Proton Driver + Main Injector Machine Parameters

Reference Design & Options

Bill Foster

Proton Driver Physics Workshop

October 6, 2004

Main Injector + Proton Driver Super-Beam Parameters

- 8.000 GeV Kinetic Energy at Injection
- 120 GeV Maximum Energy at Extraction
- 1.5E14 Protons (25 uC) in Main Injector
  - *5x Main Injector Design*
- 1.5 Second Main Injector Cycle Time
  (1.8 seconds for Synchrotron Option)

  May Improve Earlier
- Main Injector Beam Power:

  25uC * 120 GeV / 1.5 sec = **2 MW**

The MI Parameters for the CD-0 Study will be ~ Identical to the PD II Study

- The target value of 5x increase in protons per MI cycle has proven reasonable…nothing breaks badly or cries out for change

- This is somewhat remarkable since it was chosen (for convenience) to match the charge-per-pulse of the SNS linac.

DRIVER PARMETERS

PROTON DRIVER		Baseline Linac	Green Linac	Synchrotron
Stand-Alone Power	MW	2	0.5	0.5
Beam Energy	GeV	8	8	8
Cycle Rate	Hz	10	2.5	15
Protons/cycle	E13	15	15	2.5
Protons/sec	E13	150	37.5	37.5
Bunch Frequency	MHz	325	325	53
Bunch Length	nsec	0.05	0.05	5
Beam Spill	usec	1000	3000	1.5
Beam Type		H- [P,e-]	H- [P,e-]	P

Main Injector Parameters

MAIN INJECTOR		Baseline Linac	Green Linac	Synchrotron
Beam Power	MW	2	2	1.6
Beam Energy	GeV	16-120	16-120	120
Cycle Rate	Hz	0.67	0.67	0.55
Protons/cycle	E13	15	15	15
Protons/sec	E13	10.05	10.05	8.25
Bunch Frequency	MHz	53	53	53
Bunch Length	nsec	~2	~2	~2
Beam Spill	usec	10	10	10
Beam Type		P	P	P

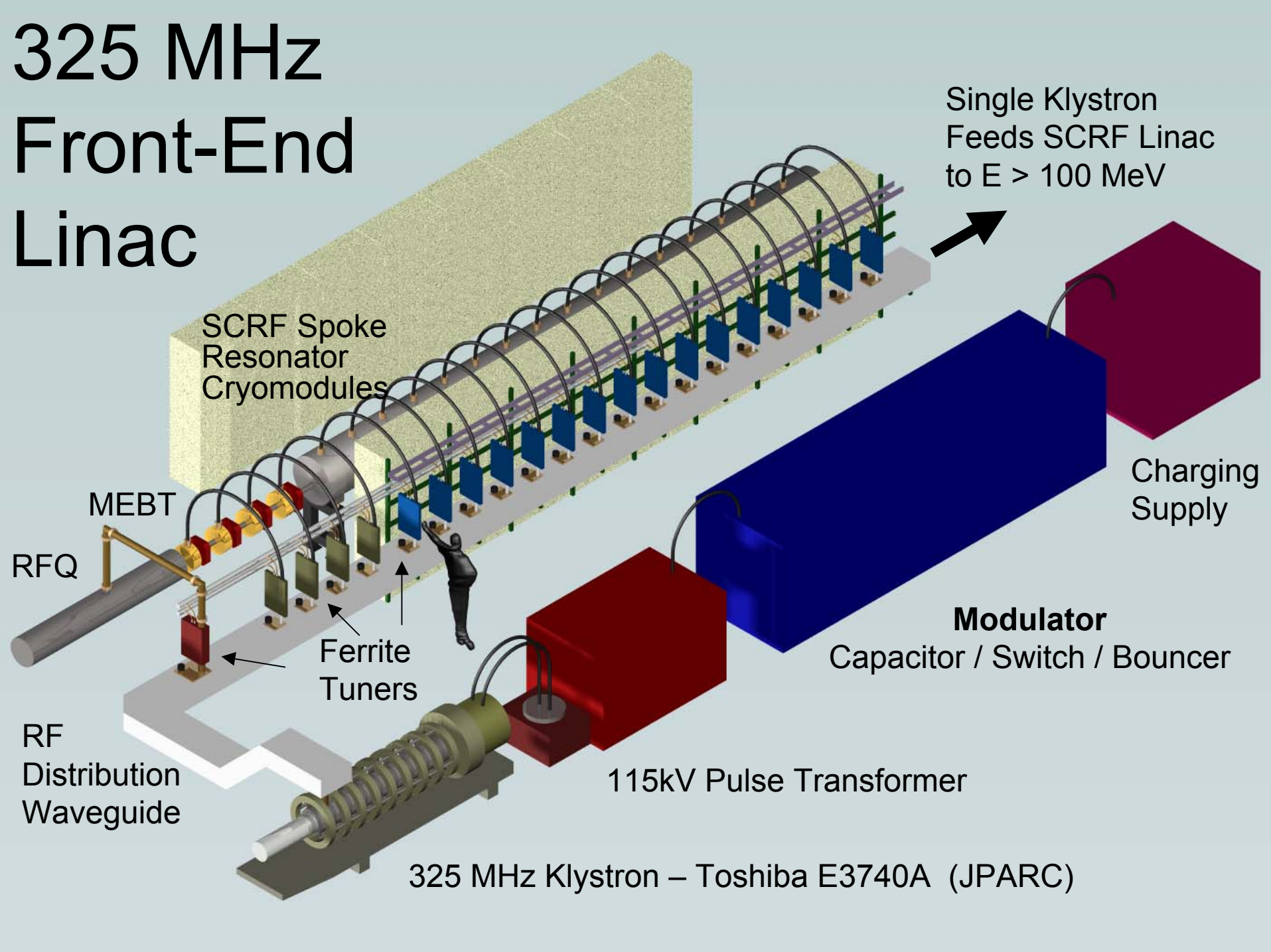
Proton Driver II Design Study

- Linac:
  http://tdserver1.fnal.gov/project/8GeVLinac/DesignStudy
- Synchrotron:
  http://www-bd.fnal.gov/pdriver/8GEV/
- Linac Parameter Book
  http://tdserver1.fnal.gov/project/8gevlinac/8_GeV_Parameter_List_Current_Version.pdf

