FERMILAB-SLIDES-21-019-DI

High Power 650 MHz Magnetron RF Power Source

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Technical approach: SRF tech and Fermilab

- Fermilab is a world leader in SRF technology for discovery science as demonstrated by delivering SRF cryomodules for LCLS-II and building PIP-II.
- SRF is a mature technology, however, to be useful in non-scientific applications, parameters such as compactness and simplicity need to be considered.
- The elimination of liquid cryogens makes SRF technology accessible for industrial applications. This can be accomplished through Conduction Cooling which has been demonstrated by Fermilab.
- The first year of this effort (FY20) investigated RF sources for SRF applications.
- Now we are integrating conduction cooling and related technologies for the first time into a prototype accelerator as part of *alternative* technology for Co-60 replacement for medical device sterilization.

Capability Improvement

Efficient, high-power X-ray source for medical device sterilization

- 1 Mci of Co-60 produces ~ 15 kW of power
- X-rays are essentially a direct replacement for Co-60 irradiation
- Due to Bremsstrahlung inefficiency, need ~ 120 kW of electron beam power to equal 1 Mci of Co-60
- Medical device production is growing by ~7% per year. To provide comparable treatment capacity, additional accelerator designs are needed. Enter SRF.
- Achieving this as compactly, simply, and efficiently as possible will improve the attractiveness of alternative technologies to help move the industry away from Co-60.
- Validation of this design is the final step before a first article of 7.5 MeV, 150 – 200 kW.

Project Overview, Goals, Deliverables

Goal: Fabricate and assemble a prototype 1.6 MeV compact SRF system to validate the integration of:

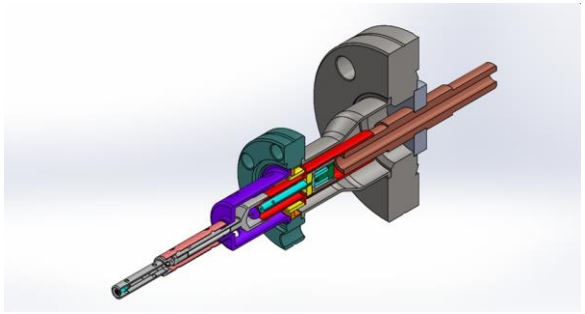
- Integrated electron gun
- Conduction cooling & Cryocoolers
- Nb_3Sn coating
- Low-heat loss RF coupler

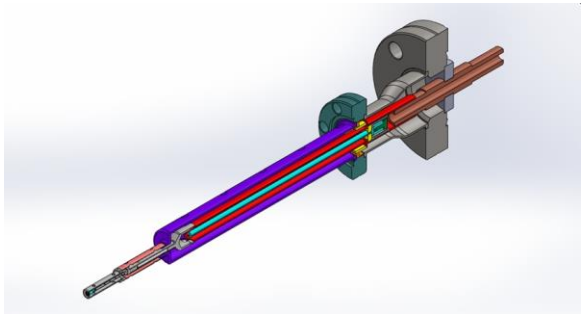
- Deliverables
  - FY21 – RF Coupler
  - FY22 – Cavity & Cryostat
  - FY23 – coated & tested cavity, commissioned system

