DAΦNE-Light Laboratory and Activity

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1 Summary

In 2025 the scientific activity at the DAΦNE-Light laboratory, was performed only using conventional sources for tests of detectors and measurements after the shutdown of DAΦNE in July 2024. About 15 experimental teams got access to the DAΦNE-Light laboratory mainly coming from Italian Universities and Research Institutions, third parties and PNRR and other projects.
The laboratory was opened to high school students for INSPYRE 2025, in the Open Day for students at the end of April 2025 and to high school teachers in November during the week dedicated to the "Incontri di Fisica". The website of DAΦNE-Light at the following link: **https://dafne-light.lnf.infn.it/** was updated with highlights and the list of publications.
Some upgrades were realised on existing experimental setups and also new instrumentation was installed.
A relevant activity in 2025 was the organisation of a one day workshop **Frascati National Laboratories and Synchrotron Radiation: Past, Present and Future** on the 4th of December that has seen the presence of more than 130 participants.

2 Activities

2.1 SINBAD IR beamline - Resp. Mariangela Cestelli Guidi

The SINBAD IR beamline offers advanced Fourier Transform Infrared (FT-IR) micro-imaging and spectroscopy capabilities, driven by a powerful synchrotron source and conventional sources. This enables researchers to conduct detailed investigations in a wide array of fields, including:

- Material Science: Characterization of the composition and structure of advanced materials.
- Biology & Radiobiology: Studying cellular processes and the effects of radiation.
- Live Cell Imaging: Monitoring dynamic changes in living cells in real-time.
- Cultural Heritage: Analyzing the composition of artifacts and artworks.
- Geophysics: Examining the mineralogical and chemical makeup of geological samples.

Access to SINBAD is granted to researchers from Italian and international institutions, including EU and non-EU teams, after a proposal review by the User Selection Panel.

2.1.1 USERS AND BEAMTIME

In 2025, the SINBAD-IR beamline provided access and support to numerous experimental teams, facilitating cutting-edge research in diverse scientific disciplines. Here is a brief view in some of the notable studies conducted:

Planetary Science & Mineralogy:

- **ASAMI**: Unveiling the Secrets of Asteroid Ryugu Mapping M. Angrisani (INAF-IAPS), Italy. FT-IR analyses were performed on Ryugu asteroid.
- **PEITHO**: Unraveling Meteorite Mineralogy. C. Carli (INAF-IAPS, Italy) conducted FT-IR spectroscopic analyses to characterize peculiar meteorites, aiming to understand their origins and parental bodies.
- Collaboration with Roma 3 University (Prof. Giancarlo della Ventura) for FT-IR analyses of terrestrial minerals.

Life science

- **MAP**: Measurements and feasibility study on Atherosclerotic Plaques samples. C. Lubritto (University of Campania), FT-IR measurements to understand if the presence of microplastic inside the atherosclerotic plaques can modify the collagen bands.

Cultural Heritage:

- **MAS**: Measurements and feasibility study on Archaeological Samples. C. Lubritto (University of Campania). The project aims to compare the ATR results with the isotopic ones, to assess if these analyses could be a valid tool to select archaeological samples (bones) suitable to be analyzed by using isotopic approach.
- **CHNet**: Collaboration with University of Tuscia, INFN – Fi, ENEA for the analysis of an illuminated parchment conserved at Diocese of Viterbo (Italy).
- **CHNet**: Collaboration with Centro Conservazione Restauro La Venaria Reale for the analyses pictorial layers standards by means of multi-sensor scanner (FTIR, XRF and UVF).
- **CHNet** Collaboration with INFN-RM3 and the Accademia delle Belle Arti of Rome for the analyses of cross section taken from "Lo Spasimo di Palermo" painting.
- **CHNet** Collaboration with Archivio Gigli for the analysis of a futuristic painting by means of multisensor scanner (FTIR, XRF and UVF), imaging techniques and Portable Raman Spectroscopy.
- **DTC-Lazio** collaboration with University of Tuscia, Roma Tre University, and INFN Roma Tre, ENEA and Direzione Regionale Musei Nazionali Lazio for the analysis of a mural painting located at Sacro Speco (Subiaco)
- Collaborative Research Agreement (cod INFN TTB_25LNF_044) with INFN – Fi and **Istituto Gemmologico Nazionale** – IGN for the study of corals used in the gemological field through advanced spectroscopic analysis techniques, with the aim of defining a diagnostic protocol for species identification.
- **DTC-Lazio** collaboration with University of Roma 3, E. Marconi: Surface characterization of marble specimens treated with the biodegradable polymer, polyhydroxyalkanoate (PHA), by using FT-IR analysis.

Beyond core research projects, the SINBAD-IR beamline actively engaged in collaborative and third-party activities.

Instrument Upgrades and Laboratory Enhancements

In 2025, the SINBAD-IR laboratory underwent significant upgrades to enhance its analytical capabilities and expand its research potential. Key improvements include:

Multimodal Analytical System:

- The MA-Multi techniques scanner was upgraded by aligning all the device and adding new optical fibers.
- A new scanner system to support large-scale artwork was designed and installed at the Building 24.

Figure 1: MA-Multimodal scanner tested on an unknown futurist painting (on the left) and the new scanner system to support large-scale artworks (on the right)

2.1.2 PROJECTS ON EXTERNAL FUNDS

Throughout 2025, the SINBAD-IR beamline actively supported a range of cutting-edge projects, including:

1) **PNRR_PE5 - CHANGES**: Cultural Heritage Active innovation for Next GEn Sustainable Society

Funded by the European Union (EU) and the Italian Ministry of University and Research (MUR), the CHANGES project (Cultural Heritage Active Innovation for Next Gen Sustainable Society) started in December 2022. INFN, through its membership in Associazione Centro di Eccellenza Beni e Attività Culturali della Regione Lazio (DTC Lazio), is actively contributing with four distinct projects. (Reference: https://www.mur.gov.it/it/news/mercoledi-03082022/pnrr-mur-selezionati-i-14-partenariati-attivita-di-ricerca)

INFN participated in the project through the Centro di Eccellenza DTC Lazio association, of which it has been a founding member since 2018.

The SINBAD-IR beamline is a vital component of CHANGES, specifically within SPOKE 7, focusing on “Protection of cultural heritage from anthropogenic and natural risks and evaluation of the effectiveness of recovery techniques using non-invasive monitoring technologies.”

- Measurement Campaign: A crucial measurement campaign was conducted at the Domus di Vigna Guidi (Terme di Caracalla, Rome) to analyze degradation processes and inform recovery strategies for the pictorial apparatus. (Fig. 4)
- Digital Accessibility: Efforts are underway to transform diagnostic data into accessible digital content, including DIGITAL TWINS, for public engagement and museum professionals.
- Dissemination: Project results were presented at national and international conferences and scientific events, ensuring broad knowledge sharing.

