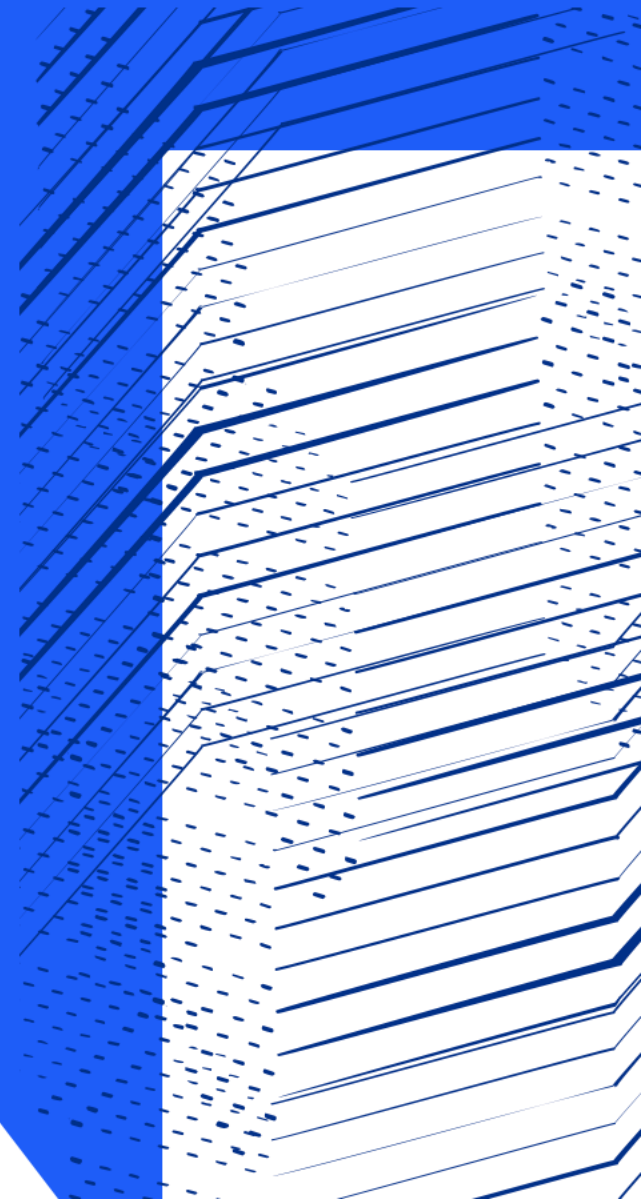
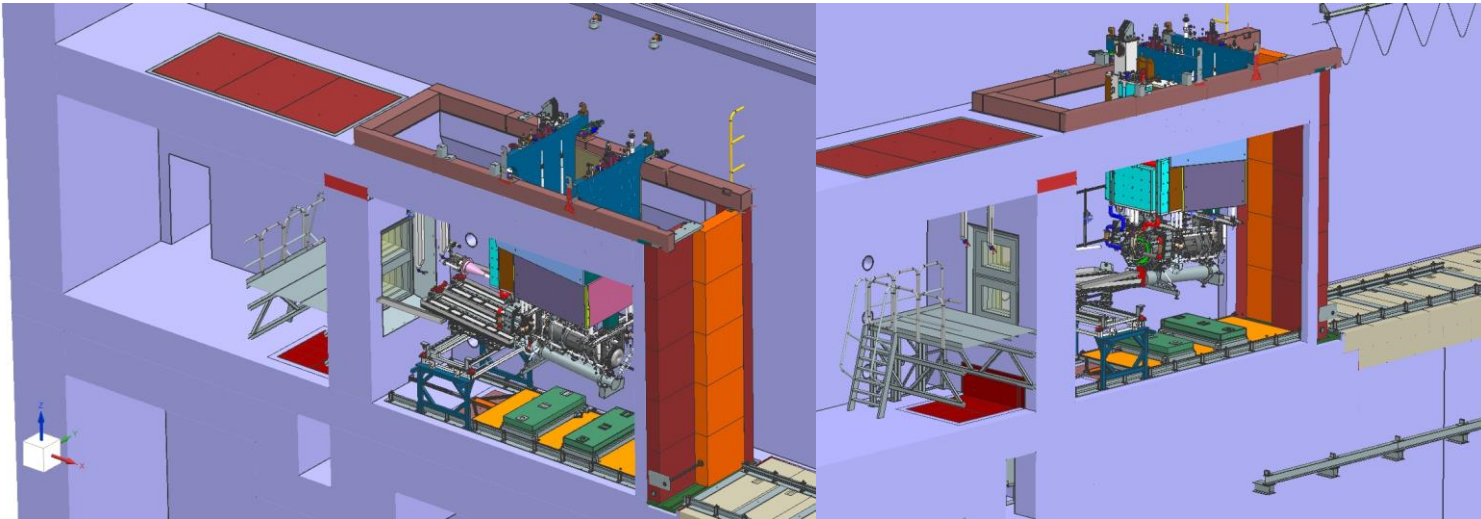




Science and
Technology
Facilities Council

LBNF Target Exchange Procedures

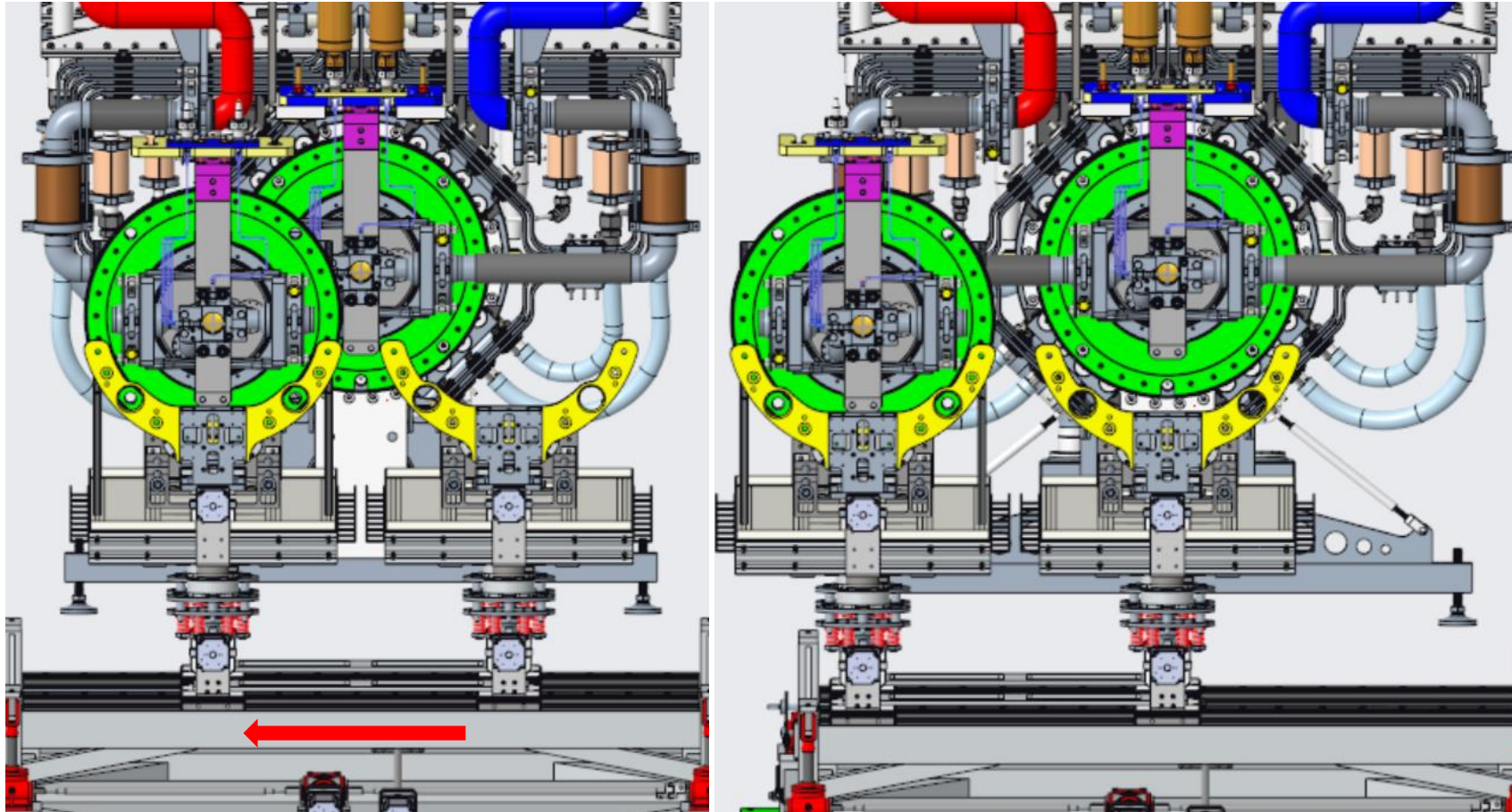
Eric Harvey-Fishenden



- Work cell shielding removed
- TXS is installed in work cell
- Container is brought into cell*
- TXS docks to container and extracts new target, container moved out of cell*
- Horn is brought into cell from chase and shielding is replaced
- TXS docks to horn, and old target is removed, new one is installed
- Shielding is removed and Horn is returned to chase
- Container is brought back into cell
- TXS docks to container and installs spent target
- Spent target is craned to morgue in container

*Target is likely to be craned into cell and staged manually

1. Select active table and align to supports horizontally



Fermilab Long Baseline Neutrino Facility – Target Exchange System
Target Remote Handling

UKRI Science and Technology Facilities Council

X AXIS

Y1 AXIS

Y2 AXIS

Y1+Y2

Z1 AXIS

Z2 AXIS

TGT1 AXIS

TGT2 AXIS

SETTINGS

000.0mm

X Limit Switch +

Home

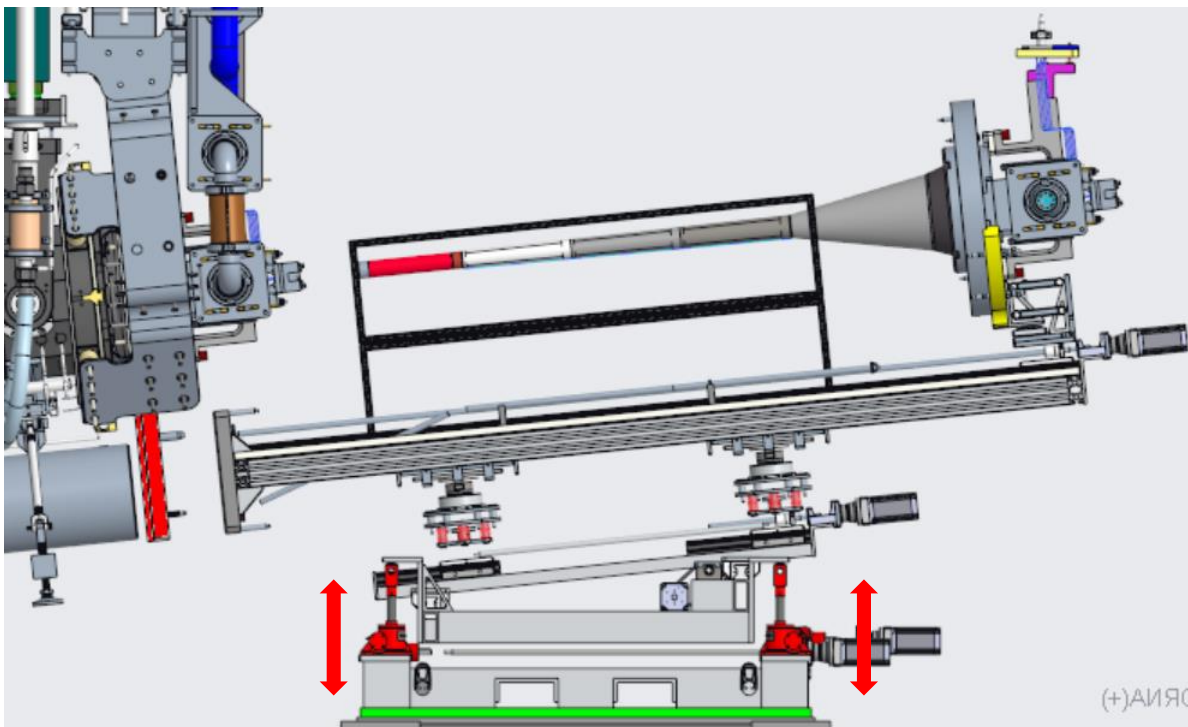
000.0mm

X Limit Switch -

X AXIS

Adjustment	X-Stage
Compliance	Ball transfer units
Diagnostics	Cameras, nominal datum switch positions on linear stage
Required Accuracy (\pm)	8.5mm
Notes	-

