Compact Multicell SRF Crab Cavity for ILC

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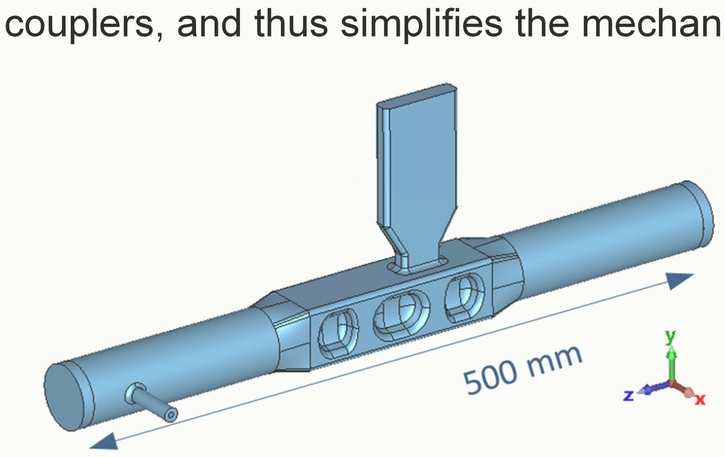
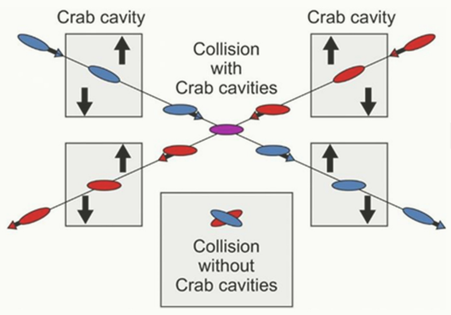
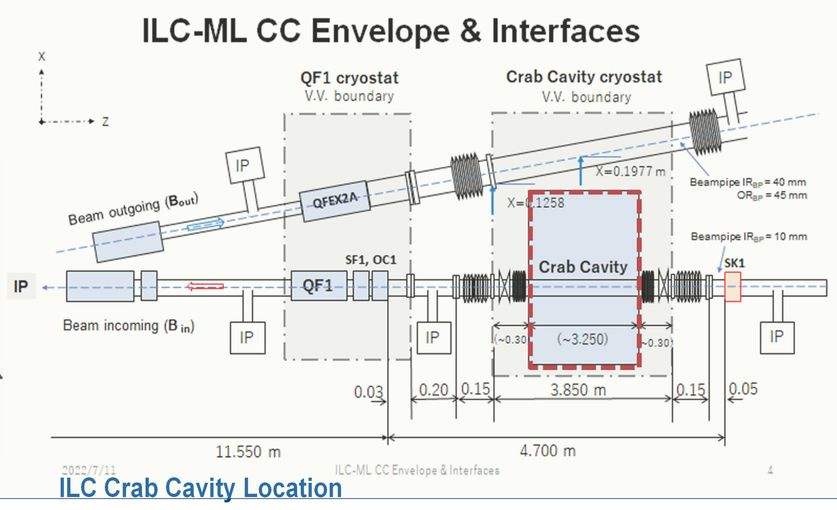
Introduction

International Linear Collider (ILC), a proposed linear electron-positron collider, plans to utilize crab cavities to enhance its luminosity. By introducing a transverse kick to the beams, the crab cavities (CC) rotate the beam bunches, allowing for increased overlap at the interaction points. High intensity of the beam current and limited transverse space along the beam pipe near the interaction point resulted in choosing superconducting technology for the ILC/CC. We present a scalable design of a superconducting Quasi-waveguide Multicell Resonator (QMiR) seamlessly connected with a beam vacuum chamber. The cavity is completely open at both ends, which avoids complex HOM couplers, and thus simplifies the mechanical design of the cavity.



