Alignment strategies and first results on Sirius Beamlines

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Summary

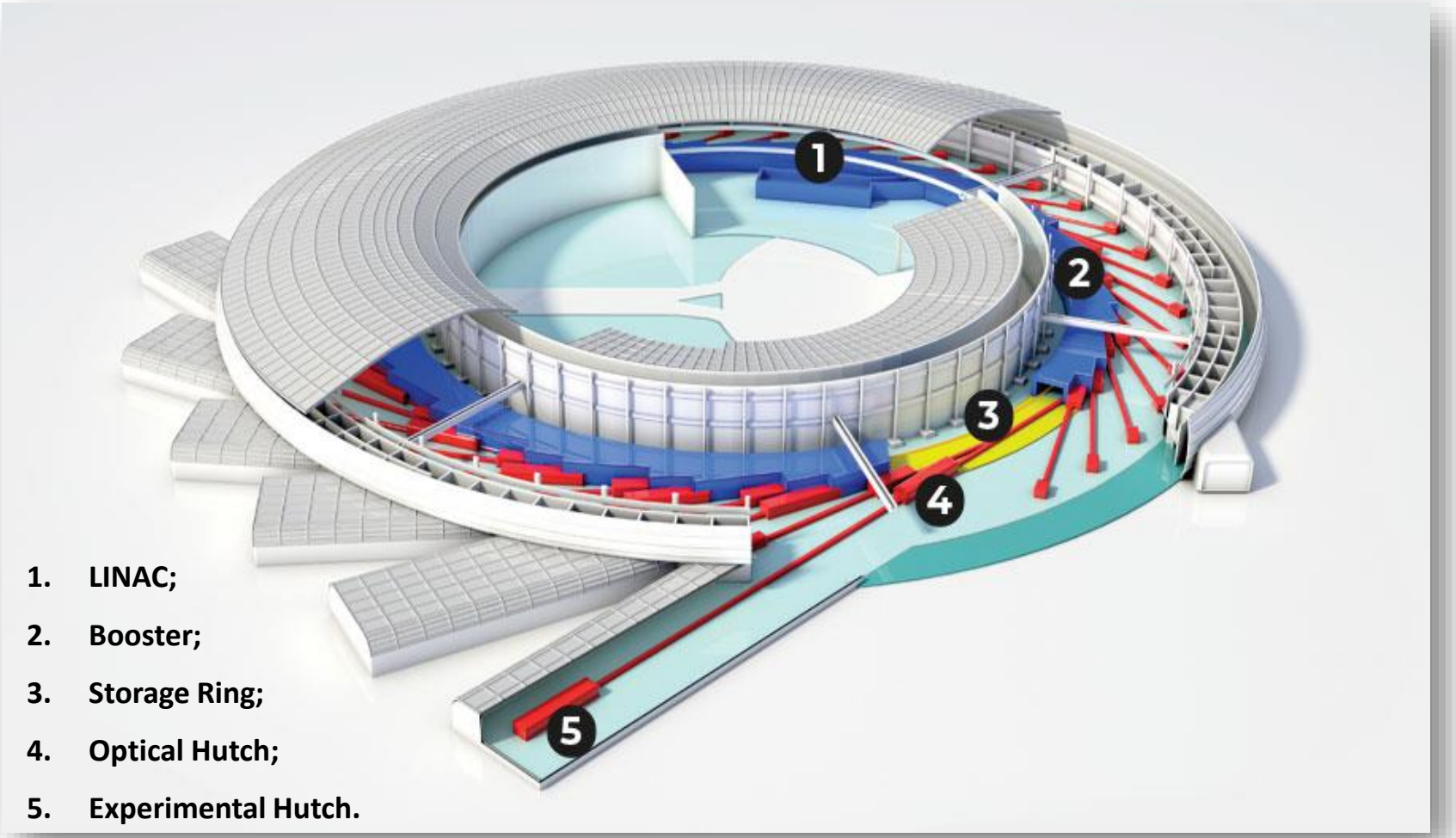
- Brazilian Synchrotron Light Source – Sirius;
- Alignment network;
- Connection between alignment networks;
- Beamline installation;
- Case studies:
  - Mirrors indirect fiducialization;
  - Detectors tunnel for the CDI beamline;
- Alignment results.

Sirius

- The newest Brazilian synchrotron light source;
- Fourth-generation light source;
- Planned to be the brighter particle accelerator of the world;
- First beamlines at commissioning and friendly users phase:
  - Manacá;
  - Cateretê;
  - Carnaúba;
  - Ema.

Synchrotron radiation accelerator

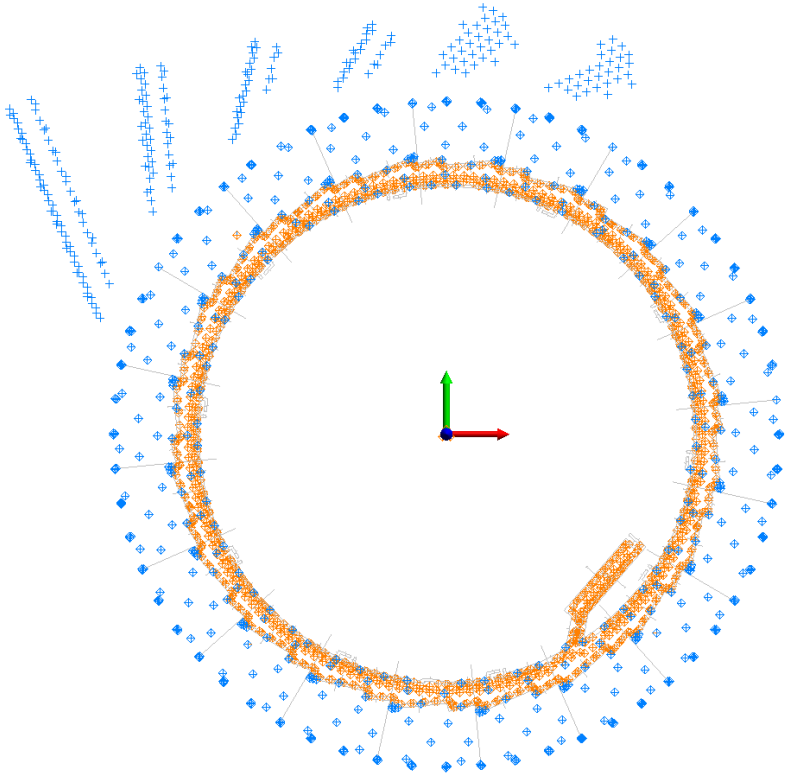
- 518 m circumference and 85 m radius;
- 3 GeV on the storage ring;
- Designed to house 38 beamlines.

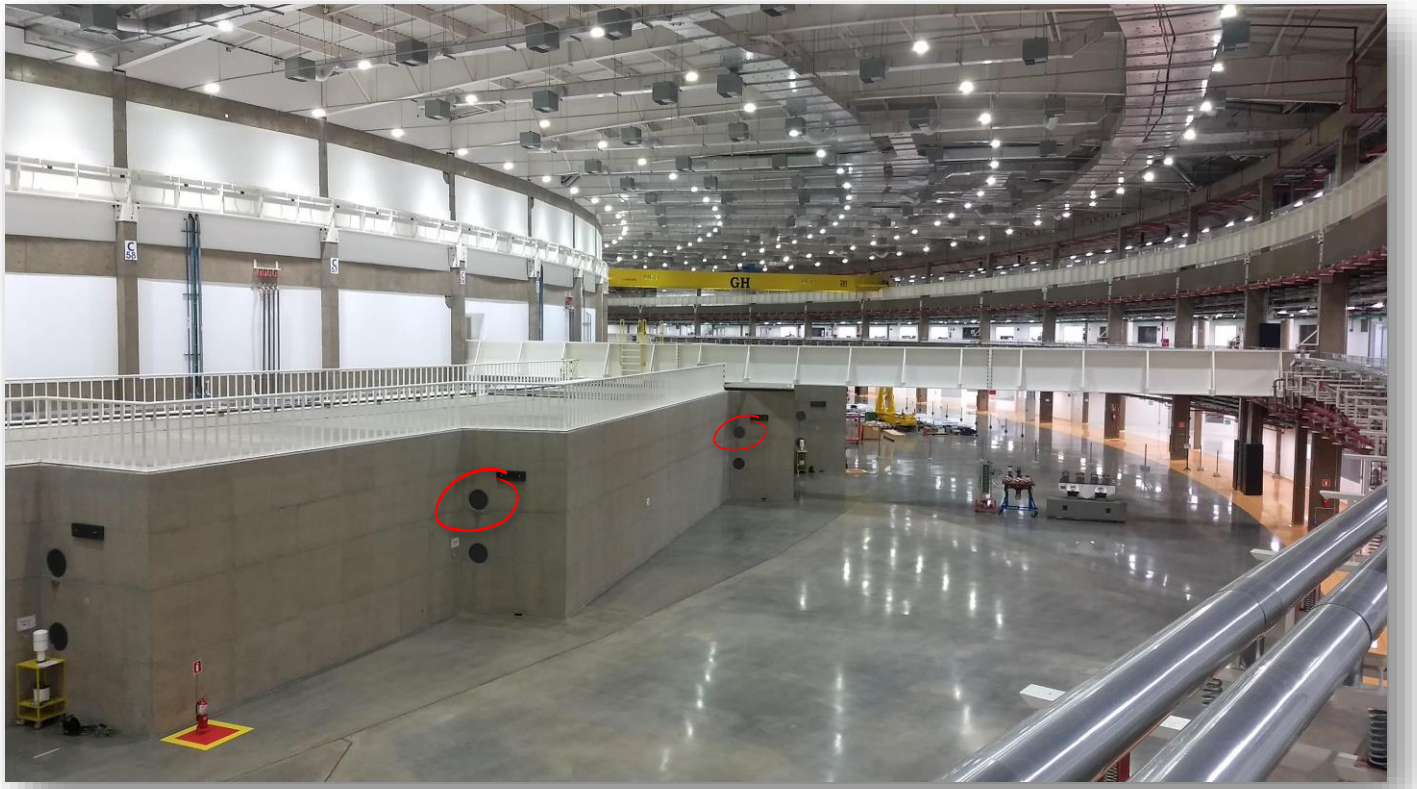


1. **LINAC;**
2. **Booster;**
3. **Storage Ring;**
4. **Optical Hutch;**
5. **Experimental Hutch.**

