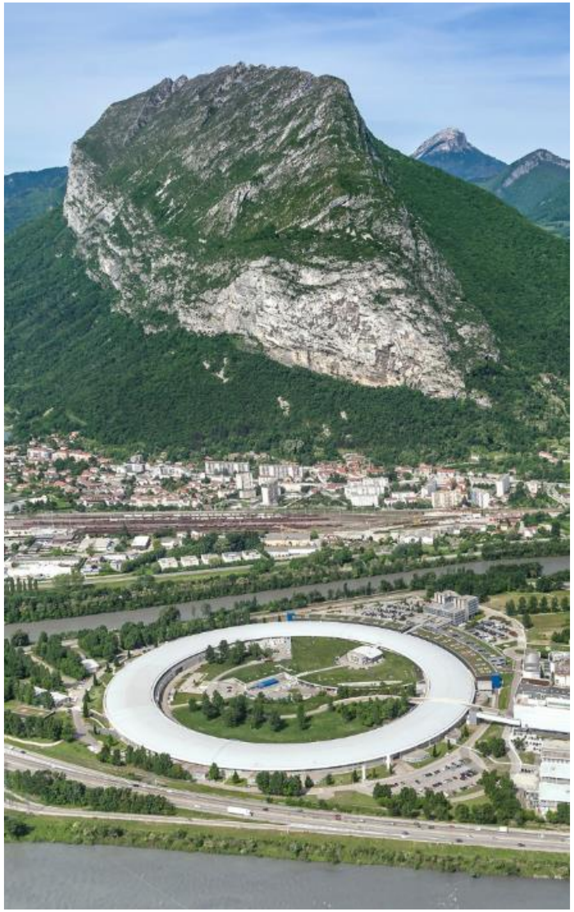


ESRF Alignment Techniques and Results

D. Martin on behalf of the
ESRF Survey and Alignment Group

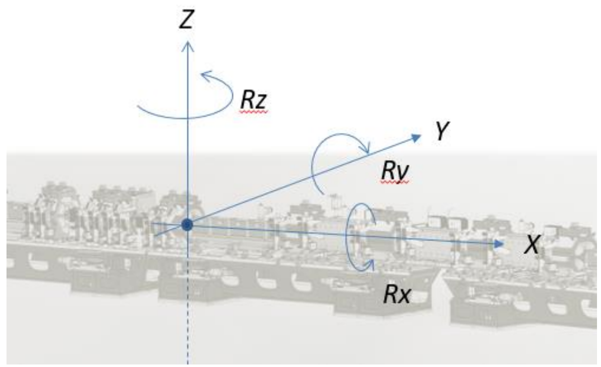
The European Synchrotron | ESRF

ALIGNMENT TOLERANCES

There were two key constraints for EBS

First respect the magnet (and other) alignment tolerances

Machine	Δx [µm]	Δy [µm]	Δz [µm]
Long. Varying field dipoles	1000	>100	>100
High gradient quadrupoles, Combined function dipoles	500	60	60
Medium gradient quads	500	100	85
Sextupoles	500	70	50
Octupoles	500	100	100

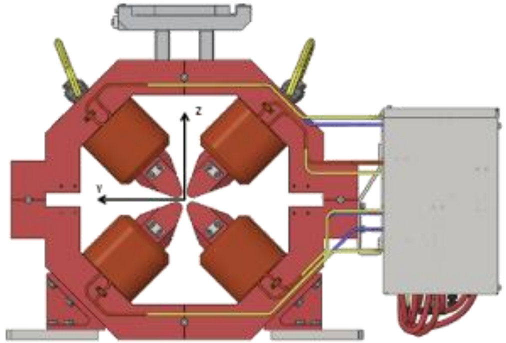


Maximum permissible error 2.5σ

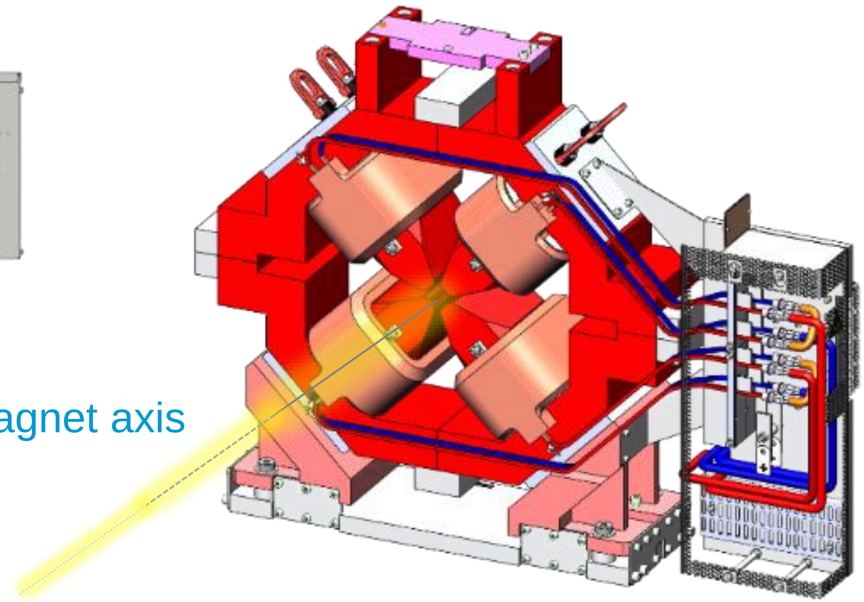
… and second ensure the new machine was in the same place as the old machine to minimize disturbance to the functioning beamlines.

FIDUCIALISATION

For a magnet, we are interested in putting the magnet axis in the right place



But we cannot *see* the magnet axis

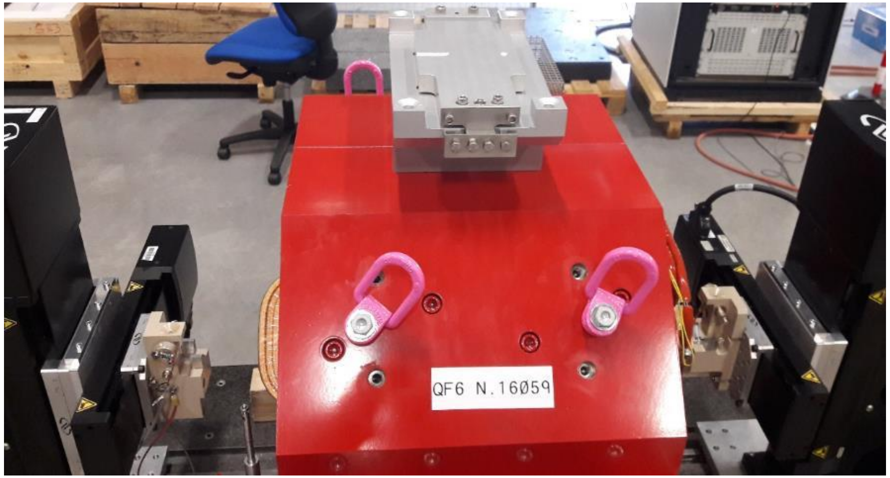


So we have to reference it with respect to external references that we can see.

ESRF FIDUCIALISATION

The original plan was for the magnet manufacturers to do the fiducialisation and shimming, but it was discovered that there were unacceptably large differences between measurements made at the ESRF* and by the manufacturers …

So the ESRF Survey and Alignment group were asked to fiducialise all of the magnets …



At the ESRF this is done on a magnet measuring bench using a stretched wire.

**The problem was with the manufacturers 3D measuring arm instruments…*

FIDUCIALISATION UNCERTAINTY

		Ux [µm]	Uy [µm]	Uz [µm]
Laser Tracker				
	Wire position	13	15	18
	Measurement	9	10	9
	Repeatability	3	3	12
*Magnet measurements**			4	4
*Magnetic Fiducialisation**			*19*	*24*
Magnet Shim Determination				*24*
Total			**19**	**34**

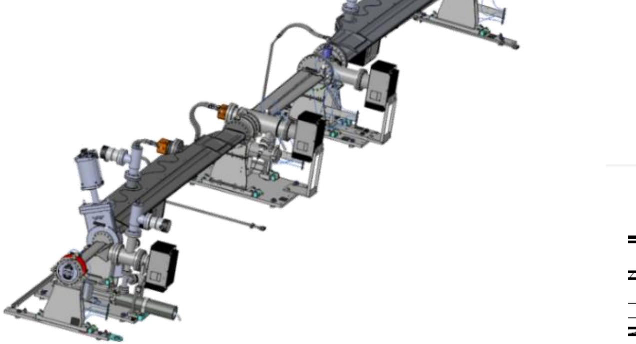
** G. Le Bec ESRF*

We combine all of these errors/uncertainties to determine the fiducialisation uncertainty contribution.

