EP R&D on Experimental Technologies

WP8.1 & 8.4 activities

Magnet Detector R&D

21st June 2022

Benoit CURE on behalf of

SHUVAY SINGH – EP/ADO-SO

Projects – WP 8

RECENT ACHIEVEMENTS

NEW 4-T MAGNET FACILITY

ADVANCED MAGNET POWERING

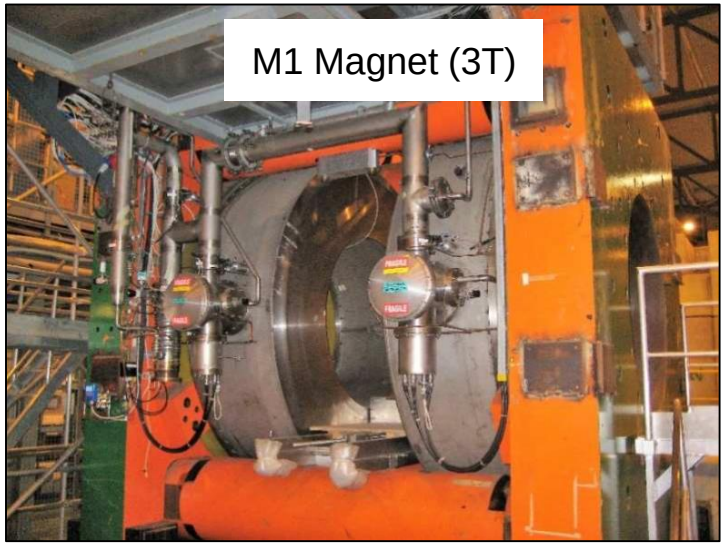
3D PRINTED CRYOGENIC MATERIALS

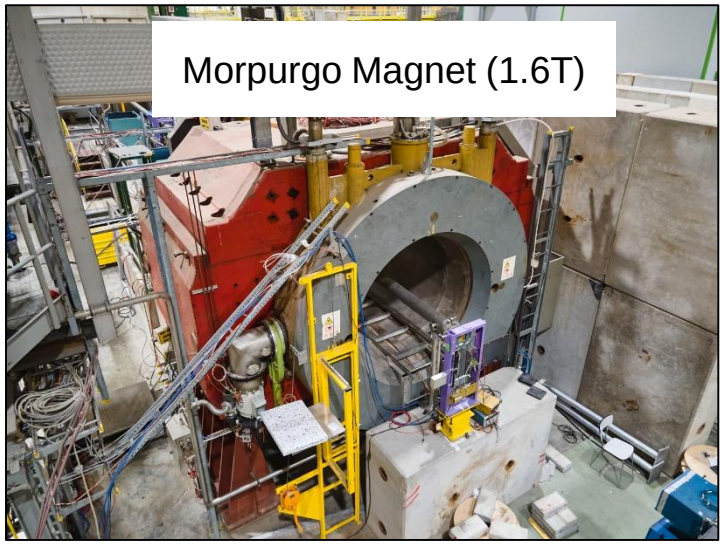
New 4-T Magnet Facility

Summary and Direction taken in 2021

- **Two magnet concepts** studied, both with a 4-T central field
- Designs bearing similarities to 2 existing SC magnets within EP in CERN North Area:
  - M1 H2 : **split coil solenoid** (SCS)
  - Morpurgo H8 : **dipole**

- **Common characteristics**
  - **4.5 K** operation temperature (with 2 K of margin)
  - **Nb-Ti/Cu Rutherford cable with aluminium stabiliser**
  - **Pancake winding** technique
  - **Iron yoke** necessary to limit the stray field **below 15 mT at 5-m distance**
  - Fully **passive thermo-siphon** helium cooling