Linac Changes

1. Adoption of TESLA-compatible RF frequencies (1300 MHz and 325 MHz)
   - This is largely invisible to the MI user since beam is re-bunched at 53 MHz
2. Consideration of a Green Version of the Proton Driver Linac with only 0.5 MW stand-alone power at 8 GeV
   - Saves $$$ but still supports 2 MW in the MI
3. Adoption of a SCRF front end
   - Start building in SMTF (Meson Lab) this year

325 MHz Front-End Linac



Three Proton Driver Variants,

Differing by Stand-alone Beam Power at 8 GeV

1. Synchrotron with 0.5 MW at 8 GeV
2. Green Linac with 0.5 MW @ 8 GeV

Will be Basis for Cost Comparison

3. Baseline Linac - 2 MW @ 8 GeV

Original Linac Design Study

Slight Differences in Beam Power Between Synchrotron & Linac

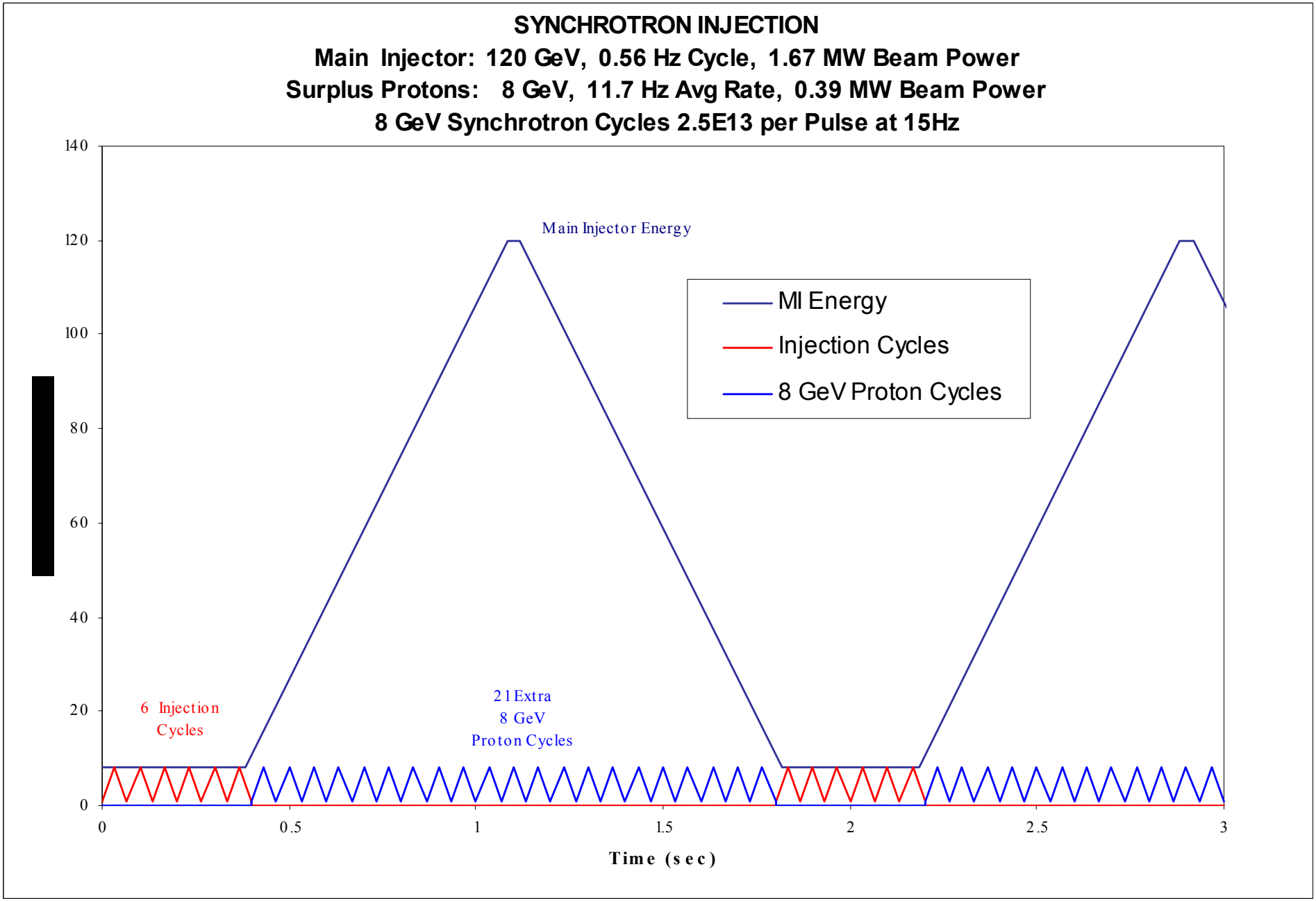
- Both the Synchrotron and Linac deliver the same charge into Main Injector
- Synchrotron needs extra time to fill 6 batches into Main Injector each cycle
- MI has ~20% faster cycle time & higher average power with the linac.

