CDR and R&D of CEPC Detector Magnet

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On behalf of magnet team

Institute of High Energy Physics

2017.11.6

outline

- **CDR of the magnet**
- **R&D progress**
- **Future plan**

CDR of the magnet

- From Pre CDR to CDR

→

Main changes between Pre CDR and CDR

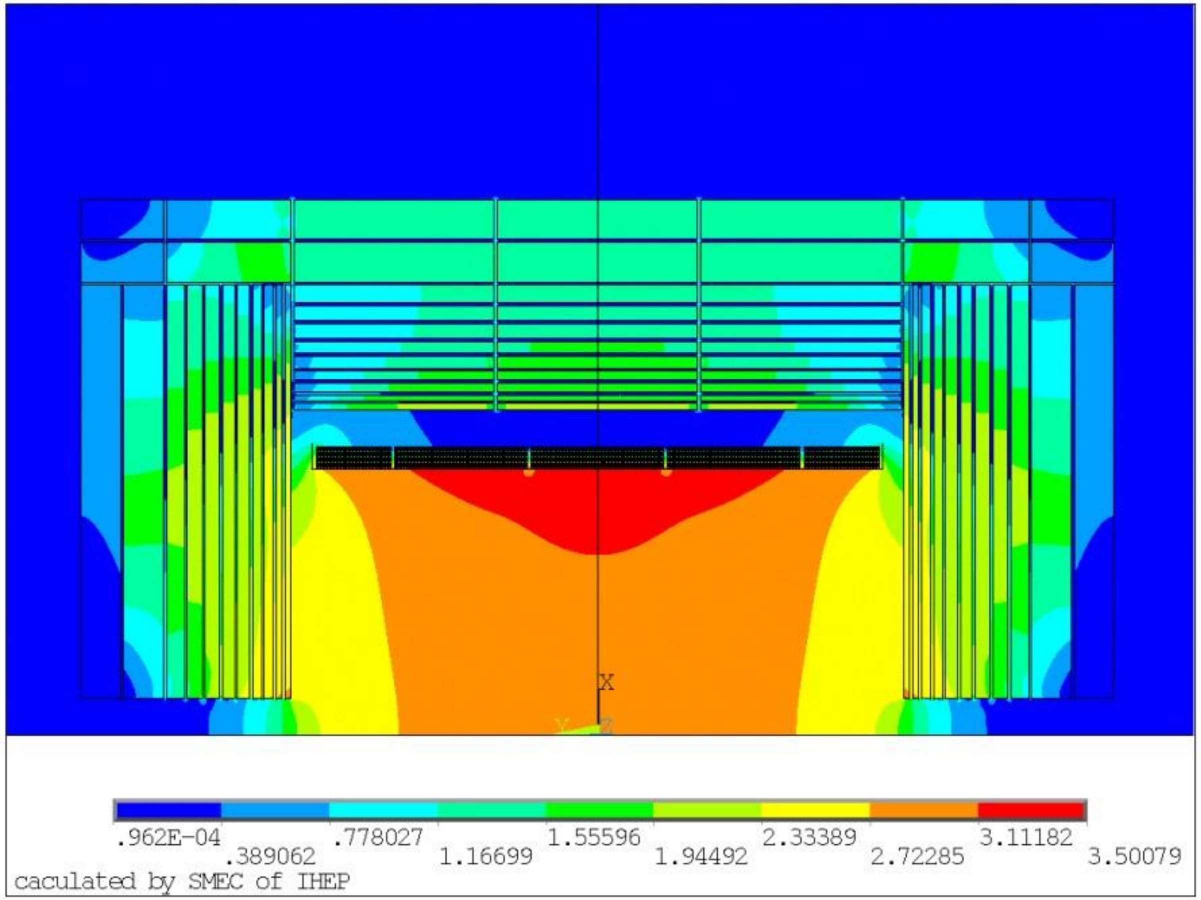
- **The central magnetic field: 3.5T → 3T**
- **Add two sections**
  - **HTS plan options**
  - **Active shielding Scenario**
- **All sections add more detail**

The Magnetic Field Requirements and Design

main parameters of the solenoid coil

The central magnetic field: From 3.5T to 3T

The solenoid central field (T)	3	Working current (kA)	15.8
Maximum field on conductor (T)	3.5	Total ampere-turns of the solenoid (MAt)	20.3
Coil inner radius (m)	3.6	Inductance (H)	10.5
Coil outer radius (m)	3.9	Stored energy (GJ)	1.3
Coil length (m)	7.6	Cable length (km)	30.4



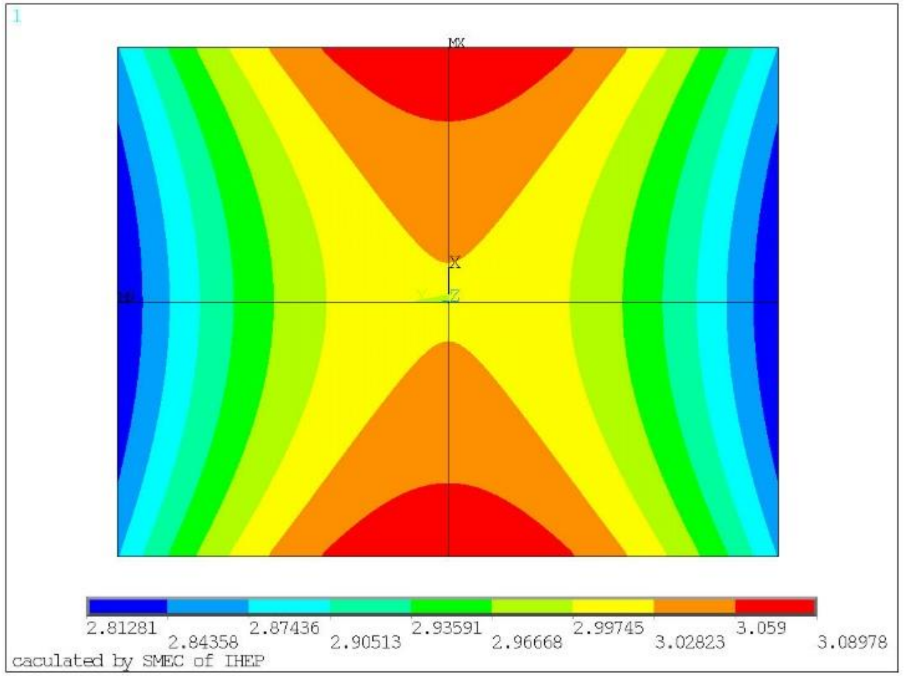
Field map of the magnet (T)

