



# Cryomodule Development at Fermilab

**Donald V. Mitchell, P.E.**

May 18, 2009  
Fermilab  
DOE SRF Review

# FNAL Cryomodule Effort



Fermilab

- **2008: CM1 built at FNAL with ALL components provided by DESY and INFN (Zanon) – Type III+**
- **3rd Harmonic Cryomodule shipped to DESY in April 2009. Completely designed and built at Fermilab.**
- **2009: Summer – begin building CM2 at FNAL Type III+ design, FNAL providing cavities. Coldmass and Cryostat provided by INFN (Zanon)**
- **Order T4CM components by August 2009. Design currently in final stages.**
  - **Fermilab procurement**
  - **Fermilab to assemble and install at NML**
- **2009: Begin working with US industry to procure 2 more T4CMs. Deliver in 2011.**
  - **Help develop US industry capabilities**
  - **Utilize FNAL facilities for cryomodule assembly**
  - **Develop at least 2 suppliers**

# FNAL Cryomodule Effort cont.



Fermilab

- In December, 2007, the design of the Type IV Cryomodule was halted due to funding constraints.
  - 95% of the 3-D model was complete.
  - 80% of the drawings were complete but needed checking
  - 4 design contractors were released from the program
- Design effort re-focused on CM2
  - Magnet package was designed to fit into CM2 (TTF III+)
  - Compatible with Fermilab's test facility requirements
  - To be fabricated and assembled in 2009
- Now with renewed funding, the T4CM will be completed
  - All US fabrication of cryomodule components
  - Magnet centered on cryostat
  - Relatively fast design modeled after the DESY Type III+
  - Get U.S. industry involved quickly

# SRF Infrastructure



# International Collaboration



Fermilab

- **3 years building a team of engineers and designers from around the world who collaborate on cryomodule design and R&D.**
- **Added German intern, with DESY experience to our design team.**
- **Added contractors to expedite the design.**
- **Exploring alternate designs for cost savings.**

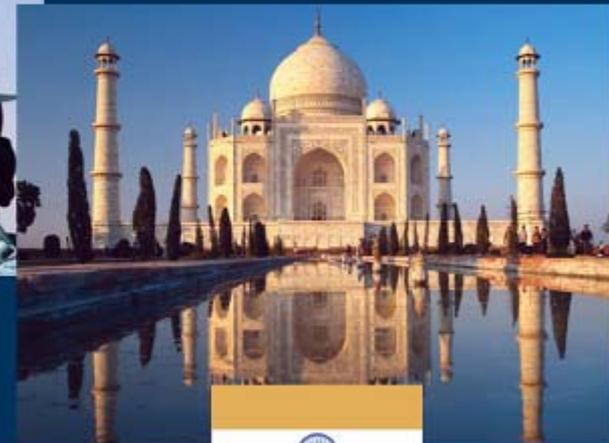
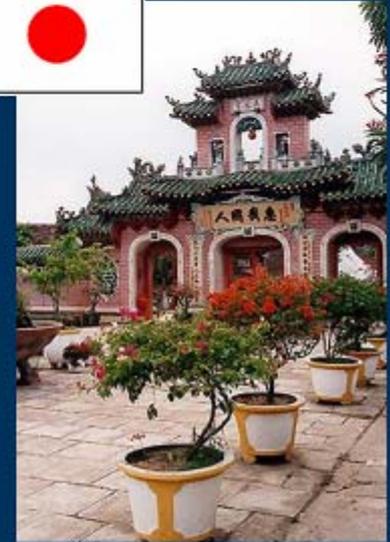
# An International Cryomodule Design Team founded in May 2006

November 2006: Training EDMS  
to the international team.



Collaboration Team:

- ▶ FNAL (USA)
- ▶ INFN (Pisa, Italy)
- ▶ INFN (Milan, Italy)
- ▶ KEK (Japan)
- ▶ RRCAT (India)
- ▶ DESY (Germany)



# Communication is essential!



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- We needed a way to share information.
- We needed common tools.
- DESY provides Team Center Enterprise (EDMS) as well as their IT services as part of their collaboration effort.

# Collaborators and their software!



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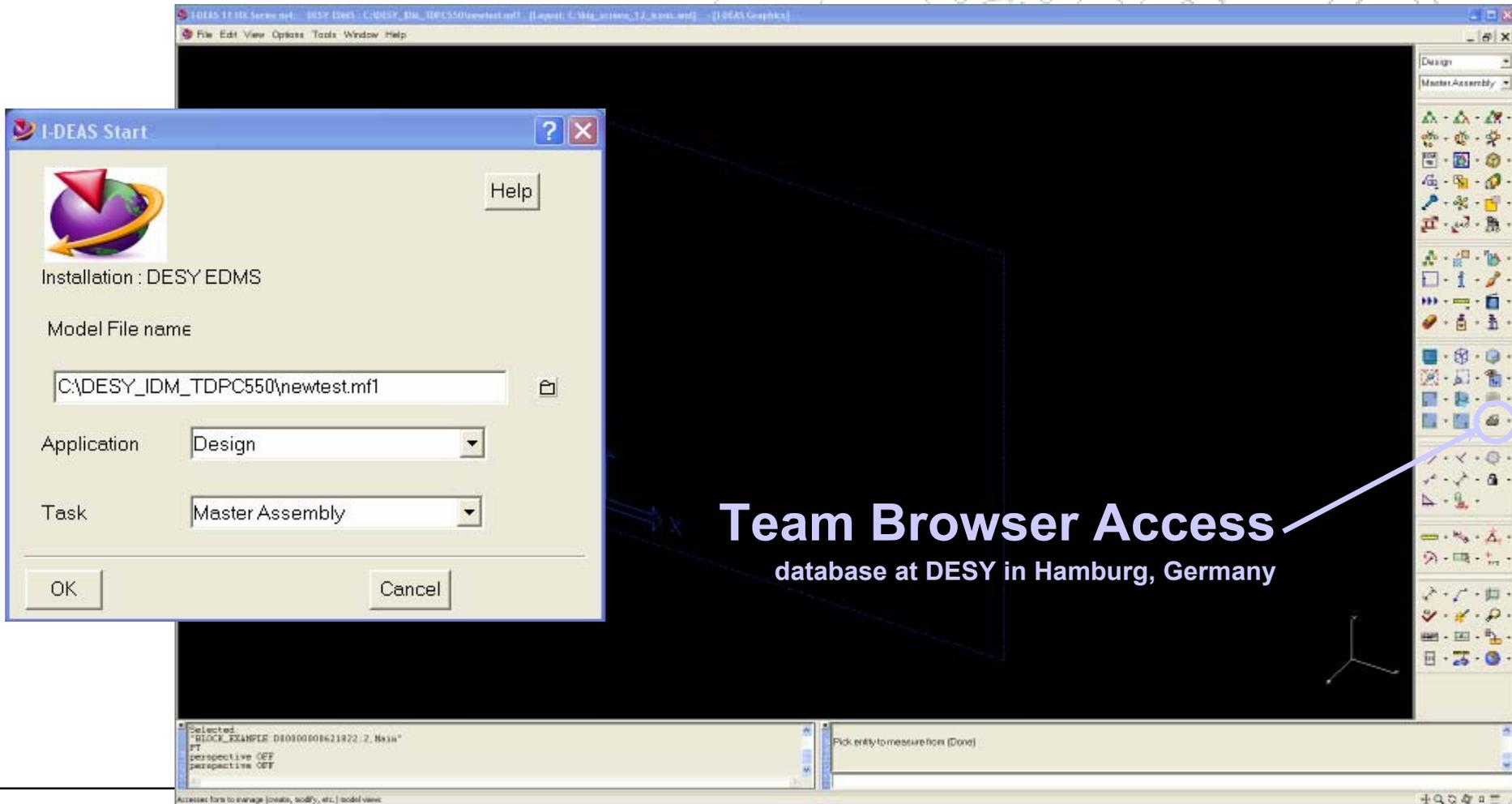
- **FNAL: I-DEAS v.12**
- **SLAC: Solidedge**
- **JLAB: I-DEAS**
- **INFN Milan: NX**
- **INFN Pisa: I-DEAS v.12**
- **KEK: I-DEAS (and others)**
- **DESY: I-DEAS v.12**
- **RRCAT: NX, I-DEAS, ACAD**
- **BARC: I-DEAS**

Note: These are all UGS CAD products and are “team browser” compatible with Team Center Enterprise. However, the current supported platform is I-DEAS v.12 with plans to add other CAD packages soon.

# The DESY EDMS Team Browser



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**Team Browser Access**  
database at DESY in Hamburg, Germany

**Team Browser**

File Edit View Tools Manage Help

**My Items**

- I-DEAS
- Model File C:\DESY\_IDM\_TDPC550\newtest.mf1
- Main

**Team Data**

- Teams for Mitchell\_Donald\_FNAL
  - 120\_05
  - ACC3\_9GHz
  - Cavity Tuning Machine
  - DESY-FNAL-CAD-Test
  - Type 4 Cryomodule Design
  - z\_weitere\_Teams

Model File Synchronization Complete  
 No Changes Required  
 Ready...

