U.S. MAGNET DEVELOPMENT PROGRAM

Area IV, All-HTS Accelerator Magnets: Request for Comments

MDP general meeting

X. Wang, 14 January 2026

CERN achieved 5.4 T in a REBCO common coil at 4.2 K

"The first powering cycle has been completed in December 2025, reaching the nominal field of **5.4 T** in each aperture, with an estimated peak field in the coils of 6.6 T.

The development path **identifies as next objectives** longer and larger REBCO coils and the investigation … of the feasibility of achieving central fields of about **10 T**, on the path toward the targeted **14 – 20 T** performance."

- From Amalia and Ezio to MDP, 18 dec 2025

Features of CERN's all-HTS approach

- Aim at fields beyond Nb_3Sn
  - Address a fundamental promise of HTS
- Generate results quickly and frequently that can be appreciated by the magnet community, sponsors and future users
  - Effective
- Use a simple technical approach to find out how HTS works in an accelerator magnet configuration in high fields
  - Modularized racetrack coils, more details https://indico.cern.ch/event/1565580/

What matters now for all-HTS accelerator magnets?

- Can an all-HTS go beyond Nb_3Sn? By how much?
- How soon can we demonstrate it?
- Can we surpass Nb-Ti first in 2 years?

- Take a simple path to find out where the end is
  - Engage conductor vendors
  - Ensure HTS can work first without being distracted

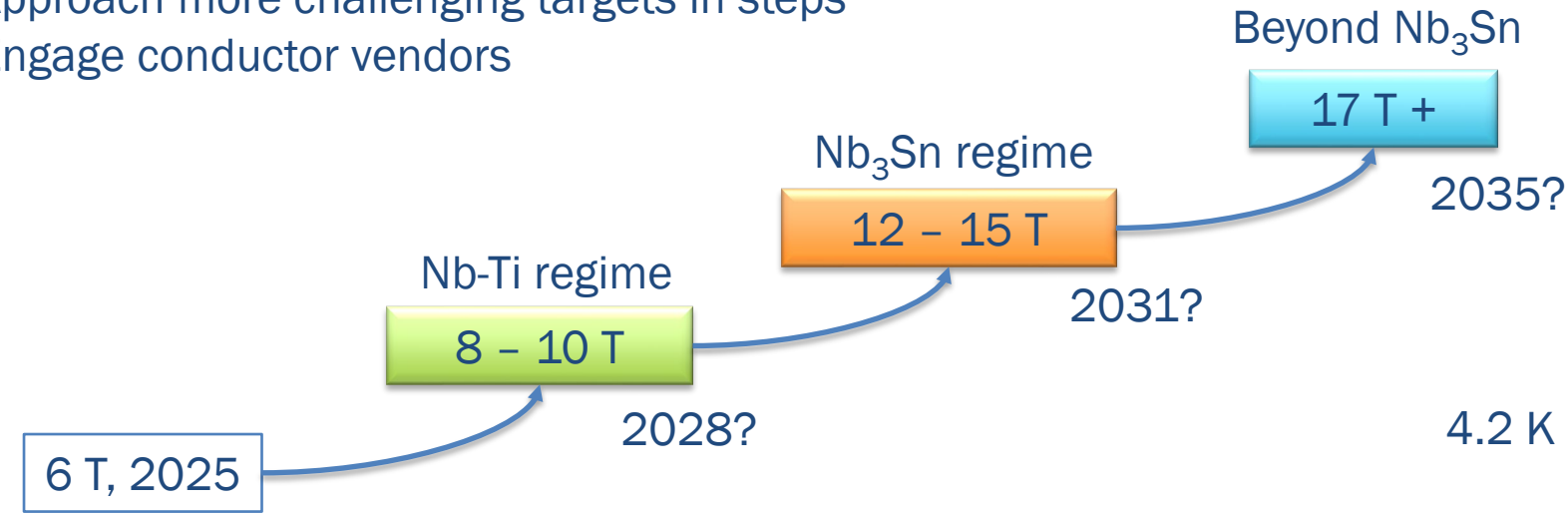
- Be mindful about, but don't be bogged down, by
  - Conductor cost, magnet design efficiency, …

