Letter of Intent

To: EGO Director - EGO Council Chair - Virgo Spokesperson

Date: 15/05/2025

From: Firenze/Urbino Group

Contact Person: Francesco Piergiovanni (francesco.piergiovanni@uniurb.it)

Subject: Expression of Interest to join VirgoLab

Dear Sir/Madam,

This letter serves as a formal expression of interest by Firenze/Urbino (Fi/Urb) Group to join the VirgoLab, as described in VIR-1025B-24. We understand that VirgoLab operates, commissions, and upgrades the Virgo interferometer, and we are willing to contribute to its mission and to the achievement of its goals.

1. Introduction

The Fi/Urb Group is a research group within the University of Urbino, the University of Firenze and the Firenze Section of the Istituto Nazionale di Fisica Nucleare, specializing in thermal noise reduction in suspension and mirror coatings, detector characterization and data analysis. Our expertise and ongoing research activities are highly relevant to the operation, commissioning, and potential upgrades of gravitational wave interferometers.

We know that details about the VirgoLab organization are still to be fully defined and clarified, and we understand that this letter does not imply any formal commitment. Nevertheless we believe that our participation in VirgoLab has the potential to be mutually beneficial, allowing us to contribute our knowledge and resources to the advancement of gravitational wave science in Europe and beyond, while also providing our members with valuable experience and opportunities within a leading international collaboration.

This letter outlines our main areas of interest and potential contributions to VirgoLab.

2. Scientific / Technological Case or Context of Opportunity

Our group has a strong background in

- *(Technology)*: The group has extensive experience in the development and implementation of monolithic suspensions aimed at reducing suspension thermal noise. For over ten years, it has been responsible for the design, production, and characterization of fused silica fibers used in the suspension systems of the test masses, initially for the Virgo+ project and later for Advanced Virgo. The group has also developed expertise in computing the thermal noise contributions from the suspension chain. The equipment for the production and characterization of silica fibers available in the EGO laboratories has been duplicated at the Urbino laboratory. This provides, on the one hand, a backup solution in case of malfunctions at EGO and, on the other hand, enables an improvement program on the equipment while ensuring operational

continuity.
Moreover, the group is actively involved in research on low mechanical dissipation coatings, with particular achievements in overcoming metrological challenges, studying the effects of post-deposition thermal treatments in amorphous oxides (such as incipient crystallization), and developing coatings based on novel materials such as nitrides and amorphous semiconductors. To facilitate the characterization of thermo-mechanical properties in thin film coatings, the group developed dedicated simulation software tools based on finite element analysis, which have been used to design and analyse the measurements of mechanical losses in materials of interest, at both room and cryogenic temperatures. At the Urbino laboratory, we have several instruments for coating characterization: two GeNS facilities for measuring mechanical dissipation (one at room temperature and the other at cryogenic temperature) housed in a cleanroom, an apparatus for measuring the thermo-optic coefficient and thermal expansion, and a furnace for heat treatments in vacuum or controlled atmosphere. In addition, we have a range of instruments for structural analysis, including optical microscopes, a scanning electron microscope (SEM), and an atomic force microscope (AFM).

- *(Detector characterization):* The group is deeply involved in several topics and has developed important expertise. Noise induced by scattered light is studied by modeling and simulation. Its effects on the estimation of astrophysical parameters have been evaluated, and a noise subtraction algorithm has been developed. The impact of noise glitches on the background of astrophysical searches is addressed, with particular attention to how they affect search sensitivity. For this purpose, the use of Machine Learning algorithms has been explored, to improve efficiency and extend the techniques typically used in the collaboration. The group has also contributed to the Rapid Response Team and the Validation of astrophysical event candidates. Additional contributions have been made to the study of spectral noise, with the identification and characterization of spectral lines, during O4 and in the commissioning phase preceding the start of the run. The group also aims to use the experience gained to extend its contribution to data quality studies.
- *(Commissioning):* The group takes part in noise hunting and characterization of on-site noise sources. In particular the assessment of magnetic noise sources is carried out. Other activities concern the evaluation of the noise level coming from human activities and civil infrastructure.
- *(Low Latency operations)* Low-latency detection of signals from compact binary coalescences (CBC). The group has long been involved in the development and maintenance and operation of the Multi-Band Template Analysis (MBTA) software and in the generation of template banks for online analysis. The use of ML has been tested to produce online statistics to assess the astrophysical significance of detected events. In addition, the group has worked on parameter estimation through the development of various software tools, such as SkyFast, aimed particularly at improving the localization of sources of CBC signals.

