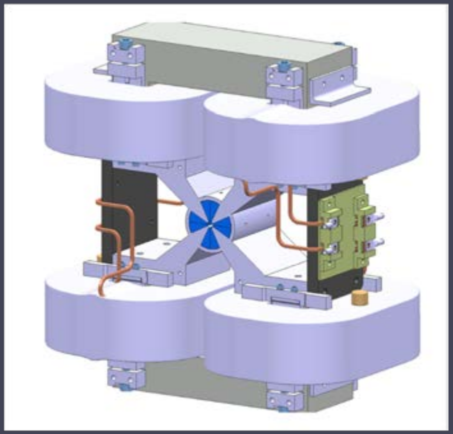
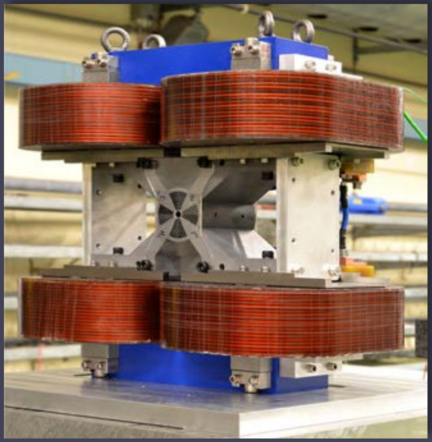




CLIC QD0 Short Prototype Final Assembly and Magnetic Measurements

Michele Modena, CERN-TE/MSC

LCWS12 International Workshop on Future Linear Colliders
University of Texas at Arlington, USA
22–26 October 2012

...Status of CLiC QD0 Prototype was presented last year at LCWS11 in Granada:

CLIC QD0 "Short Prototype" Status

Michele Modena, CERN- TE/MSC

Acknowledgments:

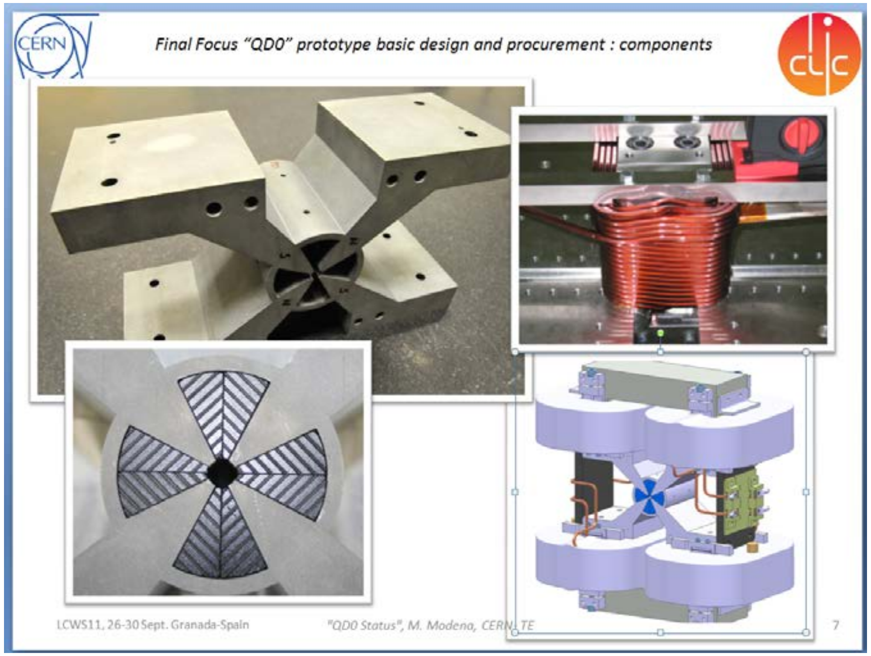
Team working (on part-time) on QD0 Magnet:
E. Solodko, P. Thonet, A. Vorozthsov and A. Bartalesi

Team working on Magnetic Measurement:
M. Buzio, O. Dunkel, J. Garcia Perez, C. Petrone

