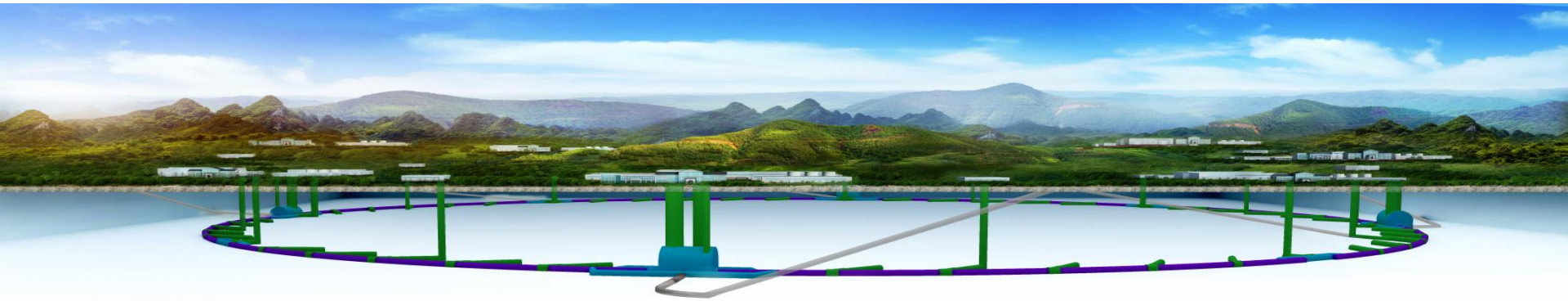
High Field Magnet Program for Accelerators in China: Status and Plan for Future

Qingjin XU
Institute of High Energy Physics (IHEP)
Chinese Academy of Sciences (CAS)
2019.9



Team Members & Collaborators

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IEE-CAS: *Xianping Zhang, Dongliang Wang, Yanwei Ma*

HIPS-CAS: *Huajun Liu, Tao Zhao, Yanlan Hu,…*

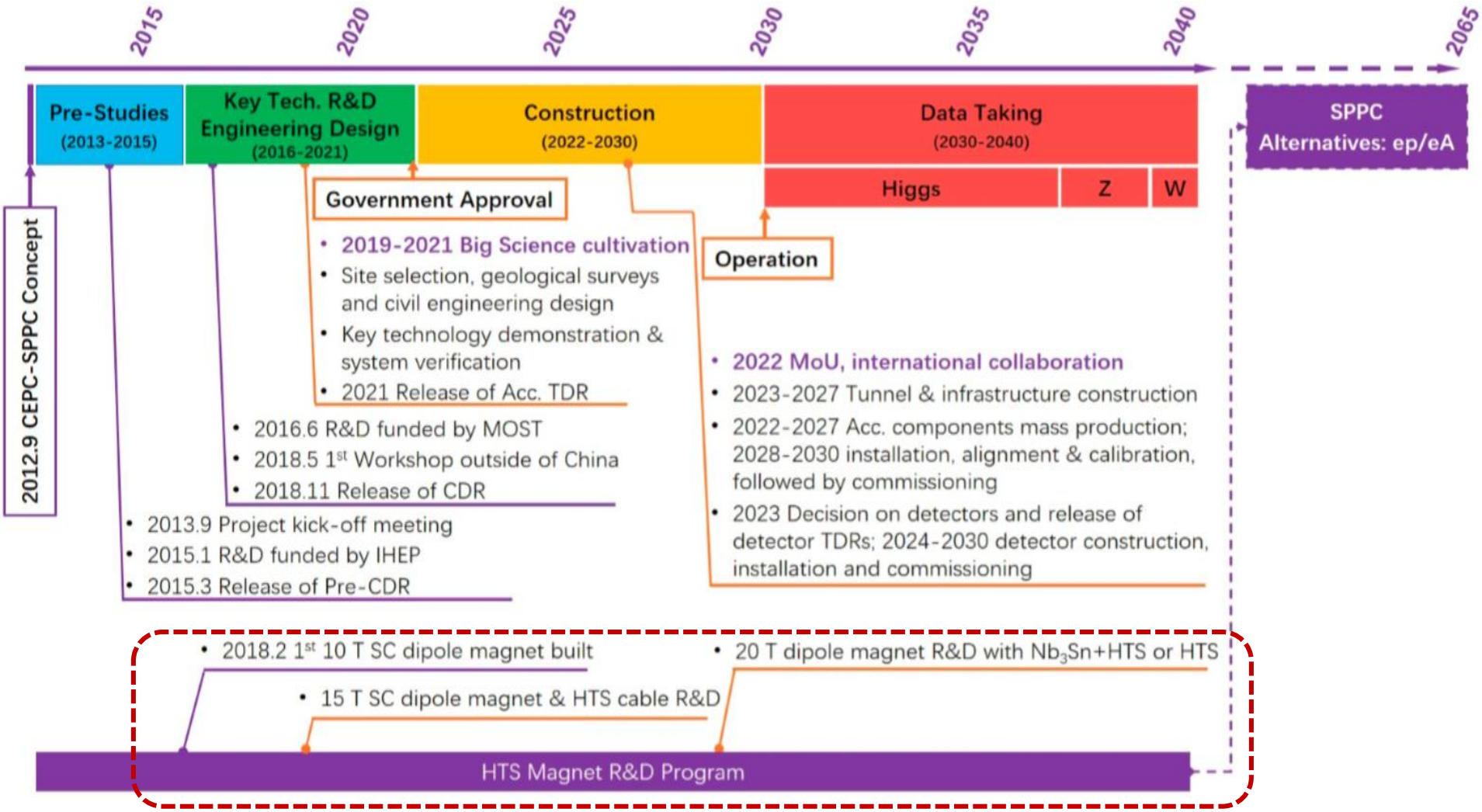
IMP-CAS: *Wei Wu, Yu Liang, Wenjie Liang, Lizhen Ma,…*

WST: *Bo Wu, Yanmin Zhu, Jianwei Liu, Jianfeng Li, Meng Li, Chao Li, …*

Toly Electric: *Yu Zhao, Hean Liao, Bingxing Lu,…*

**Work supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (CAS) Grant No. XDB25000000, the Hundred Talents Program of CAS and National natural Science Foundation of China Grant No. 11675193, 11575214, 11604335.*

