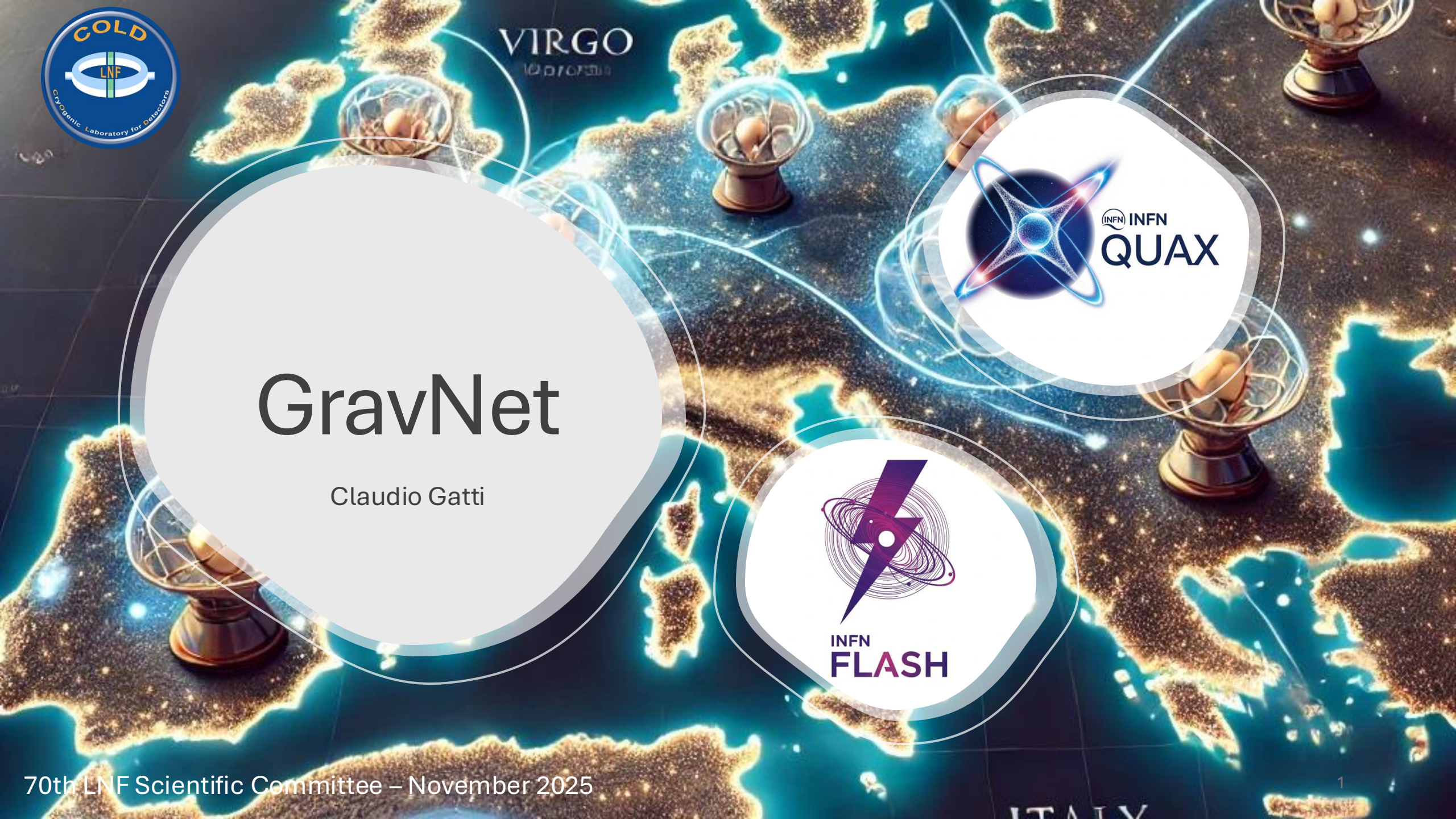


GravNet

Claudio Gatti

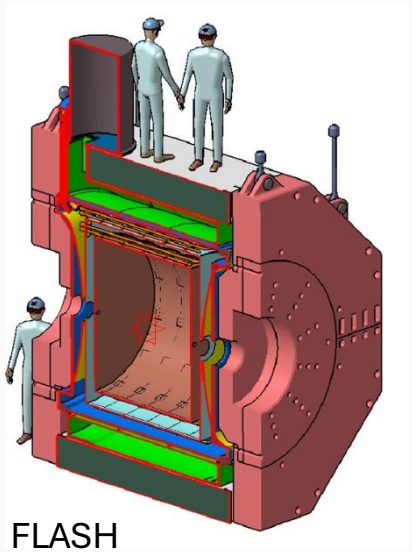
GravNet A Global Network for the Search of High Frequency Gravitational Waves

QUAX@LNF

SUPAX

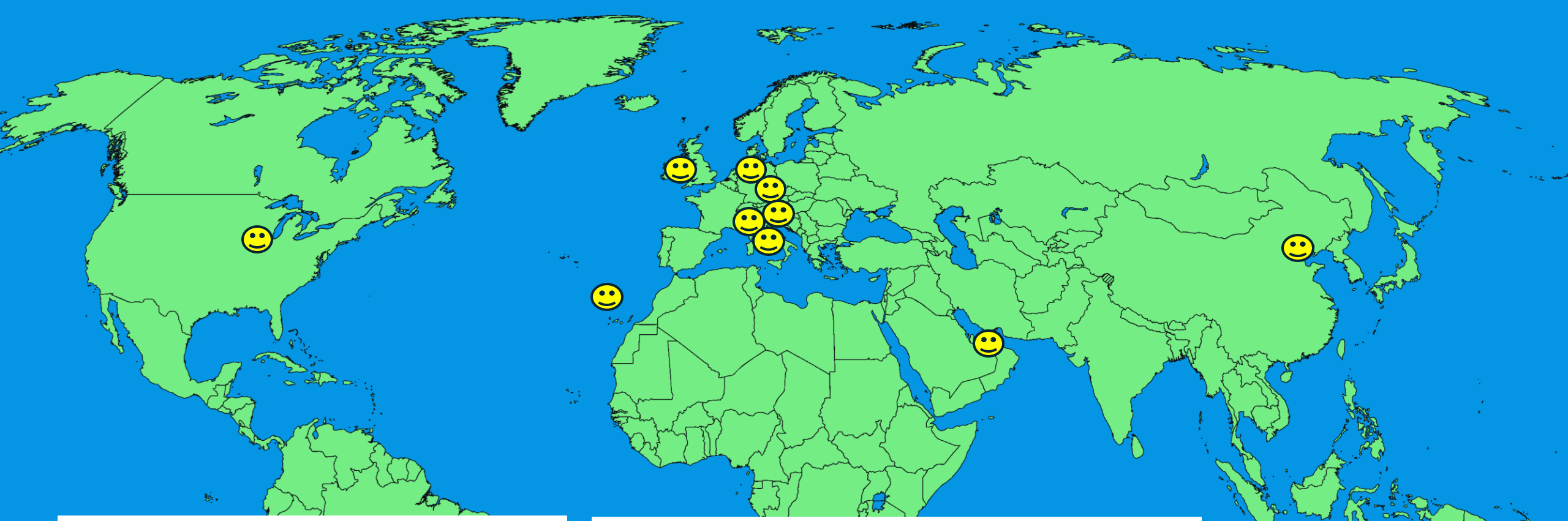
Initial sites: Mainz, Bonn, Frascati

- 3 high frequency RF cavities per site
- One RF cavity at 100 MHz
- Multi-mode readout



FLASH

Goal: Extend the network to more sites and technologies (BAW, Levitated Sensors …)

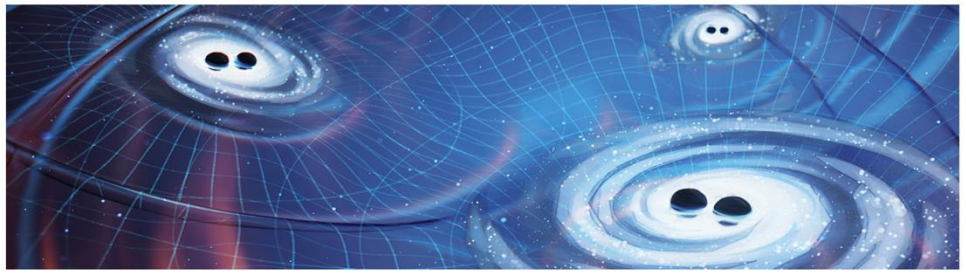


Beijing (CN): Magnetometer; Hz
Chicago (US): OLS; 100 kHz
Milan (EU-IT): BAW; 1 MHz
Perth (AU): BAW, RF Cavity; 1 MHz, 10 GHz
Mainz (EU-DE): RF Cavity, Magnetom.; Hz,10 GHz
Frascati (EU-IT): RF Cavity; 100 MHz ,10 GHz
Legnaro (EU-IT): RF Cavity, e-spin; 10 GHz
Bonn (EU-DE): RF Cavity; 10 GHz
Tenerife (EU-ES): Dielectric: 10 GHz, 30 GHz
Manchester (GB): RF Cavity: 30 GHz
Abu Dhabi (AE): Dielectric; 300 THz

GravNet – Searching for High Frequency Gravitational Waves with a Global Detector Network

Location: University of Mainz, Germany

Date: Thursday, 26th of June 2025 to Friday, 27th of June 2025



https://indico.him.uni-mainz.de/event/229/overview

FLASH

FLASH Collaboration

Bylaws of the FLASH Collaboration

September 2025

Contents

Technical Board
F. Bossi (Chair), S. Gazzana (Technical Manager), C. Ligi (Cryogenics), G. Mazzitelli (Computing), C. Gatti (PI)

WP1 Physics Reach

(L. Visinelli and F. Mescia)

- The theoretical work currently focuses on:

  - Detecting axion mini-clusters with FLASH
  - Relativistic axions and DP
  - Coupling to HFGW (within GravNet)

- Concerning future applications and detector upgrades:

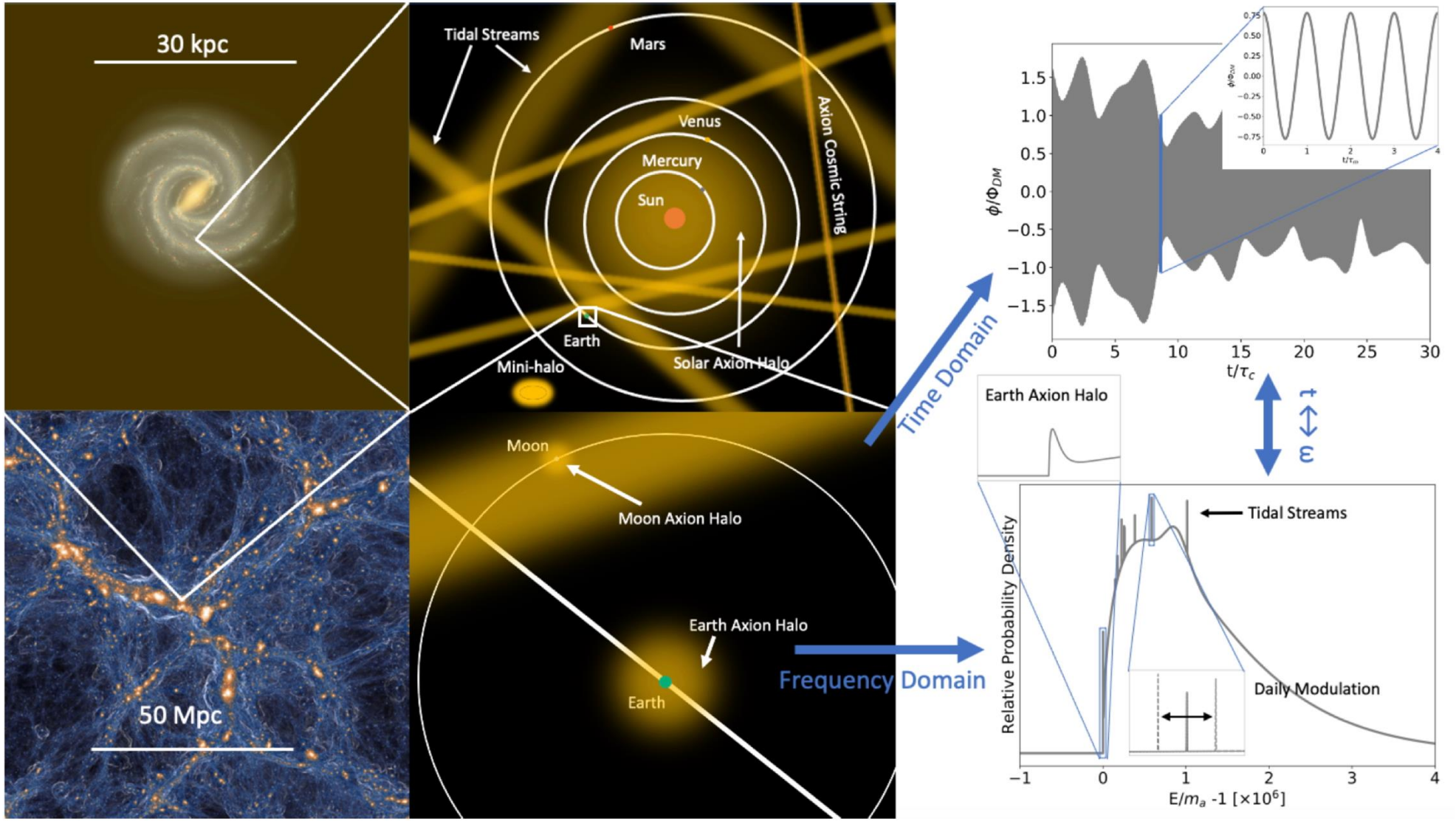
  - Investigating dilaton detection with Bulk Acoustic Wave (BAW) resonators
  - Searching for millicharged particles with FLASH

