Workshop #1

Nb_3Sn Rutherford cable characterization for accelerator magnets

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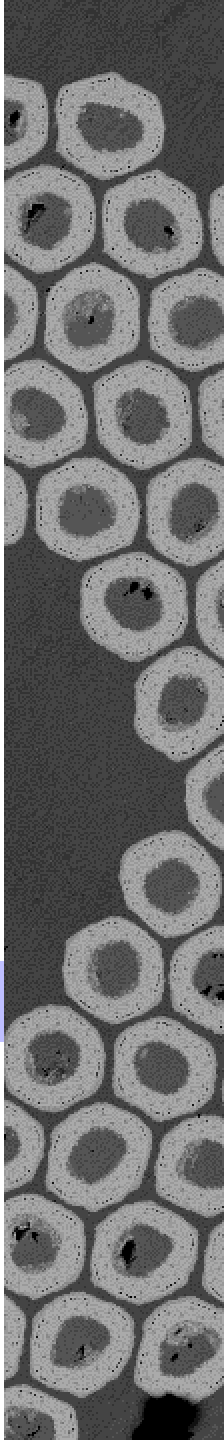

Outline

- Why this workshop *series*?
- Introduction to workshop #1
- Next steps

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Strength and limitations of Nb_3Sn 1/2

- 1961: a promising observation…

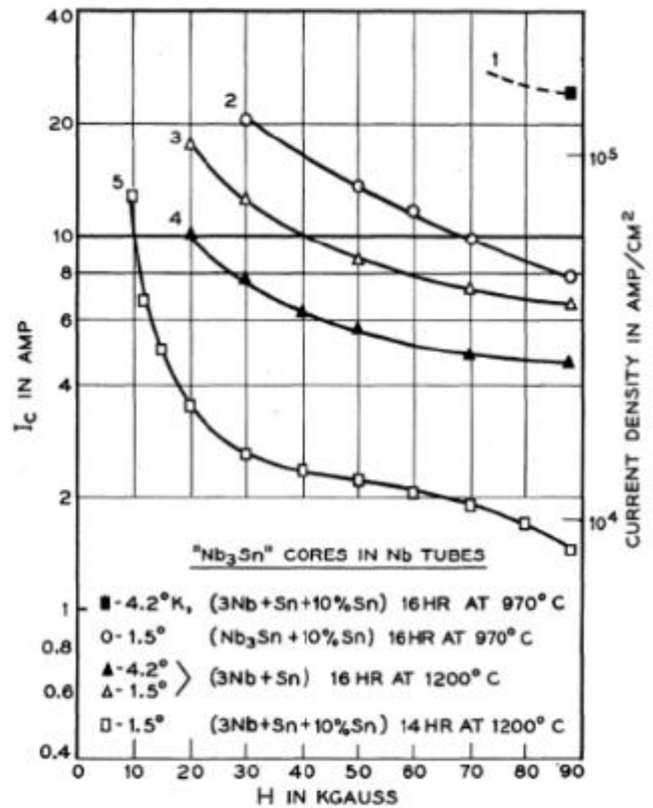
SUPERCONDUCTIVITY IN Nb_3Sn AT HIGH CURRENT DENSITY IN A MAGNETIC FIELD OF 88 kgauss

J. E. Kunzler, E. Buehler, F. S. L. Hsu, and J. H. Wernick
Bell Telephone Laboratories, Murray Hill, New Jersey
(Received January 9, 1961)

We have observed superconductivity in Nb_3Sn at average current densities exceeding 100 000 amperes/cm² in magnetic fields as large as 88 kgauss. The nature of the variation of the critical current (the maximum current at a given field for which there is no energy dissipation) with magnetic field shows that superconductivity extends to still higher fields. Existing theory does not account for these observations. In addition to some remarkable implications concerning superconductivity, these observations suggest the feasibility of constructing superconducting solenoid magnets capable of fields approaching 100 kgauss, such as are desired as laboratory facilities and for containing plasmas for nuclear fusion reactions.[1,2]

The highest values of critical magnetic fields previously reported for high current densities

Phys Rev Letters 6, 89 (1961),
submitted January 9, published February 1, 1961!



