Cryomodules Standardization

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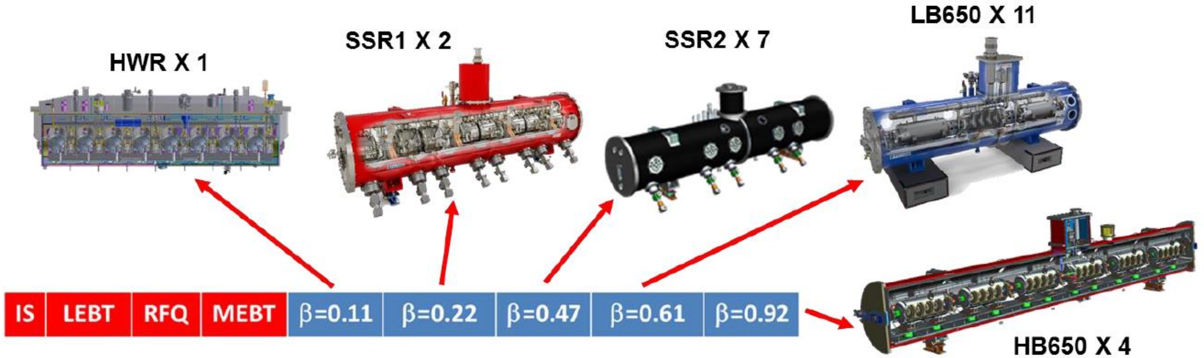
International Workshop on CM Design & Standardization

09/06/2018 OR 06/09/2018 OR 6 Sept 2018 ???

STANDARDIZATION ON PIP-II SC LINAC: CEA POINT OF VIEW



- **Standardization: why?**
  - Ease the maintenance and repair operations, and the supply / storage of consumables (less suppliers, less references)
- **Standardization: what?**
  - Common design rules: it has been agreed in June to use metric system, but which Geometric Dimensioning and Tolerancing norms: ISO 2768 or ASME Y14.5-2009?
  - Common CAD software
  - Identical components: off the shelf products, consumables, specially designed parts (C clamps, alignment supports, piping …) → see next slide
  - Assembly tooling (depending on the design concept of the different cryomodules) → good definition of the interfaces and assembly steps at the beginning of the detailed design phase
  - Specific requirements on the components: vacuum compatibility, criteria for the use in clean room, magnetic hygiene, hard-rad materials …
- **Standardization: how?**
  - To be discussed during this workshop

STANDARDIZATION ON PIP-II SC LINAC: LIST TO BE DISCUSSED

- Piping: material and diameter
- Cryogenic valves
- Vacuum components: vacuum valves, vacuum gauges, pressure transmitter …
- Safety devices: safety valve, burst disk …
- Instrumentation flanges with electrical feedthroughs
- RF cryogenic cables
- Type of gaskets / seals: beam vacuum, insulation vacuum, cryogenic circuits
- Instrumentation: temperature sensors, heaters, tuning system motors
- Fasteners: type, material, size, length, specific requirements (electropolishing , magnetic permeability, silver plating …)
- MLI: how to attach the parts: aluminum tape or Velcro?
- Alignment targets
- Cryomodule supports

Major sub-systems and components

- Cavities
- Couplers
  - Coupler installation tooling
- Tuners
- Magnetic shielding

Validation: horizontal test stand

- Cavity support system
- Cryogenic system within CM
  - Cryogenic piping
  - Cryogenic valves
- CM assembly tooling

Validation: CM test stand

- Transportation fixtures & temporary tooling

Outside CM systems

- Alignment strategy
  - Fiducials; HBCAM vs Wire frame
  - Track during/after cool down? During transport?
- Interfaces
  - RF, Cryogenic, Beam line, Vacuum
- Instrumentation
  - Inside & outside CM
  - In VTS & test cave (e.g., radiation monitors for FE monitoring)
  - Connectors and flanges
- In-tunnel transport
- CM support stands
- Performance measurement methods/techniques

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Cavities – standardization

- Interfaces
  - Lifting lugs
  - Cavity positioning lugs
  - Coupler & pick up port
  - Tuner attachment pads

Same for SSR1 & SSR2?
Same for LB650 & HB650?

