Alignment Inside Cryomodules and Requirements to Fiducials

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PXIE Cryomodule Design meeting

Outline

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- Alignment Tasks
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  - Alignment of the cavity string to the Cold Mass support
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Cryomodules Alignment Scope

- Design, develop and implement surveying and industrial alignment procedures to:
  - support the construction and installation of cryomodules
  - achieve the required absolute and relative local positioning tolerances of the cryomodule components

Alignment Requirements

- Absolute and relative alignment tolerances for PXIE cryomodules are driven by physics requirements (see Focusing in PXIE Cryomodules – V. Lebedev)
- Relative alignment tolerances:

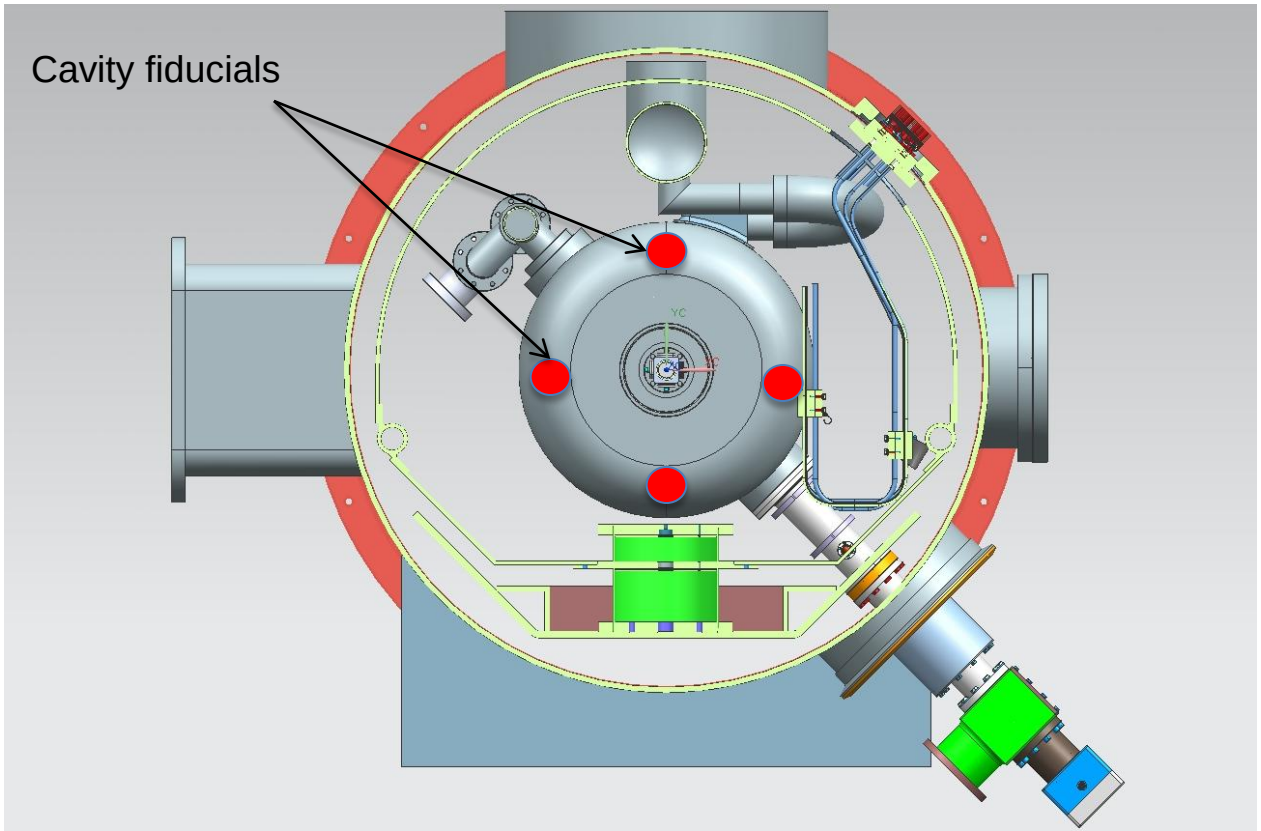
Cavities		
	Number, total	8
	Frequency, MHz	325
	b	0.22
	Operating temperature, K	2
	Operating mode	CW
	Operating energy gain at b=0.22, MV/cavity	2
	Transverse cavity alignment, mm RMS	<±1
	Angular alignment, mrad RMS	≤±10
	Coupler type – standard coaxial with impedance, W	50
	Coupler power rating, KW	>20
Solenoids		
	Number, total	4
	Operating temperature, K	2
	Current at maximum strength, A	≤100
	$\int B^2 dL$, T^2m	6.2
	Max. alignment error (center position), mm RMS	±0.5
	Max alignment error (angle) mrad	±1
	Maximum fringe field at the cavity walls, mT	10
	Each solenoid has independent powering	

