Proton Economics in PIP and PIP-II Era

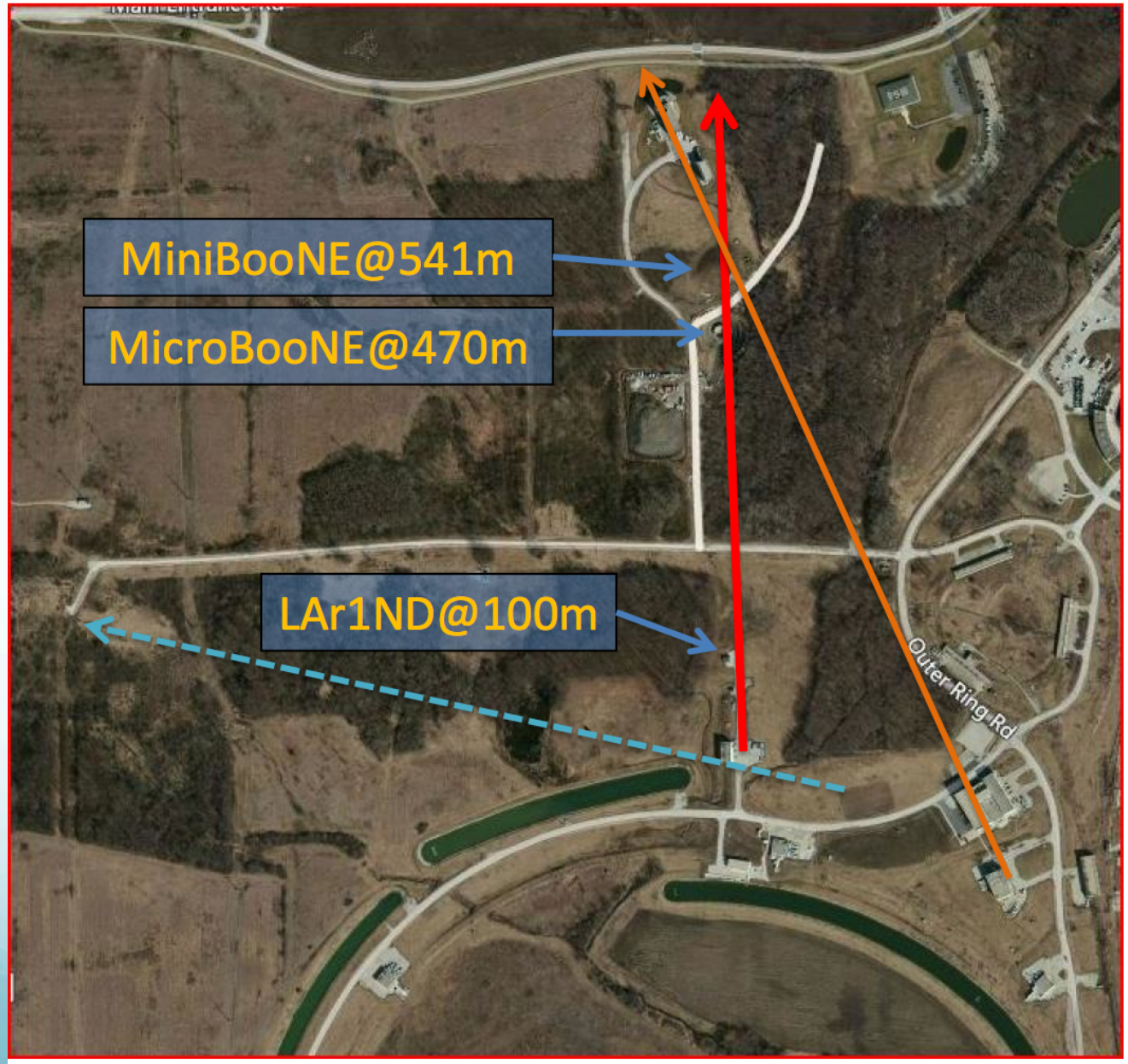
R. Rameika

PIP-II Collaboration Meeting

June 4, 2014

Our Accelerator Based Physics Program

- Now : Neutrinos
  - Main Injector NuMI Program for NOvA, Minerva and MINOS+
  - Booster Neutrino Beam (BNB) for MiniBooNE, MicroBooNE
- Coming : Neutrinos and Muons
  - BNB for Short Baseline Neutrinos
  - Booster to Muon Campus for g-2 and Mu2e
- Ultimately : Neutrinos to South Dakota – LBNE(F?)

