Indian Plan for Contribution in

Superconducting Cavity & Cryomodule Technology

Prashant Khare

Avinash Puntambekar

RRCAT,India.

THANKS

At the outset

For the great learning opportunity.

GDE Effort in cavity & Cryomodule

Cryomodule package

Value Engineering

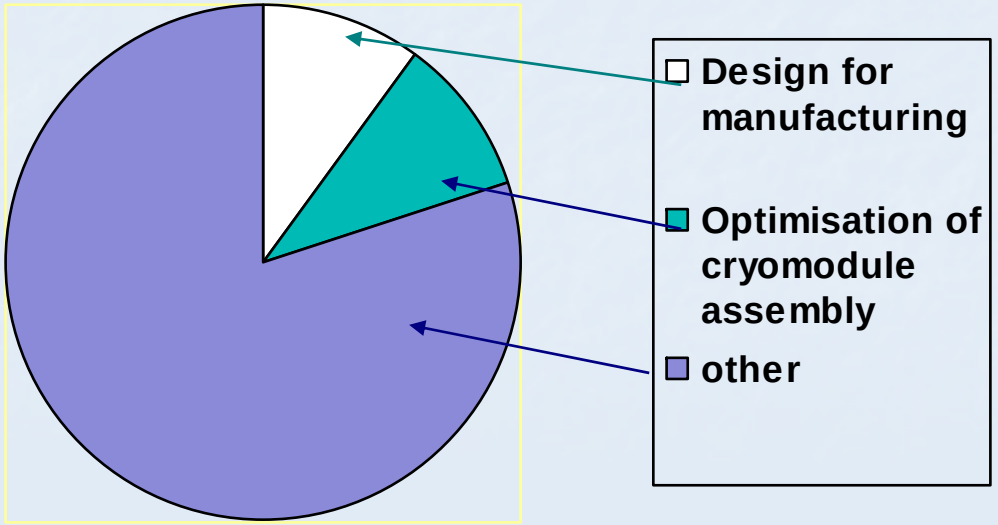
Cryogenic system package

Value Engineering

Cavity package

Value Engineering

Value engineering



Our plan for Indian contributions

Identify specific areas in the field of cavity and cryomodules.

Build a team with some persons at FNAL and backed up by a work force at Indian centres.

Present Focus: **Value Engineering**

A Design for manufacturing.

Major Points :Subsystems which need redesigning without compromising functionality.

Target - T5CM.

B. Optimization of Cryomodule Assembly : Observe and Understand Assembly of CM1 cryomodule.

Save assembly time and effort.

Analyze, simulate & predict performance of alternatives.

Mostly intermediate level of complexity.

Target - T5CM & if possible T4CM.

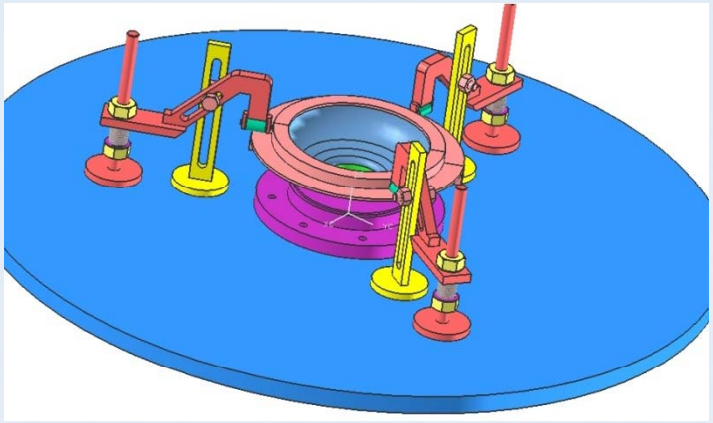
C. Attend to short term assignments entrusted to us from time to time.

Broader Picture: Embark on technology assimilation for cavity & cryomodule so that we can significantly contribute to

a. ILC collaboration.

b. Rapidly ramp up Indian SCRF technology development program.

Region of our interest (This visit)



1. Helium Vessel
2. End Group
3. Tuner (provide inputs to G. Mundra and Vikas Jain, RRCAT)
4. Modification of Electron Beam welding Fixtures

+

5. Assembly of Cryomodule

   (MLI blanket, 2K cryogen supply pipe)

6. Roller assembly for Cavities

+

7. Process Details of Electron beam welding of cavities

A. Major Points -1

- **Design of Helium Vessel of type G-4 –New Design in SS .**

Goals

Reduce cost, keeping in mind Boundary conditions set by GDE.
It should make assembly of helium vessel on cavity, more easy.

Approach

- **First phase-Titanium material (explore lower thickness keeping rigidity same).**
- **Second phase- Design with SS as material of construction.**

Status:

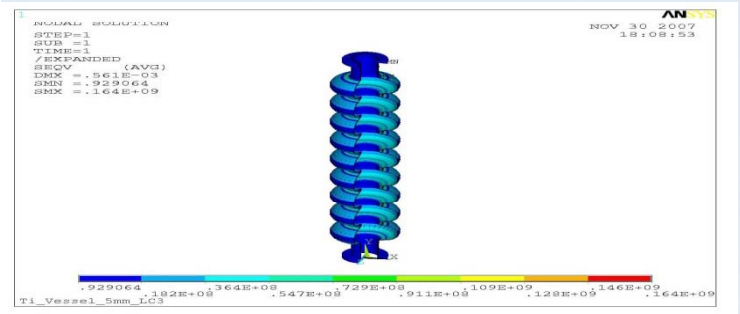
- **Design considerations fairly well understood.**
- **Preliminary Design started.**
- **First simulations (appear favorable) done by -Vikas Jain & G. Mundra -RRCAT**

Resources needed from FermiLab:

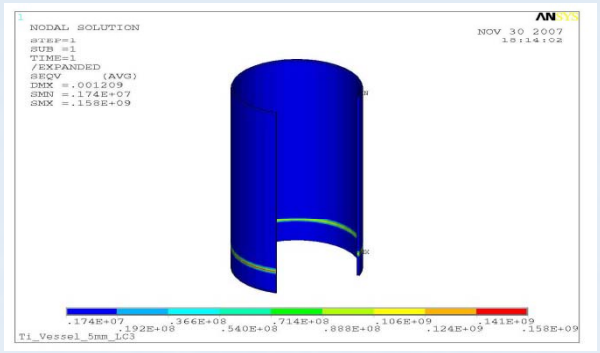
a. Review of this design by Harry Carter, Don Mitchell & L. Ristori.
b. Titanium sheet of required thickness (may be 4/5mm-supply by FNAL).

- **POSSIBLE DELIVERABLE : Optimized S.S./Titanium HELIUM VESSEL.**

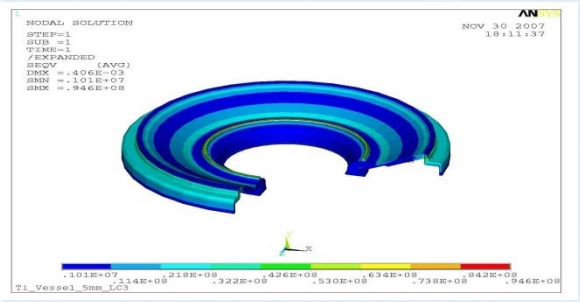
Component stress plots for LC3

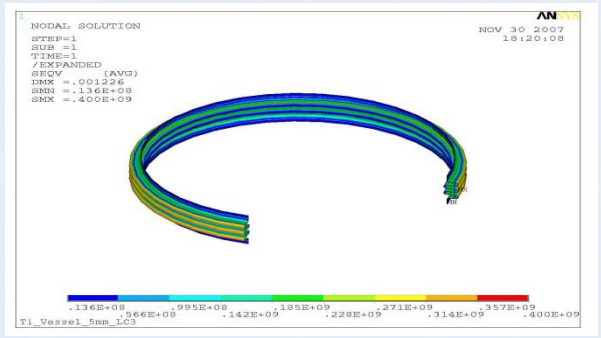


Cavity



Vessel



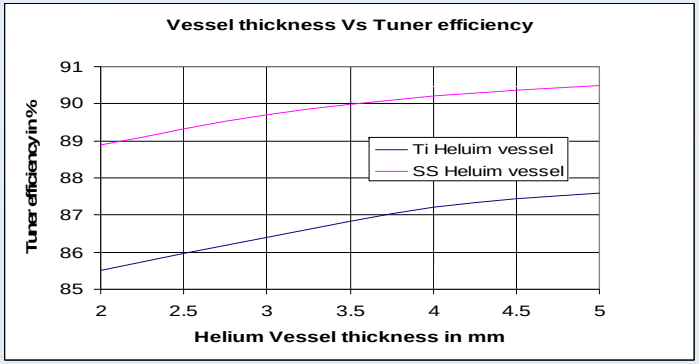


Conical flange

Bellow

By: Vikas Jain &
G. Mundra

Effect of Helium vessel thickness on Tuner Efficiency



A. Major Points -2

End Group- Design for Manufacturing

Goals

- Easy manufacturing, minmize EB welding and achieve overall Economy.
- Concurrently address the issue of reference alignment.
  (HOM coupler head or extended bracket.)

Approach

- Explore the machining of the entire end group from a single Nb block.
- Start with Copper/aluminum prototype.
- Work on the alternate ideas given by Harry Carter.
- Extensive prototyping and testing required.

Status

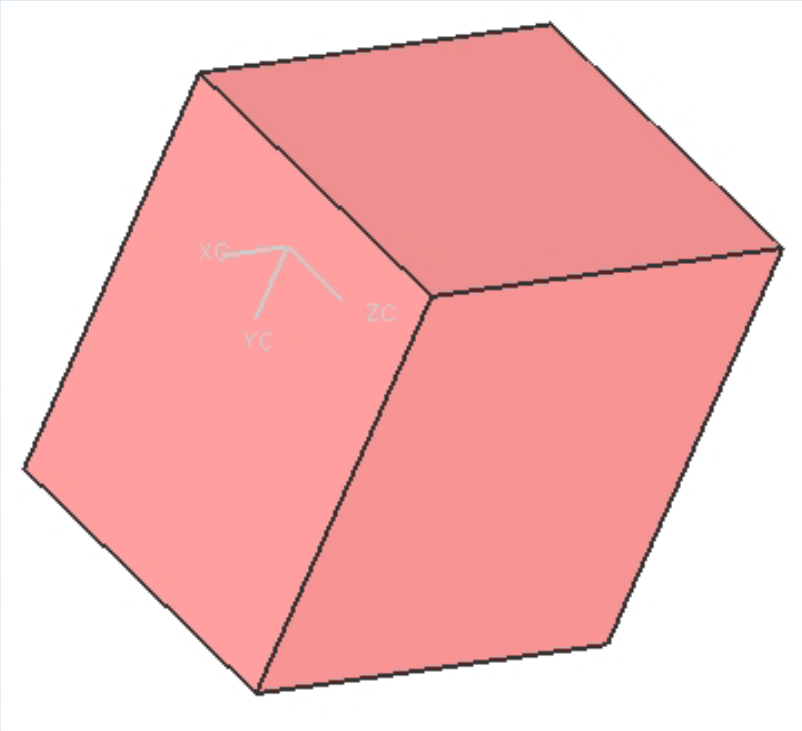
- Design considerations being understood.

Resources needed from FermiLab

a. Two bars of Nb Dia 120 mm and length 130mm
b. Nb, titanium, NbTi and some rejected parts (which may be with Mike Foley).
c. Review of our design and prototype
d. Inputs needed from Tug Arkan and Survey people.
e. Processing & testing support from FNAL.

