1 MW AGS proton driver

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Parameters and layout

Beam loss considerations

1.2 GeV Superconducting Linac

2.5 Hz AGS power supply and rf system

4 MW Upgrade

Bunch compressor ring

Cost estimate

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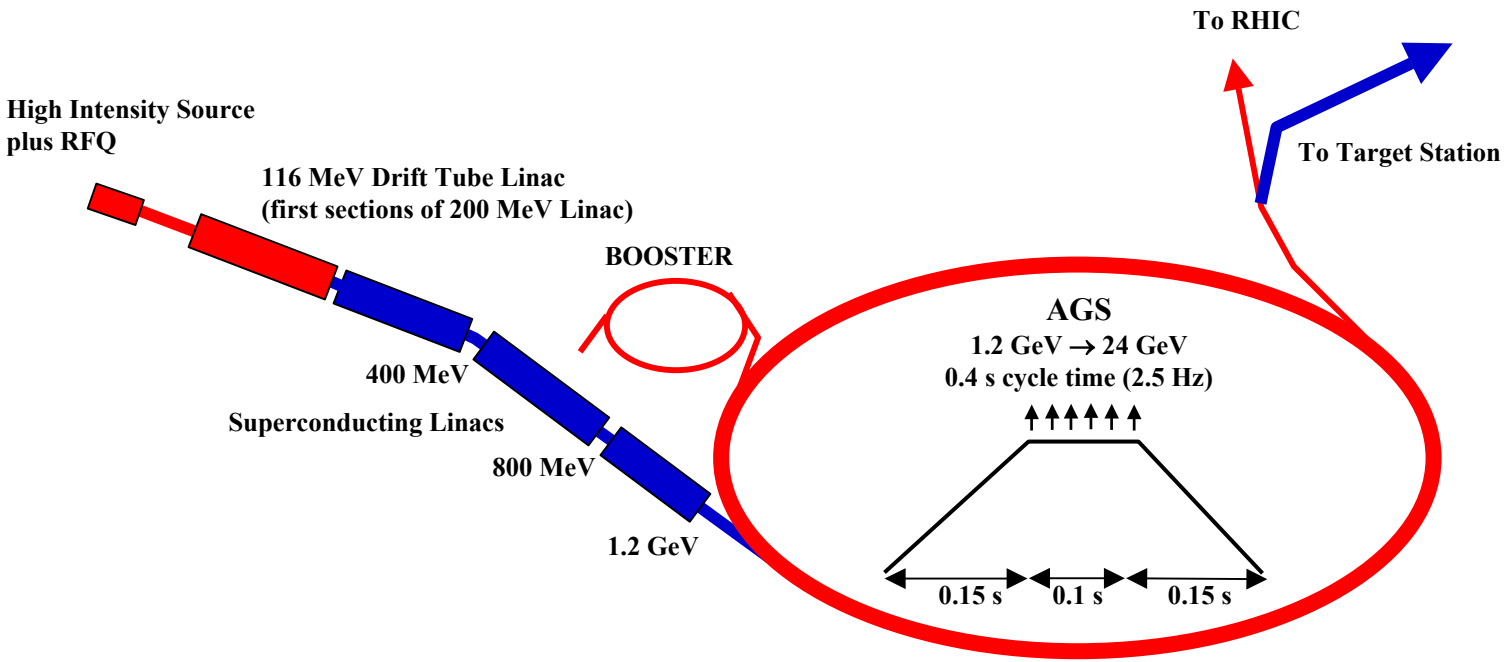
Thomas Roser
Snowmass 2001
June 30 - July 21, 2001

AGS proton driver parameters

	1 MW AGS	AGS presently
Total beam power [MW]	1	0.14
Beam energy [GeV]	24	24
Average current [μA]	42	6
Cycle time [ms]	400	2000
No. of protons per fill	1×10^{14}	$(0.6 - 0.7) \times 10^{14}$
Average circulating current [A]	5.9	4.2
No. of bunches per fill	6	6
No. of protons per bunch	1.7×10^{13}	$\sim 1 \times 10^{13}$
Time between extracted bunches [ms]	20	33
Rms bunch length [ns]	3	30
Peak bunch current [A]	400	30
Total bunch area [eVs]	5	15
Rms bunch emittance [eVs]	0.3	0.8
Rms momentum spread	0.005	0.001

