PSB BHZ Main magnets and the required trims

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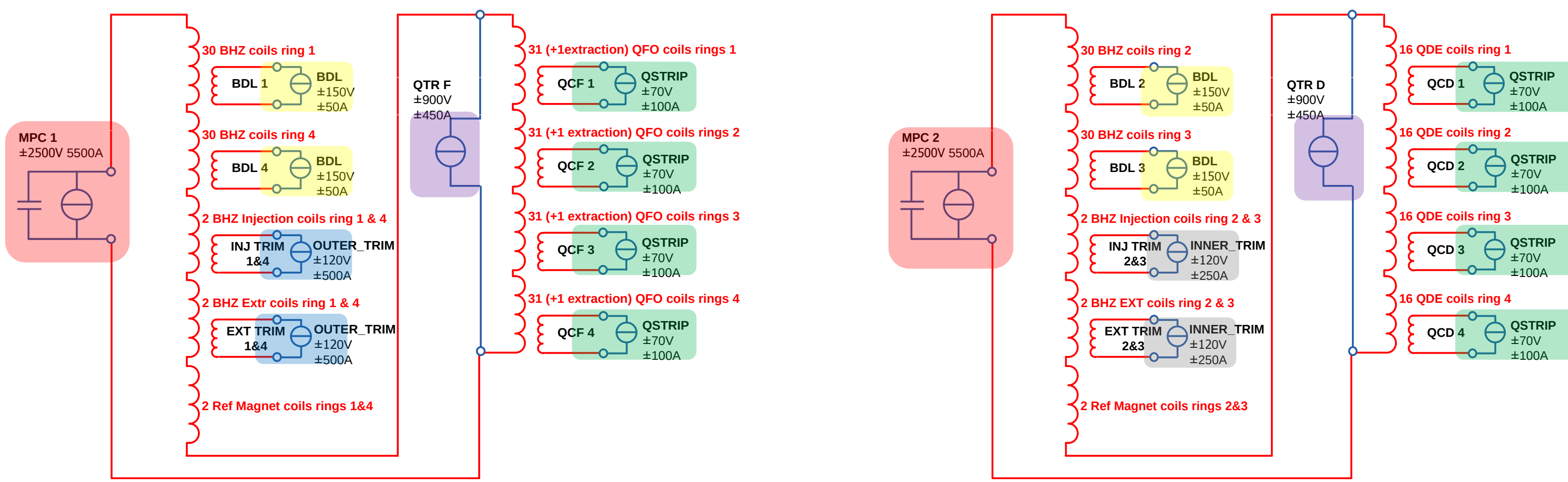
Introduction

The Main magnets will be split and powered by two MPC:

- BHZ Outer (30 x BHZ 1+4, 1 x BHZ INJ 1+4, 1 x BHZ EXT 1+4) and 32 QF all in series
- BHZ Inner (30 x BHZ 2+3, 1 x BHZ INJ 2+3, 1 x BHZ EXT 2+3) and 16 QD all in series

The MPC will drive the currents in the main bending to correct field compensating the differences between BHZ Outer (1+4) and BHZ (Inner) 2+3 due mainly to saturation.

