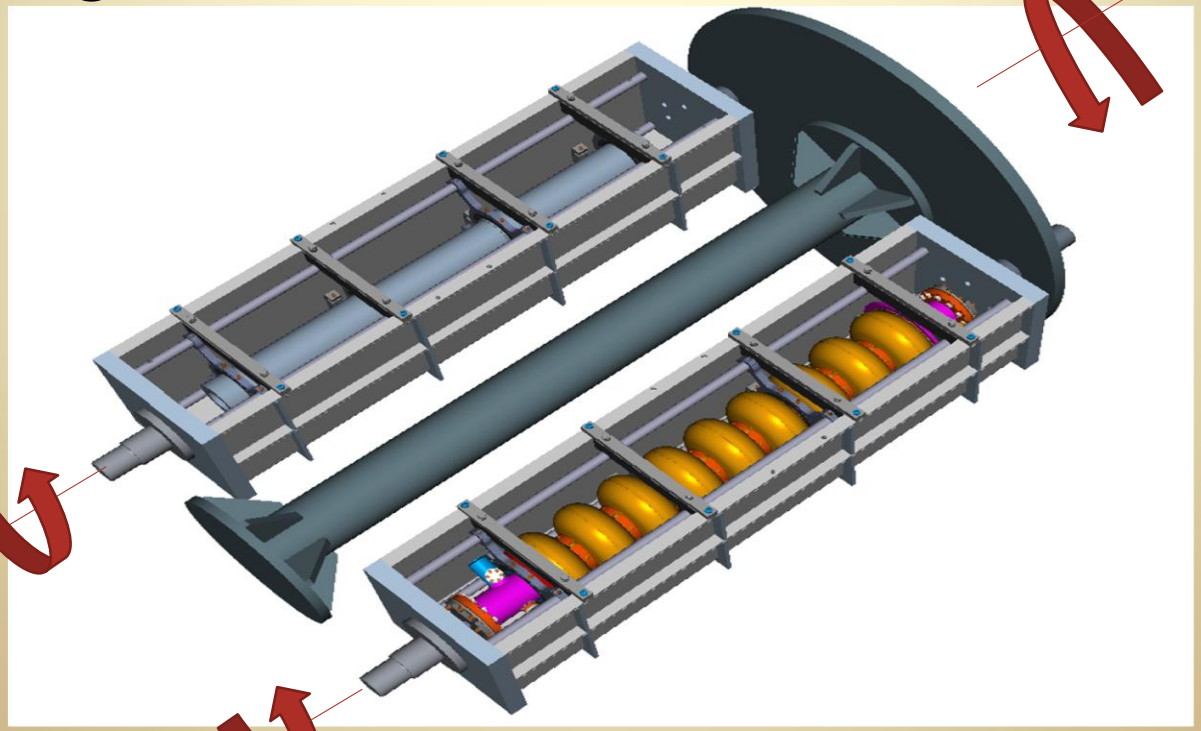
Mechanical Polishing of 1.3 GHz Niobium Cavities

TESLA Technology Collaboration Meeting
February 28 – March 3, 2011
Milano, Italy

Centrifugal Barrel Polishing (CBP)

CBP is a mechanical polishing process in which the inside of the cavity is filled with abrasive material and then rotated at high speeds.

