Karlsruhe Institute of Technology

XLS-WP5: Task Superconducting Undulators

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STFC, PSI, KIT

Task Overview

Technologies

A variety of SCU technologies at different levels of maturity will be considered:

- Low temperature planar and helical SCUs (Nb-Ti, Nb_3Sn)
- SCUs wound from HTS (REBCO) tape
- HTS (REBCO) bulk inductively excited structures

The design work will have to be accompanied by a technology development programme

Contributing partners

STFC

LTS planar and helical

PSI

HTS bulk permanent magnet, HTS staggered array

KIT

LTS, HTS planar, task coordination

STFC

Science & Technology Facilities Council | UK Research and Innovation

- NbTi
- planar
- helical

STFC: In-vacuum SCU

Technology branch

- “classical” planar Nb-Ti undulator magnet technology
- optimization towards compact FELs: In-vacuum SCUs
  - reduced magnet aperture
  - significantly increased field amplitude at given λ_u
- helical Nb-Ti undulators

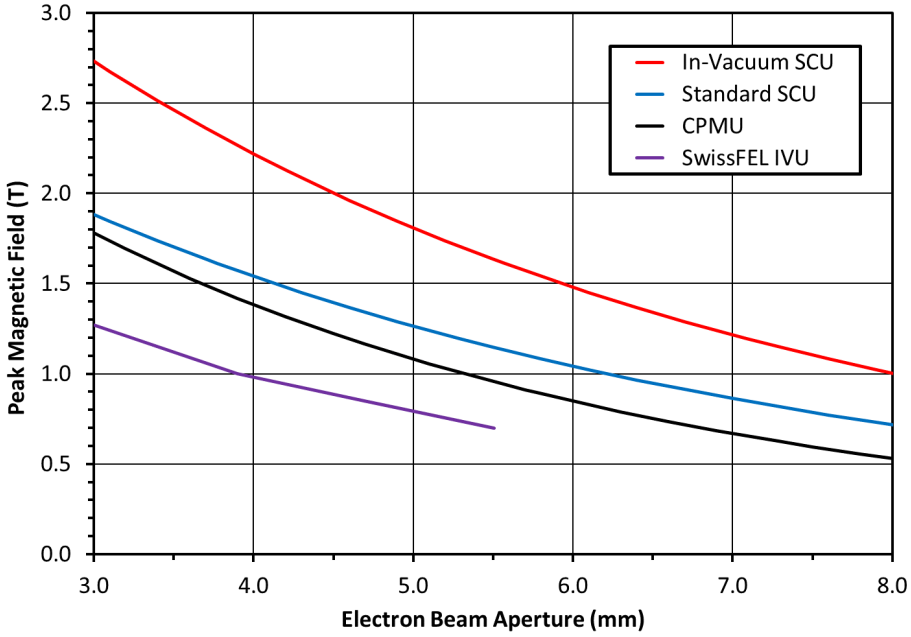
Current work

- In-vacuum SCU prototype ($\lambda_u = 15.5\,\text{mm}$, $B_0 = 1.4\,\text{T}$) tested (basic magnetic measurements)
- currently being off-line commissioned (cold test, quench protection system, fiducialisation) at Daresbury
- awaiting installation into CLARA

STFC: In-vacuum SCU

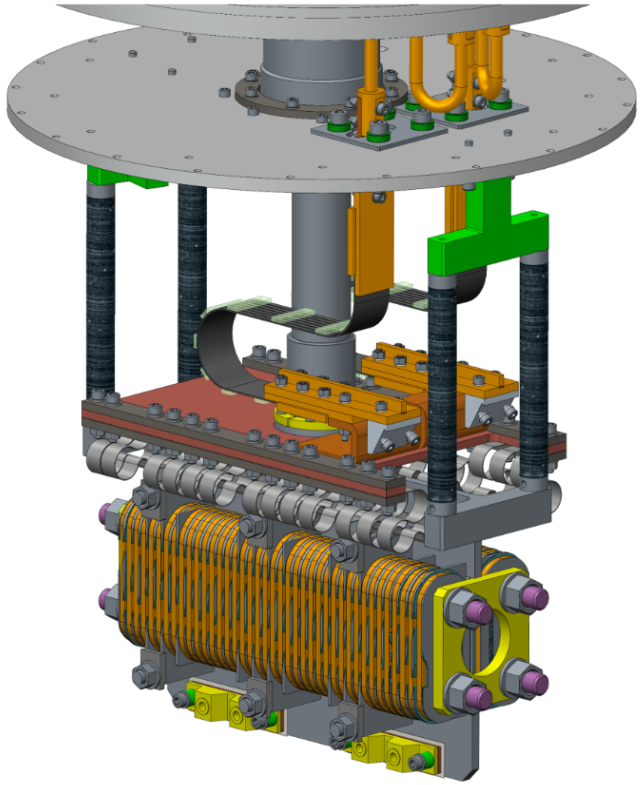
- Example 15 mm period undulator
- NbTi at 1.8 K
- Note at 4 K we typically observe a 10 % reduction in field
- In-Vacuum SCU with magnet gap 0.2 mm larger than electron beam aperture

