Hot Topic_2

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Perspective 1…
Is Nb at the end of the Road
?
More MV per meter to prepare for the coming decades

Decade Perspective for Trajectory of Nb Technology (high β)

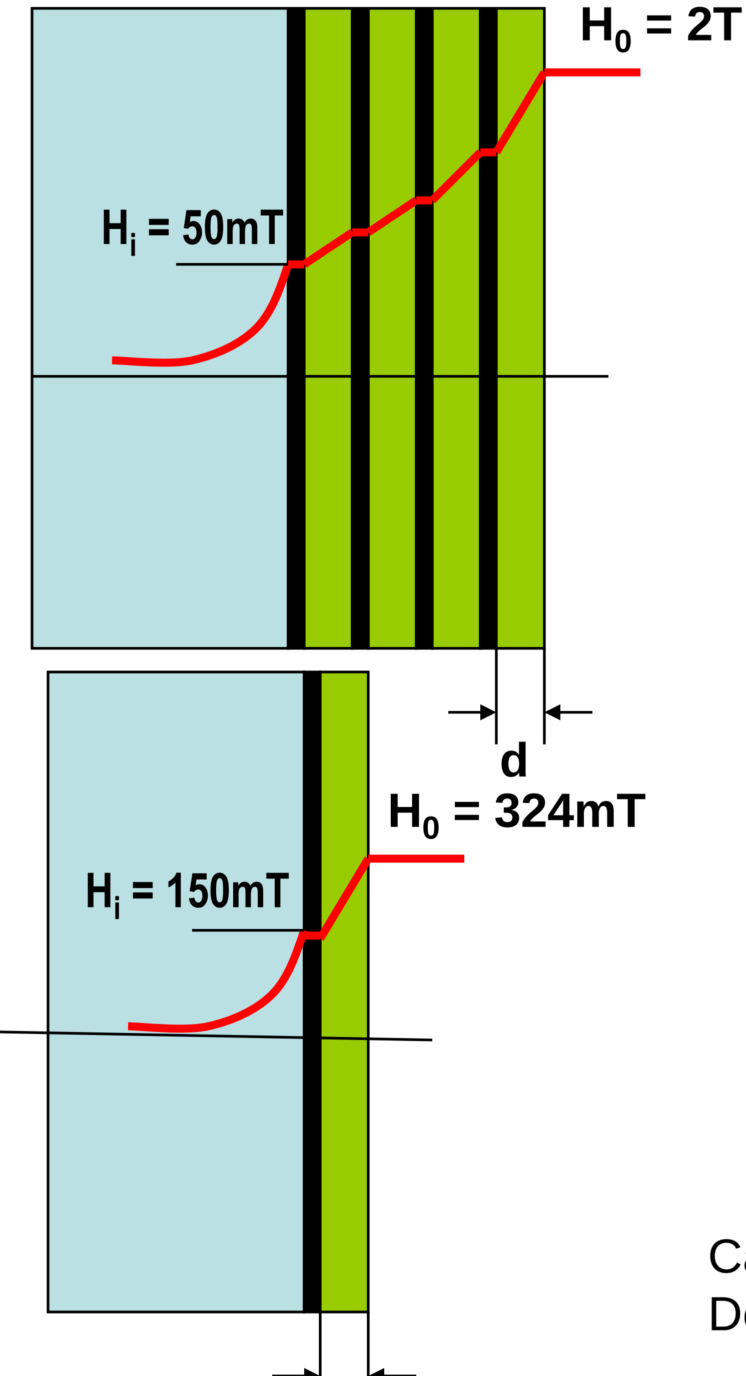
Decade	Gradient (MV/m)	Application
1965-1985	3- 4	Conception & birth
1985-1995	4 – 7	StorageRings, RLA
1990-1995	10 - 12	FEL
1995-2005	15 – 20	TTF, SASE FEL, SNS
2005-2015	25 - 30	FLASH, XFEL, PX
2015-2025	35 – 40	ILC, Muon Collider
>2025	< 50 END ?	TeV upgrade
2035	<100 e.g. Nb3Sn?	3 TeV e+e- 5 TeV $\mu+\mu-$

