DESIGN OF THE BNL PROTON DRIVER for SUPER NEUTRINO BEAM

W. T. Weng

Brookhaven National Laboratory

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OUTLINE

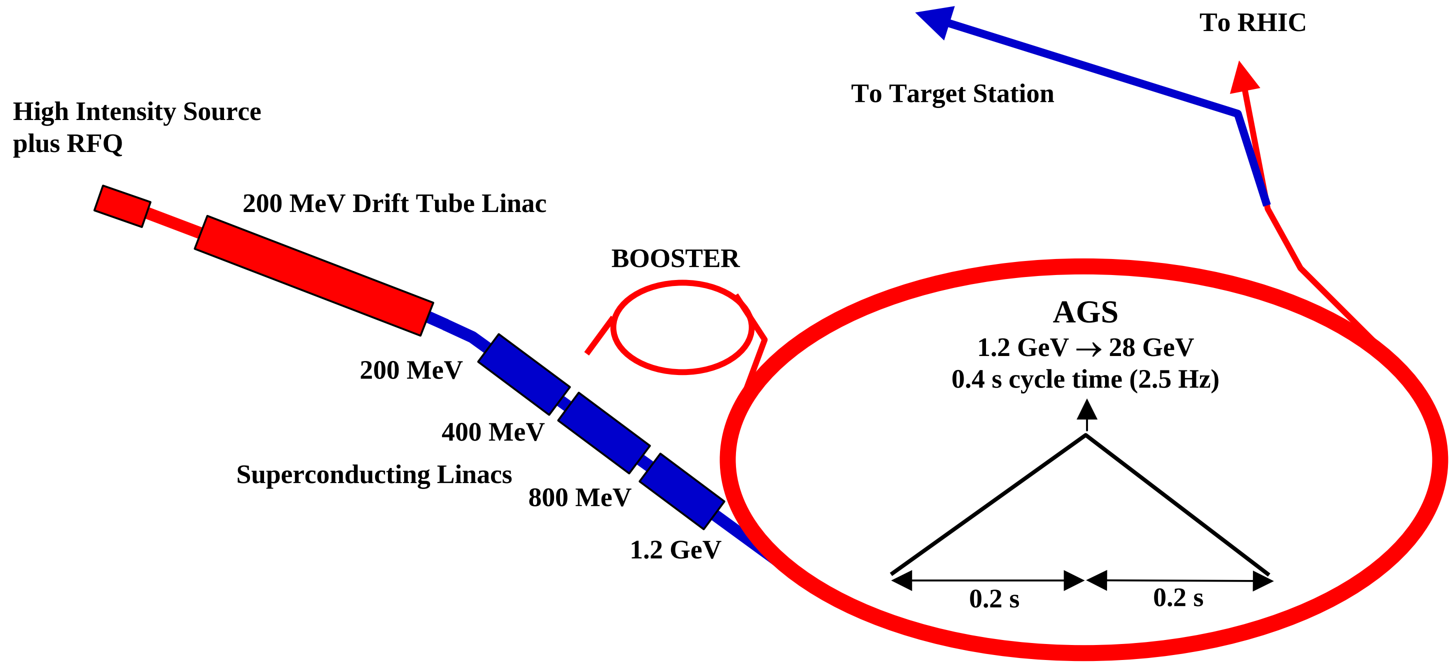
AGS Upgrade (1MW):

- Beam loss considerations
- 1.2 GeV Superconducting Linac
- H^- injection study
- 2.5 Hz AGS power supply and rf system
- Target and Horn system

AGS Upgrade (4MW)

Conclusion

AGS Upgrade to 1 MW



- 1.2 GeV superconducting linac extension for direct injection of ~ 1×10^{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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1.2 GeV Superconducting Linac

