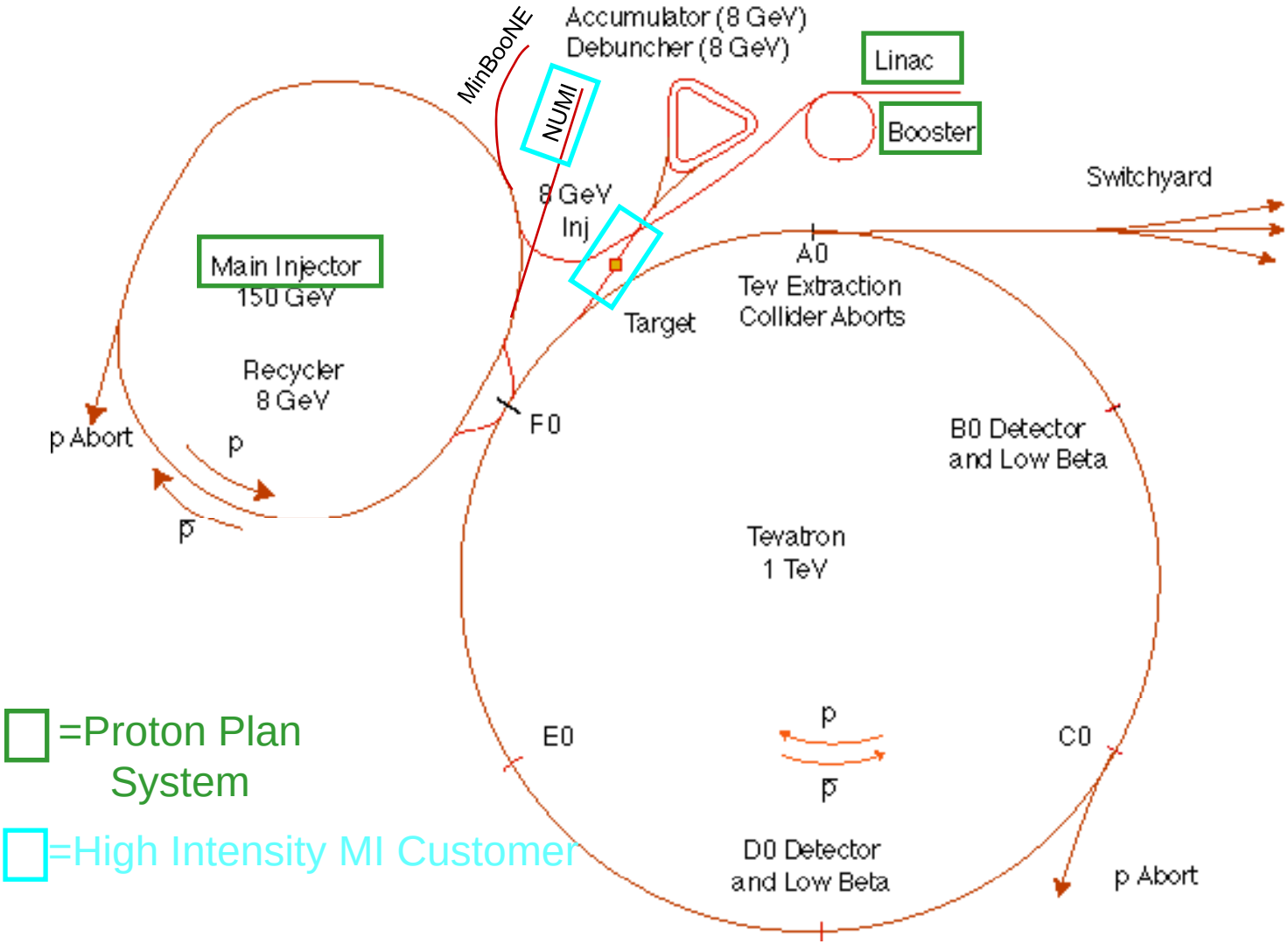
MI Upgrades
WBS 1.0.2, 2.0.2

June 5, 2007

Ioanis Kourbanis

The Fermilab Accelerator Complex



=Proton Plan System

=High Intensity MI Customer

Performance Specifications

- For NOvA MI has to be able to accelerate to 120 GeV 4.9E13p every 1.33 sec.
- The main difference from the Proton Plan (4.5E13p every 2.2 sec) is the reduction of the MI cycle time. This reduction will be accomplished with the elimination of the 8 GeV dwell time and the increase of the max. acceleration rate from 204GeV/sec to 240 GeV/sec.
- Two rf stations will be installed to maintain the same bucket area.
- The vertical Quad Bus will be upgraded to provide the higher voltage needed.

Other work included in this WBS

- Modify the RR LLRF system to accommodate transfers from Booster and slip-stacking.
  - Same functionality with the present MI LLRF system
  - Re-use hardware from the present RR and TeV LLRF systems
- Build the communications infrastructure in the two new service buildings (MI-14, MI-39).
- Remove the extraction elements from the MI-62 region (anti-proton extraction to TeV)
- Remove the 5 coalescing cavities from MI-60.
- Provide for any water cooling modifications needed.
- Provide a shielding assessment

