The 2014 Kyoto Workshop on HTS Magnet Technology for High Energy Physics
– The 2nd Workshop on Accelerator Magnet in HTS –
November 13 – 14, 2014, Kyoto, Japan

Report from WAMHTS-2 and opportunities for HTS

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WAMHTS-2

- Held at Kyoto University in November 13 – 14, 2014
- Focusing on *magnet* technology, whereas the WAMHTS-1 in Hamburg focusing on *conductors*
- 55 people (21 (Asia, pacific) +20 (Europe) +14 (US)) participated in this workshop.

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Key topics in the workshop to look at the opportunities for HTS

1. Magnet designs using assembled HTSs
2. Stability and protection
3. Tape magnetization and field quality

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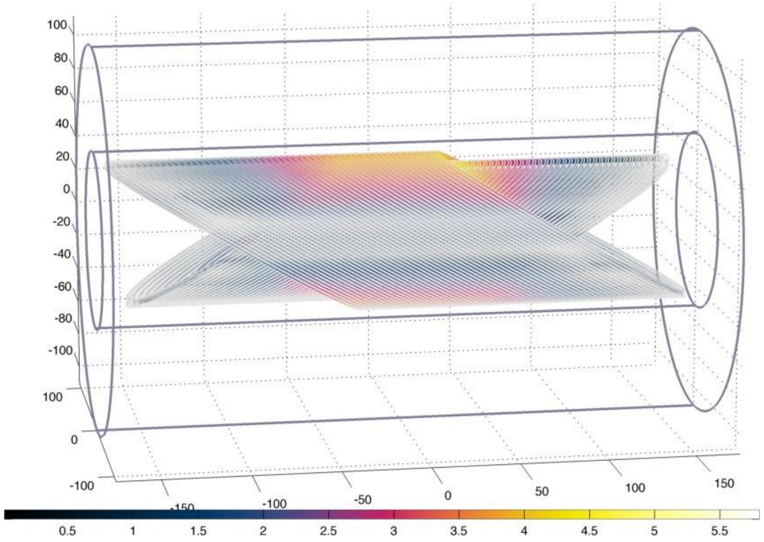
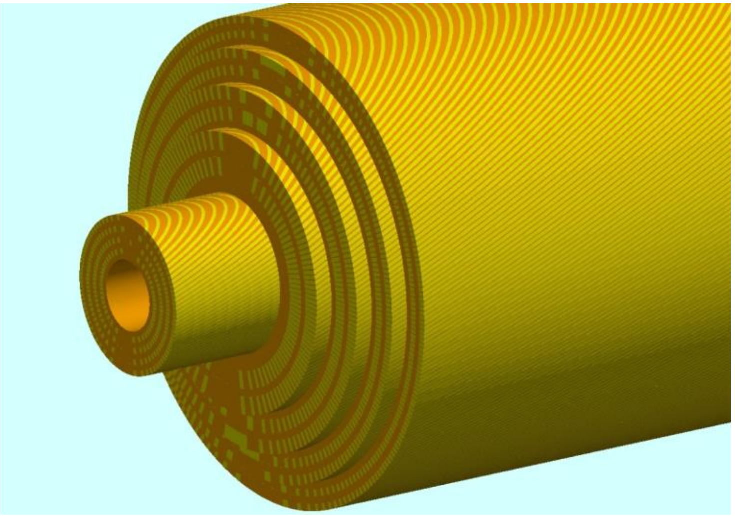
Magnet designs using assembled HTSs

Various designs have been made in Europe (EuCARD2) as well as in US.

- CCT design with BSCCO Rutherford cable
- Cosine theta design with BSCCO Rutherford cable
- YBCO stacked tapes cable block design
- Aligned block design with YBCO Roebel cable
- Cosine theta design with YBCO Roebel cable

BSCCO Rutherford cable CCT designs





- 5 T at 3 kA
- 12-strand BSCCO Rutherford cable
- 4 layers
- Je = 510 A/mm^2 (80% J_c)

