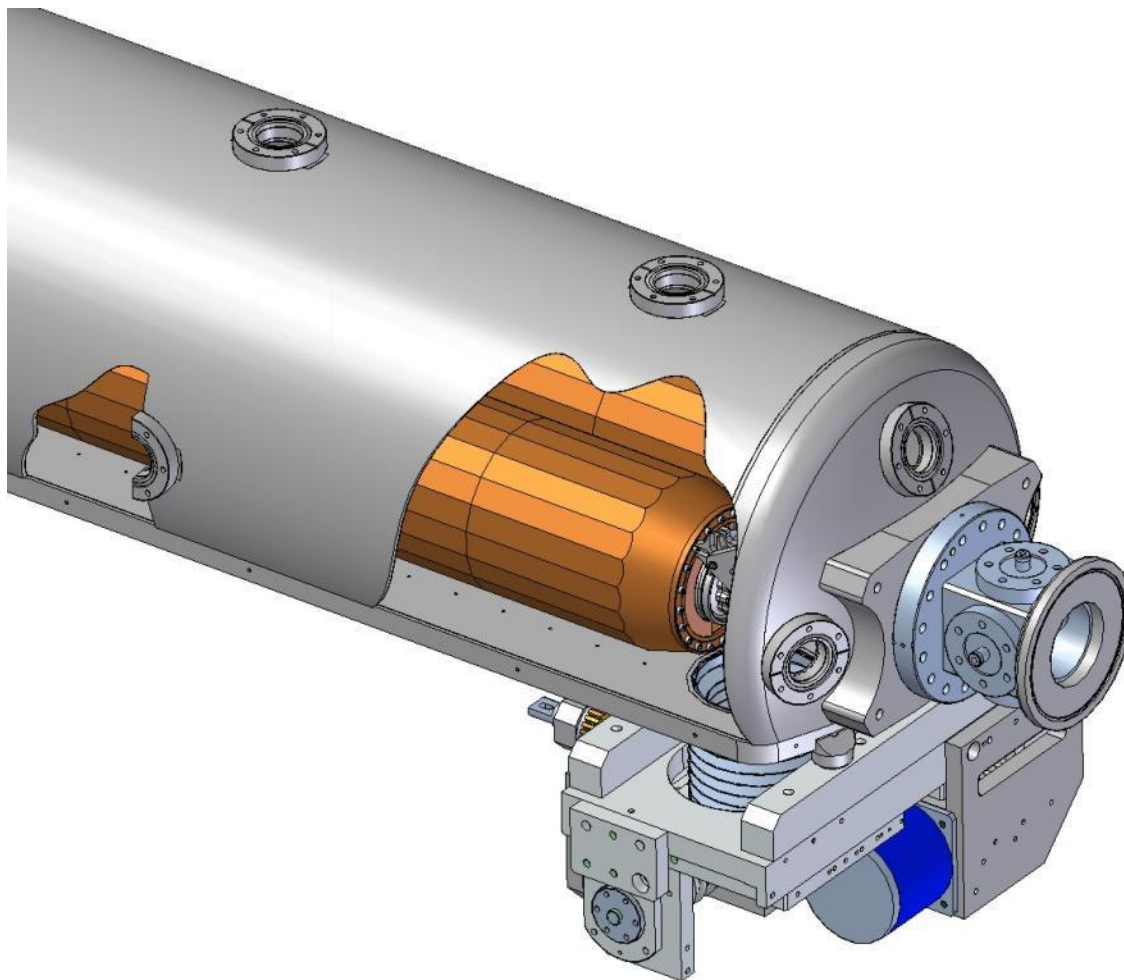


LARP

US LHC Accelerator Research Program

BNL - FNAL - LBNL - SLAC

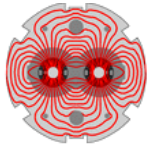


RC Status Report

17 May 2011

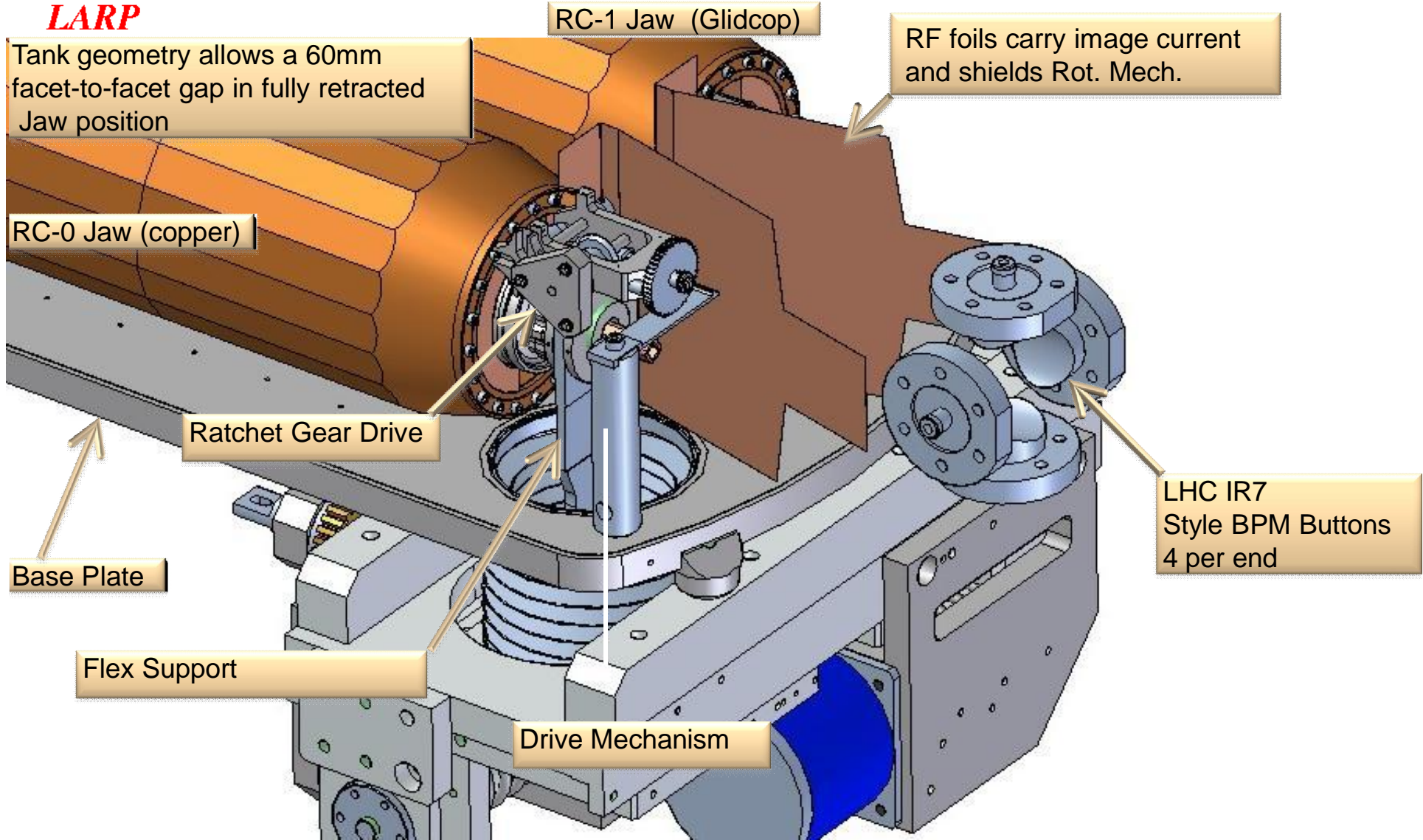
LARP CM16

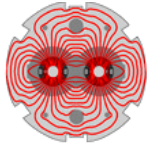
Tom Markiewicz/SLAC



LARP

SLAC RC Design Details





Summary of CM15 RC Talk on 1-Nov-2010

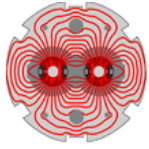
LARP

During the 6 prior months of lab tests uncovered

- Deficiencies in the primary bearing and RF bearing designs
- Deficiencies in the design of the drive unit and related hardware
- Problems with testing setup (slippage of parts prior to final welding)

Result is multiple cycles of test, failure, redesign, manufacture, install, retest

Rebuilt (& “perfect”) prototype finally moved from test lab (10/28/10) and into vacuum clean room for final welding, assembly, bake out and testing



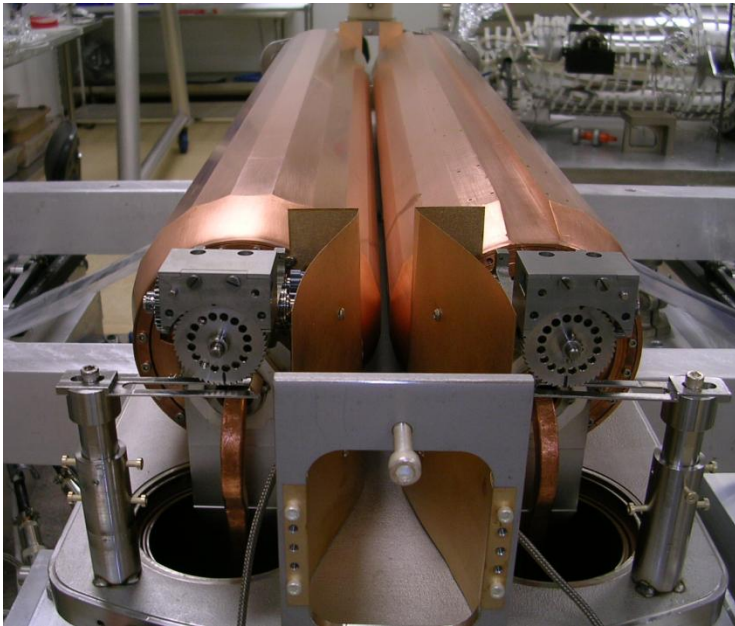
LARP

Punch List of Work Still Required as of 1-Nov-2010

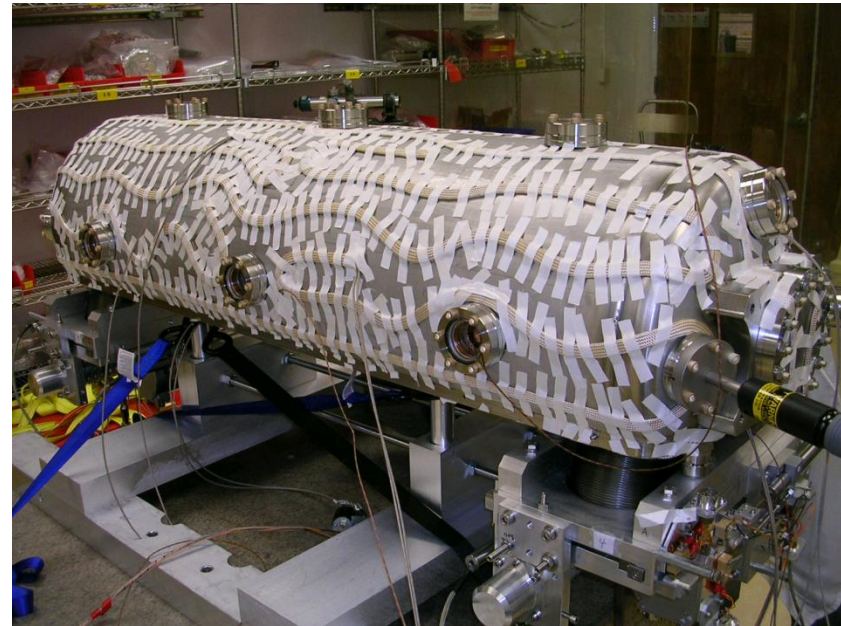
- ✓ Weld bellows to base plate and jaw supports to bellows
- ✓ Install final version of all parts
 - ✓ Rotation drives with new larger diameter W-S₂ impregnated bearings and shafts
 - ✓ Rebuilt primary jaw-support bearings and their housings
 - ✓ Parts which hold thermistors & prevent “oil-canning” of RF shields
- ✓ Weld cooling tubes into their feed throughs so that all rotation tests from this point on cause tubes to twist
- ✓ Rotation, resistance, & alignment tests
- ✓ Tests under vacuum after vessel cover welded: no more access
- Vacuum bake out & RGA scan: 2-weeks into 240°C bake
 - Estimated three weeks to achieve 9-scale vacuum
- Post bake out rotation tests



