PSB Upgrade
LIU Project

Shorter PSB Main Dipoles Magnet Design

A. Newborough

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Shorter PSB main Dipoles

Outline

Review of requested length reductions

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0.25 m reduction - Injection magnet design (BHZ162)

- Magnetic circuit design
- Coil design

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Operation

- Trim supplies (missing NI)
- Further length reduction (time constant reduction)

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Summary

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Questions

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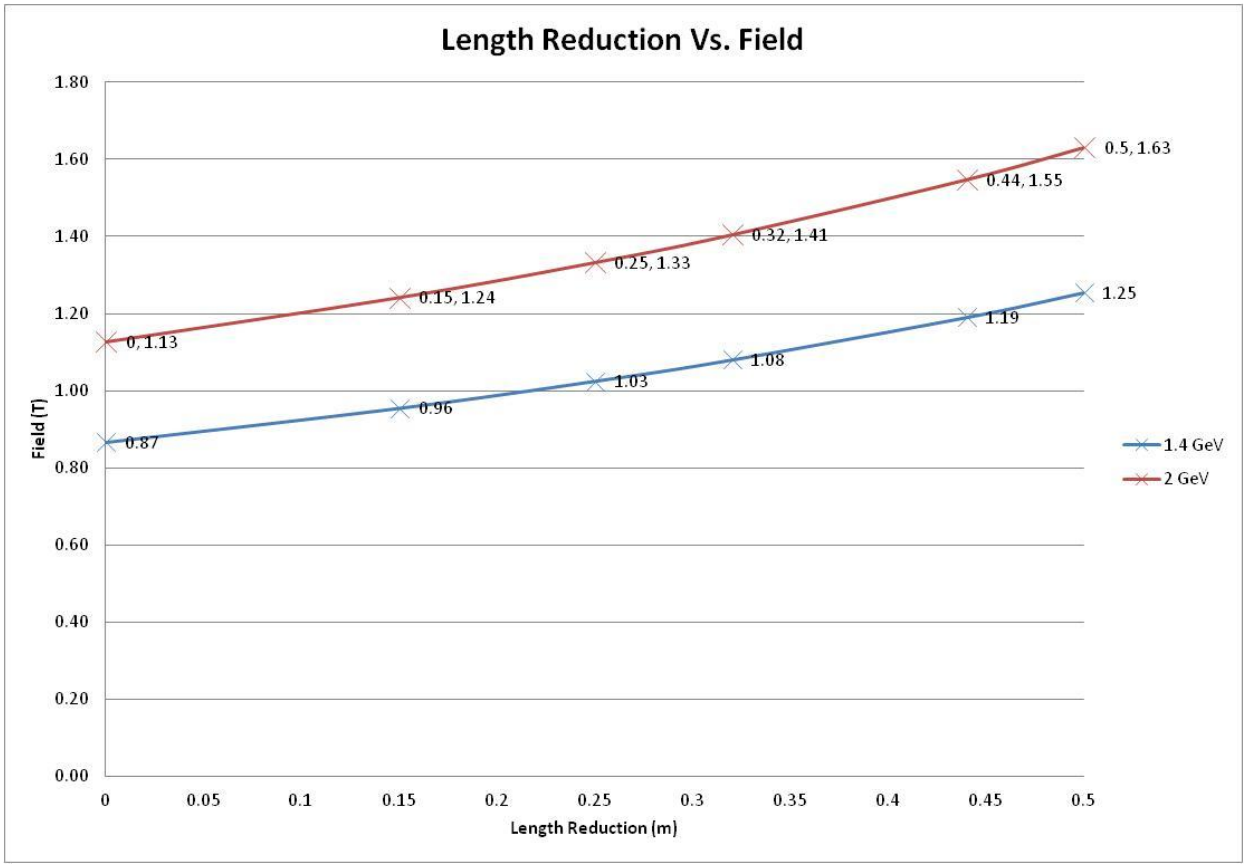
Possible length reductions



- ~~0.15 m – Installation of vacuum valves~~ (Difficult to justify, another solution exists)
- ~~0.5 m – Maximum requested~~ (Too high field!)
- 0.25 m - Half maximum requested, if magnets centres could be off-set (Preferred solution)
- ~~0.44 m to allow for external dump~~ (fits with magnet centre off-set, 0.25 m reduction)
- 0.32 m comfortable limit? (Advantages of being even shorter?)

