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Beta-SRF – A New Facility to Characterize SRF Materials near Fundamental Limits

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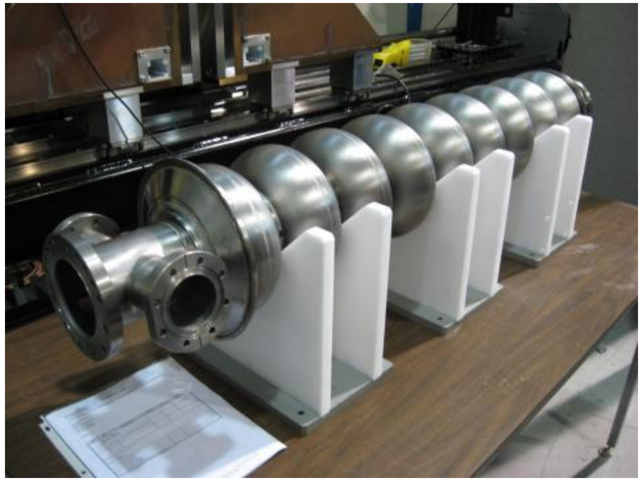
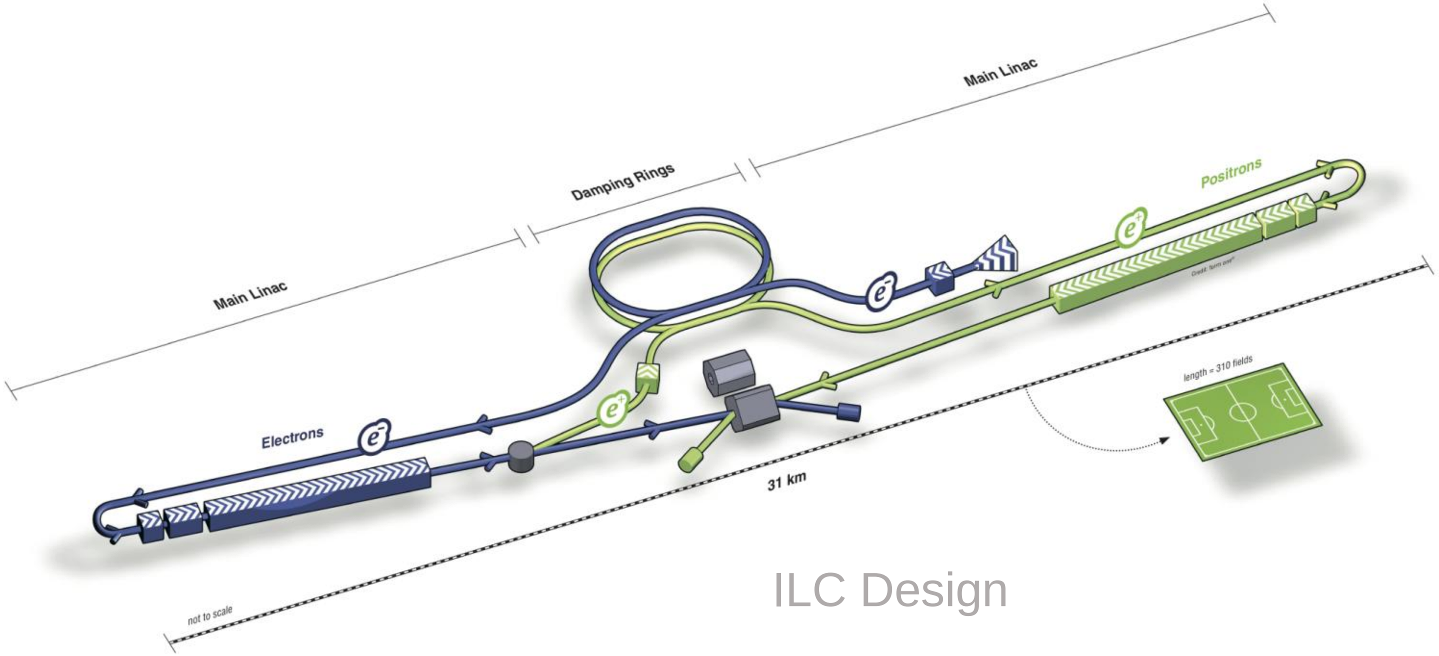
Discovery, accelerated