Source: https://omundodausinagem.com.br/sirius-nasce-uma-nova-estrela/

Alignment network

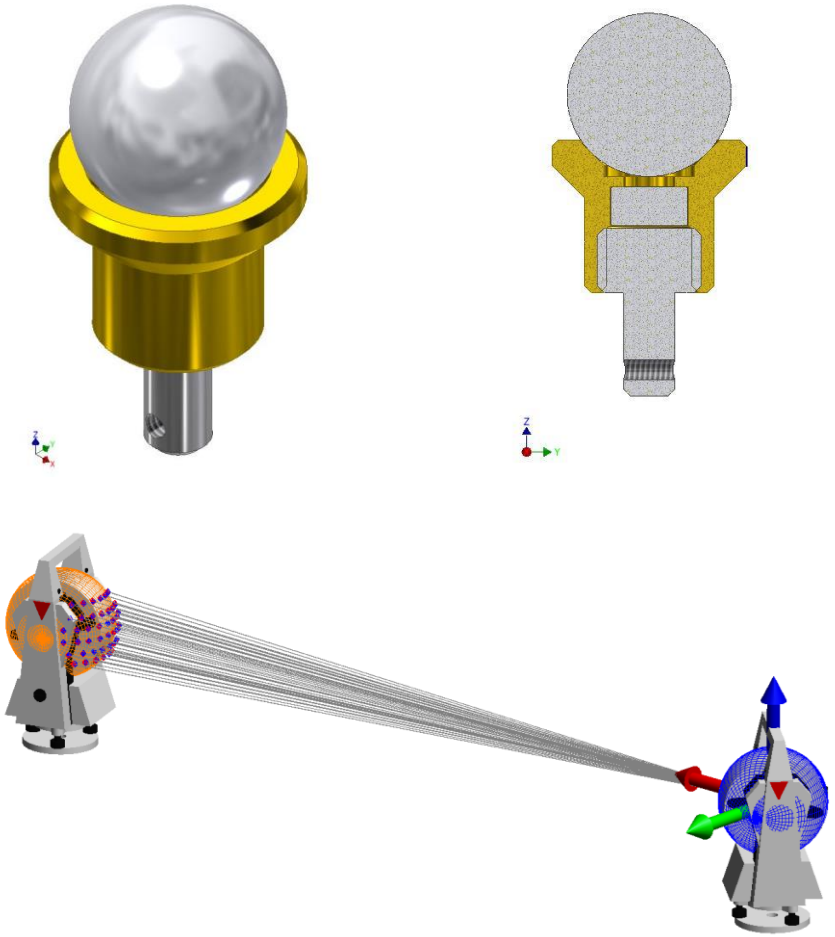




- The Sirius alignment reference is composed by 2 networks (primary SR and secondary EH) and smaller ones at beamlines and hutches (tertiary);
- Their connections were made by narrow line of sights at the radiation shielding.

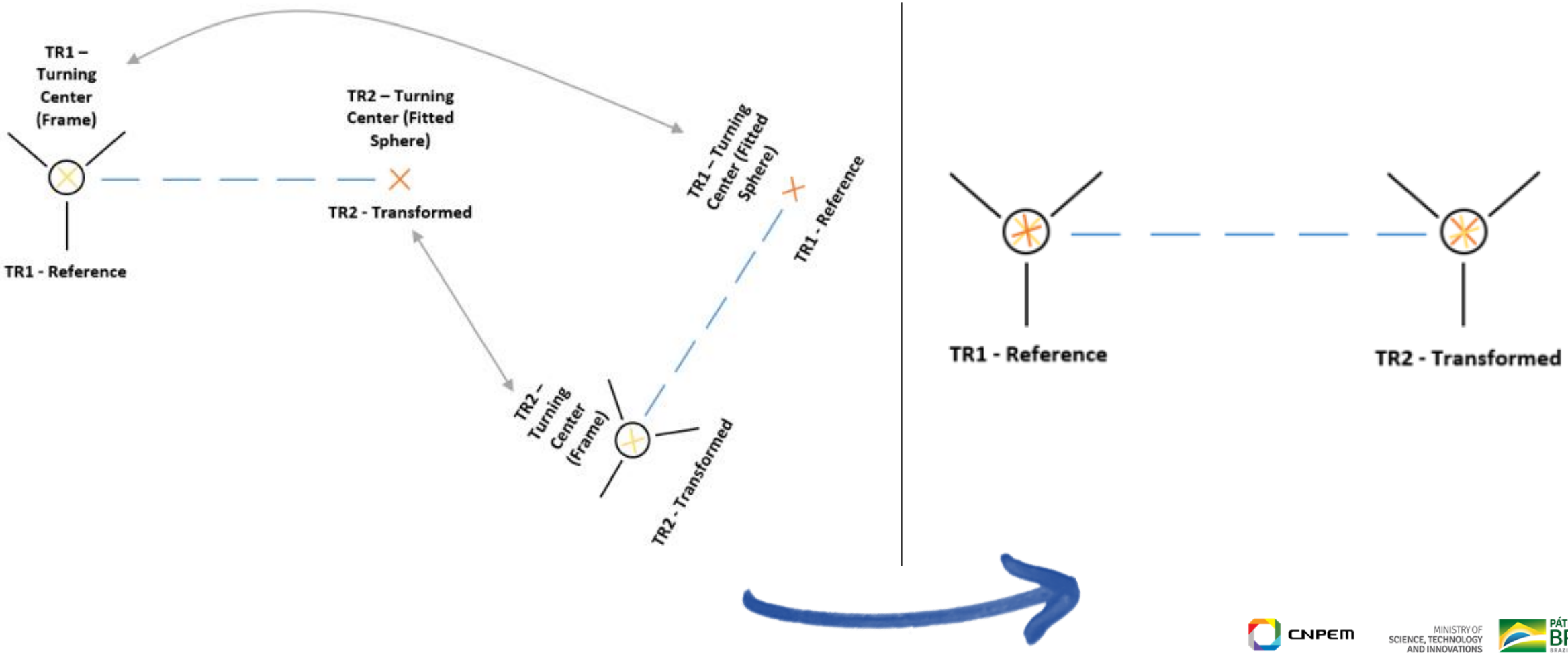
Network connection technique

- A target holder was developed to be fixed on the head of the laser trackers;
- Designed to be in use with a 0.5” SMR;
- This technique seeks to locate a tracker using another located as reference;
- The strategy consists on construct the turning center of each tracker by 2 ways;
- Firstly, by measuring a sphere and fitting its center. Secondly, by constructing a point at the origin of the instrument frame;
- Both trackers must be levelled on gravity and follow the steps described.