  No internal vacuum chamber, only high conductivity copper liner



[FLS2018, THP2WD02]

STFC: In-vacuum SCU

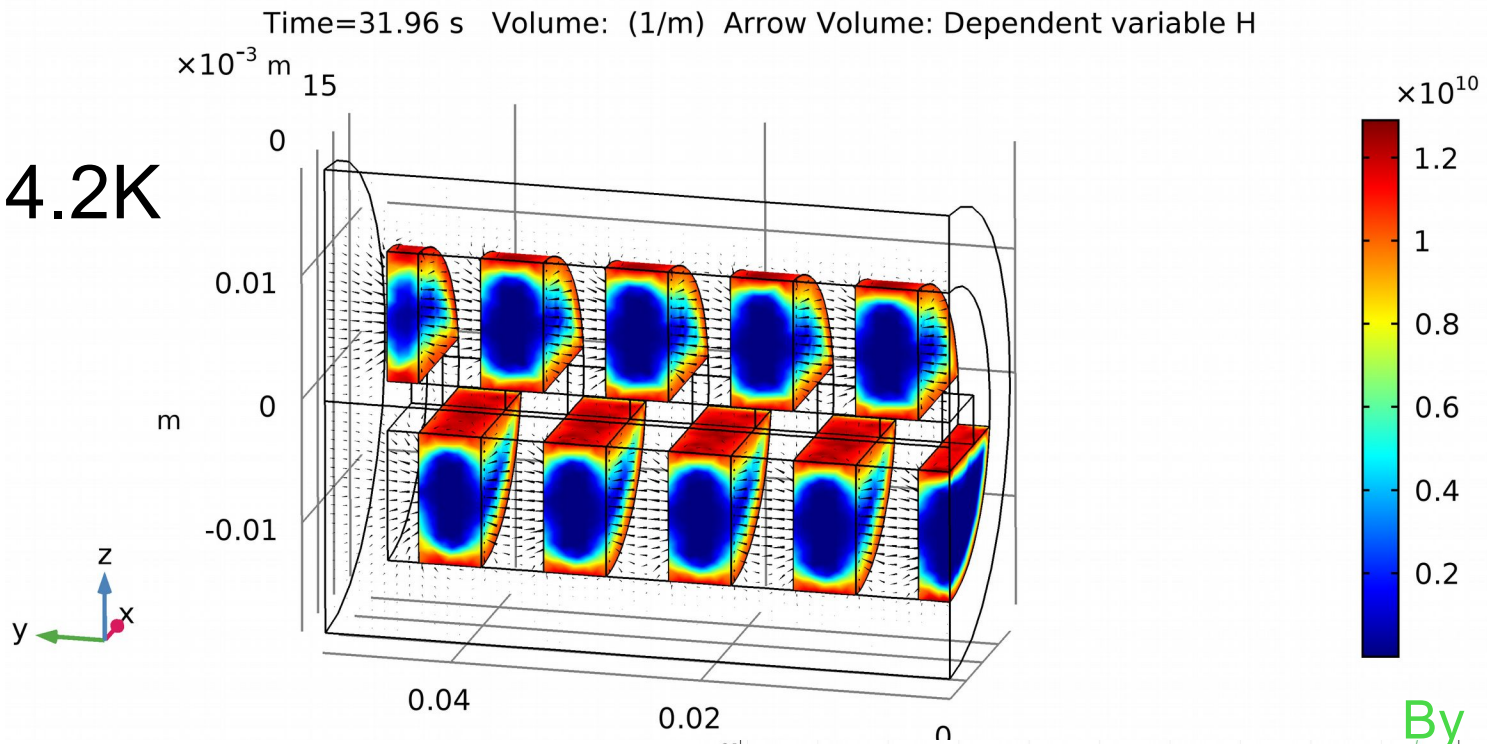


- SCU prototype in front of CLARA front end
- Start of experiment: february 2019

PSI

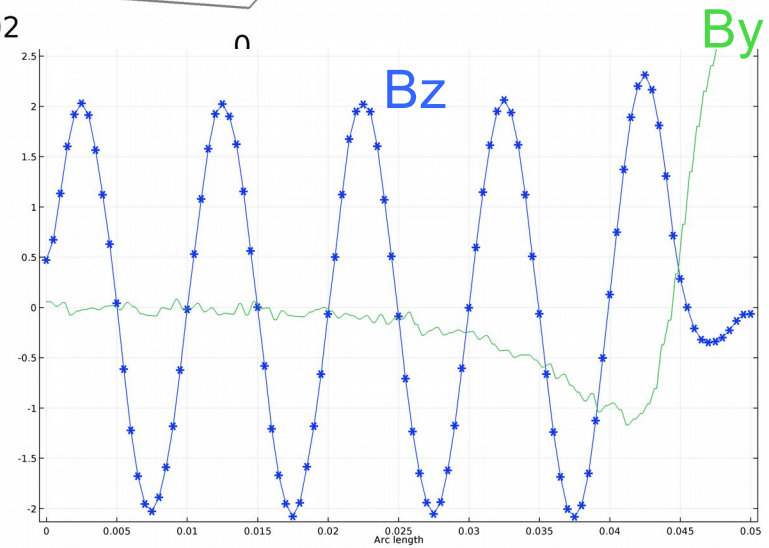
- HTS bulk permanent magnet, HTS staggered array
- planar
- helical

