Diamond-II Magnets

Chris Bailey

Diamond-II: challenges and novel solutions for upgrading the national synchrotron light facility

Rutherford Appleton Laboratory

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diamond

Overview I

Storage ring:-

96 (4) Longitudinal Gradient Dipoles : Permanent Magnet *

48 Dipole Quadrupoles : Curved pole gradient dipoles : Trim coils *

96 (2)Anti-Bends : Offset quadrupoles to provide reverse bend : Trim Coils *

300 (5) Quadrupoles :

288 (3) Sextupoles : X & Y Correctors + Skew Quads

48 Octupoles :

12 Octupole Correctors : Different design X & Y Correctors

144 Fast Correctors: Low impedance window frame *

Also interested in the cross-talk effects particularly between dipoles and adjacent magnets.

* will talk about in more detail

(Number of Variants) There are also 1 off specially modified magnets.

Overview II

Injection Magnets

S R Kickers : Shorten & redesign to accommodate new vessels

S R Injection and Booster Extraction Septum : 2 Part

Short pulsed Thin septum *

Long Permanent Magnet Thick Septum *

Booster Injection Septum

Booster Kickers : In vac common design 1 injection 3 extraction.

SR Injection Chicane: Additional magnets of possibly one of the existing designs.

Booster

Simple Dipole BB

Combined function Dipole BD & BF *

Quadrupoles, Sextupoles, and Correctors.

DL (i)

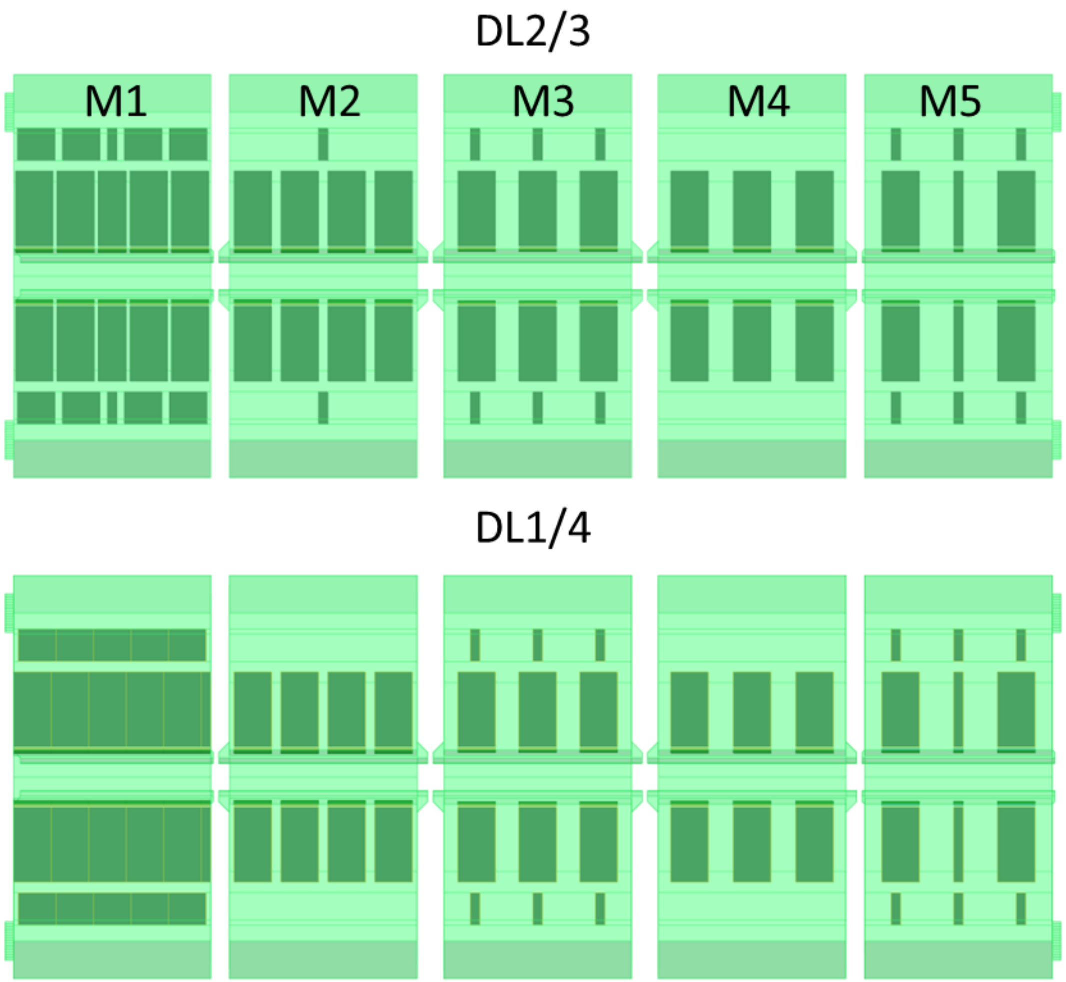
4 Version 2 different strength profiles and mirror images.

DL2/3: 0.33-0.75 T
DL1/4: 0.33-0.83 T

The yoke designs are common with small difference between the middle and end modules.