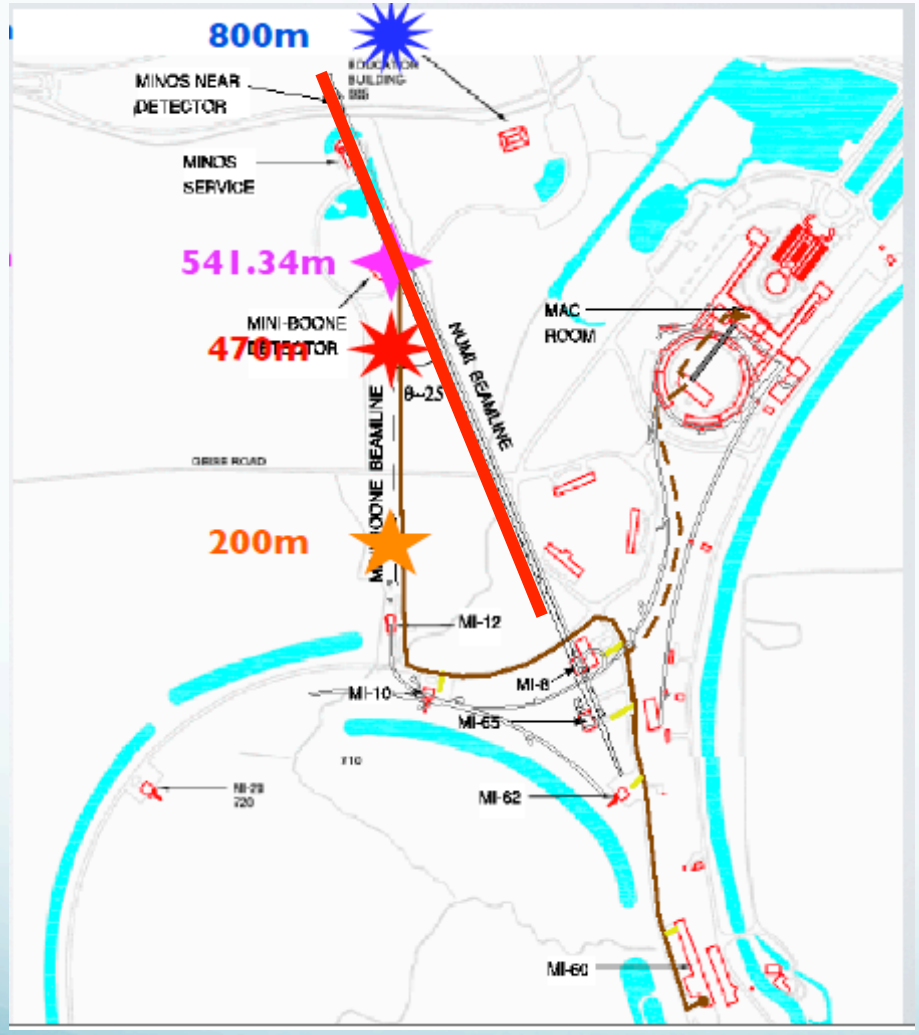


Fermilab neutrino beamlines

- BNB
- NuMI

- LBNE

Two Neutrino Beams – multiple detector sites



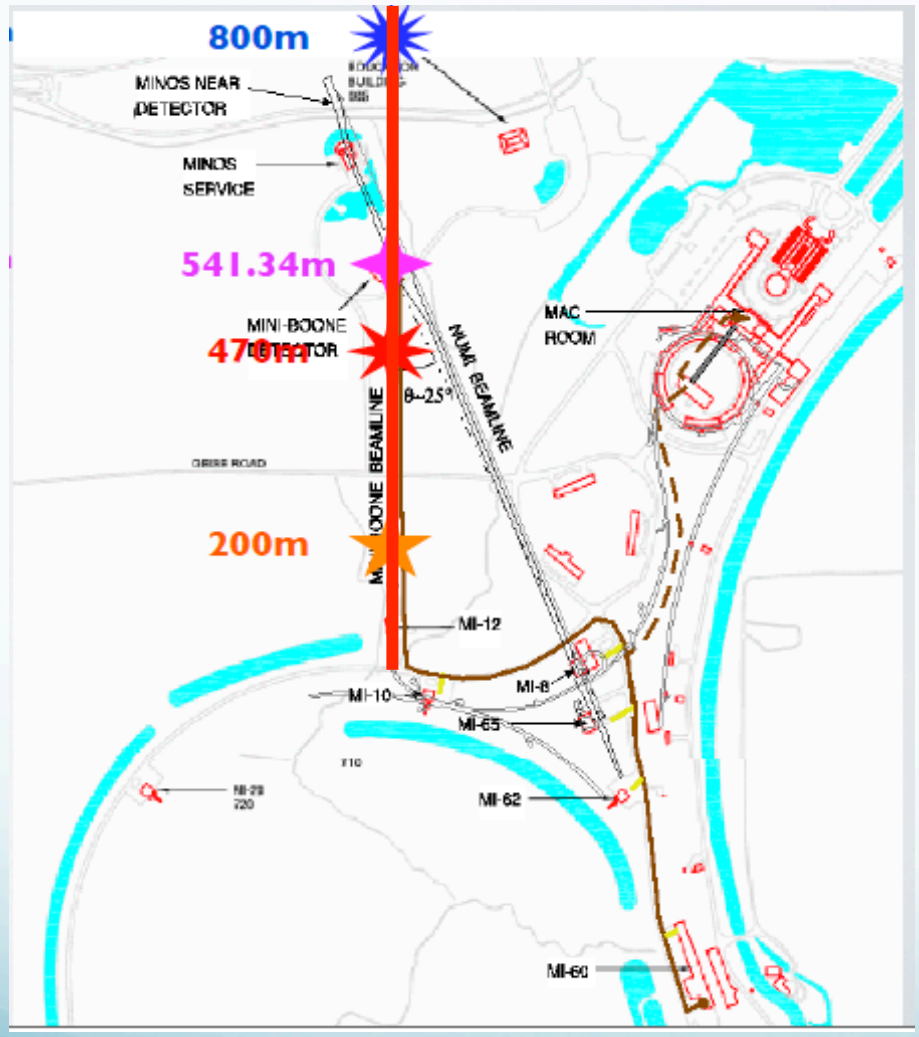
NuMI Beam is aimed down (towards Minnesota)

