Abstract for collaboration between EIC and AANL using ADL

Introduction

The creation and furnishing of the Advanced Detector Laboratory will create real conditions for research in the AANL, will deepen and raise our international collaboration to a higher level, will introduce to Armenia a culture corresponding to international standards for measuring crystals and determining their optical properties . YerPhI scientists have gained a lot of experience and knowledge in this field thanks to our international collaboration with JLab, DESY, and later with CERN. AANL teams have participated in both scientific experiments and the creation and operation of necessary equipment. We especially value our partnership with the Jefferson National Laboratory (JLab), which has long history. Starting in 1990, the collaboration between AANL and JLab not only gradually expanded and deepened, but also has great prospects for further development. The upcoming years of collaboration will include not only the planned 12-GeV energy operation of CEBAF accelerator, but also possible research and partnership for the future Electron-Ion Collider (EIC). AANL physicists have been involved for several years in measuring optical and radiation characteristics of $PbWO_4$ crystals for the JLab's NPS spectrometer and the EIC calorimeter, in studying several prototypes of calorimeters constructed with these crystals. However, due to the lack of appropriate laboratory equipment in the AANL, they worked using only the JLab technical base.

Opportunities for studying and researching calorimeters and crystals.

Electromagnetic calorimeters currently in use, and future devices require the best possible accuracy of energy and coordinate measurements, homogeneity of characteristics across full effective area (few square meters), service life of at least 10-15 years, resistance to prompt and accumulated radiation. The tolerance of external dimensions of the crystals must also be considered, as their deviation beyond limits will cause serious, sometimes unsolvable problems. To meet such requirements and select high-quality crystals, they must first be examined in advance visually, then for the quality of surface treatment, absence of deep and large cavities. It is important to measure optical transmission of the selected crystals in 200-1000 nm wavelength range. For the effective participation of the AANL in such collaborative research, it is necessary to have a laboratory equipped with appropriate tools. The crystals used in modern elementary particles experiments, and in future large-scale high-energy detectors must undergo detailed studies and preliminary tests.

The purpose of the preliminary examination of appearance of the crystals is to eliminate crystals with visible large cracks, scratches or lateral fractures from further studies. The quality of surface and internal structure of the selected crystals is studied by means of an electron microscope, such a device allows for checking surface roughness of the crystals with an accuracy of better than 10 microns, for detection of invisible to the naked eye mechanical defects. Under microscope one can look and find bubbles and sand grains deep inside the crystals. Some of the not qualified crystals found in the tests (about 10% of the total from experience), despite such shortcomings, can be used later in the calorimeter. However, the number of bubbles and sand centers should be less than 3-5, their size should not exceed 200 μm, and crystal must meet light transmission test in further inspections. In multichannel (several thousand) calorimeters there are strict limits on the size of individual modules and their deviations. For example, for CMS (80000 modules), PANDA (15000 modules) and NPS (1500 modules) calorimeters dimensions of the individual modules did not deviate from their intended engineering sizes by more than 50 microns. In some cases, such requirements may be more stringent (for example, 30 μm in case of EIC). This is determined by requirement of homogeneity across the calorimeter, by minimizing dead space between the modules. Therefore, it is necessary to check, measure and sort all the crystals according to size. The longitudinal and transverse dimensions of the Specific spectrometer allows for measurement of light transmittance and absorption in the wavelength range from 250 to 2500 nm in steps of 1nm. To study the radiation resistance of crystals, it is planned to irradiate them with electron (LUE-75) and proton (CYCLON-18) beams at AANL.

