VIP

A. Addazzi (Assoc.), N. Bortolotti (Dott.), M. Bazzi, M. Benfatto,
A. Clozza, C. Curceanu (Resp. LNF), S. Manti (Assegn.),
A. Marcianó (Ric. Str.), F. Nola (Dott.), E. Pace,
K. Piscicchia (Resp. Naz.), A. Porcelli (Assoc.), D. Sirghi (Assoc.)

1 The VIP scientific case and the experimental method

Within VIP a high sensitivity experimental test on the Pauli Exclusion Principle for electrons is being performed, together with other tests on fundamental physics principles.

The Pauli Exclusion Principle (PEP), a consequence of the spin-statistics connection, plays a fundamental role in our understanding of many physical and chemical phenomena, from the periodic table of elements, to the electric conductivity in metals and to the degeneracy pressure which makes white dwarfs and neutron stars stable. Although the principle has been spectacularly confirmed by the huge number and accuracy of its predictions, its foundation lies deep in the structure of quantum field theory and has defied all attempts to produce a simple proof. Given its basic standing in quantum theory, it is appropriate to carry out high precision tests of the PEP validity and, indeed, mainly in the last decades, several experiments have been performed to search for possible small violations. Many of these experiments are using methods which are not obeying the so-called Messiah-Greenberg superselection rule (MG). Moreover, the indistinguishability and the symmetrization (or antisymmetrization) of the wave-function should be checked independently for each type of particles, and accurate tests were and are being done.

The VIP (VIolation of the Pauli Exclusion Principle) experiment, an international Collaboration among 10 Institutions of 6 countries, has the goal to either dramatically improve the previous limit on the probability of the violation of the PEP for electrons, ($\beta^2/2 < 1.7 \times 10^{-26}$ established by Ramberg and Snow: *Experimental limit on a small violation of the Pauli principle*, Phys. Lett. **B 238** (1990) 438) or to find signals from PEP violation.

The main experimental method consists in the introduction of electrons into a copper strip, by circulating a DC current, and in the search for X-rays resulting from the forbidden radiative transition that occurs if some of the new electrons are captured by copper atoms and cascade down to the 1s state already filled by two electrons with opposite spins (Figure 1).

The energy of the 2p $\rightarrow$ 1s transition would differ from the standard K_α transition by about 300 eV (7.729 keV instead of 8.040 keV) providing an unambiguous signal of the PEP violation. The measurement alternates periods without current in the copper strip, in order to evaluate the X-ray background in conditions where no PEP violating transitions are expected to occur, with periods in which current flows in the conductor, thus providing "new" electrons, which might violate PEP.

The goal of VIP-2 *Open Systems*, due to the peculiarity to introduce new fermions (current) in a pre-existing system of identical fermions, is to establish the strongest bounds on $\beta^2/2$ obeying the Messiah-Greenberg superselection rule.

A new class of theoretical predictions, in the context of Non-Commutative Quantum Gravity, CPT deformation and Generalized Uncertainty Principle, recently emerged, predicting PEP violation at high energy scales. These models can violate Messiah-Greenberg (this is the case of Non-Commutative Quantum Gravity) and can be tested with closed systems, i.e. without current.

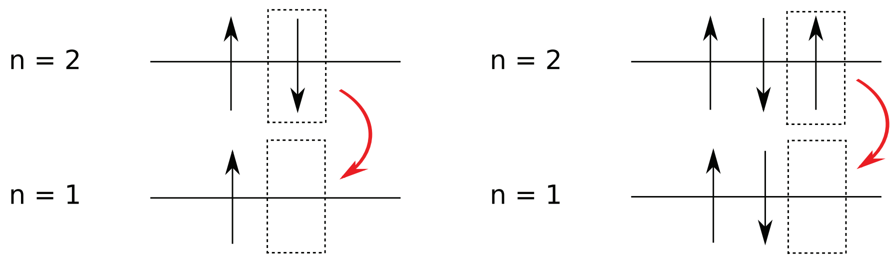

Figure 1: *Normal 2p to 1s transition with an energy around 8 keV for Copper (left) and Pauli-violating 2p to 1s transition with a transition energy around 7.7 keV in Copper (right).*

The VIP-2 *Closed Systems* experimental setups are based on extreme radio-purity targets and high purity Germanium detectors. Our goal is to improve the current limits on the new-physics emergence scale, in a regime which is not accessible to current accelerator experiments, thus providing fundamental down-top constraints to the models.

