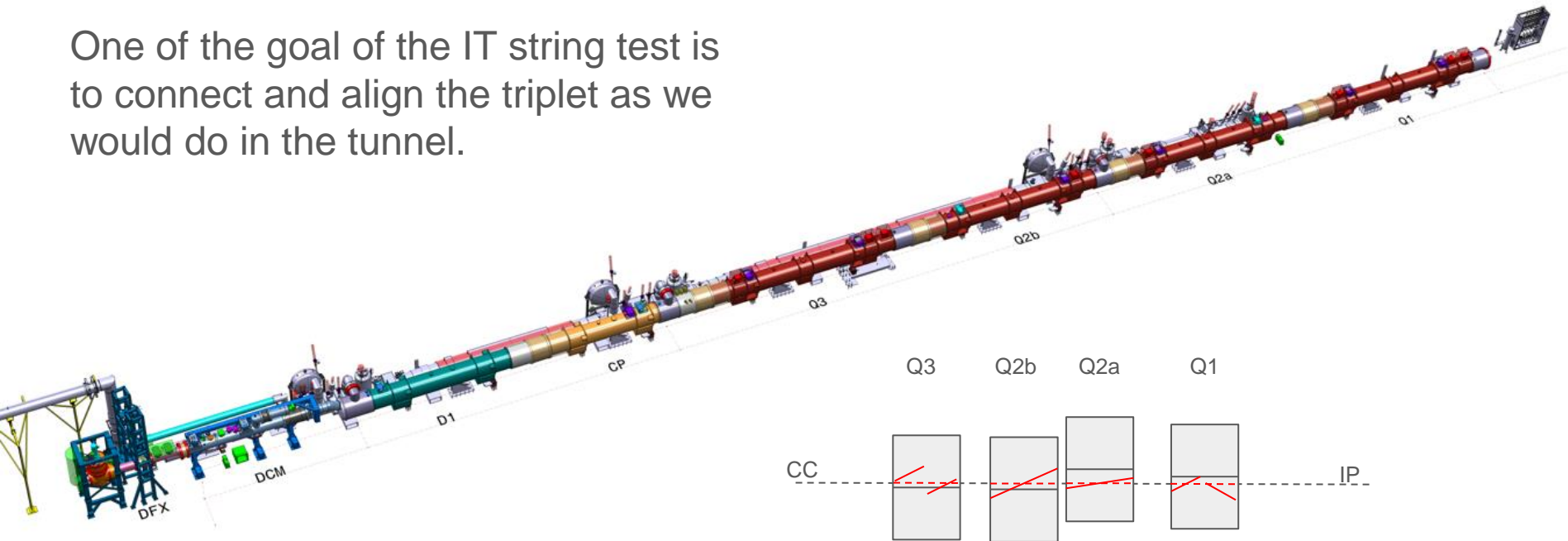


Alignment specification IT string

R. De Maria

IT String test

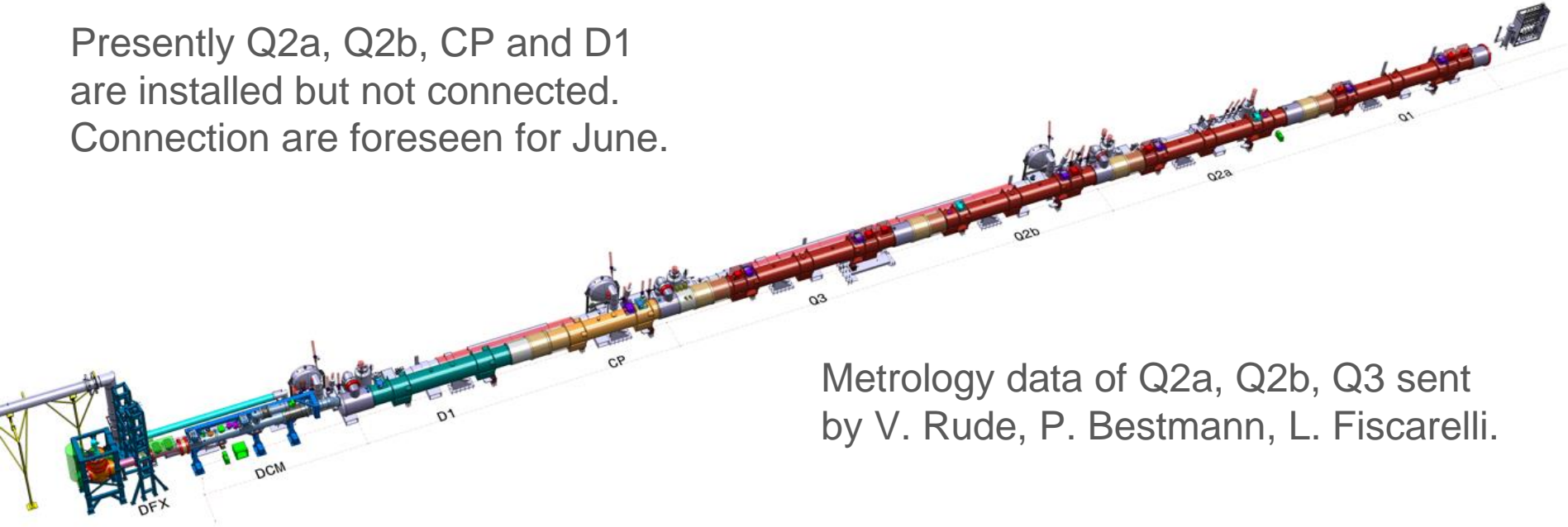
One of the goal of the IT string test is to connect and align the triplet as we would do in the tunnel.