Courtesy T. Nicol

- The beam is mainly sensitive to the solenoids angle error: rms ±1 mrad => ± 0.15 mm of pitch or yaw (1σ)

Referencing of Cavities and Solenoids

- For each cavity and solenoid, the magnetic axis will be determined with respect to the mechanical axis, which will be then related to external *temporary* fiducials used for coordinate transfer and cavity string alignment
- Each component will have 8 fiducilas glued on the upstream and on the downstream faces, 4 on each side (for cavities, the fiducials will be glued onto the magnetic shield)



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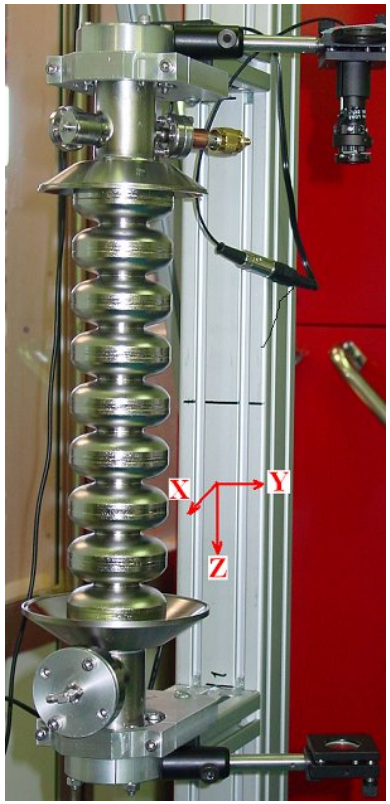
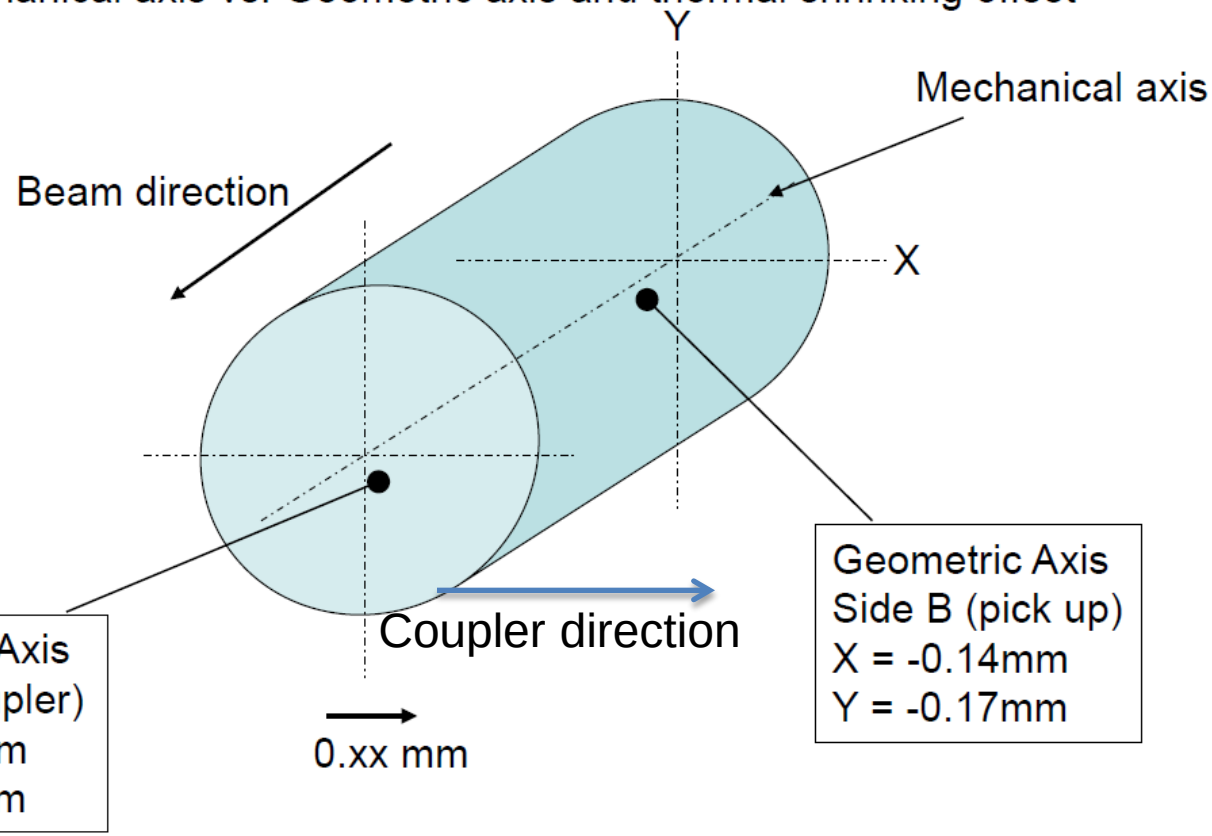
Example of Cavity Mechanical vs Geometric (Magnetic) Axis Referencing



