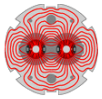



***BNL -FNAL - LBNL - SLAC***

# LARP CM17
# November 16, 2011
# CERN

# Conductor for R&D and Production

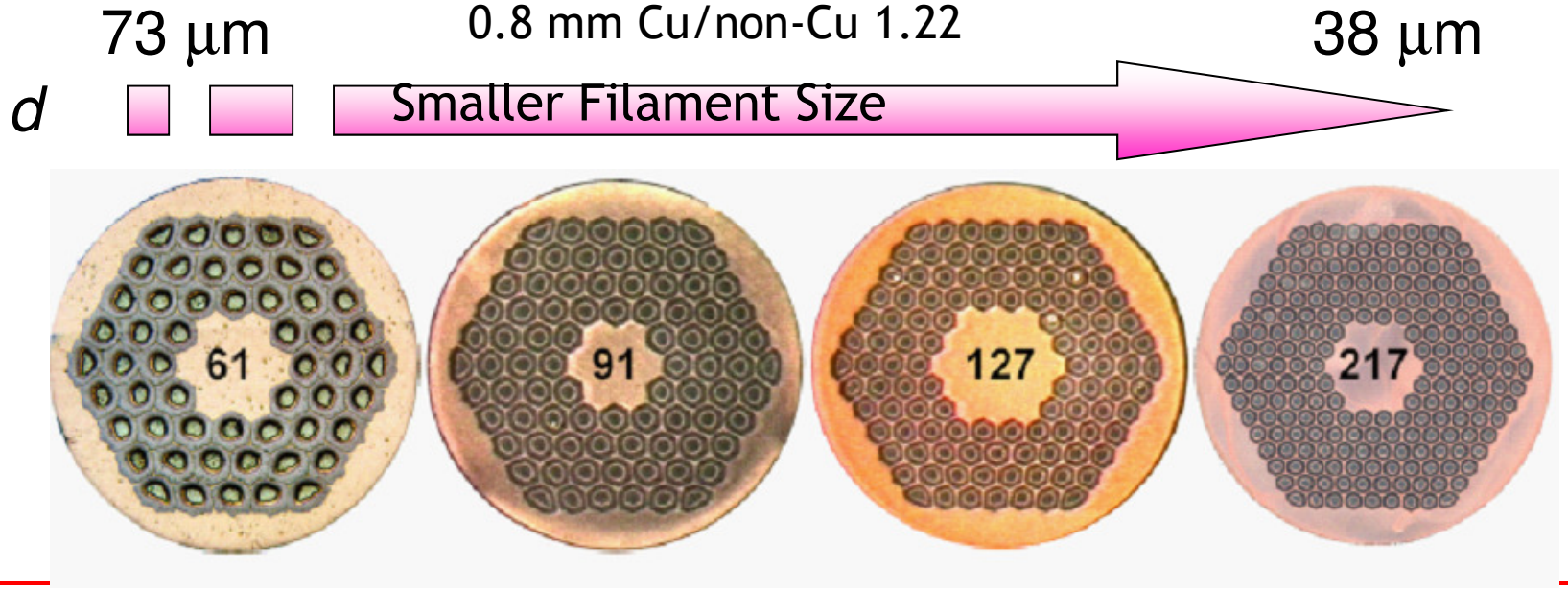
Arup K. Ghosh (BNL)


# Outline

- R&D on Smaller Filament Strand
- Ti-Ternary strand
- OST 108/127 strand production
- Production Plan for Strand and Cable
- Summary

# Pathway to smaller filament diameter

- Smaller sub-elements can minimize flux jumps and improve stability.
- Filament Magnetization decreases
- Main driver has been DOE- HEP Conductor Development Program
- And FNAL R&D Program