The VIP collaboration has extended its scientific program to the study of other issues in fundamental physics, such as models of spontaneous wave function collapse. The Continuous Spontaneous Localization (CSL) and the Diosi-Penrose (DP) models consist in non-linear and stochastic modifications of the Shrödinger equation, which induce the wave function collapse with a strength which is proportional to the collapsing quantum state' mass. In both models the collapse is related to unavoidable emission of a characteristic *spontaneous radiation*, which is not present in standard quantum mechanics. We refer to the previous activity reports for more details. The analysis of the data we collected with a dedicated setup, based on a High Purity Germanium detector, lead us to falsify the DP model in its present formulation [1]. We also set the most stringent constraints on the CSL model, in a broad range of the parameters space [2] [3]; in particular we constrained, for the first time, the correlation length r_C above the value $r_C = 10^{-7}$ m predicted by the Ghirardi-Rimini-Weber model [4]. New studies are presently ongoing, aimed to challenge generalized versions of the models, and to investigate the recently developed prediction of spontaneous collapse emerging in Quantum Gravity context.

2 From VIP to VIP-2 Open Systems setups, a brief summary of the setup developments

The first VIP setup was realized in 2005, starting from the DEAR setup, reutilizing the CCDs (Charge Coupled Devices) as X-ray detectors, and consisted of a copper cylinder, were current was circulated, 4.5 cm in radius, 50 μm thick, 8.8 cm high, surrounded by 16 equally spaced CCDs of type 55. The CCDs were placed at a distance of 2.3 cm from the copper cylinder, grouped in units of two chips vertically positioned. The setup was enclosed in a vacuum chamber, and the CCDs cooled to 165 K by the use of a cryogenic system. The VIP setup was surrounded by layers of copper and lead to shield it against the residual background present inside the LNGS laboratory, see Figure 2.

The DAQ alternated periods in which a 40 A current was circulated inside the copper target with periods without current, representing the background. VIP was installed at the LNGS Laboratory in Spring 2006 and was taking data until Summer 2010. The limit on the probability of PEP violation was found to be: $\beta\ ^2/2 < 4.6 \times 10^{29}$.

In 2011 we started to prepare a new version of the setup, VIP-2 Open Systems, for which

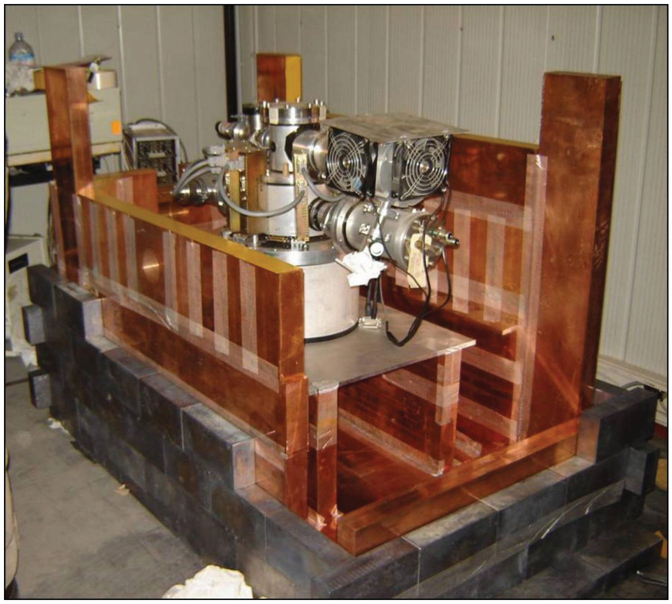

Figure 2: *The VIP setup at the LNGS laboratory during installation.*

a first version was finalized and installed at the LNGS-INFN in November 2015. The goal of the VIP-2 experiment was to improve by at least two orders of magnitude the result obtained by the previous VIP measurement ($\beta^2/2 < 4.7 \times 10^{-29}$ [5]).

In 2018 the VIP2 setup was upgraded with new SDDs and shielding, which was completed in 2019. VIP-2 collected about three years of data in the period April 2019 - May 2024, alternating periods with and without current circulating in the target.