The current criterion for “all-HTS can work”

- Robustly generating a field beyond Nb_3Sn at 4.2 K
  - Magnets can generate the main field repeatedly without degradation or burnout
- Field quality comes later but should be monitored
  - “…, but first requirement is on generation of main component” – Ezio Todesco, HiTAT-2 workshop
- The criterion will evolve as we move along

MDP can and should take bold steps to define and understand "the performance limits" of HTS

- Follow and complement CERN's technical routes
- Approach more challenging targets in steps
- Engage conductor vendors



[The 2025 Roadmaps for the US Magnet Development Program]

We need to work closely with conductor vendors

- We need capable vendors to meet our evolving needs
  - Conductor design and performance targets are evolving
- Our needs likely won't settle until we get to higher fields
  - Long-term partnership benefits magnet technology development
- Build a mutually beneficial relationship and a competitive US business
  - Be a demanding customer with a fat wallet?

Potential work on multi-tape conductor development

- Increase current and current density at a smaller bend radius at 4.2 K
  - Step 1: 12 – 15 kA at 10 T
  - Step n: 20 kA at 20 T
  - C3 wire: I_c ~ 9 kA at 10 T

- Need to collaborate with conductor vendors
  - Increasing current can make the conductor less flexible
  - Need thinner and higher current tapes

Potential work on multi-tape conductor development

- Increase the tolerance to the IxB transverse load at 4.2 K
  - Assuming a transfer function of 1 T/kA in both dipole field and peak conductor field
  - Step 1: 120 – 150 kN/m → provide margin for 10 T x 10 kA
  - Step *n*: 500 kN/m → provide margin for 20 T x 20 kA

- Impregnation between the tapes?

Ideal development scenario to break the Nb_3Sn limit as soon as possible

- Make magnets using diverse routes and options in parallel
  - Round wires + CCT, COMB, Uni-layer, …
  - Rectangular cables + CCT, block, cosθ, …
- Concentrate on reaching higher fields
  - Each route to take steady steps and deliver higher fields every 18 months
- Develop a pool of evolving options and allow survival of the fittest

How can we make it happen?

- Just do it ? or !
- Collaborate
  - Complement and learn from each other
- Generate results to boost the interest and $
  - Help PM help us
- Challenge: try to avoid premature optimization

High-field quadrupoles: a fork in all-HTS

- Develop a more complete HTS toolbox for a bigger magnet family for future colliders
  - Can have real customers such as FCC-ee

- Compare notes and cross-reference with dipole development
  - Racetrack vs. alternative designs?
  - Rectangular vs. round cable?
  - Field quality?

Summary

- Pursue 8 – 10 T dipole field as the next goal using today's conductor
  - Surpass Nb-Ti in 2 years
- Invest in vendors to develop next-generation conductor toward 12 – 14 T
  - Current, current density, bend radius, and IxB transverse strength
  - We cannot succeed alone
- Start exploring HTS quadrupole magnets using FCC-ee specs

Rephrased questions as far as I can remember correctly

- Steve
  - Is reproducibility and robustness becoming more and more important for the REBCO magnets? How do we address that? Also people need to start thinking what a REBCO program is going to cost?
  - Following Lance's comment, mechanical experts may need to weigh in on what kind of cable structure we need for future magnets to sustain unprecedented mechanical load.
- Lance
  - What infrastructure is needed for cable characterization? Cable characterization is important before we put the cable into magnet.
- Gorgio
  - Tape stack can be stronger than round wire. From this point view, why do we want to stick with round wire if we want to aim at the ultimate field for REBCO?
- Ian
  - Why do we want to use FCC-ee spec to explore HTS quadrupole magnet? Why not solenoid magnets or combined-function magnets?