To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY14 Q3

Report #7 July 1, 2014

Project Milestones

There were 4 Linac scheduled milestones, all level 3 and 11 Booster milestones of which all but one was a level 3.

The Linac WBS High Level milestone was completed in early July but the other three have not been met. However, only one of them from Linac Laser Notch system has the potential to impact the schedule completion date. Starting with the HLRF system, the Critical Design Review (CDR) slipped a couple of weeks and it is schedule for July 10th. The first milestone for Linac Laser Notch system is described as *OPG ready for installation*. The Optical Pulse Generator (OPG) module is complete and has preliminary acceptance tests done. However, during subsequent tests of the fiber amplifiers, instability in the seed diode (mode-hopping) seemed to be causing problems in the fiber amplifiers. Once this issue is resolved, the seed source will be re-installed and operated at a new temperature or a new seed source will be installed. At this point, the acceptance tests will be repeated to verify operation of each of the components. A completion date will depend if the team needs to make any other modifications to the OPG. This is the milestone which has the potential to impact the schedule completion date. The second milestone is *All three stages fiber amplifiers ready for installation*. All three fiber stages are in hand. During the initial tests for the Optical Engines amplifier, instability in the 2W amplifier due to stimulated Brillouin scattering (SBS) was observed. The team believes the problem is understood and they know how to raise the threshold for the SBS instability. L4 manager has been working with both companies, PriTel and Optical Engines on a fix for the instability. He has impressed the urgency for resolving the issue with PriTel. The expectation is that the amplifier can be complete in the next 4-6 weeks. Finally, the third and last milestone is described as *Beam Shaping Technology chosen*. The technology has been selected. However, tests of both technologies need to be documented before the manager can declare this milestone complete. This should happen during the next quarter.

Level	Task	DESCRIPTION	Original Due Date		Comment
3	1.1.1.1 High Level	Klystron critical design review (CDR)	6/30/14		Now scheduled for July 10th.
3	1.1.2.3 Laser Notch	OPG ready for installation			Instability in the seed diode – being investigated
3	1.1.2.3 Laser Notch	Three stages of fiber amplifiers ready for installation			Instability in the 2W amplifier – working with vendor
3	1.1.2.3 Laser Notch	Beam Shaping Technology chosen			Both technologies need to be documented

Table 1: Linac Milestone FY14Q3.

The Booster was able to meet 3 of the 11 milestones. The delays were largely due to labor resources and the continuing effort to bring the Recycler on line. However, late in the quarter the labor resources became available and PIP had significant jump in labor hours. The unmet milestones have made up ground over the last month and do not look to delay overall PIP or flux milestones. Additional details for each are provided in task section below.

Level	Task	DESCRIPTION	Original Due Date		Comment
3	1.2.2.3 Booster Notcher	Finish Testing of Short Kicker magnets	4/16/14		Finished 3 of 6 short kickers (labor)
3	1.2.3.2 Damper	Longitudinal damper boards tested	4/21/14		Expected done mid-July (labor)
3	1.2.2.3 Booster Notcher	Install 2 short kickers	4/23/14		Problems with power supplies
3	1.2.3.1 BPM	BPM Specification Complete	4/25/14	50%	finished in August (labor)
3	1.2.1.2 Bias	First Bias Supply Re-hab Complete	4/28/14	Done	
3	1.2.1.2 Bias	First Bias Supply Tested	5/5/14	Done	
3	1.2.2.4 Cogging	Install the FPGA board & RF feedback	5/5/14	80%	Should be done by end of FY14
3	1.2.1.2 Bias	Start Bias Supply installation	5/19/14		Will swap with next cavity refurb install
2	1.2.2.3 Booster Notcher	L12 Short Notcher Complete	6/6/14		3 short kickers finished – 3 more in production
3	1.2.2.6 Shielding	Determine shielding action	6/15/14		Working through calculations/simulations /measurements
3	1.2.5.2 Power	Receive Y-BW2 Transformer	6/16/14	Done	

Table 2: Booster Milestone FY14Q3.

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 200MHz 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

Progress continues to be made on this task. At Fermilab, the team is holding a bi-weekly meeting together with Modulator team. Main focus has been on developing a plan for acceptance test at FNAL upon receipt of the klystron in early fall 2015. Below a summary of the tasks worked on this quarter are presented.