+ **CERN Metrology Lab** for the measurements of components

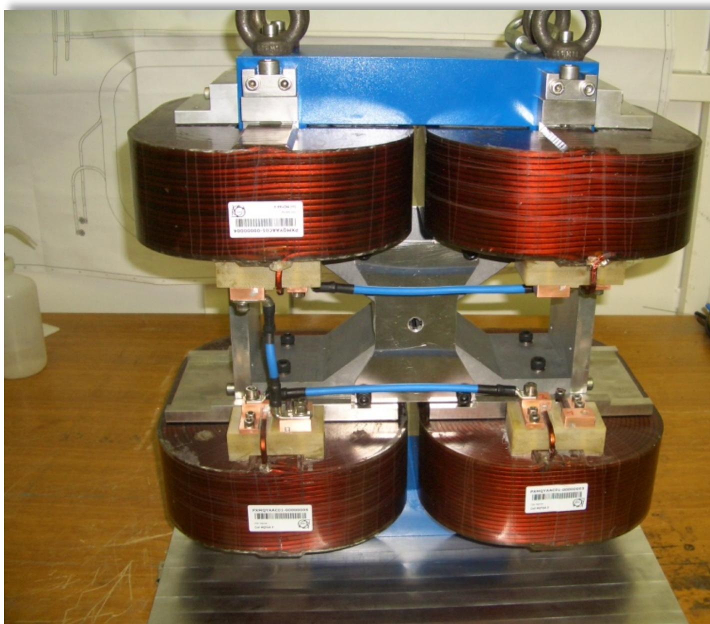
Next steps:

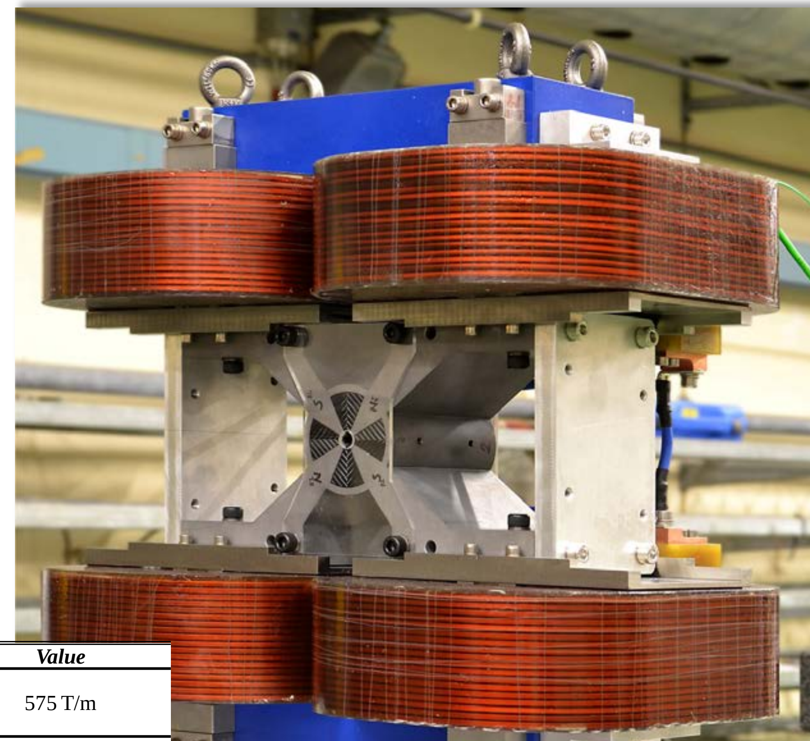
- ***Winding and impregnation of spares coils (2)***: October 2011
- ***Assembly of prototype in its FULL configuration*** : October 2011
- ***Powering tests and first SSW Magnetic Measurement***: November 2011
- ***Rotating Coils Magnetic Measurements***: December 2011
- ***Stability test*** to be planned: ex. versus temperature, external magnetic field, radiation...



