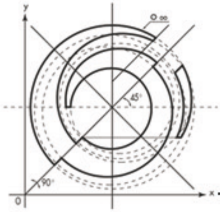
23 Mars 2004

ALSTOM plan
and
activities on LTS materials

Ch VERWAERDE

WAMS 2004



Outline

- ALSTOM situation
- LHC wires and cables
- Nb3Sn wires
  - Bronze route
  - Internal tin route

ALSTOM SITUATION

ALSTOM

ALSTOM Magnets and Superconductors, SA (MSA)

250$^+$ employes – Turnover 30M€$^+$

MSA - WIRE

Superconducting wires

(NbTi, Nb3Sn, AC wires)

Superconducting cables

(Triplet, 6+1…, Rutherford, Wire in Channel, CICC, Aluminium cladded cables, …)

MSA - MAGNETS

Magnets for High Energy Physics (LHC, …)

Magnets for Fusion Research (ITER, …)

Other Magnets (including resistive)

MSA LHC Cables for main dipoles
Up to date

Cable unit length delivery (shipped)

ALSTOM

From the beginning of project to Jan 2004 :

72.4% of the total UL1 number (target 62.5%)
35.0% of the total UL2 number (target 33.3%)
46.6% of the total UL3 number (target 33.3%)

have been delivered by MSA*

* From CERN dashboard 01-31-04

IMPROVEMENTS

ALSTOM

~~Copper can cracking~~

~~Acid cleaning~~

~~Monofilament billet decohesion~~

~~Training workers~~

~~Multifilament breaks~~

~~Monofilament billet break germination~~

~~Strand magnetization~~

~~strand coating~~

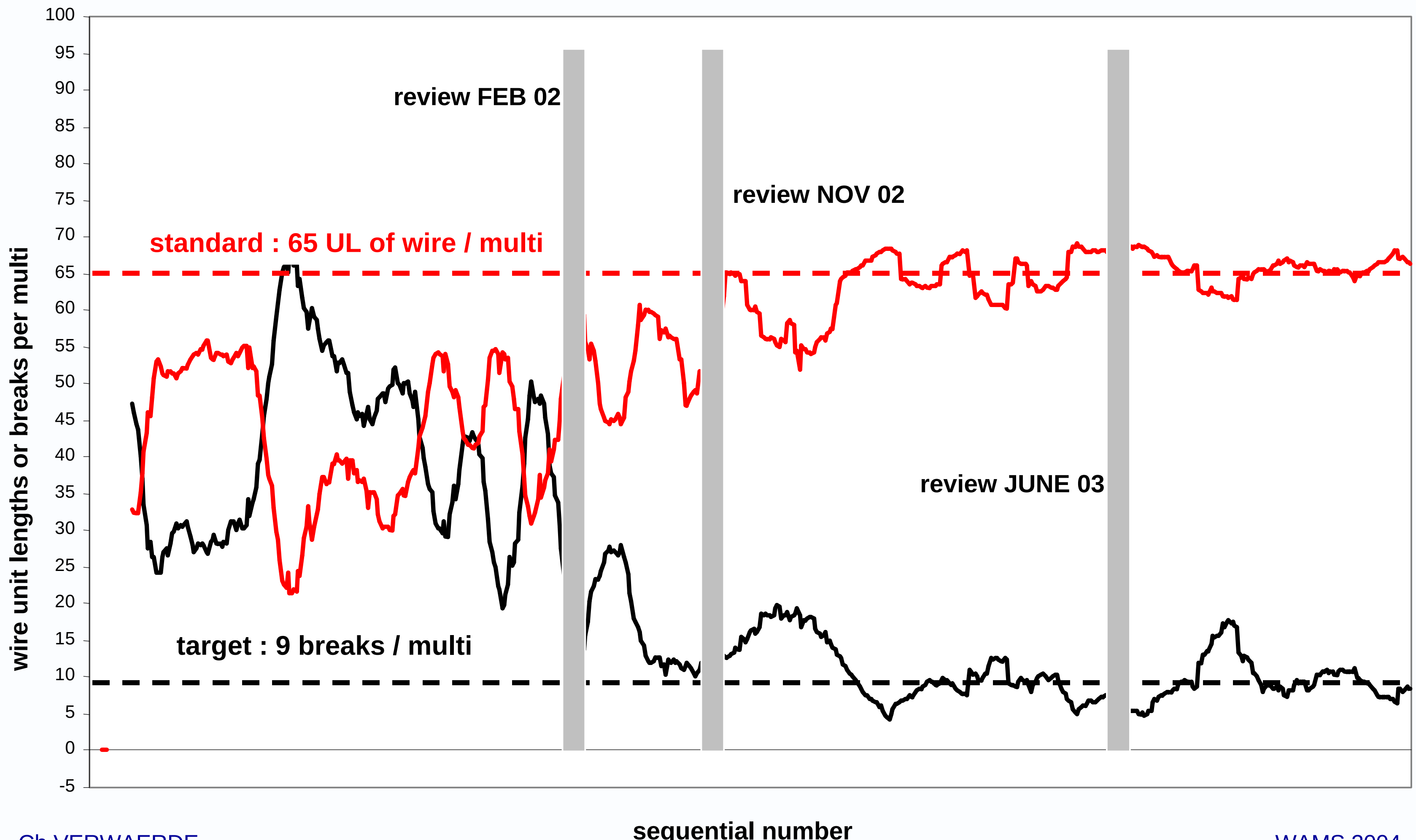
And more……………….

Main problems are behind us
(we hope so !)

