HIE-ISOLDE

Monitoring and Alignment Tracking for Hie-IsoLDE
System presentation

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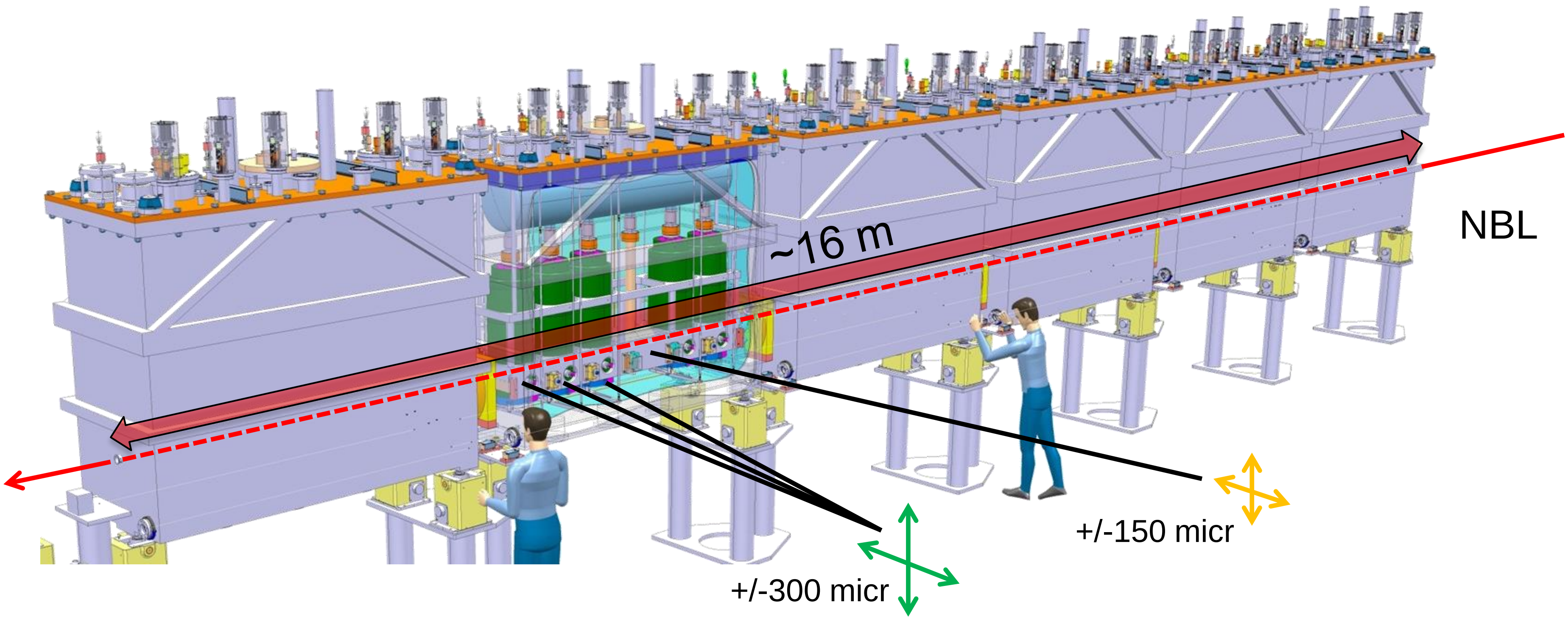
Alignment specifications
General

- Alignment and monitoring of the Cavities and Solenoids in the Cryomodules w.r.to a common nominal beam line (NBL) along the Linac
- Permanent 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

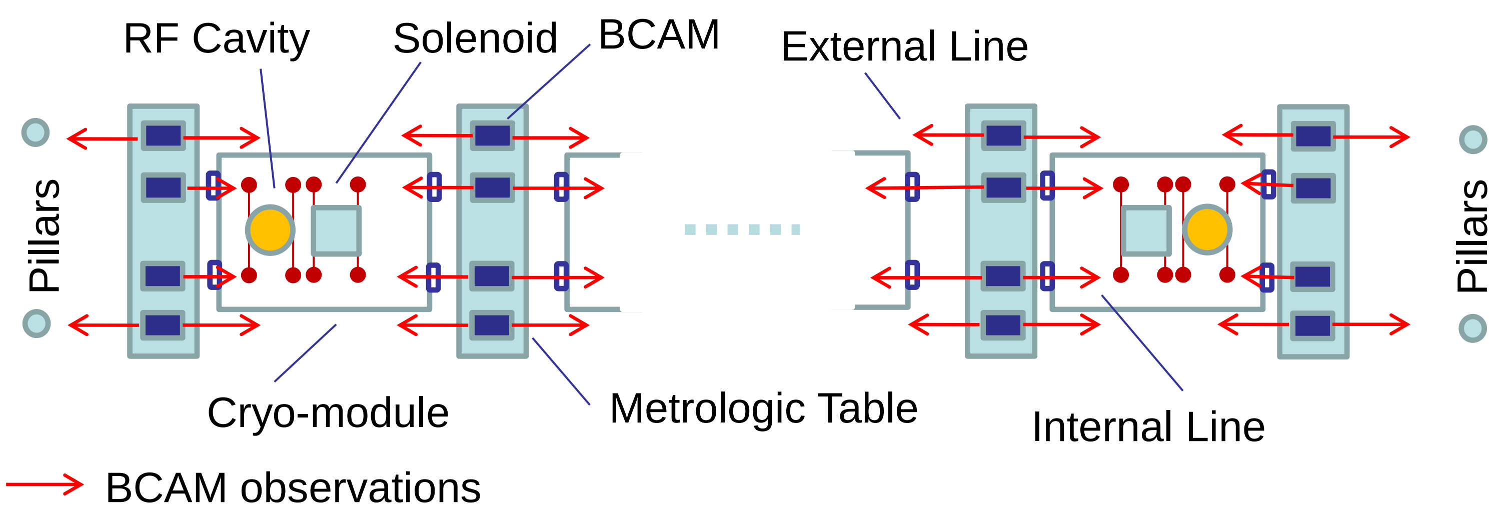
- Creation of a closed geometrical network continuously measured
- Observation and position reconstruction of Cavities and Solenoid in this Network

SYSTEM

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

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

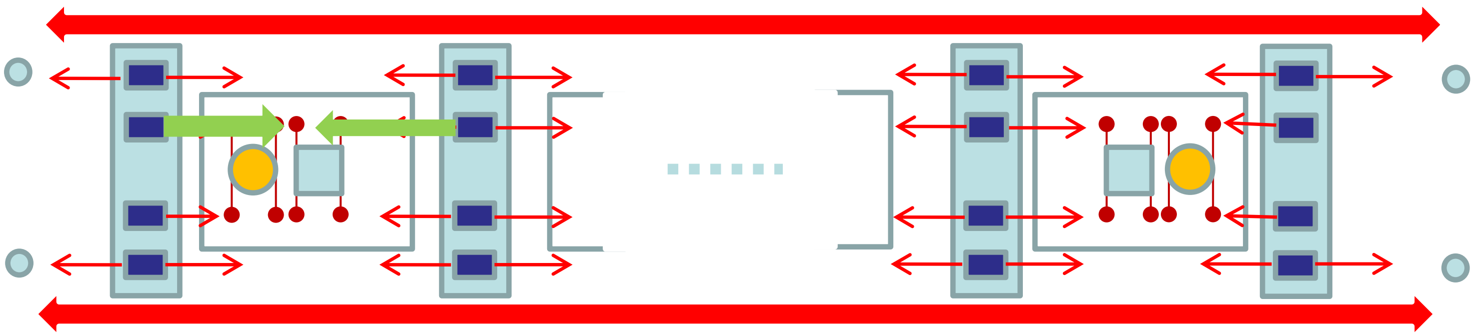
Internal Lines => Position of the targets inside the tank



