Workshop on High Intensity Hadron Facility
and
Nuclear and Particle Physics
At Kyungpook National University

The AGS As a High Intensity Proton Accelerator

Past and Future

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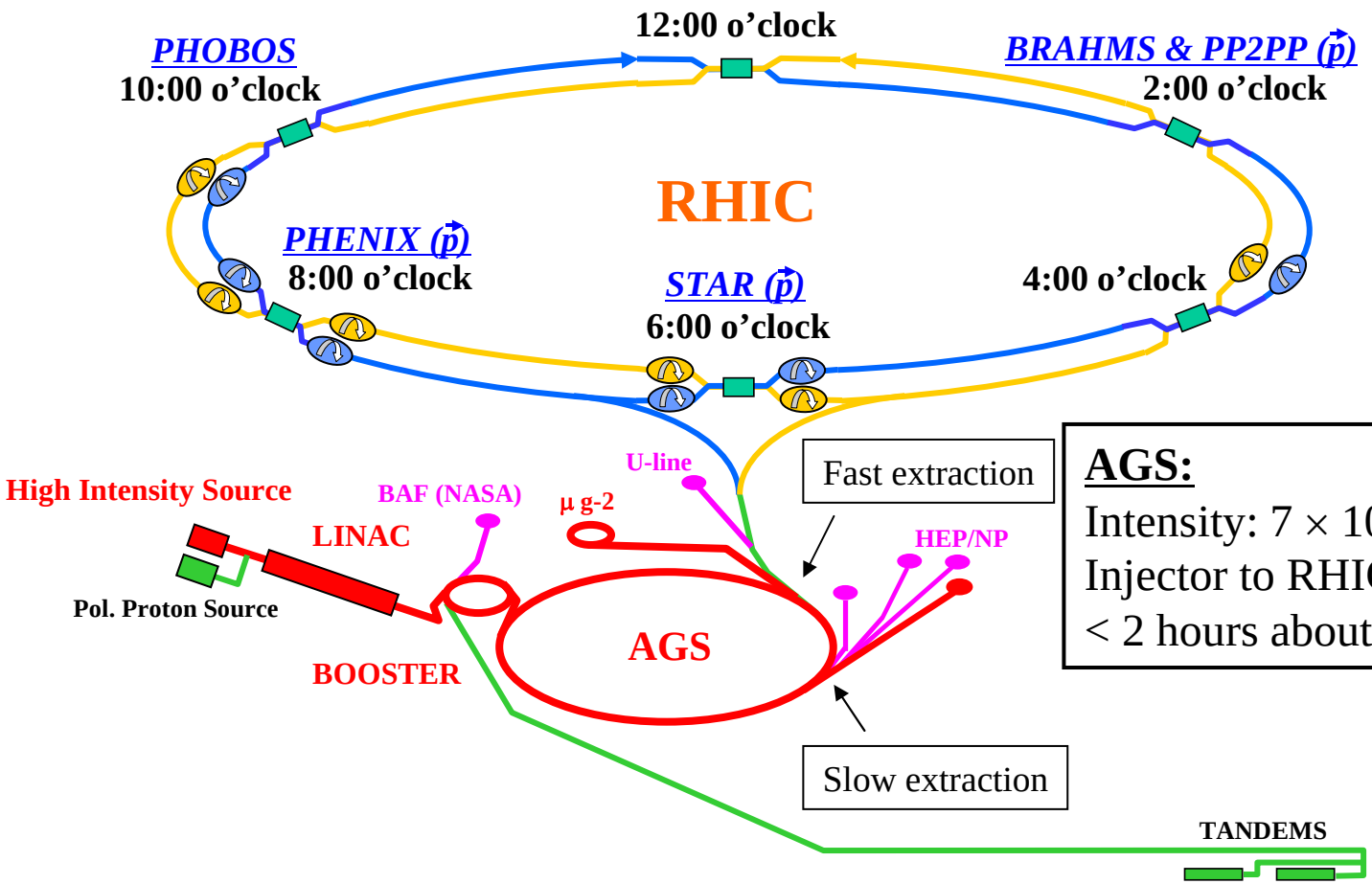
AGS/RHIC Accelerator Complex



AGS:

Intensity: 7×10^{13} protons/pulse

Injector to RHIC:

< 2 hours about every 10 hours

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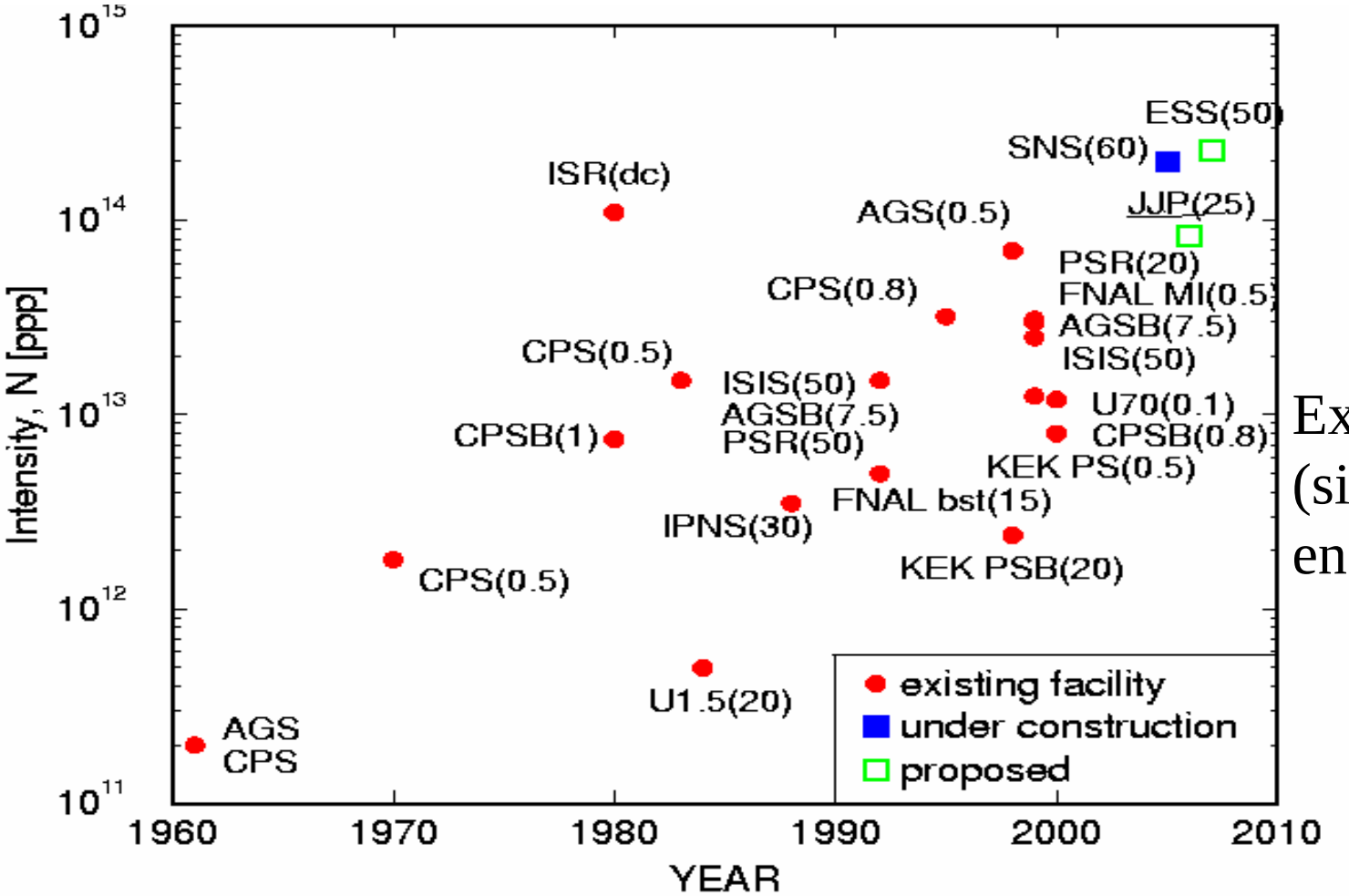
Intensity history of multi-GeV proton machines



