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Introduction of Detector magnet for CEPC

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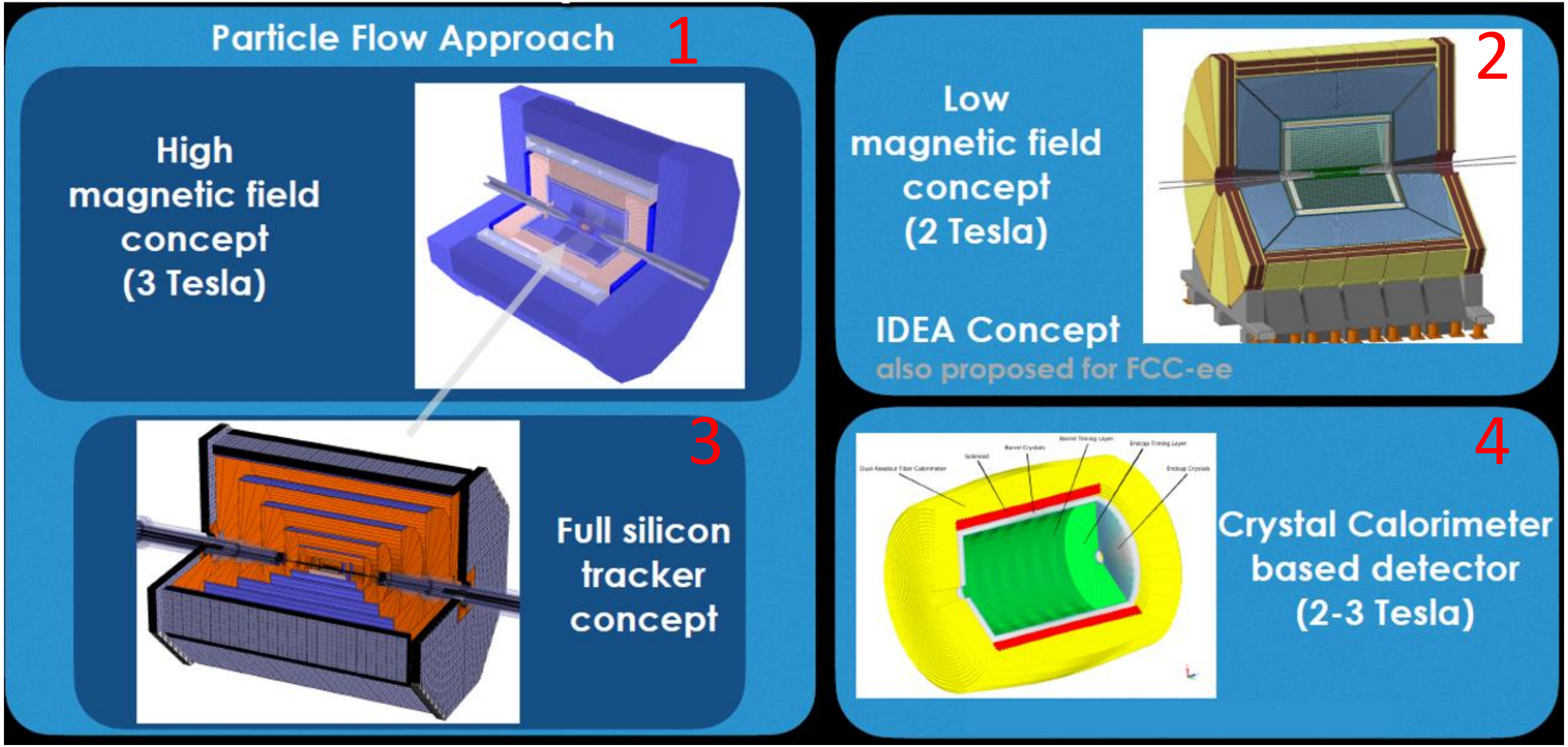
Outline

- Introduction of CEPC detector
- LTS detector magnet R&D
- HTS detector magnet R&D
- Summary and future plan

