Proton Economics

Allocation of Proton Source 15 Hz Pulses

&

Dealing With Implied Intensities

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Outline

- **Proton Source Hardware Facts**
- **Proton Source Activation Facts**
- **Beam Delivery Facts**
  - Stacking
  - MiniBooNE
  - NuMI
- **Summary of Proton Economics**
  - Details of Three Scenarios
  - “Team Proton” spreadsheet

Proton Source Hardware Facts

- **Linac operates at 15 Hz**
  - Everything operates at 15 Hz, beam or no beam
  - NTF takes “spare” cycles for treatment
    - *Lab management: NTF may take priority if needed.*
- **Booster resonates at 15 Hz**
  - Magnets/Lattice operate at 15 Hz.
  - RF, injection and extraction operate only when beam is anticipated.
    - *Many devices require 2 “pre-pulses” without beam.*
- **Limit today: ~7.5 Hz**
  - Limited by heating of Injection ORBMP magnets.
  - Administrative limit: 5.5 Hz, including pre-pulses.
  - All other systems can operate at 15 Hz.

Proton Source Activation Facts

- **Linac "beam envelope" allows for 15 Hz continuous operation**
  - But some work areas may require reclassifying
- **Booster is already limited by activation.**
  - Activation per proton:
    - *Highest for stacking cycles.*
    - *MiniBooNE swaps protons per cycle for more cycles per hour.*
  - RF cavities are the most active.
    - *Highest maintenance item in Proton Source*
    - *~100 mR/hr fields are common.*
  - Collimator system:
    - *Slated for installation 8/03.*
    - *Should allow 2X more beam at same activation level.*
  - Other improvements under study/design, e.g.:
    - *Overcoming issue with extraction "Dog Legs"*
    - *New, wider-aperture RF cavities*

Beam Delivery Facts

- **We deliver "protons per pulse" (O(10^{12}))**
  - Activation depends on "protons per hour" (O(10^{16}))
  - Experiments want "protons per year," (O(10^{20}))
    - *But I don't understand that unit.*
- **Protons/Pulse, today:**
  - 3.5 to 5.0 $\times$ 10^{12} ppp
- **Run II and MiniBooNE request:**
  - 5.0 $\times$ 10^{12} ppp
- **NuMI Request (?):**
  - More than 5.0 $\times$ 10^{12} ppp
- **Details for:**
  - Stacking,
  - MiniBooNE,
  - NuMI ...

Stacking

- **Request**:
  - 120 GeV, 5×10^{12} ppp, 1.9 to 2.2 seconds.
  - = 0.9 to 0.8×10^{16} pph
  - $\approx$ 0.43 to 0.50×10^{20} ppy (60% uptime)
- **Today**:
  - 120 GeV, 4.8×10^{12} ppp, 2.8 seconds.
  - = 0.6×10^{16} pph
  - $\approx 0.32 \times 10^{20}$ ppy (60%)
- **Forevermore.**

MiniBooNE

- **Request**:
  - 8 GeV, 5 Hz, 5×10^{12} ppp; 9.0×10^{16} pph
  - $\approx$ *7.1 ´ 10²⁰ ppy (80% uptime)*
- **Today**:
  - 8 GeV, ~3 Hz; ~3.5×10^{12} ppp, 3.5×10^{16} pph
  - $\approx$ *2.5 ´ 10²⁰ ppy*
- **Will run through 2004 (?)**

NuMI

- **Request:**
  - 120 GeV, 5×10^{12} ppp, 5 Booster cycles over 2 seconds: 4.5×10^{16} pph
    - *» 2.4 ´ 10^{20} ppy (60% uptime)*
  - Piggybacked on stacking cycles
    - *Slipstacking?*
- **Starting in 2005 (?)**
- **Other coming requests?**
  - CKM? BTeV?

