HIE-ISOLDE: COMMISIONING AND FIRST RESULTS OF THE MATHILDE SYSTEM MONITORING THE POSITIONS OF CAVITIES AND SOLENOIDS INSIDE CRYOMODULES

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Introduction and MATHILDE Concept

The HIE-ISOLDE project is an upgrade of the ISOLDE REX facility and involves design, construction, installation and commissioning of 2 low-β and 4 high-β cryomodules. The first phase, involving 2 high-β cryomodules, took place from the beginning to mid-2016. Each high-β cryomodule houses five high-β RF cavities and one superconducting solenoid. The active elements , cavities and solenoid, are operating under cryogenic (4.5K) and vacuum (10^{-11} mbar level) conditions. To run in optimum conditions, the cavities and solenoid must be aligned within a precision of 0.3 mm and 0.15 mm (1σ) respectively along the directions perpendicular to the Beam.

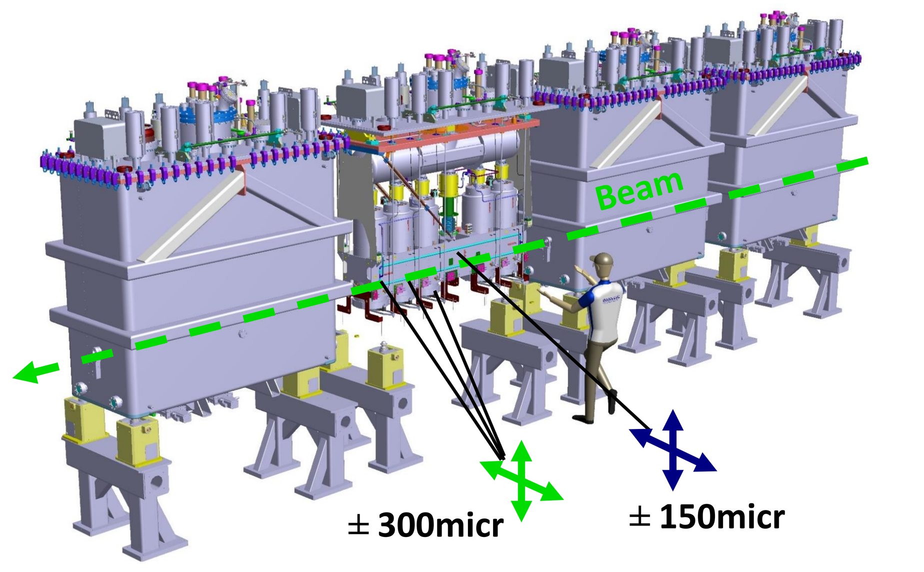


Figure 1: HIE-ISOLDE linac phase 2 configuration with 4 high-β cryomodules + alignment specifications

The Monitoring and Alignment Tracking for Hie-IsoLDE (MATHILDE) system uses a set of newly developed double-sided HIE-ISOLDE Brandeis CCD Angle Monitor (HBCAM) to measures retro-reflective targets , based on high-index (~2) glass ball properties. The targets are linked to the active elements and seen though precise viewports. The devices are fixed to metrological tables in order to create a close geometrical network linked to the Nominal Beam Line by reference pillars.