During this period, a refined data taking procedure was successfully tested (see [6] and Section 3.1) based on the modulation of the injected current with a period of 100 s. The corresponding innovative data analysis, which combines Bayesian spectral and discrete Fourier transform analyses, leads to an overall improvement of the sensitivity of about 32%. The current modulation regime will be adopted in the future VIP-3-Hybrid and VIP-3 data taking runs. Moreover, new concepts in testing the Pauli exclusion principle in bulk matter were developed, accounting for the random walk of the electrons in the target and based on semi-analytical Monte Carlo methods to simulate the signal [7, 8]. New calibration techniques have significantly enhanced the experiment's capabilities. These techniques leverage Machine Learning and Differentiable Programming algorithms [9, 10], leading to an improvement in the SDDs' energy resolution to 180 eV (FWHM) at 8 keV, a gain of approximately 10 eV over the previous state-of-the-art resolution.

3 Update on VIP-Open-Systems activities

3.1 VIP-2 Open-Systems data analyses

The whole statistics of the VIP-2 acquired data, before the shut down due to the shack renovation (see the previous reports), was analyzed and produced the strongest upper bounds on the PEP violation probability respecting MG, fulfilling the VIP-2 original goal. The analysis was published in [11]. Two, complementary, analysis frameworks were followed, a Bayesian statistical model and a frequentist Confidence Levels (CL_s) approach, with the following results:

$$\beta^2/2 \leq 3.16 \times 10^{-31} \text{ (Bayesian)} \qquad \beta^2/2 \leq 3.29 \times 10^{-31} \text{ (CL}_s\text{)}, \tag{1}$$

when the electrons propagation in the target is described by means of an electron diffusion model, and:

$$\beta^2/2 \leq 2.47 \times 10^{-43} \text{ (Bayesian)} \qquad \beta^2/2 \leq 2.57 \times 10^{-43} \text{ (CL}_s\text{)}. \tag{2}$$

if the electrons propagation is described in terms of the diffusion model [7, ?]. In the latter case, electron-atom interactions in copper occur over a characteristic time $\tau = 3.3 \times 10^{-17}$ s, therefore significantly increasing the number of independent PEP tests performed by each current electron, leading to the enhanced limits.

A common prediction of all QG formulations (including string theory, loop quantum gravity and non-commutative QG) is the existence of a minimal length on the order of the Planck scale. This implies a deformation of the Heisenberg uncertainty principle (GUP) which depends on a dimensionless parameter β – to be noticed that same notation as the PEP violation probability in literature - (which sets the scale for the emergence of the minimal length) and a related deformation/violation of spin-statistics.

During the reporting period, a refined analysis of the complete data set collected by VIP-2 in the current modulation regime was also carried out aimed to test the GUP prediction. This work formed the basis of the bachelor's thesis of Lorenzo Peppoloni, who graduated with top marks in September 2025. The analysis consists of a combined spectral and Discrete Fourier Transform Bayesian analysis. The marginalized posterior distribution of the total expected number of signal counts (S) is shown in the left panel of Fig. 3. The right panel presents, at the top, the fit to the data obtained using the parameters from the Bayesian analysis, and, at the bottom, the corresponding residual spectrum. This analysis provides the first limit on the PEP violation probability induced by GUP models. The corresponding free parameter β of GUP is constrained up to $\beta < 0.1$, which represents the strongest bound available in the literature. A paper detailing these results is currently in preparation.

4 Finalization of the upgraded VIP-3 setup

The future perspective of the VIP Open Systems experiments consists is a scan of the $\beta^2/2$ limits over selected elements, in order to perform a systematic test of the PEP validity in the atomic transitions, over the periodic table. The main technical challenge in testing materials characterized by a higher atomic number (Z) than copper, is given by the reduction of the SDD detectors quantum efficiency as a function of the increasing energy. To overcome this problem VIP, in collaboration with Fondazione Bruno Kessler (FBK, Italy) and Politecnico di Milano (PoliMi, Italy), developed new cutting edge SDD detectors characterized by double thickness, with respect to the standard detectors used in the VIP-2 experiment (1 mm versus 0.45 mm).

4.1 VIP-3 Open Systems

The VIP-3 Open Systems experiment aims to perform a search of the PEP violating atomic transitions over Z up to targets with atomic numbers as high as $Z \sim 50 - 60$ (e.g. silver, tin and zirconium), with a sensitivity comparable to VIP-2. We demonstrated, that the quantum efficiency of the new SDDs is roughly double (with respect to the standard detectors), in the energy range $(20-25)$ keV (characteristic of the $\mathrm{K}_{\alpha_{1,2}}$ transitions in the new targets) (see also the previous reports for further details).