- 18 T
- 4 layers of Bi-2212
- 8 layers of Nb_3Sn

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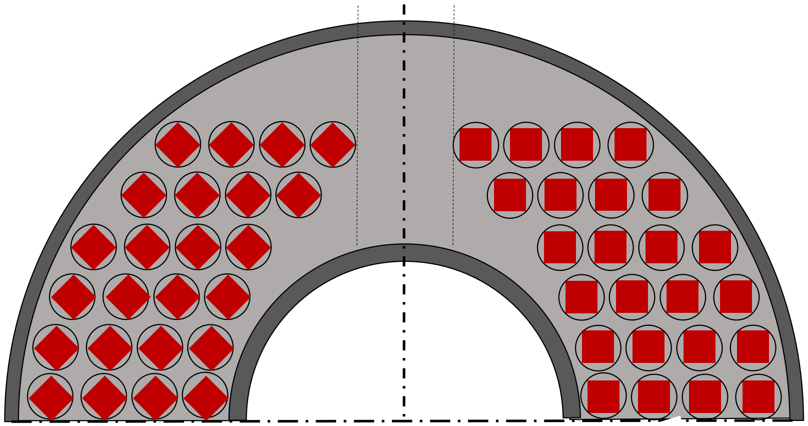
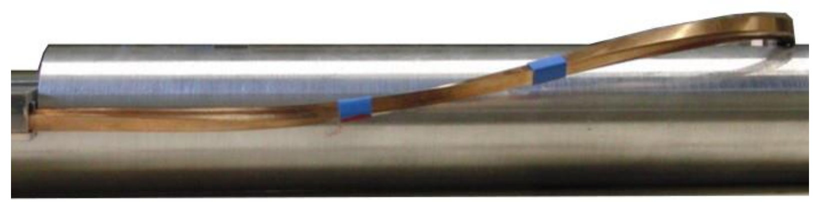
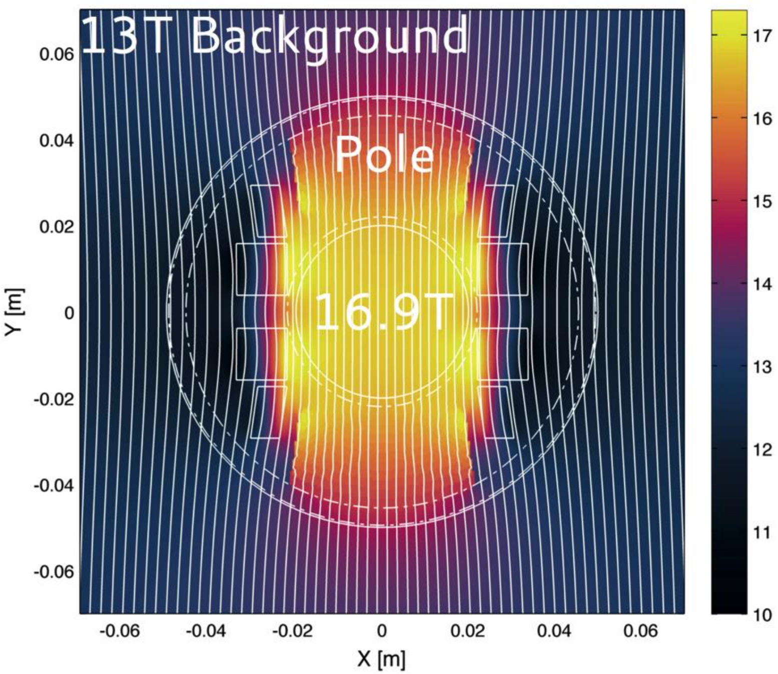
YBCO stacked tapes cable Block design



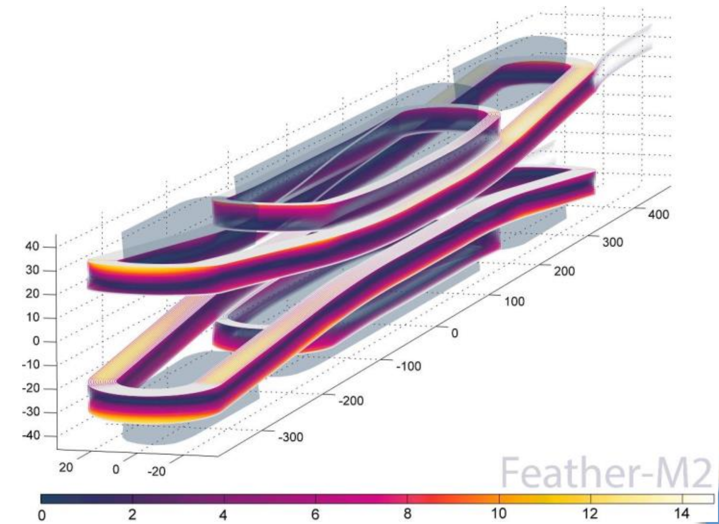
- Six pancake coils
  - 3 pancakes are flat
  - 3 pancakes have twist-and-bend heads
- In each pancake, 4-turn bundles are distributed to allow reinforcement and twisting
- “Twist and bend” test with dummy cable was carried out.