- Benefits of standardized parameters:
  - Tooling required can be the same for the cavities
    - Only remaining variation would be based on the existing facility
  - Single design operation and procurement cycle

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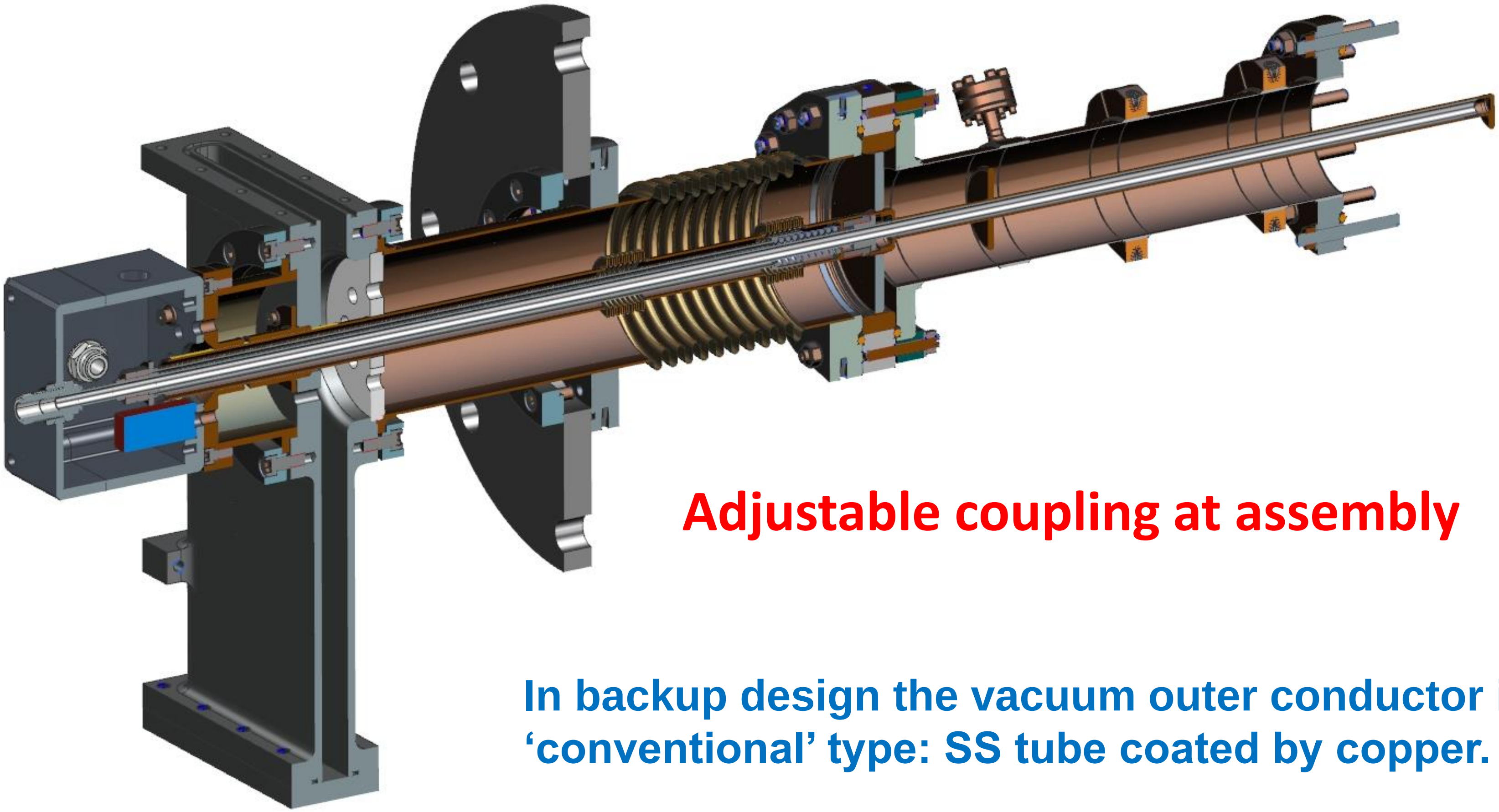
Couplers – standardization

- Coupler flange on cavity
- Thermal stages
  - 2 K, 5 K, 50 K, 300 K
- Thermal straps

Same for SSR1 & SSR2?
Same for LB650 & HB650?