# Team Center Enterprise EDMS Team Browser hosted by DESY



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The screenshot shows the Team Browser interface with the following components:

- My Items:** A tree view showing the project structure. The selected item is **T4CM\_9\_CAVITIES\_NEW\_COMPL\_ASSY, D00000000608303, v8**.
- Team Data:** A list of teams and their associated CAD data. The selected team is **1-3GHz CAVITY**.
- Item List:** A table listing items with columns for Name, Number, ItemType, Version, Status, and Priority.

Name	Number	ItemType	Version	Status	Pr...
T4CM_9_CAVI...	D00000000608303	Assembly	8	Ck	-

Name	Number	ItemType	Version	Status
BELLOWS_T4...	D00000000557123	Assembly	2	Rfl
COLDMASS_...	D00000000603463	Assembly	2	Rfl
COLDMASS_...	D00000000552763	Assembly	16	Rfl
COLDMASS_...	D00000000552803	Assembly	16	Rfl
JACK_STAND...	D00000000778912	Part	1	Rfl
JACK_UP_SP...	D00000000733782	Part	1	Rfs
MC_MOUNT_...	D00000000557603	Assembly	21	Rfl
MC_WARM_A...	D00000000578523	Assembly	6	Rfl
MOUNT_TAY...	D00000000605373	Assembly	2	Rfs
REDUCING_TE...	D00000000613853	Assembly	1	Rfl
RING_HOIST_...	D00000000746892	Part	1	Rfl
SURVEY_PLA...	D00000000578763	Assembly	7	Rfl
T4CM_9_HAR...	D00000000613943	Assembly	1	Rfl
TEMP_T4CM-9...		Drawing		
VESSEL_CRY...	D00000000601903	Assembly	13	Rfl

CAD  
data  
access

No Changes Required  
Ready...  
Delete 1 items from the model file

# EDMS Thin-Client hosted by DESY



Fermilab

My Teams: Type 4 Cryomodule Design: CAD Main Assemblies - Microsoft Internet Explorer

Address <http://teamcenter.desy.de:2345/TC51PRD/controller/home>

Search  Home Exit DESY

Advanced Search... Donald Mitchell

Check Out From Team Put to WIP Vault Make Available To Team Route Move More Actions...

**My Teams: Type 4 Cryomodule Design: CAD Main Assemblies**

You are here: [Type 4 Cryomodule Design](#): CAD Main Assemblies

	EDMS-ID	Name	Description	Life Cycle State	Project Name	Class	Cr
<input type="checkbox"/>	<a href="#">D00000000556753.A.1.6</a>	COLD_MASS_ASSY_T4CM	COLD_MASS_ASSY_T4CM	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000563513.A.1.1</a>	COLD_MASS_ASSY_T4CM_NO-MAGN	COLD_MASS_ASSY_T4CM_NO-MAGN	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000611633.A.1.6</a>	COLD_MASS_T4CM_W_MAG_ASSY	COLD_MASS_T4CM_W_MAG_ASSY	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000613373.A.1.6</a>	COLD_MASS_T4CM-9_CAVITIES_ASSY	COLD_MASS_T4CM-9_CAVITIES_ASSY	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000602063.A.1.6</a>	COLDMASS_T4CM-9_ASSY	COLDMASS_T4CM-9_ASSY	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000602203.A.1.1</a>	COMPLETE_ASSEMBLY_T4CM-9	COMPLETE_ASSEMBLY_T4CM-9	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000621533.A.1.7</a>	G2_VESSEL_CAVITY_ASSEMBLY	G2_VESSEL_CAVITY_ASSEMBLY	Working	Type 4 Cryomodule Design	Assembly	Gr
<input type="checkbox"/>	<a href="#">D00000000555263.A.1.6</a>	HGR_PIPE_ASSY-T4CM	HGR_PIPE_ASSY-T4CM	Working	Type 4 Cryomodule Design	Assembly	Or
<input type="checkbox"/>	<a href="#">D00000000563493.A.1.6</a>	HGR_PIPE_ASSY-T4CM_NO-MAGN	HGR_PIPE_ASSY-T4CM_NO-MAGN	Working	Type 4 Cryomodule Design	Assembly	Or

\*\*\* omfsvr <6529> low\_freespace: memory is already free  
You have 2 assignments in this Work List.

Web  
data  
access

# Web based “Thin-Client”



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- All team members, not just CAD users, can have immediate access to ALL electronic files, not just the 3-D and 2-D data.
- Via the web, the data is viewable.
  - BOM review
  - 3-D model and 2-D drawing file viewing and markups
  - Data file upload and download

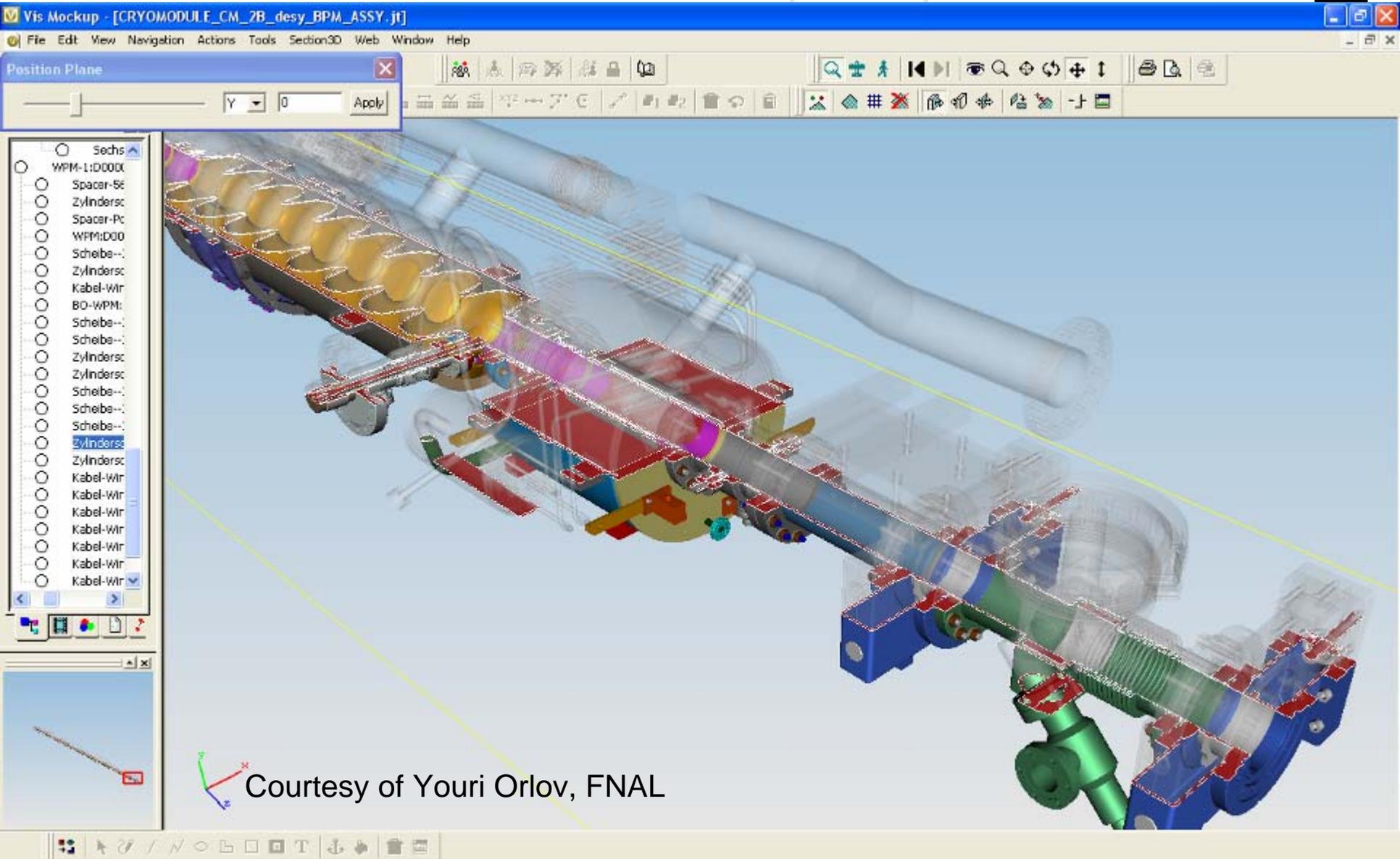
# Setting up your own environment



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- **DESY provides:**
  - **Data storage system (EDMS)**
  - **Item numbering**
  - **Design team folders**
  - **VisView licensing**
  - **EDMS Support**
- **You must provide:**
  - **the CAD software (currently, I-DEAS v.12)**
  - **Your own 2-D title blocks**
  - **Any customization to your CAD setup**

