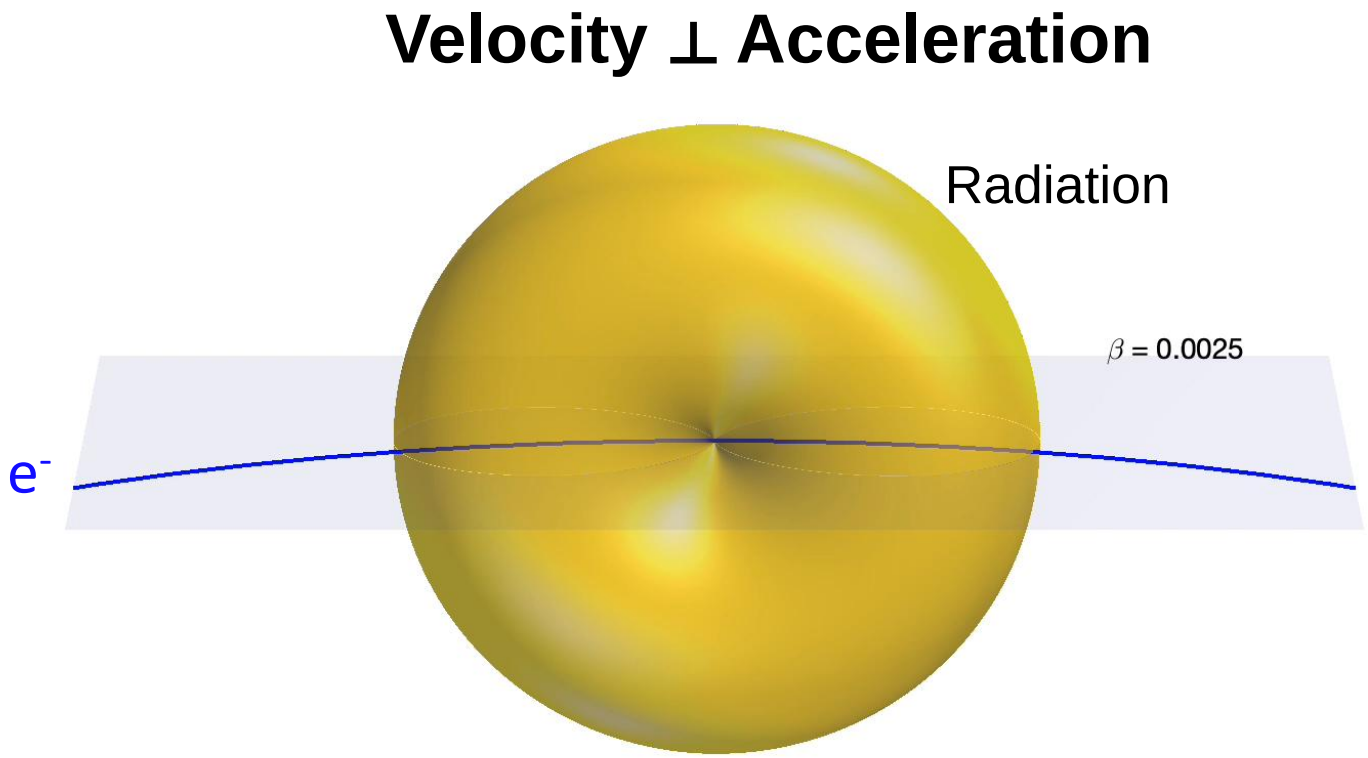
PSI Center for Photon Science

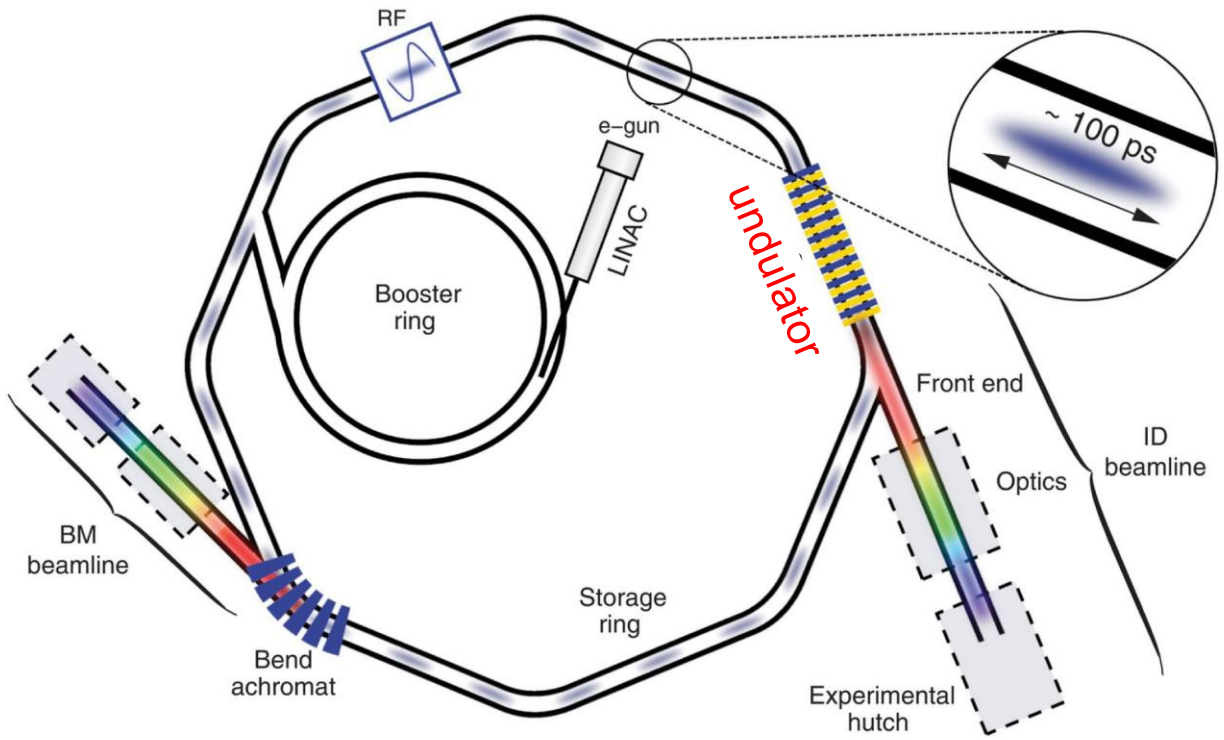
High-Temperature Superconductivity for Next-Generation Light Source Undulators

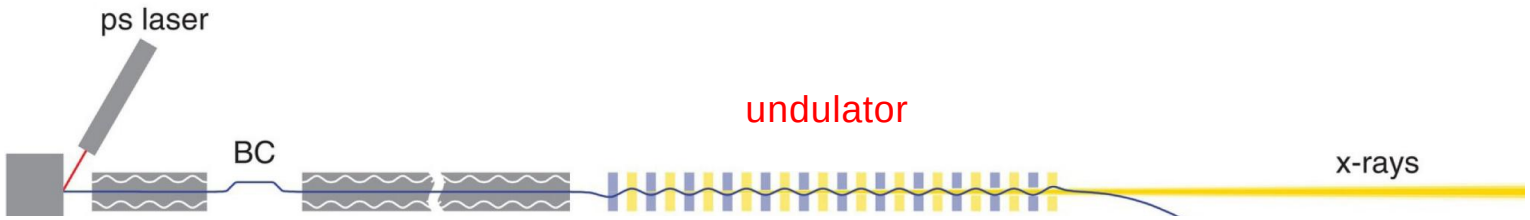
Alexandre Arsenault and Marco Calvi
October 21, 2026

