Discussion on 2G Conductor and Magnet R&D

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Overview

- General Considerations/Thoughts
- BNL HTS Magnet Projects
- Recent Test Results
- Discussion on conductor needs

General Considerations/Thoughts

- 2G conductor now has been available for some time
- For the purpose of magnet applications, it is generally regarded as an R&D conductor for demo devices
- We want to change that perception and want to convince the community that it is getting ready for real applications
- We first look for special applications where HTS offers unique advantages
- We simulate those challenging situations (such as energy and radiation depositions in magnets for Facility for Rare Isotope Beams – FRIB)
- We make magnets and do other tests to prove that it indeed offers the benefits promised
- We make several coils (and a few magnets) to show that one can consistently make reliable coils.
- Starting with the applications where HTS offers unique advantages, we then hope to move to larger volume applications
- For this, we need your support – we make progress and succeed together
- There may be some growing pains as we start putting spec and requirements as they are needed for real magnet applications

Current HTS Magnet Programs at BNL (that require significant 2G wire)

FRIB Radiation tolerant quadrupole – high energy deposition, high radiation

- Designed to operate at 40-50 K, 2-3 T
- Need to purchase 6 km, ~4mm wire or 2 km, ~12mm wire soon
  - We are opting for 12 mm wire

Successful demonstration of this magnet may open opportunity for many other HTS magnets in FRIB and elsewhere.

High field solenoids

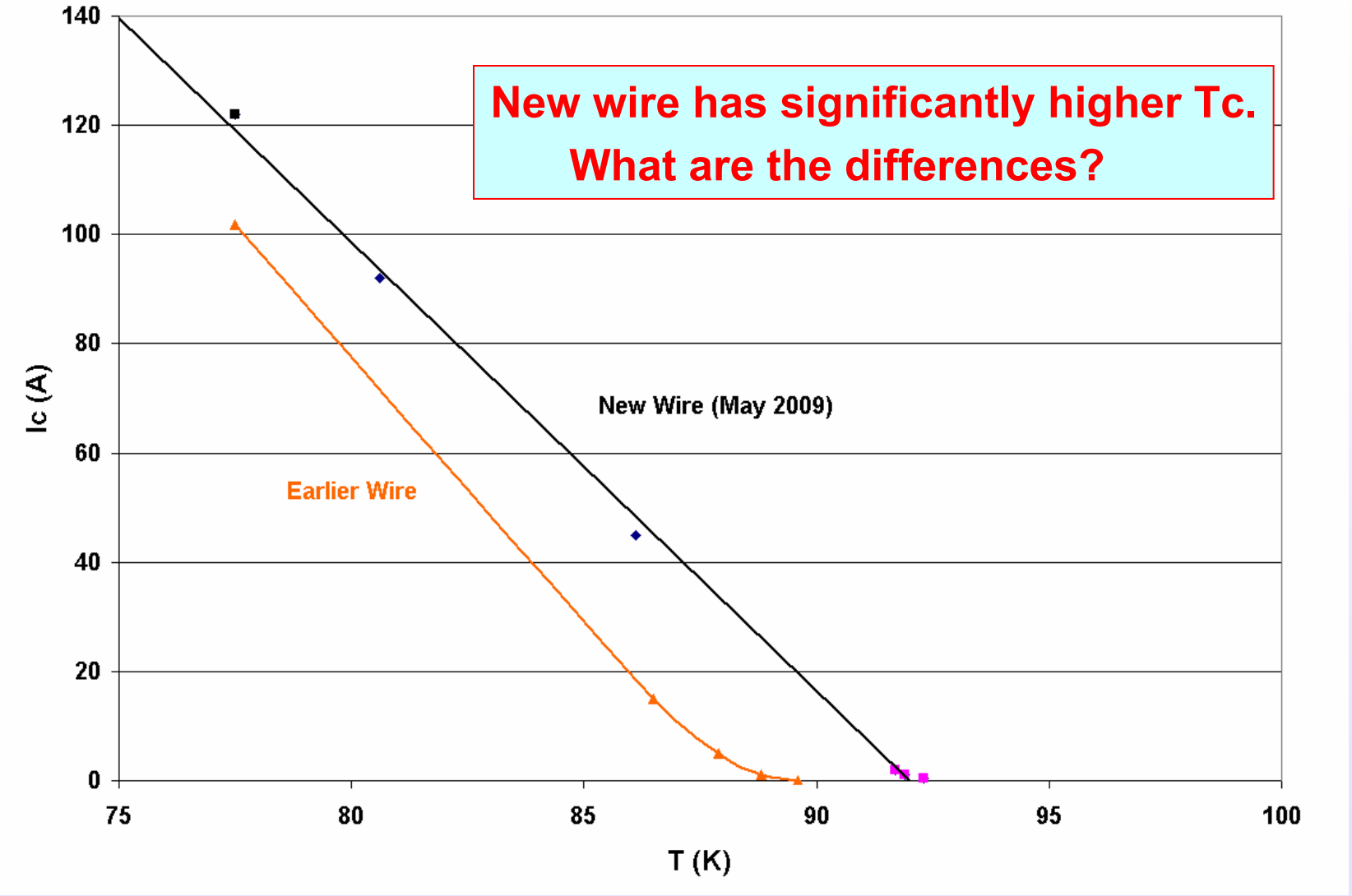
- 10 T, 100 mm HTS solenoid with PBL (SBIR funding)
  - 1.4 km addition 4 mm wire (in addition to 1.4 km purchased last year)
- 20+ T HTS solenoid with above solenoid as outsert
  - May use a combination of 4 mm and 6 mm (and may be 8 mm) wire
  - This solenoid is planned to be tested in the background field

