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Lifting system for Mu2e tracker assembly

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Final presentation

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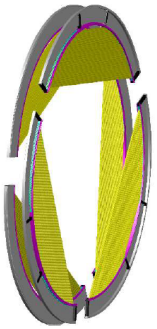
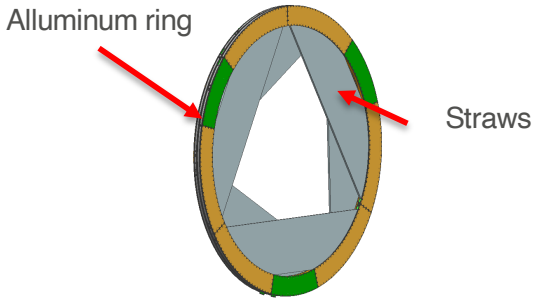
From plane assembly to station installation

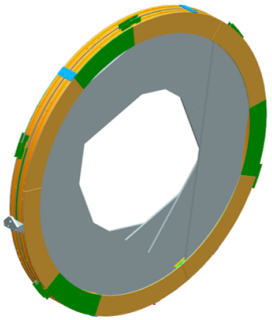
1. Six panels are assembled in a **plane** on a 1st granite table
2. **Electronics is installed** on both sides of the plane
3. Two planes are assembled in a **station** on a 2nd granite table
4. Station is **stored**
5. Station is installed in the **tracker frame**



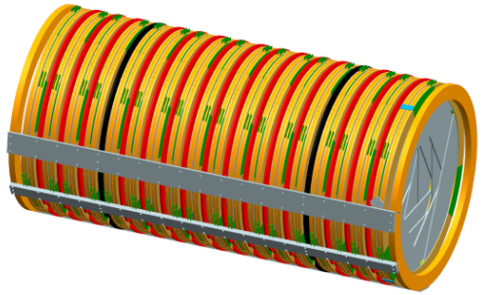
Six panels made a plane



3D view of a plane



3D view of a station, made of two planes



Tracker: 18 stations, plus structure

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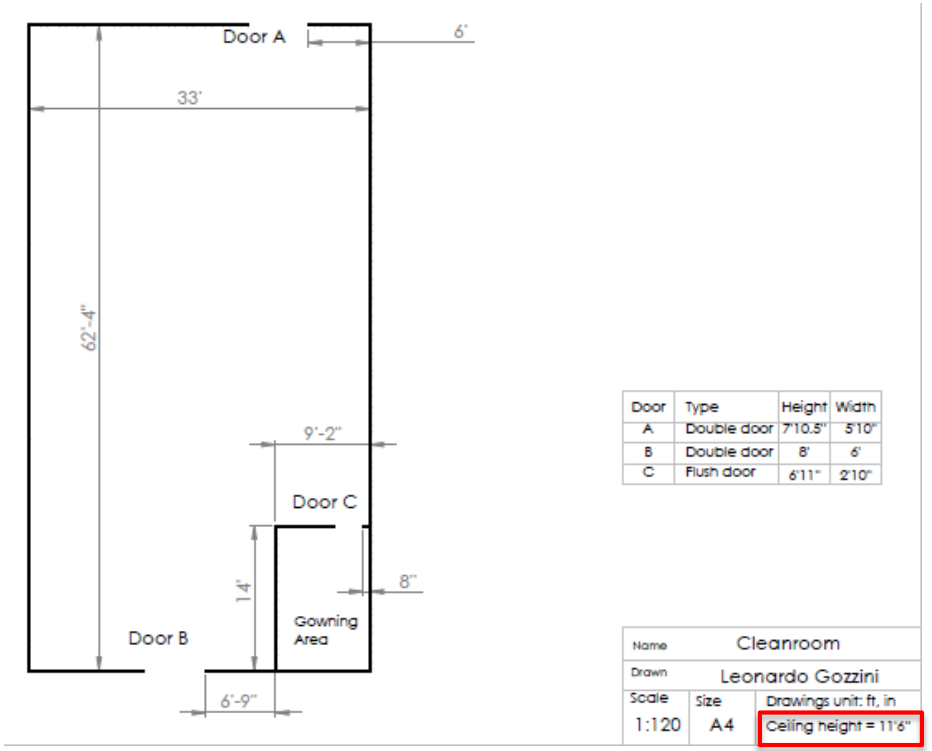
Constraints

- **Very delicate**: straw thickness is about 15 µm
- **Very expensive**: station costs about 1 million $
- **Precise positioning** in the frame is required
- Assembly procedure has to be repeated **only 18 times**: it is not convenient to use highly expensive system
- The assembly will take place in the cleanroom B at Lab. 3, whose **dimensions are limited**
- Plane and station are **light** (weight of the station = 100 kg) but are rather **large** (diameter = 1600 mm)



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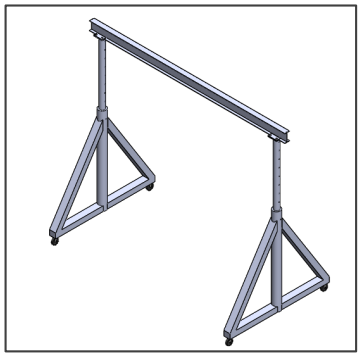
Goals

- **Conceptual study of an handling solution**, selecting off-the-shelf components and suggesting designs for custom made components
- **3D model of the entire layout and lifting system**, updated step by step basing on measurements and catalog data
- **Study of the cleanroom layout** in order to:
  - ❑ Allow enough space of movement for the lifting system and the operators
  - ❑ Reduce lifting system repositionings
  - ❑ Take advantage of the lifting system movements that present the greatest precision
- **Define** the general outline of an efficient **assembly procedure** in accordance with the characteristics of the lifting system and the constraints of the problem

Lifting system – Main structure

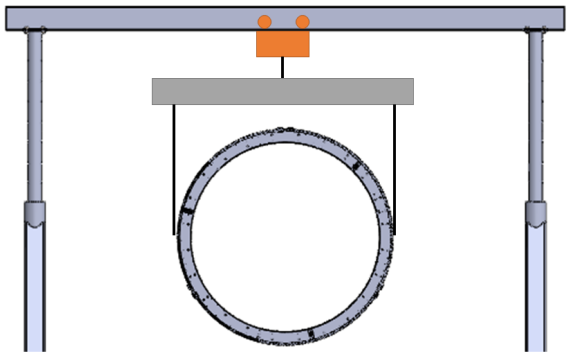
Preliminary idea: use of the FNAL gantry crane



3D model of the FNAL gantry crane with adjustable height

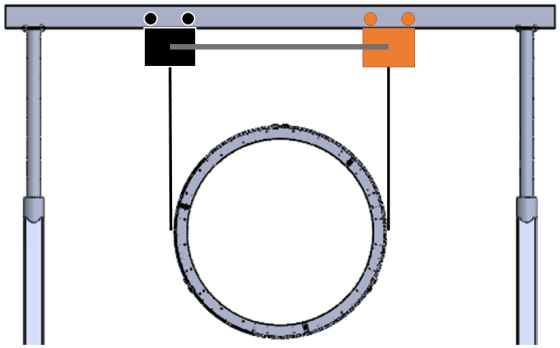
Two main solutions for the lifting equipment:

One trolley, one hoist, spreader bar



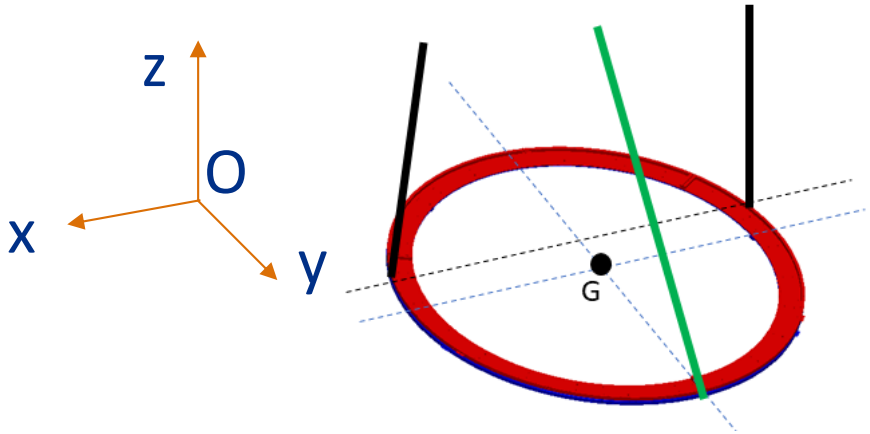
- Risk of spin around vertical axis
- Vertical space is limited

Two trolleys, two hoists



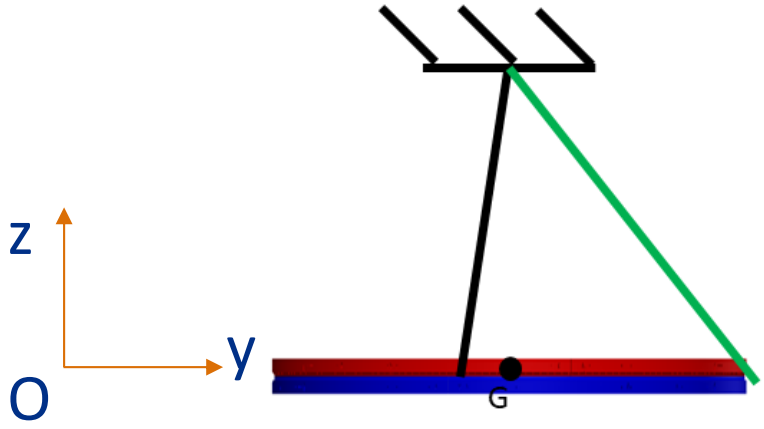
- Hoists must work in parallel
- More expensive

Handling – Preliminary solution

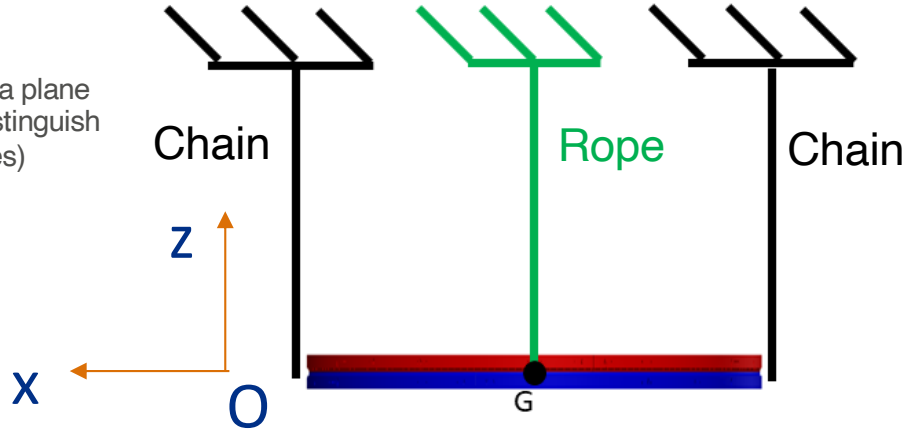


Both plane and station have **two lifting points** and a **third flange** at the bottom, needed for the correct installation in the frame.

- Two lifting brackets on both sides to support the weight of the plane/station and to lift it
- One bracket at the bottom connected to a rope to control the rotation around the x-axis
- The **misalignment** is needed to avoid uncontrolled rotation around the x-axis



Different view of a plane
(Colors only to distinguish the two sides)



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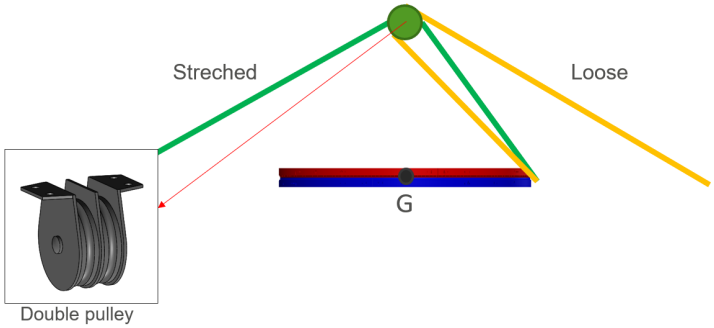
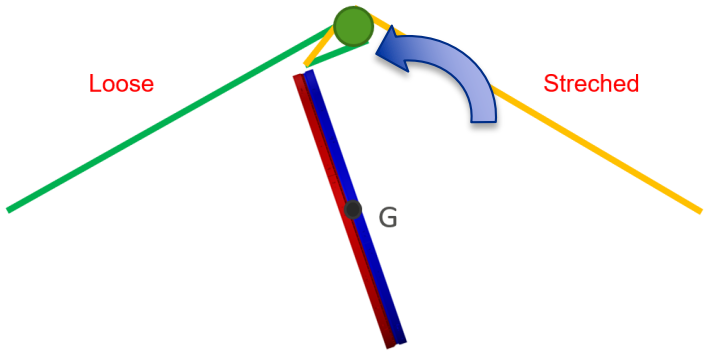
Handling – Preliminary solution problems

- We could not control the station in vertical position with the **third point at the bottom**
- **Sliding** between plane/station and the granite table
- To not stress the structure only on one side we needed two ropes instead of one that had to be connected with the third point:
  - high probability of **operator error** when connects the hook from the center to the third point
  - the double pulley needed could **lose oil** on the straws





Previous idea for the mechanism of rotation.
Only ropes are represented.