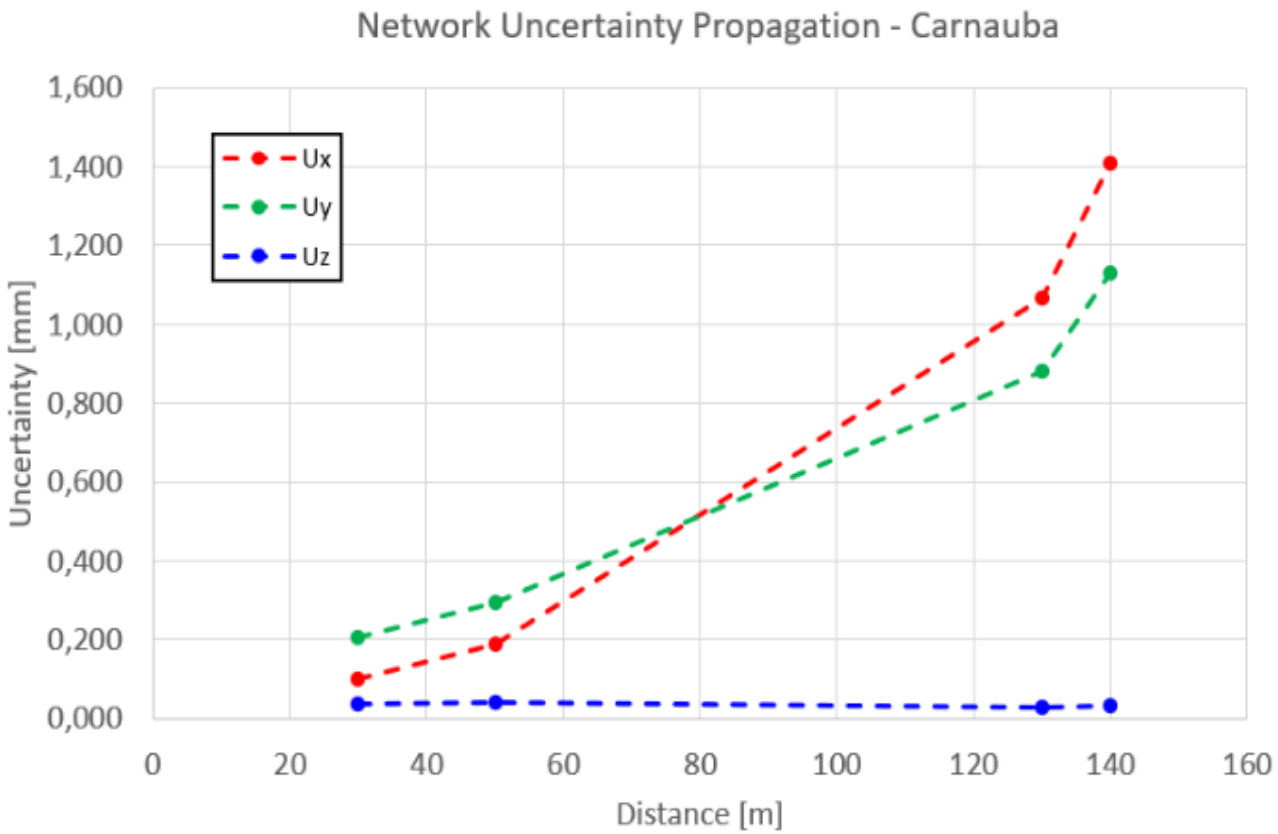
Transformation

- With the fits done, a relationship between centers should be done, followed by a 4 DOFs relationship minimization (Rx and Ry, levelling degrees of freedom, are fixed).



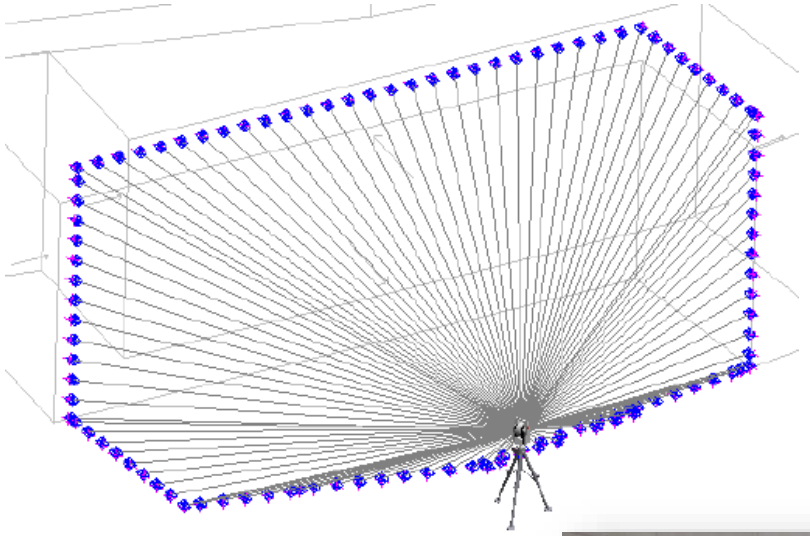
Network results and uncertainty

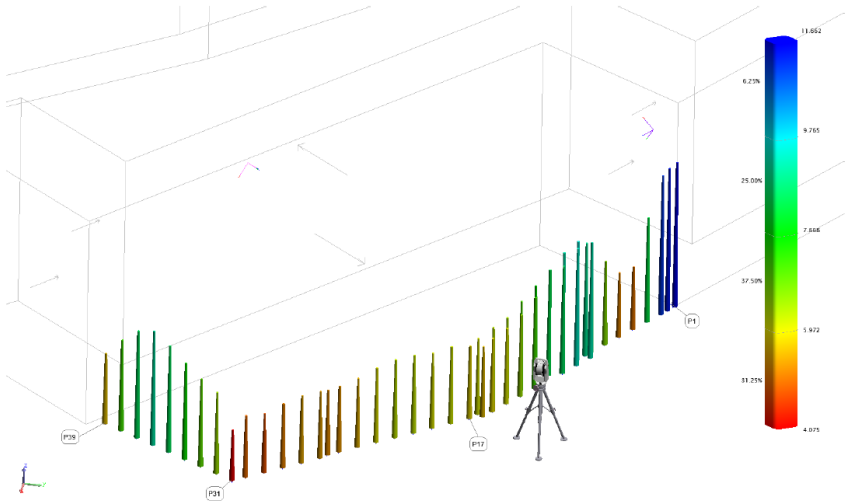
- SR result network BF to last epoch;
  - EH network BF to SR network;
    - Tertiary networks BF to EH network;
- Always preserving its levels, except hutches networks, that inherits the beamline level.
- Network uncertainty propagation study for the longest beamline of Sirius;
- Python based script, developed in-house;
- Monte Carlo simulations;
- NOTE: uncertainty for adjacent components are no greater than 0.100 mm.



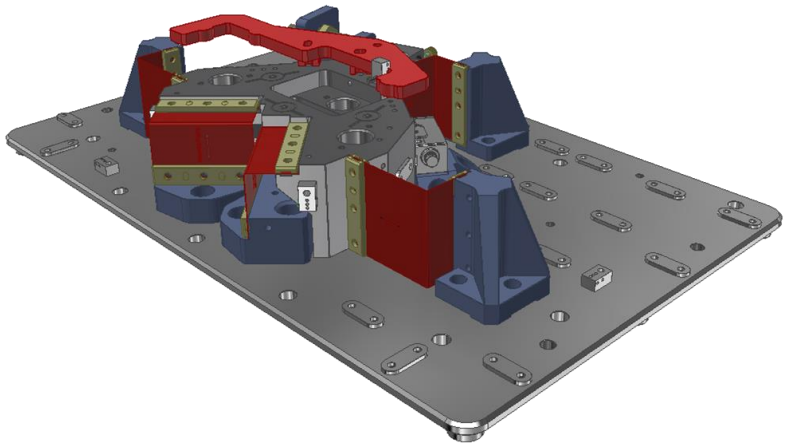
Beamline sequence install

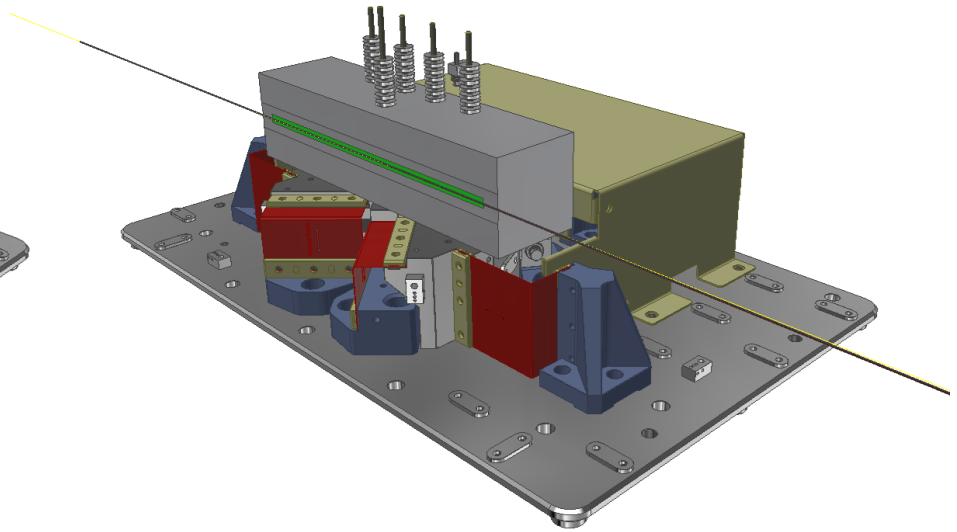
1. Data preparation from CAD to SpatialAnalyzer;
2. Blue lining of hutches perimeters;
3. As-built measurements of interfaces of hutches and equipment;
4. Blue lining of drilling marks for bolts for hutches and equipment;
5. Component fiducialization;
6. Component installation and pre-alignment;
7. Baking and vacuum commissioning;
8. Fine alignment.