2. Adjust table height to locate onto alignment pins



Long Baseline Neutrino Facility – Target Exchange System
Target Remote Handling

X1 AXIS

X2 AXIS

Y1 AXIS

Y2 AXIS

Z1 AXIS

Z2 AXIS

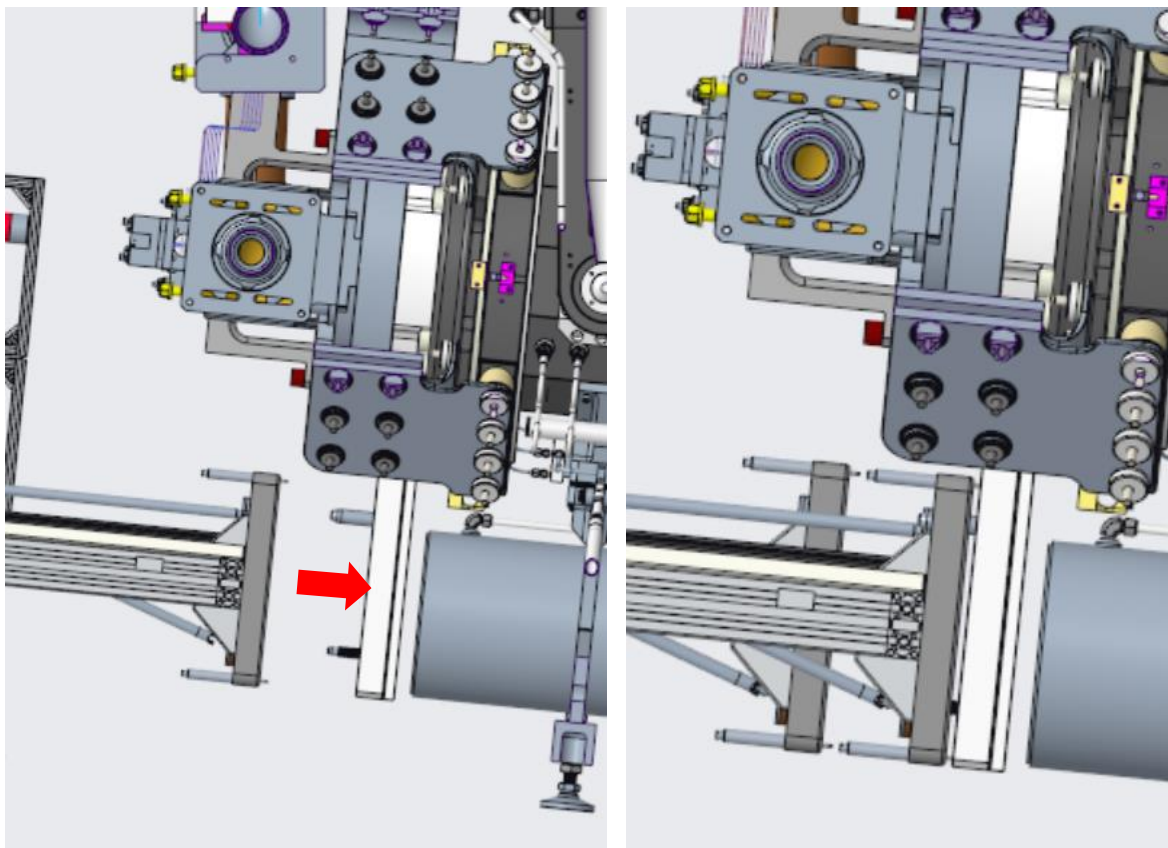
Z2 AXIS

SETTINGS

Y AXIS

Adjustment	Compliance	Diagnostics	Required Accuracy (±)	Notes
Screw Jacks (Y)	-	Cameras, nominal datum switches on Y stages	8.5mm	Angle nominally correct so height adjustments to be made synchronously F+R

3. Drive active stage forward onto pins



Long Baseline Neutrino Facility – Target Exchange System
Target Remote Handling

X AXIS

Y1 AXIS

Y2 AXIS

Y1+Y2

Z1 AXIS

Z2 AXIS

TGT1 AXIS

TGT2 AXIS

SETTINGS

000.0mm

++

+

-

--

Z1 AXIS

000.0mm

++

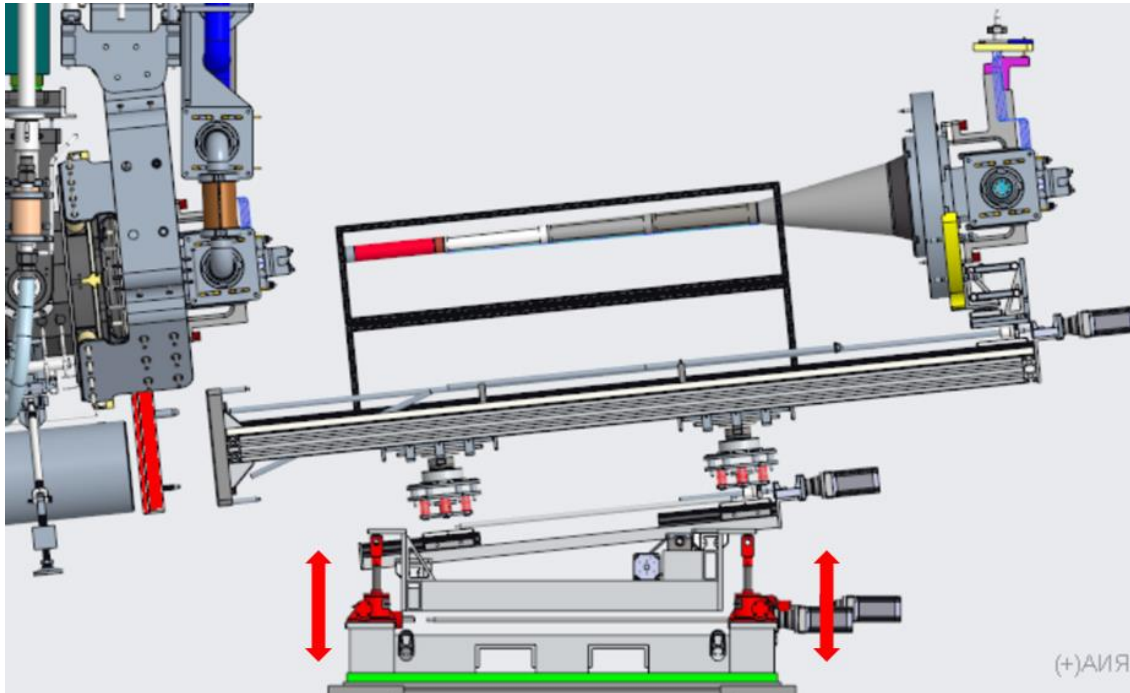
+

-

--

Adjustment	Z-Stage
Compliance	Spring Supports; Gimbals; BTU Stage
Diagnostics	Cameras, Load cells, limit approach switches
Required Accuracy (\pm)	-
Notes	Front load cells indicate whether table is too high or too low. BTU stage allows X-wise compliance to allow pins to locate

4. Adjust table height based on load cell readings



Fermilab Long Baseline Neutrino Facility – Target Exchange System

Target Remote Handling

X AXIS

Y1 AXIS

Y2 AXIS

Y1+Y2

Z1 AXIS

Z2 AXIS

TGT1 AXIS

TGT2 AXIS

SETTINGS

PS4 0.0mm PS6 0.0mm PS1 0.0mm PS2 0.0mm

0.0mm PS4 0.0mm PS3 0.0mm

000.0mm

++

+

0.0N 0.0N

MY1 LC1 LC2 MY2

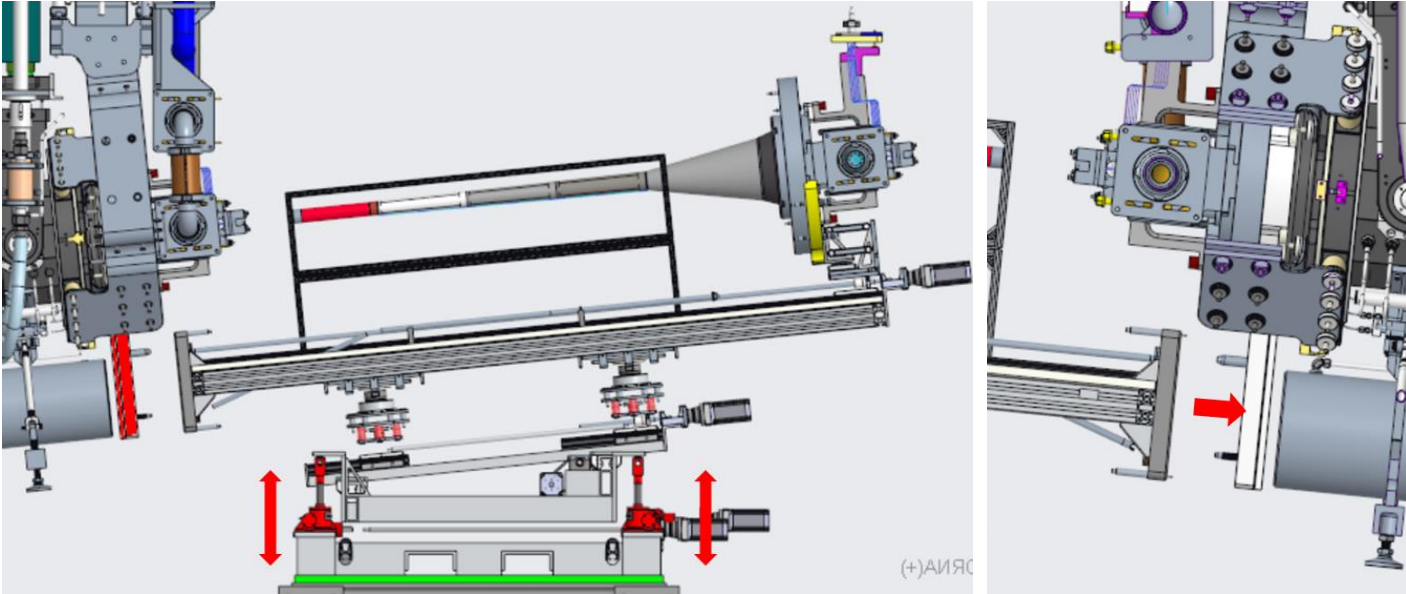
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Y AXIS

--

Adjustment	Screw Jacks
Compliance	Spring Supports; Gimbals
Diagnostics	Load cells
Accuracy (+-)	-
Notes	Change in load cell readings will validate adjustments

5. Repeat steps 2/3 iteratively until LVDT proximity sensors begin reading (13mm)

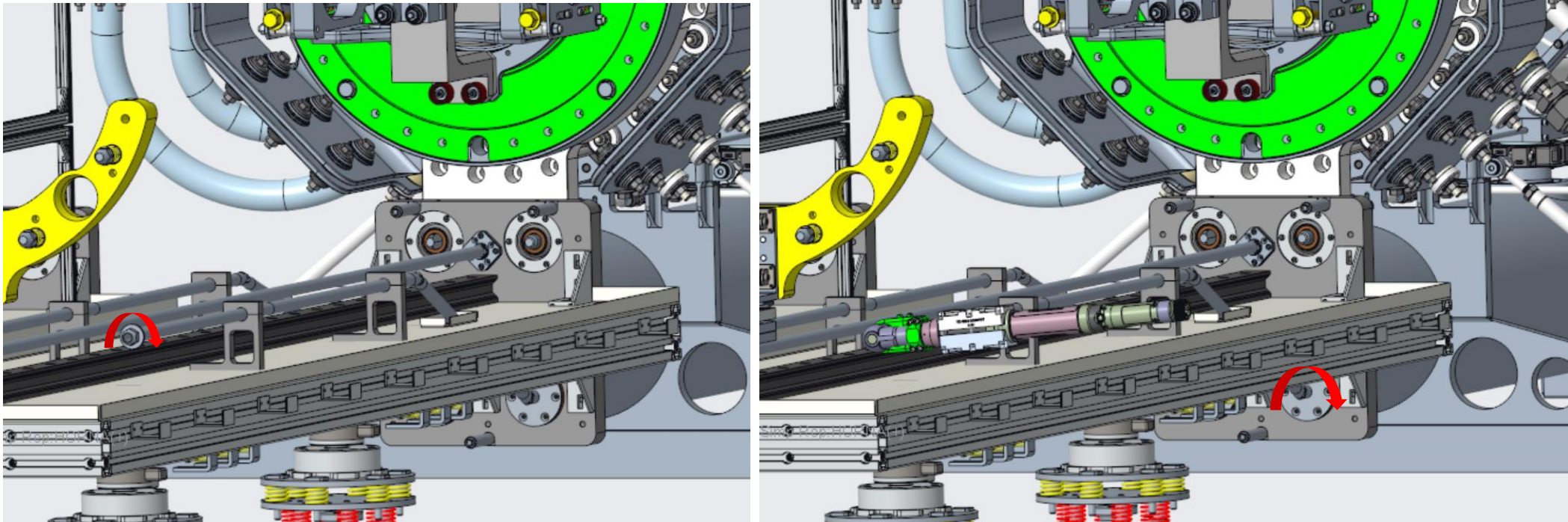


Fermilab Long Baseline Neutrino Facility – Target Exchange System
Target Remote Handling UK Science and Technology Facilities Council

