Magnetic Measurement at SIGMAPHI

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International Magnetic Measurement Workshop
CELLS / ALBA, Spain, 18-23 Sept 2011

Outline

- Introduction
- Recent developments at Sigmaphi
- A brief overview of magnetic Measurement activities at Sigmaphi
- Recent results and comparison with TOSCA
- Measurement set-up in progress – Medaustron project

Introduction

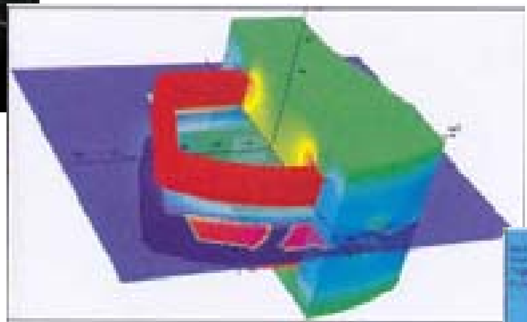
- More than 30 years of development in magnets for particle accelerators
- Sigmaphi is specialized in the design, manufacture and measures of magnets
- Sigmaphi is ISO 9001-2000 certified

Sigmaphi NEWS

DESIGN AND ENGINEERING

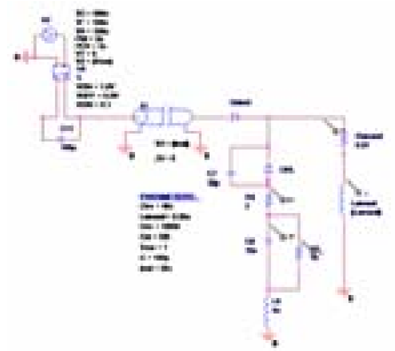
Sigmaphi has the suitable softwares and skilled engineers to design a particle beam line

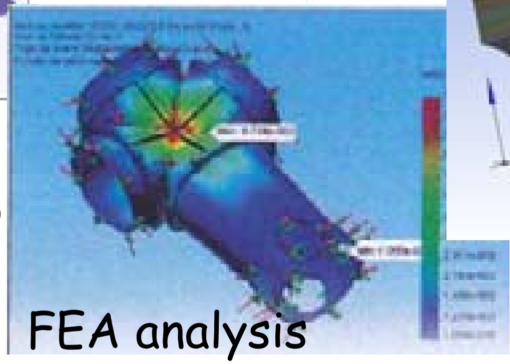
Transport



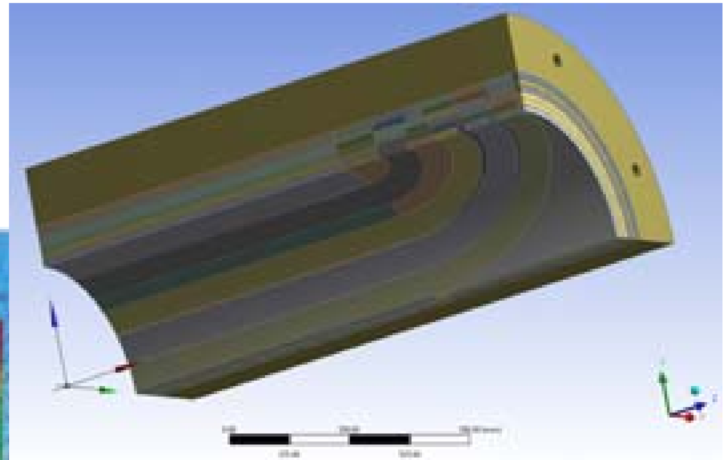
Opera 2D and 3D

Tosca Elektra Tempo





FEA analysis
Cosmosworks

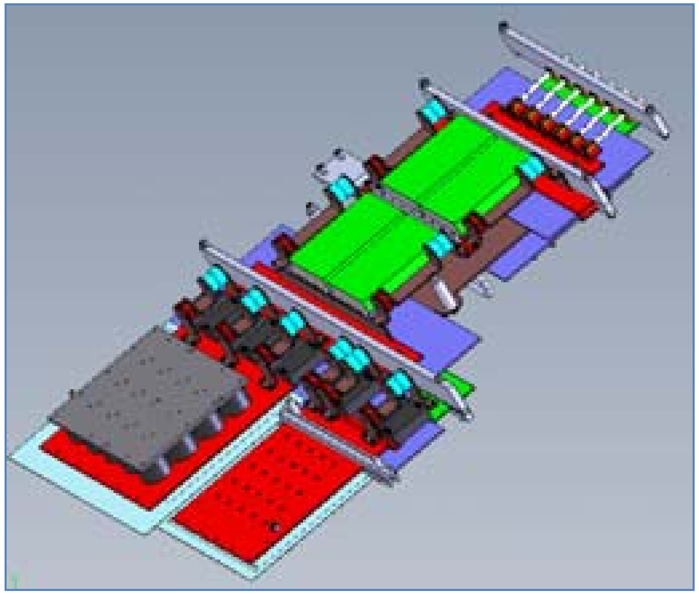


ANSYS

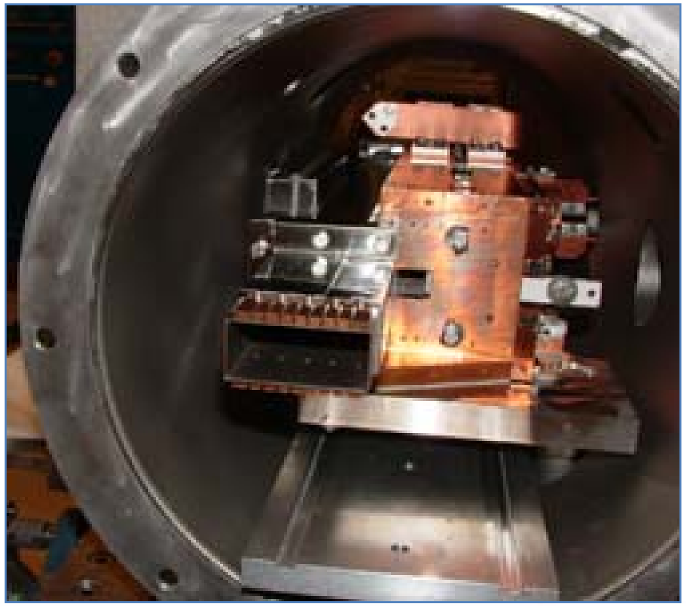
Sigmaphi NEW PRODUCTS: PULSED MAGNETS

Technology transfert : partnership with SOLEIL synchrotron

- *Development of new concept pulser and kicker for MSL*

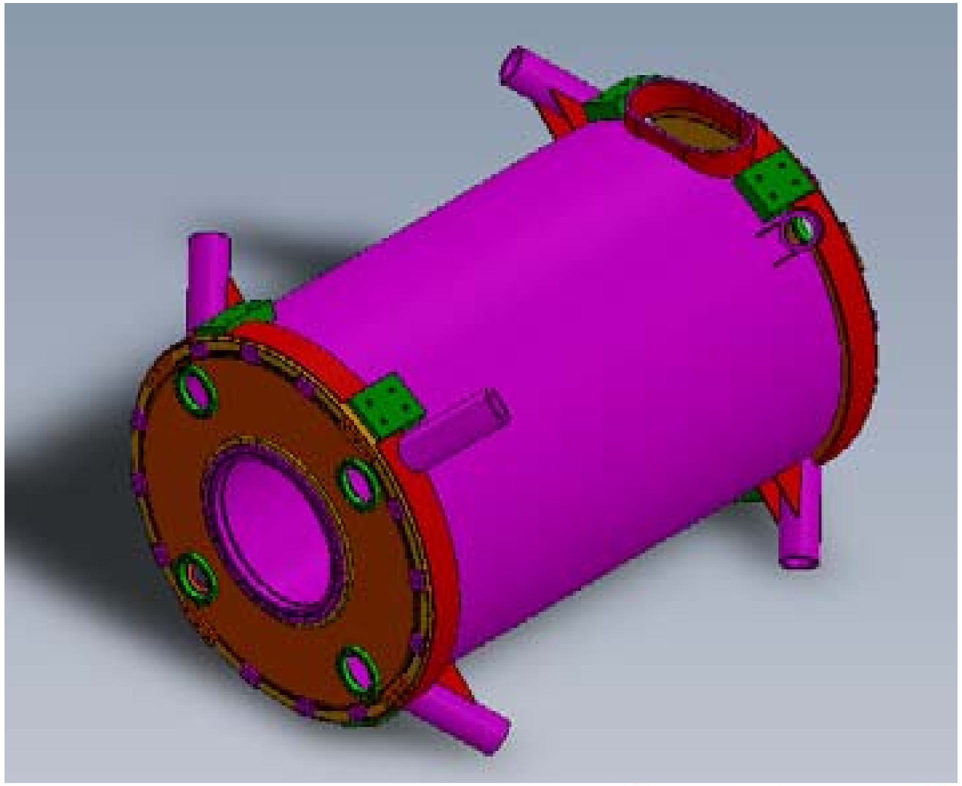


- *In-vacuum Eddy current Septum*



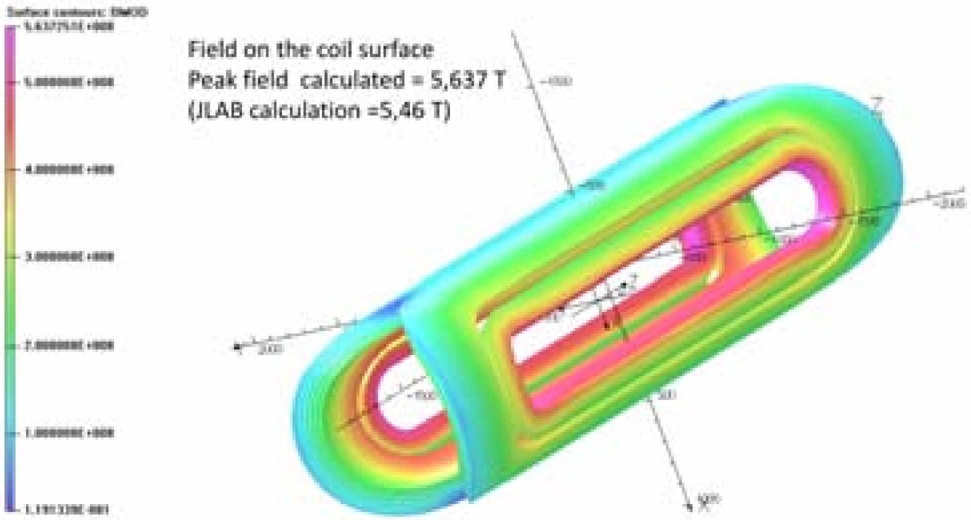
Sigmaphi NEW PRODUCTS SUPRACONDUCTIVE MAGNETS

