C^3 Quarter Cryomodule Status and Plans

Andy Haase, Martin Breidenbach, Emilio Nanni, Caterina Vernieri

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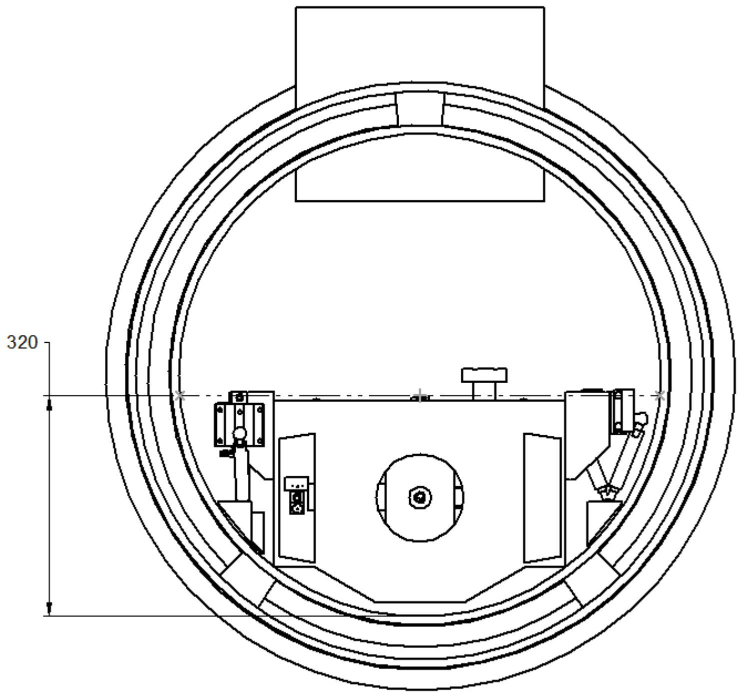
Introduction: The C3 Cryomodule (CM)

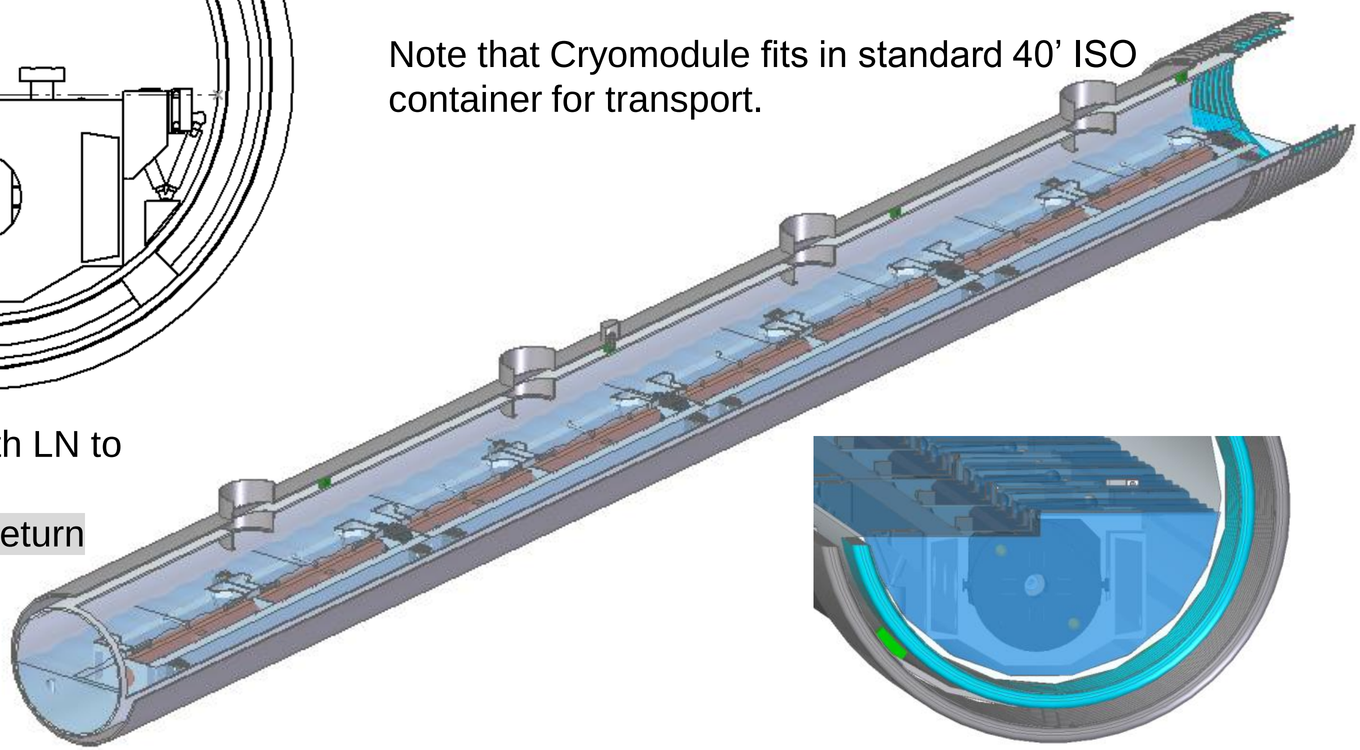


Cryomodules: the transportable assembly unit

4 rafts per Cryomodule (CM)

