Development of Superconducting RF Multi-Spoke Cavities for Electron Linacs

Contract DE-FG02-08ER8585172

Terry Grimm

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Outline

- Collaboration
- Concept
- Scientific justification
- Design
  - electromagnetic
  - mechanical
- Fabrication
- Current testing schedule and plans

Collaboration Partners

This project is done in collaboration with Old Dominion University (ODU) and with Thomas Jefferson Laboratory (JLab), particularly with Prof. Jean Delayen.

The funding is provided by the DOE SBIR program under the contract # DE-FG02-08ER8585172.

Concept of the Multi-Spoke Cavity

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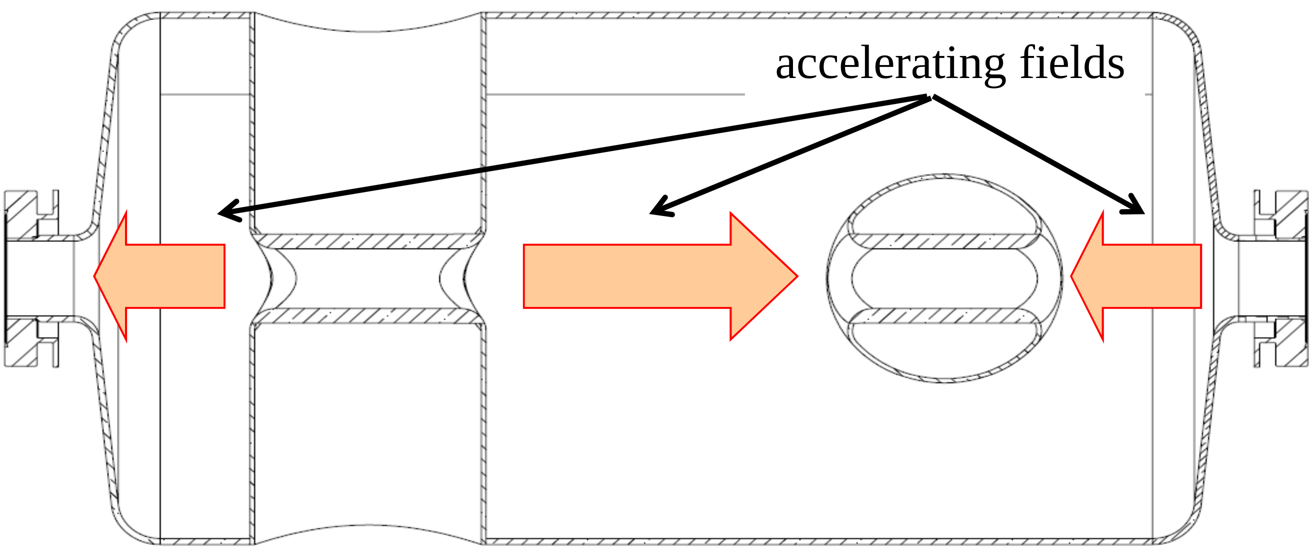
- The electric field between the spokes and between the spoke and the end-plate is used for acceleration of the beam.
- Particles are synchronized with the alternating RF wave so that they see acceleration in each of the three gaps.
- Single- and multi-spoke cavities have been successfully used with heavy ions, but this project will be the first multi-spoke cavity to accelerate electron beams.



Scientific Justification

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- Why 500 MHz
  - Reduced cryogenic losses at lower frequency
    - Commercial 4.2 K cryoplant
  - Compact structure that is more resistant to vibrations (microphonics) compared to the traditional elliptical ILC-type cavities
  - Commercial, CW microwave sources available
    - 90 kW IOTs
    - 1 MW klystrons