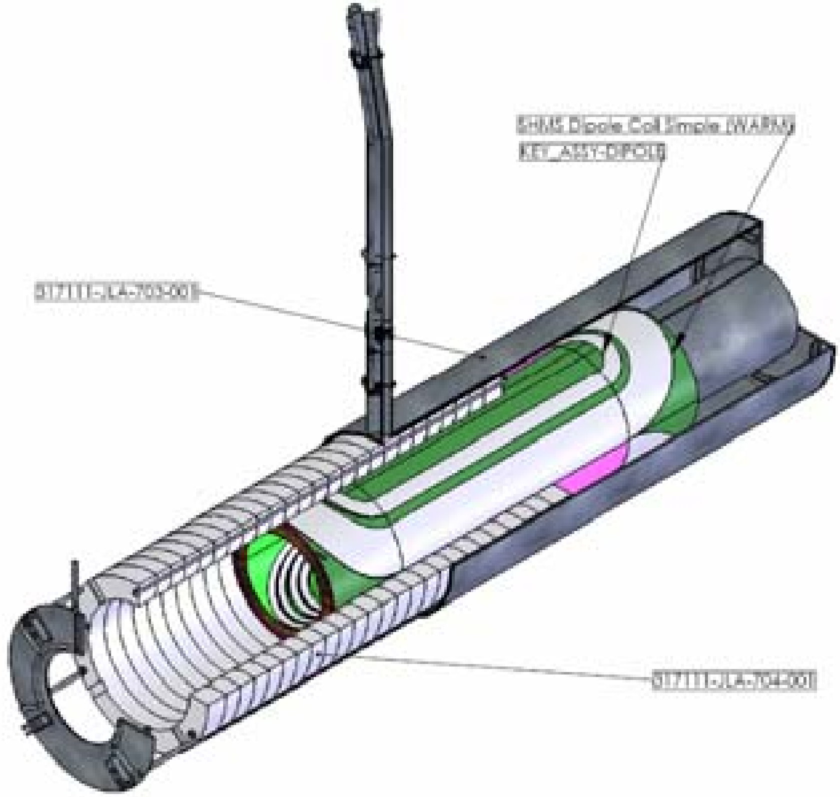
The **Q2 and Q3 Quadrupole Magnets** are the analysis magnets of a new particle spectrometer named the Super High Momentum Spectrometer (**SHMS)** which is under construction in **JLAB** experimental Hall C as part of the JLAB 12 GeV upgrade.



Sigmaphi NEW PRODUCTS SUPRACONDUCTIVE MAGNETS

JLAB SHMS dipole (4.5T)





A brief overview of Magnetic measurement activities at ΣΦ

- Hall probe
- Rotating coil
- Search coil measurement with current ramp

Hall probe measurement

Mapping up to 18 tons in the laboratory

Mapping up to 70 tons in the factory

Rotating coil measurement

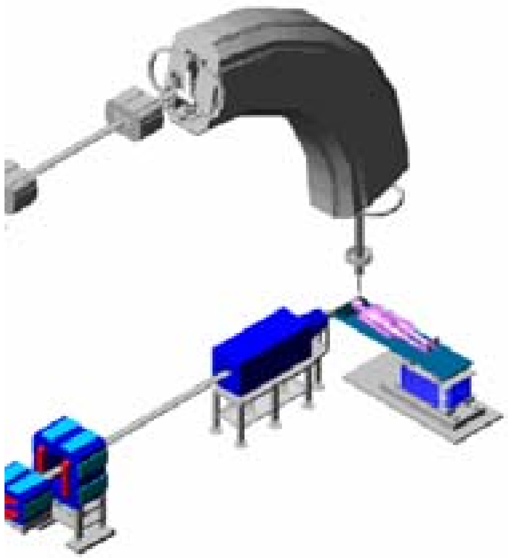
From 5kg to 500kg in the laboratory

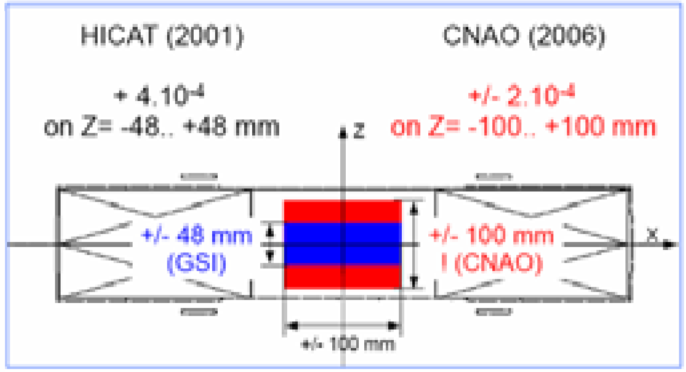
Up to 3 tons in the factory

Search coil measurement

Developped for the measurement of the 90° CNAO dipole magnet

CNAO hadrontherapy facility (Pavia - Italy)
National Center for Oncologic Hadrontherapy

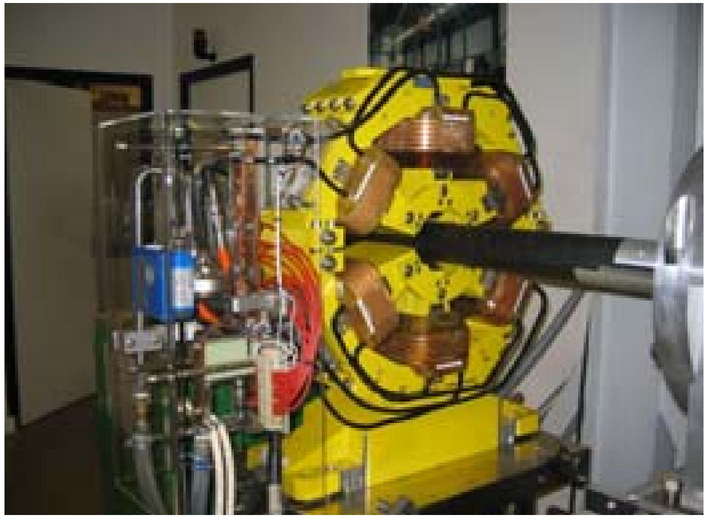


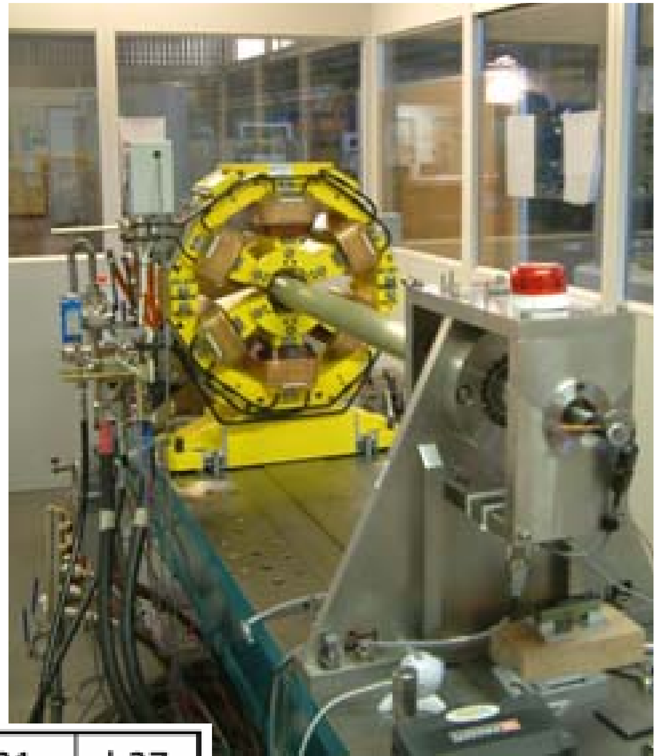


Search coil Parameter	
Radius	3670 mm
Conductor	Flat wire (2*10)
Number of turns	20
Width of the coil support	14 mm
Height of the coil	6.20 mm
Insulated wire diameter	0.635 mm
Central coil length	5764.8 mm
Fringe field coils length	500 mm
Gap between coils	3 mm
Substrate material	GP03

Measurement process

Each process is qualified and improved with cross measurements with other laboratories (SOLEIL in 2005 and CERN in few months..)





SN 26 @ 300A	dx (µm)	dy (µm)	θ (mrad)	b9	b15	b21	b27
SIGMAPHI	-6	-19	-0.010	-4.93	-8.85	-20.99	0.0
SOLEIL SYNCHROTRON	-7	-44	- 0.105	-4.76	-8.58	-20.02	0.3

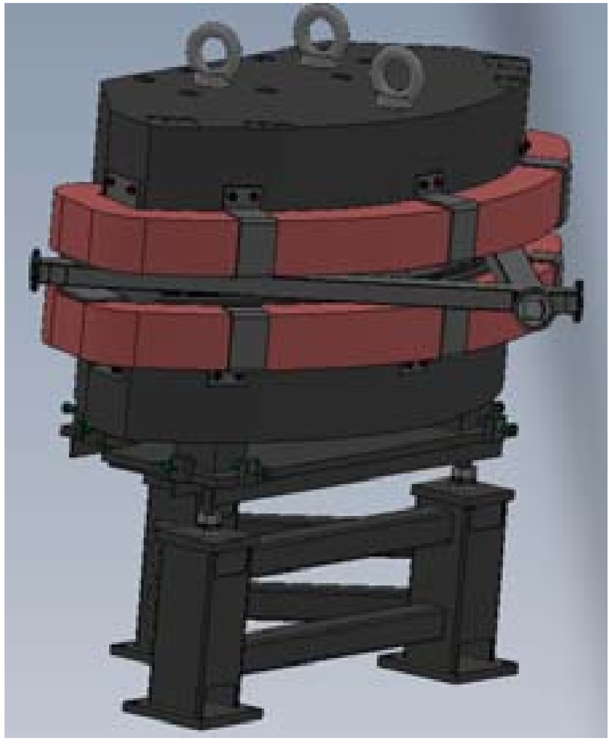
Rotating coils
Design and manufacture

D28.5 rotating coil (Rref = 13mm)

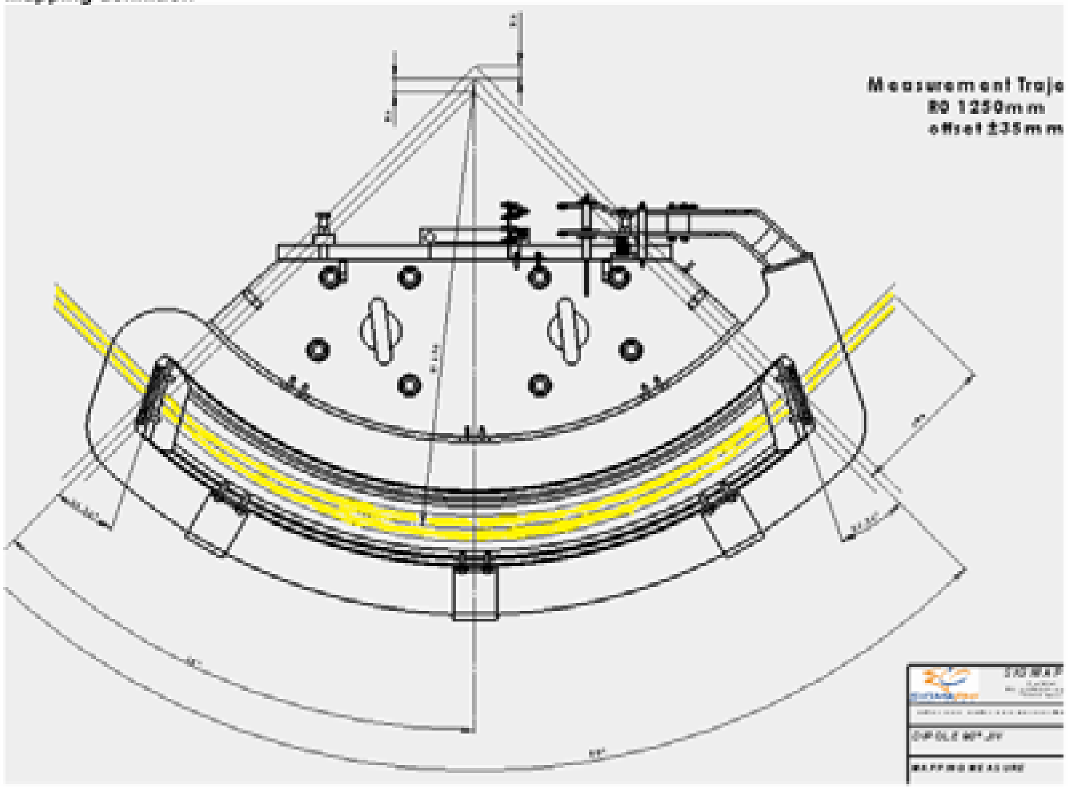
Litz wire (66 and 33 turns) welding connections

