Status of IHEP contribution to HiLumi-LHC

Qing QIN, IHEP, Chinese Academy of Sciences

15 Oct, 2018

Brief introduction on IHEP

IHEP serves as the backbone of China's large science facilities

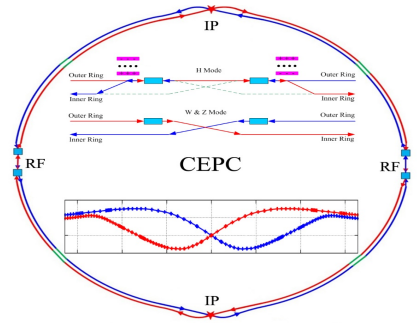
❖In operation

- Beijing Electron Positron Collider (BEPCII)
- China Spallation Neutron Source (CSNS)
- Yangbajing Cosmic Ray Observatory (ASγ & ARGO)
- Daya Bay Neutrino Experiment
- Hard X-ray Modulation Telescope(HXMT), launched on 15/06/2017
- Accelerator-driven Sub-critical System (ADS)



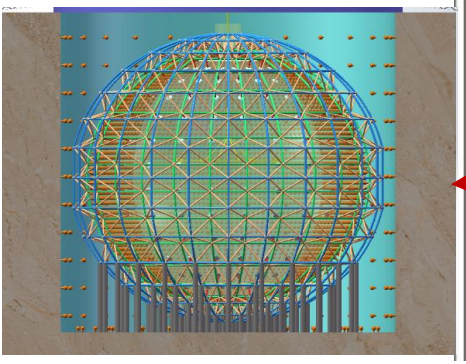

❖Under construction

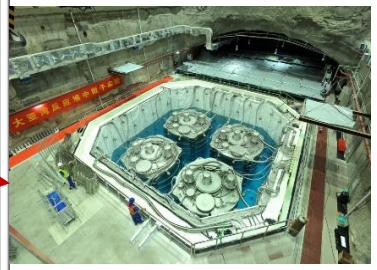
- Jiangmen Neutrino Underground Observatory (JUNO)
- R&D of the High Energy Photon Source (HEPS-TF)
- Platform of Advanced Photon Source Technology (PAPS)
- Large High Altitude Air Shower Observatory (LHAASO)

❖Planning

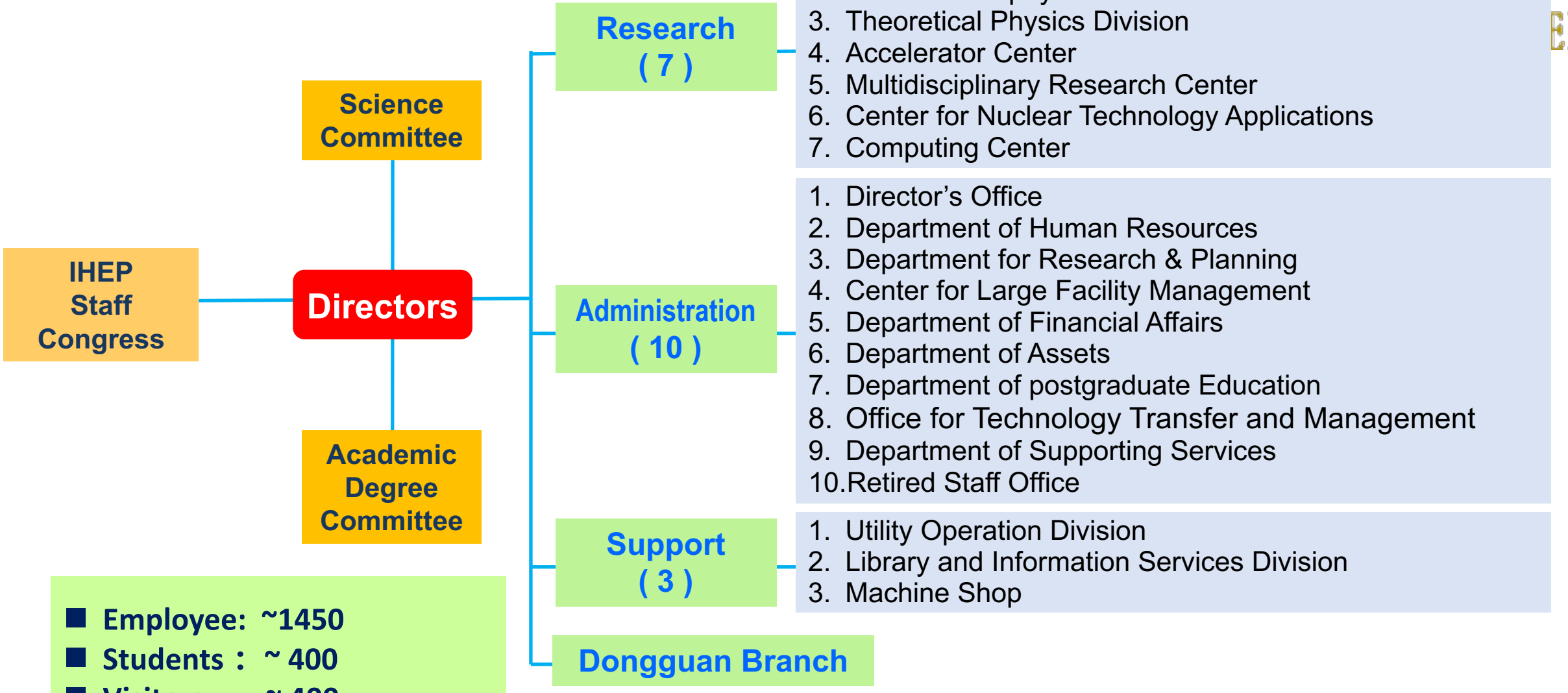
- HEPS, XTP, HERD, CEPC …





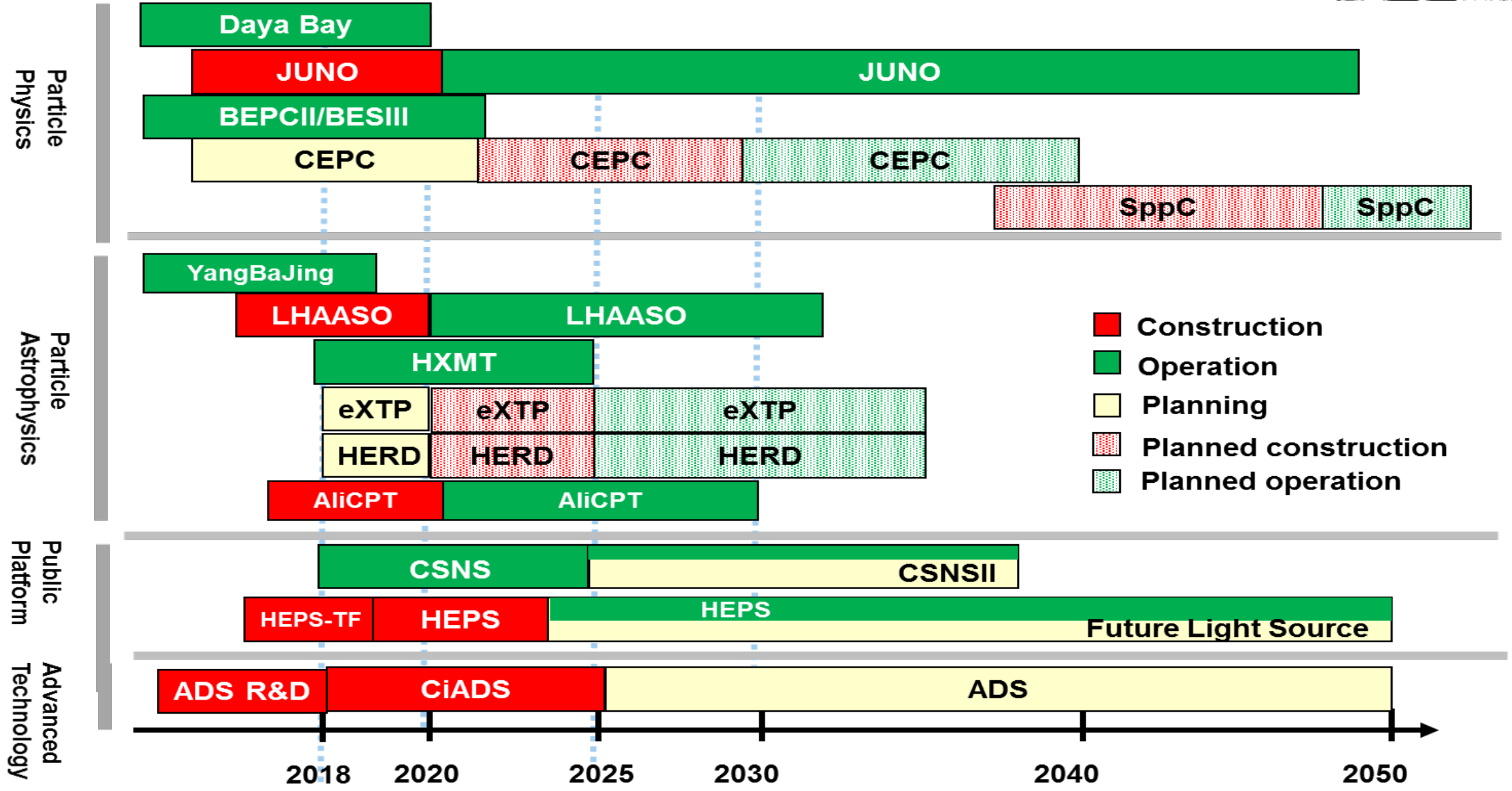
ASTANA
RUSSIA
KAZAKHSTAN
ULAANBAATAR
MONGOLIA
BISHKEK
KYRGYZSTAN
Ürümqi
XINJIANG
HEILONGJIANG
Harbin
Changchun
JILIN
NEI MONGOL
(INNER MONGOLIA)
Shenyang
LIAONING
NORTH
KOREA
PYONGYANG
HEPS
Hohhot
BEIJING
ADS
BEPC/
BSRF
SEOUL
SOUTH
KOREA
GANSU
Yinchuan
NINGXIA
Taiyuan
SHANXI
Shijiazhuang
Jinan
SHANDONG
Yellow
Sea
Xining
QINGHAI
Lanzhou
Xi'an
SHAANXI
Zhengzhou
HENAN
JIANGSU
Nanjing
ANHUI
Hefei
SHANGHAI
Shanghai
Hangzhou
ZHEJIANG
East China
Sea
NEW
DELHI
XIZANG
(TIBET)
Yangbajing
HUBEI
Wuhan
CHONGQING
Chengdu
SICHUAN
LHASSO
Chongqing
Changsha
Nanchang
JIANGXI
NEPAL
Lhasa
BHUTAN
INDIA
KATHMANDU
THIMPHU
INDIA
GUIZHOU
HUNAN
Fuzhou
FUJIAN
Taipei
Guiyang
Taiwan Strait
Taiwan
Kunming
YUNNAN
GUANGXI
CSNS
Nanning
JUNO
Daya Bay
Guangzhou
Hong Kong
Special
Administrative
Region
Macau
Special
Administrative
Region
Philippine
Sea
BURMA
Nay Pyi Taw
(administrative
capital)
HANOI
Haikou
LAOS
Gulf of
Tonkin
HAINAN
Hainan
Dao
VIENTIANE
Luzon
RANGOON
VIETNAM
PARACEL
ISLANDS
South
China
PHILIPPINES
MANILA
THAILAND
International boundary
Province (sheng), autonomous region (zizhiqu), or municipality (shi) boundary
National capital
Province (sheng), autonomous region (zizhiqu), or municipality (shi) capital
China has 23 provinces (sheng), five autonomous regions (zizhiqu), four municipalities (shi), and two special administrative regions.
China considers Taiwan its 23rd province.
Autonomous regions and municipalities

