AGS Upgrade and Neutrino Super Beam

AGS High Intensity Performance

AGS Upgrade:

- Beam loss considerations
- 1.2 GeV Superconducting Linac
- 2.5 Hz AGS power supply and rf system
- Neutrino beam production
- Cost estimate

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Thomas Roser
DOE Annual HEP Program Review
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Neutrino Working Group - AGS Super Neutrino Beam Facility

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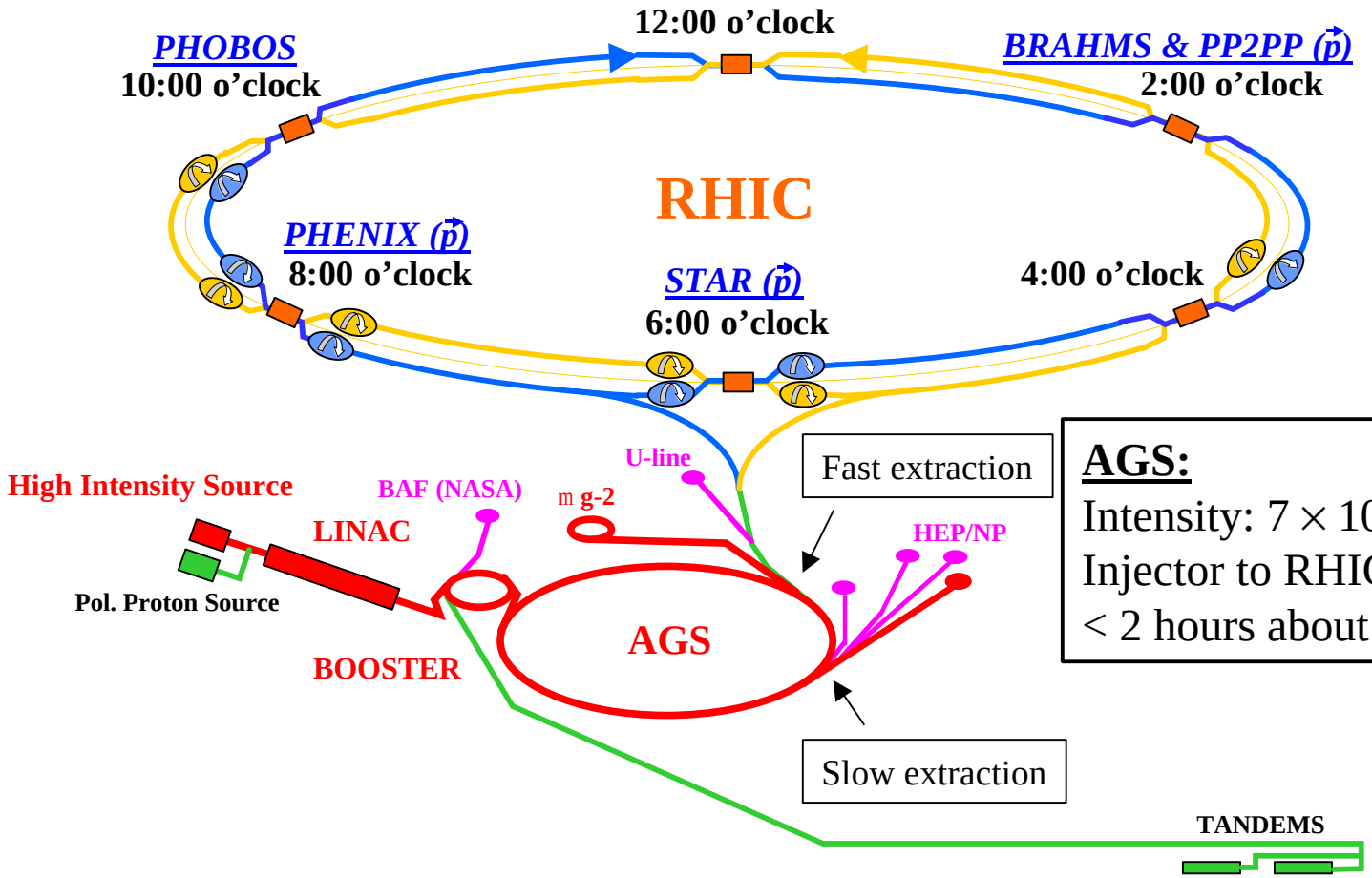
AGS/RHIC Accelerator Complex



AGS:

Intensity: 7×10^{13} protons/pulse

Injector to RHIC:

< 2 hours about every 10 hours

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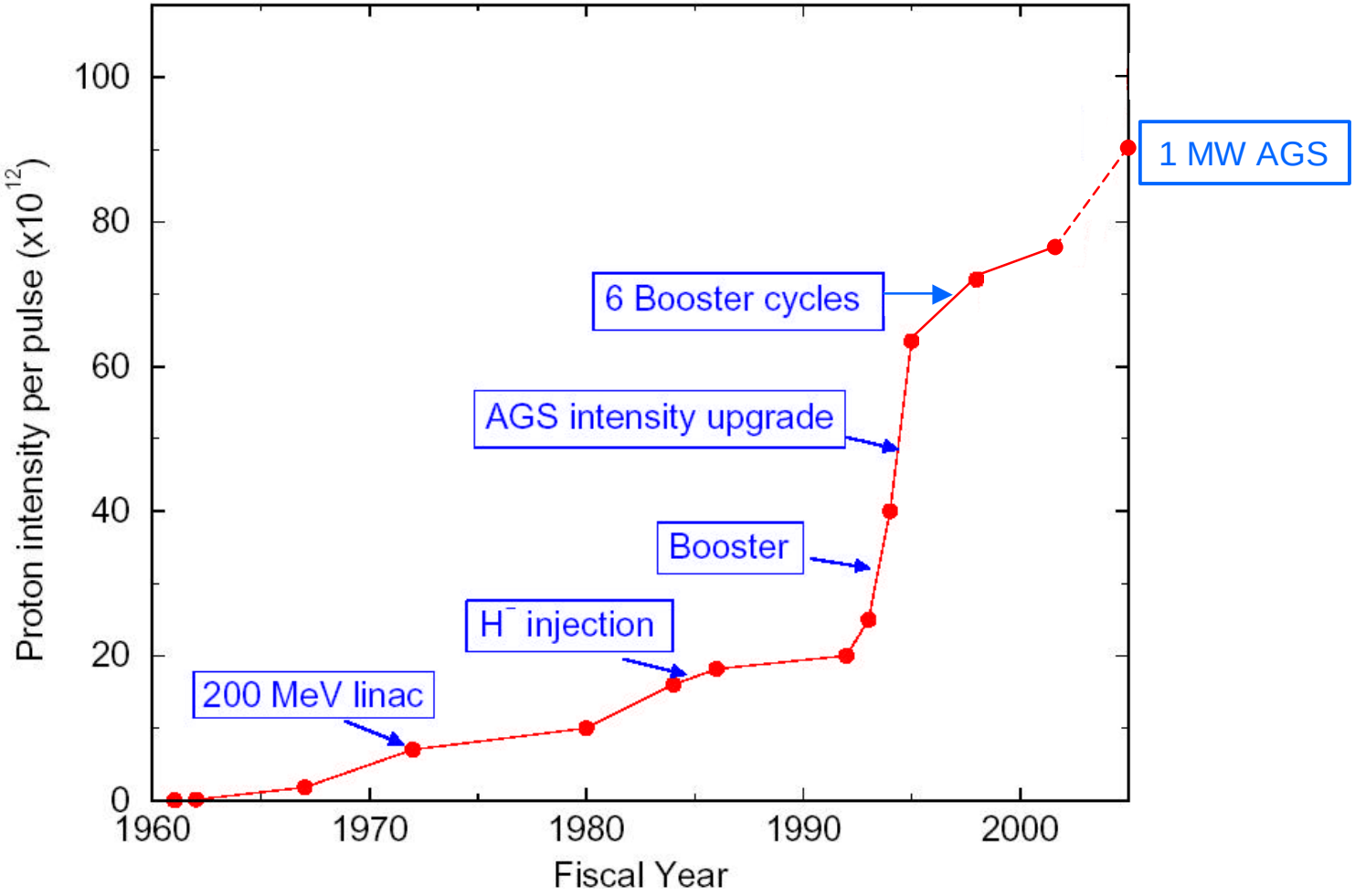
AGS Intensity History



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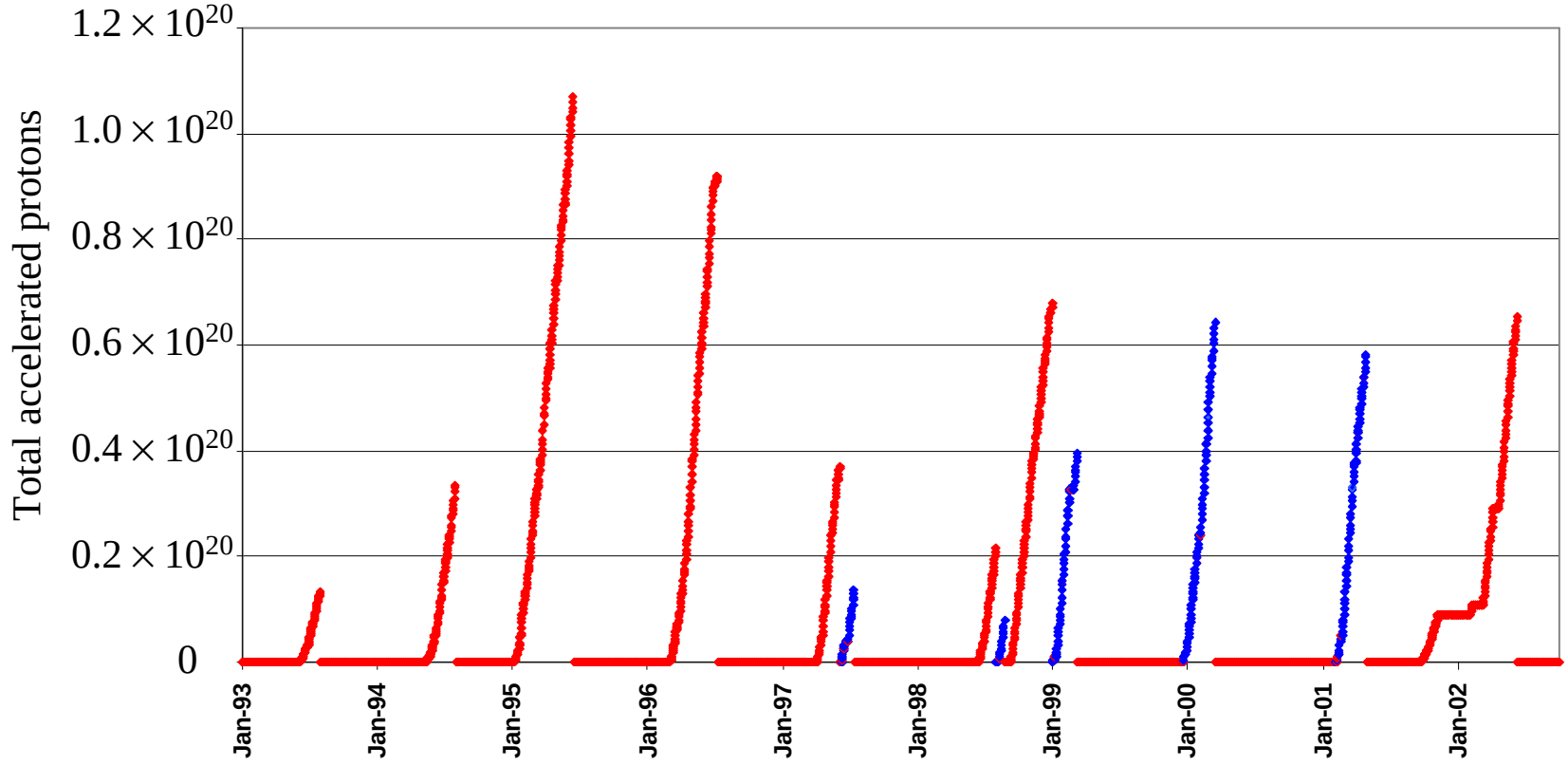
Total Accelerated Protons at the AGS



