

WBS	Parameter	Base Value	Unit	Comment
1. 0.	SPALLATION NEUTRON SOURCE			
1. 0.	Proton beam power on target	1.44	MW	
1. 0.	Proton beam kinetic energy on target	1.0	GeV	
1. 0.	Average beam current on target	1.44	mA	
1. 0.	Maximum pulse rate	60	Hz	
1. 0.	Protons per pulse on target	1.5x10 ¹⁴	protons	
1. 0.	Charge per pulse on target	24	μC	
1. 0.	Energy per pulse on target	24	kJ	
1. 0.	Average macropulse H- current	26	mA	From RFQ to injection foil
1. 0.	Linac beam macro pulse duty factor	6	%	
1. 0.	Ring filling time	1.0	ms	
1. 0.	Ring revolution frequency	1.058	MHz	
1. 0.	Ring filling fraction	68	%	
1. 0.	Ring extraction pulse length	695	ns	
1. 0.	Ring extraction beam gap	250	ns	
1. 0.	Maximum uncontrolled beam loss	1	W/m	
1. 0.	Target material	Hg		
1. 0.	Number of ambient / cold moderators	1/3		
1. 0.	Number of neutron beam shutters	18		
1. 0.	Initial number of instruments	5		
1. 3.	FRONT END			
1. 3.	Ion type	H minus		
1. 3.	Output energy	2.5	MeV	RFQ output
1. 3.	Length	7.49	m	From IS outlet flange to DTL
1. 3.	Beam-floor distance	1.270	m	50.0 in
1. 3.	Output peak current	38.2	mA	
1. 3.	1. ION SOURCE AND LEBT			
1. 3.	1. Output energy	65	keV	
1. 3.	1. LEBT length	0.12	m	
1. 3.	1. Output peak current	47.8	mA	Assuming 80% front end transmission
1. 3.	1. Ion source type	RF volume		Multicusp Cs-enhanced

1. 3. 1. Electron suppression	magnetic	Interception at low energy
1. 3. 1. LEBT focusing configuration	2 einzel lenses	
1. 3. 1. Estimated output rms norm H & V emittance	0.20 π mm-mrad	
1. 3. 1. Ion source lifetime	3 weeks	Maintenance cycle
1. 3. 1. Ion source replacement time	2 hours	With conditioned replacement ion source
1. 3. 2. RFQ ACCELERATOR		
1. 3. 2. Output energy	2.5 MeV	
1. 3. 2. Length	3.76 m	4 modules, incl. LEBT diagnostic plate
1. 3. 2. Output peak current	38.2 mA	
1. 3. 2. RF frequency	402.5 MHz	
1. 3. 2. Nominal aperture radius	3.51 mm	
1. 3. 2. Rms surface field during macropulse	1.85 Kilpatrick	
1. 3. 2. Rms macropulse structure power	630 kW	Assumes 67% of Cu Q
1. 3. 2. Number of 2.5 MW peak power klystrons	1	0.9 MW required for RFQ
1. 3. 2. Expected output rms norm H & V emittance	0.21 π mm-mrad	
1. 3. 2. Expected output rms L emittance	0.10 π MeV-deg	At 402.5 MHz
1. 3. 3. MEBT		
1. 3. 3. Output energy	2.5 MeV	
1. 3. 3. Length	3.64 m	
1. 3. 3. Output peak current	38.2 mA	
1. 3. 3. Number of quadrupoles	14	
1. 3. 3. Quads 1-4 and 11-14 clear bore dia	30 mm	
1. 3. 3. Quads 5 - 10 clear bore dia	40 mm	
1. 3. 3. Maximum integrated quad gradient	2.14/2.31 T	Narrow/wide bore
1. 3. 3. Number of two-plane beam steerers	6	Quad poletip windings
1. 3. 3. Number of rebuncher cavities	4	
1. 3. 3. Rebuncher cavity frequency	402.5 MHz	
1. 3. 3. Maximum rebuncher peak voltage integral	120 kV	
1. 3. 3. Expected output rms norm H & V emittance with errors	0.27 π mm-mrad	
1. 3. 3. Expected output rms L emittance with errors	0.13 π MeV-deg	At 402.5 MHz
1. 3. 3. Expected max rebuncher cavity rms rms field error	2 %	
1. 3. 3. Expected max rebuncher cavity rms rms phase error	1 deg	
1. 3. 3. Expected max quad rms gradient error	<1 %	
1. 3. 3. Expected max quad rms position error on sub-raft	0.025 mm	
1. 3. 3. Expected max sub-raft rms position error on major	0.04 mm	

1. 3. 3. Expected max quad rms roll error	0.06 mrad	
1. 3. 3. Expected max quad rms yaw error	0.06 mrad	
1. 3. 3. Expected max quad rms pitch error	0.6 mrad	
1. 4. 5. MEBT TRAVELING WAVE CHOPPERS		
1. 4. 5. Number of choppers	2	Chopper and antichopper
1. 4. 5. Chopper length	0.35 m	Each active structure
1. 4. 5. Full rise/fall time	10 ns	
1. 4. 5. Beam-on duty factor	68 %	
1. 4. 5. Gap	18 mm	
1. 4. 5. Total deflection voltage	+/- 2350 V	18 mrad deflection
1. 4. 5. Post chopper off/on beam-current ratio	1.0E-4	
1. 3. 3. MEBT DIAGNOSTICS		
1. 3. 3. Number of beam current toroids	2	
1. 3. 3. Number of profile monitors	5	Includes one dual-plane laser wire
1. 3. 3. Number of two-plane stripline BPMs	6	Inside quads, include phase measurement
1. 3. 3. Number of emittance scanners	1	
1. 4. LINAC		
1. 4. Ion type	H minus	
1. 4. Output energy	1000 MeV	
1. 4. Length	251.624 m	Linac length excludes space for 9 more high-beta cryomodules
1. 4. Beam-floor distance	1.270 m	50.0 in
1. 4. Peak macropulse current	38.2 mA	
1. 4. Average macropulse current	26 mA	For $P_{\text{klystron}} = 550 \text{ kW}$
1. 4. Average beam current	1.56 mA	
1. 4. Average output beam power	1.56 MW	Expected value for linac
1. 4. RF duty factor	7.2 %	HV gate duty factor
1. 4. Expected output H & V rms norm emittance w/ errors and wo/ jitter	0.41 $\pi\text{mm-mrad}$	
1. 4. Expected output transverse centroid jitter	+/- 0.25 mm	
1. 4. Expected output H & V rms norm emittance w/ errors and w/ jitter	0.45 $\pi\text{mm-mrad}$	

