

String Assembly

Alick Macpherson

on behalf of

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With inputs from
BE-RF-SRF

Benoit Frere-Bouniol, Gabriel Pechaud, Max Gourragne, Sauro
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and from
EN-MME & EN-ACE

Daniel Del Alamo Mitogo, Pierre Minginette, Raphael Leuxe, Tommi Mikkola
Mateusz Sosin,

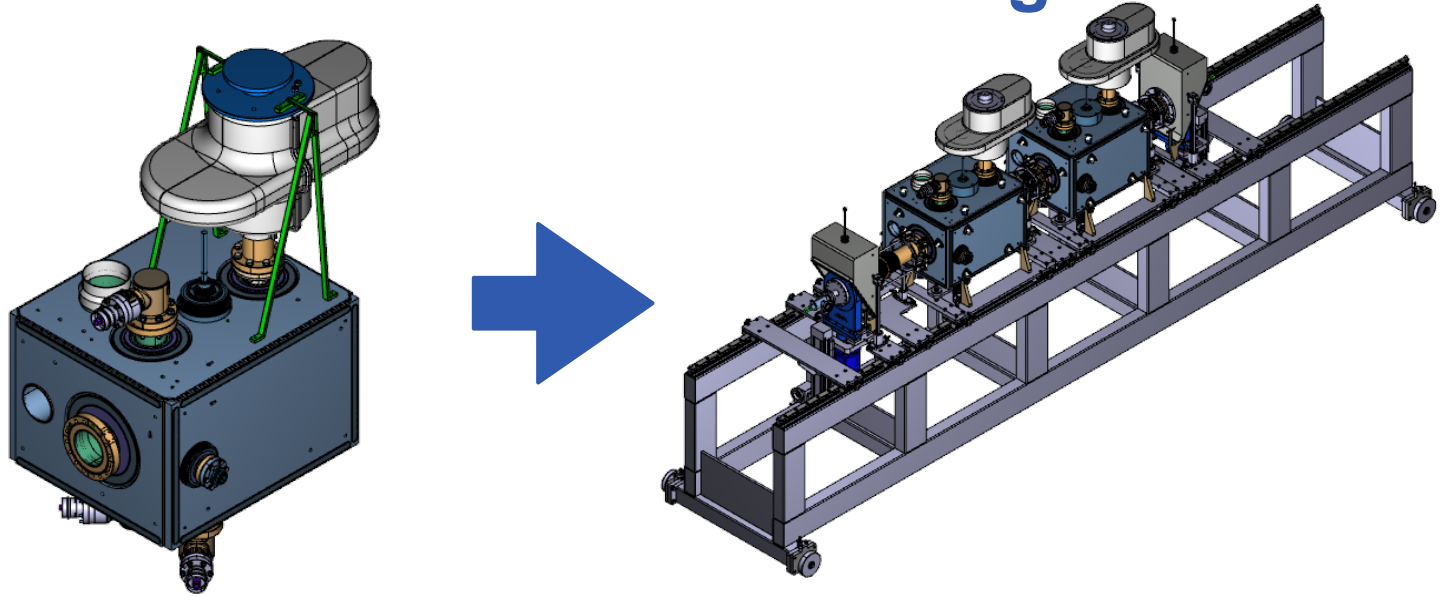
and Eric's BE-RF-PM Team
Eric Montesinos, Sebastien Calvo, Emile Gropelier,
Antoine Boucherie, Frida Eriksson

Outline

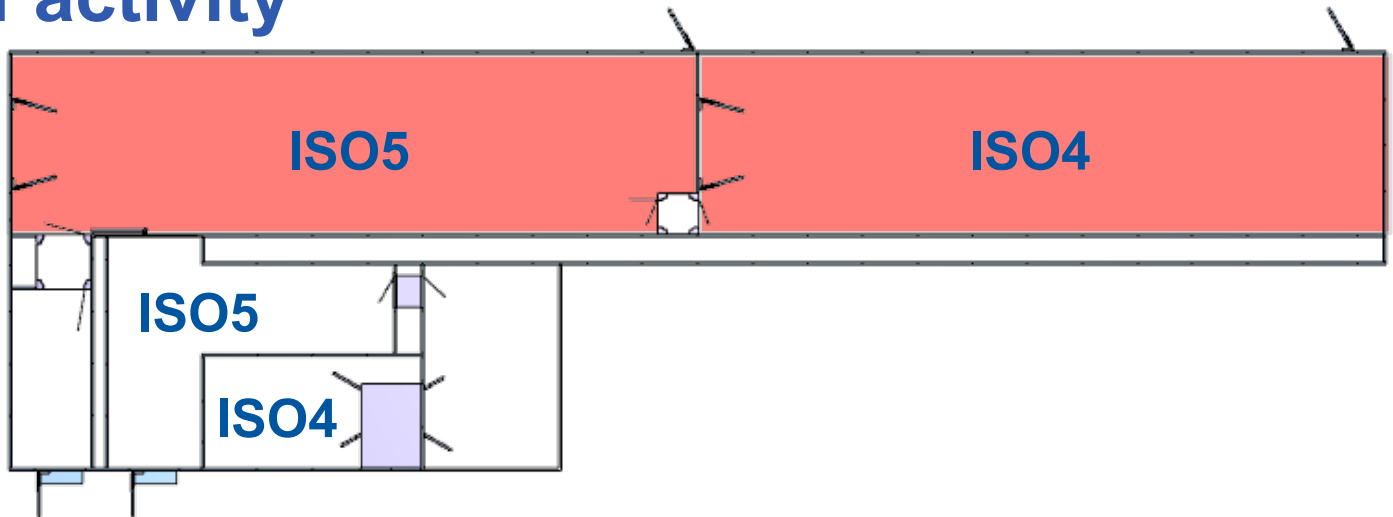
- **Workflow**
- **String Assembly Preparation**
- **Installation and Alignment in ISO5**
- **String Assembly in ISO4**
- **Post assembly measurements**
- **Discussion about schedule**

String Assembly

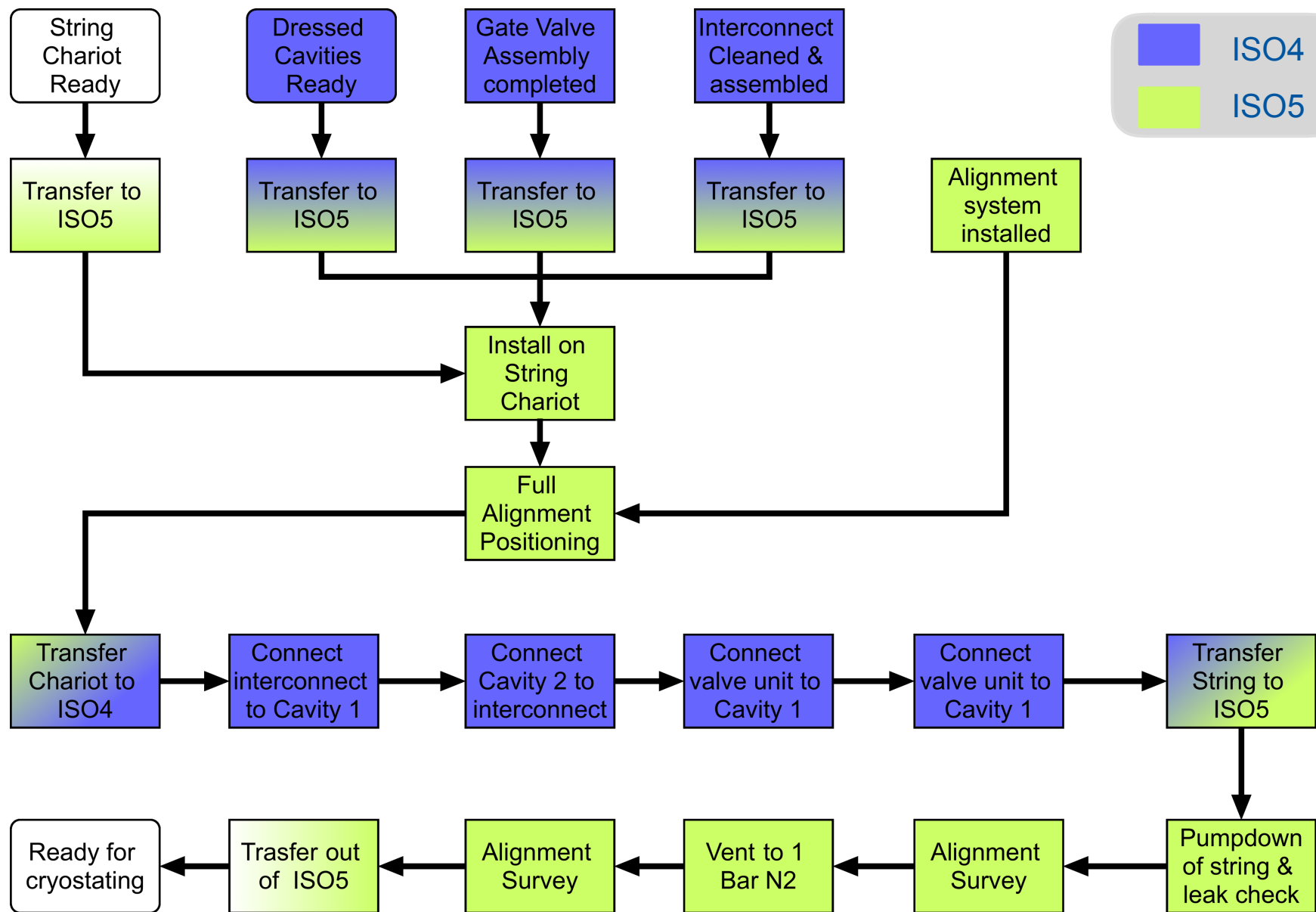
- Objective: Dressed Cavities to String



- Zones of activity



String Assembly Workflow



String Assembly Preparations

String Chariot: Preparation Outside Cleanroom

- **Mount chariot on rail system outside cleanroom**

- Chariot engaged on floor guidance rail system
- Cleaning of chariot:
 - Removal of loose dust by cleanroom vacuum cleaner
 - Wipe down with wipes + ethanol
 - Wipes: 55% cellulose + 45% polyester
 - Ethanol: 96% alcohol + 2% methyl ethyl ketone
 - Blow-off with filtered air (N₂ 78.9%, O₂ 21%, Ar 0.93%, CO₂ 0.03%)
 - 2 -stage filtering: 0.2um at bottle + 0.05um at pistollet

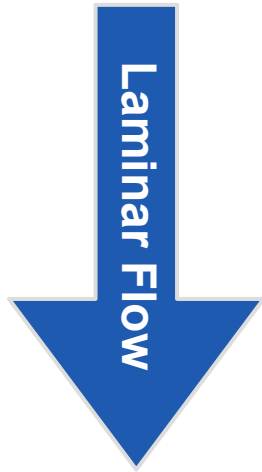
- **Transfer into ISO5 zone**

- Open doors & bring chariot into ISO5.
- Chariot air dried in pass through: blow-off directed to the outside.
- Close doors
- Cleaning of chariot
 - Wipe down with cleanroom wipes + alcohol
 - Wipes: 100% polyester
 - Sterile Alcohol: 70% Isopropanol +30% purified water (by volume)
 - Blow-off with filtered air (N₂ 78.9%, O₂ 21%, Ar 0.93%, CO₂ 0.03%)
 - 2 -stage filtering: 0.2um at bottle + 0.05um at pistollet
- Sit in laminar flow overnight

Interconnect Sub-Assembly

- **Bellows Assembly:**

- Assume bellows delivered cleanroom ready
- Assemble into rigid frame to be used on string chariot
- Tooling designed with flange gaskets held in place
 - Gaskets are standard annealed OF copper

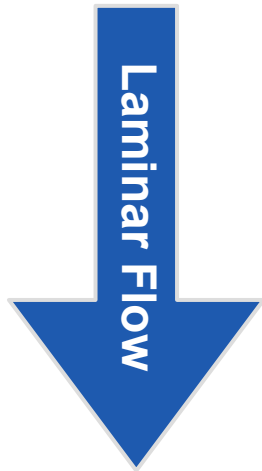


**Assembly
in ISO5**

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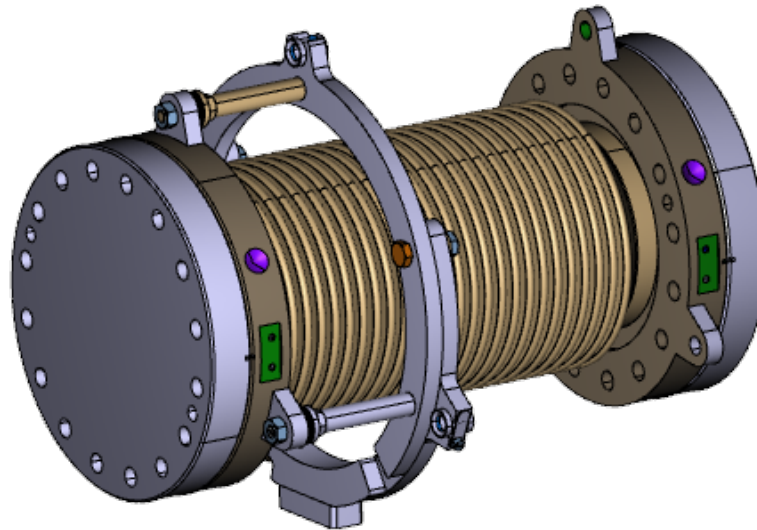
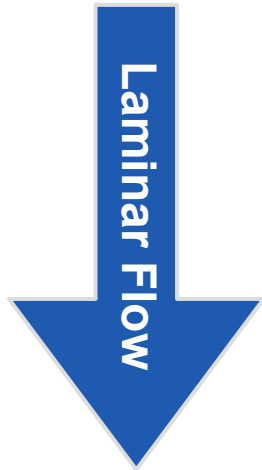