… involving complex effects

Strength and limitations of $Nb_3Sn^{2/2}$

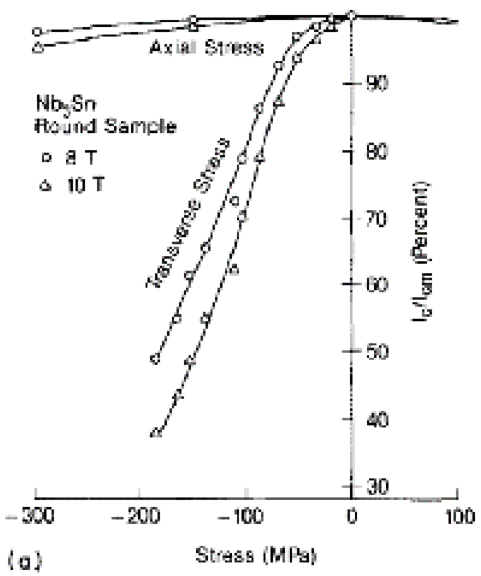
- Nb_3Sn performance is not only limited by the critical surface… but also by mechanical effects at the microstructure level

Effect of transverse compressive stress on the critical current and upper critical field of Nb_3Sn

J. W. Ekin
Electromagnetic Technology Division, National Bureau of Standards, Boulder, Colorado 80303

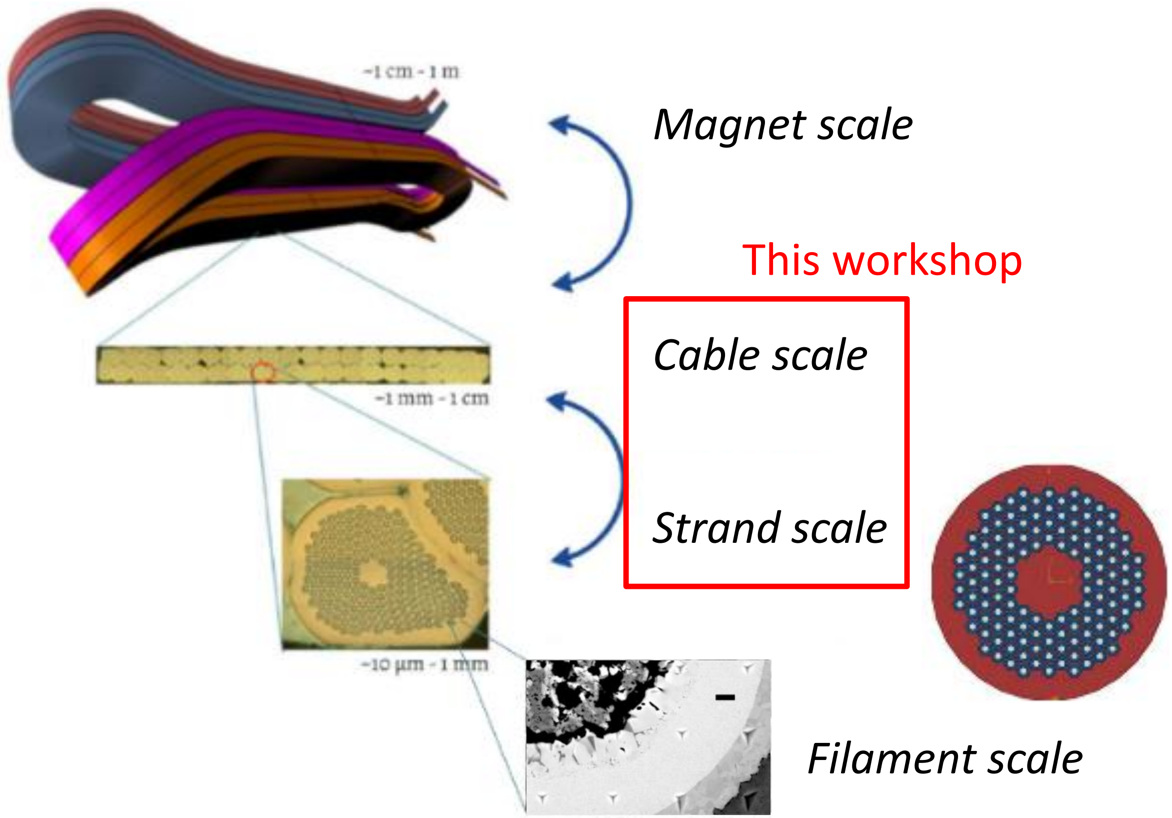
(Received 29 May 1987; accepted for publication 3 September 1987)

