Superconductor Wire, Coils and Systems at Hyper Tech

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Hyper Tech

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

Outline

- NP-SBIR Phase II

  NbTi –Cable in Conduit (CIC) for Magnets

- NP- SBIR Phase I

  Nb_3Sn and MgB2 CIC cables for Magnets

- Potential New NP application

  MgB2 CIC power cables for Brookhaven EIC

- NP-SBIR Phase I

  MgB2 Shielding Tubes for Brookhaven EIC

- NP-SBIR Phase I

  Impact Forming of RF Nb and Cu RF cavities with no EB welding

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Hyper Tech Research Inc.

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

For Superconducting Dipoles and Quadrupoles for Electron Ion Collider

Mike Tomsic
Matt Rindfleisch
CJ Thong
Xuan Peng
Dean Panick

Hyper Tech

Development partners

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

Dr. Peter McIntyre
Dr. Daniel Chavez

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

Dr. Mike Sumption

grant sponsor: DOE NP

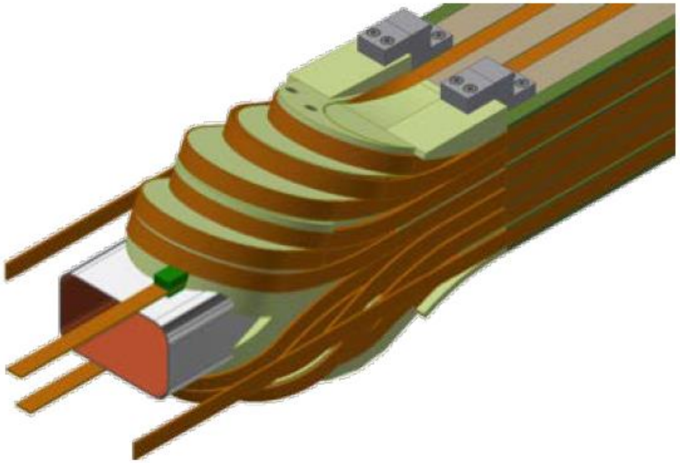
Grant No. DE-SC0015198

EIC Magnet R & D

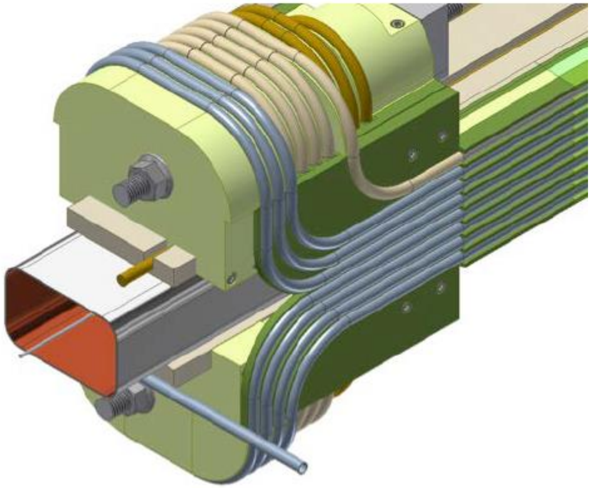
- Texas A&M has been designing and prototyping of super-ferric magnets for the ion collider ring and for the booster
- Design and prototyping of high field, large aperture, compact super-conducting magnets for the collider Interaction Regions and Final Focus

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

NbTi Rutherford cable



NbTi Cable-in-Conduit



Pros: Uses mature cable technology (LHC).

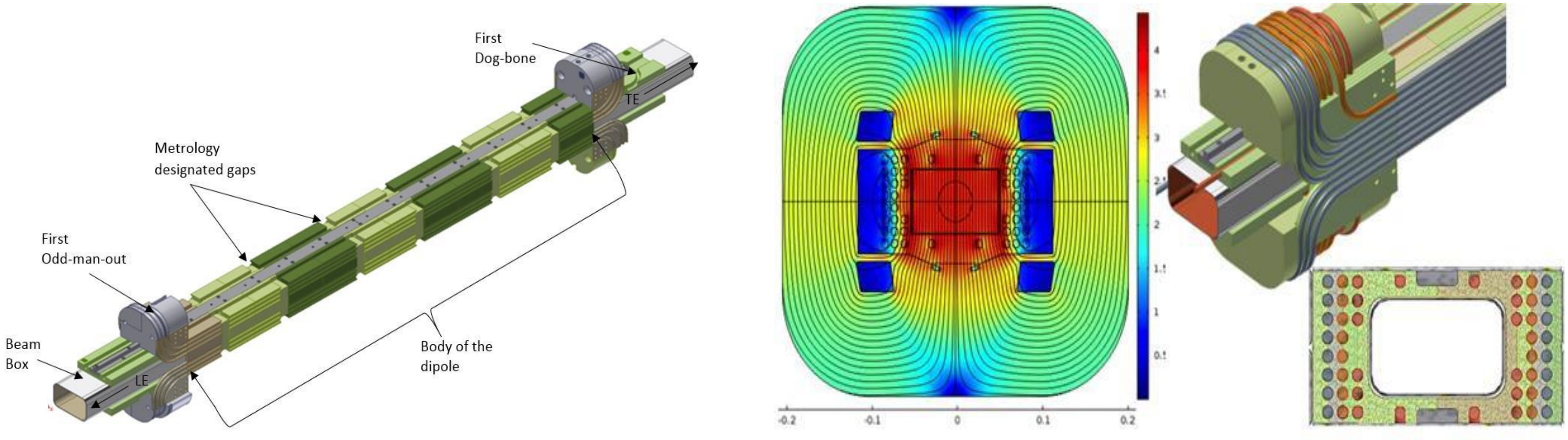
Cons: Ends tricky to support axial forces.

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

Cons: Cable required 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 completed a Design for the magnet and its conductor, and ARL has built a magnet winding and 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.

The CIC cable that has been demonstrated

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 EIC arc dipole will require a ~400 m long continuous length of CIC conductor. So Hyper Tech in this Phase II developed the method to weld long continuous lengths of the cable.

