FinalTerm Review

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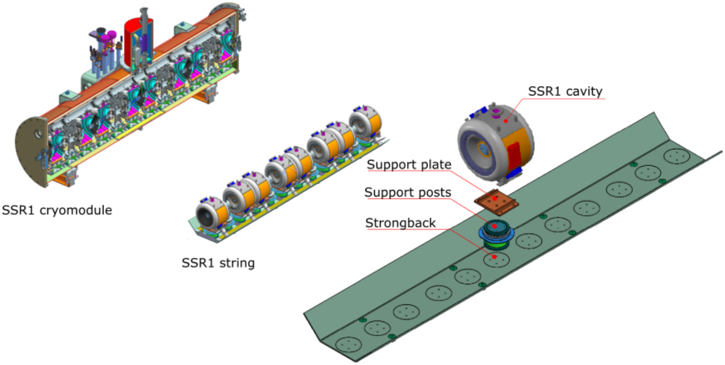
Outline

PIP-II project

SSR1 Cryomodule

This project consists in upgrading the existing linear accelerator (LINAC) at Fermiab to higher energies

- The SSR1 cryomodule is a section of PIP-II project



Assembling procedure SSR1 coldmass

Main steps

The SSR1 coldmass assembling procedure can be divided in four main steps:

String Assembly

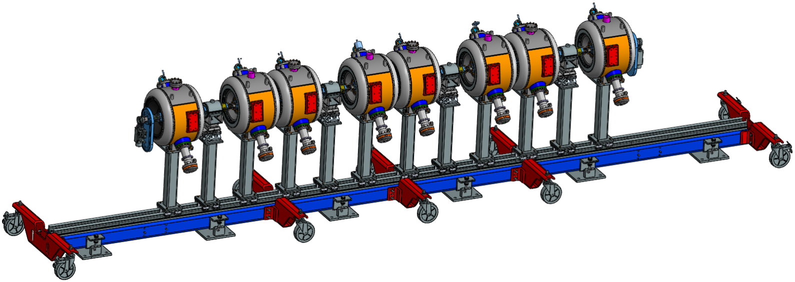
String Stiffening

String Lifting

String Alignment

Step 1

The SSR1 string is assembled in the cleanroom and supported by rail system

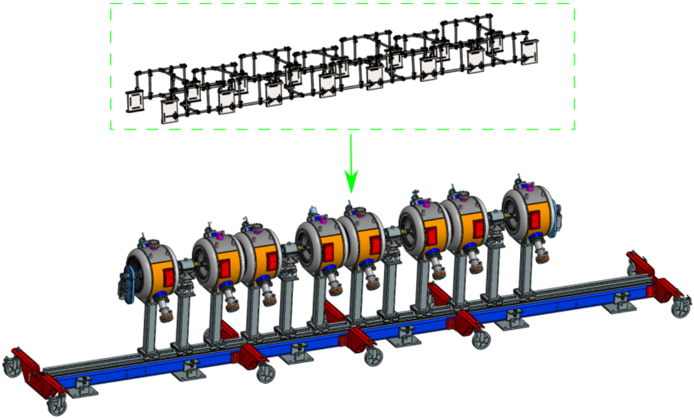


Assembling procedure SSR1 coldmass

String Stiffening

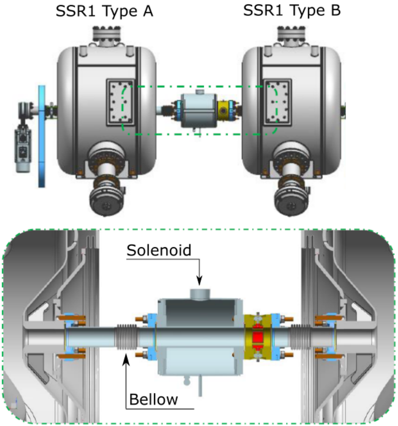
Step 2

Stiffening of the SSR1 string assembly with an external frame



Stiffening frame
Introduction

Since the cavity-cavity link is not rigid, before any handling operation it is necessary to stiff the string with an external structure.