Activities going on in 2012 and magnet was finally assembled and tested in two configuration: with ***$Nd_2Fe_{14}B$*** *and with* ***Sm_2Co_{17}*** *permanent magnet blocks.*

Final assembly of the magnet in Fall 2011:



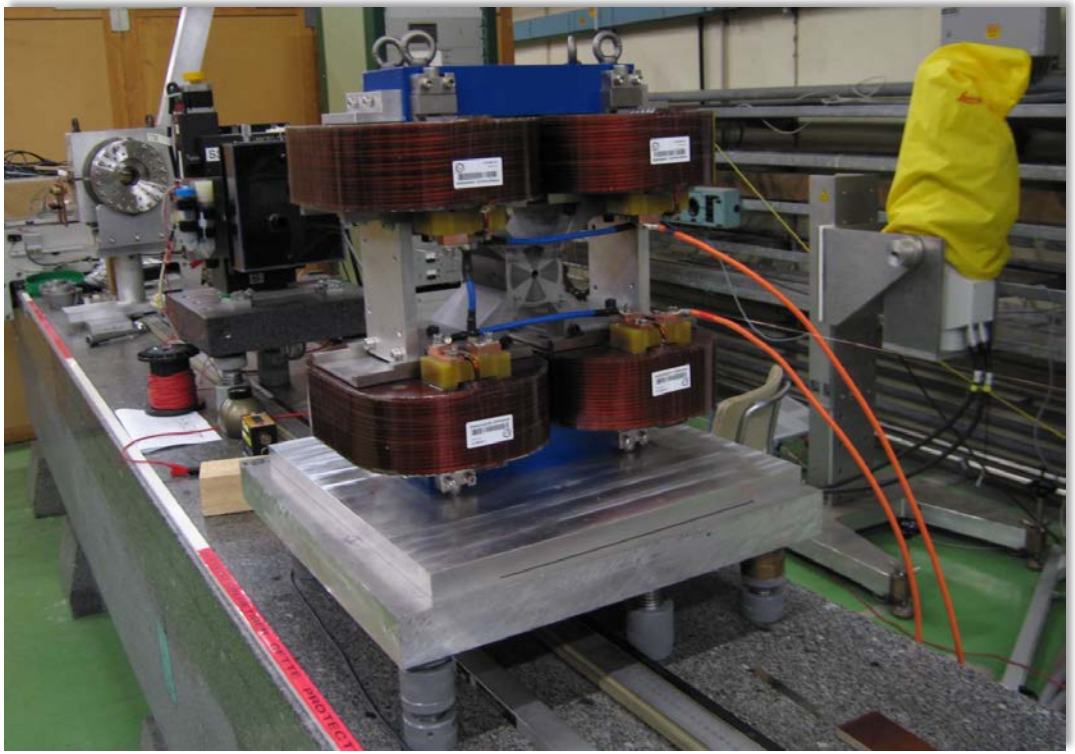


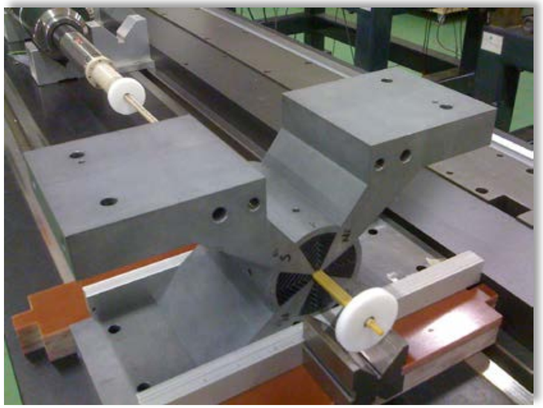
Parameter	*Value*
"Nominal" field gradient	575 T/m
Magnetic length	2.73 m
Magnet aperture (for beam)	7.6 mm
Magnet bore diameter	8.25 mm * * *Including a 0.30 mm vacuum chamber thickness*
Good field region(GFR) radius	1 mm
Integrated field gradient error inside GFR	< 0.1%
Gradient adjustment	+0 to -20%