Detector hall is 300 feet below surface

Booster Neutrino Beam is shallow

Detector halls ~10m below Surface

Two Neutrino Beams – multiple detector sites



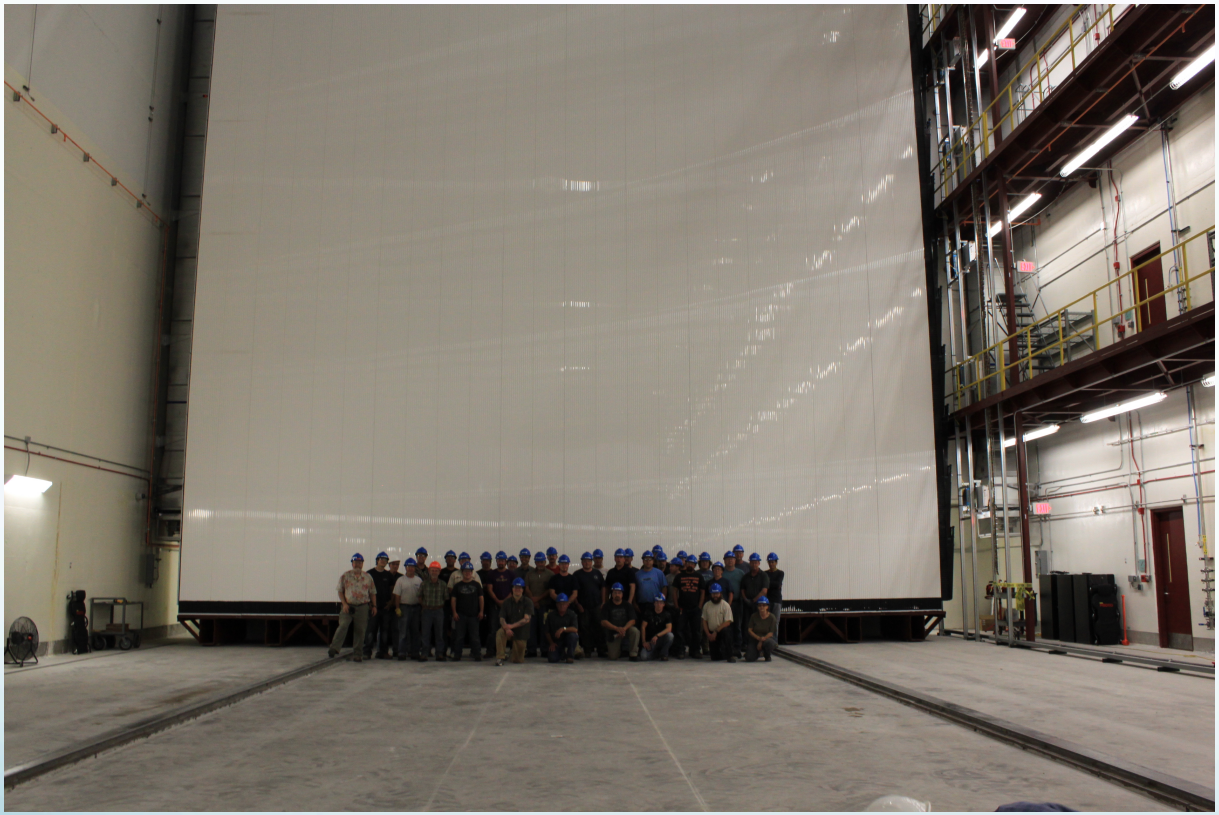
NuMI Beam is aimed down (towards Minnesota)

