



Position determination of HL-LHC components: uncertainty of measurements

Alignment review 2019

Vivien RUDE

2019-08-27

Outline

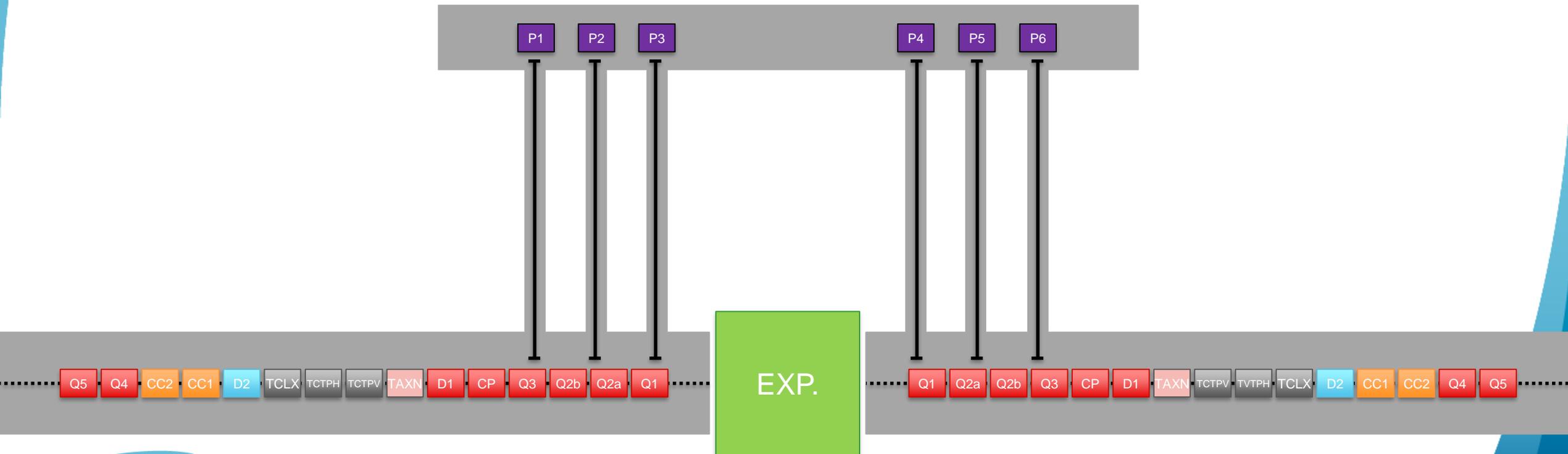
- **Introduction:**
 - Possible sources of uncertainty
 - Cases reviewed
 - A short reminder on the configuration of sensors
- **Uncertainty of measurement concerning:**
 - Internal monitoring
 - The position of cryostats along one side of the tunnel
 - The position of cryostats along one side of the tunnel w.r.t. the other side
- **Sensors configuration:**
 - Review of weak points and key points
 - Two proposals of improvement

Some possible sources of uncertainty concerning the position of HL-LHC reference axis in the tunnel:

- Cold mass construction
- Beam screen vs cold bore axis
- Cold mass position in the cryostat
- Determination of the position of the cryostat in the tunnel (using alignment sensors)

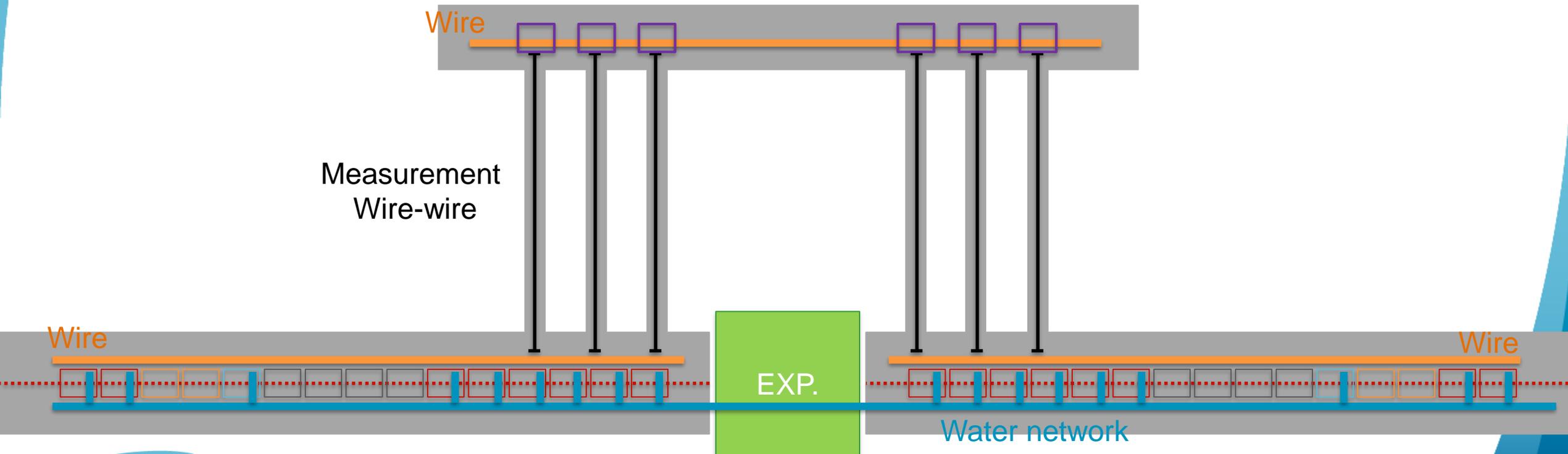
Review of 3 cases concerning the uncertainty of measurement:

- Internal monitoring of Q1, Q2a, Q2b, Q3, CC1, CC2
- Position of the components cryostat along one side of the tunnel
- Position of the components cryostat along one side of the tunnel w.r.t the other side



