Brazilian Synchrotron Light Laboratory

Overview of the Magnetic Measurement Activities at Sirius

James Citadini

21st International Magnetic Measurement Workshop

24th – 28th June 2019

MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATION AND COMMUNICATION

PÁTRIA AMADA BRASIL

BRAZILIAN GOVERNMENT

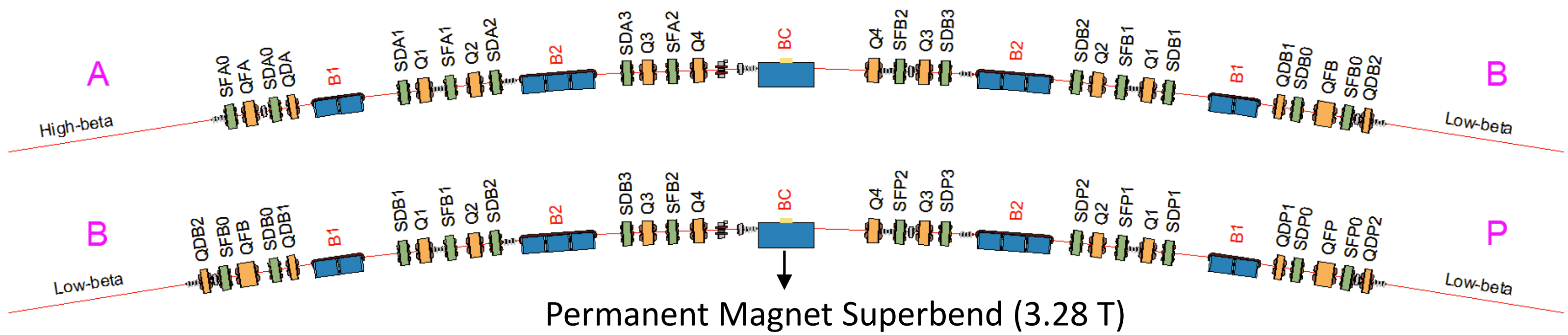
IMMW21

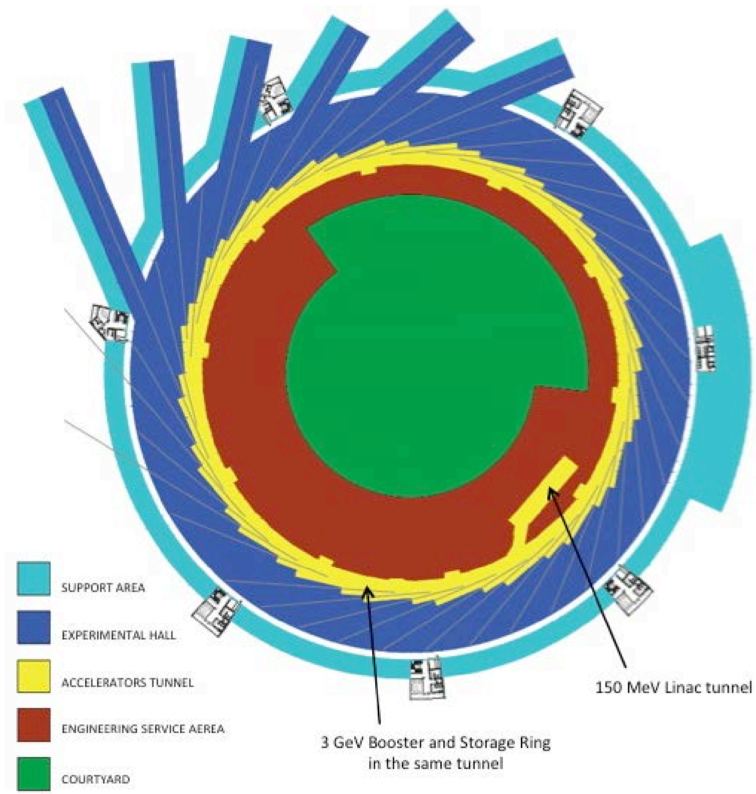
Outline

- Sirius Project and Status
- Magnetic Measurement Systems
- Measurement Results
  - Quadrupoles and Sextupoles: Rotating Coil Measurements
  - Dipoles: Hall Probe Measurements
- Next Steps

Sirius Project and Status

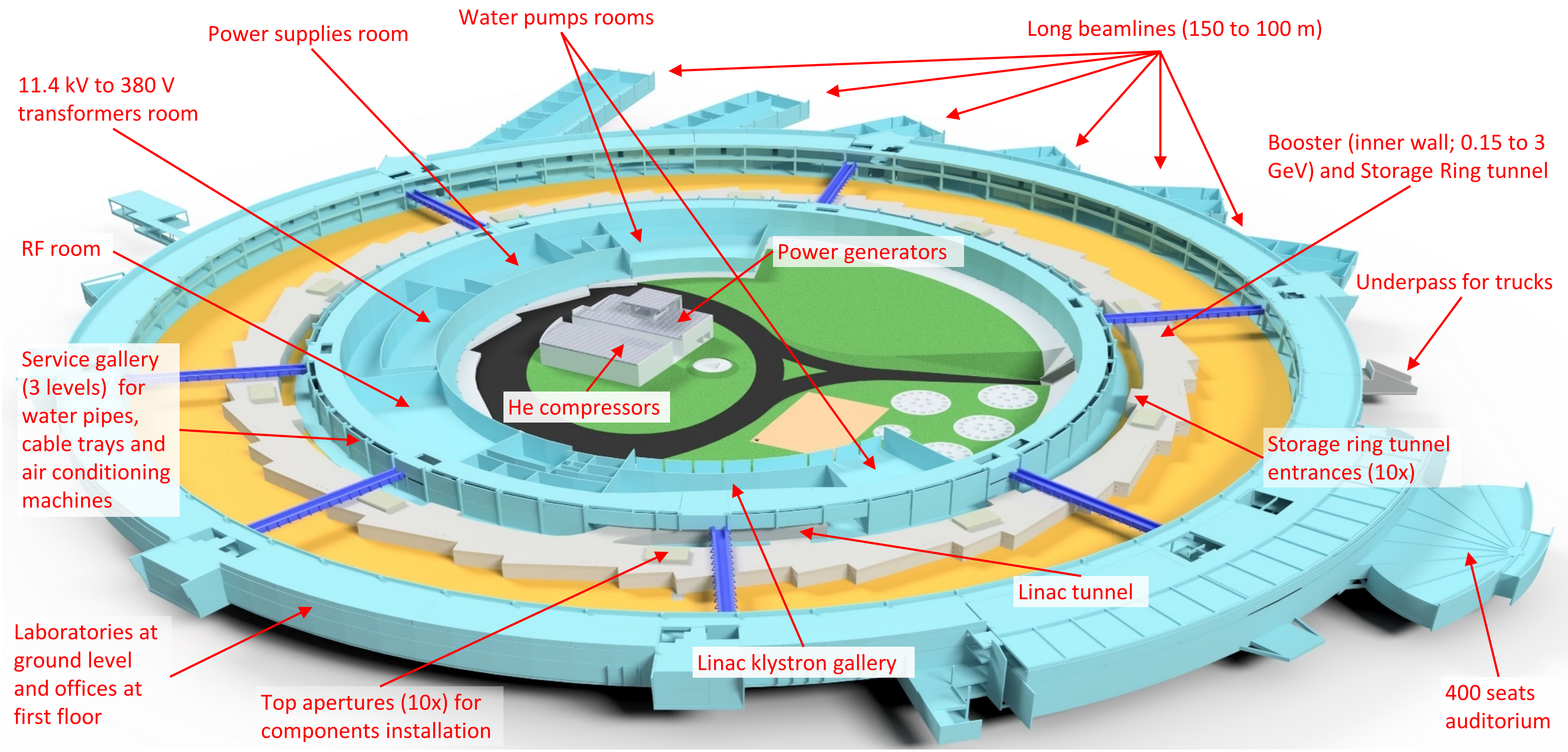
Sirius





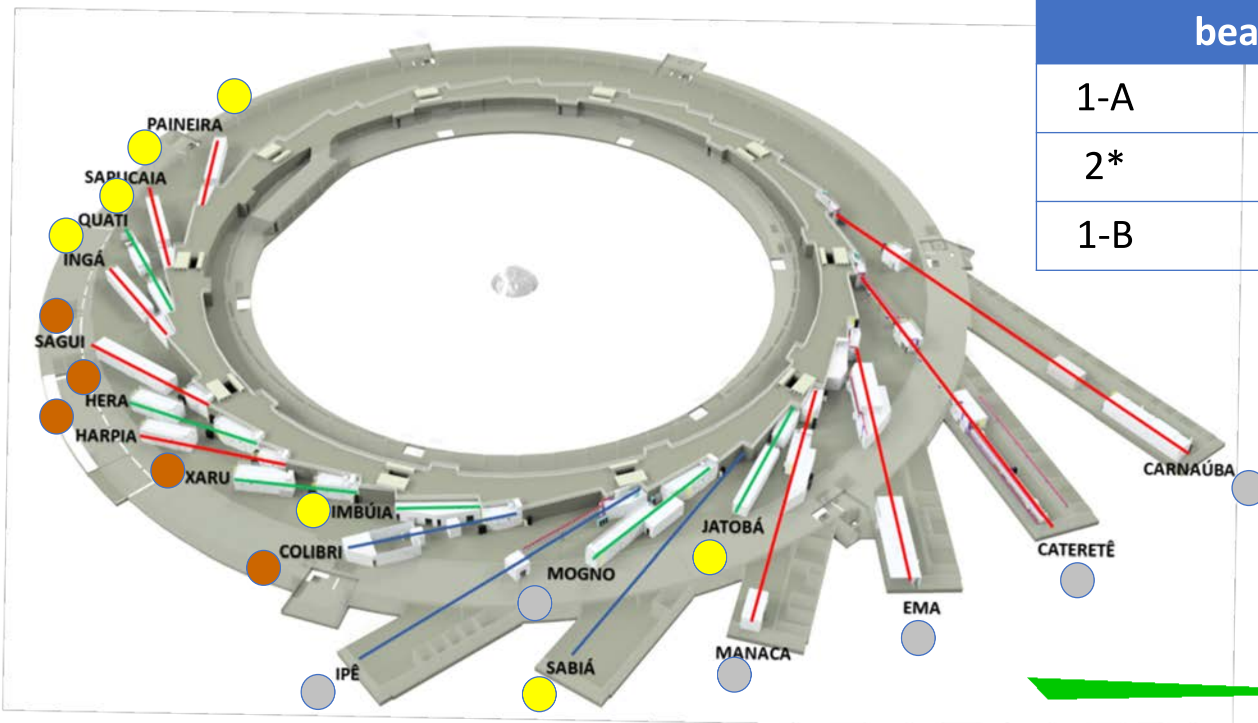
Storage Ring	
Beam energy	3.0 GeV
Circumference	518.4 m
Lattice	20 x 5BA
Hor. emittance (bare lattice)	250 pm.rad
Hor. emittance (with IDs)	→ 150 pm.rad
Nominal current, top up	350 mA
Long straight sections	5 x 7.5 m
Short straight sections	15 x 6.5 m
Superbend peak field	3.28 T
Superbend critical energy	19.6 KeV

Building



Power supplies room
Water pumps rooms
Long beamlines (150 to 100 m)
11.4 kV to 380 V
transformers room
Booster (inner wall; 0.15 to 3 GeV) and Storage Ring tunnel
RF room
Power generators
Underpass for trucks
Service gallery (3 levels) for water pipes, cable trays and air conditioning machines
He compressors
Storage ring tunnel entrances (10x)
Linac tunnel
Laboratories at ground level and offices at first floor
Linac klystron gallery
Top apertures (10x) for components installation
400 seats auditorium

Beamlines



Phase	Number of beamlines	Status	First Beam
1-A	6	Construction	2019
2*	5	Funding	2020
1-B	7	Design	2021

wiki-sirius.lnls.br

3.2T Superbend

Short period undulator

Long period undulator

* Mainly refurbished beamlines from the UVX machine

Sirius Status

Magnets installation

Sirius Status

Booster

Splitting the installation time with Booster beam tests.