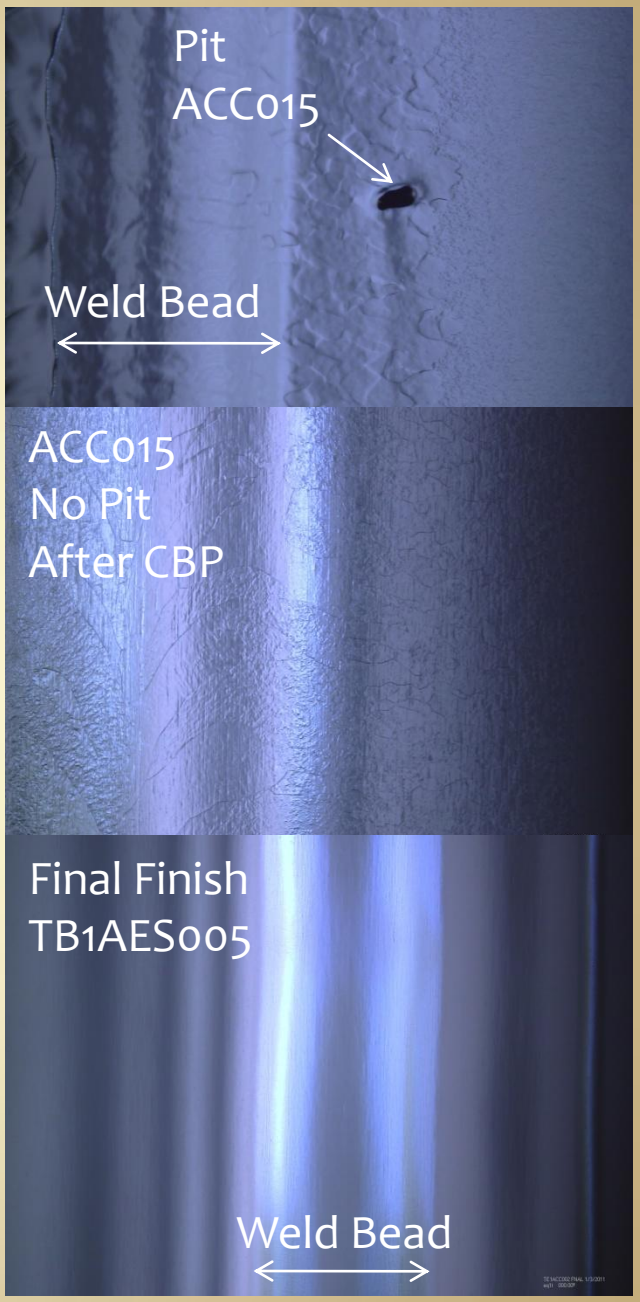
Main Shaft up to 115 RPM



Individual Barrels 115 RPM in opposite direction to main shaft

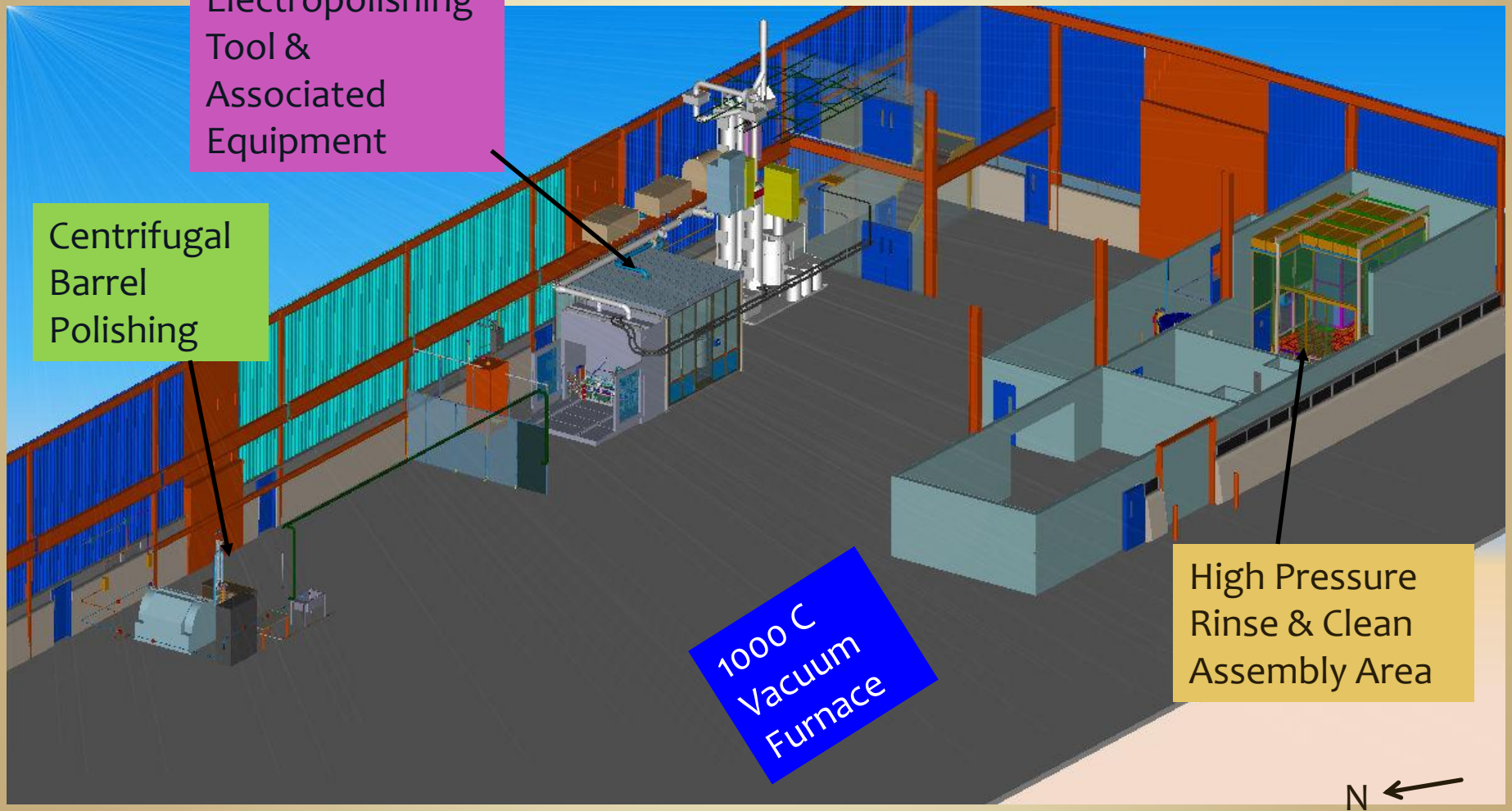
Why do CBP?

- Uniform Surface Finish
  - Remove weld beads and associated defects created from E-beam welding.
- Smooth Surface Finish
  - (Ra) on the order of 10s of nanometers. Best by EP alone is around 100 nanometers.
- Environmentally Friendly.
  - Most likely will still require a small amount of chemistry(on the order of 5-10 microns compared to 120 microns for EP)
- Potential for cheaper installed & operating cost
- Repair of pit defects that chemistry can't remove
- Simple Technology
  - Should prove to be a very repeatable process
  - Easy transfer to industry



Location of Centrifugal Barrel Polisher – IB4

General Layout of Integrated Cavity Processing Apparatus & CBP



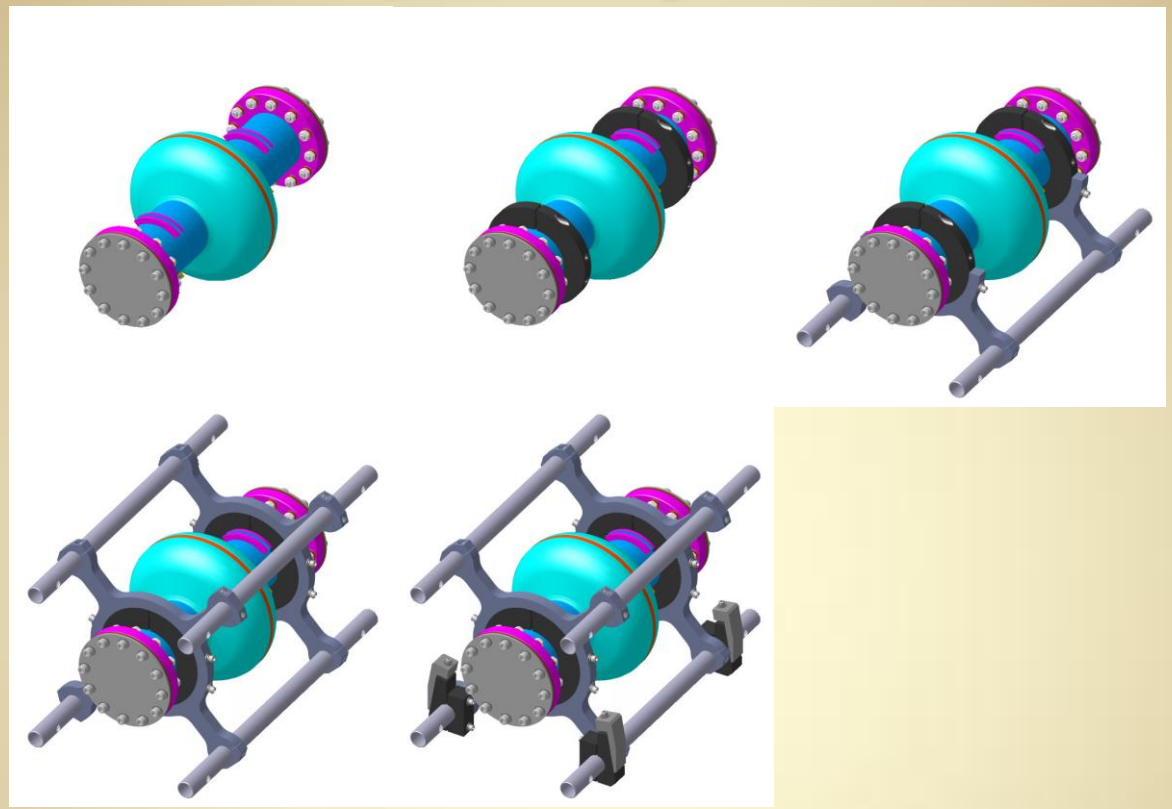
Centrifugal Barrel Polisher & Rinse Station

