Magnets & magnetic measurements

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XV FOOT Collaboration Meeting
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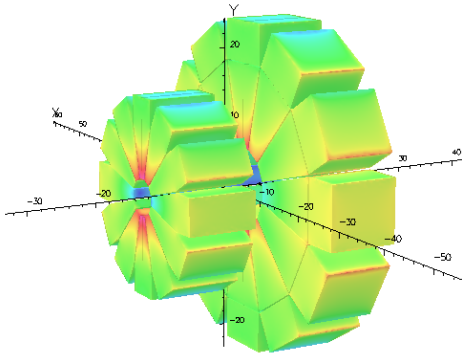
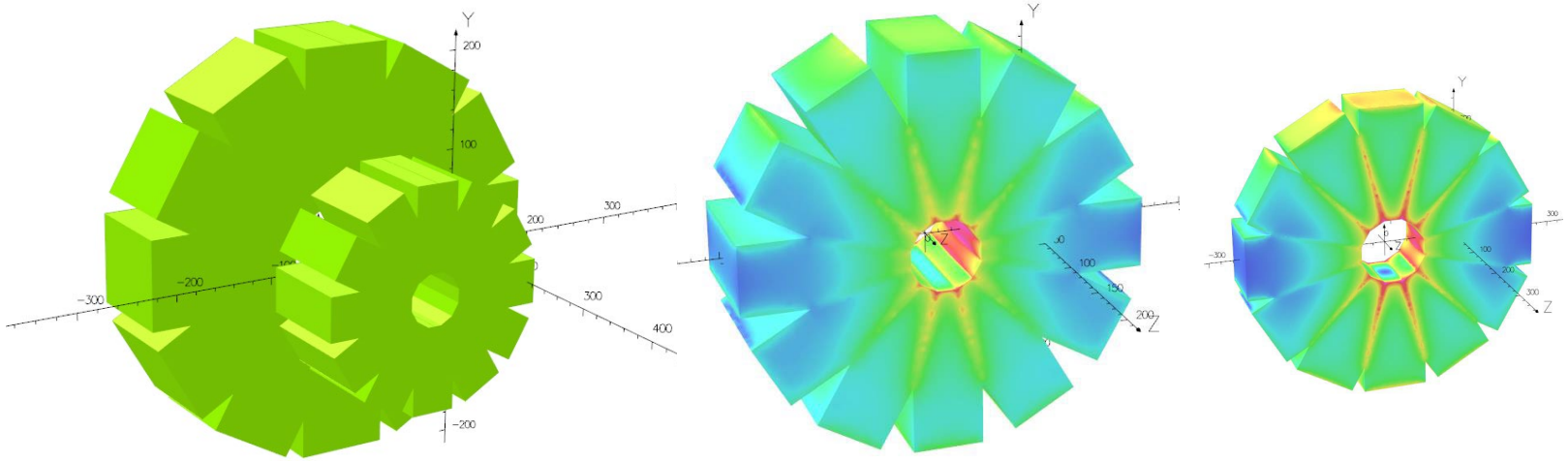
Magnetic system

Technical specifications with proposed preliminary system design (2019?)

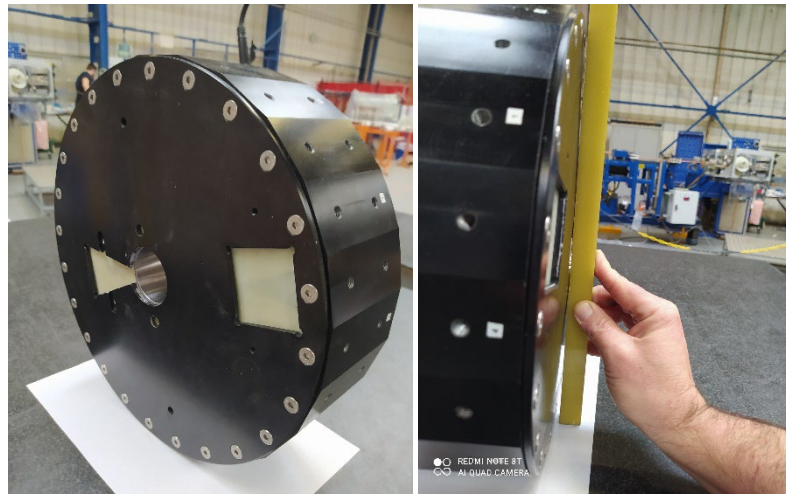
- Two dipoles
- Halbach 12 sectors

	M1	M2
Bore radius (mm)	25	53
Lmag (mm)	>127	>173
B_y (T)	>1,3	>0,86
$\int B_y \, dz$ (T m)	>0,166	>0,151
GFR (mm)	>20	>47
Homogeneity in GFR	$<1*10^{-2}$	$<6*10^{-2}$





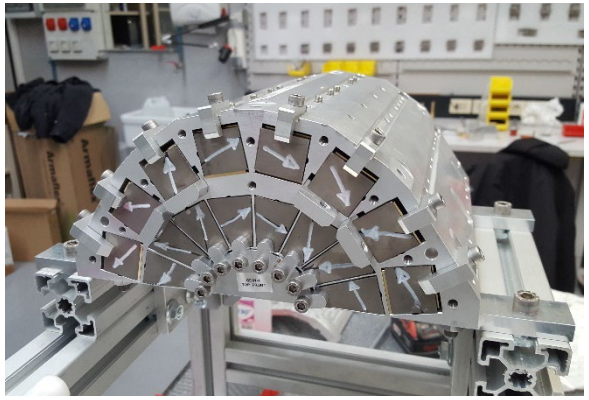
April 2021: Design with Samarium Cobalt YXG32 and «monoblocks» system