Ning Feipeng

The Magnetic Field Requirements and Design

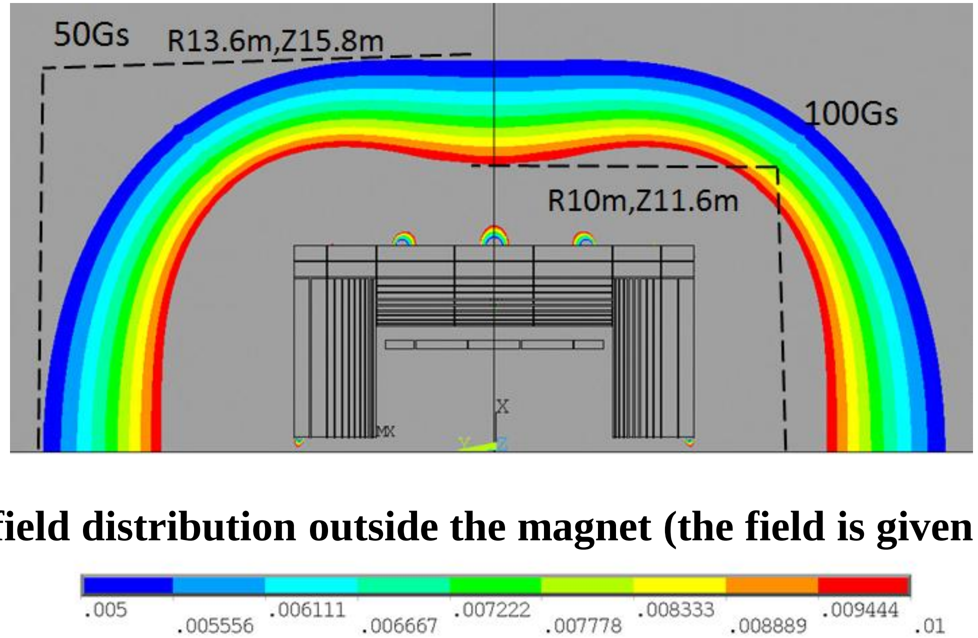
The non-uniformity of Tracking Volume (diameter 3.62m, length 4.7m) is 9.1%.

$$B_p = \frac{B_{max} - B_{min}}{B_{center}} = 9.11\%$$



magnetic field distribution of the Tracking Volume

Stray field		
50 Gs	R direction	13.6 m
	Z direction	15.8 m
100 Gs	R direction	10 m
	Z direction	11.6 m



Stray field distribution outside the magnet (the field is given in T)

HTS option

- Compared with the use of LTS(low temperature superconductor), the HTS(high temperature superconductor) detector magnet has the following highlights:
  - 1. Three HTS supplier existed in China
  - 2. It is possible HTS cost 10 times cheaper in 5 years
  - 3. Working at a relatively high temperature (20 K), cooling get easier
  - 4. More stability, HTS magnet not easy to quench
  - 5. Cost maybe comparable with the LTS magnet especially in the case of active shielding design(without iron yoke)
  - 6. Push the development of full HTS high field solenoid magnet

Ning Feipeng

HTS option

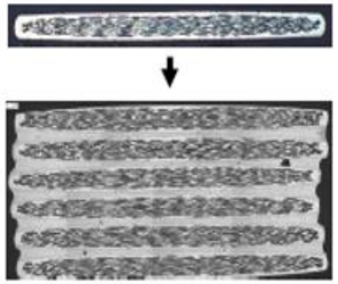
Which HTS conductor is suitable for CEPC detector magnet?

Twisted stacked Tape by MIT

CORC® by ACT

Roebel cable by KIT

HTS stack cable



Parameters of CEPC detector magnet if based on stack cable

Central magnetic field	3 T	Working current	8 kA
Maximum vertical field on cable	2.7 T	Ampere-turns	$20*10^6$
Inner diameter of coil	3.6 m	Inductance	38.4 H
Outer diameter of coil	3.7 m	Stored energy	1.2 GJ
Length of the coil	7.5 m	Operating temperature	20 K

Future work of HTS plan:

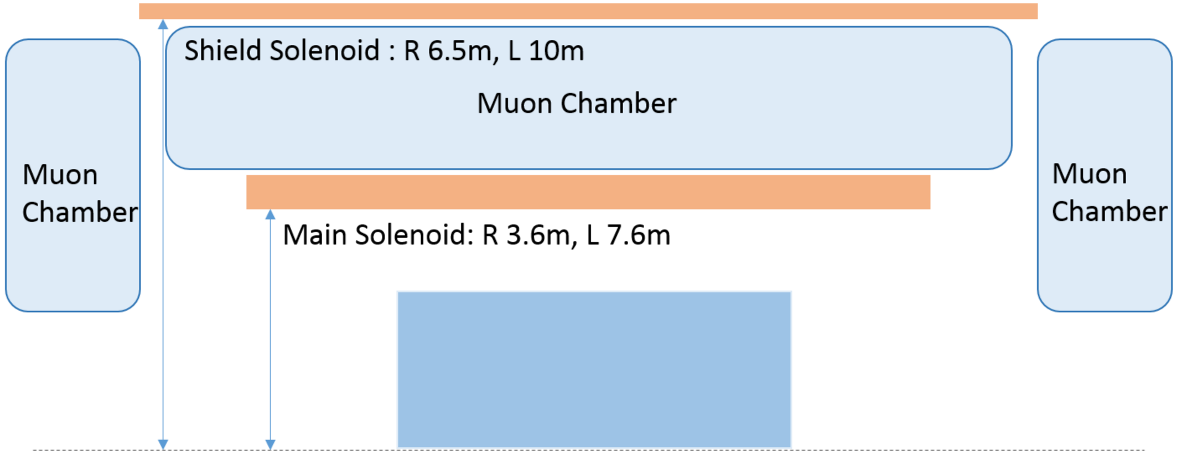
I) YBCO cable research. Select proper HTS cable or develop new cable for large detector magnet

