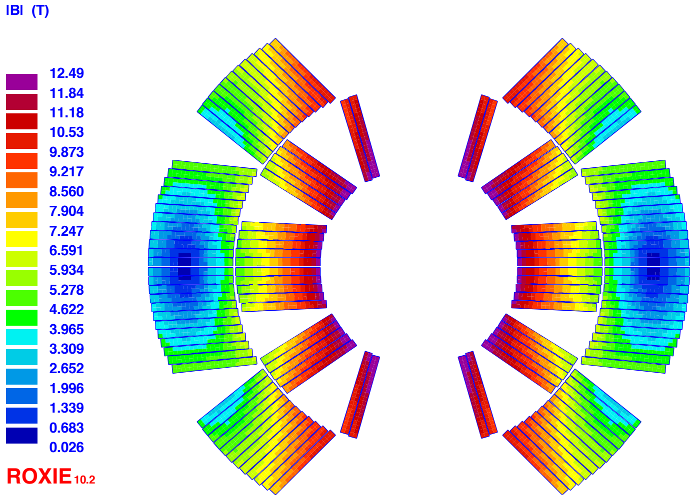
The INFN proposal for the 14–16 T Nb_3Sn cos-theta dipole in the HFM program

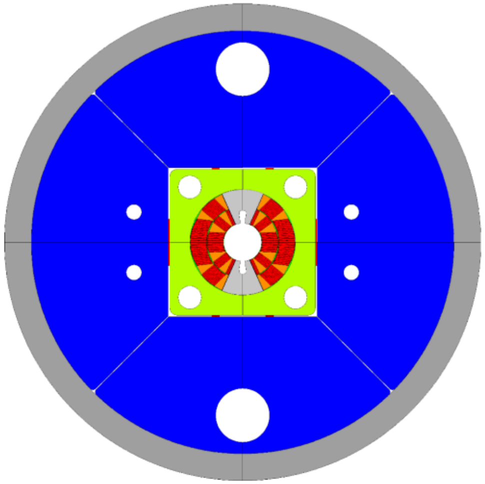
Authors: Massimo Sorbi, Stefania Farinon
on behalf of **INFN team** (Milan-LASA & Genova)

Date: 1 November 2023

From FalconD - 12 T dipole…

- The actual program under the CERN/INFN collaboration (KE 4102 agreement) foresees a 12 T demonstrator, to pave the road toward a high field dipole magnet for FCC-hh
- The magnet was "simplified" to a two-layers coils, Bladder & Key technology, coils built by industry (winding, heat-treatment, impregnation), assembling at LASA, preliminary test at LASA, final test at CERN





- Talk of Stefania Farinon in this meeting:

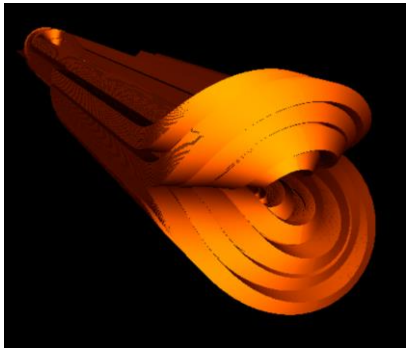
  WP3.2 - Nb3Sn single aperture cosΘ bladder & keys 12T FALCON D dipole model - INFN

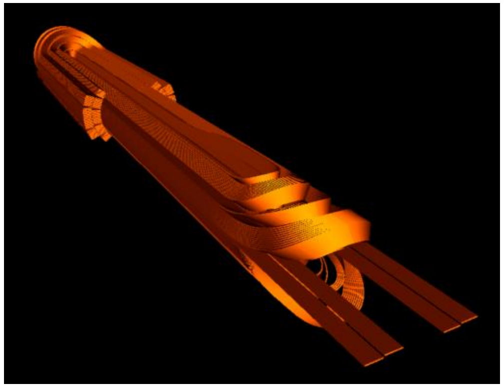
…To a 14^+ T dipole

- This new program has the ambition to study and realize a real demonstrator cos-theta dipole for FCC-hh, to go beyond the 14 T field level
- The main goal of the project is to achieve a very homogeneous field of 14 T in the bore with a large margin of operation in order to pursuit the scope, in principle to reach 16 T
- The dipole magnet design incorporates four layers of Nb_3Sn Rutherford cable winding.
- The configuration aims to optimize magnetic field homogeneity, minimize undesired field harmonics, and ensure overall stability.
- By exploring the capabilities of Nb_3Sn and advance superconducting magnet technology, our project aims to contribute to scientific understanding and create opportunities for practical applications in various fields.

14^{+} T dipole

- The proposed project represents a natural extension of the Falcon Dipole project
- It benefits from the valuable insights gained during the construction of the FalconD 12 T Nb_3Sn cos theta dipole in the INFN/CERN collaboration
- It benefits from the availability of some dummy/spare coils produced for FalconD to set mock-up for assembly tests and explore mechanical limit





- It can be built & tested in house, in the research Superconducting Magnet Laboratory at LASA of IRIS program (Genova & Milan joint), hopefully with a more rapid iteration from the construction to test phases.