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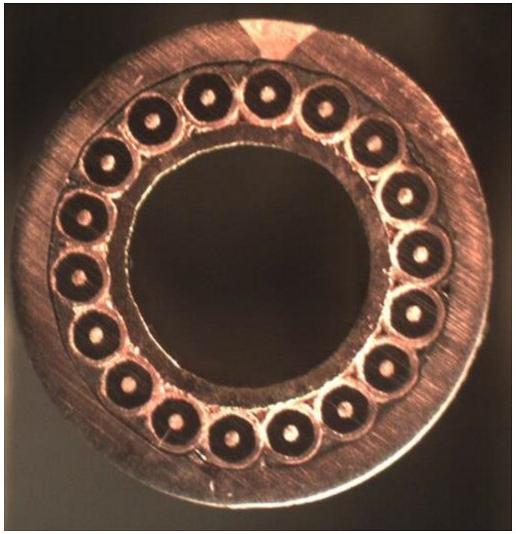
Laser-welded CIC-CTFF NbTi cables

- The manufacturing long length CIC cables has been demonstrated under this STTR Phase II grant for small diameter NbTi CIC cables
- 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 and coils manufactured at Hyper Tech.



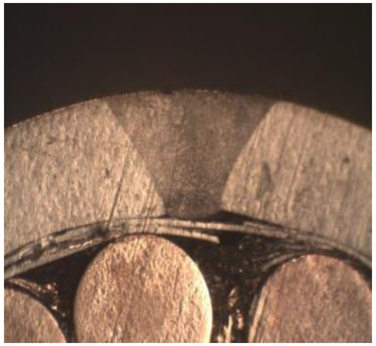
CIC-CTFF Cabling Steps

Perforated Inner Tube

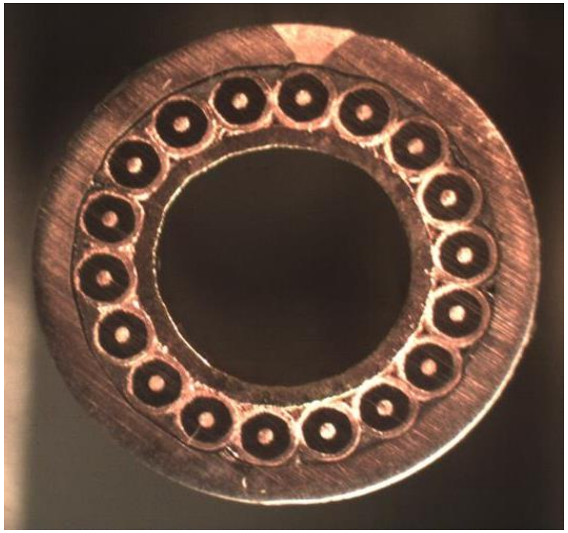
Stranding and Tape Wrapping

Pre-Cable

Continuous Tube Forming and Filling Machine



Laser Weld of Outer Sheath



Cross Section of Final NbTi Cable

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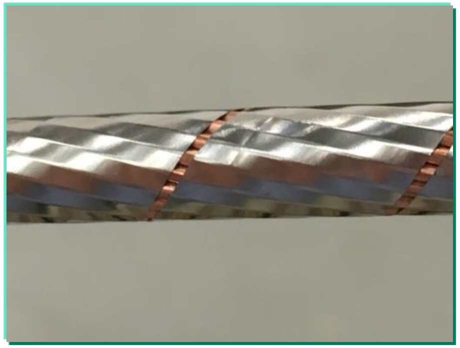
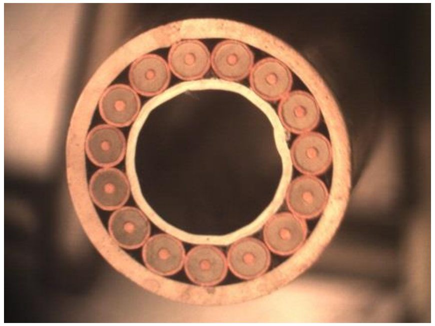
CIC-CTFF Cable Length Demonstrations

Demonstration of cable lengths for 3T magnet cable and ATC wound the cable into a coil



Picture of Pre-Cable

Welded CIC-CTFF Cable



Cross Section

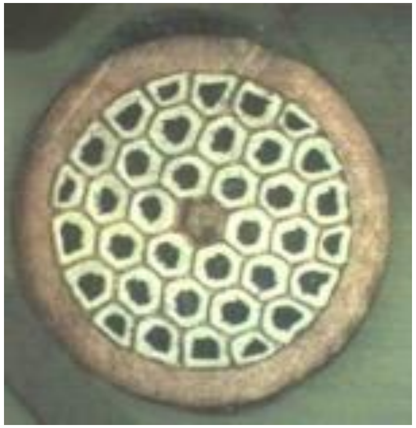
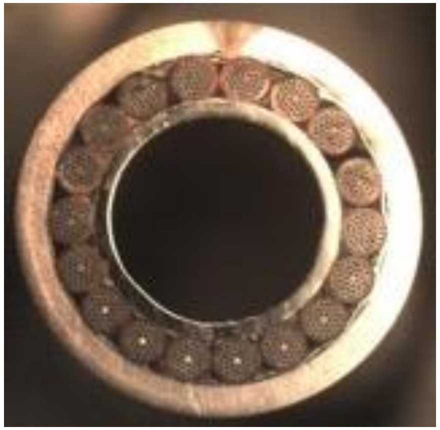
Eddy Current Device for Detecting Flaws in the Laser Welded Tube

Controller

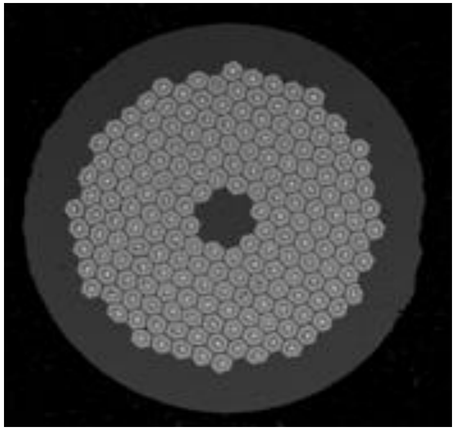
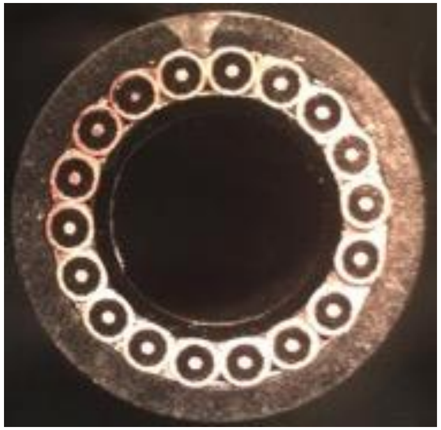
Pick-Up Coil

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.
We demonstrated the feasibility for future applications.