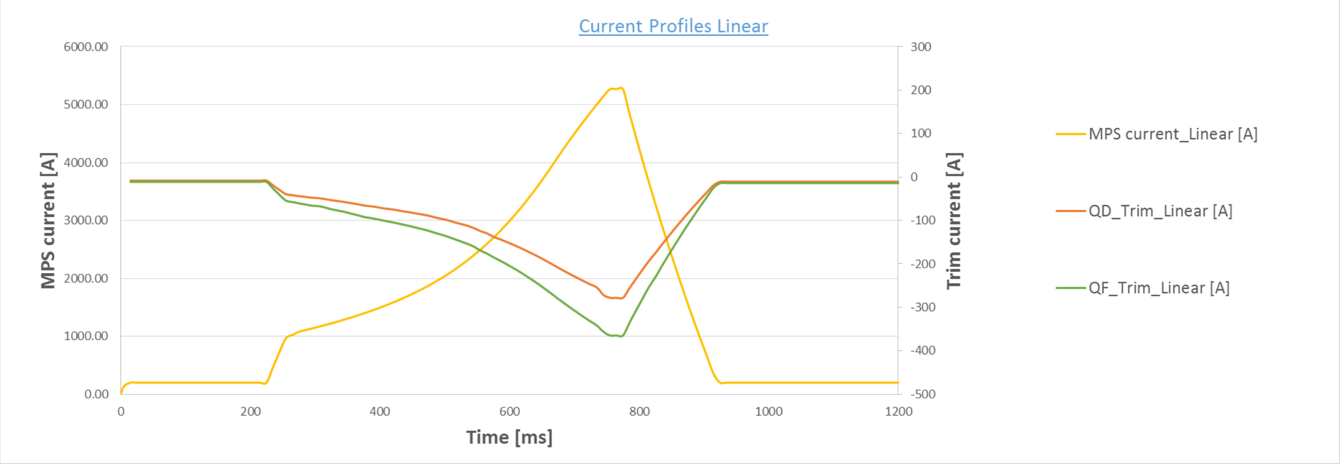
Parallel trim converters act on the QF and QD magnets to achieve the correct gradients, while isolated trim converters will compensate for differences between the two BHZ INJ & EXT magnets.
The BDL and QSTRIP trim converters compensate for differences between rings.



Images courtesy of F. Boattini

Starting Point

- Currents extracted from 2 GeV cycle provided by A. Blas, courtesy of J.L. Sanchez Alvarez
- Not necessarily the worst case in terms of ramp rates but matches for peak currents



Does not take into account separate powering of the inner and outer gaps and saturation!

Magnet / Circuit	Integrated Field / Gradient	MPS or TRIM Current
Bending Inner Outer	1.824 Tm	5268 A
QF	6.758 T/m	Bending -365 A
QD	-6.841 T/m	Bending -278 A

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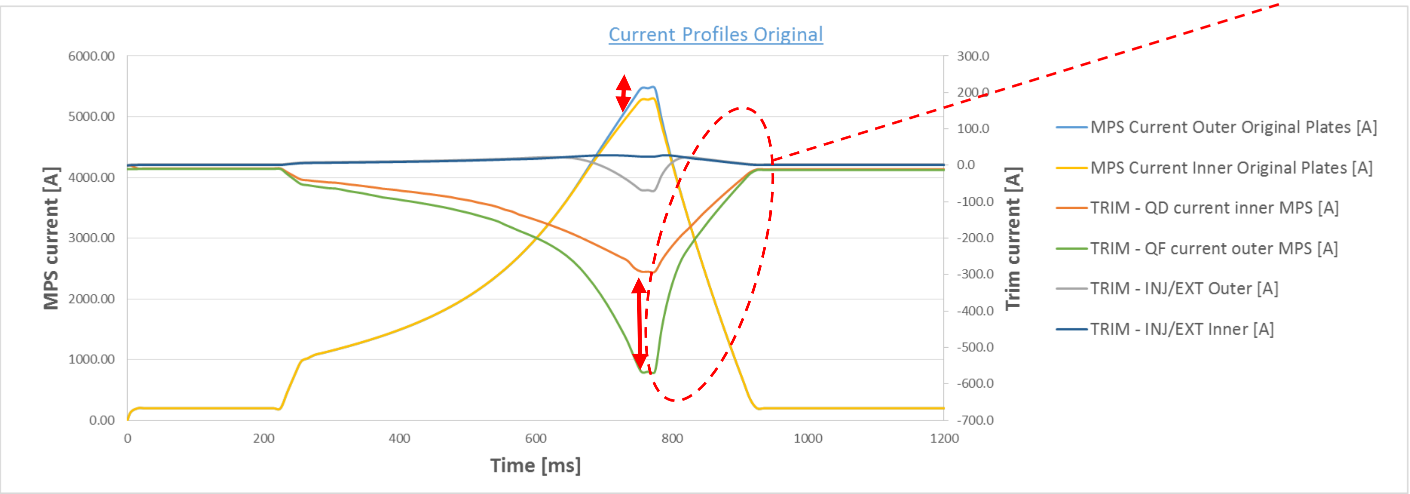
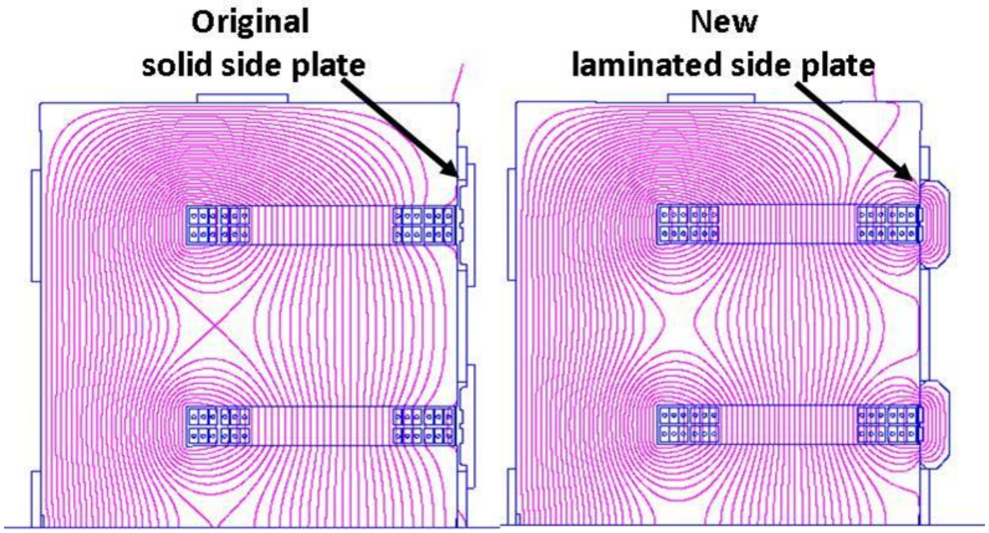
Current Situation going to 2 GeV (no modifications to the BHZ main magnets)

