Overview of the alignment strategy for SOLEIL II machine

S. Ducourtieux, Y. Delalande, C. Bourgoin, M. Sebdaoui, B. Leluan, A. Lestrade, E. Lazarowicz

SOLEIL II
La science éclaire l'avenir
Science lights up the future

Contents:

- Soleil II project in few key figures
  - Alignement constraints and tolerances
- Metrological approach to better control the alignment uncertainty of the machine components with laser tracker.
  - Reproducibility measurements on few case studies
  - Uncertainty budget
  - Recent developments to better control the alignment process with laser tracker
- Conclusion

Soleil II project in few key figures

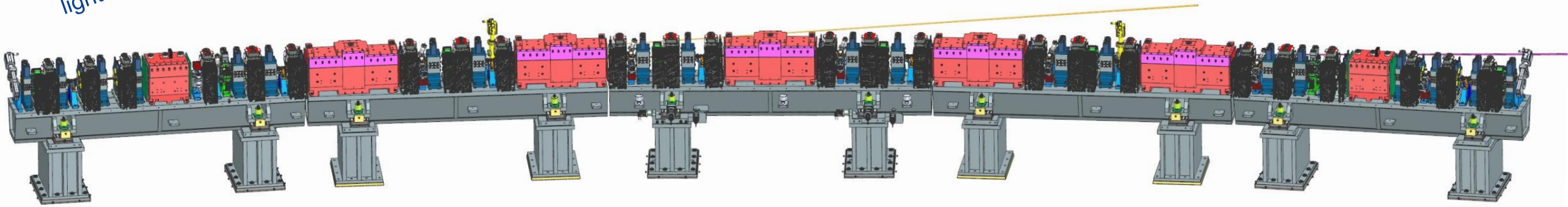
2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
TDR phase		SOLEIL II phase 1: construction						SOLEIL II phase 2 : toward full performance					

Dark period

Upgrade of booster ring and storage ring
Modification and adaptation of a group of beamline

Beamlines to take full advantage of the coherence and the low emittance electron beam thanks to the availability of the latest generations of insertion devices (IDs) and state-of-the-art new beamline components

Fourth-generation light source



SOLEIL

- LINAC energy: 110 MeV
- Booster: 0.1 - 2.75 GeV
- Circumference: 354 m
- Energy: 2.75 GeV
- Emittance: 3.9 nm.rad
- 317 electromagnets (a magnet every 90 cm)
- 56 girders
- 29 beamlines

SOLEIL II

- LINAC energy: 150 MeV
- Booster: 0,15 – 2.75 GeV
- Circumference: 354 m
- Energy: 2.75 GeV
- Emittance: 85 pm.rad
- 1277 permanent and electro-magnets (a magnet every 28 cm)
- 86 girders
- 29 beamlines

Brightness and flux density will be highly increased.

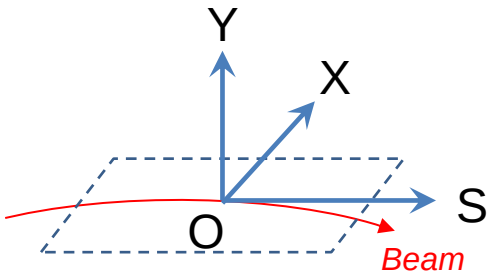
The lattice is very compact thanks to the use of numerous permanent magnets, but it is also very sensitive to misalignments:

⇒ Tight alignment tolerances
⇒ A major improvement in our alignment techniques is required

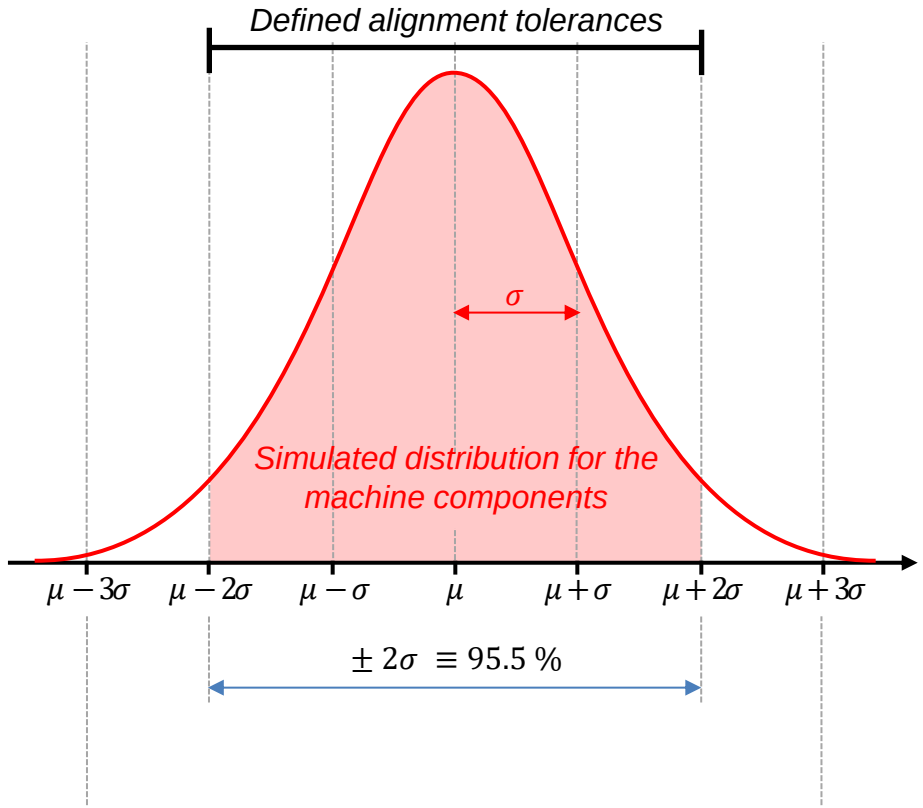
Alignment tolerances

Last alignment tolerances as specified in 2024:

Tolerances given by Alignment and Accelerator Physics groups.
Distributions are truncated to $\pm 2\sigma$ for a confidence level of 95.5 %.



Point to check for alignment	September 2024 (simulation inputs for Accelerator Physics)	Defined alignment tolerances
Magnet on a girder	$\sigma_{T_X} = \sigma_{T_Y} = 25\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_X} = \sigma_{R_Y} = \sigma_{R_S} = 100\ \mu rad$	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-200\ \mu rad < R_X, R_y, R_S < 200\ \mu rad$
Magnet on section matching girders	$\sigma_{T_X} = \sigma_{T_Y} = 10\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_X} = \sigma_{R_Y} = \sigma_{R_S} = 100\ \mu rad$	$-20\ \mu m < T_X, T_Y < 20\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-200\ \mu rad < R_X, R_y, R_S < 200\ \mu rad$
Girder to girder (close or on both side of a straight section)	$\sigma_{T_X} = \sigma_{T_Y} = 25\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_X} = \sigma_{R_Y} = 10\ \mu rad$ $\sigma_{R_S} = 60\ \mu rad$	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$ $-20\ \mu rad < R_X, R_y < 20\ \mu rad$ $-120\ \mu rad < R_S < 120\ \mu rad$
Circumference	$\sigma_C = 1\ mm$	$-2\ mm < C < 2\ mm$



Objective:

- reduce critical discontinuities in beam path
- preserve the RF synchronization between storage and booster ring

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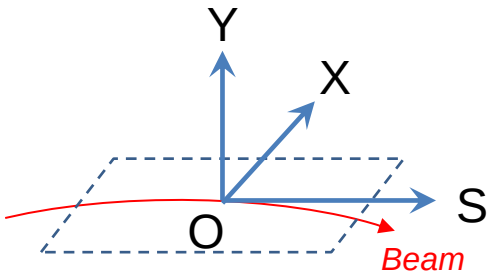

Laser tracker MPE: +/-15 µm + 6 µm/m
MPE at 3 m: 33 µm
MPE at 10 m: 75 µm

Objective :

- reduce critical discontinuities in beam path
- preserve the RF synchronization between storage and booster ring

Alignment tolerances

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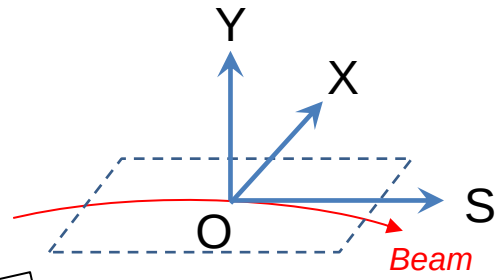


Point to check for alignment	September 2024 (simulation inputs for Accelerator Physics)	Defined alignment tolerances
Magnet on a girder	$\sigma_{T_X} = \sigma_{T_Y} = 25\ \mu m$ $\sigma_{T_S} = 50\ \mu m$ $\sigma_{R_X} = \sigma_{R_Y} = \sigma_{R_S} = 100$	
Magnet on section matching girders	σ_T $\sigma_{R_X} = \sigma_R$	
Girder to girder (close or on both side of a straight section)	σ_{T_X} $\sigma_{R_X} =$ σ_{R_S}	
Circumference	σ_C	

The big question is : are those tolerances realistic if we only use laser tracker ?

In practical, what kind of performance can we achieve with laser tracker ?

We need experimental information to comfort us in the fact that it is achievable.