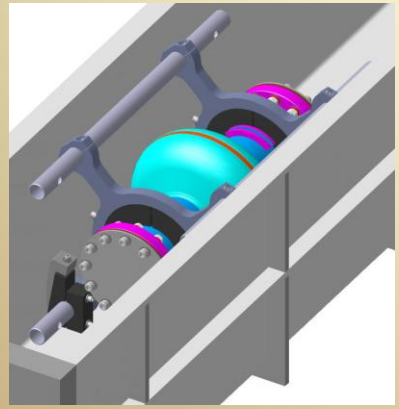
Processed so far:
Two 9- Cell Tesla Type Cavities
Eight 1-Cell Tesla Type Cavities
Two 1-Cell 3.9 GHz Cavities

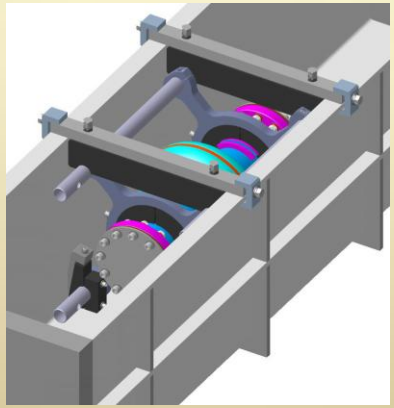
Currently Processing:
2 9-Cell Tesla Type Cavities Concurrently

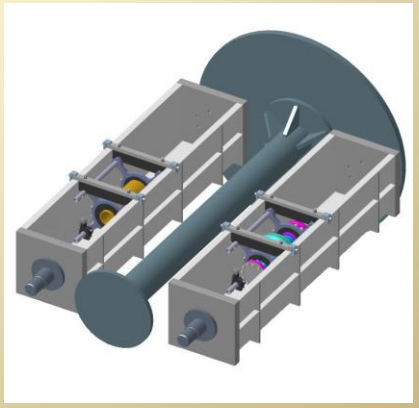
Probably Next for Processing:
4 9-Cell Tesla Type Cavities with Pits
1 Single-Cell Tesla Type Cavity
2 Coupon Cavities
& hopefully 1 re-entrant cavity

Cavity Preparation

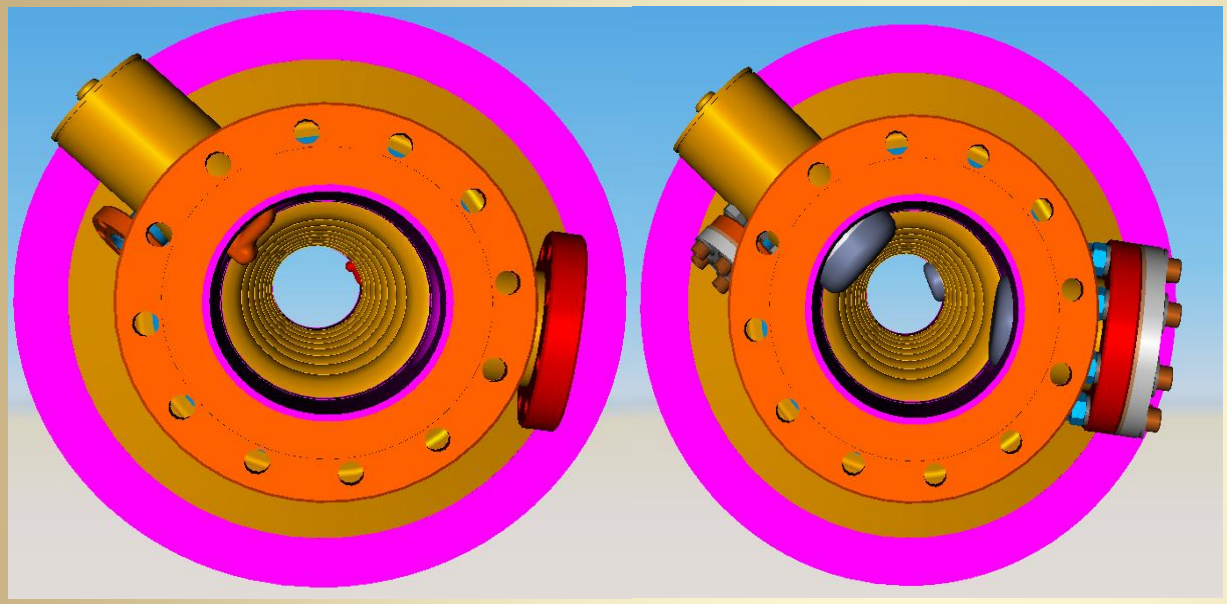


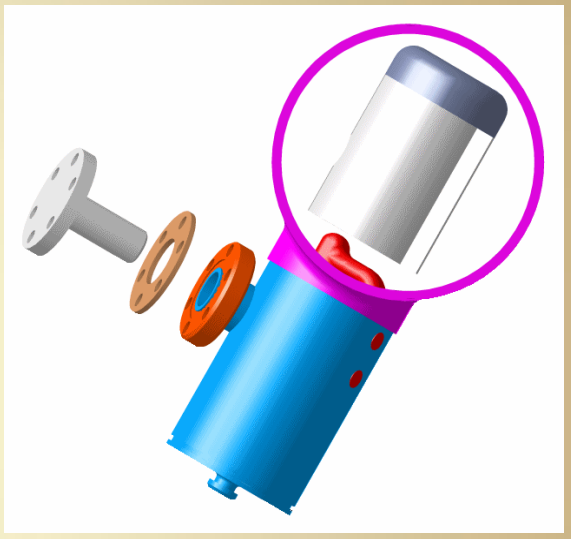


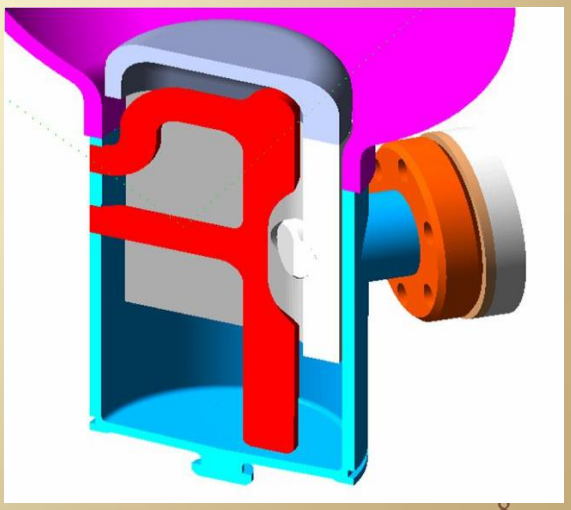




9 Cell Cavity Tumbling







- HOM Can Must Be Protected or the Antenna Would be Destroyed.
- Caps are Made From Niobium to Avoid Contamination.

