Superconductor Wire, Coils and Systems at Hyper Tech

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DOE-NP SBIR/STTR Exchange Meeting
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Wires: MgB_2 , High Jc Nb_3Sn
Cables: MgB_2, NbTi, Nb_3Sn, YBCO
Coils: MgB_2, NbTi, Nb_3Sn,
YBCO, BSCCO
Systems: MRI, SMES, FCL, Motors,
Generators, Wind Turbine
Generators

Hyper Tech Research Inc.

Phase II Title: Long Length Welded NbTi -CIC Superconducting Cable for Accelerator Applications,

For Superconducting Dipoles and Quadrupoles for Thomas Jefferson Laboratory Electron Ion Collider

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Dean Panick

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Development partners

Accelerator Research Lab (ARL)
Accelerator Technology Corp. (ATC)

Dr. Peter McIntyre
Daniel Chavez

CSMM
Center for Superconducting and Magnetic Materials

Dr. Mike Sumption

grant sponsor: DOE NP

Hyper Tech Research
Columbus, OH, USA
42,000 sq ft facility

Grant No. DE-SC0015198

Outline

⌘ Motivation of SBIR project

⌘ Phase II efforts

⌘ Background on technology

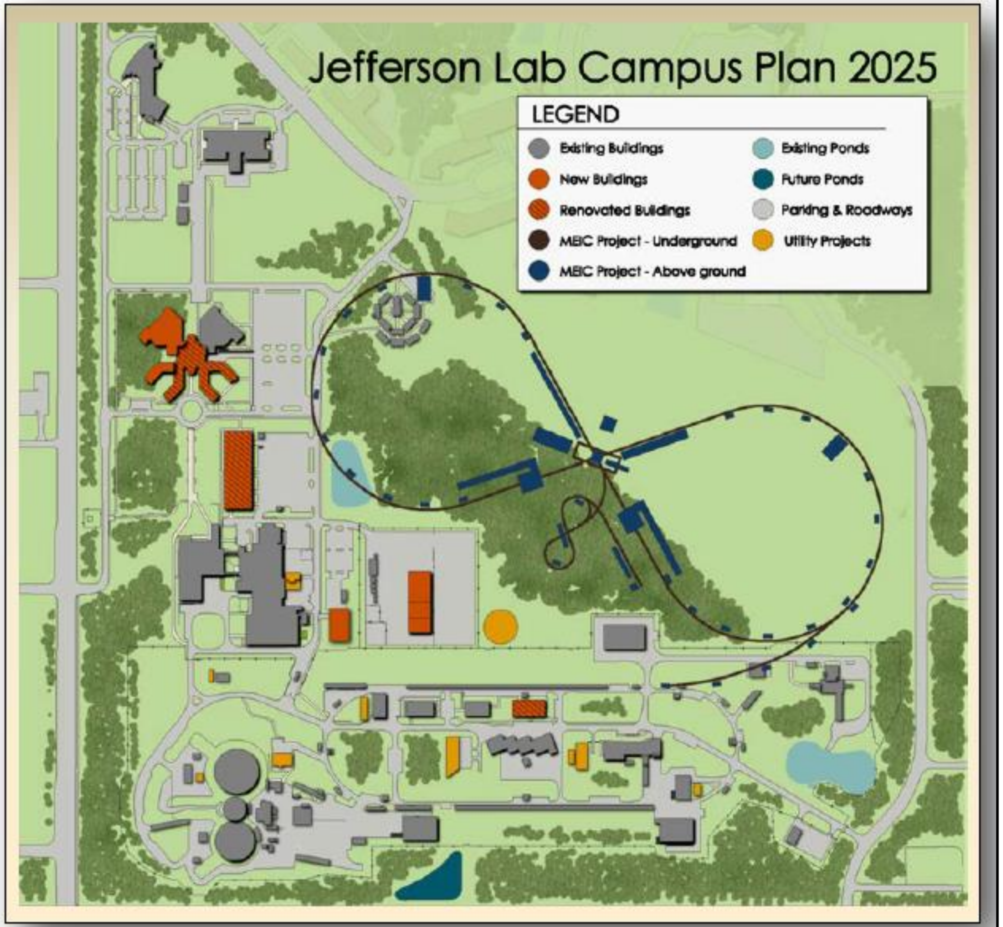
- CIC
- NbTi Superconductors
- MgB_2 superconductors
- Nb_3Sn superconductors

Motivation of project: JLab MEIC

JLab MEIC Figure 8 Concept

- **Initial configuration:**
  - 3-10 GeV on 20-100 GeV ep/eA collider
  - Optimized for high ion beam polarization:
    - polarized deuterons
  - Luminosity:
    - up to few x 10^{34} e-nucleons cm^{-2} s^{-1}
- **Low technical risk**
- **Upgradable** to higher energies
  250 GeV protons on 20 GeV electrons
- **Flexible** timeframe for Construction
  consistent w/running 12 GeV CEBAF
- Thorough cost estimate completed
  presented to NSAC EIC Review
- Cost effective **operations**

→ Fulfills White Paper Requirements



Current Activities

- Site evaluation (VA funds)
- Accelerator, detector R&D
- Design optimization
- Cost reduction