OUTPUT: outer wire

number of breaks per billet since start of project mobile average on 20 billets (in black)

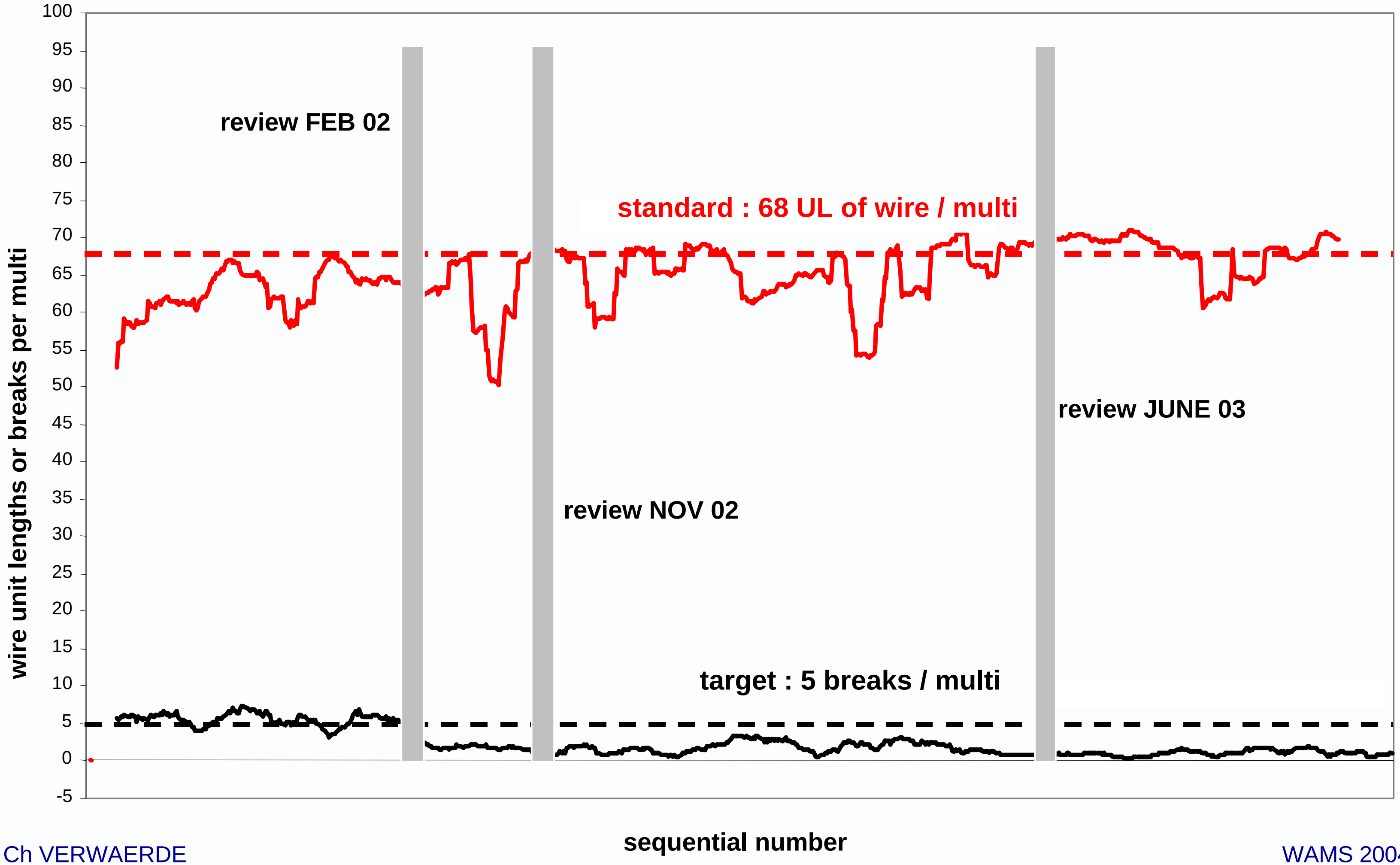
number of actual useful unit lengths produced per billet since start of project (in red)



OUTPUT: inner wire

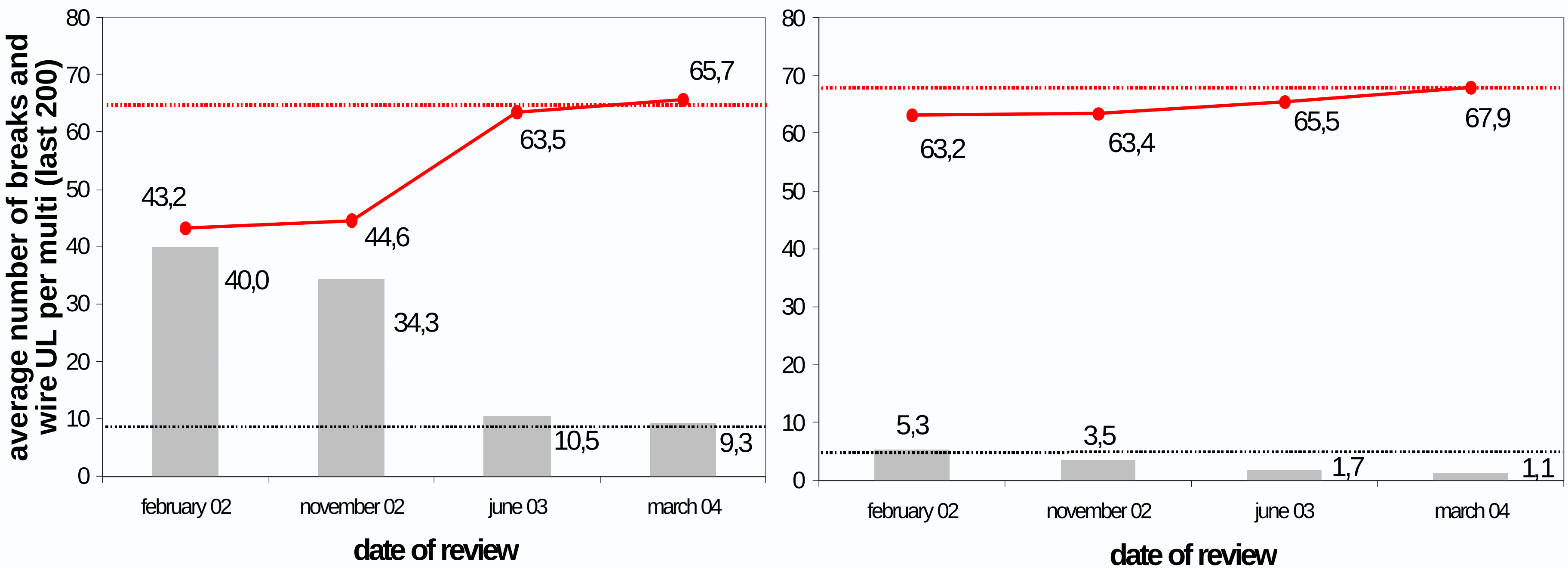
number of breaks per billet since start of project mobile average on 20 billets (in black)

number of actual usable unit lengths produced per billet since start of project (in red)



