Procurement, Measurement and Installation of 2 Octupoles for ATF

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CERN – European Organization for Nuclear Research

Outline:

- *Octupoles proposal and specification*
- *Components procurement*
- *Assembly and measurements*
- *Shipment and installation at ATF*

Octupole for ATF: Octupole proposal and specification

ICA-JP-0103-Appendix 13

Collaborative Research Contract

The High Energy Accelerator Research Organization/KEK (hereinafter referred to as "A"), and The European Organization for Nuclear Research/CERN (hereinafter referred to as "B'), hereinafter referred to as the Parties collectively, or Party individually, hereby conclude a collaborative research contract under the Agreement on Collaborative Work (ICA-JP-0103) between parties signed on 13 February 2009.

The Parties hereby agree as follows:

Article 1. (Title and Scope of Collaborative Research)
The Parties desire to and agreed to execute following collaborative research.

The CERN procurement of 2 Octupoles for further exploration of nanometre beam size beam dynamic was agreed in 2014 after a proposal presented at the CERN-Midterm Collaboration meeting.
This would have been part of the hardware CERN contributions for the prosecution of the ATF program.

CERN-ATF2 midterm collaboration

R. Tomás, M.J. Barnes, A. Latina, T. Lefevre, M. Modena,
Y. Papaphilippou, J. Pfingster, D. Schulte, S. Stapnes and A. Yamamoto

Abstract

This report describes the CERN R&D midterm projects in ATF and ATF2 in the framework of an increased collaboration between KEK and CERN. Direct contributions from CERN to the operational budget of ATF are considered.

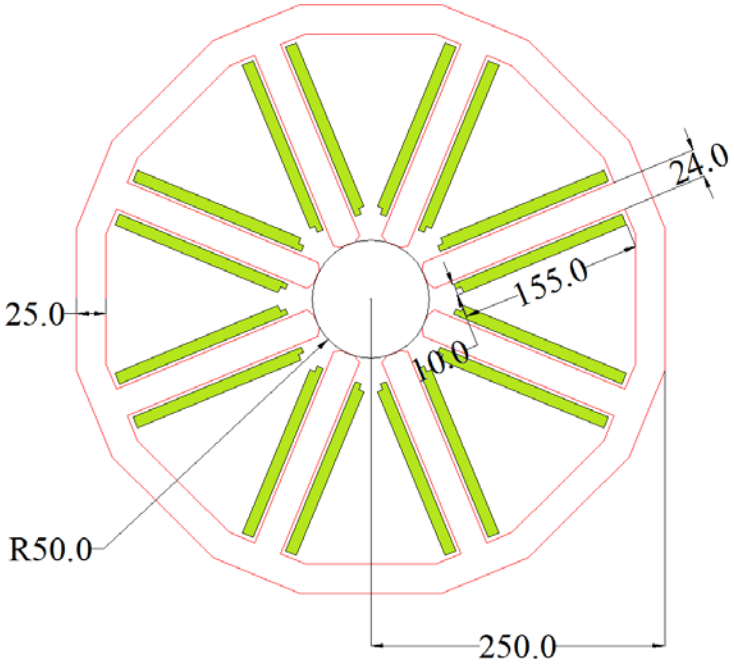
PACS numbers:

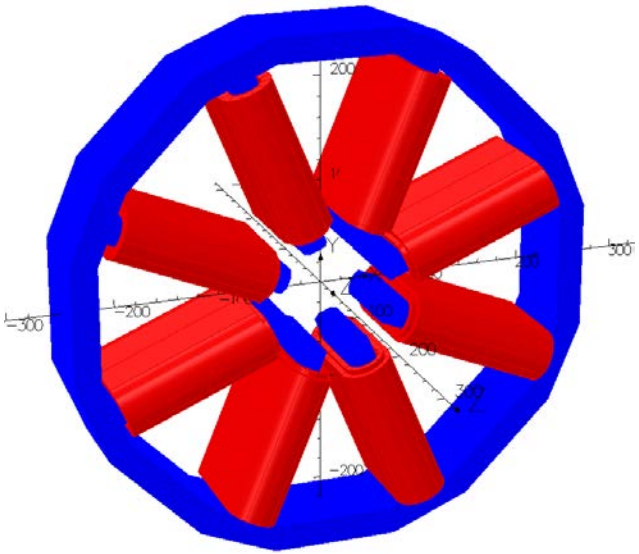
Octupoles for ATF: Octupoles Specification

A first specification from Beam Dynamic Team was considering 2 identical octupoles with an integrated strength of 560 T/m^2.
The magnet conceptual design was started on this strength requirement.

The magnet design was mainly driven by layout and manufacturing boundary conditions.

PARAMETER	*UNITS*	*VALUE*
Gradient,	T/m^3	5284
Integrated gradient	T/m^2	560
Aperture radius	mm	50
Iron length	m	0.100
Magnetic length	m	0.106
Coil number of turns		61
Conductor size	mm x mm	5 x 5
Ampere-turns	A	1200
Current	A	19.7
Resistance (per coil)	mΩ	14
Conductor length (per coil)	m	19.9
Conductor mass (per coil)	kg	4.5
Yoke mass	kg	56
Total mass	kg	92





Octupoles for ATF: Octupole Specification

In 2015 two different octupole strengths and integrated gradients were finalized. A new requirements was specified in the document SLAC-TN-14-019. (NOTE: later the final position of the 2 magnets evolved, and this bring to a further strengths revision, the final).

