

QUART&T's got facilities

WP7 - M. Faverzani and A. Rettaroli

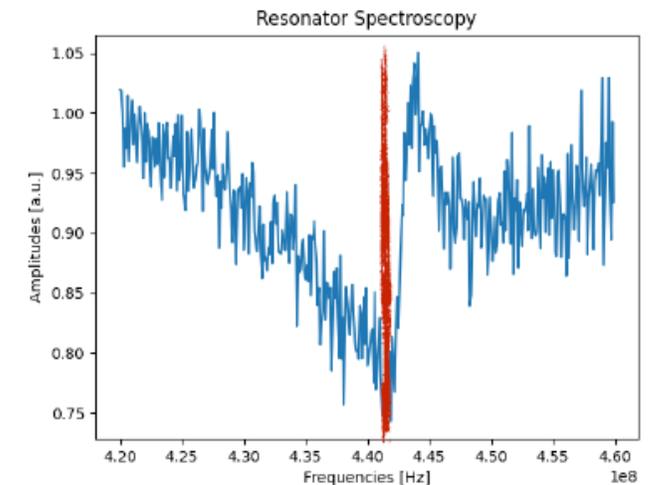
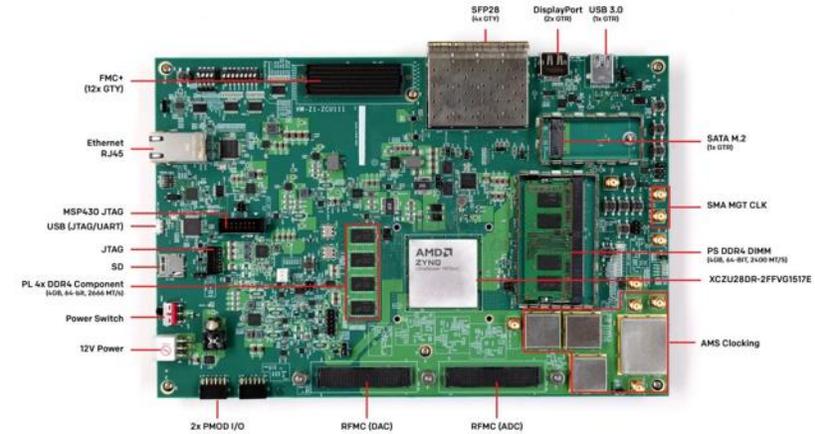
6 facilities:

1. INFN – Bologna
2. INFN – Laboratori Nazionali di Frascati (LNF)
3. INFN – Lecce
4. INFN – Milano Bicocca
5. INFN – Pisa
6. INFN – Trento Institute for Fundamental Physics and Applications (TIFPA)

INFN - Bo

WP7 – Bologna

- The group owns an AMD/Xilinx Zynq Ultrascale+ RFSoc ZCU111 Evaluation kit (main board + XM500 balun card)
- 8 ADC/DAC embedded (4/6 Gsps, 12/14 bit)
- Building expertise in usage of QICK and QIBO during the last year of the Qub-IT project
- Participated in the single qubit characterization at LNF in May 2024
- Successful test for single-tone spectroscopy
- Used local RF oscillators at LNF for up/down conversion
- In Bologna, a RF oscillator (6 GHz) of the Electronic Service can be borrowed for short periods of time (1-2 weeks)



WP7 – Bologna

- We plan to buy a RF oscillator in 2026 to be used with the ZCU111 for the Drive and Readout/Feedback control at frequencies not directly reachable
- Ongoing: purchase of a new VFE-100 board by «Intermodulation Products» as a replacement of the XM500 front-end card (access to ADC/DAC without undesired attenuators and filters)
- We also plan to gain experience with the usage ZCU208 (Gen. 3)
- Preliminary contacts in 2024 with the FE group (ZCU208 available in Ferrara)
- The idea is to provide support at the LNF group in the data acquisition, if necessary even using some hardware available at the LAB

VFE-100
Front-end card for 1st generation RFSoc evaluation board



- 8 single-ended inputs, 10MHz - 4 GHz
- 8 single-ended output, 10 MHz - 4 GHz
- Additional DAC for DC bias on each output
- 4 digital input ports and 4 digital output ports
- SMA connectors
- Compatible with AMD Xilinx Zynq UltraScale+ ZCU111 evaluation board

