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U.S. DEPARTMENT OF ENERGY

LBNL work on Bi-2212 and US-CDP Plans

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EuCARD 2

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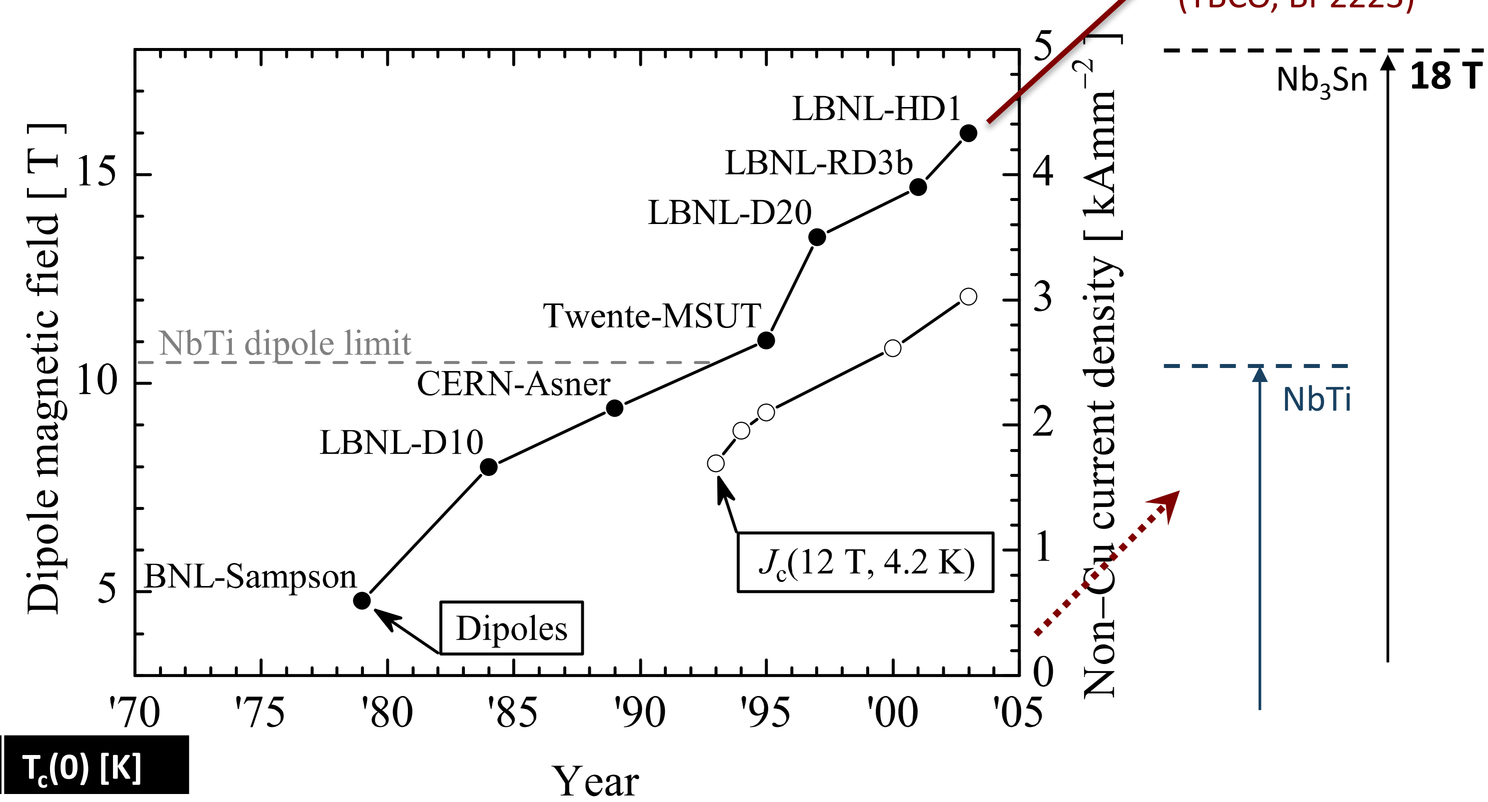
Outline

- Motivation for development of Bi-2212 wire and magnet technology
- Progress on Bi-2212 magnet technology
- Bi-2212 conductor improvement and limitations
- Future plans for conductor and magnet design