⇒ We apply a metrological approach

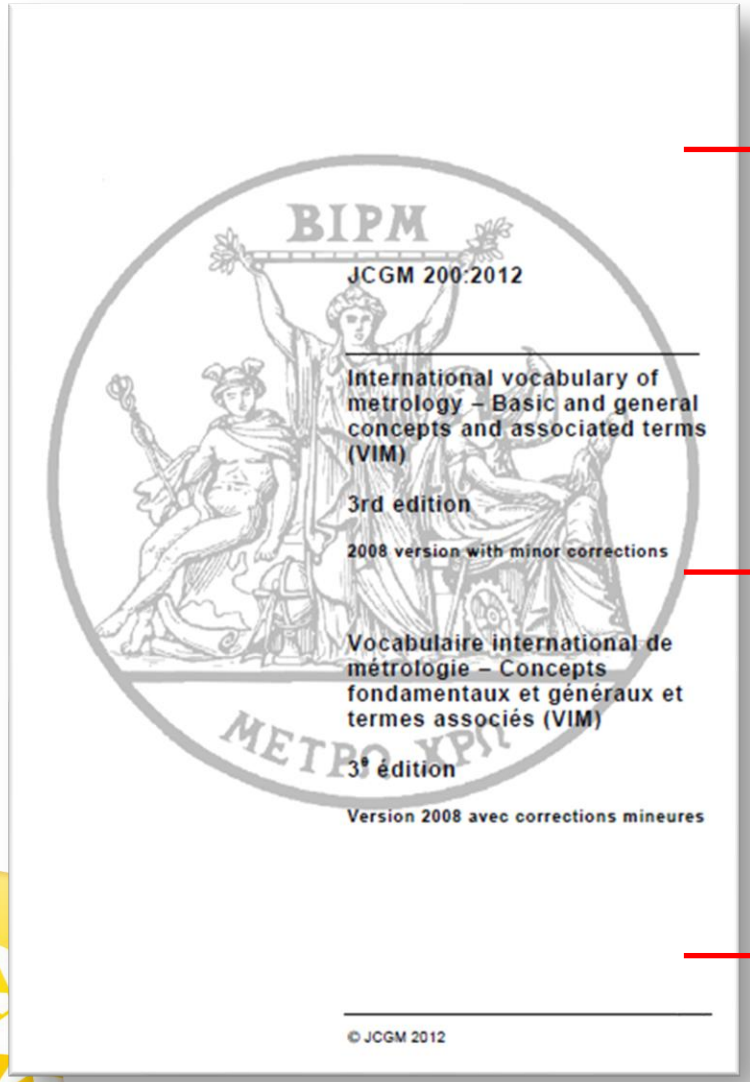
Laser tracker MPE: +/-15 µm + 6 µm/m
MPE at 3 m: 33 µm
MPE at 10 m: 75 µm

Objective :

- reduce critical disc… …eam path
- preserve the RF synchronization between storage and booster ring

Reproducibility measurements with laser tracker

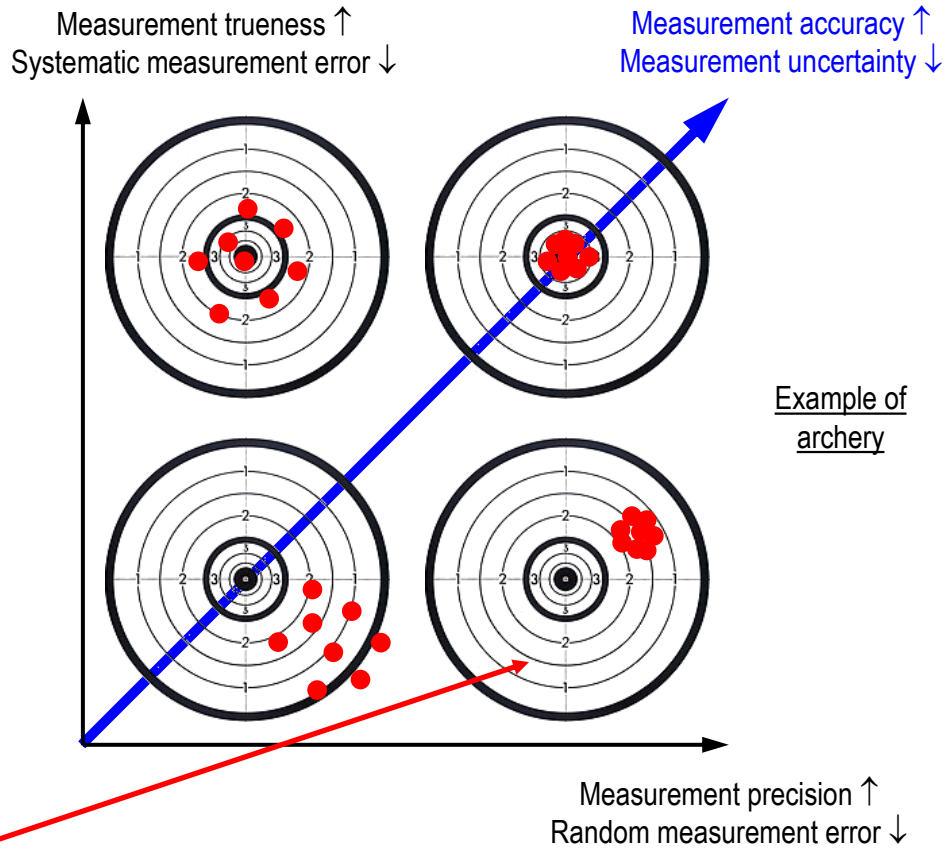
Reproducibility measurements to comfort us in the fact that it is achievable.



2.20 (3.6, Notes 1 and 2)
repeatability condition of measurement
repeatability condition
condition of **measurement**, out of a set of conditions that includes the same **measurement procedure**, same operators, same **measuring system**, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time

2.24 (3.7, Note 2)
reproducibility condition of measurement
reproducibility condition
condition of **measurement**, out of a set of conditions that includes different locations, operators, **measuring systems**, and replicate measurements on the same or similar objects

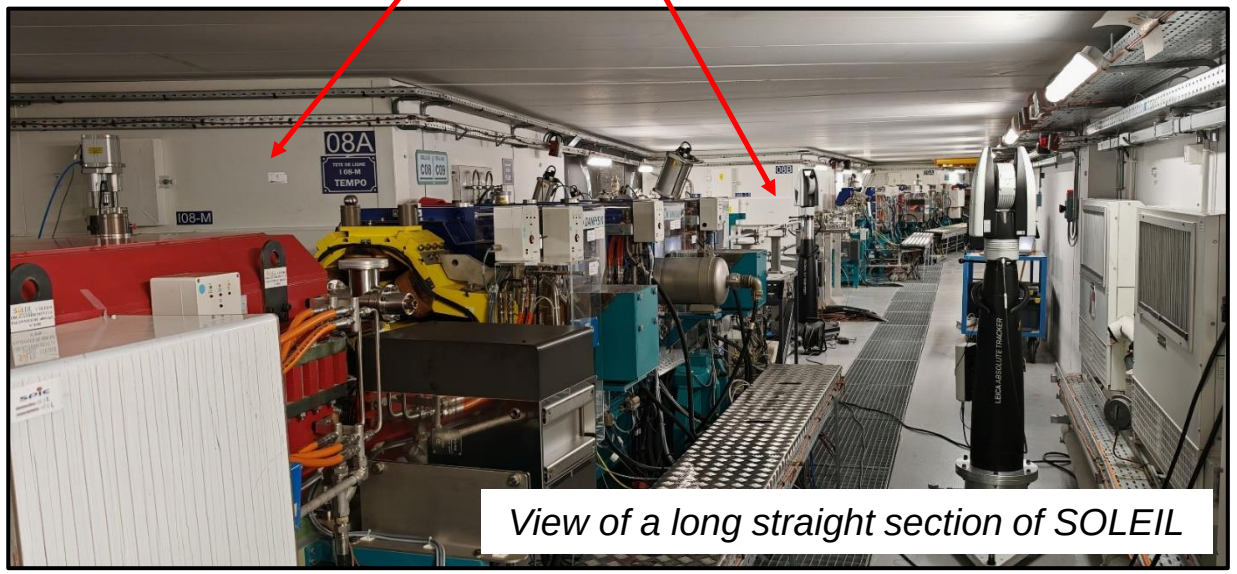
2.15
measurement precision
precision
closeness of agreement between **indications** or **measured quantity values** obtained by replicate **measurements** on the same or similar objects under specified conditions



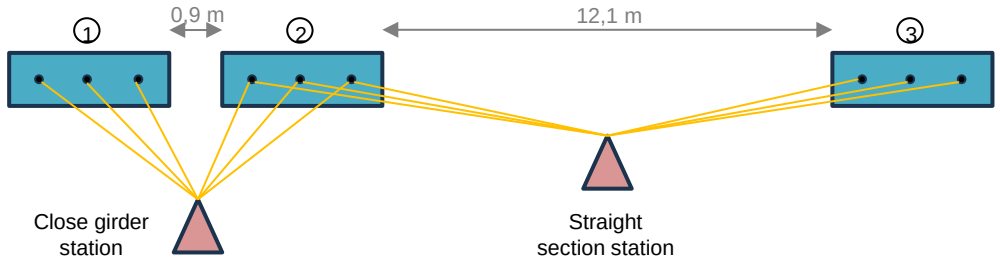
Reproducibility measurements with laser tracker

Three specific case studies :

Point to check for alignment	Defined alignment tolerances
Magnet on a girder	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$
Magnet on section matching girders	$-20\ \mu m < T_X, T_Y < 20\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$
Girder to girder (close or on both side of a straight section)	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$



View of a long straight section of SOLEIL



Girder prototype for SOLEIL II

Reproducibility measurements with laser tracker

Condition of measurement for the prototype girder :

2.24 (3.7, Note 2)
reproducibility condition of measurement
reproducibility condition

condition of **measurement**, out of a set of conditions that includes different locations, operators, **measuring systems**, and replicate measurements on the same or similar objects

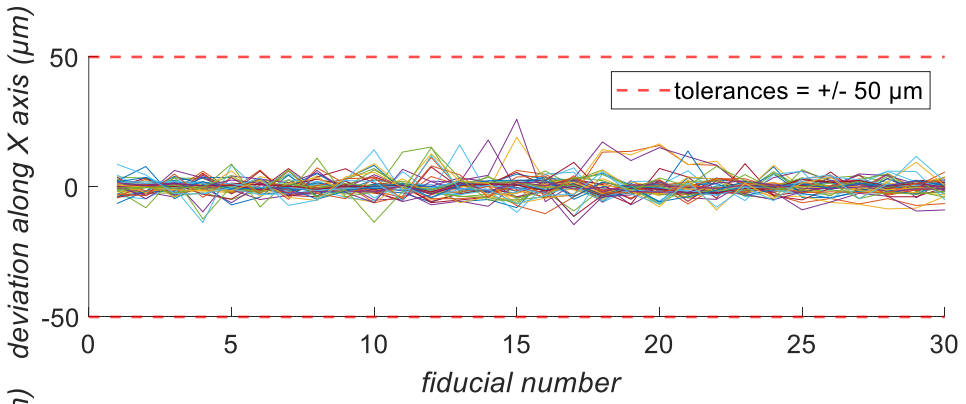
- 30 fiducials to be measured (directly fixed to the magnets)