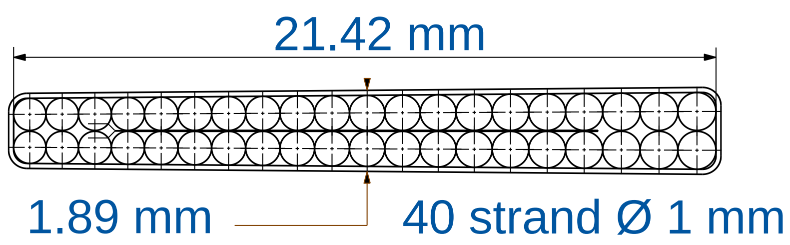
  Talk of Lucio Rossi on Thursday 2 November:

  The IRIS infrastructure in Italy

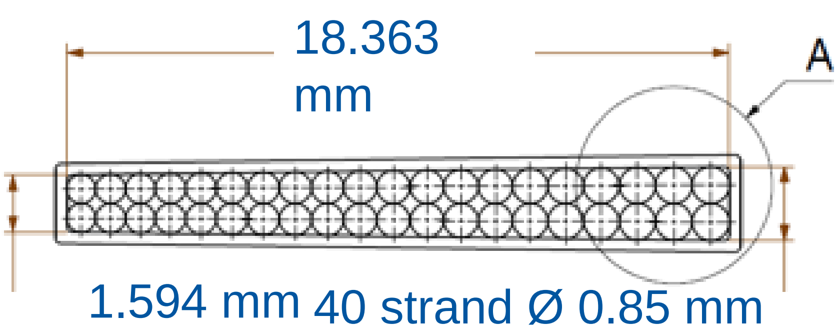
14^+ T dipole

- Preliminary electromagnetic studies indicate that it is possible to use cable of FalconD (1st double-pancake) and of MQXF (2nd double-pancake)

Inner Pancake	
Material	RRP Nb3Sn
Strand diameter [mm]	1
Copper / non Copper	0.9
RRR	>150
Fiber glass insulation [mm]	0.15
Stainless steel core [μm]	25
Jc @ 12 T, 4.2 K [A/mm2]	

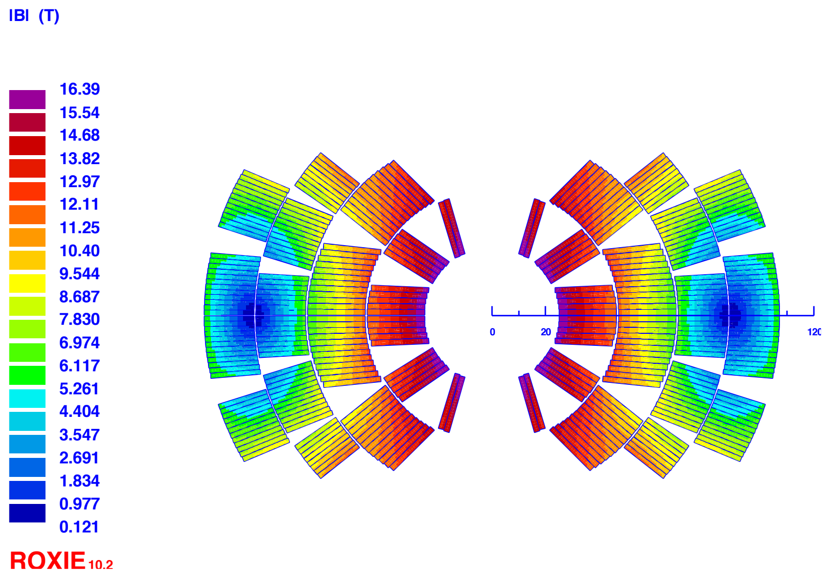


Outer Pancake	
Material	RRP Nb3Sn
Strand diameter [mm]	0.85
Copper / non Copper	1.2
RRR	>150
Fiber glass insulation [mm]	0.15
Stainless steel core [μm]	25
Jc @ 12 T, 4.2 K [A/mm2]	



14^+ T dipole

- Preliminary electromagnetic studies



Magnet parameters	14 T	16 T
Aperture [mm]	50	50
Operating Current [kA]	13	15
Operating Temperature [K]	1.9	1.9
Bore field [T]	14	16
Peak field [T]	14.38	16.39
Margin on Load Line [%]	23%	12%
Temperature Margin [K]	4.93	2.96
Field quality	To be optimized	To be optimized

14^+ T Dipole: Mechanic

- Bladder & Key technology probably the most promising solution -> baseline
- Exploring other solutions, for example “limited” stress management (to alleviate peak stress, in case also B&K does not control stress in all phases)

Time line

- Year 1 (Jan-2024):

- Electromagnetic design -> maximize temperature margin, easy windability, conductor and cable feasibility;
- 2D Mechanical design -> control peak stress
- Material choice for the components and manufacturing processes (curing, impregnation, etc.);
- Test and studies on critical aspects and on design choices (splicing, quench protection, etc.).

- Year 2:

- Finalize the design based on simulation results and insights gained from mockup testing;
- Procure necessary materials, components and tooling;
- Set up the cold test station at the LASA laboratory in Milan;
- Continue studying and refining the quench protection system to ensure safety and efficient energy removal during operation.

- Year 3:

- Conductor initial tests to test windability under realistic conditions
- Analyze test results and identify any areas for improvement and if needed refine the design and manufacturing process to address any observed issues;
- Construction of the first dummy coil
- Start the procedure for mechanical assembly

- Year 4:

- Finalize the design and manufacturing process for the four-layer Nb_3Sn accelerator magnet;
- Start the manufacturing of the final magnet version, with spares.
- Finalize the test station settings

- Year 5:

- Test the magnet and make measurements in different operating conditions.

Conclusions

- We launch the proposal of a 5 years program to realize a Nb_3Sn 14-16 T model dipole for FCC-hh, cos-theta solution
- Fruitful Collaboration between CERN – INFN
- Each may contribute for 50% in costs
- Benefit from technical exchange
- We hope in more rapid answer and iteration from designing – modelling – realizing phases for the in house construction & preliminary test