- Benefits of standardized parameters:
  - Single design operation
  - Larger procurement
    - Coupler procurement can be complex
    - Validated manufacturing procedures at vendor can be used on larger quantities
      - Lower QA issues & greater reliability
    - Potentially lower cost per coupler due to volume discounts

650 MHz coupler, conventional (backup) design.



Adjustable coupling at assembly

In backup design the vacuum outer conductor is 'conventional' type: SS tube coated by copper.

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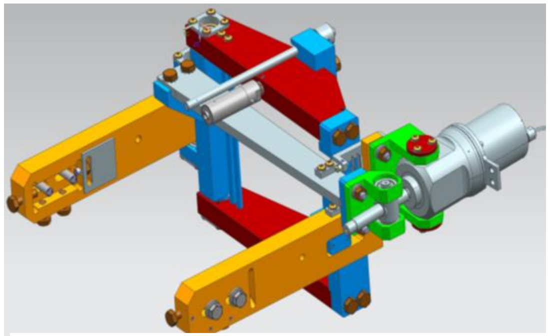
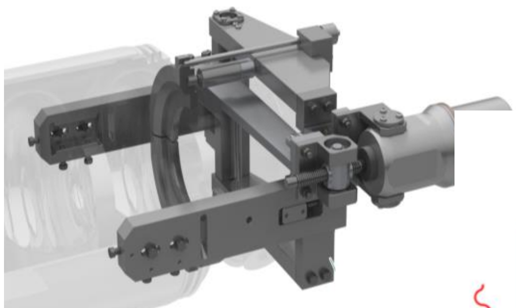
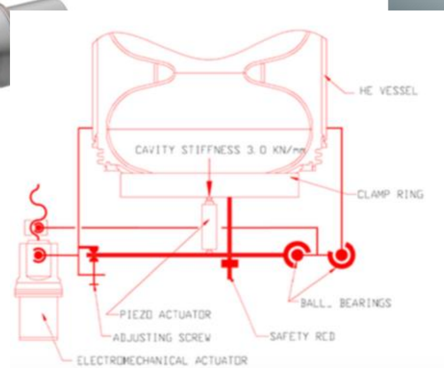
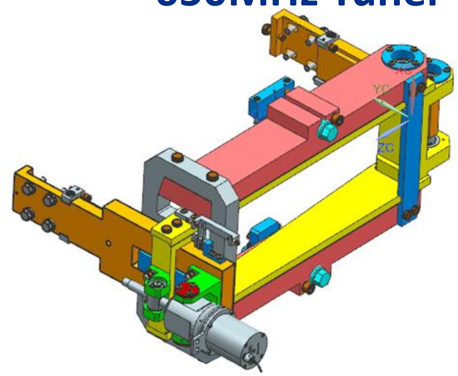
LCLS II Tuner

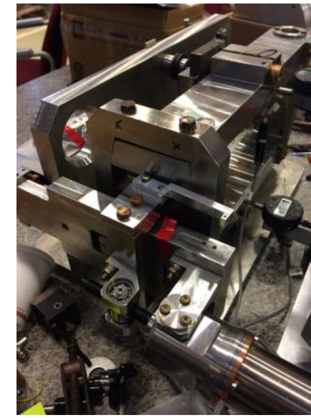


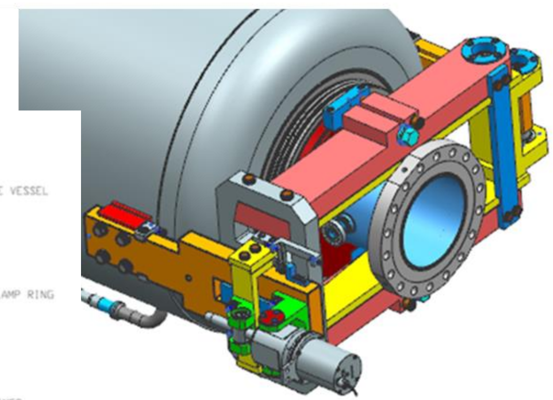




650MHz Tuner







Tuner characteristic (based on warm measurements and LCLS II test)

Coarse tuner range ~300kHz
Coarse tuner res. ~1Hz/step
Back/lash coarse tuner ~40Hz

Fine tuner range ~6-8um (1.5kHz)
Fine tuner resolution ~ 0.1Hz

Tuners – standardization

- Tuner interface with cavity
- Piezo & motors
- Stiffness of the system
- Algorithm development

Same for SSR1 & SSR2?
Same for LB650 & HB650?