Detector hall is 300 feet below surface

Booster Neutrino Beam is shallow

Detector halls ~10m below Surface

NOvA has started data taking

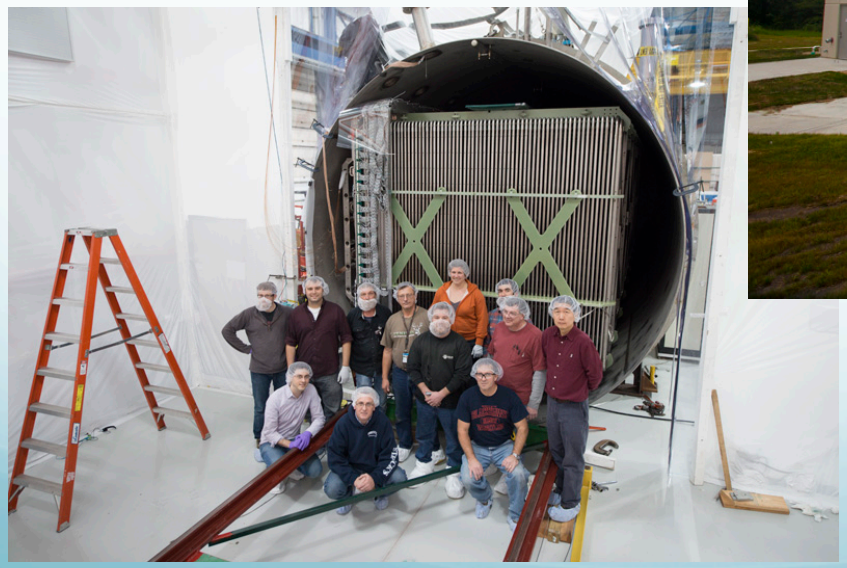


Minimum NOvA Physics sensitivities Are based on 6×10^{20} POT/year for 6 years

Longer running will Be desired (pre- PIP-II, LBNF)

MicroBooNE turning on in 2015

Physics requirement is
6.6×10^{20} POT



Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x

Neutrino Cross-section/Nucleon x

Number of Nucleons

Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x  A really big number

Neutrino Cross-section/Nucleon x

Number of Nucleons

Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x

A really small number

Neutrino Cross-section/Nucleon x

Number of Nucleons

Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x

Neutrino Cross-section/Nucleon x

Number of Nucleons  A really big number

Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x ⟵ **BEAM = Protons + Target/horns**

Neutrino Cross-section/Nucleon x

Number of Nucleons ⟵ **Detector = Mass + Efficiency**

Neutrino Experiments in their 1st runs are STATISTICS limited

Neutrino Events/Unit Time =

Neutrino Flux x ← **BEAM = Protons + Target/horns**

Neutrino Cross-section/Nucleon x

Number of Nucleons ← **Detector = Mass + Efficiency**

Experiment Criteria

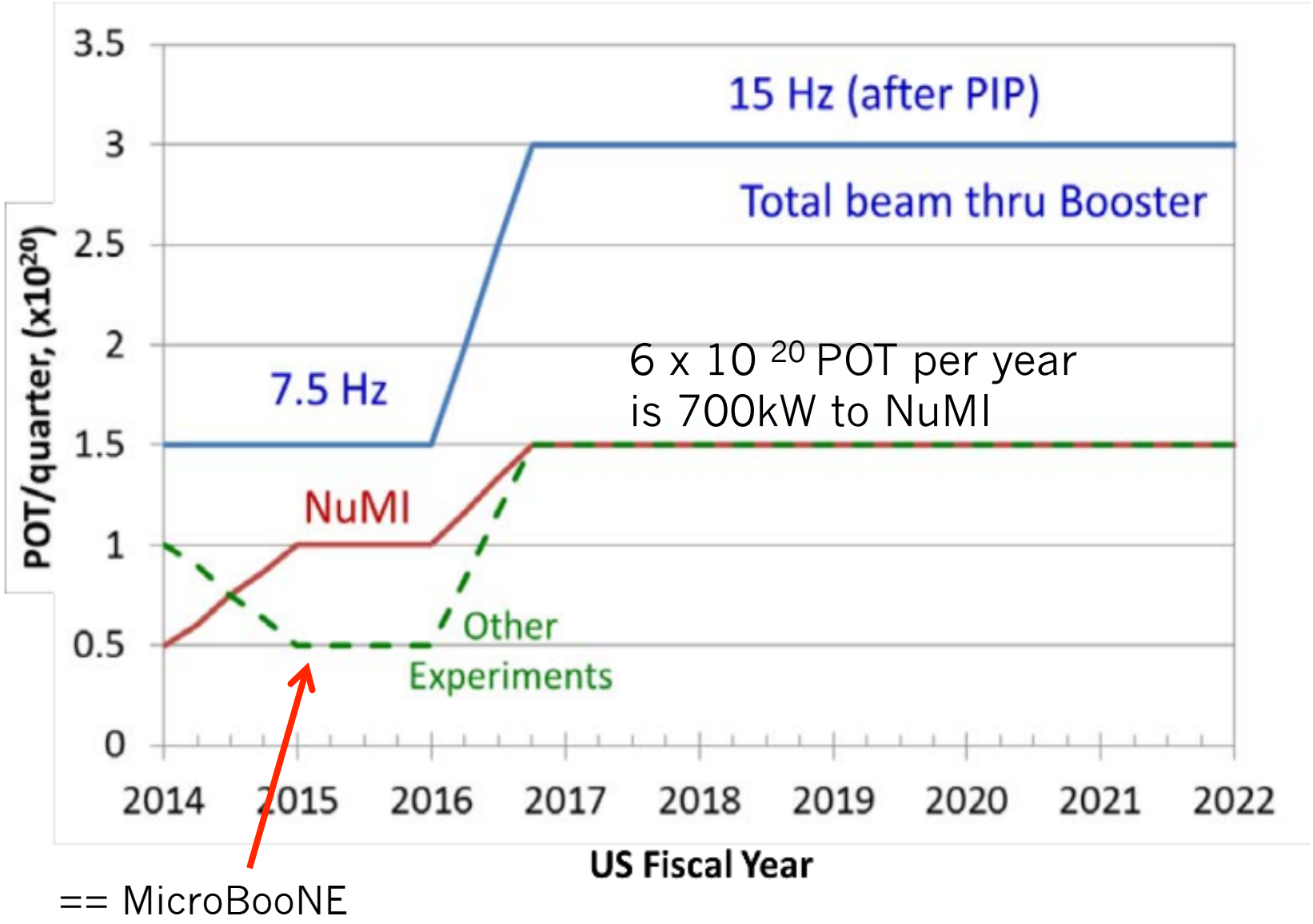
- From the recent P5 report, regarding LBNF :

The minimum requirements to proceed are the identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial vol- ume, and 1.2 MW beam power upgradable to multi-megawatt power.

