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I.FAST Period 2 Review – Task 11.3

Permanent Magnet Quadrupoles & Combined Function Magnets for Ultra Low-Emittance Rings

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I.FAST Period 2 Review
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WP11.3:
Permanent Magnet Quadrupoles & Combined Function Magnets for Ultra Low-Emittance Rings

Deliverables

- **D11.3** Prototype adjustable PM quadrupole and combined function magnets: *due ~~M28~~ M44 (Nov 2024)*

Milestones

- **MS31** Magnets constructed and tested: *due ~~M25~~ M44 (Nov 2024)*

- Late delivery owing to
  - increased cost of blocks → redesign of magnet
  - lack of available resources at Kyma for mechanical design

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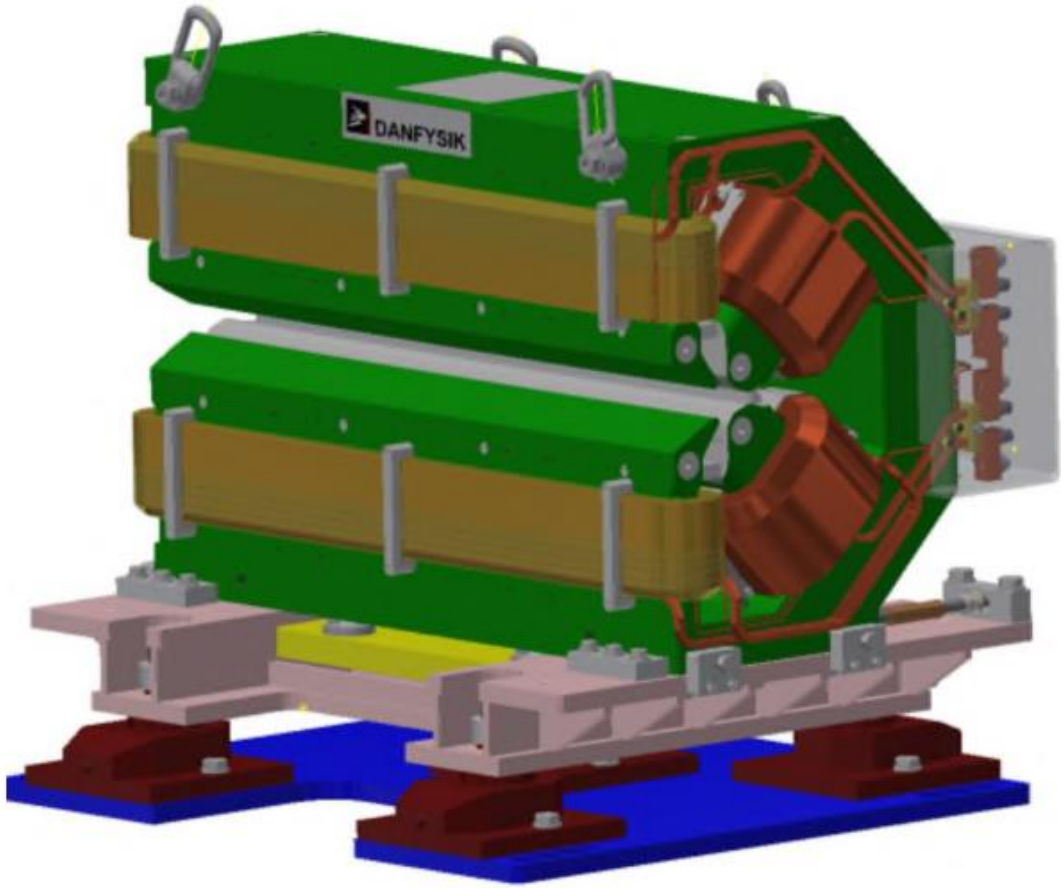
Introduction