QMiR Crab Cavity for ILC and its cross-section showing the distance between opposite electrodes

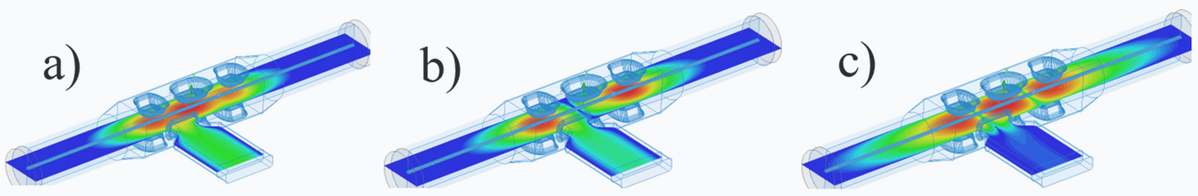




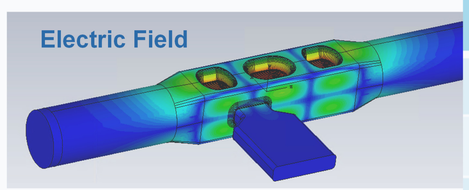
ILC Crab Cavity Location

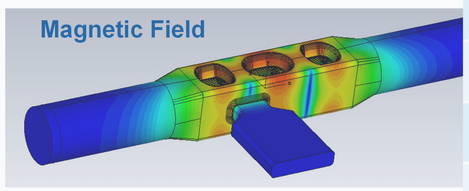
EM Design

Multiple electrodes immersed in a hollow rectangular waveguide form a trapped-mode resonator. The trapped dipole π-mode induces a transverse kick and efficiently deflect charged particles passing through the cavity. The single waveguide port is used to feed RF power to the operating mode and to extract the same order modes (SOM).

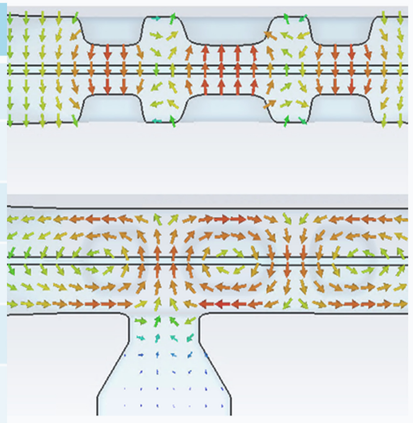


Electric field maps of trapped dipole modes in the QMiR cavity, two SOM (a) and (b) and operating π mode (c)



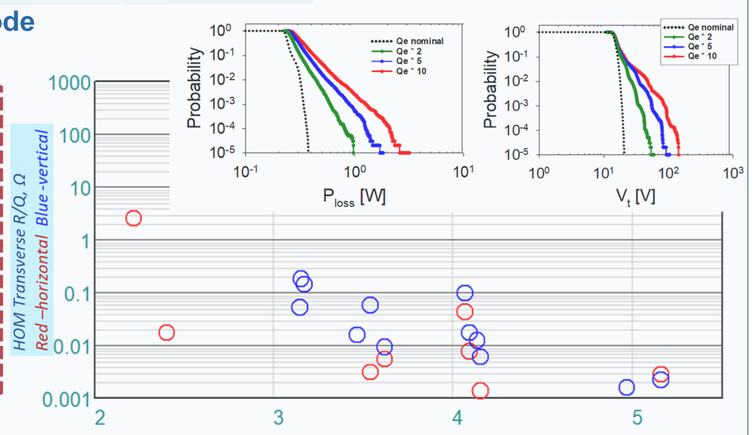


Freq	2600 MHz
V_{kick}	0.92 MV
$(R/Q)_t$	225 Ω
G-factor	160
Bp, max	70 mT
Ep, max	35 MV/m
W_{STORED}	0.24 J



