FCC Conductor Development at Bruker EAS

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Outline

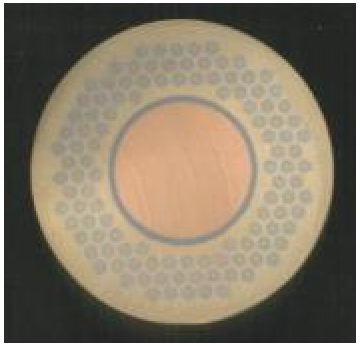
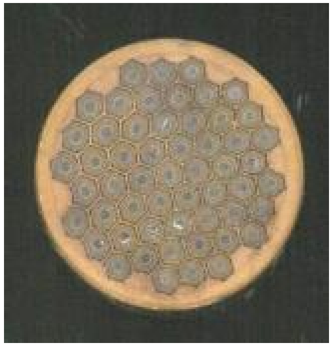
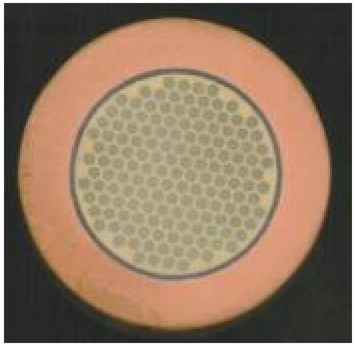
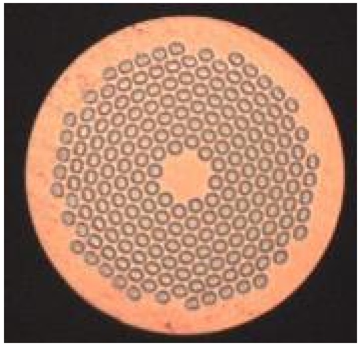
- ➤ Nb_3Sn Conductors at Bruker EAS
- ➤ Nb-barrier Nb_3Sn PIT for HEP Hi-Lumi Upgrade
  - concept and design
  - Production statistics of Nb-barrier HEP PIT
  - Results on rolled samples
- ➤ Progress of jc within the last year
- ➤ Conclusions - Outlook

Nb_3Sn Conductors at Bruker EAS

- Bruker EAS has a long term experience in development and manufacturing of Nb_3Sn superconductors.

- This comprises fabrication of Nb_3Sn conductors by different manufacturing routes:

  - Internally Stabilized Bronze Route: 1970 - 2000
  - Internal Tin Route: 1986 – 1990
  - Outer Stabilized Bronze Route: 1980 – today
  - Powder In Tube Route: 2004 - today

Targeted Nb_3Sn Performance Required for FCC

- Target specification for HEP-grade Nb_3Sn conductors for use in FCC comprise counteracting goals for current conductor designs:

Final Targets for FCC Conductor

		Nb_3Sn
Wire diameter	mm	**~ 1**
Non-Cu Jc (16 T, 4.2 K)*	A/mm^2	**≥ 1500**
$\mu_o\Delta M$(1 T, 4.2 K)	mT	**≤ 150**
$\sigma(\mu_o\Delta M)$ (1 T, 4.2 K)	%	**≤ 4.5**
Deff	µm	**≤ 20**
RRR	-	**≥ 150**
Unit length	km	**≥ 5**
Cost	Euro/kA m**	**~ 5**

*Je ~ 600 A/mm^2
*Cu:non Cu ~ 1

** 16 T, 4.2 K

Targets derived from the larger context of magnet design requirements

12/04/2016 A. Ballarino, CERN

- Increase of jc (4.2 K, 16 T) at high RRR at reduced filament (strand) dimension are challenging
- Additional requirement will be stable strand performance after cabling

Reduced scope for initial Nb_3Sn R&D towards FCC requirements

Conductor development strategy

Intermediate goals (4 years program)

		Nb_3Sn	
Wire diameter	mm	~ 1	
Non-Cu Jc (16 T, 4.2 K)*	A/mm²	≥ 1500	
~~μoΔM(1 T, 4.2 K)~~	~~mT~~	~~≤ 150~~	
~~σ(μoΔM) (1 T, 4.2 K)~~	~~%~~	~~≤ 4.5~~	
Deff	μm	~~≤ 20~~	< 50
RRR	-	≥ 150	
Unit length	km	~~≥ 5~~	≥ 0.1
Cost	Euro/kA m**	~~~ 5~~	

*Je ~ 600 A/mm²

*Cu:non Cu ~ 1

** 16 T, 4.2 K

Scalability and potentials for large production

12/04/2016

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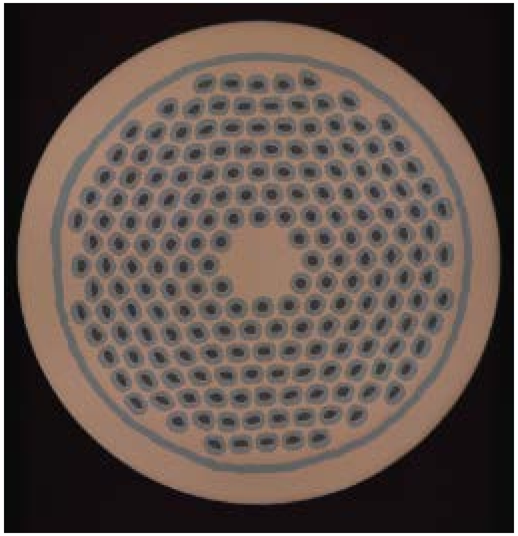
Concept and design

