

The 23rd International Conference on Cyclotron and their Applications CYC2022

Engineering Design and Fabricating Technology for SC Magnets in Cyclotron

Reporter:Xinglong Guo

Bama Superconductive Technology

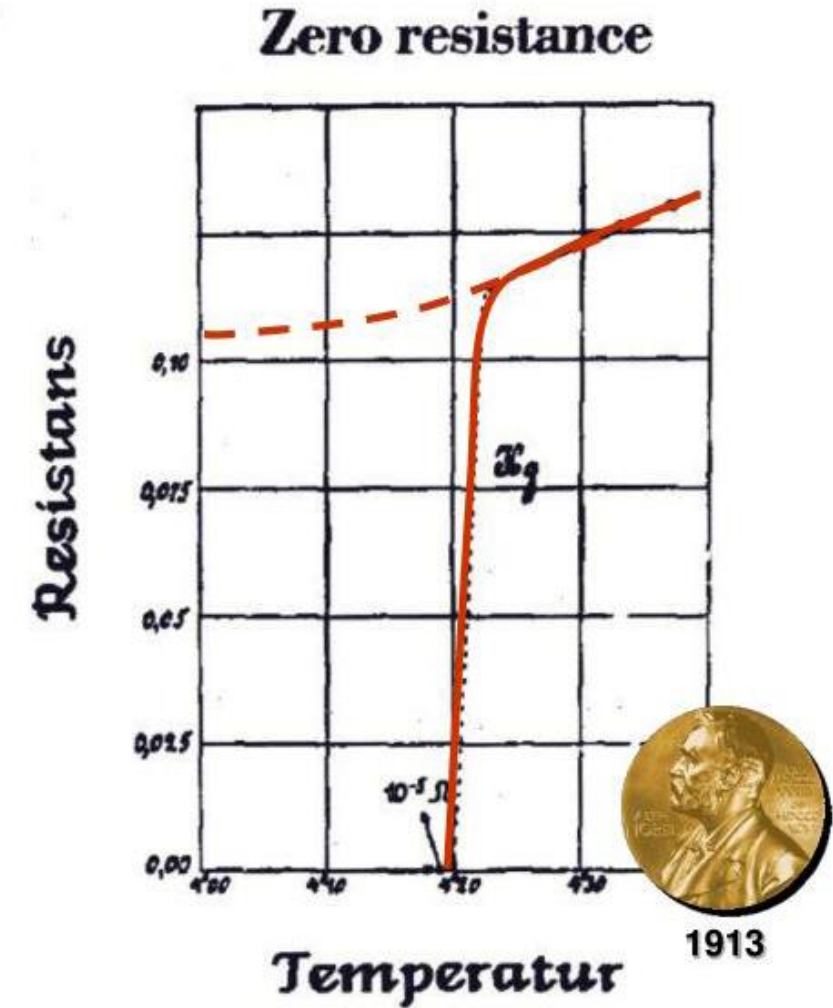
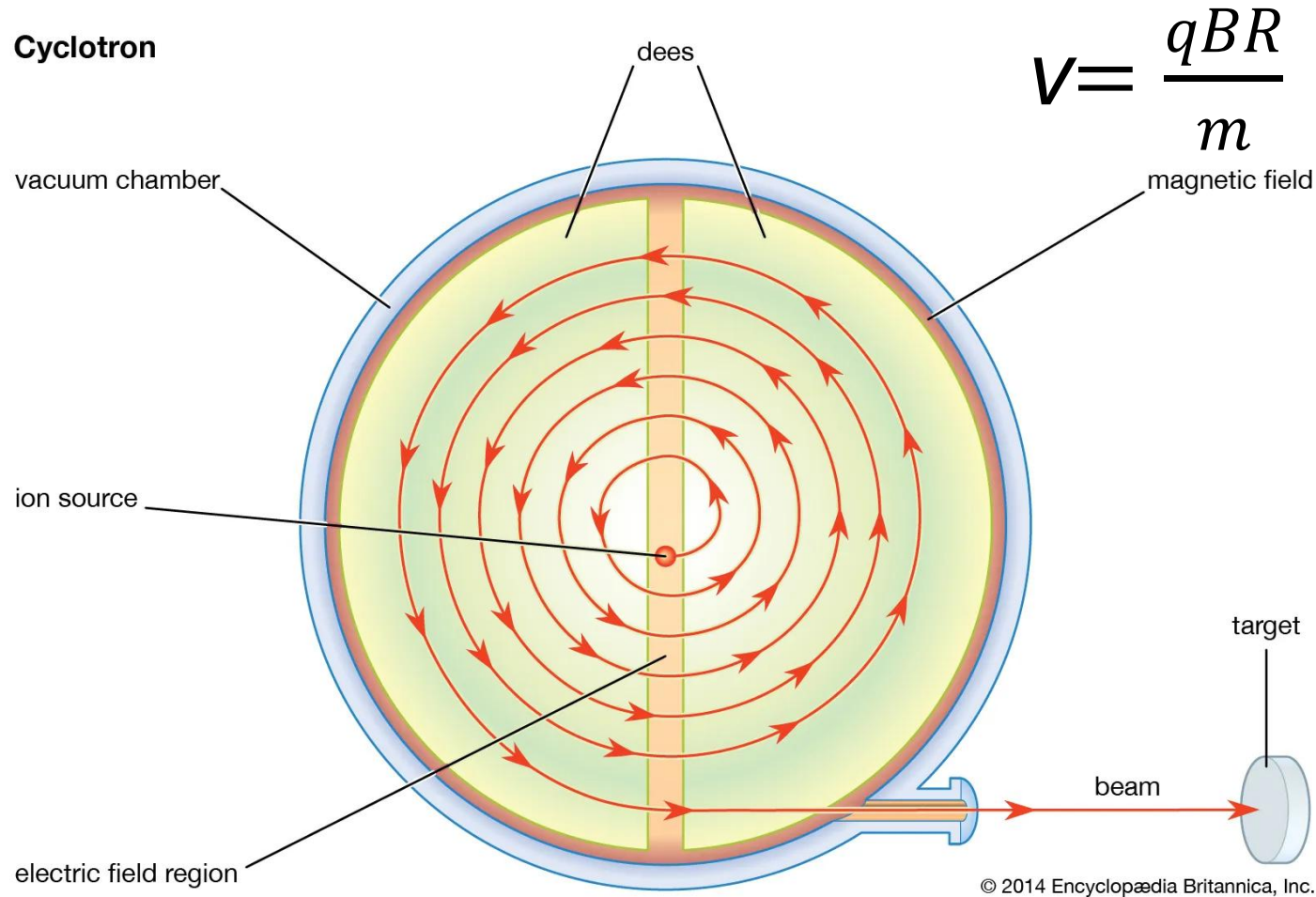
Date:2022-12-09



Out line

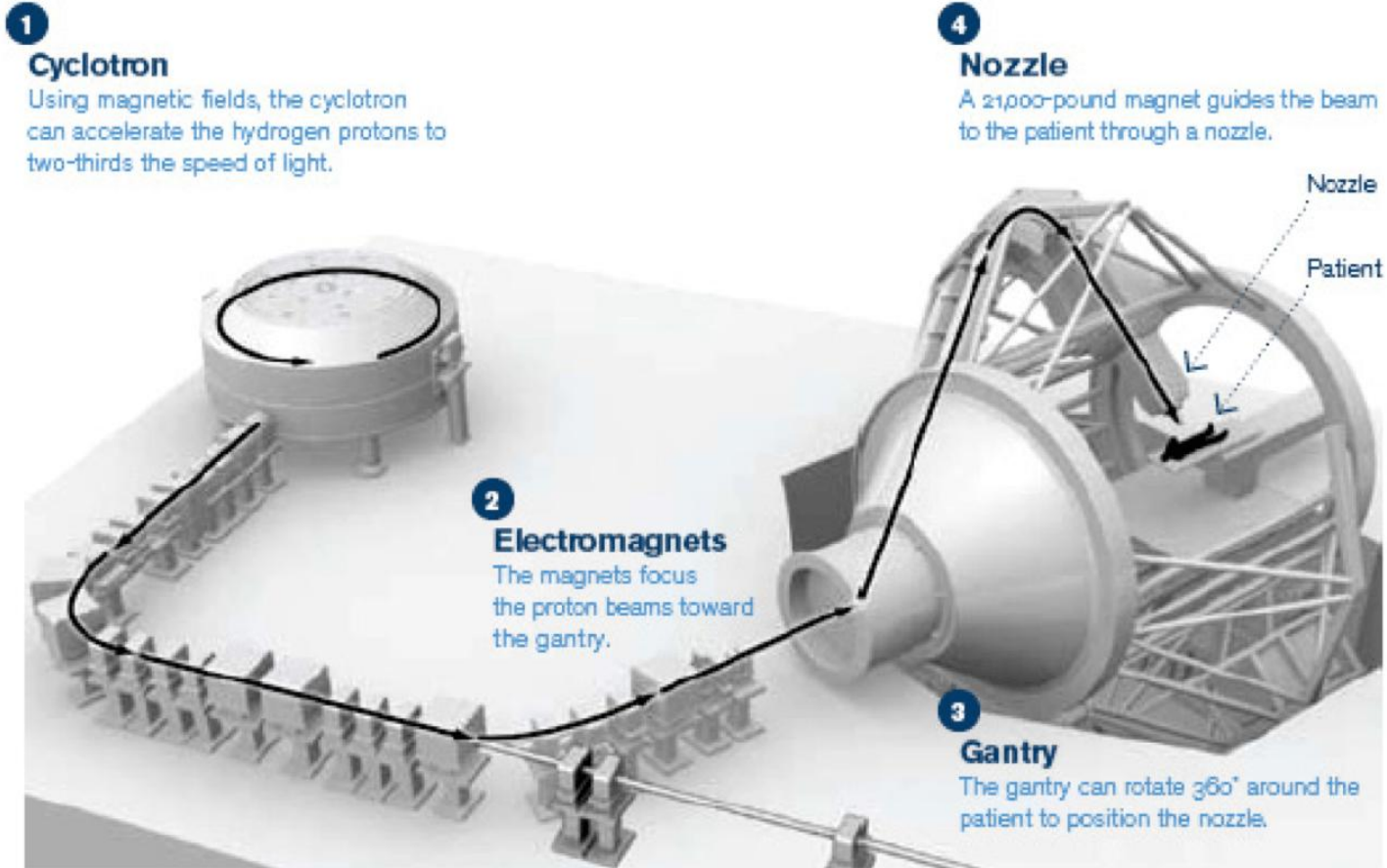
- 01 SC Magnets Application in Cyclotron
- 02 Trends of SC Magnets in Cyclotron
- 03 Typical SC Magnets Cases in Bama Co.
- 04 Cryogenic Products in Bama Co.
- 05 Summary