MgB2 strand and CIC-CTFF Cable

Nb3Sn strand and CIC-CTFF Cable

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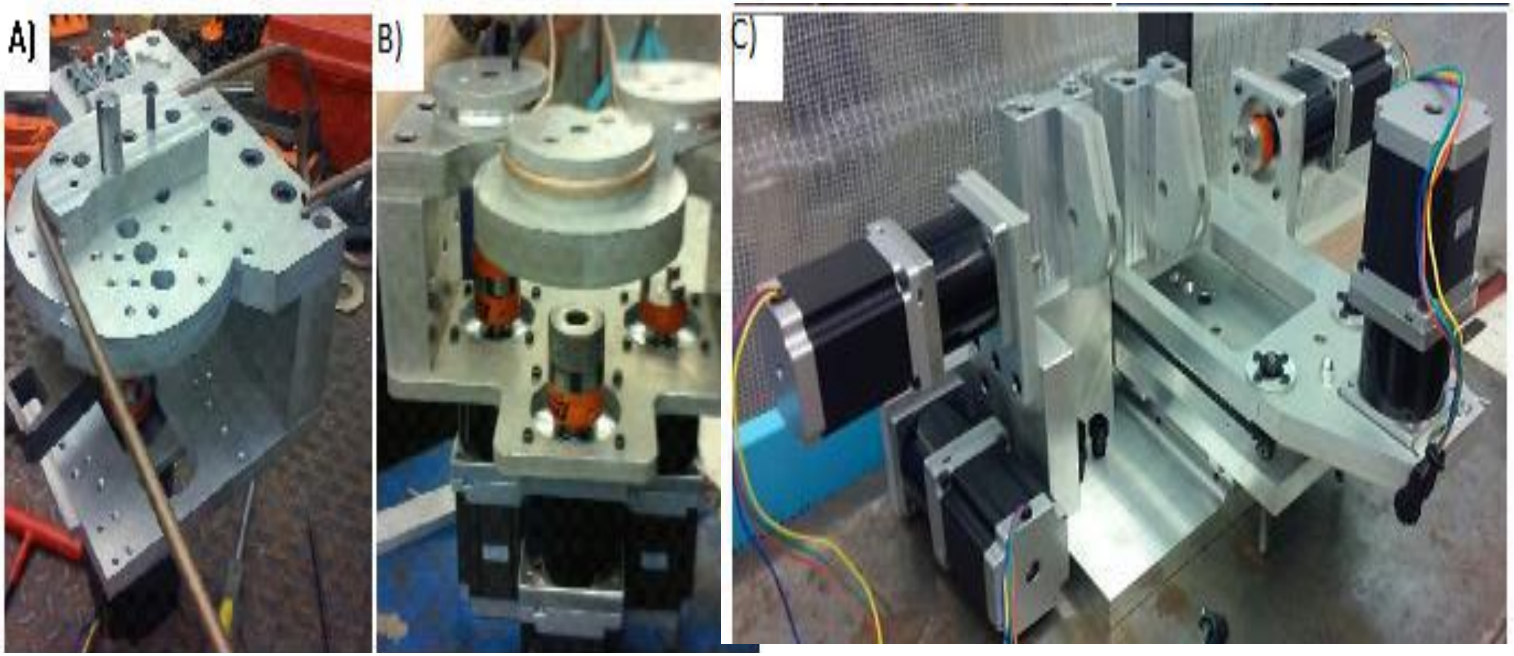
ARL Bending Tools for Dipole Magnets



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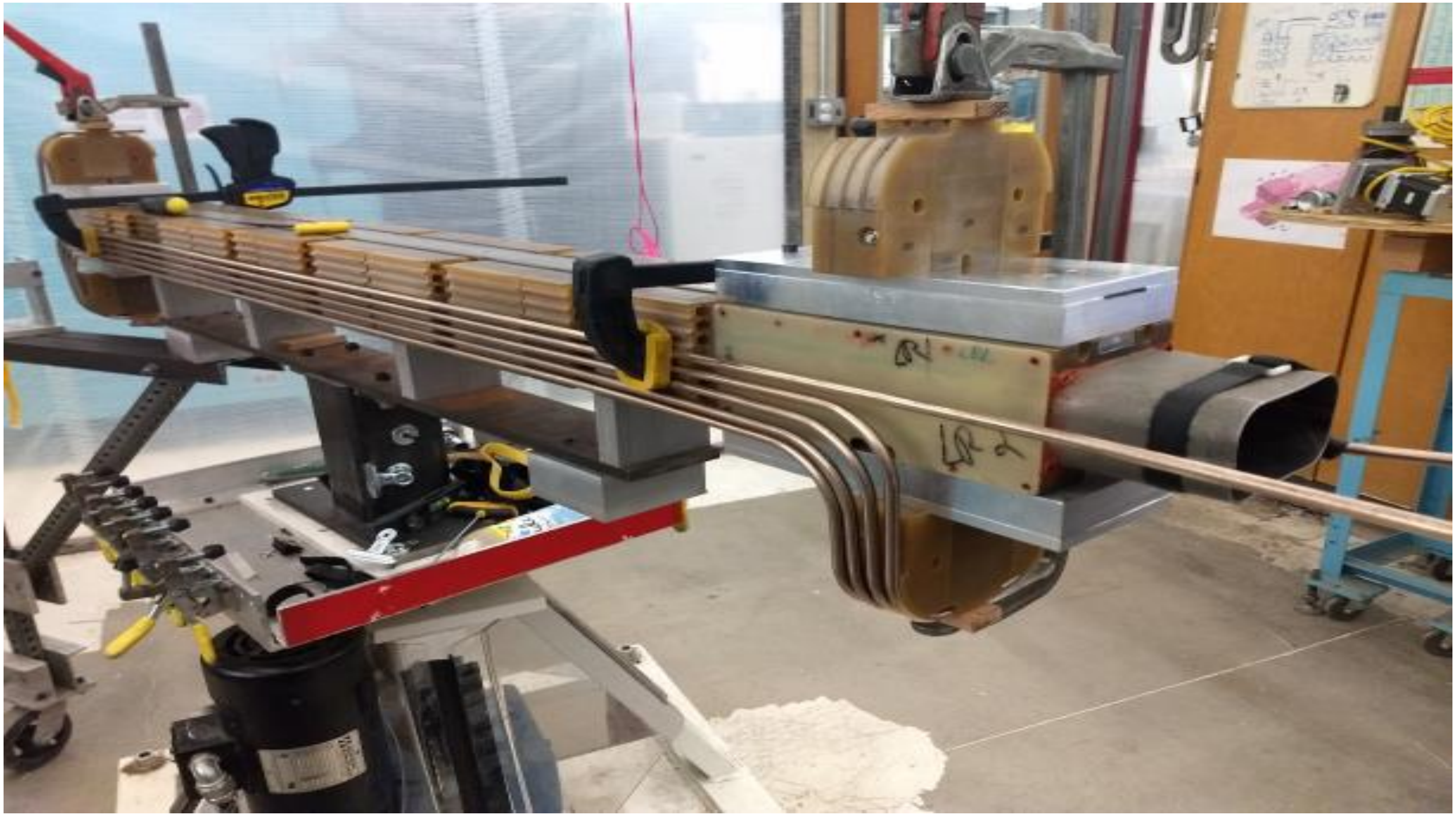
During the Phase II ATC team wound a coil using ATC's and Hyper Tech's CIC-CTFF cable