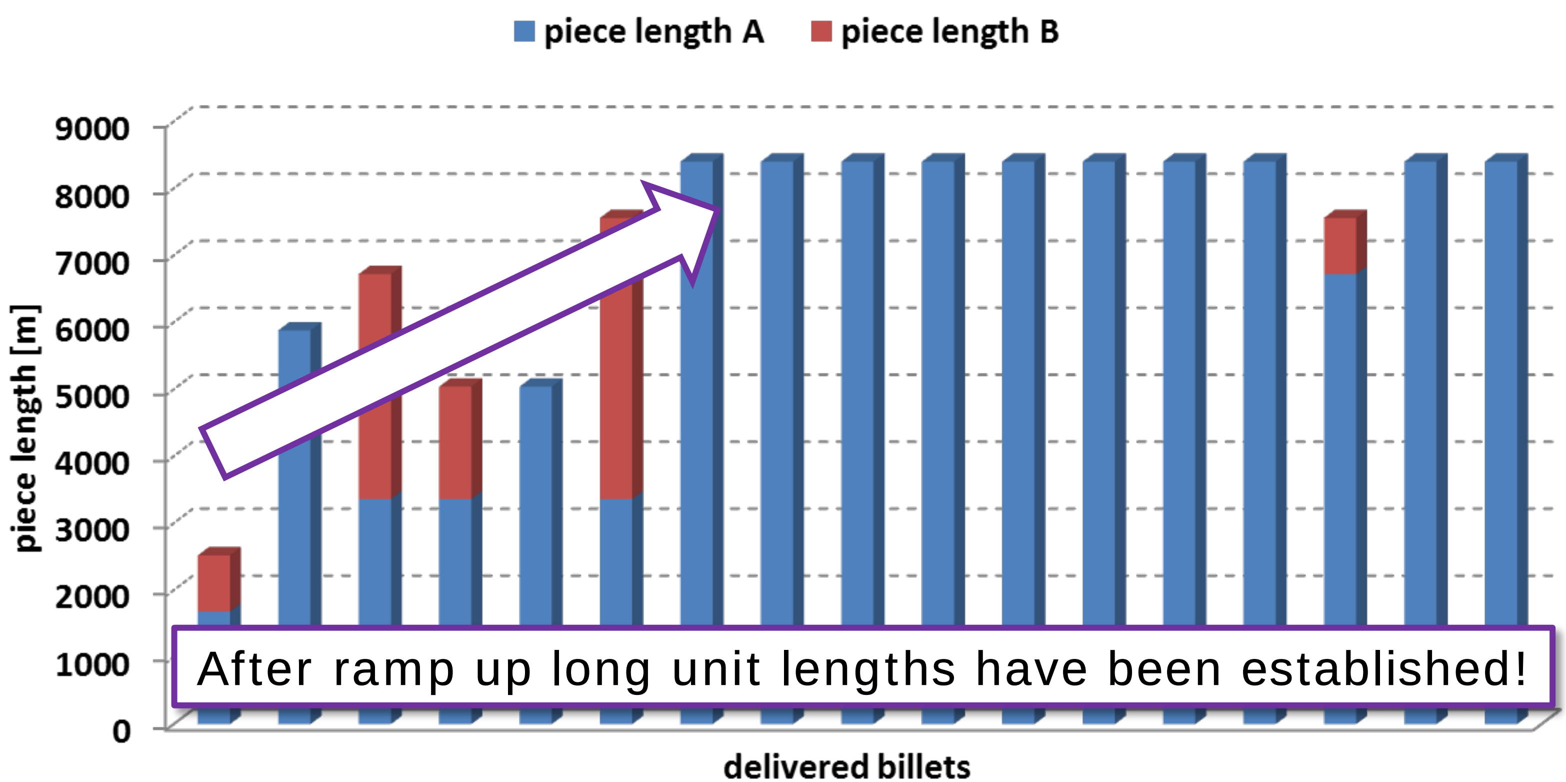
- New developed conductor layout with Nb diffusion barrier to protect the outer stabilizing Cu
- Advantages:
  - ✓ Filaments with enhanced Sn content influences the reaction kinetics and increases jc
  - ✓ A higher degree of freedom is given to choose the heat treatment parameters
  - ✓ Smaller filament diameters are possible
  - ✓ No reduction of RRR performance due to rolling (15%)