# CDP-Conductor R&D – 217 stack Ti-Ternary

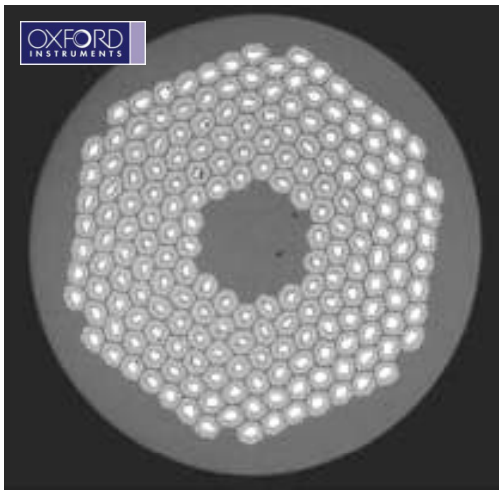
Development of 217 sub-element stack

3000 A/mm$^2$ class could not be processed

2400 A/mm$^2$ class processed to 1.07 mm in one piece

However, it had a low RRR for optimized Jc 665C/48h

Need thicker barrier or reduced Sn content




| **WireDia, mm** | 1.001 | 0.800 | 0.701 |
|---|---|---|---|
| **Ds, um** | 51 | 40 | 35 |
| **Jc(12T), A/mm2** | 2428 | 2482 | 2424 |
| **Js, A/mm2** | 2987 | 3093 | 3313 |
| **RRR** | 25.6 | 7.3 | 4.6 |

- Very difficult to maintain High-Jc and RRR > 50 for smaller filaments

# Conductor R&D – 217 stack cont.

Requires new design of sub-element

- Target "54/61 component dimensions" for wires with diameter of 0.8mm.
  - Increase starting Nb filament diameter
  - Increase spacing between Nb filaments
  - Increase initial barrier thickness

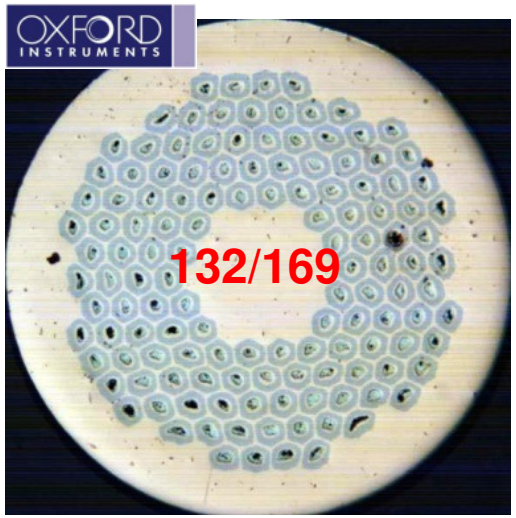

New 2700 A/mm$^2$ class conductor being developed under CDP. First results Aug-Sep'12

We may have to accept a reduced $J_c$

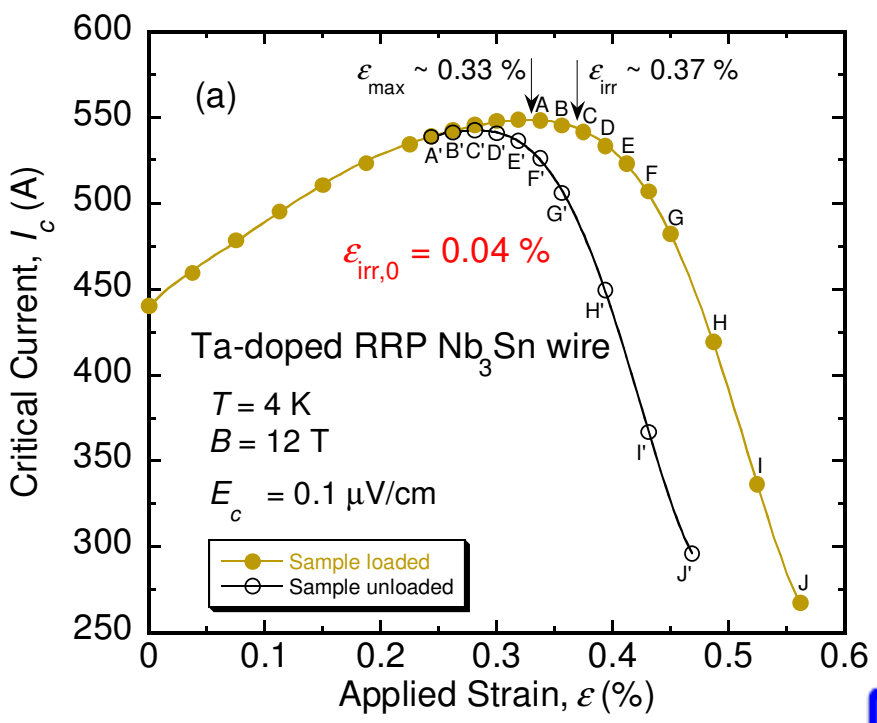
- To obtain smaller sub-elements
- To obtain high RRR
- To obtain longer piece lengths