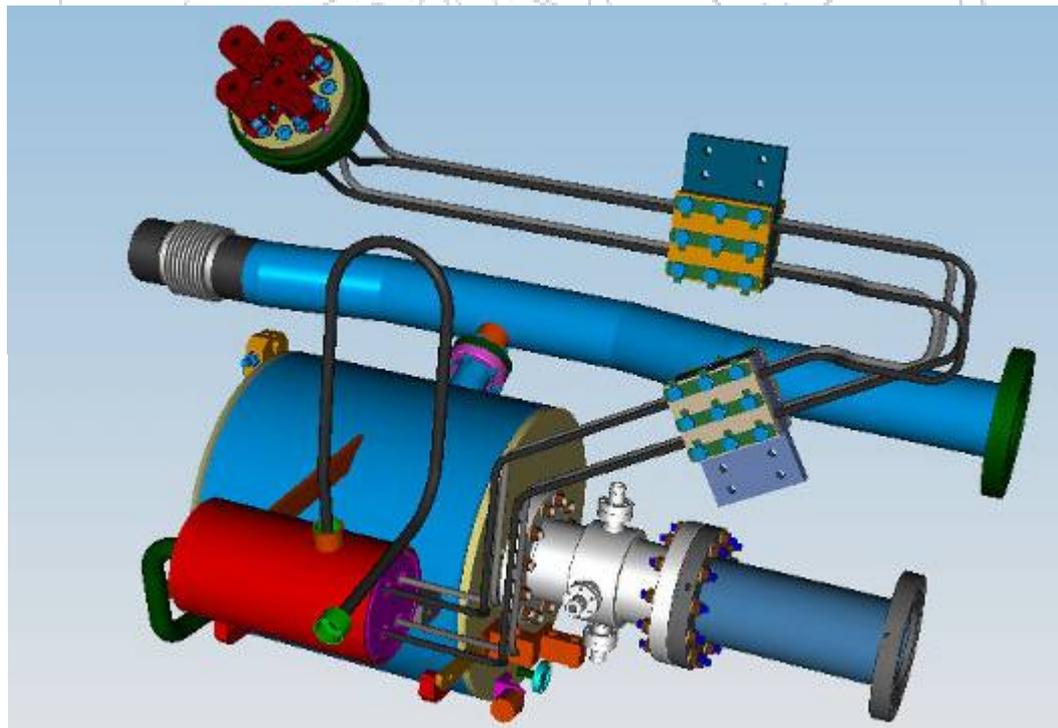
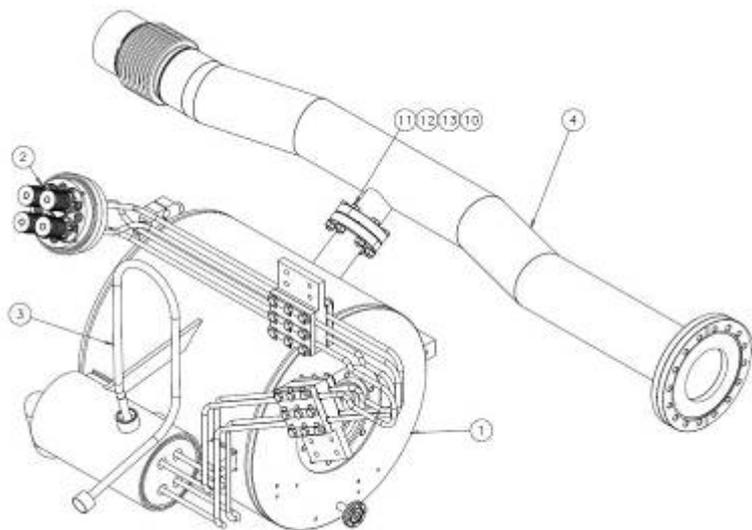
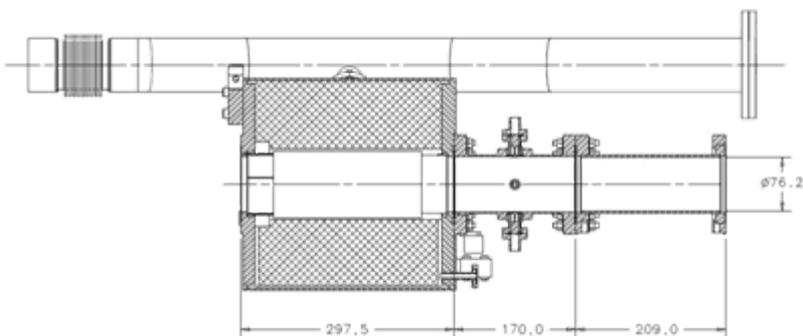
# CRYMODULE 2 (CM2) Design