Alignment strategy: minimize only average offsets (not RMS) to preserve bellow range.

Status

Presently Q2a, Q2b, CP and D1 are installed but not connected. Connection are foreseen for June.

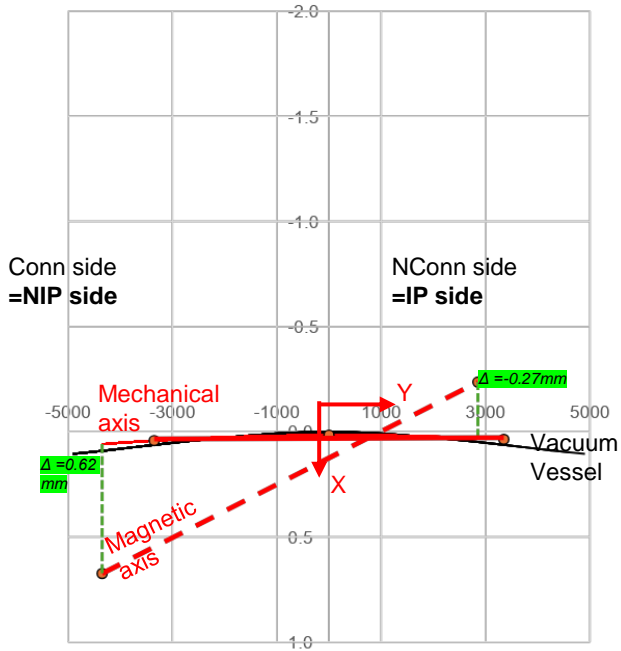


Metrology data of Q2a, Q2b, Q3 sent by V. Rude, P. Bestmann, L. Fiscarelli.