Multi-Spoke vs Elliptical

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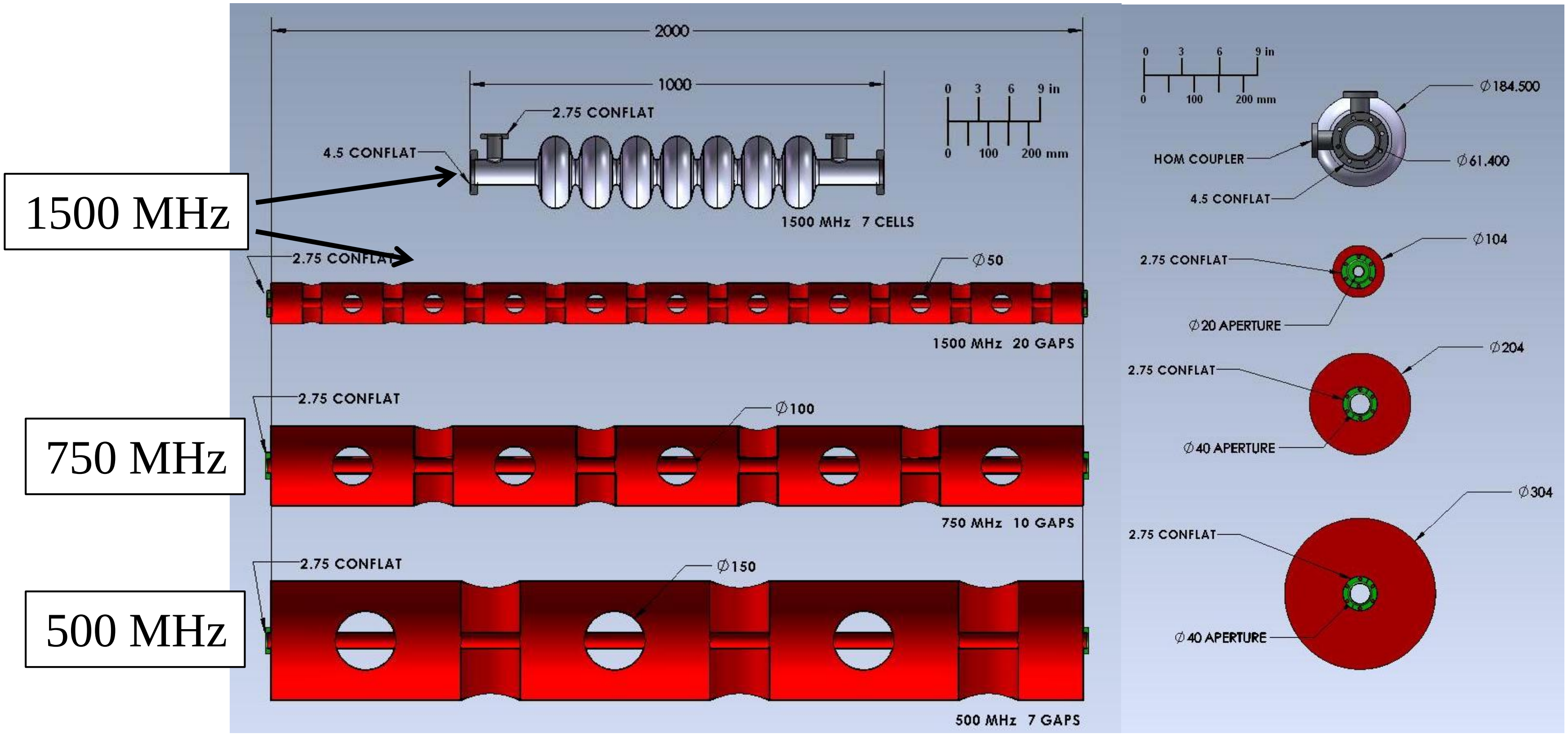

- The multi-spoke cavity is significantly more compact than an elliptical cavity at the same frequency.
- The operating frequency can then be reduced without sacrificing “real estate gradient” and benefit from the 4.2ºK operating temp.

