

From: William Pellico, PIP Leader

Bob Zwaska: PIP Deputy Leader, Fernanda G. Garcia: PIP Linac Manager, Keith Gollwitzer: PIP
Booster Manager, Kenneth Domann: PIP Planning Controls

Subject: Proton Improvement Plan

Project Quarterly Summary FY14 Q4

Report #8 Oct 12, 2014

Project Milestones

There were 5 Linac scheduled milestones, all level 3. Out of these five, four were met.

Linac WBS High Level RF: *Critical Design Review (CDR)* was successful complete July 10th.

Linac WBS Modulator: *Approval to build 53 cells prototype modulator*. This milestone comes 60 days ahead of schedule. The reason for that was two-fold: first, the AD/EE support robust design of the modulator combined with encouraging results from the preliminary multi-cell testing and second due to PIP end-of year budget redistribution. This early start on the ability to procure long-lead items for the full voltage prototype unit pushes the schedule for early completion by approximately 5 months.

Linac WBS Utilities / LCW Upgrade / CUB 55 LCW spare pump: *Complete 55 LCW spare system*. This milestone was not met this quarter due to issues with contractors overrun the budget during the preparatory work. A more detailed explanation of what happened will be discussed later in this report.

Linac WBS Utilities / Power Distribution: *Complete installation of L1 pulse transformer &*

Linac WBS Utilities / Vacuum: *Complete vacuum upgrade*. Both these milestones were complete and with that, mark the completion of two more Level-4 WBS within PIP Linac.

Booster had 1 level 1, 2 level 2 milestones, 1 level 3 milestones. The level 3 milestone was for completing the conversion of the first Booster RF cavity bias supply. The level 2 milestones were for the Booster damper and beam position monitor (BPM) specification completion. These are discussed in the task section below. Table one below summarizes the 3 high level milestones completed or scheduled for FY14 Q4.

Table 1 PIP High Level Milestones

		FY14	
2	1.2.2.3	L12 Short Notcher Complete	Q3
2	1.2.3.2	Longitudinal Dampers Complete - boards installed & operational	Q4
1	1.2.1.1	Anode Supplies	Q4

The two milestones not completed and noted in red above were delayed early in FY14 due to unavailable labor. Both required labor that had been involved in the startup of the Recycler and MI after the yearlong NOvA shutdown. Labor was allocated in the third quarter and both of these tasks are moving ahead and will be completed in FY15. More details are provided in the individual task section below.

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 Systems

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

A Critical Design Review (CDR) was remotely conducted between CPI, SLAC and Fermilab in July 10th. The review was a success and no significant concerns were encountered with the design. A final report was submitted a couple of days from the reviewers with follow-up questions which were addressed by the manufacturer technical team about 25 days later. This review marks a completion of a milestone. At Fermilab, efforts continue to assemble the team who will be involved with the in-house acceptance testing. The main focus is on the availability of the modulator to perform the test. Initial plans were to use one of the two bouncer modulators in the NLM building. However, the usage of such equipment is not certain due to the NML schedule. Another alternative is to use a third bouncer modulator which is partially complete, but will require about ~\$1/4M investment to make it operational. PIP management is encouraging the team to look for another alternative, as beyond the klystron testing, this modulator has no other certain usage at the moment. With that direction, the project manager contacted Craig Burkhart at SLAC to inquire about the possibility to have the acceptance testing done at SLAC. At this initial stage of this proposal, Craig seems to think that testing at SLAC is possible. In this scenario, the testing would be performed with the P2-Marx. More detail and careful thought of what would take to do that is ongoing at the end of the quarter. Also, P2-Marx is undergoing a life testing but there is a possibility that it also be tasked to other SLAC-mission activities, which only one of them is time critical. So depending on the time expect for the testing to occur, the equipment may be available.