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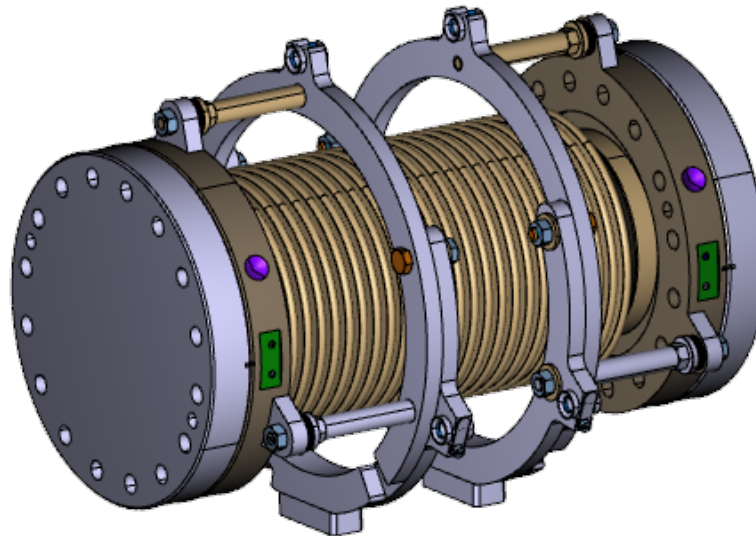
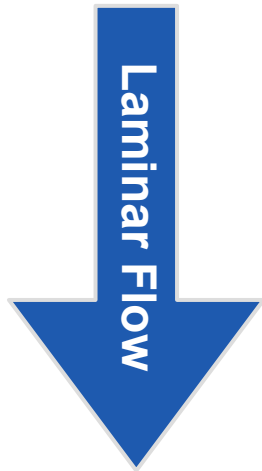


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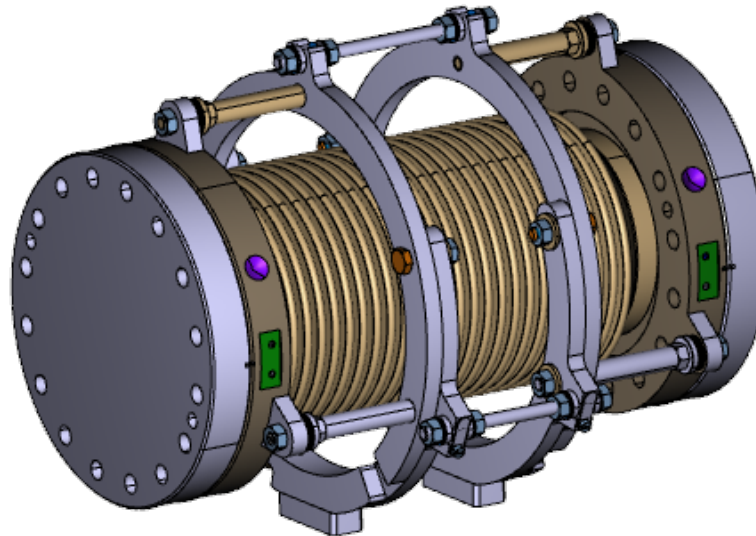
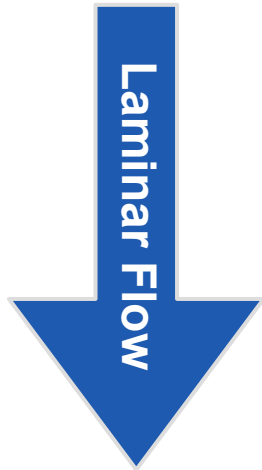


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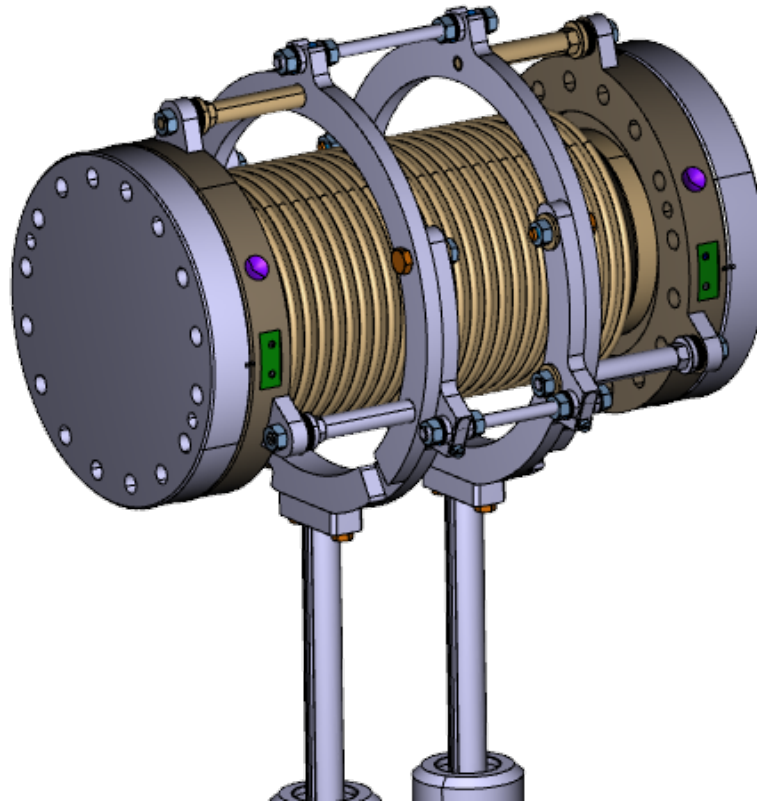
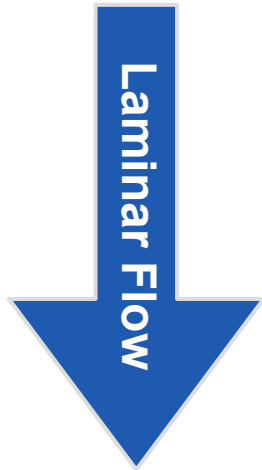


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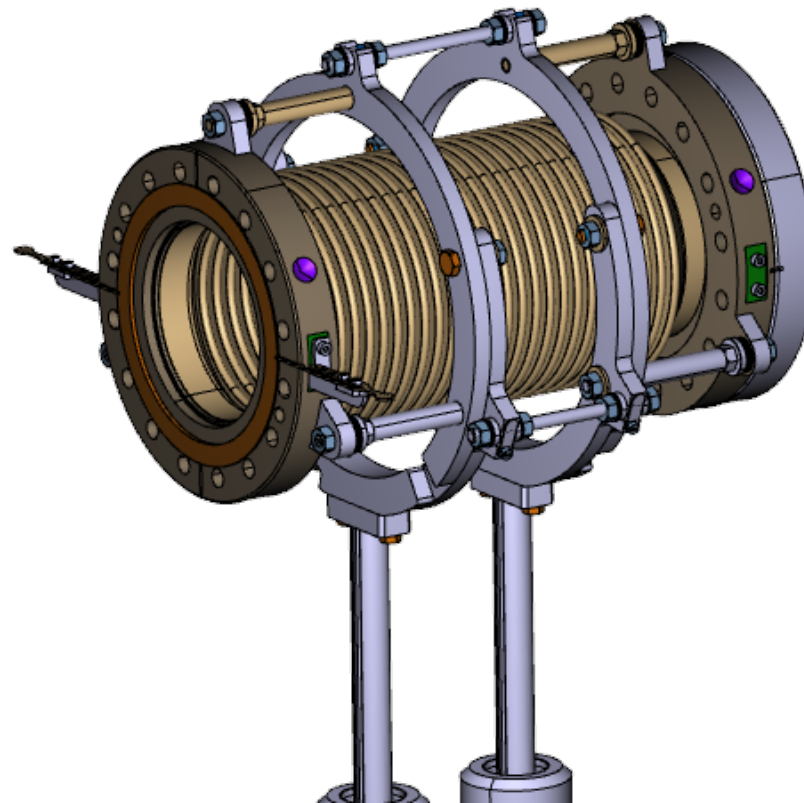
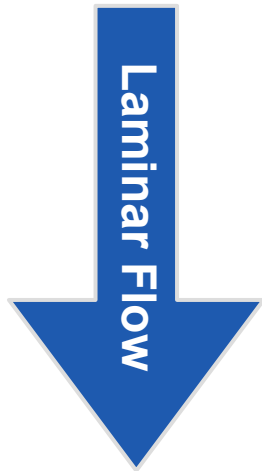
**Assembly
in ISO5**

Object wrapped in plastic
ready for ISO4.
Flanges left exposed

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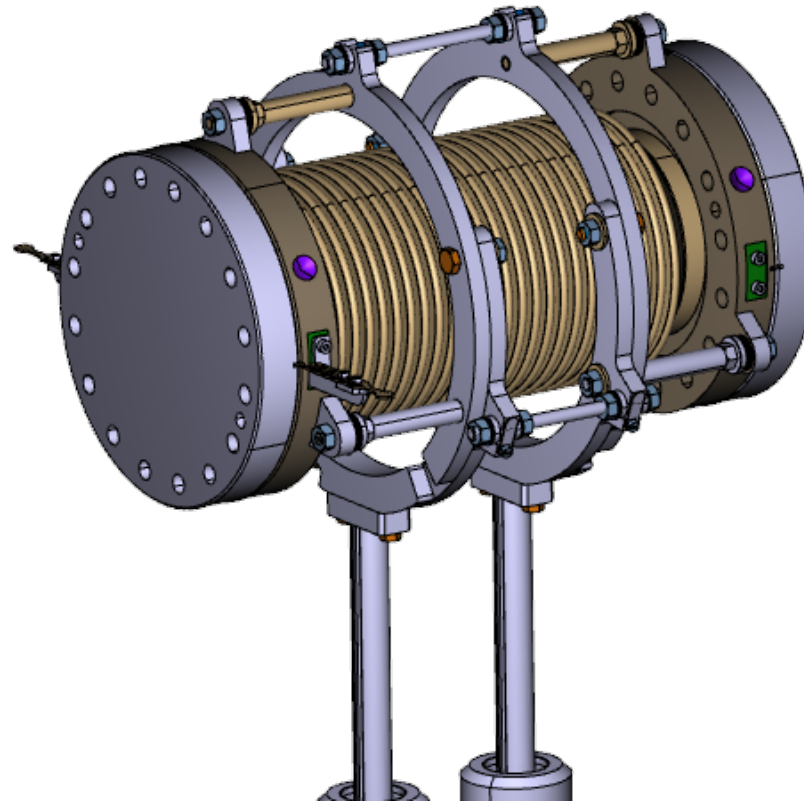
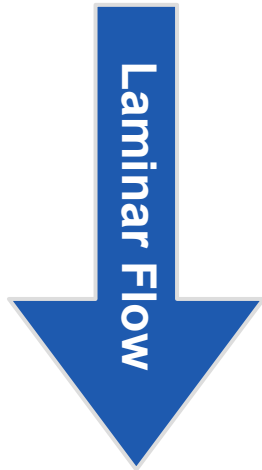
**Assembly
in ISO4**

Cleanliness to be checked by blow through with N₂

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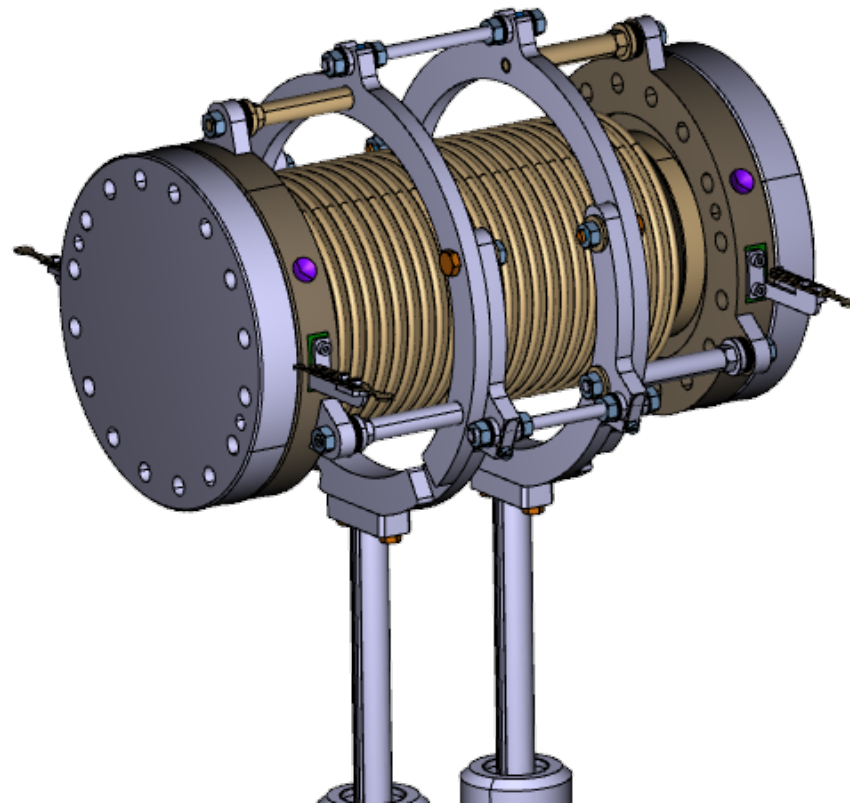
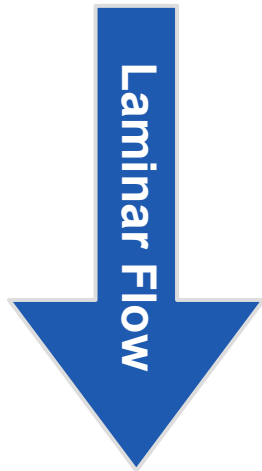


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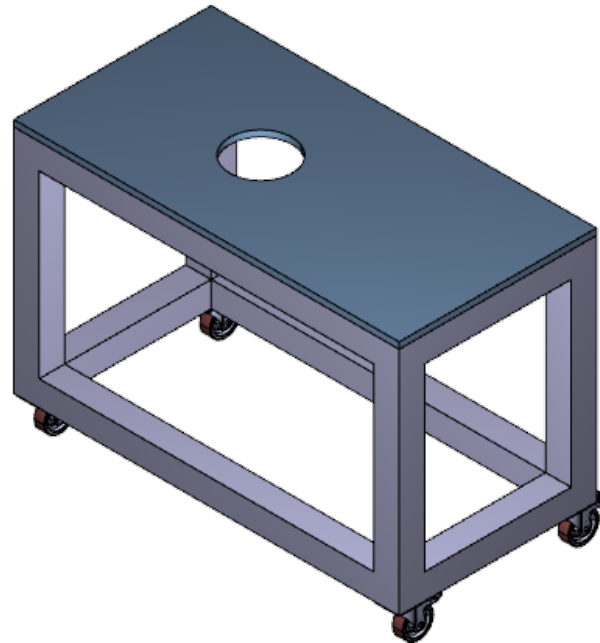