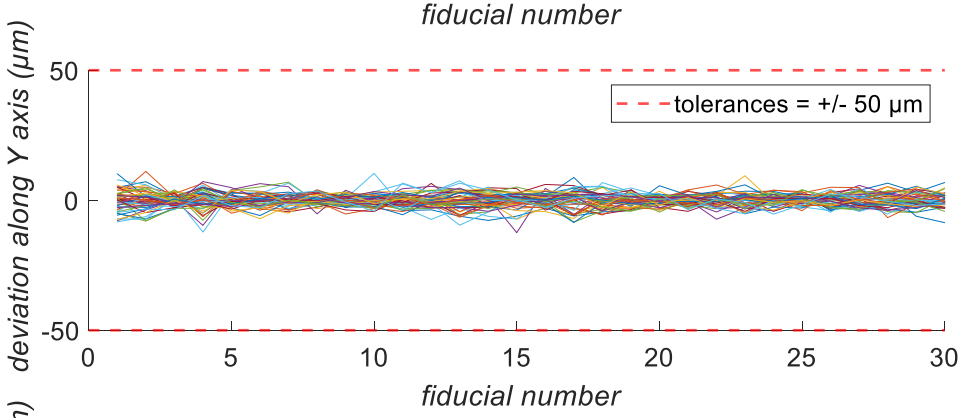
- On a standard concrete slab (no specific care for vibrations coming from the floor)
- Air conditioning of the building : 21 +/- 1 °C with lot of perturbations due to air flow
- No protection to protect the beam from air turbulences

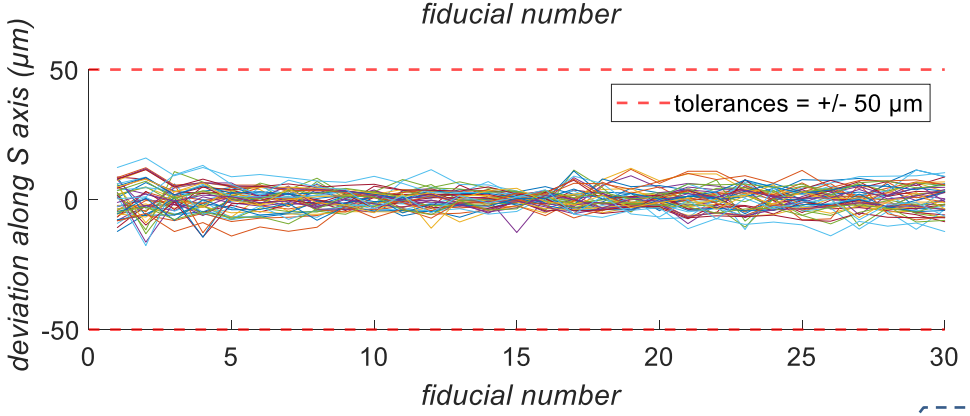
} ⇒ different environmental conditions

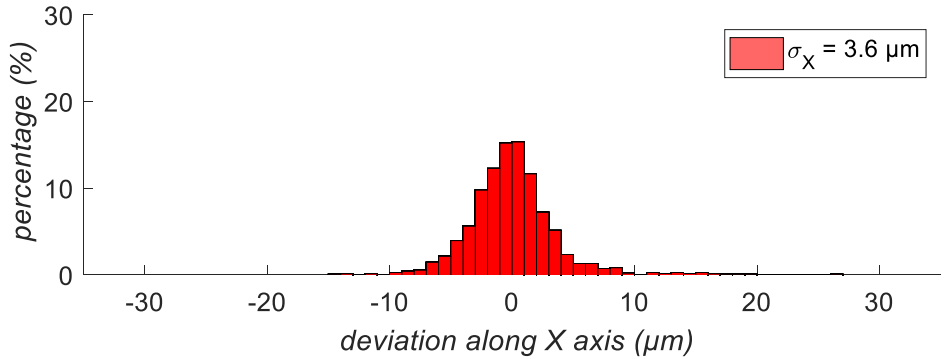
- 10 different operators (some are well experimented, others are beginners) ⇒ operator effect
- 3 different laser trackers, two AT930 and one AT960 ⇒ deviations between the different instruments included
- Two-face measurements 10 seconds for integration time
- 55 measurements spread over 1 month ⇒ drifts of the system (girder and instruments) included
- Sometime measurements are made with 3 trackers in parallel
- Trackers are not necessarily positioned at the same place
- 3 different prisms used ⇒ deviations between the different prisms, (centring, sphericity, diameter, repositioning…) included
- A measurement protocol has been written to describe step by step the sequence of the measurement process ⇒ possible user interpretations excluded
- …