YBCO Roebel cable aligned block design



- Tapes oriented in the direction of the field lines to maximize critical currents
- Baseline YBCO Roebel cable, 12 mm x 1.2 mm
- Feather – M2 test magnet will be fabricated



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Stability and protection

- Slow normal zone propagation and forming hot spot before detection
  - Reported as common issue with various magnets such as high field research magnets (Tohoku Univ., NHMFL, etc.)
- Various models developed to clarify phenomena
- Various detection schemes proposed
- This topic will be discussed intensively at WAMHTS-3.

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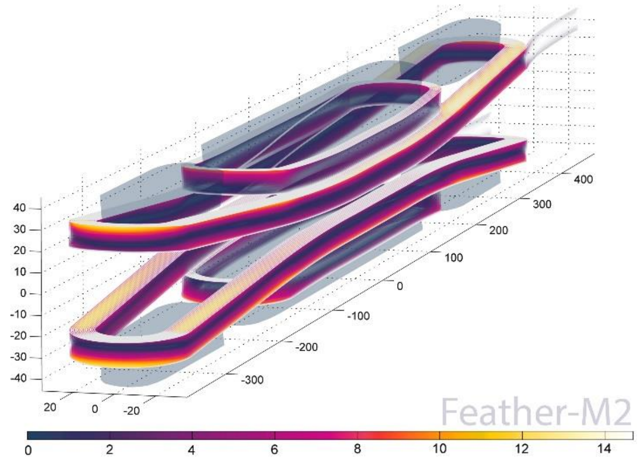
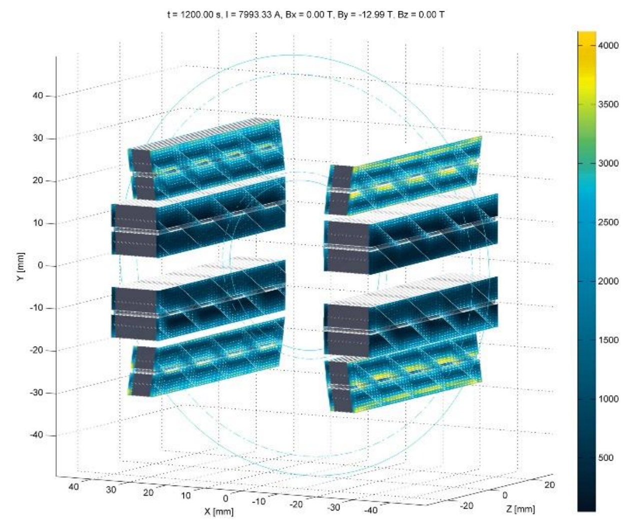
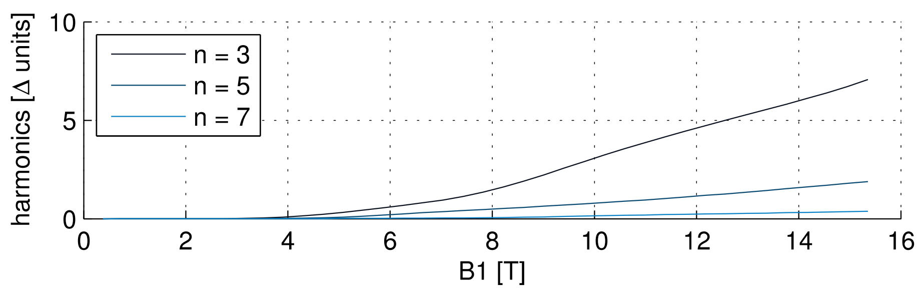
Tape magnetization and field quality

- Numerical simulations
  - Simulation of Feather – 2 at its straight section
  - Development of 3D model for cosine theta dipole magnets
  - 2D simulation of a dipole magnet for rotating gantry for carbon cancer therapy … not reported at WAMHTS-2
  - 2D simulation to compare the experimental results
- Experiments
  - Small dipole magnets consisting of racetrack coils wound with coated conductors
    - Bath-cooled in liquid nitrogen
    - Conduction-cooled by GM cryocooler