Frascati National Laboratories

FLASH

THEORY WORKING GROUP

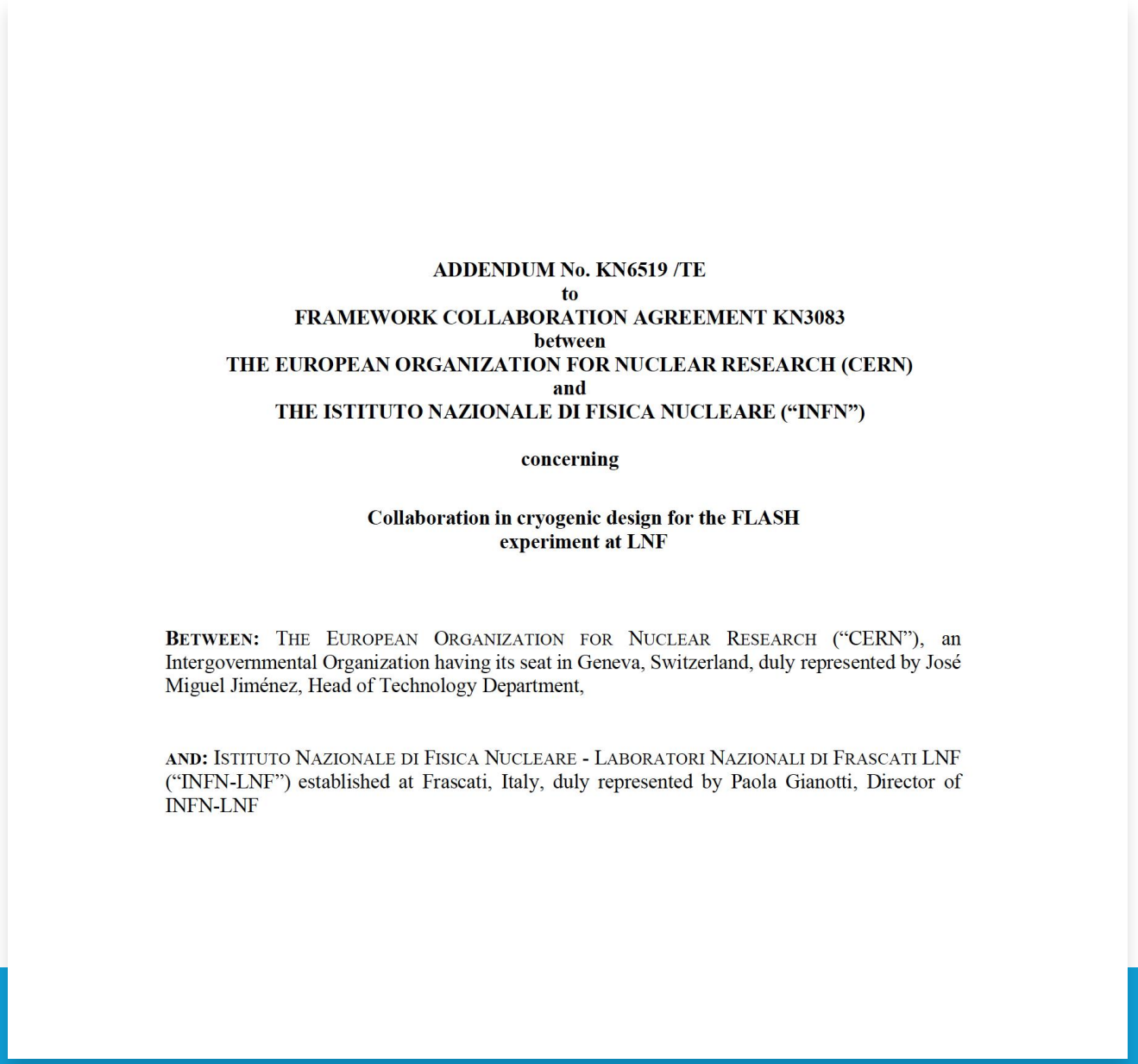
Detecting axion miniclusters in FLASH?



Visinelli arxiv:2011.05377

WP2: Cryostat Mechanical Design and Cryogenics (C. Ligi)

- Signed by CERN and LNF a Collaboration Agreement for the cryogenic design of the FLASH experiment.
- A PhD student in engineering from La Sapienza University is now working with the Cryogenic Service at CERN.
- A report on FLASH cryogenics is expected in summer 2026 and the final report on its mechanical design before summer 2027.



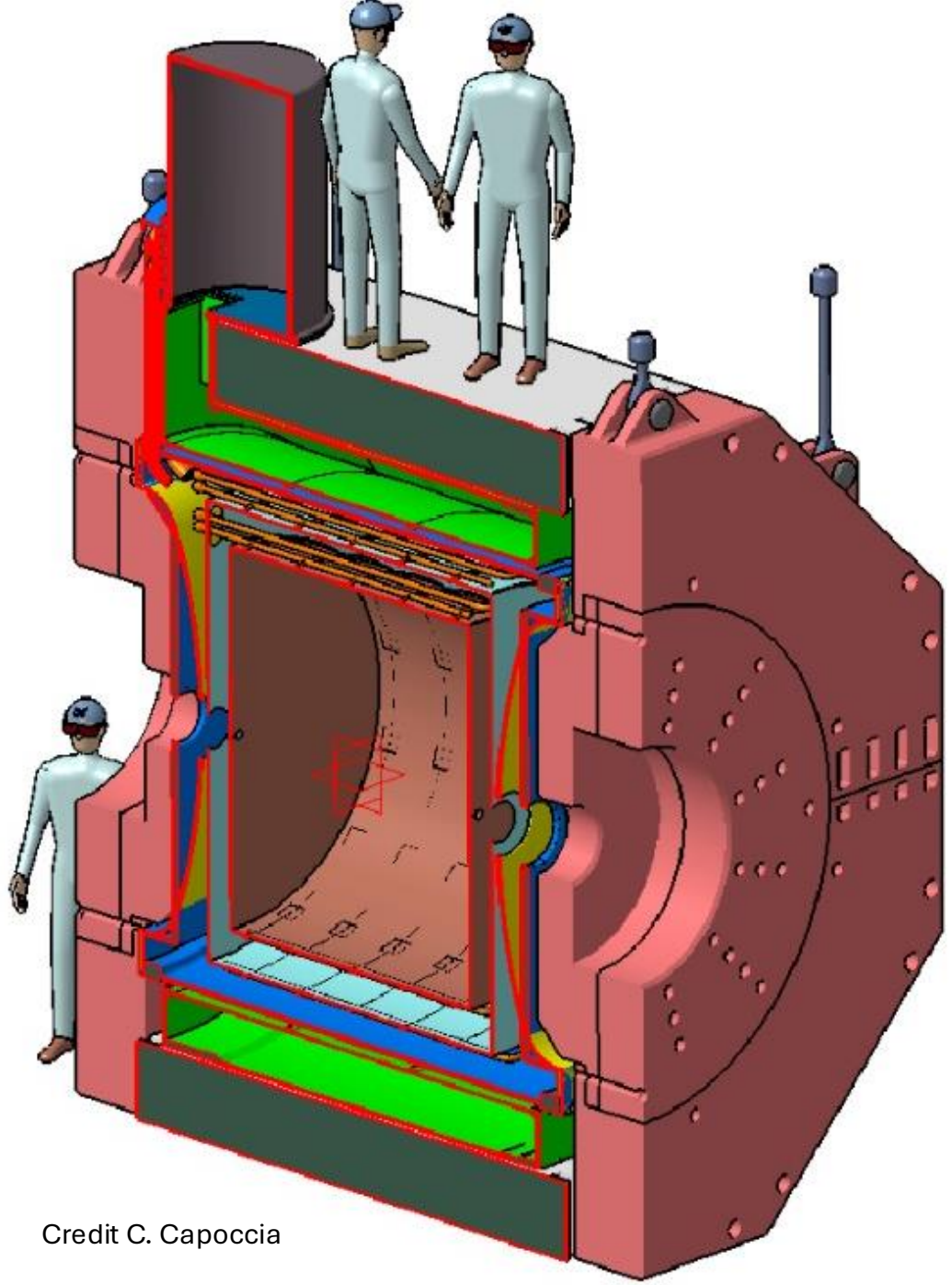
ADDENDUM No. KN6519 /TE
to
FRAMEWORK COLLABORATION AGREEMENT KN3083
between
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
and
THE ISTITUTO NAZIONALE DI FISICA NUCLEARE ("INFN")

concerning

Collaboration in cryogenic design for the FLASH experiment at LNF

BETWEEN: THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH ("CERN"), an Intergovernmental Organization having its seat in Geneva, Switzerland, duly represented by José Miguel Jiménez, Head of Technology Department,

AND: ISTITUTO NAZIONALE DI FISICA NUCLEARE - LABORATORI NAZIONALI DI FRASCATI LNF ("INFN-LNF") established at Frascati, Italy, duly represented by Paola Gianotti, Director of INFN-LNF



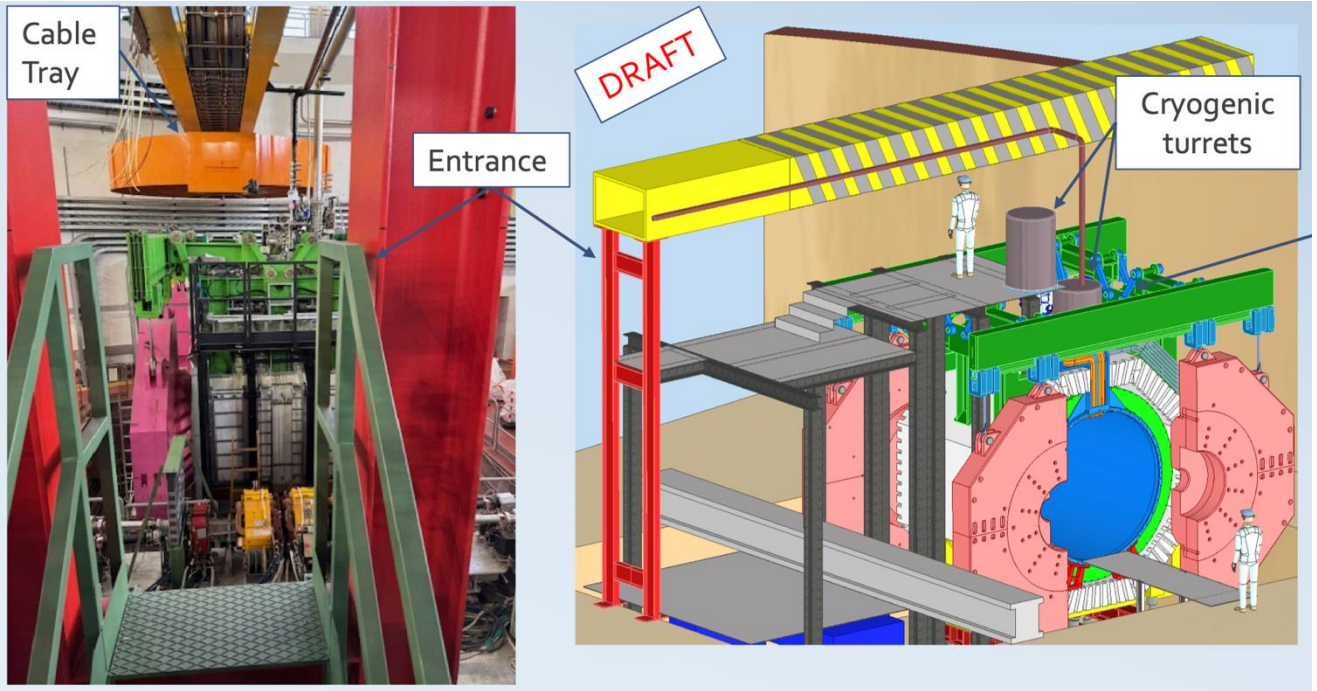
Credit C. Capoccia

Ongoing Work

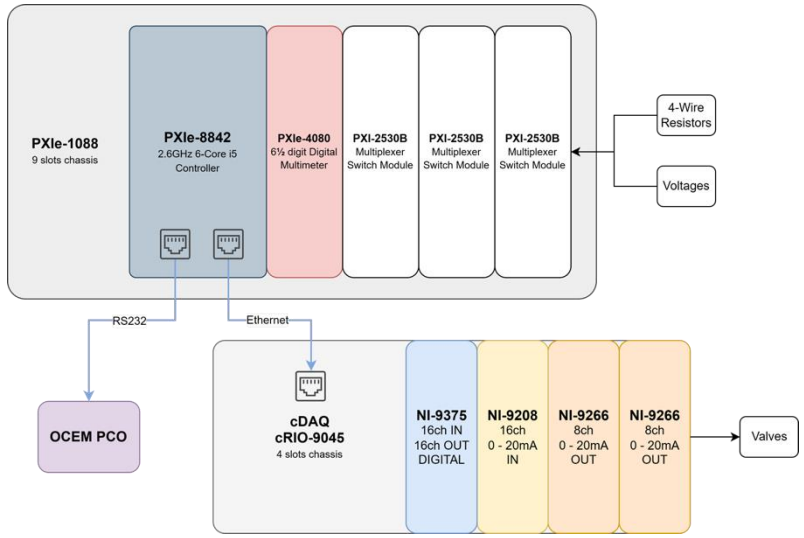
- Definition of the RF cavity cryostat general layout details
- Cryostat cryo/mechanical design of
  - RF cavity
  - vacuum shield
  - 70 K radiation shield
- Cryogenic turret cryo/mechanical design
- Cryogenic transfer lines design

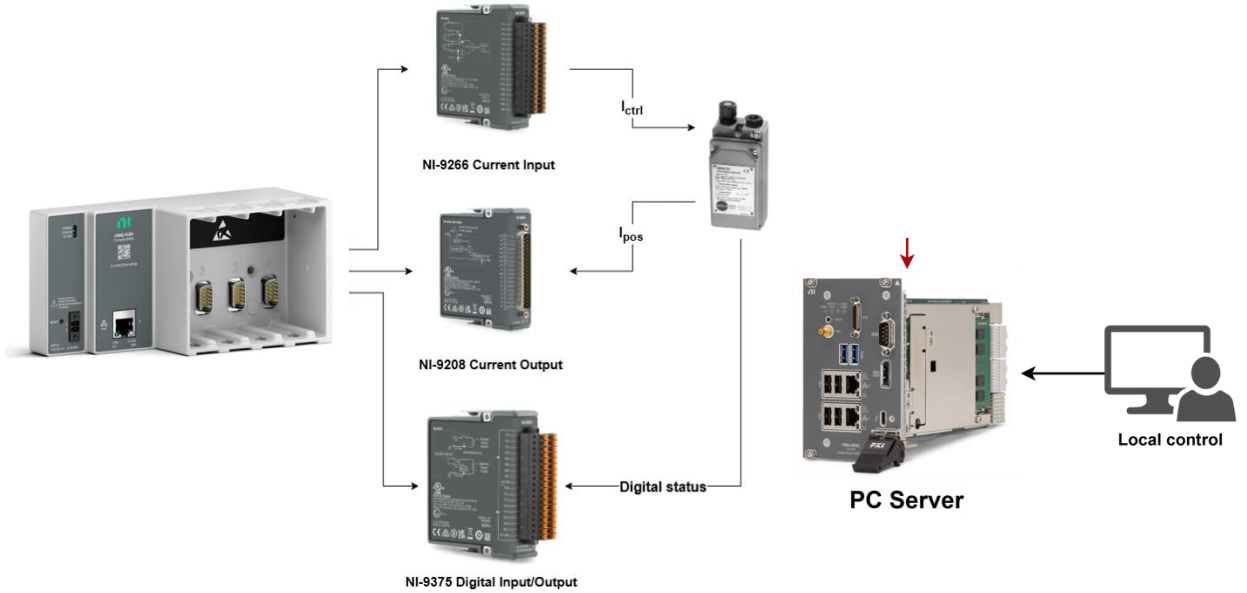
Carpentry Structure

for the access to the experimental and technical area and for hosting the new cryogenic turret



Credit F. Rosatelli





FINUDA Control System

- Reconstructed the operating diagram for the magnet control and cooling system and the various components involved.
- A new architecture was designed to replace the old control system, the instruments were identified, and the purchase process ongoing.