Cryomodule CM2

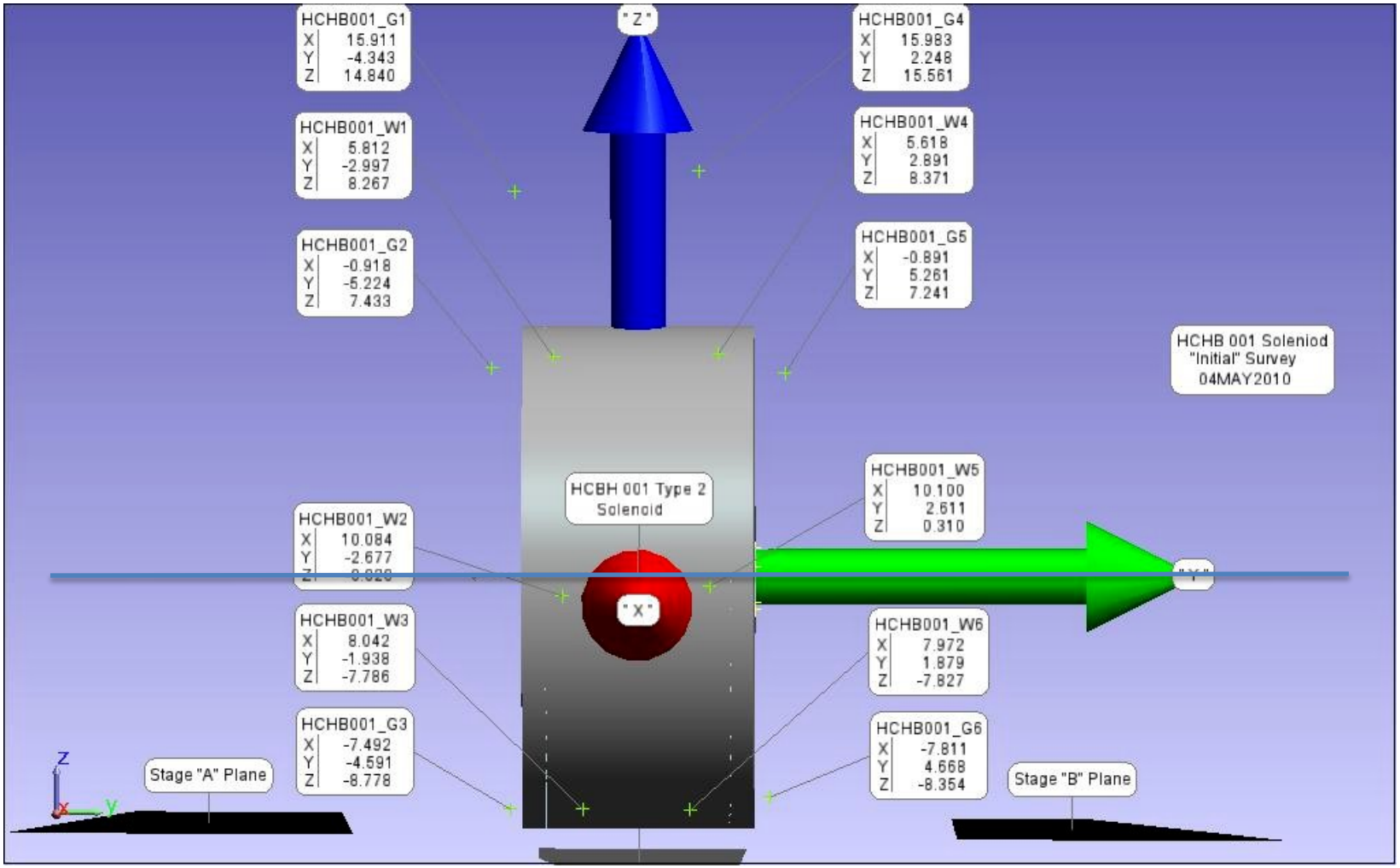
Cavity TB9AES008 (No. 1)

