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Cryomodule Performance of the Main Linac Prototype Cavity for Cornell's Energy Recovery Linac

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Introduction

Cornell's Energy Recovery Linac (ERL) is a 100 mA, low emittance, next generation light source. Main-linac accelerating cavities must damp higher-order modes (HOMs) to prevent beam breakup, and require very high fundamental mode Q (>2×10^{10} at 1.8 K and 16.2 MV/m). The cavity has been designed and have been commissioned in three stages to demonstrate that high Q can be preserved in a fully outfitted cryomodule.

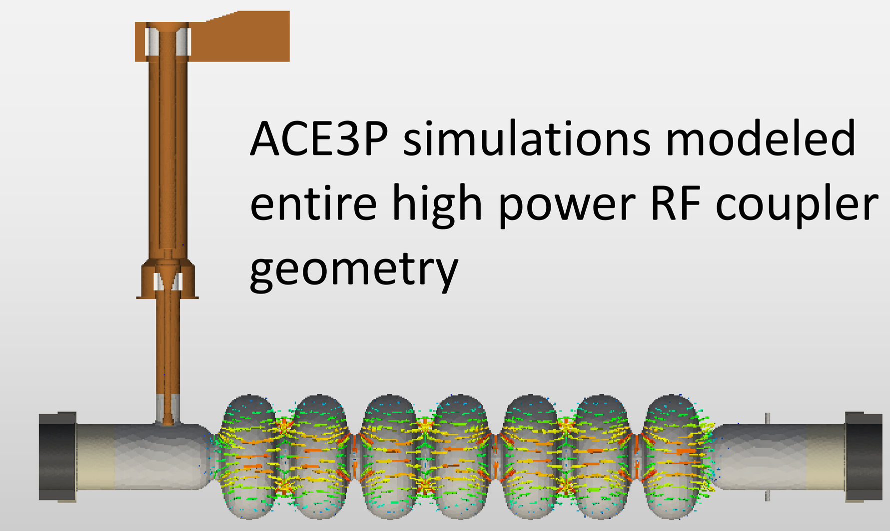
World Record Cryomodule Quality Factor Set in HTC-3

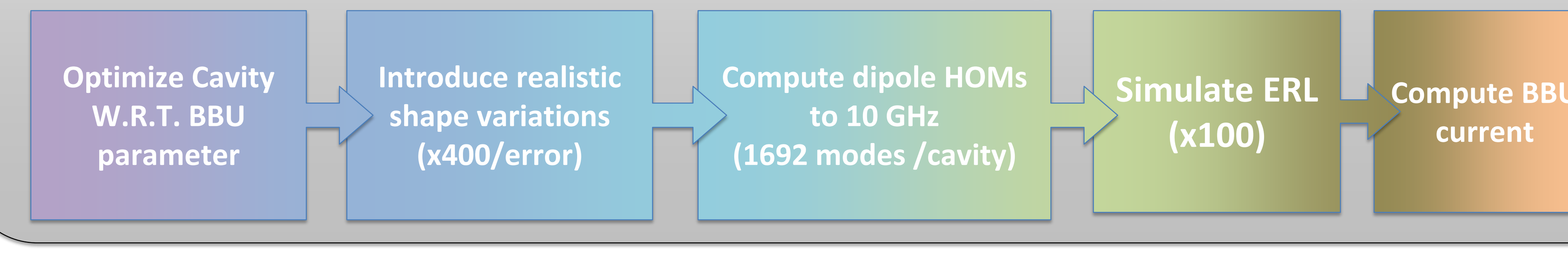
Temperature [K]	Q_0 @ 16.2 MV/m
2.0	**3.5×10^{10}**
1.8	**6.0×10^{10}**
1.6	**1.0×10^{11}**

Cavity Design

Maximize beam breakup current
- Fundamental mode $Q \geq 2 \times 10^{10}$
- Limit peak surface fields
- Strongly damp dipole HOMs