Laboratori Nazionali di Frascati

LNf dilution unit

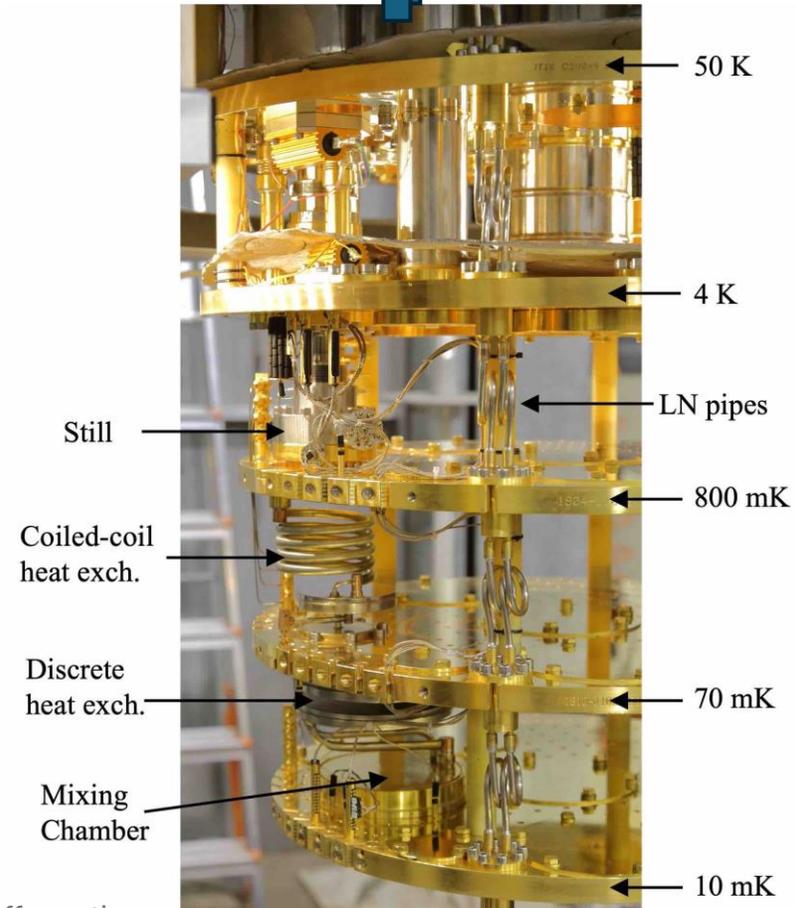
$$T_{base} = 8 \text{ mK}$$

Cooling power:
 $500 \mu\text{W}$ @ 100 mK

- 3 high-attenuation input rf lines
- 1 low-loss SC output rf line

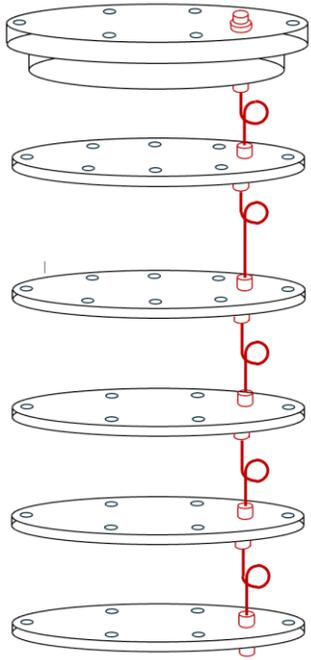
RF instrumentation:

- VNA
- Signal gen. (LO and drive)
- Mixers
- Wavefunction gen.
- Digital oscilloscope (DAQ)



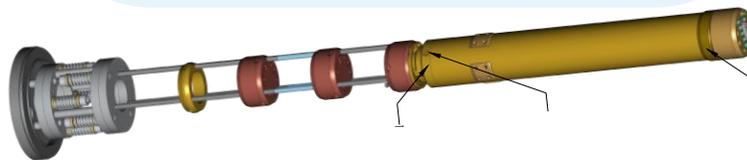
LNf setup upgrades

8 new RF lines in Leiden C. cryostat



New BLUEFORS cryostat

- 16 RF lines; 4 are low-loss SC
- 72 DC wires
- Cryogenic Variable Temperature Noise Source
- Insertable cold probe



Upgrade of an old cryostat:

Will be provided with Sumitomo Pulse Tube (1.2 W@4.2 K).