In addition, we have a number of small programs and planning for future proposals.

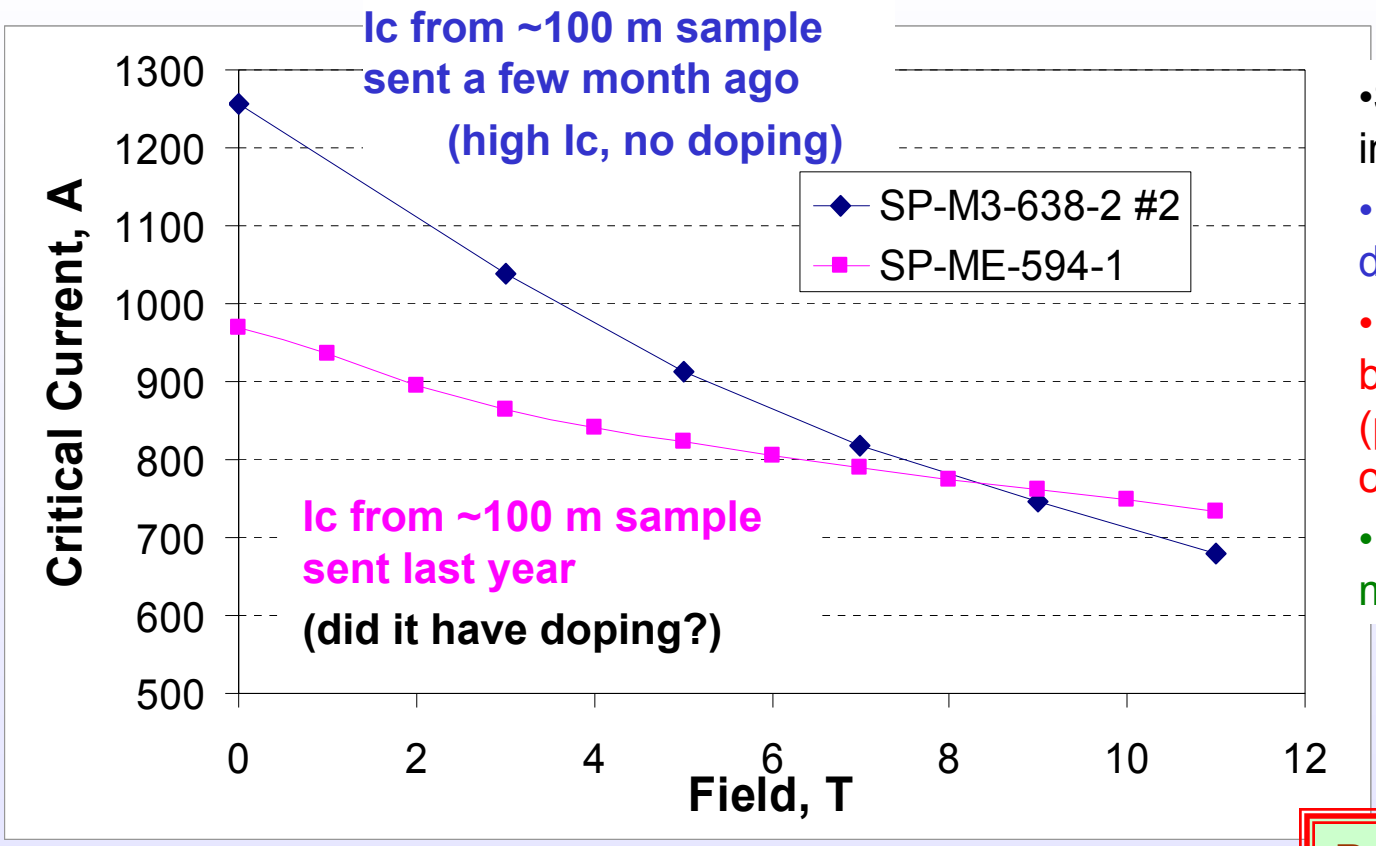
Type of Conductor

- We have two types of applications: (a) high field, 4 K operation and (b) medium field (2T-3T) high temperature (>40 K). It is possible that the two may benefit from two different pinning.
- Please help us sort various conductors supplied and the conductor to be available for future use by giving us a bit more information on the conductor. We would like to use only those conductors (pinning, etc.) that you undertake to continue manufacturing in future.
- We would like to know more about whenever the changes made in the basic conductor. We also need to know more about details on doping, high Ic, single pass, multi pass, high field, advanced pinning, etc., etc.
- This will help us choose proper conductor for various future applications.

Different Wires from SuperPower Tested at BNL



Critical Current as Function of Field (parallel) in Two SuperPower Wire



- Self-field Ic at 4 K improved.
- However, a significant difference at high field.
- Wire from the last year batch was better (particularly in the ratio of high field to low field).
- Is doping playing a major role here ???

But what happens to the angular dependence?

How much is the difference in the lowest value?

Recently supplied wires are not yet tested:

- 350 meter high Ic wire
- 700 meter HF wire

High Ic Wire

SuperPower Inc.

Did this run have a thicker coating?

Was it a multi-pass run?

Ic of SCS4050 2G HTS wires delivered to PBL (SP-Particle Beam Laser-20090910)

Spool I.D.	Ic (A) Average	STDEV (%)	Ic (A) Minimum	Packaging Information
20090910-1	170	1.5	165	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "798.50" end at the outside of the spool with ~30 cm leader attached.*
20090910-2	164	2.3	158	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "857.80" end at the outside of the spool with ~30cm leader attached*
20090910-3	165	3.3	154	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "912.80" end at the outside of the spool with ~30cm leader attached*
20090910-4	178	2.2	171	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "1037.80" end at the outside of the spool with ~30cm leader attached*
20090910-5	156	5.4	137	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "981.01" end at the outside of the spool with ~30cm leader attached*
20090910-6	159	2.9	151	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "981.01" end at the outside of the spool with ~30cm leader attached*
20090910-7	155	6.4	134	*The wire is wound on a spool with YBCO side outwards. Internal Tape I.D. is marked on the tape. "1046.01" end at the outside of the spool with ~30cm leader attached*

High Field Wire

SuperPower Inc.

Which of the two wires would have a higher Ic at high fields?