II) Study the quench detection, transmission and protection of the HTS coil

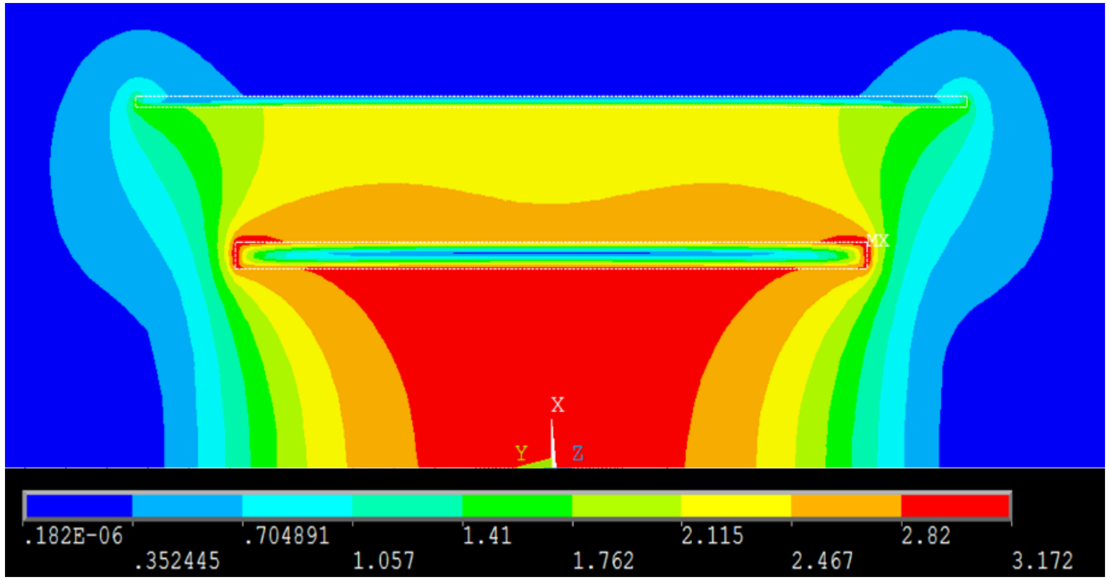
III) HTS coil prototype development

Active shielding Scenario

- **The active shielding design has been applied widely for commercial MRI magnets. Comparing to the one solenoid and yoke design, this design achieves a similar performance while being much lighter and more compact, which has been improved by FCC previous studies .**
- **The main solenoid provides 5 T central field over an room temperature bore of 7.2 m and a length of 7.6 m. The outer solenoid provides -2 T central field, with a radius of 6.5 m and a length of 10 m.**



Sketch figure of the active shielding magnet, with the available areas for muon chambers

