High Gradient Cryomodule Prototype for the International Linear Collider

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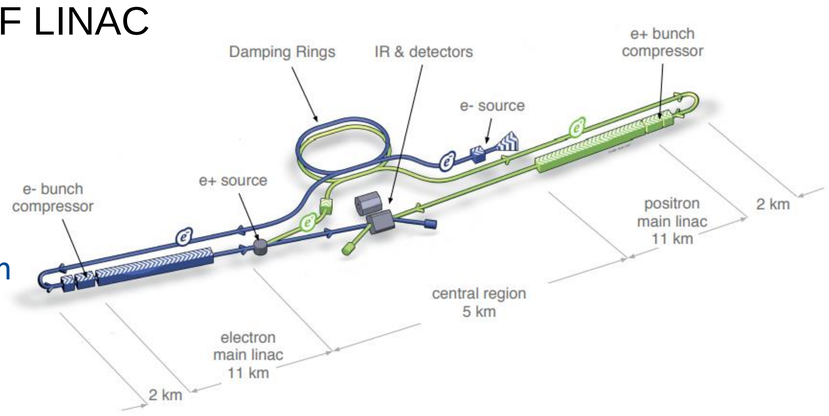
Necessity of High Gradient/High Q_0 for ILC Realization

- The world is ready for a new **Higgs factory** for BSM physics
- ILC is a ready to go technology:
  - Uses SRF cavities; capable of very high Q_0 and gradients
- Largest cost driver is the average accelerating gradient of the main SRF LINAC

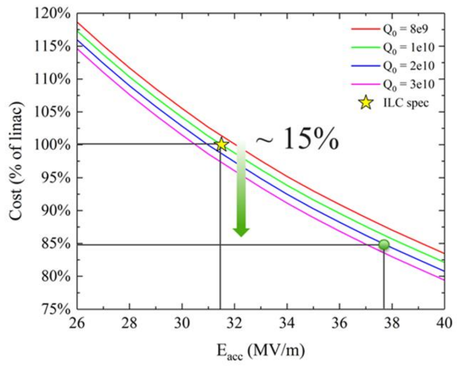
Baseline cavity specs:
Q_0=1x10^{10} @
$E_{acc,avg}$=31.5 MV/m



- Increasing the baseline cavity specs allows for either:

Lower Cost

Cost Estimation of 250GeV ILC LINAC



Increasing:
$E_{acc,avg}$=31.5➔38MV/m
Q_0=1x10^{10}➔2x10^{10}
allows for a **15% reduction in cost** of main SRF LINAC

Higher Luminosity

FNAL Workshop on HL-HG ILC:

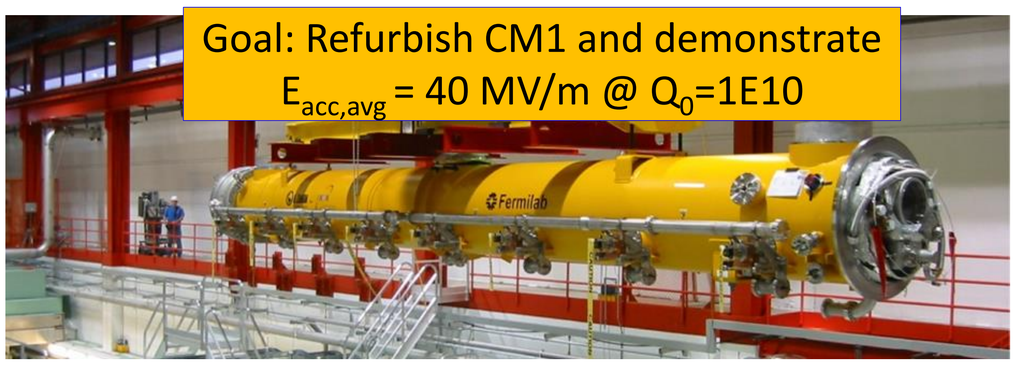
- Proposed a high luminosity/high gradient **ILC upgrade enabled by recent progress made in High G/Q_0 R&D:**