This is the first of several contributions to the overall alignment uncertainty…

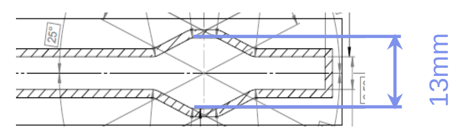
VACUUM CHAMBERS

There are several families of vacuum chambers:

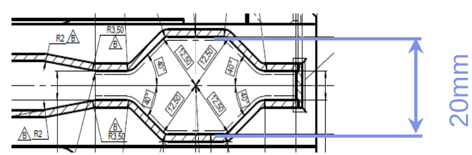



Magnet pole positions impose tight mechanical tolerances …

Low profile cross section

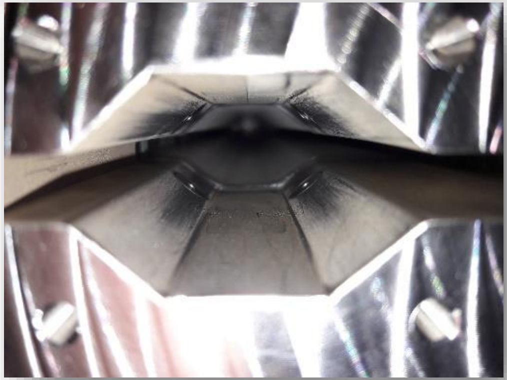


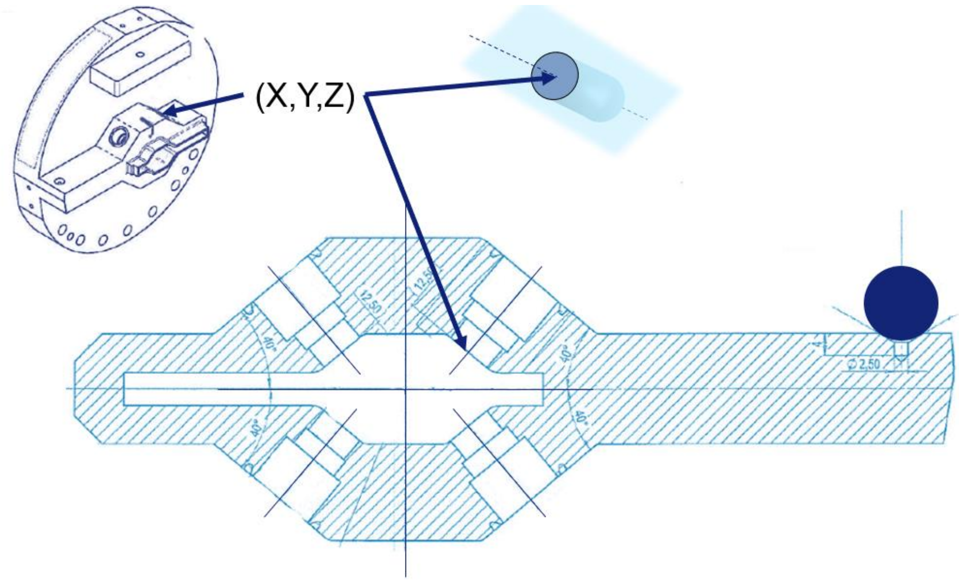
High profile cross section



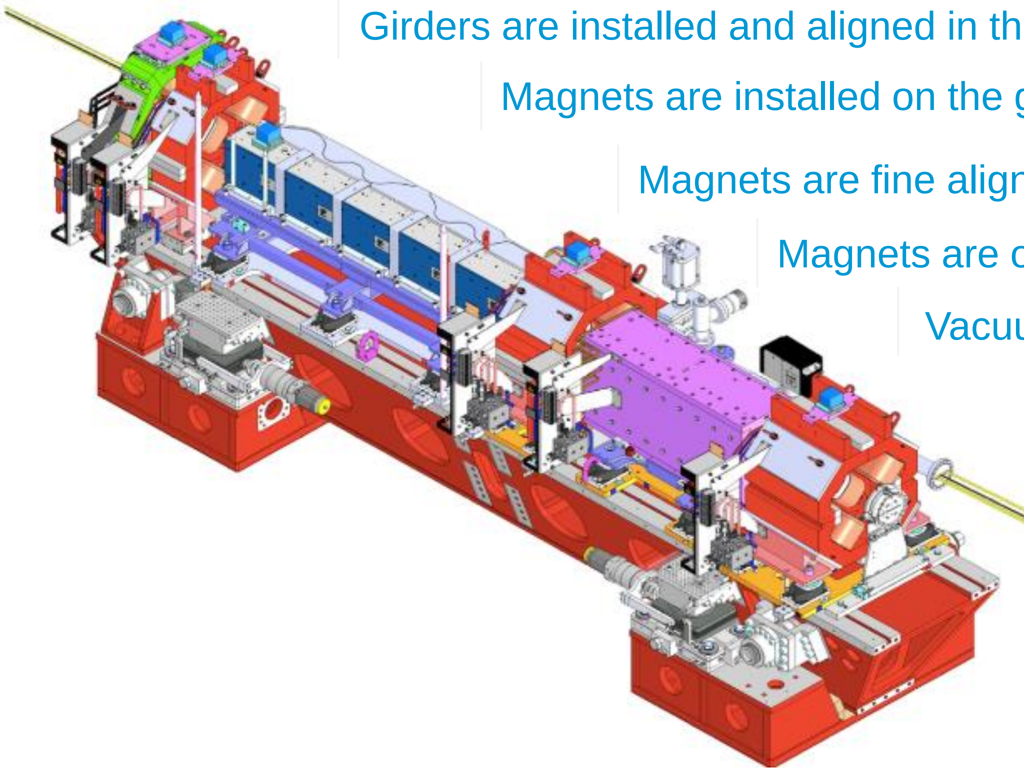
BPM tolerances ~100 um…

BPM FIDUCIALISATION





GIRDER ASSEMBLY



Girders are installed and aligned in the horizontal plane

Magnets are installed on the girder 0.5 mm

Magnets are fine aligned 0.05 mm

Magnets are opened

Vacuum string is installed

BPMs aligned 0.1 mm

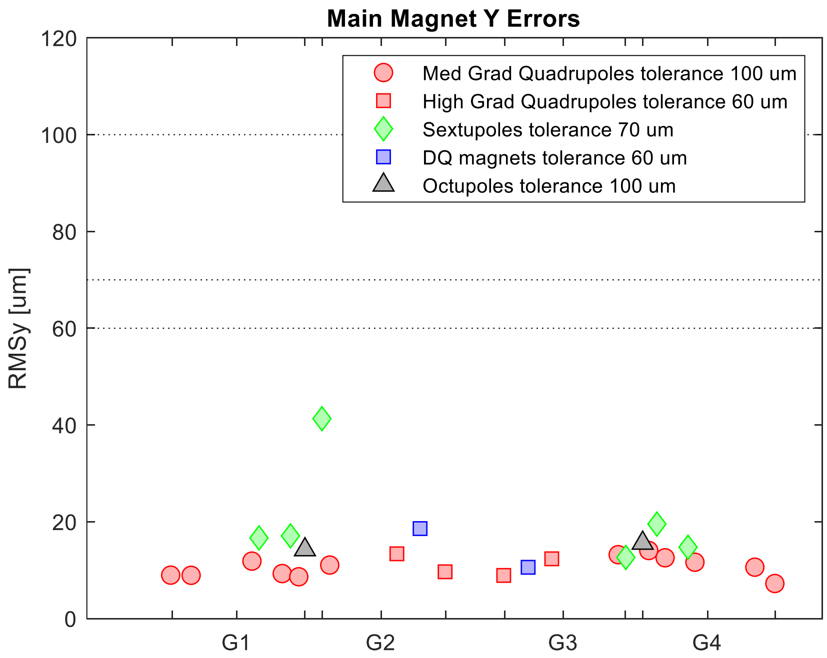
Magnets are closed

Fine magnet alignment check and survey

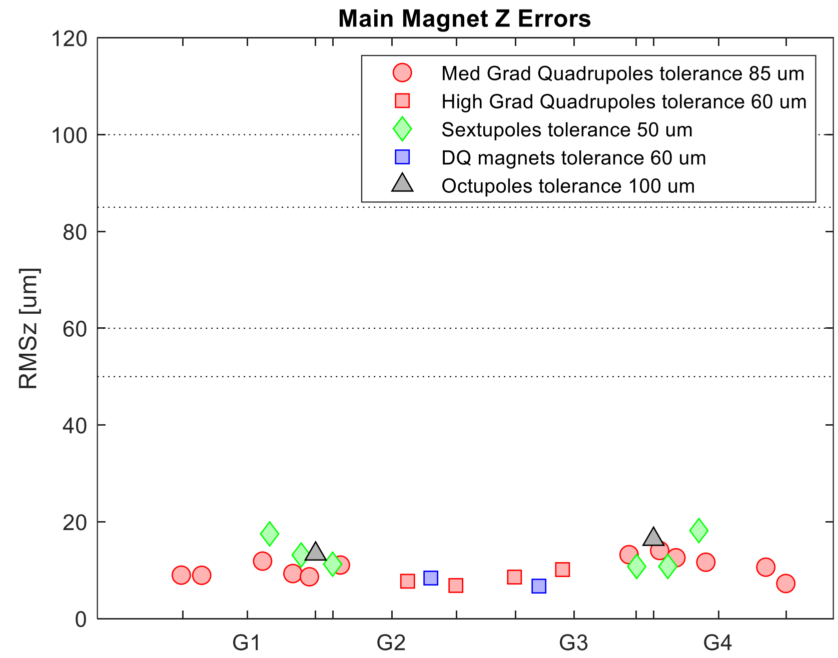
Assembly was made at ESRF01 – a dedicated building