Ø 0.85 mm – Øfil ≈ 40 µm

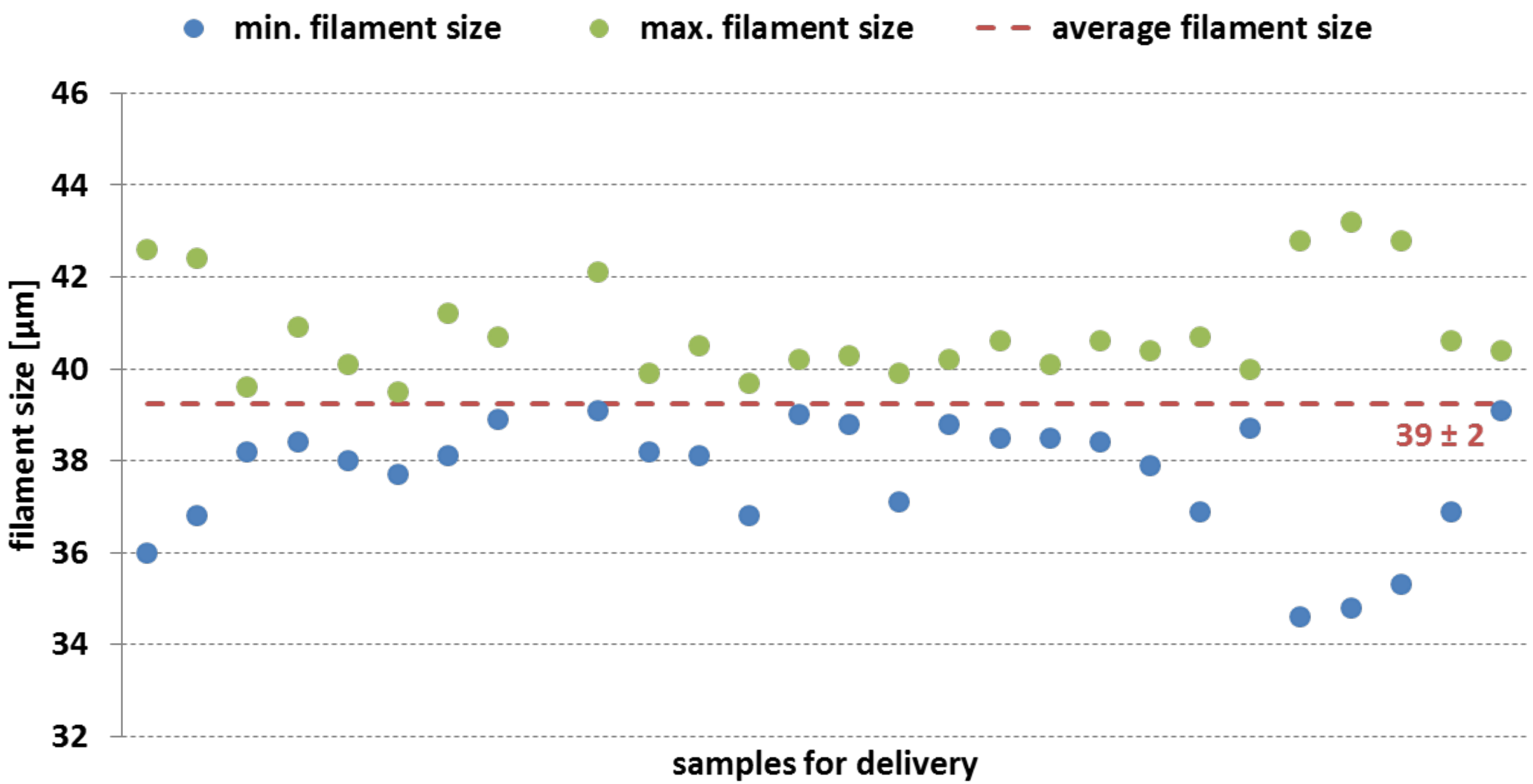
Production statistics of Nb-barrier HEP PIT Nb_3Sn conductors – 1

- Total amount of 124 km (∅=0.85mm) ≈ 630 kg delivered to CERN (Hi-Lumi Upgrade)
- Additional ~ 100 km completed -> currently characterized in laboratory