Beam energy	$0.2 \rightarrow 0.4$ GeV	$0.4 \rightarrow 0.8$ GeV	$0.8 \rightarrow 1.2$ 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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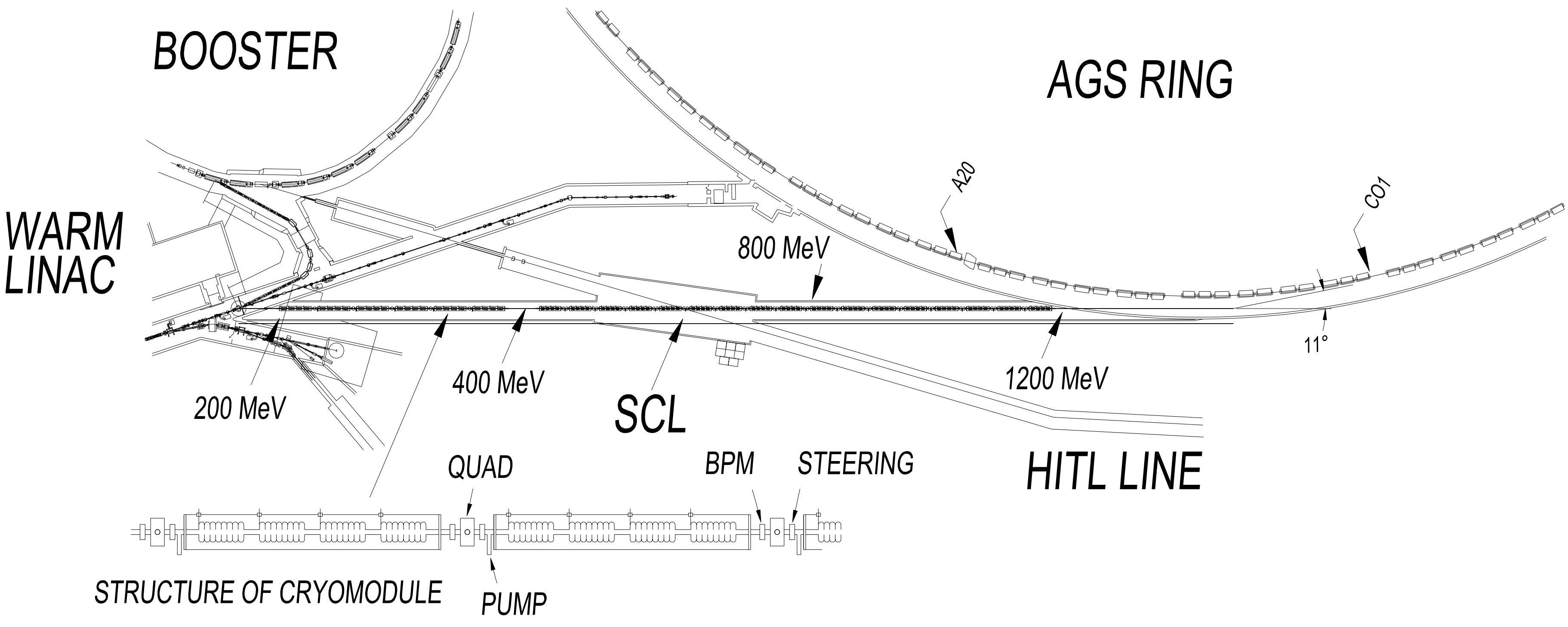
Layout of the 1.2 GeV SCL



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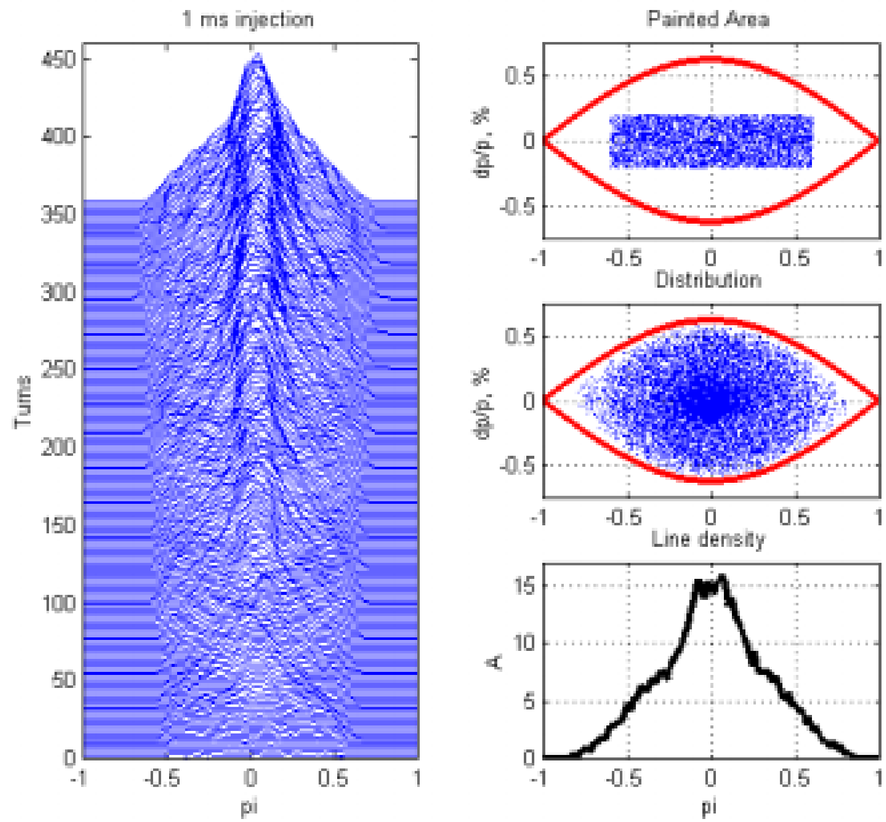
Beam Loss at H^- Injection Energy

	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
$N_P / (\beta^2\gamma^3 A)$, $10^{12} / \pi$ 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