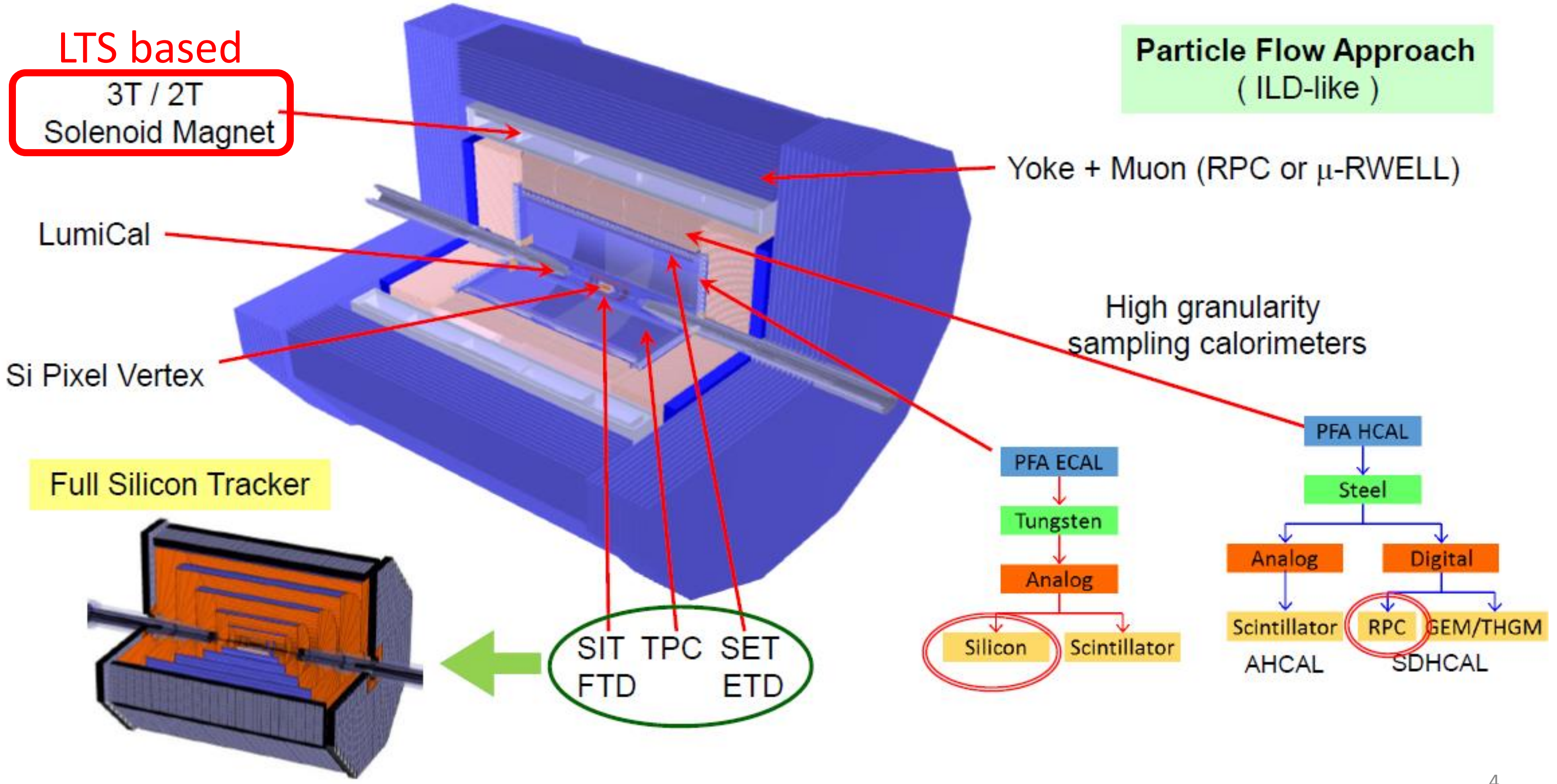
Introduction of CEPC detector



2 interaction points

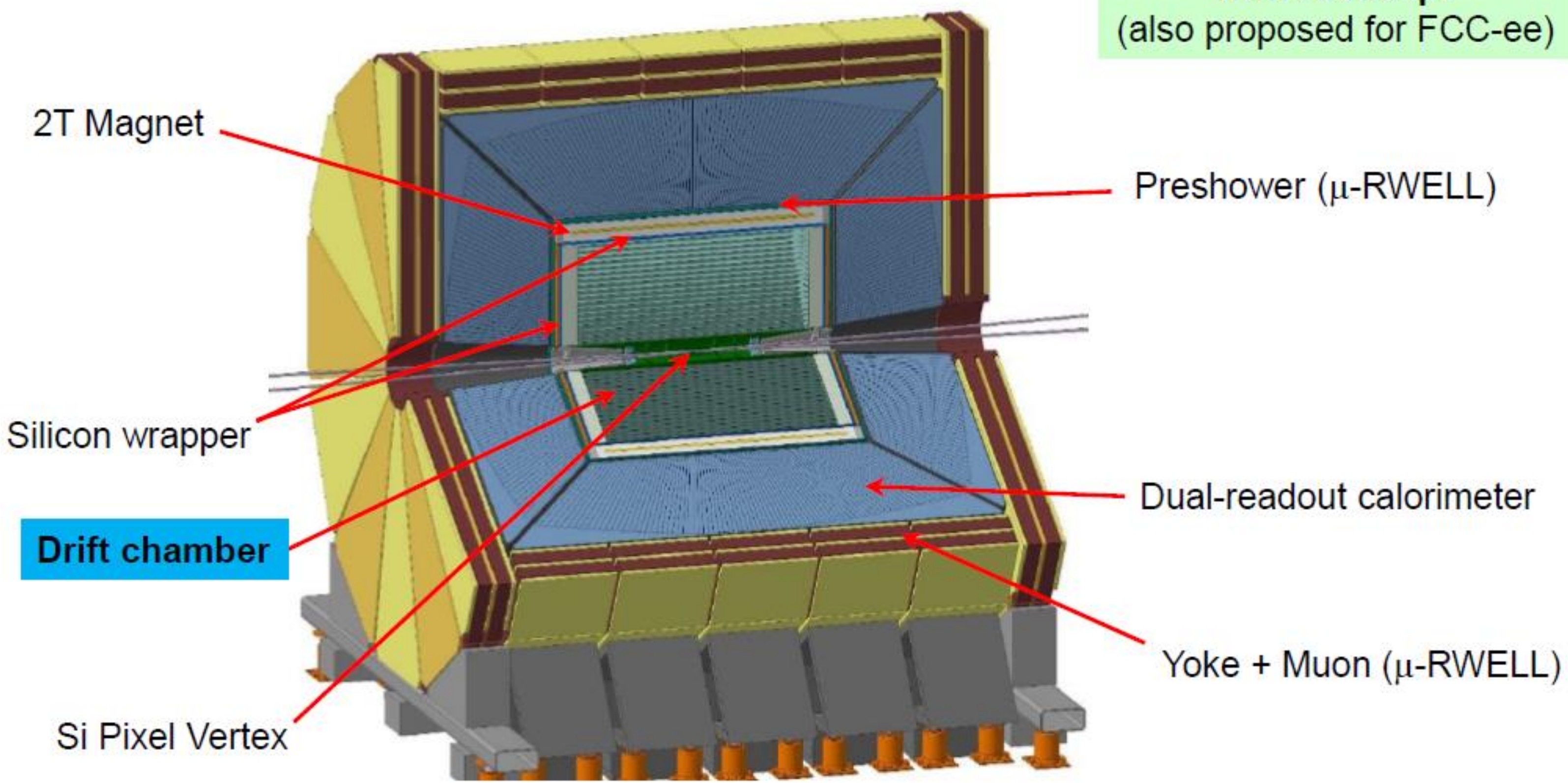
Final two detectors WILL be a mix and match of different options

CEPC Detector in CDR (1 & 3)



CEPC Detector in CDR (II)

IDEA concept
(also proposed for FCC-ee)