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0.25 m reduction - Injection magnet design (BHZ162)

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0.25 m reduction - Injection magnet design (BHZ162)

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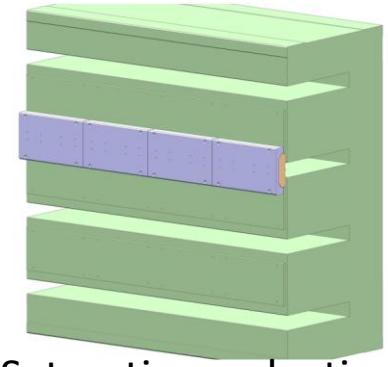
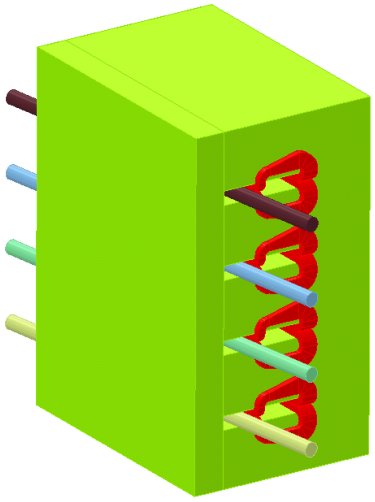
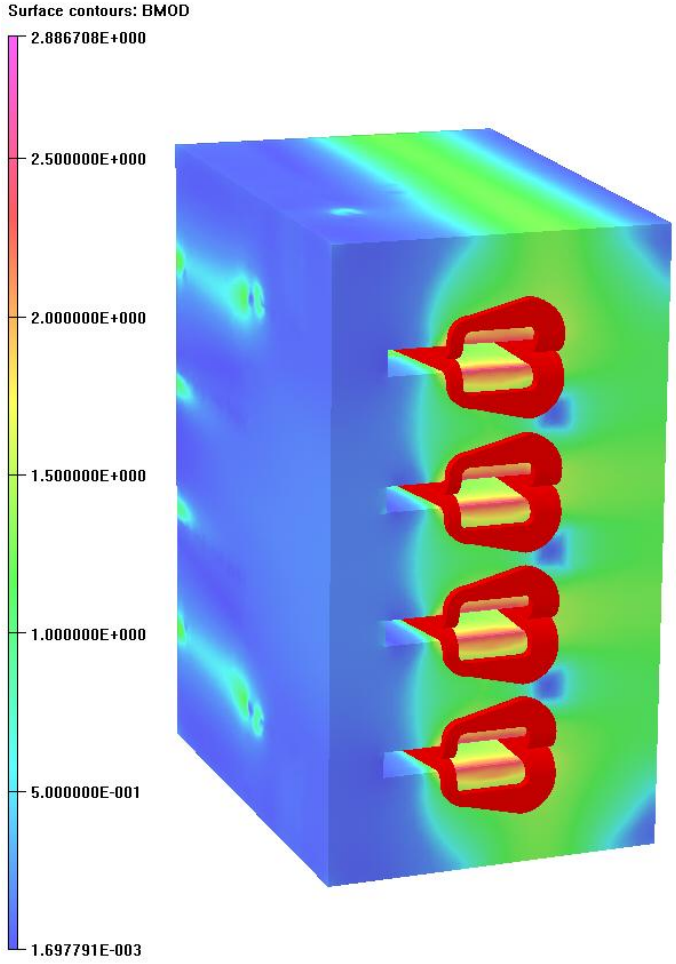
		Now 2 GeV	0.25 m shorter 2 GeV
Iron Length	m	1.537	1.287
Magnetic Length	m	1.612	1.368
gap	m	0.07	0.07
Length reduction	m	0	0.25
Magnetic Field, B	T	1.127	1.333
Integrated Field, BDL	T.m	1.824	1.824
Number of Turns	#	12	14
Peak Current (Mains)	A	5200	5200
Missing Current for N + Saturation (trim)	A	1-4%*	105 (2%)
RMS Current	A	2500	2500
Total Resistance	Ohms	0.023	0.030
Total Power	kW	141.3	187.5
* Depending on the saturation reduction			