Exp. Growth (similar to max. energy history)

BNL AGS and CERN PS still leading after more than 40 years!

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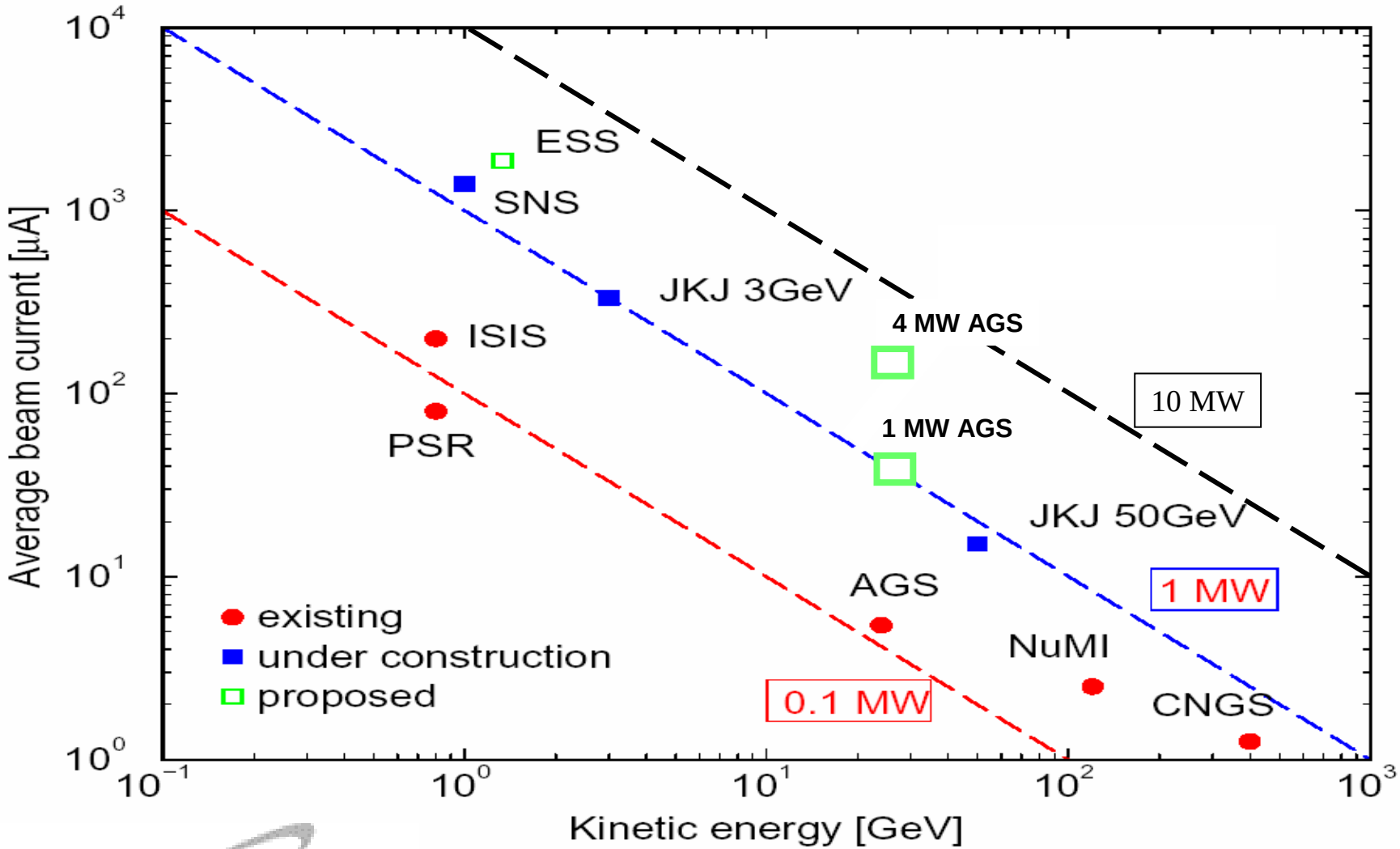
High Beam Power Proton Machines