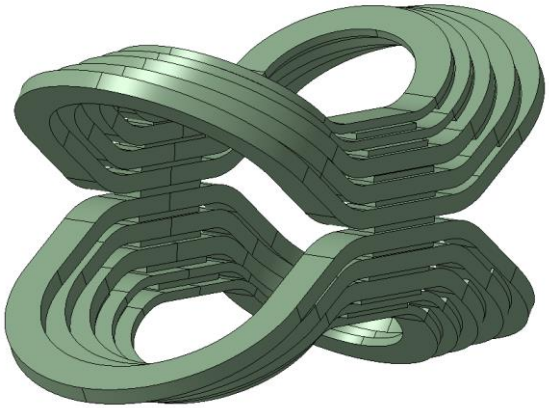


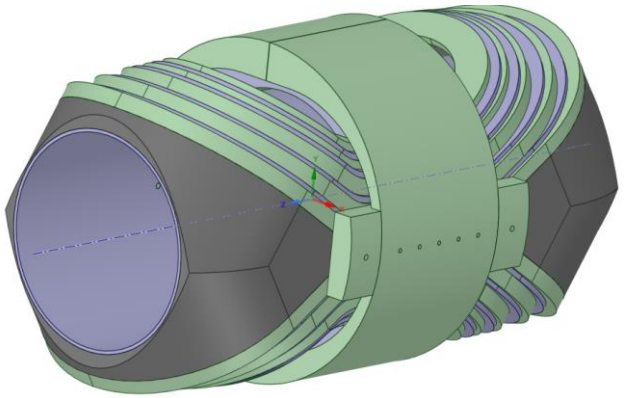


The Magnadon

***MAG**net for **N**orth **A**rea with a **D**ipole C**ON**cept*

~ 2 m bite radius / outer bore like the jaws of a Megalodon



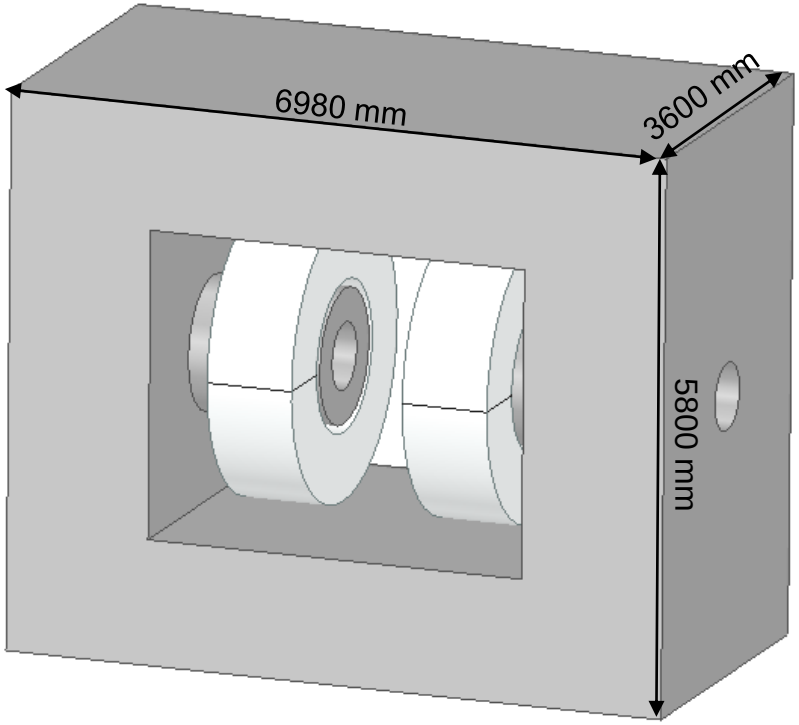


- **New design** with a tilted racetrack “skateboard” shape
- **Compatible** with Morpurgo iron yoke
- Was considered as potential magnet for **MADMAX** collaboration (Special thanks to **CEA - IRFU Saclay** for fruitful discussions)
- **More complex winding process and mechanical structure** to be further developed, compared to SCS.
- **Decision end 2021 to continue with the Split Coil Solenoid at this stage**, with its conventional double pancake.

Specifications	
Field at Center	4 T
Free warm bore diameter	1400 mm
Total Stored Energy	80 MJ
Peak field in conductor	5.5 T
Stray field at 5 m	11 mT