Alternative EM Designs

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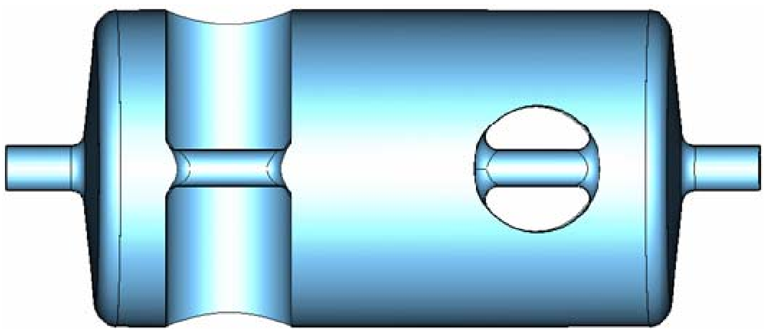

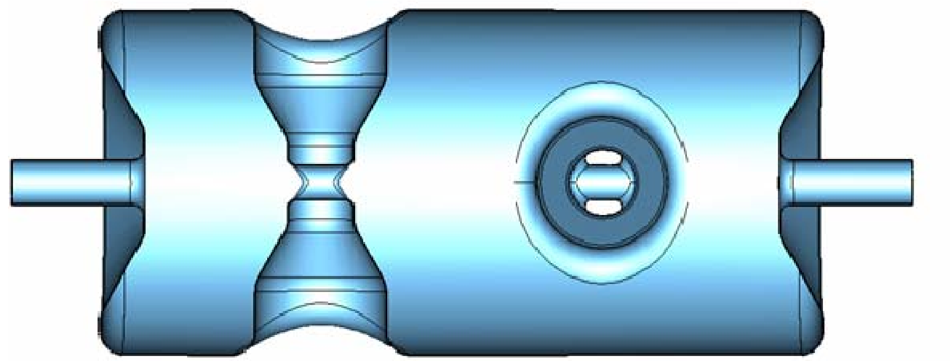

“Basic” EM Design

- Simpler for fabrication, better suited for prototype
- Lacks the performance of the “advanced” option

“Advanced” EM Design

- More complicated for fabrication
- Higher accelerating fields lead to savings for the mid-to-large scale project where R&D costs are spread out over many cavities