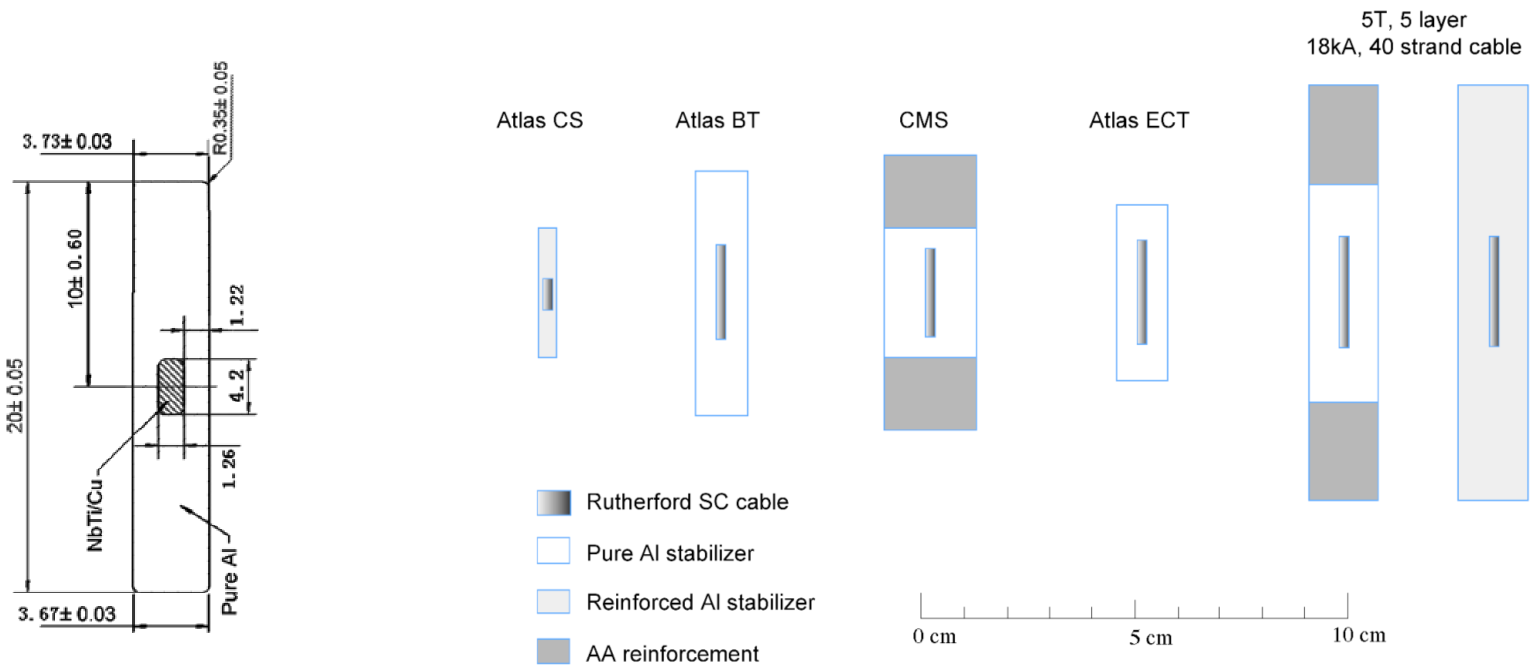


Field map of the active shielding magnet

R&D progress

- Development progress of Al-based SC conductors

  Al-based Superconducting conductor was mainly used for large detector magnets, such as ATLAS and CMS, …, FCC detector. We had the experience of using in BEPCII-BESIII detector.



Cross sections of Al stabilized and reinforced conductors previously used and will be used

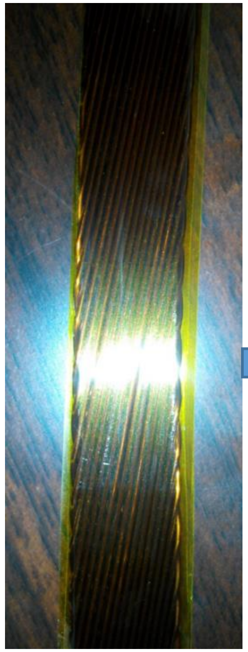
Zhao Ling

Progress of the Rutherford cable

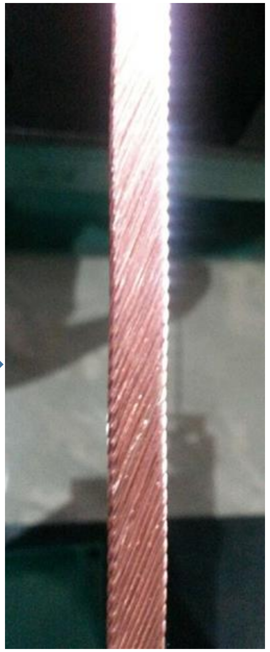
- Cooperation with Toly Electric Ltd. in 2015
- Development of Rutherford cable in the first step by using old machine
- New cabling machine and tension control system of strands were put into use in 2016

Zhao Ling

Progress of the Rutherford cable



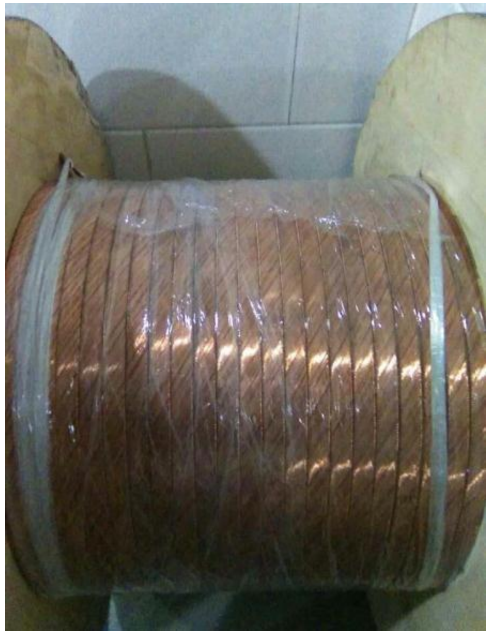
Number of strands： 20
Strand diameter： 1.0mm
Materiel: Copper
Complete time: 2015.5



Number of strands ： 17
Strand diameter ： 0.727mm
Materiel: Nb/Ti
Complete time: 2015.7

Number of strands ： 24
Strand diameter ： 0.727mm
Materiel: Nb/Ti
Complete time: 2015.8

Number of strands ： 18
Strand diameter ： 1.2mm
Materiel: Nb/Ti
Complete time: 2016.2



Number of strands ： 32
Strand diameter ： 1.2mm
Materiel: Nb/Ti
Tangle： 17.32
Length： 》100m
RRR： 》100
Complete time: 2016.5