Summary of Proton Economics

Booster Hardware Issues

Radiation Issues

Scenario	Cycles	Batches				Rep Rt.	Protons Deliv'd (E16/hr)*			Total	
		Pre-p.	Stack	MB	NuMI	Ave Hz	Stack	MB	NuMI	E16/hr	/Now#
Stack	30	2	1			1.5	0.9	0.0	0.0	0.9	15%
Stack + MB	30	2	1	10		6.5	0.9	9.0	0.0	9.9	165%
Stack + MB	25	2	1	9		7.2	1.1	9.7	0.0	10.8	180%
Stack + NuMI	30	2	1		5	4.0	0.9	0.0	4.5	5.4	90%
Stack + MB + NuMI	42	2	1	14	5	7.9	0.6	9.0	3.2	12.9	214%
SlipStack + NuMI	42	2	2		10	5.0	1.3	0.0	6.4	7.7	129%
SlipStk + MB + NuMI	42	2	2	14	10	10.0	1.3	9.0	6.4	16.7	279%

- * Assumes 5 ´ 10^{12} ppp
- # Now » 6 ´ 10^{16} pph
- Lab Management: Not committing to running MiniBooNE & NuMI simultaneously.
- Proton Source management: Be prepared, anyway.

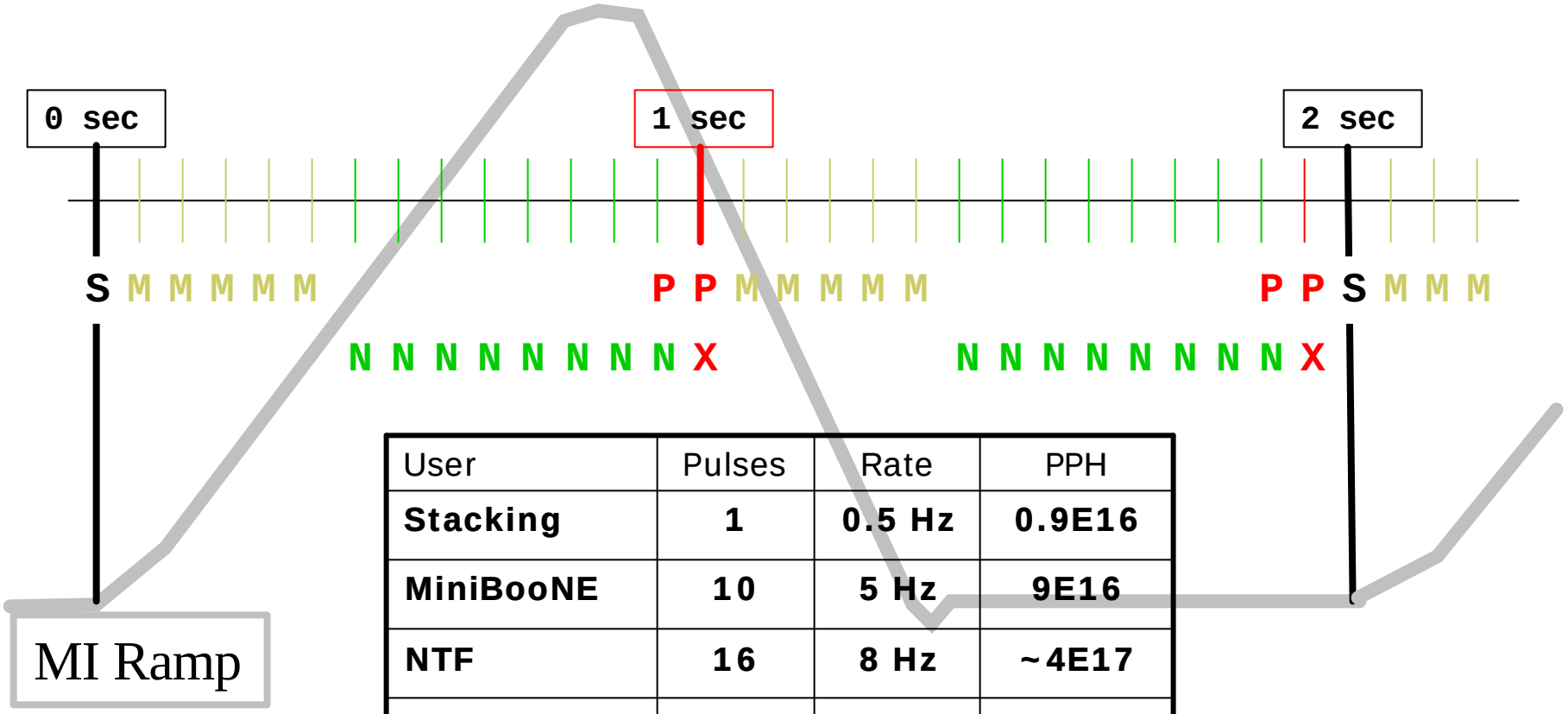
Details of Three Scenarios

1. Stacking, MiniBooNE and NTF, 2.0 sec stacking period.
2. Same, 1.7 sec stacking period.
3. Stacking, MiniBooNE, NuMI and NTF, 2.8 sec stacking/NuMI period,
   - "Be prepared."