1. 4.	Expected output L rms emittance w/ errors	0.6 π MeV-deg	At 805 MHz
1. 4.	Expected output rms energy spread	0.33 MeV	
1. 4.	Maximum output energy jitter	+/- 1.5 MeV	99.99%
1. 4.	Maximum phase centroid jitter	+/- 3.7 deg	At 805 MHz; 99.99%
1. 4.	Beam halo outside 5 sigma transverse	< 1x10 ⁻⁴	
1. 4.	Beam residual inside chopper gap	< 1x10 ⁻⁴	
1. 4.	Expected max quad gradient rms	0.14 %	Limit +/- 0.25 %
1. 4.	Expected max quad transverse displacement rms	0.07 mm	Limit +/- 0.13 mm
1. 4.	Expected max quad roll rms	3 mrad	Limit +/- 5 mrad
1. 4.	Expected max quad tilt rms	6 mrad	Limit +/- 10 mrad
1. 4. 2. DTL ACCELERATOR			
1. 4. 2.	Output energy	86.8 MeV	
1. 4. 2.	Length	36.569 m	Tank 1 entry plane to tank 6 exit plane
1. 4. 2.	RF frequency	402.5 MHz	
1. 4. 2.	Average synchronous phase	-37 to -26	Phase ramped
1. 4. 2.	Number of tanks	6	
1. 4. 2.	Maximum field	1.3 Kilpatrick	At tank 1
1. 4. 2.	Bore radius	12.5 mm	
1. 4. 2.	Focusing structure	FFODO	
1. 4. 2.	Focusing period	6 beta-lambda	
1. 4. 2.	Number of quads	145	
1. 4. 2.	Quadrupole type	permanent mag	
1. 4. 2.	Integrated quad gradient	1.295 T	
1. 4. 2.	Quad location	inside DTs	
1. 4. 2.	Number of steering dipoles	24	
1. 4. 2.	Average operating vacuum pressure	1.8E-07 Torr	
1. 4. 2.	Tank 1 length	4.152 m	Between inside end walls
1. 4. 2.	Tank 1 number of cells	60	
1. 4. 2.	Tank 1 number of post couplers	19	
1. 4. 2.	Tank 1 energy gain	5.023 MeV	
1. 4. 2.	Tank 1 stored energy	4.81 J	
1. 4. 2.	Tank 1 average $E_0 T$	1.393 MV/m	
1. 4. 2.	Tank 1 shunt impedance ZT^2	27.56 M Ω /m	
1. 4. 2.	Tank 1 unloaded Q	35,887	
1. 4. 2.	Tank 1 external Q	23,803	
1. 4. 2.	Tank 2 length	6.063 m	Between inside end walls

1. 4. 2. Tank 2 number of cells	48	
1. 4. 2. Tank 2 number of post couplers	23	
1. 4. 2. Tank 2 energy gain	15.362 MeV	
1. 4. 2. Tank 2 stored energy	16.77 J	
1. 4. 2. Tank 2 average $E_0 T$	2.779 MV/m	
1. 4. 2. Tank 2 shunt impedance ZT^2	45.03 MΩ/m	
1. 4. 2. Tank 2 unloaded Q	39,919	
1. 4. 2. Tank 2 external Q	26,646	
1. 4. 2. Tank 3 length	6.324 m	Between inside end walls
1. 4. 2. Tank 3 number of cells	34	
1. 4. 2. Tank 3 number of post couplers	16	
1. 4. 2. Tank 3 energy gain	16.88 MeV	
1. 4. 2. Tank 3 stored energy	21.84 J	
1. 4. 2. Tank 3 average $E_0 T$	2.969 MV/m	
1. 4. 2. Tank 3 shunt impedance ZT^2	42.48 MΩ/m	
1. 4. 2. Tank 3 unloaded Q	42,212	
1. 4. 2. Tank 3 external Q	29,204	
1. 4. 2. Tank 4 length	6.411 m	Between inside end walls
1. 4. 2. Tank 4 number of cells	28	
1. 4. 2. Tank 4 number of post couplers	27	
1. 4. 2. Tank 4 energy gain	16.77 MeV	
1. 4. 2. Tank 4 stored energy	21.23 J	
1. 4. 2. Tank 4 average $E_0 T$	2.914 MV/m	
1. 4. 2. Tank 4 shunt impedance ZT^2	42.49 MΩ/m	
1. 4. 2. Tank 4 unloaded Q	42,472	
1. 4. 2. Tank 4 external Q	29,222	
1. 4. 2. Tank 5 length	6.294 m	Between inside end walls
1. 4. 2. Tank 5 number of cells	24	
1. 4. 2. Tank 5 number of post couplers	23	
1. 4. 2. Tank 5 energy gain	15.984 MeV	
1. 4. 2. Tank 5 stored energy	22.05 J	
1. 4. 2. Tank 5 average $E_0 T$	2.836 MV/m	
1. 4. 2. Tank 5 shunt impedance ZT^2	38.56 MΩ/m	
1. 4. 2. Tank 5 unloaded Q	42,526	
1. 4. 2. Tank 5 external Q	29,338	
1. 4. 2. Tank 6 length	6.341 M	Between inside end walls

1. 4. 2. Tank 6 number of cells	22
1. 4. 2. Tank 6 number of post couplers	21
1. 4. 2. Tank 6 energy gain	14.307 MeV
1. 4. 2. Tank 6 stored energy	21.47 J
1. 4. 2. Tank 6 average E_0	2.705 MV/m
1. 4. 2. Tank 6 shunt impedance ZT^2	37.71 MΩ/m
1. 4. 2. Tank 6 unloaded Q	42,412
1. 4. 2. Tank 6 external Q	30,728