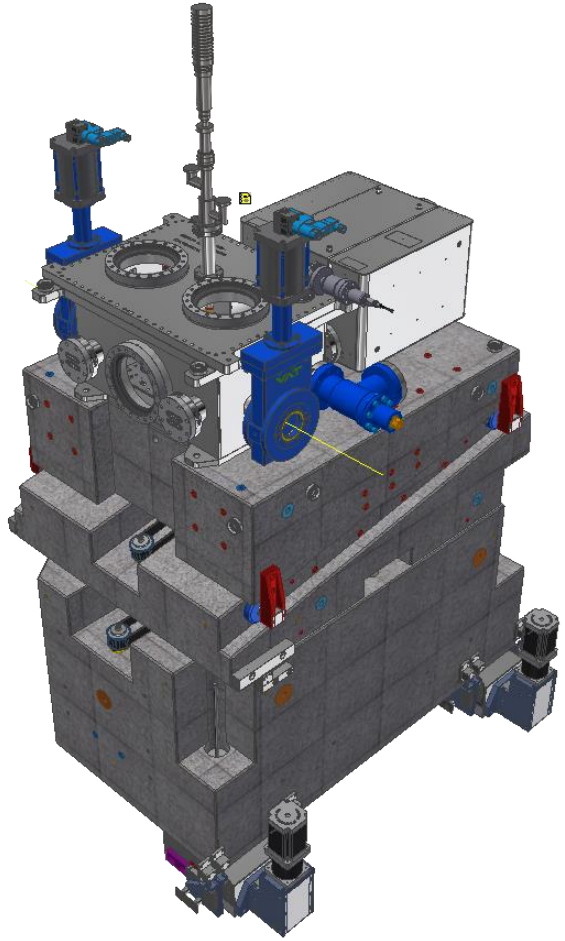




Mirrors indirect fiducialization



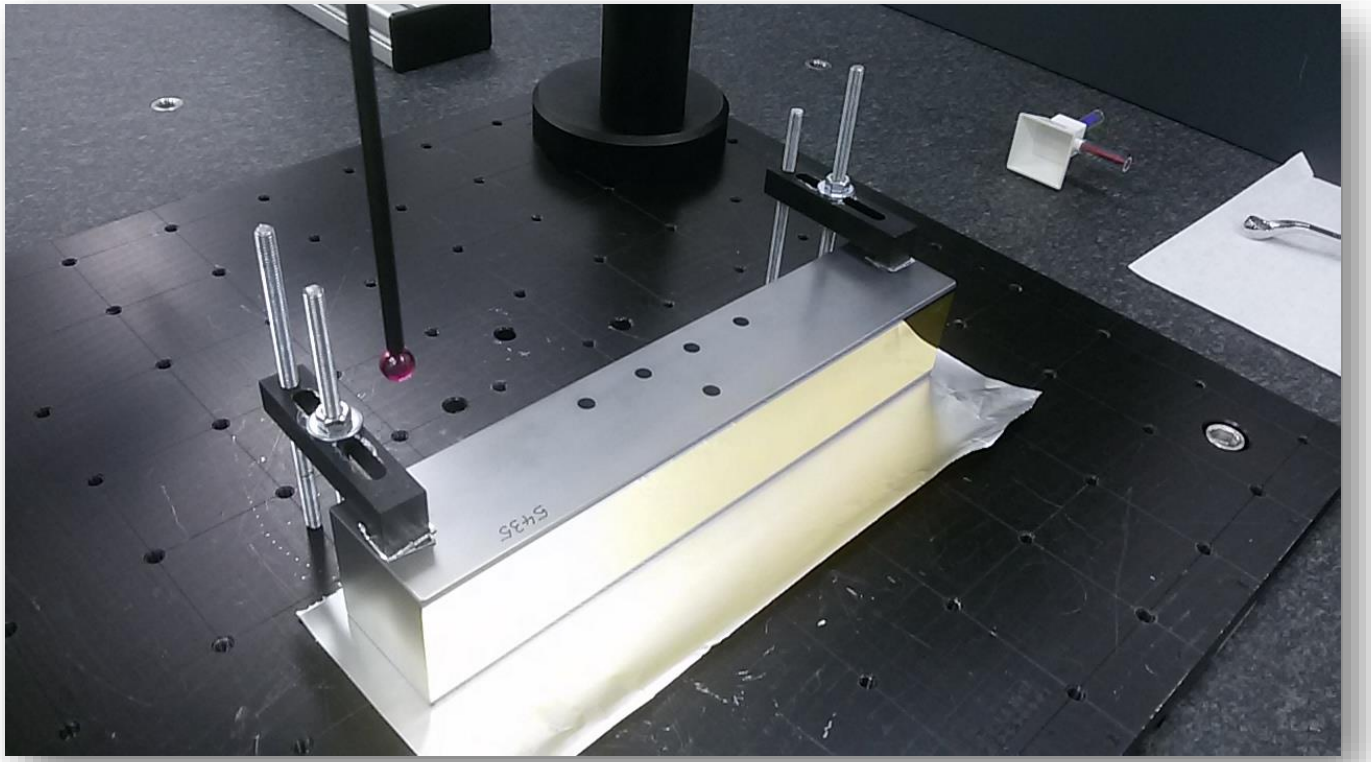


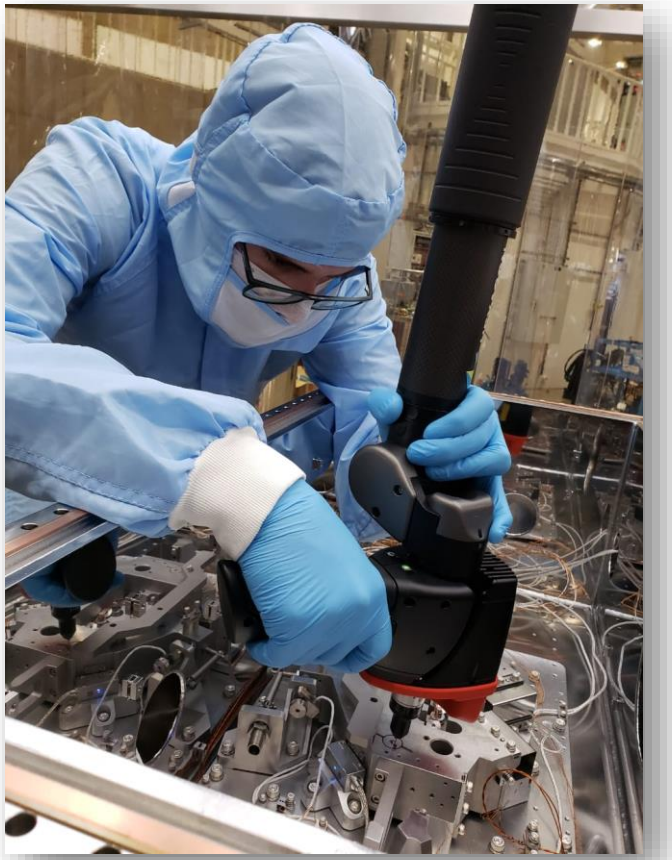


- Fiducialization: externalize references of the component;
- Vacuum and cleanliness demands;
- 2 measurement steps.

Fiducialization equipment

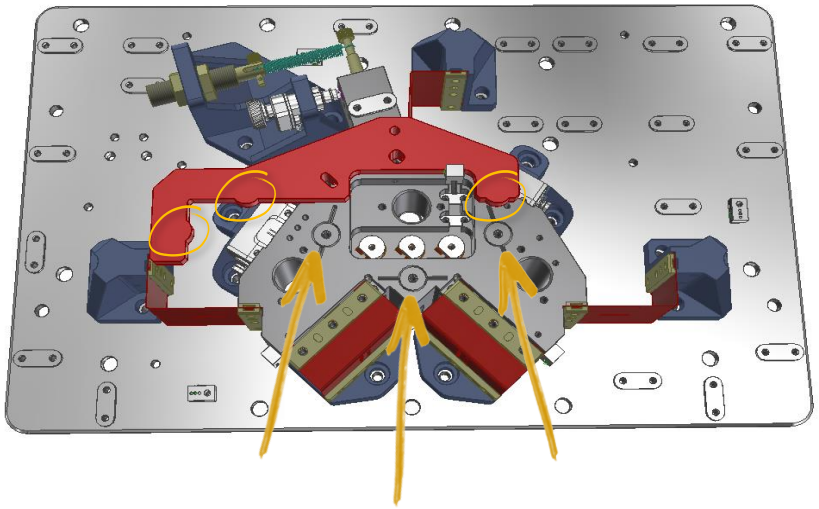
- Mirror substrate measured in a CMM;
- Mechanism measured with an Articulated Measuring Arm.

