# Development of the Aluminum stabilized superconductor for CEPC


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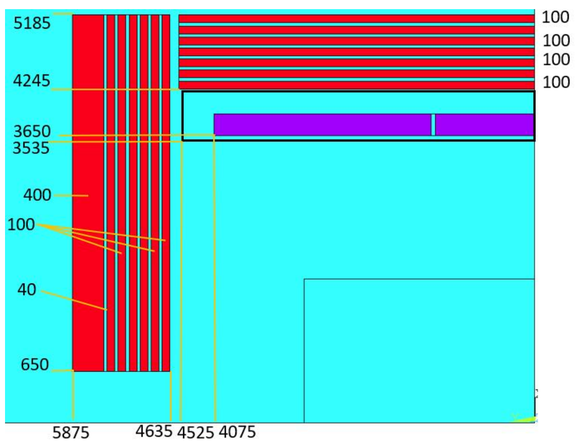
## Introduction

The Circular Electron Positron Collider （CEPC), to be hosted in China in a circular underground tunnel of approximately 100 km in circumference. A 3 Tesla superconducting solenoid magnet with cold bore of 7.07m serves as a key component of the large electron collider, providing a uniform and stable magnetic field for the detector.

Al-stabilized NbTi cable is and has been the universal choice until now for the detector magnets. Considering the large diameter of the coil and the 3 Tesla magnetic field, the conductor must satisfy simultaneously mechanical and industrial feasibility requirement. Two of all possible configurations have been studied in the CEPC R&D project.

## Cold Mass Design

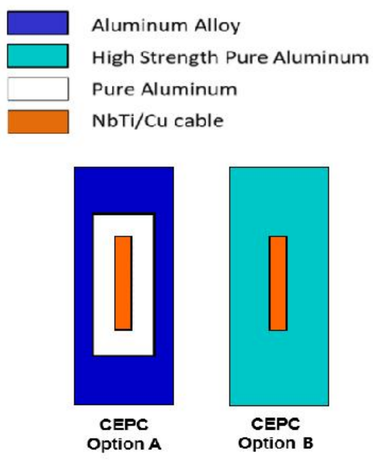
The main magnetic and geometrical design parameters of the cold mass are given respectively in table I. The cold mass has an overall thickness of 307mm. It consists of 276mm thick superconducting winding surrounded by a 30mm thick cylider.

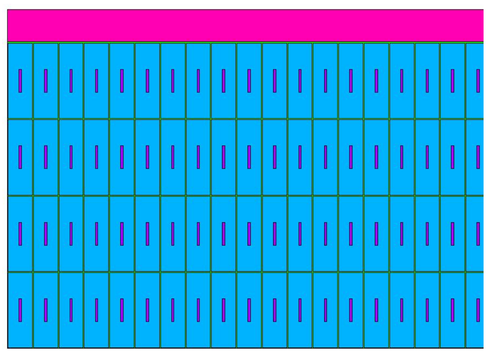



Geometrical design of the Magnet

| | |
|---|---|
| Central magnetic field | 3 T |
| Inner diameter | 7.3m |
| Operating current | 17000 A |
| conductor peak magnetic field | 3.47T |
| Inductance | 11 H |
| Stored Energy | 1.54 GJ |
| Total number of turns | 1400 |
| Total cable length | 33km |

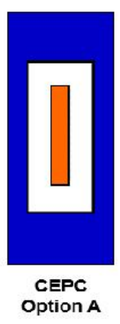
## Conductor Design



view of the winding

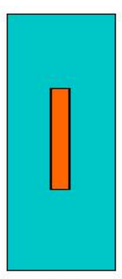
| Material | Von Mises stress, MPa |
|---|---|
| **Coil at 4.2 K** | |
| Pure Aluminum | 11.2-44 |
| SC cable | 180-234 |
| Al alloy Support | 34.3-57.2 |
| **Coil at 4.2 K, energized** | |
| Pure Aluminum | 40.3-46.2 |
| SC cable | 49.4-184 |
| Al alloy Support | 57.1-117 |




56mm*22mm

| Material | Von Mises stress, MPa |
|---|---|
| **Coil at 4.2 K** | |
| Pure Aluminum | 4.4-86.1 |
| SC cable | 174-243 |
| Al alloy Support | 4.6-36.2 |
| **Coil at 4.2 K, energized** | |
| Pure Aluminum | 41.5-95.9 |
| SC cable | 54.9-221 |
| Al alloy Support | 43.2-87.4 |

Maximum Von Mises stress in conductor's components



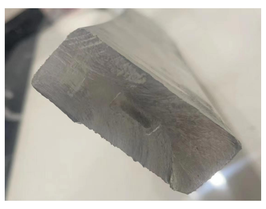

68mm*22mm

## R&D of Box configuration conductor

Box configuration superconductor is obtained through a secondary co-extrusion process on the outside of aluminum-stabilized superconducting cable.