Configuration of alignment systems

- 3 wires
- 1 (or several) water network
- 6 measurements wire-wire



Configuration of alignment sensors

Long range FSI

Internal FSI

Water Network

HLS

WPS

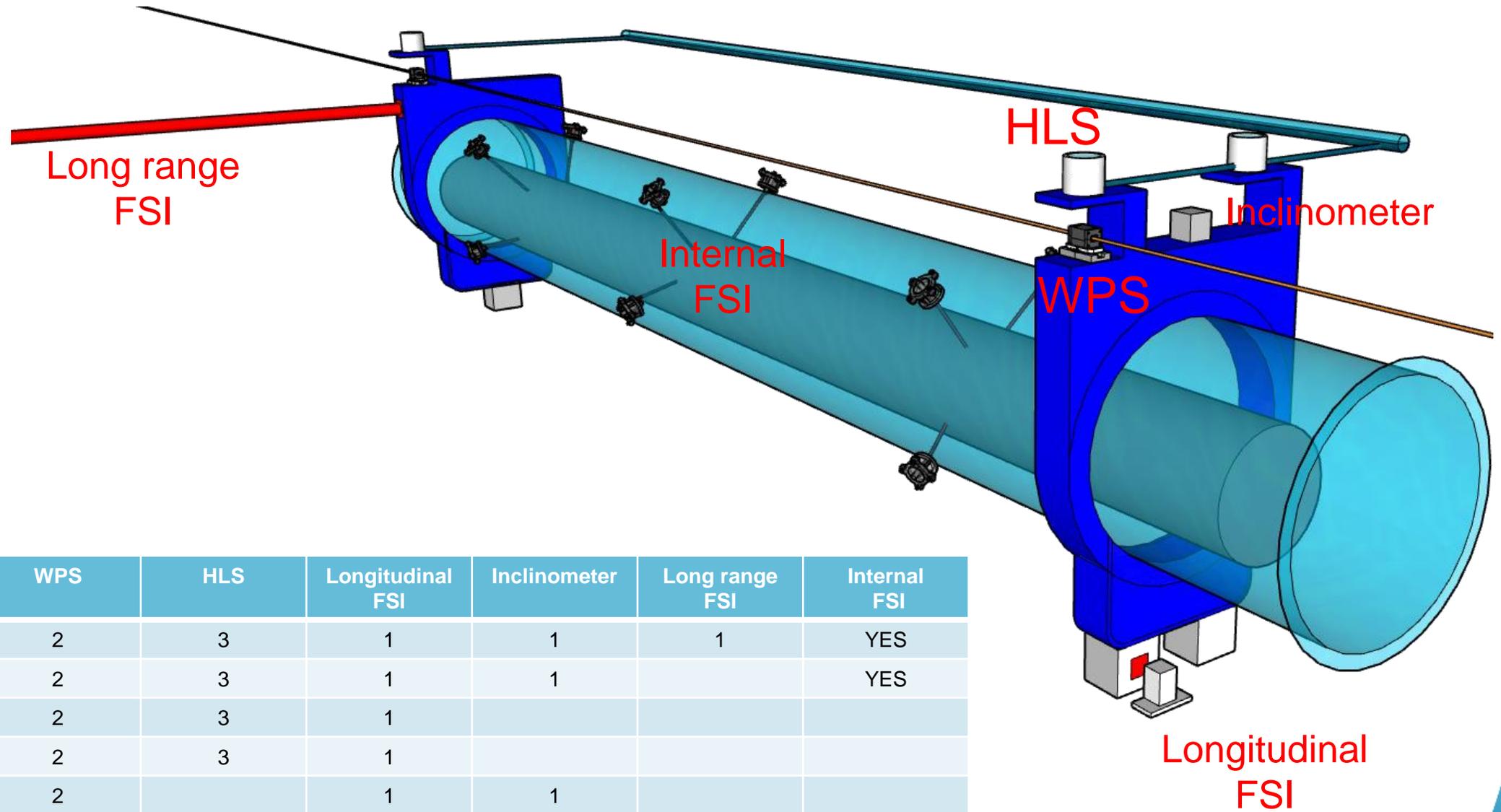
Inclinometer

wire

Longitudinal FSI

Sensors	Largest standard uncertainties	Value	Combined standard uncertainty
WPS	Calibration of WPS	5 μm	20 μm
	Shape of wire	10 μm	
	Position of WPS in the framework of the vacuum vessel	15 μm	
HLS	Calibration of HLS	5 μm	40 μm
	Shape of water	30 μm	
	Position of HLS in the framework of the vacuum vessel	15 μm	
Longitudinal FSI	Calibration of Longitudinal FSI	5 μm	300 μm
	Position of Longitudinal FSI in the tunnel framework	300 μm	
	Position of the target in the framework of the vacuum vessel	15 μm	
Inclinometer	Calibration of inclinometer	15 μrad	100 μrad
	Position of the inclinometer in the framework of the vacuum vessel	100 μrad	
Long range FSI 14 m	Calibration of the Long range FSI	35 μm	40 μm
	Position of the FSI in the framework of the UPS plate	15 μm	
	Position of the target in the framework of the vacuum vessel	15 μm	
Internal FSI	Calibration of Short range FSI	10 μm	20 μm
	Position of the target in the framework of the cold mass	15 μm	
	Position of the FSI in the framework of the vacuum vessel	15 μm	

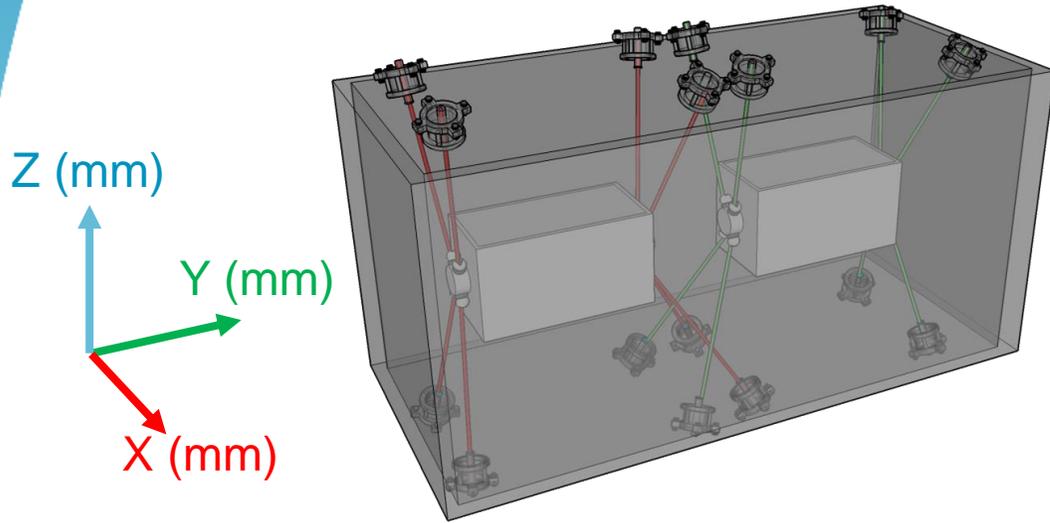
Configuration of alignment sensors



	WPS	HLS	Longitudinal FSI	Inclinometer	Long range FSI	Internal FSI
Q1, Q2a, Q3	2	3	1	1	1	YES
Q2b	2	3	1	1		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES

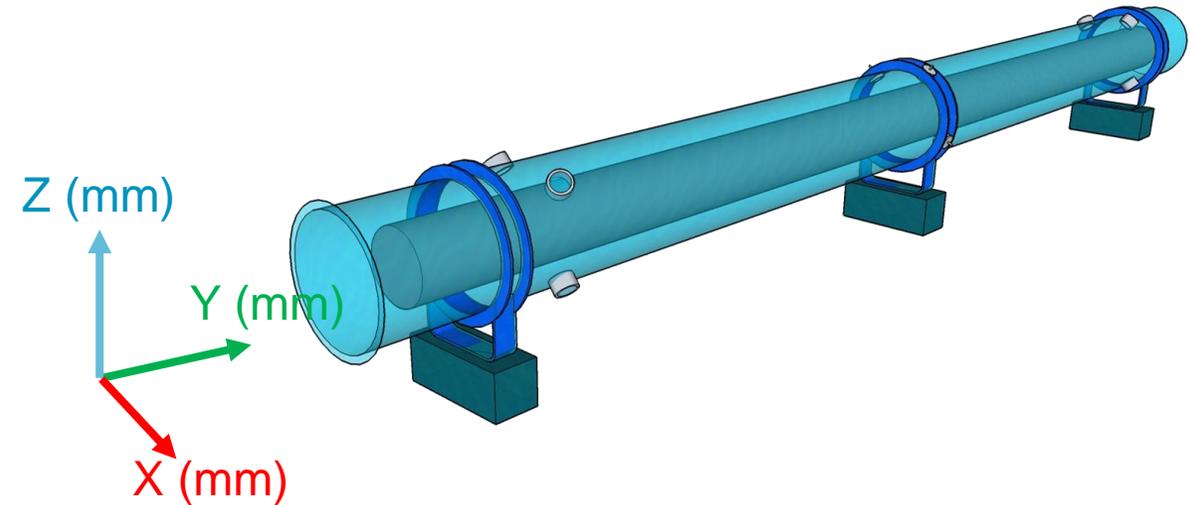
Case 1: Uncertainty of measurement concerning internal monitoring

Crab-cavity



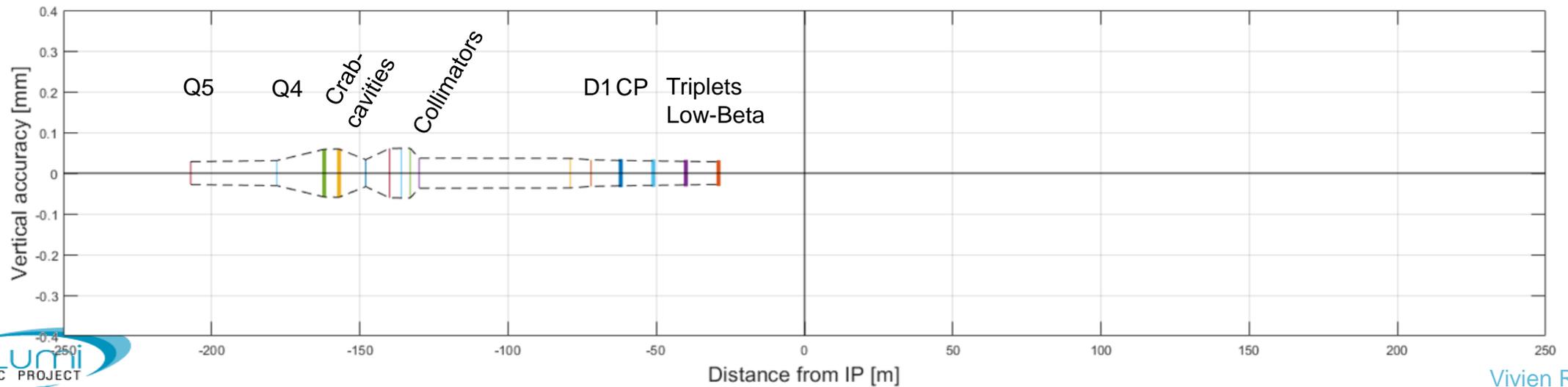
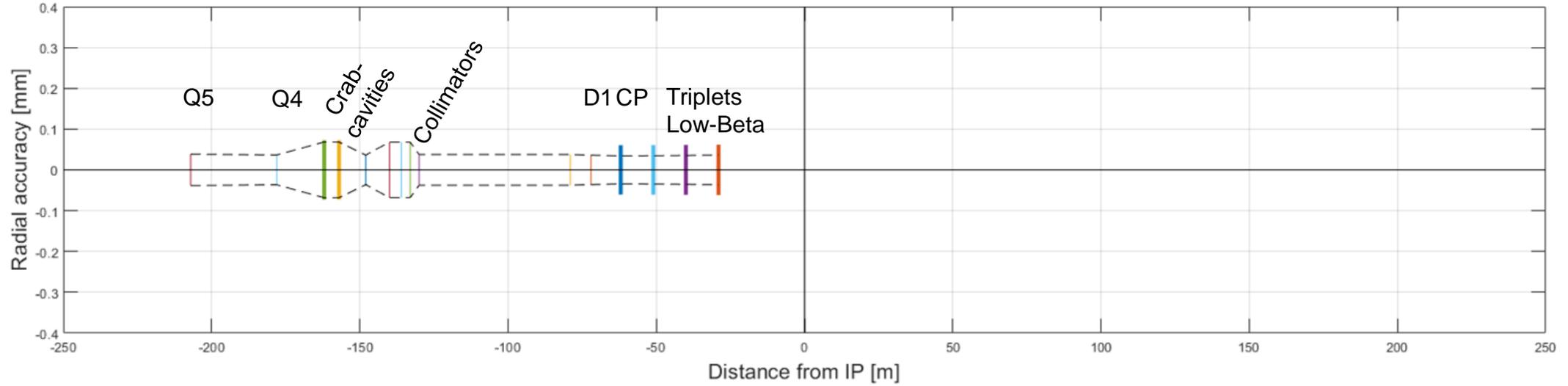
Parameter	Standard uncertainty (1σ)
Tx (radial)	+/- 25 μm
Ty (longitudinal)	+/- 45 μm
Tz (vertical)	+/- 10 μm
Rx (pitch)	+/- 30 μrad
Ry (roll)	+/- 150 μrad
Rz (yaw)	+/- 70 μrad
Scale	+/- 60 ppm