Alignment specifications

Alignment System

Top view

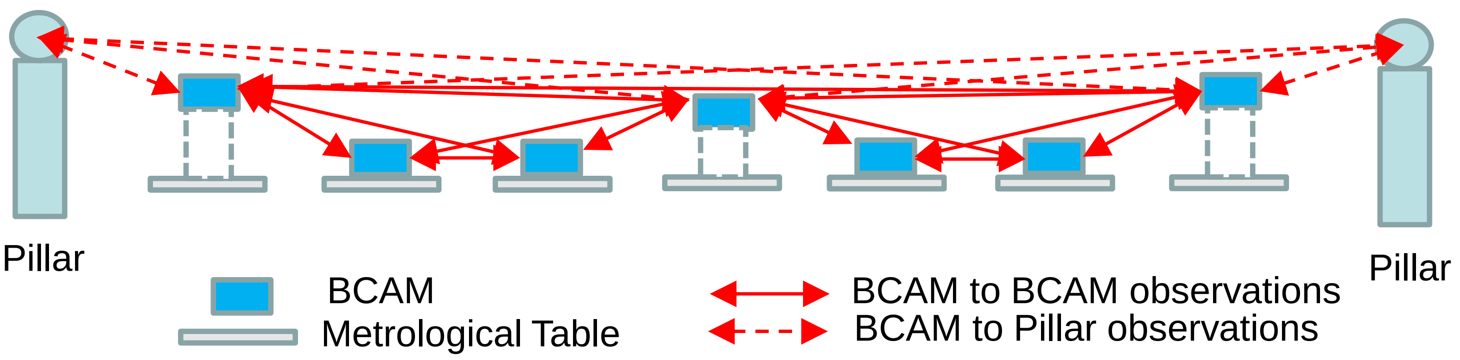


Overlapping zone of BCAM obs. on external lines

Double sided targets observations on internal lines

=> Redundancy

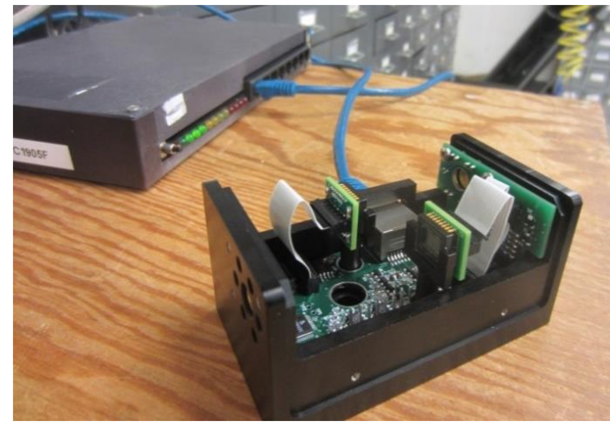
Side view
Ext. line
Overlapping



HBCAMs

Developed on 1999 by Brandeis University for ATLAS Muon alignment

Thanks to: J. Bensinger
K. Hashemi



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

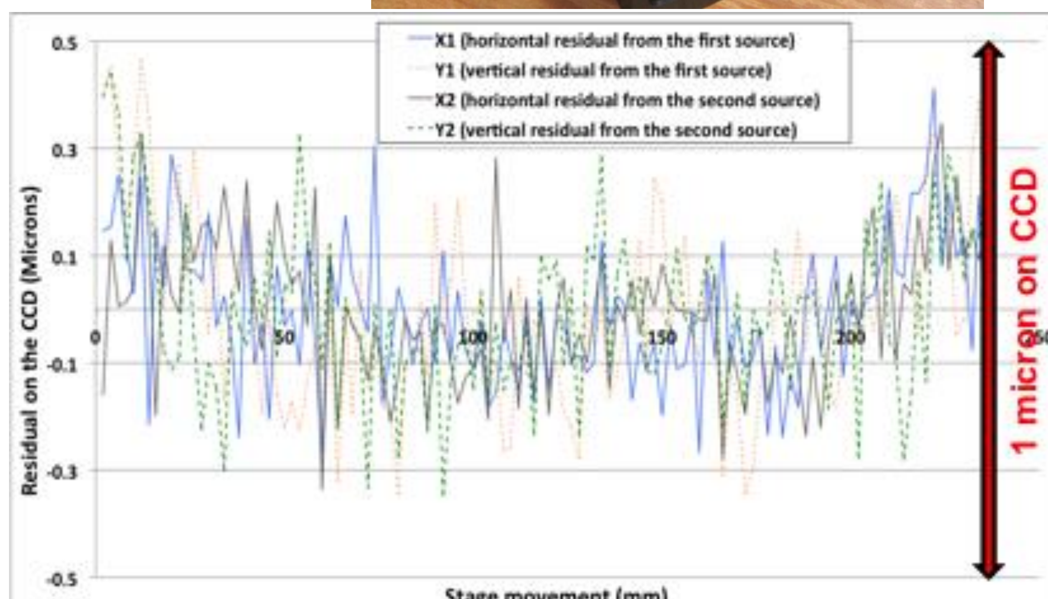
Original BCAM → **HBCAM**
Camera focal length: 72 mm → 49 mm – 50 mm
Sensor: 336 x 243 pixels 10 micr → 659p × 494p, 7.4 microns
Field of view: 40 mrad x 30 mrad → ~ 100 x 70 mrad
Sources: Laser Diodes 650 nm + Calibration of their power
+ Additional synchronized illumination system

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

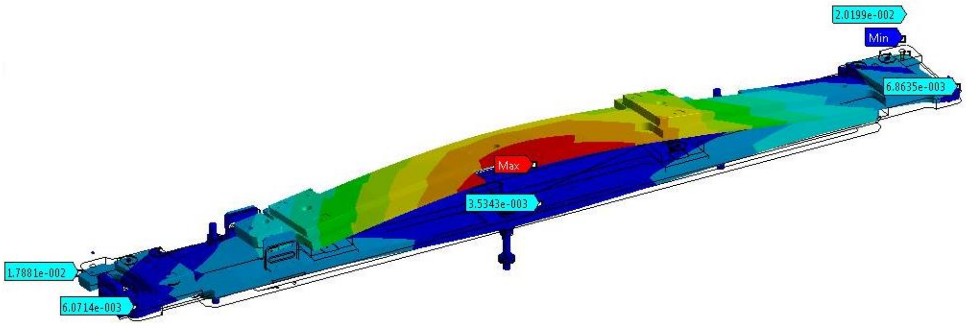
Cable length BCAM/Driver > 60 m
+ Connection on the side

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

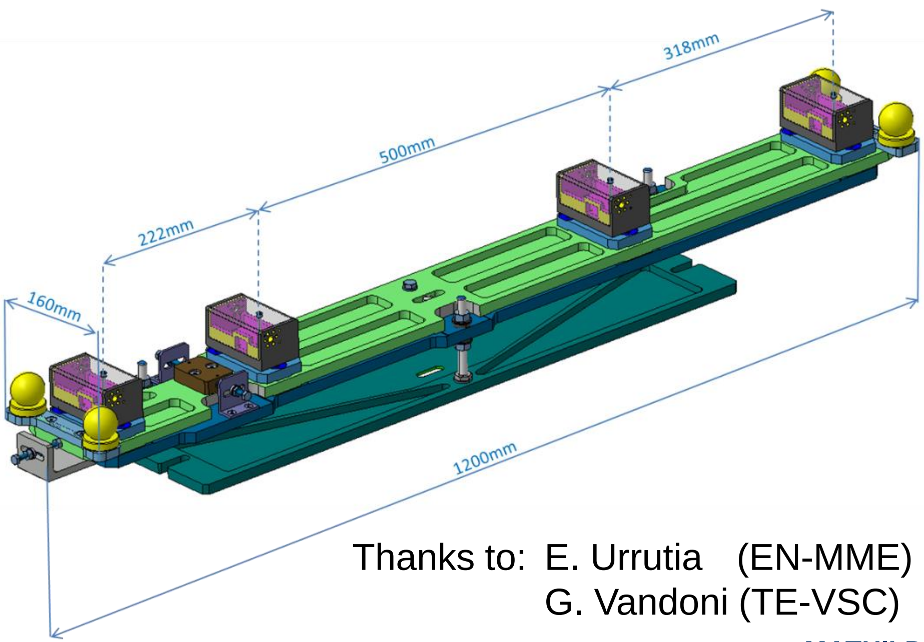


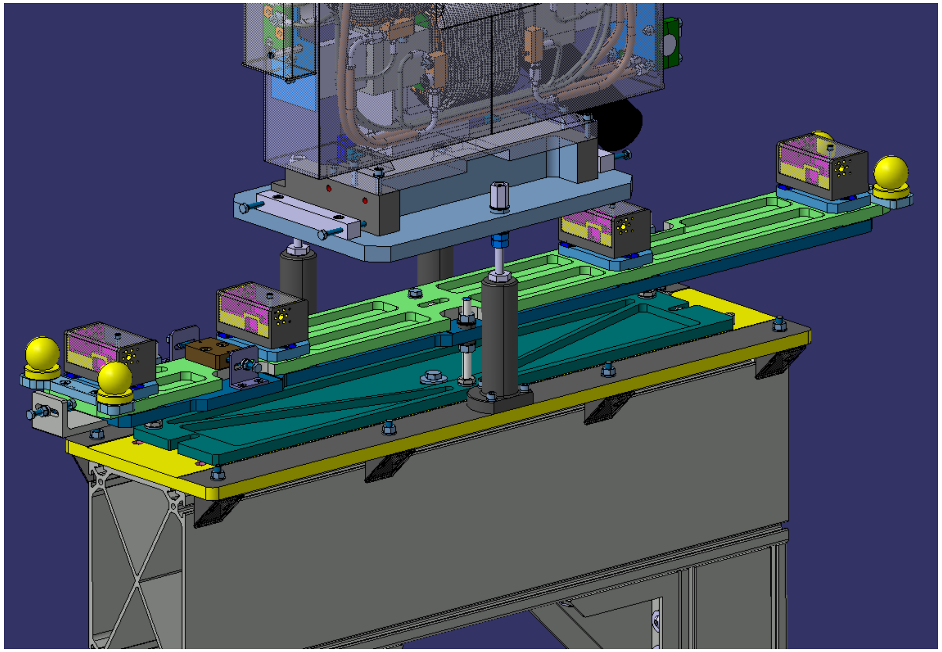
Metrologic table

- Integration in a busy space
- Metrology of the HBCAM supporting interface and fiducial marks
- Table inserted as an ensemble
- Holes to lighten the table (~11kg with adjustment)
- Supporting decoupled from the DB and the Steerer



→ Close to final design, price inquiry launched

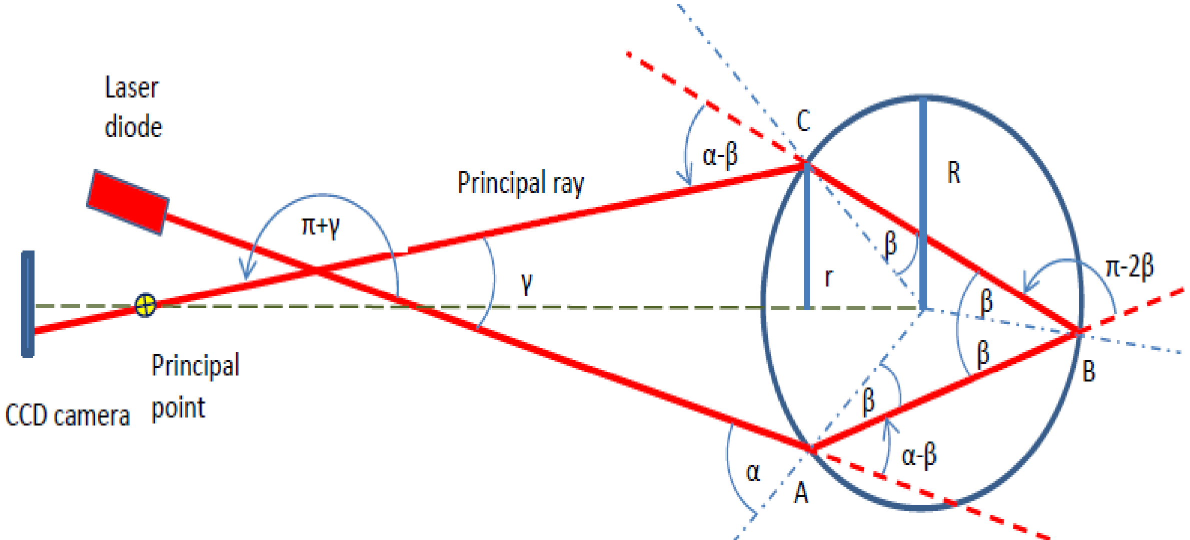




Thanks to: E. Urrutia (EN-MME)
G. Vandoni (TE-VSC)