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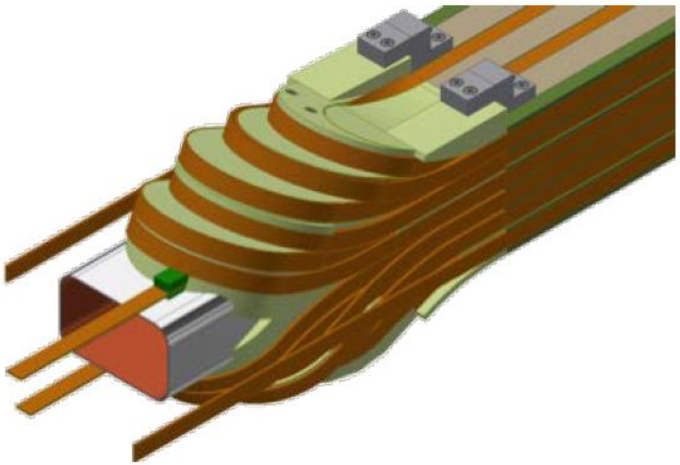
Slide from 2015 Dr. F. Pilat presentation

Motivation of project: MEIC Magnet R & D

- JLab is collaborating with Texas A&M for the design and prototyping of super-ferric magnets for the ion collider ring and for the booster
- Design and prototyping of high field, large aperture, compact super-conducting magnets for the collider Interaction Regions and Final Focus

- Texas A&M developed 2 approaches to winding cable for the super-ferric magnets:

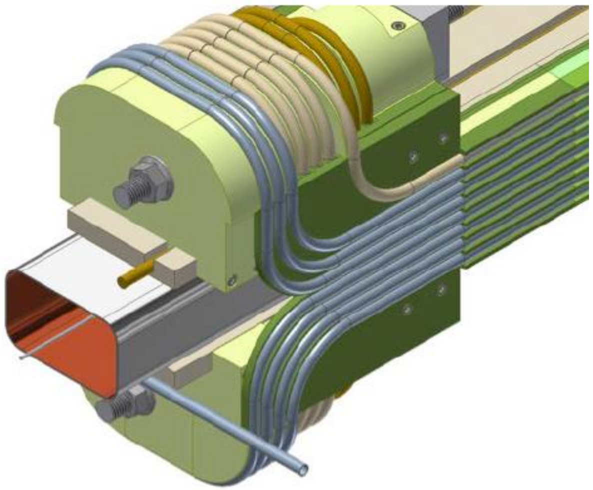
NbTi Rutherford cable



Pros: Uses mature cable technology (LHC).

Cons: Ends tricky to support axial forces.

NbTi Cable-in-Conduit

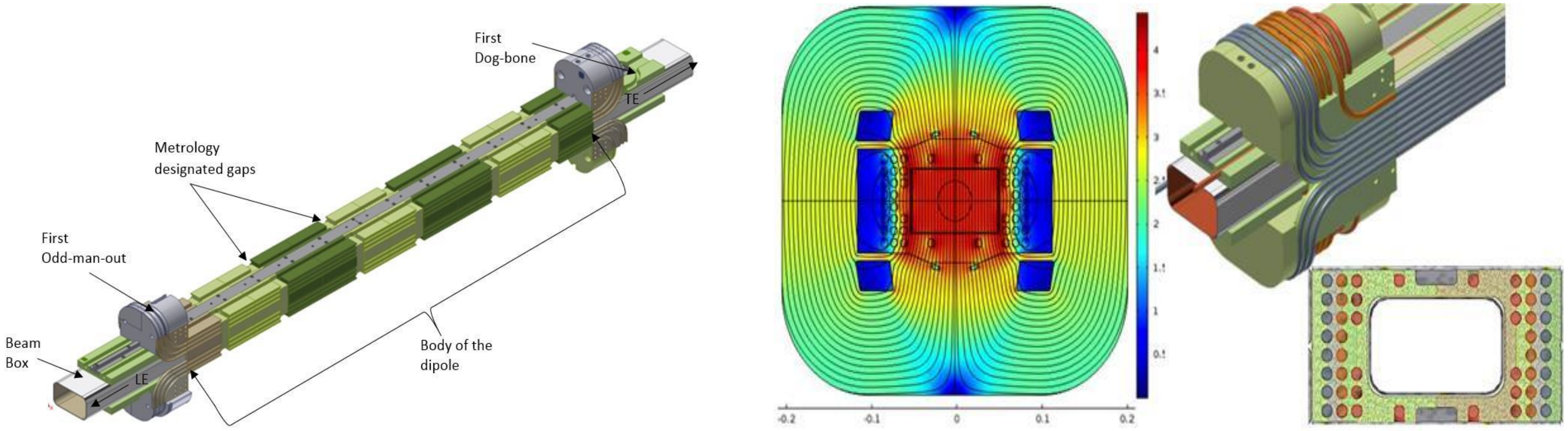


Pros: - Semi-rigid cable makes simpler end winding.
- Semi-rigid round cable can be precisely located.
- Cryogenics contained within cable.

Cons: Cable requires development and validation.

Cable-in-conduit technology

The ARL group has developed a design for a superferric dipole that utilizes a round NbTi cable-in-conduit (CIC) conductor. ARL has completed a Design for the magnet and its conductor, and ARL has built a magnet winding to develop the fabrication tooling and methods.