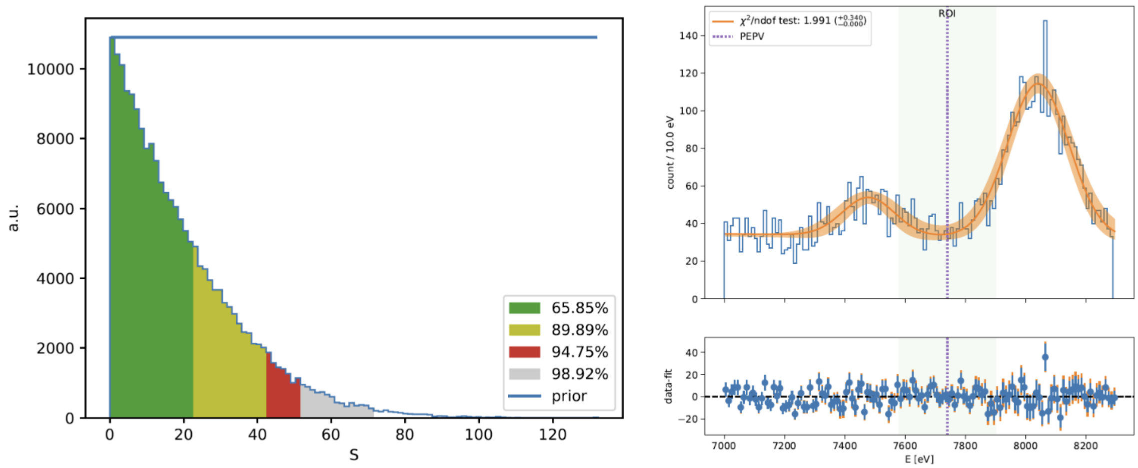

Figure 3: Left panel - marginalized posterior of the total expected number of signal counts, obtained from the analysis of the data collected in current modulated regime. Right panel - Corresponding fit of the new data set.

During the reporting period, the production of the full set of new (1 mm thick) SDDs was completed. VIP-3 exploits 8 SDD arrays (with respect to the 4 SDD arrays used in VIP-2), facing two target strips, where the modulated current will be circulated. The SDDs have been installed, and final cabling and mounting were finalized. The vacuum chamber and cryogenic system were successfully tested. Test measurements are currently being finalized at LNF (see Fig. 4). The setup is scheduled for installation at LNGS by March 2026, when data taking will start in current modeulation regime with the Ag target.

VIP-3 will take data over the period 2026–2029. Further extending the search to elements with atomic numbers $Z > 60$, while maintaining a sensitivity comparable to VIP-2, requires a significant enhancement in the quantum efficiency of the detectors. This improvement will be achieved through the development of layered structures of 1 mm thick SDDs, an effort that is currently underway.

5 VIP-2 Closed Systems Activities in 2025

The VIP collaboration is investigating possible violations of the spin–statistics relation (i.e., PEP violation) within the framework of several QG models (see also previous reports). In this case the phenomenology is enriched by the fact that PEP violation can occur without the neet to inject new electrons in the system.

The strategy of the measurements is to search for the X-rays signature of PEP-violating K_α and K_β transitions in selected targets. A dedicated phenomenological model was developed for the analyses. It consists in extracting the upper limit $\bar{S}$ of the expected number of total signal counts, generated by PEP violating K_α and K_β transitions in the target. A Bayesian comparison of $\bar{S}$ with the theoretically expected photons emission, due to PEP violating atomic transitions, then provids a limit on the characteristic energy scale Λ of the model.

The VIP Closed Systems experimental activity is realized in collaboration with the Low Radioactivity Laboratory at LNGS (team lead by Matthias Laubenstein). Theoretical analyses are carried out in collaboration with several leading groups in the field, including the ones lead by Marcianò (Fudan University), Addazzi (Sichuan University), Mavromatos (King's College),

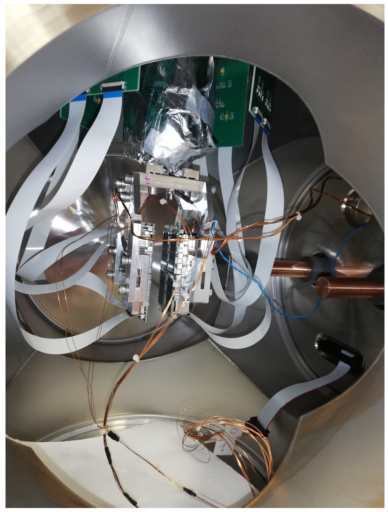

Figure 4: View of the inner part of the VIP-3 apparatus; inside the vacuum chamber, the four arrays of innovative 1-mm-thick SDDs are visible.