SUMMARY OF HIGH TOLERANCE MAGNET ESRF01 ASSEMBLY ERRORS

Summary statistics for the assembly of the Octupole, Quadrupole, Sextupole and DQ magnets on the girders at ESRF 01…

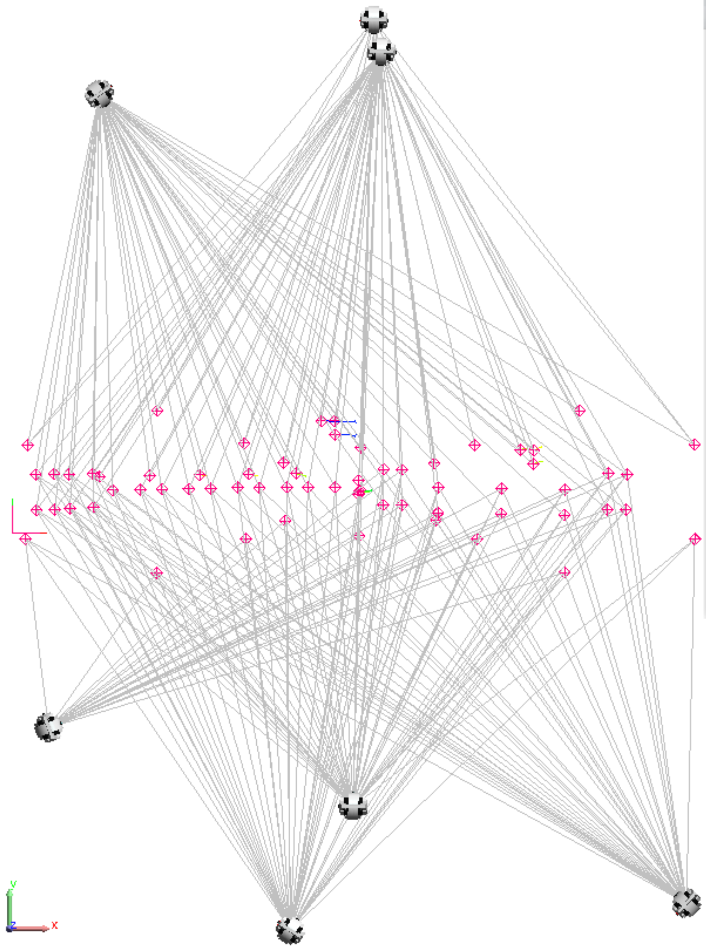


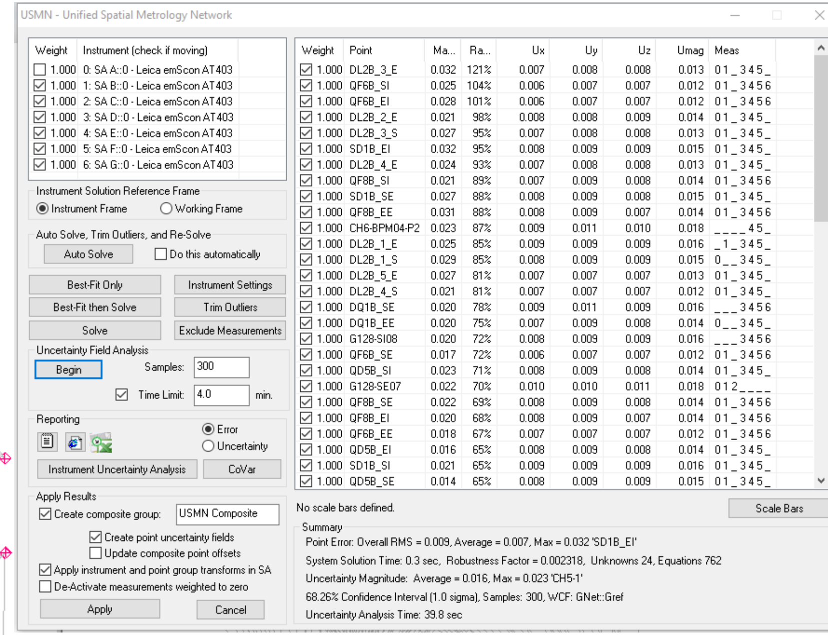
SD_y =16 um



SD_z =17 um

GIRDER ALIGNMENT UNCERTAINTY





	Ux [µm]	Uy [µm]	Uz [µm]
Measurements	6	7	6
Difference to nominal	126	24	25
Overall uncertainty		16	17
Total	**126**	**30**	**31**

EBS INSTALLATION IN THE TUNNEL

Plates Pre-Tracing

Plates Setting Out

Plates Alignment

Plates Control

Girder Pre-Alignment

Girder Fine-Alignment

Girder Control

Girder Touch-ups

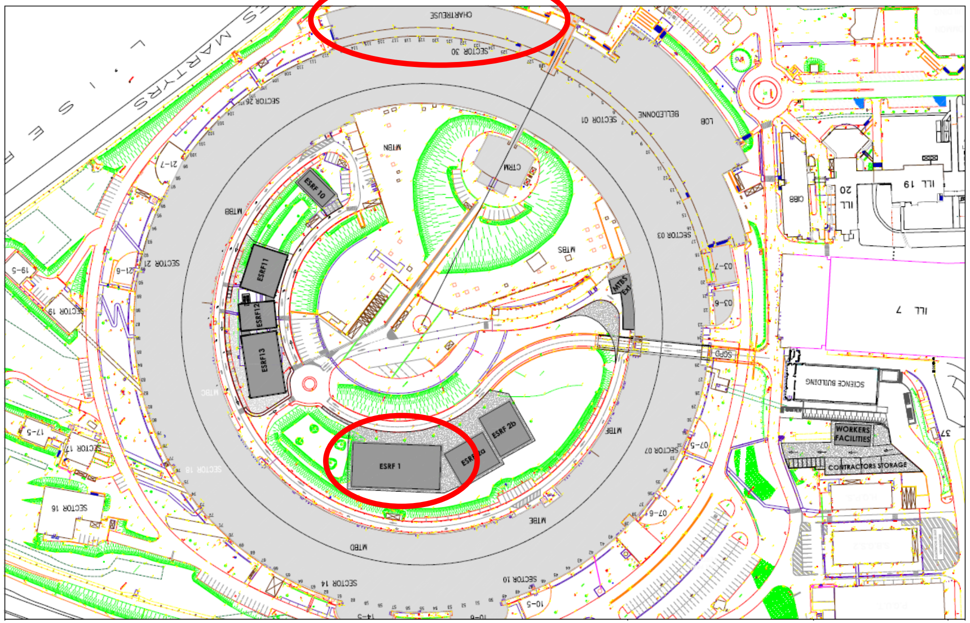
Girder Re-control

DQ2 Alignment

DQ2 Control

HLS Installation

STORAGE AND TRANSPORT



Storage place	Quantity	Comments
G.L.D.	90	Girder direct access with a crane
ESRF 01	9	End of the assembly process
Chartreuse hall	30	Non standard girders + ID24 entry point

