LiteBIRD(-LNF):

the measurement of the B-mode polarization of the CMB

Contributed by the INFN-LNF Group:
L. Porcelli, S. Dabagov, G. Delle Monache,
D. Hampai, G. Modestino.

The measurement of the B-mode polarization of the CMB: the path towards the next space experiment

Giovanni Signorelli
INFN Sezione di Pisa

INFN Laboratori Nazionali di Frascati - 8 June 2022

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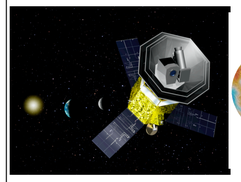
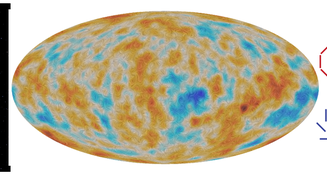
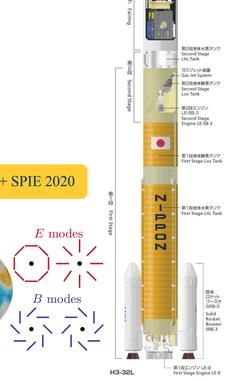
LiteBIRD overview

- Lite (Light) satellite for the study of *B*-mode polarization and Inflation from cosmic background Radiation Detection
- JAXA's L-class mission selected in May 2019
- Expected launch in late **2029** with JAXA's H3 rocket
- **All-sky 3-year survey**, from Sun-Earth Lagrangian point L2
- Large frequency coverage (**40–402 GHz**, 15 bands) at **70–18 arcmin** angular resolution for precision measurements of the **CMB *B*-modes**
- Final combined sensitivity: **2.2 μK·arcmin**

📖 Hazumi+ SPIE 2020

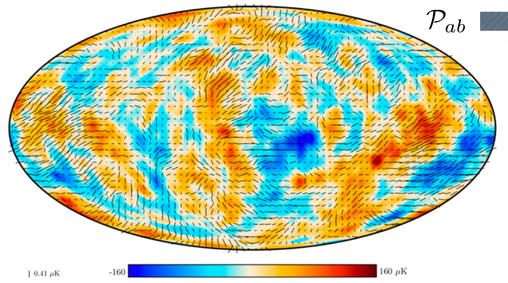






How do we measure polarization?

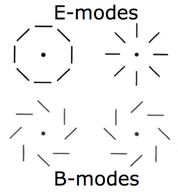
- Monopole term: 2.725 K blackbody — $O(1)$
- Dipole term: 3.355 mK — $O(10^{-3})$
- Anisotropy: 100 μK rms — $O(10^{-4})$
- Tensor perturbations produce a background of primordial gravitational waves — $O(10^{-6 \div 7})$
  - E-mode polarization: 3 μK rms
  - B-mode polarization: <500 nK rms



$\mathcal{P}_{ab}$

$$E \sim \partial_a \partial_b \mathcal{P}_{ab}$$

$$B \sim \epsilon_{ac} \partial_b \partial_c \mathcal{P}_{bc}$$



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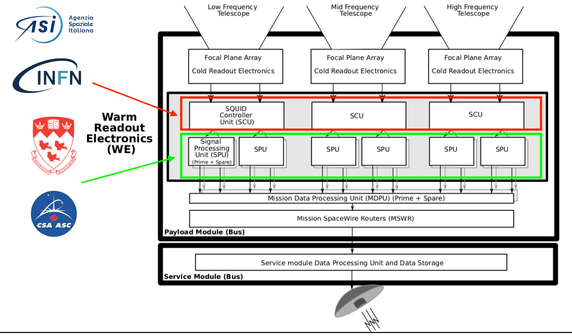
LiteBIRD readout system: INFN contributions

INFN is part of the ASI-lead italian contribution
- hardware and software/simulation/analysis
- PI(lead), MIB, FE, MI, TS, RM1, RM2

Two main hardware contributions:
- SQUID Controller Unit (SCU) for 3 telescopes: electronics, thermo-mechanical design, interfaces, shielding
- Flight qualification of critical components: in particular, DAC LTC1668 (required, but not qualified yet)

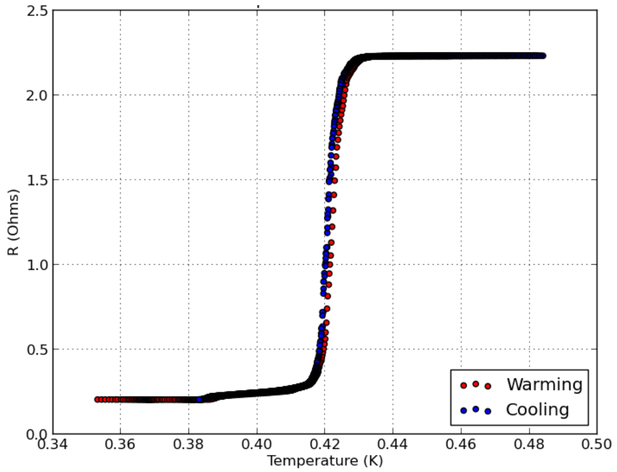


Slide courtesy: G. Signorelli.