1. 4. 5. DTL DIAGNOSTICS

1. 4. 5. Number of beam position and phase monitors 12

1. 4. 5. Number of beam loss monitors 12

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1. 4. 4. Module 1 synchronous phase	-30 deg	
1. 4. 4. Module 1 stored energy	6.63 J	
1. 4. 4. Module 1 average $E_0 T$	1.983 MV/m	Average over module length
1. 4. 4. Module 1 shunt impedance ZT^2	21.89 MU/m	Average over module length
1. 4. 4. Module 1 unloaded Q	16,310	
1. 4. 4. Module 1 external Q	12,309	
1. 4. 4. Module 2 length	12.946 m	Physics length
1. 4. 4. Module 2 cell-to-cell coupling	5.1 %	
1. 4. 4. Module 2 energy gain	23.979 MeV	
1. 4. 4. Module 2 synchronous phase	-30 deg	
1. 4. 4. Module 2 stored energy	8.23 J	
1. 4. 4. Module 2 average $E_0 T$	2.139 MV/m	Average over module length
1. 4. 4. Module 2 shunt impedance ZT^2	24.02 MU/m	Average over module length
1. 4. 4. Module 2 unloaded Q	17,418	
1. 4. 4. Module 2 external Q	13,089	
1. 4. 4. Module 3 length	14.001 m	Physics length
1. 4. 4. Module 3 cell-to-cell coupling	4.8 %	
1. 4. 4. Module 3 energy gain	26.074 MeV	
1. 4. 4. Module 3 average synchronous phase	-29.5 deg	Phase ramped
1. 4. 4. Module 3 stored energy	8.83 J	
1. 4. 4. Module 3 average $E_0 T$	2.14 MV/m	Average over module length
1. 4. 4. Module 3 shunt impedance ZT^2	25.71 MU/m	Average over module length
1. 4. 4. Module 3 unloaded Q	18,432	
1. 4. 4. Module 3 external Q	13,597	
1. 4. 4. Module 4 length	14.995 m	Physics length
1. 4. 4. Module 4 cell-to-cell coupling	4.56 %	
1. 4. 4. Module 4 energy gain	28.412 MeV	
1. 4. 4. Module 4 average synchronous phase	-28 deg	Phase ramped
1. 4. 4. Module 4 stored energy	9.41 J	
1. 4. 4. Module 4 average $E_0 T$	2.143 MV/m	Average over module length
1. 4. 4. Module 4 shunt impedance ZT^2	27.29 MU/m	Average over module length
1. 4. 4. Module 4 unloaded Q	19,311	
1. 4. 4. Module 4 external Q	13,975	
1. 4. 4. Rms tolerance for distance between end gaps of segs	0.15 mm	Limit +/- 0.25 mm
1. 4. 4. Rms tolerance between adjacent gaps in a segment	0.03 mm	Limit +/- 0.05 mm
1. 4. 4. Rms tolerance of seg. end transverse displacement	0.3 mm	Limit +/- 0.5 mm

1. 4. 5. CCL DIAGNOSTICS			
1. 4. 5. Number of beam position and phase monitors	16		
1. 4. 5. Number of beam loss monitors	24		
1. 4. 5. Number of current monitors	2		
1. 4. 5. Number of wire scanners	8		
1. 4. 5. Number of Faraday cups	1		
1. 4. SUPERCONDUCTING RF LINAC			
1. 4. Output energy	1000 MeV		
1. 4. Length	157.321 m	23 cryomodules + 22 warm spaces	
1. 4. RF frequency	805 MHz		
1. 4. Transition energy between sections	387 MeV	Design value	
1. 4. Focusing structure	Doublet	warm quads between cryos outside vacuum	
1. 4. Number of quad doublets	32	Includes doublets for unoccupied space	
1. 4. Number of quads with H&V dipole windings	64	32 Powered	
1. 4. Quad type	EM		
1. 4. Peak med beta cavity surface field	27.5 MV/ m	Uncertainty is +/- 2.5 MV/m	
1. 4. Peak high beta cavity surface field	35.0 MV/ m	Uncertainty is +2.5 / -7.5MV/m	
1. 4. Medium beta cavity geometrical beta	0.61		
1. 4. High beta cavity geometrical beta	0.81		
1. 4. Number of med beta cryomodules	11		
1. 4. Number of high beta cryomodules	12		
1. 4. Warm space between cryomodule valves	1.6 m	Between gate valves	
1. 4. Period length med beta	5.839 m		
1. 4. Period length high beta	7.891 m		
1. 4. Length of 186 MeV differential pumping section	2.35 m	CCL to SRF distance	
1. 4. Length for nine additional high beta cryomodules	71.019 m		
1. 4. Warm beam pipe vacuum	1.E-09 Torr		
1. 4. SRF LINAC CAVITIES			
1. 4. Cavity type	elliptical		
1. 4. Cavity operating mode	pi		
1. 4. Cavity material	Niobium		
1. 4. Cavity material thickness	4 mm	3.8 mm after processing	
1. 4. Cavity operating temperature	2.1 K		

1. 4.	Number of cells per cavity	6	
1. 4.	Cavities per cryomodule med beta	3	
1. 4.	Cavities per cryomodule high beta	4	
1. 4.	Med beta coupling constant	1.61 %	
1. 4.	High beta coupling constant	1.61 %	
1. 4.	Q ₀ med beta	>5e9	
1. 4.	Q ₀ high beta	>5e9	
1. 4.	R/Q ₀ med beta	220-440 Ω/m	Function of beam velocity
1. 4.	R/Q ₀ high beta	170-570 Ω/m	Function of beam velocity
1. 4.	Medium B Cavity external Q	7.30E+05	
1. 4.	High Beta Cavity external Q	7.00E+05	
1. 4.	External Q variation	+/- 20 %	
1. 4.	Typical band width, med β, high β	550, 575 Hz	FWHM; f(1/2)=f ₀ /(2Q _{ex})
1. 4.	Cavity stiffeners	yes	
1. 4.	Expected Lorentz force detuning coefficient-med beta	2 Hz/(MV/m) ²	
1. 4.	Expected Lorentz force detuning coefficient-high beta	2 Hz/(MV/m) ²	
1. 4.	Lorentz force coefficient variation	+/- 50 %	
1. 4.	Microphonic amplitude limit	+/- 100 Hz	Six sigma
1. 4.	Cavity active length med beta	0.682 m	
1. 4.	Cavity active length high beta	0.906 m	
1. 4.	Total cavity length med beta	1.067 m	
1. 4.	Total cavity length high beta	1.291 m	
1. 4.	E _{peak} /E ₀ med beta	1.84	
1. 4.	E _{peak} /E ₀ high beta	1.53	
1. 4.	B _{peak} /E _{peak} med beta	2.10 mT//MV/m	
1. 4.	B _{peak} /E _{peak} high beta	2.14 mT//MV/m	
1. 4.	E ₀ med beta	13.4 - 16.4 MV/m	
1. 4.	E ₀ high beta	17.9 - 24.4 MV/m	
1. 4.	B _{peak} med beta	52.0 - 63.5 mT	
1. 4.	B _{peak} high beta	58.9 - 80.3 mT	
1. 4.	SRF LINAC CRYOMODULES		
1. 4.	Shield static heat load med beta cryomodule	170 W	
1. 4.	Shield static heat load high beta cryomodule	200 W	
1. 4.	2.1 K static heat load med beta cryomodule	25 W	