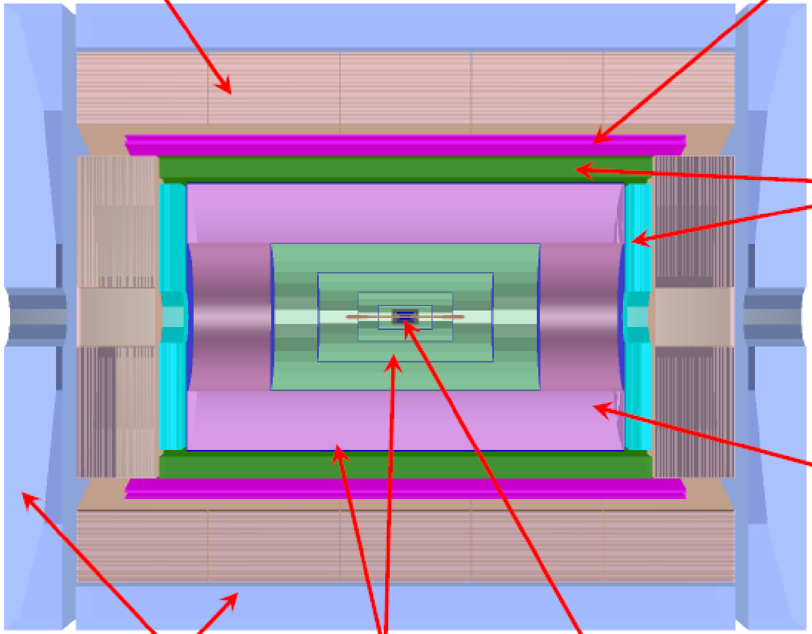


The 4th Conceptual Detector Design

Scint Glass PFA HCAL

Advantage: Cost efficient, high density

Challenges: Light yield, transparency, massive production.



Muon+Yoke Si Tracker Si Vertex

Solenoid Magnet (3T / 2T) Between HCAL & ECAL

HTS based

Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

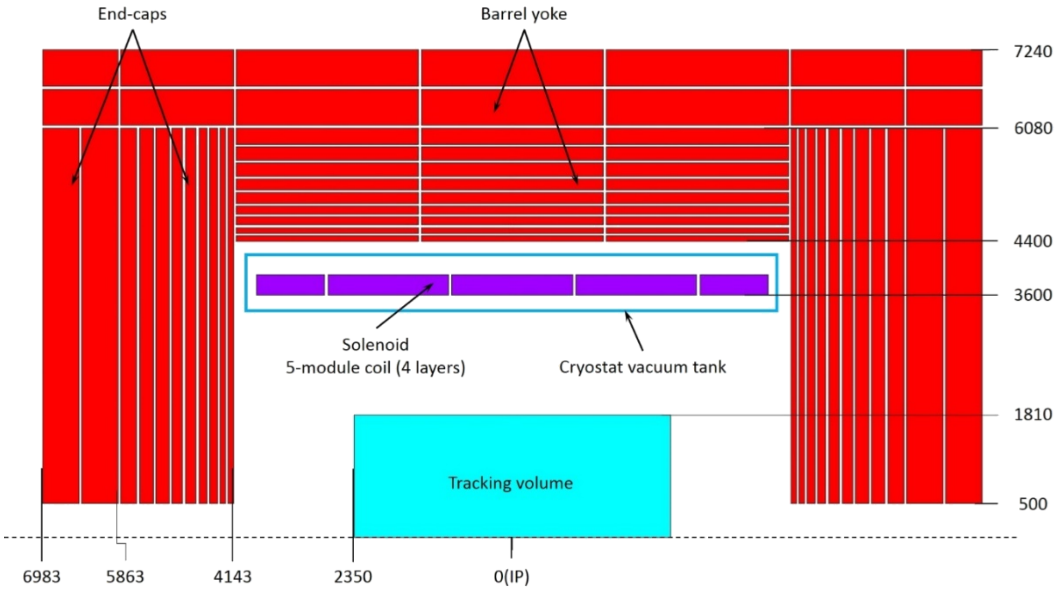
Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

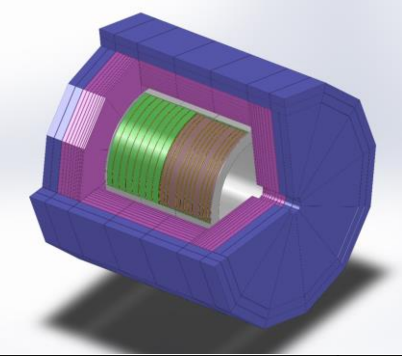
A Drift chamber that is optimized for PID

Advantage: Work at high luminosity Z runs

Challenges: sufficient PID power; thin enough not to affect the moment resolution.

LTS detector magnet R&D





The solenoid central field (T)	3
Coil inner diameter (mm)	7200
Coil outer diameter (mm)	7800
Coil length (mm)	7600
Working current (kA)	15779
Total ampere-turns (MAt)	20.323
Inductance (H)	10.46
Stored energy (GJ)	1.3
Cable length (km)	30.35

LTS detector magnet R&D

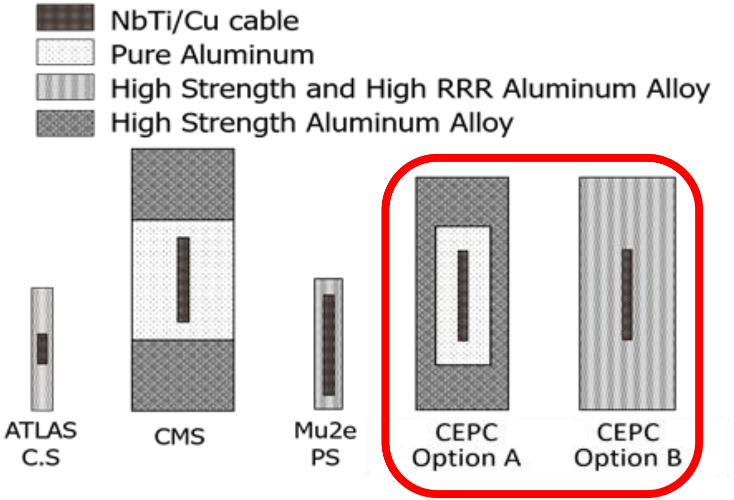
• LTS conductor development

Requirements:

- Low mass: particles are easy to pass through
- High RRR： Low temperature resistance, can be used as a stabilizer of superconductors.
- Mechanical strength: can bear electromagnetic force
- Ic: 50kA@4T
- Al stabilizer—NbTi— Rutherford cable:

  56mm*22mm

Two options of CEPC aluminum stabilized LTS conductor are on R&D.