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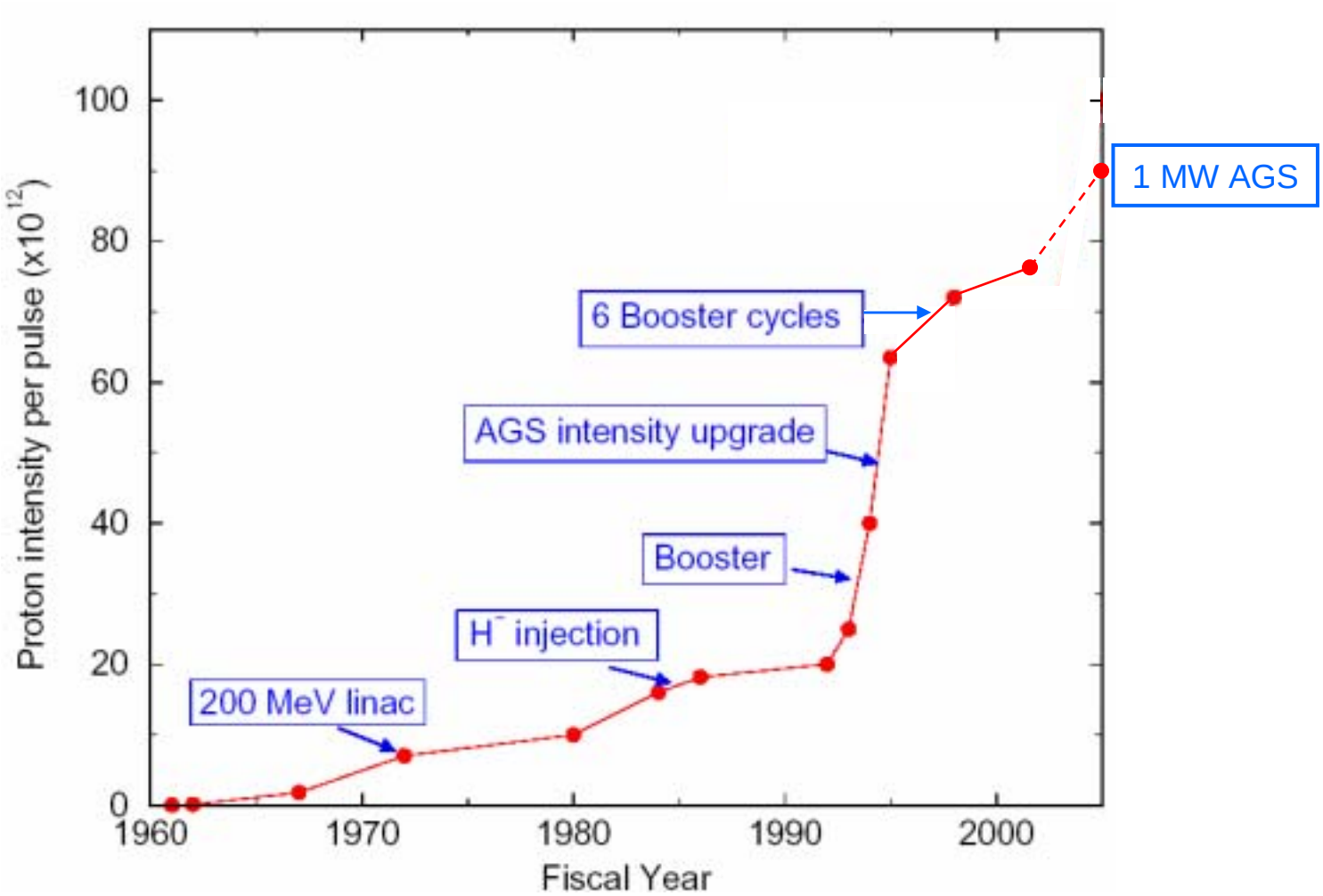
AGS Intensity History



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200 MeV Linac performance

– H^- source	35 keV	80 mA
RFQ	750 keV	60 mA
LEBT	750 keV	45 mA
Tank 1	10 MeV	38 mA
Tank 9	200 MeV	37 mA

– $\varepsilon_{norm}=10\pi$ mm.mr

– $\Delta E \approx \pm 1.2$ MeV

– RF chopper at 750 keV

– 120×10^{12} H^- per pulse at 7.5 Hz

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Booster performance

– 15×10^{12} protons per pulse (peak: 23×10^{12})

– Injection: horizontal painting, vertical missteering

360 turns, chopped to 180 - 270 degrees

$\dot{B}$ = 3 T/s

– $\varepsilon_{norm} \approx 50\ \pi$ mm mrad

– RF: 45 kV (h=1), 22 kV (h=2)

– $\dot{B}_{max}$ = 9 T/s

– Eddy current correction coils driven by back-leg windings

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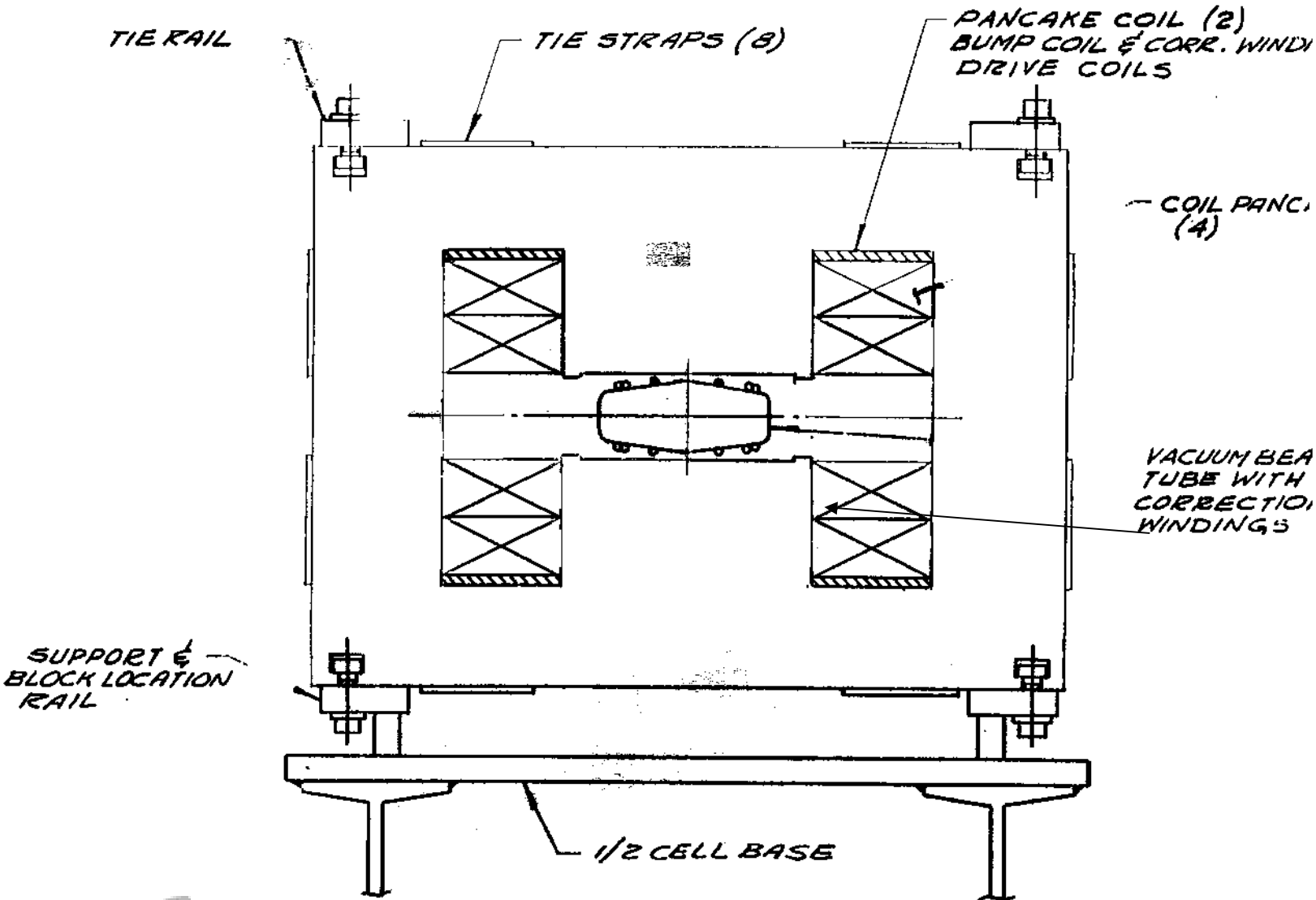
Booster Power Limit

