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

Coordinators: M. Diwan, W. Marciano, W.Weng

Contributors and Participants

J. Alessi, D. Barton, D. Beavis, S. Bellavia, J. Brennan, B. Bromley, Mu-Chu Chen, M. Diwan, R. Fernow, J. Gallardo, R. Hahn, S.Kahn, H. Kirk, Y. Y. Lee, D. Lowenstein, H. Ludewig, W. Marciano, I. Marneris, R. Palmer, Z. Parsa, A. Pendzick, C. Pearson, D. Raparia, T. Roser, A. Ruggiero, J. Sandberg, N. P. Samios, C. Scarlet, N. Simos, N. Tsoupas, J. Tuozzolo, B. B. Wang, B. Viren, P. Yamin, M. Yeh, Wu Zhang

Brookhaven National Laboratory, P. O. Box 5000, Upton, NY 11973-5000

W. Frati, J. R.Klein, K. Lande, A. K. Mann, R. Van Berg, and P. Wildenhain

University of Pennsylvania Philadelphia, PA 19104-6396

R. Corey

South Dakota School of Mines and Technology, Rapid City, S. D. 57701

D. B. Cline, K. Lee, B. Lisowski, P. F. Smith

Department of Physics and Astronomy, University of California, Los Angeles, CA 90095

I. Mocioiu, R. Shrock

C. N. Yang Institute for Theoretical Physics State University of New York,

Stony Brook, NY 11974

C. Lu and K. T. McDonald

Joseph Henrry Laboratories, Princeton University, Princeton, NJ 08544, USA

Renato Potenza

Instituto Nazionale di Fisica Nucleare,Dipartimento de Fisica e Astronomia,

Universita di Catania, 64, Via s. Sofia, I-95123 Catania, Italy

George Evangelakis

Physics Department, University of Ioannina, Greece

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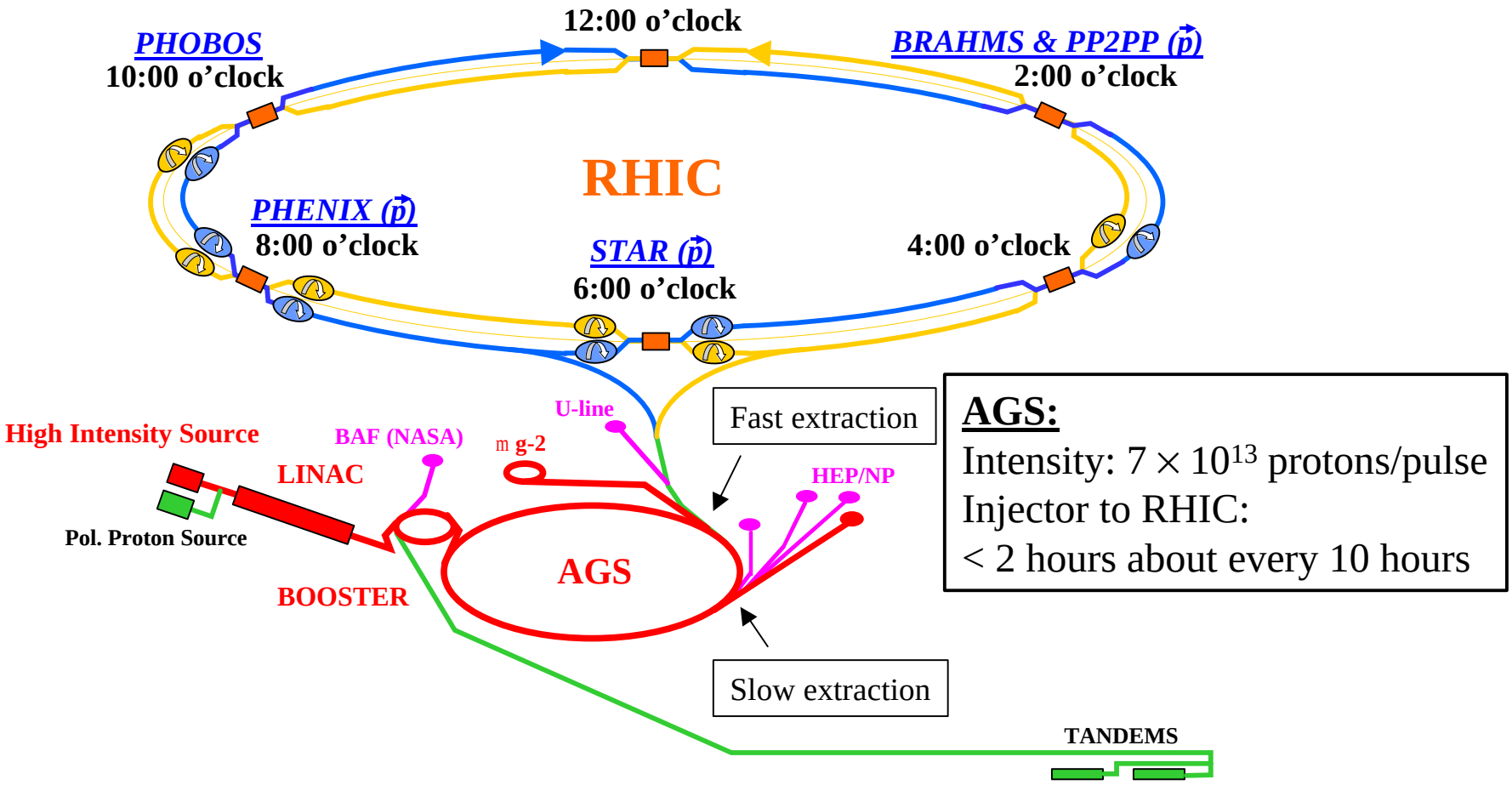
AGS/RHIC Accelerator Complex