IHEP Organization

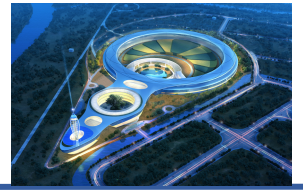


- Employee: ~1450
- Students： ~ 400
- Visitors: ~ 400
- Budget： ~ 1.2 B RMB/yr

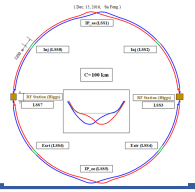
Current & future projects in IHEP

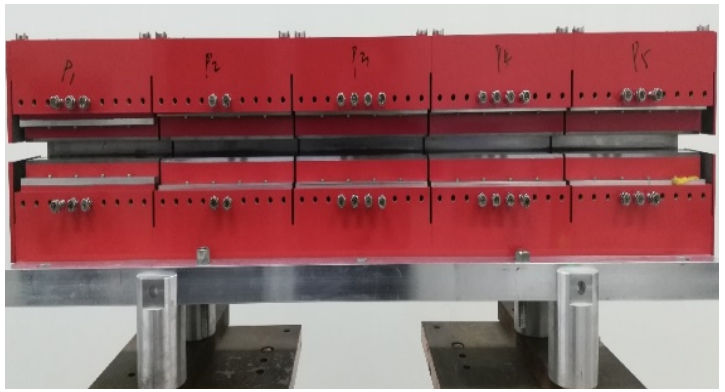


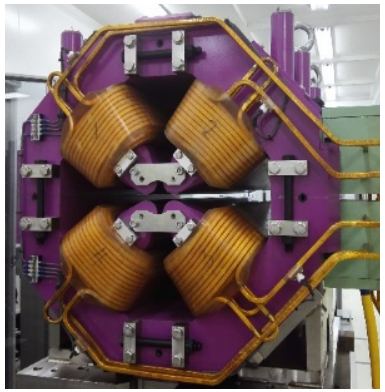
HEPS

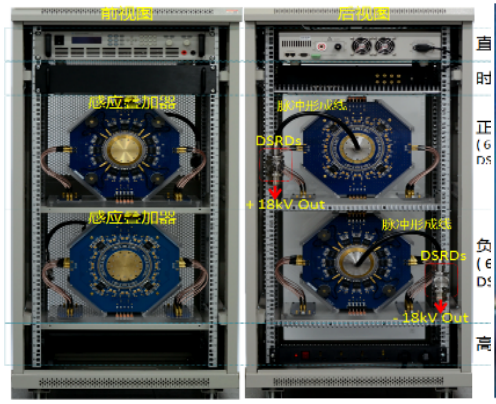


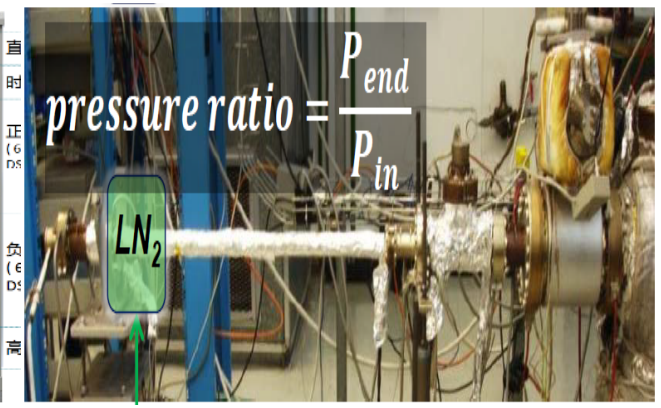
CEPC/SppC

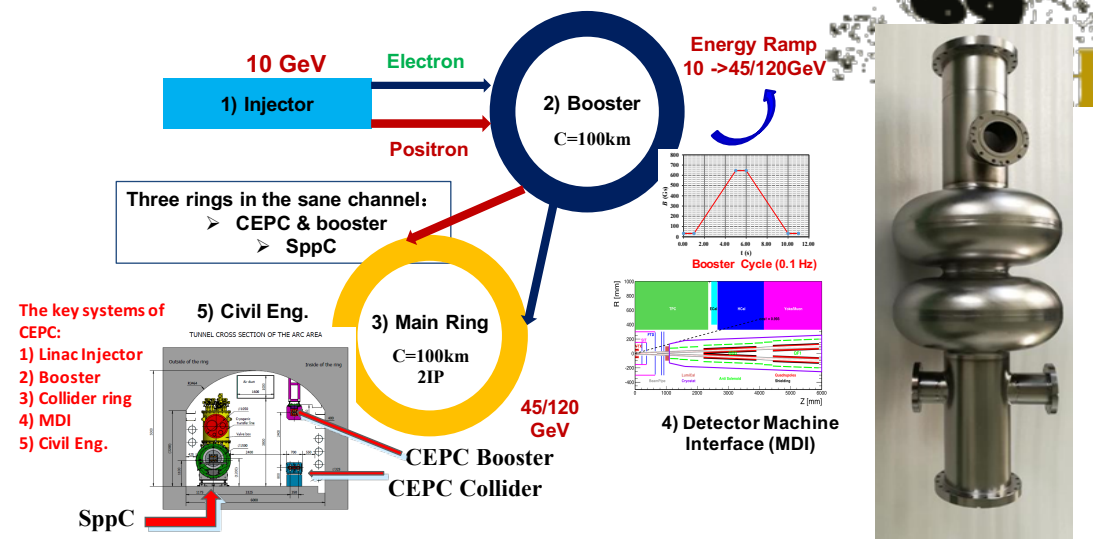


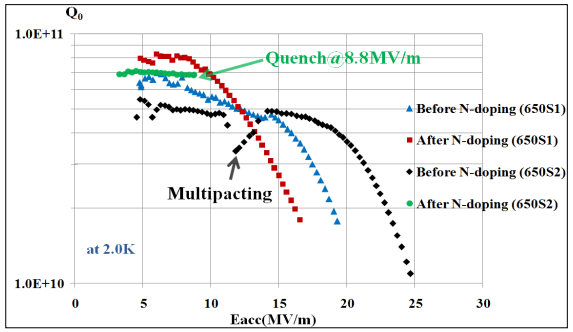


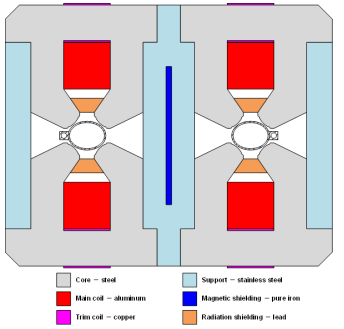


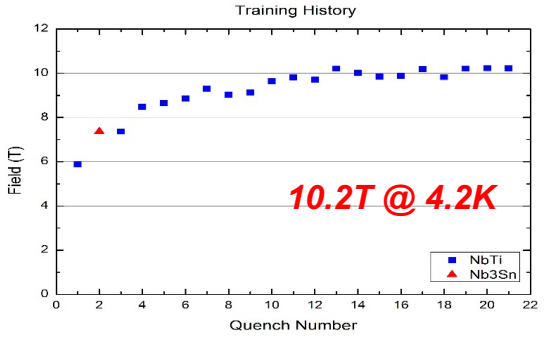


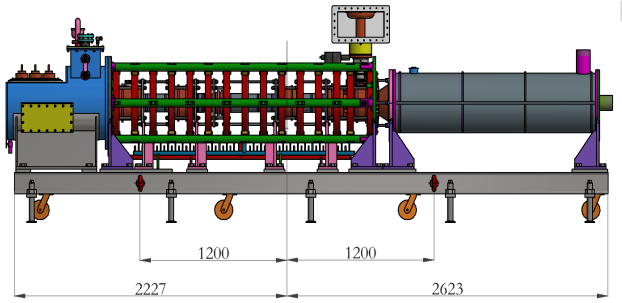












Collaboration on accelerator between CERN & IHEP

From CERN 81-14, yellow book

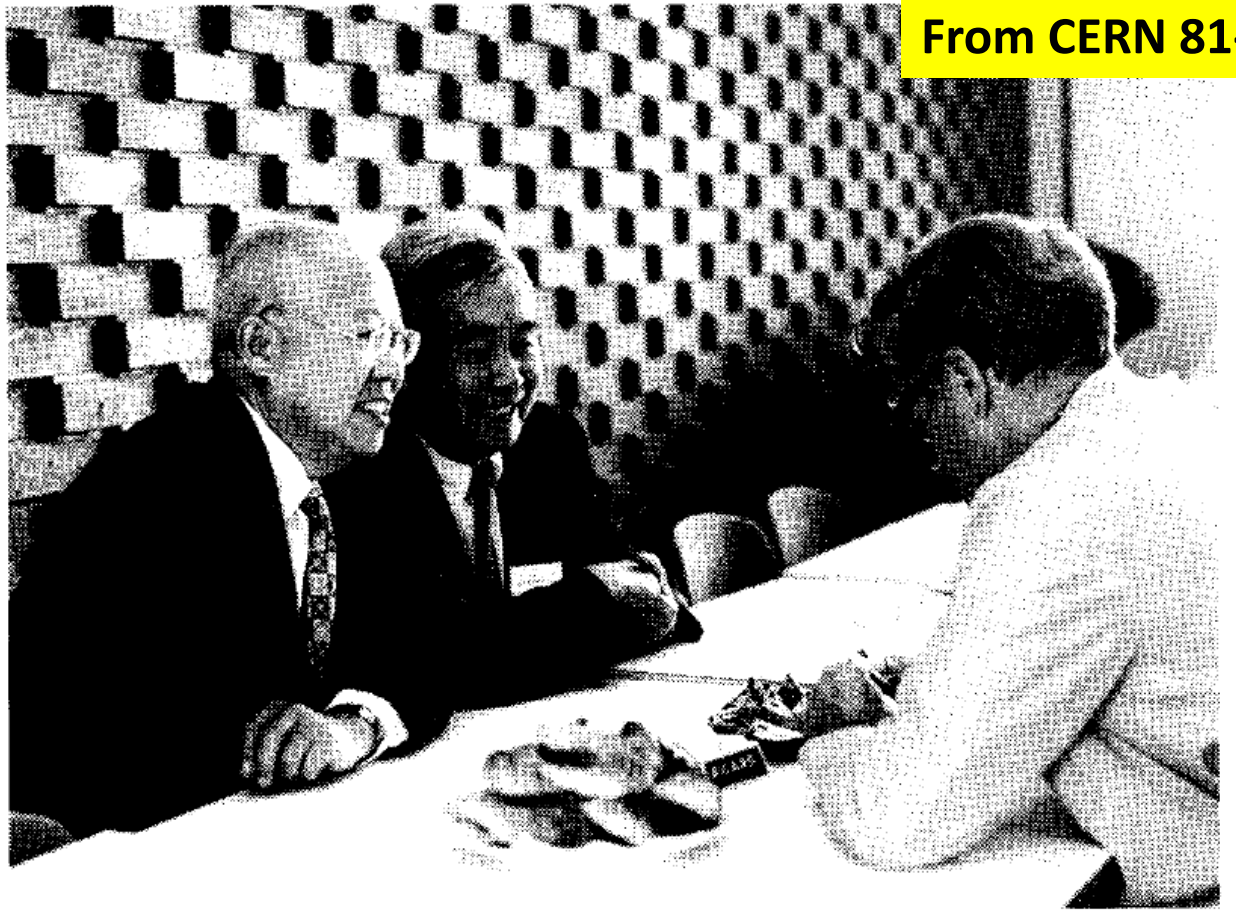


Plate 1 Chang Wen-yü (centre) with Luke C.L. Yuan (left) talking to Kjell Johnsen at CERN, June 1973. (Photo CERN)

Plate 12 E.J.N. Wilson (second from left), W. Pirkl (fourth from left) and Fang Shou-hsien (extreme right) at Guilin airport, October 1978. (Photo X)

- **SPS & BEPC (1978 – 1995)**
- **LEP & LHC (1992 – 2002)**
- **LHC & HL-LHC (2012 – Now)**

- China-CERN collaboration meeting in Sept
- MoU signed for HL-LHC collaboration
- A total amount of ~2M Euro from IHEP/CAS will be invested for CCT magnet manufacture

European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

NON-DISCLOSURE AGREEMENT

This non-disclosure agreement ("Agreement") is entered into by and between THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH ("CERN"), an Intergovernmental Organization with its seat at Geneva, Switzerland, and INSTITUTE FOR HIGH ENERGY PHYSICS ("IHEP"), at Beijing, China.