- *Other scenarios would include CKM, different cycle times for NuMI and/or MiniBooNE, the MuCool experiment, BTeV (?) etc.*

1. Stacking, MiniBooNE & NTF

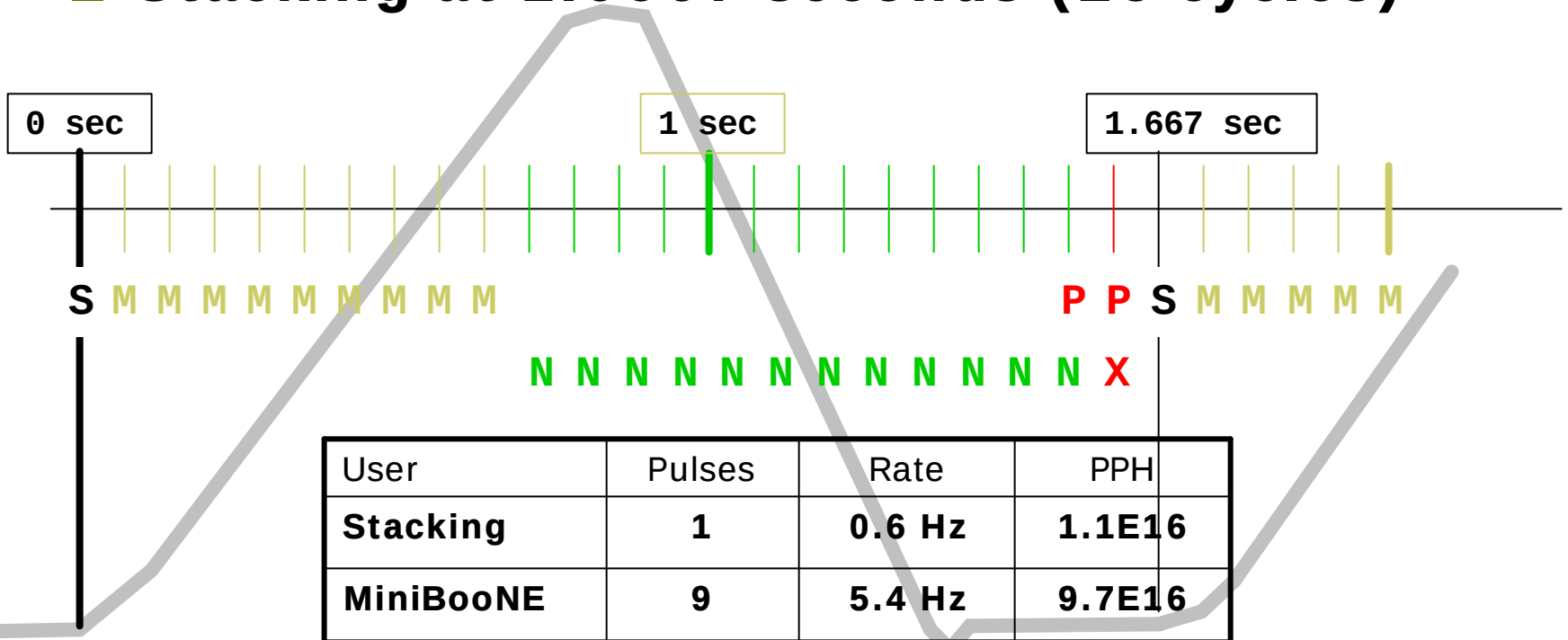
- Stacking at 2.0 seconds (30 cycles)



User	Pulses	Rate	PPH
Stacking	**1**	**0.5 Hz**	**0.9E16**
MiniBooNE	**10**	**5 Hz**	**9E16**
NTF	**16**	**8 Hz**	**~4E17**
No Beam	**2**	**1 Hz**	**-**
Tot Booster	***13***	***6.5 Hz***	***10E16***