A Gallery of Main Injector Cycle Options

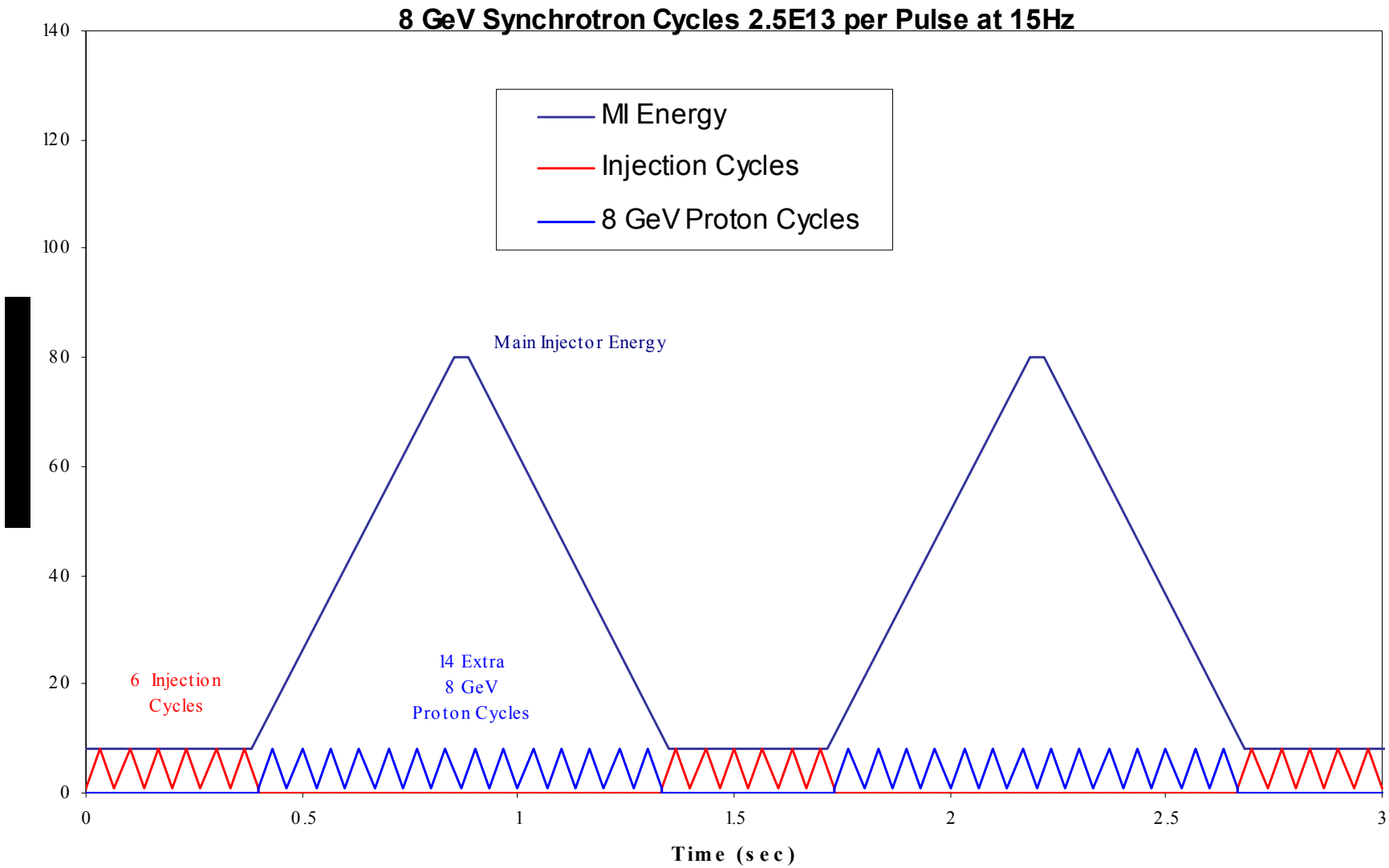
1. Synchrotron Booster Injection
2. 8 GeV Linac Injection

- As MI energy is dropped, increasing fraction of time is wasted on Booster Injection Cycles
- Linac Allows MI to deliver full 2 MW beam power at reduced beam energy.
  - Flexible neutrino program