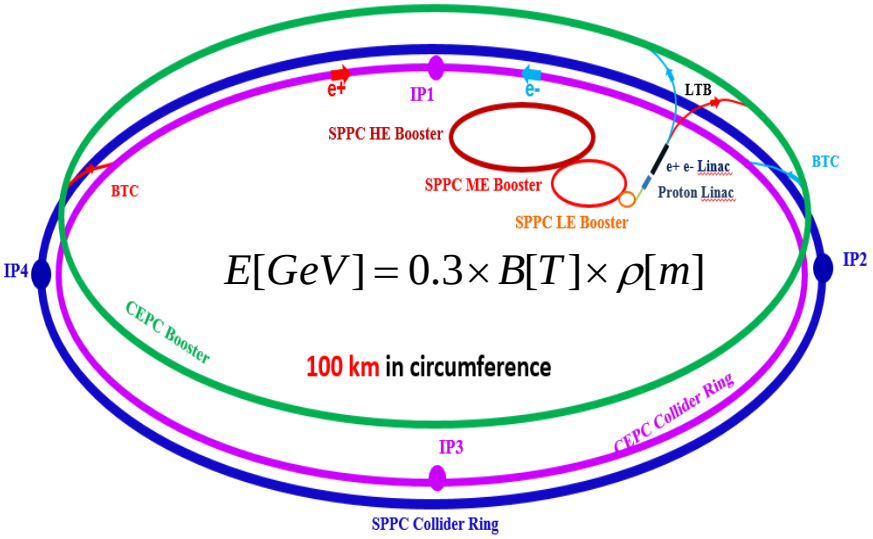
CEPC-SPPC Project Timeline



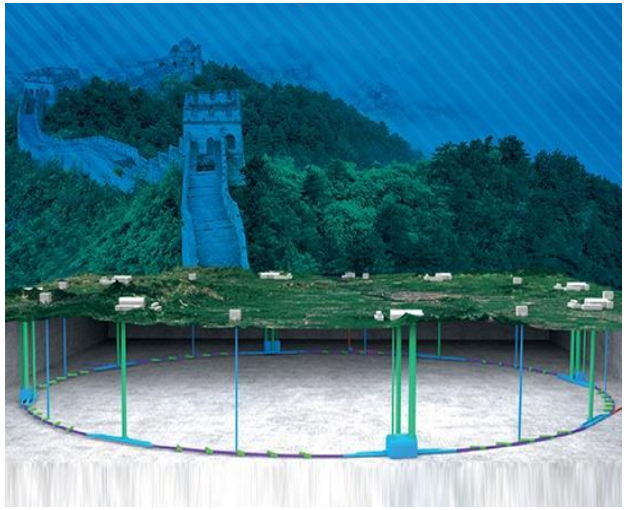
SPPC Magnet Design Scope (V201701)

Main dipoles

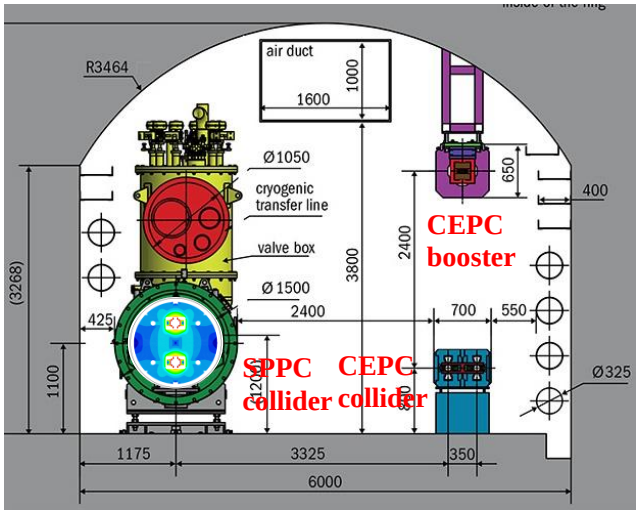
- *Field strength: 12-24 Tesla to get 75-150 TeV in a 100-km tunnel*
- *Baseline Iron-Based Superconductor (IBS), Nb_3Sn/ReBCO as options*
- *Aperture diameter: 40~50 mm*
- *Field quality: 10^{-4} at the 2/3 radius*