- *(Simulation)*: The group has developed the OctoPyUs software for mechanical simulation of the suspension and attenuation chain, based on the impedance matrix method. Over the years, OctoPyUs has evolved into a versatile and practical tool that effectively supports the design, optimization, and analysis of suspension systems. The software also enables the estimation of suspension thermal noise. In this context, the group has made significant contributions to the development of the suspension thermal noise module in the GWINC software for Virgo+, Advanced Virgo, and Advanced Virgo+.

3. Description of the Proposed Contribution

Our proposed involvement in VirgoLab would encompass the following potential contributions:

Area	Activity	Project	Technical Team
Technology	Provide support when necessary for the maintenance and enhancement of the monolithic suspensions of the test masses	Detector Operations and Maintenance	Mechanics & Vacuum
	Participate in the development of a new coating for O5, including thermo-mechanical and thermo-optical characterization.	Detector Upgrades	Optics & Light
	Development of monolithic suspensions for large test masses	Detector Upgrades	Mechanics & Vacuum
	Prototyping silica suspensions of the marionette stage to reduce suspension thermal noise.	Detector Upgrades	Mechanics & Vacuum
	Working on selected candidate materials for high performance coatings (nitrides, amorphous semiconductors, crystalline oxides) to achieve readiness for post O5 upgrades.	Detector Upgrades	Optics & Light
Detector characterization	Study of noise glitches during the O4 run, including the assessment of the impact of glitches (e.g. 25-minute glitches) on CBC search with the MBTA pipeline. Modelling and subtraction of the stray light.	Detector Operations and Maintenance	Computing & Software
Commissioning	Characterization of environmental noise coupling and its evolution during the O4 observational campaign.	Detector Commissioning	Infrastructure
Low Latency operations	Maintenance and operation of the MBTA pipeline. Production of template banks for O5.	Detector Operations and Maintenance	Computing & Software

	Testing innovative methods and implementations, such as machine learning and GPU acceleration, for background studies and improving CBC signal significance..	Detector Operations and Maintenance	Computing & Software
Simulation	Analysis of the mechanical behavior of suspension systems using OctoPyUs. Evaluation of suspension thermal noise.	Detector Commissioning and Detector Upgrades	Controls & Simulations

We are also open to contributing to other areas based on the evolving needs of VirgoLab and the expertise within our group. We are open to exploring ways to engage with the existing VirgoLab Technical Teams and Projects, with the aim of understanding where our skills and resources might contribute.

4. Costs, Calendar and Resources

Initially, our contribution will primarily involve the efforts of our existing personnel, currently includes approximately 9 FTEs, distributed among the following activities:

- Operation and commissioning.
- Detector upgrades for O5.
- Upgrades for the post-O5 phase.
- Data analysis and low-latency operations.

We understand that the successful accomplishment of VirgoLab tasks, particularly the timely installation and commissioning of the O5 upgrade, will demand a strong presence at the EGO site. Our group is committed to supporting that effort as much as reasonably possible.

We anticipate the need for:

- travel to EGO for the production of silica fibers, mounting of test mass payloads, on-site detector characterization and commissioning activities, low-latency operation face to face, and participation in Collaboration meetings;
- use of the fiber production machine located in the clean room of building 1500W;
- use of the clean rooms in the central building and in building 1500W;
- support from EGO's mechanical design services and mechanical workshop for the maintenance and improvement of the fiber production and characterization machines.
- access to the auxiliary channels for commissioning and detchar purposes.

We understand that Member Labs are in charge of maintaining and operating the equipment they provide.

We are aware that financial resources are allocated by EGO Council, national funding agencies, or research organizations. We will explore potential funding opportunities through our institution and national agencies to support our involvement in VirgoLab.

We are prepared to work towards the establishment of a MoA with EGO should our application be successful.

5. Stakeholders and Requirements

Our primary stakeholders are the University of Urbino, the University of Firenze and the Firenze Section of the Istituto Nazionale di Fisica Nucleare (INFN). We understand that as a contributing group, our main requirements would be to have effective communication channels within VirgoLab, opportunities for our members to actively participate in relevant projects and technical teams, and recognition for our contributions to the scientific and technical advancements of Virgo.

We are ready to discuss our potential participation further and provide any additional information that may be required. We look forward to the possibility of joining the VirgoLab and contributing to its continued success.

Sincerely,

Francesco Piergiovanni on behalf of Firenze/Urbino Group