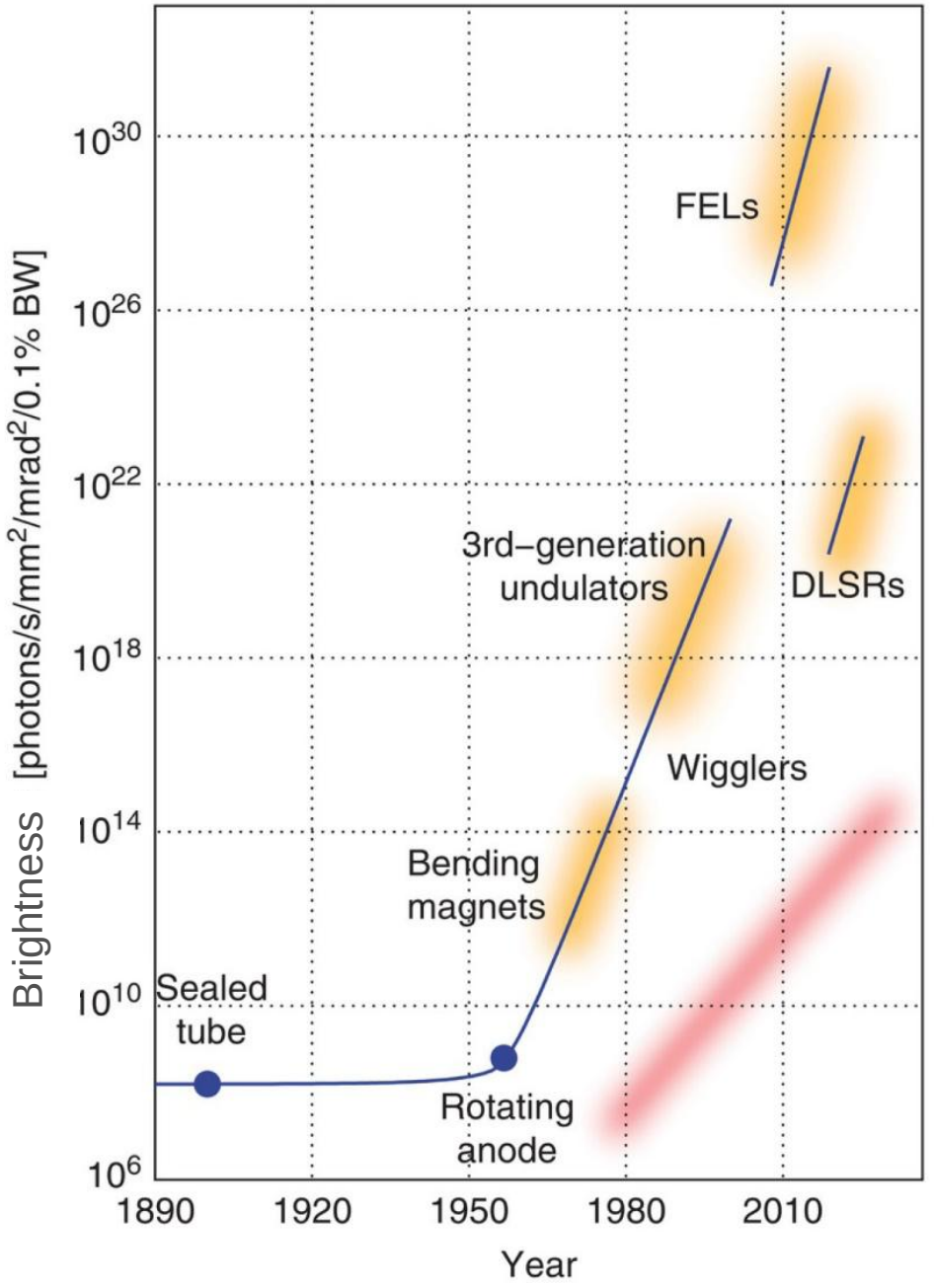
Introduction



Introduction

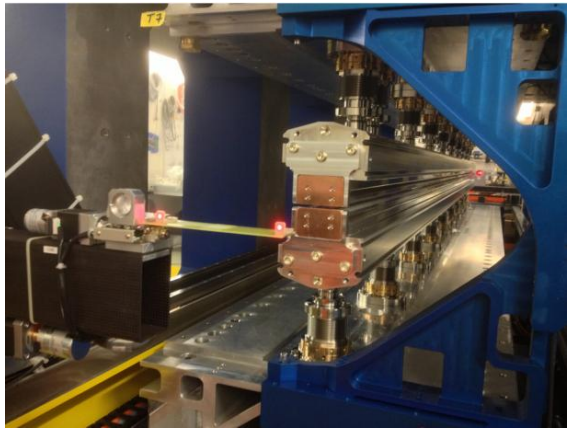


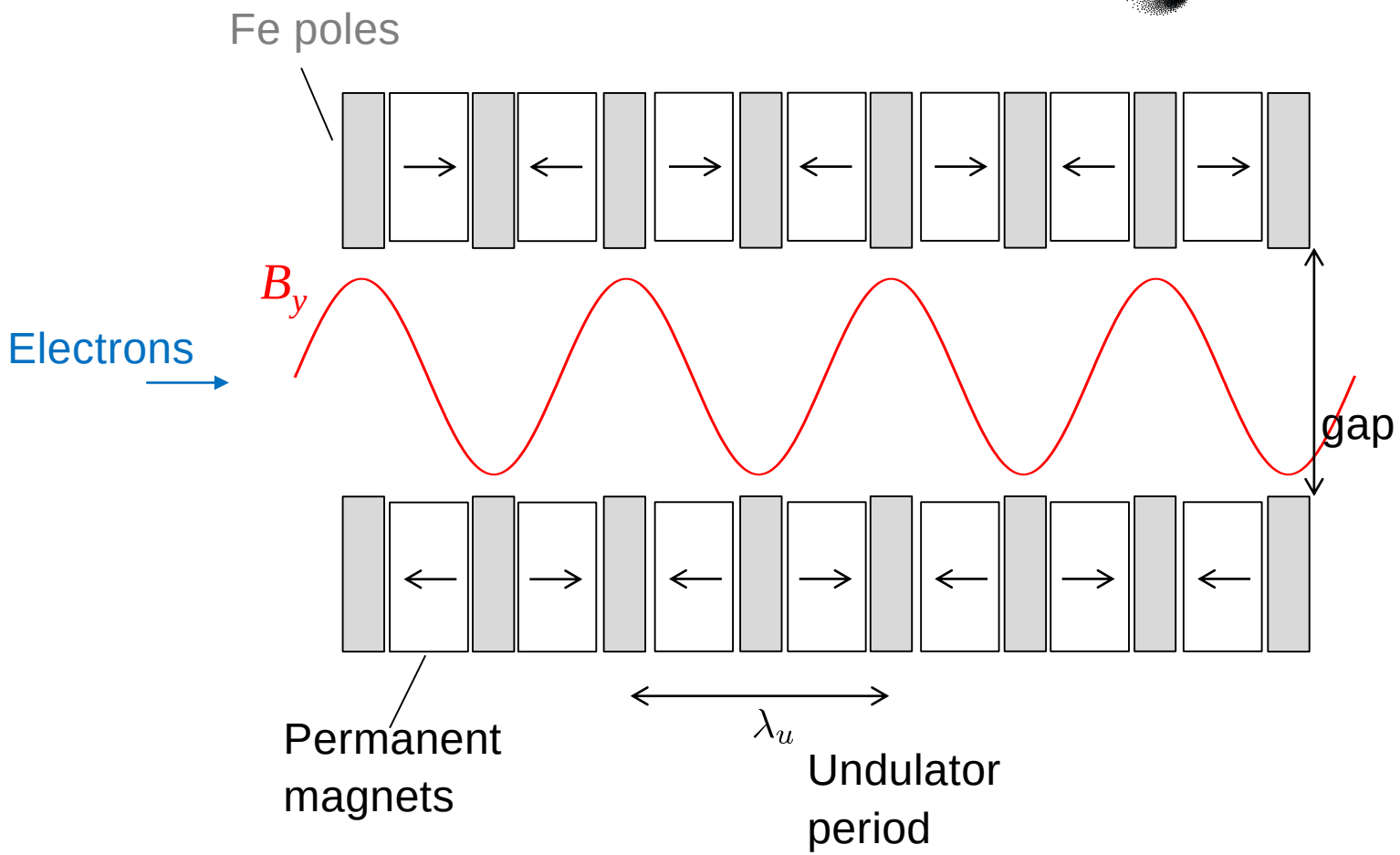




Introduction



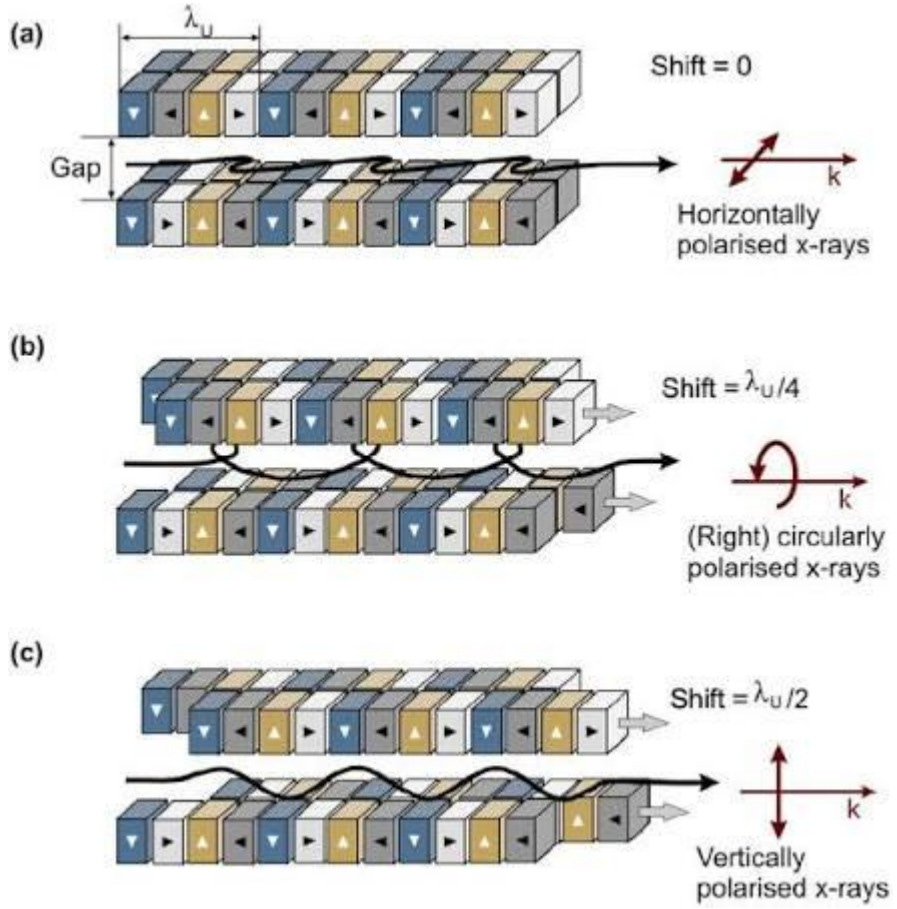




Synchrotron radiation is achieved with the use of oscillating electrons, typically produced by undulators

$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{1}{2}K^2\right) \qquad K \propto B_0\lambda_u$$

Introduction



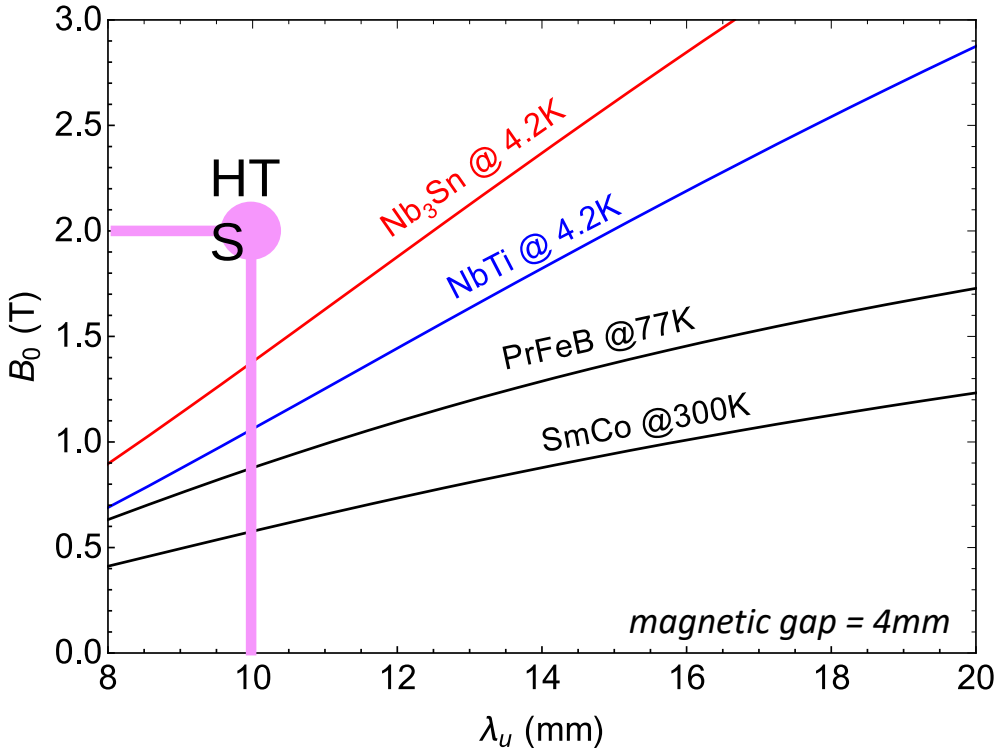
$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{1}{2}K^2\right) \qquad K \propto B_0\lambda_u$$

Different magnetic fields produce different light polarizations

Introduction

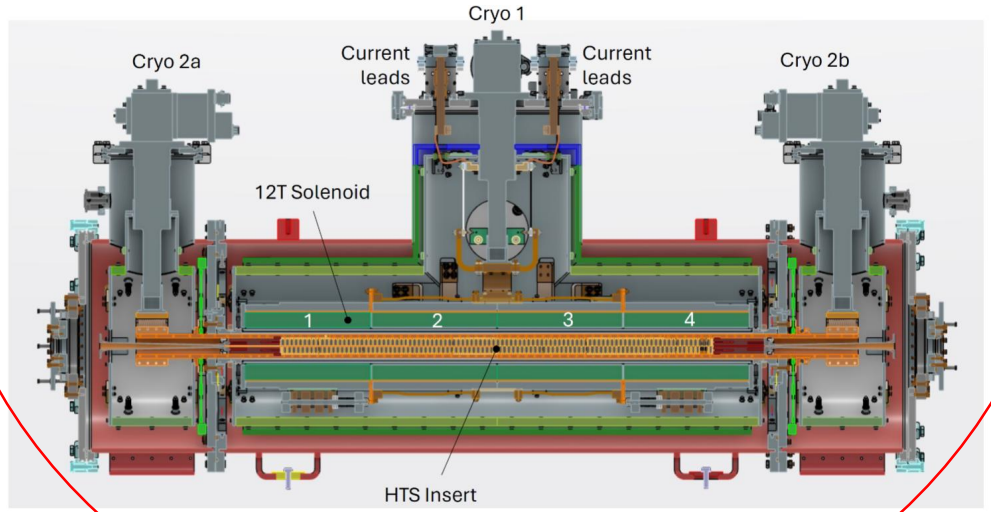
To increase the flux and energy of synchrotron radiation, need higher magnetic fields and lower undulator period

$$\lambda = \frac{\lambda_u}{2n\gamma^2}\left(1+\frac{1}{2}K^2\right) \qquad K = \frac{B_0 e}{mc}\frac{\lambda_u}{2\pi}$$

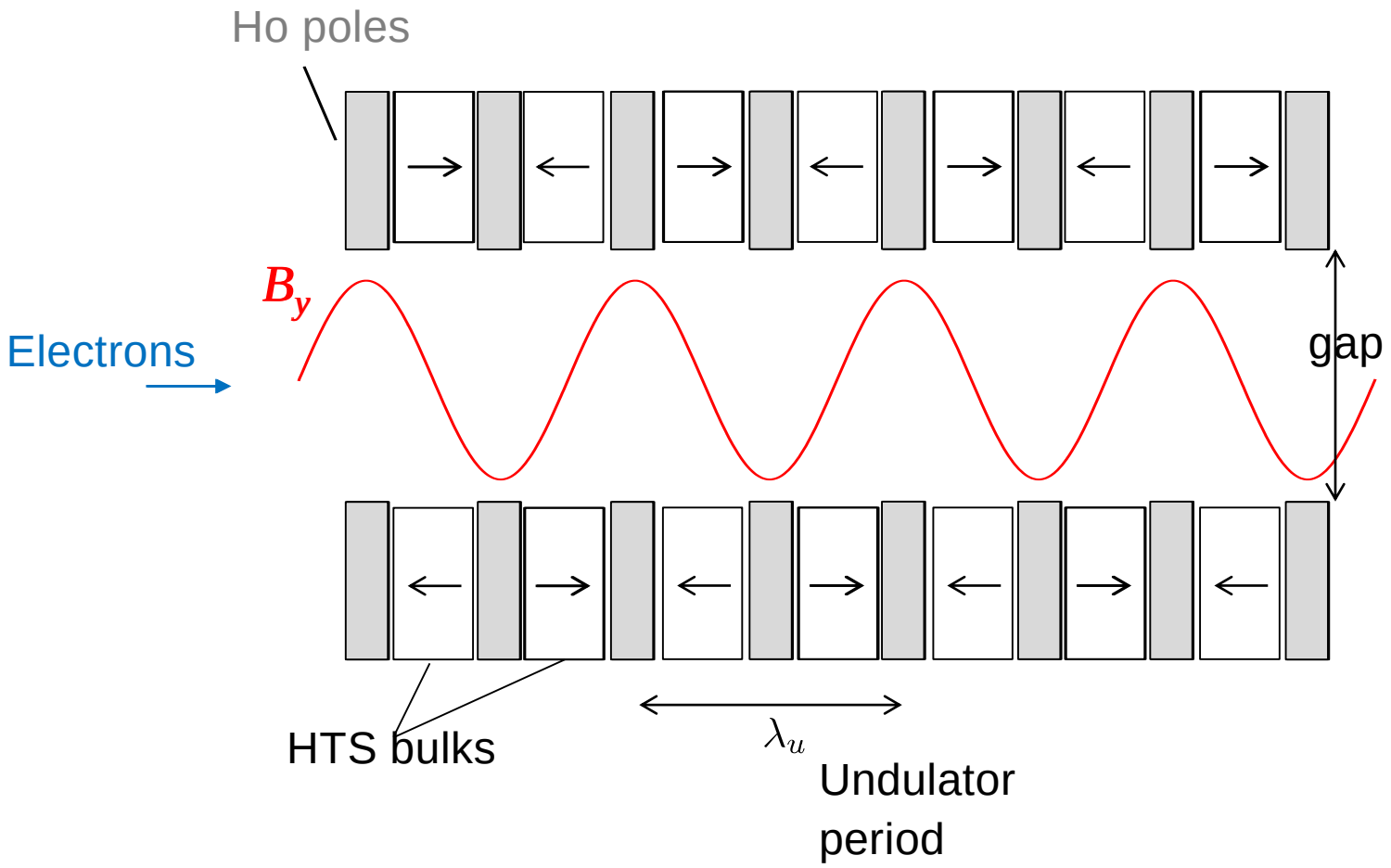


2 HTS undulator architectures investigated at PSI

Bulk HTS undulator



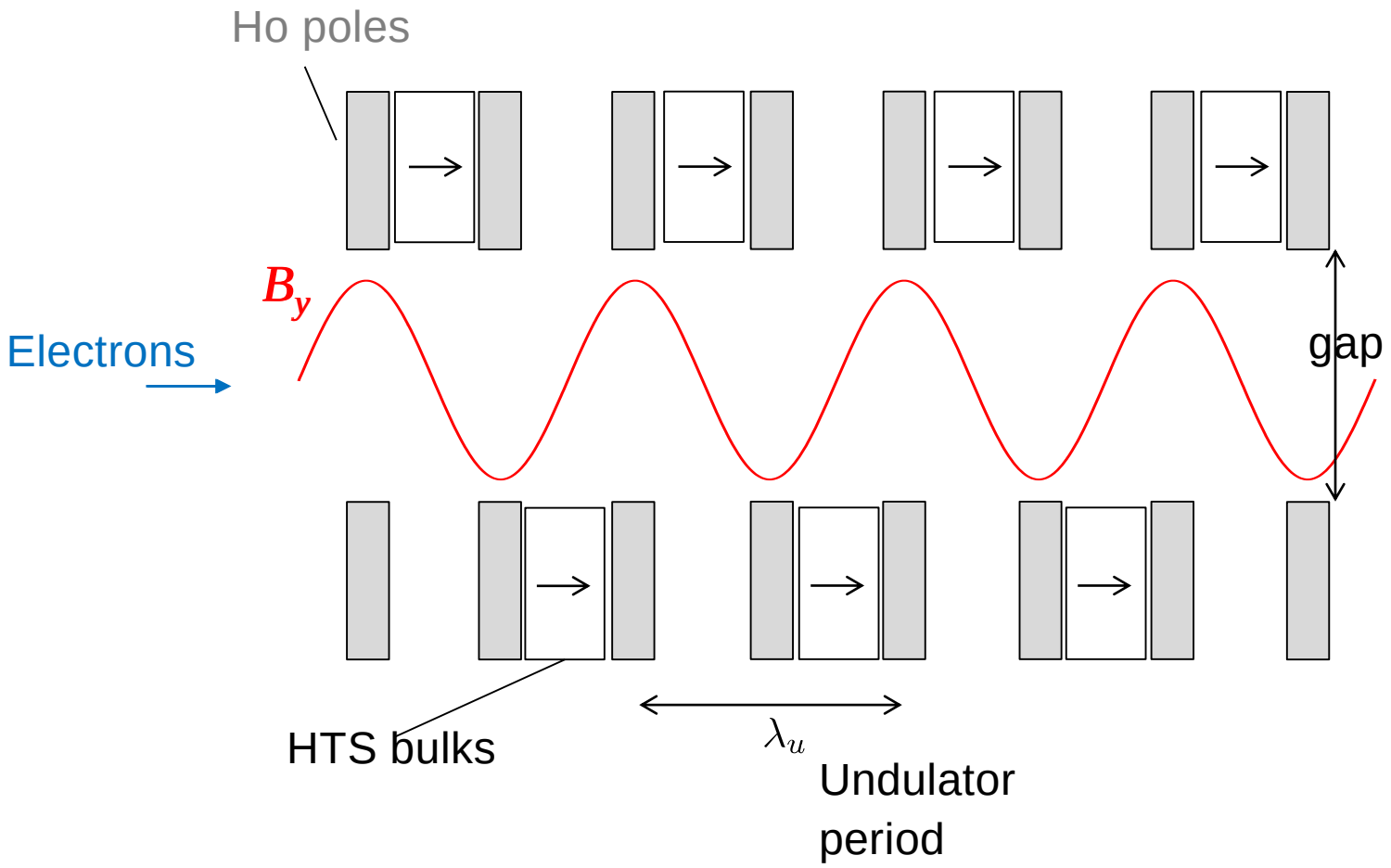
HTS bulk undulator



- HTS bulks have higher engineering current density than HTS tapes
- Aim: 2T at 10mm period and 4mm gap

$$\lambda = \frac{\lambda_u}{2n\gamma^2}\left(1+\frac{1}{2}K^2\right) \qquad K = \frac{B_0 e}{mc}\frac{\lambda_u}{2\pi}$$