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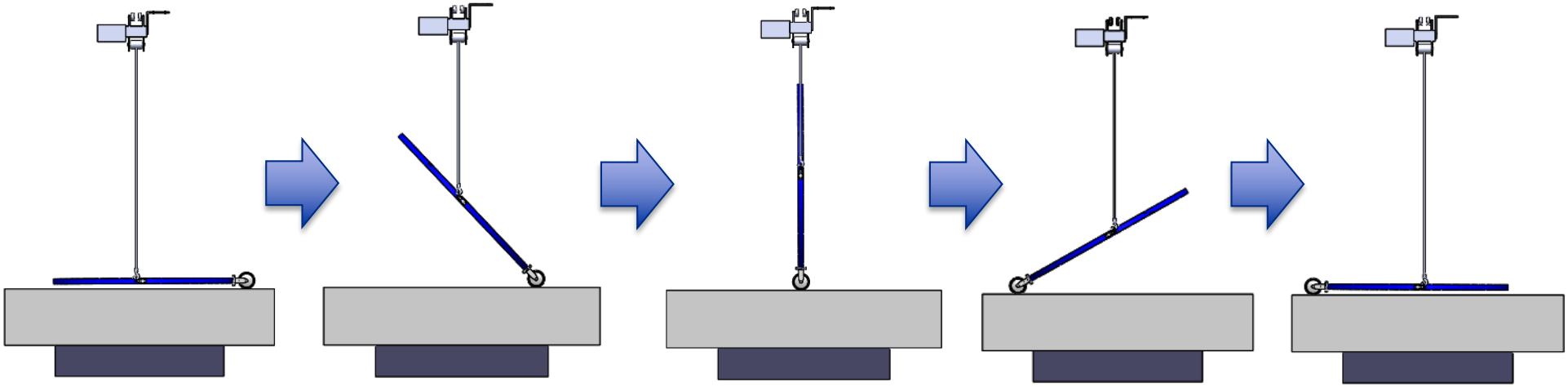
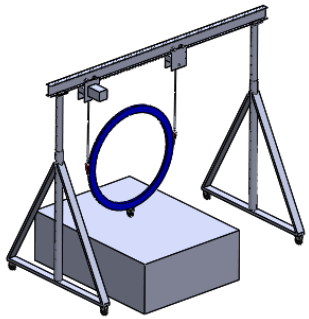
Handling – Wheel solution





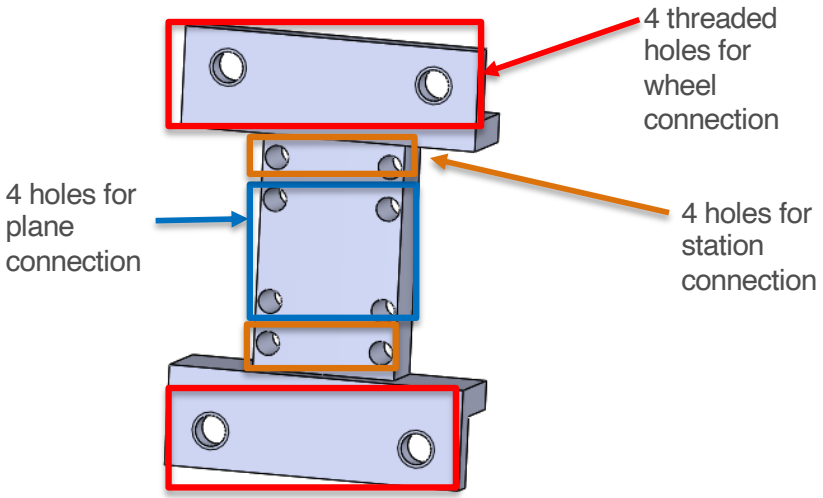
- The wheel can be easily installed when the plane is horizontal and placed on spacers, stands or something similar
- Rotation up to 180°
- Vertical placing with third point at the bottom
- The use of a rubber wheel can reduce shocks

Handling – Flange adapter

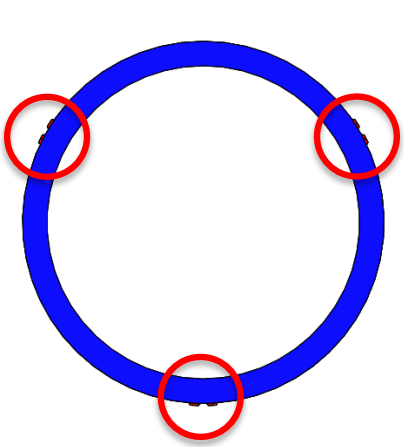
We need a flange adapter that connects the wheel to the plane.

Considerations for the conceptual design:

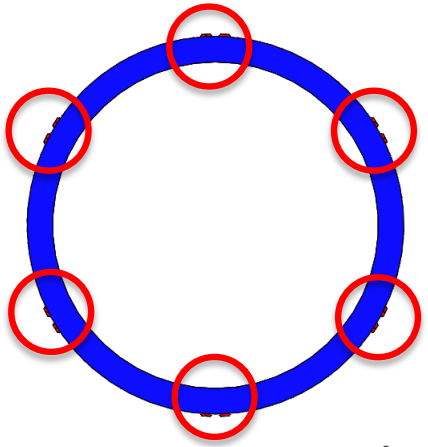
- Usable both for plane and station
- Take in account the presence of the "ears"



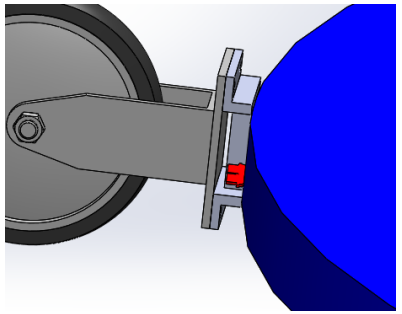
Conceptual design of the flange adapter

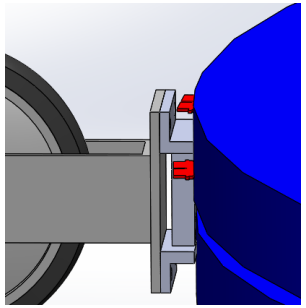


Plane: 3 couples of ears at 120° each other



Station: 2 plane rotated 180° each other. 6 couples of ears at 60° each other





3D views of the connections: wheel – plane (on the left); wheel – station (on the right). Ears in red.

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Layout – Outline of the study

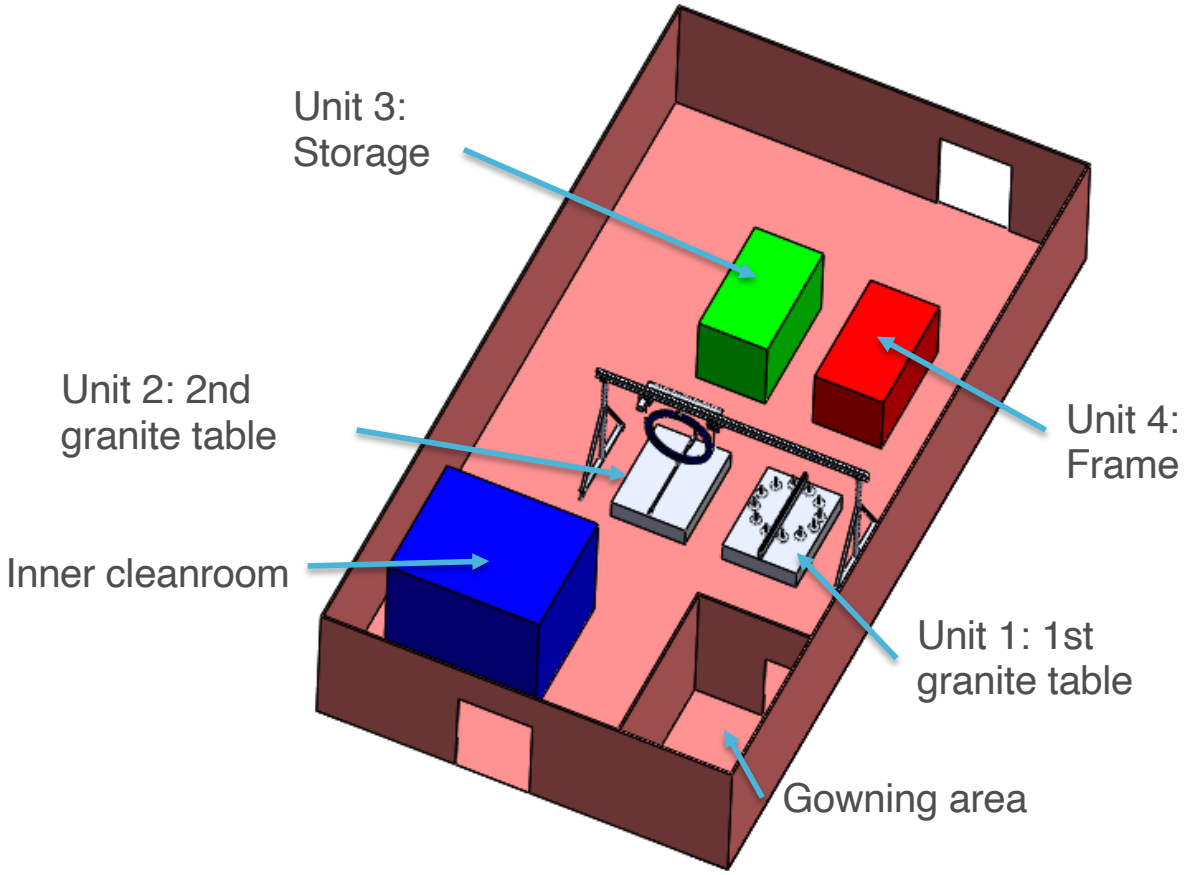
1. What are the cleanroom dimensions?
2. What is there currently inside?
3. What are its dimensions and location?
4. What will be there inside at the start of the assembly procedure?
5. How to place them efficiently?