X AXIS	PS1 0.0mm	0.0mm	PS2 0.0mm
Y1 AXIS	000.0mm	0.0N	000.0mm
Y2 AXIS	++	PS3 0.0N	++
Y1+Y2	+	LC1	+
Z1 AXIS	-	MZZ	-
Z2 AXIS	--	0.0N	--
TGT1 AXIS		LC2	
TGT2 AXIS		MZ1	
SETTINGS		Z1 AXIS	

Adjustment	Compliance	Diagnostics	Accuracy (\pm)	Notes
Z-Stage/Screw Jacks	Spring Supports; Gimbals; BTU Stage	Load cells, proximity sensors	-	-

6. Tighten docking plate captive nuts



Adjustment

Manipulator/End of arm tooling

Compliance

Spring Supports; Gimbals; BTU Stage

Diagnostics

Load cells, proximity sensors

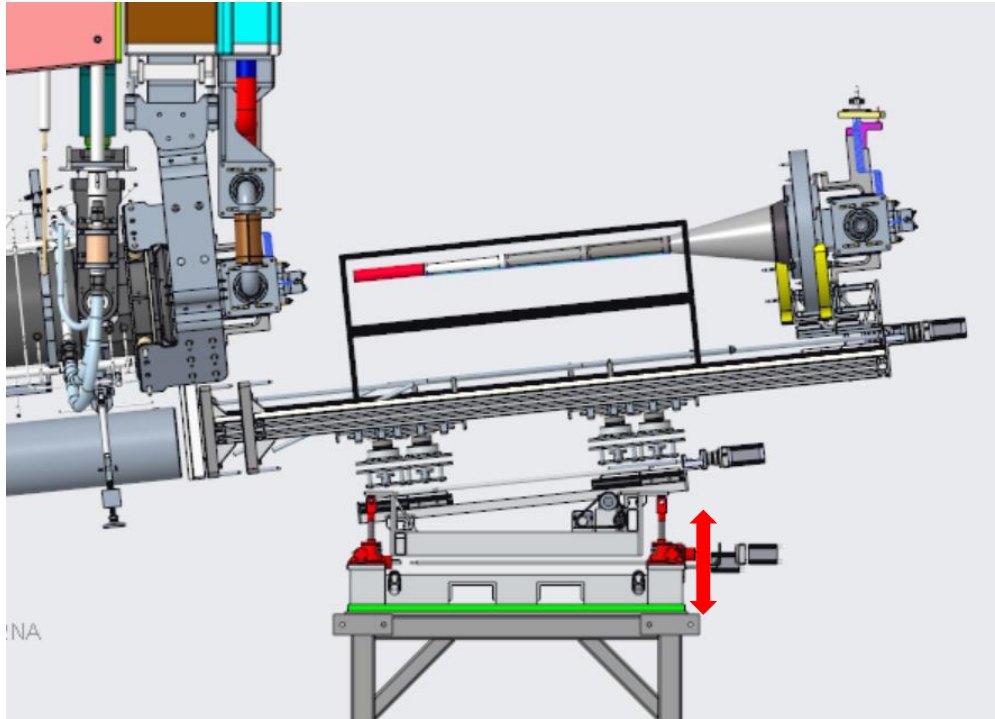
Accuracy (\pm)

-

Notes

-

7. Adjust table angle based on load cell/proximity sensor readings



Long Baseline Neutrino Facility – Target Exchange System

Target Remote Handling

- X AXIS
- Y1 AXIS
- Y2 AXIS
- Y1+Y2
- Z1 AXIS
- Z2 AXIS
- TGT1 AXIS
- TGT2 AXIS
- SETTINGS

PS4 0.0mm

PS6 0.0mm

PS4 0.0mm

000.0mm

++

+

-

--

Y AXIS

PS1 0.0mm

PS2 0.0mm

PS3 0.0mm

000.0mm

++

+

-

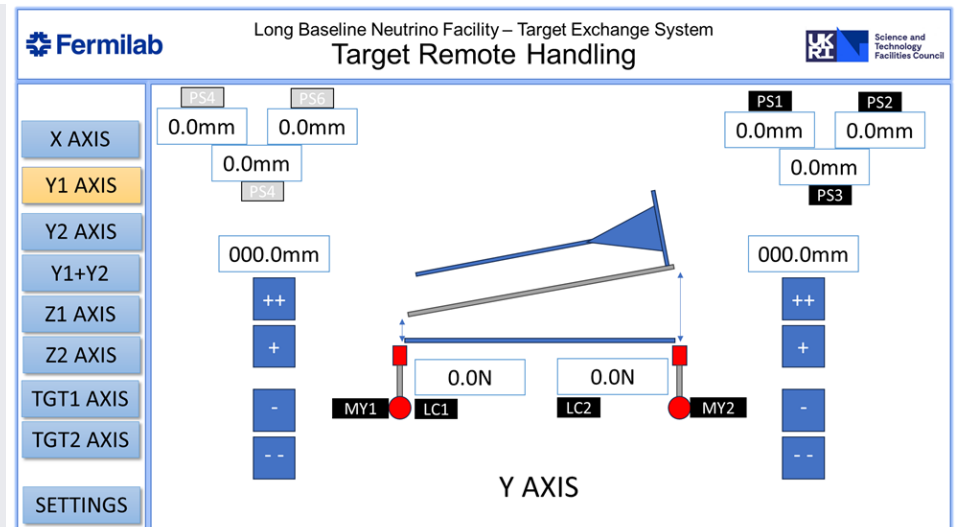
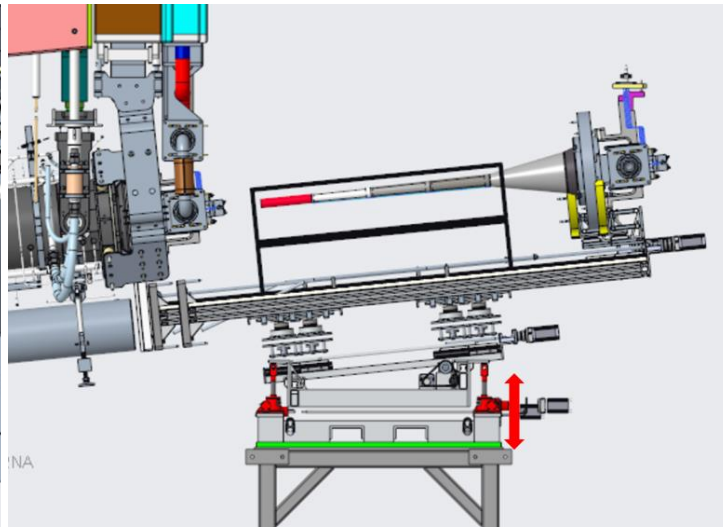
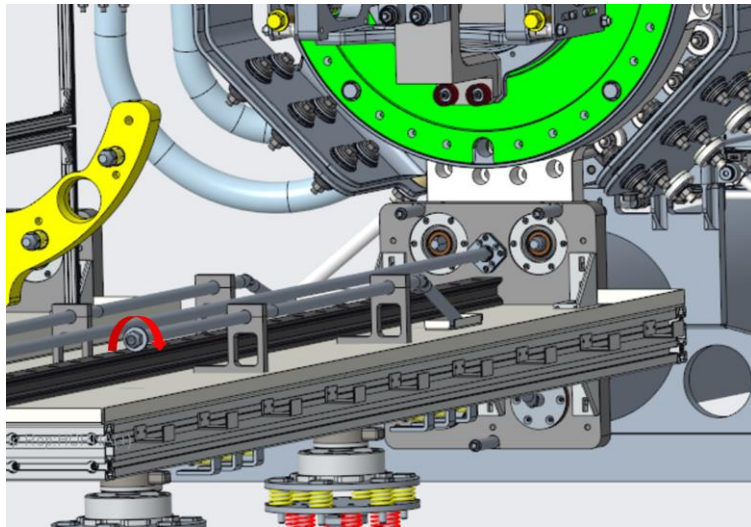
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Adjustment	Rear Screw Jacks
Compliance	Spring Supports; Gimbals
Diagnostics	Load cells, proximity sensors
Accuracy (±)	-
Notes	

LBNF Target Exchange System TDR/Peer Review

Slide 9

8. Repeat steps 6/7 iteratively until load cell readings stop changing and proximity sensors read 0 (gap is closed)

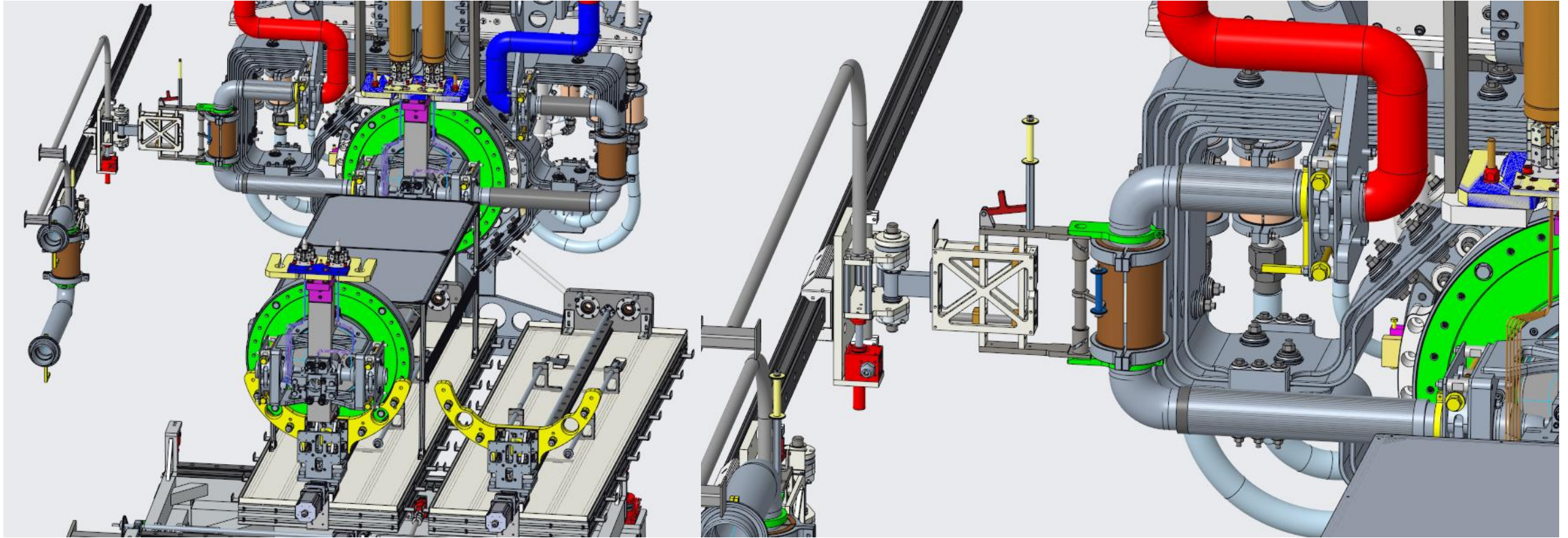


Adjustment	Screw Jacks
Compliance	Spring Supports; Gimbals; BTU Stage
Diagnostics	Load cells, proximity sensors
Accuracy (\pm)	-
Notes	Repeat procedure for other table - without step 4, steps 6,7,9 should be much closer to final alignment

