Essential Equipment for AANL Advanced Center for Detection Technologies

To conduct methodological works at the AANL, and for research programs in the framework of International Collaborations with JLab, EIC and NICA we need to have a laboratory room equipped with:

- *Device for accurate (2-3 μm) measurements of crystal dimensions,*
- *Microscope to check the quality of surface and for internal impurities (hollows, sand grains) of crystals,*
- *Device for measuring optical transmission of crystals in the range of 300-900 nm,*
- *Oven for thermal annealing of crystals to recover radiation damage,*
- *Test setup with amplitude and time measurement electronics (ADC, TDC, crate etc.),*
- *Computer and DAQ with recording and processing systems (PC + DAQ) for testing of the EmCal prototype, to teach and train young professionals and students.*
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TECHNICAL CHARACTERISTICS OF THE DEVICE / EQUIPMENT

Device name	Technical description:
1.OCEAN OPTICS USB-4000+Fiber&Connector Price: $4500	- wavelength range 200-1100 nm - wavelength resolution 1.5 nm - Integration time 10 μs–10 s - Power supply 5 V, 250 mA - weight < 1 kg
2.PerkinElmer Lambda 950/1050 spectrometer Price: $10000	- wavelength range 175-3300 nm - with double beam and monochromator - resolution ≤ 0.20 nm - weight ~70 kg
3.Mitutoyo Electronic Digital Height Gage + Price: $3500 High surface quality laboratory optical table (Stainless Steel or Granite) Price: $3500	- measurement accuracy 1-2 μm - with digital measuring panel - table dimensions 100 cm × 100 cm - surface plane ~1-2 μm
4.Scanning electron microscope with EDS & WDS and nano-manipulator JEOL 6300, JEOL 5910, or Scanning Electron Microscope SU3900, or Digital Measuring Microscope SVM-2515	- magnification ×350,000 (5 μm) - dimensions < 50 cm × 50 cm - weight < 20-30 kg

Price: $15000	
5.Drying oven, laboratory vacuum with thermal control and stabilization Price: $10000	- Temperature range 20-1000 ^{o}C - Temperature stability 0.05^{o}C - program controllable
6. Transportation costs: $1500	
Equipment: $46500 USD + 35%	
Total: ~$65,000	
Data acquisition system for Multichannel Detectors (DAQ)	Desktop Computer
	VME Crate and modules
€3,000	1. CAEN VME Crate, VME8010 7U 21 slot
€2,240	2. CAEN VX1718 VME–USB 2.0 Bridge (10Mby/sec)
€2,390	3. CAEN VX2718 VME–PCI optical Bridge (80Mby/sec)
€2,910	4. V792 16 Channel Multi-event QDC
€3,780	5. V965 16 Channel Dual Range Multi-event QDC
€5,230	6. V1290N–2eSST 16 Channel Multi-hit TDC (25 ps)
€5,070	7. V1190B–2eSST 64 Channel Multi-hit
	NIM Crate and modules
€4,900	1.WNIM8301300W NIMcrate with fan
€3,950	2.WNIM8303300W NIM crate with out fan
€2,860	3.N979 - 16 Channel Fixed Gain Fast Amplifier
€4,090	4. N841 - 16 Channel Leading Edge Discriminator
€5,230	5. N843 - 16 Channel Constant Frac. Discriminator
€1,880	6. N625 - Quad Linear Fan-In Fan-Out

€1,830 €2,700 €2,190 €250 Total €51,500*	7. N113 - Dual OR 12 In-2 Out . 8. N405 - Triple 4-Fold Logic Unit/Majority with Veto 9. N455 - Quad Coincidence Logic Unit Shipping and handling (DAP Yerevan)

Scientists to engage in ACDT

- Mkrtchyan Hamlet Gegham, Phys. Math. Doctor 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. He studied prototypes of calorimeters based on $PbWO_4$ crystals, measured characteristics of $PbWO_4$, studied their radiation damage and methods of restoration.
- Asaturyan Arshak Razmik, Phys. Math. Candidate of Sciences, 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. He 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 Volodia, 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. He built several electromagnetic calorimeters made of heavy glass, scintillation pre-shower detectors, prototypes of a calorimeter based on $PbWO_4$ crystals.
- Mkrtchyan Arthur Hamlet, Phys. Math. Candidate of Sciences, 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 devices for detection and identification of particles, and experiments carried out with them. He studied calorimeters made of $PbWO_4$ crystals, measured optical transmission of the crystals, studied radiation effects in them and methods of their restoration.
- Tadevosyan Vardan Hovhannes, 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. He measured optical characteristics of $PbWO_4$ crystals, studied effect of radiation damage of the crystals and methods of restoring their properties.

- Shahinyan Albert Hayrapet, 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. He 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.

The opportunity and cientific activities to be supported by equipment in ACDT

The above-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. 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. In these three best centers of the world, 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 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. The creation and furnishing of the proposed laboratory room will create real conditions for such 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. 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 taken into account, 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 researches, it is necessary to create a laboratory equipped with appropriate equipment. It will also be very useful to other scientific and educational centers of Armenia (Ashtarak Phys. Inst., Yerevan State University). The crystals used in modern elementary particles experiments, and in future large-scale high-energy detectors must undergo detailed studies and preliminary tests. Among them are:

- **Microscopic examinations of external and internal heterogeneities of crystals**

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, which must be equipped with EDS and WDS systems, by use of nano-manipulator (JEOL 6300, JEOL 5910) in conjunction with VSL. 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.

- **Accurate measurement of crystals**

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 crystals must be measured at least with accuracy of 5 microns, for example with a Mitutoyo Electric Digital Height device.

- **Measurements of optical transmission of the crystals**

Perkin-Elmer-Lambda and Ocean-Optics-USB-4000 devices will be used to measure optical transmission of the crystals in the longitudinal and transverse directions. The Perkin-Elmer-Lambda photo-spectrometer operates in ultraviolet-to-visible range of wavelength of dual beam, is equipped with a dual monochromator, and a large camera for sample placement. The spectrometer allows for measurement of light transmittance and absorption in the wavelength range from 250 to 2500 nm in steps of 1 nm. Reproducibility of measurements and uncertainty is about 0.2%.

It should be noted that meeting the optical requirements is not enough for the crystals to be considered good. Indeed, it was found that 5% of crystals with good optical characteristics had other defects that led to non-homogeneity of light collection.

The longitudinal transmittance of the crystal will be measured with the Perkin-Elmer Lambda 950 spectrometer in the range of 200 to 900 nm light wavelength. To study the radiation resistance of crystals, it is planned to irradiate them with electron (LUE-75) and proton (CYCLON-18) beams at AANL.

Despite all its good features, the Perkin-Elmer Lambda weighs about 70 kg, so it is impossible to use it in the measurements that must be made immediately after the radiation of the crystals. This gap will be filled by having a nearby "light" Ocean-Optics device. Despite its modest accuracy (15%), the gradual deterioration of the crystal's optical transmittance can be measured very quickly immediately after the accumulation of step-by-step radiation dose. Combining this data with the Perkin-Elmer Lambda 950 measurements 2-5 hours or days after irradiation can reveal short-term and long-term damages to the crystal and follow their spontaneous recovery.

- **Repair of radiation damage of crystals**

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.