Current Media

Step 1

Cutting, Time as needed

+ Soap & Ultrapure Water

Removal Rate – 11 um / hr

Step 2

Intermediate Polishing, 12 hours

+ Soap & Ultrapure Water

Removal Rate – 3 um / hr

Step 3

Intermediate Polishing, 15 hours

Water + 400 Mesh Alumina

Step 4

Intermediate Polishing, 20 hours

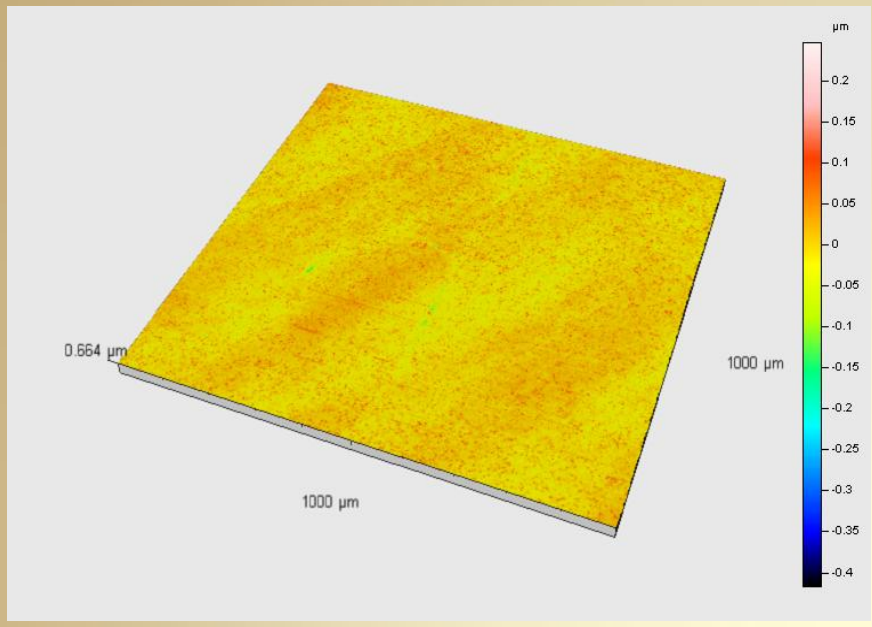
Water + 800 Mesh Alumina

Step 5

Final Polishing, 40 hours

Removal rate of final 3 steps is hard to measure, but not nearly as much as 1st 2 steps

Results- Mirror Like Surface



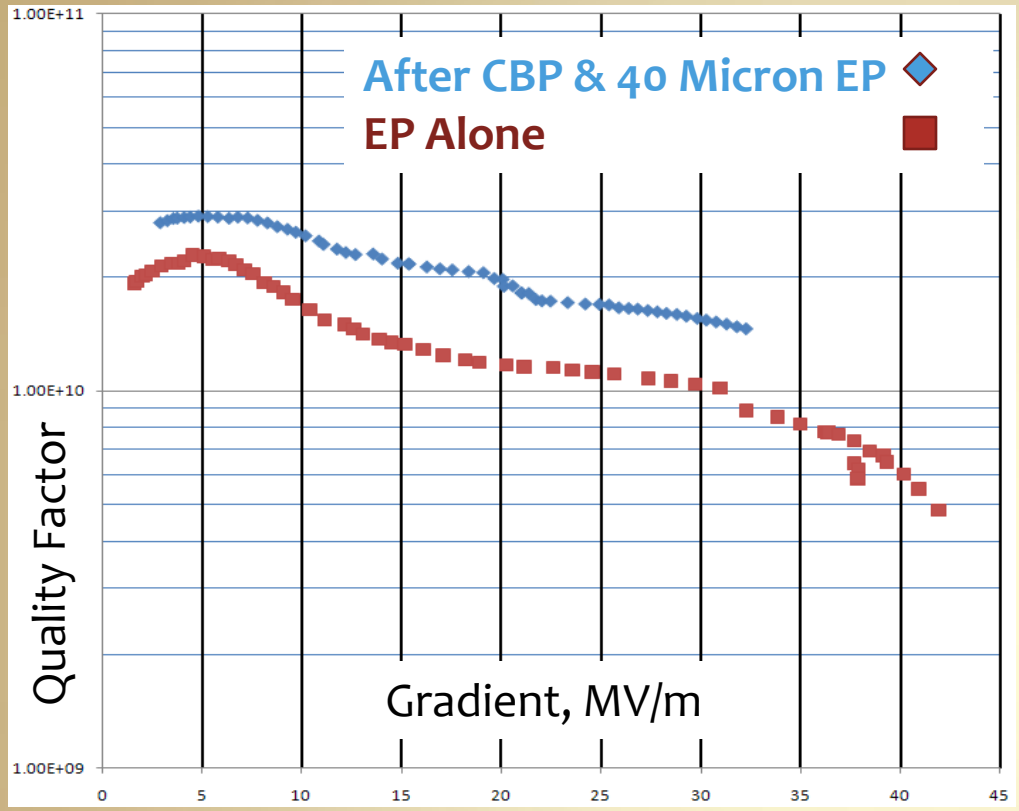
Single Cell Polished to Mirror Finish

Ra = 0.0139 µm +/- 0.00216 µm
Rz = 0.139 µm +/- 0.0242 µm

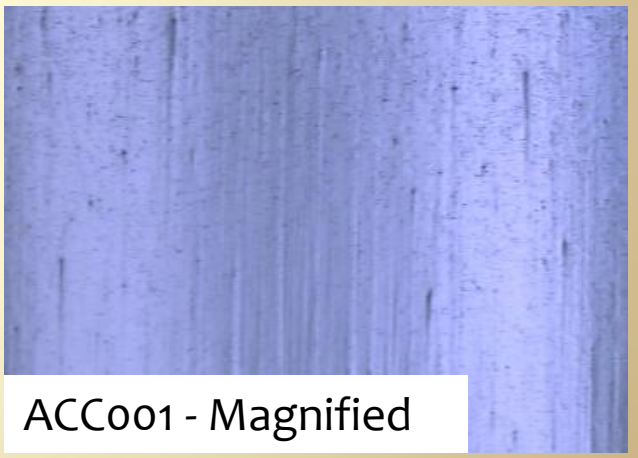
Typical finish achieved by fine polishing.