1. 4.	2.1 K static heat load high beta cryomodule	28 W
1. 4.	Cavity dynamic heat load per med beta cryomodule	16 W
1. 4.	Cavity dynamic heat load per high beta cryomodule	18 W
1. 4.	Magnetic field at cryomodules from rebar	0.0001 T
1. 4.	Cavity displacement tolerance relative to cryomodule	+/-1 mm
1. 4.	Cavity tilt tolerance relative to cryomodule	+/-1 mrad
1. 4.	Cryomodule alignment tolerance	+/-1 mm

1. 4. SRF LINAC POWER COUPLERS

1. 4.	Power couplers per cavity	1
1. 4.	Number of power couplers	81
1. 4.	Maximum power of coupler	550 kW
1. 4.	Power coupler design	KEK-B
1. 4.	Power coupler vacuum	5.E-09 Torr

1. 4. SRF LINAC HOM COUPLERS

1. 4.	HOM couplers per cavity	2
1. 4.	Number of HOM couplers	2 x 81
1. 4.	HOM coupler design	TTF

1. 4. SRF LINAC TUNERS

1. 4.	Number of tuners	81
1. 4.	Tuner tuning rate	3000 Hz/min
1. 4.	Tuner tuning range	+/-100 kHz

1. 4. 12. SRF LINAC CRYOPLANT

1. 4. 12.	Primary circuit temperature	2.1 K
1. 4. 12.	Primary circuit pressure	0.041 bar
1. 4. 12.	Primary circuit margin	100 %
1. 4. 12.	Secondary circuit temperature	5 K
1. 4. 12.	Secondary circuit pressure	3 bar
1. 4. 12.	Secondary circuit margin	100 %
1. 4. 12.	Shield circuit temperature	35-55 K
1. 4. 12.	Shield circuit pressure	4.0-3.0 bar
1. 4. 12.	Shield circuit margin	50 %

1. 4. 9. SRF LINAC FOCUSING QUADRUPOLES

1. 4. 9. Aperture diameter	80 mm
1. 4. 9. Effective length	0.41 m
1. 4. 9. Max gradient	7.2 T/m
1. 4. 5. SRF LINAC DIAGNOSTICS	
1. 4. 5. Number of beam position and phase monitors	32
1. 4. 5. Number of beam loss monitors	64
1. 4. 5. Number of current monitors	6
1. 4. 5. Number of wire scanners	32
1. 4. 1. RF POWER SYSTEMS	
1. 4. 1. Modulator type	IGBT
1. 4. 1. 402.5 MHz klystron peak RF power	2.5 MW
1. 4. 1. Total number of 402.5 MHz klystrons	7
1. 4. 1. Number of 402.5 MHz klystrons per DTL tank	1
1. 4. 1. Number of 402.5 MHz klystrons per transmitter	1
1. 4. 1. Number of 402.5 MHz klystrons per modulator	2
1. 4. 1. Number of 402.5 MHz circulators	7
1. 4. 1. 402.5 MHz klystron efficiency	58 %
1. 4. 1. 402.5 MHz RF field tilt rms tolerance in tank	0.1 %
1. 4. 1. 805 MHz CCL klystron peak power	5 MW
1. 4. 1. Number of 805 MHz klystrons per CCL module	1
1. 4. 1. Number of CCL 805 MHz klystrons	4
1. 4. 1. Number of 5 MW HEBT 805 MHz klystrons	2
1. 4. 1. Number of 805 MHz klystrons per transmitter	1
1. 4. 1. Number of 805 MHz klystrons per modulator	2
1. 4. 1. Number of 805 MHz circulators	6
1. 4. 1. 805 MHz 5 MW klystron efficiency	55 %
1. 4. 1. SRF klystron peak power	0.55 MW
1. 4. 1. Number of SRF cavities per klystron	1
1. 4. 1. Number of SRFL 805 MHz klystrons	81
1. 4. 1. Number of SRF klystron circulators	81
1. 4. 1. 805 MHz klystron total RF power	35.1 MW
1. 4. 1. Number of SRF cavities per klystron	1
1. 4. 1. Number of SRF klystrons per transmitter	6 or 5
1. 4. 1. Number of SRF klystrons per HV power conditioner	12 or 11

1. 4. 1. 805 MHz 550 KW klystron efficiency	63 %	Wall plug to klystron output
1. 4. 1. RF module phase dynamic rms tolerance	0.5 deg	Limit +/- 0.75 deg
1. 4. 1. RF module amplitude dynamic rms tolerance	0.5 %	Limit +/- 0.75 deg
1. 4. 1. RF module phase static rms tolerance	<1 deg	Limit +/- 1.0 deg
1. 4. 1. RF module amplitude static rms tolerance	0.6 %	Limit +/- 1.0 %
1. 4. 1. RF field response time	100 μ s	Depends on DTL CCL Nb linac

