Design and preparatory work to host the new EDIPO test facility (MAG-4.3-T025)

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(on behalf of the EDIPO collaboration)

SWISS PLASMA CENTER

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Outline

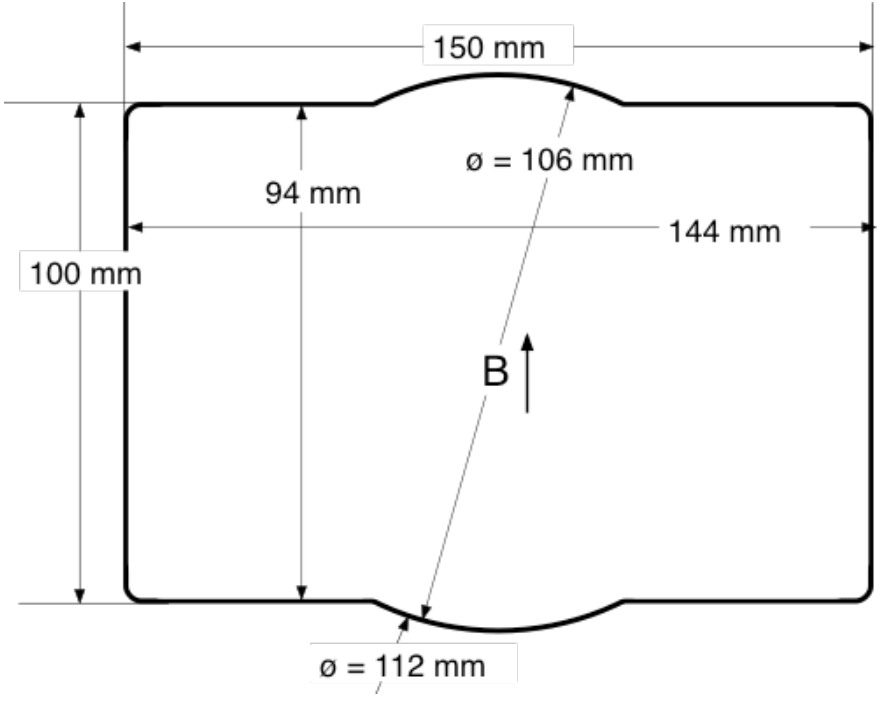
- **Goals and design constraints**
- Strand and cable
- Conceptual design of the new magnet
  - Magneto-static analysis
  - Mechanical analysis
  - Quench protection
- Conclusions and plan for 2020

Goals

- **Main targets** of the upgraded test facility:
  - **15 T** in a **large aperture**
  - Operation at **4.2K** and **85%** of **short sample limit**
  - Homogeneous field length of 1000 mm
  - **Wide range of temperature**: T_{sample} = 4.2 - 80 K
  - **High-current**: $I_{sample} \leq$ 100 kA

Design constraints

- The coil aperture shall fit a 3-mm-thick vacuum chamber able to host:
  - **SULTAN samples** (94×144 mm aperture)
  - A **counter-cryostat** to test 100-mm-OD dipole inserts at variable temperature



Design constraints

- The coil aperture shall fit a 3-mm-thick vacuum chamber able to host:
  - **SULTAN samples** (94×144 mm aperture)
  - A **counter-cryostat** to test 100-mm-OD dipole inserts at variable temperature
- Overall assembly length ≤ 2500 mm
- Overall assembly diameter ≤ 1420 mm
- Overall assembly weight ≤ 20 t
- Operating temperature: 4.2 K
- Operating current ≤ 18 kA
- Dump voltage to ground ≤ 1 kV (sym ground)
- Allowable coil hot spot temperature: 350 K

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Strand and cable

- A 1.1 mm strand proposed for the magnets of CERN's Future Circular Collider (FCC) could be also appropriate for EDIPO
- The proposed cable is a very high aspect ratio Rutherford cable
- Short dummy lengths have been cabled at LBNL
- Winding tests will be carried out in ~March 2020 at CERN