Source: Mini-Workshop on Girders and Alignment – 10-11 May 2021- Thierry Brochard (ESRF)

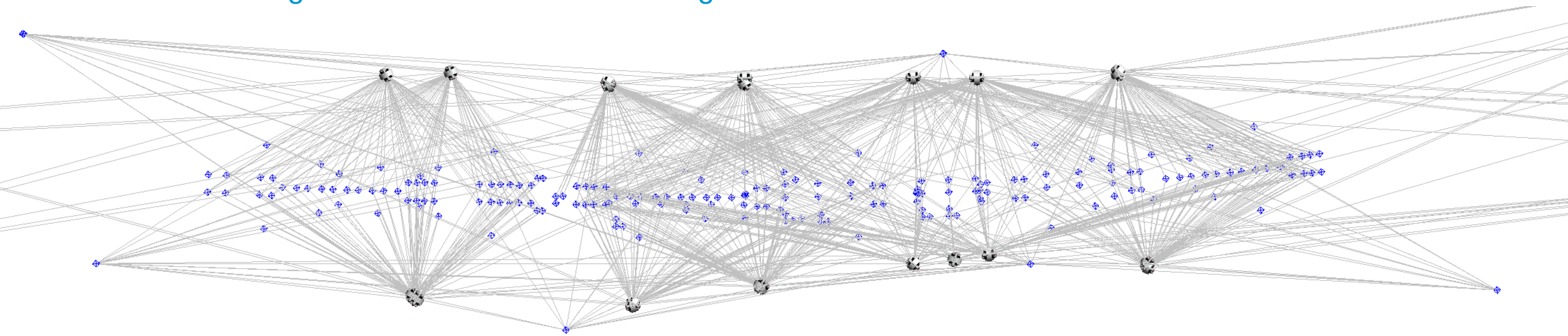
INSTALLATION

Girders were:

- transported from storage on a truck,
- unloaded using a crane,
- transported to a gantry,
- lifted into the tunnel using the gantry, and
- transported to their final position with the transport module.

EFFECT OF STORAGE, TRANSPORTATION, INSTALLATION AND BAKEOUT

After the installation and initial alignment in the tunnel all of the girders were remeasured like they were during in ESRF01. This was done again after the bakeout was finished in the tunnel.



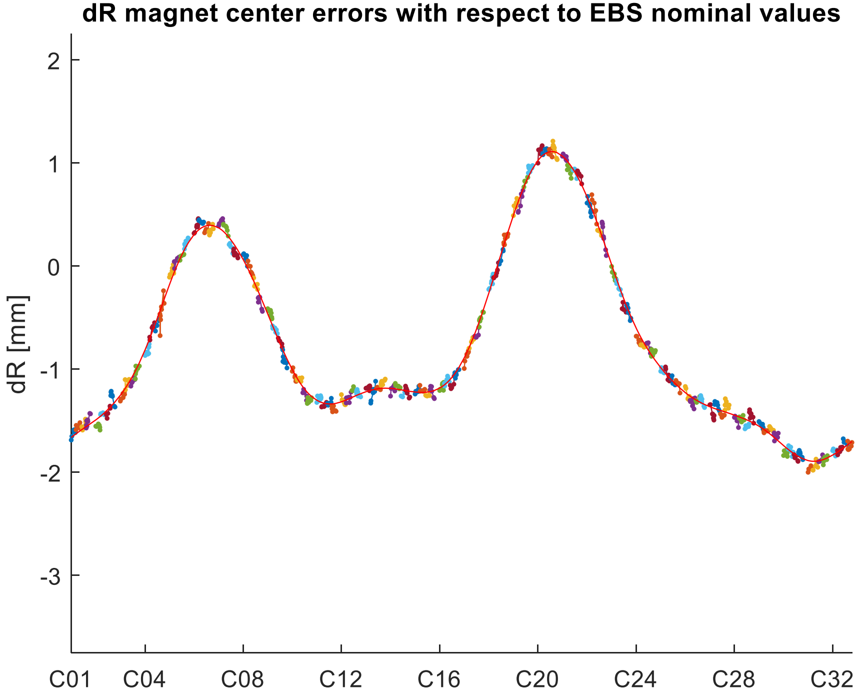
The magnet positions were then adjusted onto the magnet positions measured at ESRF01.

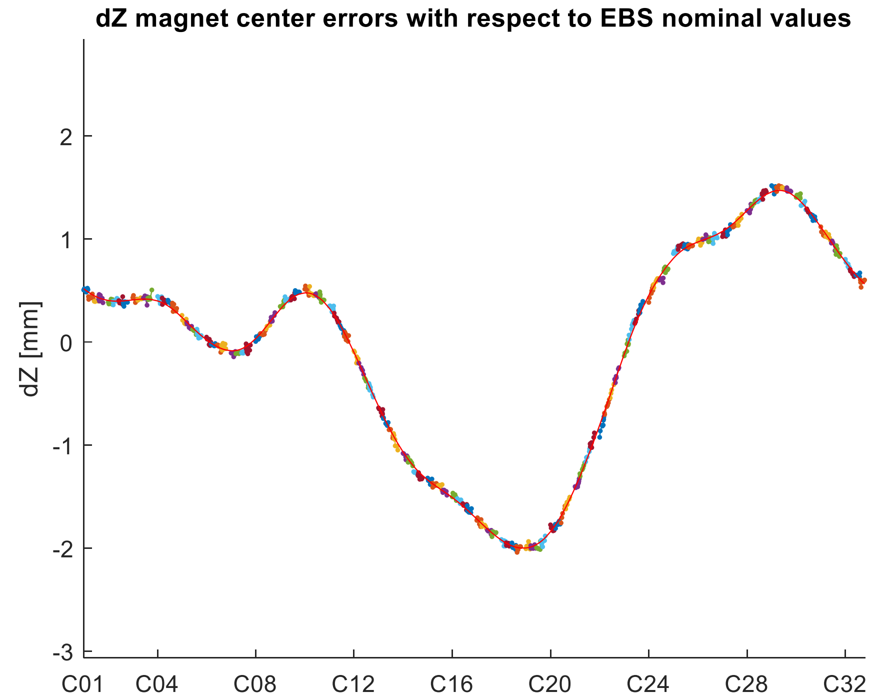
Survey	Uy [µm]	Uz [µm]
ESRF01 (see previous slide)	16	17
After transport (3D adjustment on ESRF01)	17	20
After bakeout (3D adjustment on ESRF01)	19	21

These results suggest the effect of transport was ~10 µm – and the effect of bakeout on the alignment less than that …

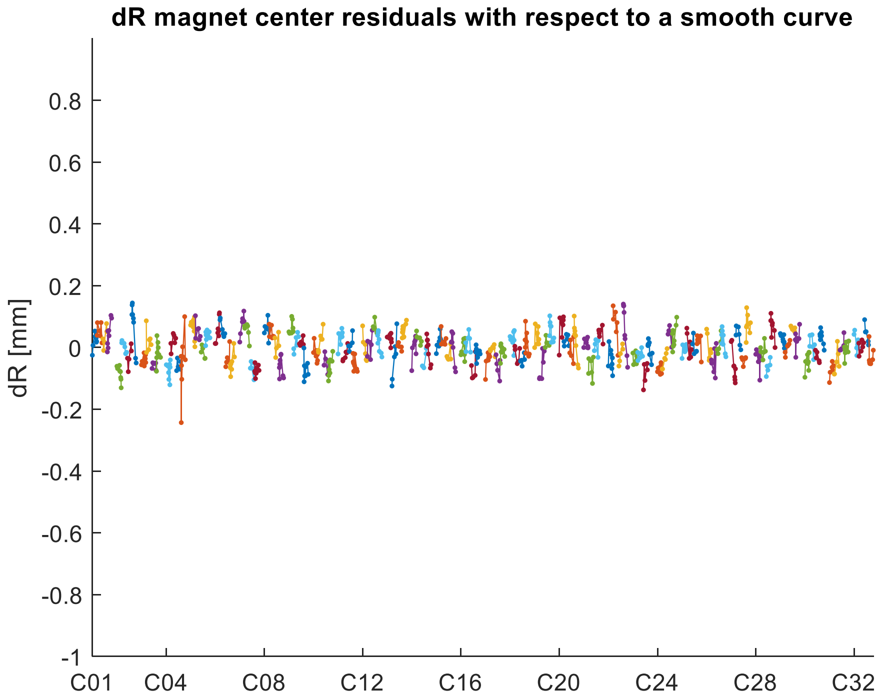
ESRF01 was the building where the girders were assembled.

