Proton Plan
WBS 1.2.1
Booster RF Repetition Rate Limit and RF System Reliability Issues

Director's Review
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Booster RF Repetition Rate Limit

- Current and Anticipated Booster Timelines Operate at or Below a "7 Hertz" Repetition Rate

CURRENT $23 MI CYCLE TIMELINE - MIXED MODE

A 2 Second Timeline - Supporting P-Bar Production, NuMI and MiniBooNE.
Only Slip Stacking P-Bar Production Beam.
5 "Trailer Hitched" Shots of MiniBooNE Beam.

Time	#15 Hz Ticks	Event	Purpose	Comments
0.000	1	**$12 Pre-Pulse**	RF Warm-Up	
0.067	2	**$12 Pre-Pulse**	RF Warm-Up	
0.133	3	**$14 Beam**	P-Bar Production	
0.200	4	**$14 Beam**	P-Bar Production SS	
0.267	5	**$19 Beam**	NuMI Batch 1	
0.333	6	**$19 Beam**	NuMI Batch 2	
0.400	7	**$19 Beam**	NuMI Batch 3	
0.467	8	**$19 Beam**	NuMI Batch 4	
0.533	9	**$19 Beam**	NuMI Batch 5	
0.600	10	**$1D Beam**	MiniBooNE 1	
0.667	11	**$1D Beam**	MiniBooNE 2	
0.733	12	**$1D Beam**	MiniBooNE 3	
0.800	13	**$1D Beam**	MiniBooNE 4	
0.867	14	**$1D Beam**	MiniBooNE 5	
0.933	15	$11 Null Cyle	Null #1	**A "Comfortable" Timeline for the Booster RF System**
1.000	16	$11 Null Cyle	Null #2	
1.067	17	$11 Null Cyle	Null #3	
1.133	18	$11 Null Cyle	Null #4	
1.200	19	$11 Null Cyle	Null #5	
1.267	20	$11 Null Cyle	Null #6	
1.333	21	$11 Null Cyle	Null #7	
1.400	22	$11 Null Cyle	Null #8	
1.467	23	$11 Null Cyle	Null #9	
1.533	24	$11 Null Cyle	Null #10	
1.600	25	$11 Null Cyle	Null #11	
1.667	26	$11 Null Cyle	Null #12	
1.733	27	$11 Null Cyle	Null #13	
1.800	28	$11 Null Cyle	Null #14	
1.867	29	$11 Null Cyle	Null #15	
1.933	30	$11 Null Cyle	Null #16	
2.000	Repeat the Above			
Calculator	Active	Duty Factor	Equivalent Hertz	
Total	14	0.467	7.000	
MiniBooNE	5	0.167	2.500	

ANTICIPATED $23 MI CYCLE TIMELINE - MIXED MODE

A 2.2 Second Timeline - Supporting P-Bar Production, NuMI and MiniBooNE.
Slip Stacking P-Bar Production and NuMI Beam.
Only 1 "Trailer Hitched" Shot of MiniBooNE Beam.

Time	#15 Hz Ticks	Event	Purpose	Comments
0.000	1	**$12 Pre-Pulse**	RF Warm-Up	
0.067	2	**$12 Pre-Pulse**	RF Warm-Up	
0.133	3	**$14 Beam**	P-Bar Production	
0.200	4	**$19 Beam**	NuMI Batch 1	
0.267	5	**$19 Beam**	NuMI Batch 2	
0.333	6	**$19 Beam**	NuMI Batch 3	
0.400	7	**$19 Beam**	NuMI Batch 4	
0.467	8	**$14 Beam**	P-Bar Production SS	
0.533	9	**$19 Beam**	NuMI Batch 1 SS	
0.600	10	**$19 Beam**	NuMI Batch 2 SS	
0.667	11	**$19 Beam**	NuMI Batch 3 SS	
0.733	12	**$19 Beam**	NuMI Batch 4 SS	
0.800	13	**$19 Beam**	NuMI Batch 5	
0.867	14	**$1D Beam**	MiniBooNE 1	
0.933	15	$11 Null Cyle	Null #1	**This Demonstrates that the Current System Can Support Slip Stacking of Both P-Bar Production and NuMI Beams.**
1.000	16	$11 Null Cyle	Null #2	
1.067	17	$11 Null Cyle	Null #3	**Even Though this Cycle is Somewhat Longer, the Number of Successive Non-Null Operations is Maintained at 14.**
1.133	18	$11 Null Cyle	Null #4	
1.200	19	$11 Null Cyle	Null #5	
1.267	20	$11 Null Cyle	Null #6	
1.333	21	$11 Null Cyle	Null #7	
1.400	22	$11 Null Cyle	Null #8	
1.467	23	$11 Null Cyle	Null #9	
1.533	24	$11 Null Cyle	Null #10	
1.600	25	$11 Null Cyle	Null #11	
1.667	26	$11 Null Cyle	Null #12	
1.733	27	$11 Null Cyle	Null #13	
1.800	28	$11 Null Cyle	Null #14	
1.867	29	$11 Null Cyle	Null #15	
1.933	30	$11 Null Cyle	Null #16	
2.000	31	$11 Null Cyle	Null #17	
2.067	32	$11 Null Cyle	Null #18	
2.133	33	$11 Null Cyle	Null #19	
2.200	Repeat the Above			
Calculator	Active	Duty Factor	Equivalent Hertz	
Total	14	0.424	6.364	
MiniBooNE	1	0.030	0.455	