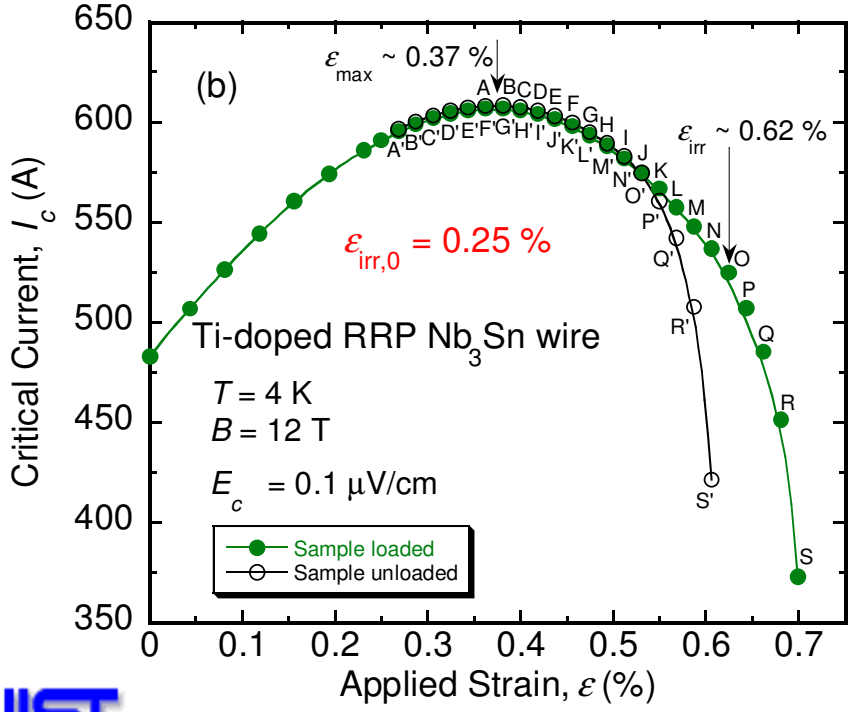
# Conductor R&D: Another Option– 169 stack Intermediate to 127 and 217 stack

- Two billets 150/169 design, Ta-Ternary delivered to FNAL at 0.7 mm.
  - sub-element $D_s$ ~ 36 μm, Jc(12T)~ 2500 A/mm$^2$, RRR>100
- 2-3 billets are being fabricated for CERN (Possible FRESCA II strand).
  - Ti-Ternary, 1.0 mm
  - Ds ~ 50 μm, Jc > 2500 A/mm$^2$, RRR >75



# Ti-Ternary vs. Ta-Ternary




NIST

## Ti-doped $Nb_3Sn$ wire more strain tolerant than Ta-doped

**Influence of Ta and Ti doping on the irreversible strain limit of ternary Nb3Sn superconducting wires made with restacked-rod process***
N. Cheggour, L. F. Goodrich, T. C. Stauffer , J. D. Splett , and X.F. Lu, A. K. Ghosh, G. Ambrosio
*Supercond. Sci. and Tech.*, 20, (2010)

