HIE-ISOLDE Workshop : The Technical Aspects
November, 28th 2013

Latest developments of the HIE-ISOLDE Alignment and Monitoring System

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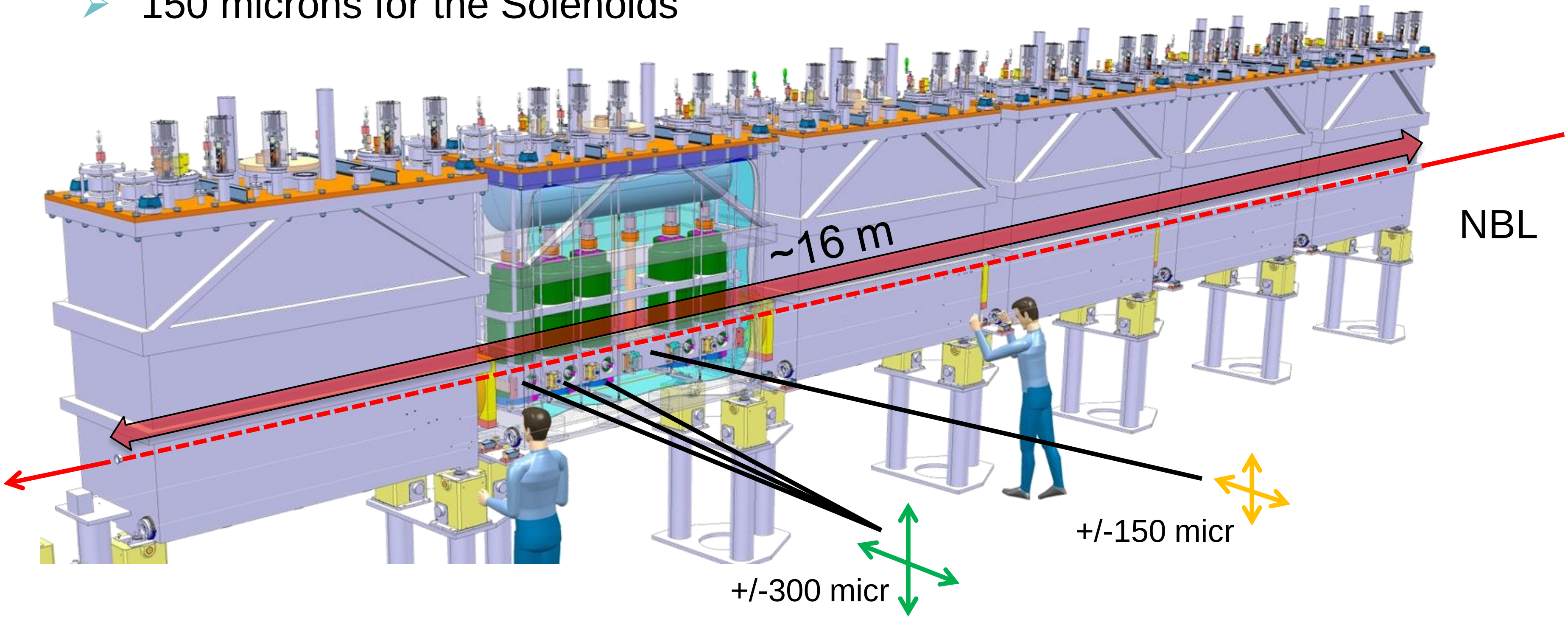
Alignment specifications
General

- HIE-ISOLDE : Upgrade of the existing REX-ISOLDE
- Alignment and monitoring of the Cavities and Solenoids in the Cryomodules w.r.to a common nominal beam line (NBL) along the Linac
- Permanent and Modular system
- Precision asked along radial and height axis at 1 sigma level :
  - 300 microns for the Cavities
  - 150 microns for the Solenoids



Alignment specifications

Alignment System

CONCEPT

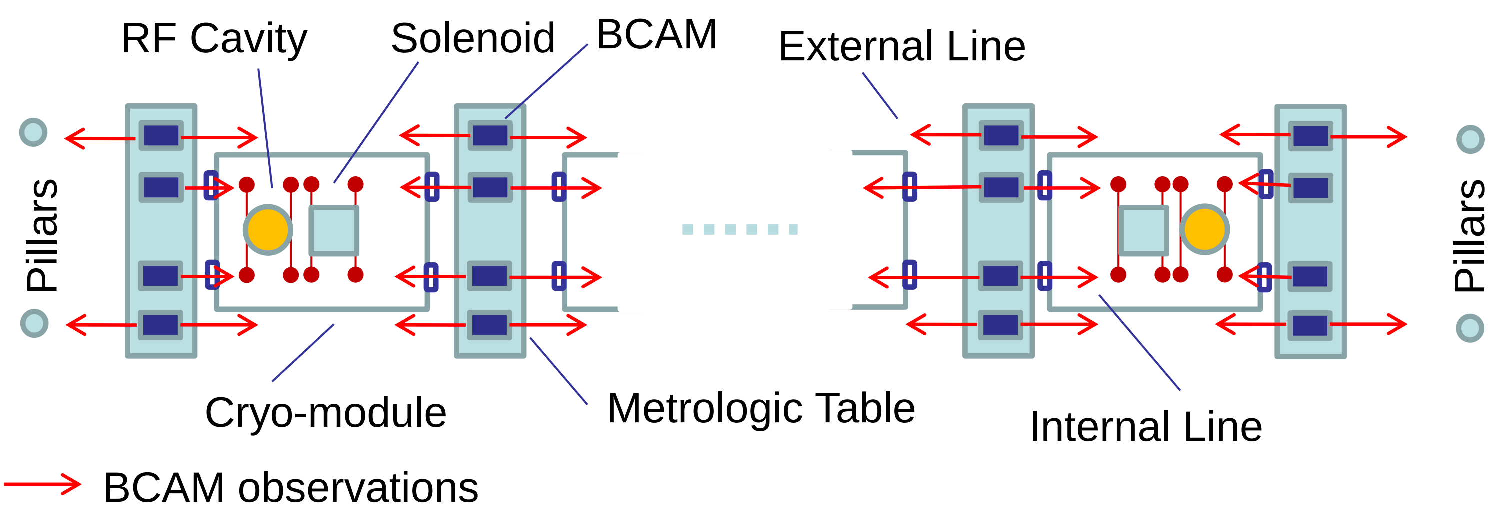
- Creation of a closed geometrical network continuously measured
- Observation and position reconstruction of Cavities and Solenoid in this Network

SYSTEM

- RF cavities and solenoid equipped with targets
- Interface Atmosphere / High Vacuum → Precise viewp*orts*
- BCAM cameras fixed to inter-module metrological tables

External Lines => Position and orientation of metrological tables and BCAMs

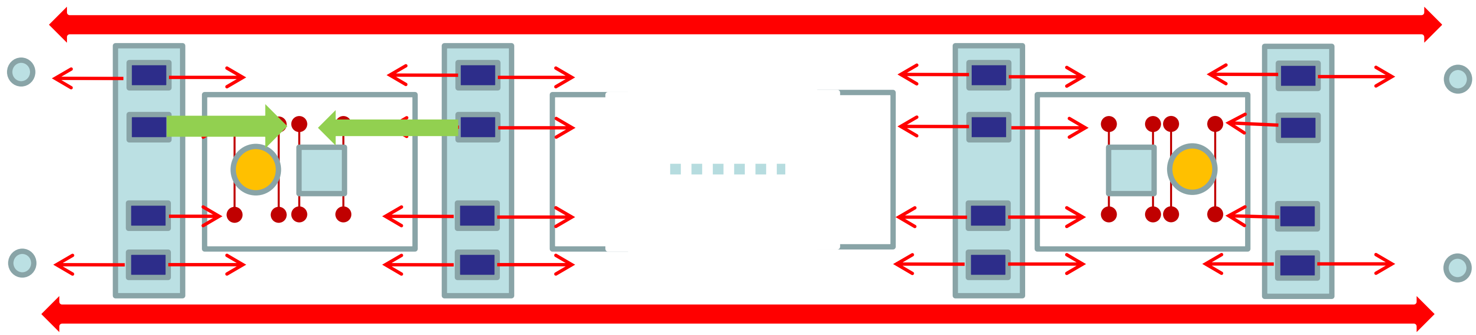
Internal Lines => Position of the targets inside the tank