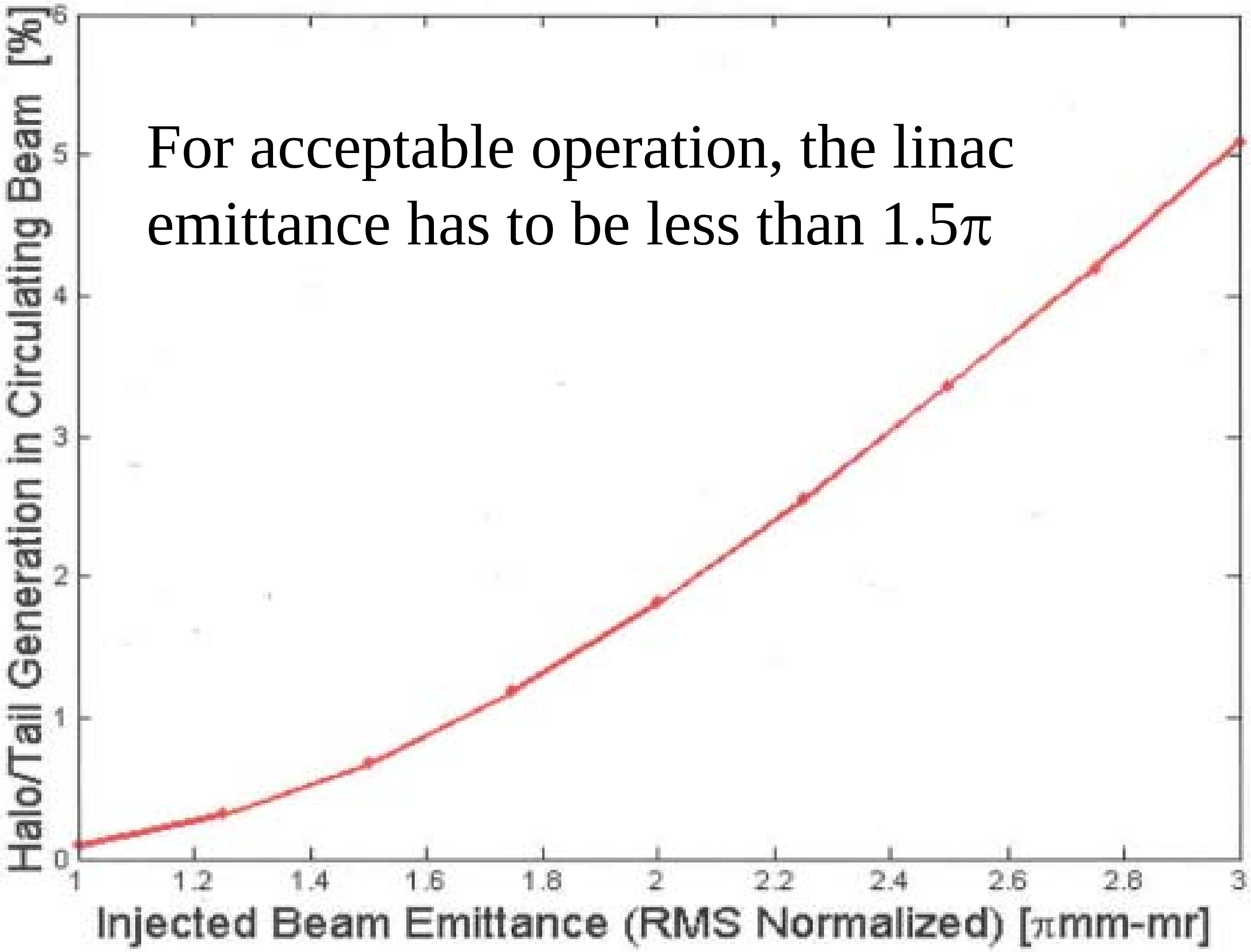
AGS Injection Simulation

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



Halo in AGS as Function of Linac Emittance



Linac Emittance Improvement

750 keV Line Upgrade Options

Emittance at source 0.4 pi mm mr (rms,nor)

Line Configuration	Transmission	RMS Emittance growth (x,y,z)	Comments
(**A**)Present (RFQ, 12 quads,3 bunchers, fast & slow chopper)	~70 %	450%, 500%, 300%	-7 meter long
(**B**)RFQ + DTL (no 750 keV line)	100 %	64%, 40%, 64%	-Requires new chopping in LEBT -0.07 long
(**C**)RFQ +3 quads +2 Bunchers	100 %	16%, 0%, 74%	-Requires new chopping in LEBT -0.5 meter
(**D**)Present, with 2 modified triplet, and splitting fast & slow choppers	98%	31%, 11 %, 222%	-5 meter long