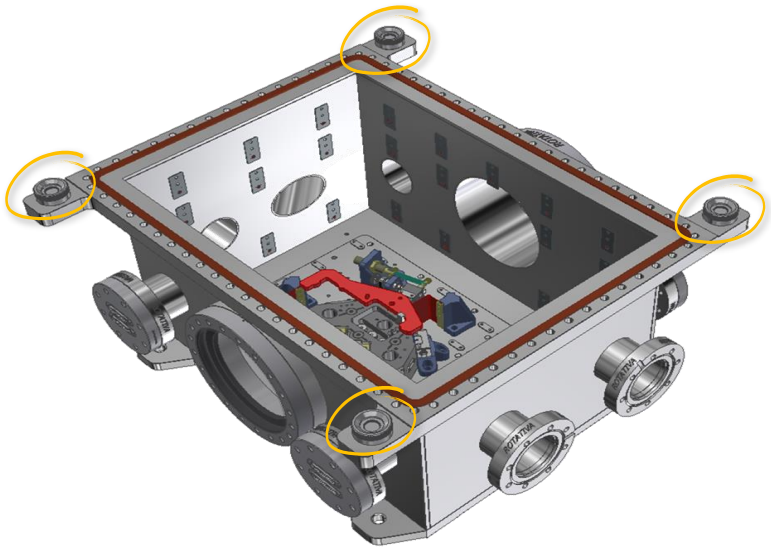


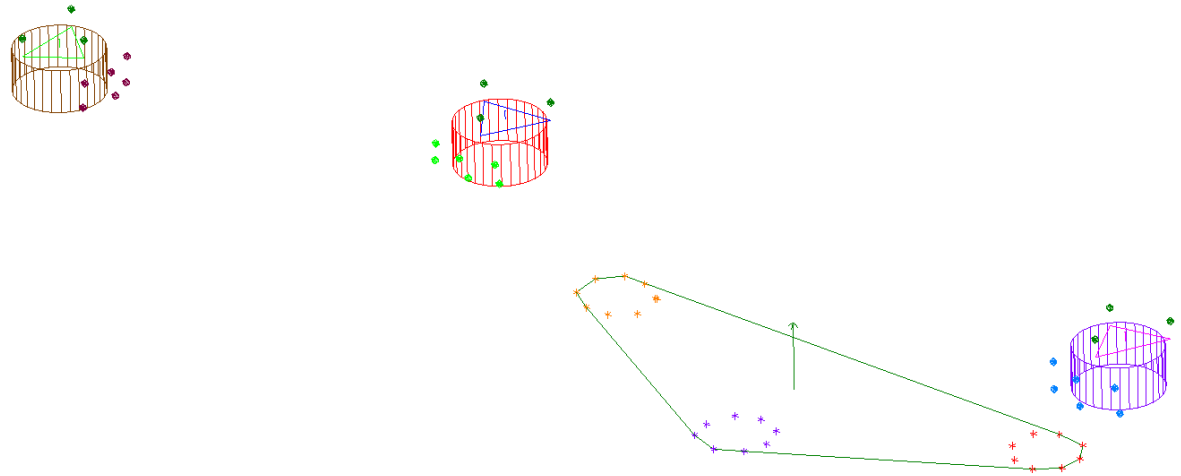


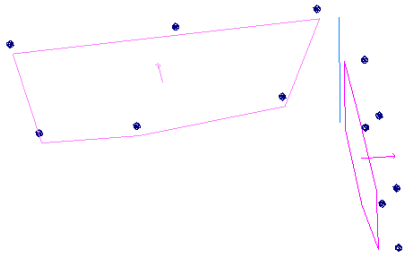
Arm measurement

- Mechanism assembly layout measurement.









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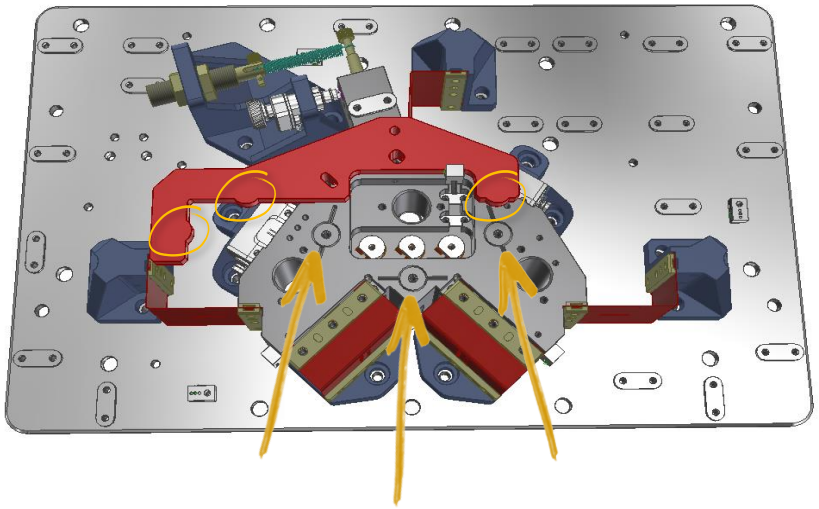
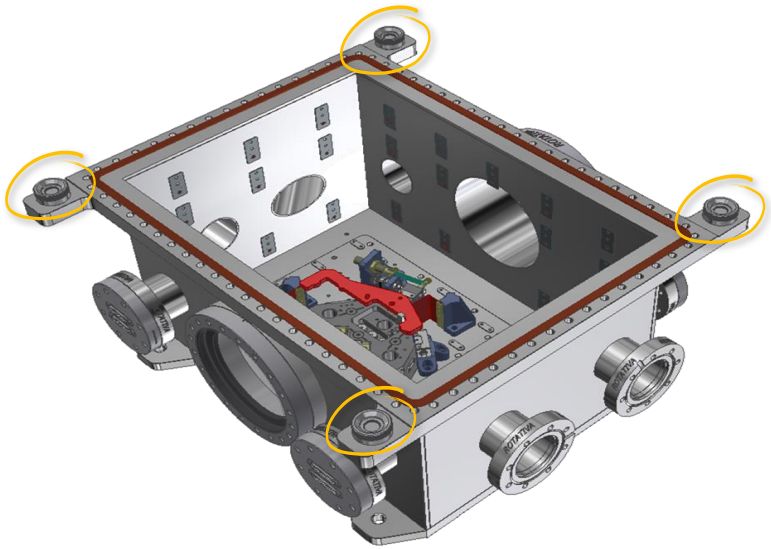
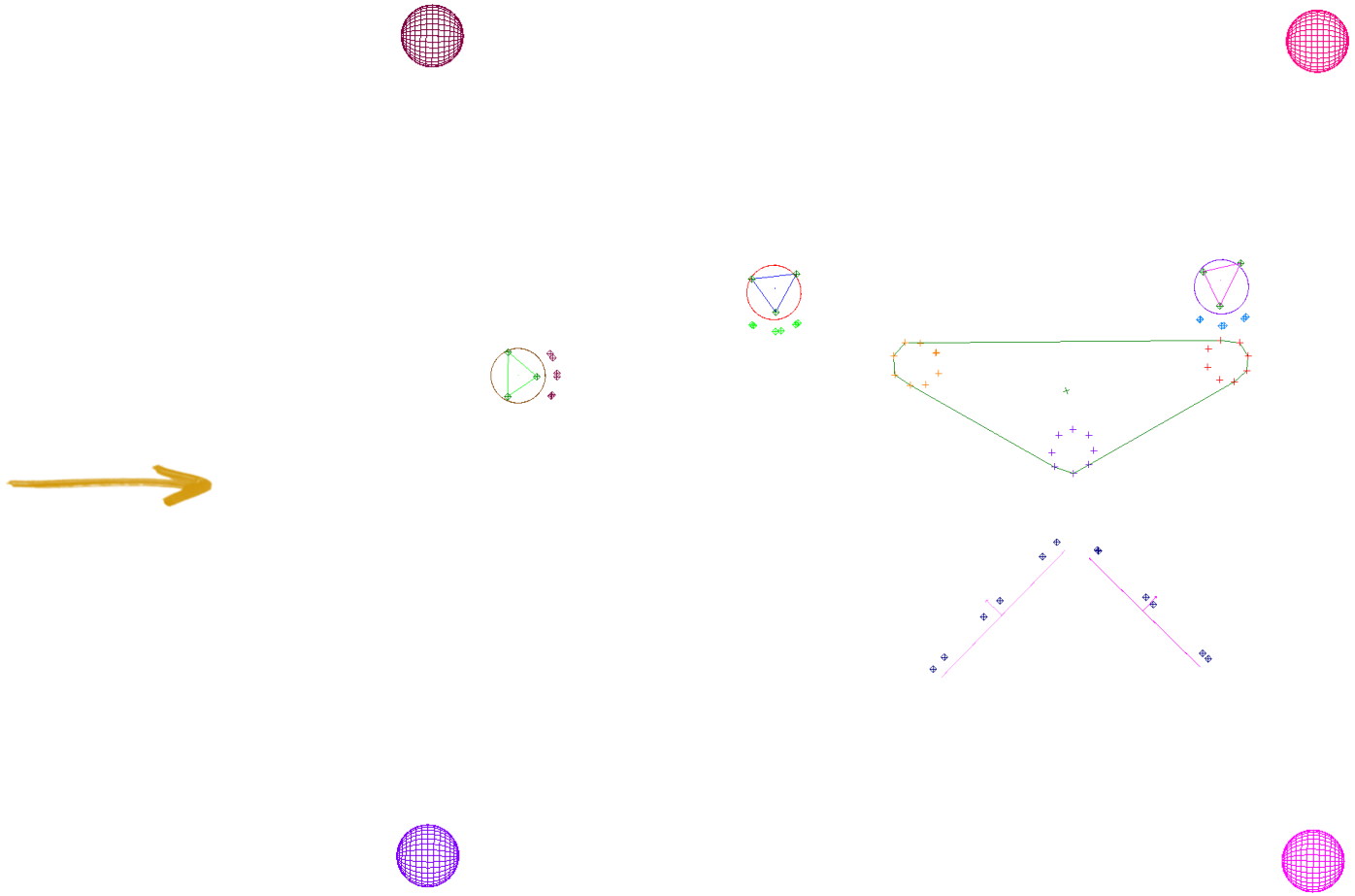
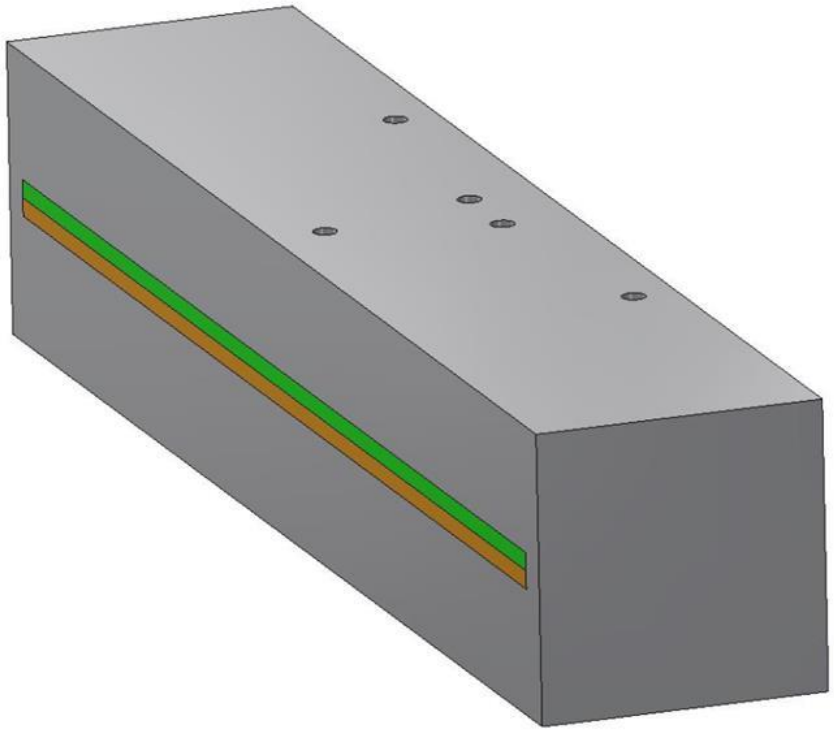