Strand parameters

Strand type	FCC	
Diameter	1.1	mm
Technology	RRP 108/127	
Cu:non-Cu	1	
RRR	>150	
Min. J_c @ 15 T (12 T), 4.2 K	1640 (3000)	A/mm^2
$D_{eff,max}$	60	µm

Cable parameters

Number of strands	44	
Bare width*	26.2	mm
Bare thickness*	1.95	mm
Compaction	81	%
Insulation thickness	150	µm

*After reaction

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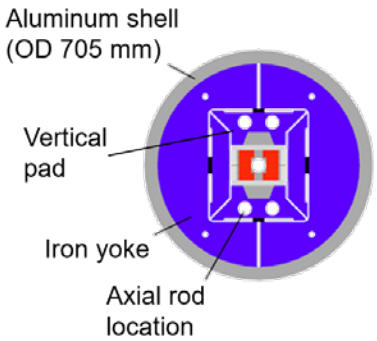
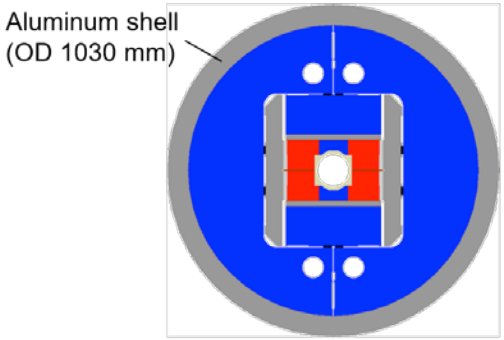
Flared-ends coil-block designs

- The former EDIPO was a 12.35 T dipole based on a CICC design
- The new dipole will look more like an accelerator-type magnet
- The main features of the proposed flared-end design have been validated in HD2 and FRESCA2
- The designs also rely on the conceptual design of LD1

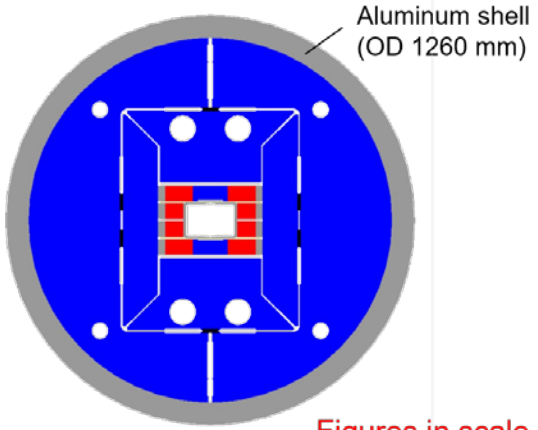
HD2
(13.8 T at 4.2K, 2008)



FRESCA2
(14.6 T at 1.9K, 2018)