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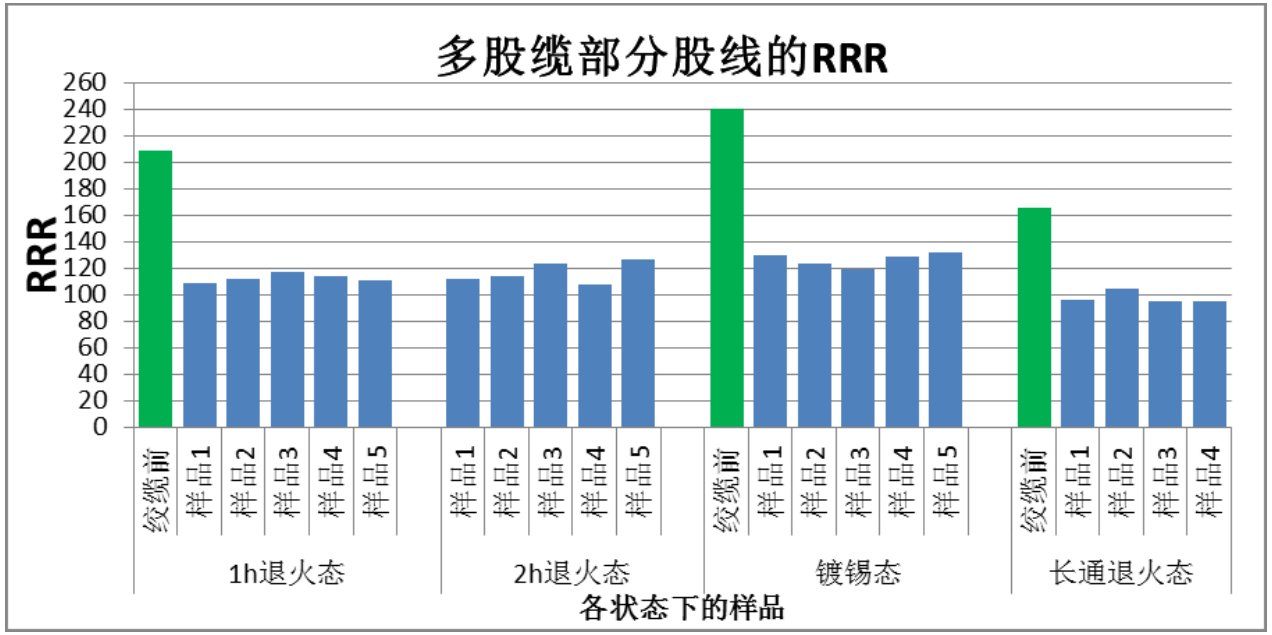
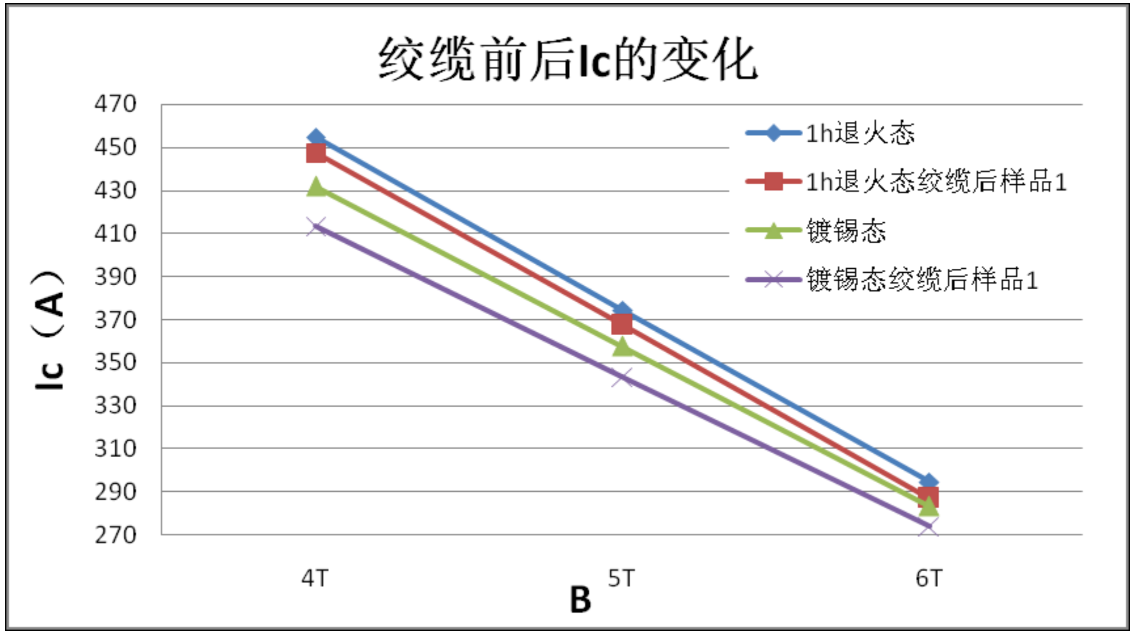
Strand of Rutherford cable test results