AGS:

Intensity: 7×10^{13} protons/pulse

Injector to RHIC:

< 2 hours about every 10 hours

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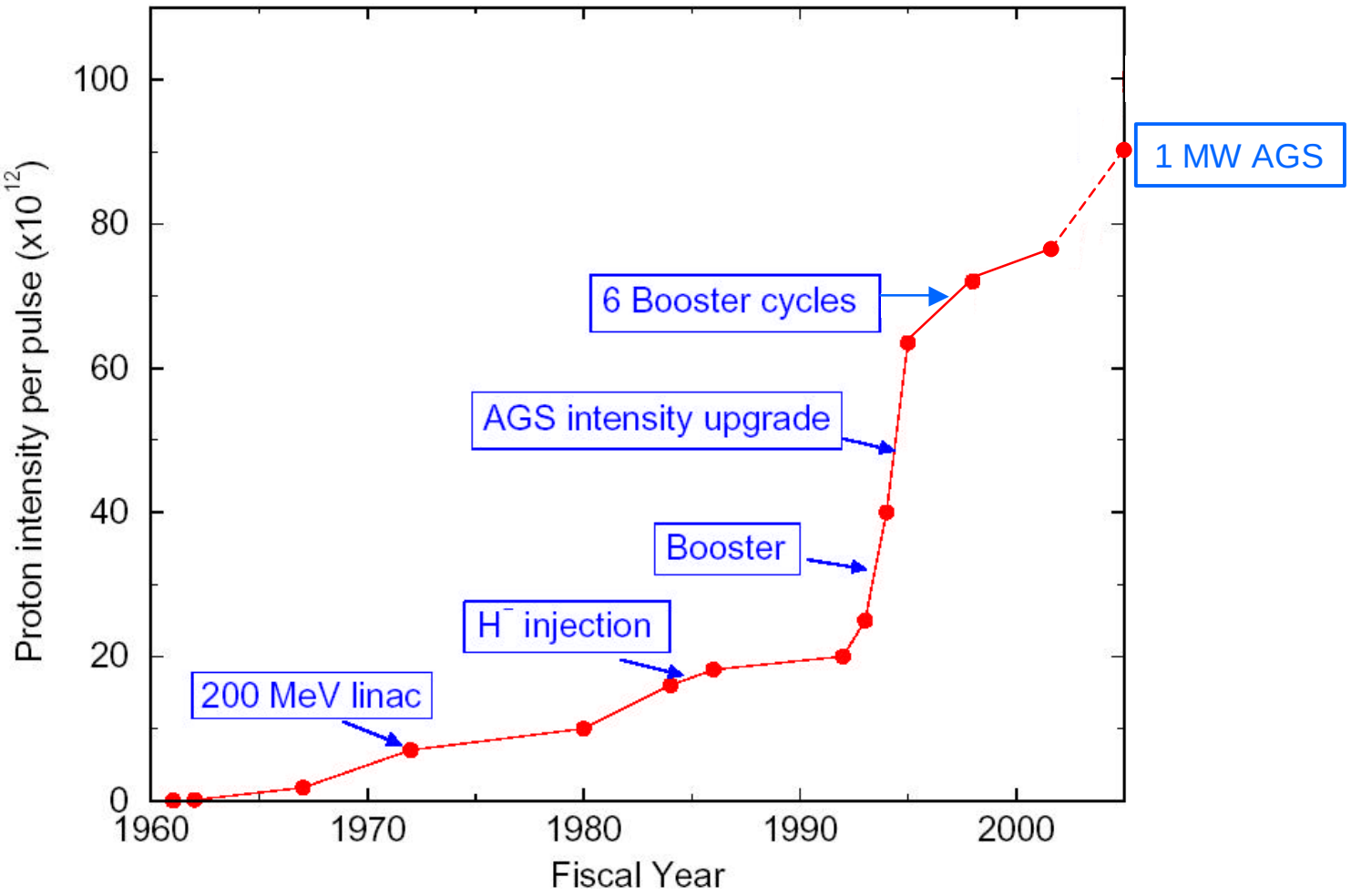
AGS Intensity History