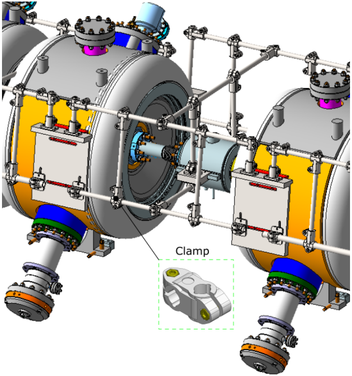


Expansion joints (Bellows) are inserted between cavity-magnet and BPM-cavity to compensate thermal shrinkage

It is necessary to protect the Bellows from undesired loads, especially form torsional loads

Stiffening frame
Concept

The conceptual design is a truss beam tube structure connected to each cavity and solenoid.



- Structure modularity

  It is easy to increase the number of the elements or modify their relative position

- Adjustable system

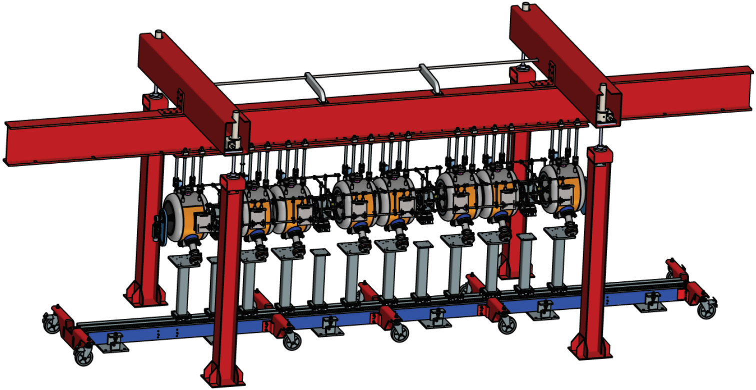
  Using slotted holes and connecting tubes by clamp, it is possibile to compensate manufacturing/assembly misalignments

Assembling procedure SSR1 coldmass

String Lifting

Step 3

The string is lifted from the rail system to be mounted on the coldmass support (strongback)



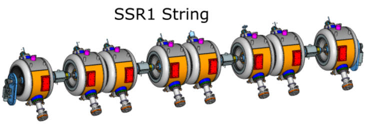
Lifting tooling

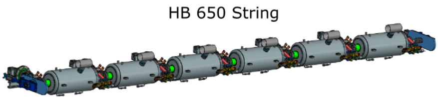
Concept

- Four points lifting structure
- Standard beam shape
- Mechanical lifting system
- Bolted connection to facilitate the assembly and transportation

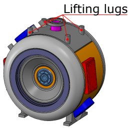
Lifting tooling
Requirements

- SSR1 and HB 650 strings assemblies (PIP-II projects) need to be lifted

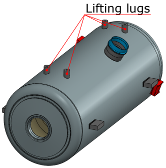




- String lifted by the lifting lugs
- Maximum deflection allowed: $1mm$
- Loads
  - SSR1 String weight: $1250kg$
  - HB 650 String weight: $1500kg$