Simulation of Feather – M2







Harmonics at 2/3 aperture less than 10 units

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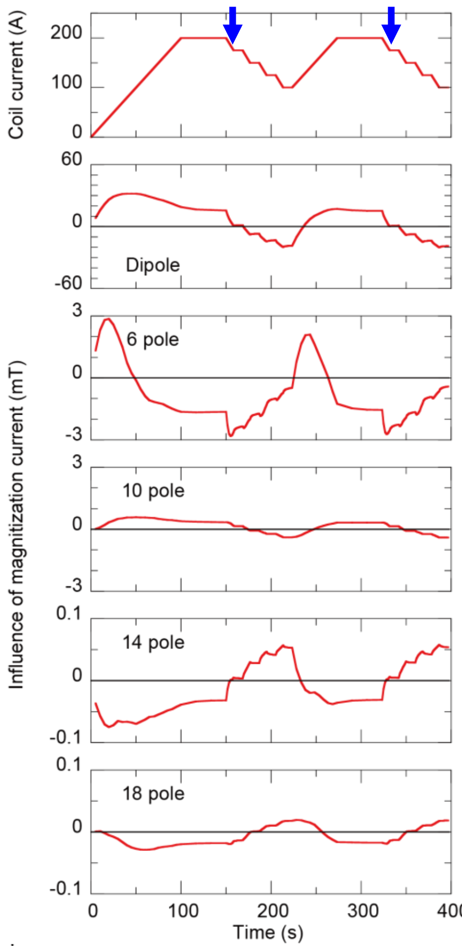
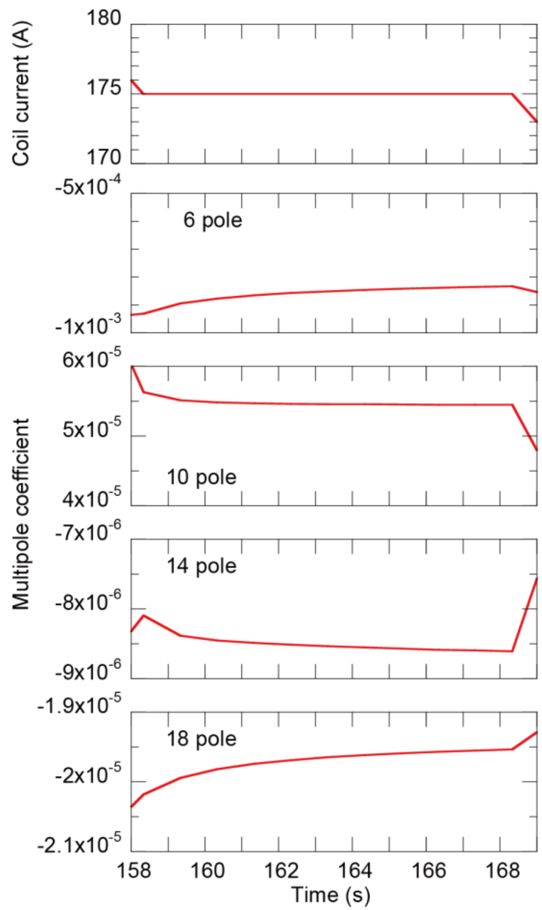
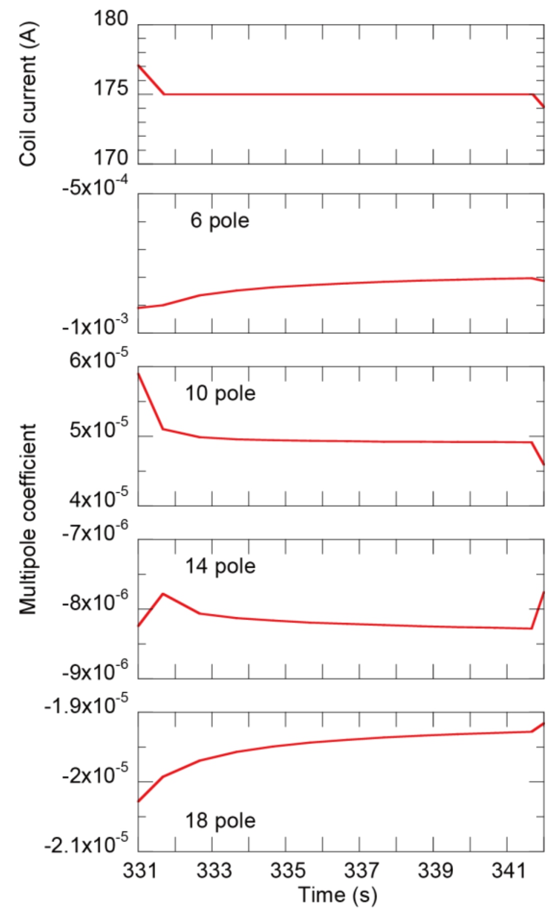
Calculated harmonics in a dipole magnet for rotating gantry for carbon cancer therapy (2D model)