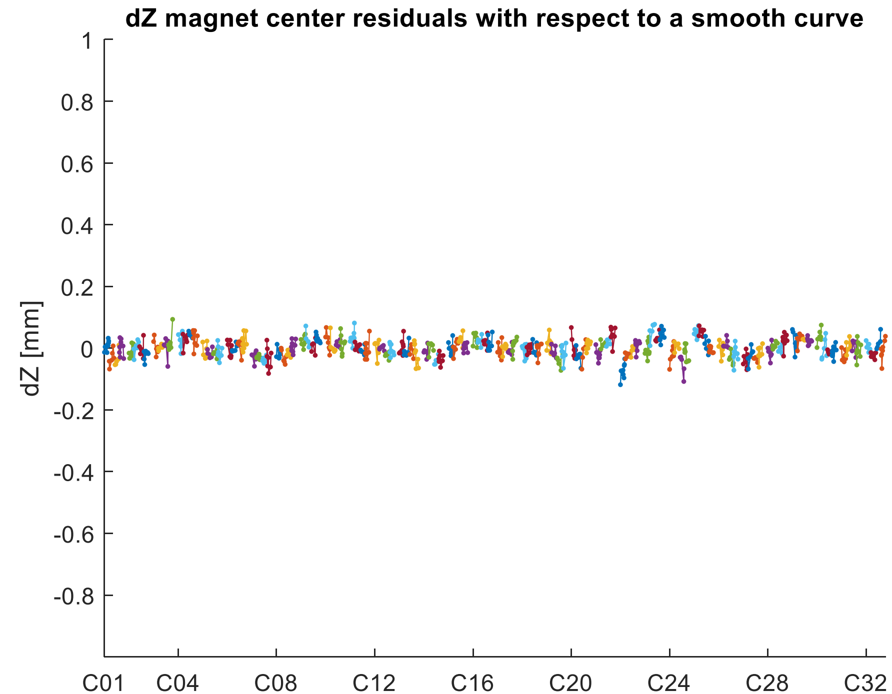
NOVEMBER 2019 – AFTER FINAL ALIGNMENT - ERROR





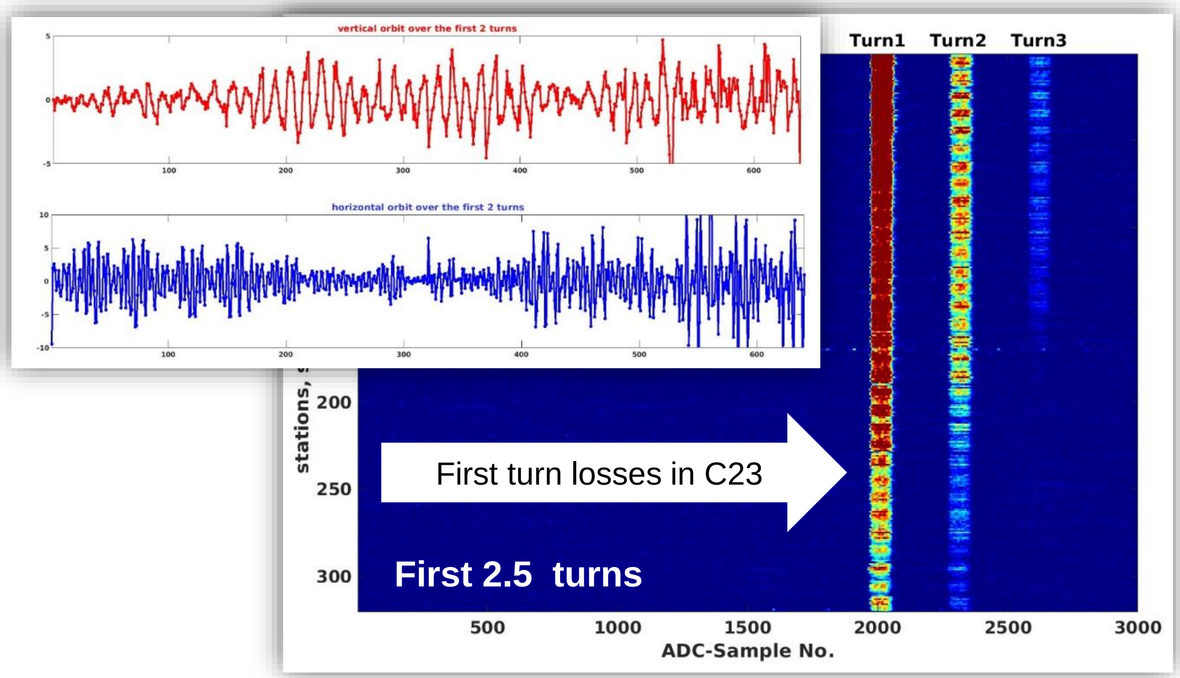
NOVEMBER 2019 – AFTER FINAL ALIGNMENT - RESIDUALS