1. Measurements of the cleanroom and the necessary equipment
2. 3D model of the layout
3. Study of an efficient layout

What there is inside:

- 2 granite tables (needed)
- An inner cleanroom that will not be removed but only relocated (not needed)
- Some unnecessary equipment that will have to be removed

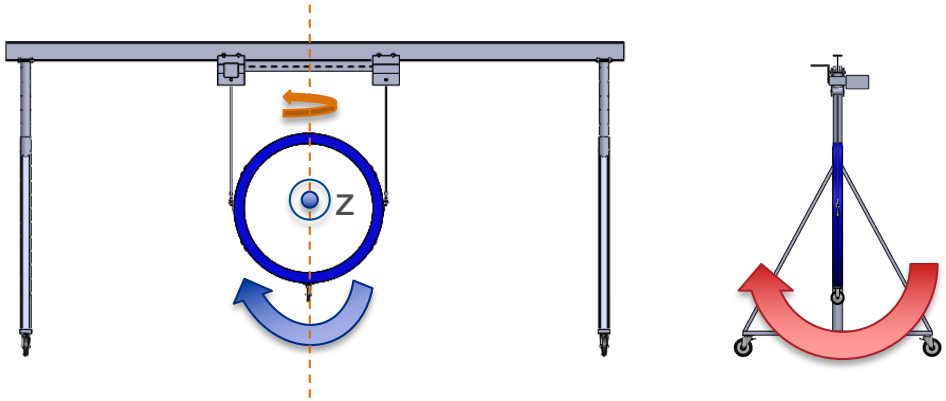
Layout – Proposed layout



Considerations:

- Use **mainly hoists and trolley movements** (motorized, more precise) instead of gantry crane movement (moved manually)
- **Guarantee enough space** to:
  - Crane movements
  - Operators (almost 3 ft of clear space around tables, storage and frame)
- **Frame close to the exit door**
- **A 22 ft I-beam is required**

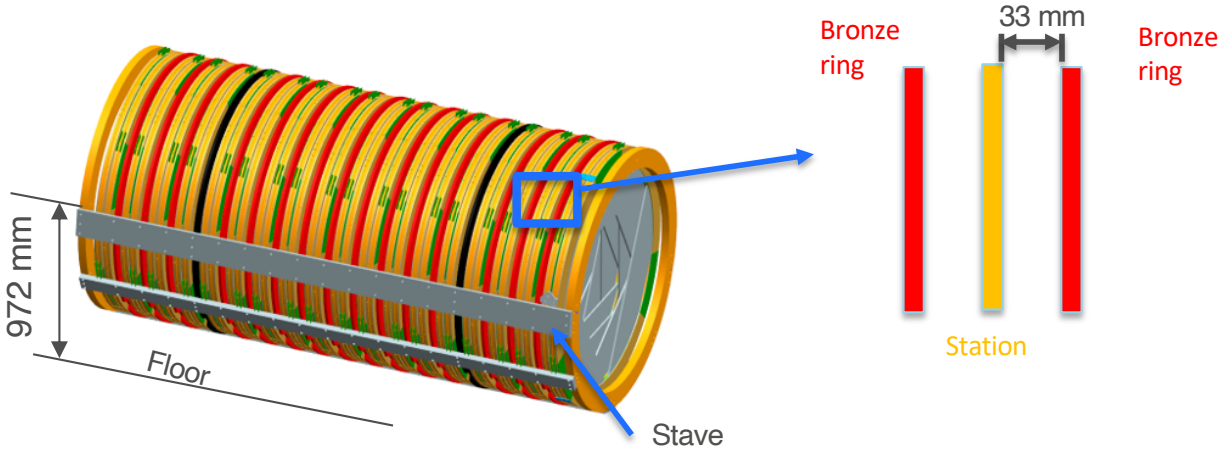
Oscillations – Problem



The problem of a lifting system that uses chains are oscillations: the use of two trolleys limits oscillations around vertical axis and z-axis but not around the I-beam axis

The strongest constraint on the design of a locking/damping system is due to the installation in the frame:

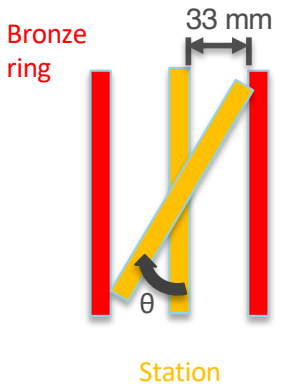
- Station is lifted up to 1 m from the floor (stave height) and lowered up to 6 inches
- Bronze ring – station gap = 33 mm



Main geometric constraints of the installation in the frame

Oscillations – Considerations

- Damping systems are risky:
  - ❑ The amplitude of oscillation during the station movements is **hard to estimate**
  - ❑ An amplitude more than 2° around the lifting brackets axis is enough to hit the bronze rings
- **Limited space** impedes to remove locking/damping system under the station during the installation
- Locking flanges on the top of the station has to be removed before the tracker will be installed in the detector solenoid and their **position is hard to reach**



$$\theta = arctan\left(\frac{33mm}{810mm}\right) = 2.3°$$

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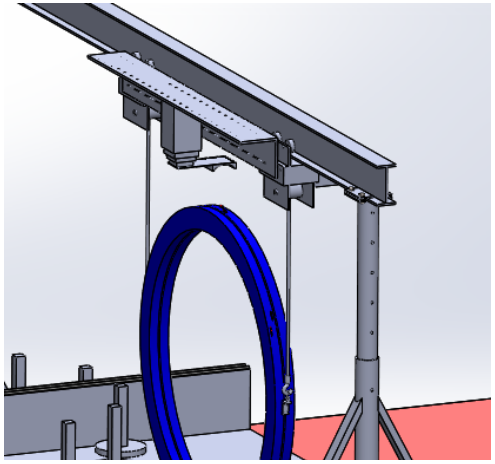
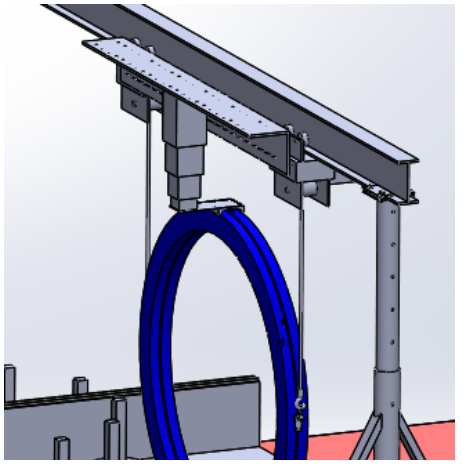
Oscillations – Proposed solution