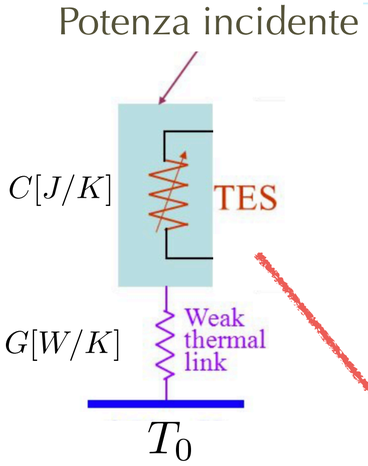
Transition-Edge Sensors

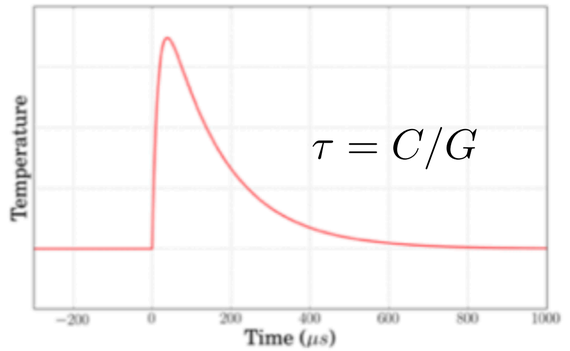
- "Thermometers" that enable us to measure tiny temperature variations
- Superconducting films at their phase transition

steep $R(T)$



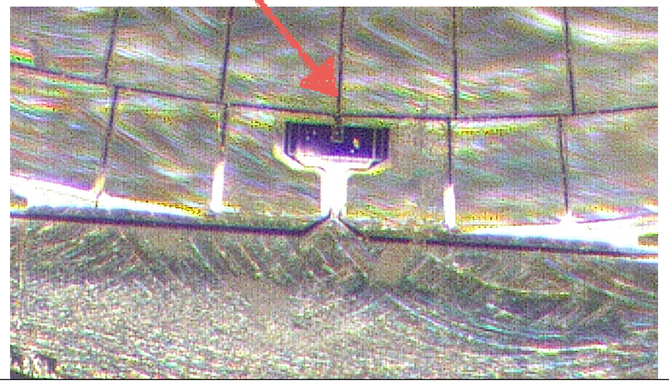
$$P_{\rm ott} = C\frac{{\rm d}T}{{\rm d}t} + G\,(T - T_0)$$





$$\frac{10\ \Omega}{1\ {\rm mK}} = 10^4\ \Omega/{\rm K}$$

$$100\ {\rm nK} \Rightarrow 1\ {\rm m}\Omega$$



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Slide courtesy: G. Signorelli.

Workshop 'LiteBIRD-Italia 2023 @ INFN-LNF (LB-ITA23@INFN-LNF)'

May 22 – 24, 2023
Laboratori Nazionali di Frascati (Rome), Italy
Europe/Rome timezone

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La missione spaziale LiteBIRD, a guida giapponese (JAXA) ma con significativa partecipazione europea, ha come obiettivo principale di rivelare le onde gravitazionali primordiali generate durante l'inflazione, attraverso misure di estrema precisione della polarizzazione del CMB. La partecipazione italiana consiste di nodi universitari, ASI (principale finanziatore italiano), INAF e INFN. Il gruppo LNF, recentemente coinvolto, ospita il workshop in cui viene presentato lo stato di avanzamento del progetto verso l'approvazione della fase-B, in tutte le sue componenti: sviluppo strumentale, simulazioni, analisi e vincoli modellistici.

Il 22 e 23 maggio si passeranno in rassegna le attività in corso da parte della collaborazione italiana.