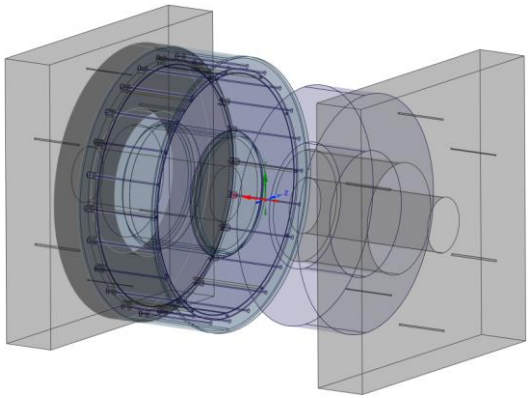
Split Coil Solenoid Magnet in 2021

Presented at 2021 EP R&D Days

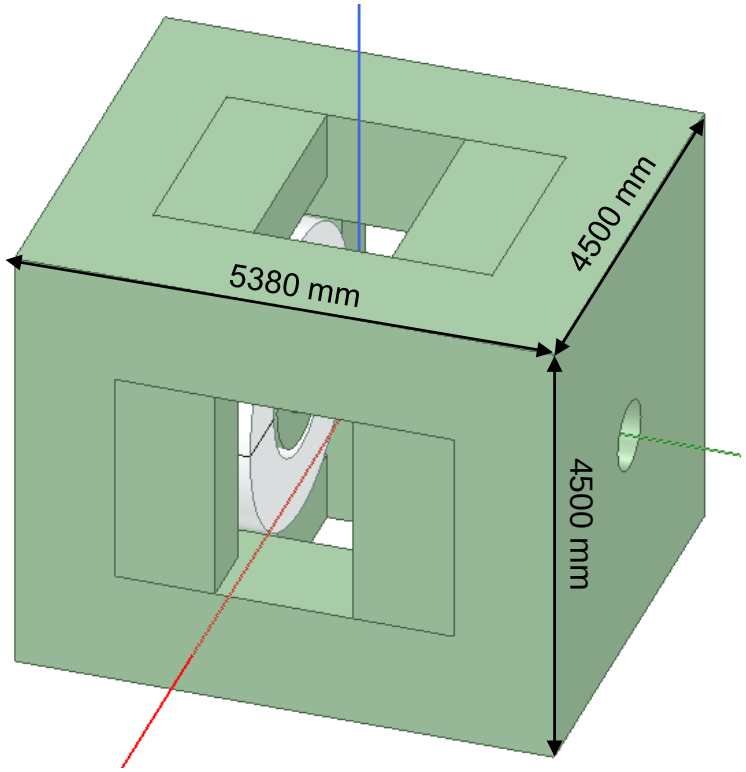


Specifications	
Field at Center	4 T
Free gap	1000 mm
Free bore diameter	700 mm
Total Stored Energy	130 MJ
Axial coil length	900 mm
Peak field in conductor	5.7 T
Stray field at 5 m	9 mT

- Coils supported by the yoke end plates with tie-rods
- Cryostat takes large compression load



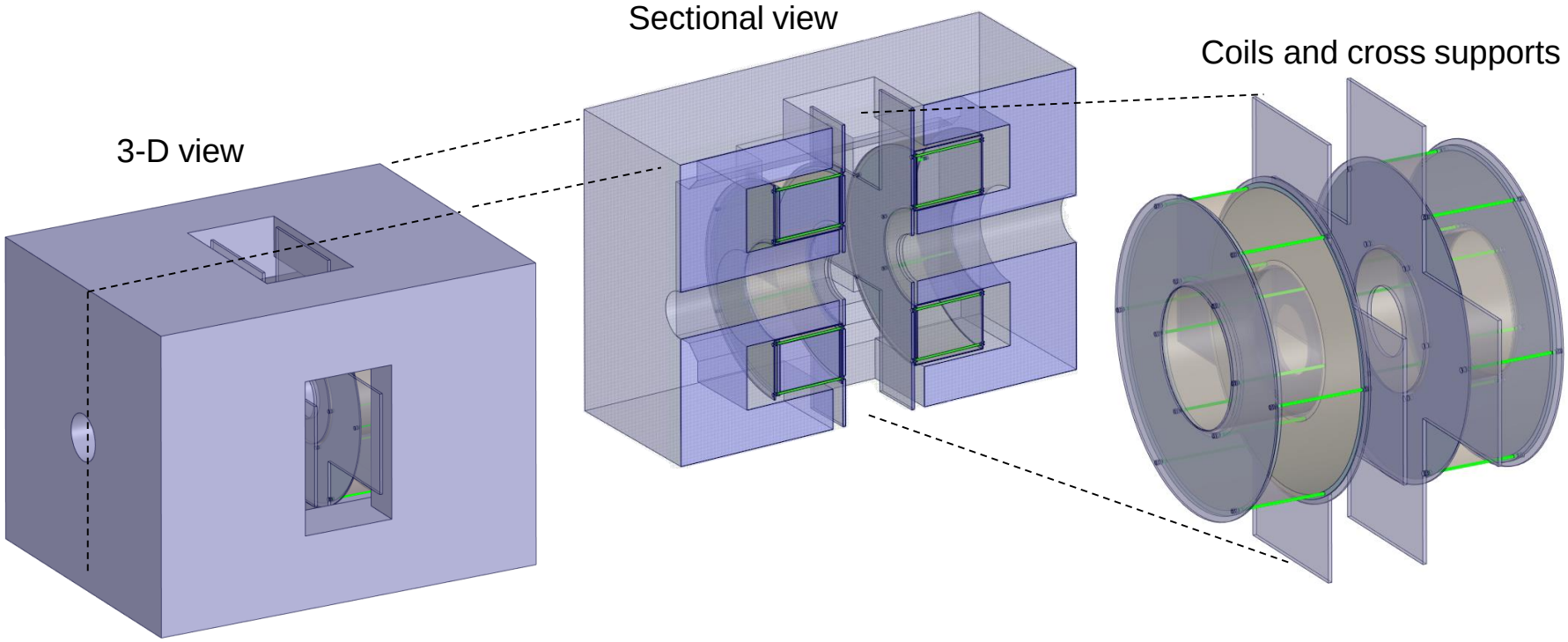
Split Coil Solenoid 2022 improved Design