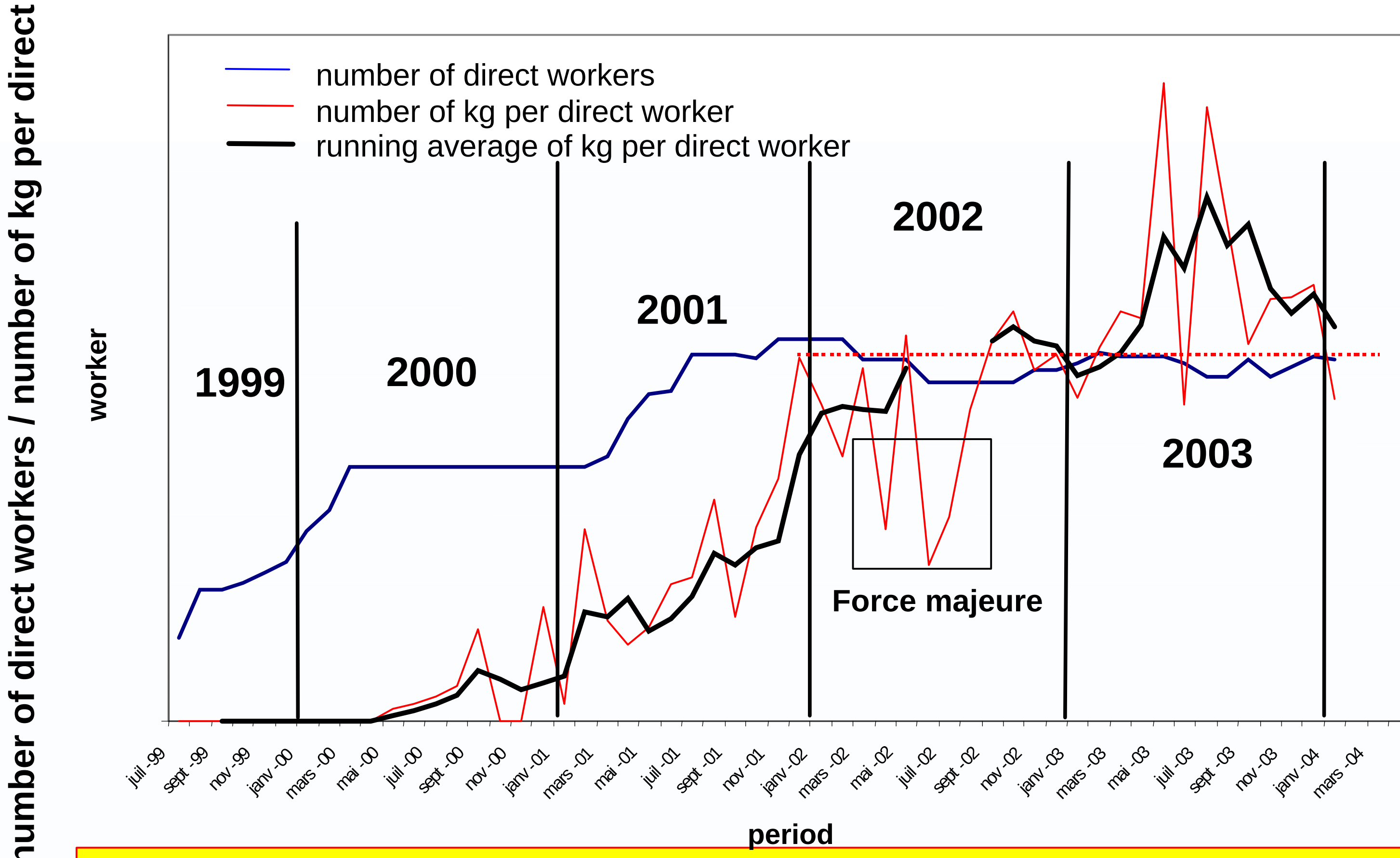
IMPROVEMENTS (2)

production yield continue to increase :