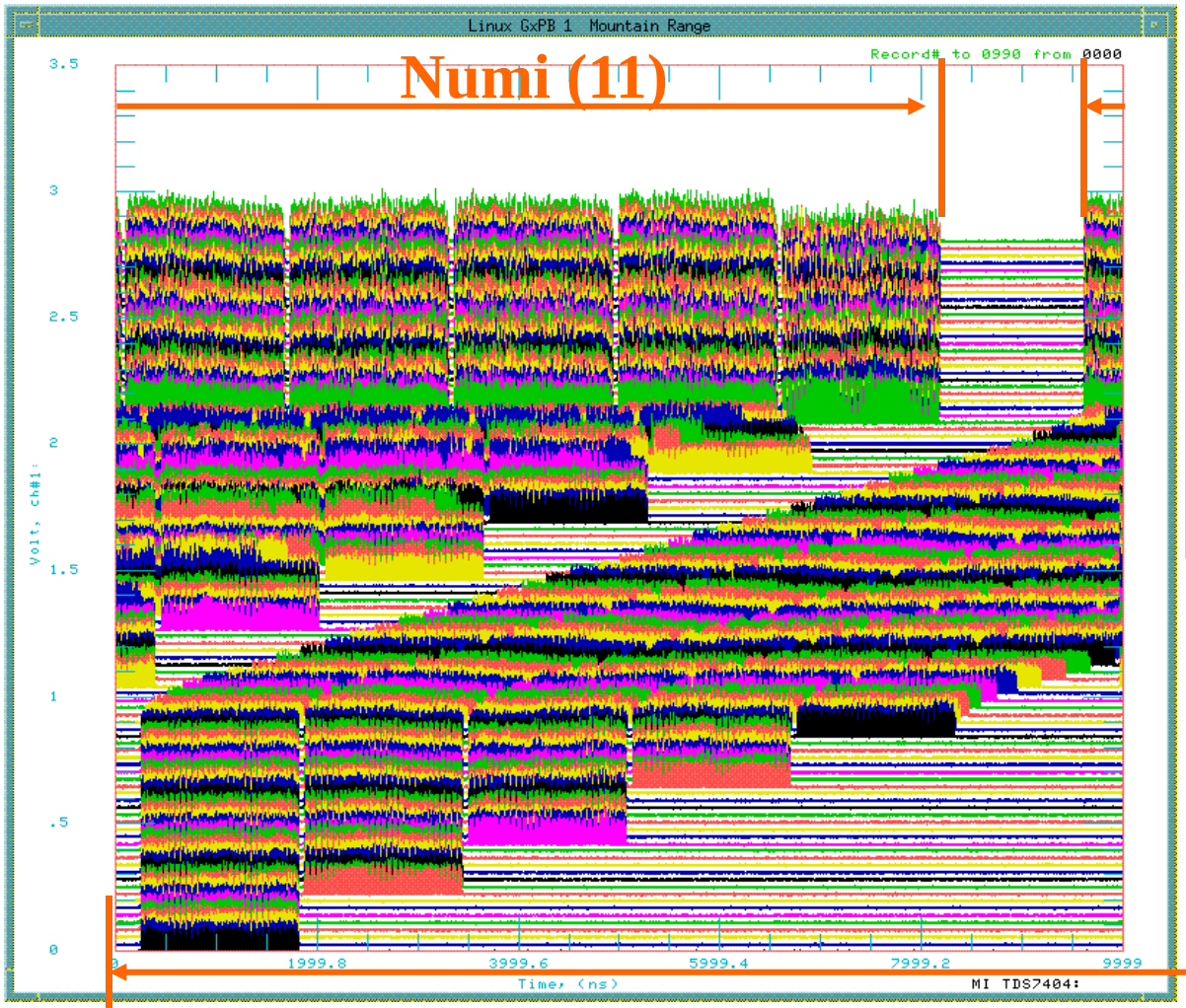
Status of the Proton Plan multi-batch slip stacking

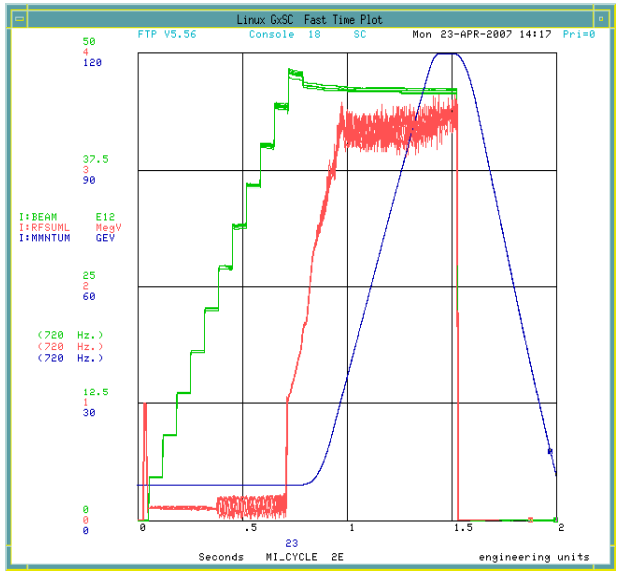
- We have successfully accelerated in MI intensities larger than 4.6E13p using multi-batch slip stacking with good efficiencies (~92%).
- We have delivered to the NuMI target beam intensities larger than 4.0E13p with very good efficiency and minimal losses in the beamline.
- We have demonstrated the multi-batch slip stacking operation in mixed mode (two different Booster events with different intensities).

❖ The Proton Plan MI collimators are expected to be ready for installation during the summer 07 shut-down.

  ❖ We expect to have all the parts delivered in the next couple of weeks.

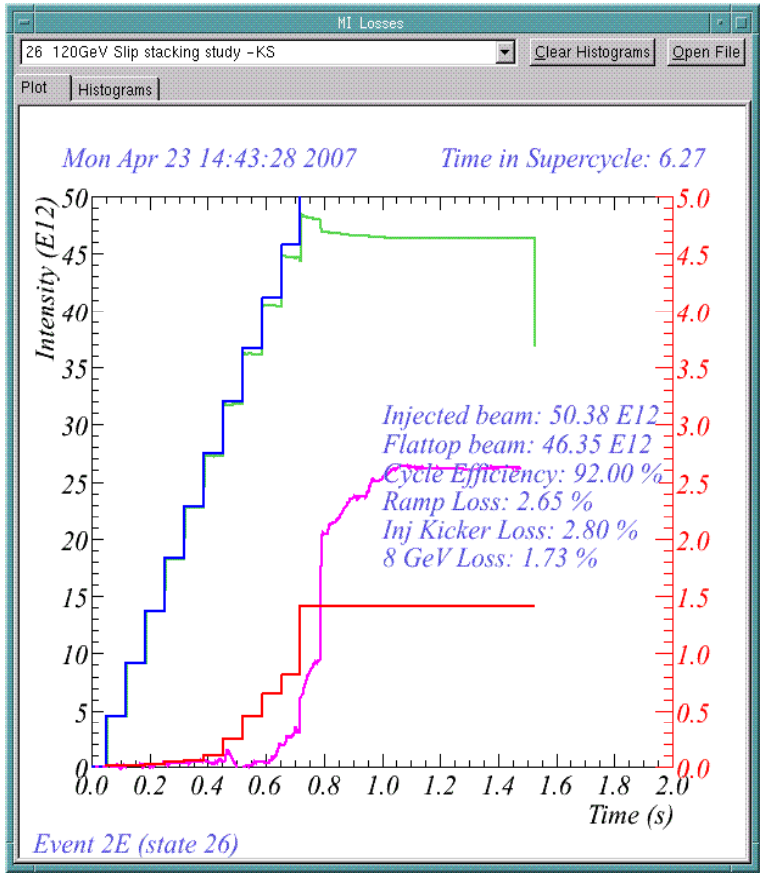
Proton Plan multi-batch slip stacking status