Coil wound by ATC using CIC-CTFF NbTi cable

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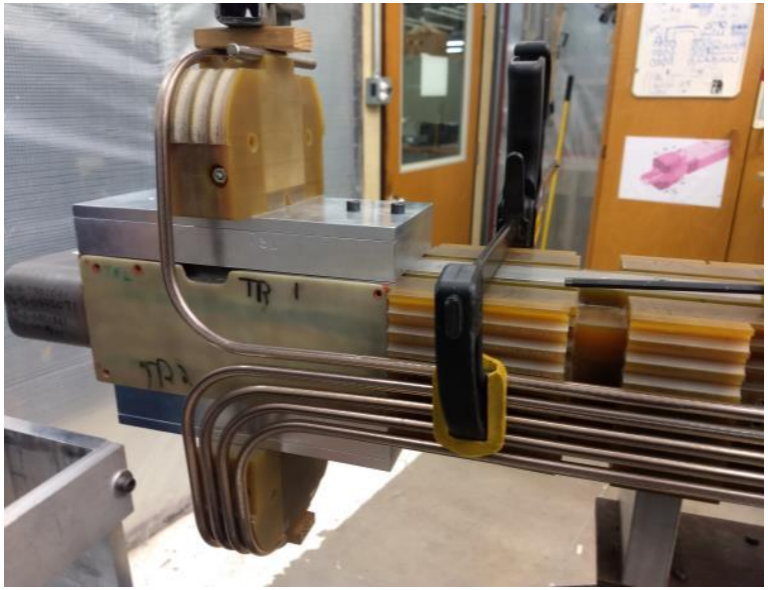
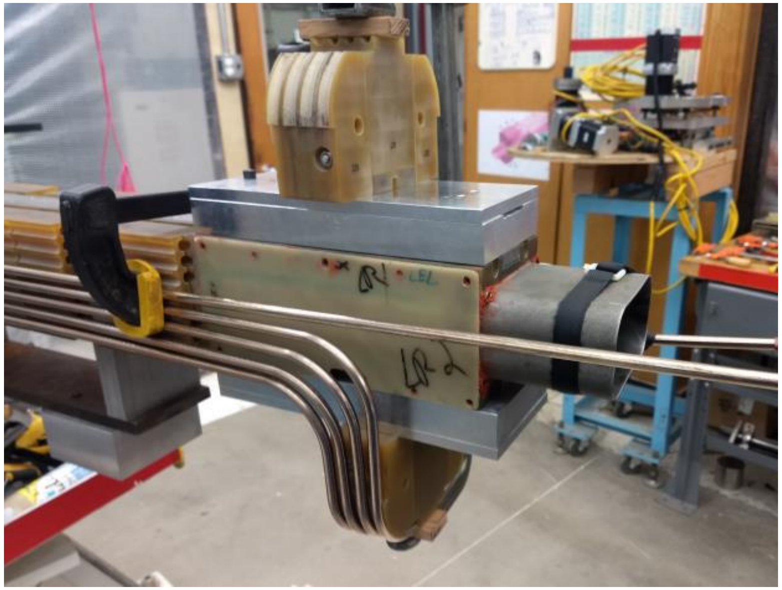
Test that has been performed on CIC-CTFF Cable and Coil

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.





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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, and a two layer design for magnets