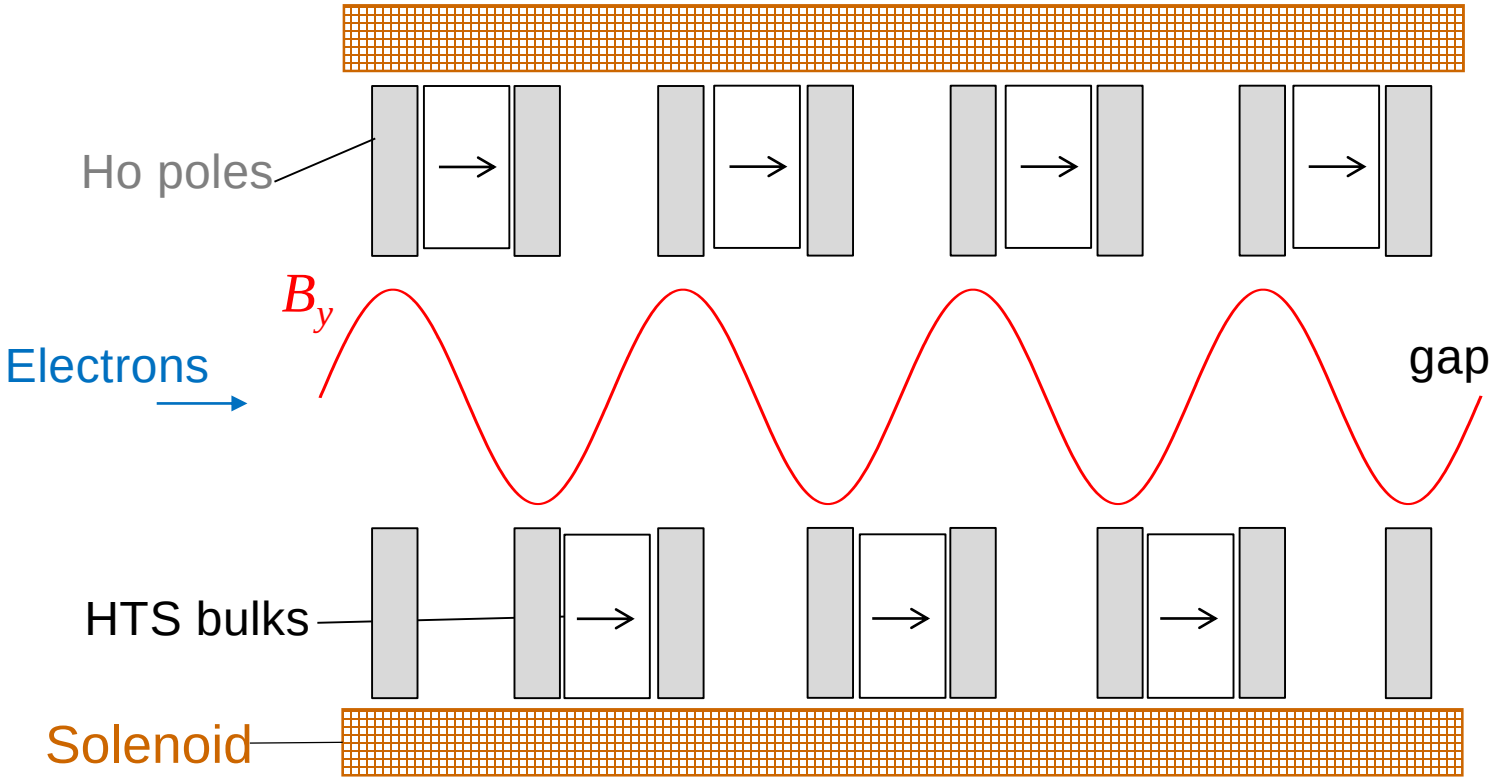
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HTS bulk undulator

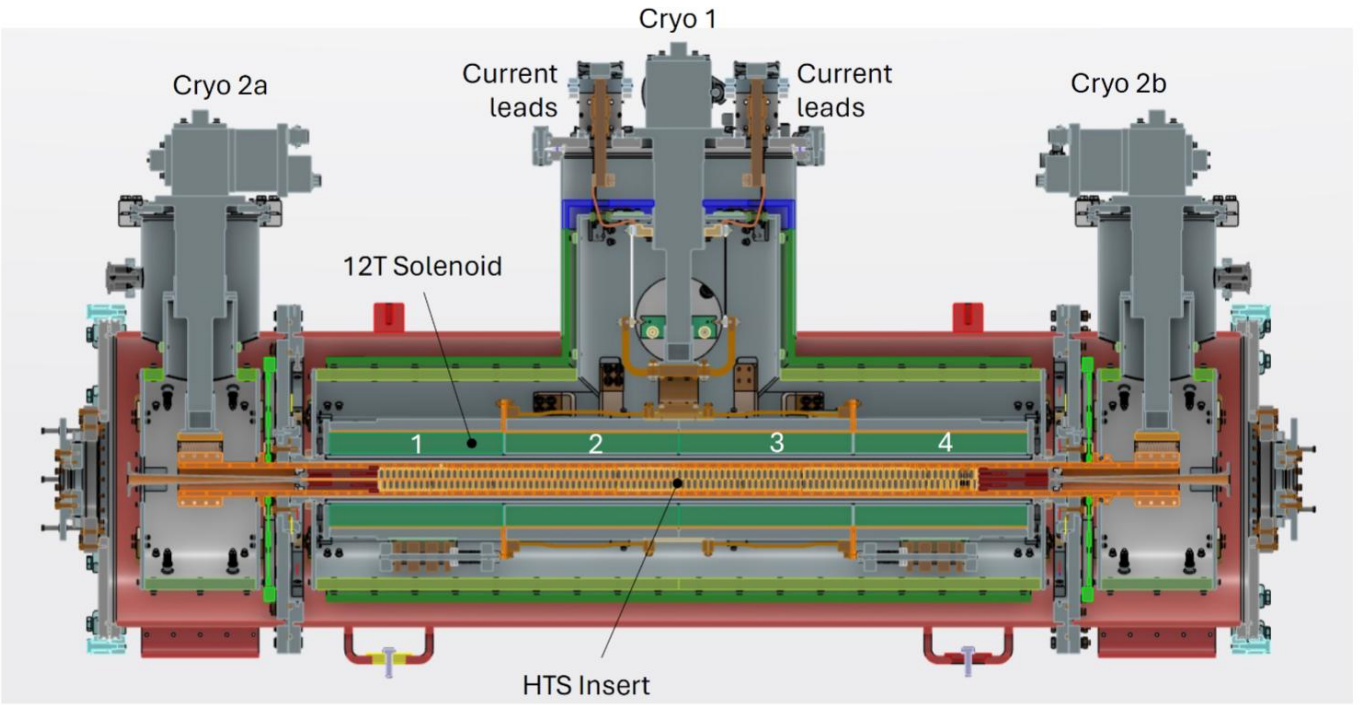


- HTS bulks have higher engineering current density than HTS tapes
- Aim: 2T at 10mm period and 4mm gap

$$\lambda = \frac{\lambda_u}{2n\gamma^2}\left(1+\frac{1}{2}K^2\right) \qquad K = \frac{B_0 e}{mc}\frac{\lambda_u}{2\pi}$$