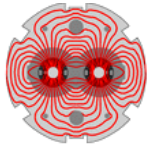
Collimator Assembled, Tank Welded Shut Rotation, Resistance, Alignment Good One New Large Problem



Assembly complete on 13-Mar-11



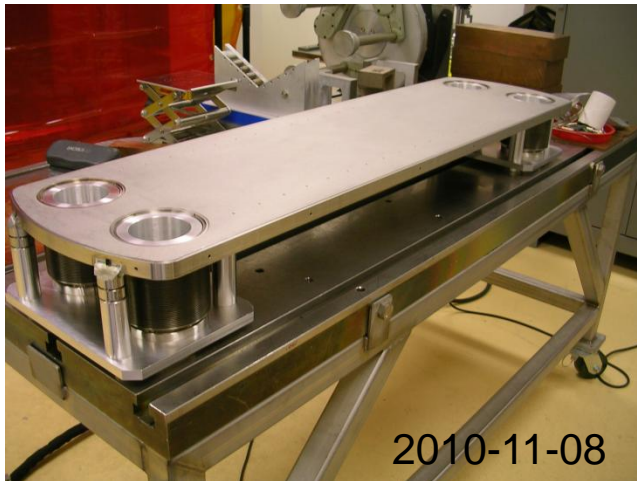
All Welding complete
Heater Tape & Thermocouples
28-Apr-11



LARP

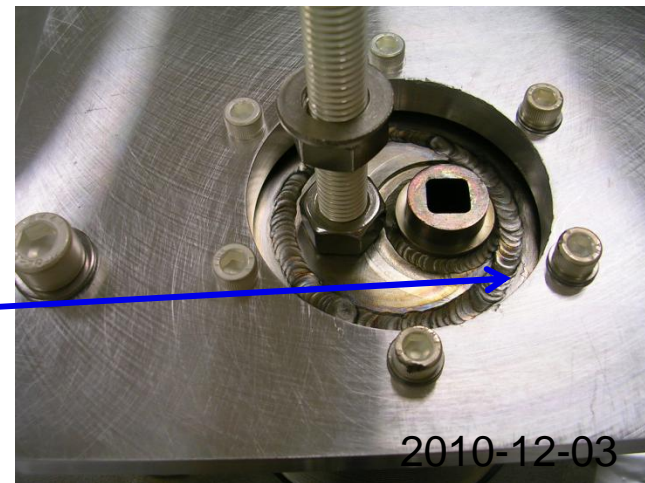
Baseplate, Bellows & Jaw Support Welds

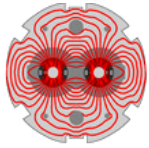
Bellows Fixtured, Protected and Welded to Vacuum Side of Baseplate



Cooling Tube Feedthrough Welded to A286 SS Jaw Support

Bellows Plug Held by Fixture and Welded to Bottom of Bellows



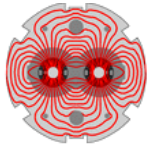


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Leak Checking Bellows Welds

Leak Rate in mbar-l/sec (1.2E-9)





LARP

Rebuilding and Reassembly of Rotation Drives and Main Rotation Bearings

Rotation Drives

Bearing on Naked Shaft

2010-12-22

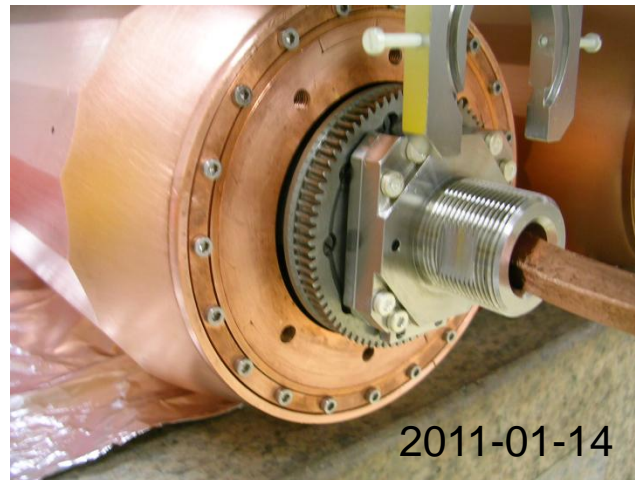


2011-01-14



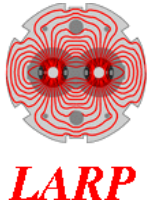
W-S₂ Coated Bearings

2011-01-13

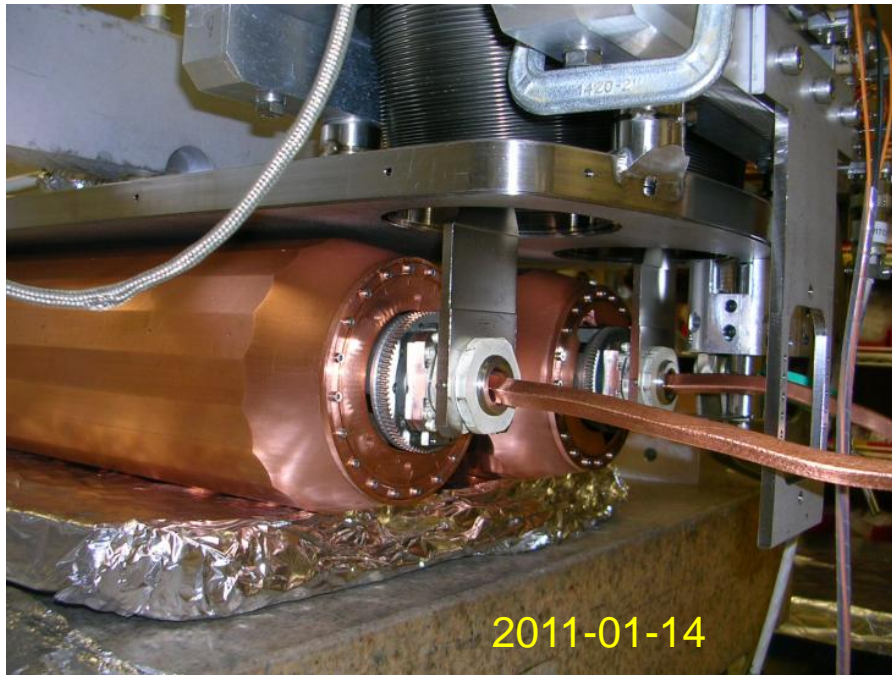


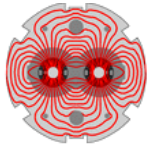
2011-01-14

Main Bearing in Threaded Housing on Shaft About to be Captured by Jaw Support



Remounting All Hardware onto Jaw Shafts for Last Tests Where We Are Free to Rotate Jaw as Much as Needed