- **Target removal**

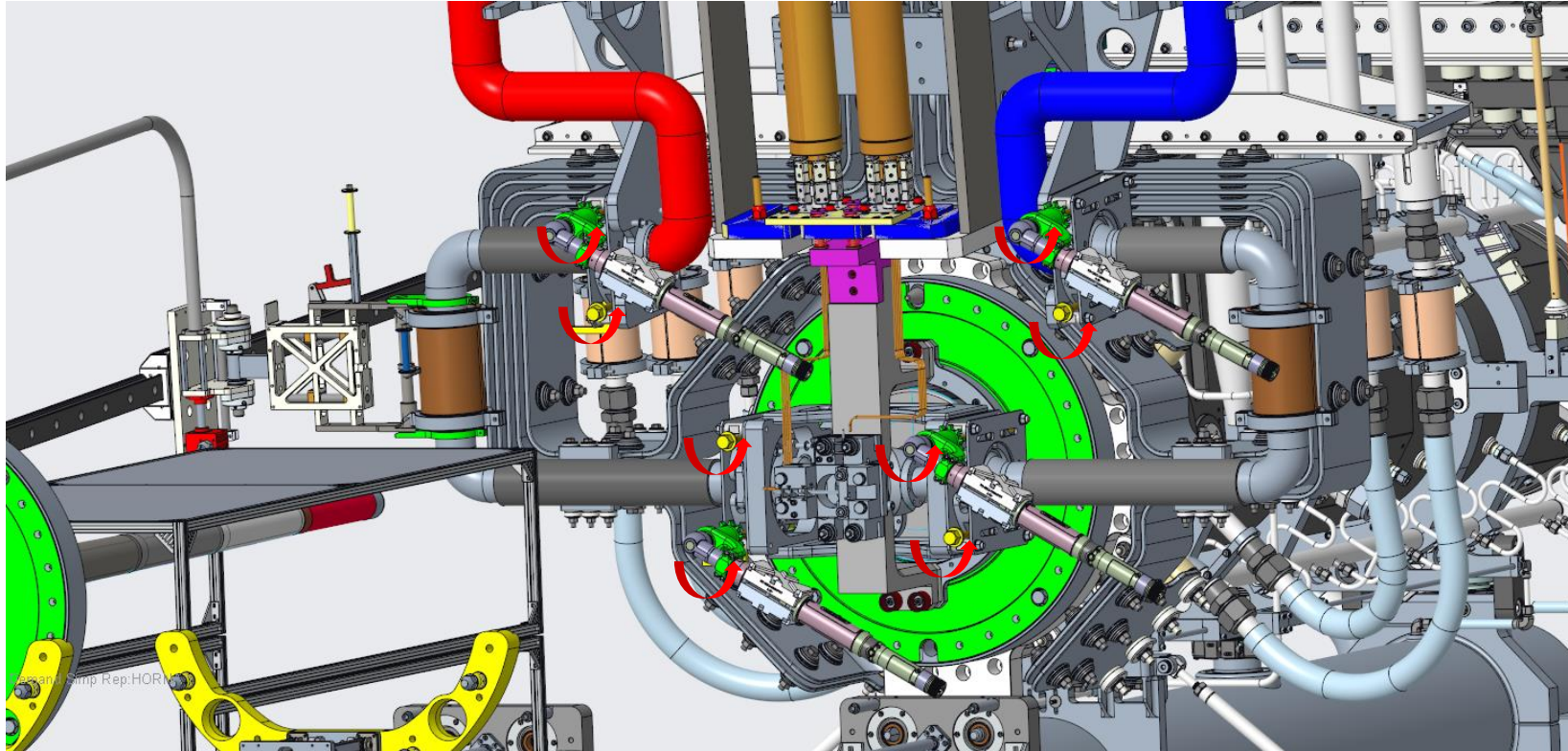
Target Removal	Operation	Tool	Diagnostics	Notes
1	Align and attach helium flex line tooling	Helium line exchange tool		TXS not docked, replacement target moved furthest away from pipe handling procedures
2	Break helium line chain clamps	Nutrunner EOAT	Visual rotating "marker" on turnbuckle	TXS stages may have to be relocated for access
3	Retract helium flex lines	Helium line exchange tool		Spent helium flex lines are rotated out of the way and pushed DS next to horn module
4	Drive target carrier to used target	TXS Target slide	Motor count readout, limit approach and limit switches	TCM allows target carrier to align to target
5	Tighten target carrier captive bolts	Nutrunner EOAT	Nutrunner controller/HMI	4 captive M16 bolts fix target to carrier, may also pull carrier flush to target plate if not already in full contact
6	Break target position thermometer electrical connection	Crane/EOAT		Lift instrumentation line from top of module 2x M14 captive nuts secure IL bracket
7	Loosen target bolts	Nutrunner EOAT	Nutrunner controller/HMI	4x M16 Captive bolts in Aluminium Bronze Spiralock insert
8	Displacement controlled removal	Jacking screws/Nutrunner EOAT	-	Controlled removal of target carrier – avoids overloading motors if any binding/sticking occurs (through-holes in "green plate")
9	Drive target carrier/target back to "start"	TXS Target slide	Motor count readout, limit approach and limit switches	

1. Align and attach helium flex line tooling



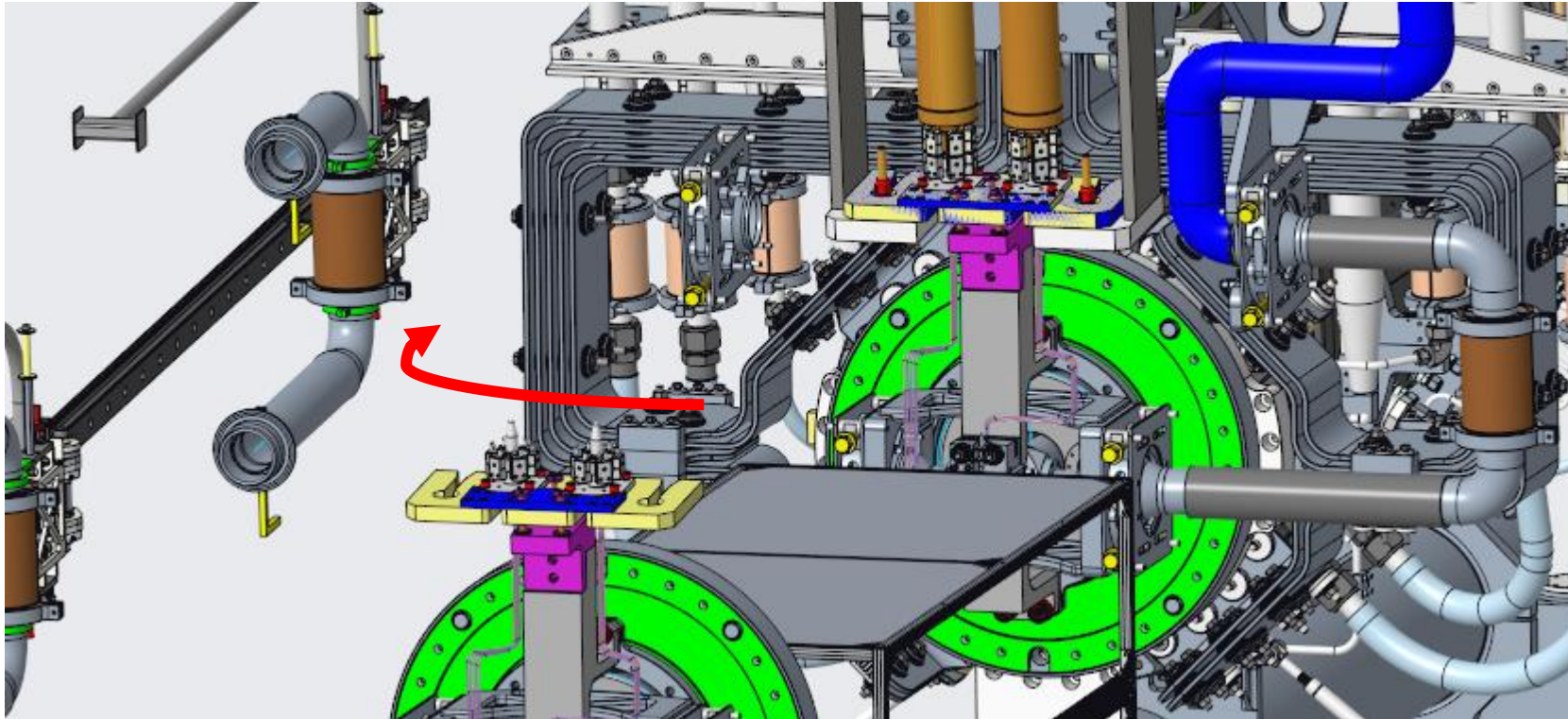
Tool	Diagnostics	Notes
Helium line exchange tool		TXS not docked, replacement target moved furthest away from pipe handling procedures

2. Break helium line chain clamps



Tool	Diagnostics	Notes
Nutrunner EOAT	Visual rotating “marker” on turnbuckle	TXS stages may have to be relocated for access

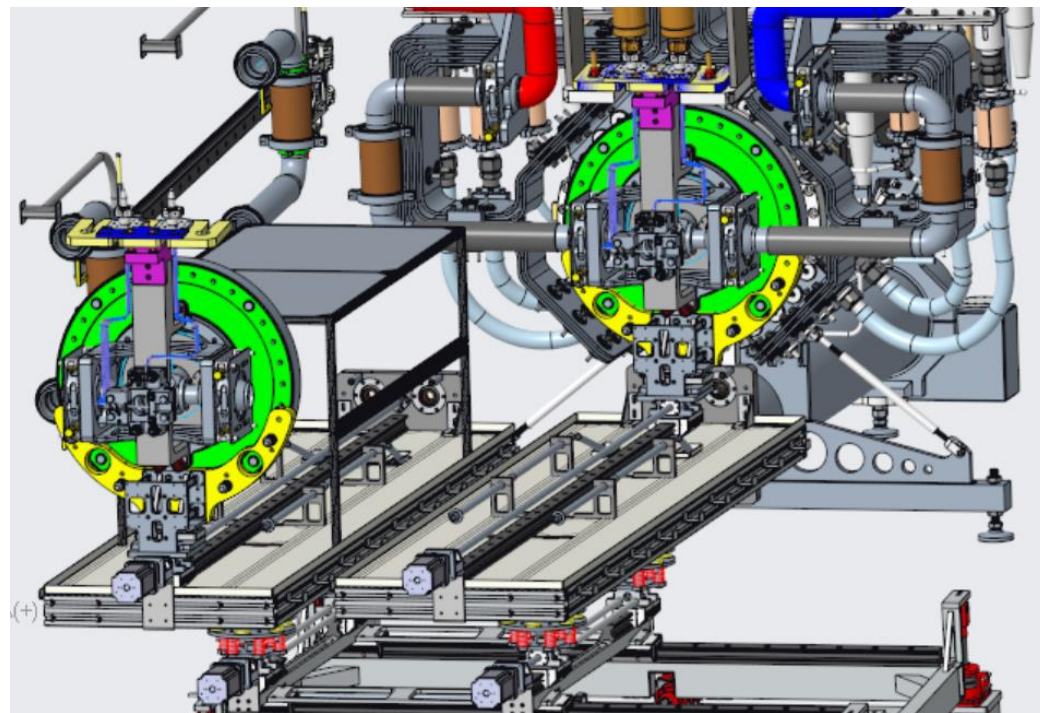
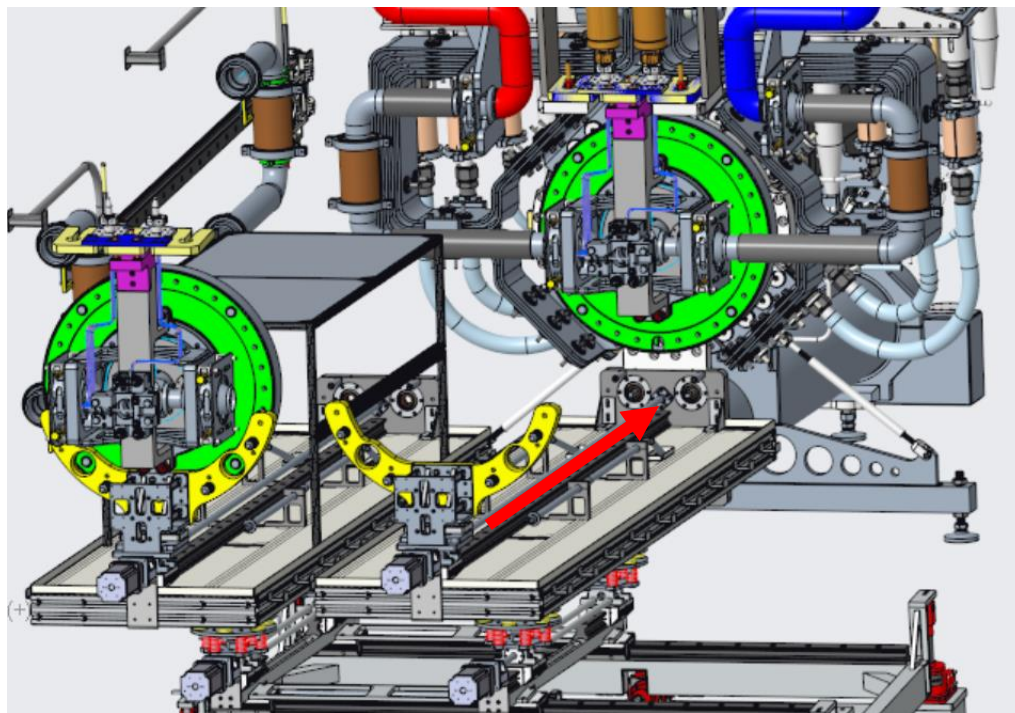
3. Retract helium flex lines