1. SC Magnets Application in Cyclotron



Construct smaller, less costly cyclotrons using superconducting technology, CYC1975

Typical SC Magnets in Cyclotron for Proton Therapy

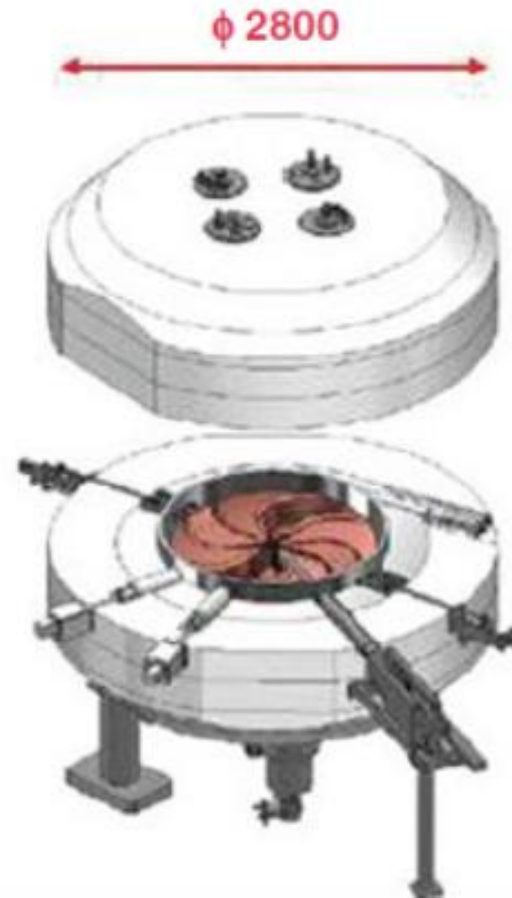
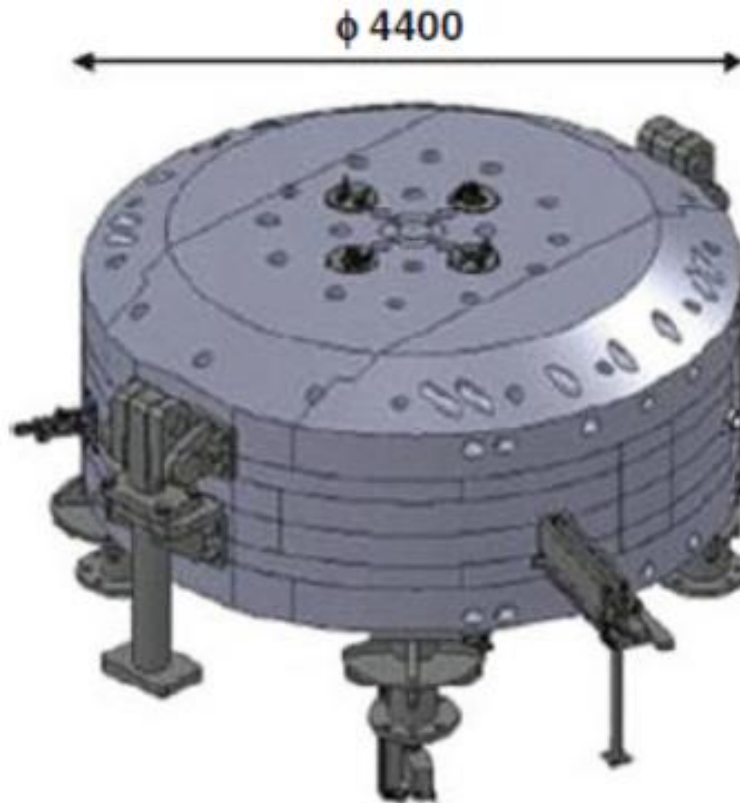


Typical SC Magnets in Cyclotron for Proton Therapy (2)

Normal conducting, 220 t

Superconducting, 50 t

Synchrocyclotron, 5 t.



D2800

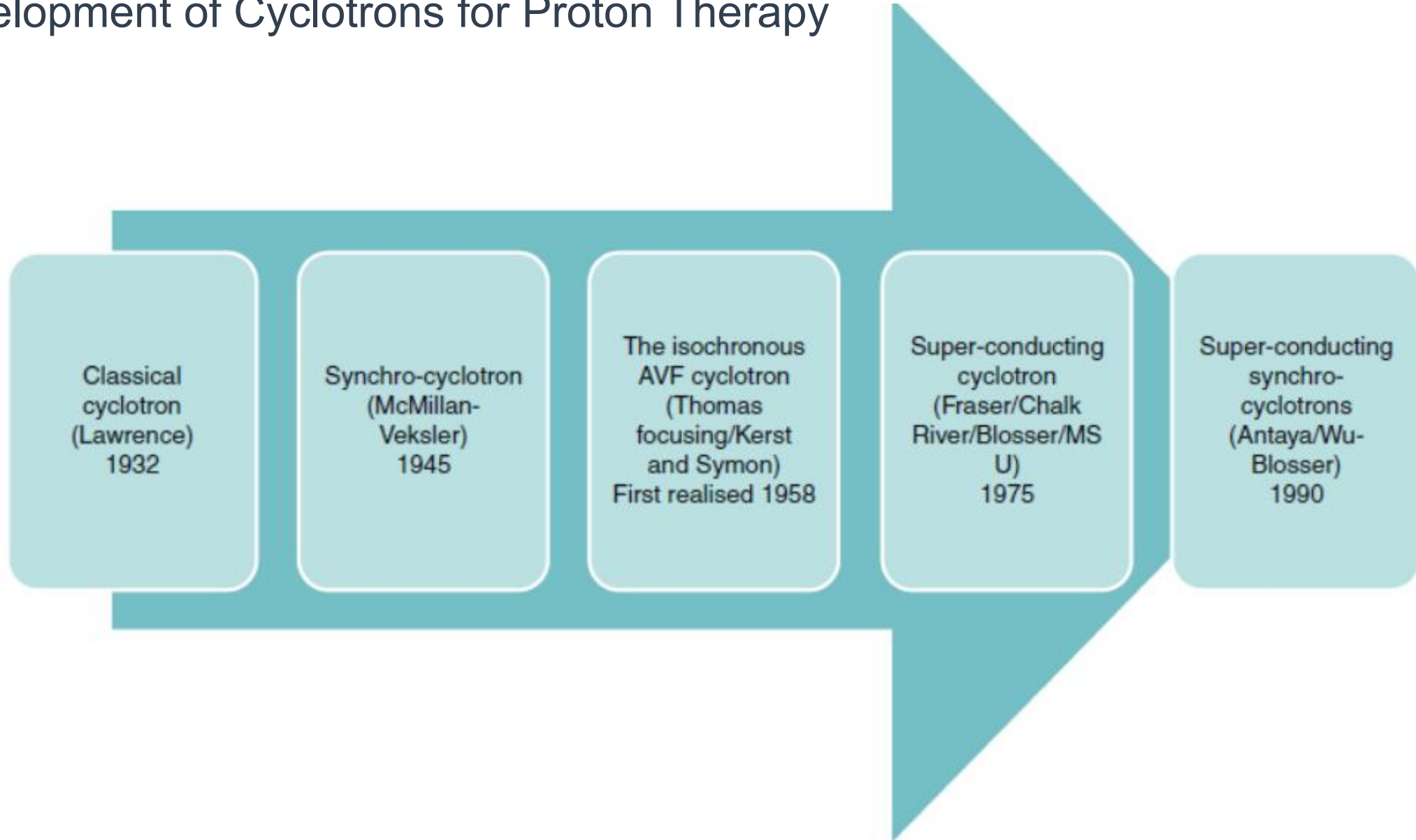
Iron-free variable energy

(70-230 MeV) ,

Typical SC Magnets in Cyclotron for Proton Therapy (3)