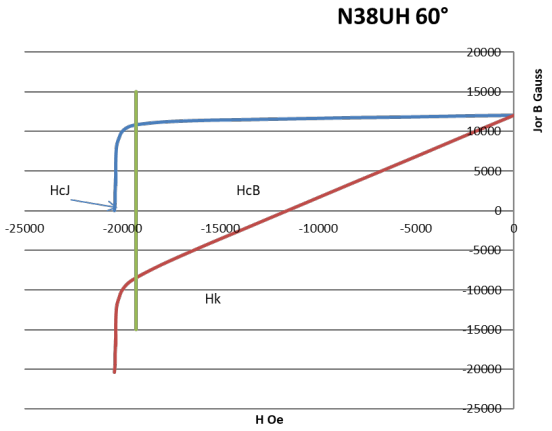


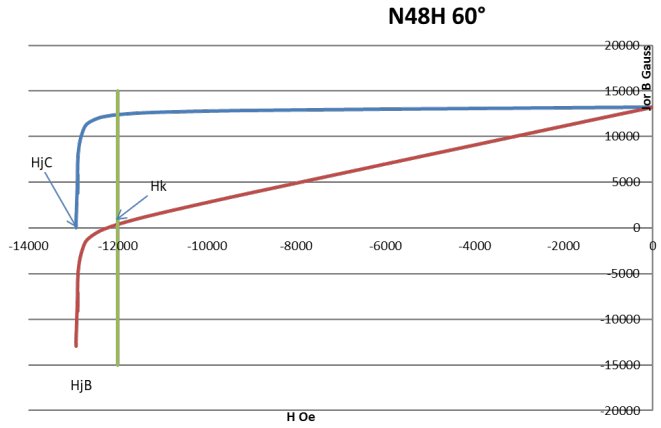
March 2022: problems in fabrication

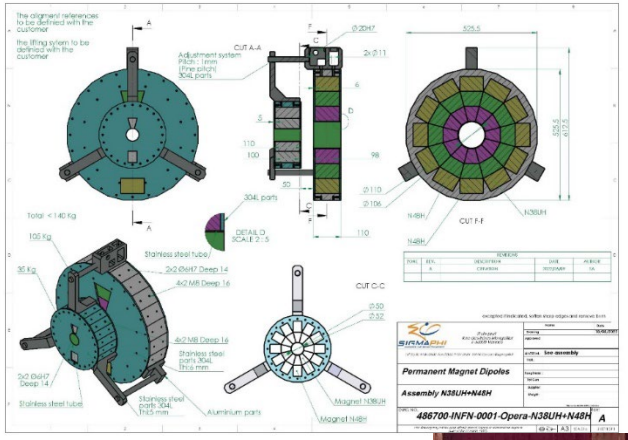
Magnetic system – new design

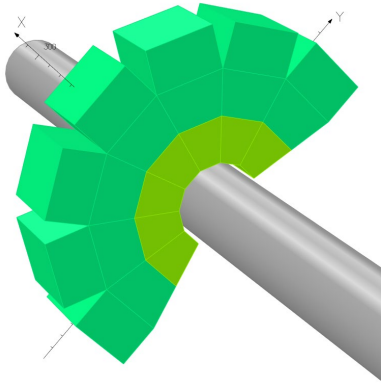
- New case: housing in cells (example from previous magnets)
- New choice of PM material: Neodymium-Iron-Boron
- Analysis of forces