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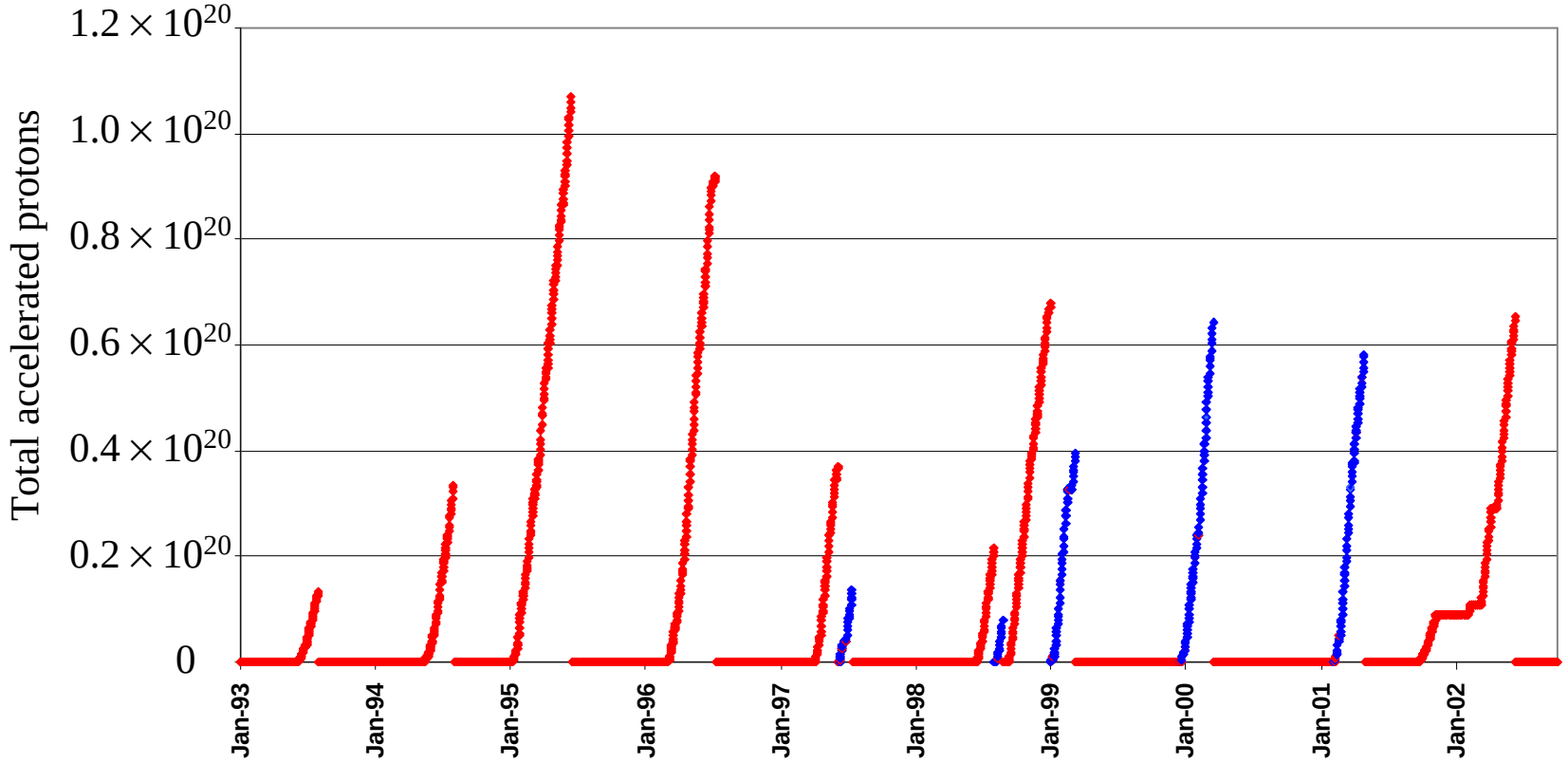
Total Accelerated Protons at the AGS



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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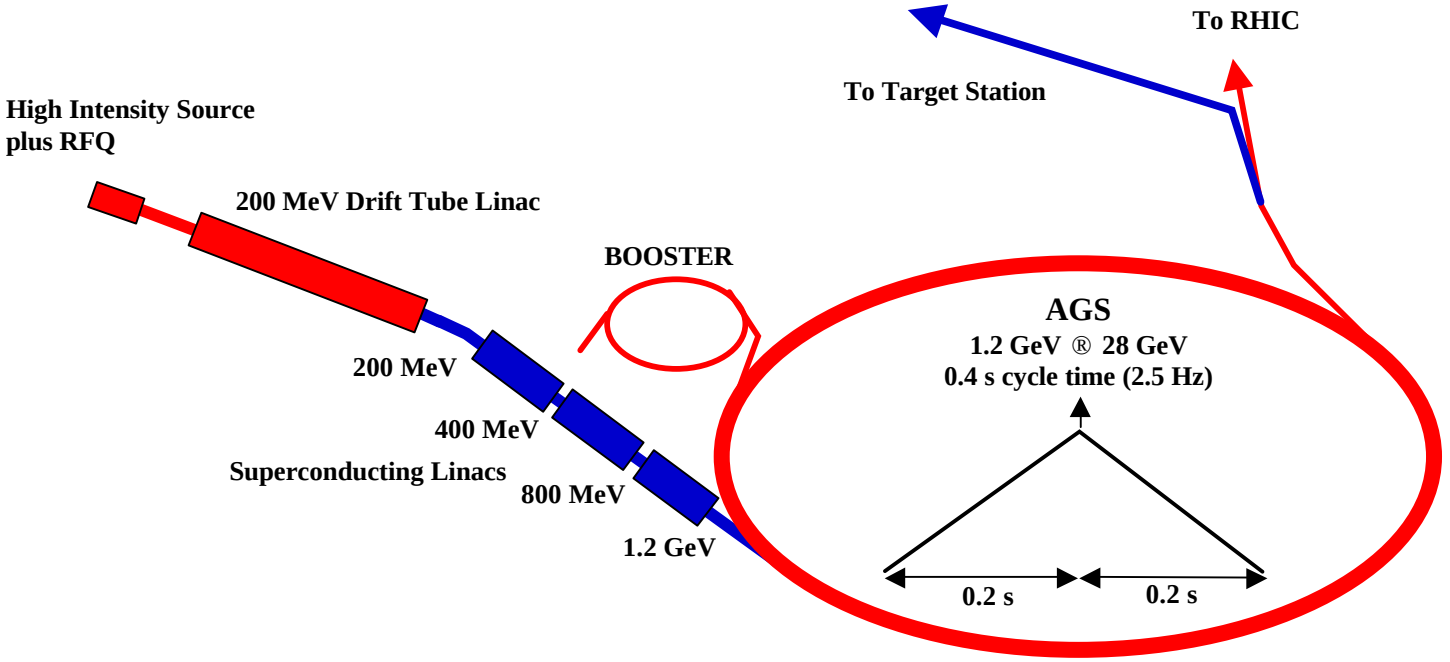
AGS Upgrade to 1 MW