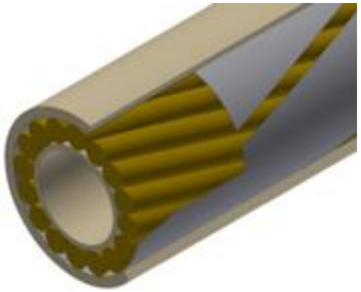


3.5 T CIC-based design for the Ion Ring arc dipole (left) magnetic field design (center) winding design (*upper right*); cross-section of winding structure (*lower right*).

The CIC innovation has the enormous benefit that it eliminates the cryostats (the CIC cable is the cryostat), gives robust structure to the windings, and dramatically simplifies the interconnections for cryogenics.

Motivation behind current project

cabling wires onto perforated spring tube



cutaway showing foil over-wrap

Cross section showing NbTi strands

- Challenge: the cable must be pulled into a sheath tube, and the sheath tube must be drawn down onto the cable to compress the superconducting wires against the perforated spring tube core. ARL has made reasonable lengths segments (150 meters).

- But each 4-m long MEIC arc dipole will require a ~400 m long continuous length of CIC conductor. What is needed is a method to continuously form a tube onto the cable and longitudinally weld the seam to make an arbitrarily long CIC segment.

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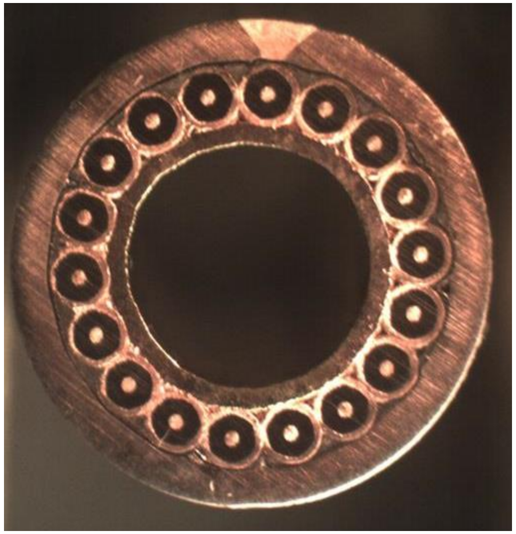
Laser-welded CIC-CTFF NbTi cables

- The feasibility of manufacturing long length CIC cables has been demonstrated under this STTR Phase II grant for small diameter NbTi CIC cables (over 100 meters).
- CuNi outer sheath formed around cable and laser welded in tube form at Hyper Tech.
- Both TAMU and Hyper Tech have performed leak and bend tests on cables manufactured at Hyper Tech.



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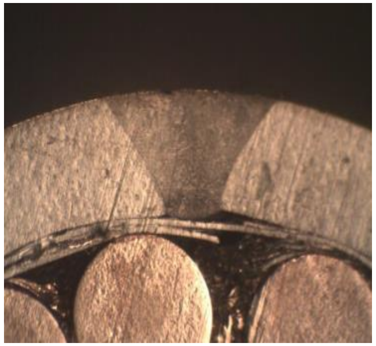
CIC-CTFF Cabling Steps

Perforated Inner Tube

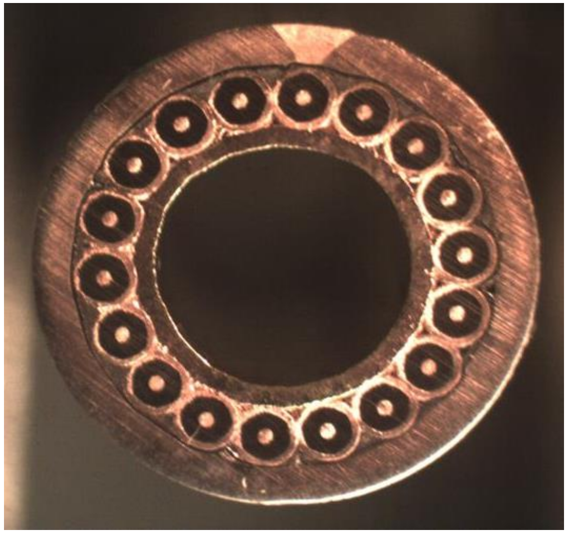
Stranding and Tape Wrapping

Pre-Cable

Continuous Tube Forming and Filling Machine



Laser Weld of Outer Sheath



Cross Section of Final NbTi Cable

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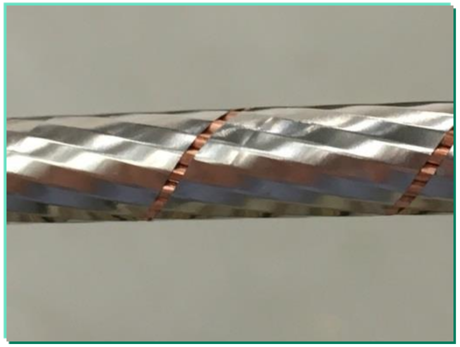
CIC-CTFF Cable Length Demonstrations