WHEREAS

Each party possesses proprietary and confidential information (hereafter referred to, in whole or in part, as the "Information") concerning the prototype and the series production of MCBRD magnets for the HL-LHC project, and wishes to exchange such Information with the other party, in order to manufacture the MCBRD series (the "Purpose").

The parties desire to set forth the terms and conditions under which they are willing to exchange and safeguard such Information;

NOW IT IS HEREBY AGREED AS FOLLOWS:

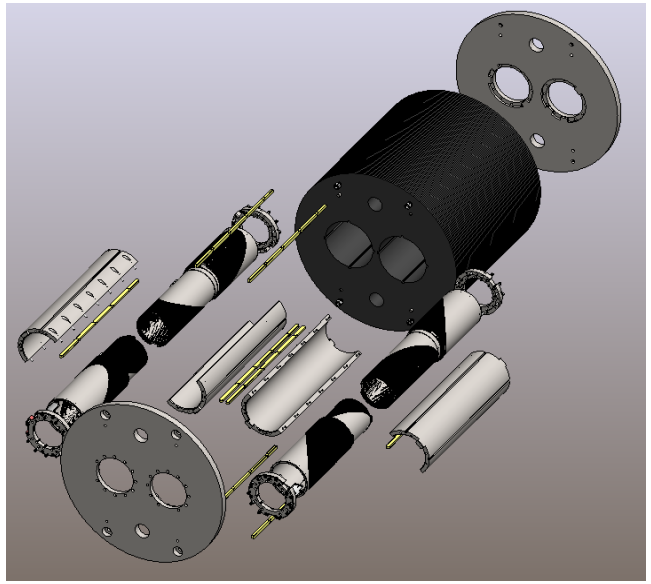
1. This Agreement shall apply to Information disclosed by one party (the "Disclosing Party") to the other party (the "Recipient Party") which has been identified as confidential or restricted, or which can be reasonably understood as such, whether disclosed before, on or after the date of this Agreement. Information includes but is not limited to materials, experimental techniques or results, designs, drawings, reports, computer programmes, samples or prototypes and expertise in the framework of the HL-LHC project and more specifically in the design, manufacturing, test and analysis of the MCBRD magnets (the so-called CCT magnets). This is in connection with or arising from the Information in any form, such as but not limited to any documents, photographic and electronic formats, which shall be settled for the exchange of information.
2. The Recipient Party shall keep the Information confidential, shall not without the Disclosing Party's prior written permission reproduce the Information or disclose it to any other party, and shall use the Information solely for the Purpose. The Recipient Party shall limit the circle of recipients of the Information to its officers, personnel or agents who reasonably need to receive the Information in order to achieve the Purpose and shall ensure that they are aware of and comply with the obligations defined in this Agreement. The Recipient Party shall use the Information in accordance with best practice and professional standards, and in no event for military applications.
3. The Recipient Party shall use the same degree of care as it uses to protect its own information of a similar nature, but no less than reasonable care, to prevent the unauthorized reproduction, disclosure or use of the Information.
4. The obligations defined in section 2 above shall not apply in respect of information:
   - which has become public knowledge other than as a result of a breach of this Agreement by the Recipient Party; or
   - which, in a lawful manner, the Recipient Party has obtained from a third party without any obligation of confidentiality; or
   - which the Recipient Party has developed independently of the Information; or
   - which the Recipient Party is required by law to disclose. In this case, the Recipient Party shall notify the Disclosing Party of such disclosure and shall ensure that the recipients are aware of and comply with the obligations defined in this Agreement.

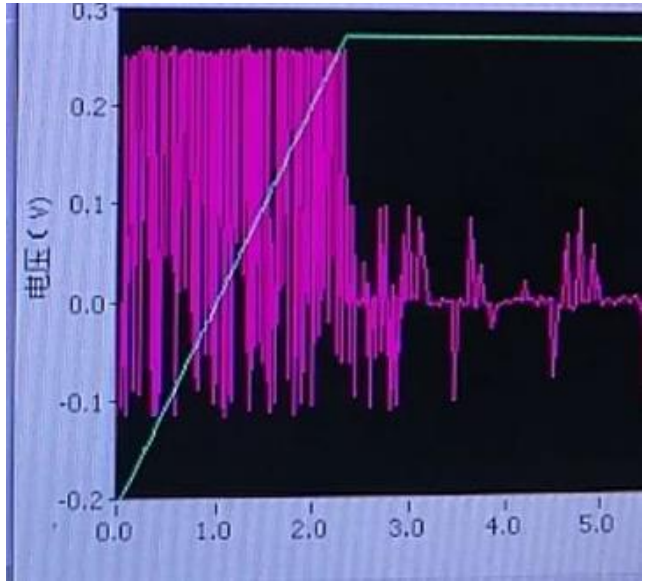
www.cern.ch

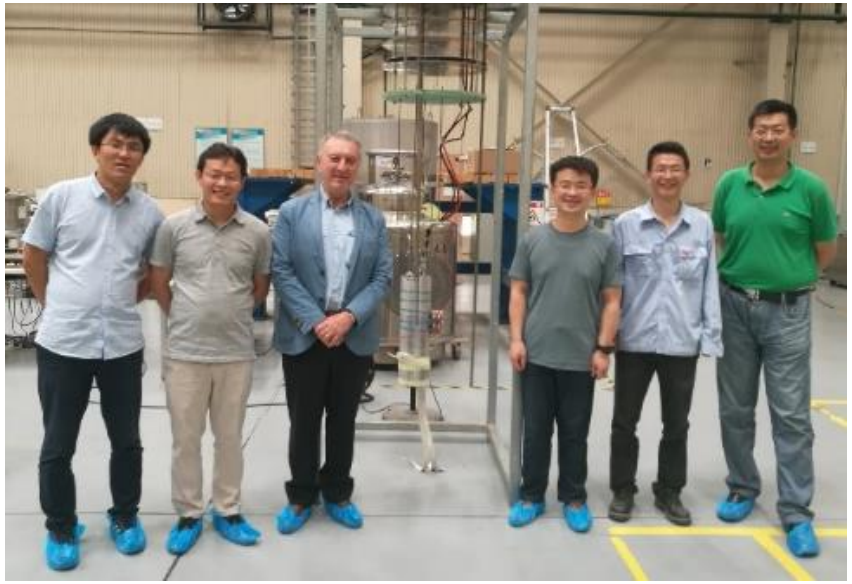
HL-LHC Collaboration – Accelerator technology

❖CCT magnet for HL-LHC

- China will provide 12 units CCT corrector magnets for HL-LHC before 2022
- A 0.5m model and 2.2m prototype to be fabricated and tested by June 2019

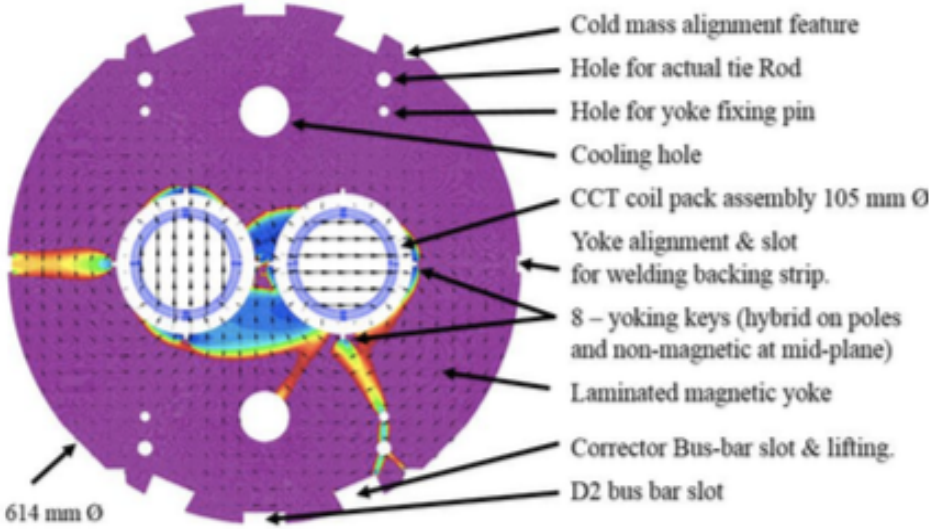






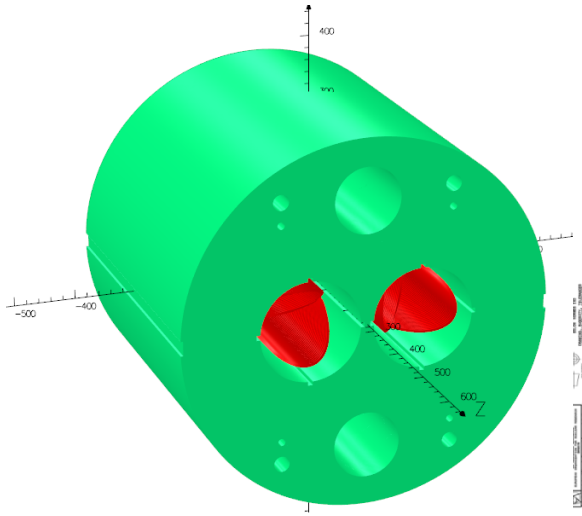
Magnet specifications of the short 0.5-m model

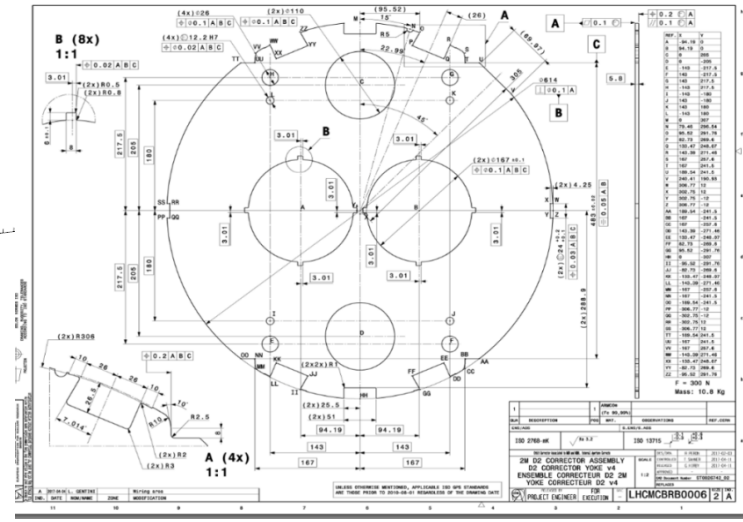
- ❖Mechanical length: 0.5 m
- ❖Integrated field: 0.757 Tm
- ❖Aperture: 105 mm (cold)
- ❖Beam distance: 188.19 mm
- ❖Current : 422 A
- ❖Ramps rates: 100 s to target value
- ❖Yoke: 614 mm in diameter



2D design from CERN

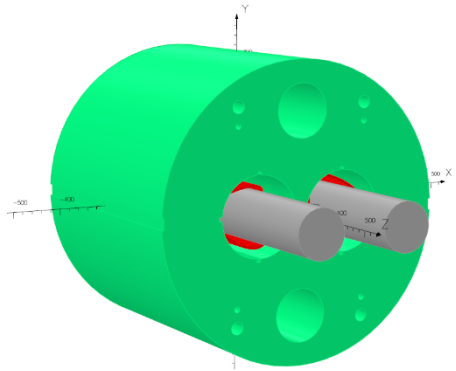
Bore field / T	2.64
Current / A	422
Layers	5+5
CCT angle /°	30
Gap per turn /mm	5.2(0.6)
Turns per layer	55
Integrated field / Tm	0.757
Peak field / T	3.1
Io/Ic	55%
Slot size in former	2 mm*5 mm,0.6 mm for rib
Coil size & length /mm	Φ614/539.4