Sirius Status

Storage Ring

(12 sections already assembled

with vacuum chambers)

Installation of storage ring electromagnets already finished

Currently finishing installation of the storage ring superbends

Sirius Status

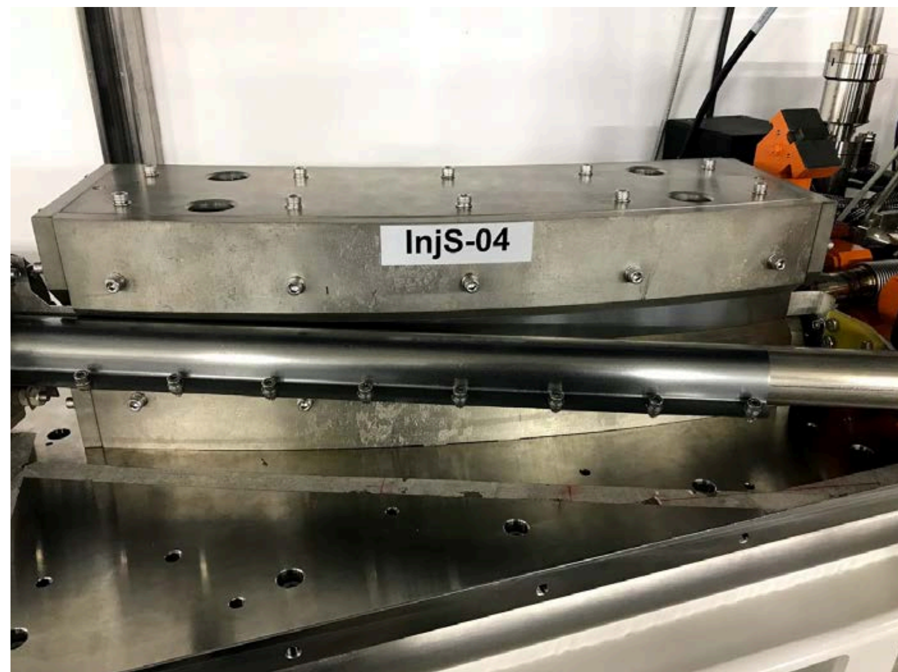
NEG coating activation

Vacuum system assembling process

Sirius Status

Installation of RF cavity solid state amplifiers

Booster out-vacuum septum for injection



Sirius Status

Sirius optical clutch

Sirius Carnauba beamline

Sirius Status

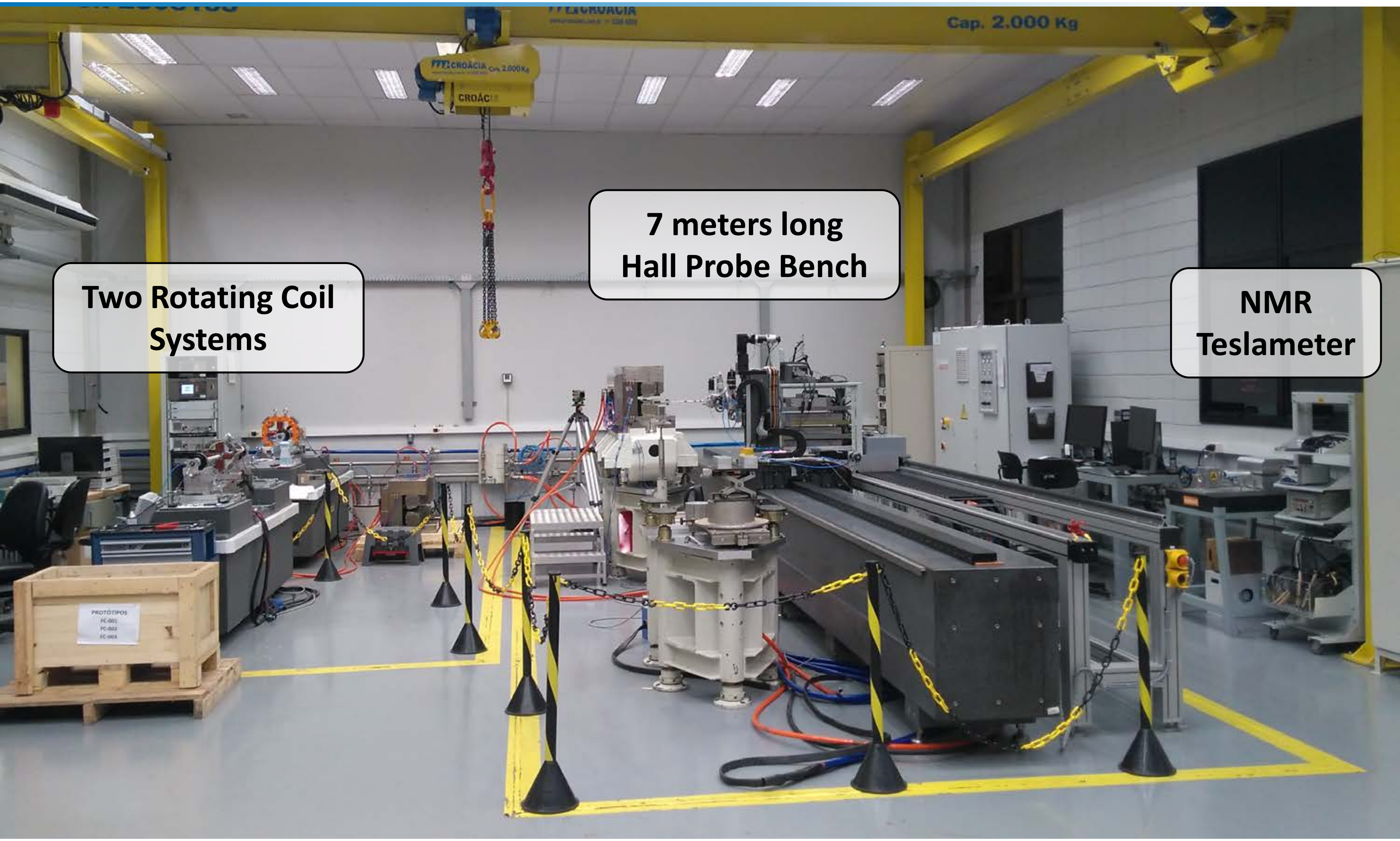
- Booster beam tests (without RF cavity): More than 15000 turns!

Booster stripline signal.

- Schedule:
  - Booster commissioning in July.
  - Storage Ring delivery in early August.
  - Tests of all Sirius subsystems until the end of August.
  - September – First beam in the Storage Ring.
  - January – Startup of the first beam lines.