A large reversible degradation of the critical current of multifilamentary Nb_3Sn superconductors has been observed when uniaxial compressive stress is applied transverse to the conductor axis at 4 K. In bronze-process multifilamentary Nb_3Sn, the onset of significant degradation occurs at about 50 MPa. In an applied field of 10 T, the magnitude of the effect is about seven times larger for transverse stress than for stress applied along the conductor axis. The transverse stress effect increases with magnetic field and is associated with a reversible degradation of the upper critical field. The intrinsic effect of transverse stress on the upper critical field is about ten times greater than for axial stress. Although axial stresses on the Nb_3Sn filaments are greater than transverse stresses in most applications, the transverse stress effect will need to be considered in the internal design of large magnets because of the greater sensitivity of Nb_3Sn to transverse stress. It is shown that the transverse stress from the Lorentz force on the conductor is proportional to conductor thickness. This will place limits on conductor dimensions and the spacing between distributed reinforcement in large magnets. The effect may be particularly significant in cabled conductors where large transverse stress concentrations can occur at strand crossover points.



Nb_3Sn raises multiscale questions

- **Macro**scopic behaviour of the magnet is controlled at the **micro**structure level



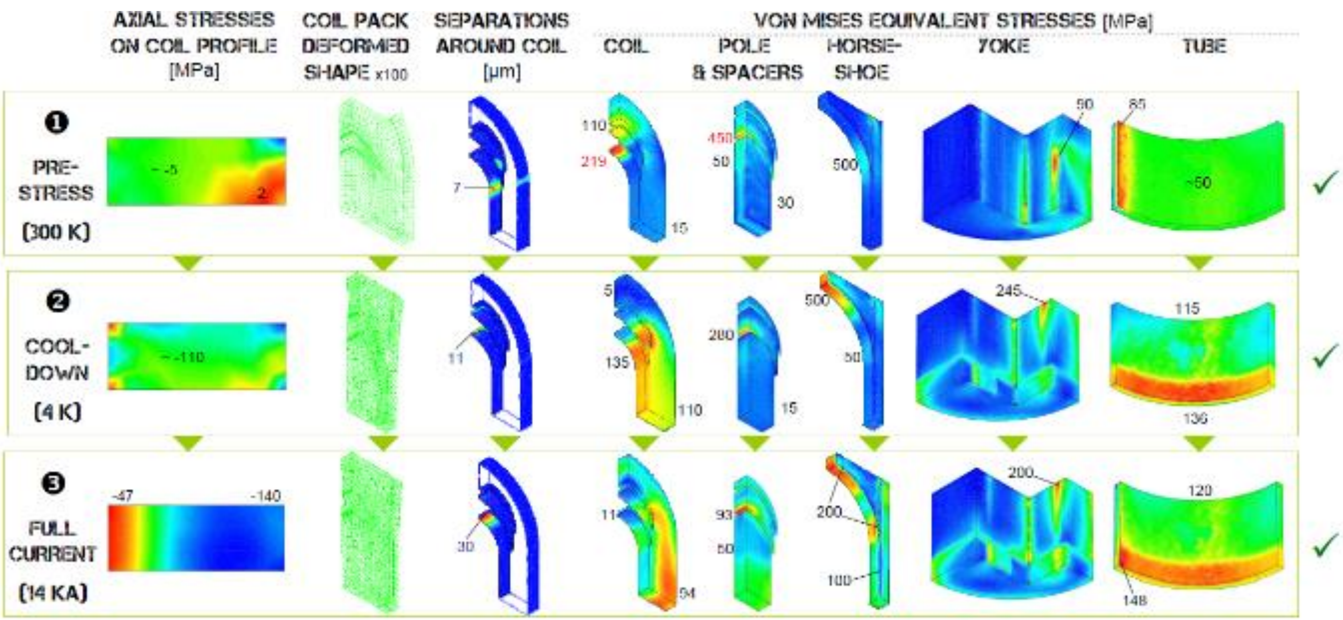
Questions encountered along the way

- Possible showstoppers:
  - Heat treatment optimization
  - Brittleness: R&W *vs* W&R
  - Series production of strand (unit lengths, procurement strategies)
  - J_c optimization (production methods, Cu/nCu ratio, flux pinning…)
  - Reversible/permanent effect of transverse/longitudinal stress/strain
  - Electromagnetic stability (self-field instabilities…)
  - Stress management at the magnet level (criterion?)
  - Accounting for quench-back effects
  - …