Motivation: Higher fields require HTS materials

Record Nb_3Sn dipole magnets

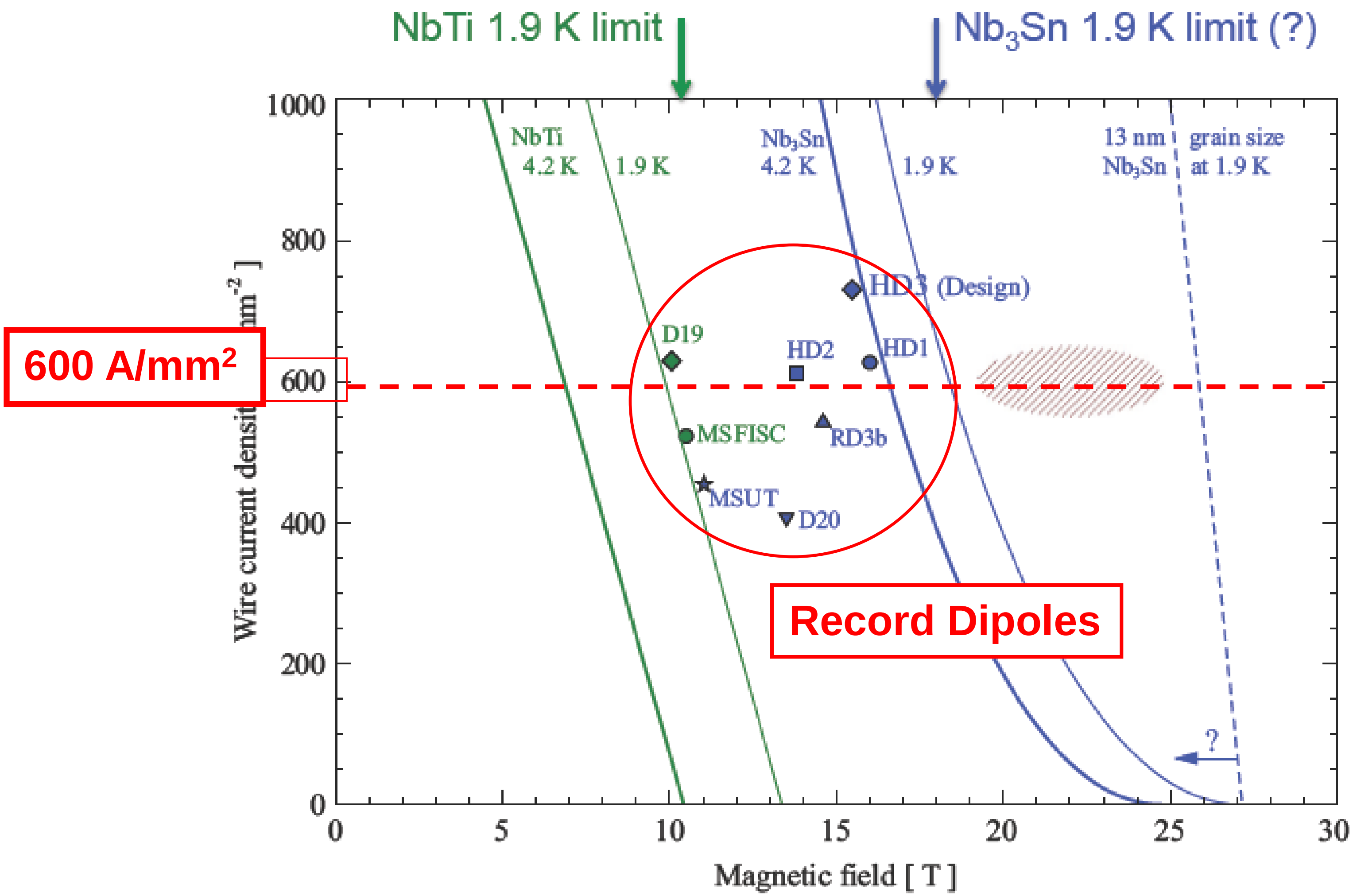


	$H_{c2}(0)$ [T]	$T_c(0)$ [K]
NbTi	14	9.5
Nb_3Sn	30	18
MgB_2	3.5-35	32-40
$YBa_2Cu_3O_7$	>100	93
Bi-2223	>100	108
Bi-2212	>100	95

No intrinsic H_{c2} limitations

Dietderich, Godeke, *Cryogenics* **48** (2008)