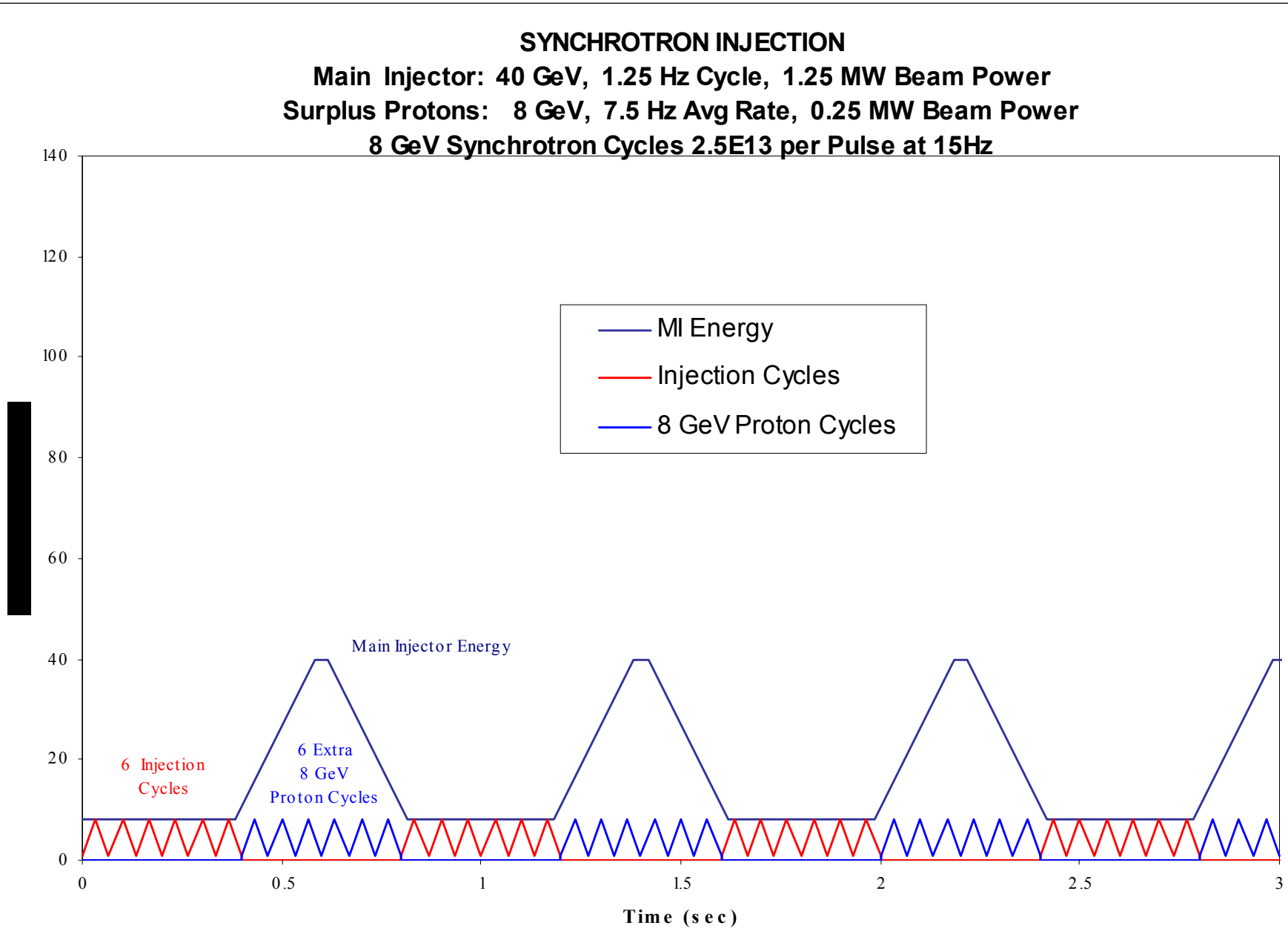
120 GeV MI with Synchrotron Injection



80 GeV MI with Synchrotron Injection

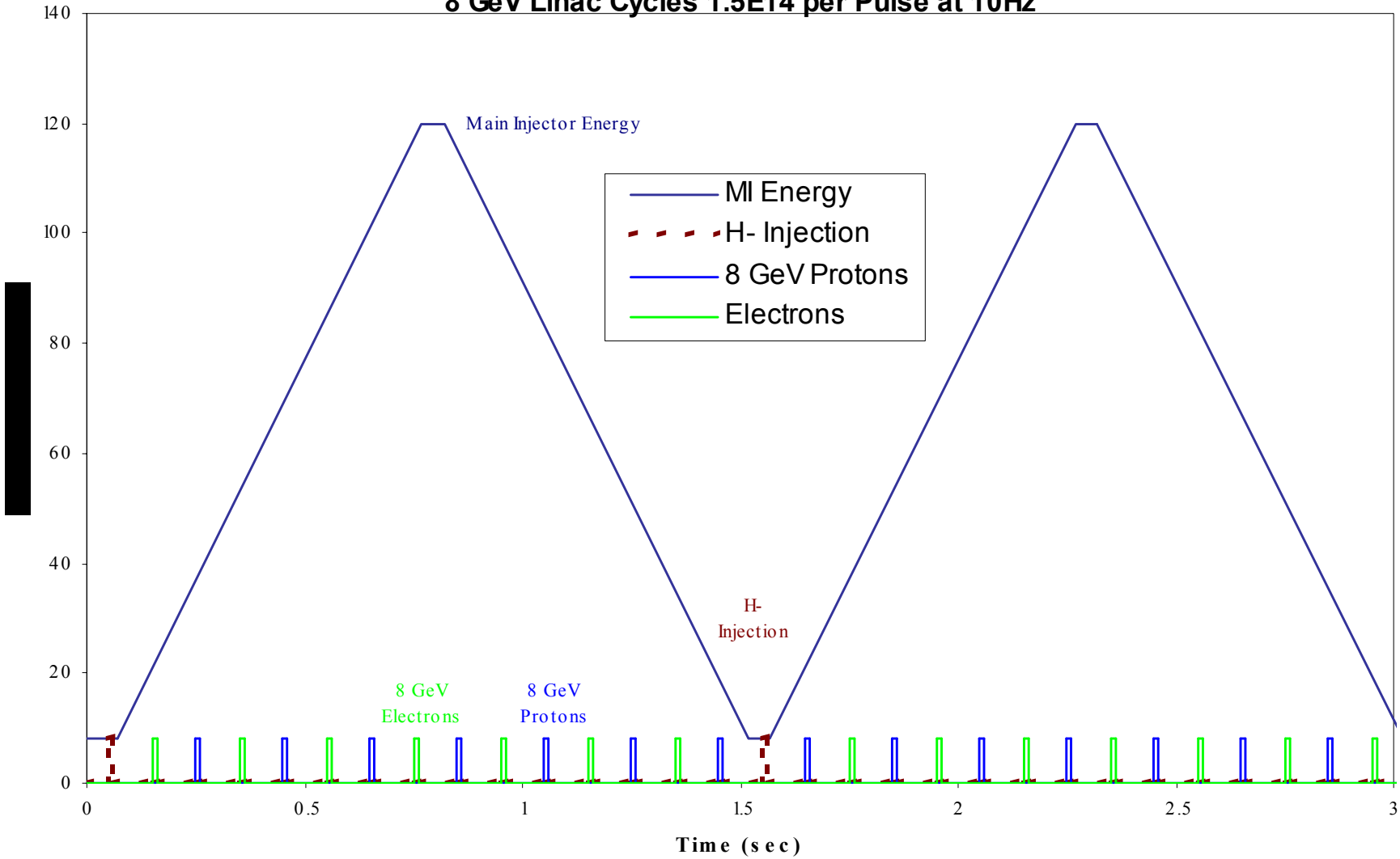


40 GeV MI with Synchrotron Injection

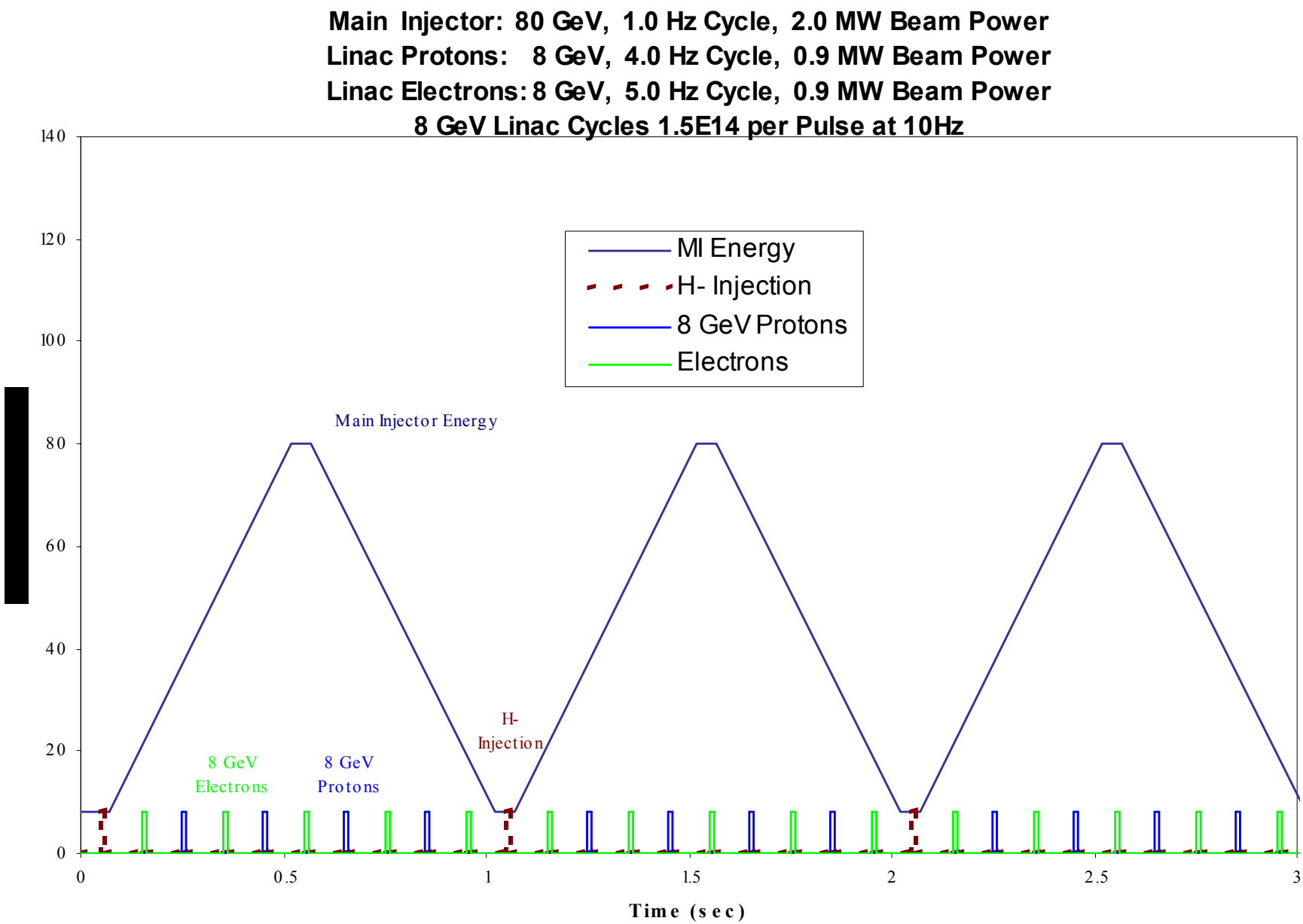


120 GeV MI with LINAC Injection