LTS detector magnet R&D

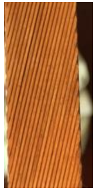
- Development of 32 strands and 16 strands Rutherford cables， Compared with the original wire, the Ic is controlled to drop less than 5%, and the RRR value of copper is controlled to drop by 1/3

- 1 km 16 strands aluminum stabilized superconducting cable， Shear strength between aluminum and twisted cable is more than 30MPa. It has been used in the superconducting magnet prototype of the China spallation neutron source EMuS project

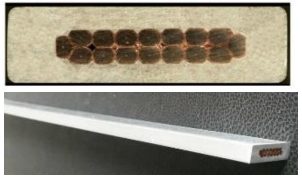
Real cable

EMuS coil

- Long Dummy cable and dummy coil, 6061 + copper， $22*56mm^2$
- Continue the research of secondary aluminum coating.



NbTi Rutherford cable



Small size Al stabilized cable $4.7*15mm^2$

Long small size cable

Dummy cable $22*56mm^2$

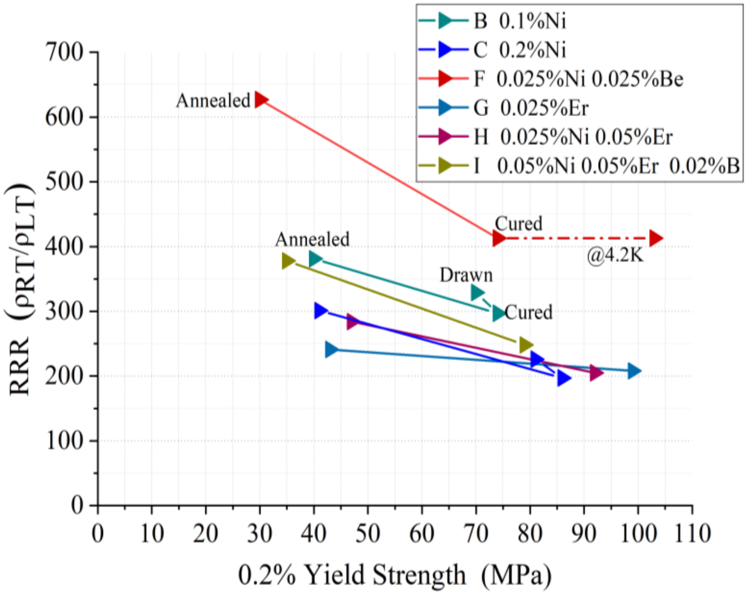
Long Dummy cable （$22*56mm^2$）

LTS detector magnet R&D

- R&D of High Strength and High RRR Aluminum- Stabilizer for Superconducting Cable

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

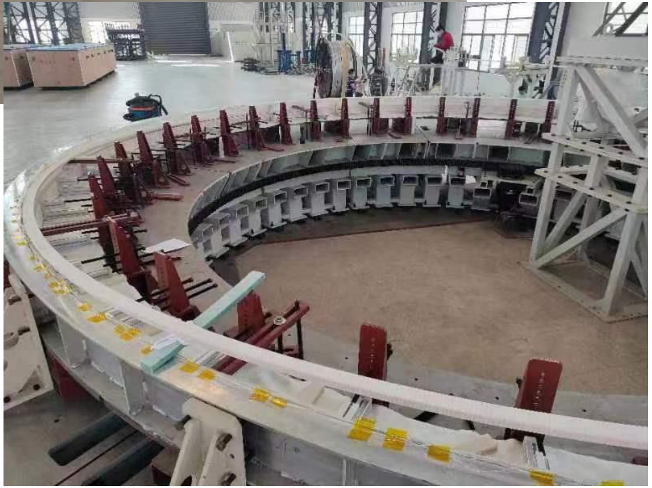
- By doping Ni-0.025% Be-0.025%, annealing, cold-working and curing.
- The Al-0.025%Ni-0.025%Be alloy prepared from 4N8-aluminum achieved high 0.2% yield strength of 75MPa (R.T.) with RRR of 417 after cold working of 21% and annealing at 130℃ for 15hrs.



LTS detector magnet R&D

Winding platform of Dummy coil

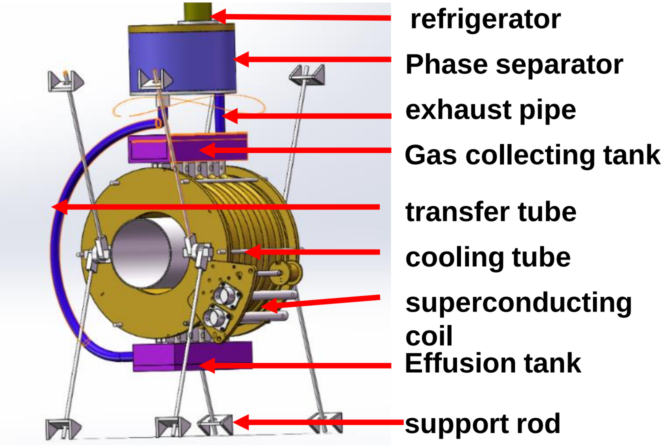
- Dummy cable: 6061 Aluminum alloy, cross section 56mm*22mm
- Dummy coil: 4 layers, 10 turns per layer.



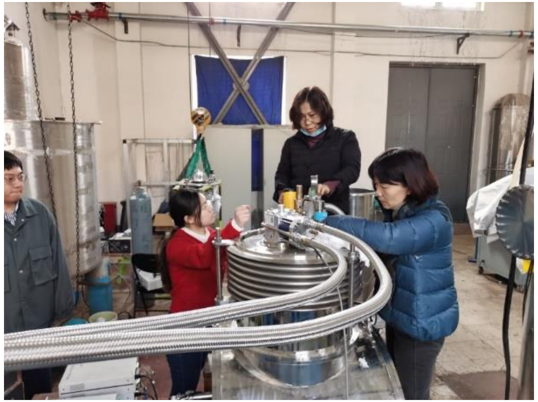
LTS detector magnet R&D

Liquid helium thermosiphon cooling method study:

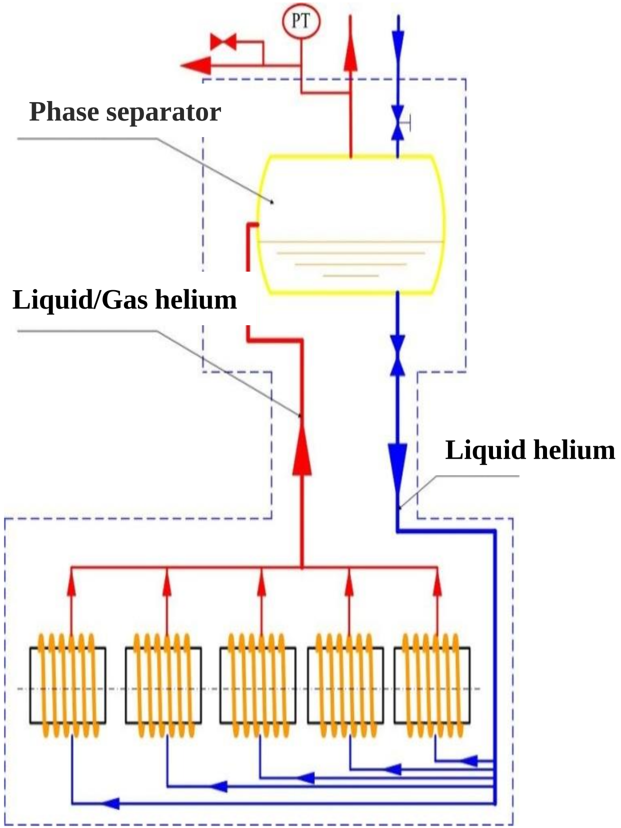
➢For large diameter coils, the temperature difference is small and the temperature is more uniform;
➢Less quench caused by low temperature system failure;
➢Siphon cooling experiment with a small coil.



Design diagram of thermosiphon cooling small magnet

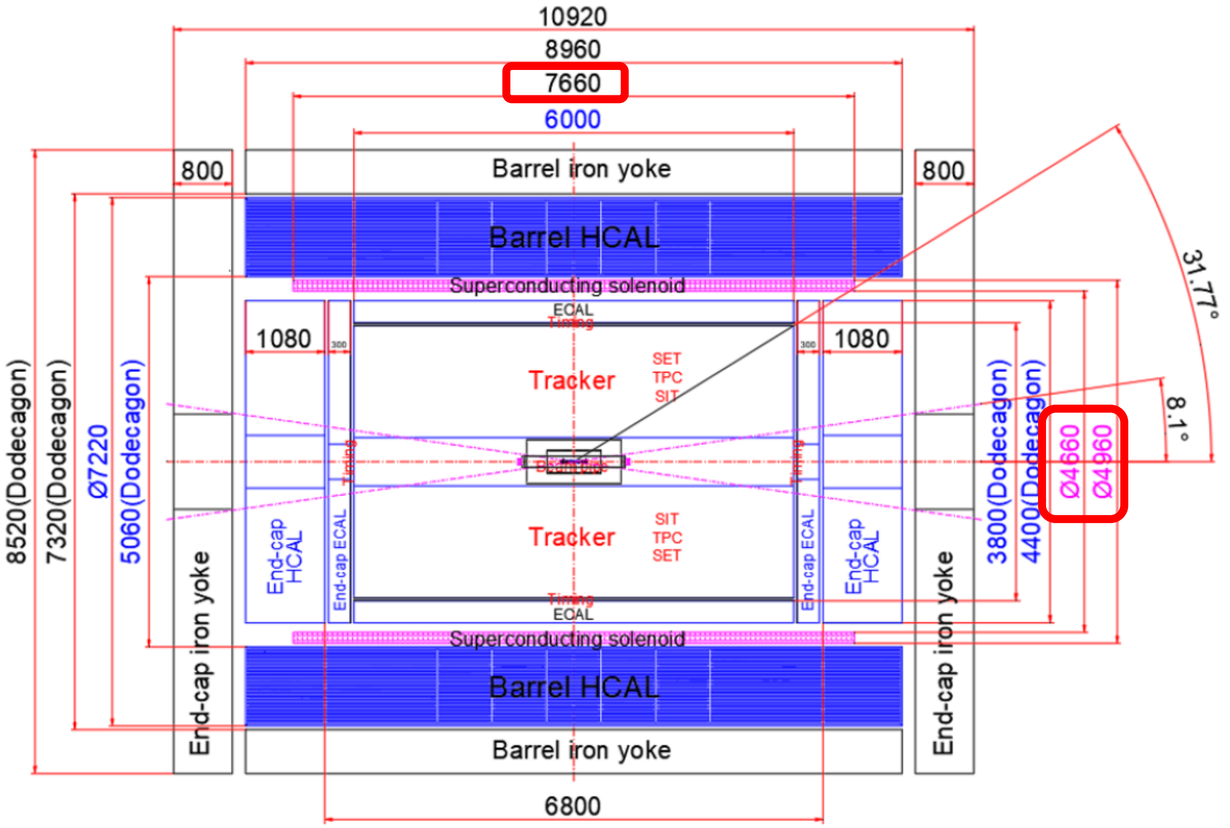


Thermosiphon cooling experiment of small magnet



Schematic diagram of liquid helium siphon cooling

HTS detector magnet R&D

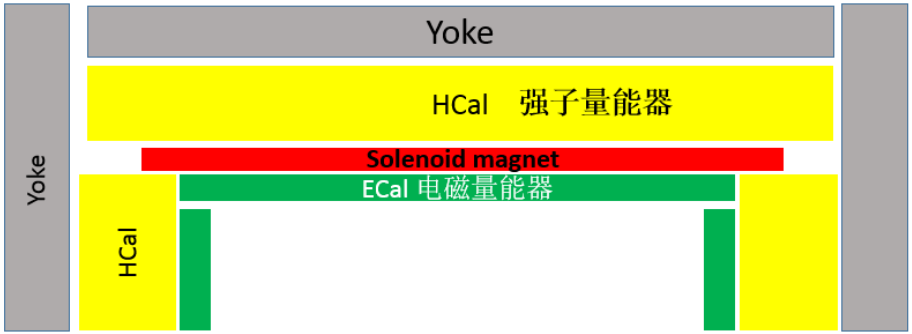


Magnetic field	3 T
Inner Diameter	4660 mm
Outer Diameter	4960 mm
Magnet thickness	150 mm
Length	8000 mm
Radiation thickness	< 1.5X0

HTS detector magnet R&D

The 4th Conceptual Detector Design: The solenoid magnet locates between Hcal and Ecal.