2. Stacking, MiniBooNE & NTF

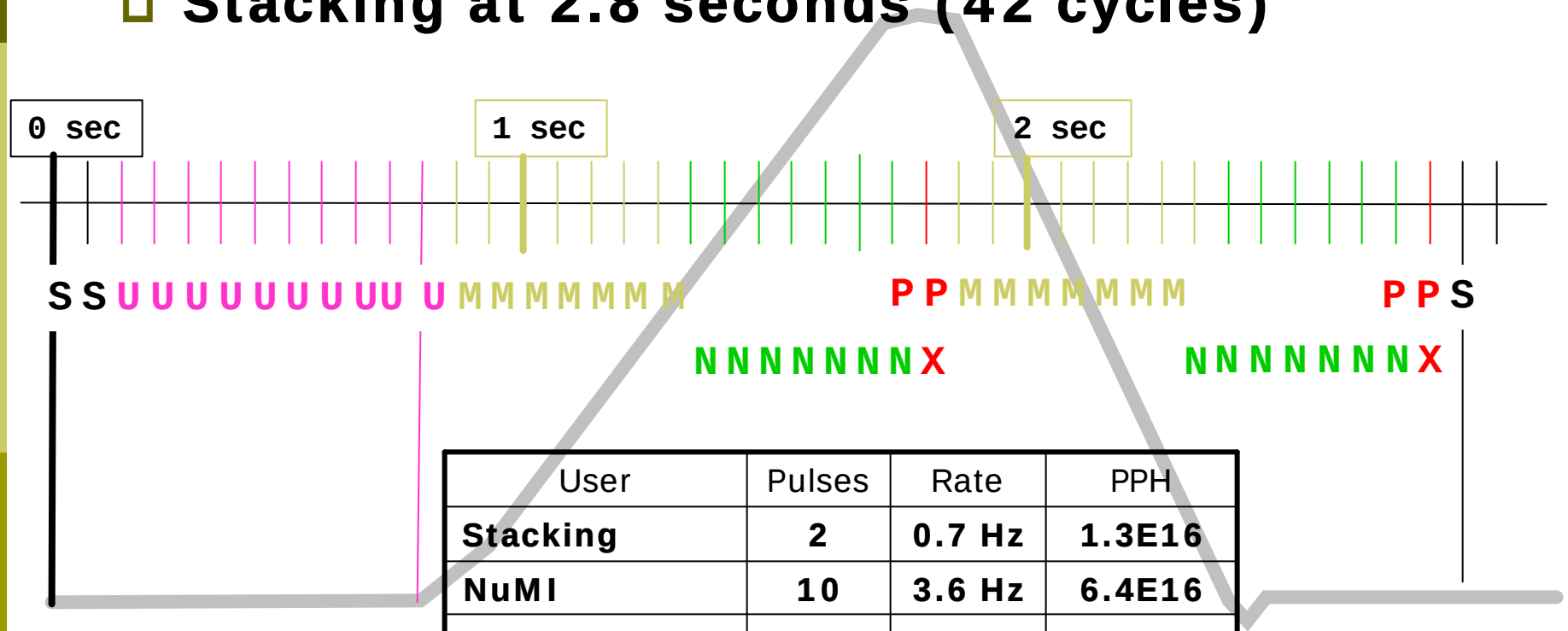
- **Stacking at 1.6667 seconds (25 cycles)**



User	Pulses	Rate	PPH
Stacking	**1**	**0.6 Hz**	**1.1E16**
MiniBooNE	**9**	**5.4 Hz**	**9.7E16**
NTF	**12**	**7.2 Hz**	**~3E17**
No Beam	**2**	**1.2 Hz**	**-**
Tot Booster	***12***	***7.2 Hz***	***11E16***

3. Slip Stacking, NUMI, MiniBooNE & NTF

- Stacking at 2.8 seconds (42 cycles)



User	Pulses	Rate	PPH
Stacking	**2**	**0.7 Hz**	**1.3E16**
NuMI	**10**	**3.6 Hz**	**6.4E16**
MiniBooNE	**14**	**5 Hz**	**9.0E16**
NTF	**14**	**5 Hz**	**~2E17**
No Beam	**2**	**0.7 Hz**	**-**
Tot Booster	***28***	***10 Hz***	***16.7E16***