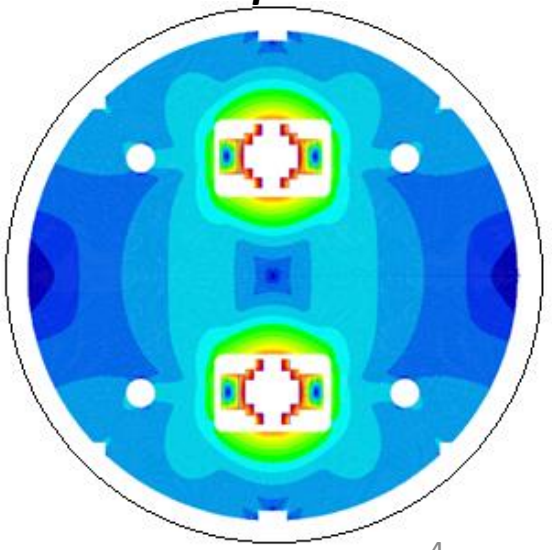
Site study of the CEPC-SPPC



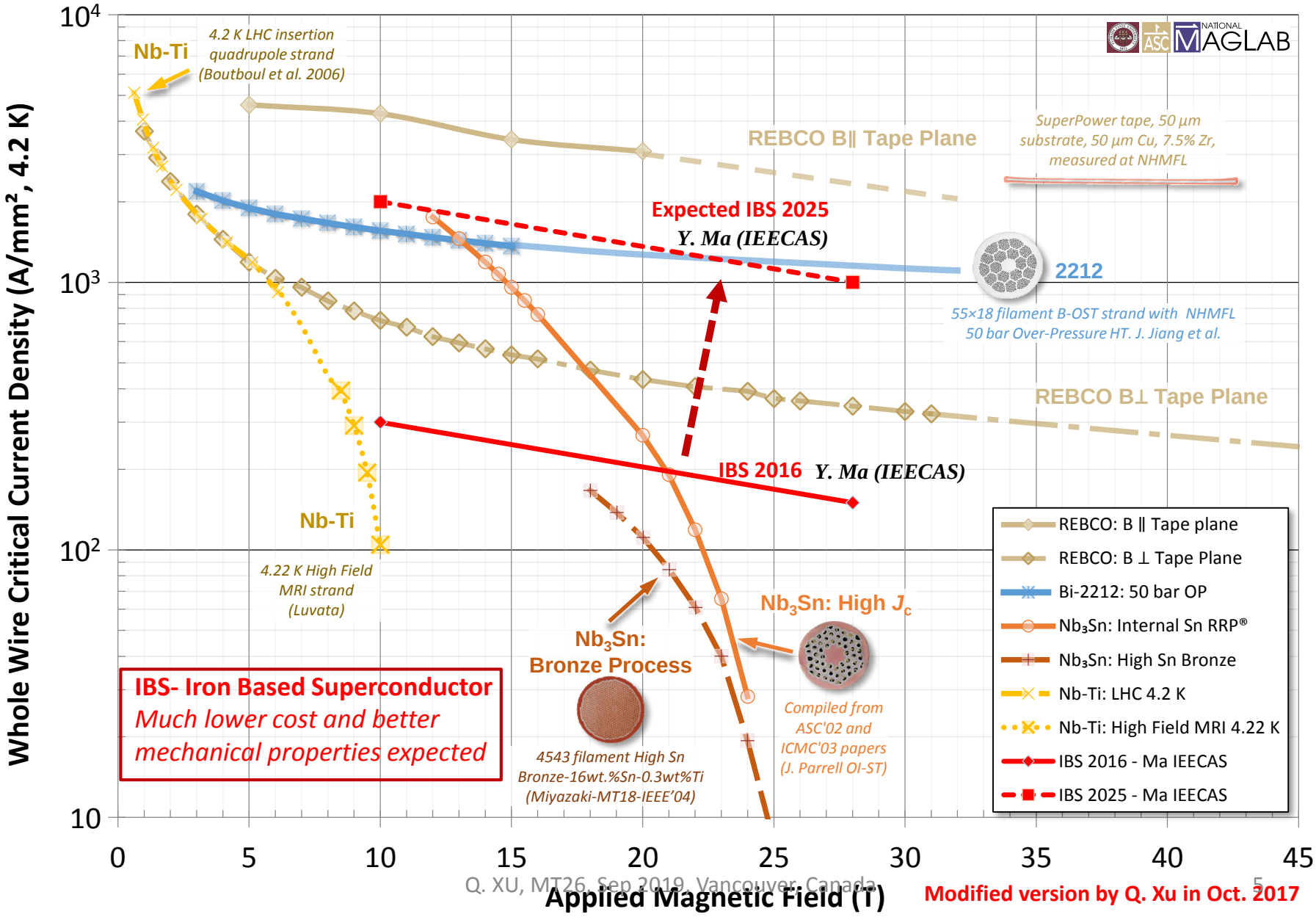
6-m width Tunnel for CEPC-SPPC



SPPC 12-T Dipole with IBS



J_e of IBS: 2016-2025



Modified version by Q. Xu in Oct. 2017

Domestic Collaboration for HTS R&D

Applied High Temperature Superconductor Collaboration (AHTSC)

- R&D from **Fundamental sciences** of superconductivity, **advanced HTS superconductors** to **Magnet & SRF technology**.
- **Regular meetings every 3 months** from Oct. 2016
- **Goal**:
- **Increasing J_c** of iron-based superconductor **by 10 times**.
- **Reducing the cost** of HTS conductors to be **similar with "NbTi conductor"**
- Industrialization of the **advanced superconductors, magnets and cavities**

Proposal for
Strategic Priority Research Program of Chinese Academy of Sciences (CAS)
Science and Technology Frontier Research
for High Field Applications of High Temperature Superconductors

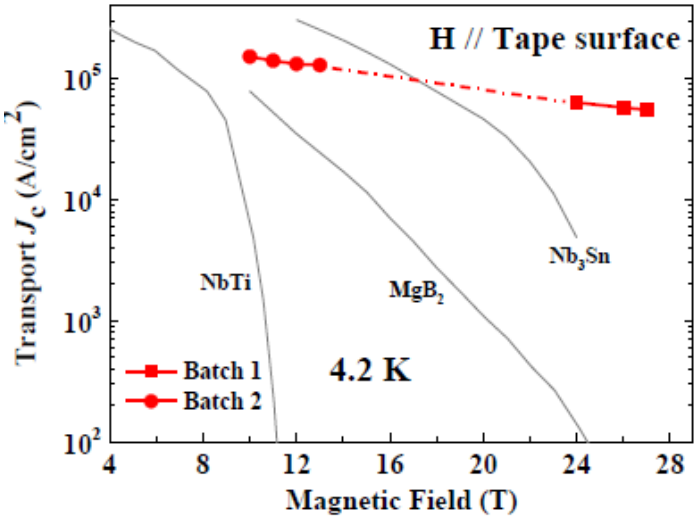
Ranked No. 1 in 7 candidates by Academic Committee of CAS

360M RMB for 2018-2023

Latest Progress on IBS wires

Wed-Af-Or14-07

Y. Ma (IEECAS) et al.



Transport property of IBS tape (2017):

Short tape (~4 mm wide, 0.3 mm thick):