\+ « side problems »
  - Heat-treatment-proof tooling
  - Test facilities (need for high field/high pressure)
  - FEM model parameters
  - Difficult *in-situ* observation of the reaction process

Some (old) ‘trauma’ of mine[1/2]

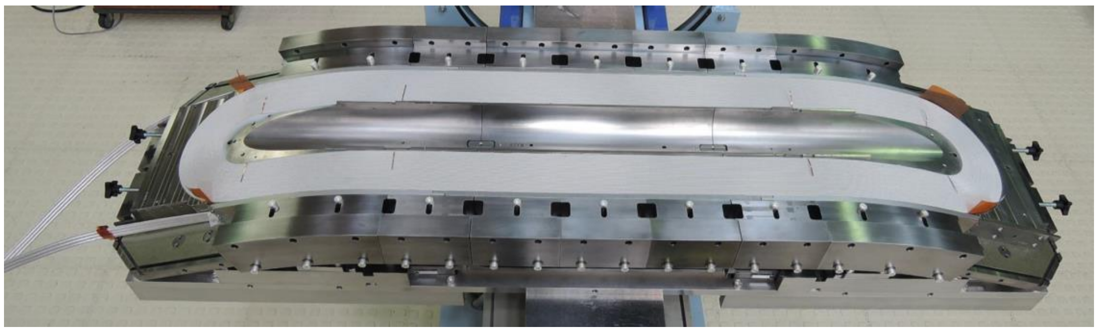
- Which Youg modulus in FEM for the insulated/impregnated cable?
- How to measure it experimentally?
- Which design critetion in terms of admissible stresses? σ_{VM} < 150 MPa??



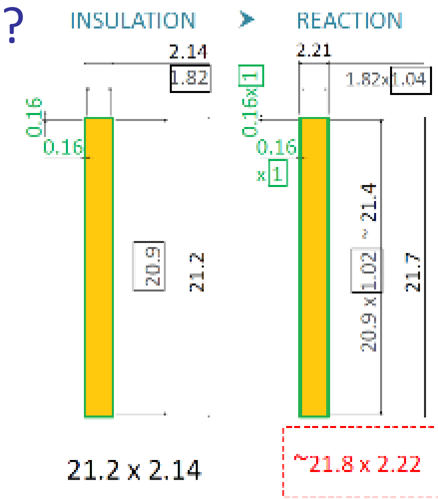
SMC mechanical models (CAST3M)

Some (old) ‘trauma’ of mine$^{2/2}$

- What cable dimensions to consider in the CAD design?
- What longitudinal contraction expected?

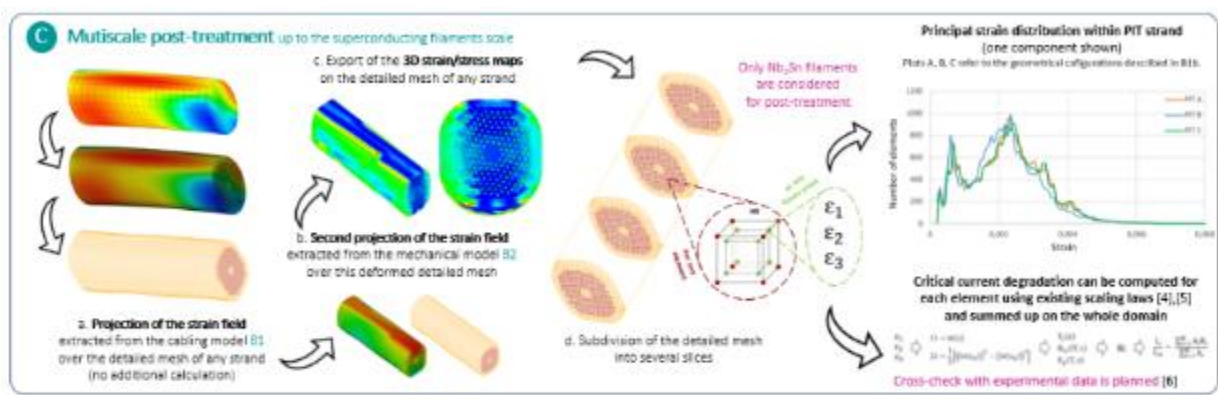


FRESCA2 coil



FRESCA2 cable sketch

- Which driving parameter(s) for the electromagnetic performance? (scaling laws)



CoCaSCOPE program

Why now?