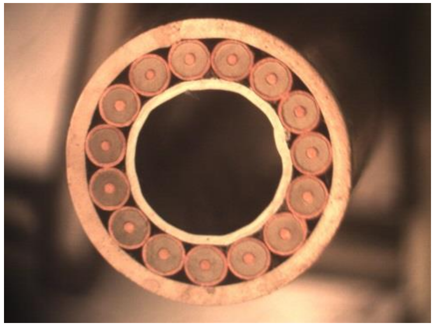
Demonstration of cable lengths for 3T magnet cable

- 2 meter lengths of NbTi cable completed
- 10 meter lengths of NbTi completed
- over 100 meter length of NbTi completed
- ATC wound coil using the NbTi cable -completed



Picture of Pre-Cable

Welded CIC-CTFF Cable



Cross Section

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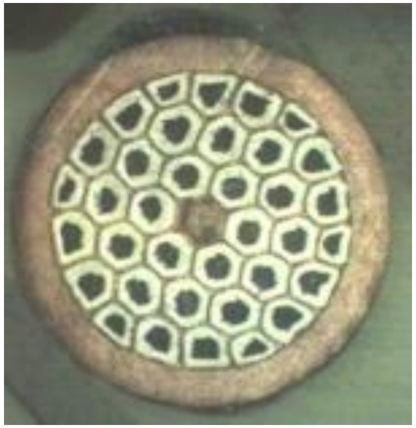
Eddy Current Device for Detecting Flaws in the Laser Welded Tube

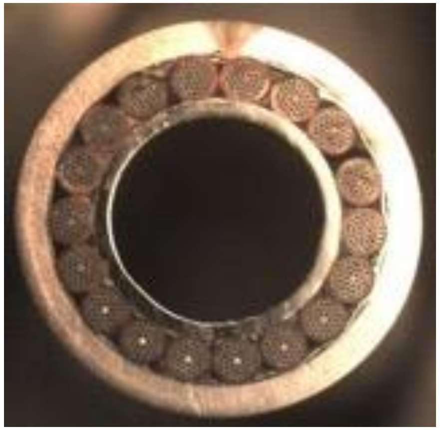
Controller

Pick-Up Coil

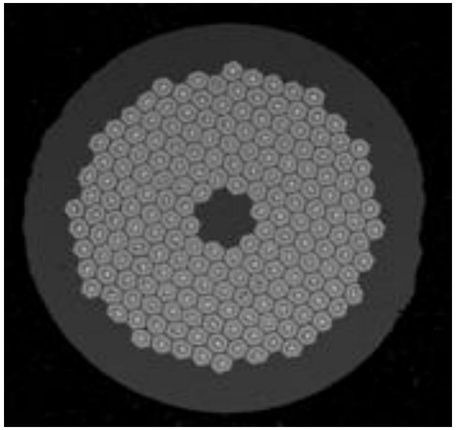
Cross Section of CIC-CTFF cables, MgB2 wires and Nb3Sn wires

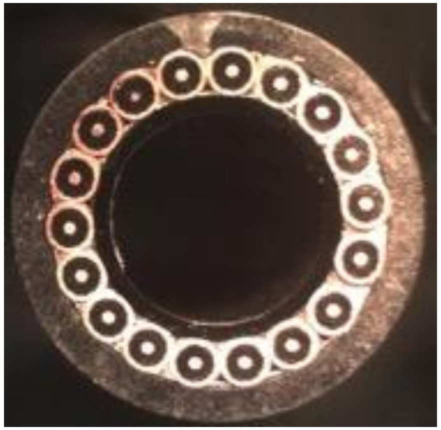
Under a NP SBIR Phase I we demonstrated CIC-CTFF MgB2 and Nb3Sn cables, It did not turn into a Phase II. However we demonstrated the feasibility for future applications. Also in future we intend to apply the cable approach to round (Re)BCO superconductors