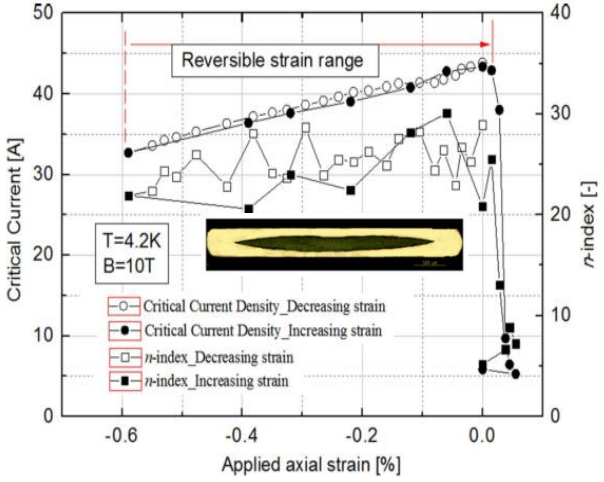
I_c~423 A (J_c>1450 A/mm^2) @ 4.2 K, 12 T

100 meter long tape:

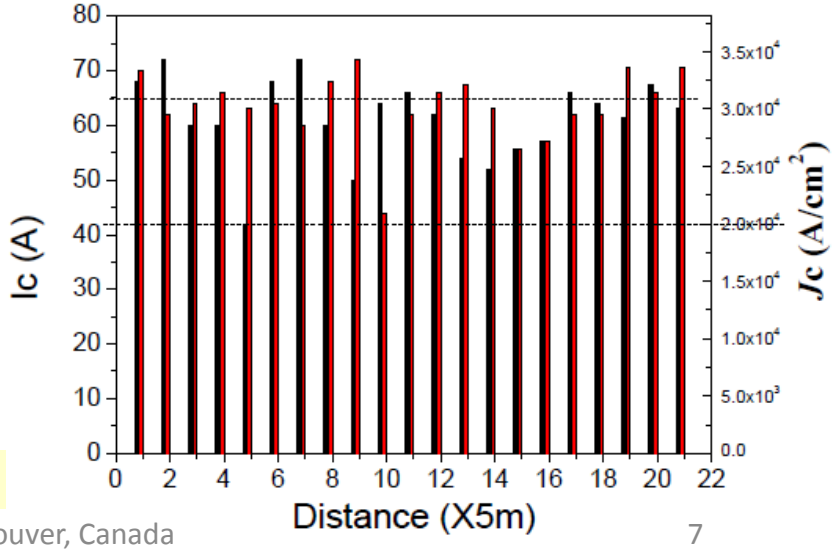
J_c>200 A/mm^2 @ 4.2 K, 12 T

115 meter 7-core tape

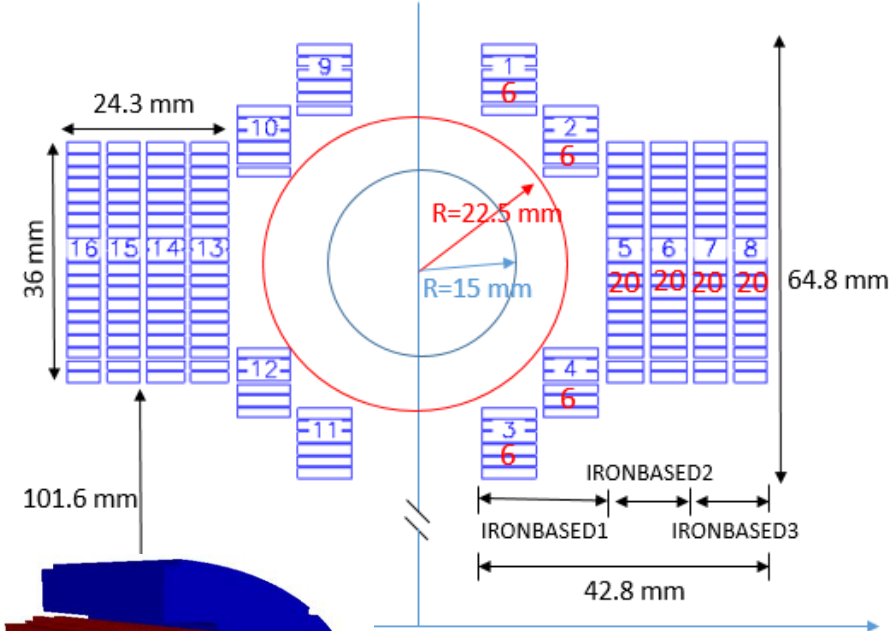
Supercond. Sci. Technol. 31 (2018) 015017