The trims could go to zero faster, but the change in rms would be rather small (with high DI/DT!)



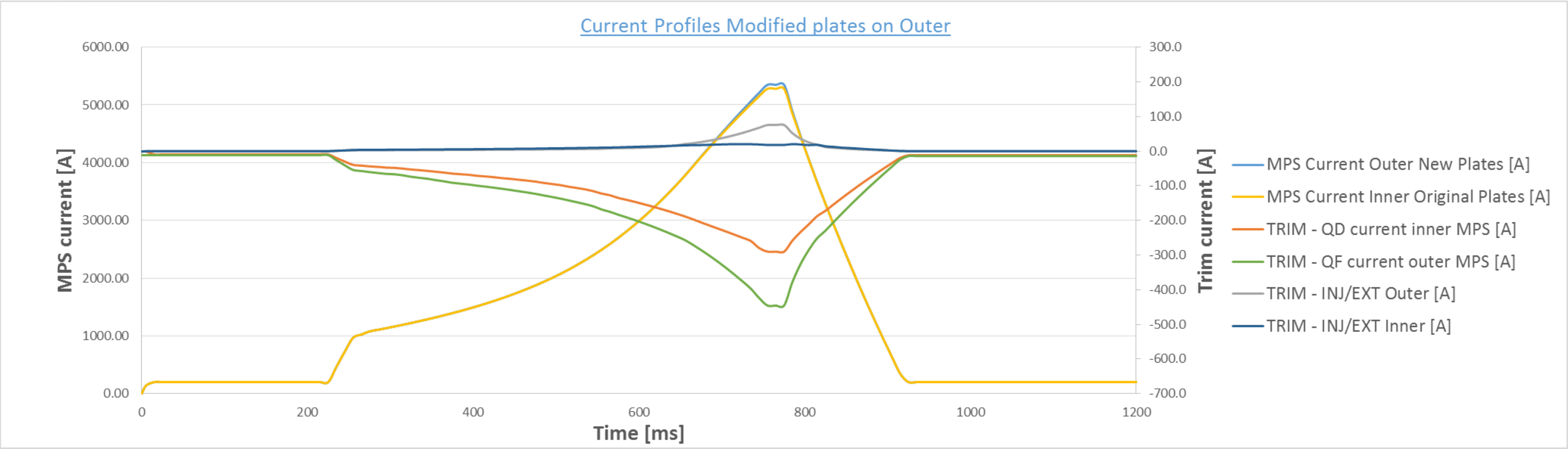
Magnet / Circuit	Integrated Field / Gradient	MPS or TRIM Current
Bending Outer	1.824 Tm	5470 A
Bending Inner	1.824 Tm	5282 A
QF	6.758 T/m	Bending Outer -567 A
QD	-6.841 T/m	Bending Inner -292 A
INJ/EXT Outer	1.824 Tm	Bending Outer +18 to -45 A
INJ/EXT Inner	1.824 Tm	Bending Inner +16 A