**Assembly
in ISO4**

Vacuum Valve Sub-assembly

Assembly
in ISO4

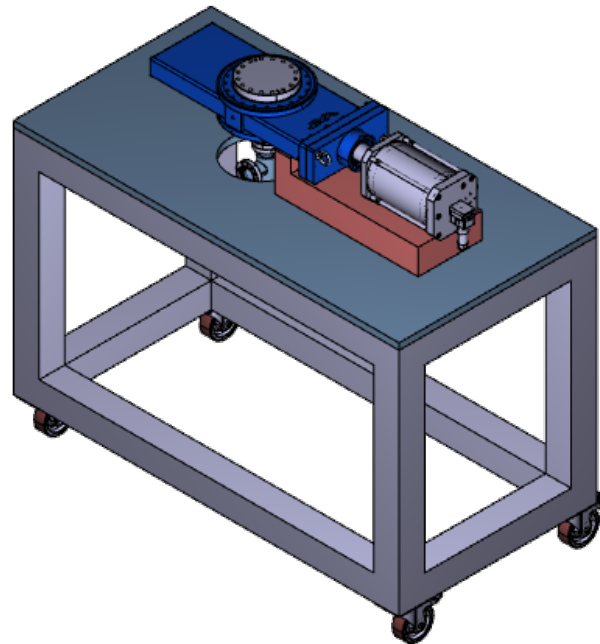
- Sub-assembly + support frame: a rigid unit
 - Support structure merged with mounting on chariot
- Vertical mounting
 - May need to N₂ flush to reduce trapped particulate
 - Simplifies assembly process (with gaskets etc)
- Sub-assembly leak tested before transfer to string chariot



Vacuum Valve Sub-assembly

Assembly
in ISO4

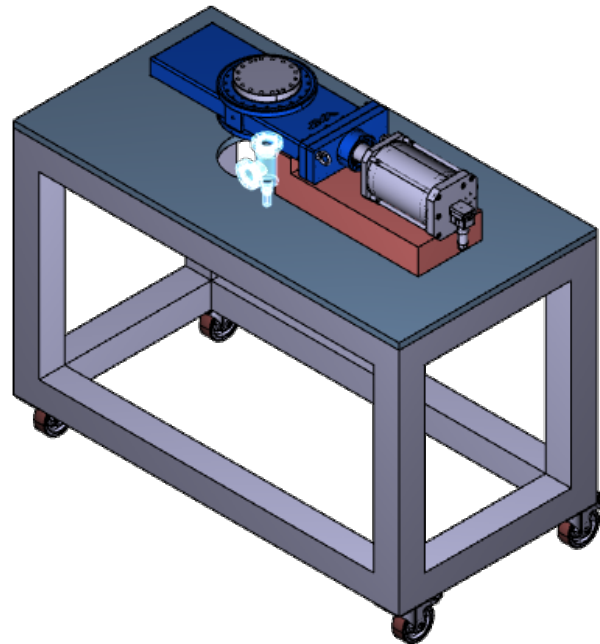
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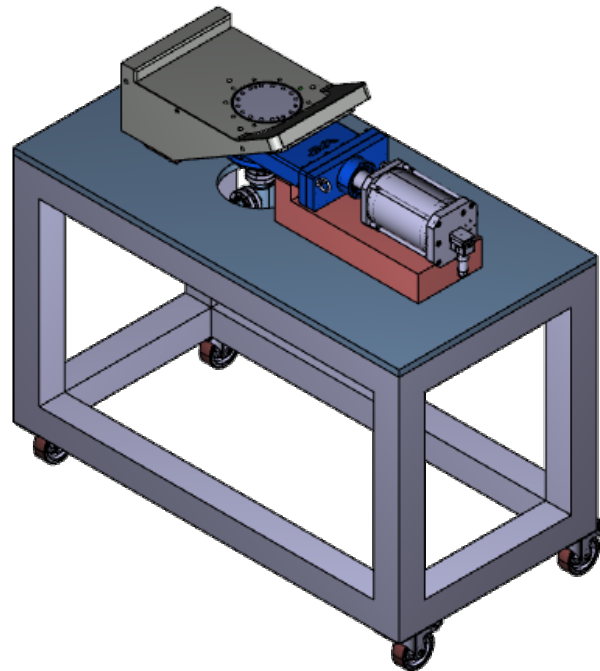
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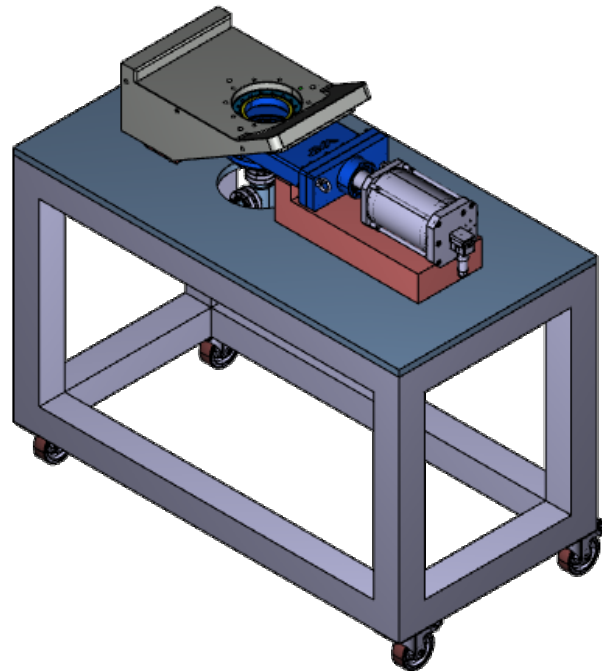
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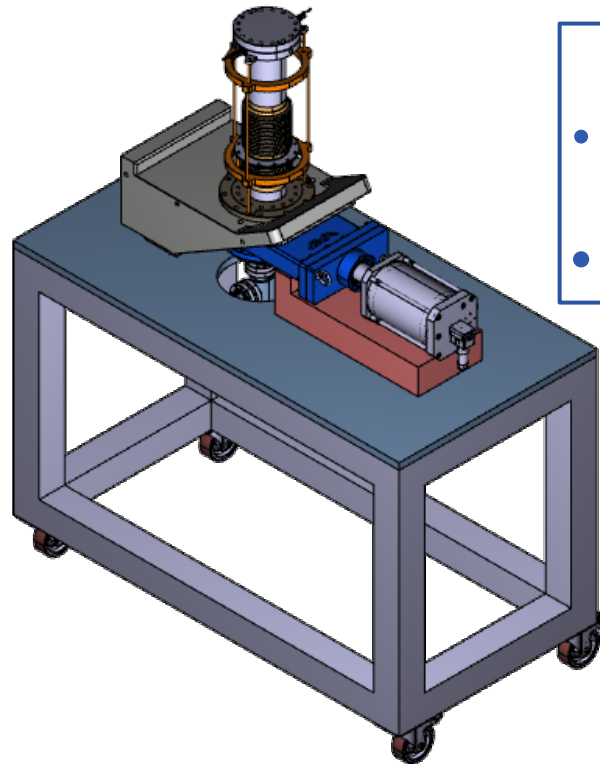
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Vacuum Valve Sub-assembly

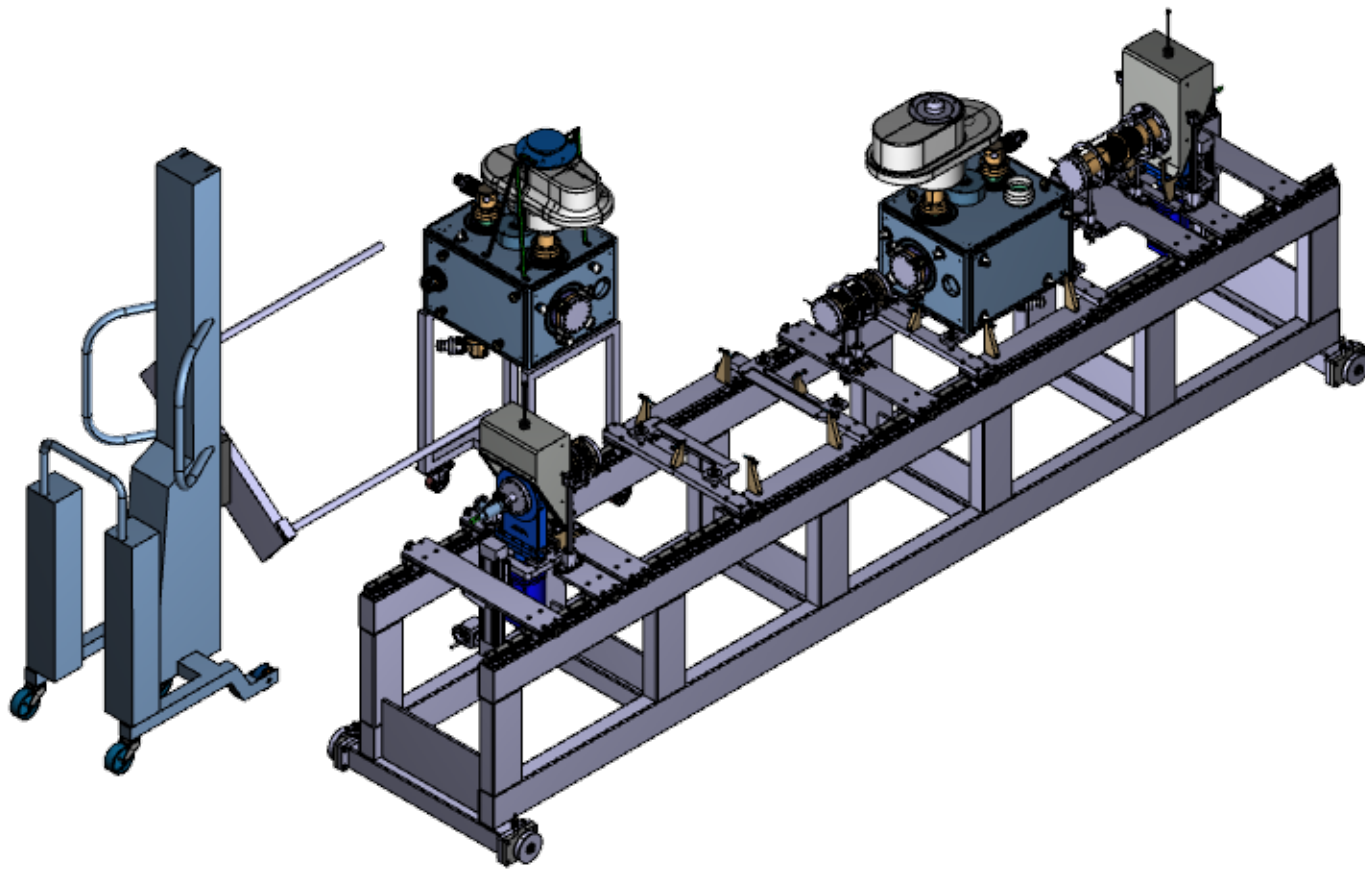
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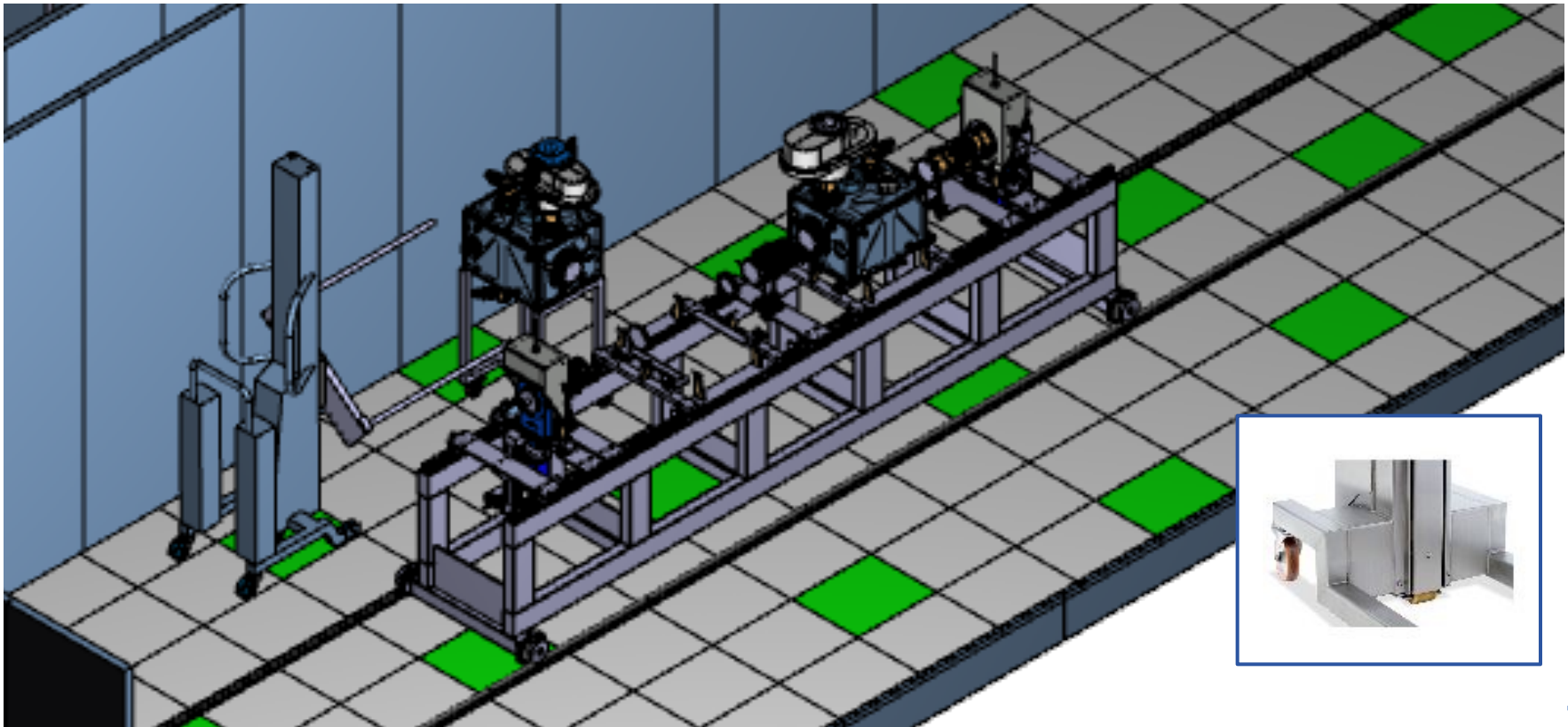
- Vertical mounting :
- Not ideal as assembly can collect particulate
 - **Is there a better way?**