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Recording 22/05/2023: Link, Password = $8ib8!xk
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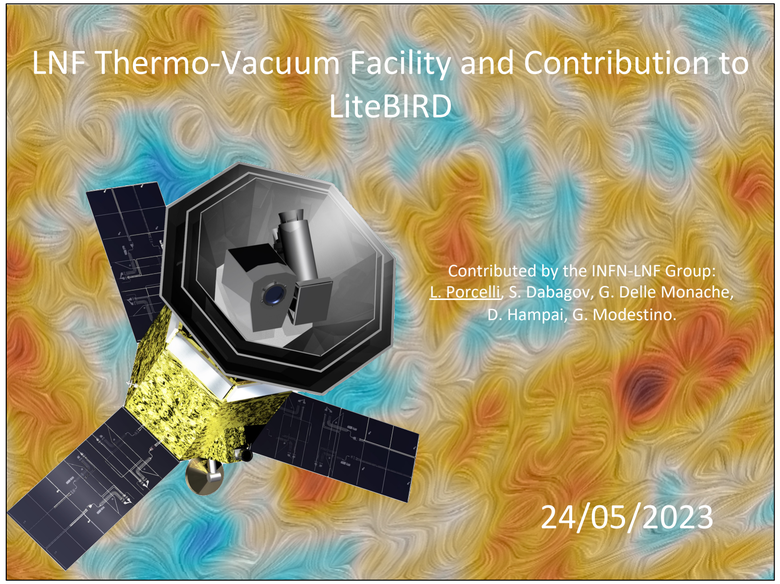
Recording 24/05/2023: Link, Password = dymi&#M6

Ultimo Aggiornamento: 26/05/2023.

LOC:

Luca Porcelli (Chair), Giovanni Delle Monache, Sultan Dabagov, Dariush Hampai, Giuseppina Modestino.



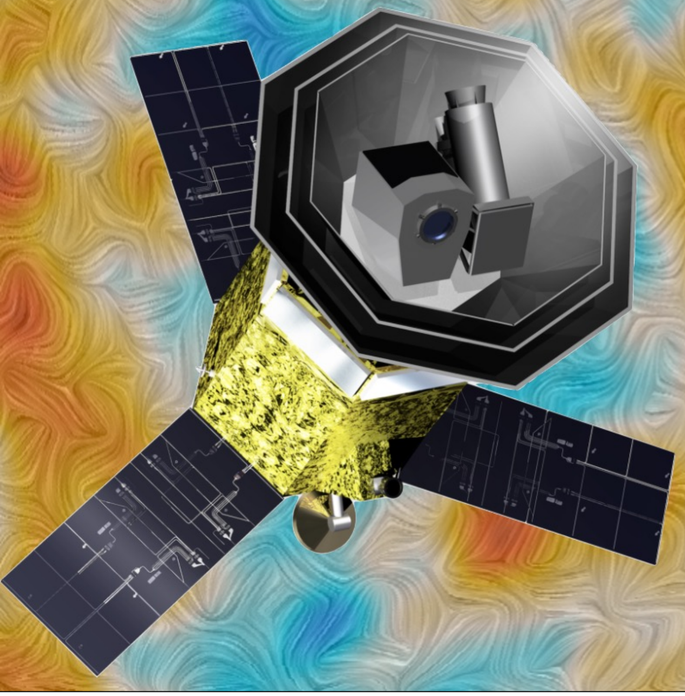
https://agenda.infn.it/event/35371/

Proposed Activity @ INFN-LNF

Foreseeable activity as of July 2022:

- Thermal balance test (and correlation to models with the software Thermal Desktop) thanks to the ‘pocket’ cryostat (see following slides).
- (Non)destructive irradiation testing @ XlabF (Dabagov and Hampai), with extrapolation at longer wavelengths, and X-ray circuitry diagnostics on specifically dedicated and instrumented optical bench.
- Involvement in data analysis, modelling and simulations for the physical processes of interest, at ‘cosmological’ level, with Modestino, Dabagov and Porcelli, and eventually involving PhD students.
- Involvement in PA/QA of the flight hardware.