- Fourth generation synchrotron light sources make use of multi-bend achromat lattices to reduce beam emittance and increase radiation brightness
- Lattices require combined function dipole-quadrupole (DQ) magnets
- Diamond-II upgrade will require 48 DQ magnets drawing 2.3 kW each
- Goal of WP11.3 – test if equivalent field requirements can be met by a permanent magnet based solution



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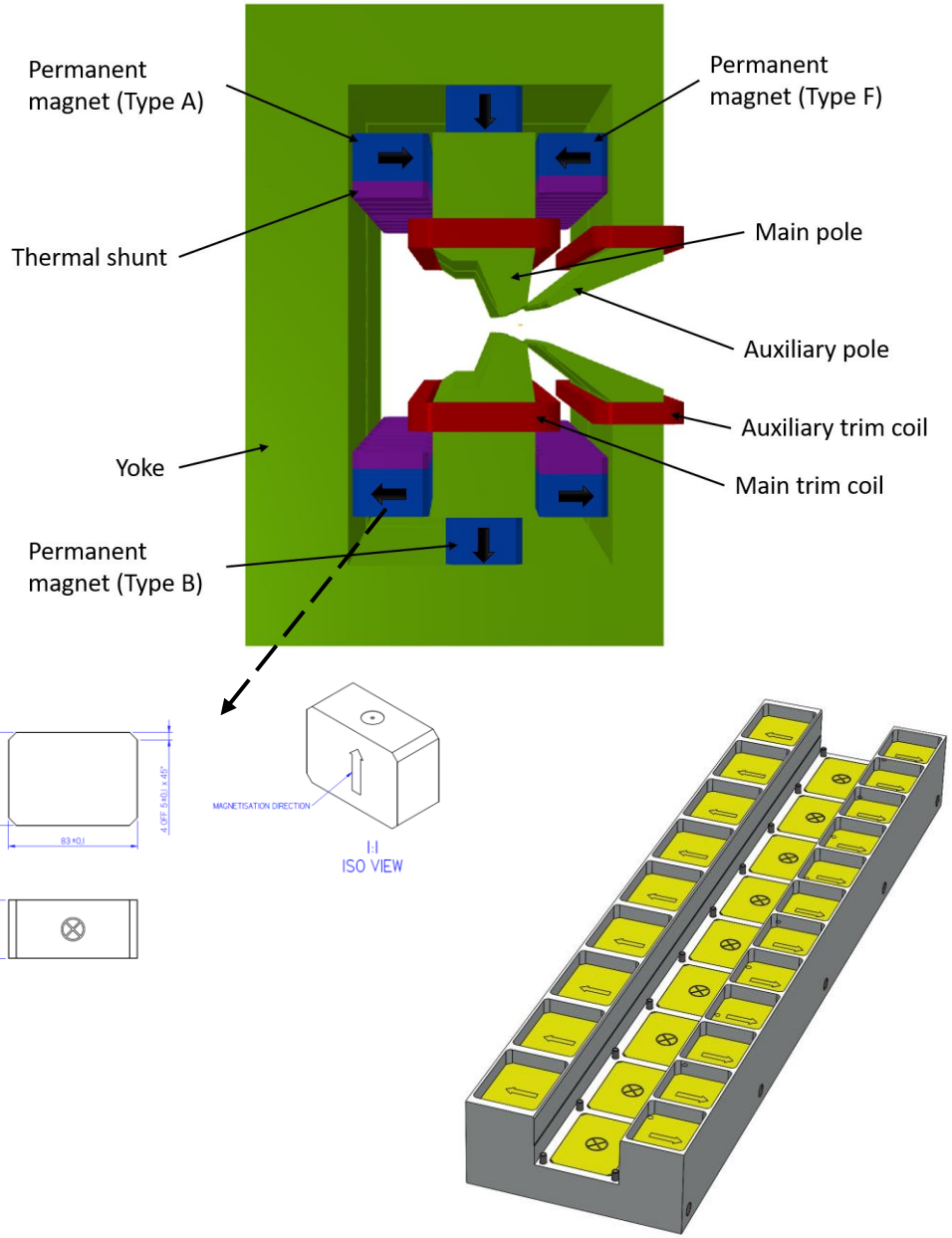
HEPTO Magnet Prototype