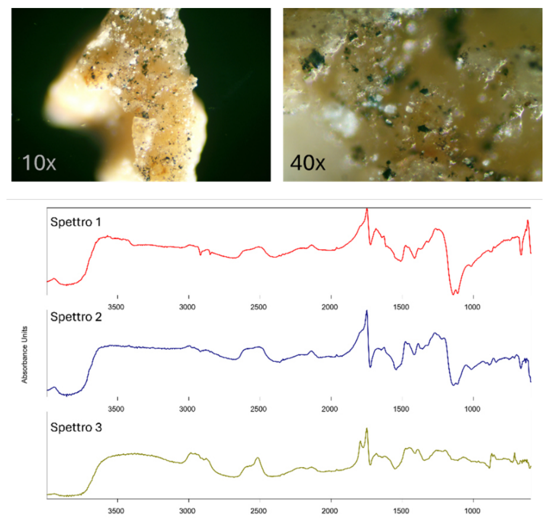

Figure 2: FTIR analyses of a sample taken from the mural painting of “Domus di Vigna Guidi” (Terme di Caracalla) in Rome.

2) SUNSTONE: “SESAME’s Upgrading Network for Scientific user Training and Outreach into the Next Era”.

Funded by the European Union’s Horizon Europe program (HORIZON-INFRA-2024-SESAME-IBA, G.A. 101177314), SUNSTONE (”SESAME’s Upgrading Network for Scientific user Training and Outreach into the Next Era”) is a strategic initiative designed to significantly strengthen the SESAME (Synchrotron Light for Experimental Science and Applications in the Middle East) facility.

Project Timeline: June 30, 2024 – December 31, 2027 (42 months).

Project Goals: This collaborative project unites eight leading research infrastructures and organizations from Europe and the Middle East, with the Paul Scherrer Institut as a key associate participant. SUNSTONE’s core objective is to ensure the long-term sustainability and enhancement of SESAME, a vital research hub serving its eight member nations: Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine, and Turkey. Furthermore, the project aims to expand SESAME’s reach and impact into Africa.

As part of the project, INFN will provide training for SESAME's BEATS XCT beamline users.

Learn more about SUNSTONE project here: *https://sunstone.sesame.org.jo/*

During 2025 WP3 proceeded with the organization and implementation of phase one foreseen within the SESAME SUNSTONE Training Program which took place online in April 2025 (https://sunstone.sesame.org.jo/news-events/sesame-sunstone-training-programme-phase-one-concluded/). The sessions attracted strong participation from **158 attendees across 36 countries,** with high levels of engagement and interaction throughout. All presentations and training materials are now freely accessible on Indico, offering continued learning opportunities for those who were unable to attend live (https://indico.sesame.org.jo/event/31/timetable/).

Throughout four online sessions, participants explored a range of scientific domains where synchrotron radiation plays a critical role. The lectures included:

- Introduction to Synchrotron Radiation
- Archaeology and Cultural Heritage Using X-ray Computed Tomography
- Environmental Science Using Soft X-rays
- Science in Operando Conditions Using X-ray Absorption Spectroscopy

All the information about the WP3 progress in the organization of SUNSTONE training are deeply discussed in the deliverable D3.2 submitted in December 2025 and available at this link: https://sunstone.sesame.org.jo/deliverables-results/.

3) INFN OPEN: "Open INnovation from Fundamental Nuclear Research".

Funded by the PON Governance and Institutional Capacity 2014-2020 program, Axis 2 – Specific Objective 2.1 – Action 2.1.1 (CUP: I55F21002820007) with 1.7 Meuro , INFN OPEN ("Open INnovation from Fundamental Nuclear Research") is a strategic initiative designed to accelerate the transfer of scientific and technological knowledge developed by INFN.

Project Timeline: November 23, 2021 – August 31, 2025.

Project Goals:: To Strengthen INFN's Capabilities: Enhance the technical and organizational skills necessary to translate fundamental research into tangible innovations; to promote Knowledge Transfer: Effectively facilitate the dissemination and application of INFN's scientific and technological advancements; to drive National Innovation: Contribute to the technological and industrial innovation of the Italian economy.

The Dafne-L contribution to the project included a market study of compact particle accelerators for cultural heritage, specifically examining the MACHINA (compact accelerator for cultural Heritage studies) case:

2.2 DXR1 Soft X-ray Beamline - Resp. Antonella Balerna

The DAΦNE soft X-ray beamline, DXR-1, is mainly dedicated to soft X-ray absorption spectroscopy (XAS). The X-ray source of this beamline is one of the 6-poles equivalent planar wiggler devices installed on the DAΦNE electron ring (0.51 GeV) for the vertical beam compaction. The 6 wiggler poles and the high storage ring current (higher then 1 Ampere) give a useful X-ray flux for measurements well beyond ten times the critical energy. The useful soft X-ray energy range is 900 eV - 3000eV where the lower limit is given by the Beryl crystals used in the double-crystal monochromator and the higher limit is given by the wiggler working conditions. The beamline had users up to July 2024.
Being involved in the ARTEMISIA project (see SINBAD-IR scientific activity) for the XRF measurements, with the development of a portable XRF system, in 2025, some activities related to cultural heritage were performed. Having performed all security issues in the building 24 in this year it was more easy to use the XRF system for in-situ mapping measurements.
The ARTEMISIA XRF system using a conventional Rh X-ray source and an Amptek OEM (original equipment manufacturer) SDD detector assembled at LABEC was used to map the presence of different atomic elements in a small painting of G. Favretto (Venezia 1849-1887), on an unknown futuristic painting and on many panels with different pictorial layers to be used as references or scientific database to determine the pigments of real paintings.
In the framework of the Summer Student Scholarships for Scientific and Technological Research Activities, Camilla Merola (Univ. Roma "Sapienza"), was hosted in the DAΦNE-Light laboratory for two months to learn more about X-ray fluorescence spectroscopy and data analysis under the supervision of Dr. Antonella Balerna and Dr. Lucilla Pronti. The main tasks of her activity concerned the processing and interpretation of XRF spectra from a reference panel of pictorial materials with various combinations of pigments, dyes, and binders chosen with historical accuracy by the Centre for Conservation and Restoration "La Venaria Reale" and of XRF maps from a real painting, as well as a deeper understanding of the ARTEMISIA system and its dedicated software. Single-point spectra were analysed using the PyMca software with the goal of identifying the optimal fitting parameters for each spectrum, determining the presence of different atomic species, and refining the background correction. Raster scans data achieved using the ARTEMISIA software required the development of Python scripts to make them compatible with the PYMca software. These data were then directly recognised and processed by PyMca, enabling elemental distribution maps to be produced through batch processing in the ROI Imaging Tool. This tool enabled the visualisation of the characteristic spatial distribution of each element, as can be seen in Fig.3.