Nb is approaching the end of the Road

- Fundamental critical magnetic field
  - Hsh = 1.2 Hc (GL prediction)
- Hc = 2000, Hsh = 2400 (0 K), 2300 (1.8 K) Still valid
  - see pulsed rf tests (poster by Nick Halles)
- Single cell LL and RE shape cavities are ~2000 Oe at ~1.8 K (KEK and Cornell)
  - Equivalent gradients ~50 MV/m
- How should we prepare for future decades?(>2020)
  - For the future of our young community
- Near Future : 2010 – 2020
  - Must still address our present challenges for 30 – 40 MV/m
    - Yield, quench, field emission, mass production…

Possible Paths to G >> 50 MV/m

- Multilayers Nb/Nb3Sn (NbN) Gurevich
- New high kappa materials
  - Nb3Sn (most experience so far)
  - NbN
    - Best results 500 Oe at 10^{10} Q
  - MgB2 (just starting, samples RF– no cavities)
    - RF measurements show rf losses do not rise until 700 Oe (Tajima/Tantawi)
  - HiTc (YBCO)
    - Very complex, short coherence length
    - Not recommended



Example: Nb_3Sn layers with d = 30nm
λ_0 = 65 nm and H_{c1} = 2.4T

Peak rf field H_0 = 2T < H_{crit}

Internal rf field H_i = 50 mT (high-Q regime)

A Nb cavity coated by a single Nb_3Sn layer of thickness d = 50nm and an insulator layer in between

If the Nb cavity can withstand H_i = 150mT, then the external field can be as high as

$$H_0 = H_i \exp(d / \lambda_0) =$$
$$150 \exp(50/65) = 323.7mT$$

Can the new techniques of Atomic Layer Deposition (ALD) play a role here?

What is the rf critical field for high kappa materials like Nb3Sn? Theory?

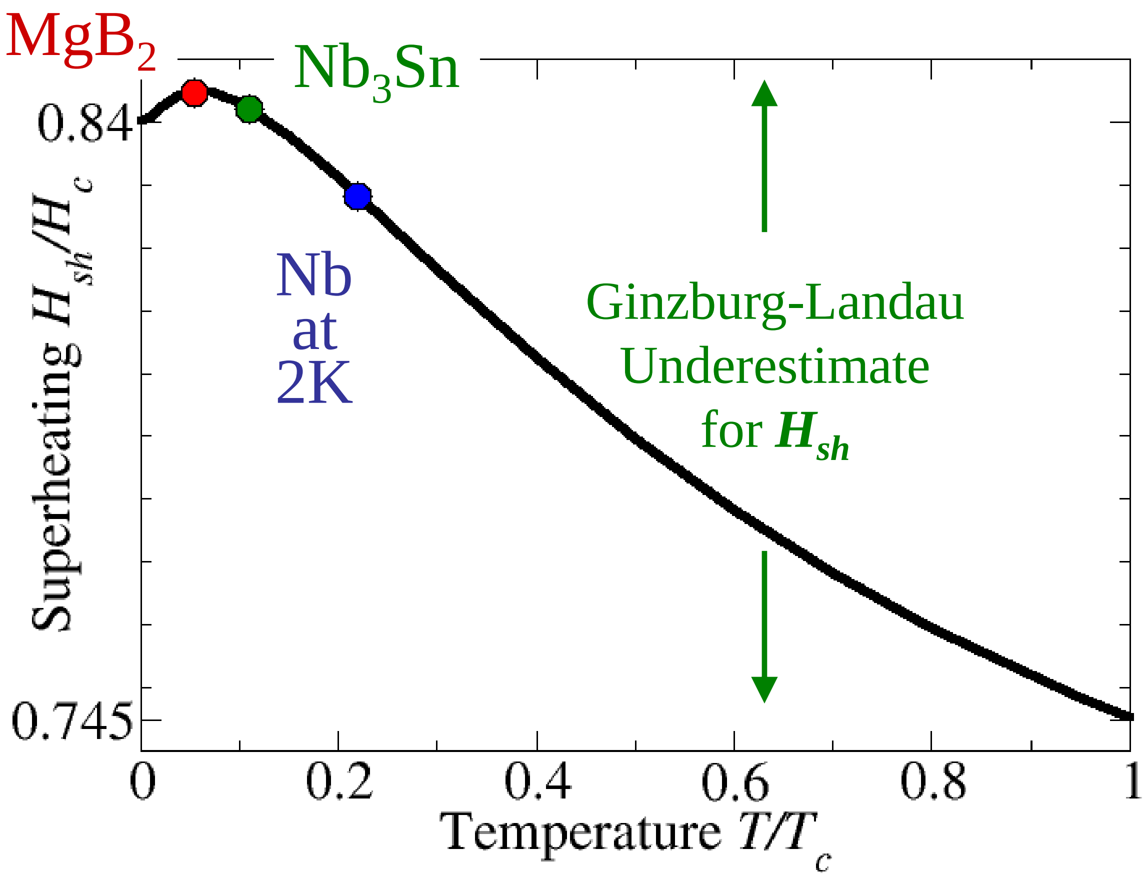
- Up till now we only had the Ginzburg Landau (GL) Prediction
  - Hsh = 0.75 Hc for large kappa
- But GL is a phenomenological theory
- Valid only near Tc