# Comparison of RRP® Ti-Ternary billets andTa-Ternary billets

***N. Cheggour*** NIST

| RRP Architecture & Sub-element size | | $\varepsilon_{irr,0}$ (%) | | $J_{cmax}$ 12 T & 4 K (A/mm$^2$) | |
|---|---|---|---|---|---|
| **Design** | **Size (μm)** | **Ta** | **Ti** | **Ta** | **Ti** |
| 54/61 | 63 | 0.04 | 0.24 | 2668 | 2940 |
| 90/91 | 50 | -- | 0.19 | -- | 2632 |
| 108/127 | 43 | 0.04 | 0.25 | 2716 | 2939 |
| 198/217 | 33 | 0.04 | 0.20 | 2499 | 2731 |

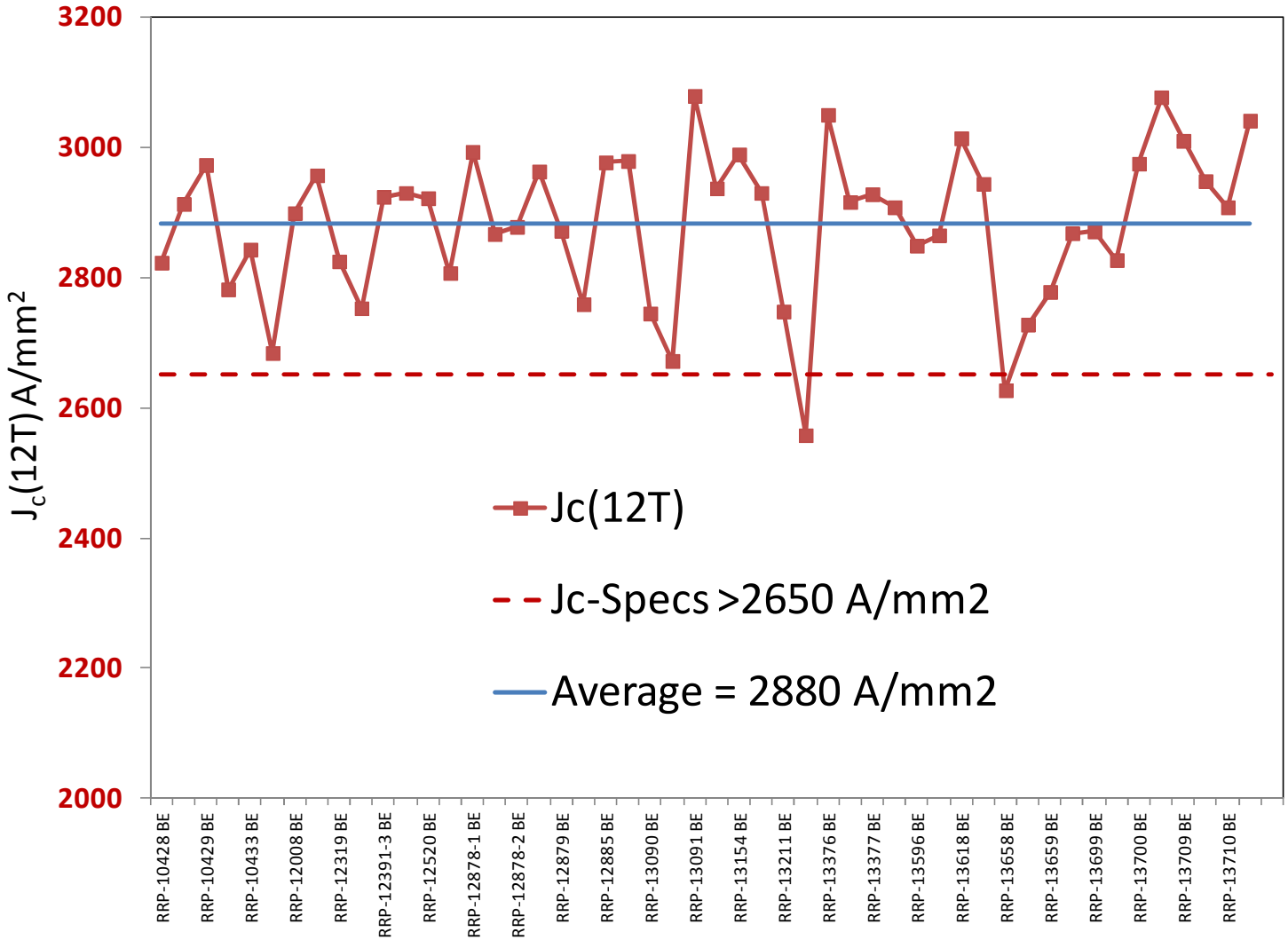
# Ti-Ternary 108/127 RRP Strand

- CDP program
  - 90 kg of 1.5 wt% Ti delivered in Mar'2011
    - Meets specification
    - Jc (12T) > 2650 A/mm$^2$, Jc(15T) > 1400 A/mm$^2$, RRR >60