CIG
B8E7E93404

Credit Capuano, Petrucciani, DiPirro

WP3: RF Cavity

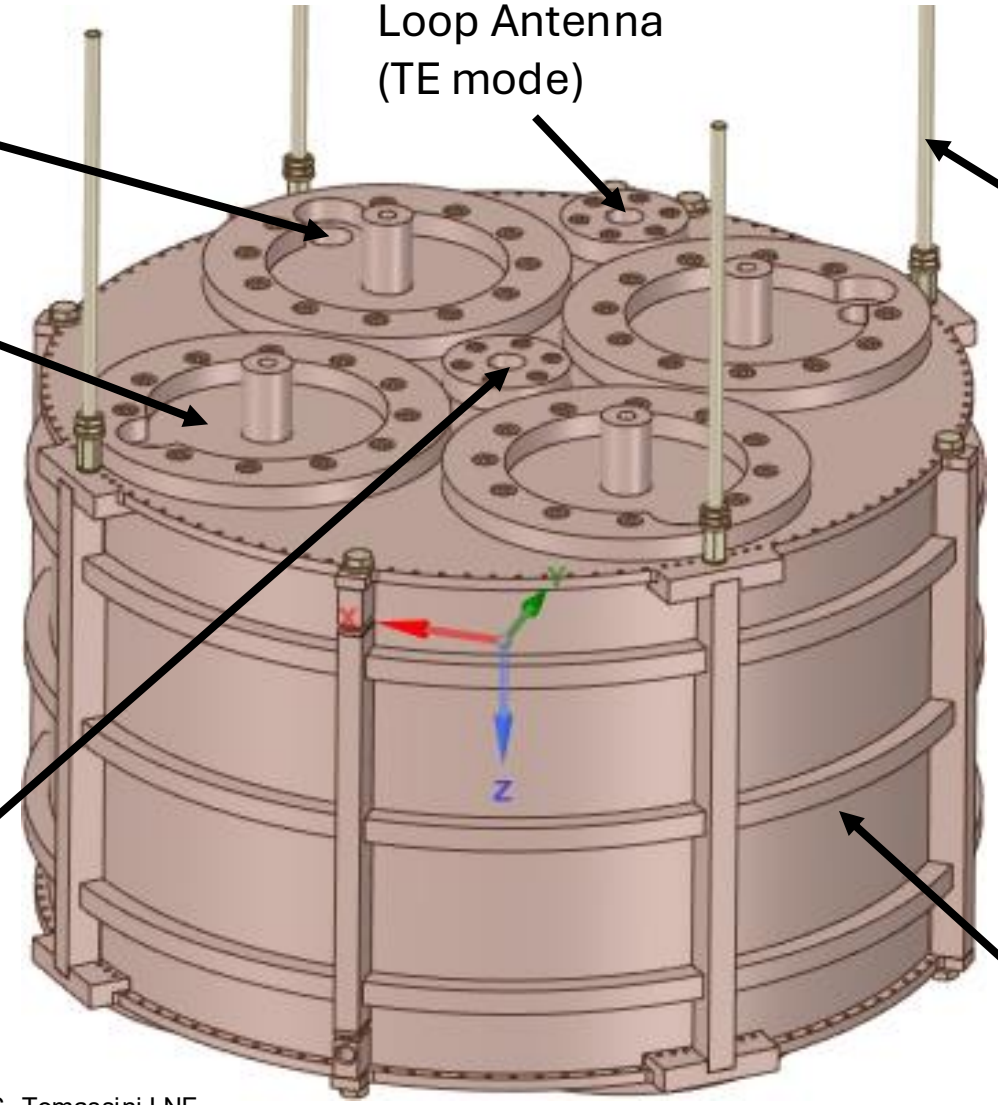
(S. Tocci and A. Diaz)

Electromagnetic design ongoing and proceeding in synergy with mechanical design:

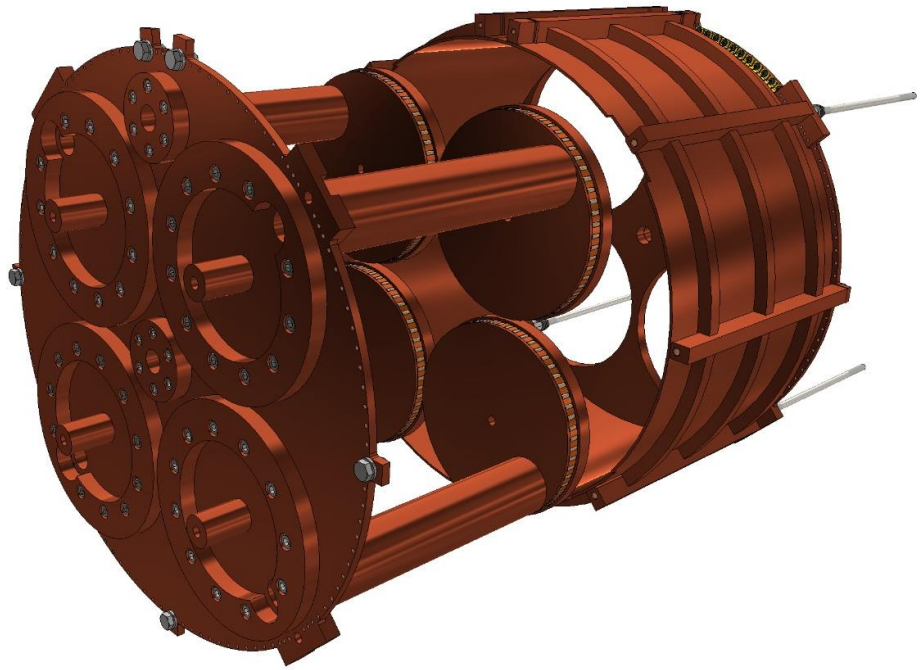
- **Electromagnetic design** is in its final phases. The main parts of the FLASH detector have been defined
- New **mechanical designs** for the cavity and tuners have been developed and electromagnetically simulated.
- The dimensions and mechanics of the **FLASH prototype** have been defined and electromagnetic simulations to extract the main parameters have begun

CURRENT STATUS SIMULATIONS ACTIVITY FOR FLASH	STATUS
Simulate the coupling effect between two orthogonal TE modes induced by the loop antenna	**In progress**
Study capacitive tuning	To be started
Study the effect of mechanical vibrations produced on the antennas (monopole and loop)	**In progress**
Perform an EM analysis to find the optimal monopole configuration for all TM modes of interest	**In progress**
Define the exactly position of the loop antenna on cavity end caps	**In progress**
Develop an algorithm for optimal monopole length	To be started
Calculate the maximum effective tuning sensitivity with optimal β (e.g., β=2)	**In progress**
Fine tuning with dielectric rod	**In progress**
Analyze the effect of losses from the mechanical moving parts of the tuners on the Q factor for all modes	To be started

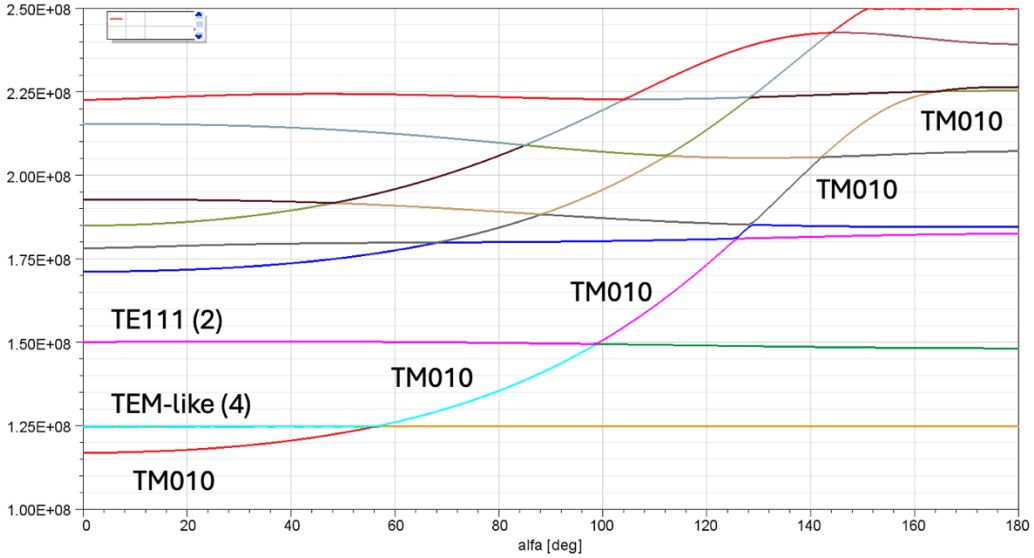
Mechanical Design FLASH cavity and prototype



S. Tomassini LNF
S. Tocci LNF



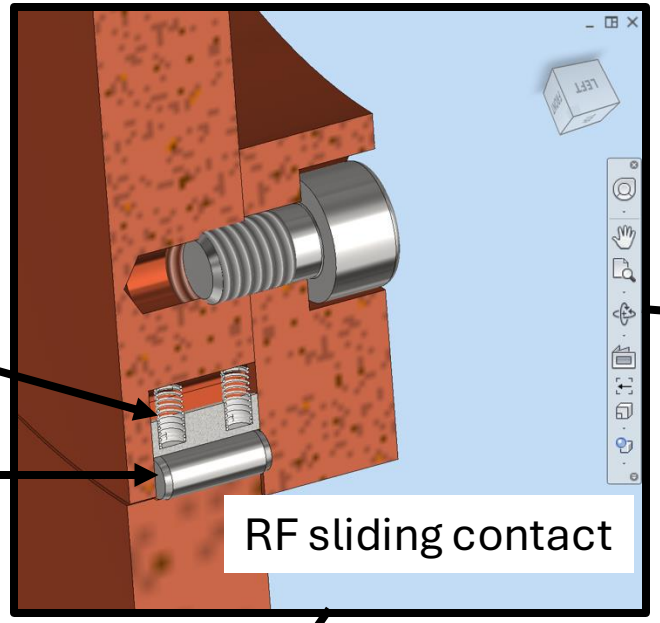
Credit S. Tomassini



Credit S.Tocci

Tuning System

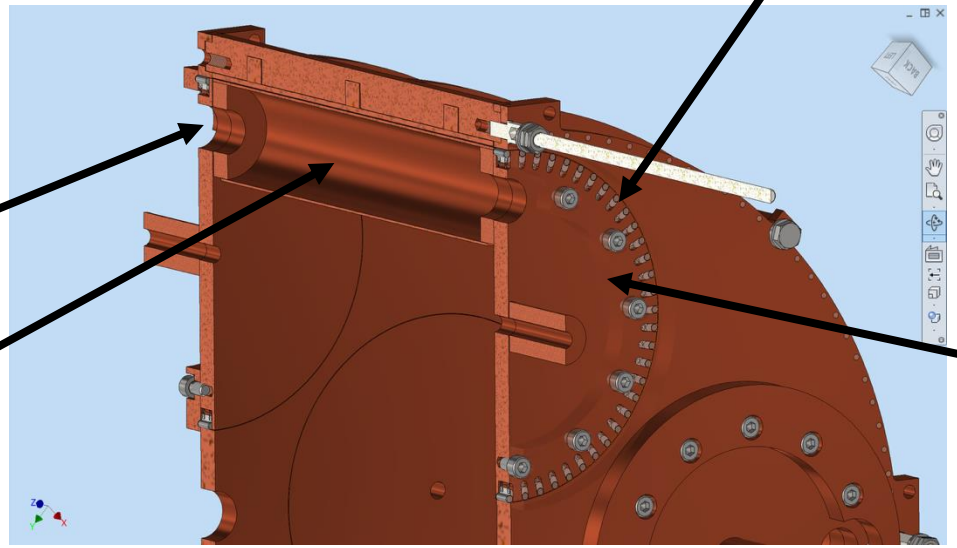
Mechanical Design: Tuners sliding contacts



Springs

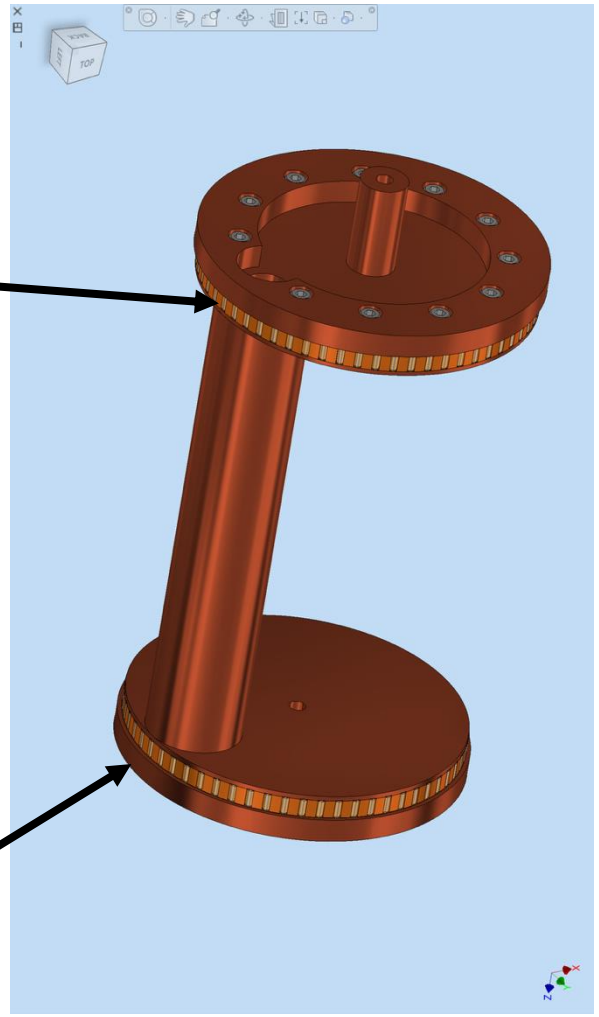
Metal contact

RF sliding contact



Vacuum Hole

Tuner



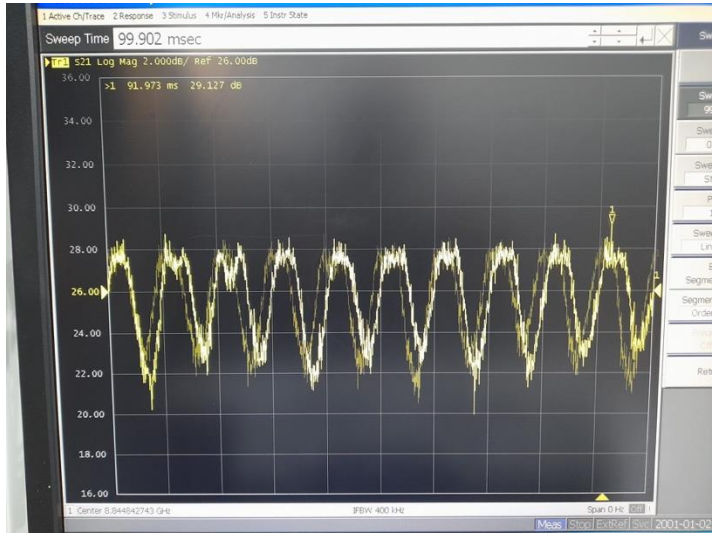
Rotating disk

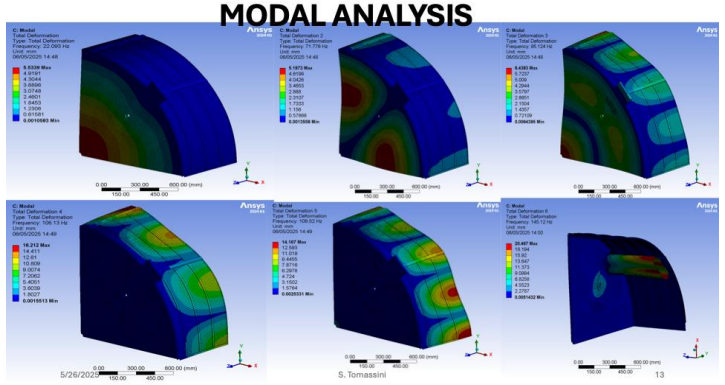
Credit S. Tomassini

Analysis of Mechanical Vibrations

Vibrations, especially from the tuners, degrade the stability of the resonant frequency