A large ultra-thin & transparent solenoid magnet:



Magnetic field	3 T	Current	29700 A
Inner diameter	4660 mm	Inductance	0.53 H
Outer diameter	4960 mm	Stored energy	234 MJ
Magnet thickness	**150 mm**	Cold mass	20 ton
Length	8000 mm	Total weight	35 ton

Innovative: The first proposal of high-temperature superconductivity for large detector magnets

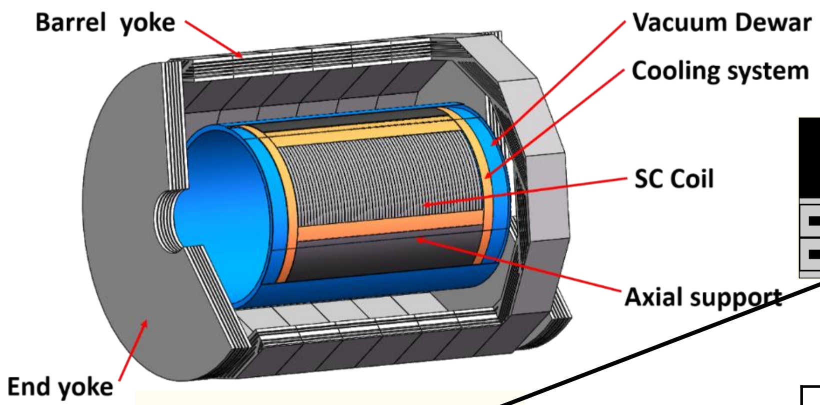
Advantages:

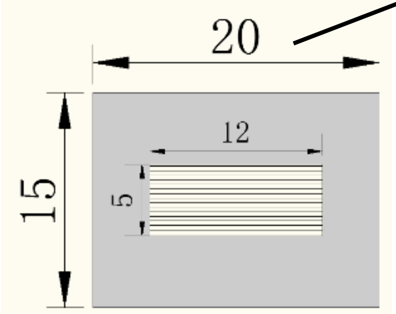
- Stable, can work at 20K, with a large temperature margin and stable operation;
- Transparent, the main material is hastelloy;
- High strength, HTS tape can withstand a tensile force of 400MPa, much higher than 150MPa of LTS NbTi wire;
- Supply, three Chinese manufacturers with sufficient supply

Disadvantages:

- The technology is immature, need to develop all processes from HTS cables to magnet technologies;
- The cost of magnets is high.

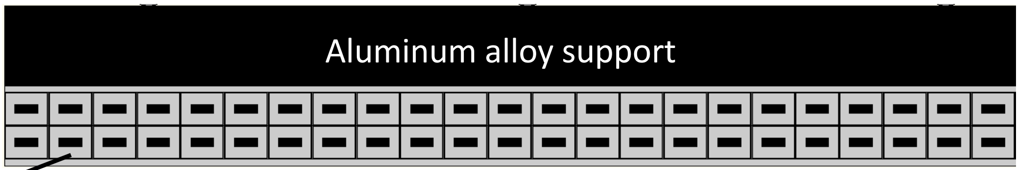
HTS detector magnet R&D





HTS cable: **ASTC(Al** stabilized HTS **S**tacked **T**ape **C**onductor)

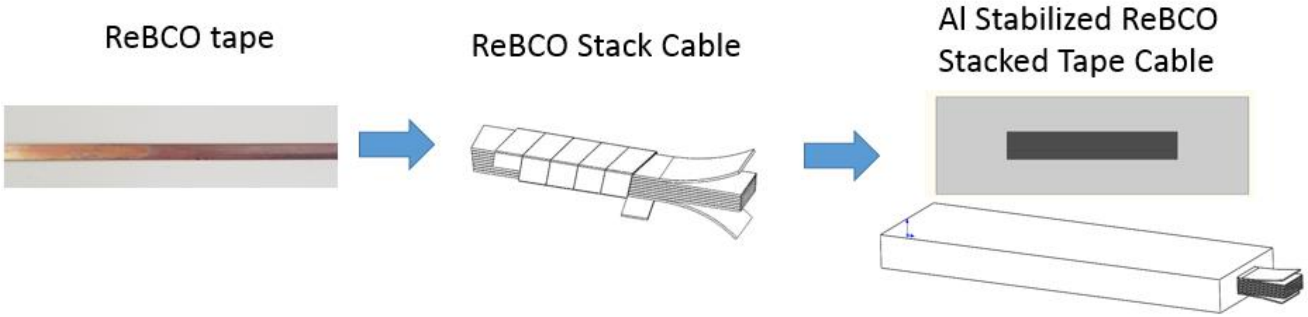
HTS coil conceptual design:



layers	2	HTS cable length (km)	9
Turns per layer	300	10 or 12 mm wide tape length (km)	315
Tape layers of ASTC cable	35	ASTC weight (ton)	9
Current (A)	29700	Tape cost (million ¥ Yuan)	100

HTS detector magnet R&D

HTS cable: **ASTC(Al** stabilized HTS **S**tacked **T**ape **C**onductor) cable conceptual design



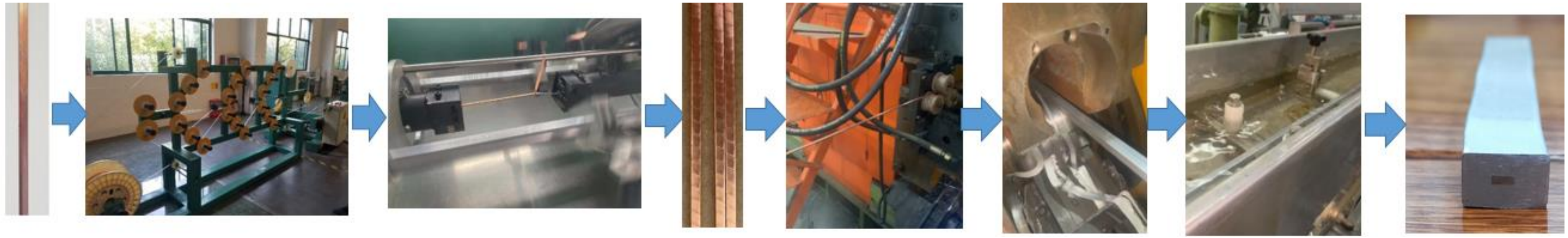
- Advantage: Simple structure, easy to produce, has experience and processing equipment;
- Disadvantage: uneven current distribution, High dynamic loss, influence of shielding current, large AC loss, and so on.