To become a **4K test station**

LNf setup upgrades

Purchased new readout electronics
for qubits

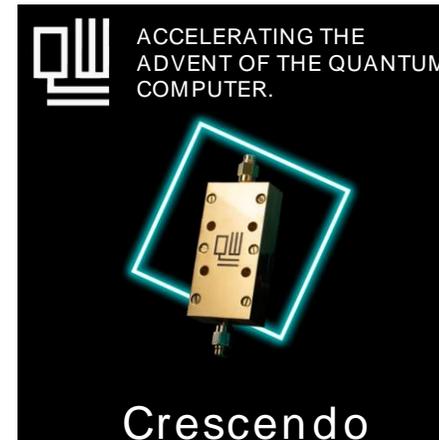
 KEYSIGHT **M5301A**



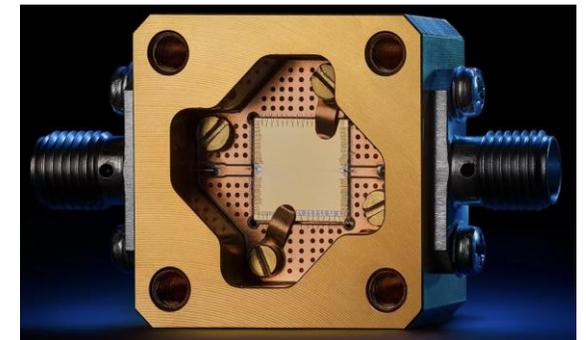
4 channels
400 MHz bandwidth
2.4 GS/s rate
FPGA integrated

- TWPAs purchases to be done
- TWPAs from collab (WP6)

QuantWare



 SILENT WAVES



INFN - Le

INFN LECCE / EMFL-IRIS Infrastructure / Omnics Lab

Laboratory for Magnetism and Superconductivity



Cryogenic superconducting magnet (10.5 T, 0.3-300 K)



Oxford dilution refrigerator (down to 10 mK, vector magnet 6T/1T/1T)



Lakeshore Cryogenic RF probe station (8 K, 0.5 T and 70 GHz)

NEW INSTRUMENTATION [PNRR-IRIS]

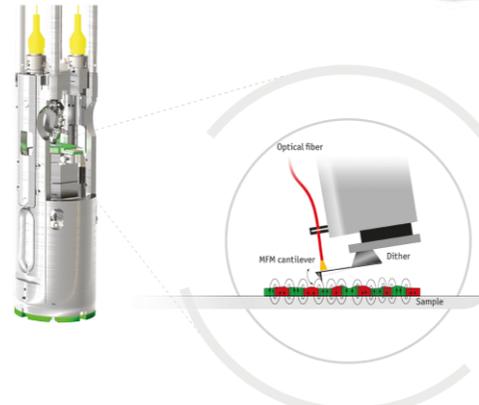


close-cycle SQUID magnetometer

close-cycle superconducting magnet for physical properties measurement



split pair cryogen-free magnet system for combined magneto-optical and FMR measurements



scanning probe microscope (MFM, PFM up to 9T and 2K)