ACE3P simulations modeled entire high power RF coupler geometry

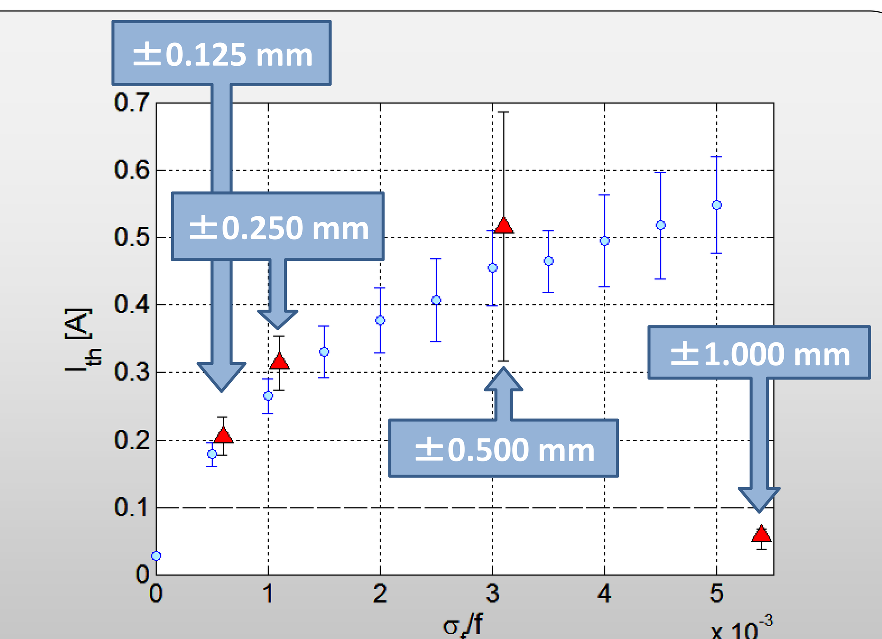




ERL Simulation

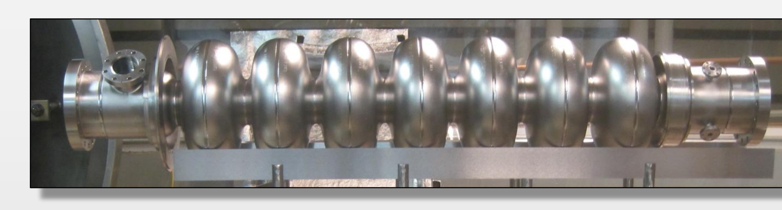
Simulation results
- Cavities with realistic shape variation preserves baseline HOM properties
- Threshold current well above 100 mA

Variation	I_{th}: Top 90%	I_{th}: Top 10%
0.125 mm	0.177 A	0.235 A
0.250 mm	0.274 A	0.354 A
0.500 mm	0.318 A	0.668 A
1.000 mm	0.037 A	0.067 A

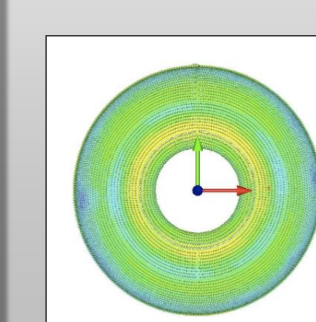


Threshold current through ERL vs relative cavity-to-cavity frequency spread. Fabrication tolerances within 0.5 mm of design specification, should support above 100 mA current at 5 GeV.

Cavity Fabrication

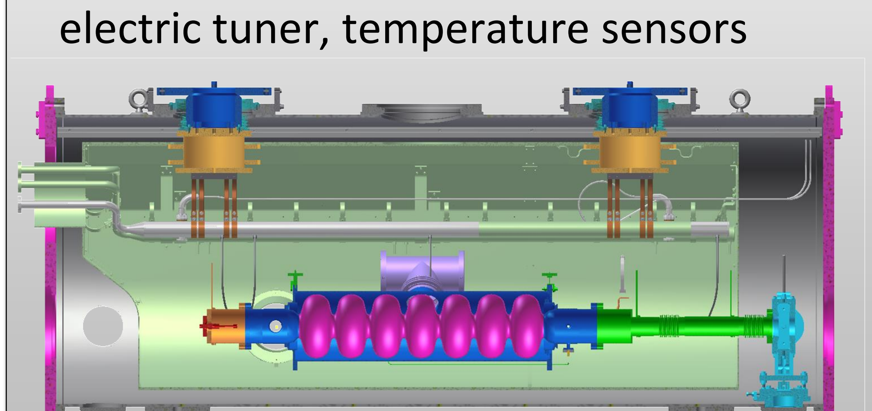


Prototype cavity preparation
- Half-cells stamped and measured
- Dumbbells tuned, trimmed and welded
- Cavity tuned and baked at 650°C for 12 hr
- Bulk BCP, ultrasonic, final BCP
- High pressure rinse (HPR), clean assembly
- Received 120°C bake for 48 hr
- Successful vertical test