1. 5. 1. HEBT BEAM LINE

1. 5. 1. Ion type	H minus	
1. 5. 1. Output energy	1000 MeV	
1. 5. 1. Length	169.49 m	Diff pumping to injection septum center
1. 5. 1. Beam-floor distance	1.270 m	50.0 in
1. 5. 1. Length of additional linac dump beam line	42 m	
1. 5. 1. Length of linac to achromat matching section LAMS	40 m	
1. 5. 1. Number of LAMS FODO cells	5	8.0 m per FODO cell
1. 5. 1. Length of achromat	59 m	
1. 5. 1. Number of achromat FODO cells	4	14.0 m per FODO cell
1. 5. 1. Achromat total bend angle	90 deg	
1. 5. 1. Achromat maximum dispersion	6.8 m	
1. 5. 1. Length of achromat to ring matching section ARMS	70 m	
1. 5. 1. Number of ARMS FODO cells	7.5	8.0 m per FODO cell
1. 5. 1. Number of Ludewig betatron collimators	2	
1. 5. 1. Number of betatron foil collimators	4	
1. 5. 1. Location of momentum collimator	achromat center	
1. 5. 1. Rms energy spread at achromat center	0.72 MeV	
1. 5. 1. Energy scrape with momentum collimator	+/- 3.0 MeV	
1. 5. 1. Energy total jitter before energy corrector	+/- 1.5 MeV	
1. 5. 1. Energy total jitter after energy corrector	+/- 0.2 MeV	
1. 5. 1. Total time ave energy spread at foil	+/- 4.0 MeV	
1. 5. 1. Number of energy sweeps per macropulse	100	
1. 5. 1. Expected output H&V rms norm emittance w/ errors and wo/ jitter	0.41 π mm-mrad	
1. 5. 1. Extected output transverse centroid jitter	+/- 0.2 mm	
1. 5. 1. Expected output H&V rms norm emittance w/ errors and w/ jitter	0.50 π mm-mrad	
1. 5. 1. Operating vacuum pressure	5E-8 to 1E-8 Torr	From SRFL to Ring

1. 5. 1. HEBT MAGNETS			
1. 5. 1. Number of 11.25 deg C type dipoles	8		
1. 5. 1. 11.25 deg dipole field	0.21 T		
1. 5. 1. 11.25 deg dipole gap	80 mm		
1. 5. 1. 11.25 deg dipole length	5.3 m		
1. 5. 1. Number of 7.5 deg dipoles	1		
1. 5. 1. 7.5 deg dipole field	0.21 T		
1. 5. 1. 7.5 deg dipole gap	80 mm		
1. 5. 1. 7.5 deg dipole length	3.55 m		
1. 5. 1. Number of 12 cm bore quadrupoles	32	26 (HEBT) + 6 (linac dump)	
1. 5. 1. 12 cm bore quad gradient	5.5 T/m		
1. 5. 1. 12 cm bore quad length	0.5 m		
1. 5. 1. Number of 21 cm bore quadrupoles	8	Same as ring quads	
1. 5. 1. 21 cm bore quad gradient	3 T/m		
1. 5. 1. 21 cm bore quad length	0.5 m		
1. 5. 1. Number of 26.4 cm bore injection dump quadruples	1		
1. 5. 1. Number of 12x12 cm dipole correctors	14		
1. 5. 1. Number of 24x24 cm correctors	4		
1. 5. 1. Expected dipole magnetic field errors	+/- 0.01 %	Integrated at full acceptance	
1. 5. 1. Expected quadrupole magnetic field errors	+/- 0.1 %	Integrated at full acceptance	
1. 5. 1. Expected corrector magnetic field errors	+/- 1 %	Integrated at full acceptance	
1. 5. 1. Expected magnet offset rms	0.1 mm		
1. 5. 1. Magnet pitch and yaw rms tolerance	1 mrad		
1. 5. 1. Magnet roll rms tolerance	1 mrad		
1. 5. 1. Number of dipole PS	3	700 A and 40,40,150 V	
1. 5. 1. Number of quadrupole PS	26	200-800 A and 15-60 V	
1. 5. 1. Number of corrector bipolar PS	18	20 A and 30 V	
1. 4. 5. HEBT RF CAVITIES			
1. 4. 5. Number energy corrector cavity	1		
1. 4. 5. Energy corrector cavity location	115 m	From the last cavity of linac	
1. 4. 5. Energy corrector frequency	805 MHz	Same as CCL	
1. 4. 5. Energy corrector aperture diameter	48 mm		
1. 4. 5. Energy corrector peak voltage gain EoTL	4 MV		
1. 4. 5. Number energy spreader cavity	1		
1. 4. 5. Energy spreader cavity location	174 m	From the last cavity of linac	

1. 4.	5. Energy spreader frequency	805.0 +/- 0.1 MHz	Same as CCL
1. 4.	5. Energy spreader aperture diameter	48 mm	
1. 4.	5. Energy spreader peak voltage gain EoTL	4 MV	
1. 5. 7. HEBT DIAGNOSTICS			
1. 5.	7. Number of beam position and phase monitors	37	
1. 5.	7. Number of beam loss monitors	55	Includes both fast and slow monitors, and linac dump transport
1. 5.	7. Number of current monitors	5	Includes one for injection dump
1. 5.	7. Number of wire scanners	11	
1. 5.	7. Number of harps	2	
1. 5.	7. Number of beam in gap monitors	1	
1. 5.	7. Number of phase width monitors	1	
1. 5. ACCUMULATOR RING			
1. 5.	Ion type	proton	
1. 5.	Output energy	1000 MeV	
1. 5.	Ring circumference	248.0 m	
1. 5.	Beam-floor distance	1.224 m	48.2 in
1. 5.	Average beam power	1.5 MW	Average power in ring
1. 5.	Peak bunched beam current	52 A	
1. 5.	Proton magnetic rigidity	5.6575 Tm	
1. 5.	Max uncontrolled beam loss	1 W/m	
1. 5.	Unnormalized 99% total emittance ($\epsilon_x + \epsilon_y$)	240 π mm-mrad	434 π mm-mrad normalized
1. 5.	Ring betatron acceptance	480 π mm-mrad	
1. 5.	Adjustable scraper acceptance	240-300 π mm-mrad	
1. 5.	Collimator acceptance	300 π mm-mrad	
1. 5.	Longitudinal rf bucket area	19 eV-sec	
1. 5.	Expected longitudinal bunch area (99%)	13 eV-sec	
1. 5.	Total Injected energy spread	+/- 4 MeV	
1. 5.	Total extracted energy spread	+/- 10 MeV	
1. 5.	RF system momentum acceptance	+/- 1.0 %	
1. 5.	Vacuum chamber full-beam momentum acceptance	+/- 2.0 %	
1. 5.	Zero betatron amplitude momentum acceptance	+/- 3.8 %	
1. 5.	Bunching factor	0.48	Dual harmonic RF
1. 5.	Expected space charge tune shift	0.15	Uniform-beam tune shift 0.1