Ic of SCS4050 2G HTS wires delivered to PBL (SP-PBL-20090923)

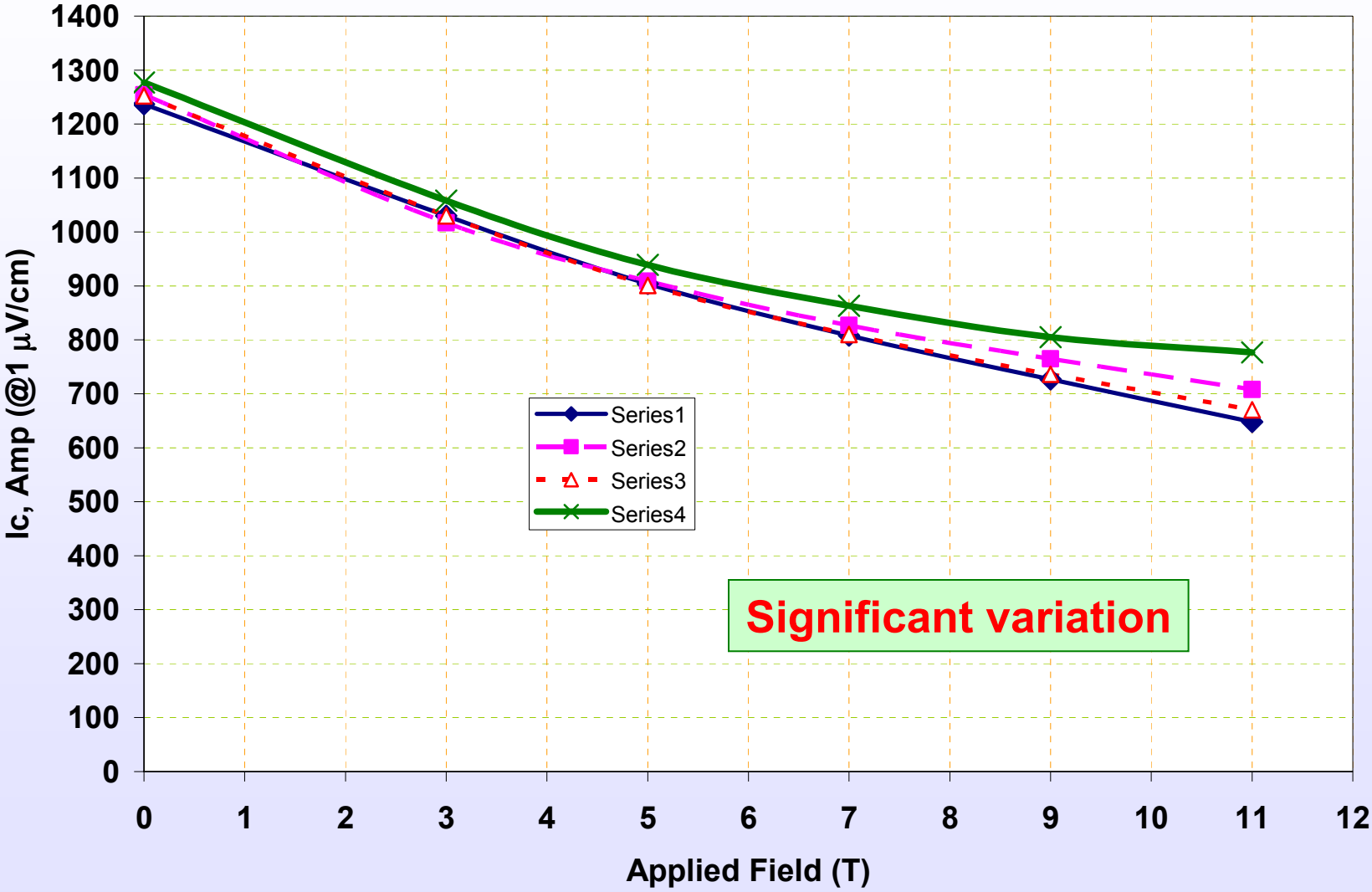
Spool I.D.	Ic (A) Average	STDEV (%)	Ic (A) Minimum	Packaging Information
20090923-1a	88	1.84	85	
20090923-1b	94	2.8	91	*The wire is wound on a spool with HTS side outwards. Internal Tape I.D. is marked on the tape. 30cm leader between HTS segments. "1482.10" end at the outside of the spool with ~30 c m leader attached*
20090923-2a	85	4.4	80	
20090923-2b	86	1.7	84	The wire is wound on a spool with HTS side outwards. Internal Tape I.D. is marked on the tape. 30cm leader between HTS segments. "1184.02" end at the outside of the spool with ~30 c m leader attached
20090923-3a	90	2.0	87	
20090923-3b	92	3.4	87	*The wire is wound on a spool with HTS side outwards. Internal Tape I.D. is marked on the tape. 30cm leader between HTS segments. "1547.3" end at the outside of the spool with ~30c m leader attached*
20090923-4a	91	1.2	88	
20090923-4b	95	2.9	92	The wire is wound on a spool with HTS side outwards. Internal Tape I.D. is marked on the tape. 30cm leader between HTS segments. "1821.4" end at the outside of the spool with ~30 c m leader attached