Superconducting Radiofrequency (SRF) Cavity

ARIEL 9-cell



ISAC QWR



ILC Design

SRF Cavities: Underlying technology for modern linear accelerators

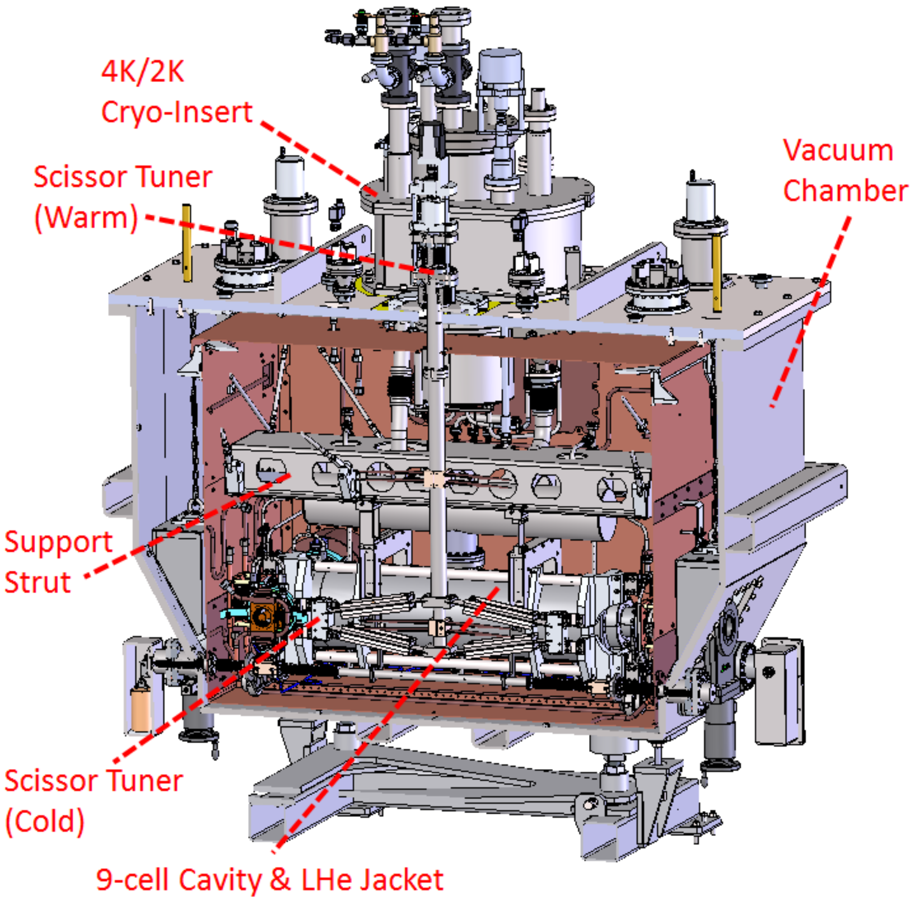
- Developed since the 1960s
- CW: high power LINACs
- High-gradient: shorter LINACs at higher energies

Application Examples:

- RIB Facilities: TRIUMF ARIEL, FRIB
- Light-Source : LCLSII, E-XFEL (768 cavities)
- Electron-positron Collider: ILC (~ 16,000 cavities)

SRF Cavity Performance

Operations: **LHe (2K/4K)**



ARIEL Cryomodule

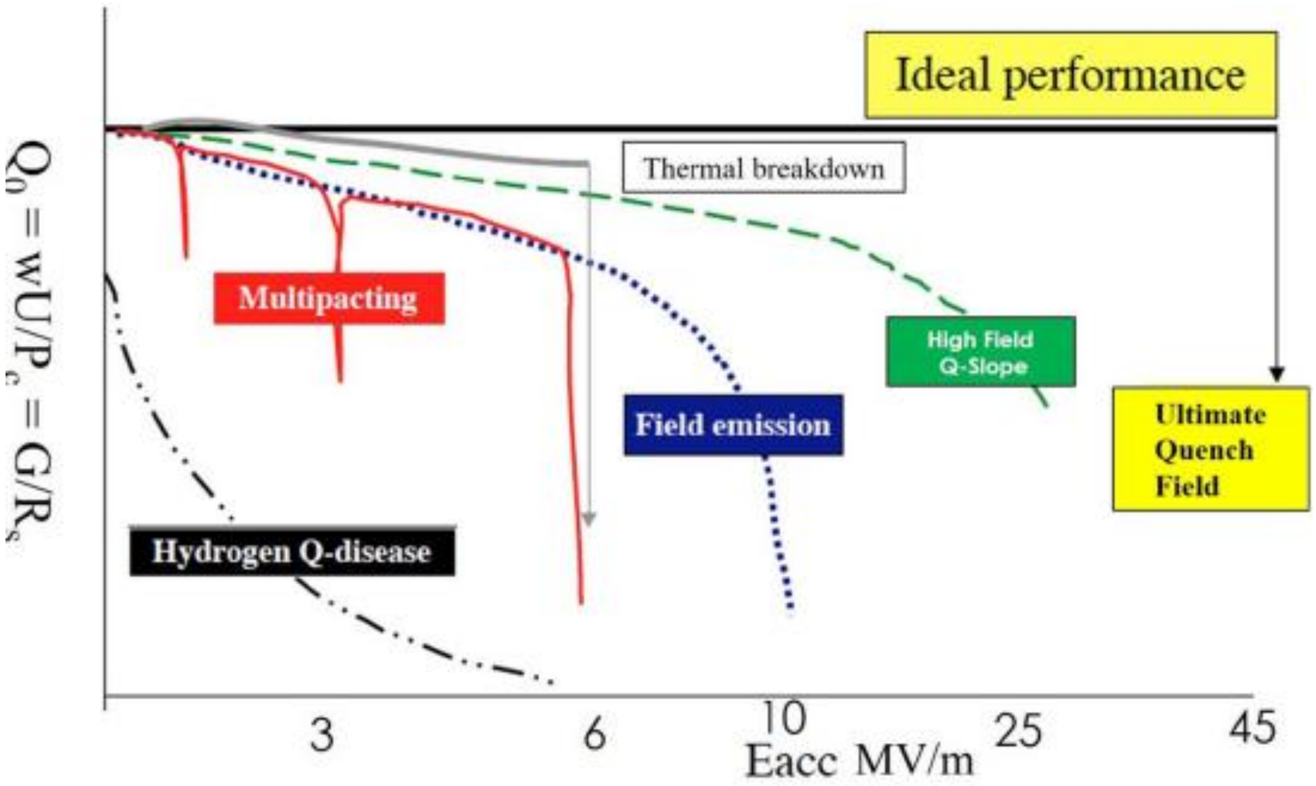
Important Parameters

- **Q_0 (Quality Factor)**
  - ~ 1/(Power Cryogenic)
  - ~ 1/R_s: SC Surface Resistance
  - Intrinsic Material Properties