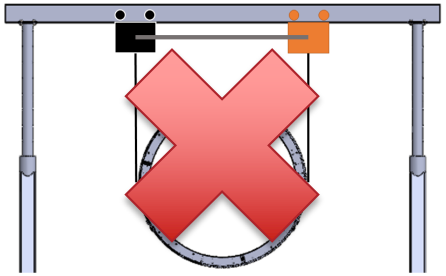
Preliminary idea: locking system easy to remove

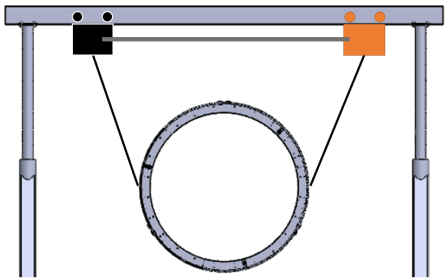
Telescoping columns with a locking groove at the end to lock rotations around vertical and I-beam axis





Larger distance between trolleys to reduce oscillation around z-axis

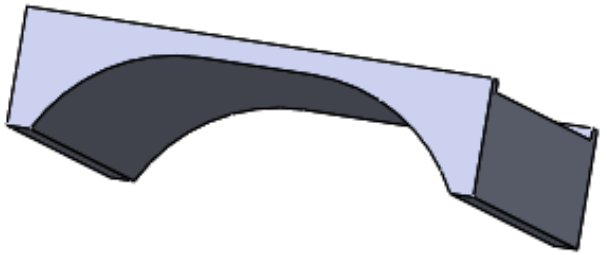




Oscillations – Locking groove

Considerations for the conceptual design:

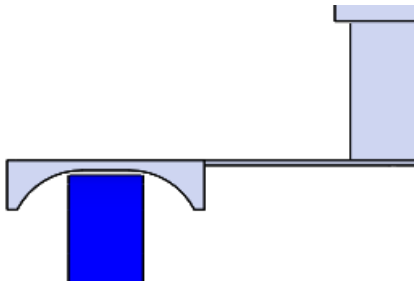
- Usable both for plane and station
- Take in account the presence of "ears"
- Centering should be facilitated



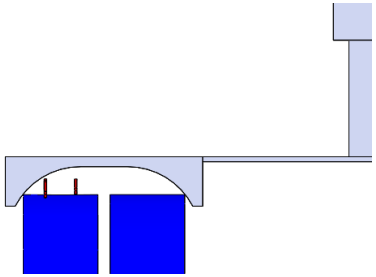
3D view of the locking groove

This is only a preliminary sizing of the locking groove.
Further development are needed:

- Optimize the profile of the groove to have the best locking
- Find a soft material for the inner surface of the groove that can absorb shocks but that wears little to avoid contaminating the cleanroom



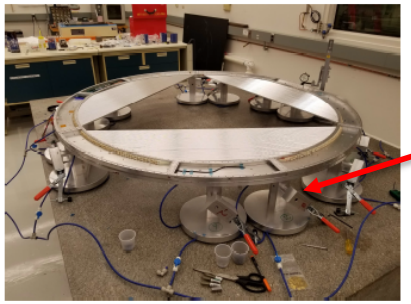
Locking system acting on plane



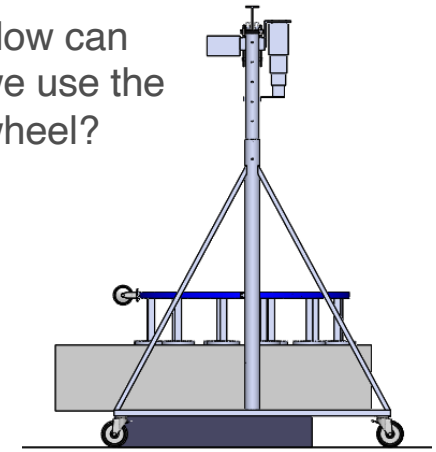
Locking system acting on station. Ears are visible

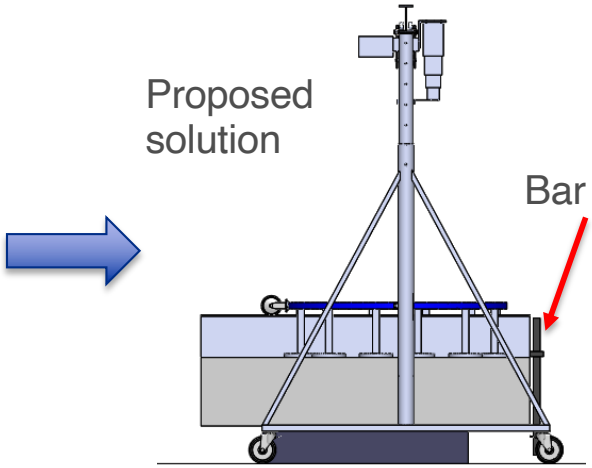
Assembly procedure – Step 1

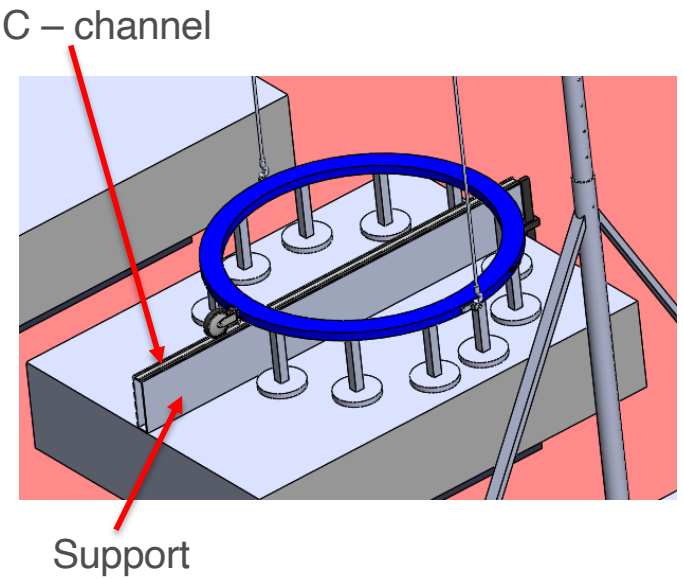
- Plane is assembled on 1st granite table and electronics is installed on the top side
- Stands are needed for the plane assembly but obstruct the use of the wheel and the possibility to install electronics on the other side



How can we use the wheel?