	TDR Baseline	6× Luminosity upgrade, with Q = 1×10^{10}	6× Luminosity upgrade, with Q = 2×10^{10}
Energy [GeV]	250	250	250
Luminosity [×10^{34}]	1.35	8.1	8.1
Total capital cost (no labor) [B ILCU]	5.5	8.0	7.73
Total AC power [MW]	132	286	267
Cyomodules (including cavities) [B ILCU]	1.93	1.93	1.93
Conventional Facilities, CF (all) [B ILCU]	1.43	1.63	1.63
Refrigeration system [B ILCU]	0.5	1.3	1.0
High power RF (linac only) [B ILCU]	0.6	1.2	1.2
Damping ring [B ILCU]	0.33	0.66	0.66
Positron source [B ILCU]	0.23	0.69	0.69
Beam Dumps [B ILCU]	0.07	0.21	0.21
Other systems (not including CF) [B ILCU]	0.41	0.41	0.41
Tunnel length [km]	20	20	20
Gradient [MV/m]	31.5	31.5	31.5
Q	1×10^{10}	1×10^{10}	2×10^{10}
Repetition rate [Hz]	5	15	15
Number of bunches	1,312	2,624	2,624
Beam power [MW]	5.3	31.5	31.5
Total RF pulse length [ms]	1.618	2.35	2.35

More info @: arXiv:1910.01276

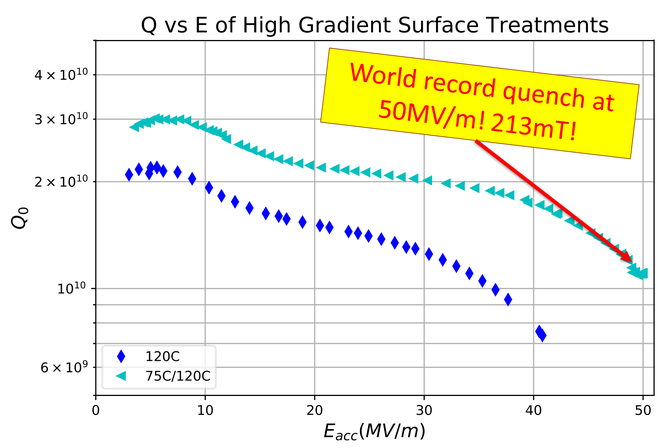
Refurbishing a Cryomodule for High Gradient

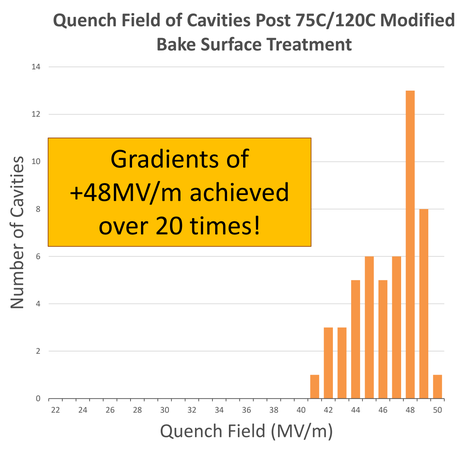
- In the context of ILC cost reduction, FNAL plans to lead the assembly of a High Gradient Cryomodule (HGC)
- Partners at **national and international institutions** such as JLab, Cornell, KEK, CEA, DESY, and TRIUMF
- CM1 will be disassembled and upgraded with cavities processed using **new techniques developed** since the ILC Technical Design Report



Unprecedented Performance in Single Cells with New High Gradient Surface Treatments