Planar Undulator - Staggered Array

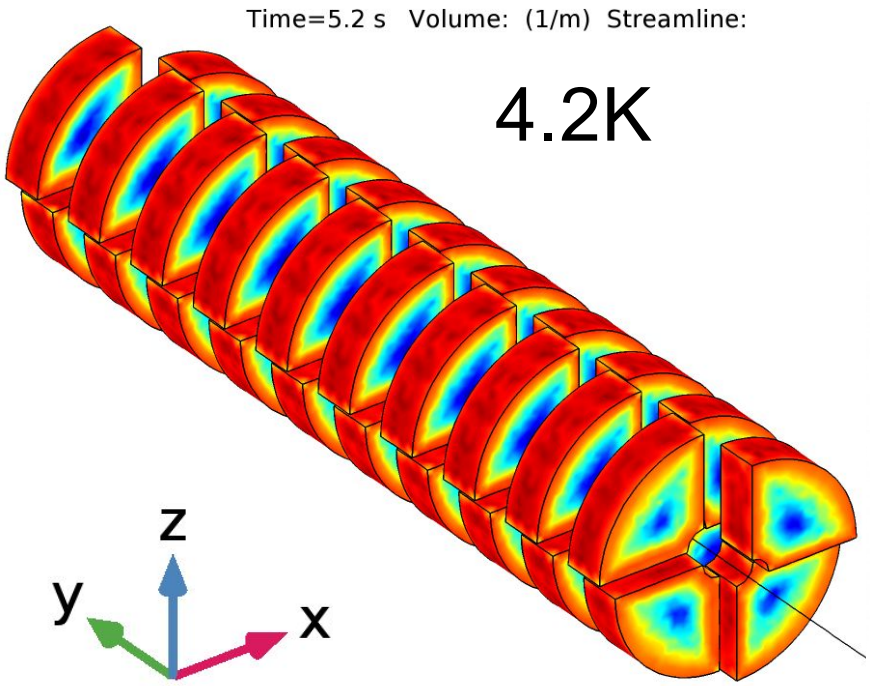


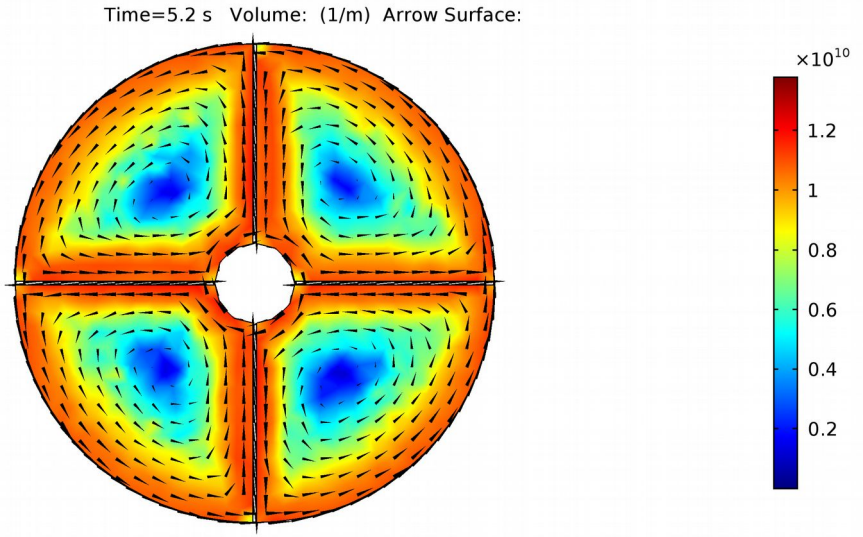
4.2K

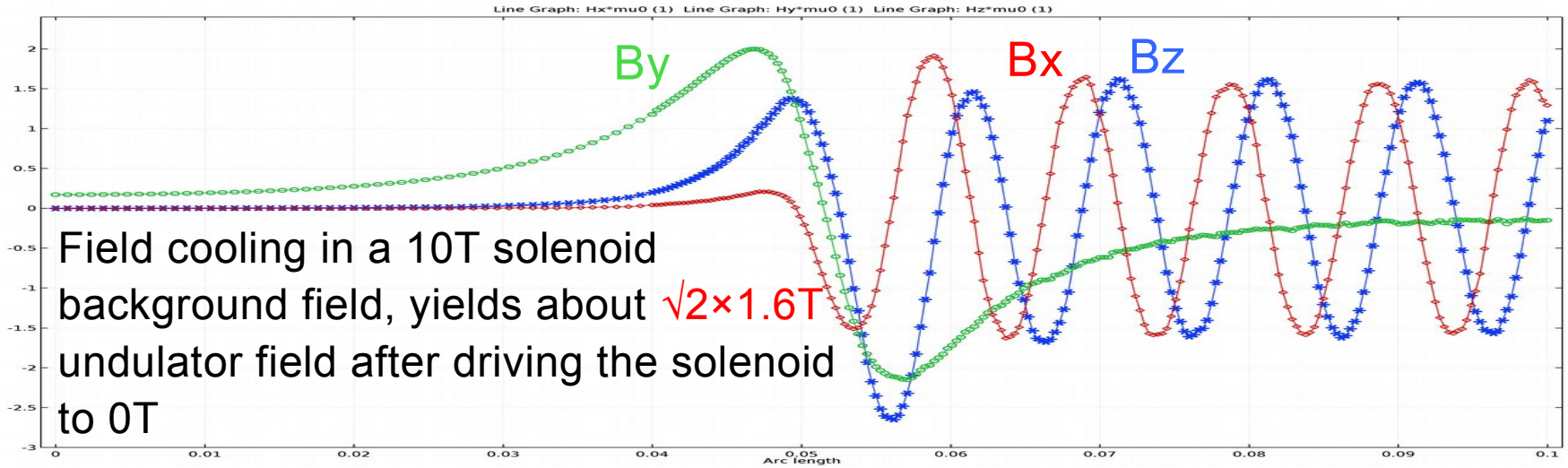
Field cooling in a 10T solenoid background field, yields about 2.0T undulator field after driving the solenoid to 0T