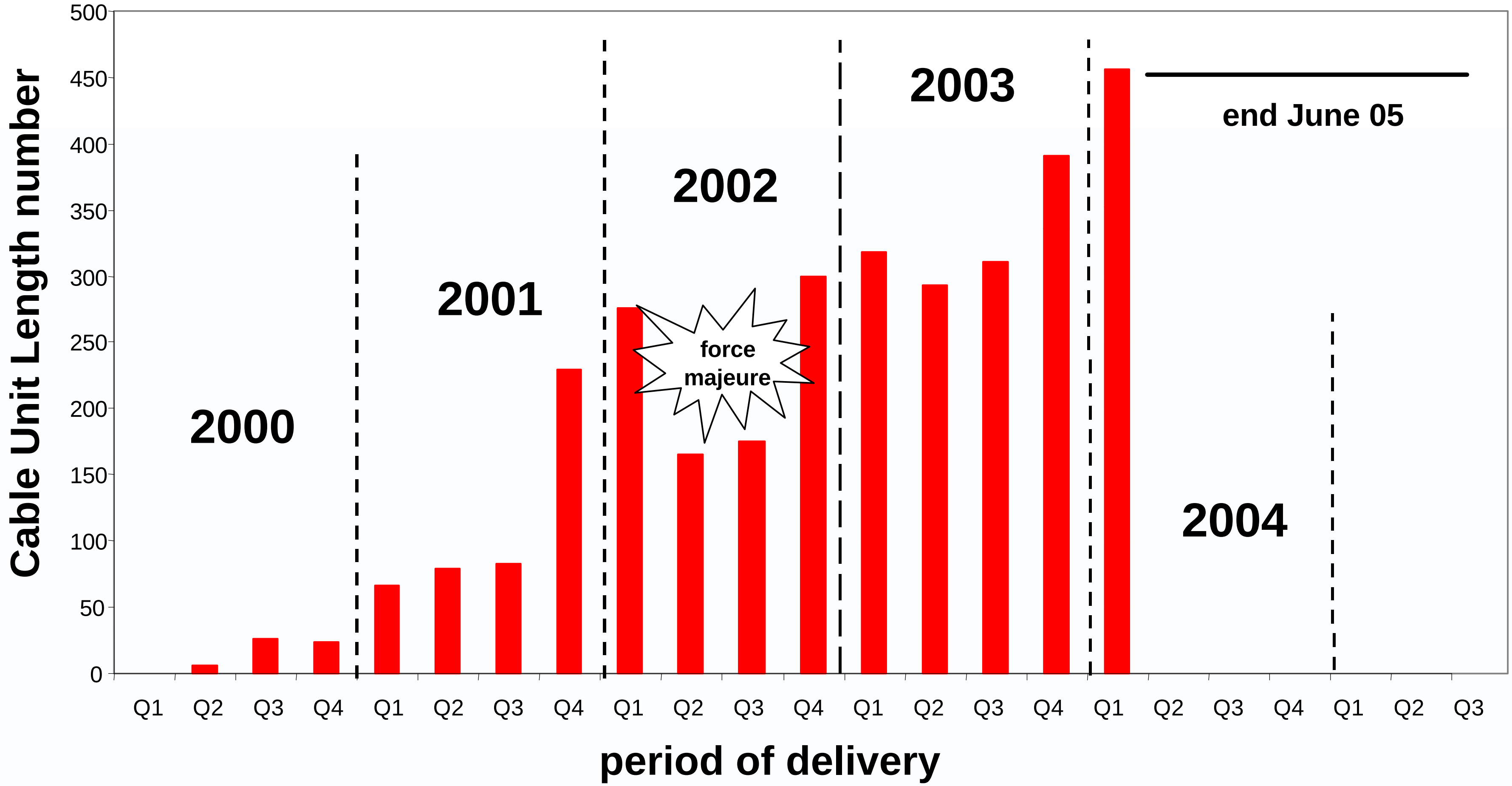
Targets of breaks and yields are definitively achieved on last 400 multi-filament billets

IMPROVEMENTS (3)



The "plateau production" reached in early 2003 has been achieved on a long period of more than one year : it is really a plateau

cable unit length delivery (shipped) : up to date (2)



MSA forecast end of cable delivery in June 2005

Nb3Sn Wires

- Bronze route
- Internal tin route
    - CEA Quadrupole
    - ITER
    - High energy physics

Nb3Sn Wires

- Bronze route
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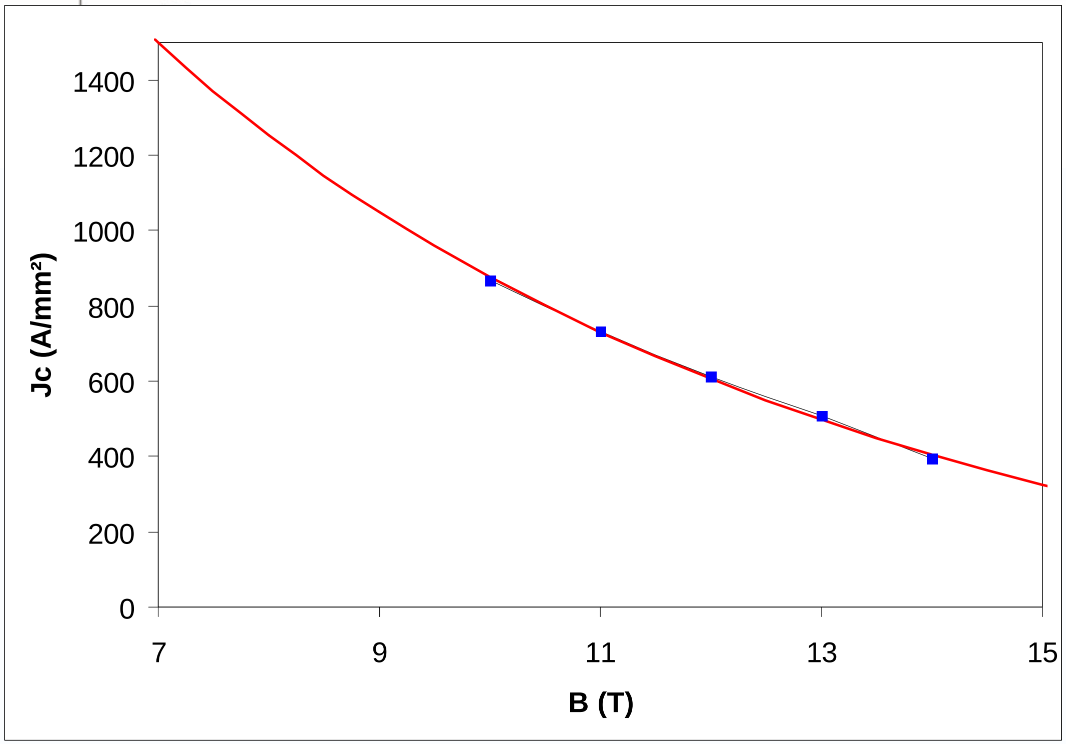
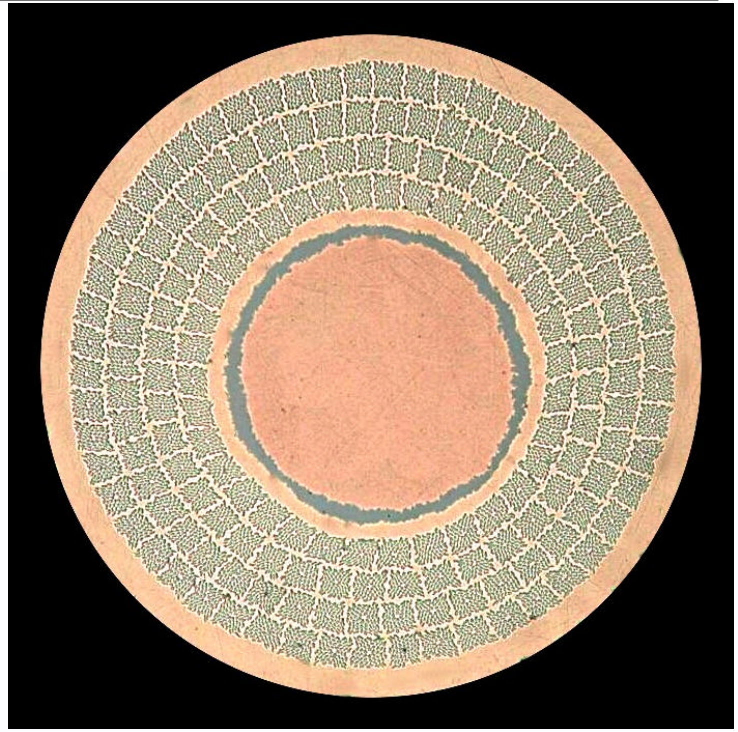
Typical wires for RMN application