Illuminati (University of Salerno), and the group led by Finster (University of Regensburg).

5.1 VIP Closed-Systems: advances in the theoretical interpretation

During the reporting period, the refined spin–statistics model was finalized. The study of the algebra for annihilation and creation operators compatible with deformed Poincaré symmetry was initiated by Balachandran [A. P. Balachandran et al., Phys. Rev. D 75, 045009 (2007)]. Since then, most works have focused on a restricted version of the full algebra, ensuring the involutive character of particle exchange. In this framework, particles are described as generalized bosons or fermions, referred to as twisted bosons and twisted fermions.

In our work, we carried out the first analysis of the complete algebra and found that the previously neglected components play a crucial role both theoretically and phenomenologically. The full algebra not only accommodates twisted bosons and twisted fermions but also allows smooth interpolations between these limiting cases. This generalized picture yields fully consistent quantum field theories, potentially UV-complete. Importantly, it also provides the first relativistic generalization of the quon model.

Based on the full algebra, we addressed a longstanding problem, present since the introduction of twisted statistics in θ-Poincaré, concerning the normalization of PEP-violating states, and we rigorously derived the Pauli-violating transition rates. The corresponding data analysis is currently being finalized, and a paper reporting these results is in preparation.

5.2 VIP Closed Systems: advances in experimental activities and data analyses

During the reporting period, we finalized the realization of a prototype setup based on a Broad Energy Germanium (BEGe) detector combined with dedicated pulse-shape analysis tools (see previous reports). This system is aimed to achieve a low-energy threshold of a few keV and serves a dual purpose: (i) to improve sensitivity in the energy domain where QG effects are expected to emerge, and (ii) to develop a versatile detector able to measure spontaneous radiation emitted by various targets in the 1–15 keV range for testing new predictions of collapse models (see Section

6)

Specifically, during this period the installation of the isolation system in the new ultra-low background STELLA laboratory at LNGS (INFN) was completed:

- The system includes pneumatic isolators (see Figure 5) and a soundproof enclosure, designed to suppress microphonic noise by approximately one order of magnitude.
- The data acquisition system was also completed. A new acquisition system was developed, based on the dedicated, 14 bits resolution digitizer. This allows the acquisition of the pulse waveform, together with the energy spectrum information, which will improve the capabilities of the pulse shape discrimination analysis. The single pulse recording time was extended from the previous 2.5 us up to 30 us and more; moreover, the amplitude resolution was improved by a factor four, passing from the previous 12 bit to 14 bit. An additional factor of four comes from the ability to set a full-scale value of 0.5 Volts (increasing the overall sensitivity by a factor of 16). Additionally, we acquire data through two parallel channels: one with a full scale of 2V and another one with a full scale of 0.5V. This provides an amplified low-energy component, which can be effectively calibrated by comparison with the spectrum of the channel with the lowest sensitivity.

Figure 5: The improved BEGe experimental setup is shown, which is supported by pneumatic suspensions. The whole system is then enclosed by a soundproof box.

A test data-taking campaign began in December 2025 using a lutetium target, and the resulting calibrated energy spectrum is shown in Figure 6. The lower energy threshold was improved from 13 keV to approximately 6 keV, thereby fulfilling our original goal. A technical paper reporting on this activity is under preparation.