- Continuous progress + recent encouraging results
  - ▸ LARP/US magnet development program: HD, HQ…
  - ▸ NED/EuCARD: SMC, RMC, FRESCA2
  - ▸ CERN HFM program: eRMX, RMM…
  - ▸ HiLumi: 11 T dipole, 4m-long MQXF
  - ▸ EuroCirCol, FCC: new design concepts
  - ▸ Strong implication in China and Japon

FRESCA2 structure

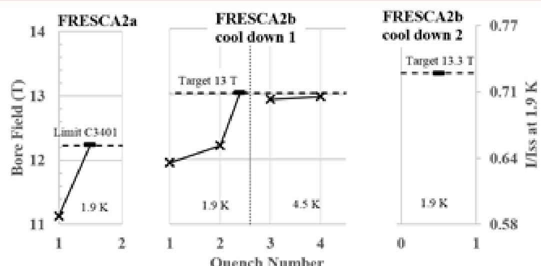
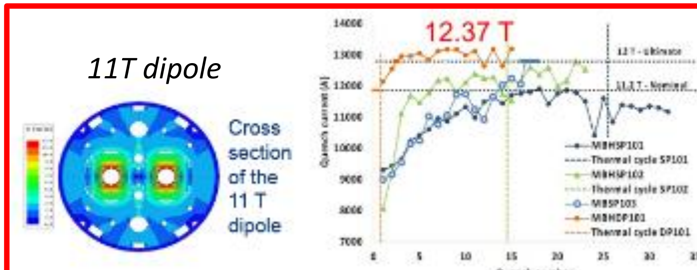
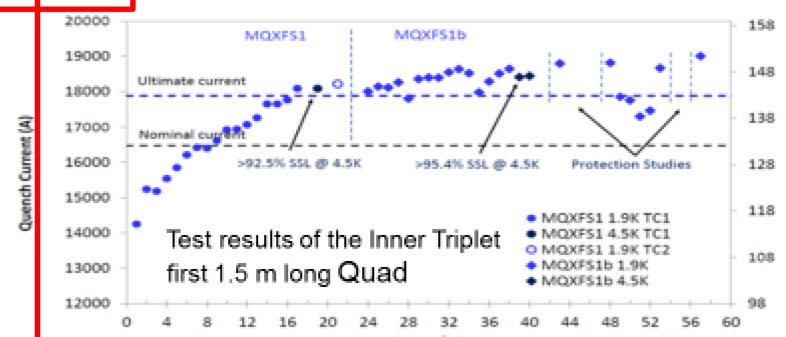


Fig. 5. Training curves of assemblies FRESCA2a and FRESCA2b. The crosses indicate training quenches; the dashes indicate the current level reached without quench.

4m-long MQXF



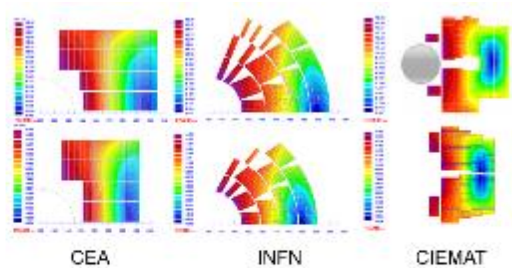
MQXFS

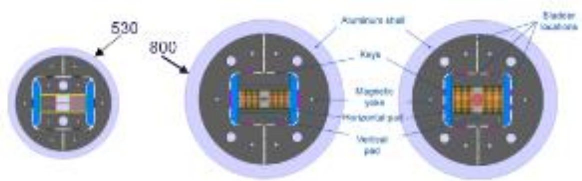


→ 16 T Nb_3Sn magnets are credible…

Why now?