Figure 3: Example of the spatial distribution of Fe and Pb in a 17th-century portrait by an unknown artist, shown alongside the corresponding visible image.

Part of the scientific activity performed in 2025 concerned also the XRF data analysis of spectra of various materials measured at the BM5 beamline of the ESRF-EBS synchrotron radiation facility (Grenoble France) taken using a multichannel HPGe detector developed within the WP2 of the EU project LEAPS INNOV.

2.3 DXR2 UV branch Line - Resp. Marco Angelucci

The DXR2 beamline at DAΦNE-Light operates with UV radiation on an extended spectral range from 120 nm to 800 nm. The UV radiation can be used in a wide range of experiments such as reflectance/transmittance, ageing and response of optical systems and detectors. The UV light has been used at the DXR2 branch-line in many and different research fields from biological to high energy physics experiments, to study solar-blind UV diamond-based detectors or FOAM for space missions. Furthermore, coupling the UV radiation and IR spectroscopy it is possible to study in real time the evolution of analyzed samples, measuring the variation of IR spectra during UV exposure.

The facility operates with UV radiation obtained as synchrotron radiation (SR) or standard sources (Deuterium lamp for the Deep UV 120-250 nm, HgXe lamp in the 200-650 nm range, broad UV/VIS source in the 200-800 nm range, and different LED sources between 255 and 465 nm).

To address the evolving technical needs, the beamline has been upgraded with new setups. Previous developments had already introduced discrete LED sources and broadband continuous light systems spanning multiple wavelengths. In 2025, the laboratory further focused its efforts on UV based measurement setups, while also advancing new tools for light characterization. As part of these activities, it has been equipped with UV–Vis sensors capable of μW level detection and with dedicated experimental configurations designed to support absorption, transmittance, and reflectivity measurements.

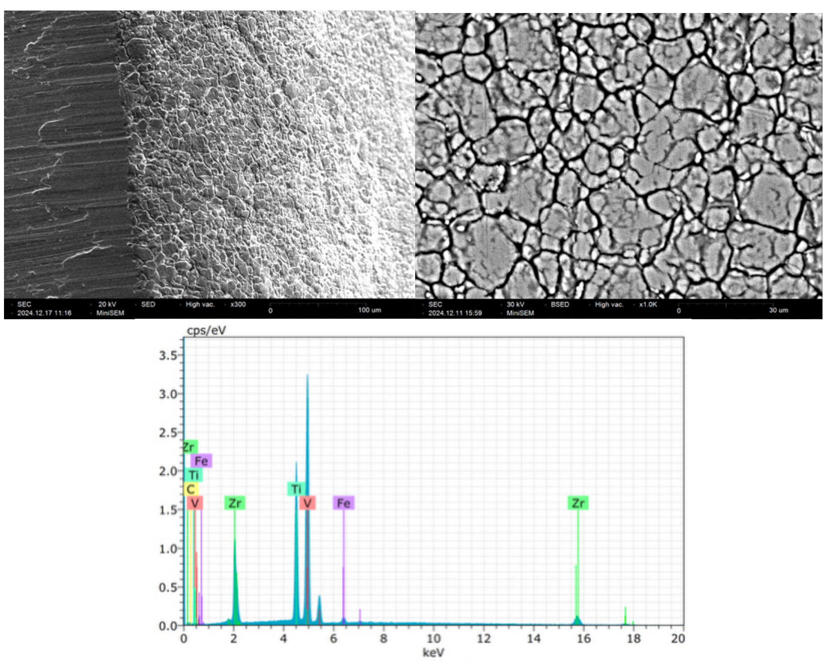

Figure 4: SEM Images (top) and EDX spectrum (bottom) of a NEG-coated sample

The laboratory continued its involvement in the structural and elemental characterization of NEG coated samples using SEM EDX. This activity, carried out in collaboration with the XUV laboratory within the ongoing partnership with BNL, was further expanded in 2025. During this period, additional samples were analyzed, allowing the investigation campaign to progress and to consolidate the characterization workflow.

The laboratory was also involved in the structural and elemental characterization of NEG-coated samples using SEM-EDX. This activity is conducted in collaboration with the XUV laboratory as part of the partnership with BNL.

2.4 XUV beamlines and laboratory - Resp. Roberto Cimino

This laboratory hosts three bending Magnet beam lines and their "state of the art" UHV spectroscopy systems. Two beamlines are design to offer monochromatic light with a photon energy range from 30 eV to 1000 eV the third one will provide un-monochromatized SR light. The Low Energy Beam line, (LEB) will cover the photon energy range from 30 to 200 eV and the High Energy Beam line (HEB) will offer monochromatic photons from 60 to 1000 eV. The third beamline, WINDY, (White lIght liNe for Desorption Yields) offer collimated SR for photodesorption studies on accelerator's beam-pipe samples up to 3-meter in length. The three beamlines still need some extensive use of SR delivered by DAΦNE to be finally commissioned. During 2024 DAΦNE did not produce any usable light.

Even if no SR was available, we have managed to consolidate all the three beamlines and their experimental stations hosting and promoting some mainstream projects.

During this year, the laboratory continued to work on ET-ITALIALNF project, funded by Gr II, focusing on studies related to the development of active and passive mitigation methods for ice and charging in the future bf Einstein Telescope(ET).

We have an ongoing collaboration with the group studying and designing the new Electron-Ion Collider (EIC) at the Brookhaven National Laboratory (BNL), USA. This collaboration is officially operated since 2023 through a Statement of Work (SoW, Doc No. EIC-VSG-SOW-011). This SoW concerns surface studies required for qualifying the hadron storage ring vacuum chamber of the EIC. During 2025, the laboratory conducted studies specifically on NEG-coated samples produced by BNL.

Furthermore, the laboratory continued its collaboration with the BNL Vacuum Group to develop a Secondary Electron Yield (SEY) measurement system. This system will be used by BNL for the quality control of coated screens to be installed in the EIC hadron storage ring vacuum chamber. Furthermore, the laboratory has maintained its collaboration activities with national and international groups (including CNR, INFN-Roma Tor Vergata, the ET International Collaboration, Virgo, ONERA, CEA, and others) on various topics that leverage the expertise and experimental equipment available at the laboratory.

Hereafter we describe with some more details all those activities performed in the spirit of opening some of our resources to external users.