AGS proton driver layout



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Beam loss at H^- injection energy

	AGS Booster	PSR	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

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Beam losses in AGS

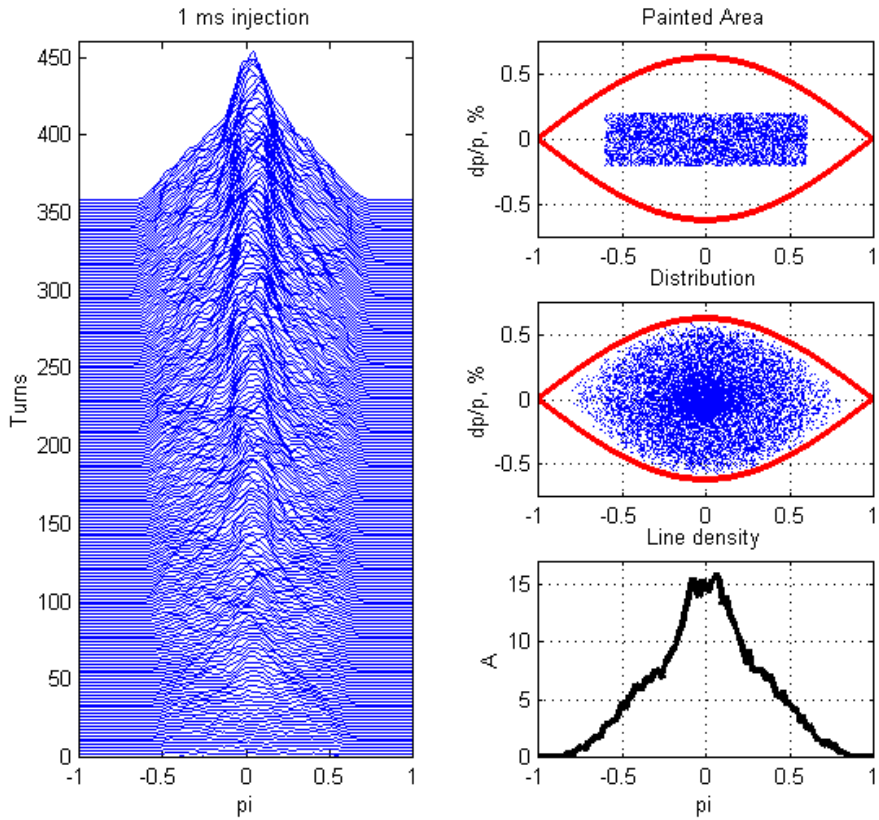
Major loss points	Present AGS		1 MW AGS	
	% particles	Beam power	% particles	Beam power
Injection and early accel.:				
Controlled			3.0 %	1.5 kW
Uncontrolled	30 %	1.9 kW	0.3 %	0.2 kW
Transition	2.0 %	0.4 kW	1.0 %	2.9 kW
Total:		2.3 kW		4.6 kW

- Injection modeled after SNS but much lower repetition rate and less foil traversals
  → Allow 30 times more beam loss
- Transition losses are presently dominated by beam momentum spread required for AGS injection stacking. Direct injection should eliminate chromatic transition losses.
- 4.6 kW should be acceptable for hand maintenance.