- **E_{acc} (Accelerating Gradient)**
  - Number of cavities required
  - Limited by
    - ✓ Field Emission (High E_{peak})
    - ✓ SC Quench (High B_{peak})
  - Surface Preparation & Geometry

SRF Limitations

Typical Q vs E curve [Padamsee]



Limitations for

Higher Gradient

- Multipacting
- Field Emission
- Thermal quench
- High-field Q slope

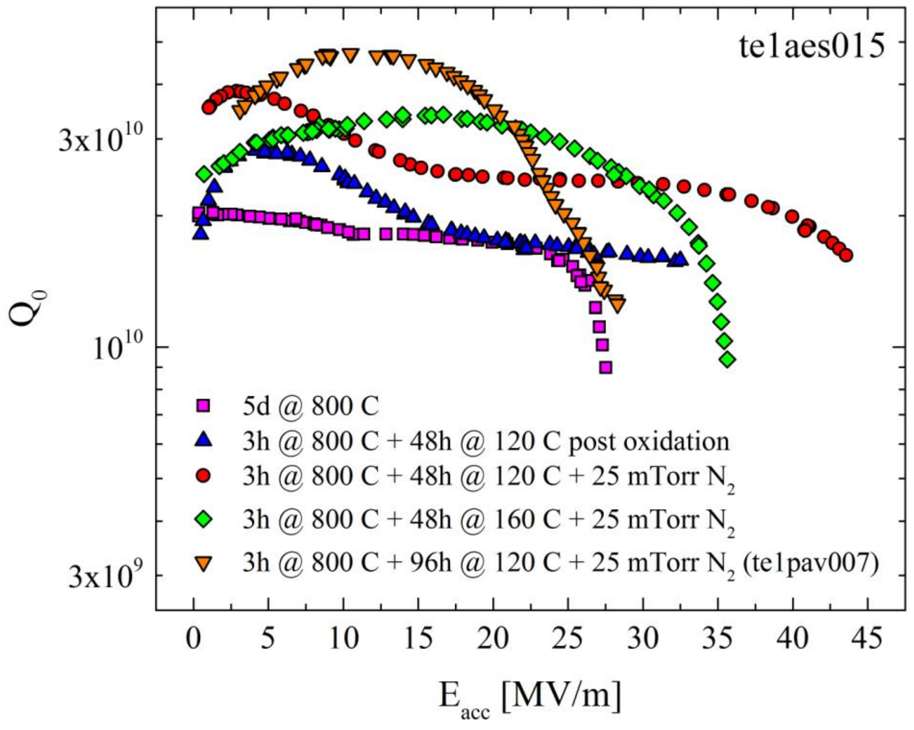
Higher Q_0

- Q-disease
- Trapped Flux

Solutions

- **Geometry** Optimization
- **Surface** Processing
- Cleanroom **Assembly**
- **Magnetic Shielding**
- **Cooling** Procedure
- **Doping** Recipe