	Isochronous cyclotrons		Synchrocyclotrons	
	IBA/SHI Cyclone®230	VARIAN ProBeam®	MEVION Monarch S250	IBA S2C2
Weight	220 ton	90 ton	20 ton	50 ton
Diameter	4.34 m	3.1 m	<1.8 m	2.5 m
Height	2.1 m	1.6 m	<1m	1.56 m
Coil	Resistive	NbTi	Nb3Sn	NbTi
Cooling	Water	He-Cooled	Cryogen-free	Cryogen-free
Beam time structure	CW	CW	Pulsed	Pulsed
Peak field	2.9 T	3.8 T	9 T	5.7 T

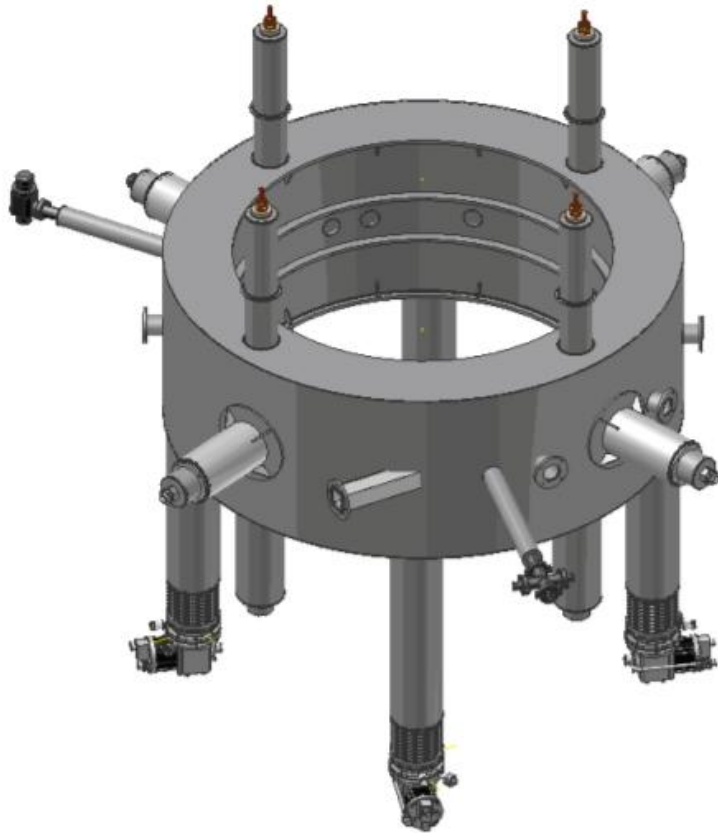
Development of Cyclotrons for Proton Therapy



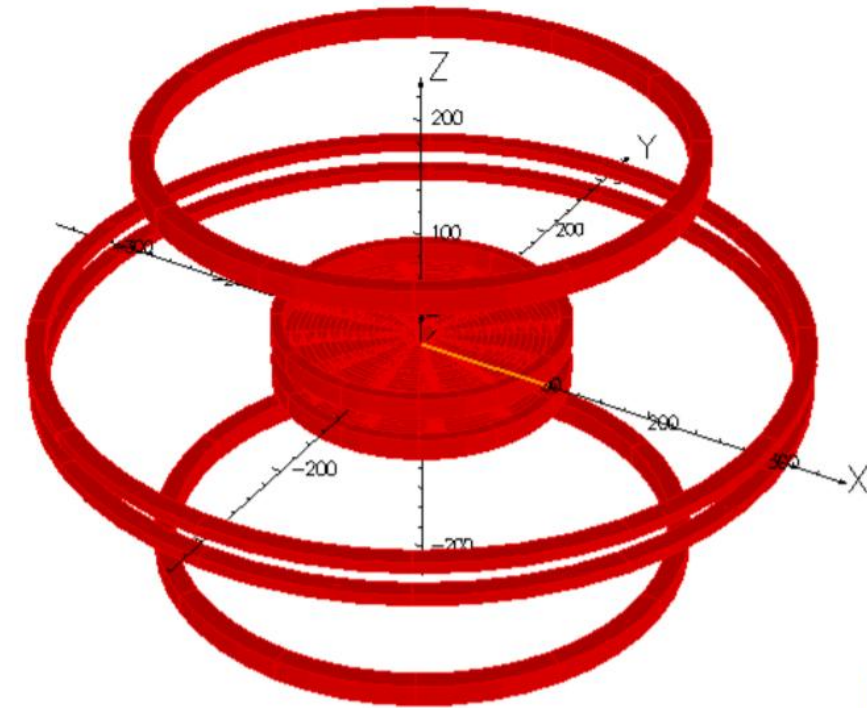
Pearson, Emma et al. "Development of Cyclotrons for Proton and Particle Therapy." 2016

2. Trends of SC Magnets in Cyclotron

Compact SC AVF cyclotron, 4T
Conduction cooled by cryocoolers,
Sumitomo



Ironless cyclotron, MIT



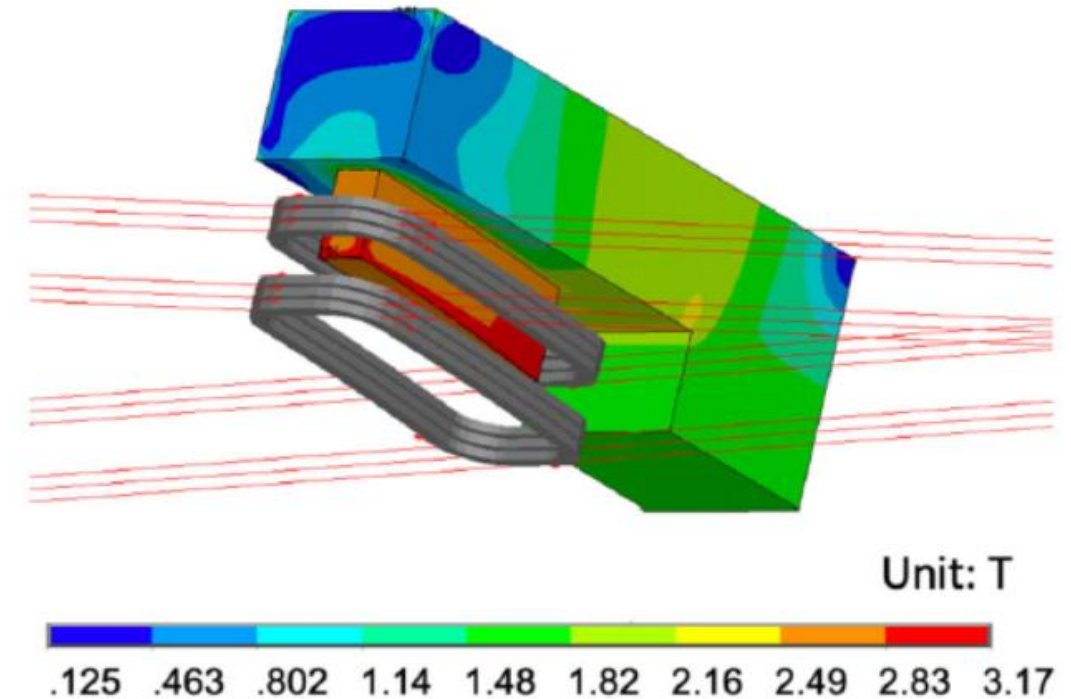
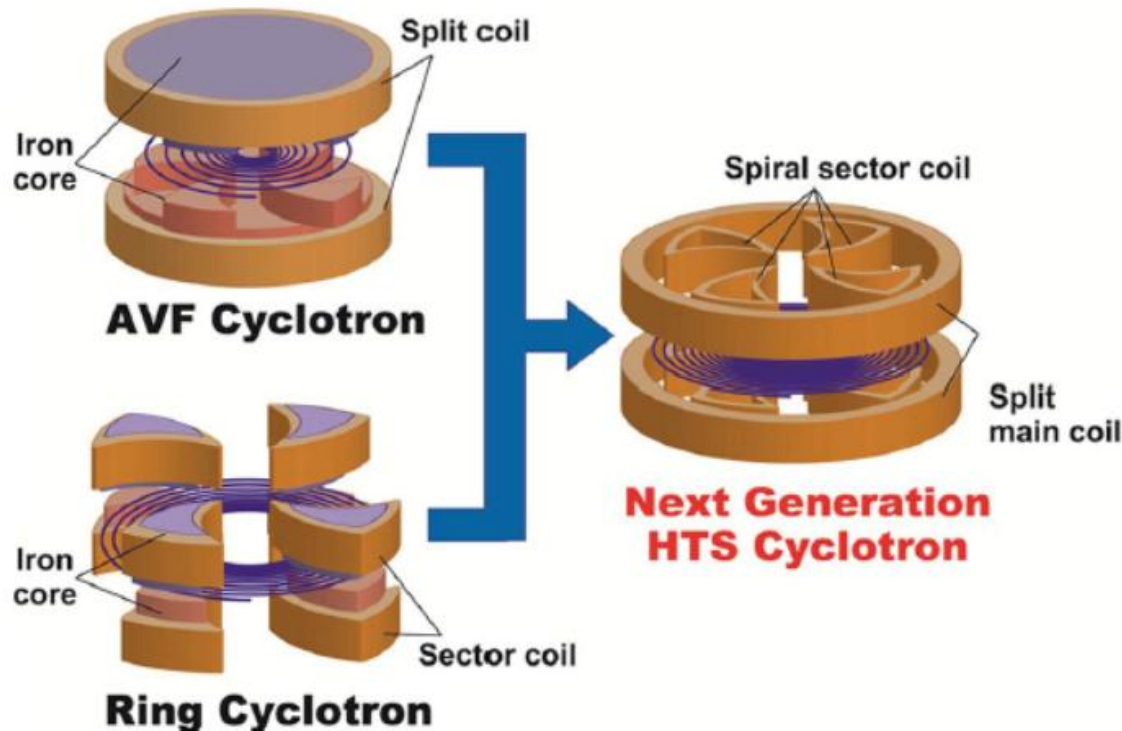
Opera