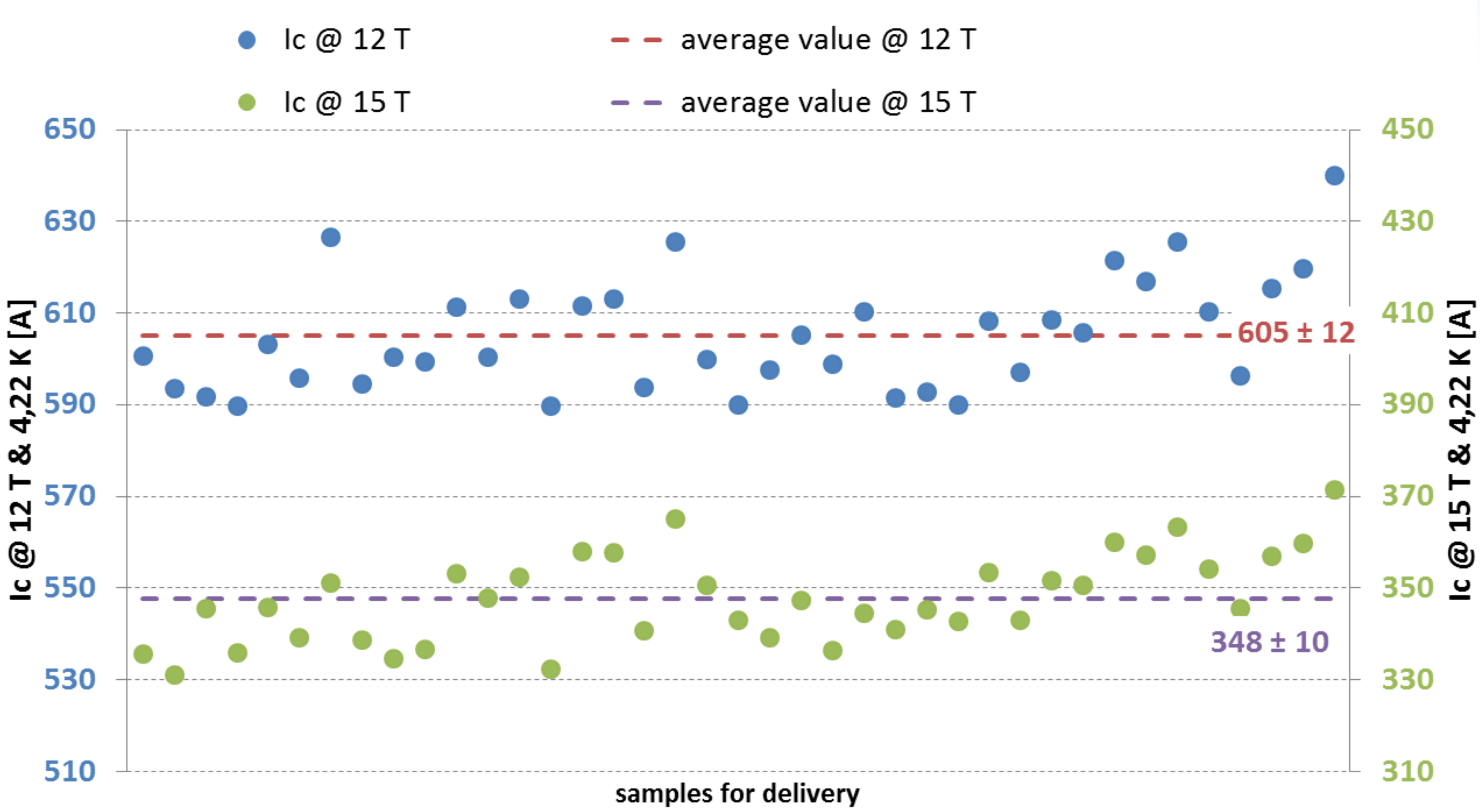


Production statistics of Nb-barrier HEP PIT Nb_3Sn conductors – 2

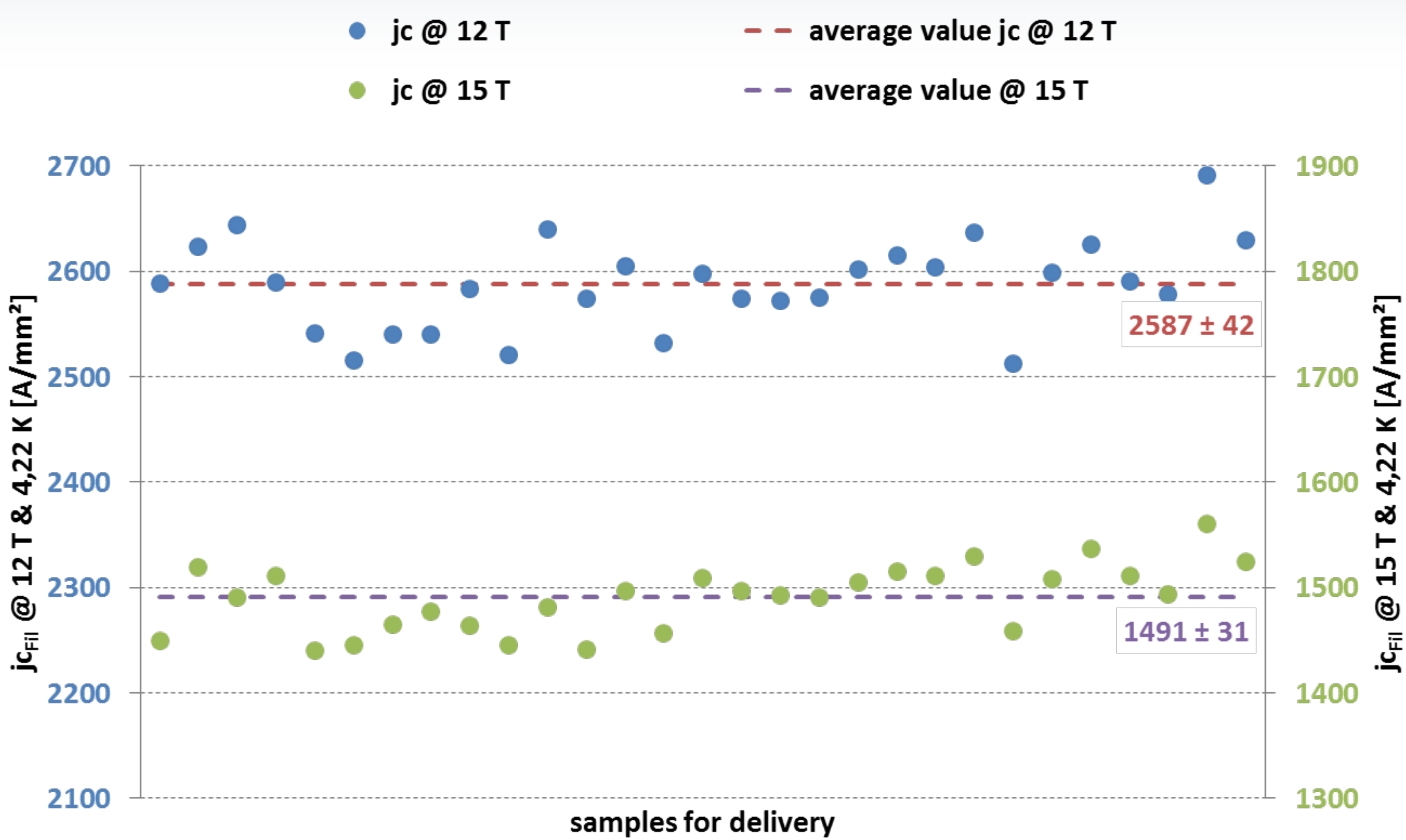
- Stable wire layout and production with an average filament Ø ~ 40 µm for wire diameter Ø 0.85 mm with 192 filaments