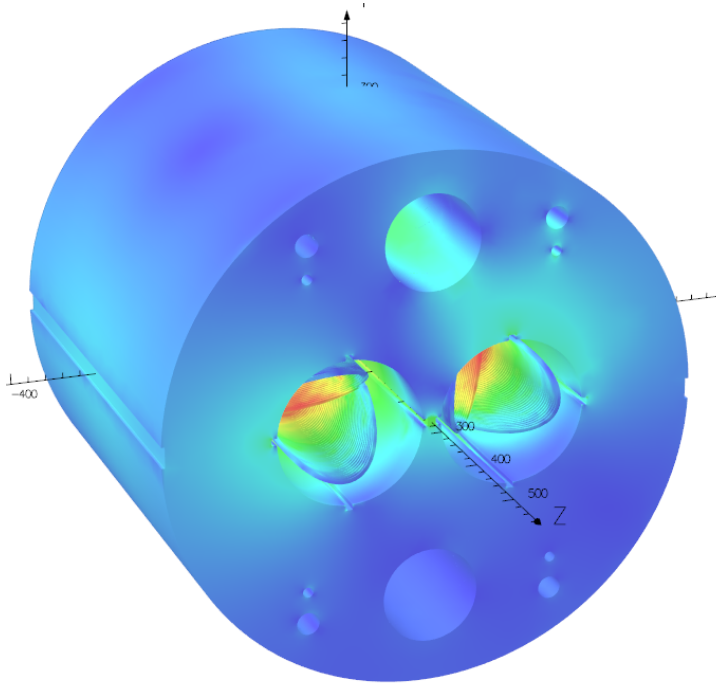


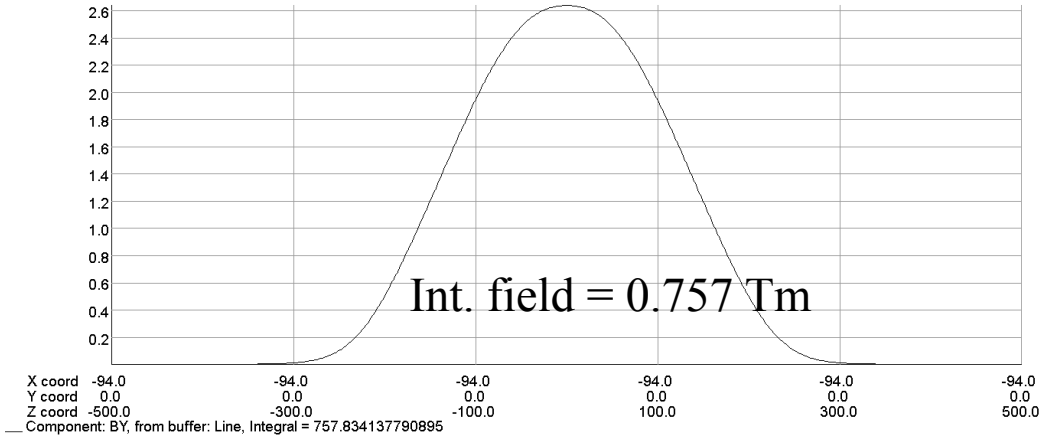


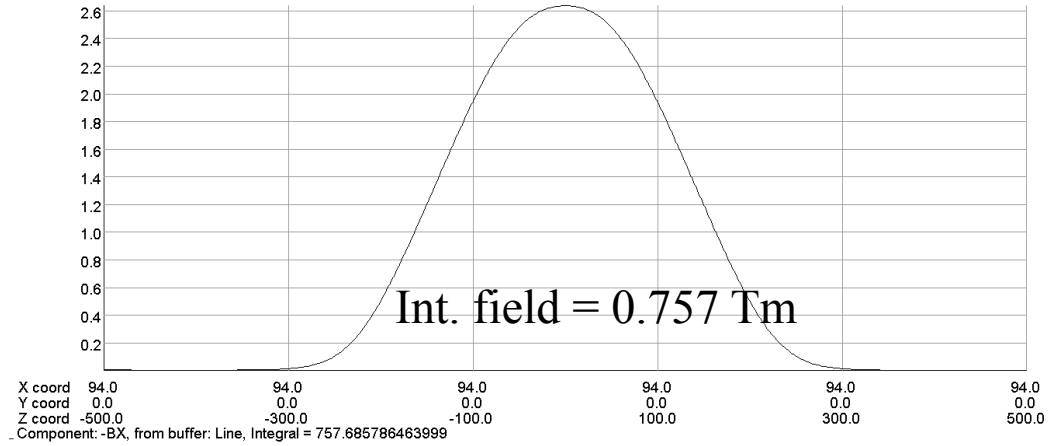
Magnetic Field Calculation in OPERA-3D

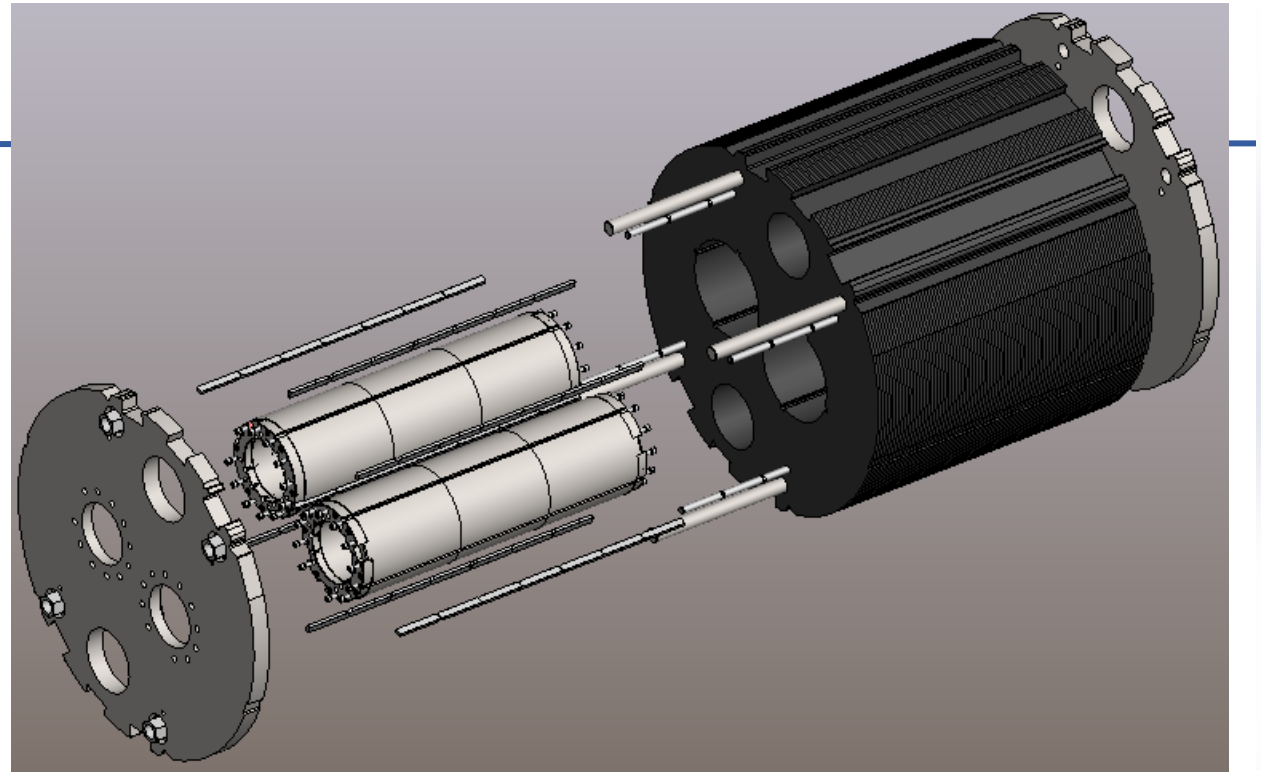
Coil gap：15
Iron core：30
Background：120



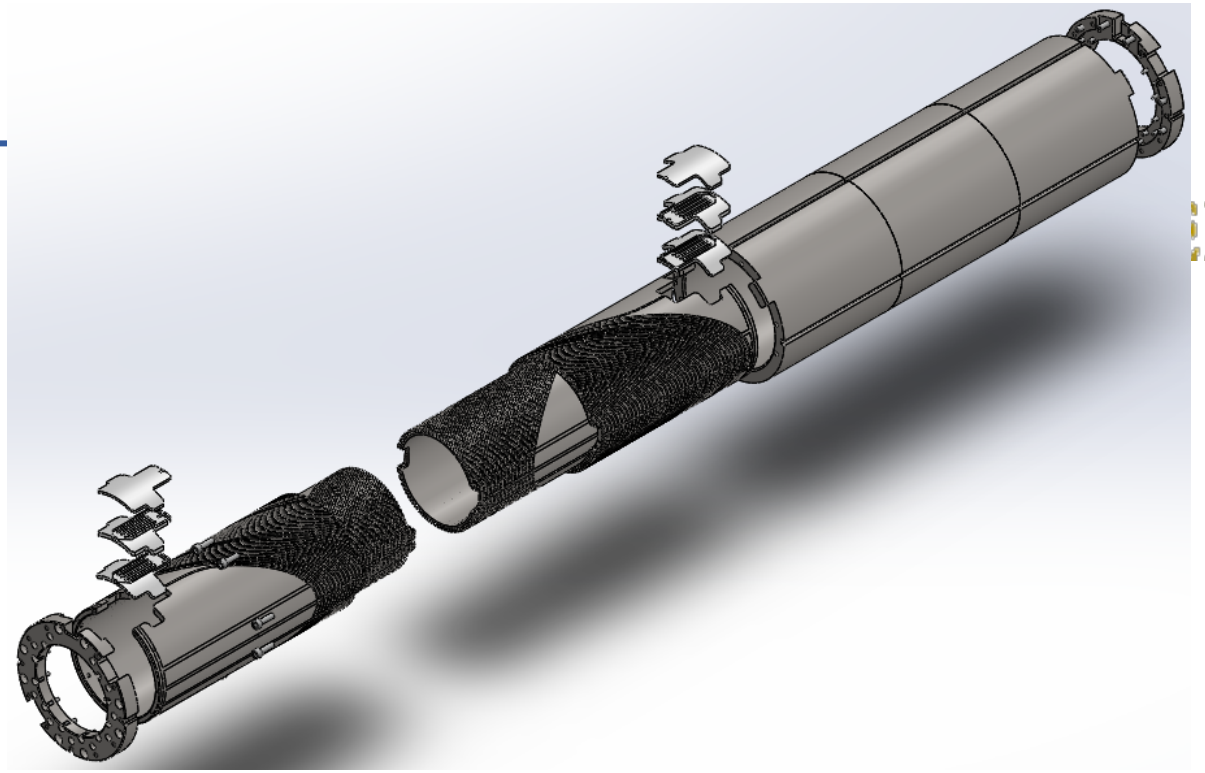








The whole structure



The coil structure

Parameters of superconducting wire

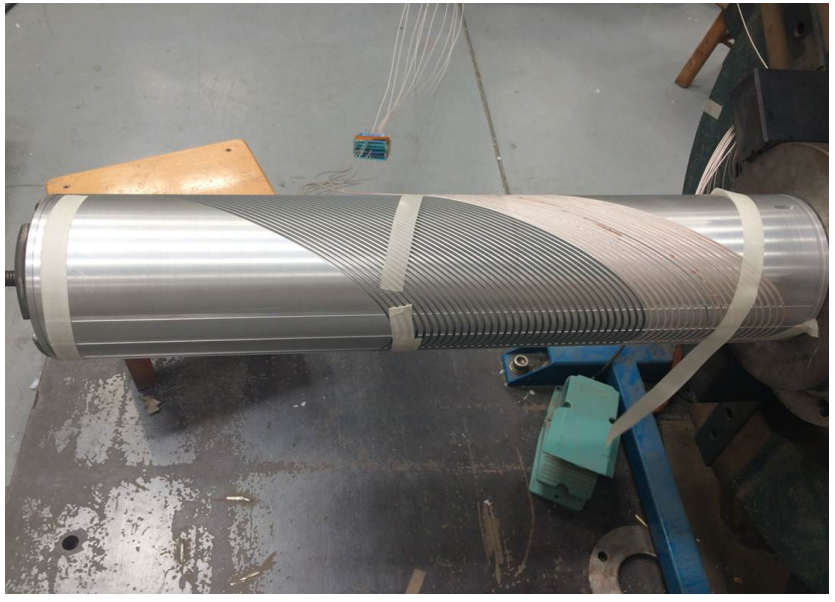
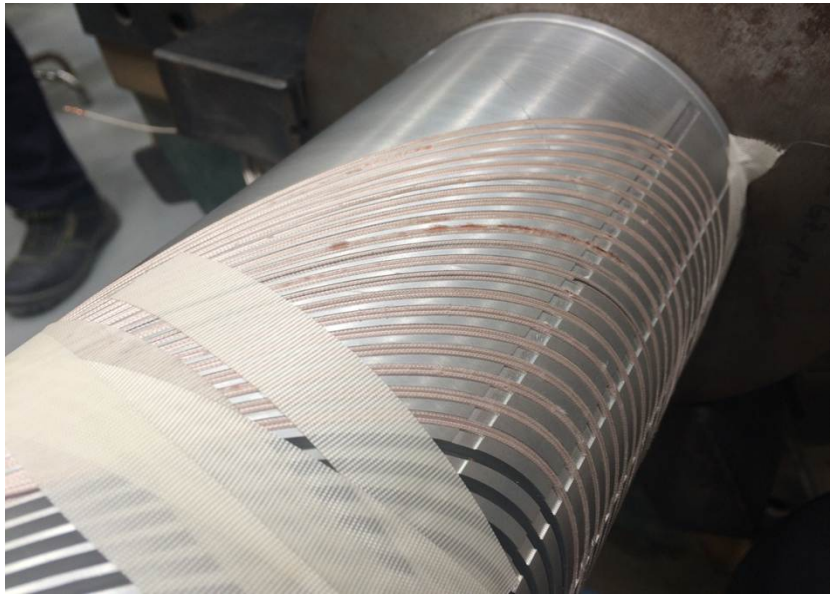
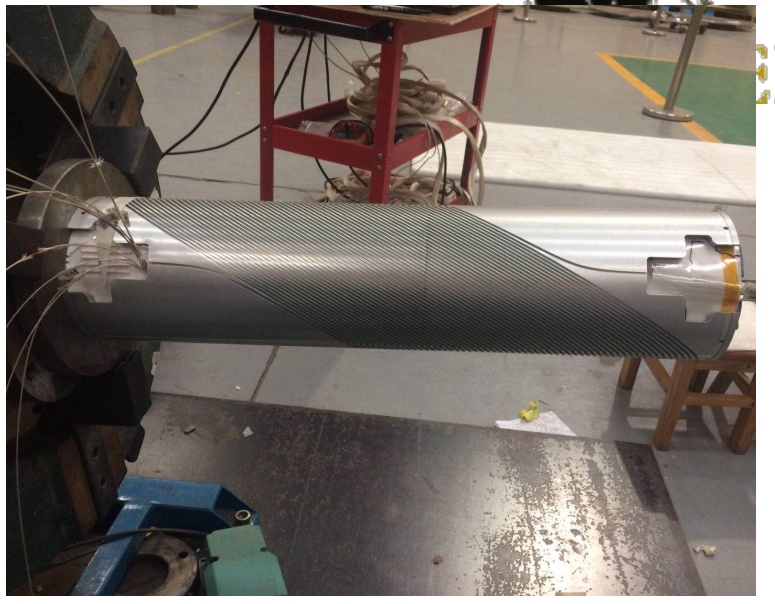
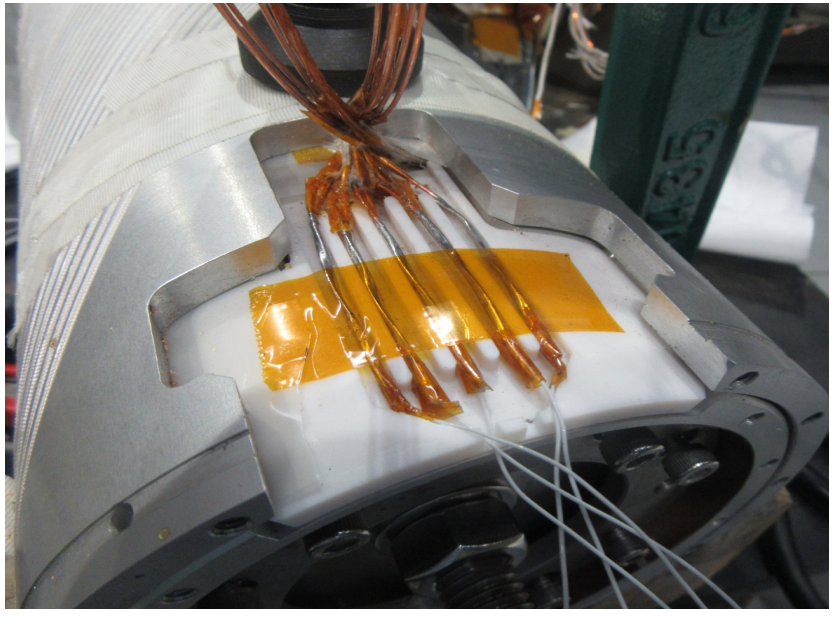
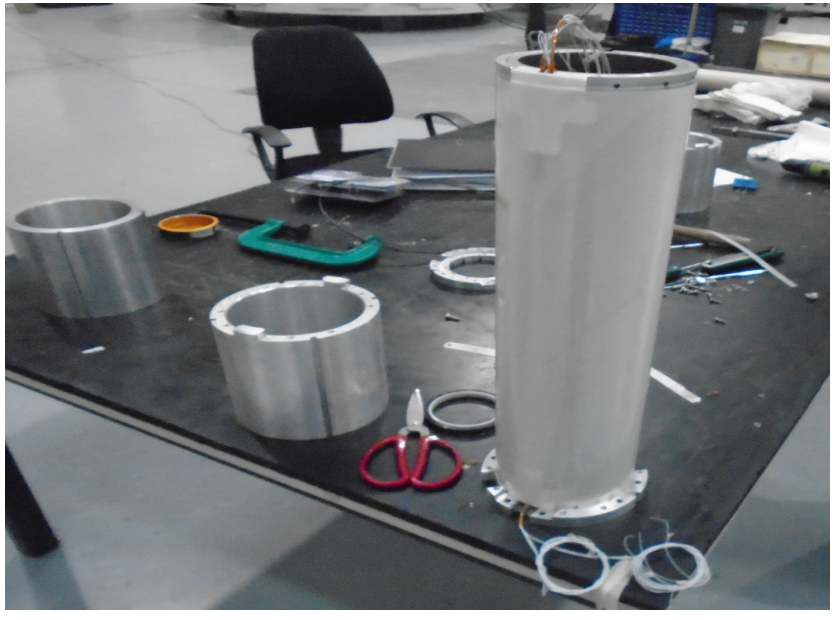
Insulated size (mm)	Insulation meterial	Number of filament	Cu/non-Cu ratio	Critical current@4.22K (A)	RRR(273K/ 10K)
Φ0.99±0.01	Kapton+S glass	≥192	1.3±0.13	>767@3T, >700@4T	>100
Insulation voltage >2500V					

Three-coordinate measuring result of outer former