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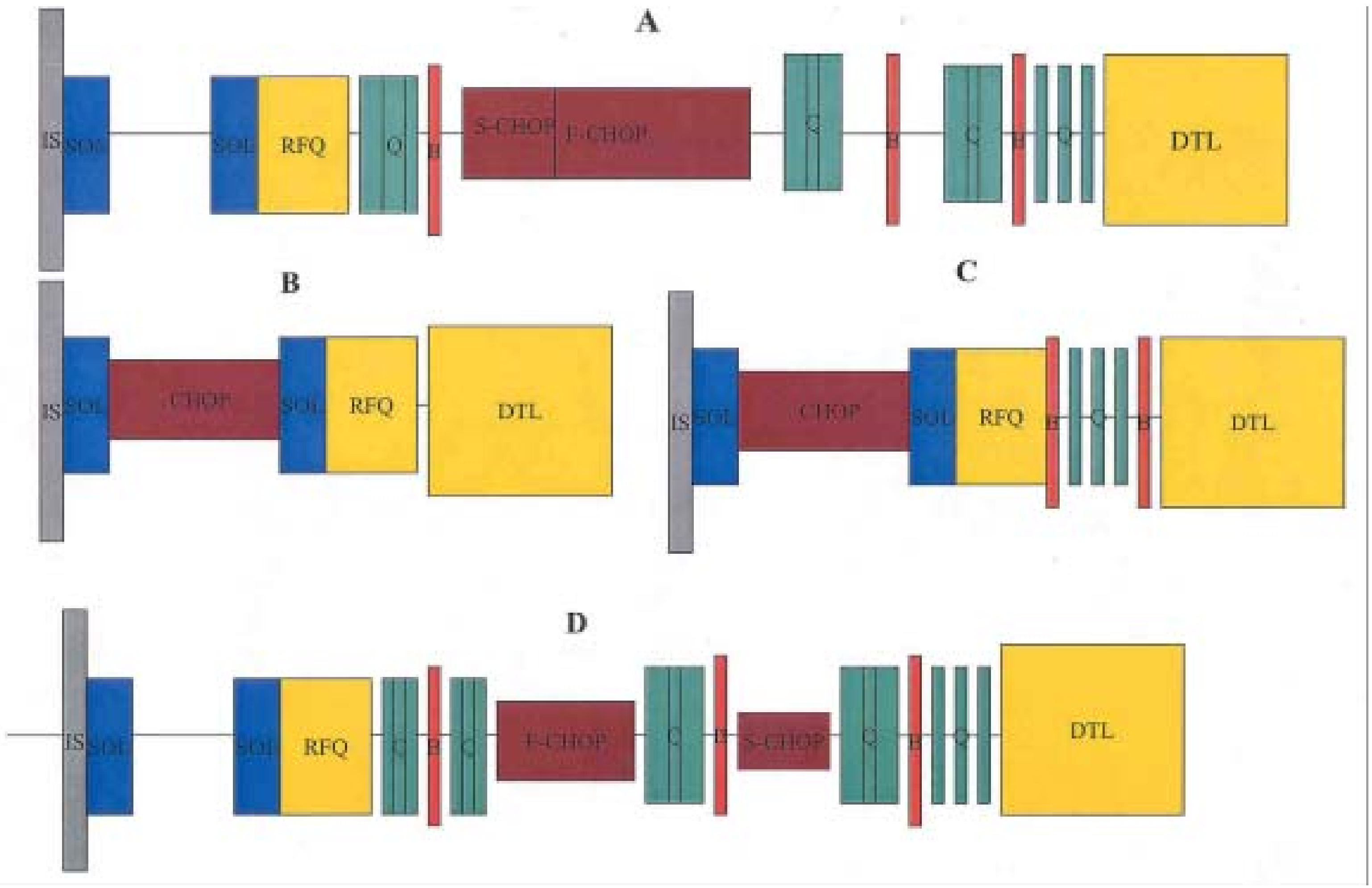
Options Layout



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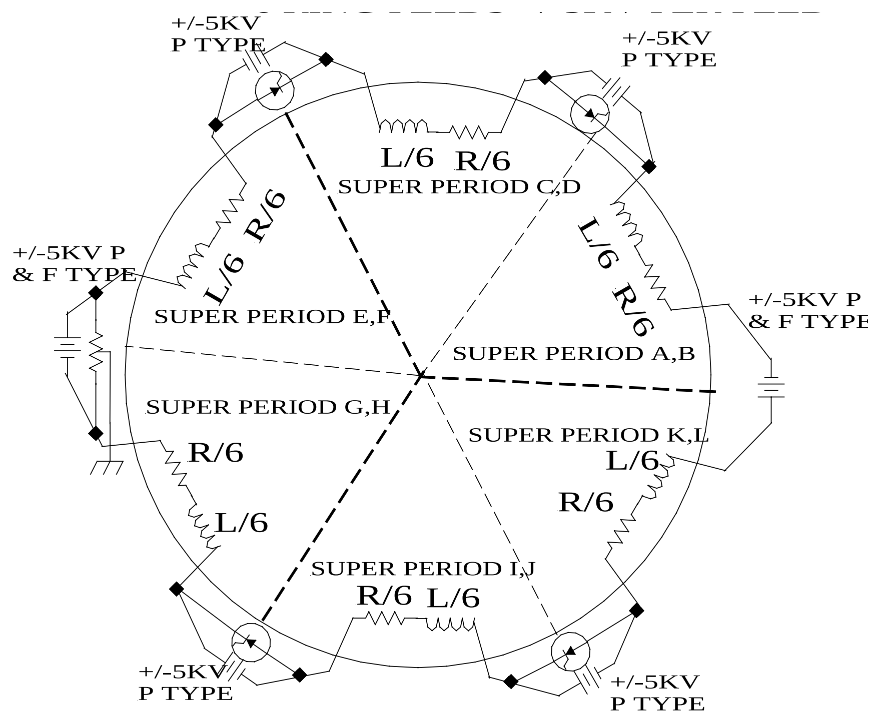
New AGS Main Magnet Power Supply