POSSIBLE DELIVERABLE : Produce prototype for chemical processing and testing.

Planned sequence of operations



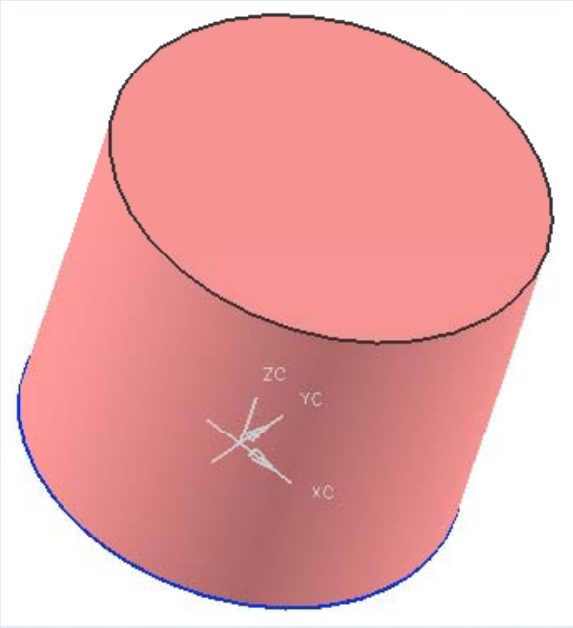
Size 120*120*130mm

Cost $ 3900
(@110/lb)

Rolled sheets are expensive

STEP 1

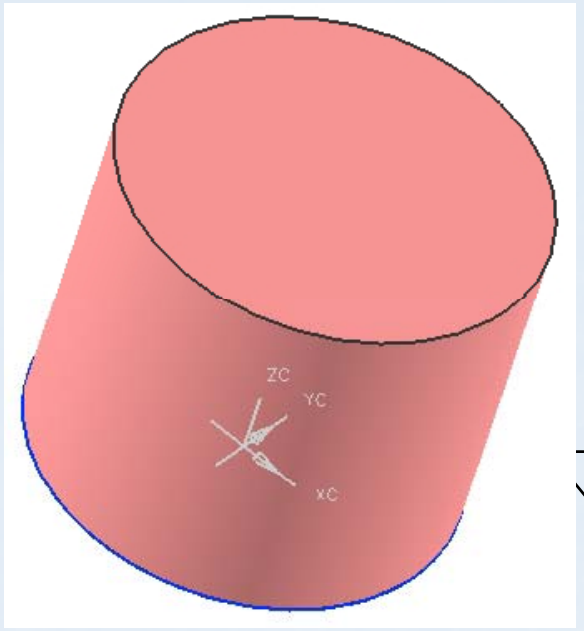
IF Required turning will be done



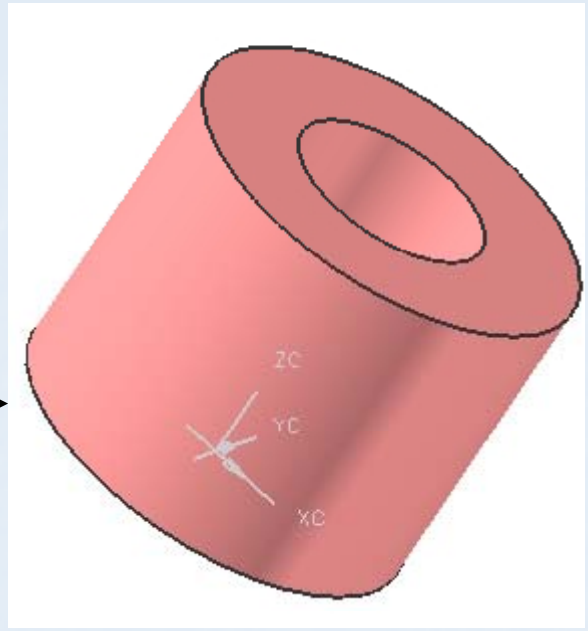
SIZE	Diameter 120 mm
	Length 130 mm
Allowance	6 mm on diameter
	10 mm on length
COST	$ 3100 (@$110/lb)

ESTIMATED COST OF MACHINING (in India) ~ $ 2 K !!!! TOTAL COST<10K

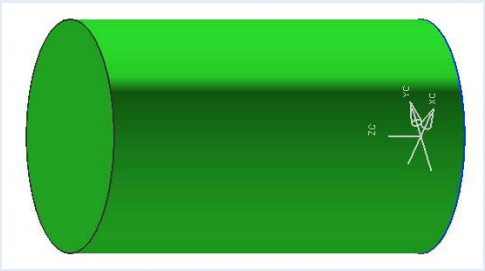
STEP 2



Wire cut operation



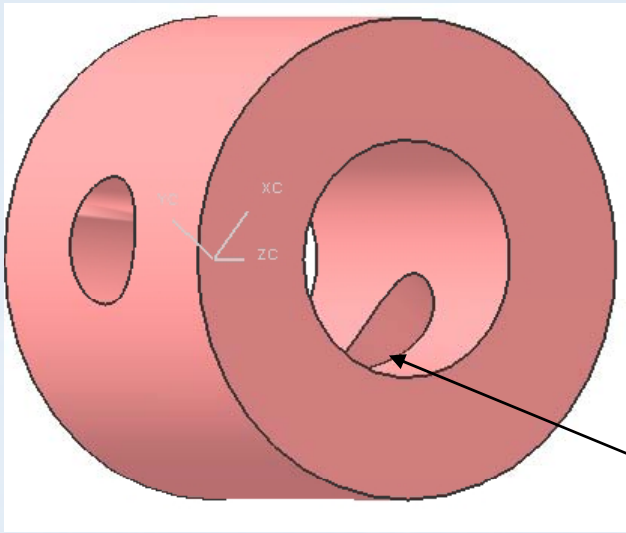
Scooped out bar



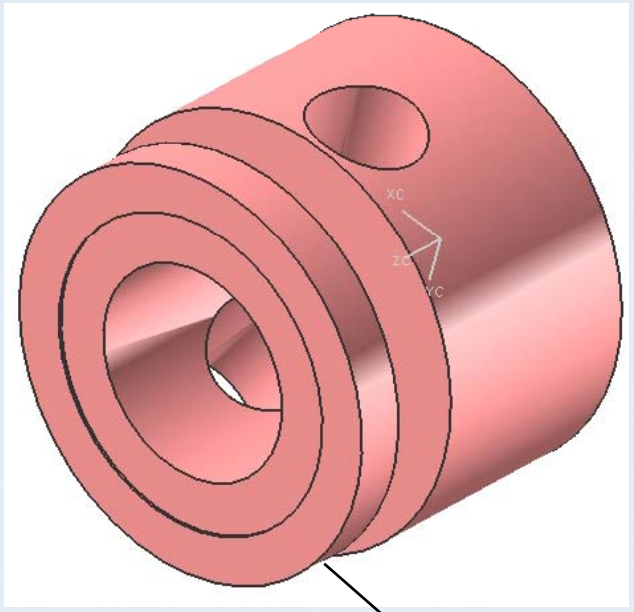
Size -- Dia 76 mm

Length 130 mm

STEP 3 RADIAL DRILLING



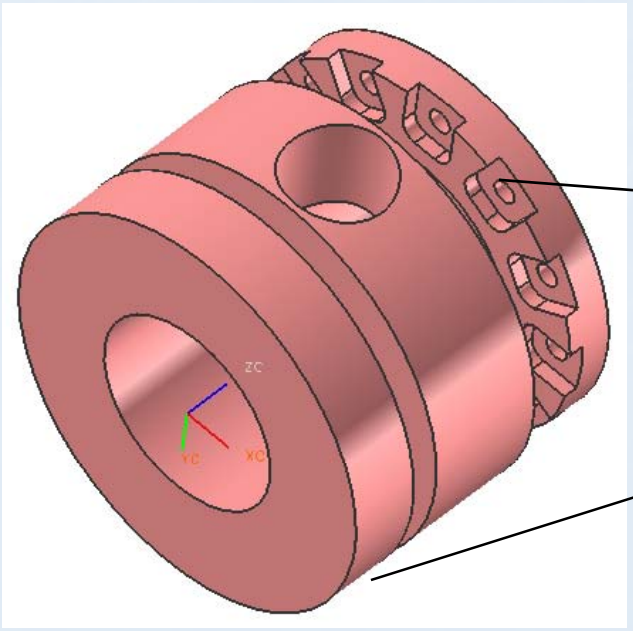
With smooth radius to avoid sharp edge using form tool.



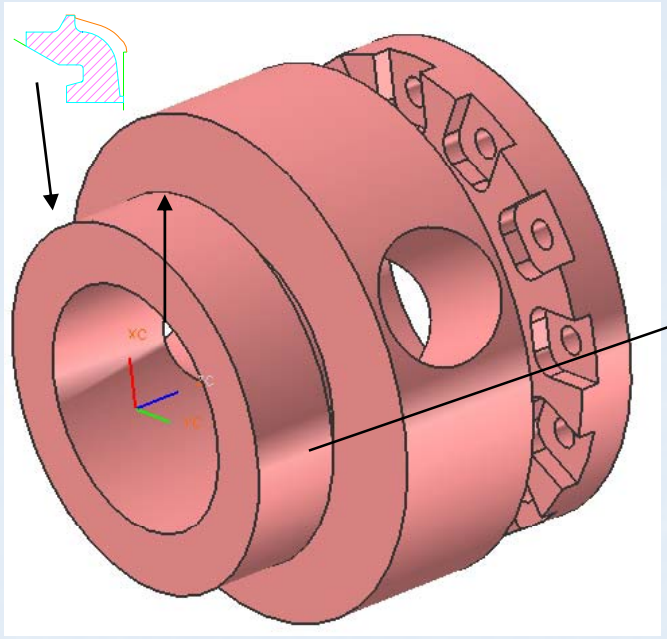
STEP 4 Turning outer flange

Dia. 114 mm

(DON'T NEED THESE SEATS)



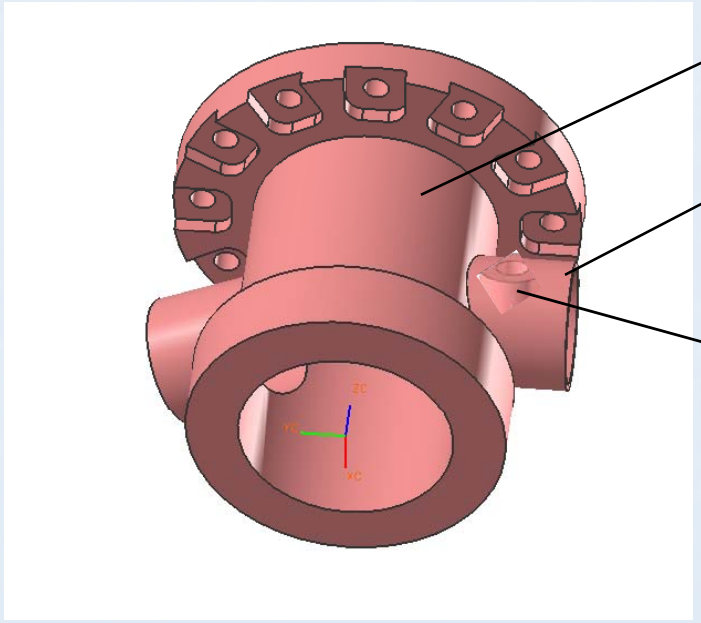
STEP 5 Turning Inner Flange



STEP 6

FINISHING INNER FLANGE TO PERFECT SHAPE (KEPT SIMPLE HERE)

STEP 7



MILLING OFF EXTRA MATERIAL

Final turning for beam pipe and ports.