MgB2 strand and CIC-CTFF Cable





Nb3Sn strand and CIC-CTFF Cable

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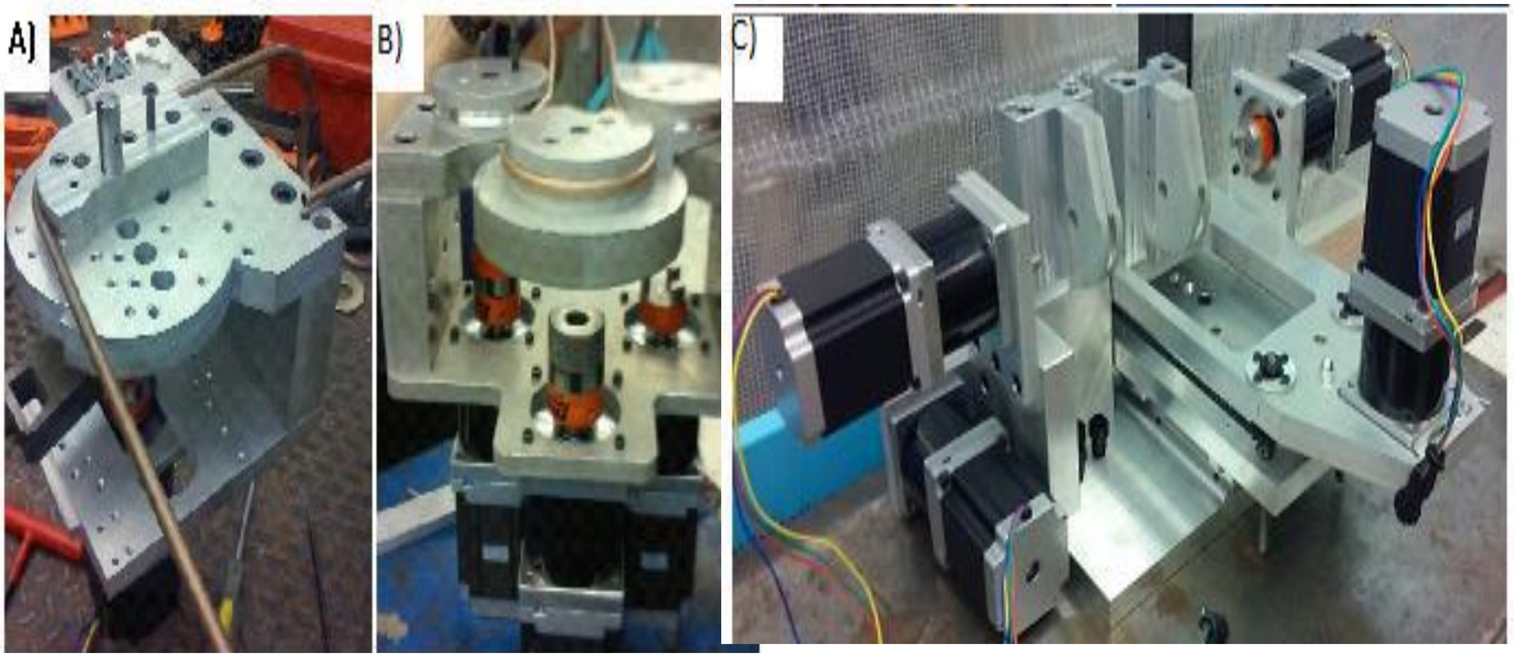
ARL Bending Tools for Dipole Magnets



Motorized bending tools: a) bender to form 180° U-bend while maintaining round sheath; b) bender to form a dog-bone end for the sextupole winding turn; c) bender to flare the U-bend to form a 90° end winding.

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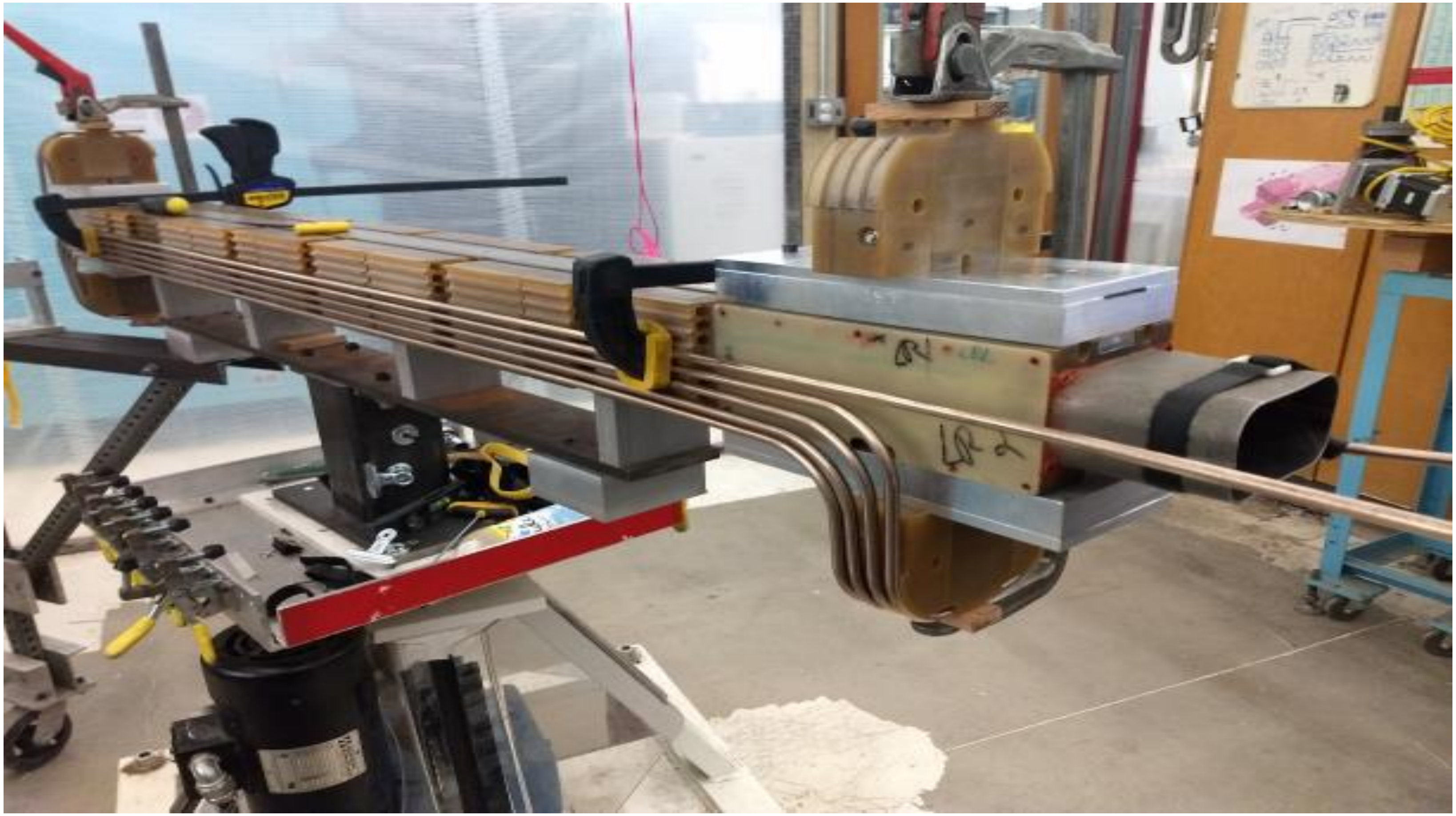
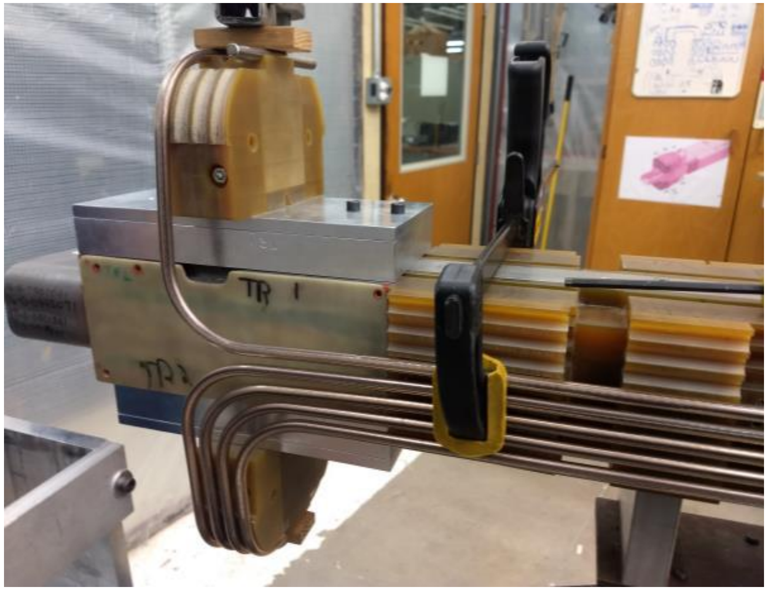
During the Phase II ATC team wound a coil using ATC's and Hyper Tech's CIC-CTFF cable