Future Situation going to 2 GeV
(With laminated side plates on the BHZ outer gaps)



The measurement campaign has shown the introduction of the laminated side plates on the outer gaps will minimise the differences between the inner and outer rings as well as minimise the QF trim requirement.

Future Situation going to 2 GeV
(With laminated side plates on the BHZ outer gaps)



Magnet / Circuit	Integrated Field / Gradient	MPS or TRIM Current
Bending Outer	1.824 Tm	5350 A
Bending Inner	1.824 Tm	5280 A
QF	6.758 T/m	Bending Outer -446 A
QD	-6.841 T/m	Bending Inner -290 A
INJ/EXT Outer	1.824 Tm	Bending Outer +75 A
INJ/EXT Inner	1.824 Tm	Bending Inner + 18 A

Margin for the QF and QD?
(With laminated side plates on the BHZ outer gaps)

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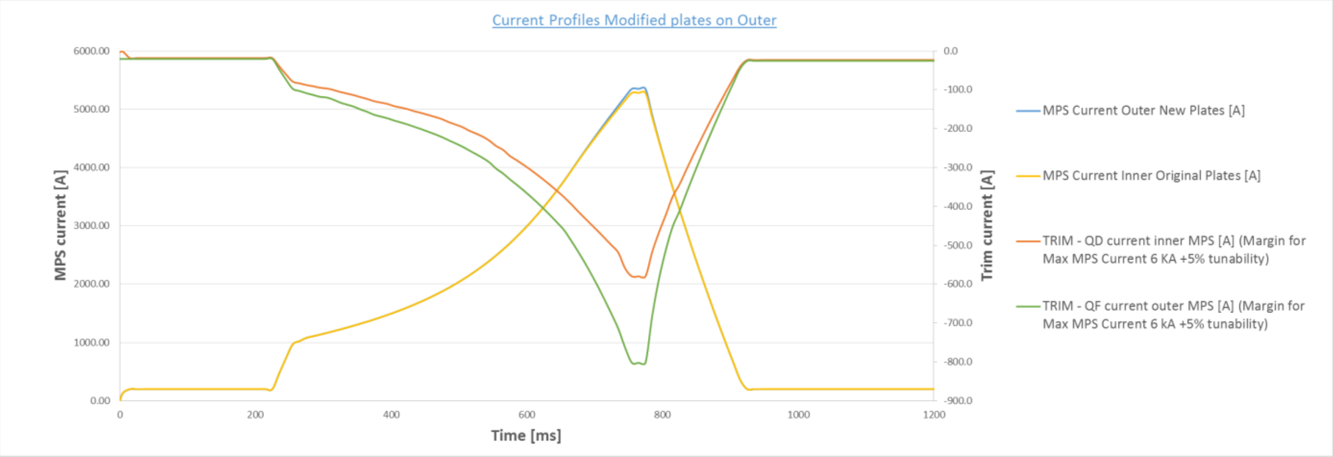

To be discussed!