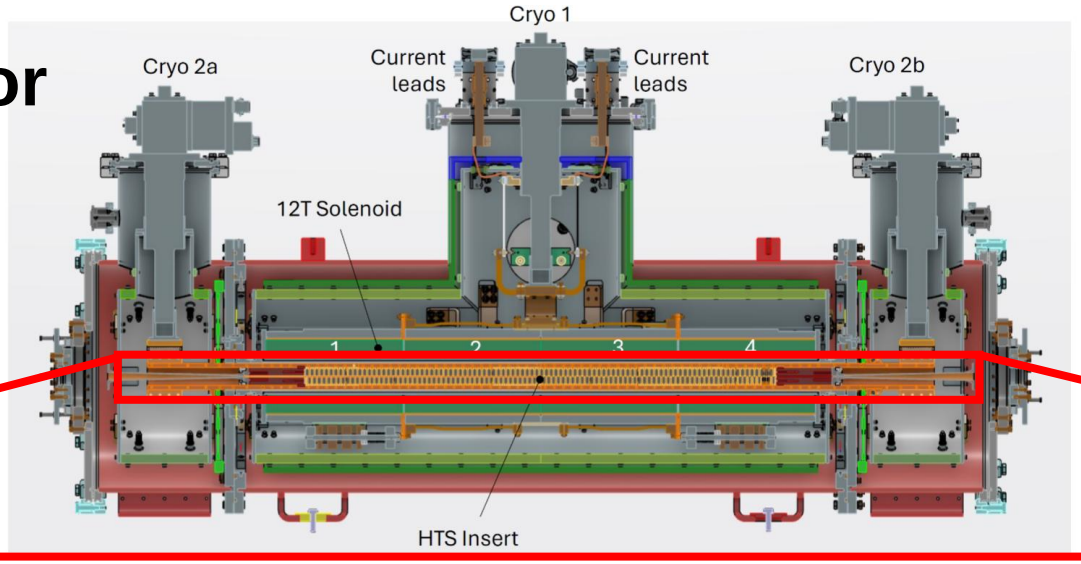
HTS bulk undulator

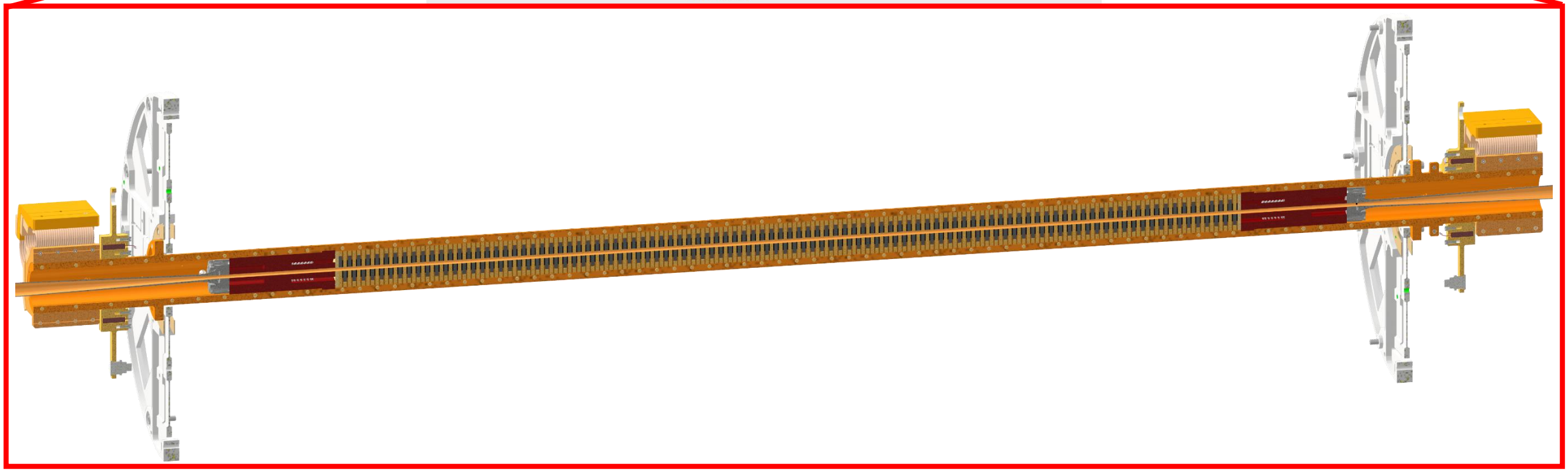
- Design of the full undulator



HTS bulk undulator

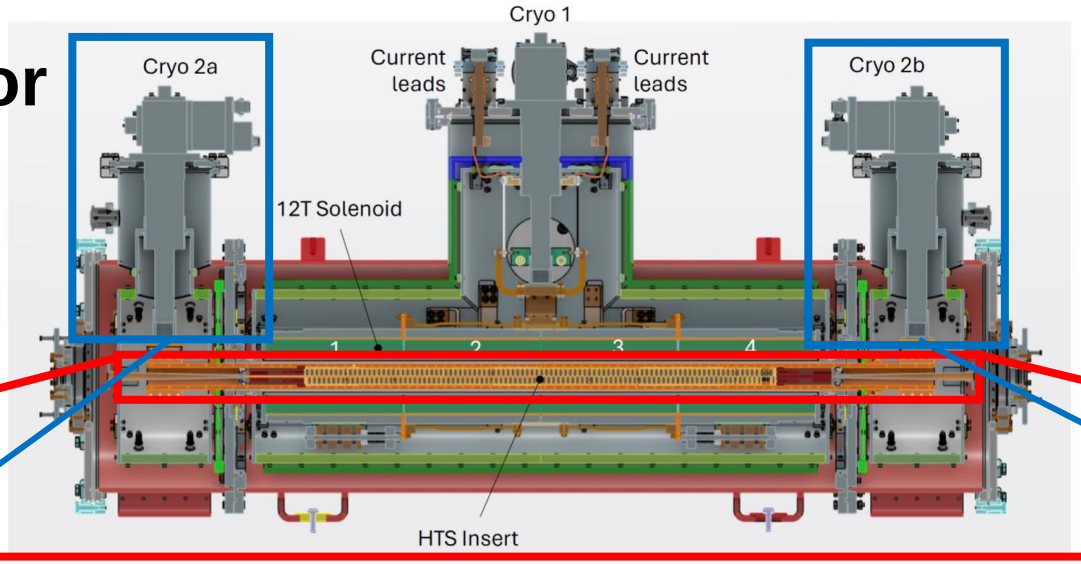
HTS insert





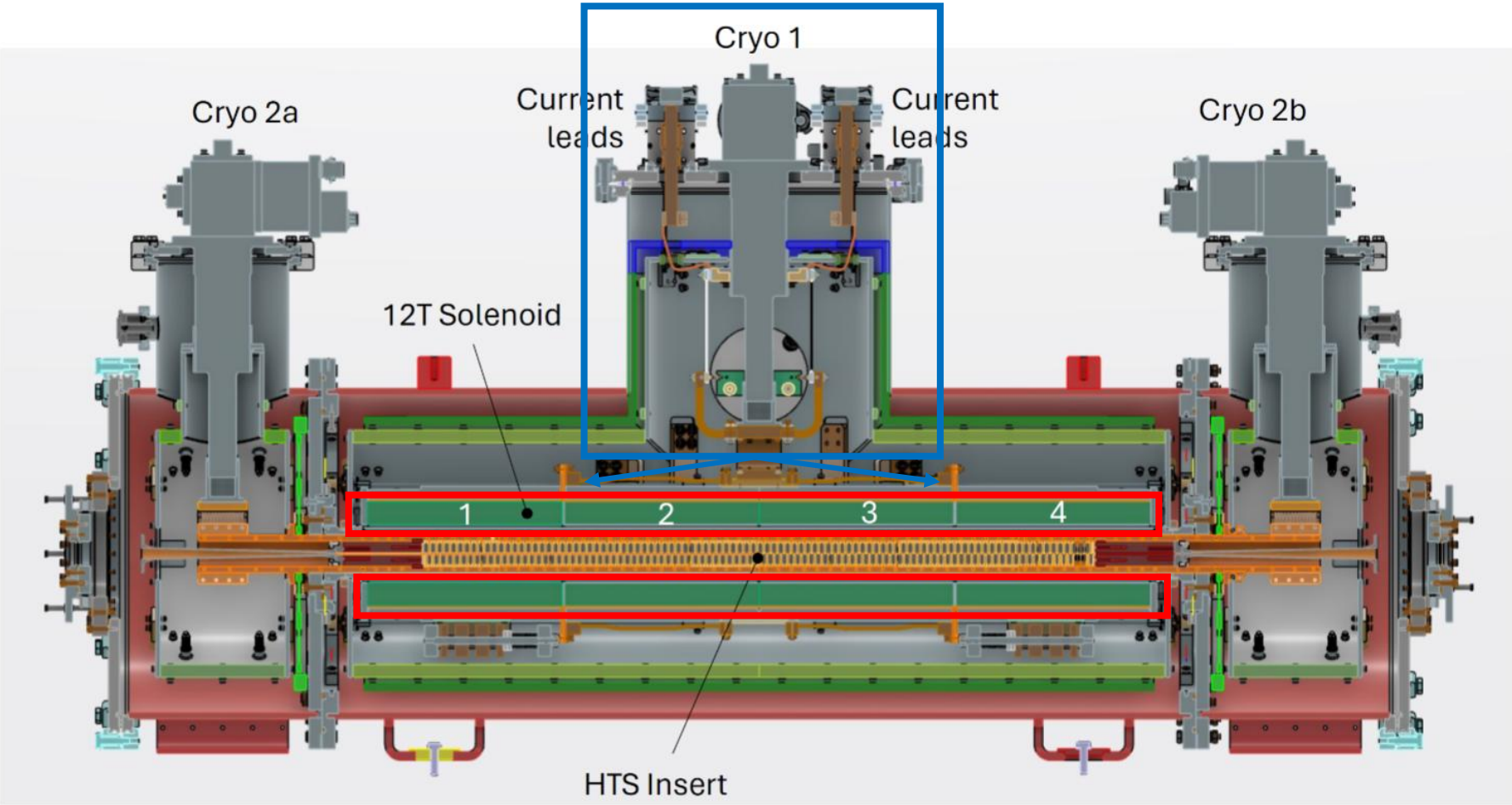
HTS bulk undulator

HTS insert cooling

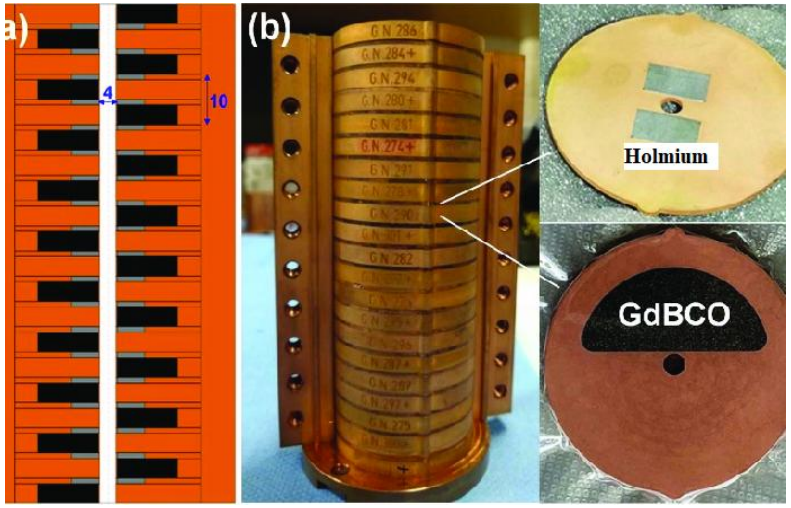


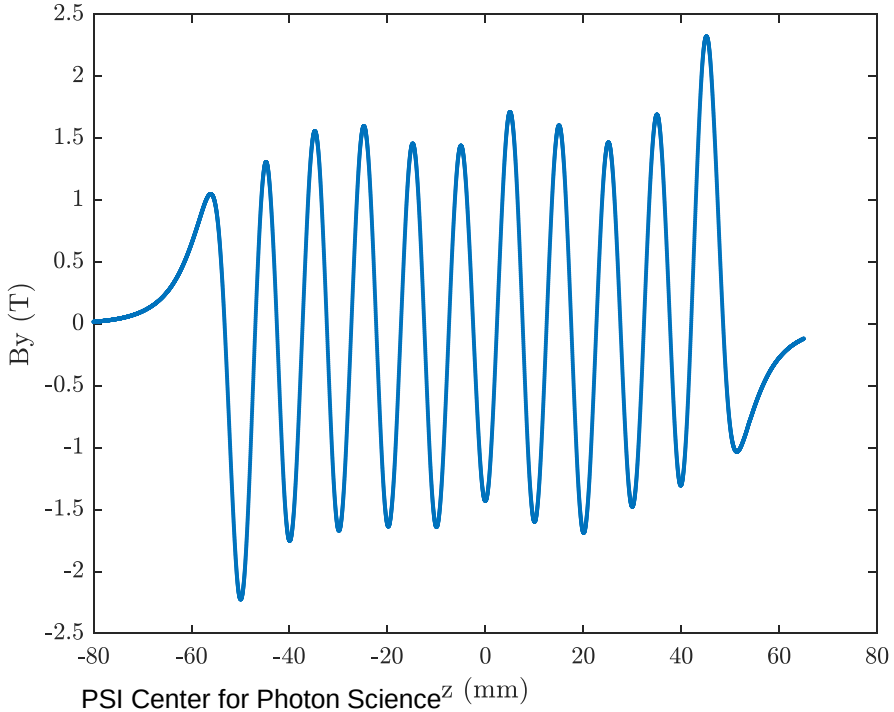
HTS bulk undulator

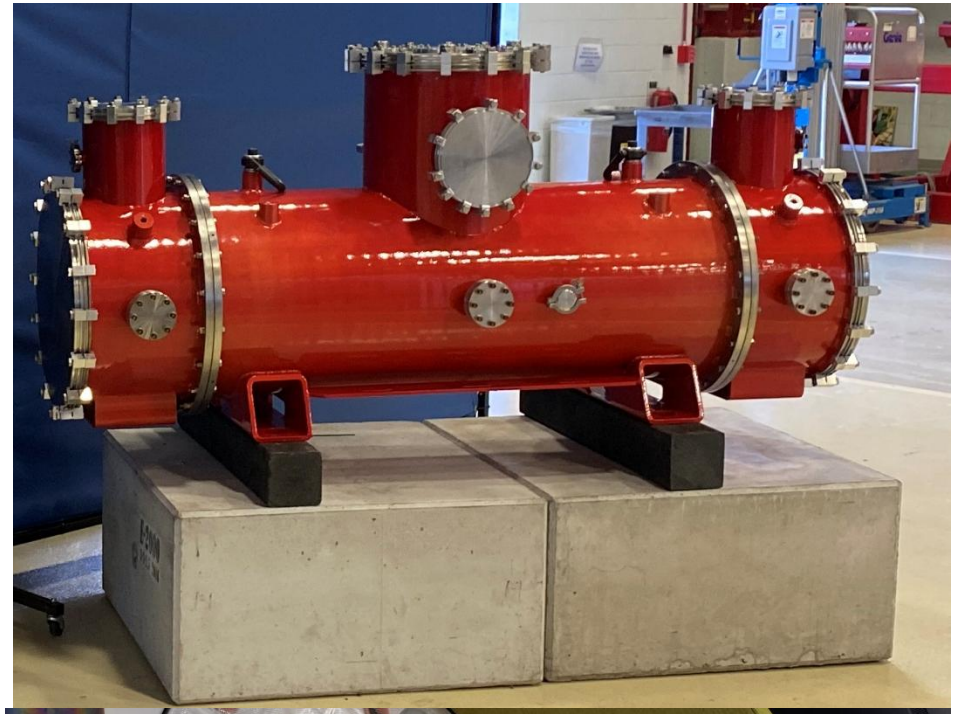
Solenoid cooling



HTS bulk undulator



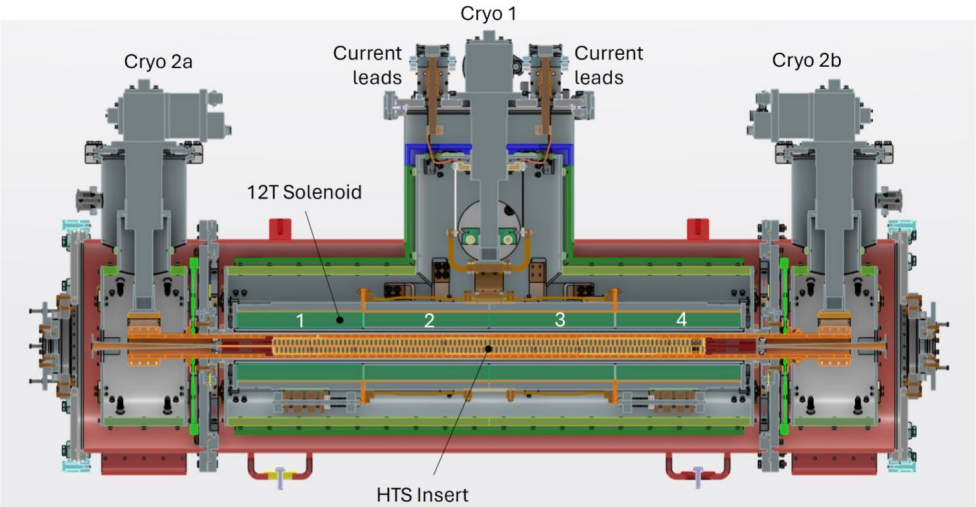




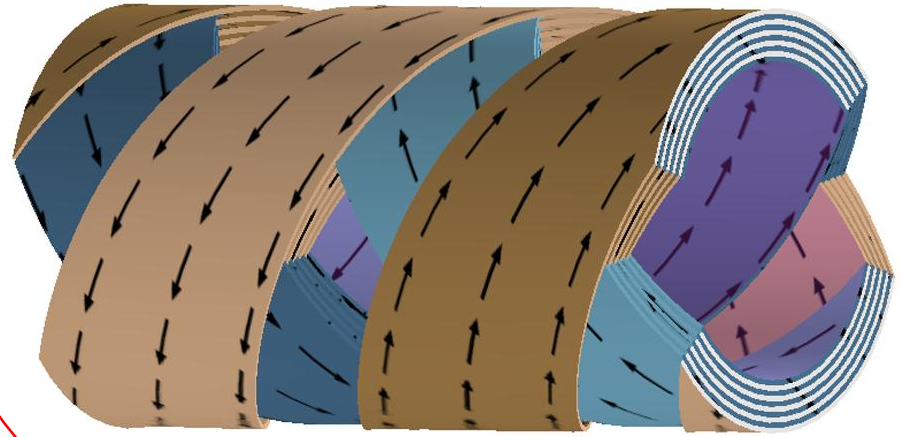


2 HTS undulator architectures investigated at PSI

Bulk HTS undulator

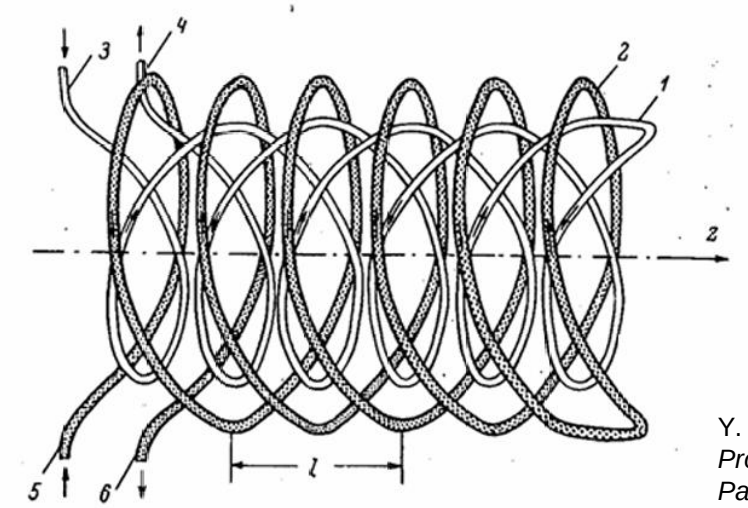


CASPerLE

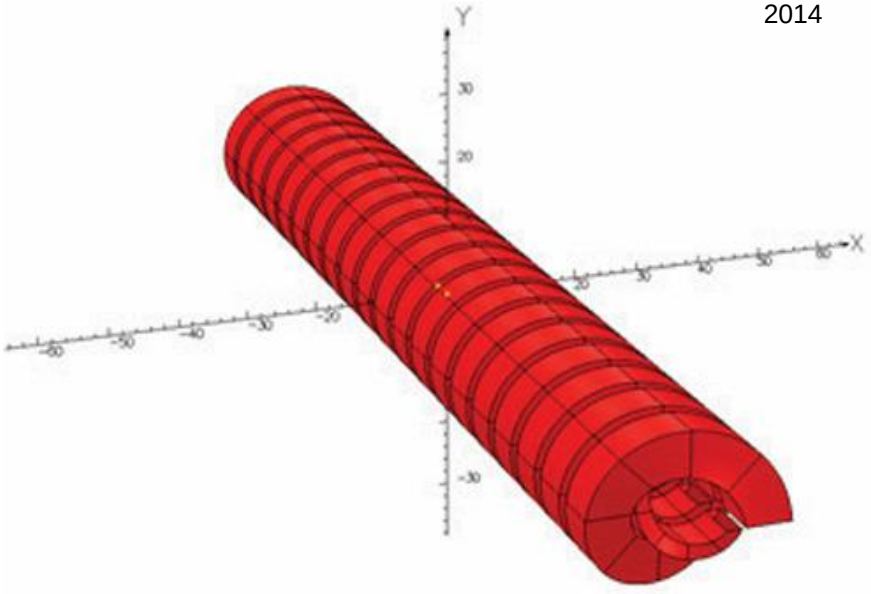


CASPerLE undulator

- Universal superconducting undulator
- Concentric helical undulators
- Inner helix -> Right-handed
- Outer helix -> Left-handed