Leaving the reinforcement of tuner port (not shown).

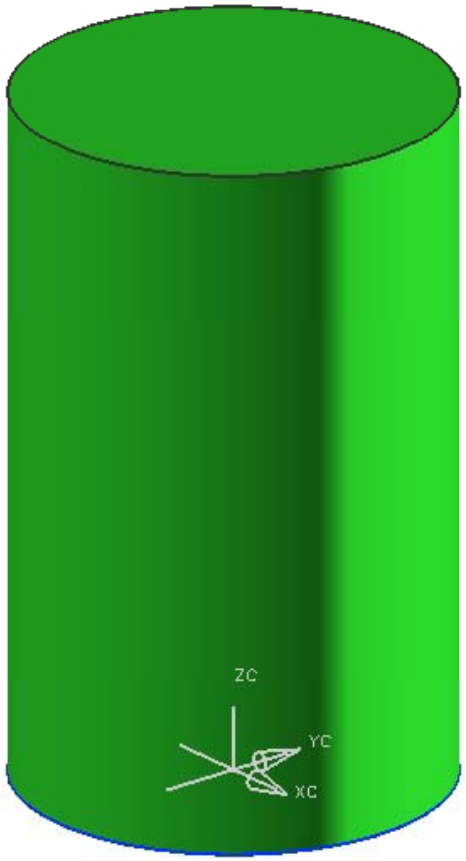
This part is present as an integral part on the HOM pipe.

Budgetary Quote

On basis of planned sequence of operation

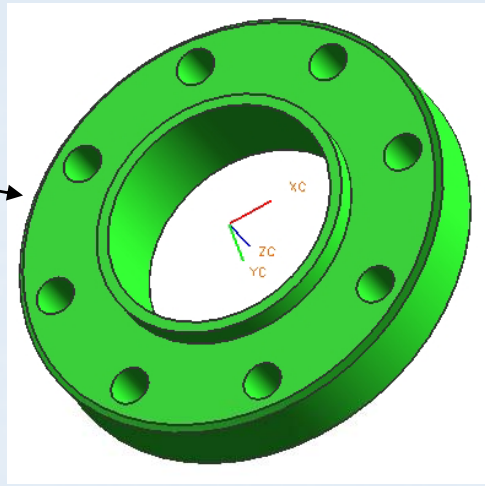
Machining Cost ~$ 2 K

STEP 8 Recovery of Flanges from the scooped out bar



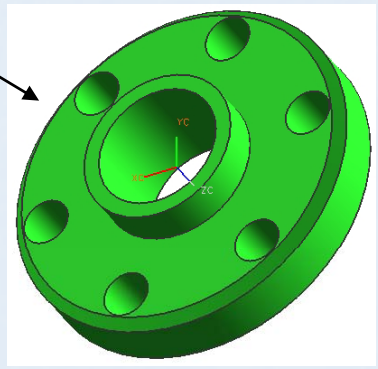
Size -- Dia 76 mm

Length 130mm



DIA 61MM

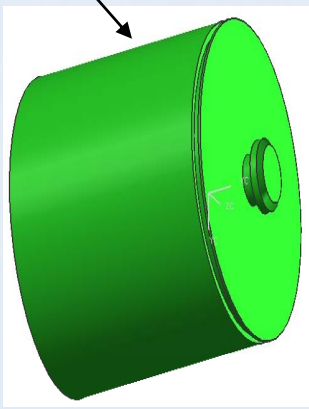
LENGTH 30



STEP 9

DIA 34MM

LENGTH 18MM



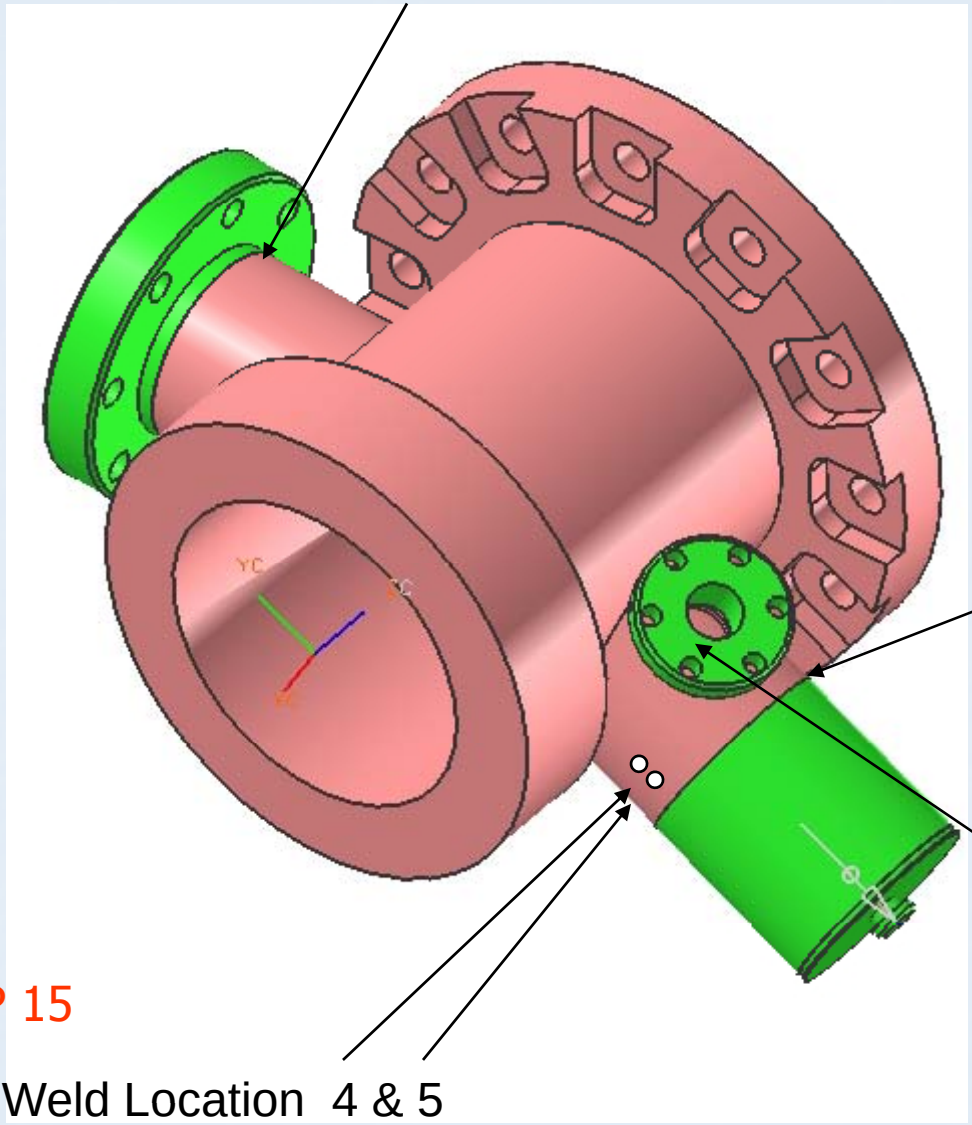
STEP 10

DIA 46MM

LENGTH 70MM

STEP 12

Tuner Port E.B. Weld Location-1



STEP 13

HOM port weld location -2

Step14

Welding of flange of pickup port -3

STEP 15

E.B. Weld Location 4 & 5

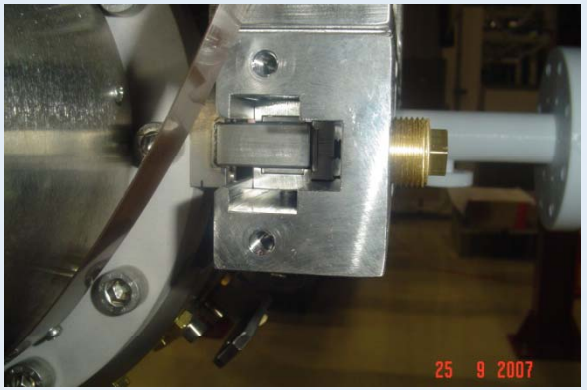
Two more EB welds for form tail

Issues to be examined

- Can we get Nb as a thick hollow cylinder.
- Alternatively ,is it available as a bar?
- Sealing with clamps is a must. If not then suitable seal has to be developed.
- Alternate option of using existing design of Nb-Ti flange is always available.
- Further cost reduction if scrap Nb can be recycled.

A. Major Points -3

- **HGR Pipe: Design for Manufacturing**
- **Design a different alignment block**



Goals

- **Loosening up the tolerances from the HGR pipe.**
  Required straightness 3mm in 12 m.
- **Attempt to remove the machining of the pads.**
- **Simplification of the Roller support of the cavities.**

Status

- **Design considerations being understood.**
- **Preliminary Design yet to start.**

Approach

- **Use the needle bearing block as a steering mechanism.**
- **The concept may be tested on one eighth cryomodule proposed at RRCAT.**

Resources needed from FermiLab

Review of this design by Harry Carter, Don Mitchel ,Tug Arkan & Mike McGee.

- **POSSIBLE DELIVERABLE : RRCAT to build one eighth cryomodule then we can prototype these ideas.**

A. Major Points -4

EB welding Fixture- Design for Manufacturing

Goals

1. Prevention of one cycle of EB welding.
2. Control of welding distortion.

Status

- Design considerations fairly well understood.
- Preliminary Design started.
- Conceptual design reviewed and agreed by Mike Foley.

Strategy

a. Control distortion by changing sequence of tacking & compensating pressure.

b. By Preheating with E beam.

c. Other methods to be tried.

The setup is designed to help us in trials also.