- Margin to be determined on the MPS current?
  - Allowing for using the full 6 kA + 5% tunability?
- Any saturation of the quadrupoles increases margin as the trim current is removed from the MPS current

Magnet / Circuit	Integrated Field / Gradient	MPS or TRIM Current [Margin 6kA + 5%]
Bending Outer	1.824 Tm [2.022 Tm]	5350 A [6000 A]
Bending Inner	1.824 Tm [2.022 Tm]	5280 A [5883 A]
QF	6.758 T/m [7.20 T/m]	Bending Outer -446 A [-802 A]
	RMS current	160 A [288 A]
QD	-6.841 T/m [-7.29 T/m]	Bending Inner -290 A [-580 A]
	RMS current	112 A [223 A]

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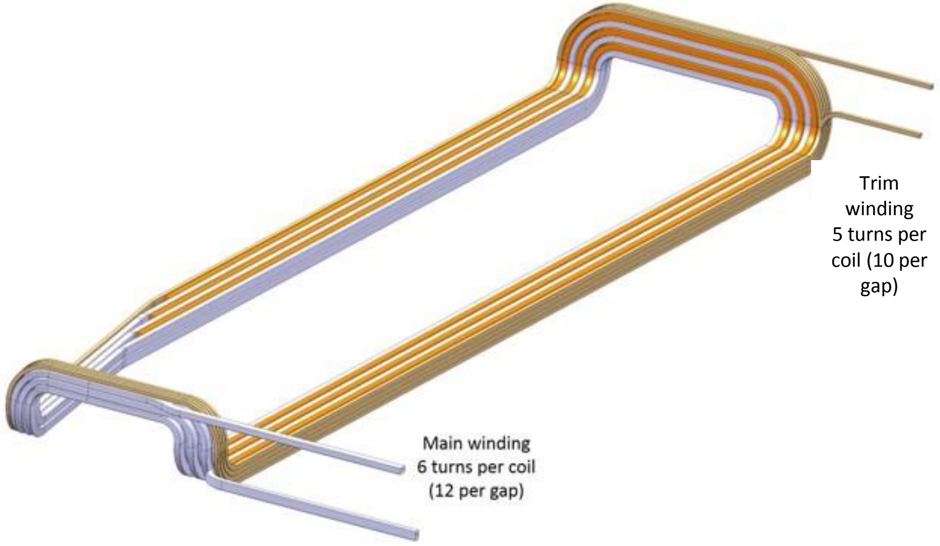
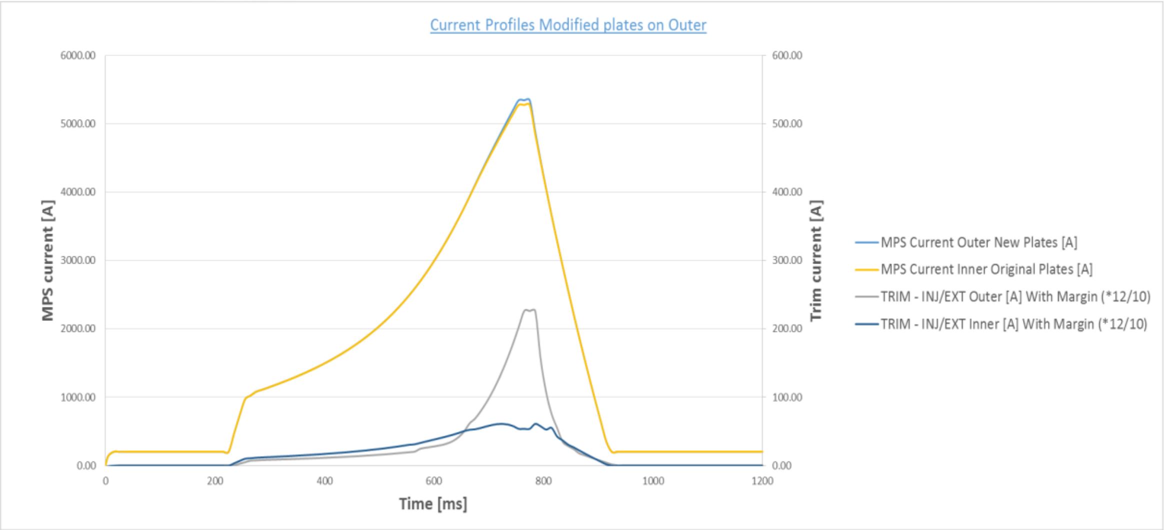
BHZ Main INJ/EXT magnets (Original side plates)

- Two new magnets are to be built, one for each of the INJ & EXT regions.
- The new magnets will include new coils with trim windings to compensate for differences already seen at 1.4 GeV which will become worse at 2 GeV.
- The existing magnets once removed will be fitted with the new coils to act as dedicated spares.
- The magnets are to be powered with pairs of apertures connected in series:
    - INJ 1+4
    - INJ 2+3
    - EXT 1+4
    - EXT 2+3



Margin for the BHZ INJ/EXT Outer and Inner
(With laminated side plates on the BHZ main outer gaps)



To be discussed!