Sethna: 2007
Eilenberger (Pure BCS) Results !

Superheating field $H_{sh}(T)$ from the Eilenberger Equations

And large κ (so not applicable for Nb)

13% larger ***Hsh*** at low ***T*** than Ginzburg-Landau estimate !



Hrf-critical =
Hsh ~ 0.9 Hc

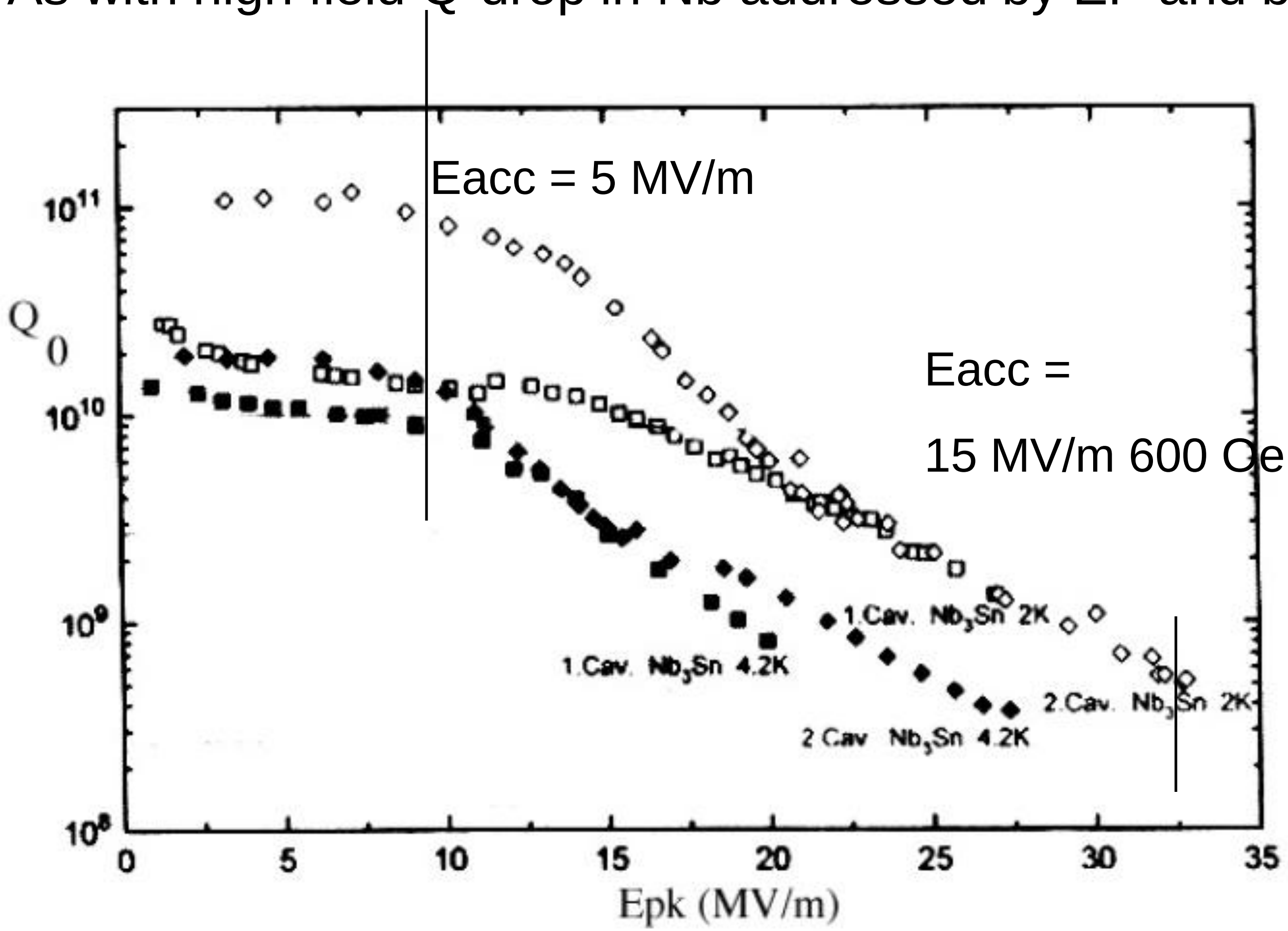
Which means

Theory gives hope for 100 – 200 MV/m !

- Eilenberger (BCS) theory predicts
- $\boldsymbol{E_{acc}}$ ~ 120 MV/m for perfect Nb_3Sn
- and 200 MV/m for perfect MgB_2 !!
- This is a strong motivation for materials and cavity push
- But be prepared for a long road to realization..
- Remember how long we took for Nb to reach 30 MV/m..starting in 1965 ! – 45 years
- Can we do it? Where are we now?

Best CW Result for Single Cell Nb3Sn Cavity 1300 MHz (Mueller and Kneisel)

- Q-slope observed in CW measurements may be addressed by improved material preparation
- As with high field Q-drop in Nb addressed by EP and baking.