Helical Undulator - Double Staggered Array

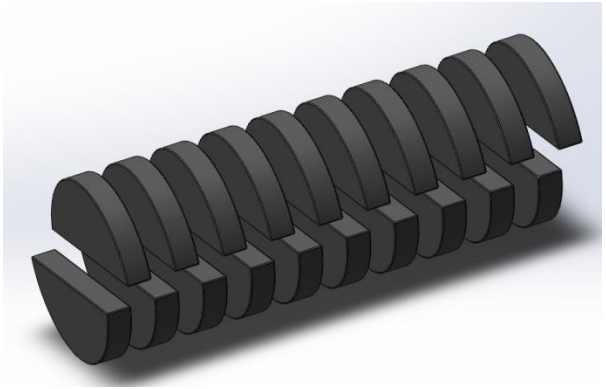


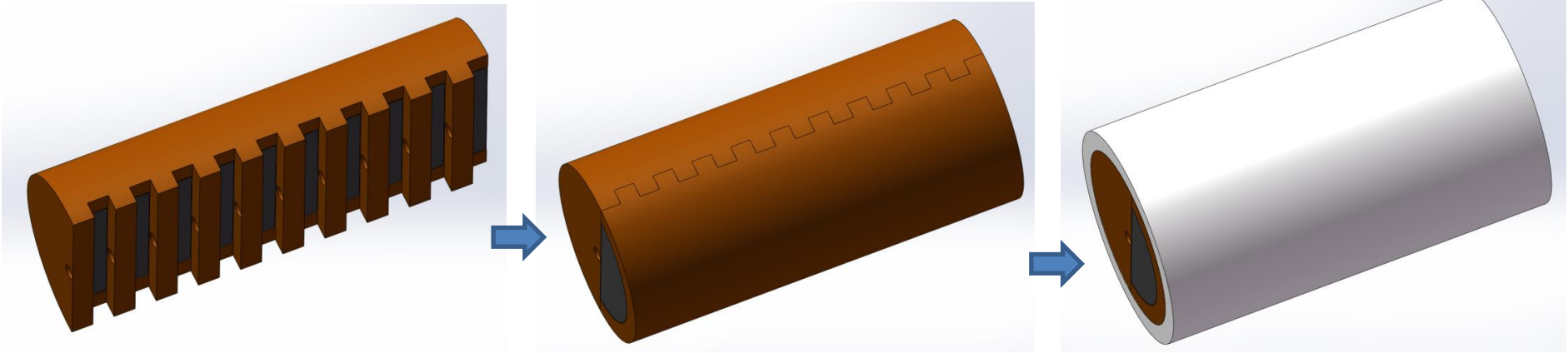




Field cooling in a 10T solenoid background field, yields about √2×1.6T undulator field after driving the solenoid to 0T