	1# outer former1	2# outer former1	1# outer former2	2# outer former2	Criterion
Groove bottom size（different grooves）	-0.0239	-0.0437	-0.0983	-0.0442	122.6-123
Groove bottom size（same groove）	-0.0218	-0.0377	-0.0415	-0.0121	122.6-123
Inner circle size	-0.0214	-0.0118	-0.0066	Qualified	118.98-119.035
Outer circle size	0.0029	Qualified	Qualified	Qualified	132.97-133.028
Groove width	Qualified	1.9965	Qualified	Qualified	2-2.04
Groove profile	Qualified	Qualified	Qualified	Qualified	0.05
Inner circle roundness	Qualified	Qualified	Qualified	Qualified	0.03
Outer circle roundness	Qualified	Qualified	Qualified	Qualified	0.03
Coaxially	Qualified	Qualified	Qualified	0.0329	0.03

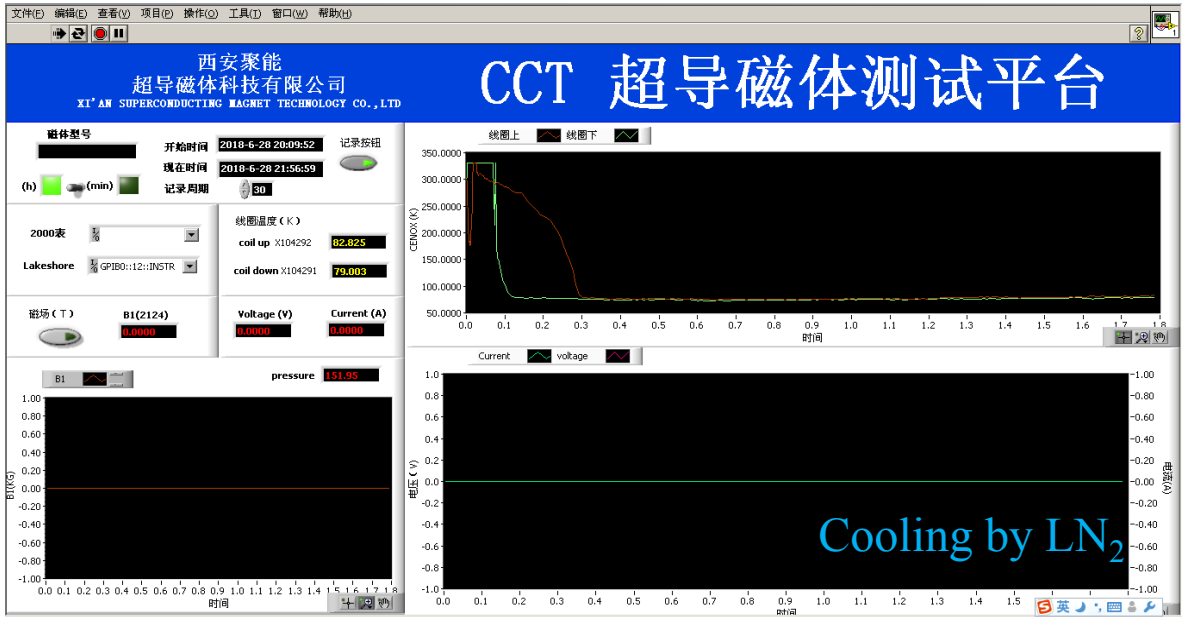
Because od different materials and processes, there will be some deformation in the process.