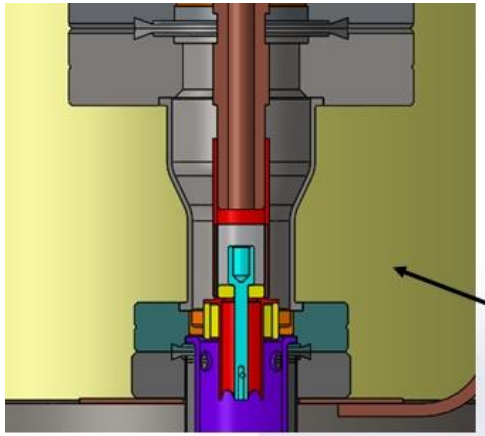
Progress to Date

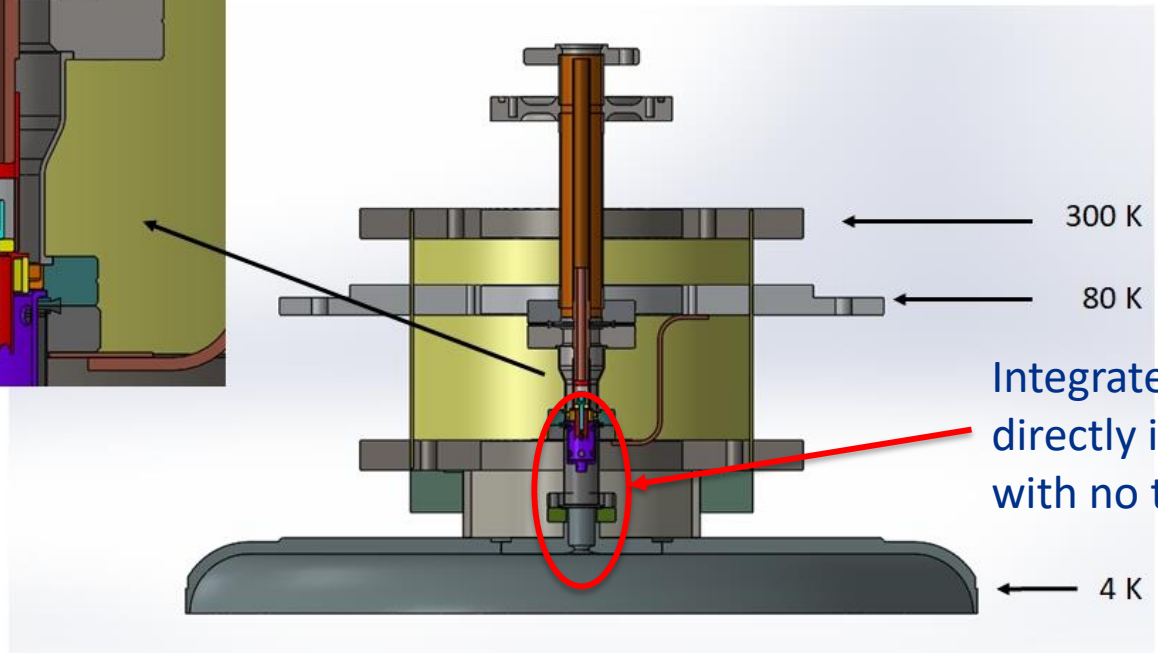
We are in the process of finalizing design work of major components

1. Gun design
   - Lengthening to improve thermal distribution
   - Impacts Cryostat design









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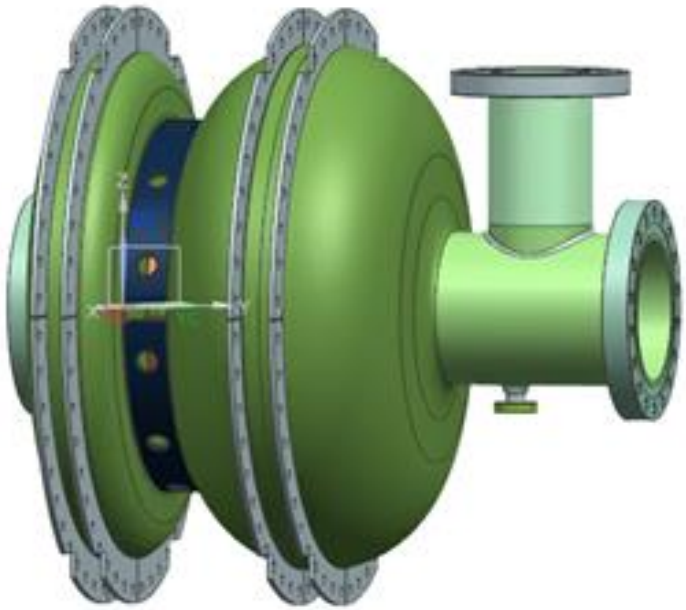
Progress to Date