- Benefits of standardized parameters:
  - Single design operation
  - Larger procurement
    - Piezo & motors are long lead and expensive items if purchased individually
      - Potentially lower cost per item due to volume discounts
  - Cavity may be different, but tuner the same for algorithm

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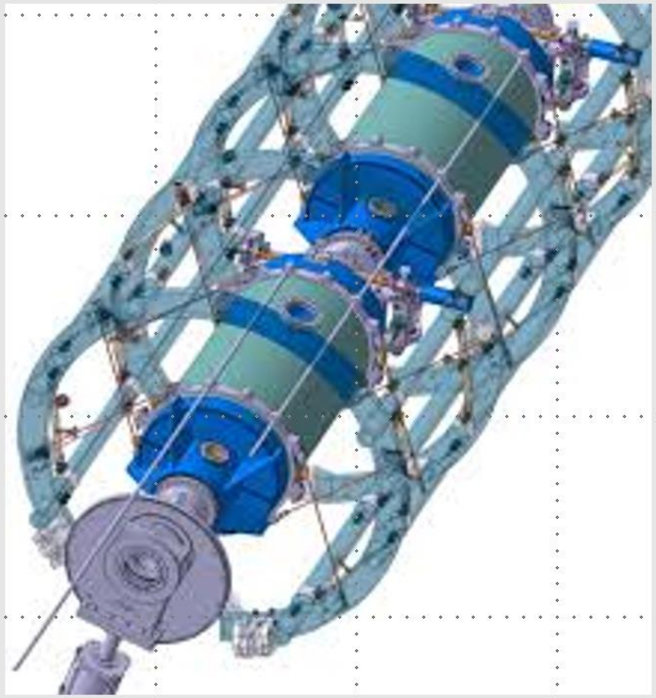
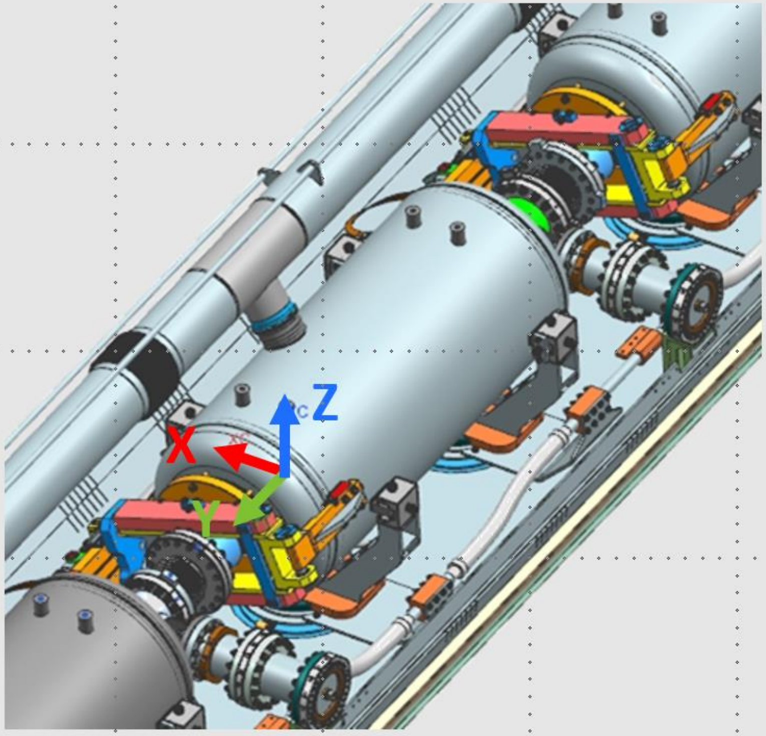
Cavity support system

- Spaceframe, strongback are options for PIP-II (not for HWR)



ESS magnet support and space frame



Cavity support system – standardization

- Strongback?
  - Validate in SSR1
- Spaceframe?
  - 650 MHz only

Same for SSR1 & SSR2?
Same for LB650 & HB650?