- LARP
  - 400 kg order ( ~ 12 billets) placed
    - 280 kg delivery Oct'2012
    - 120 kg delivery Dec'2012

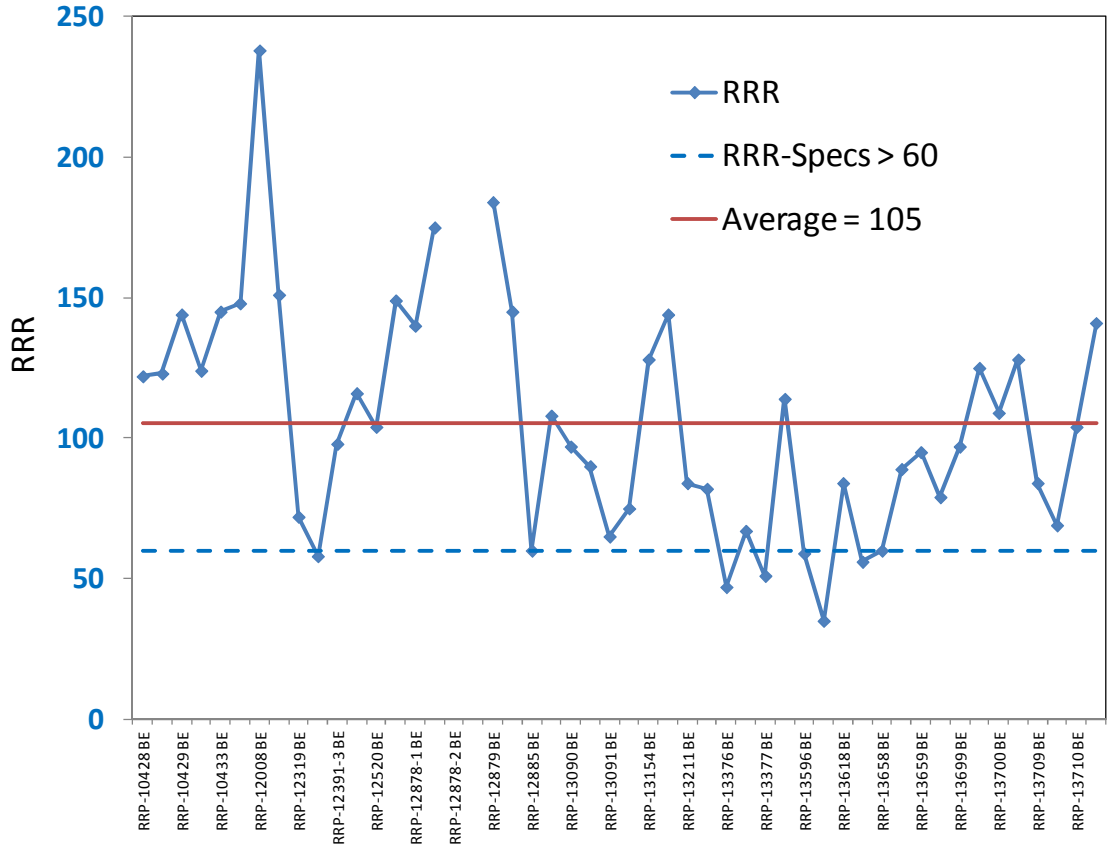

# Ta-Ternary 108/127 Production at OST

- Presently OST is producing Ta-Ternary 108/127 for LARP
- OST provides the following test results for samples taken from the front-end (FE) and back-end (BE) of each billet which typically yields ~ 35 kg of wire.
  - Ic and n-value at 12, 13, 14 and 15 T
  - Jc at 12 and 15 T (required by Specs)
  - Wire average diameter
  - Non-Cu fraction
  - RRR
- Samples are reacted using a schedule optimized for the 54/61 stack wire
  - 210C/48h + 400C/48h + 665C/50h