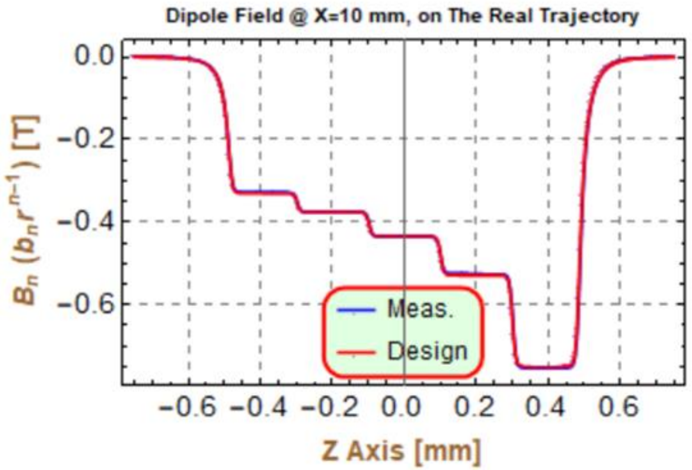
Iron yoke ~385 kg
Permanent magnet blocks
Sm2Co17 – using 2 sizes of block
~50 kg.

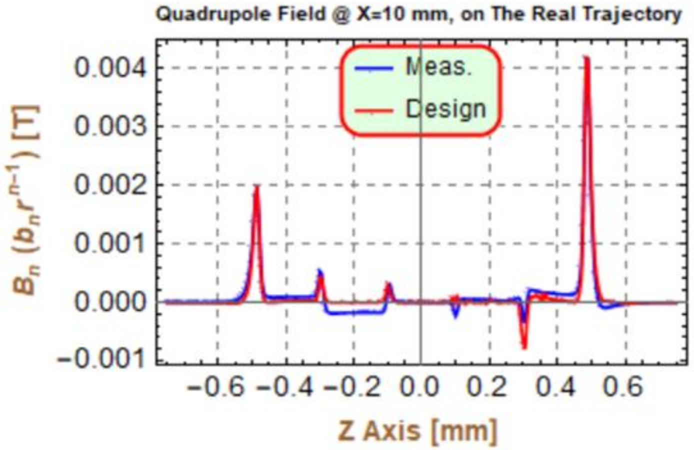
Prototype built and tested with some resulting design revisions.

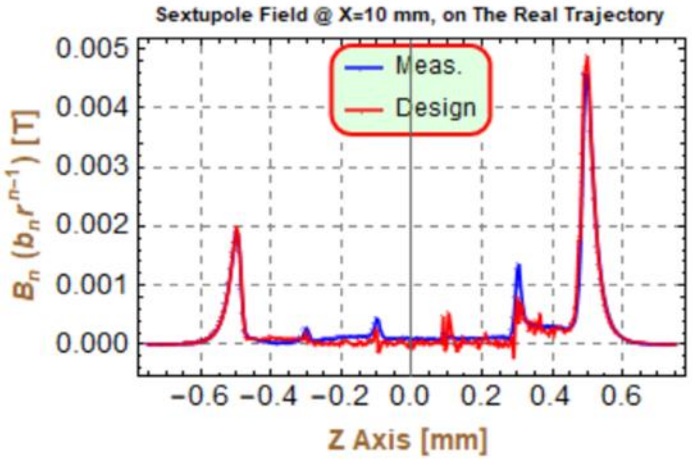


DL (ii)

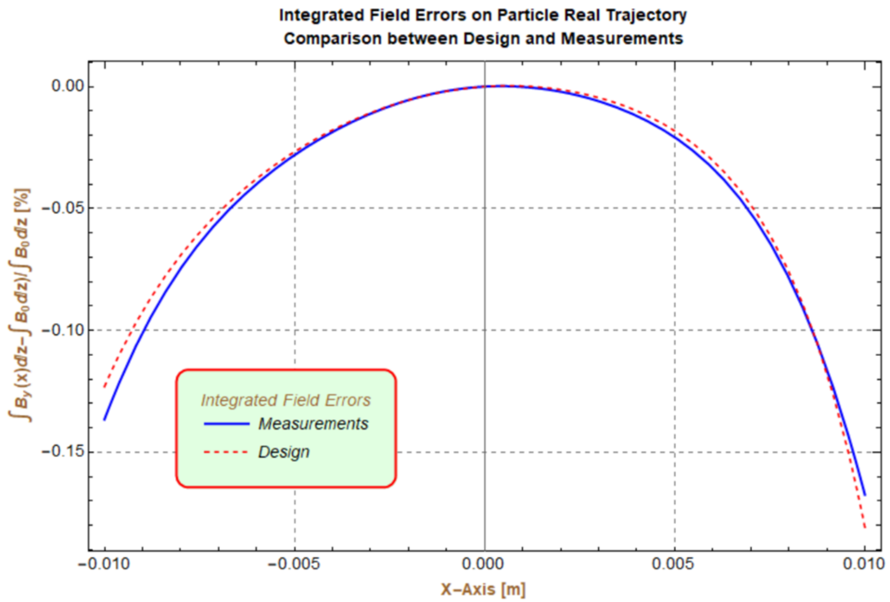
DL (iii)







	4-Pole	6-Pole	8-Pole	10-Pole	12-Pole	14-Pole	16-Pole
Model Straight(Br)	1.5	-8.7	1.4	-3.6	4.4	-4.3	0.9
Measurements(Br)	5.0	-9.0	1.7	-2.8	2.5	-3.4	2.4
Model_Trajectory	1.1	-8.4	0	-0.6	-2.9	-6.1	-1
Meas_Trajectory	0.8	-8.9	0.6	-1.9	-4.6	-4.4	1.6



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DQ (i)

Combined Dipole Quadrupole with

Central Field 0.6951 T

Central Gradient -32.97 T/m

Over ±5mm Horizontal Good field region.

Requirement for auxiliary pole to reach quality.

Practical build: Straight yoke with curved poles

Prototype built, tested and design revised as a result.