LARP

Final Version “Pawls” to Prevent Backlash

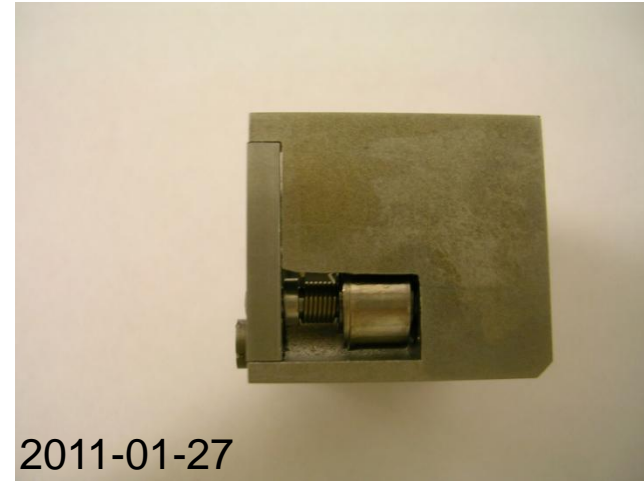
L/R Symmetric Mo Housing

2011-01-27

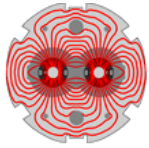


Underside w/Spring Visible

2011-01-27

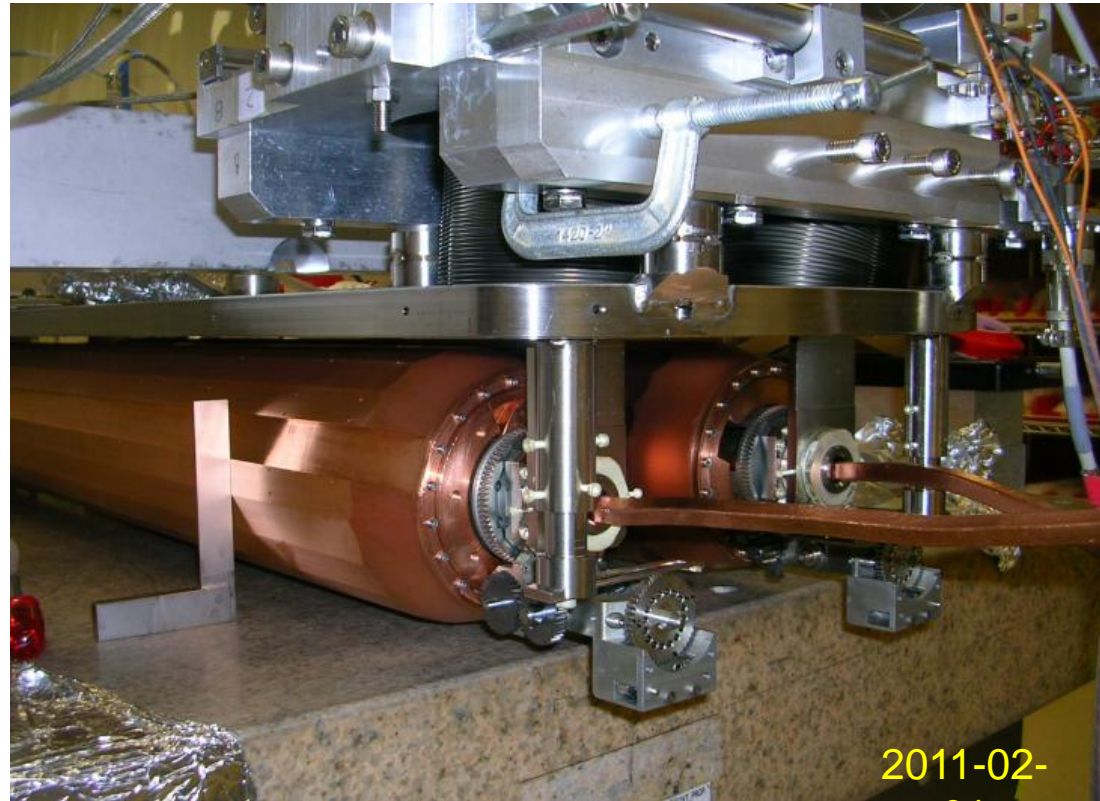


2011-01-27

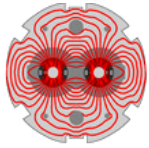


LARP

Assmann Visit 1 Feb 2011



Each Jaw Rotated 360 degrees (several times, facet by facet) to check that drive unit does not slip and that each of the 20 facets is perpendicular to beam gap after required number ($8 \times 48 = 384$) of pushes against actuator



LARP

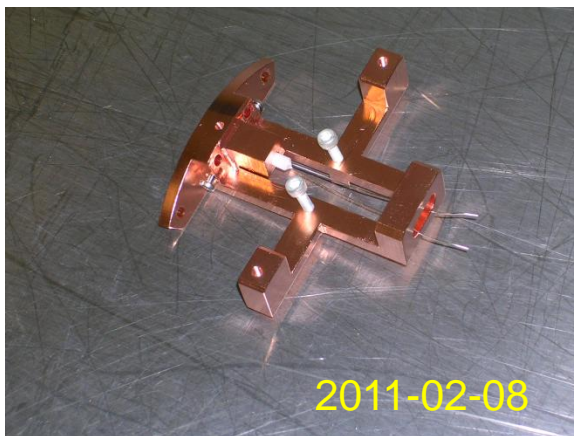
RF Continuity Hardware

“Wiper” and BeCu Foil for RF Continuity between Jaws and Vacuum Tank

Rhodium Coated RF “Wiper”



Thermistor Holder

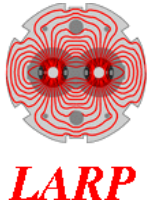


BeCu Foil

Wiper/Foil
Held to
Rotating
RF Bearing
by
Thermistor
Holder

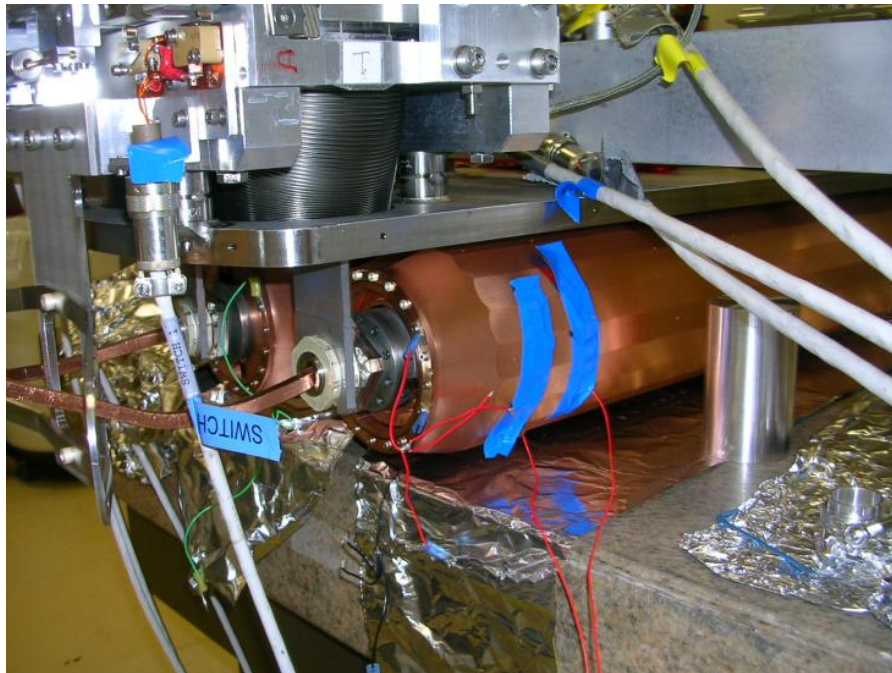


-
Unit Also
Controls
Shape and
Orientation
of Foil

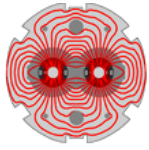


RF Continuity: $R \sim 1-2 \text{ m}\Omega$

Checked for each facet of each side of both jaws

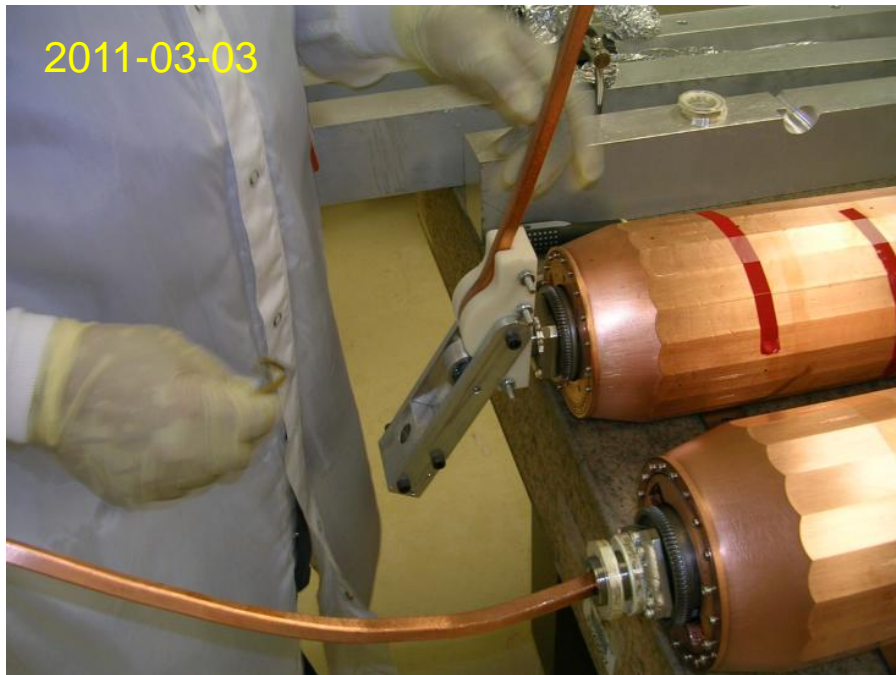


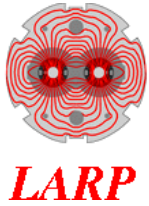
Example: 4-wire resistance = $0.5 \text{ m}\Omega$



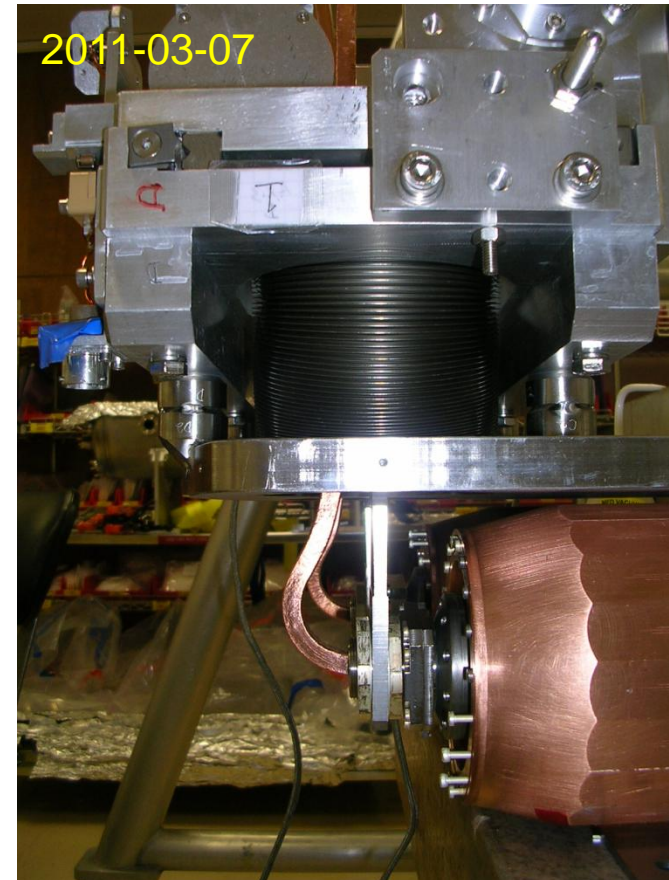
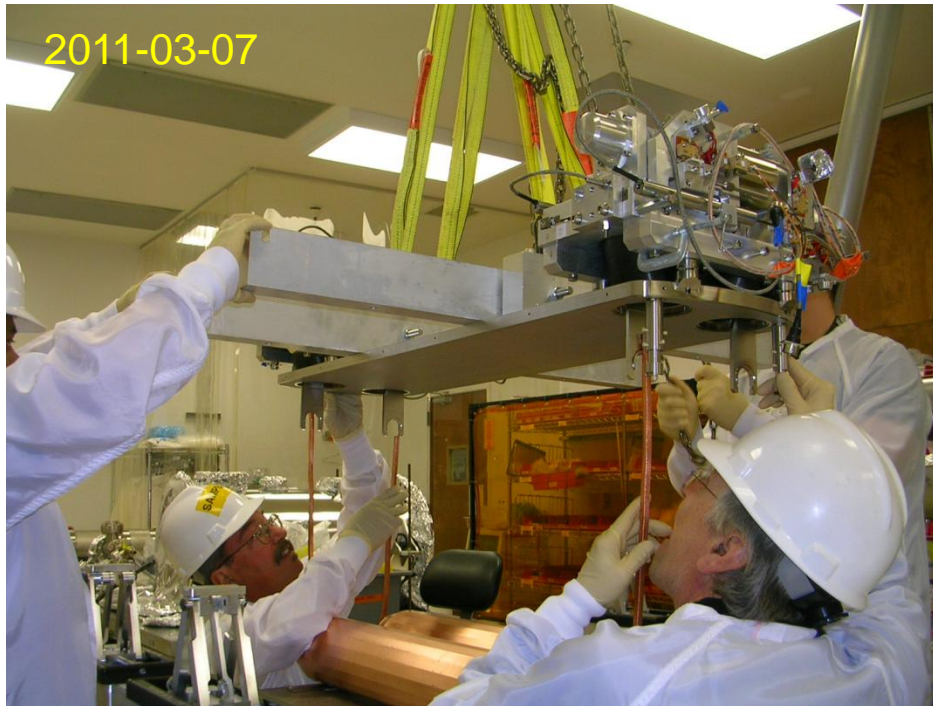
LARP