CLIC QD0 Main Parameters		**100mm prototype**	**Real magnet 2.7m**
Yoke			
Yoke length	[m]	0.1	2.7
Coil			
Conductor size	[mm]	4×4	4×4
Number of turns per coil		18×18=324	18×18=324
Average turn length	[m]	0.586	5.786
Total conductor length/magnet	[m]	0.586×324×4=760	5.786×324×4=7500
Total conductor mass/magnet	[kg]	26.8×4=107.2	265.2×4=1060.8
Electrical parameters			
Ampere turns per pole	[A]	5000	5000
Current	[A]	15.432	15.432
Current density	[A/mm²]	1	1
Total resistance	[mOhm]	896	8836
Voltage	[V]	13.8	136.4
Power	[kW]	0.213	2.1

(magnet assembly: courtesy of : ***C. Lopez and P. Thonet****)*

The magnetic measurements systems utilized:





<u>"Single Stretched Wire":</u> well known method: utilized for Gdl and magnetic axis measurements
(Expected repeatability: ~ 1 unit (10^{-4}); expected accuracy: better of 10^{-3})

<u>"Vibrating Wire"</u> *new method* utilized for magnetic axis measurement
(Resolution: 1 μm)

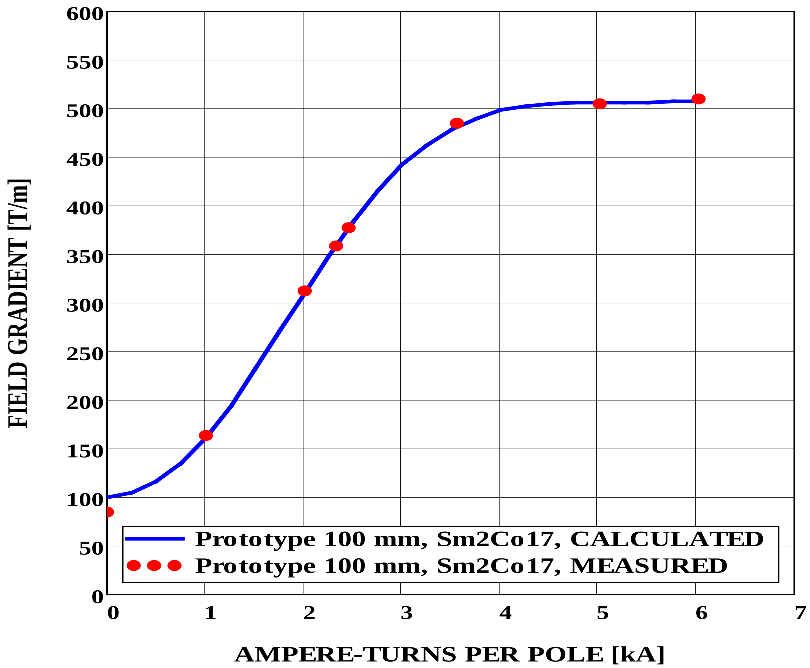
<u>"Oscillating Wire"</u> *new method* utilized for magnetic multipoles measurement
(Expected repeatability: ~ 4 units; expected accuracy: ~ 4 units,)

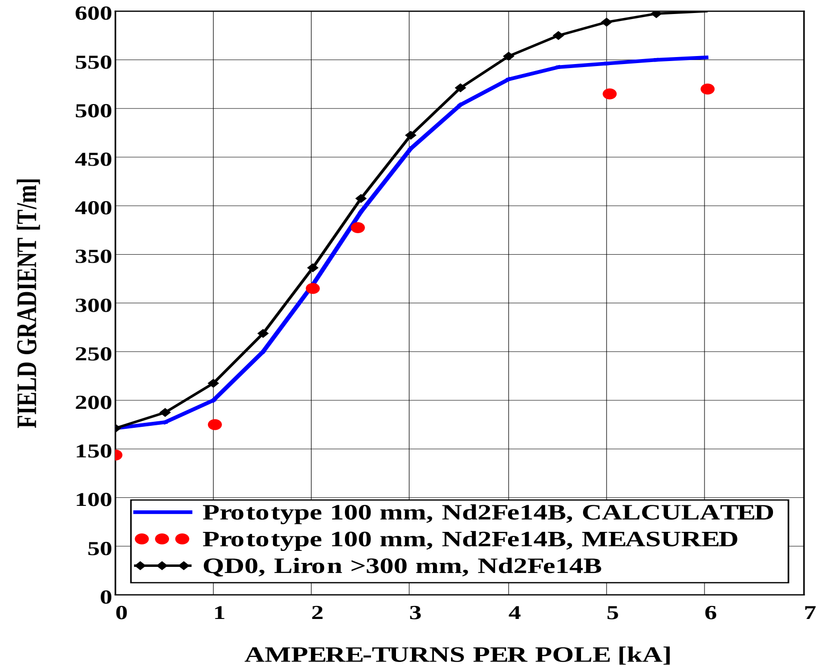
EXPECTED future use of an "ad hoc" rotating coil system under commissioning (right pictures)