Test by WTS

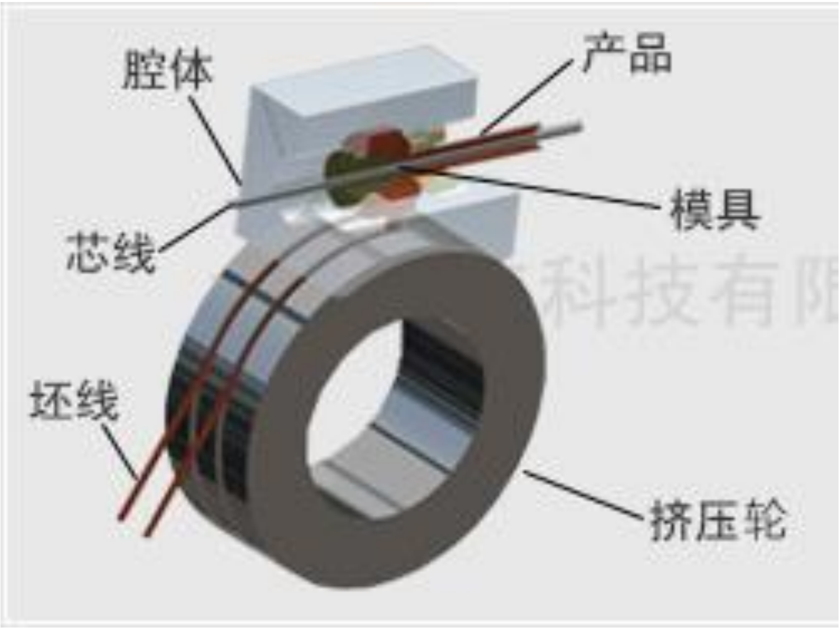


1. RRR value declined by about 1/3 after the stranding process

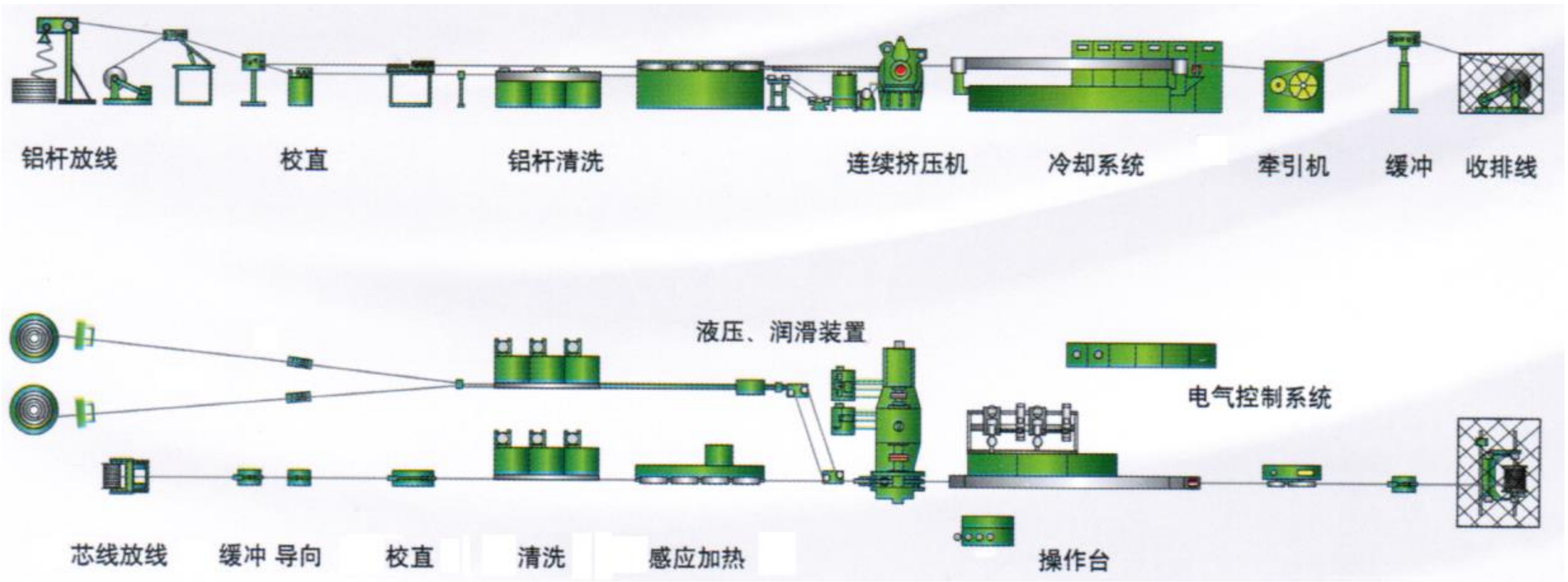
2.Less affected by larger twist pitch of strands.

The decrease of the critical current is less than 7% after the stranding process.

Extrusion of Aluminum with insert of Rutherford cable



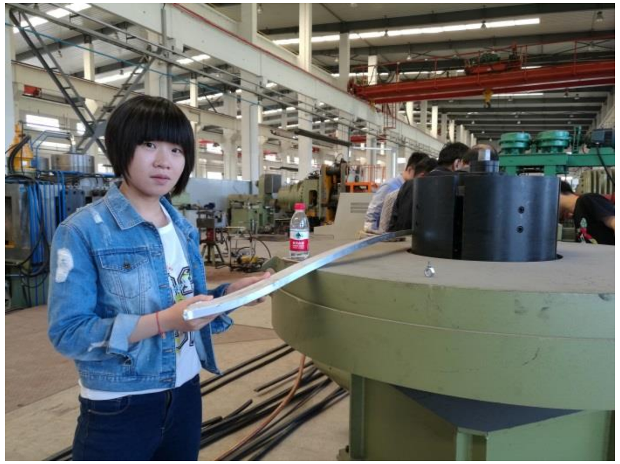
Conform technics



Process Drawing

Aluminum cladding process study and improvement

Zhu Zian, Yuan Ye, Hou Zhilong ,Mu Zhihui



Continuous extrusion and continuous cladding technology

Engineering Research Center of the Ministry of education for continuous extrusion

Dalian Conform Ltd.（Dalian Jiaotong University）

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Insert progress

- **Completed two rounds of insert process:**

  Hollow aluminum alloy, Aluminum alloy + copper cable

- **Result: Depression in the middle and the tooling needs to be improved(2016.4)**

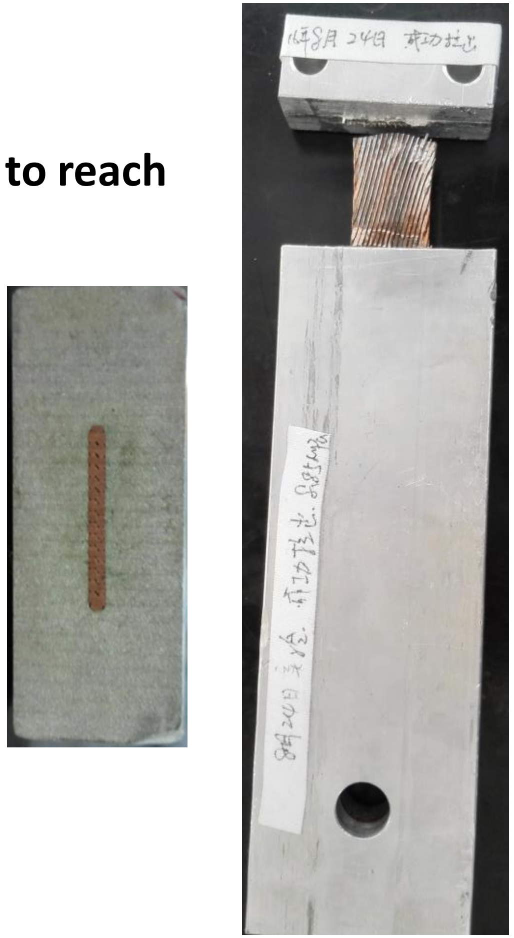
  The strands of the cable are separate after the tooling improvement.