- Repetition is limited to linac rate of 10Hz
  - Magnet lamination is matched to 10Hz 1mm
  - Vacuum chamber --- Inconel chamber with eddy current correction winding
- AC voltage and phase change
  - Large amount of virtual power pulsing
  - Limited to 7.5Hz

AGS Booster Dipole Eddy Current Corrector



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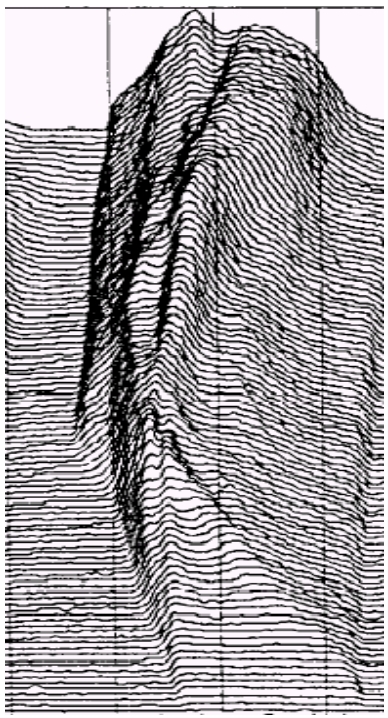
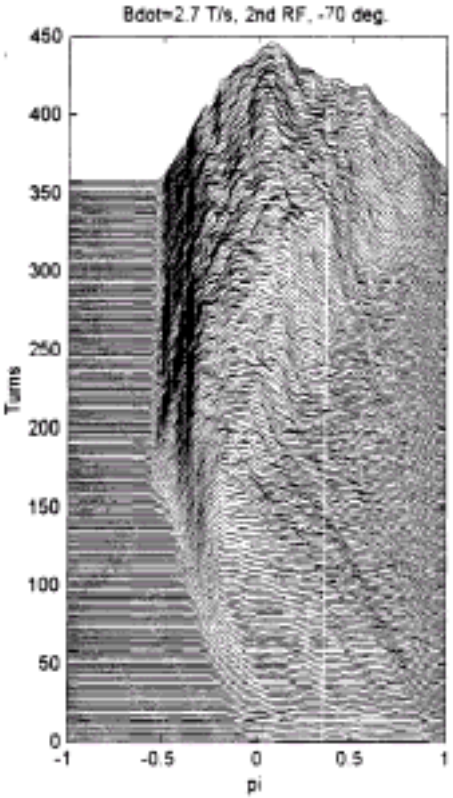
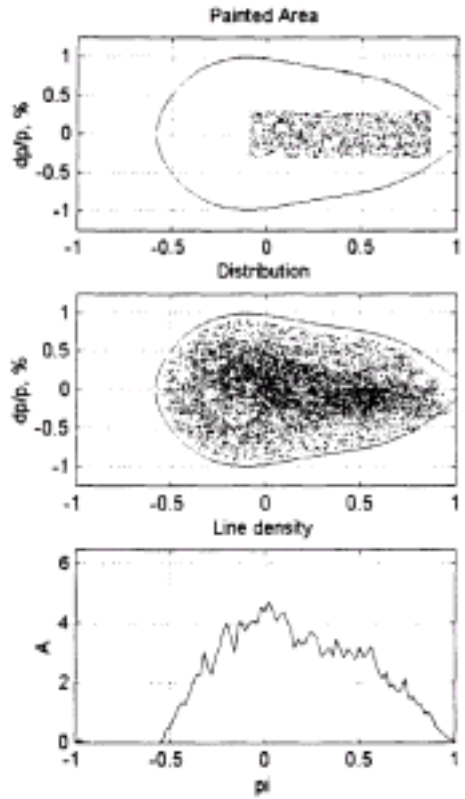
H^- injection into the Booster

Measurement



Simulation





Injected:

23×10^{12} ppb

1.3 eVs

18×10^{12} /eVs

Circulating:

17×10^{12} ppb

3.0 eVs

5×10^{12} /eVs

High B dot gives effective long. phase space painting.

Injection period is approx. equal to synchrotron period.

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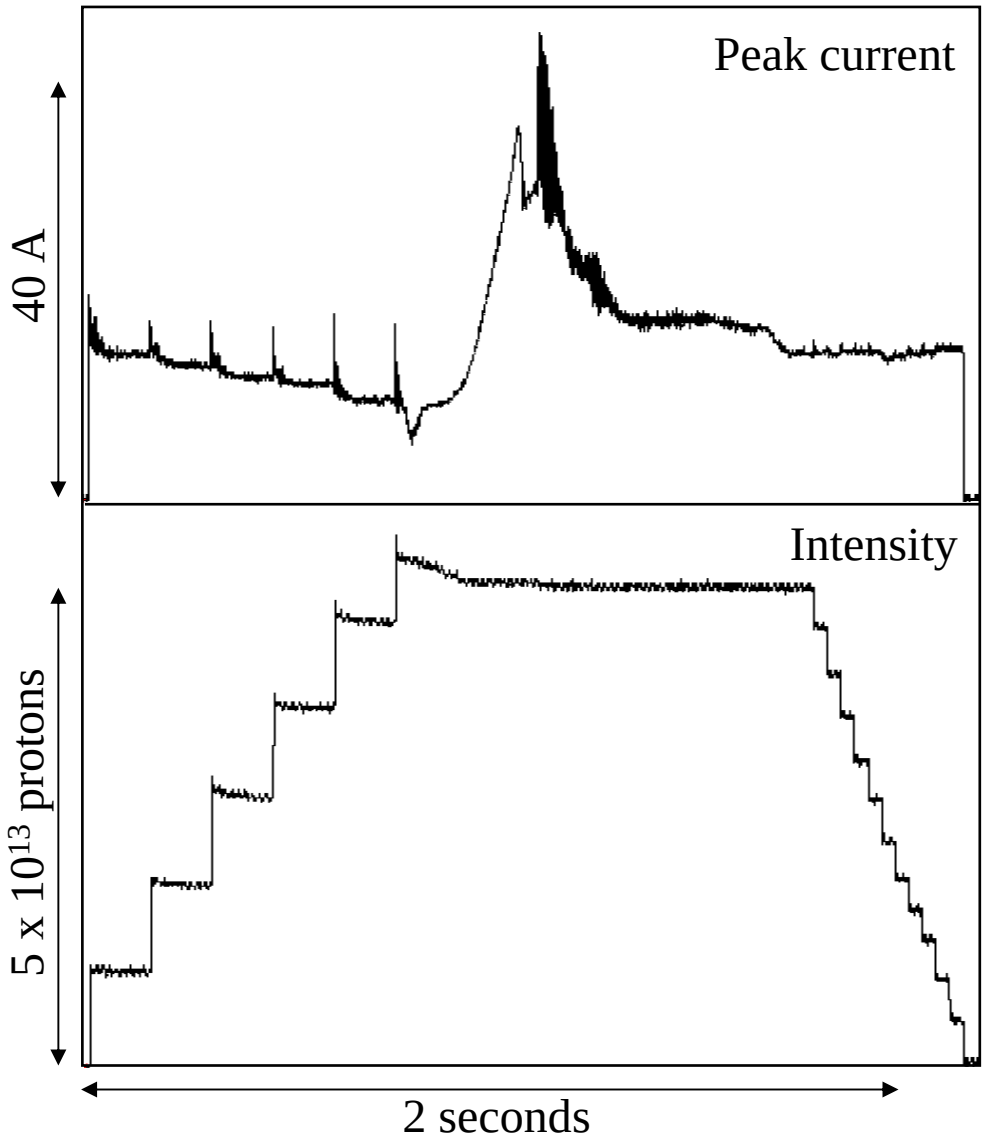
AGS performance for g-2 operation

