Long Term ILC Gradient R&D

Cost Effectiveness and TeV ILC Upgrade

Seamless Cavity
Large-Grain Niobium Cavity
Vertical Electro-polishing

Alternative Shape Cavity
Thin Film Cavity

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Jefferson Lab & GDE

The 1st Baseline Assessment Workshop

September 7-10, 2010, KEK

Questions

- Is it a credible claim that the cost of ILC SRF linac can be brought down
  - **by seamless cavity (through better yield and possibly by reduced manual labor)?**
  - **by using large-grain niobium material (through reduced material cost and elimination of the need of electropolishing)?**
  - **by alternative cavity processing techniques such as vertical EP?**
- Is it viable to raise ILC energy reach (for TeV upgrade) by using alternative cavity shapes?
- Is thin film cavity a potential solution to both energy reach & cost of a future collider or an open-ended R&D?
- Does/Will GDE take responsibility of these topics?

Cost Saving by Seamless Cavity ?

- Most lower performing (< 25 MV/m) welded 9-cell cavities are limited by one sub-mm sized defect near equator EBW in one cell while other superior cells capable of 30 – 40 MV/m.
  - **Throwing away a ~1 m^2 formed niobium for 1 mm^2 defective area is not cost effective.**
  - **It is suspected that EBW plays a role in the birth of these limiting defects.**
- Answer: probably yes - if EBW is confirmed to play a crucial role in birth of limiting defects; Existing DESY experience is encouraging; data set too small to justify; US will take serious look at this led by FNAL in FY11.
- Catch: burden shifted to production of suitable seamless tuning – a matter of R&D and hence may takes a while to make case.

Courtesy of W. Singer

Tubes: Roy Crooks: Black Laboratories, L.L.C., Newport News, VA

High purity Nb tube production developed and coordinated with ATI Wah Chang

Heavily deformed billet, processed for fine grain structure

Shaped by forward extrusion and flow-forming (more in presentation of Roy Crooks)

Black Lab. Tubes.

1,3 GHz cells hydroformed at DESY from Black Lab tubes

Cracks in few cells at the iris

W. Singer. DESY Experiences in Hydroforming. Hydroforming Workshop, September 1, 2010, FNAL, USA

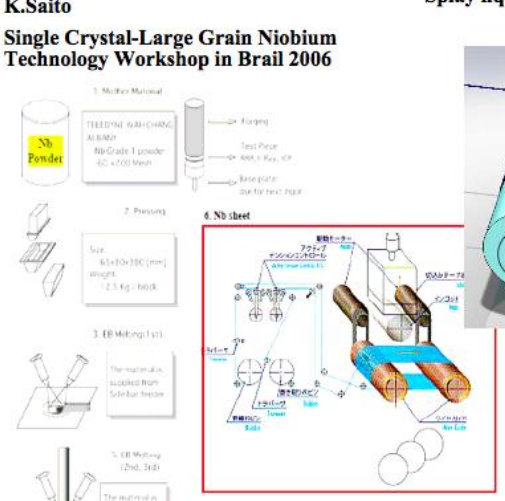
Courtesy of W. Singer

Cost Saving by Large-Grain Nb ?

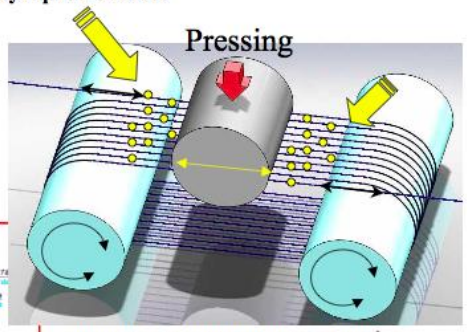
- Advocates of large-brain material claim cost saving is possible because of reduced material cost (due to direct ingot slicing) and reduced processing cost (due to the ability of reaching high gradient without EP) .
  - **Recent success of multi-wire slicing developed by KEK/Tokyo Denkai increases the attractiveness of large-grain Nb.**
  - **Excellent result of recent electropolishied 9-cell fine-grain Nb cavity and perspective of cheaper EP processing (due to advances in 9-cell EP reliability and reproducibility) argue against the claim.**
  - **Data from some lab suggest EP is still necessary for high gradient 9-cell large-grain cavities.**
- Answer: probably yes. More 9-cell data needed to justify.
- Catch: burden shifted to fabrication; faces same challenge of local defect near equator EBW as for fine-grain Nb.