Saturation reduction on ring magnets planned for 2 GeV operation





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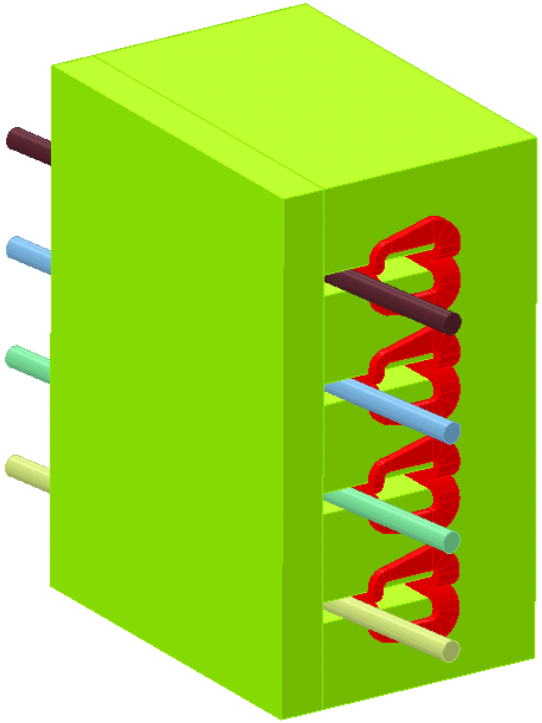
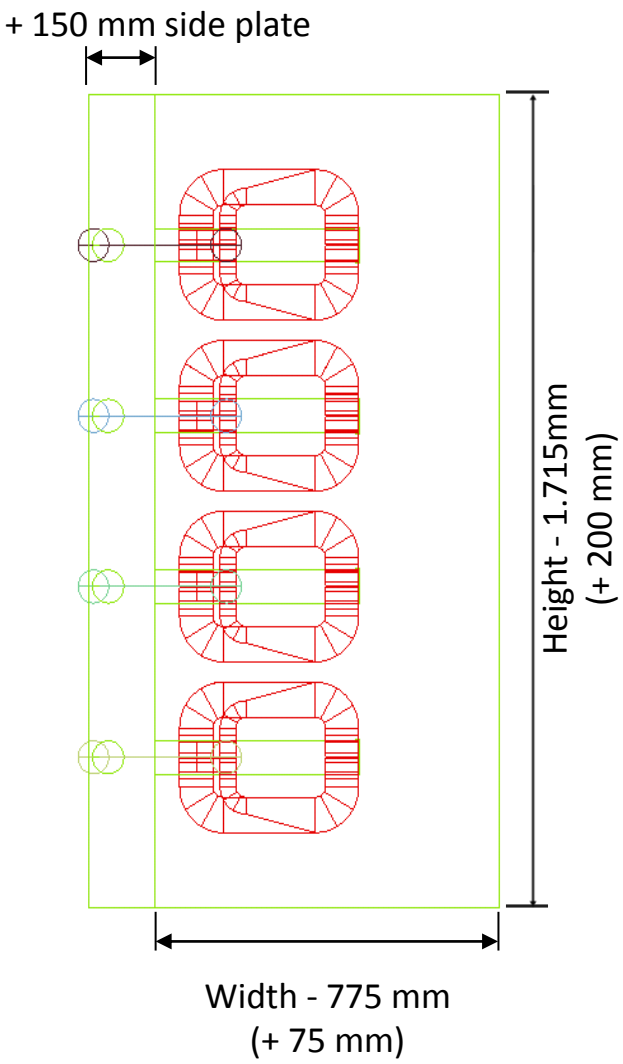
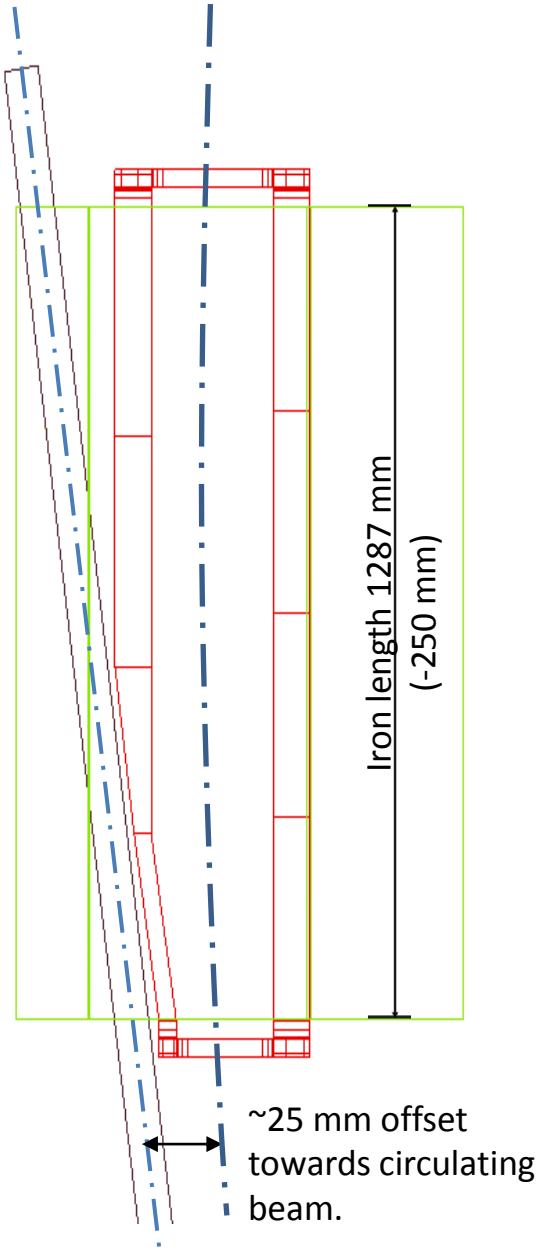
Magnetic circuit design







