thus far without problems. The cabinet for the charging supplies was manufactured and has been delivered [Fig. 1]. The charging supply control cards have all been drafted and are currently being fabricated. The controls crate has been assembled and has all of the cards installed except the FPGA card which still needs to be redesigned, drafted, and assembled.

Figure 1: Linac Marx-Modulator Charging Supply cabinet

Figure 4: Linac Marx-Modulator : 54 cells prototype unit

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. A large part of the past quarter was spent trying to understand the instability consisting of large power spikes in both the forward and reverse directions from the second (power) fiber amplifier when the pump power was increased to its design level. The investigation lasted most of the quarter and was finally traced to an interaction of the seed laser pulse structure with acoustic phonons in the fiber, commonly known as SBS. Simply increasing the keep-alive pulses with a burst of 200 MHz pulses resolved the instability at the highest power levels. Based upon this result, a second generation hardware keep-alive circuit was designed.

Once the instability was resolved, the last fiber amplifier was installed, connected to the CW amplifier delivery fiber and used to transport the beam from the CW amplifier into the free-space optics box. This beam was used for alignment and testing of the piezo-mirror control and Optical BPM's (OBPM's) final wiring and computer interface.

In addition, the transport and dump enclosures were completed and installed on an extension of the optical cart (for lab testing). The transport optics (piezo-mirrors & OBPM's were installed and tested with beam.

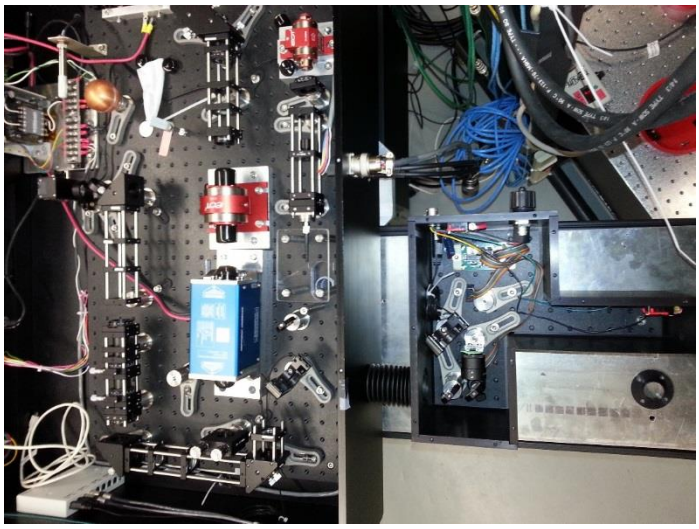

Figure 3. Mounting of transport enclosure for lab testing.

After the alignment of the free space optical components, the positions of the optical telescope lenses were optimized. Following the alignment process, commissioning of the last fiber amplifier in the chain begun. During the commissioning process an erroneous value was sent to the amplifier causing damage to the gain fiber. The unit has been sent back to the manufacturer for repair. In the meantime optics optimization continues.

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*

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 1.1.5 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. Enough PIP tasks have been completed so that in FY16Q1 the Booster was capable of operating 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

This task is complete with the delivery of the final documentation.

WBS 1.2.1.2 Bias Supply

This task is complete.

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 nineteenth cavity tuner set was refurbished and put into operation during FY16Q1. This task is complete.

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. During FY15Q4, the vendor has delivered, and we have accepted, the balance of one set of ferrites. The vendor had encountered a problem making the second set of ferrites (low value of permeability). The vendor has corrected the problem; the balance of ferrites were delivered FY16Q2.

Fermilab Technical Division is using the ferrite cores with other sub-assemblies to build new tuners. The assembly group has gained experience building the new tuners. Now, assembly is about three weeks to complete a tuner. Fifteen tuners have been built and passed acceptance tests.

WBS 1.2.1.7 Replacement 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 were done to compare with the simulation. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); the last set of measurements were done during the final refurbished cavity tuner set certification. Simulation model verification continues.

The task has been renamed from new to replacement. Fermilab has recognized that any new/replacement cavities should work with PIP II. Requirements satisfying now and for the future have been determined. A review of the technical specifications was held as well as presented to the Fermilab Accelerator Advisory Committee (AAC). The review panel and AAC agreed that the specifications meet the needs of PIP and PIP II.