K.Saito

Single Crystal-Large Grain Niobium Technology Workshop in Brail 2006



Splay liquid abrasives



Slicing used very thin piano wire (0.16Φ) and liquid abrasive

This technology is established technology on silicon wafer slicing. However, the experts had very critical opinions about my idea.

Courtesy of K. Saito

Cost Saving by Vertical EP ?

- There are many technical reasons to support the argument of cheaper (and maybe more reproducible) EP by doing it in vertical orientation.
  - **Extensive effort has been going on at Cornell for many years.**
  - **Recent 9-cell cavities treated by Cornell VEP appear to be of extremely high quality due to further process optimization.**
  - **Recent JLab experience of high gradient 9-cell testing without final EP (just heavy EP and vacuum furnace heat treatment) increases VEP's attractiveness.**
- Answer: yes. And VEP offers added incentive of being a more logical solution to scale up for mass-production.
- Catch: horizontal EP is raising the bar due to global effort and investment – with 9-cell processing and testing to ≥ 40 MV/m at increased frequencies. VEP needs to catch up with limited resources.

Is Alternative Cavity Shape a Viable Solution to Higher ILC Energy Reach ?

- There is clear physical reason and convincing 1-cell cavity experimental data to support the argument that ACD shapes hold promise for higher gradient by using the same processing technology for baseline cavity.
  - **Low-loss shape (LL): excellent 1-cell experimental results by KEK; continued 9-cell effort at KEK – in collaboration with Jefferson Lab; progress limited by available resources.**
  - **Re-entrant shape (RE): record setting 1-cell experimental result by Cornell in collaboration with KEK.**
  - **"New" Low-surface-field shape (LSF) designed by SLAC offers further optimized parameters.**
- Answer: yes.
- Catch: faces same challenge of local defect near equator EBW as for baseline shape; increased requirements for field emission suppression.

KEK Cavity ICHIRO#7 S0 Studies at JLab

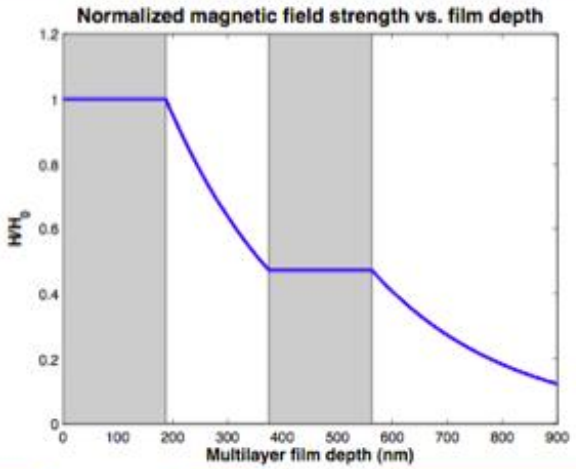
Photo courtesy of F. Furuta

Is Thin Film Cavity a Potential Solution or an Open-Ended R&D ?

- It is clear bulk Nb technology is reaching a physical limit. Further breakthrough in SRF acceleration (gradient reach or per MV/m cost) can only be expected by switching to new material via thin film coated cavity.
- Many technical hurdles, lots of efforts needed.
- Level of effort low; mainly curiosity driven; Project direction with milestones necessary to avid “open ended” R&D.
- Milestones needs to be defined in consideration of ILC time line and development of other acceleration technologies.
- Positive side: potential return very high; no lack of enthusiastic next generation researchers.