Installation and Alignment in ISO5



Installation of Sub-Assemblies on Chariot

- **Sub-assemblies placed on string chariot by lifter**
 - Commercial cleanroom lifter
 - 5th wheel mechanism => easy rotation of lifter
 - Lifter to cavity interface: hook and eye-bolt
 - Position flexibility so cavity mates with rail system



Installation of Sub-Assemblies on Chariot

- **Sub-assemblies to be installed**

- 2 Fully dressed cavities
- 1 interconnecting bellows
- 2 gate valve assemblies

**Assembly
in ISO5**

- **Preparation of sub-assemblies**

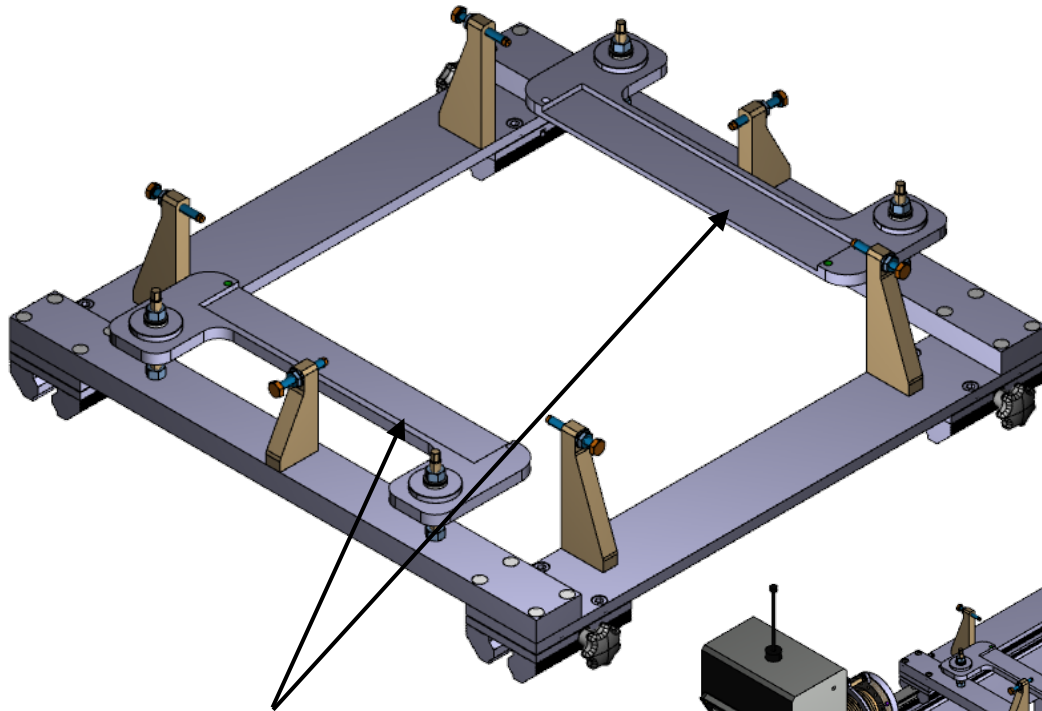
- Dressed Cavity: Prepared in ISO4.
 - Beam port flanges closed with PVDF caps
- Interconnecting Bellows:
 - Prepared in ISO4 & closed with PVDF caps
 - Installed in mounting frame with gaskets installed
- Gate valve assembly
 - Prepared in ISO4 and leak checked
 - beam ports closed with PVDF caps
 - Installed in mounting frame

- **Bellows & vacuum valves**

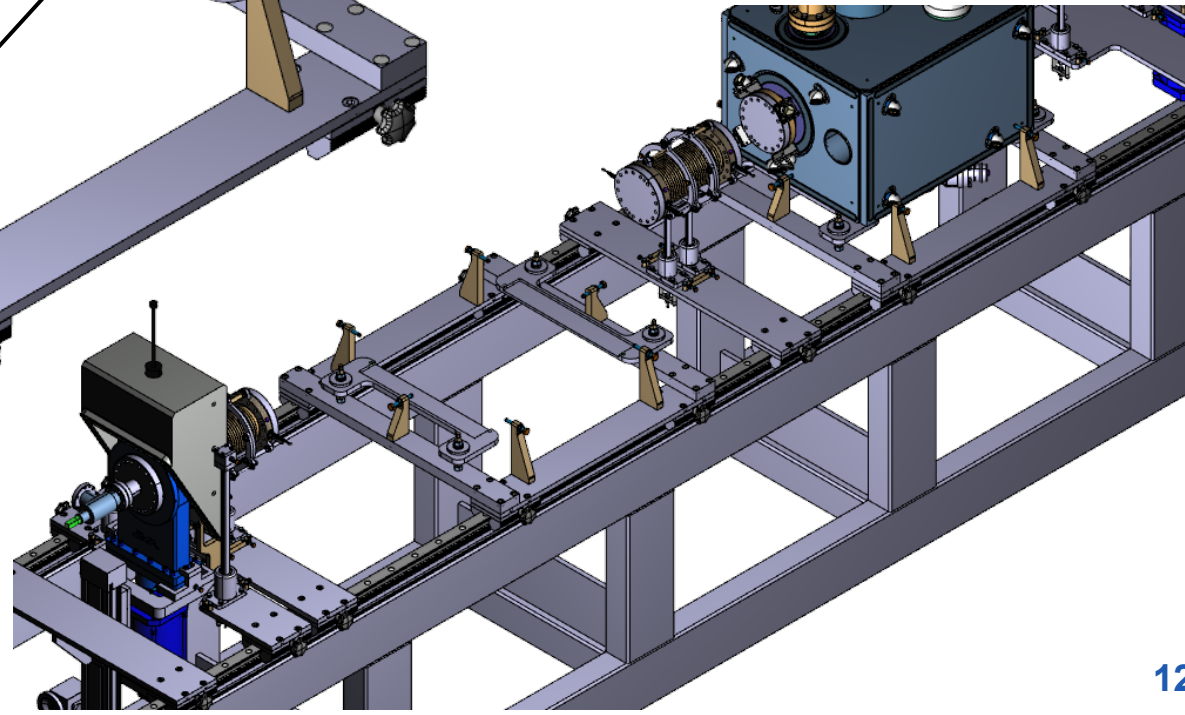
- Delivered from supplier as ISO4 compatible units (triple bagged)
 - Introduced to ISO4 via cleanroom SAS

Alignment/positioning in ISO5

- **Manual process with numerous fin adjustments**
 - Many threaded screws => not inherently clean
 - Alignment adjustment restricted to ISO5

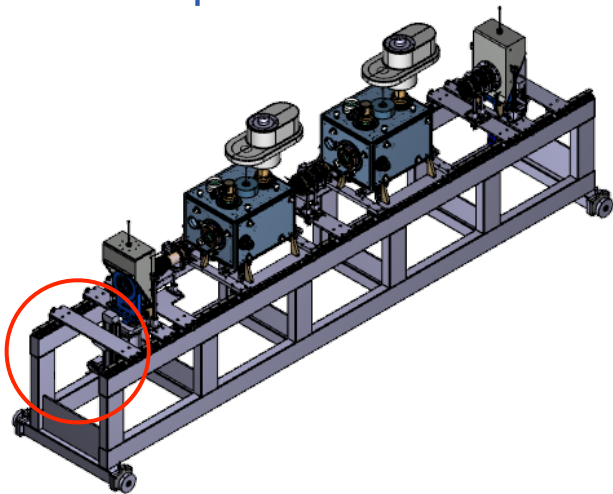


Plates are attached to cavity

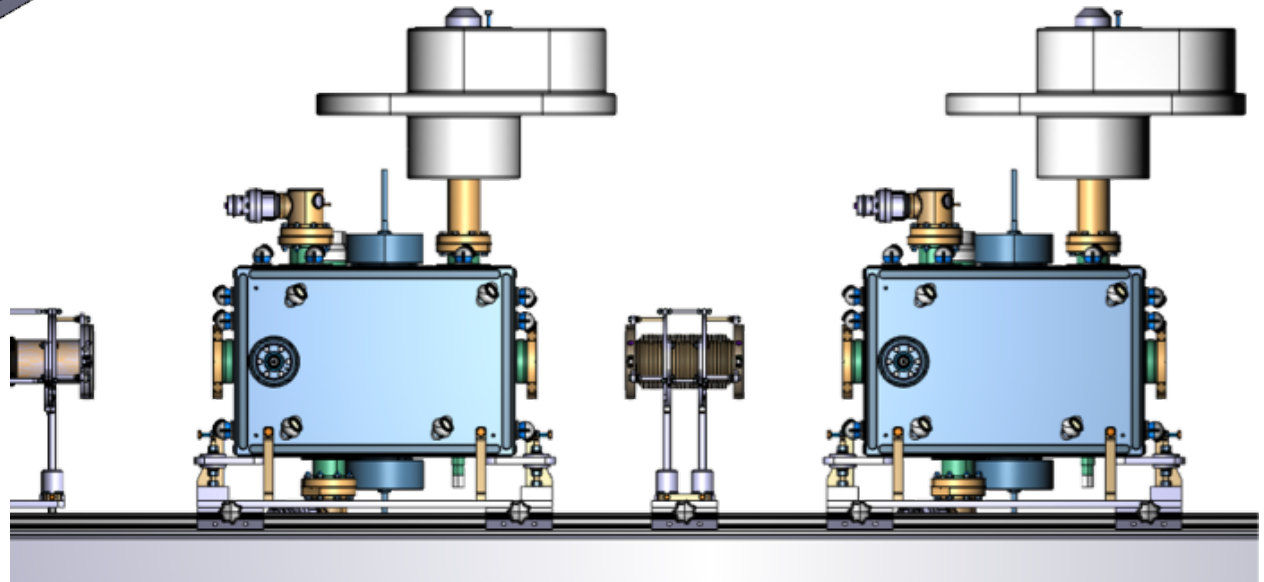
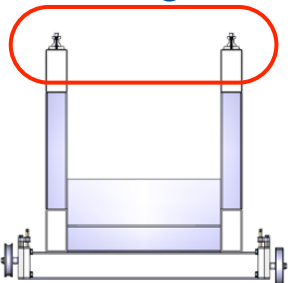


Alignment - Overview

- **String Chariot has a well defined precision rail system**
 - Align all sub-assemblies wrt each other & parallel to rail system.
 - Required alignment:
 - Cavity flanges in-line concentricity $< 100\mu\text{m}$
 - Intra-cavity roll < 0.1 deg
- **Chariot rigidity**
 - required to maintain alignment during translation (ISO5 to ISO4)