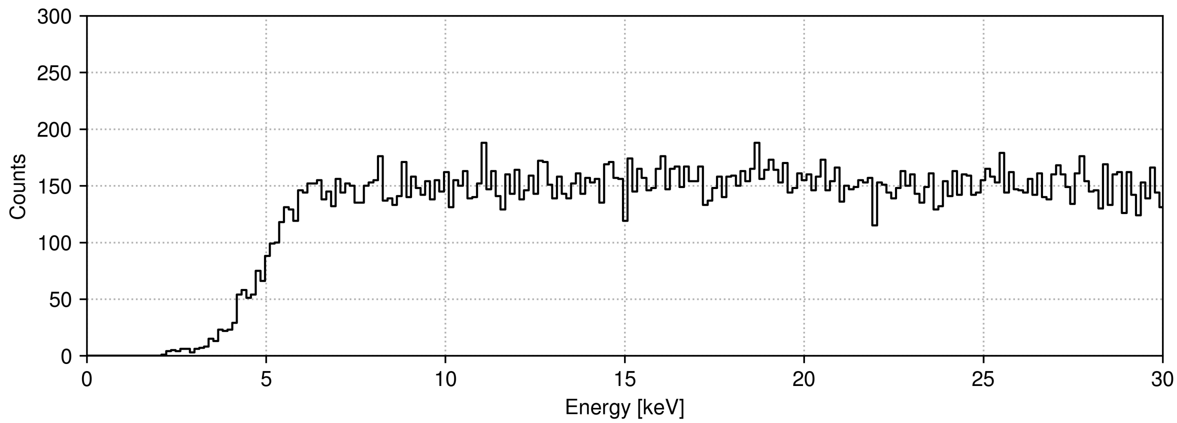

Figure 6: *Calibrated energy spectrum corresponding to the test data taking with the prototype BEGe based detector.*

In parallel, development of an improved Machine Learning (ML)–based pulse-shape discrimination algorithm was finalized. This also represented part of the summer research project of S. H. Yip (University of California, Berkeley). The new ML approach aims to improve energy resolution, enhance the signal-to-background ratio, and lower the energy threshold. Traditional methods are less effective in noisy conditions, particularly in our region of interest, where noise can lead to signal rejection and inaccurate feature extraction. To address this, the algorithm employs a denoising autoencoder to reconstruct clean signals from noisy inputs, enabling reliable feature extraction even at low energies, followed by a convolutional neural network (CNN) to reject background events. The paper reporting on these activities was recently published [12].

During 2026, a data-taking period of 2–3 months will be conducted, followed by event selection based on pulse shape analysis and subsequent data analysis.

We are continuing the design of the first experiment dedicated to measuring anisotropies in PEP-violating transitions induced by QG (see the previous report for more details).

6 Collapse Models experimental/phenomenological activity 2025

During the reporting period, we continued our experimental and theoretical investigations aimed at searching for spontaneous radiation emission signals within the framework of dynamical collapse models. Our collaboration with leading theoretical groups in the field (e.g. with Lajos Diosi (Eötvös University), Angelo Bassi (University of Trieste), and Sandro Donadi (Queen's University Belfast)) remained highly productive. More in detail:

- In Ref [13], spontaneous radiation emission was calculated in the case of correlated electron–nucleon emission for both the CSL and DP models, considering both white and non-Markovian noise. This work provided the first prediction of a distinctive spontaneous radiation signal from different collapse models in the 1–15 keV energy range and for different emitting atoms. During the reporting period, we finalized an enhanced version of the spontaneous radiation emission rate. This improved model incorporates intracule functions to calculate electron–electron distances within the atom, yielding a more precise determination of how the signal energy spectrum depends on the specific collapse model in the 1–15 keV energy range. A paper reporting these results is currently in preparation.

- The model mentioned above [13] stimulated a fruitful collaboration with the XENON collaboration, which proposed a joint analysis of their data to test the model. This analysis produced new world-leading limits on the free parameters of the Markovian CSL and DP models, improving on the previous best constraints by two orders of magnitude and a factor of five, respectively. Moreover, the original values proposed for the strength and correlation length of the CSL model have been experimentally excluded. A paper reporting these results was accepted for publication in Phys. Rev. Lett.
- The analysis of data collected with the HPGe detector, aimed at constraining the non-Markovian gravity-related Károlyházy collapse model, has also been completed, providing the most stringent limit currently available in the literature. A paper describing this work was submitted for publication.
- Furthermore, a study of relativistic time fluctuations in the context of the Continuous Spontaneous Localization and Diósi–Penrose models was published (see reference 4 in the publications list 2025). This work has received significant media attention and has been featured in several press releases (see e.g. https://phys.org/news/2026-01-twitch-quantum-collapse-hint-tiny.html).

Building on these studies, we are advancing with the design of a dedicated experimental setup. We are continuing the R&D of a specialized detector with high resolution and high detection efficiency for photons emitted by optimized external targets in the 1–15 keV range. During the 2026–2027 period, based on the results from the prototype BEGe-based test setup (see Section 5.2), we will optimize a dedicated setup. This setup will be enhanced with upgraded front-end electronics, including a low-noise data acquisition system and a high-insulation, low-noise amplifier.