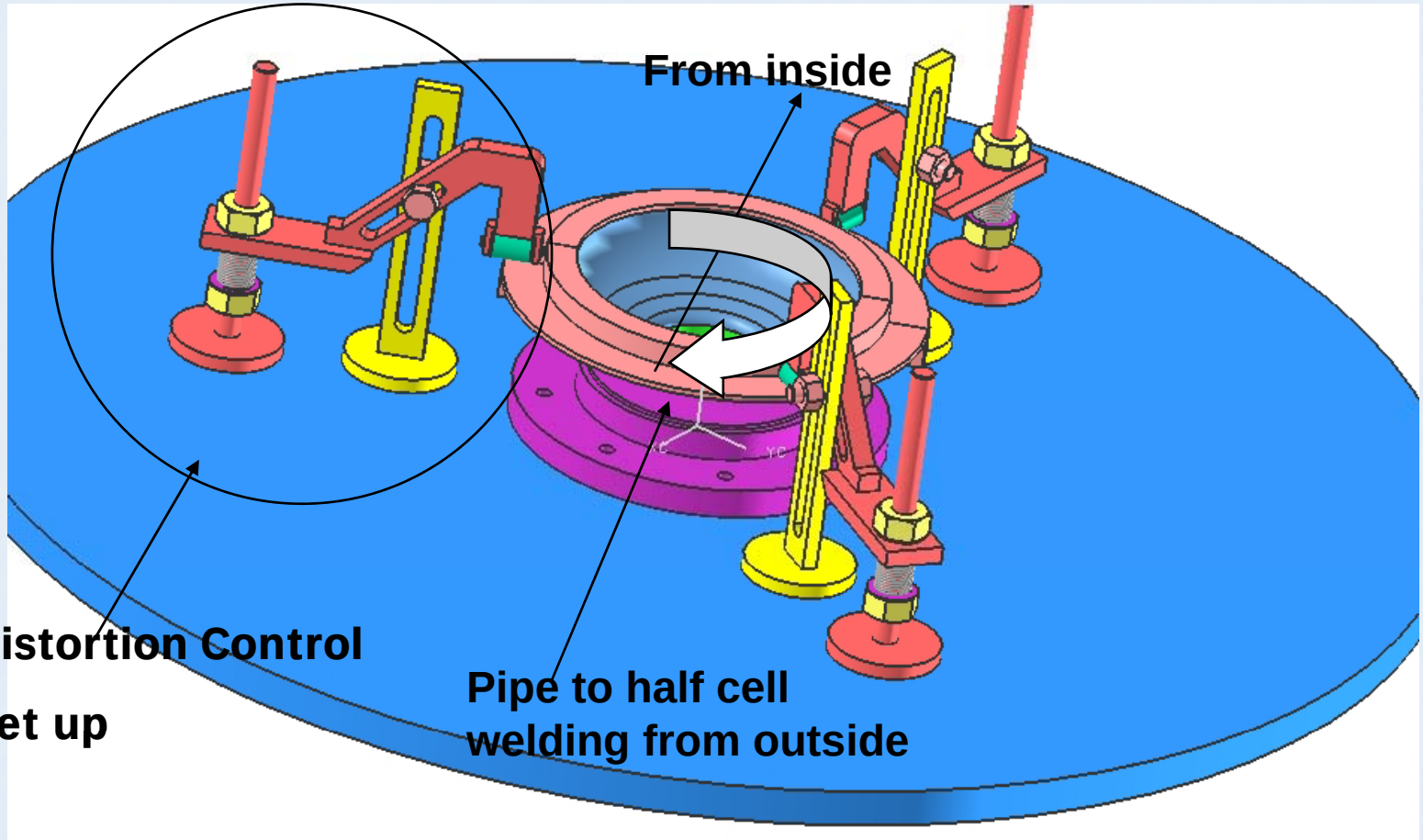
Resources needed from FermiLab

a. A few (may be 7-8) rejected half cells and NbTi cones.

POSSIBLE DELIVERABLE Design may be completed by May 2008.

New Concept of EB weld Fixture

Case study : Pipe to half cell welding

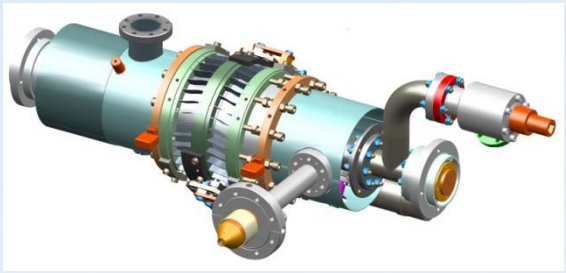


Possibility of saving one pump down cycle as no need to disassemble the fixture

This slip ring type concept can be applied for many other similar application

A. Major Points -5

- **Design of slow Tuner- New Design**



Goal

Lesser complexity.
lower cost and greater reliability.

Status

Four Ideas proposed by Indian Team of Mr Mundra & V Jain.

- **Design considerations fairly well understood .**
- **Reviewed by Harry Carter.**
- **Scissor concept selected for further analysis.**
- **Finite element analysis underway**

Strategy

Extensive analysis and prototyping will follow. for the best alternative.

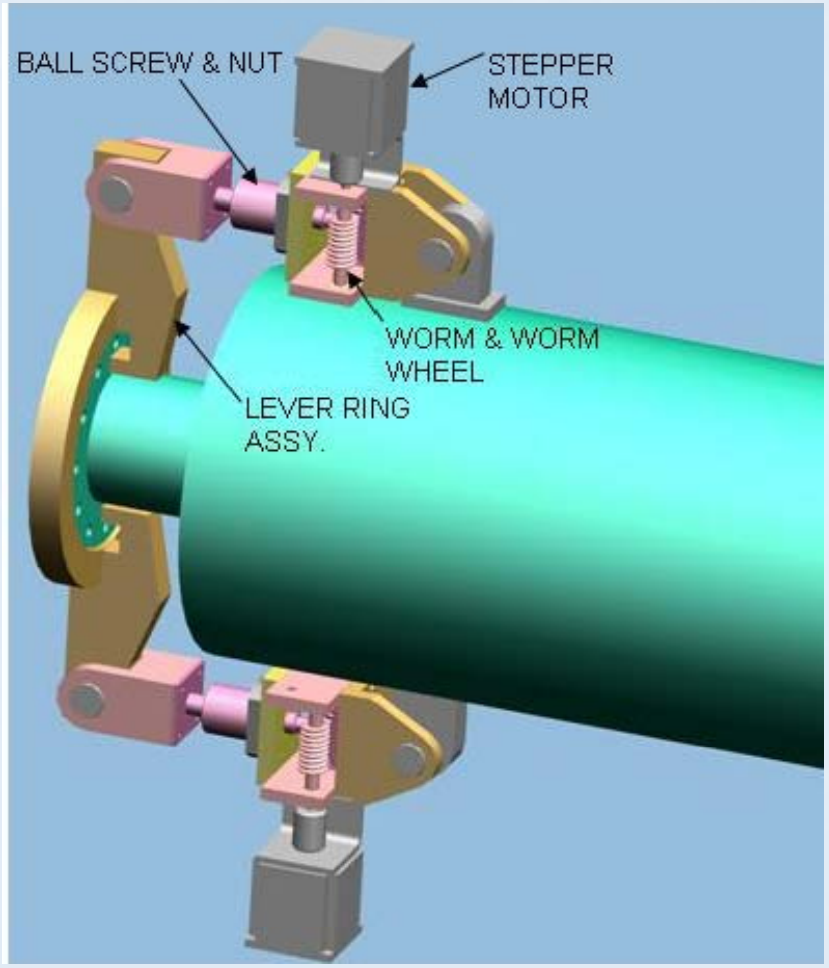
Resources needed from FermiLab

Two Cold motors and one piezo tuner set.
Continuous interaction with Harry Carter and Don Mitchell.

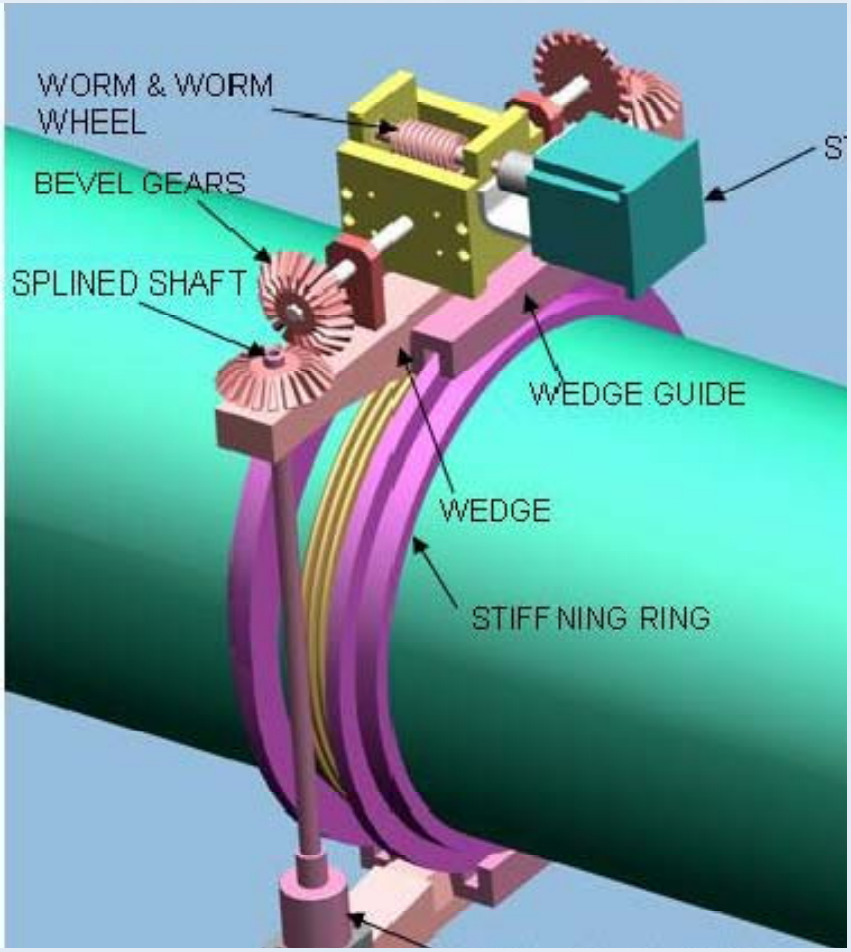
Deliverables

Time schedules can be given after consultation with GM and VJ.