- 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

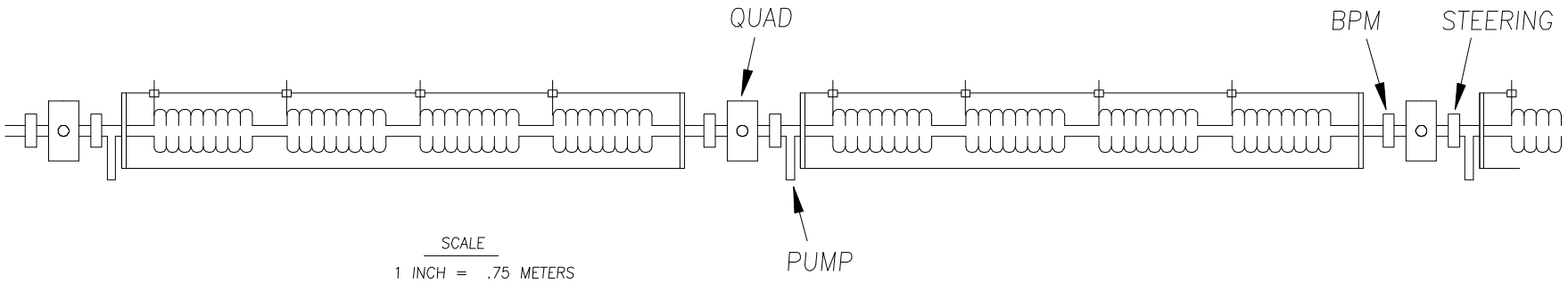
	present AGS	**1 MW AGS**	**4 MW AGS**	J-PARC
Total beam power [MW]	0.14	1.00	4.00	0.75
Beam energy [GeV]	24	28	28	50
Average current [μA]	6	36	144	15
Cycle time [s]	2	0.4	0.2	3.4
No. of protons per fill	0.7×10^{14}	0.9×10^{14}	1.8×10^{14}	3.3×10^{14}
Average circulating current [A]	4.2	5.0	10	12
No. 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}

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

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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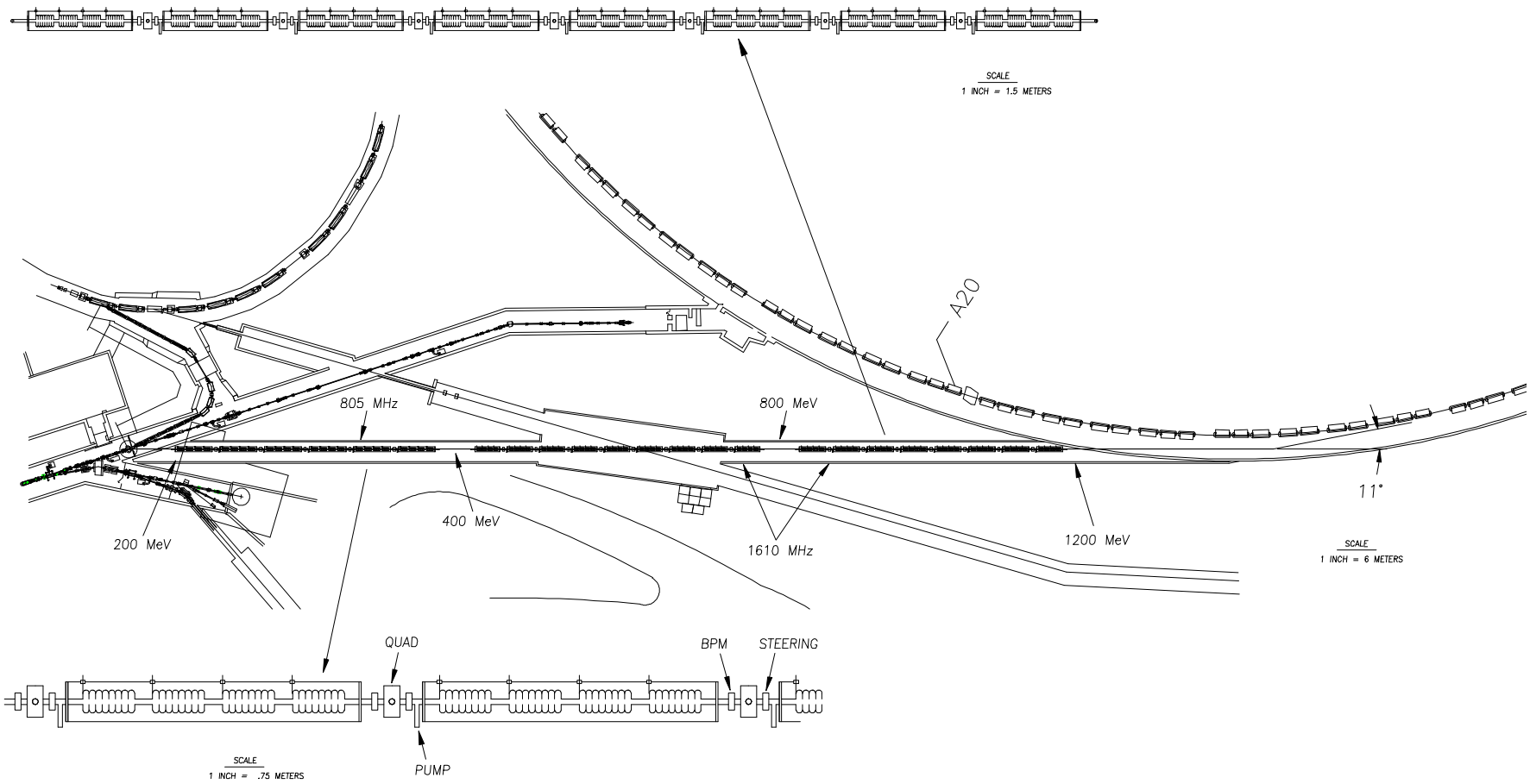
1.2 GeV Superconducting Linac