Mass * Power * Time

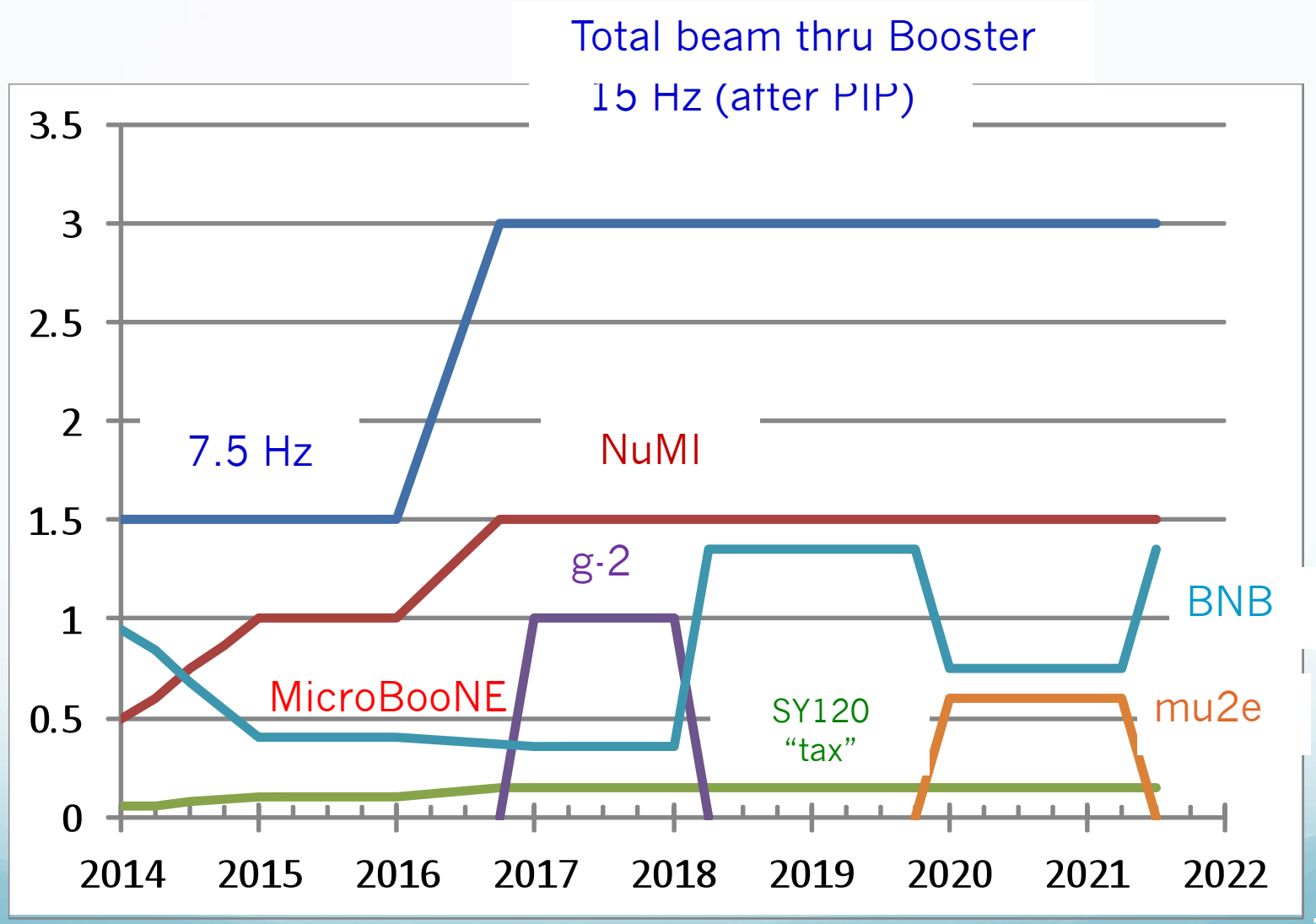
Muon Experiments

- Mu2e and g-2 will not run together
- Booster Neutrino Beam CAN run with either
- Schedules matter in trying to understand the proton economics issues in the short term
- In general, issues of beam structure, timing, etc. are more important than just the # of POTs