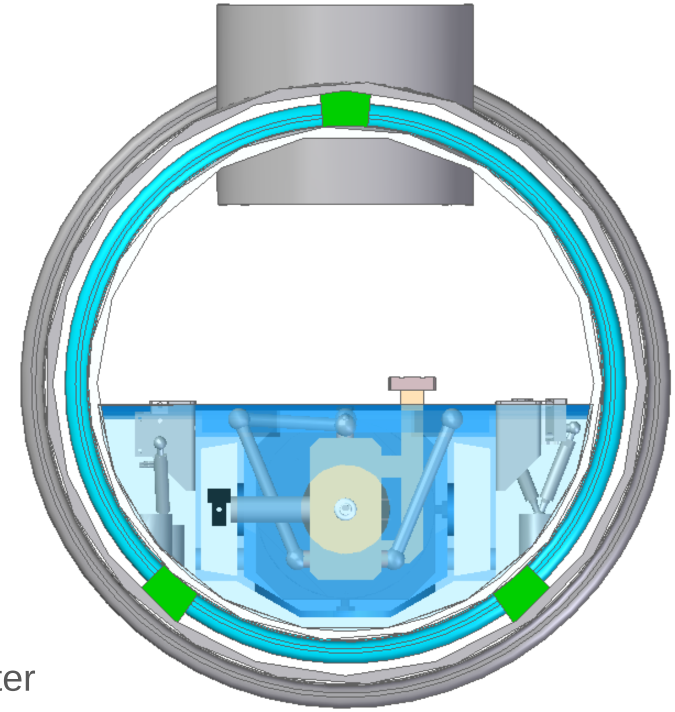
2 accelerator structures and 1 quad per raft

Note that Cryomodule fits in standard 40’ ISO container for transport.



Cryomodules: filled with LN to cover the structures
Provide space for N2 return

Introduction: LN Cooling



- Accelerator is under LN in a vacuum insulated cryostat
- LN flows into page
- Nitrogen vapor counter-flows
- Gravity drives LN flow
- Pressure difference drives vapor flow
- Distributed re-liquifiers condense the cold vapor.
- The design optimization (Cost) loop:
  - String length sets N2 flow rate > area
  - Structure size sets LN depth
  - Together this establishes the minimum vessel diameter
  - Want small vessel diameter but also efficiently sized/located re-liquifiers
  - Critical is what “takes up space” in the vessel.

Introduction: Quarter Cryomodule (QCM)

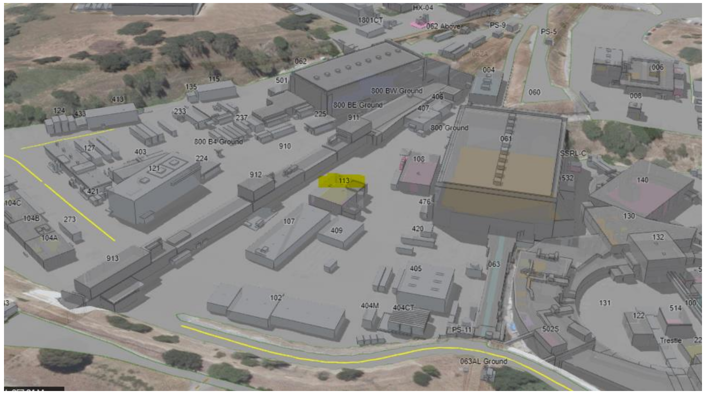
- A system is being prepared to allow testing of one forth of the proposed C3 cryomodule
- This Quarter Cryomodule (QCM) system will allow testing of 2 full scale 1m long accelerating structures with a quadrupole magnet and instrumentation
- The system is designed to accommodate full RF drive with beam interaction (future configuration).
- Initial tests are planned for evaluation with no beam or RF power but using “artificial” heating to allow mechanical evaluation
- A summary of plans and current work follows

Quarter Cryomodule (QCM) System Elements

- **Facility**
- **Cryo Vessel**
- **Connections, Instruments**, Measurements, particularly relevant is the presentation:
  - The alignment of the modules of the Cool Copper Collider (C^3) with the Rasnik 3-point alignment system
- **Nitrogen System**
- Accelerator Structures. For details see presentations including:
  - High Gradient Testing of a Meter-Scale Distributed-Coupling C3 Accelerating Structures
  - A Wakefield Resilient, High Shunt Impedance Accelerating Structure for the Cold Copper Collider
  - Cold Copper High Gradient Single-Cell Structure Tests
  - Luminosity Studies for the Cool Copper Collider
  - Multi-bunch beam dynamics studies in the C3 main linac
  - HOM Detuning and Damping of C-Band Distributed Coupling Structure
  - Distributed Coupling Linac for Efficient Acceleration of High Charge Electron Bunches
- **Accelerator Mounting and Supports**
- **QCM Test Plans**