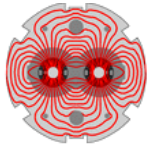
Bending the Cooling Tubes





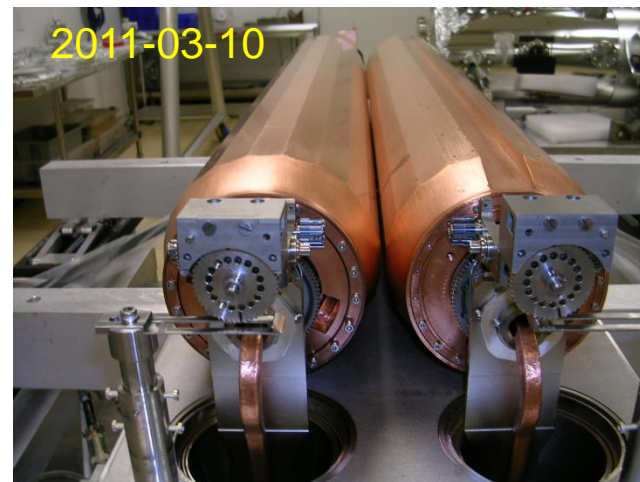
Cooling Tubes Threaded through Feedthroughs in Plates Holding Jaw Supports at Bottom of Bellows

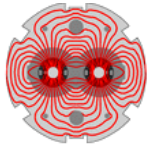




LARP

Actuator Positioning Critical





LARP

Rotation Test 1 Successful

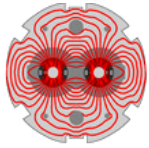
**Tubes captured, Pre-weld of Internal Parts (13-Mar-2011)
First Permanent “Twist” of Long Straight Length of Cooling Tubes**

Before



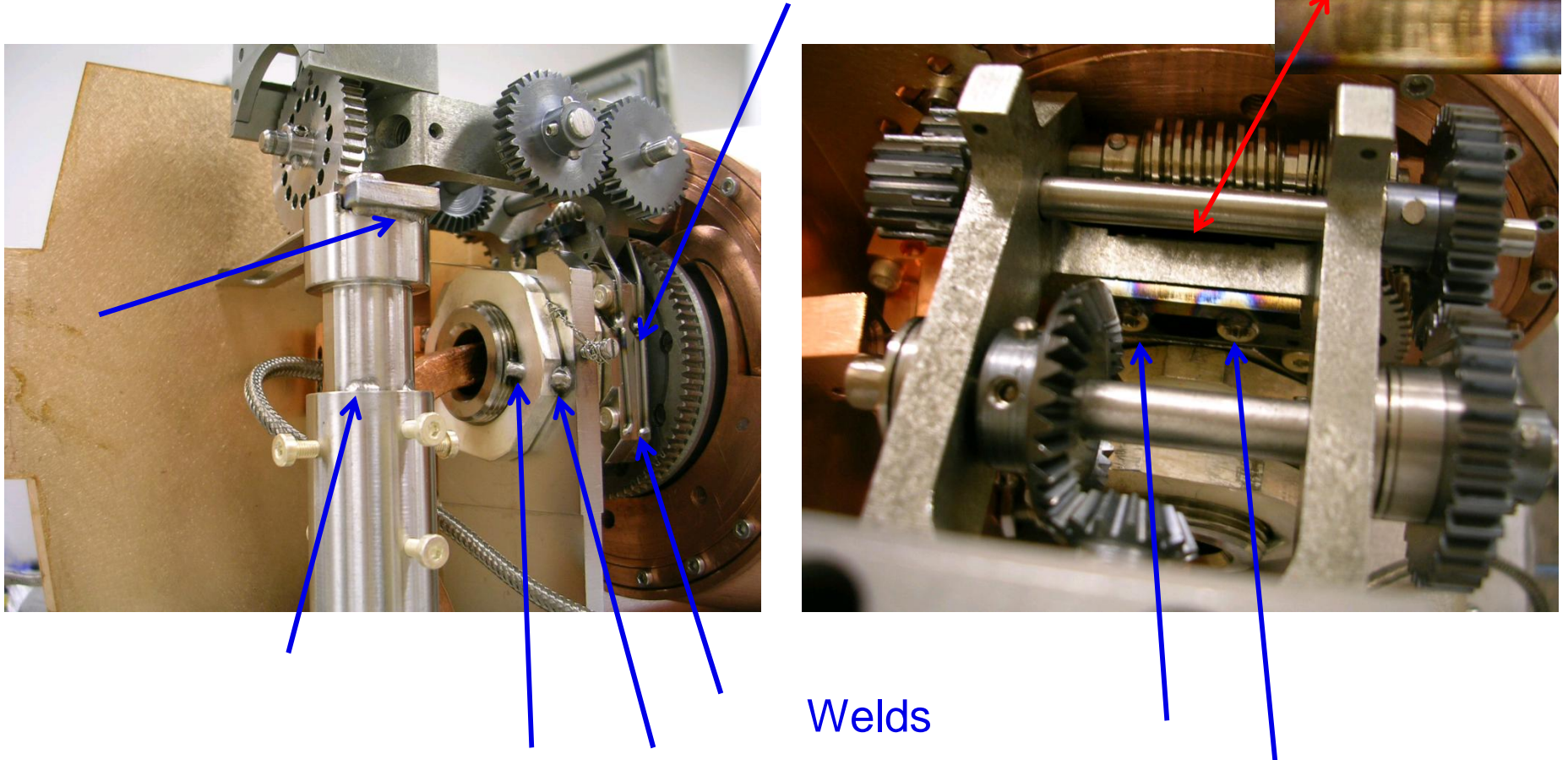
After





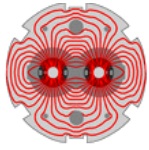
LARP

Rotation Test 2 Successful After Internal Parts Welded (16 Mar-2011)



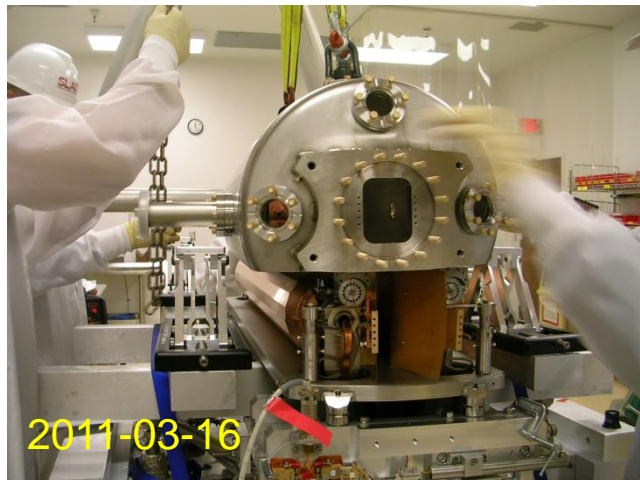
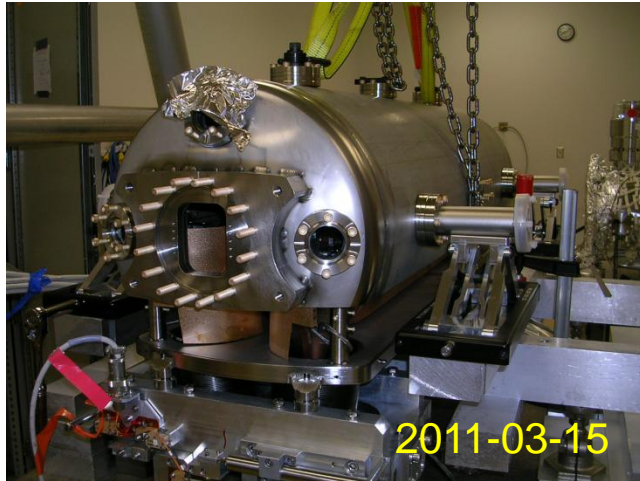
Welds

Post Alignment Check as Before: Collimating Facets \perp to beam
(required adjustment of switches as actuator moved in weld)