Experimental devices developed for experiments at electromagnetic and proton-ion beams are exposed to intense radiation, which can accumulate up to tens or millions of rad in a total dose. In this case, color centers are formed in the crystal of the calorimeter, which significantly impairs their optical transparency, absorbing most of the light needed for registration. The changes caused by radiation can be gradually restored spontaneously, but it will take days or months. The best method of forced restoration of optical permeability lost due to electromagnetic radiation in $PbWO_4$ crystals is thermal annealing in special laboratory oven (Laboratory Vacuum Drying Oven). Thermal annealing of severely damaged crystals is carried out by keeping them at a temperature of 200-400 ^{0}C for about 8-10 hours. The crystals are placed in oven in which the temperature is gradually raised (1-2 ^{0}C per minute) to a pre-programmed point, kept constant for about 8-10 hours, and then gradually reduced to room temperature. Such an oven will be widely used to solve many other experimental problems, such as optical gluing, or to separate glued optical parts from each other, to make soft optical touch pads.

Main Goal

EIC group collaboration will provide opportunity of studying calorimetry at AANL, involving more young people in international collaborations as well as bringing outside research to be done here on site. Radiated particle registration requires specific methodology of detection, each particle has its specific behavior , for particle identification set of detectors is used, for example Aerogel to detect Kaons, Lead Tungsten crystals to detect neutral particles, TF1 crystals to detect heavy particles...

With ADL equipment we will start research of crystal properties for detector used around the world as well as we will develop our own prototypes here on site. Research on rad damage of crystals, recovery, transmittance study. Methodology of gain monitoring for detectors will also be developed on site, as well as curing multiple systems will be design and proposed for development. AANL will have partnership in upcoming EIC project in collaboration with Jlab and Brookhaven Lab, opening new wide opportunities for scientific research.

Team of Scientists

Below mentioned members of the A. Alikhanyan National Scientific Laboratory (Yerevan Physics Institute) are highly qualified specialists in the field. They have extensive experience in the design, construction, and operation of various detectors for the detection and identification of high energy elementary particles, in particular calorimeters based on heavy glass:

- Mkrtchyan Hamlet , Doctor Professor of Science, Leading Researcher, has been working at AANL since 1964. At the Jefferson National Laboratory in the United States, within the framework of international collaboration, he participated in the construction of elementary particle detectors, and in number of experiments made with them. Researched prototypes of calorimeters based on $PbWO_4$ crystals, measured characteristics of $PbWO_4$, studied their radiation damage and methods of restoration.

- Asaturyan Arshak , PhD of Science, Senior Researcher, has been working at AANL since 2004. In the framework of AANL-JLab international collaboration he participated in the design and construction of the elementary particle detectors and in experiments carried out with them. Studied optical characteristics of $PbWO_4$ crystals, built and tested prototypes of calorimeters built from them. He studied radiation damage of crystals and methods of recovery.

- Voskanyan Hakob , researcher, has been working at AANL since 1980. In the framework of AANL-JLab international collaboration he participated in design and construction of detectors for high energy elementary particles and in the experiments performed with them. Built several electromagnetic calorimeters made of heavy glass, scintillation pre-shower detectors, prototypes of a calorimeter based on $PbWO_4$ crystals.

- Mkrtchyan Arthur , PhD of Science, Senior Researcher, has been working at AANL since 2004. In the framework of AANL-JLab international collaboration participated in the design and construction of devices for detection and identification of particles, and experiments carried out with them. Worked with calorimeters made of $PbWO_4$ crystals, measured optical transmission of the crystals, studied radiation effects in them and methods of their restoration.

- Tadevosyan Vardan , researcher, has been working at AANL since 1986. In the framework of AANL-JLab international collaboration, he participated in the design and construction of electromagnetic calorimeters, and in more than 80 experiments conducted with those detectors. Measured optical characteristics of $PbWO_4$ crystals, studied effect of radiation damage of the crystals and methods of restoring their properties.

- Shahinyan Albert , Tech. Candidate, Senior Researcher, has been working at AANL since 1975. Within the framework of AANL-JLab international collaboration he participated in the design and construction of various elementary particle detectors and in experiments performed with those devices. Built a number of electromagnetic calorimeters made of heavy glass crystals, studied their optical characteristics, investigated quantum efficiency and time resolution of photo-sensors, long term stability of spectrometric electronics.