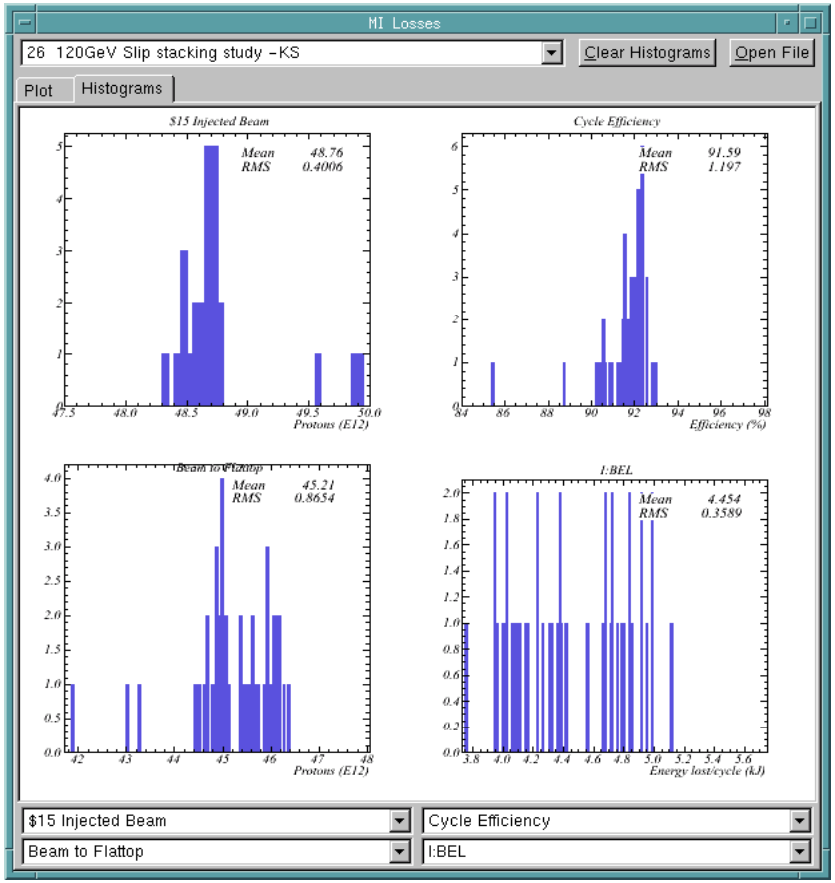




- Record:
  - 4.63E13 protons to MI abort at 120 GeV.
  - 92% efficiency
- Goal:
  - 4.5E13 protons to 120 GeV (NuMI + pBar)
  - 95% efficiency (Collimators)

Proton Plan multi-batch slip stacking status (2)