- A factor of 12/10 for difference between # turns on main and trim coils
- Margin to be determined by the difference in performance of the steel and field given by MPS
  - 250% request by MSC

(Seems to be a good optimisation with the space available for trim windings and an existing converter design)

- If the full MPS 6 kA was applied there may or may not be enough margin! (depends on the performance of the steel)

Magnet / Circuit	Integrated Field / Gradient	MPS or TRIM Current [Margin *12/10 *2.5]
Bending Outer	1.824 Tm	5350 A
Bending Inner	1.824 Tm	5280 A
INJ/EXT Outer	1.824 Tm	Bending Outer +75 A [+230 A]
INJ/EXT Inner	1.824 Tm	Bending Inner +18 A [+60 A]

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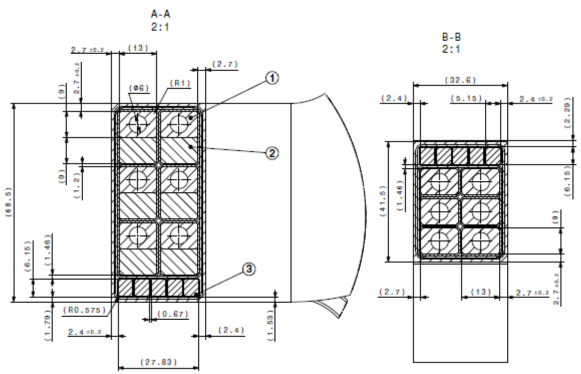
INJ/EXT TRIM COIL DESIGN

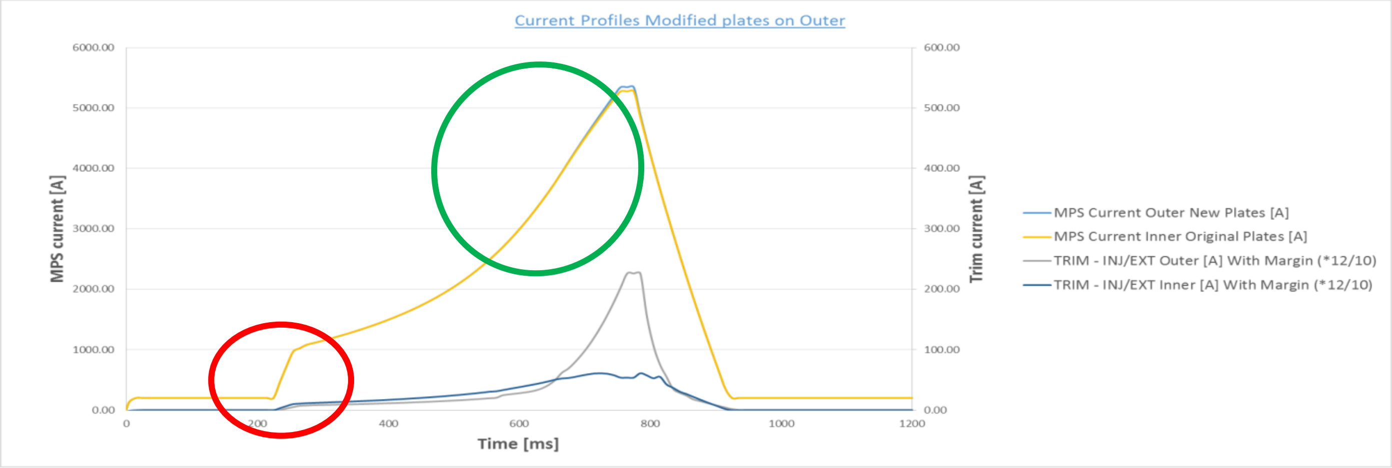


Coil design by E. Solodko

TRIM windings	INJ/EXT Inner *2	INJ/EXT Outer *2
Turns per gap, #	10	10
Circuit Length per gap, m (not including cables)	~50	~50
Cooling	Indirect	Indirect
Peak Current, A (with margin * 2.5)	60	230
RMS Current, A (with margin * 2.5)	27	56
Resistance per gap at 20 DegC, mΩ	26	26
Resistive Voltage per gap, V	1.6	6.0
Inductance per gap, mH	1.0	1.0
Max DI/DT, A/s	60/0.1	230/0.1
Induced Voltage per gap, V	0.6	2.3