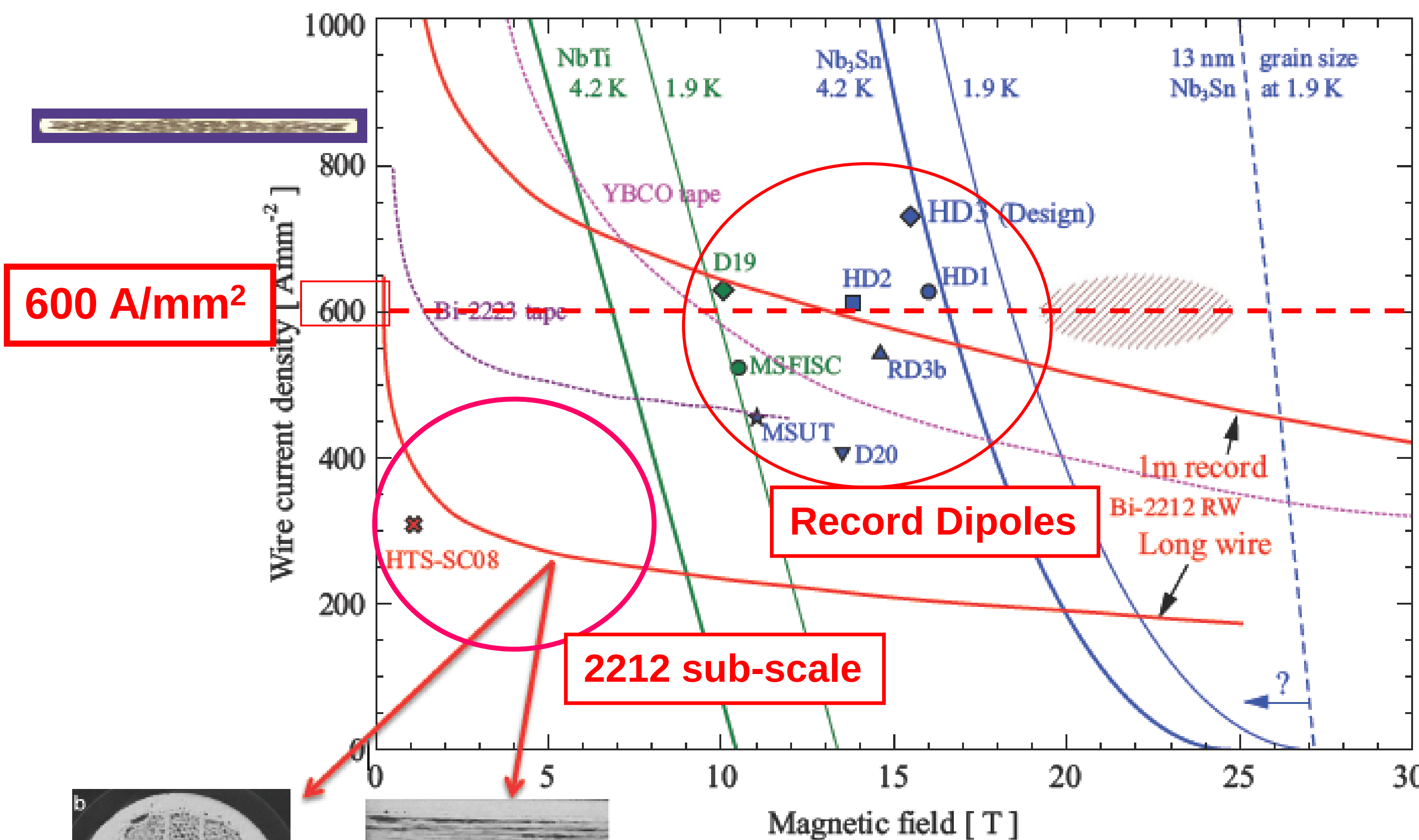
Bore field in dipoles versus wire J_e

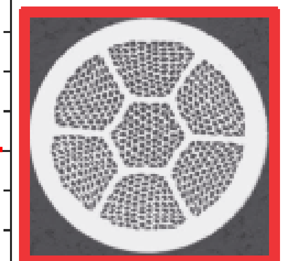


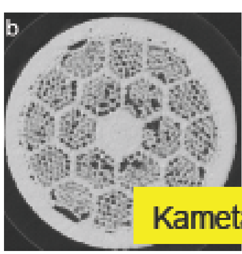
Record dipoles from optimized wires: J_{wire} ~ 600 A/mm², $J_{winding}$ ~ 450 A/mm²

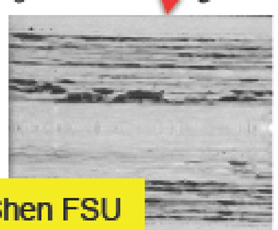
Godeke *et al.*, *to be published* (2012)