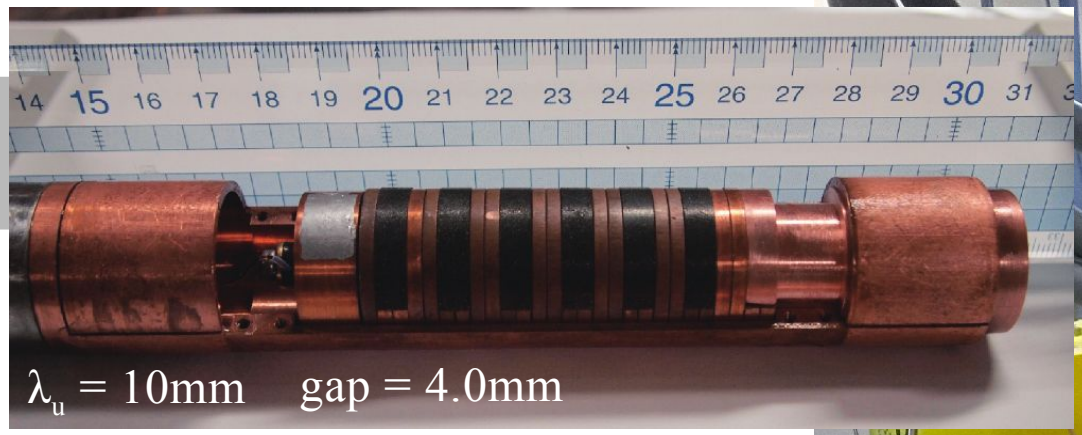
Shell-based HTS bulk undulator prototype (10 periods)





Test in a 12T solenoid – Uni Cambridge

[R. Kinjo et al. Applied Physics Express 6 (2013) 04270]



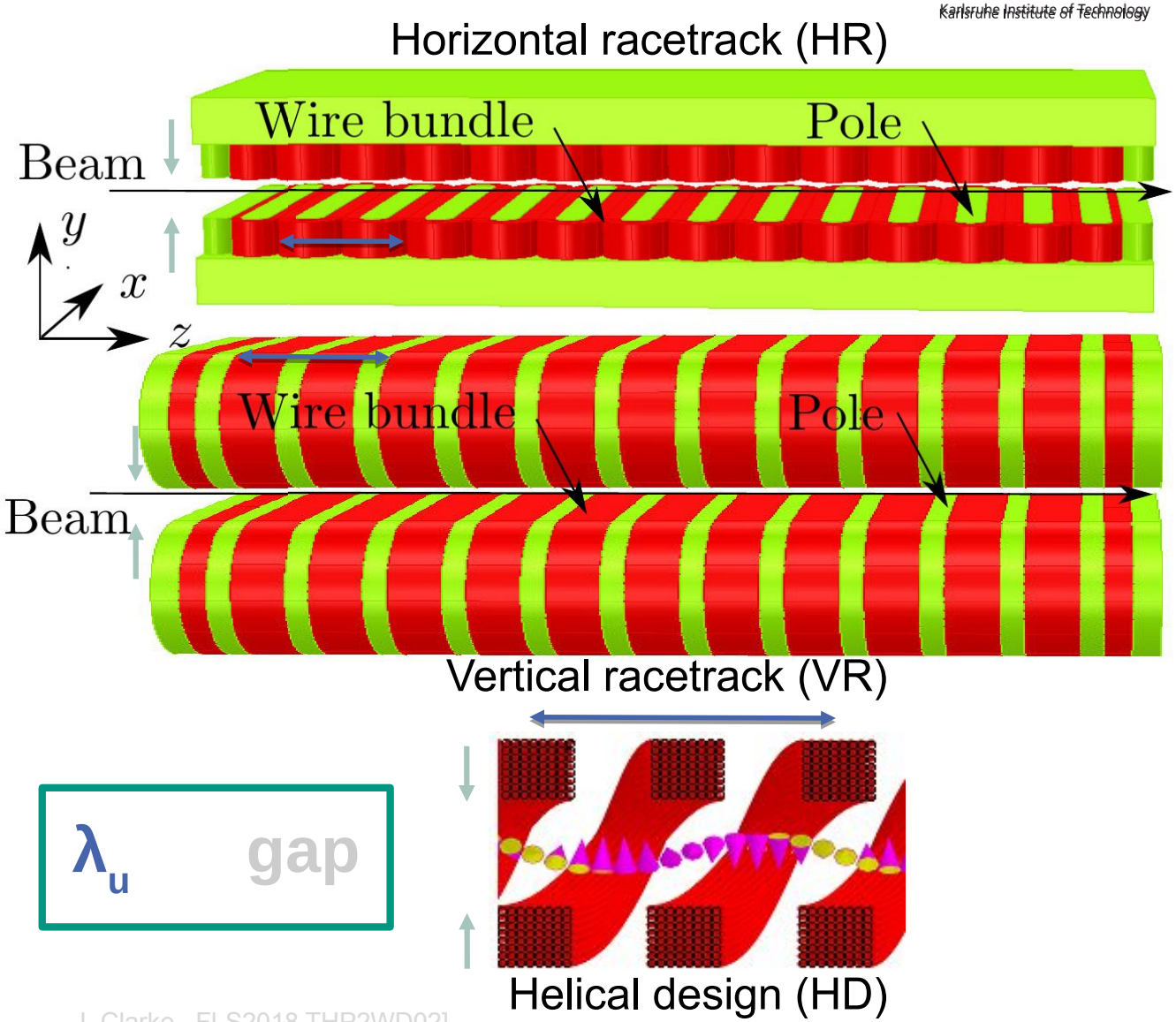
Test (Spring 2018) of a planar staggered array undulator made of GdBCO bulks, in a 12T solenoid, where the field could be continuously changed between +12T down to -12T and the temperature of the sample controlled between 2K and 300K in a clear bore of 100mm diameter.