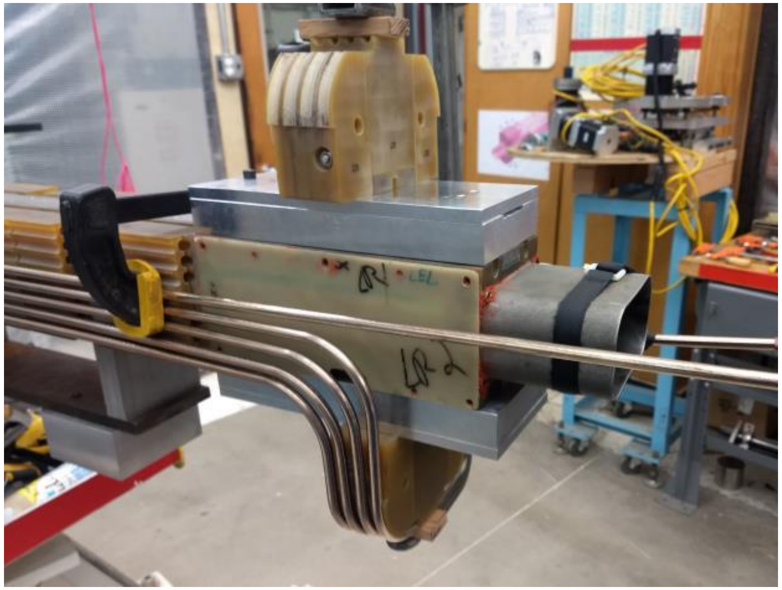


Coil wound by ATC using CIC-CTFF NbTi cable

Test that has been performed on CIC-CTFF Cable and Coil

1.-Helium leak check the as fabricated cable.
2.-High pressurize test to 600 psi and helium leak check again.
3.-Dunk the cable in LN2 and helium leak check again.
4.-Coil was fabricated
5.-The coil was 600psi and then helium leak checked again.





Work under no cost extension and Phase II and II B plans

No Cost Extension

1. Phase II work concentrated on demonstrating technology for 3T cable
2. We have funds left to purchase CTFF tooling for 6T cable design
3. We are working on repair welding procedures, on chance a full coil is made and there is a helium leak in a weld area when the full coil winding is completed.

Follow on work.