Initial QCM Facility

- A location at SLAC is currently being prepared for QCM install/use
- The building has existing infrastructure
  - Fork lift accessible work area
  - Adequate electrical power
  - Overhead crane/hoist
  - Room for additional mobile hoists
  - Large liquid nitrogen storage vessel



- Preparations underway or in planning include
  - **Nitrogen systems**
  - Locating/anchoring the cryostat and other significant elements
  - Electrical equipment and thermal load power supplies
  - Accelerator handling equipment and plans
  - All related safety equipment and procedures
- *Once the initial mechanical evaluations are complete the QCM will be reconfigured/relocated for RF and beam testing*.

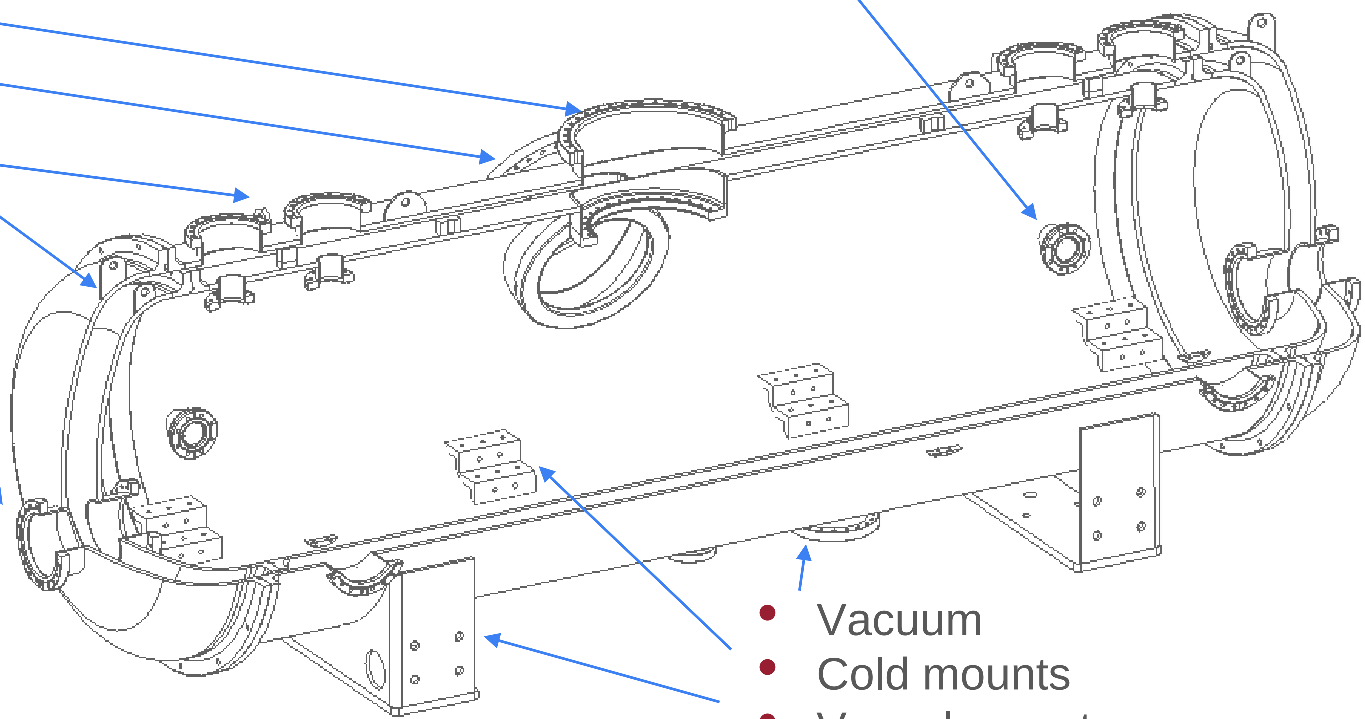
QCM Vessel/Cryostat

- The Cryostat is on order, delivery is anticipated later this year
- Some key elements of the cryostat include:
  - Bolt on “heads” both ends
    - Standard O-ring seals on the room temperature flanges
    - The cold flanges include provision for alternate seals
      - LN rated spring energized PTFE O-rings
      - Indium wire seal (flanges include jack screws for disassembly)
      - Also possible to utilize flat gaskets or delta/omega type seals
  - Attachment points on the inner cold vessel to accommodate a range of installation/mounting features
  - Inner vessel support/locating blocks that can be changed or adjusted if needed
    - “Load path” from structure supports to foundation
    - Adjustments for anti-rock as needed
  - A central alignment pin to fix the inner vessel cold position
  - Ports for high power RF feed
  - An array of flanges for nitrogen handling, instrumentation, and more
    - Except for the vessel head ends all flanges are CF
    - May opt for O-ring seals on the warm flanges