New Tuner Design Some prelim concepts

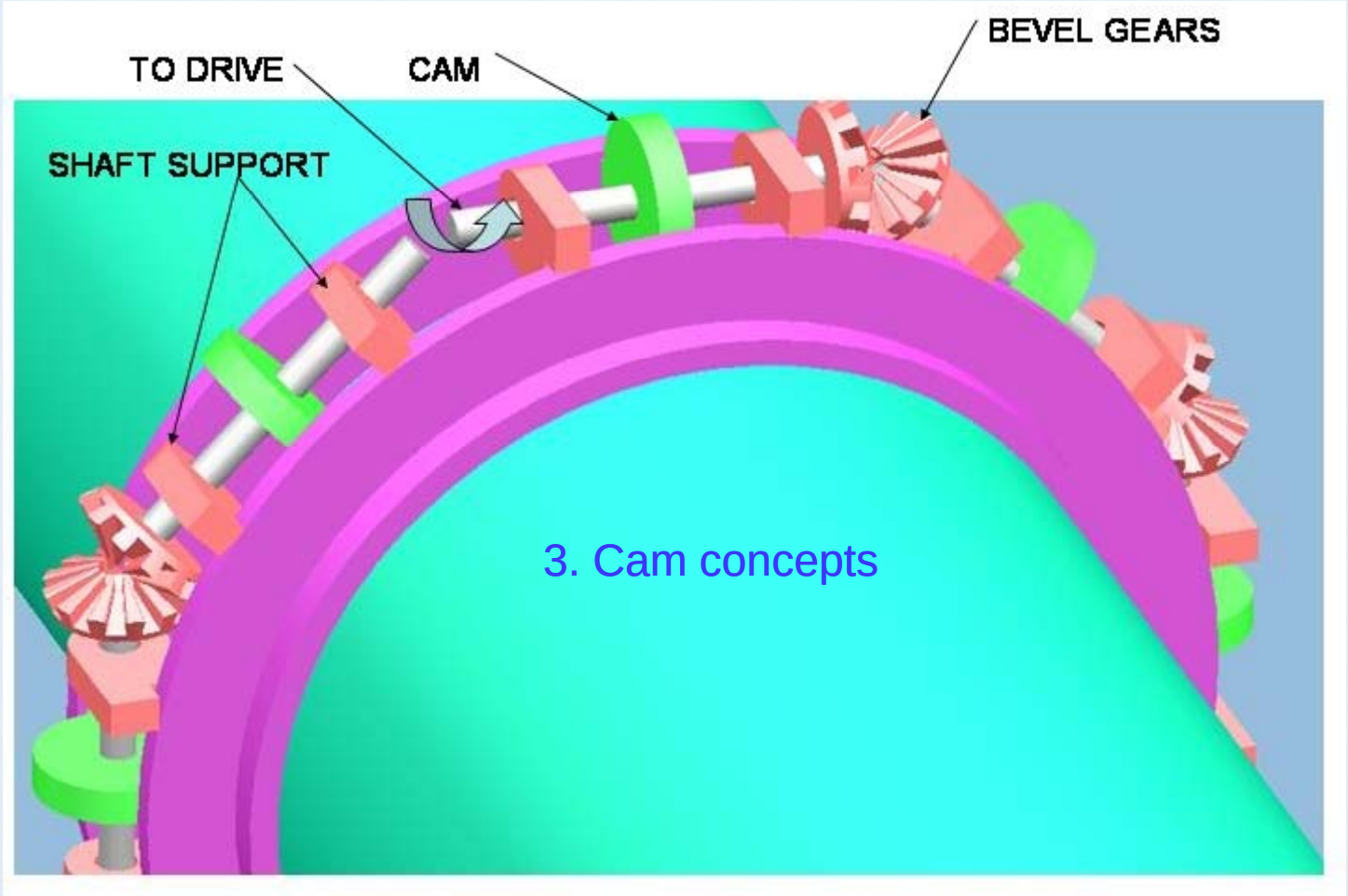


1. Lever Arm concept

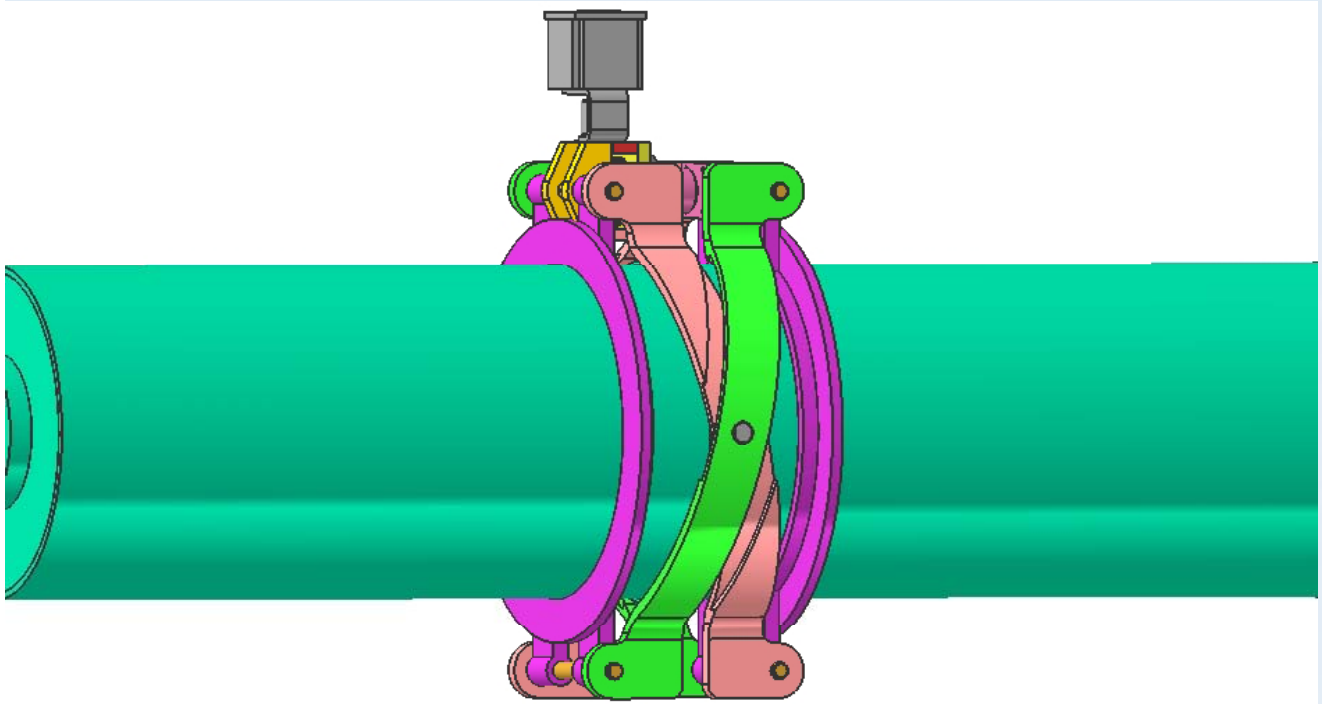


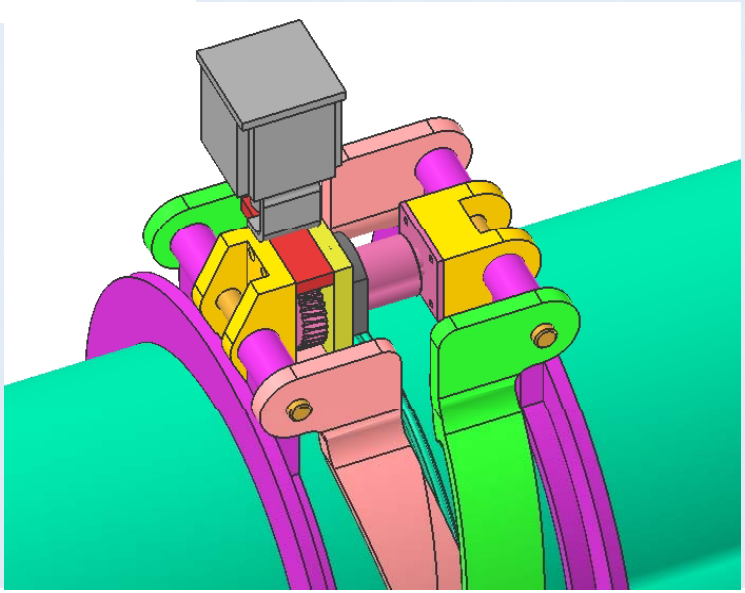
2. Wedge concept

New Tuner Design Some prelim concepts….

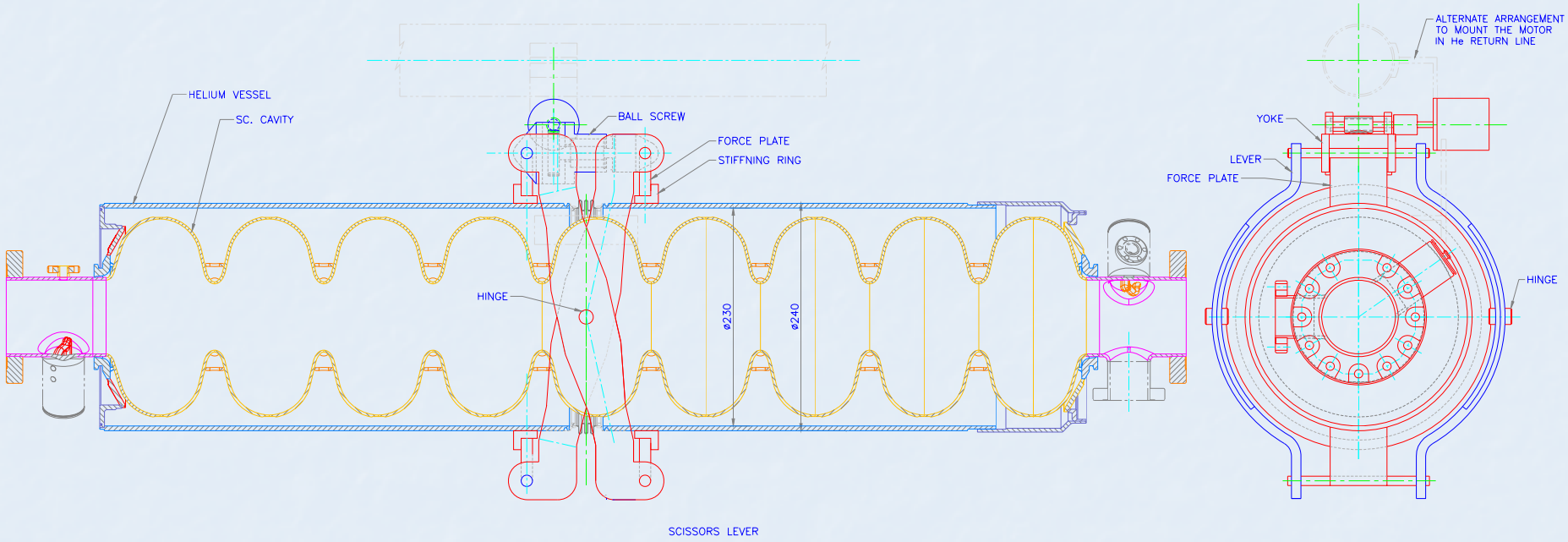


4. Scissor concepts





Selected to be worked on further



SCISSIORS TUNER ARRANGEMENT FOR 9 CELL 1.3 GHz SC CAVITY

Scissor concepts- drawing

A. Major Points -6

Goals

- Explore the development of transition joint between SS and Niobium.
- Explore brazed copper joint and Explosion bonding.
- Design considerations being understood.
- The most challenging task.
- Two joints, helium vessel to 2K pipe and helium vessel to Nb cavities being considered.

Resources needed from FermiLab.

Evaluation of test pieces.

- Deliverables : Understandably no dates can be given for this task.

B. Optimisation of assembly

- **Titanium pipe welding of bellows.**
- **MLI blanket**
  a. Pre-stitched, 1/8 length put on Big Bertha.
  b. 2K line & coupler..
- **Assembly of roller bearings.**

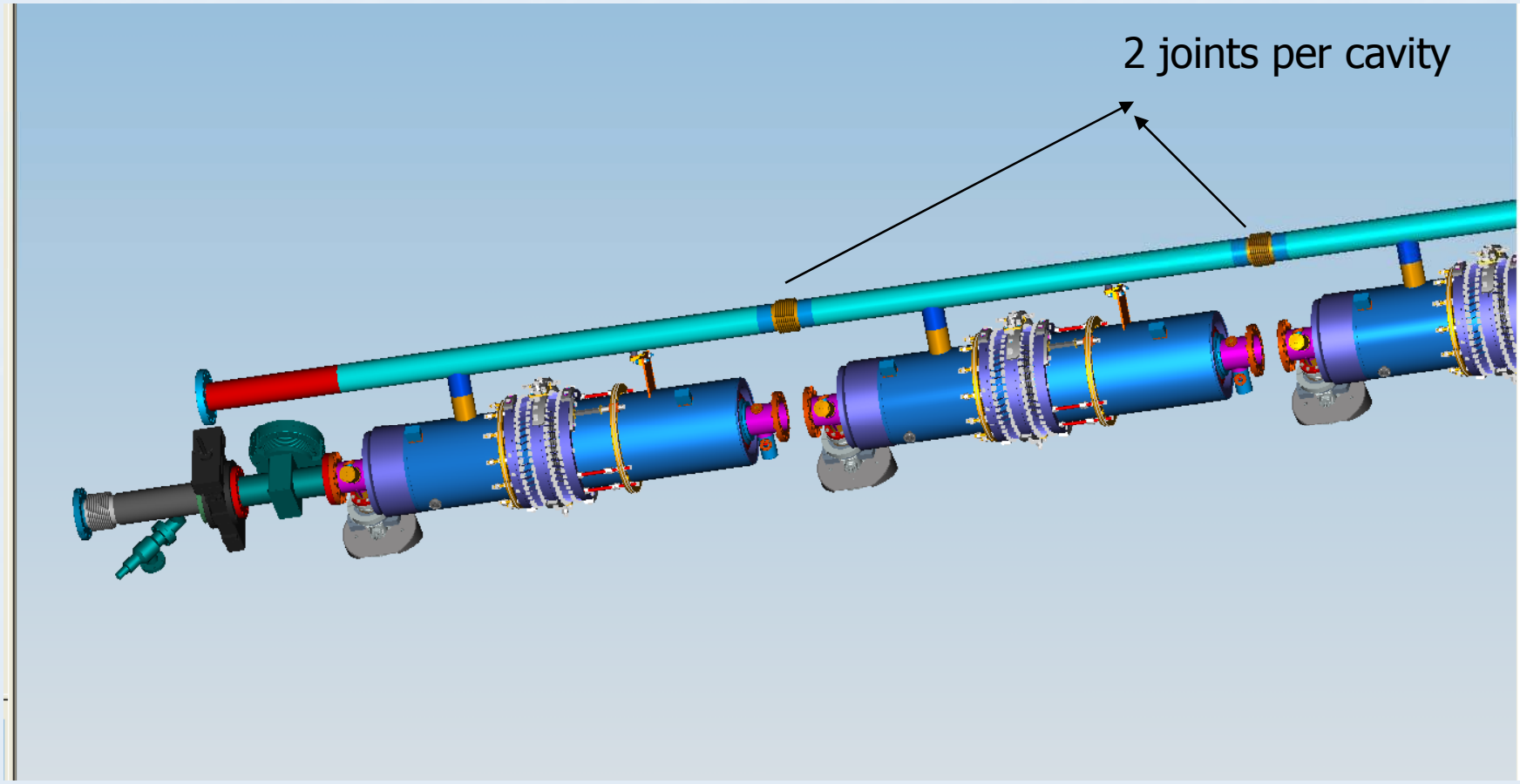
- **If the blade tuner is to be used the assembly can be simplified.**
- **Invar post locking bracket design.**
- **Gate valve support to be done again**
- **Lot of rework effort goes into magnetic shield fitment.**