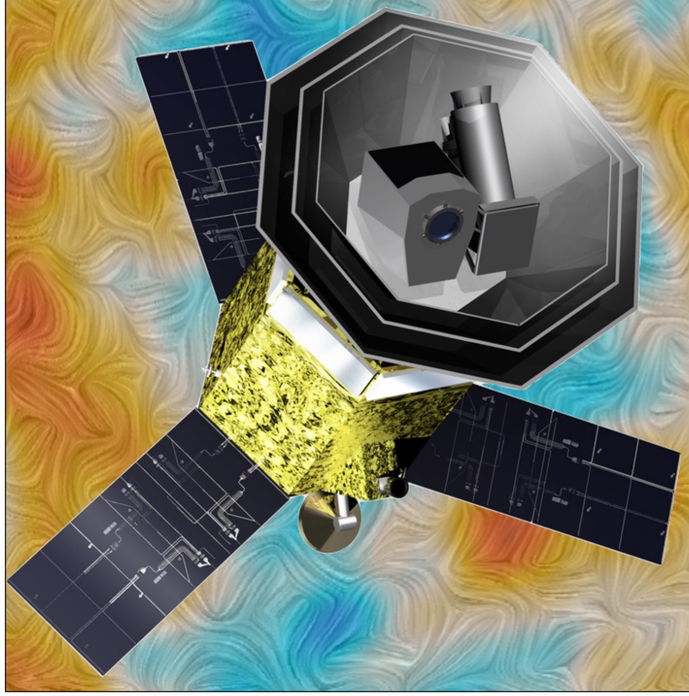
LNF Thermo-Vacuum Facility and Contribution to LiteBIRD



Contributed by the INFN-LNF Group:
L. Porcelli, S. Dabagov, G. Delle Monache,
D. Hampai, G. Modestino.

24/05/2023

LNF Thermo-Vacuum Facility Completion



Contributed by the INFN-LNF Group:
L. Porcelli, S. Dabagov, G. Delle Monache,
D. Hampai, G. Modestino.

05/06/2023

LNF Thermo-Vacuum Facility Completion

Activity as of today:

- Thermal balance test (and correlation to models) thanks to the 'pocket' cryostat which is at our disposal, and that is being instrumented in a dedicated space.
- (Non)destructive irradiation testing @ X-Lab (Dubagov and Hampai), with extrapolation at other wavelengths, and X-ray circuitry diagnostics in specifically dedicated and instrumented optical bench.
- …

31-12-2023	**WP2000 (SCU): Completamento primo test termico rappresentativo e confronto con la simulazione **

LNF Thermo-Vacuum Facility Completion

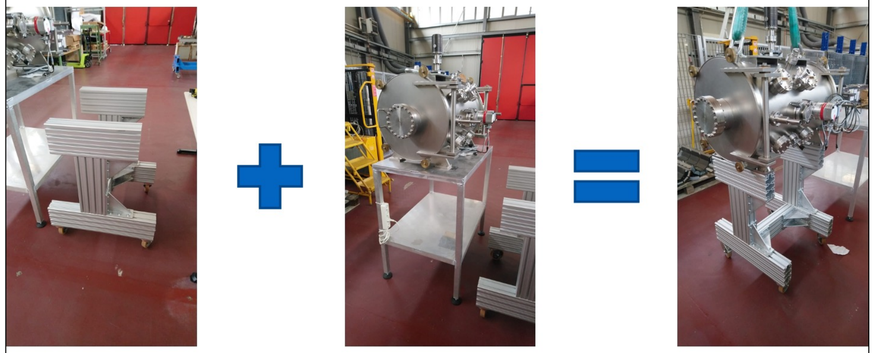
The ‘pocket’ cryostat is being instrumented in a dedicated space:

- LNF in-kind.
- Specifically designed for (lunar) thermo vacuum tests and thermal balance tests.
- $p < 10^{-6}$ mbar.
- *$-200\ °C < T < 100\ °C$*.

LNF Thermo-Vacuum Facility Completion

The ‘pocket’ cryostat is being instrumented in a dedicated space:

- New, stronger, custom-made stand (LNF in-kind) with wheels.



LNF Thermo-Vacuum Facility Completion

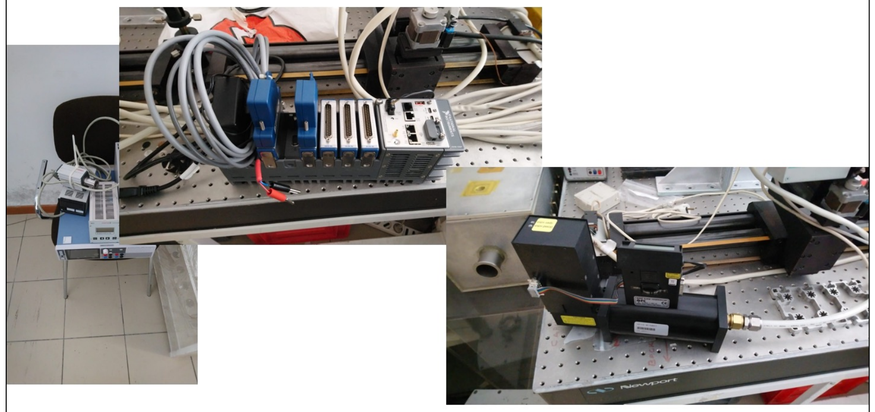
The ‘pocket’ cryostat is being instrumented in a dedicated space:

- Mass of the system (as of now) = 315 kg.
- Maximum allowed mass PER single wheel = 400 kg.