1. Diameter = 1mm
2. Cu/NonCu ratio= 0.2 à 0.5
3. Filament diameter = 2 à 4 µm
4. Type of wire : bronze route
5. Electrical properties:
    a. N-value @ 14 T ~ 40
    b. Ic @ 14 T ~ 170 A

MSA wire for RMN application





9800 filaments

Cu/NonCu=0.2

Φ_{wire}=0.800 mm

T = 4.2K

N-Value $_{12T}$ = 55

B(T)	10	11	12	13	14
Ic (A)	365	308	258	214	166
$J_{c\ Non\ Cu}$ (A/mm²)	868	732	613	509	395

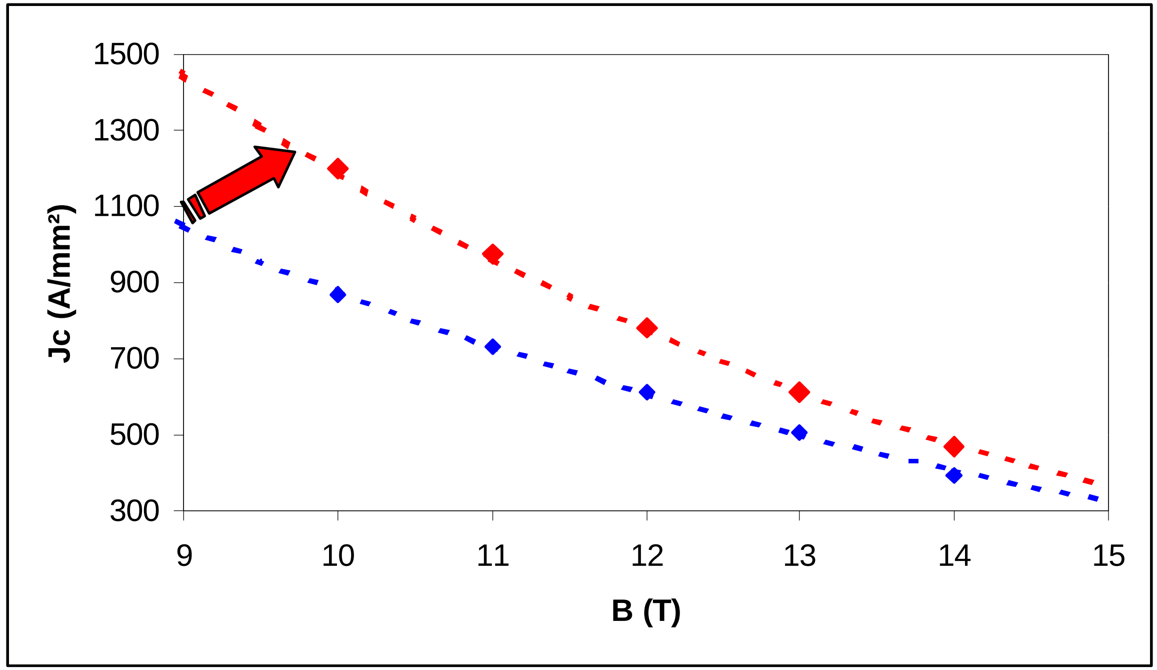
Optimisation of the wire

microstructure optimisation

Optimisation HT

+

No change of the layout



B(T)	10	11	12	13	14
Jc $_{\text{Non Cu}}$ (A/mm²)	868	732	613	509	395
Jc $_{\text{Non Cu}}$ (A/mm²) optimised	1197	974	**781**	614	468

Nb3Sn Wires

- Bronze route
- Internal tin route
    - CEA Quadrupole
    - ITER
    - High energy physics