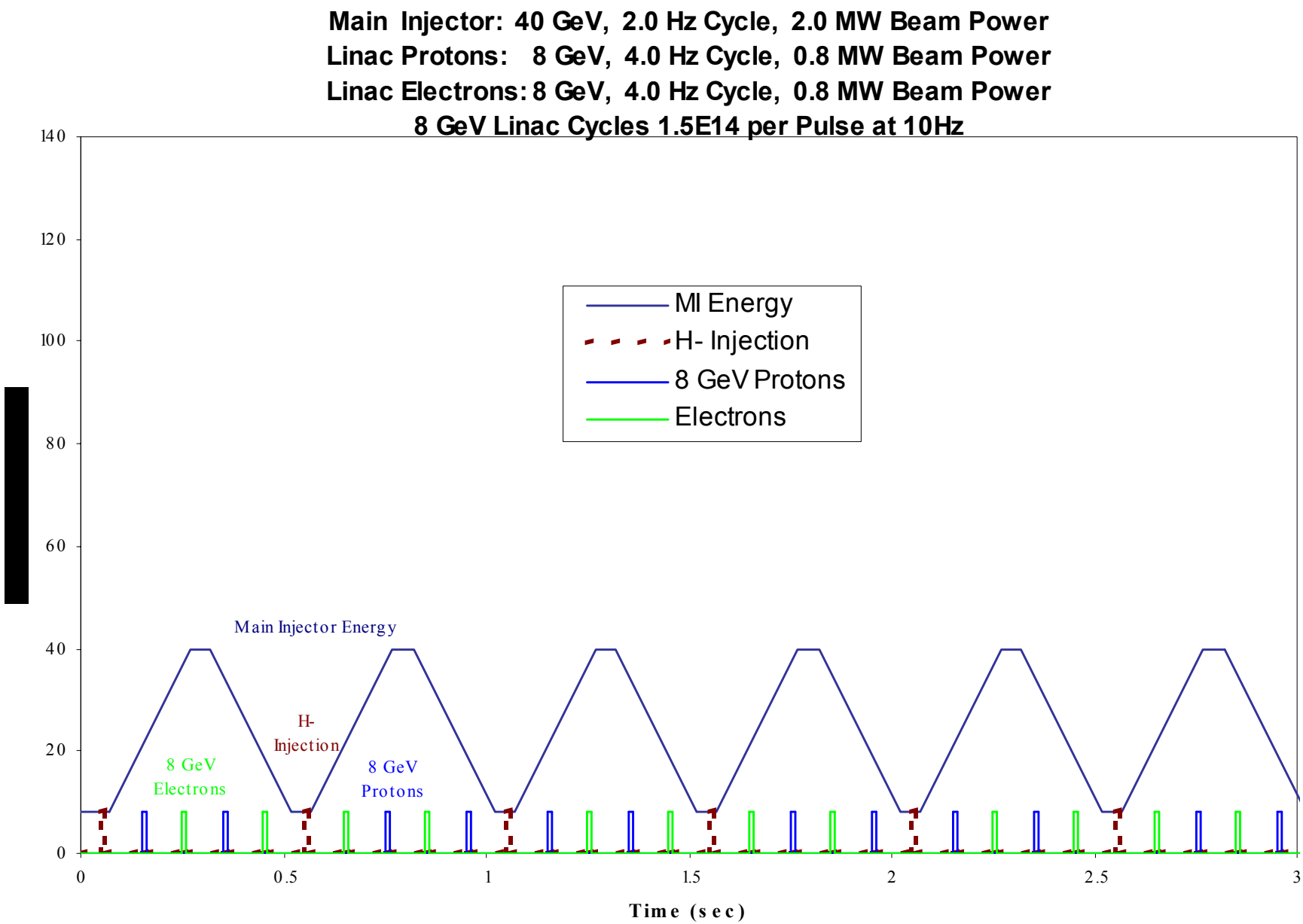
Main Injector: 120 GeV, 0.67 Hz Cycle, 2.0 MW Beam Power
Linac Protons: 8 GeV, 4.67 Hz Cycle, 0.93 MW Beam Power
Linac Electrons: 8 GeV, 4.67 Hz Cycle, 0.93 MW Beam Power
8 GeV Linac Cycles 1.5E14 per Pulse at 10Hz