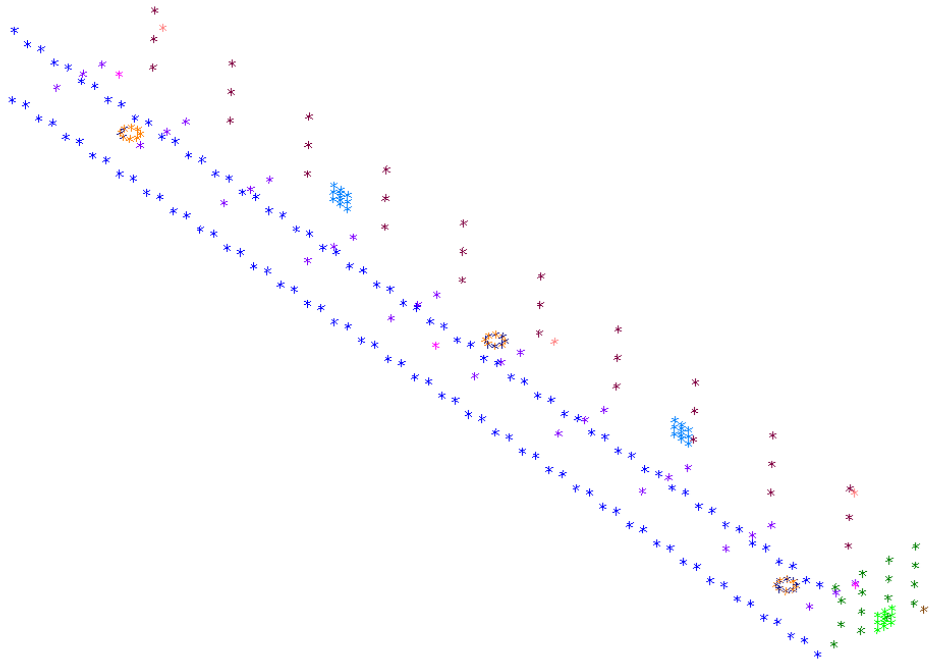




CMM measurement

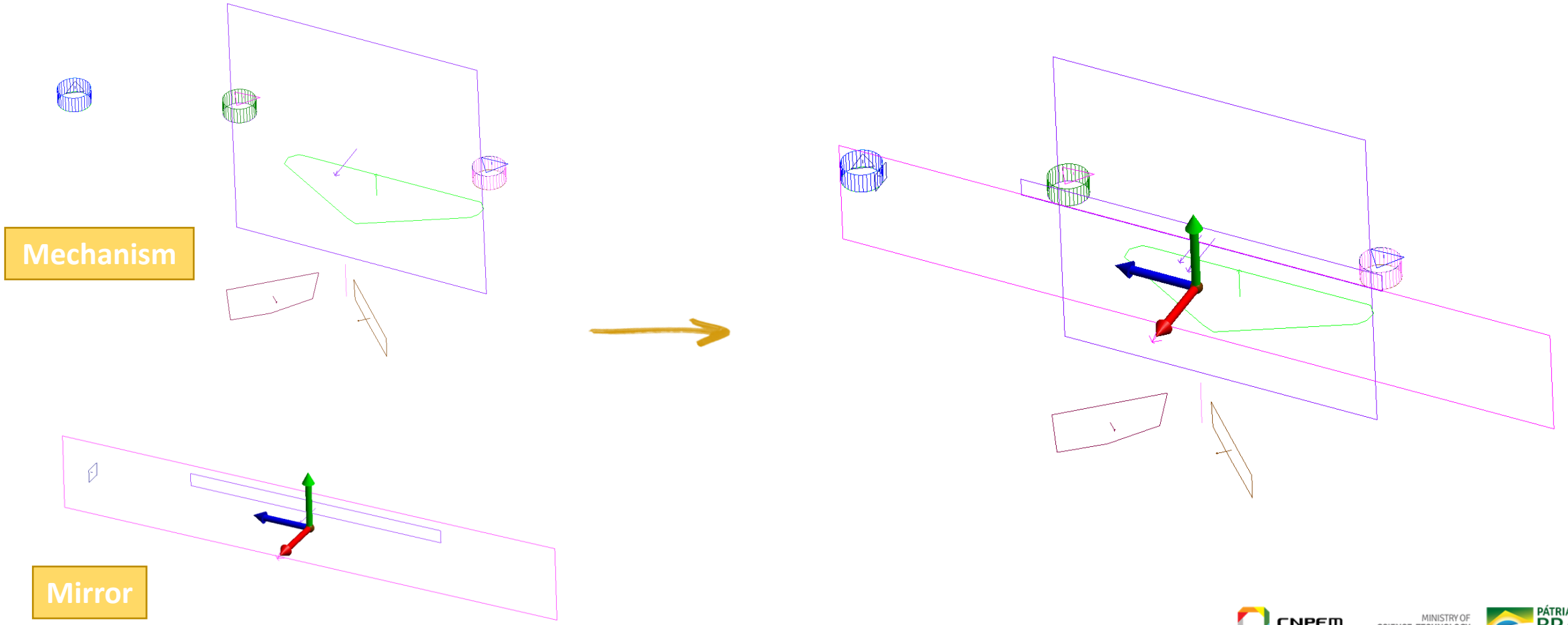
- Mirror substrate measurement.





Virtual matching

- Indirect: mechanism and mirror substrate virtually matched;
- Matching geometries constructed from measured points on substrate and mechanism.



Uncertainty estimation

- Hexagon 7 axis ROMER basic volumetric accuracy: $\pm 35\ \mu m$;
- Depends on other factors (operator, arm position etc.);
- Process repeated five times.

v1				
	Tx	Ty	Tz	Mag
mm	0.000	0.024	-0.013	0.027
	Rx	Ry	Rz	
mrad	-0.0528	0.0705	0.1793	

v2				
	Tx	Ty	Tz	Mag
mm	0.007	0.011	0.007	0.015
	Rx	Ry	Rz	
mrad	0.0343	0.1279	-0.0469	

v3				
	Tx	Ty	Tz	Mag
mm	0.003	0.004	0.001	0.005
	Rx	Ry	Rz	
mrad	0.0675	-0.1568	-0.0112	

v4				
	Tx	Ty	Tz	Mag
mm	-0.022	-0.015	0.006	0.027
	Rx	Ry	Rz	
mrad	-0.0876	-0.1867	-0.2027	

v5				
	Tx	Ty	Tz	Mag
mm	0.012	-0.023	-0.001	0.026
	Rx	Ry	Rz	
mrad	0.0380	0.1446	0.0821	

CATERETE - M1				
	Tx	Ty	Tz	Mag *
2 Sigma	0.026	0.038	0.016	0.049
	Rx	Ry	Rz	
2 Sigma	0.1328	0.3189	0.2869	