1. 5.	Lattice superperiods	4	
1. 5.	Max dispersion in straight sections	<0.3 m	Dominated by injection chicane/bump
1. 5.	Arc lattice	4 FODO cells	
1. 5.	Arc FODO cell length	8 m	
1. 5.	Straight section lattice	2 doublets	
1. 5.	Short drift in long straights	2X6.85 m	
1. 5.	Long drift in long straights	12.5 m	
1. 5.	Phase advance per arc FODO cell	90 deg	
1. 5.	Nominal betatron H tune	6.4	Adjustable range 6 - 7
1. 5.	Nominal betatron V tune	6.3	Adjustable range 4 - 7
1. 5.	Transition gamma	5.23	
1. 5.	Frequency slip factor	-0.198	
1. 5.	Natural H chromaticity	-8.1	Nominal tunes
1. 5.	Natural V chromaticity	-7.0	Nominal tunes
1. 5.	Maximum dispersion function	3.9 m	Nominal tunes
1. 5.	Maximum H/V β function	27.0/14.9 m	Nominal tunes
1. 5.	Ring V beamline offset wrt HEBT beamline	-46 mm	
1. 5.	Offset for injection H static bump	100 mm	
1. 5.	Number of injected turns	1060 turns	
1. 5.	Revolution period	945 ns	
1. 5.	Ring injection pulse length	645 ns	
1. 5.	Ring injection gap length	300 ns	
1. 5.	Ring extraction pulse length	695 ns	
1. 5.	Ring extraction gap length	250 ns	
1. 5.	Space charge longitudinal impedance iZ/n	-196 Ω	
1. 5.	Expected resistive wall longitudinal impedance Z/n	(1+i)0.7 Ω	At revolution frequency
1. 5.	Expected resistive wall transverse impedance Z	(1+i)6.2 k Ω /m	At revolution frequency
1. 5.	Expected broad band longitudinal impedance $ Z/n $	8 Ω	
1. 5.	Expected broad band transverse impedance $ Z/n $	94 k Ω /m	
1. 5.	Expected kicker longitudinal impedance $ Z/n $	<50 Ω	
1. 5.	Expected kicker transverse impedance, $Re(Z/n)$, $Im(Z)$	20, 200 k Ω /m	Below 10 MHz
1. 5.	Expected kicker transverse impedance, $Re(Z)$, $Im(Z)$	120, 80 k Ω /m	At 50 MHz

1. 5. 2. RING INJECTION SYSTEM

1. 5. 2.	Foil size HxV	4x8 mm	3 open sides
1. 5. 2.	Foil thickness	300 μ g/cm ²	
1. 5. 2.	Linac beam missing foil	4 %	

1. 5. 2. Stripped electron beam dump	copper	Water cooled Cu block
1. 5. 2. Transverse painting scheme	correlated	
1. 5. 2. Average foil hits per proton	6	
1. 5. 2. Number of H and V in-ring kicker magnets	4 and 4	
1. 5. 2. Number of injection kicker PS	8	110A-100V to 1400A-800V
1. 5. 2. Programmable injection kicker PS	yes	
1. 5. 2. Number of dc in-ring horizontal bump magnets	4	IDH1-IDH4
1. 5. 2. Expected injection dipole magnetic field errors	+/- 0.1 %	Integrated at full acceptance
1. 5. 2. Expected injection kicker field errors	+/- 1.0 %	Integrated at full acceptance
1. 5. 2. Number of injection dc PS (4 dipole, 2 septum, 1 quad)	7	820-4000 A and ~20 V

1. 5. 3. RING MAGNET SYSTEM

1. 5. 3. Core material	1006 steel	Solid core
1. 5. 3. Number of H frame sector dipoles	32	33 w/ reference dipole
1. 5. 3. Dipole magnetic field	0.7935 T	Bending radius = 7.996 m
1. 5. 3. Dipole bend angle	11.25 deg	HGFW = 230 mm
1. 5. 3. Dipole gap	170 mm	
1. 5. 3. Dipole pole width	450 mm	
1. 5. 3. Dipole magnetic path length	1.43 m	
1. 5. 3. Dipole radius of curvature	7.639 m	
1. 5. 3. Dipole sagitta	38.5 mm	
1. 5. 3. Number of arc regular quadrupoles	28	
1. 5. 3. Bore of arc regular quads	210 mm	
1. 5. 3. Magnetic length of arc regular quads	0.50 m	
1. 5. 3. Magnetic gradient of arc regular quads	4.7 T/m	
1. 5. 3. Number of arc large quadrupoles	8	
1. 5. 3. Bore of arc large quads	264 mm	
1. 5. 3. Magnetic length of arc large quads	0.50 m	
1. 5. 3. Magnetic gradient of arc large quads	4.7 T/m	
1. 5. 3. Number of straight section long quadrupoles	8	
1. 5. 3. Bore of straight section long quads	300 mm	
1. 5. 3. Magnetic length of straight section long quads	0.70 m	
1. 5. 3. Magnetic gradient of straight section long quads	4.3 T/m	
1. 5. 3. Number of straight section short quadrupoles	8	
1. 5. 3. Bore of straight section short quads	300 mm	
1. 5. 3. Magnetic length of straight section short quads	0.55 m	
1. 5. 3. Magnetic gradient of straight section short quads	4.3 T/m	