Finalizing design work of major components

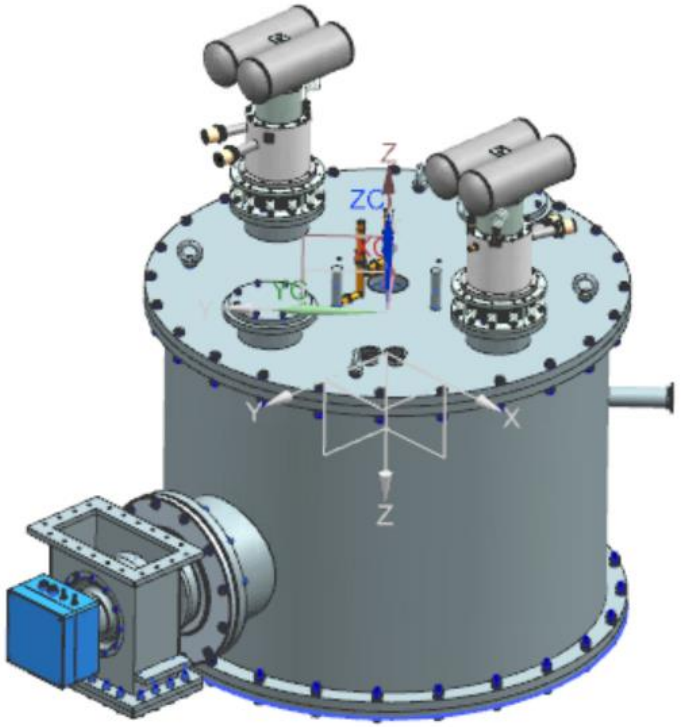
2. Cavity Design
   - Completed
     - RF and beam transport simulations
     - Structural design
     - Niobium material procurement
   - In progress
     - Production drawings
     - Fabrication bid package

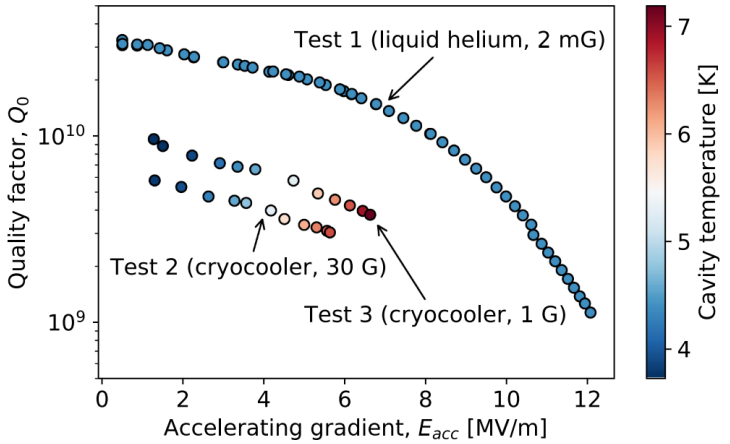


Progress to Date

Finalizing design work of major components

3. Cryostat Design
   - Completed 3D modeling of all components
     - Vacuum jacket
     - Thermal and magnetic shields
     - Cavity support, coupler interface
   - In progress
     - FEA analyses of the above components
   - Next
     - Fabrication drawing and bid package
     - Cryomech PT425 now available (2.5 W @ 4.2 K)





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Nonproliferation

Presently, X-ray sterilization represents about 1% of the medical device sterilization market whereas Co-60 services 40-50%.

- However, 7 new X-ray facilities have been announced and will become operational in the next two years.
- Capacity issues in the medical device sterilization market are driving new interest in alternative technologies.
- A forecast presented at the 2019 Midwest Medical Device Sterilization Workshop projected the need for 200 – 400 new accelerator systems in the next 10 years.*

* https://indico.fnal.gov/event/21411/attachments/38999/47262/C._Malice_E._Craven_-_E-beam_and_X-ray_What_Why_How.pdf

Technical Challenges

- Coating of single-ended cavity
  - Double ended cavities have been coated very reliably by Fermilab with excellent performance.
  - The coating process continues to be aggressively developed
  - Our coating needs are still 18 months away.
- Determination of dynamic losses (under RF and with beam)
  - This will be a fundamental validation of the heat budget that enables the compact SRF concept.
- Economical RF power
  - Not part of this effort, but cost of RF power will become the major single expense of an accelerator system.

Future Work

FY21:

- The majority of work in this year is procurement of long-lead items.
- Other items are preparation of the test cave and acquiring diagnostics

FY22

- Testing of RF supplies & bare cavity. Begin Nb_3Sn coating.

FY 23

- Final integration and commissioning