Proton Needs vs Limitations of Existing Proton Source

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At the Proton Driver Part of the
Public Presentation on Long Range Planning

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Fermilab

Note: All of the following slides come from Peter Kasper's and Doug Michael's presentations to the subcommittee on the Proton Driver

Low Energy Physics Potential of a Proton Driver

Peter Kasper

26-Sep-2003

http://home.fnal.gov/~kasper/talks/LRPC.ppt

Topics Covered

- A physics program based on 8 GeV protons from the Booster or a Proton Driver (linear or circular) will likely fall into one or more of the following categories
  - Neutrino Physics
  - Fundamental Neutron Physics
  - Muon Physics
- In all cases, high intensities will be required in order to create a state of the art facility.
  - What might be achieved with the Booster?
  - What more could be done with a Proton driver?

What can we do with what we have?

- Enormous progress has been made recently on increasing the output from the Booster
- However the physics potential of NuMI and MiniBooNE make it worth the effort to push as high as we can.
- Even greater output is possible but we can only go so far
  - These experiments represent a great starting point for high intensity programs at both high and low energies
  - The Booster will hopefully be able to meet their needs in the short term
  - A Proton Driver not only allows the programs to advance but opens up other interesting possibilities

Proton Availability – Near Term

- Booster Now
  - ~5e16 p/hr (limited by tunnel activation)
  - ~5e12 p/cycle maximum sustainable intensity
  - 6.5 Hz maximum beam cycle rate @ 5e12 p/cycle = 1.2e17 p/hr
  - 1.8e17 p/hr (Shielding Assessment limit) = 5e12 @ 10 Hz
- Pbar Production + Full MiniBooNE (Booster limit ? 1.2e17 p/hr)
  - 5e12 @ (0.5+5.0) Hz = 1.0e17 p/hr
  - 5e12 @ (1.0+5.0) Hz = 1.1e17 p/hr (with slip-stacking)
- Pbar Production + NuMI
  - 5e12 @ (1.0+2.5) Hz = 6.3e16 p/hr
  - 5e12 @ 3.0 Hz = 5.4e16 p/hr available to MiniBooNE
- NuMI will want to increase protons to the MI
- MiniBooNE will want to increase rep rate

Proton Availability – Medium Term

- Increase rep rate to 10 Hz (Booster limit ? 1.5e17 p/hr)
  - Full 9E16 p/hr rate for MiniBooNE/BooNE
- Introduce fast stacking in MI for NuMI and Pbar and raise Booster limit to SA value of 1.8e17 p/hr
  - MI must handle 6E13 p/cycle
  - Minimum MI Cycle time goes to 2.27 sec
  - MI gets 5e12 @ 5.3 Hz = 9.5e16 p/hr
  - 8 GeV users can get 8.5e16 p/hr (still OK for BooNE)
- Shorten MI acceleration cycle to 1 sec (few $10M's)
  - Minimum MI Cycle time goes to 1.8 sec
  - MI gets 5e12 @ 6.7 Hz = 1.2e17 p/hr
  - 8 GeV users can get 6.0e16 p/hr (probably adequate)