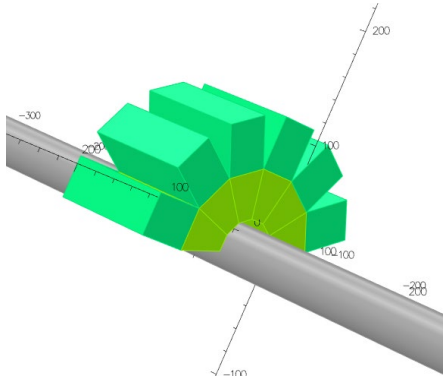


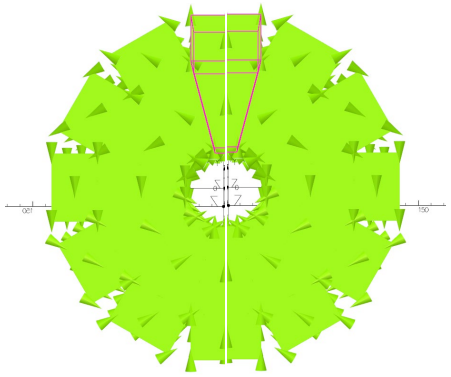




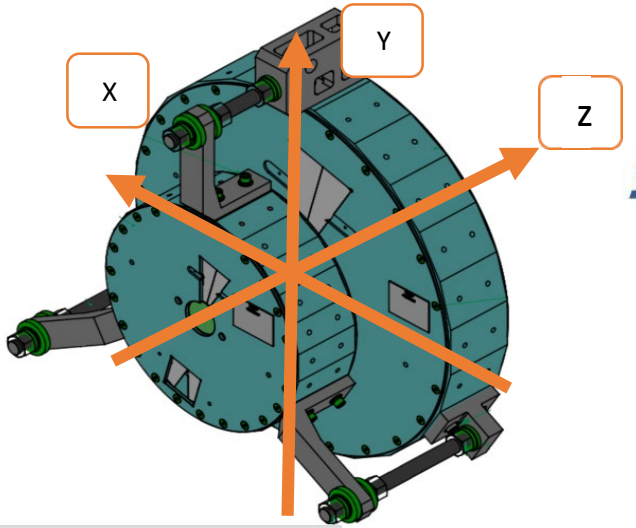








Measurements @SigmaPhi

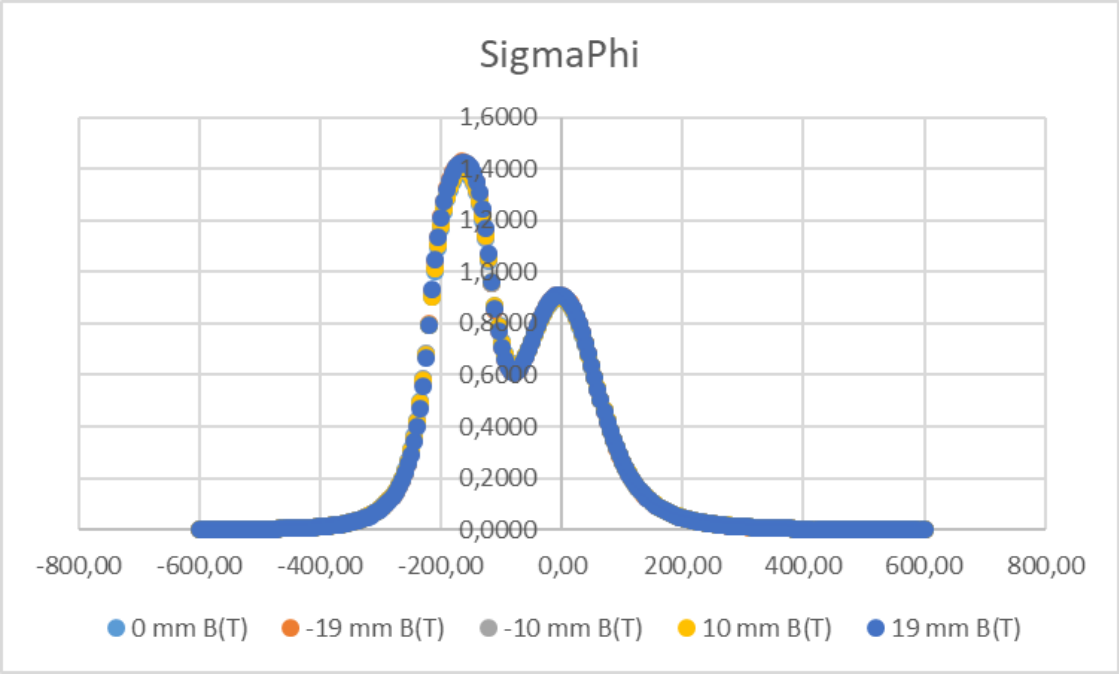


5 longitudinal scans

x=0mm, x= ± 10mm, x= ± 19mm

z from -600mm to +600mm with step Δz=5mm

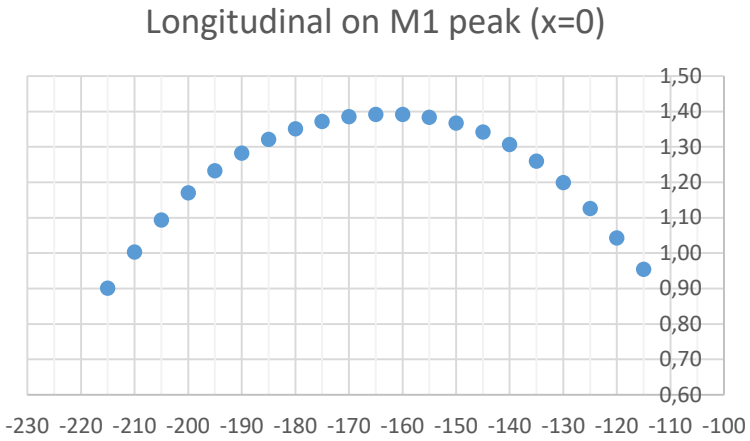
y=0mm

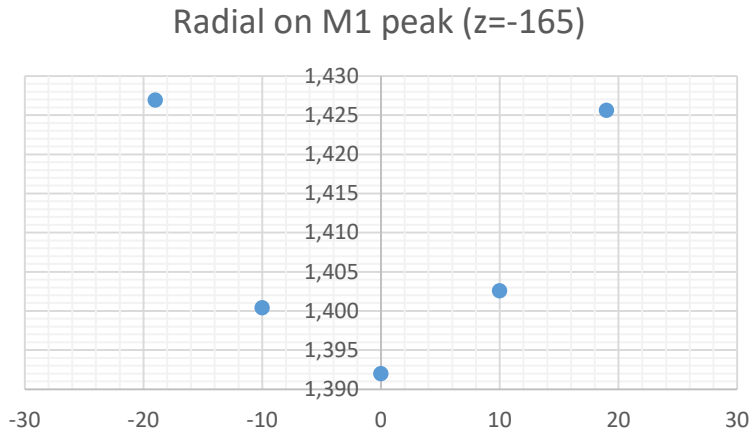


SigmaPhi has also performed individual measurements of M1 and M2

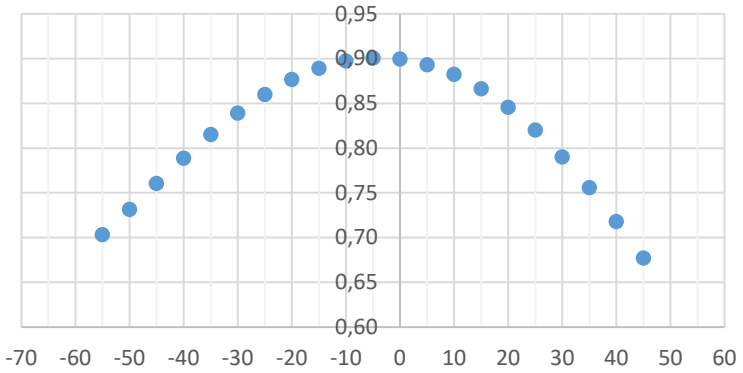
Measurements @SigmaPhi

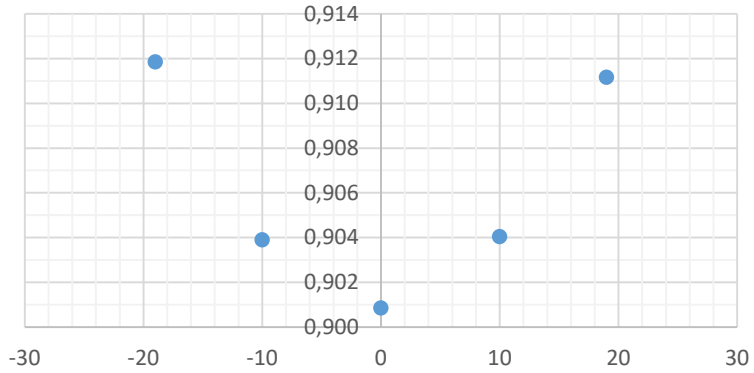
M1
By max= 1,3920 T
z max= -165 mm
(parabolic fit: 14008 T @ z= -163.7 mm)





M2
By max=0,9009 T
z max= - 5 mm
(parabolic fit: 8998 T @ z=-4.76 mm)

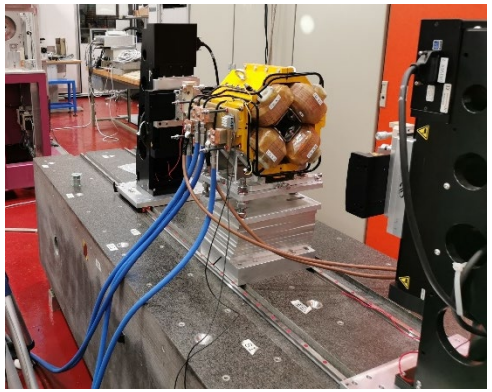




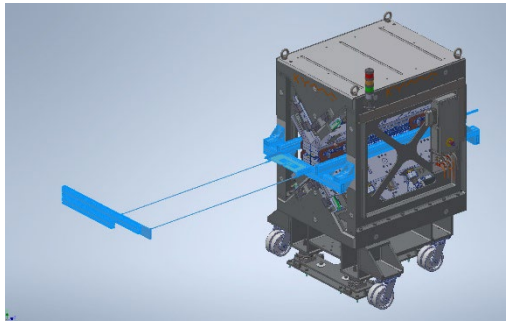
Integrated field of the system (M1+M2): $\int B_y dz$ = 322.37 T mm

Measurements @ LNF

The LNF magnetic measurements laboratory is operated by the Electrotechnical Engineering Group