Tool	Diagnostics	Notes
Helium line exchange tool		Spent helium flex lines are rotated out of the way and pushed DS next to horn module

- **Target removal:** Dock removal table to target supports

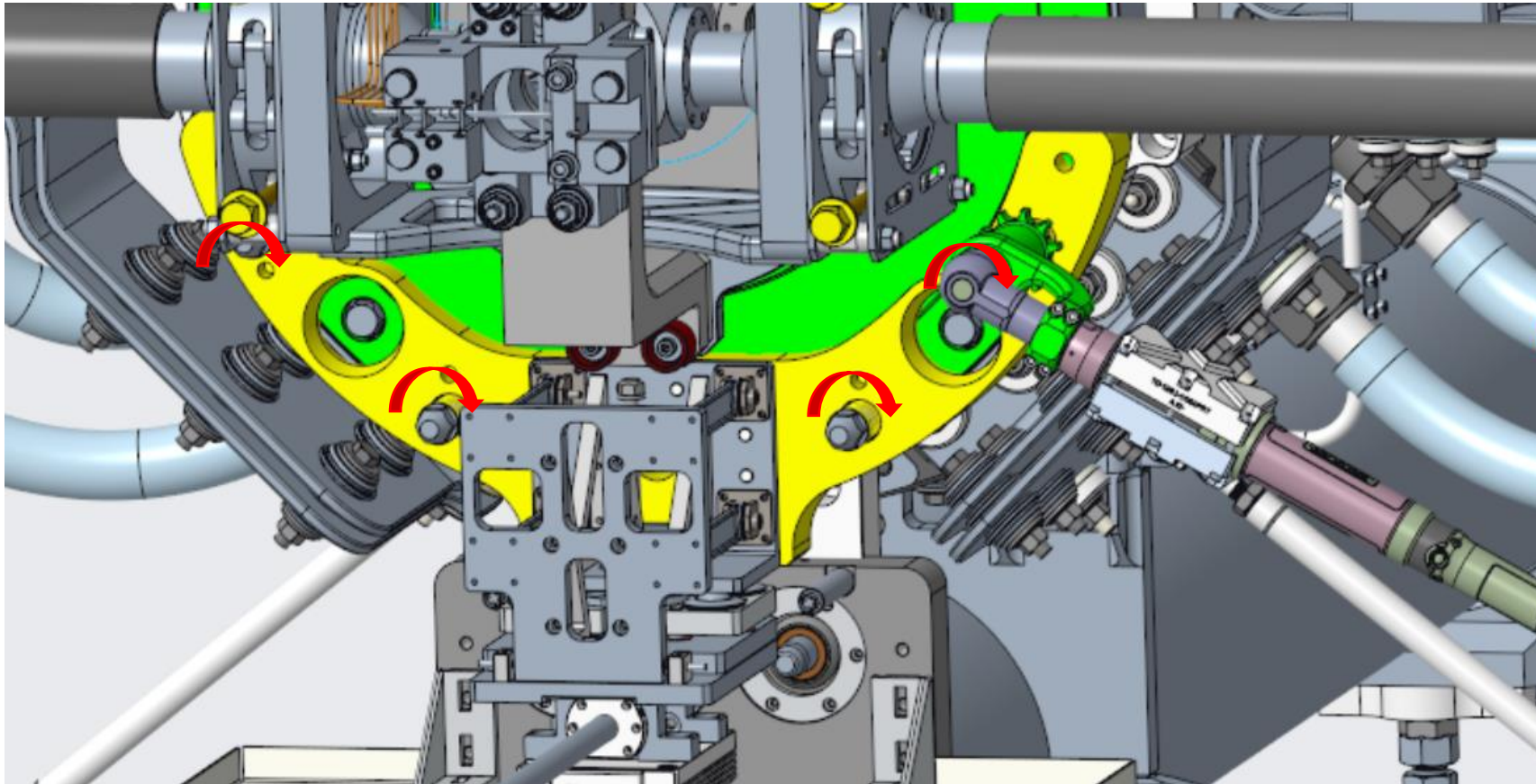
4. Drive target carrier to used target



Tool	Diagnostics	Notes
Target slide	Motor count readout, limit approach and limit switches	TCM allows target carrier to align to target

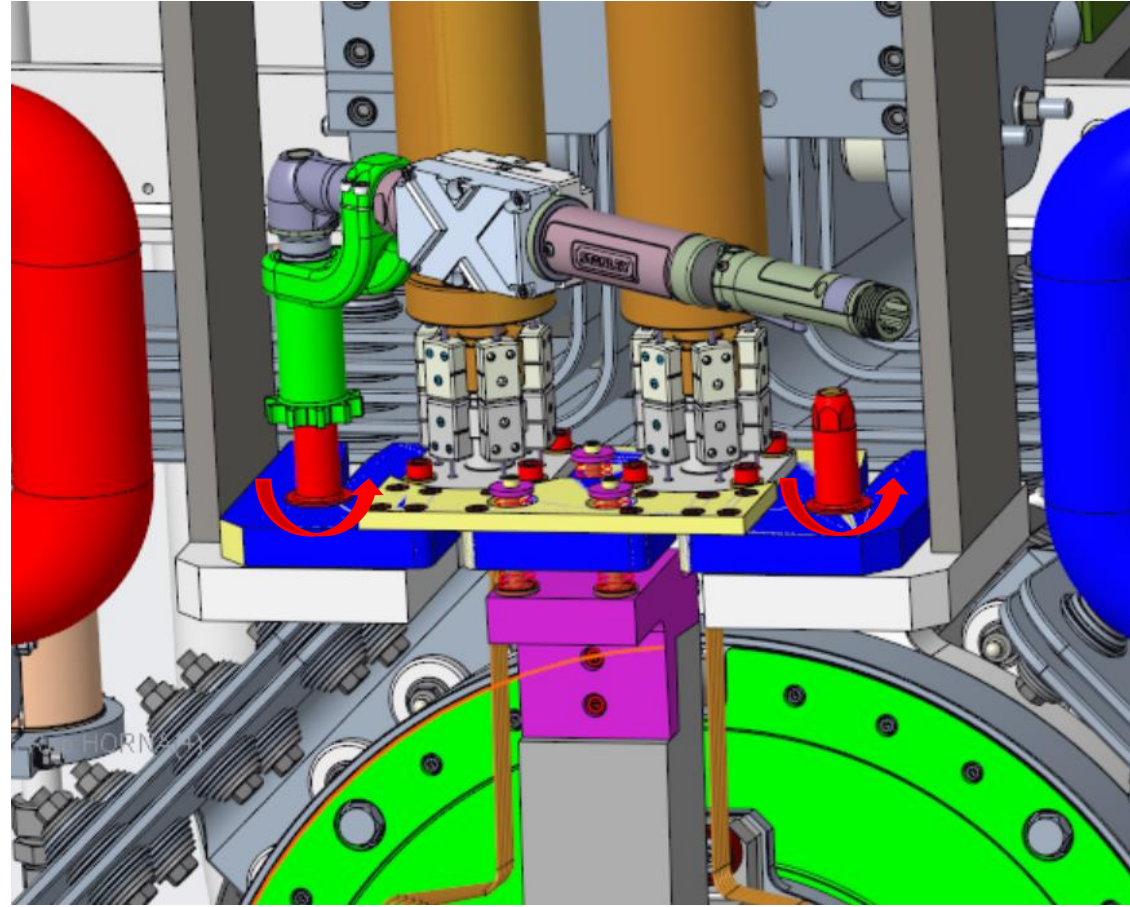
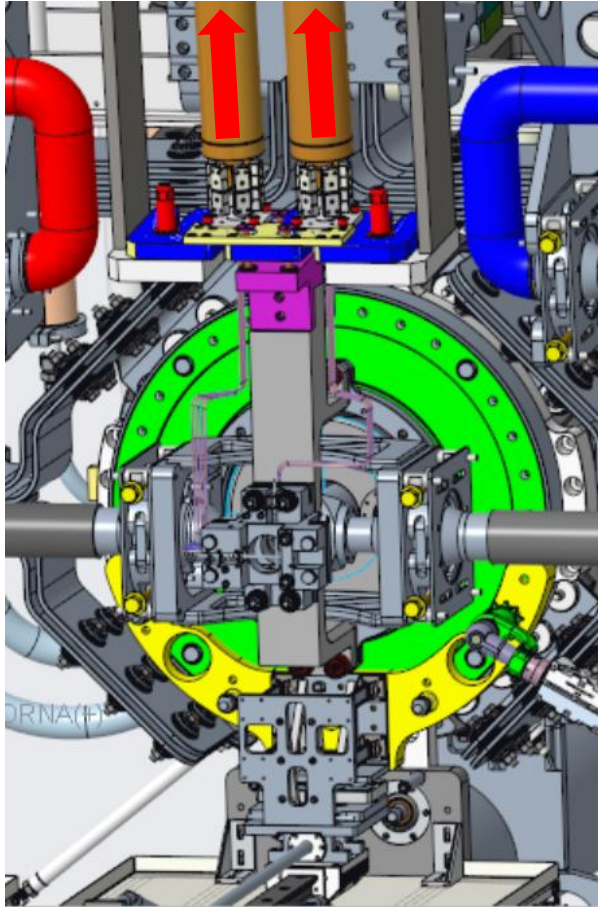
*helium flex lines would be disconnected at this stage

5. Tighten target carrier captive bolts



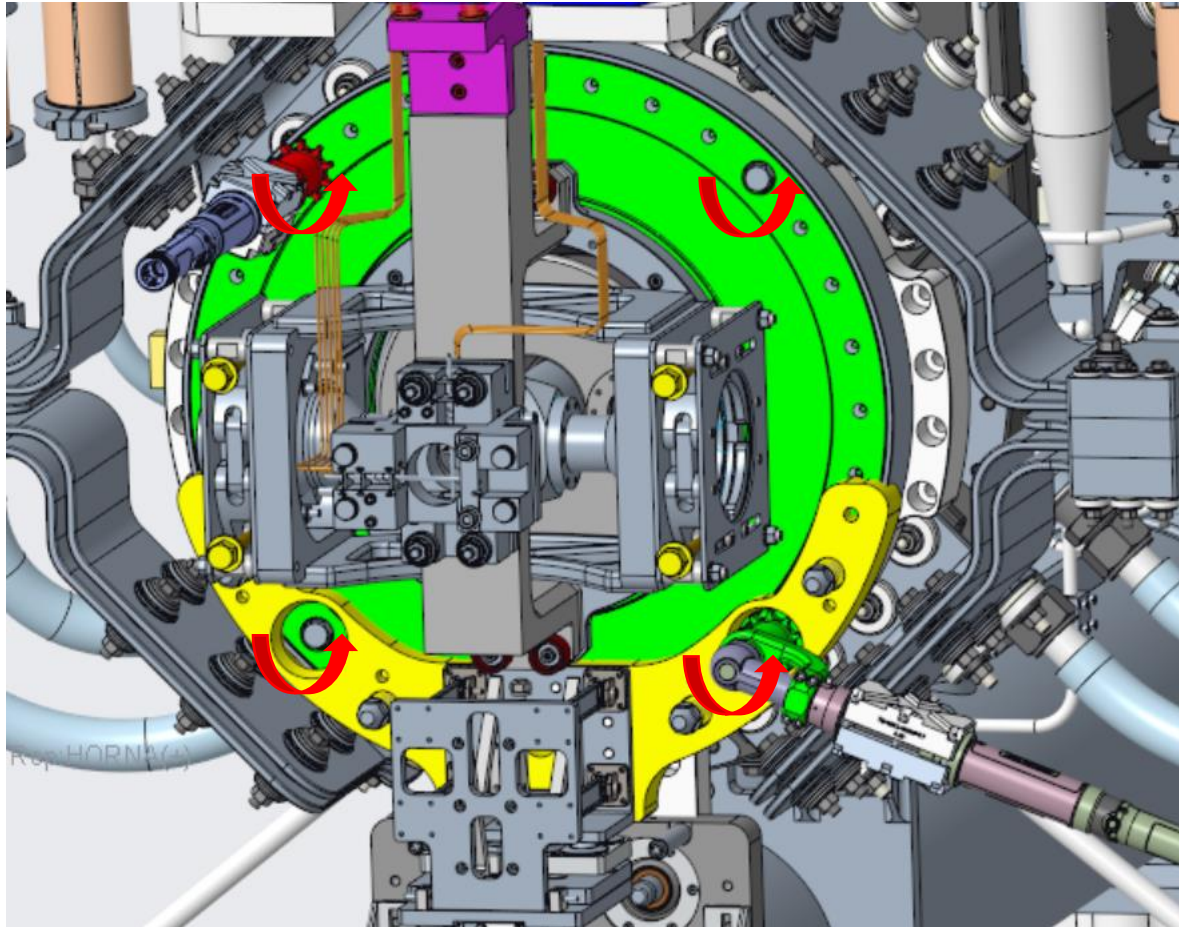
Tool	Nutrunner EOAT/Manipulators
Diagnostics	-
Notes	4 captive M16 bolts fix target to carrier, may also pull carrier flush to target plate if not already in full contact