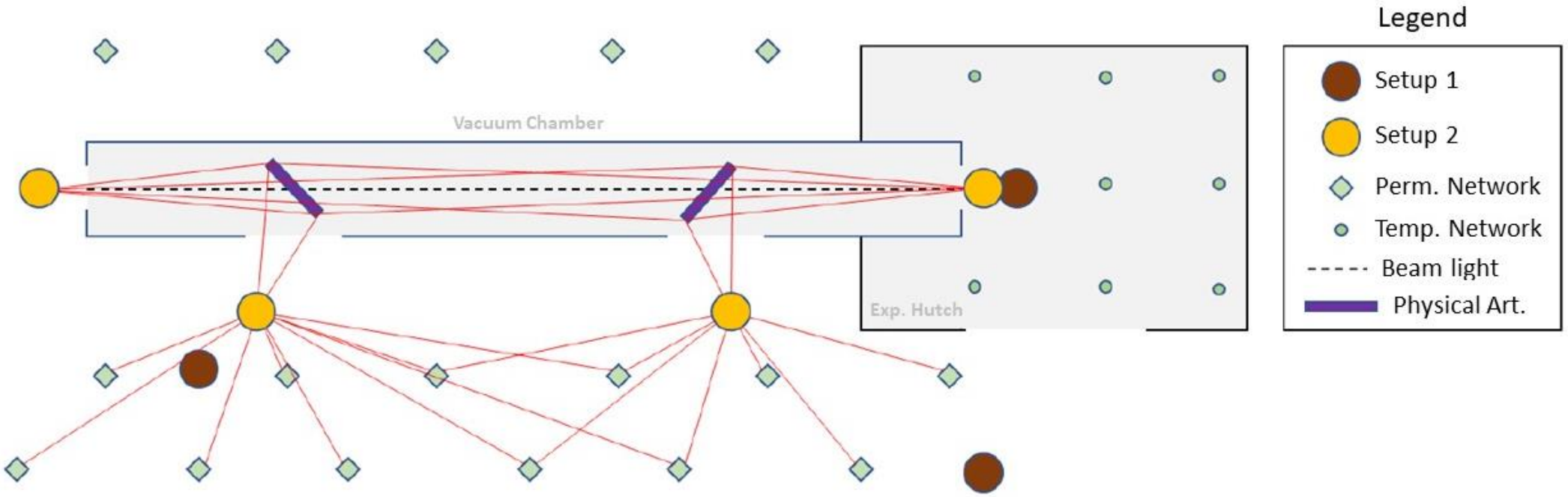
** magnitude expressed as* $\sqrt{Tx^2 + Ty^2 + Tz^2}$

Detector tunnel - CDI beamline

- Vacuum chamber 30 m long;
- Carriage supporting X-ray detector;
- Critical straightness and trajectory orientation over whole tunnel;
- Disc of confusion tolerance: Ø1 mm;
- Acceptance test after AVS installation.

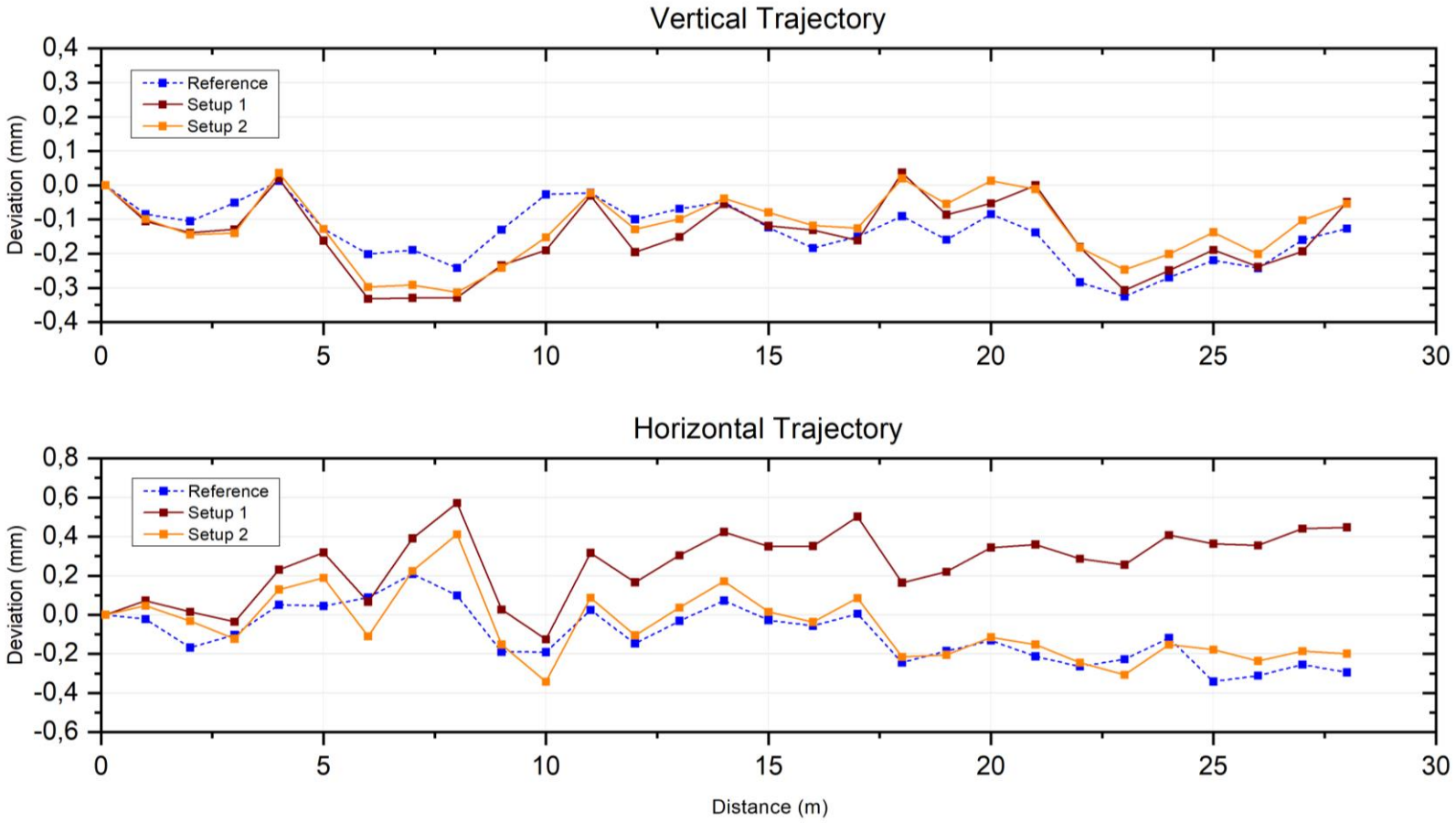
Setups

- Two setups involving laser trackers and physical artifacts;
- One reference measurement done with a laser alignment system.



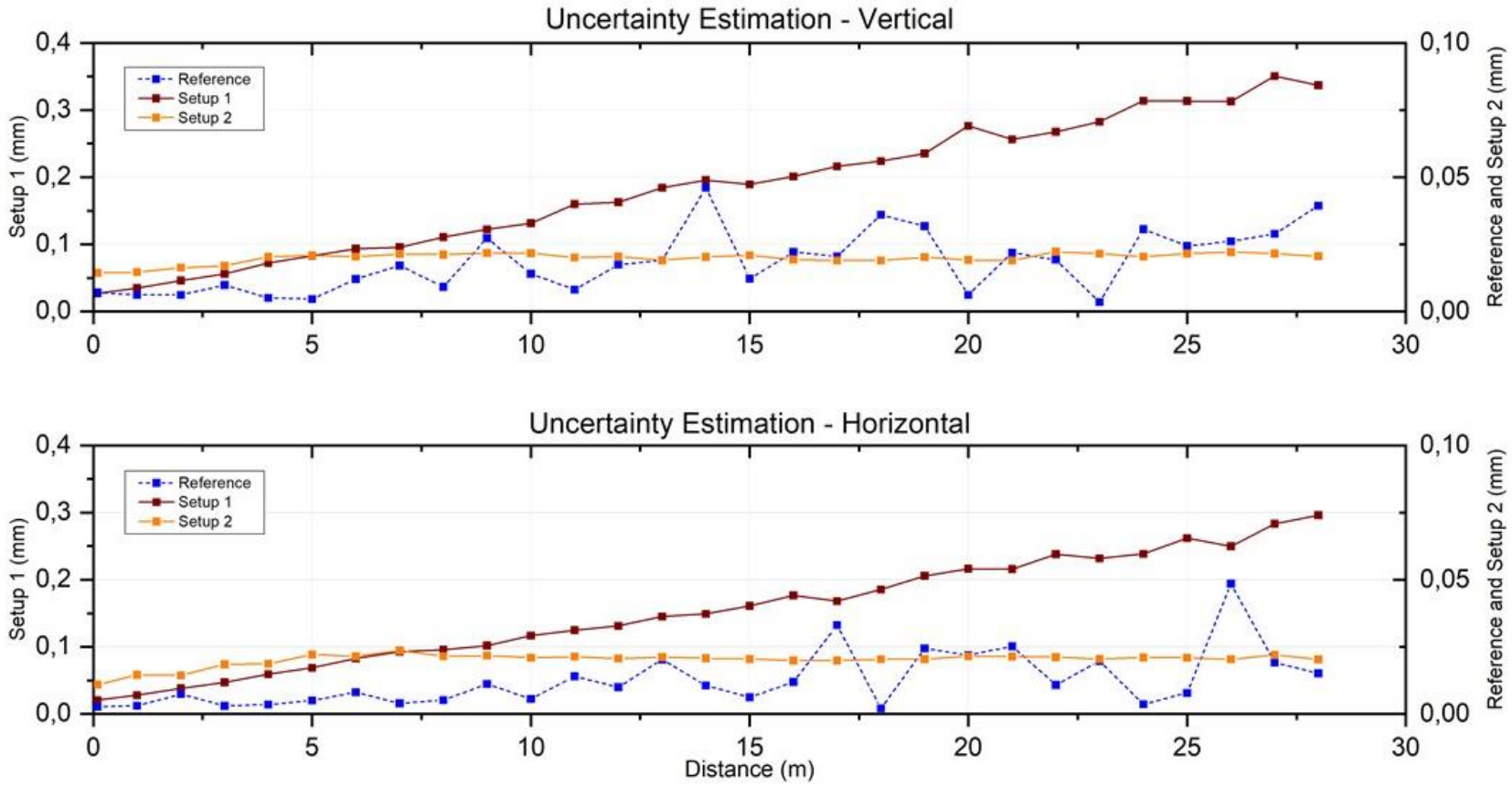
Results - Trajectory

- All setups well describe the vertical form and orientation;
- Instruments precisely levelled on gravity;
- Horizontally, graph shows that only the setup 2 can replicate the reference curve;
- Setup 2 stations located indirectly by the permanent network using the artifacts;
- “Cross measurements” of the artifacts;
- Artifacts positioned on the line of sight of the movement system.