Alignment specifications

Alignment System

Top view

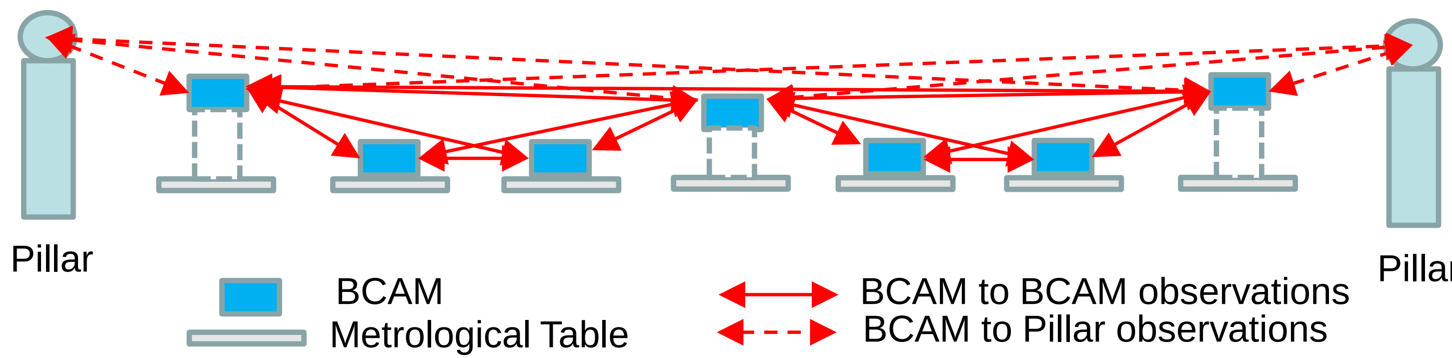


Overlapping zone of BCAM obs. on external lines

Double sided targets observations on internal lines

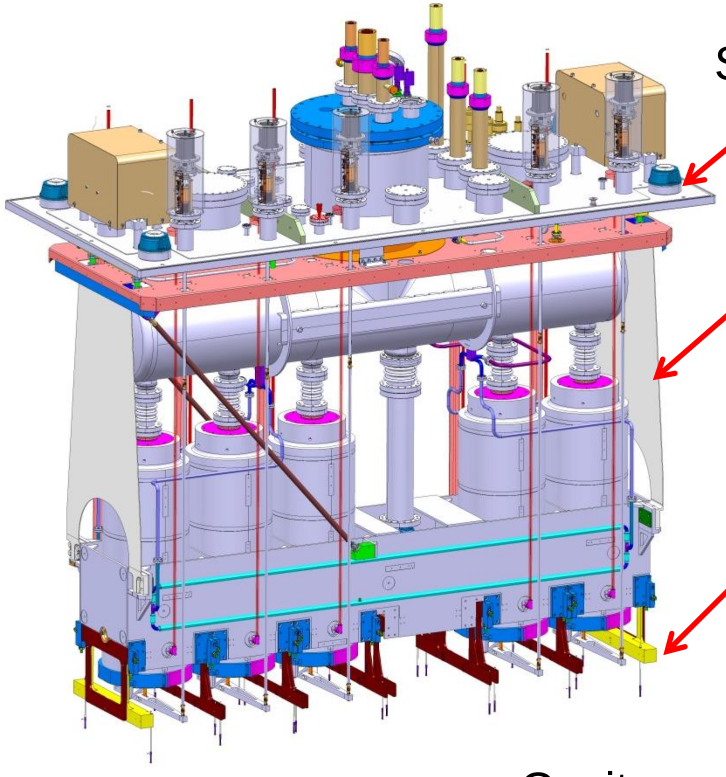
=> Redundancy

Side view
Ext. line
Overlapping



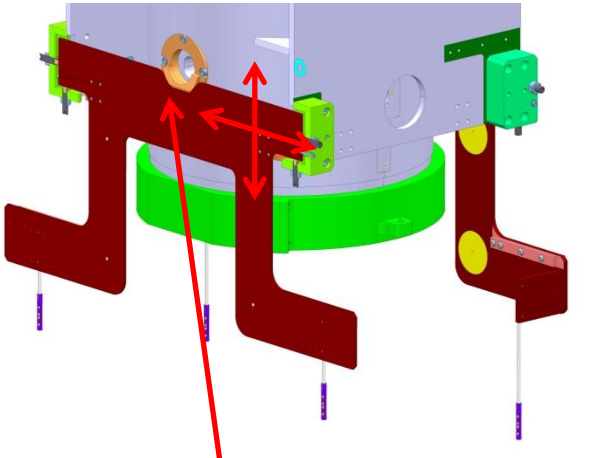
Supporting and adjustment

Cryomodule assembly in ISO Class 5 clean room



Survey sockets → Assembly / CM pre-alignment

Frame suspension and adjustment



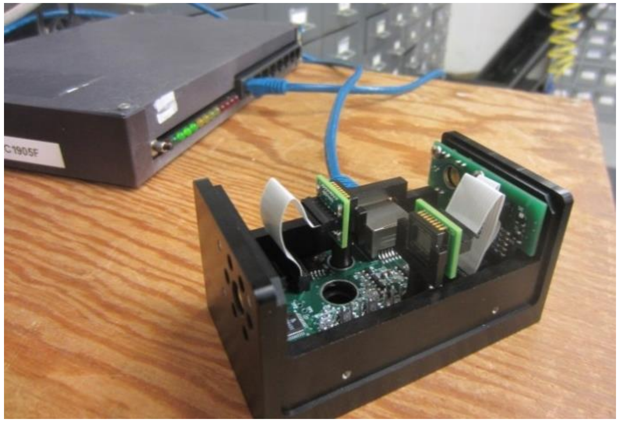
Cavity and solenoid isostatic support: Sphere – V-shape

- Precise adjustment
- Solenoid adjustment allowed in operational conditions
- Used as Target support

BCAMs

Developed on 1999 by Brandeis University for ATLAS Muon alignment

OSI (Open Source Instruments) http://alignment.hep.brandeis.edu/
http://www.opensourceinstruments.com/



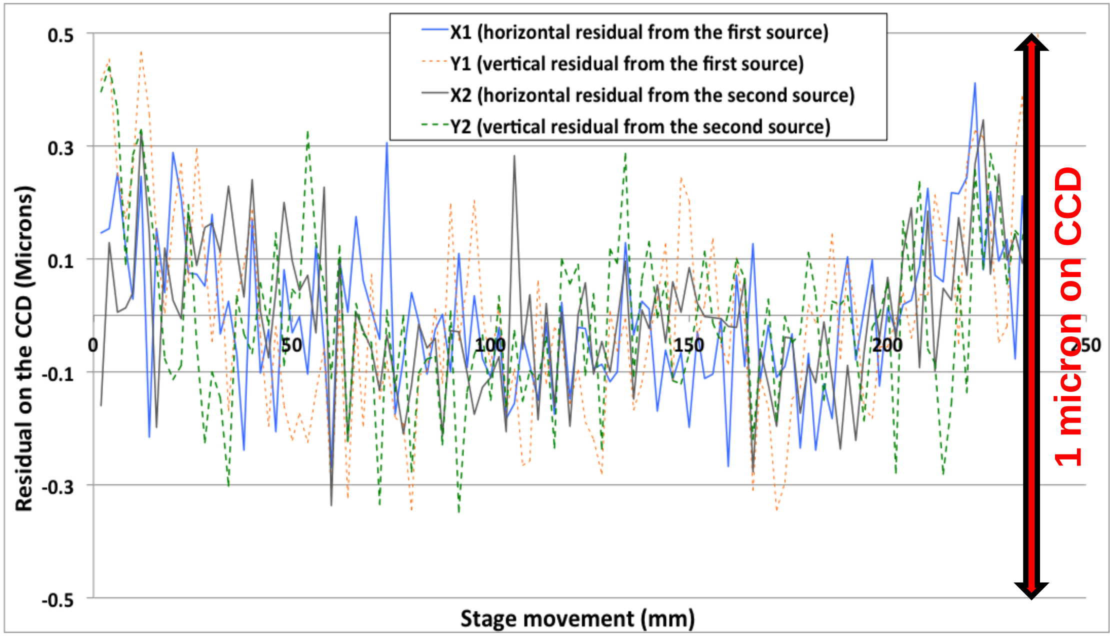
Original BCAM → **HBCAM**
Camera focal length: 72 mm → 49 mm – 50 mm
Sensor: 336 x 243 pixels 10 micr → 659p × 494p, 7.4 microns
Field of view: 40 mrad x 30 mrad → ~ 100 x 70 mrad
Sources: Laser Diodes 650 nm + Calibration of their power
+ Additional synchronized illumination system