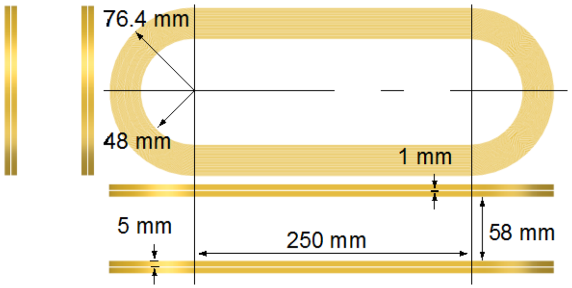


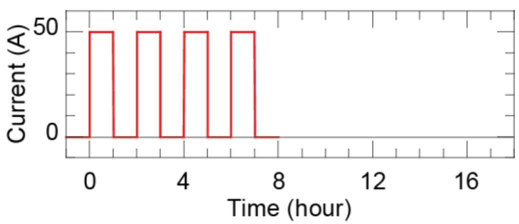


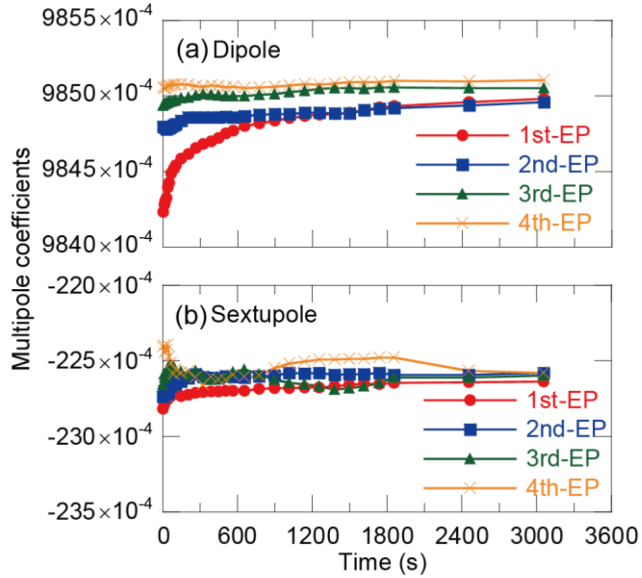
- Reproducible
- Harmonics less than 10 units
- Drifts of harmonics less than 1 unit

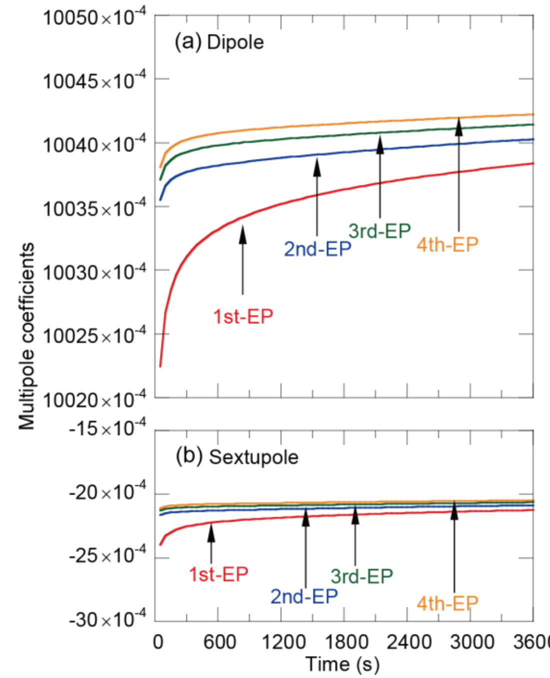
Field measurements in dipole magnet consisting of four racetrack coils bath-cooled in LN_2