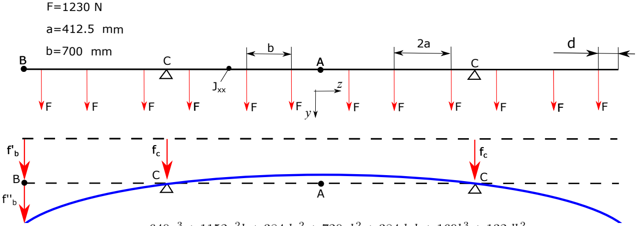


SSR1 cavity

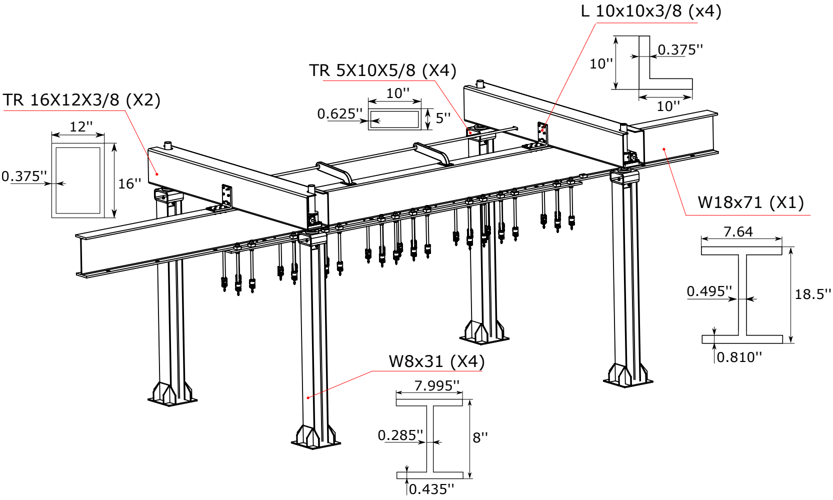


HB 650 cavity

- Design for stiffness
- The Lifting beam is the critical component
  - An eccessive lifting beam deflection could cause undesidered effects
- The maximum displacement of the lifting beam can be estimated by using a classical beam theory
  - In this phase HB 650 string assembly load configuration was used (worst case)



$$f''_b = F\frac{640a^3 + 1152a^2b + 384da^2 + 720ab^2 + 384dab + 169b^3 + 132db^2}{48EJ_{xx}}$$

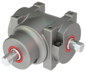


L 10x10x3/8 (x4)
0.375''
10''
10''
TR 5X10X5/8 (X4)
10''
0.625''
5''
TR 16X12X3/8 (X2)
12''
0.375''
16''
W18x71 (X1)
7.64
0.495''
18.5''
0.810''
W8x31 (X4)
7.995''
0.285''
8''
0.435''

The Lifting system is composed by four worm screw jacks placed on each column and a mechanical transmission to syncronise the motion

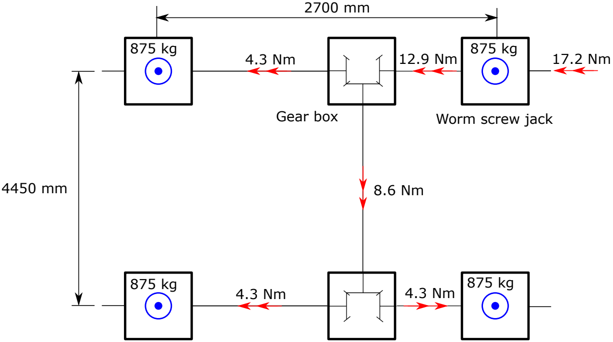
Capacity [kN]	Gear ratio	Torque to raise 1 kN [Nm]	Maximum input torque [Nm]
100	1:24	0.5	21.5

NOOK INDUSTRIES
Product code:
Actionjac EM10

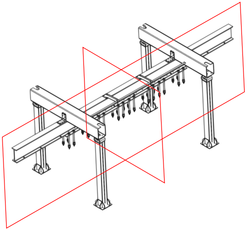


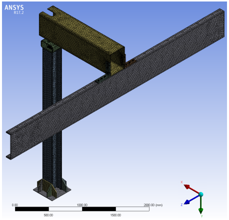
Gear ratio	Maximum input torque [Nm]
1:1	32

NOOK INDUSTRIES
Product code:
GB120



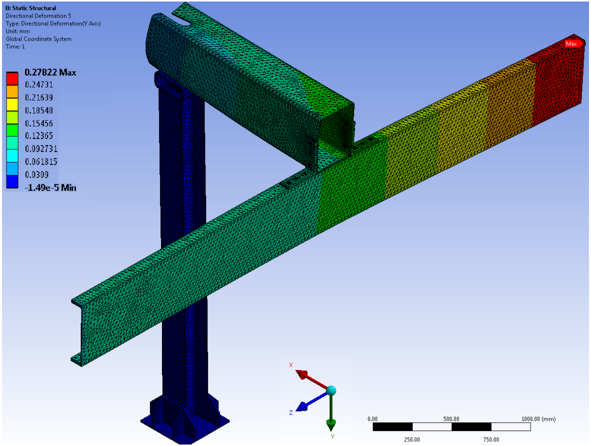
The structure has been numerically simulated by FEM software:Ansys Workbench®