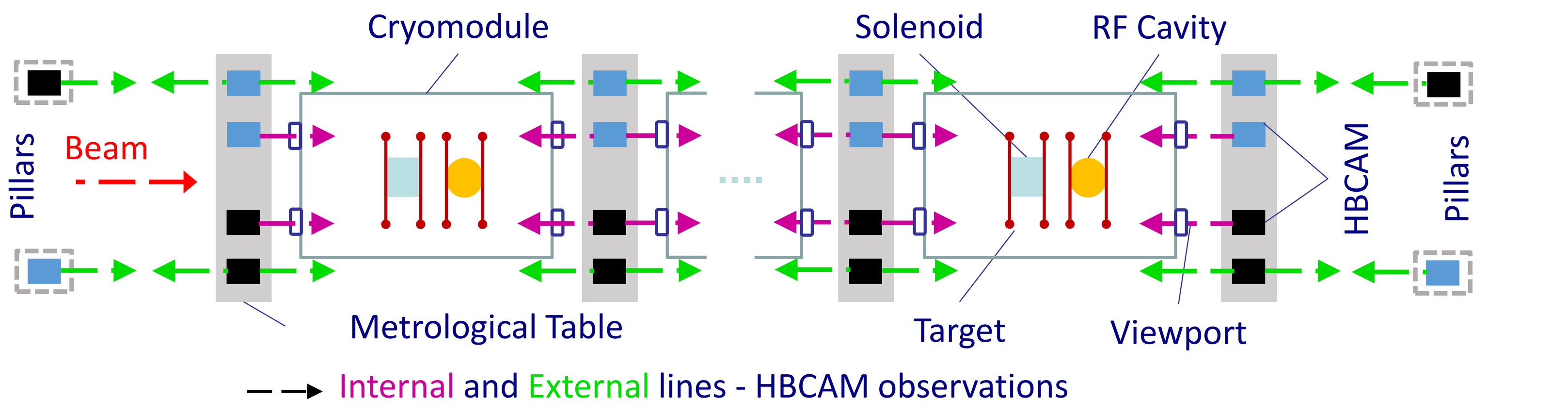
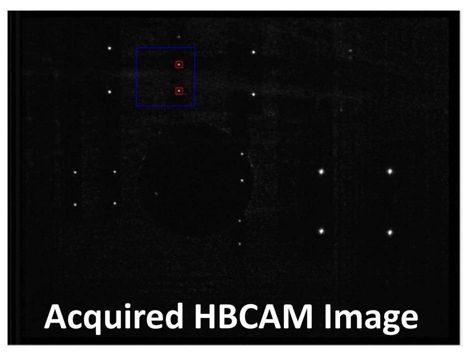
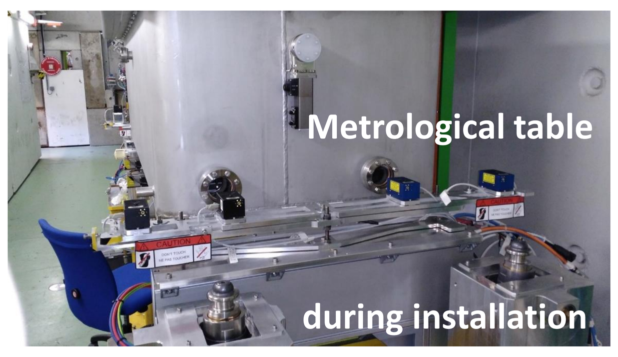


Figure 2: Top view of the alignment and monitoring system principle

MATHILDE Phase 1 Set up





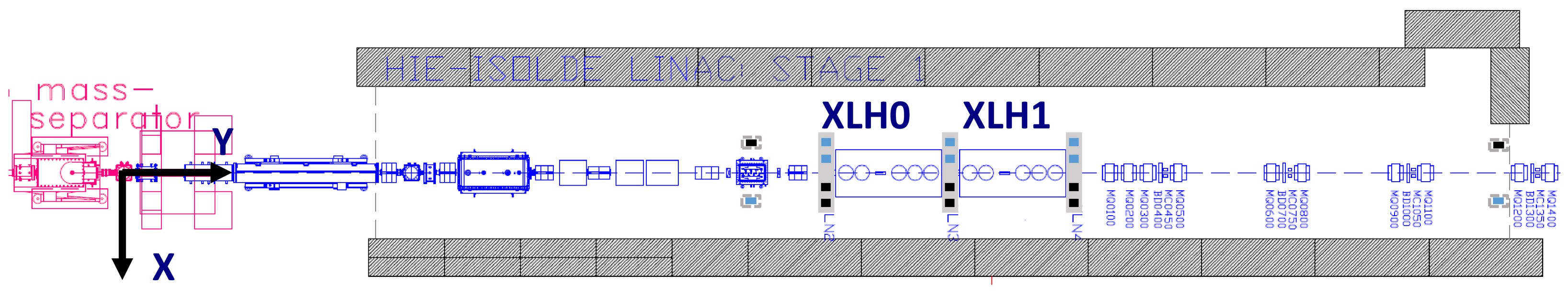
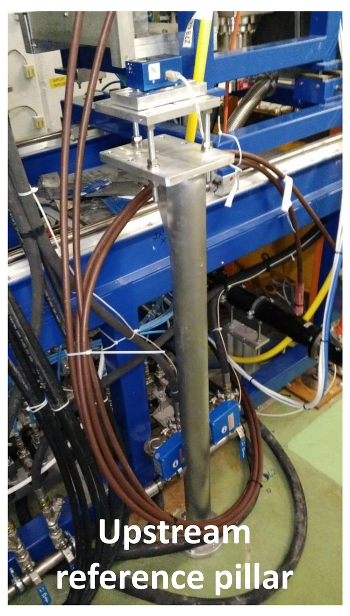