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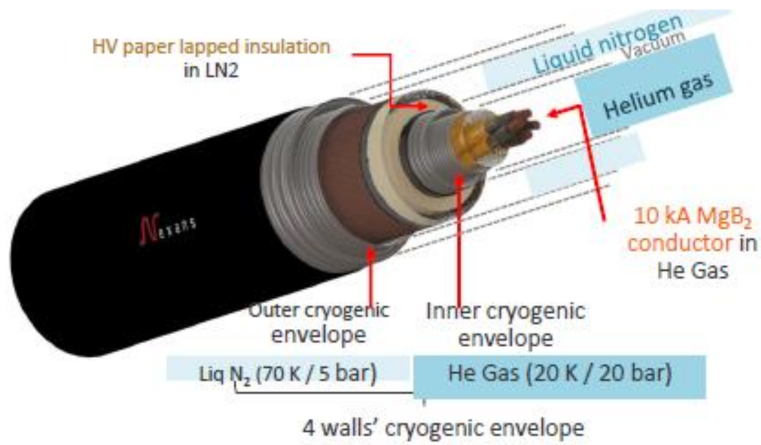
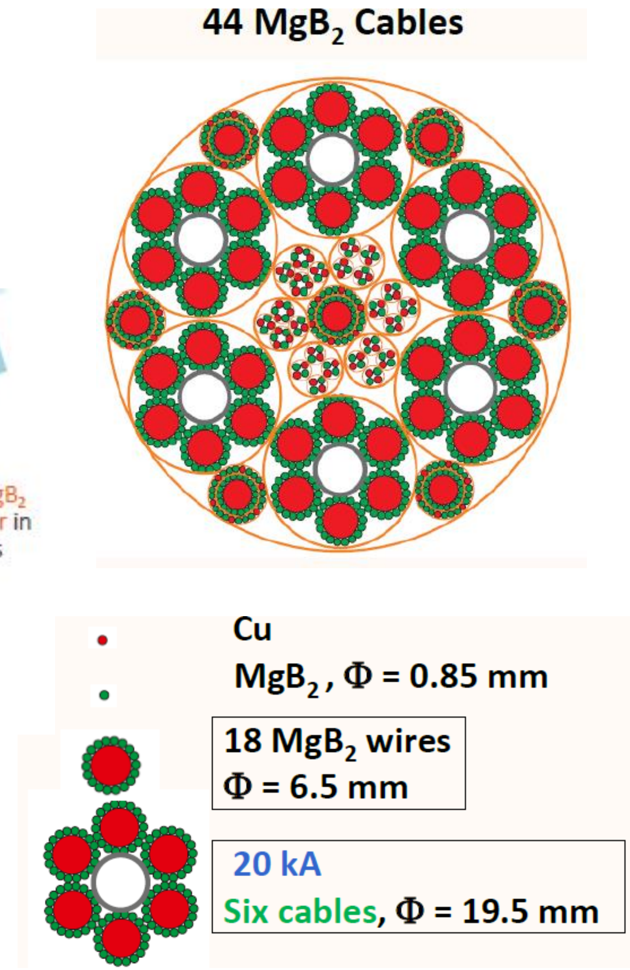
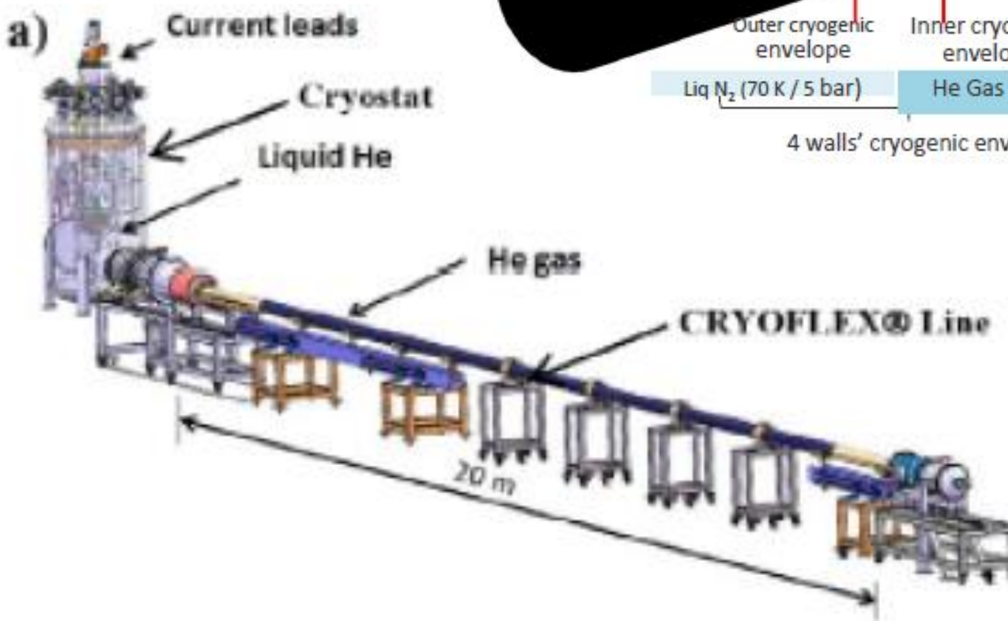
MgB_2 cable links