The detailed magnets design was started following these main aspects:

- Mechanical design simpler as possible concerning the installation aspects in ATF. (in order to not perturb the existing equipments as vacuum chambers and BPMs).
- Air cooled coils were chosen to simplify, installation, service requirements and globally magnet design and costs.
- Magnet bore was chosen to be compatible with the existing vacuum chambers/BPMs, to provide an adequate field quality and enough iron saturation (to simplify the operation and quality at low gradients).

SLAC-TN-14-019

Specifications of the octupole magnets required for the ATF2 ultra-low β^* lattice*

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[2] *European Organization for Nuclear Research (CERN), CH-1211 Geneva 23, Switzerland*

[3] *High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*

(Dated: May 8, 2014)

Abstract

The Accelerator Test Facility 2 (ATF2) aims to test the novel chromaticity correction for higher chromaticity lattices as the one of CLIC. To this end the ATF2 ultra-low β^* lattice is designed to vertically focus the beam at the focal point or usually referred to as interaction point (IP), down to 23 nm. However when the measured multipole components of the ATF2 magnets are considered in the simulations, the evaluated spot sizes at the IP are well above the design value. The designed spot size is effectively recovered by inserting a pair of octupole magnets. In this note we addressed the technical specifications required for these octupole magnets.

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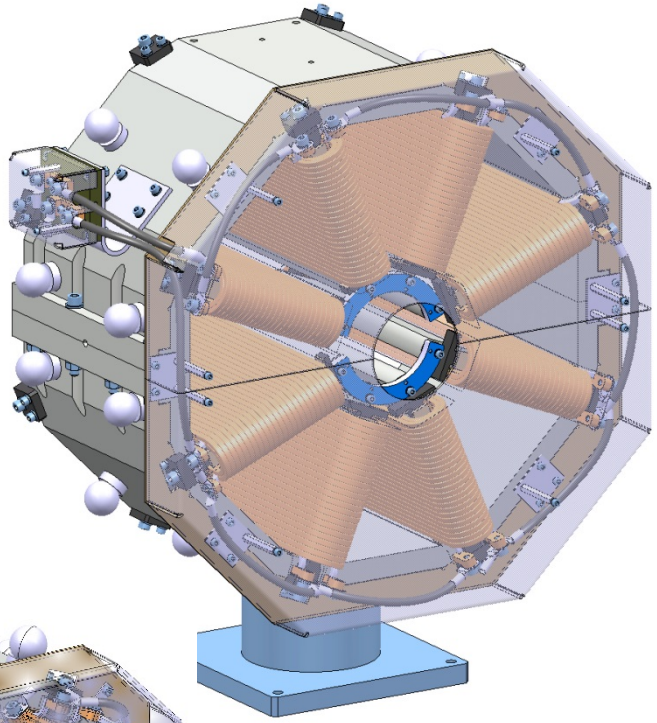
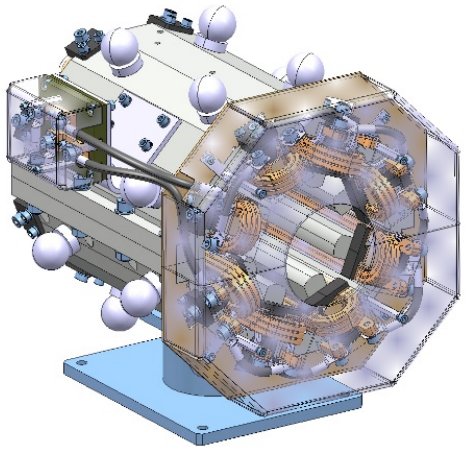
Octupoles for ATF: Octupole Specification

The designs converged to the following detailed 3D views and parameter set. The final required integrated gradient were:
212 and 2046 T/m^2