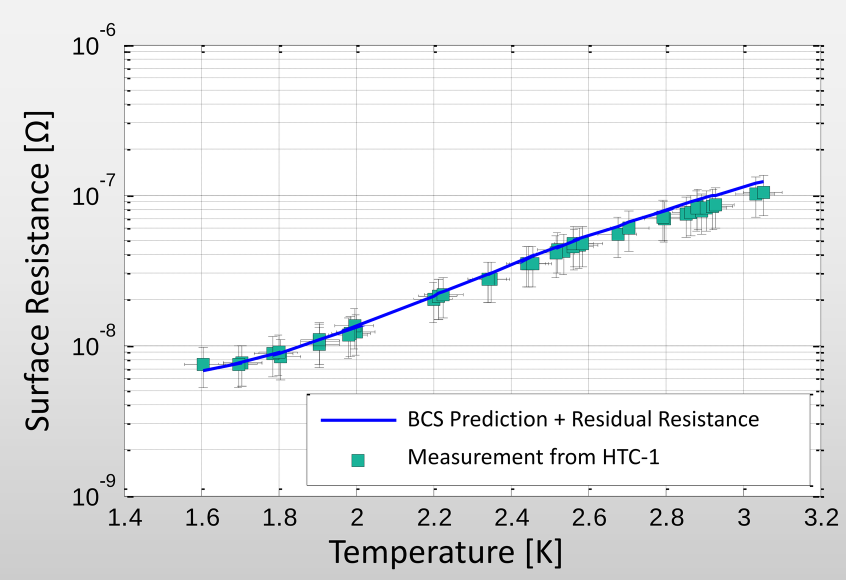


HTC-1

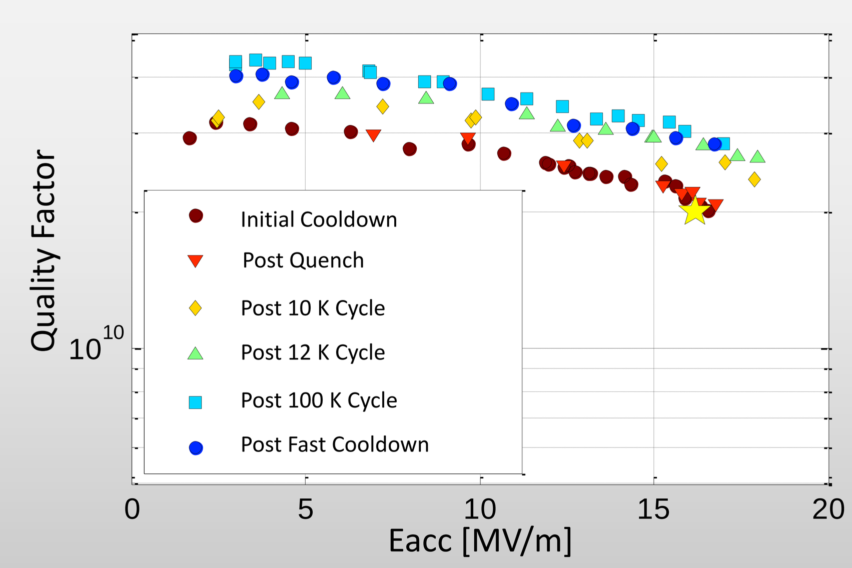
Cryomodule Configuration
- RF input via **axial** probe.
- **No HOM absorbers**
- Instrumentation: Slow tuner, fast piezo electric tuner, temperature sensors