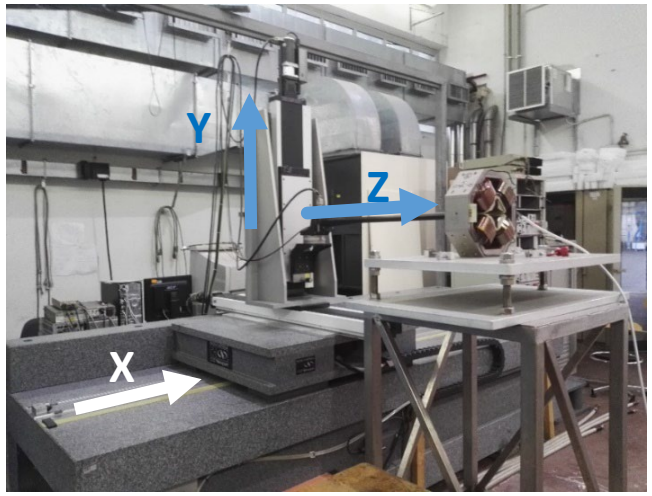
Stretched wire



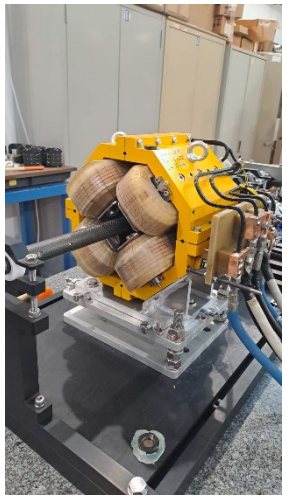
Mole Hall probe bench

Reference magnet

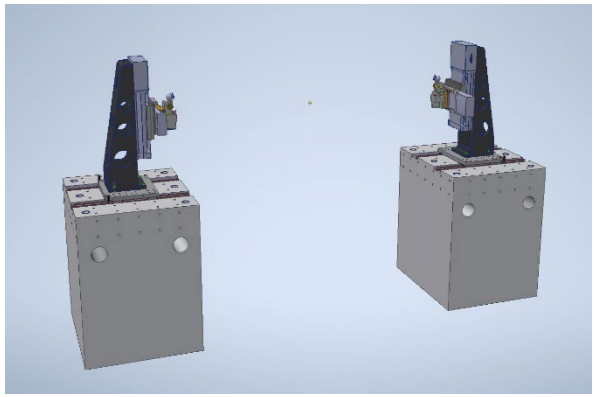
Cooling plant



Current 5 axis Movement System



Rotating coil

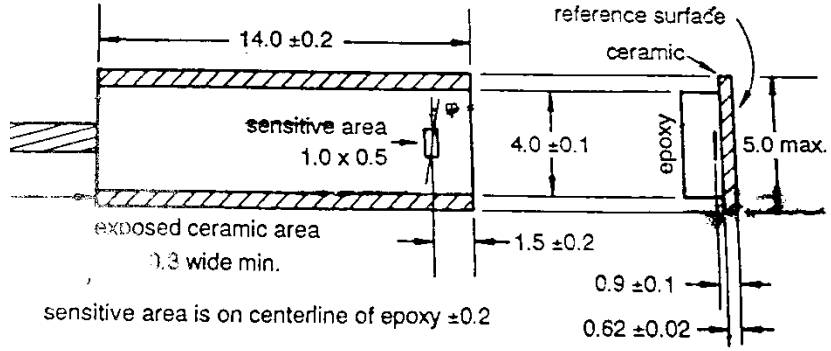


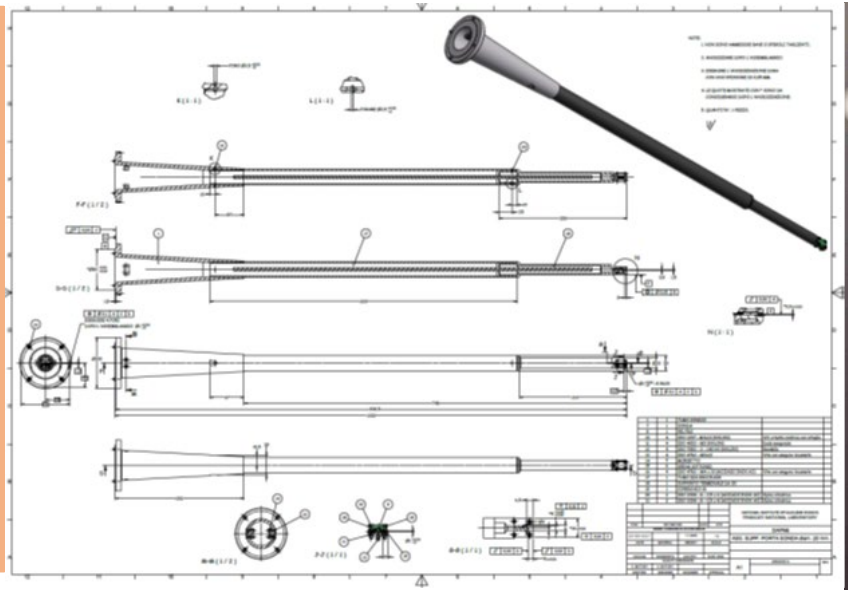
Pulsed wire bench

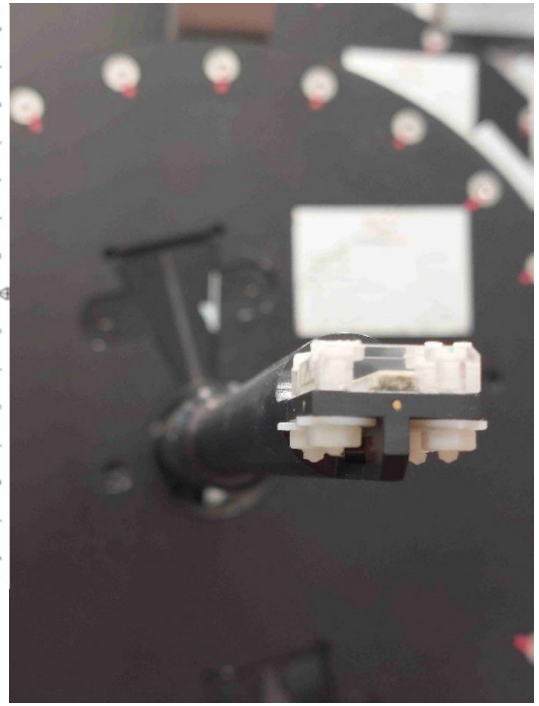
Power supplies – different sizes

Measurements @LNF

- Instrumentation: 1D Hall probe on a 5 axis movement system on a granite bench (B_y)
- Probe precision: $\pm 10^{-4}$ reading $\pm$ 6×10^{-4} full scale
- Sensitive area 1.0 x 0.5 mm^2
- Positioning accuracy: ±10 µm
- Room temperature



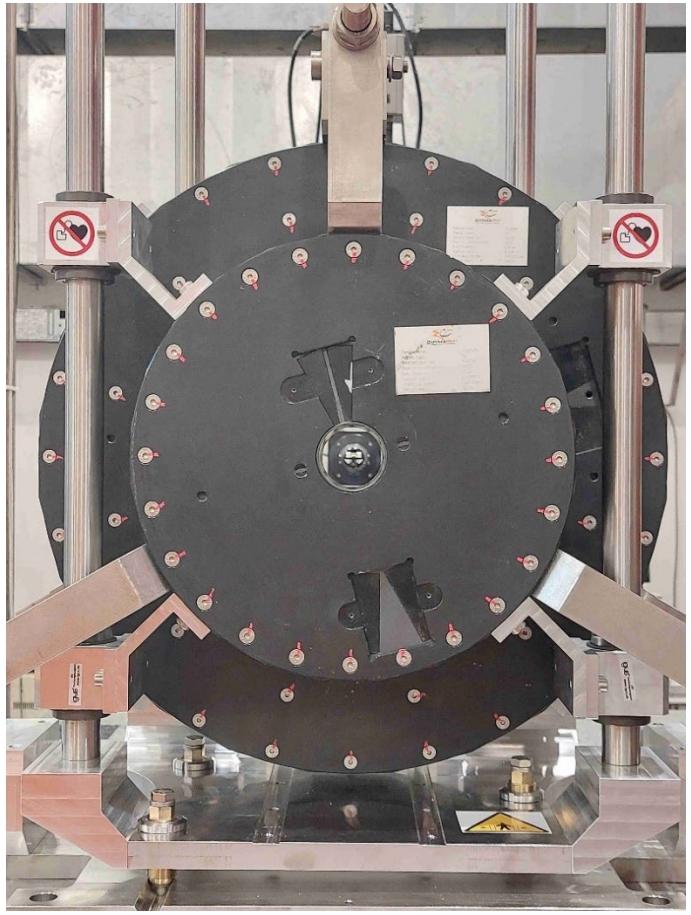


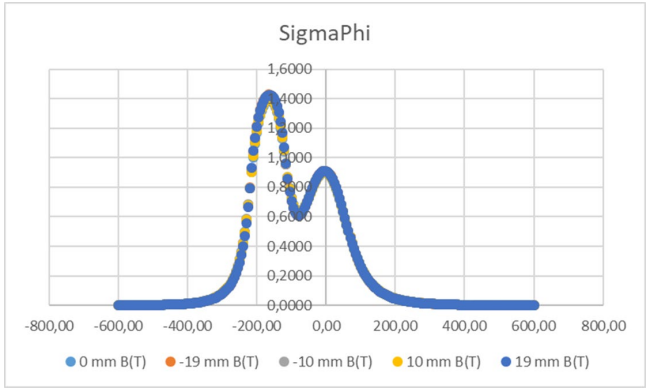


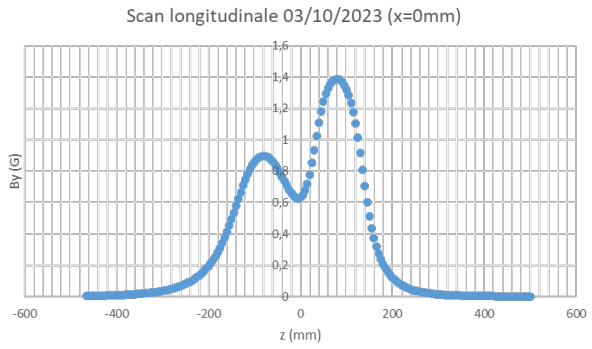
- Alignment by Mechanical Engineering Group with laser tracker