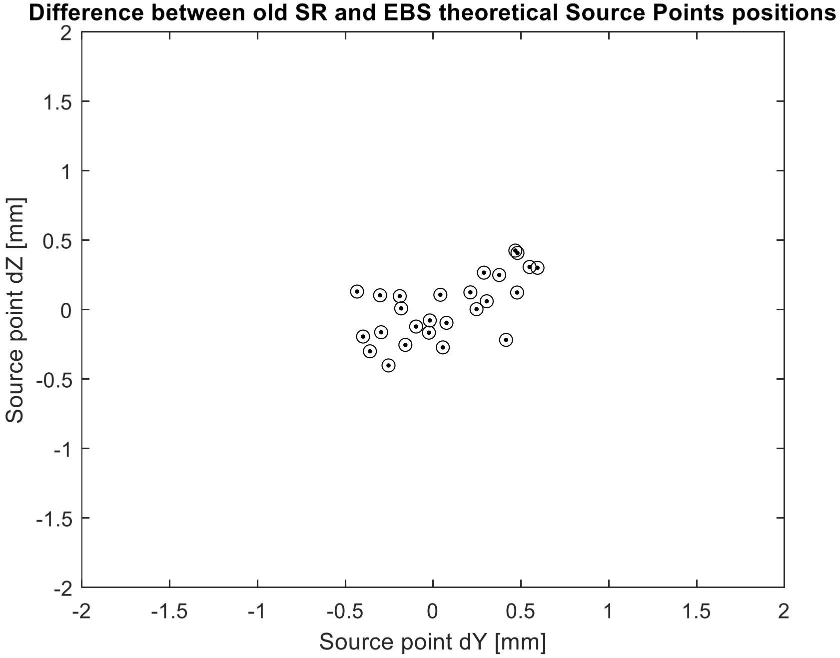
U_R=52 um
U_Z=30 um

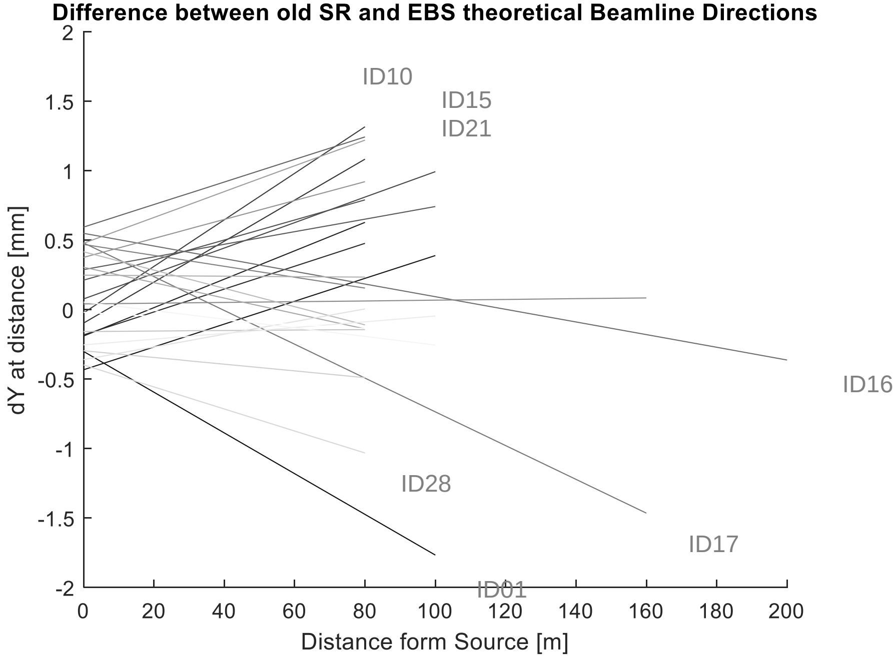
28 NOVEMBER 2019 AT 19hrs FIRST TURNS IN EBS-SR



BEAMLINES

Recall the second major constraint – put the machine back where the old machine was…





RMS Y [mm]	RMS Z [mm]	RMS Direction [urad]
0.32	0.22	8

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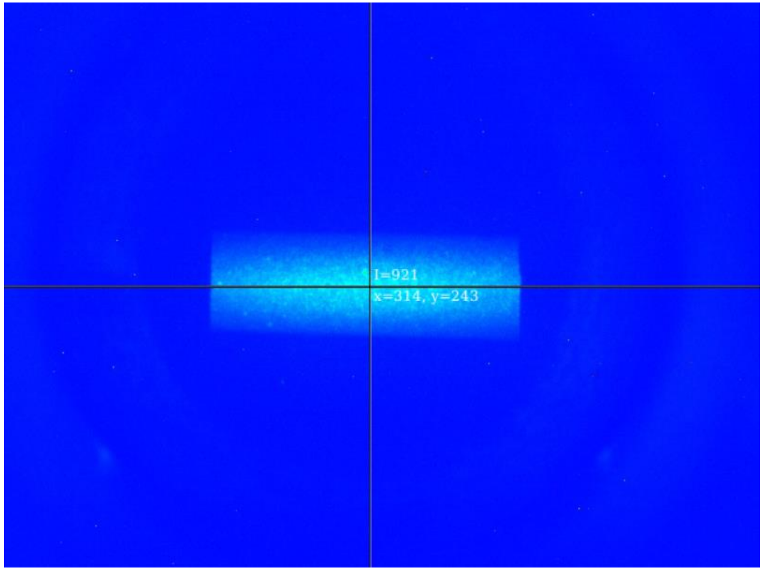
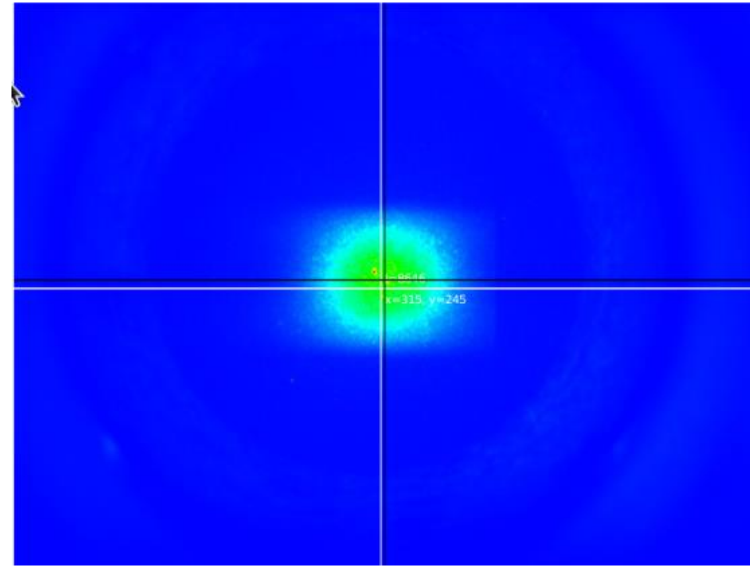
IMAGE OF PHOTON BEAM ON ID09 JANUARY 30 2020



Old SR
26 November 2018

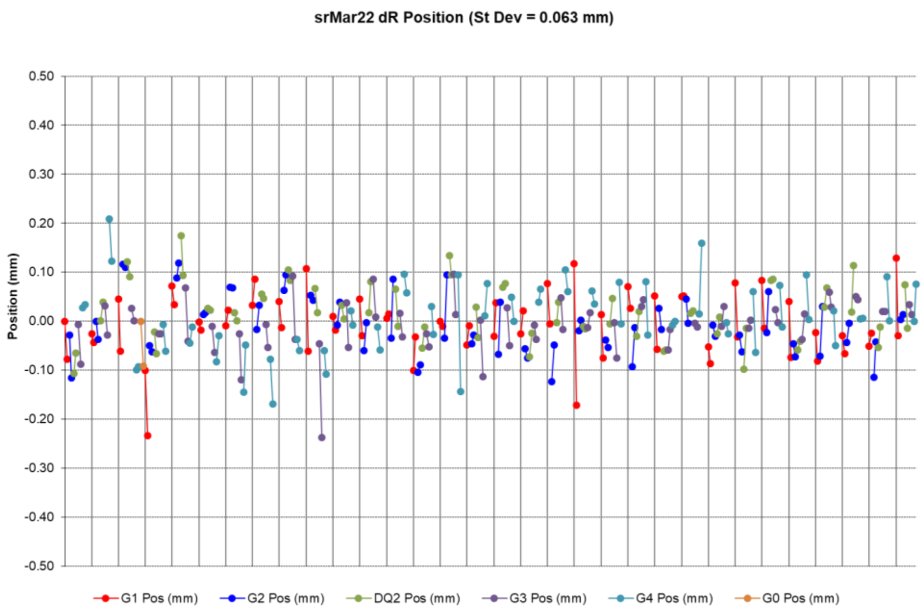


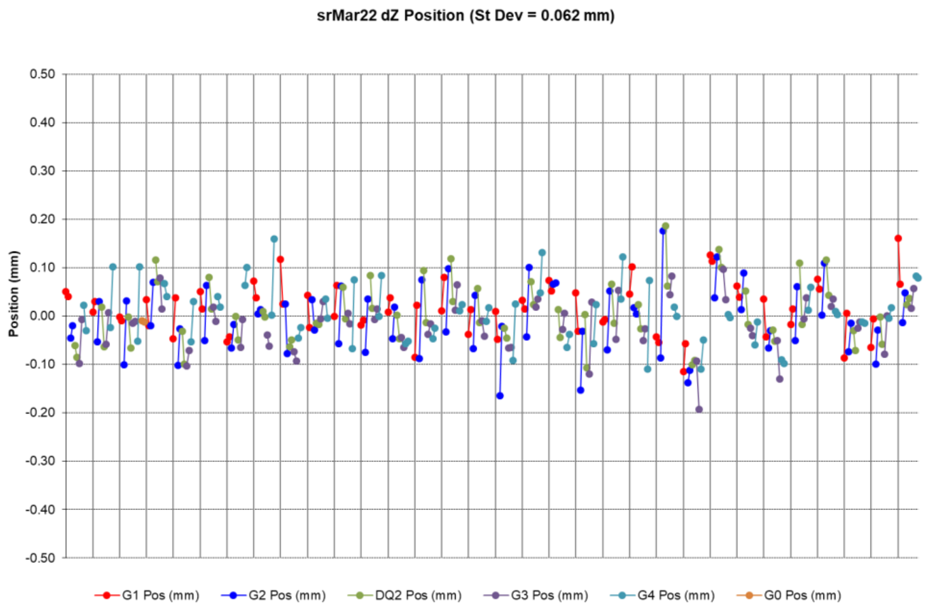
EBS
30 January 2020

…The EBS X-ray beam at distances varying from 45 to 160m was found within fractions of millimetres from its position in December 2018…