Targets
High Index Glass Balls

- 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)

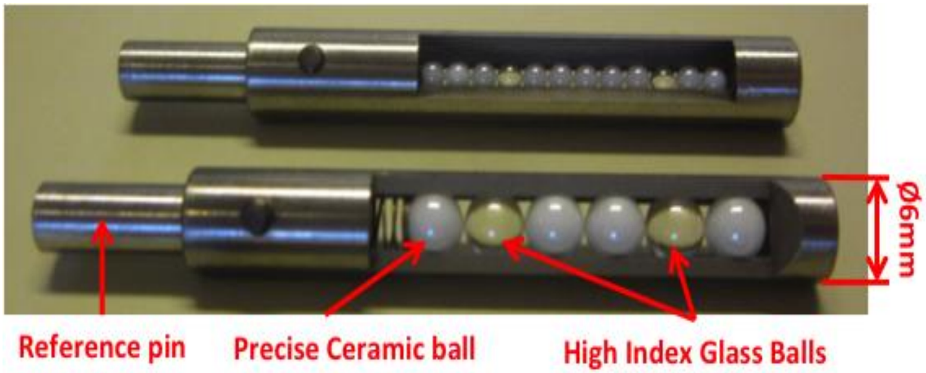


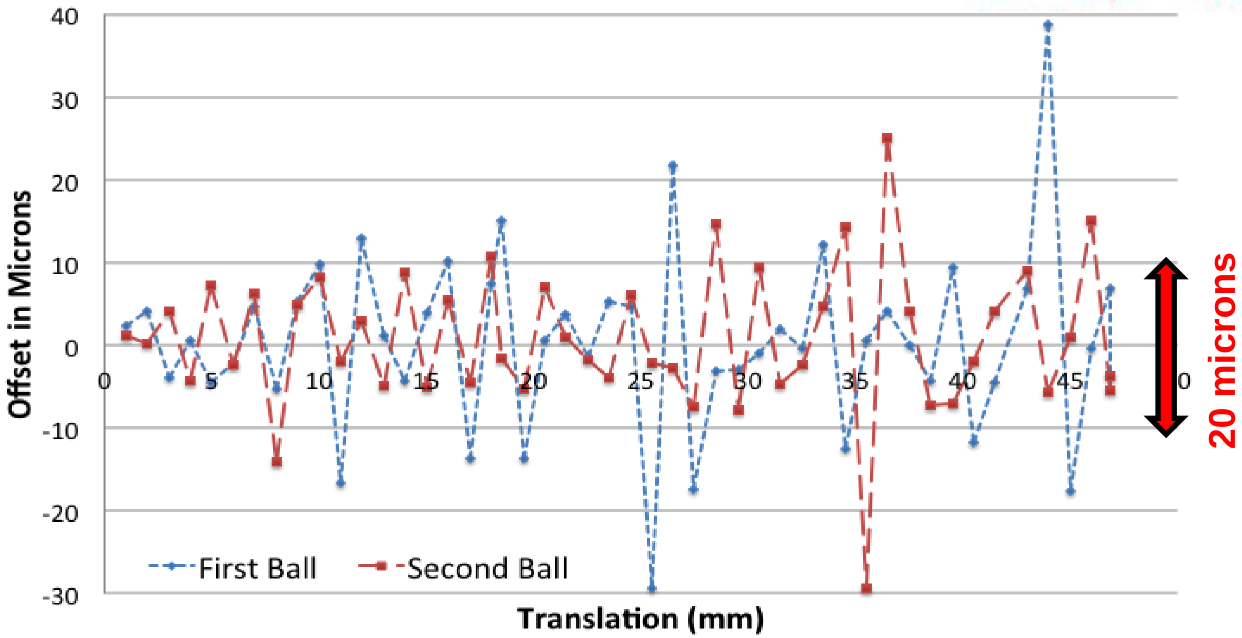
Thanks to: M. Šulc (Liberec Universtiy, Czech Republic)

Targets
High-Index Glass

High Index glass balls based TARGETS:

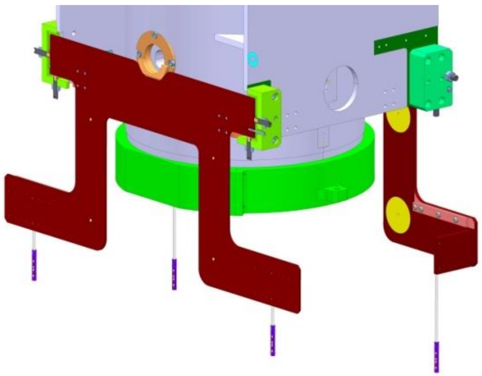
- Based on high index glass balls (Ø2 or 4mm)→ Retro reflective effect
- Double Sided
- Flashed by HBCAM Lasers
- Possibility of multi-balls targets
- Good geometrical results
- High vacuum compatible: tested
- Cryogenic conditions (5K) compatible: tested





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

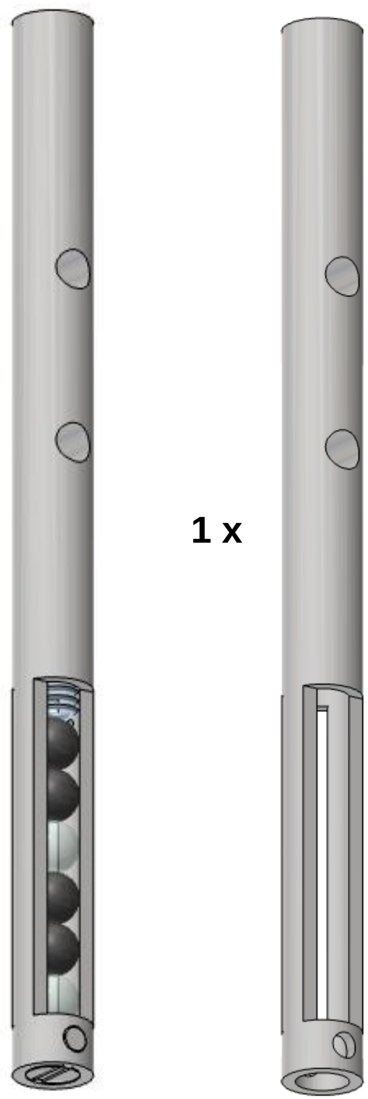
Targets
High-Index Glass



Final design:

- Ø4mm Glass ball
- Target loading by the bottom
- External diameter 6mm
- Titanium body
- 5 different lengths/CM

→ Order to be placed soon



1 x Titanium target body

1 x  Stainless steel spring

4 x  Ø4mm Ceramic Ball

2 x  Ø4mm glass Ball

1 x  Ø2mm Stainless steel pin

1 x  Titanium target plug

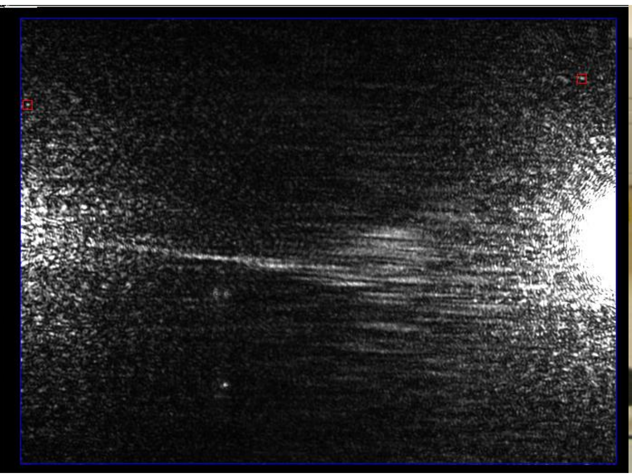
Viewports

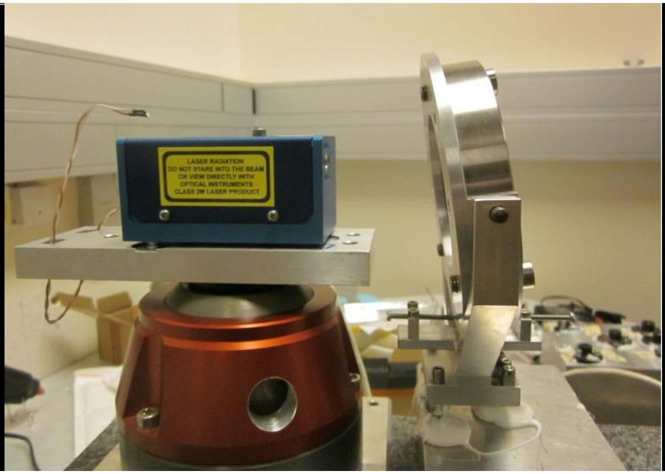
A viewport with an angle:

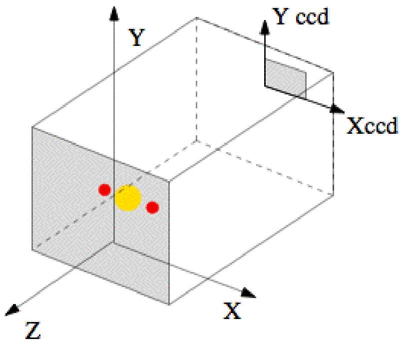
Viewport with 5 degree angle w.r.t. the HBCAM axis

→ Avoiding parasitic reflection for passive target observation

→ Viewport mounted with a 5 deg. angle in the flange





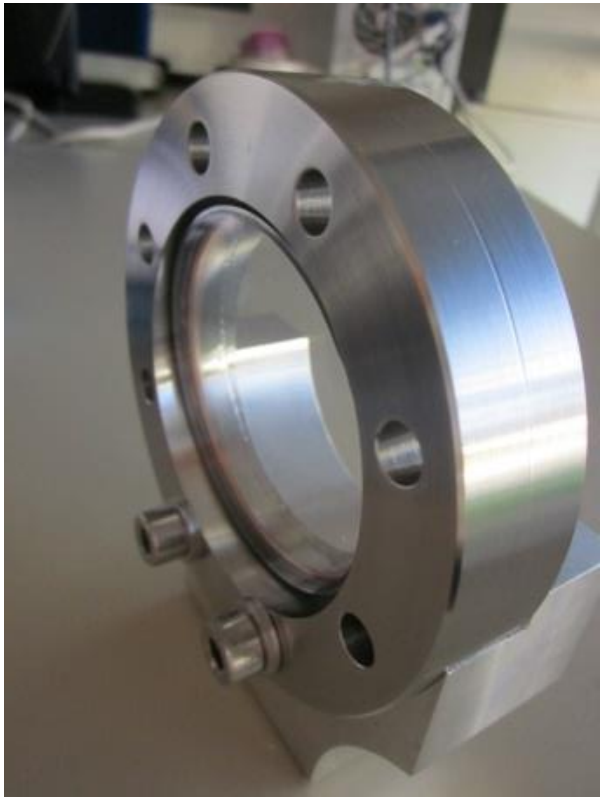


Minimum rotation values:

- Around Y 4 deg.
- Around X 3 deg.