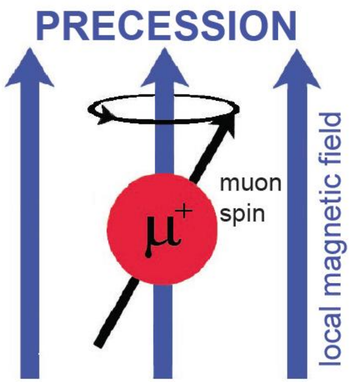
SRF Materials R&D

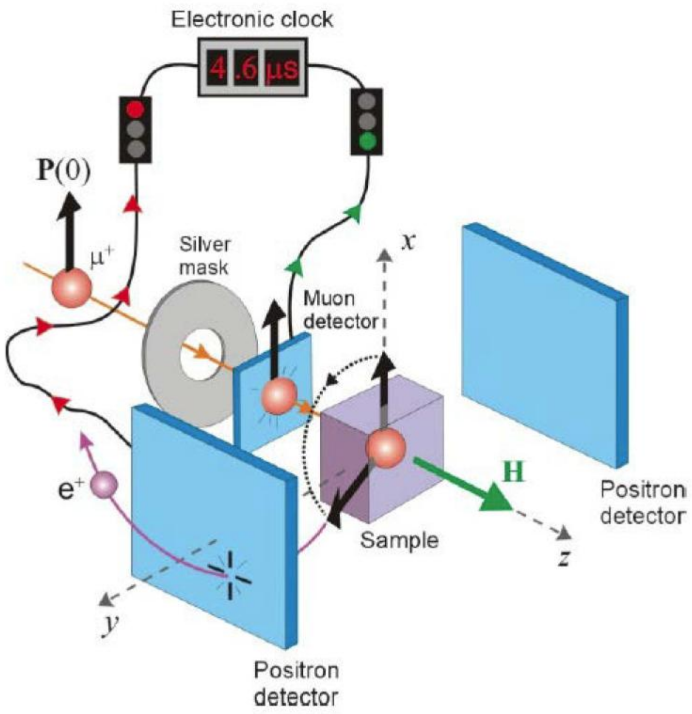


State-of-the-art SRF Materials

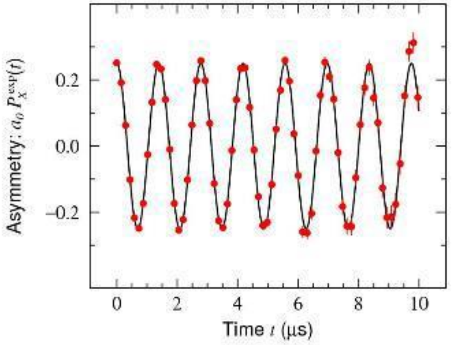
- **Alternatives to Bulk Nb**
- **Doping / Heat Treatment Nb**
  - Bulk Nb fundamental limits
  - Optimum doping recipes
  - TRIUMF Induction Furnace
- **New materials:**
  - Nb3Sn, MgB2, SIS Multilayers
  - Pushing magnetic field limit

Beta-decay MR Techniques



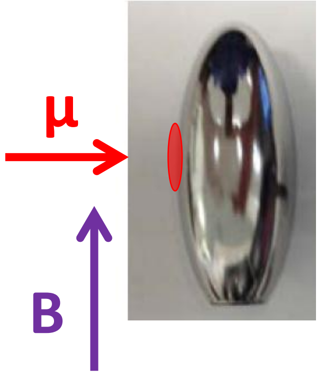


μ^+, ^8Li



Advantage

- Local Probe of Magnetic Field
- Allow sample-size studies (not cavity)



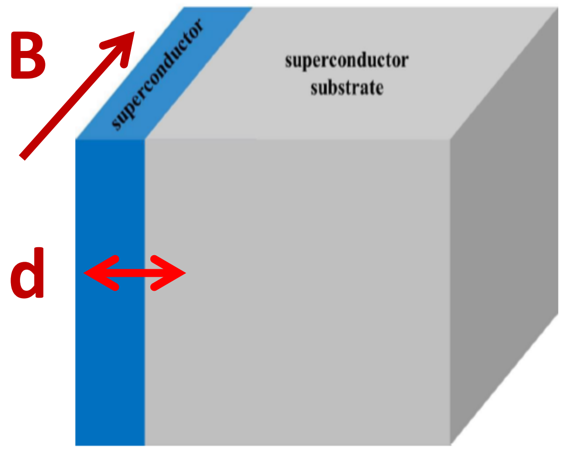
Principle

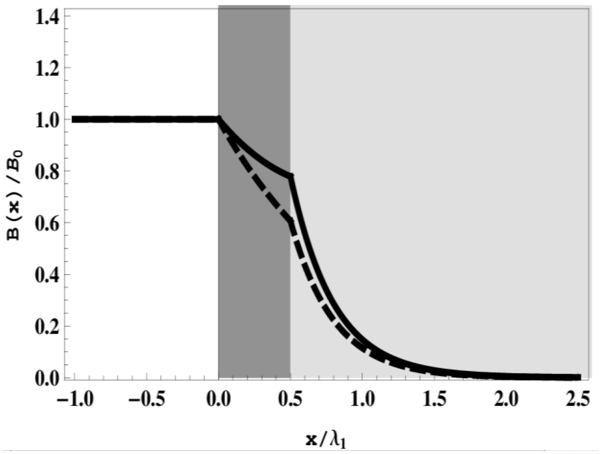
- Implant μ^+, $^8Li^+$
- Precession: ω_L ~ local B-field
- Beta-decay detection

Beta-NMR vs muSR Techniques

Surface vs Bulk Studies

- Muon **(d: 100 μm)** **vs** ^{8}Li **(d: 0-200 nm)**
- Beta-NMR = **depth resolved surface/interface study ->** Multilayer SIS material, thin-film