Largest magnets in Diamond II ~1200 Kg, special ~1.5 times larger…

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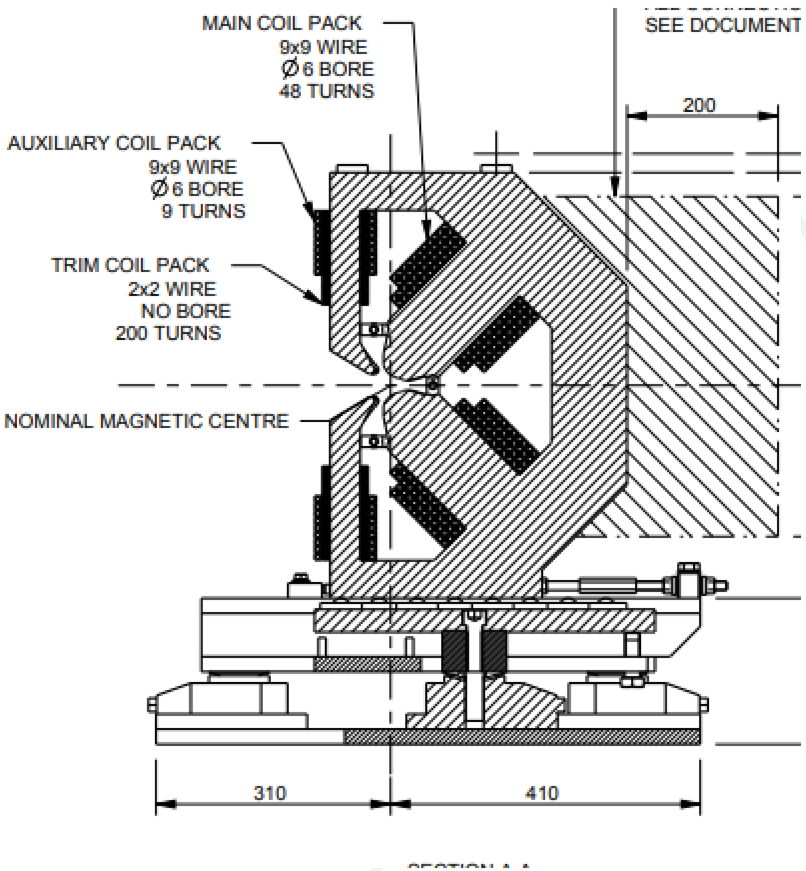
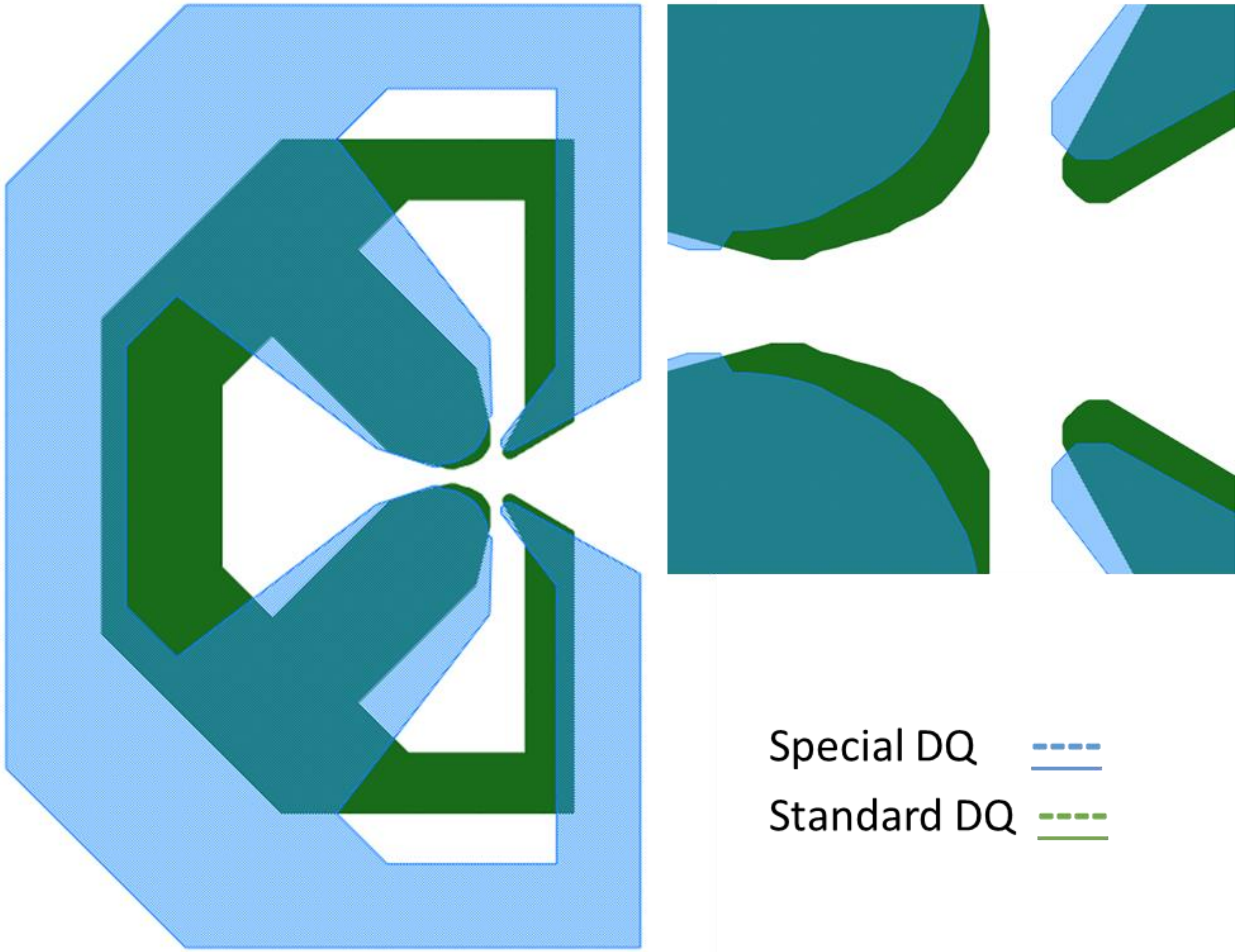
DQ (ii)