Focusing on drifts of harmonics







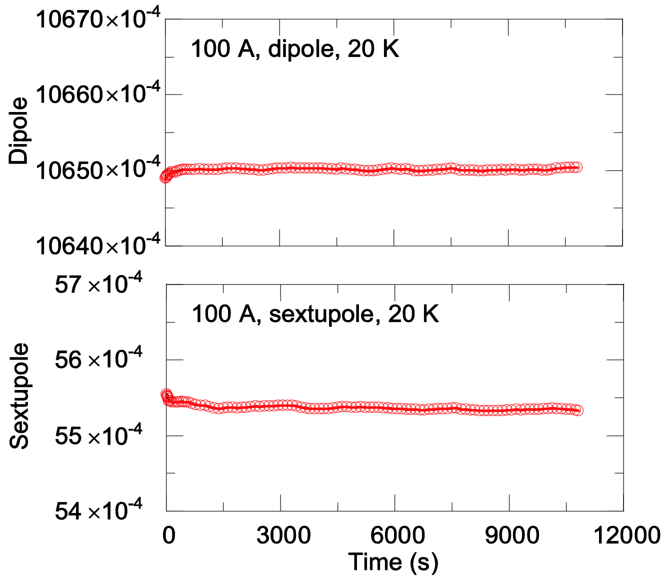


- In 50 min., dipole drifts 7.4×10^{-4}; sextupole drifts 1.4×10^{-4}
- Measurements agree with 2D calculation qualitatively.
- SUST**28**(2015)035003

Field measurements in dipole magnet consisting of four racetrack coils conduction-cooled by GM cryocooler

Focusing on drifts of harmonics

100 A (0.725 T @conductor)

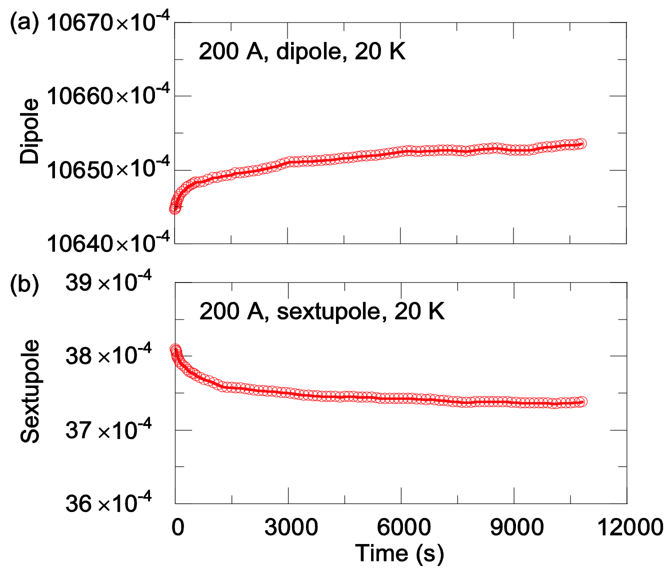


Drift in 3 hours

Dipole: 1.4×10^{-4}

Sextupole: 0.22×10^{-4}

200 A (1.45 T @conductor)



Drift in 3 hours

Dipople: 8.9×10^{-4}

Sextupole: 0.72×10^{-4}

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How to manage this issue?

1. We have to accept the existence of the large magnetization in coated conductors: their influence on field harmonics ~ mostly less than 10 units
2. Good news: reproducible magnetization
3. 3D modeling will enable us the magnetic field design considering the magnetization: we can design a coil, not assuming uniform current but considering the non-uniform current distribution.
4. Drift in harmonics caused by the decay of magnetization is another concern, but,
   - not very large drift*:* at the order of unit, most possibly less than 10 units
   - dipole drifting more but higher harmonics drifting less

Summary of the report

- Magnet designs using assembled HTSs
  - The applicability of assembled coated conductors should be verified in test coils.
  - Rutherford cables of Bi-2212 are attractive, but the fabrication process of (long) coils should be established.
- Stability and protection
  - A big concern; to be focused in WAMHTS-3
- Tape magnetization and field quality
  - It looks possible to mange.
  - More experiments as well as analyses are needed.