LNF Thermo-Vacuum Facility Completion

The ‘pocket’ cryostat is being instrumented in a dedicated space:

- Control electronics is being assembled (thanks to Bruno Ponzio).



05/06/2023 Telecon with INFN Referees

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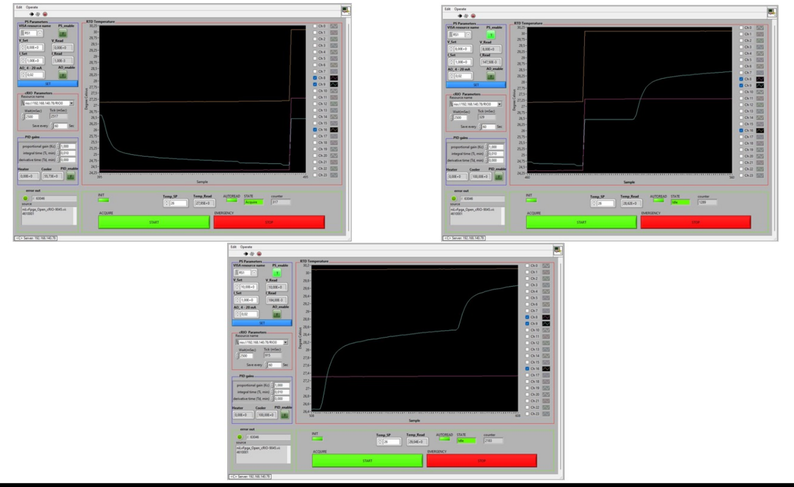

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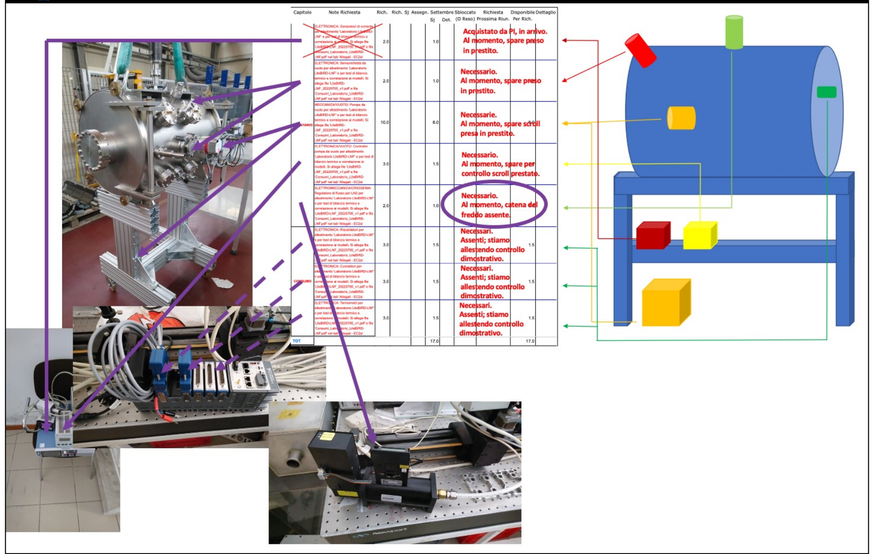
LNF Thermo-Vacuum Facility Completion



05/06/2023 Telecon with INFN Referees

LNF Thermo-Vacuum Facility Completion

‘Pocket’ cryostat: in-kind endowment to the effort:

- Mechanics and cryostat: ‘ready’.
- NI Compact Rio and control system: ‘ready’.
- Pumps and control system: ‘ready’.
- ‘Cold chain’: MISSING.
- LabVIEW VI fine tuning: TBD.

31-12-2023	**WP2000 (SCU): Completamento primo test termico rappresentativo e confronto con la simulazione **

Proposed Team and FTE Sharing

Team Members as of June 2023:

- Luca Porcelli (Staff Researcher - III Level - LR) = 40% FTE.
- Sultan Dabagov (Executive Researcher - I Level) = 30% FTE.
- Giovanni Delle Monache (Senior Technologist - II Level) = 40% FTE.
- Dariush Hampai (Senior Technologist - II Level) = 20% FTE.
- Giuseppina Modestino (Staff Researcher - III Level) = 70% FTE.
- Sandra Savaglio (Full Professor @ Unical) = 30% FTE.