- **There is a great improvement from the latest result, but the shear strength 8MPa not enough to reach 20MPa.**

2016.1
Hollow aluminum alloy

2016.2
Aluminum alloy + copper cable

2016.5~6:
Aluminum alloy + copper cable



2016.8:
Aluminum alloy + copper cable

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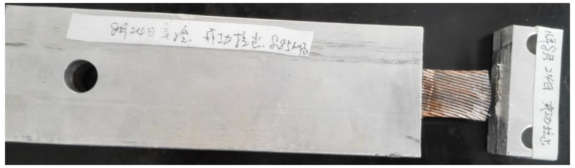
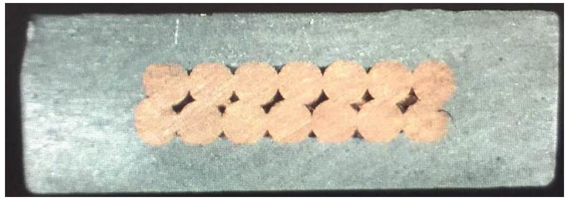
R&D progress

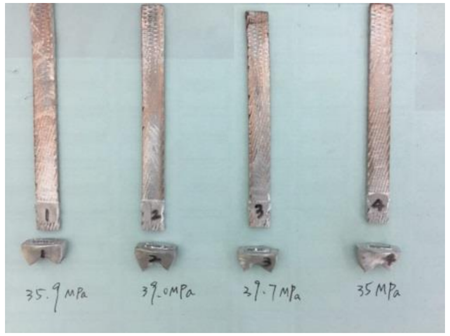
- Different aluminum alloy and copper cable shear strength test
  - ✓ The shear strength is larger than the required (20MPa) in the latest test. We used 99.99% aluminum material to improve the shear strength.



Number of strands： 32
Strand diameter： 1.2mm
Materiel :COPPER+Al
Length： 1m
Complete time: 2016.8
Shear strength（copper &Al）：
8.85 MPa

Dimensions: 15*4.7mm^2
Number of strands： 14
Materiel : COPPER+Al(99% purity)
Complete time: 2017.4
Shear strength（COPPER &Al）：
10 MPa