2.4.1 ET-ITALIA@LNF

Overview

The ET-ITALIA@LNF project is organized in three WPs:

- WP1: Frost Mitigation and Electrostatic Charging
- WP2: Material Properties
- WP3: Passive mitigation method for electrostatic charging

Gases composing the residual vacuum in the low-frequency detector chambers of ET can form a contaminant ice layer ("frost") on the surfaces of the cryogenic mirrors (T 10 K). Depending on the thickness of this ice layer, various detrimental effects may impact the detector's performance.

Studying the mirror vacuum system and reducing contaminants on the optical surfaces at cryogenic temperatures is a necessary passive strategy for maintaining detector efficiency. This is the focus of WP2 activities (in collaboration with the LATINO Vacuum Laboratory in Frascati), which aim to characterize the outgassing properties of materials.

The WP1 activities are carried out entirely in the XUV laboratory and aim to explore the use of low-energy electrons as an active method to remove ice from cryogenic optics through Electron Stimulated Desorption (ESD). This defrosting method will inevitably result in electrostatic charging, which has already been shown to affect gravitational wave detection in operating interferometers. In principle, electrons can not only induce ice desorption but can also help mitigate charging issues by tuning their kinetic energy appropriately. In this way, electrons can serve as a mitigation method for both ice desorption and charge neutralization. The electron-based discharging method relies on understanding the SEY characteristics of each material.

Electrostatic charging coming from the beampipe is one the few known contributions to optics charging phenomenon. This is already experienced in Virgo, where it has been observed that electrostatic charges, generated by low energy electrons coming from ion pumps, propagate along the beampipes finally impinging on the test masses. In this framework, in collaboration with the vacuum groups of LNF and EGO-Virgo, the aim of WP3 is to carry out a R&D activity to develop a passive mitigation strategy for the electrostatic charging coming from the beampipe. The idea is to install an electrostatic ring in selected baffles of the vacuum pipe. Opportunely polarized at a given voltage, such rings can catch electrons coming from the ion pumps and propagating along the vacuum tube.

Activities

- During this year, following the publication of first results demonstrating the possibility to use electrons to neutralize charges of both polarity at room and cryogenic temperature (RT and LT) [4], preliminary experiments have been performed to extend the study to samples after H2O molecules adsorption. Test have been done to reproducibly measure SEY of a Si sample on increasing the ice thickness and to find the right experimental conditions to characterize charging/neutralization parameters. Results will come. The activity has been presented in different national and international meetings as talk or poster contribution [a; b; e; h-k].

- The experimental set-up equipped with a Kelvin probe to study the charge spatial distribution on big dielectric samples (1 inch), has been tested and the Labview data acquisition code has been implemented.

- An experimental system has been designed, mounted and set-up at Building 24 (Fig. 1). It intends to mimic a section of a long pipe (in a reduced scale) to study the electron propagation and to test the possibility to introduce electrostatic rings to capture electrons along their path. As shown in the picture, the system is composed of vacuum sections connected to each other and to an ion pump at one end. After evacuating the system by a turbomolecular pump, the ion pump has been switched on and used both to maintain the vacuum (p 10-9 mbar) and to be the source of propagating electrons. In front and at 90° with respect to the ion pump port, two metallic flat screens have been placed (Fig. 1). Each screen is insulated from the vacuum tube and can be electrically connected to a picoammeter to measure the electron current generated by the ion pump. Moreover, each screen can be put at a given potential (between -500 V and 500 V) to study, for each geometry, the effect of voltage in capturing charges coming from the ion pump. Along the tube some other screens with annular shape (electrostatic rings) are mounted. Also in this case, they can be connected to a picoammeter to measure the electron current and to be put at a given potential. The whole system has been commissioned, and it is ready to perform the first measurements. The concept of the study has been reported at national and international meeting [b; g; k-l].

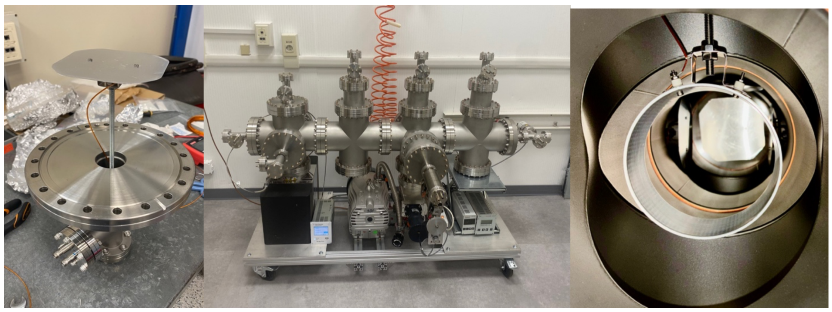

Figure 5: (Center) Overview of the experimental setup to measure the charges emitted by an ion pump and propagating along a pipeline. (Left) Detailed view of one of the metallic screens mounted in the upper flange, facing the ion pump port, and at 90° with respect to the ion pump to collect charges emitted once the ion pump is switched on. (Right) One of the electrostatic rings mounted inside the vacuum line. Both types of screens can be connected to two different picoammeter for current measurements and can be held at a given voltage between -500 V and 500 V.

2.4.2 Collaborations

Einstein Telescope (ET) International collaboration

The activities carried out within ET-ITALIA@LNF project are of general interest in the international framework of R&D scheme for ET. Indeed, with the activities on frost and charging mitigation of cryogenic mirrors, the laboratory is involved in the ET-ISB Division II (Optics) collaboration, in the ET-ISB Division IV (Vacuum and Cryogenics) [b; g]. With the R&D activities connected also to the development of new electron sources compliant with cryogenic environment to mitigate charge and frost formation, from this year, the laboratory has been involved in the "ET mirrors, cryogenics, vacuum and ellipsometry" working group [i] , a collaboration between scientists of KIT (DE), OTH (DE), TNO (NL) and Maastricht University (NL).

Thanks to the competences reached in the last years on neutralization by using low energy electrons, the laboratory has been involved for advising and collaborating in proposal "STEIN - Satellite Test of Einstein's gravitation theory" for the call for F3 Fast mission opportunity in ESA's science program. Among others, proposers of the call are colleagues from ONERA, CEA and INFN-Trento with whom the laboratory collaborates since years on topics related to SEY and surface properties of materials of interest for accelerators and aerospace.