(magnetic measurements development : courtesy of ***P.Arpaia, M.Buzio, J.Garcia, C.Petrone, L.Walckiers)***

***Two** campaigns of measurements were done in 2012 with QD0 prototype in two different configuration:*
- in January 2012: the magnet equipped with the $\underline{Nd_2Fe_{14}B}$ blocks was measured with the Vibrating wire system
- in August 2012: the same type of measurement was done for the configuration with $\underline{Sm_2Co_{17}}$ blocks .

Here below are shown the results of the MEASURED gradients (red dots, extrapolated from the INTEGRATED gradients effectively measured), versus the COMPUTED gradients (blue curves).



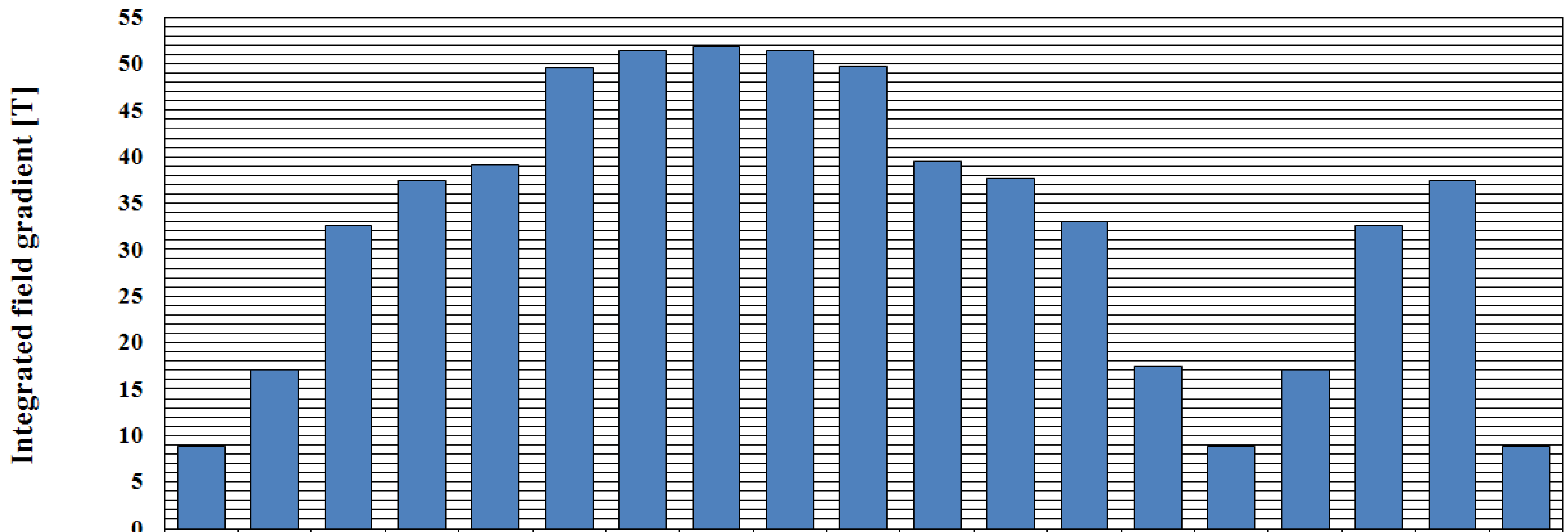


The measured Gradient in the configuration with Sm_2Co_{17} blocks (left) is in very good agreement with the FEA computation. This is not the case for the $Nd_2Fe_{14}B$ blocks (rigth) were a difference of ~ - 6% at maximum gradient is visible. This could have 2 possible explanation (the 1^{st} was excluded by a further FEA cross-check):

1) The Permendur saturate at lower level than expected. → The magnetization curve extracted from the Test Report of the raw material provided by the Supplier was utilized for the FEA computation that confirm that the problem is not coming by the Permendur quality.