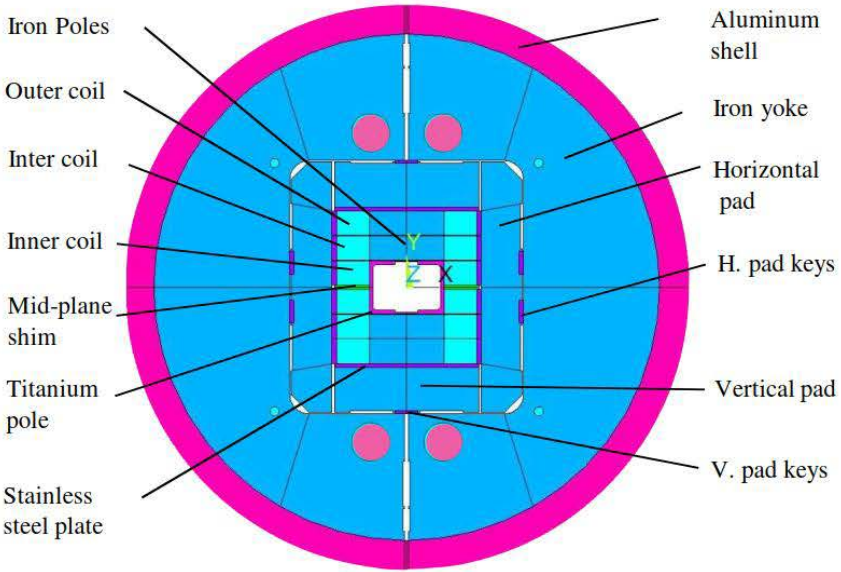
Proposed EDIPO design

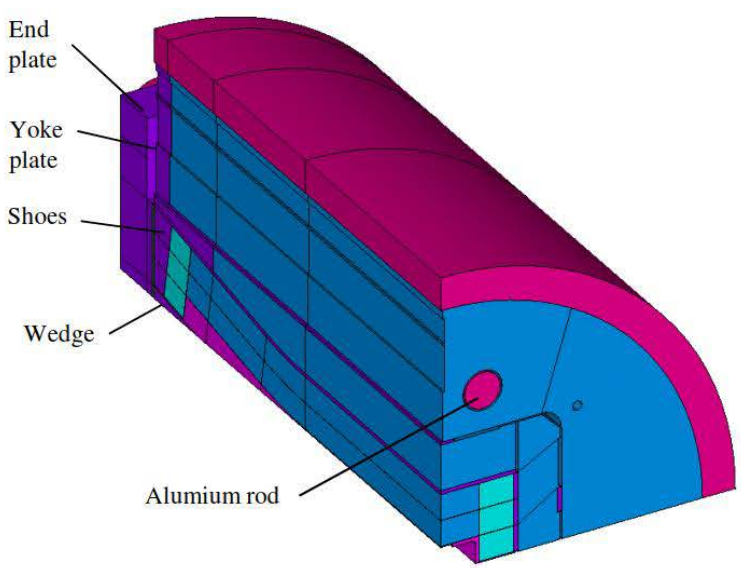


Figures in scale

Magnet layout

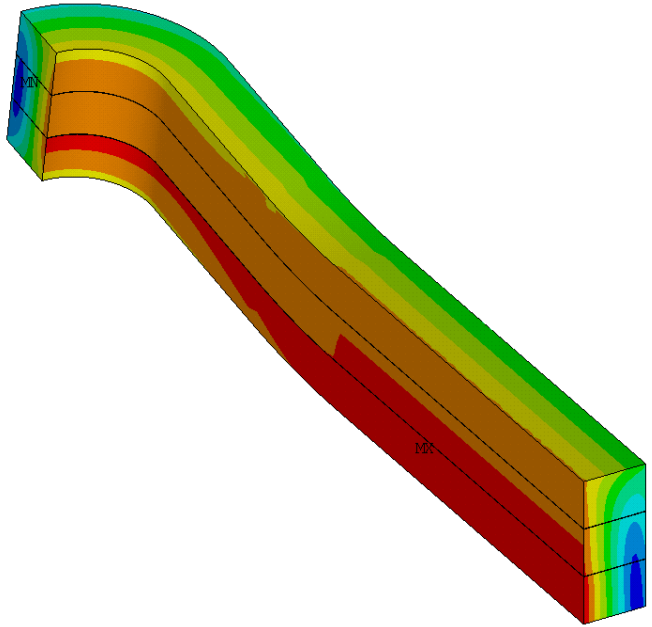
- Shell-based mechanical structure:
  - Al shell preloaded with pressurized bladders and locked with keys
  - Axial preload given by end-plates and rods
  - Coil pre-stress minimizes motion during coil powering