- A quarter structure modeled
  - Taking advantage of double symmetry
- Bonded contact
- HB 650 string load configuration

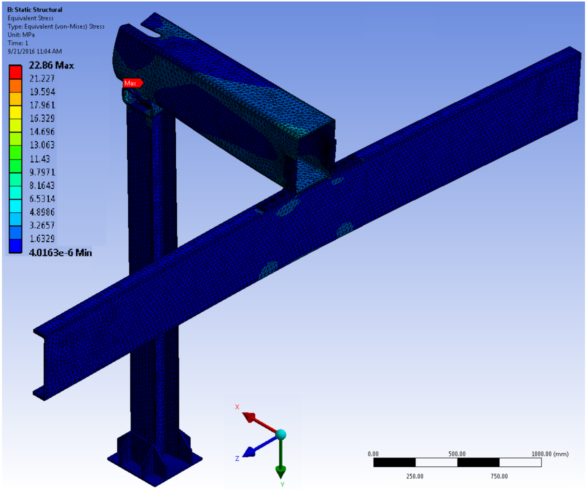
Displacement along y axis



Maximum displacement

0.28<1 mm

Von Mises Stress



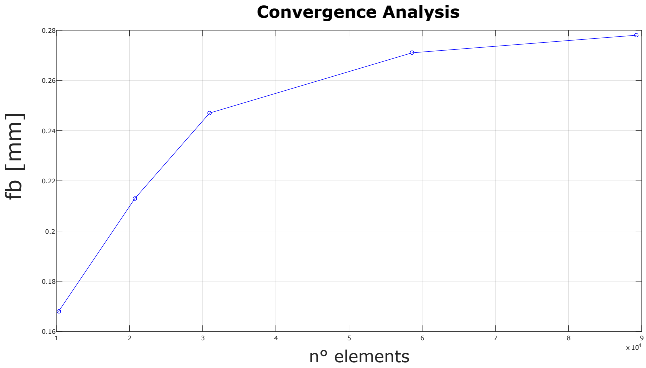
Maximum Stress

23 MPa

Lifting tooling

Numerical simulation: Convergence

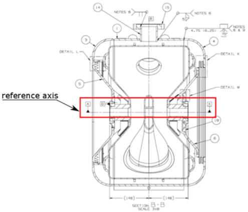
	n° elements	cpu time [s]	f_b [mm]
1	20750	9.4	0.195
2	30951	16	0.247
3	40492	20	0.267
4	89247	38	0.278

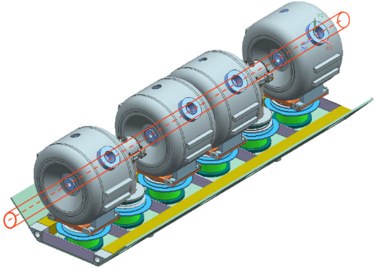


Step 4

It is necessary to have the axis of the cavity geometrically aligned with beam axis within a tight range of tolerance

- In the case of SSR1 cavity the maximum error allowed is 1 mm
- The SSR1 cavities will be aligned according to the geometric axis (Axis A) with the help of the laser tracking technology



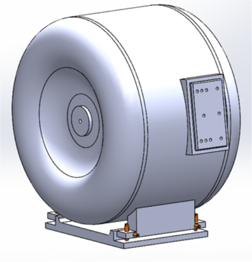


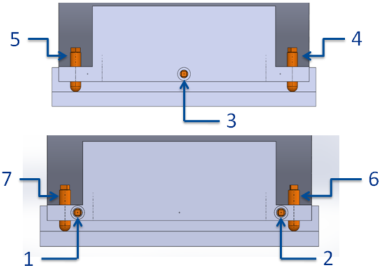
Alignment System

Description

The alignment is achieved through a total of seven screws

- The screws are designed to reduce the friction
- The tip of each screw is in contact with a reference surface
- It is possible to control each degree of freedom of the cavity by adjusting the screws