Prototype "Basic" EM Design

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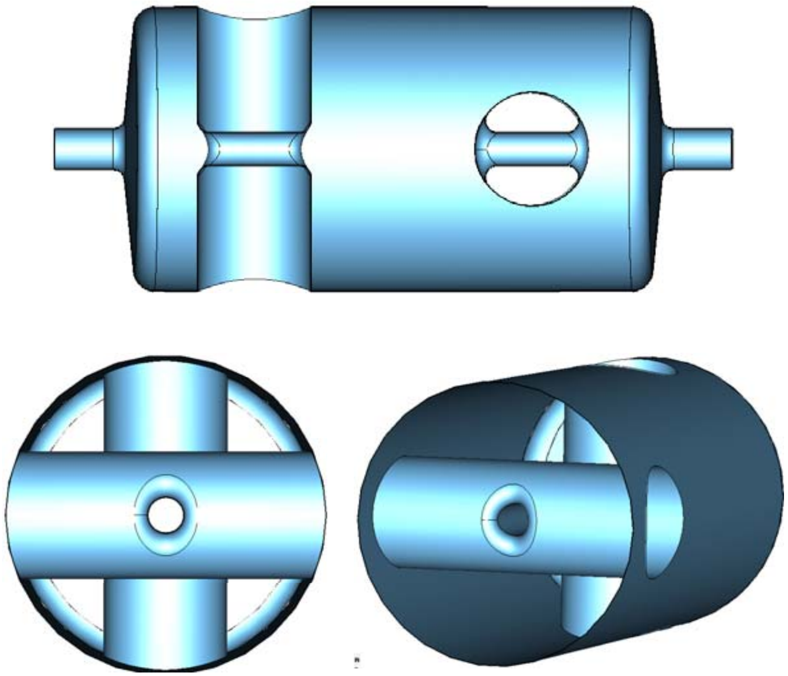
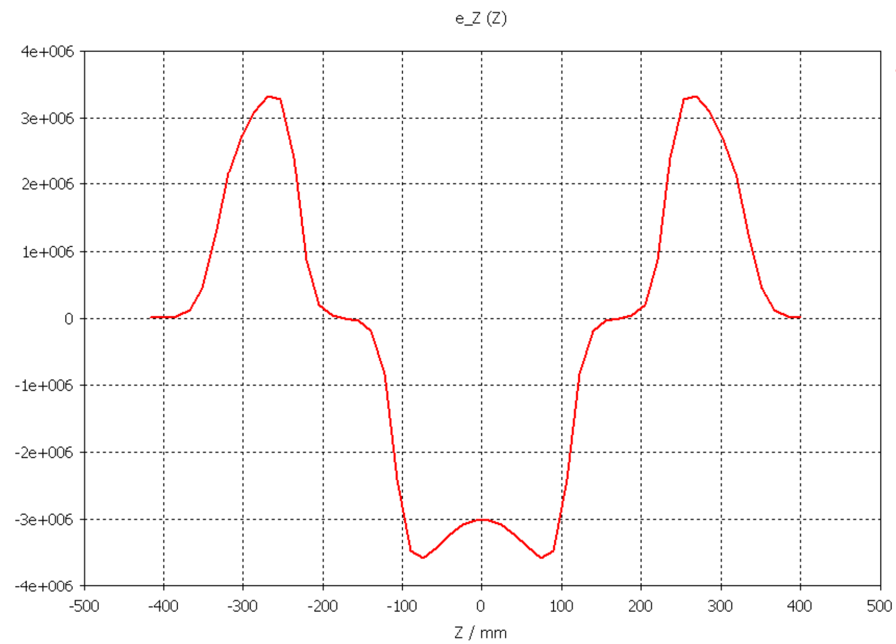
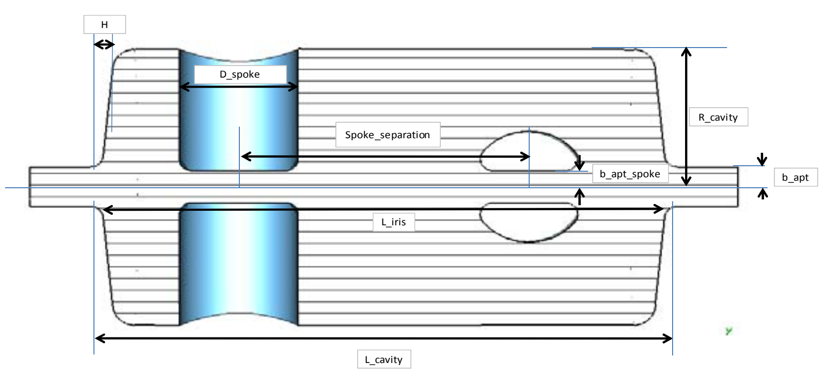
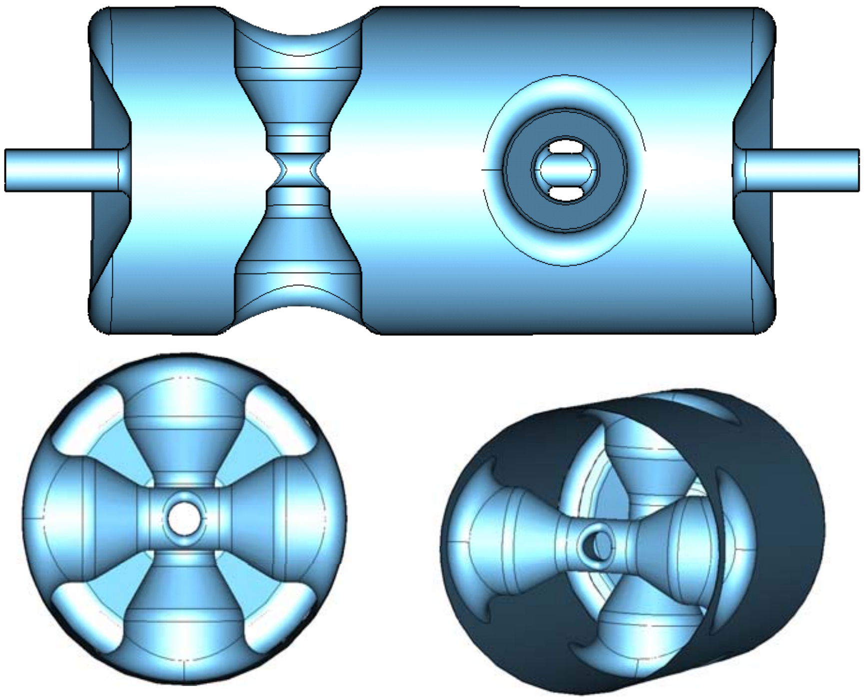