SRF Exp Configuration

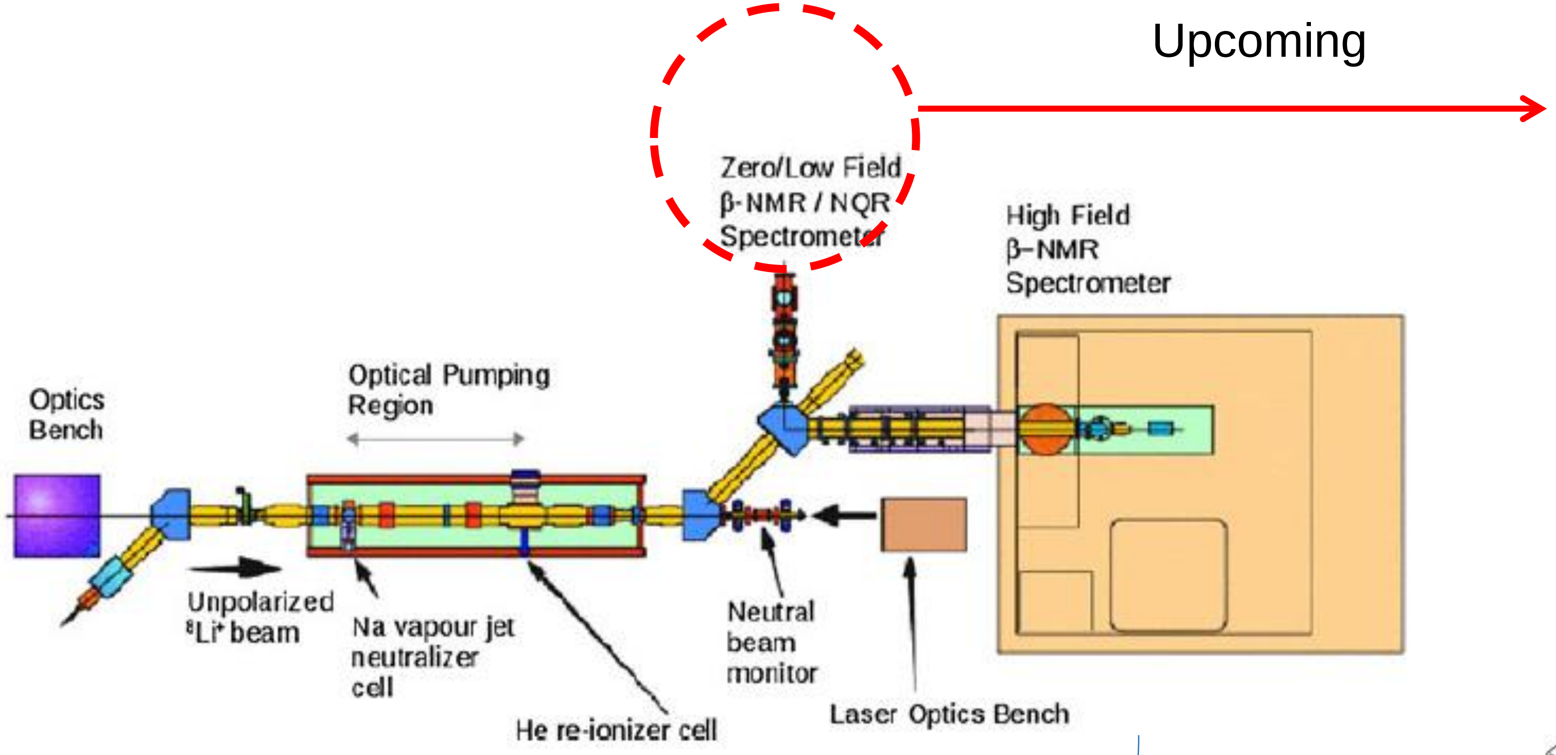
Requirement for SRF Material Study

- B-field // sample face (simulate B-field on RF surface)
- High-field ~ 200 mT
- Depth-resolved for thin films

Available Facilities at TRIUMF

- muSR: parallel B-field up to 300 mT
- betaNMR:
  - High ⊥ B-field up to 9 T (not suitable for SRF)
  - Low // B-field up to 24 mT (field too low)