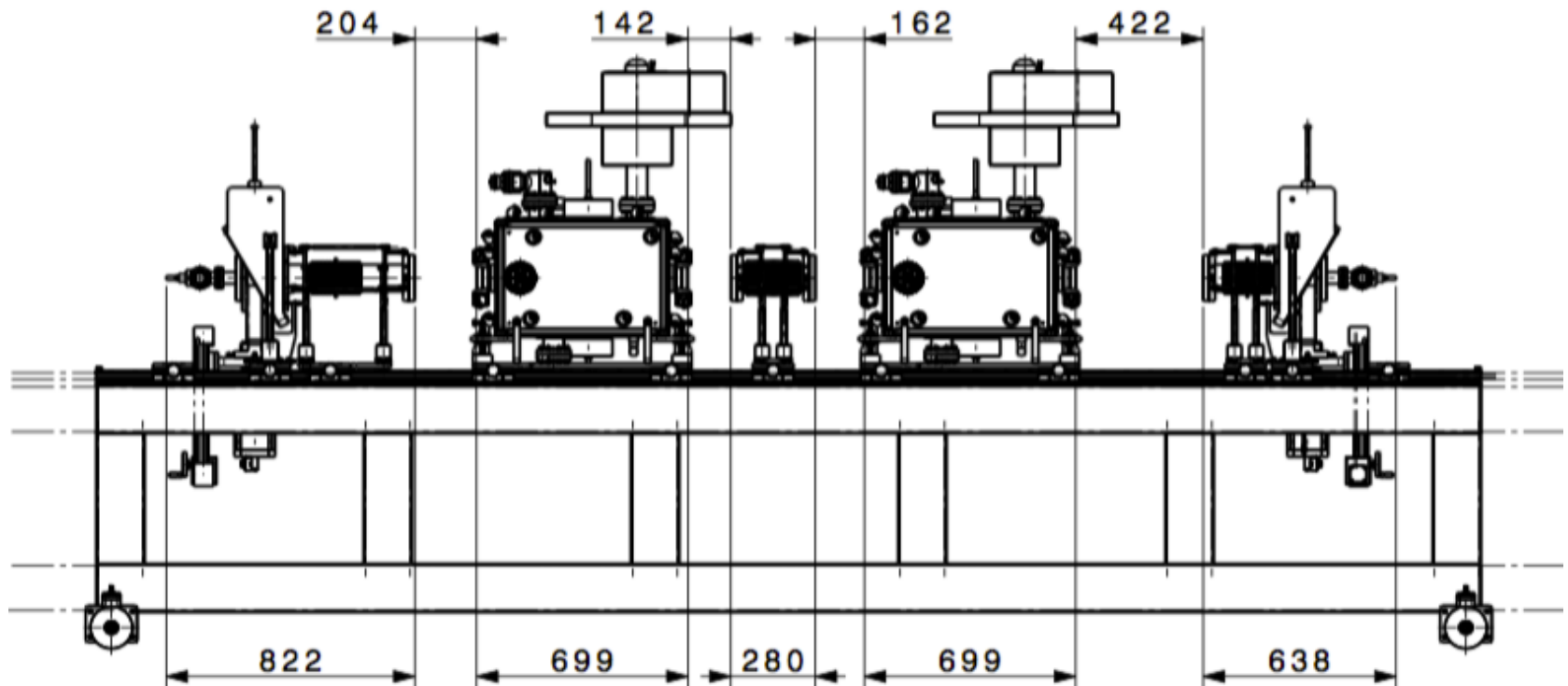
Precision guide rails



String Assembly: Dimensions

- **Alignment & positioning**

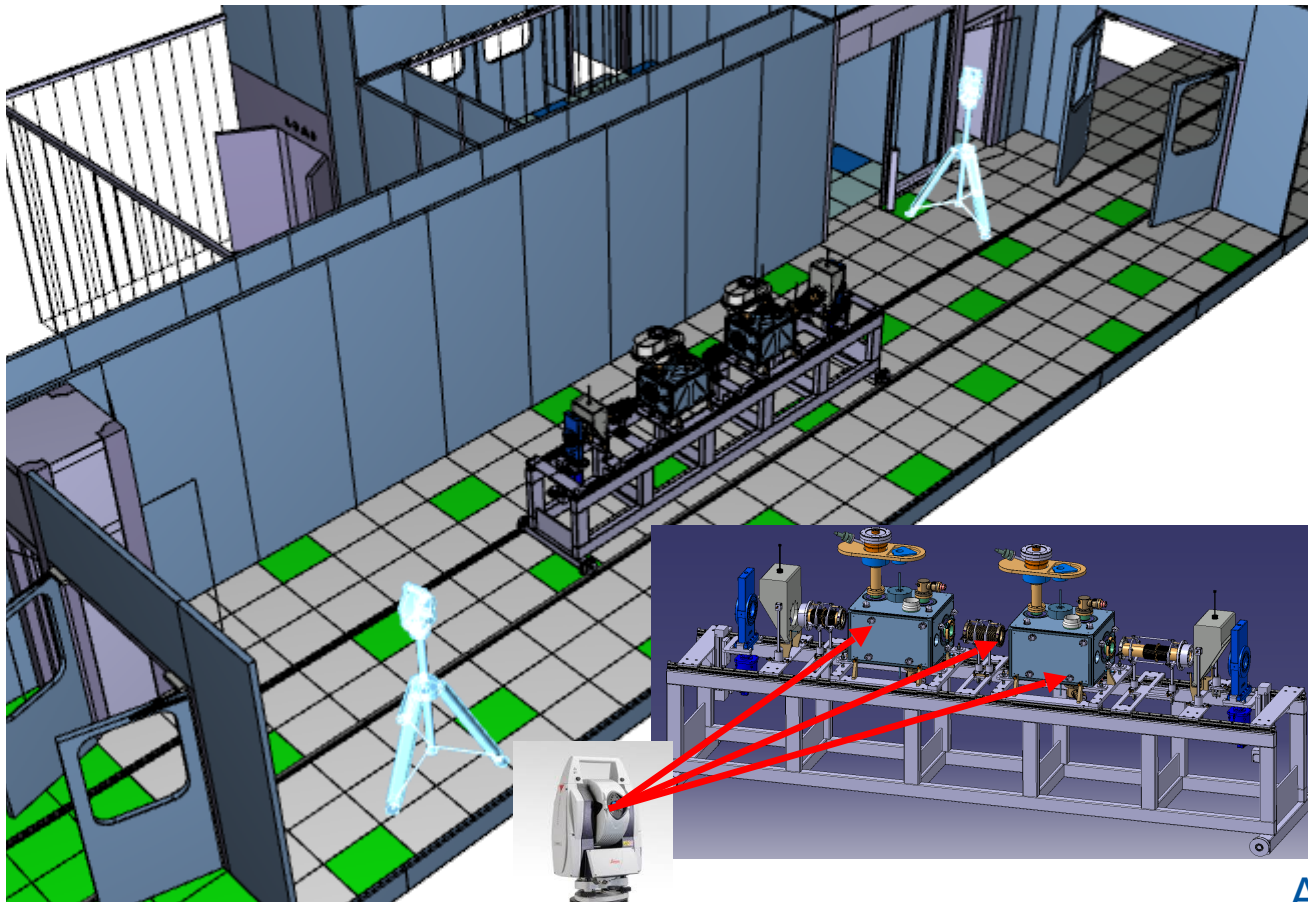
- Limited working space between sub assemblies
- Sub-assemblies can slide on rail system to make space
 - Also needed for parallelism check wrt to chariot rails



Alignment of sub- assemblies

ISO5

- Line of sight alignment to fiducial markers
 - 2 - 3 m distance is optional => wall mounting preferred
 - Rigid support in cleanroom to be developed
 - Cleanliness of Laser scanners to validated or bagged



AT401 laser tracker 15

Alignment Process

- **Alignment Overview**

- Placement of sub-assemblies on String Chariot
- Align to 100um precision wrt each other & rail system
- Plastic wrap surfaces not directly involved in assembly
- Transfer chariot to ISO4 zone
- Assemble by sliding sub-assemblies on chariot rail
- Transfer chariot back to ISO5 zone
- Make leak check, then alignment survey

- **Alignment process**

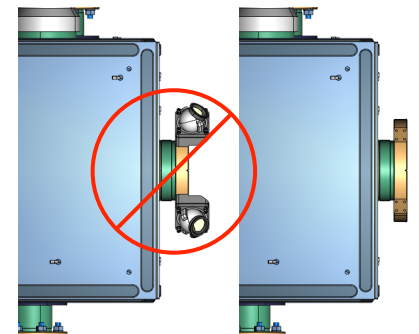
- Relies on precision of string chariot rail system
- Assumes position placement not lost in transfer ISO5 to ISO4
- **Loss of position placement of sub-assemblies**
 - => loss of flange-flange mating**
 - => Compromise of clean & simple ISO4 assembly

Alignment Issues

- **String chariot rail system designed to deliver conflict-free mating of flanges**
 - Sub assemblies should slide together without any misalignment
 - To be confirmed by assembly tests in-situ with dummy loads
 - Need to confirm transfer from ISO5 to ISO4 maintains sub-assembly positioning
- **OPTIONS: if sub-assembly positioning is NOT maintained in transfer:**
 - A.** Requires Alignment survey and repositioning in ISO4
 - Impies laser tracker system in ISO4
 - Prevents bagging non-assembly sections of string
 - B.** String Chariot returned to ISO5 and re aligned
 - C.** Make minor realignment adjustments in ISO4 so flanges mate
 - This is seen as a last resort step for an on-the-day fix.
- **Key concerns:**
 - Must limit propagation of particulate by bagging non-assembly areas
 - For streamlined clean assembly => no fiducials on beam ports



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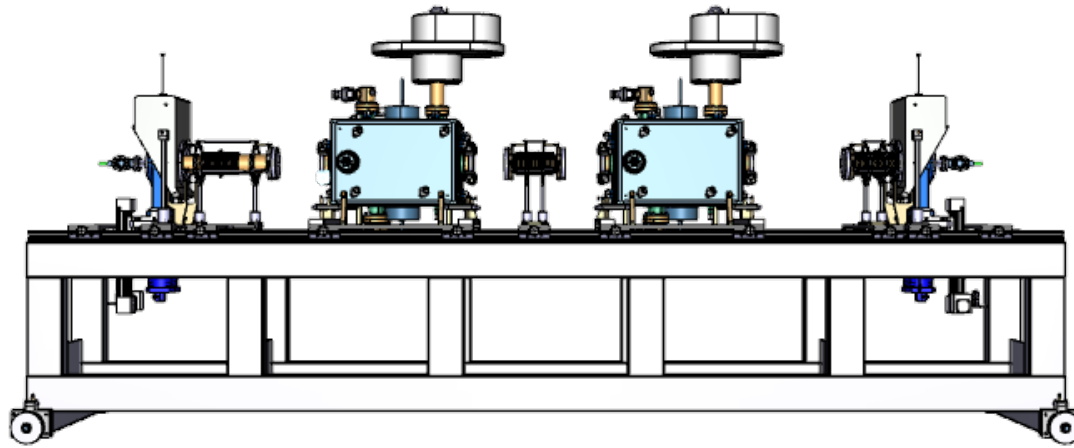
String Assembly in ISO4

Transfer from ISO5 to ISO4

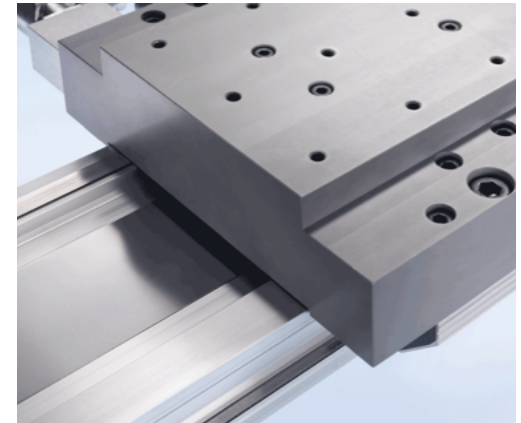
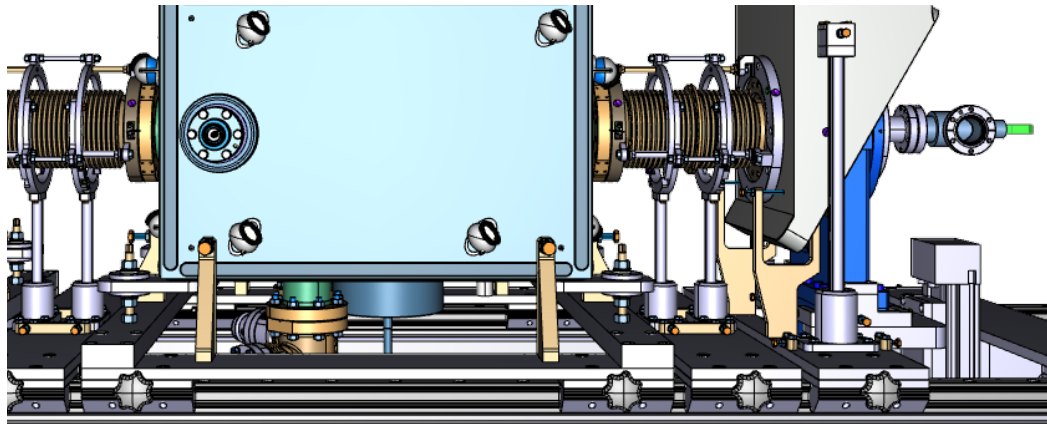
- **Assumptions: String chariot in ISO5**
 - Sub assemblies mounted on chariot & fully aligned
 - Sub-assemblies wrapped in plastic to mitigate particulate flow in ISO4
 - Non-assembly areas wrapped in LDPE plastic sheet
 - Implies alignment survey is not possible in ISO4
 - Must not prevent sliding motion of sub -assemblies on rail system
- **Chariot Transfer from ISO5 to ISO4**
 - Re-clean once string chariot & with sub-assemblies aligned & wrapped
 - perform gentle wipe down, then N₂ blow-off.
 - Move to door way, open doors, & push chariot through
 - Close doors and position chariot midway in ISO 4
- **Repeat transfer process for tools + assembly components**
- **Let chariot + tools sit in laminar flow overnight**

String Assembly - Sliding into place

- **Sub-assemblies slide on rail system**
 - Translation is manual: heaviest object = 250kg
 - Alignment ensures flange-2-flange engagement



ISO4



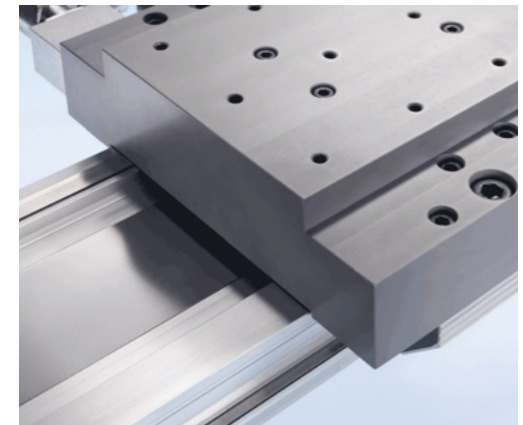
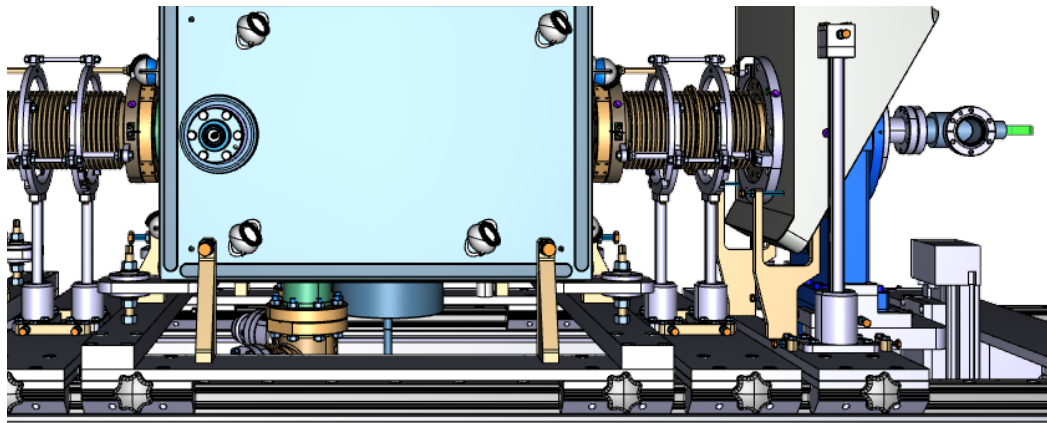
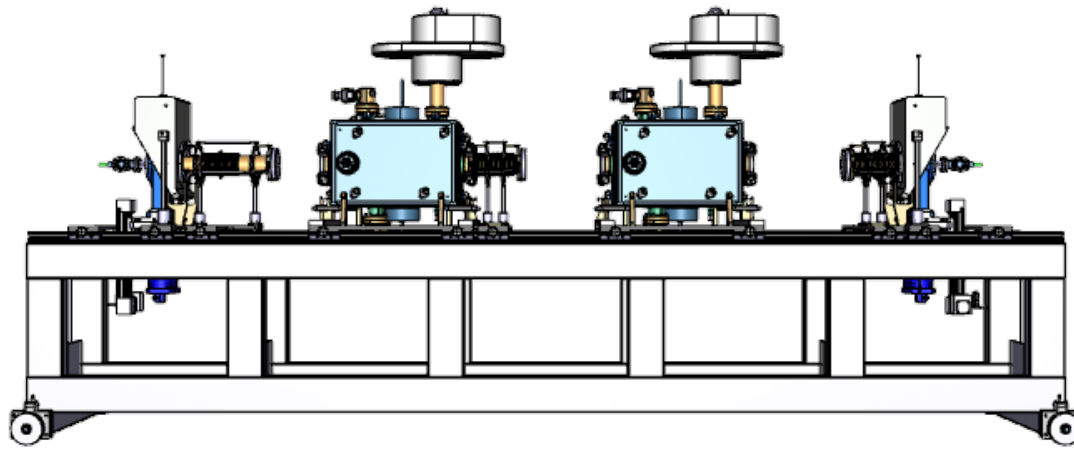
Rail system: Franke lubricant free rail system (in stainless steel)