# Jc(12T) for 24 billets
# AVG: 2880 ±115 A/mm²

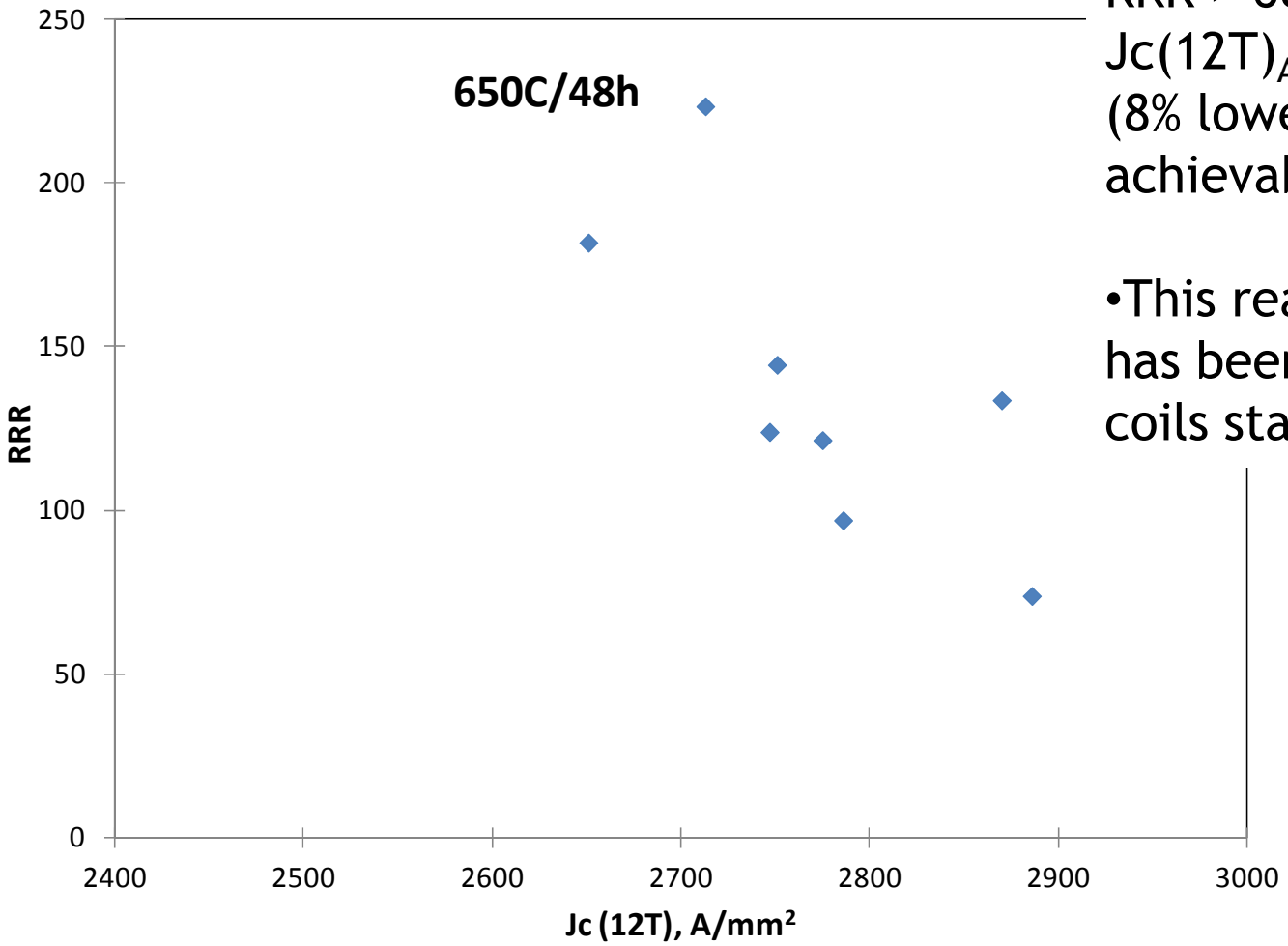


# RRR for 24 billets
# Some measurements are <60




**RRR is not under control !**

# Alternate HT schedule study of 8 billets



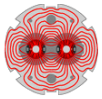

- 650C/48h will ensure RRR > 60
  $Jc(12T)_{AVG}$ ~ 2750 A/mm$^2$ (8% lower than maximum achievable)

- This reaction schedule has been adopted for HQ coils starting with coil 15

# 108/127 Strand Production and Cabling Plan

| Month | 108/127 Delivery, kg | Coil ID | Cable ID | Strand Req. kg | Cable Unit Lengths | 108/127 0.778mm kg | Ti-108/127 0.778 mm kg |
|---|---|---|---|---|---|---|---|
| Nov-10 | | | | | | | 0 |
| Dec-10 | 42 | | | | | 42 | 0 |
| Jan-11 | | | | | | 42 | 0 |
| Feb-11 | 32 | | | | | 42 | 0 |
| Mar-11 | 130 | HQ1 C14 | B1015 B1017 | 42 | 1 | 130 | 90 |
| Apr-11 | | | | | | 130 | 90 |
| May-11 | | | | | | 130 | 90 |
| Jun-11 | | | | | | 130 | 90 |
| Jul-11 | | | | | | 130 | 90 |
| Aug-11 | | HQ1 C15-C18 | B1020C | 72 | 4 | 58 | 90 |
| Sep-11 | 115 | | | | | 173 | 90 |
| Oct-11 | | | | | | 173 | 90 |
| Nov-11 | 57 | LHQ-C01 | B1021C | 72 | 1 | 158 | 90 |
| Dec-11 | 125 | | | | | 283 | 90 |
| Jan-12 | 194 | LHQ-C02 | B10xxC | 72 | 1 | 405 | 90 |