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. The design of the enclosure has been completed and it is near completion by an outside vendor. The delivery of this device is schedule for next month. The gate driver circuit board – card that controls each cell separately -- has been redesigned and laid out, with the circuit boards ordered. A modification on the cell design was incorporated after discovering that some capacitors were damaged during the short circuit test. The design now includes two snubber capacitors, which increased the di/dt capability of each cell. Short circuit testing continues on single cells to improve performance. The charging supply design has started, which will allow for full loading conditions and 15Hz operation. A feed-forward control system is being designed, which will be tested on the present modulator to show the capabilities of feed-forward to reduce pulse to pulse variations. A circuit board is being designed by Linac group to test the feed-forward system on the present tube modulator.

An important step towards building a full voltage prototype was reached. Project Manager re-evaluated the end-of-year funds and re-distributed among few tasks which demonstrated to have a robust and advanced design. AD/EE support modulator was among these tasks. With that, additional funds were released this quarter allowing the team to proceed with the long-lead items to build a full voltage modulator. Most of the parts have been ordered for the 53 cell design, with many parts having already arrived. With the additional funds, a milestone originally schedule for FY15/Q1 has been met this quarter.

WBS 1.1.1.3 7835 Procurement

No news on this task.

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

During this quarter, a final presentation on the simulation study done on the DTL using Parmila and TraceWin codes were presented at the PIP meeting. Suggestions on how to retune some of the Electro-Quadrupole Magnet (EQM) inside the drift tubes were presented. A machine study was carried out trying to implement the new gradient values. At the end of the study period, a hybrid configuration was achieved. Under these circumstances, no significant change on the beam loss profile or beam quality was noticed. Another attempt will most likely occur after resuming beam operations upon completion of the site-wide shut down. Lastly, at the end of this quarter, a paper outline was drafted with the deadline to be complete in 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

The Laser Notch program has progressed during the 4th quarter on several fronts. The main accomplishment during this quarter was to complete the construction of the Vacuum Optical Cavity, the alignment of the cavity on the bench, the installation of the cavity on the RFQ and the construction of the test laser system for monitoring the mirror reflectivity. Figure 1 shows the Vacuum Optical Cavity mounted on a test fixture for aligning the internal mirrors. Here, the rear sealing surface of the flange that mates up with the RFQ is shown. Also shown is the viewport for the input laser and one of the high reflectivity cavity mirrors along with its adjustable holder. The second picture shows the cavity installed on the RFQ and the first quad in the MEBT. The viewport is covered to protect the glass and coating.

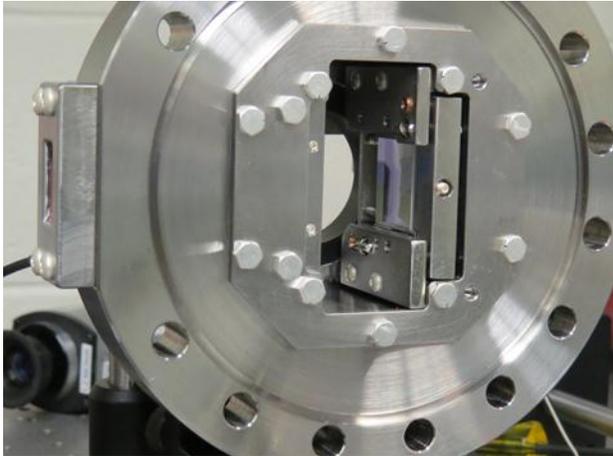


Figure 1: Vacuum Optical Cavity on test bench for mirror alignment.



Figure 2: The Vacuum Optical Cavity installed in the MEBT.

Other work includes the identification and purchase of a more stable laser seed source which will be better matched to the free space amplifier gain spectrum and the purchase of the free space laser amplifier system.

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

This quarter was extremely busy for this particular task. The L1 transformer was successfully lowered to the Linac basement and staged at the temporary storage area July 19. After completing this phase, the team started focusing on the details and plans for the final installation. The task started on time at the beginning of the lab wide shut down. The installation, which took 12 days to complete, went very smoothly. The primary side of the transformer was energized first without any load to bring the coil to a stable temperature and remove any moisture trapped in it. After 4 days under these conditions, the

secondary side was energized and load was applied to the unit. The transition was successful and the installation is complete. Some details of the installation can be seen on Figure 3.