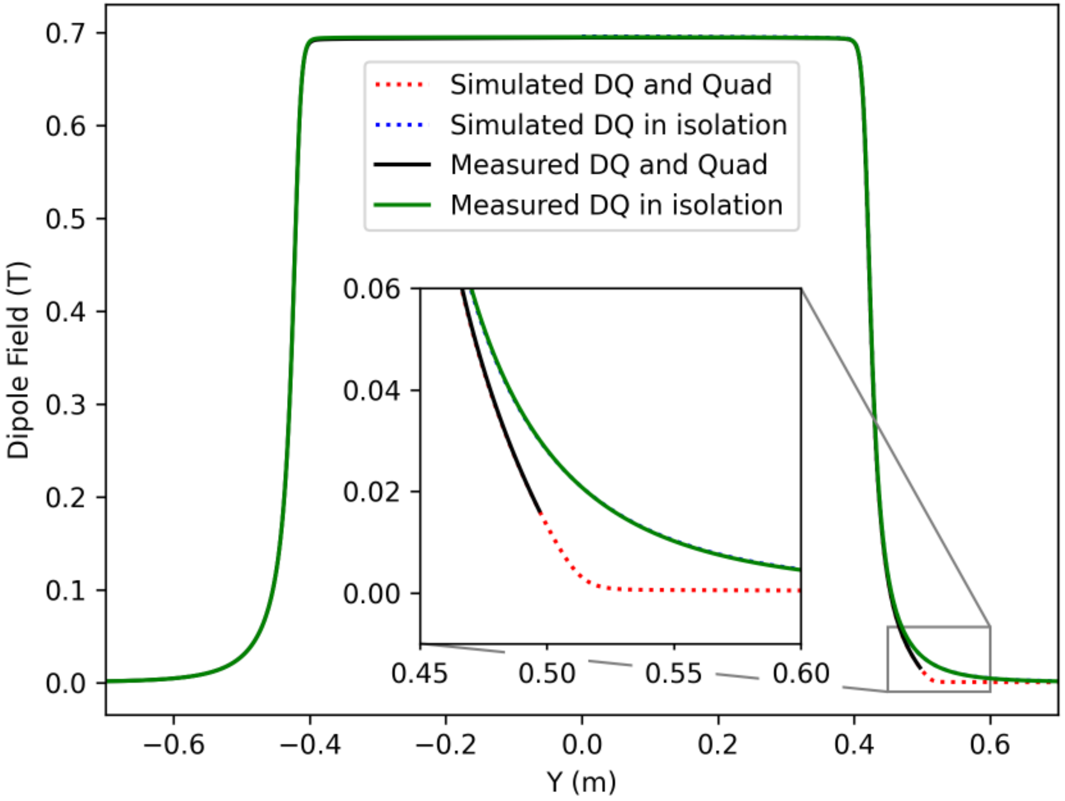

MAIN COIL PACK
9x9 WIRE
Ø 6 BORE
48 TURNS
SEE DOCUMENT
200
AUXILIARY COIL PACK
9x9 WIRE
Ø 6 BORE
9 TURNS
TRIM COIL PACK
2x2 WIRE
NO BORE
200 TURNS
NOMINAL MAGNETIC CENTRE
310
410


Special DQ
Standard DQ

DQ (iii) - Cross talk.

DQ will be in close proximity to quadrupoles so we need to investigate effects of cross talk.

Simulation.
Testing with prototype and spare Diamond DDBA Quad



AntiBend (i)

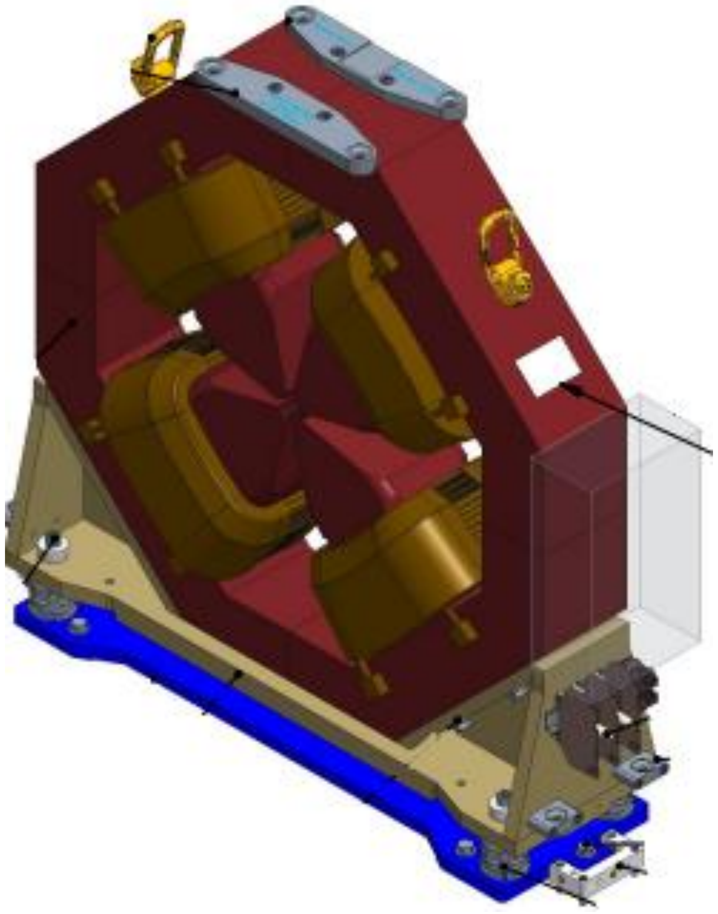
Also combined function but quadrupole with dipole component rather than other way around.
Dipole by Offsetting quad.