Q2a-P3

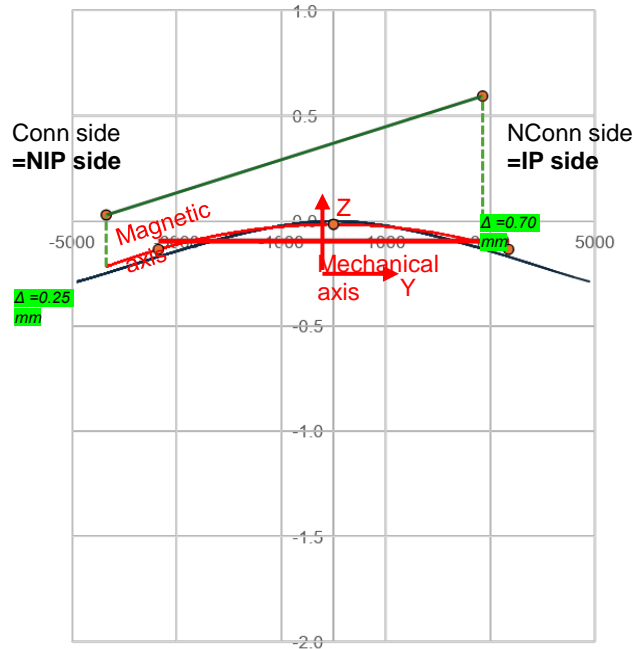
Radial

WARM Ambient pressure : SM18
Radial measurement



Vertical

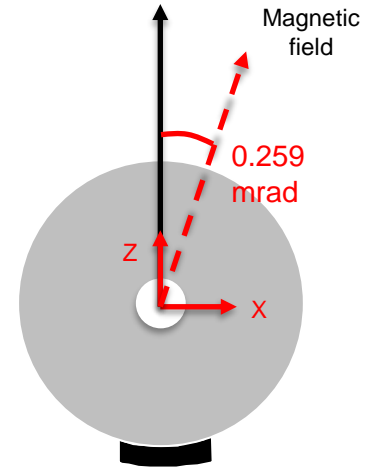
WARM Ambient pressure : SM18
Vertical measurement



Roll

WARM Ambient pressure : SM18

Magnetic field
Mechanical direction
(Z axis)