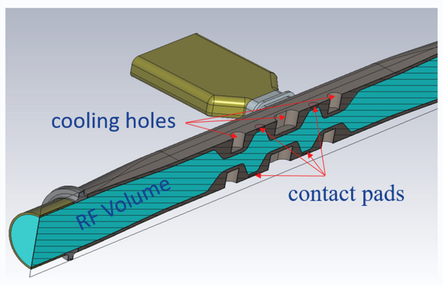
Parameters of the Operating Dipole Mode

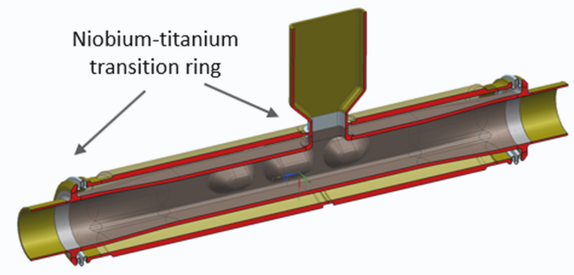
- ✓ High efficiency single cavity
- ✓ Simple and compact
- ✓ NO HOM-couplers (!)
- ✓ Sparse, low-Q HOMs
- ✓ **4 QMiR cavities can provide 3.7 MV Kick for 1 TeV ILC**



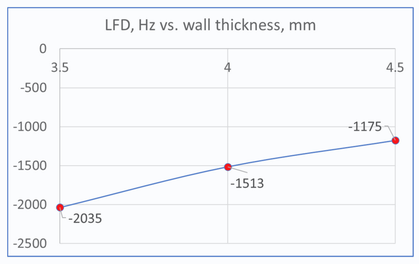
Mechanical Design

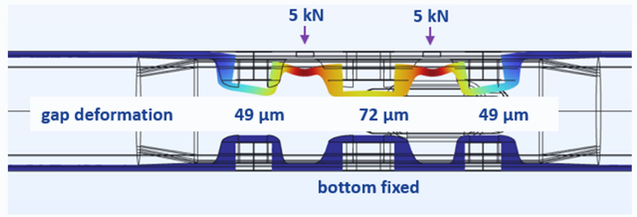
The operation of SRF resonator at a high gradient requires both efficient cooling and mechanical stability since the operating mode frequency may deviate beyond a narrow bandwidth because of LFD and micro-phonics effects. Due to the poor thermal conductivity of Nb at 2 K, the typical cavity wall thickness is limited to 3...5 mm. The relatively simple cavity geometry makes it possible to mill cavity parts with high precision from a solid Nb ingot



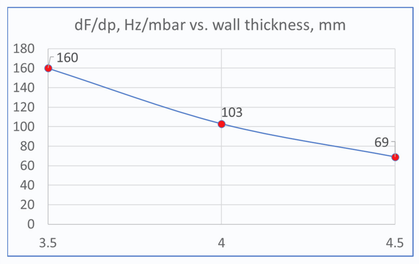


Mechanical model of a bare QMiR cavity (let) and with welded LHe vessel (right)

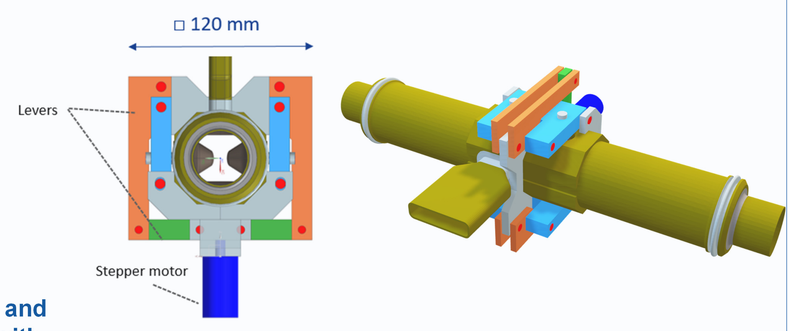




Mechanical analysis of the QMiR cavity with 4 mm wall



Calculated coefficients LFD (top) and dF/dP (bottom) of a QMiR cavity with different wall thicknesses



Compact double 2-lever frequency tuner

Conclusion

We propose a novel design of a compact and simple multi-cell SRF crab cavity, which fully complies with the ILC operational specifications. Cavity operation at nominal gradient has low cryogenic losses (<1.3 W) and requires about 1.5 kW CW input power. The broadband wakefield signal is radiated and absorbed in the beam vacuum chamber. The QMiR CC is recommended for prototyping at a recent ILC-CC technology down-selection meeting [FRIBA04]. The near-term plan is to complete mechanical design of the cavity, manufacture, process and test it at high gradient operation at the Fermilab Vertical Test Stand (VTS).