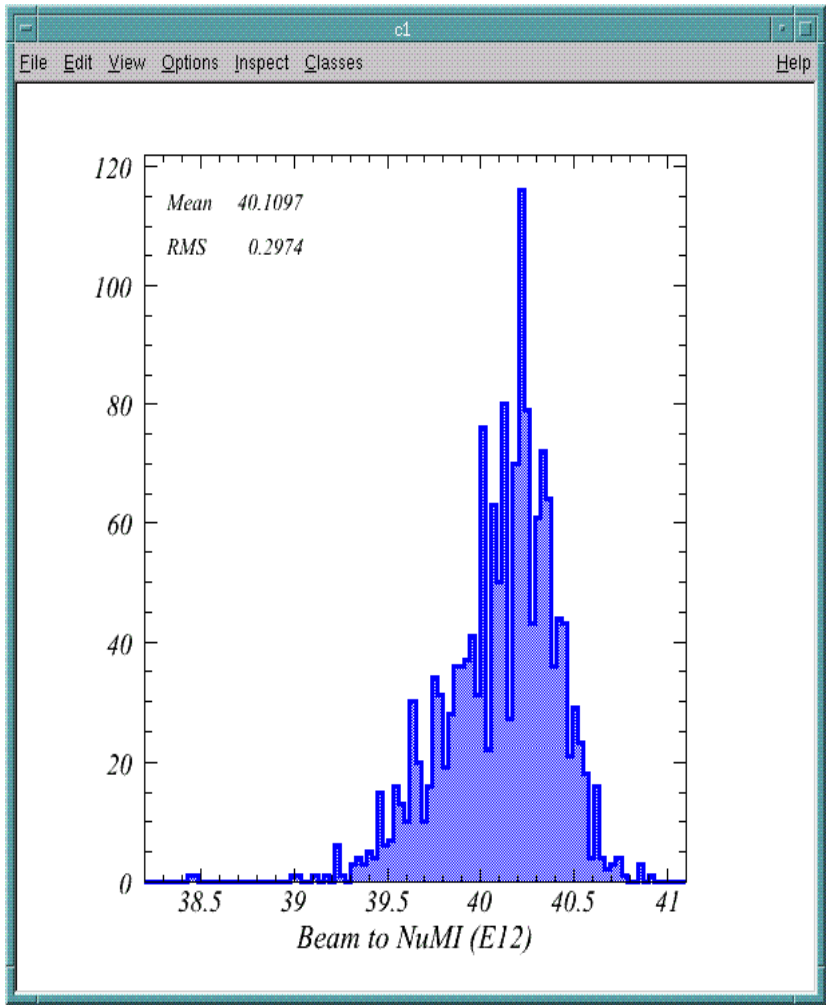


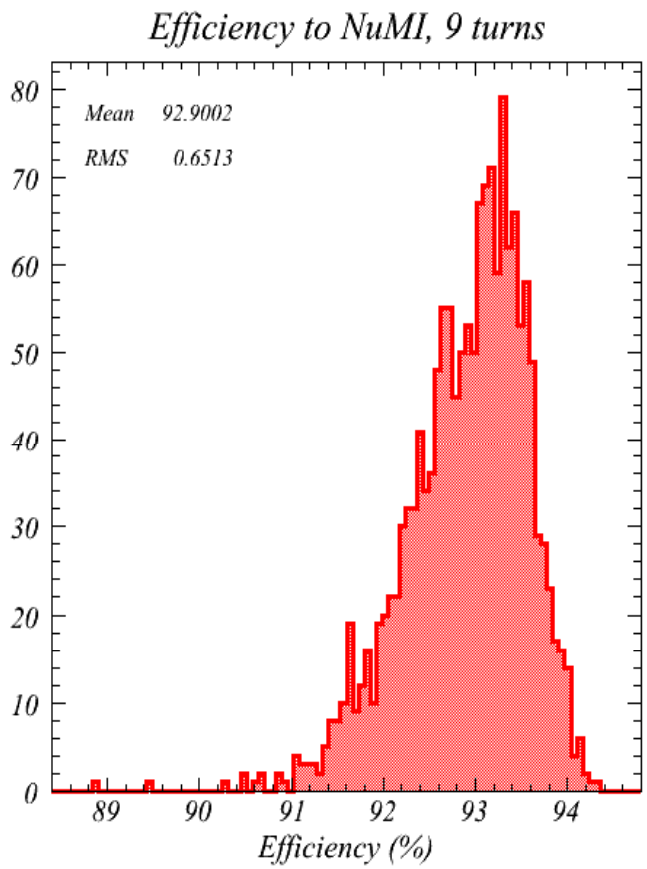


Different losses during multi-batch slip stacking

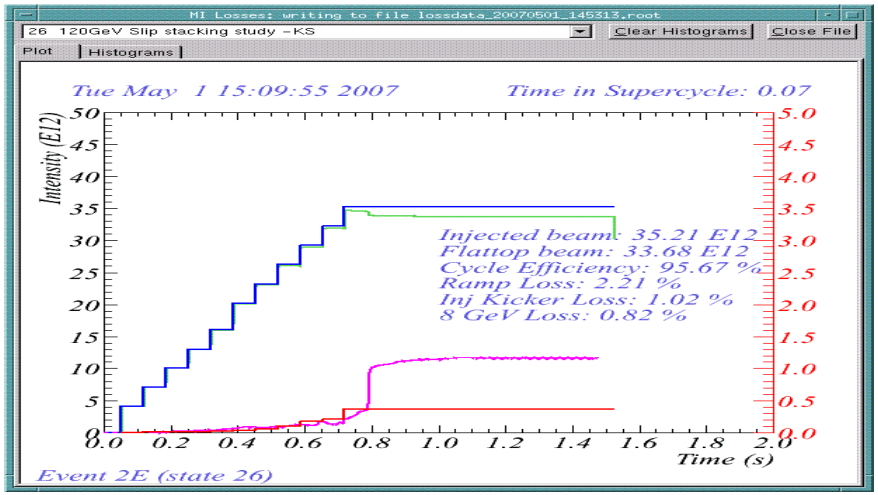
Histograms of intensities and efficiencies during the multi-batch slip stacking study.

Beam Intensity and efficiency of the slipped stacked beam to the NuMI target

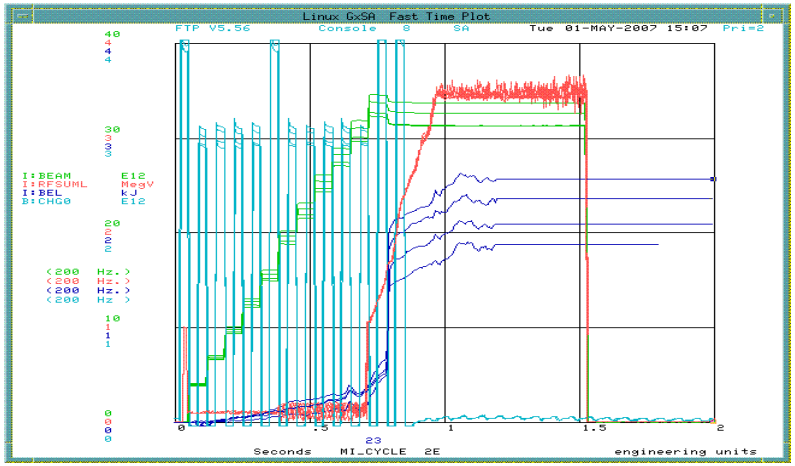




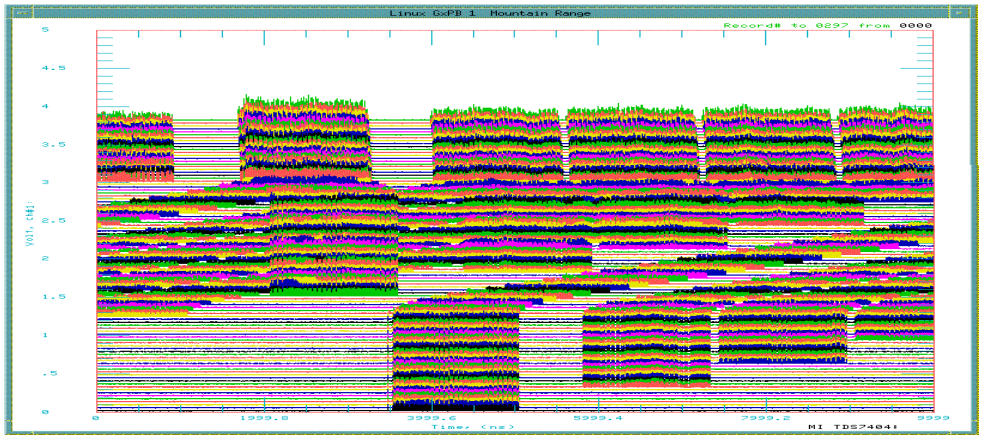
Mixed Mode MI Operation with multi-batch slip stacking



MI beam efficincies during mixed mode.