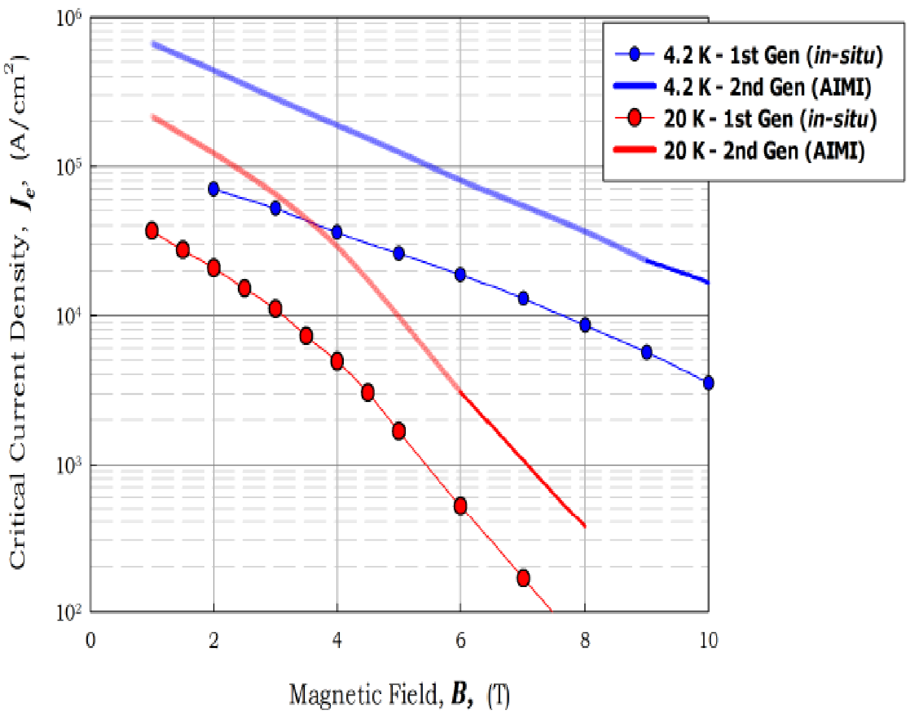






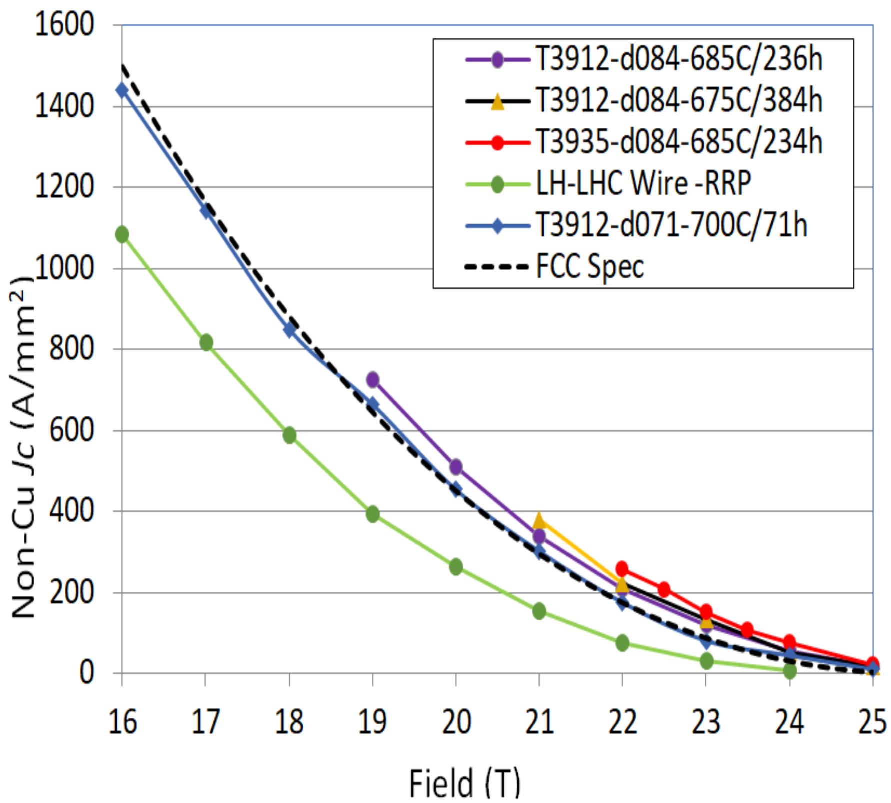
New World Records for Superconductor Performance

2nd Generation MgB2 Wire



Funded by DOE- Fusion

Nb3Sn wire – Artificial Pinning



Funded by DOE-HEP

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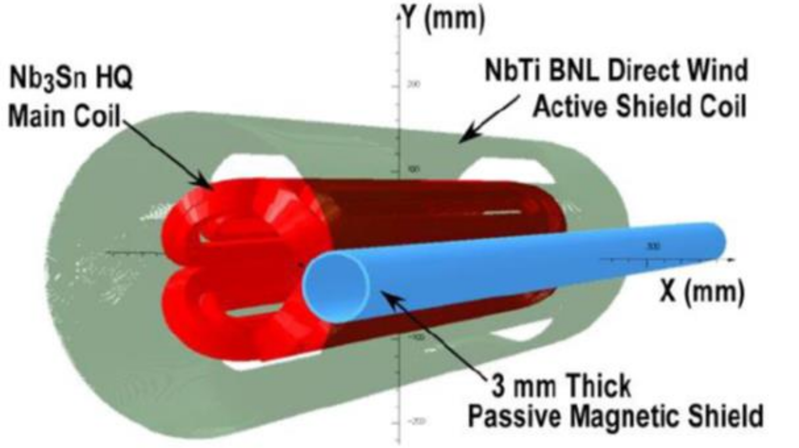
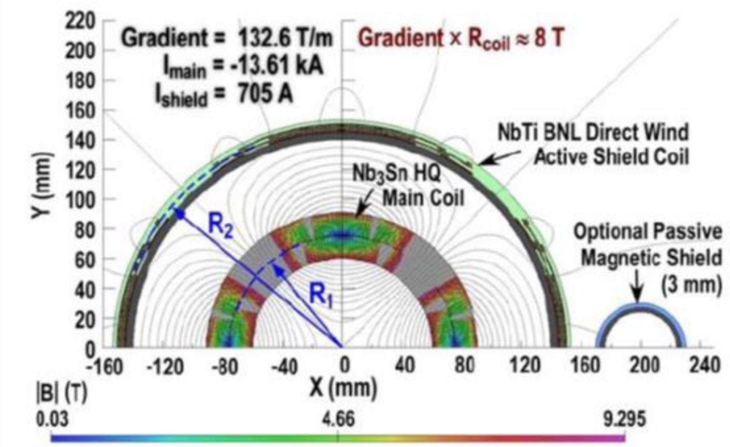
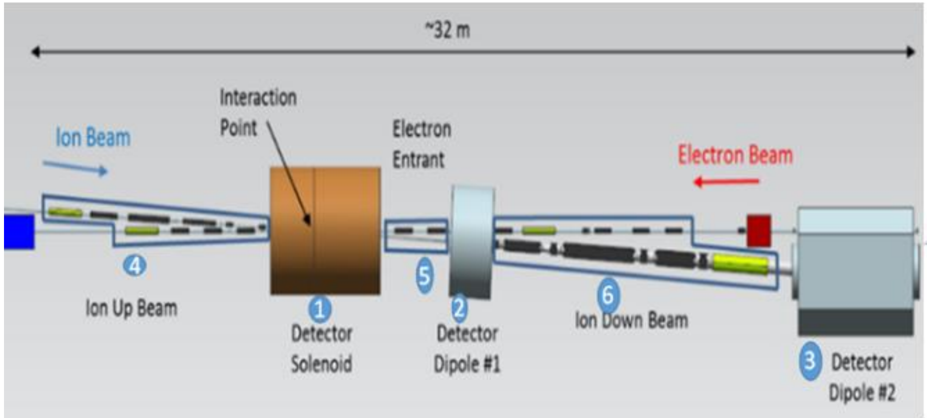
NP – Phase I - MgB_2 shielding placement

