Project X
Cryogenic Segmentation Issues

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Outline

- Key Functional Requirements and Design Issues
- Cryogenic segmentation
- Summary

Key Cryogenic System Functional Requirements

IC-1

- *8 GeV Pulsed Linac (5Hz)*
  - 19 SC solenoids
  - 2 x SSR*-1 cryomodules
  - 3 x SSR-2 cryomodules
  - 7 x TSR** cryomodules
  - 40 TESLA style CM (β = 0.81 and β = 1)
  - Elliptical cavities at 2.0 K
  - Spoke resonators < 4.5K

IC-2

- *3 GeV CW Linac*
  - 4 x SSR-0 cryomodules
  - 2 x SSR-1 cryomodules
  - 3 x SSR-2 cryomodules
  - 8 x TSR cryomodules
  - 20 TESLA style CM (β = 0.81 and β = 1)
  - All SRF at 1.8 K

IC-2 v2

- *3 GeV CW Linac below*
  - 1 x SSR-0 cryomodules
  - 2 x SSR-1 cryomodules
  - 4 x SSR-2 cryomodules
  - 7 x 650 MHz CM (β = .61)
  - 12 x 650 MHz CM (β = .9)
  - 9 x 1.3 GHz CM (β = 1)
  - Temperature TBD
- *8 GeV Pulsed Linac*
  - TBD x 1.3 GHz CM (β = 1)

- *Allow cool-down and warm-up of limited-length strings of SRF components*
- *Protect SRF cavities from over pressurization during fault conditions*

*– Single Spoke Resonator (SSR), ** – Triple Spoke Resonator (TSR)

Key Design Issues

- Multiple CM Designs
  - Some designs already exist based on TESLA
- Cryogenic Distribution
  - JT heat exchanger
  - Relieving requirements
- Heat Loads (CW vs Pulsed sections)
  - CW CM heat load peaks at 240 watts

Factors to Consider

- Existing accelerator experience
- Types of cryomodules
- Heat Loads and JT Heat Exchanger Location
- Reliability & Availability
- Technical Risk
- Cost
- Warm space requirements (beam optics)
- Commissioning and Upgrade scenarios

Existing Accelerator Experience

- Use of segmentation varies from machine to machine
  - Wide range of machine designs & sizes
    - ILC – ~30 km linac, most cryomodules ~ identical
    - CEBAF -- 20 cryomodules in each linac, each CM removable
    - FRIB – ~ 300 m linac, at least 2 separate cryomodule designs
- There is no “one-fits-all” answer to cryogenic and vacuum segmentation
- Iterative Process:
  - Make choices, look at design and cost implications, change as required

Types of Cryomodules

- Project X will consist of a variety of cryomodule designs
- Cryomodules may be provided by different sources and arrive at different times
- Segmentation could allow for phased installation and commissioning

Heat Loads

- Significantly higher dynamic heat load in CW operation
  - Operation in CW requires special attention to superfluid heat conduction and vapor velocity (two-phase flow regime and pressure drop)
  - Impacts the size, and thus location, of the JT heat exchanger
    - 240 w at 2.0K JT heat exchanger is about 1m x 0.3m x 0.3m

Three options for JT heat exchanger placement

- At the plant
- At the segment
- At the cryomodule

Reliability & Availability

- Vacuum space should be divided to allow efficient leak testing
  - Searching for leaks impacts commissioning schedule and availability
- Additional complicated devices may result in lower overall reliability
- By contrast, ability to quickly warm up and repair small sections of components may well lead to overall better availability
- Project X total availability is listed at 90%

Technical Risk

- Segmentation should take into account that those components containing items of higher technical risk are more apt to require warm up and repair
- For Project X
  - TESLA style CM in pulsed mode have lower risk due to FLASH history and testing
  - SSR CM in CW mode have high technical risk
  - 650 MHz CM in CW mode have high technical risk
  - TESLA style CM in CW mode have moderate technical risk

Cost

Segmentation adds cost due to:

- Parallel cryogenic transfer line
- Interface boxes
- Added tunnel length (1-3 m per isolation)
- Added tunnel diameter or alcoves

  (to accommodate transfer line and U-tube pulling)
- Increased probability for ODH event

Summary

- A segmentation solution for IC-2 v2 was developed for costing purposes
- The next iteration will benefit from better understanding of the functional requirements, reliability, and cost implications
- Close cooperation between cryogenics and cryomodule working groups is essential for the development of an effective solution
- Collaboration experience and recommendations are welcome