# CM2 Magnet Development



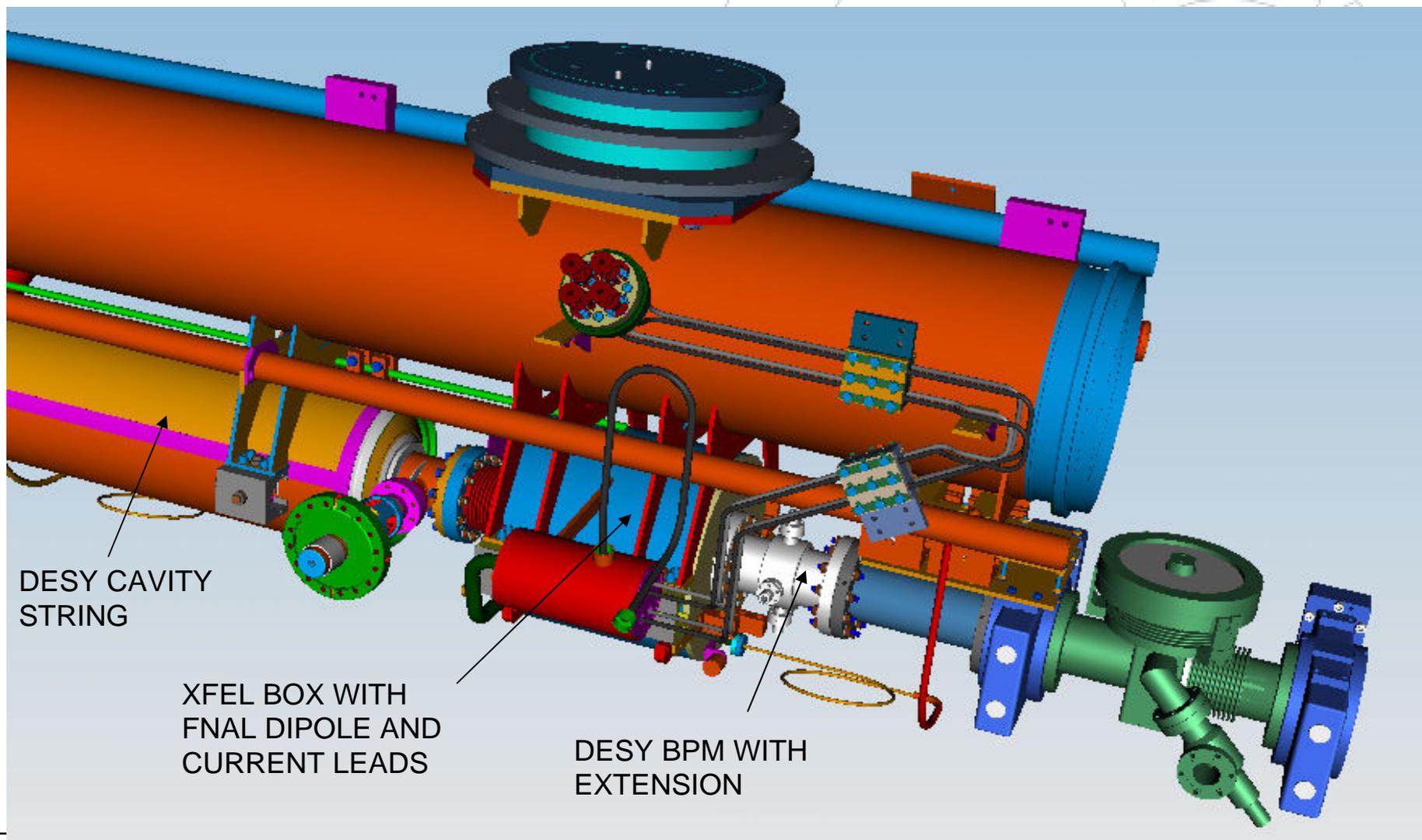
Fermilab



# DIPOLE MAGNET w/ DESY BPM



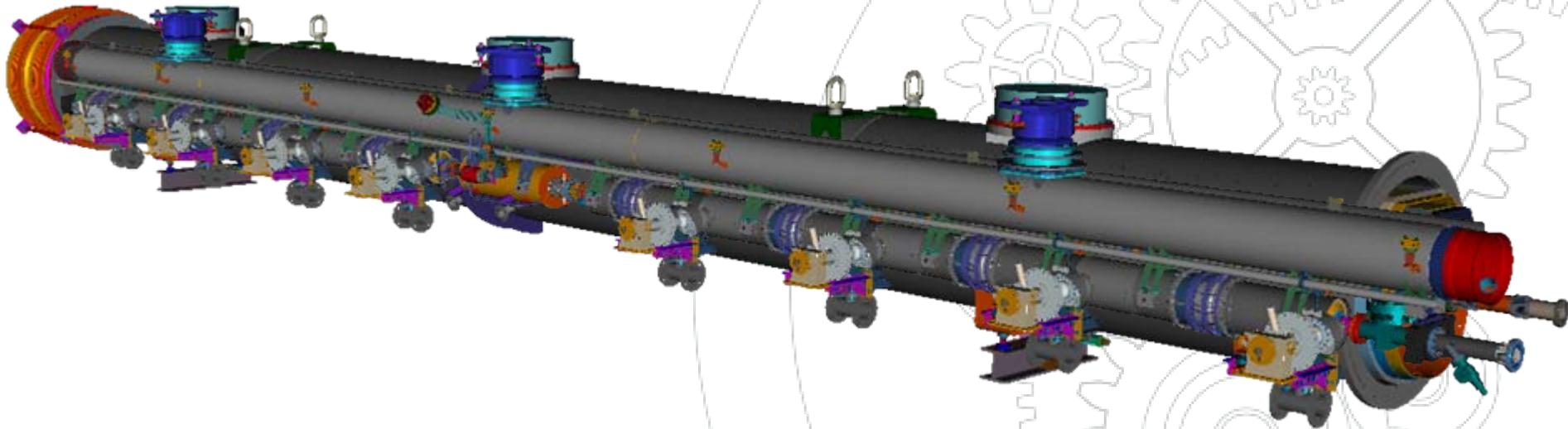
Fermilab



# Type IV Cryomodule (T4CM)



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↑  
**Magnet Package located  
under center post for  
more stability**

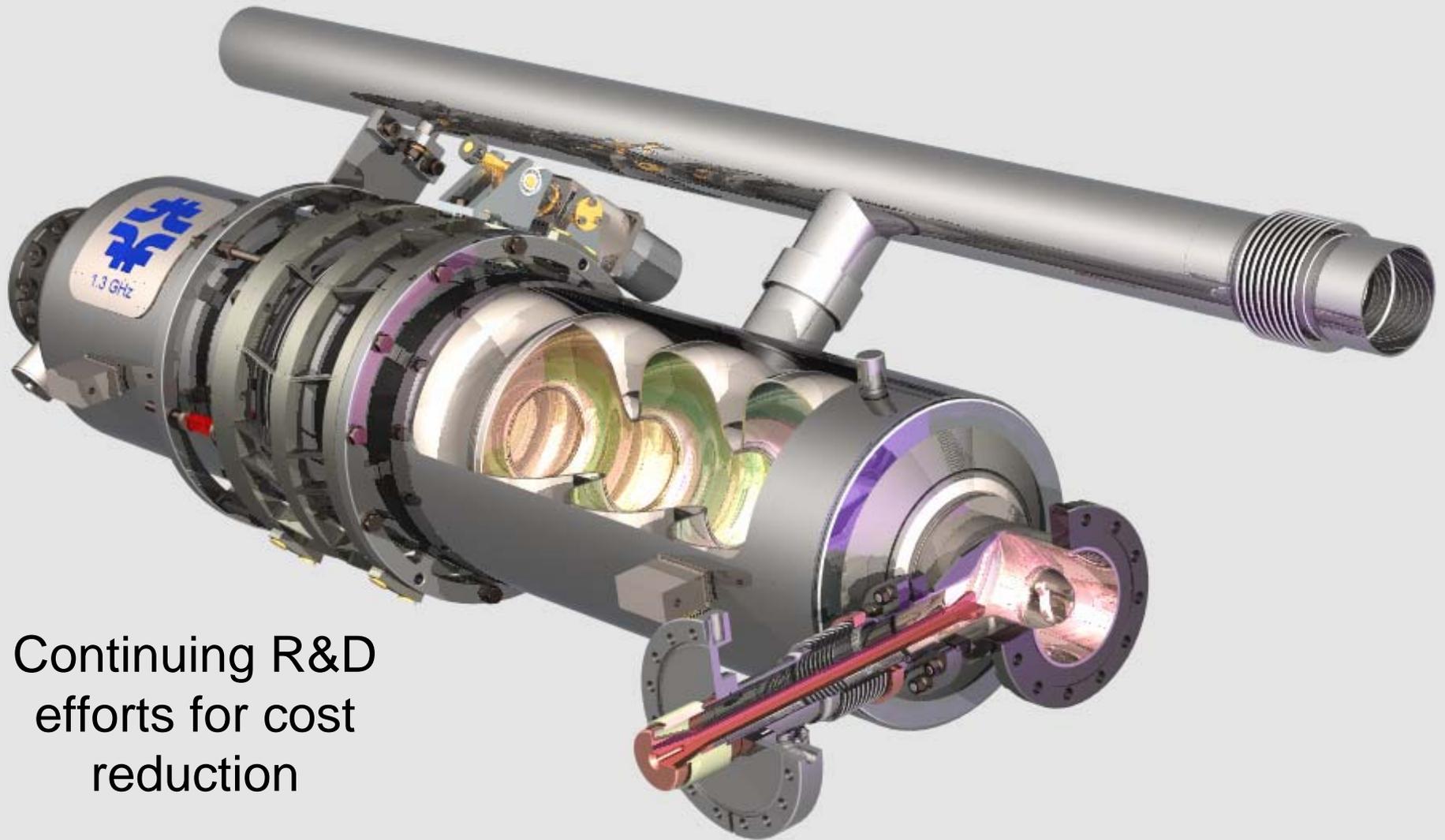
# Cryomodule Schedule



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Cryomodule Name	Type	Coldmass	Cavities	Design	Assembly	Installation	Comments
CM1	Type III+	DESY/INFN	DESY	N/A	2008	2009	Currently at NML
3rd Harmonic	3.9 GHz	FNAL	FNAL	Complete			Shipped to DESY
CM2	Type III+	DESY/INFN	AES/Accel	Mag Pkg.	2009	2010	Components at FNAL. Dressing cavities.*
CM3	T4CM	FNAL	AES/Accel	Aug-09	2010	2011	Final design tweaks. Procurement in process.*
CM4	T4CM	Vendor 1	AES/Accel	2010	2011	2012	CM3 design. Vendor to procure and assemble.*
CM5	T4CM	Vendor 2	AES/Accel	2010	2011	2012	CM3 design. Vendor to procure and assemble.*
CM6	T4CM	Vendor	AES/Accel	2011	2012	2013	Vendor to cost-reduce, redesign, assemble.*

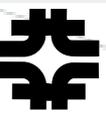
\*All assembly will be completed at Fermilab using Fermilab facilities and infrastructure.