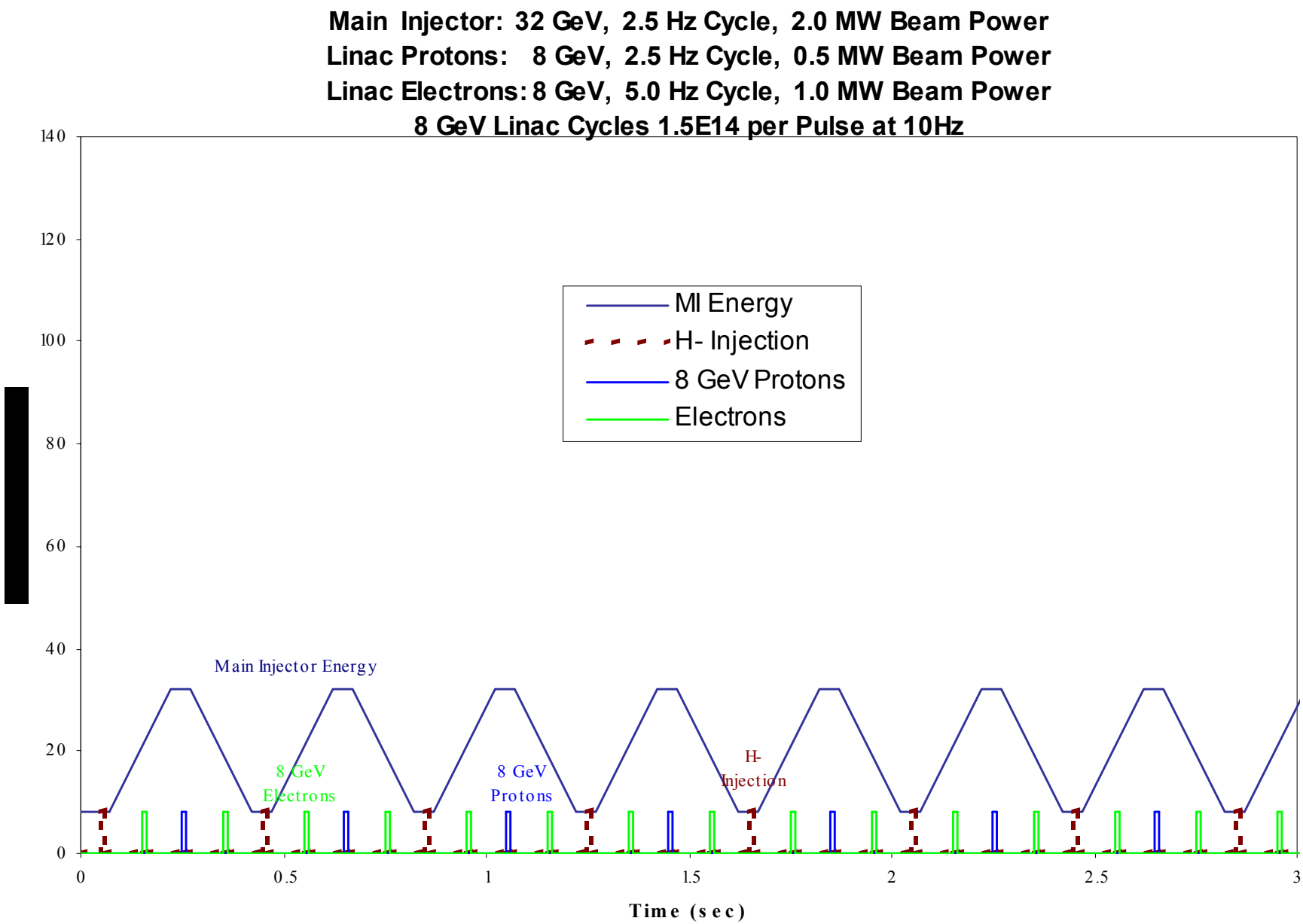
80 GeV MI with LINAC Injection



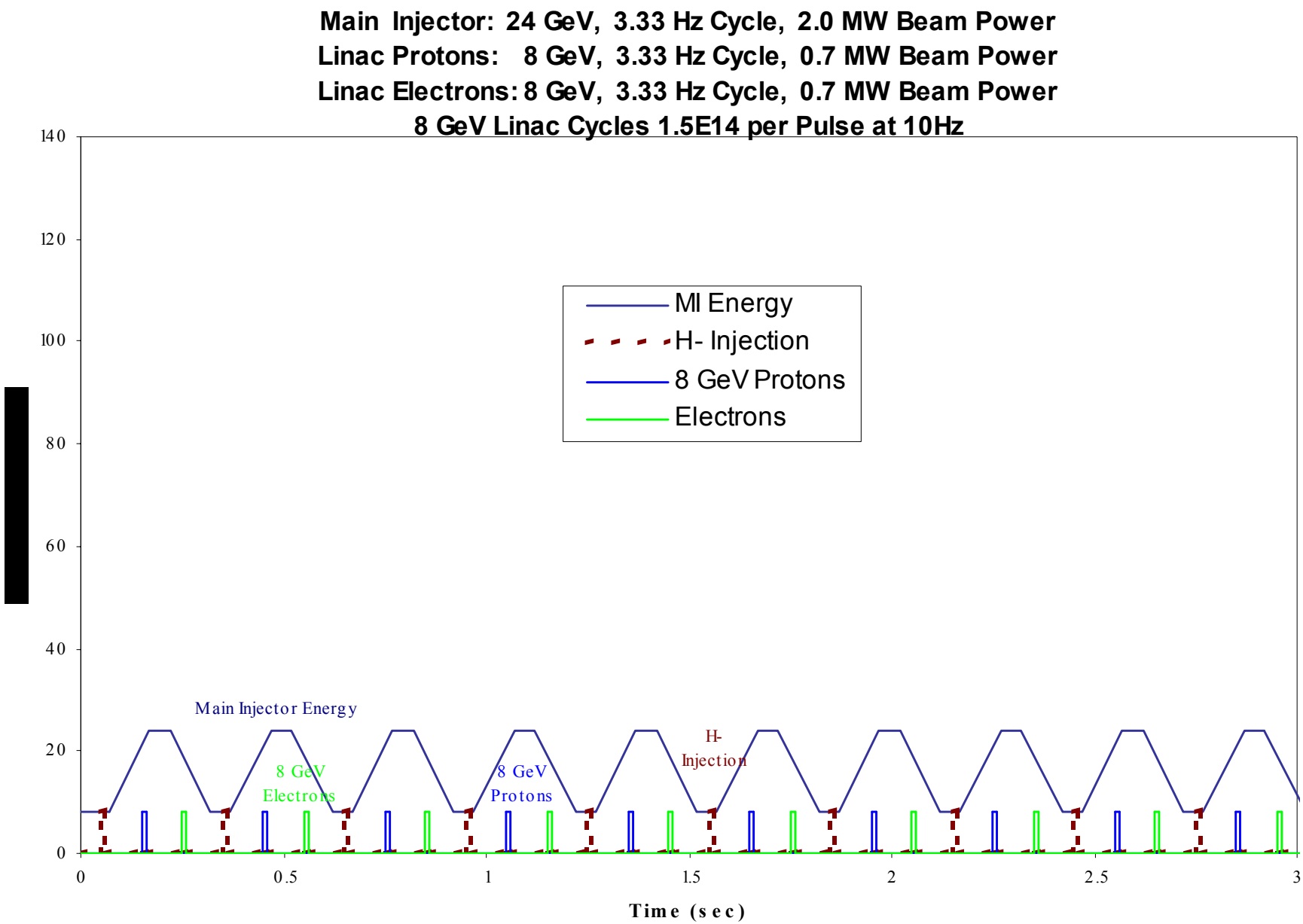
40 GeV MI with LINAC Injection



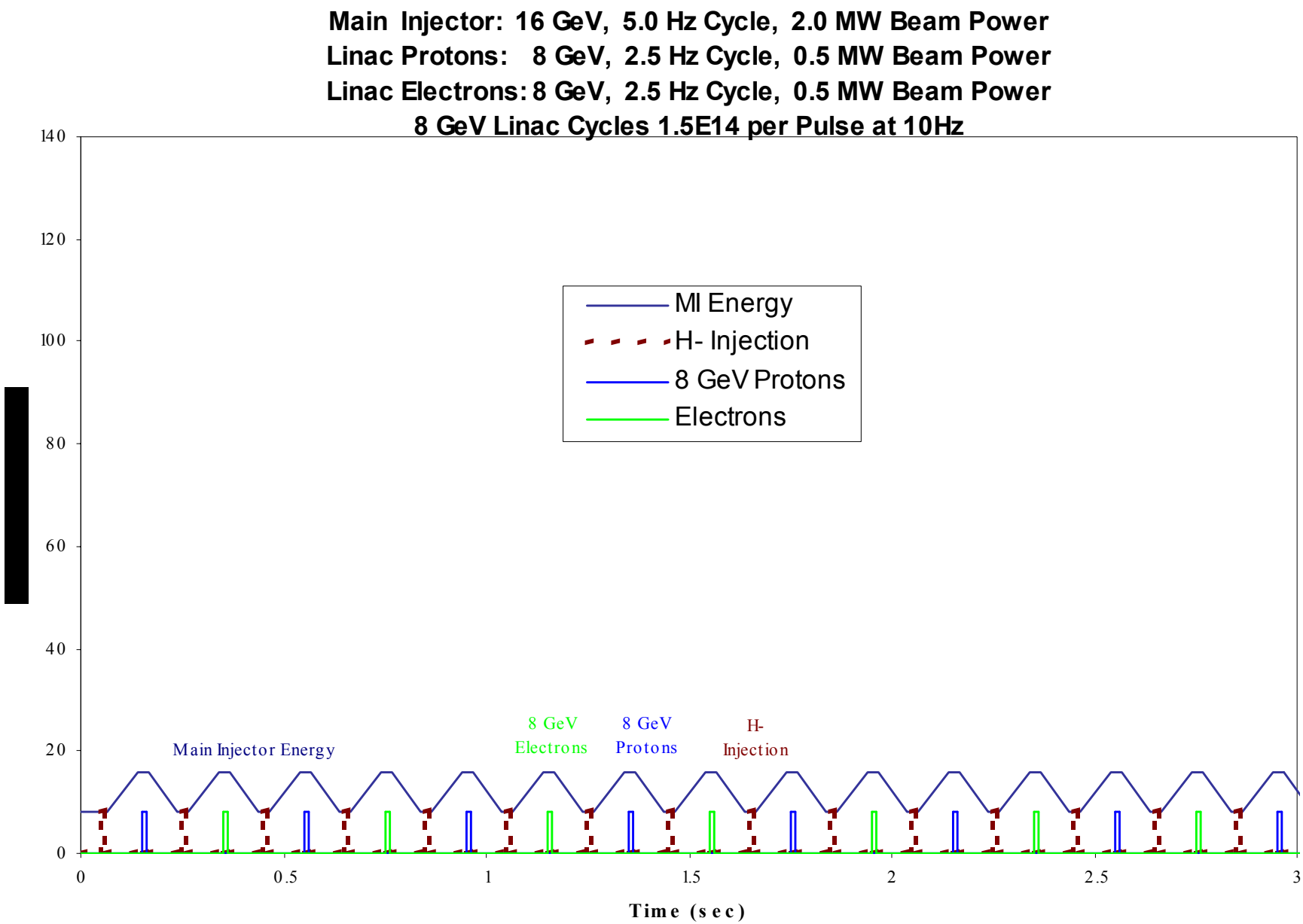
32 GeV MI with LINAC Injection

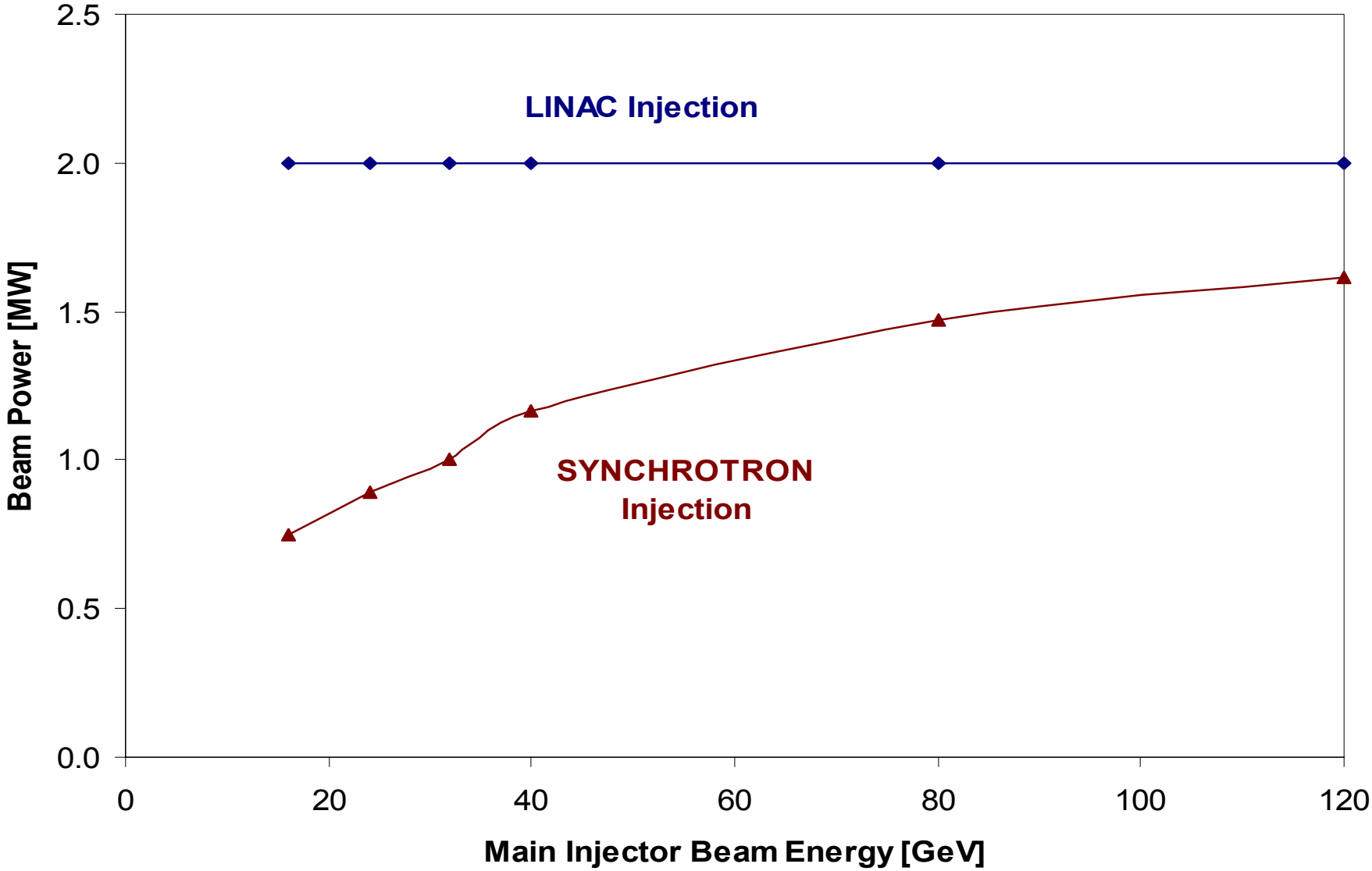


24 GeV MI with LINAC Injection

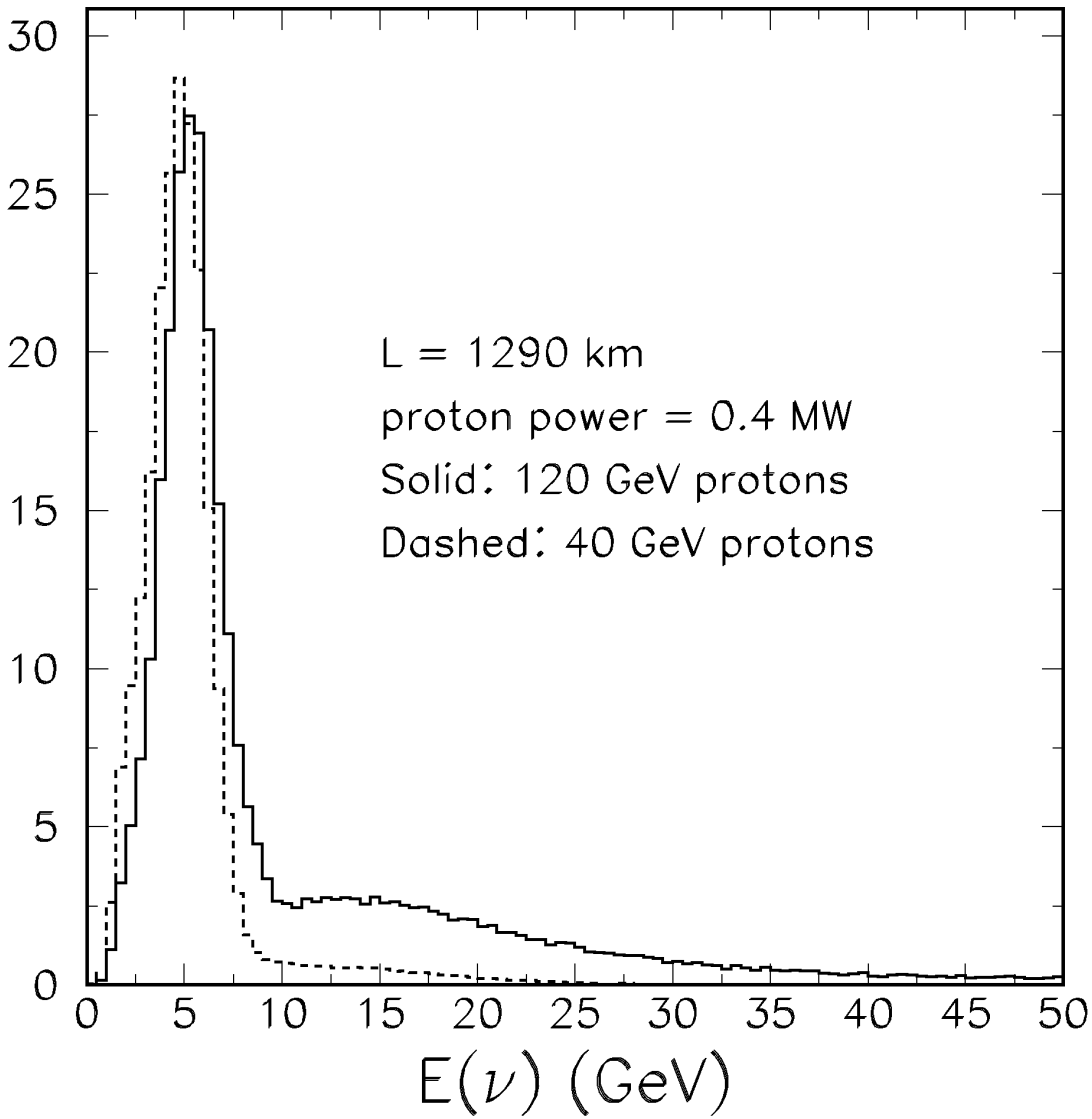


40 GeV MI with LINAC Injection




MI BEAM POWER vs. Main Injector Beam Energy,
8 GeV Linac and Synchrotron Injection
Main Injector Intensity = 1.5E14 Protons
LINAC Injection
SYNCHROTRON
Injection
Beam Power [MW]
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
Main Injector Beam Energy [GeV]

Running at Reduced Proton Energy Produces a Cleaner Neutrino Spectrum



Running at 40 GeV reduces tail at higher neutrino energies.

Same number of events for same beam power.

(Plot courtesy Fritz & Debbie)

Some Off-Label Usages of the Linac Proton Driver

- 8 GeV Electrons
- 8 GeV Protons or H-
- Continuous Extraction From Recycler
- Continuous Extraction for 120 GeV Stretcher Ring in MI Tunnel
- Muon/Neutrino Factory Applications

Document some of these at this Workshop