

## SRF MAIN LINAC CRYOMODULE DESIGN AT FERMILAB \*

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### Abstract

Fermilab, in conjunction with our colleagues at KEK, RRCAT, and BARC, is developing several main linac SRF cryomodules in support of Fermilab's Project-X and the International Linear Collider. The Type IV Cryomodule (T4CM) will allow Fermilab to design, fabricate, and test our first cryomodule completed entirely in the USA. This cryomodule will also probe the stability question of mounting a magnet system under the center, fixed support post. Using the T4CM as the baseline, Fermilab and our Indian colleagues are developing a unified cryomodule for Project-X which will allow for options to mount up to three magnets with either  $\beta_1$  or  $\beta_{.81}$  cavities. Fermilab has also supported the development of the S-1 Global cryomodule which will be built and tested at KEK. Fermilab's commitment is to deliver two fully dressed cavities and all supporting components. To accomplish these designs, modern CAD tools using parametric designs, 3-D visualization JT files, and collaboration tools have been implemented. With these designs, Fermilab has spearheaded the effort to work collaboratively using a common database; DESY's EDMS.

### INTRODUCTION

With DESY's cryomodule development as a template, an international team of engineers and scientists began, in 2006, to develop the next generation of 1.3 GHz cryomodules. The original focus of this cryomodule development was to mount a magnet at the center position under the more stable cold-post. This was a small design modification from the standard Type III cryomodule at DESY. This new cryomodule became known as the Type IV Cryomodule. As the focus of Fermilab's SRF program began to solidify, the scope of the design grew to include the industrialization of cryomodule fabrication. Within US budget limitations, the scope of our work changed again to include more international collaborators. We expanded the Type IV cryomodule design to include mounting points for multiple magnets and to allow for  $\beta_1$  and  $\beta_{.81}$  cavities. This new cryomodule became known as the Unified cryomodule with the intent of incorporating multiple options into one cryomodule design suitable for Project-X and the International Linear Collider.

### TYPE IV CRYOMODULE DEVELOPMENT

Utilizing modern CAD techniques, so that design modifications can be implemented quickly, was central to the development of the type IV cryomodule. Designing with key parametric parts and a well-defined coordinate

system, all driven by Excel, allowed us to make positional changes to components such as the helium gas return pipe (HGRP), cavities, couplers, and alignment mounts. A master spreadsheet is easily modified with shrinkage calculations predefined. Some of the cavity shrinkage calculations were performed using an FEA approach and then used as inputs into the master spreadsheet. The Excel cell values were then linked to spreadsheets controlling the master coordinate system part and also onto key components such as the HGRP and vacuum vessel. A few updates in the CAD system and the top level assembly updates. The same strategy was deployed on the unified cryomodule design.

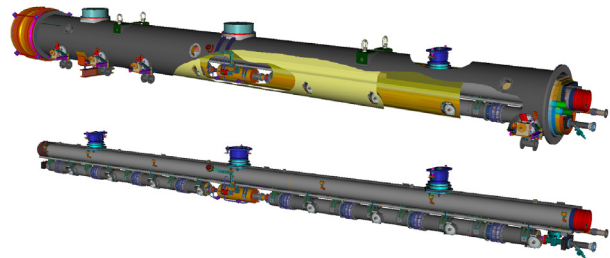


Figure 1: Type IV Cryomodule.

### UNIFIED CRYOMODULE

It became apparent that the type IV cryomodule design was not flexible enough to support Project-X or the future ILC. There were too many options that had not been explored and too many cost-saving opportunities that needed to be implemented. With a strong push to support Project-X, an effort was made to support a single, unified, cryomodule design that could house either  $\beta_{.81}$  or  $\beta_1$  cavities. At lower energies, there was also a need to place multiple magnets into the cryomodule. The proposal was made to use three of the nine cavity slots as optional locations for magnets. The chosen cavity slots are at the 2, 5, and 8 cavity positions. At higher beam energies, and when no magnet is necessary, an option for mounting nine cavities is available.