- 6 single bunch transfers from Booster
- Peak intensity reached: 72×10^{12} ppp
- Bunch area: 3 eVs at injection
  10 eVs at extraction
- Intensity for g-2 ops: $50\text{-}60 \times 10^{12}$ ppp
- Strong space charge effects during accumulation in AGS
- 2nd order transition energy jump limits available momentum aperture.
- Chromatic mismatch at transition causes emittance dilution
- Dilution needed for beam stability



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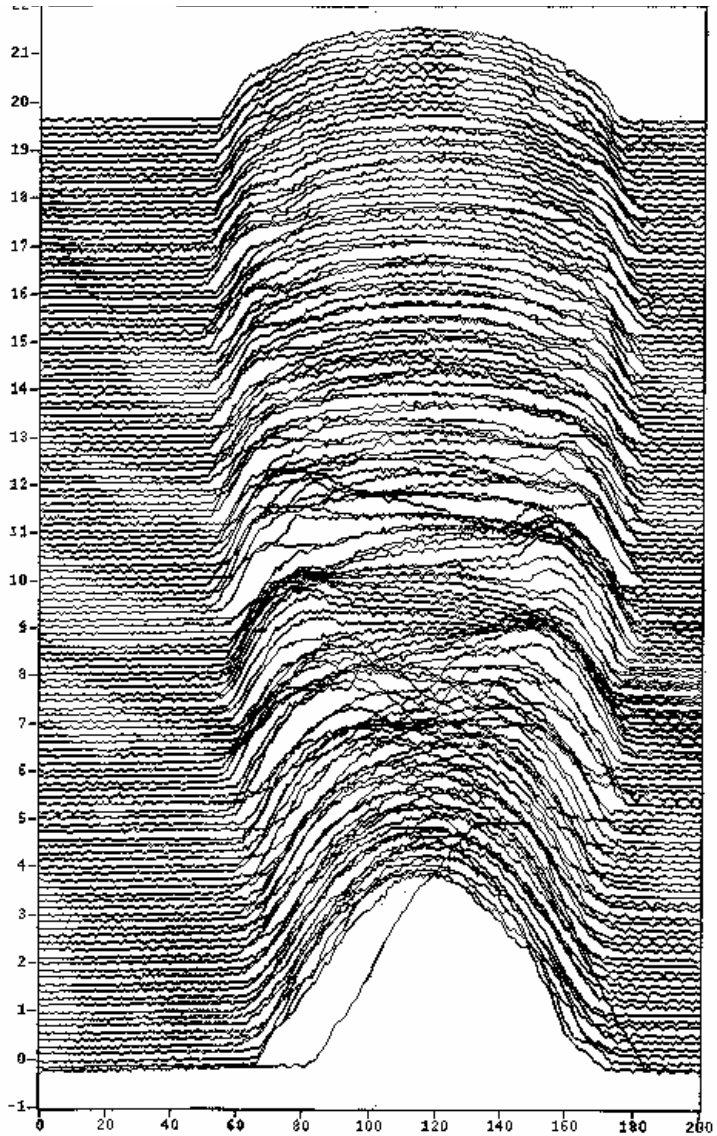
Controlled dilution at AGS injection

Longitudinal emittance dilution
at AGS injection through mismatch
followed by smoothing with
high frequency (93 MHz) cavity.

Needed to avoid excessive
space charge tune spread and
coupled bunch instabilities.



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AGS Proton Driver Parameters

	present AGS	**1 MW AGS**	**4 MW AGS**	JKJ
Total beam power [MW]	0.14	1.00	4.00	0.75
Beam energy [GeV]	24	28	28	50
Average current [μA]	6	36	144	15
Cycle time [s]	2	0.4	0.2	3.4
No. of protons per fill	0.7×10^{14}	0.9×10^{14}	1.8×10^{14}	3.3×10^{14}
Average circulating current [A]	4.2	5.0	10	12
No. of bunches at extraction	6	24	24	8
No. of protons per bunch	1×10^{13}	0.4×10^{13}	0.8×10^{13}	4×10^{13}
No. of protons per 10^7 sec.	3.5×10^{20}	23×10^{20}	90×10^{20}	10×10^{20}

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ν Oscillation Physics with Very Long Baseline

- Precise measurement of Δm^2_{32} :

  ν_μ disappearance experiment with good energy resolution.
- Detection of CP violation in neutrino sector :

  Detection of $\nu_\mu \rightarrow \nu_e$ appearance

  Detection of asymmetry between $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ processes
- Measurement of θ_{13} :

  Detection of $\nu_\mu \rightarrow \nu_e$ appearance
- Allows the measurement of the sign of Δm^2_{32} :

  Observation of the matter enhancement effect in $\nu_\mu \rightarrow \nu_e$ appearance

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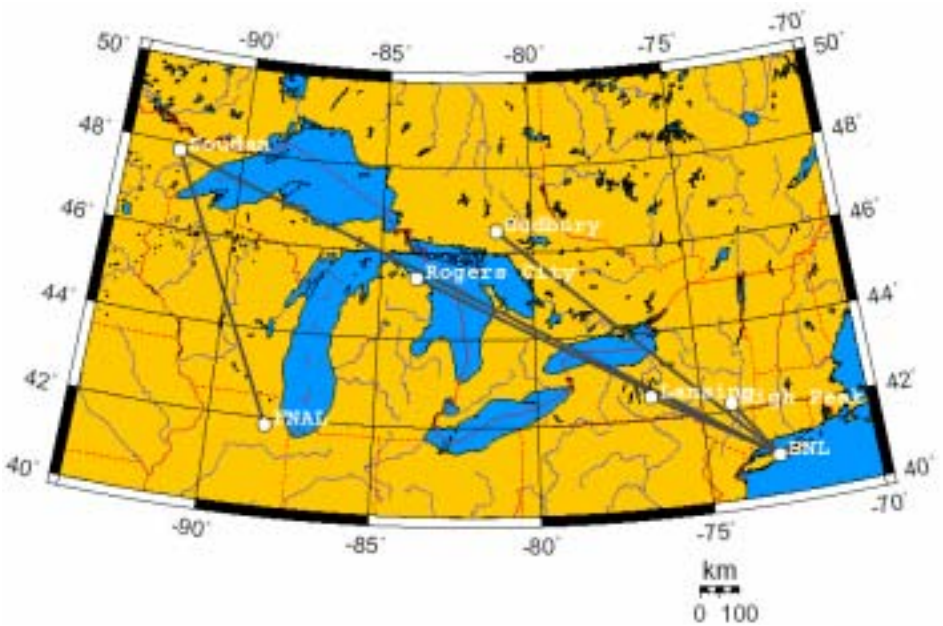
Possible Baselines from BNL