Mechanical axis vs. Geometric axis and thermal shrinking offset



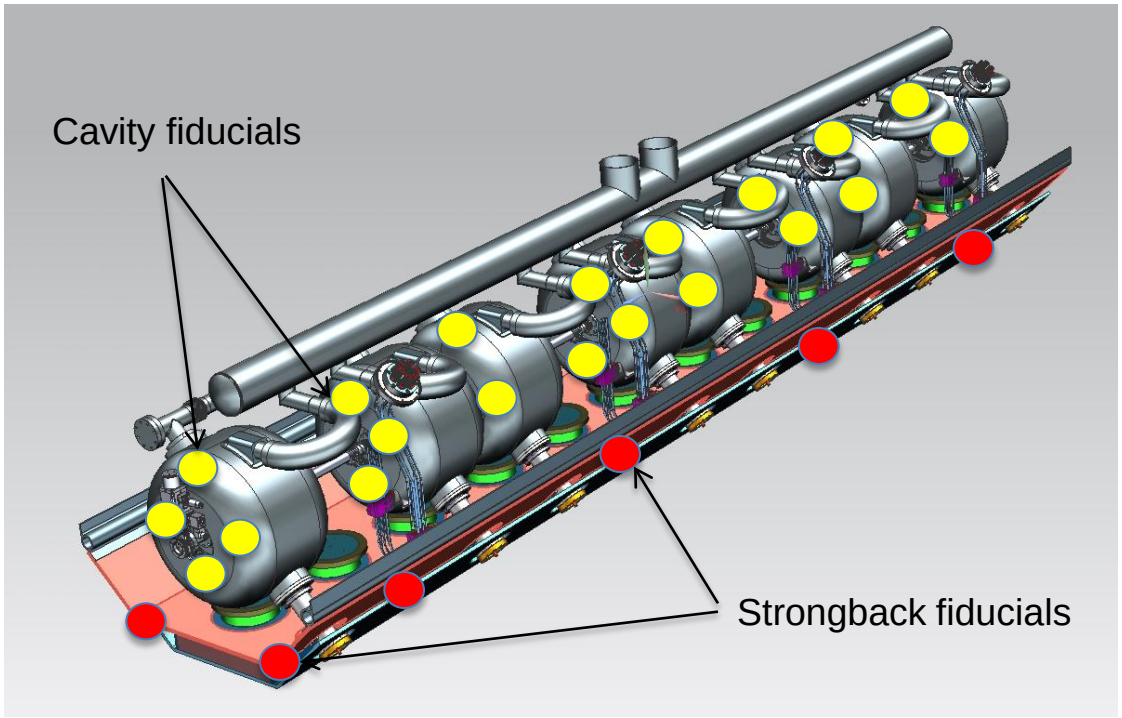
11-October-2011 T. Khabiboulline

Example of Solenoid Geometric (Magnetic) Axis Referencing



Alignment of the Cavity String to the Cold Mass Support

- The relative alignment of the components *within the cavity string:* ±0.5 mm transverse error and ±1 mrad pitch and yaw angle error
- High-accuracy Laser Tracker reference control network established in the assembly area:
  - processed as 3-D trilateration (+ precision leveling)
  - relative errors < ±0.1 mm at 95% confidence level
- More fiducials installed on the cold mass strongback - used as referencing points for the cavity string alignment



Courtesy T. Nicol

Alignment of the Cavity String to the Cold Mass Support

- Cavity supporting structure must remain in position < 0.1 mm

- The component supporting stand adjustment system must be designed to allow very fine movements, within 0.1 mm range