Snippets from Assembly

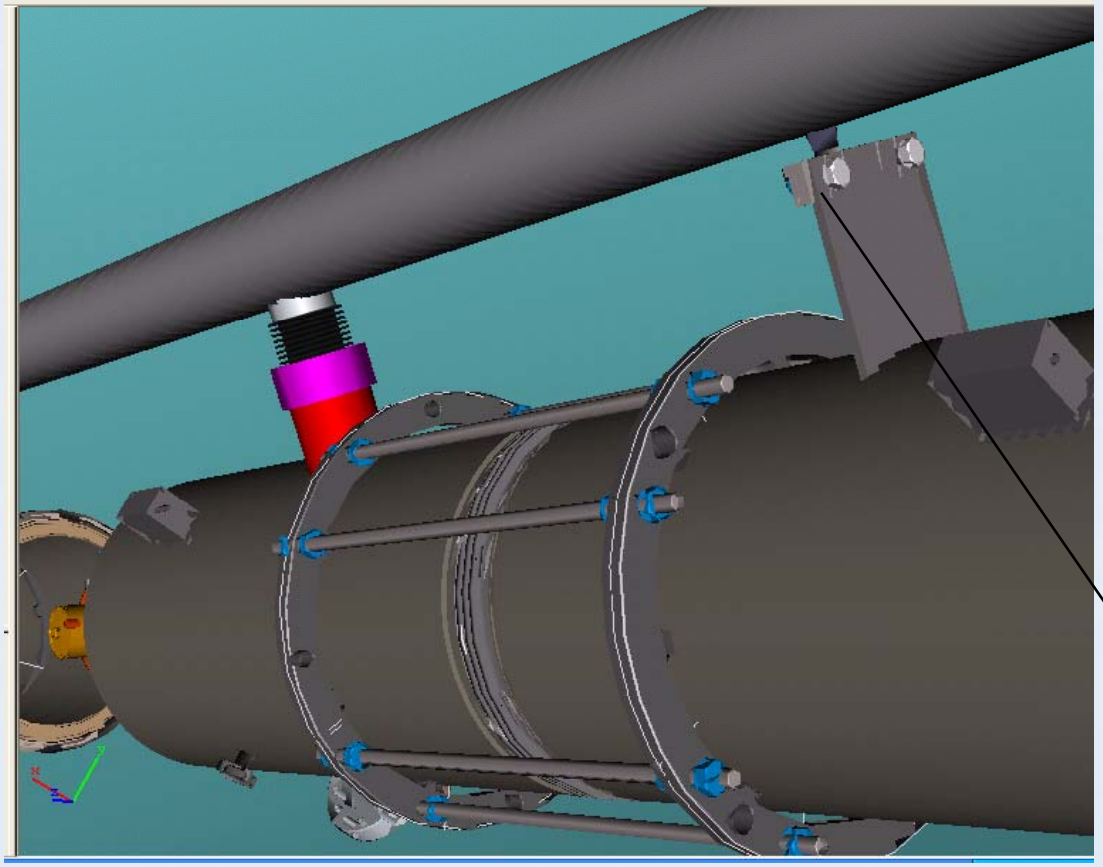
V.E.1

Assembly of 2K supply line

2K supply Line – (Present)



Proposed Scheme



1. **One flexible hose / bellow per cavity.**

2.Maximum axial movement in extreme bellow will be 9mm.Esaily taken up by flexible hose.

Horizontal support.
Circumferential strap

Allows contraction

Details

Sequence of Operation

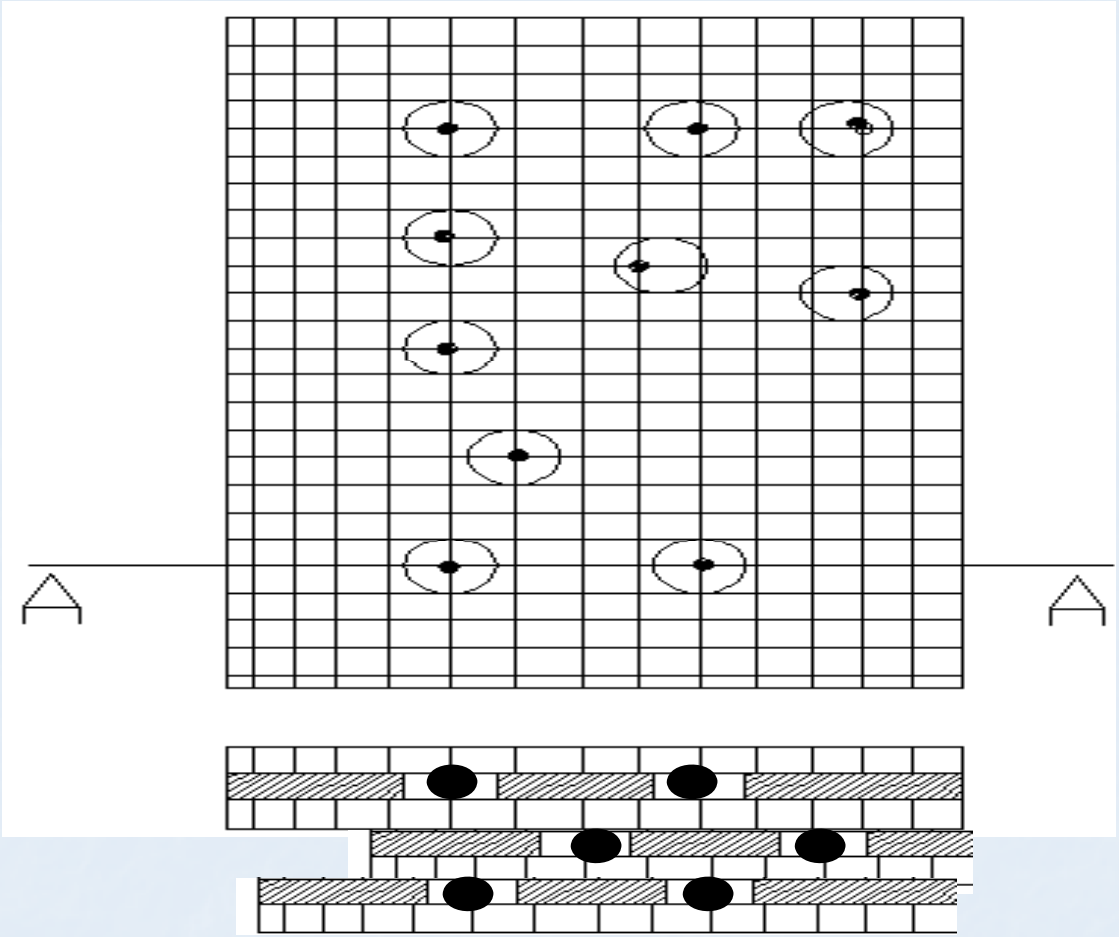
- The segments are welded insitu and the exercise comprises of
- Cutting all 8 titanium segments to size.
- Clamping them with suitable fixtures on the cryomodule. Their clamping becomes difficult as they get misaligned after weld shrinkage takes place.
- 8x2=16 welding in a "difficult to approach' location. All the welding operations are done in shielded argon atmosphere. This is an arduous job.
- Vacuum leak check with gaseous helium after weld.
- Copper braids are attached to 2k line for cooling of HOM coupler and tuners.

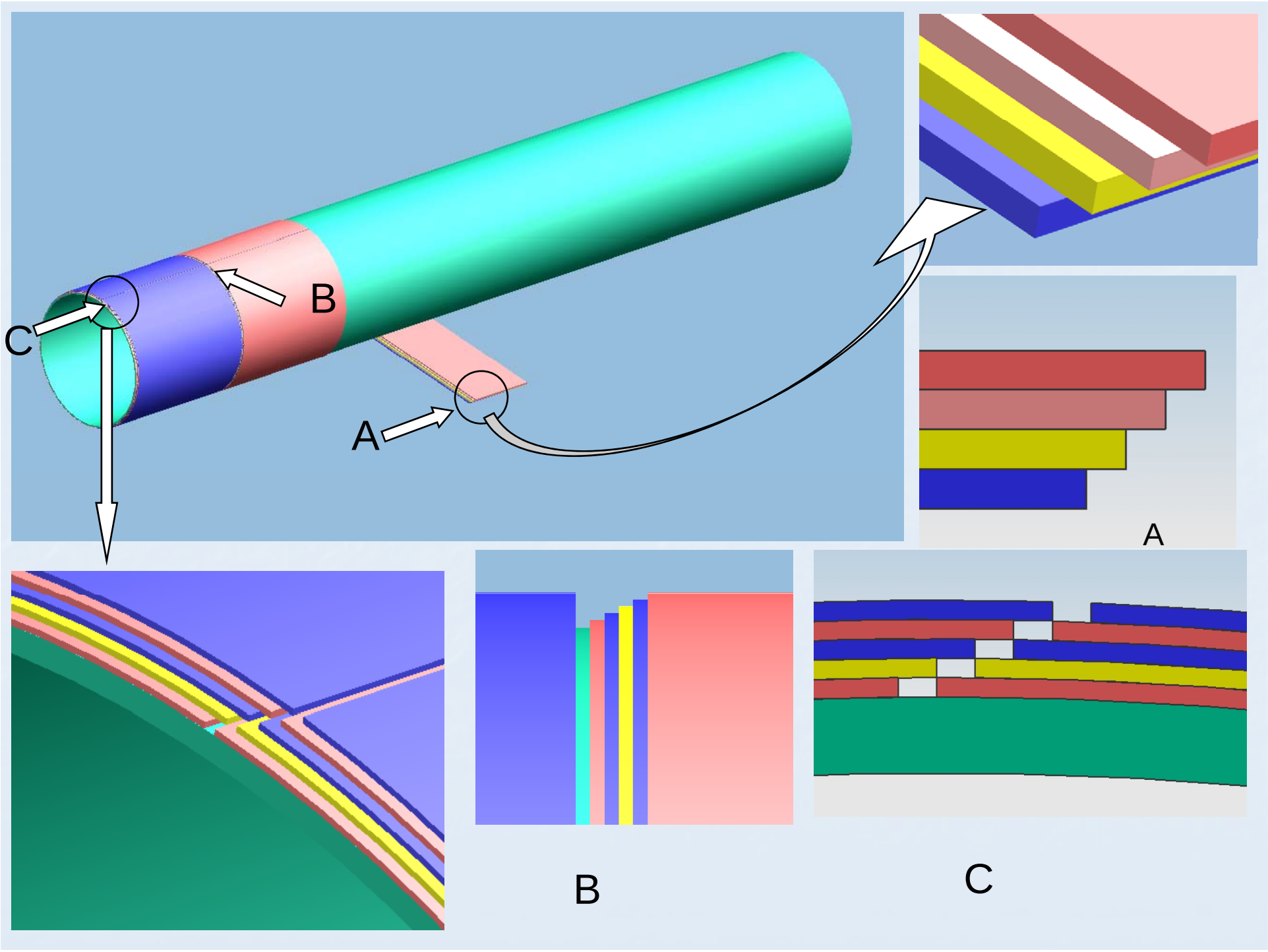
Advantages

- Significant saving in cryomodule assembly time and money by reducing no of welds from 16 to 8.These are insitu welds.
- The cryomodule assembly time may get reduced by a lot.
- Ease of operation. No clamps, misalignments etc.
- Compatible with T5CM (next generation cryomodule) with SS pipe and SS bellow.
- With flexible hose it may become cheaper.
- Vacuum leak check becomes easier and less time consuming.