Pearson, Emma et al. "Development of Cyclotrons for Proton and Particle Therapy." 2016

Trends of SC Magnets in Cyclotron (2)

HTS, Ironless, AVF cyclotron

HTS, for 2 GeV FFAG Accelerator, CIAE, China



Ueda H, "Conceptual design of next generation HTS cyclotron," 2013

W. Fu, et al., "Fabrication and Test of a 1:4 Scaled HTS Coil for the Defocusing Magnet of 2 GeV FFAG Accelerator," 2022

3. Suzhou Bama Superconductive Technology Co., Ltd.



- ◆ Specialized supplier of SC magnets for industry, medical , scientific instrument and big scientific project.
- ◆ Specialized supplier of serialized GM cryocooler, Helium compressor, Cryo vacuum pumps
- ◆ Located in Suzhou, China, with production sit about 5000 m², 100+ staffs

BAMA, Supplier of Technology & Equipment for Ultimate Environment Creation

Cryogenics
<-1.5K-20K-200K



◆GM Cryocooler

SC Magnets
1.5T-9T-14T-40T->



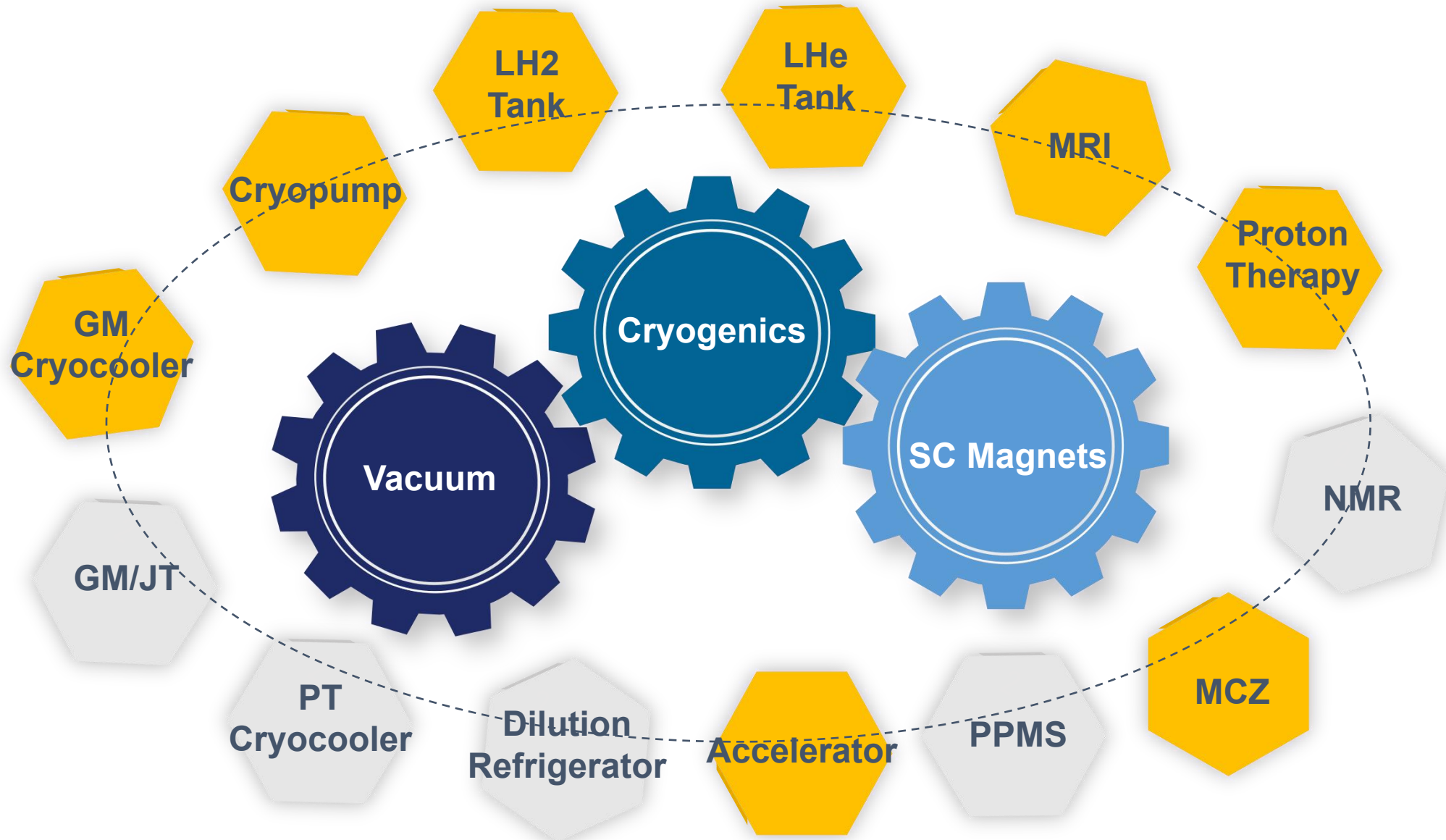
- ◆MCZ
- ◆Big Science Engineering
- ◆Medical
- ◆Instruments

Vacuum
<-1E-9Pa--1E-5Pa

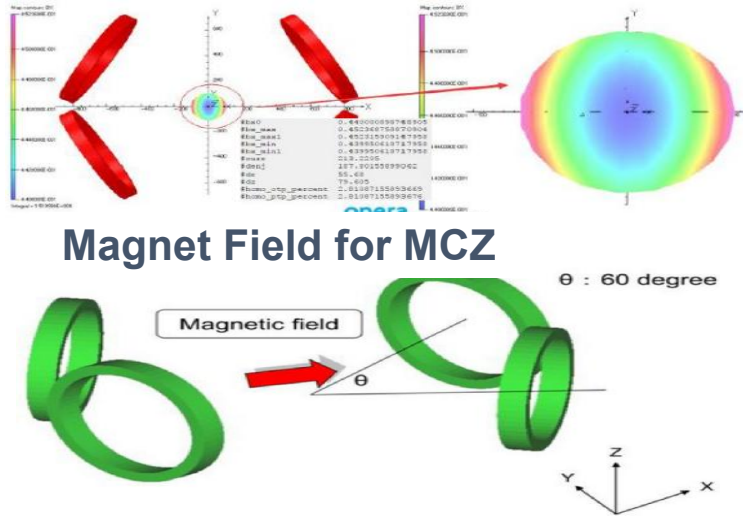


◆Cryopumps

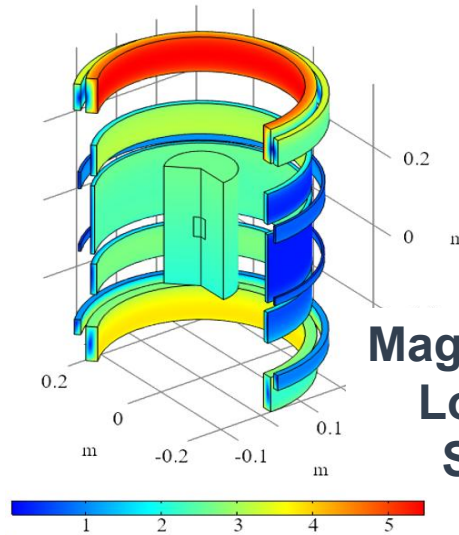
BAMA, Supplier of Technology & Equipment for Ultimate Environment Creation