Viewports

With the help of :
G. Vandoni (TE-VSC)



Atmosphere / Vacuum interface

- Parallel plates window
- Studied and validated for:
  - Wedge angle
  - Parallel plate effect
  - Deformation due to vacuum

- Angle w.r.t HBCAM axis ≈ 5 deg
  integrated in the viewport design
  Special request to the manufacturer
  effect corrected by software

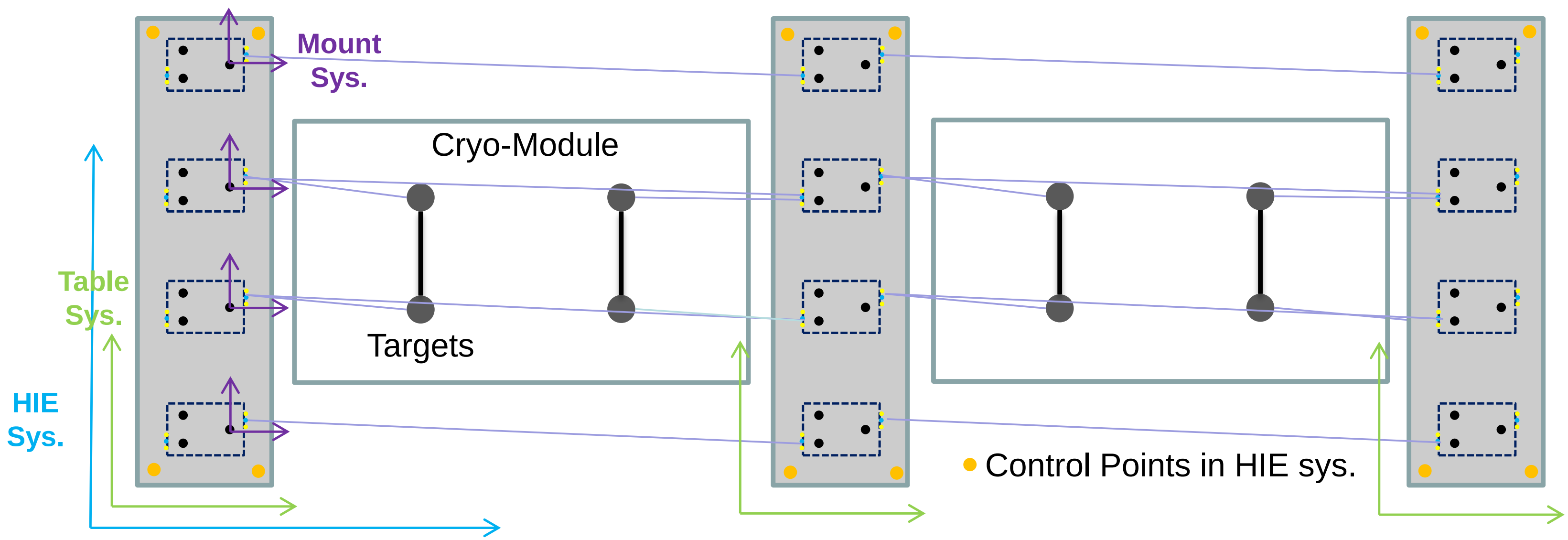
→ Viewport for 2 CM delivered and validated

Software Coordinate Systems

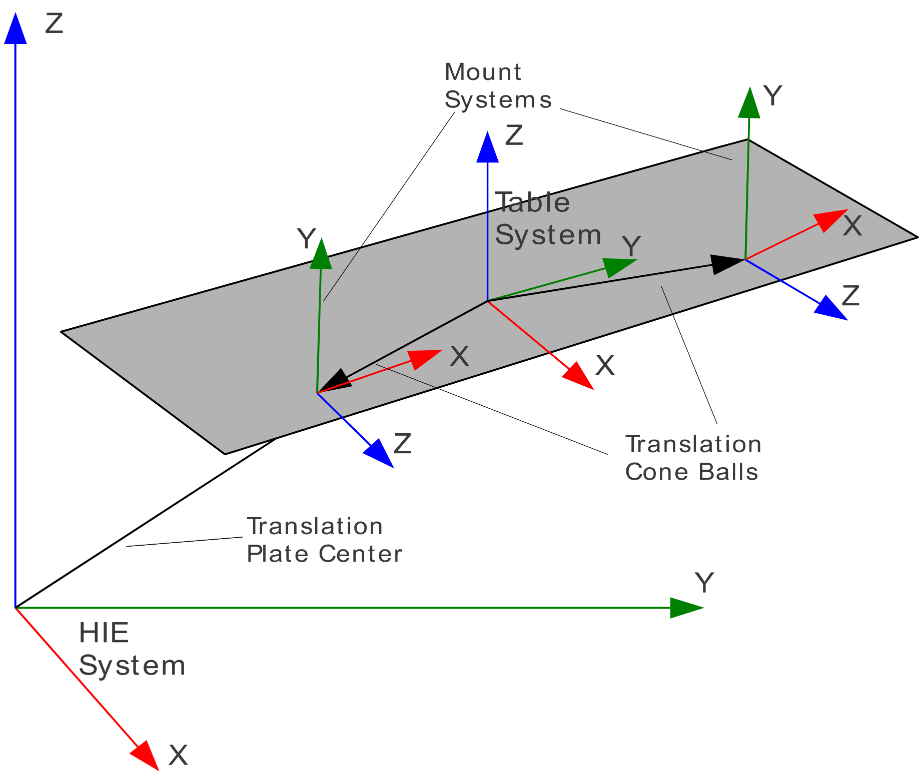
Each element has a specific coordinate system atached

Hierarchical scheme of coordinates systems :

Topmost:	HIE system	→ Link to the NBL
For each table:	Table system	→ Link between the HBCAMs
For each HBCAM:	Mount system	→ Calibration parameters
	CDD System	→ Observations
	Pivot point, lasers sources,....	



Software
Adjusted Parameters



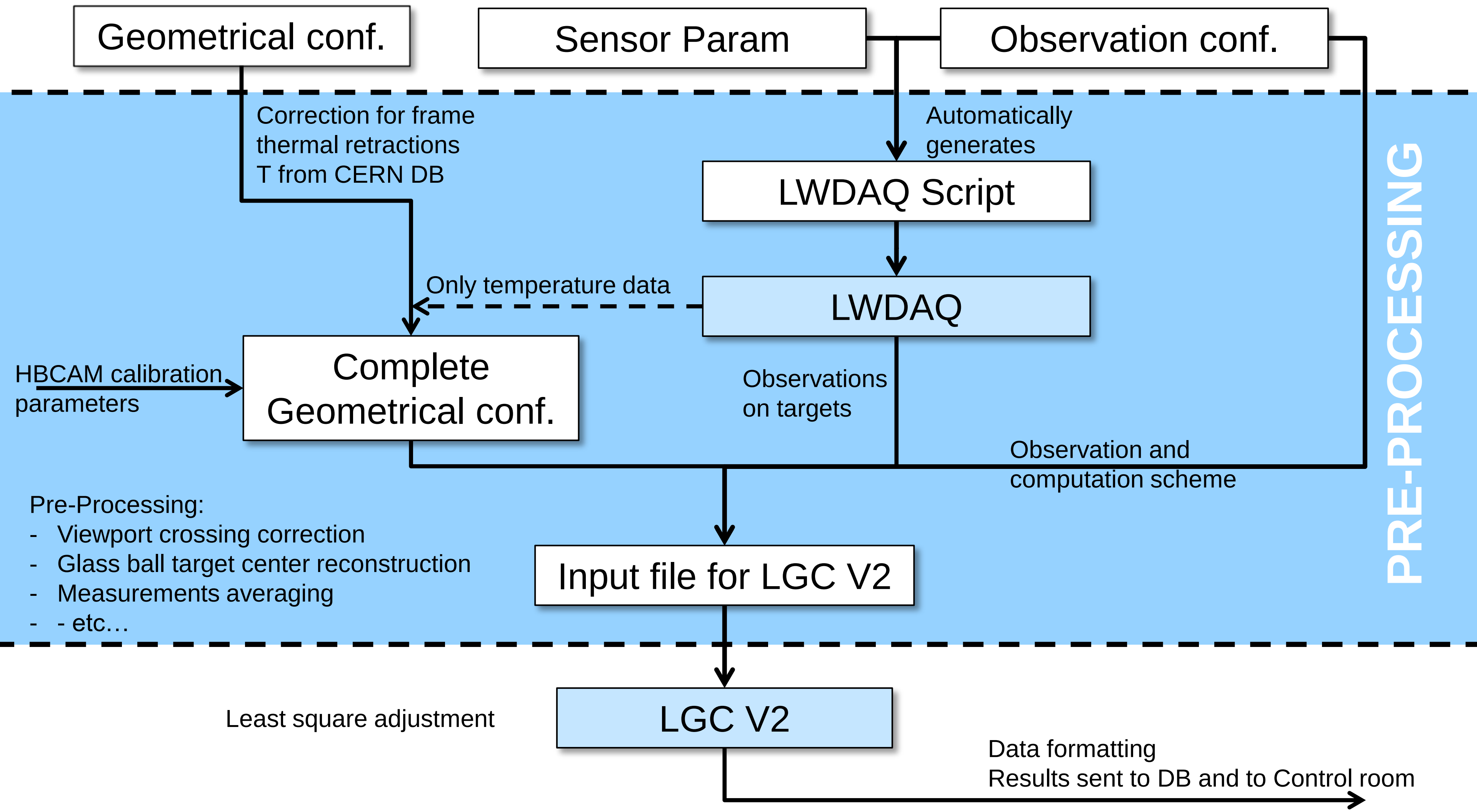
Translations and rotations for each table need to be estimated: 6 parameters per table in the setup