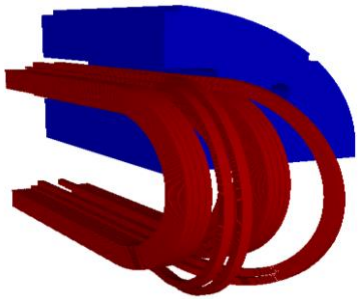


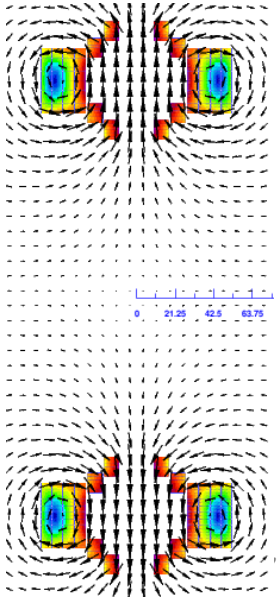
IEEE TAS 27 (2017) 7300705

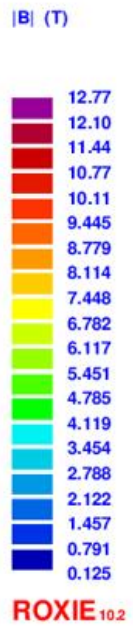


The 12-T Fe-based Dipole Magnet

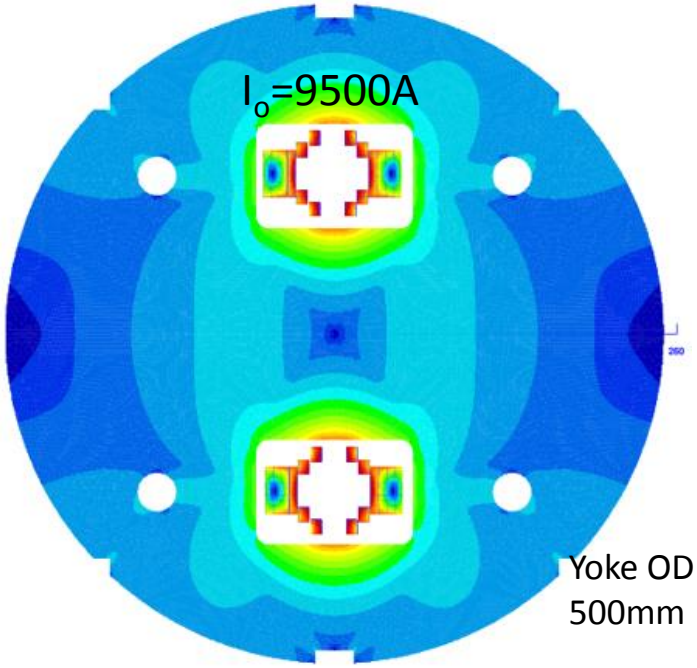








IJMPA 2019,34(13n14),1940003



Field quality	2D with R_f=13.3mm	3D with R_f= 8/13.3 mm
b3	0.45	0.79/1.91
b5	1.01	-0.65/-2.24
b7	0.46	0.08/0.67
b9	-0.27	-0.13/-0.22
a2	3.53	-1.00/-2.31
a4	0.49	-0.46/0.69
a6	0.33	0.26/2.49
a8	0.58	-0.12/0.84
a10	2.23	0.06/2.18

Conceptual design with expected J_e of IBS in 2025

Strand	diam.	cu/sc	RRR	Tref	Bref	Jc@ BrTr	dJc/dB
IBS	0. 802	1	200	4. 2	10	4000	111

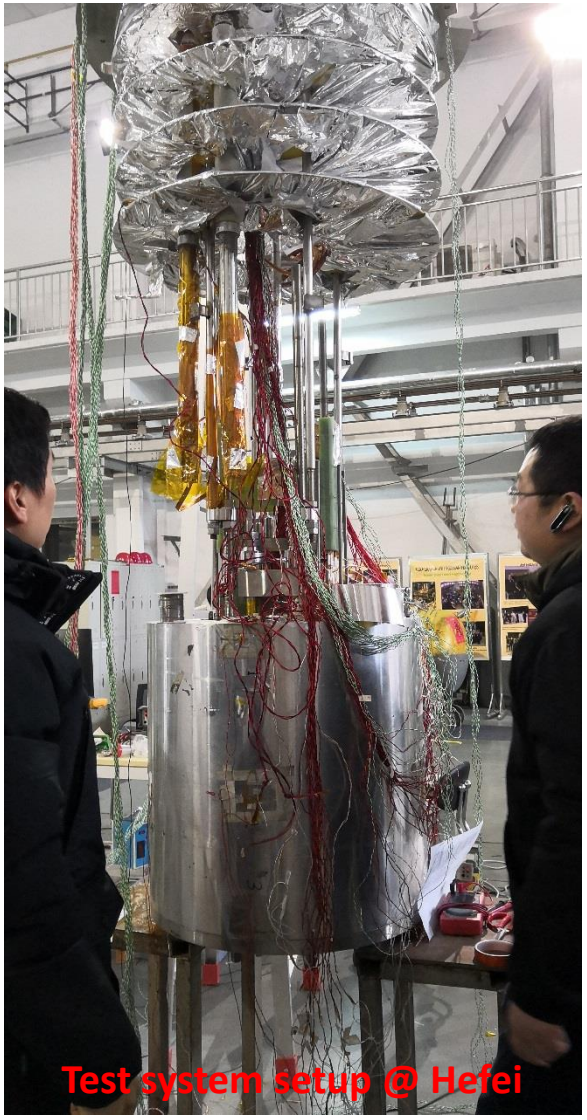
- For 100-km SPPC, **3000 tons of IBS** is needed
- Target cost of IBS: **20 RMB /kAm @12 T**
- Total cost for IBS conductors: **~10B RMB**

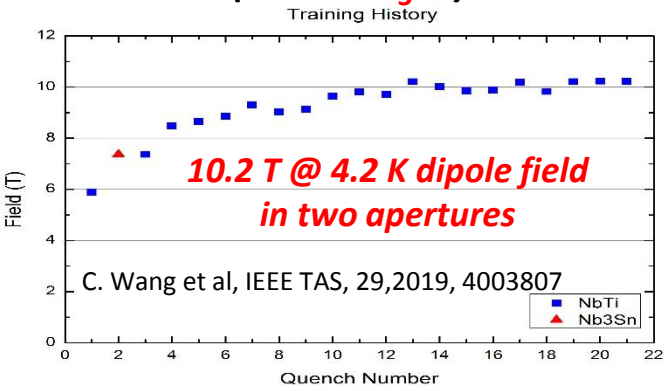
The 1st NbTi+Nb_3Sn high-field dipole magnet

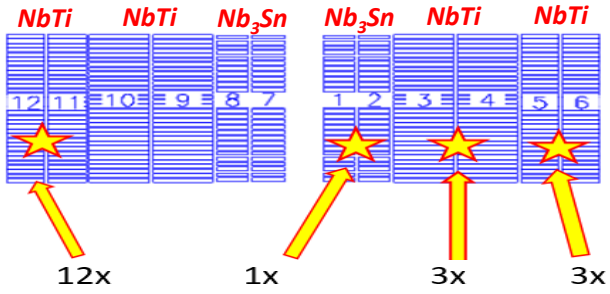
Test results of LPF1

(NbTi+Nb_3Sn)