Al-stabilized cable

Dummy cable
56*22mm
Aluminium alloy+ copper4.7mm*15mm



Box superconductor
56*22mm
Electrical grade Aluminium +4.7*15mm cable

- **Achieved the box configuration superconductor** from the electrical grade aluminum and 4.7mm*15mm cable **by a second coextrusion process**.
- Next, many attempts have been made by 6061 Alloy+10mm*33mm cable , but all failed because Aluminum Alloy need more higher temperature.

- Rutherfod cable:
  32 strands of NbTi
  pitch: 129mm
  fill factor: 86%
  **Ic decay after stranding: <5%**
- First extrusion:
  10mm*33mm(good)
- Second extrusion:
  22mm*56mm(failed)

Rutherford cable 32 strands

first co-extrusion pure Aluminum +Rutherford cable10*33mm

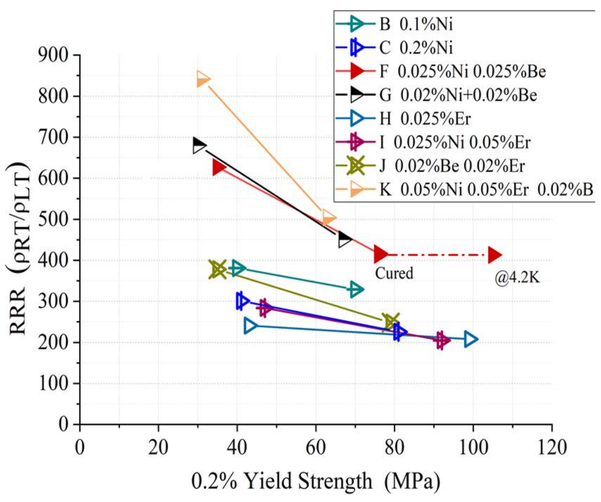
second co-extrusion 6061Alloy+cable(failed)

## R&D of High Strength and High RRR Aluminum- Stabilizer

**Yield strength > 100 MPa@4.2K, 74 MPa at room temperature, RRR value > 400**

- By doping Ni-0.025% Be-0.025.
- The Al-0.025%Ni-0.025%Be alloy prepared from 4N8-aluminum achieved high 0.2% yield strength of 75MPa (R.T.) with RRR of 417.

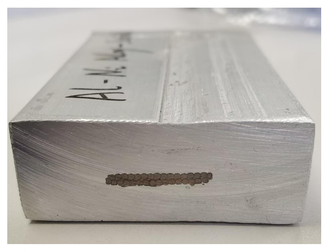
| | |
|---|---|
| Poisson's ratio | 0.33/0.34 |
| Young modulus | See the curve |
| Thermal expansivity | $14.23\times10^{-6}$ $K^{-1}$ |
| $4.2KRp_{0.25}$ | 105MPa |



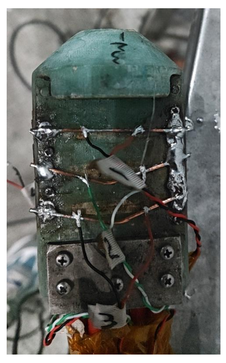

## Progress of Al-Ni-Be Stabilizerd conductor

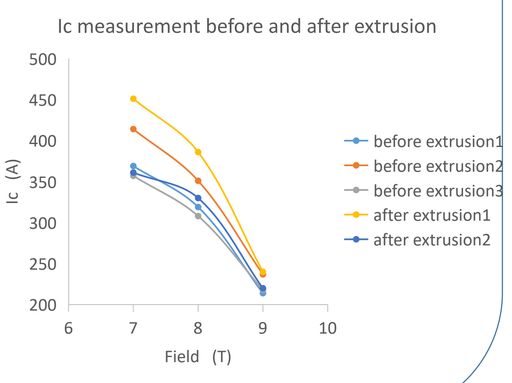
Rutherford cable 32 strands

The 32 strands Rutherford cable is inclosed inside the Al-Ni-Be alloy through a coextrusion process, and the size after that is 56*22mm. The critical current of strands e before and after coextrusion process was measured, and the measurement results are shown in the figure as below.



first co-extrusion Al-Ni-Be stabilizer +Rutherford cable 56mm*22mm






## Conclusions

The stranding process for Rutherford cables and the coextrusion process for aluminum-stabilized superconductor have been established. The feasibility of the secondary coextrusion process has been verified using electrical grade Aluminum. However, the secondary coextrusion process based on aluminum alloy has not been get a good result. So Al-Ni-Be Stabilizerd conductor would be our choice for the ref-TDR.