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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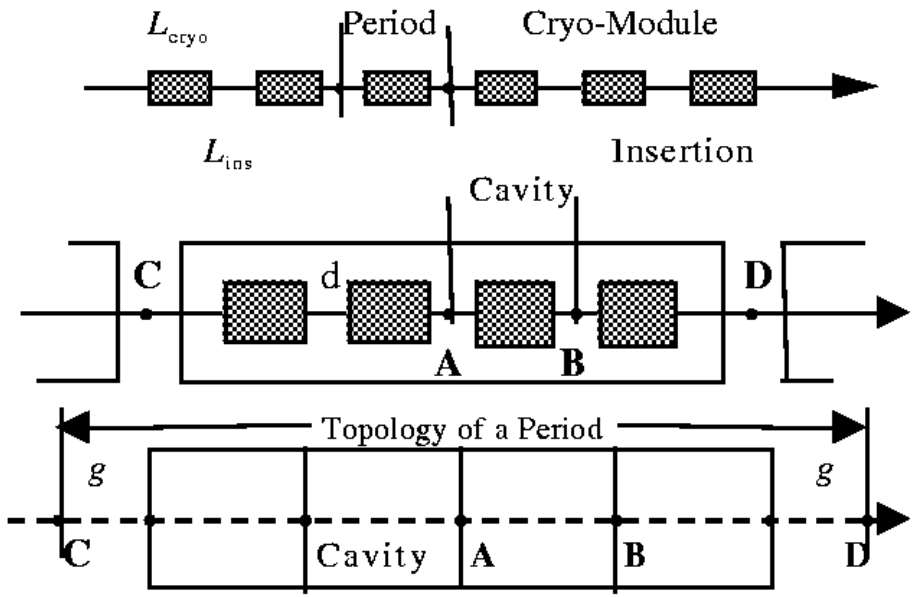
1.2 GeV Superconducting Linac

Beam energy	0.116 → 0.4 GeV	0.4 → 0.8 GeV	0.8 → 1.2 GeV
Rf frequency	805 MHz	1610 MHz	1610 MHz
Accelerating gradient	11.9 MeV/m	22.0 MeV/m	21.5 MeV/m
Length	75.4 m	43.9 m	42.6 m
Beam power, linac exit	17 kW	34 kW	50 kW



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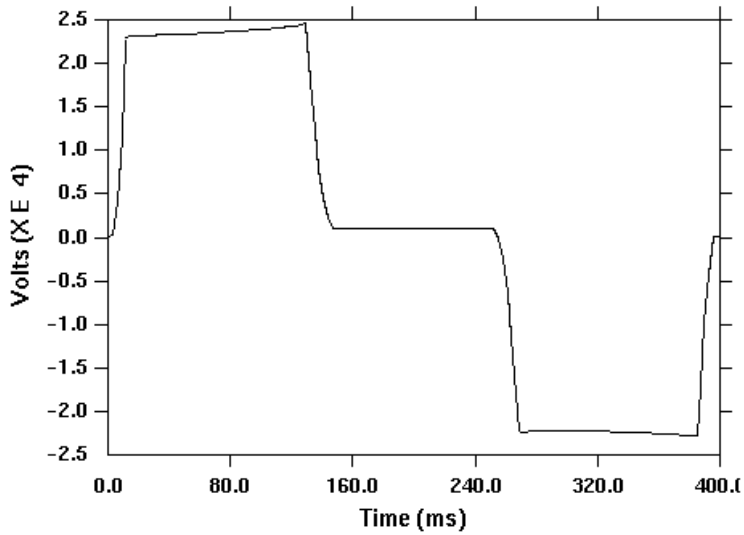
New AGS main magnet power supply

		presently:
• Repetition rate	2.5 Hz	1 Hz
• Peak power	110 MW	50 MW
• Average power	4 MW	4 MW
• Peak current	4.2 kA	5 kA
• Peak total voltage	± 25 kV	± 10 kV
• Number of power converters / feeds	6	2