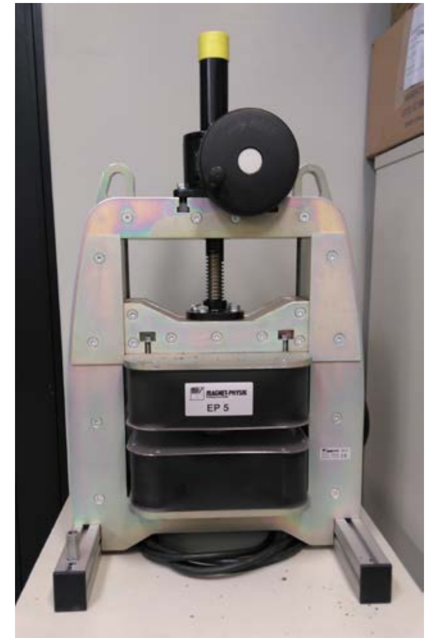
Magnetic Measurement Systems

Magnetic measurement laboratory

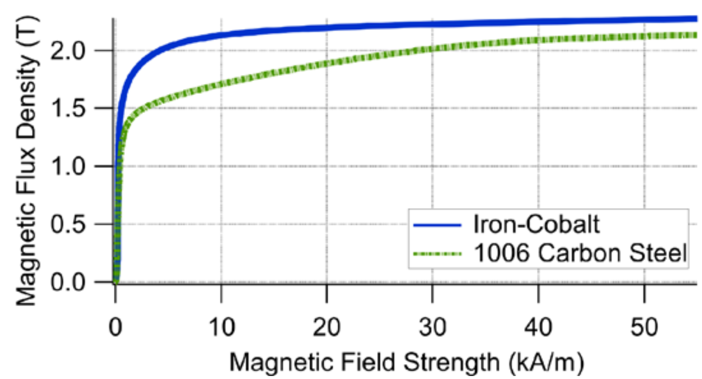


Magnetic measurement laboratory

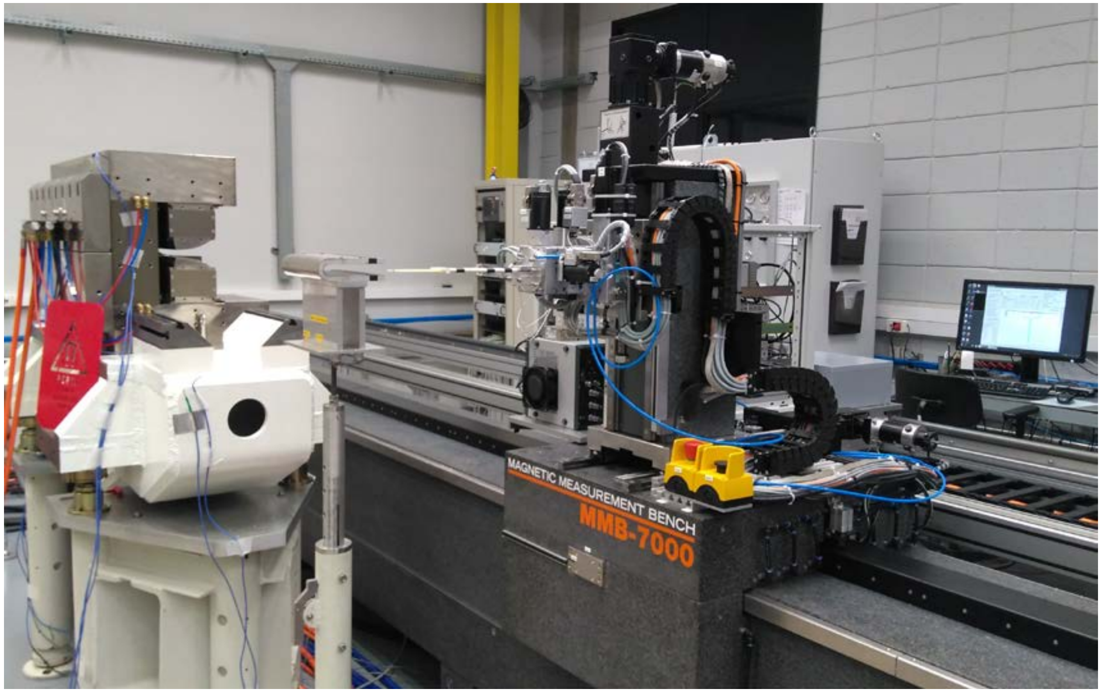
Helmholtz Coil System



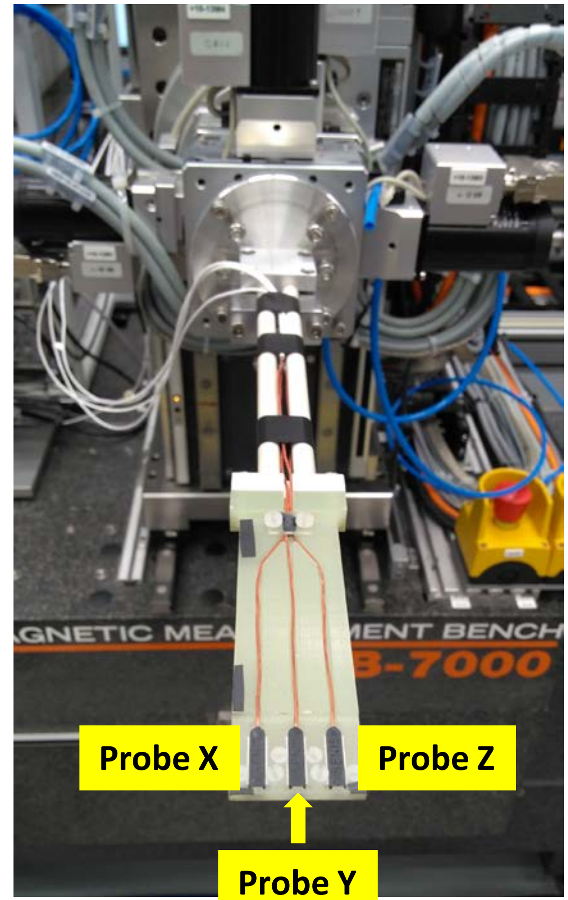
Permeameter



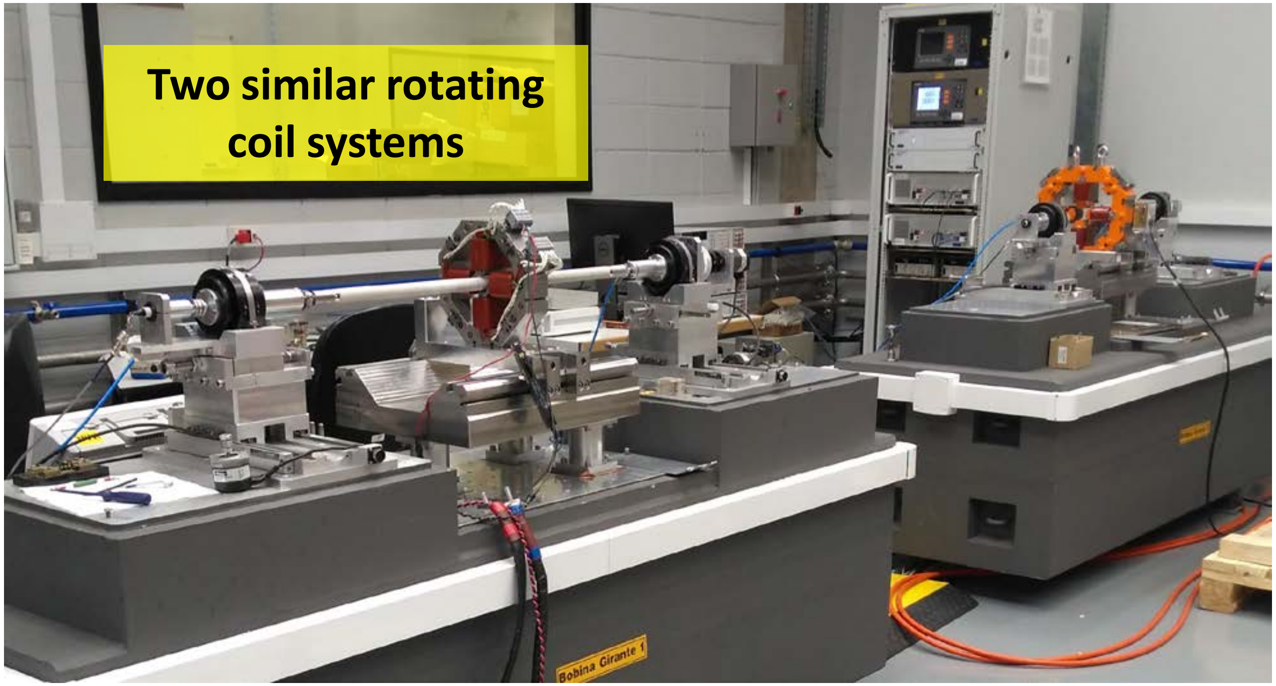
Hall Probe Bench



Hall Probe Bench	
7 m-long granite table	
Hall probes calibrated against NMR measurements	
Roll, Pitch and Yaw	< ± 15 mrad
Horizontal and vertical straightness	< ± 12 µm
Longitudinal Linear Error	< ± 6 µm

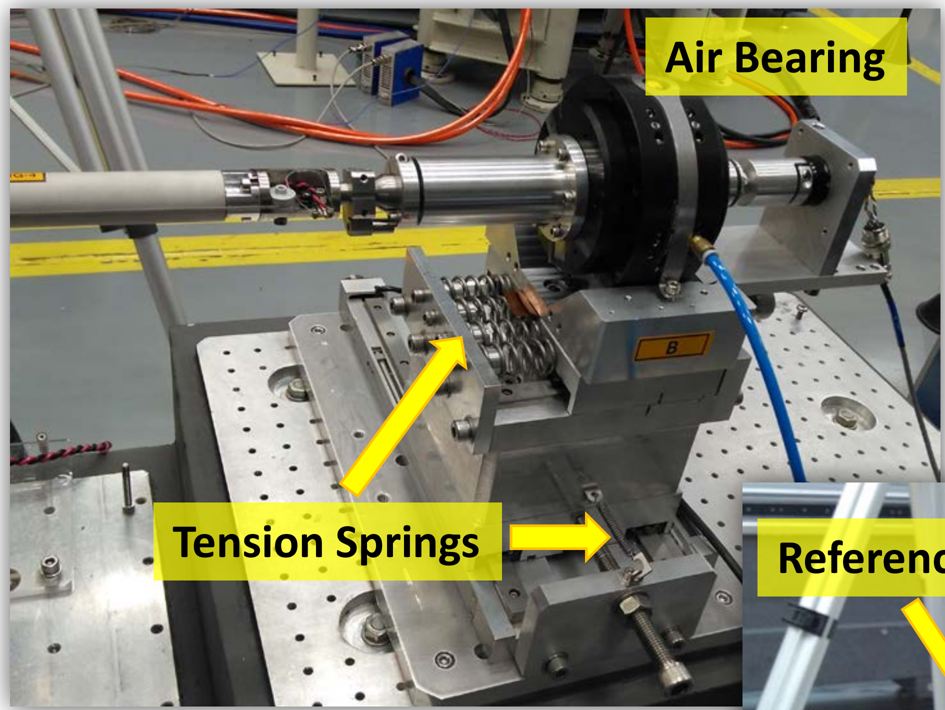


Rotating Coil

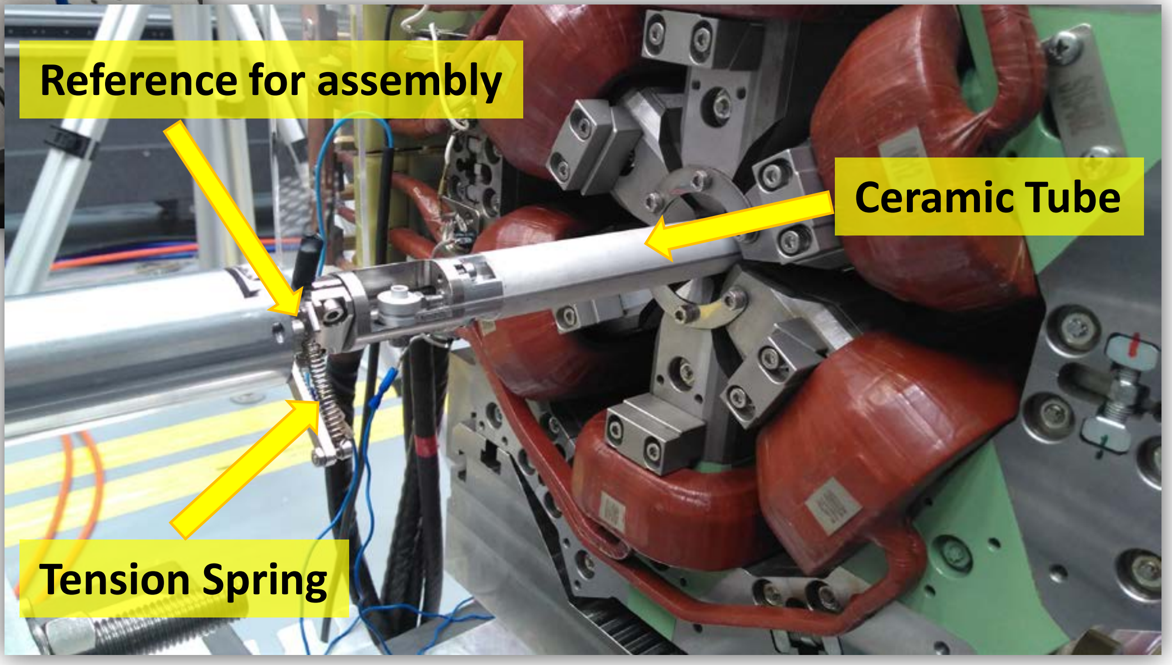


- Air bearings
- 360000 pulses encoder
- Coil mounted on a ceramic tube
- Springs tensioning system for precision assembly