7 Events organization in 2025

In 2025 the following events related to the physics of VIP, and, more generally to quantum mechanics, were organized:

- High Precision X-ray Measurements 2025, 16-20 June 2025, INFN-LNF, Frascati, Italy,

  (https://agenda.infn.it/event/43727/)
- Testing Quantum Foundations in the 2025 Quantum Year, 20-22 October 2025, INFN-LNF, Frascati, Italy.

  https://agenda.infn.it/event/47405/overview

8 Activities in 2026

It follows a schematic description of the activities which will be performed during 2026:

- The VIP-3-Hybrid setup will be installed at LNGS within spring 2025 and will take data for optimizing the setup. In parallel the full VIP-3 setup realization will be finalized. VIP-3 will be installed at LNGS within early 2026, and the data taking will start in current modulation regime.

- The upgraded BEGe based setup will be installed at LNGS within spring 2025. A data taking period of 2/3 months will be performed.
- The data analyses (from both HPGe and BEGe detector based setups) will be refined, in the contexts of beyong STandard Model Physics, such as Non Commutative Quantum Gravity, Generalized uncertainty principle and CPT deformation induced PEP violation.
- We will continue the investigation of experimental signatures of models of dynamical wave function collapse. Based on the expertise acquired in the optimization of germanium based detector systems, we will design an experiment dedicated to the simultaneous measurement of quantum gravity and quantum collapse signals.
- Other studies related to Quantum Foundations (such as J-PET and Quantum Biology) will be continued.

Acknowledgements

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We acknowledge support from the Centro Ricerche Enrico Fermi - Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi" (Open Problems in Quantum Mechanics project).

9 List of Conference Talks by LNF Authors in 2025

1. C. Curceanu, "Quantum Foundations and Living Light: Collapse Models, Consciousness, and Biophotons, Workshop Mind and Consciousness", Timisoara, Romania, November 6–7, 2025.
2. C. Curceanu, "Probing Quantum Gravity and Quantum Collapse models in the Cosmic Silence, Workshop Quantum Universe 2025 Particles, Gravitation, and Cosmology", 27 – 31 October 2025, Avellino (AV) – Italy.
3. C. Curceanu, "Il gatto di Schrödinger va nei laboratori sotterranei: sveleremo il segreto del collasso della funzione d'onda?, Workshop Un secolo di Meccanica quantistica", Torino, 15-16/10/2025.
4. C. Curceanu, "Testing Quantum Mechanics Underground: From Pauli Exclusion Principle Violations to Spontaneous Collapse, Bridging high and low energies in search of quantum gravity", Cost Action CA23130 First Annual Conference Paris, 7 – 11 July 2025.
5. C. Curceanu, "Schrödinger's Cat goes Underground: Testing Quantum Mechanics in the Cosmic Silence", Invited Colloquium University of Vienna, 16th June 2025
6. C. Curceanu, "Experimental test of the Quantum (Gravity) Collapse Models and QG (Pauli Exclusion Principle)", Invited Colloquium COST Action – RQI, WG2, 15 May 2025

7. C. Curceanu, “High-precision tests of the Pauli Exclusion Principle in proton-nucleus interactions using the SPES Cyclotron”, International Workshop on future research program with the high power Cyclotron of SPES-LNL, 12 - 13 May 2025.

8. C. Curceanu, “Probing Quantum Foundations Underground: From Spontaneous Collapse to Pauli Exclusion Principle Violations”, World Quantum Days in IFIN-HH 8–10 Apr 2025 National Library of Physics.

9. C. Curceanu, “Bridging QM with QG – experiments at Low Energies Experimental test of the Pauli Exclusion Principle and... more (Schroedinger’s cat)”, COST Action – BridgeQG – WG4, Low-energy high-precision experiment, 1st April 2025 (online).

10. C. Curceanu, “Experimental test of the Pauli Exclusion Principle and...more (Schroedinger’s cat)”, GSSI Astroparticle Colloquium 12 March 2025.

11. S. Manti, “Searching for Pauli Exclusion Principle Violations in Proton Systems as a Probe of Physics Beyond the Standard Model”, Perspectives at IBF Workshop, 8-10 October, LNGS, Italy.

12. S. Manti, “AI-Enhanced BEGe Detectors for Low-Energy X-ray Collapse Model Tests”, Testing Quantum Foundations in the 2025 Quantum Year, 20-22 October 2025, Frascati, Italy.

13. S. Manti, “AI-Enhanced BEGe Detectors for Low-Energy X-ray Collapse Model Tests”, EINN2025, 27-31 October 2025, Paphos, Cyprus.