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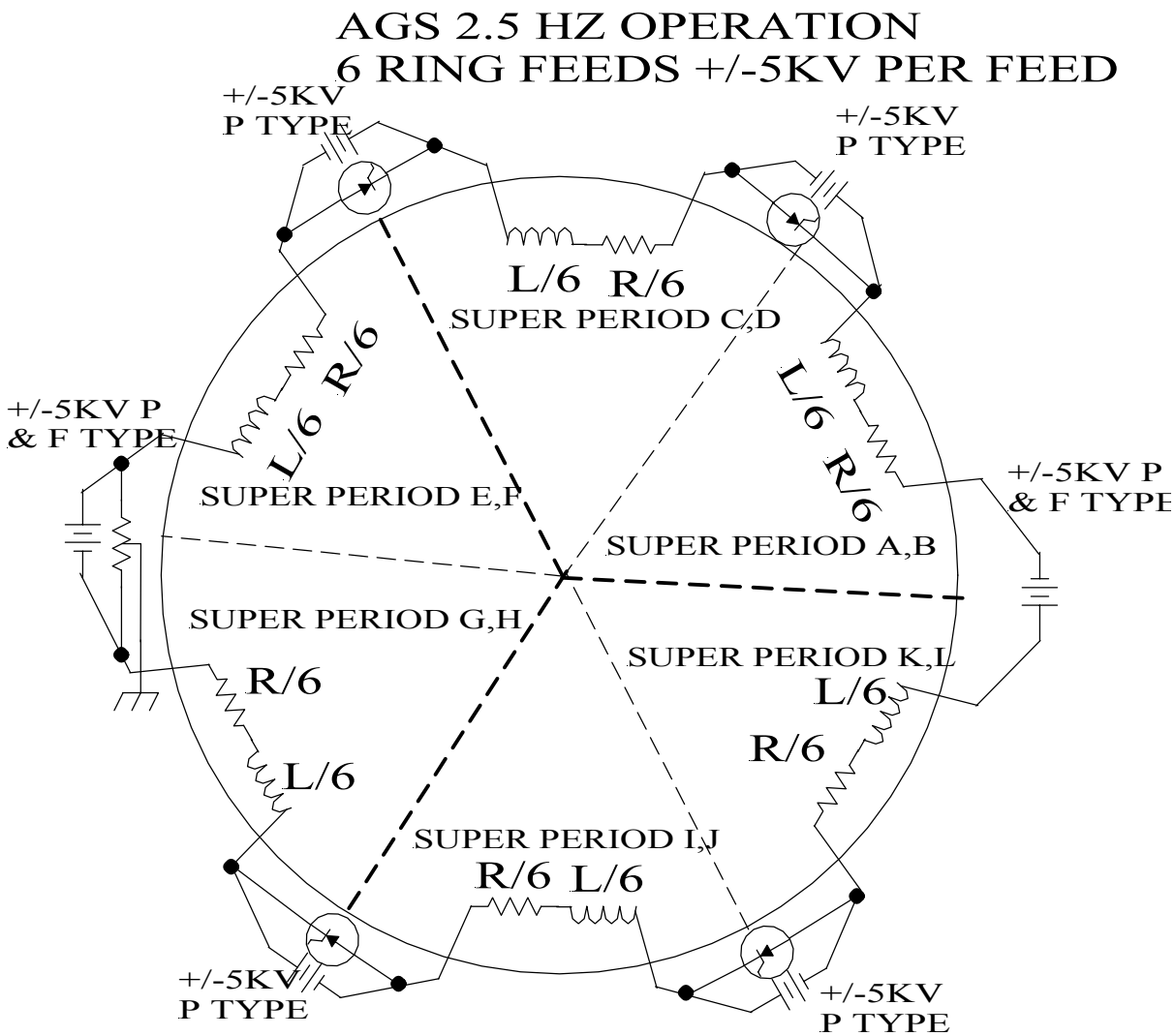
Distribution of current feeds



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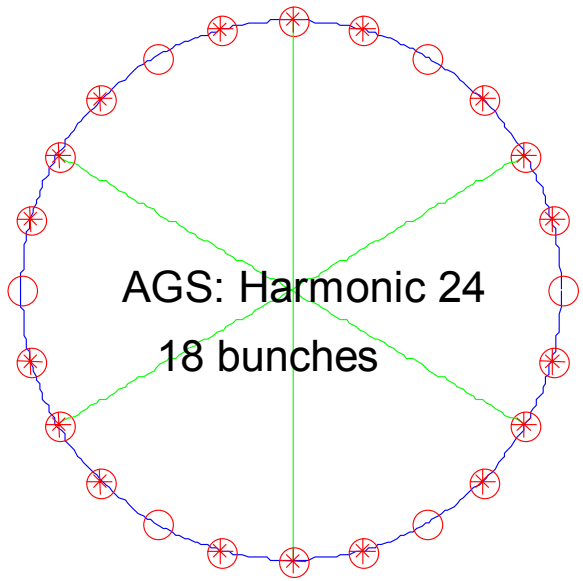
AGS rf system upgrade