Rotating Coil



Rotating Coil	Booster	Storage Ring
Unbucked tungsten radial coils		
Number of turns	10	9
External Radius [mm]	18.15	13.013



Coil positioning error:
± 0.1 mrad

Measurement Results

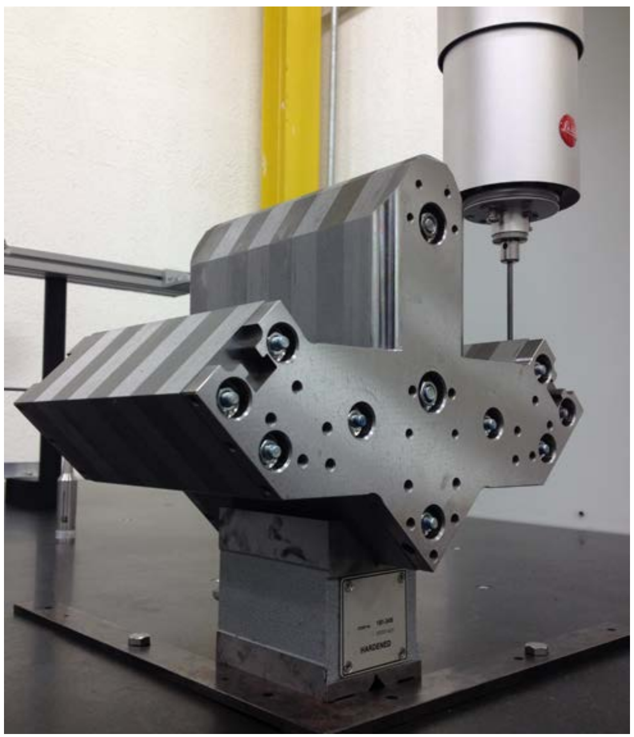
Measurement Results

- Excitation curves measured with the rotating coil systems for all Sirius quadrupoles, sextupoles and slow correctors
- 2D field maps measured for all dipoles with the Hall probe bench
- Sorting algorithm applied to all Booster and Storage Ring electromagnets before installation
- Storage ring fast corrector prototype measured and approved

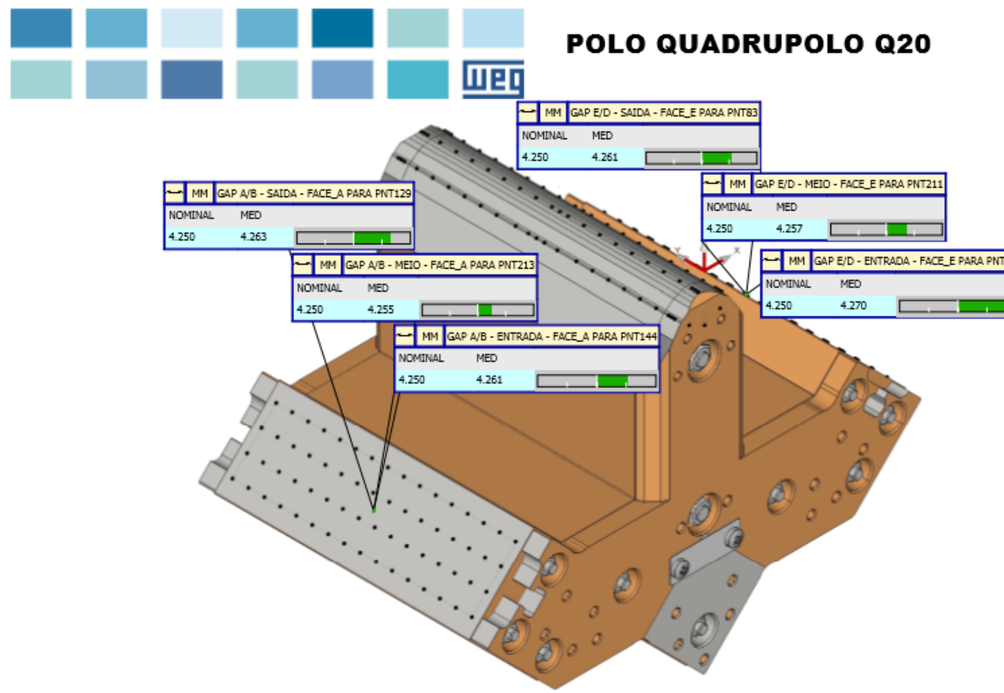
External Manufacturer (WEG)

- **LNLS:** simulation, design & magnetic measurement
- **WEG:** manufacturing, quality control, mechanical measurements

Material: Laminated (0.5 mm) Silicon Steel

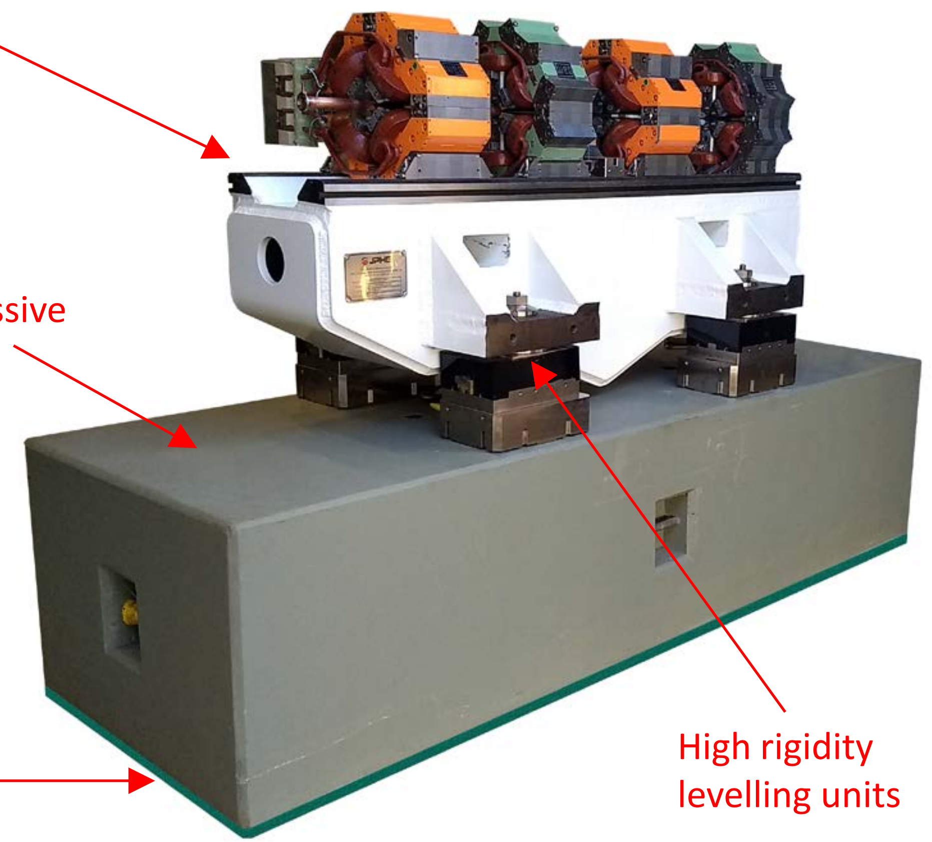


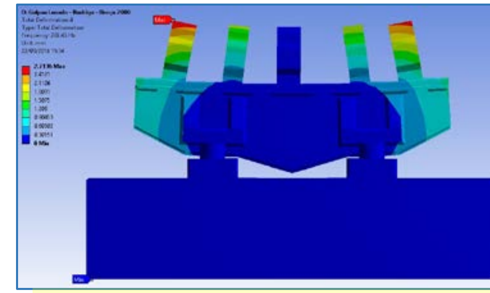
Storage Ring quadrupole (single pole) measurement at CMM