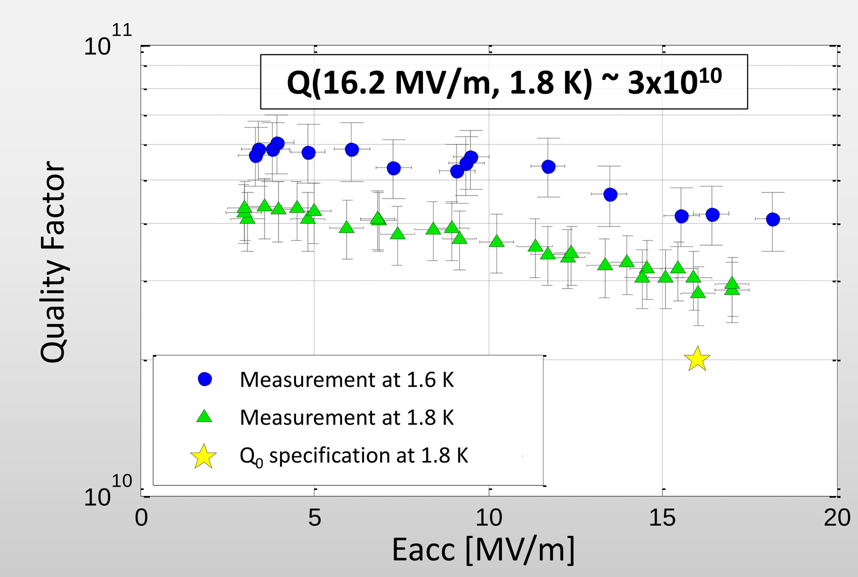
Cryomodule configuration in HTC-1 and HTC-2



RF Surface Characterization
- Superconducting properties:
  - Tc = 9.15 K
  - Resid. resistance = 6.5 nΩ



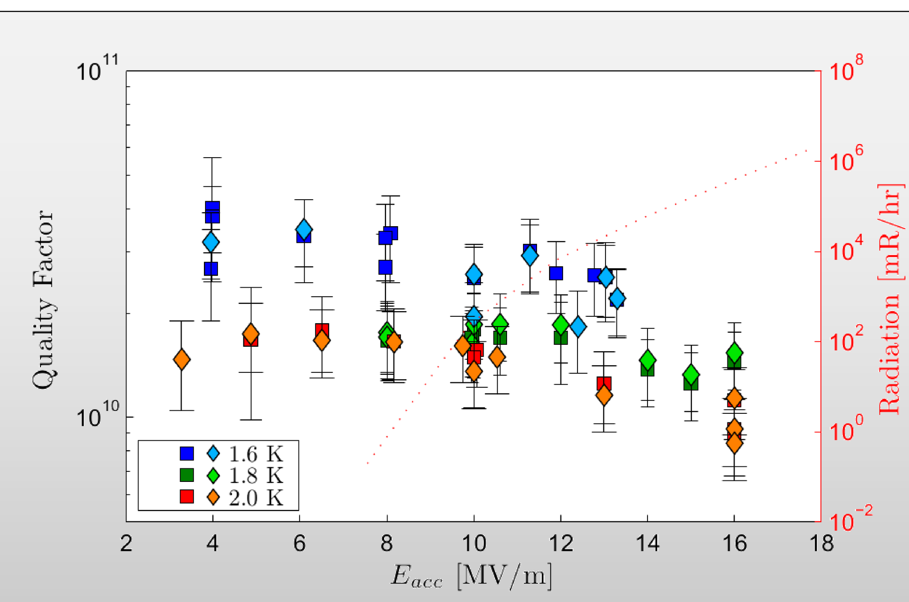
Temperature Cycling
- Measured Q vs E before and after increasing temperatures and slow cooling
- Q vs E measured at 1.8 K