Booster and MI intensity during mixed mode cycle injection.

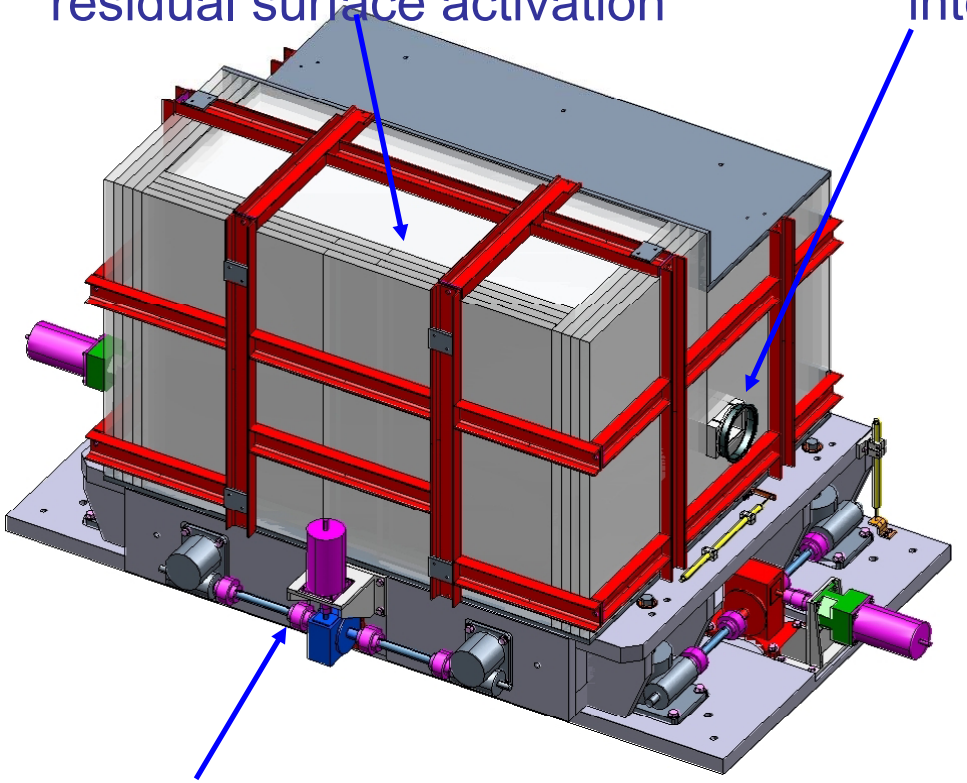


Mountain range picture of the MI injection during the multi-batch slip stacking for mixed mode.

Proton Plan MI Collimator Design and Installation

Marble cladding to reduce residual surface activation

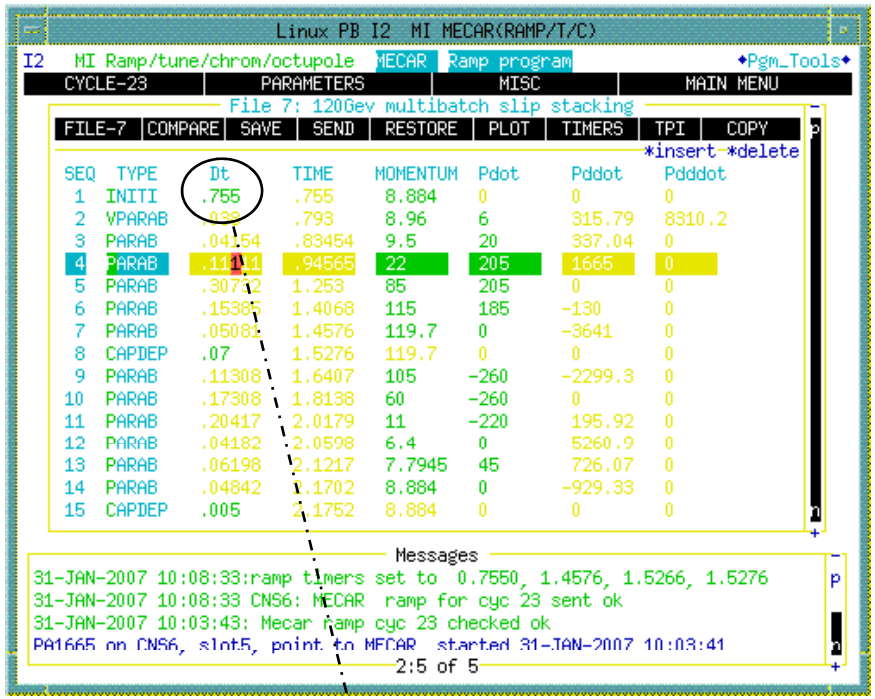
"Booster style" fixed aperture with integrated shielding