HV system: Fermilab decided to use the LANL/SNS-type of connector on the klystron and pulse transformer end. This decision together with a full drawing package was released to CPI. The cable

chosen is Dielectric Sciences 2024 TVJ. The cable assembly drawing was not disclosure to CPI at this point in time.
Another topic in discussion is the choice of oil and how to deal with fire suppression mitigation if a lower flash-point mineral oil is to be used. The simulation baseline is mineral oil, which has a lower flash-point. An option is to use vegetable oil. However, using vegetable oil impacts the design criteria for the transformer tank. This type of oil is not supposed to be exposed to oxygen and for operation is desirable to have a nitrogen head on it all the time. For long service and avoid impregnation, the tank will have to be vacuum tight which is incompatible to the connector chosen. In addition, the oil isn't stable in ultraviolet light, so there are concerns about the region around the socket of the klystron where there is X-ray production. On the flip side, vegetable oil does not swell the cable like mineral oil does.

Test Setup: Few locations around the lab were identified which after further consideration most of them were eliminated except the NML building (current housing ASTA). The bouncer modulator and transformer designed for the 10MW, 1.3GHz klystron will work with the PIP klystron as well. The transformer is on hand and the modulator is half constructed. Given the infrastructure of this area was designed to operate a 10MW klystron; it will be a relatively inexpensive place to perform klystron tests. Discussions with other klystron users about constructing a more versatile klystron test and operation facility at NML has been initiated. At least three existing or procured klystrons at the laboratory can make use of the modulator, pulse transformer, and controls infrastructure we would use for testing our klystron. We are currently trying to organize cost and schedule between the interested parties.

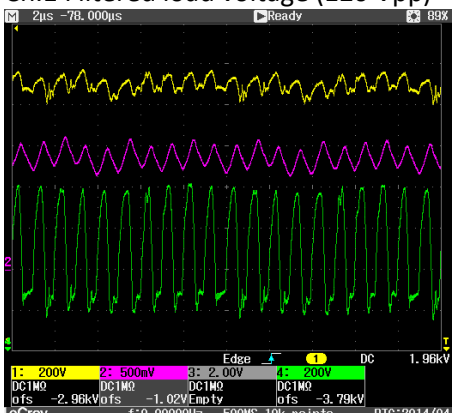
RF equipment: During this quarter the 200MHz water load was removed from the storage area, cleaned, reassembled and hydro-test. The load is leak tight and no major assembly was found compromised. Current is back in the box for storage awaiting a power test.

WBS 1.1.1.2 Linac Modulator

AD/EE Support Marx Modulator Design

The team continued with testing of the 9 cell prototype this quarter. They were successful able to run in pulse-width modulator (PWM) mode at 900V/cell with a 100 ohm load. However, this design was not able to achieve the ripple specification, presenting a ripple of > 100 Vpp at 240 & 120 kHz. Some issues were found during test: a 240 kHz ripple was found. It was traced to a bad 5.6 μF snubber capacitor on some of the cells, most likely they were damage during the excessive short circuit tests which exceed the 1,500 Amps peak rating during sparks. Technical personnel replaced the caps and ripple continue between 120-240 kHz. More investigation pointed to an inductive resistor in the filter network. Component was replaced and the ripple continued. This time was related with A/D converter, which takes the desired waveform signal and converts into the appropriate pulse width modulated interleaved pulses that feed each cells. Found that the output was not steady to applied input voltage. Experimented by running the cells with a fixed PWM conversion and was able to reduce the ripple significantly. A new A/D converter will be tested with better specification to eliminate the issue. After making all the changes, the Marx regulating cells were able to achieve de design criteria of 50 Vpp of ripple as shown in figure 1 below.

Initial Ripple
Ch.4 Voltage out of stripline
Ch.1 Filtered load voltage (120 Vpp)



Final Ripple
Ch.4 Stripline output voltage
Ch.3 Filtered load voltage (~50 Vpp)

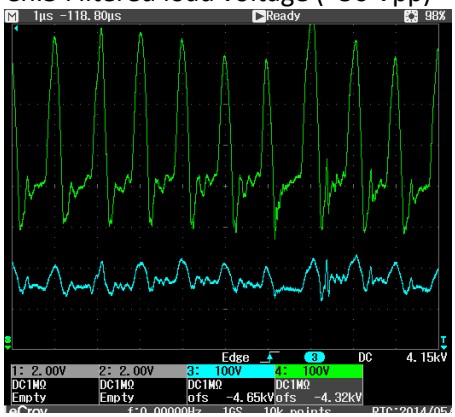


Figure 1: EE support Marx Modulator ripple study.

This set of tests revealed many features that have been addressed in the design, for example, changing the cell structure to accommodate two 5.6 µF snubber capacitor in parallel, looking into ways to reduce short circuit current, technical team started building the low inductive stripline, purchase parts for building cabinet to house high voltage modulator and efforts continue on building the control system for 54 cell generator.