Specifications	2021	2022
Field at Center	4 T	4 T
Free gap	1000 mm	1000 mm
Free bore diameter	700 mm	700 mm
Total Stored Energy	130 MJ	**106 MJ**
Axial coil length	900 mm	**600 mm**
Peak field in conductor	5.7 T	5.7 T
Stray field at 5 m	9 mT	**15 mT**

- Iron yoke redesigned to be symmetrical in X and Y direction
- Yoke mass reduced by **230 tons** (-30%: 800 tons → 570 tons)
- Simplification of assembly with smaller and thinner iron pieces

Split Coil Solenoid 2022 improved Design

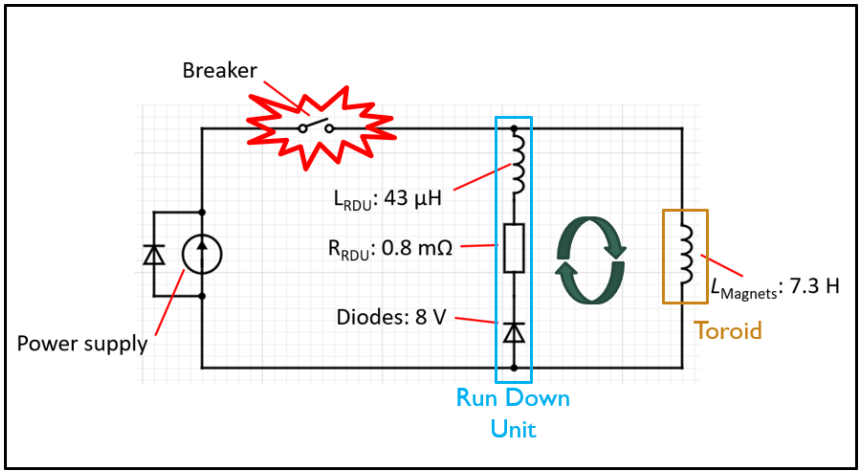


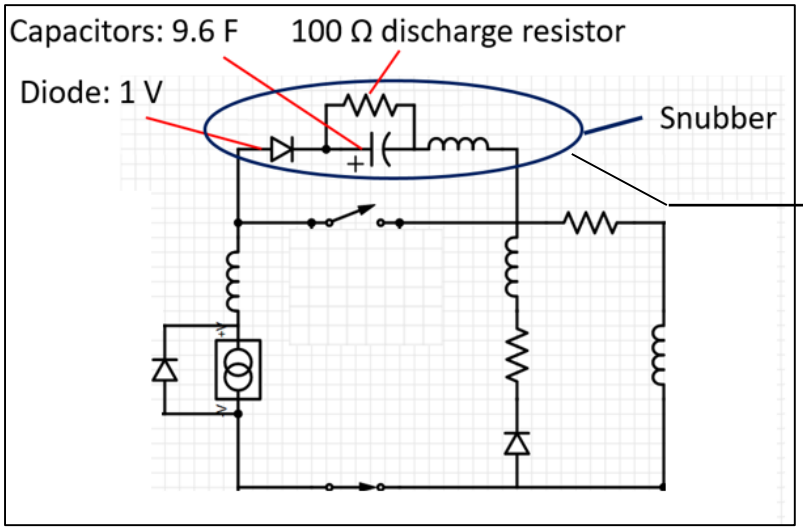
- **New support structure** design simplifies the assembly and reduces conductive heat loads
- Forces of the coils are directed away from the center and supported directly by the iron yoke via the center Cross-Supports
- This allows for **tie-rods** with smaller diameter and the **cryostat to be significantly thinner** wrt 1st design