Horizontal and vertical motion

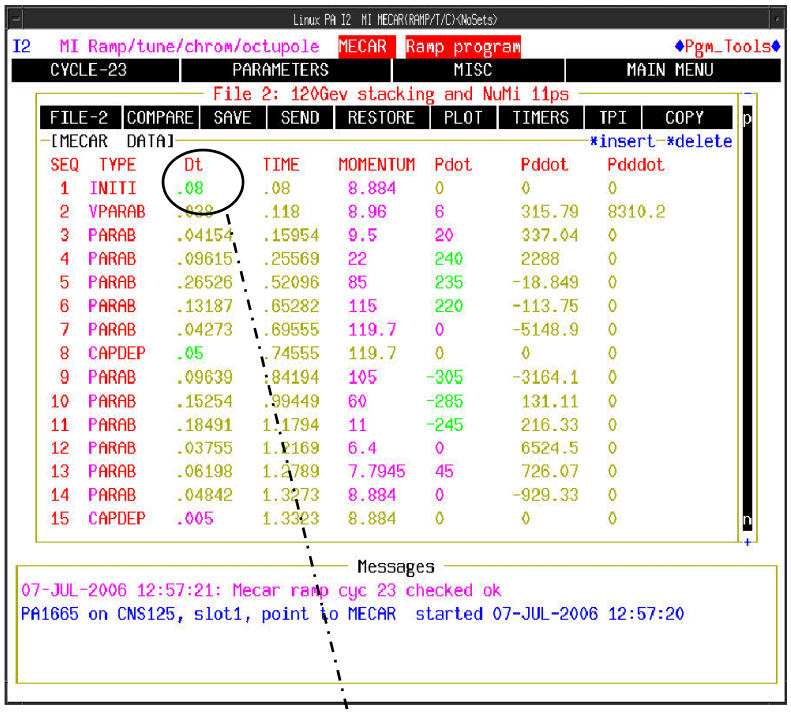
Installation will require re-routing of water and power.

MI Ramps



8.9 GeV dwell 0.755 sec

Current MI ramp (mixed mode)

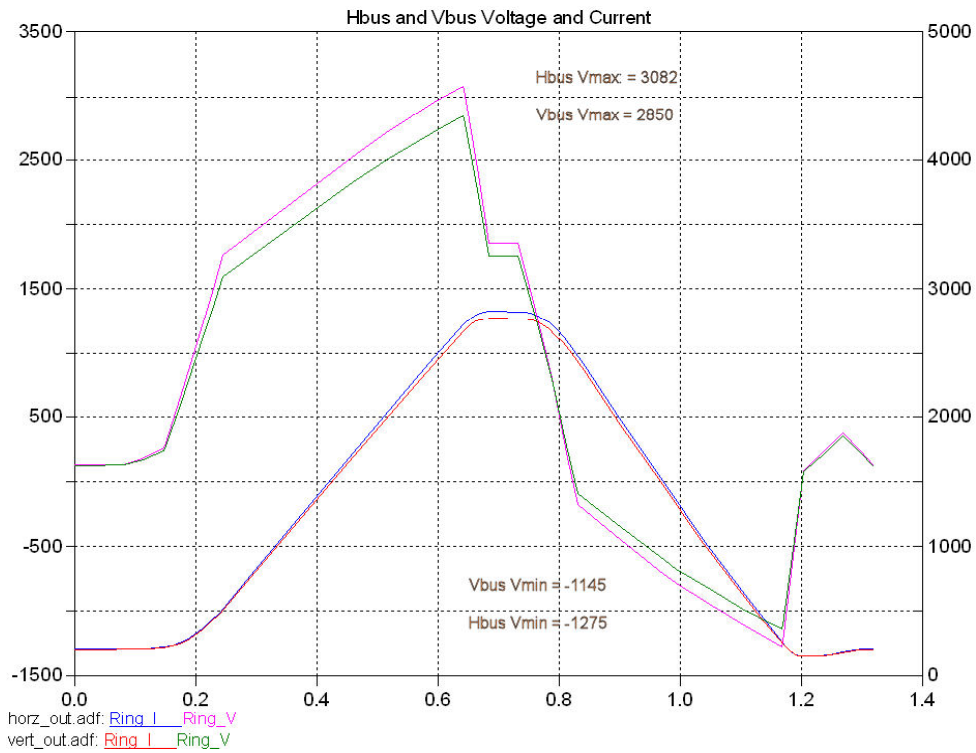


8.9 GeV dwell 0.08 sec

NOvA MI Ramp

MI Quad Bus Modifications

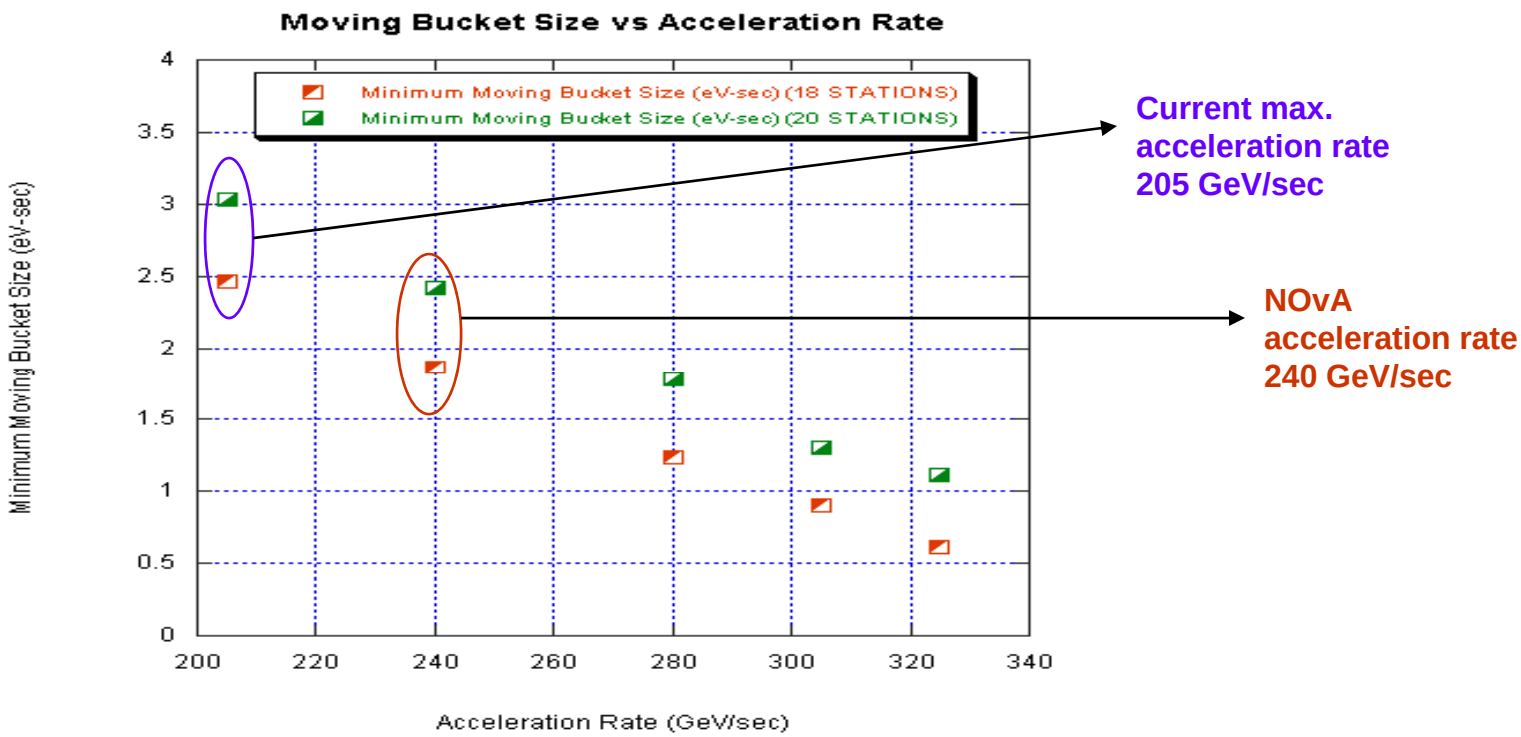
- During the NOvA ramp we are going to exceed the maximum available voltage of the defocusing (vertical) bus.
- We plan to increase the available voltage at the defocusing bus by replacing one of the transformers with a higher voltage one and modifying the corresponding supply.
- These modifications are similar to the ones done recently on the focusing quad bus in order to accommodate the installation of the wide aperture quads.