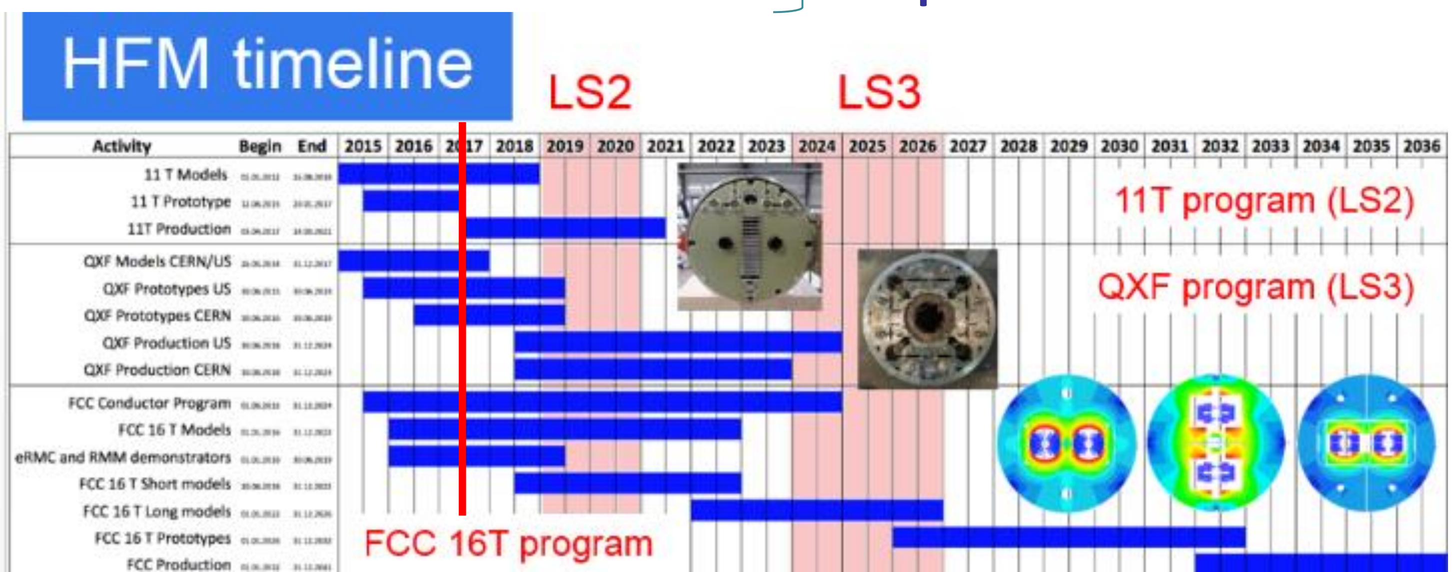
- FCC: a clear timeline proposal





We are at the crossroads between R&D/demonstrator magnets and first Nb_3Sn magnets operating in accelerators

→ Perfect timing for consolidating the huge amount of R&D feeback acquired worldwide!



[courtesy of F. Bordry, L. Bottura, G. de Rijk]

Intention of the workshop series

- This workshop *series* aims at sharing experience gained worldwide in the field of Nb_3Sn conductor characterization.

- At the end of the series, the idea is to set-up a **best practice manual** resulting from the discussions having taken place all along the workshops.

- From today, we can evaluate that 3 to 5 workshops could be necessary.