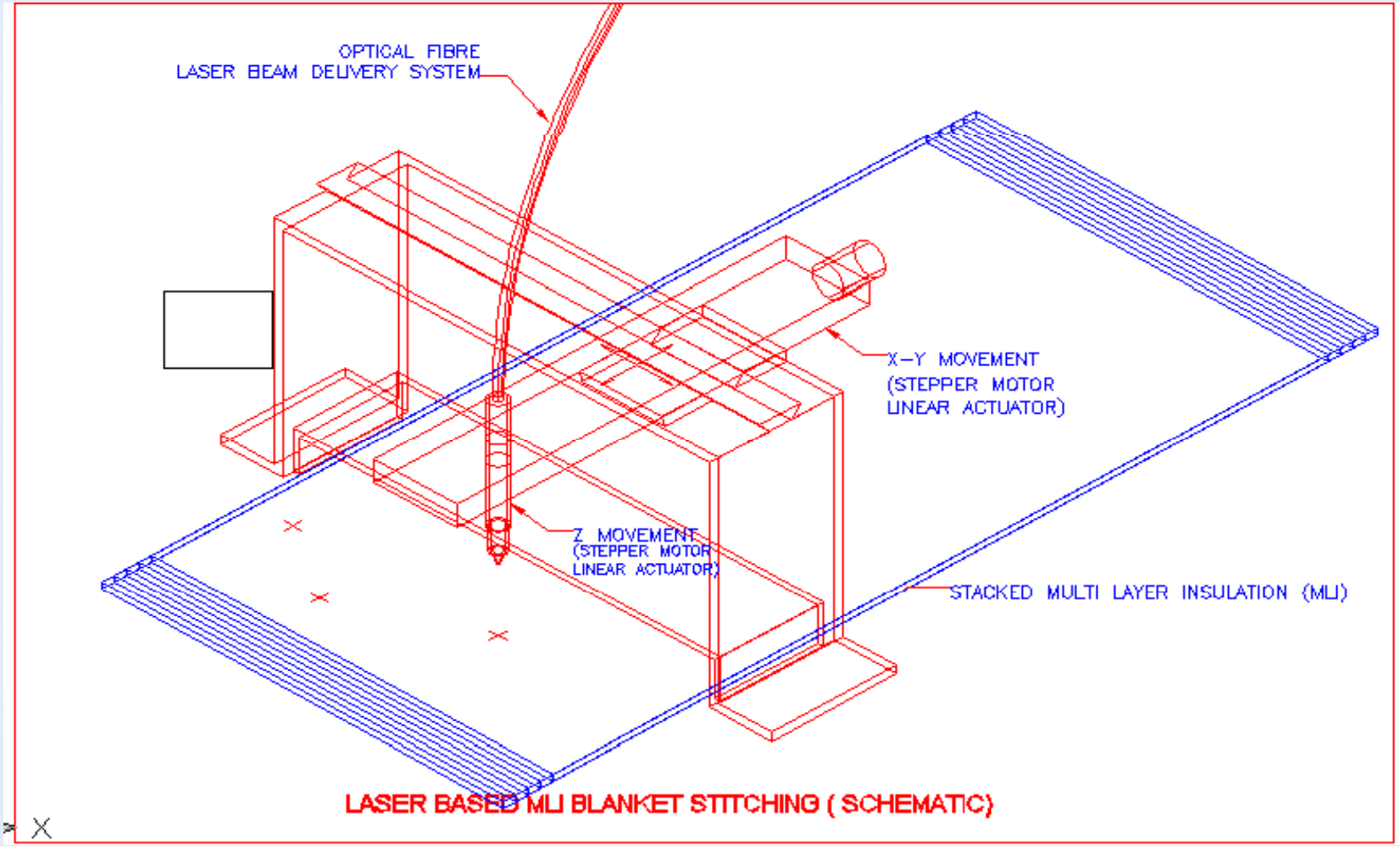
V.E.2
New concept for making MLI blankets & It's Assembly

MLI blanket




C
B
A
A
B
C

MLI Blanket Manufacturing station (Laser based)