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

The investigation of possible benefits of using a higher order harmonic cavity continues; in particular, for beam capture and transition crossing. The investigation is focused upon 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. A mock-up of the tuner was built and measurements have been made. An analysis of the measurements is underway to compare with the simulations. A fixture is being built to test the final power amplifier (PA) to make certain that the PA will work sufficiently at the higher frequencies. Figure 4 below is the latest 3D model of the perpendicular cavity.

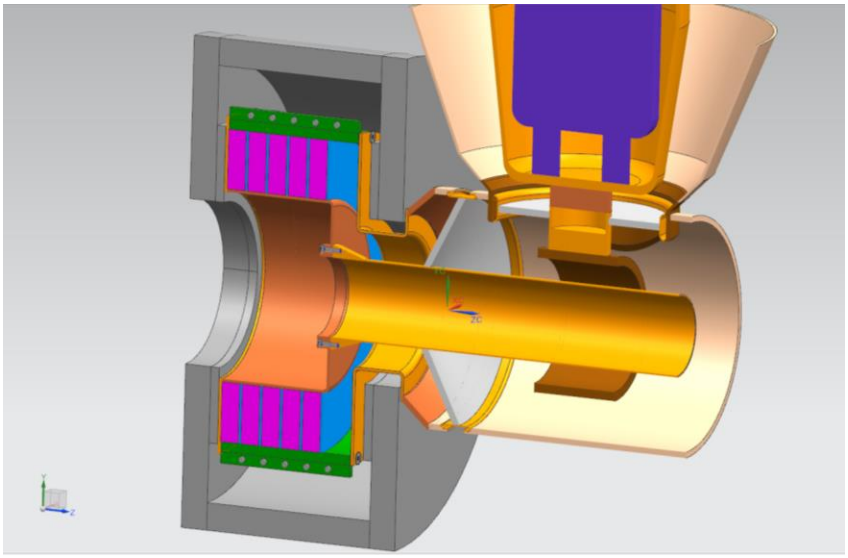

Figure 4 3D model of perpendicular 2nd harmonic cavity

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 has commenced with the completion of the refurbishment task (1.2.1.5). 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 was completed during the 2015 shutdown. This new station was commissioning and put into operation in FY16Q1.

The remaining two RF stations will be completed in the 2016 summer shutdown. An initial conceptual layout has been done for these two stations. Clearing of space and preparing these areas has begun.

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.

Studies have been done investigating of injecting beam earlier. By injecting beam earlier, the resulting beam should have a smaller energy spread. A plan to slowly implement the early beam injection scheme has been developed. Studies continue.

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. Part of the upstream absorber mask was removed. By removal, of the activated mask, the area upstream of the absorber will hopefully not be susceptible to as much gamma ray shine from activated components. The part of the mask that remained, is further into the absorber shielding and hence workers in the area will have less exposure. During FY16, activation measurements of components of the absorber and the near the absorber will be done to see if the activation caused by the notch beam is contained within the absorber. We will continue studies to understand.

WBS 1.2.2.4 Booster Cogging

Studies of the new cogging board and code were concluded in FY15Q3. The cogging board was put into operation. This task is finished with the exception for interfacing with Linac laser notching system in FY16 or FY17.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems. A group has started studies of using existing collimation components. These studies include simulations, beam loss observations and exercising collimators movements. A new primary collimator has been built; it was installed during FY16Q2. Initial studies have been done and analysis is on-going.

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 analyses and write-up investigating beam loss as well as TLM responses was completed. The documentation has been sent to the Shielding Assessment Review Panel. 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 design work for the beam position monitor system is complete and procurement has started. This task has stalled due to personnel being redirected to solving instrumentation problems concerning Fermilab achieving 700 KW.

WBS 1.2.3.2 Dampers

Studies were conducted which showed that the damper board and code work and will perform the needed function. During FY15Q4, the final programming was done. The dampers were commissioned in FY16Q1 and are part of operations. This task is essentially complete with the exception of the final documentation.

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

This task is complete.

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. The last procurement was started at the end of FY15. The end of the PIP vacuum work will be done during the 2016 summer shutdown.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs, Labor and Obligations Updates (FY16 Q1)

The FY16 second quarter continued with the assumption that carryover and other funds removed from PIP after FY15 would not return. PIP mangers continued to plan to the reduced funding. Managers re-assessed all remaining tasks in an effort to reduce M&S but maintain projected labor. A RLS was

developed to meet the new funding guidance that had minimal impact to labor and PIP progress. A final PIP budget for FY16 and including out years has not yet been formally provided. A final decision is pending and should be ready for release soon – but we have modified our plans based upon the numbers shown in the table below.