Notice reflection of graph paper and writing →

Results – ACC001

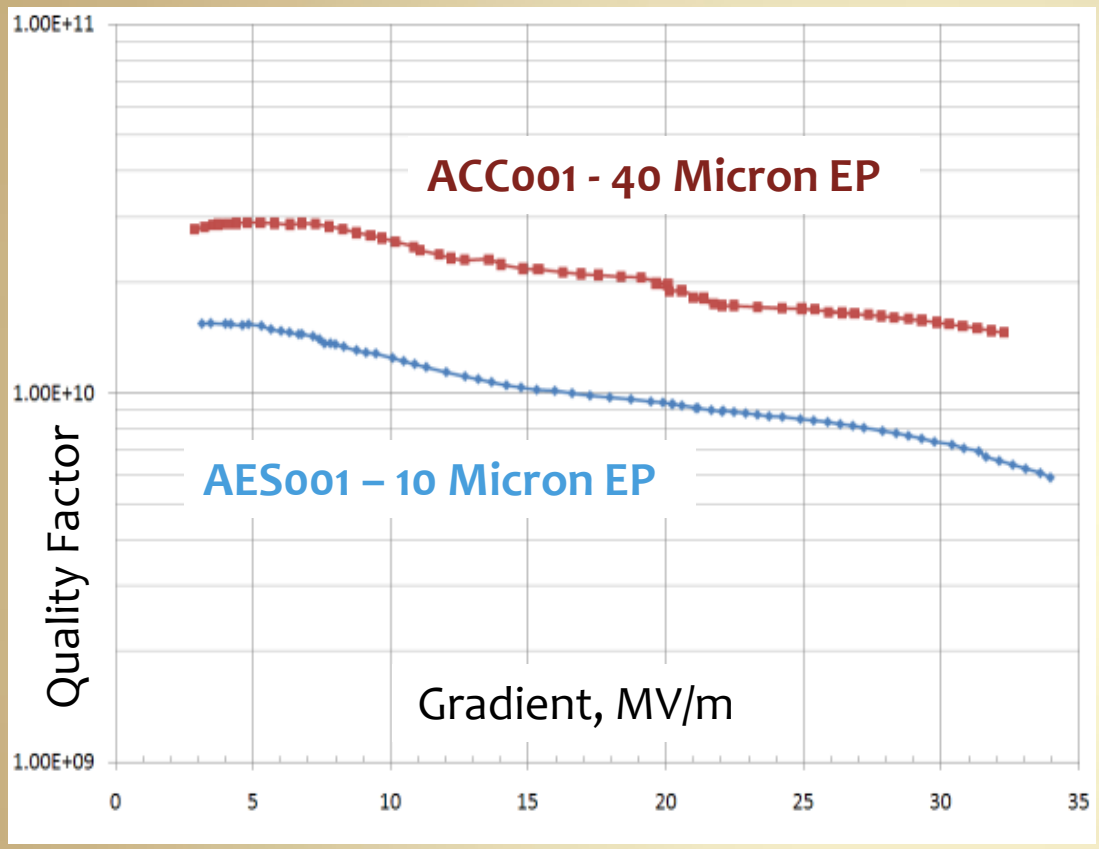



ACC001


ACC001 - Magnified

First cavity processed with colloidal silica tested worse that processing by EP because the first polishing step was 5 hours instead of 12, leaving **imbedded media** in the cavity