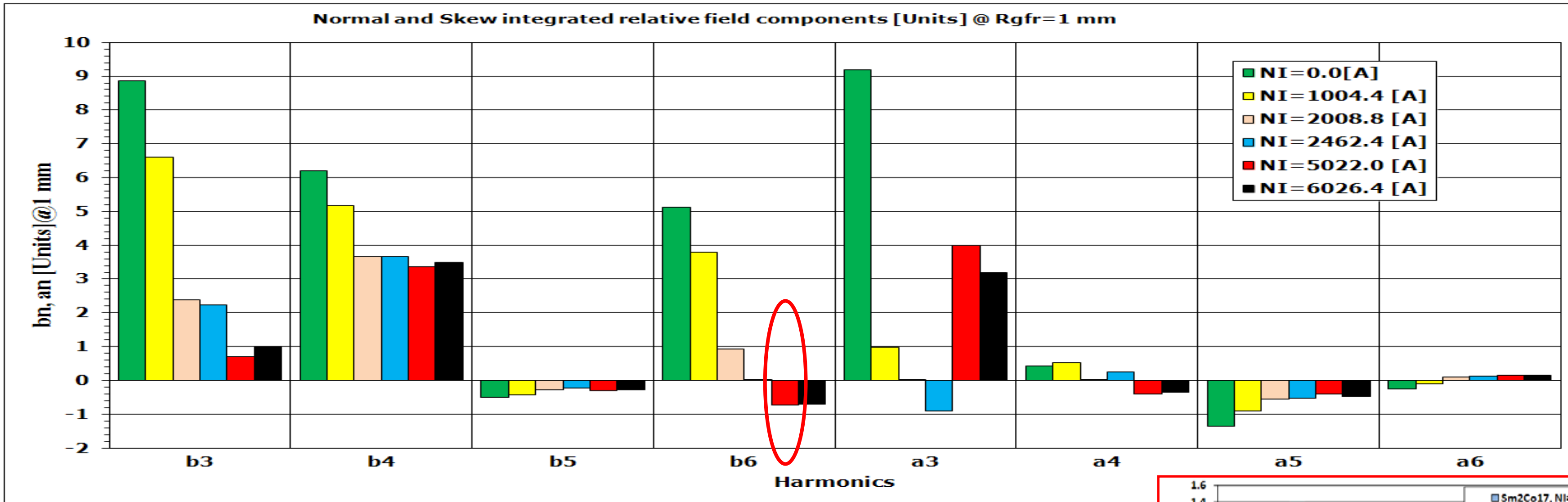
2) The quality (magnetization module and/or direction) of the $Nd_2Fe_{14}B$ PM blocks is not the expected one → we should get more indication of this possibility when the PM blocks measuring device (by Helmholtz coils) will be delivery to the MM Section.