- The cavity string must be aligned in warm state with an offset (to be determined by engineers) to compensate for thermal shrinking

- API Laser Trackers and precision optical and electronic levels will be used as instrumentation for the alignment of cavity string

- Use a threshold based on the rms alignment sensitivities corresponding to 0.10 mm error bar to flag misalignments:
  - previous optimization study => 1.5 ratio of required resolution chosen to quantify physical misalignments (67% of most stringent budgeted allowance of 0.15 mm)
  - relative measurement errors between points => 0.050 mm range
  - methodology + instrumentation => absolute max error of 0.15 mm

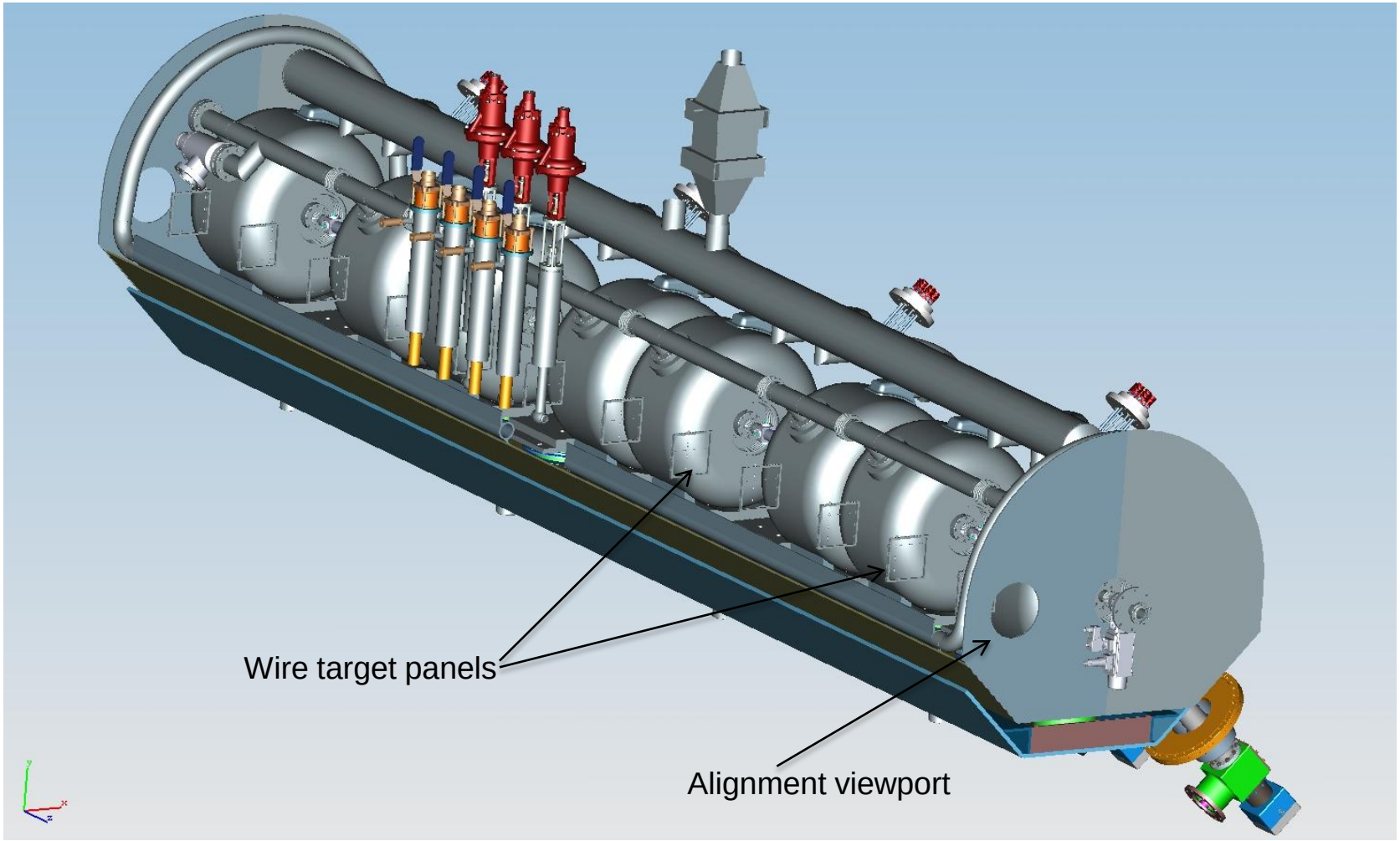
- After completion of cavity string alignment and transfer to the strongback referencing points, the cavities and solenoids temporary fiducials, as well as the fiducials on both sides of the strongback, can be removed