Slow extracted beam (Kaon decay)

Fast extracted beam (g-2)

Note: Lower total accelerated protons in later years due to much shorter running time

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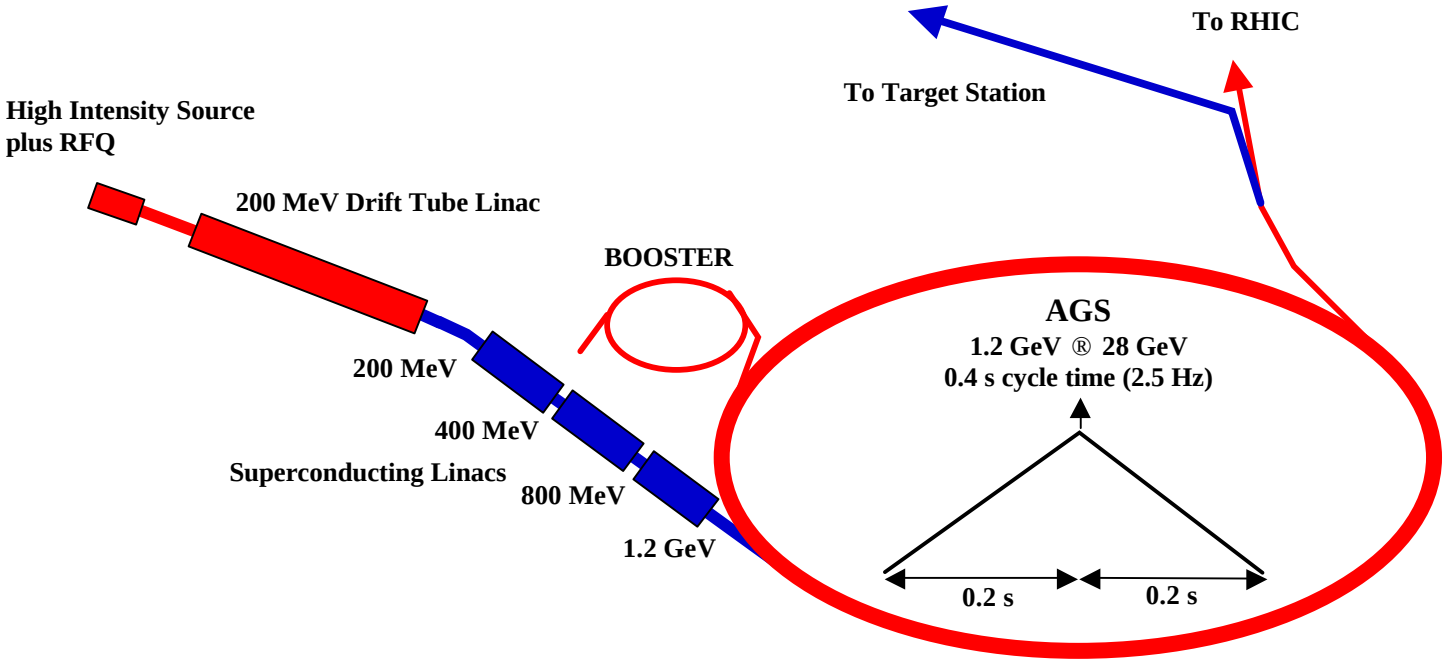
AGS Upgrade to 1 MW



- 1.2 GeV superconducting linac extension for direct injection of $\sim 1 \times 10^{14}$ protons
  - 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)

AGS Proton Driver Parameters

	present AGS	**1 MW AGS**	**4 MW AGS**	J-PARC
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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Beam Loss at H^- Injection Energy

	AGS Booster	PSR LANL	SNS	1 MW AGS
Beam power, Linac exit, kW	3	80	1000	50
Kinetic Energy, MeV	200	800	1000	1200
Number of Protons N_P, 10^{12}	15	31	100	100
Vertical Acceptance A, π μm	89	140	480	55
$\beta^2\gamma^3$	0.57	4.50	6.75	9.56
N_P / ($\beta^2\gamma^3$ A), 10^{12} / π μm	0.296	0.049	0.031	0.190
Total Beam Losses, %	5	0.3	0.1	3
Total Loss Power, W	150	240	1000	1440
Circumference, m	202	90	248	807
Loss Power per Meter, W/m	0.8	2.7	4.0	1.8