Bore field in dipoles versus wire J_e









Bi-2212: Round wire with significant potential

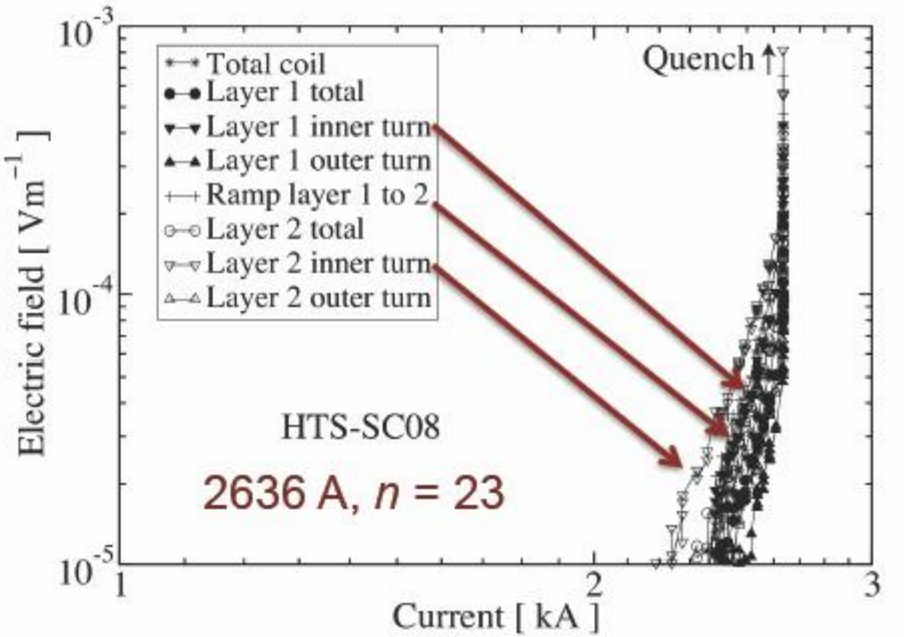
Kametani et al., *Supercond. Sci. Techn.* 24 (2011)
Godeke *et al.*, *to be published* (2012)

Bi-2212 technology status

'Best of breed' so far: HTS-SC08

- After reaction: Minor leakage (5 spots/side)

- Coil performance, 4.2 K, self-field (~1 T)



Coil performance

- Coil achieves 85% of *round wire* witness
- Limited by inner turns and ramp
- HTS-SC10: 2417 A (within 10%)

W&R Bi-2212 is realistic

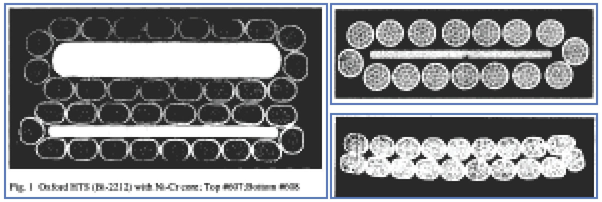
Pending issues

- ✔ Increase wire J_e by factor 3 – 4
- ✔ Coil homogeneity (inner turns limit)
- ✔ Stress-strain sensitivity Bi-2212
- ✔ Leakage
- ✘ Further compatibility studies
- ✘ Quench protection(?)

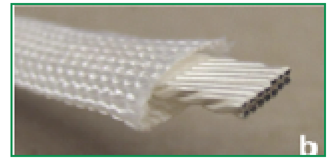
- Materials compatibility

Bi-2212 dipole technology at LBNL

1998 ⇨ 1999 ⇨ 2000 ⇨ 2001 ⇨ 2002 ⇨ 2003 ⇨ 2004 ⇨ 2005 ⇨ 2006 ⇨ 2007 ⇨ 2008 ⇨ 2009 ⇨ 2010 ⇨ 2011 ⇨ 2012 ⇨

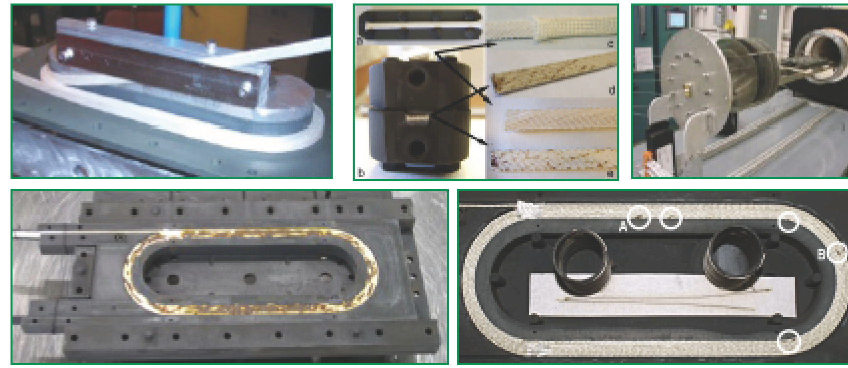


Rutherford cable developments
(with IGC, OST, Showa > 4.5 km SMES cable)