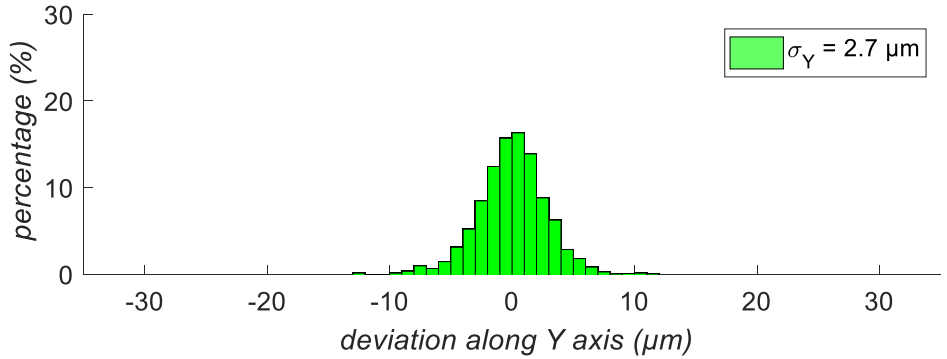
Results on the prototype girder

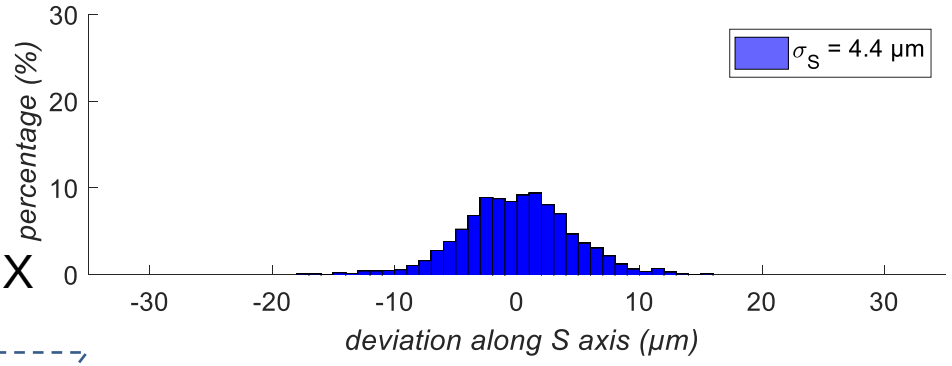


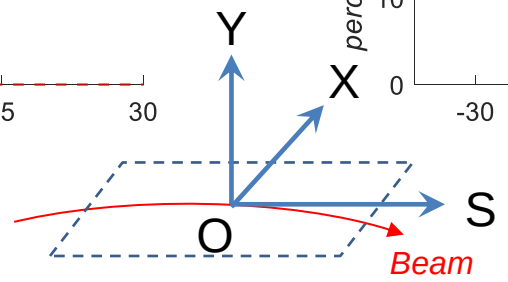




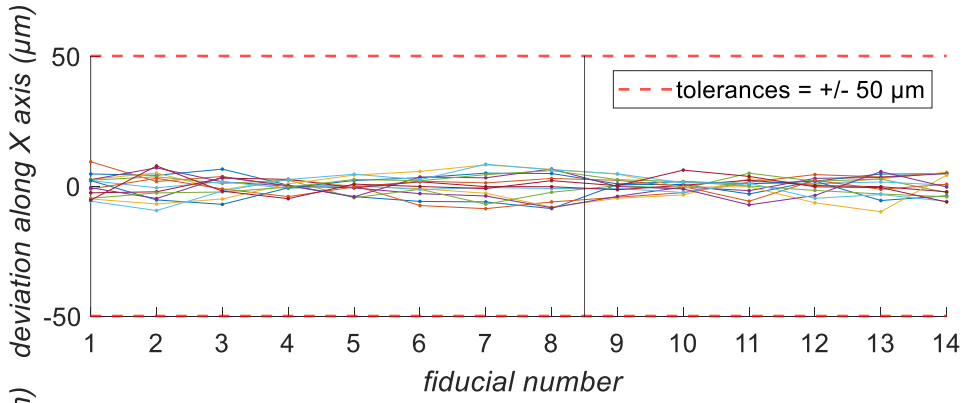


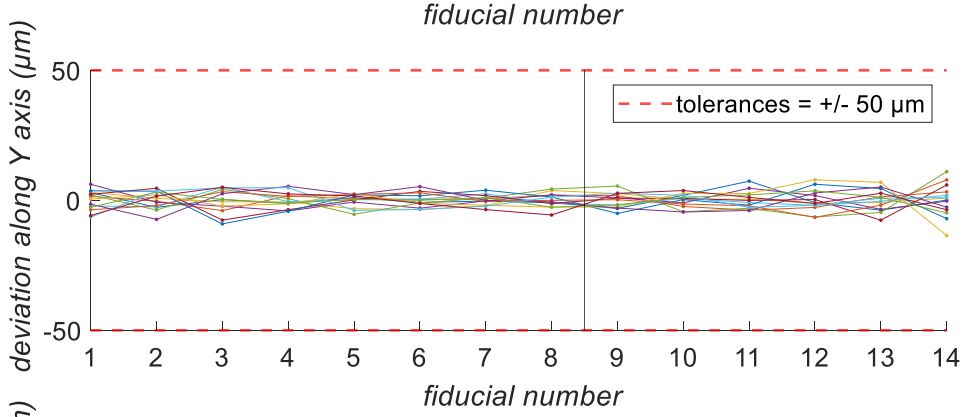


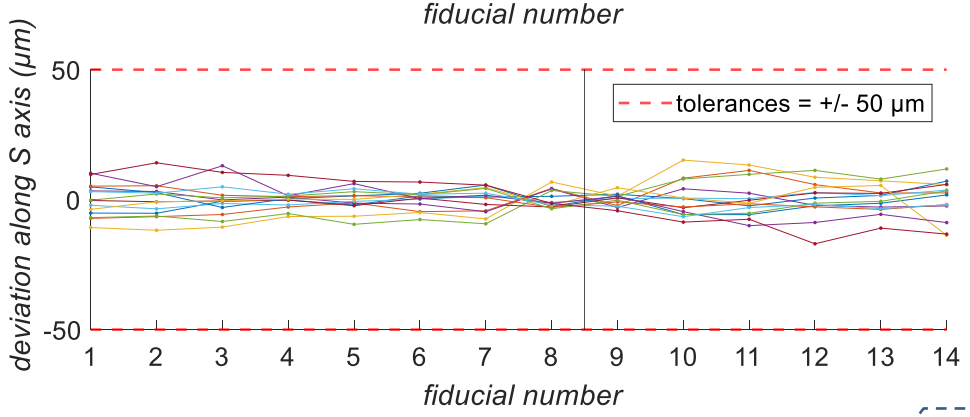


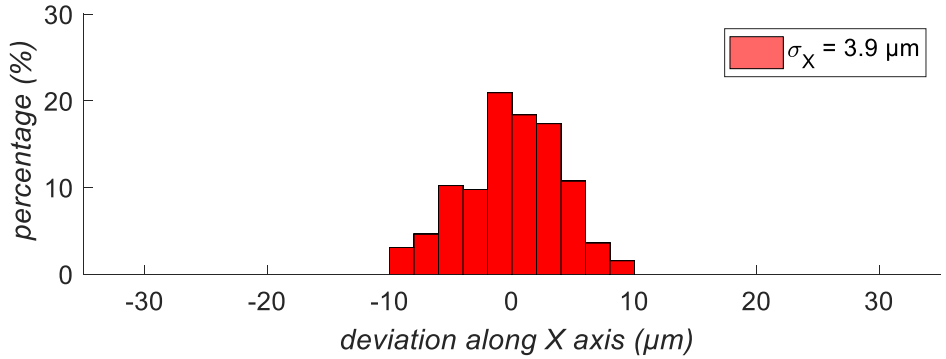


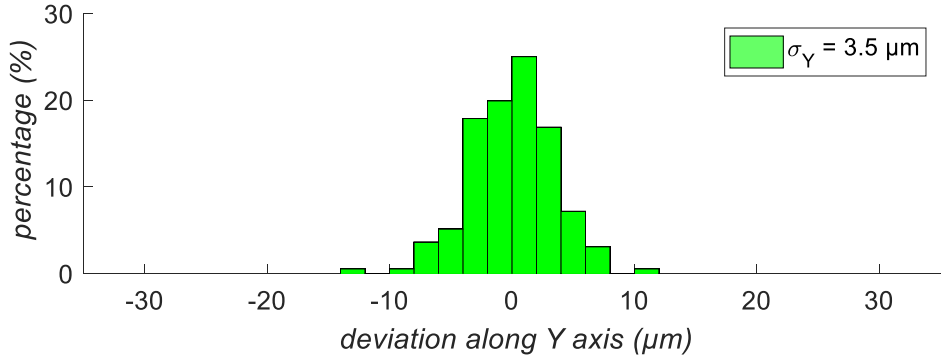
Results for two close girders

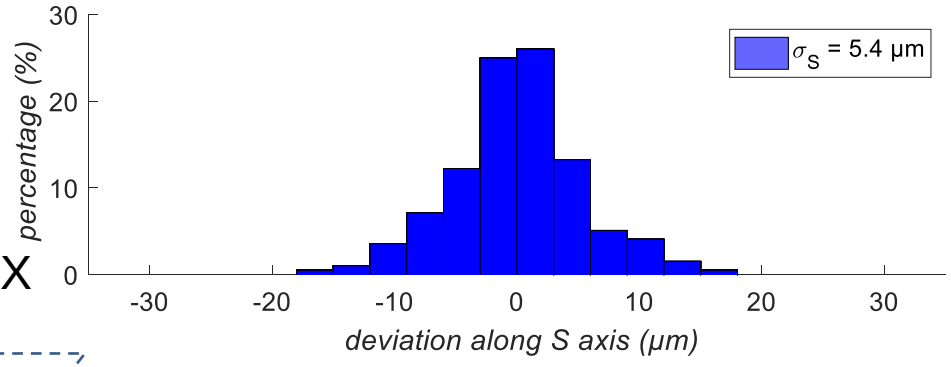


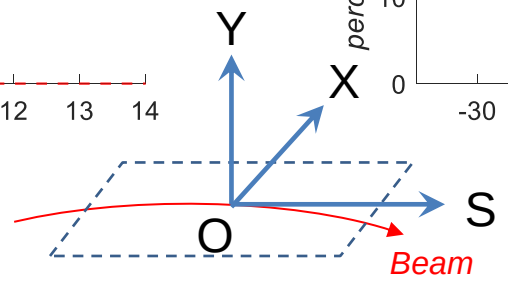




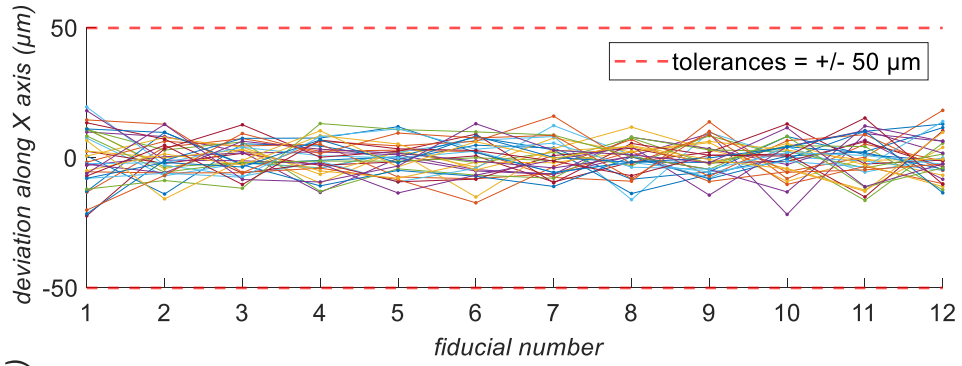


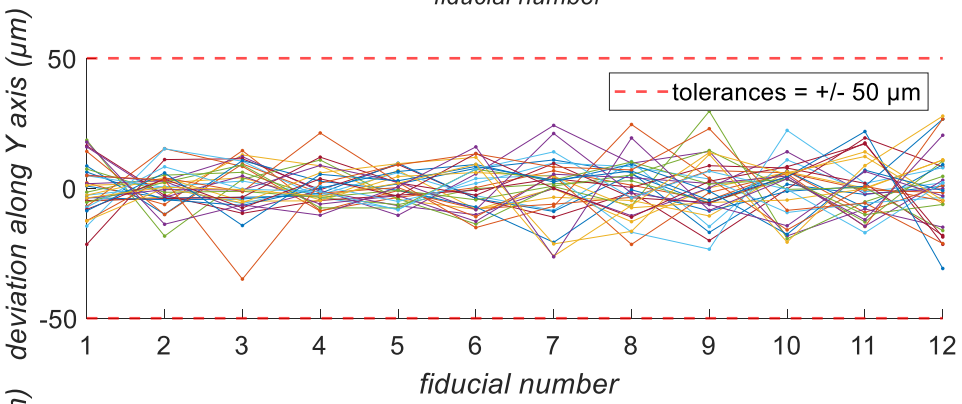


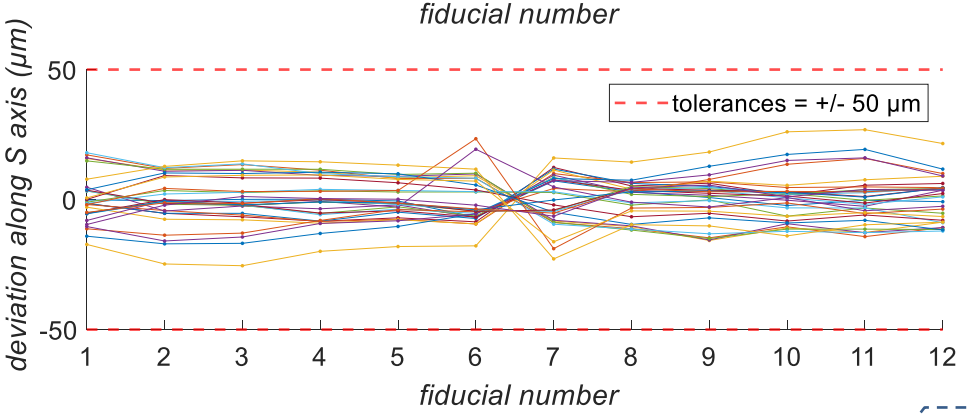


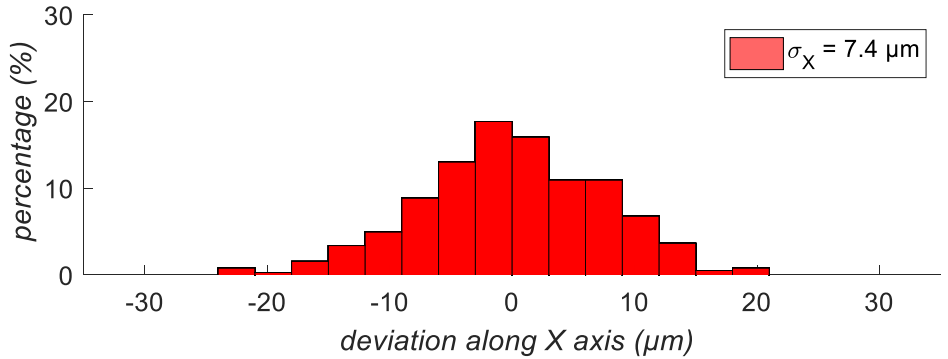


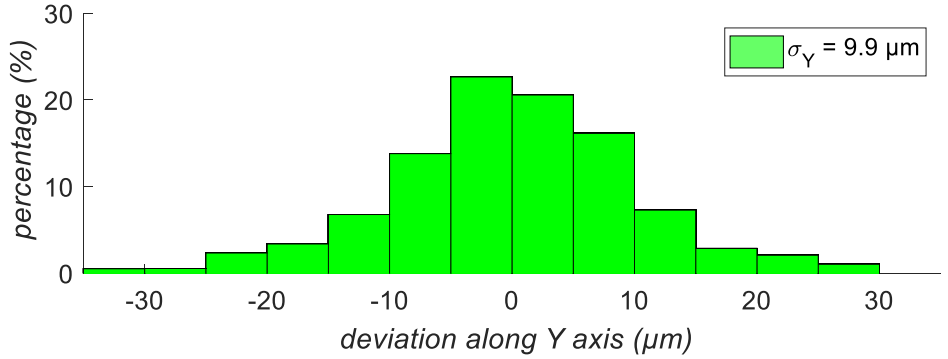
Results for two girders on both side of a straight section