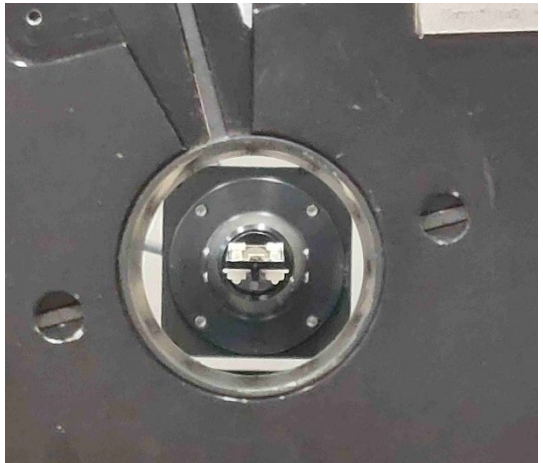
Measurements @LNF

- LNF holder diameter doesn't allow the same measurements taken at SigmaPhi (probe cannot move of ±19mm inside the bore)
- In order to have more flexibility, our measurements start on the magnet with the larger bore i.e. M2, hence different sign in x axis wrt SigmaPhi data
- Z=0 for SigmaPhi is almost at M2 center while at LNF is at the geometrical center between M1 and M2
- During alignement, a displacement of 1 mm has been detected between the mechanical axis of the two magnets









Measurements @LNF

03/10/2023

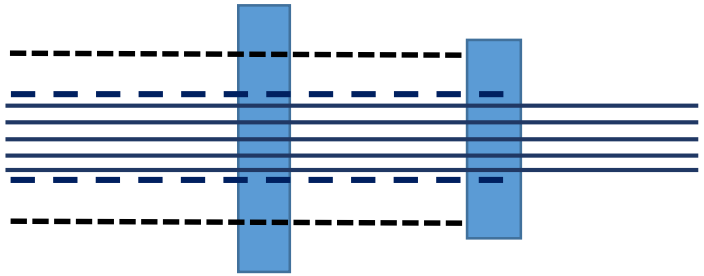
- Preliminary longitudinal scan: range z(-465; +499), step Δz=5 mm @ x=0, y=0
- Radial scan on M1 peak
- Radial scan on M2 peak
- Reset of x=0 value (delta x= 1 mm)

04/10/2023

- 5 longitudinal scans z(-465; +499), step Δz=2 mm @ x=0, ±4mm, ± 8mm (y=0)

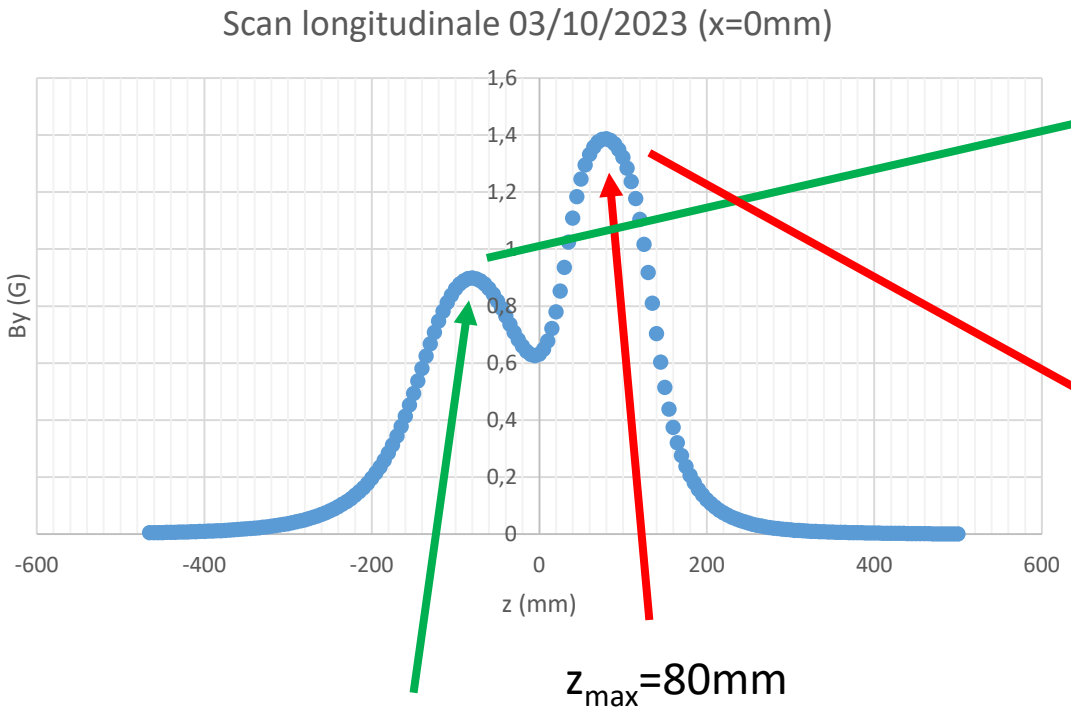
05/10/2023

- 2 longitudinal scans on reduced z range (-465; 299), step Δz=2mm @ x=±10mm
- 2 longitudinal scans on reduced z range (465; 17), step Δz=2mm @ x=±19 mm
- Even though on a reduced z range, these measurements are useful for comparison with SigmaPhi measurements



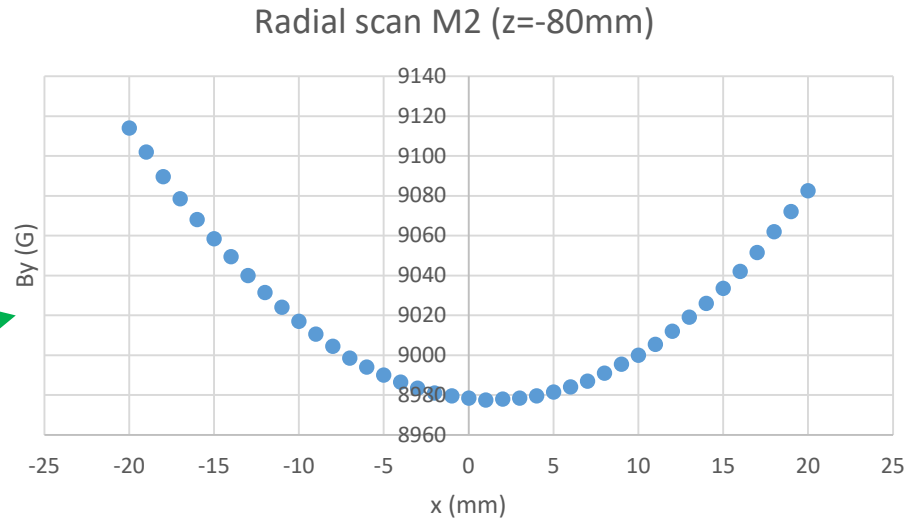
Measurements @LNF

Preliminary longitudinal & radial scans (03/10)