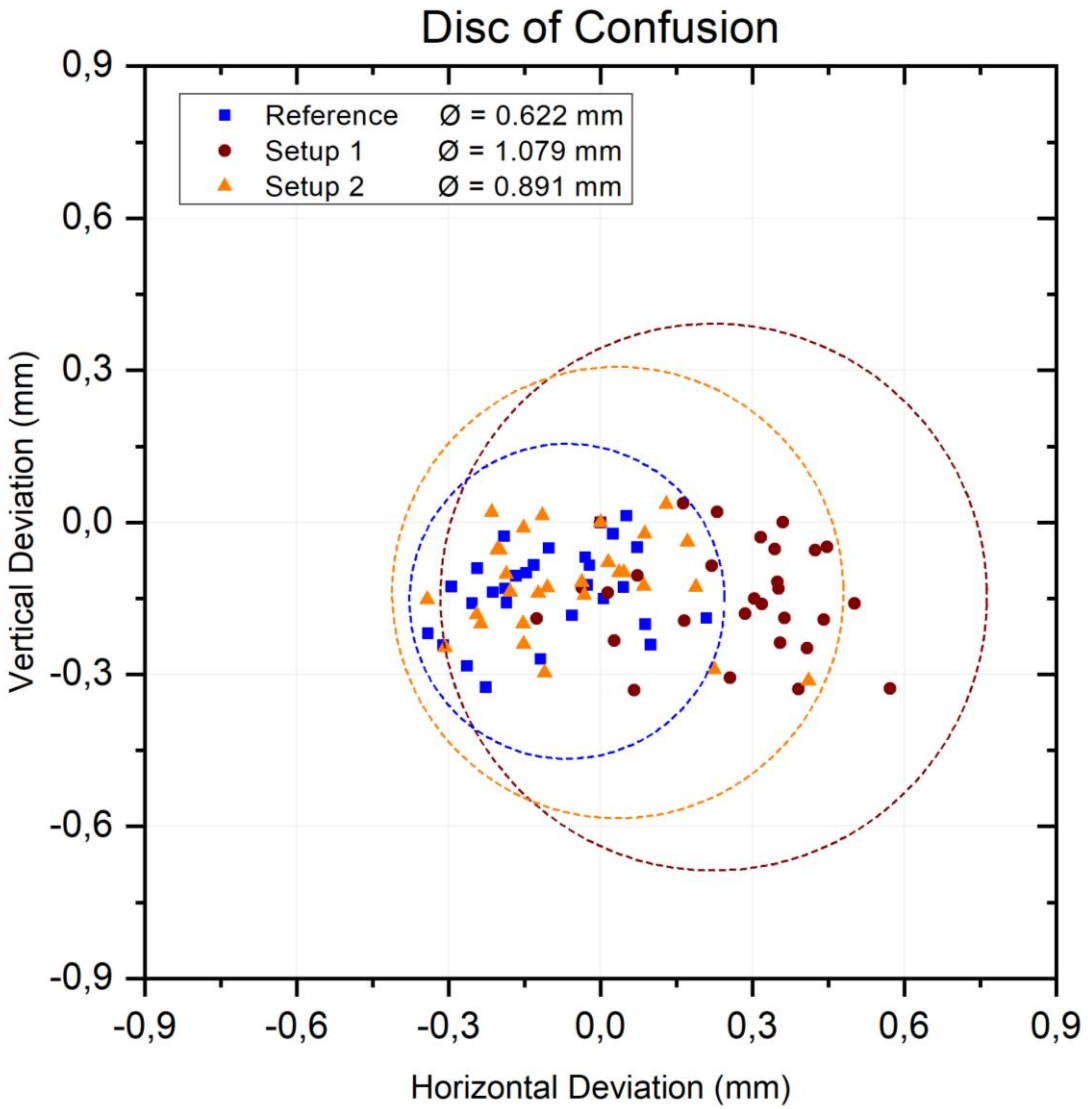


Results - Uncertainty estimation

- Reference: StdDev for the 3 measurements of each point;
- Tracker: USMN algorithm from SA;
- Two vertical axis: setup 1 on the left, reference and setup 2 on the right;
- As expected, setup 1 uncertainty increases proportionally to the distance;
- Also, the USMN algorithm propagates de network uncertainty;
- Hypothesis for the lower uncertainty of setup 2:
  - Two stations measuring simultaneously, decreasing the distance impact;
  - Artifacts located inside the DoC measurement volume.

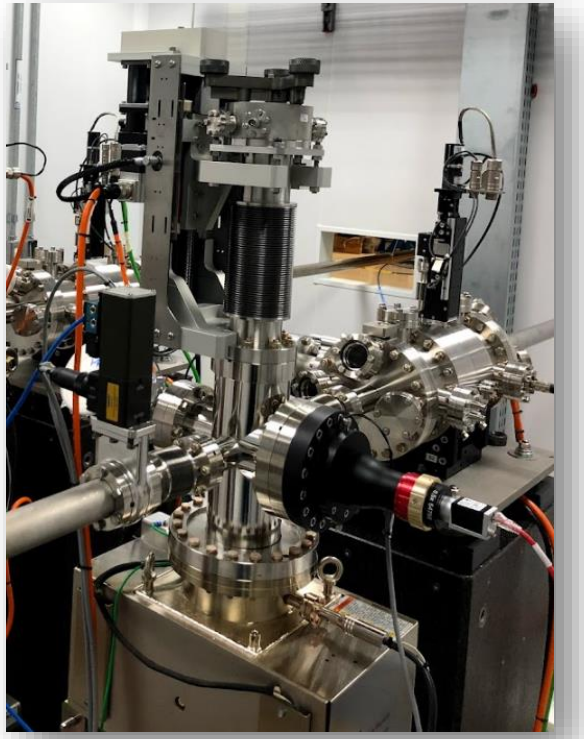


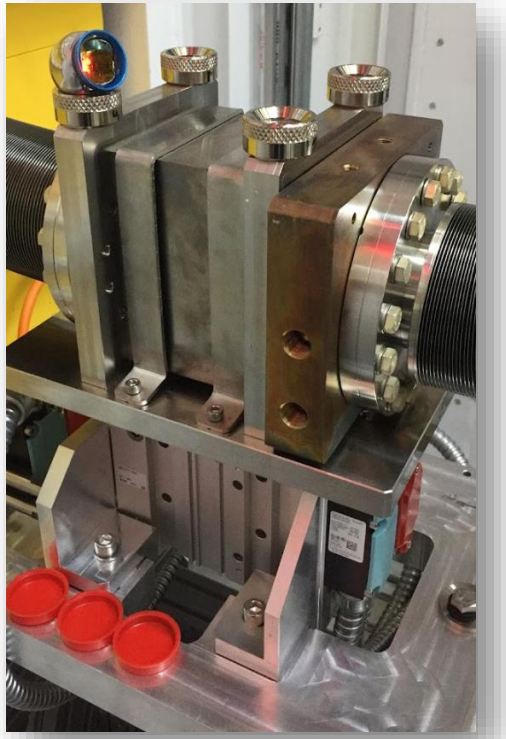
Disc of Confusion



- Disc of confusion compile information of trajectory, orientation and form;
- The diameters considers the uncertainty of the most extreme point included by the circle;
- The three circles are very close to the tolerance.
- But the uncertainty estimation study showed that the setup 1 must be reproved:
  - It makes the circle extrapolate the diameter tolerance (1 mm);
  - High deviations when compared to the reference curve;
- The DoC shows a good relation between the reference points and the setup 2:
  - The location using physical artifacts indicates a satisfactory result.

Alignment results





- Commissioning phase at late 2019;
- Some beamlines completed the installation and alignment process;
- Compilation of results for the first four beamlines;
- Average of the principal coincident components.

Alignment results						
Components	**X [mm]**	**Y [mm]**	**Z [mm]**	**Rx [mrad]**	**Ry [mrad]**	**Rz [mrad]**
Mirrors	-0,01	0,01	1,11	0,04	0,03	0,02
Collimators	0,04	-0,06	-0,19	0,23	-0,11	0,28
DVFs	0,03	-0,08	2,16	1,04	2,81	0,06
Shutters	0,05	-0,06	-0,13	0,05	0,09	0,13

Alignment and Metrology Team - Sirius

Thank you!