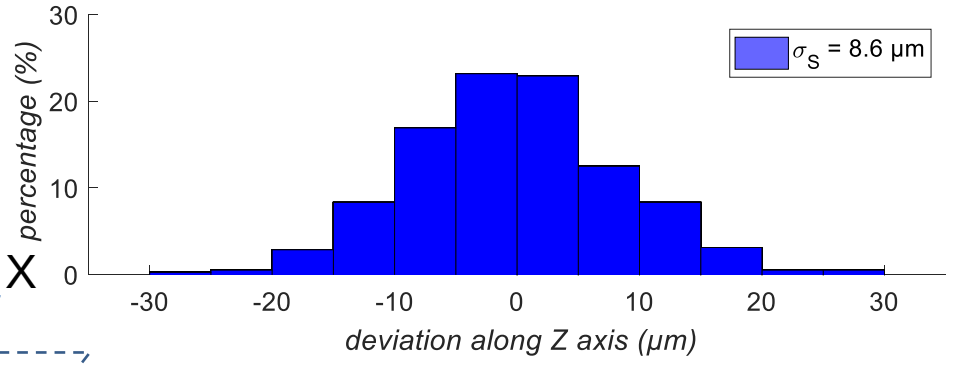


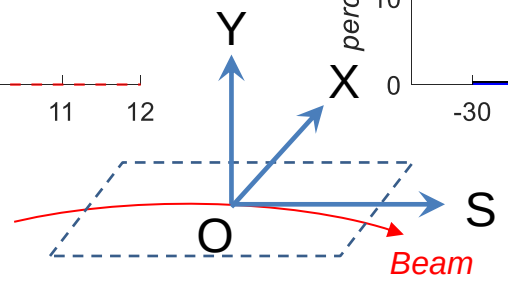








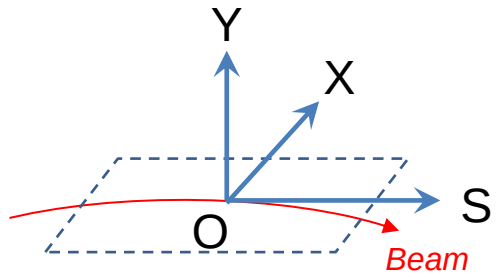




Results synthesis

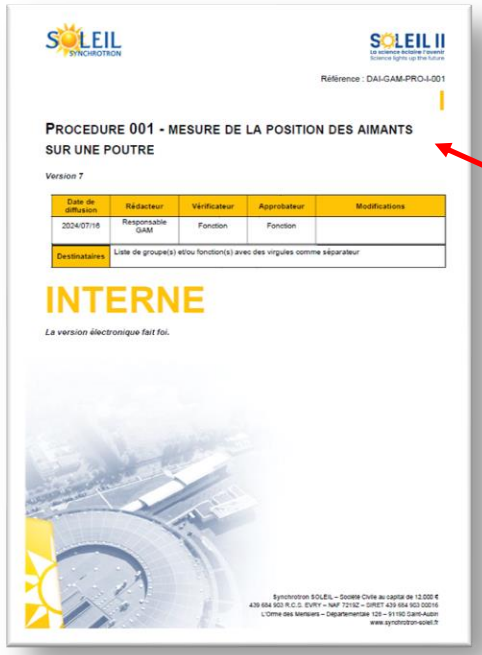
Synthesis of the measurement results obtained with laser tracker for the three specific case studies :

Point to check for alignment	Defined alignment tolerances	Reproducibility test
Magnet on a girder	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.6\ \mu m \quad \sigma_{Ty} = 2.7\ \mu m \quad \sigma_{TS} = 4.4\ \mu m$
Magnet on section matching girders	$-20\ \mu m < T_X, T_Y < 20\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.6\ \mu m \quad \sigma_{Ty} = 2.7\ \mu m \quad \sigma_{TS} = 4.4\ \mu m$
Girder to girder (close)	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.9\ \mu m \quad \sigma_{Ty} = 3.5\ \mu m \quad \sigma_{TS} = 5.4\ \mu m$
Girder to girder on both side of a straight section	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 7.4\ \mu m \quad \sigma_{Ty} = 9.9\ \mu m \quad \sigma_{TS} = 8.6\ \mu m$



In each case, we are inferior or equal to 10 µm. It seems to be very good !! But …..

Precautions taken prior to measurements


SOLEIL SYNCHROTRON — SOLEIL II

Référence : DAI-GAM-PRO-I-001

PROCEDURE 001 - MESURE DE LA POSITION DES AIMANTS SUR UNE POUTRE

Version 7

Date de diffusion	Rédacteur	Vérificateur	Approbateur	Modifications
2024/07/16	Responsable GAM	Fonction	Fonction	
Destinataires	Liste de groupe(s) et/ou fonction(s) avec des virgules comme séparateur			

INTERNE

La version électronique fait foi.

1. We use a protocol to fix every details of the measurements and a script in Spatial Analyser.


HEXAGON

Calibration Certificate Metrology

Calibration Certificate Metrology with measurement values issued by Manufacturer

Product : Leica Absolute Tracker AT930
Article No.: 576661
Serial No. : 752566
Certificate No. : 752566-20240410
Inspection Date: April 10, 2024
P.O. Number :

Customer : SYNCHROTRON SOLEIL
L'Orme des Merisiers
91190 ST AUBIN
FR

Certification Location:
Leica France, Service center
8 Rue Marc Seguin
41100 VENDOME
France

Status : After Inspection

Compliance
The Calibration Certificate Metrology with measurement values issued by Manufacturer corresponds to the Customer Certificate Metrology in accordance with DIN 55 350 Part 18-4.2.2.

Certificate :
We hereby certify that the product described has been tested with the following result:
☒ Compliance The test results are within the specification of the product.
☐ Non-Compliance The test results are not within the specification of the product.

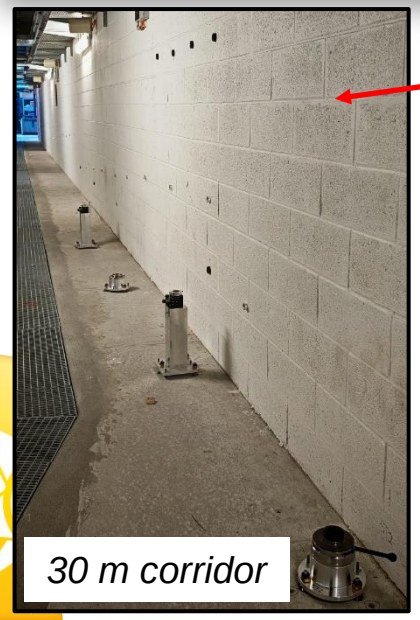
The test equipment used is traceable to national standards or to recognized procedures.
This is established by our Quality Management System, audited and certified to ISO 9001 by an independent national accreditation authority.

HEXAGON MI France

April 10, 2024

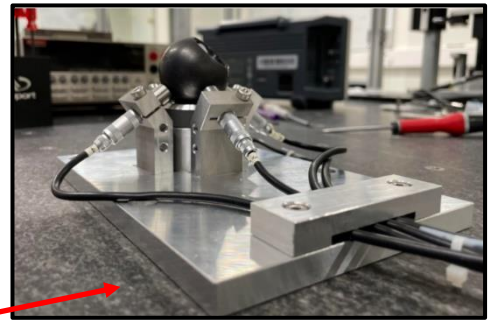
G.Ganglof
Service Engineer

2. Each tracker is recertified once a year by Hexagon.


30 m corridor

3. We compensate for geometrical errors and ADM offset before every important operation, using a specific bench recommended by Hexagon / LEICA.

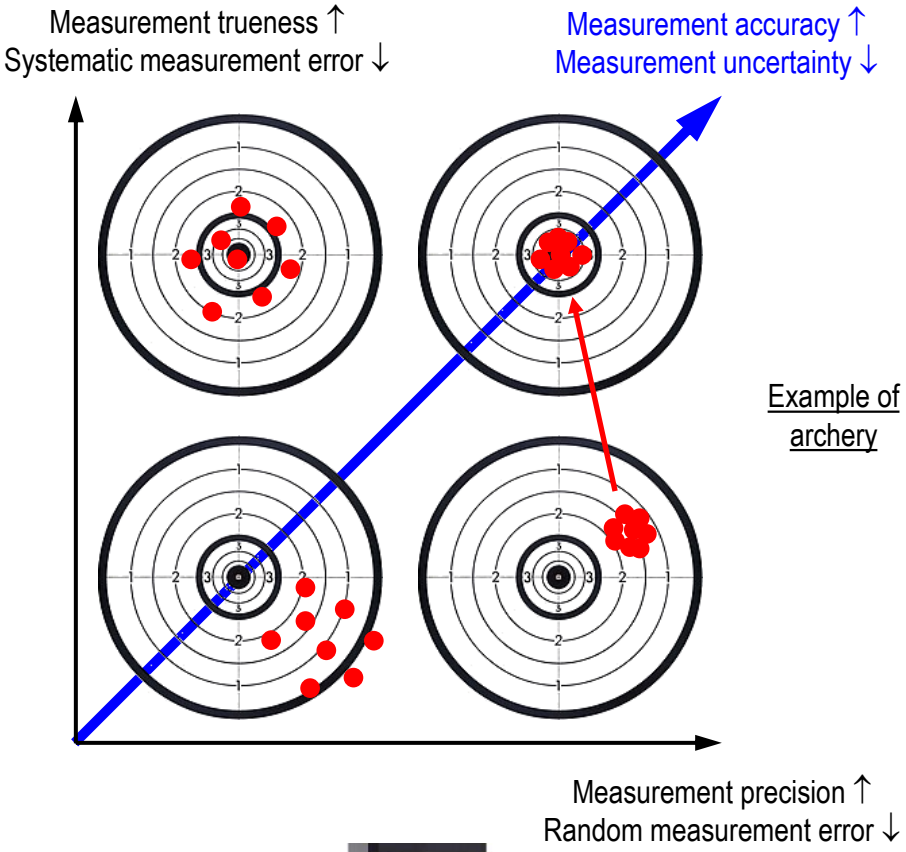
4. We qualify every SMR we use to quantify their defaults (sphericity, diameter, optic center and mechanical center coincidence) on specific benches (CMM, comparison with reference prism, …) and select the best ones.


Setup to test SMR positioning repeatability

What is needed to improve our measurement ?

Reproducibility measurements have limitations because we don't check for measurement trueness, and trueness is one of the key component to improve measurement accuracy and reduce measurement uncertainty.