Mounting: "Plug-in" isostatic system under the chassis
Double sided model → Chain of BCAMs

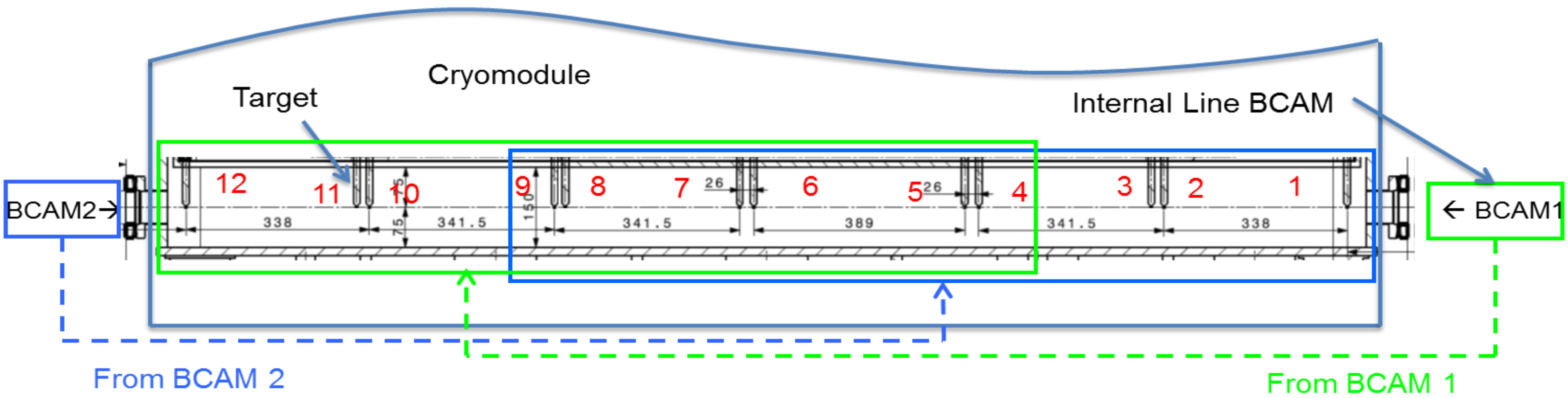
Resolution: 5 micro radians constructor (OSI)
→ Same range
Accuracy of 50 micro radians to absolute
→ Same range

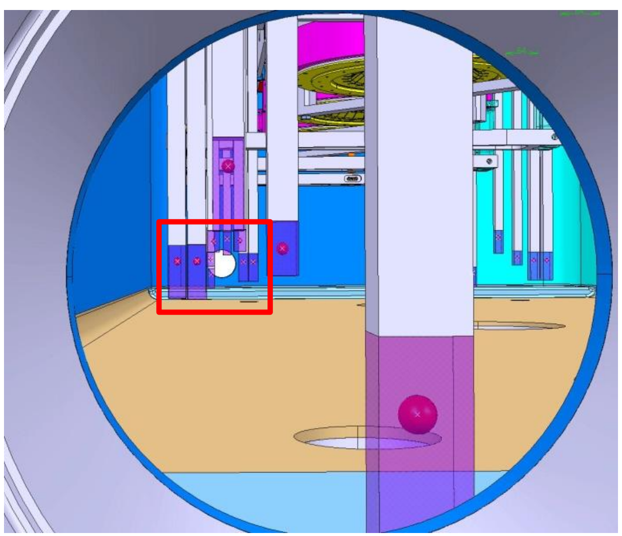
Cable length BCAM/Driver > 60 m
+ Connection on the side

Delivered calibrated (focal length, position diodes, geometric relationship with plate support)