Triplet

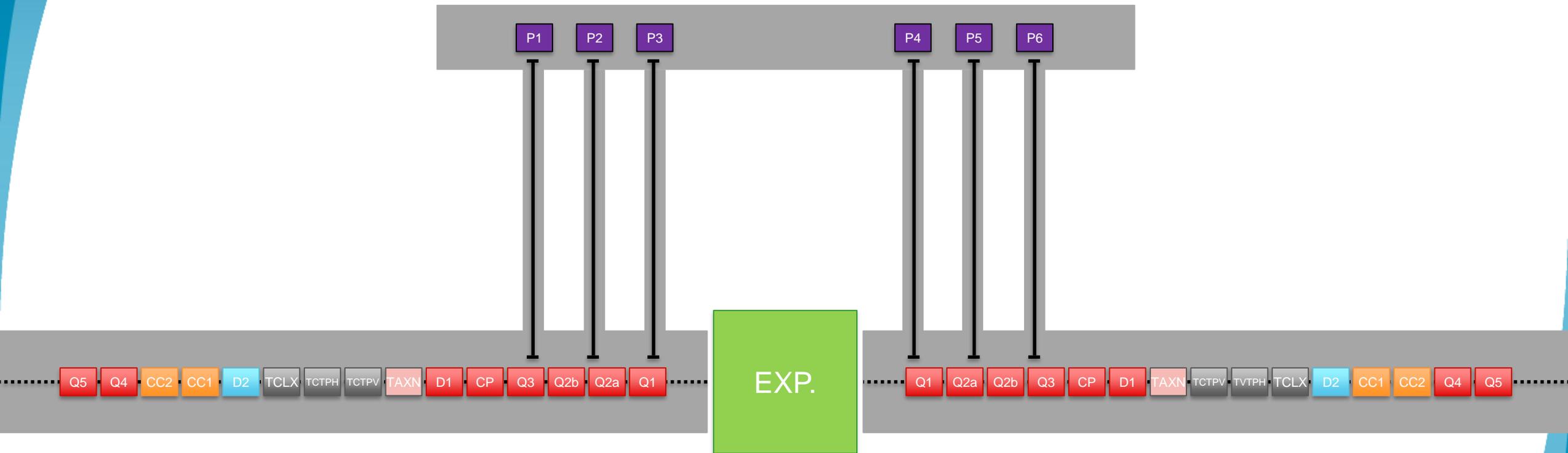


Parameter	Standard uncertainty (1σ)
Tx (radial)	+/- 50 μm
Ty (longitudinal)	+/- 55 μm
Tz (vertical)	+/- 15 μm
Rx (pitch)	+/- 5 μrad
Ry (roll)	+/- 1500 μrad
Rz (yaw)	+/- 5 μrad
Scale	+/- 10 ppm

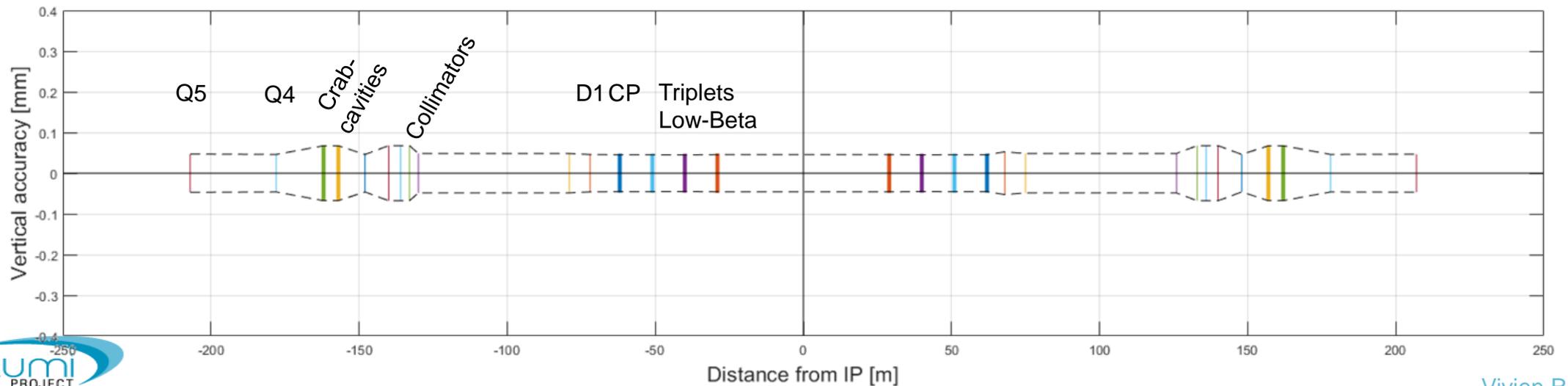
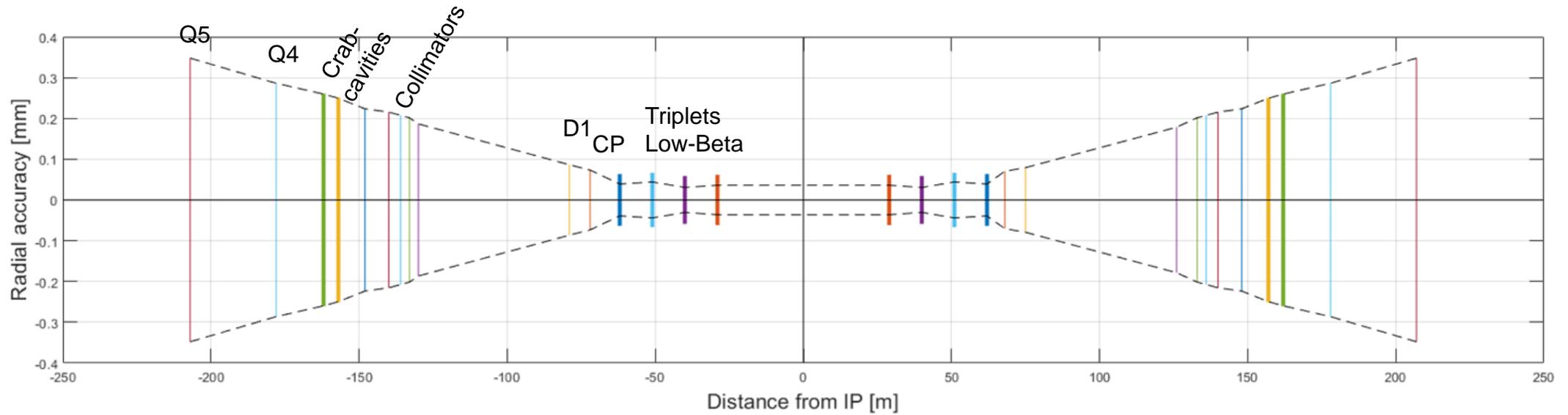
Case 2: Uncertainty of alignment concerning components cryostats along one side