Multilayer Film Approach

$$H \sim e^{-z/\lambda}$$



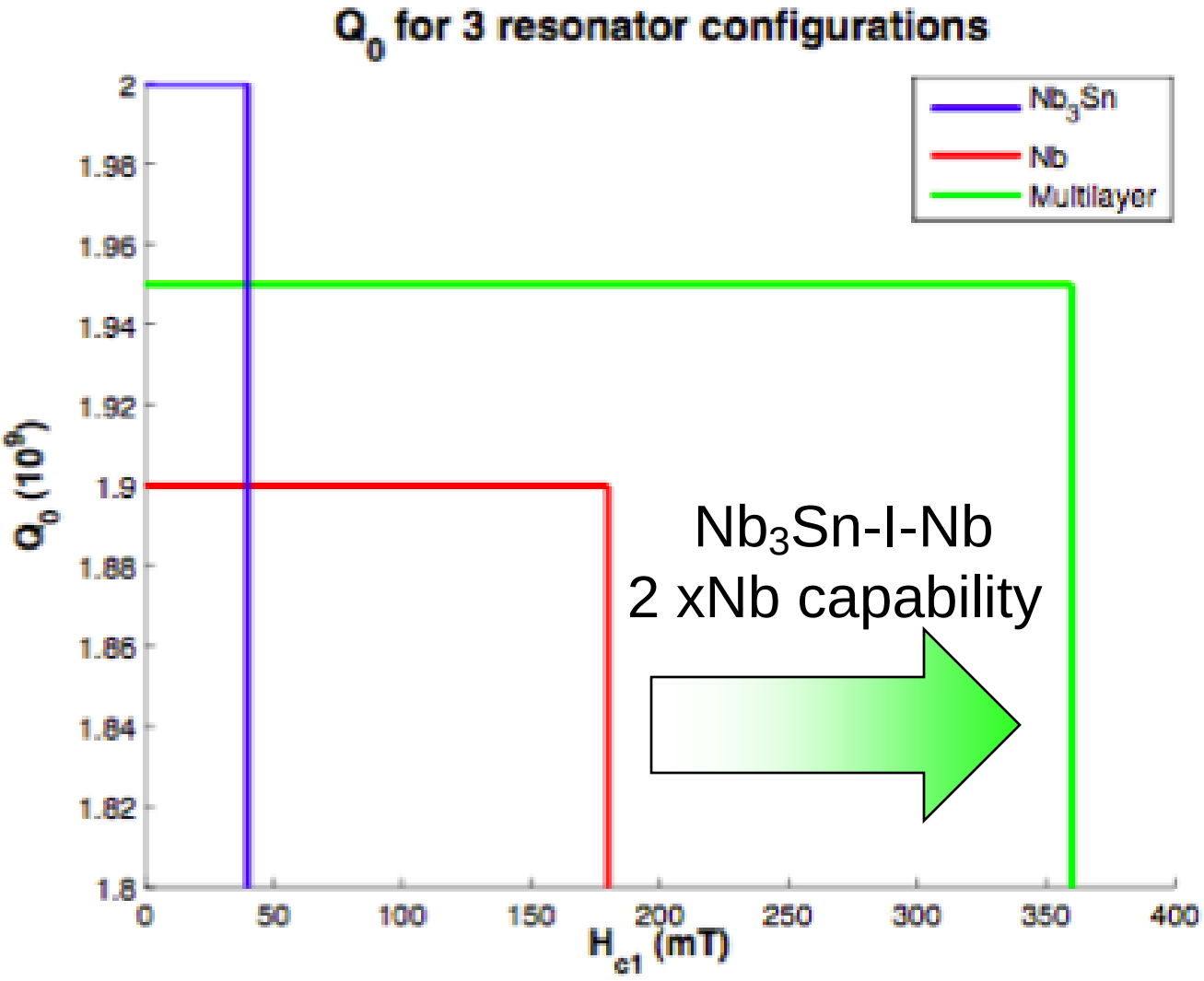
dielectric

superconductor

cavity volume | NbTiN layer | bulk Nb

Cavity fields screened from bulk by alternating thin film layers of SC and insulator. Layer thickness $d < \lambda$.

Courtesy of D. Bowring



Courtesy of D. Bowring

JLab Experimental Multi-Layer Work

Sputtering Photos

Courtesy of D. Bowring

Final Remarks

- ILC gradient R&D priority given to baseline design in TDP-1 and TDP-2 toward TDR in 2012.
- Many important ACD topics exist both in terms of enabling cavity performance & making technology cheaper.
- Advocates have been pushing continuously - but frankly speaking there has been little impact (resource limit).
- Many of the ACD topics deserve support ramp up NOW and some likely need continued effort beyond 2012.
- We need guidance as to whether GDE (via Cavity Group) takes “ownership” of these topics before 2012.
- We also need guidance as to whether ILC should take project responsibility to guide long term R&D (such as thin film coated cavity) to avoid “open ended” research.