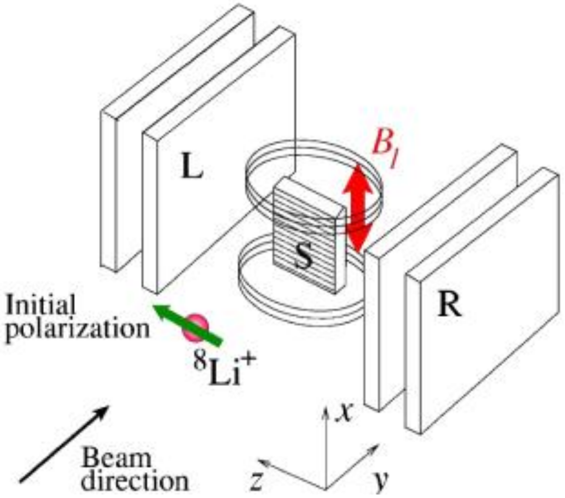
Beta-SRF Facility



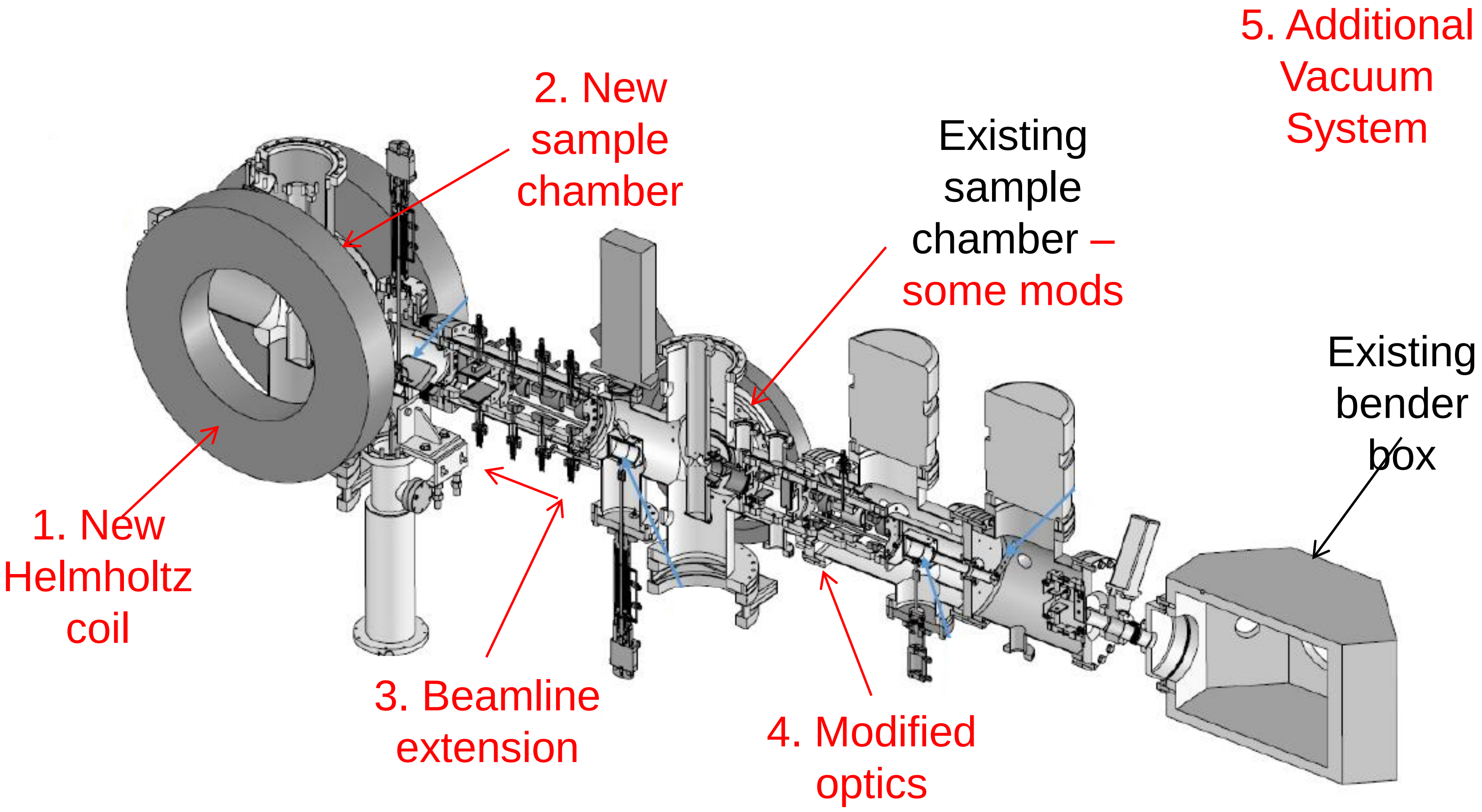
Current Beta-NMR Beamline

beta-NMR for SRF Feature

- Combine SRF expertise (surface treatment) with worldwide-unique material science probe
- High // B-field (up to 200 mT) → applicable other studies (superconductivity)



Beta-SRF Beamline Extension Design



- Detailed design has been approved and finalized
- All of the components have currently been ordered

Conclusion

- SRF cavity -> mature technology for current LINACs and future collider
- Development over the years resulted to:
  - Fabrication: surface treatment, assembly procedure, heat treatment
  - Operation: Cryomodule design, cooldown procedure

- Active cutting-edge SRF research:
  - Quest for higher gradient and quality factor
  - Doping + heat treatment recipes
  - Alternative materials

- TRIUMF offers:
  - Unique world-wide facility -> beta-SRF and muSR
  - Integrated research: SRF and material (superconductivity) research

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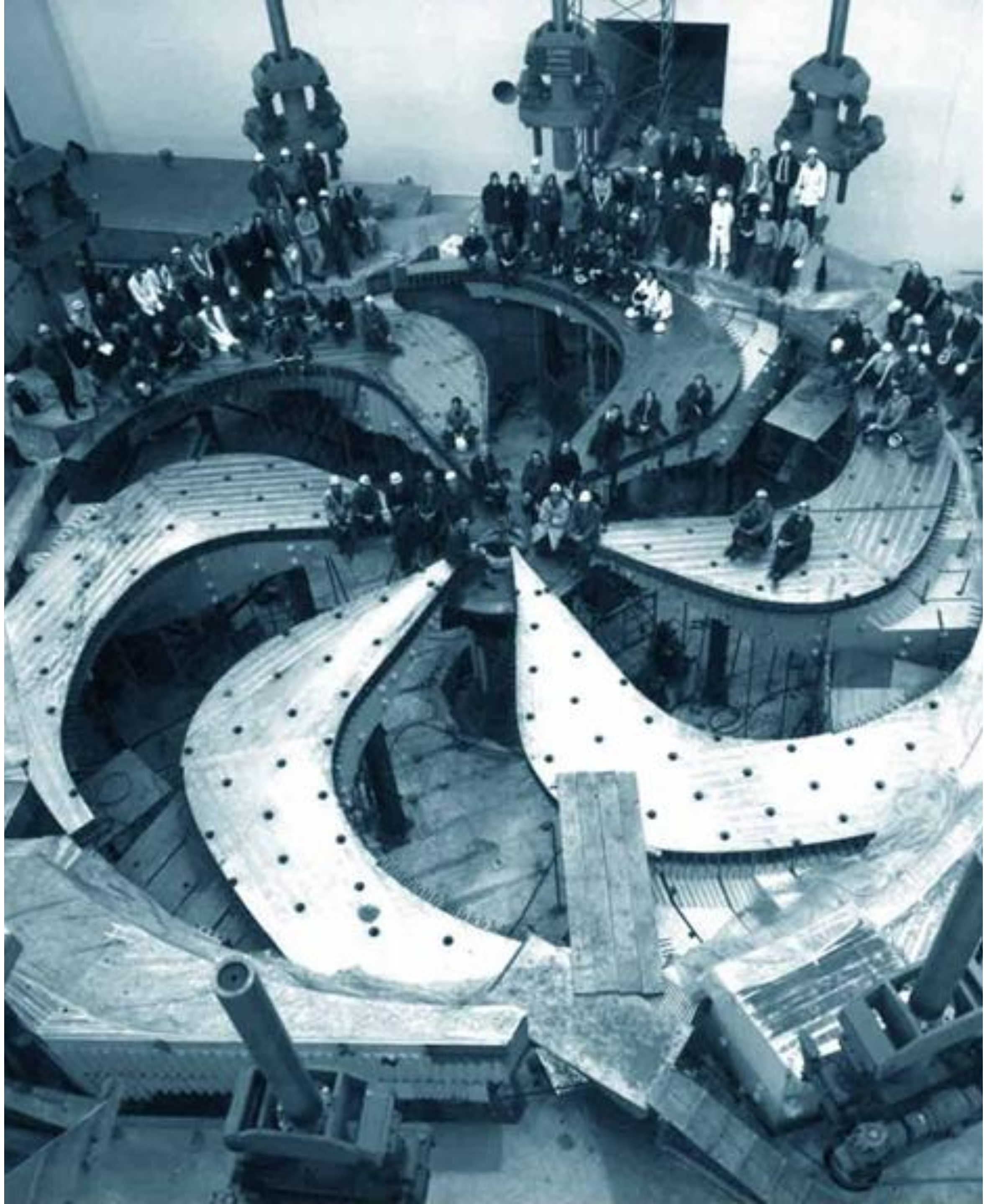
Thank you
Merci