Figure 3.: Linac L1 transformer installation



Fig. a: 3-phase transformer on the truck bed ready to be lifted.

Fig. b: Transformer (center) and switch gear (left) placed at final location.

Fig. c: Switch gear populated with breakers and the transformer enclosure complete.

The successful installation fulfills a Level 3 milestone 4 days later than expected and marks a completion of a Level-4 WBS within PIP.

WBS 1.1.5.2 LCW distribution

There are two main topics under this task: Dual Temp System Upgrade and CUB Chiller #3 backup pump.

Dual Temp System: A lot of work was done this quarter for the upgrade of the Linac dual temp system. As reported on the last quarter, the option chosen was the rooftop air conditioning unit – rather than continue with water heating/cooling type. PIP L4 manager hold meetings with all interested parties, such as FESS lead and supervisor engineers, FESS operations group, Linac building manager and AD/Operations to come up with an installation schedule. During this quarter the appropriate documentation was created; a DP-18 was generated, bid process was initiated and at the end of the quarter, all approvals and Note to Proceed (NTP) was created. Preparatory work was performed such as a controlled removal of the pipe insulation (asbestos mitigation) and relocation of the FIRUS lines which were identified to interfere with the new duct air path that needs to be installed in the gallery. The pre-meeting with contractors, FESS personnel and PIP L4 manager occurred at the end of this quarter. Despite the tight schedule, the installation of the air duct in the gallery is still on schedule to be complete within the shutdown timeframe.

CUB Chiller #3 backup pump: At the end of the last quarter, the L2 Linac manager discovered that the preparatory work performed by the T&M pipefitters contractor overrun the entire estimated budget for this part of the job. Immediately the task was put on hold by the L2

manager and an emergency meeting was held between PIP-L2, L3, L4 managers and FNAL/FESS Lead Engineer and FESS Task Manager associated with this project. After discussing options and evaluating the situation, L2 manager decided to move forward with T&M contract for electrical and mechanical trade but proceed with fixed price contract for the pipefitter. Also, a new cost estimate was generated and upon extensive explanation of the cost increase, additional funds were approved to this task to cover the remaining work. FESS team proceeded with the creation of the appropriate documentation; a DP-18 was generated and the bid process opened at the beginning of September. However, additional delays occurred on the business service department (BSSD) and the final approval and (NTP) was issued at the end of the quarter.

The re-plan generated after the emergency meeting counted with the mechanical and electrical part to proceed on schedule. However, this was not accomplished either. FESS justification was that another job initiated at CUB building was late and a decision was made by FESS Operations team to postpone the beginning of PIP job until the completion of the ongoing on. The reason given was that PIP could interrupt the progress and by postponing the start time would prevent Fermilab from being accused for holding up the work. This is an unfortunate situation. Despite the obstacles encountered on getting this task launched again, PIP team is confident that this task will be complete this calendar year. Because of all these constraints, a L3 milestone scheduled to occur FYQ4 was not met, which was the completion of the 55 LCW spare pump.

WBS 1.1.5.3 Vacuum System

All the parts expected to be delivered from the machine shop arrived few days prior the beginning of the shutdown 2014. At the beginning of the shutdown, the team was ready to start installing the new 400 MeV turbo pumps, vacuum isolation valves and vacuum instrumentation. Figure 4 shows the old and the new pump installed in one out of the 4 locations in the Linac 400 MeV transfer line.

Figure 4: Side by side comparison between the old vacuum turbo pump and the new one



Figure 4.a: Old turbo pump



Figure 4.b: Old turbo pump located at 400 MeV chopper region

The installation of this equipment went flawlessly and the machine is once again under vacuum. With that, the team met one level 3 milestone this quarter which was Linac vacuum upgrade complete. Also this milestone marks the completion of another Level-4 WBS within PIP.

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

Final design work has been done. The anode supply transformers (ordered at the end of FY13) are in the process of being manufactured. Parts for the anode supply system have been purchased and received. Vendor problems with delivery of the housings for the supplies has delayed the construction and testing of the supplies to FY15Q1.