2009 ⇨ 2010 — VHFSMC

2011 ⇨ 2012 — BSCCo



W&R Bi-2212 racetracks with Showa and OST
Reach 85% of RW along loadline => **Technology OK**

Beyond 16 T dipole fields

- Optimize and refine Nb_3Sn
- Develop W&R Bi-2212
  - Collaborations
    - **SWCC** Showa Cable Systems Co. Ltd.
    - **OST** Oxford Instruments
    - **VHFSMC** U.S. National Program on Bi-2212
      - » BNL, FNAL, FSU, LBNL, NCSU, NIST, TAMU
    - **BSCCo** U.S. collaboration on Bi-2212
      - » BNL, FNAL, FSU, LBNL (+OST, CERN, Nexans)
- Side path: YBCO, Bi-2223, …

Leading roles for LBNL

2006 – 2012: Bi-2212 subscale coils

- Purchase wire, make and insulate cable
- Coil on Inconel 600 former, react, pot, test
- 2 Ag dummies & 11 Bi-2212 coils to-date

2013 onwards: Bi-2212 dipole inserts

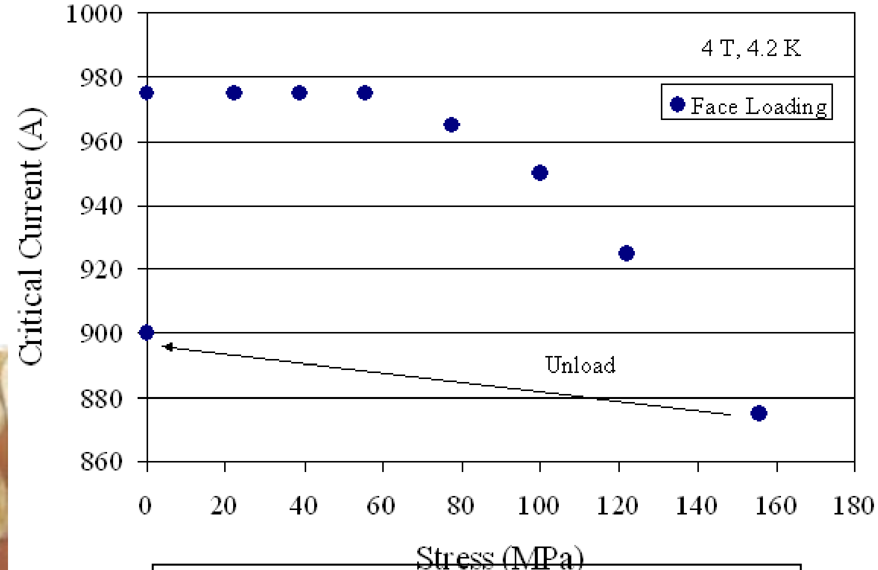
- Low strain, high J_e insert for HD3

Bi-2212 is an enabler for MAP and HE-LHC

Stress and Strain Sensitivity of Bi-2212

Transverse loading on Rutherford cable

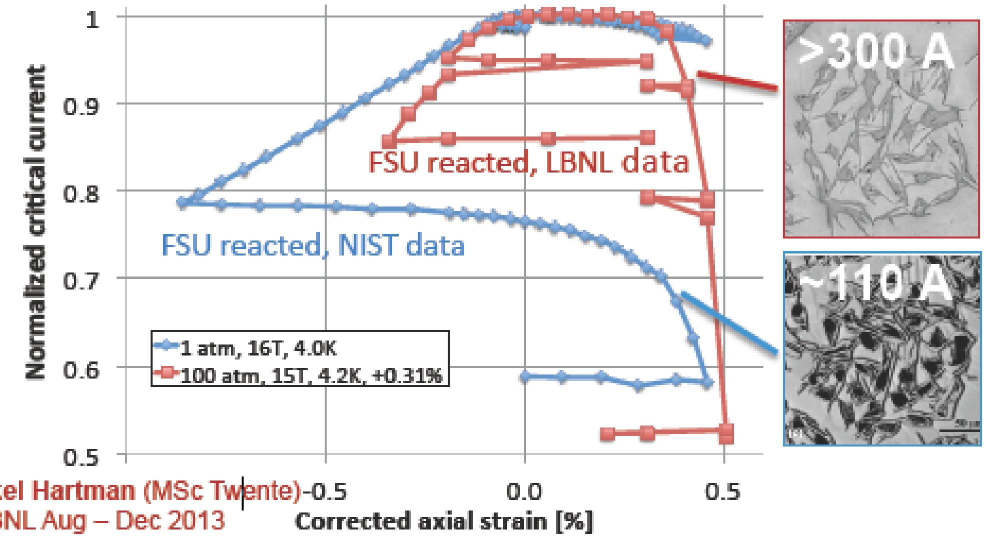
- Ic reduction at 60 MPa
- 20 T dipole inserts: 150+ MPa
  - Likely more