6. Break instrumentation line (IL) connection



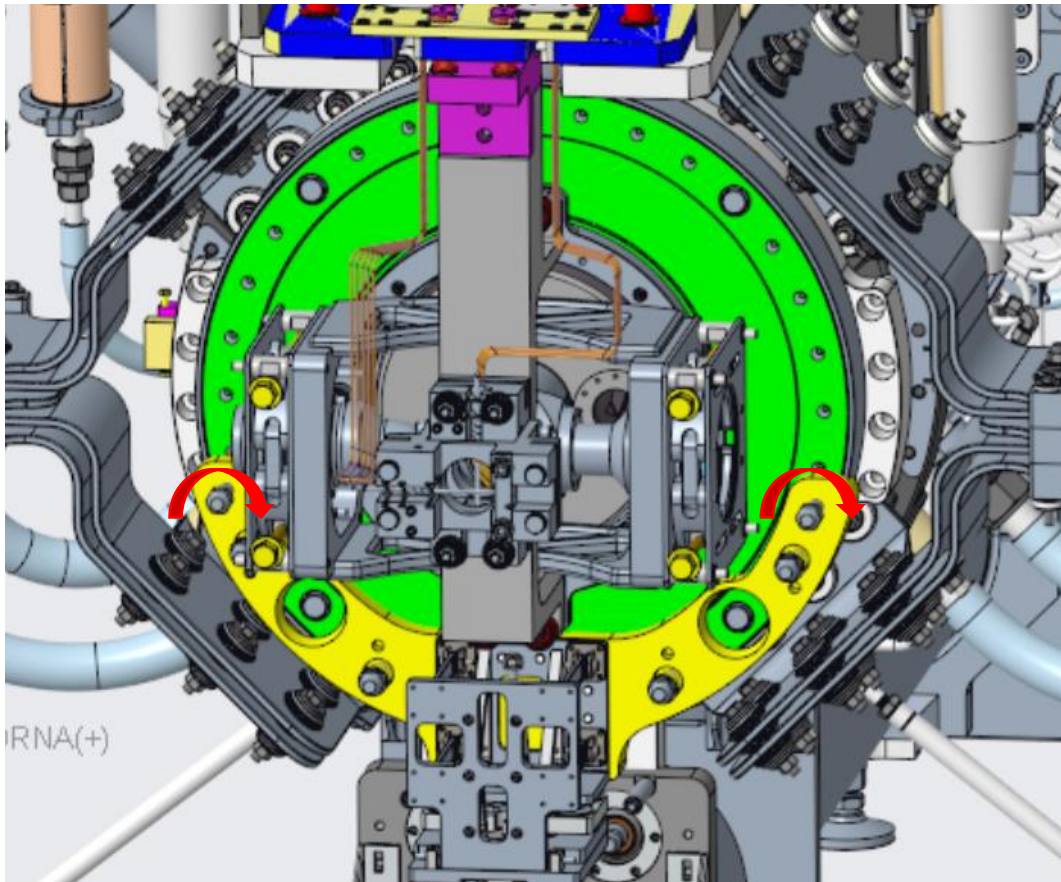
Tool	<ol style="list-style-type: none"> 1. Crane removes instrumentation lines 2. Nutrunner EOAT loosens captive nuts
Diagnostics	-
Notes	<p>Lift instrumentation line from top of module</p> <p>2x M14 captive nuts secure IL bracket</p>

7. Loosen target bolts



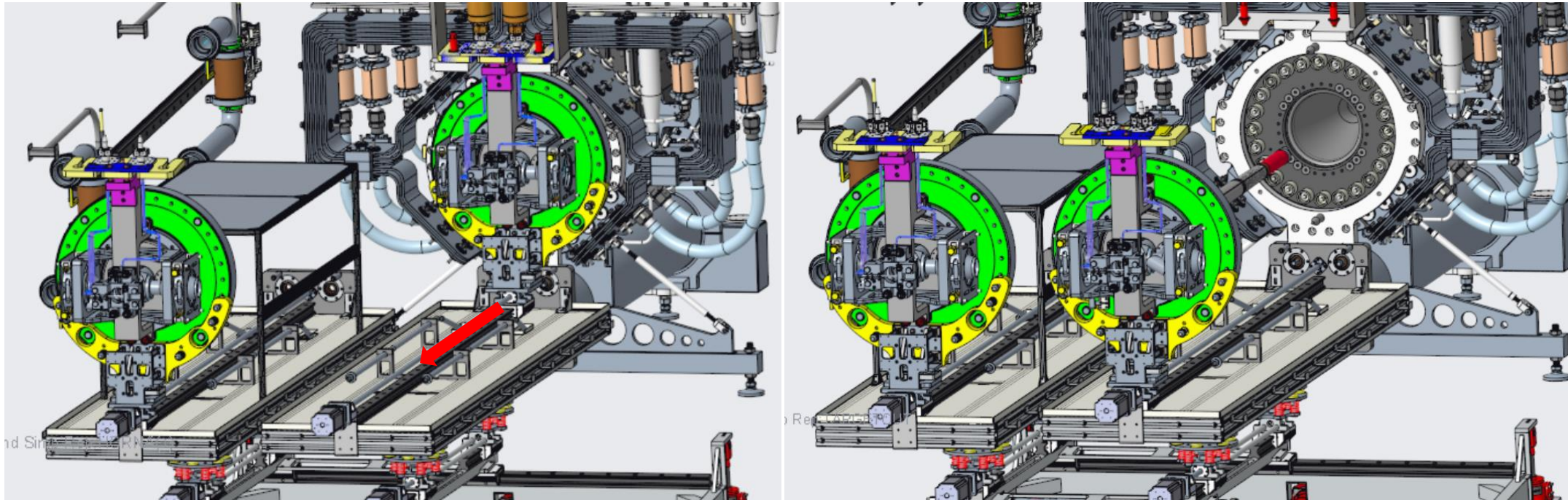
Tool	Nutrunner EOAT
Diagnostics	Nutrunner controller/HMI
Notes	4x M16 Captive bolts in Aluminium Bronze Spirallock insert

8. Displacement controlled removal (if needed)



Tool	Nutrunner EOAT, jacking screws
Diagnostics	-
Notes	Controlled removal of target carrier – avoids overloading motors if any binding/sticking occurs (through-holes in “green plate”)

9. Drive target carrier and target back to “start”
 Then “un-dock” removal stage and retract

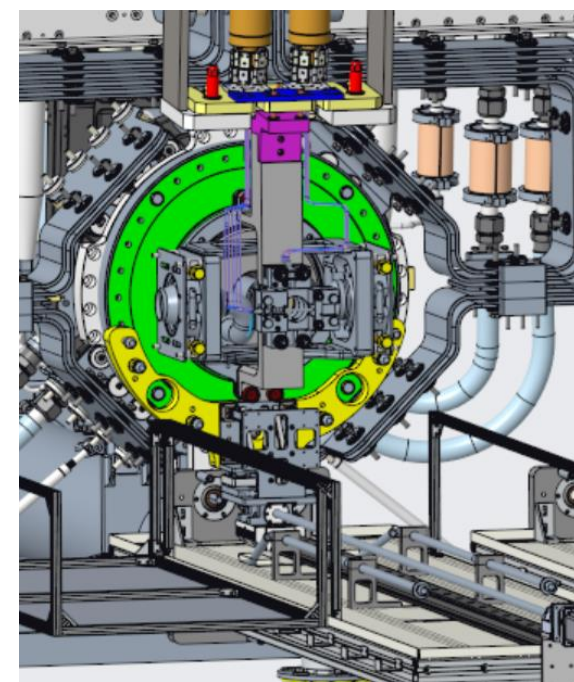
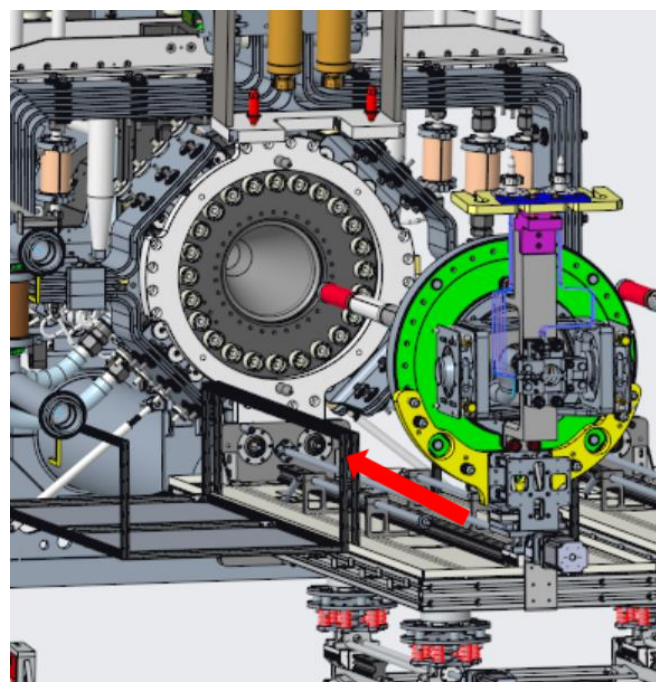
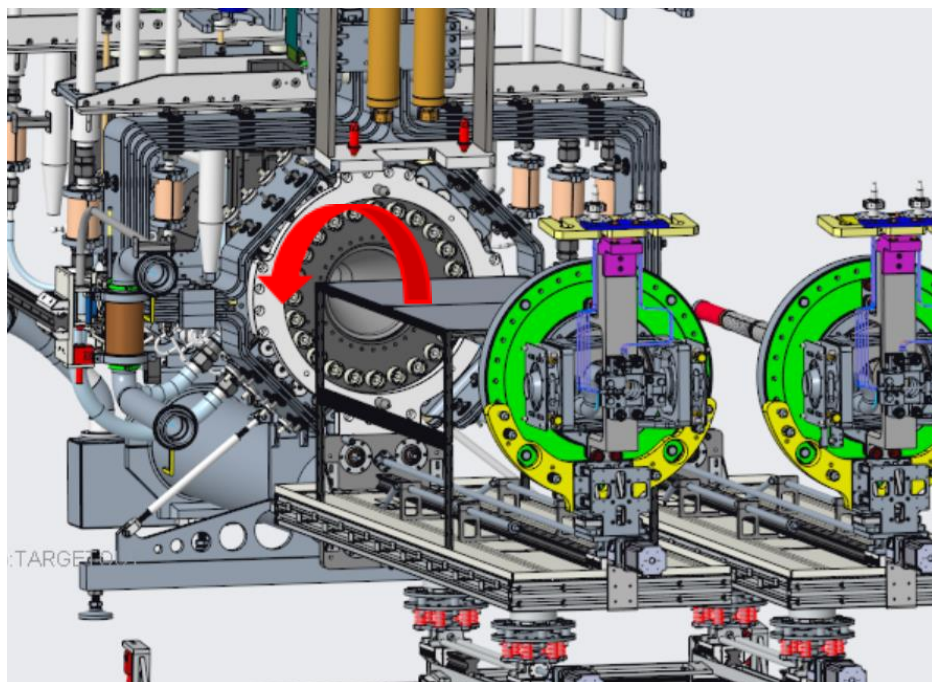


Tool	Diagnostics	Notes
TXS Target slide	Motor count readouts, limit approach and limit switches	-