- Benefits of standardized parameters:
  - Design for individual module types would be derivations
  - Concept validated earlier with one module type
  - Tooling for assembly will also be similar in concept

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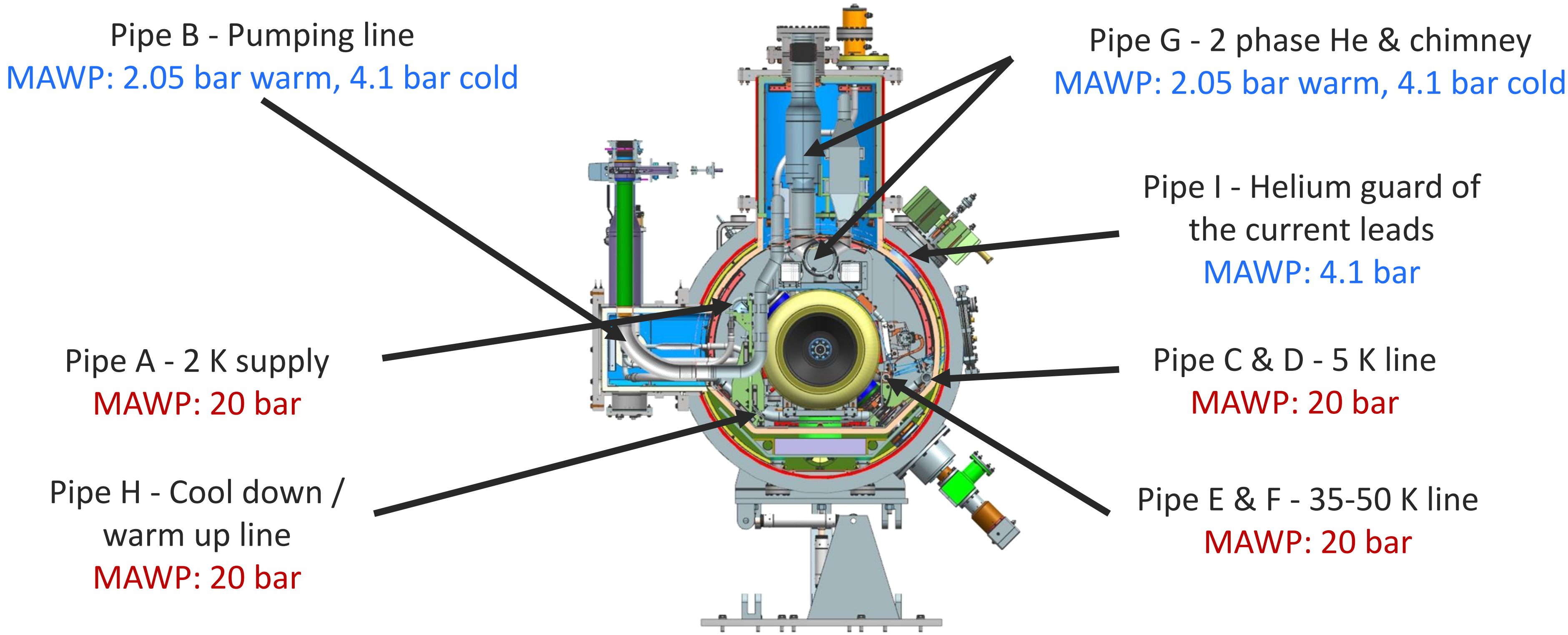
3. Cryogenic layout of the cryomodules

All cryomodules have the same layout and the same pressure design values.
All cryomodules need to be compatible with a fast cool down:

- Above 20 K/hour through the Q-disease regime 90 - 175 K.
- Above 120 K/hour through the superconducting transition at 9.2 K



Cryogenic system – standardization

- Heat exchangers
- Valves
- U-tubes

Same for SSR1 & SSR2?
Same for LB650 & HB650?