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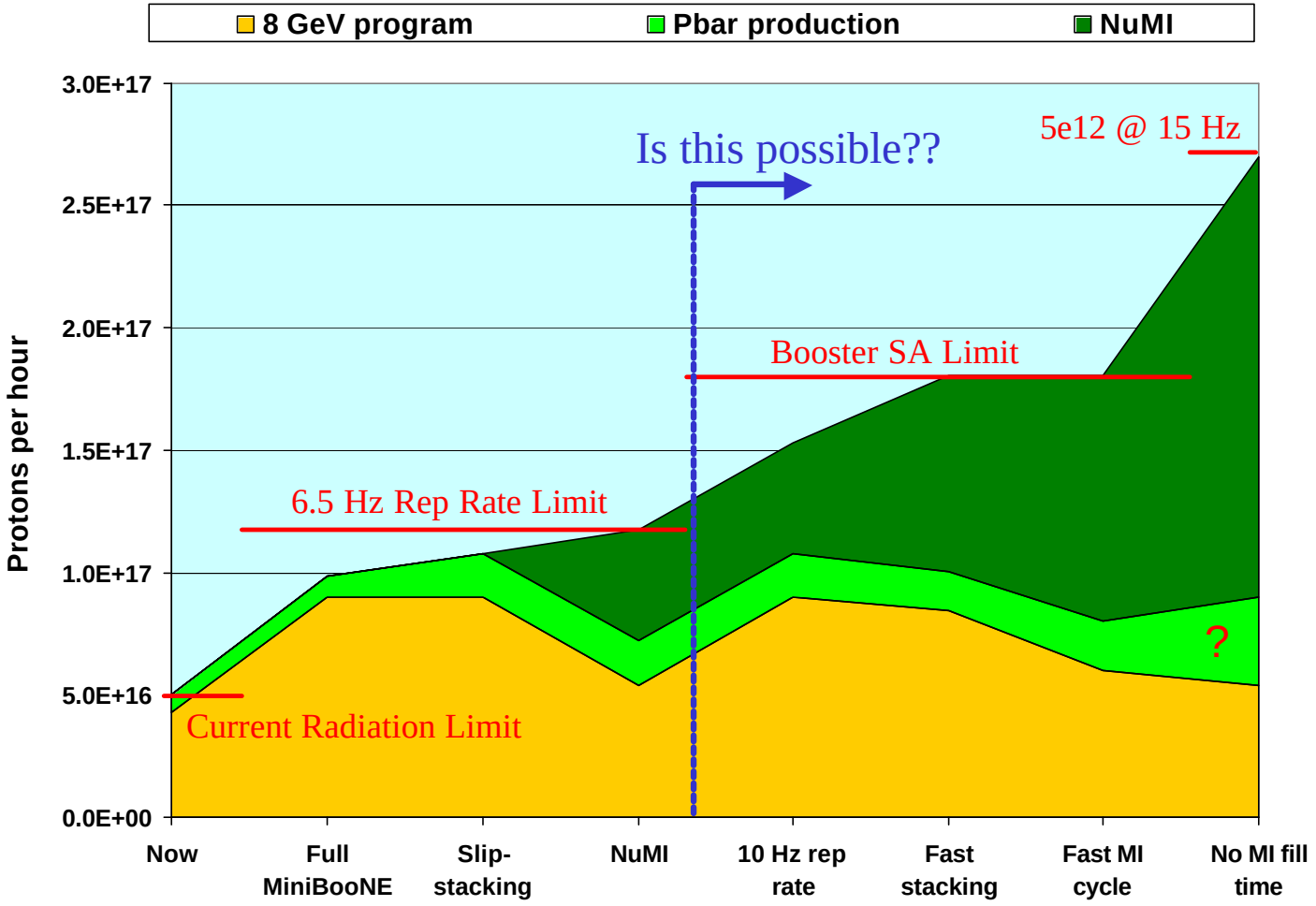
Proton Availability – Far Term

- Eliminate MI fill time??
  - Booster fills recycler while MI is accelerating
    - Assumes the recycler is not being used for P-bar's
  - Recycler is used to do slip-stacking and to fill the MI
  - Minimum MI cycle time is reduced to 1 sec.
  - 12 x 5e12 Booster batches per second exceeds both the Booster SA limit and the assumed rep-rate limit
- Assume maximal Booster i.e. 5e12 @ 15 Hz = 2.7e17 p/hr
  - MI gets 5e12 @ 12 Hz = 2.2e17 p/hr
  - 8 GeV users can get 5.4e16 p/hr
  - Is this even possible?
- Additional gains will require a new proton source

Summary of Possible Booster Output



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Recap

- The present facility can be made to meet the needs of MiniBooNE
- NuMI goals are challenging and may require significant MI and possibly Booster upgrades
- MiniBooNE and NuMI will be able to live together but as time goes on and demand goes up, there are significant issues that must be addressed.
- Upgrading to 10 Hz (if radiation can be controlled) will make a MiniBooNE successor possible.
- A fast slip-stacking scheme (if it can be done) will greatly benefit NuMI and leave sufficient protons for BooNE etc.
- Further increasing the MI's output will significantly reduce protons to any 8 GeV users.
- In the long term the only solution is a new proton driver

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Recap

- The pre
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What does “Control Radiation” mean?