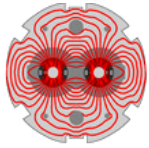


LARP

Tank Installation and Alignment



FARO arm Alignment



LARP

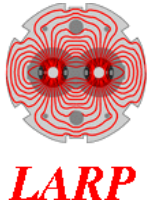
Tank Seam Welded then Leak Tested



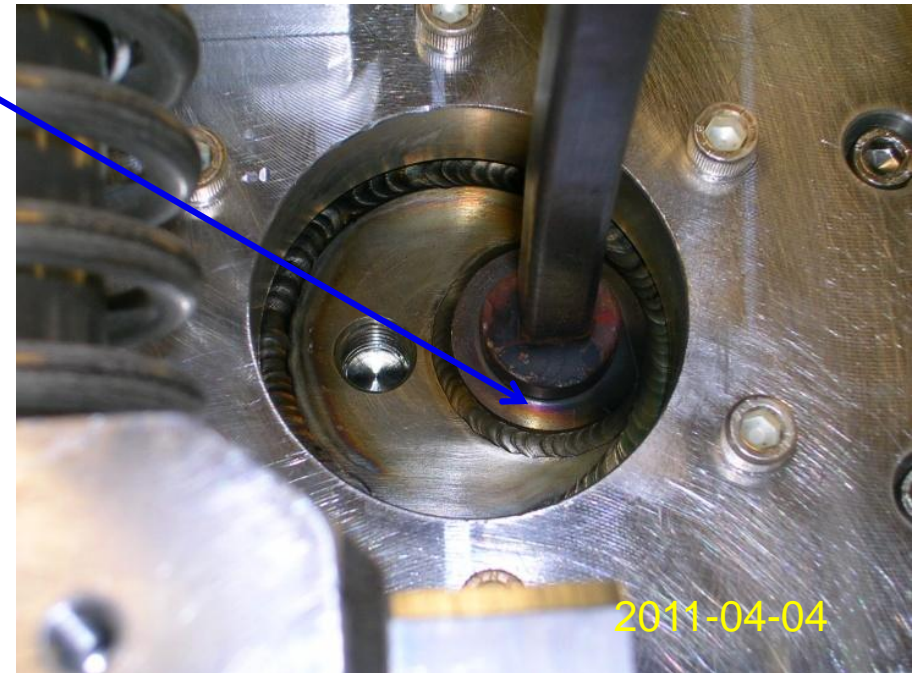
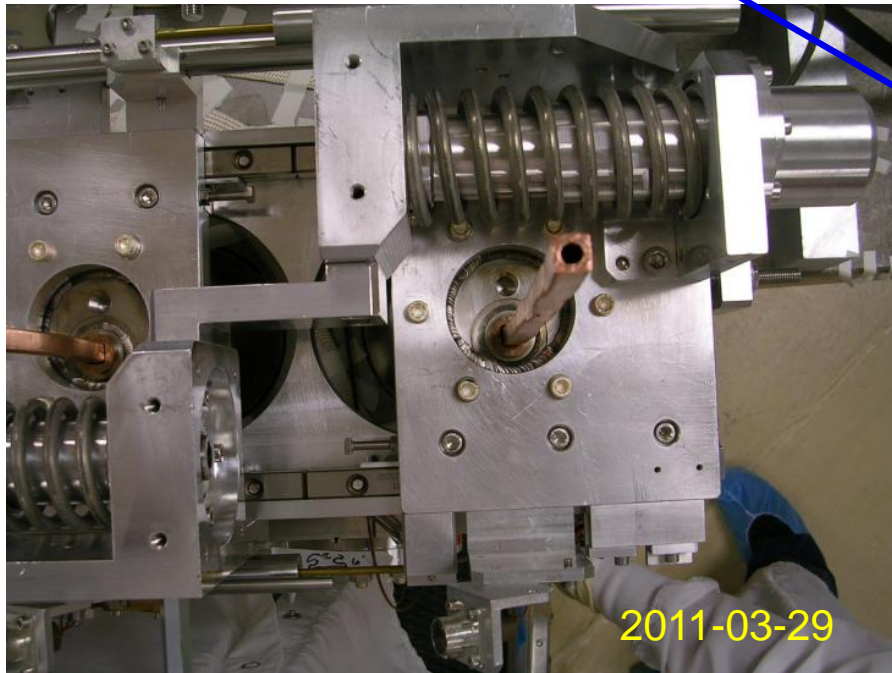
Tubes sealing
cooling tube feedthroughs
to check vacuum quality of
tank weld



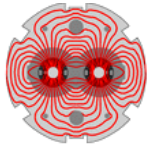
Leak Rate = $4.7\text{E}-10$ mbar-l/s



Copper Cooling Tubes Before and After TIG Braze to Copper Feedthrough



In principle, tank is now vacuum tight

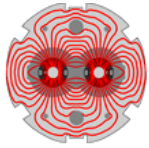


LARP

Immediate Check of Tank Vacuum on 2011-04-04 Indicates MASSIVE leak of cooling tubes to vacuum vessel



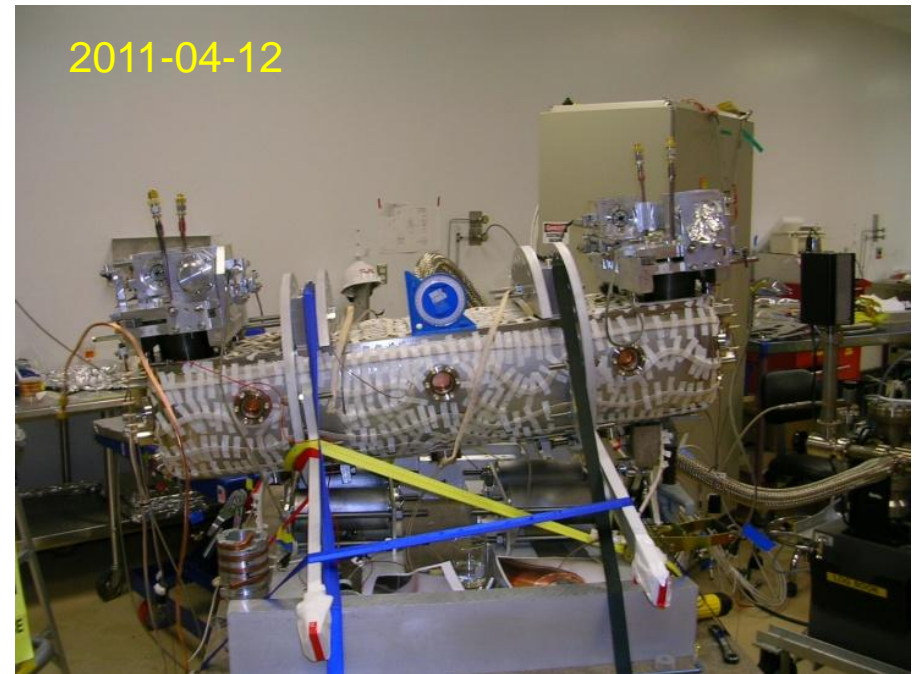
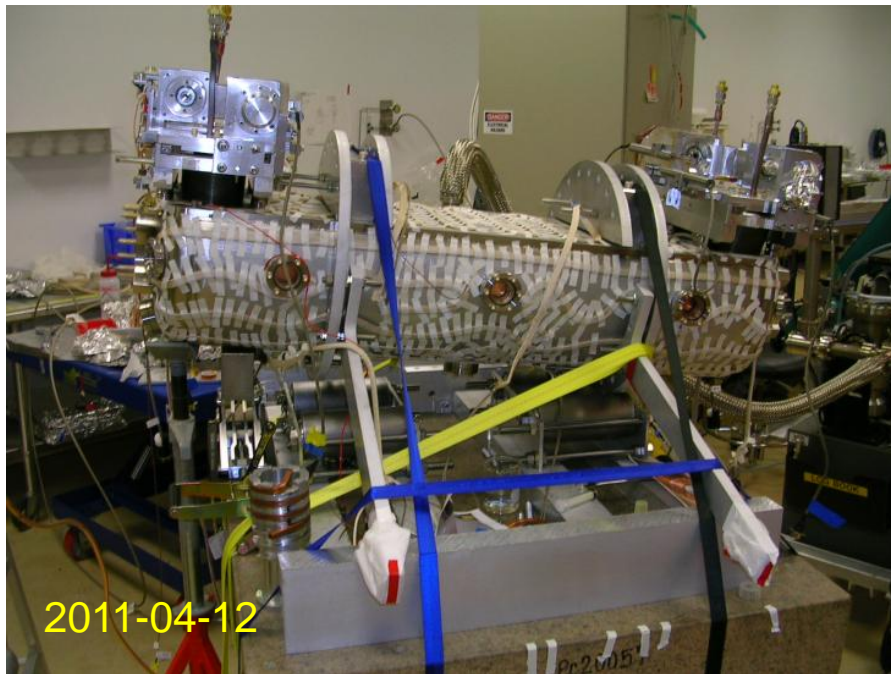
Would be a “water-to-vacuum” leak if the lines had cooling water in them



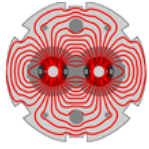
LARP

To make a long story short, we find ...

Each Jaw Is Damaged Very Near the End of the Jaw



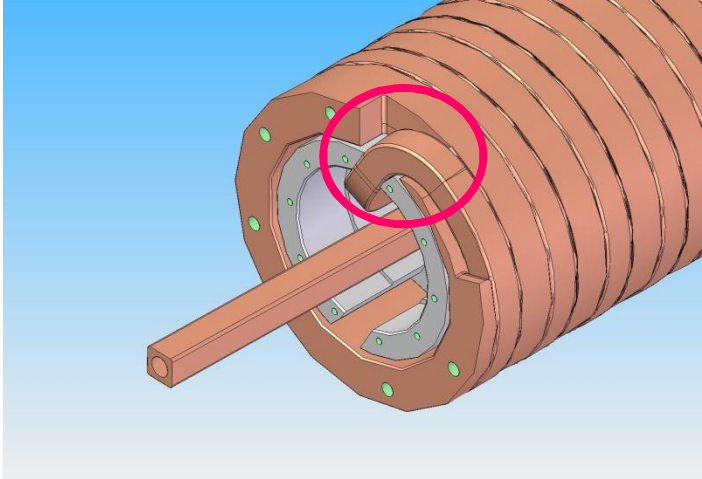
Pour 60mL Alcohol Into Each Cooling Tube
Find that it Drains Out Cracks at the Very End of Each Jaw