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Laminar Flow

ISO4



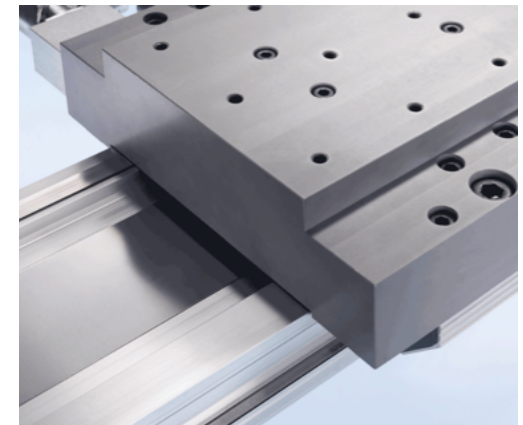
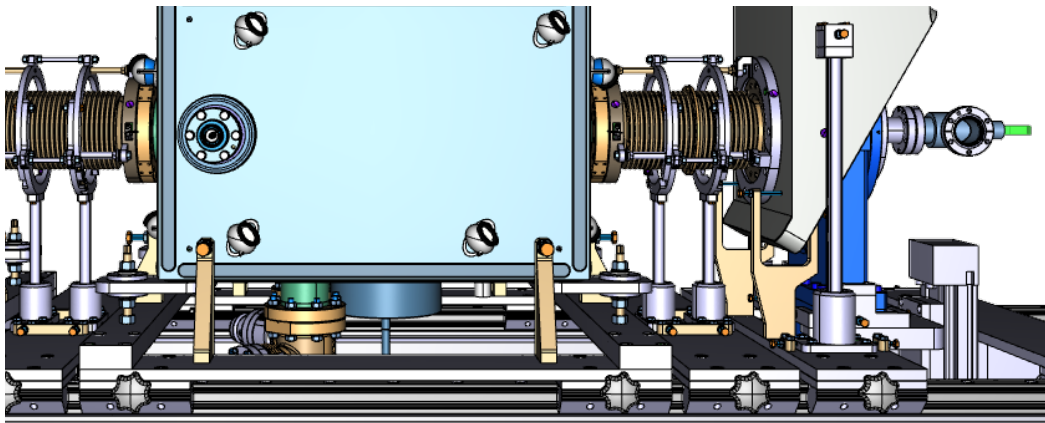
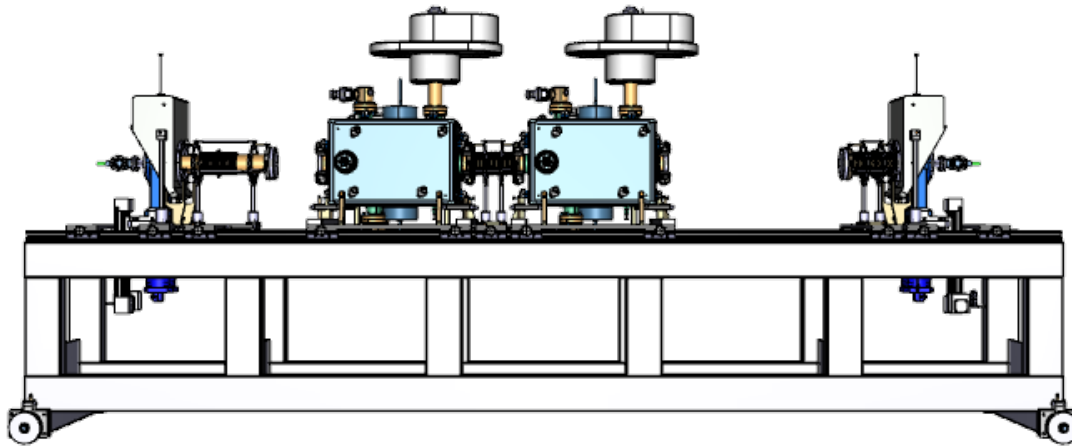
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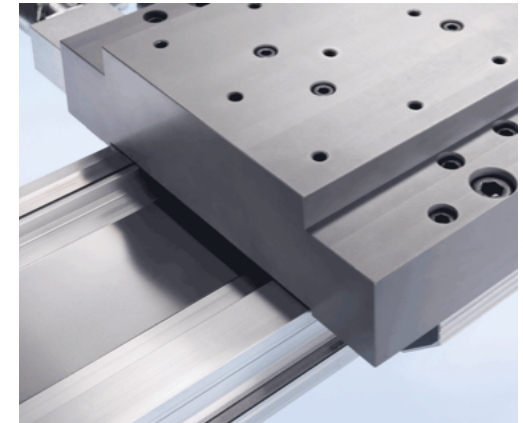
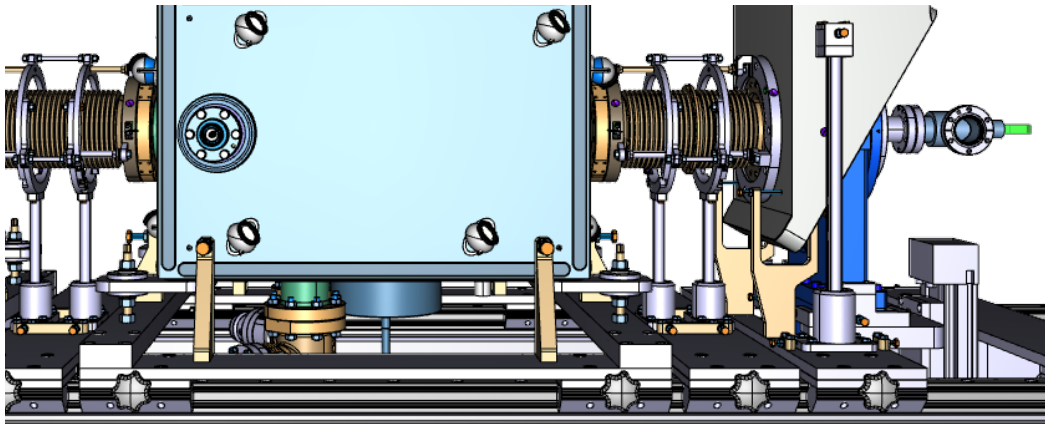
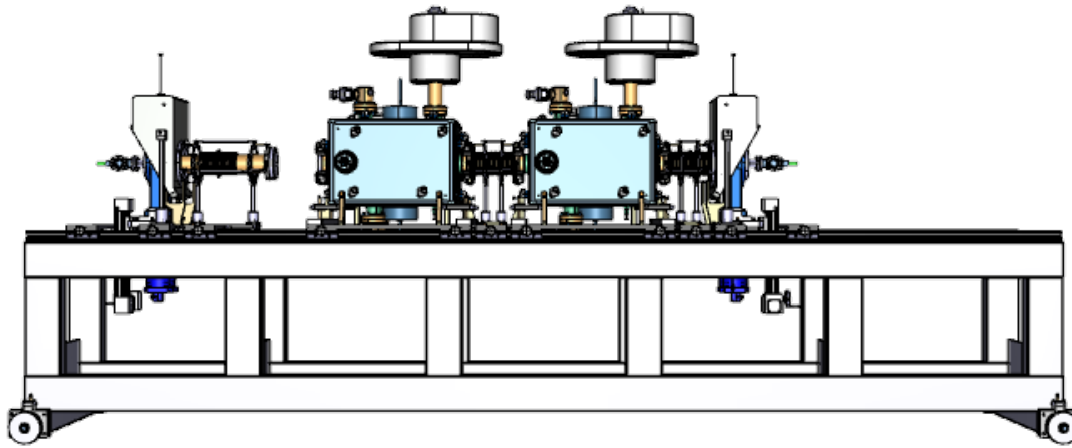
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ISO4



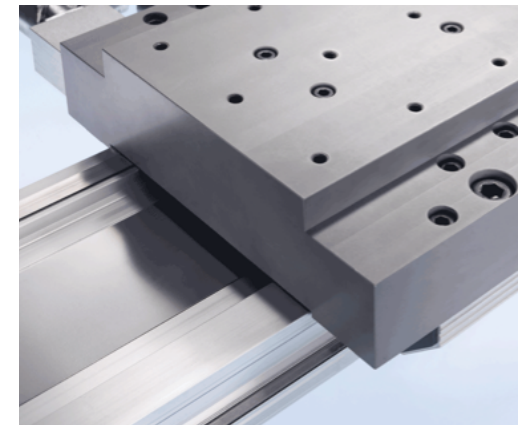
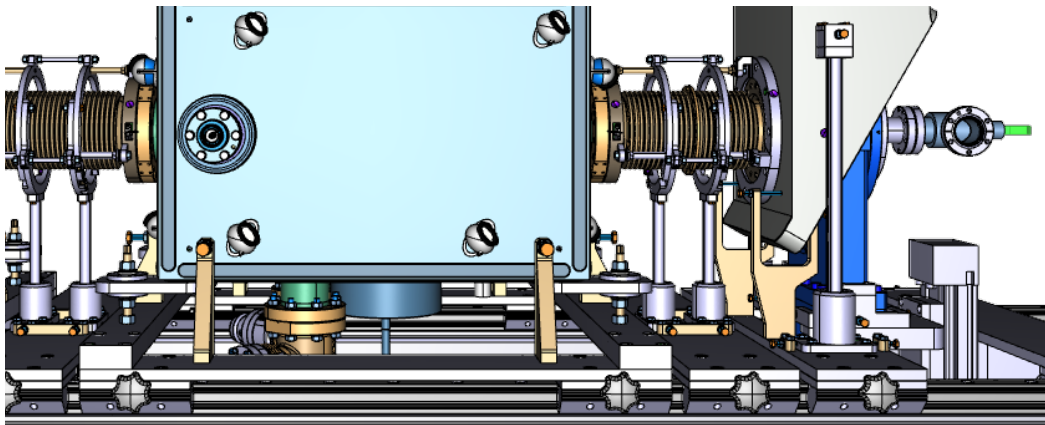
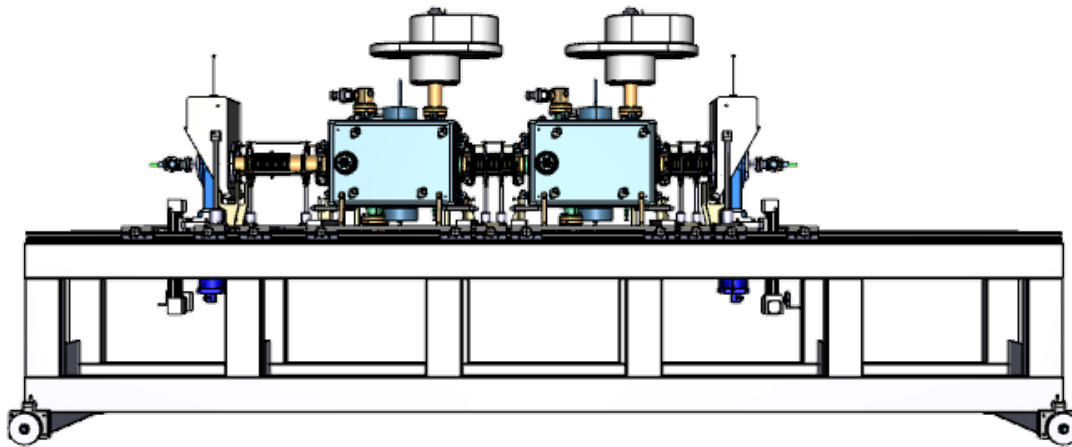
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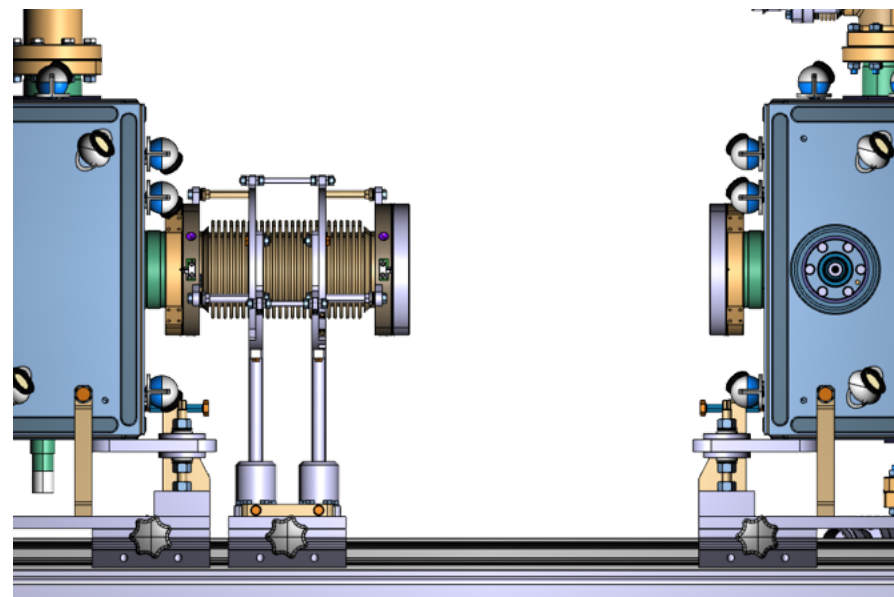
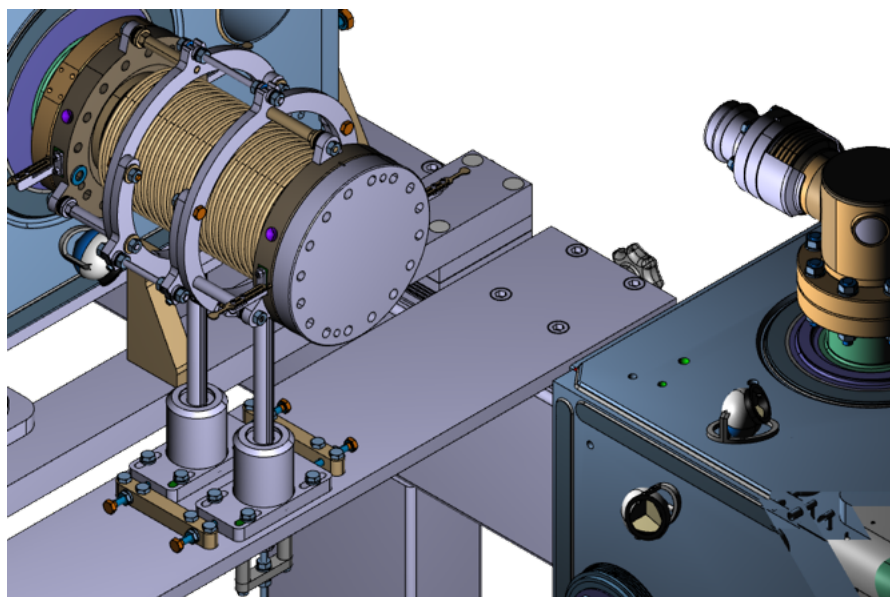
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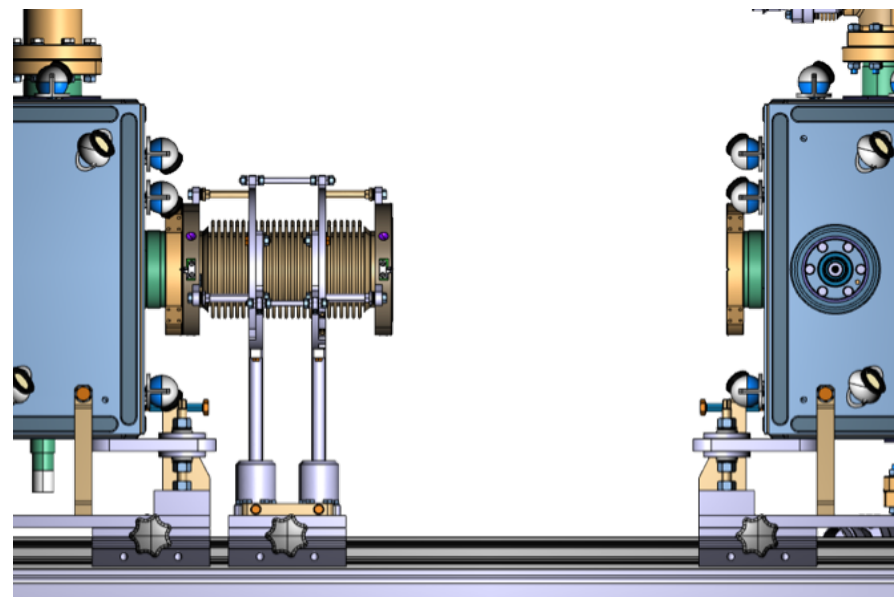
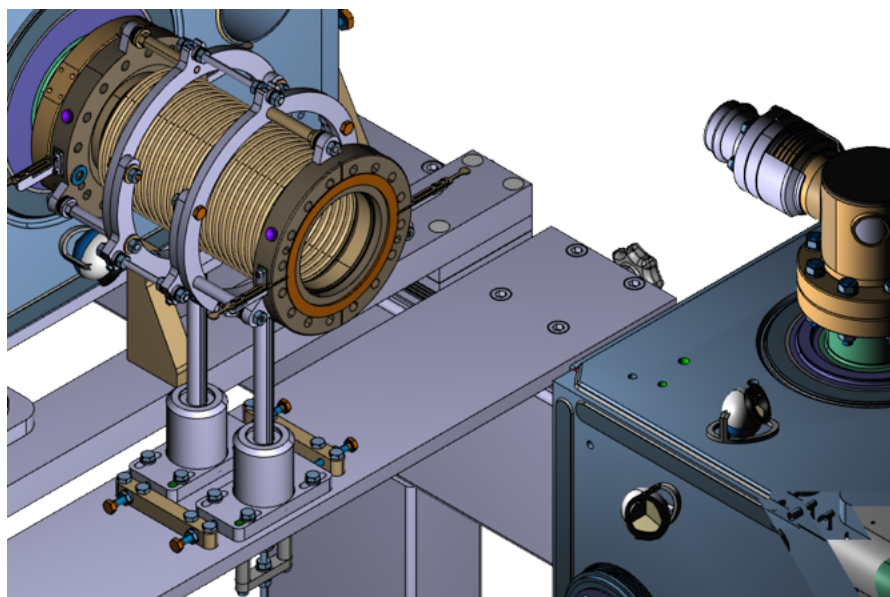
Flange mounting