- Parameter studies
- Collecting and compiling data

Simulations of superconducting undulators

LTS material
Nb-Ti
Nb_3Sn

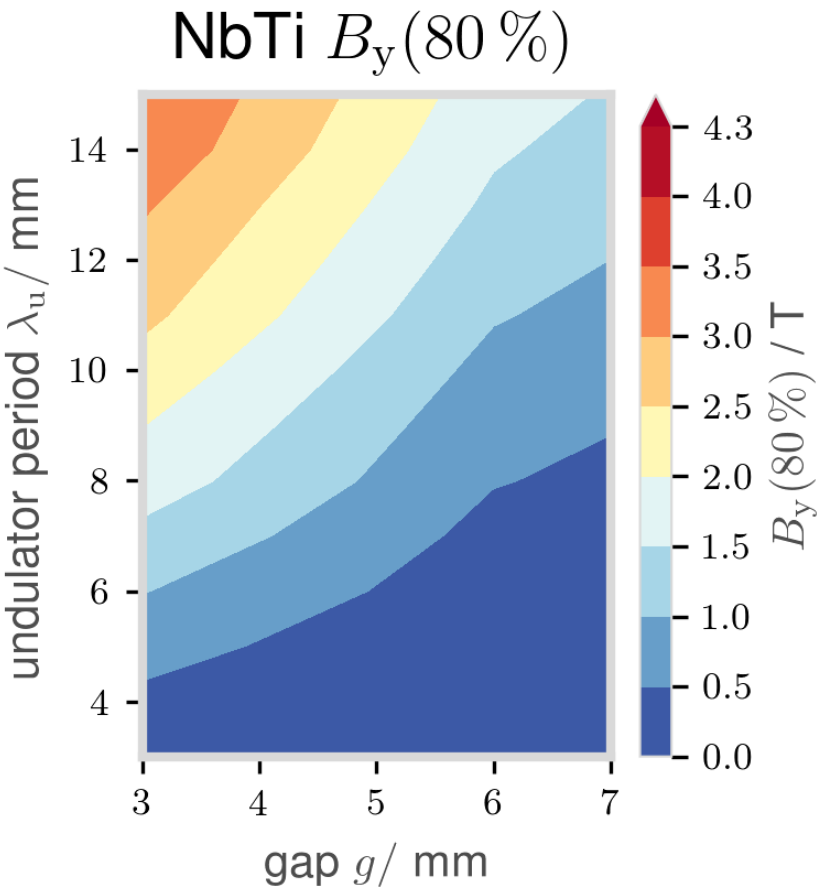
HTS material
YBCO

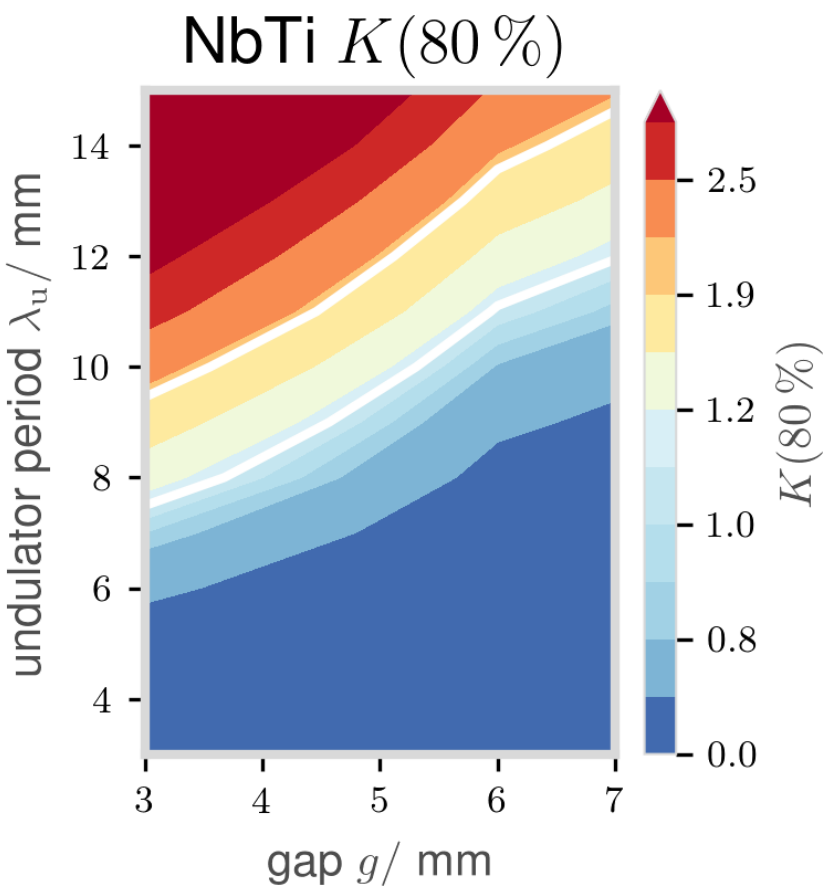


J. Clarke, FLS2018 THP2WD02]
D. Schörling, Superconducting Wiggler Magnets for Beam-Emittance Damping Rings, PhD (2012)

NbTi (vertical racetrack)