QCM Vessel/Cryostat

- Instrumentation access
  - Rasnik

- RF feed
- Access
- Nitrogen handling
- Lifting/handling
- Beam line (also optical alignment)



- Vacuum
- Cold mounts
- Vessel mounts

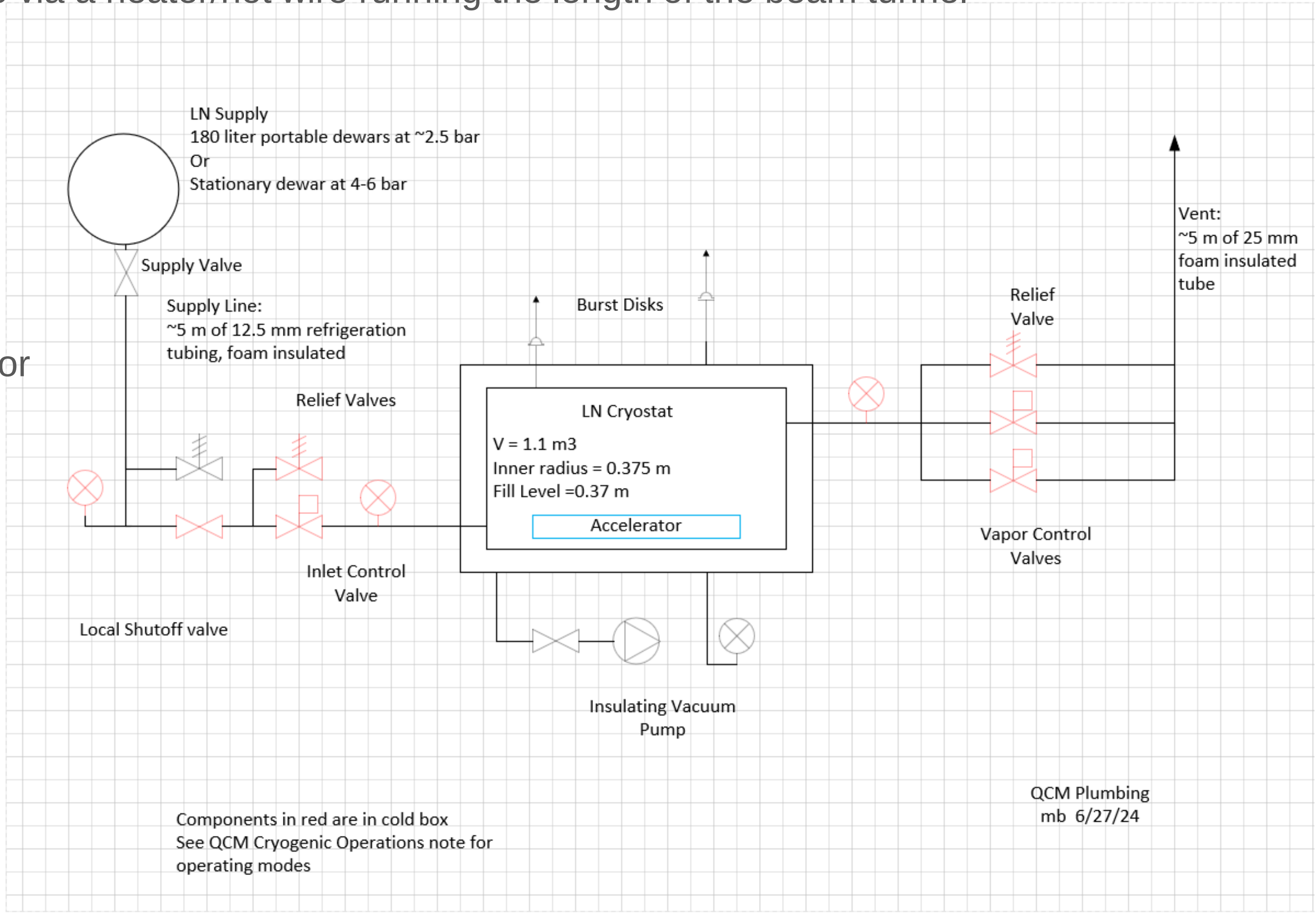
QCM Instruments - access ports

- Temperatures
  - Structure surface and internal
  - Waveguide feed (future configuration)
- Pressures
  - Vacuum vessel
  - Cold vessel
  - LN feed system
  - Structure pressure (used during hot wire heating for controlling heat transfer)
- Nitrogen flow rates
- Heating system power
- RF connections
  - Diagnostic only in early tests
  - High power feeds
- Optical inspection/observation ports
- Acoustic/vibration
  - Multiple accelerometers
- Alignment
  - Rasnik system support
  - Optical beam line