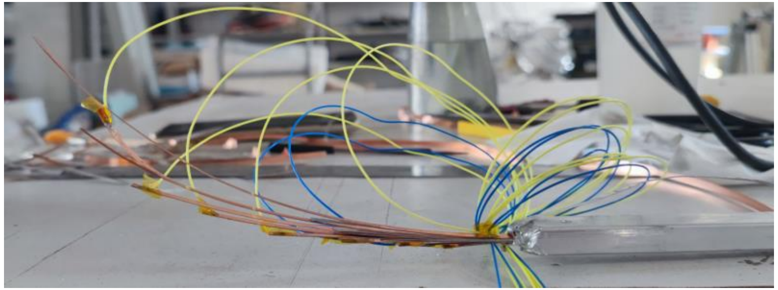
For detector magnets, we can accept its disadvantages for a long time DC steady state.

HTS detector magnet R&D

HTS cable: **ASTC(Al** stabilized HTS **S**tacked **T**ape **C**onductor) development

Small size cable: 15*10mm^2 **,** ReBCO Tape Width: 4 mm, thickness: 80 μm; tape layer: 16





HTS detector magnet R&D

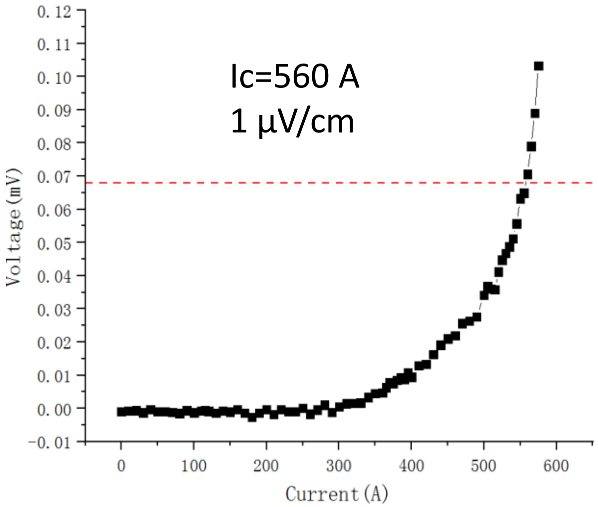
After optimization and improvement：

Test cable: ReBCO tape layer: 7, Other: ss304 tape and Al tape instead

Test result (1 μV/cm):

Ic = 560 A@77K, self-field

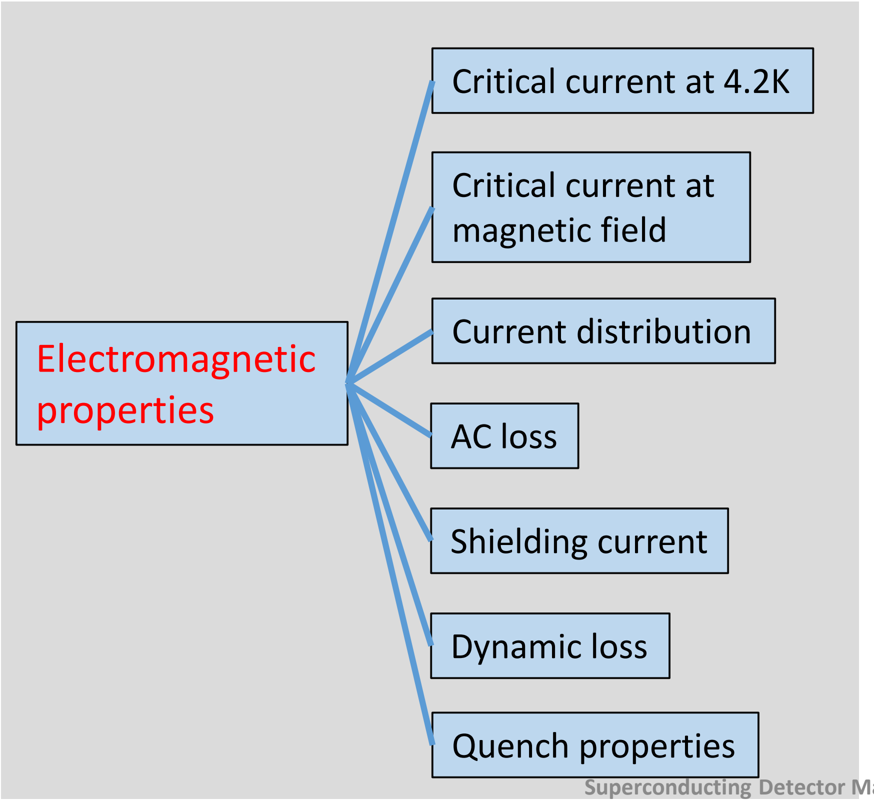
Cable has a little performance degradation.
Doing the research of the Full HTS tapes cable.
Optimization and improvement are also needed.