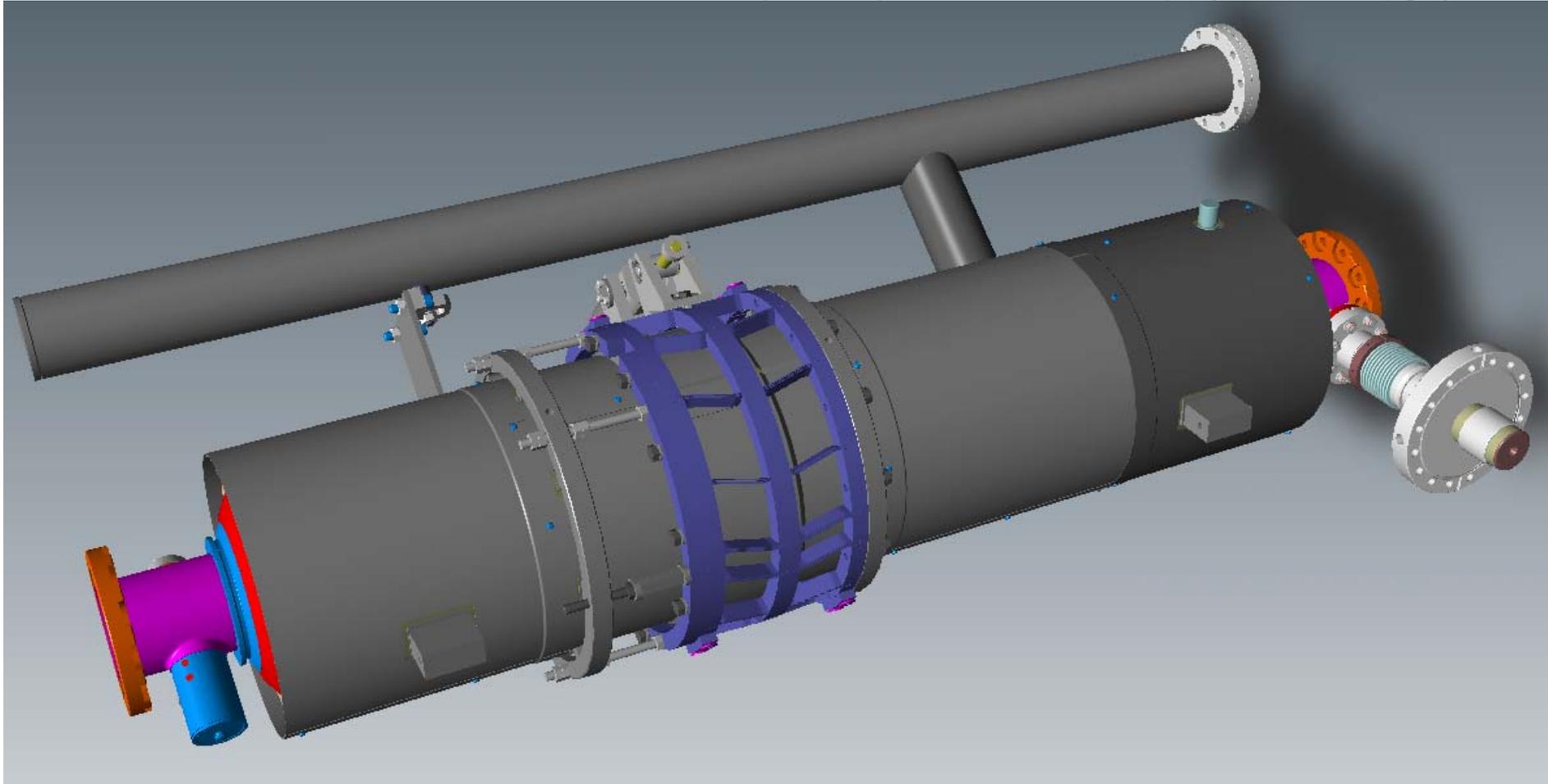
Continuing R&D  
efforts for cost  
reduction

INFN Bladetuner, FNAL procured cavity and He vessel

# Current Dressed Cavity Design



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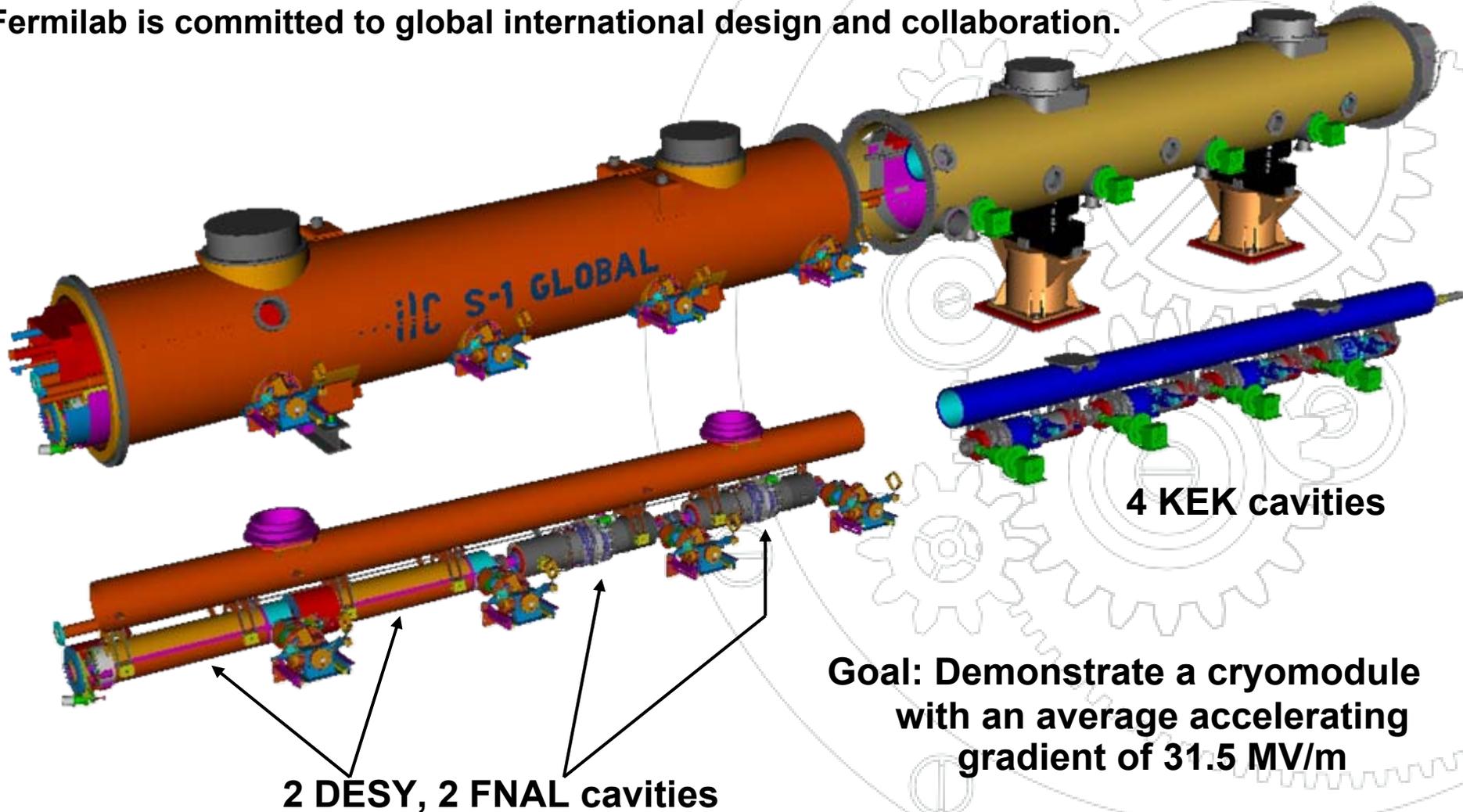


# S1-Global Cryomodule



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Fermilab is committed to global international design and collaboration.



4 KEK cavities

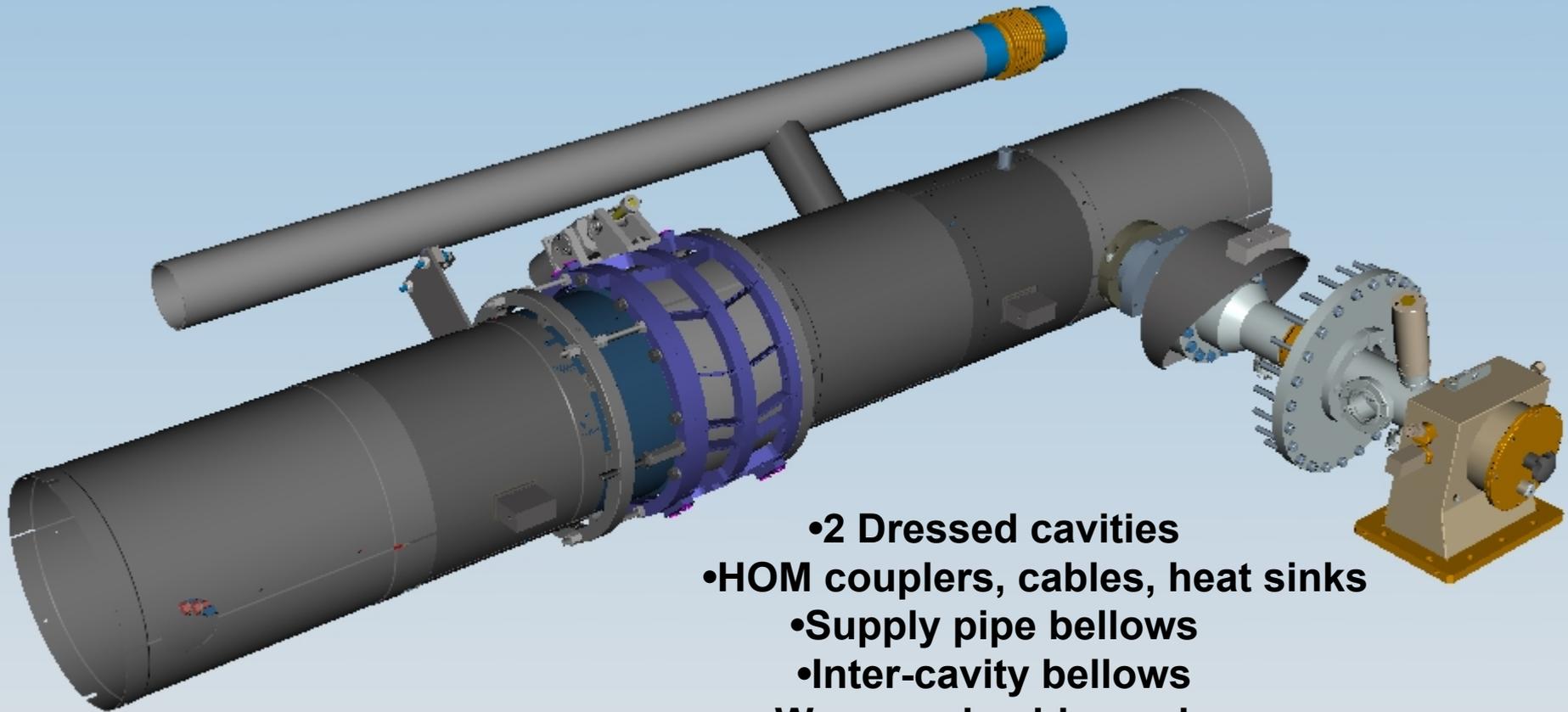
**Goal: Demonstrate a cryomodule with an average accelerating gradient of 31.5 MV/m**