Figure 3: Local coordinate system + layout of the first phase of the HIE-ISOLDE project comprising two cryomodules (XLH0 and XLH1) + MATHILDE system installed: 2 metrological tables and 4 reference pillars



Supporting scheme and adjustment possibilities

- Each cavity and solenoid has 2 hollow half spheres mounted and centred on its beam entry / exit points
- Spheres (Beam ports) are supported by V-Shaped grooves machined on, so-called, omega plates
- Omega plates are maintained in a supporting frame hanging from the top plate
- The top plate is lying on top on the vacuum vessel, which is sitting on 3 adjustable jacks

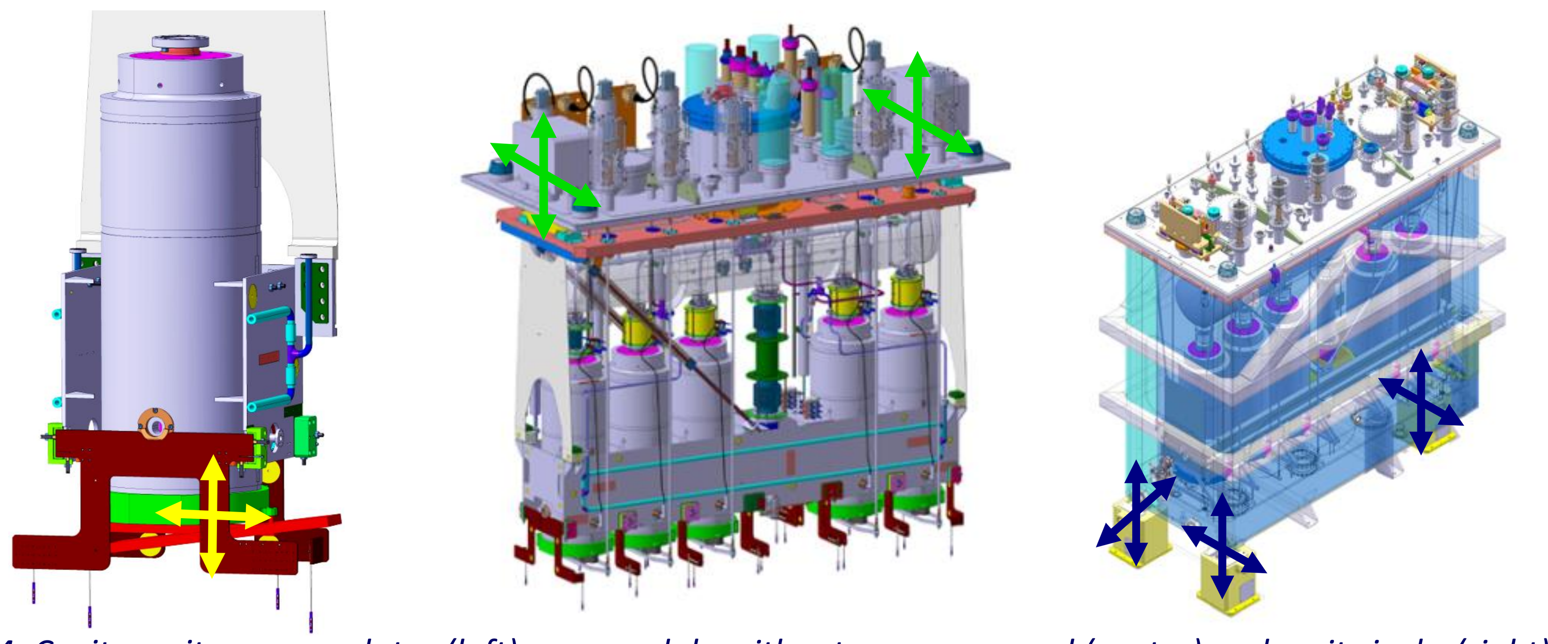


Figure 4: Cavity on its omega plates (left), cryomodule without vacuum vessel (centre) and on its jacks (right)