Quadrupole using LHC design

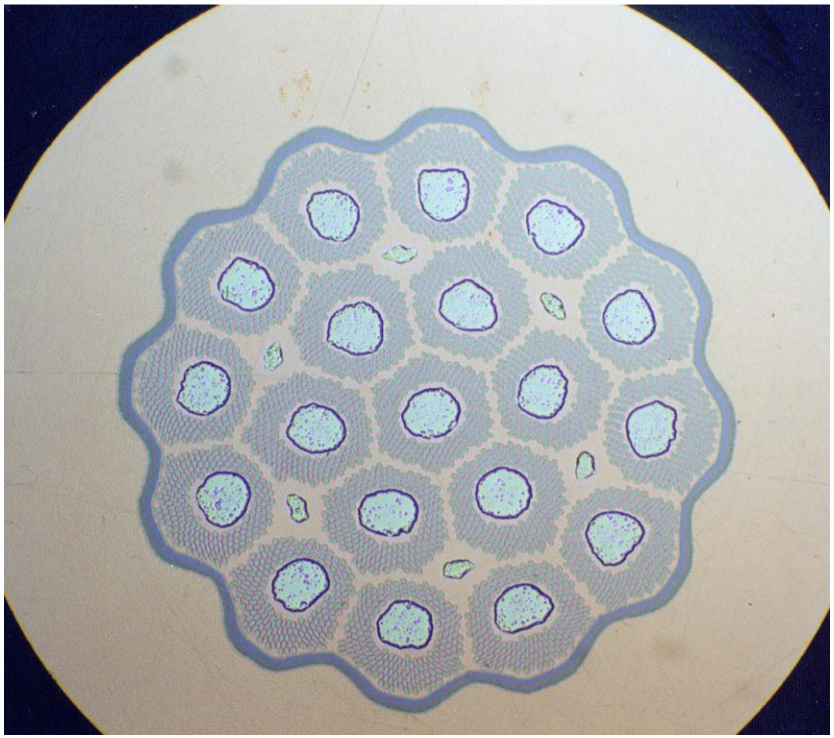
- Wire specification

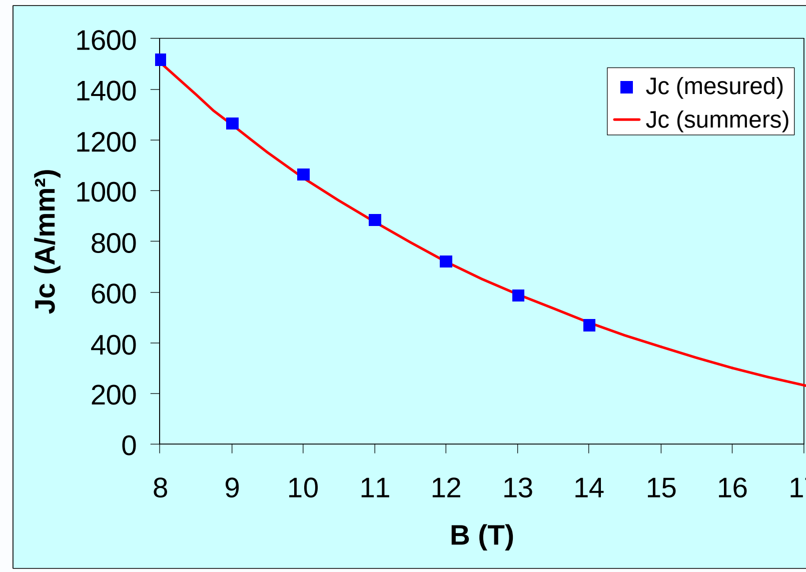
  1. $I_c \geq 405$ A à 7 T
  ($\leftrightarrow$ $J_c \approx$ **700 A/mm²** à12T& Copper/NonCopper ratio=1.4)
  2. $W_h \leq 450$ mJ/cm³ non Copper)

- Rutherford cable

  1. With inox insert
  2. Dimensions similar to the LHC cable)

CEA Quadrupole





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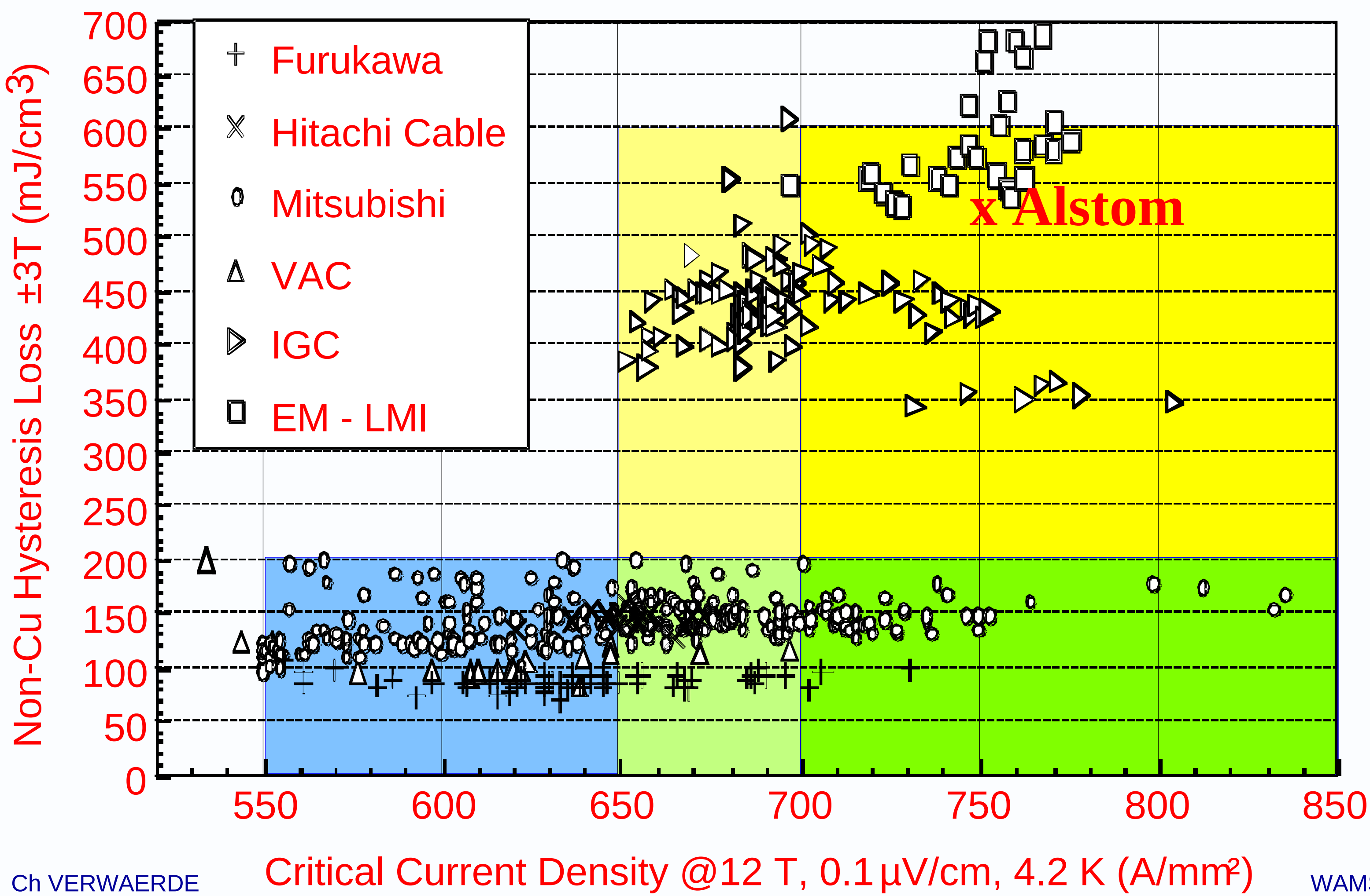
Non copper losses = 530 mJ/cm^3