SOME RECENT MEASUREMENT RESULTS
comparison with TOSCA

1/ JYVASKILA, 90° dipole magnet
Nominal field : 1.36T, massive yoke

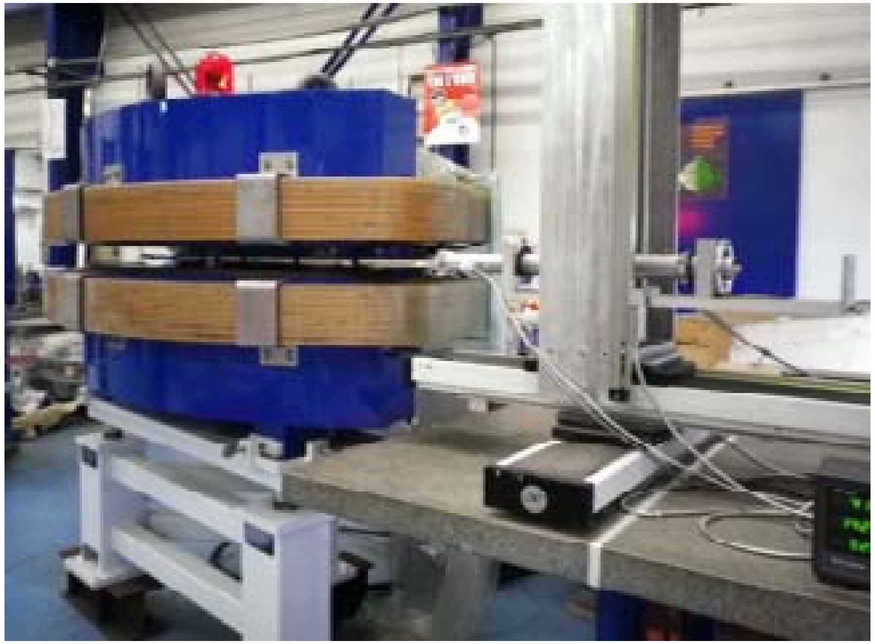


Mapping definition

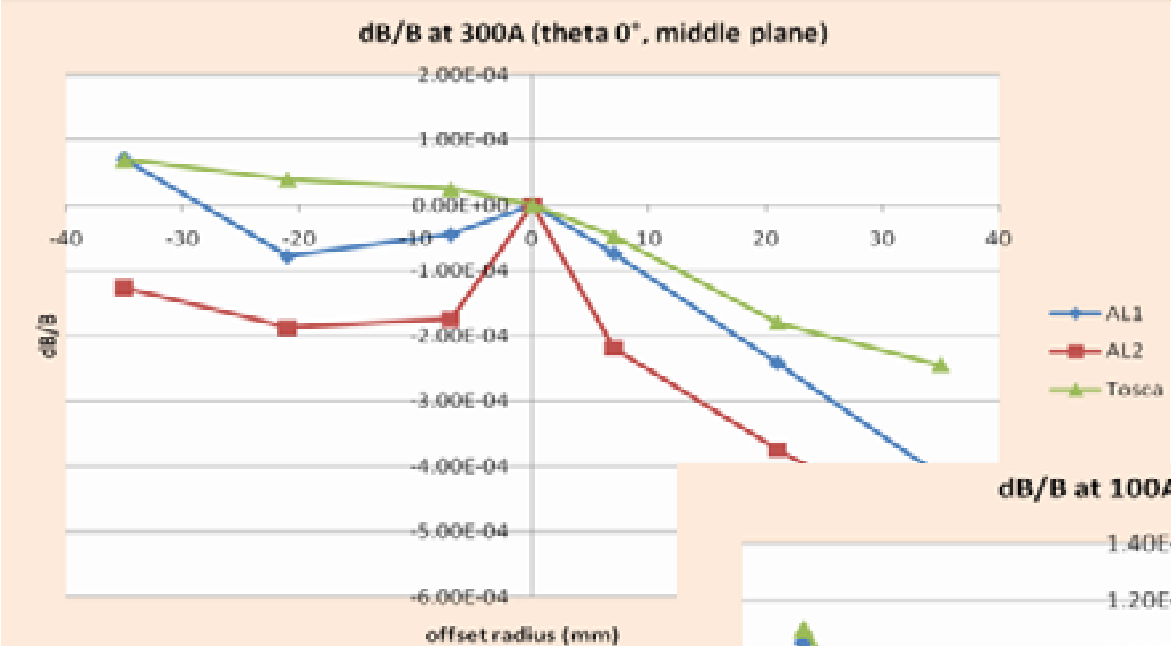


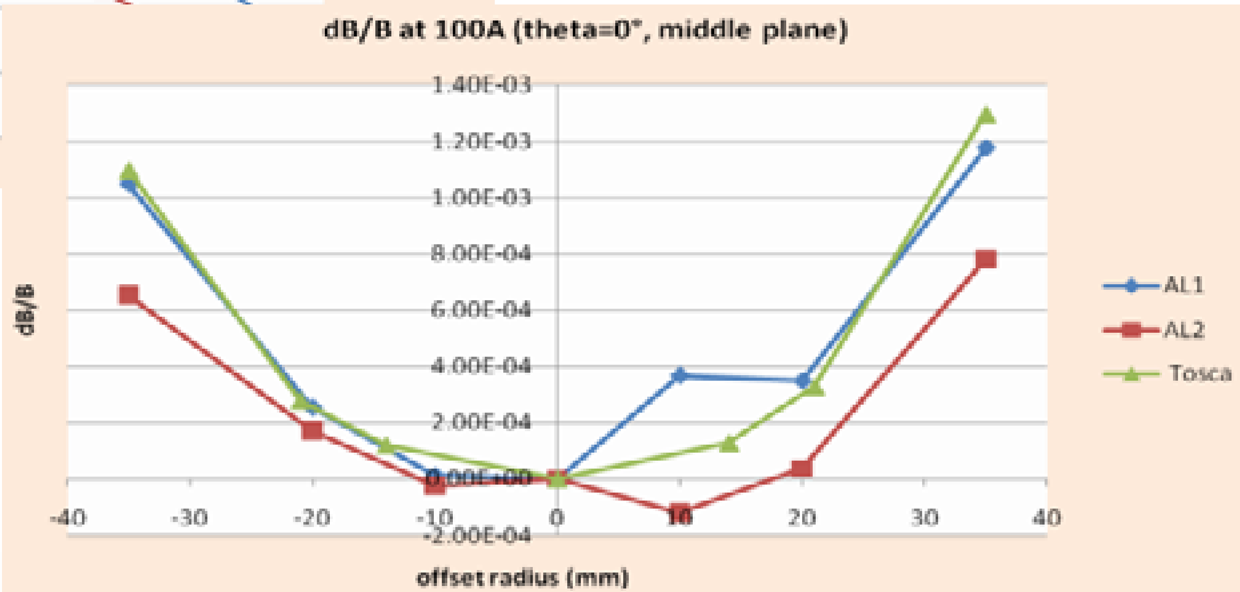
Mapping steps defined with TOSCA

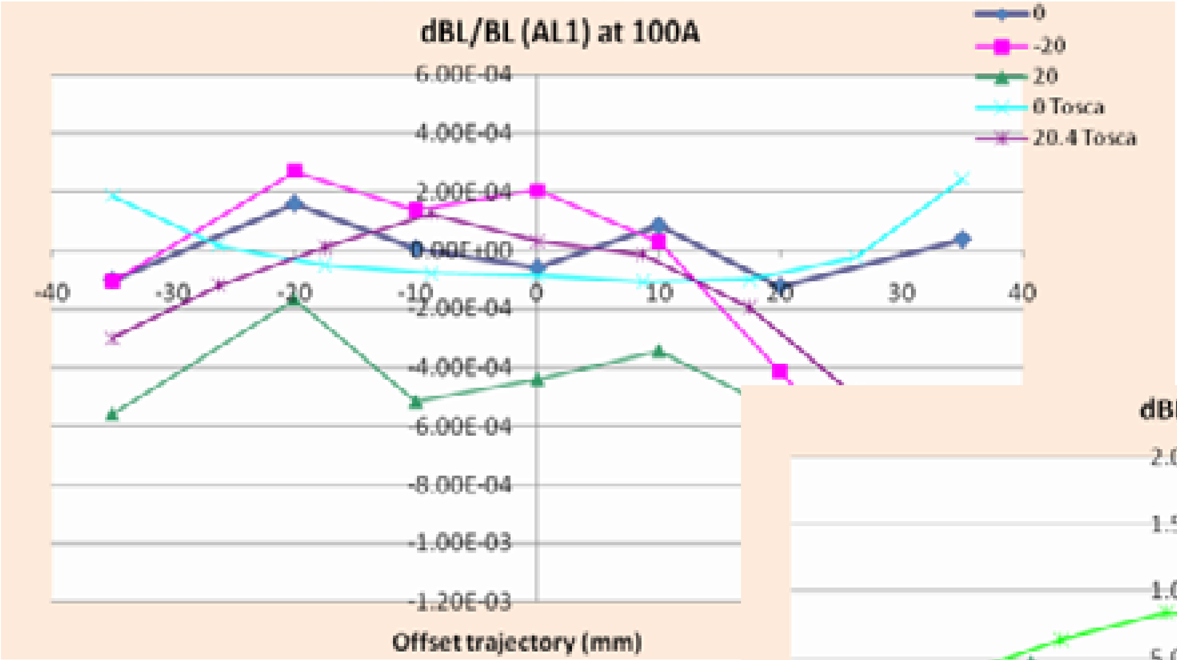
Mapping (OFFSET TRAJECTORIES)
- 7 trajectories (R_0 , offset ± 10, offset ± 20, offset ± 35mm with Ro=1250mm)
- Vertical planes (y=0, y=+20, y=-20mm)
- Steps
- Curve parts
  - step 1° from theta 0 to theta 36°
  - step 0.5° from theta 36° to theta 45°
- Straight parts
  - Step 10mm from z0mm to 100mm
  - Step 15mm from z100mm to z400mm