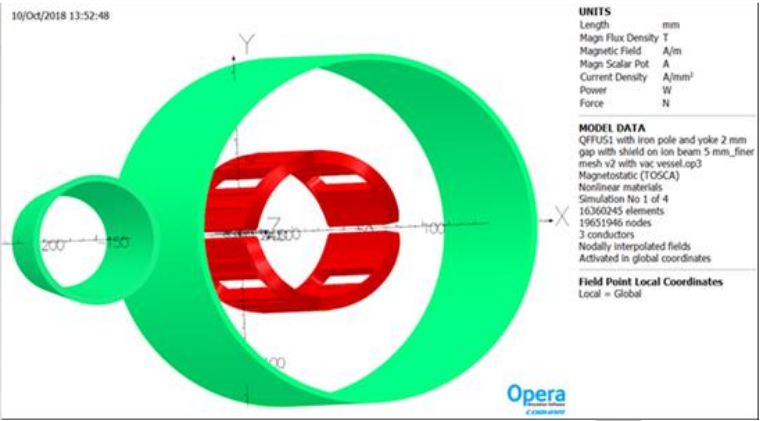
Placement of MgB_2 tube for passive magnetic shielding for EIC at BNL





IR Lattice and candidate magnet for MgB_2 shielding for EIC at J-Lab





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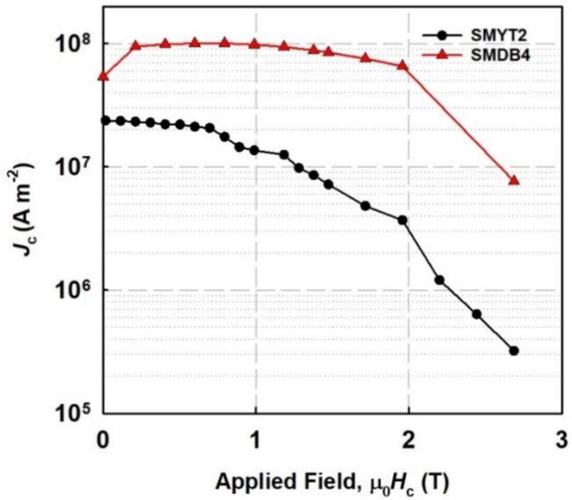
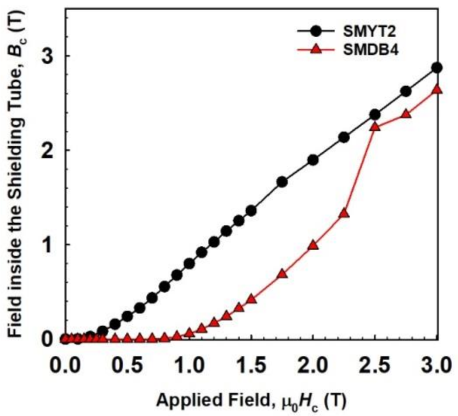
DOE SBIR Phase I summary

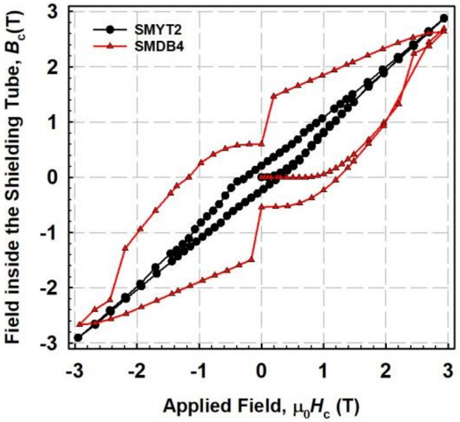
MgB_2 cylinders fabricated by Hyper Tech

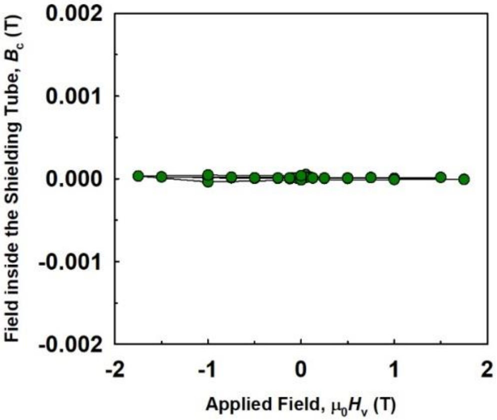
- length: 150 mm
- OD: ~ 30 mm
- OSU characterized two cylinders



Best J_c reaches 10^8 A m^2 at 1 T, 4.2 K







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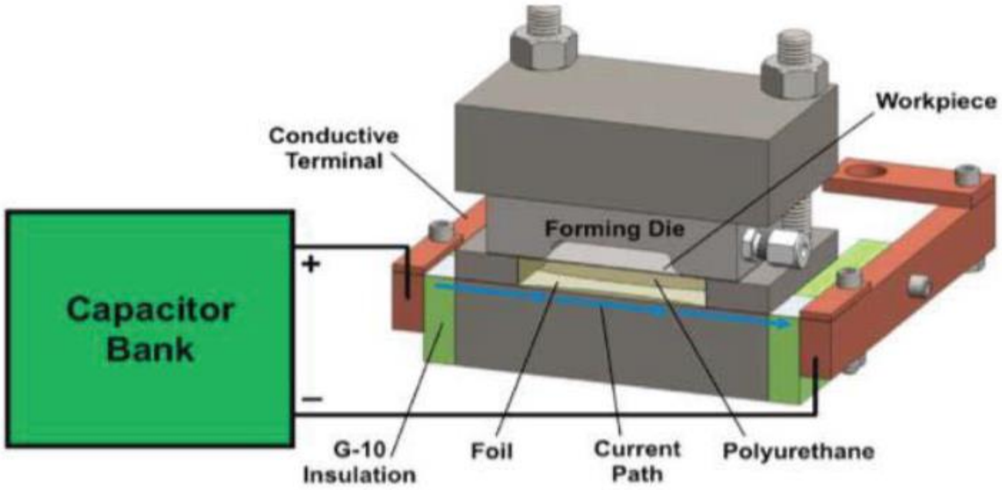
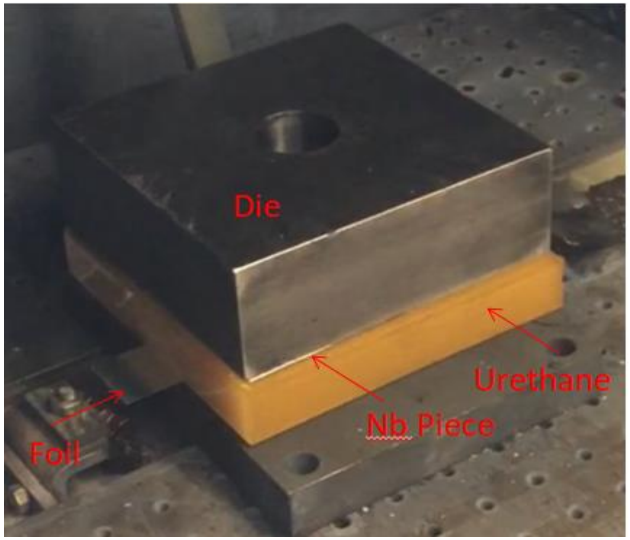
Best MgB_2 tube completely shielded 0.7 T in DC field and 1.75 T in AC field with elevated amplitude at 4.2 K.