Field strengths 0.2037T

Gradients >60T/m 17 mm radius
or > 80T/m 14.5 mm inscribed radius.

Offsets 2-4 mm and 3.4-7.8 mm

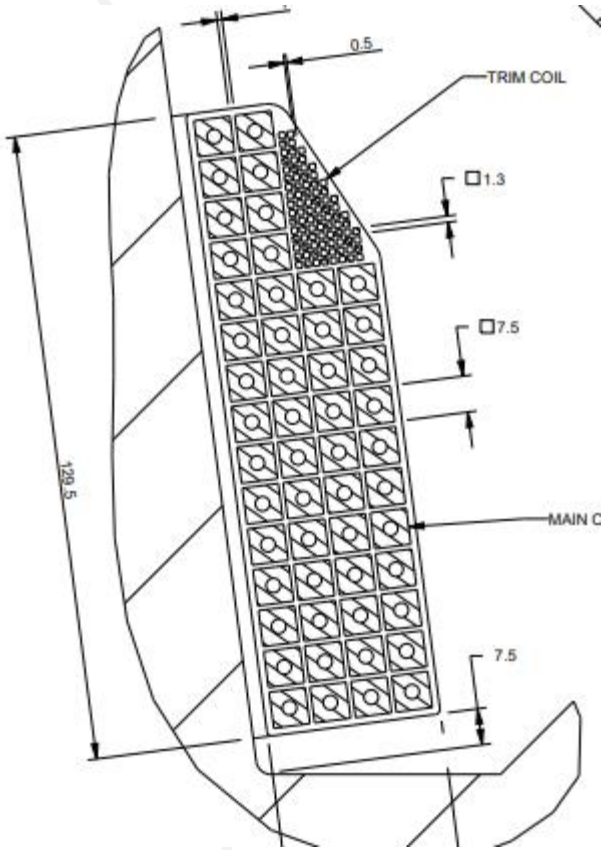
Tuning ranges ±10mT independent of gradient.
Equivalent to ±125µm.
Trim Power supply capable of double this but field quality affected.

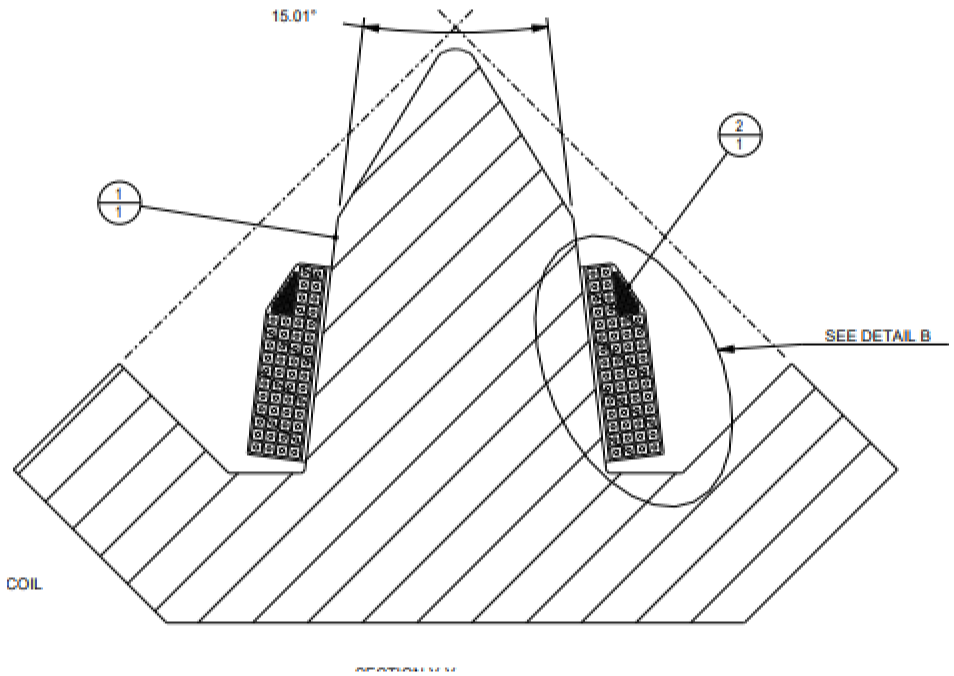


Antibend (ii)

Info on A turn balance…
Main Coils 52 Turns < 180 A.
Wired as Quadrupole.
Max 80 T/m

Trim Coils 77 Turns < ±4A
Wired as Dipole.
Gives ±10 mT
Cooled by contact with main water-cooled coils.