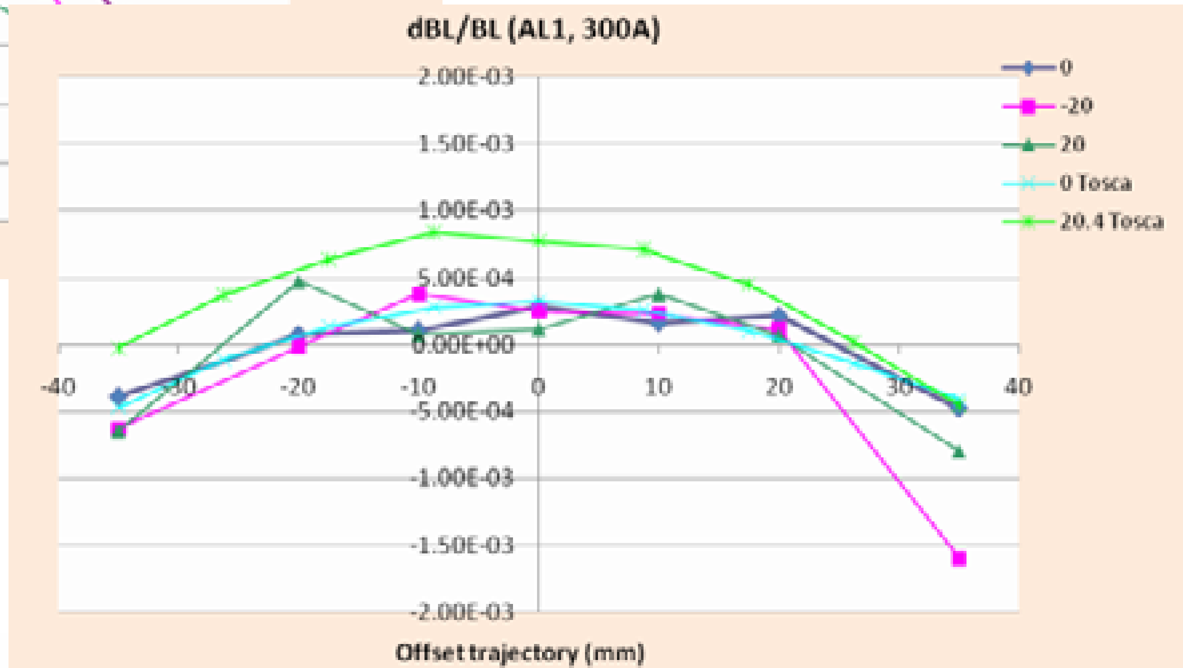


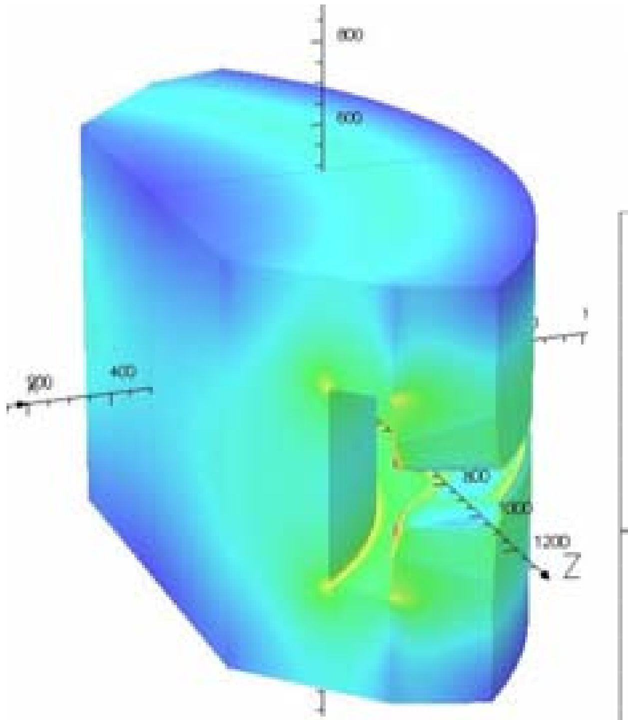
Measurement accuracy
- Hall probe qualification = 0.2Gauss
- Power supply stability = 60ppm


dB/B at 300A (theta 0°, middle plane)
2.00E-04
1.00E-04
0.00E+00
-1.00E-04
-2.00E-04
-3.00E-04
-4.00E-04
-5.00E-04
-6.00E-04
-40
-30
-20
-10
0
10
20
30
40
dB/B
offset radius (mm)
AL1
AL2
Tosca


dB/B at 100A (theta=0°, middle plane)
1.40E-03
1.20E-03
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E+00
-2.00E-04
-40
-30
-20
-10
0
10
20
30
40
dB/B
offset radius (mm)
AL1
AL2
Tosca


dBL/BL (AL1) at 100A
6.00E-04
4.00E-04
2.00E-04
0.00E+00
-2.00E-04
-4.00E-04
-6.00E-04
-8.00E-04
-1.00E-03
-1.20E-03
-40
-30
-20
-10
0
10
20
30
40
Offset trajectory (mm)
0
-20
20
0 Tosca
20.4 Tosca

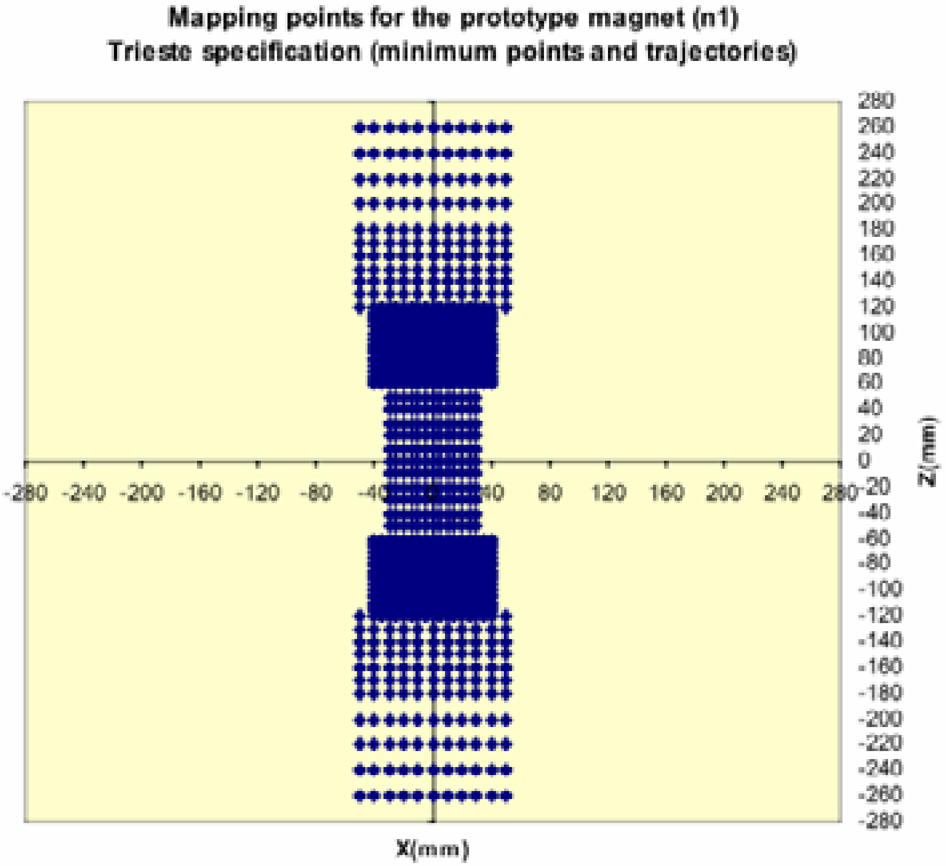

dBL/BL (AL1, 300A)
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
-5.00E-04
-1.00E-03
-1.50E-03
-2.00E-03
-40
-30
-20
-10
0
10
20
30
40
Offset trajectory (mm)
0
-20
20
0 Tosca
20.4 Tosca



		specification	TOSCA	MEASURE AL1	MEASURE AL2
	Bo(Gauss)	Expected <20	/	<30	
	ΔLeff (mm)	Expected 3mm	1.2	2	
	Linearity B, B/3	/	21%	20%	
	current(A)	300	300	300	300
	NI (A.t)	/	46200	46200	46200
	Bo (T)	1.36	1.392222	1.416049	1.416021
	Leff ½ magnet (mm)	/	981.49	981.21	982.29
	Total Leff (mm)	1963 +/-1	1962.98	1963.5	
	BL0 (T.mm)	/	1366.445	1389.423	1391.118
	angle (°)	26.26 +/-1	26.16	26.32	26.08
	dB/B	<+/- 5.10^{-4}	-3.15E-04	-4.85E-04	-5.16E-04
Bmax	dBL/BL plan0	<+/- 9.10^{-4}	7.92E-04	7.59E-04	1.00E-03
	current(A)		100	100	100
	NI (A.t)		15400	15400	15400
	B (T)		0.562031	0.565385	0.565838
	Leff 0 (mm)		982.70	983.29	983.58
	BL0 (T.mm)		552.310	555.940	556.549
	angle (°)		26.37	26.06	26.38
	dB/B		1.30E-03	1.18E-03	9.00E-04
Bmin	dBL/BL		3.52E-04	2.83E-04	2.10E-04

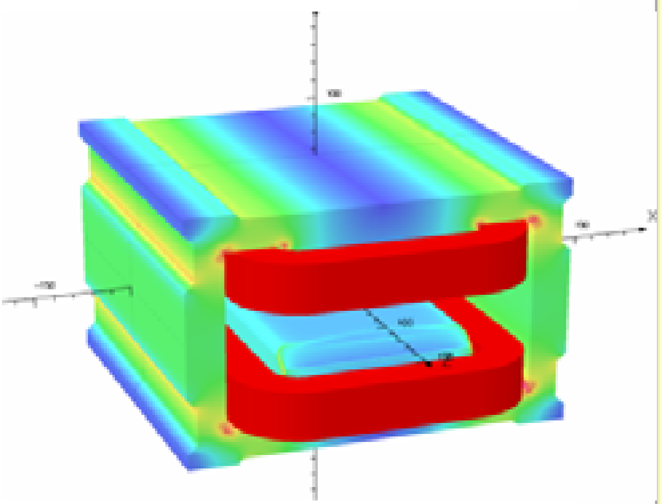
SOME RECENT MEASUREMENT RESULTS
comparison with TOSCA