Increase the performance while:

- Reducing the Losses
- Controlling the Losses
- Hardening Against Inevitable Losses

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Concluding Remarks

- The Booster WILL max out
- A Proton Driver will provide a future for the lab's growing neutrino program
- It will provide the lab with the flexibility to respond to possible discoveries in the current program
- It also opens up possibilities for other new facilities attracting new user communities
- A surprising amount of work has been done to produce the present level of physics and machine studies
- **Further progress will depend on an indication from the lab that it is serious**

Semi-Coherent Thoughts on Fermilab's Long Baseline Future

Doug Michael

Sep. 26, 2003

On the way to the proton driver: MINOS

Doug Michael September 26, 2003

MINOS Running Plan

- Draft Fermilab Long-Range Plan:
  - NuMI beam commissioning starting in Dec. 2004.
  - 4 years of physics running for MINOS starting in April 2005.
  - Goal for protons on target in first year = 2.5 x 10^{20}
  - Plans are being developed for increased proton intensity.
- New MINOS Running Request (May 2003)
  - MINOS has submitted a request to Fermilab for 5 years of running with a total of 25 x 10^{20} protons on target in that time.
  - MINOS has provided updated physics sensitivity curves based on 7.4, 16 and 25 x10^{20} total protons on target. (Original MINOS physics sensitivity was based on 7.4 x 10^{20} pot.)
  - There are several options for providing this number of protons.
- The performance of MINOS has always depended on the NuMI beamline being far more intense than any other.

Doug Michael September 26, 2003

25e20? Is this guy a nut?

- 10 years at the nominal first year plan
- 5 years if all that is done is just a factor of 2 in the proton intensity… Possible by reducing the MI cycle time.
- Using the Recycler to hide the cycle time of the Booster could be a cost effective means of another 30-50% increase in intensity. Just this and the MI cycle time can yield a 0.8 MW proton source.
- Then squeeze out another 20-30% of improvement through stacking in the Main Injector and/or increase in intensity from the Booster…
- … Perhaps this is the hitch. Can it survive this?