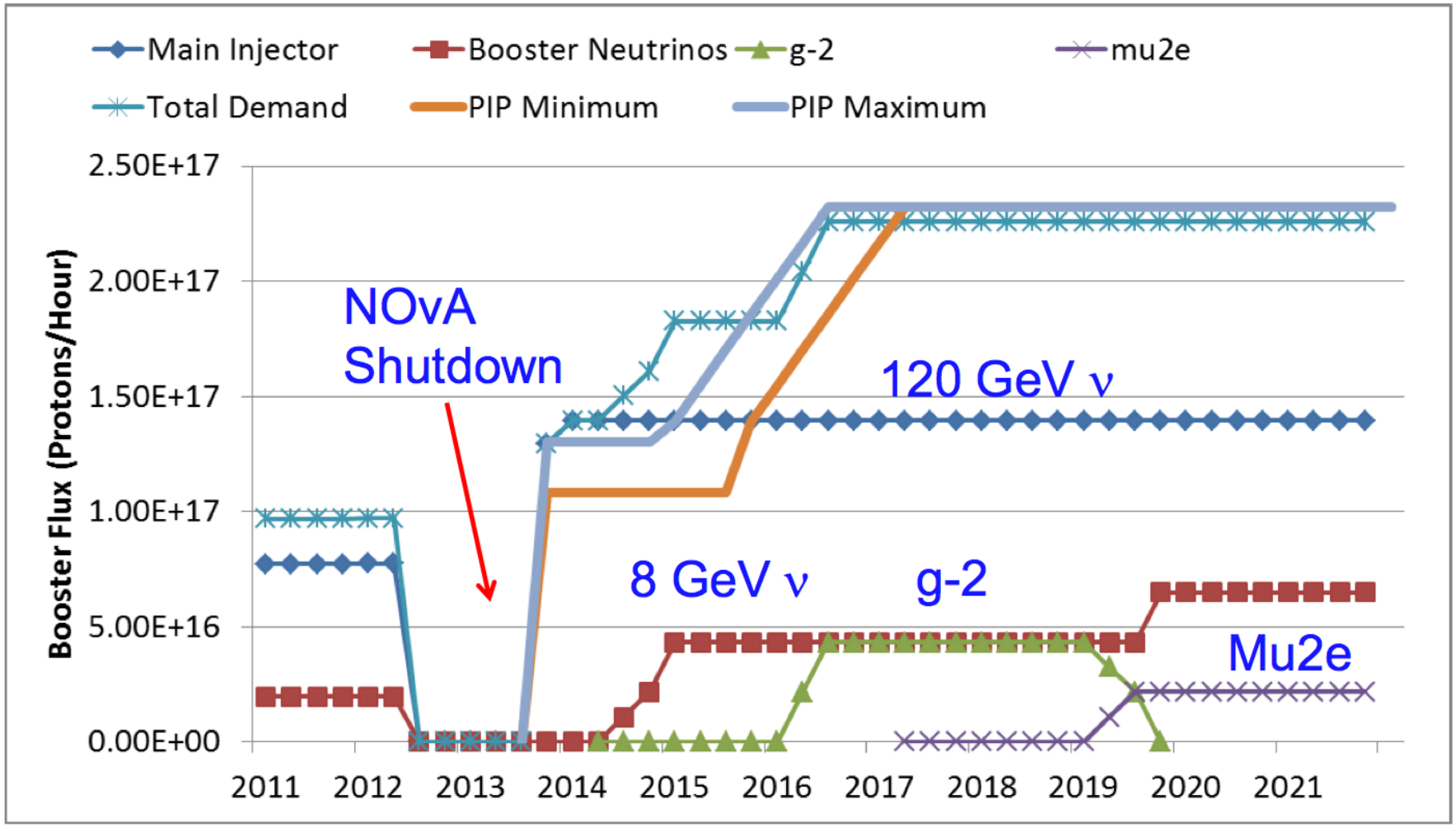

3.5
3
2.5
2
1.5
1
0.5
0
POT/quarter, (x10^20)
15 Hz (after PIP)
Total beam thru Booster
7.5 Hz
6 x 10 20 POT per year
is 700kW to NuMI
NuMI
Other
Experiments
2014
2015
2016
2017
2018
2019
2020
2021
2022
US Fiscal Year