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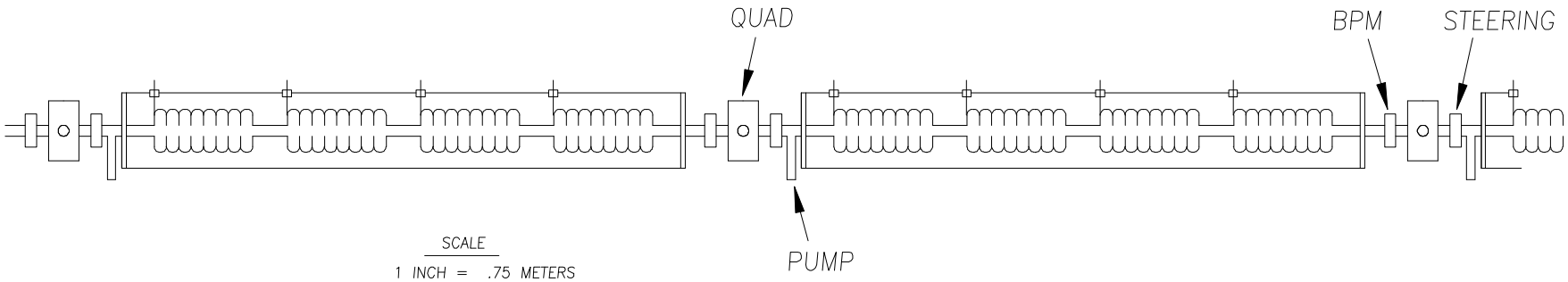
1.2 GeV Superconducting Linac

Beam energy	0.2 → 0.4 GeV	0.4 → 0.8 GeV	0.8 → 1.2 GeV
Rf frequency	805 MHz	1610 MHz	1610 MHz
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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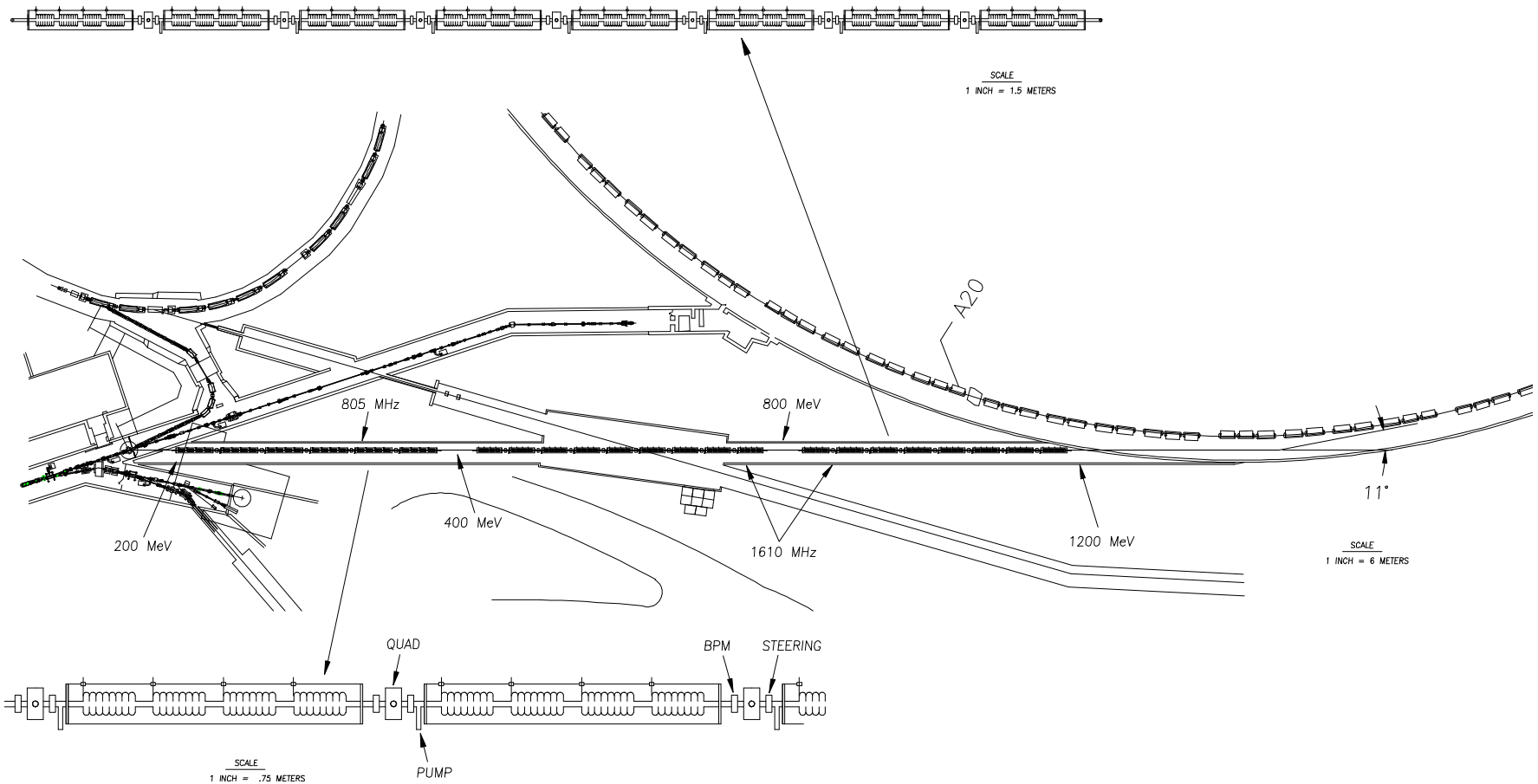
1.2 GeV Superconducting Linac