		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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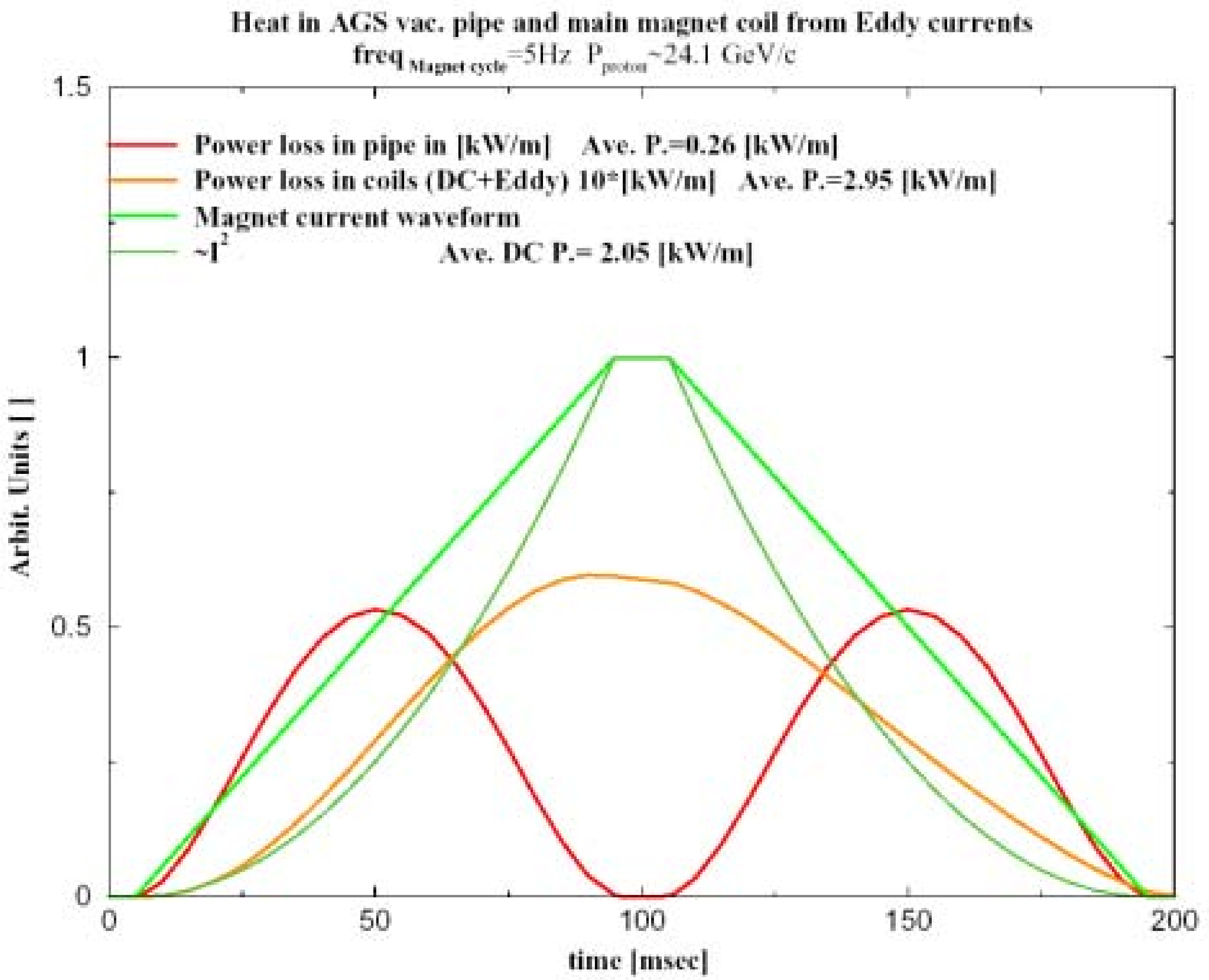
Eddy Current Losses in AGS Magnets



For 2.5 (5.0) Hz:

In pipe: 65 (260) W/m

In coil: 225 (900) W/m

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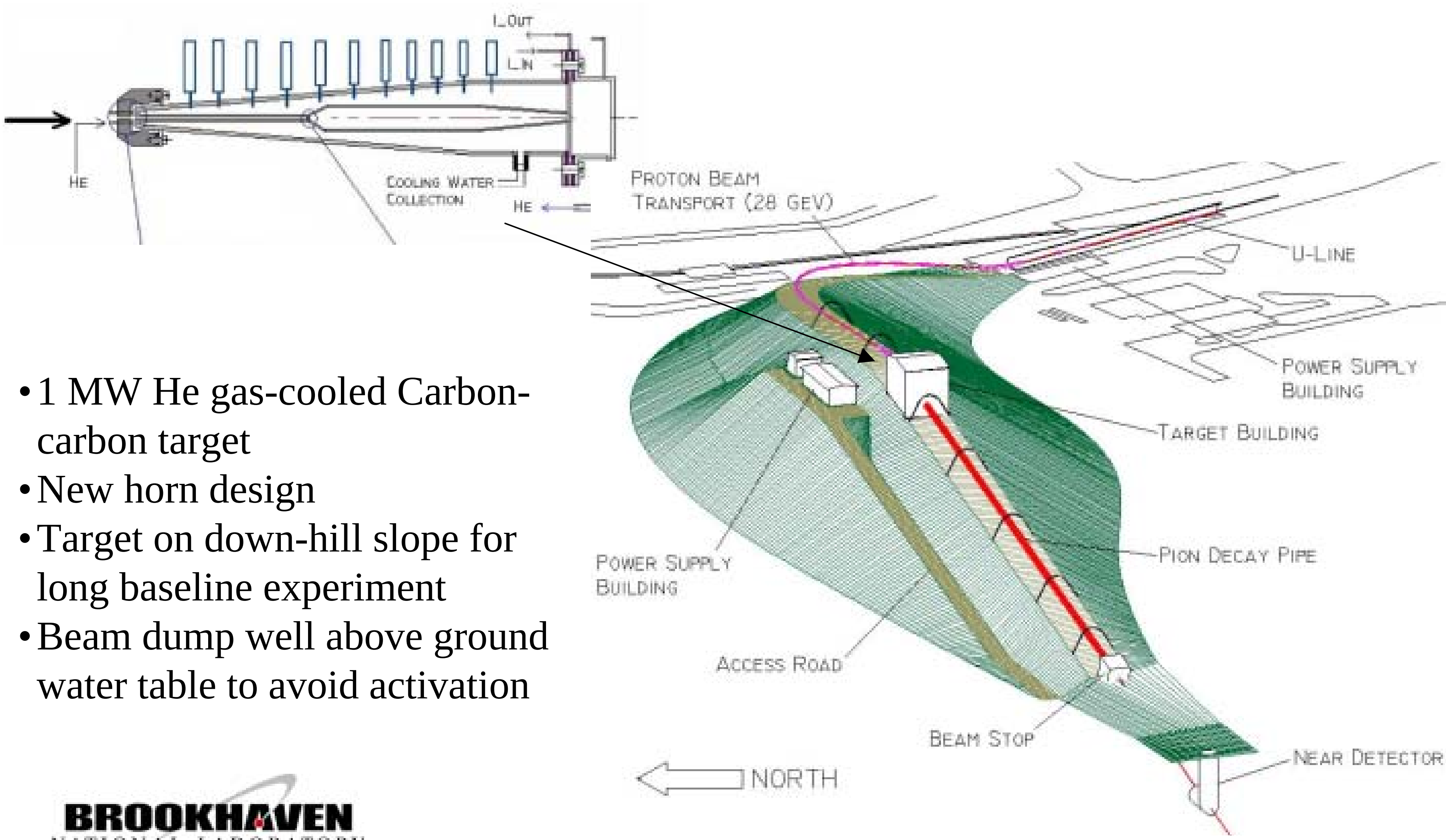
AGS RF System Upgrade