Fast Correctors

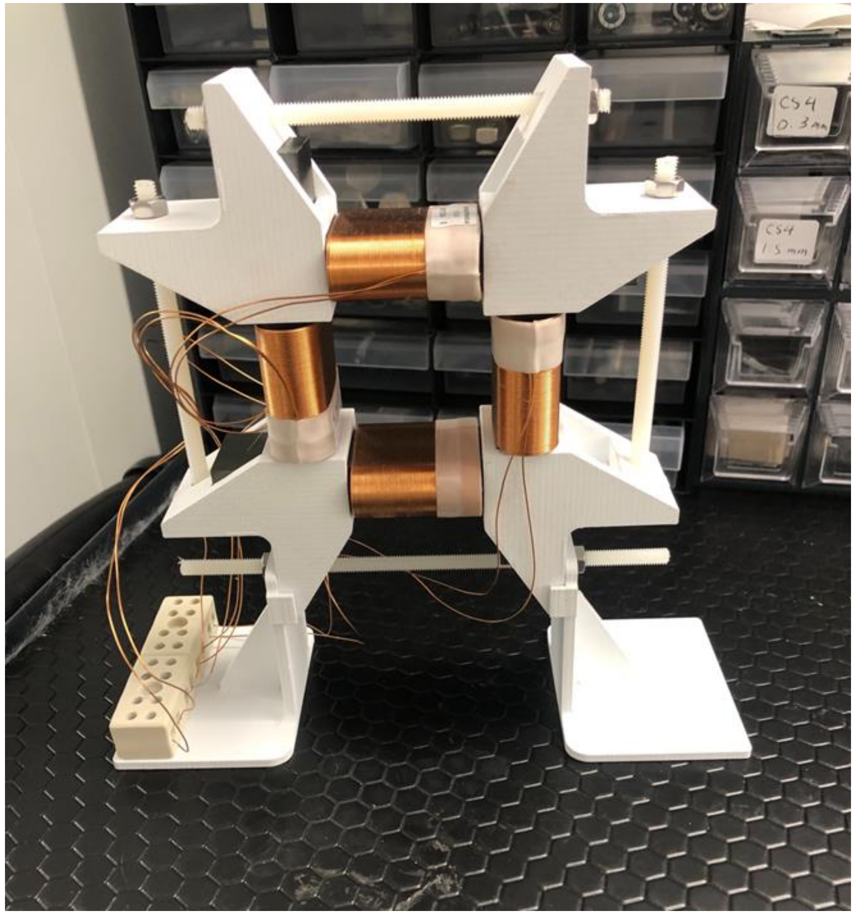
Part of integrated Orbit feedback system in Lorraine's talk coming up

Lower frequency controlled with correctors on Sext / Oct

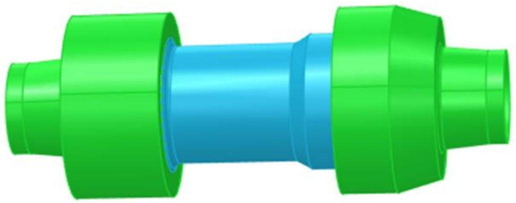
Leaves Low field but high frequency requirements

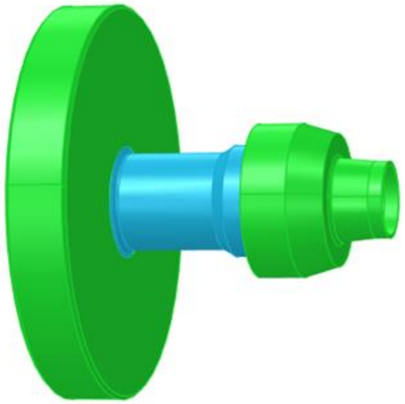
Simple low inductance design.

Prototyping: Off the shelf Ferrites + 3d print structure + manufactured coils.



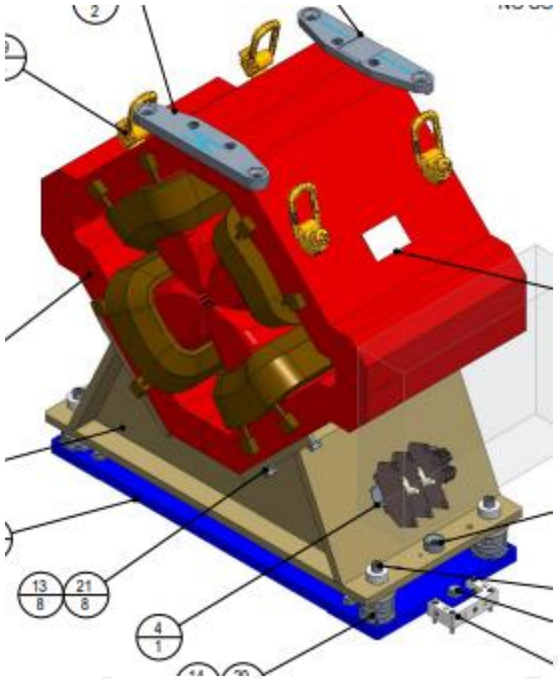
Prototype ready for power supply testing



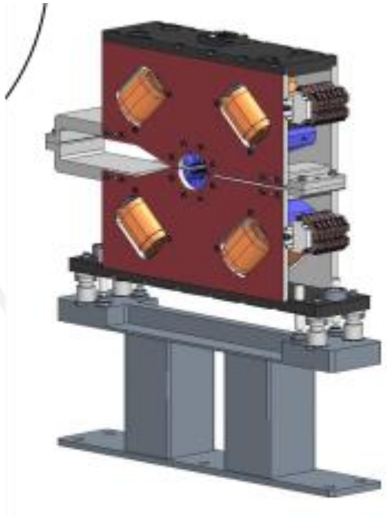


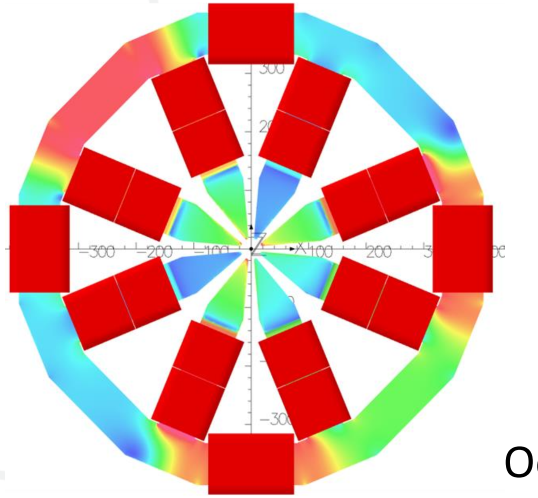
Mock up Vessels to be made to test Attenuation and Phase lag