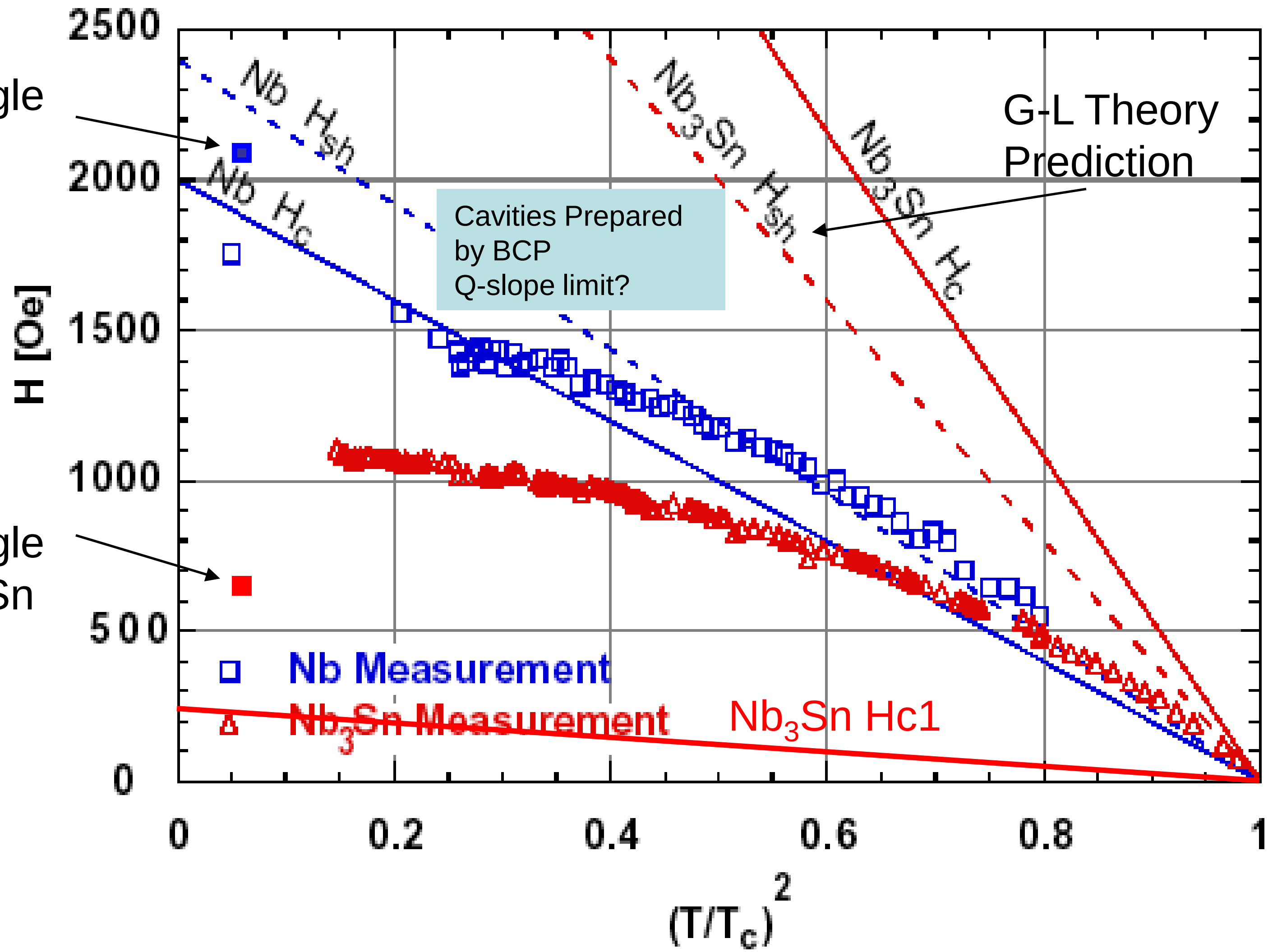


Pulsed Measurements Encouraging
Measured RF Critical Field for : Nb_3Sn Using High Pulse Power
(Calibrated results with Nb)

Important: Hrf-crit for Nb3Sn > Hc1..

Best single cell Nb cavity result

Best single cell Nb_3Sn cavity result



Suggestions for Next Steps for Nb3Sn or NbN

- Nb3Sn: Repeat solid state diffusion method with best Nb of today
- NbN: Sputtered Nb in N atmosphere
- Add large-scale thermometry for both CW and pulsed measurements
- Identify lossy spots
- Dissect bad regions as with Nb cavities
- Surface analysis to identify problems
- Improve methods guided by results.
- Repeat pulsed RF measurements for fundamental critical field with improved materials

Is there a realistic application for 100 MV/m gradient? (>2020)

- 3 TeV linear collider (like CLIC)
- If a linear collider at this energy/luminosity/background makes sense
- Instead of 5 TeV Muon Collider.

What Future Accelerator(s) Will Need 100 MV/m ?

- 3 TeV e+e- linear collider? 5 TeV muon collider
- At present CLIC is the only high gradient technology being developed
- 12 GHz, recently decreased from 30 GHz
- **How can SC version improve on CLIC?**
- Same gradient 100 MV/m
- Same AC operating power 400 MW !
- 2 X Higher luminosity
  - Higher Beam Power
- Use 10 MW klystrons, 2400
  - Don’t need two beam high rf power generation Smaller background for HEP
- Less energy spread on collision

Main Parameter Comparison

	FLC Future Linear Collider (Nb3Sn)	CLIC
Center of Mass Energy (TeV)	3	3
RF Frequency (GHz)	1.3	12
Gradient (MV/m) Q value at 2 K	100 5×10^{10}	100 10^4
Overall Site length (km)	50	50
Luminosity (cgs units)	12	6
Beam Power (MW)	60	14
Site AC Power (MW)	400	400

Other FLC Technology Aspects Are Not Too Far off !

Duty Factor %	1.4	
QL	2 x10^7	
P/cavity (kW)	400	
RF pulse length(ms)	5	
AC power for Cryo (MW)	60	
AC power for RF (MW)	300	

Reminder of Decade Perspective for Trajectory of Nb Technology (high β)

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