Collaboration with EIC (Electron Ion Collider) at Brookhaven National Laboratory (BNL - USA)

Overview

The mitigation of electron cloud buildup in high-luminosity circular accelerators like the hadron storage ring of the EIC relies heavily on the development and experimental surface characterization of technical materials with low SEY. Our laboratory possesses the experience and the "state of the art" equipment to perform such investigations. Detailed material and surface studies are indeed needed for qualifying the hadron storage ring vacuum chamber, where new beam screens with a low SEY coating need to be inserted into the present Relativistic Heavy Ion Collider (RHIC) beam tubes to suppress electron cloud buildup and guarantee operation with the high luminosity beams of the EIC. Electron cloud, dynamic vacuum, material coatings and their surface and bulk properties at low operating temperatures as well as under electron, and ion bombardment are critical to guarantee the accelerator does not suffer any limitation induced by the detrimental collective effects driven by instabilities.

The interaction with the working group at BNL, which is studying and designing the future EIC, is carried out through two different paths:

- Statement of Work (SoW, Doc No. EIC-VSG-SOW-011) between BNL and INFN.

The SoW is for surface studies needed for qualifying the thin films of carbon and NEG produced by BNL and sent in our laboratory where SEY and XPS measurements at Room Temperature of different samples are performed, also as a function of different treatments as electron irradiation (scrubbing or conditioning) and thermal activation (only for NEG coating).

- Collaboration to develop a SEY measurement system.

The qualification of materials after production is a crucial step to ensure that the coatings meet the required specifications before being installed in the hadron storage ring. Having an in-house measurement system for this purpose is vital to avoid costly and time-consuming validation by external laboratories. For this reason, the laboratory is involved in a collaboration with the BNL Vacuum Group to develop a SEY measurement system. This system will be delivered to and used by BNL for quality control of the coated screens to be installed in the EIC hadron storage ring vacuum chamber. This system is part of the INFN contribution to the EIC and is highly regarded and appreciated.

Activities

- During this year, three equivalent NEG samples have been considered (named as NEG-1, NEG-2 and NEG-3), all belonging to the same production batch. NEG-1 and NEG-2 have been used as reference and for comparison, after specific treatments (or measurements), with NEG-3. This latter underwent a series of consecutive cycles, each of which consisting of a thermal activation followed by 100 hours of air exposure. To carry out this activity the experimental chamber has been modified, adding a valve in the fast entry lock to perform N2 venting of NEG samples before air exposure.

- Basing on BNL indication, the sample activation procedure has been set up.

Sample activation is done in the UHV preparation chamber by irradiation, using a tungsten filament placed in the rear part of the sample holder. The filament is heated by using a current generator connected to it and a K-type thermocouple is in contact with the sample plate allowing to monitor the temperature with a precision of +/- 1°C. The sample is heated following a thermal ramp of the type reported in Fig. 2: after keeping the sample at 120 °C for 24 hours, a temperature of 240 °C is maintained for the subsequent 4 hours. A current of about 2.8 A x 2.3 V and 4.6 A x 4.9 V is set in the first and in the second part of the thermal ramp, respectively. After switching off the heater, the ambient temperature is restored after about 3 - 4 hours.

NEG-1 sample underwent one activation/air exposure cycle. NEG-2 has never been activated. A total of 11 activations has been performed for NEG-3 sample, followed by an equal number of air exposure.

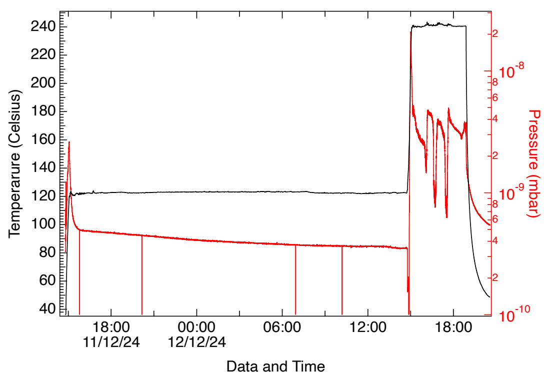

Figure 6: Temperature (black) and pressure (red) data acquired during activation procedure.

SEY and XPS characterizations have been done on NEG-1 and NEG-3 samples, and after each specific step of a cycle for NEG-3. For NEG-3, SEY and XPS measurements have been acquired also 12 hours, or 3 weeks, after the end of an activation. It is to be intended that in that period the sample remained in UHV condition (base pressure of 3 x 10-10 mbar) and did not undergo to air exposure.

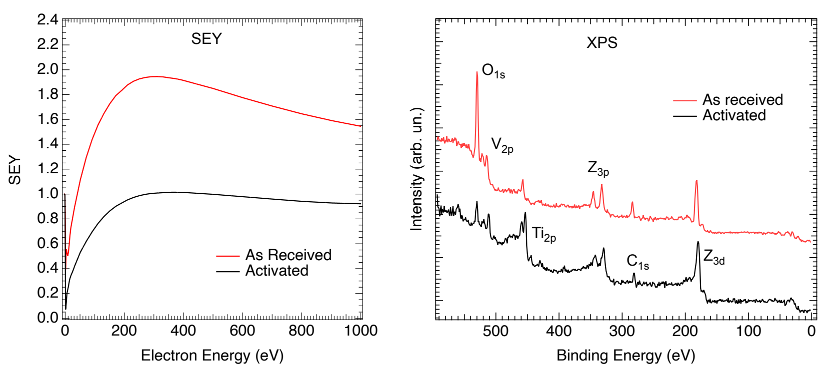

Figure 7: SEY (left) and XPS (right) spectra for NEG3 sample "As Received" and after Activation.

To investigate the effect of activations on sample morphology, SEM measurements have been done on NEG-3 after the first and the fifth cycle. For comparison, a SEM measurement has been performed on as received NEG-2 sample.

Scrubbing in a region (2 x 2 mm2) of NEG-3 sample has been performed after the fifth cycle. The characteristics (SEY) of the scrubbed region have been monitored in the subsequent cycles and compared with not-scrubbed area of the sample. Scrubbing was repeated after the last activation also. For the sake of comparison, scrubbing has been performed on NEG-1 sample as received to probe the effect induced by activation on a scrubbed sample.

In Fig. 4, by way of example, some representative results are reported.