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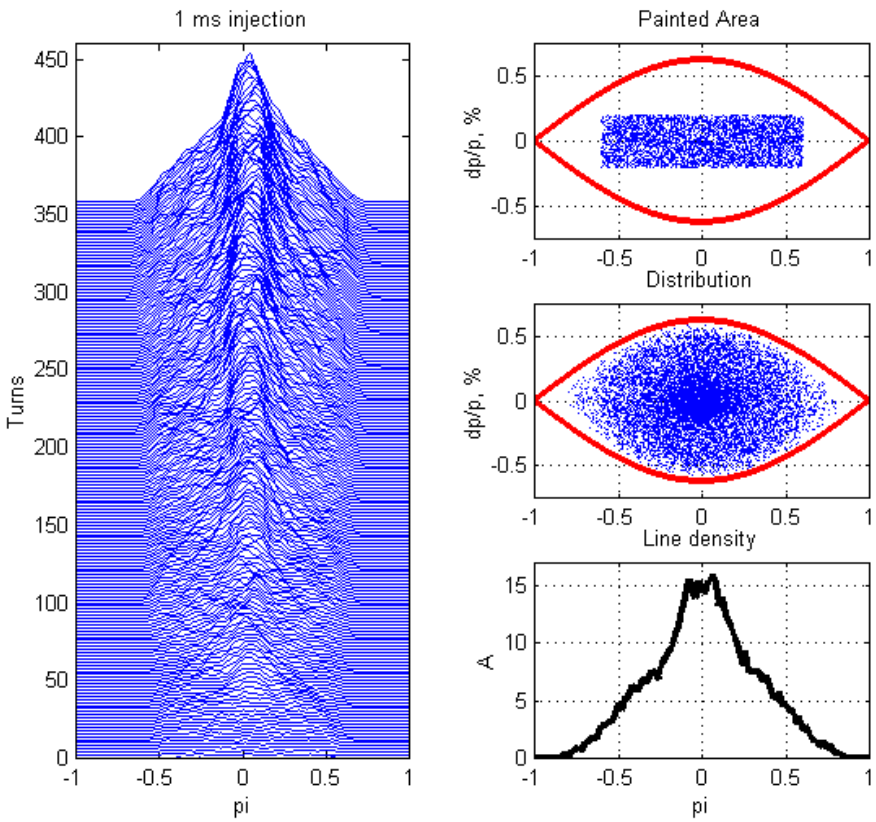
AGS Injection Simulation

Injection parameters:

Injection turns	360
Repetition rate	2.5 Hz
Pulse length	1.08 ms
Chopping rate	0.65
Linac average/peak current	20 / 30 mA
Momentum spread	± 0.15 %
Inj. beam emittance (95 %)	12 π μm
RF voltage	450 kV
Bunch length	85 ns
Longitudinal emittance	1.2 eVs
Momentum spread	± 0.48 %
Circ. beam emittance (95 %)	100 π μm



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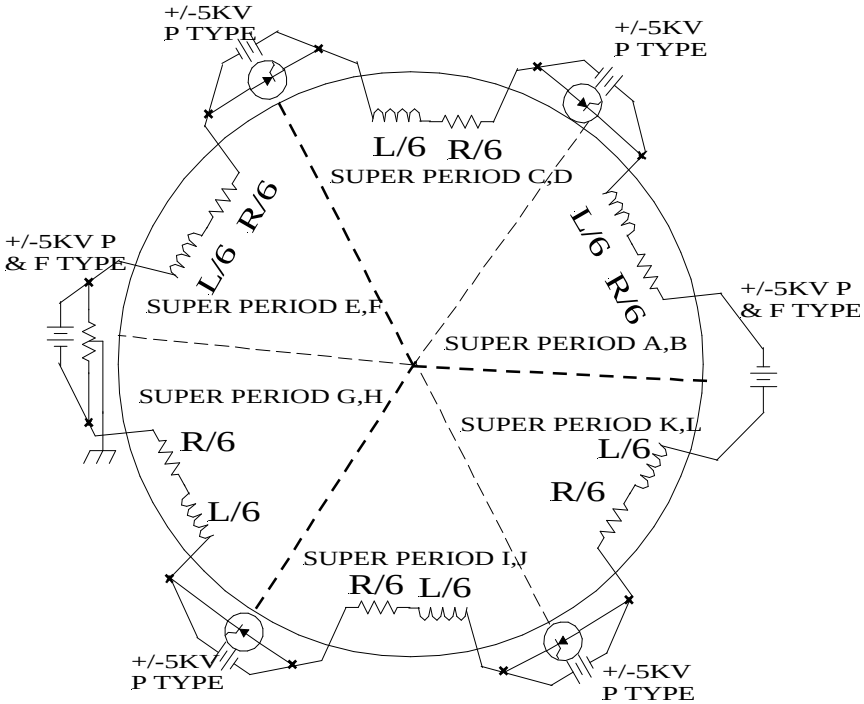
New AGS Main Magnet Power Supply