OCTU2



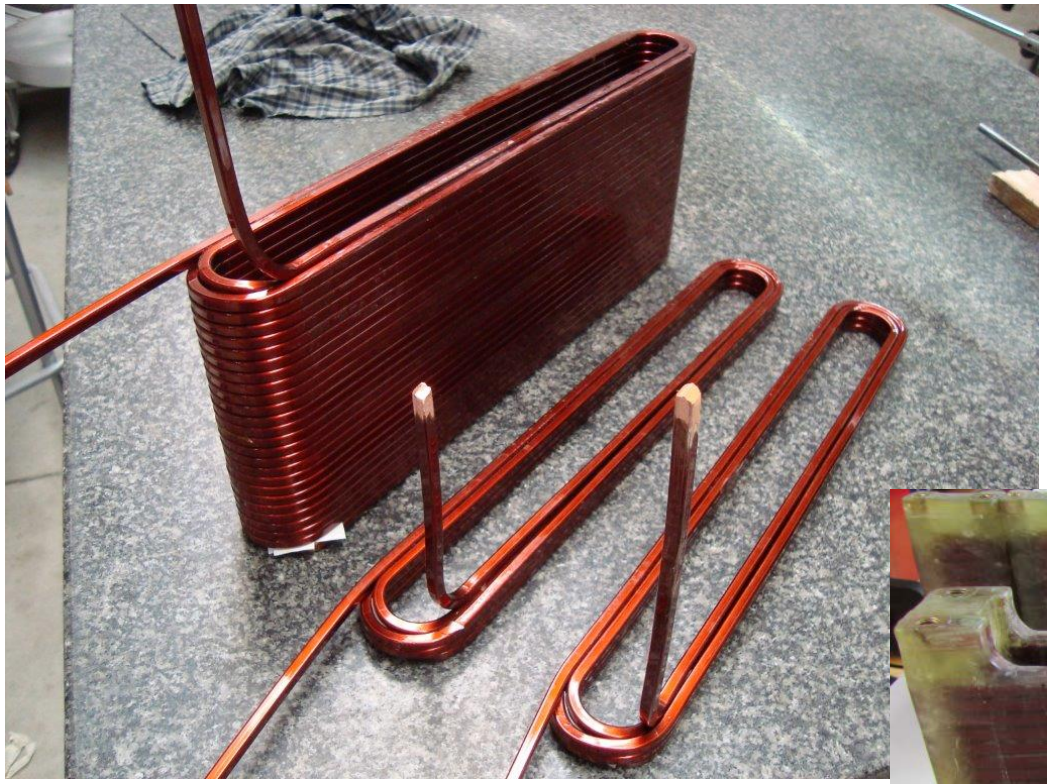


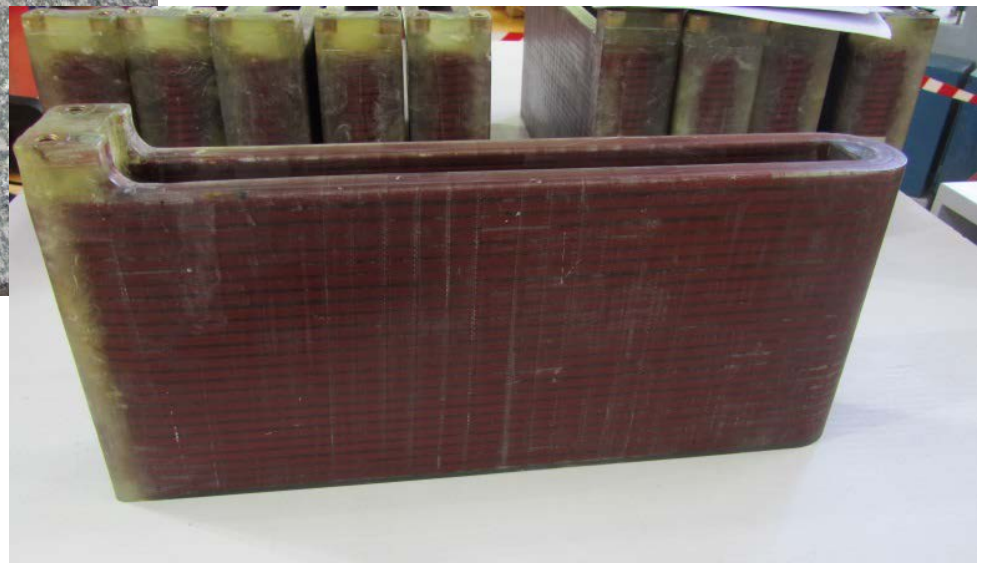
OCTU1

	OCTU1	OCTU2
Maximum Integrated gradient [T/m^2]	212	2046
Max. Gradient [T/m^3]	708	6820
Magnetic length [mm]	300	300
Aperture radius [mm]	52	52
Ampere-turns [A] (per coil)	180	1800
Number or turns (per coil)	6	50
Max. Current [A]	30	36
Max. Voltage [V]	0.63	5.8
Max. Current density [A/mm^2]	0.9	1.0
Max. Power [W]	19	210
Max. Pole field [Gauss]	166	1600
Resistance at 20 °C (as measured at NORMATEF) [mOhm]	21	162
Conductor length [m]	35	291
Conductor mass (one coil) [kg]	1.5	12.5
Total magnet mass [kg]	90	330
Max. magnet length (with cover) [mm]	360	419
Max. height (with support) [mm]	373	718
Max. width [mm]	386	677

Octupoles for ATF: Components procurement

Procurement of main components was done with industry:
- Coils were procured with S.E.F. Sarl, Labège - F