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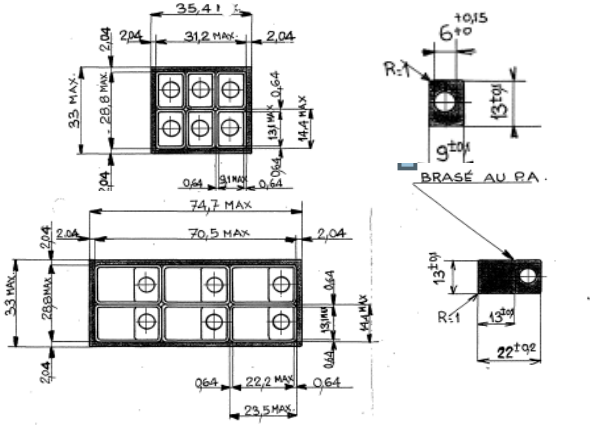
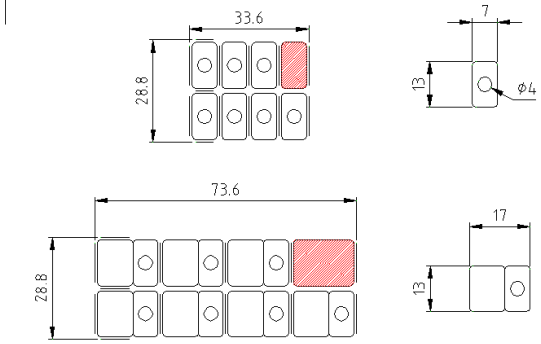
Coil design

Now - 12 turns (2 x 6)

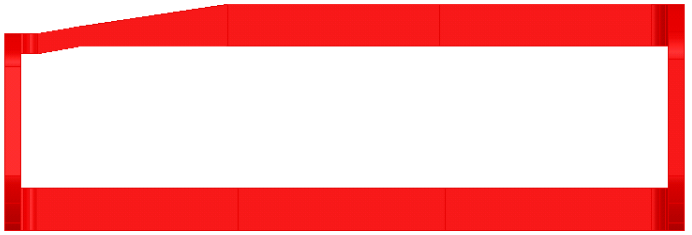


Short - 14 turns (2 x7)



		Now 2 GeV	0.25 m shorter 2 GeV
Number of turns	#	12	14
Peak current (Mains)	A	5200	5200
Missing current for N + saturation (trim)	A		105
RMS current	A	2500	2500
Number of coils per gap	#	2	2
Resistance per gap	Ohms	0.006	0.008
Total resistance	Ohms	0.023	0.030
Power per gap	kW	35	47
Total power	kW	141.3	187.5
Number of cooling circuits per gap	#	2	7
Required cooling flow per gap	L/min	16.8	22.4
Total cooling flow	L/min	67.2	89.6
Pressure drop	bar	11	5.6
Current density (hollow conductor only)	A/mm	28.5	32.2
Current density (+solid)	A/mm	9.8	12.1
Cooling channel diameter	mm	6	4
Temperature rise	°C	30	30
Water velocity	m/s	4.96	4.25

As today the BHZ 162 will require a special coil design with hollow and solid conductor combined, ~10 mm more space is available.



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Operation

		Now 2 GeV	0.25 m shorter 2 GeV
Iron length	m	1.54	1.29
Magnetic length	m	1.61	1.37
Gap	m	0.07	0.07
Length reduction	m	0	0.25
Magnetic field, B	T	1.127	1.333
Integrated field, BDL	T.m	1.824	1.824
Number of turns	#	12	14
Peak current (Mains)	A	5200	5200
Missing current for N + saturation (trim)	A		105
RMS current	A	2500	2500
Total resistance	Ohms	0.023	0.030
Total power	kW	141.3	187.9
Total cooling flow	L/min	67.2	89.6
Pressure drop	bar	11	5.6
Temperature rise	°C	30	30
Water velocity	m/s	4.96	4.25