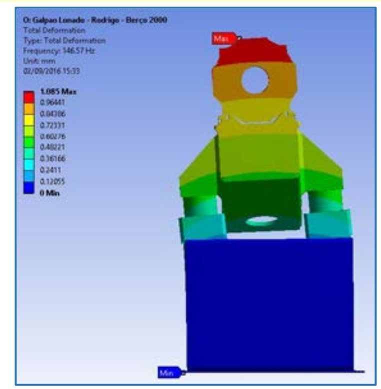
Mechanical Tolerances: ± 30 µm

High stability girder





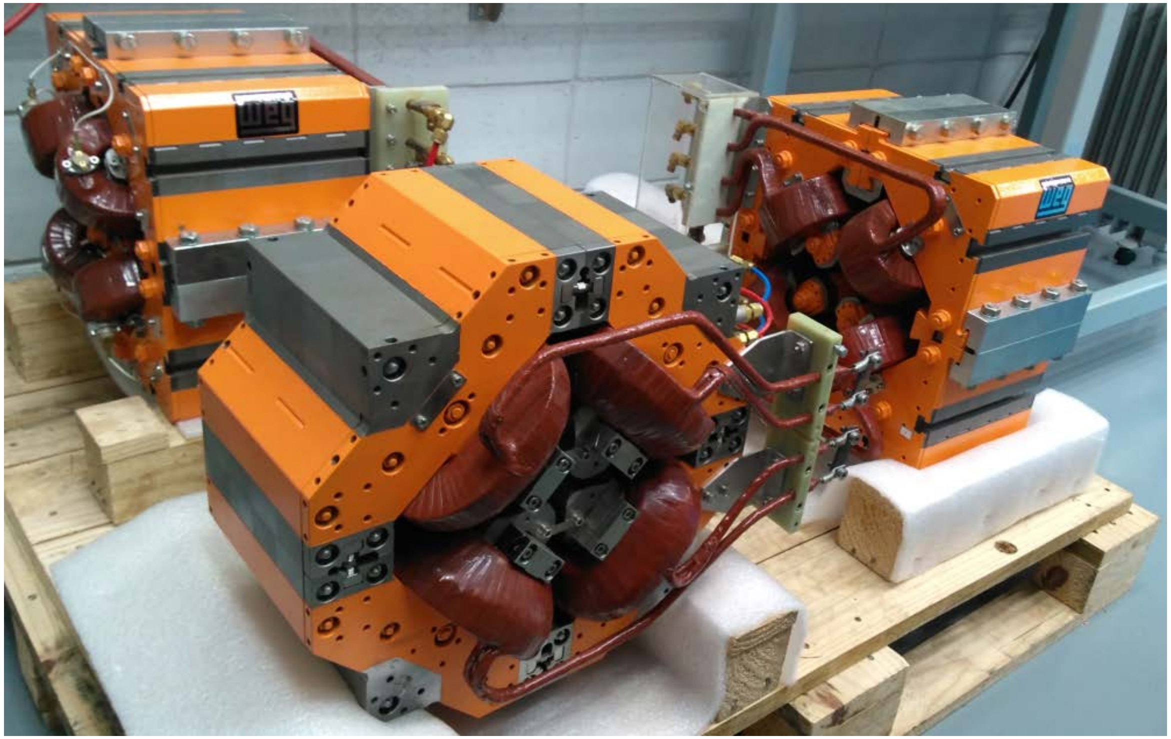
V 1st mode: 268 Hz



H 1st mode: 152 Hz

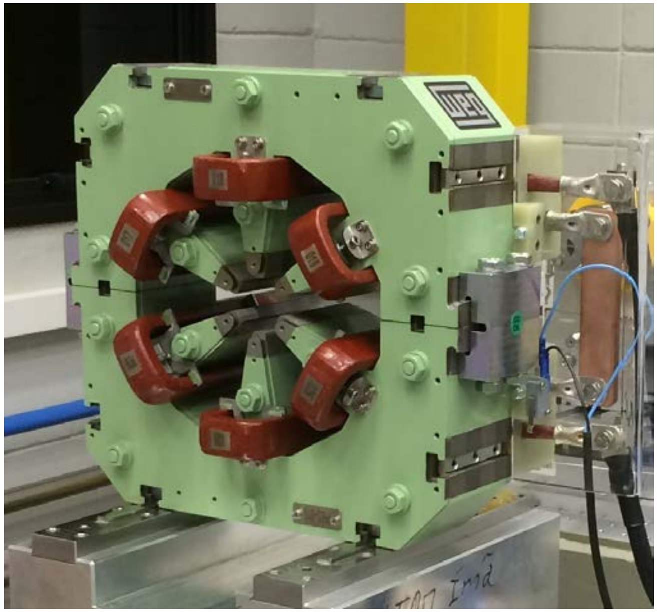
Multipole Magnets aligned by mechanical definition using reference surfaces of magnets and girder

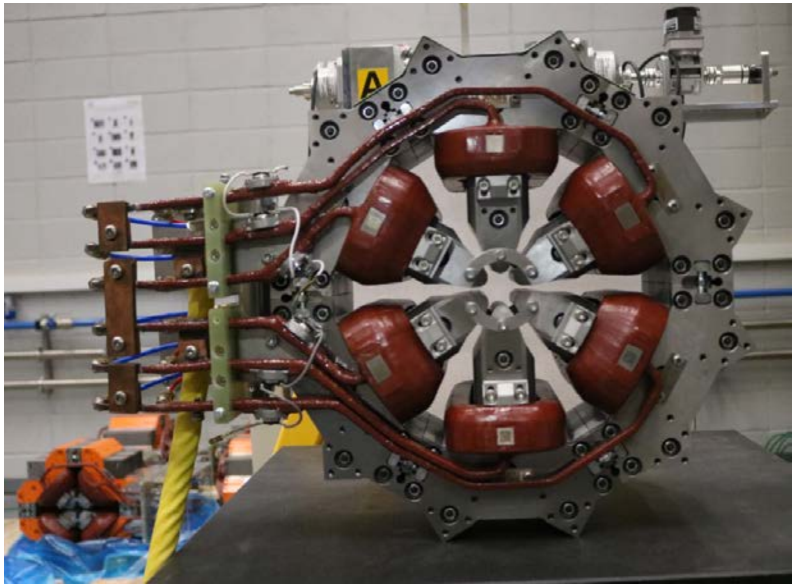
Quadrupoles



	Booster			Storage Ring		
Quadrupole	**QF**	**QD**	**QS**	**Q14**	**Q20**	**Q30**
Number of magnets	50	25	1	70	170	30
Length [m]	0.2	0.1	0.1	0.14	0.20	0.30
Bore diameter [mm]	40	40	40	28	28	28
Maximum Field Gradient [T/m]	18.7	5.2	1.6	37.2	45.4	45.4

Sextupoles



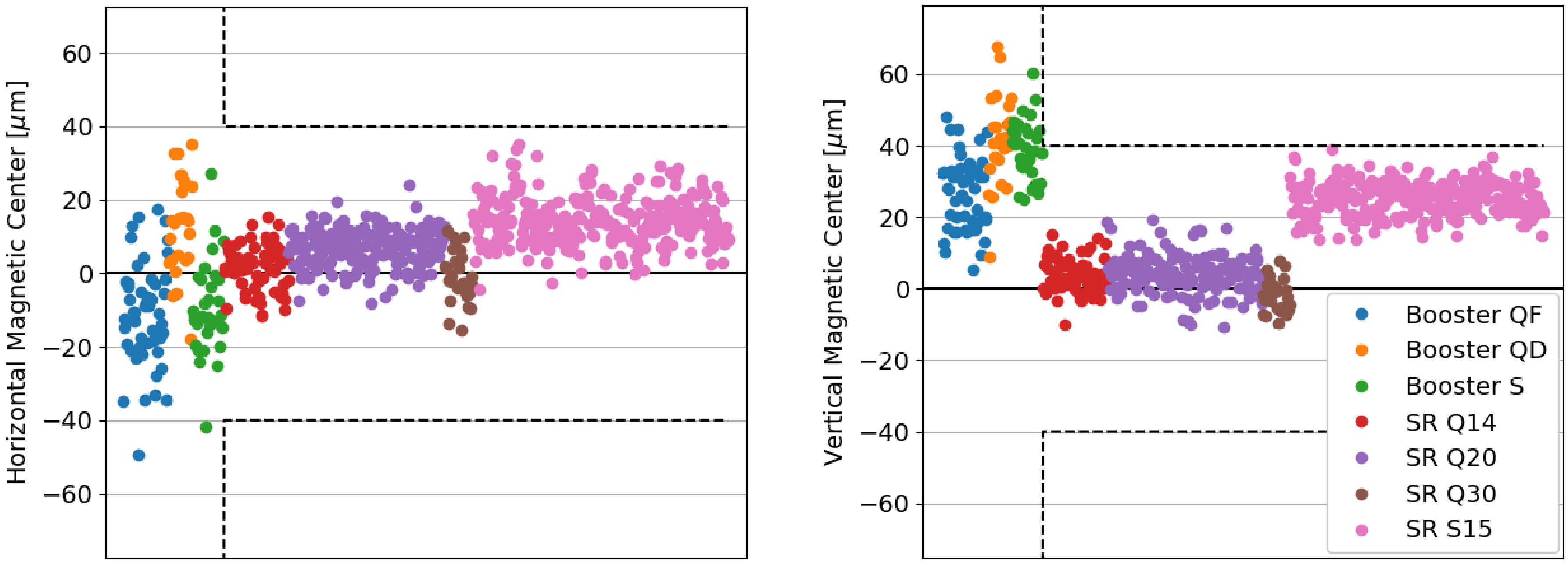


The storage ring sextupole has additional coils to provide horizontal and vertical slow dipolar correctors as well as skew quadrupolar field.

Sextupole	Booster	Storage Ring
Number of magnets	35	280
Length [m]	0.1	0.15
Bore diameter [mm]	40	28
Maximum Sextupole Field Gradient [T/m²]	200	2402

Quadrupoles and Sextupoles: Rotating Coil Measurements

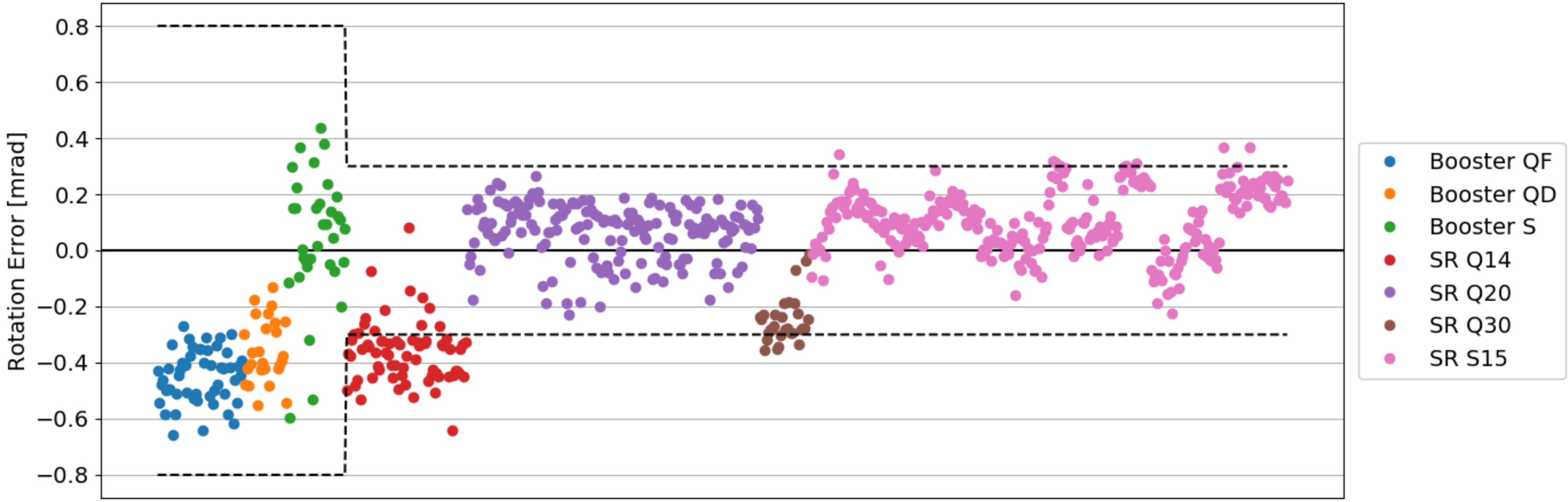
Magnetic center offset for Sirius quadrupoles and sextupoles.



*Dashed lines are the tolerances: 160 μm for Booster magnets and 40 μm for storage ring magnets.