- Hybrid Electromagnet-Permanent Magnet Tuneable Optics (**HEPTO**) to meet same field requirements as DQ electromagnets for Diamond-II.
- Dipole **0.7 T**, Gradient **33 T/m**.
- Effective length **0.870 m**.
- Main source of field: **NdFeB** permanent magnet blocks (originally purchased for an undulator).
- Dipole and gradient fields require independent tuning of **±2.5%** for commissioning purposes.
- Field tuning achieved by **air-cooled trim coils**.
- Yoke and poles made from **XC06 low-carbon steel**.



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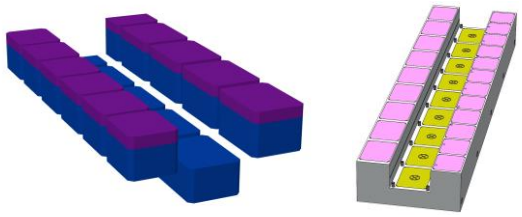
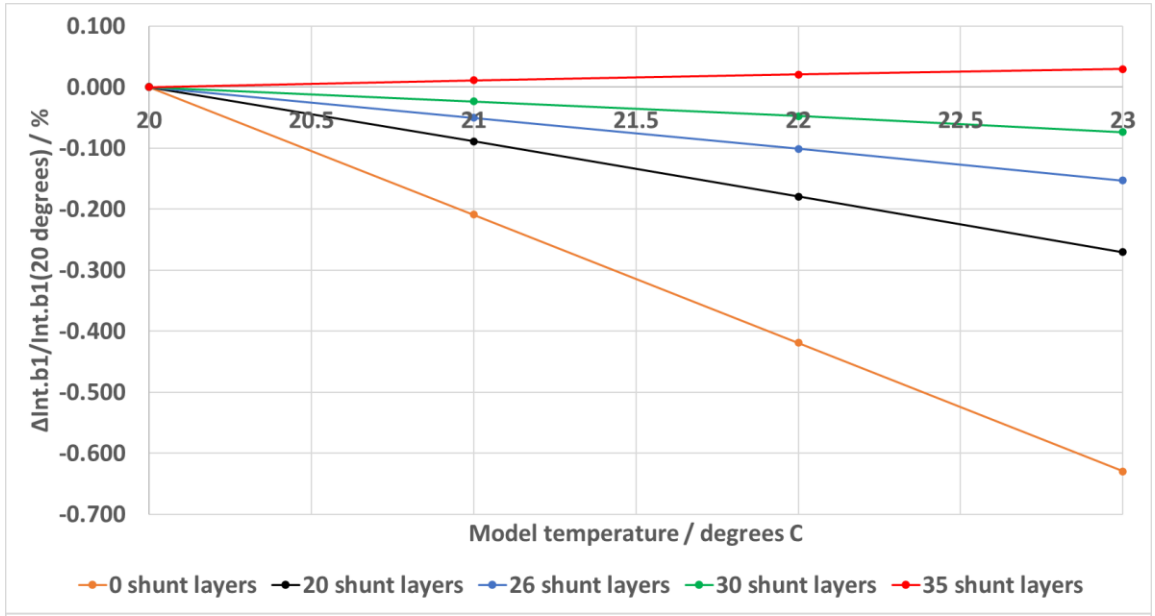
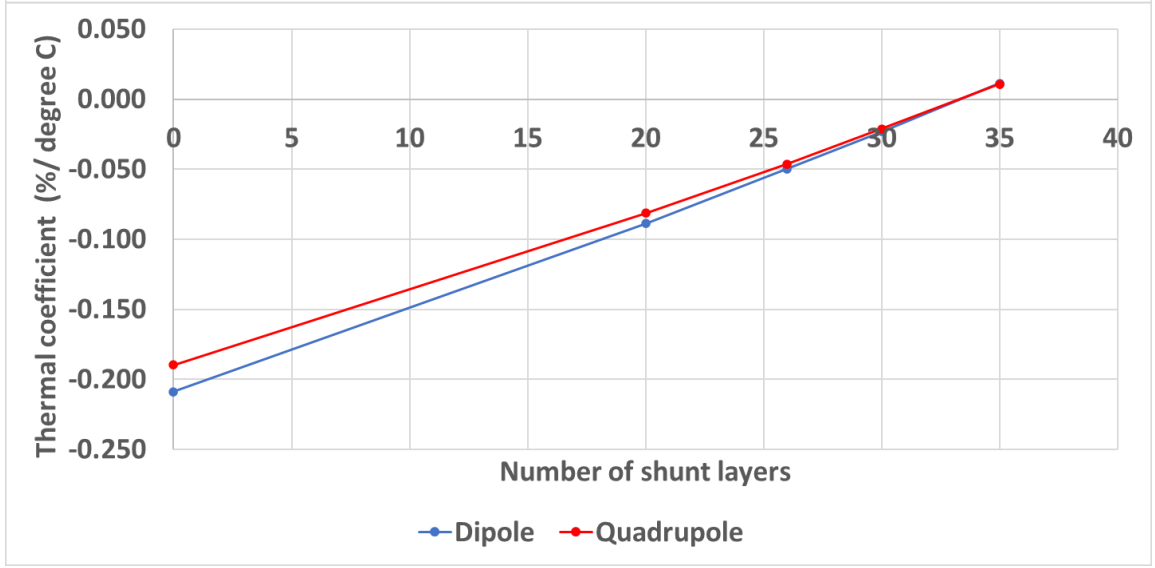
Thermal Shunts