- The required number of turns for a reduction of 250 mm is 14.3
- The missing current (~2%) can be supplied by trim supplies (2 per magnet – inner and outer gaps)
- The trim supplies will allow the integrated field to be matched to the other ring magnets
- It will be desirable that the time constant of the shorter dipole is smaller than the existing magnets (trims can slow the field but not speed it up!)
- Characterization / field tracking maybe possible with a spare BHZ magnet before installation avoiding the need for a dedicated online measurement

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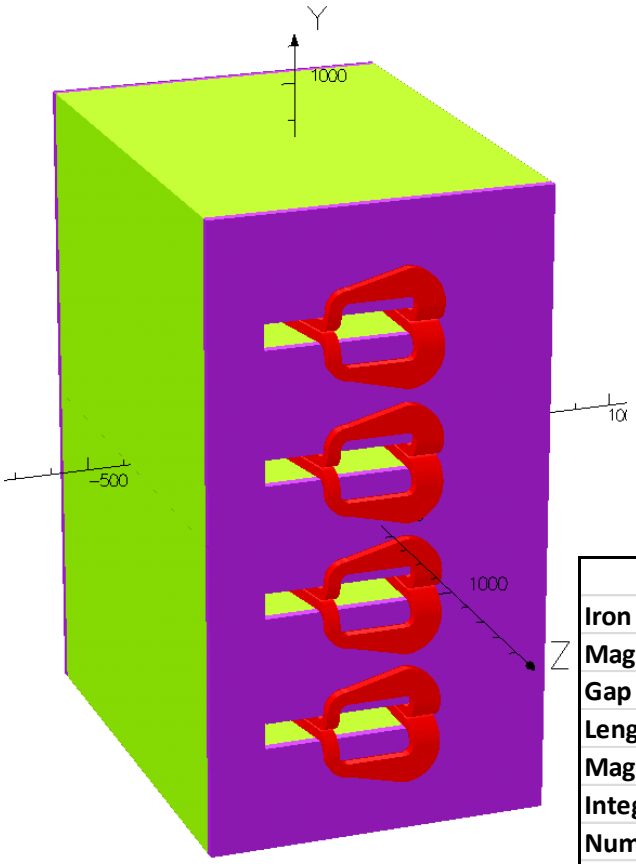
Operation

Advantages of being even shorter?



- If the currently magnetic end plates of 25 mm in thickness are changed to a non magnetic stainless steel, it will be possible to reduce the eddy current effects and thus minimise the time constant of the magnet.
- The mechanical reduction will remain at 250 mm, however the magnetic length will be reduced.
- This additional reduction in magnetic length increases the required trim current from 2 to 6%, due to a greater mismatch in the required number of turns (14.3 to 14.8). This increase may allow more flexibility to match the integrated field in the existing magnets, but power supply costs will increase.
- The increase in field due to the further reduction in magnetic length still remains within comfortable limits.

		Now 2 GeV	0.25 m shorter 2 GeV	0.3 m shorter 2 GeV
Iron length	**m**	1.54	1.29	1.24
Magnetic length	**m**	1.61	1.37	1.32
Gap	**m**	0.07	0.07	0.07
Length reduction	**m**	0	0.25	0.30
Magnetic field, B	**T**	1.127	1.333	1.384
Integrated field, BDL	**T.m**	1.824	1.824	1.824
Number of turns	**#**	12	14	14
Peak current (Mains)	**A**	5200	5200	5200
Missing current for N + saturation (trim)	**A**		105	306

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Summary

- Shorter main bending magnets seem feasible. Two designs will be required with different coil arrangements between the BHZ162 and BHZ11 due to the injection chamber passing through the yoke.

- Higher field levels will dictate an increase of ~200 mm in height, ~75 mm return yoke (interior), ~150 mm return yoke (exterior side plate) to minimise saturation.

- Trim supplies to compensate for missing turns will be required, depending on the design of the magnet they must deliver between 2 and 6 % of the required current. The trim supplies will match the integrated fields in the shorter magnets to the existing ring magnets. Two supplies per magnet will be required, one for the inner rings and one for the outer rings.

- The characterization of the shorter magnets and field tracking with the old magnets can be made before installation. An online measurement may be necessary for operation – further study is needed.

- The two shorter magnets will increase the total load (resistance/inductance) of the PSB main circuit by up to 5 %.

- The cost for the magnets is estimated at 1 MCHF for 2 units plus 2 spares (the cost of cabling, power supplies, controls etc… is not included), design and fabrication is at least 2 years.