C. Wang et al, IEEE TAS, 29,2019, 4003807

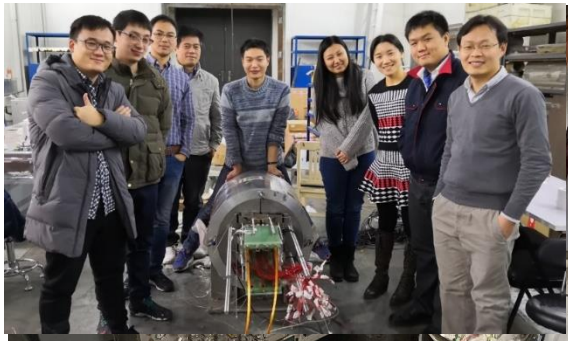


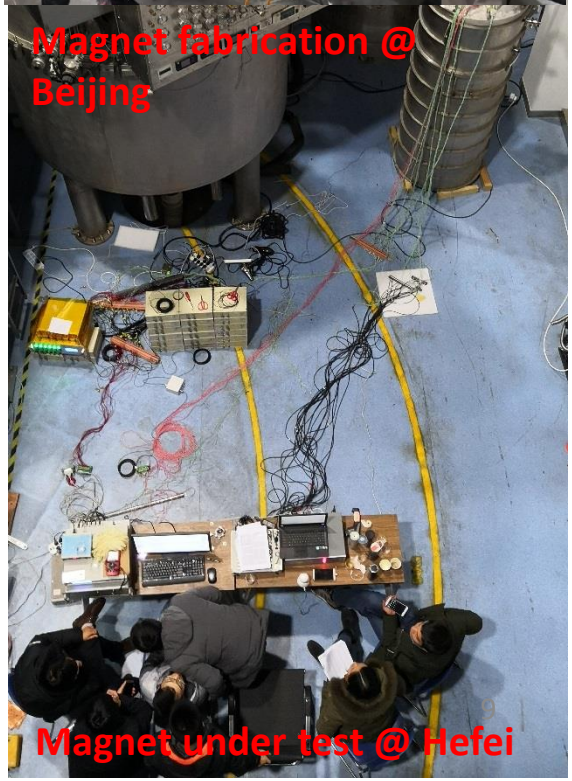




- ***Performance limited by the outermost NbTi coil.***
- ***Very possibly caused by less of pre-stress.***
- ***Being tested again now with higher Pre-stress (from 30 MPa to 80 MPa).***