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Current Main Injector Ramp

- Bend Ramp

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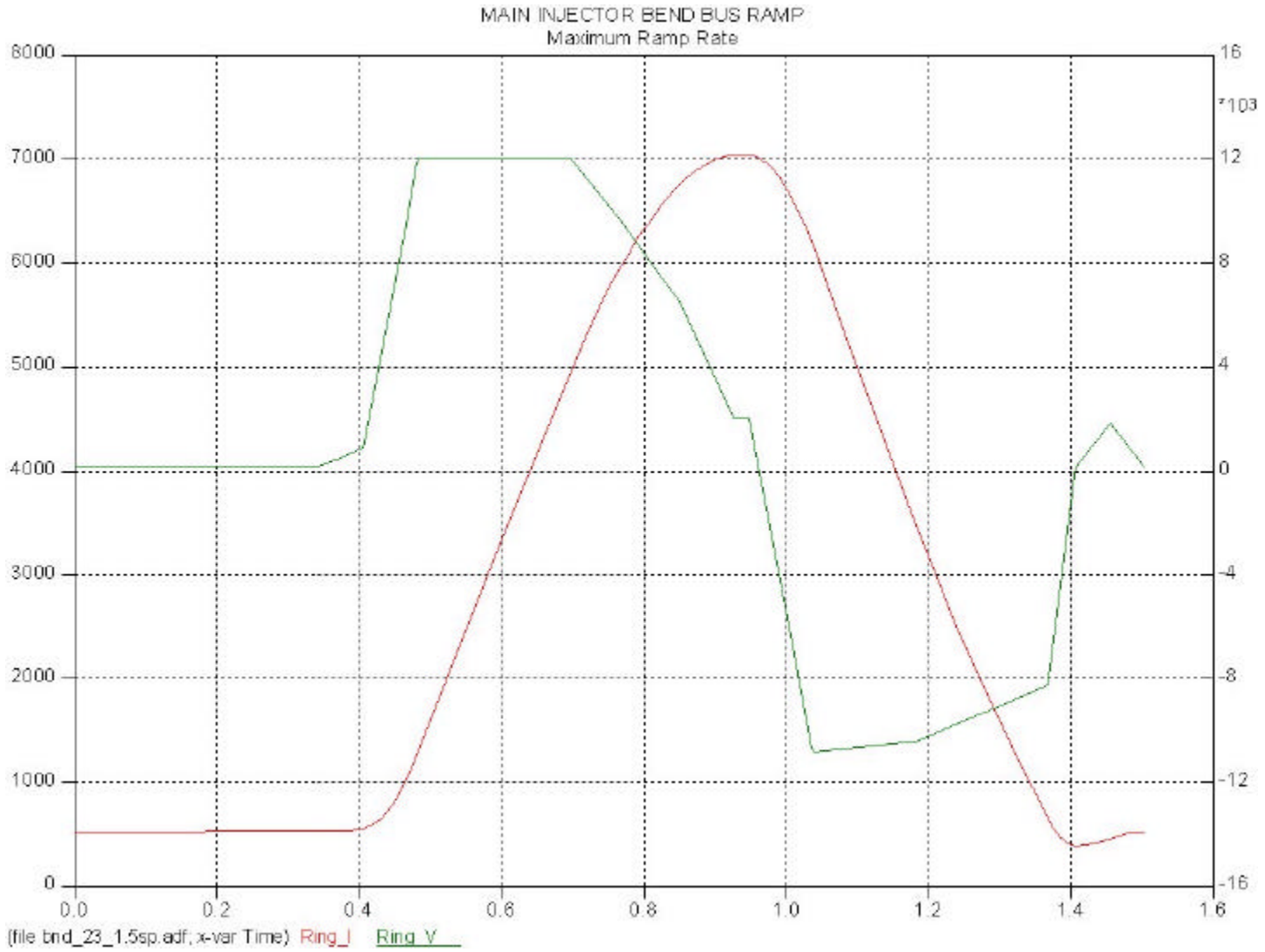
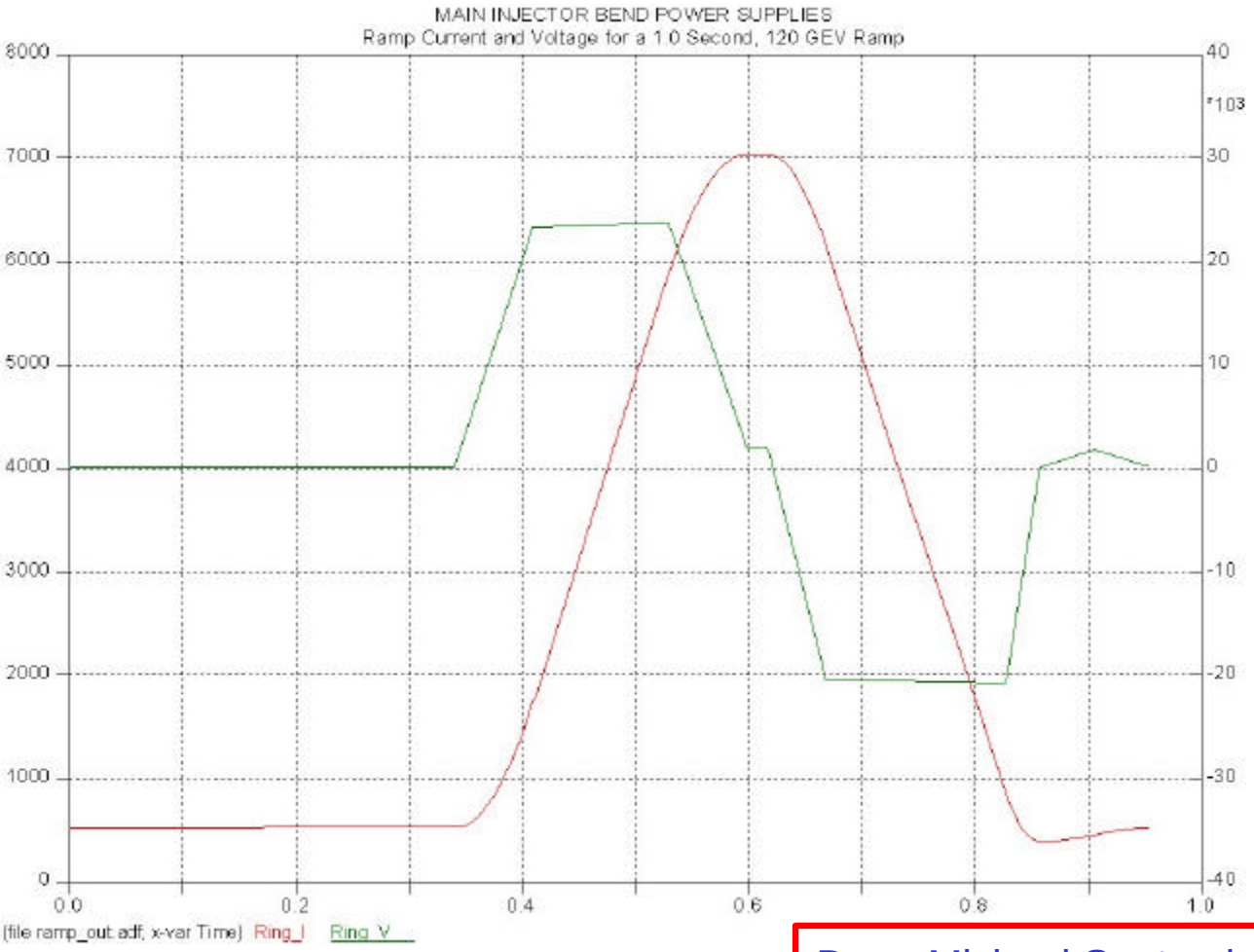