E-mail Francesco Sette to all staff on 31/01/2020

MARCH 2022 – 28 MONTHS AFTER FINAL ALIGNMENT





U_R = 63 um *was 53 um in 11/2019*

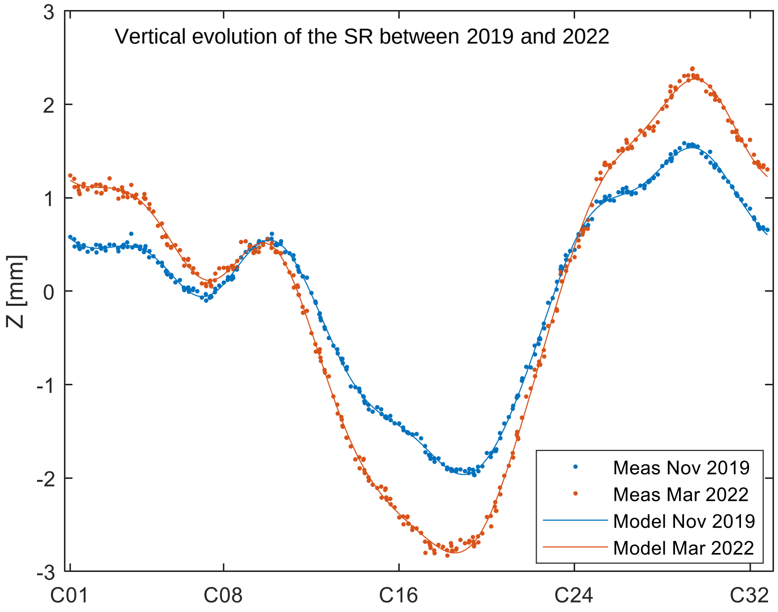
U_Z = 62 um *was 30 um in 11/2019*

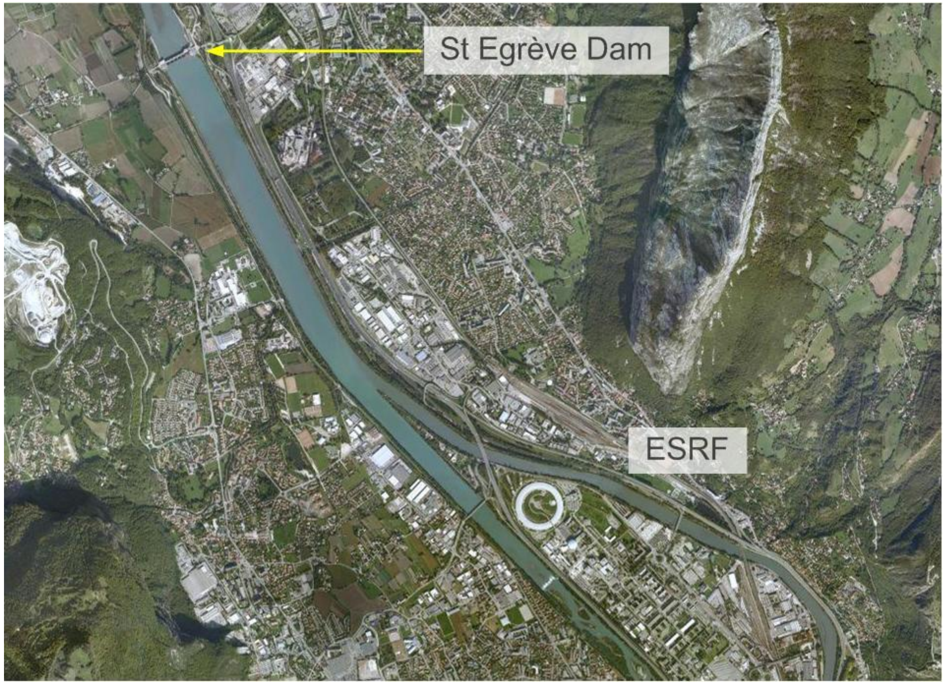
TEMPORAL AND SPATIAL DEFORMATION - GENERAL SITE MOVEMENTS

Every site is different, has different site movement signatures and evolves differently.

Recall smoothing:

U_R = 63 um *was 53 um in 11/2019*
U_Z = 62 um *was 30 um in 11/2019*





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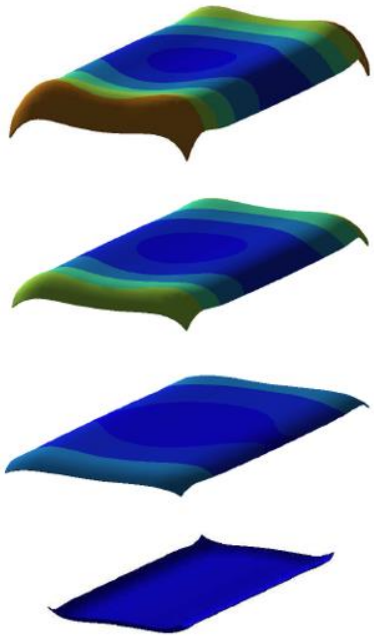
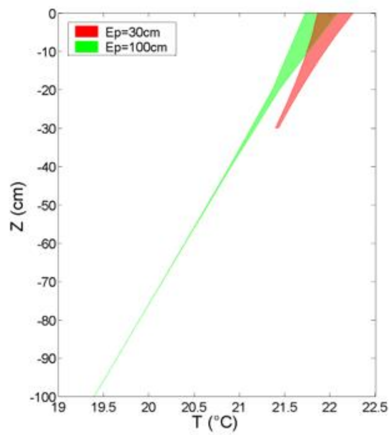
TEMPORAL AND SPATIAL DEFORMATION – FLOOR AND GIRDER MOVEMENTS

Generally magnets are installed on supports (girders) that are themselves installed on a concrete floor …

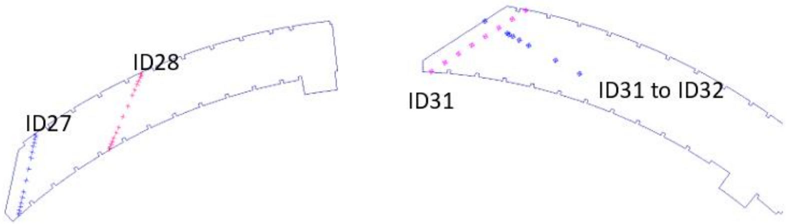
Concrete floors are subject to thermally induced movements – temperature variations over the day and year

