# Review of “Precision Laser Metrology for Accelerators and Detector Complexes” project: Proposal for Extension of JINR Participation in 2022-2023

The Precision Laser Inclinometer (PLI) is an instrument to detect ground inclinations with high precision in direct angular measurement and as feedback sensor for high precision laser metrology instruments. The working principle briefly is:

* The PLI uses the displacement of the laser ray reflected from a liquid (oil) surface when the base support is tilted by ground oscillations.
* The angle of the reflected light is twice larger than the support tilt angle θ.
* The detection of the laser spot displacement by a position-sensitive quadrant photodetector is in both directions, therefore the combined slope and azimuth can be easily calculated.

The current PLI size is 50x40x30 (or 55x45x30) cm3 and its weight is 65 (or 50) kg. The device can do precision registration of angular oscillations of the Earth's surface under the influence of microseismical phenomena: surface microseismical waves, deformation of the Earth's surface by the Moon and the Sun, irregular movements of the earth's crust.

The main goal of the project in its second extension (2022-2023) is to create an innovative compact monolithic PLI (20x20x20 cm3 and less than 10 kg). The authors foresee use in

* Interferometric Gravitational Antennas (VIRGO, possibly Telescope Einstein).
* Seismic isolation systems for NIKA, LHC and possibly FCC colliders.
* PLI networks in Armenia and Uzbekistan for earthquake prediction.

In addition, the project plans to test extensively the actively developed metrological toolkit: Laser Reference Line, Interferometric Distance Meter and Seismic Insulated Platform.

**The JINR group achieved the following results in 2019-2021**

* Creation of the Metrological Laboratory (ML) DLNP
* Creation of a network of four PLIs at CERN (CERN-JINR Agreement).
* Creation of a monitoring system for angular oscillations of the Earth's surface on the territory of the VIRGO Interferometric Gravitational Antenna (IGA)
* Forecast of earthquakes using the PLI network
* Laser Fiducial Line
* Interferometric Distance Meter
* Research platform seismically isolated from angular vibrations of the Earth's surface
* The PLI has been patented

**The planns in the next two years 2022-2023 are**:

* Put into operation the innovative Compact Precision Laser Inclinometer, the next generation of PLI.
* Deploy a network of five PLIs in the LHC tunnel and obtain the world's first online visualization of the passage of surface seismic waves under the LHC collider.
* Test the Compact PLI in the conditions of the IGA VIRGO.
* Test a Compact PLI for recording seismic activity in Armenia and Uzbekistan.

**The requested budget for the extension is 192 kUSD,** 160 kUSD from JINR and 32 kUSD from BMBF and from Armenia. 132 kUSD are devoted to the compact PLI, and 20 kUSD for each of the components of the metrological toolkit: Laser Fiducial Line, Interferometric Distance Meter, and Seismic isolated platform. The required resources are adequate to the amount and complexity of the tasks.

**The group composition is relatively well balanced**. The members have sufficient knowledge and experience to successfully complete the project. At the same time the list of co-authors is much longer than the participants with allocated contribution in the attached table. It is important to clarify the FTE of the authors who are not in Table 9, p. 28.

The main question is probably how well such technological project is integrated in the scientific plans of JINR. It provides wide range of possibilities for scientific collaboration in different fields outside of Particle Physics. Recently a grant from CERN & Society Foundation was approved to exploit PLI as earthquake (very) early warning system (studying prompt gravity signals). I encourage the authors to quantify possible funding from such external sources and the benefits for JINR.

**The reviews of the referees V.M.Grebenyuk and V.A.Nikitin are positive and support the requested extension.** They underline the experience of the group, the successful completion of the previous project stages, and the important achievements. The referees indicate that the required resources are adequate. They also rise several questions which should be answered by the authors of the project. I agree with these questions and comments and add them to my review:

1. The requested extension is two years, and its end coincides with the end of the corresponding theme. The number of tasks is very significant, did the authors consider launching new theme with longer scope?
2. It would be good to strengthen the metrology group and attract new young members.
3. Would the authors quantify the expected increase in the beam stability and collider luminosity due to the seismic isolation system?
4. How exactly the two PLI helped to improve the operations of VIRGO?
5. What is the expected precision of the earthquake predictions in Armenia and Uzbekistan, mentioned in the project?

I noted that some of the suggestions by the internal referees had been considered in the current version of the project. In addition, I have the following comments:

1. The project spends a lot of time to describe the technical details and convincingly shows the feasibility of the developments. However, it does not discuss the relations with the external collaborations and entities, where the PLI would be installed, the principles of funding, collaboration, or participation in the physics program. For example, do the authors plan to become members of VIRGO and participate in the data analysis/publications?
2. The CPLI has very good perspectives in seismology since it is portable, can be calibrated easily and can be integrated with different DAQ modules. Recently approved grant from CERN & Society Foundation to exploit PLI as earthquake (very) early warning system (studying prompt gravity signals). The project does not mention anything on this subject while the CERN representatives are in the authors list.
3. I congratulate the authors on [receiving the patent](http://www.jinr.ru/posts/patent-for-laser-inclinometer-received/) for the PLI, even if they do not mention it in the project.
4. The project shows good example of knowledge transfer and I encourage more developments in this direction.

**I completely agree with the opinion of both referees and propose to extend the “Precision Laser Metrology for Accelerators and Detector Complexes” project in 2022-2023.**

Peter Hristov

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