Figure 2: Unified Design for Project-X and ILC.

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While Fermilab took on the design task of the  $\beta 1$  cryomodule, our Indian colleagues at BARC and RRCAT have been working on the  $\beta.81$  cryomodule. Both design teams were free to implement any cost reduction ideas. Due to time constraints, Fermilab chose to use standard components similar to those found in the type III cryomodule. However, some components have been slightly redesigned to reduce cost. Conversely, our Indian colleagues have proposed many design changes to drastically reduce cost. The newly proposed cavity wedge tuner is one such design change that shows some real promise.

### BETA .81 CAVITY DEVELOPMENT

Since the Unified cryomodule can house either  $\beta 1$  or  $\beta.81$  cavities, a decision had to be made. Do we extend the space between cavities, or do we add additional cells to the  $\beta.81$  cavity? In either design, the coupler to coupler spacing must be maintained. Although the  $\beta.81$  cryomodule does not require the same full-length as a  $\beta 1$  cryomodule, the choice to use one single cryogenic vessel for both designs was selected to reduce cost and complications. Studies are ongoing to consider using an 11-cell cavity versus a shorter 9-cell cavity. The length of the 11-cell cavity is so close to the  $\beta 1$  cavity length that the same cavity helium vessel can be used for both. This is the preferred design for a  $\beta.81$  cavity. RF studies along with stability studies will help decide if an 11-cell,  $\beta.81$  cavity is possible.

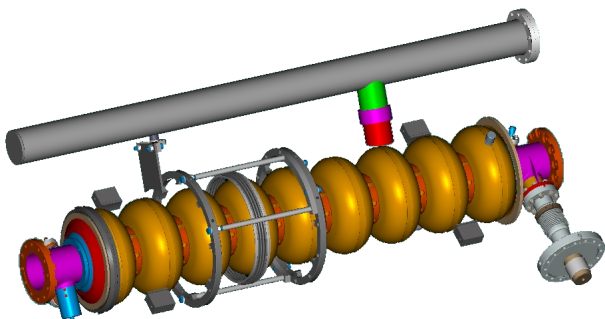


Figure 3: 9-Cell,  $\beta 1$ , 1.3 GHz Cavity.

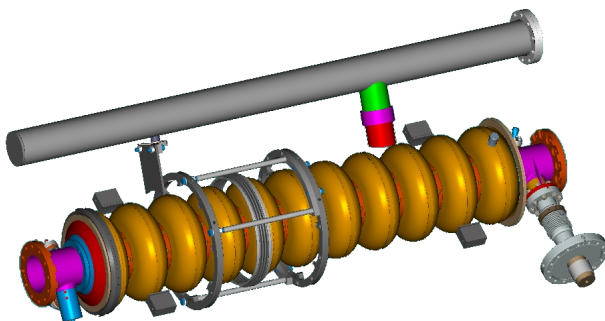


Figure 4: 11-Cell,  $\beta.81$  Proposed Cavity.

### EDMS

International collaboration is never easy but improvements have been made in electronic data management (EDMS) that have allowed our collaboration to share data. DESY supports the ILC program by providing Teamcenter Enterprise; an industry accepted data management software tool that allows all collaborators to work out of a single database. Our database is located in Hamburg, Germany at DESY. For CAD users, using I-DEAS and NX, Teamcenter Enterprise provides a portal into the CAD data via a team browser. For engineers and scientists, documents and CAD data can be accessed and viewed through the web browser known as the thin client. The data is immediate and live with complete revision control and fast access to viewable file formats such as CGM, PDF, and JT. Users in the US, Germany, Italy, and Japan have had good success sharing data within this system. Our Indian colleagues have not had much success accessing data through the EDMS due to security issues within their country. Getting collaborators to use the system effectively has been difficult but as the technology becomes better, great advances toward this effort will be made.