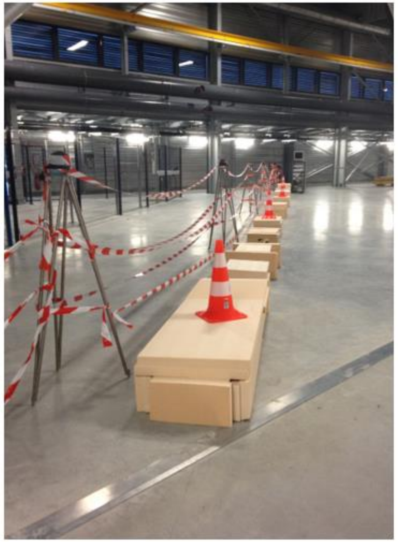


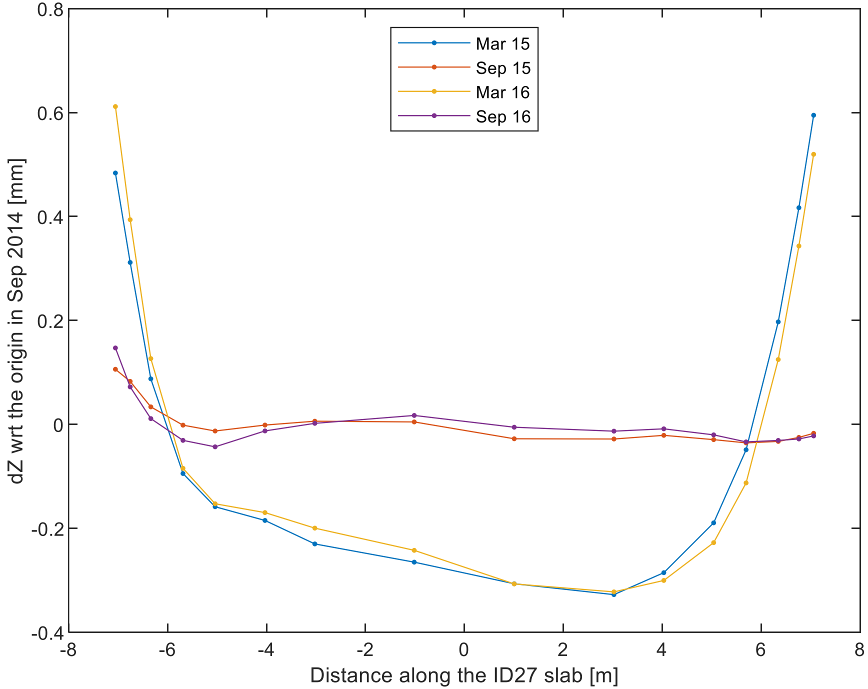


A number of experiments have been made at the ESRF to study this …

TEMPORAL AND SPATIAL DEFORMATION – FLOOR AND GIRDER MOVEMENTS

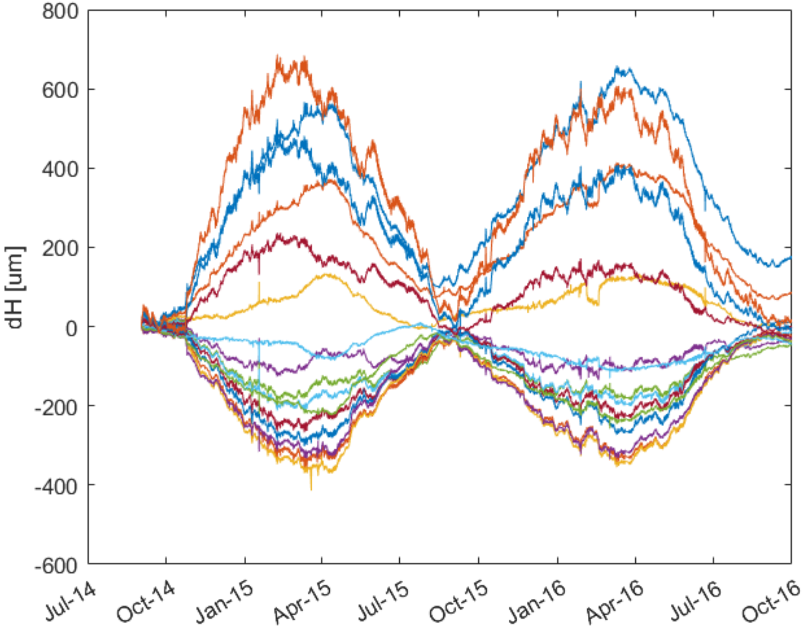


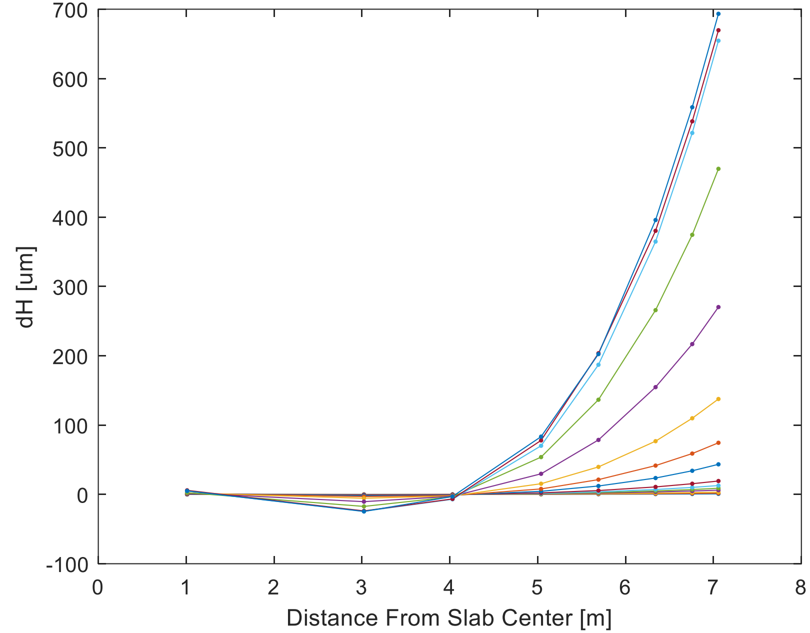




TEMPORAL AND SPATIAL DEFORMATION – FLOOR AND GIRDER MOVEMENTS

Bending movements vary between 0 and 700 µm over 6 months depending on time and position





1hr	2hrs	4hrs	8hrs	12hrs	24hrs	48hrs	1wk	2wks	4wks	2mo	4mo	6mo
1	2	3	6	9	13	19	43	74	138	270	470	655
1	1	3	5	7	10	15	34	59	110	217	374	521
0	1	2	4	5	7	11	24	42	77	155	266	365
0	1	1	2	3	4	6	12	21	40	79	137	187
0	0	0	1	1	1	2	5	8	15	30	54	70
0	0	0	0	0	0	0	-1	-2	-2	-3	-3	-7
0	0	0	0	0	-1	-1	-2	-3	-6	-10	-17	-24
0	0	0	0	0	0	0	1	1	2	2	2	5

Again every site and floor is different, but the principle is the same…

TEMPORAL AND SPATIAL DEFORMATION – FLOOR AND GIRDER MOVEMENTS

Recently experiments were made at the ESRF to create a closed vertical ID angle bump using girder movements.

The experiment worked well and it was shown that ID bumps using the girders are both feasible and achievable

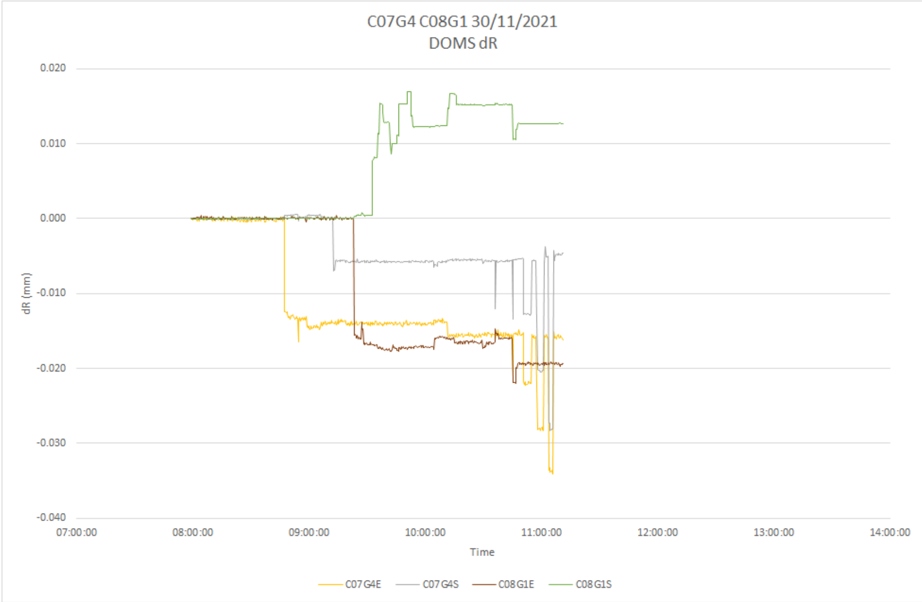
However, during the experiment, we found there were coupled parasitic horizontal movements. These movements were observed both in the beam and with capacitive captors installed to measure them.

There were both one-off and repeatable movements.

It is important to note that the girders were tested before installation and parasitic coupled movements were not observed in unconstrained girders.

It is postulated these movements are constraints introduced into the rigidly fixed girder as a result of small movements of the floor similar to those measured in the previous slides.

We would like to do more tests to see if this is a reasonable mechanism to explain what we have observed.



Girder Movements with Beam, MDT Review, Lee Carver, David Martin, Gilles Gatta, Thierry Brochard, Simon White

MANY THANKS FOR YOUR ATTENTION