| Feb-12 | 132 | | | | | 537 | 90 |
| Mar-12 | | | | | | 537 | 90 |
| Apr-12 | | LHQ-C03 | | 72 | 1 | 465 | 90 |
| May-12 | | LHQ-C04 | | 72 | 1 | 393 | 90 |
| Jun-12 | | | | | | 393 | 90 |
| Jul-12 | | | | | | 393 | 90 |
| Aug-12 | | | | | | 393 | 90 |
| Sep-12 | | | | | | 393 | 90 |
| Oct-12 | 280 | | | | | | 370 |
| Nov-12 | | | | | | | 370 |
| Dec-12 | 180 | | | | | | 550 |
| Jan-13 | | | | | | | 550 |
| Feb-13 | | | | | | | 550 |
| Mar-13 | | | | | | | 550 |

- Cable ID ending in R denotes cable made using standard 2-pass method
- Cable ID without R denotes cable made using 1-pass with annealed strand
- Cable ID ending in C denotes cable made with annealed strand with core.
- HQ1: 1 m HQ, LHQ: 4 m
- 1 UL of HQ1 requires 18 kg, LHQ: 72 kg




# Summary

- Prospects for conductor with filament diameter much less than 50 μm at 0.8 mm.
  - 150/169 ⇨ 45 μm ⇨ 2 years
  - 192/217 ⇨ 39 μm ⇨ 3-4 years

- Ti-Ternary production has been phased in
  - LARP- MAG-M-8002 Rev. F
  - Changes to Rev. E
    - (Nb-1.5wt%Ti) –Ternary
    - Jc(15T) > 1400 A/mm$^2$

- OST production of Ta-Ternary 108/127
  - RRR not under control
    - Reducing Sn-content to increase RRR is one option
    - Presently, reaction schedule for HQ coils modified to 650C/48h to increase RRR