More Conductor Test Results

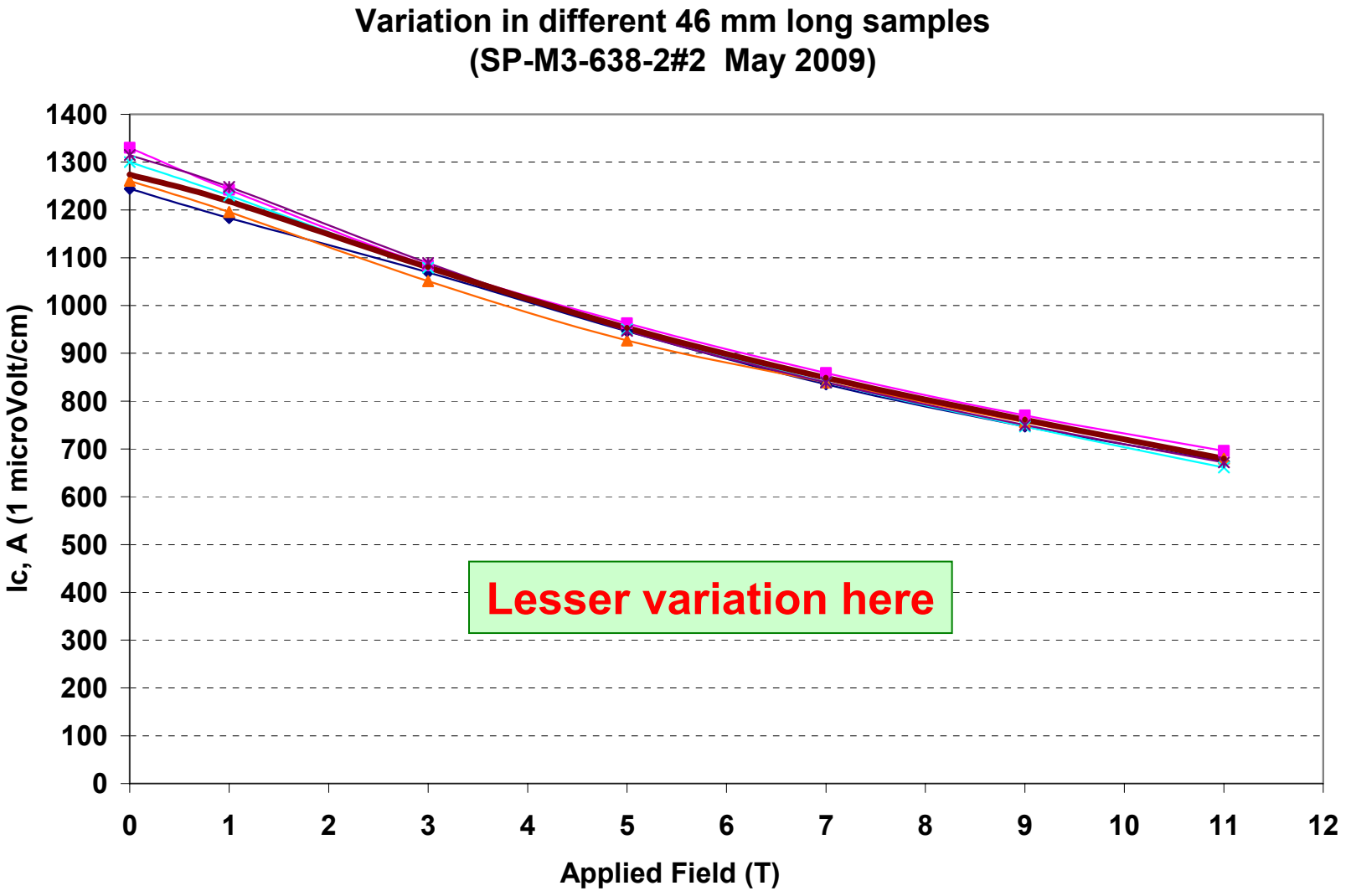
- Understanding of the variations in the conductor performance along the length is important to building magnets that can be reliably used in real applications.
- Remember, the magnet performance is limited by the weakest link and not by the champion.