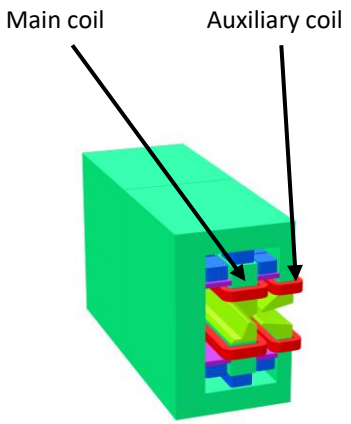
- Thermal shunt material can only be purchased from suppliers in large batches.
- Spare **FeNi** thermal shunt material purchased from Soleil (42 sheets for €1600).
- Material cut and glued to type A and F magnet blocks.
- Enough material to produce 26 layers of 0.5 mm thick sheets.
- Predicted thermal stability -0.05%/°C. 0.01% variation typical due to power supply fluctuation in electromagnets.

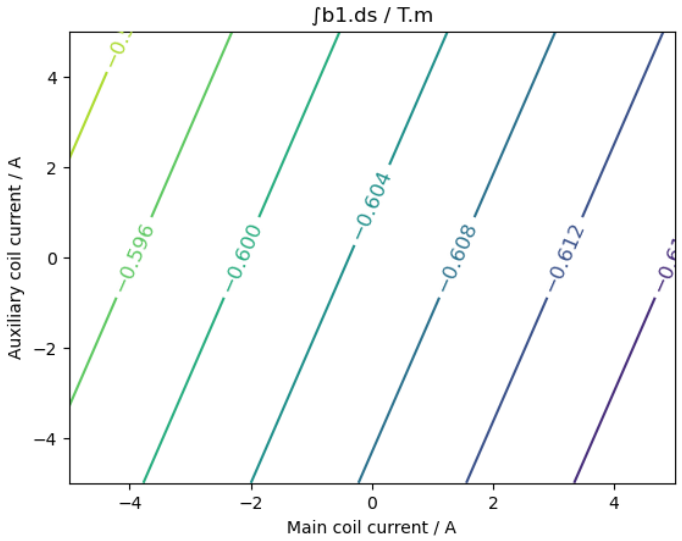


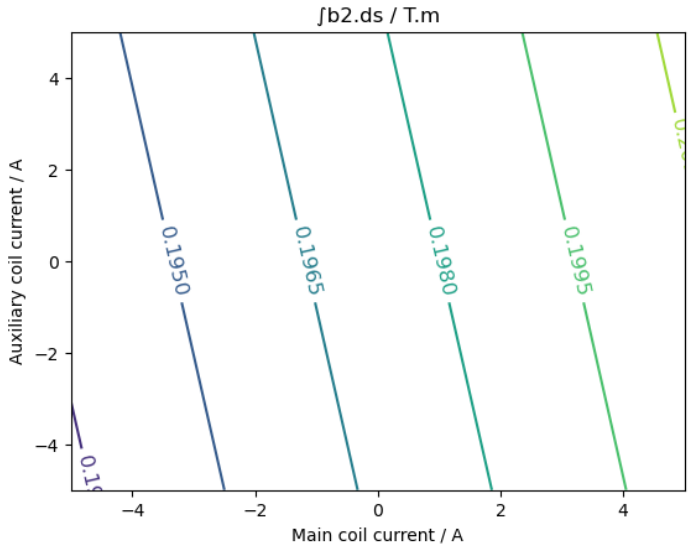


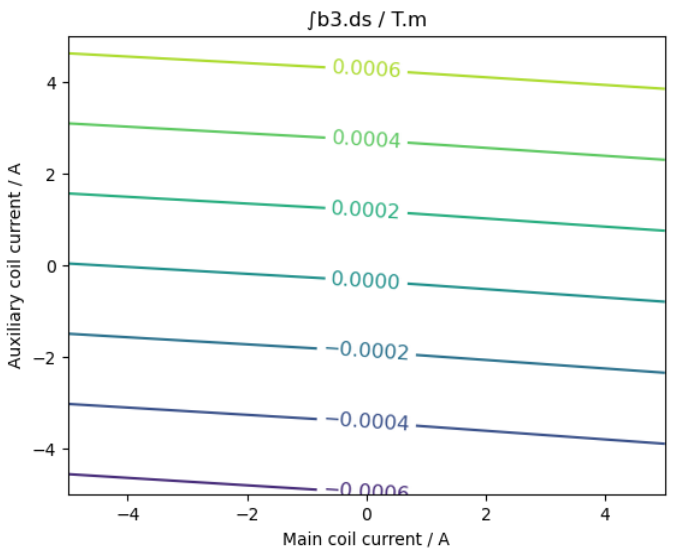


Field Tuning









Change in $\int b_1$ .ds / %	Change in $\int b_2$.ds / %	Main coil current / A	Auxiliary coil current / A
0	0	-0.05	-0.01
-2.5	0	-4.93	-1.32
+2.5	0	4.82	1.32
0	-2.5	-1.65	-0.42
0	+2.5	1.54	-0.42

Main coil turns	64
Main coil pair maximum power / W	30.6
Auxiliary coil turns	36
Auxiliary coil pair maximum power / W	16.4
Electromagnet DQ power dissipation / W	2300