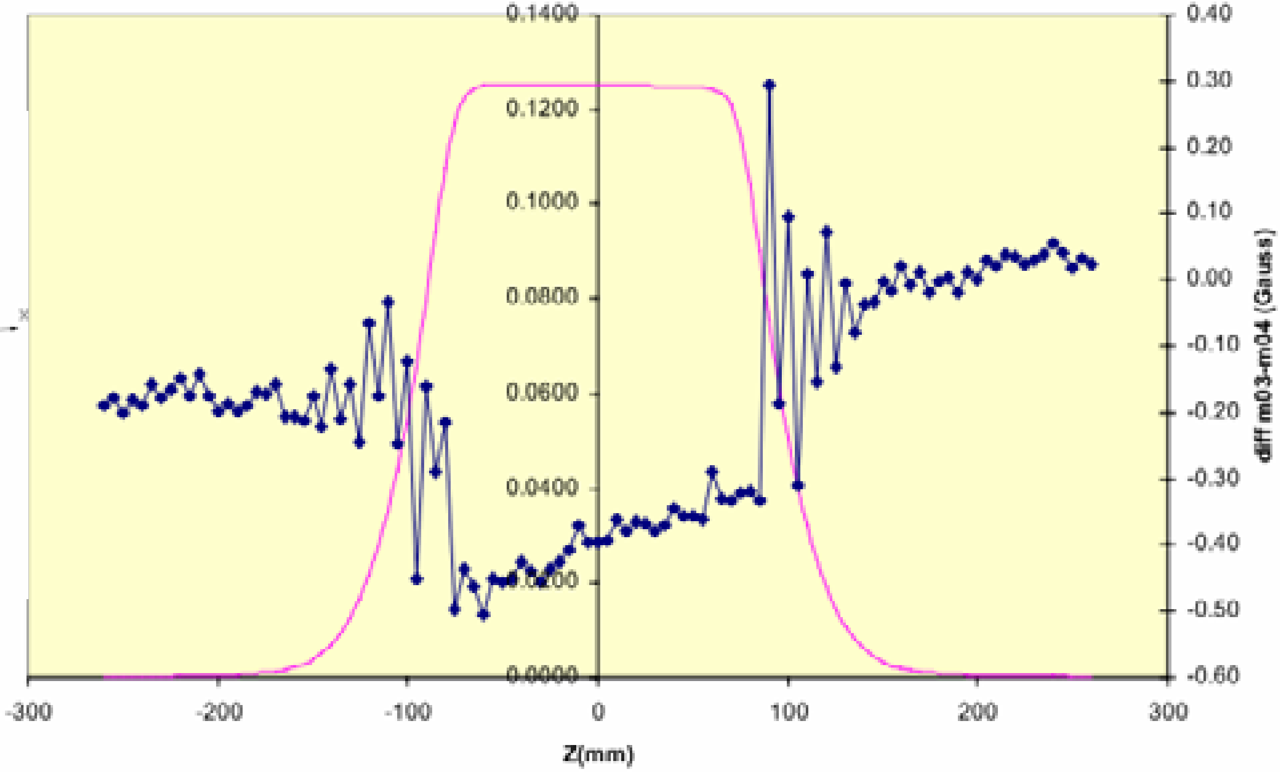
2/ TRIESTE, 3A dipole magnet, quantity 5
Laminated magnets, Bo=0.125T, 100A

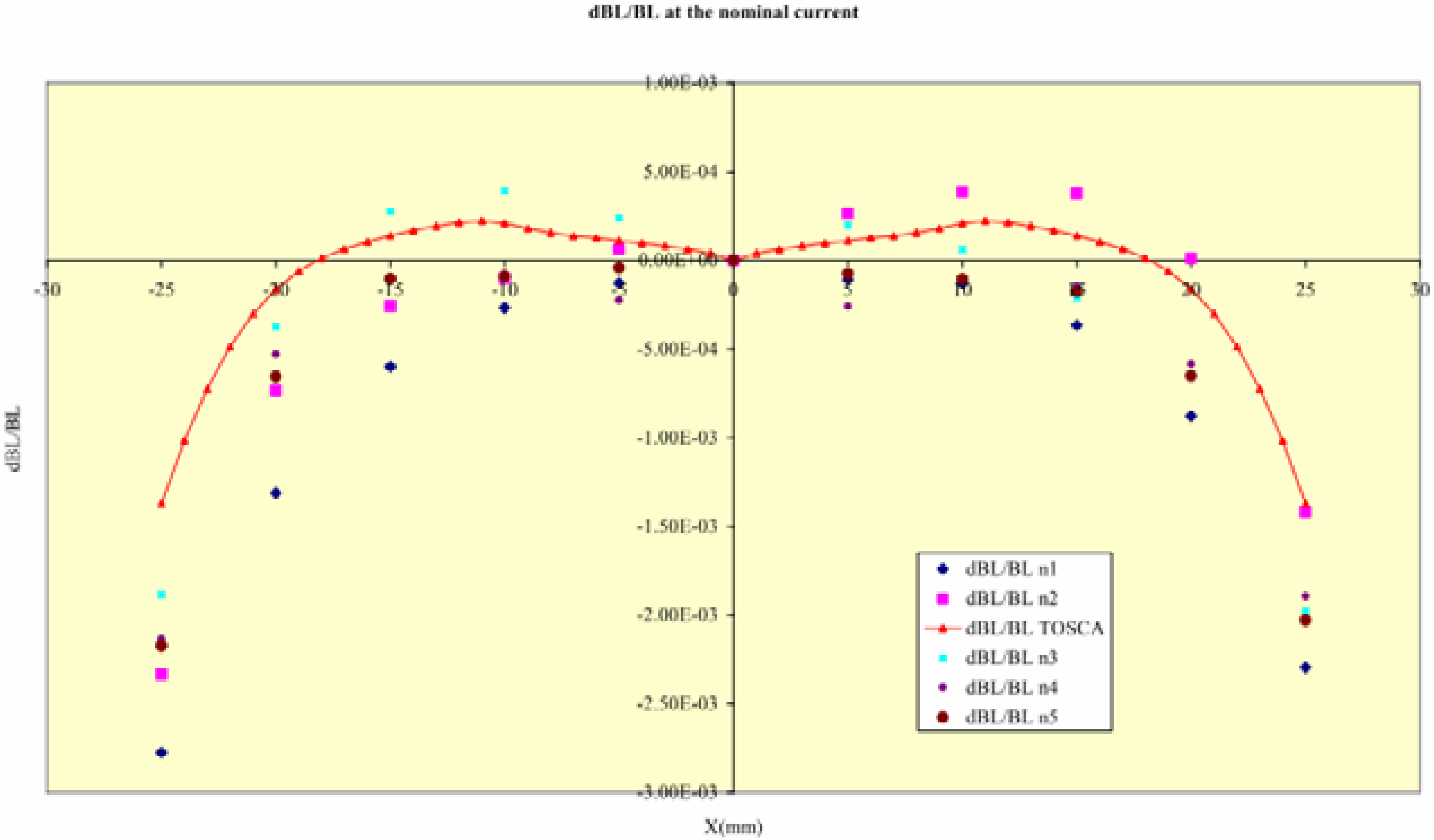


One trajectory reproducibility (magnet n1 at 101.5A, central trajectory measured two times)

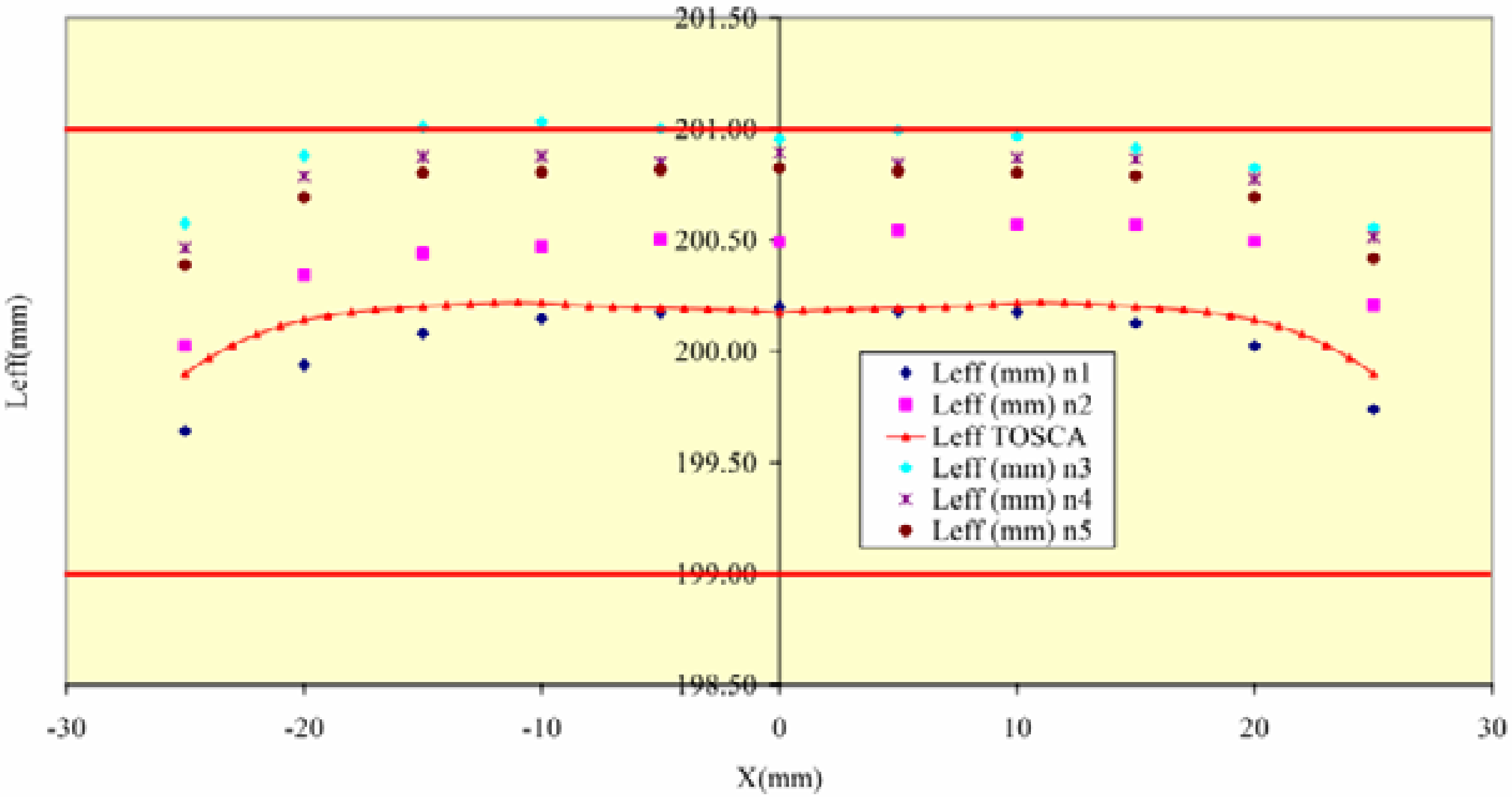
	m03	m04	diff	
Leff(mm)	200.20	200.22	-0.016	mm