If our 3 laser trackers have a common bias (calibration bias for example), we can't detect it during reproducibility measurement !!



The only solution to detect this trueness error is to compare laser tracker with another technique : this is one of the reason why we plane to measure the prototype girder with a 3D Coordinate Measuring Machine (3D CMM).

High accuracy and large volume CMM (Altera M 40.20.15 from LK metrology) available at G2Metric Magny-les-Hameaux (12 km from SOLEIL)

- Measurement volume : 4 m x 2 m x 1,5 m
- Equipped with REVO 5-axis measurement system (Renishaw)
- Maximum permissible error (MPE): 3,8 µm + L/350 (L in mm)
- Expected uncertainty for a 3.2 m long girder : 13 µm

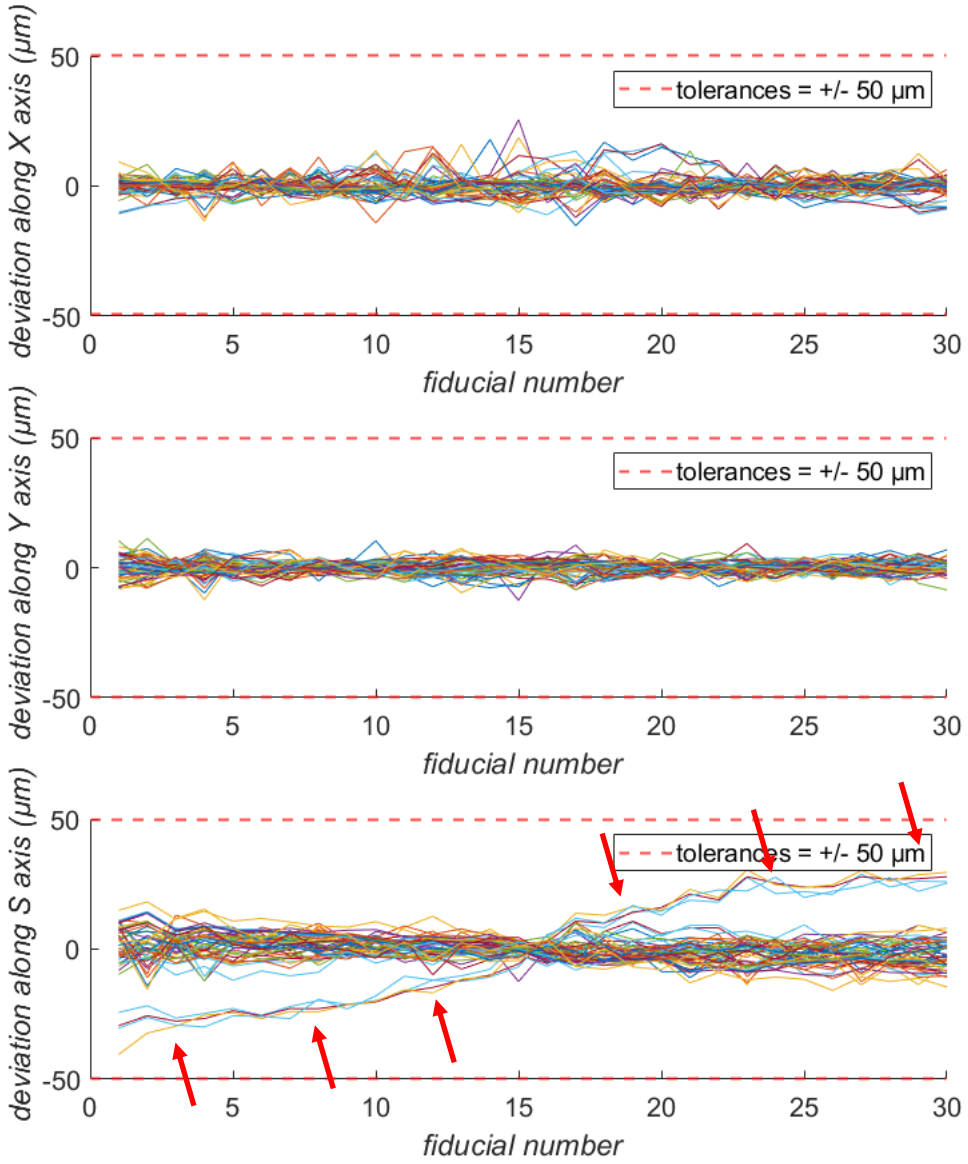
What is needed to improve our measurement ?

We also need some metrological references and standards to check our laser trackers and calibrate them.

Length standard bar with known length (determined by interferometry) to check laser tracker accuracy (Traceable to International System of Units SI)

The prototype girder could be used as a reference form (not traceable so SI but with a sufficient measurement history) sufficiently stable in time to check our laser trackers or subcontractor instruments.

Drift of tracker detected using a reference



Reproducibility test on the prototype girder with a poorly compensated laser tracker (44 µm ADM offset).

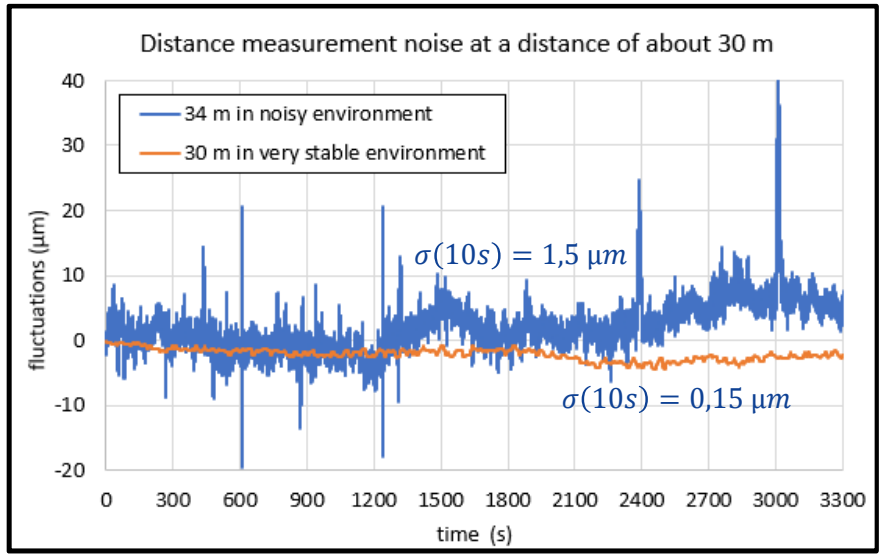
This is very sensitive…

The prototype girder can be used as a reference object to check the tracker measurement reliability.

What is needed to improve our measurement ?

But we also need some real time indicators to let us know that something is going wrong with the laser tracker during an operation (Survey, metrology of a component, …)

- Indicator based on the standard deviation of the signal acquired continuously during the measurement of 1 point (already operational on our system via script)
  - ⇒ Provide information on the stability of the measurement (presence of vibration, air turbulence, …)



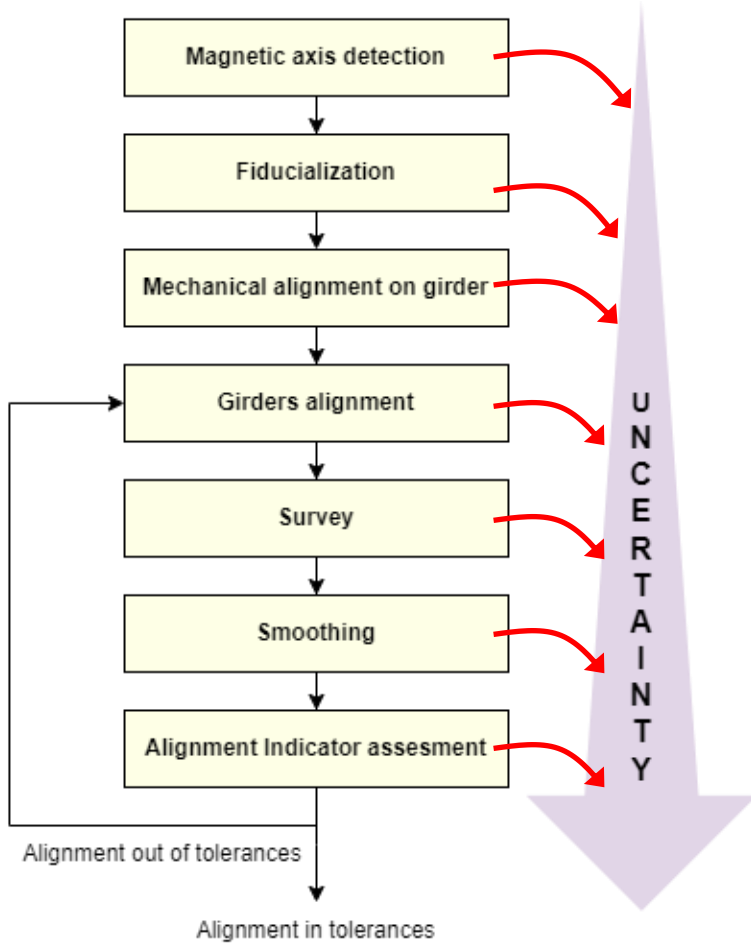
- Indicator based on the deviation between the measurements realized during a two-face measurement (script under development)
  - ⇒ Provide information about the geometrical error amplitude and on the quality of the geometry compensation

- indicator (under development) related to the drift of the ADM offset (under development)

Back to the results

If we only consider the measurement made with laser trackers, and if we can validate the measurement trueness, then yes, the measurements are very good.

Point to check for alignment	Defined alignment tolerances	Reproducibility test
Magnet on a girder	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.6\ \mu m \quad \sigma_{Ty} = 2.7\ \mu m \quad \sigma_{TS} = 4.4\ \mu m$
Magnet on section matching girders	$-20\ \mu m < T_X, T_Y < 20\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.6\ \mu m \quad \sigma_{Ty} = 2.7\ \mu m \quad \sigma_{TS} = 4.4\ \mu m$
Girder to girder (close)	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 3.9\ \mu m \quad \sigma_{Ty} = 3.5\ \mu m \quad \sigma_{TS} = 5.4\ \mu m$
Girder to girder on both side of a straight section	$-50\ \mu m < T_X, T_Y < 50\ \mu m$ $-100\ \mu m < T_S < 100\ \mu m$	$\sigma_{Tx} = 7.4\ \mu m \quad \sigma_{Ty} = 9.9\ \mu m \quad \sigma_{TS} = 8.6\ \mu m$



But we must keep in mind that the measurements represent only one contribution to the final uncertainty for the magnet positioning in the machine and of course many other sources of uncertainty must be considered.