Relations between mount systems on the same table are fixed

→ Tables considered as a floating rigid body

Software Data flow

Description of the full system by 3 XML files

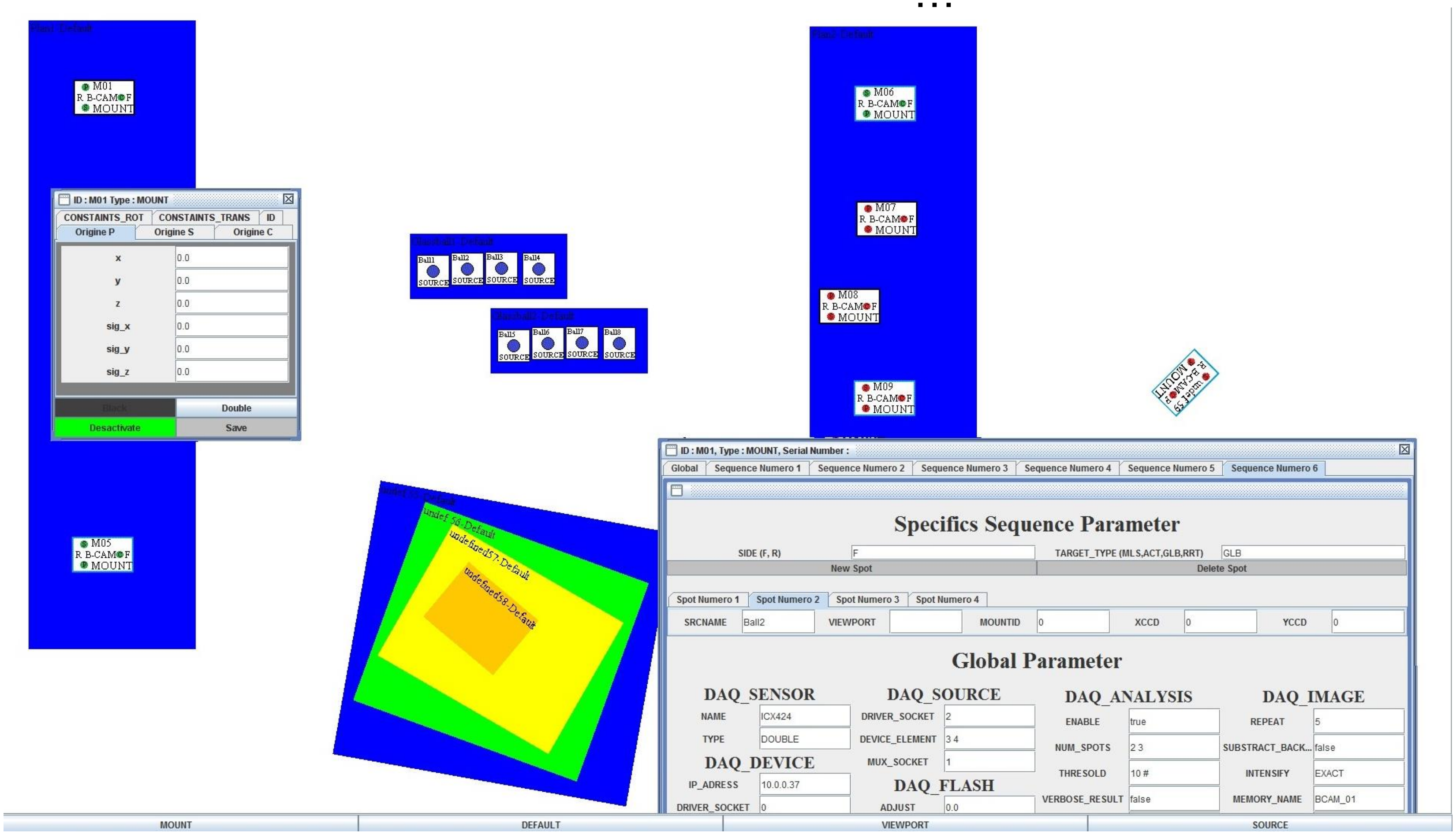


Software GUI

GUI developed

→ Automated generation of the XML Files

- Geometrical (frame hierarchy,..)
- Observation configuration
- …



Conclusion

ALIGNMENT SYSTEM MAINLY VALIDATED

HBCAMs

- Proved and used devices
- HBCAM developed, validated and procured

METROLOGICAL TABLE

- Integrated in the Inter-Tank area
- Close to final design

VIEWPORTS

- Fit well to the theory → Easy BCAM observation corrections
- High optical quality needed
- Delivered and validated

TARGETS

- Passive high index glass balls
- Targets ordered

SOFTWARE

- Development on-going
- Use of LGC V2

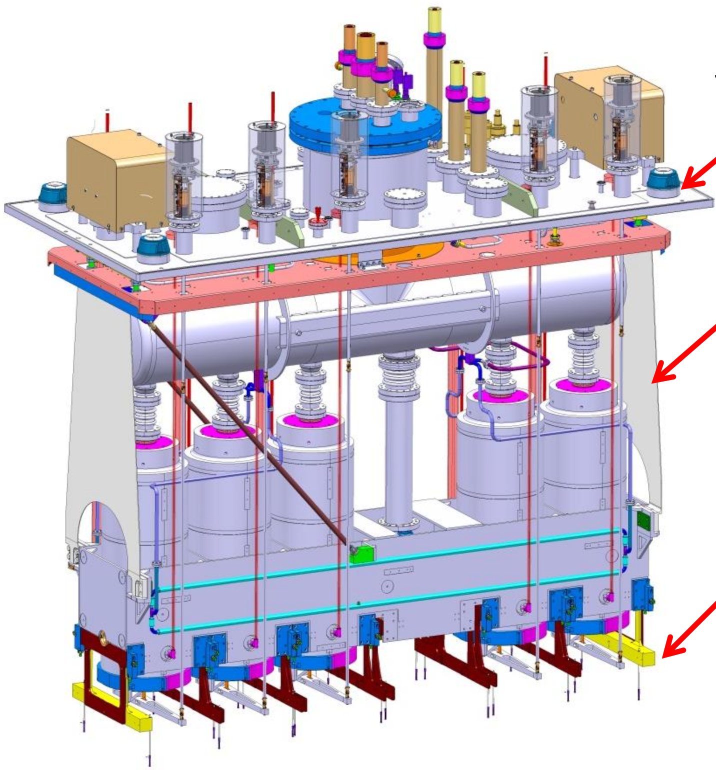
Acknowledgement:

This research project has been supported by a Marie Curie Early Training Network Fellowship of the European Community's Seventh Framework Programme under contract number (PITN-GA-2010-264330-CATHI).