Other Storage ring magnets

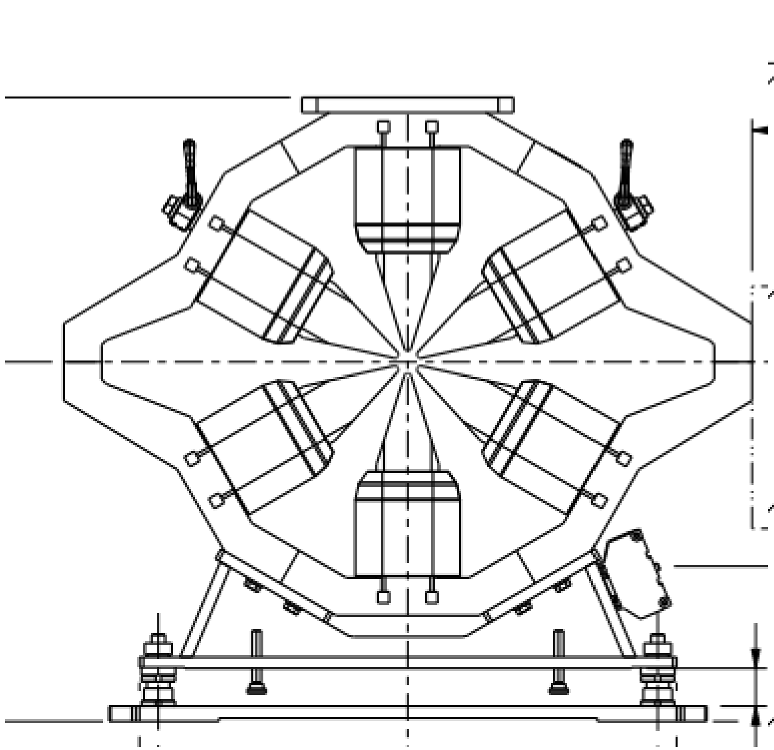


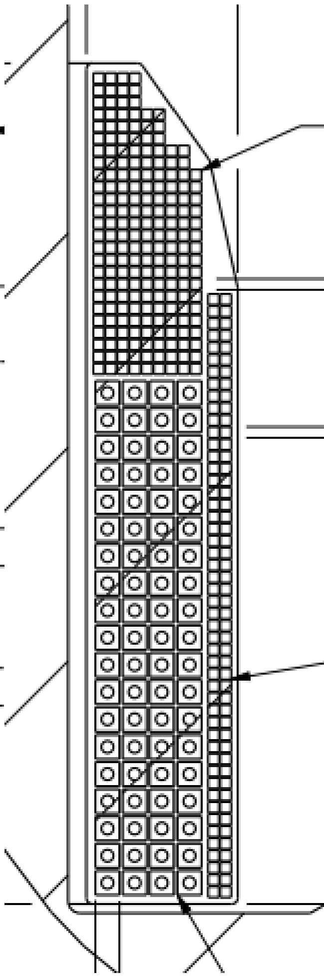
Quadrupole





Octupole & Octupole corrector





Sextupole & coil detail

Septum

Aim to make Septum for booster extraction and storage ring injection the same.

Each, 2 Part design:

- Pulsed Thin Septum
  - In Vacuum
  - 400mm long
  - 1 mm separation
  - 0.6 T Field
  - 10 µS full sine pulse ~4kA. < 10kV

- Permanent magnet 'Thick' Septum
  - Out of Vacuum.
  - ~1.6 m long
  - 8.5 mm minimum separation
  - modules at 0.6 T, 1.0 T and 1.5 T (6/7 total 4/5 1.5 T ?) ~200 mm each.
  - Remotely controlled tuning to be decided.

Thick Septum

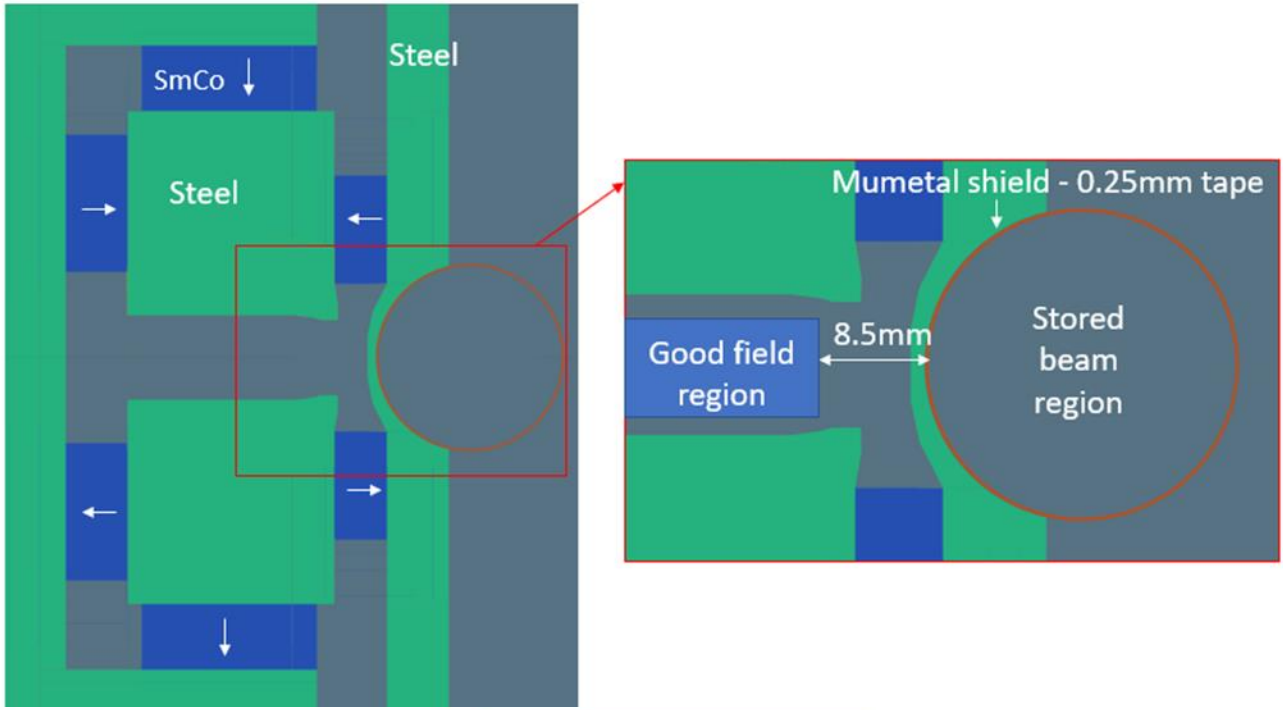
PM septum reduces shot-to-shot jitter for injected beam position and angle, and stored beam disturbance.