SLAC Marx Modulator Update

After a successful presentation of the third stage study from SLAC experts early this quarter, the follow-up questions raised during the presentation were answered by the SLAC team. One of the major points raised was the question about beam loading levels used during the simulation and response from the modulator to compensate for it. What was shown during the presentation represented a factor of 10 lower beam loading than expected in operation conditions. SLAC expert simulated a +/- 20% variation in beam current from the nominal and demonstrate that the modulator continue to successful compensate for it.

Based on the additional requirement to have feedback compensation, SLAC proposed a Stage 4 Study development. In this stage, they will validate the concept of the feedback Marx cell to compensate systematic pulse-to-pulse stability issues; perform stability analysis with different load conditions (such as aging triode, cavity loading, etc.); incorporate a cell model in the SLAC triode modulator circuit model to take care of the compensation; modify a single cell and experimentally demonstrate the close-loop feedback system being proposed. The deliverable will be a final report presented to Fermilab team. Current the management is deciding which course of action to take.

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 the latest and improved DTL lattice was translated to TraceWin code. This code will be used to benchmark with results obtained with old PARMILA code.

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 team continues to make forward progress with the optical cavity/vacuum chamber. The team believes to be on track to have the final prints and the internal components ready for installation during the lab wide shut-down in the fall. Significant improvements were made in the design of the optical cavity that will facilitate alignment of the system.

After receipt of the amplifier, tests were conducted with the fiber amplifier. It was noticed instability on the fiber amplifier chain, modes hoping in the range of operation. This non-linearity issue will require modifications to the fiber amplifier in order to meet the requirements. This has been a collaborative effort between Fermilab team, Pritel and Optical Engines. Pritel has built another laser seed source with different spectral attributes to test the operation of the amplifier at no cost to the project. At this point in time, the modification required will probably be a different gain fiver which will raise the threshold of the instability beyond the operation point for average power. All these problems contributed to the team miss three L3 milestones this quarter which was explained earlier in this report. Most certainly there will be some extra charge for the new gain fiber, but still well within the budget for this 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*

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

During this quarter the team continued developing the plan for L1 transformer installation. The goal is to complete installation during the lab wide shutdown in the fall. L4 manager is holding weekly meetings with representatives from electrical, mechanical, safety, and operations. Some of the hazard analysis forms have already been drafted and have been circulating for comments. T&M contracts and requisitions have been produced and signed off. In a nutshell, the plan is to have the transformer moved from the current storage area to the Linac basement middle July and stage nearby its final location. In order to accomplish this Linac basement area was rearranged and cleaned in order to allow a vacancy footprint area nearby the final location. This will also be the area designated for long-term storage of the old transformer which will then be declared as spare for the other 2 identical transformers still in use in Linac.

WBS 1.1.5.2 LCW distribution

A fair amount of work was done in this task which constitutes of two main topics: Dual Temp System and CUB Chiller #3 backup pump.

Dual Temp System: AD/FESS engineers have been looking at different options for the replacement of the current water Dual temp System pipes. Among all the options looked and studied, a rooftop AC unit was identified as the best long term option to be considered, therefore abandoning the water heating/cooling entirely. A location for the unit has been selected. Current the team is moving along with the final engineering efforts for this upgrade, creating drawings and preparing packages for reviews in order to receive final approval for the building modification. The expectation is to be ready to install during the lab wide shut-down this fall.

CUB Chiller #3 backup pump: All parts and requisitions required to start this job are either on hand or complete. The plan is to initiate this effort right after a schedule job that FESS/CUB has related with the Linac heat exchanger, which forces Linac cooling to be on a non-standard operational configuration anyway. Therefore, this pump installation will begin right after the completion of the heat exchanger leaving for the shutdown only the verification that controls will automatically switch pumps in an event of a failure of the primary. The completion of this installation will increase Linac reliability for the 200MHz system.

WBS 1.1.5.3 Vacuum System

Experts are currently, waiting for fall shutdown to start in order to finish installation of the last rougher pump in the Linac tunnel and the 400MeV area turbo pump installation. Some miscellaneous material and parts were ordered this quarter in order to prepare for installation.

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. Preparations are being made to assembly and test the anode supplies in FY14Q4.

WBS 1.2.1.2 Bias Supply

The retrofit of the first bias supply finished. It is undergoing testing. The retrofit was documented to be the procedure for the remaining bias supplies. There are many pieces (cables and cooling pipes) which were being specified as the retrofit proceeded. A second supply was retrofitted and a third 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 eleventh 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 ten weeks. During the FYQ14Q2, another previously refurbished cavity developed a severe RF problem; it was removed from the tunnel and investigated. It was discovered to be sparking from a 40 year old repair of the tapered section of the cavity. The repair required cutting the cavity itself to work on the damaged tapered section. This cavity tapered section was repaired, a new ceramic window was installed and the cavity was tested for vacuum leaks. In FY14Q4, this cavity will be tested and re-installed. Meanwhile, we

inspected as much of the tapered sections of all of the cavities in situ and found evidence of one other damaged tapered section. The cavity with damaged taper has been removed and the refurbishment of this cavity has commenced.