- Benefits of standardized parameters:
  - Concept validated earlier with one module type
  - Reliability increased
  - Vendors validated

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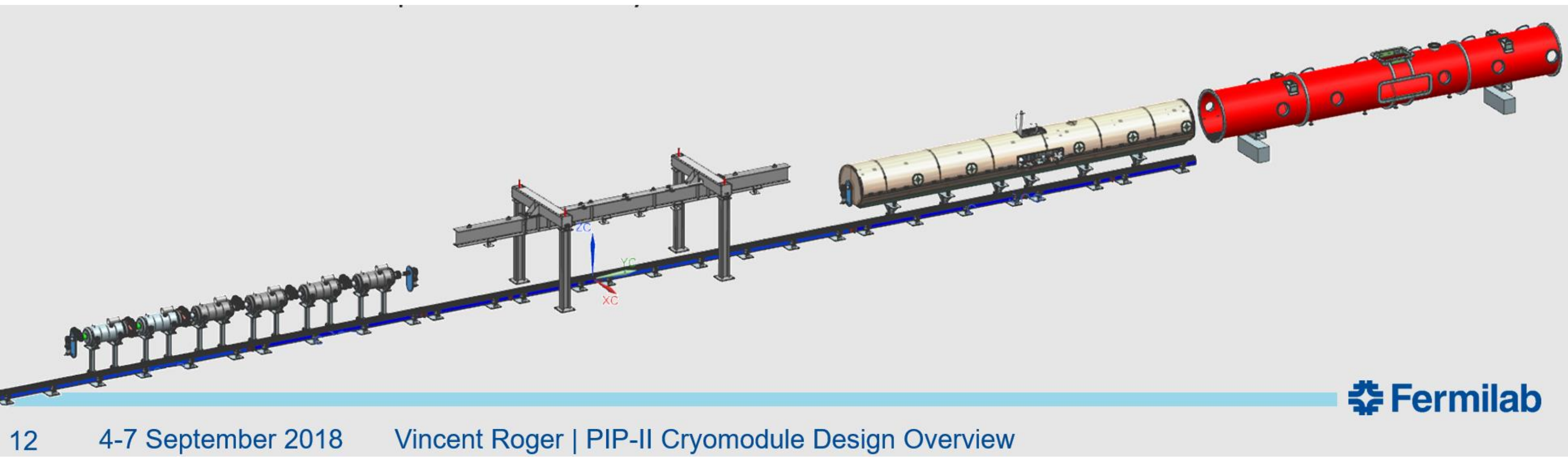
ZC
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XC
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12
4-7 September 2018
Vincent Roger | PIP-II Cryomodule Design Overview

Tooling – standardization

- Includes cleanrooms, processing facilities, assembly
  - Each facility to have separate tooling
  - Interfaces to the components may be standardized
- Constraints:
  - Facility interfaces – may be difficult to standardize across Partners

- Benefits of standardized parameters
  - Tooling changes for facilities (e.g. cleanroom) takes time
    - Configuration changes can be few weeks to months
  - Increases reliability
  - Decreases cost for the facility

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Multiple methods available

Fermilab

Transportation fixtures – standardization

- Benefits of standardized parameters
  - Tooling can be validated for the transport boundary conditions
  - Increased reliability
  - Consolidated design across the modules

Outside CM systems

- Alignment strategy
  - Fiducials; HBCAM vs Wire frame
  - Track during/after cool down? During transport?
- Interfaces
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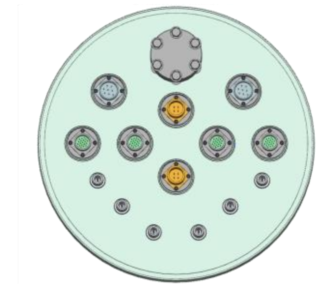
4. Interfaces