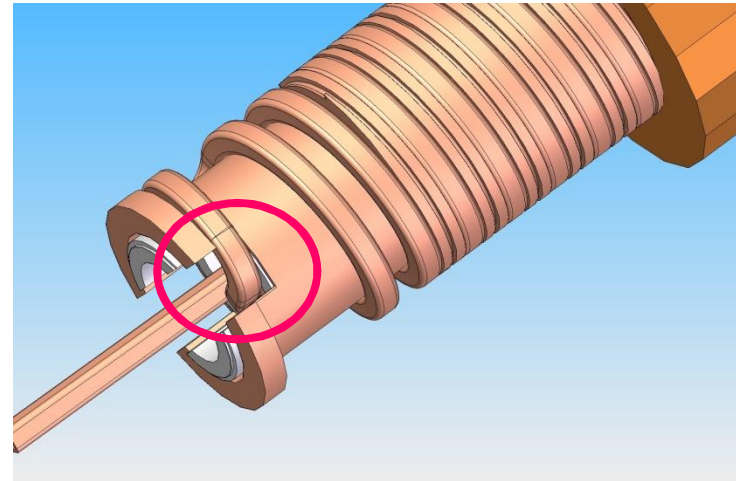
LARP

Possible Leak Locations

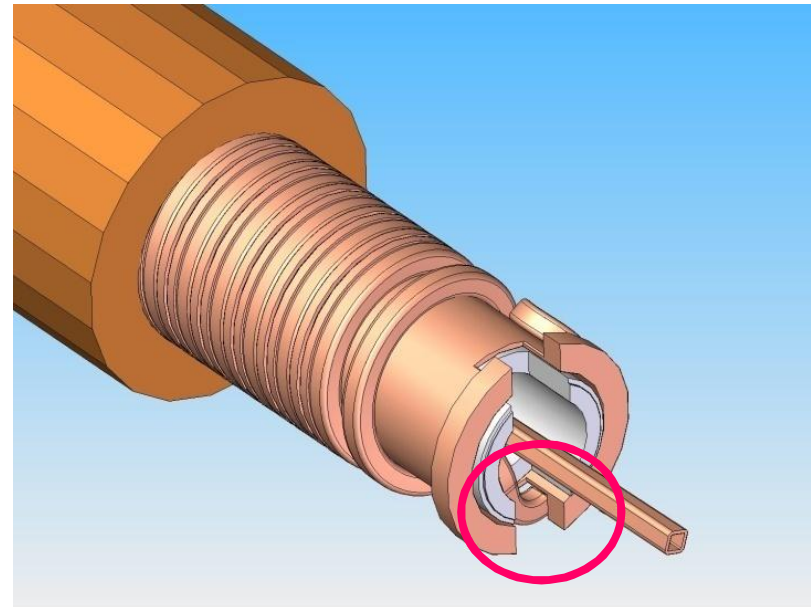
Upbeam Side of RC0 Jaw

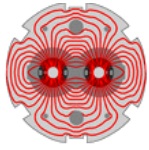


Downbeam Side of RC1 Jaw



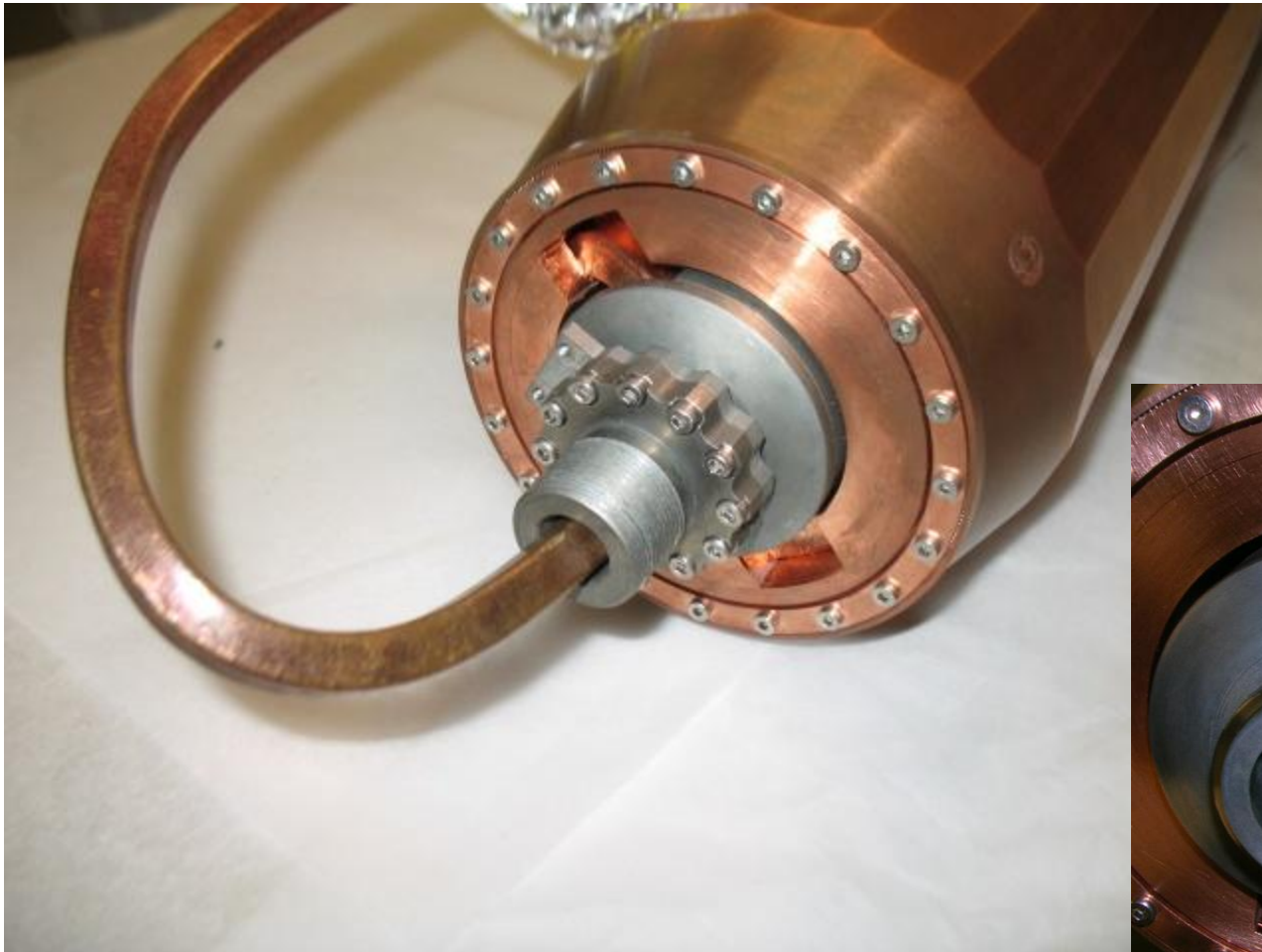
Recall that Cooling Tube Enters from Opposite Side of Jaw then Begins its Spiral around the Mandrel

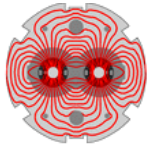




LARP

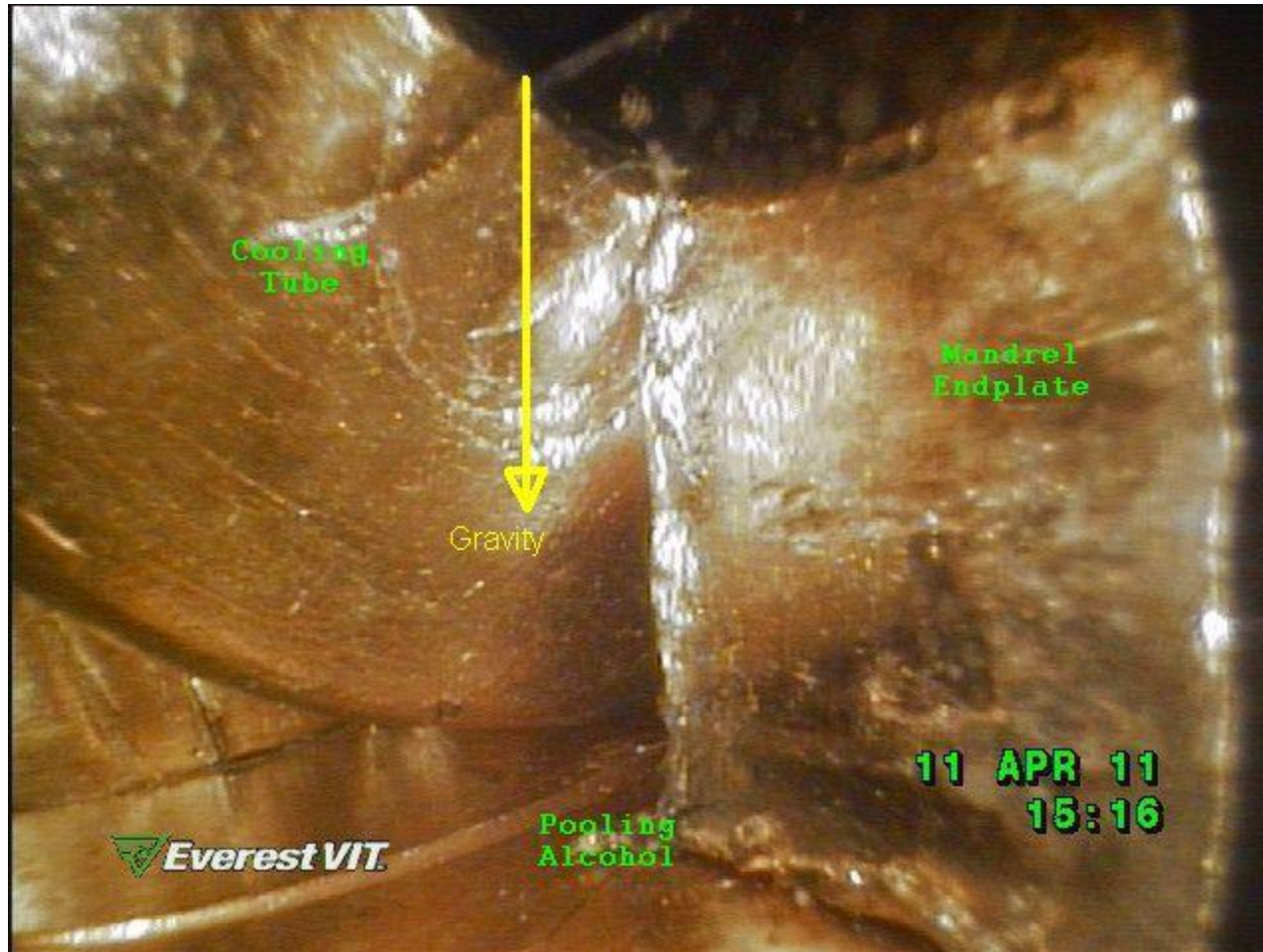
Photos of Downbeam RC1 Location

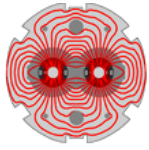




LARP

Boroscope Photo of DownBeam End of RC1

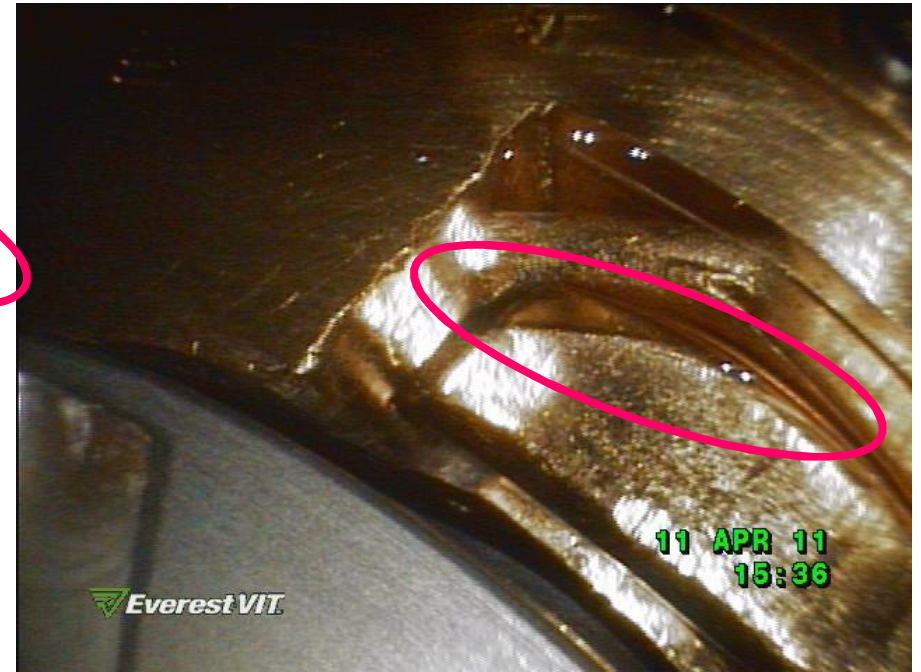
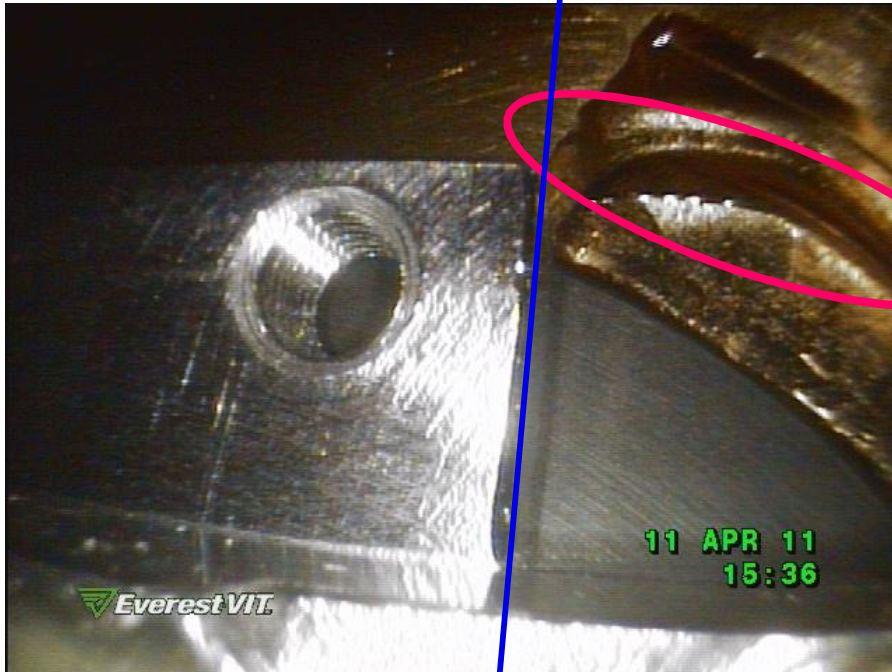