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

		presently:
Rf voltage/turn	1 MV	0.4 MV
harmonic number	24	6 - 12
Rf frequency	~ 9 MHz	3 - 4.5 MHz
Rf peak power	3 MW	
Rf magnetic field	18 mT	



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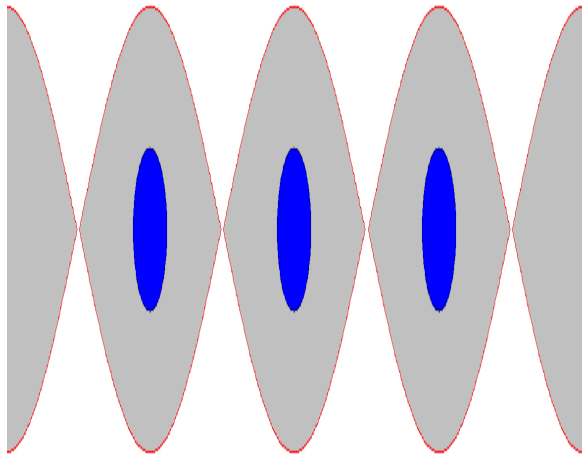
Bunch merging and compression

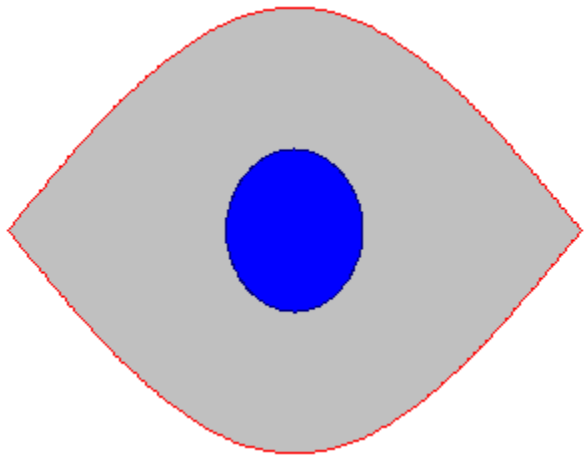
Adiabatic quad pumping:

h = 24
1.2 eVs/bunch

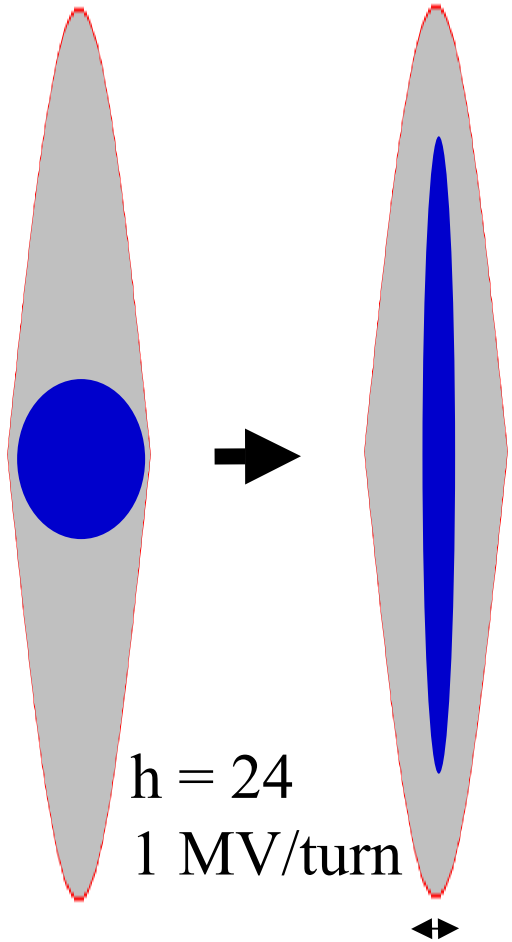


Adiabatic
merging:

h = 6
100 kV/turn
~ 5 eVs/bunch



80 ns



h = 24
1 MV/turn

15 ns (3 ns rms)