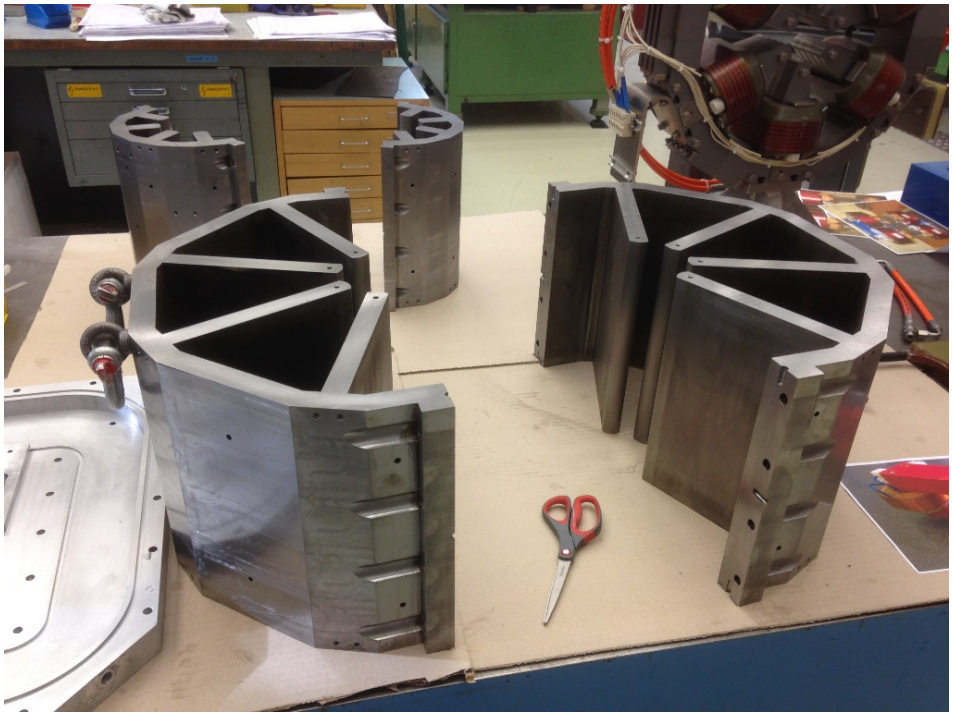


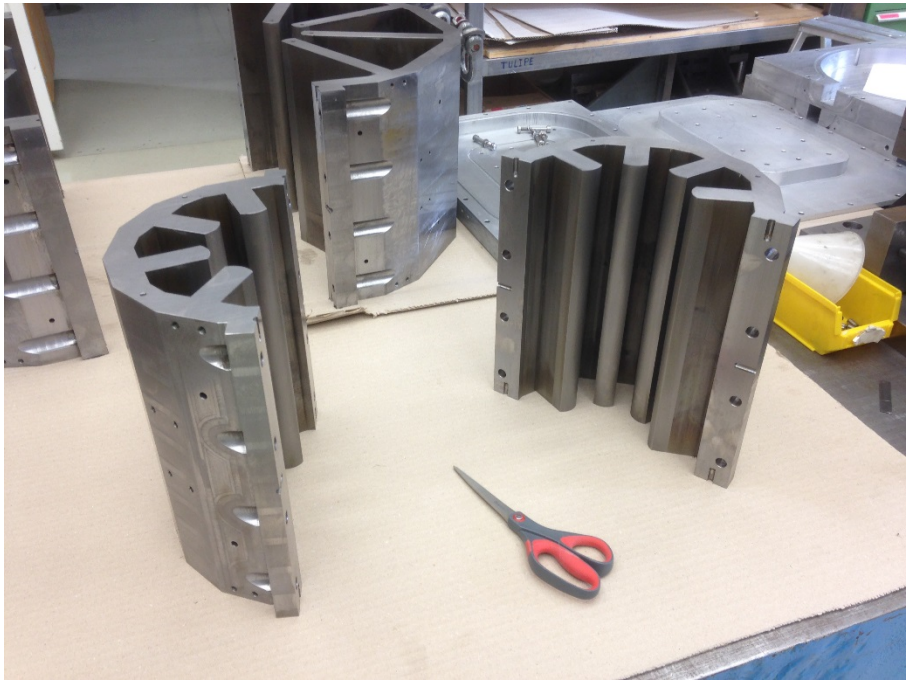


20 coils were procured (8 + 8 + 4 spares)

Octupoles for ATF: Components procurement

- Iron yokes, made in ARMCO iron grade and machined by EDM (Electro Discharge Machining), were procured with: Röttgers Værktøj A/S Odense - DK





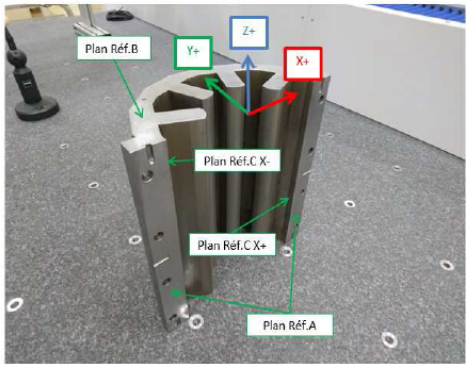
Octupoles for ATF: Components procurement

Iron yokes were measured at CERN Metrology Lab and accepted even if with some out of tolerance respect to the design (specified tolerance were know to be quite difficult to be achieved on so big pieces…). Final tolerance of the critical parts (e.g. poles surface) are in the range of 150 µm. As expected the OCTU1 iron yokes (that are smaller) are more precise respect to OCTU2 iron yokes.