Case 3: Uncertainty of alignment concerning components cryostats along one side w.r.t. the other side

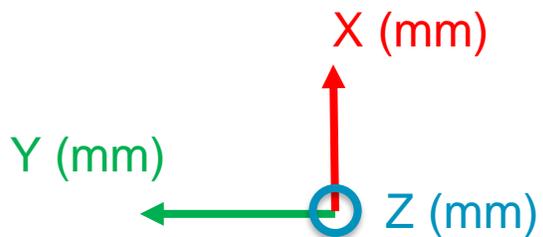


Case 3: Uncertainty of alignment concerning components cryostats along one side w.r.t. the other side

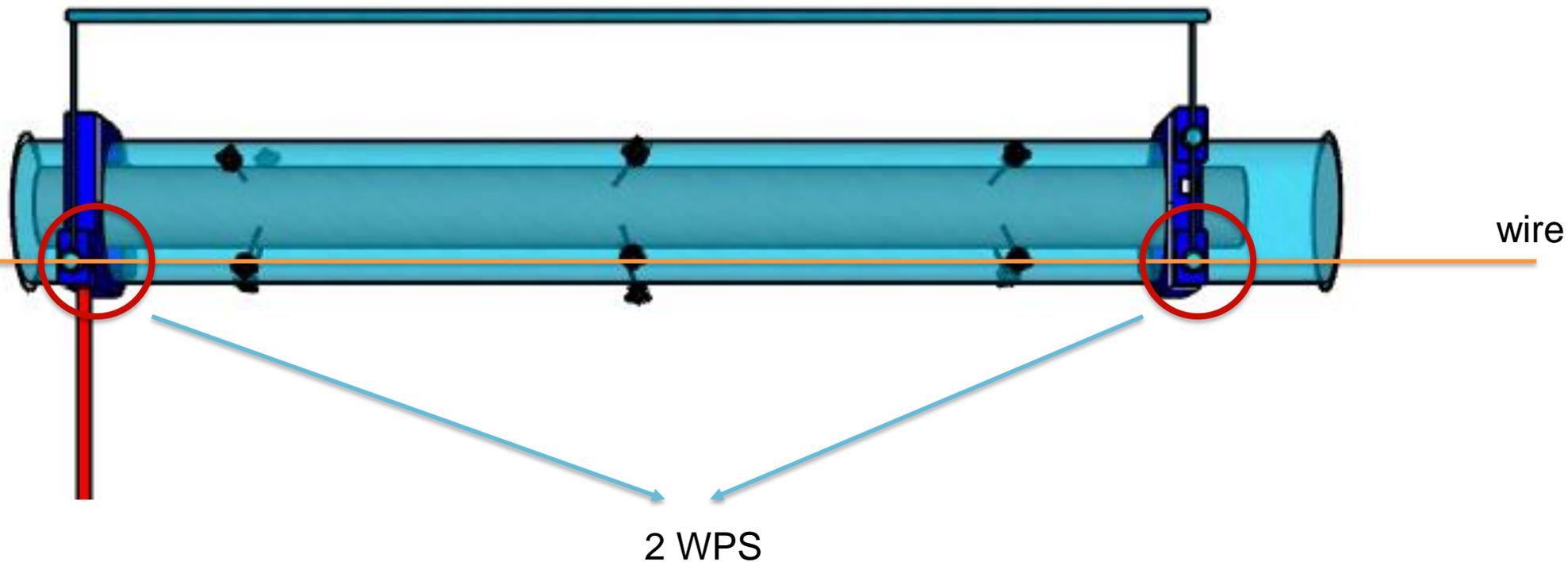


Weak points : Radial direction -- > Tx / Rz (yaw)

No redundancy

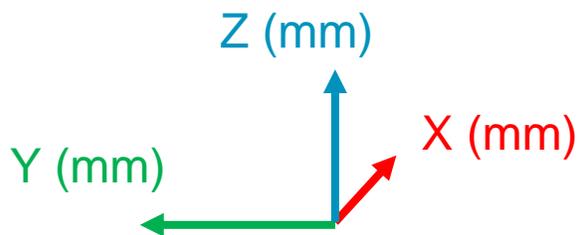


	WPS	HLS	Long. FSI	Incl.	Long range FSI	Internal FSI
Q1, Q2a, Q3	2	3	1	1	1	YES
Q2b	2	3	1	1		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES

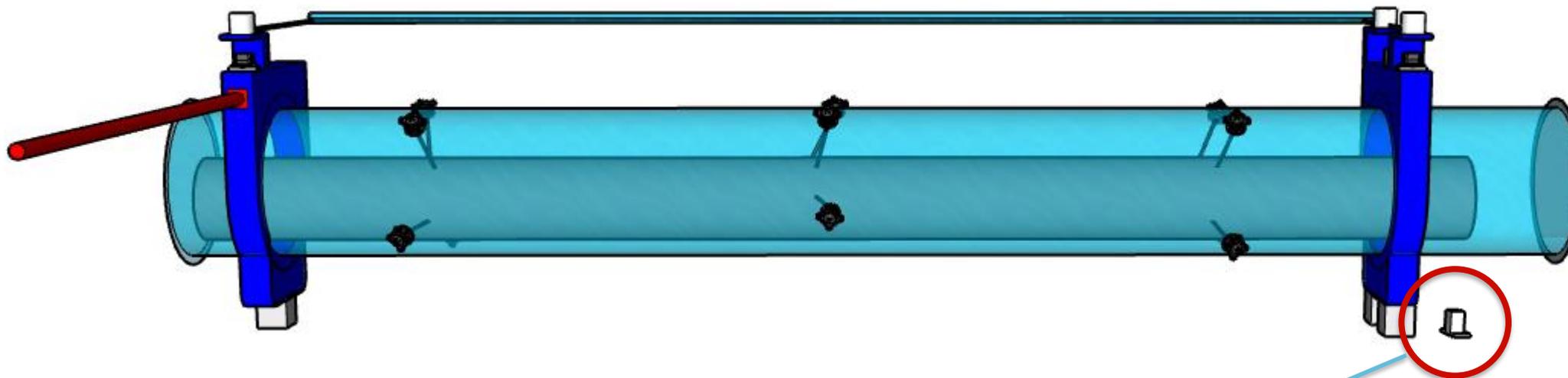


Weak points : Longitudinal direction → Ty

No redundancy



	WPS	HLS	Long. FSI	Incl.	Long range FSI	Internal FSI
Q1, Q2a, Q3	2	3	1	1	1	YES
Q2b	2	3	1	1		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES

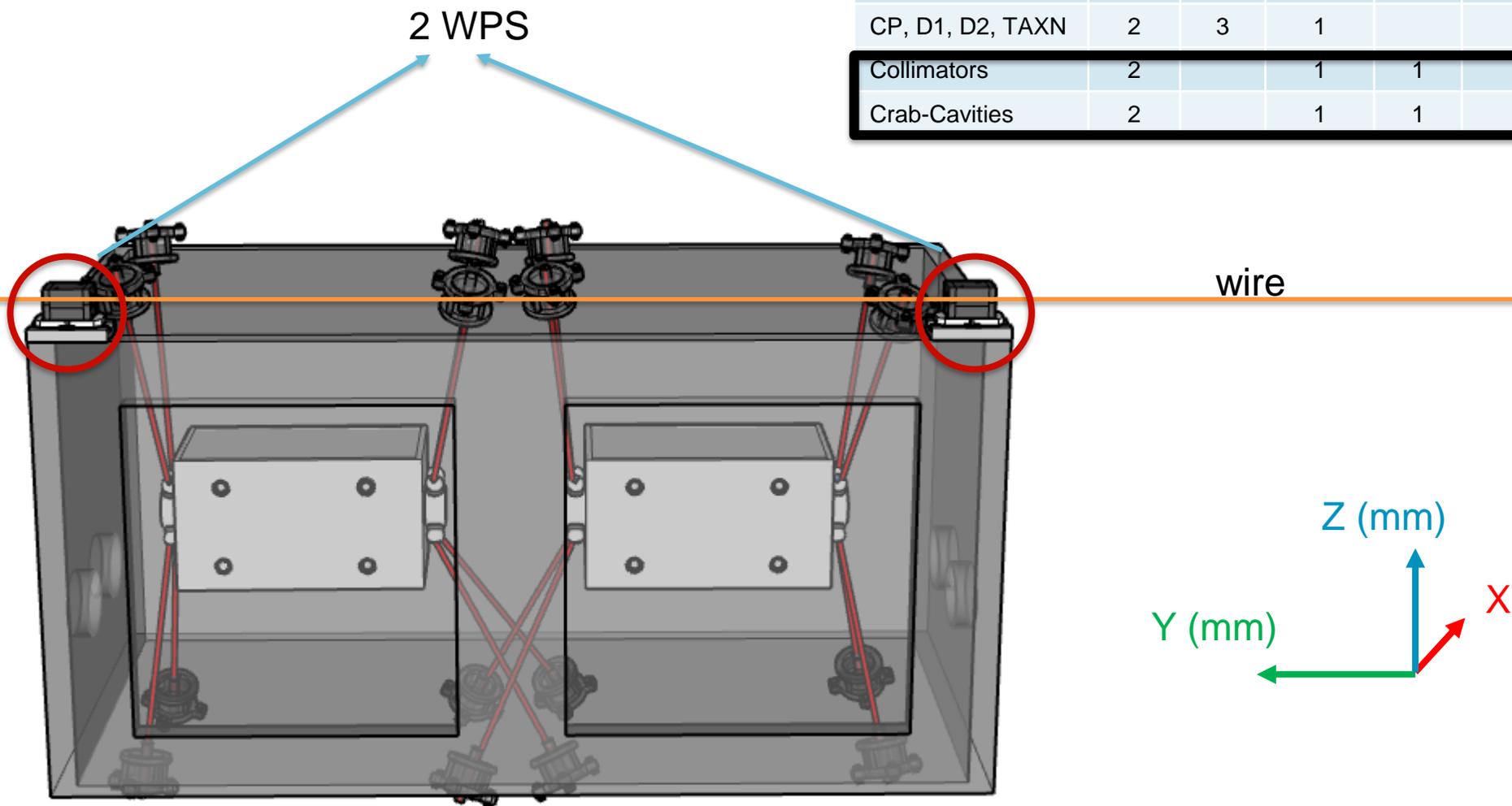


1 Longitudinal FSI

Weak points : Vertical direction \rightarrow Tz, Rx (pitch)

