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The upgrade of the CERN Proton Synchrotron Booster transfer line magnets

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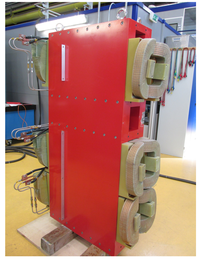
Abstract

The Proton-Synchrotron Booster (PSB), in operation since 1972, is the first of several pre-injectors in the way to the Large Hadron Collider (LHC) located at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland.

The PSB was installed as part of the CERN Proton-Synchrotron (PS) upgrade in order to achieve higher beam intensity, where it first accelerated protons up to an energy of 800 MeV. By 1988, the PSB was capable of providing 1 GeV protons to the PS. After which in 1999, in preparation for LHC operations it was upgraded to 1.4 GeV. Finally during the Second Long Shutdown between LHC operations (LS2) which is currently underway, it is undergoing a latest upgrade to 2 GeV in order to ease the injection of high intensity and high brilliance beams into the PS, and thus help removing bottlenecks in the LHC injector chain. Along with the upgrade to 2 GeV, the connection of the new LINAC 4 to the PSB is also taking place. Replacing the 50 MeV LINAC 2, the LINAC 4 will accelerate negative hydrogen ions (H-, consisting of a hydrogen atom with an additional electron) to 160 MeV which when arriving at the PSB will be stripped of the electrons.

Largely untouched during decades of operation, many of the magnets in the existing transfer lines from the new LINAC 4 to the PSB, and the PSB to the PS will be upgraded as they no longer meet the increased requirements due to the two energy increases. Other magnets have come to the 'end of life' or will be changed to minimize and harmonize the number of magnet and power converter families in use and thus reduce the number of spares required.

Injection Upgrade 50 > 160 MeV

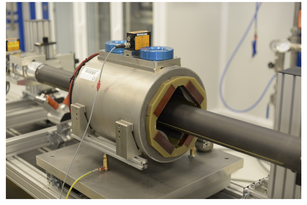


Vertical Bending Magnet (IBV)

Parameter	Units		Comment
Type of Magnet		3 aperture window frame	
Number of Magnets		1 + 1 spare	
Overall Height	(mm)	1692	
Overall Width	(mm)	763	
Overall Length	(mm)	992	
Iron Length	(mm)	720	
Aperture [H x W]	(mm)	[120 x 122]	
Mass	(kg)	1800	
Operation		DC	
Nominal Current	(A)	414	
RMS Current	(A)	414	
Resistance	(Ω)	0.04 - 0.055	(aperture 2 & 4 - aperture 1)
Inductance	(H)	0.008 - 0.011	(aperture 2 & 4 - aperture 1)
Disipated Power	(kW)	23	all apertures powered
Cooling		Water	
Pressure Drop	(bar)	11	
Water Flow	(l/min)	15	
Temperature Rise	(°C)	22	
Turns		70 - 90	(aperture 2 & 4 - aperture 1)
Integrated Field	T.m	0.26 - 0.33	(aperture 2 & 4 - aperture 1)
Nominal Field	T	0.3 - 0.38	(aperture 2 & 4 - aperture 1)

Combined H/V Corrector Magnet

Parameter	Units		Comment
Type of Magnet		Combine HV corrector	
Number of Magnets		18 + 4 spare	
Overall Height	(mm)	257	
Overall Width	(mm)	257	
Overall Length	(mm)	255	
Iron Length	(mm)	229	
Aperture [H x W]	(mm)	153 x 153	
Mass	(kg)	60	
Operation		Pulsed	
Nominal Current	(A)	35	
RMS Current	(A)	2.6	
Resistance	(Ω)	1.5	per plane
Inductance	(H)	0.042	per plane
Disipated Power	(W)	10	per plane
Cooling		AIR	
Temperature Rise	(°C)	14	
Turns		180	
Integrated Field	T.m	0.016	
Nominal Field	T	0.041	



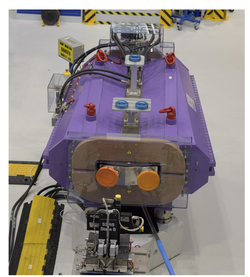
Injection Quadrupole Magnets

Parameter	Units		
Type of Magnet		Tapered Pole Quadrupole	
Number of Magnets		18 + 2 spare	
Overall Height	(mm)	420	
Overall Width	(mm)	595	
Overall Length	(mm)	460	
Iron Length	(mm)	400	
Aperture Radius	(mm)	75	
Mass	(kg)	200	
Operation		Pulsed	
Nominal Current	(A)	95	
RMS Current	(A)	7.5	
Resistance	(Ω)	0.475	
Inductance	(H)	0.033	
Disipated Power	(W)	27	
Cooling		AIR	
Temperature Rise	(°C)	4	
Turns per pole		54	
Integrated Gradient Field	T	1.04	
Nominal Gradient	T/m	2.3	

Extraction Upgrade 1.4 > 2.0 GeV

Vertical Bending Magnet (BV1)