Thanks for your attention

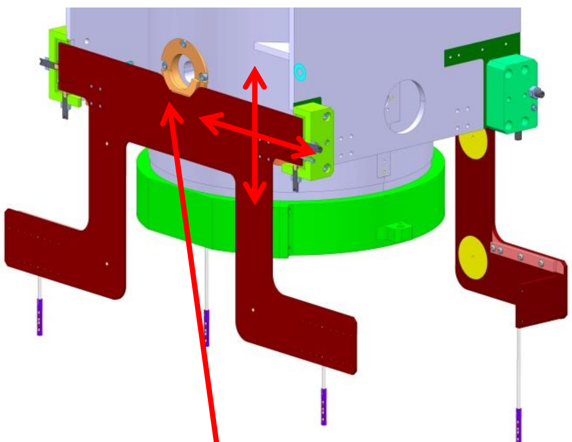
Supporting and adjustment

Cryomodule assembly in ISO Class 5 clean room



Survey sockets → Assembly / CM pre-alignment

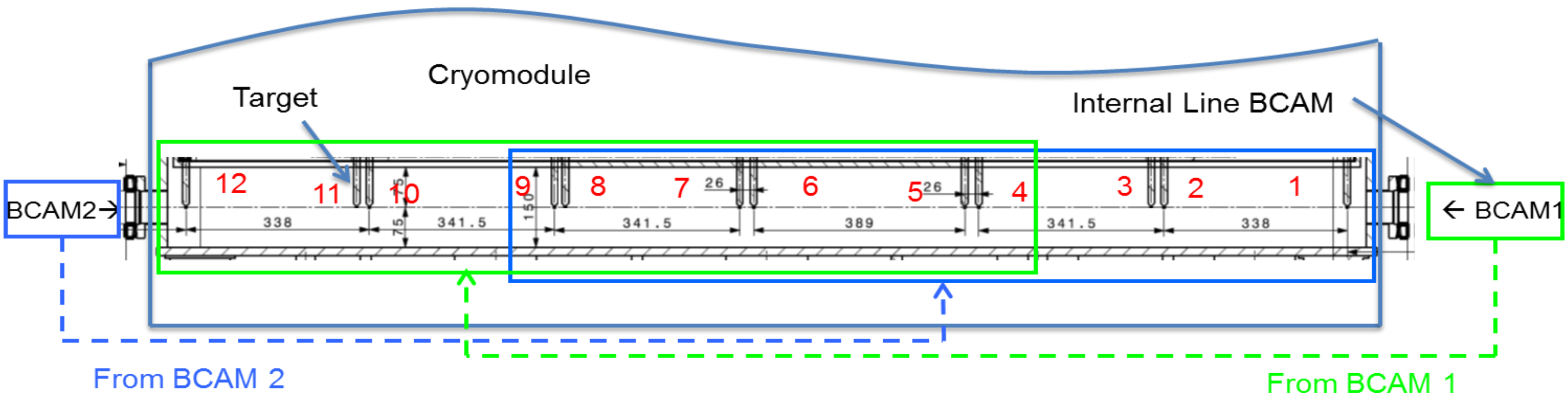
Frame suspension and adjustment

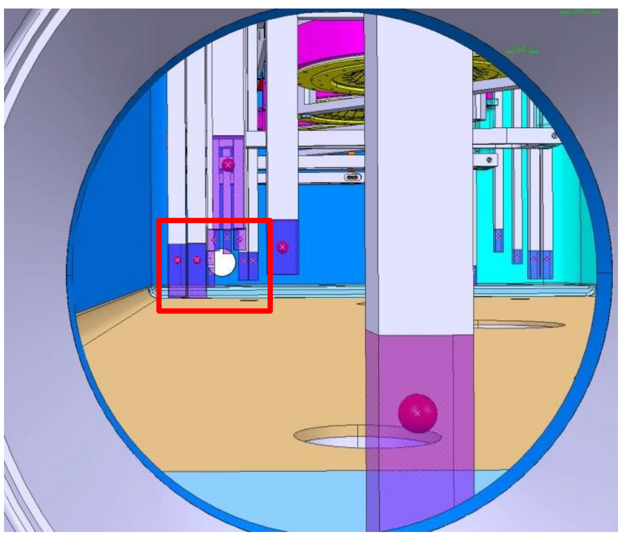


Cavity and solenoid isostatic support: Sphere – V-shape

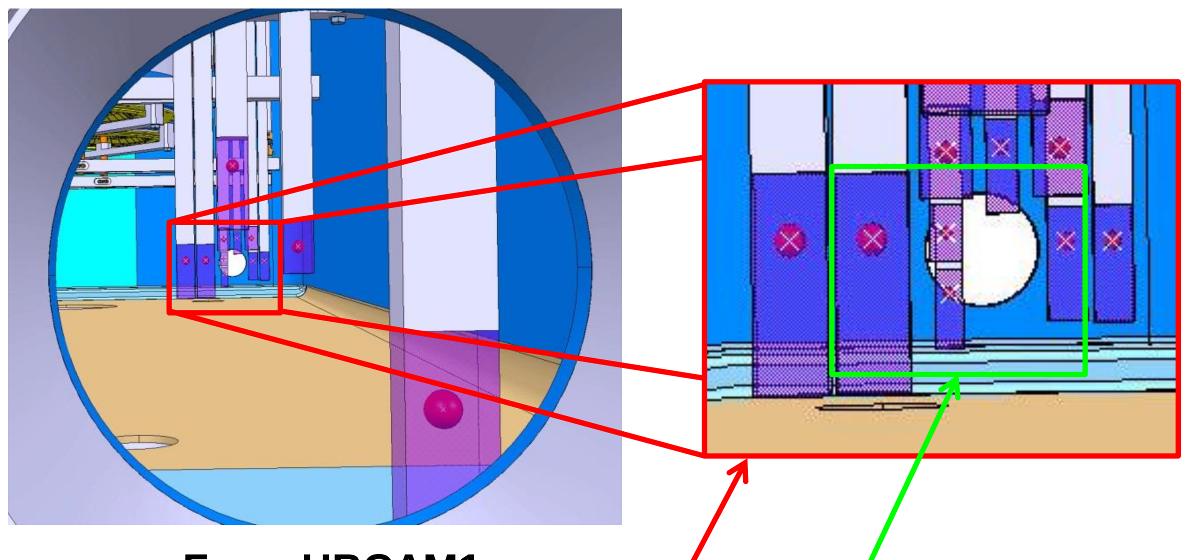
- Precise adjustment
- Solenoid adjustment allowed in operational conditions
- Used as Target support

Targets Integration





From HBCAM2

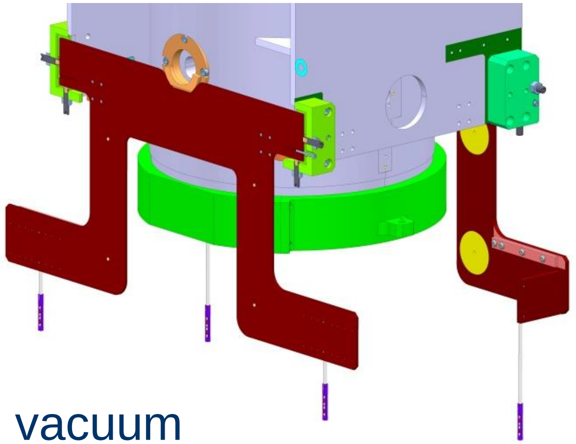


From HBCAM1

HBCAM vs BCAM Field of view

Targets Overview

Constraints → HIGH VACUUM - CRYO CONDITIONS - SIZE



Studied Target Types

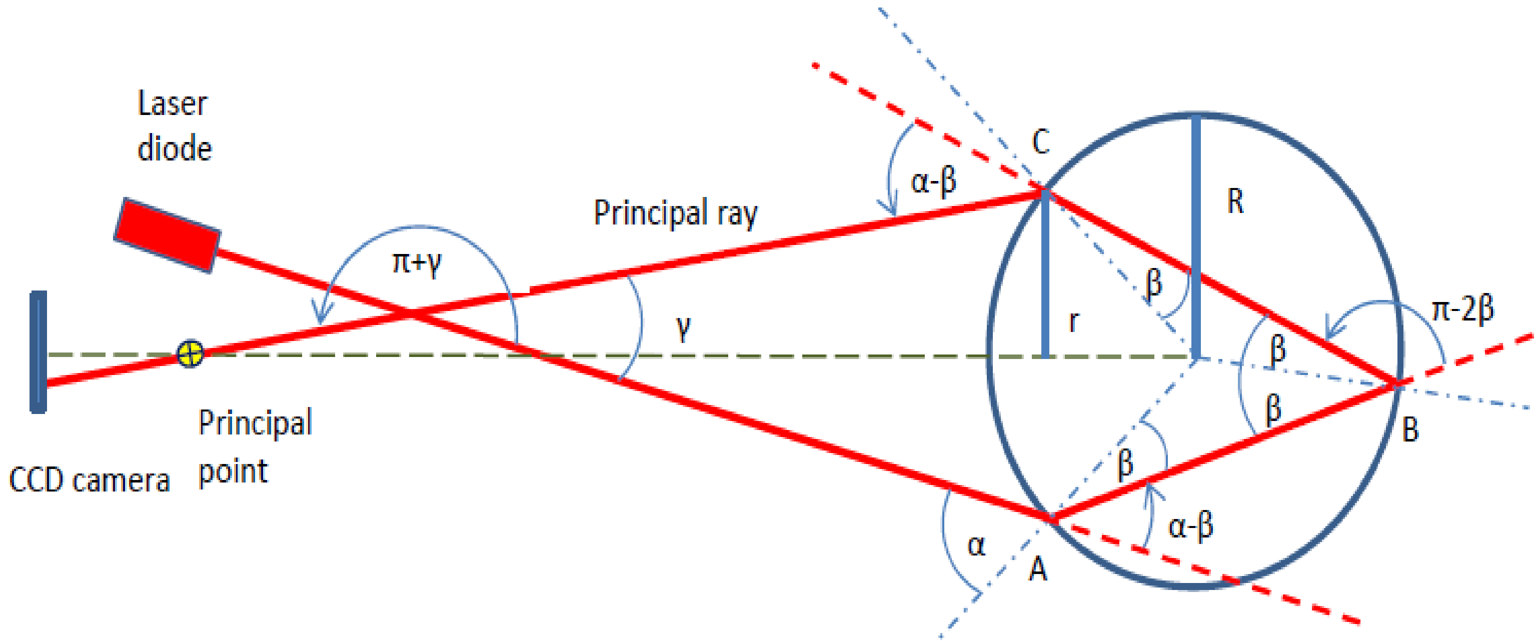
- **Silica Silica optical fiber end**
  - \- feed-through needed, one-sided target
  - \+ easy light level control, OK with cold and vacuum (tested)
- **Silica Silica optical fiber ended by a ceramic ball**
  - \- feed-through needed, connection fiber/ball
  - \+ visible from all positions, good diffuser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

Targets
High Index Glass Balls

High index glass ball:

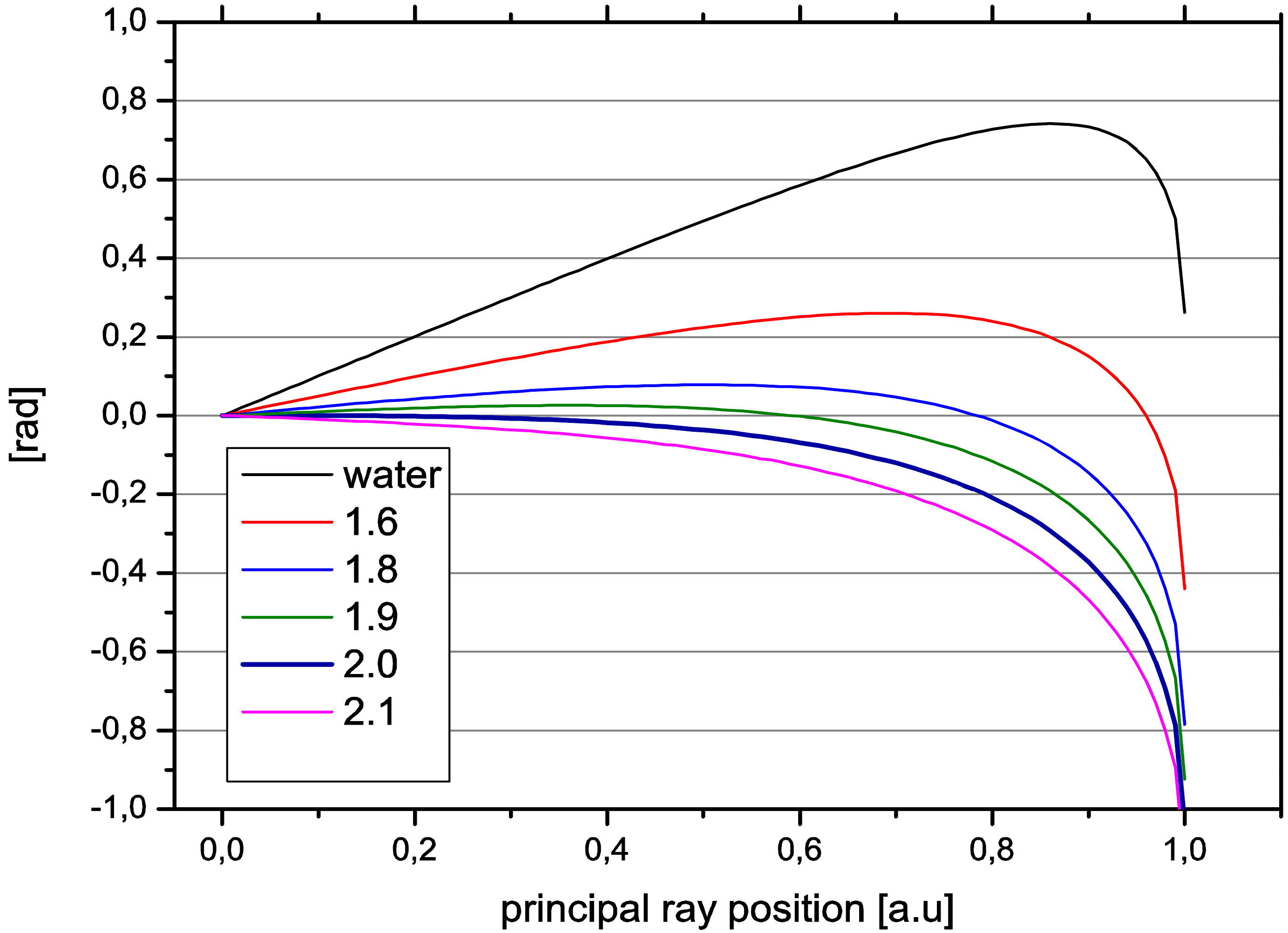
- Developed by OHARA Inc., Kanagawa, Japan
- Material : S-LAH79
- Off the shelf
- Available from diameter 1mm to 10mm
- Diameter Tolerance (µm) : 0/-3
- Sphericity (µm): 2
- Refracting index of 1.993 for HBCAM Lasers (650nm)