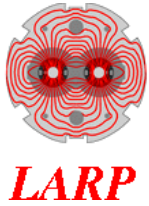
LARP

Downbeam End of RC1

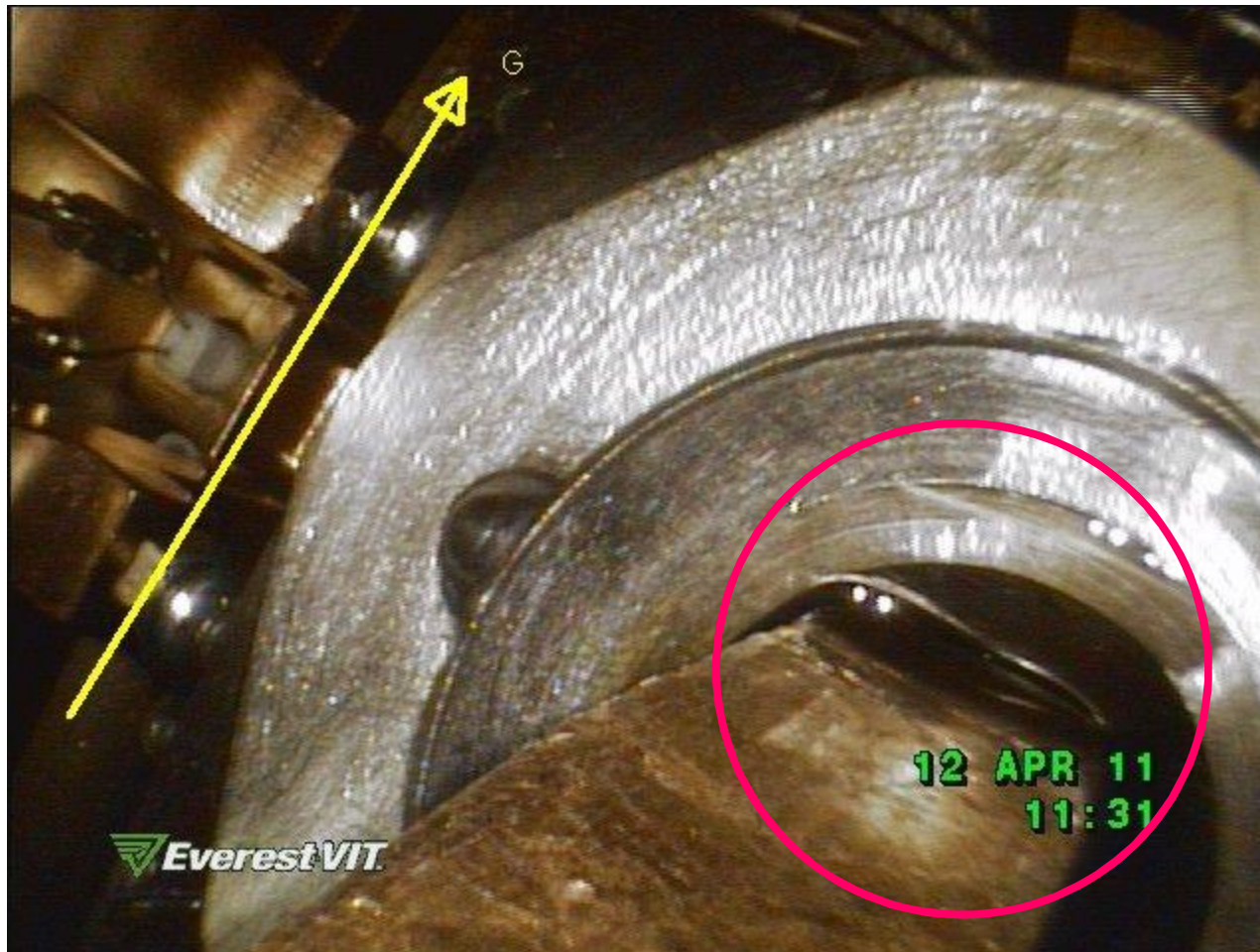
GRAVITY

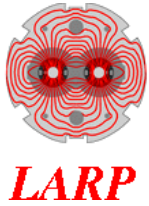


Liquid seems to be on inner surface of tube
No "crack" or "hole" visible

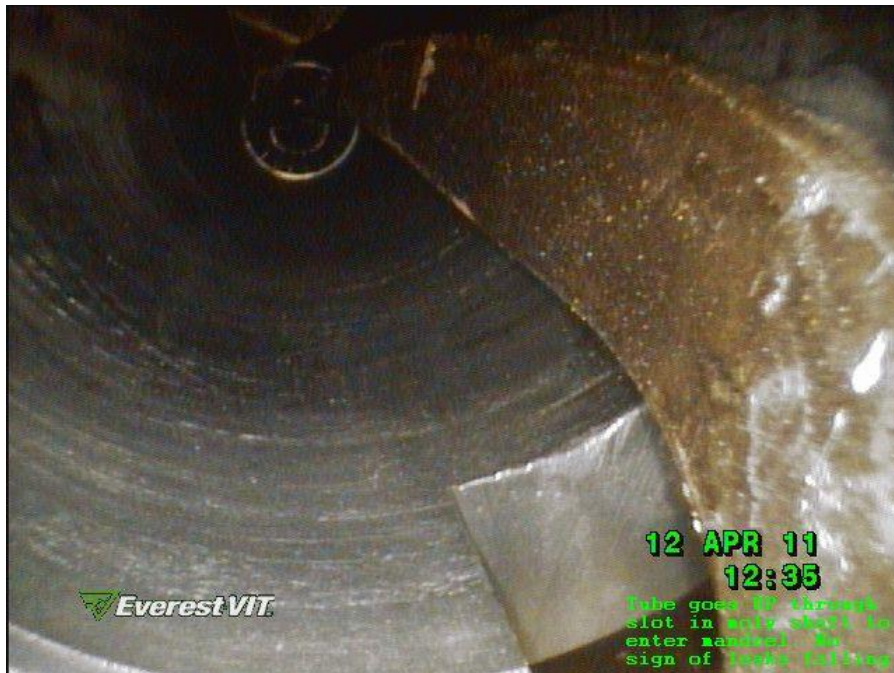


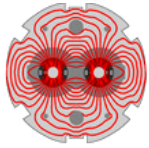
Upbeam end of RC0 Alcohol Accumulating on Tube from other end as it exits the rotation bearing housing





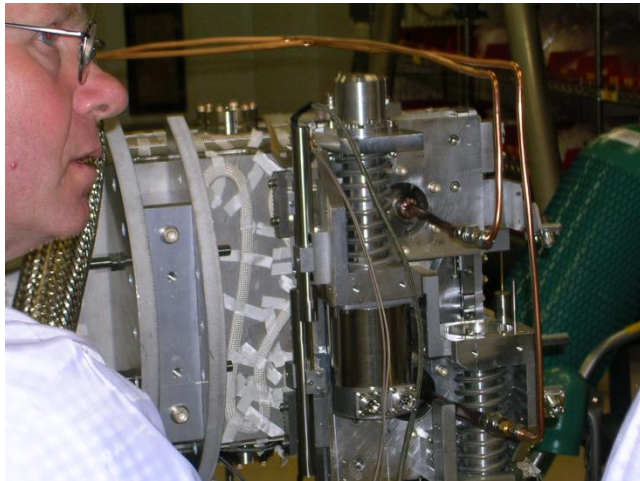
No Sign of Alcohol on Tube as it Enters Mandrel of RC0 nor on Long Runs of Tube in Center of the Mo Shaft



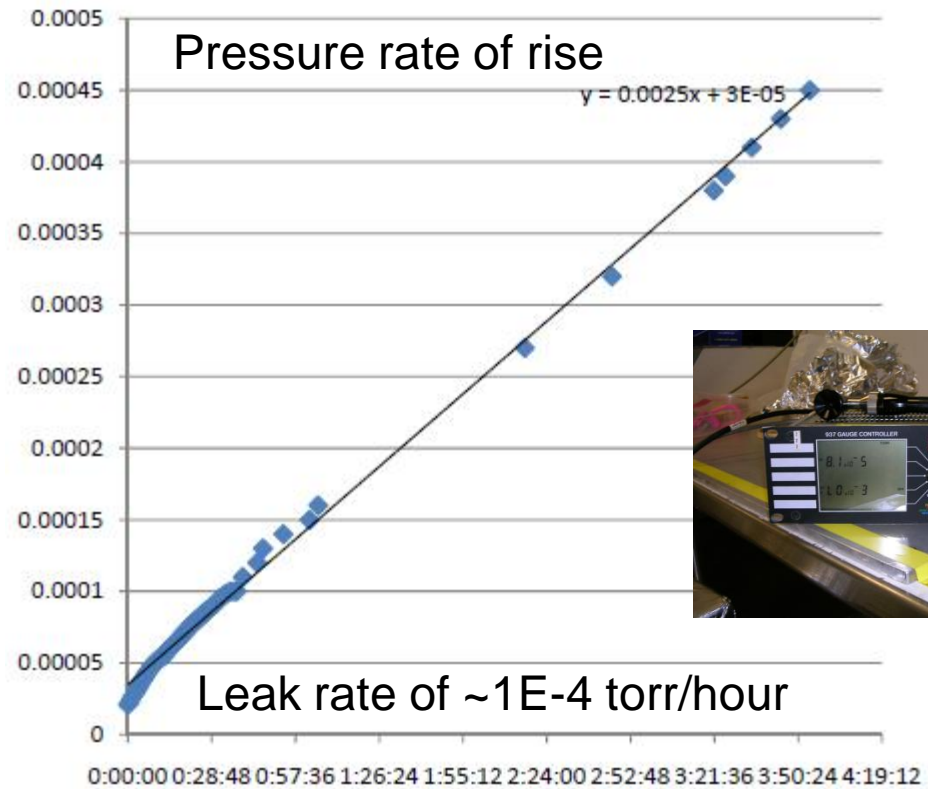


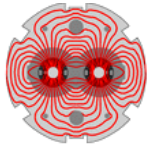
LARP

When Cooling Tubes Capped and Tank Pumped Vacuum IS Good



Pressure: 1.9E-5 Torr (via Cold Cathode Gauge)
Leak rate: 5.9E-10 mbar-l/sec (on the Adixen)