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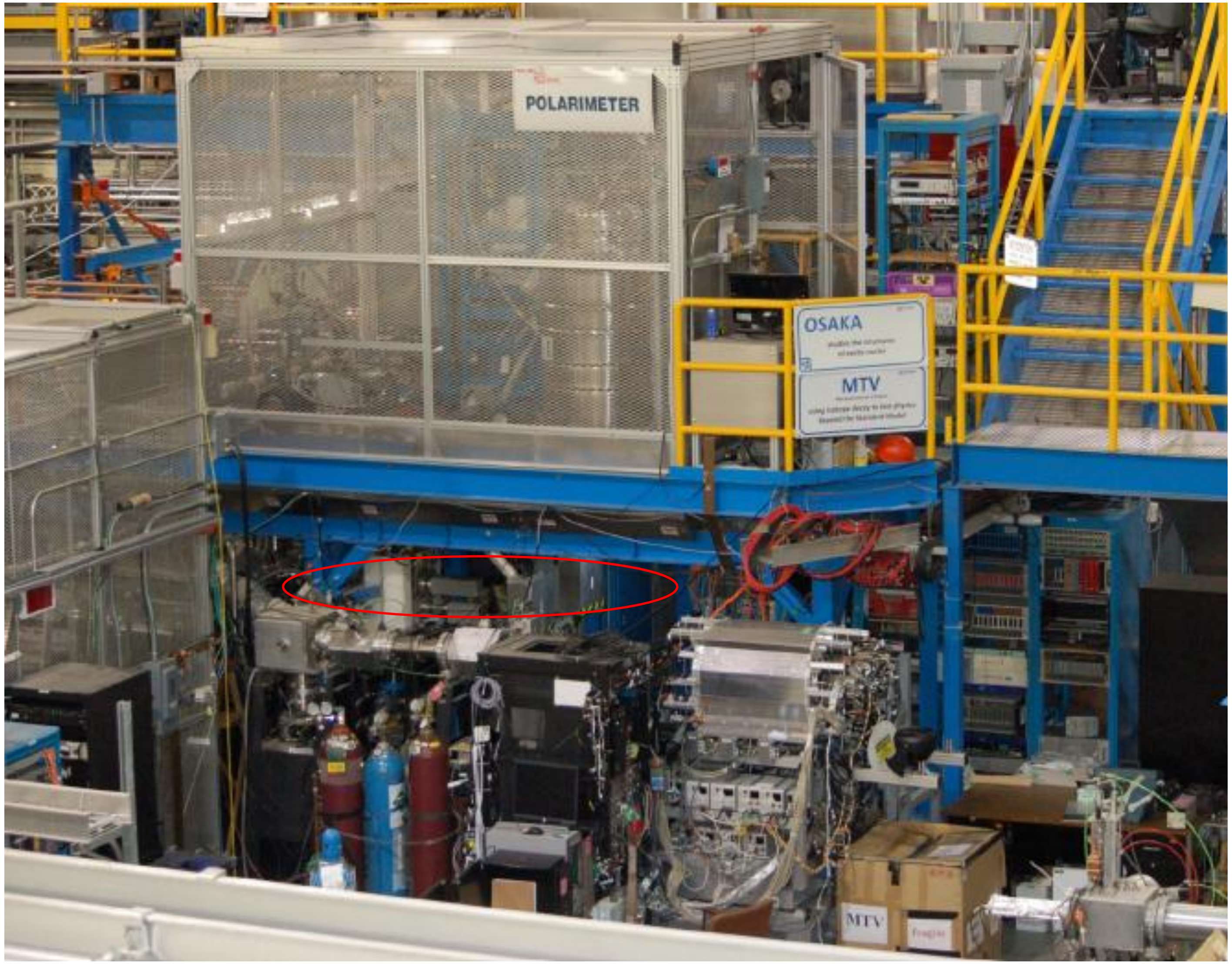
Backup Slides: Beta-NMR Site