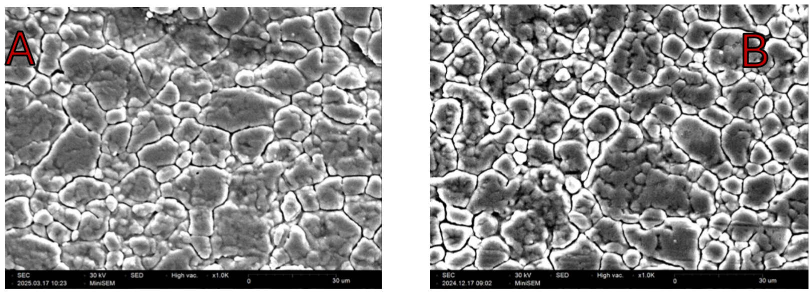

Figure 8: SEM images of NEG3 before (A) activation after (B) activation

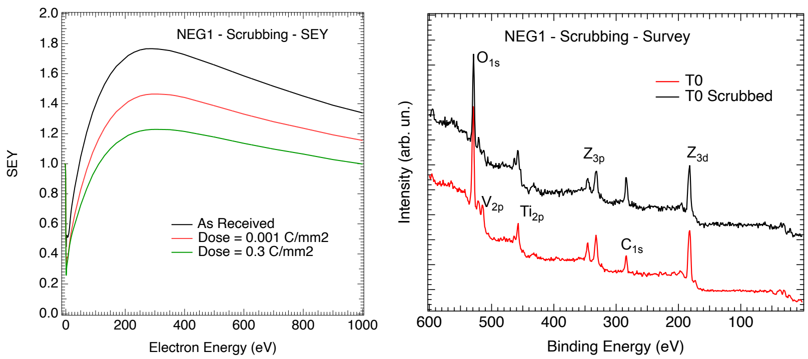

Figure 9: SEY (left) and XPS (right) spectra acquired before and after scrubbing process on NEG1 sample.

All the measurements will be included in the needed project deliverable report. In addition, they have been also presented in national and international meetings [d; f]. The talk given at SIF 2025 on this topic has been selected as one of the best oral presentations and awarded with a publication that will come the next year.

- During this year, all part of the SEY measurement system have been made available, assembled and tested at LNF in Building 24.

As shown in the picture of Fig. 6, the system will be composed of: a UHV m-metal main chamber with pumping system and a 4-axis manipulator; a StSt insertion chamber with pumping system and samples carousel; a stable support for the chambers; sources and electronics for SEY measurements and electron irradiation experiments.

The acquisition software has been also developed in our laboratory.

Accelerators' related activities and collaborations

Past and present involvement in surface studies on material of interest for accelerators has resulted in three publications on feasibility studies Future Circular Collider (FCC) [1-3].

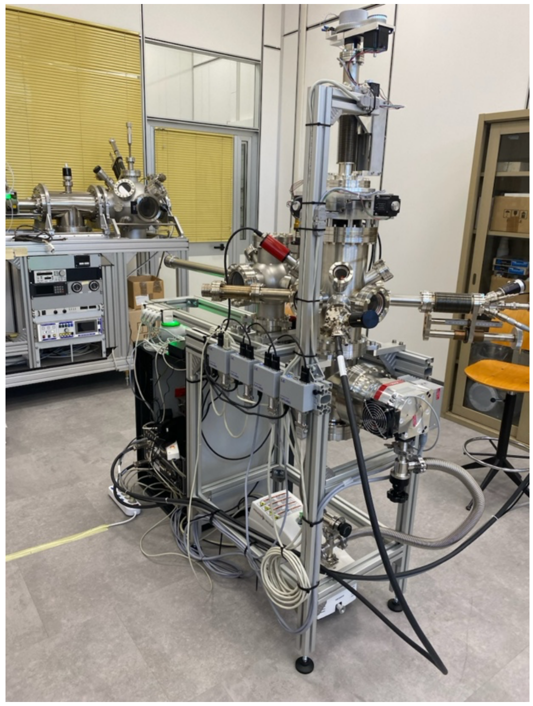

Figure 10: UHV vacuum system for SEY measurements.

2.5 Workshop - Frascati National Laboratories and Synchrotron Radiation: Past, Present and Future

INFN has a long-standing tradition in the use of synchrotron radiation and in the construction of accelerators dedicated to its use. The tradition started with the use of the ADONE 1.5 GeV electron storage ring up to 1993 and continued with the DAFNE electron-positron 0.5 GeV collider. INFN is now developing at Frascati a new user facility EuPRAXIA@SPARC_Lab based on plasma acceleration. This new facility in the framework of the EuPRAXIA EU project should produce FEL radiation beams for a wide range of applications.

For all these reasons the DAΦNE-Light group decided to organise a workshop (Fig. 11) on the story of synchrotron radiation at Frascati from its early beginnings (e-synchrotron) up to nowadays with talks related to the past and to all the people who made it possible, to the present and to the future scientific activities (**https://agenda.infn.it/event/47493/**).

The workshop was held on the 4th of December 2025 and has seen the participation of more than 130 persons.

For the workshop many posters were realised reporting all the information found in the LNF archives regarding the first synchrotron radiation measurements performed in Europe in 1963 at the LNF laboratory using the electron synchrotron and the synchrotron radiation activities at the PULS and PWA facilities using the ADONE electron storage ring up to 1993.

After a general introduction given by Roberto Cimino, the first talk on the birth of synchrotron radiation and the key role of Frascati was given by Giorgio Margaritondo, Settimio Mobilio and

Figure 11: Poster of the workshop.

Enrico Bernieri gave talks on the PULS and PWA facilities using ADONE, Gianfelice Cinque and Mariangela Cestelli Guidi presented the beginnings and the present of the DAΦNE-Light facility while Riccardo Pompili, Stefano Lupi, Federica Stocchi and Francesco Stellato spoke about the future radiation facilities being realised in the LNF laboratories. The workshop was really appreciated because young scientists could learn something about the story of synchrotron radiation activities at LNF while people that are part of its history could meet after a long time and remember also who made many of these possible possible and is no longer alive.

3 Acknowledgments

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4 List of Talks, Posters and Proceedings