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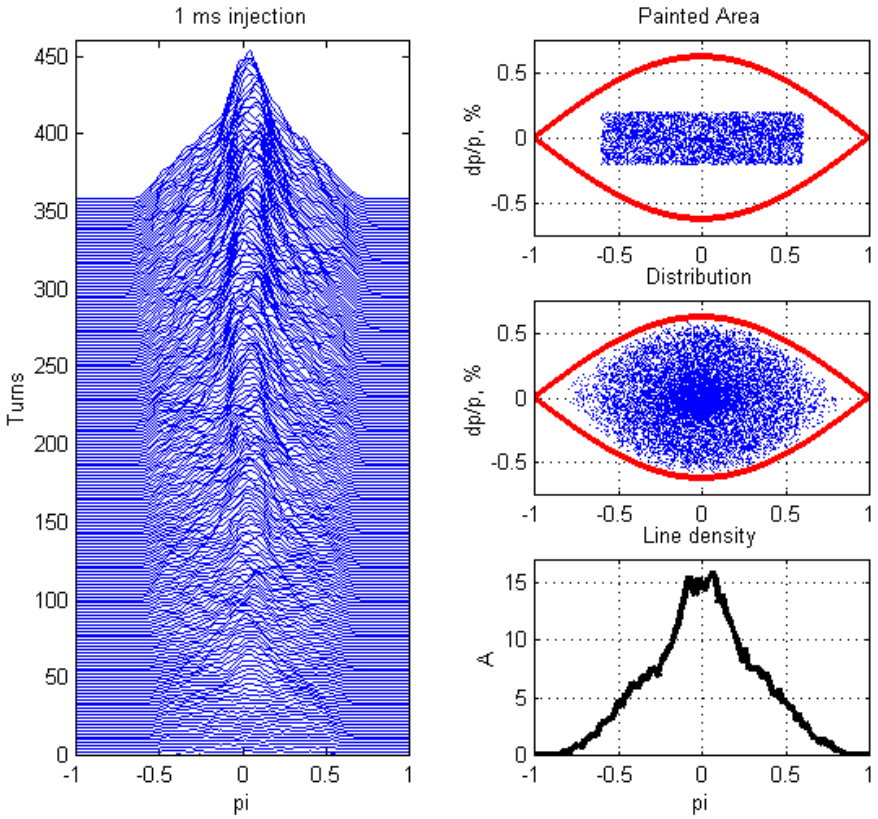
AGS Injection Simulation

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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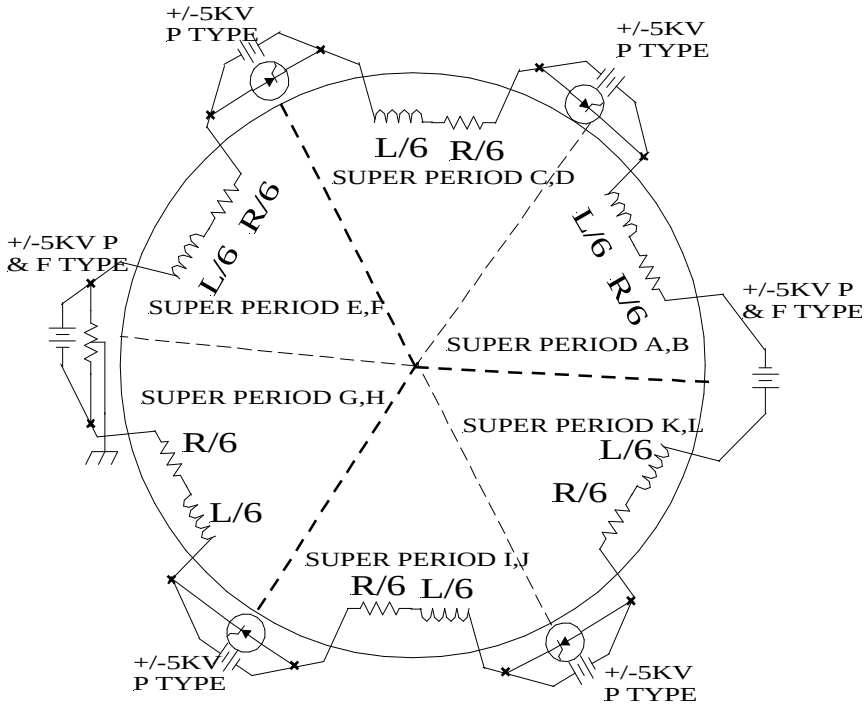
New AGS Main Magnet Power Supply