Q. XU, MT26, Sep 2019, Vancouver, Canada

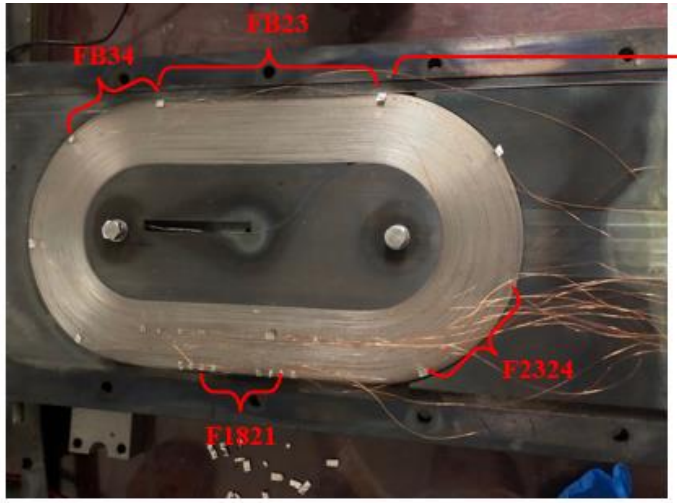


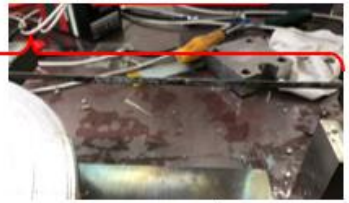


Performance of the 1st IBS Racetrack Coil

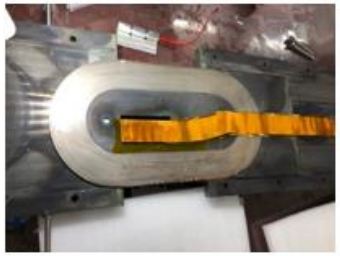
Mon-Mo-Po1.04-13

Test results of IBS coil with background field

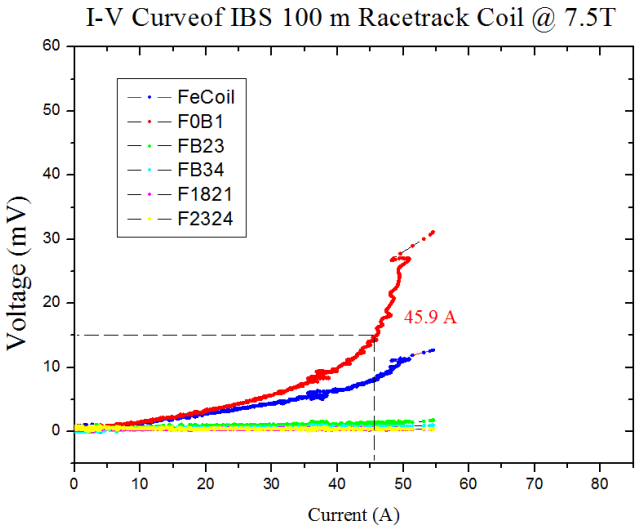


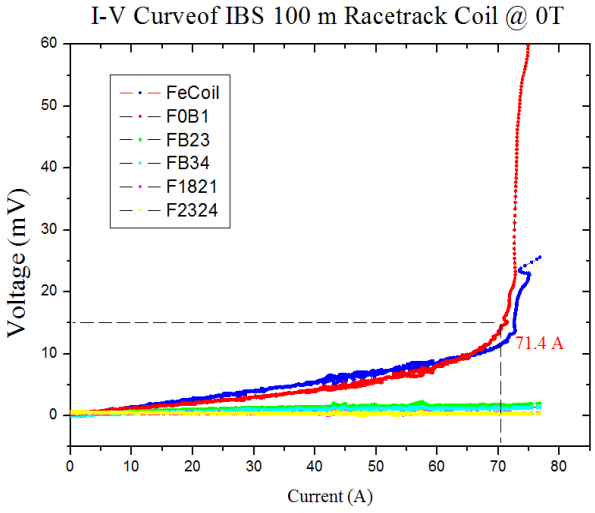


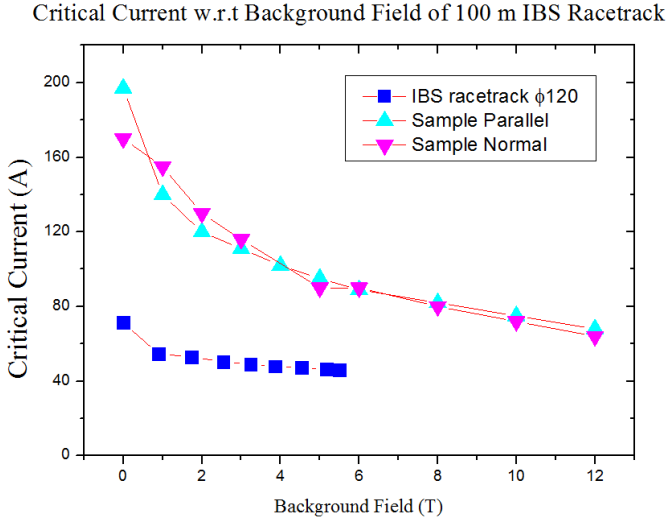
Outer Joint



Inner Joint







Fabrication of IBS solenoid and test at high field

Wed-Af-Or14-08

Performance of IBS solenoid coil at 24T

IOP Publishing
Supercond. Sci. Technol. **32** (2019) 04LT01 (5pp)
Superconductor Science and Technology
https://doi.org/10.1088/1361-6668/ab09a4

Letter

First performance test of a 30mm iron-based superconductor single pancake coil under a 24T background field

Dongliang Wang[1,2,5], Zhan Zhang[3,5], Xianping Zhang[1,2], Donghui Jiang[4], Chiheng Dong[1], He Huang[1,2], Wenge Chen[4], Qingjin Xu[3,6] and Yanwei Ma[1,2,6]

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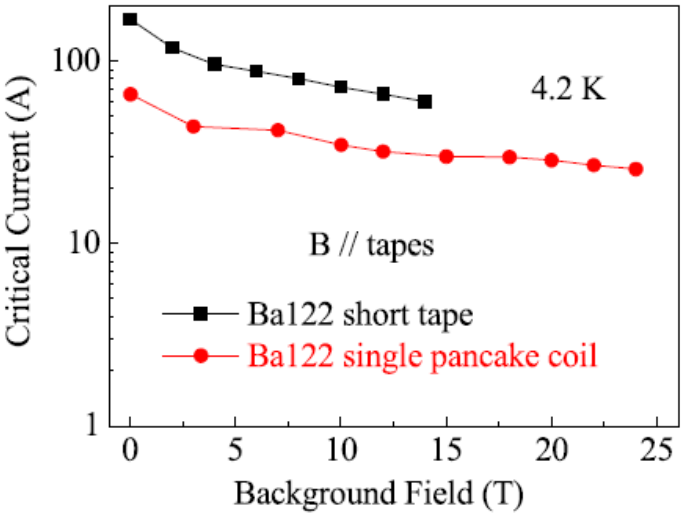

Viewpoint by NHMFL

'From a practical point of view, **IBS are ideal candidates for applications**. Indeed, some of them have quite a **high critical current density, even in strong magnetic fields**, and a low superconducting anisotropy.

Moreover, **the cost of IBS wire can be four to five times lower than that of Nb_3Sn**……

IOP Publishing
Supercond. Sci. Technol. **32** (2019) 070501 (3pp)
Superconductor Science and Technology
https://doi.org/10.1088/1361-6668/ab1fc9

Viewpoint

CrossMark

Constructing high field magnets is a real tour de force

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E-mail: jaroszy@magnet.fsu.edu

This is a viewpoint on the letter by Dongliang Wang *et al* (2019 *Supercond. Sci. Technol.* **32** 04LT01).

Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty

R&D of High Field Dipole Magnets

R&D Roadmap for the next years

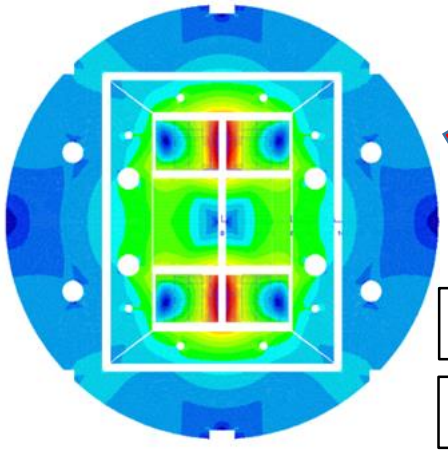
Field (T)

20

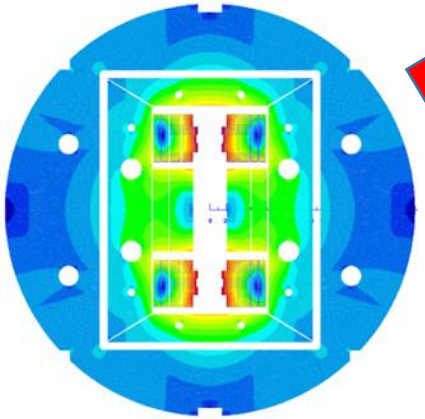
10

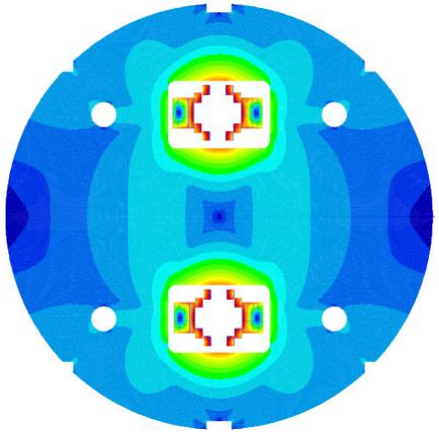
SPPC dipole field: baseline 12 T, optimum 20-24T