1. **A. Balerna** on behalf of the LEAPS - INNOV EU project - WP2 XAFS-DET collaboration, *First XRF spectra with a LEAPS-INNOV XAFS-DET HPGe detector using synchrotron radiation.* **SILS 2025**, Cagliari, 10 September **(2025)**
2. **A. Balerna** on behalf of the LEAPS - INNOV EU project - WP2 XAFS-DET collaboration, *First fluorescence spectra with LEAPS-INNOV HPGe detector using synchrotron radiation.* **HPXRM 2025**, LNF, 17 June **(2025)**
3. **M. Quispe**, ... A. Balerna et al, *Comparison of FEA Simulations and Experimental Data for a New Germanium Detector for X-ray Spectroscopy at Synchrotron Facilities*, **MEDSI2025 - 13th International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation**, Lund, Sweden, 15-19 September **(2025)**
4. **N. Goyal**, S. Aplin, A. Balerna et al, *Next Generation Multi-element monolithic Germanium detectors for Spectroscopy: First integration at ESRF facility*, **VCI 2025 - Vienna Conference on Instrumentation**, Vienna (Austria) 17 - 21 February **(2025)**
5. (Talk) L. Spallino, M. Angelucci, and R. Cimino. Vacuum issues and possible mitigations in cryogenic gravitational wave detectors and cold mirrors test benches. MAD25 Workshop: Materials for Advanced Detectors, Berlin, 6 – 7 October **2025**
6. (Talk) L. Spallino, M. Angelucci, and R. Cimino. Activities at LNF: status and perspectives. III Workshop on ET-LF TM Tower Integration, La Biodola (Isola d'Elba), 28 Settembre – 1st October 2025.
7. (Talk) L. Spallino, D. Alesini, M. Angelucci, S. Bini, P. Chimenti, R. Cimino, G. De Bernardis, S. De Biase, G. Di Raddo, R. Di Raddo, A. Liedl, V. Lollo, M. Pietropaoli, V. Sciarra, G. Viviani, M. Zottola. Vacuum Facility at LNF-INFN. SIF2025 Congresso Nazionale della Società Italiana di Fisica, Palermo, 22 - 26 September 2025.
8. (Talk awarded as one of the best communications) L. Spallino, M. Angelucci, R. Cimino, C. Hetzel, S. Verdu Andres, D. Weiss. Surface studies on candidate materials for the future Electron Ion Collider. SIF2025 Congresso Nazionale della Società Italiana di Fisica, Palermo, 22 - 26 September 2025.
9. (Talk) L. Spallino, M. Angelucci, and R. Cimino. Mitigation of some unusual noise sources for cryogenic mirrors in gravitational wave detectors. SIF2025 Congresso Nazionale della Società Italiana di Fisica, Palermo, 22 - 26 September 2025.
10. (Talk) M. Angelucci. Electron Cloud Mitigation Strategies for the EIC: INFN's Research on Coated Surfaces. ePIC Italia, Padova, 16 - 18 June 2025.
11. (Talk) L. Spallino, M. Angelucci, and R. Cimino. ET Activities at LNF: Status and Future Directions. II Workshop on ET-LF TM Tower Integration, Orsay (Parigi), 25 - 27 March 2025.
12. (Talk) L. Spallino, M. Angelucci, and R. Cimino. Low energy electrons for frost and electrostatic charging mitigation in future gravitational wave detectors; a status report. XV ET Symposium, Bologna, 26 - 30 May 2025.
13. (Talk) L. Spallino, M. Angelucci, and R. Cimino. Low energy electron irradiation to mitigate frost and charge formation on cryogenic mirrors of GWDs. Field emission for electron sources in KATRIN, Darwin, XLZD, ET and more, Karlsruhe (GE), 22 - 23 May 2025.

14. (Poster) L. Spallino, M. Angelucci, and R. Cimino. R&D activities at LNF-INFN on cryogenic vacuum issues in future cryogenic gravitational wave detectors. IUVSTA Workshop 109: APPEC Tech Forum Vacuum & Cryogenics Industry meets Academia, Maastricht (Olanda), 24 - 26 November 2025.

15. (Poster) L. Spallino, M. Angelucci, and R. Cimino. Studies on active and passive mitigation strategies for frost and electrostatic charging issues in future gravitational wave detectors. 4th Einstein Telescope Annual Meeting, Opatija (Croatia), 11 - 14 November 2025.

16. (Poster) M. Angelucci, P. Chimenti, A. Liedl, M. Pietropaoli, L. Spallino, G. Viviani, and R. Cimino, J. Gargiulo, D. Sentenac L. Francescon, and A. Pasqualetti. R&D activity to develop a passive mitigation strategy for electrostatic charging in future gravitational wave detectors. XV ET Symposium, Bologna, 26 - 30 May 2025.

5 Lectures and outreach

1. **A. Balerna**, *Atoms, X-rays and Synchrotron Radiation*, INSPYRE 2025 – INternational School on modern PhYsics and REsearch - INFN Frascati National Laboratory, 10 April 2025

2. **A. Balerna, M. Romani,L. Pronti** , G. Viviani, M. Pietropaoli, *OPEN Labs Scuole 2025 - DAΦNE-Light facility*, 29 April 2025, Frascati.

3. **A. Balerna, L. Pronti, M. Romani**, G. Viviani, V. Sciarra, M. Pietropaoli, M. Cestelli Guidi. *Studio e caratterizzazione dei materiali attraverso l'uso di sorgenti convenzionali e luce di sincrotrone. un approfondimento sui materiali che costituiscono i beni culturali.*, Incontri di Fisica 2024, XXV Edizione Corso di formazione e aggiornamento in Fisica Moderna - INFN Frascati National Laboratory, 20 November 2025

4. L. Pronti, A. Balerna, M. Romani, G. Viviani, V. Sciarra, M. Pietropaoli, M. Cestelli Guidi "Studio e caratterizzazione dei materiali attraverso l'uso di sorgenti convenzionali e luce di sincrotrone. Un approfondimento sui materiali che costituiscono i Beni Culturali", 20 November 2025, Frascati.

5. M. Romani, L. Pronti, "Le Indagini Scientifiche applicate ai Beni Culturali per la ricostruzione dei processi creativi". Workshop held in the context of Enacting Artistic Research (EAR) project, 3 July 2025 (online event).

6. L. Pronti, A. Balerna, M. Romani, M. Cestelli-Guidi, "Macro X-ray fluorescence scanning (MA-XRF) as tool in the authentication of paintings and revealing hidden details", High Precision X-ray Measurements 2025, 16–20/06/2025, Frascati (RM)

7. F. Volpi, L. Pronti, M. Romani, C. Invernizzi, M. Ioele, G. Tranquilli, F. Fumelli, S. Sechi, A. Donati, M. Cestelli Guidi, "Portable Macro Scanning ER-FTIR Spectroscopy for Non-invasive Conservation of paintings", International Conference on Analytical Techniques for Heritage Studies and Conservation, TECHNART 2025, 6-9/05/2025, Perugia, Italy

8. L. Pronti, M. Romani, A. Balerna, E. Gigli, M. Angelucci, G. Viviani, V. Sciarra, M. Cestelli Guidi, "Integrated Scanning System for Molecular and Elemental Analysis of Paintings: Preliminary results on an Unknow Futurist Painting", International Conference on Analytical Techniques for Heritage Studies and Conservation, TECHNART 2025, 6-9/05/2025, Perugia, Italy.