### S-1 GLOBAL CRYOMODULE

An international effort is under way to construct the first international cryomodule utilizing components provided by ILC collaborators from the US, Germany, Italy, and Japan. The cryomodule is being assembled in Japan at KEK. Two cavities will come from DESY, two from the US, and four from KEK. The cryomodule cold mass components are being provided by INFN in Italy. This will be the first time that a high gradient cryomodule will be produced by an international collaboration. Fermilab will provide, in 2010, two high gradient cavities, tuners, couplers, magnetic shielding, and all hardware to support this initiative.

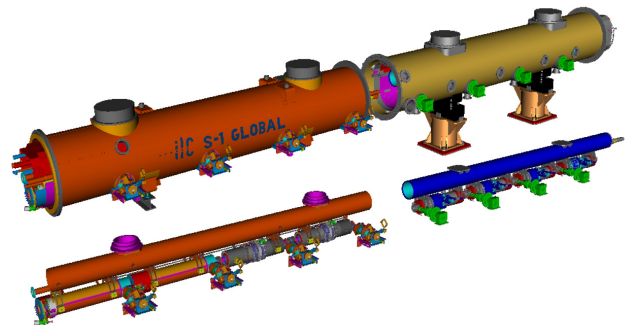


Figure 5: S-1 Global Cryomodule Development at KEK.

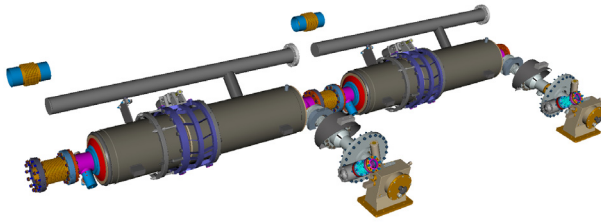


Figure 6: FNAL Deliverable to S-1 Global Effort.

## CONCLUSION

As time progresses and our scope refined, our collaboration strengthens and our design solidifies into a simple multipurpose cryomodule for use on Project-X and ILC. Cost-saving measures will continue to be implemented and vendor interaction will grow. Fermilab's infrastructure is expanding to handle this growth and to be ready to design the next-generation cryomodule.

## CURRENT FABRICATION AT FERMILAB

In 2008, Fermilab's first 1.3 GHz cryomodule (CM1) was assembled and moved to the New Muon Lab (NML) for installation into the new test beamline. All the components for this cryomodule were produced and delivered to Fermilab by INFN and DESY. This cryomodule, a DESY type III cryomodule, has yet to be tested. In April 2009, the 3rd Harmonic cryomodule was completed, assembled entirely at Fermilab, and shipped to DESY for testing and installation into FLASH/TTF. Currently at Fermilab, in Technical Division's ICB, the components for CM2, another type III cryomodule, are being staged. We are waiting for functional cavities to be fabricated, tested, and qualified for usage before we can finalize the assembly of CM2. Currently, components for CM3 are being ordered. CM3 is a unified cryomodule design. Assembly of CM3 will take place in late 2010. These three cryomodules, along with CM4, 5, and 6, will all be installed at NML in the years to come.



Figure 7: Recently Completed 3<sup>rd</sup> Harmonic Cryomodule.

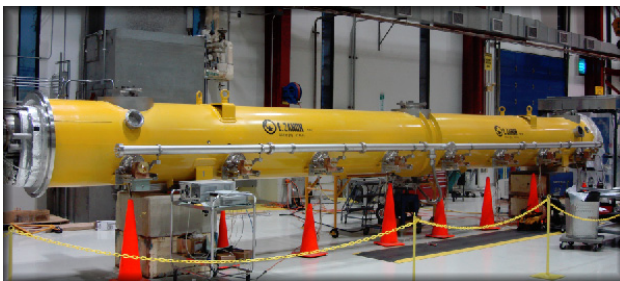


Figure 8: CM1 at FNAL Ready for Installation at NML.