RAPPORT DE CONTROLE

Nom du plan de contrôle:	ATF SMALL OCTUPOLE HALF YOKE		
Nom de la pièce:	ATF SMALL OCTUPOLE HALF YOKE		
N° de plan et indice:	/	Date:	29/03/2016 14:04
		Contrôleur:	HAERINCK Cyril
Client:	LOPEZ Carlos		
N° de pièce:	1	CMM type:	PRISMO_ULTRA
N°EDMS:	1607042	Incertitude de mesure:	1.2 µm + L/500 mm
Fournisseur:	/	Température:	20°C ±1°C
Projet:	ATF JAPON		

Informations relatives au référentiel de mesure

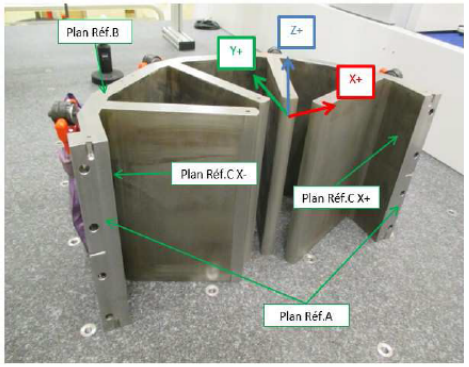


Construction du référentiel de base:
- Orientation primaire: Plan Réf.A
- Orientation secondaire: Plan Réf.B
- Origine: X, Y, Z = Intersection entre les plans Réf.A, Réf.B et le plan médian construit avec les plans Réf.C X- et X+

RAPPORT DE CONTROLE

Nom du plan de contrôle:	ATF BIG OCTUPOLE HALF YOKE		
Nom de la pièce:	ATF BIG OCTUPOLE HALF YOKE		
N° de plan et indice:	/	Date:	23/03/2016 16:03
		Contrôleur:	HAERINCK Cyril
Client:	LOPEZ Carlos		
N° de pièce:	1	CMM type:	PRISMO_ULTRA
N°EDMS:	1607042	Incertitude de mesure:	1.2 µm + L/500 mm
Fournisseur:	/	Température:	20°C ±1°C
Projet:	ATF JAPON		

Informations relatives au référentiel de mesure

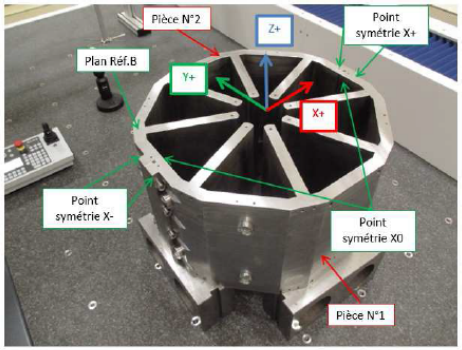


Construction du référentiel de base:
- Orientation primaire: Plan Réf.A
- Orientation secondaire: Plan Réf.B
- Origine: X, Y, Z = Intersection entre les plans Réf.A, Réf.B et le plan médian construit avec les plans Réf.C X- et X+

RAPPORT DE CONTROLE

Nom du plan de contrôle:	ATF BIG OCTUPOLE YOKE ASSEMBLE		
Nom de la pièce:	ATF BIG OCTUPOLE ASSEMBLE		
N° de plan et indice:	/	Date:	24/03/2016 14:42
		Contrôleur:	HAERINCK Cyril
Client:	LOPEZ Carlos		
N° de pièce:	1 AP DEMONTAGE-REMONTAGE	CMM type:	PRISMO_ULTRA
N°EDMS:	1607042	Incertitude de mesure:	1.2 µm + L/500 mm
Fournisseur:	/	Température:	20°C ±1°C
Projet:	ATF JAPON		

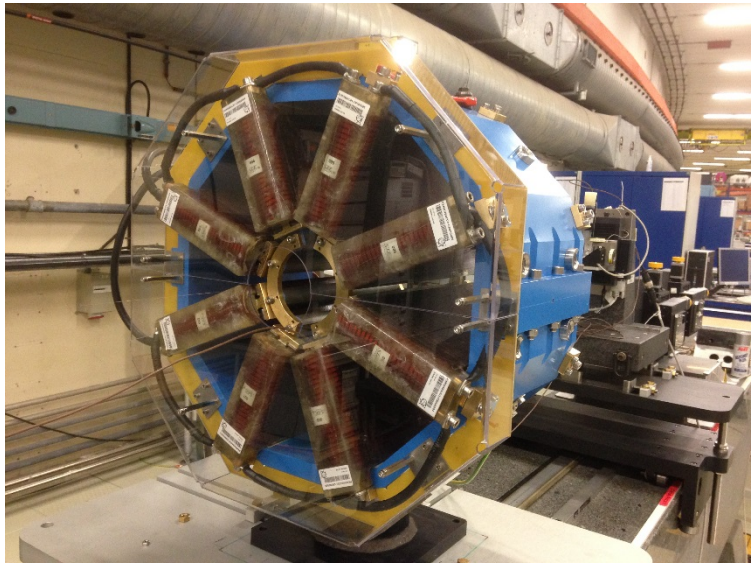
Informations relatives au référentiel de mesure