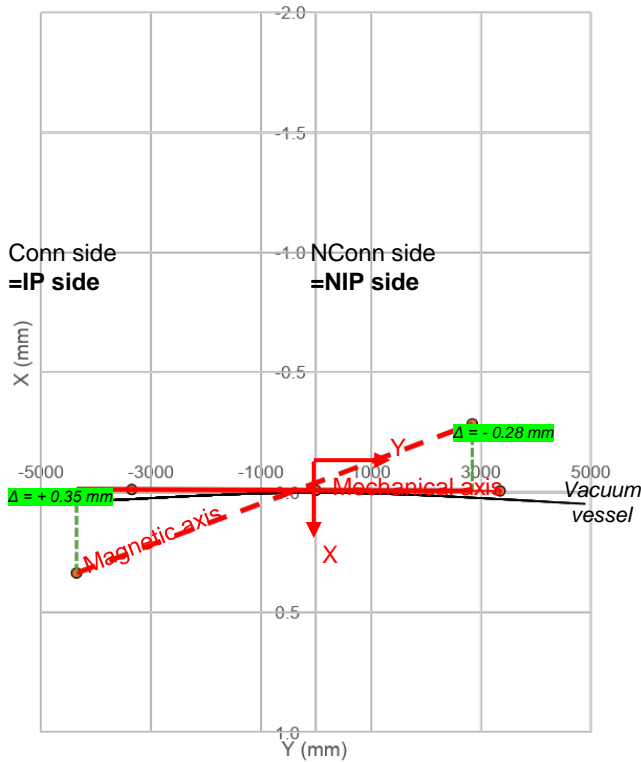


View from Conn side to Nconn side
=View from NIP side to IP side

Q2b-P2

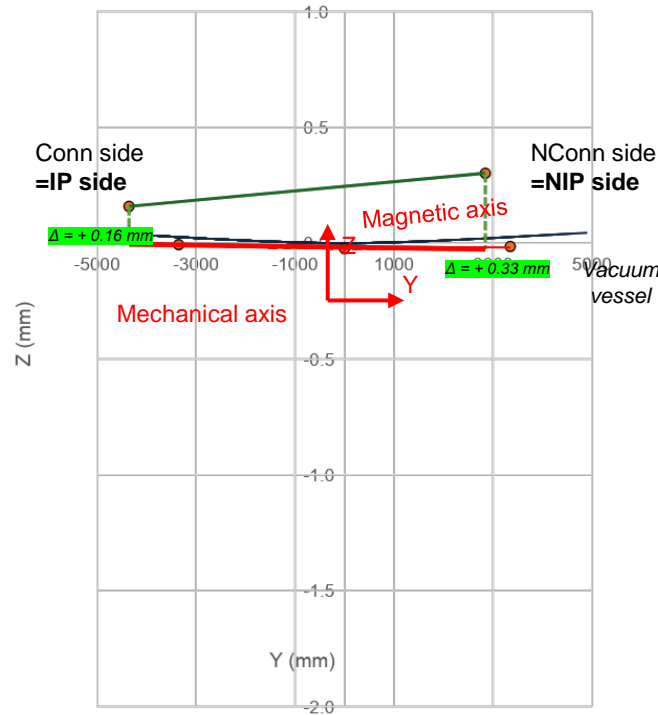
Radial

WARM Ambient pressure : SM18
Radial measurement



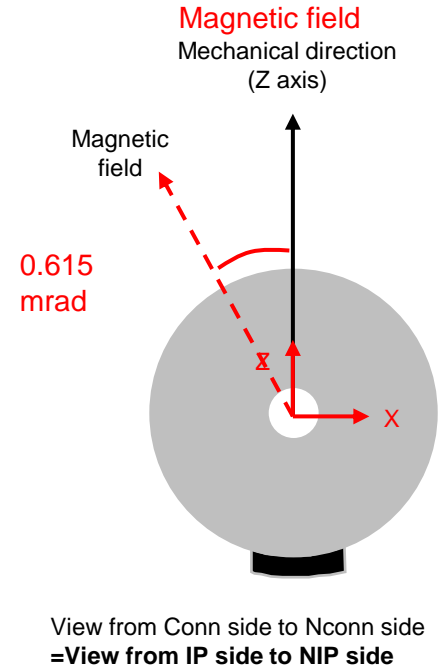
Vertical

WARM Ambient pressure : SM18
Vertical measurement



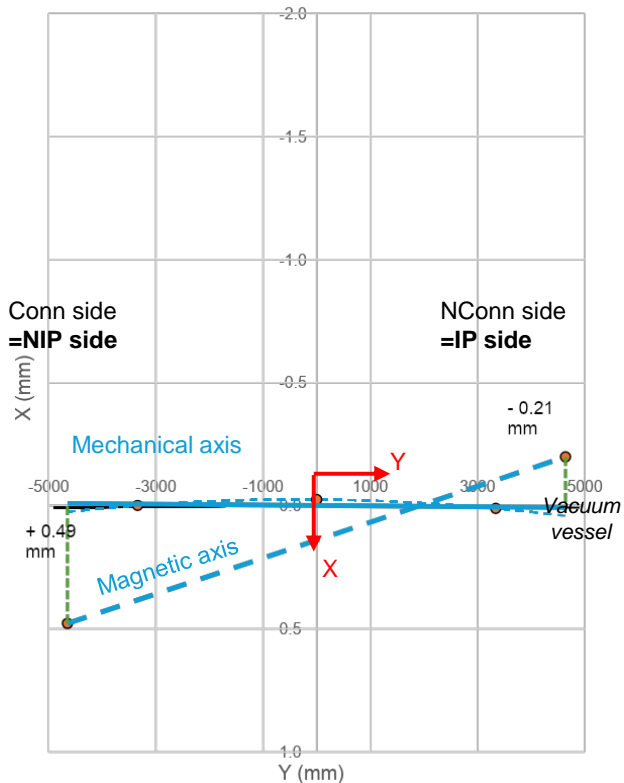
Roll

WARM Ambient pressure : SM18



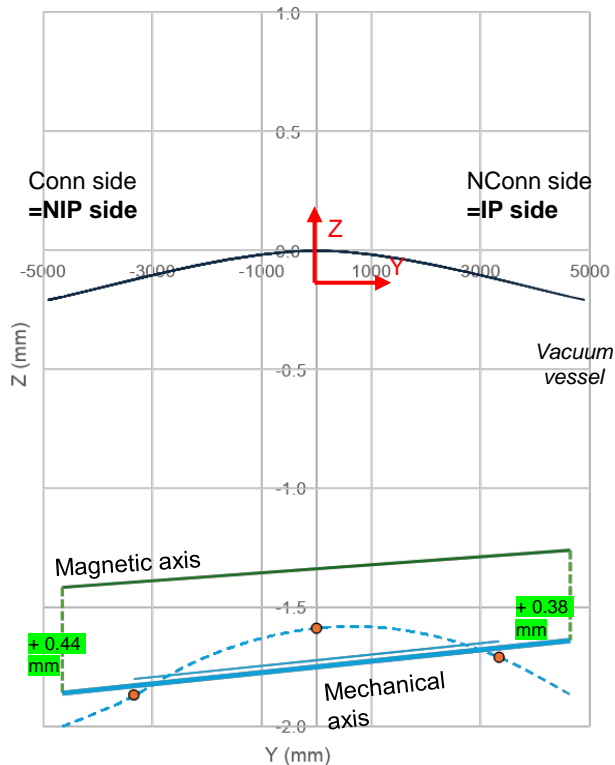
Radial

COLD NOMINAL SM18
Common axis measured
Radial measurement



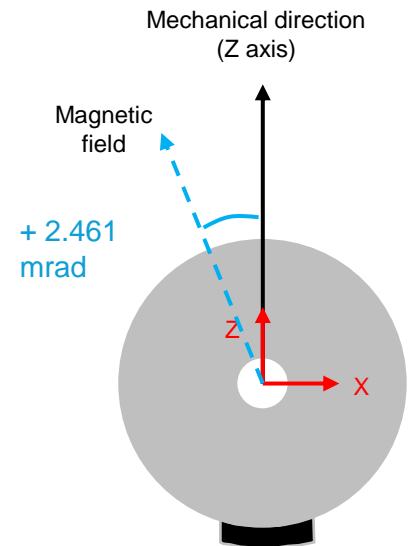
Vertical

COLD NOMINAL