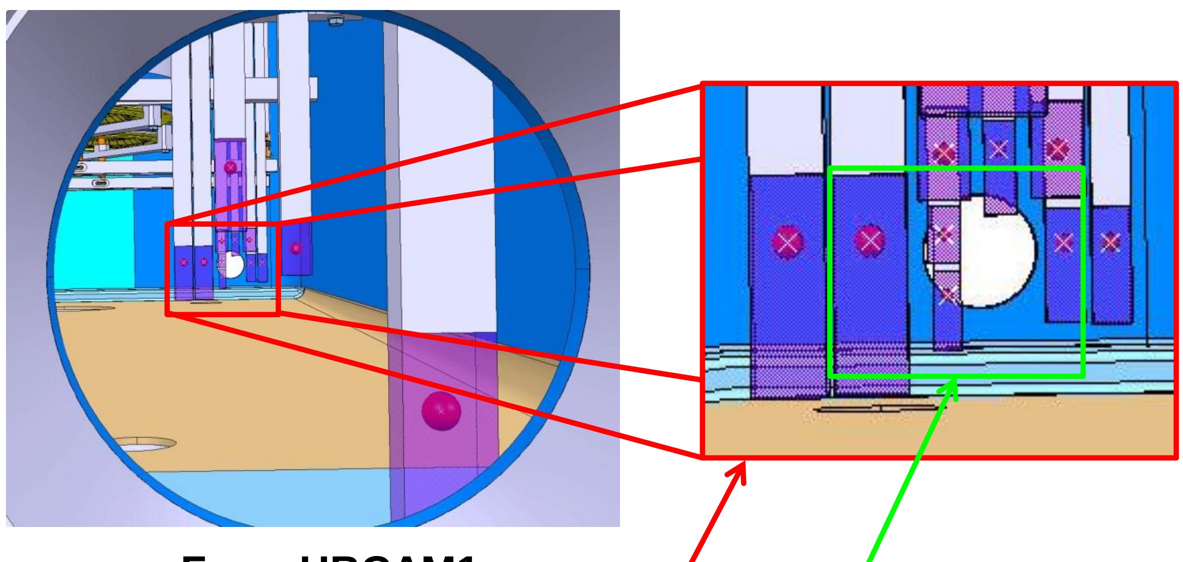


Targets Integration





From HBCAM2

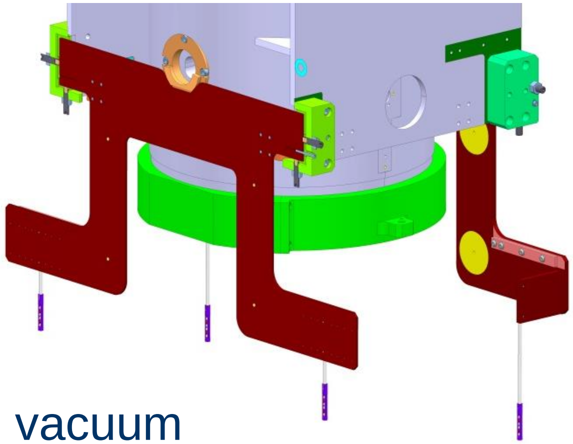


From HBCAM1

HBCAM vs BCAM Field of view

Targets Overview

Constraints → HIGH VACUUM - CRYO CONDITIONS - SIZE



Studied Target Types

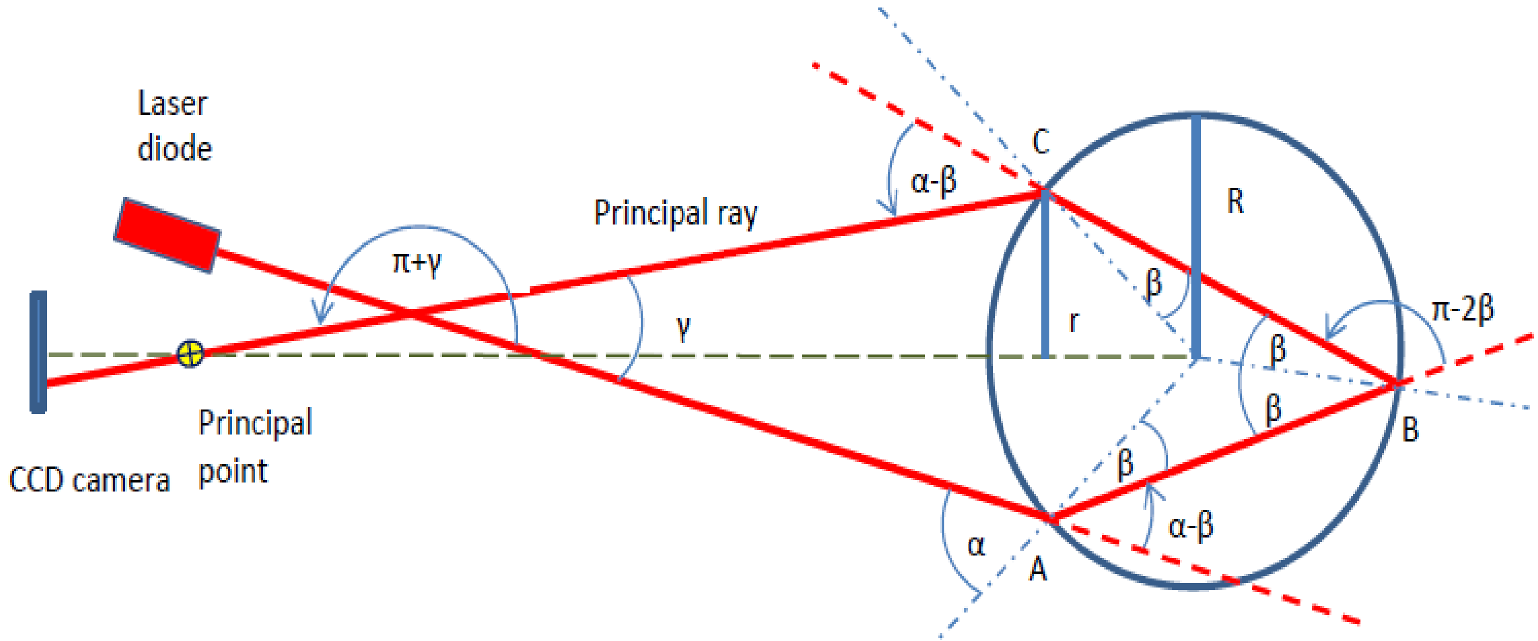
- **Silica Silica optical fiber end**
  - \- feed-through needed, one-sided target
  - \+ easy light level control, OK with cold and vacuum (tested)
- **Silica Silica optical fiber ended by a ceramic ball**
  - \- feed-through needed, connection fiber/ball
  - \+ visible from all positions, good diffuser
- **Retro-reflective targets**
  - \- illumination needed, all targets in one shot
  - \+ double-sided, passive target, no feed-through

High Index Glass Balls

High index glass ball:

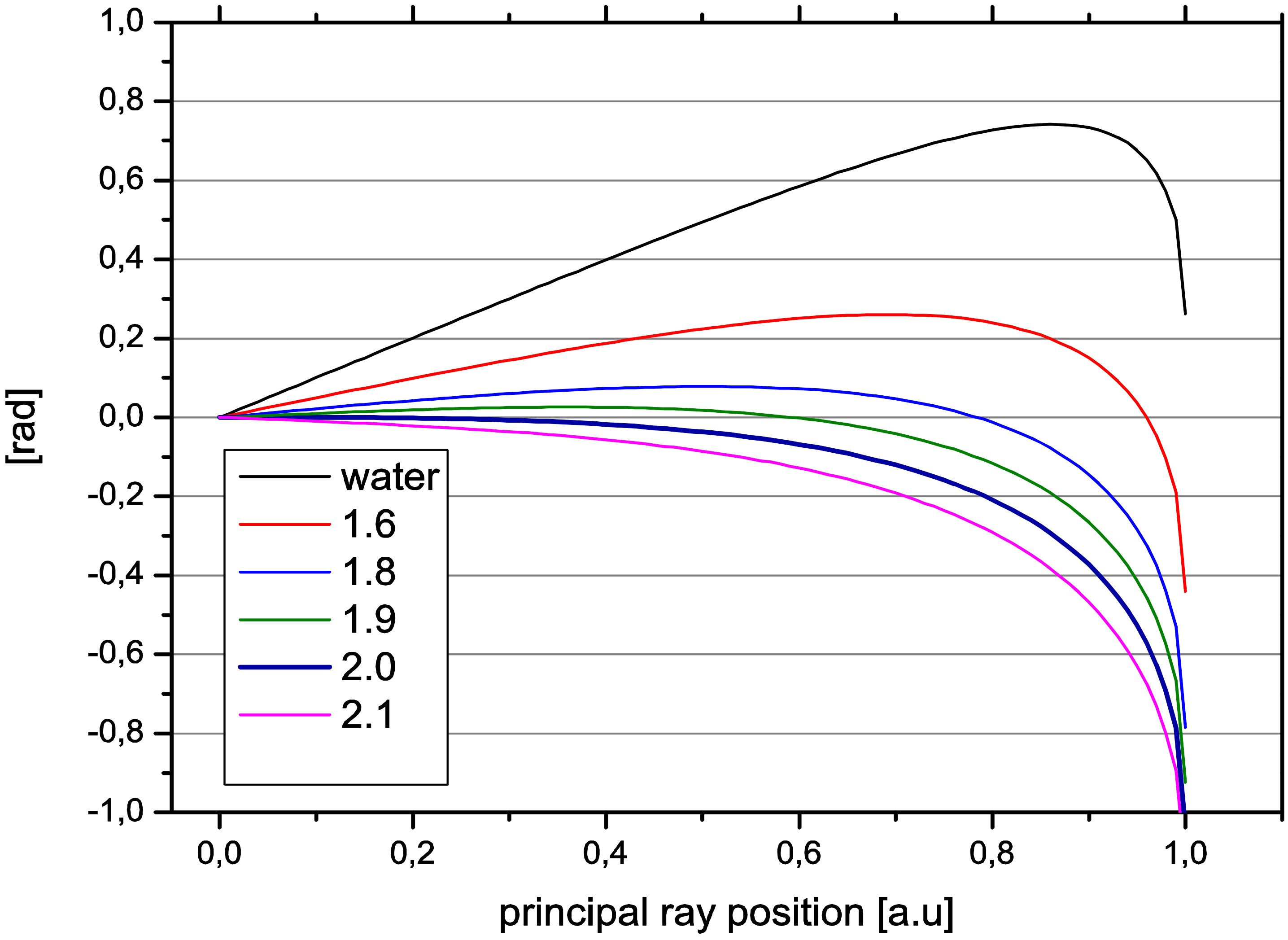
- Developed by OHARA Inc., Kanagawa, Japan
- Material : S-LAH79
- Off the shelf
- Available from diameter 1mm to 10mm
- Diameter Tolerance (µm) : 0/-3
- Sphericity (µm): 2
- Refracting index of 1.993 for HBCAM Lasers (650nm)