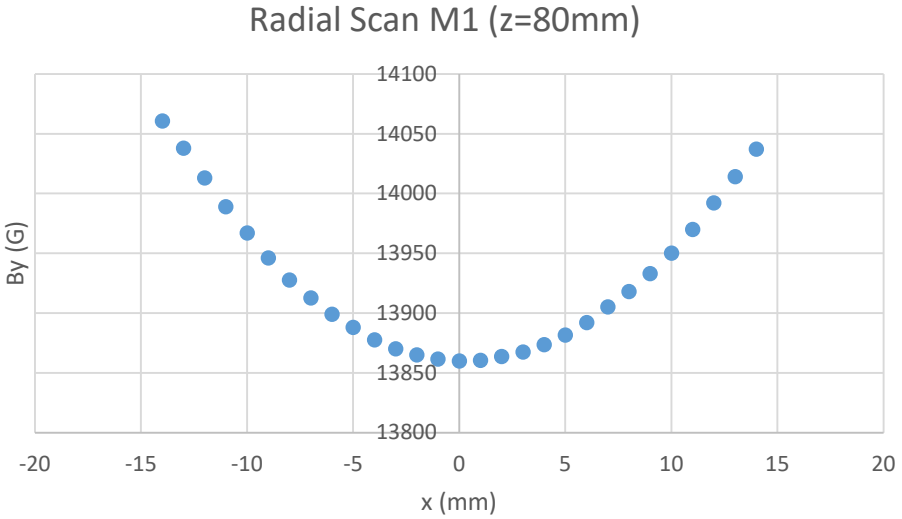


z_{max}=80mm

z_{max}=-80mm



Parabolic fit: x_{max}=1.34mm



Parabolic fit: x_{max}=0.41mm

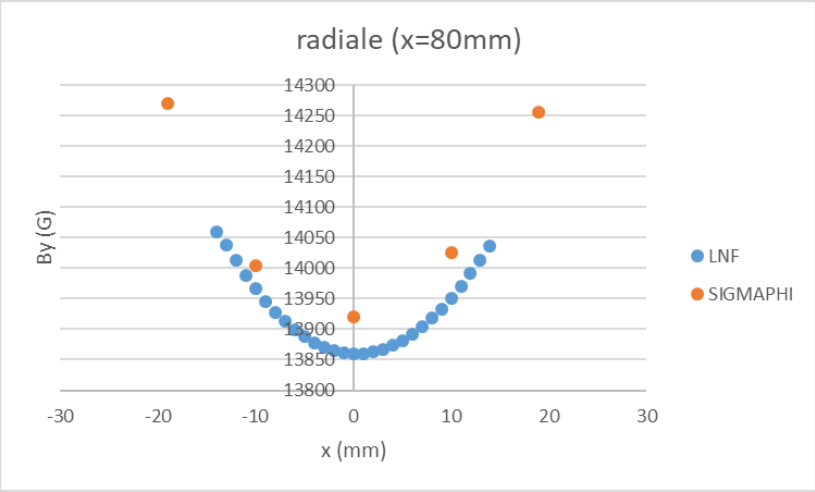
Reset of coordinates: x=0 on previous x=1 mm

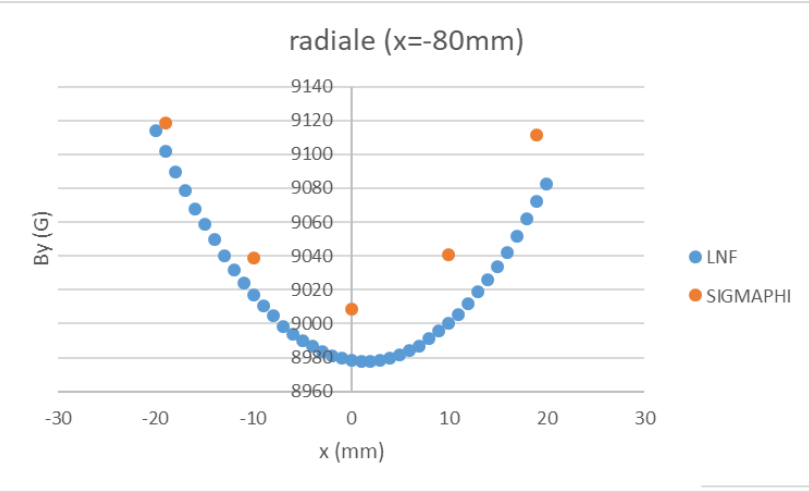
Comparison LNF – Sigmaphi measurements

Comparison between radial measures: LNF peak values are lower that SigmaPhi ones

ΔBy(@M1)=60G ΔBy(@M2)=31G

variation of 4 10^{-3} for M1, 3 10^{-3} for M2 → acceptable for this kind of measurements

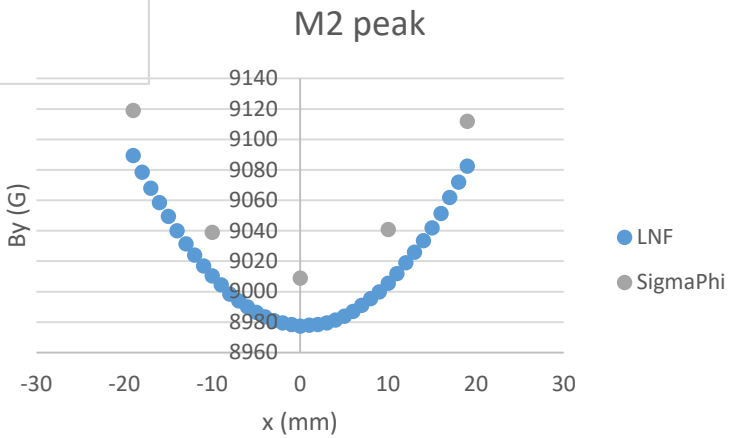




Field quality:

M1: 0.8% @ x=10mm, 2.5% @ x=19mm

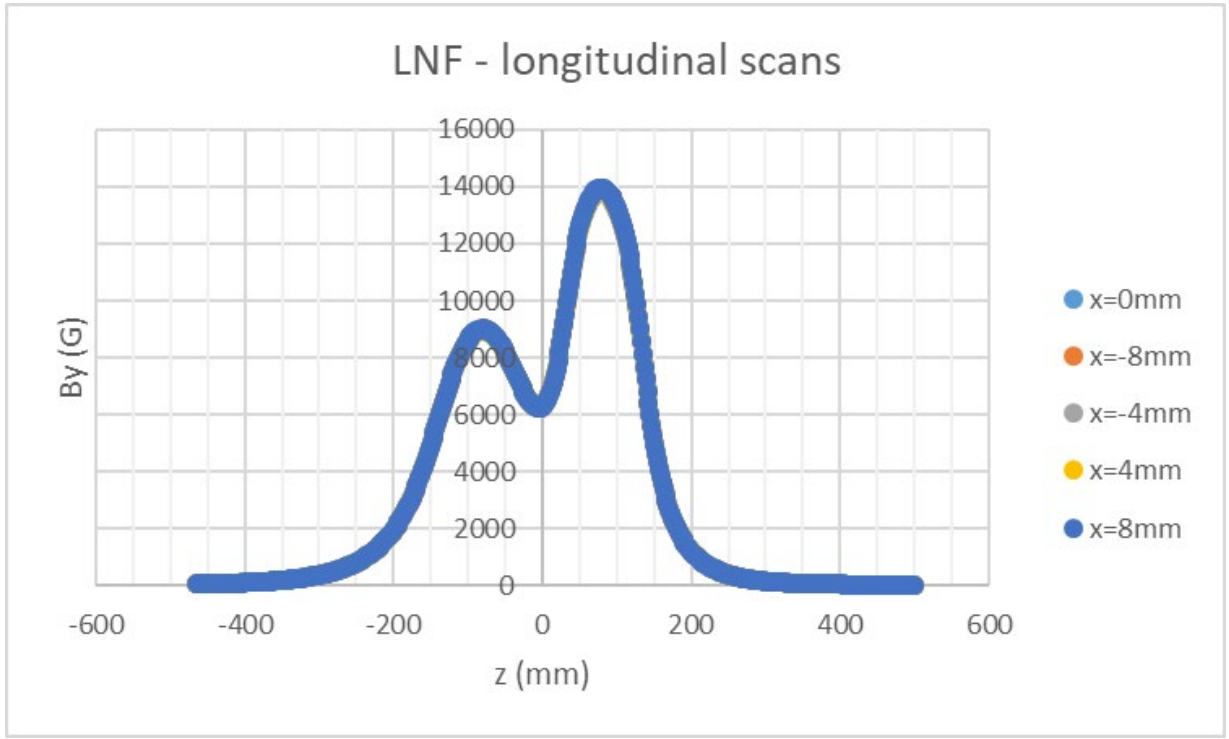
M2: 0.35% @ x=10mm, 1.22% @ x=19mm

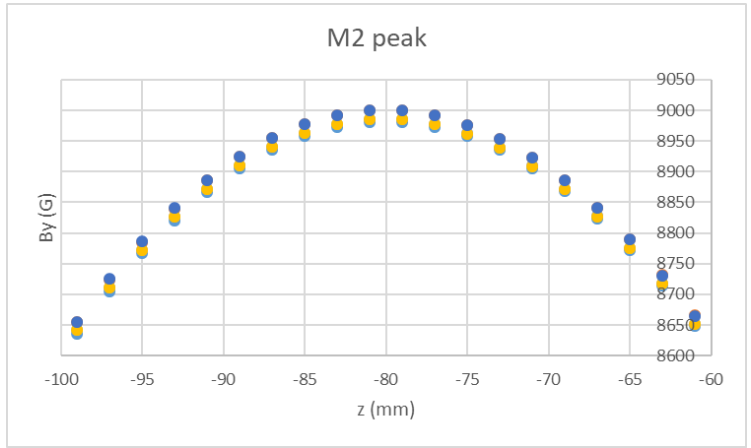


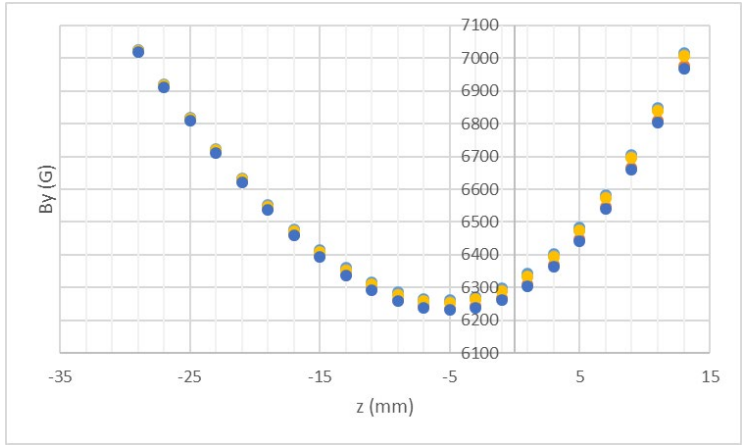
Measurements @LNF

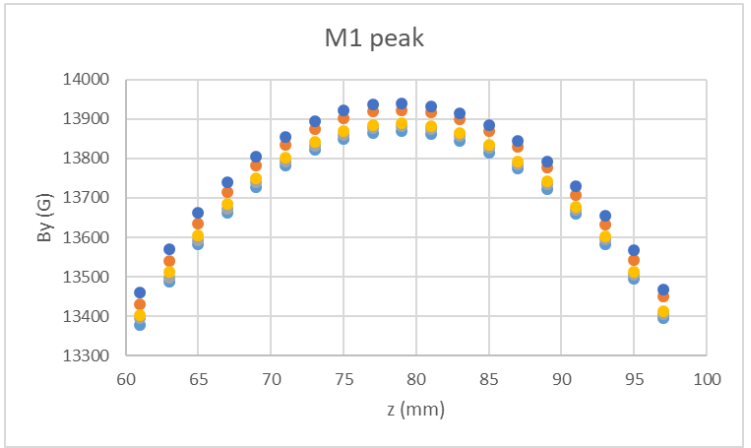
5 longitudinal scans:

z full range, x=0, ±4mm, ± 8mm (y=0)



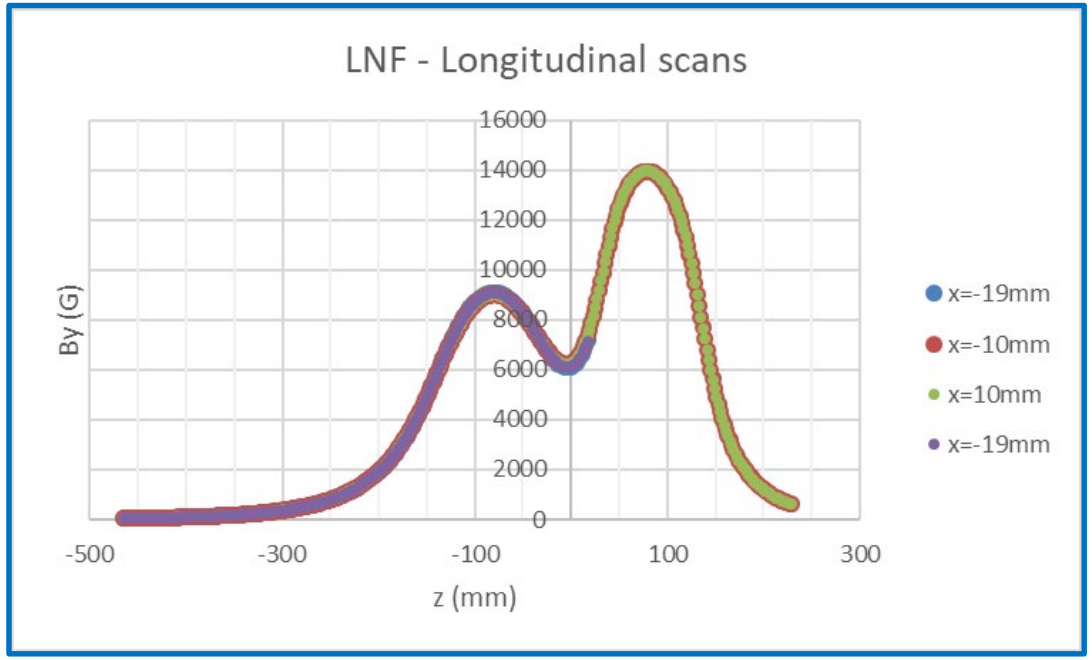




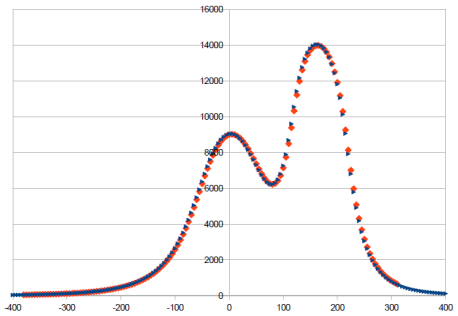


Measurements @LNF

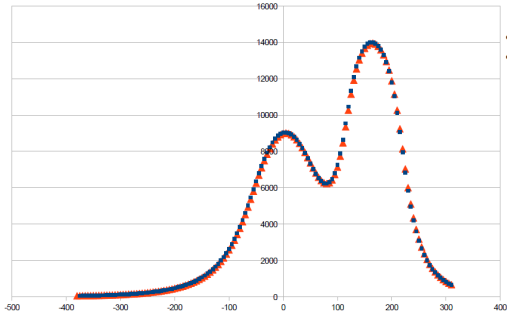
+4 longitudinal scans: z reduced range, x=0, ±10mm, ± 19mm (y=0)