Common axis measured
Vertical measurement



Roll

COLD : SM18
Magnetic field

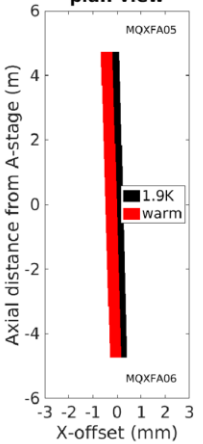


View from Conn side to Nconn side
=View from NIP side to IP side

Magnetic axis - common

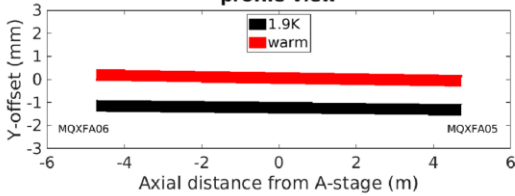
MQXFA06/MQXFA05 Alignment
 SSW 2-magnet centerline axes wrt warm Mole axes at zero
 04Oct2024, 1.9K, and 16Oct2024 warm

Horizontal Offsets
 plan view



1.9 K MQXFA06 end: X= 0.185, Y= -1.149 mm
 1.9 K MQXFA05 end: X= -0.145, Y= -1.313 mm
 Warm MQXFA06 end: X= -0.053, Y= 0.190 mm
 Warm MQXFA05 end: X= -0.433, Y= -0.062 mm