We are very open to people and ideas, and very welcoming for inclusion of further team members here at INFN-LNF.

LiteBIRD-LNF x 2024

Objective: perform the first tests on the (flight) electronics of interest.

- **2023 Results:**
  - Local activity started:
    - Setting up and instrumenting the ‘pocket’ cryostat for tests on the electronics of interest.
    - Defining a strategy for (non)destructive irradiation testing and X-ray circuitry diagnostics.
    - Defining a strategy for teaming with the wider collaboration in order to get involved in data analysis, modelling and simulations for the physical processes of interest, at ‘cosmological’ level.
  - Wider collaboration joint:
    - Organisation of the Workshop 'LiteBIRD-Italia 2023 @ INFN-LNF (LB-ITA23@INFN-LNF)’: https://agenda.infn.it/event/35371/
- **2024 Objectives:**
  - Finalise setup and instrumentation of the ‘pocket’ cryostat for tests on the electronics of interest.
  - Perform the first thermal balance test on the electronics of interest, and, eventually, on the very flight hardware.
  - Proposing a strategy for (non)destructive irradiation testing and X-ray circuitry diagnostics.
  - Teaming with the wider collaboration in order to get involved in data analysis, modelling and simulations for the physical processes of interest, at ‘cosmological’ level.

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Timetable
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Come Accedere ai LNF
Modulo di Registrazione
Lista Partecipanti
Accesso Internet
Dove Alloggiare
Scheda Comportamentale

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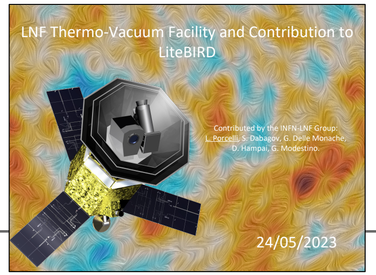

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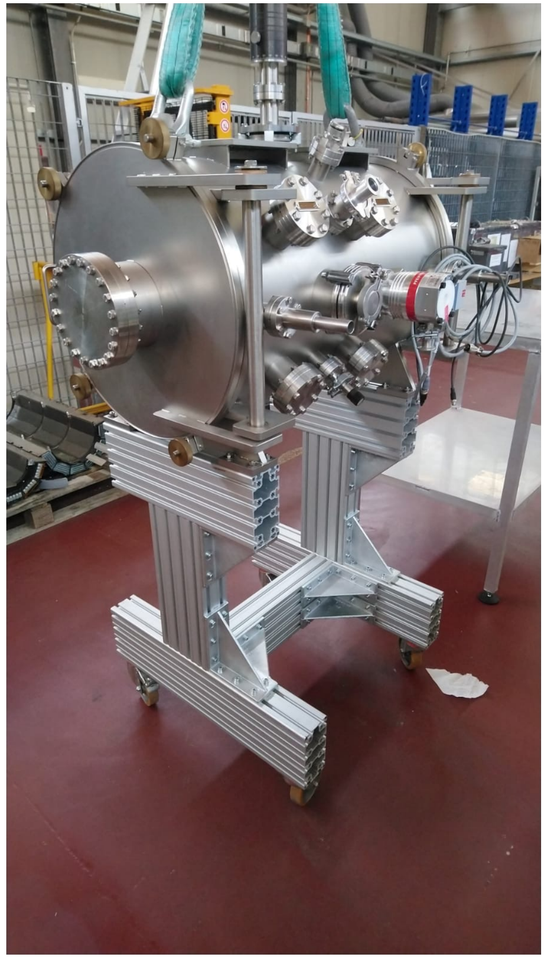

- **FTE (LNF):** L. Porcelli (RL, 40%), S. Dabagov (30%), G. Delle Monache (40%), D. Hampai (20%), G. Modestino (70%) + S. Savaglio (Unical, 30%) = 6 PP (2.30 FTE)
- **Richieste CSN2 2024 (overall, TBD):** missioni 5k, consumo 5k, altri cons 5k, inventario …k, license SW …k, apparati …k, servizi …k
- **Richieste LNF 2024 (mesi-uomo):** Elettronica 1; Impianti Fluido …; Criogenia …
- **Fondi Esterni:** N/A