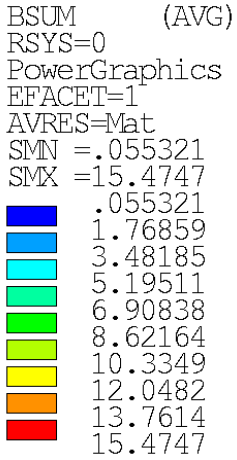


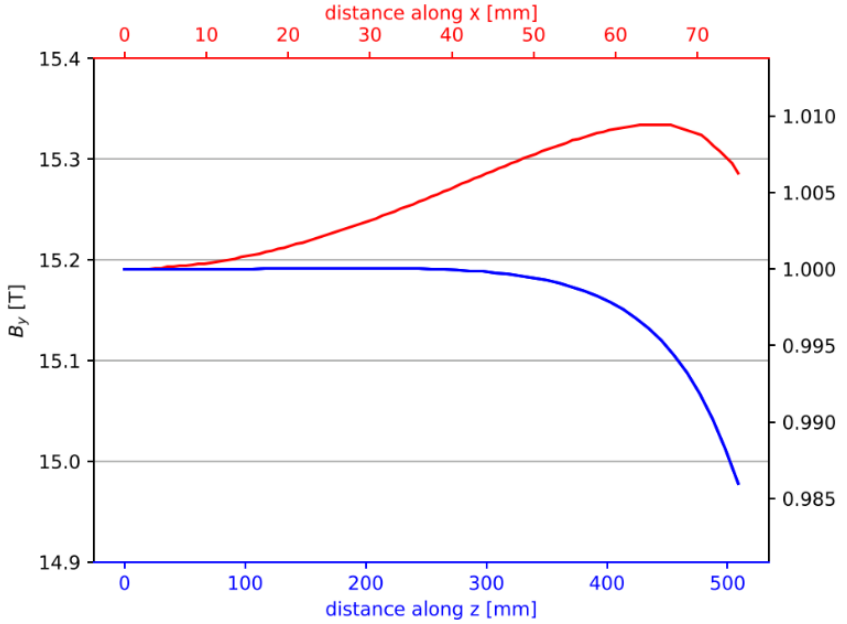


3D magneto-static analysis

- I_{op} = 14.6 kA (85% of I_{ss} at 4.2 K)
- Field homogeneity of ±1 % in the test well.
- Uniform field region (1%): 980 mm.