But it can be faster!



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Reducing the MI Cycle Time

- This is one thing that can "work for sure" to deliver more protons. But beware of the pbar cycle time! 2.0 s is lower limit?
- Will be useful before and after completion of a new proton source.
- Some specific studies have been done of what is necessary to set an MI ramp time of 1.17 s and 0.62 s (Proton driver study, Mishra, Wolf, Marriner, others)
  - 1.17 s ramp time may be achievable for very little cost (<$2M?)
  - 0.62 s ramp time costs $25M for magnet power? + $25M for RF? Needs more study.
    - Additional magnet power supplies (and places to put them)
    - Replace some magnets?
    - x2 RF power (Complete overlap with high intensity needs)
    - x2 RF voltage (More cavities and/or higher voltage per cavity (new cavities?), Currently there are 18 cavities. HI requires 20. Depending on the exact intensity and ramp time this requires 20<N<36 equivalent? Use straight section at MI 30 (Marriner))
- Beyond a very first step, additional RF voltage, beyond that available to the cavities will be necessary quickly… New RF cavities. Universities could help make a partial step particularly inexpensive?
- The MI has enough RF power now for 6e13 protons acc to 120 GeV in 1.5s.
- Technically, should be possible by 2008

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Conclusions

- We don't know what the neutrino oscillation future holds.
- Long baseline experiments offer a completeness in measurement capabilities not possible with other techniques
- Protons are the key to these experiments. Don't bother without making the investment in protons.
- Fermilab cannot delay getting started in increasing the protons. Things which can be done in the existing complex must be done as soon as possible while bringing the proton driver into operation in the next decade.