QCM Nitrogen System

- The C3 design losses are 2.5 kW/m
- The QCM system will allow testing to 5 kW/m (10 kW) or more
  - Heating will be via a heater/hot wire running the length of the beam tunnel

- LN flow to 0.1 kg/s
- Nitrogen system controls will allow study of performance/behavior
  - Thermal load
  - LN supply
  - Gaseous Nitrogen Venting

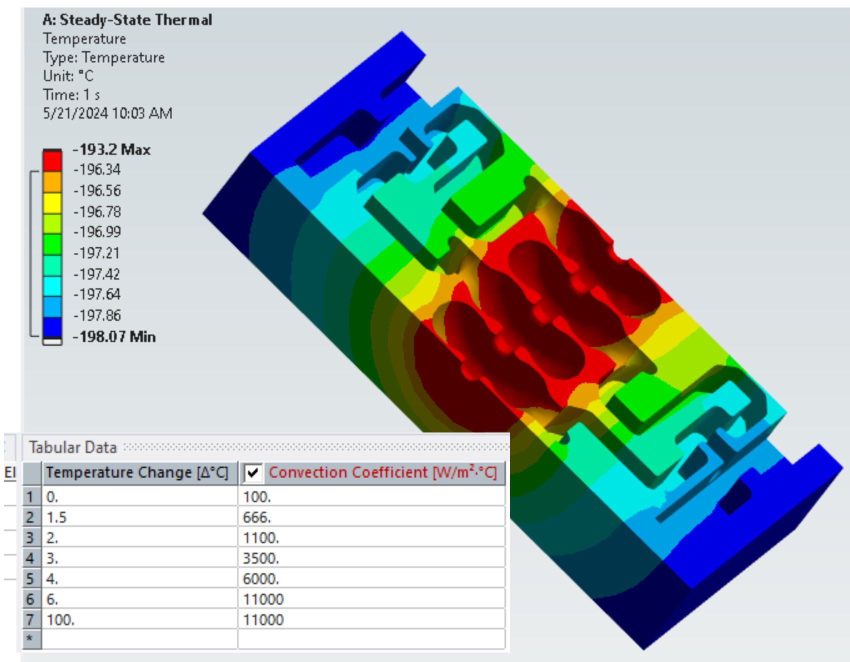


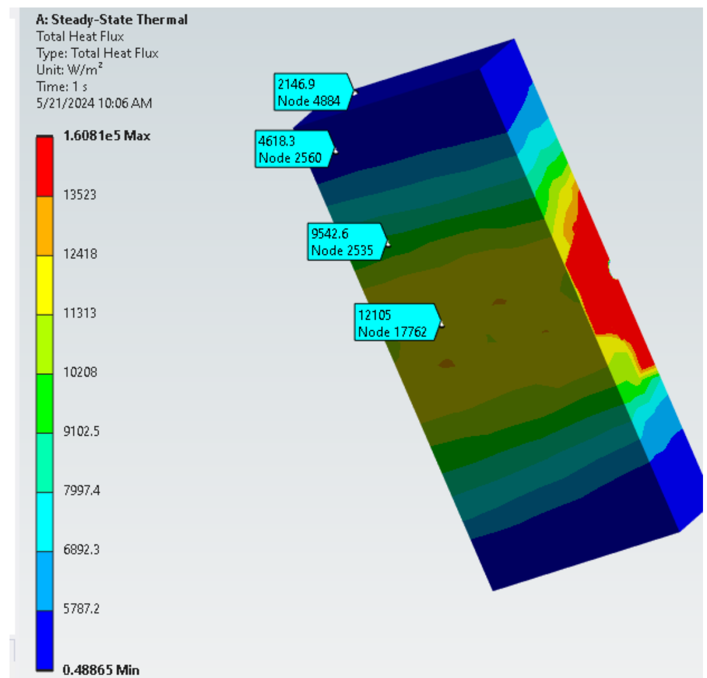
QCM Accelerator Structures

- As noted previously, accelerator tests, design developments, and plans are covered in several talks/presentations
- In addition to RF performance related development, test plans for QCM include **investigation of thermal mechanical performance**.
- To get information as early as possible, initial tests in the QCM will include use of simplified/mechanically representative structures to investigate:
  - Basic fabrication precision but with an emphasis on learning about behavior with LN thermal cycling
  - Mounting and alignment techniques/instrumentation
  - Simulated RF heating to investigate cooling excited vibrations/distortions/motion
- Material for the 1^{st} of these test structures is on order

QCM Accelerator Structures (2)