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Summary of preliminary cost estimates

1.2 GeV Superconducting Linac	$ 90.2 M
AGS power supply	$ 32.0 M
AGS rf upgrade	$ 8.6 M
AGS injection channel	$ 3.7 M
Transfer line to target	$ 6.5 M
Total	$ 141.0 M

(Direct cost, no contingency)

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Cost estimate

AGS proton driver cost estimate [M$] (direct cost, no contingency, no EDIA)

8-Apr-01

	Magnets	Rf source	Rf cavities	Vacuum	PS	Diagn.	Cryo	Utilities	Civil	**Total**	Incr. El. Power [MW]	
LE SC Linac (116 - 400 MeV)		1.0	30.0	3.1		0.5	1.0	0.5		**36.1**		0.5
ME SC Linac (400 - 800 MeV)		1.0	16.6	1.8		0.5	1.0	0.5	4.5	**25.9**		0.5
HE SC Linac (800 - 1200 MeV)		1.0	15.4	2.6		0.5	1.0	0.5	7.2	**28.2**		0.5
AGS Injection channel	1.0			1.0	1.0	0.2		0.5		**3.7**		0.5
AGS main power supply (2.5 Hz)					24.0				8.0	**32.0**		
AGS rf upgrade		4.0	4.1					0.5		**8.6**		2.5
Transfer line to target	2.0			0.5	1.0	0.5		0.5	2.0	**6.5**		1.0
Phase 1 total	**3.0**	**7.0**	**66.1**	**9.0**	**26.0**	**2.2**	**3.0**	**3.0**	**21.7**	**141.0**		**5.5**
4 MW upgrade:												
Bunch compression ring	20.0	2.0	2.0	4.0	2.0	3.0	2.0	1.0	8.0	**44.0**		1.0
HE Linac extension to 1.5 GeV			12.0							**12.0**		
AGS main power supply (5 Hz)					13.0					**13.0**		
AGS rf upgrade		5.0	5.0					7.5		**17.5**		7.5
Phase 2 total	**20.0**	**7.0**	**19.0**	**4.0**	**15.0**	**3.0**	**2.0**	**8.5**	**8.0**	**86.5**		**8.5**
Total	**23.0**	**14.0**	**85.1**	**13.0**	**41.0**	**5.2**	**5.0**	**11.5**	**29.7**	**227.5**	**0.0**	**14.0**

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Towards 4 MW

	Upgrade I	Upgrade II	Upgrade III
Linac intensity/pulse	1.2×10^{14}	2.4×10^{14}	2.4×10^{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	1.0×10^{14}	2.0×10^{14}	2.0×10^{14}
AGS rep. rate	2.5 Hz	2.5 Hz	5.0 Hz*
Rf peak power	3 MW	6 MW	8 MW
Rf gap volts/turn	1 MV	1 MV	1.5 MV
AGS extraction energy	24 GeV	24 GeV	24 GeV
Beam power	1 MW	2 MW	4 MW
Bunch area	5 eVs	10 eVs	10 eVs
Compressor ring	no	yes	yes

* Symmetric cycle (0.1 s up, 0.1 s down) without flattop.