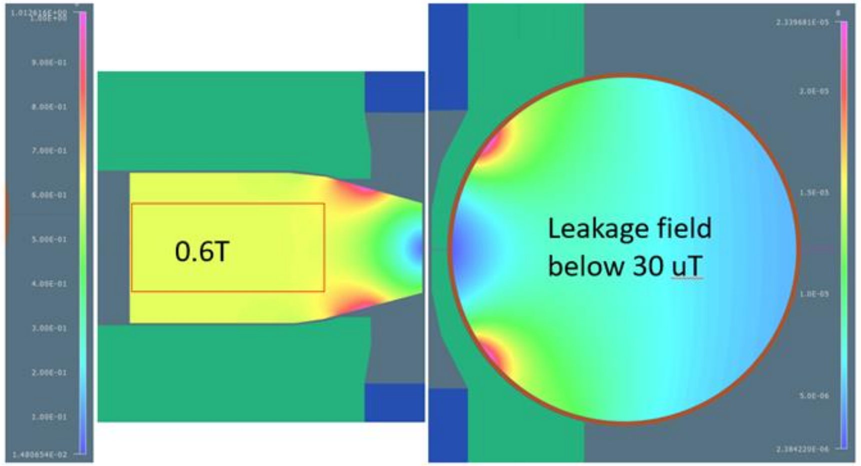
Different strength modules to optimise shielding close to the stored beam (0.6T end module, up to 1.5T further away from the beam)

Fully PM Booster extraction septum not practical due to minimum thickness that can be reached.

Assembly around vacuum vessel still to be designed.

Still Investigating into possible field tuning mechanisms – electromagnet vs mechanical shunts





Field uniformity and leakage in the end module (two different scales)

Thin Septum

The whole assembly will be in vacuum

Probably iron powder cores, nano crystalline material investigated.

Dimensions specified to keep pulse voltage <10kV

Copper plate – primary shield.

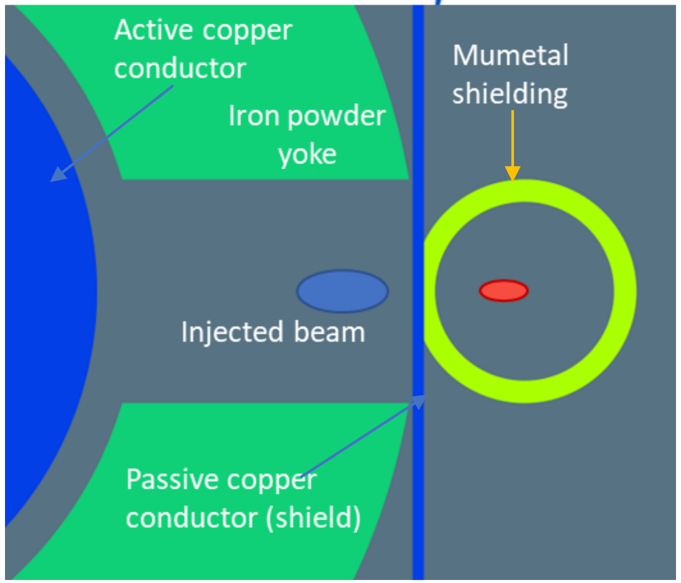
Shielding of circulating channel, Mu metal tube?

Outstanding Questions.

End treatment for joining channels?

Feed Throughs?

Prototyping.



Booster

Also complete new booster, all cycling at 5 Hz for 0.1-3.5 GeV ramp.

Consisting

Number	Magnet	Peak Field T	Gradient T/m		Peak Current A
38	Defocussing Dipole	-0.987	-8.24	-44	900
36	Focussing Dipoles	-0.423	11.2	-36	590
4	Normal Dipole	-0.954	0	0	510
20	Quadrupoles	-	30	-	250
44	Sextupoles	-	-	300	11
96	Correctors H & V	±0.1	-	-	5.5

Summary

~1300 Magnets to deliver.
~100 Assemble on Site.
~900 Measure and fiducialise on site.

8 Contracts for numbers of Magnets.
2 For Parts.
Another 6 or so orders for 1-4 magnets each.

Challenges with all of them.

Measurements aided by Stretch wire magnetic field system, mounted on CMM, integration in progress. Will also be able to use Hall probe. On CMM carriage.