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Organizing committee

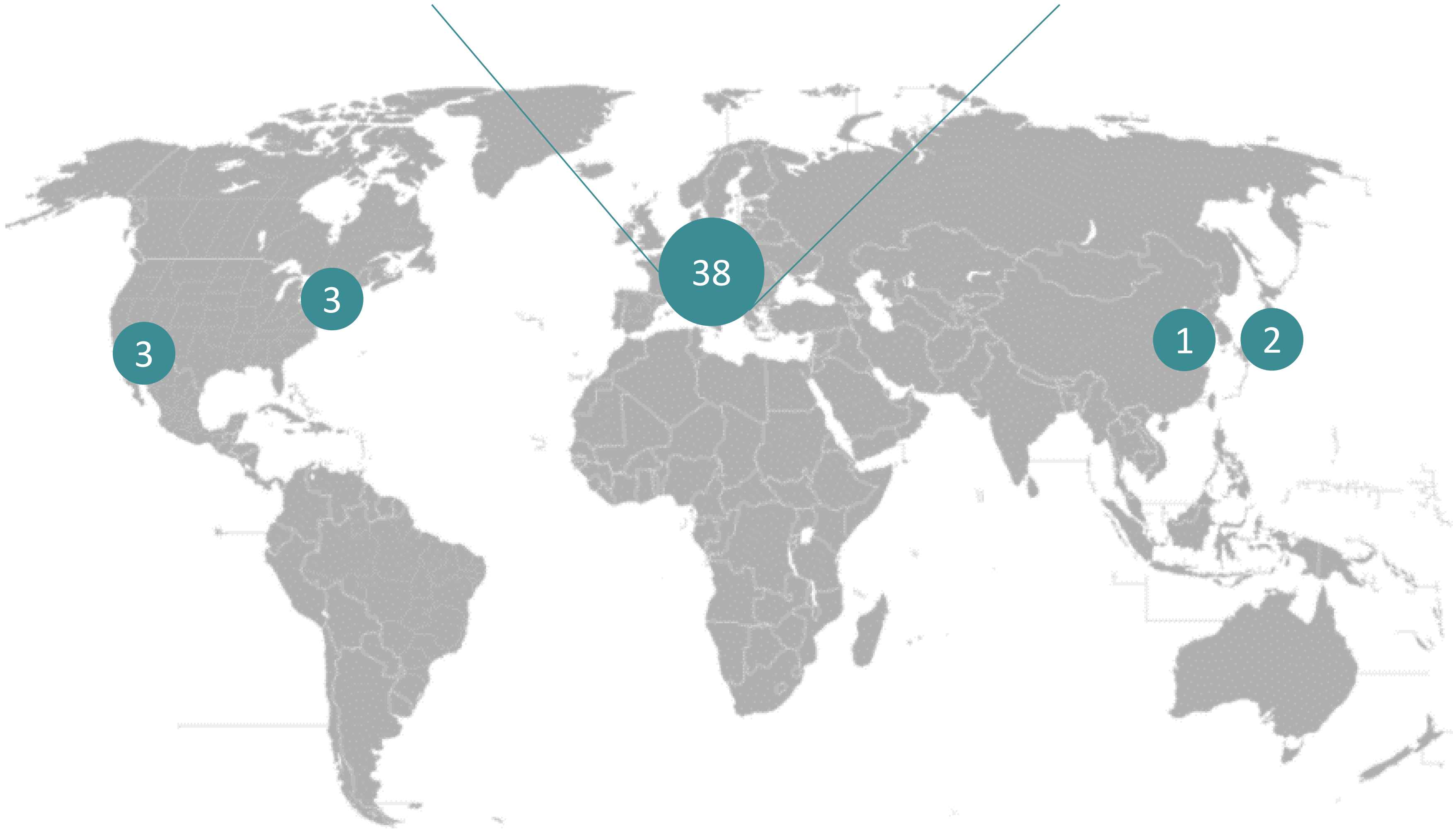
- Organization
  - **Cecile Noels** @ CERN
  - Natacha Lomet @ CEA Paris-Saclay
- Logistics/support
  - Hi-Lumi collaboration
  - Luis Garcia and Fernand Toral @ CIEMAT
  - Pierre Védrine @ CEA Paris-Saclay
- Scientific committee
  - Bernardo Bordini, Paolo Ferracin, Friedrich Lackner @ CERN
  - Maria Durante, Hélène Felice, Pierre Manil @ CEA Paris-Saclay

Useful documents

- Agenda
- Letter of intent
- Guidelines for the presenters
- List of participants
  - Including affiliation, contact, background and interest

47 participants

CERN	CEA	INFN	CIEMAT	ENEA	EFJ
15	9	5	4	2	1



Topics

- **Session #1 | Introduction to the workshop series**
- **Session #2 | Mechanical characterization of impregnated conductor**
  Session chairs: Paolo Ferracin, Friedrich Lackner
- **Session #3 | Dimensional changes during heat treatment**
  Session chairs: Hélène Felice, Bernardo Bordini
- **Session #4 | Wrap-up and close out**

Guidelines to the presenters

- Besides the scientific results that you wish to present, please keep significant time to present the experimental **setups and procedures**.

- Do not hesitate to present **negative or partial results** if you think they can bring constructive input.

- Please take some time at the end of your talk to conclude on the problems and success encountered and try to draw conclusions (even negative) that could **serve the whole community** rather than sticking to the specificities of a particular project.

Guidelines to the attendees

- Ask questions ;-)

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Proceedings

- **The idea is to come out with proceedings** highlighting the common/diverging conclusions arising from the presentations and discussions in each session.
- These proceedings will not be a list of abstracts or papers.
- They will be short (approx. 2 pages per session).

- Following the workshop, the scientific committee and chairmen will edit the proceedings of each session.
- The proceedings will be reviewed by all the presenters before being shared and open for comments.
- Unless specific request, the proceedings will be made public.

Next worshop(s)?

- Will be discussed in the wrap-up session:
  - Next topics
  - Workshop regularity/location
  - Method to set a best practice manual
  - Coordinated research programs?

- So please stay with us for the last session (ending at 18:30)!

Thank you