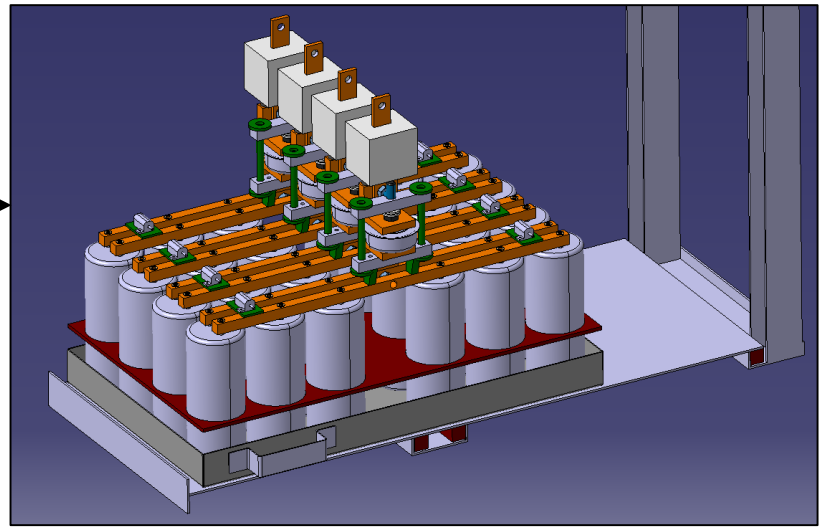
Advanced Magnet Powering

Detector Magnet Powering System: Snubber

- An **arc suppression system** (Snubber), has been implemented in the ATLAS Toroid magnet during LS2
- Against **arcing of the power circuit breakers** that occurs when triggering a discharge due to parasitic inductance in the powering/discharge circuit