*2 indicates that we will have four power converters: INJ 1+4, INJ 2+3, EXT 1+4, EXT 2+3, values to be doubled for two gaps!

INJ/EXT TRIM COIL DESIGN



Coupled Voltage, V-main to V-trim	
Inductance MAIN, mH	1.3
CASE 1: Main DI/DT, A/s	3350/0.26
CASE 1: Main induced voltage, V	17
CASE 1: V-main (12 turns) to V-trim (10 turns), V	14
CASE 2: Main DI/DT, A/s	760/0.03
CASE 2: Main induced voltage, V	33
CASE 2: V-main (12 turns) to V-trim (10 turns), V	27.5

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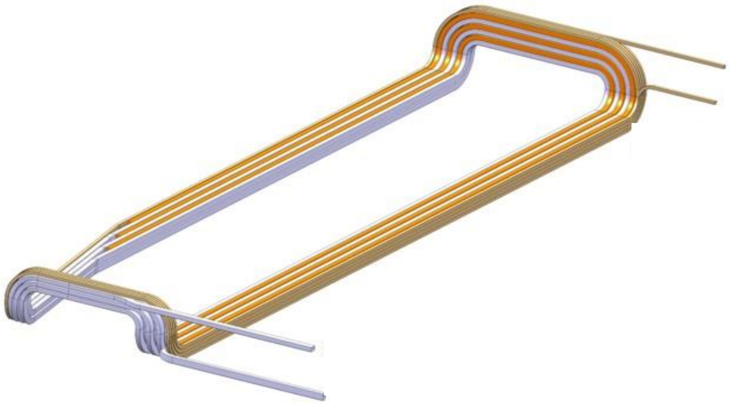
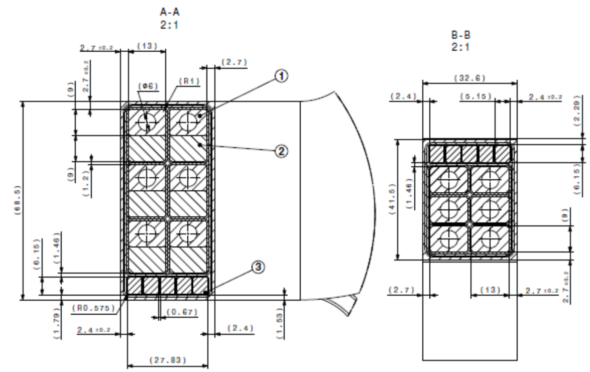
INJ/EXT TRIM COIL DESIGN and converter requirements





TRIM windings	INJ/EXT Inner	INJ/EXT Outer
# of converters	2	2
Peak Current, A (with margin * 2.5)	60	230
Resistance per circuit, 50 Deg C (not including cables), mΩ	60	60
Resistive Voltage per circuit, V	3.6	13.8
Inductance per circuit (not including cables), mH	2.0	2.0
Induced Voltage per circuit, V	1.2	4.6
Coupled Voltage per circuit, V	55	55
Total Voltage (not including cables, PC), V	60	73.4

Summary

- The proposal is to install the laminated side plates on the outer gaps of the 30 normal magnets

- Two new special magnets with additional isolated trim circuits will be produced and the existing magnets will be fitted with new coils including the trims to act as dedicated spares.
  - The requirements for the trim circuits to compensate for the differences between the magnet design and steel properties have been discussed with EPC and a solution is almost set.

- The required margin for the QF and QD trim converters needs to be determined. The option for sizing them to the 6 kA of the MPC with the possibility of 5% ‘tunability’ of the gradients has been presented but is it required and what are the cost involved?

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Questions?