WBS 1.2.1.2 Bias Supply

The first retrofit bias supply was installed and part of operations in FY14Q4. The retrofit of the second bias supply is finished. A third supply was retrofitted but waits to be high-power testing. A fourth retrofit has started.

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 twelfth 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. No new problems/issues were encountered during this quarter.

The cavities with taper damage were repaired. One taper-repaired cavity has been put back into operation. The other taper-repaired cavity is nearing the end of refurbishment and will be tested soon.

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 permeability 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 for most of FY14Q4. A purchase order for enough ferrite cores to build twenty tuners has been placed. Other components need to build new tuners have been ordered. Technical Division has started production of some sub-assemblies.

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.

In addition, we are starting to investigate possible benefits of using a higher order harmonic cavity; in particular, for beam capture and initial acceleration. 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 samples have been procured and properties have been tested as suitability for a perpendicular biased cavity.

WBS 1.2.1.8 Cavity 1013

The cavity was put under vacuum a while ago and is leak tight. Refurbished tuners were attached to cavity 1013 and went through extensive testing in FY14Q4. The cavity tested well and has been put into operation for several weeks prior to the shutdown.

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

Part of the upgraded power systems that was tested in parallel with operations were connected to a single long notcher kicker magnet. This configuration was successful during operations. After the commissioning of part of the power system, a long kicker magnet was replaced by two short kicker magnets. This configuration was operational for several weeks prior to the shutdown.

During the shutdown, the remainder of the short kicker magnets has been installed. The remaining part of the power systems was also installed. When the shutdown ends, the entire Booster notcher system will be commissioned. A spare kicker magnet is in the process of being constructed by Technical Division. It will be tested in FY15Q1.

WBS 1.2.2.4 Booster Cogging

A new electronics board has been used to mimic the existing system. The further capabilities of this prototype board are being implemented and tested. Code development associated with the new board is on-going. Beam tests of delivering clogged beam to a downstream accelerator were done prior to the shutdown and will continue in FY15Q1.

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 will involve the effectiveness of the passive shielding; active detectors and radioactive source terms for penetrations are being done.

A Total Loss Monitor system of eight long detectors has been installed; each detector covers three Booster periods. During FY15, beam loss tests and measurements will be done.

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*

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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. Plans for installation during the shutdown in FY14Q4 are proceeding.

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 FY14Q4 shutdown, some vacuum work will be done.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs and Obligations Updates (FY14 Q3)

The FY14 fourth quarter had no significant budget changes. Budget allocations were met in most of the tasks but several larger expected expenditures were not allocated. The first of these was due to PIP putting on hold labor and some material purchases for new cavities. As noted in the previous quarterly report, an alignment of PIP to the P5 and PIP II plans has begun. A component of the alignment is to understand Booster RF cavities as required for PIP II and beyond. Another task affected by the alignment to P5/PIP II was the Linac high power klystron and gallery upgrade. The original plan to run

Linac to 2025 and possibly beyond has been changed to 2023 and the start of PIP II. Funds allocated to these task are being allocated to those items suited for 2023 PIP II operations. PIP to PIP II alignment discussions are ongoing with plans to complete a document describing the necessary work to be released in FY15. Two other tasks that did not spend their planned M&S/Labor budget were modulator and Booster anodes. These items were discussed above but in summary they are expect to fully obligate their resources in FY15.

PIP budget and labor through September of FY14 are provided below. As mentioned in the FYQ3 report, a bump in labor was provided in the third quarter followed by a flattening of labor. This quarter labor was also impacted by the shutdown which started in September. A number of PIP technicians were required to move off PIP and do work related to the shutdown.

Table 2 PIP FY14 final budget table summary

FY14 PIP OBL BUDGET K\$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	7,652.0	6,105.6	88.2	1,458.2
Labor	5,778.5	5,060.3		718.2
FY14 Sums	13,430.5	11,165.9	88.2	2,176.4

Table 3 PIP FY14 labor summary through August