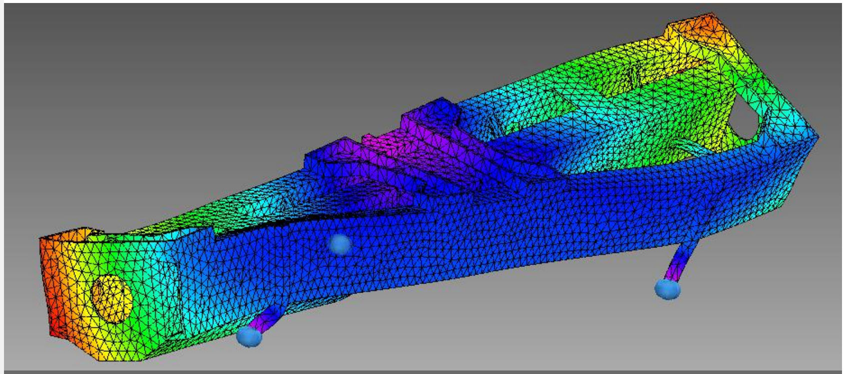
- A representative section of accelerating structure is shown
- Preliminary temperature gradient and surface heat flow simulations are encouraging.
- With the structure oriented as planned, most heat is removed on the vertical surfaces, very little heat transfer is required on the horizontal

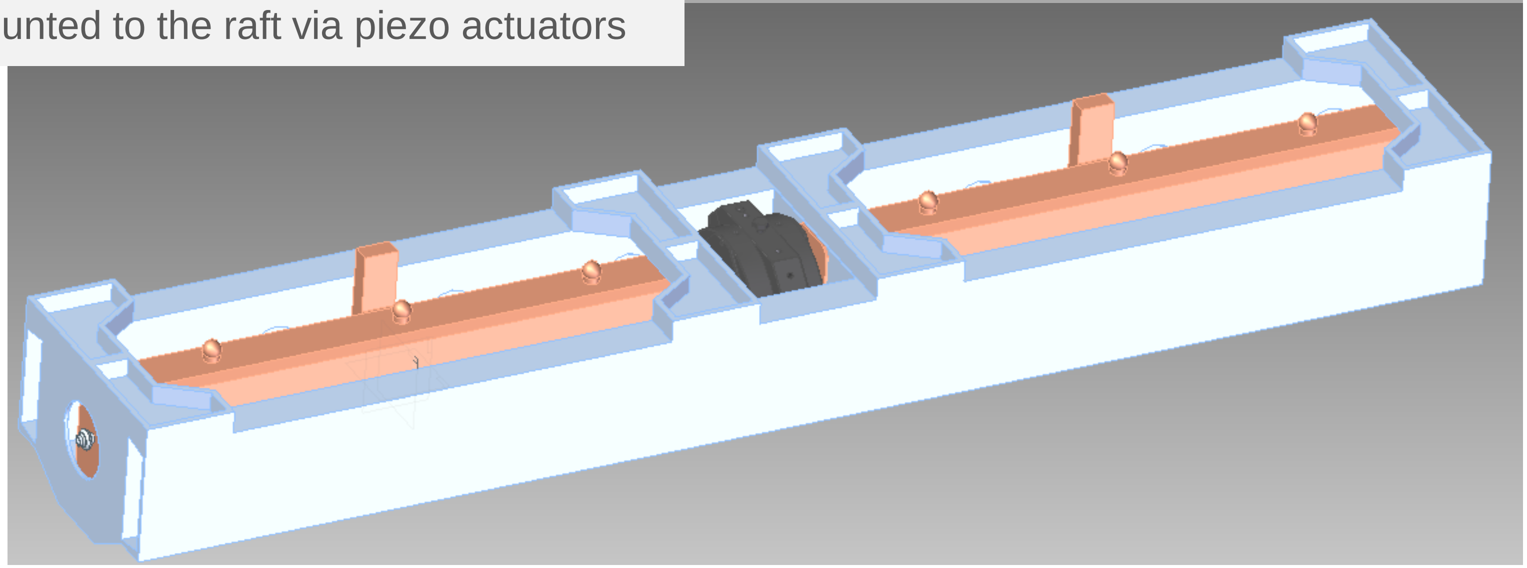




QCM Supports/Alignment

- If the support frame (raft) is supported at 3 points, one of the principle vibrational modes is twisting as shown
- As the Quad must be most closely controlled the baseline configuration locates the quad in the center of the raft
- Initial configuration will provide stepper and piezo motion of the entire raft
  - 5 DOF
- Testing will reveal if the quad should be mounted to the raft via piezo actuators





QCM Supports/Alignment

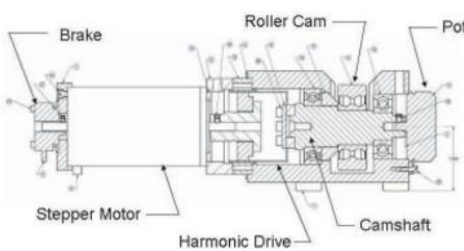
- Plan is to learn from others… and learn by doing
- See Rasnik presentation for pre-beam based alignment developments

Solutions Currently in use at SLAC

- Problems solved in the LCLS Cryo-modules, undulators, and more
- The 5 roller cam undulator alignment system has proven sub-micron performance

https://www.slac.stanford.edu/pubs/slactns/tn04/slac-tn-10-072.pdf

A single module design can be used at all 5 roller cam supports. It consists of an aluminum block housing a 0.75mm lift camshaft with roller cam follower bearing supported on 2 deep groove ball bearings. A cross section of the assembly is shown in Figure(1).