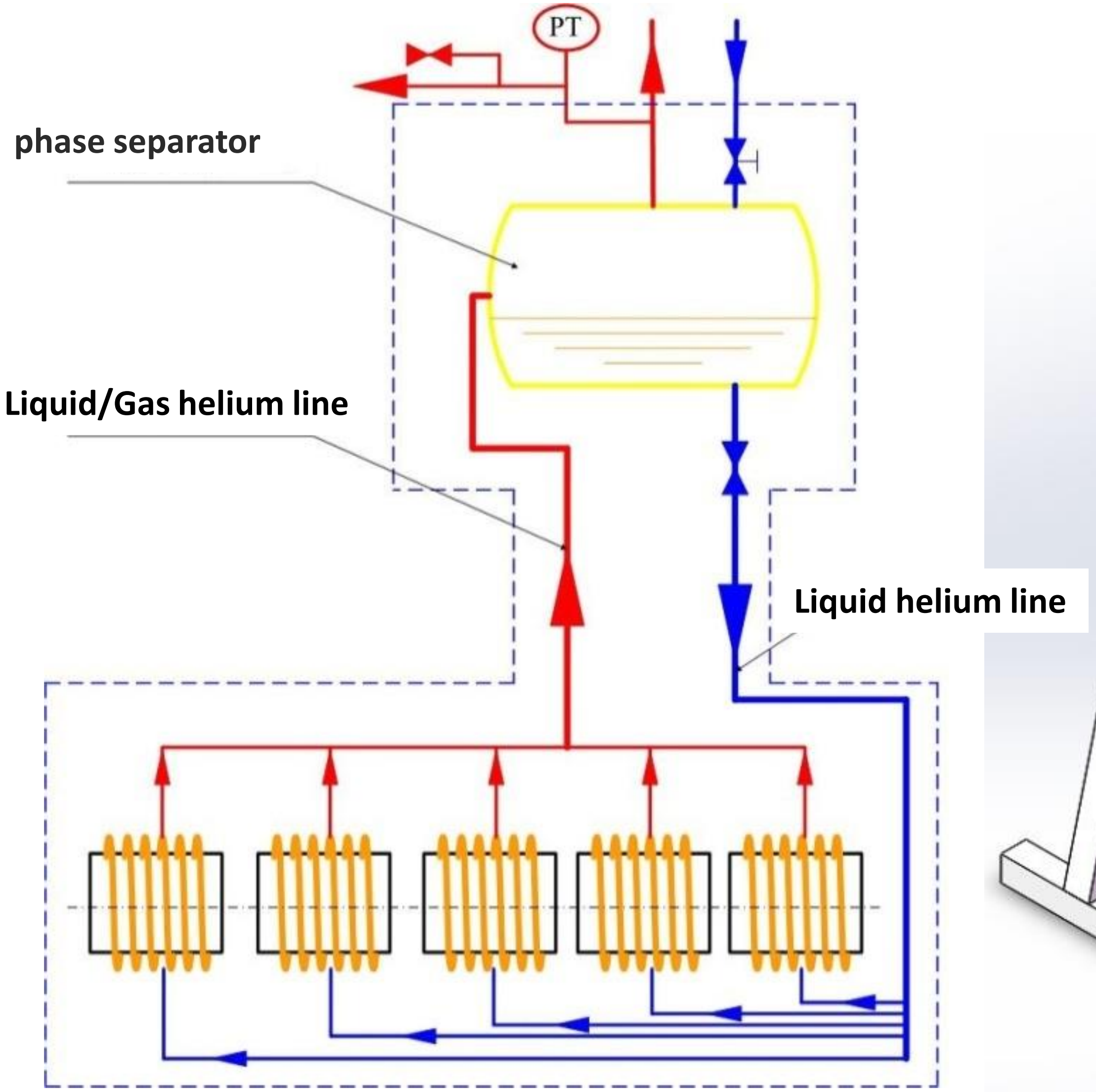


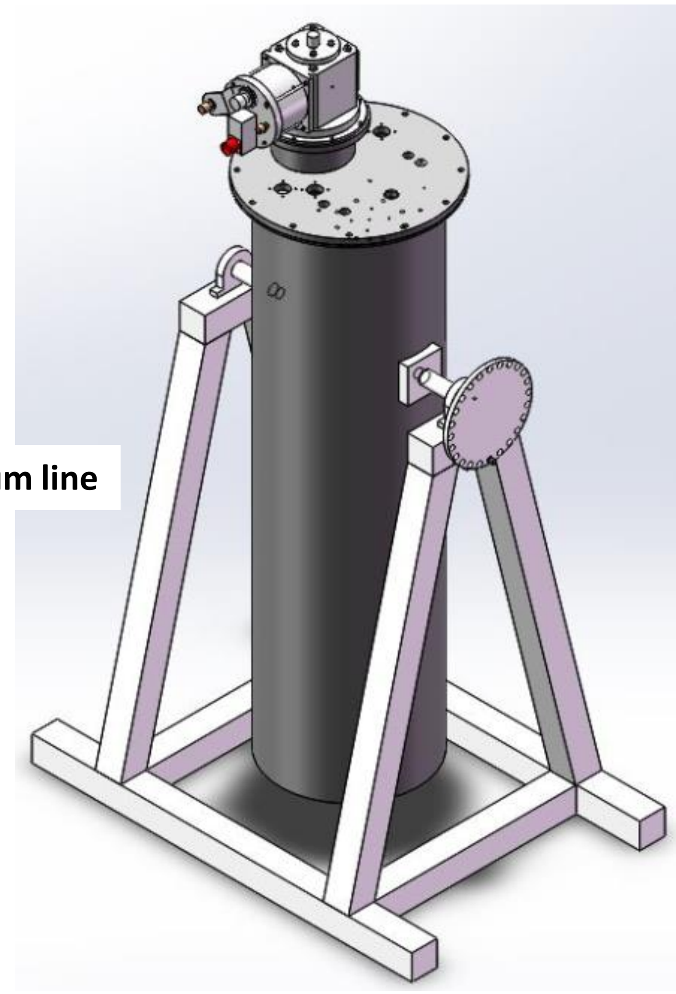
Dimensions: 15*4.7mm^2
Number of strands： 14
Materiel : COPPER+Al(99.99% purity)
Complete time: 2017.8
Shear strength（COPPER &Al）： >**35MPa**

Meifen Wang

Progress of coil cooling research

- The magnet coils will be cooled by liquid helium thermosiphon conductive cooling method.
- Set up a small thermal siphon principle experiment device



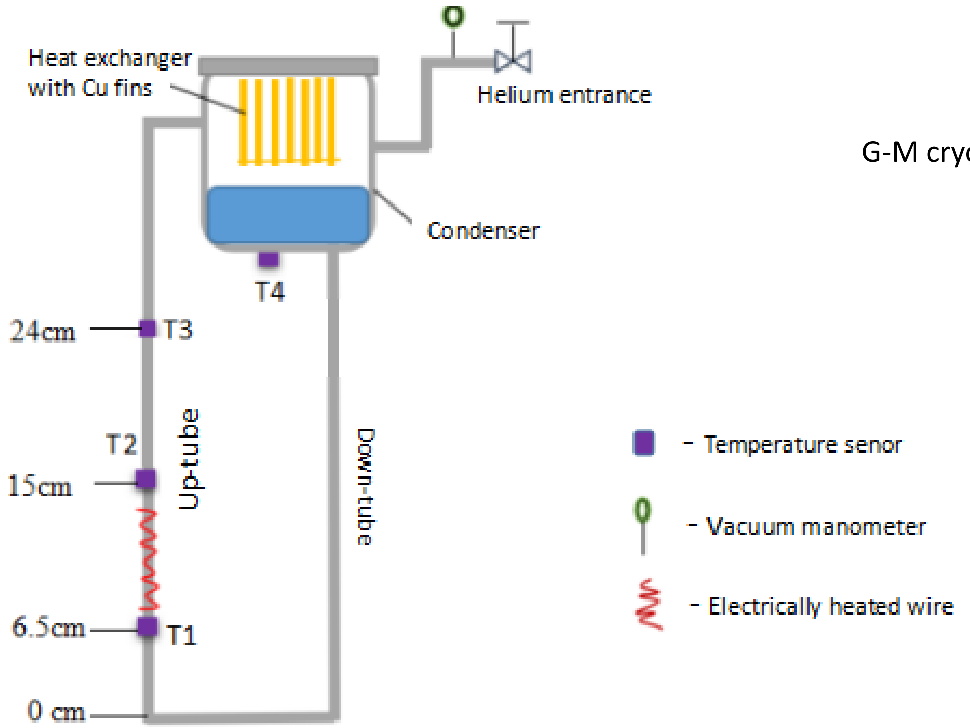


Baotang Zhang, Meifen Wang

Magnet Cryogenics

- A mini set-up for thermal siphon study based on liquid helium LTS

  - Building a two-phase natural circuit loop, helium was used as the working fluid;
  - Investigate the heat and mass transfer characteristics experimentally;
  - Obtain temperature profile with heat flux and critical heat flux
  - Numerical modelling of mass flow rate in a thermal syphon



Schematic of the circuit loop

Experimental apparatus

Summary

- Several designs have been completed on the requirements of different central field and different thickness of yokes, compared the key parameters such as homogeneity/stray field/cost etc.
- Some progress in the development of specific LTS superconductor, thermal siphon cooling
- HTS option was initially proposed
- We keep iron yoke structure as the default option in the CDR, and the Active Shielding scenario as an candidate option

Next Steps

- **1. Further development of long Al-based NbTi conductor (>100m, RRR/Ic measurement)**
- **2. Study of thermal siphon cooling system**
- **3. Study of HTS option**

Thank you for your attention!

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