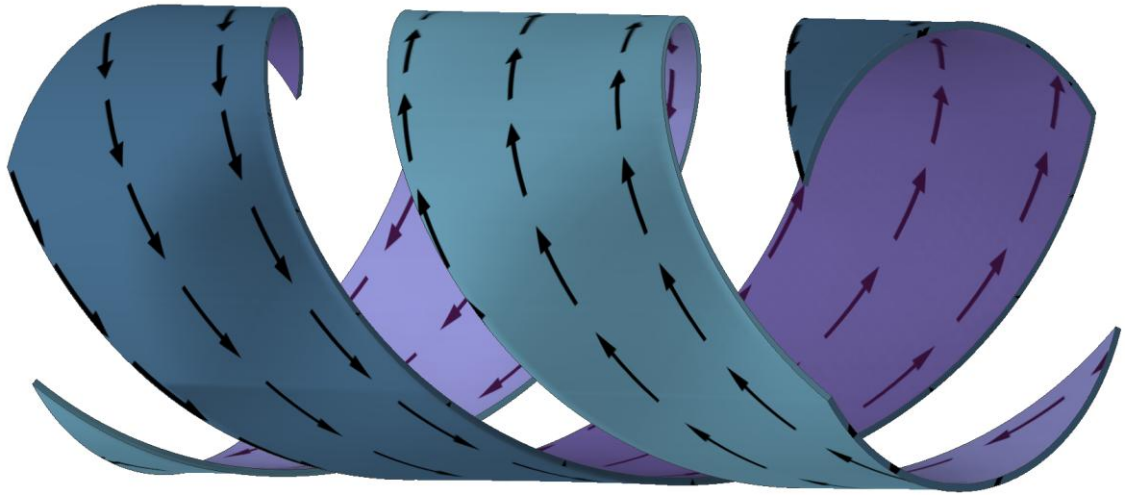


Y. Ivanyushenkov, *Proceedings of the 5th Int. Particle Accelerator Conf.*, vol. IPAC2014, p. 3 pages, 2014



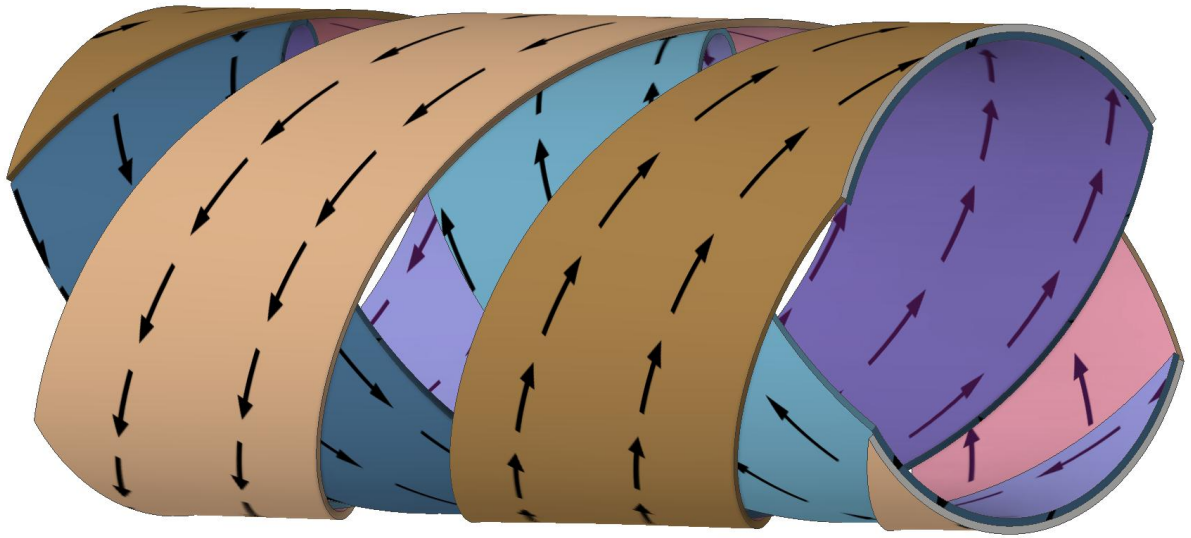
CASPerLE undulator

CASPER undulator: Intertwined helices
Layer 1



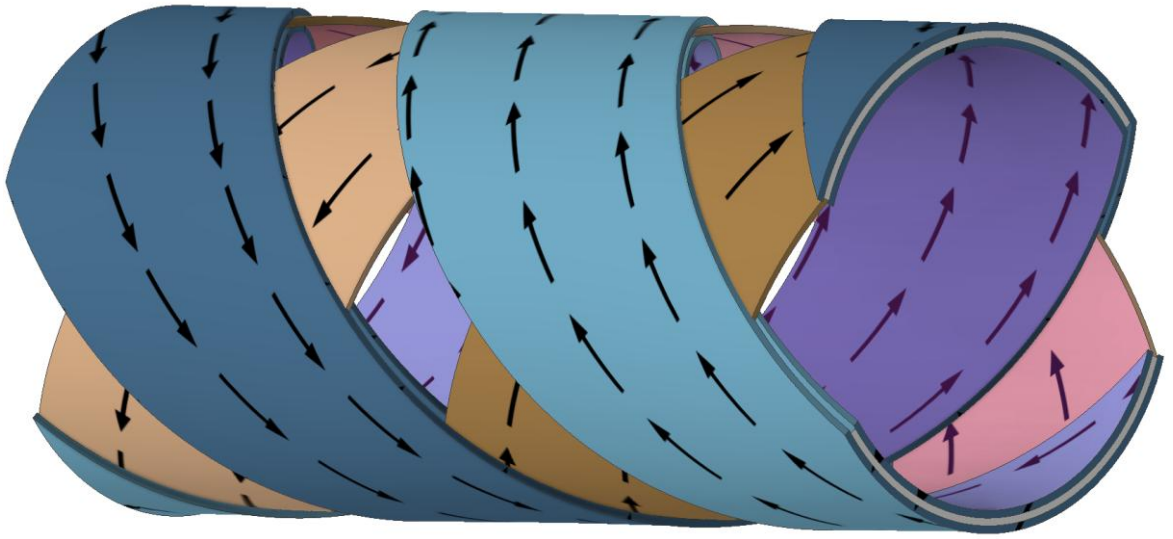
CASPerLE undulator

CASPER undulator: Intertwined helices
Layer 2



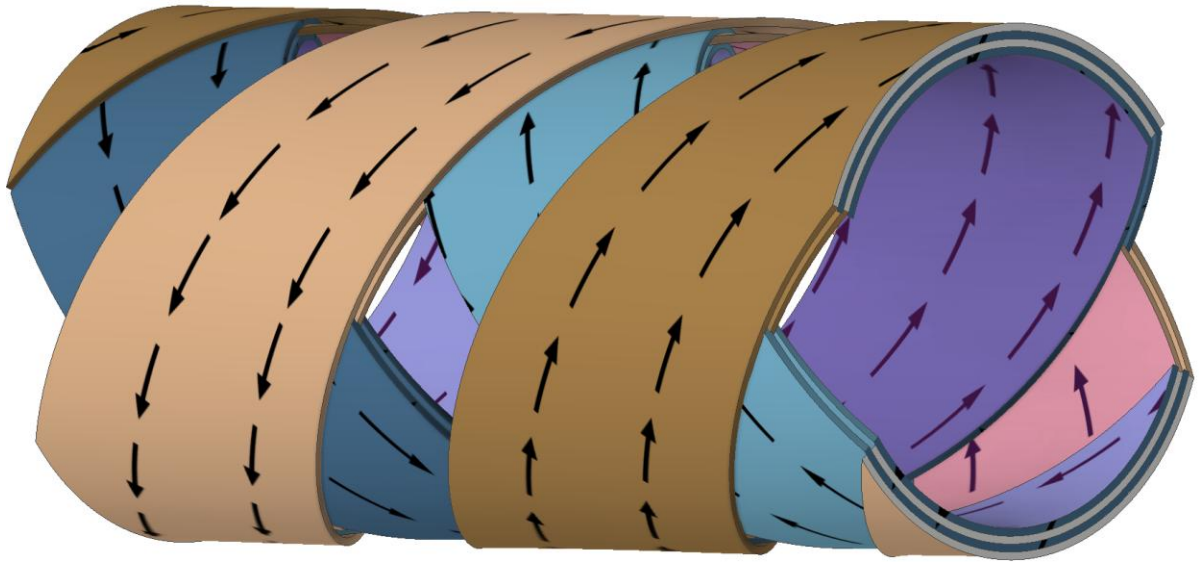
CASPerLE undulator

CASPER undulator: Intertwined helices
Layer 3



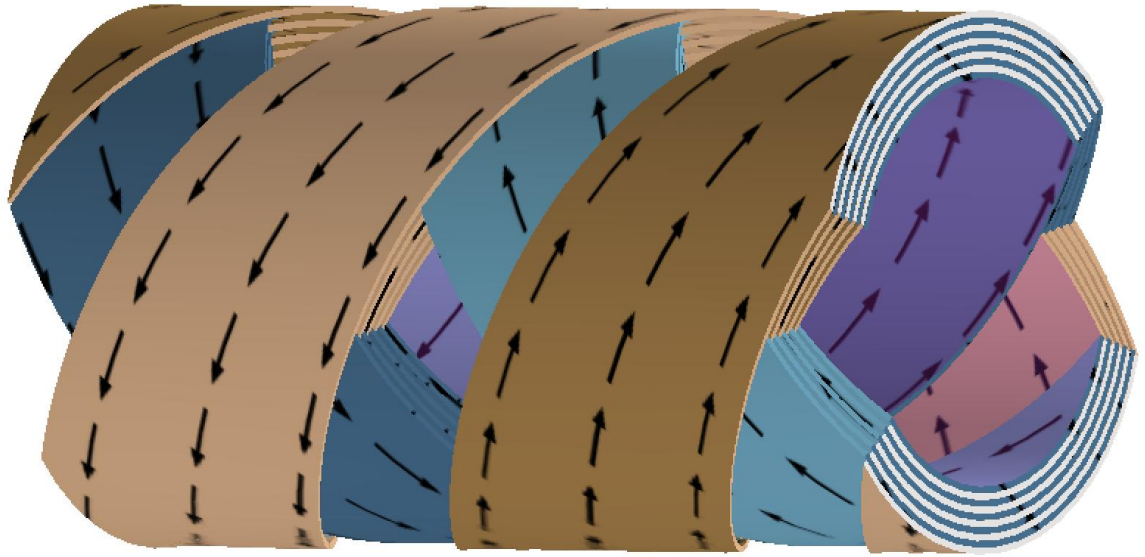
CASPerLE undulator

CASPER undulator: Intertwined helices
Layer 4

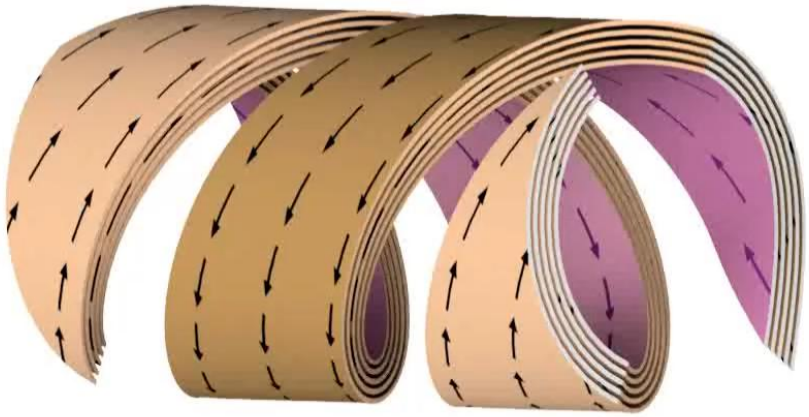


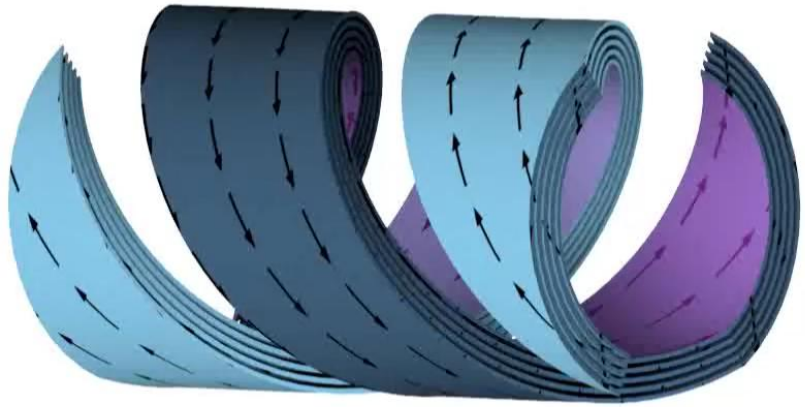
CASPerLE undulator

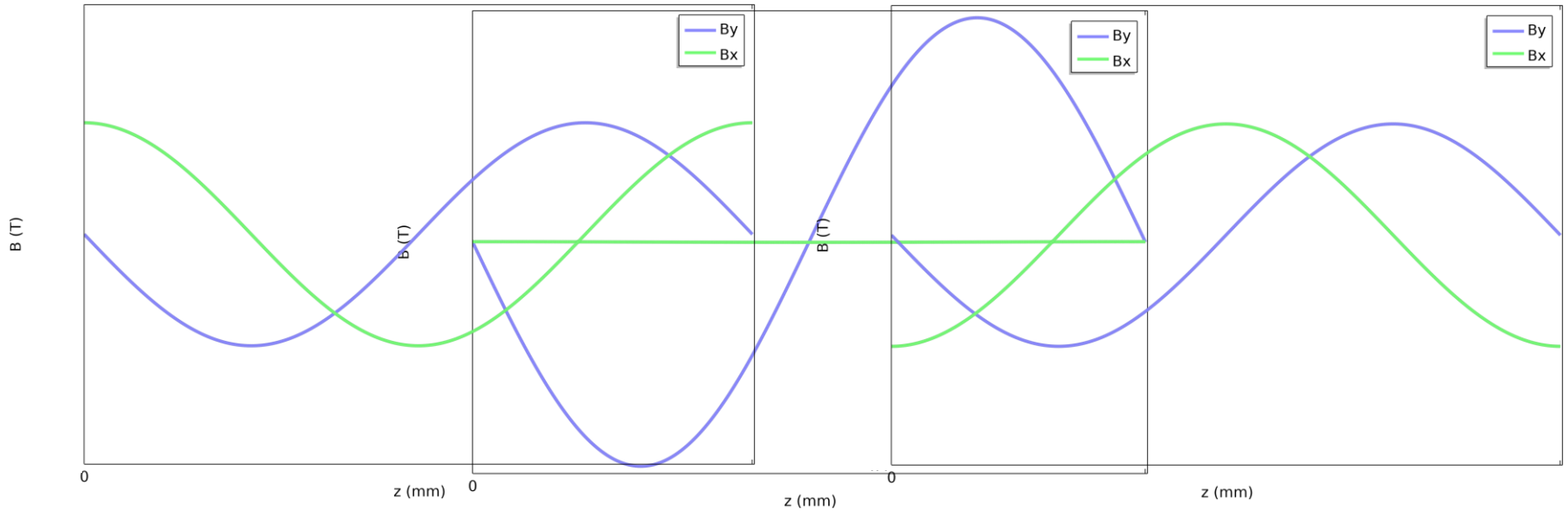
CASPER undulator: Intertwined helices
Layer 10