Backup Slides: Magnet Coil - Stangenes

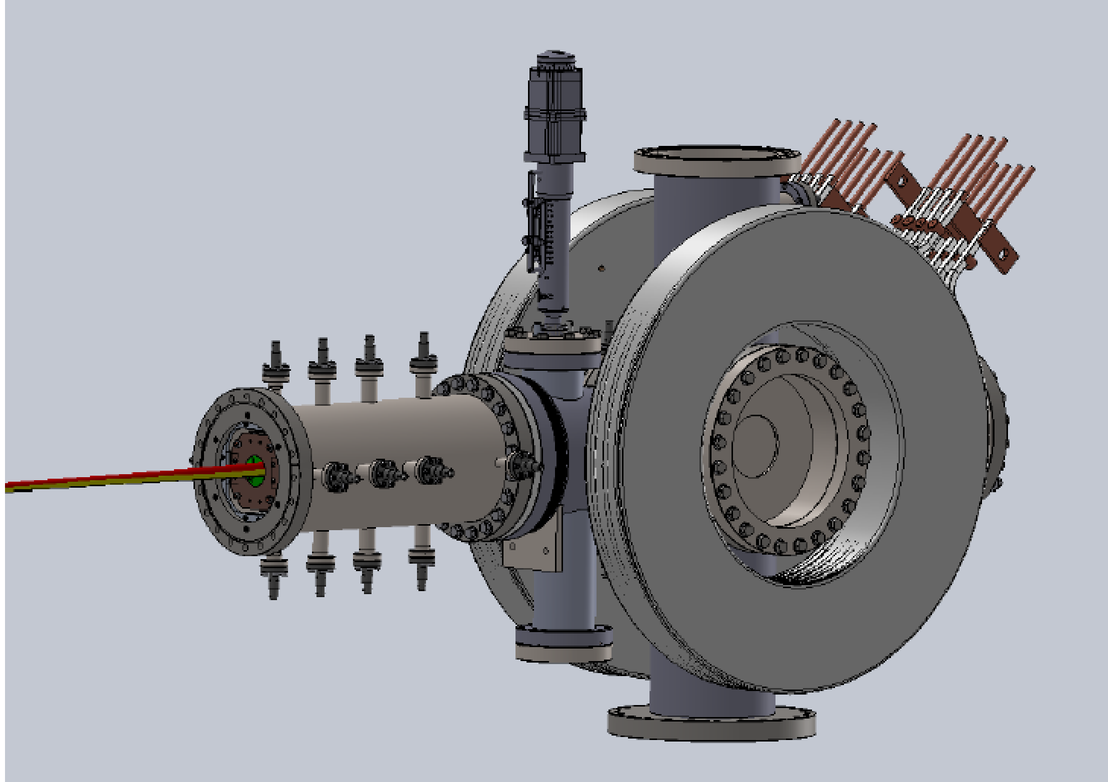
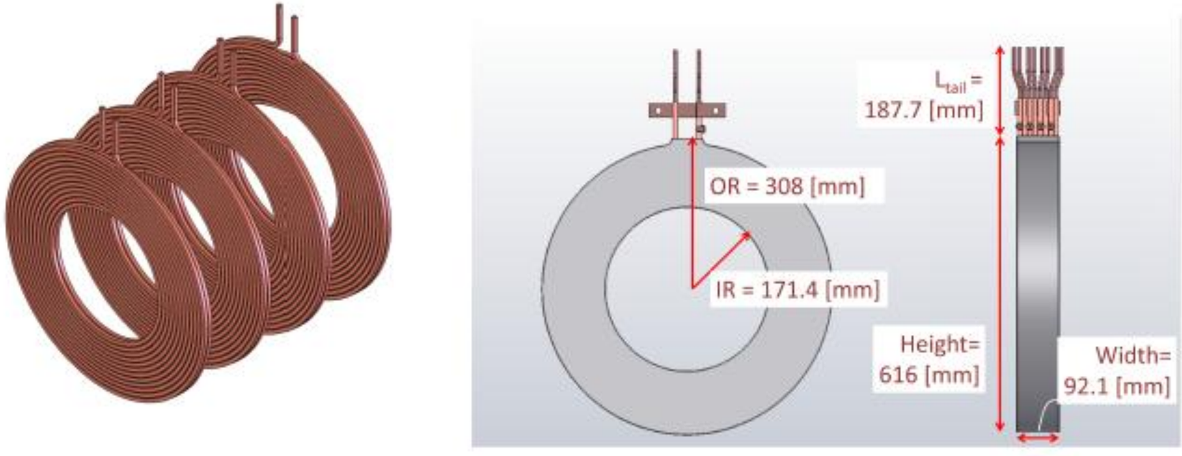


Figure 4: Coil pair position in beamline (ILE2617) with no interference observed. Note that not all beamline components are shown.



(a) (b)

Figure 6: (a) Exploded view of coil conductor pancakes. (b) Size and dimensions of single coil.

Backup Slides: Beam Optics