BNL to:

Lansing	350 km
Soudan	1770 km
Lead (Homestake)	2540 km
WIPP	2880 km

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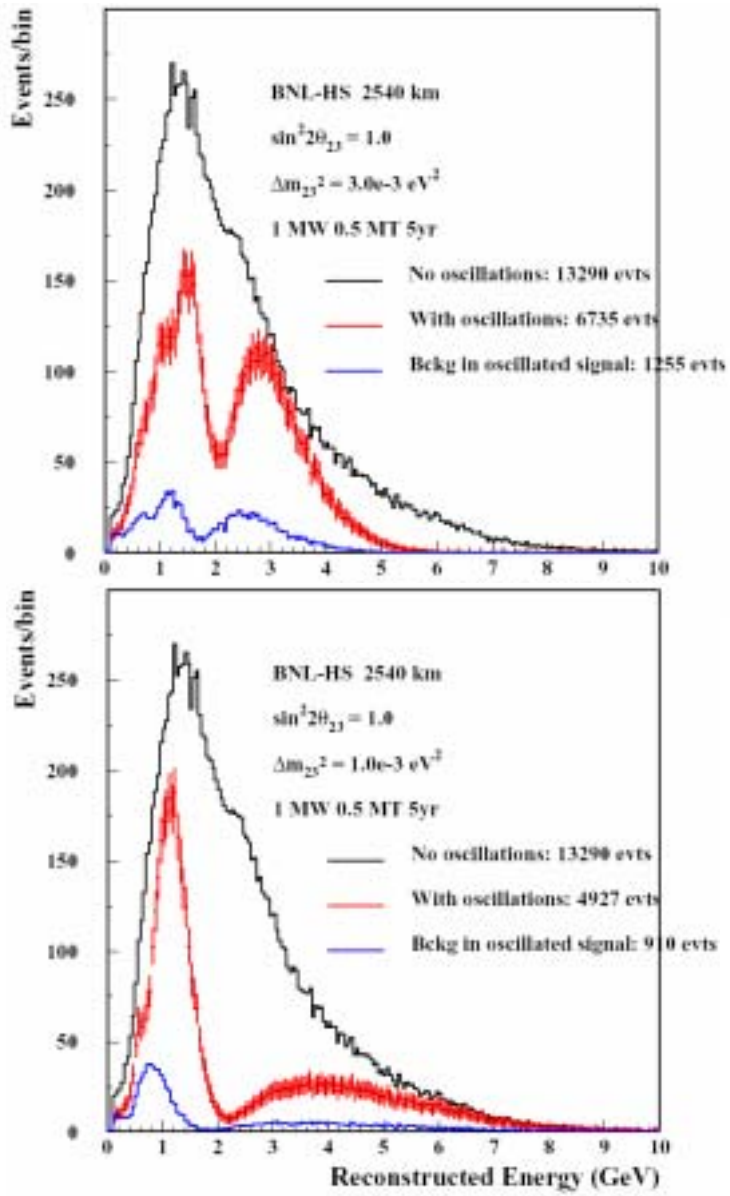
Δm_{32}^2 by Disappearance from BNL to Homestake

- Spectra of quasi-elastic events seen at the Homestake Mine (2540 km from BNL) for a ½ MT H_2O č detector, 1 MW proton beam, and 5 Snowmass years
  - Upper figure shows $\Delta m_{32}^2 = 0.003$ eV^2
  - Lower figure shows $\Delta m_{32}^2 = 0.001$ eV^2



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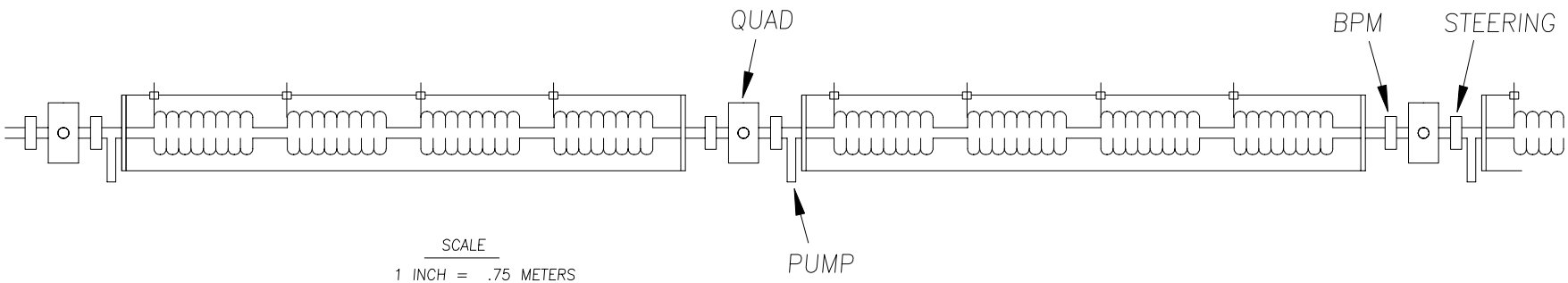
AGS Intensity Upgrades

- Needed upgrades
  - 1.2 GeV superconducting linac extension for direct injection of ~ 1×10^{14} protons per pulse into AGS
    - low beam loss at injection
    - high repetition rate possible
    - further upgrade to 1.5 GeV and 2×10^{14} protons per pulse possible (x 2)
  - 2.5 Hz AGS repetition rate
    - triple existing main magnet power supply and magnet current feeds
    - double rf power and accelerating gradient
    - further upgrade to 5 Hz possible (x 2)

1.2 GeV Superconducting Linac

Rf frequency	805 MHz	1610 MHz	1610 MHz
Beam energy	0.2 → 0.4 GeV	0.4 → 0.8 GeV	0.8 → 1.2 GeV
Accelerating gradient	10.8 MeV/m	23.5 MeV/m	23.4 MeV/m
Length	37.8 m	41.4 m	38.3 m
Beam power, linac exit	17 kW	34 kW	50 kW