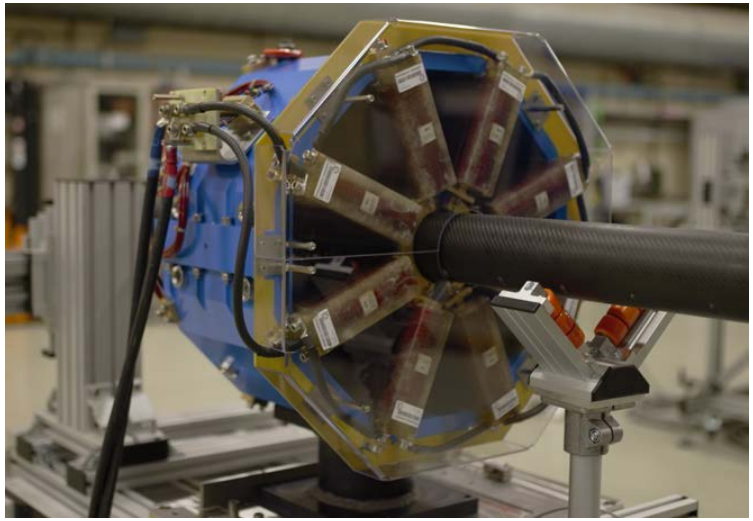


Construction du référentiel de base:
- Orientation primaire: Plan Réf.B
- Orientation secondaire: Droite passant par les points de symétrie X- et X+
- Origine: X = Point de symétrie X0
  Y = Droite passant par les points de symétrie X- et X+
  Z = Plan Réf.B

Octupoles for ATF: CERN Measurements

The 2 magnets were assembled in June-July 2016 and tested at CERN in August.





Magnetic measurement reports are available in CERN-EDMS (N° 1725782 and 1725791).

The transfer functions were accurately measured up to the maximum (nominal) design integrated gradient and beyond.
In fact it was later asked to define and check an "ultimate" working points at which the magnets could work.
This "ultimate" current was set to 50 A, a value compatible with the thermo-switches of the magnets coils (remind: air cooled).

	(Nominal) Design Integrated Gradient (T/m^2)	(Nominal) Measured Integrated Gradient(T/m^2)	Ultimate Measured Integrated Gradient (T/m^2)
OCTU1	212 (30 A)	218 (28.0 A)	390.66 (50A)
OCTU2	2046 (36 A)	2060.6 (32 A)	3166.9 (50 A)

Octupoles for ATF: CERN Measurements

OCTU1:

Comp.	Units (average)
b5	-0.93
a5	-0.53
b6	0.37
a6	-0.41
b7	-0.17
a7	0.04
b8	-0.02
a8	-0.12
b9	-0.01
a9	0.01
b10	0.01
a10	0.01
b11	0.02
a11	-0.06
b12	-0.27

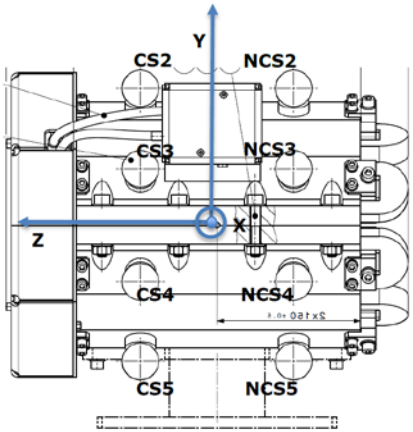
OCTU2:

Comp.	Units (average)
b5	2.20
a5	-1.11
b6	1.06
a6	-0.35
b7	-0.15
a7	0.01
b8	-0.04
a8	-0.02
b9	0.02
a9	-0.03
b10	0.02
a10	0.00
b11	0.00
a11	0.01
b12	-0.27

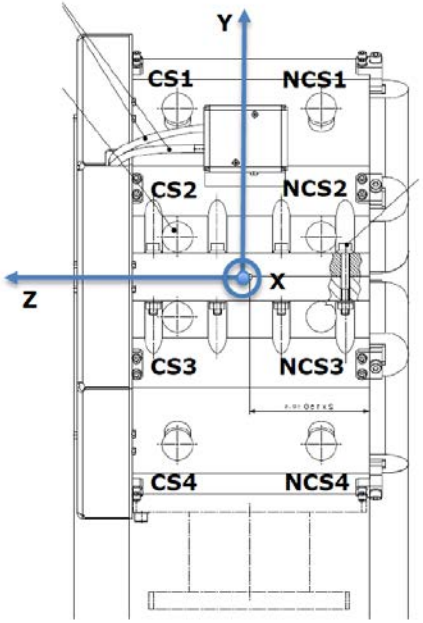
The field homogeneity is specified in terms of magnetic multipoles in 10^{-4} with respect to the main field at a reference radius of 20 mm. The results at 50 A are here presented.

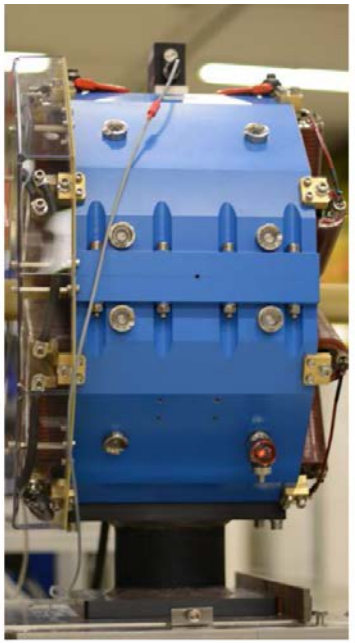
Measurements were done with a rotating coils system calibrated for the specific magnets by a stretched wire bench measurements.