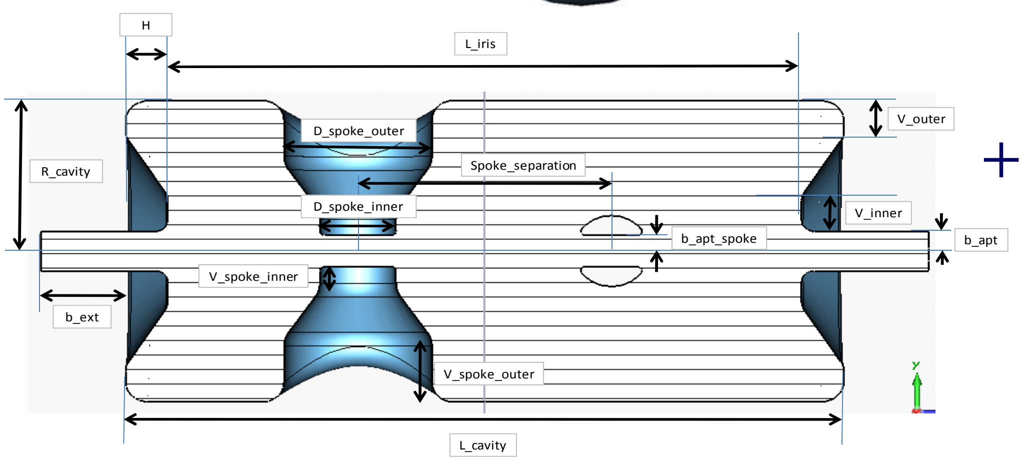


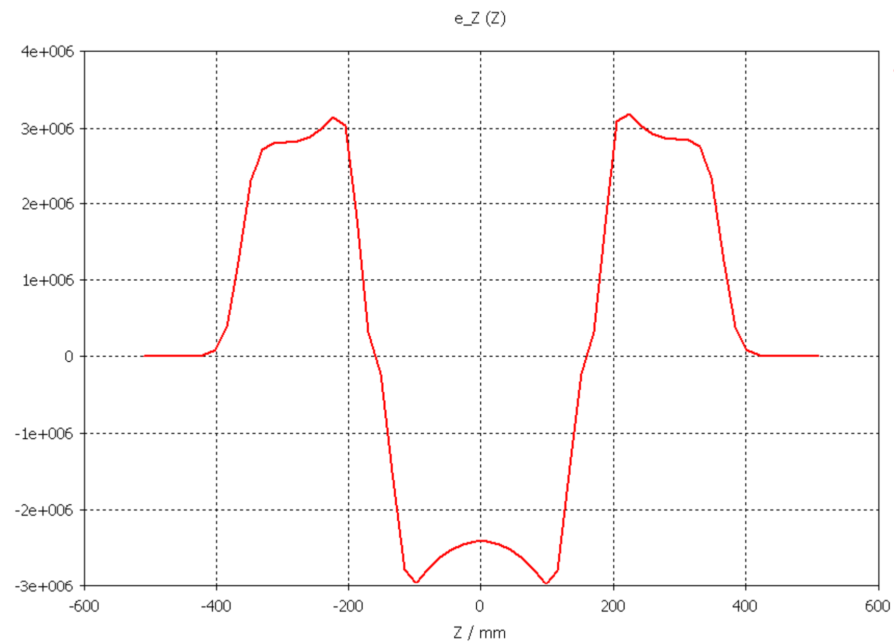


- \+ Simpler for fabrication
- \+ Better suited for prototype
- – Lacks the performance of the "advanced" option