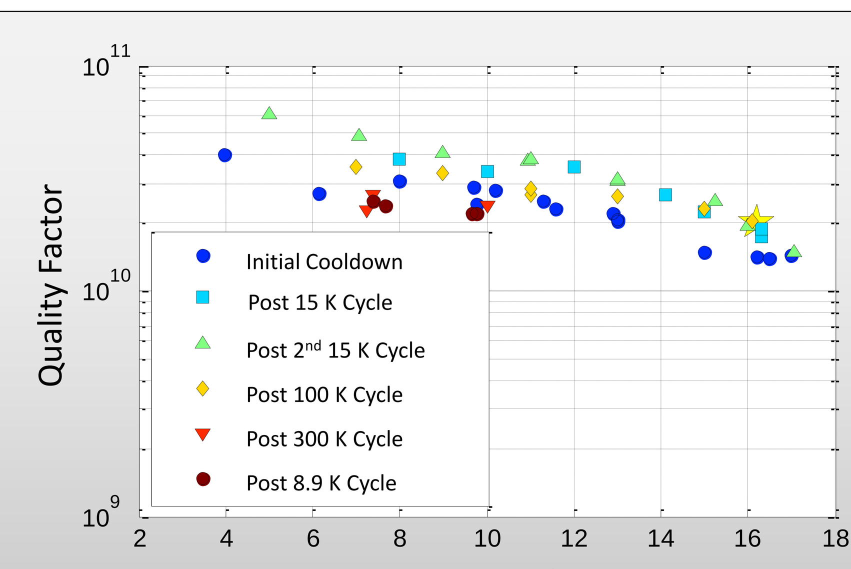
HTC-1 Final Q vs E Results
- Best results obtained after 100 K cycle
- Q(1.8 K, 16.2 MV/m) exceed design specifications
- Q(1.6 K, 5.0 MV/m) sets quality factor record for multi-cell cavity tested in horizontal orientation

HTC-2

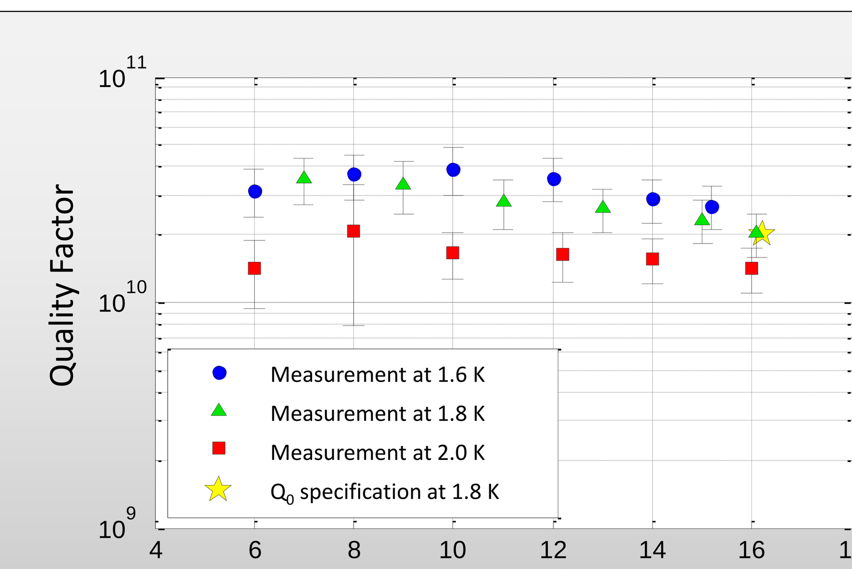
Cryomodule Configuration
- No cavity surface processing between HTC-1 and HTC-2
- Side mounted RF input coupler
- **No HOM absorbers**
- Same instrumentation as HTC-1



HTC-2 Initial Q vs E Results
- Initial Q lower than design specifications
- Field emission from end cell far from RF input coupler produced radiation



Temperature Cycling
- Thermal cycling again increased quality factor
- Thermal cycling to below Tc did not yield a statistically significant change in Q

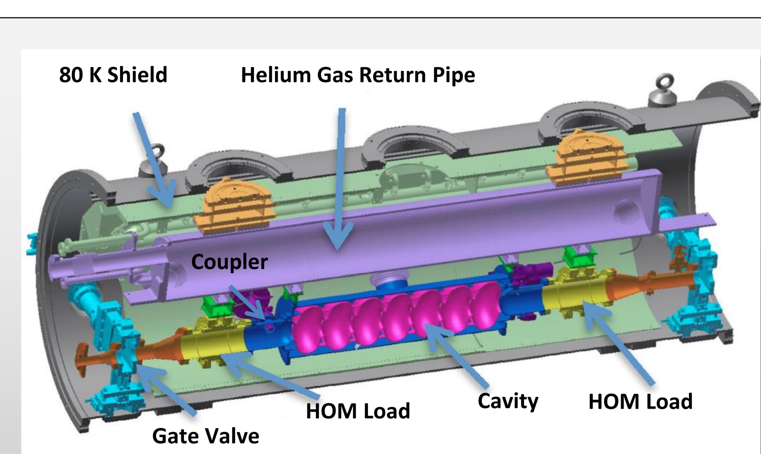


HTC-2 Final Q vs E Results
- Quality factor, gradient specifications met
- Administrative limits prevented higher field measurements. (Not quench)