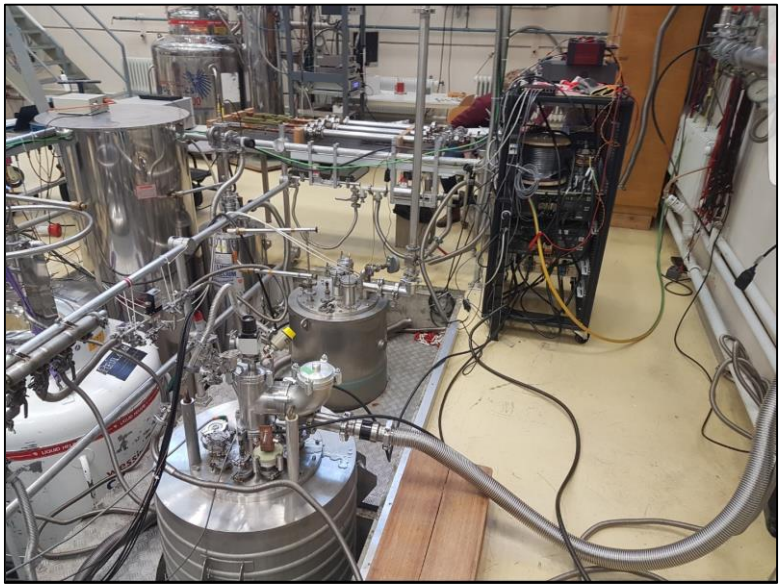


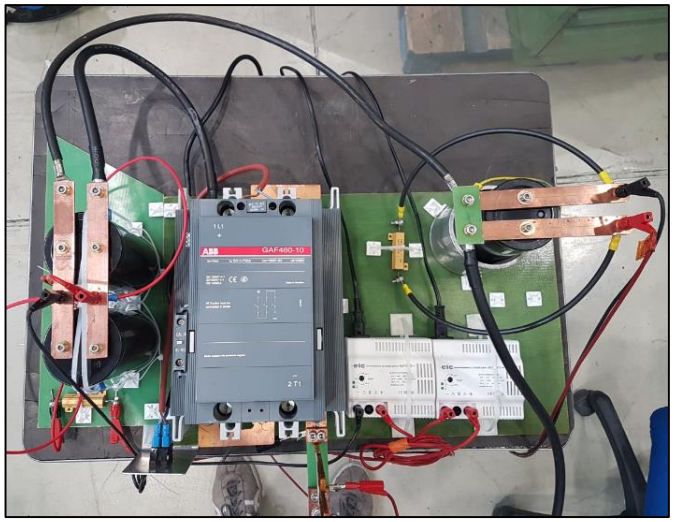


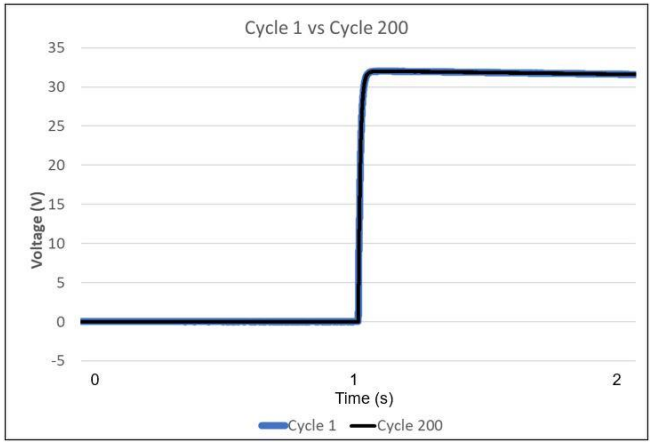


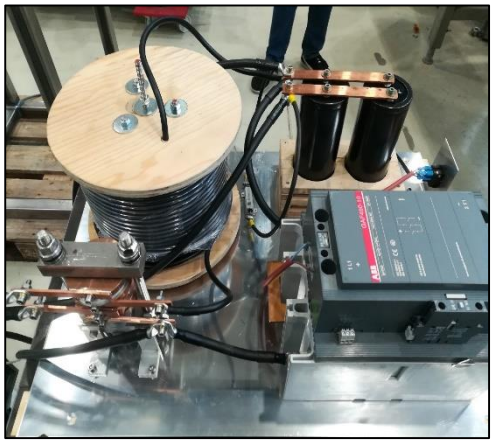
Steps during Snubber Development

- a 1/50th **scale snubber** was produced and successfully tested in December 2020 at TE-CRG Cryolab with a SC magnet, to determine proof of concept, degree of effectiveness and repeatability of operation
- **Endurance charge-discharge cycle** tests of electrolytic capacitors showing capability for a 20-year operation time









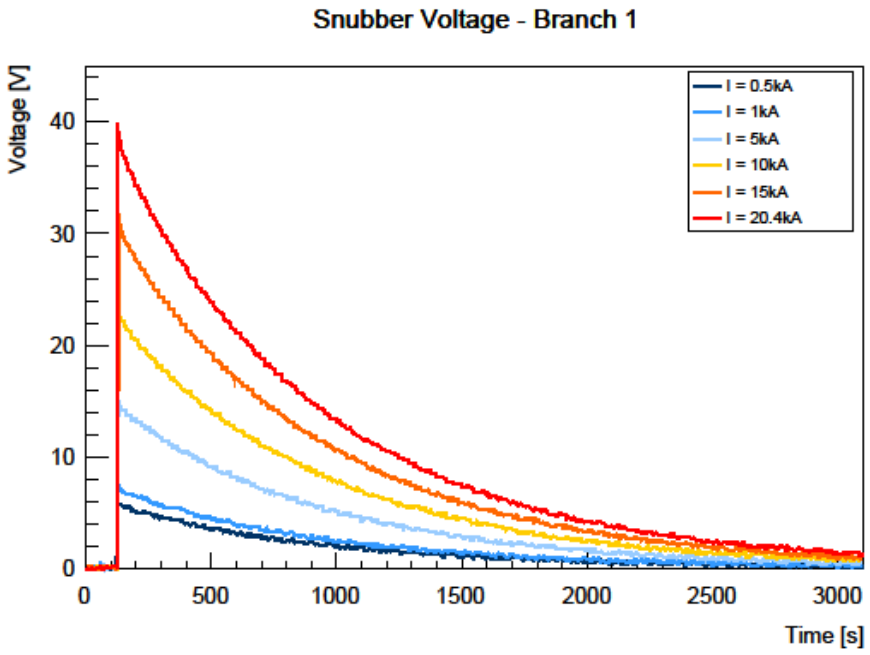
Snubber Manufacture and Installation

- Snubber manufactured and installed into the ATLAS Toroid circuit in November 2021
- Instrumentation commissioning completed in December 2021