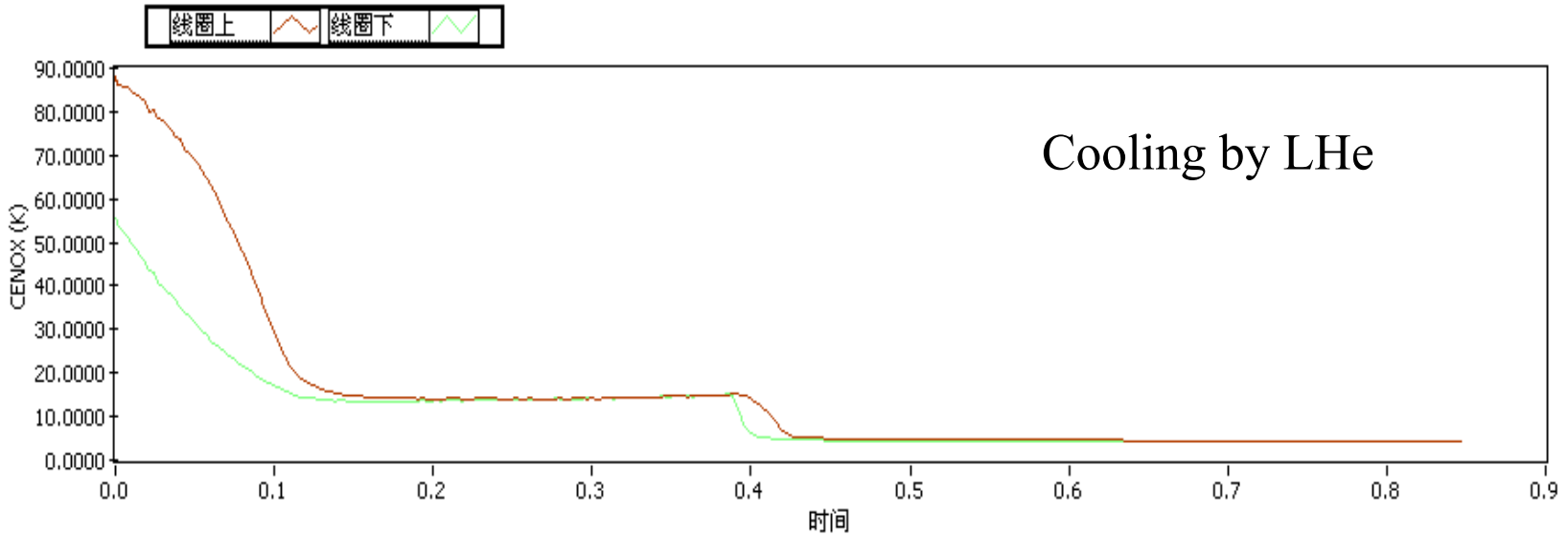
CCT magnet manufacture


CCT magnet test procedure


Test preparation

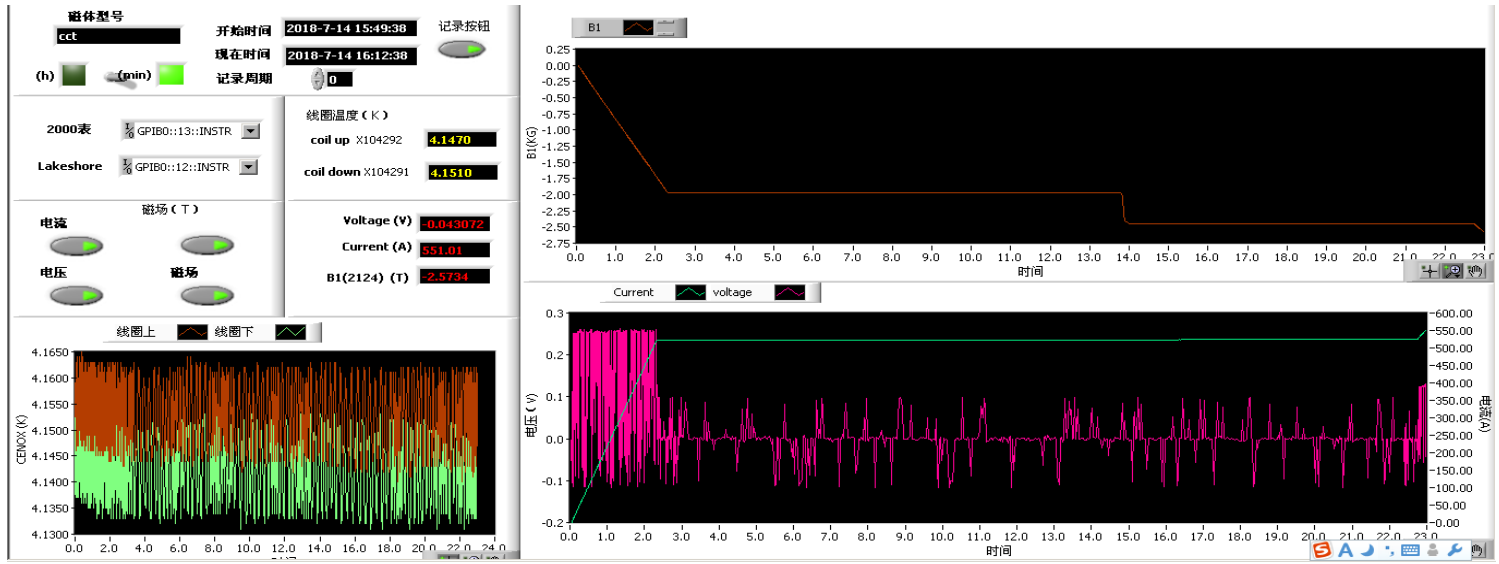




CCT magnet test procedure

data	time	details	comment
2018/7/14	8:40	cooling by LN2	check
2018/7/14	9:20	cooling by LN2	76K, 75k
2018/7/14	10:05	discharge of LN2	77K.76k
2018/7/14	11:00	dry under nitrogen	98K,88K
2018/7/14		dry with heating	
2018/7/14	12:20	cooling by LHe2	102K ,95k
2018/7/14	13:50	cooling by LHe2	41cm
2018/7/14	14:05	excitation 1A/s	
2018/7/14		excitation 2A/s	483A quench
2018/7/14	15:10	excitation 3A/s from 0 to 460A, 1A/s from 0 to 470A, pause, excitation	471A quench
2018/7/14	15:18	excitation 4A/s	469.4A
2018/7/14	15;28	excitation 4A/s	529A
2018/7/14	15:44	excitation 4A/s	543A
2018/7/14	15:49	excitation 4A/s	520A last 20 min, 551A quench

CCT magnet test procedure



Coils test procedure

- The wire of inner 6# and outer 5# quench first
- The wire of inner 7# and outer 2# quench later

CCT production schedule

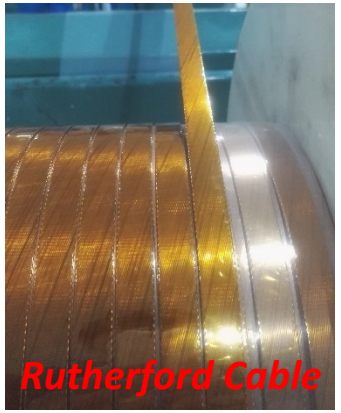
NO.	(date)	department	schedule																	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	内容		10th Sept.	17th Sept.	24th Sept.	1st Oct.	8th Oct.	15th Oct.	22nd Oct.	29th Oct.	5th Nov.	12nd Nov.	19th Nov.	26th Nov.	3rd Dec.	12nd Dec.	17th Dec.	22nd Dec.	27th Dec.	7th Jan.	14th Jan.
1	Three-dimension design	Department of design																			
2	engineering drawing	Department of design																			
3	Jig design	Department of design																			
4	superconducting wire	Department of supply																			
5	former and yoke sample machines	Department of supply																			
6	inner former machine (1#,2#)	Department of supply																			
7	outer former machine (1#,2#)	Department of supply																			
8	other parts machine	Department of supply																			
9	yoke machine	Department of supply																			
10	former checkout	quality department																			
11	1# inner former winding	production department																			
12	1# outer former winding	production department																			

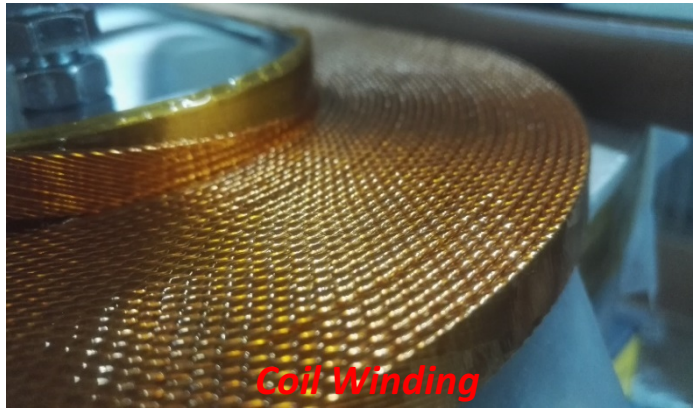
NO.	(date)	department	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	内容		21st Jan.	28th Jan.	4th Feb.	11st Feb.	18th Feb.	25th Feb.	4th Mar.	11st Mar.	18th Mar.	25th Mar.	1st Apr.	8th Apr.	15th Apr.	22nd Apr.	29th Apr.	6th May	13rd May	20th May
6	inner former machine (1#,2#)	Department of supply																		
7	outer former machine (1#,2#)	Department of supply																		
8	other parts machine	Department of supply																		
9	yoke machine	Department of supply																		
10	former checkout	quality department																		
11	1# inner former winding	production department																		
12	1# outer former winding	production department																		
13	1# coil assemble	production department																		
14	1# coil VPI	production department																		
15	1# coil test	production department																		
16	former checkout	quality department																		
17	2# inner former winding	production department																		
18	2# outer former winding	production department																		
19	2# coil assemble	production department																		
20	2# coil VPI	production department																		
21	2# coil test	production department																		
22	whole assembly	production department																		