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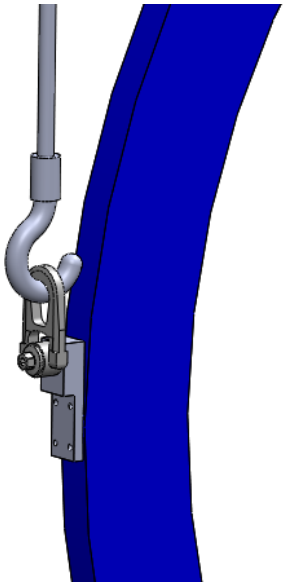
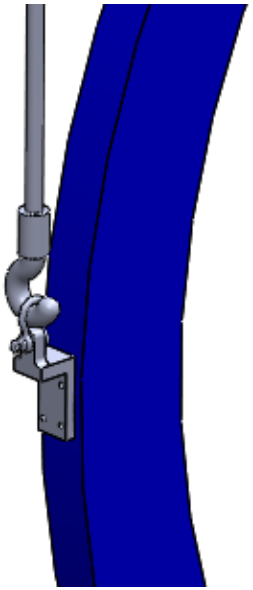
Assembly procedure – Plane lifting brackets

- Conceptual design based on the existing station lifting brackets design
- 180° of plane/station rotation must be allowed



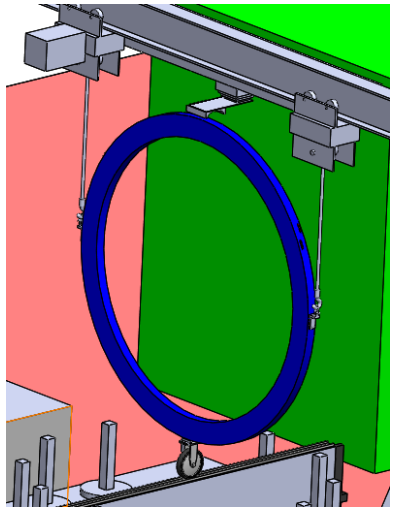
Hoist ring solution



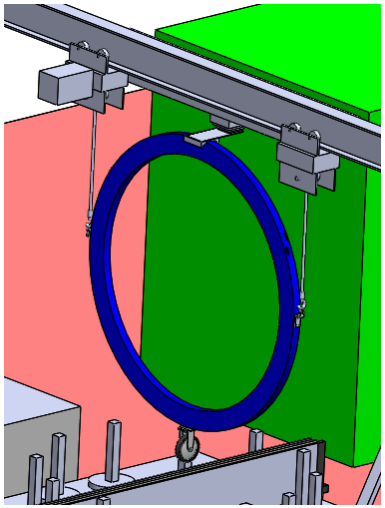
Shackle solution

Shackle solution should reduce more the risk of contact between plane and hook

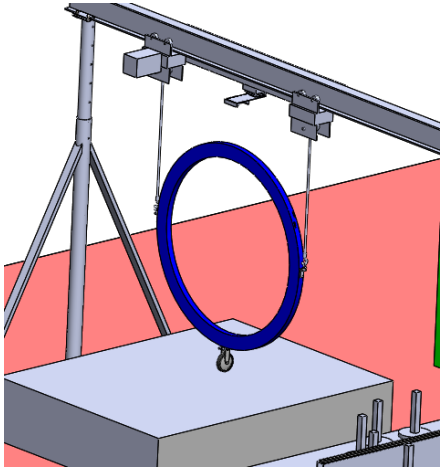
Assembly procedure – Step 2



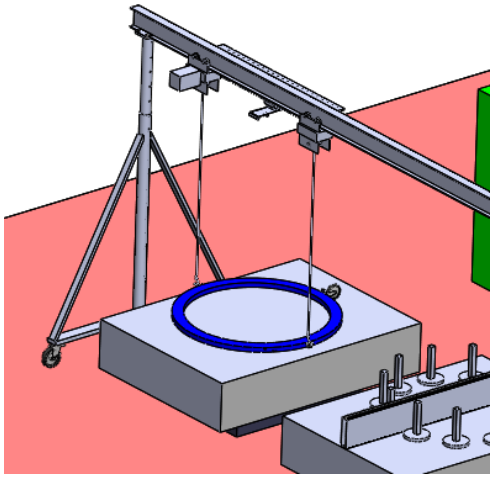
1) Plane is placed vertical.



2) The locking mechanism acts and then the plane is lifted up.

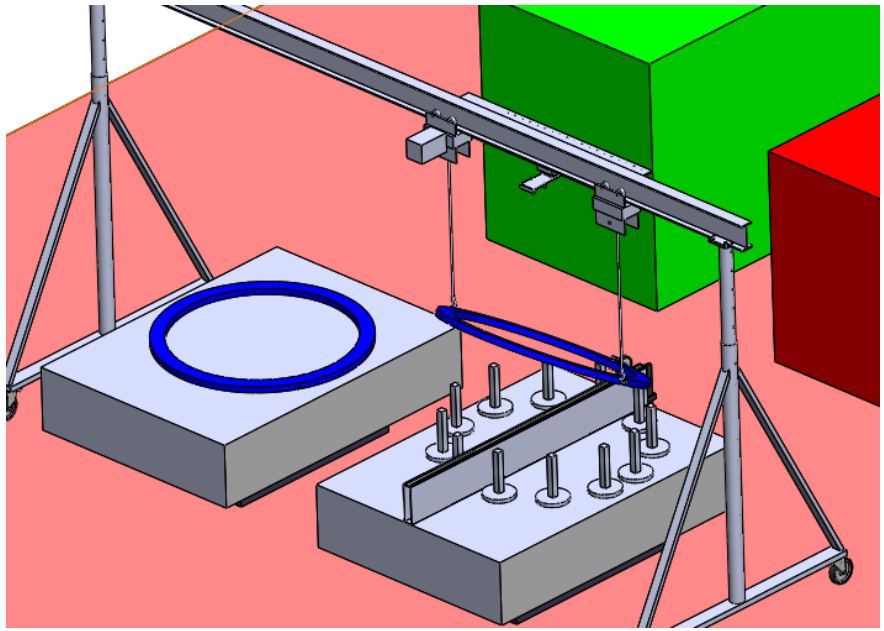


3) Motorized trolley moves the plane to the other table. The plane is lowered and the locking mechanism is disengaged.



4) The plane is placed horizontal and the electronics is installed on the other side.

Assembly procedure – Step 3.1



The 2nd plane is ready on the 1st granite table and is moved.