2 DESY, 2 FNAL cavities

# Deliverable for S-1 Global



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- 2 Dressed cavities
- HOM couplers, cables, heat sinks
  - Supply pipe bellows
  - Inter-cavity bellows
- Warm and cold coupler
  - Magnetic shielding
- Bladetuner with motor and drive
- Seals, cables, and mounting hardware

# Plug Compatibility



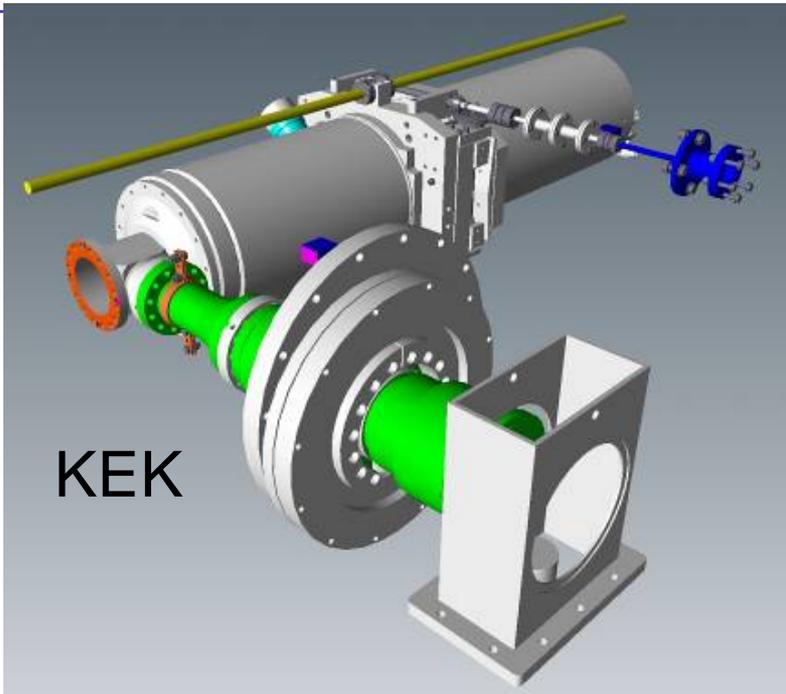
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- **ILC – GDE pursuing plug compatibility in R&D phase as means to allow cavity development w/o redesign of cryomodule for each design iteration.**
- **FNAL leading the effort in defining boundaries of plug compatible items.**
- **FNAL extending plug compatible concept to  $\beta = 0.81$  cryomodules with unified 2/5/8 cryomodule to minimize design/development time.**

# Plug Compatibility

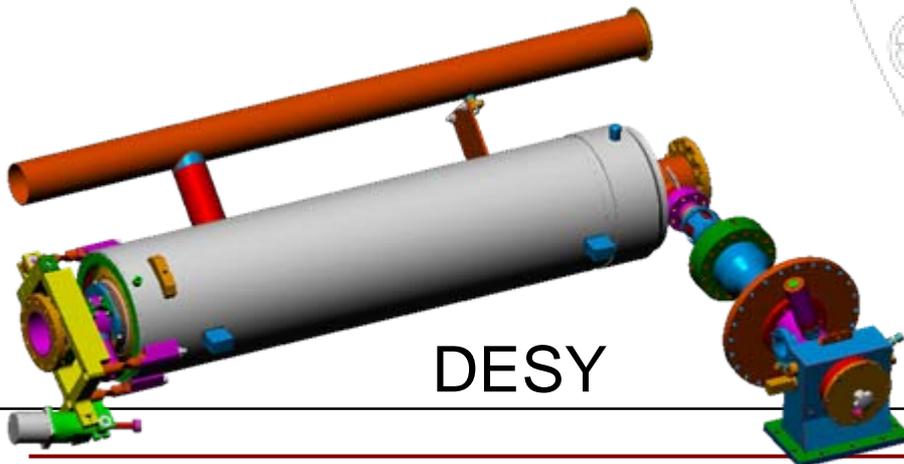


Fermilab

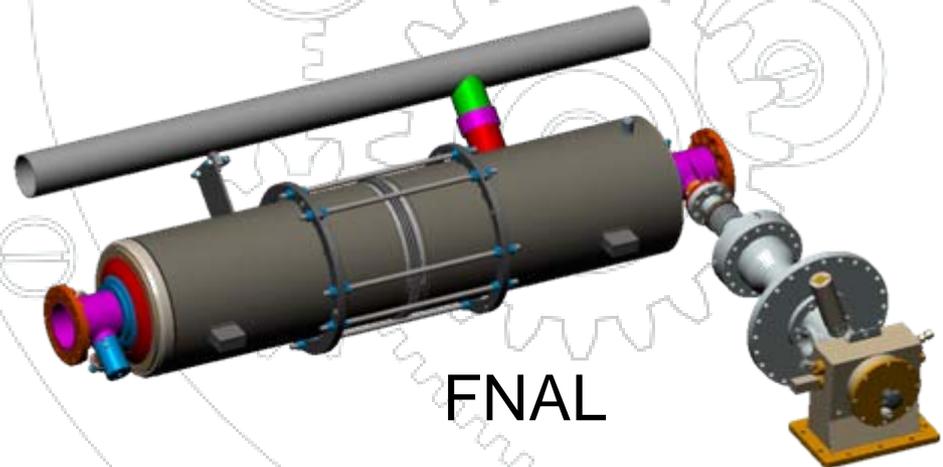


KEK

FNAL and KEK are currently discussing compatibility issues between varying cavity designs. Example: the KEK cavity has a different sized coupler and is mounted at the opposite end of the DESY and FNAL cavities.