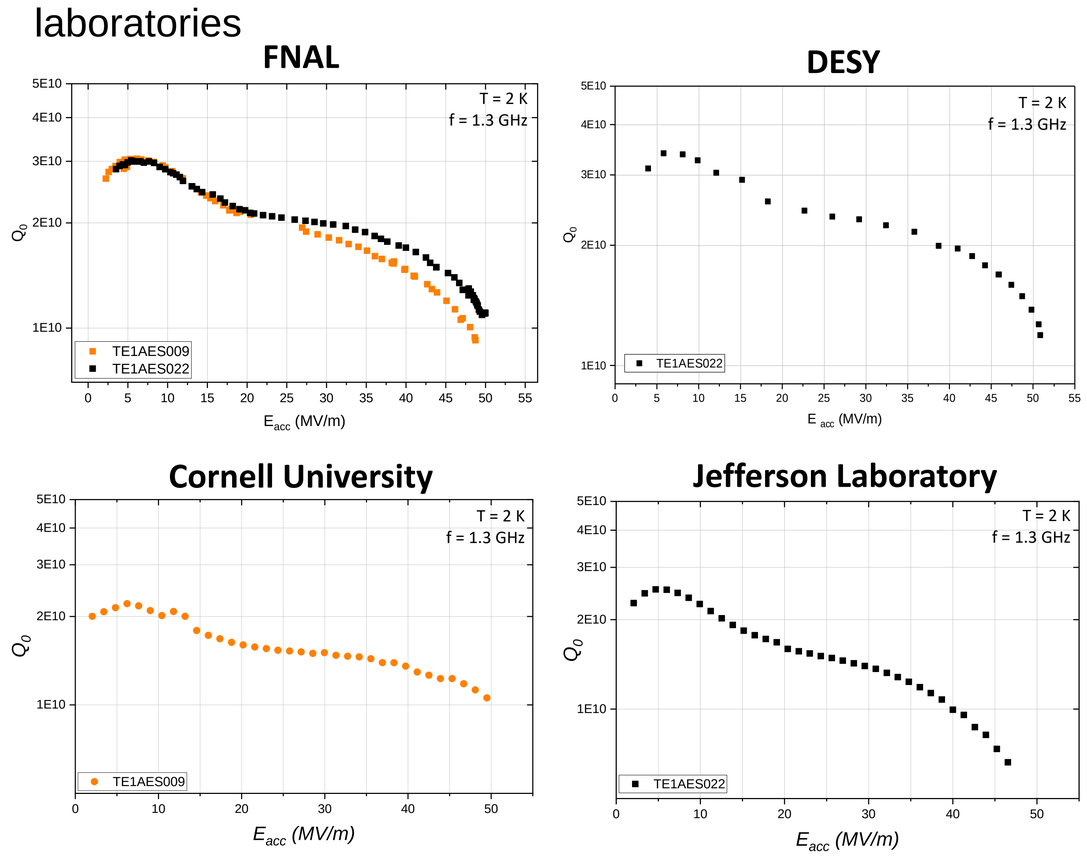
- Consistently achieve very high gradients with the FNAL developed **75C/120C** modified bake surface treatment





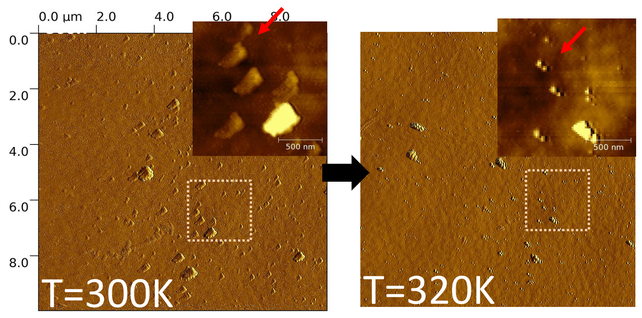
Reproducibility of High Gradients at Other Labs

- Two 1.3 GHz single cell cavities processed at FNAL with the **75C/120C** treatment were sent around the world for testing
- Very **high gradients of +47 MV/m confirmed** by other laboratories



Material Science Studies to Uncover Mechanisms Responsible for Record High Gradients

- To better tailor surface treatments that further push the limits of record breaking performance, **material science techniques** are used to understand the microscopic mechanisms responsible for improved gradients and Q_0.



- Cryo Atomic Force Microscopy (AFM) images taken of **75C/120C** cavity cutouts show the growth and dissociation of nano-hydrides
- Improved performance is linked to **dissociation of these nano-hydrides**

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