		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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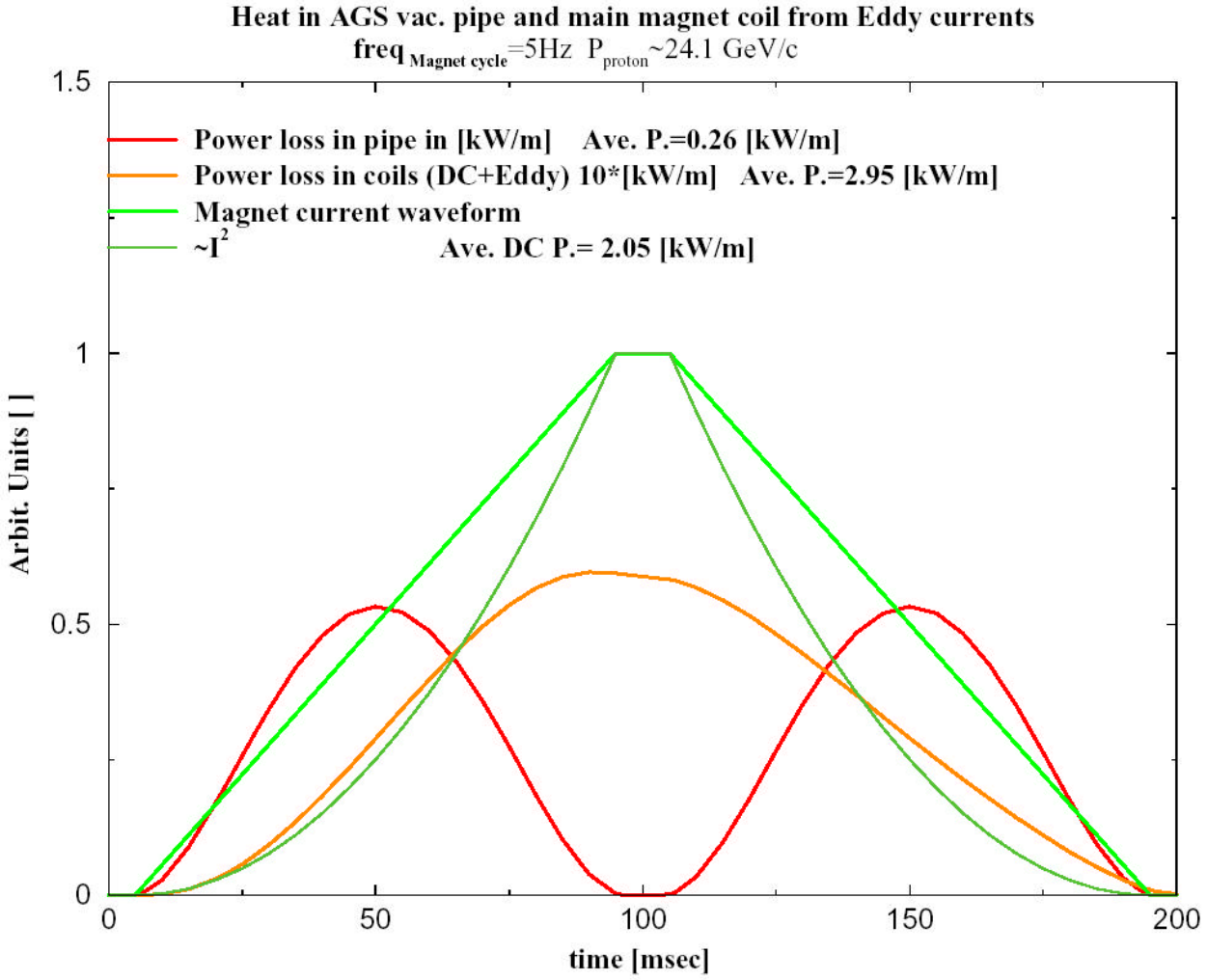
Eddy Current Losses in AGS Magnets



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

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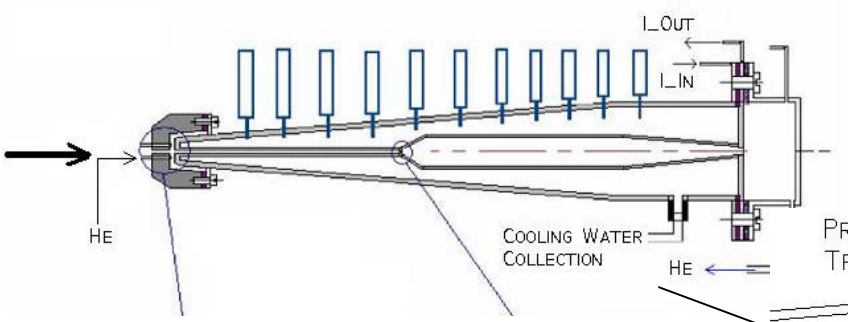
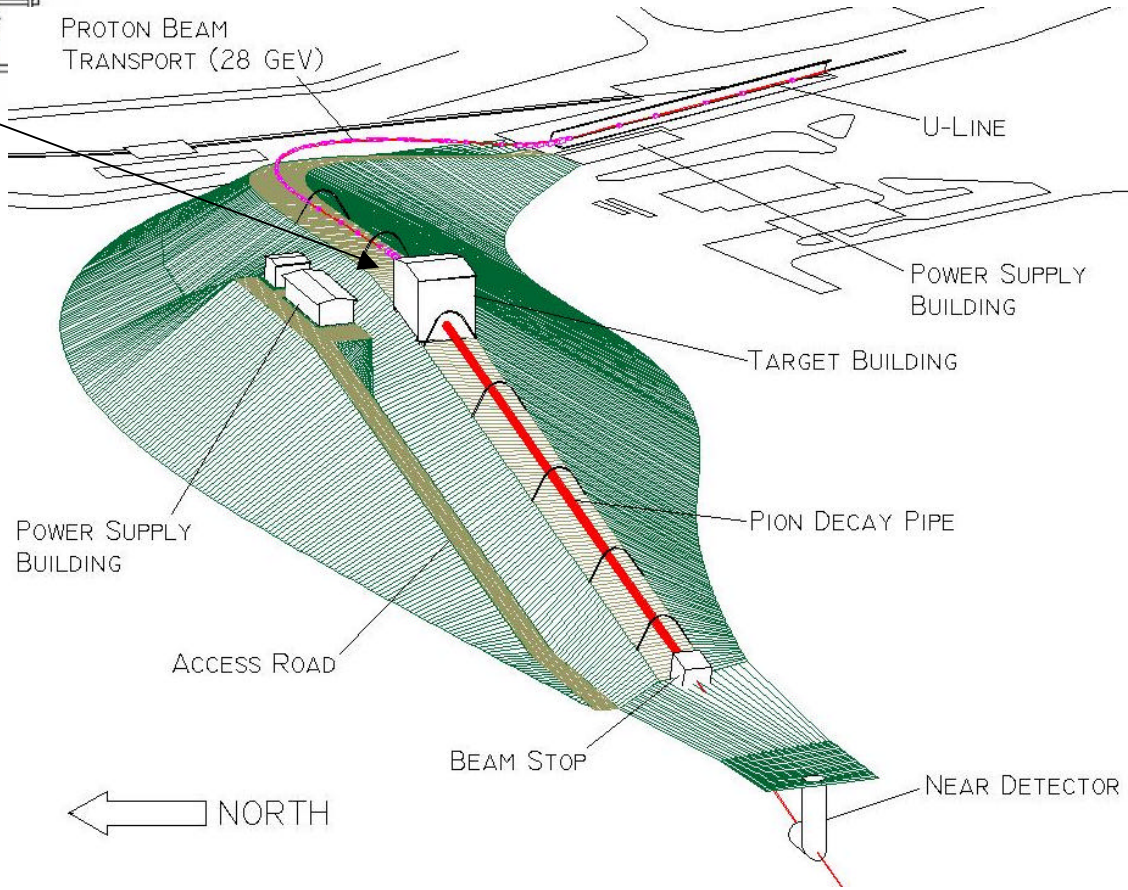
AGS RF System Upgrade