DESY



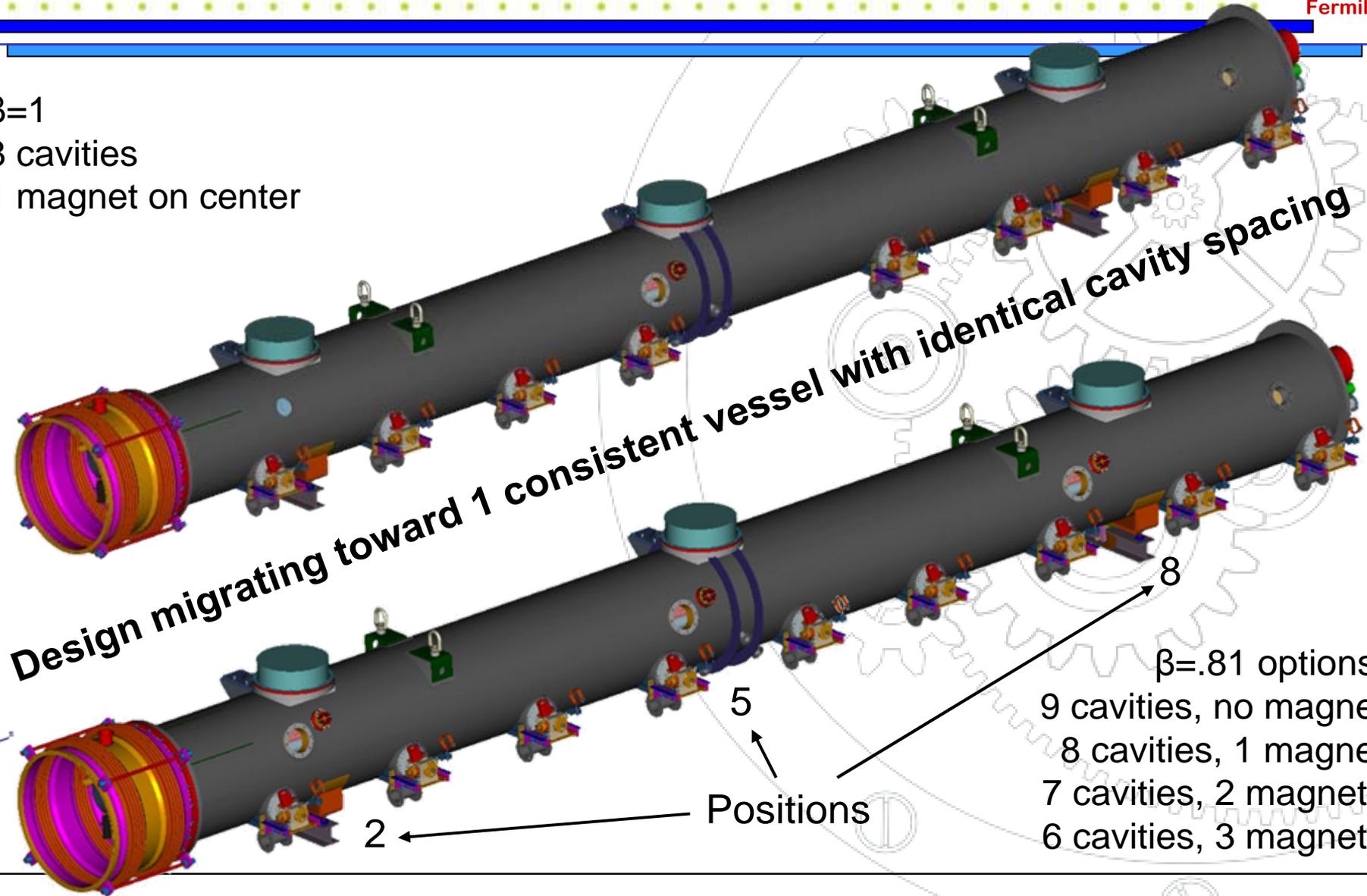
FNAL

# $\beta=1$ and $\beta=.81$ cryomodules



Fermilab

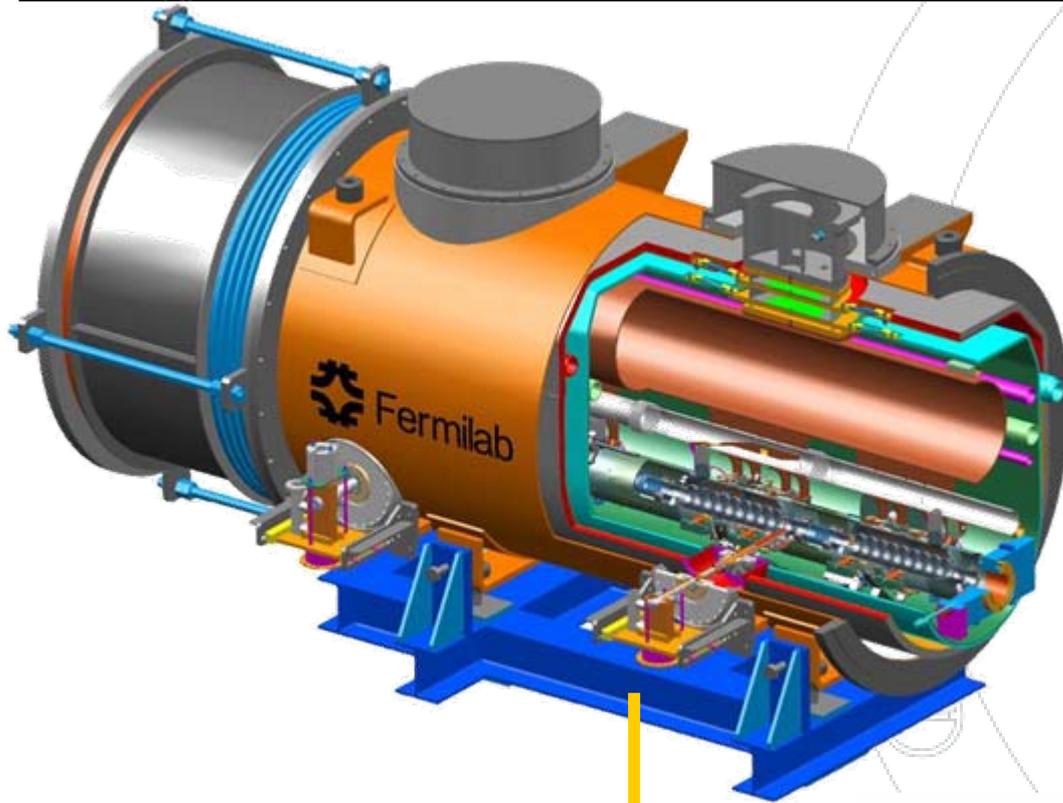
$\beta=1$   
8 cavities  
1 magnet on center



# 3.9 GHz, 3<sup>rd</sup> Harmonic

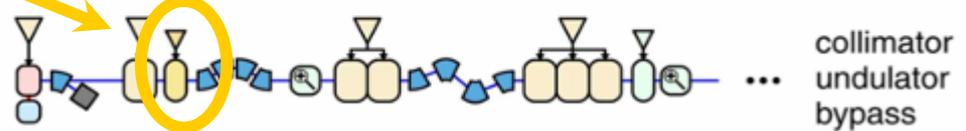


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**FLASH linac with 3rd harmonic rf**