- Study the dynamic of the oscillating structures
- Determine the impact on the RF modes
- Determine the damping of oscillations due to the presence of 1.1 T magnetic field



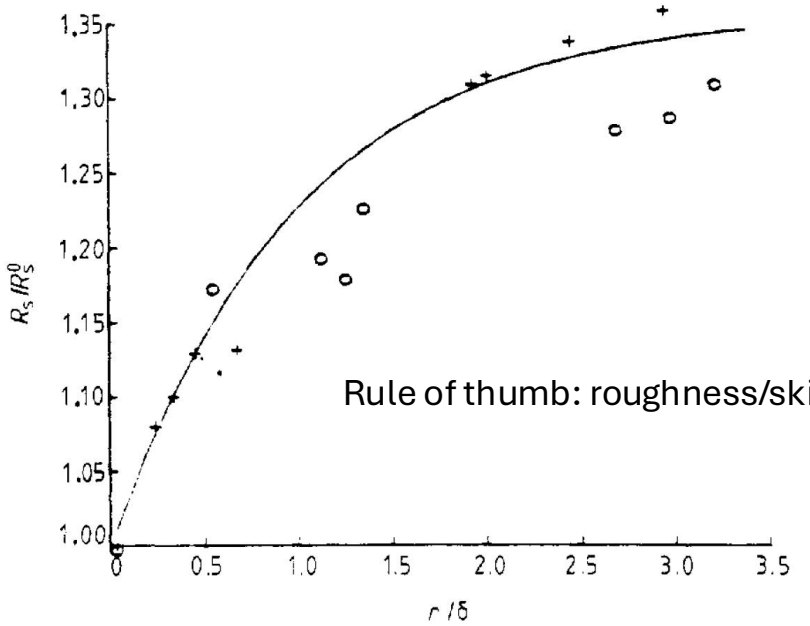


PhD student in engineering in La Sapienza University

Ente finanziatore: ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)
Tematica: Dinamica di strutture oscillanti sotto l'azione di campi elettromagnetici e in stato di coazione termica nell'esperimento FLASH ai Laboratori Nazionali di Frascati

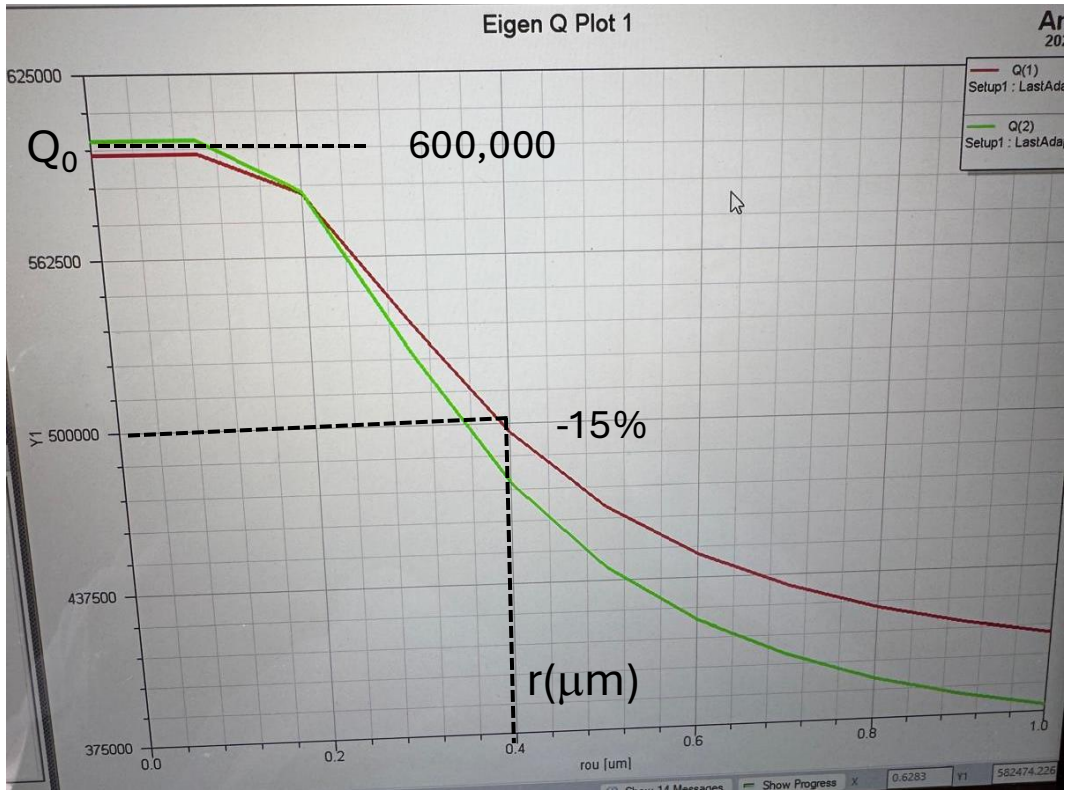
Surface Roughness

A Hernandez et al 1986 J. Phys. E: Sci. Instrum. 19 222



Rule of thumb: roughness/skin depth<1

For cryogenic copper at 100 MHz we expect a skin depth delta=1 micron (RRR=50 in the CDR) and no less than 0.6 micron (in the anomalous limit for very high RRR).



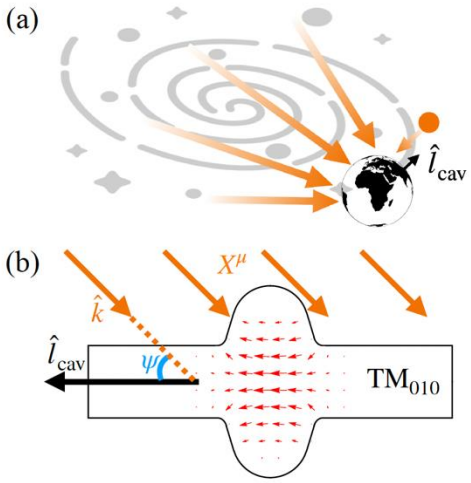
The target is roughness below 0.4 microns:

1) 1 micron mechanical
2) 0.5 micron chemical surface treatment

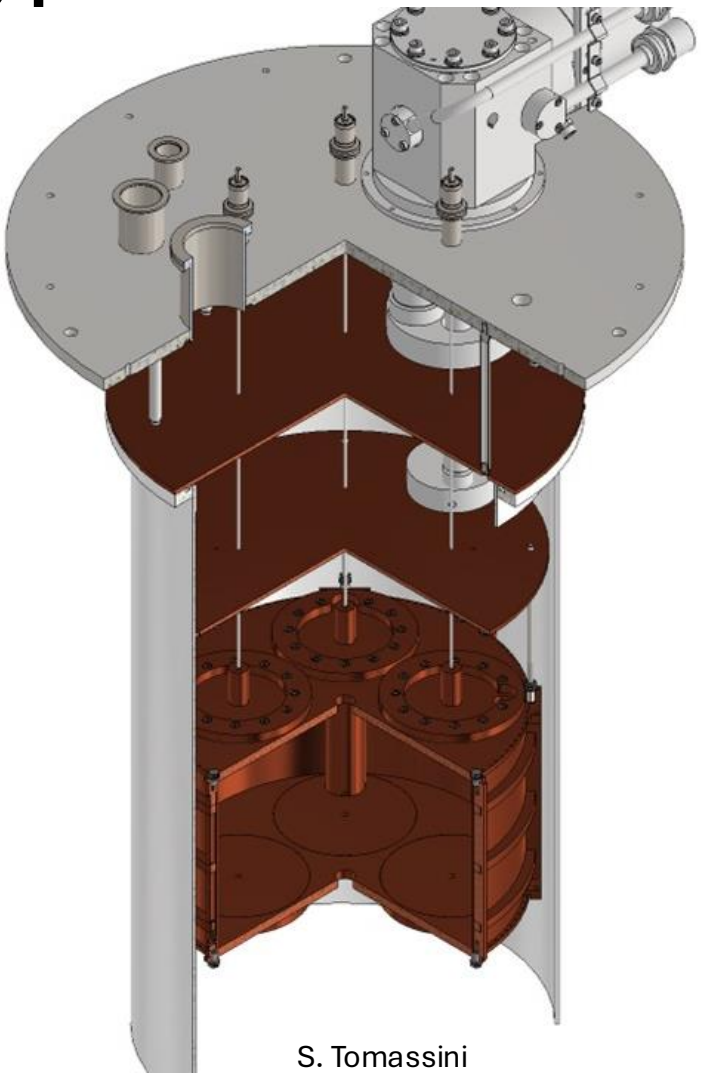
700MHz Prototype

- 4K cryostat (Ligi, Iungo, Beatrici, Tocci)
- Cavity mechanical design(Tomassini)
- Manufactoring (Uni Bonn)
- Surface treatment (LNL)

Galactic dark photons as decay products from scalar dark matter



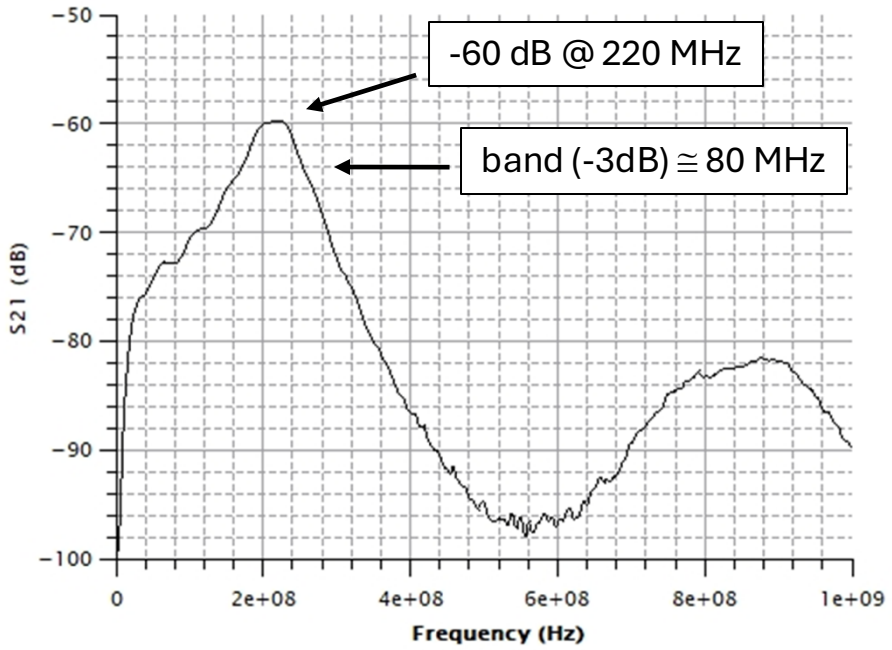
arXiv:2402.03432v2



S. Tomassini
A. Iungo

WP4: Signal Amplification and Acquisition

(P. Falferi and G. Lamanna)



Credit P. Falferi

PostAmp Gain (200 MHz) ≅ 15 dB

MSA #425-1 Gain (200 MHz) ≅ 15 dB
MSA #425-1 Bandwidth ≅ 80 MHz

Further tests in preparation:

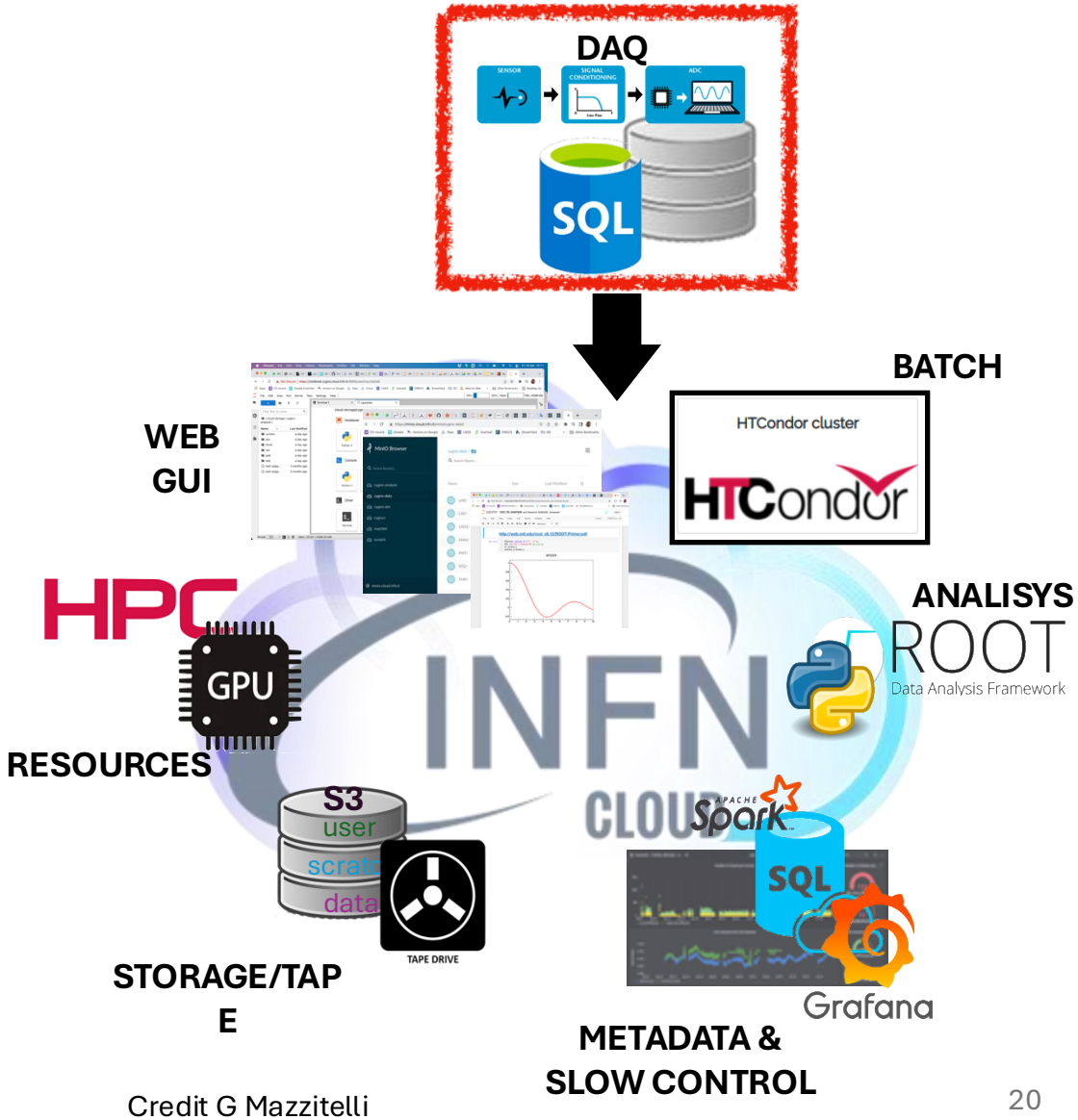
1. in B field at Camerino Uni. Shielding under study in Liverpool Uni.
2. Multiplexing to more SQUIDS in Pisa Uni.