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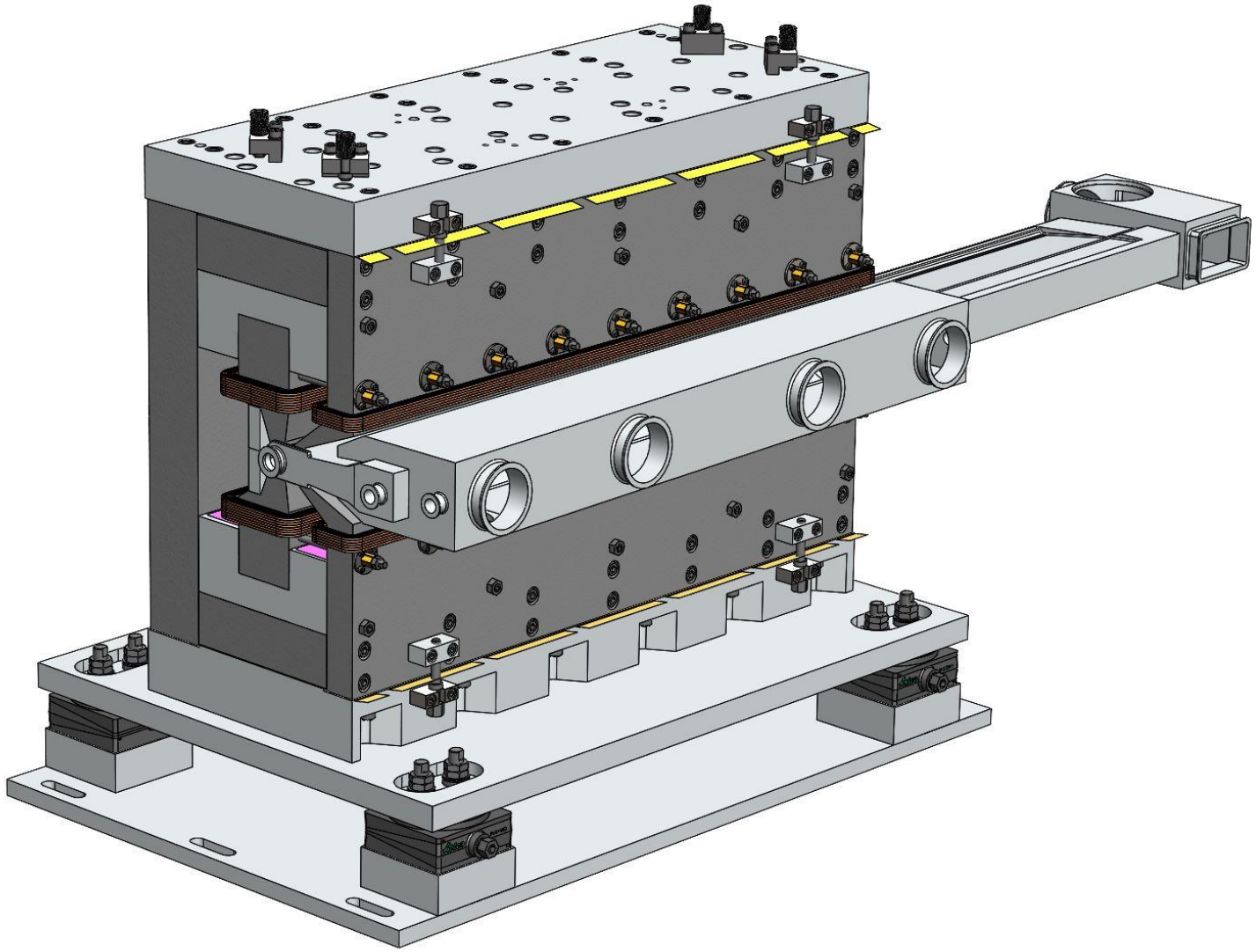
Full Mechanical Design

- Mechanical design of the prototype magnet has been completed.
- Design allows mechanical shimming of built prototype to shim field strength and quality.
- Engineering drawings have been completed.
- Procurement of mechanical components is ongoing.



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Conclusions and Future Planning

- Magnetic design of HEPTO prototype magnet using spare undulator magnet blocks is complete.
- Maximum power requirement per magnet (5 A per coil) = 50 W.
- Equivalent electromagnet requires 2.3 kW + water cooling.
- Mechanical design and drawings are complete.
- Procurement of prototype components is ongoing.
- On track to construct the prototype at Kyma by end of October 2024.
- Afterwards, magnetic measurements will be used to verify the performance of the prototype with respect to magnetic modelling at Daresbury Laboratory.

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Thank you

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