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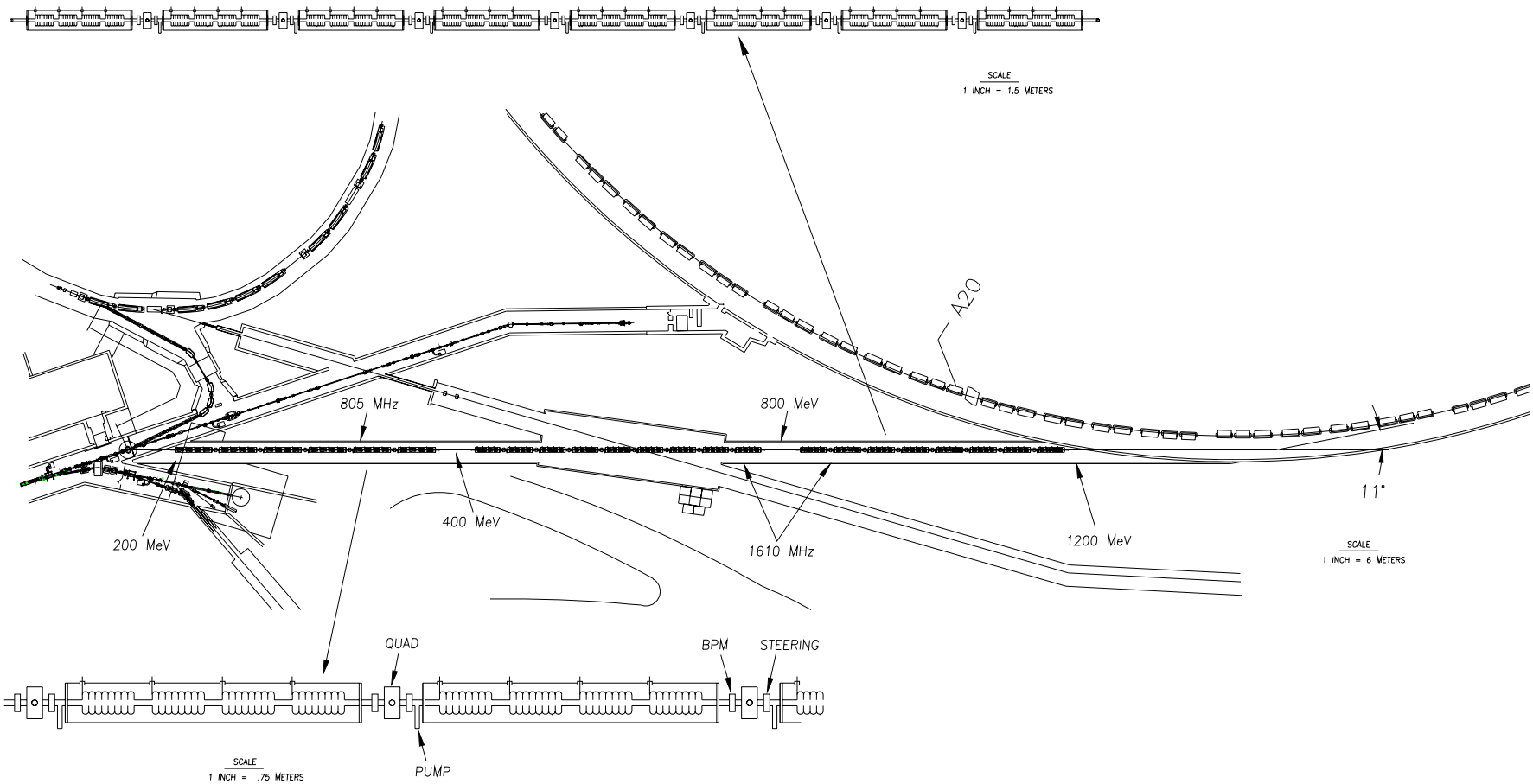
1.2 GeV Superconducting Linac



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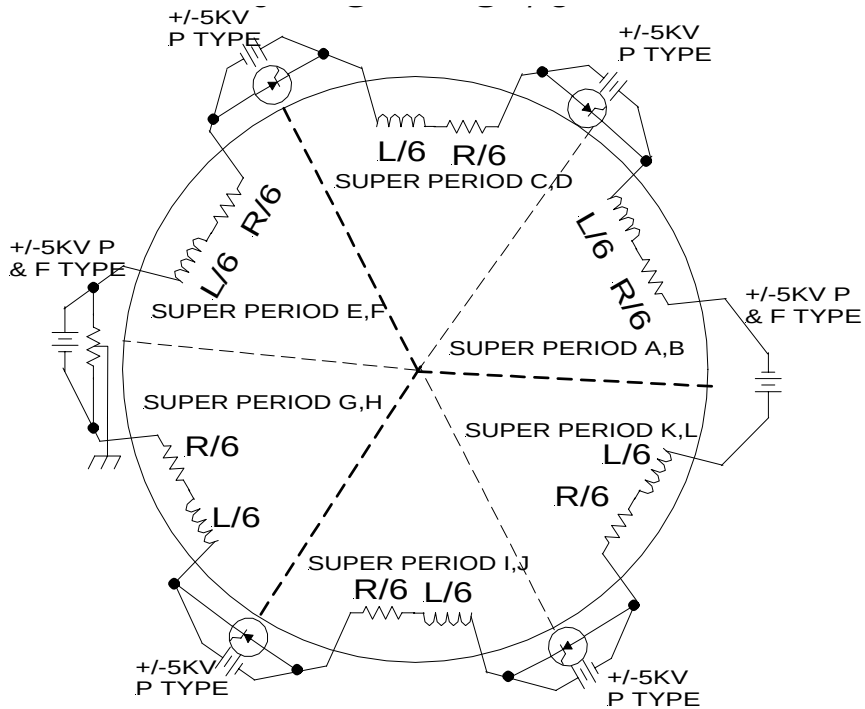
New AGS Main Magnet Power Supply

		presently
Repetition rate	2.5 Hz	1 Hz
Peak power	110 MW	50 MW
Average power	4 MW	4 MW
Peak current	5 kA	5 kA
Peak total voltage	± 25 kV	± 10 kV
Number of power converters / feeds	6	2



