Aluminum Stabilized Stack ReBCO Tape Cable for CEPC Detector Magnet

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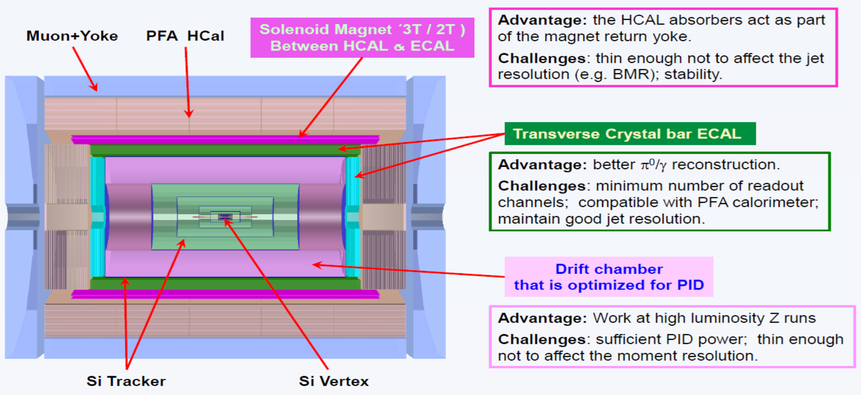
Introduction

- **For Circular Electron Positron Collider (CEPC) detector magnet**



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.

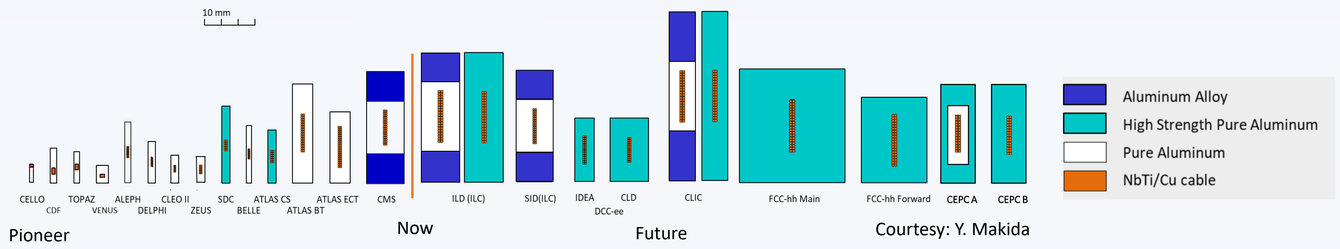
Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.
Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

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.

- **Requirements for conductor**
  1. Operating current ~30 kA@4.2 K, self-field
  2. Self-stabilization
  3. transparency
  4. Sufficient mechanical strength



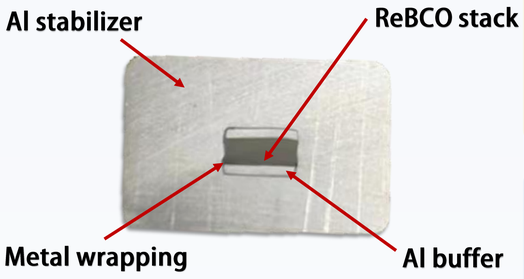
Courtesy: Y. Makida

- Aluminum stabilized cables are the mainstream choice for detector magnets
- REBCO is an excellent material with high current density and large temperature margin

Aluminum stabilized Stack ReBCO Tape Cable (ASTC) *First proposed in the world!

- **Aluminum stabilizer**
  1. Detector magnets need to be transparency
  2. Pure aluminum has better conductivity (RRR>800@4.2K) and thermal conductivity(1318~1964 $W/m \cdot K$ @4.6~10.1K)at low temperatures than copper

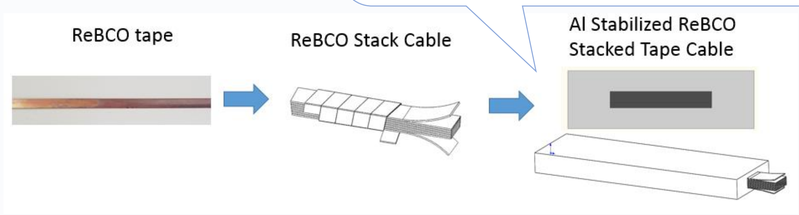
- **Metal wrapping tape**
  1. Wrap around the superconducting stack to assist in fixation
  2. Copper is currently used, and aluminum will be replaced in the future