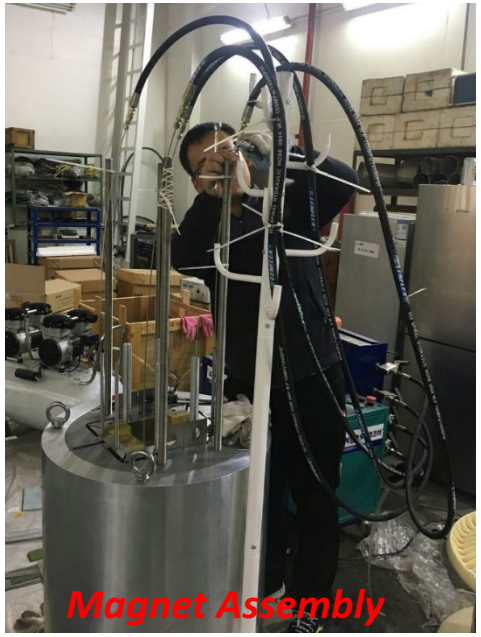
SC Magnet Experiences of Chinese Team

High field twin-aperture dipole magnet R&D: 10.2T @ 4.2K


Cabling Machine

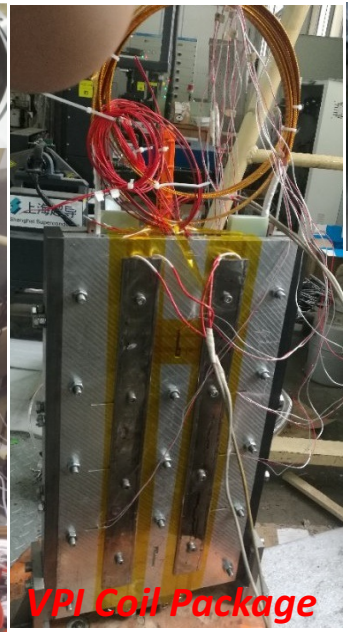

Rutherford Cable

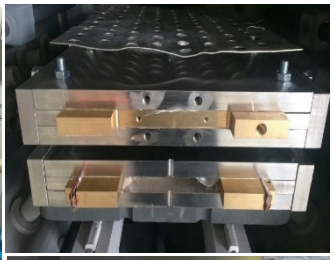

Coil Winding


Magnet Assembly

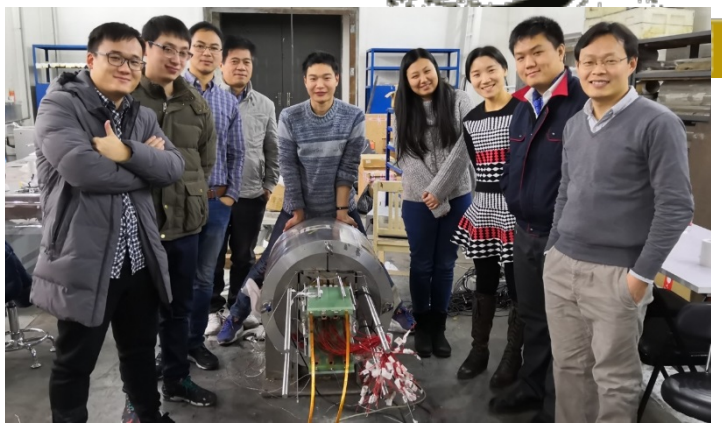

Impregnated Coil

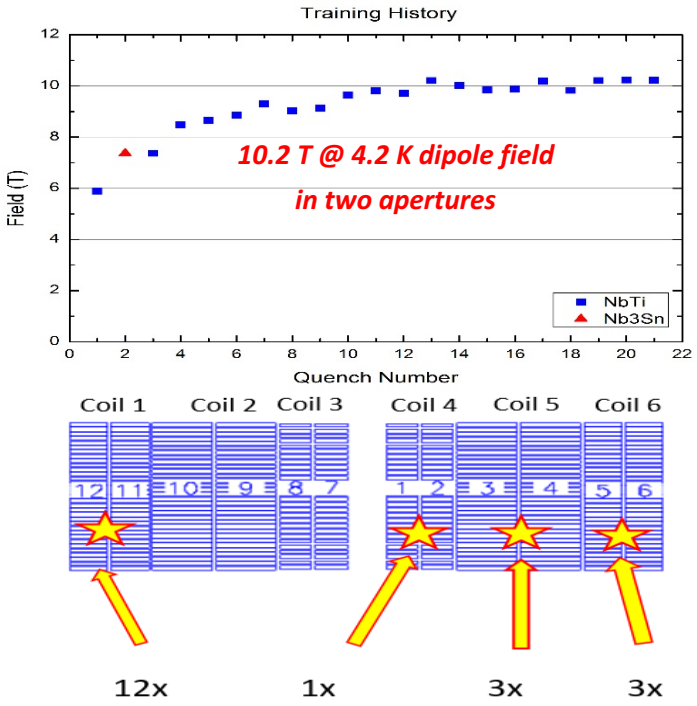

VPI


VPI Coil Package



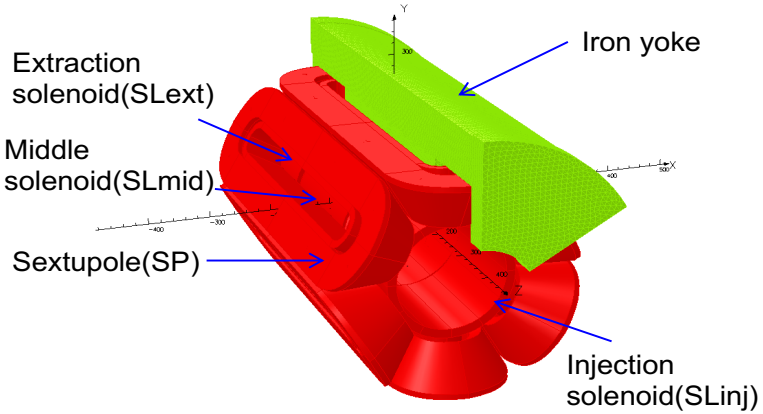

Heat Reaction



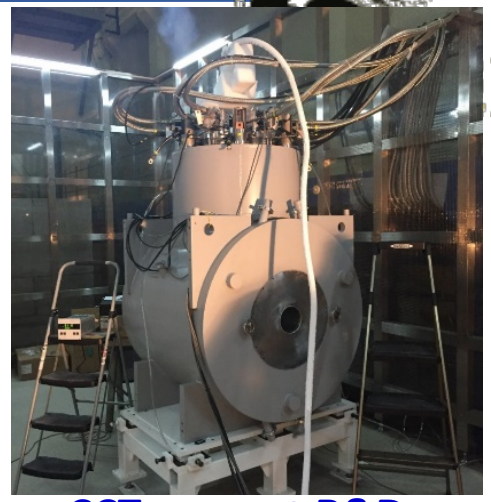


Super-FRS dipole prototype for FAIR

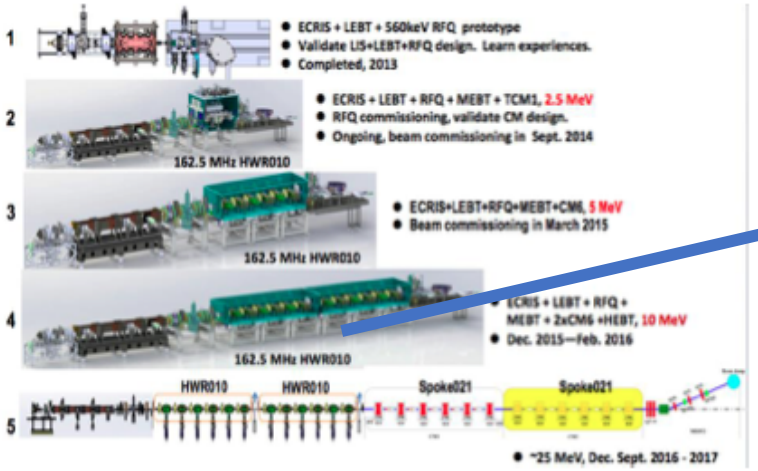
7T magnet for Penning trap



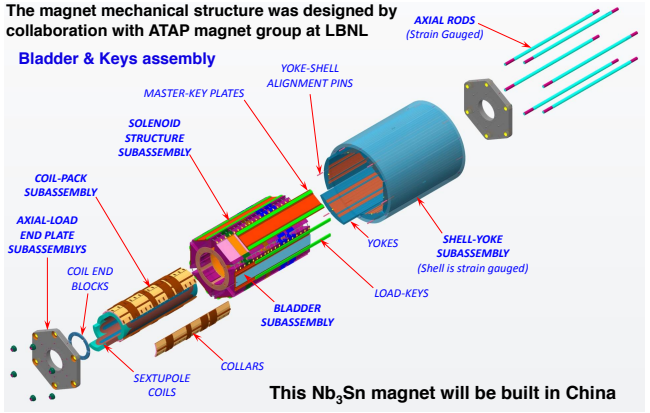
28 GHz ECRIS



CCT magnet R&D



Focusing solenoids for ADS SC Linac

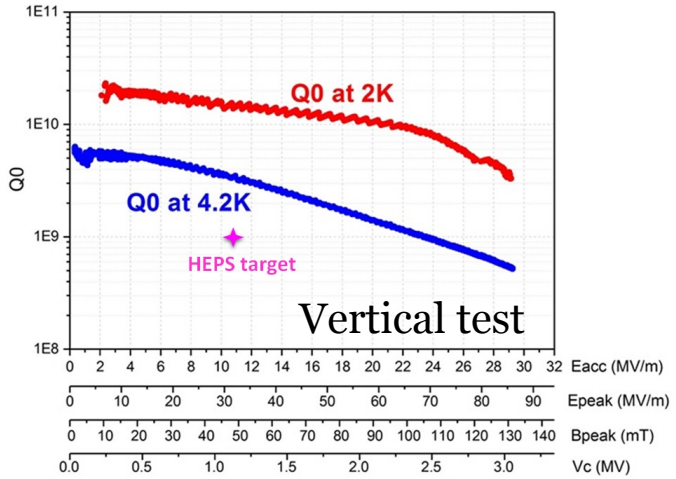


45 GHz ECRIS (Nb_3Sn)

Possible collaborations – Superconducting RF technology

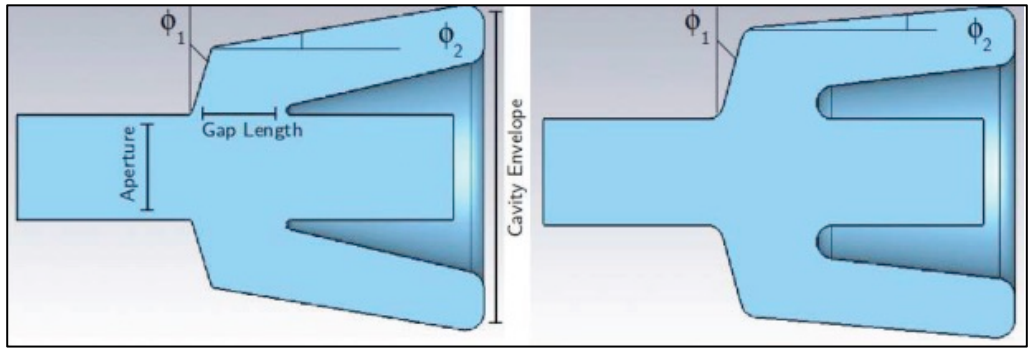
HOM-damped low-frequency β=1 SRF cavities

166.6MHz SC cavity (HEPS)



[1] P. Zhang et al., "The 166.6 MHz Proof-of-principle SRF Cavity for HEPS-TF", SRF2017, TUPB034.

200MHz SC cavity (HL-LHC)



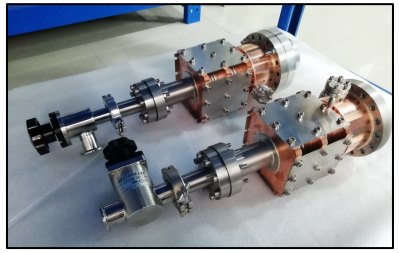
[2] R. Calaga, R. Tomas, "A 200 MHz SC-RF System for the HL-LHC", IPAC2016, TUPMW034.

[3] R. Calaga, HL-LHC RF Road-map: Technological Aspect, present at Chamonix 2014.

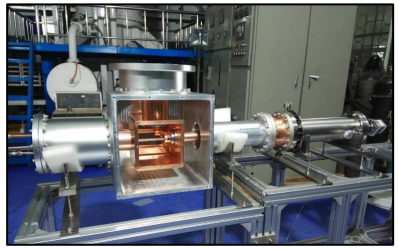
Similar RF requirements

Superconducting RF technology

ERL 1.3GHz
30kW CW

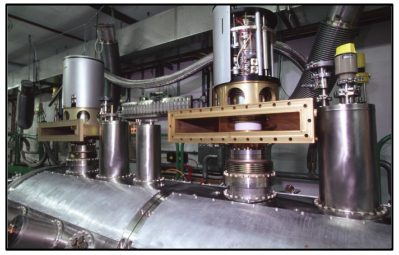


HEPS 166MHz
300kW CW

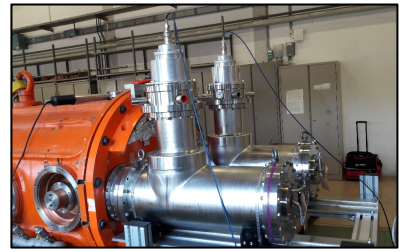


500MHz 300kW CW

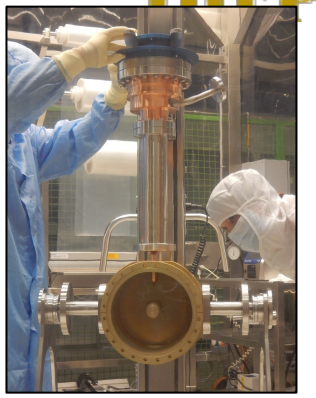
LHC 400MHz
500kW CW



SPS 200MHz
500kW CW



Crab 400MHz



Since 2000s

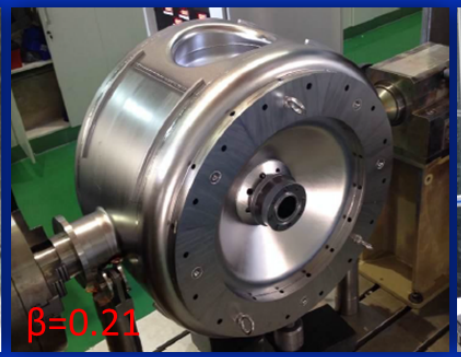
Mutual interests

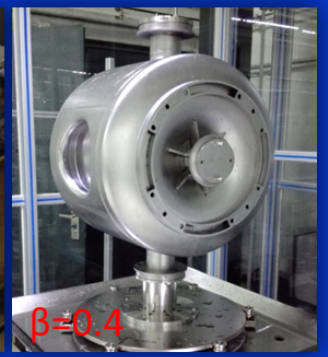
Since 1990s

SPS 200MHz 2MW SSPA

SRF cavities developed at IHEP

325MHz Spoke (CADS)