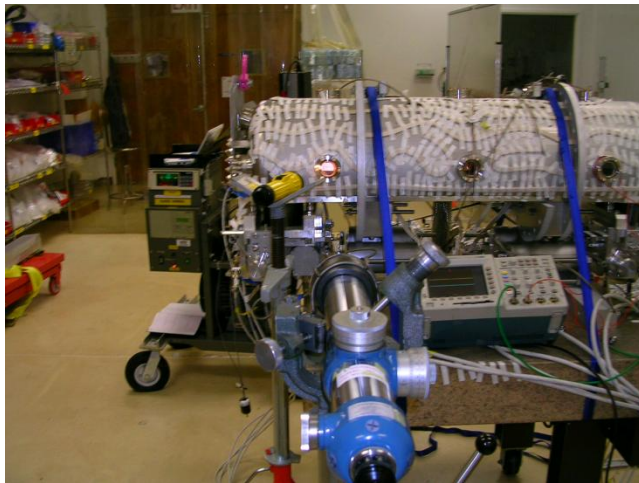




LARP

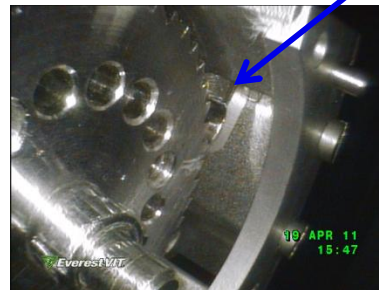
Rotation Test 3 Successful Under Vacuum (18 Apr-2011)

Alignment Via Telescope
and Scribed Lines



Pawl Alignment Post Rotation
Checked Via Boroscope
(no slippage)

RC1 Pawl



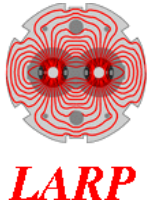
RC0 Pawl



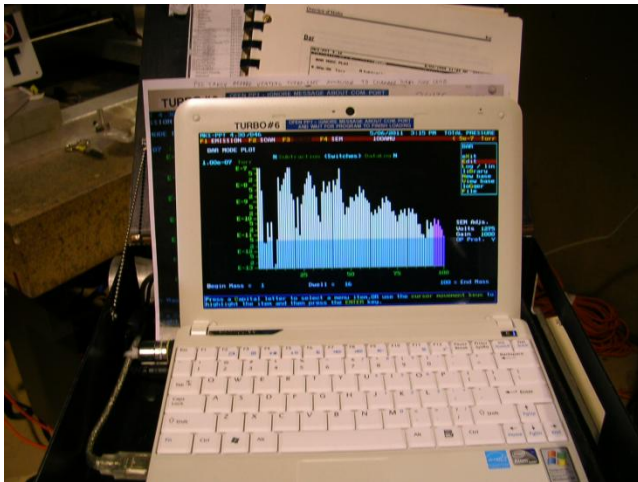
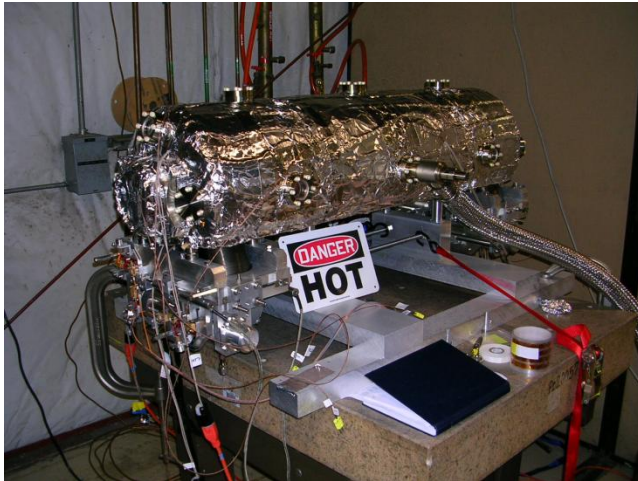
Scribed Lines



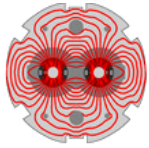
Crack in Mo Stable



Pressure and Leak Rate Good Enough to Begin Vacuum Bakeout of Vessel with Capped Cooling Coils 2011-04-29



T~240°C and P=6.1E-7 at RGA Input on 2011-05-12



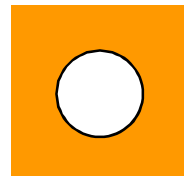
LARP

Post Mortem has Begun, but No Conclusion

I (we?) never anticipated that the cooling tubes might be subject to damage and I (we) believe that with the knowledge that they might be vulnerable this problem will not happen again.

Speculation as to cause:

- Copper grain boundary growth coupled with stress on material could result in cracks at boundaries
- Work hardening from bending
- Damage from TIG welds/brazes

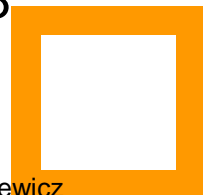


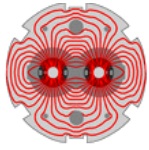
RC0 Jaw Material: SLAC in-stock magnet conductor

- OFE 102 copper: 3/8" square with 3/16" hole w/ 6 braze cycles

RC1 Jaw Material: New order from Luvata, 101 OFE COPPER F68 Class 1, w/documentation

- 10mm square w/ 7mm square hole; 3 braze cycles





LARP

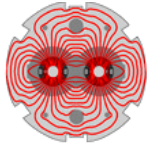
Metallurgy: Samples to IMR Labs

“Large non-equiaxed grains consistent with hydrogen annealed OFE copper. Porosity was rated per ASTM F 68 Plate 1. Porosity was observed within and across grains.



“The samples conform to **ASTM F68 Metallographic Class 4 for porosity** resulting from oxygen contamination.”

* Material purchased as Grade 1 OFE with test data sent by manufacturer



Furnace Runs to try to Duplicate Problems

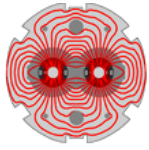
LARP Bent & Straight Samples



Straight Sample on Braze Oven Stand

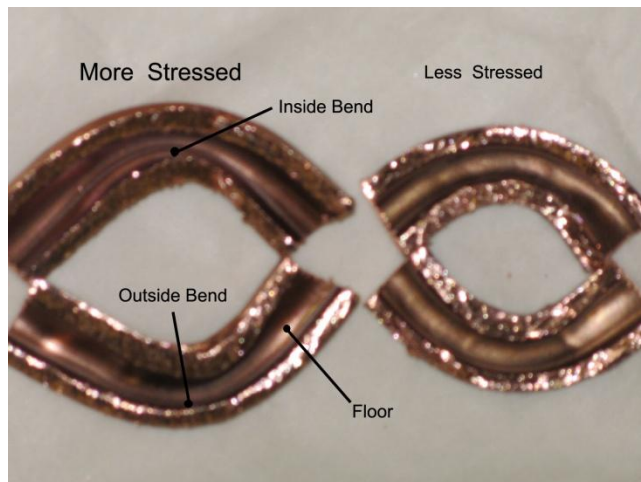
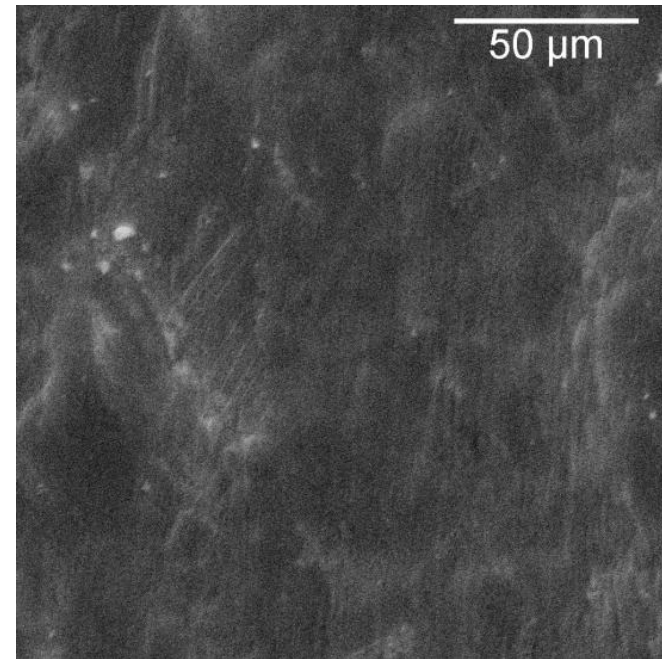


32# Tungsten Block to Provide Stress

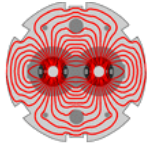


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Sectioned Bends & SEM of Material Stressed by Bending



No Conclusions



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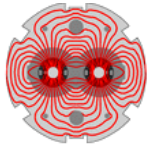
Status & Plan Going Forward

Prototype RC finished

- Jaws cannot be cooled
- Overall volume will soon pass SLAC/CERN vacuum requirements
 - In 2nd of ~3 week bake
- All mechanical tests look good
 - Will need to do a last test rotation in vacuum after the bake

Plan: TBD

- Preferred
 - Ship to CERN asap
 - Lab tests at CERN: Impedance, mechanical, vacuum, metrology
 - Install without cooling in SPS for operation & impedance tests
 - Install in HiRadMat test beam for destructive tests
 - But integrity of water circuit under shock untestable
- Other choice: dissect & destroy at SLAC
- More HW?: 2nd prototype, 2nd HiRadMat test device, different design,...



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Thermistor & Tank Rotation Hardware