Vertical Offsets
 profile view

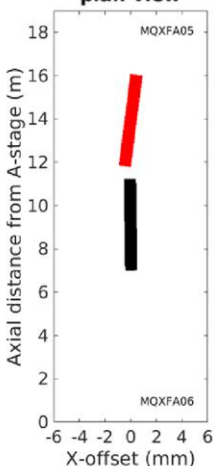


SSW_R_20241004_161009_AC_PtchYaw, SSW_R_20241004_154612_AC_PtchYaw

Magnetic axis - individual

Alignment Relative to MQXFA06/MQXFA05 Average Center Line
 04Oct2014 - cold TC2, 4.5K

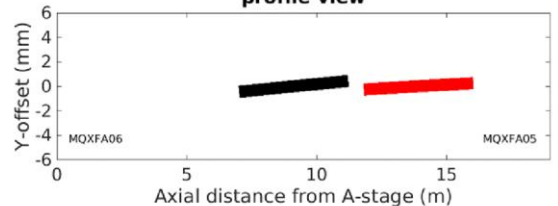
Horizontal Offsets
 plan view



MQXFA06 Lead End: X= 0.046, Y= -0.440 mm
 MQXFA06 Interface End: X= -0.046, Y= 0.440 mm
 MQXFA05 Interface End: X= -0.453, Y= -0.257 mm
 MQXFA05 Lead End: X= 0.453, Y= 0.257 mm

A06 roll angle = 0.82 mrad
 A05 roll angle = -2.34 mrad
 Delta angle = -3.11 mrad
 Ave angle = -0.73 mrad

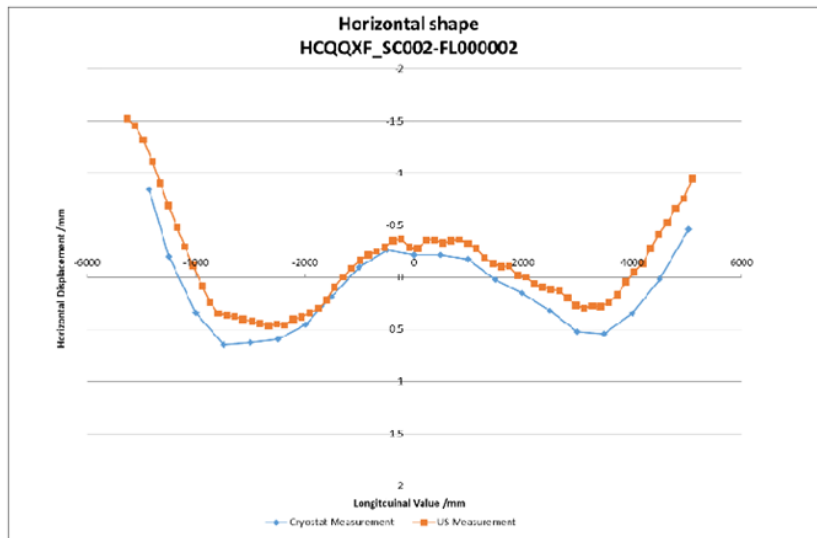
Vertical Offsets
 profile view



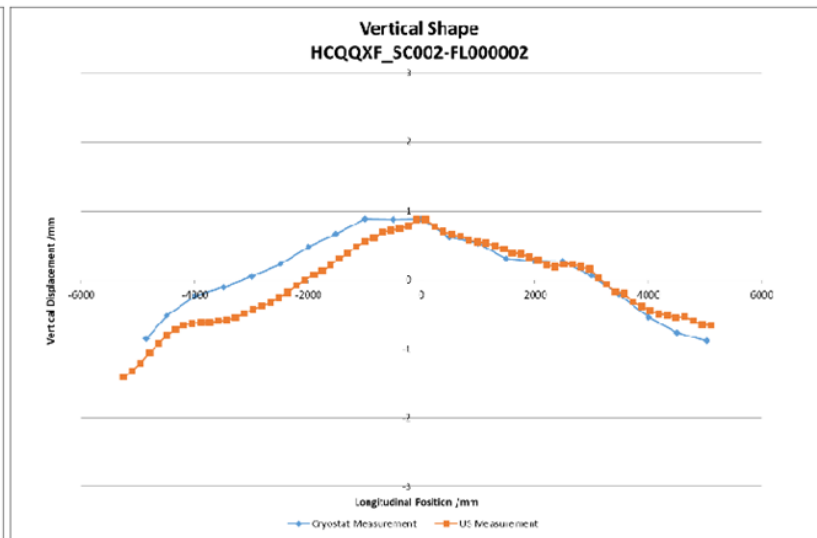
SSW_R_20241004_161009_AC_PtchYaw, SSW_R_20241004_154612_AC_PtchYaw