Study carried out by M. Šulc, Technical University of Liberec

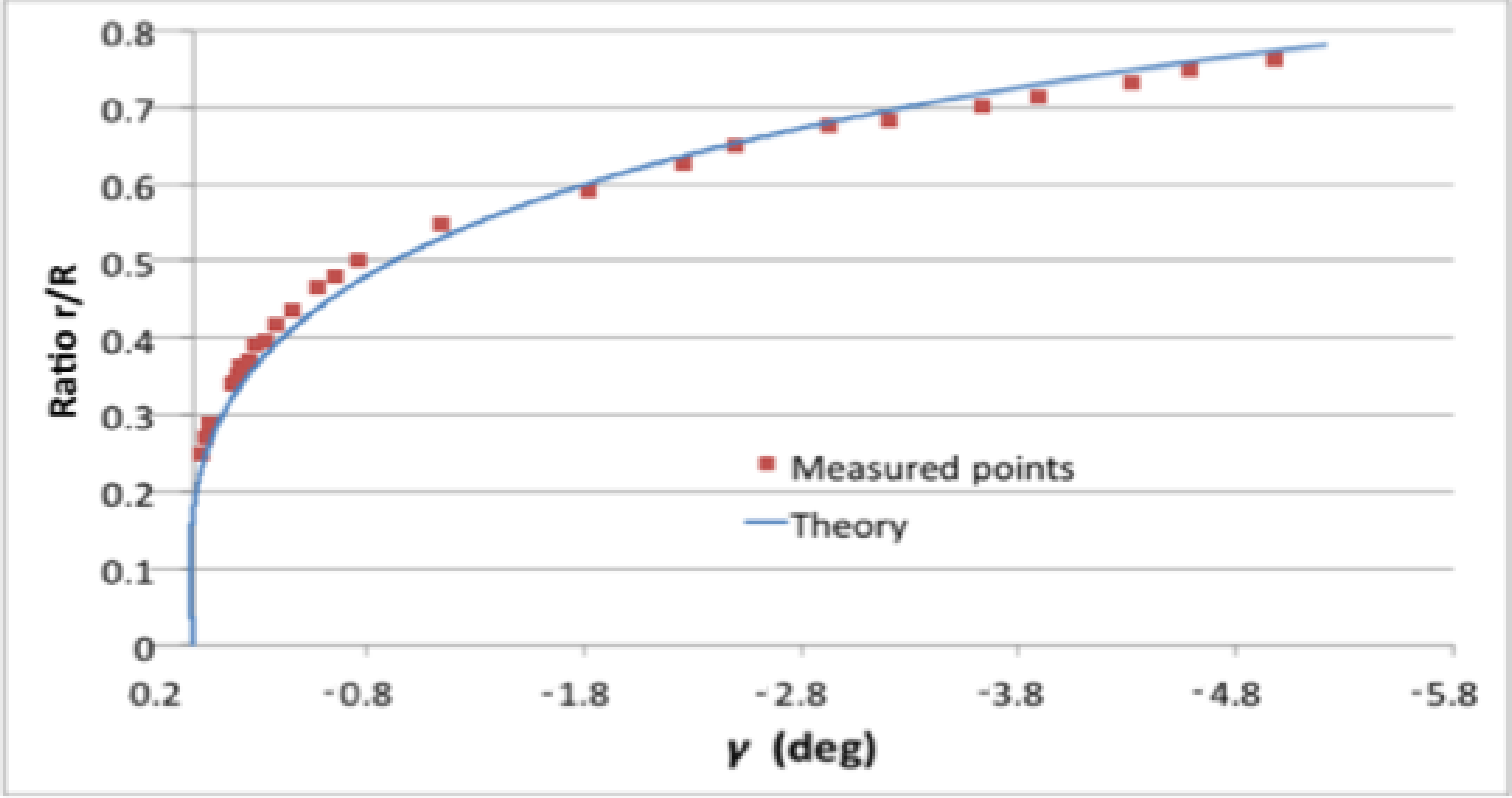


$$\gamma = 4 \cdot arcsin\left(\frac{1}{n}\frac{r}{R}\right) - 2 \cdot arcsin\left(\frac{r}{R}\right)$$