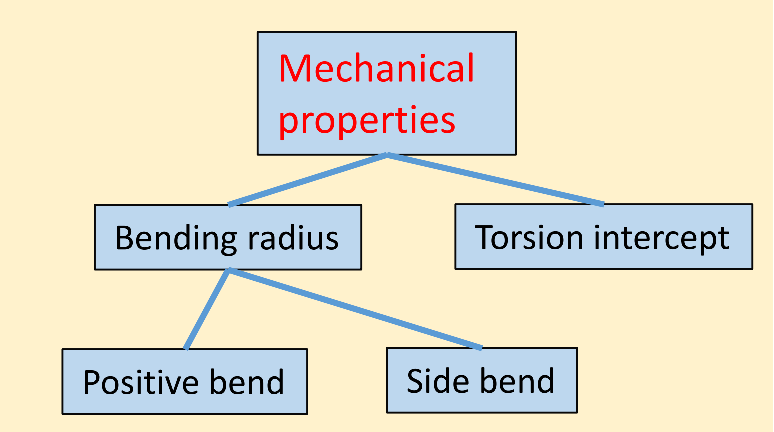


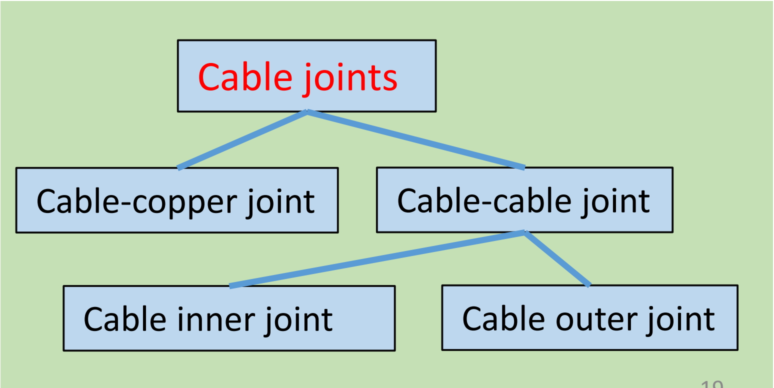
Cable test at 77 K

HTS detector magnet R&D

- Work in progress

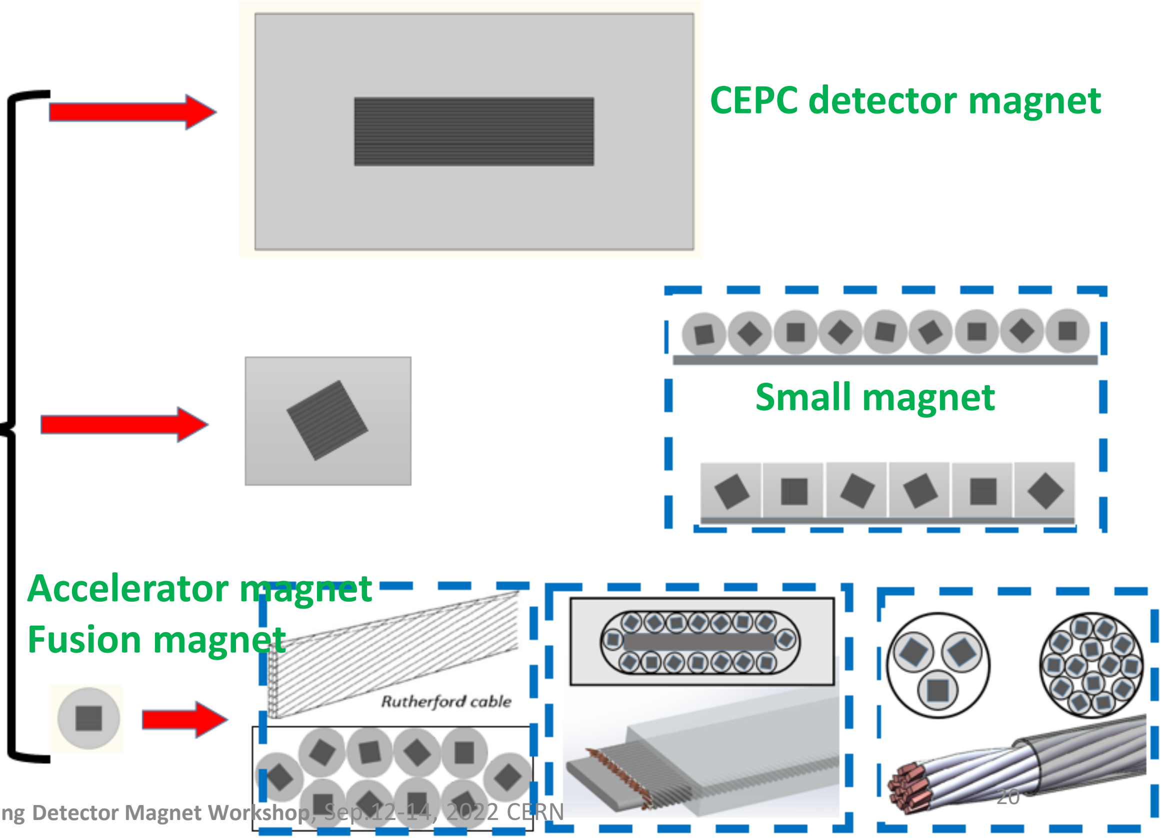






HTS detector magnet R&D

Further development based on ASTC cable:



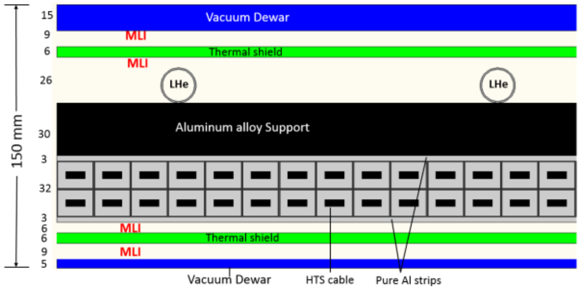
Conceptual design of the ultra-thin & transparent cryostat

Thickness of the magnet: **150 mm**

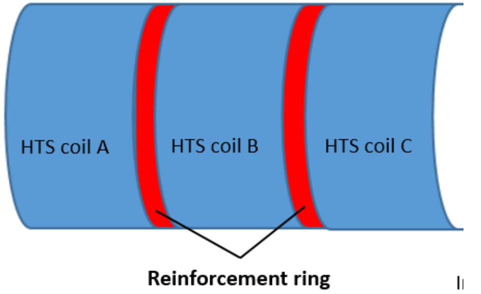
Including: vacuum cryostat, thermal shield, cold mass, Multi-layer insulation, support structure, liquid helium pipe, liquid nitrogen pipe, wires and so on.

Thanks to the large temperature margin of HTS, We can consider the structure of adding **reinforcement rings** and **support rods**. Sacrificing heat leakage for radial space.

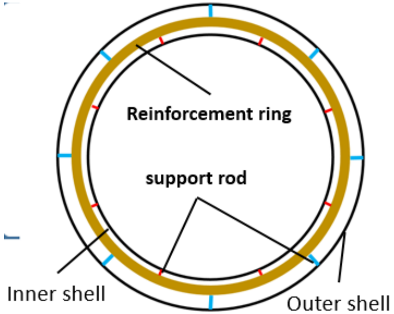
Conceptual mechanical design



Divide the coil into three parts



Install the support rod on the reinforcement ring



Low thermal conductivity support rod: ss304, G10, carbon fiber

Summary and future plan

1. The R&D of detector magnets for CEPC is ongoing. LTS and HTS detector magnet plans.
2. Aluminum stabilized LTS cable and HTS cable are being developing and make progress.
3. High strength and RRR aluminum stabilizer is being developing.
4. Solenoid coils and Ultra-thin cryostat will be studied in the future.

Welcome collaborators **Thanks**