ZNA vector network analyzer @ 67 GHz, four channels

EU and IT infrastructures



EU / EMFL-ISABEL



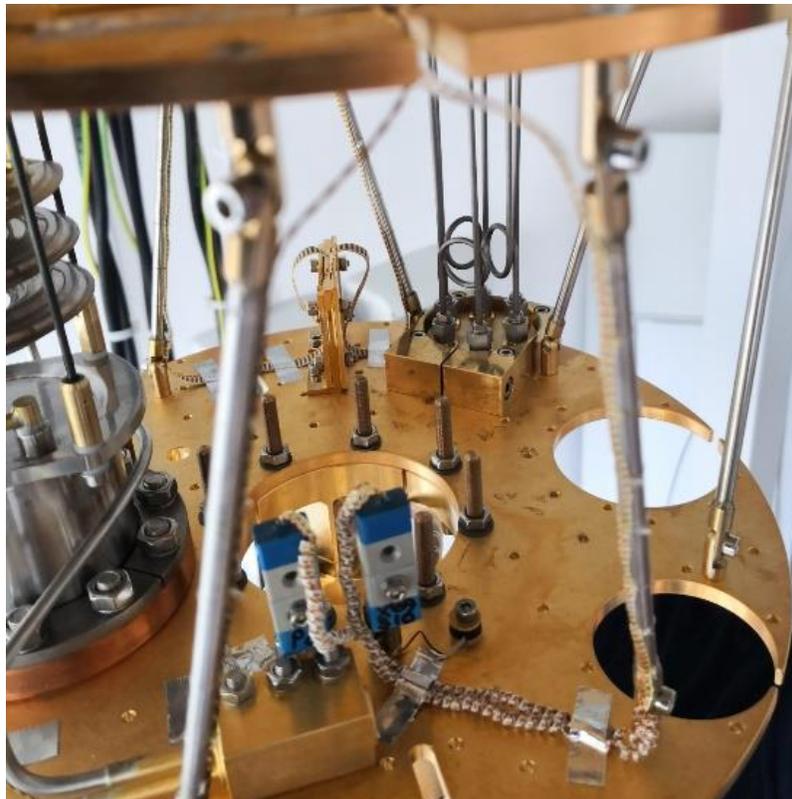
IT Magnetism Network



INFN LECCE / EMFL-IRIS Infrastructure / Omnics Lab

Measurement capabilities

Oxford dilution refrigerator (down to 10 mK, vector magnet 6T/1T/1T)



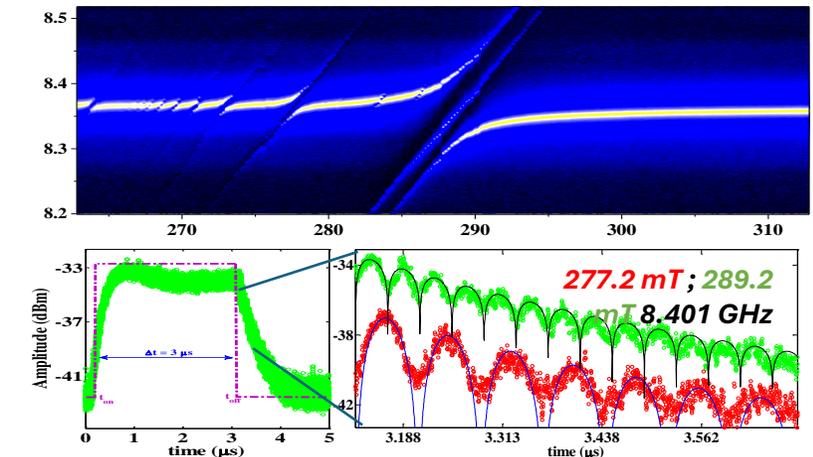
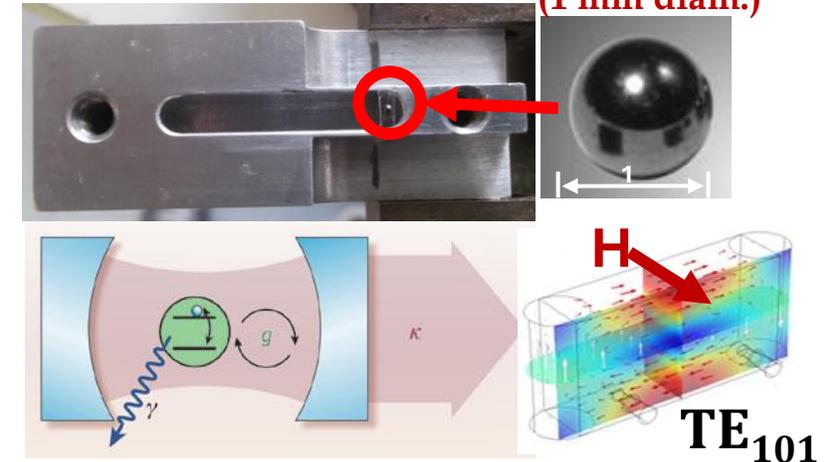
SETUPS AVAILABLE:

- Magnetotransport down to 15mK
- MW measurements up to 67GHz, four channels (VNA) (8K)
- Vector magnet 6T/1T/1T (18 GHz, 15mK))
- High field up to 10.5 T (and beyond within EMFL)
- Magnetometry (1K, 9T)

QMEASUREMENTS CAPACITIES

- Strong coupling measurements in cavity resonators
- Qubit measurements: to be tested in operative conditions, possible need for improvement in sample box (shielding and sample temperature) and MW lines (attenuation and filtering)

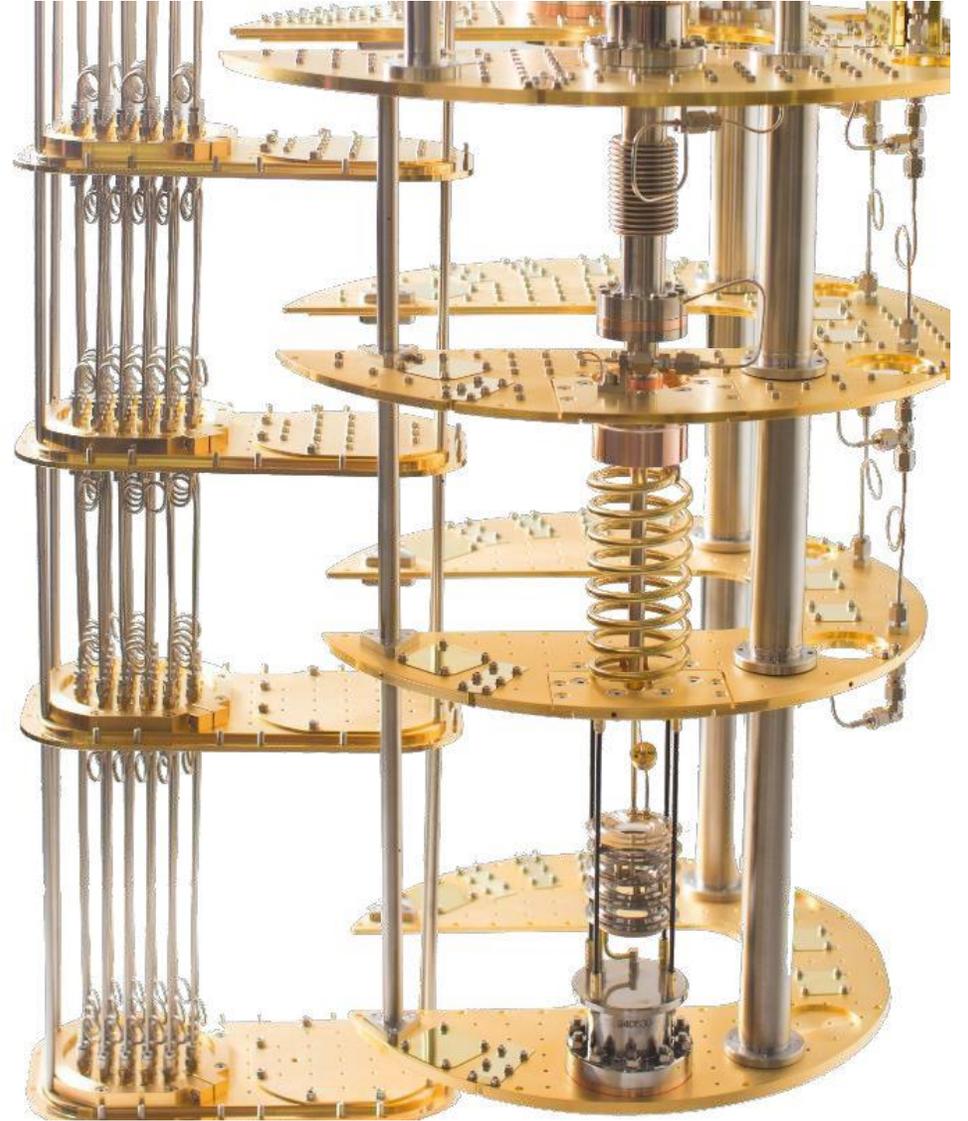
YIG sphere (1 mm diam.)