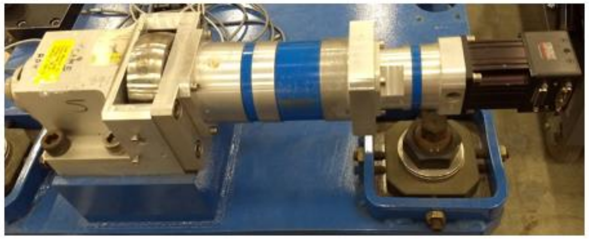


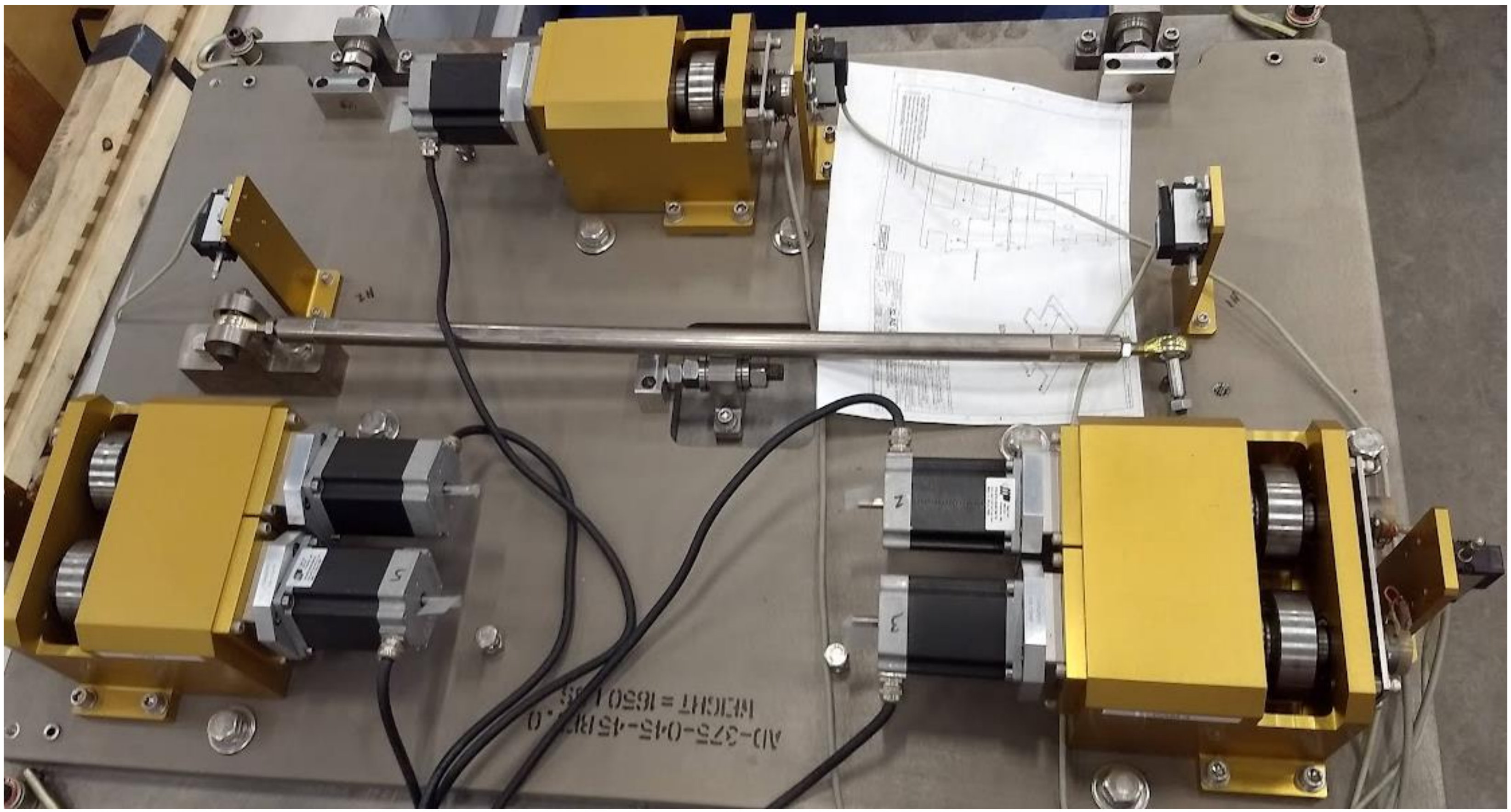
Figure 1: Cross section of roller cam module

*Work supported in part by the DOE Contract DE-AC02-76SF00515. This work was performed in support of the LCLS project at SLAC.