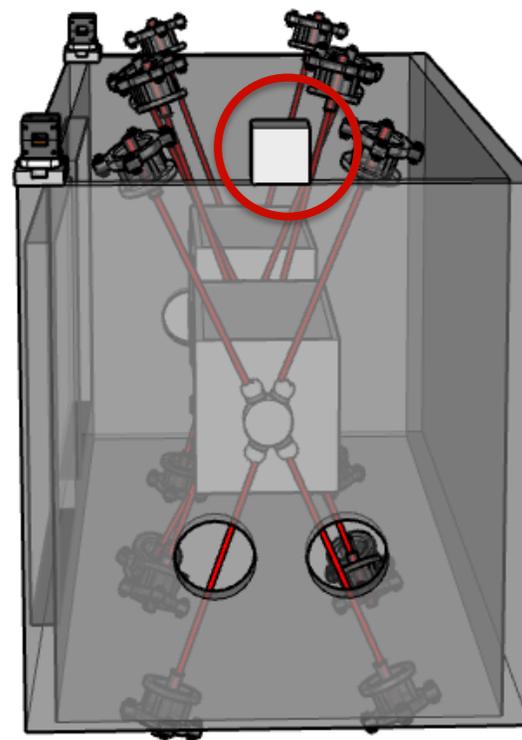
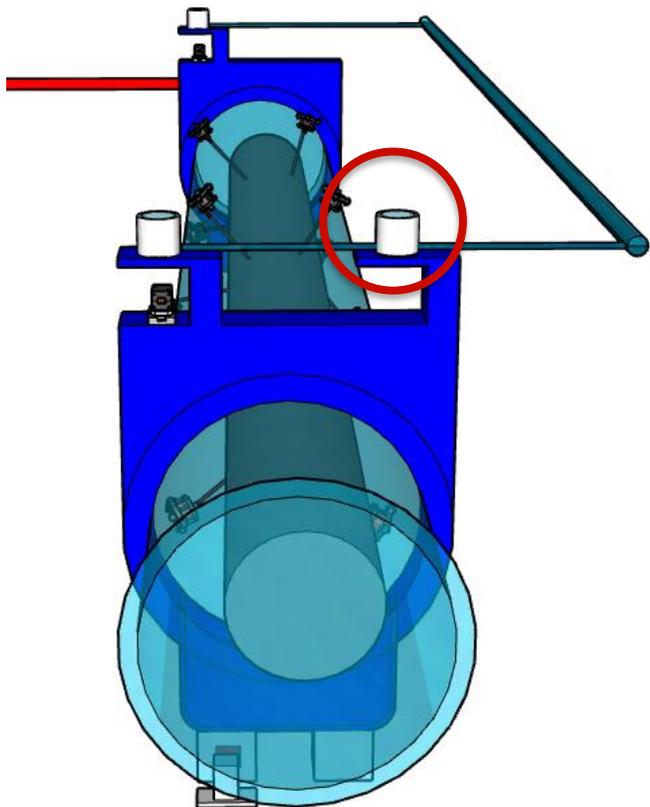
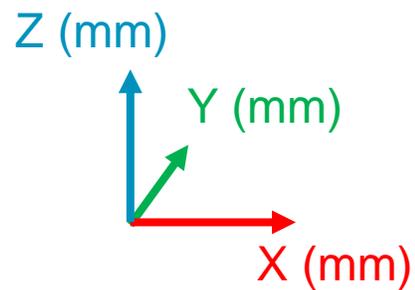
No redundancy

	WPS	HLS	Long-FSI	Incl.	Long range FSI	Internal FSI
Q1, Q2a, Q3	2	3	1	1	1	YES
Q2b	2	3	1	1		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES



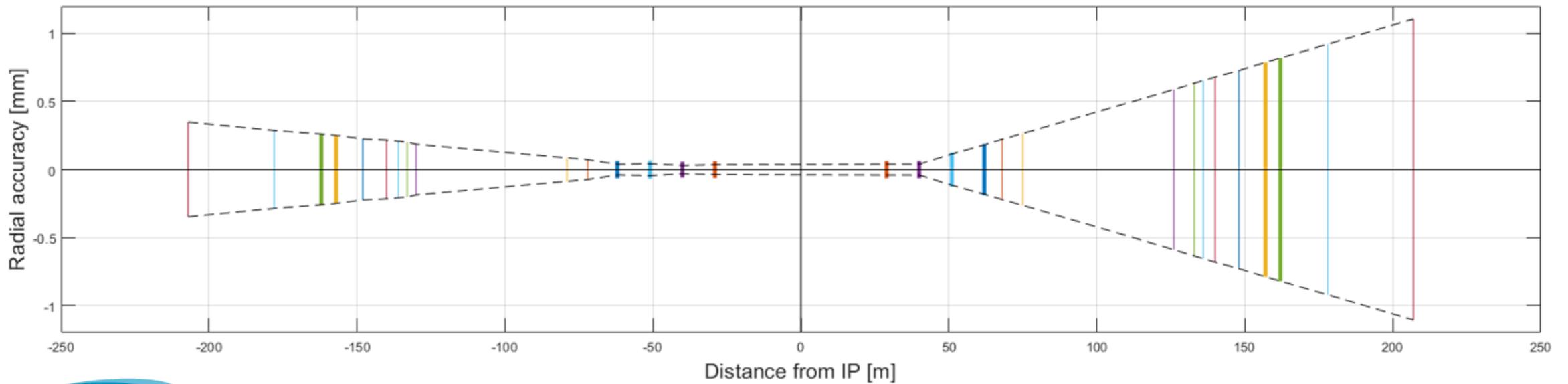
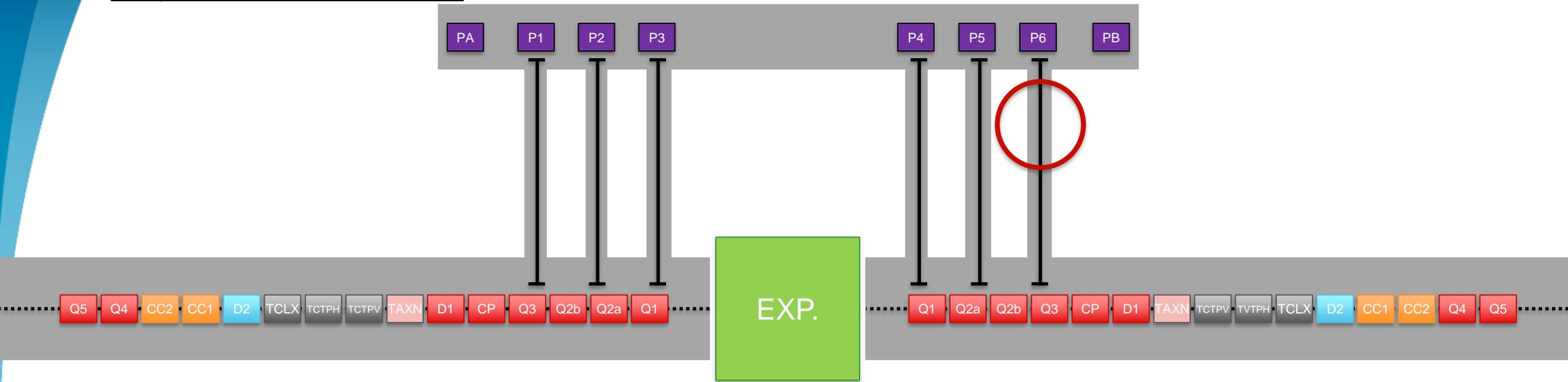
Weak points : Vertical direction \rightarrow Ry (roll)

No redundancy



	WPS	HLS	Long. FSI	Incl.	Long range FSI	Internal FSI
Q1, Q2a, Q3	2	3	1	1	1	YES
Q2b	2	3	1	1		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES