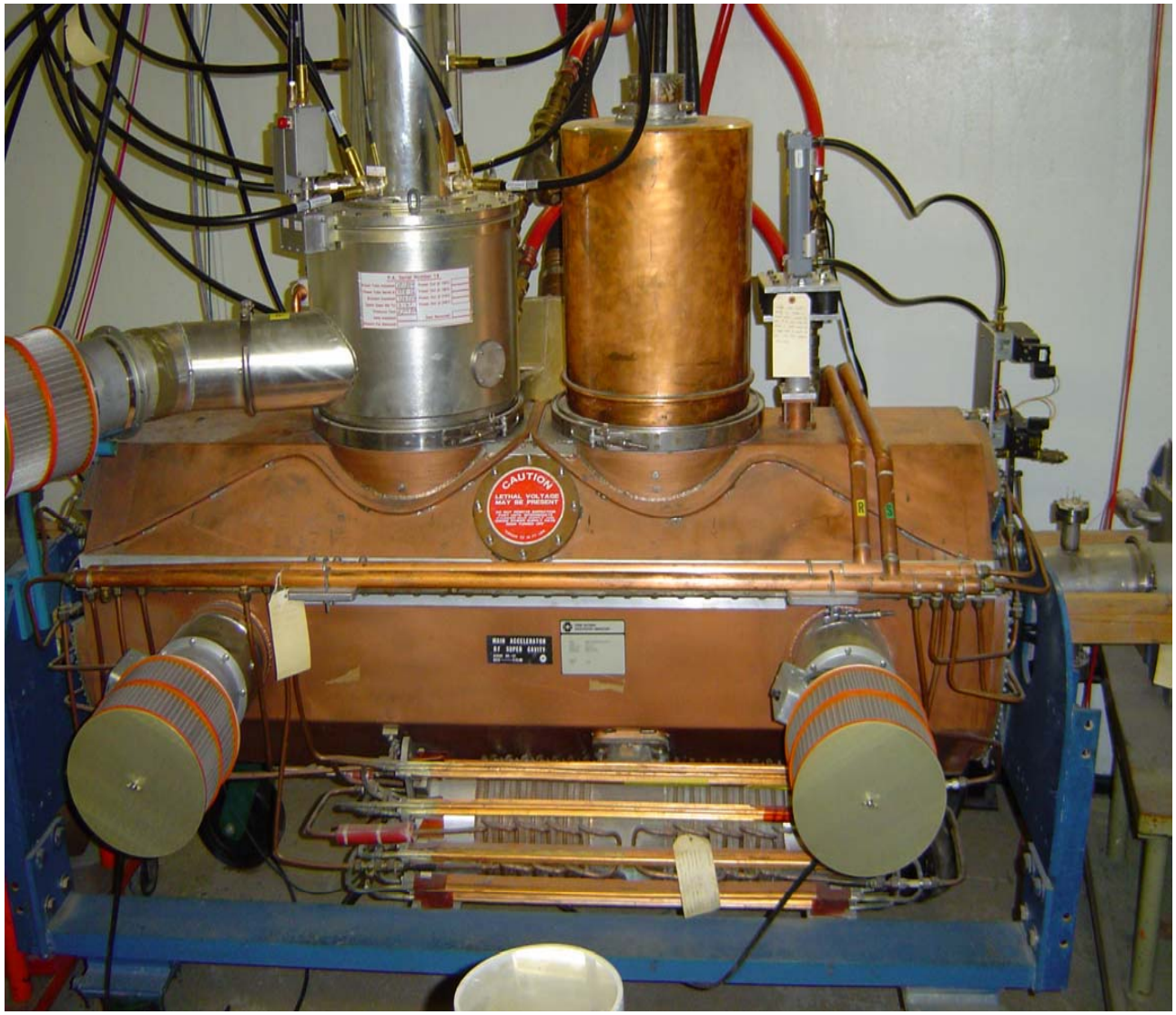
MI RF Cavities

- In order to maintain the same bucket after transition with the faster NOvA ramp we need to install two extra rf cavities.
- The two cavities will come from spares and will be installed at locations where penetrations and utilities already exist.
- We need to fabricate the supplies required for the operation of the two cavities along with the power tube assemblies and the solid state drivers.
- The biggest challenge of this job is the manufacturing and installation of the bus bars for the cavity tuners.
  - The bus bars for the existing cavities were installed at the early stages of the MI-60 rf service building when there was no roof.