D.R. Dietderich, et al. TAS 2001

Required I_c through overpressure reaction

- 888 ± 1°C, 99:1 bar $Ar:O_2$ ➞ > 600 A/mm^2 @ 20 T
- ...but only 0.3 – 0.4% reversible strain range



Maijkel Hartman (MSc Twente)
@ LBNL Aug – Dec 2013

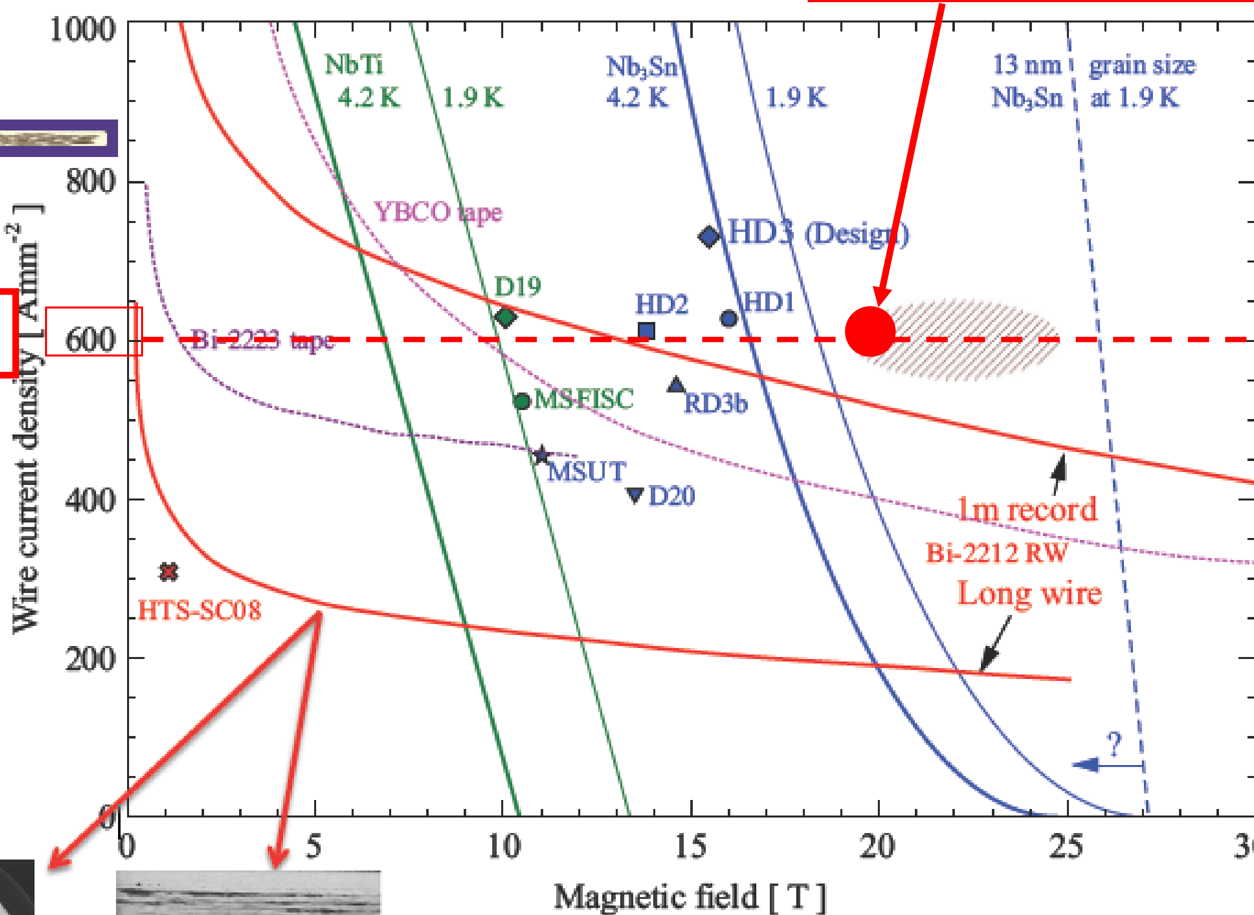
Over Pressure Processed Wire

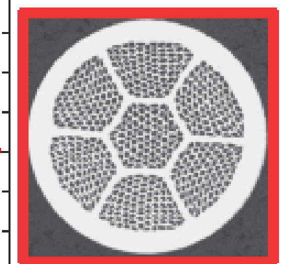
- 3 times more current (8 cm)
  - Composition not yet optimum
  - Still need long lengths of conductor
- However no improvement in strain tolerance

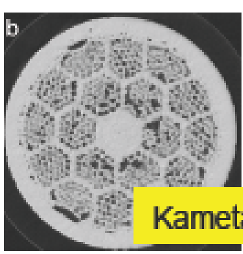
Bore field in dipoles versus wire J_e

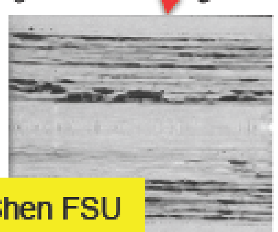