Octupoles for ATF: CERN Measurements: magnetic axis



OCTU1:





OCTU2:

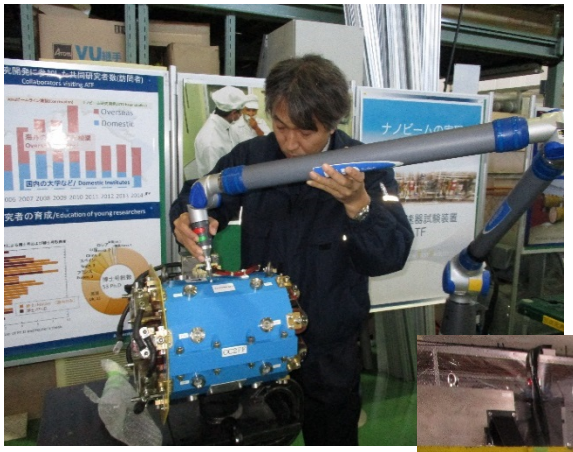
Installation checks/tests:

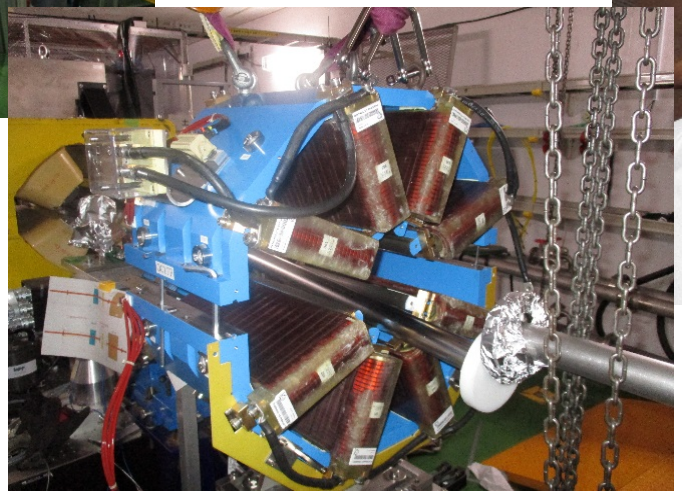
The OCTU2 magnet has been measured, opened-reclosed, and re-measured afterword. The magnetic center moves of +0.002 mm in x direction and - 0.003 mm in y direction which are in the range of the magnetic measurement uncertainty. Multipoles variation change less than 0.1 unit. The test demonstrates the very good mechanical repositioning of the two magnet parts.

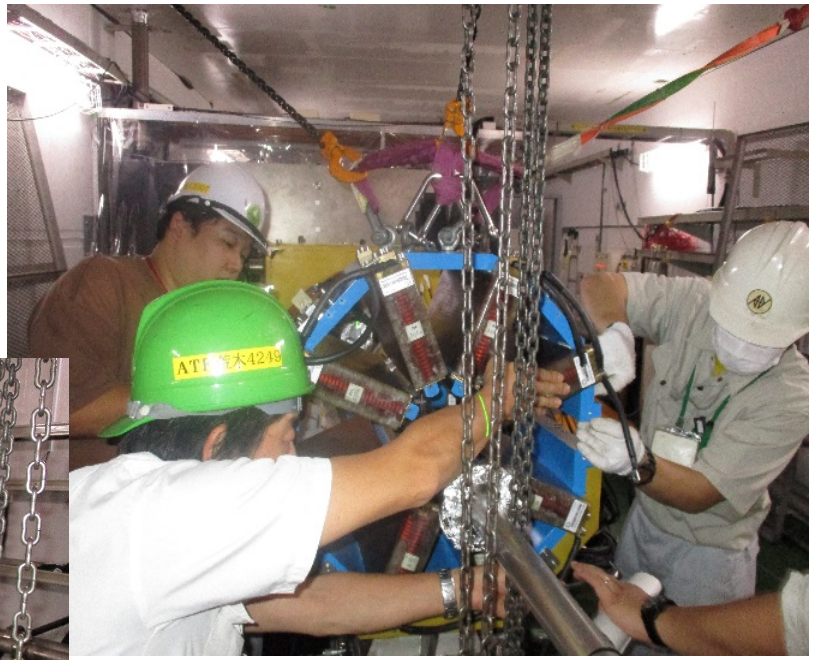
Magnetic centres coordinates were provided respect to the reference systems (defined by the metrology spheres supports)

Octupoles for ATF: Installation

The magnets were sent to ATF in August. A long term temporary transfer was settled. A tax of 8% on the value was paid by CERN to avoid stay limitation in Japan, but if we reimport them before end 2018 we could save some extra EU taxes.
The alignment reference system (network of external spheres) was checked by ATF Survey Team and results found in very good agreement with CERN measurements.
The magnets were finally installed in ATF on the 9 -11 Nov. 2016.