HIE-ISOLDE
Glass ball theory

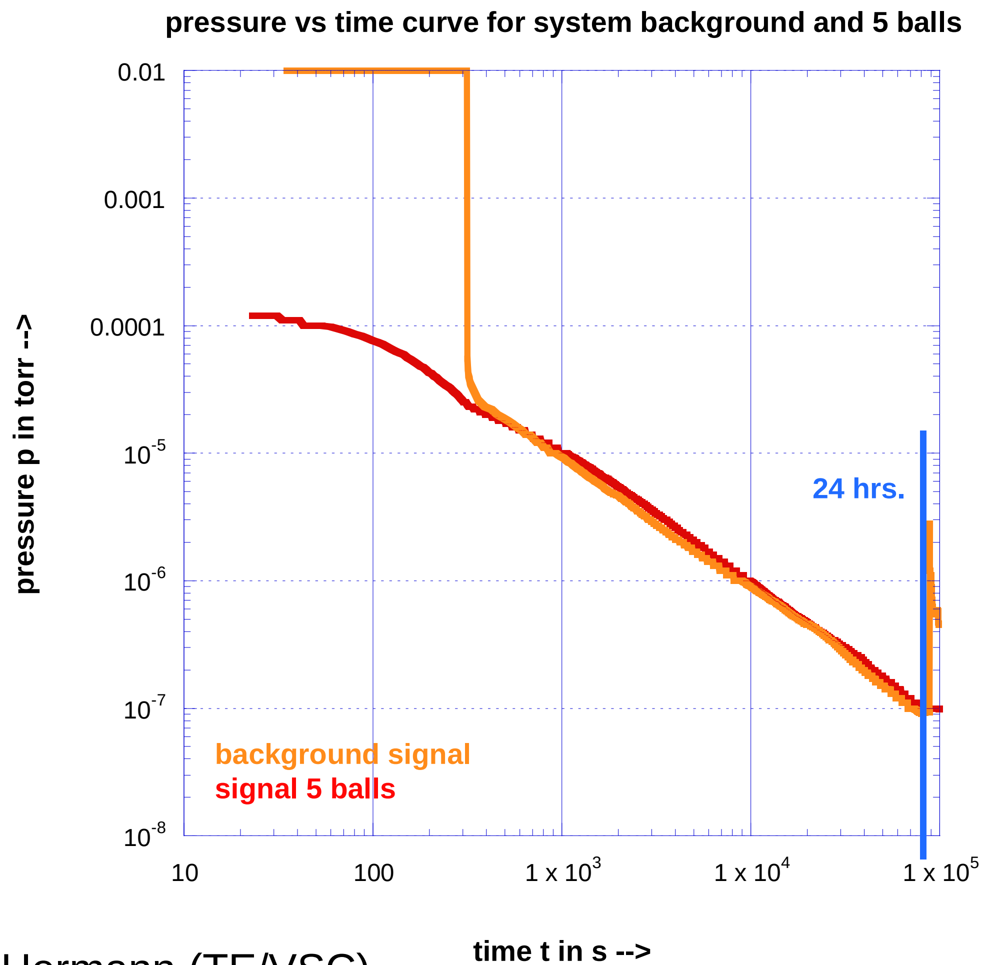


Test results



Fit well to the theory

Targets Outgassing

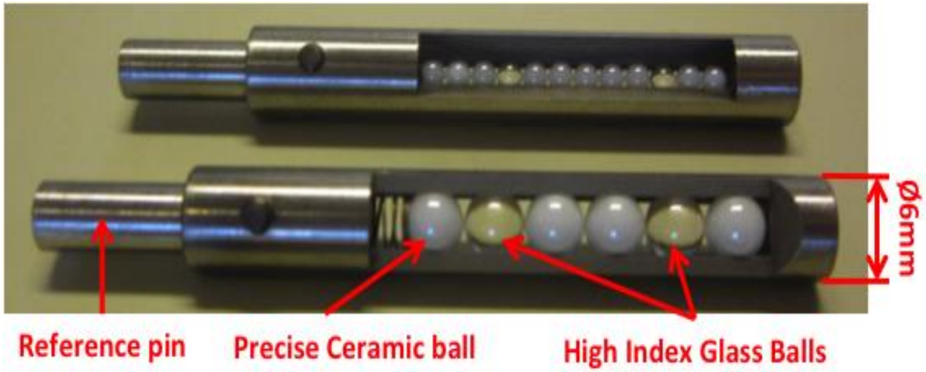


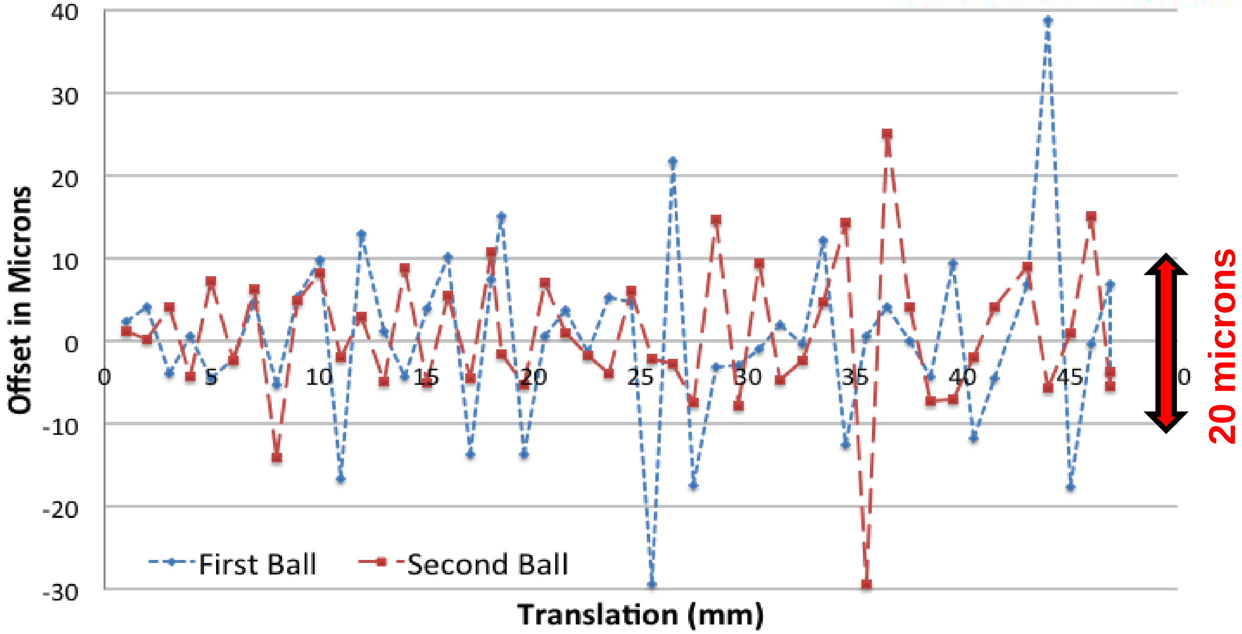
Test done by Mario Hermann (TE/VSC)

Outgassing at background level. Test done with an equivalent of 20 Ø4mm balls or 80 Ø2 mm balls.

High Index glass balls based TARGETS:

- Based on high index glass balls (Ø2 or 4mm)→ Retro reflective effect
- Double Sided
- Flashed by HBCAM Lasers
- Possibility of multi-balls targets
- Glass balls: Vacuum compatible
- Good geometrical results





Distance to target: 1.2 m
Scan over 40% of the field of view
Precision of the reconstructed movement: ~10 microns at one sigma level
Expectation: around 10 urad

Conclusion

ALIGNMENT SYSTEM MAINLY BASED ON WELL KNOWN ELEMENTS

BCAMs

- Proved and used devices
- New HBCAM inside the specifications

TARGETS

- All alternatives seem to work well (Fibers – Ceramic balls – Retro targets)
- Passive high index glass ball target looks promising → “Final” validation test on-going

VIEWPORTS

- Studied and fitting well to the theory → Easy BCAM observation corrections
- Be careful in the choice of the viewport → High optical quality needed

SOFTWARE:

- Under development
- Simulation of metrol. table position reconstruction → ~20 microns at 1 sigma level

GOAL: BE READY FOR THE VACUUM AND CRYOGENIC TESTS OF 1st CRYOMODULE

Acknowledgement:

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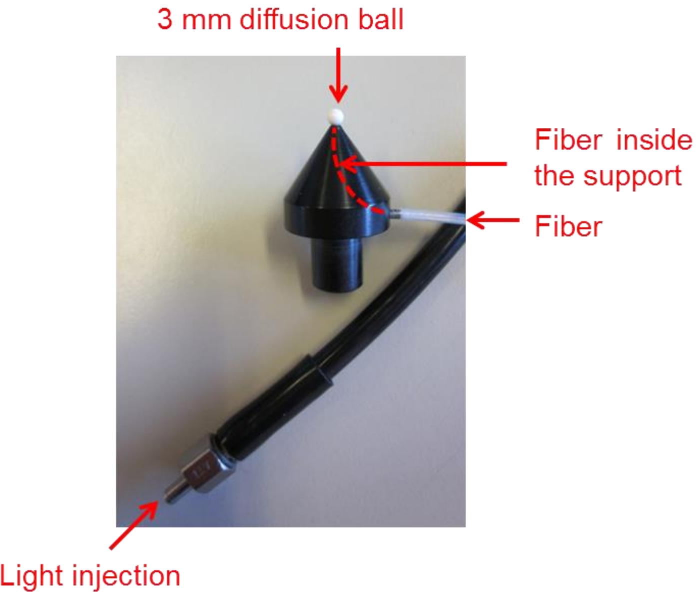
Thanks for your attention

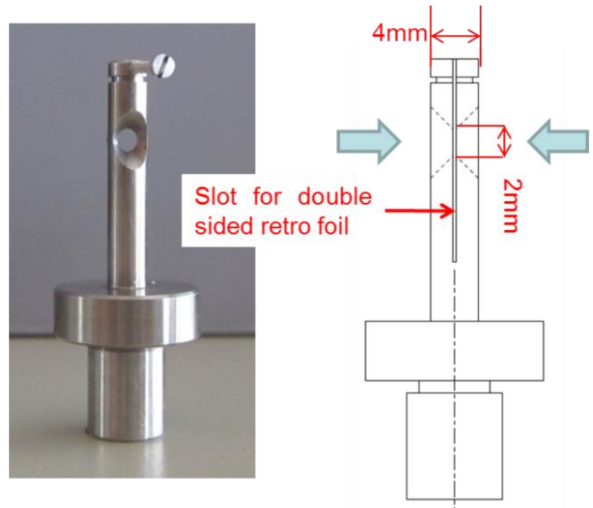
Targets
Double-sided

Three types of “double sided” targets considered

Laser illuminated ceramic balls	Retro-reflective bi-directional target	Retro-reflective high-Index Glass ball target



Test prototype for an illuminated ceramic ball synchronized to the acquisition system

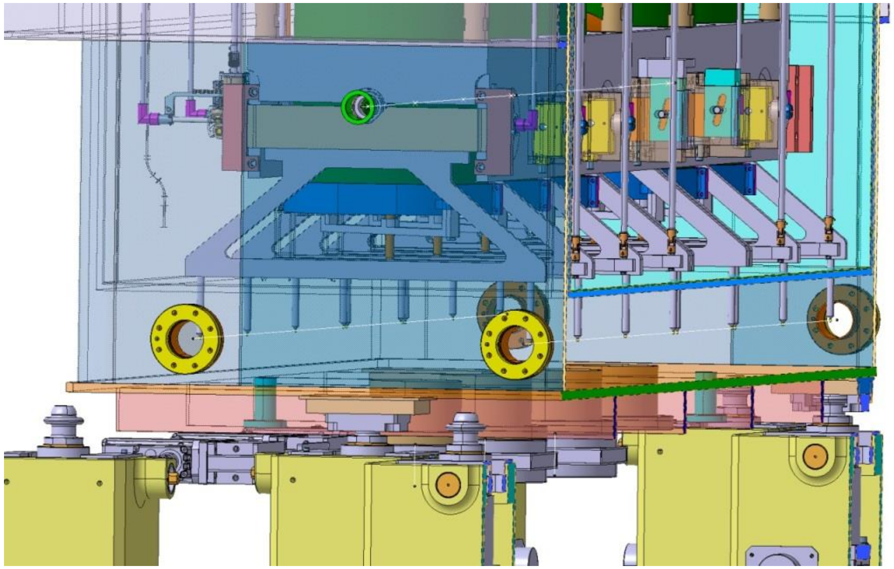


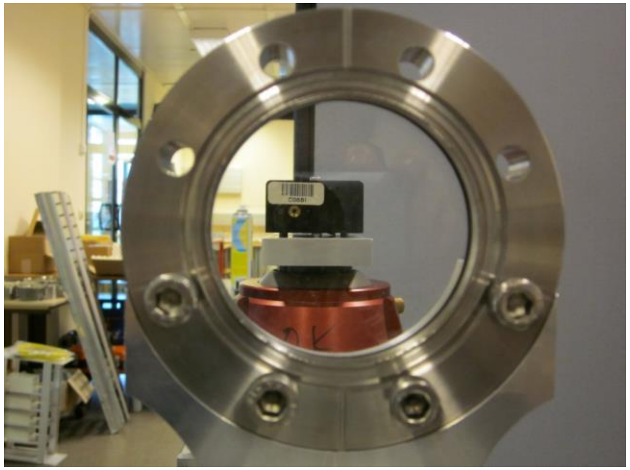
Double sided retro-reflective target Prototype