		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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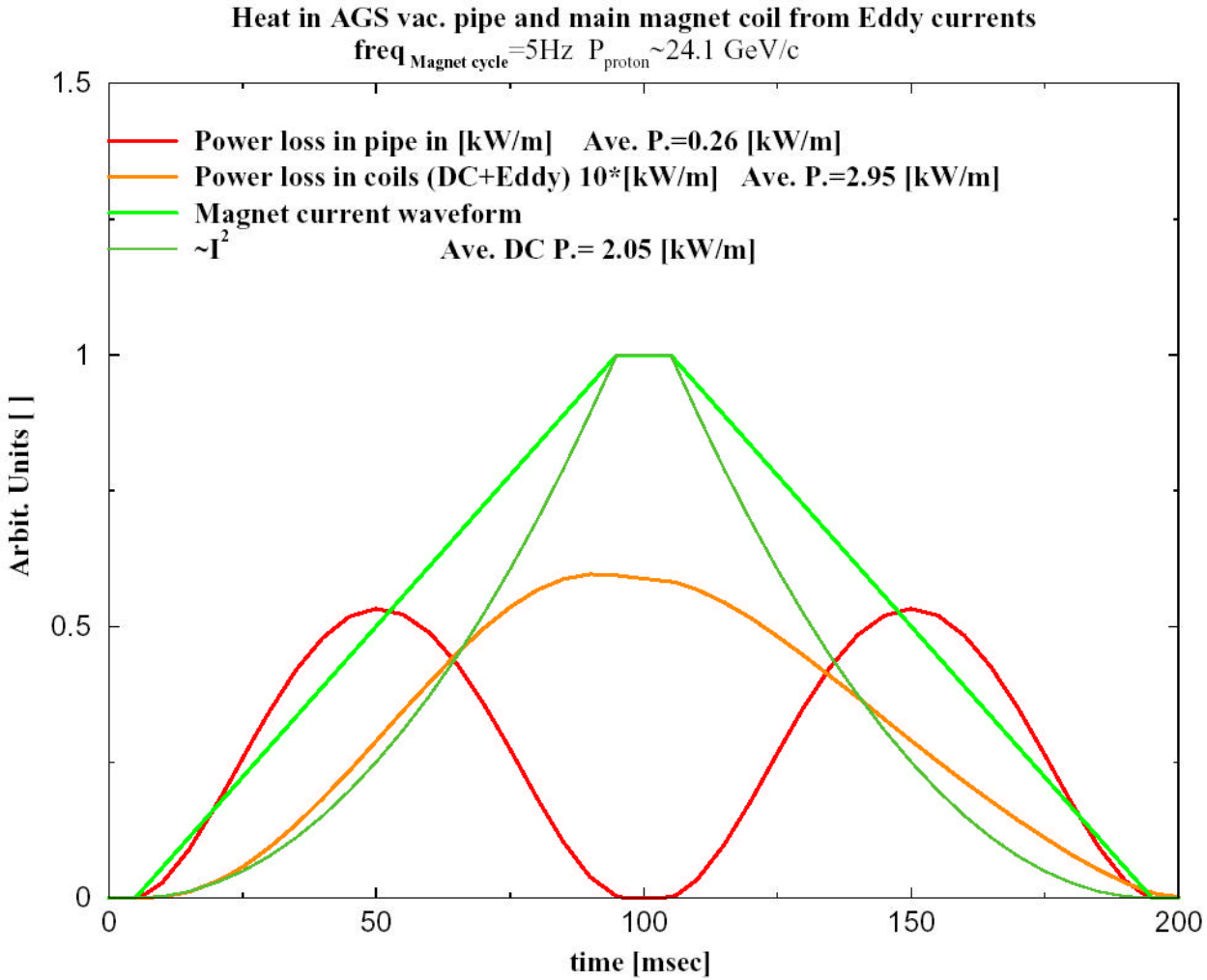
Eddy Current Losses in AGS Magnets



For 2.5 (5.0) Hz:
In pipe: 65 (260) W/m
In coil: 225 (900) 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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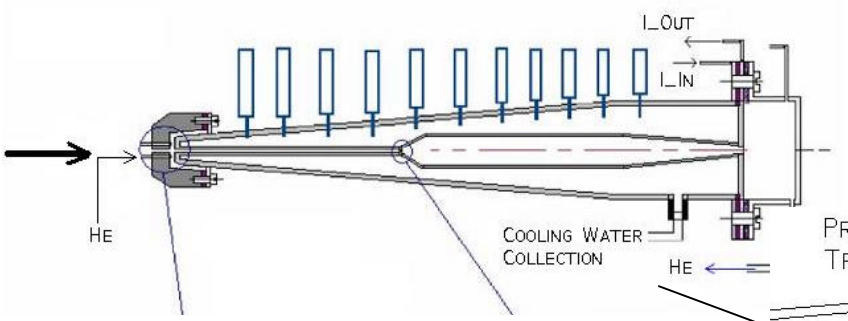
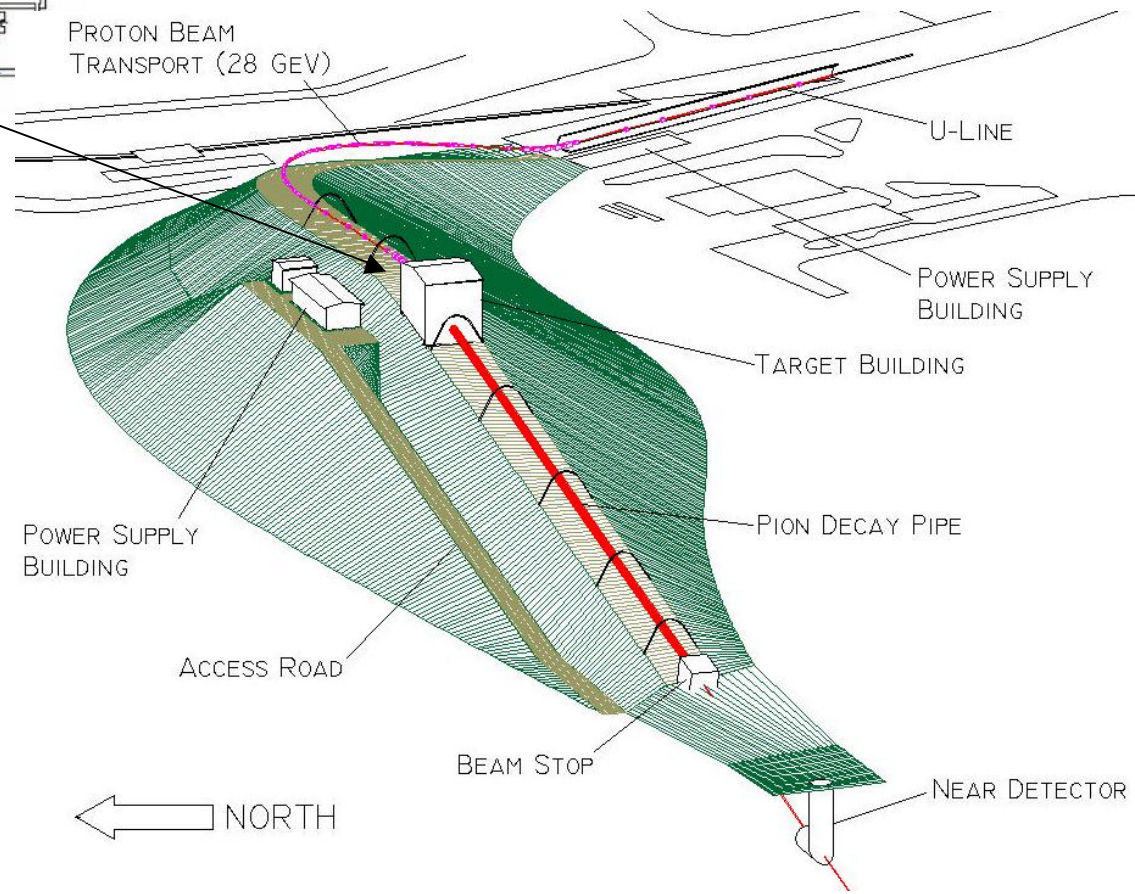
Neutrino Beam Production