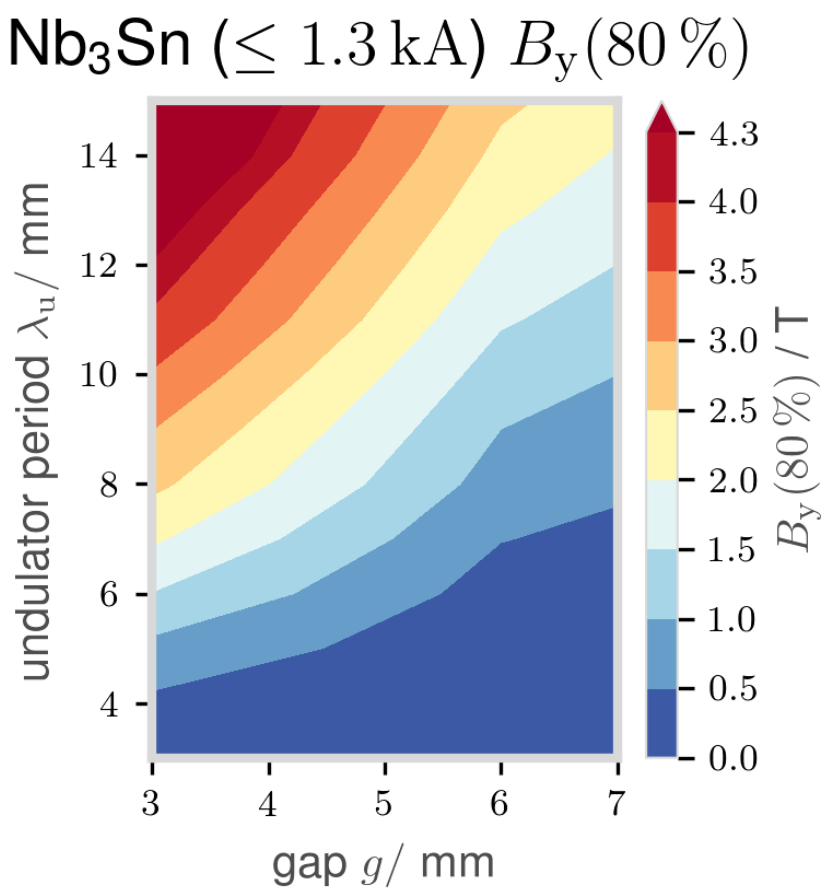
L. Bottura, “A practical fit for the critical surface of NbTi,” IEEE Transactions on Applied Superconductivity, vol. 10, no. 1, pp. 1054 –1057, 2000.

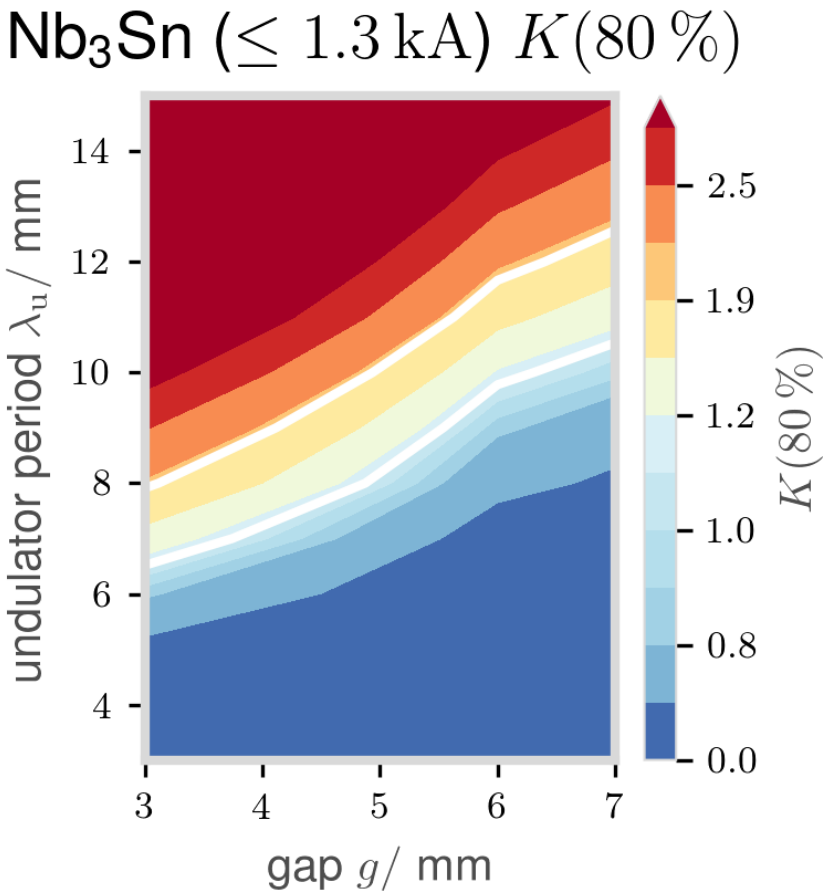




Nb_3Sn (vertical racetrack)