$NbTi+Nb_3Sn$
2*ϕ10 aperture
10T @ 4.2K



Nb_3Sn+HTS
2*ϕ45 aperture
15T @ 4.2K





Nb_3Sn+HTS or HTS
2*ϕ45 aperture
20T @ 4.2K
With 10^{-4} field quality

Mon-Mo-Po1.04-14

Tue-Mo-Or7-05

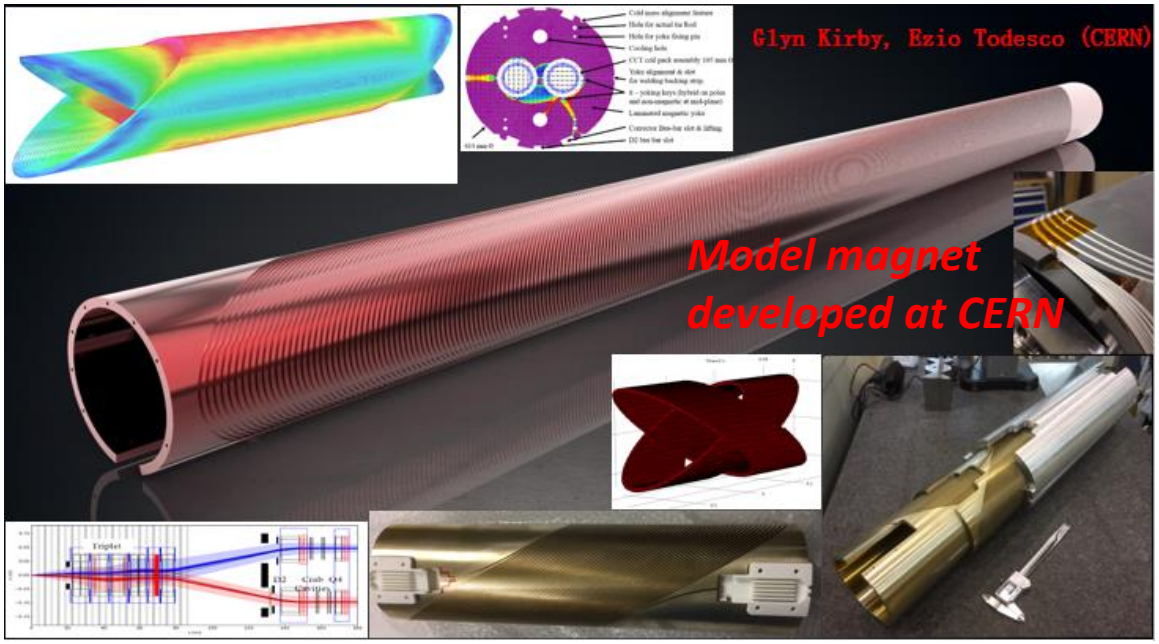
IEEE TAS 2019, 29(7), 4003807
IJMPA 2016, 31(33):1644018
IEEE TAS 2016, 26(4): 4000404

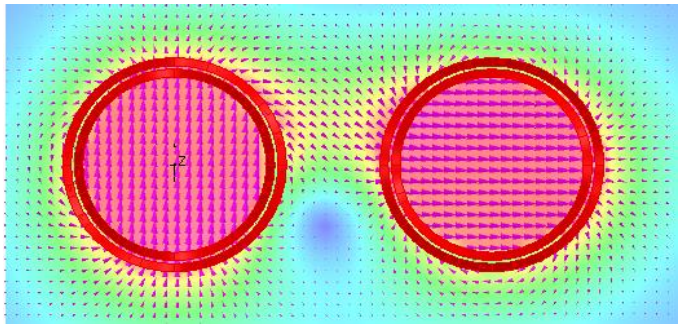
2018 ***2028*** ***year***

CERN & China Collaboration

China provides 12+1 units CCT corrector magnets for HL-LHC before 2022

*2*2.6T dipole field in the two apertures. 2.2m prototype being fabricated.*

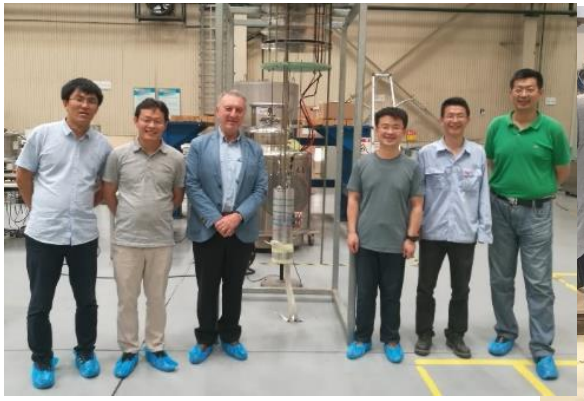


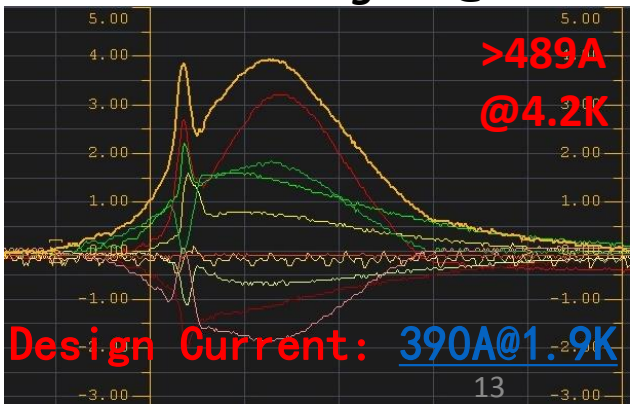


Model magnet R&D In China

- ✓ The 1st coil reached 543A @ 4.2K with 5 quench, 83.4% loadline.
- ✓ The 2nd coil reached 489A with 5 quench.
- ✓ Design current 390A @1.9K.

Fabrication and test of the 1st coil for the 0.5m model magnet @ Xi'an





Summary

- ***High field magnet technology*** *is the key to the success of the high energy accelerators in future.*
- ***SPPC design scope:*** *12-24 T IBS magnets to reach 75-150 TeV with 100 km circumference.*
- *Strong domestic collaboration for the advanced HTS conductor R&D: Make IBS the High-T_c and High-Field "NbTi" conductor in 10 years!*
- ***R&D of high field magnet technology:*** *the 1st twin-aperture model dipole (NbTi+Nb_3Sn) reached 10.2 T @ 4.2 K; 12-15 T model magnet being developed.*
- ***CERN & China Collaboration on accelerator technology:*** *Start with the HL-LHC CCT magnets, and more in future.*
- *Expecting more collaborations with worldwide labs in future.*

Thanks for your attention!

Sep. 22 2019