WP5: Data Analysis and Computing

(K. Schmieden and G. Mazzitelli)

GravNet Computing Model

- MIDAS Triumf based **DAQ**; fast (test with QUAX ongoing with 70MB/s on disk) and slow control drivers under development
- **online data filtering** for axion/HFGW search under study
- local **data buffer** (3TB NVMe) and metadata (SQL)
- **streaming server** for online data monitoring, pre-analysis and alert on events
- remote **storage and tape** backend @CNAF with RUCIO data management
- **data access** and **analysis facility** (notebooks, batch system, experiment software/CVMFS) open to all the members of the collaboration



Credit G Mazzitelli

WP6: FINUDA Decommissioning and FLASH Commissioning (S. Gazzana)

We found the option of outsourcing the dismantling work to an external company too expensive.

A new disassembly procedure was agreed with the Safety and Protection Service (S. Vescovi).

Some delay in the operations inevitable.

- Refurbishing and certification of the original FINUDA assembly tools.
- Extraction of the FINUDA Clepsydra
- Dismounting of Scintillators and Phototubes

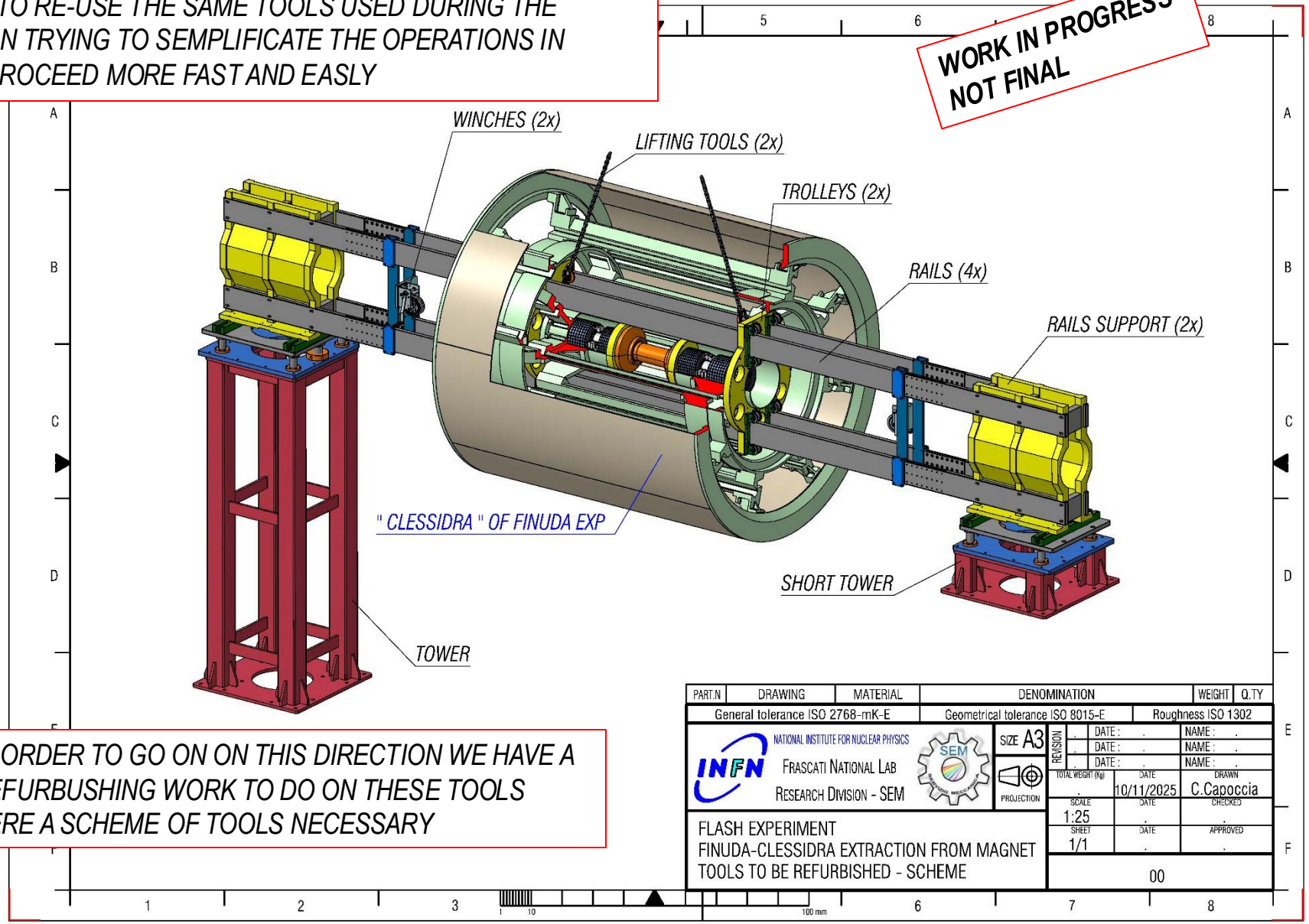
Ongoing activities:

- Maintenance and testing of hydraulic and endcap handling systems.
- Certification of the DAFNE cryogenic plant.

TOOLS & PROCEDURE TO REMOVE THE ‘’CLESSIDRA” OF FINUDA EXPERIMENT FROM MAGNET

THE IDEA IS TO RE-USE THE SAME TOOLS USED DURING THE INSTALLATION TRYING TO SEMPLIFICATE THE OPERATIONS IN ORDER TO PROCEED MORE FAST AND EASLY

WORK IN PROGRESS NOT FINAL



IN ORDER TO GO ON ON THIS DIRECTION WE HAVE A REFURBUSHING WORK TO DO ON THESE TOOLS HERE A SCHEME OF TOOLS NECESSARY

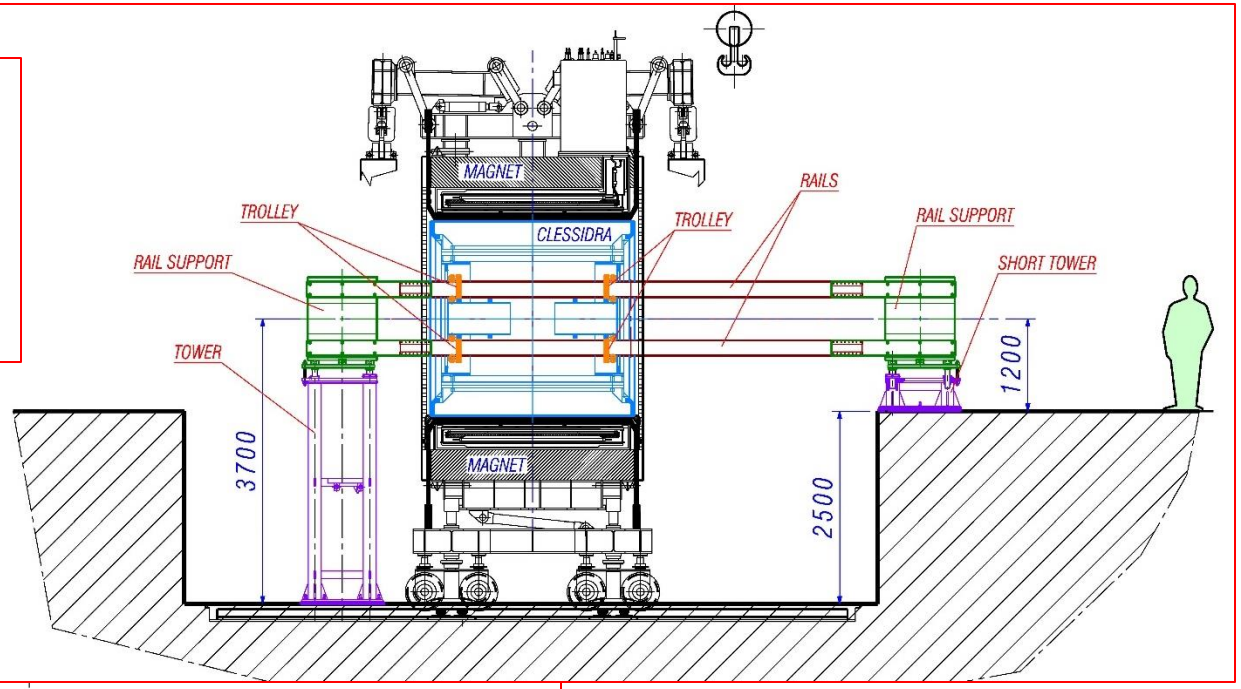
Credit C. Capoccia

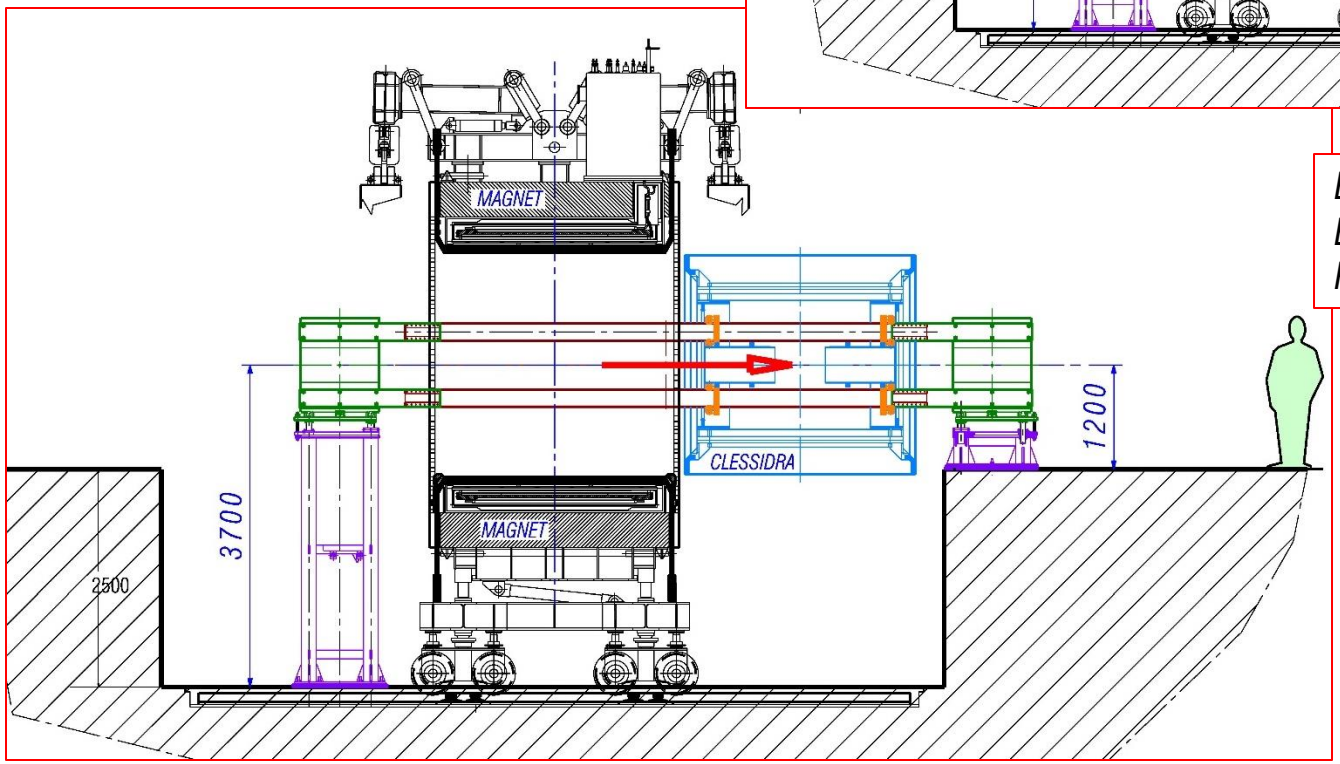
STARTING POINT OF PROCEDURE:

HERE A SCHEME OF TOOLS INSTALLED:

- *TOWERS*
- *RAIL SUPPORT*
- *RAILS*
- *TROLLEY*

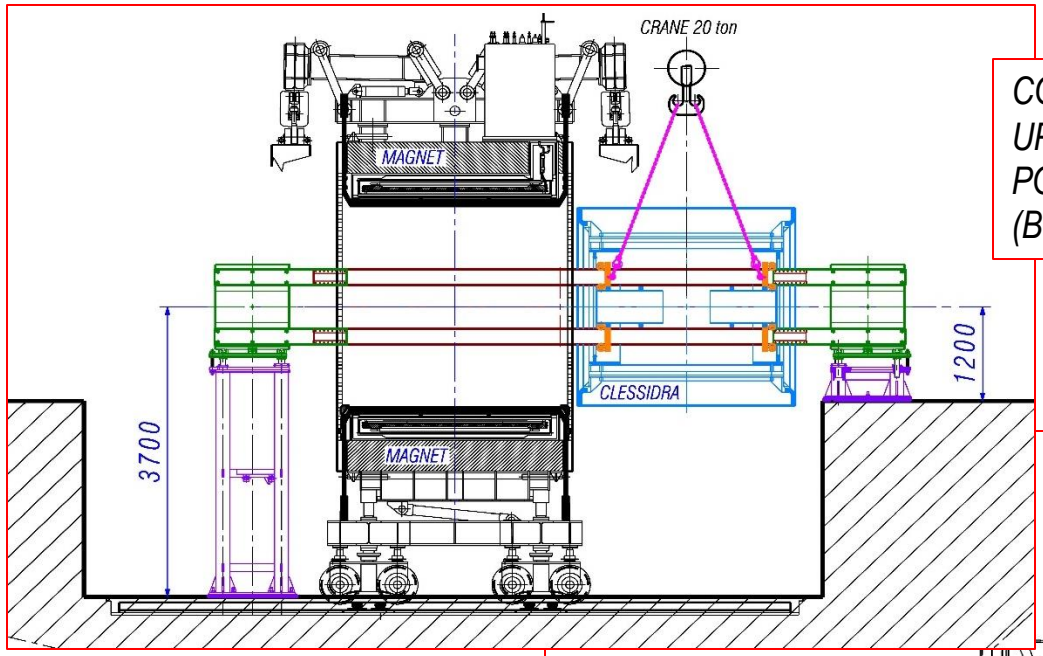
WORK IN PROGRESS NOT FINAL





EXTRACTION: THE ''CLESSIDRA", PULLED BY WINCHES, TRANSLATE FOLLOWING RAILS LEAVING THE MAGNET

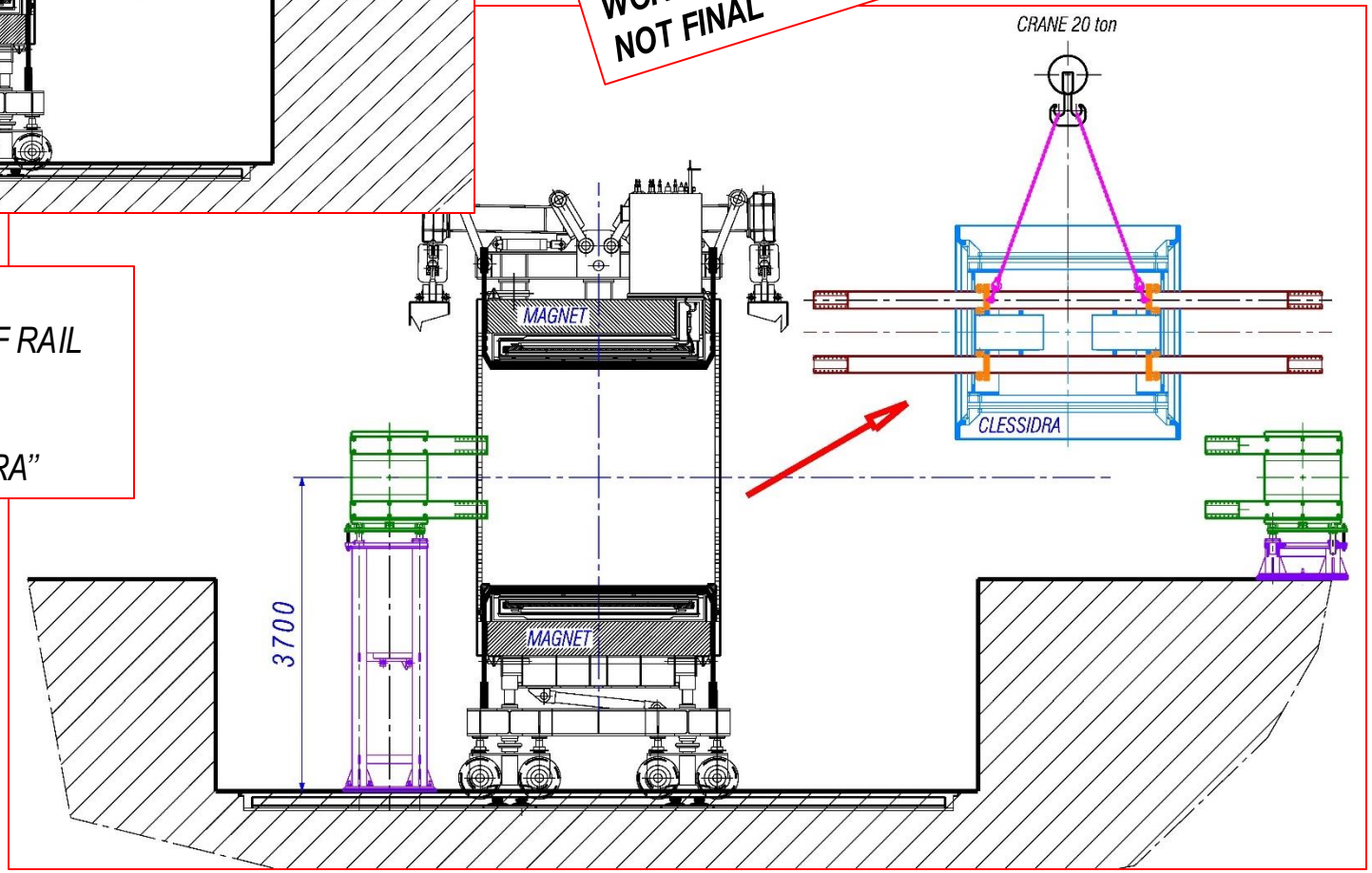
Credit C. Capoccia

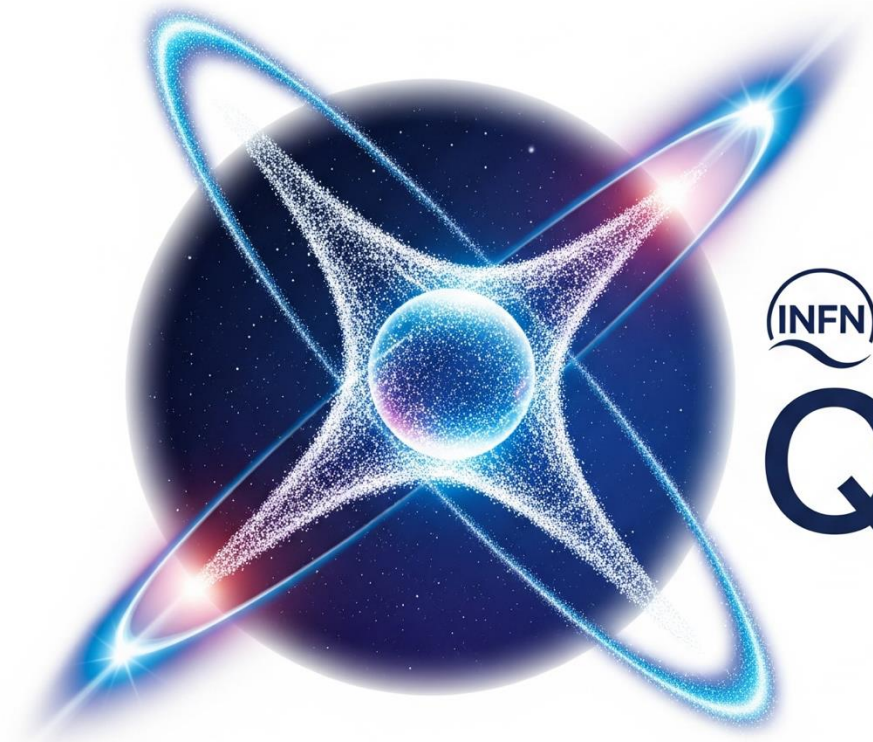


CONNECTION TO CRANE: REMOVING THE UPPER COVER OF ''CLESSIDRA'' IS POSSIBLE TO CONNECT THE TROLLEYS (BOTH) BY CHAIN TO THE CRANE

WORK IN PROGRESS NOT FINAL

TAKE-AWAY THE ''CLESSIDRA'': DISMOUNT THE CONNECTIONS OF RAIL WITH SUPPORT AND FIXED THEM TOGETHER WITH TROLLEY THAN MOVE AWAY THE ''CLESSIDRA''

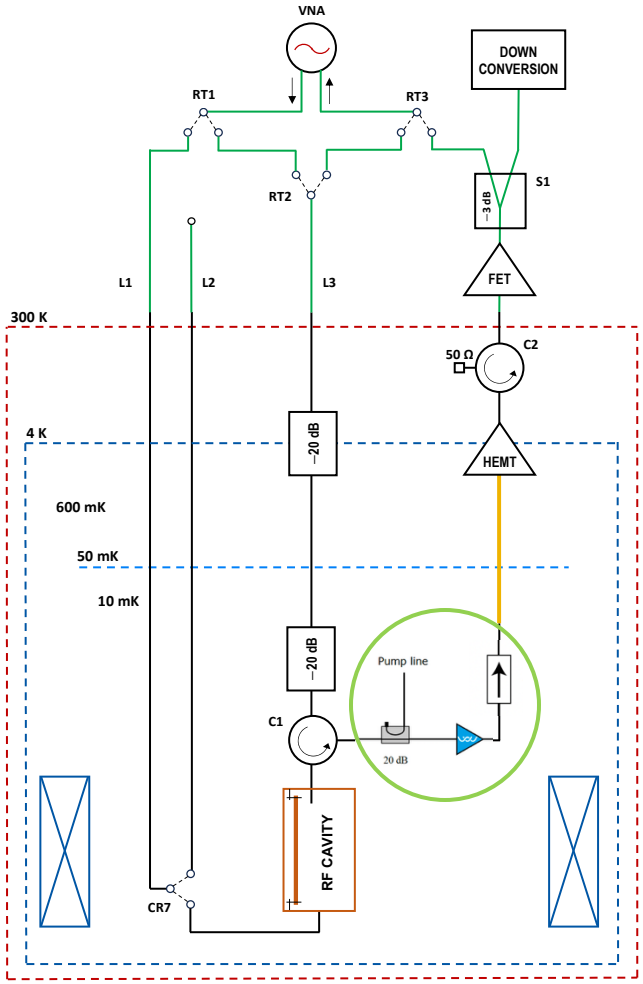




INFN INFN

QUAX

QUAX@LNF



Phys. Rev. D 110, 022008 (2024)

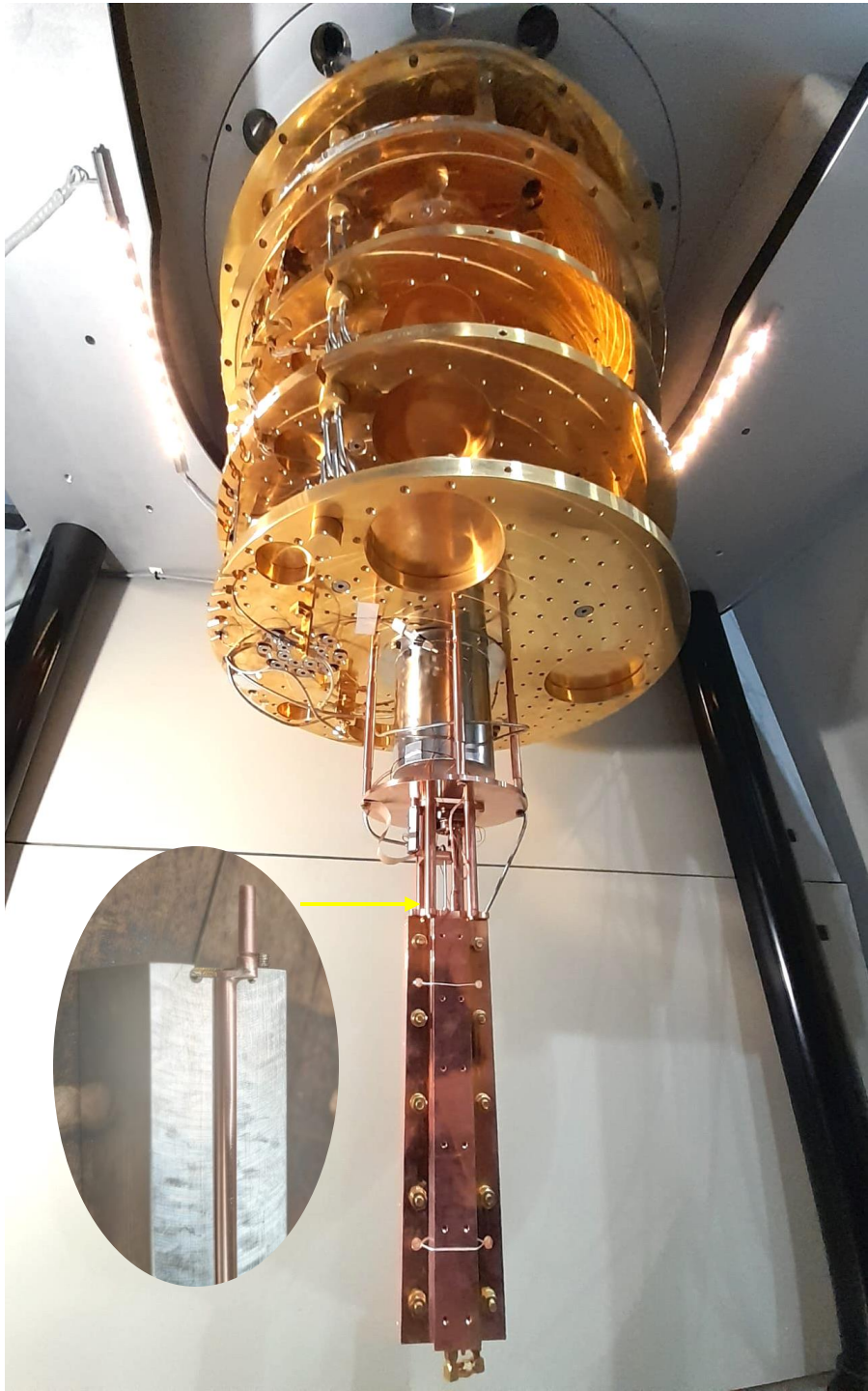
INFN QUAX

New QUAX@LNL results in PRL
https://doi.org/10.1103/4dv9-72t5

Improvements in LNF haloscope:

- Quantum limited TWPA amplifier
- Improved cavity tuner
- Calibration Noise source
- Multi-mode acquisition for HFGW
- GPS time acqusition
- New digitizer
- MIDAS DAQ

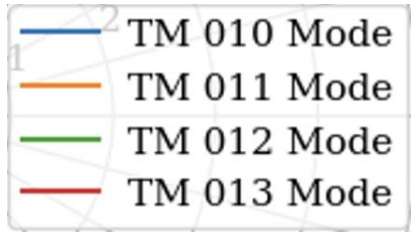
Technical stop of two months for a leak in the new thermal switch. Sending it back for repairs.