9. M. Romani, L. Pronti, G. Capobianco, E. Gorga, I. Landèche, B. Valenti, A. Balerna, G. Verona Rinati, G. Bonifazi, M. Ioele, B. Lavorini, M. Angelucci, G. Viviani, V. Sciarra, S. Serranti and M. Cestelli Guidi, "New Insights About Giorgio De Chirico's Painting Technique: the Automatic Materials Recognition of the Artwork Mobili nella Stanza (1927) by Machine Learning and Chemometric Approach Based on Spectroscopic Data", International Conference on Analytical Techniques for Heritage Studies and Conservation, TECHNART 2025, 6-9/05/2025, Perugia, Italy (poster)

10. L. Lanteri, E. Marconi, L. Pronti, "Le indagini scientifiche svelano la tecnica pittorica di Petrus. Piano diagnostico e risultati preliminari", Convegno internazionale "i paesaggi benedettini: territorio, patrimonio culturale e spiritualità, 25-28/11/2025, Subiaco-Cassino-Farfa.

11. L. Caneve, M. Cestelli Guidi, "Tecnologie innovative per la conoscenza e la fruizione del Patrimonio Culturale: ricerca, sviluppo e applicazioni", Convegno internazionale "i paesaggi benedettini: territorio, patrimonio culturale e spiritualità, 25-28/11/2025, Subiaco-Cassino-Farfa.

12. M. Angrisani, X. Shehaj, E. Palomba, G. Pratesi, M. Romani, M. D'Amore, T. Catelani, M. Cestelliguidi, A. Longobardo, F. Dirri "Space Weathering and Regolith Dynamics on Ryugu: Lessons from Ryugu Sample Analysis" , Workshop on Bennu and Ryugu: Samples from the Early Solar System is scheduled for October 7–9, 2025, at the Lunar and Planetary Institute (LPI) in Houston, Texas (online event).

6 Publications

1. E. N. Gimenez, A. Balerna et al. ″Development of a New Generation Multi-Element Monolithic HPGe sensor for XAFS applications.″. SRI 2024 - Journal of Physics: Conf. Series **3010**, 012144 (2025). **DOI: 10.1088/1742-6596/3010/1/012144**

2. N. Goyal, S. Aplin, A. Balerna et al. ″Progress in the Development of Multi-Element Monolithic Germanium Detectors in LEAPS-INNOV Project: Insights from Detector Performance Simulation. ″. SRI 2024 - Journal of Physics: Conf. Series **3010**, 012120 (2025).
DOI: 10.1088/1742-6596/3010/1/012120

3. N. Goyal, S. Aplin, A. Balerna et al. ″Next Generation Multi-element monolithic Germanium detectors for Spectroscopy: First integration at ESRF facility. ″. Nucl. Instrum. Meth. A **1081**, 170835 (2026).
https://doi.org/10.1016/j.nima.2025.170835

4. L. Pronti, M. Romani, A. Balerna et al. ″TA Workflow-Driven Multisensor Scanning System for In Situ Extensive Hyperspectral Chemical Imaging of Paintings.″ Anal. Chem.**99** 28124–28131 (2025).
https://pubs.acs.org/doi/10.1021/acs.analchem.5c04231

5. N. Goyal, F.J. Iguaz, S. Aplin, A. Balerna et al. ″Development & first performance evaluation of multielement monolithic HPGe detector for spectroscopy applications. ″. Submitted to Nucl. Instrum. Meth. A the 14th of December 2025
https://arxiv.org/abs/2512.08389

6. Pronti L, Romani M, Balerna A, Cappella D, Tamascelli S, Brandalesi S, Mantoan A, Angelucci M, Cestelli Guidi M. A Workflow-Driven Multisensor Scanning System for In Situ

Extensive Hyperspectral Chemical Imaging of Paintings. Anal Chem. 2025 Dec 16. Technical note.
https://10.1021/acs.analchem.5c04231

7. Giorgianni, F., Romani, M., Puphal, P., Isobe, M., Spitz, L., Guidi, M. C., ... & Udina, M. (2025). Terahertz light driven coherent excitation of a zone-folded Raman-active phonon mode in the spin-ladder system α-NaV 2 O 5. Physical Review B, 111(20), 205138.
https://doi.org/10.1103/PhysRevB.111.205138

8. Pronti L., Romani M., Lanteri L., Bizzarri F., Colantonio C., Pelosi C., Ruberto C., Castelli L., Mazzinghi A., Spizzichino V., Cestelli-Guidi M., Non-Invasive Investigation of a 16th-Century Illuminated Scroll: Pigments, Fillers, and Metal-Based Decorations. Minerals 2025, 15, 1252.
https://doi.org/10.3390/min15121252.

9. Crincoli L., Demitra, R., Lollo, V., Pellegrini D., Pitti M., Pronti L., Romani M., Ferrario M., Biagioni A. Advanced ceramic plasma discharge capillaries for high repetition rate operation. Sci Rep 15, 12456 (2025).
https://doi.org/10.1038/s41598-025-96882-y

10. Tarquini O., Lorenzetti, E. G., Pronti, L., & Felici, A. C. (2025). A study of the polychromy of Campana's panels. Conservar Património, 49, 136–146.
https://doi.org/10.14568/cp36608

11. F. Volpi, L. Pronti, M. Romani, A. Balerna, M. Angelucci, V. Sciarra, G. Viviani, C. Invernizzi, M. Cestelli Guidi, "Diagnostica avanzata pre il restauro: il ruolo del macro-scanner infrarosso nel monitoraggio della pulitura dei dipinti", Atti del Convegno dello Spoke 7 - Changes "La tutela della città storica tra rischi naturali, antropici e del cambiamento climatico" in press

12. F. Volpi, L. Pronti, M. Romani, C. Invernizzi, M. Ioele, G. Tranquilli, F. Fumelli, S. Sechi, A. Donati, M. Cestelli Guidi, "Portable macro-scanning ER-FTIR spectroscopy for non-invasive conservation of paintings", Journal of Cultural Heritage (under revision).

13. Future Circular Collider Feasibility Study Report. Volume 3 Civil Engineering, Implementation and Sustainability. M. Benedikt, F. Zimmermann, B. Auchmann, et al. Eur. Phys. J. Spec. Top. 234, 5113 (2025)
https://doi.org/10.1140/epjs/s11734-025-01958-5.

14. Future Circular Collider Feasibility Study Report. Volume 2 Accelerators, technical infrastructure and safety. M. Benedikt, F. Zimmermann, B. Auchmann, et al. Eur. Phys. J. Spec. Top. (2025)
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15. Future Circular Collider Feasibility Study Report. Volume 1: Physics, Experiments, Detectors. M. Benedikt, F. Zimmermann, B. Auchmann, et al. Eur. Phys. J. (2025).
https://doi.org/10.1140/epjc/s10052-025-15077-x.

16. The role of secondary electron yield in mitigating electrostatic charging in future gravitational waves detectors. L. Spallino, M. Angelucci, A. Liedl, R. Cimino. Vacuum, 233, 113969 (2025).
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