4 MeV	130 MeV	380 MeV	1000 MeV
3.3 mm		~250 $\mu$ m	10 $\mu$ m
65 A			2.5 kA

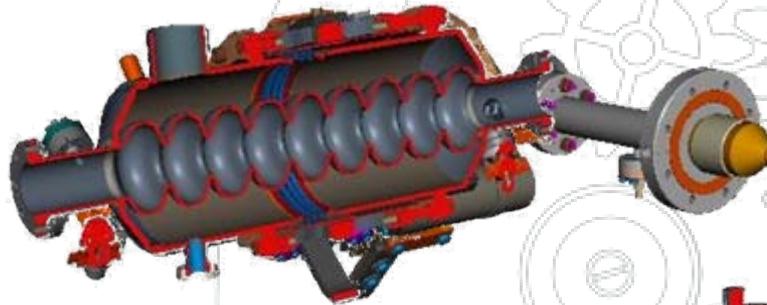


# 3.9 GHz vs. 1.3 GHz Cavities

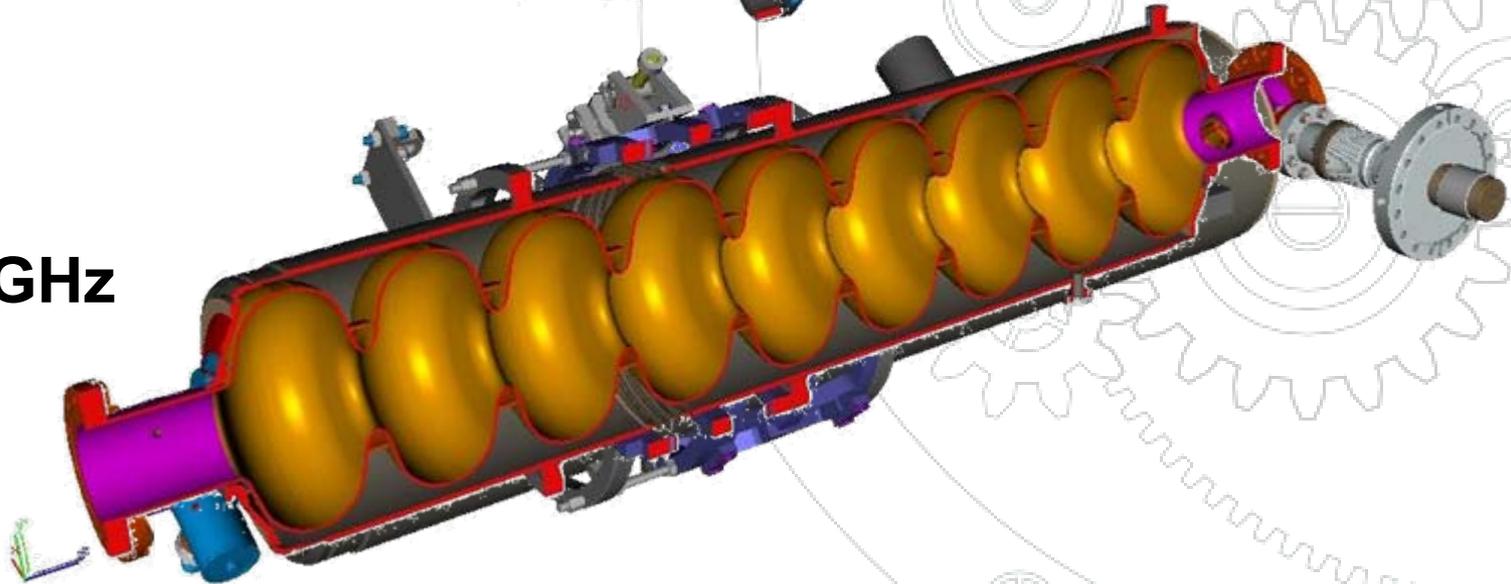


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3.9 GHz



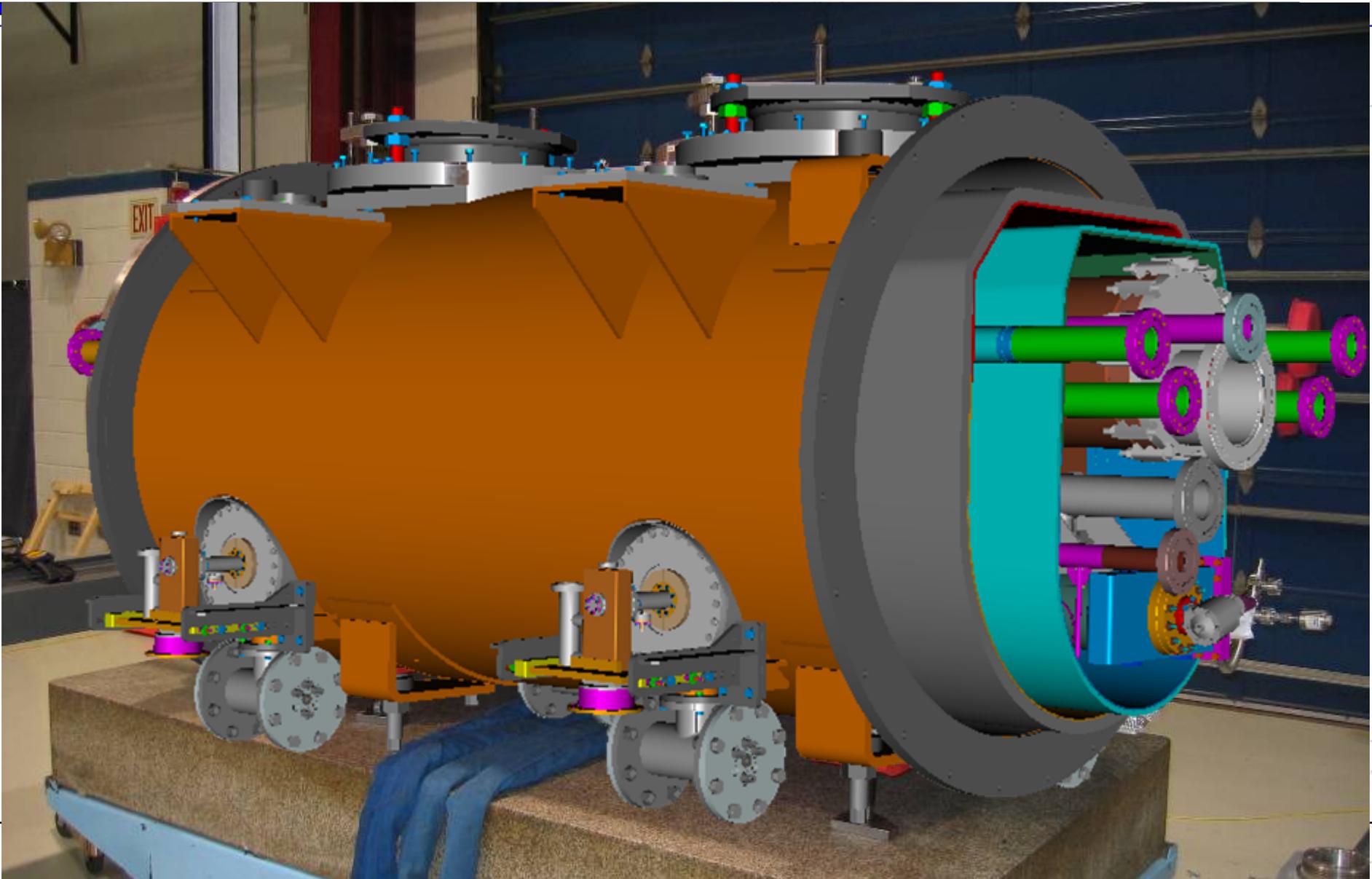
1.3 GHz



# 3<sup>rd</sup> Harmonic: Design to Reality



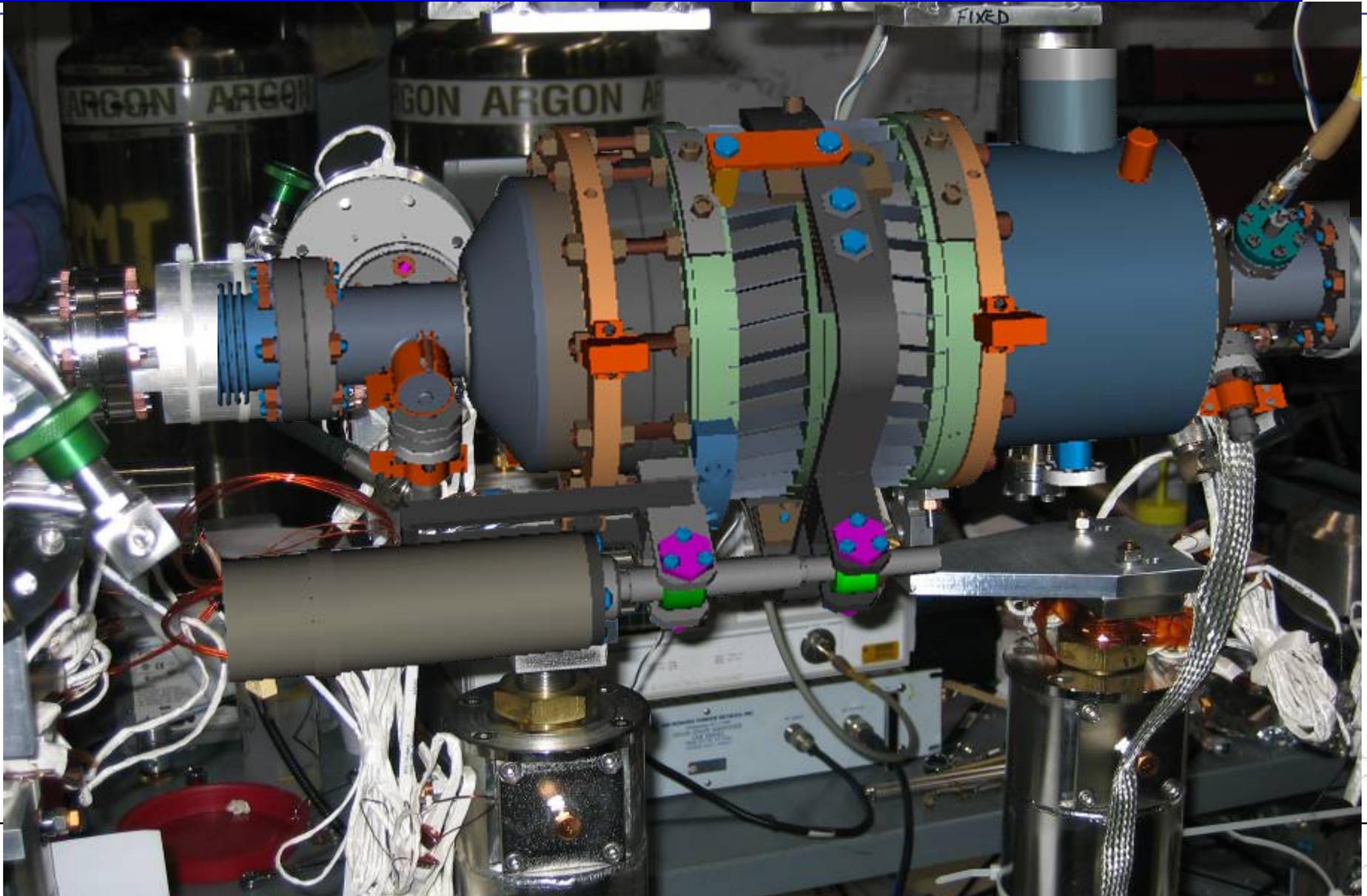
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# Cavity Design



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# 3<sup>rd</sup> Harmonic Ships to DESY



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**3rd Harmonic safely transported to DESY!**

**Maximum acceleration on coldmass; 1.2 g (transverse) and 1.1 g (vertical)**

# Indian Collaboration



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- **Helium Gas Return Pipe (HGRP) redesign**
  - Uses standard pipe with lower tolerances
  - Lower cost
  - Laser welded components
- **Solid End-group design**
- **Explosion bonded Nb-to-SS joint development**
- **Needle bearing redesign**
- **Scissor tuner**
- **Wedge tuner**
- **Thermal blanket design rather than single sheets**
- **Two-phase pipe redesign**
  - Single pipe
  - Bellows connection down to each cavity
- **$\beta$ .81 cryomodule design is 1st deliverable to Fermilab**

# Summary



- **Developed skills with 3<sup>rd</sup> harmonic design**
- **Established international collaboration**
  - **Common database**
  - **Open communication**
  - **Developed CAD skills in cryomodule design**
- **Began GDE R&D on S1-Global design**
- **Performed shipping studies and delivered 1<sup>st</sup> completed cryomodule overseas**
- **Developing new designs for future cryomodules**
- **Developing cost reduction strategies**