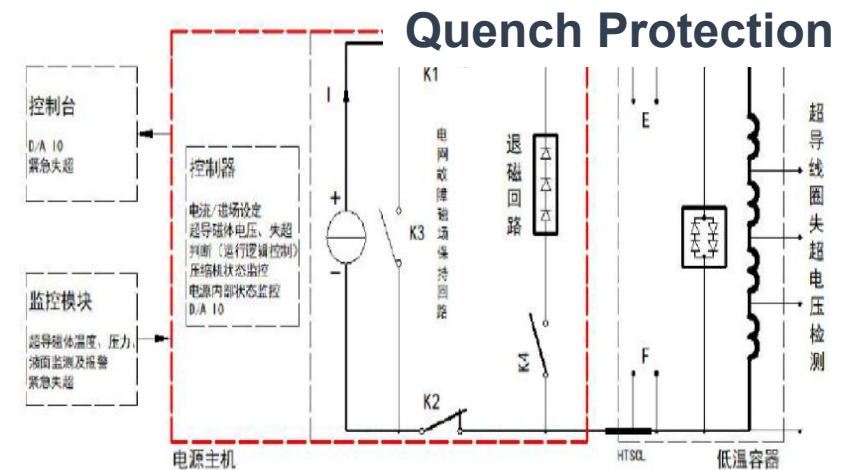
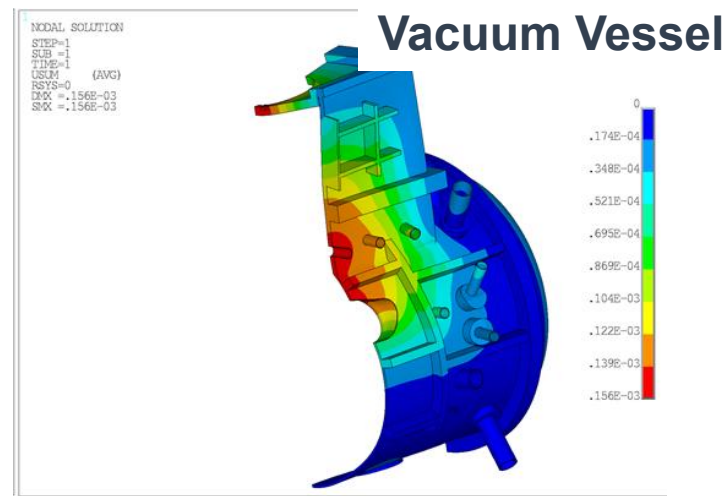
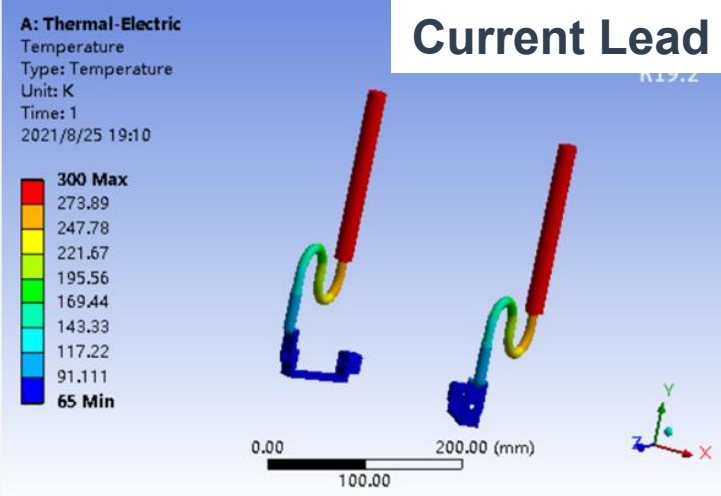
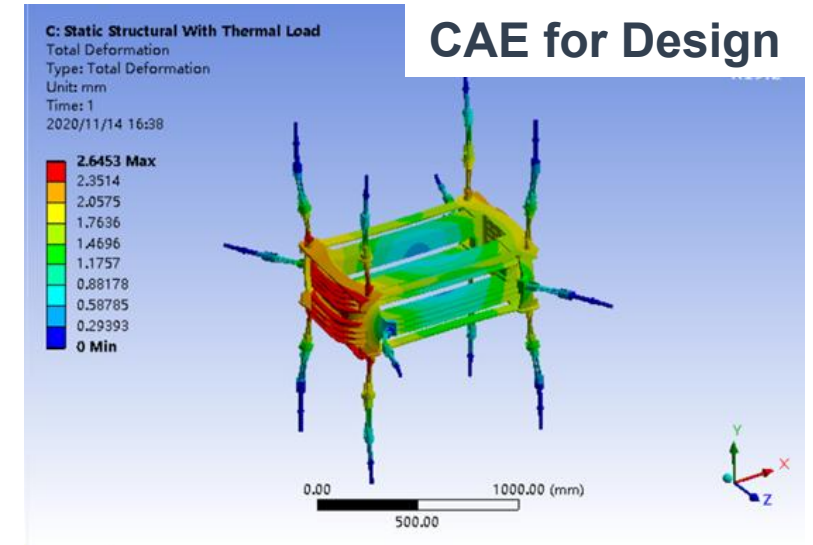
Engineering Design for SC Magnets, NbTi-Nb₃Sn-HTS



Surface: Magnetic flux density norm (T)



Magnet Field for Low-gravity Simulator



Fabricating Technology for SC Magnets



Vacuum Brazing Furnace

◆ For HTS Leads, Copper HX...



Automatic Coil Winding Machine

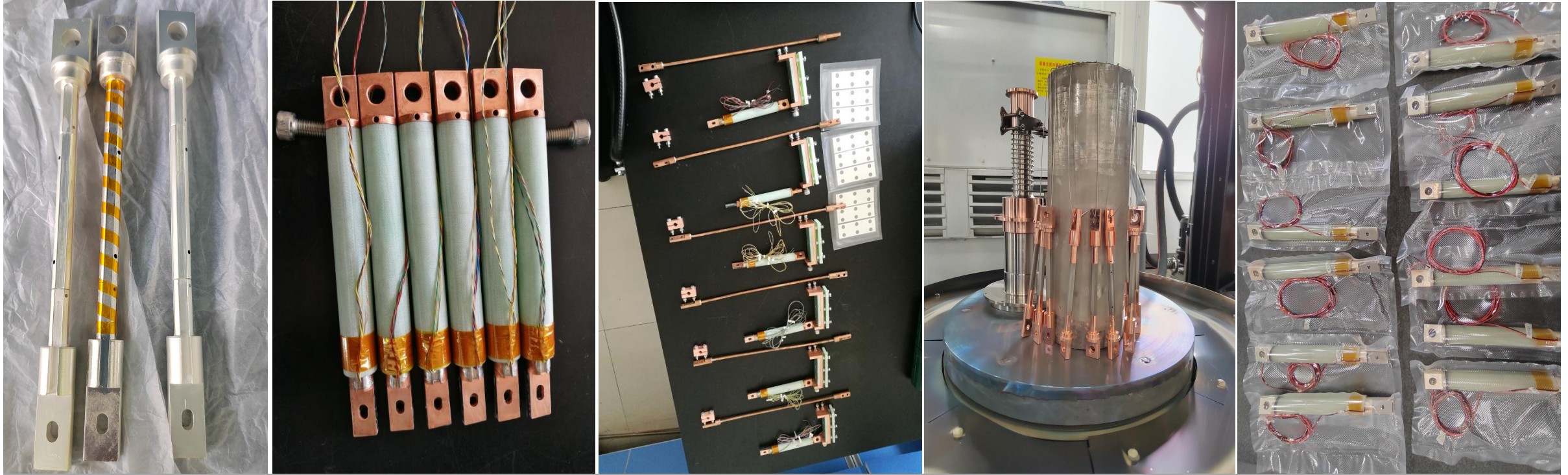
◆ For NbTi, YBCO Coils



VPI for SC Coils

◆ For NbTi, YBCO, Nb₃Sn
◆ D-3.5m, P-6 Bar

HTS Current Leads



HTS Current Leads, Customize or Standard, Design and Fabricate

◆ BSCCO, 100A-1000A @ LN₂, Lower Heat leak @ 60K-4K.

Production Capacity

- ◆ SC Magnets ~ 30-50 Sets/Year
- ◆ Cryopump ~100-300 Sets/Year
- ◆ CryoCooler ~200~500 Sets/Year
- ◆ Maintenance Service



Production Site



Cryopump Zone



Cryocooler Zone

- ◆ Design, fabricating, measuring equipment, 10 Mil+ CNY
- ◆ Design engineer, manager engineer, technician worker, 100+ staff
- ◆ Perfect production line for SC Magnet