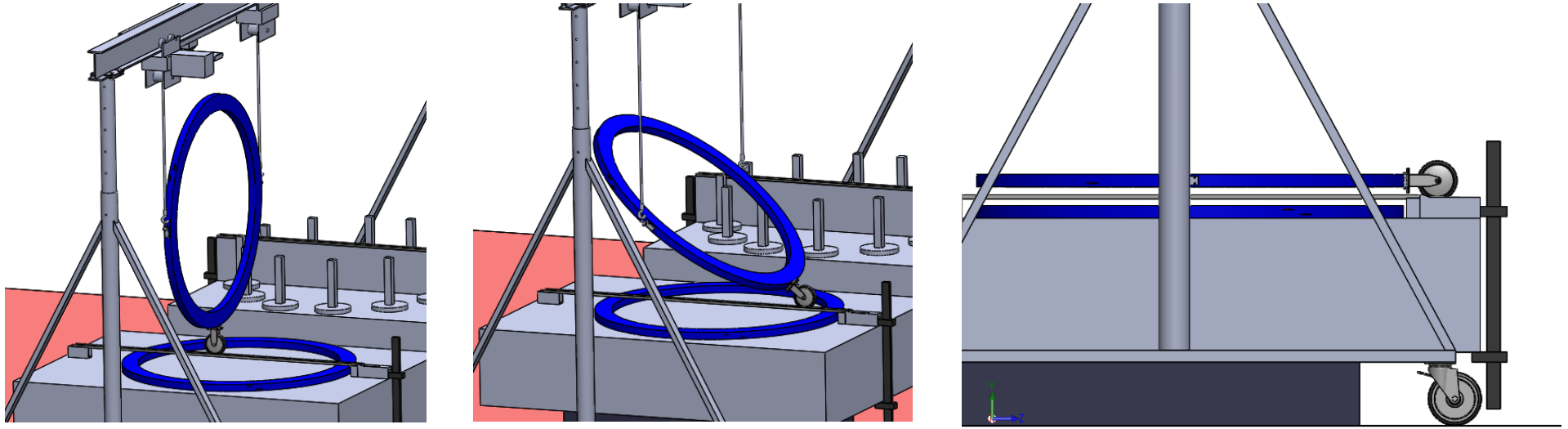
Problems:

- Where and how to place the 2nd plane horizontal to **install electronics** on the other side?
- How to **assemble** the two planes in a **station**?

The use of another table would take space in the cleanroom and require other crane movements.

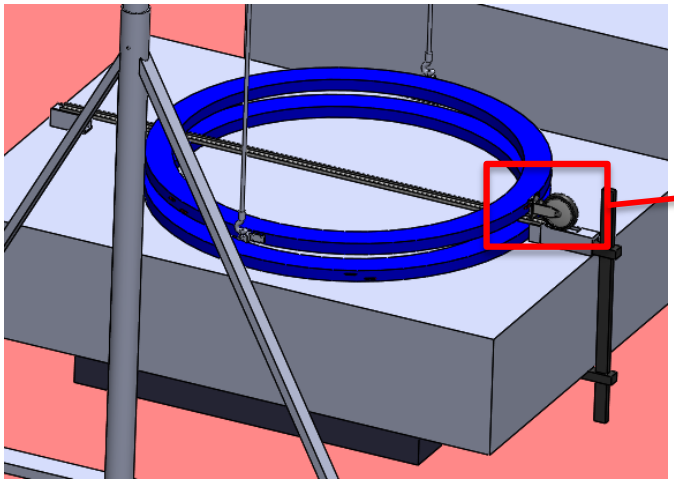
Assembly procedure – Step 3.2

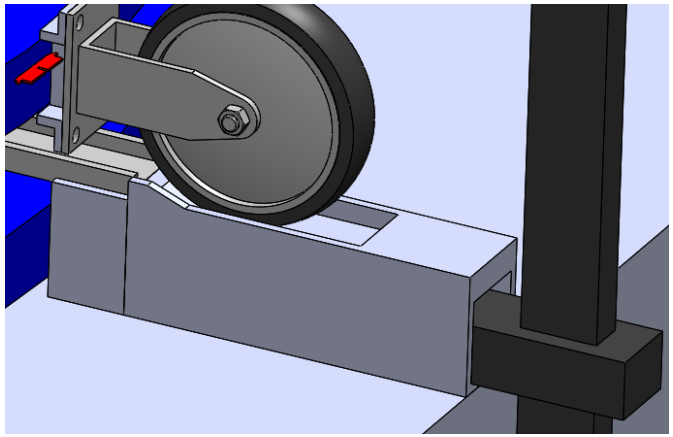
Preliminary idea: use a C-channel above the 1st plane to lower the wheel of the 2nd plane in the middle and then use only the hoist motor (more precision than to move crane) to place the 2nd plane horizontal.



From left to right: horizontal positioning of the 2nd plane.

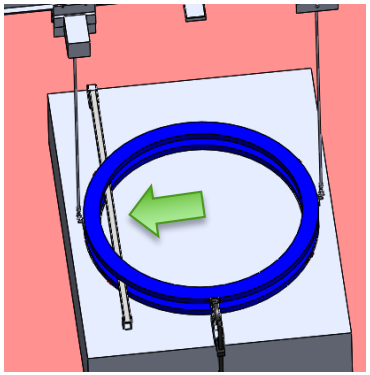
Assembly procedure – Step 3.3





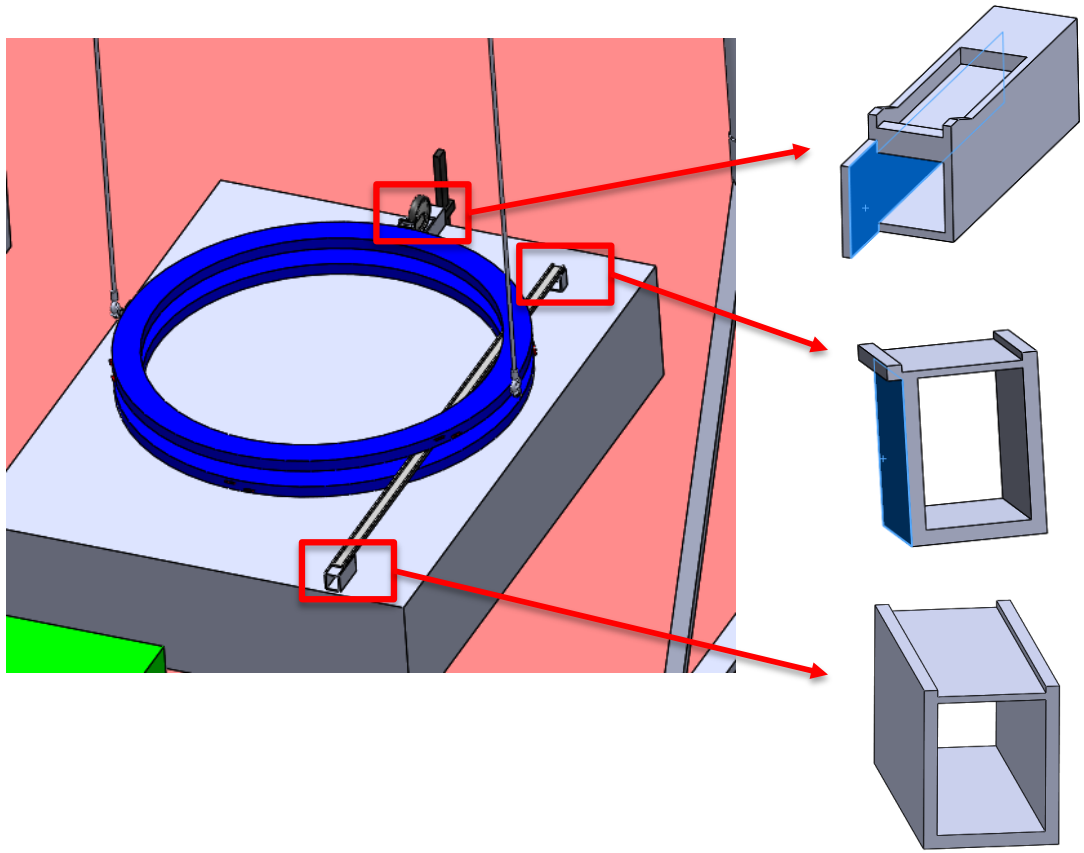
Detail of safe stops for the wheel

How to remove the c-channel in a safe way?