Booster RF Repetition Rate Limit

- Increase of Repetition Rate Beyond 7 Hertz Will Accommodate Additional Beam for MiniBooNE
- 9 Hertz is Considered to be a Practical Limit Without Major RF System Adjustments with 1 Exception
- Various Obstacles to Higher Rates Require Investigation and Action
- Issues Center on Component Heating and Available AC Power

PROPOSAL ONE
$23 MI CYCLE TIMELINE - MIXED MODE

2.2 Second Timeline - Supporting P-Bar Production, NuMI and MiniBooNE.
Slip Stacking P-Bar Production and NuMI Beam.
Multiple "Trailer Hitched" Shots of MiniBooNE Beam.

Time	#15 Hz Ticks	Event	Purpose	Comments
0.000	1	**$12 Pre-Pulse**	RF Warm-Up	One Way of Achieving the 9 Hertz Goal. This Proposal Maximizes Instaneous Heating While Reducing Overall Duty Factor Somewhat by Having Only 2 Pre-Pulse Cycles. Beam for MiniBooNE is Maximized. Critical to this Working is the Effectiveness of Re-Installed Cavity Cooling and the Adequacy of AC Power Distribution to Gallery RF Stations. Operating NuMI Only Has Similar Cycle Characteristics.
0.067	2	**$12 Pre-Pulse**	RF Warm-Up	
0.133	3	**$14 Beam**	P-Bar Production	
0.200	4	**$19 Beam**	NuMI Batch 1	
0.267	5	**$19 Beam**	NuMI Batch 2	
0.333	6	**$19 Beam**	NuMI Batch 3	
0.400	7	**$19 Beam**	NuMI Batch 4	
0.467	8	**$14 Beam**	P-Bar Production SS	
0.533	9	**$19 Beam**	NuMI Batch 1 SS	
0.600	10	**$19 Beam**	NuMI Batch 2 SS	
0.667	11	**$19 Beam**	NuMI Batch 3 SS	
0.733	12	**$19 Beam**	NuMI Batch 4 SS	
0.800	13	**$19 Beam**	NuMI Batch 5	
0.867	14	**$1D Beam**	MiniBooNE 1	
0.933	15	**$1D Beam**	MiniBooNE 2	
1.000	16	**$1D Beam**	MiniBooNE 3	
1.067	17	**$1D Beam**	MiniBooNE 4	
1.133	18	**$1D Beam**	MiniBooNE 5	
1.200	19	**$1D Beam**	MiniBooNE 6	
1.267	20	**$1D Beam**	MiniBooNE 7	
1.333	21	$11 Null Cyle	Null #1	
1.400	22	$11 Null Cyle	Null #2	
1.467	23	$11 Null Cyle	Null #5	
1.533	24	$11 Null Cyle	Null #6	
1.600	25	$11 Null Cyle	Null #7	
1.667	26	$11 Null Cyle	Null #8	
1.733	27	$11 Null Cyle	Null #9	
1.800	28	$11 Null Cyle	Null #10	
1.867	29	$11 Null Cyle	Null #11	
1.933	30	$11 Null Cyle	Null #12	
2.000	31	$11 Null Cyle	Null #13	
2.067	32	$11 Null Cyle	Null #14	
2.133	33	$11 Null Cyle	Null #15	
2.200	Repeat the Above			

Calculator	Active	Duty Factor	Equivalent Hertz
Total	20	0.606	9.091
MiniBooNE	7	0.212	3.182

Booster RF Repetition Rate Limit

- Re-Install and Investigate Adequacy of RF Cavity Drift Tube Cooling. WBS 1.2.7 Addresses this Issue.
- Investigate if the Lack of Ferrite Tuner Cone Cooling is Acceptable for 9 Hertz Operations
- Modify the Ferrite Bias Program to Achieve Lower Currents During Booster Null Cycles. Expected to Lower Total RMS Power and Reduce Transformer Heating.
- Investigate Heating Limitations of West Gallery Ferrite Bias Supply Power Transformers for 9 Hertz Operations
- Existence of Inadequate Differential Pressure in the East and West Gallery LCW Distribution Piping is Not Viewed as a Fundamental Problem for 9 Hertz Operations

- Available Yard AC Power Has Been Measured and Found to be Adequate for Present Repetition Rates Only