Over Pressure Processing

600 A/mm²









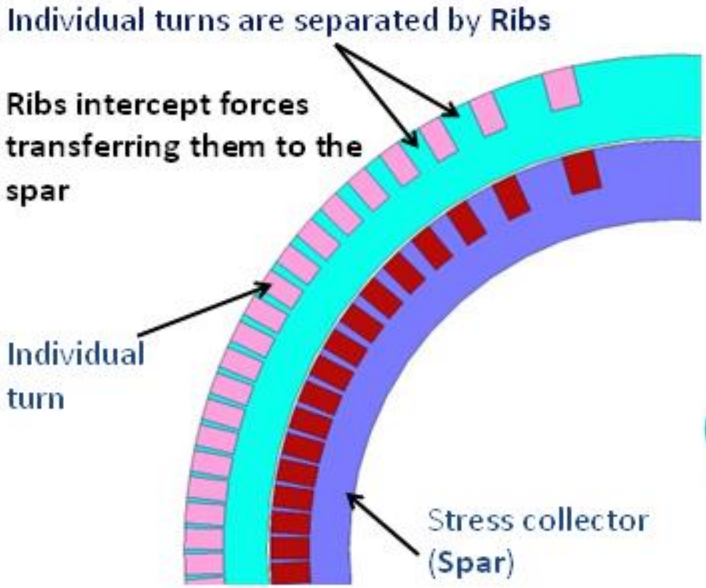
Kametani, Shen FSU

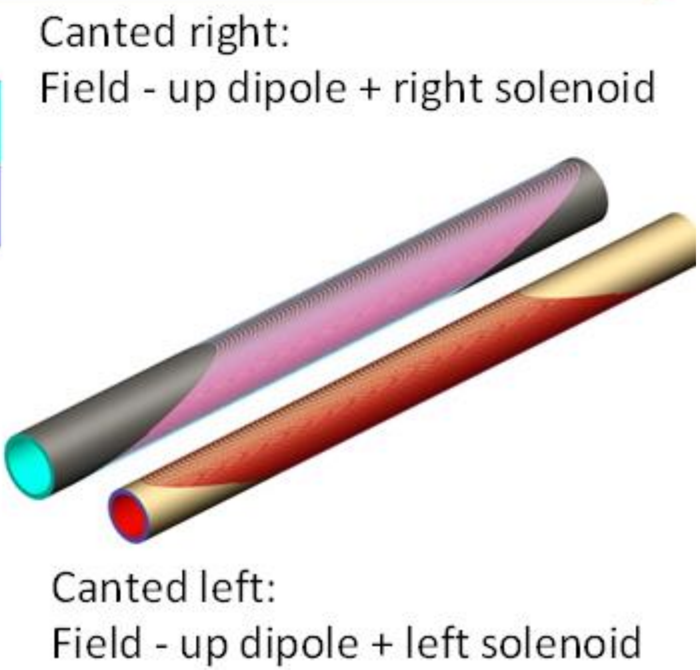
Bi-2212: Round wire with significant potential

Kametani et al., *Supercond. Sci. Techn.* 24 (2011)
Godeke *et al.*, *to be published* (2012)

New Coil Concept to limit stress -- CCT

S. Caspi,
Tuesday session



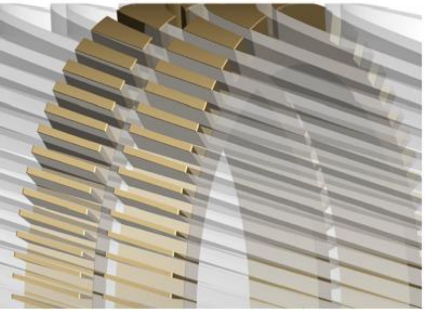


Unique turns distribution

$$J_z \sim \cos\vartheta$$

*D.I. Meyer and R. Flasck "A new configuration for a dipole magnet for use in high energy physics application", Nucl. Instr.and Methods 80, pp. 339-341, 1970.)