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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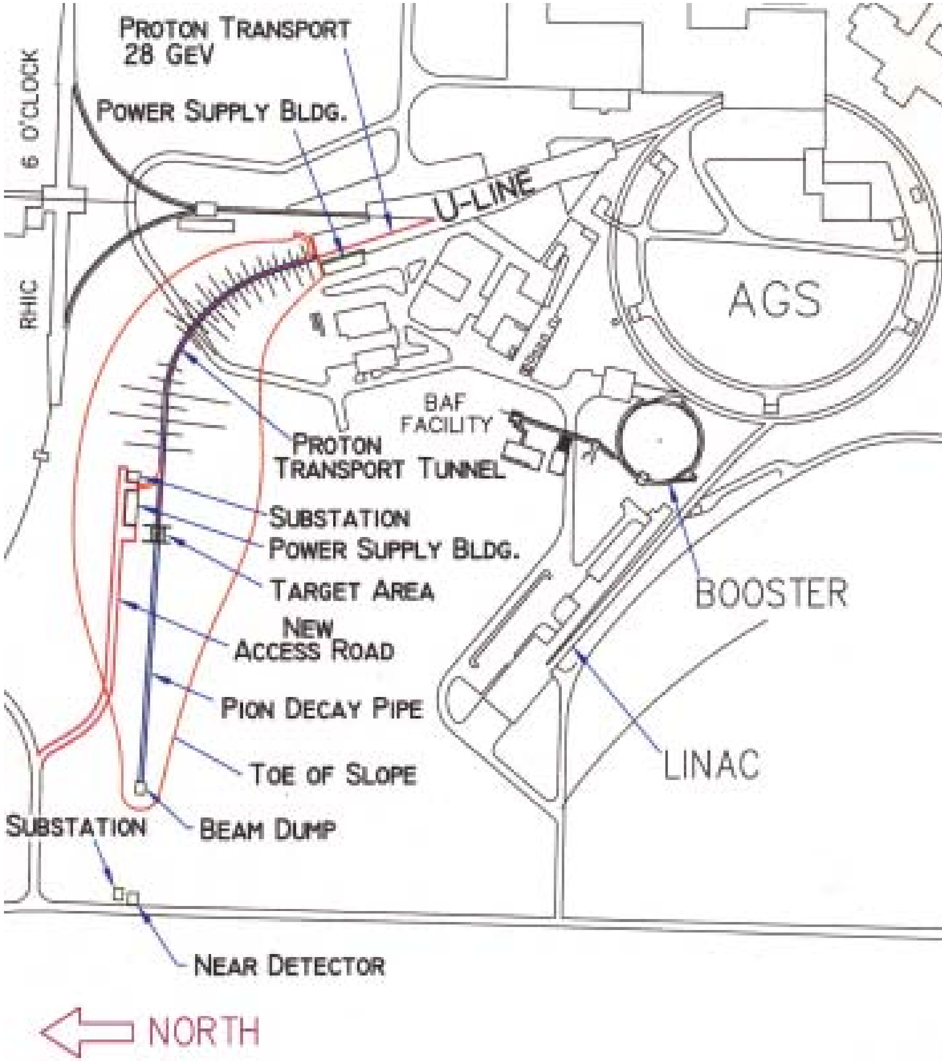
Super Neutrino Beam Geographical Layout



- BNL can provide a 1 MW capable Super Neutrino Beam for $104M FY03 (TEC) dollars
- the neutrino beam can aim at any site in the western U.S. the Homestake Mine is shown here)
- there will be no environmental issues if the beam is produced atop the hill illustrated here and the beam dumped well above the local water table
- construction of the Super Neutrino Beam is essentially de-coupled from AGS and RHIC operations

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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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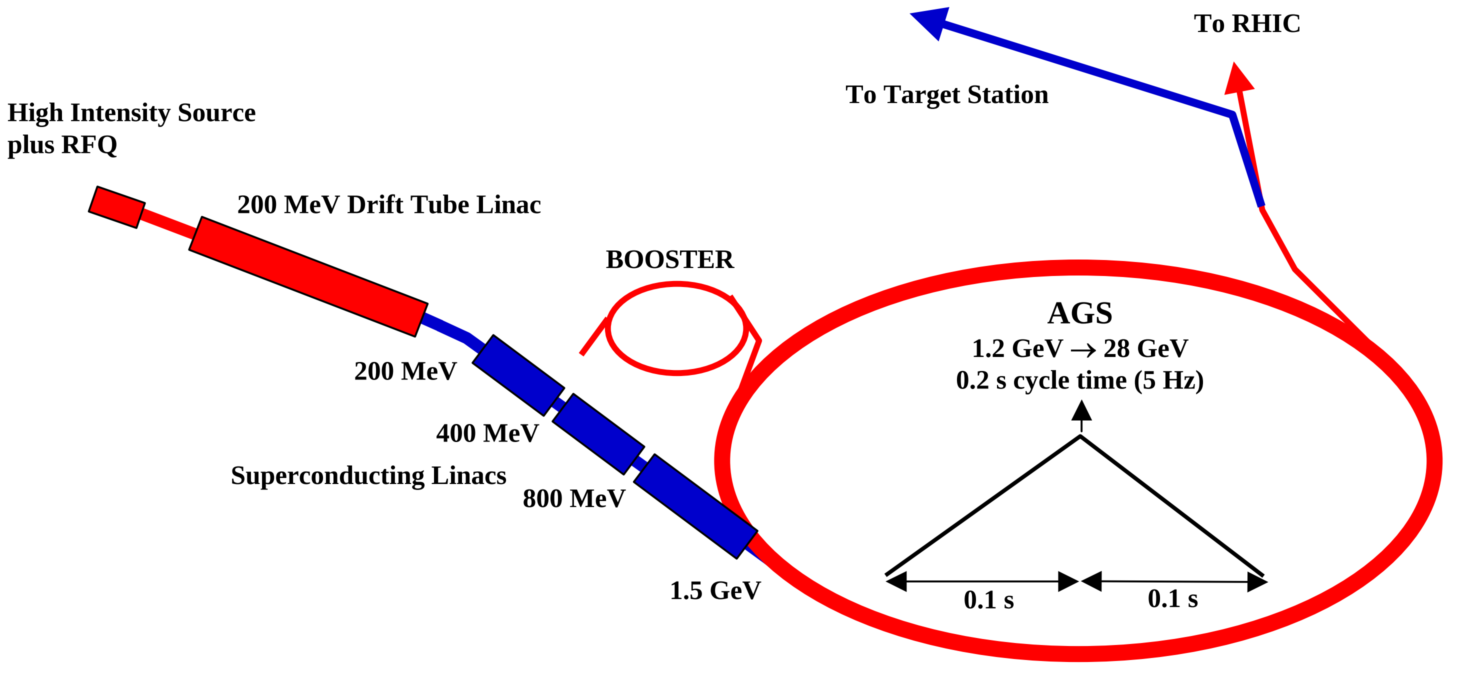
4 MW AGS Proton Driver Layout