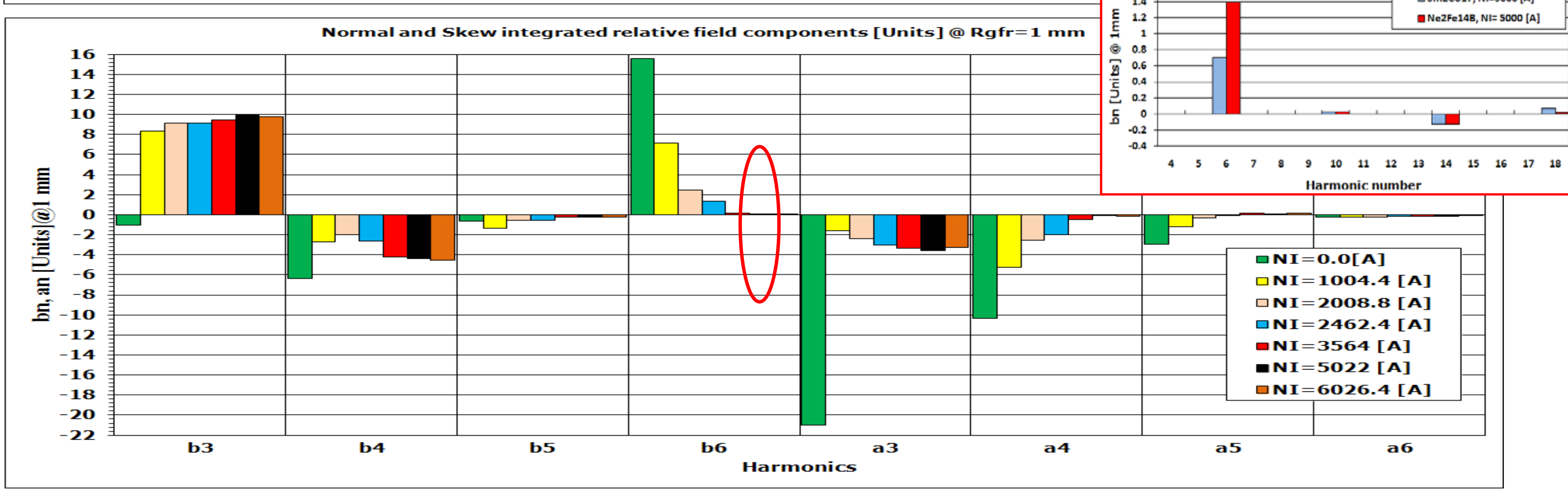
The below diagram shows a typical cycle of measurement of the INTEGRATED gradient versus the magnet powering (total coils current NI) in this case for configuration with Sm_2Co_{17} blocks.
To be noted as no demagnetization nor hysteresis effects are visible(same gradient for same current all along the cycles)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GL [T]	8.900	17.050	32.600	37.350	39.150	49.550	51.450	51.900	51.450	49.650	39.500	37.700	33.000	17.400	8.900	17.050	32.600	37.400	8.900
NI [A]	0.0	1004.4	2008.8	2332.8	2462.4	3564.0	5022.0	6026.4	5022.0	3564.0	2462.4	2332.8	2008.8	1004.4	0.0	1004.4	2008.8	2332.8	0.0

The below histograms provides, for both QD0 configurations, the magnetic harmonic content (multipoles) versus the magnet powering; upper graph for $Nd_2Fe_{14}B$, lower graph for Sm_2Co_{17}.
For comparison (small hystogram): the first computed "permitted" integrated mutipole at NI=5000A: b6=1.4 units (with NdFeB) and b6=0.7 units (with SmCo).





Conclusions (*preliminary*):

- The measured Gradient in the configuration with Sm_2Co_{17} blocks is in very good agreement with the FEA computation. The configuration with $Nd_2Fe_{14}B$ blocks shows a difference, at the maximum gradient, of ~ - 6% with the computed values. This effect is probably due to not correct magnetization (module and/or direction) of some of the $Nd_2Fe_{14}B$ PM blocks (to be investigate).

- The Field Quality shows that the measured permitted field harmonic components are in agreement with the computation. The presence of all the other components ("not permitted" normal and skew) depends by the inevitable manufacturing tolerances and imprecision of the Permendur core part and in the magnetization module and/or direction of the PM blocks.

  Anyway, to not be forget that:
  - The accuracy of the MM wire system: > ± 4 units.
  - The field harmonics were measured at r=3 mm and than results SCALED to r=1 mm (radius at which field quality is specified). The scaling (that include also a 3D→2D approximation), introduces some numerical approximation.

- The measured field harmonics are well inside the required tolerances (10 units) at the required (maximum) gradient.

- The stability of the magnetic axis was confirmed inside ± 5μm all along the powering curve of the quadrupole. This is another important good results toward a real application of such compact FF quadrupole design.

- The planned future measured with a dedicated Rotating Coils system should give more information and crosscheck of the magnet Field Quality.

- Other measurements could be planned to better discriminate the contributions to the Field Quality of the quadrupolare structure in Permendur and of the PM blocks.