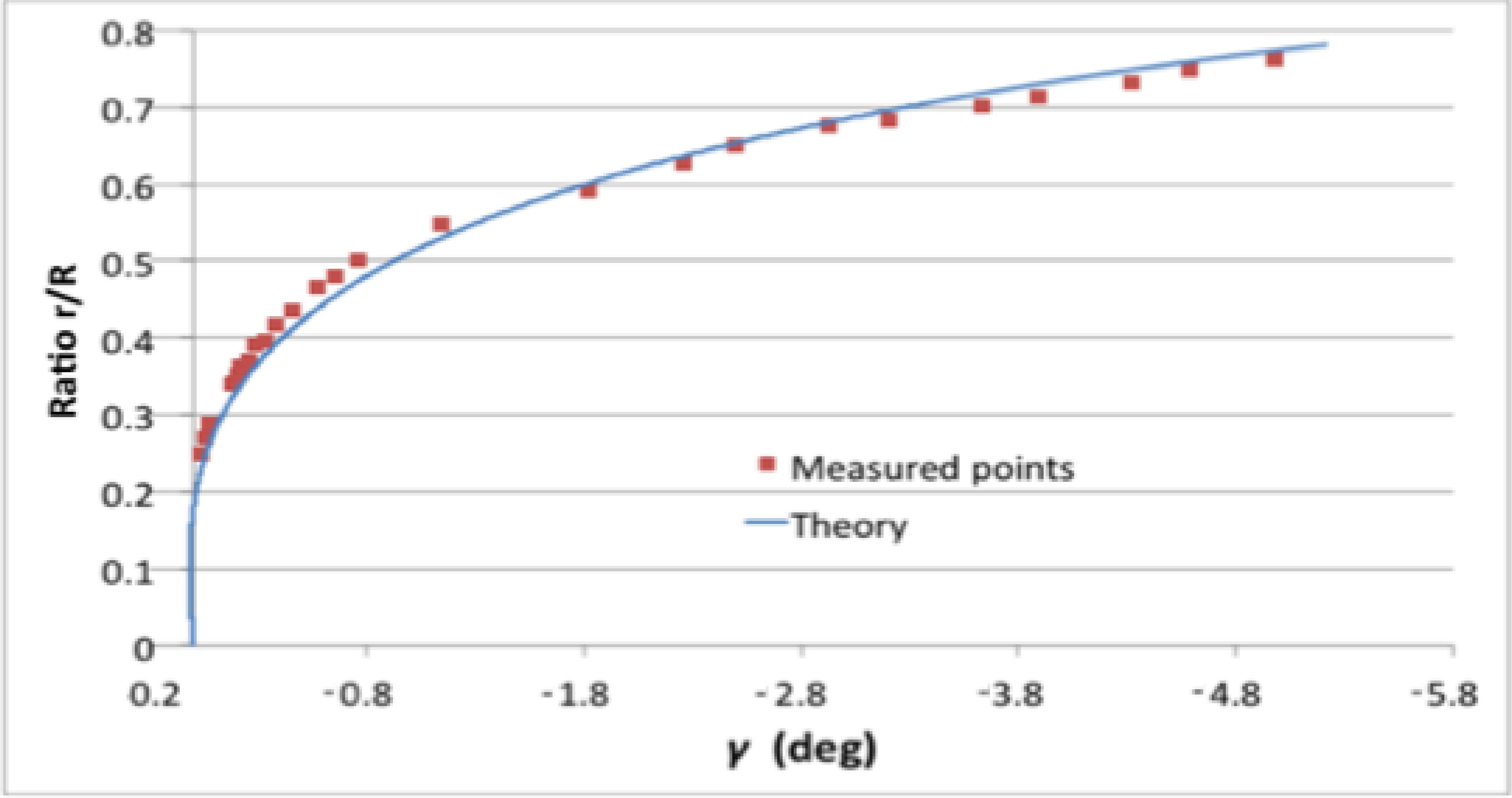
Study carried out by M. Šulc, Technical University of Liberec



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

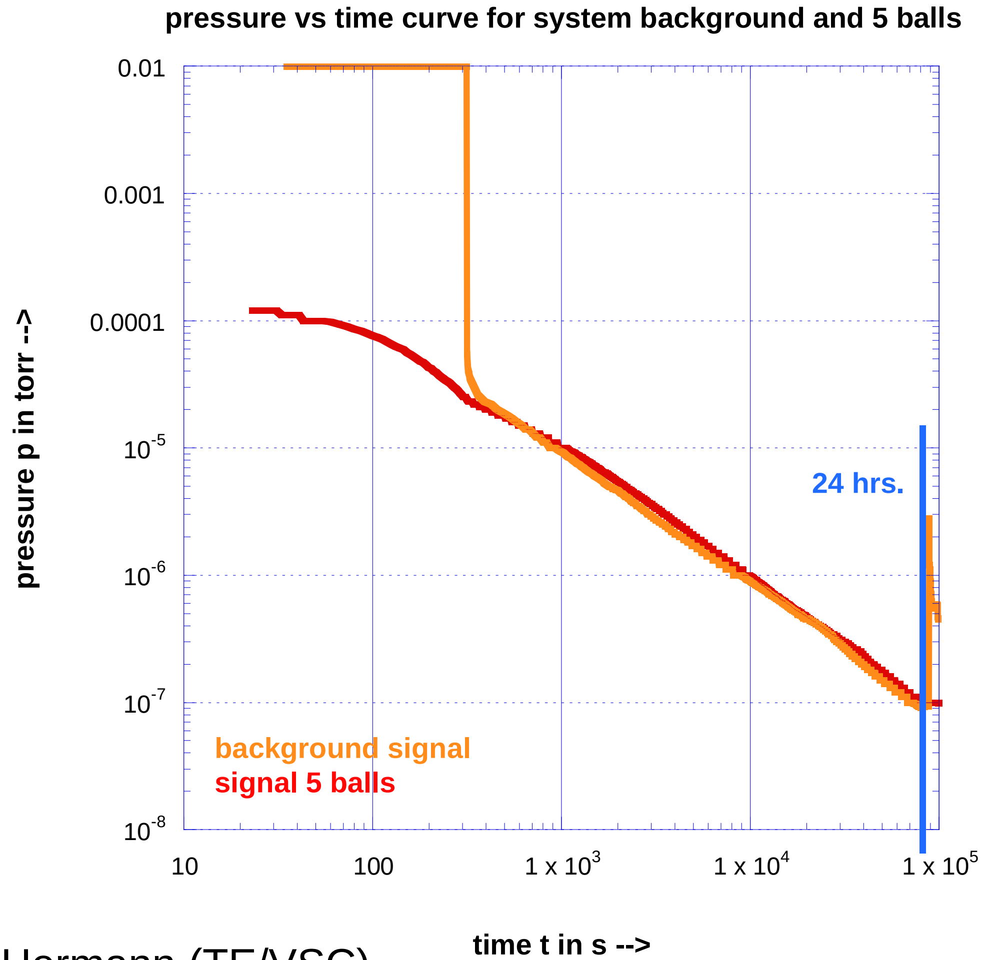
Glass ball theory





Fit well to the theory

Targets
Outgassing



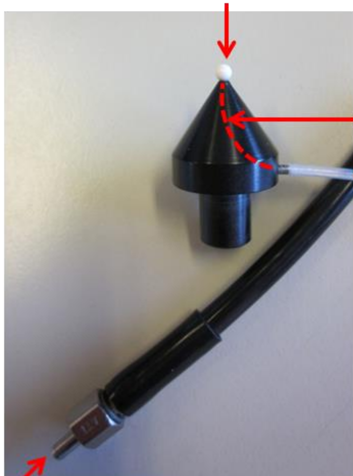
Test done by Mario Hermann (TE/VSC)

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

Three types of “double sided” targets considered

Laser illuminated ceramic balls

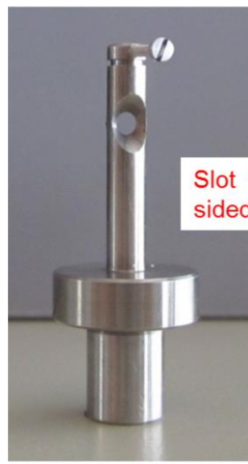
3 mm diffusion ball

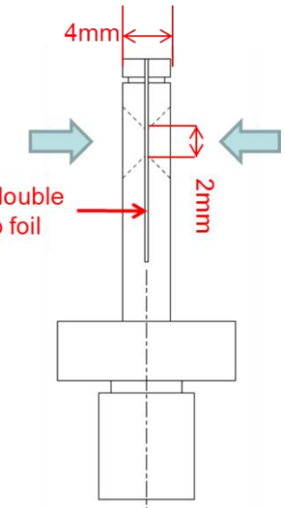


Test prototype for an illuminated ceramic ball synchronized to the acquisition system