Parameter	Units		
Type of Magnet		window frame	
Number of Magnets		2 + 1 spare	
Overall Height	(mm)	514	
Overall Width	(mm)	357	
Overall Length	(mm)	1198	
Iron Length	(mm)	800	
Aperture [H x W]	(mm)	131 x 62	
Mass	(kg)	780	
Operation		Cycled DC	
Nominal Current	(A)	380	
RMS Current	(A)	129	
Resistance	(Ω)	0.189	
Inductance	(H)	0.038	
Disipated Power	(kW)	3.1	
Cooling		Water	
Pressure Drop	(bar)	11	
Water Flow	(l/min)	2	
Temperature Rise	(°C)	26	
Turns		52	
Integrated Field	T.m	0.72	
Nominal Field	T	0.8	



Horizontal Bending Magnet (BT.BHZ10)

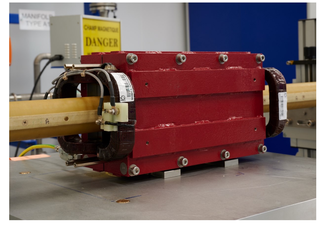
Parameter	Units		Comment
Type of Magnet		Tapered window frame	
Number of Magnets		1 + 1 spare	
Overall Height	(mm)	1965	
Overall Width	(mm)	1702	
Overall Length	(mm)	2160	
Iron Length	(mm)	1840	
Aperture [H x W]	(mm)	128 x (298 - 603)	Horizontal aperture is tapered
Mass	(kg)	9200	
Operation		Cycled DC	Can operate in DC
Nominal Current	(A)	405	
RMS Current	(A)	245	
Resistance	(Ω)	0.252	
Inductance	(H)	0.408	
Disipated Power	(kW)	15.1	
Cooling		Water	
Pressure Drop	(bar)	8	
Water Flow	(l/min)	19.5	
Temperature Rise	(°C)	11	
Turns		190	
Integrated Field	T.m	1.49	
Nominal Field	T	0.748	

Horizontal Bending Magnet (BTM.BHZ10)

Parameter	Units		Comment
Type of Magnet		Curved H Dipole	
Number of Magnets		1 (spare coils)	
Overall Height	(mm)	1810	
Overall Width	(mm)	1480	
Overall Length	(mm)	2740	
Iron Length	(mm)	2350	
Aperture [H x W]	(mm)	98 x 380	
Mass	(kg)	17800	
Operation		Cycled DC	Can operate in DC
Nominal Current	(A)	845	
RMS Current	(A)	508	
Resistance	(Ω)	0.054	
Inductance	(H)	0.226	
Disipated Power	(kW)	13.9	
Cooling		Water	
Pressure Drop	(bar)	9.4	
Water Flow	(l/min)	25.2	
Temperature Rise	(°C)	8	
Turns		132	
Integrated Field	T.m	3.25	
Nominal Field	T	1.41	

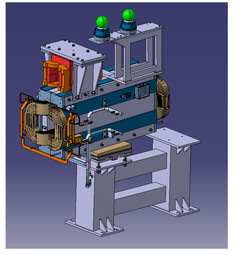
BT/BTP Quadrupole Magnets

Parameter	Units	
Type of Magnet		Tapered Pole Quadrupole
Number of Magnets		8 + 2 spare
Overall Height	(mm)	1100
Overall Width	(mm)	1040
Overall Length	(mm)	810
Iron Length	(mm)	570
Aperture Radius	(mm)	75
Mass	(kg)	2525
Operation		Cycled DC
Nominal Current	(A)	377
RMS Current	(A)	135
Resistance	(Ω)	0.23
Inductance	(H)	0.092
Disipated Power	(kW)	4.2
Cooling		Water
Pressure Drop	(bar)	7
Water Flow	(l/min)	2.45
Temperature Rise	(°C)	22
Turns per pole		54
Integrated Gradient Field	T	5.8
Nominal Gradient	T/m	9.05



Vertical Corrector Magnet

Parameter	Units		
Type of Magnet		Window Frame	
Number of Magnets		2 + 1 spare	
Overall Height	(mm)	203	
Overall Width	(mm)	250	
Overall Length	(mm)	424	
Iron Length	(mm)		
Aperture [H x W]	(mm)	66 x 94	
Mass	(kg)	60	
Operation		Pulsed	
Nominal Current	(A)	33	
RMS Current	(A)	2	
Resistance	(Ω)	1.322	
Inductance	(H)	0.044	
Disipated Power	(W)	5.3	
Cooling		AIR	
Temperature Rise	(°C)	8	
Turns		240	
Integrated Field	T.m	0.052	
Nominal Field	T	0.149	



Vertical Bending Magnet (BV2)

Parameter	Units	
Type of Magnet		window frame
Number of Magnets		1 + 1 spare
Overall Height	(mm)	842
Overall Width	(mm)	696
Overall Length	(mm)	1080
Iron Length	(mm)	880
Aperture [H x W]	(mm)	144 x 120
Mass	(kg)	921
Operation		Cycled DC
Nominal Current	(A)	391
RMS Current	(A)	138
Resistance	(Ω)	0.24
Inductance	(H)	0.064
Disipated Power	(kW)	4.6
Cooling		Water
Pressure Drop	(bar)	11
Water Flow	(l/min)	3
Temperature Rise	(°C)	22
Turns		168
Integrated Field	T.m	0.69
Nominal Field	T	0.69