1. 5. 3. Number of 27x27 cm dipole and multipole correctors	28	
1. 5. 3. Number of 36x36 cm dipole correctors	8	
1. 5. 3. Number of 41x41 cm dipole correctors	8	
1. 5. 3. Number of 21x21 cm sextupole & octupole correctors	8+8	
1. 5. 3. Expected ring dipole magnetic field errors	+/- 0.01 %	Integrated at full acceptance
1. 5. 3. Expected ring quadrupole magnetic field errors	+/- 0.01 %	Integrated at full acceptance
1. 5. 3. Expected chromatic sextupoles field error	+/- 1.0 %	Integrated at full acceptance
1. 5. 3. Expected corrector magnetic field errors	+/- 1.0 %	Integrated at full acceptance
1. 5. 3. Expected magnet rms offset	0.1 mm	
1. 5. 3. Expected magnet rms roll	0.2 mrad	
1. 5. 3. Magnet pitch & yaw rms alignment tolerance	0.5 mrad	
1. 5. 3. Magnet twist rms tolerance	0.5 mrad	
1. 5. 4. RING POWER SUPPLIES		
1. 5. 4. Number of dipole primary PS	1	4600 A, 400 V
1. 5. 4. Number of quad primary PS	6	900-1000 A; 300-500 V
1. 5. 4. Number of dipole and sext corr bipolar PS	56	20 A and 30 V; pending PCR
1. 5. 4. Number of skew quad and oct corr PS	18	20 A and 60 V; pending PCR
1. 5. 4. Number of quad corr PS	7	50 A and 30 V; pending PCR
1. 5. 5. RING VACUUM SYSTEM		
1. 5. 5. Average operating vacuum pressure	1.0E-08 Torr	
1. 5. 5. Chamber material	Stainless steel	TiN coating
1. 5. 6. RING RF SYSTEM		
1. 5. 6. RF system type	1st and 2nd harm	
1. 5. 6. Cavity length	1.7 m	
1. 5. 6. Accelerating gaps per cavity	2	
1. 5. 6. Harmonic 1 frequency	1.058 MHz	
1. 5. 6. Number of harmonic 1 cavities	3	
1. 5. 6. Harmonic 1 total voltage	40 kV	
1. 5. 6. Harmonic 2 frequency	2.115 MHz	
1. 5. 6. Number of harmonic 2 cavities	1	
1. 5. 6. Harmonic 2 total voltage	20 kV	
1. 5. 6. Beam loading compensation	dyn. tune & f. f.	dynamic tuning and feed forward
1. 5. 6. Low level loop bandwidth	>4 kHz	

1. 5. 7. RING DIAGNOSTICS			
1. 5. 7. Number of beam position monitors	44	Striplines at each quad	
1. 5. 7. Number of beam loss monitors	87	Fast and slow monitors	
1. 5. 7. Number of beam current monitors	1		
1. 5. 7. Number of wire scanners	1		
1. 5. 7. Number of foil video monitors	2	Primary and secondary stripping locations	
1. 5. 7. Number of beam in gap monitors/cleaners	1	Kicker with PMT detectors	
1. 5. 7. Number of ionization profile monitors	2	Residual gas ionization monitor 1 ea H	
1. 5. 7. Number of tune measurement systems	3 or 4	1. BIG Kicker excited and FFT analyzed 2. Low power high frequency 3. 400 MHz 4. Perhaps quadrupole oscillation	
1. 5. 7. Number of electron detectors	5	Argonne style	
1. 5. 7. Number of octupole moment monitors	1		
1. 5. 8. RING COLLIMATION			
1. 5. 8. Number of independent adjustable scrapers	4		
1. 5. 8. Scraper material	Platinum		
1. 5. 8. Number of Ludewig type collimators	3		
1. 5. 8. Halo attenuation ratio in ring	20:1	For 480 π mm mrad acceptance	
1. 5. 8. Power absorption capacity per collimator	20 kW		
1. 5. 9. RING EXTRACTION			
1. 5. 9. Extraction type	single turn	Fast kicker and Lambertson	
1. 5. 9. Beam extraction time gap	250 ns		
1. 5. 9. Kicker rise time	200 ns	0 to 97%	
1. 5. 9. Kicker flattop time	700 ns		
1. 5. 9. Number of fast ferrite kicker sections	14		
1. 5. 9. Kicker core length per section	400 mm	Core spacing 80 mm	
1. 5. 9. Vertical displacement at Lambertson entrance	168 mm		
1. 5. 9. Beam extracts to target with 13 of 14 kickers inoperable	yes		
1. 5. 9. Number of PFNs	14		
1. 5. 9. Number of PFN PS	14		
1. 5. 9. Lambertson horizontal bend angle	16.8 deg		
1. 5. 9. Lambertson rotation angle	2.6 deg		
1. 5. 9. Lambertson core length	2.1 m		
1. 5. 9. Lambertson magnetic field	0.8 T		

1. 5. 9. Expected extraction Lambertson magnetic field errors +/-	0.1 %	Integrated at full acceptance
1. 5. 9. Expected extraction kicker field errors +/-	1.0 %	Integrated at full acceptance
1. 5. 9. Number of Lambertson PS	1	2000 A, 20V

1. 5. 10. RTBT BEAM LINE

1. 5. 10. Ion type	proton	
1. 5. 10. Output energy	1000 MeV	
1. 5. 10. Length	150.75 m	Lambertson center to target
1. 5. 10. Beam-floor distance	0.996 to 1.041 m	Start at 39.2 in and end at 41.0 in
1. 5. 10. Output beam power	1.5 MW	Average power
1. 5. 10. Beam spot size on target H x V	200 x 70 mm	
1. 5. 10. Number of Ludewig betatron collimators	2	
1. 5. 10. Number of 11.6 m FODO cells	15	
1. 5. 10. Ring extraction dump beam line length	28 m	
1. 5. 10. RTBT elevation wrt ring	-0.183 m	
1. 5. 10. Operating vacuum pressure	1E-8 to 1E-7 Torr	From ring to target

1. 5. 10. RTBT MAGNETS

1. 5. 10. Number of 16.8 deg H switcher dipole	1	
1. 5. 10. Switching dipole gap	170 mm	
1. 5. 10. Number of 21 cm bore quads	23	
1. 5. 10. Number of 31 cm bore quads including 2 for dump	4	
1. 5. 10. Number of 36 cm bore spreading quadrupoles	5	
1. 5. 10. Number of 24 x 24 cm dipole correctors	15	
1. 5. 10. Number of 36x36 cm spreading correctors	4	
1. 5. 10. Expected RTBT dipole magnetic field errors +/-	0.01 %	Integrated at full acceptance
1. 5. 10. Expected RTBT quadrupole magnetic field errors +/-	0.1 %	Integrated at full acceptance
1. 5. 10. Expected RTBT corrector magnetic field errors +/-	1.0 %	Integrated at full acceptance
1. 5. 10. Magnet offset rms alignment tolerance	0.1 mm	
1. 5. 10. Magnet pitch and yaw rms alignment tolerance	1 mrad	
1. 5. 10. Magnet roll rms alignment tolerance	1 mrad	Extraction and RTBT
1. 5. 10. Number of dipole PS	1	2000A-50V and 900A-80V
1. 5. 10. Number of quadrupole PS	21	700A-50V to 800A-120V
1. 5. 10. Number of corrector bipolar PS	19	20 A and 30 V