- Omega plate moving into the supporting frame
- Only possible during assembly in the ISO5 clean room
- Omega plate welcomes MATHILDE Targets

- 2 sets of Motors moving the supporting frame
- Done during assembly and under cryogenic steady state
- Only reliable in vertical axis
- Do not require access in the shielding
- Range: ±5mm by 50 μm steps

- Adjust the cryomodule jacks
- Move the whole cryomodule
- Done during installation and under cryogenic steady state
- Require access in the shielding
- At cold, risk to damage the bellows of the elements surrounding the cryomodule

Relative alignment of the cavities and solenoid: **only possible during assembly**

XLH0 and 1 Cool Down

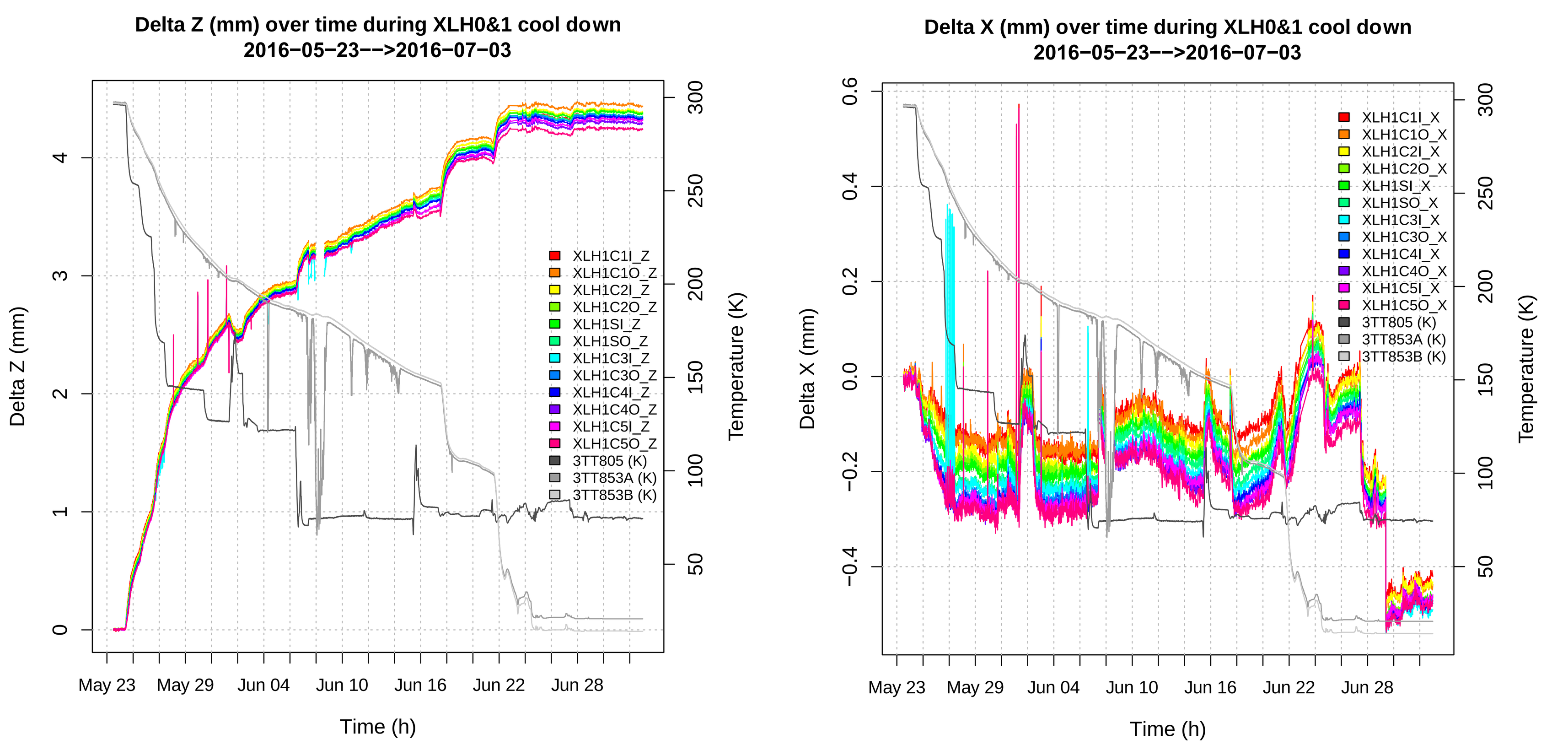


Figure 5: Movement of the XLH1 cavity (Cx) and solenoid (S) entry (I) and exit (O) beam port centres w.r.t. the first measurement done during the cool down period

- XLH0 and XLH1 cryomodules installed in first half 2016
- Cool down period from may 23rd 9:00 CEST to July 2nd 2016 23:30 CEST

- Vertical movement:
  XLH0 : + 4.3 mm / XLH1 : + 4.2 mm
- All in **agreement** with the thermo-mechanical calculations

- Lateral movement:
  XLH0 : 0.8 mm / XLH1 : 0.5 mm
- Movement expected
- Experimental Feedback : limited to ± 1 mm

- 2686 computations results:
  2583 Good 90 failed 13 contained errors

Parasitic reflection on the thermal shield, mostly occurring during its cool down, disturbing the detection of the targets on the HBCAM acquired images. Alignment corridors designed to minimize the parasitic reflection are mostly effective, but have a couple defaults caused mainly by assembly tolerances.
On some acquisition, targets are not or wrongly detected.
→ MATHILDE Improvement axis

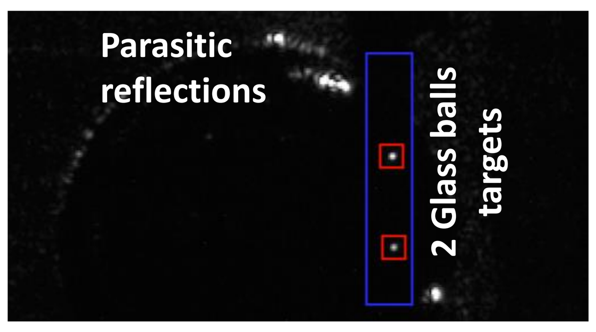


Figure 6: detail on an acquired HBCAM image

- Per computation: 364 HBCAM Images acquires **227** observations **157** unknowns in 4:30 min
- Wrongly or not detected targets:
  152 observations / **~380 000** (total number of observation during the cool down)
- Along Z, the position of the beam port centre is highly dependent on the temperature sensor of the omega plate. This temperature serves to correct the omega plate shape pre-computation. Erratic behaviour happened only on one sensor, altering by ~0.15 mm the beam port centre for a misreading of 100K → MATHILDE Improvement axis.