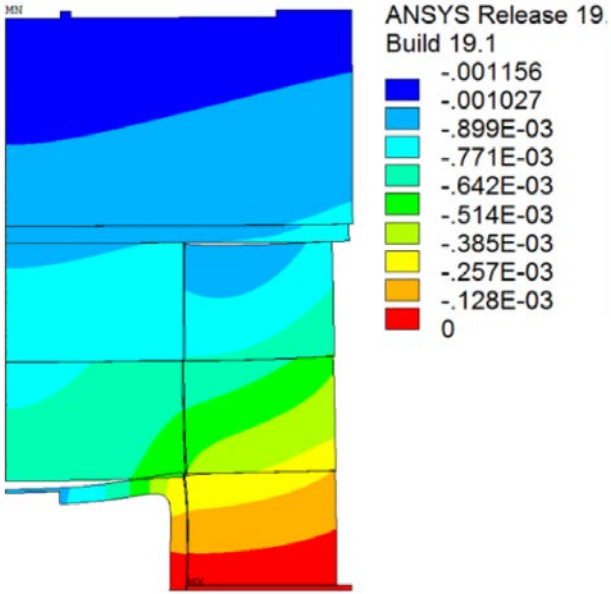




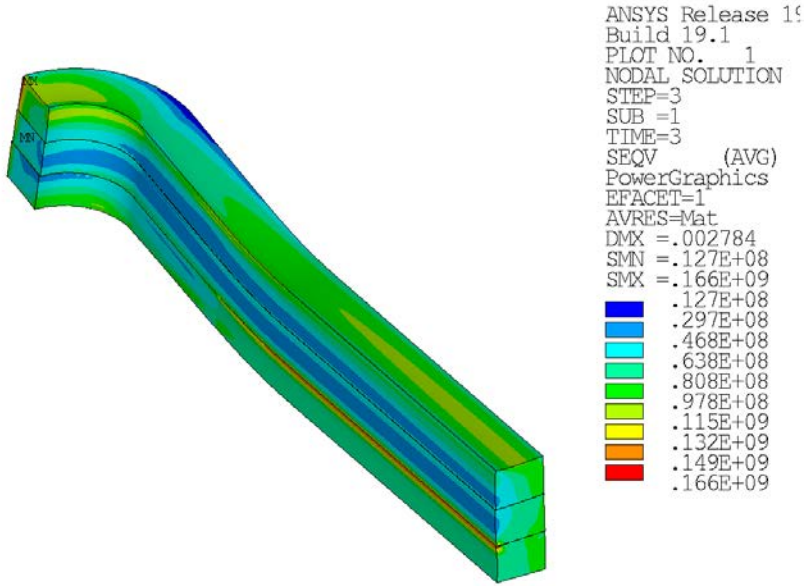
3D mechanical analysis

- 3 loading steps are modelled:
  1. Key insertion at room temperature
  2. Cool-down
  3. Powering at 14.6 kA

Vertical displacement at nominal field (m)



Equivalent stress at nominal field (Pa)

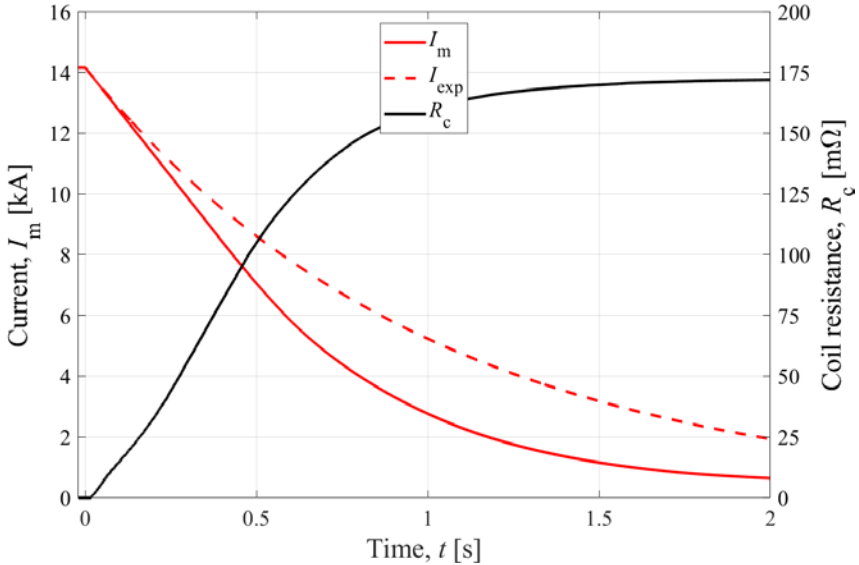


Nominal field

Quench analysis

- Magnet protection based on energy extraction
- Analysis performed using LEDET software:
  - Quench-back affects significantly the magnet discharge
  - T_{hs} = 190-235 K if the voltage is limited to 1.5 kV (V_{ground} = ±0.75 kV)
  - R = 106 mΩ

Simulated magnet current and hot-spot temperature for a voltage of 1.5 kV



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Conclusions and plan for 2020

- We have a conceptual design of EDIPO that satisfies the stringent design requirements, namely:
  - 15 T in a large aperture
  - Operation at 4.2 K and 85% of short sample limit
  - Homogeneous field length of 1000 mm
- The conceptual design activities are close to completion.
- Dummy cabling tests have been conducted.
- **Plan for 2020:**
  - Engineering design (technical engineer starts working at SPC in March).
  - Integration in the existing facility.
  - Winding tests using the dummy cables.
  - Cabling ~800 m of the actual EDIPO cable.