FY16 PIP OBL BUDGET K$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	4,977.2	663.6	15.6	4,298.0
Labor	6,142.5	2,963.2		3,179.3
FY15 Sums	11,119.7	3,626.8	15.6	7,477.3

Table 1 PIP FY16 (through Dec) budget table

Chart 1 and 2 below shows that labor has been consistent this past quarter except again for instrumentation – which was pulled off of PIP to resolve issues with the Recycler DCCT and other items. We had expected this to be remedied in the next quarter but it has taken longer and now looks to be getting back on track in FY16 Q3. However, PIP's overall forecasted labor and actual has been in very good agreement.

Chart 1 Labor: Forecasted vs Actual

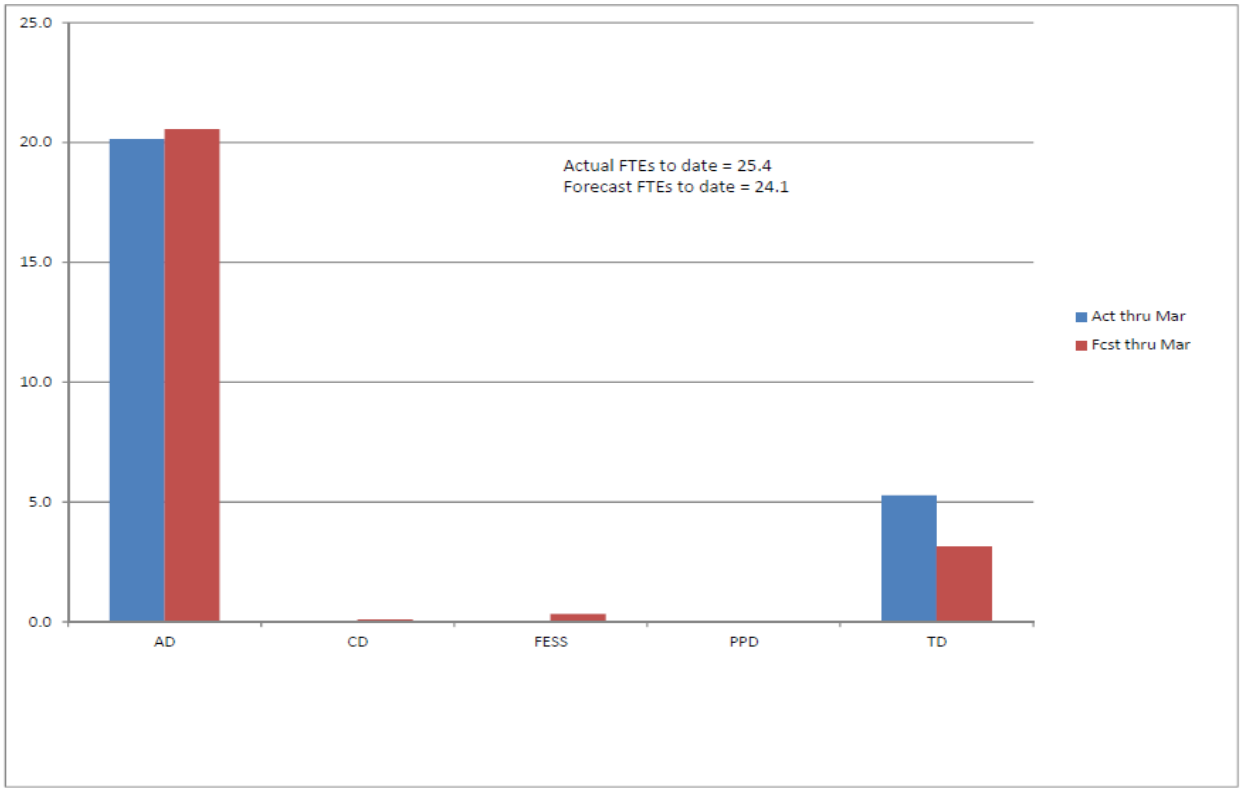

Chart 2 Labor trends - note the Anode task bump at end of FY15 – line designates start of FY16