Cryomodule cold adjustment

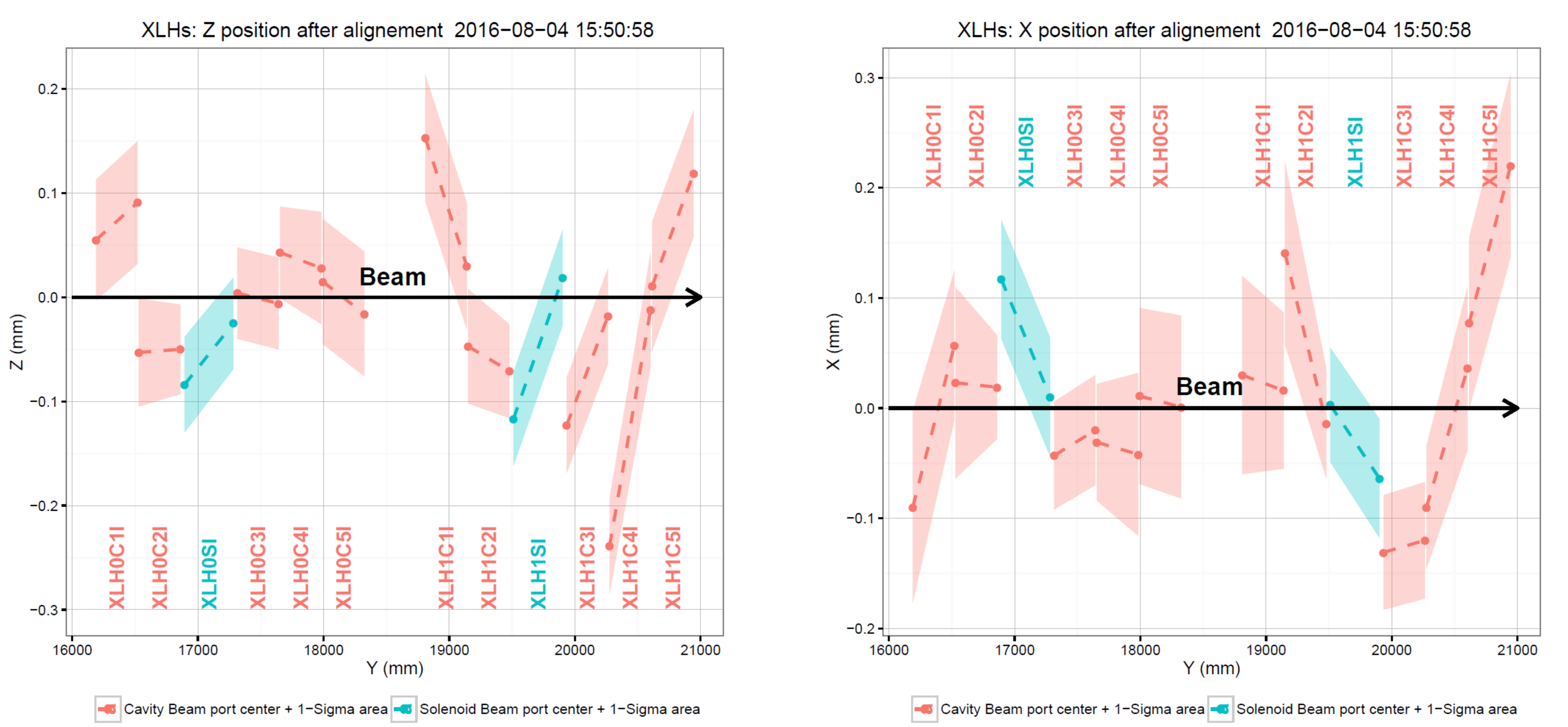


Figure 7: Position after adjustment of the cavity and solenoid beam port centres along Z (left) and X (right)

- Correction applied to align the cavity and solenoid beam port best fit lines on the HIE-ISOLDE Beam line:

In height / Along Z			Laterally / Along X	
Upstream	Downstream	Cryomodule	Upstream	Downstream
+0.35 mm	-1.15 mm	XLH0	-0.58 mm	+0.55 mm
+0.05 mm	-0.75 mm	XLH1	-0.66 mm	+1.00 mm

- First step: vertical alignment
- Use of the remote motors moving the frame
- No access to the tunnel
- Only MATHILDE system observations

- Second step: lateral alignment
- Cryomodule support jacks adjusted
- Under cryogenic (4.5K) and vacuum steady state
- Observation by AT401 and MATHILDE

- Precision w.r.t. the datum: **<0.1mm at 1σ**
- Relative position **kept** during cool down for both cryomodule with respect to the fiducialisation
- Long-term stability under evaluation → Over 1 month: average displacement of 0.015 mm (s=0.03 mm) along X and -0.005 mm (s=0.02 mm) along Z.

Conclusion

- 5 years of Research and Development
- Successful MATHILDE installation for the first phase of the project with two cryomodules
- **Good results** in accordance with the needed precisions
- Allow measurements with a **wide variety** of cryomodule states: under vacuum or cryogenic conditions, in operation, etc

- Monitoring **reliable and robust**
- Room for improvement in the measurement strategy and acquisition software
- Long-term stability of the system under evaluation
- First beam delivered on September, 12th 2016
- Addition of two cryomodules (2017/2018) → Two metrological tables to install