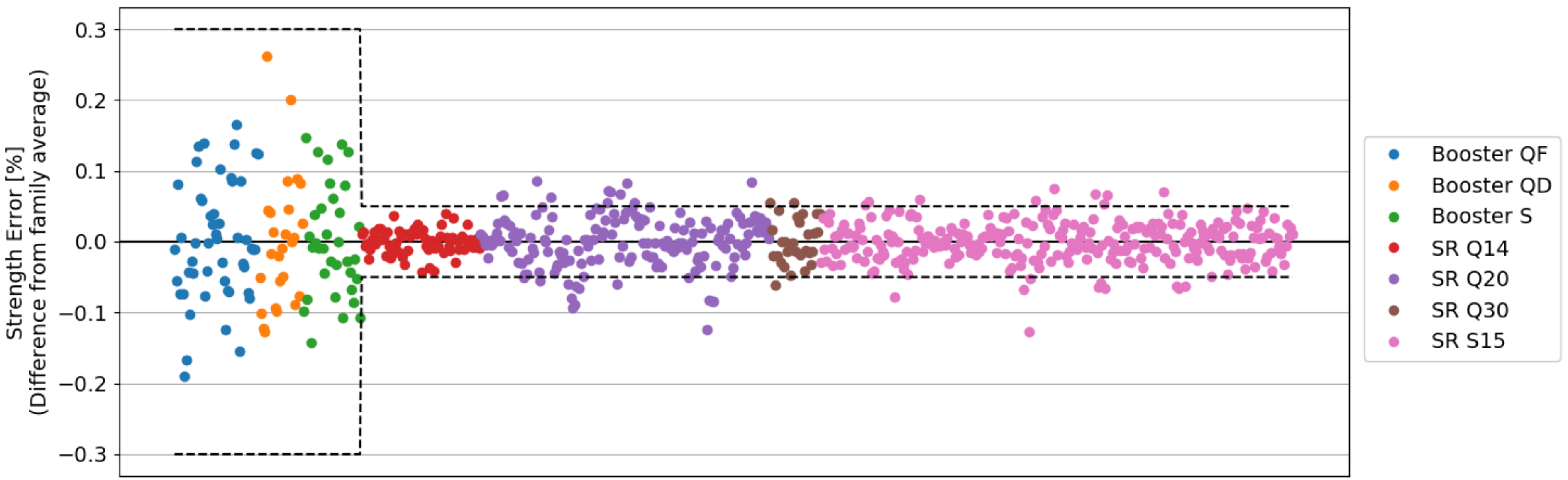
Quadrupoles and Sextupoles: Rotating Coil Measurements

Rotation error for Sirius quadrupoles and sextupoles.



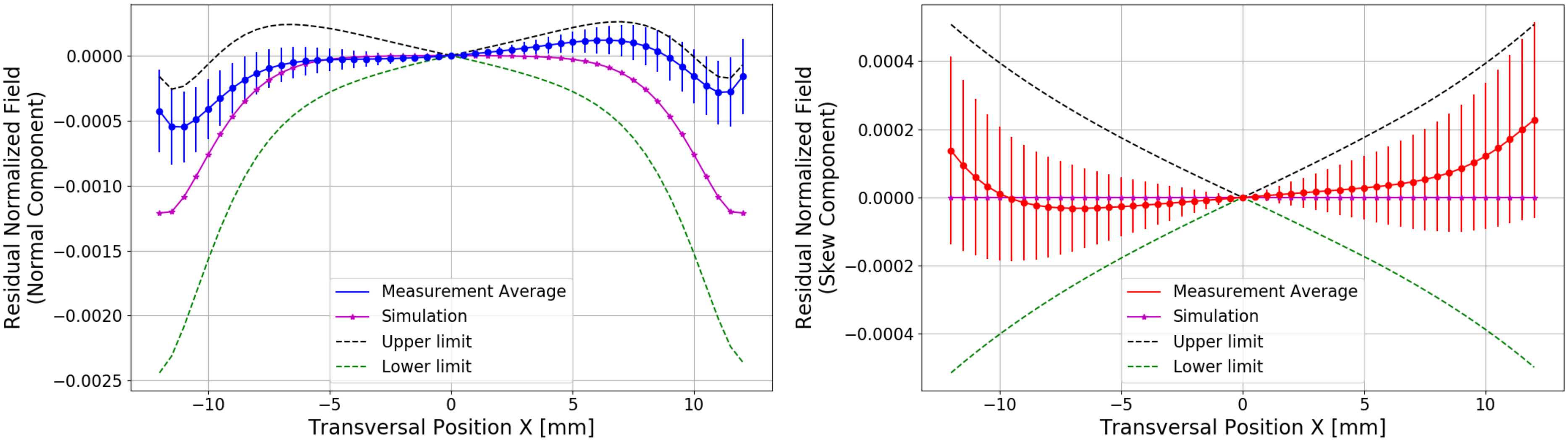
Quadrupoles and Sextupoles: Rotating Coil Measurements

Difference from average strength for Sirius quadrupoles and sextupoles at nominal current.



Quadrupoles and Sextupoles: Rotating Coil Measurements

Average residual field for the storage ring sextupoles (S15) at nominal current.



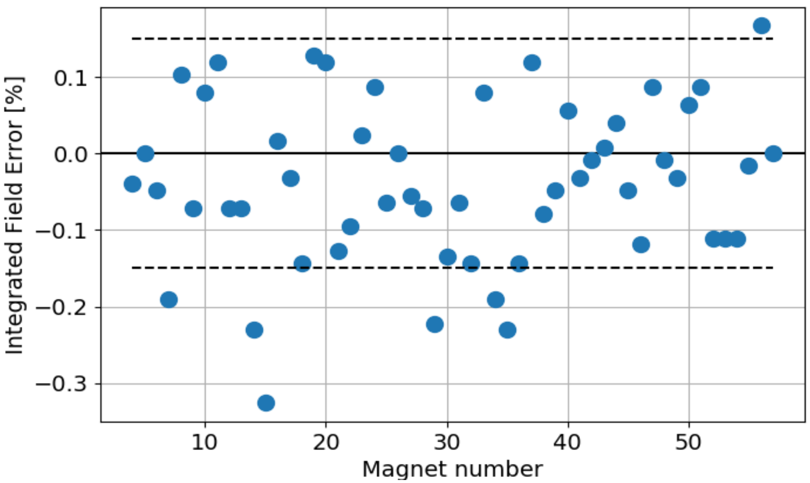
Booster Dipoles

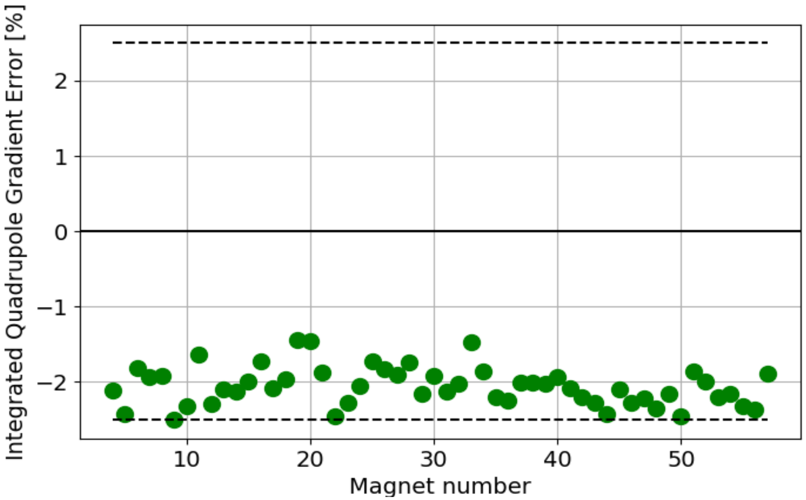
- H-shape dipole
- > 2000 laminations holded only by screws.
- Measured with a 1.3 m long L-shaped stem.
- Challenging for stable measurements.

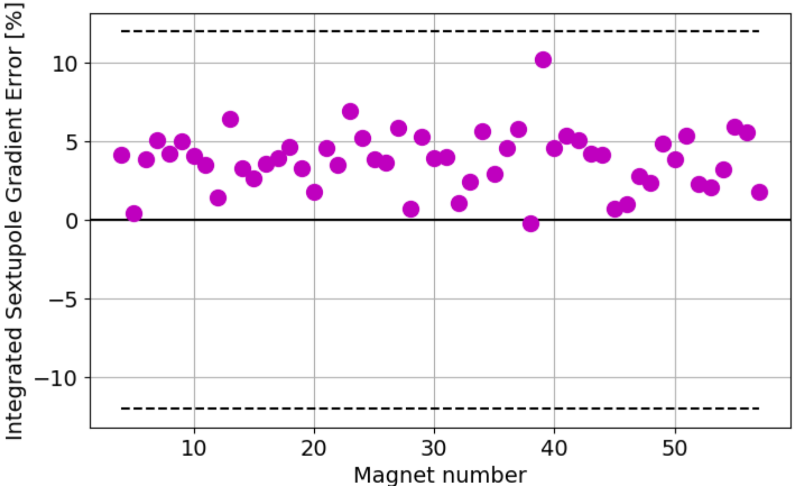
Booster Dipoles	
Number of magnets	50
Length [m]	1.2
Central gap [mm]	28
At extraction energy:	
Field [T]	1.03
Quadrupole gradient [T/m]	2.03
Sextupole gradient [T/m²]	21

Booster Dipoles: Hall Probe Measurements

Integrated field and gradients over trajectory for Booster dipoles.

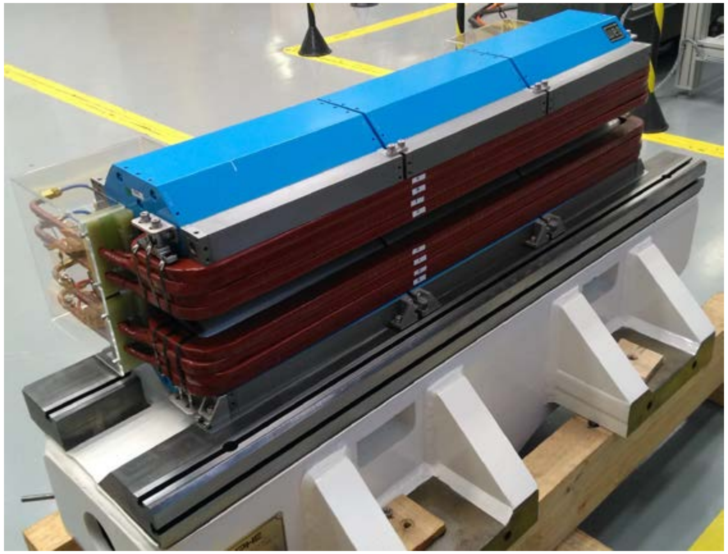


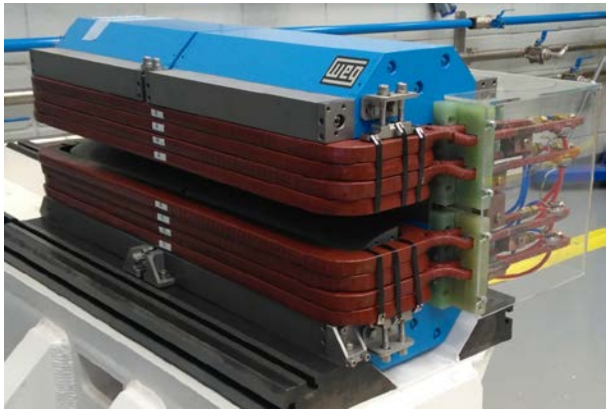




Storage Ring Electromagnetic Dipoles

- Magnets with 2 or 3 straight modules
- Modules mounted at angle on the girder
- Same power supply and same pole profile for both magnets