Uncertainty components for a magnet alignment

#	source of uncertainty	uncertainty	unit	distribution law	sensitivity coefficient	sensitivity dependant	sensitivity units	uncertainty (µm)	Along X axis: value of standard uncertainty	Along X axis: squared uncertainty (µm²)	Along X axis: contribution to the combined	Along X axis: Rank	Along Y axis: value of standard uncertainty	Along Y axis: squared uncertainty (µm²)	Along Y axis: contribution to the combined	Along Y axis: Rank
3	Y stage minimum step	0,3	µm	normal	0	1	µm	0,3					0,3	0,1	0,0	
4	Stage backlash	0,1	µm	normal	0	1	µm	0,1	0,1	0,0	0,0		0,1	0,0	0,0	
5	X stage accuracy	0,6	µm	normal	0	1	µm	0,6	0,6	0,4	0,1					
6	Y stage accuracy	0,6	µm	normal	0	1	µm	0,6					0,6	0,4	0,1	
7	X stage bidirectionnal positionning repeatability	0,4	µm	normal	0	1	µm	0,4	0,4	0,2	0,0					
8	Y stage bidirectionnal positionning repeatability	0,15	µm	normal	0	1	µm	0,15					0,15	0,0	0,0	
9	Wire sag (evaluated and compensated)	5	µm	normal	0	1	µm	5					5	25,0	3,5	
10	Influence of the wire tension reproducibility along Y axis	2	µm	normal	0	1	µm	2					2	4,0	0,6	
11	Wire setup reproducibility (can be improved)	10	µm	normal	0	1	µm	10	10	100,0	24,6	1	10	100,0	14,0	1
12	X thermal drift (thermal stability of the lab 1°C, drift = 0)	1	°C	normal	0	0	µm/°C	0	0	0,0	0,0					
13	Y thermal drift (thermal stability of the lab 1°C, drift = 7 µm/°C) (voir si amélior	1	°C	normal	0	7	µm/°C	7					7	49,0	6,9	6
14	Limit of sensitivity for the wire technique (to be evaluated)	??														
15	Uncertainty on the shim thickness along X/Y/Z (could be reduced)	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
16	Repeatability of the magnet re-positionning on the pin (to be reevaluated)	1	µm	normal	0	1	µm	1	1	1,0	0,2		1	1,0	0,1	
17	XY threshold for pre-alignment	2,5	µm	normal	0	1	µm	2,5	2,5	6,3	1,5		2,5	6,3	0,9	
18	Wear of the plane locating the wire along Y	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
19	Wire diameter uncertainty (10% of 100 µm) (could be reduced if measured)	10	µm	normal	0	0,71	µm	7,07	7,1	50,0	12,3	2	7,1	50,0	7,0	5
20	Uncertainty on the shim thickness (angular effet on X)	2	µm	normal	0	1	µm	2	2	4,0	1,0					
21	Uncertainty on the shim thickness (angular effet on Y)	2	µm	normal	0	0,5	µm	1					1	1,0	0,1	
22	Repeatability of magnetic center position determination	2	µm	normal	0	1	µm	2	2	4,0	1,0		2	4,0	0,6	
	Magnet fiducialisation :															
23	Sauterelle repeatability (to be estimated)	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
24	Sauterelle calibration (to be estimated)	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
25	Fiducialisation uncertainty (to be estimated)	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
26	Sauterelle thermal expansion along Y (30 cm)	1	°C	normal	0	7,2	µm	7,2					7,2	51,8	7,3	4
	Magnet assembly on the girder															
27	Pin hole position uncertainty / Pin diameter uncertainty (interval)	15,0	µm	uniform	0	0,3	µm	4,3	4,3	18,8	4,6					
28	Girder residual vertical bending	10	µm	normal	0	1	µm	10					10	100,0	14,0	1
29	Girder out of flatness (0,5 m width, 10 µm/m) + roughness (Ra = 1,6 µm) along X	5	µm	normal	0	1	µm	5	5	25,0	6,1	3				
30	Girder out of flatness (3,2 m long, 10 µm/m) + roughness (Ra = 1,6 µm) along S	32,0	µm	uniform	0	0,3	µm	9,2					9,2	85,3	11,9	3
31	Upp															
32	Upp															
33	Gird															
34	Displ															
35	Girder bending due to thermal expansion en plinth contrain	???														
36	Vertical girder bending due to vertical thermal gradien in the girder	???														
37	Horizontal girder bending due to horizontal thermal gradien in girder	???														
	Girder Metrology with Laser Tracker :															
38	Reproducibility of the magnet position measurement with laser tracker	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
39	SMR default (centering, sphericity, ...)	2,5	µm	normal	0	1	µm	2,5	2,5	6,3	1,5		2,5	6,3	0,9	
40	SMR repositionning in the fiducial	2,5	µm	normal	0	1	µm	2,5	2,5	6,3	1,5		2,5	6,3	0,9	
41	Fiducial wear	???														
	Girder handling, transportation and alignment:															
42	Girder storing and transportation effect (to be evaluated)	5	µm	normal	0	1	µm	5	5	25,0	6,1	3	5	25,0	3,5	
43	Girder deformation	???														
44	Magnet displacement along X axis	???														
45	Magnet displacement along Y axis	???														
46	Magnet displacement along S axis	???														
47	Alignment uncertainty along X axis	???														
48	Alignment uncertainty along Y axis	???														
49	Alignment uncertainty along S axis	???														
	Geodetic network:															
50	wall (then monument) stability over time															
51	season effect on the wall and the machine															

38 Reproducibility of the magnet position measurement with laser tracker | 5 | µm | normal | 0 | 1 | µm

We have identified about 60 uncertainty components, 38 are quantified, the others must be evaluated.

Uncertainty components for a magnet alignment

#	source of uncertainty	Along X axis: value of standard uncertainty (µm)	Rank	Along Y axis: value of standard uncertainty (µm)	Rank
	Magnet Metrology :				
9	Wire sag (evaluated and compensated)			5	
11	Wire setup reproducibility (can be improved)	10	1	10	1
13	Y thermal drift (thermal stability of the lab 1 °C, drift = 7 µm/°C) (voir si améliorable)			7	
15	Uncertainty on the shim thickness along X/Y/Z (could be reduced)	5		5	
18	Wear of the plane locating the wire along Y	5		5	
19	Wire diameter uncertainty (10% of 100 µm) (could be reduced if measured)	7,1	2	7,1	
	Magnet fiducialisation :				
23	Sauterelle repeatability (to be estimated)	5		5	
24	Sauterelle calibration (to be estimated)	5		5	
25	Fiducialisation uncertainty (to be estimated)	5		5	
26	Sauterelle thermal expansion along Y (30 cm)			7,2	
	Magnet assembly on the girder				
28	Girder residual vertical bending			10	1
29	Girder out of flatness (0,5 m width, 10 µm/m) + roughness (Ra = 1,6 µm) along X	5			
30	Girder out of flatness (3,2 m long, 10 µm/m) + roughness (Ra = 1,6 µm) along S (interval)			9,2	3
32	Upper yoke removal and reinstallation -vertical position impact (à vérifier)			7	
	Girder Metrology with Laser Tracker :				
38	Reproducibility of the magnet position measurement with laser tracker	5		5	
	combined uncertainty : u (µm)	**18,0**		**25,7**	
	expanded uncertainty (k=2) : U (µm)	**36,0**		**51,4**	
	interval for a confidence level of 95,4 % (µm)	**+/- 36**		**+/- 51,4**	
	alignment tolerance (µm)	**+/- 50**		**+/-50**	

After simplification

Measurement doesn't seem to be a problem.

Magnet metrology, fiducialisation step and magnet assembly on a girder are problematic.

Improvement and last development

Current stretched wire metrology bench

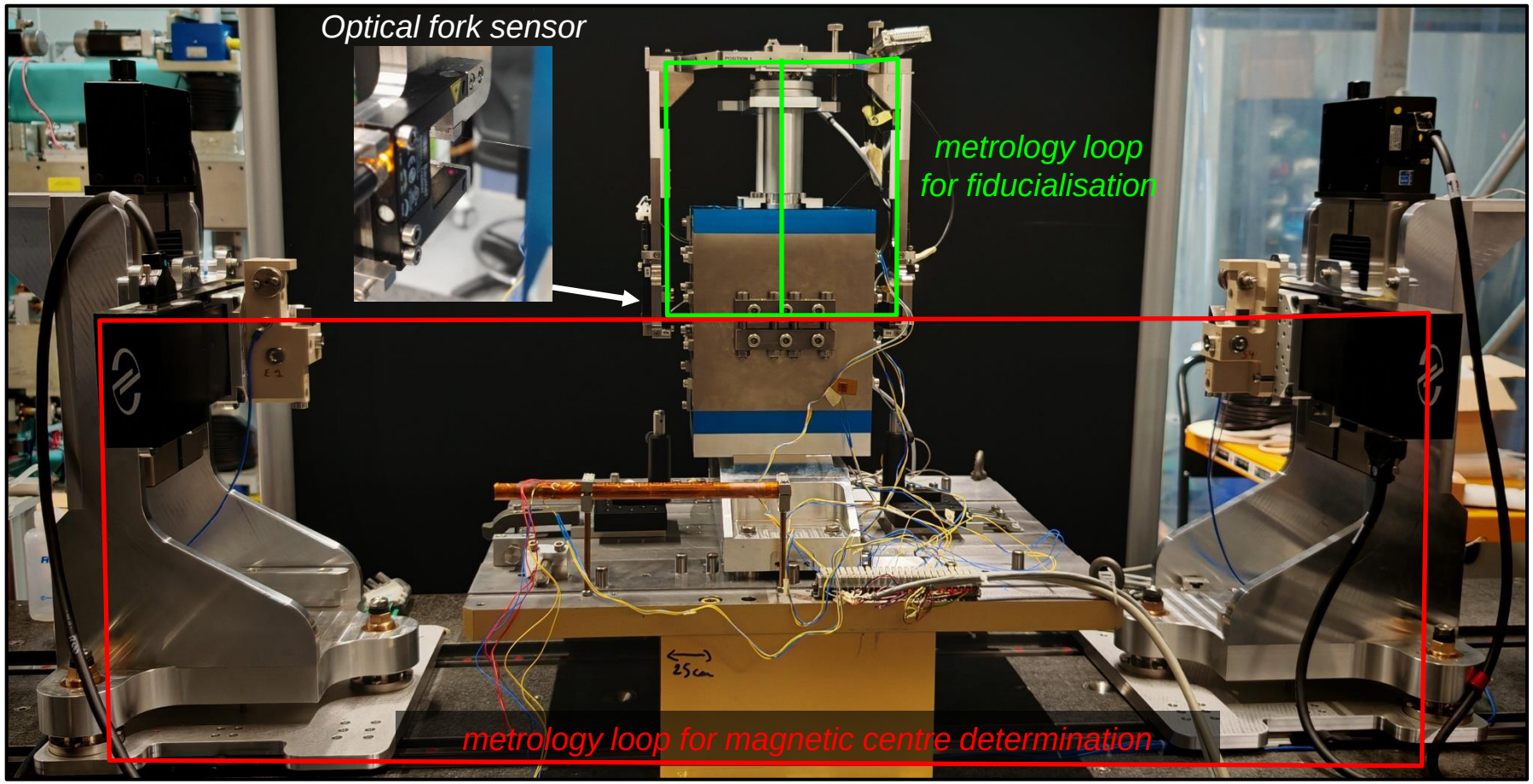
For fiducialisation we use a mechanical reference that creates a link between the wire and the fiducials.