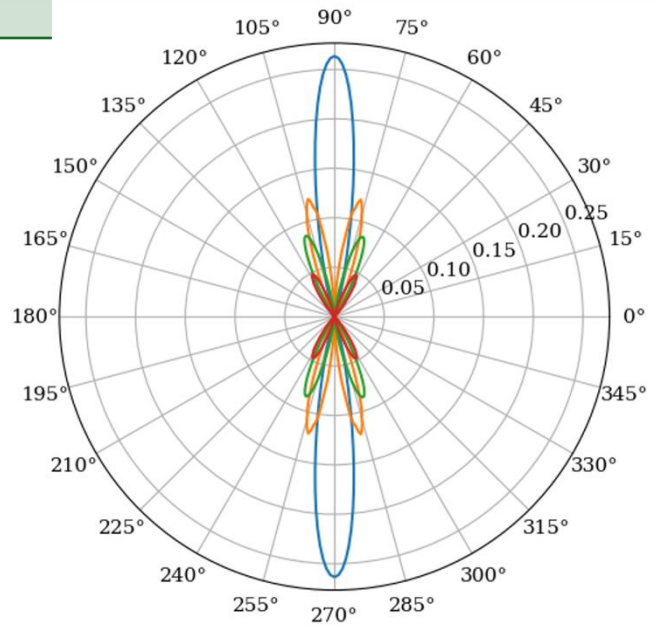


Multi-Mode Detection for HFGW

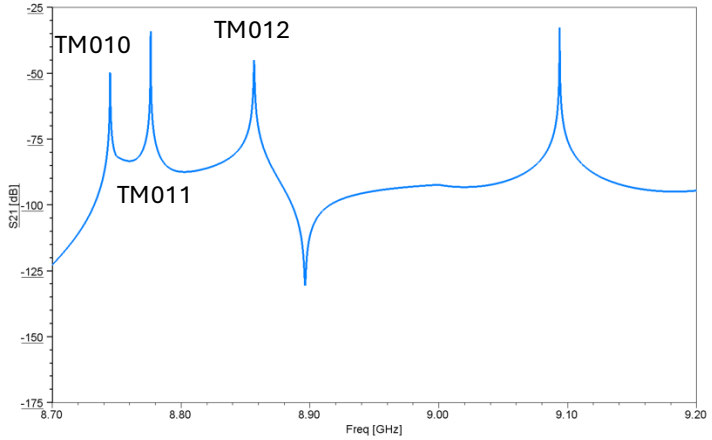
Acquisition setup for the next QUAX@LNF data take

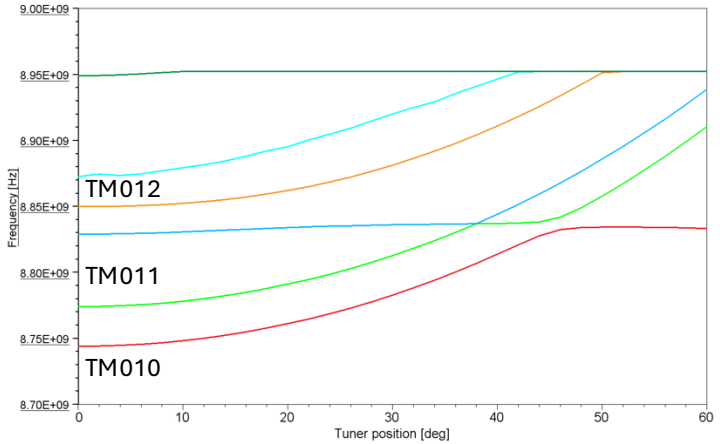
Mode QUAX@LNF	Resonant Frequency [GHz]	Q factor (@4°K)
TM010	8.67	1e5
TM011	8.69	1e5
TM012	8.75	1e5



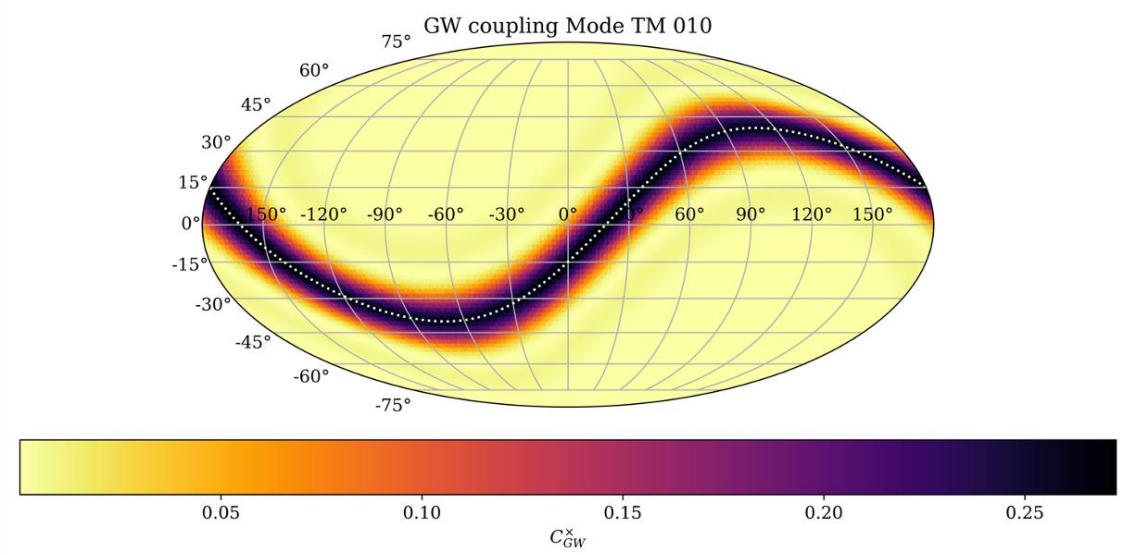


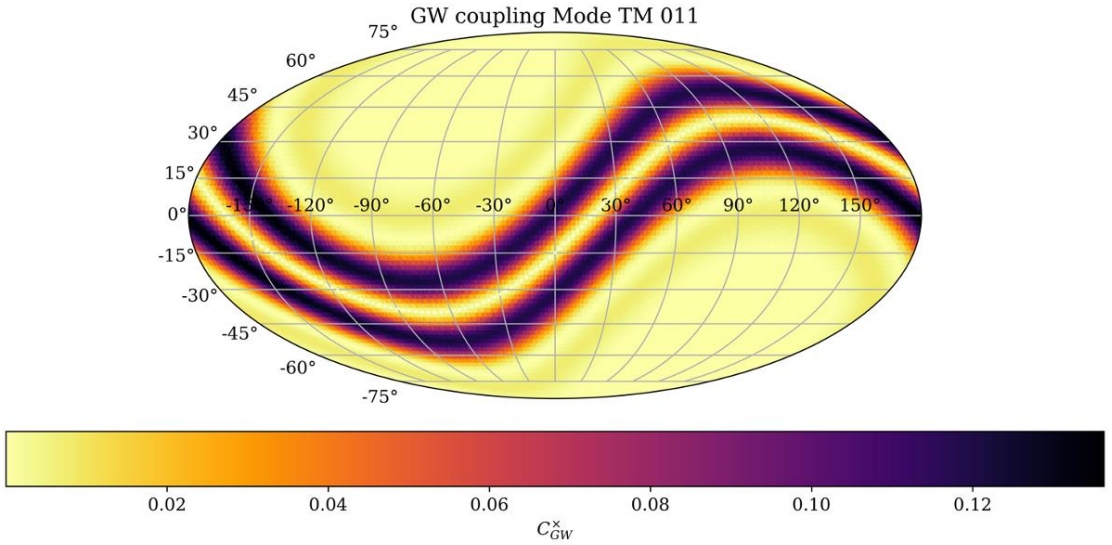
Credit Y. Kim





Daily Modulation

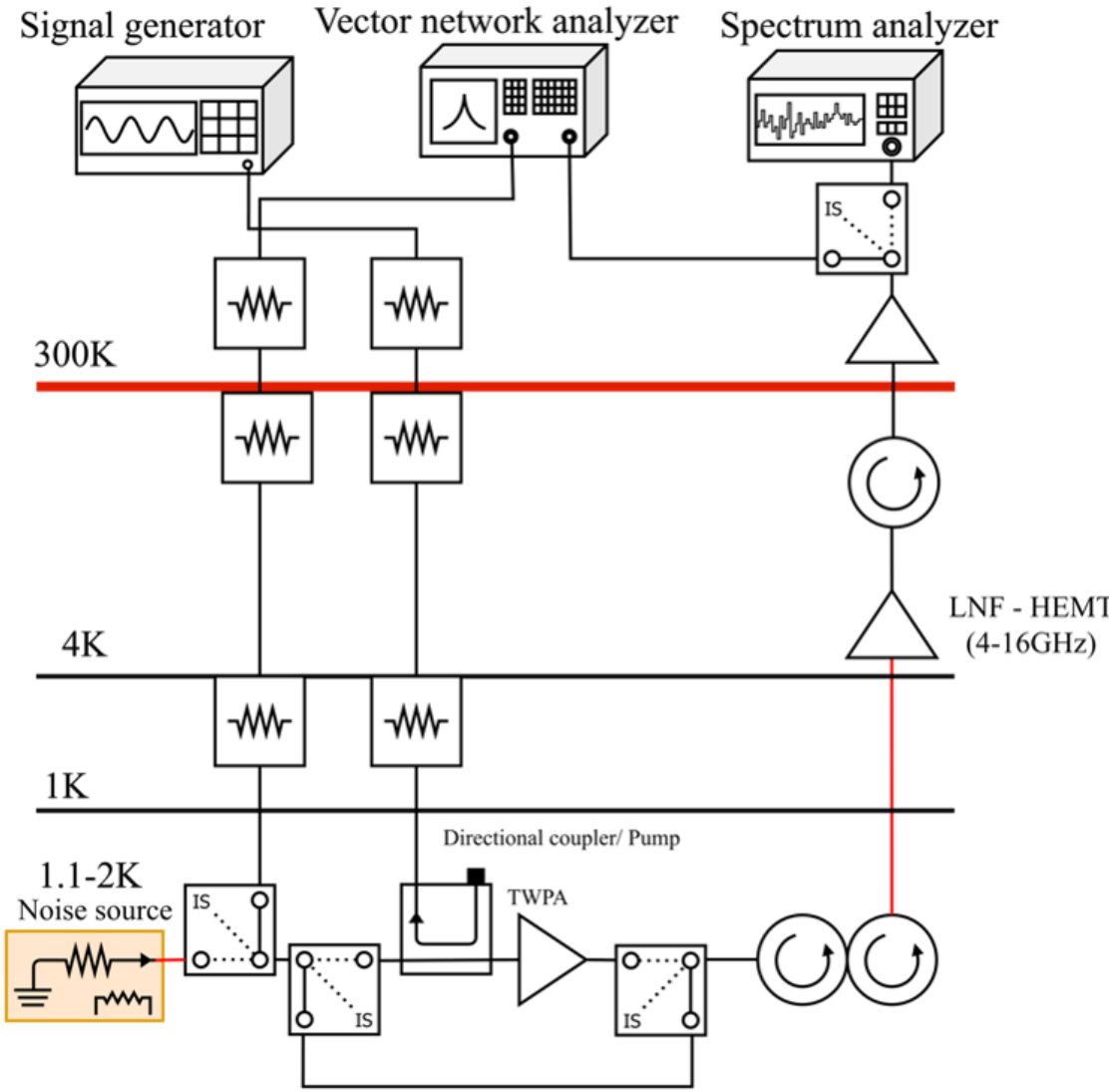


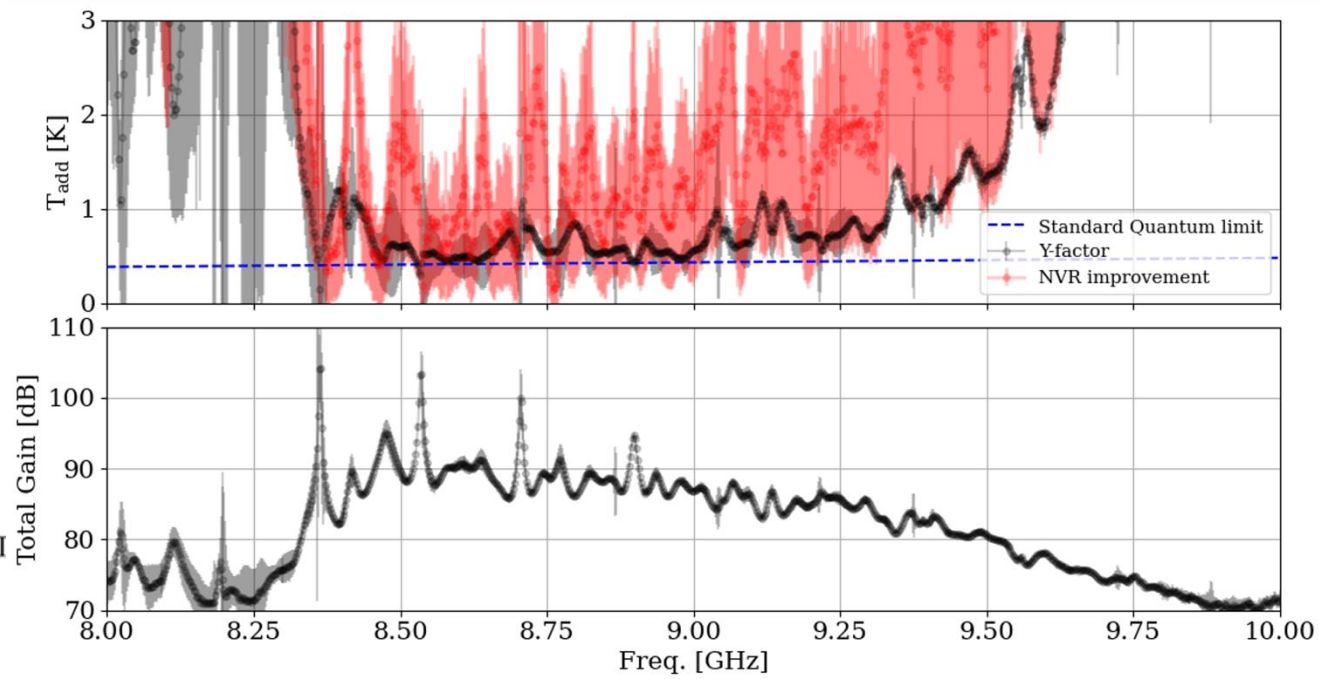


Credit Y. Kim

Coupling to GW from different directions

Characterization of TWPA Amplifier

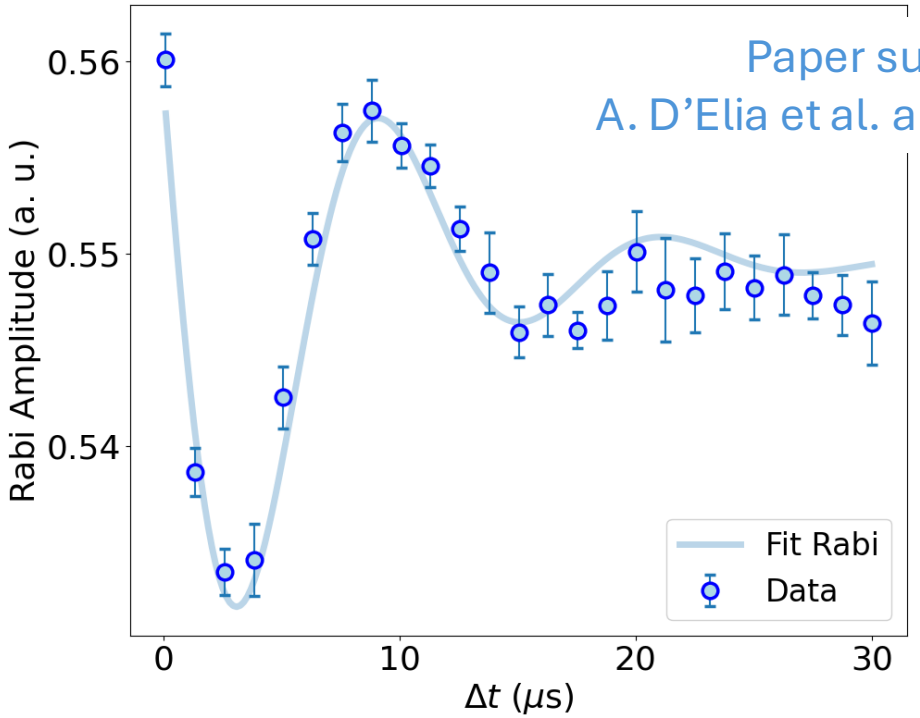




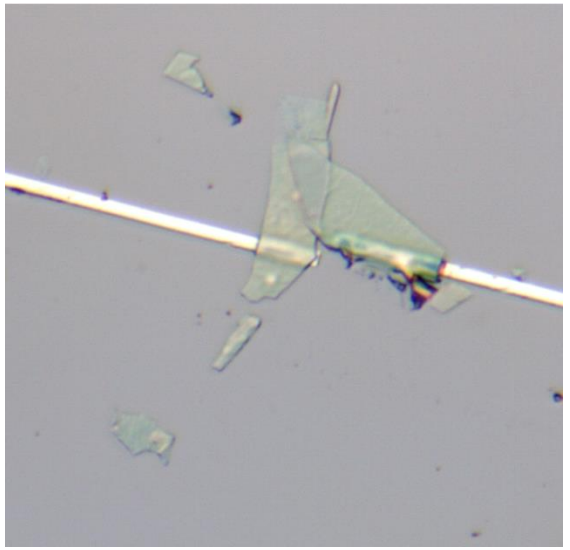
In collaboration with Y. Kim (Mainz) and S. Horodenski (Bonn) that joind at LNF the COLD team (led by A. Rettaroli) in October for the TWPA characterization.