But Active targets

But Not High-Vacuum compatible

Viewports





Atmosphere / Vacuum interface

- Parallel plates window
- Viewports at CM ends (off the shelf)

Study of viewport effects on BCAM observations

- Viewport 6.55 mm thick
- 3 opt. quality classes tested
- Wedge angle
  - 10 micro-rad
- Parallel plate effect
  - 1 Deg → 40 microns
  - Match the theory → correction by software
- Deformation due to vacuum
  - Less than 0.015 deg of angular deviation

Viewports

Wedge angle

Window	Given wedge angle (microrad) from window's technical data	Wedge angle observed (microrad)	Influence on target at 1m (micr)	Influence on target at 2m (micr)
A	25	5	2.5	5
B	50	10	5	10
C	500	300	150	300

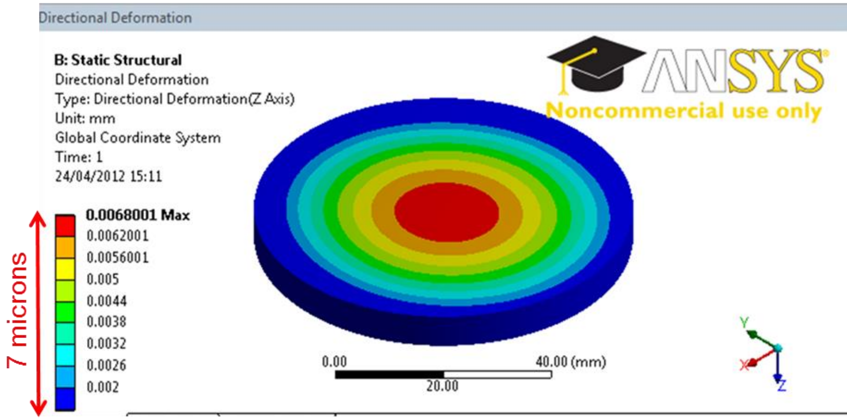
- 10 microrad wedge angle acceptable

Parallel Plate Effect

- Incident angle change of 1gon (0.9deg) → 37 microns radial object "displacement"
- Match the theory by a few microns → Easy observation correction by software
- Adjustment of the Window within less than 1 degree → Ease the correction

Vacuum deformation

- Less than 7 microns deformation at the center
- Less than 0.015 degree of angular deviation
- Deformation measurements Liberec University (CZ):
  - ✓ Results match the calculated deformations by a few microns
  - ✓ Same deformation on both side → Parallelism kept

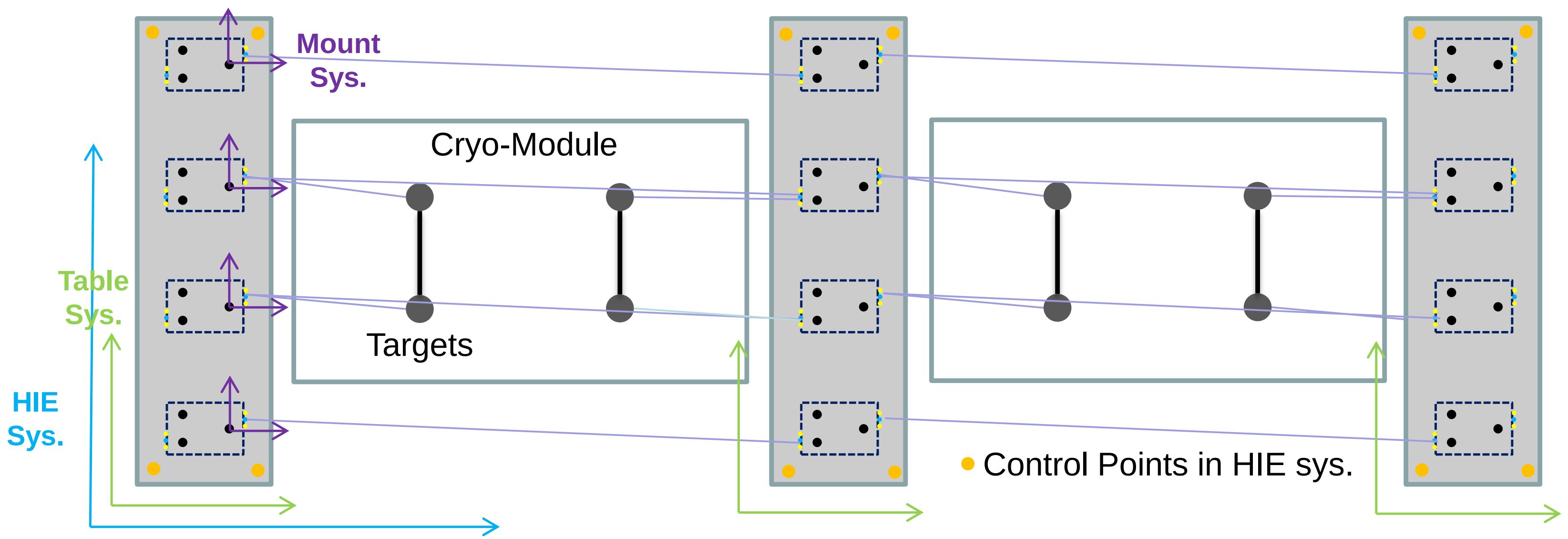


Software Coordinate Systems

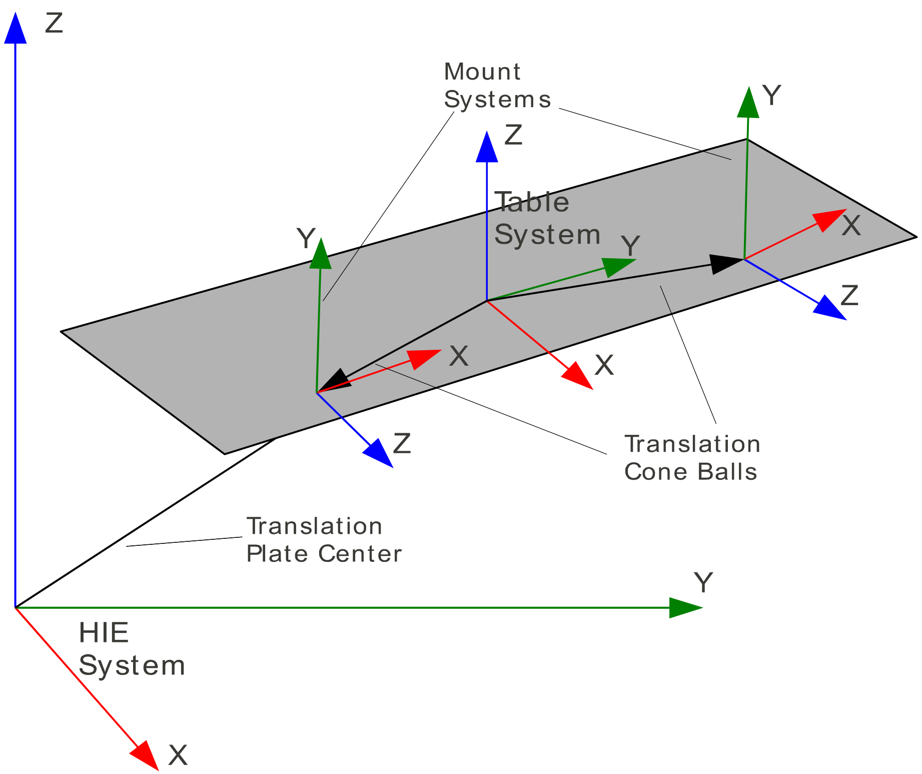
Each element has a specific coordinate system atached