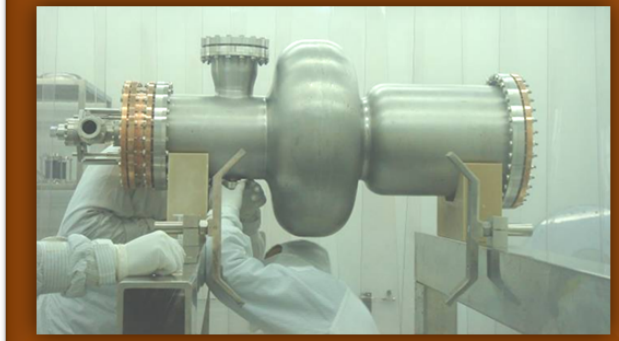




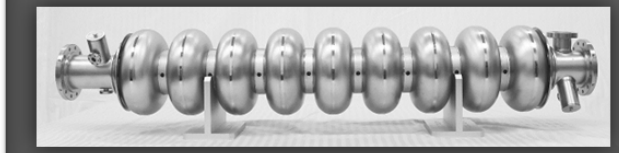
325MHz HWR

650MHz 5-cell (CADS)

500MHz (BEPCII)



1.3GHz 9-cell (ILC)



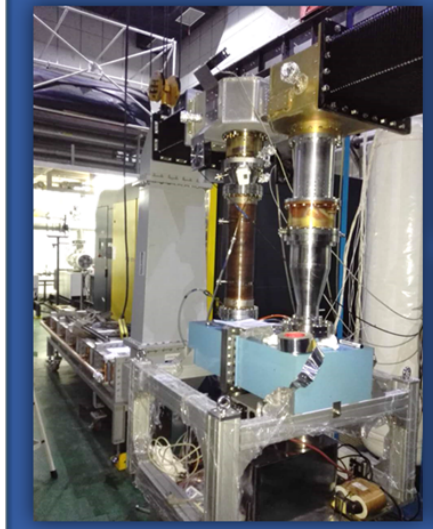
650MHz 2-cell, 1.3GHz 9-cell (CEPC)

166MHz QW (HEPS-TF)

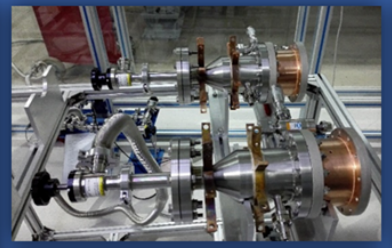
Couplers developed at IHEP

BEPCII 500MHz

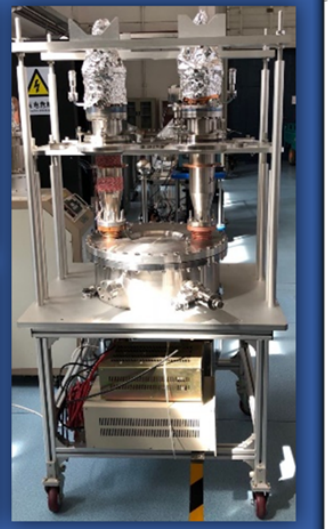
CADS 650MHz



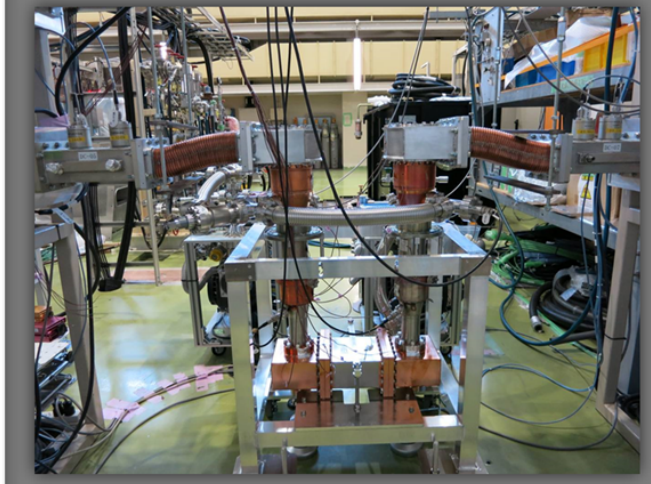
CADS 325MHz (Spoke, RFQ)

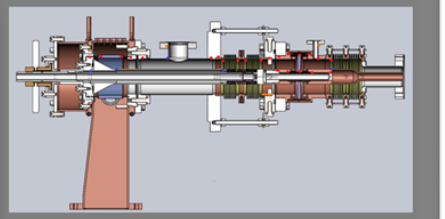


CADS 162.5MHz

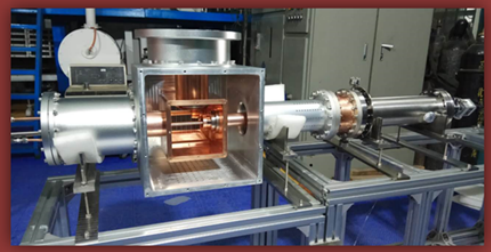


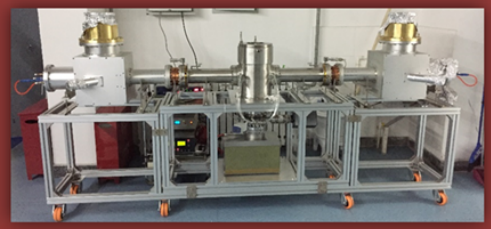
ILC 1.3GHz FPC (double-window)



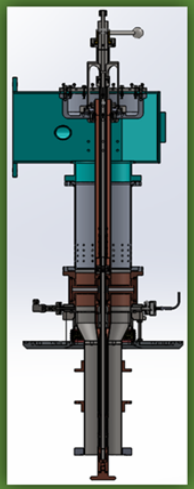


166.6MHz 200kW (HEPS-TF)





CEPC 650MHz



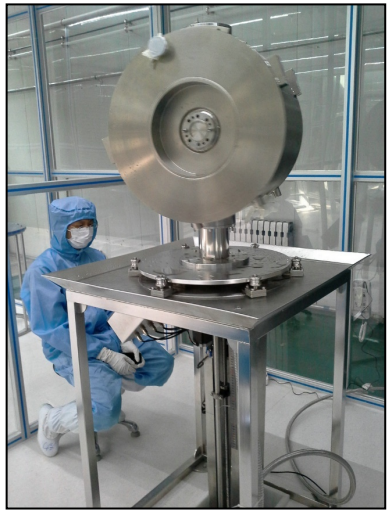
SRF infrastructure at IHEP

100W@2K cryo system

Largest 2K cryo in China

ISO4&ISO5 clean room

High-pressure rinsing

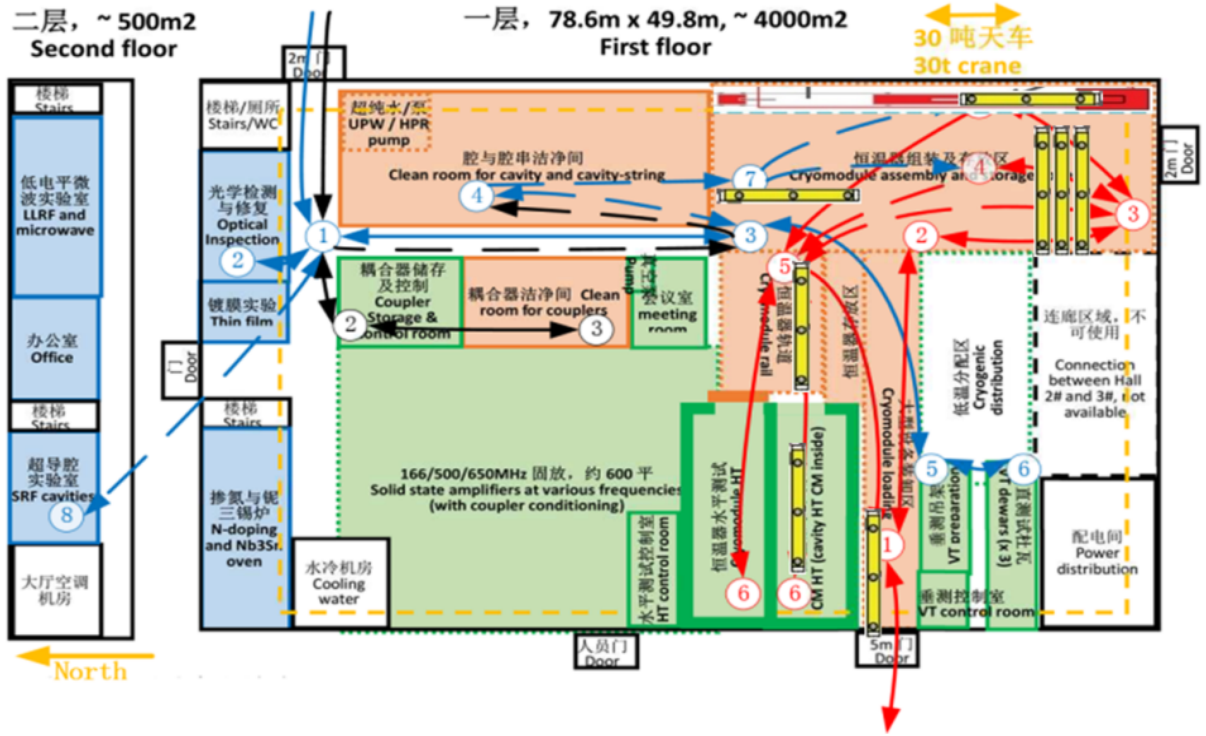


Chemical polishing system

SRF infrastructure in Huairou – new site for light source HEPS

❖Platform of Advanced Photon Source Technology R&D (PAPS)

- Mass production (~200 cavities/year), cleanroom, cavity post-process, couplers
- Cryogenic system: 300W @ 2K, cavity vertical & horizontal test, cryo-module test
- Area: 4500m^2, to be completed in 2020, largest SRF infrastructure in China



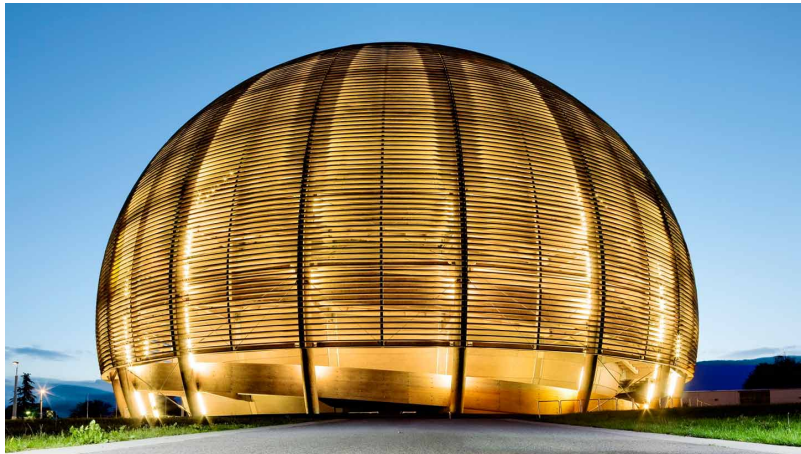
Possible collaboration – Cryogenic technology

- Simulation of large scale cryogenic system, developing the related software.
- Control of the cryogenic system, improving the efficiency of system operation and reduce the recovery time once fault occurs.
- Design of large scale 2K cryogenic system.
- IHEP has a lot of experiences on the cryomodule and cryostat development. If possible, IHEP can provide supports or contributions to CERN in this area.



Conclusion

- Accelerator physics & technology collaborations between CERN and IHEP are historical and very much beneficial to both sides.
- HL-LHC will be a good chance for China to join the international collaborations in accelerator-based large science facility.
- A Chinese team led by IHEP will contribute the CCT magnet production, and hope to have more collaborations on SRF, cryogenics tech as well.



Thanks for your attention!