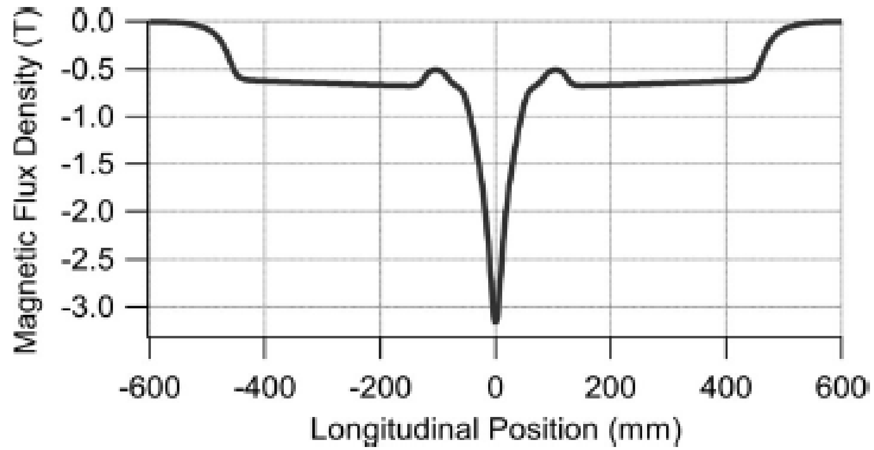
Storage Ring Electromagnetic Dipoles	B1	B2
Number of magnets	40	40
Length [m]	0.85	1.26
Central gap [mm]	24	24
Field [T]	0.564	0.567
Quadrupole gradient [T]	7.58	7.60

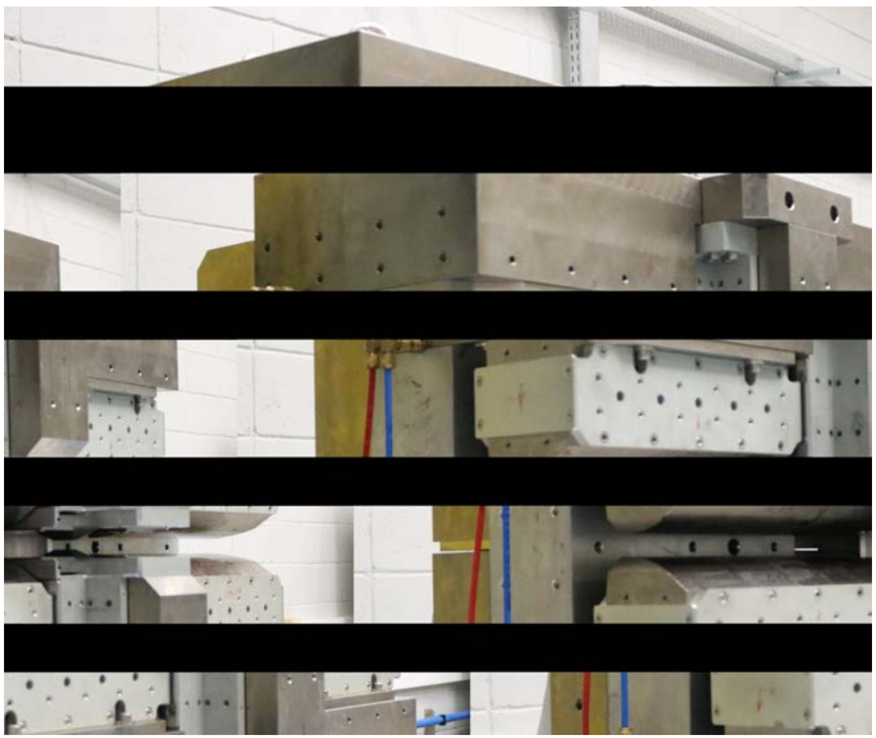
Storage Ring Superbend

- In-house production
- NdFeB permanent magnet blocks
- Low carbon steel for the yoke and low field poles
- Iron-Cobalt for high field poles.

Storage Ring Superbend

- Peak field of 3.2 T
- 19 keV photon critical energy
- 10% emittance reduction due to superbend longitudinal gradient





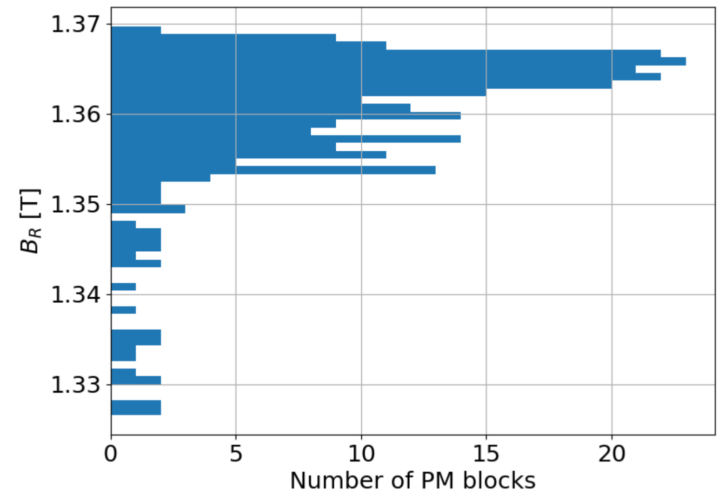
Storage Ring Superbend	
Number of magnets	20
Length [m]	0.8
Minimum Gap [mm]	10.2
Peak Field [T]	3.28
Integrated Field [T.m]	-0.75
Integrated Quadrupole Gradient [T]	6.25

Storage Ring Superbend

Magnetization measurement of the first PM blocks batch with the Helmholtz coils system:

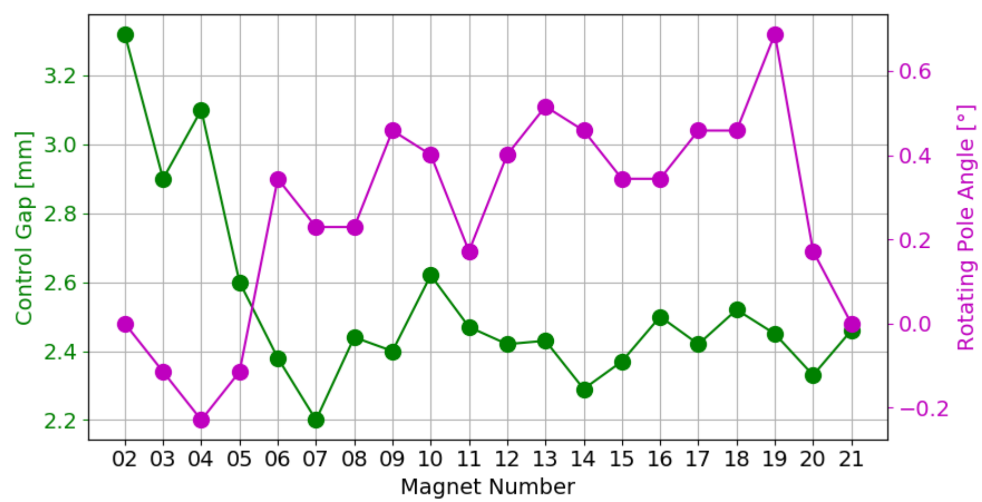
Amplitude error = 0.6 %

Angular error < 1°



Included movable parts for field adjustment in the superbend design to compensate for magnetization errors:

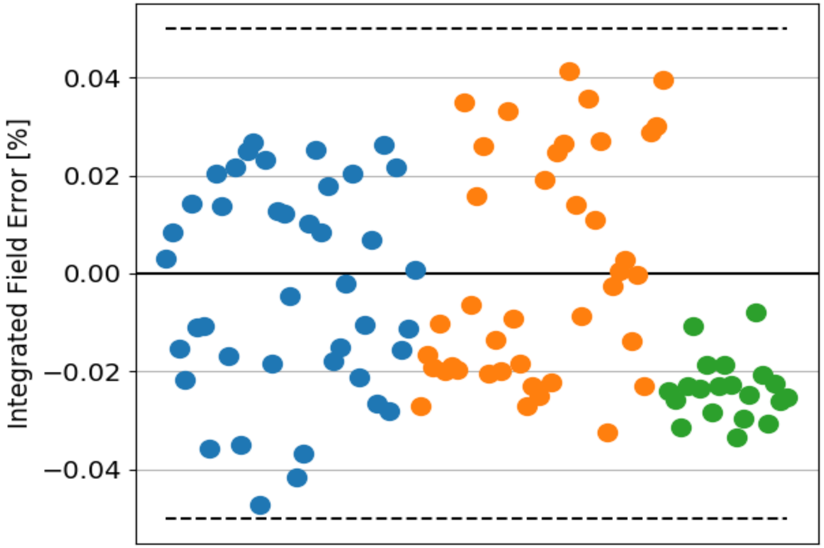
Parameter	Integrated Field Variation [%]	Integrated Gradient Variation [%]
Control Gap	3.1	3.1
Rotating Pole Angle	< 0.06	±3.8

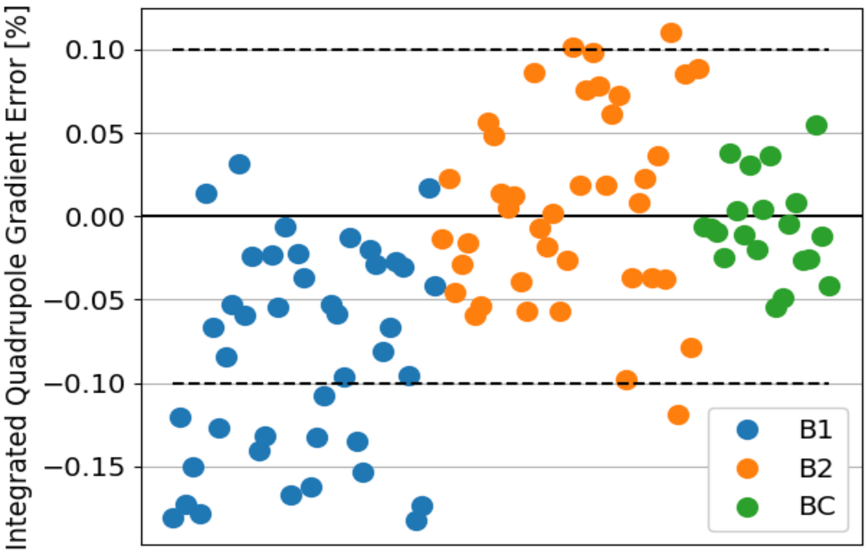


Control gap and rotation pole angle for BC magnets after field adjustment.