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	

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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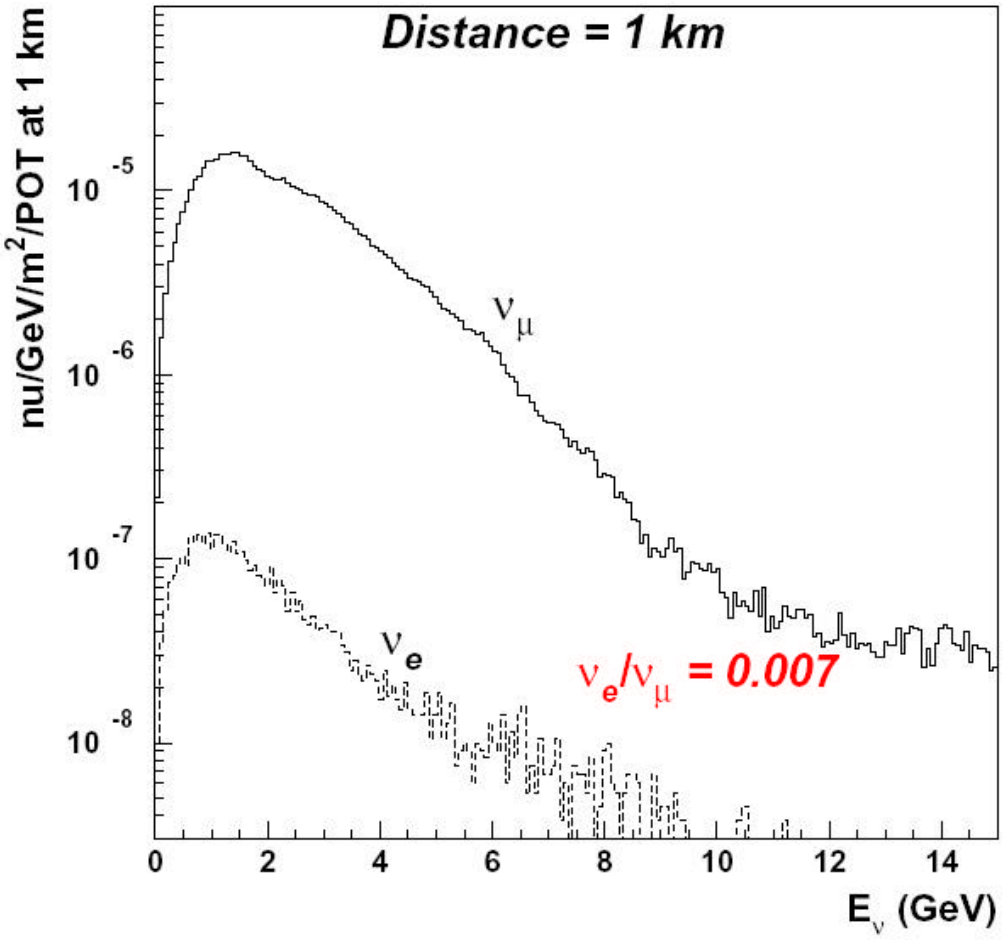
Neutrino Spectrum at 1 km