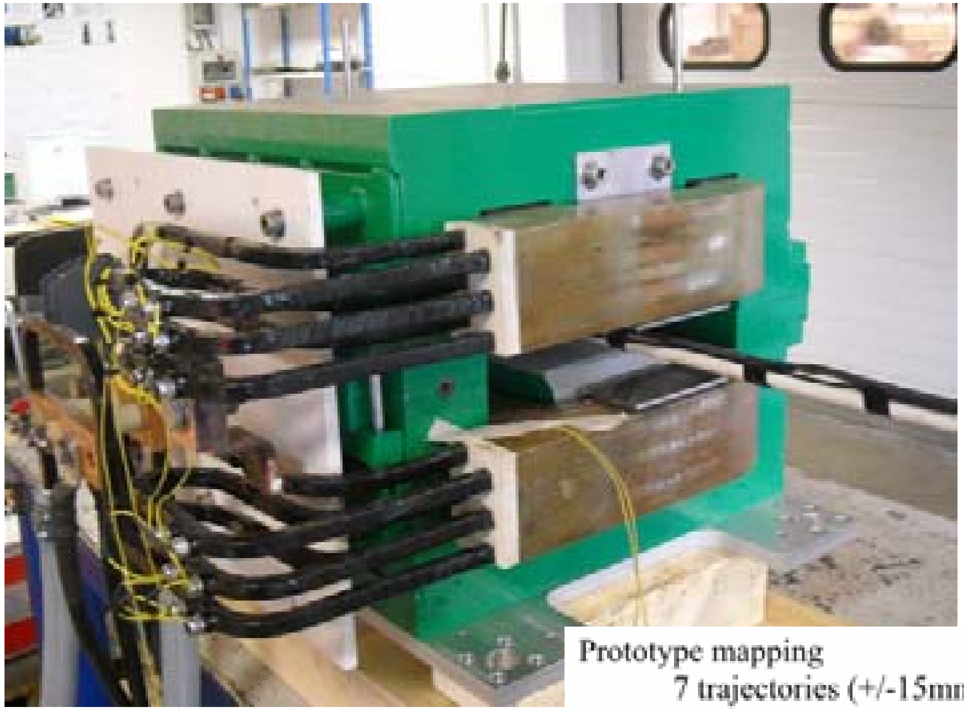


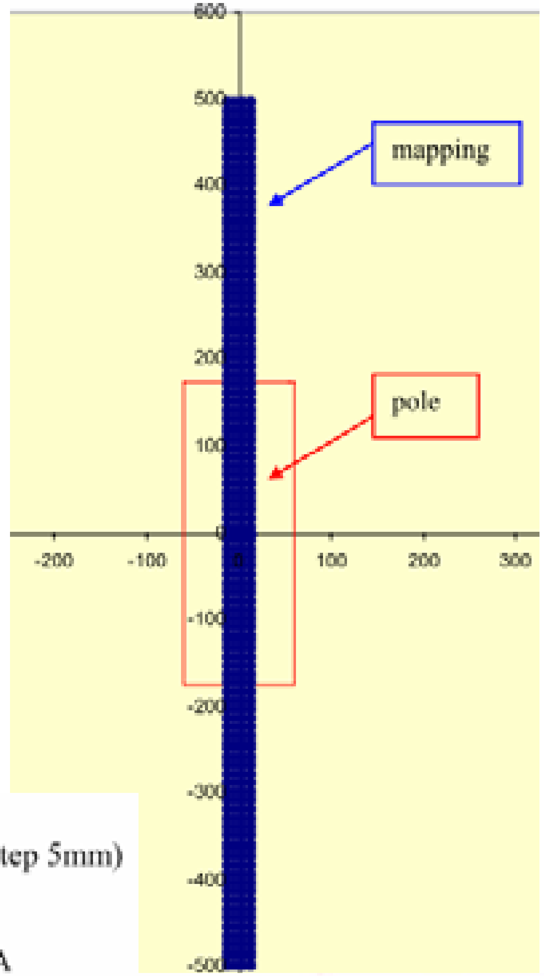

dBL/BL at the nominal current
1.00E-03
5.00E-04
0.00E+00
-5.00E-04
-1.00E-03
-1.50E-03
-2.00E-03
-2.50E-03
-3.00E-03
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
dBL/BL
X(mm)
dBL/BL n1
dBL/BL n2
dBL/BL TOSCA
dBL/BL n3
dBL/BL n4
dBL/BL n5

Effective length at the nominal current



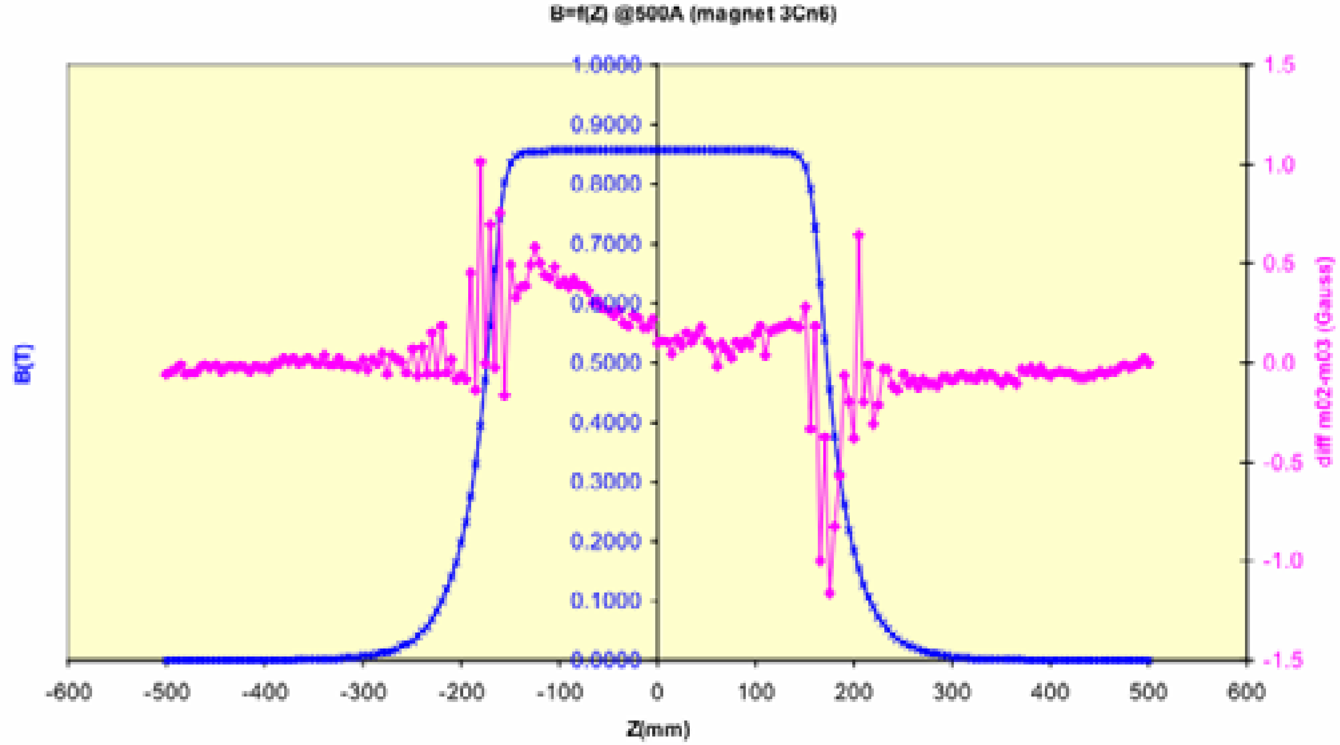
3/ TRIESTE, 3C dipole magnet, quantity 7
Laminated magnets, Bo=0.85T, 500A





Prototype mapping
7 trajectories (+/-15mm in X axis, step 5mm)
+/- 500mm in Z axis, step 5mm
at y=0
at 200A, 300A, 400A and 500A and 0A

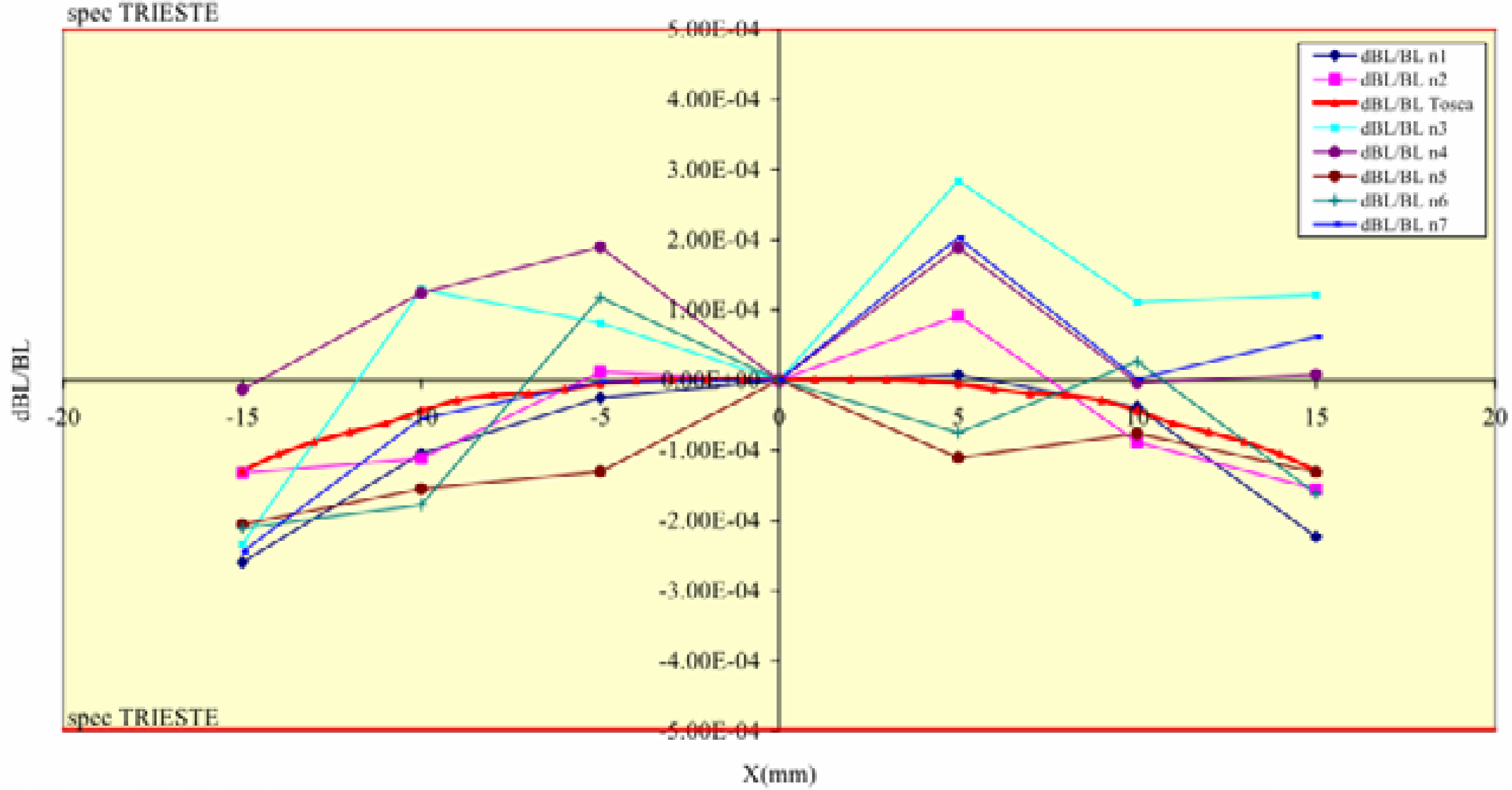
One trajectory reproducibility – Integrated field and effective length