- **Flange interface is vertical**
 - Gaskets held by “fingers” compatible with flanges
 - Provides alignment positioning cross check
- **Protective caps:**
 - Standard flanges held by 2 loosely tightened screws
- **Flange to flange mounting**
 - Control particle count: Require < 20 counts/min (for $>0.5\mu\text{m}$)



Flange mounting

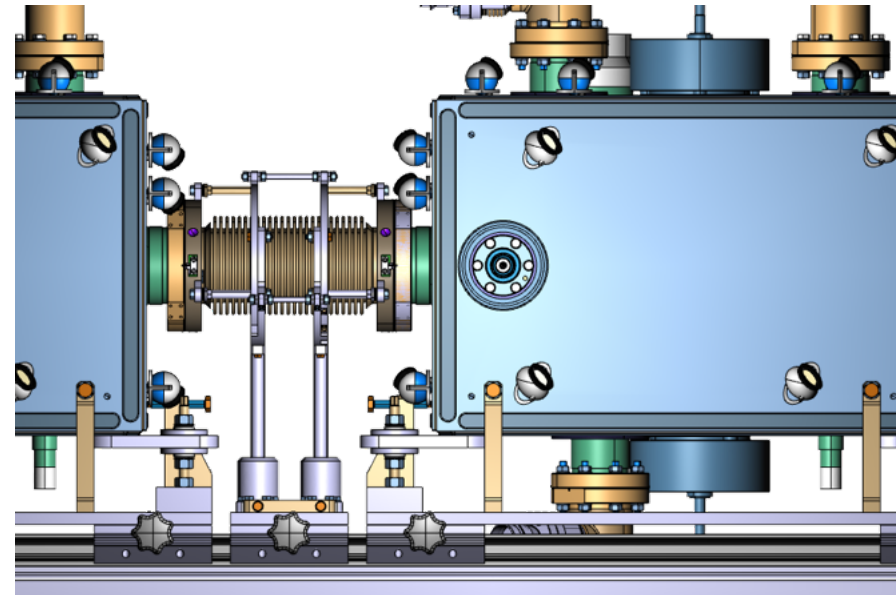
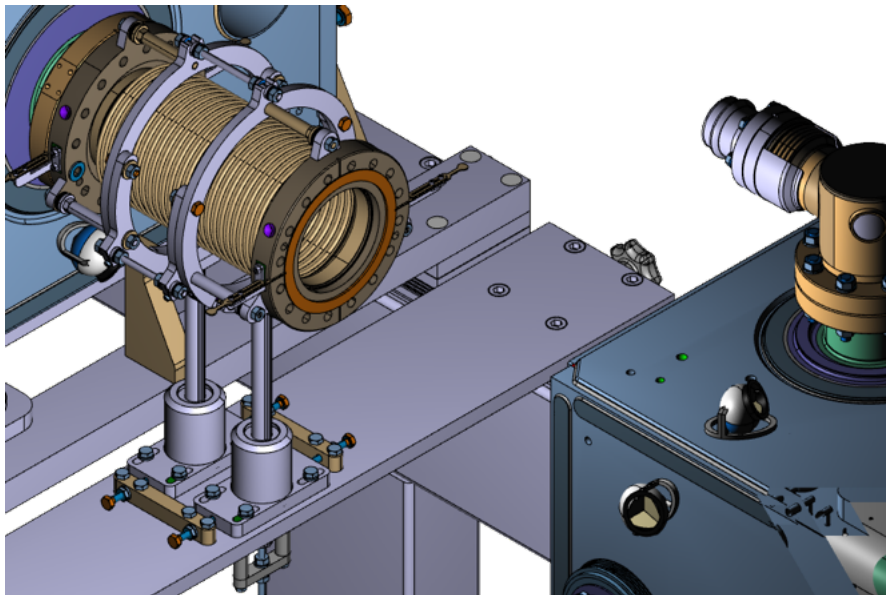
- **Flange interface is vertical**
 - Gaskets held by “fingers” compatible with flanges
 - Provides alignment positioning cross check
- **Protective caps:**
 - Standard flanges held by 2 loosely tightened screws
- **Flange to flange mounting**
 - Control particle count: Require < 20 counts/min (for $>0.5\mu\text{m}$)



Flange mounting

ISO4

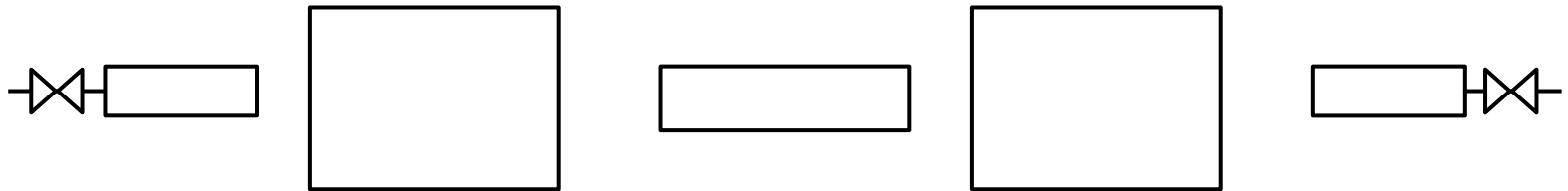
- **Flange interface is vertical**
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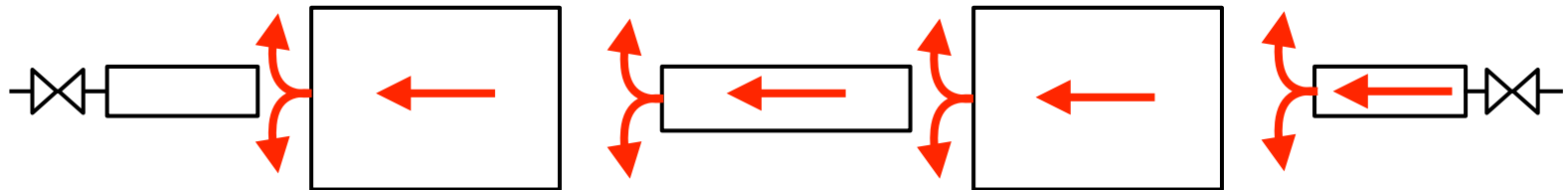
Connection of sub assemblies

- **Baseline: Assembly done without N₂ over pressure**
 - **Concern:** Long term RF surface contamination from particulate in interconnect and end valves
 - **Question:** Would N₂ flush evacuate particulate during assembly, and reduce risk of RF performance loss?

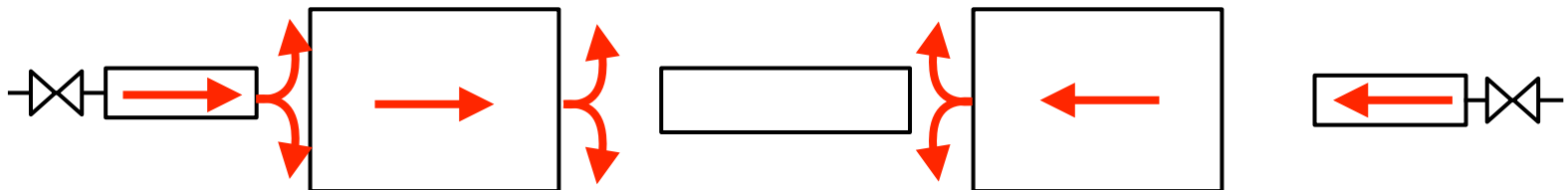
Baseline



Single ended flush



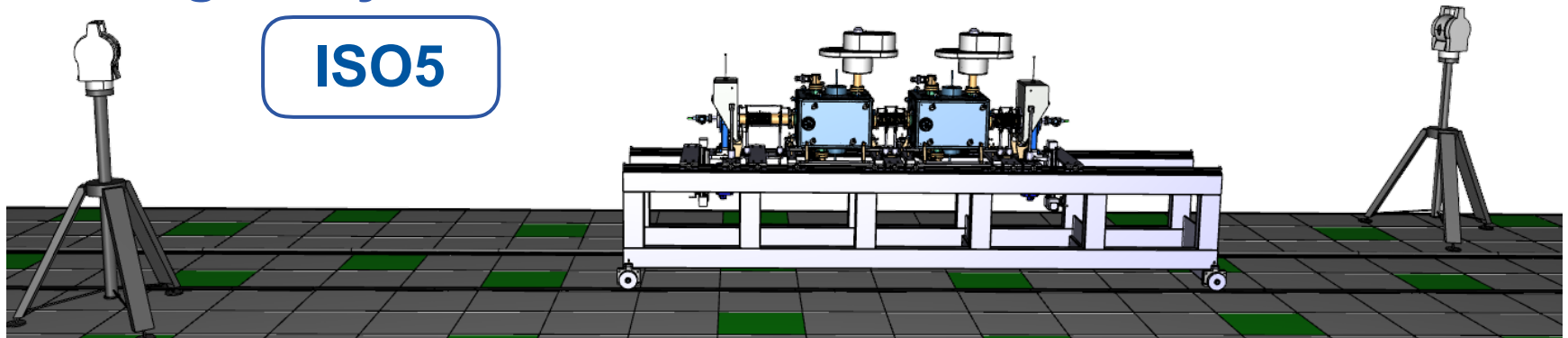
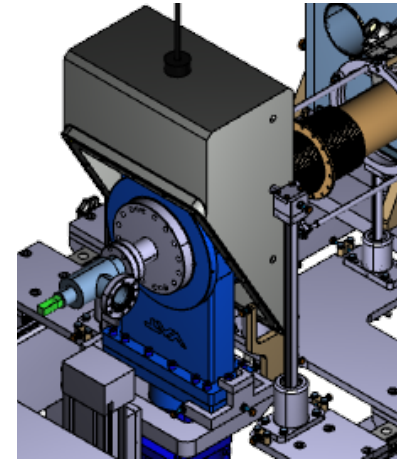
Double ended flush