P. Kasper & "Team Proton": Cycle Counting Spreadsheet

- http://www-bd.fnal.gov/proton/ProtonCommittee

MiniBooNE

Program	Booster Batches		Fraction of year allocated	Booster Beam Trains	Cycle time (sec)	Booster Intensity **5.0E+12** 1	Booster Rate (Hz) **7.5** 2	Booster protons/hr **1.8E+17** 3
BooNE	10		0.80	1	2.00	4.0E+12	6.00	7.1E+16
BooNE	0	#	0.00	0	0.00	0.0E+00	0.00	0.0E+00
NuMI	0					0.0E+00		
Pbar	0					0.0E+00		
BooNE	0	#	0.00	0	0.00	0.0E+00	0.00	0.0E+00
CKM	0					0.0E+00		
						Average of MI modes:	0.00	0.0E+00
						# fast spill cycles per slow spill cycle:		0.00

Kasper Spreadsheet Assumptions

Program Requests

Pbar	**7.5E+19**	p/year				
NuMI	**3.6E+20**	p/year				
BooNE	**5.0E+20**	p/year	**10**	batches @	**5**	Hz
CKM	**2.2E+19**	p/year	**5.0E+12**	p/second	**6**	sec slow spill

Up Time (fraction of year)

Booster	**0.8**
MI	**0.6**

Machine Parameters

22 clicks for MI acceleration

2 clicks for slip-stacking (used if Pbar batches > 1 or NuMI+Pbar batches > 6)

1 click added to MI cycle for debunching for CKM

2 Booster prepulses required before beam cycles

2 seconds minimum MI cycle time for Pbar

MiniBooNE & Pbar with slip-stacking

Program	Booster Batches		Fraction of year allocated	Booster Beam Trains	Cycle time (sec)	Booster Intensity **5.0E+12** 1	Booster Rate (Hz) **7.5** 2	Booster protons/hr **1.8E+17** 3
BooNE	10		0.20	1	2.00	4.0E+12	6.00	7.1E+16
BooNE	10		0.60	1	2.00	4.0E+12	7.00	8.6E+16
NuMI	0					0.0E+00		
Pbar	2					4.0E+12		
BooNE	0	#	0.00	0	0.00	0.0E+00	0.00	0.0E+00
CKM	0					0.0E+00		
						Average of MI modes:	7.00	8.6E+16
						# fast spill cycles per slow spill cycle:		0.00

MiniBooNE, Pbar, & NuMI with fast slip-stacking

Program	Booster Batches	Fraction of year allocated	Booster Beam Trains	Cycle time (sec)	Booster Intensity **5.0E+12** 1	Booster Rate (Hz) **7.5** 2	Booster protons/hr **1.8E+17** 3
BooNE	10	0.20	1	2.00	4.5E+12	6.00	8.2E+16
BooNE	10	0.60	1	2.40	4.5E+12	10.00 !	1.5E+17
NuMI	10				4.6E+12		
Pbar	2				4.8E+12		
BooNE	0 #	0.00	0	0.00	0.0E+00	0.00	0.0E+00
CKM	0				0.0E+00		
					Average of MI modes:	10.00 !	1.5E+17
					# fast spill cycles per slow spill cycle:		0.00

MiniBooNE, Pbar, NuMI, & CKM

Program	Booster Batches	Fraction of year allocated	Booster Beam Trains	Cycle time (sec)	Booster Intensity **5.0E+12** 1	Booster Rate (Hz) **7.5** 2	Booster protons/hr **1.8E+17** 3
BooNE	10	0.20	1	2.00	4.6E+12	6.00	8.3E+16
BooNE	10	0.42	1	2.40	4.6E+12	10.00 !	1.9E+17 !
NuMI	10				6.6E+12 !		
Pbar	2				6.9E+12 !		
BooNE	30	0.18	3	7.93	4.6E+12	5.29	7.7E+16
CKM	6				5.0E+12		
					Average of MI modes:	8.55 !	1.5E+17
					# fast spill cycles per slow spill cycle:		7.45

- Being studied by Team Proton.
- No published recommendations, yet.

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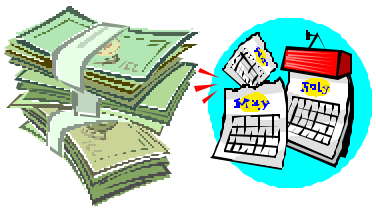
Conclusions

- **Proton Source limited by activation.**
  - Several improvements underway to increase flux without increasing activation:
- **Hardware limit now: 7.5 Hz.**
  - Upgrade ORBMP injection:



- **Can do some of requested program now.**
- **Must coordinate requests on the PS with our abilities to satisfy these requests.**