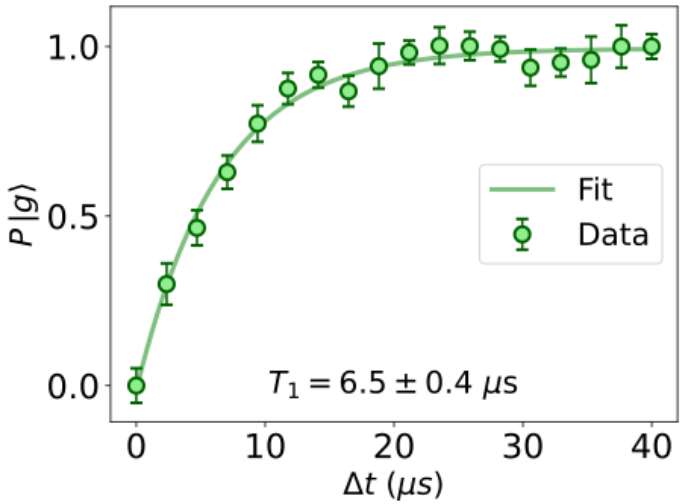

COLD
LNF
CryOgenic Laboratory for Detectors

Coherent Oscillations in Weakly Anharmonic NbSe2 Qubit



Paper submitted!
A. D'Elia et al. arXiv:2509.17160

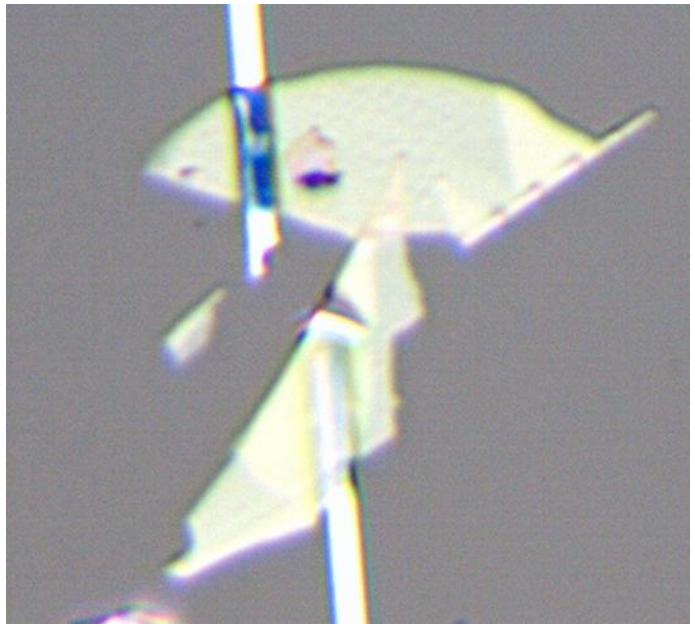


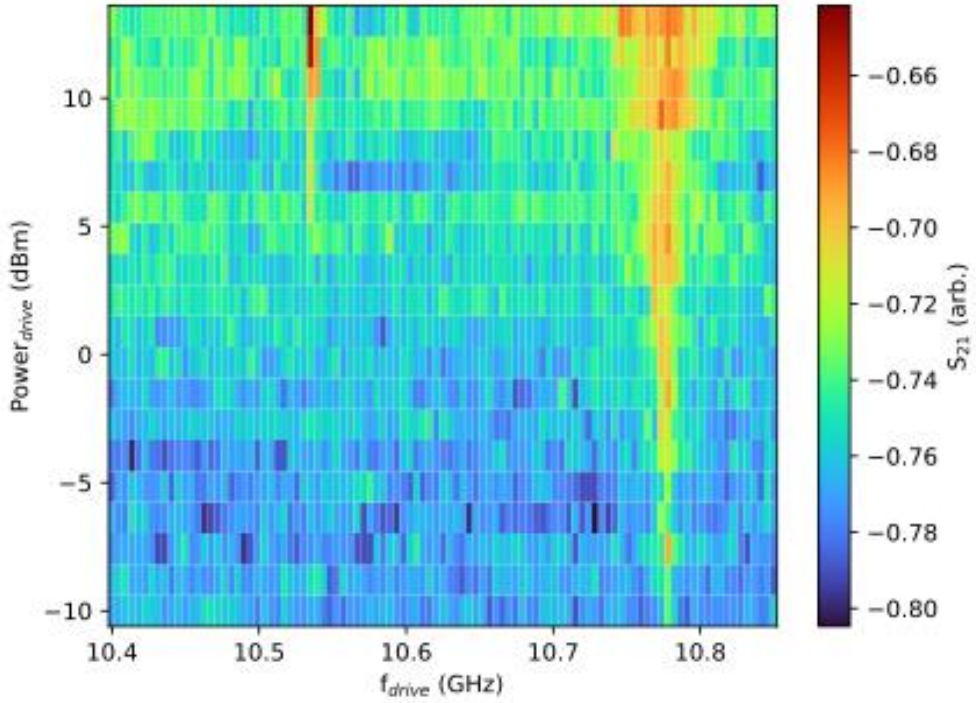


$$\nu_{qubit} = 12.6\ GHz$$
$$T_1 \sim 6.5\ \mu s$$

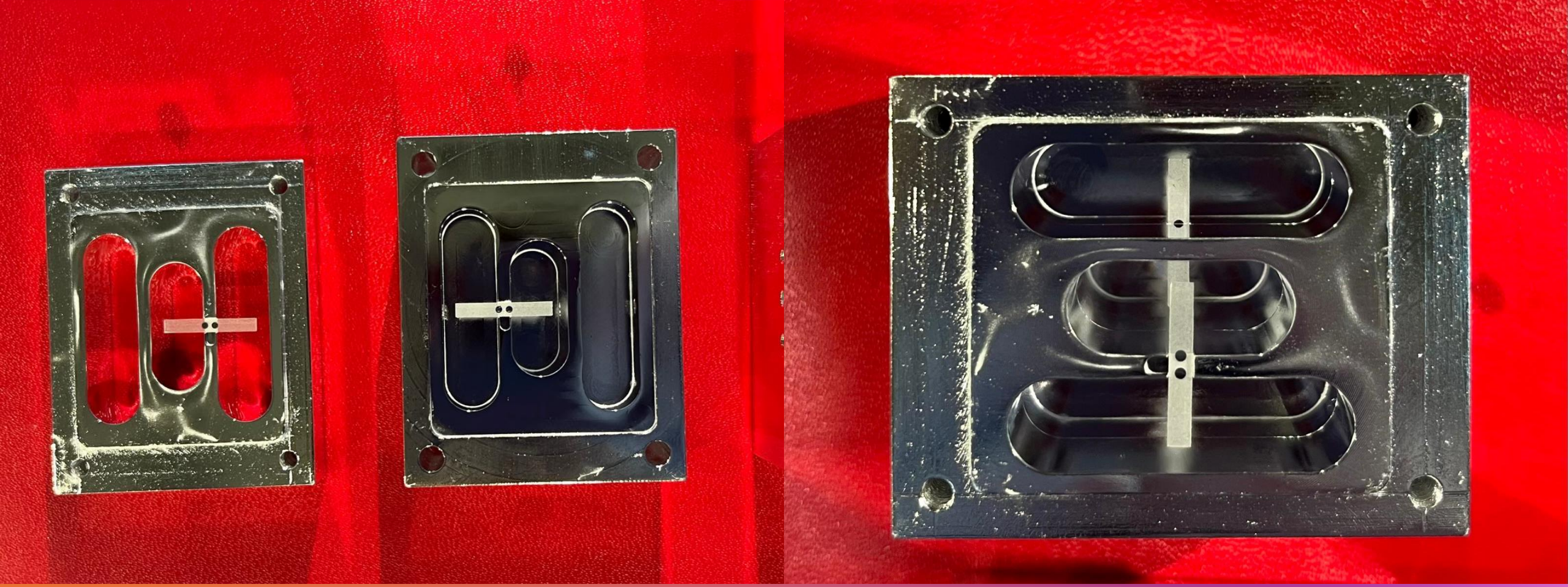
Resilience
PI Alessandro D'Elia

New $NbSe_2$ Qubit with large anharmonicity





- Frequency ~10.8 GHz
- Anharmonicity ~400 MHz
- Full Rabi, Ramsey and Echo characterization
- New paper in preparation!

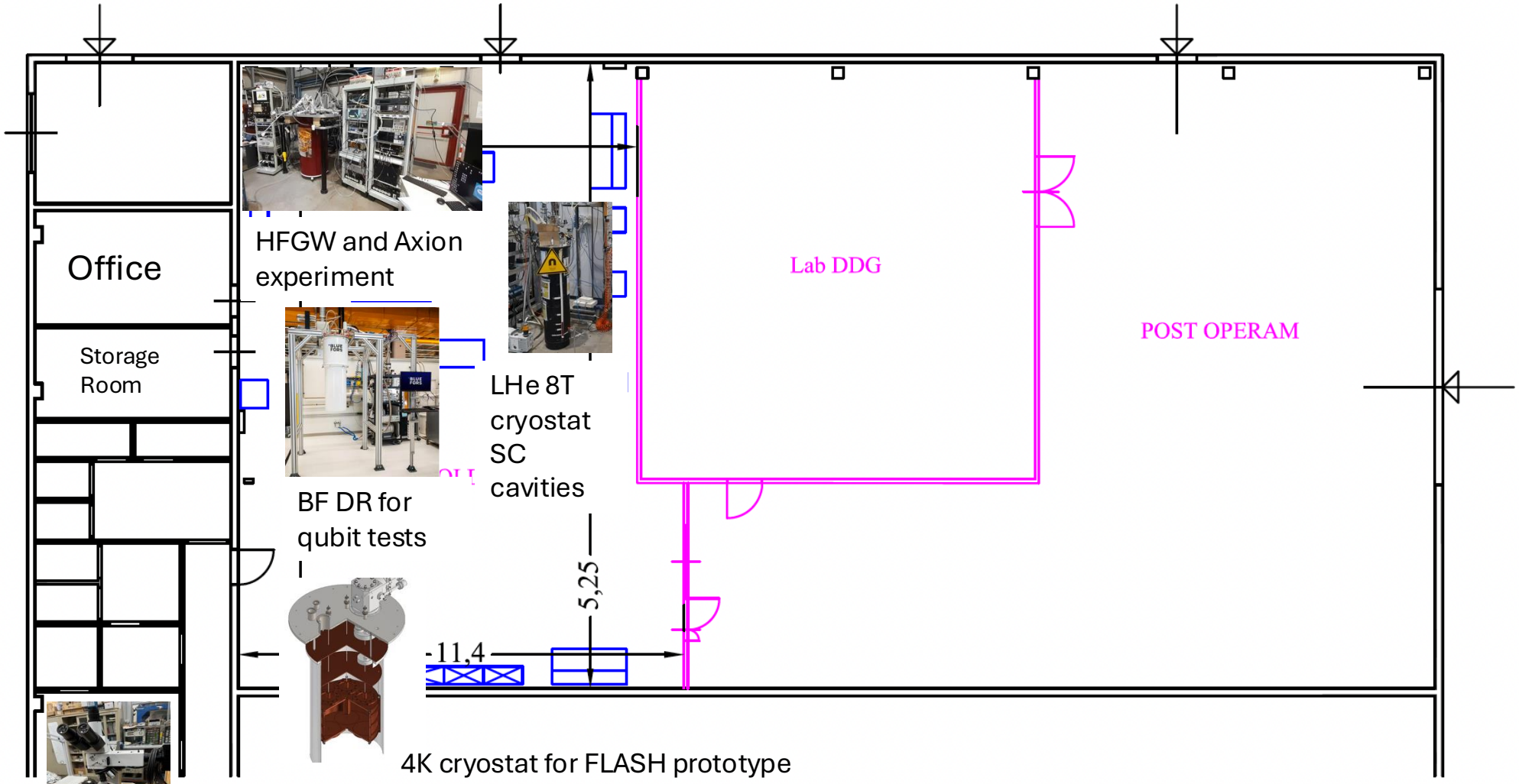


2 Qubits Photon-Counter

The resonant cavity was fabricated at INFN-LNL and the qubits at CNR-IFN (not the final qubit design).

A. Piedju et al. Nuovo Cimento proceedings IFAE 2025

COLD Lab expansion works



In summary

- GravNet Collaboration expanding.
- FLASH Collaboration is taking shape; Collaboration with CERN started; Periodic FLASH meetings; Engineering PhD students from La Sapienza etc.
- WP teams formed and work is progressing.
- Test of FLASH prototype foreseen in summer 2026: investigating the possibility of doing relativistic-DP searches.
- Preparing QUAX@LNF/GravNet multimode run; TWPA amplifier characterized; 2 months technical stop for a leak in the thermal switch
- Submitted paper on first NbSe2 qubit! New paper in preparation with results on new more anharmonic samples.
- LNL sent the triple cavity for the 2-qubits photon counter. We are now commissioning a foundry to produce the qubits.