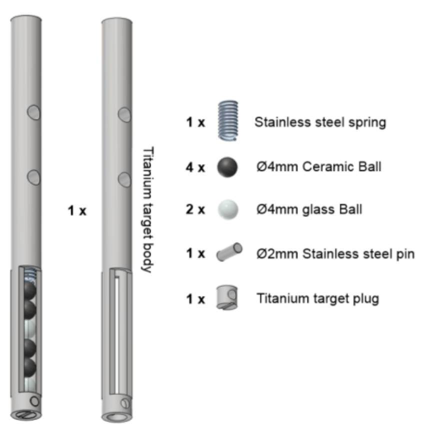
Alignment

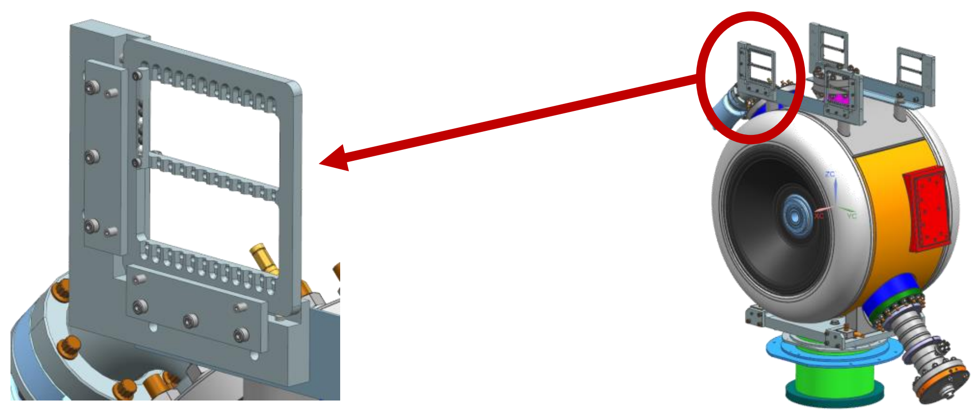
Cryomodules will be tested at PIP2IT and then they will be set up in the PIP2 Linac. Therefore, it is essential to have a common interface.

- It will be better to use the same cryomodule movers.
- Instrumentation connector need to be standardized. Detoronics or Ceramtec connectors will be used.



- The same fiducials on each cavity and solenoid will be used





Fermilab

4. Interfaces

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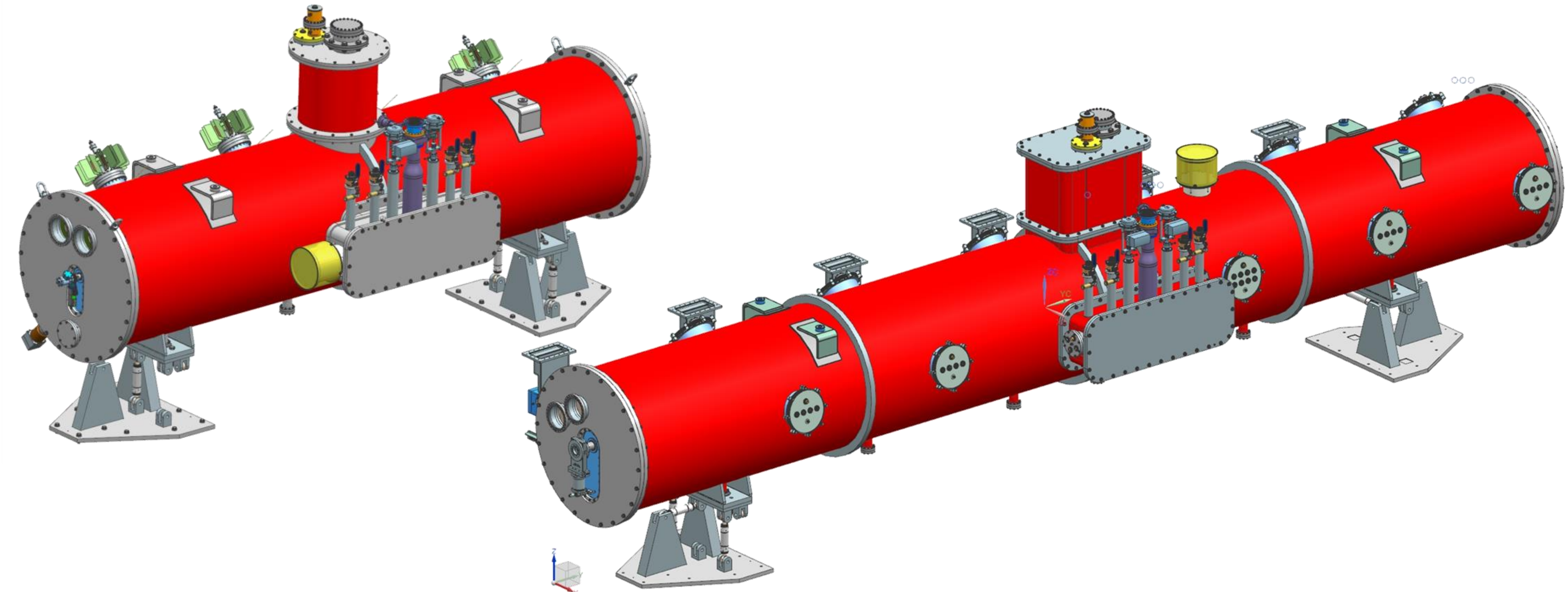
- Cryomodules need to be designed in order to accommodate the same cryomodule stands. These stands allow a movement of +/- 30 mm in all directions