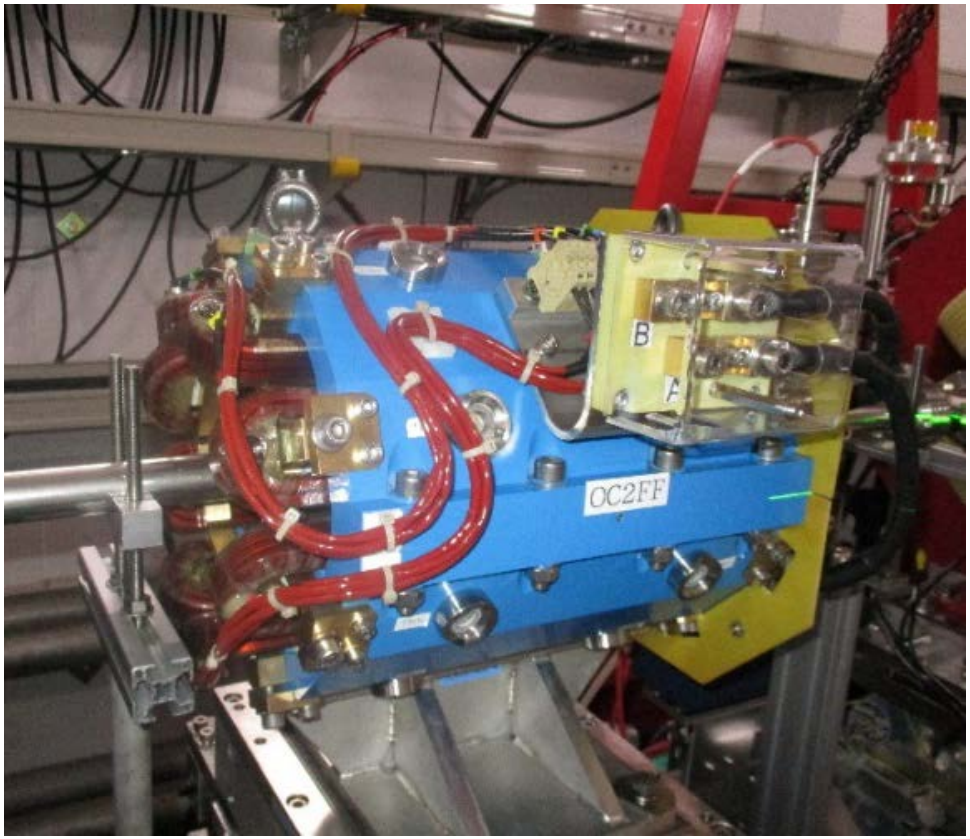




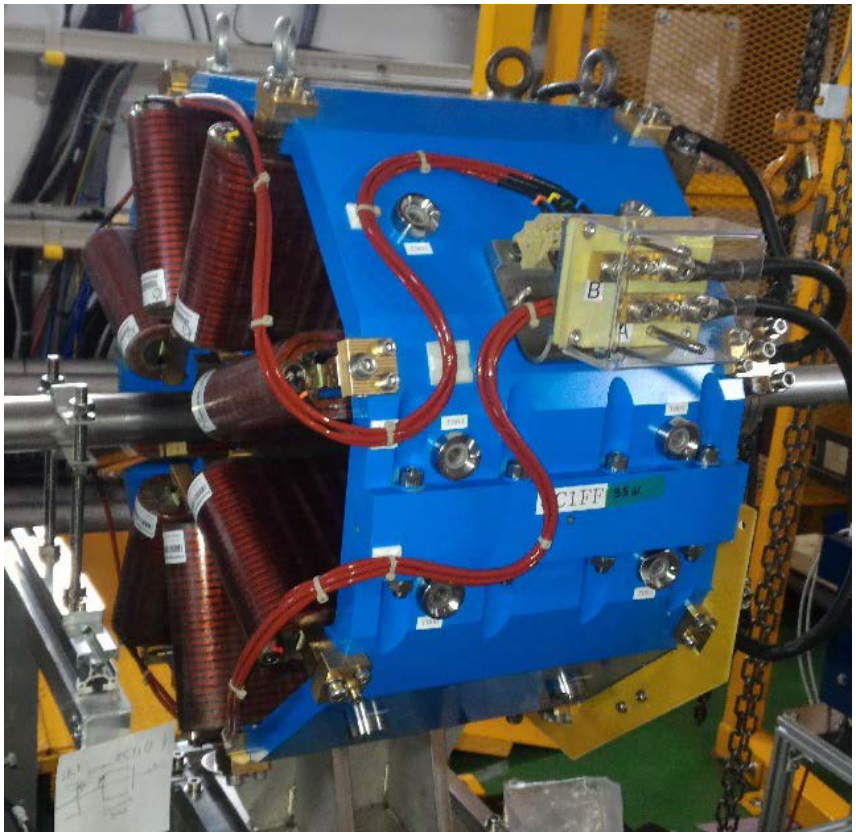


Octupoles for ATF: Installation

Installation is now completed. Both magnets are mounted on micrometric tables.
First electrical checks at installation were done with a temporary power supply (final ones were under procurement) all tests were positive.
First operation results will be presented tomorrow by F. Plassard.



OCTU1 installed in ATF



OCTU2 installed in ATF

Acknowledgment:

A. Aloev, C. Lopez, E. Solodko

(for magnet design, components procurement and magnet assembly)

M. Duquenne

(for magnet fiducialization)

C. Petrone

(for magnetic measurements)

Thank you for the attention