Snubber installed in CT-2 breaker

Snubber Commissioning Discharges

- Snubber successfully commissioned at several magnet current values during ATLAS toroid recommissioning in March 2022.
- Snubber behaved as expected – time constant consistent with calculations
- **After two 20.4 kA current discharges, the breaker temperature increase is below 2-degree per discharge, a five-fold improvement with respect to the previous run !**

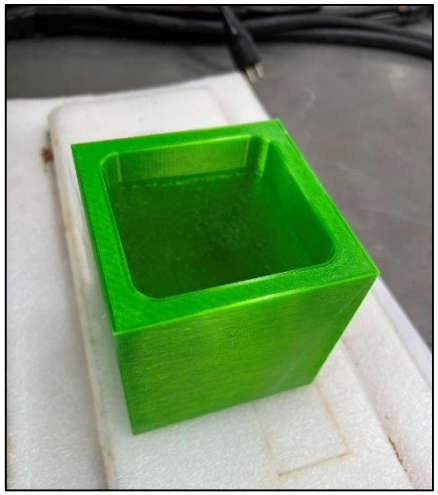


Time constant	
Expected	Measured
900 s	867 s

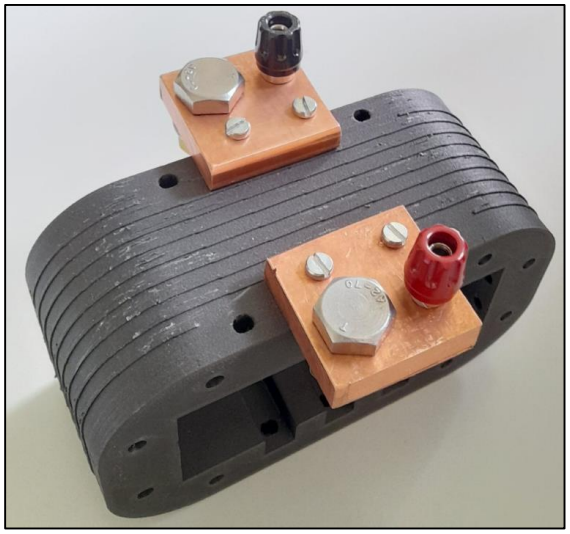
Compatibility of 3D printed materials for cryogenic temperature applications

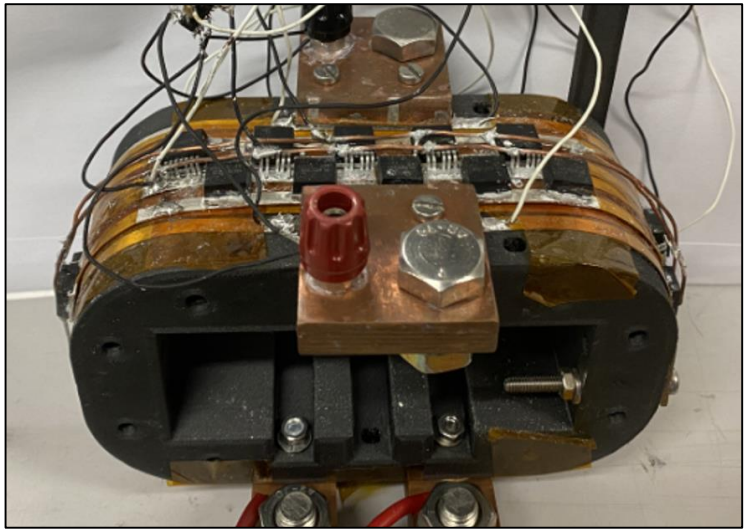
Testing 3D printed plastics at low temperature

- **Initial idea** was to check feasibility of using **easy-to-build** support structure for sample testing and detector magnets
- A study was launched to study cryogenic stability of a few 3D-printed materials
- Several materials have been found to withstand repeated thermal cycling without damage, the carbon powder reinforced material is of particular interest
- Compressive and tensile tests with EN-MME are on-going to determine accurate characteristics at 77K



Candidates have been found that are leak tight to liquid nitrogen whilst showing repeatability





Demonstrated as support structures for HTS sample testing

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