Field Dependence within Wire

Variation in ~46 mm pieces from the same spool
(SP-M3-638-2#2 May 2009)



Field Dependence within Wire



In-field Testing of SuperPower Wire at 4 T

Barrel for in-field testing inside the magnet bore

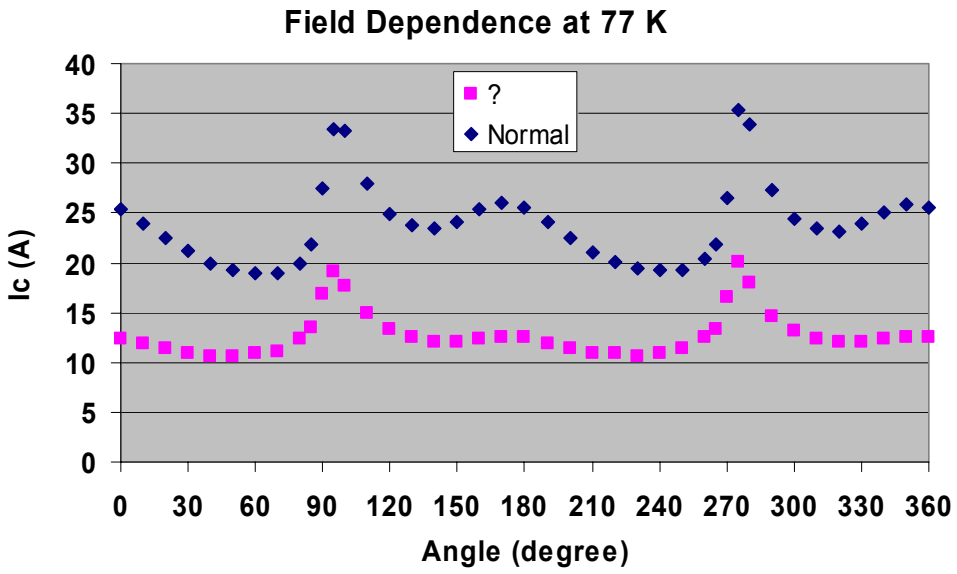
H_A

- We have tested five samples of wire in–field at 4K
- One was tested last year and four this year
- The same exact procedure was used in all test
- As reported last year, the wire developed a defect during the high field testing
- The first of the four, tested was also developed a similar defect
- However, three other tested did not exhibit this behavior