- **Target insertion**

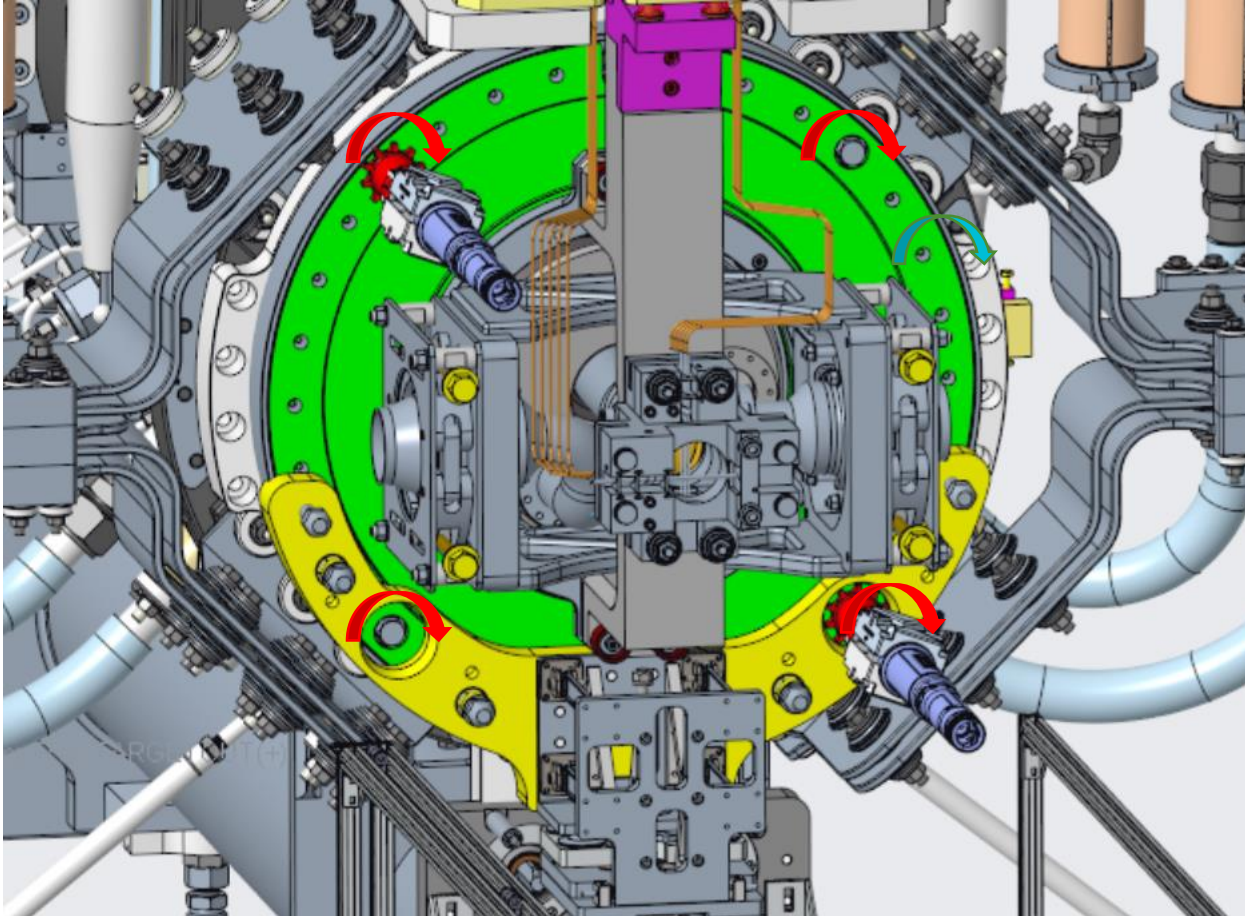
Target Insertion	Operation	Tool	Diagnostics	Notes
1	Drive new target to supports	Target slide	Motor count readout, limit approach and limit switches	Flip over "target cover frame" TCM allows target to find alignment pins
2	Tighten target bolts	Socket/manipulators	Nutrunner controller/HMI	4x M16 Captive bolts in Aluminium Bronze Spirallock insert
3	Make target position thermometer connection	Crane/EOAT		Lower instrumentation line from top of module
4	Loosen target carrier captive bolts	Socket	Nutrunner controller/HMI	
5	Drive target carrier back to "start"	Target slide	Motor count readout, limit approach and limit switches	
6	Install helium flex lines	Helium line exchange tool		
7	Make helium line chain clamp connection	Socket/manipulators	Nutrunner controller/HMI/rotating markers	TXS stages may have to be relocated for access

- **Target insertion:** Dock insertion table to target supports
1. Drive new target to supports



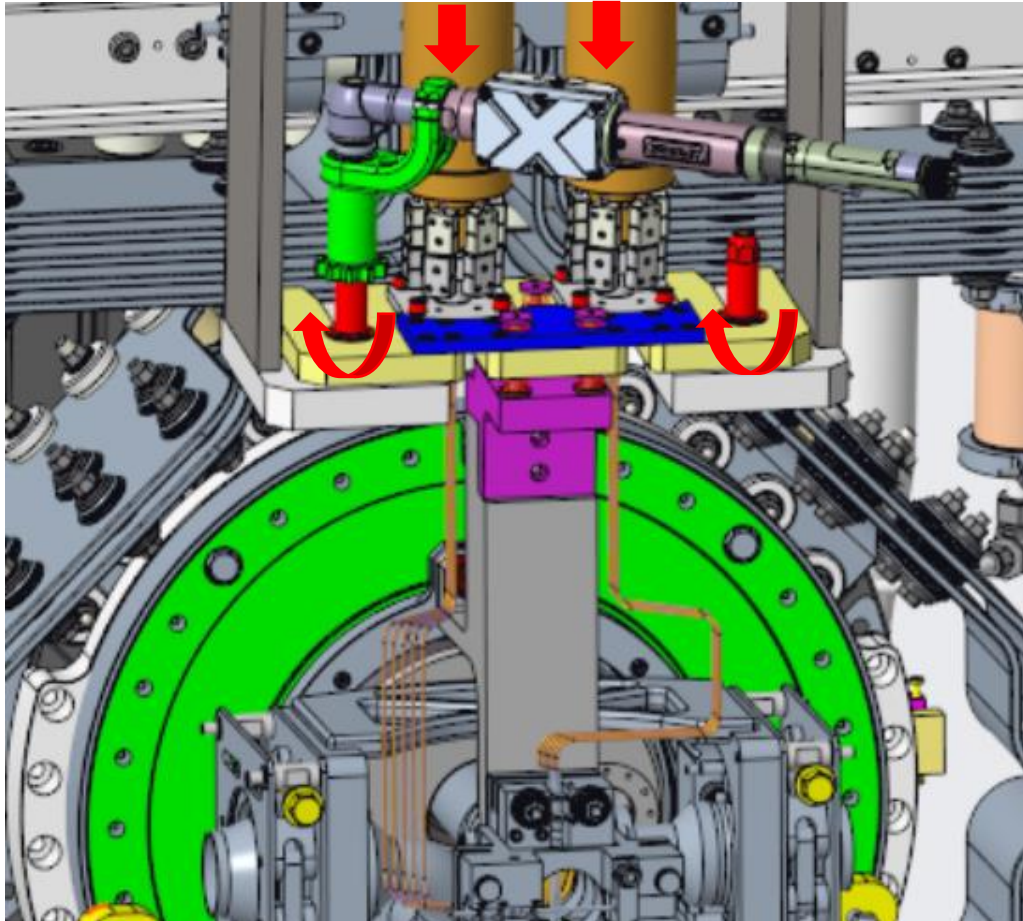
Tool	Diagnostics	Notes
Target slide	Motor count readout, limit approach and limit switches	Flip over “target cover frame” TCM allows target to find alignment pins

2. Tighten target bolts



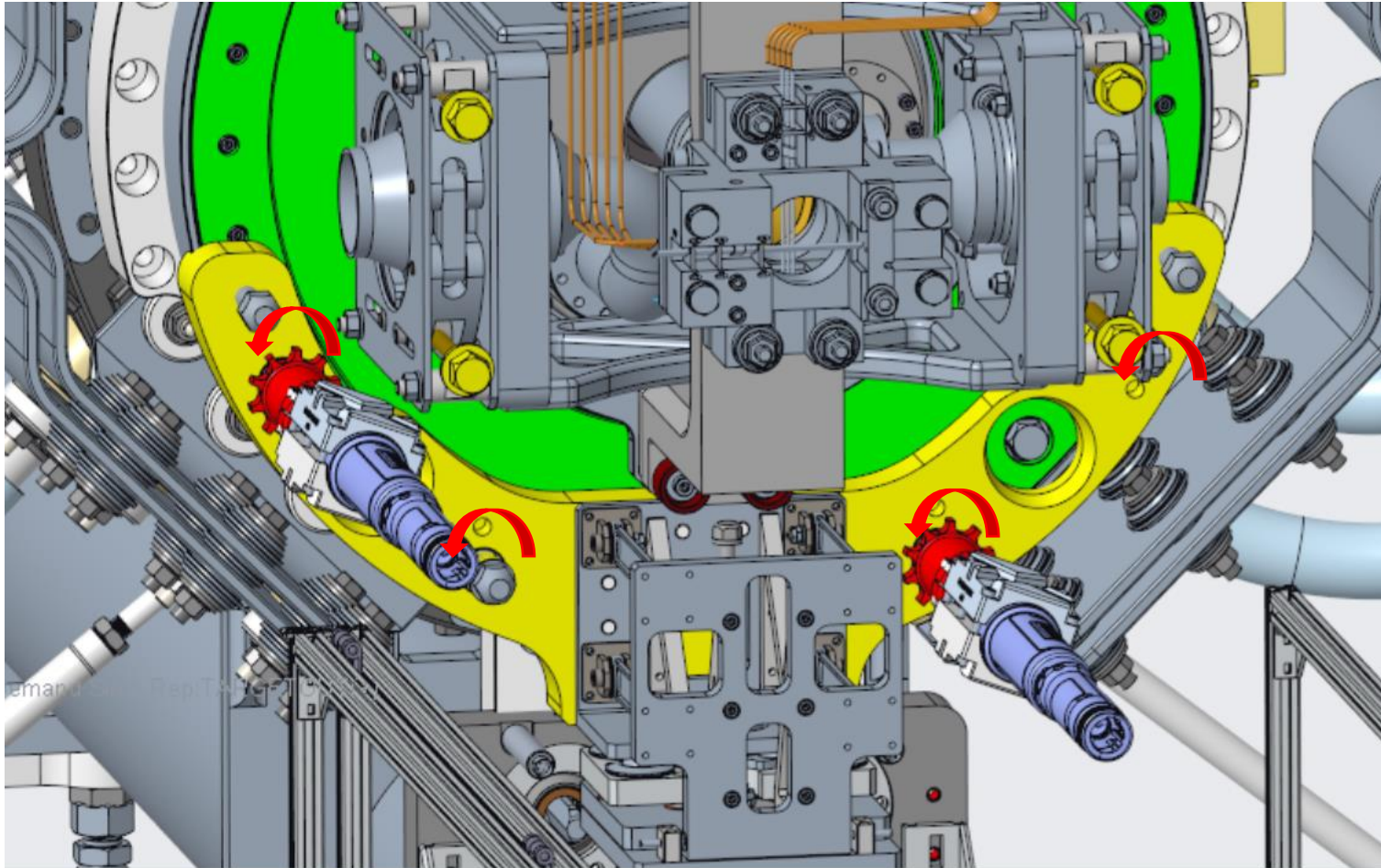
Tool	EOAT Nutrunner
Diagnostics	Nutrunner controller/HMI
Notes	4x M16 Captive bolts in Aluminium Bronze Spirallock insert