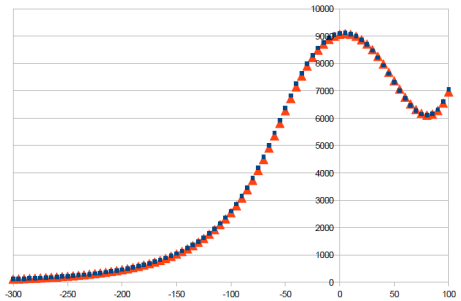
X= 10 mm



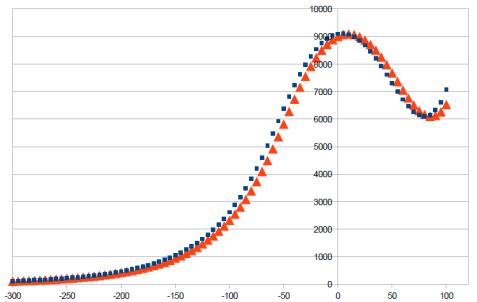
x= -10 mm



X= -19 mm



x= 19 mm



With the exception of x=0 scan, we cannot directly compare LNF and SigmaPhi integrated field: LNF measurements are limited in z, hence we cut the SigmaPhi measures at the same length in order to compare the results. These values are NOT the physical integral values

SIGMAPHI integral field (@x=0) = 322.37 T mm

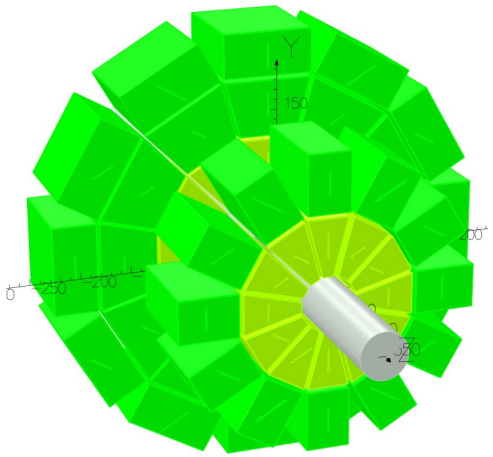
LNF integral field (@x=0) = 320.95 T mm

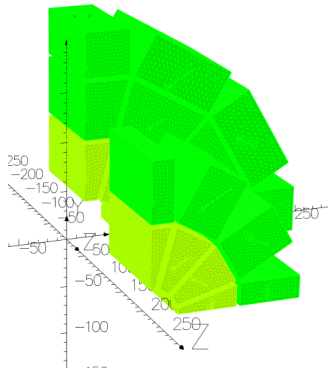
Δ difference ≈ 4 10^{-4}

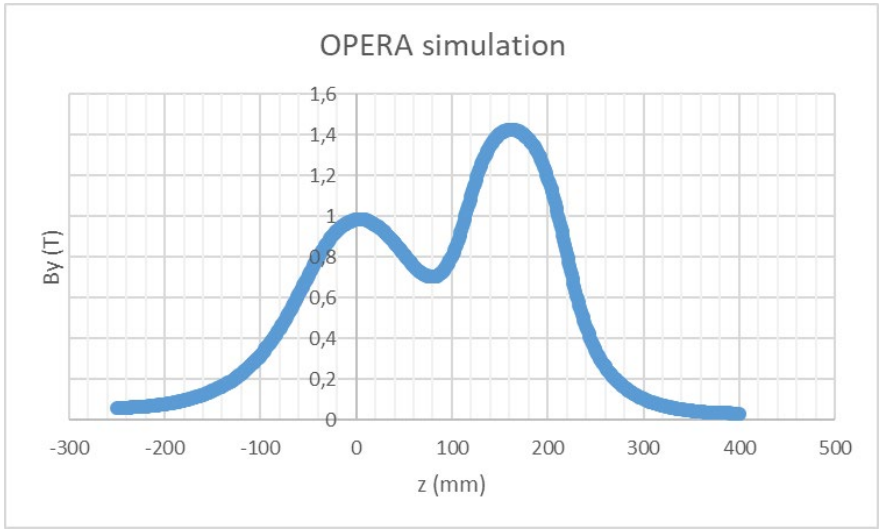
		x=-19mm	x=-10mm	x=0mm	x=10mm	x=19mm
M1	B_{max} SigmaPhi (G)	14269	14004	13920	14026	14256
	B_{max} LNF (G)	---	13954	13867	13974	---
	Δ (%)	---	**0,36**	**0,38**	**0,37**	---
	Homogeneity SP (%)	2,51	0,60		0,76	2,41
	Homogeneity LNF (%)	---	**0,63**		**0,77**	---
M2	B_{max} SigmaPhi (G)	9119	9039	9009	9041	9112
	B_{max} LNF (G)	9089	9011	8981	9012	9090
	Δ (%)	**0,33**	**0,31**	**0,31**	**0,32**	**0,24**
	Homogeneity SP (%)	1,22	0,33		0,36	1,14
	Homogeneity LNF (%)	**1,21**	**0,34**		**0,35**	**1,22**
min	By SigmaPhi (G)	6106	6223	6265	6216	6102
	By LNF (G)	6112	6223	6262	6214	6096
	Δ (%)	**-0,10**	**0,01**	**0,05**	**0,03**	**0,11**
Int.	SigmaPhi (T mm)	324,83	322,94	322,37	323,20	324,69
	SigmaPhi (T mm)	*152,23*	319,39	321,99	319,67	*152,21*
	LNF (T mm)	*151,16*	318,33	320,95	318,52	*151,09*
	Δ (%)	*0,70*	**0,33**	**0,32**	**0,36**	*0,74*

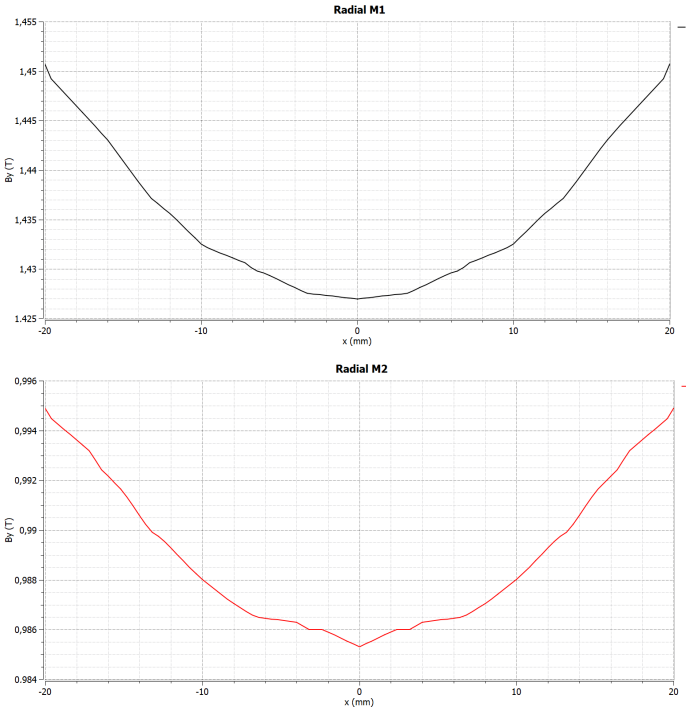
Conclusions & work in progress

- SigmaPhi measurements validated
- Measure with smaller step available – including radial scan
- 3D model in progress – for extraction of other values or mapping









- Technical note in preparation