“Advanced” EM Design







– More complicated for fabrication

+ Better suited for mass production of units for the mid-to-big scale project

EM parameters – basic and advanced designs

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- disadvantages of advanced design
  - cavity size larger (by ~20-25% in both radius and length)
  - more complicated spokes and cavity end-plates geometry
  - higher total amount of losses for the same B_{peak}
- advantages of advanced design
  - Accelerating voltage increased by more then 55%
  - R/Q is increased by ~31%
  - Geometric factor is increased by ~38%

	Basic	Advanced
Frequency (MHz)	500	500
Vo (MV)	4.07	6.32
Ea (MV/m)	7.36	11.6
Eo (MV/m)	16.89	18.73
Epeak (MV/m)	21.69	29.47
Bpeak (mT)	80.0	80.0
Bp/Ep (mT/(MV/m))	3.69	2.71
Rres (nOhm)	5.0	5.0
R_{BCS} (nOhm)	79.0	79.0
Pd (W)	29.64	39.13
T (K)	4.2	4.2
Q	1.27E+09	1.77E+09
G (Ohm)	106.9	147.8
R/Q (Ohm)	438.9	576.6
TTF	0.83	0.76

Mechanical Cavity Design

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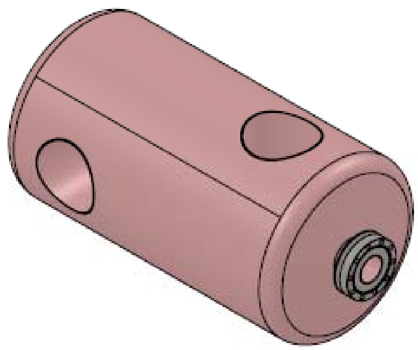
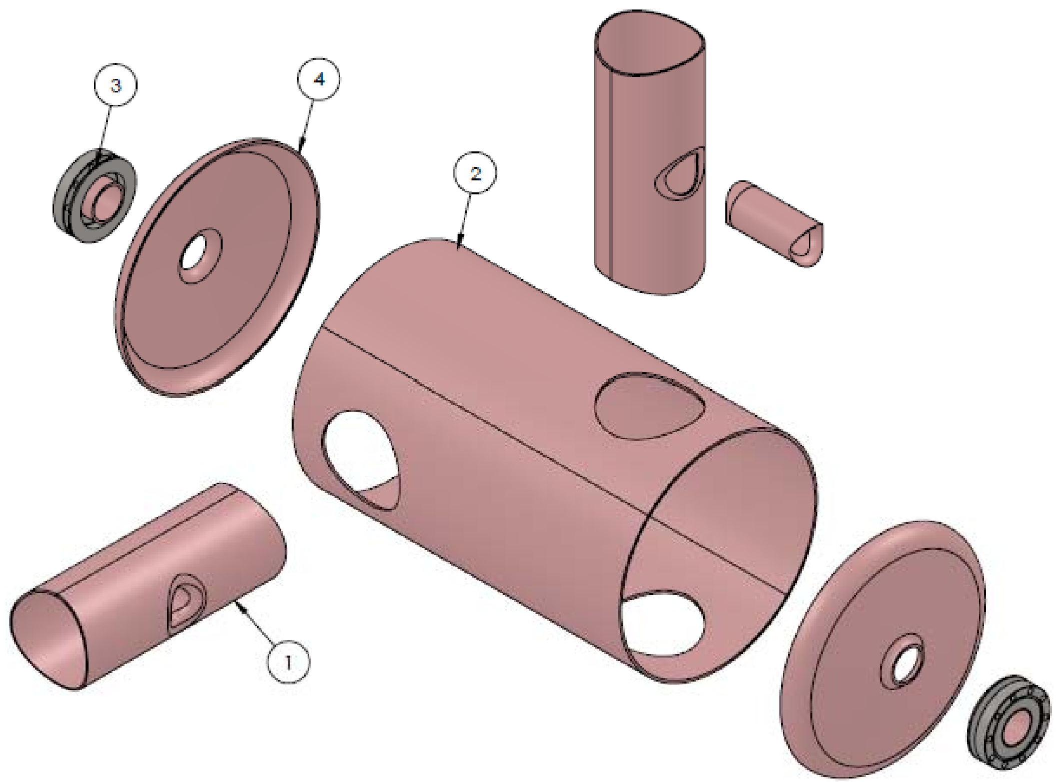
- The production drawings detailing the manufactured parts and assembly process are produced