- 1 MW He gas-cooled Carbon-carbon target
- New horn design
- Target on down-hill slope for long baseline experiment
- Beam dump well above ground water table to avoid activation

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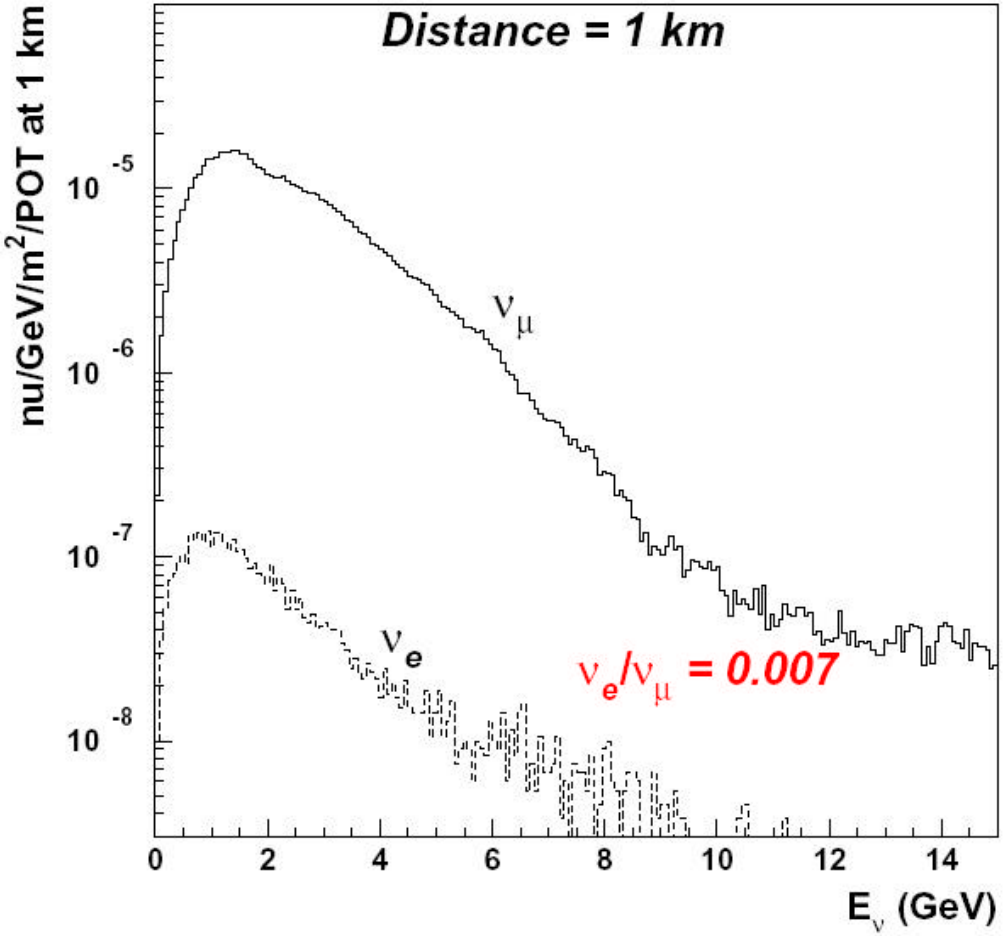
Neutrino Spectrum at 1 km

Low Z (Carbon) target seems feasible for 1 MW, 28 GeV proton beam.

Thin low Z target minimizes reabsorption which increases flux of high energy neutrinos