Alignment of the Cavity String to the Cold Mass Support

- Special alignment wire target panels (4 per each component, 1 upstream and 1 downstream on each left-right side) – used for relative optical measurement with respect to external reference points
- Each panel has two intersecting wires forming a crosshair along the diagonal, creating 24 configurations
- Wire thickness 0.25 mm (to be confirmed) spaced 5 mm? (to be determined) horizontally and vertically
- The alignment panels have a two-fold function:
  - assist in the initial assessment of transport stability from the assembly area to the beamline enclosure
  - provide a mean for post-cooling survey of the components through adjustable alignment viewports
- Instrumentation used to transfer wire targets position to external reference points:
  - API Laser Trackers
  - precision optical levels
  - precision optical alignment telescopes (dual setup)
- The error budget analysis based on optical instrument specs and observation procedure shows an estimated measurement error of ± 0.05 mm - 0.15 mm (distance dependent)
- NOTE: The achievable accuracy of the optical method requested by the project is at the limit of the tolerance requirements (for solenoids angle error)

Alignment of the Cavity String to the Cold Mass Support

Alignment wire targets system



Courtesy T. Nicol

Alignment of the Cavity String to the Cold Mass Support

Example of alignment dual telescopes setup for the 3.9 GHz Cryomodule

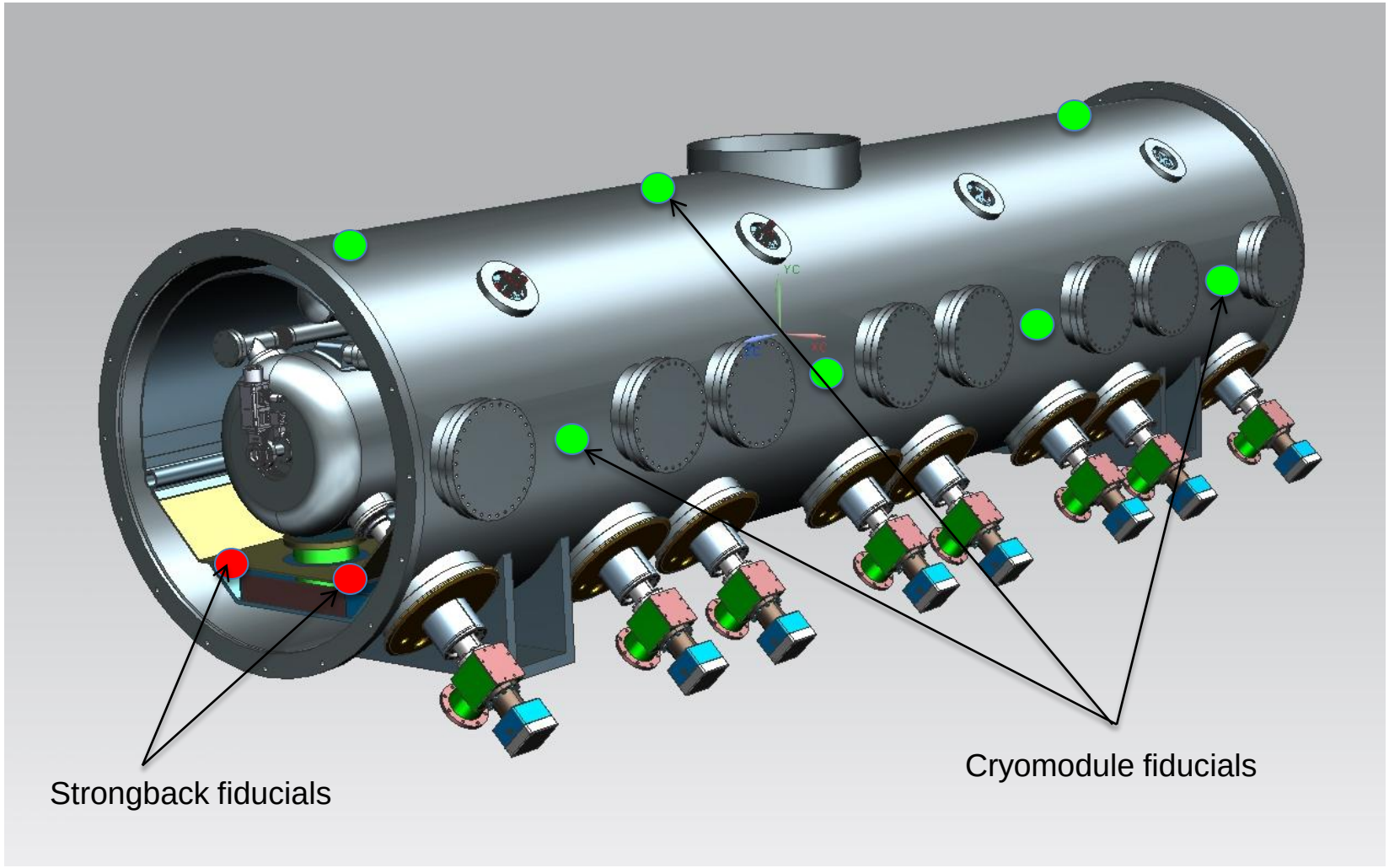
Alignment of the Cold Mass into the Vacuum Vessel

- The Cold Mass will be aligned into the vacuum vessel, using the strongback referencing points, by aligning the cavity string centerline in its theoretical position inside the cryomodule

- After alignment, the cryomodele beamline will be transferred to external referencing points permanently installed on all sides of the vacuum vessel; those are the cryomodele fiducials to be used for alignment in the PXIE beamline

- The final positions of the alignment wire targets will be also transferred to the cryomodele fiducials for future surveys