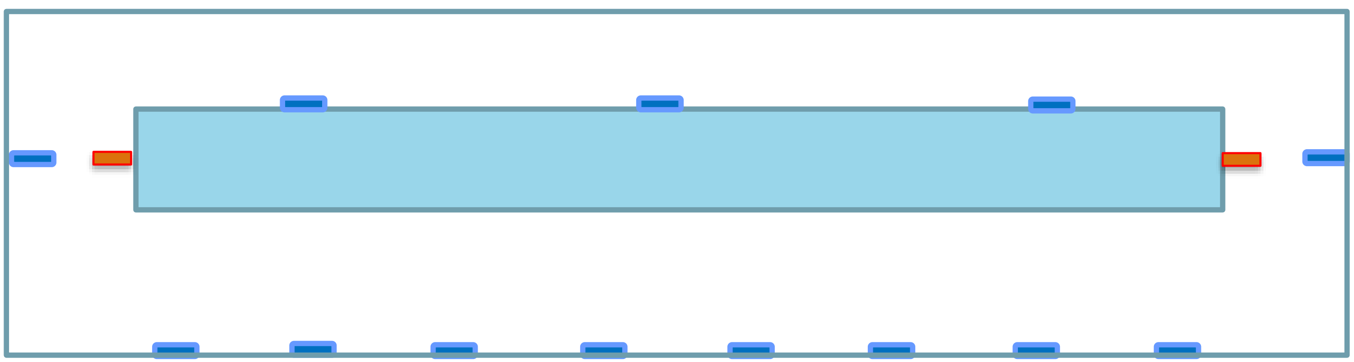
Q0 (Heat Load) Measurement

- Method A – Mass flow change (Fermilab Production)
  - Measure mass flow delta to extrapolate heat load
- Method B – Measure compensation heater
  - Maintain constant mass flow
  - Measure RF compensation heater power
- Method C – dP/dT (JLAB Production)
  - Close JT valve to allow pressure rise due to known heater powerdynamic heating
  - Close JT valve to allow pressure rise due to dynamic heating
  - Measure pressure rise dP/dT to calculate the heat load

Gradient Measurement Comparison

- Method A – Forward Power (Production method)
  - Waveguides assembly does not change
  - Calibration is stable
  - Less affected by environment
- Method B – Transmitted Power
  - Transmission line less rigid
  - May require configuration changes due to signal levels
  - More connections/disconnections
  - VTS to cryomodule changes can happen
  - VTS measurement error propagation
- Method C – Reflected Power
  - Pulsed Power Uncertainty
  - Complicated RF calibration

Field Emission Monitoring



Ion chamber detectors

Faraday Cups

CMTS-1 at Fermilab

STANDARDIZATION ON PIP-II SC LINAC: LIST TO BE DISCUSSED

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Summary

- Long list of systems that could benefit from standardization
- Some items already attempted to be common
  - HB/LB 650 couplers
  - HB/LB 650 tuners
  - Tuner motors and piezo for SSR & 650 MHz CMs
  - Strongback as a common concept
    - Once validated, will be used for SSR1 & SSR2
  - CM stands & movers within the tunnel
- Performance measurement method needs to be standard
- A long way to go…