Production statistics of Nb-barrier HEP PIT Nb_3Sn conductors – 3

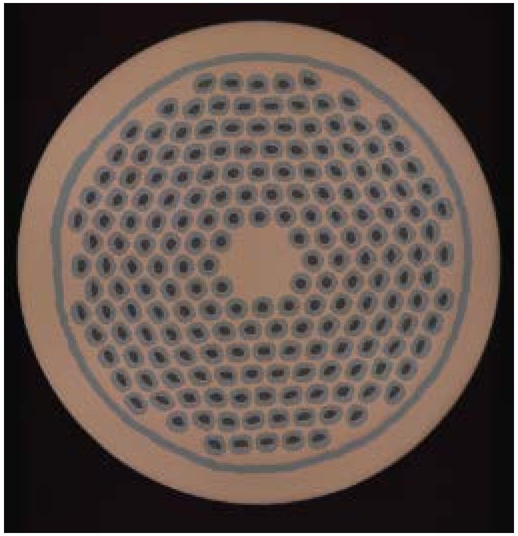


Production statistics of Nb-barrier HEP PIT Nb_3Sn conductors – 4

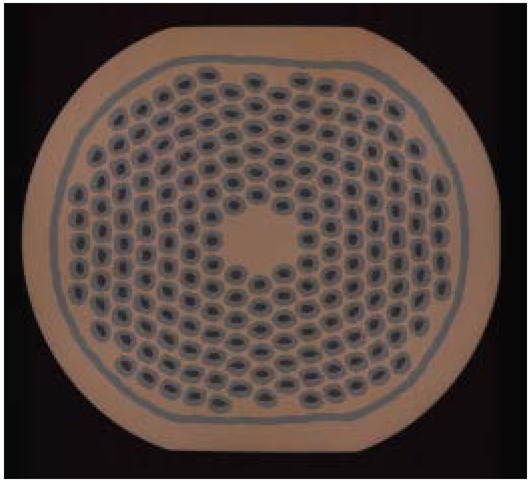


Results on rolled samples - 1

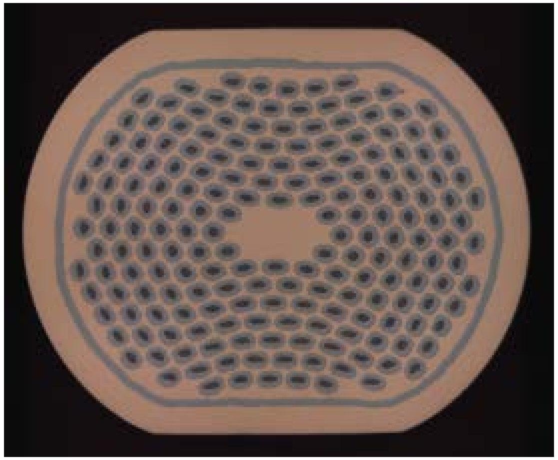
- *Examples of rolled samples: 10% & 15% diameter reduction*