CASPerLE undulator





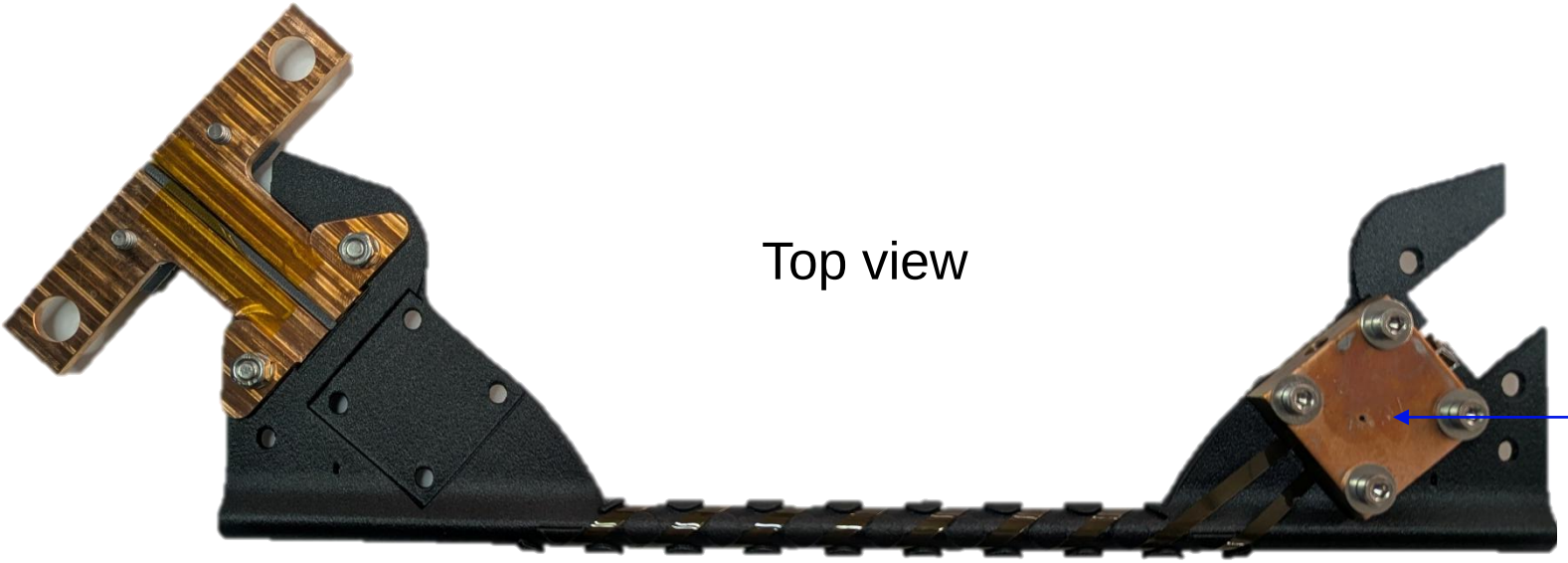


CASPerLE undulator

Half coil

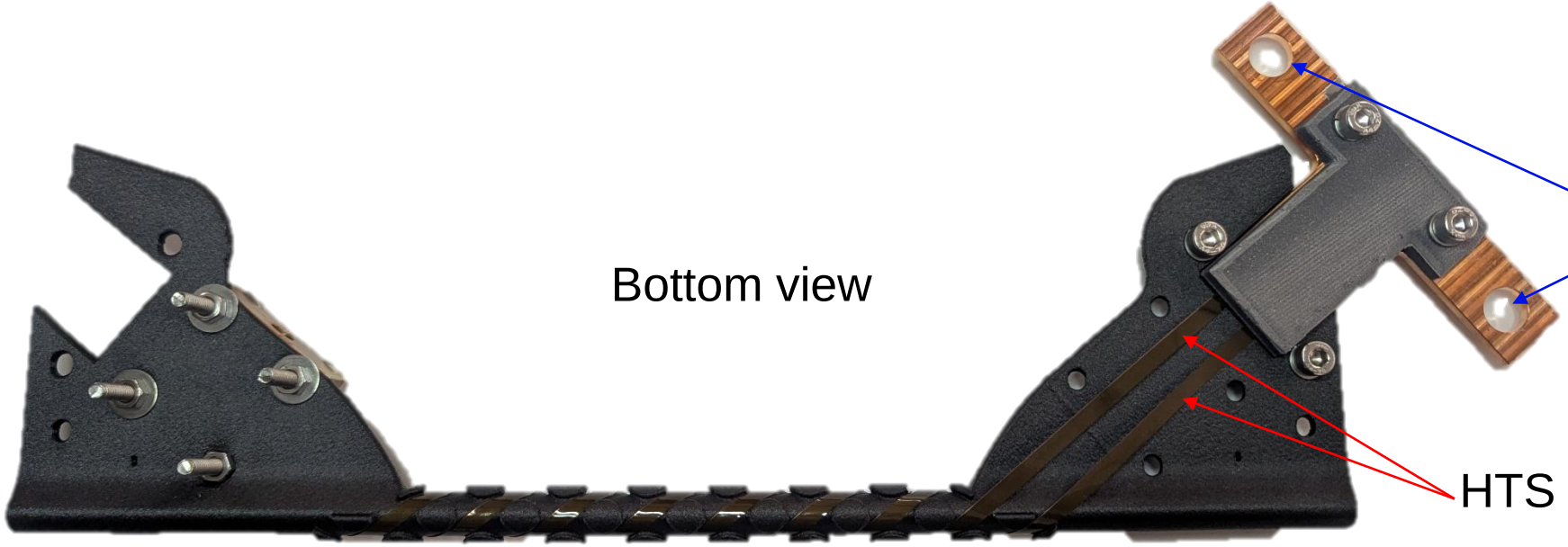
Mandrel 3D printed from carbon fiber reinforced nylon (PA6-CF20)