- Creation of this defect is a source of serious concern

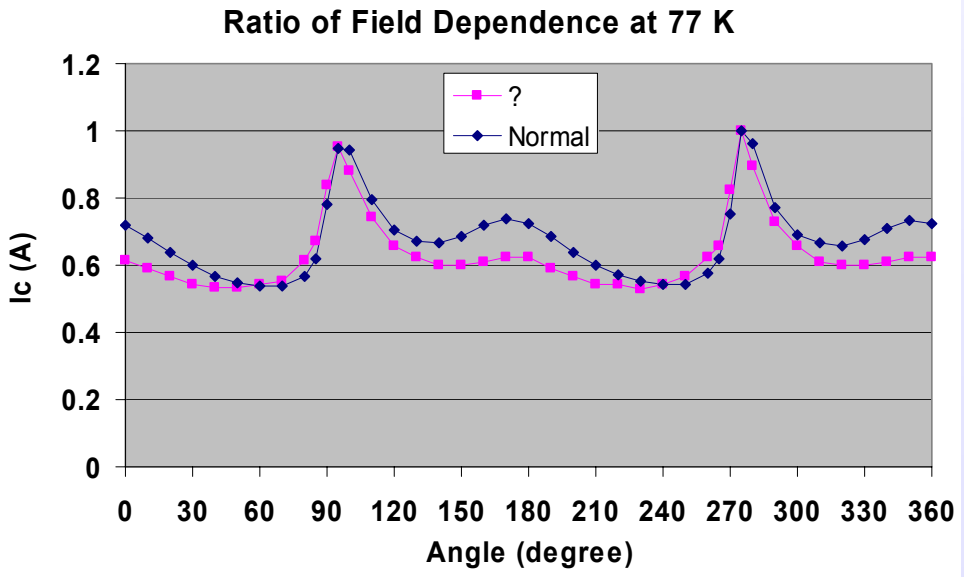
- The defect is very localized. We kept putting v-taps in smaller and smaller length and were able to locate the defect within ~3 mm
- All voltage was generated from that area
- The defect was interesting as it did not change the n-value and primarily reduced the Ic as if part of the conductor is removed
- **Understanding of this is critical (I have brought that wire here for further analysis – imaging, etc.)**

Comparison of Anisotropy (before and after the creation of the defect?)



Angular dependence was measured before and after the high field 4 K test during which the defect (?) was created

There was practically no change in the n-value which indicates that the wire was not degraded (damaged?). It appears as if a part of the conductor is removed



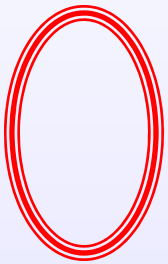
Tapestar Measurements

Do Tapestar measurements point to a local region where a defect may possibly get developed.

Please mark such dip in the next shipment.

You can also send us a separate sample (with such dip) to see if such defect is creating during the conductor testing at the location marked.

Plots removed from the public version



There should ***NOT*** be any doubt about the conductor if it is to be used in real application.

We have to work together to remove challenges.

Possible Areas of Collaboration (as mentioned during the last visit)

- High field all HTS solenoid (Superpower inner, BNL outer).
- Measurements of the performance of conductor as a function of temperature, field and direction of field. This is particularly important for doping studies. In order to better characterize the conductor we should have continuous curves with several points.
- Study of the performance of coils as a function of temperature for the coils made with the conductors having different dopings.
- Identifying applications and developing magnet designs where HTS would play a significant role (and if we can find source of funding, then build and test the system as well).

Quotes Received from SuperPower

K11129

K11128

Information removed from the public version

K11127

- We realize that the quotations that we are receiving are not for production article.
- We request performance/price matrix from both vendors. It is up to the vendors how they set the price. We analyze that matrix.
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A Candid Discussion for Developing Quotations for Magnet Wire

- For magnet use, we want to set the technical specifications at the operating point.
- So far specifications for HTS wire have been set by vendors at a point where it is convenient to them. Request for quotation at the operating point indicates that we are now moving to next phase.
- We realize that HTS wire has not yet as matured in production as LTS wire has (particularly for in field performance). Therefore, there has been a need for flexibility.
- As such we do not want the manufacturer to waste its wire. That is not sustainable at this stage and is not good for anyone. All wire must be usable somewhere.
- Therefore, development of specifications is a balancing act.
- But remember, we have to deliver a product (magnet) to our funding agency.
- Option to provide additional wire for magnet to reach design value even when the specs are not met is, in our opinion, an approximately right balance.
- However, it always looks good when the specs are met and wire is delivered on time.
- In addition, a steady improvement in performance and reduction in cost is essential to making HTS magnet competitive. This is where we have a major common interest.

Discussion on Current and Future Need