Alignment of the Cold Mass into the Vacuum Vessel



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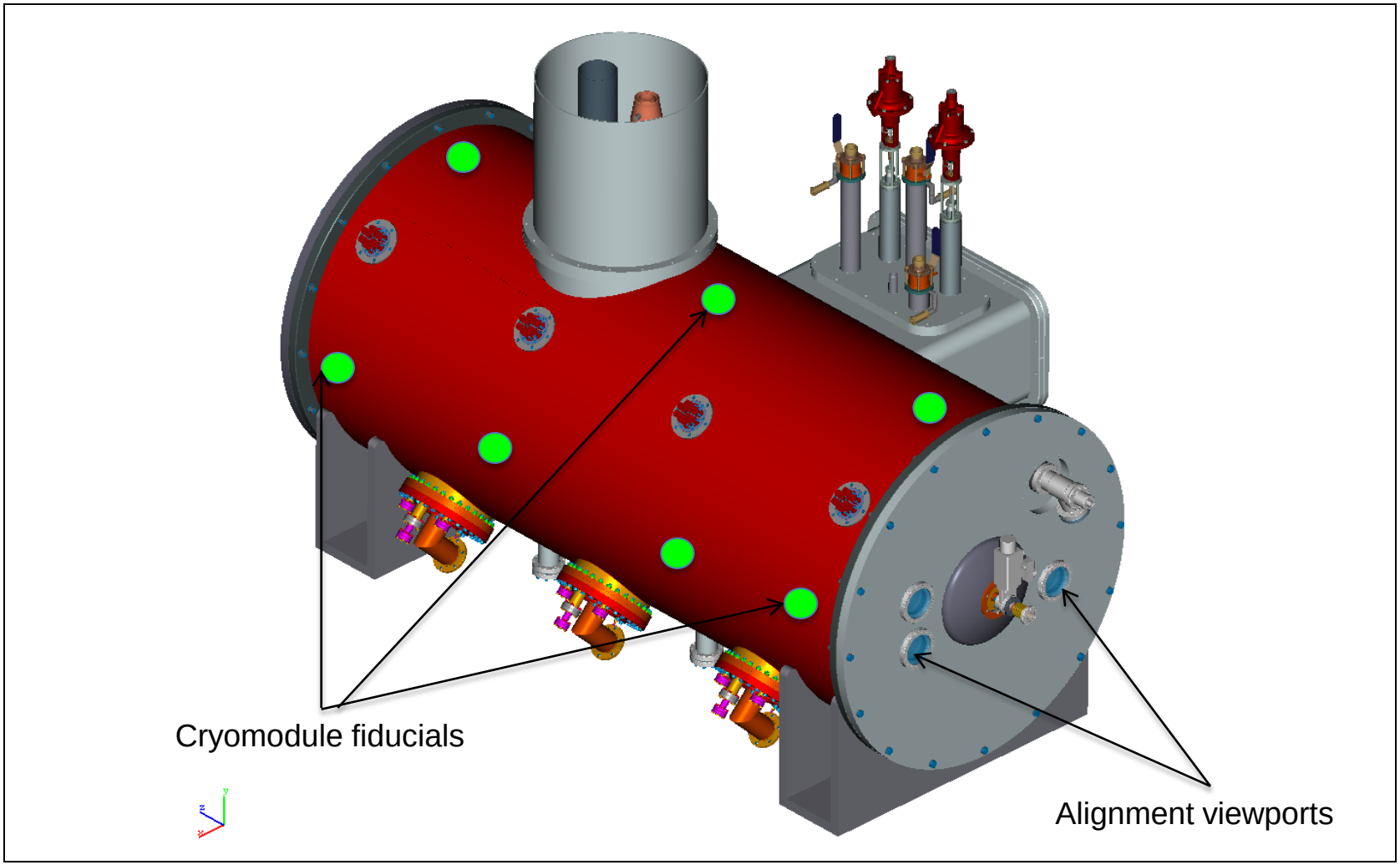
Alignment of the Cold Mass into the Vacuum Vessel



Courtesy T. Nicol

Summary and Conclusions

- Cryomodule error budget analysis (among others) < ± 0.25 mm
  - referencing of cavities mechanical and magnetic axis < ±0.10 mm
  - cavity string alignment = ±0.10-0.15 mm
  - cold mas to vessel alignment and referencing to vessel = ± 0.1 mm
  - string misalignments due to shipping = ±0.1 mm ?
  - thermal cycling (warm up, cool down) = ±0.05 mm ? (Y. Terechkine)

- Based on the proposed procedure and instrumentation the cavity string, including the solenoids, can be aligned within tolerance
- However, based on the chosen optical method for monitoring the cavity string, the tolerance for determining the angular displacements of the solenoids is within the measurements noise