INFN - MiB

Milano – Bicocca: cryostats

- Now: one dry $^3\text{He}/^4\text{He}$ cryostat + one wet with coax lines, HEMT and circulators
- By June, two brand new dry cryostats Proteox by Oxford instruments procured within NQSTI (PNRR)
 - 400 μW @ 100 mK
 - each instrumented with 10 semirigid coax lines, 3 of which in Nb with HEMTs + double junction circulators
 - one additional insert with semirigid coax + HEMTs + circulators for fast sample switching
 - cold cryoperm for magnetic shielding
 - one cryostat equipped with 6-1-1 T vector magnet
- New, joint lab with 5 refrigerators is being built, in the meantime temporary labs



Milano – Bicocca: readout and electronics

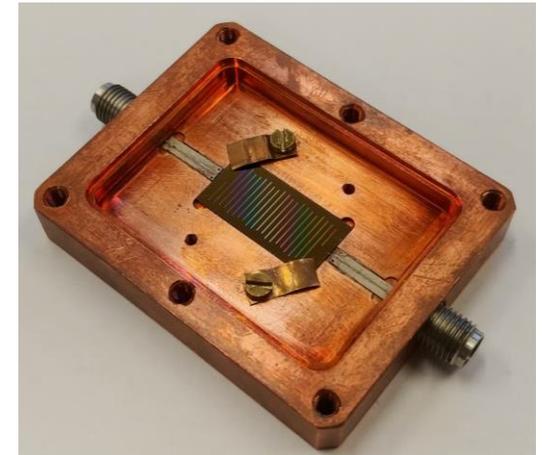
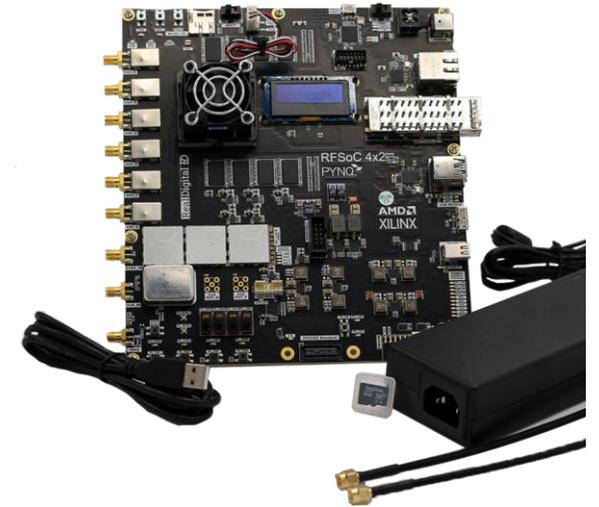
- Several RFSoc boards:
 - ZCU111: 8x ADC 4 GSPS; 8x DAC 6.5 GSPS
 - RFSoc 4x2: 4x ADC 5 GSPS; 2x DAC 9.85 GSPS
 - already used for this characterization of trasmons: [arxiv:2409.05988](https://arxiv.org/abs/2409.05988)
 - ZCU216 by the end of the year: 16x ADC 2.5 GSPS; 16x DAC 9.85 GSPS
- Quantum controller by Quantum Machines OPX+: 8x 400 MHz outputs; 2x 400 MHz inputs; 10x digital outputs
 - up/down converter Octave: 5x up-converted 2-18 GHz outputs; 2x down-converted 2-18 GHz inputs

Parametric amplifiers:

- JPA from NIST: tunable center frequency 6-10 GHz
- 2x JTWPA from *Silent-Wave (Argo and Carthago)* by the end of the year
- KI-TWPA developed within MiSS/DARTWARS and in collaboration with NIST

Ancillary instruments:

- VNAs, Spectrum Analyzers, AWGs, Synthesizers, ...
- Extensive use of Qibocal ([arxiv:2410.00101](https://arxiv.org/abs/2410.00101)), Qibolab([arxiv:2308.06313](https://arxiv.org/abs/2308.06313)), and Qibosoq ([arxiv:2310.05851](https://arxiv.org/abs/2310.05851))