Ø = 0.85 mm



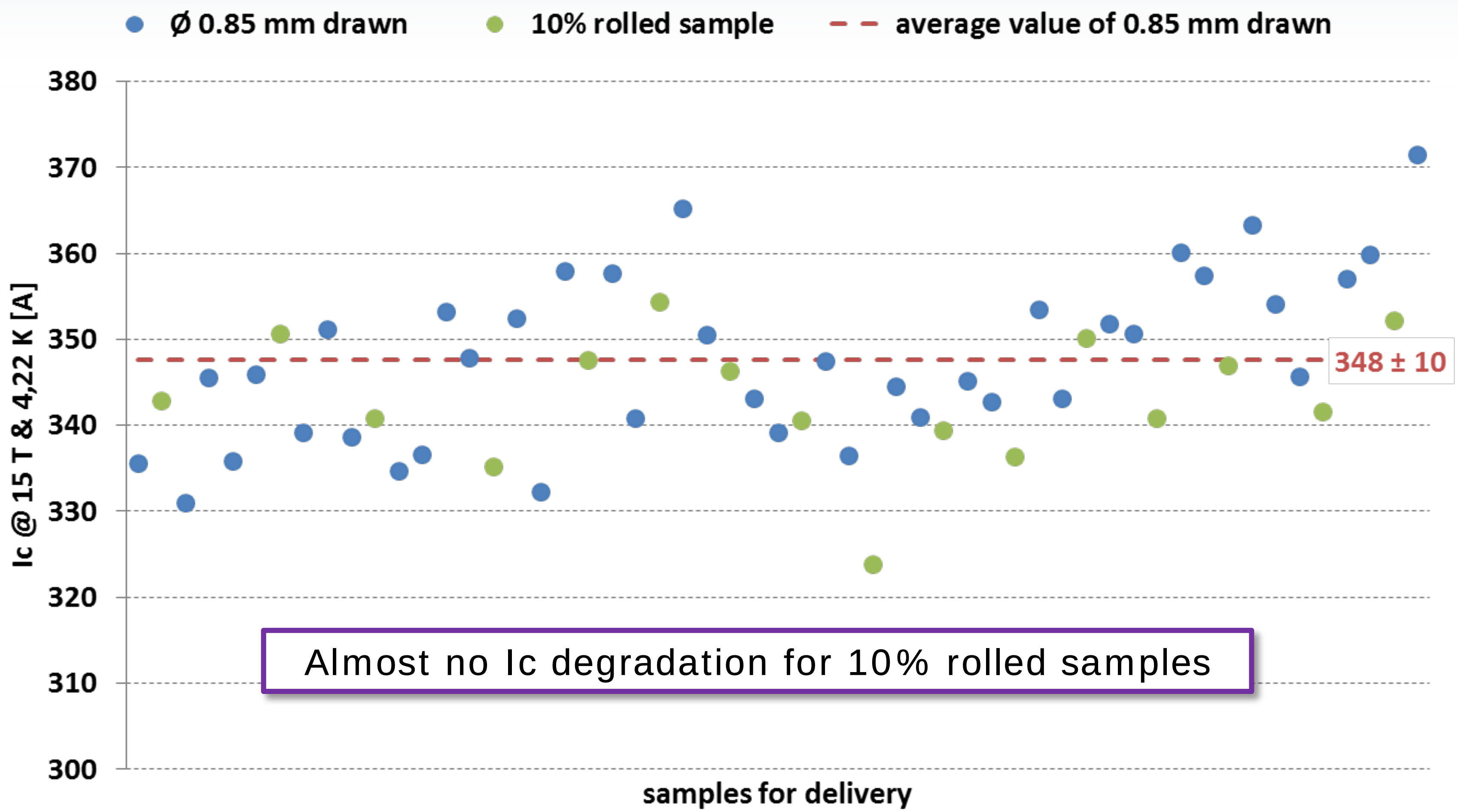
Ø = 0.85 mm – rolled 10%



Ø = 0.85 mm – rolled 15%

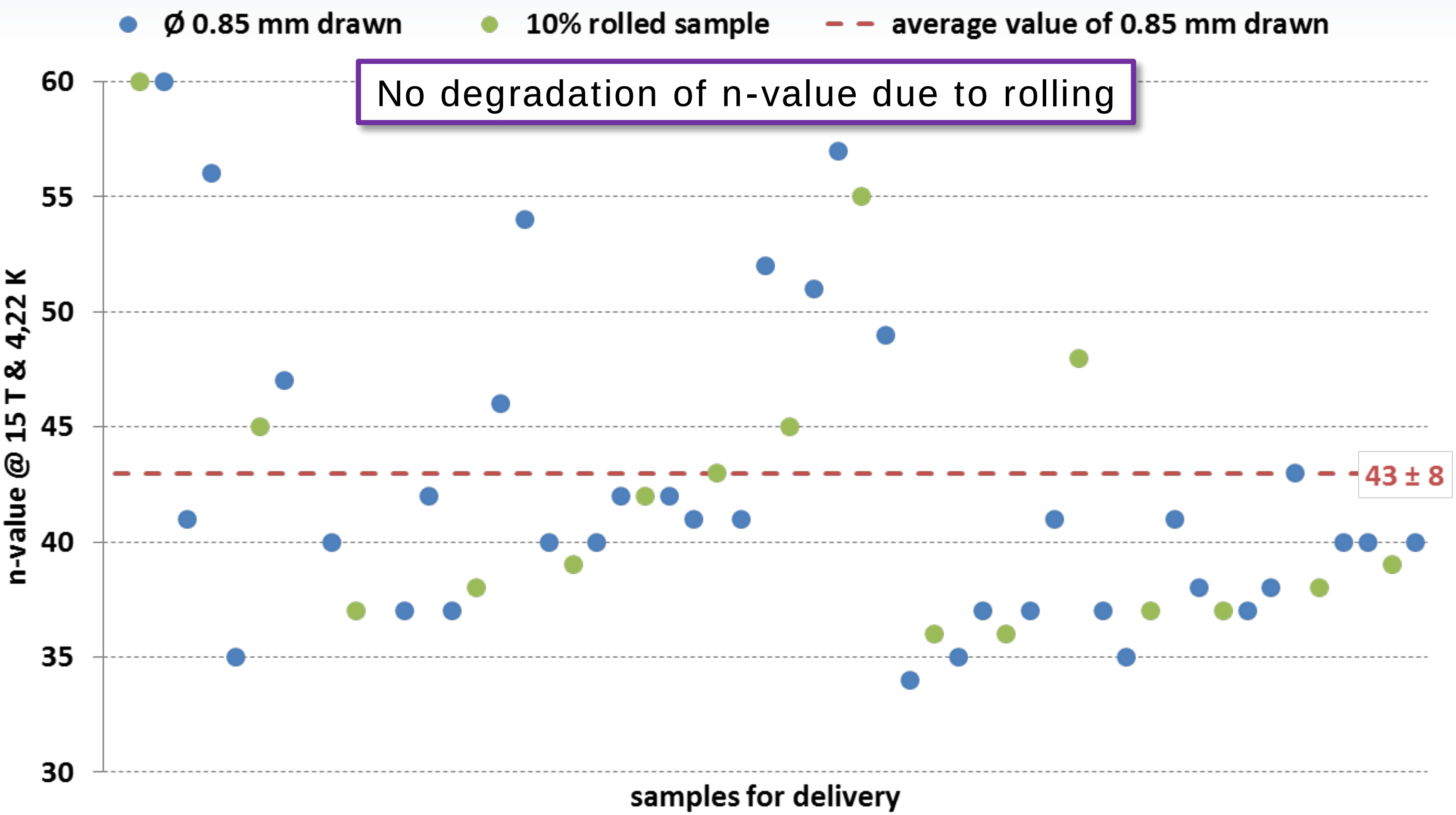
As expected no barrier defect caused by rolling