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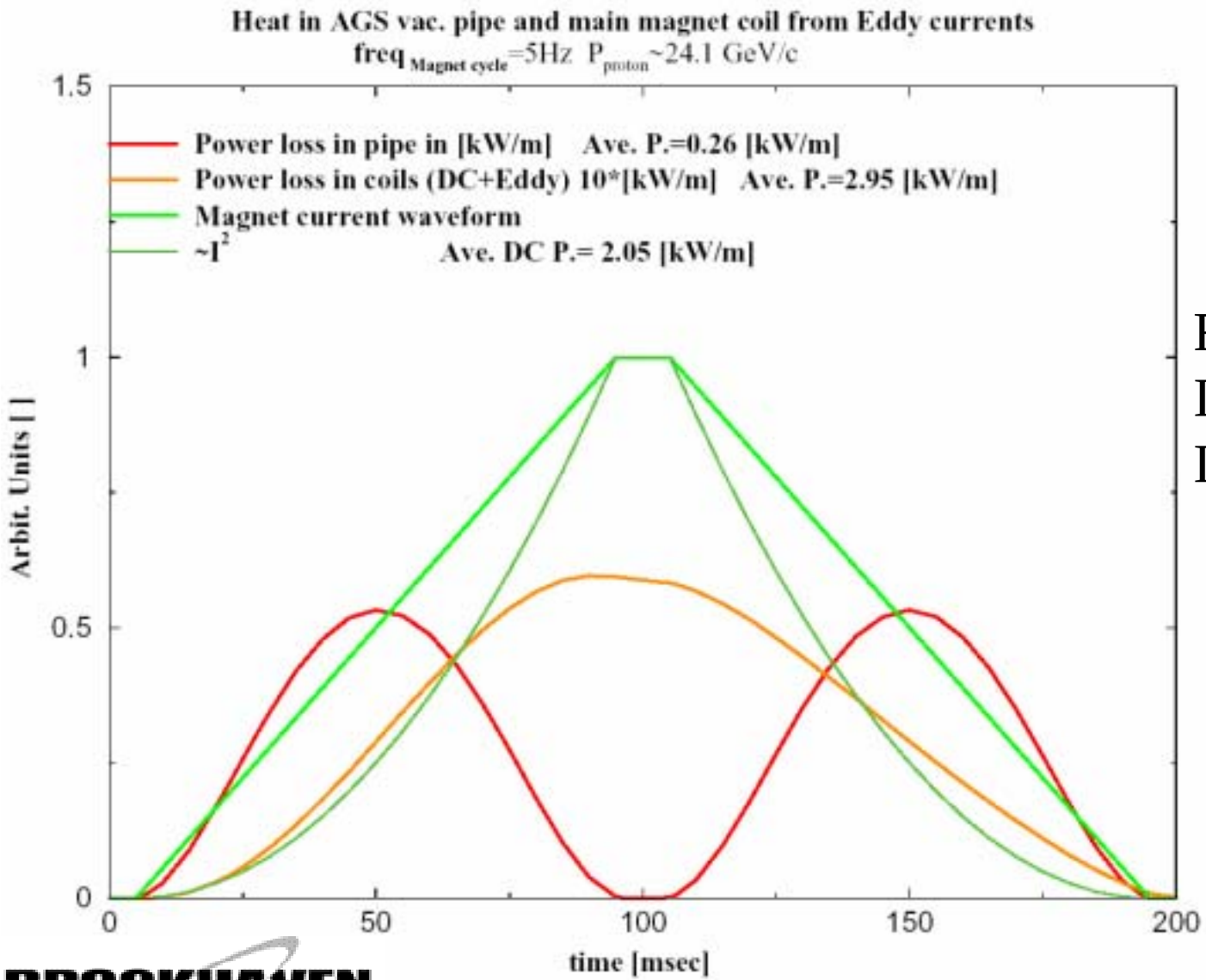
Eddy Current Losses in AGS Magnets



For 2.5 Hz:
In pipe: 65 W/m
In coil: 225 W/m

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AGS RF System Upgrade

Use present cavities with upgraded power supplies
(two 300 kW tetrodes/cavity)

		presently:
Rf voltage/turn	0.8 MV	0.4 MV
Harmonic number	24	6 - 12
Rf frequency	~ 9 MHz	3 - 4.5 MHz
Rf peak power	2 MW	
Rf magnetic field	18 mT	

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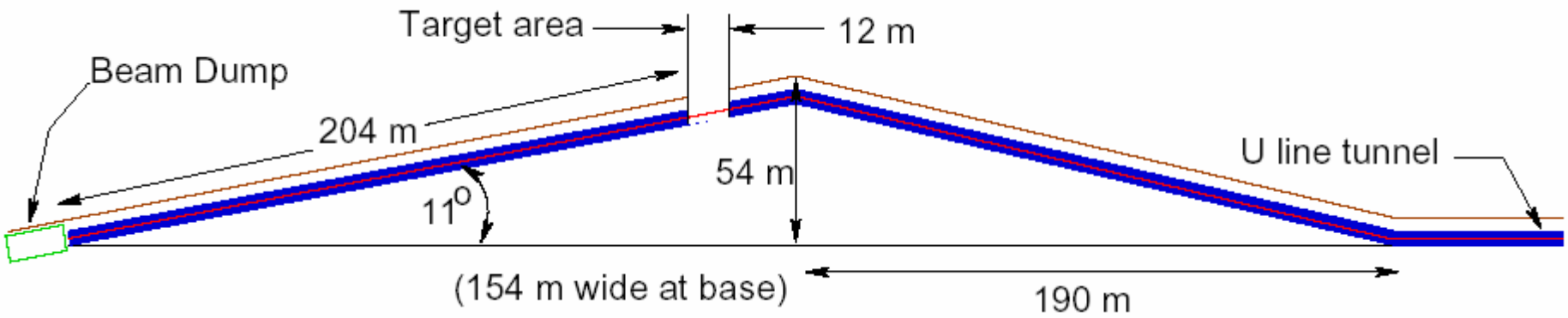
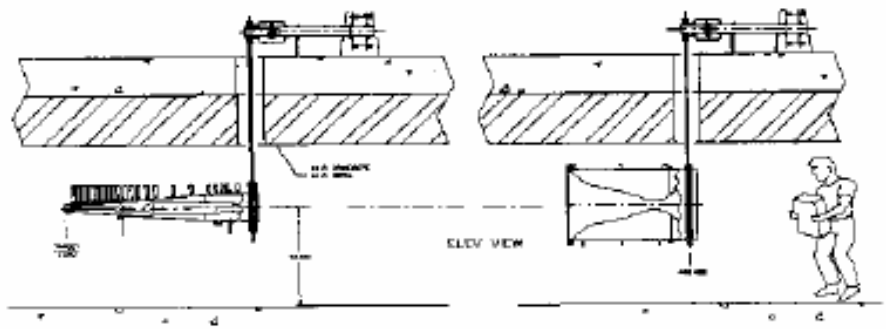
Neutrino Beam Production



- Two horn design
- Target on down-hill slope for long baseline experiment
- No underground construction to avoid ground water



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Towards 4 MW

	Upgrade I	Upgrade II	Upgrade III
Linac intensity/pulse	1.0×10^{14}	2.0×10^{14}	2.0×10^{14}
Linac rep. rate	2.5 Hz	2.5 Hz	5.0 Hz
Linac extraction energy	1.2 GeV	1.5 GeV	1.5 GeV
$\beta^2\gamma^3$	9.6	14.9	14.9
Beam power	54 kW	144 kW	288 kW
AGS intensity/pulse	0.9×10^{14}	1.8×10^{14}	1.8×10^{14}
AGS rep. rate	2.5 Hz	2.5 Hz	5.0 Hz
Rf peak power	2 MW	4 MW	8 MW
Rf gap volts/turn	0.8 MV	0.8 MV	1.5 MV
AGS extraction energy	28 GeV	28 GeV	28 GeV
Beam power	1 MW	2 MW	4 MW