INFN - Pi

Today

Cryostats

- Bluefors SD $T < 22$ mK with 4x RF (20 GHz) + 48 DC in an EMI shielded room
- Custom Chase $T < 300$ mK with DC capabilities

Electronics

- Vector Network Analyzer up to 44 GHz
- Arbitrary Waveform Generator up to 12 GS/s

Cold (4 K) amplification

- HEMT amplifier 0.3 - 14 GHz



Tomorrow

Cryostats

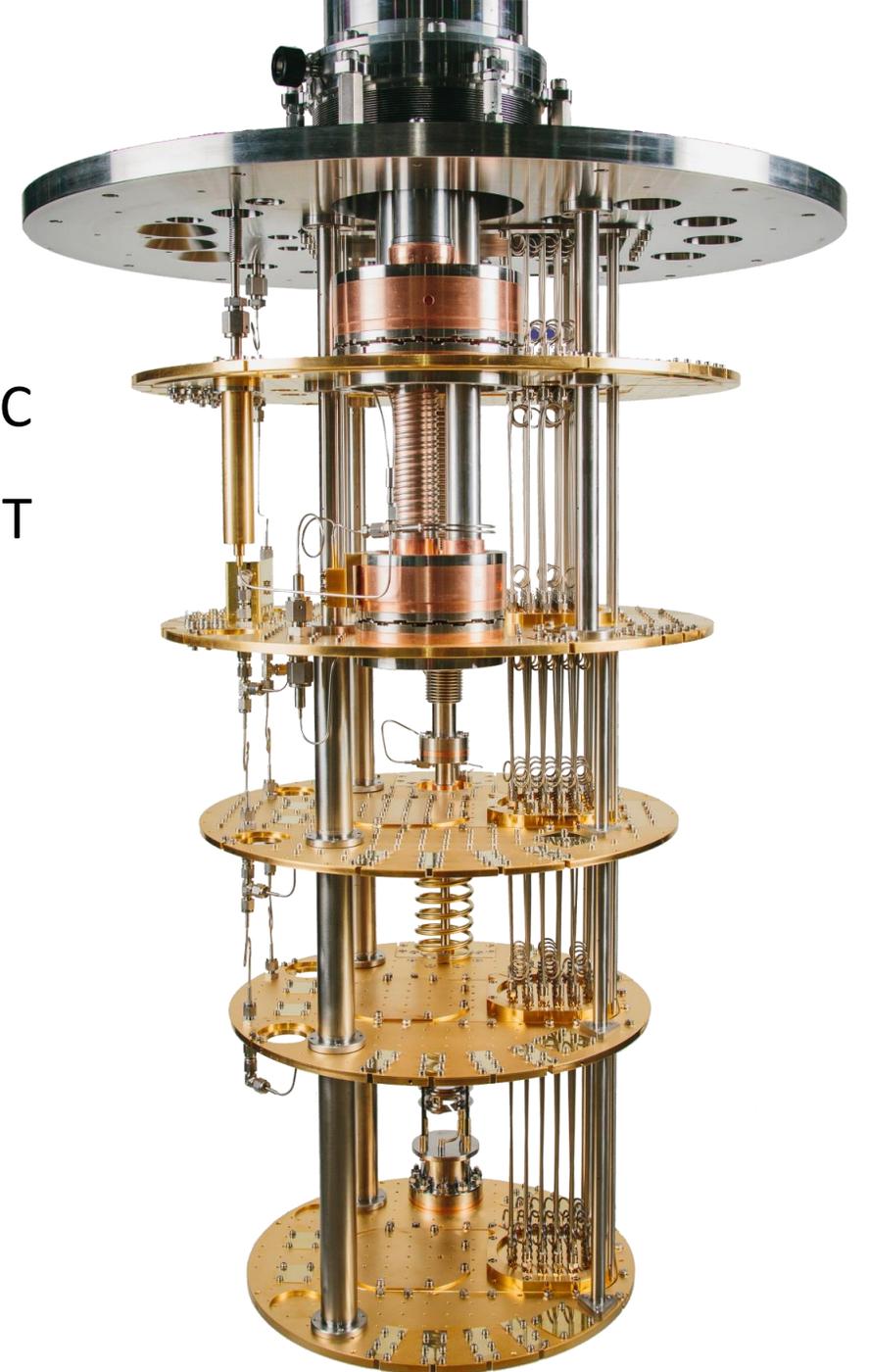
- Oxford Instruments Proteox MX with 8 RF lines, 48 DC lines, removable secondary insert, triaxial magnet 6-1-1 T
(Delivery 06/2025)