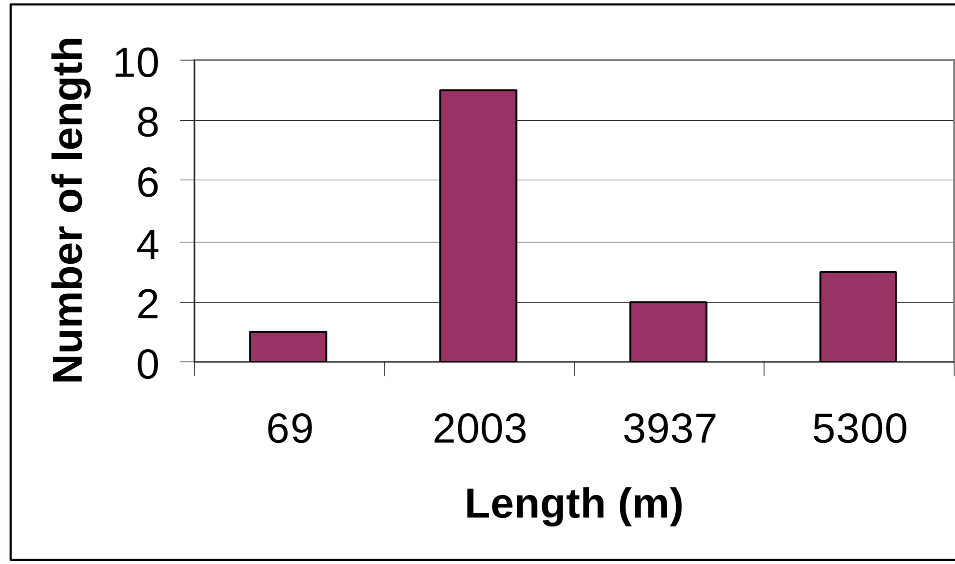
Cross section of the designed billet

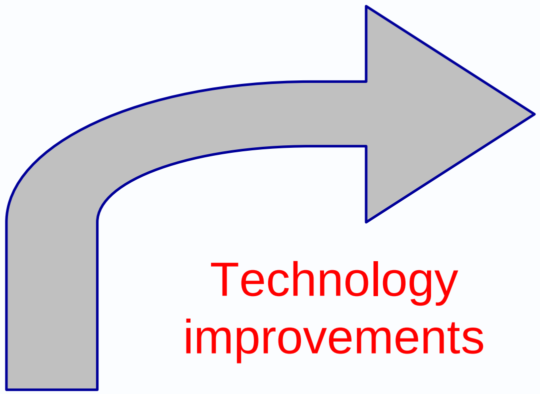
State of the art in year 2000 :
(P.J. Lee)