1. Currently ATC is working on a NP SBIR Phase I on the development of a two layer cable and coil design for a 6T magnet- ATC plans on submitting a Phase II – on Dec 10th

2. Hyper Tech plans on submitting a Phase IIB proposal to develop and demonstrate the CIC-CTFF two layer cable for 6T magnets -also on Dec 10th

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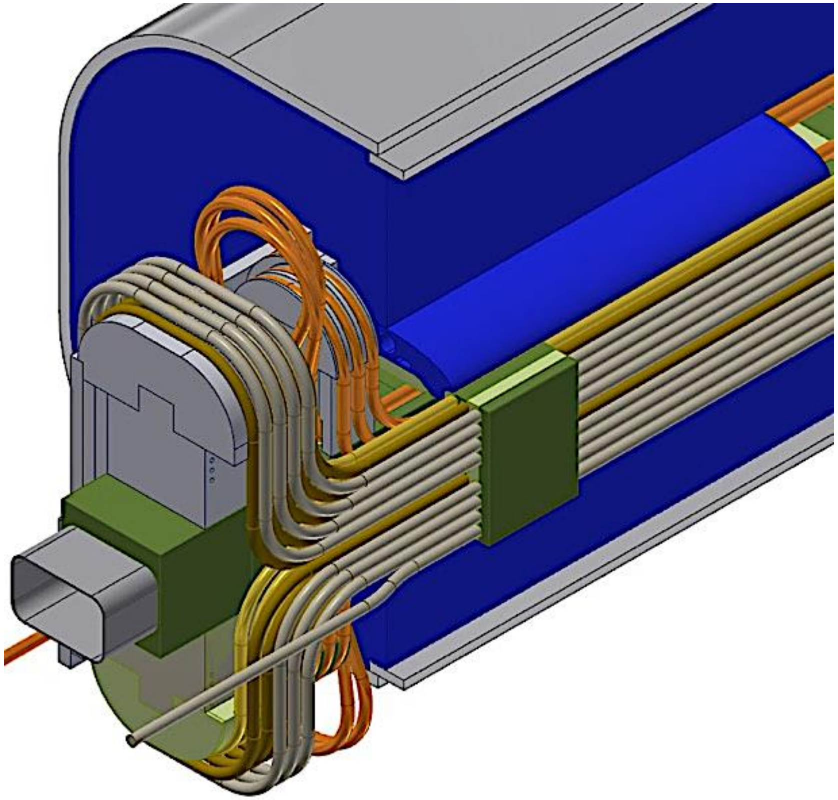
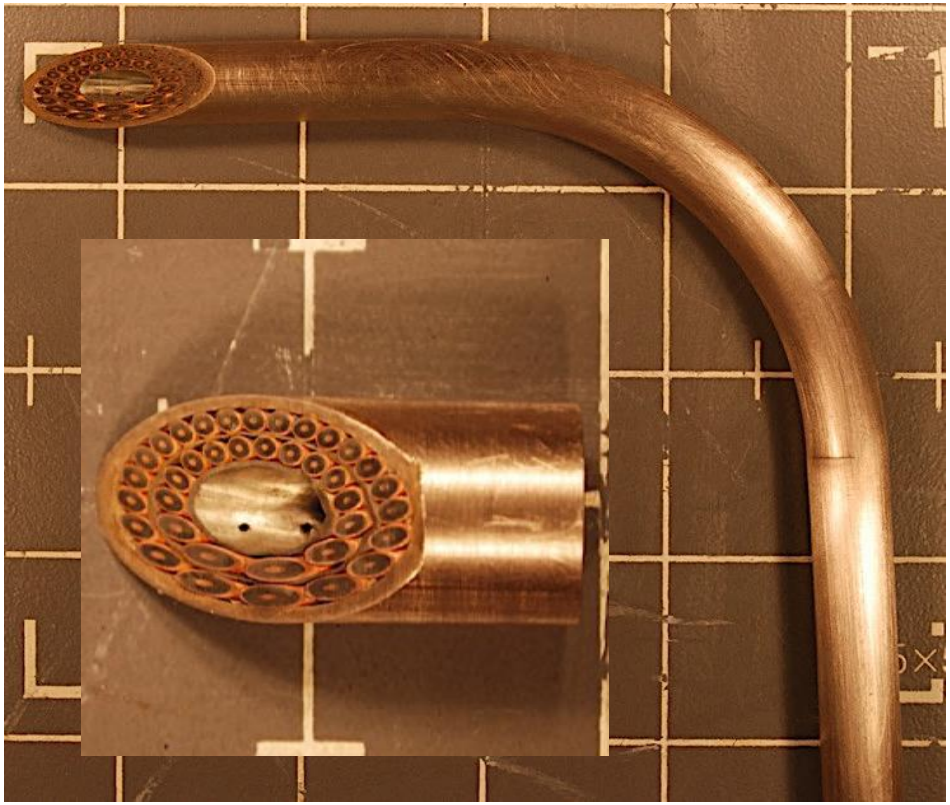
6 T dipole using 2-layer CIC.





ATC SBIR Phase I

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CIC cable technology potential

Commercialization possibilities:

- Cables - NbTi, Nb_3Sn, MgB_2 , and YBCO for physics applications
- Low AC loss cables for Superconducting Magnetic Energy Storage,
- Cables for 10-20MW wind turbine generators
- Cables for high speed motors and generators for passenger aircraft

Advantages

- Thermal: internal cooling directly on the wire, do not have to worry of getting heat out through insulation and epoxy for coils.
- Mechanical: robust outer sheath and cable design, plus localized stress control on each strand.
- Multiple number of strand conductors in the cable, a single layer design for 3T magnets, and a two layer design for 6T magnets