CNC

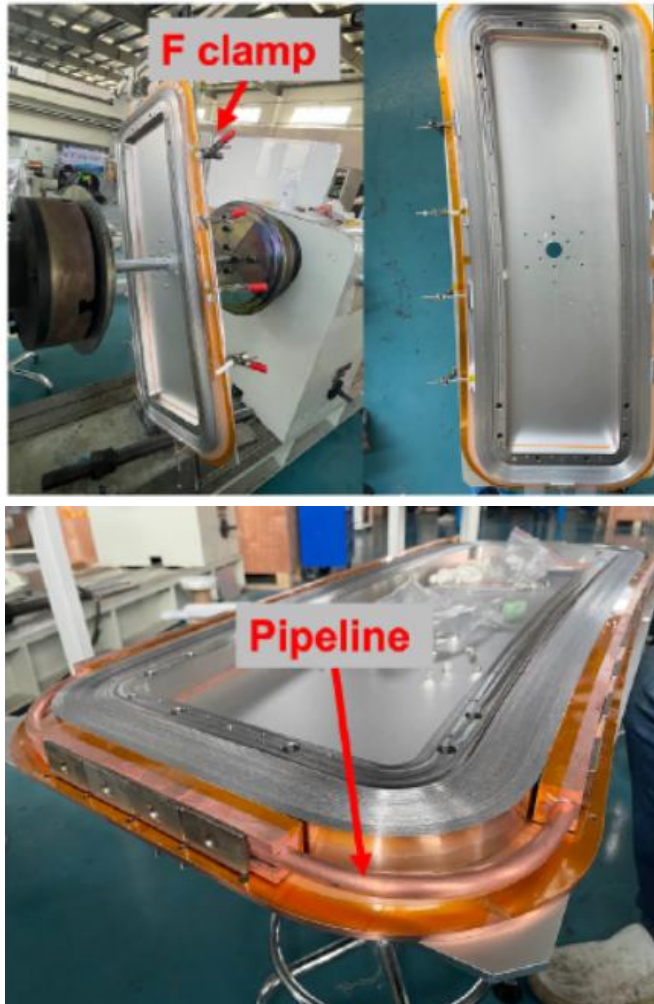


Baking Oven



Measurement System

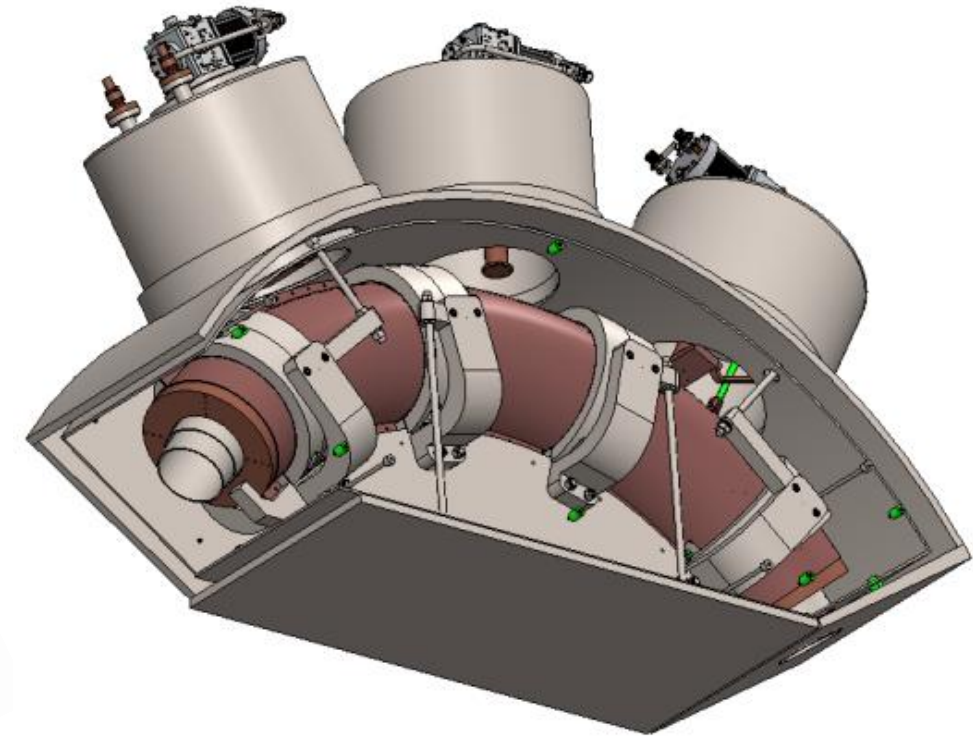
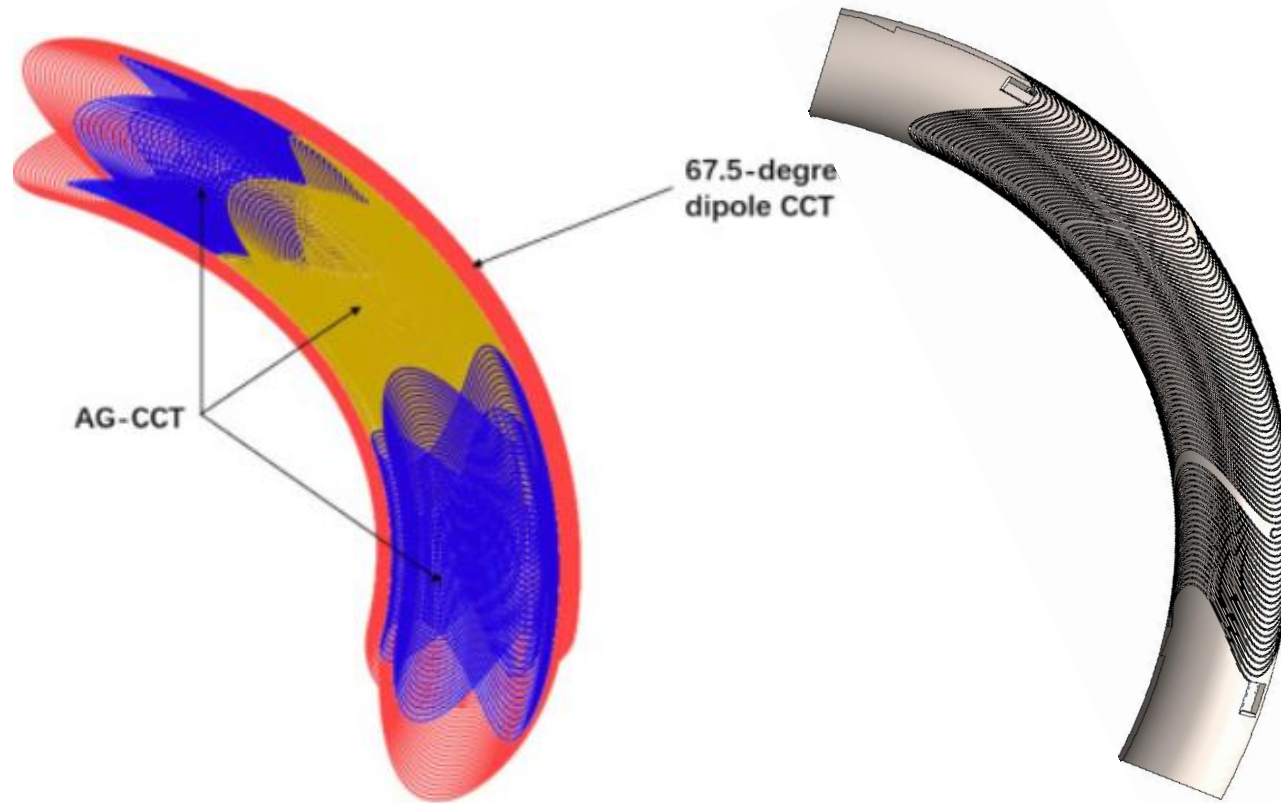
Fabricating of HTS Coil for FFAG Accelerator



Collaboration with CIAE, China

W. Fu, et al., "Fabrication and Test of a 1:4 Scaled HTS Coil for the Defocusing Magnet of 2 GeV FFAG Accelerator," 2022

Engineering Design Study of an AG-CCT Gantry for Proton Therapy

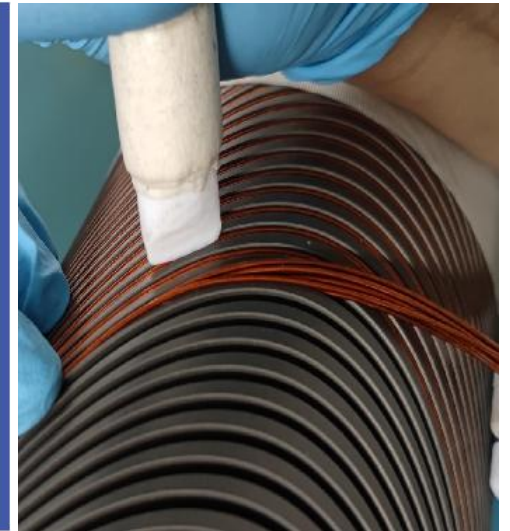
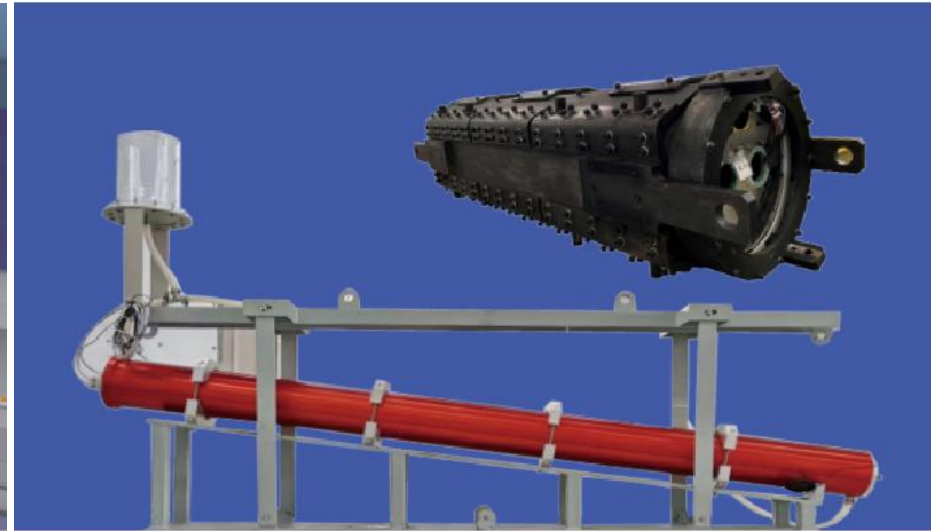
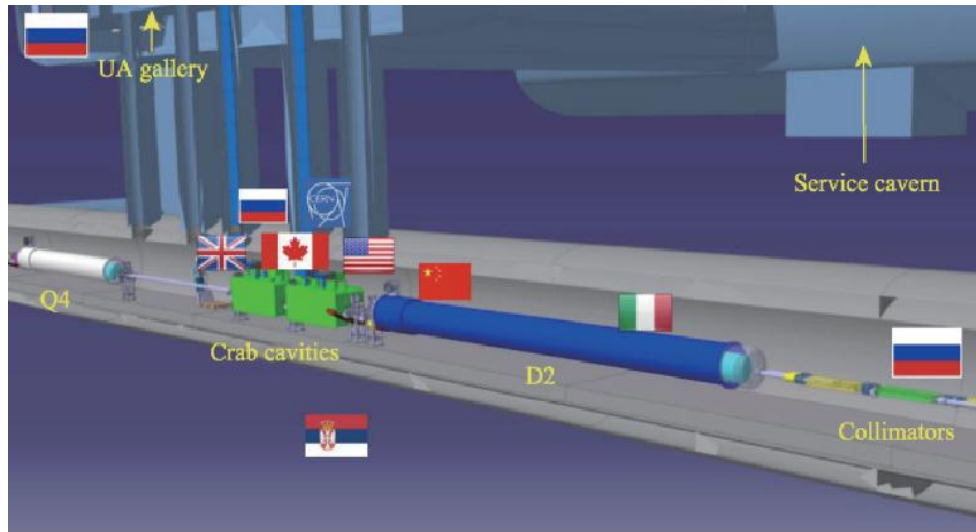