Storage Ring Dipoles: Hall Probe Measurements

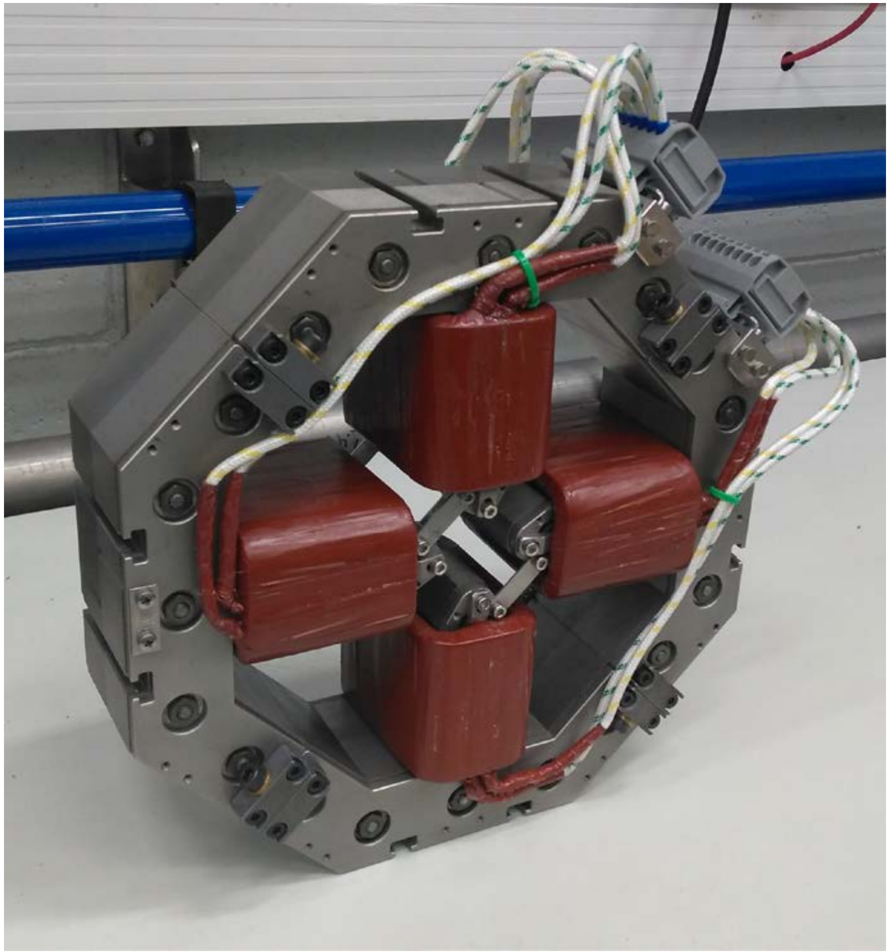
Integrated field and gradient over trajectory for all storage ring dipoles.





*Electromagnetic dipoles (B1 and B2) at nominal current.

Fast Correctors



- **Prototype:** The response frequency attenuation for the fast corrector is -3dB at 11.5kHz

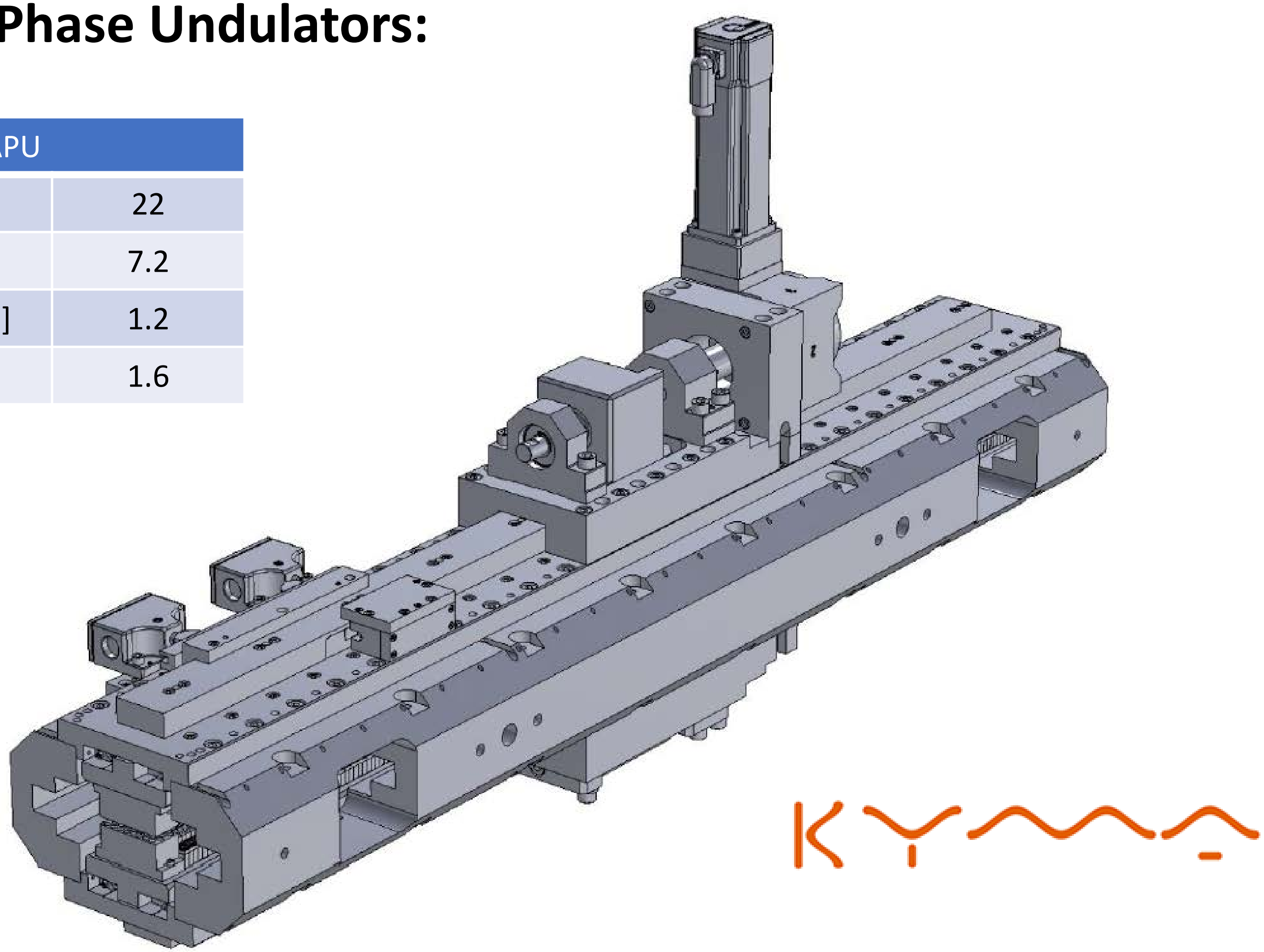
- **Currently under production**

Storage Ring Fast Correctors	
Number of magnets	80
Maximum horizontal and vertical strength	30 µrad

Insertion Devices

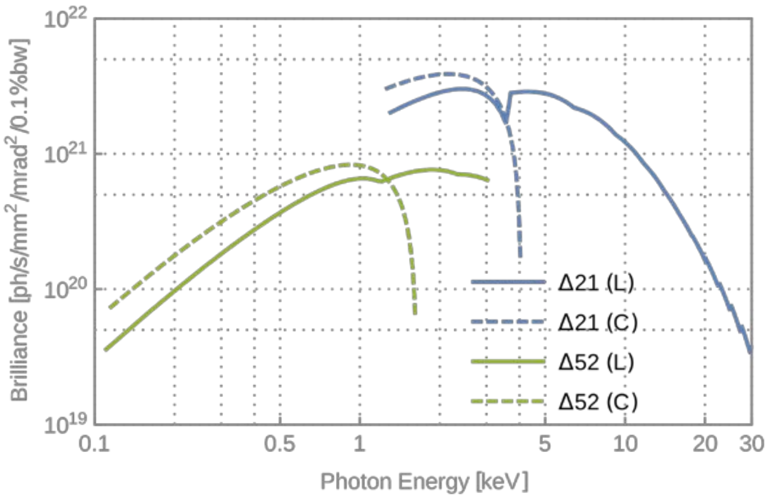
Adjustable Phase Undulators:

APU	
Period [mm]	22
Gap [mm]	7.2
Total length [m]	1.2
Maximum K	1.6

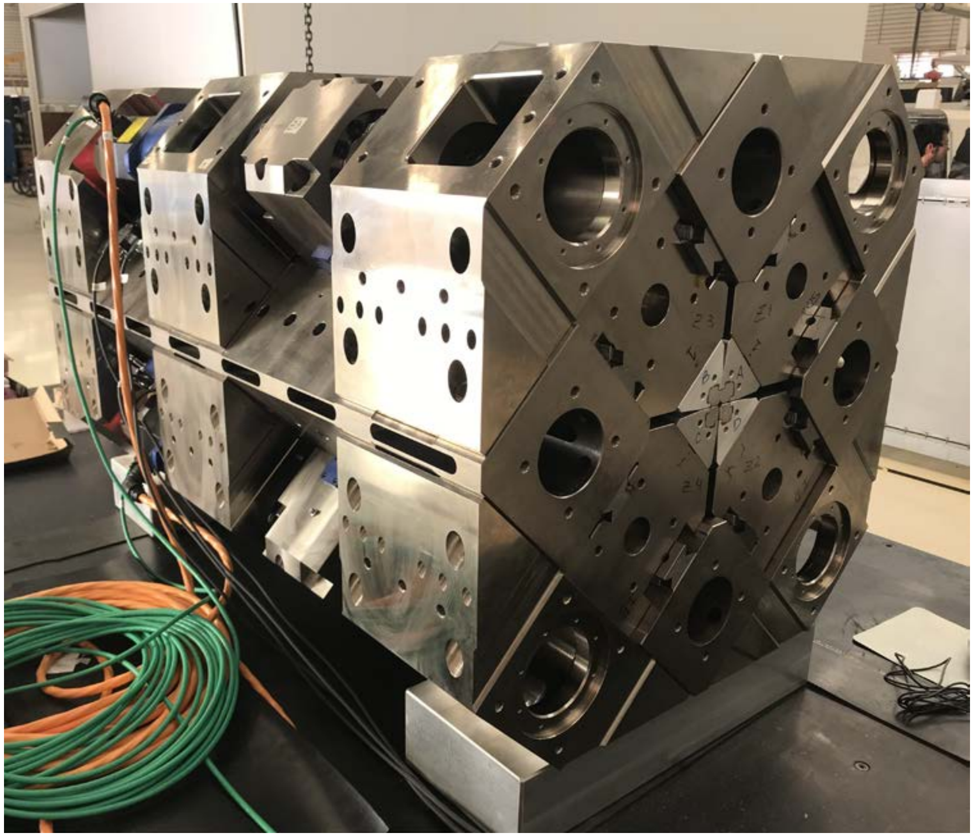


Insertion Devices

Delta Undulators:



	Delta 21	Delta 52
Period [mm]	21	52
Gap [mm]	7	14
Total length [m]	2.4	3.6
Maximum K	2.1	5.8



Sirius Delta undulator prototype.

Next Steps...

- Extensive temperature tests for the Superbend.
- Measurements and installation of the fast correctors.
- Reassembly and Developments of measurements systems for insertion devices.
- Mechanic and automation tests for the delta prototype.
- Redesign of the keepers and assembly of the first delta prototype.
- Vacuum chamber challenges for installation and NEG coating activation.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Thank you for your attention!