1. 5. 7. RTBT DIAGNOSTICS

1. 5. 7. Number of beam position monitors	17	
1. 5. 7. Number of beam loss monitors	43	Fast and slow monitors
1. 5. 7. Number of current toroids	5	
1. 5. 7. Number of wire scanners	5	
1. 5. 7. Number of harps	2	

1. 6. TARGET SYSTEMS

1. 6. Number of target stations	1	
1. 6. Beam power missing target	4 %	Primarily due to window scattering
1. 6. Number of neutron beam shutters	18	
1. 6. Number of neutron beam lines	24	
1. 6. Beam-to-floor distance	1.981 m	78 in
1. 6. Design power level on target	2 MW	Nominal beam power on target is 1.44 MW

1. 6. 1. TARGET ASSEMBLIES

1. 6. 1. Front cross section of target VxH	104x 399 mm	
1. 6. 1. Beam spot size on target VxH	70x200 mm	
1. 6. 1. Tolerance on beam centroid H&V	+/- 2 mm	
1. 6. 1. Normal peak current density	0.25 A/m ²	
1. 6. 1. Normal time ave power within beam spot	90 %	
1. 6. 1. Time ave current density over beam spot	0.143 A/m ²	
1. 6. 1. Normal single pulse peak density	2.57x10 ¹⁶ protons/m ²	
1. 6. 1. Off normal single pulse density	3.2x10 ¹⁶ protons/m ²	For 2 pulses max
1. 6. 1. Unscheduled beam off > 5s	50 per day	
1. 6. 1. Unscheduled beam off >300 s	10 per day	
1. 6. 1. Target material	Hg	Hg inventory < 2.0 cubic m
1. 6. 1. Hg nominal operating temperature	60 - 90 deg C	
1. 6. 1. Hg target nominal operating pressure	0.3 MPa	
1. 6. 1. Hg power loading	1.2 MW	
1. 6. 1. Shell material	316 SS LN	
1. 6. 1. Shell temperature	<200 deg C	
1. 6. 1. Shroud material	316 SS LN	
1. 6. 1. Shroud cooling	light water	
1. 6. 1. Target plug material	Fe-alloy, water, SS	

1. 6. 2. AMBIENT MODERATORS			
1. 6. 2. Number of moderators	1		
1. 6. 2. Moderator material	light water		
1. 6. 2. Position	Upstream below target		
1. 6. 2. CRYOGENIC MODERATORS			
1. 6. 2. Number	3		
1. 6. 2. Moderator material	supercritical H		
1. 6. 2. Position	downstream below		
1. 6. 2. Viewed face	120 x 100 mm		
1. 6. 2. Pre moderator	light water		
1. 6. 2. Non grooved surfaces	yes		
1. 6. 2. Poison upstream top only	Al clad Gd		
1. 6. 2. Decoupler upstream top only	Cd		
1. 6. 3. REFLECTOR ASSEMBLIES			
1. 6. 3. Reflector material	Be / Pb		
1. 6. 3. Configuration	nested cylinders		
1. 6. 3. Coolant	heavy water		
1. 6. 3. Outer diameter of Be	0.64 m	With heavy water	
1. 6. 4. TARGET VESSEL			
1. 6. 4. Material	316 SS		
1. 6. 4. Atmosphere	He	At < 0.1 MPa	
1. 6. 4. Proton beam window material	Inconel 718		
1. 6. 4. Proton beam window thickness	4.0 mm		
1. 6. 4. Proton beam window coolant	light water		
1. 6. 4. Proton beam window coolant thickness	1.5 mm		
1. 6. 5. TARGET SYSTEM SHIELDING			
1. 6. 5. Number of single channel shutters	12		
1. 6. 5. Number of multi channel shutters	6		
1. 6. 5. Shutter configuration	ISIS type	Light water cooled	
1. 6. 5. Neutron HxV channel within single shutter	200 x 220 mm		

1. 6. 9. BEAM DUMPS			
1. 6. 9. Number of beam dumps	3		
1. 6. 9. Minimum target diameter	300 mm		
1. 6. 9. Tolerance on beam center	+/- 50 mm		
1. 6. 9. Atmosphere	He	At 0.1 MPa	
1. 6. 9. Reentrant	yes		
1. 6. 9. Maximum single pulse energy	42 kJ		
1. 6. 9. LINAC DUMP			
1. 6. 9. Beam stop material	graphite	Under evaluation	
1. 6. 9. Shielding material	Fe alloy		
1. 6. 9. Cooling mechanism	passive		
1. 6. 9. Maximum power	≤ 7.5 kW	Under evaluation	
1. 6. 9. Operational hours per year	500 h		
1. 6. 9. Maximum horizontal beam size	60 mm		
1. 6. 9. Maximum vertical beam size	60 mm		
1. 6. 9. RING INJECTION DUMP			
1. 6. 9. Beam stop material	Cu		
1. 6. 9. Shielding material	Fe alloy		
1. 6. 9. Cooling mechanism	Forced light		
1. 6. 9. Maximum power	water		
1. 6. 9. Operational hours per year	200 kW		
1. 6. 9. Maximum horizontal beam size	5000 h		
1. 6. 9. Maximum vertical beam size	200 mm		
1. 6. 9. 100 mm			
1. 6. 9. RING EXTRACTION DUMP			
1. 6. 9. Beam stop material	graphite	Under evaluation	
1. 6. 9. Shielding material	Fe alloy		
1. 6. 9. Cooling mechanism	passive		
1. 6. 9. Maximum power	≤ 7.5 kW	Under evaluation	
1. 6. 9. Operational hours per year	500 h		
1. 6. 9. Maximum horizontal beam size	200 mm		
1. 6. 9. Maximum vertical beam size	200 mm		