Results AES005

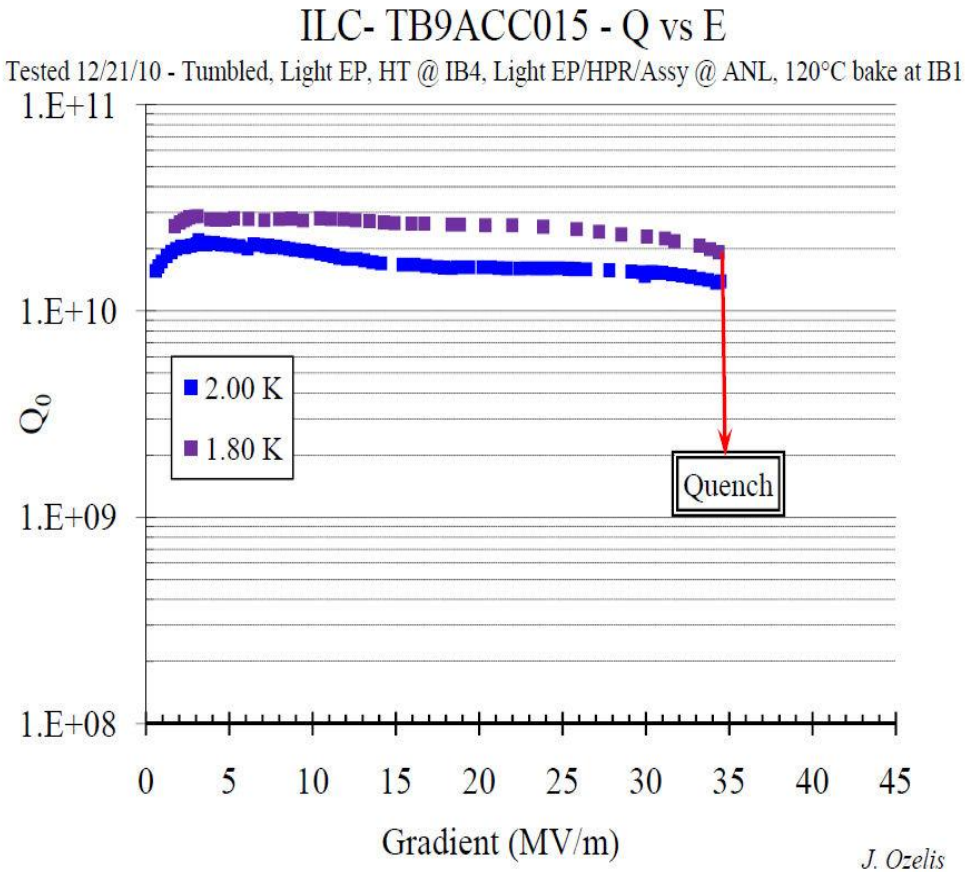


AES005 After CBP

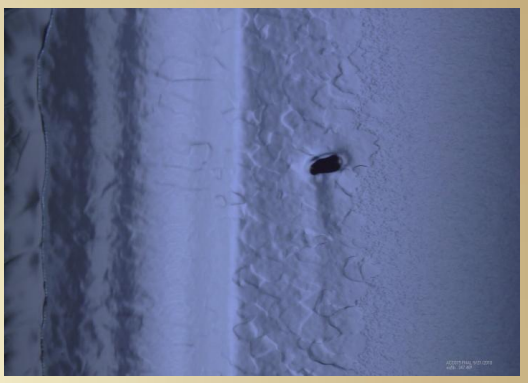
AES005 After 10 Microns EP

It is probable that the contamination layer is more than 10 microns deep and more EP is needed for AES005.

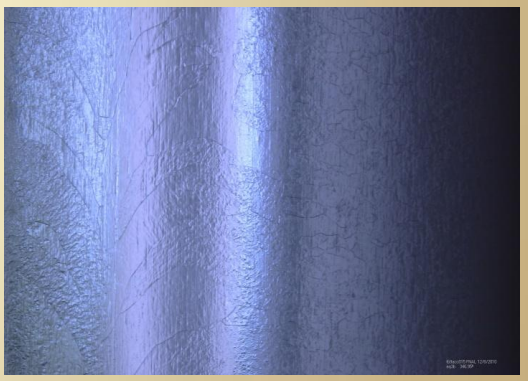
Results – Pit Repair



Had a large (~200micron) pit in cell 3 – previously processed and tested at JLab to 19 MV/m