== MicroBooNE

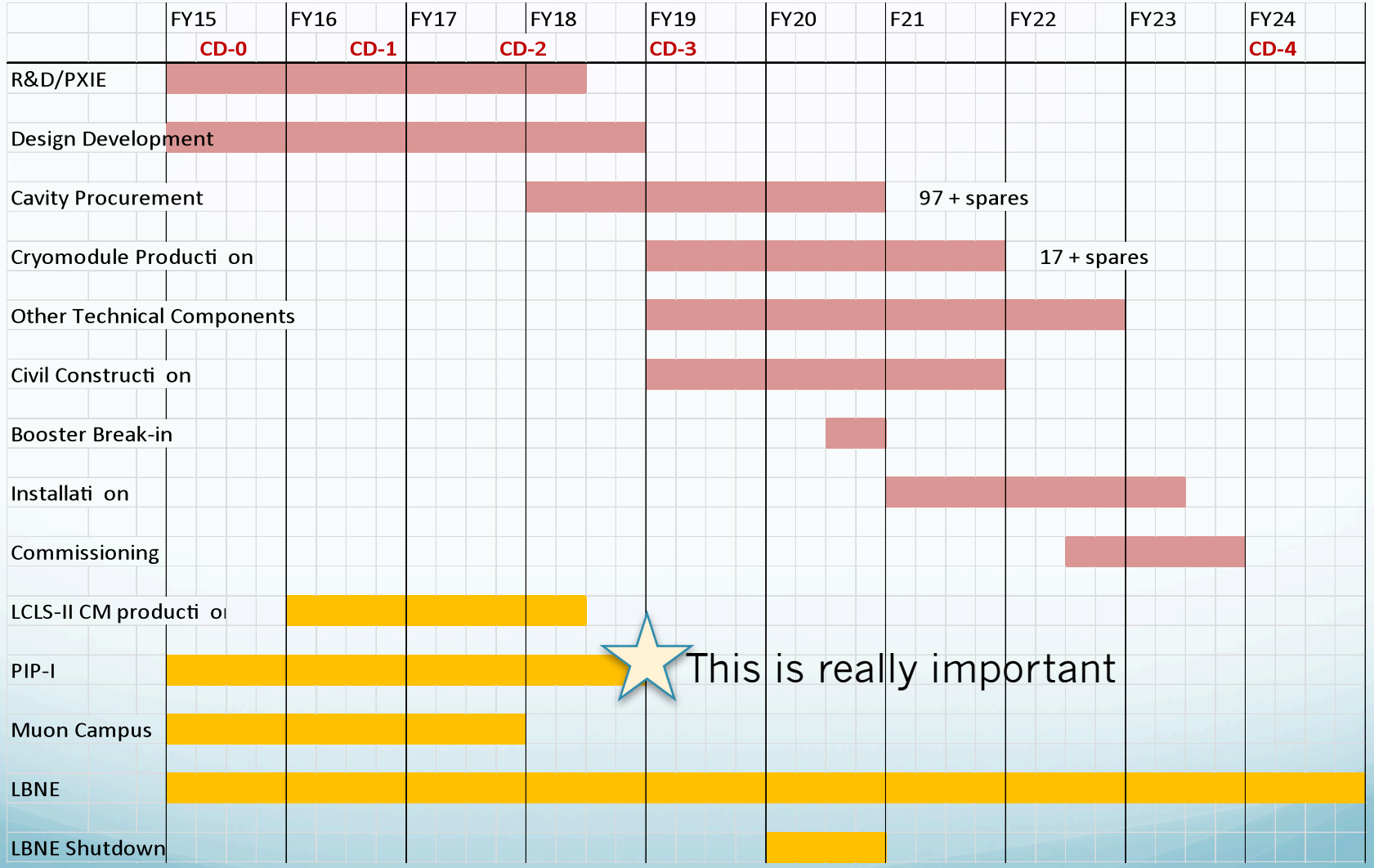
Proton delivery scenario (approximate, no shutdowns shown)



Proton improvement plan projections



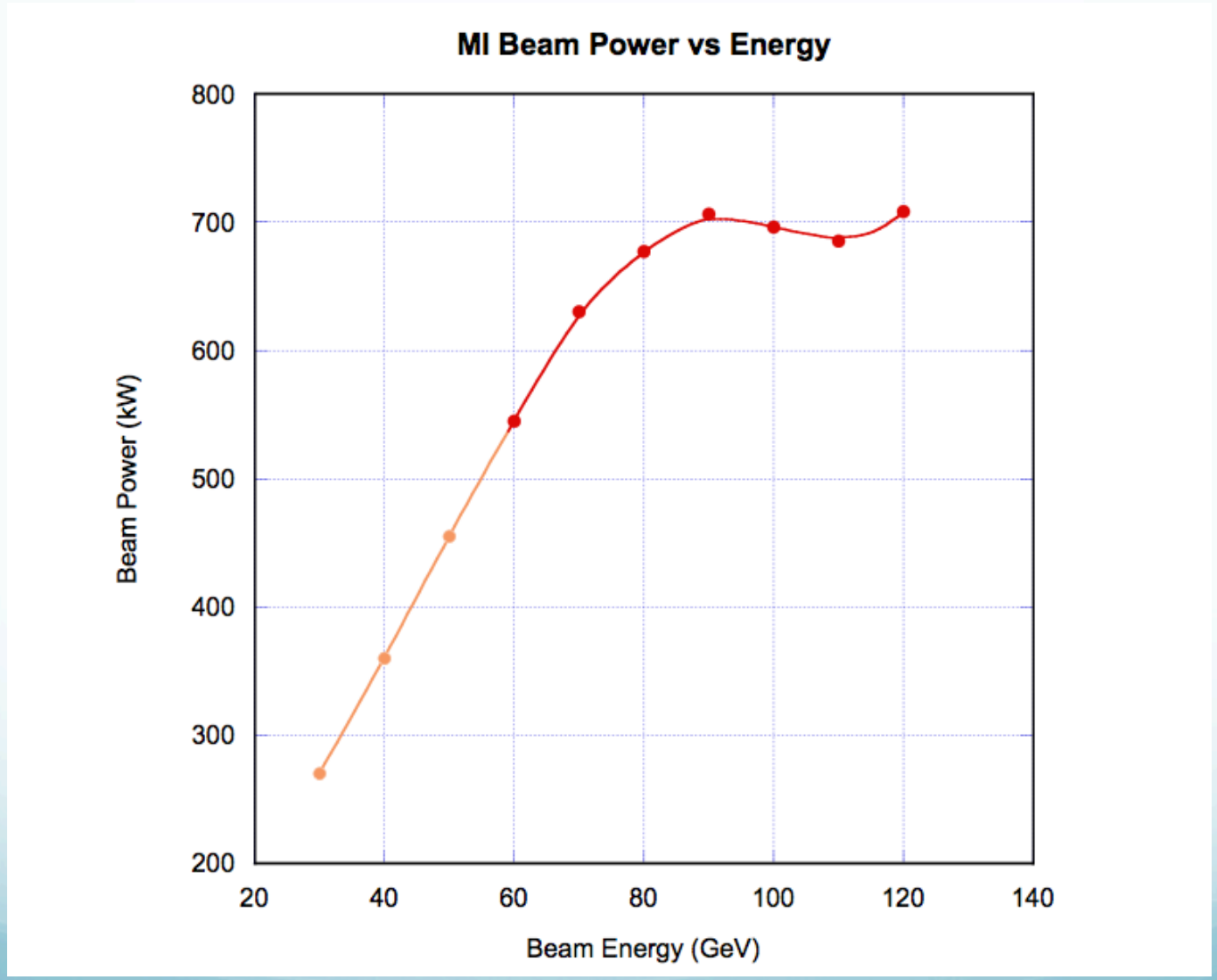
http://www-ad.fnal.gov/proton/PIP/PIP_index.html