Bucket Area vs. Acceleration Rate



MI rf Cavity



Modulator and Bias Supplies

Power tube assembly and solid state drivers

Original Installation of MI bus bars for rf cavity tuners

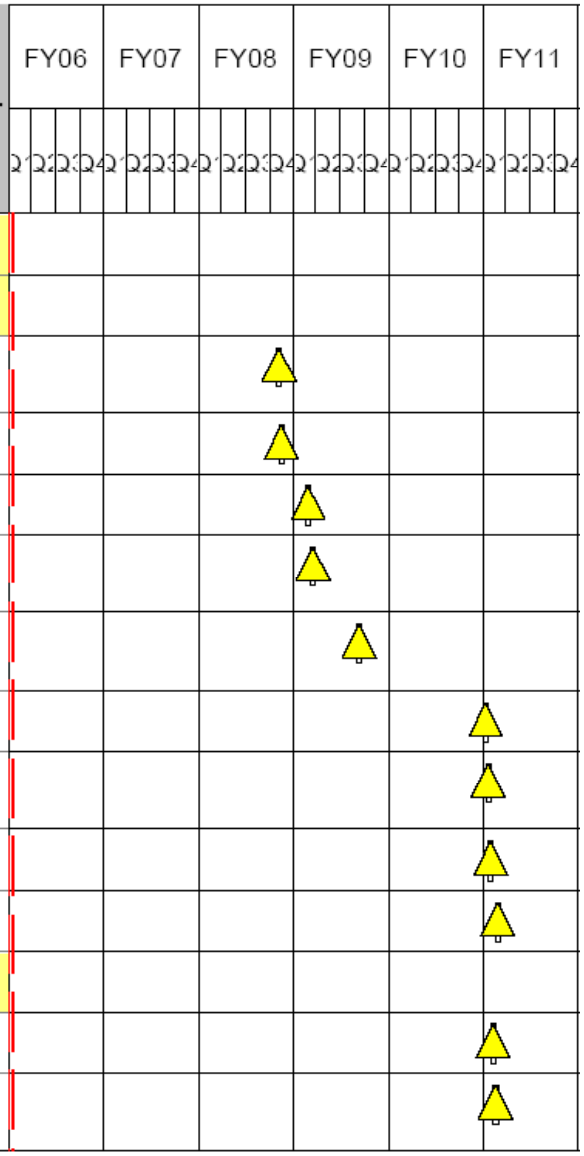
Cost Overview MI Upgrades

(Fully Burdened FY07 $)

		ANU MI Upgrades Cost Estimate $K (FY07$)						
		Estimated Cost (w/Indirects)			Contingency %			Total Project Cost
WBS	Name	M&S	Labor	Total	M&S Cont %	Labor Cont %	Total Cont %	
	Main Injector Upgrades	**$1,063**	**$1,434**	**$2,497**	**30%**	**25%**	**27%**	**$3,172**
1.0.2	**Main Injector Upgrades Planning, Engineering & Design**	**$99**	**$773**	**$872**	**48%**	**27%**	**29%**	**$1,125**
1.0.2.1	MI Modifications	$77	$631	$708	55%	27%	30%	$923
1.0.2.2	MI RF Cavities	$22	$143	$164	24%	23%	23%	$202
1.0.2.3	MI Radiation Safety	$0	$0	$0	0%	0%	0%	$0
2.0.2	**Main Injector Upgrades Construction**	**$964**	**$660**	**$1,624**	**28%**	**23%**	**26%**	**$2,047**
2.0.2.1	MI Modifications	$246	$97	$343	37%	29%	35%	$461
2.0.2.2	MI RF Cavities	$718	$563	$1,282	25%	22%	24%	$1,585

Main Injector Upgrades Milestones

Activity ID	Activity Desc.	Date	Milestone Tier
L.2 -- WBS L2 Manager's Milestone			
2.0.2.2.5.1	MI RF Cavities Bus Bar Fabrication & Installation Complete	28Jul08	L.2
1.0.2.3.2.1	MI Shielding Assessment Complete	05Aug08	L.2
1.0.2.2.4.1	MI Cavity Pre-install Testing Complete	25Nov08	L.2
2.0.2.2.5.2	MI RF Cavities Fabrication of Ferrite Bias Supplies Complete	09Dec08	L.2
2.0.2.2.5.3	MI RF Cavities Fabrication of Modulators Complete	05Jun09	L.2
1.0.2.1.6.1	MI 2.5 Mhz Cavities Removal Complete	05Oct10	L.2
1.0.2.1.6.2	MI Decommissioing of A1 Extraction Line Complete	12Oct10	L.2
2.0.2.2.5.5	MI LCW System Mods Complete	20Oct10	L.2
1.0.2.1.6.3	MI Machine Timing Complete	17Nov10	L.2
T.3 -- Fermilab Director or NOVA Management Milestone			
2.0.2.1.4.1	MI Vertical Quad Bus Upgrade Complete	02Nov10	T.3
2.0.2.2.5.4	MI RF Cavities (2) Installation & Testing Complete	11Nov10	T.3



MI Upgrades Risks

- Risk Registry for all risks is in WelcomRisk®
  - 8 Risks entered with mitigations for this WBS
    - 0 high, 1 moderate, 7 low
  - Moderate risk with RR LLRF design takes longer than expected
    - Several months float on tasks and reasonable contingency (~30%)

- High risk for all of ANU is insufficient manpower (NOvA-DocDB-1446)

Conclusions

(Fully Burdened FY07 $)

- Very few upgrades are required for MI to meet the NOvA goals.
  - Only 10% larger intensity from the Proton Plan
  - Most of the cycle time reduction is achieved by the elimination of the 8 GeV dwell time.
  - The max. acceleration rate is increased by 18% by upgrading one of the quad supplies and installing two extra rf cavities.
- The total cost is $2.5M (no contingency)
  - 27% contingency and the risks are small.
  - The biggest cost driver is the installation of the two extra rf cavities.
- Recent results with multi-batch slip stacking are very encouraging for the success of both Proton and NOvA Plans.