But Active targets

Retro-reflective bi-directional target





Double sided retro-reflective target Prototype

But Not High-Vacuum compatible

Retro-reflective high-Index Glass ball target

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

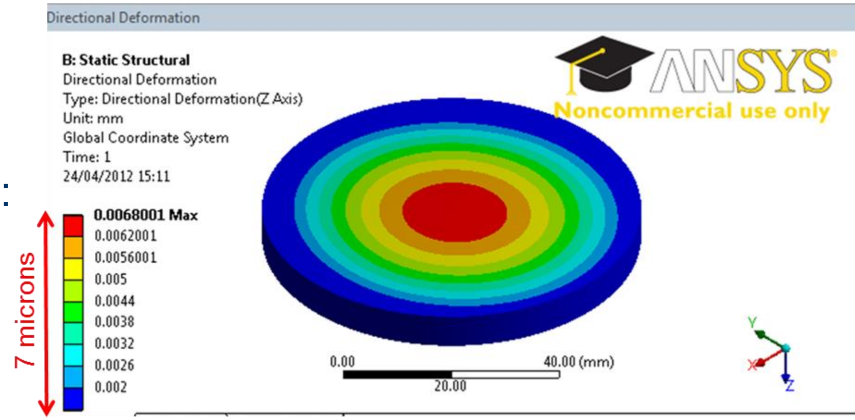
- 10 microrad wedge angle acceptable

Parallel Plate Effect

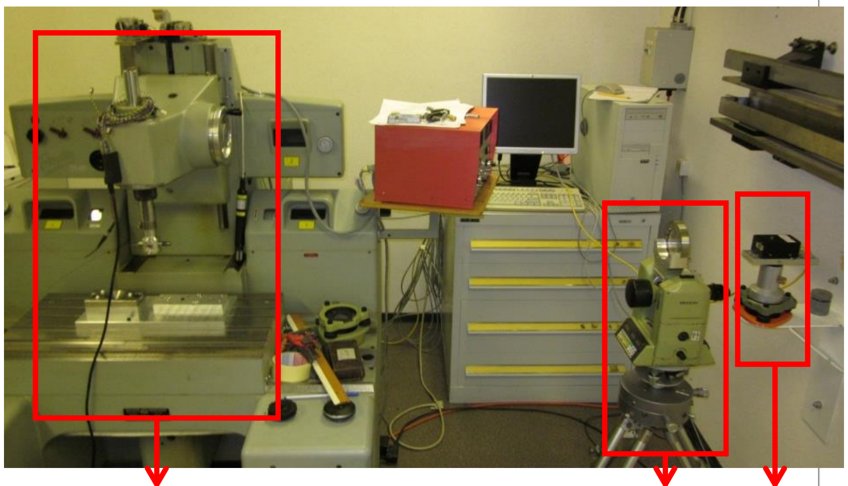
- Incident angle change of 1gon (0.9deg) → 37 microns radial object "displacement"
- Match the theory by a few microns → Easy observation correction by software

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



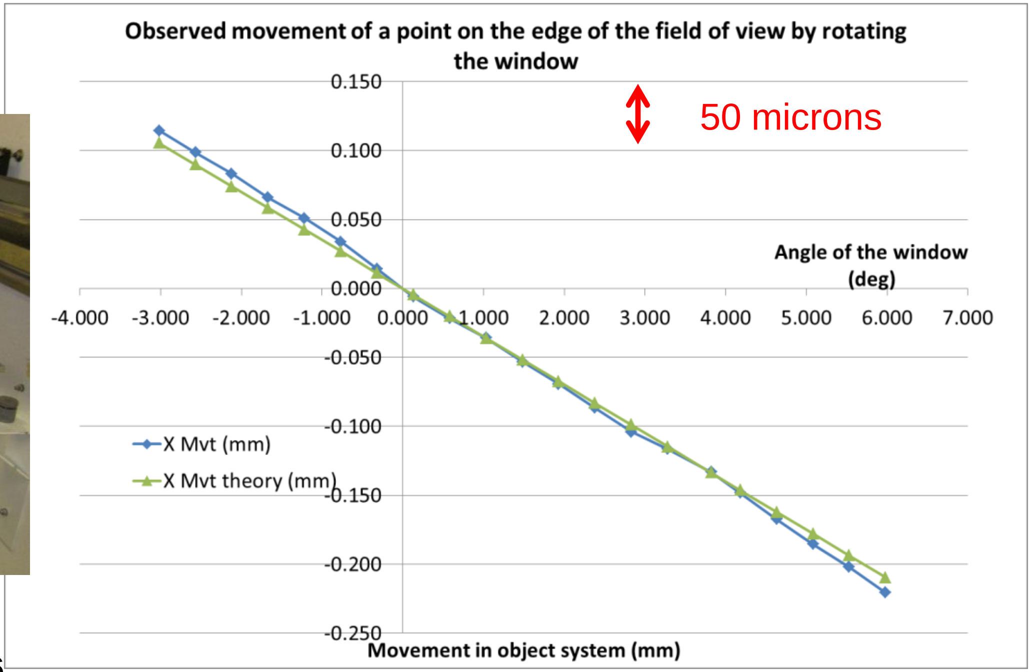
Parallel plate effect on image at different incident angles



Optical fiber attached to a Coordinate-measuring machine controlled with an interferometer

Window mounted on a theodolite (rotation) and a translating holder

BCAM W0226



Difference Theory/observed:
Average: 0 micr
Standard deviation: 6 micr

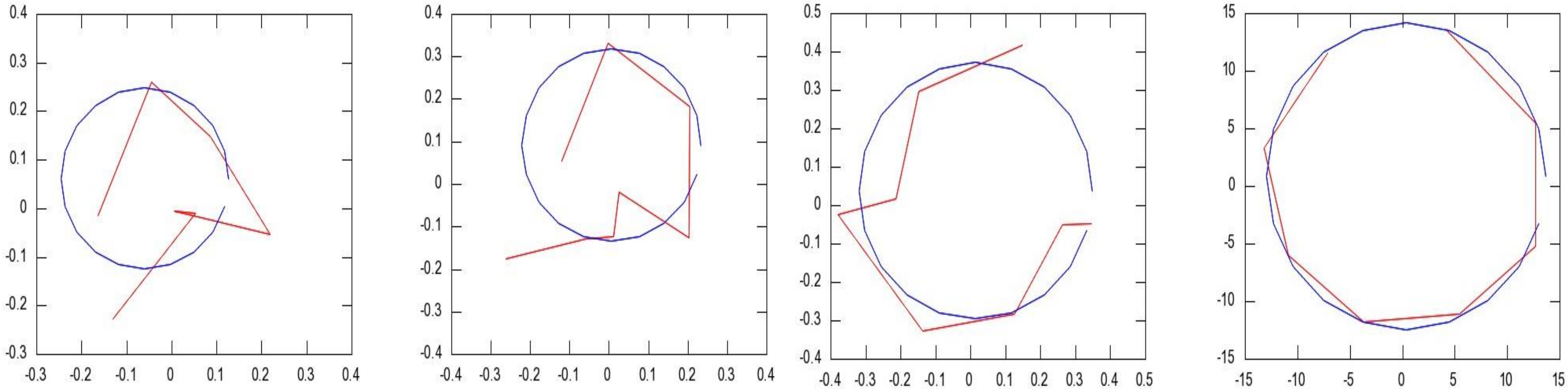
BCAM to Target distance: 1.3 m

- 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

Wedge angle and wedge angle effect evaluation

Principle: Measure a fix point through the window → Rotation of the window around the main axis → Observation of the point image coordinate change → Calculation of the wedge angle

Window A,1 (micr) | Window A,2 (micr) | Window B (micr) | Window C (micr)



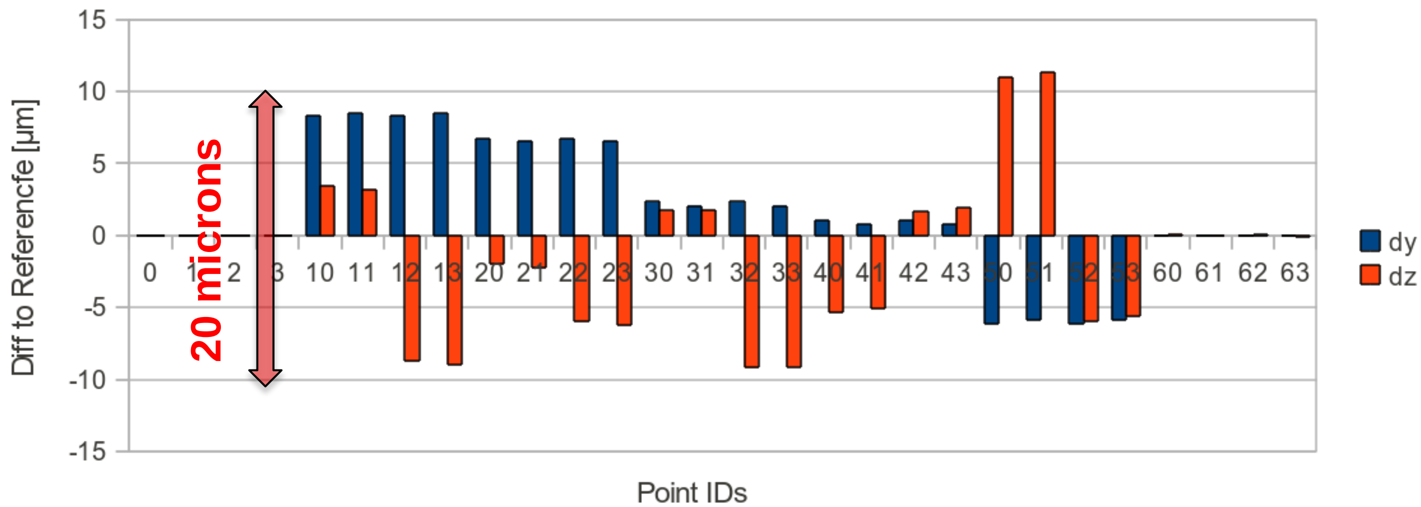
Tests: Nicolas Gauthé

In red: measurements on the CCD
In blue: best fit circle

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
Viewports better than manufacturer data

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