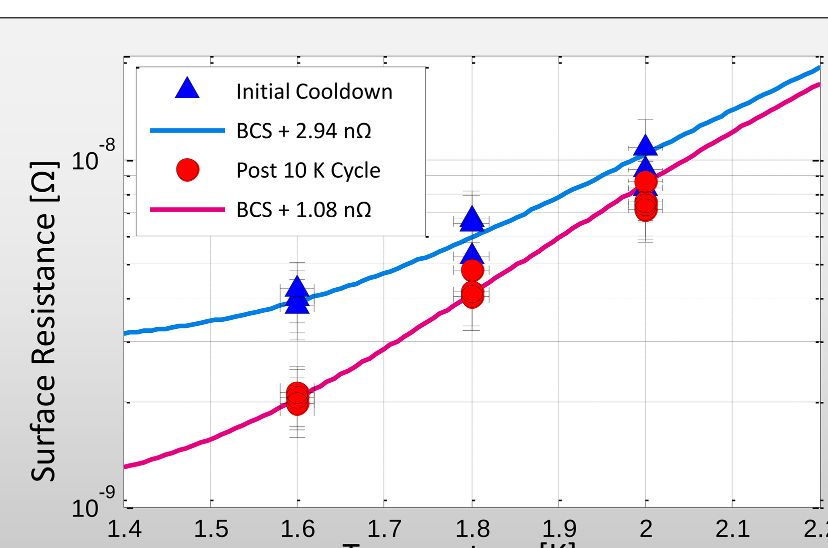
HTC-3

Cryomodule Configuration
- <5 um BCP, 16 hour HPR
- Side mounted RF input coupler
- Two beam line HOM absorbers
- Tuner with piezos, temperature sensors, etc. installed

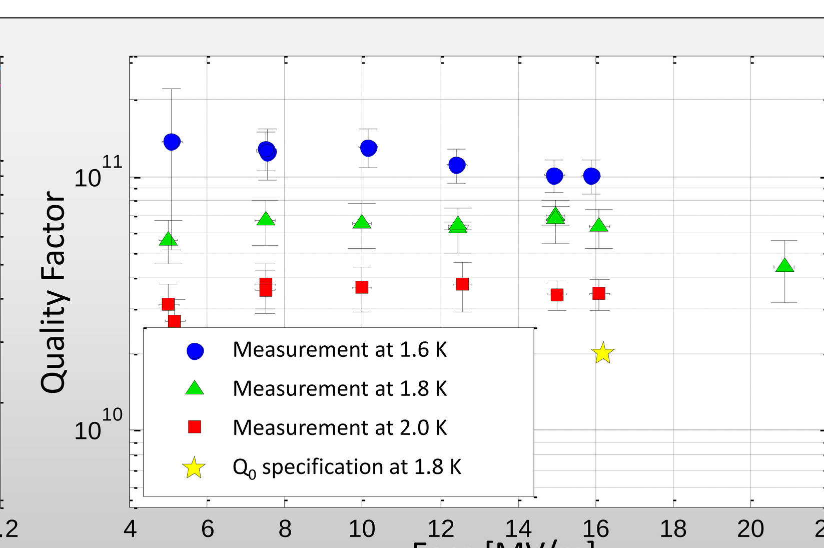
Experimental measurements
- Quality factor vs Eacc, temperature
- Thermal cycling studies
- HOM figure of merit measurements
- HOM load heating
- Microphonics levels



HTC-3 Cross-section, including HOM Loads



Temperature Cycling
- Thermal cycling increased quality factor by reducing residual resistance



HTC-3 Q vs E Final Results Results
- Far exceeded both quality factor, and gradient specifications, even at 2.0 K

Next Steps
- Cavity beam tests
- Full cryomodule underway

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LEPP, the Cornell University Laboratory for Elementary-Particle Physics, and CHESS resources have merged and a new lab, (CLASSE), has formed. CLASSE develops and operates facilities and provides infrastructure for the study of beams and accelerators, photon science, particle physics and the early universe, serving students, the public and scientists from Cornell and elsewhere. LEPP's primary source of support is the National Science Foundation.