Mathematical model

Introduction

- The cavity can be considered as a rigid body
- The axis of instantaneous rotation is defined each time by the contact points of the screws which are not moving
- An idealized joint is chosen in order to develop a mathematical model even if the Screw-Surface interaction is not predictable

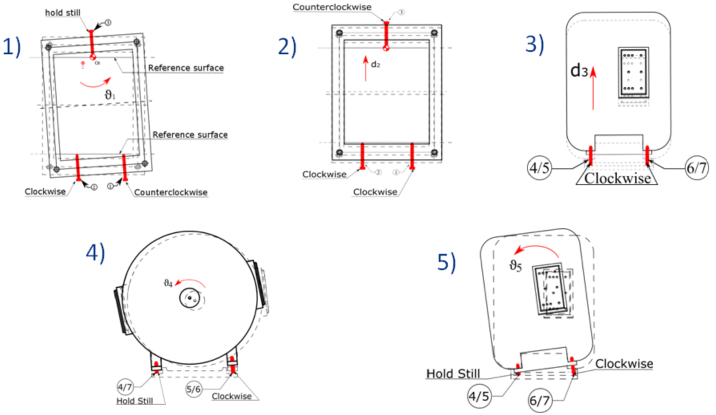
↓

The alignment process can be modeled as a multi-link serial robot

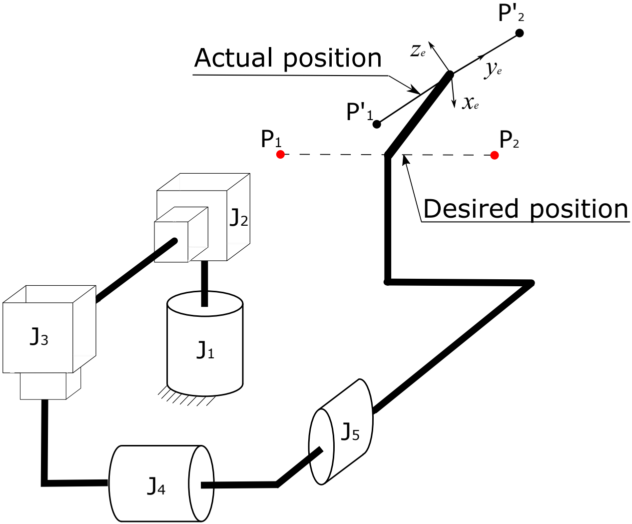
↓

In a serial robot the End-Effector configuration does not depend on the joint variable variation sequence, whereas in the rigid body case it does

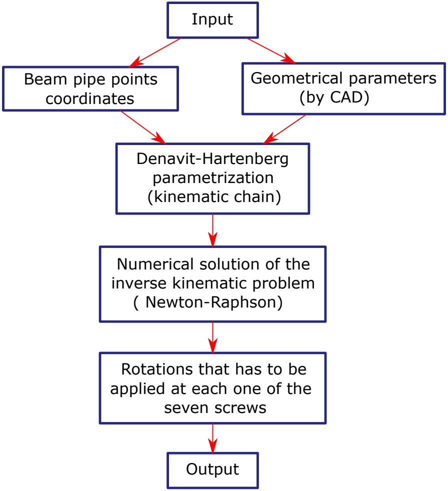
- The kinematic chain consists in three revolute joints and two prismatic joints
- The cavity has been assumed as the End-Effector