But this link is not absolute only differential, it means that the magnetic center is not known and can't be deduced from the fiducial positions.

To make this link absolute, the dimensions of the mechanical reference used must be accurately determined from the zero position of the sensor that detects the wire to the cones where it is installed.

The bench must be improved.

Hard to achieve !!



With courtesy of Magnetism and Insertion Device group

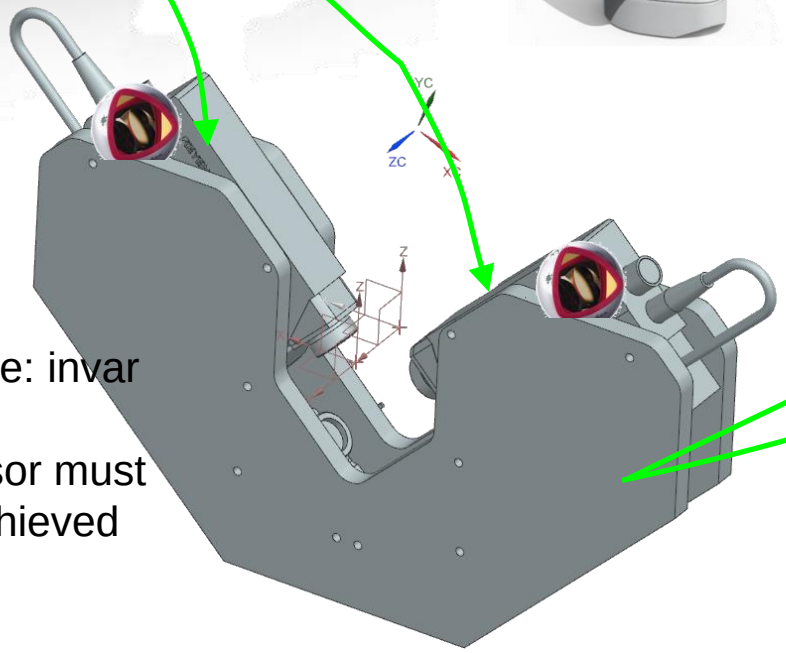
New axis of development for magnet alignment

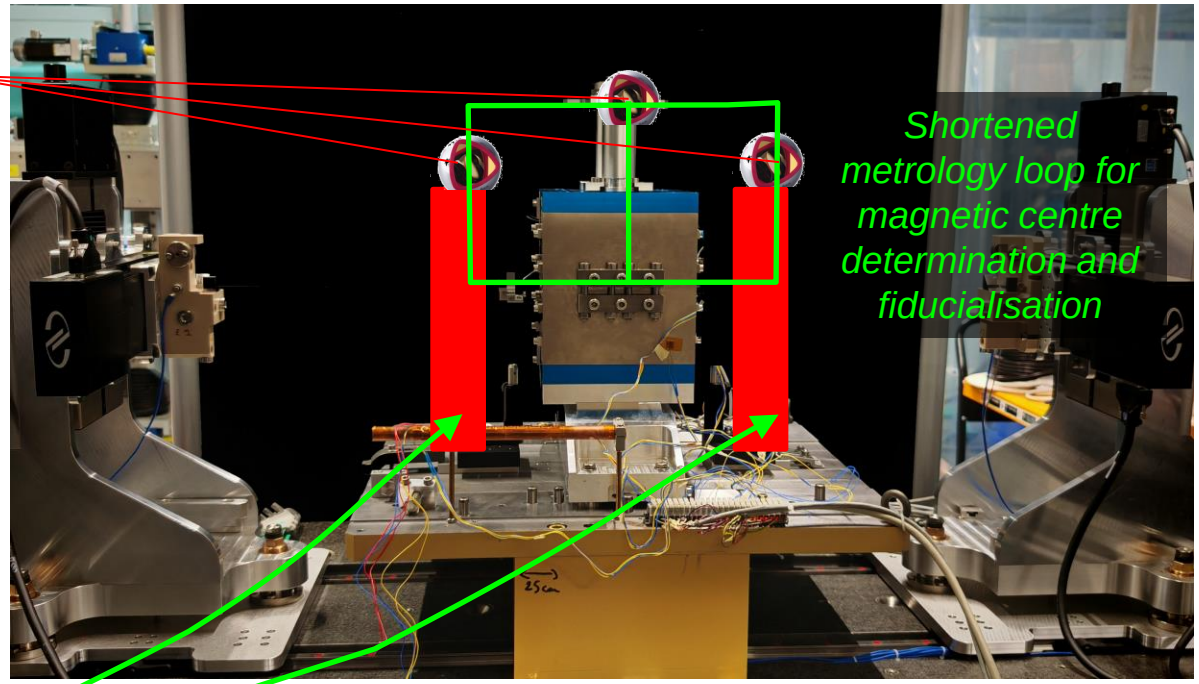
In regards of the results obtained, why don't we use laser tracker to participate to fiducialisation and alignment steps.

Objective: make the system more reproducible, more stable and absolute.

KEYENCE
LS-9006
Optical
micrometre

Sensor linearity already tested at better than 1 µm using interferometry





We need:

- a stable metrology frame: invar or zerodur
- zero position of the sensor must be linked to fiducials: achieved using CMM

SOLEIL II
La science éclaire l'avenir
Science lights up the future

Conclusion and perspectives

- SOLEIL II lattice is still not definitive even if we are very close from the end.
- Simulation of machine performance are still running and discussion with physicist are still ongoing to try to relax tolerances and to better match aligner reality.
- Despite all, presented measurements are encouraging
- Alignement uncertainty need to be better controlled to be more comfortable with specified tolerances
- Tolerances seem to be achievable, but we must:
    - change our alignment strategy
    - continue to improve our measurement capabilities (magnet metrology, fiducialisation and alignment on a girder)
    - perfectly control laser tracker (compensation, calibration, …)

References

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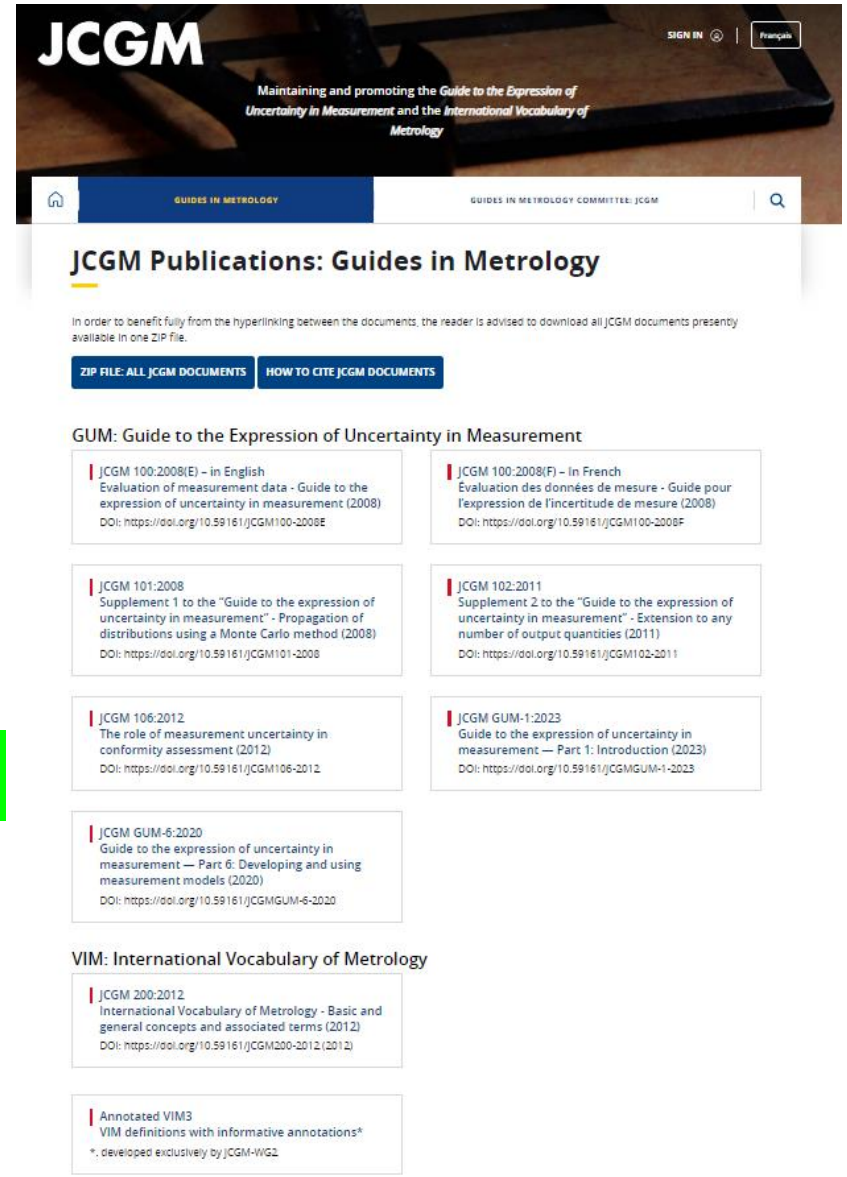

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- Emma LAZAROWICZ (apprentice)
- Yann DENIS (operator 20%)
- Alain LESTRADE (scientific advisor 20%)

Thank you for your attention