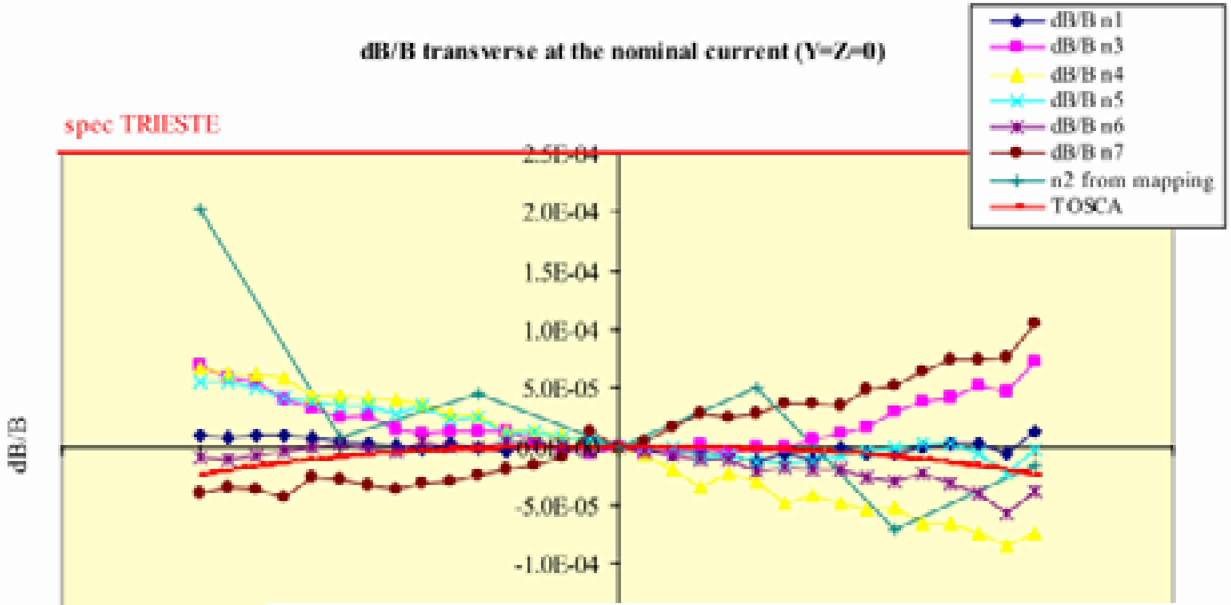
	m02	m03		
average curre	500.00	499.99		
BL (T.mm)	316.801	316.797	0.004	T.mm
Bo(T)	0.857260	0.857250	0.10	Gauss
Leff(mm)	369.551	369.551	0.0005	mm

Comparison between magnets / SPEC and TOSCA values

dBL/BL at the nominal current



Comparison between magnets / SPEC and TOSCA values

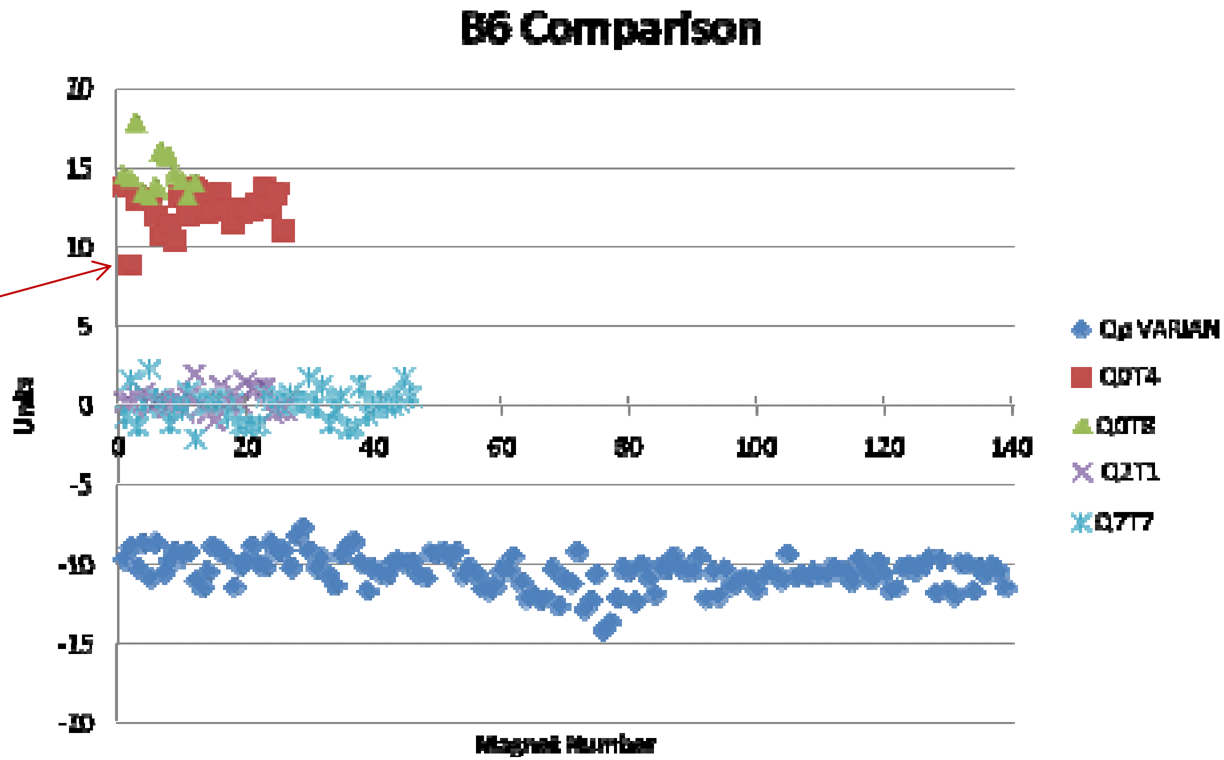


	Trieste specification	Tosca calculation	Magnet n1 to n7
Bo	0.85 T at 500A	0.860 T @ 500A 0.432 @ 250A	> 0.8572 T at 500A
Leff	370mm	370.45 @ 500A	369.16 < Leff (mm) < 370.78
dLeff	≤ 1mm	0.14mm	≤ 1.16 mm
dB/B +/- 15 mm	< 0.05 %	2.5 E-5	Δ < 1.5 E-4
dBL/BL +/- 15 mm	< 0.1 %	1.30E-4	Δ < 5.2 E-4

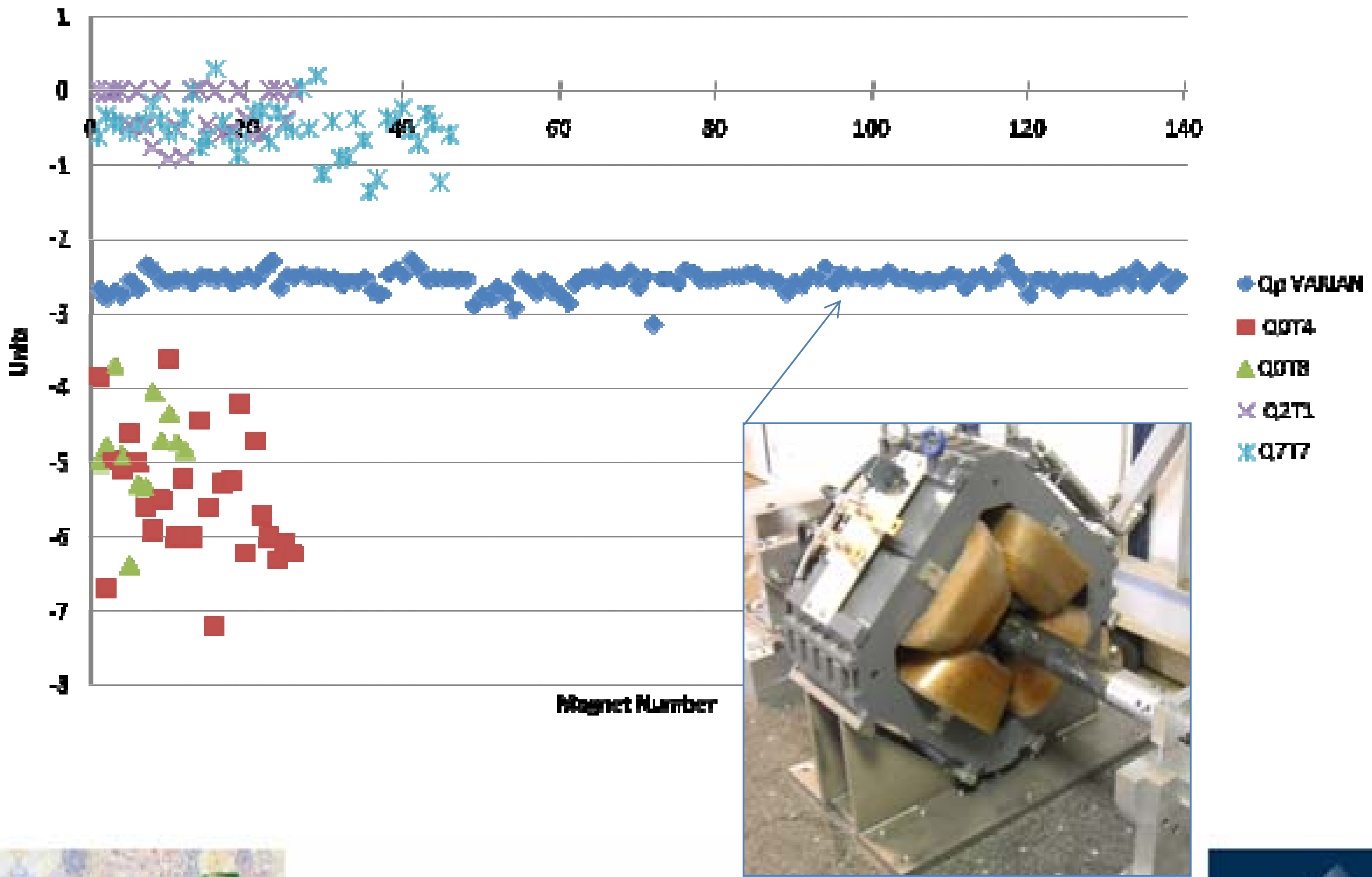
HARMONICS / SERIAL PRODUCTION SURVEY

Link beetween design / manufacturing process and measurement results

For example : magnet multipole components distribution



B10 Comparison



Q2T1	26 magnets					
	dx	dy	Angle	B2	b6	b10
Theoric goal	0	0	0	0.0216	1.00	0.00
Average	-16	-16	-1.6940	0.0224	0.34	-0.29
Std Dev	54.57	63.02	0.804	0.0000	0.65	0.32
Max	100	-188	-3.647	0.0223	1.91	0.01
Min	-149	77	-0.454	0.0225	-0.90	-0.90
Range	249	265	3.193	0.0002	2.81	0.91
Average+2S	93	110	-0.085	0.0224	1.64	0.35
Average-2S	-125	-142	-3.303	0.0223	-0.97	-0.92
Interval	218	252	3.217	0.0001	2.60	1.26