The C-channel slide sideways

Assembly procedure – Step 3.4



Conceptual design of supports

From top to bottom:

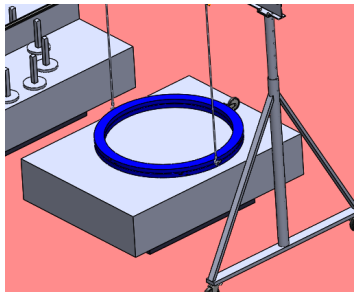
1. Fixed support: locked by a bar clamp
2. Removable support 1: connected to the fixed support through the particular shape
3. Removable support 2: the good positioning is guaranteed by the c-channel groove

Further developments:

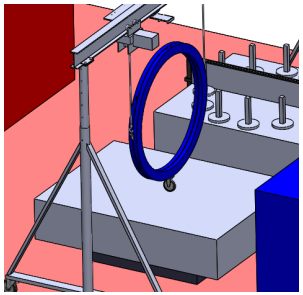
- Find a solution to have low friction between supports and granite table
- How to pull/push the supports?

Assembly procedure – Step 4

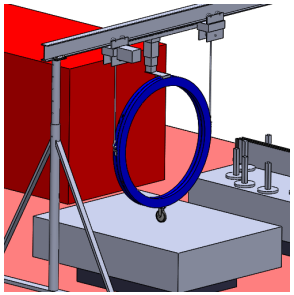
In this step the station is:



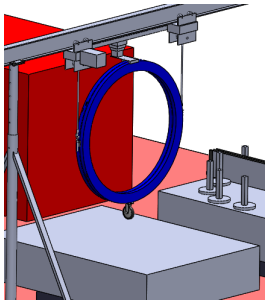
1) Assembled



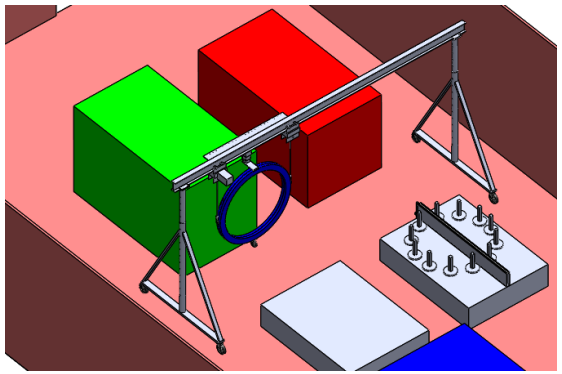
2) Rotated vertical



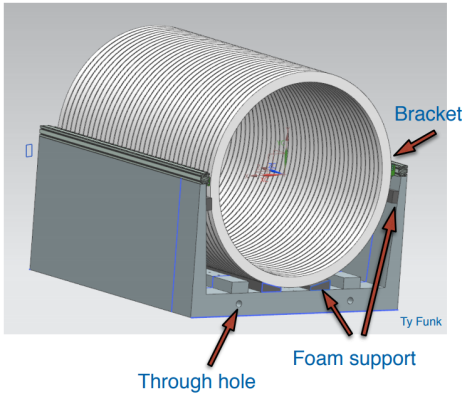
3) Locked



4) Lifted up



5) Moved to the storage



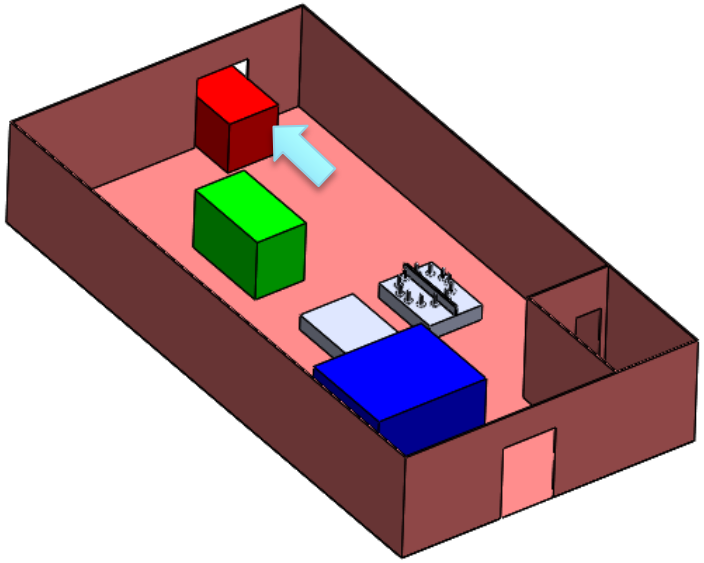
Conceptual design of the storage. From *T-Tracker assembly*, G. Gallo et al., 09/11/2018

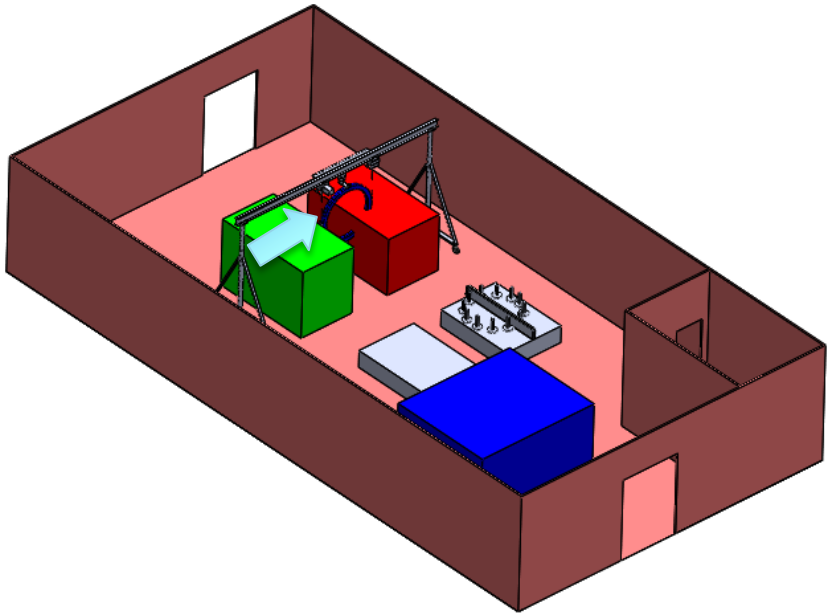
- The storage design is currently work in progress
- When the station is stored, an operator removes the wheel and installs the third point for the frame installation

Fermilab

Assembly procedure – Step 5 & 6

Step 5: Station is moved from the storage to the frame.





Step 6: When the frame is completed, it is put on wheels and brought out of the cleanroom.

Conclusion and next steps

The purpose of my work is to give a clear idea of the assembly procedure, find out and visualize the main problems and suggest some feasible solutions.

1. Detail the final steps of the procedure (more geometric data on storage and frame are needed)
2. Finalize the selection of standard components needed and update the 3D model to check all the geometric constraints
3. Finalize the design of custom made components
4. Assembly and testing

Thank you for your attention!