Mechanical Cryomodule Design

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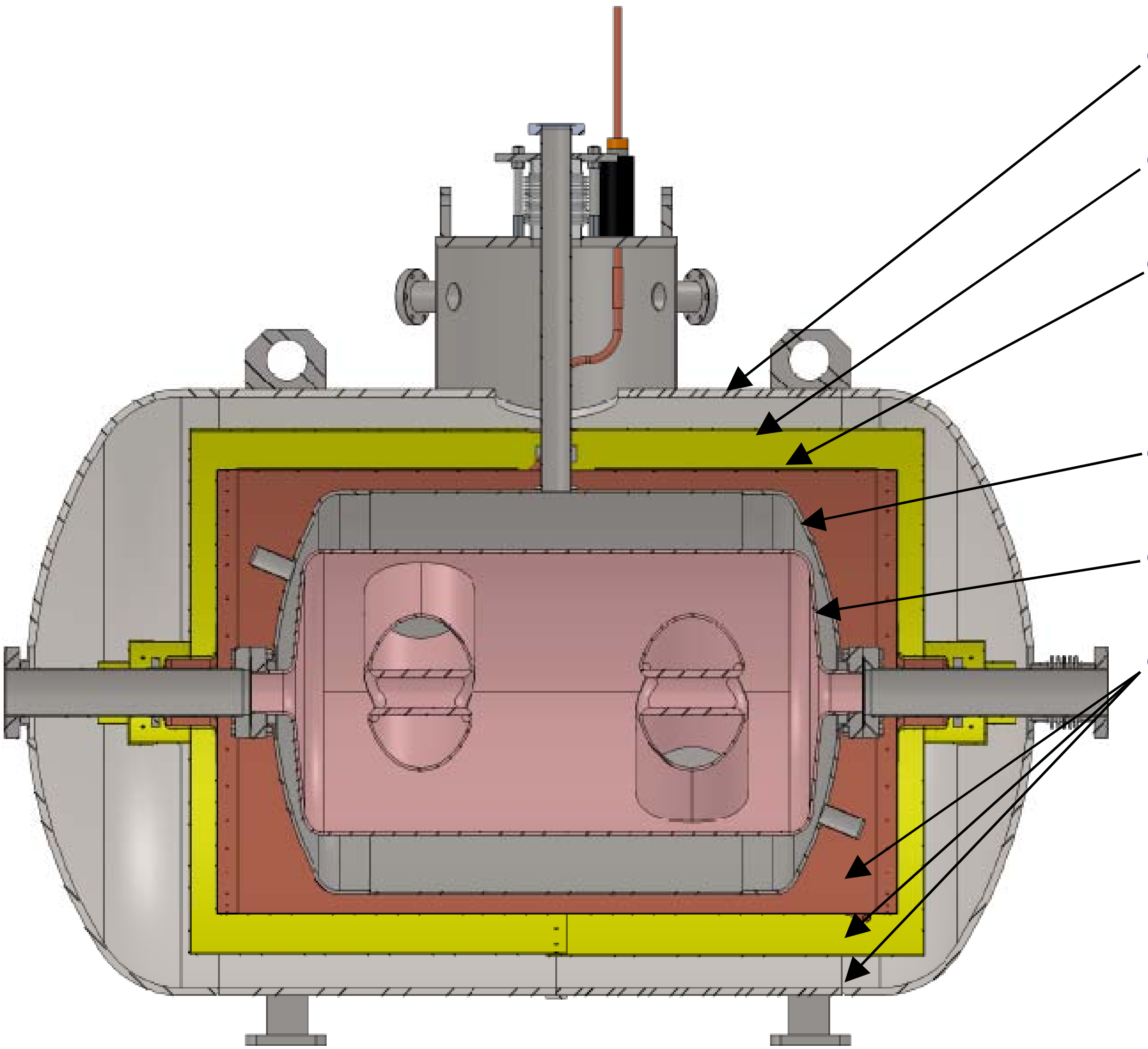
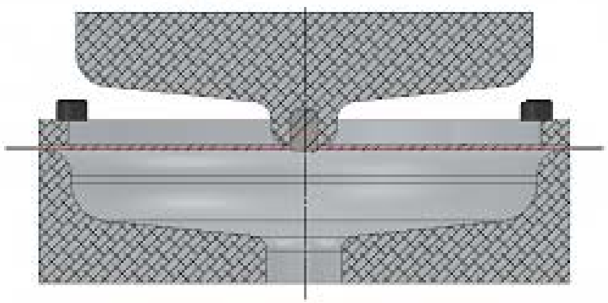