Cryostating control measurements @ CERN

Horizontal Shape



Vertical Shape



seen from CS to NCS side
(NIP-side to IP-side)

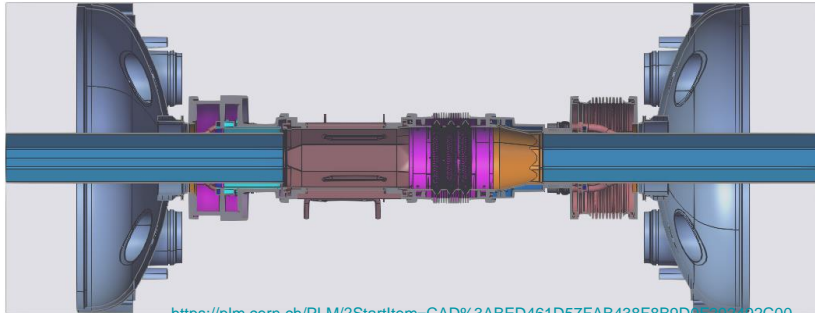
Status

Present measurement workflow allows to specify desired offsets, need to digest and complete measurements.

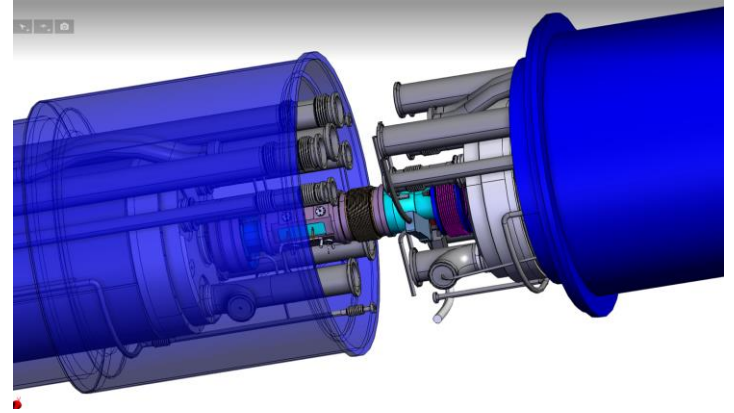
Tilts needs to be corrected at the installation time, while offsets are not possible.

String test does not have BPMs and beam screen. Unfortunately not possible to test BPM, DRF interconnections in the string.

Still very useful to verify in-situ realistic misalignments.



<https://plm.cern.ch/PLM/?StartItem=CAD%3ABED461D57FAB438F8B9D0F232492C00E>



<https://plm.cern.ch/PLM/?StartItem=CAD%3A878D444236C44A8F9F40419495AE41BF>

Q1-Q2A	PIM/W-B	Multiple bellows in interconnection. Most critical is PIM bellow:
Q2A-Q2B	PIM/W-B	
Q2B-Q3	PIM/W-B	
Q3-CP	PIM/W-B	Transversal $\leq \pm 3$ mm; (Axial: $\leq \pm 1$ mm after cool down);
CP-D1	PIM/W-B	Torsion $\leq \pm 1$ mrad.