Top view



HTS joint

Bottom view

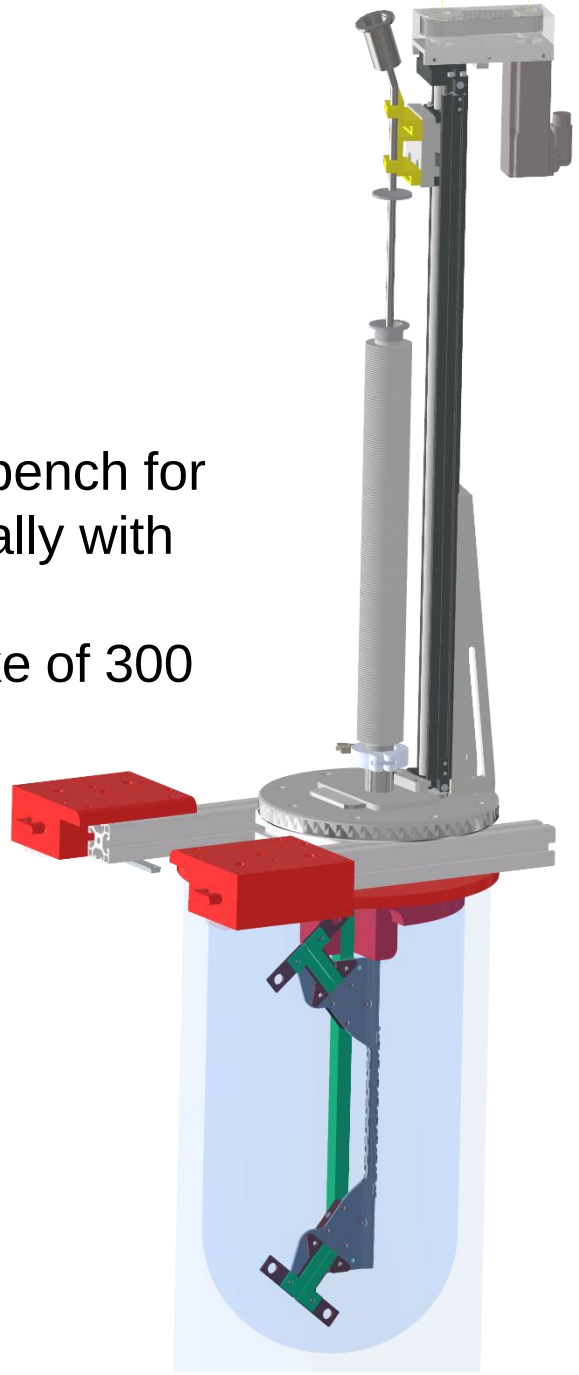


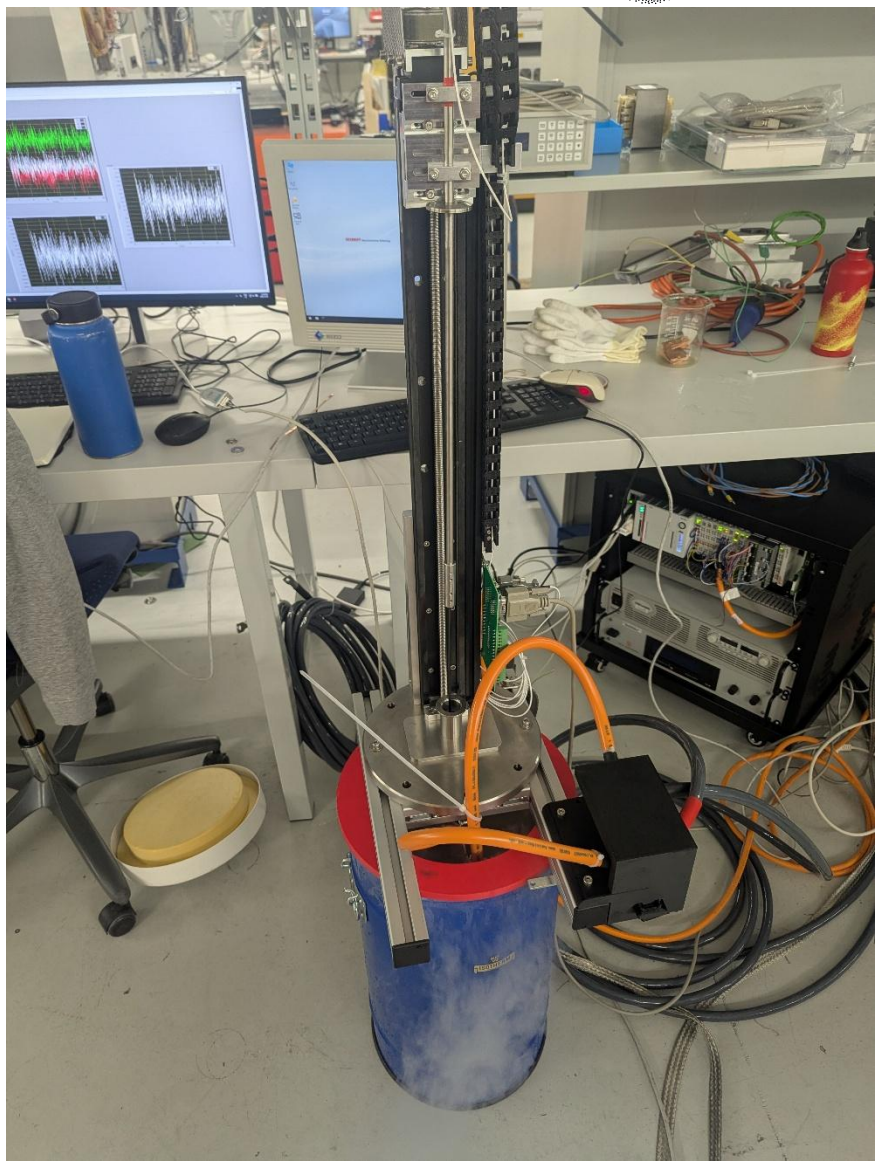
Current leads

HTS tapes with insulations

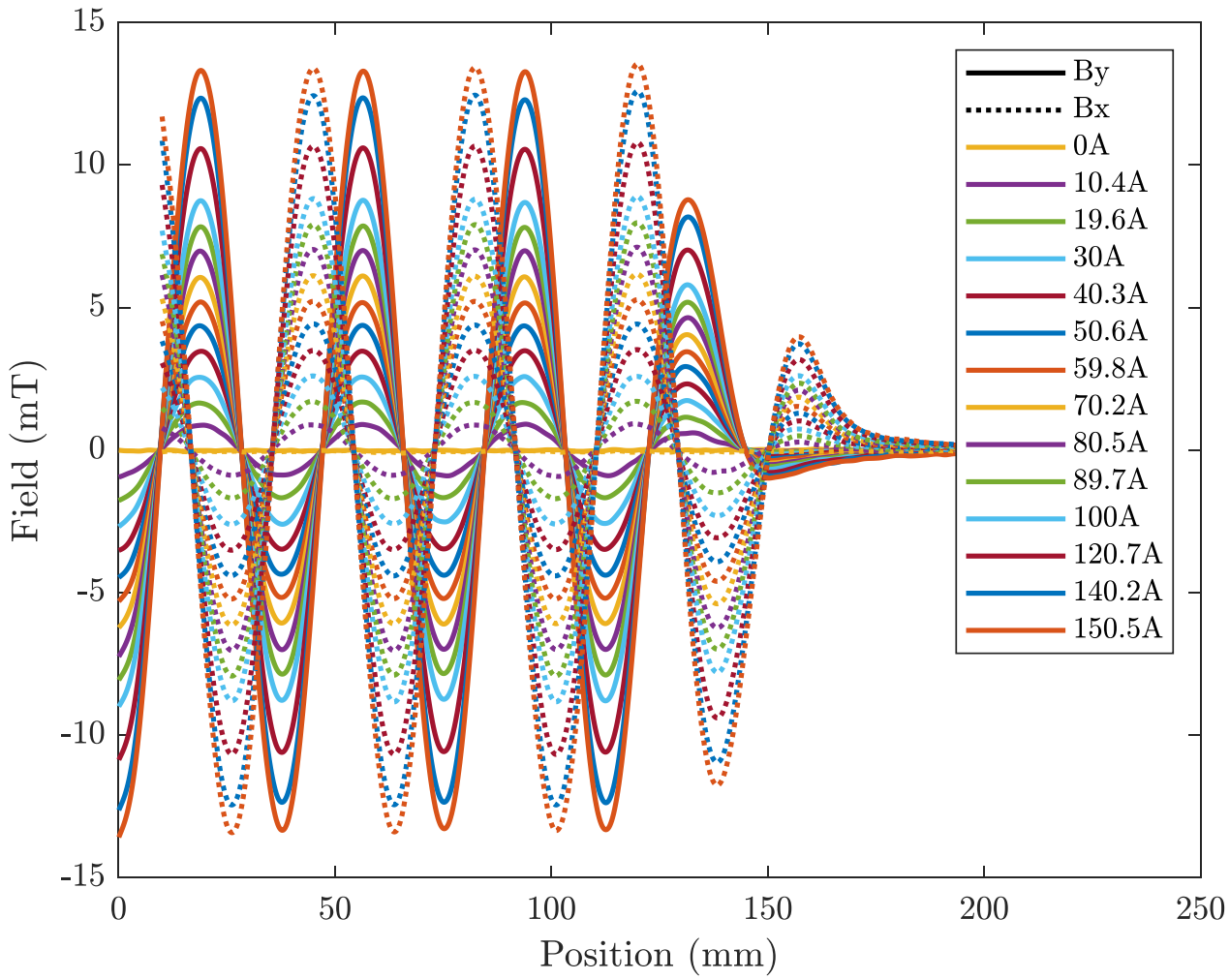
CASPerLE undulator

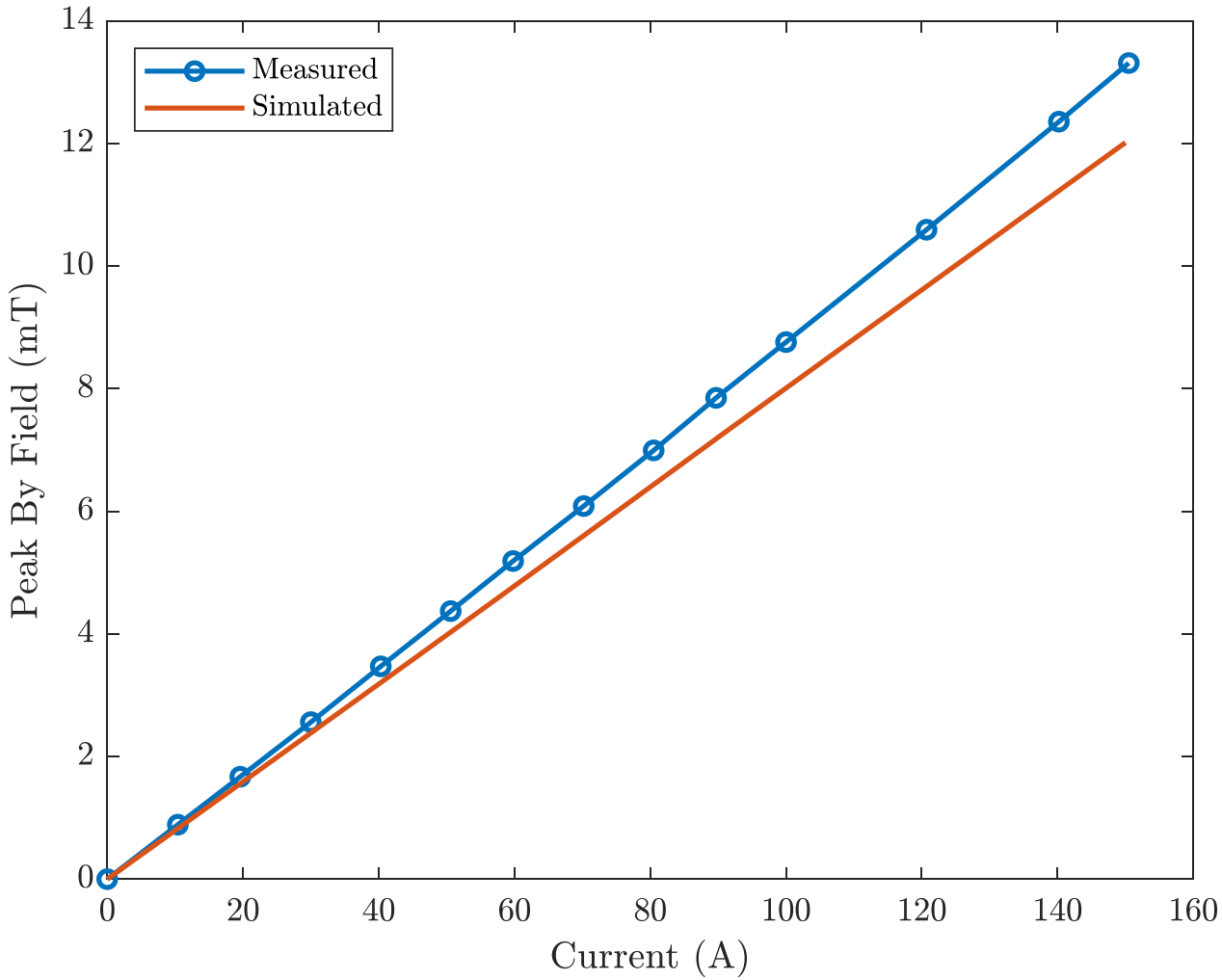
- Developed a vertical measurement bench for testing in liquid nitrogen and eventually with cryocoolers
- 3-axis Hall probe moves with a stroke of 300 mm





CASPerLE undulator





Conclusion

- 2 main HTS undulator concepts are being investigated at PSI
- HTS bulks are promising for achieving high fields at low period lengths
- The CASPerLE coils allow for variable polarization at small periods

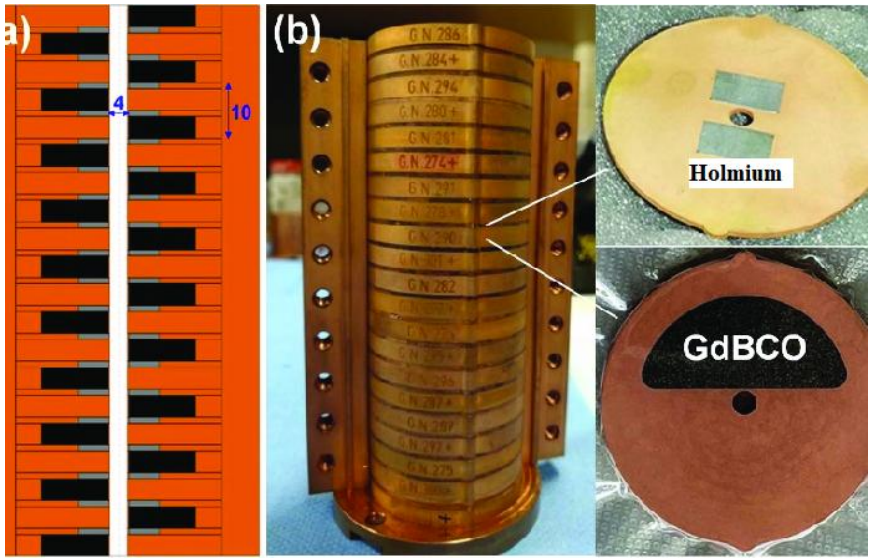
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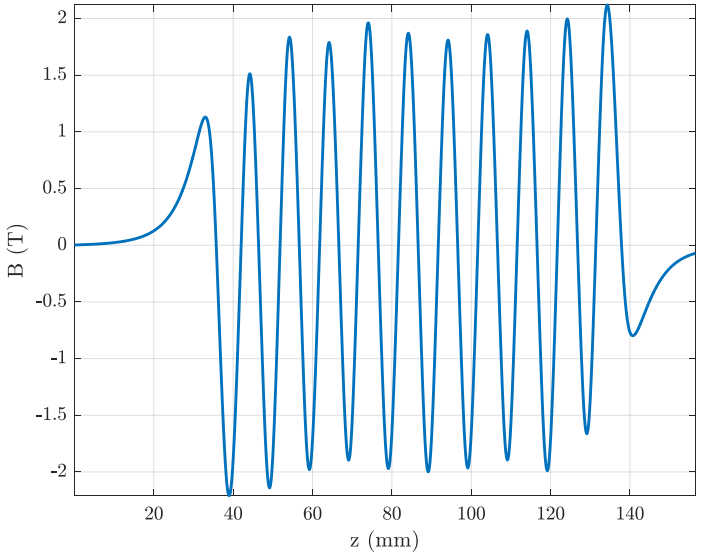
- *PSI* : M. Calvi, X.Liang, S.Hellmann, L.Huber, S.Reiche, M.Bartkowiak, C.Calzolaio, Prof. M. Stampanoni, Prof L.Patthey, F. Marone & G.Lovric
- CAN: Tomas Hlasek, Filip Antoncik & Jan Plechacek
- EUXFEL: T. Schmidt
- *CHART* : Prof. H.R.Ott & Prof. L.Rivkin
- *Uni Cambridge* : J.Durrell, A.Dennis, Y. Shi
- *King's College London*: M.Ainslie
- *Spring8* : T.Ishikawa, M.Yabashi, H.Tanaka
- *UniKyoto* : R.Kinjo, T.Kii, H.Ohgaki
- *Uni Malta* : N.Sammut, A.Sammut, J.Cassar
- *SENIS* : Prof.R.Popovic, S.Spasic, S.Dimitrijevic
- *KIT* : Prof. M.Noe
- *Fermilab*: C.Boffo, M.Turenne, F.McConologue, V.Martinez, J.Hayman
- Zhangjiang lab: K. Zhang, D. Wei



Introduction

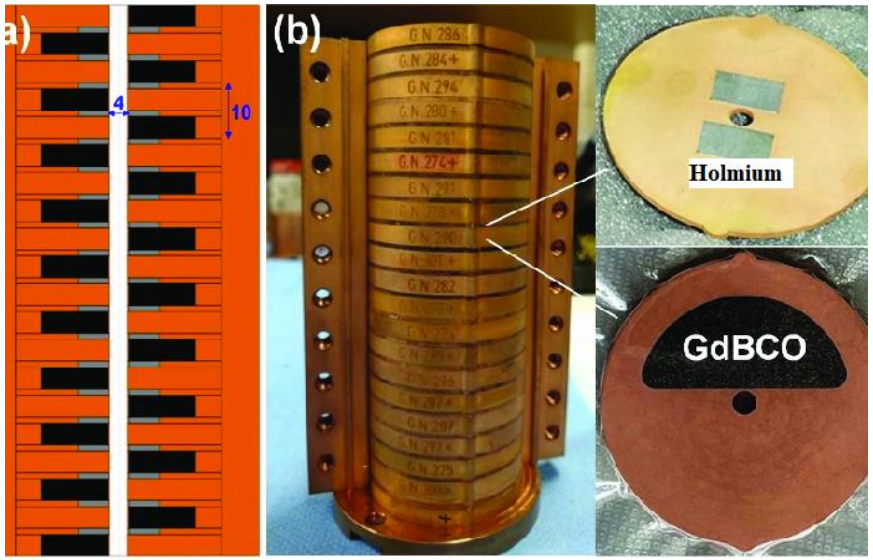
- Managed to get good experimental results on a 10 cm prototype

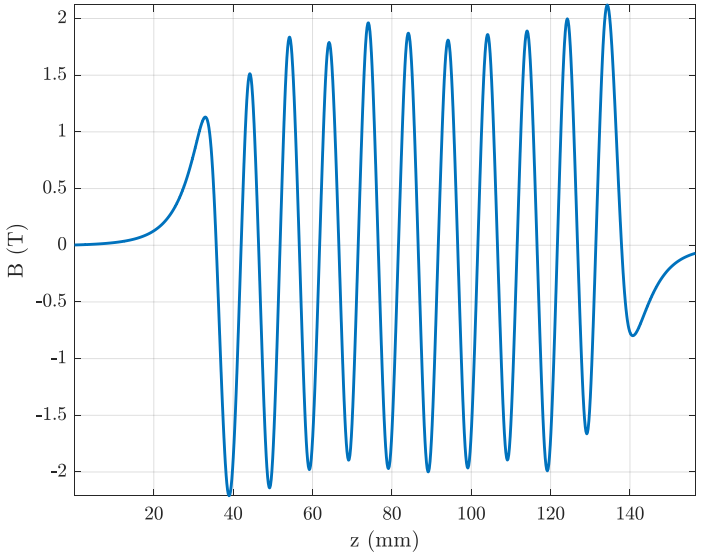




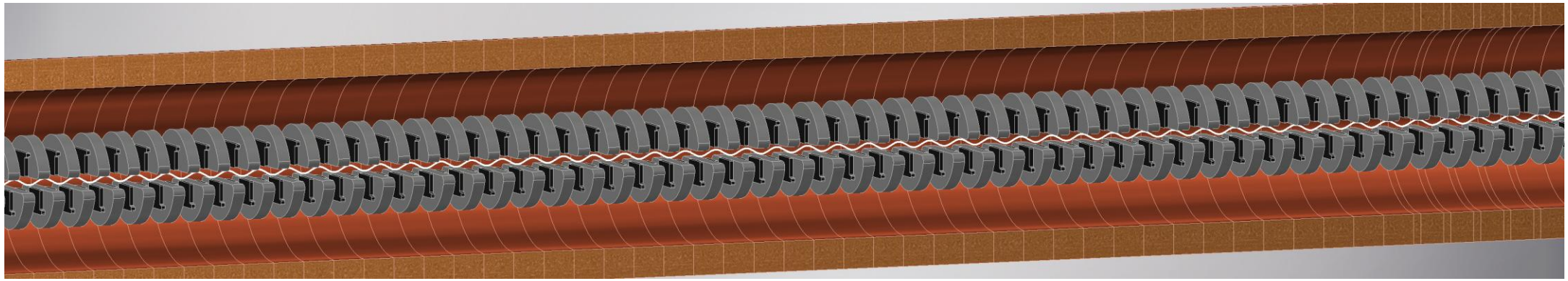
Introduction

- Managed to get good experimental results on a 10 cm prototype





- Next step, 200 bulks!