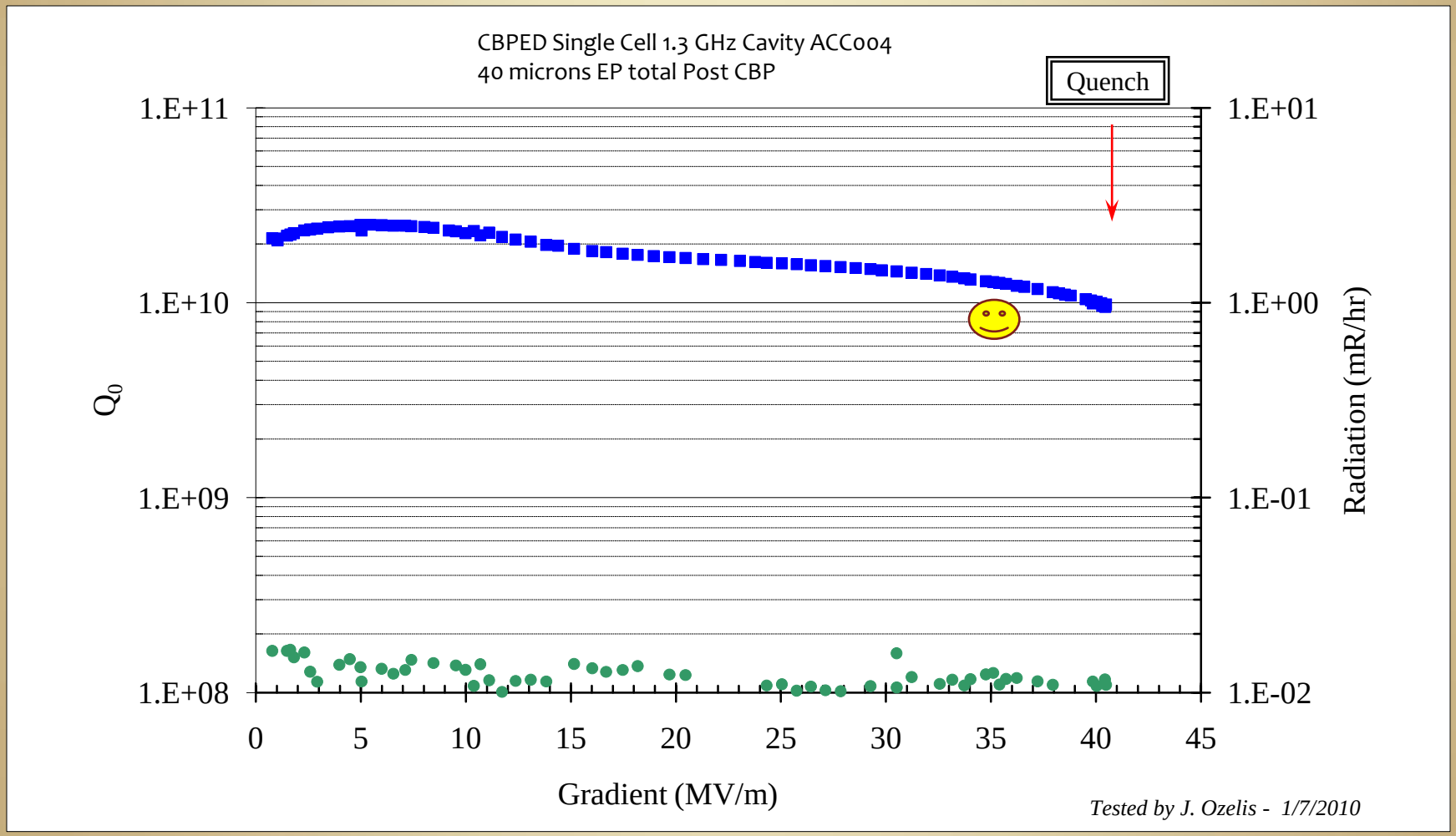


Before CBP

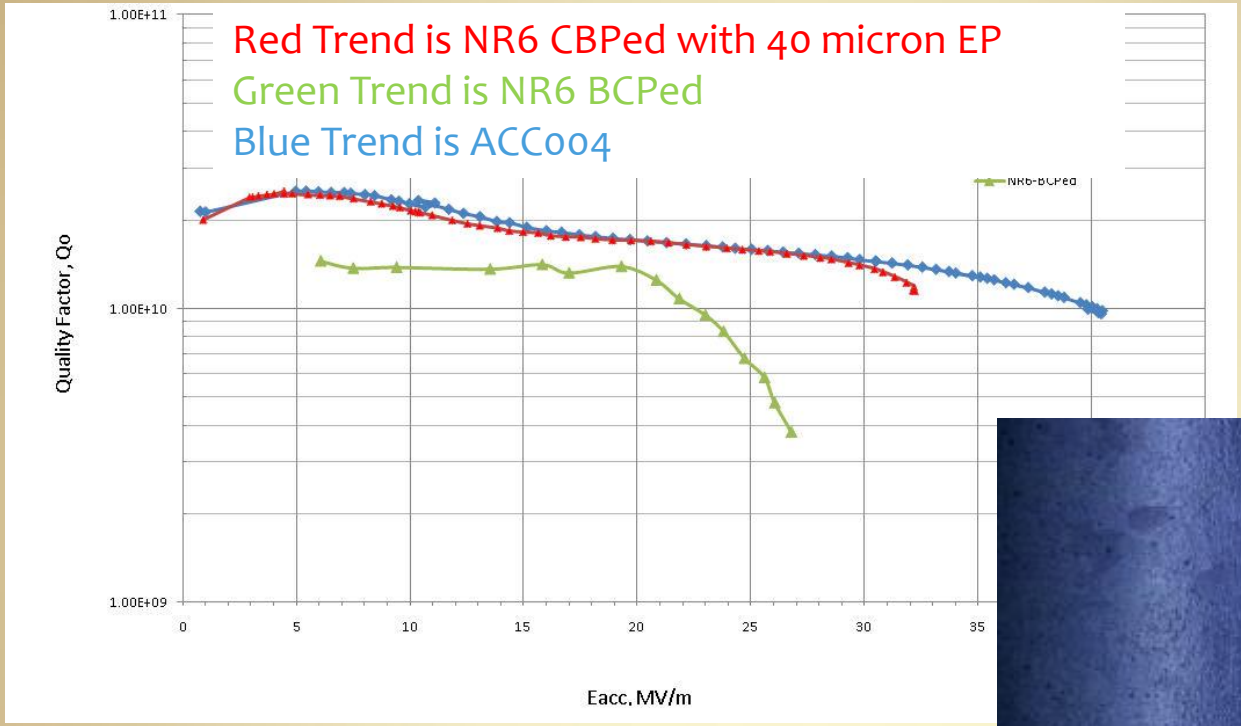


After CBP and 40 microns Ep

Results - Single Cell Cavity ACC004



Results - Single Cell Cavity NR6



NR6 and ACC004 have similar Q vs. E trends until 30 MV/m and were processed with completely different medias.

NR6 was tested after tumbling and reached as high as any of the other 6 single cell cavities from Niowave/Roark from that lot.
Weld bead was successfully removed but surface shows general pitting after processing.

Results RRCAT2 Single Cell Performance

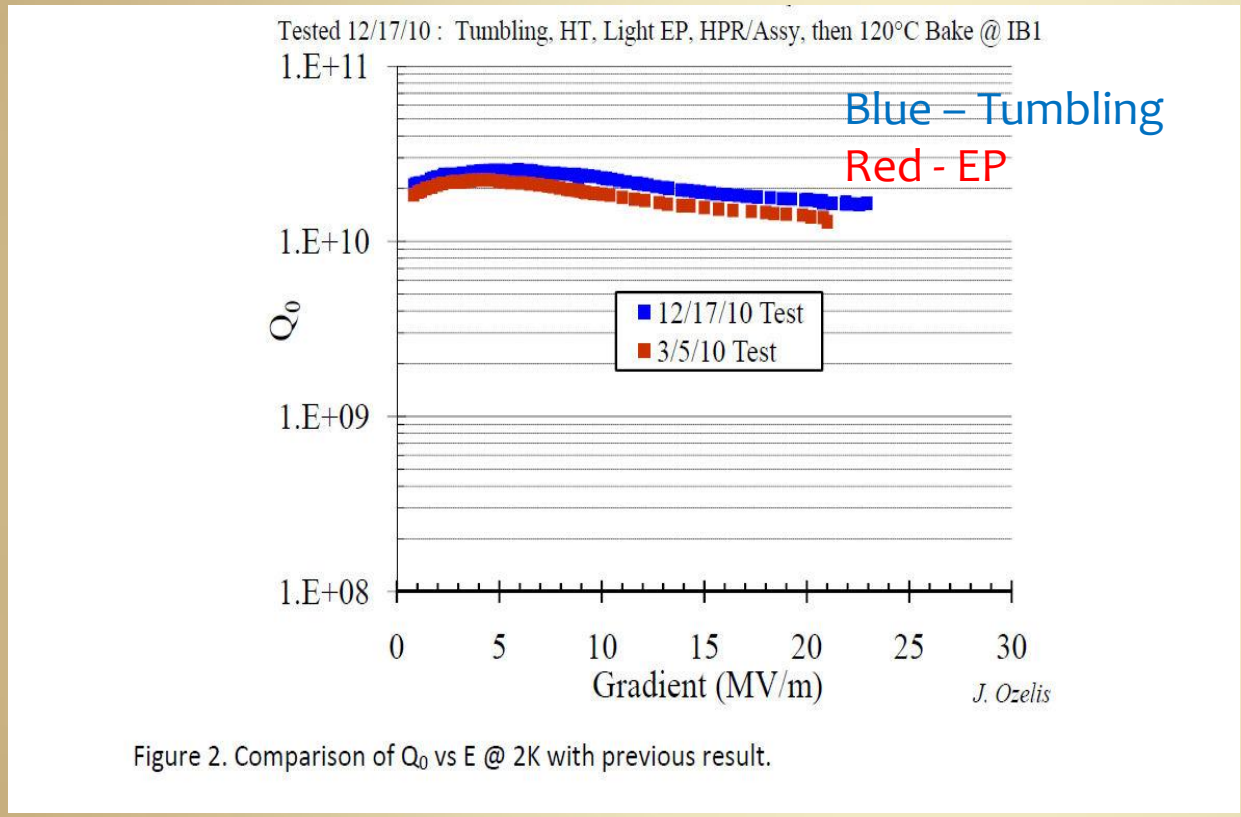
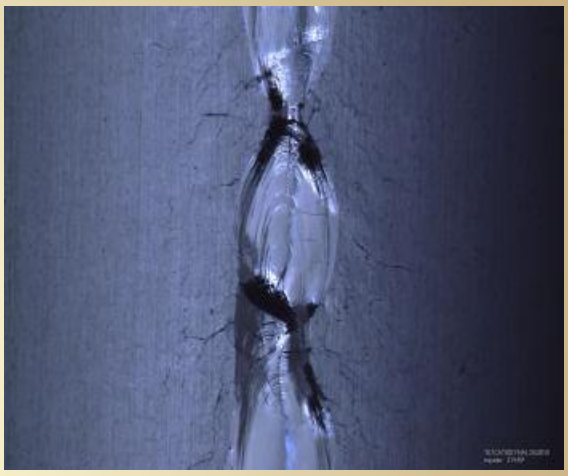


Figure 2. Comparison of Q_0 vs E @ 2K with previous result.