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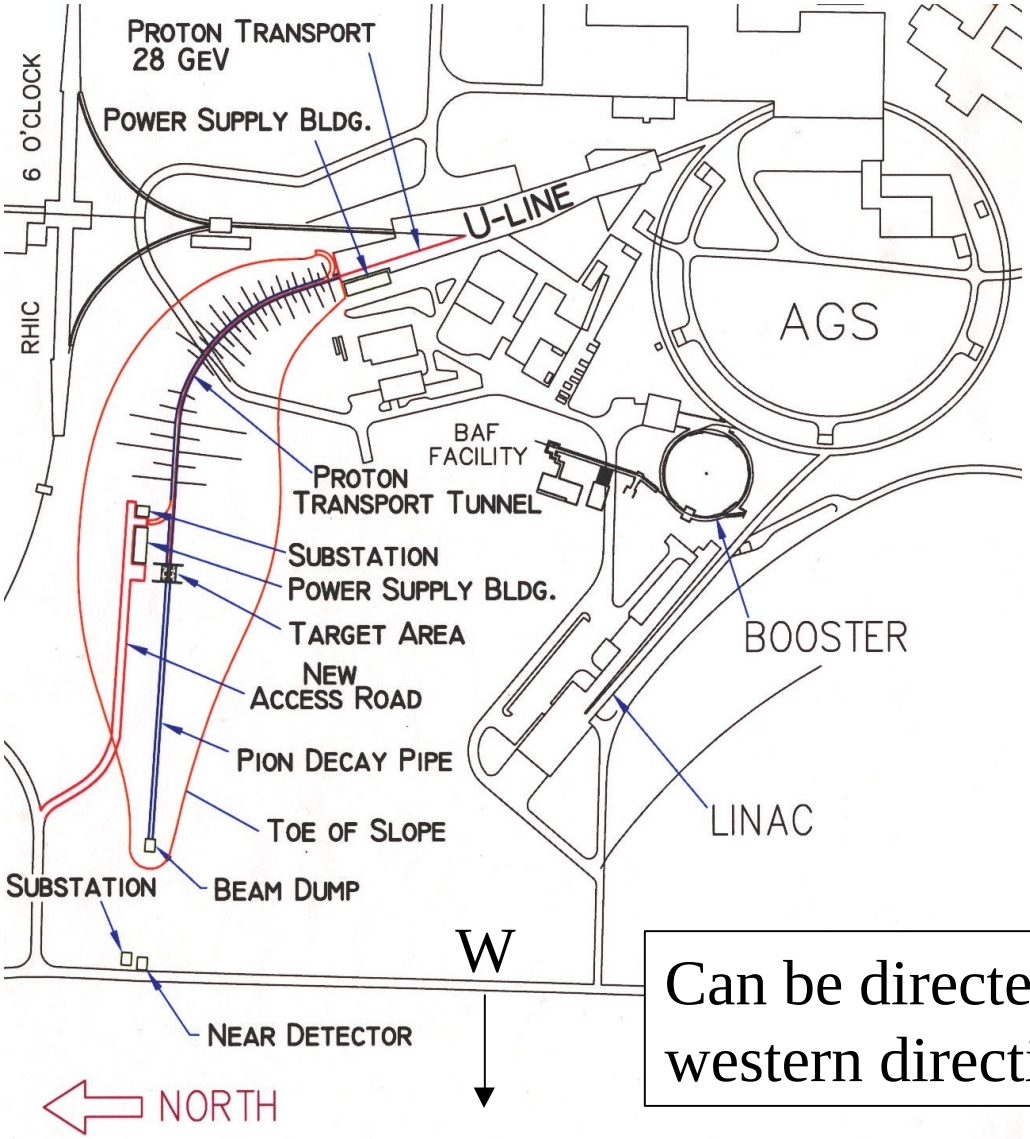
Beam Line to Homestake Mine



Can be directed to any western direction.

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Summary of Preliminary Cost Estimates

1.2 GeV Superconducting Linac	$ 99 M
AGS upgrade	$ 58 M
Neutrino beam production	$ 62 M
Total direct cost	$ 219 M
Total Estimated Cost	$ 345 M

(incl. 15% EDIA; 30% contingency;13% BNL project overhead)

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Path 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

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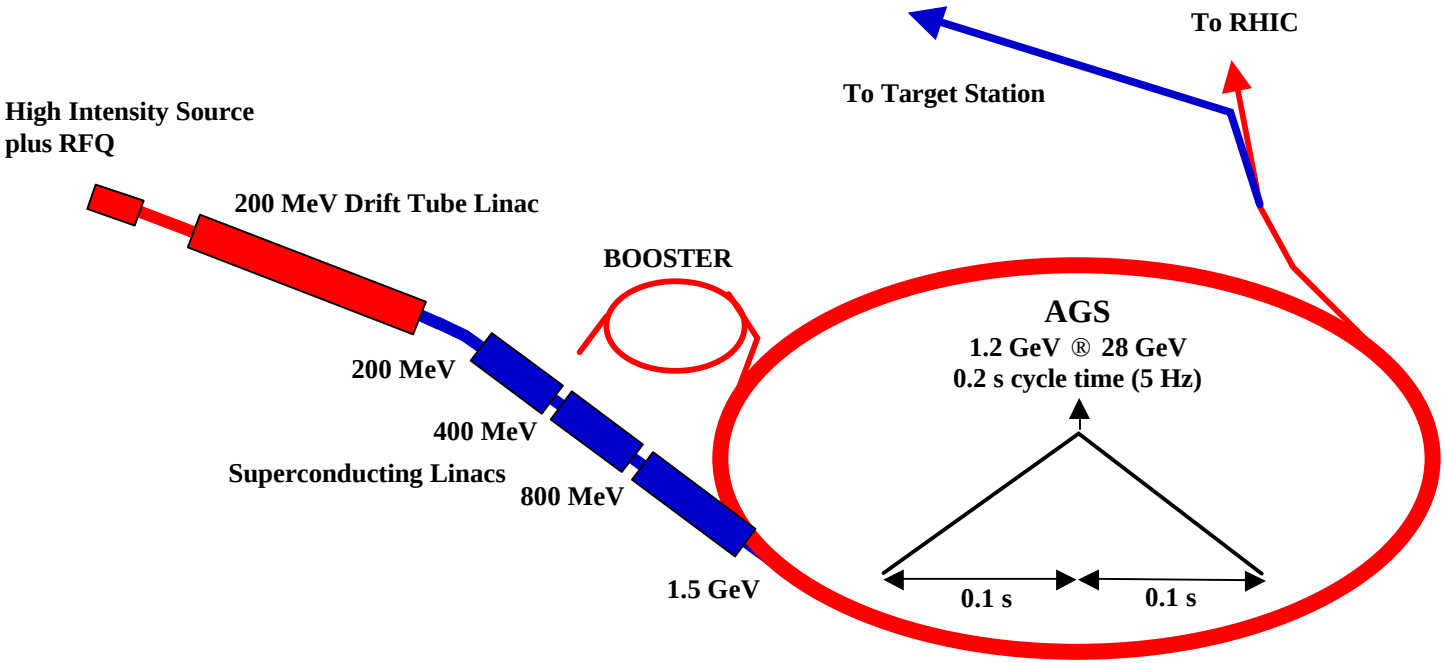
4 MW AGS Proton Driver Layout



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Conclusion

An upgraded AGS with 1 MW (further upgradeable to 4 MW) beam power is a cost effective proton driver for a neutrino superbeam for very long baseline experiments.