Aluminium thermal shield

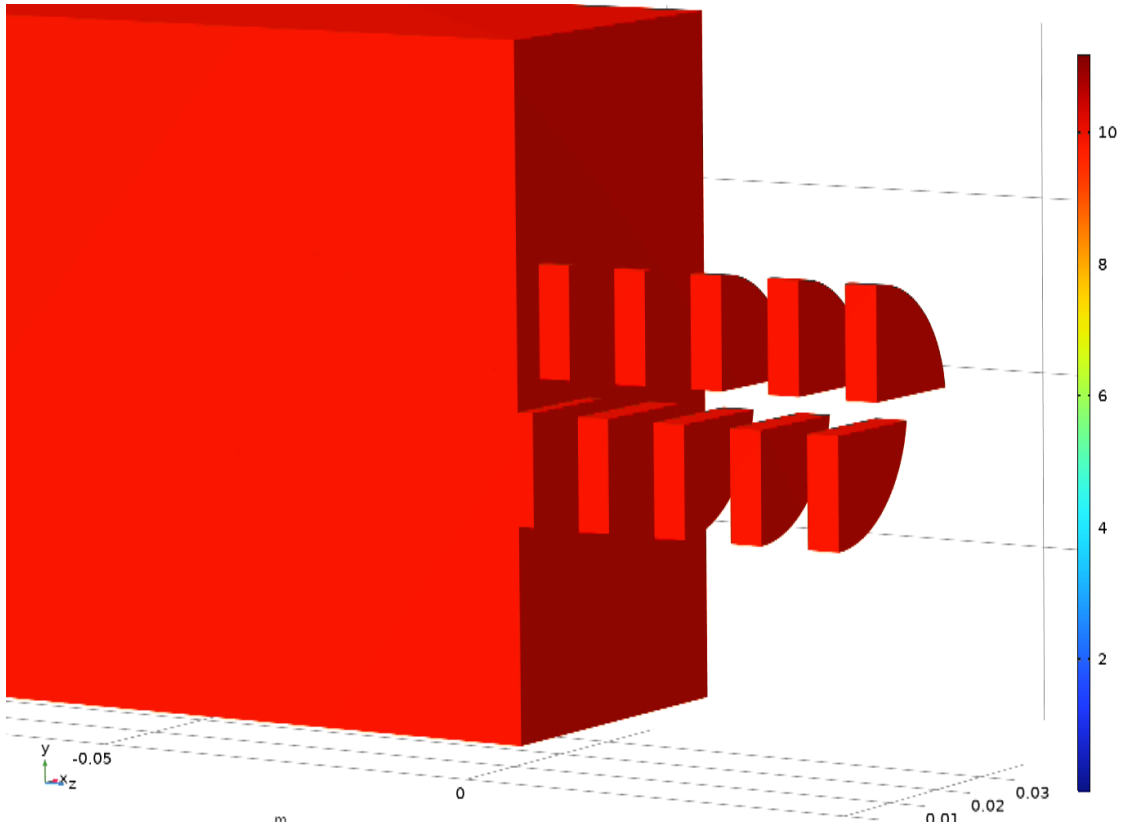


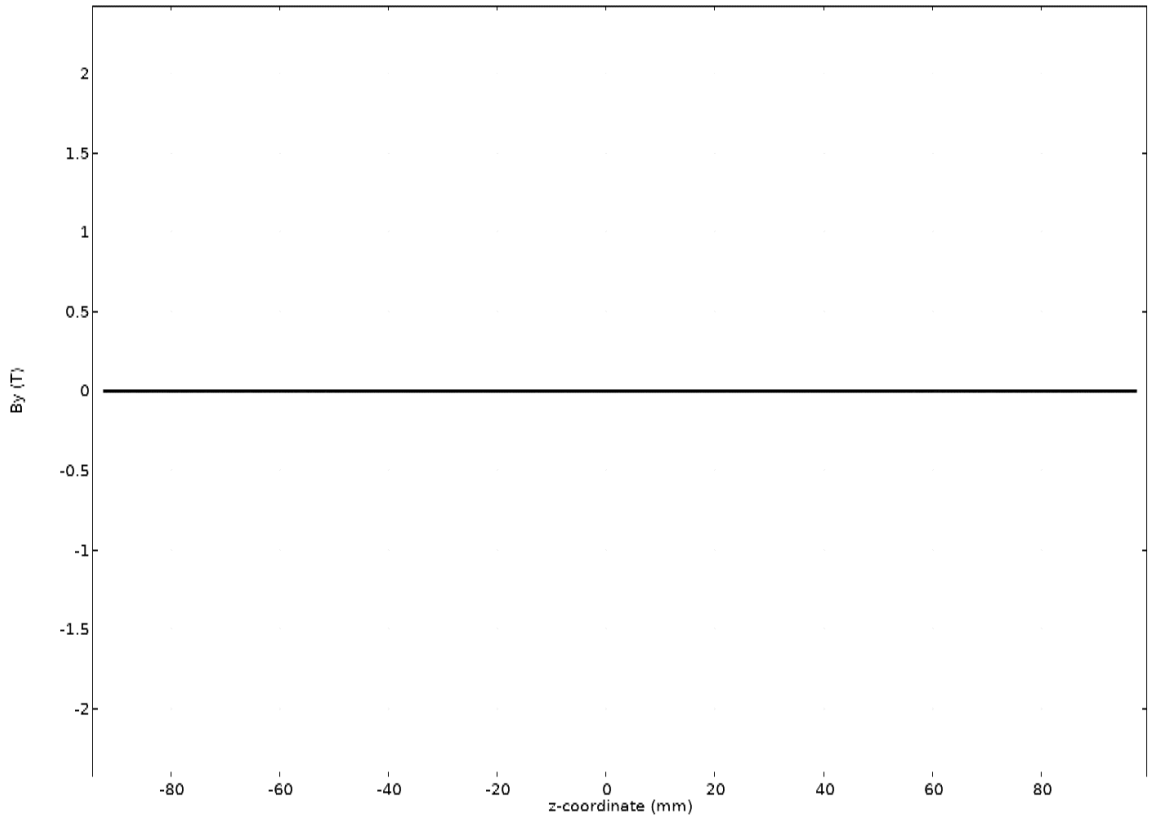




Introduction

- HTSU field cool magnetized at 10K in a field of 10T





CASPerLE : End terminations





Option 1: Looping each tape back



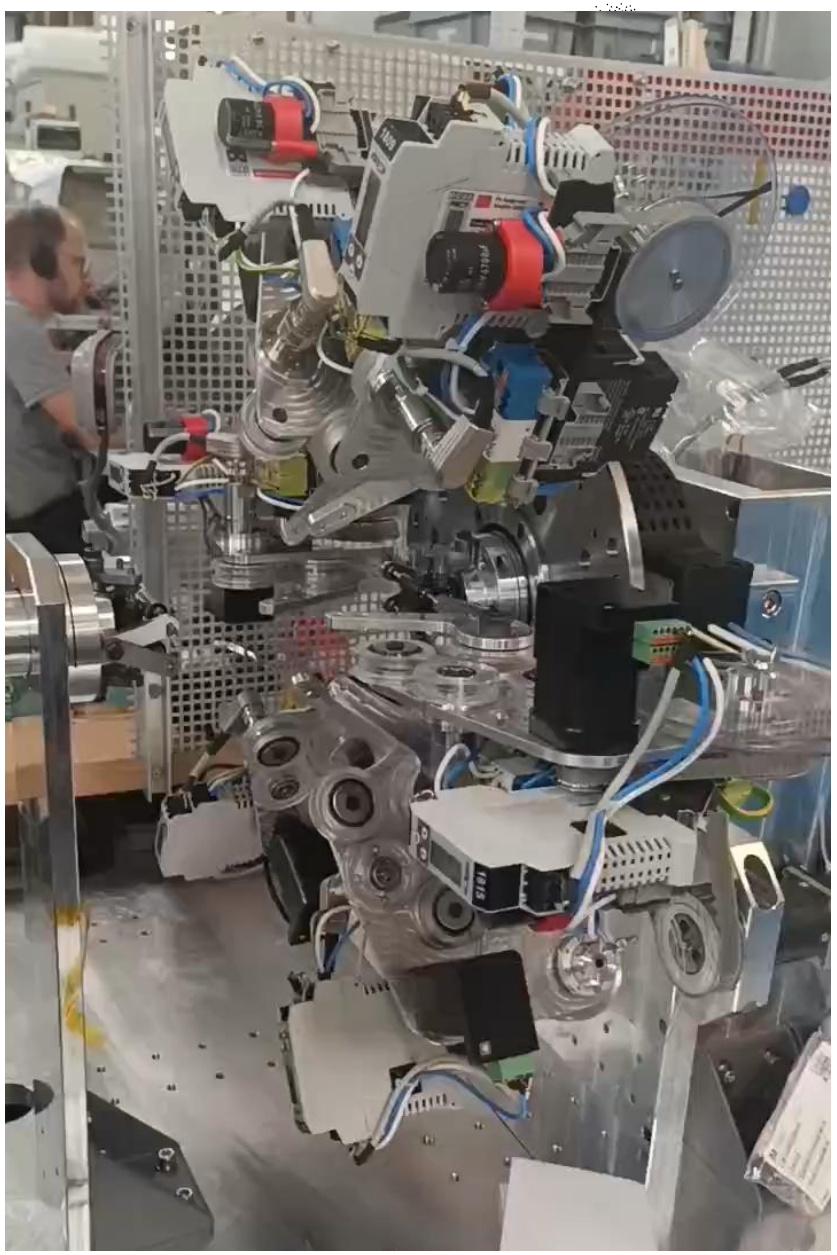


Option 2: Splicing each tape layer in series

CASPerLE : Joints and winding

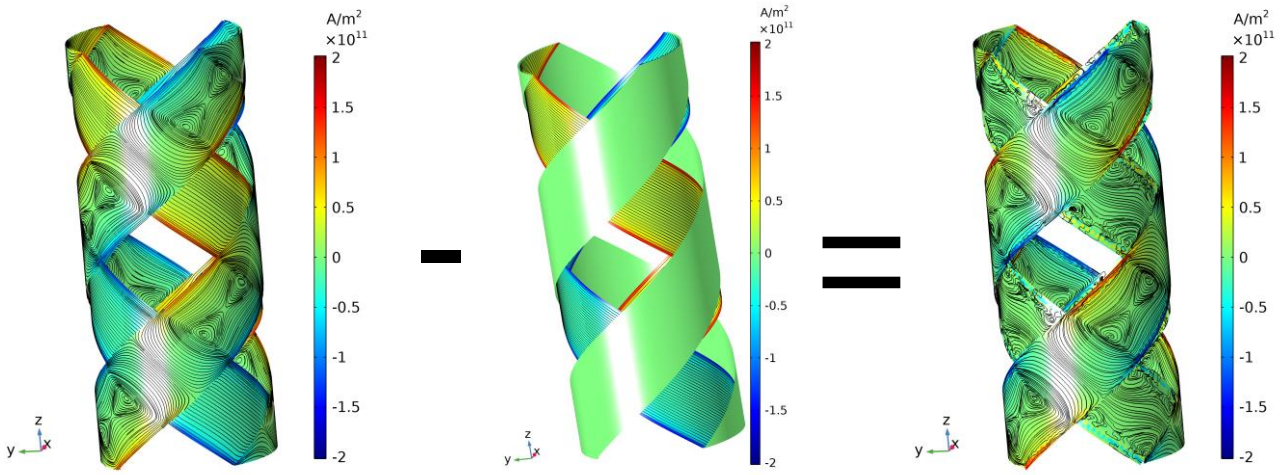
Winding

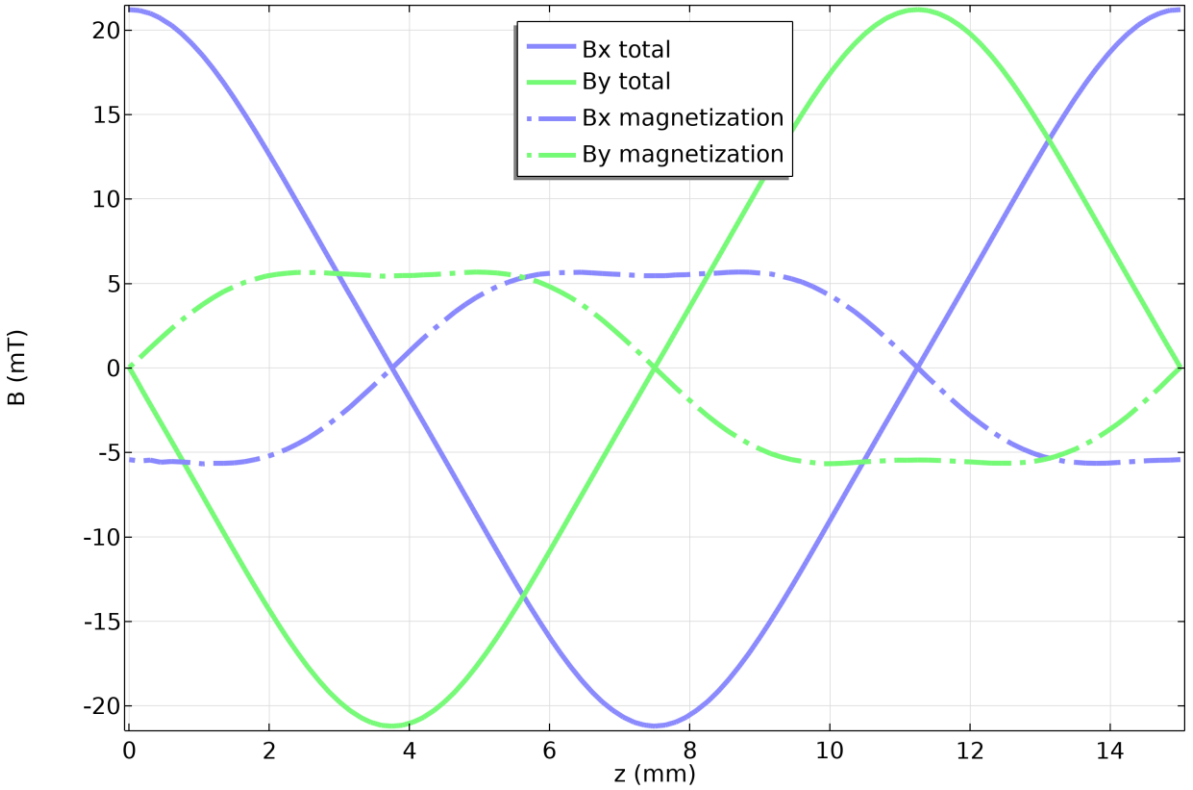




CASPerLE : Magnetization currents

Single helix powered





Magnetization currents reduce the field by ~20%