Results on rolled samples – 2
Ic @ 15 T & 4,22 K

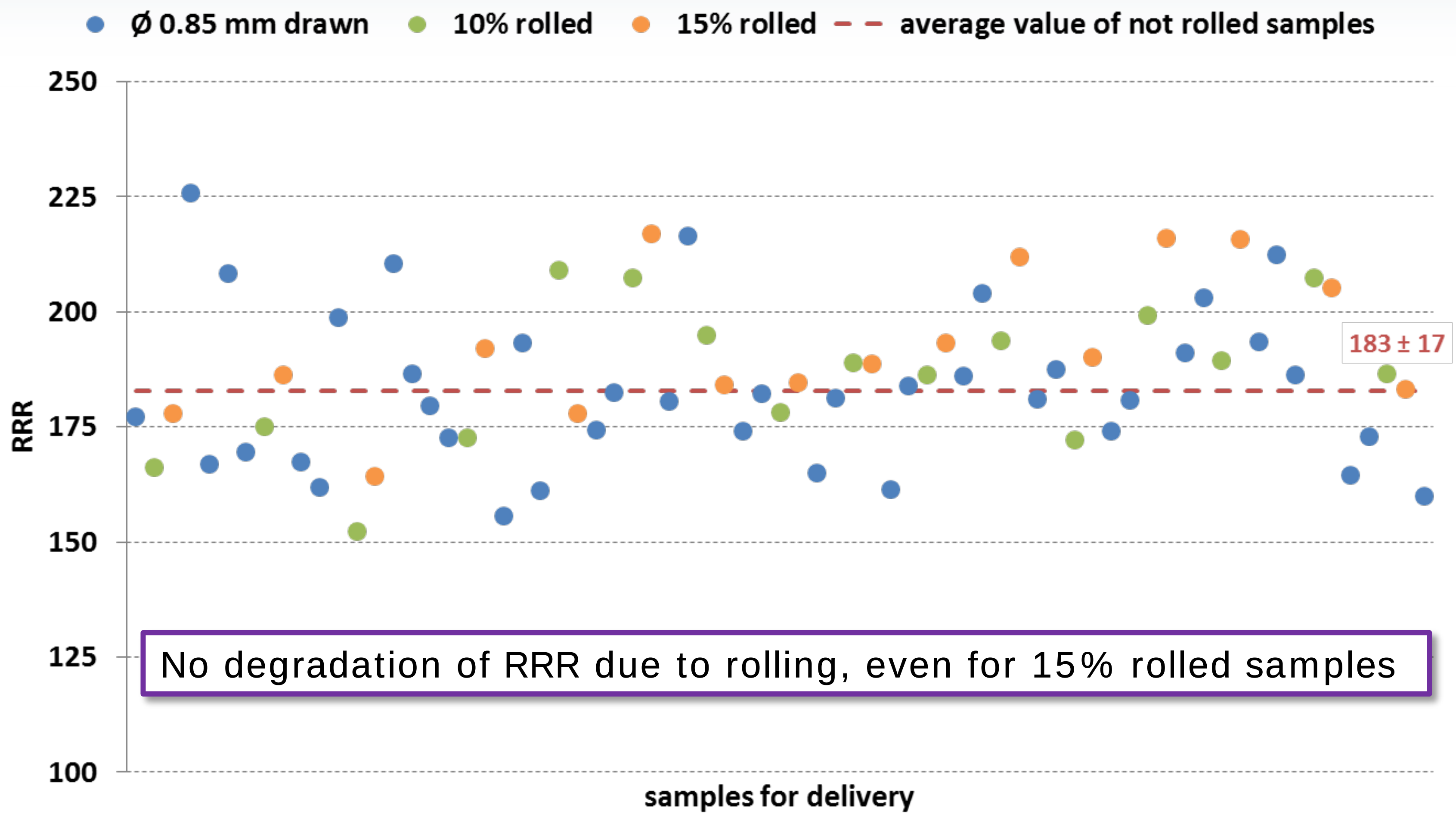


Results on rolled samples – 3

n-value @ 15 T & 4,22 K



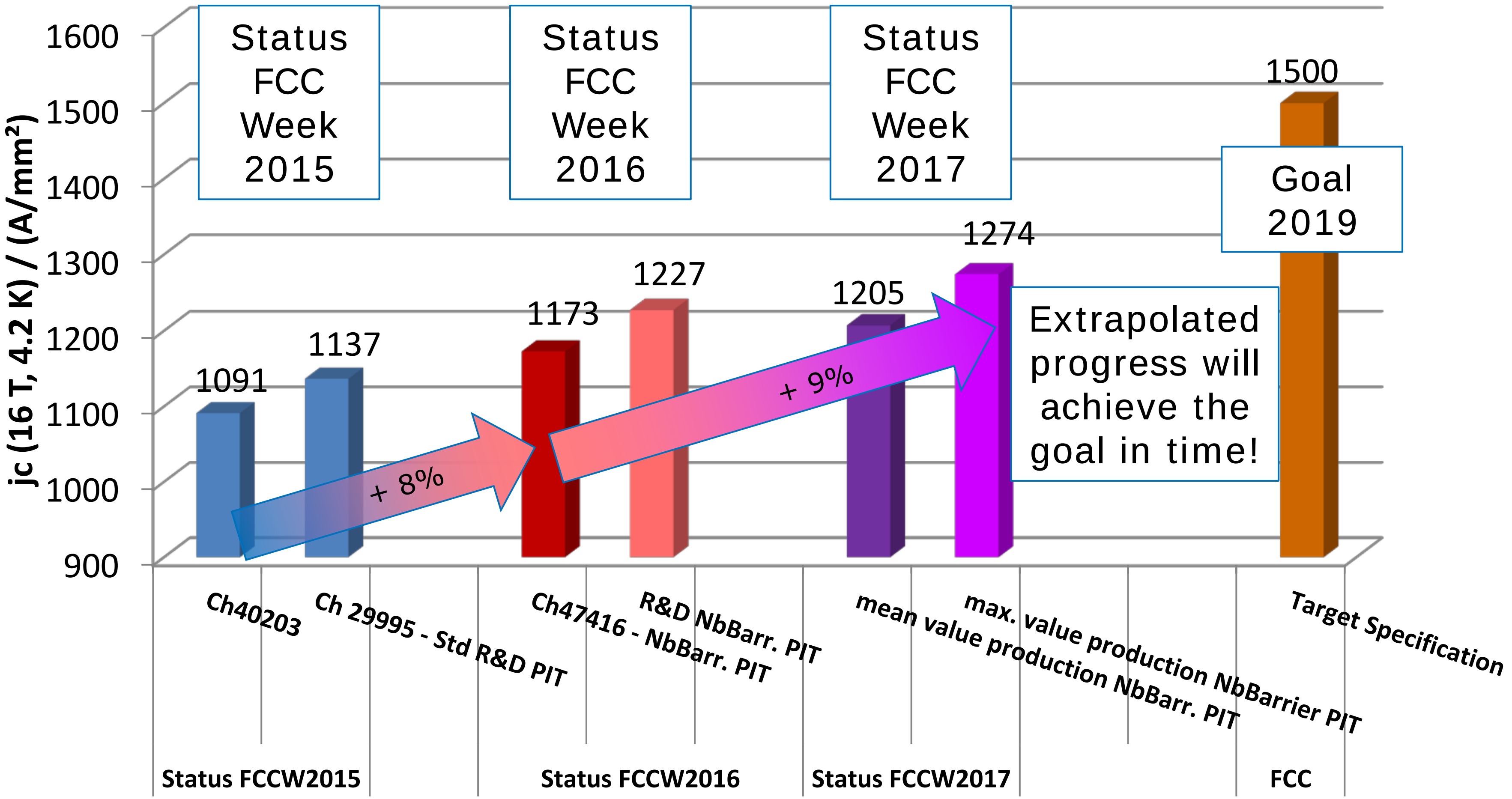
Results on rolled samples – 4
RRR



No degradation of RRR due to rolling, even for 15% rolled samples

Progress in jc (16 T, 4.2 K)

- Improvement by enhanced Sn and protection by Nb barrier



Conclusions - Outlook

- We see us on a very good path to achieve the required technical conductor performance
- Future R&D work to focus on further grain refinement where we see highest potential for better pinning properties and thus improved jc (B)
- While further performance enhancement still needs to be pursued we will also put high priority on the cost target
- Experience from production for Hi-Lumi shows that further expected benefit from "learning curve" will not be sufficient to achieve targeted cost goal
- Special attention needs to be given to significantly reduce cost of starting materials and our wire deformation process

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