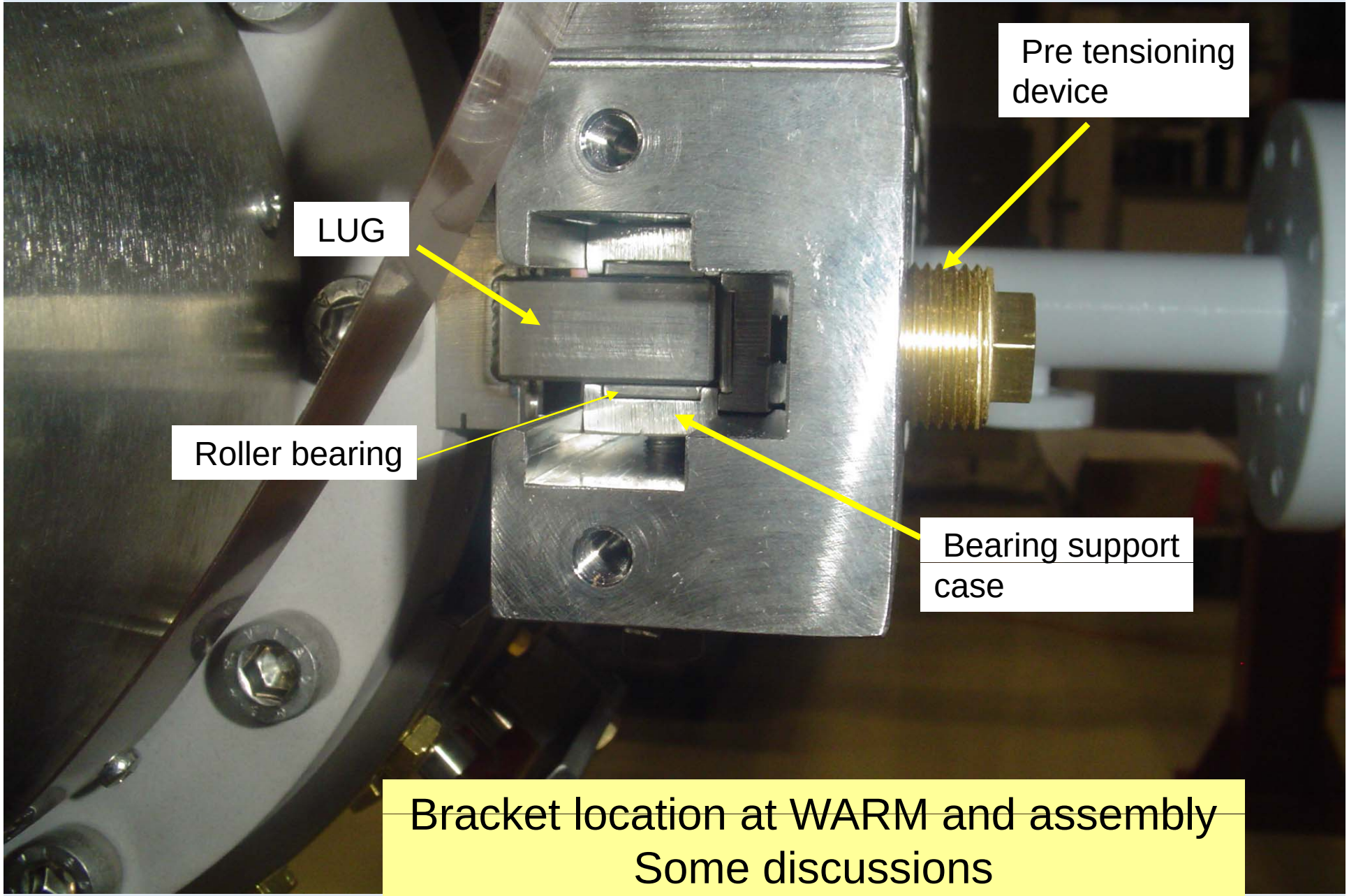
Details

This scheme will address following Issues

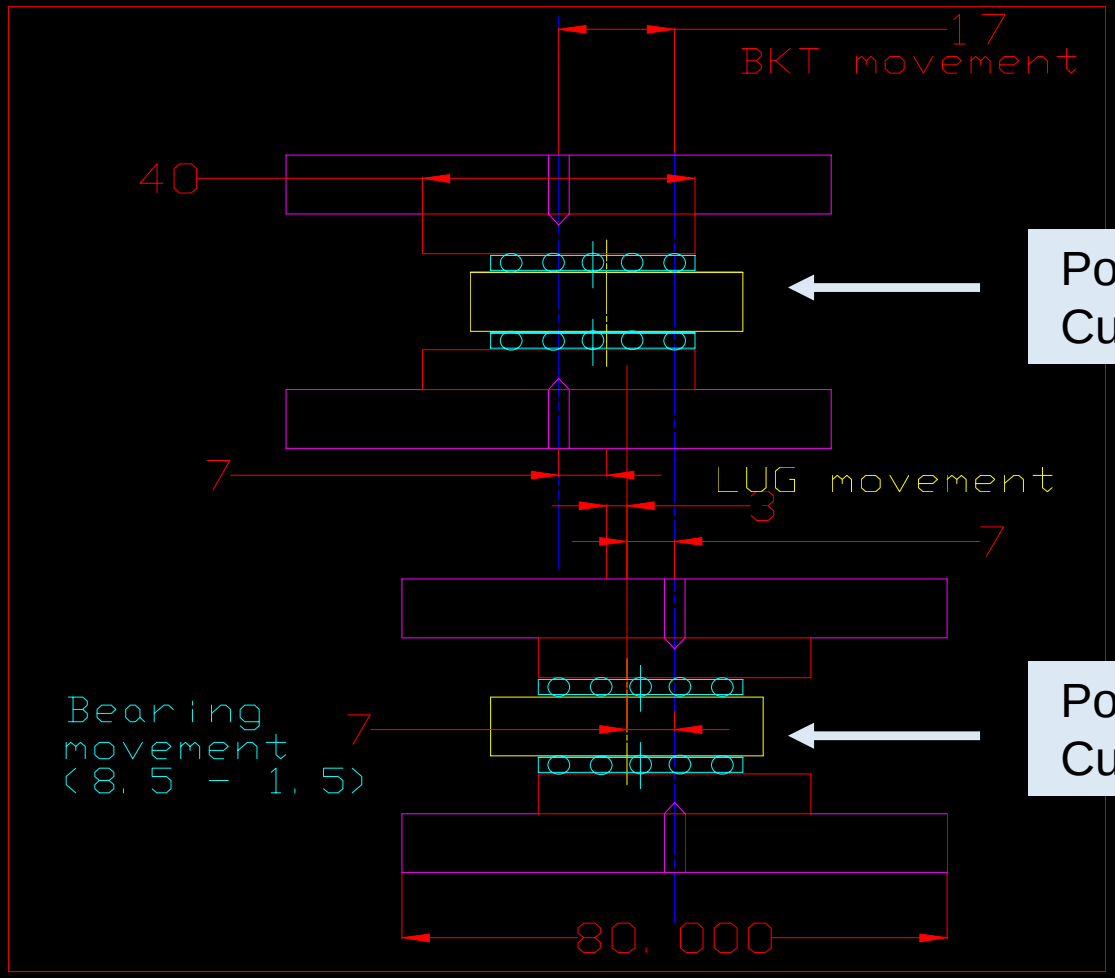
- It is a rough guess that the assembly of 30 layer blanket can be performed in half a day.
- It will be significantly better from heat leak point of view as there will be negligible chances of outer layer coming in contact with vacuum vessel.
- MLI wrapping procedure will also save at least 1 hour per coupler.
- The cost of MLI blanket will be significantly less than that of MLI blankets available from industry because of automation due to laser and lesser no. of workers needed.

V.E.3

Roller Bearing assembly

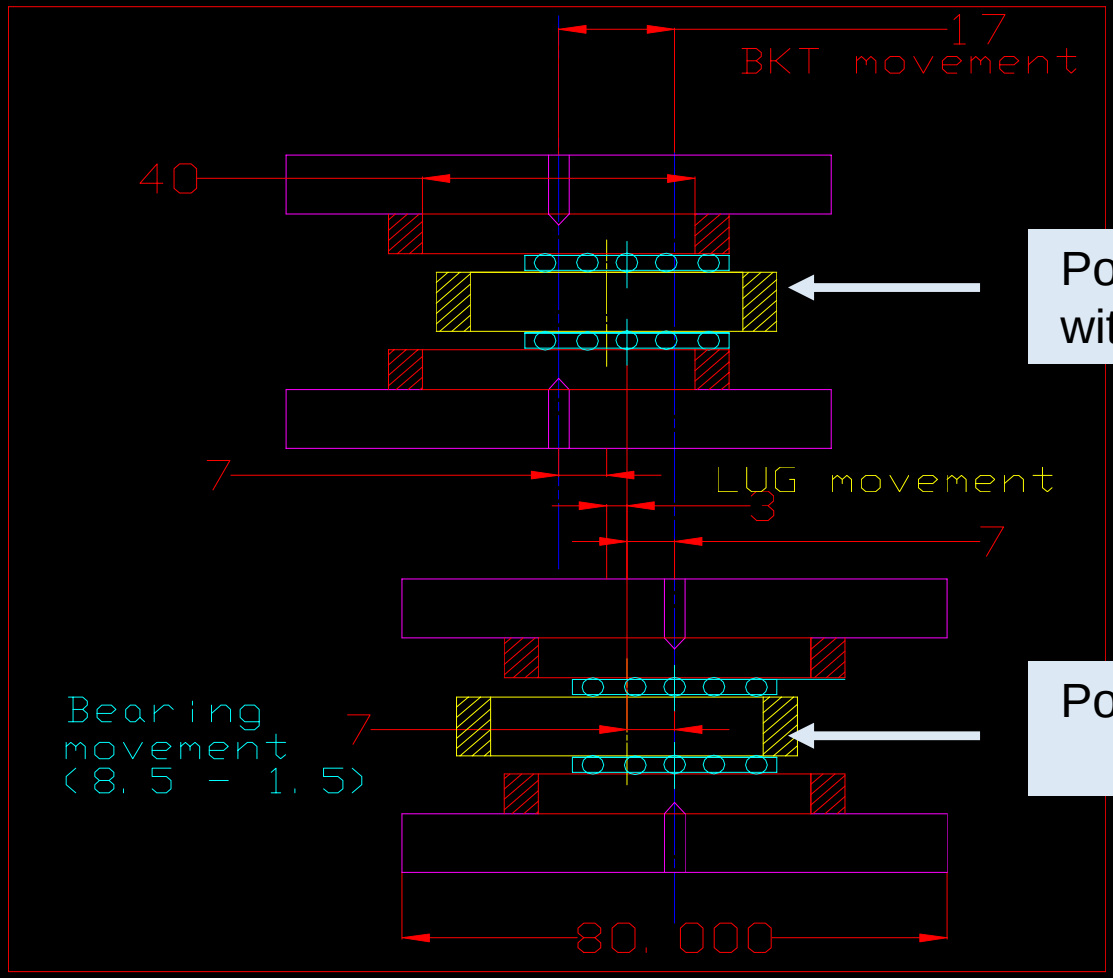


Bracket location at WARM and assembly
Some discussions



Position at WARM
Current design

Position at COLD
Current design



Comments :

1. Do we need bearing to be locked against over travel ?
2. Increase LUG length and Bearing support by 5 mm each side ?
3. Assembly could be less critical.
4. Issues relating stability during shipment ?

Details

- This change will be inexpensive,
- Save significant amount of assembly time.16 such locations are there.
- During transportation there will be no threat of over travel and the cavity falling out of the roller bearing.
- With the proposed alignment block (DM3)we intend to lock the over travel. Is it prudent?

C. Assignments Given & Completed

- Thermal contraction recalculation for subsystems of 1.3GHz cryomodule. COMPLETED.
- Thermal contraction calculation for 3.9GHz cryomodule to understand new position of couplers- COMPLETED.
- Proposed -Piping Connection alteration for 3.9 GHz –PENDING.

October 9, 2007

- **SUMMARY OF CRYMODULE CALCULATIONS ON THERMAL SHRINKAGE**
- After checking the spreadsheet, there are certain changes that we would like to propose
- 1. In the earlier sheet, coefficient of thermal contraction (α) taken for all calculations is the one at room temp. As the value of (α) changes drastically as we reduce the temp, it may be better if we use cumulative thermal contraction factor from room temp to 2 K.
- MaterialCoeff. Of Linear expansion (alpha)Cumulative thermal expansion coeff factor from(300-100)KCumulative thermal expansion coeff factor from(100-4)KStainless Steel1.73E-05270 E-05 38 E-05Titanium8.9E-06140 E-0517 E-05Invar3.00E-0636 E-05 4 E-05Niobium7.3E-06126E-0522E-05
- This will mean a big change
- Ex. Cold mass support shrinkage 4175 * 270E-05 = 11.273 for (300K – 100K)
- 4175 * 38E-05 = 1.587 for (100K – 4K)
- Total = 12.86 mm
- Ignoring Integral factor this will amount to 21.668 mm {a difference of 8.8 mm). This is closer to reality.
-
- 2. Another suggestion is regarding positioning of HGR support location at warm. It is proposed that the centre of the lug on the titanium vessel and centre of HGR support bracket coincide at 2 K and a calculated offset is kept in warm position. This will ensure better equilibrium and freer movement over the bearing. The proposed values are given in the excel sheet attached.
- 3. We have calculated contractions values at two different temperatures 300-100 K and 100-4 K in addition to total contractions. This could be helpful during tuning adjustment at intermediate temperature.
- 4. From point of view of ease in assembly it may be better if length of needle bearing is increased from 30 mm to 50 mm. There is sufficient space on the bracket. So it will not introduce any drawing change. During assembly it will not be necessary to measure very accurately where the lug should sit. There are 16 such assemblies and may be consuming lot of assembly time. We have later consulted Tug Arkan and Chuk Grimm, they agree.
- 5. The position of possible monitoring points (WPM and coupler locations) has been also calculated. This may be cross checked with actual cool down positions during cool down for validation of calculations.

October 17, 2007

- **SUMMARY OF 3.9 GHz CRYOMODULE CALCULATIONS ON THERMAL SHRINKAGE**
- The calculations and the new positions on couplers are shown in the attached excel sheet.
- 1. Basis of our calculations is (as per drawing) that the 4th Lug from the downstream side will be fixed on the shapes(brackets).
- 2. The maximum movement due to shrinkage at cold will be experienced by the third cavity from the down stream side .This will try to move by 1.46mm towards downstream side.
- 3. Similar movements of other couplers are as follows
- Coupler no 1 0.97mm towards downstream
- Coupler no 2 0.27mm towards downstream
- Coupler no 4 0.75mm towards downstream
- 4. In future if there is a need to reduce this shrinkage then we can do away with fixing the position of lug and have the invar rod anchored to He GRP just below the fixed support. In this case the movement of the 3rd coupler will become 0.803mm.Which will be the maximum coupler movement.
- Coupler no 1 0.32mm towards downstream
- Coupler no 2 0.39mm towards downstream
- Coupler no 4 0.096mm towards downstream
- 5. Just as in 1.3GHz cryomodule calculations we have taken cumulative thermal contraction figures.

D. Technology Assimilation

- A concurrent activity.
- All the "design for manufacturing" tasks will help in this process (helium vessel design, alignment block design etc)
- Information being gathered on forming and EB welding issues of niobium cavities. Design for manufacturing a major consideration.
- A larger participation in cavity processing & testing infrastructure.
- Thermal shrinkage estimation and how to build the cryomodule around it , is well understood. Want to learn radiation shield design and have an overview of ILC cryogenic system.
- Plan to understand cryogenic test facility for cavities so that we can upgrade cryogenic test facility at RRCAT.
- Interacting with Lance Cooley for SC material R & D.
- Interacting with Mike McGee to understand results of cryomodule shipment exercise. Planning to use similar fixtures for transportation of our cryomodule/subsystems.

How To contribute More

FEW THOUGHTS

1..Participate in cryomodule assembly process as team members.

This will help us in identifying

- **Some other potential areas for value engineering.**
- **Help us in concretizing our thoughts about the areas already selected.**

2.Identify new packages through "Blank envelop" Concept

-Essentially For Short term Assignments
-Use EDMS system to test it as a platform for exchange
-Maintain dialogue on technical issues.

Harry and Don Mitchell to propose technical assignments
-Keep SM and VCS informed.
-Locate interested engineers.
DON HAS ALREADY POSTED FIRST PROBLEM

Work Plan For Coming Months

During Visit

- Get all technical information on the 6 major issues identified (4 fairly completed and 2 in progress).
- Obtain views on different Value engineering concepts and after return start analyzing how the alternatives thought by us would work. (completed 3 pending 3)!!!!
- Additional information to be obtained on various topics.

After Return

- Advance new design concepts for various sub systems & propose design for review.
- Propose fabrication of one eighth length cryomodule & build it.
- Start prototyping.
- Evaluation of first prototypes at FermiLab / RRCAT.

We Appreciate

- Your patience with lots and lots of entry level questions for last 3 months

  (specially Harry, Don and Tom Peterson).

But Hope To

Contribute Effectively.