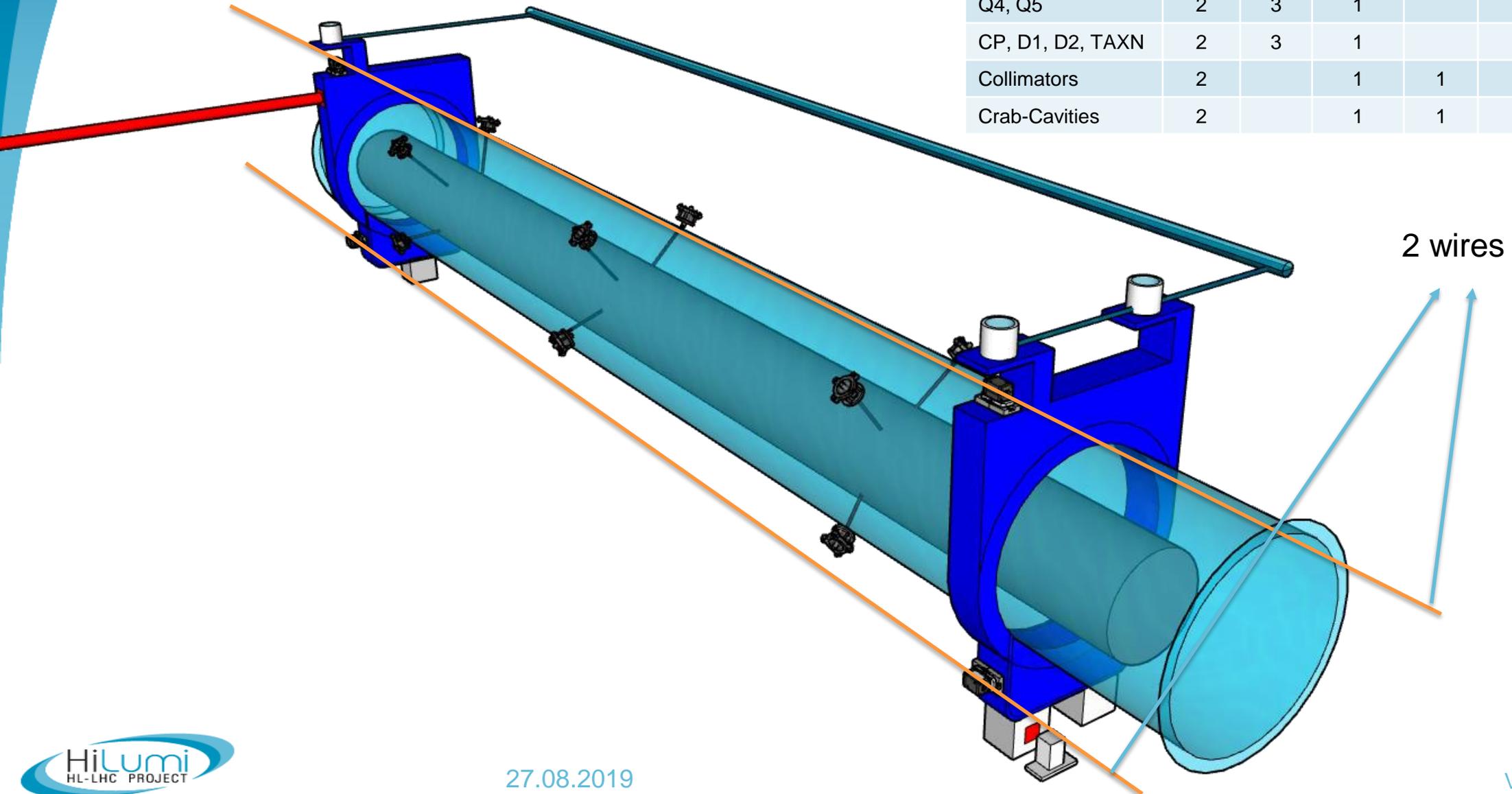
Key point : Borehole



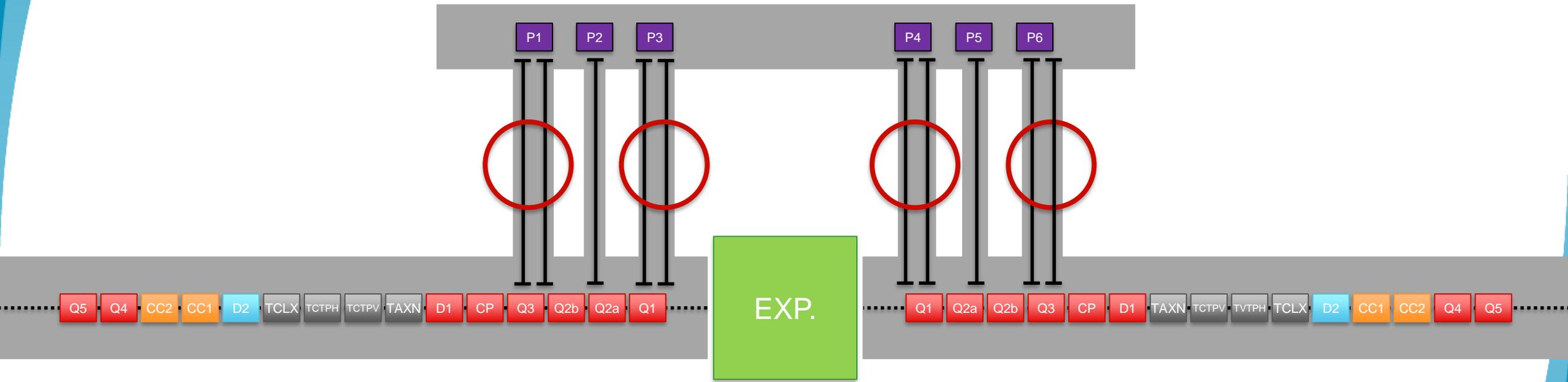
Proposal 1 : 2 wires for the triplet

Redundancy in 5 DOF

	WPS	HLS	Long-FSI	Incl.	Long range FSI	Internal FSI
Q1, Q2a, Q3	4	3	1	0	1	YES
Q2b	4	3	1	0		YES
Q4, Q5	2	3	1			
CP, D1, D2, TAXN	2	3	1			
Collimators	2		1	1		
Crab-Cavities	2		1	1		YES



Proposal 2 : Double Long range FSI for the borehole



Thank you
for your attention