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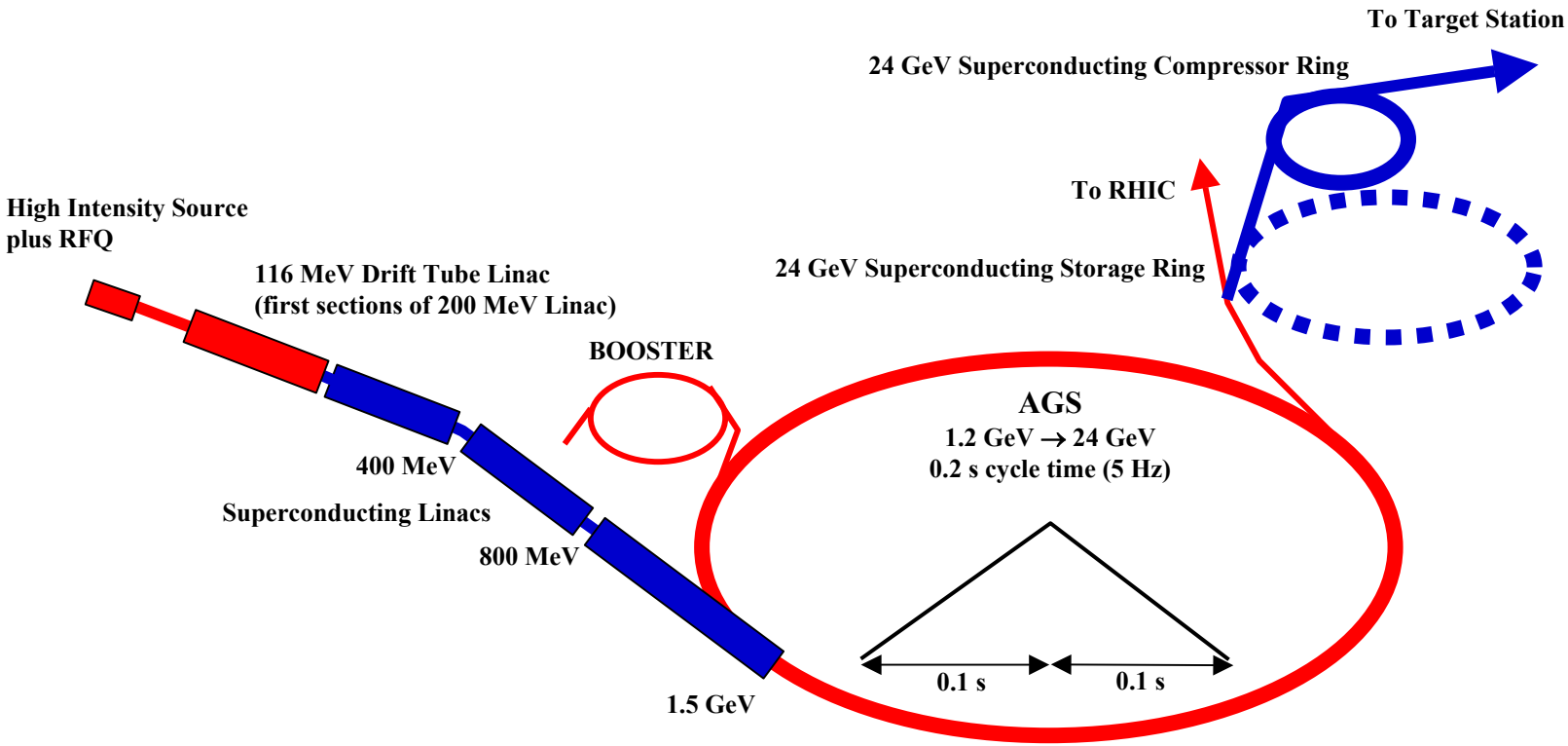
4 MW AGS proton driver layout



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Compressor ring

Small superconducting ring to compress a single 24 GeV, 10 eVs bunch to 3 ns rms length. Small size reduces space charge tune shift and gap volt requirements.