Hierarchical scheme of coordinates systems :

Topmost:	HIE system	→ Link to the NBL
For each table:	Table system	→ Link between the BCAMs
For each BCAM:	Mount system	→ Calibration parameters
	CDD System	→ Observations



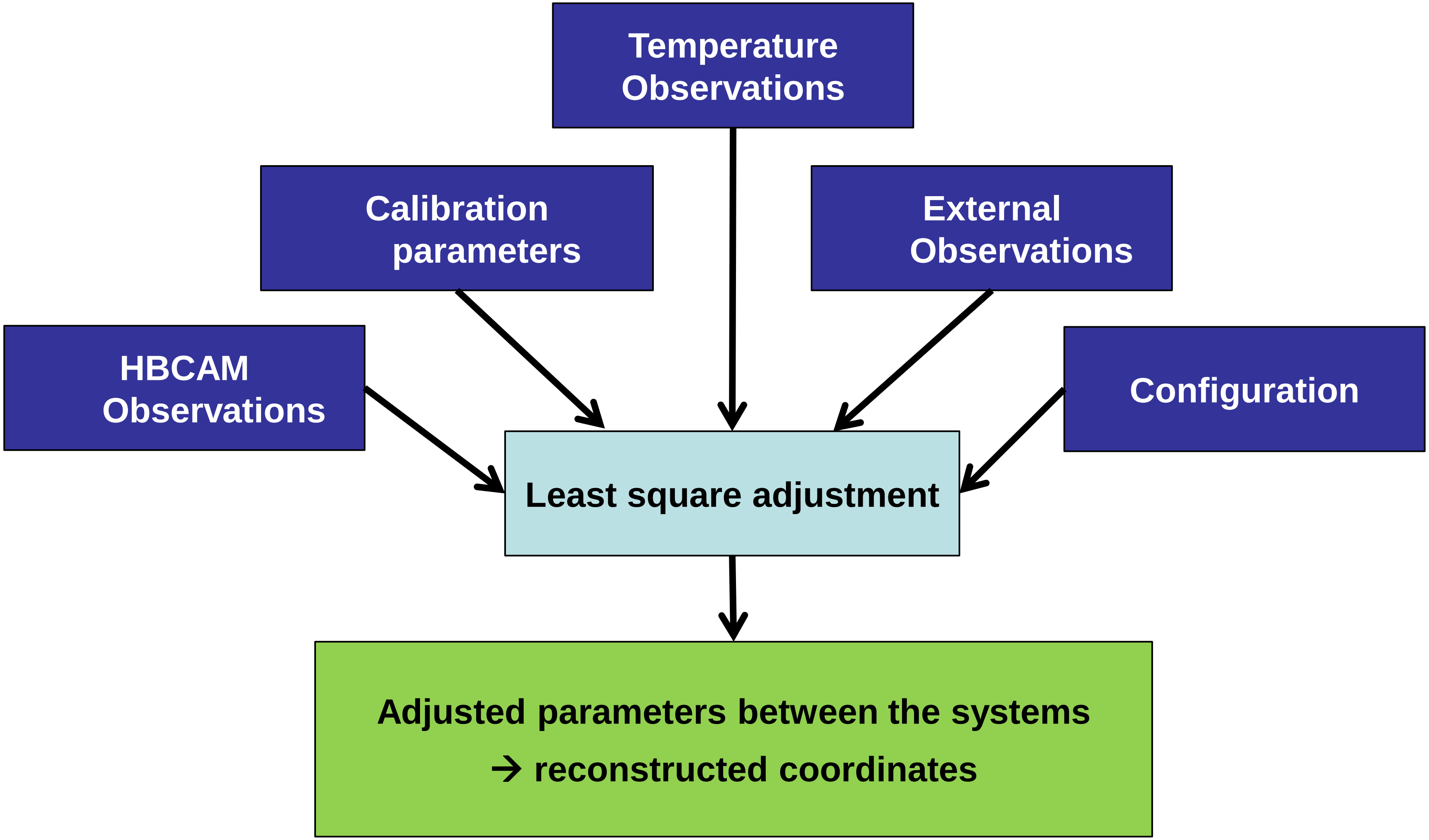
Software Adjusted Parameters



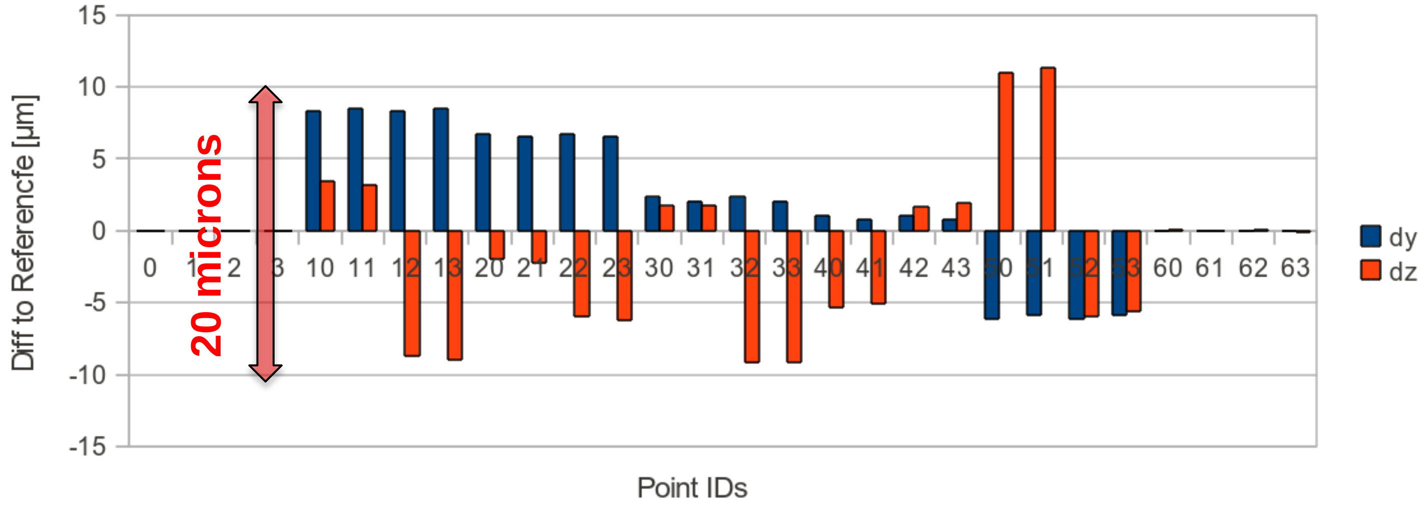
Translations and rotations for each table need to be estimated: 6 parameters per table in the setup

Relations between mount systems on the same table are fixed → Tables considered as a floating rigid body

Software Adjustment



Software
Simulation results



Σ_0^2=0.0117	σty [µm]	σtz [µm]	σrx [µrad]	σry [µrad]	σrz [µrad]
0	0.49	0.53	1.54	3.51	1.2
1	9.19	10.72	34.5	4.16	3.78
2	12.72	15.38	38.2	3.59	3.39
3	13.67	16.87	38.02	2.82	2.69
4	12.73	15.6	38.27	3.56	3.39
5	9.21	11.01	34.54	4.18	3.78
6	0.9	1.07	3.18	3.93	1.23

Overlapping improves the results by a factor 2

Still some error budget for the reconstruction of the targets