M. Sosin WG meeting #78

FRAS bellows physical limits and definition of safety function thresholds

- To provide FRAS correct operation, the **bellows safety functions thresholds** shall be defined within the **mechanical deformation limits of the bellows**
- To allow the FRAS adjustment range of ± 2.5 mm, ± 1 mrad (worst case) – the bellows safety functions thresholds shall allow for such a motion range (unless bellows physical limits are lower – e.g. for “Standard RF module”)

Type (Bellow type acronym)	Bellows transversal deformation limit	Bellows axial deformation limit	Torsion Limit	Comments
TAXS-Q1 bellow (TAXS-Q1)	$\leq \pm 5$ mm	$\leq \pm 10$ mm	$< \pm 1$ mrad	[1]
PIM -bellow (PIM)	$\leq \pm 3$ mm	$\leq \pm 1$ mm (after cool down)	$< \pm 1$ mrad	Q1-D1 region [2]
W -bellow (W-B)	$\leq \pm 4$ mm	$\leq \pm 5$ mm	$< \pm 1$ mrad	Q1-D1 region [3][4]
Standard RF module (SRM)	$\leq \pm 2$ mm	$\leq \pm 20$ mm	± 1 mrad	D1-Q6 region [5]
Large Radial Movement (LRM)	$\leq \pm 10$ mm	$\leq \pm 20$ mm	$< \pm 1$ mrad	D1-Q6 region [5]
Deformable RF Bridge (DRF)	$\leq \pm 5$ mm	$\leq \pm 20$ mm	$< \pm 1$ mrad	D1-Q6 region [5]
DCM-D1 connection (DCM)	$\leq \pm 10$ mm	$\leq \pm 15$ mm	$< \pm 1$ mrad	[6]
TCTPXV-TCLPX collimators bellows (C-B)	$\leq \pm 2.5$ mm	$\leq \pm 15$ mm	± 2 mrad	TCTPXV, TCTPXH, TCLPX [7] interconnections handled by robot.
Cryo jumpers	Vertical ± 30 mm; horizontal ± 25 mm (FRAS ultimate transversal motion of ± 2.5 mm is accounted)			Input from M. Merli
CRABs RF Waveguide (CC-RF)	$\leq \pm 2.5$ mm	$\leq \pm 2.5$ mm	$< \pm 1$ mrad	[8]

[1] J. Perez-Espinos, "Movement range of beamline expansion joints at both side of TAXS", Working Group on Alignment, Meeting #65, <https://indico.cern.ch/event/1278996/>

[2] C. Garion, Working Group on Alignment, Meeting #11, Torsional deformation of PIM bellows, <https://indico.cern.ch/event/725603/>

[3] D. Ramos, Y. Leclercq, Working Group on Alignment, Meeting #11, Torsional deformation of HL-LHC IT W-bellows, <https://indico.cern.ch/event/725603/>

[4] D. Ramos, Y. Leclercq, Working Group on Alignment, Meeting #13, "W" sleeves limits of solicitations, <https://indico.cern.ch/event/731474/>

[5] M. Chastre Rodrigues, E. Page, G. Bregliozzi, V 1.6 Optics: 2022 HL-LHC Beam Vacuum Layout For LSS5R, EDMS 2045739

[6] Mail exchange with Y. Leclercq (2024-06-27)

[7] Mail exchange with Francois-Xavier Nuiri (2022-03-01)

[8] Meeting with E. Montesinos 2024-09-30. Values still to be confirmed – simulations and analysis performed by C. Sharp

Yellow marked – still under final investigations/definition

M. Sosin WG meeting #78

Follow up

Need to have also Q1 measurements. Ideally we should have all cold measurements, or at least all warm. I need to digest the values. ID cards do not have yet a glossary document to explain how the values are defined and measured.

For production would important to know also the position of the interfaces to estimate the offsets of all bellows such as BPMs and critical lines.

For the string test, I propose to position the magnets with magnetic axis aligned before the connection. Measure the offsets between interfaces and evaluate the residual range of motion to be compatible with 2.5 mm offset and 1 mrad range roll.

Very important to verify the possibility to correct Q3 roll angle at installation time and it is operational alignment margins. If Q3 would positionally locked and/or roll not corrected, coupling correction will be critical.