Electronics

- Keysight Qubit Controller for few qubit operation
(Delivery 03/2025)

Cold (4 K) amplification

- HEMT amplifier 4 - 8 GHz (Delivery 04/2025)



TIFPA

Cryogenic laboratories at



Istituto Nazionale
di Fisica Nucleare

TIFPA

Trento
Institute for
Fundamental
Physics and
Applications

UniTn Cryogenic Lab



Fridge:

- DR Janis, $T_b = 30$ mK
- 2 input lines, 1 output lines + switches

Liquid He (with recovery line)

RF instrumentation:

- VNA Copper Mountain C2220 20 GHz
- Spectrum Analyzer HP 20 GHz
- Signal generator Anapico 20 GHz
- Signal generator Marconi 5.4 GHz
- AWG Siglent SDG7102A 1 GHz
- etc. ...

Activities

Characterisation of devices at mK
Fast testing in liquid He at 4K



Cryogenic laboratories at



Istituto Nazionale
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TIFPA

Trento
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Physics and
Applications

FBK Cryogenic Lab



Fridges:

- DR Bluefors LD250, $T_b = 8$ mK
8 input + 2 output lines
(in expansion)
- Cryocooler, $T_b \sim 4$ K

**BLUE
FORS**



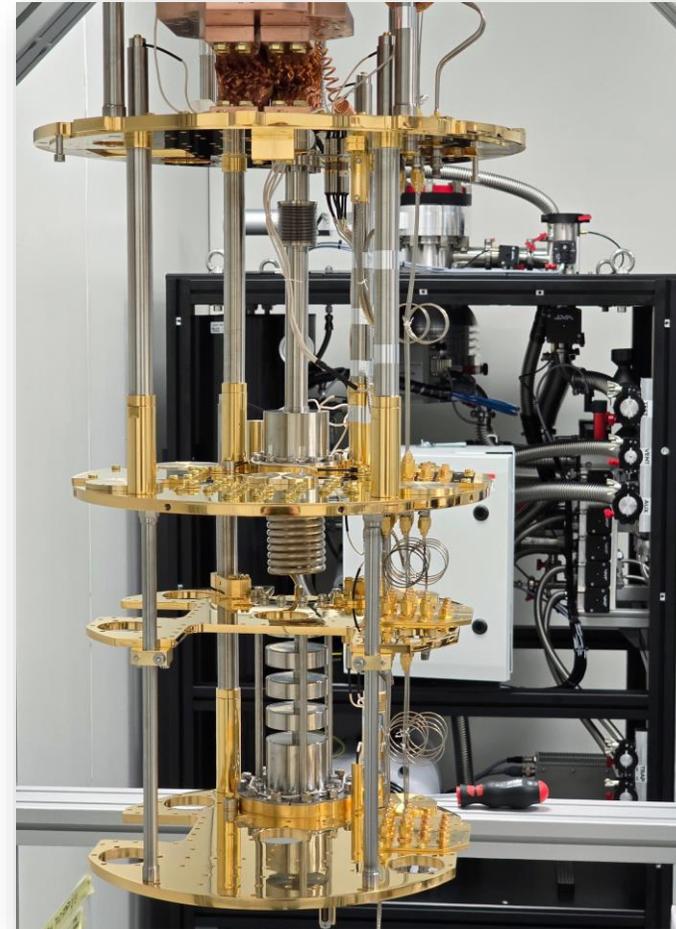
RF instrumentation (R&S):

- VNA ZNB 26 GHz
- Signal generator SMB-100B
- Spectrum analyzer FPL
etc. ...



Qubit control:

- RFSoc board 4x2 Kit



Activities

- Characterisation of devices
- Fast testing with cryocooler
- Qubit measurements (RFSoC)