Post assembly measurements

Post- Assembly Transfers & Measurements

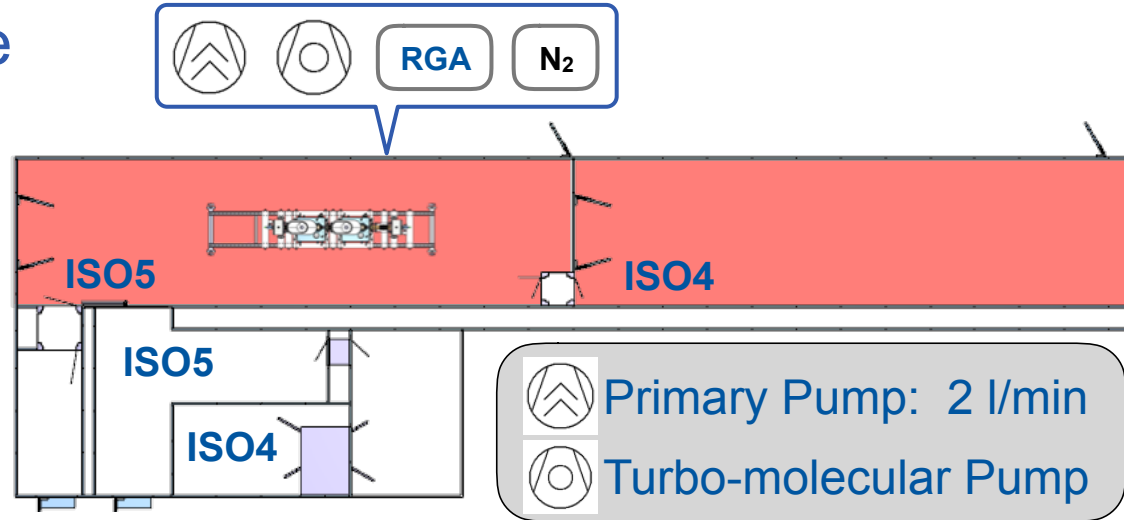
- String assembly is finished & string is closed in ISO4
- Chariot manually pushed on rail system back to ISO5
- **Once in ISO5 Area**
 - Connection of pumping line for leak test
 - Pumpdown to 10^{-6} mBar
 - Leak Check
 - Alignment survey with string under vacuum
 - Vent to 1 Bar of N_2 in string
 - Alignment survey
- **String ready to leave cleanroom**



Putting the String Under Vacuum

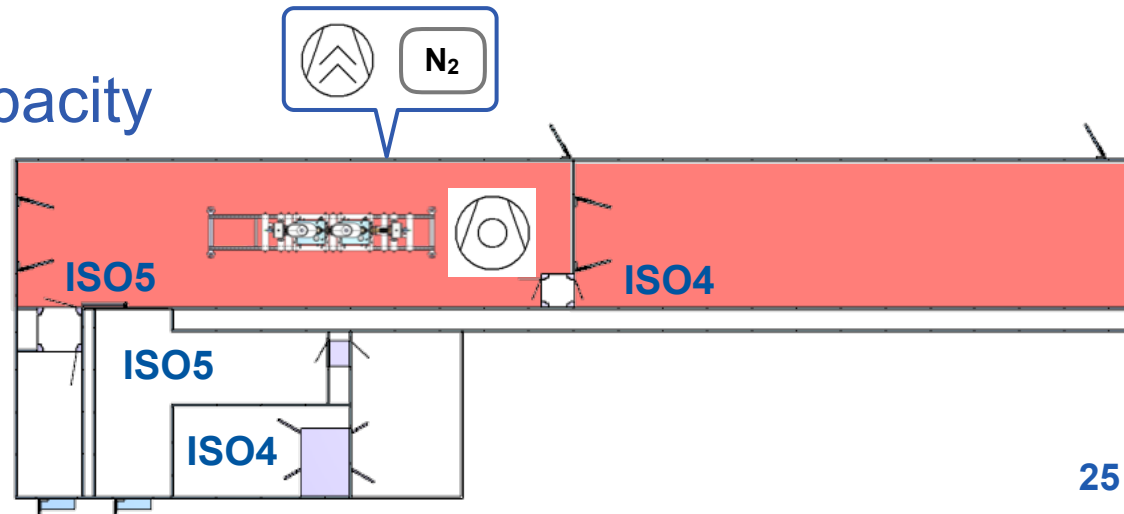
- **Baseline: Pumping system exterior to cleanroom**

- ~ 3 m connection line
- RGA analysis
- Simple connection to string



- **Optional: Needed insufficient pumping power**

- Turbo pump in ISO5
- Improve pumping capacity
- No RGA



Pumping Line

- **Pumping unit is external to cleanroom**
 - Pumping line passes into cleanroom via patch panel
 - Pumping line makes valve to valve connection to string
 - Interfaces: ISO-CF DN-40 inox flanges
 - Pumping line: ~3m long flexible line
 - Mobile pumping group: slow dry pumping units
 - **Primary Pump:** Pumping speed of 2 l/min
 - **Turbo-molecular Pump:** 50 l/sec for $P < 10^{-2}$ mBar
 - **N₂ flush:** Bottled N₂ with 0.20 & 0.05 μm filter
- **To Note**
 - Assumed that leak test done at 10^{-6} mBar.
 - => Ion pump is presently not foreseen in pumping group
 - **Question:** Should we leak test at higher vacuum levels?
 - **Observation:** No bakeout of assembled string is foreseen
 - **Question:** Should bakeout of assembled string be added?
 - If so, assume after string assembly (outside cleanroom)



Leak Check

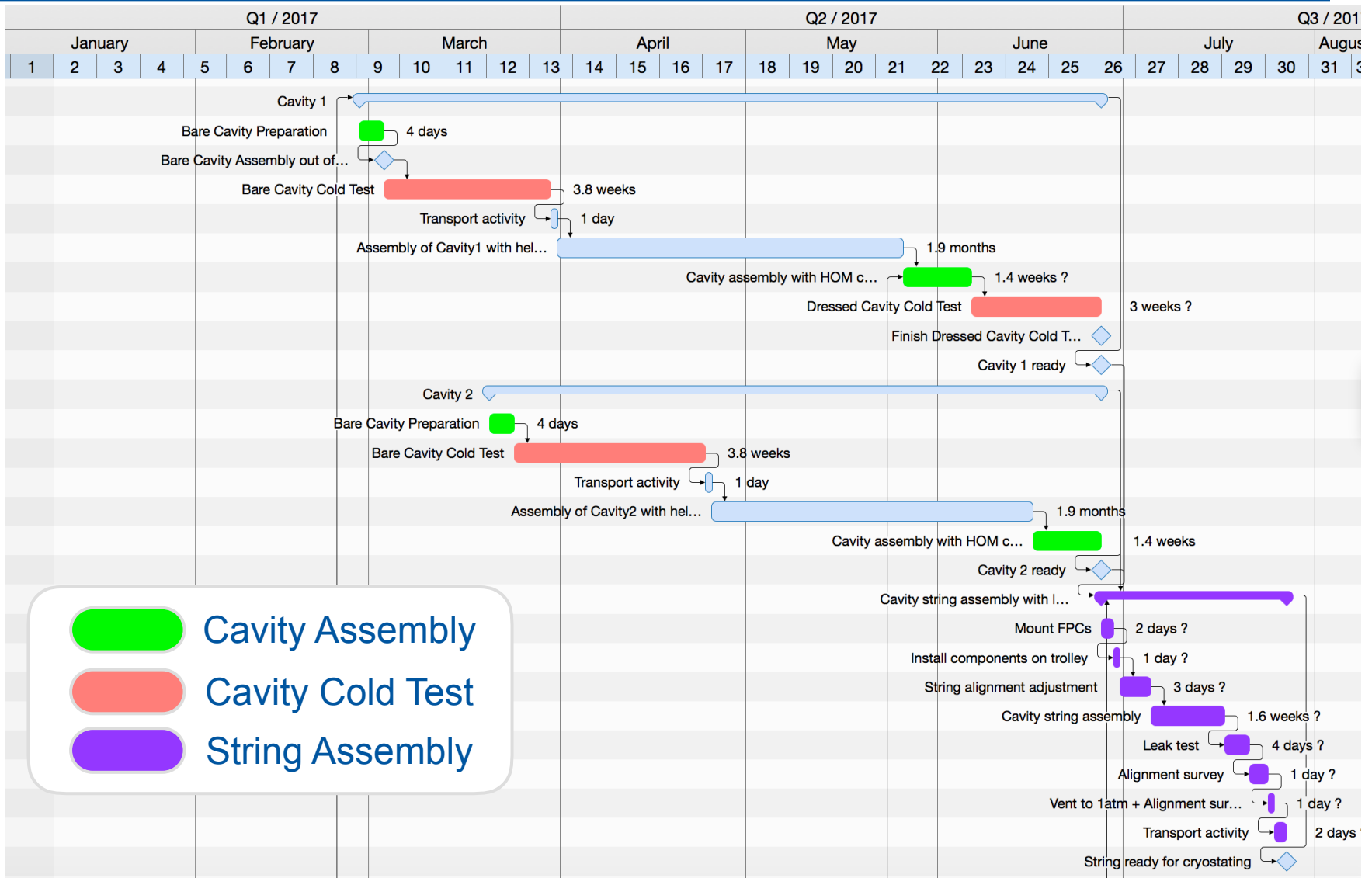
- **Pumping unit is external to cleanroom**
 - Pumping line makes valve to valve connection to string (ISO-CF Flanges)
 - Mobile pumping group: slow dry pumping unit (Turbomolecular + Primary)
- **Connection of pumping line:**
 - Clean pumping line valve.
 - Start overpressure flush on pumping line
 - Open pumping line valve & connect pumping line to string.
 - String valve remains closed
 - Standard 3-rinse cycle on pumping line with filtered N₂. (0.05 μm filter)
 - Take reference RGA mass scan. Requires pressure < 10⁻⁶ mBar
 - Flush with N₂ to ~0.9 Bar
 - Slowly open string valve, then pump string to < 10⁻⁶ mBar. Pumping at 2 l/min
 - Continuous opening: 1 valve tap turn in 10sec
- **Leak Detection Check**
 - Bag areas around flanges and blow helium inside
 - Leak detection on pumping line. Acceptance level < 2 x 10⁻¹⁰ mbar.l / s
 - Repeat RGA mass scan

Steps after leak check

- **Remove plastic bags for helium leak check**
- **Preform alignment survey with string under vacuum**
 - Standard survey with laser tacker
- **Vent string with N₂ to 1 Bar**
 - Stop and isolate turbo pump
 - Open N₂ line (micro valve + gauge + safety valve outside Cleanroom)
 - Once string at 1 Bar, close string valve then N₂ supply valve
- **Preform alignment survey with string at 1 Bar**
 - Standard survey with laser tacker
- **Disconnect and reseal pumping lines**
- **Move string out from cleanroom. String at 1 Bar pressure**
 - Manually pushed out of clean room
 - 2 teams: 1 inside to push, 1 outside to receive
- **Handover of String to cryostating team**

Discussion about schedule

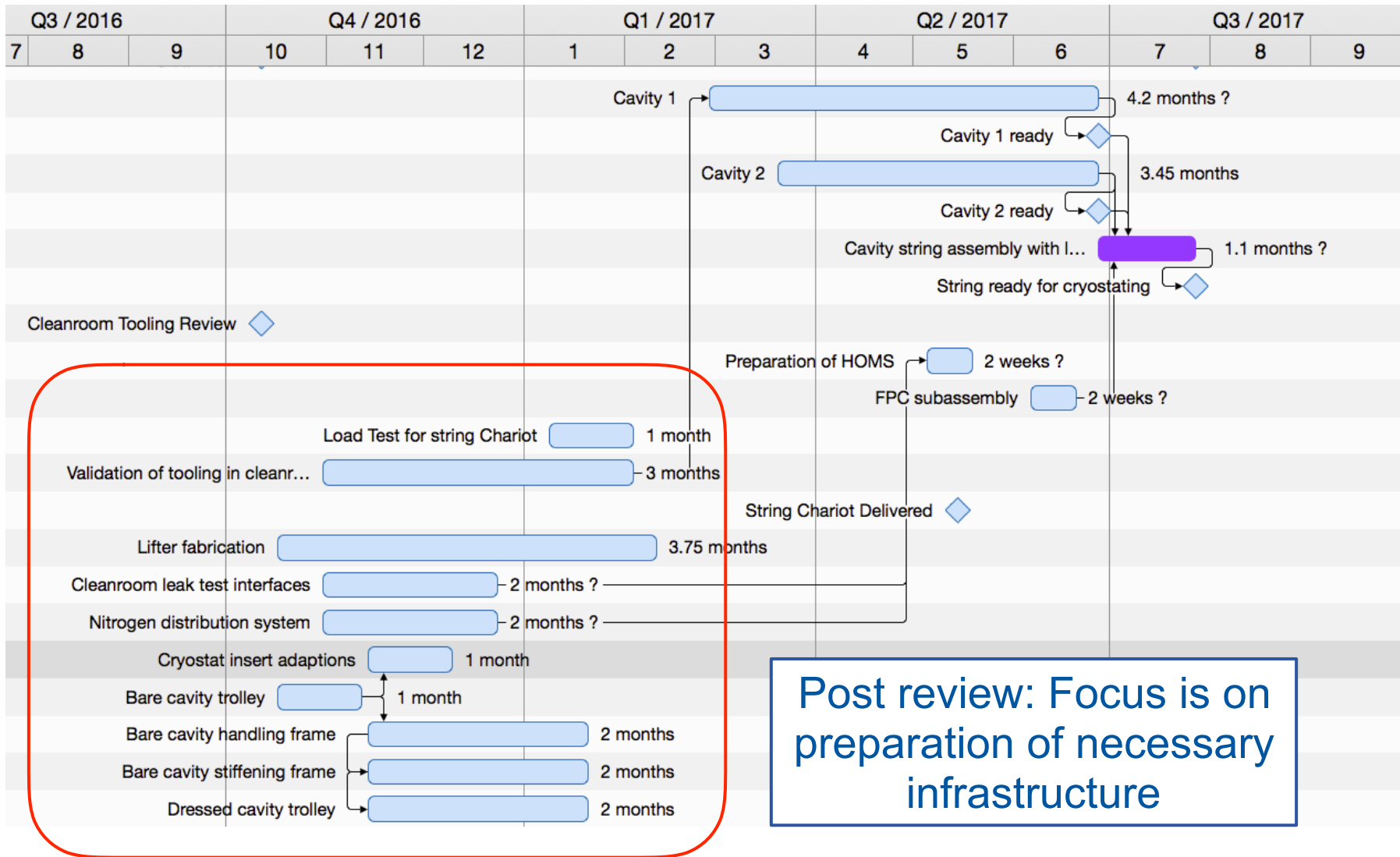
Schedule



In Present schedule, string assembly is 1.1 months duration
 - But this includes mounting the FPCs



Support Infrastructure



Summary Observations & Issues

- **String assembly workflow**
 - Now defined & tooling moving from conceptual to actual
- **CERN cleanroom requirements**
 - Starting to clarify. Instrumentation of cleanroom can now be done
- **Precision alignment**
 - Key for a clean and simple assembly sequence in ISO4
- **String assembly**
 - Done without N₂ flush. Risk of contamination from end flanges?
- **Do we need bakeout of assembled string (outside cleanroom)?**
- **Is vertical end-valve sub-assembly the best way?**
- **Should we expect ISO4 ready bellows from supplier?**
- **Nitrogen blow-off is foreseen with filtered bottled N₂**
 - Should we move to a N₂ boil of system?
 - For safety (ODH) issues could we default to clean compressed air?