- Circumference 200 m
- Energy 24 GeV
- Dipole field ~ 4 Tesla
- Packing factor 60 %
- Transition gamma ~ 40 ($d\gamma_T/d\gamma < 4$)
- Momentum acceptance ± 5 % (FFAG type lattice?)
- Rf frequency 6 MHz (h = 4)
- Rf Voltage per turn 200 kV
- Bunch length compression (rms) 20 ns → 3 ns

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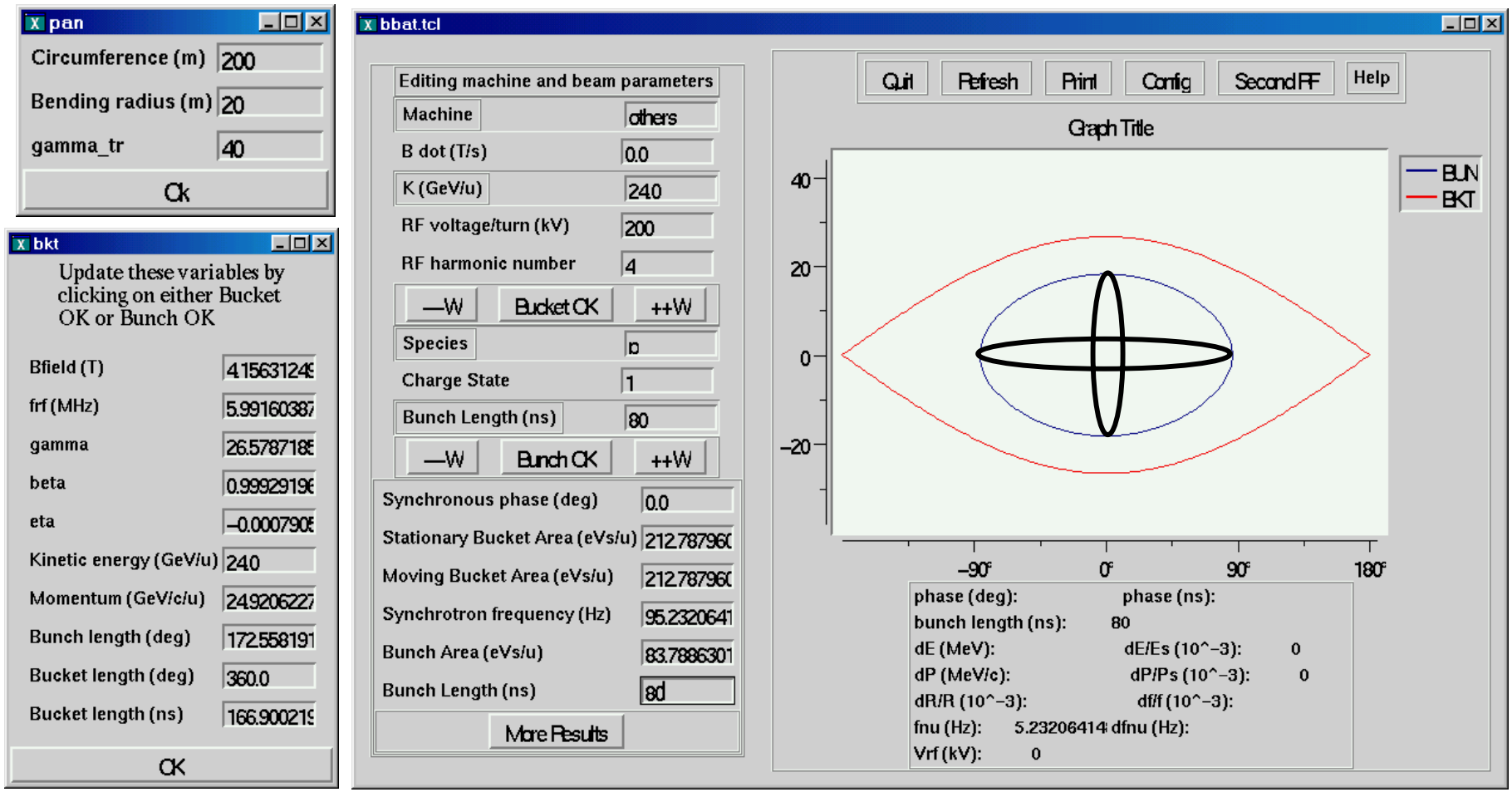
Bunch compression



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