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 core samples from two different 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 has delivered cores that are acceptable. During FY14Q3, a new tuner was built using new all new ferrites (see figure 2 below). This new tuner is attached to a refurbished cavity that is now undergoing testing. Extra heating measurements during the testing are being done to ensure the new ferrites are acceptable before placing a large order.

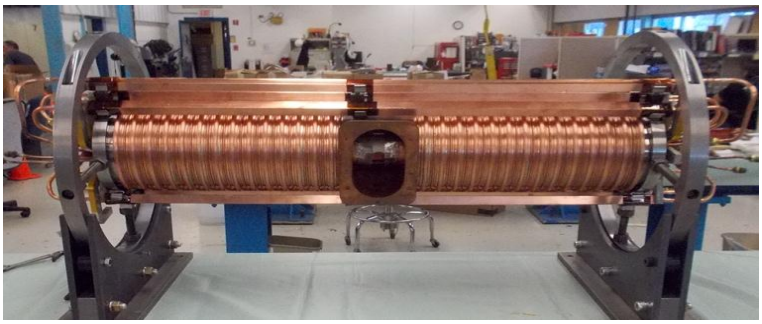


Figure 2: New Booster tuner.

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.

WBS 1.2.1.8 Cavity 1013

The cavity was put under vacuum a while ago and is leak tight. Refurbished tuners will be attached to cavity 1013 and under go extended testing during FY14Q4. 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 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. They are in email contact with the original person while they resurrect the codes, procedures and analyses. 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 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

The upgraded power systems were tested in parallel with operations. There have been some problems with clock/timing issues that are being worked upon. A completed short kicker magnet was tested with the upgraded power system. Assembly of the remaining kicker magnets has started after the successful testing of the short kicker magnet. During the next quarter, a part of the upgraded power system will be connected to an operational long kicker magnet.

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 cogged beam to a downstream accelerator is proceeding nicely.

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 have been planned and will be conducted in

FY14Q3. The studies will involve the effectiveness of the passive shielding, active detectors and determining radioactive source terms for penetrations.

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 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 third quarter in FY14 has had one significant change. A funding reduction of $1M was requested from AD management to offset an operations funding shortfall. This required PIP to reduce some tasks and the management fund. There will be no noticeable impact to PIP this year since tasks being impacted (items not purchased) were to be used in outlying years. However, we are re-working the schedule accordingly and will have a better understanding after RLS update is revised. Additionally, the laboratory and the DOE have received the P5 report and are now in the process of addressing the guidance provided in it. A significant part of the P5 plan is the status of PIP II (revised Project X). PIP has recently started discussions on the alignment of PIP and PIPII. It is expected to have a significant impact to several tasks.

PIP budget and labor through June of FY14 are provided below. As previously mentioned, a bump in labor was provided in this quarter.

FY14 PIP OBL BUDGET K$	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	7,852.7	4,019.2	82.1	3,751.4
Labor	5,577.7	3,813.1		1,764.6
FY14 Sums	13,430.4	7,832.3	82.1	5,516.0

Table 3: M&S PIP funding through June FY14.

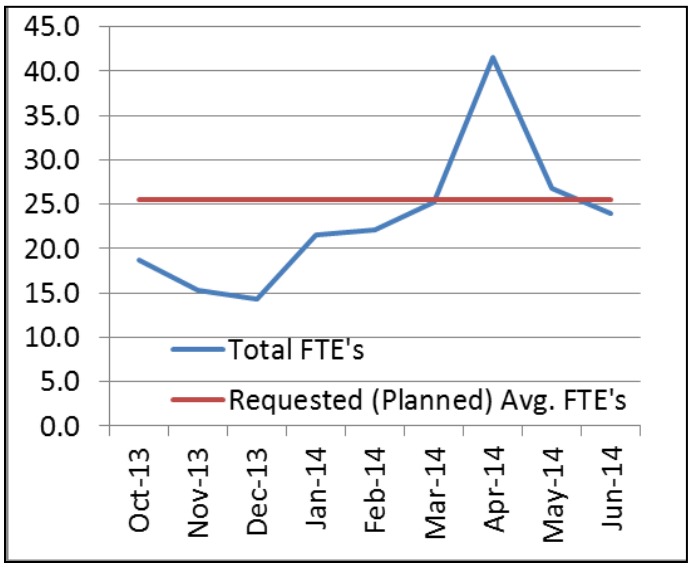


Figure 3: PIP recorded labor