Q7T7	46 magnets					
	dx	dy	Angle	B2	b6	b10
Theoric goal	0	0	0	0.0801	1.00	0.00
Average	-4	-28	-0.8022	0.0830	-0.01	-0.50
Std Dev	111.32	46.24	1.262	0.0002	0.94	0.33
Max	205	-127.042243	-4.090	0.0825	2.30	0.29
Min	-206	89	1.104	0.0835	-2.10	-1.34
Range	411	216.042243	5.194	0.0010	4.40	1.63
Average+2S	219	64	1.722	0.0834	1.86	0.15
Average-2S	-226	-121	-3.326	0.0826	-1.89	-1.16
Interval	445	185	5.048	0.0008	3.74	1.31

MEDAUSTRON project

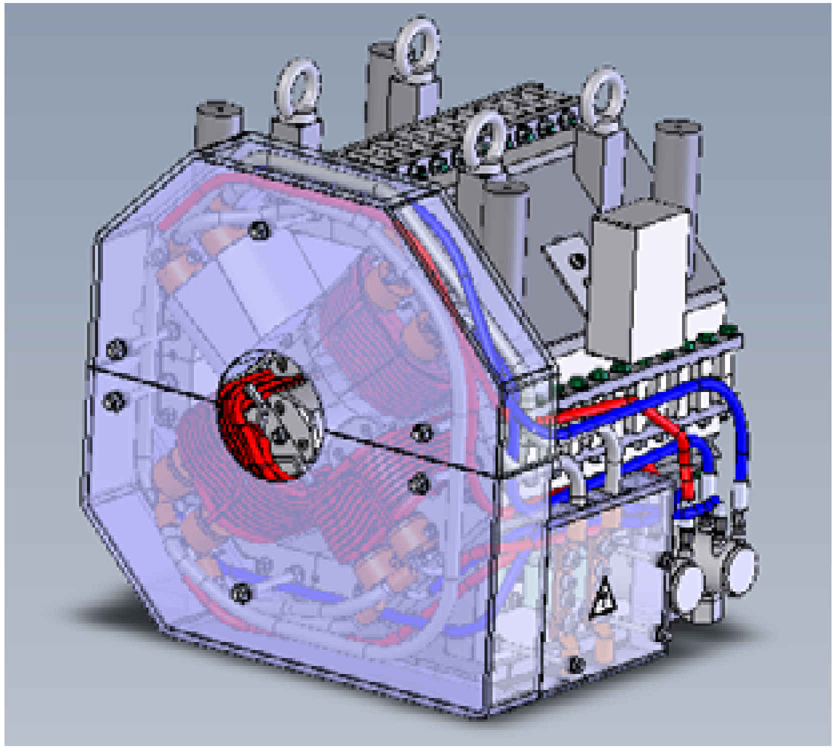
ebg *Med*Austron
2700 Wiener Neustadt – Austria

Centre for ion therapy and research in Austria

For more detail : presentation given by Thomas Zickler

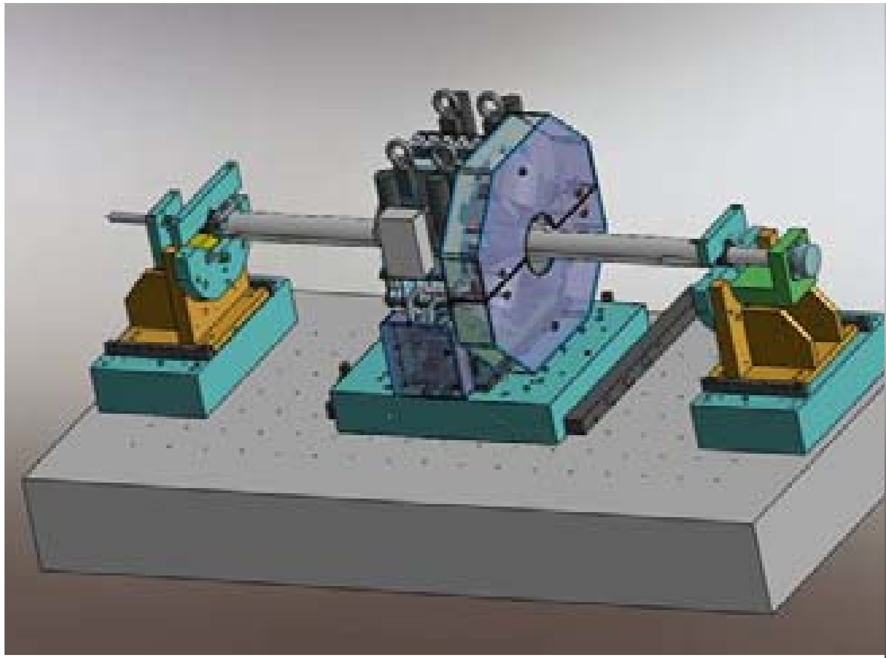
Quadrupole Magnets for the Medium and High Energy Beam Transfer Lines

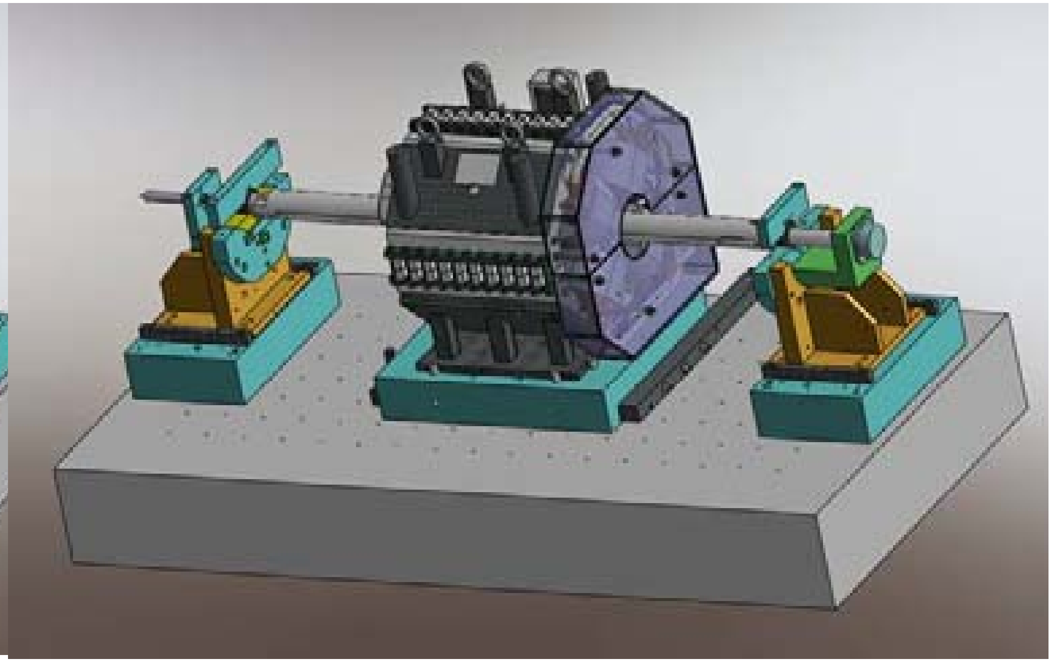
11 MQZB
81 MQZE



MEDAUSTRON project

Upgrade of our rotating coil bench
A new girder, used for both type of magnets and for the rotating coil calibration
A new rotating coil, active length 1150mm, Rmeas=30mm in carbon fiber

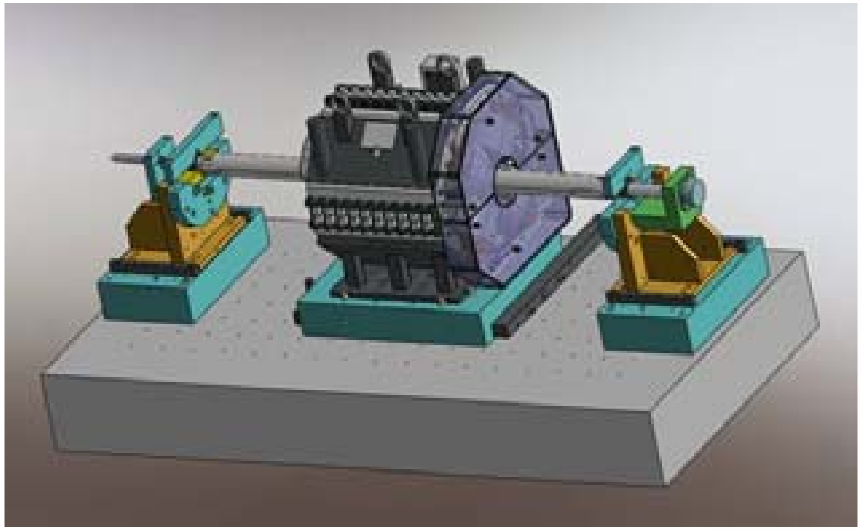


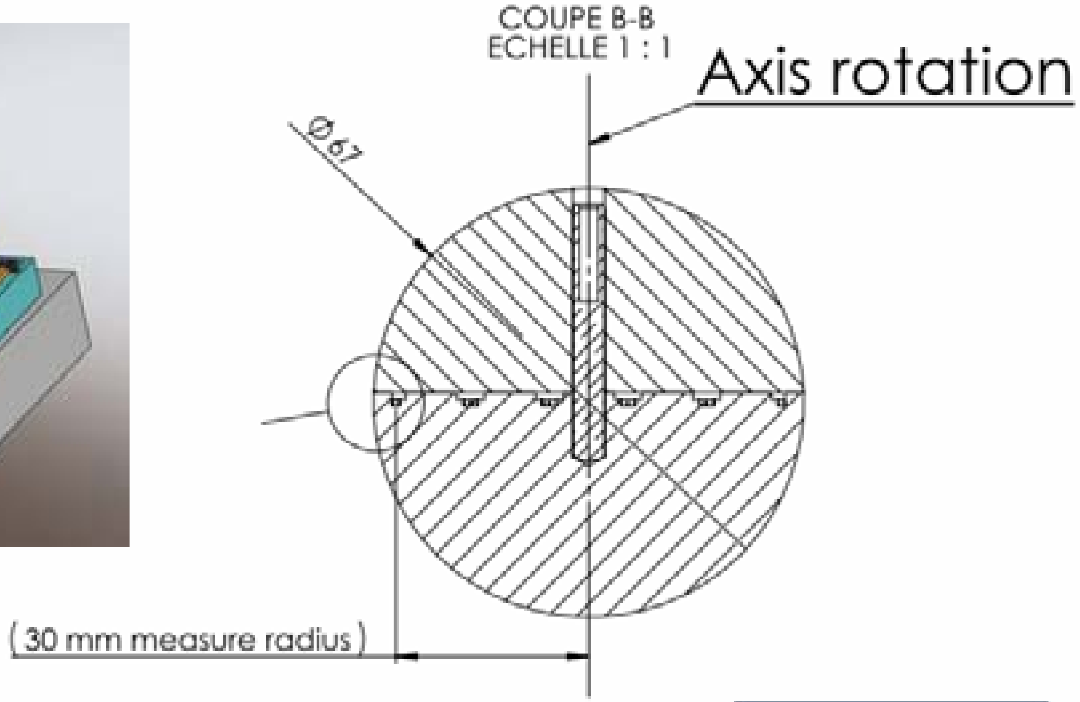


MEDAUSTRON project – Main issues

Magnet degaussing in bipolar, minimum current value 1.38A

Measurement Qualification with a cross-check measurement of 5 prototypes at CERN





THANK YOU
FOR YOUR ATTENTION