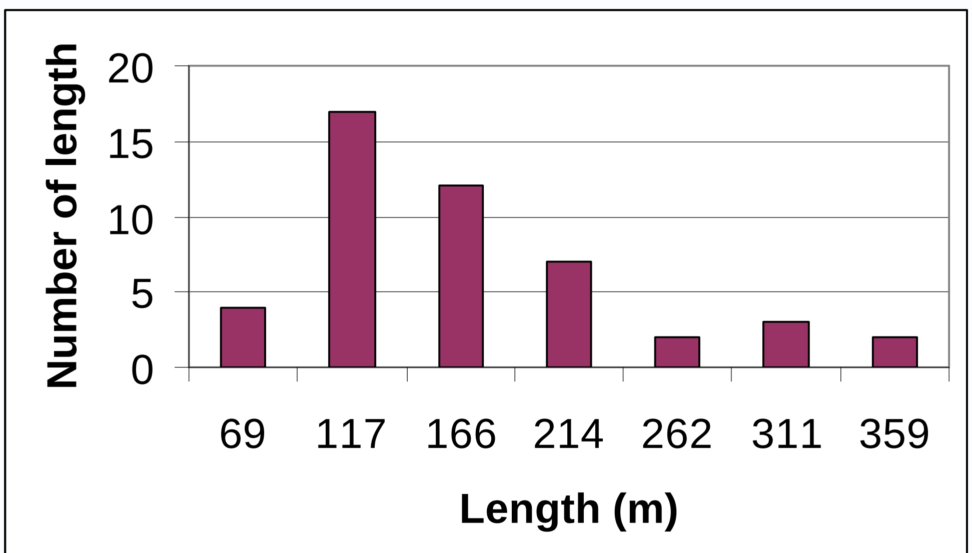
Improvement

Unit length





Technology improvements



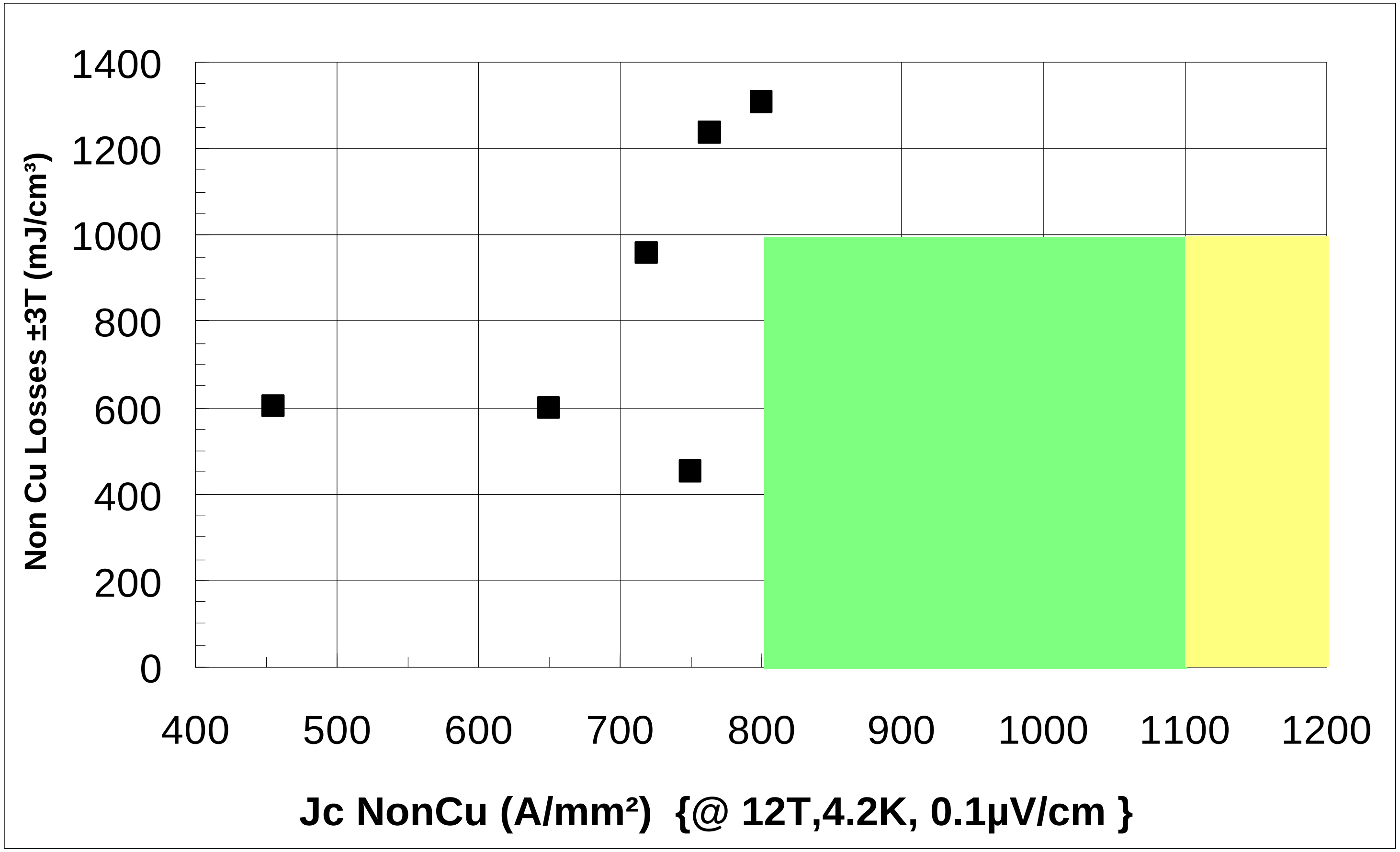
Nb3Sn Wires

- Bronze route
- Internal tin route
    - CEA Quadripole
    - ITER
    - High energy physics

EFDA technical specification

Parameter	
Diameter (mm)	0.81 mm ± 3 µm
Chrome coating	2 µm +0,5/-0,0 µm
Cu / Non Cu ratio	0.90 - 1.5
Twisting (mm)	≤ 20 mm
Ic (4.22K;12T;0.1µV/cm)	>200 A 800A/mm² & Cu/NonCu=1 (Target : 1100A/mm² & Cu/NonCu=1)
N-value @12T & 4,2K	>20
RRR	>100
Losses (± 3T)	< 1000 mJ/cm³
Unit length	>1500 m

old results (1997)



Presently, manufacturing of new Nb3Sn billets for EFDA contract

Nb3Sn Wires

- Bronze route
- Internal tin route
    - CEA Quadripole
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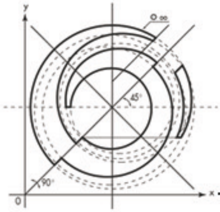
    - High energy physics



High energy physics needs

1. Quadrupole magnet for TESLA (CEA Collaboration)

- Nb_3Sn conductors :
  - non-Cu J_C up to 2000 A/mm^2 @12 T and 4.2 K
  - Losses : effective diameter < 50 µm
- Cable :
  - To manufacture a Rutherford cable

2. Care

- Nb3Sn conductors :
  - non-Cu JC up to 1500 A/mm2 @15 T and 4.2 K
  - Losses : effective diameter < 50 µm

Work program : Taguchi method

		State 1	State 2
1	Type of diffusion barrier	A	B
2	Diffusion barrier material	A	B
3	Filament diameter	A	B
4	Spacing between filament	A	B
5	Sn/Nb ratio	A	B
6	Number of sub elements	A	B
7	Cu/Non Cu ratio	A	B

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www.alstom.com