14. F. Nola, “Probing Pauli Principle Violations through Neutron Star Equation of State”, Testing Quantum Foundations in the 2025 Quantum Year, 20-22 October 2025, INFN-LNF, Frascati.

15. K. Piscicchia, “Searching for signal of Quantum Collapse and Quantum Gravity in the cosmic silence of the Gran Sasso Underground Laboratories” High Precision X-ray Measurements 2025, INFN-LNF, Frascati, 16-20 June 2025 (https://agenda.infn.it/event/43727/) (Invited talk)

16. K. Piscicchia, “Quantum foundations phenomenology in underground experiments at LNGS, Workshop on Fundamental Physics with Exotic Atoms”, INFN-LNF, Frascati, 23-25 June 2025 (https://agenda.infn.it/event/46674/) (Invited talk).

17. K. Piscicchia, “Searching for signal of quantum collapse and quantum gravity in the cosmic silence of the Gran Sasso Underground Laboratories”, 111 Congresso Nazionale SIF, Palermo, 24 September 2025 (https://www.sif.it/attivita/congresso/111).

18. K. Piscicchia, “Searching for signal of quantum collapse through X-ray Emission Patterns Causal Fermion Systems 2025”, Regensburg, 6-10 October 2025 (https://causal-fermion-system.com/conference2025/program/) (Invited talk).

19. K. Piscicchia, “Searching for signals of wave function collapse in the cosmic silence”, 23 October 2025, Fudan University, Shanghai, China (Invited seminar).

20. K. Piscicchia, “Investigating the Quantum-Gravity Connection in the Cosmic Silence of the Gran Sasso Underground Laboratories”, 27 October 2025, Tsung-Dao Lee Institute, Shanghai, China (Invited seminar) .

21. K. Piscicchia, “Tracing Gravity-induced Collapse through X-ray Emission Patterns Chiba PIERS 2025”, 5 November 2025, Chiba, Japan (https://chiba2025.piers.org/) (Invited talk).

22. A. Porcelli, “VIP-2 Improved sensitivity on measuring the Pauli Exclusion Violation using the modulation of the current”, Testing Quantum Foundations in the 2025 Quantum Year, 20–22 ott 2025, INFN- LNF, Frascati.

10 Publications in 2025

1. S. Manti, S. H. Yip, M. Bazzi, N. Bortolotti, M. Bragadireanu, I. Carnevali, A. Clozza, L. De Paolis, R. Del Grande and C. Guaraldo, *et al.* Machine-learning-enhanced event selection for BEGe detectors in the VIP experiment, JINST **21** (2026) no.01, P01036 doi:10.1088/1748-0221/21/01/P01036 [arXiv:2512.09777 [physics.ins-det]].

2. A. Porcelli, K. V. Eliyan, G. Moskal, N. N. Protiti, D. L. Sirghi, E. Y. Beyene, N. Chug, C. Curceanu, E. Czerwiński and M. Das, *et al.* μPPET: Investigating the Muon Puzzle with J-PET Detectors, Universe **11** (2025) no.6, 180 doi:10.3390/universe11060180

3. F. Napolitano, M. Bazzi, N. Bortolotti, M. Bragadireanu, M. Cargnelli, A. Clozza, L. De Paolis, R. Del Grande, C. Guaraldo and M. Iliescu, *et al.* Testing the Pauli Exclusion Principle and fundamental symmetries with the VIP underground experiment, PoS **DISCRETE2024** (2025), 047 doi:10.22323/1.481.0047

4. N. Bortolotti, C. Curceanu, L. Diósi, S. Manti and K. Piscicchia, Fundamental limits on clock precision from spacetime uncertainty in quantum collapse models, Phys. Rev. Res. **7** (2025) no.4, 043166 doi:10.1103/p6tj-lg8l [arXiv:2504.06109 [quant-ph]].

5. N. Chug, C. Curceanu et al. (J-PET Collaboration), Studies of CPT symmetry in positronium decays with the 192 plastic strip J-PET detector, Phys.Rev.D **113** (2026) 3, 032003

6. M. Rädler, C. Curceanu et al. (J-PET Collaboration), Simulation Studies of a Brain PET Insert for the Total Body J-PET Tomograph, Contribution to 2025 IEEE NSS MIC RTSD

7. K.Tayefi Ardebili, C. Curceanu et al. (J-PET Collaboration), Development of a Cost-Effective Total Body J-PET From Plastic Scintillators: Definitive Design, Contribution to: 2025 IEEE NSS MIC RTSD

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