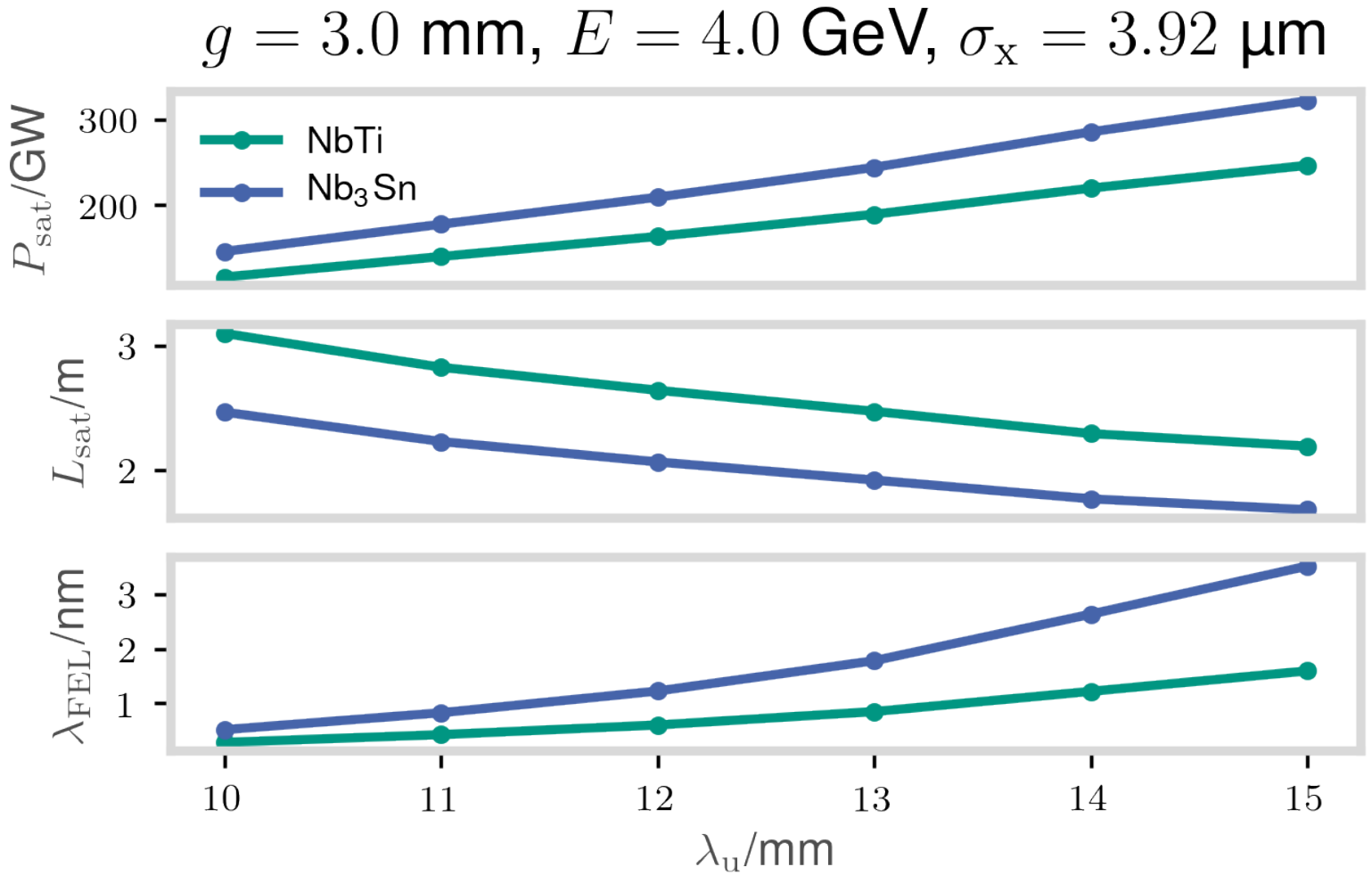
L. Summers, M. Guinan, J. Miller, and P. Hahn, “A model for the prediction of Nb3 Sn critical current as a function of field, temperature, strain, and radiation damage,” IEEE Transactions on Magnetics, vol. 27, no. 2, pp. 2041 –2044, 1991.





Saturation power and length

Ming Xie, Exact and variational solutions of 3D eigenmodes in high gain FELs, NIM Sec. A, 2000; 10.1016/S0168-9002(00)00114-5



Summary and outlook

	planar	helical
NbTi	data compilation	feasibility experiments
Nb_3Sn	simulations	parameter studies
HTS	feasibility experiments	parameter studies

Thank you for your attention.