FY15
FY16
FY17
FY18
FY19
FY20
F21
FY22
FY23
FY24
CD-0
CD-1
CD-2
CD-3
CD-4
R&D/PXIE
Design Development
Cavity Procurement
97 + spares
Cryomodule Producti on
17 + spares
Other Technical Components
Civil Constructi on
Booster Break-in
Installati on
Commissioning
LCLS-II CM producti o
PIP-I
This is really important
Muon Campus
LBNE
LBNE Shutdown

Performance Parameter	PIP-II	
Linac Beam Energy	800	MeV
Linac Beam Current	2	mA
Linac Beam Pulse Length	0.6	msec
Linac Pulse Repetition Rate	15	Hz
Linac Beam Power Capability (10-15% DF)	~200	kW
Mu2e Upgrade Potential (800 MeV)	>100	kW
Booster Protons per Pulse (extracted)	6.4×10^{12}	
Booster Pulse Repetition Rate	15	Hz
Booster Beam Power @ 8 GeV	120	kW
Beam Power to 8 GeV Program (max)	40	kW
Main Injector Protons per Pulse (extracted)	7.5×10^{13}	
Main Injector Cycle Time @ 120 GeV	1.2	sec
Main Injector Cycle Time @ 80 GeV	0.8	sec
LBNE Beam Power @ 80-120 GeV	1.2	MW
LBNE Upgrade Potential @ 60-120 GeV	>2	MW

Performance Parameter	PIP-II	
Linac Beam Energy	800	MeV
Linac Beam Current	2	mA
Linac Beam Pulse Length	0.6	msec
Linac Pulse Repetition Rate	15	Hz
Linac Beam Power Capability (10-15% DF)	~200	kW
Mu2e Upgrade Potential (800 MeV)	>100	kW
Booster Protons per Pulse (extracted)	6.4×10^{12}	
Booster Pulse Repetition Rate	15	Hz
Booster Beam Power @ 8 GeV	120	kW
Beam Power to 8 GeV Program (max)	40	kW
Main Injector Protons per Pulse (extracted)	7.5×10^{13}	
Main Injector Cycle Time @ 120 GeV	1.2	sec
Main Injector Cycle Time @ 80 GeV	0.8	sec
LBNE Beam Power @ 80-120 GeV	1.2	MW
LBNE Upgrade Potential @ 60-120 GeV	>2	MW

8 GeV program in LBNE era?



8 GeV program in LBNE era

subsequent sections of this document. Note that the concept presented here is capable of delivering 1.2 MW of beam power to LBNE at all energies between 80-120 GeV. For 120 GeV operations significant beam power is also available to support an 8 GeV program in parallel with LBNE. However, for LBNE operations at 80 GeV or below any beam power delivered to an 8 GeV program would come at the expense of beam power to LBNE. This situation could be ameliorated by upgrading the Booster to 20 Hz operations, and while this possibility is currently under investigation it remains outside the purview of this report.

BNB future

- BNB can run at 5 hz, limited by the focusing horn
- Studies underway to see how we can improve the beam via new focusing with new target and new horns

Fermilab has world class neutrino beams!

More protons make them even better!

Summary

- Fermilab's future includes an exciting program of experiments that use our accelerator complex
- Increasing the number of protons and reliability of the complex will be critical to the success of these experiments
- Completion of the PIP as soon as possible will benefit the short term program immensely
- PIP-II offers the opportunity for the future long-baseline neutrino program get to physics results as quickly as possible after construction completion
- Ideas for new experiments are emerging and will continue to do so as the PIP programs develop