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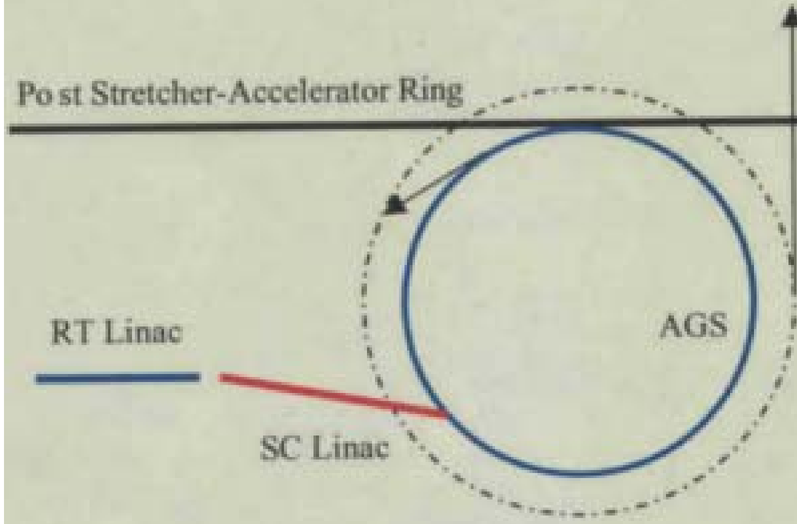
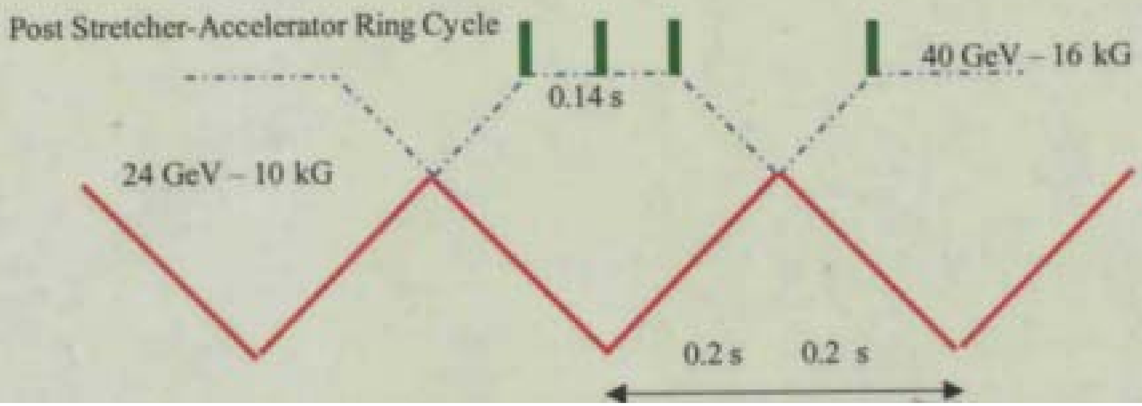
AGS after Burner



GeV	kG	MW	š mm mrad
1.2	0.75	--	48.83
24.0	9.74	0.86	3.76
28.0	11.30	1.00	3.24
35.0	14.04	1.25	2.61
40.0	15.99	1.43	2.29



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Additional Work Planned

1. Reduction of the Linac Emittance
2. Cryogenic System Design
3. LLRF Tuning and Feedback of SCL
4. Transition Crossing in the AGS
5. Beam Collimation
6. Optimization of the Target and Horn System
7. Improvement of Upgrade Path

Conclusions

1. The feasibility has been demonstrated for a 1MW upgrade for the AGS
2. It is possible to further upgrade the AGS to 4MW

Such a high power proton driver is essential for very long base line neutrino experiment and also for the neutrino factory.

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