Conduction cooled by 3 GM Cryocoolers

Collaboration with HUST, China

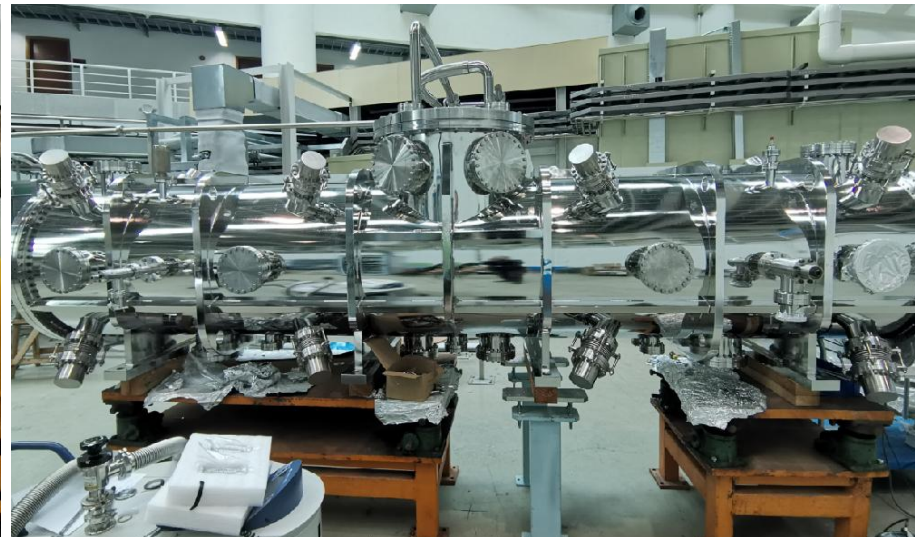
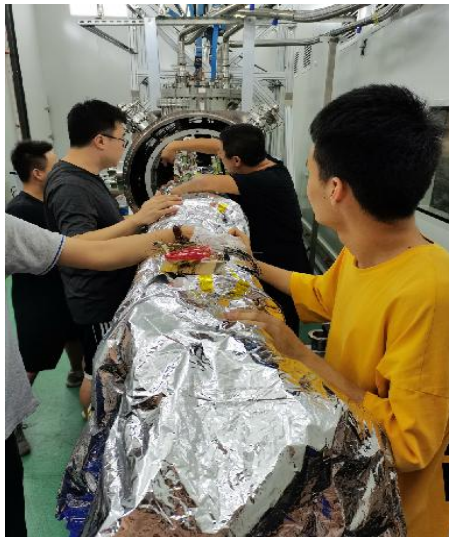
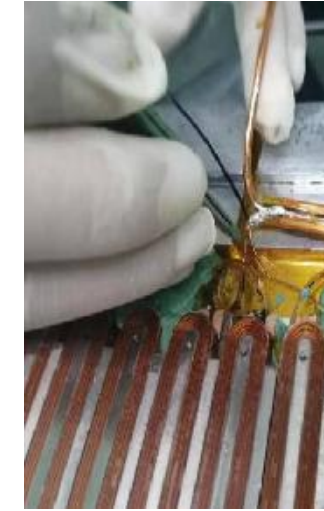
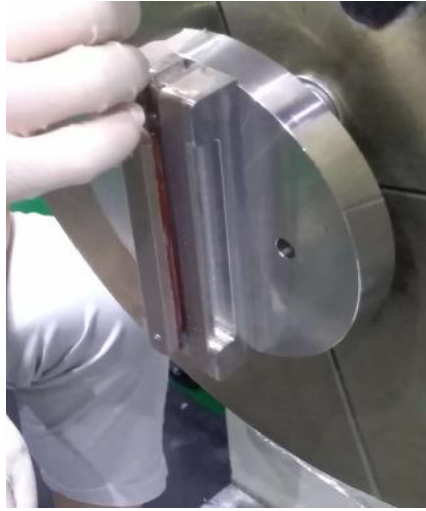
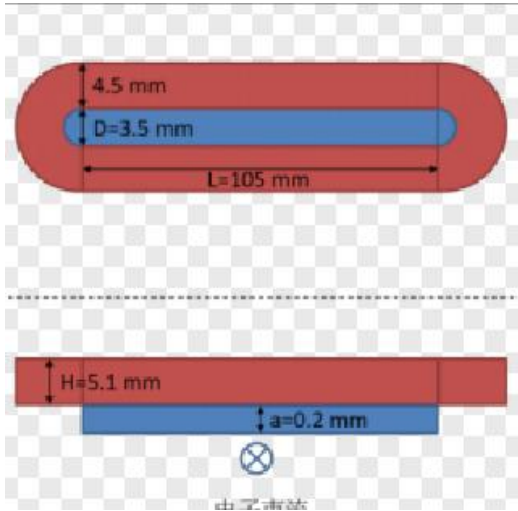
R Zhao, et al, "Achieving a realistic design for a superconducting gantry with large momentum acceptance for proton therapy," 2021

Fabricating of CCT Coils for HL-LHC



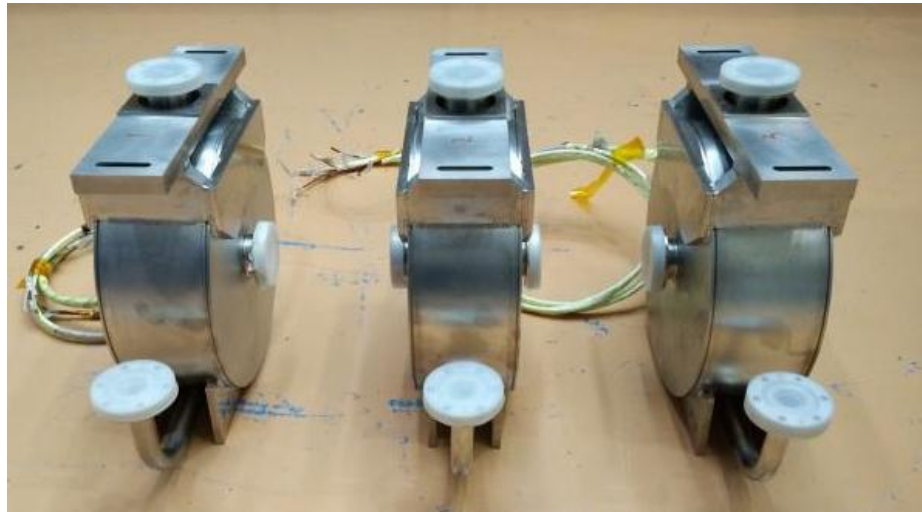
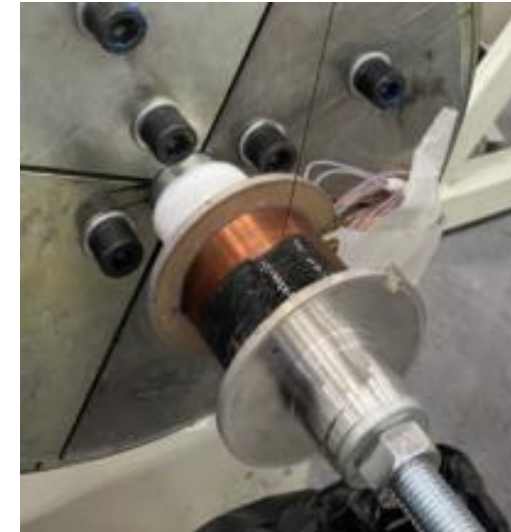
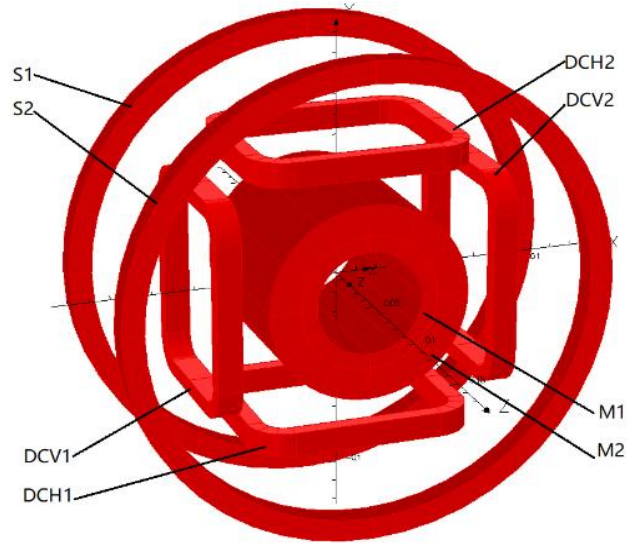
Collaboration with IHEP, China