EuCARD'13 10-14 June 2013 CERN S. Caspi 14



- Canted Cosine-Theta (CCT) made from laminations
- Potential for CTE machining to conductor

S. Caspi, et al.

Nuclear Instruments and Methods in Physics Research A 719 (2013) 44–49

Conductor Development Program

Ken Marken – DOE

Daniel Dietderich (manager) – LBNL

CDP Advisory Board

- BNL – Arup Ghosh
- FNAL – Giorgio Ambrosio, Lance Cooley
- FSU – David Larbalestier, Peter Lee
- LBNL – Arno Godeke
- TAMU – Al McInturff

Funds received from DOE

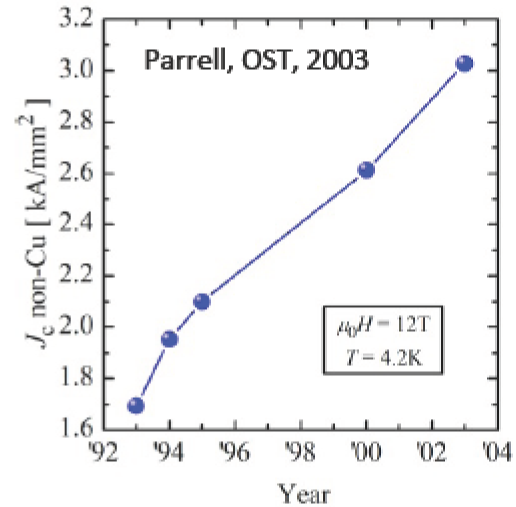
- Request proposals
- CDP Management provides Task guidelines
- Advisory Board reviews proposals
- Tasks are deemed most important for HEP
- OST delivers wire and reports
- Characterization is performed on wire by BNL, LBNL and NIST

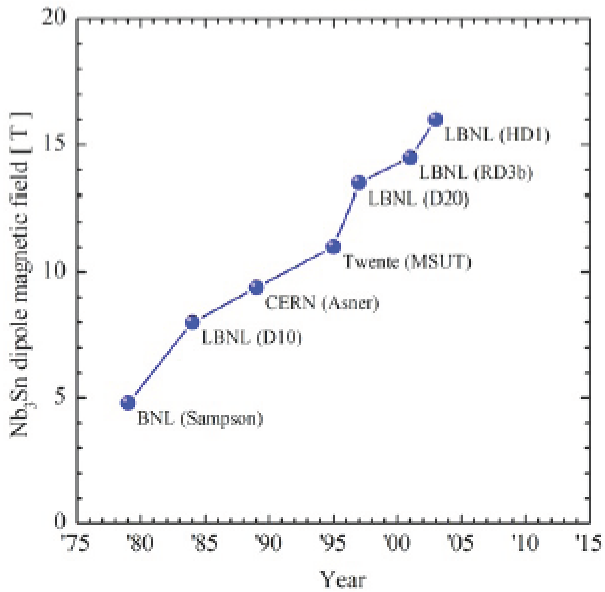
Wire available to HEP magnet programs

CDP steers core US Conductor Development based on HEP magnet needs

CDP has driven Nb_3Sn J_c to >3000 A/mm^2

- Enables high field magnets and LARP





CDP – Bi-2212

- Majority of funds still focusing on issues with Nb_3Sn for Hi-Lumi
- CDP has invested in Bi-2212 for several years and the investment will grow over the next 2-3 years
- Presently supporting fabrication of 3 billets at Oxford Superconducting Technologies
- Funds are available for near term Bi-2212 R&D

Summary

- The critical current is now at a level useful for high field magnets (~600 A/mm^2)
  - However, still need long lengths of Bi-2212 conductor
- Still need to improve insulation and materials compatibility
- Controlling the stress on the conductor is the dominate issue in high field magnets of Bi-2212 -- (< 50 MPa - 100MPa?)
  - Use of the Canted Cosine-Theta (CCT) coil design address this issue