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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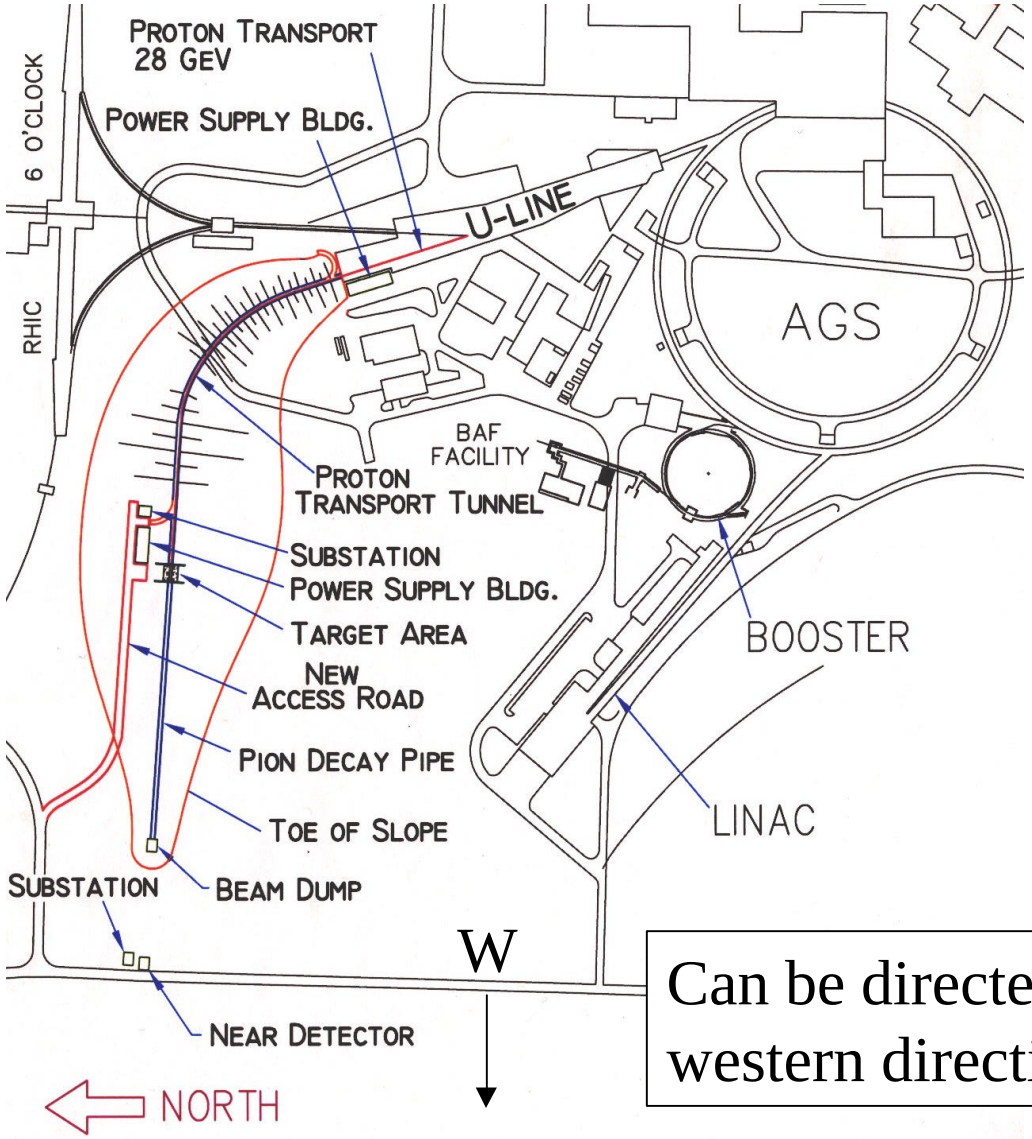
Beam Line to Homestake Mine



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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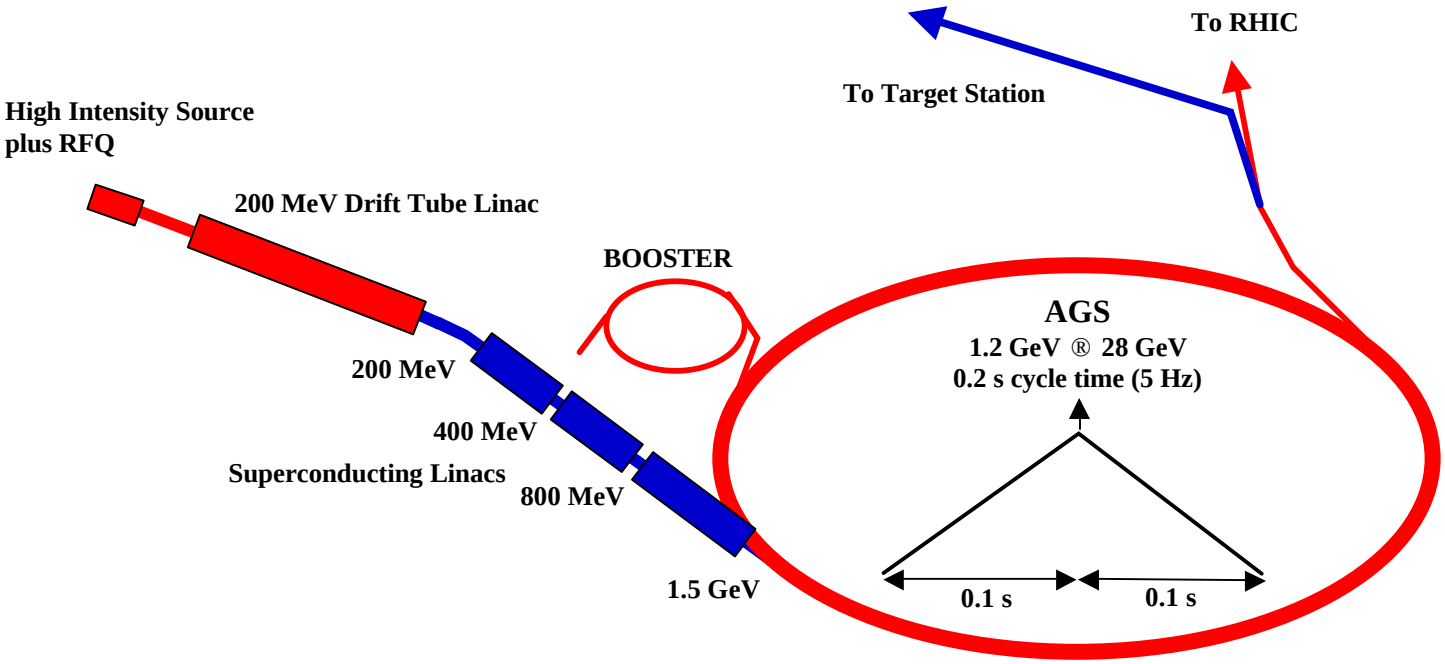
Path Towards 4 MW

	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

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.