Complete kinematic chain



The model has been implemented in Mathcad



Test assembly SSR1 cavity

Necessary components

Strongback

Support posts

SSR1 cavity

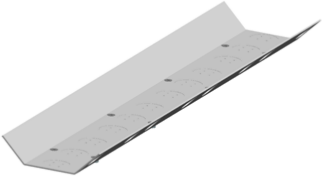
Support plate

Alignment screws

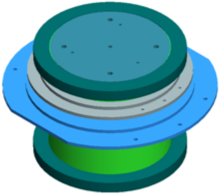
Test assembly SSR1 cavity

Necessary components

CAD models

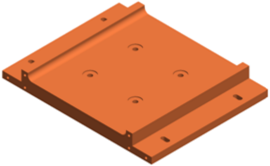


Strong-back

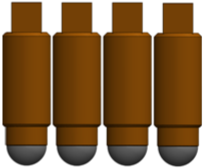


Support posts

SSR1 cavity



Support plate

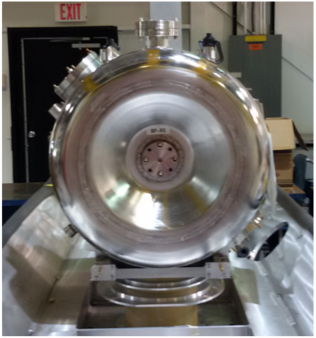


Alignment screws

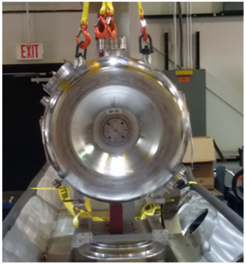
Test assembly SSR1 cavity

Assembling

Strong back lifting



Assemby completed

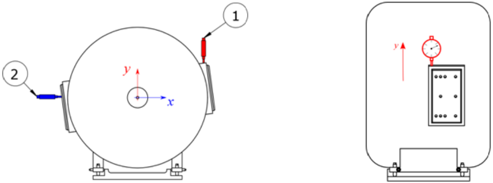


Transportation of the cavity
(Overhead crane)

- Measurements were achieved using an analog gauge
- It was possible to measure only the displacement in a specific direction
- It is necessary to find a method to compare the measurements with the numerical code output

Test measurements
Setup

- A direct measurement of the beam pipes position is not possible
- The gauges were placed on two plane surfaces of the cavity (Tuner plates) which are related to the axis of the cavity (CMM)
- The displacement of two points of the cavity in two orthogonal direction was measured
- The initial position of the gauges with respect to the cavity was obtained by caliper measurements



Test measurements

Setup

Test measurements

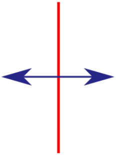
Results

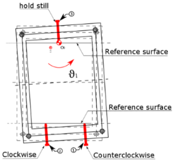
Test 1

- 360° counterclockwise rotation screw 1
- 360° clockwise rotation screw 2
- Screw 3 fixed

Measurements

	Δ_2 [mm]	Average value [mm]
1	0.781	0.784
2	0.785	
3	0.778	
4	0.789	
5	0.786	





Mathcad code output

$AS1 = 366$ deg

$AS2 = -367$ deg

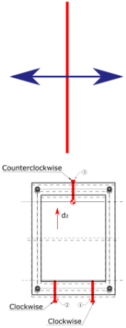
$AS3 := \frac{-d2 \cdot mm \cdot 360 \cdot deg}{P2} = 0$ deg

Test 2

- 360° clockwise rotation screw 1
- 360° clockwise rotation screw 2
- 360° counterclockwise rotation screw 3

Measurements

	Δ_1 [mm]	Average value [mm]
1	1.046	
2	1.042	
3	1.055	1.048
4	1.044	
5	1.052	



Mathcad code output

$AS1 = -361$ deg

$AS2 = -361$ deg

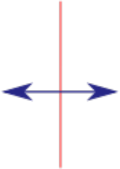
$AS3 := \frac{-d2 \cdot mm \cdot 360}{P2} = 361$ deg

Test 3

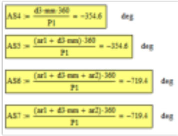
- 360° clockwise rotation screw 4
- 360° clockwise rotation screw 5
- 720° clockwise rotation screw 6
- 720° clockwise rotation screw 7

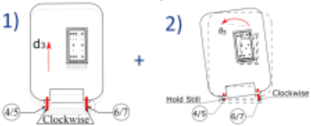
Measurements

	Δ_1 [mm]	Average value [mm]
1	1.975	1.981
2	1.983	
3	1.979	
4	1.985	
5	1.982	



Mathcad code output





Conclusions

- It is possible to align the cavity with the screws system
- Process repeatability has been verified (five measurements for each case)
- Mathematical model has been successfully validated
- It would be necessary the use of laser tracking technology in order to have a precise alignment and remain within the tolerance constrain requirement

Conclusions

- This process must be performed in order to use the numerical code