NP Phase I -Electropulse Forming SRF Cavities

Electropulse high velocity forming uses high pressure and high speed metalworking that dramatically improve formability, decrease material damage and improve dimensional tolerance comparing to conventional methods.

The forming die is above the work sheet and there is a short distance between them. Upon discharge of the capacitor bank, the high current turns foil into rapidly expanding vapor, which pushes the urethane and in turn the workpiece into the forming die.





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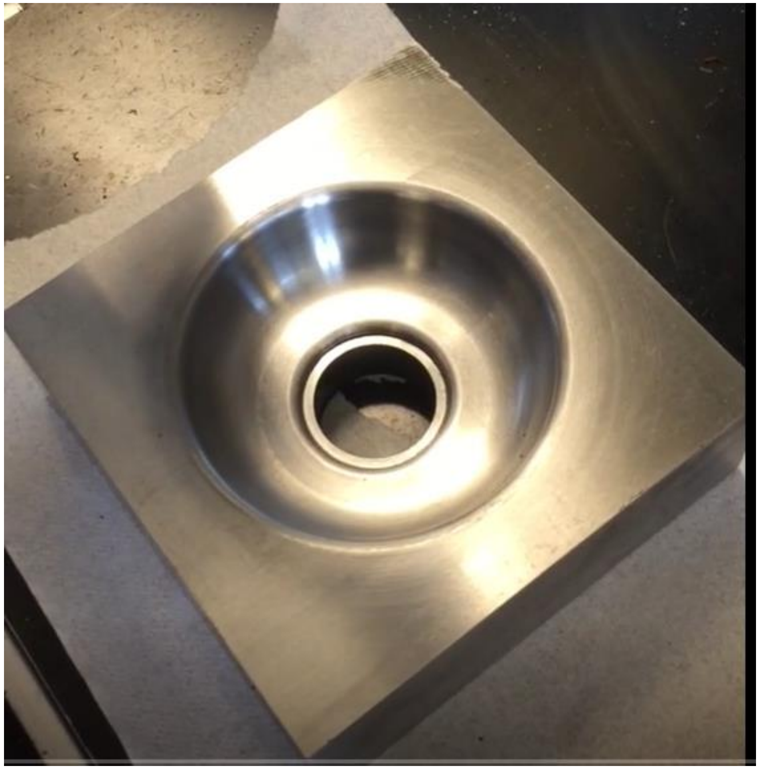
Impulse-forming of Nb half-cell



We have successfully demonstrated the deformation of flat Cu and Nb workpieces into half-cells (which could be welded together to form a whole cell. The above figure shows the as-formed half cells of Nb with 4" OD. All the finished surfaces are as clean and smooth as the original material surfaces.

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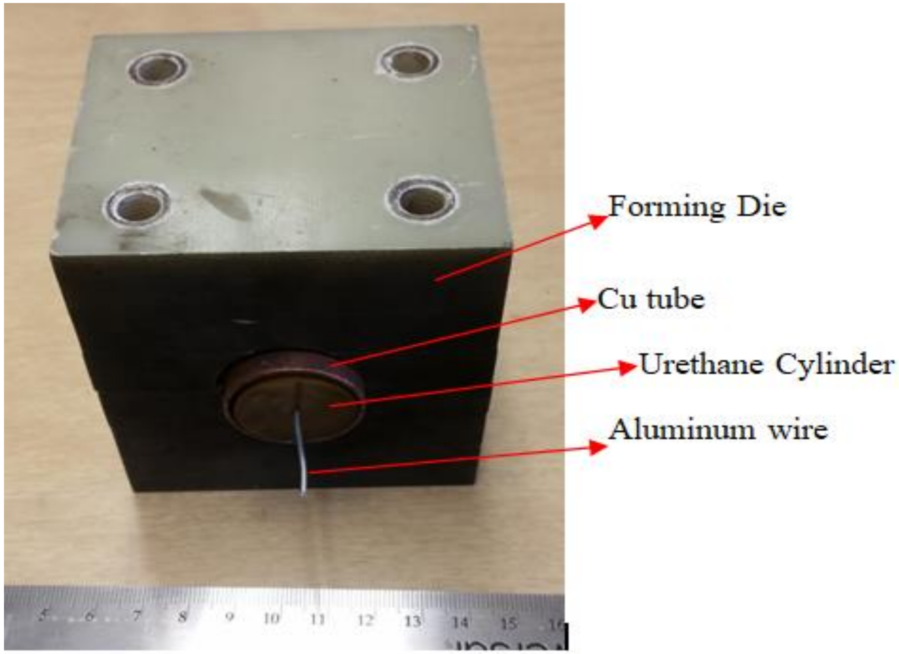
Phase I work on Impulse-forming of Cu whole-cell



This final shape matches the die we fabricated, We could alter the die geometry such that a Nb tube can be expanded (bulged) out radially to form the SRF cavity shape and make single Nb whole cell or even multiple cells. The additional formability allow us to form the shape with electro-pulse forming only, with no necking (unlike the hydroforming approach) or by welding together half cells.

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---- thank you for your attention