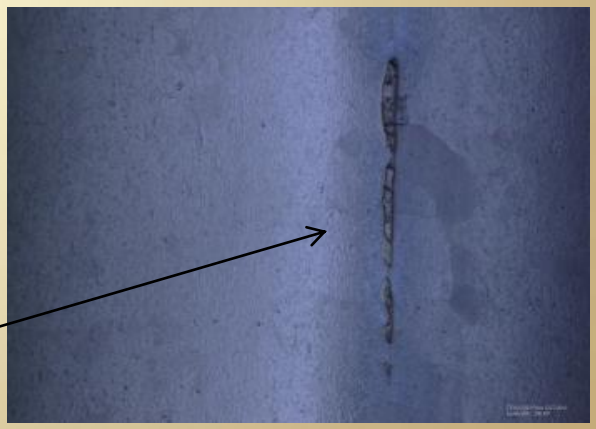
Blue – Tumbling

Red - EP



Irregular weld

Voids in weld by x-ray

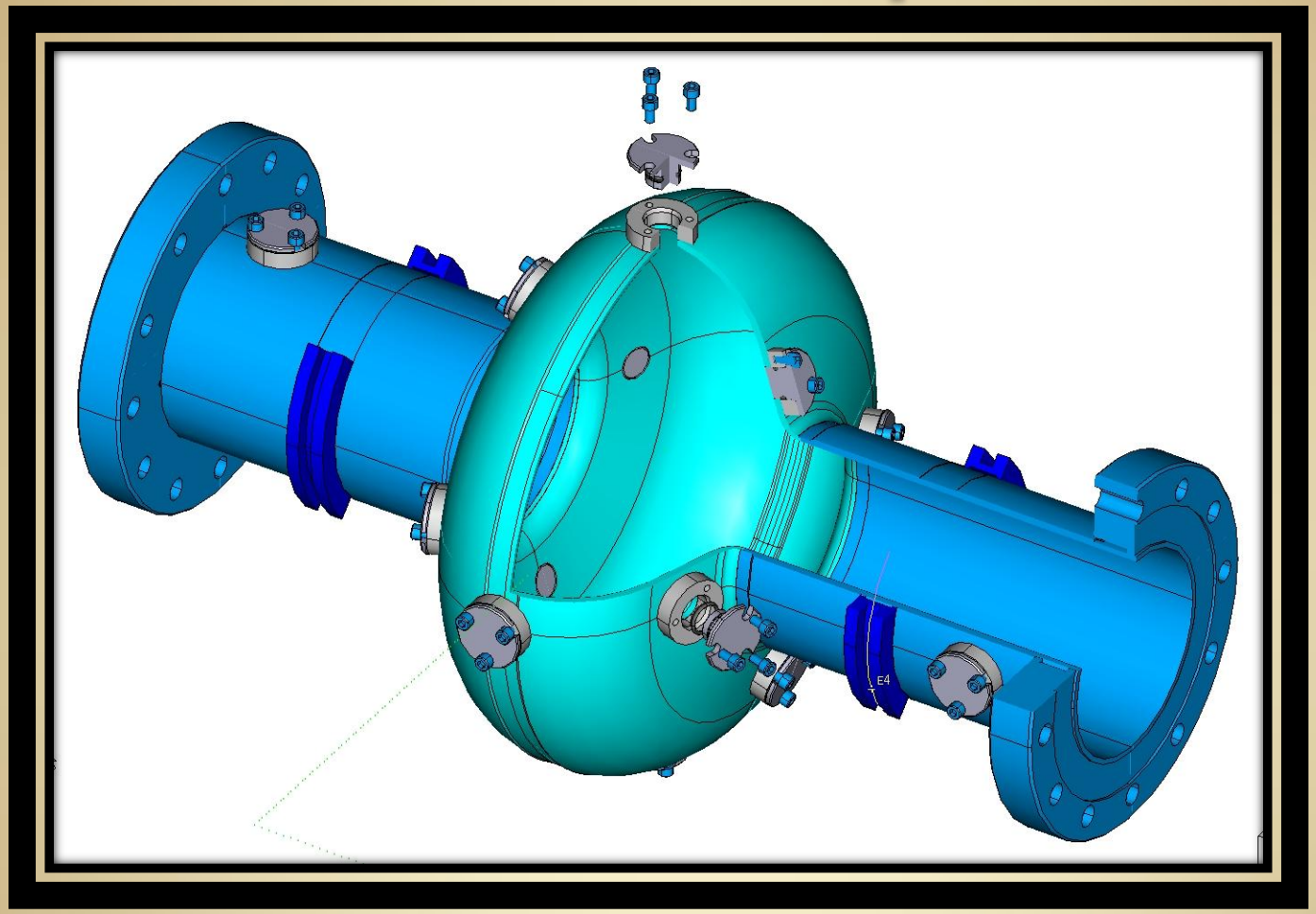


After Processing Still Large Areas of Weld Bead Not Removed

Conclusions & Future Plans

- Conclusions
  - Preliminary R&D on CBP has identified a process that can yield mirror like finishes
  - Between 40 and 20 microns of material still need to be removed by chemistry.
  - Further work need to be done to perfect the CBP procedure.
- Future Plans
  - Use coupon cavity to fine tune CBP process.
  - Hopefully process re-entrant cavity to mirror finish in collaboration with Cornell.
  - Correlate Ra to cavity performance.
  - Evaluate amount of chemistry needed after CBP.
  - Prepare single cell cavities for thin film studies.
  - Examine processing 650MHz cavities

Future Plans - Coupon Cavity



- With the use of coupon cavities perfect process.
  - Use Surface Profilometry and SEM/EDS to determine the average surface roughness and chemical contamination present after each step.

Acknowledgements

- Cavity Testing
  - Joe Ozelis
- Centrifugal Barrel Polishing Operation
  - Dave Burk
  - George Steuer
- Baseline Cavity Processing
  - Brent Stone
  - Jim Folkie
  - Damon Bice
- Optical Inspection
  - Evgeny Toropov
  - Dmitri Sergatskov
- Kenji Saito for communications and information about the CBP process.
- Camille Ginsburg for help in general.