3. Make instrumentation line connection



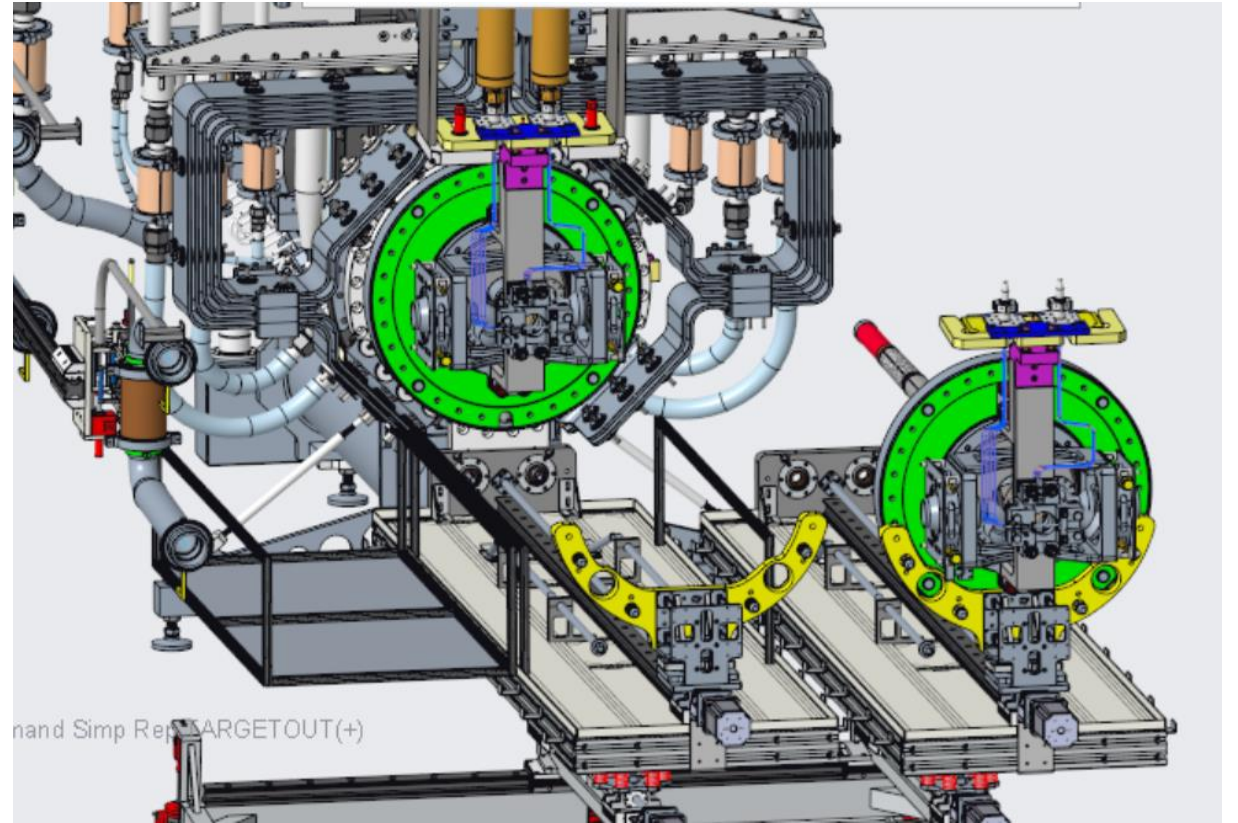
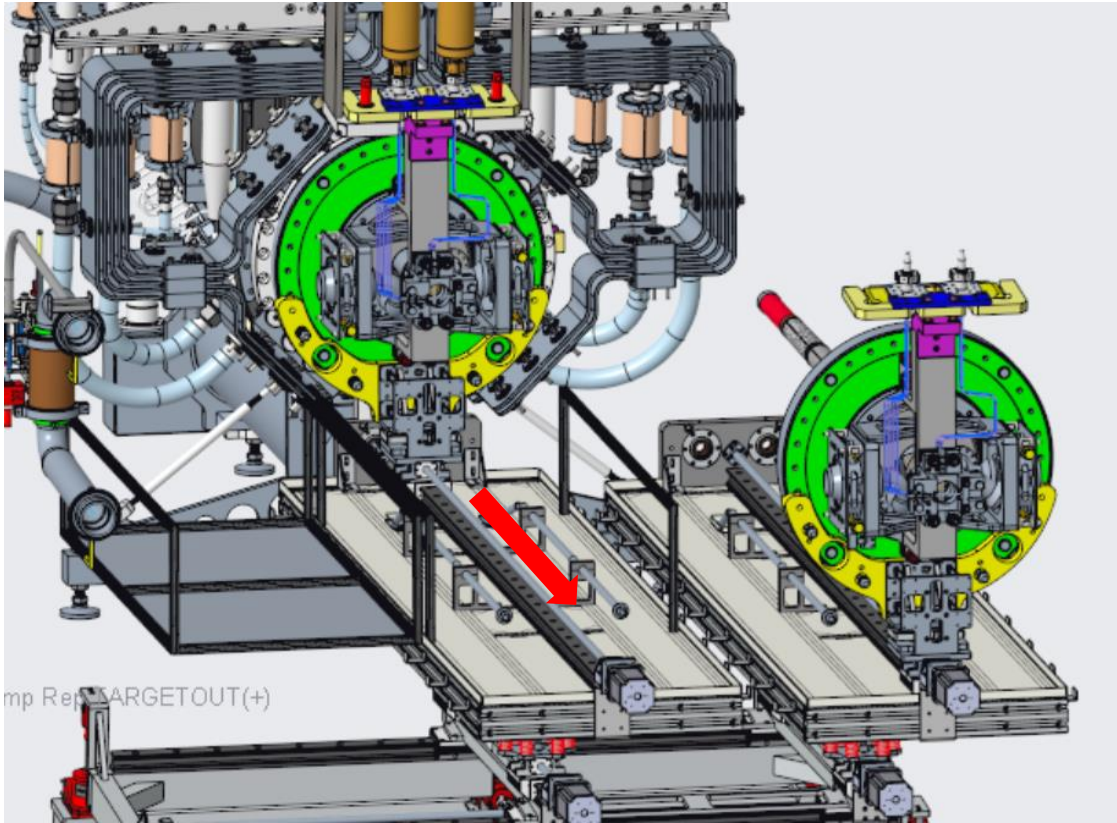
Tool	<ol style="list-style-type: none">1. EOAT Nutrunner tightens captive nuts2. Crane lowers instrumentation lines
Diagnostics	-
Notes	2x M14 captive nuts secure IL bracket Lower instrumentation line from top of module

5. Loosen target carrier captive bolts



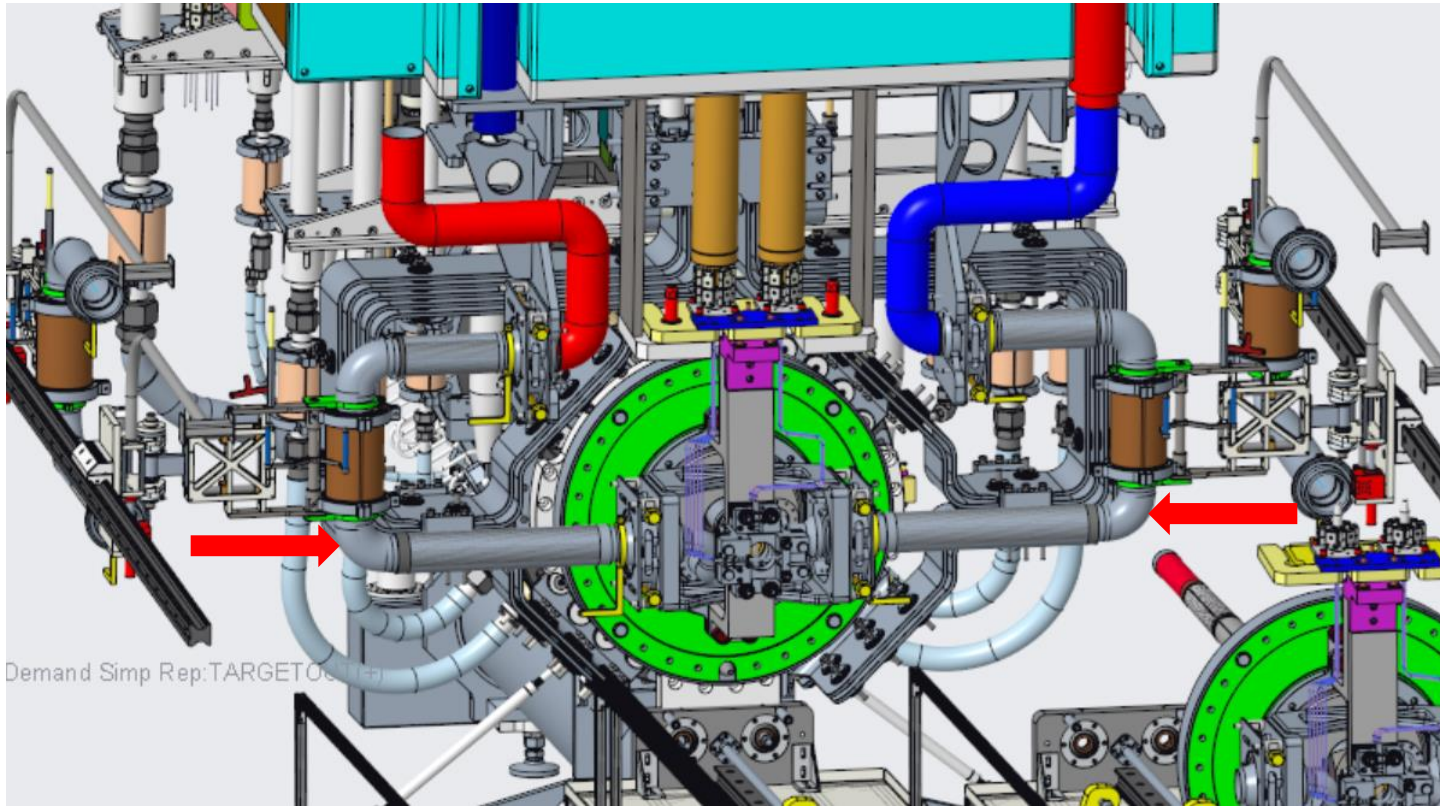
Tool	Nutrunner EOAT
Diagnostics	Nutrunner controller/HMI
Notes	-

6. Drive target carrier back to “start”, decouple TXS/horn



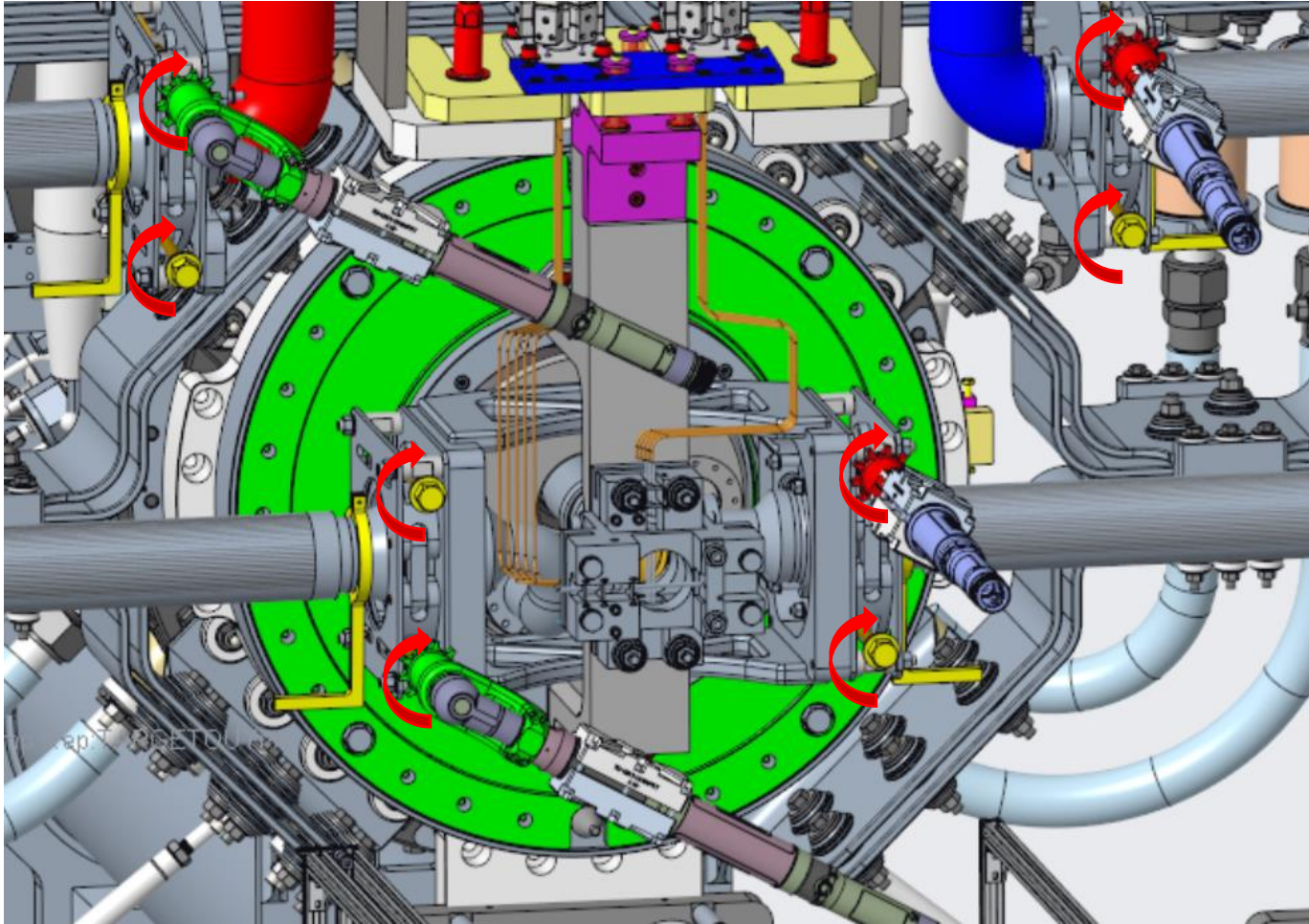
Tool	Diagnostics	Notes
Target slide	Motor count readout, limit approach and limit switches	Displacement controlled removal of target carrier is possible

4. Install helium flex lines



Tool	Diagnostics	Notes
Helium line exchange tool		

4. Make helium line chain clamp connection



Tool	Nutrunner EOAT
Diagnostics	Visual rotating "marker" on turnbuckle
Notes	TXS stages may have to be relocated for access