Why a new system?

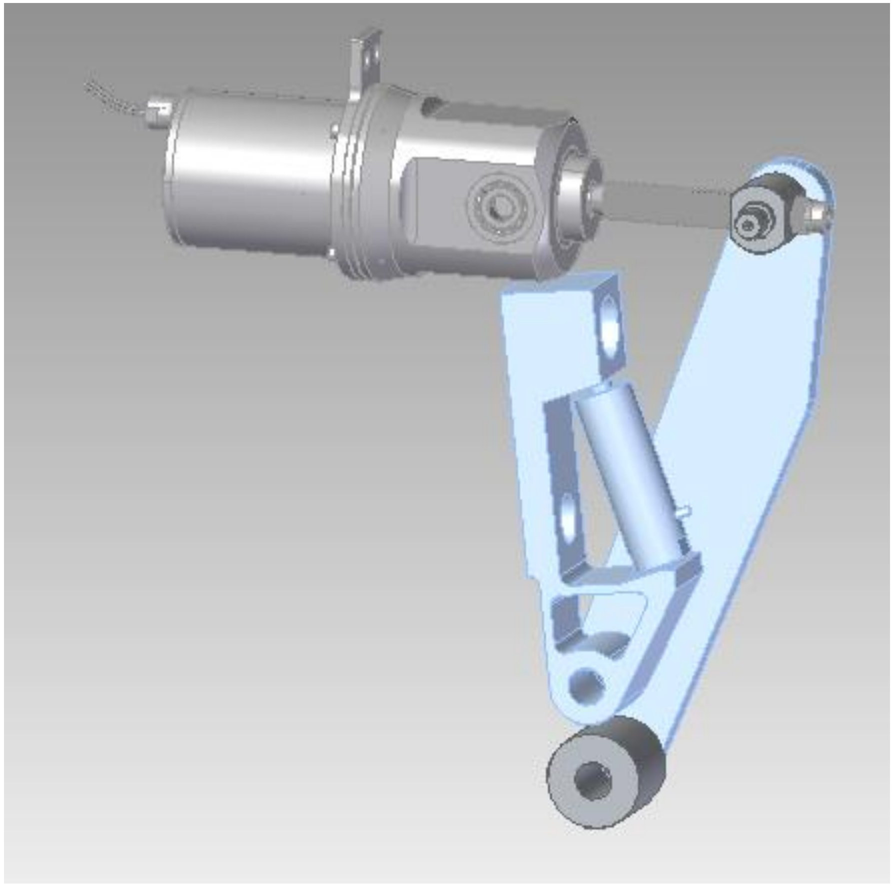
The 5 DOF roller cam undulator system could be adapted to operation in LN

It doesn’t have the high frequency capabilities currently planned for C3



QCM Supports/Alignment

- It is anticipated that several versions of accelerator structure and support frame mounting will be investigated as performance and cost is optimized
- Shown is an initial mount design based on existing LCLS-II hardware
- This configuration is fairly compact and easy to implement.
  - Used in pairs
  - Rides on “V” block
- Looking at a full flexure based mount (at least for the piezo stage)
- Plan to investigate raft slow/structure fast configurations
  - Look to optimize fast stage DOF



QCM Test Plans

Tests/Work that don't require QCM but are closely coupled

- Structure fabrication and straightening
  - Planned for structure in final RF design now
- Structure and Quad mounting/aligning in the support frame (raft)
  - **Design and procure the support raft as required for support and Rasnik**

Once installed, many tests will utilize the capabilities of the QCM system

- Installation and mounting of the raft in the vessel
- Room temperature alignment in the vessel
  - Actuator performance
  - Measurements (Rasnik plus conventional)
- Characterize movement on cool to LN
  - **Look to minimize and/or find consistency**
- Verify actuator performance cool (precision, frequency response)
- Verify Rasnik and other alignment techniques when cool, in LN, no heating
- Investigate behavior with heating / LN cooling
  - Use the heaters and instrumentation to understand system performance.
  - **Especially boiling driven displacement**
- Validate assembly procedures suitable for full CM usage
  - Overhead beam/rail
- Once all this and more is complete, the QCM will be relocated and used for "real" tests with RF and beam

Summary/Questions

- The QCM system will allow for characterization of many aspects of the C3 system even before high power RF and beam testing begins
- It is anticipated that considerable performance improvement and design optimization will result from the full scale testing made possible by the QCM system
- Questions/Comments/Suggestions?
  - Sorry to be remote and missing out on related presentations and discussions
  - Happy to receive e-mail inquiries etc.
- Thanks!