Fabricating of SC undulators and HTS Current Leads



Collaboration with SINAP, China

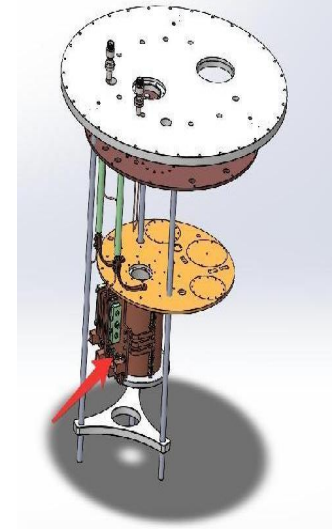
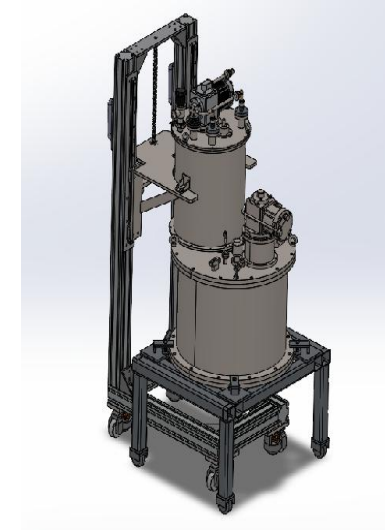
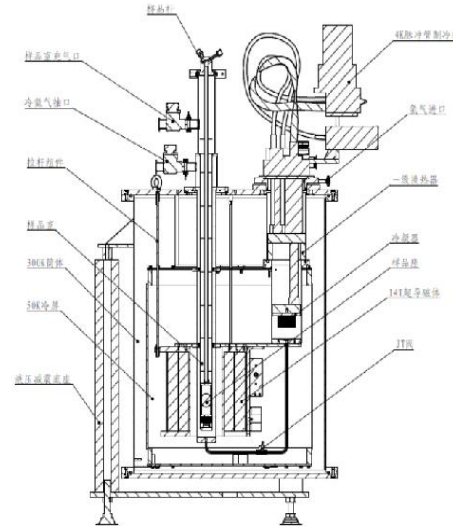
Fabricating of SC Solenoid for CiADS



Collaboration with IMP, China

Design and Fabricating of SC Magnet for Instrument

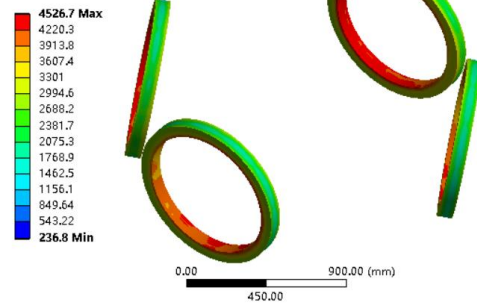
- ◆ 3T, NbTi magnet
- ◆ 5T, NbTi magnet
- ◆ 9T, NbTi magnet
- ◆ SC magnets custom made
- ◆ Magnet combined with cryostat
- ◆ Temperature control 1.5 K ~ 60 K
- ◆ Low vibration
- ◆ Cooling by cryogen or cryocooler



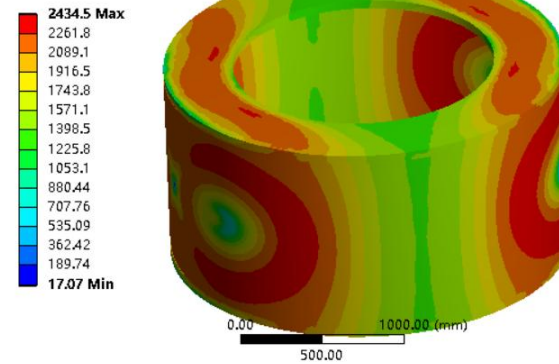
Collaboration with SINAP, China

Design and Fabricating of SC Magnet for MCZ

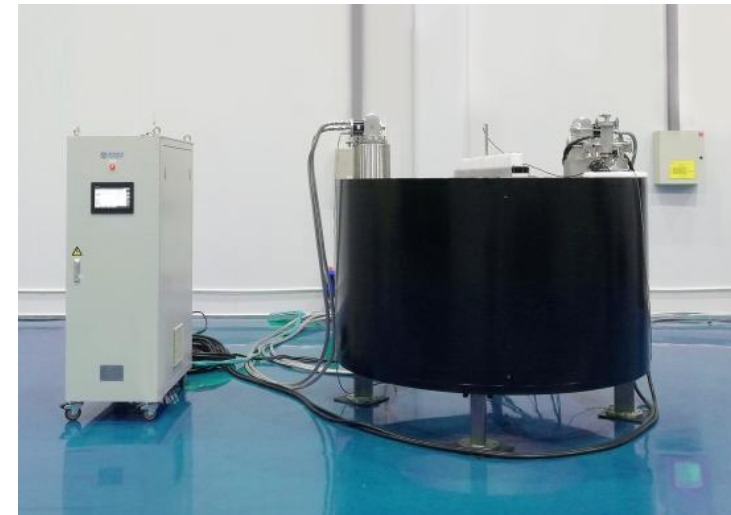
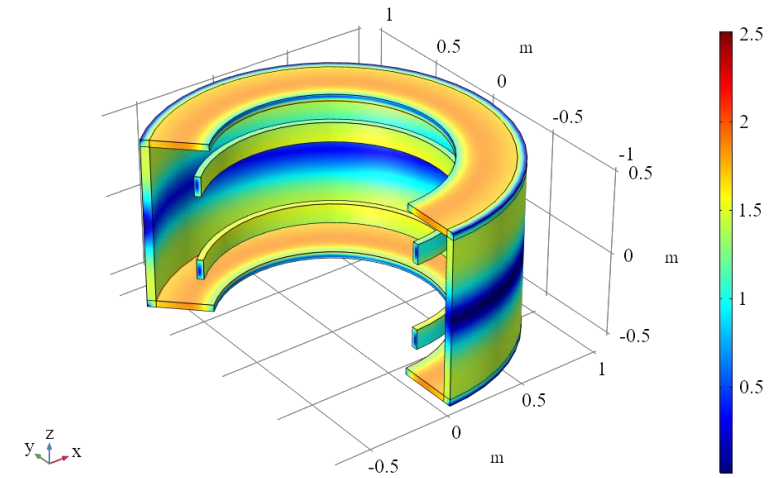
B: Magnetostatic
Total Magnetic Flux Density On the Coils_Q235
Type: Total Magnetic Flux Density
Unit: mT
Time: 1



B: Magnetostatic
Total Magnetic Flux Density On the Iron_Q235
Type: Total Magnetic Flux Density
Unit: mT
Time: 1



Volume: Magnetic flux density norm (T)



Cryopumps

Model	CTPW 200C	CTPW 250C	CTPW 320C	CTPL 400C	CTPL 550C	CTPL 720C
Pumping Speed N2 (L/S)	1700	2400	5000	5000	15000	21000
Capacity H2(Std.L)	12	16	40	24	85	120
Ultimate (Pa)	10 ⁻⁷					
Flange	GB,ISO,ANSI,UVG,CF,LF					
Cooldown (min)	100	100	100	120	180	180
Weight (KG)	30	35	45	70	120	210
Application	crystals grow、coating industry、scientific research...					



GM Cryocooler

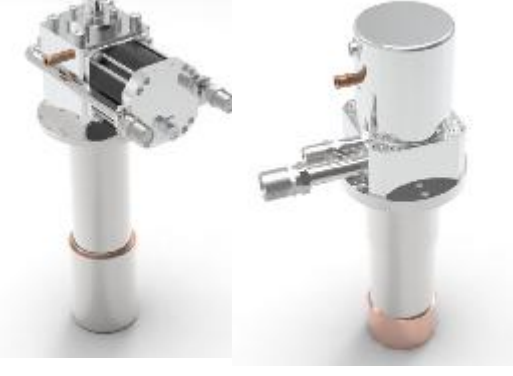
4 K Cryocooler



10 K Cryocooler



70 K cryocooler



Performance	4 K Cryocooler			10 K Cryocooler		70 K cryocooler	
	BMC401	BMC412	BMC418	BMC205	BMC215	BMC717	BMC725
Ultimate	< 2.3K	< 3.5K	< 3.5K	< 8K	< 6K	< 14K	< 25K
Cooling Capacity (50Hz)	3W@45K	50W@43K	42W@50K	65W@70K	70W@65K	40W@20K	266W@80K
	0.16W@4.2K	1.2W@4.2K	1.8W@4.2K	5W@20K	15W@20K		
Cooldown	< 150min	< 60min	< 60min	< 30min	< 60min	< 70min	< 15min
Maintenance (h)	10000h	10000h	10000h	10000h	10000h	8800h	8800h
Weight	8KG	18KG	19KG	15KG	18KG	25KG	18KG

Helium Compressor for Cryocooler



Cooling Mode: Water-Cooled, Air-Cooled

Capacity: 1.5 kW - 5.5kW - 7.5 kW – 10 kW

Custom cryocooler and compressor design

Summary

- ◆ SC magnets make smaller, less costly cyclotrons
- ◆ Trends of SC magnets: HTS, Ironless, conduction-cooled ...
- ◆ We focus on SC magnets engineering design and fabricating technology
- ◆ We provide cryopump, GM cryocooler, helium compressor, custom

BAMA

Supplier of Technology & Equipment for Ultimate Environment Creation

Thanks for your Attention