- **Core: ReBCO stack**
  1. YBCO belt from Chinese supplier is adopted
  2. Long-term stable DC operation of cables is not sensitive to the requirements of dynamic losses. In this case, the stacked structure is the simplest
  3. Large temperature margin

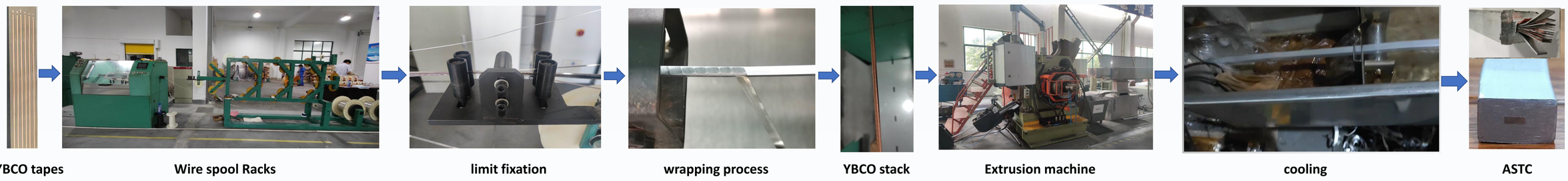
- **Aluminum buffer layer**
  1. Pure aluminum of the same width as ReBCO tape is used as a stress buffer
  2. Protect the internal superconducting tapes from contact damage during the manufacturing process

Co-extrusion : Aluminum is soften by the friction, and then extruded through the mold export. In this process, the ReBCO tapes will inevitably enter the dangerous environment of high temperature and complex stress.



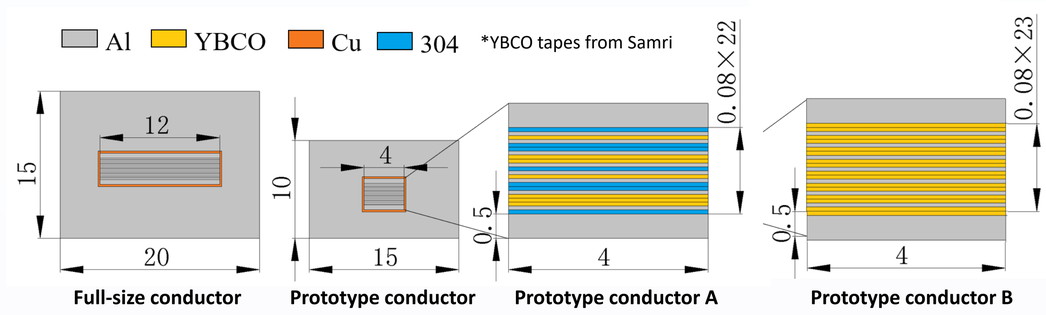
- Advantage: Simple structure, easy to produce; No welding, one-piece molding; Large proportion of stabilization; Have experience and processing equipment
- Disadvantage: Uneven current distribution; No transposition: High dynamic loss, large AC loss; Influence of shielding current;

◆Manufacturing process



Prototype conductor

Prototype conductors with smaller cross-section were developed to save costs.

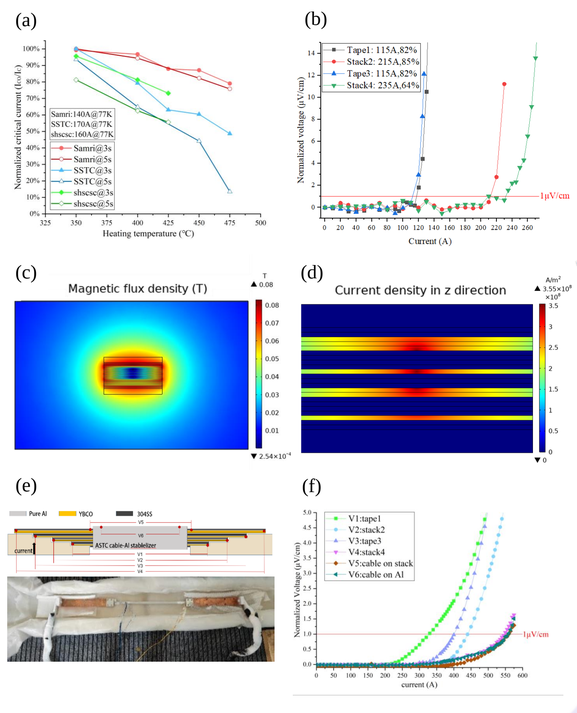


➢Prototype cable A:

- In the previous study, the effect of high temperature on the critical current of YBCO tapes from three major vendor is measured as shown in Fig (a).
- The Ic of the 4 superconducting stacks/tapes in the core wire is shown in Fig (b), single tape and double stack retain more than 80% Ic.
- Fig (c)(d): Based on the self-consistent model, the magnetic field distribution and current density distribution of the cable are simulated, and the Ic is 547A@77K.
- The measured critical current of the cable is 555A@77K.
- Superconducting stacks/tapes in conductors do not quench at the same time as the cable quenches, but in a certain order:

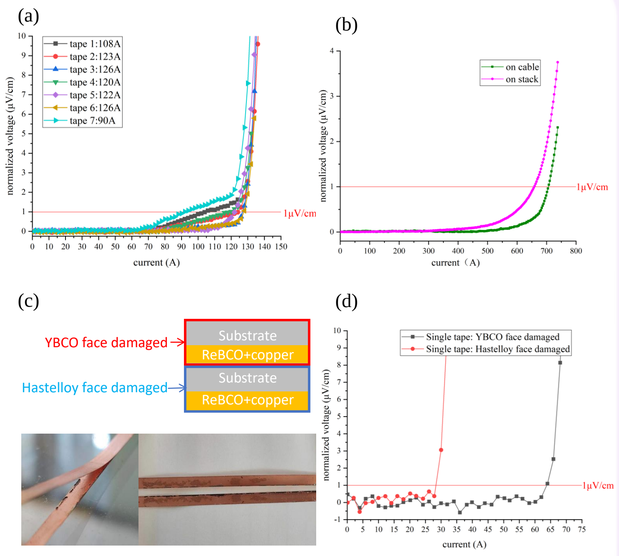
  V1 (325) –V3 (405) –V2 (445) –V4 (550) –V5 (555) –V6 (555)

- **This results prove that at least 80% of the IC can be retained after the co-extruded process for YBCO tapes from Samri.**



➢Prototype cable B:

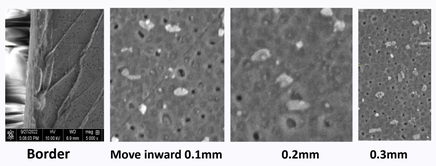
- The Ic of the partial double-stacks in cable is summarized in the fig (a), with an average value of about 120A, 50% retained.
- A distinct linear resistance occurs when the current reaches 65A, which is considered interlayer resistance. This means that the surfaces of this YBCO tapes are not cleaned well.
- Fig (b): The measured critical current of the cable is 705A@77K, approximately 70% of the target value.
- Fig (c)(d): Adhesion of the copper plating layer is discussed: it does not directly reduce the Ic, but it causes attenuation when shear or misalignment causes the copper plating to peel off.



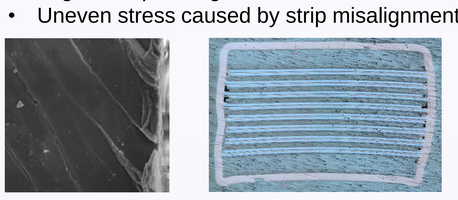
☼ Factors that affect the Ic of ASTC

✓Mechanical damage

The edge of the superconducting layer is crushed by complex forces in the co-extrusion process, affecting about 5%



- Extension of microcracks caused by the original strip slitting
- Uneven stress caused by strip misalignment



✓High temperature

- Further cooling the process temperature is still an important direction for process adjustment and improvement.
- A real-time temperature monitoring and control equipment in the co-extrusion process is being installed

✓Surface cleaning of YBCO tapes

✓Stacked misalignment

✓The thickness of the copper plating

More research is ongoing!