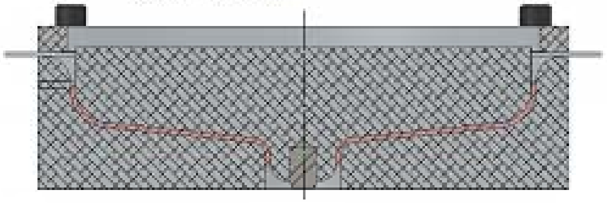
- Vacuum vessel
- Mu-shield
- LN2 copper shield
- LHe cryovessel
- Nb cavity
- Mylar superinsulation in the cryomodule vacuum

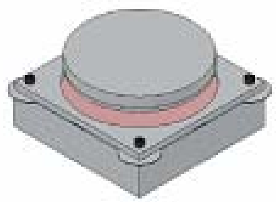
Fabrication

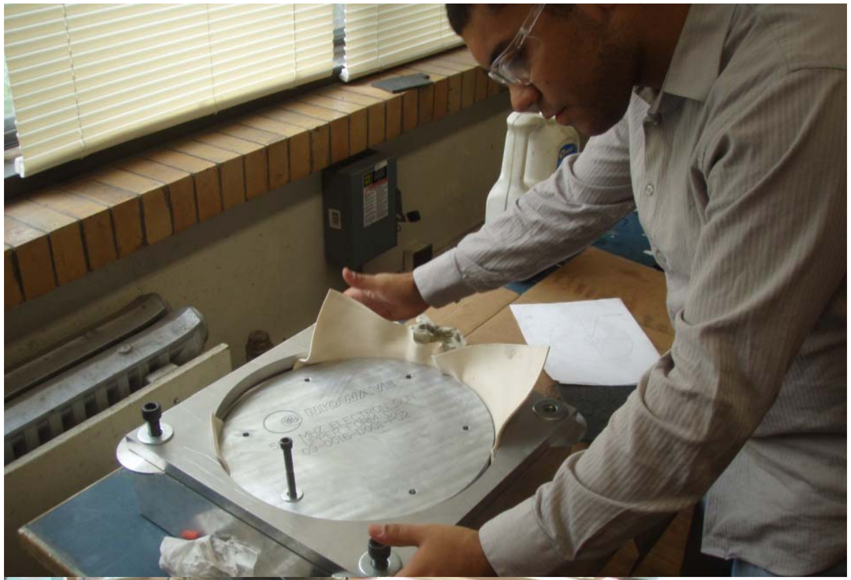
OP-1 PREFORM



OP-2 POSTFORM







Deep drawing of copper prototype of the niobium 4 mm thick end-plate for confirmation of the fixture feasibility

Fabrication [2]

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mu-metal magnetic shield and the liquid He cryovessel

machined niobium parts

copper thermal shield

vacuum vessel ready for

Testing Plans

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- Nominally, the DOE SBIR Phase-II project lasts from mid-2009 until mid-2011
- The cavity and cryomodule design has been finished and approved with the collaborators
- The full niobium cavity is in fabrication and expected to be finished by November 2010, with cryomodule assembled by the end of the year 2010 (6 months early)
- First beam test is possible at the Niowave diagnostic beamline in early 2011 (subject to additional funding)