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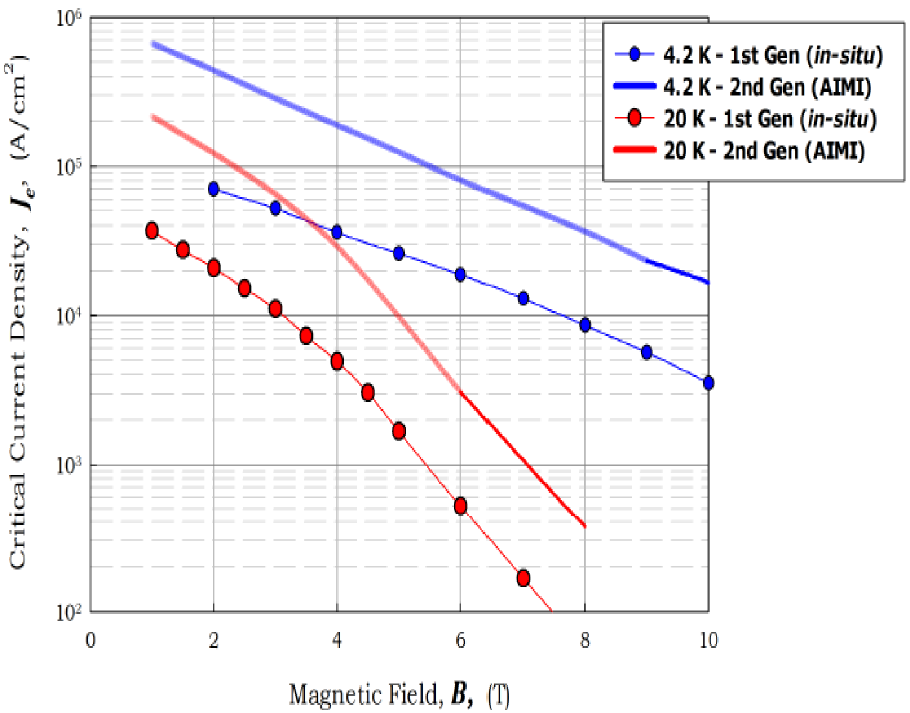
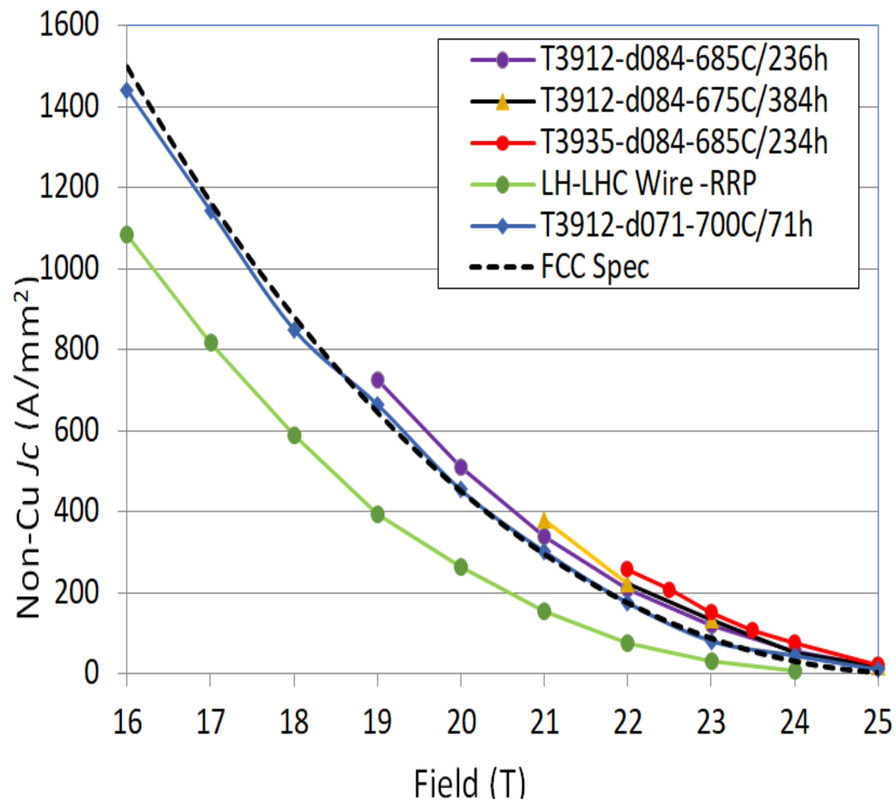
New World Records for Superconductor Performance

2^{nd} Generation MgB2 Wire



Funded by DOE- Fusion

Nb3Sn wire – Artificial Pinning



Funded by DOE-HEP

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Other Areas Technology that might be of interest NP community.

Sister Company- Eden Cryogenics- Cryogenic Customer examples- Fermilab, JL, SLAC, NASA, ORNL, etc.

Sister Company -Global R&D Inc- nano thickness (less than 800 nm thickness- multiple layers) inorganic membranes for gas separation (oxygen), SOFC, water filtration (funded by DOE- Advanced Manufacturing SBIR Phase I, II, and IIA)

New way to reduce cost of making complicated permanent magnet shapes, partnered with Advanced Magnet Laboratory

New Dynamic Forming Process for making RF cavities for accelerators and Qubit shielding- funded by NP- SBIR Phase 1

MgB2 Bulk Shapes (tubes) for beam shielding- SBIR Phase I.

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---- thank you for your attention