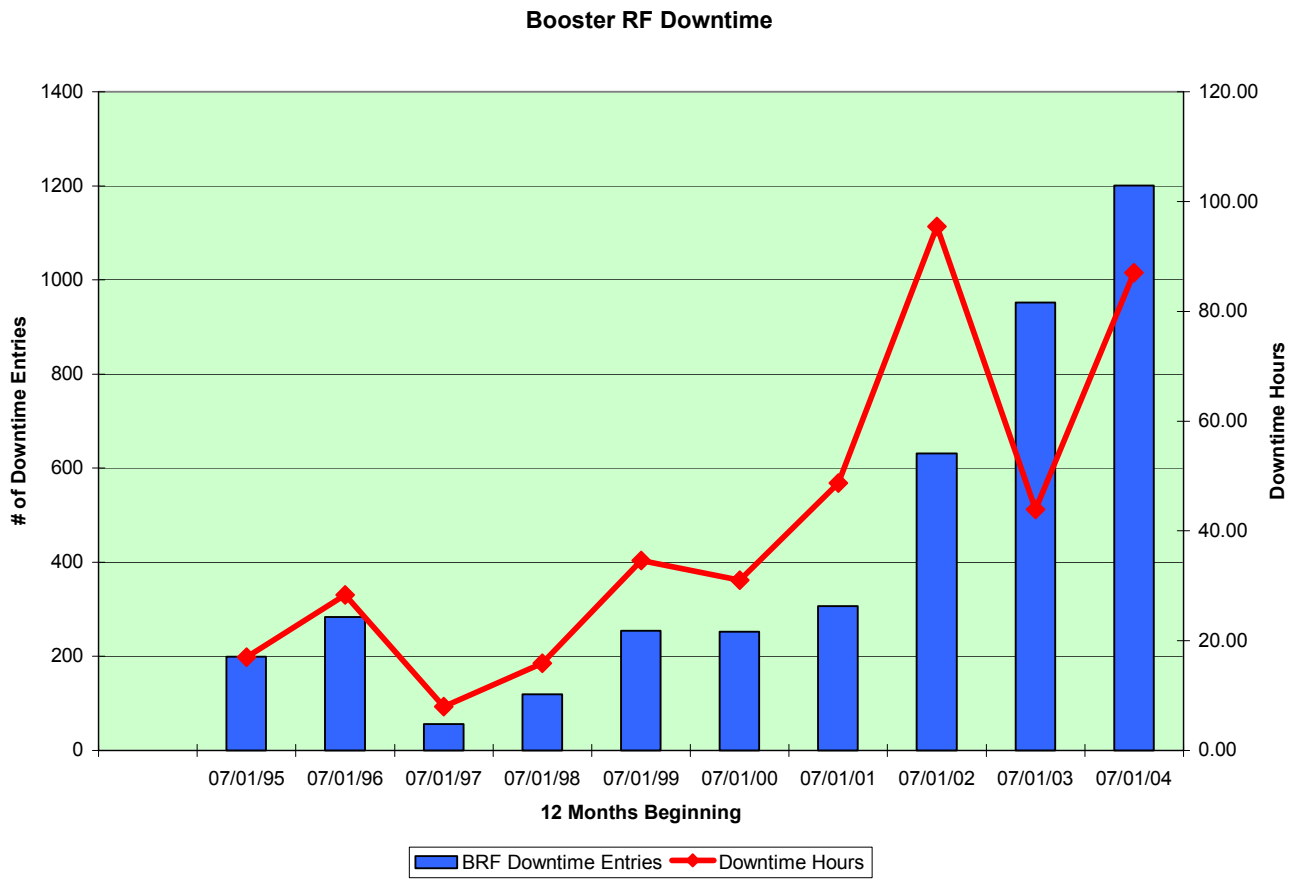
Booster RF Repetition Rate Limit

- Two 1000 kVA Transformers Power All Booster RF Stations. Each of these is Approximately 35 Years Old.
- Measurements Indicated 600 kVA RMS and Nearly 1500 kVA Peak Loads for the Current 7 Hertz Timeline
- Satisfaction of Such a Load Normally Indicates Selection of a 1050 kVA Transformer
- Increasing the Present RF Repetition Rate for these Transformers is Strongly Discouraged
- The Present Situation is Exacerbated by the Fact that there are No Spares Available for these Transformers

- Achievement of 9 Hertz Operation Can Only be Achieved by Replacement of these Transformers and their Associated Panelboards

Booster RF Reliability

- Two Metrics Demonstrating Booster RF Reliability are Shown in the Below Chart. The Marked Rise is Associated with the Start of MiniBooNE Operations in 2002.



Booster RF Reliability

- The Booster RF System is Amongst the Oldest and Original of Systems Still in Use at the Laboratory and Exhibits Relatively Poor Reliability While Becoming Increasingly Difficult to Repair
- Increased Duty Factors, Lack of Available Downtime for Required and Scheduled Maintenance, and Higher Levels of Equipment Activation Have All Led to More Problems
- Distinct Points of Failure are Multiple and Distributed. There are No Quick, Easy or Cheap Fixes.
- Expensive RF Power Tubes Wear Out – But at Least these Tubes are Still Available from EIMAC/CPI
- Going to 9 Hertz will Make Problems Worse
- Upgrading the System with New Solid State Drivers, Modulators and Power Amplifiers, as Used in the Main Injector, is Recommended
- Replacement of East and West Anode Power Supplies is Also Recommended for Any Operations Beyond 9 Hertz