Experimental Physics Division

http://epd.yerphi.am/EPD.htm

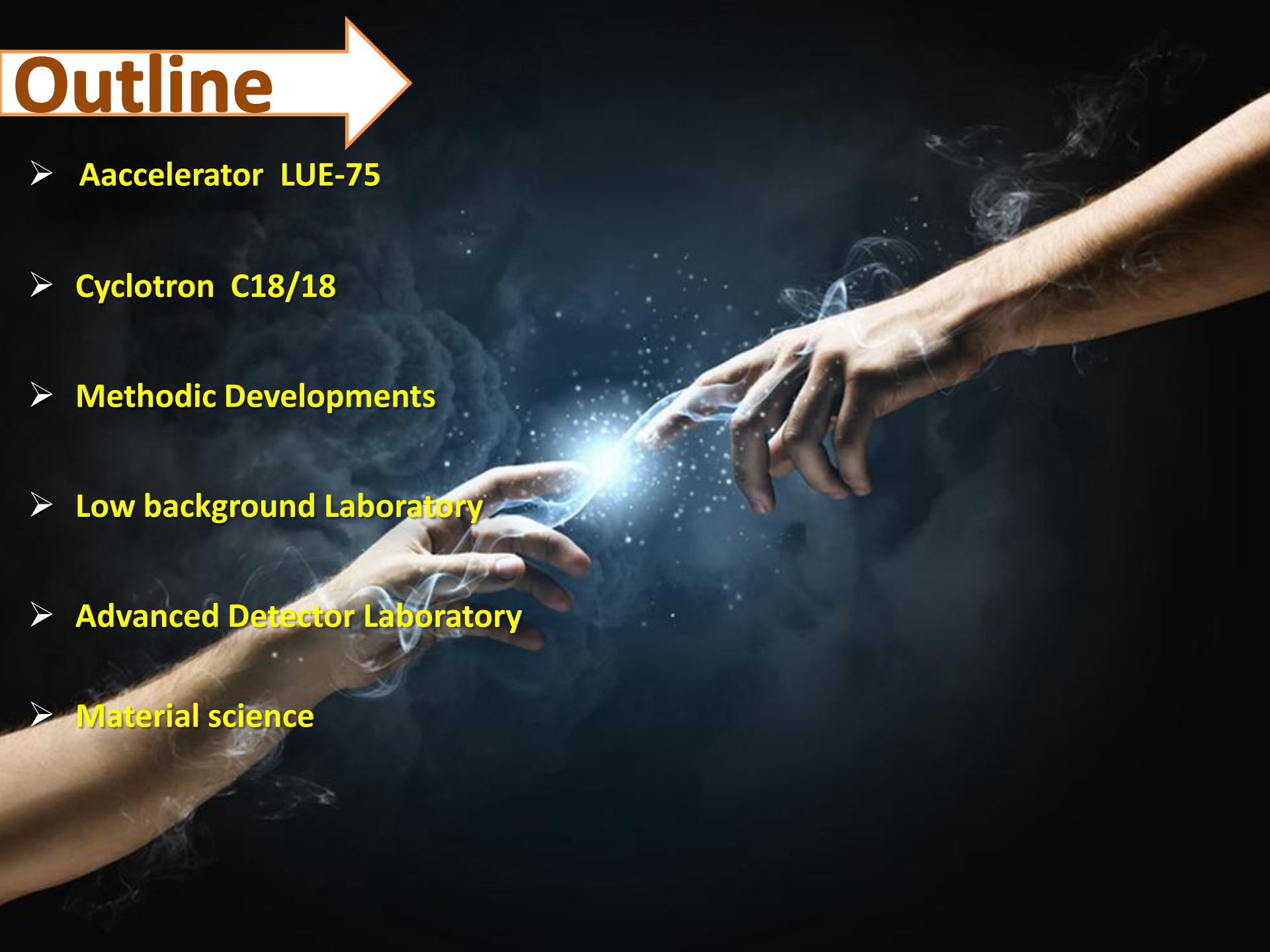
Hrachya Marukyan

Overview of research areas of EPD at AANL

25 April 2024 , Yerevan, Armenia

Outline

- Aaccelerator LUE-75
- Cyclotron C18/18
- Methodic Developments
- Low background Laboratory
- Advanced Detector Laboratory
- Material science



Electron Linear Accelerator LUE – 75

Number of accelerating sections	4
Field frequency	2.7973 GHz
Number of RF blocks	3 klystrons
RF power per unit	20 MW
Repetition rate	50 Hz
Beam energy	10 –75 MeV
Average beam intensity	10^{-18} - 10^{-5}A
Bunch duration	≤ 36 ps
ΔE/E (FWHM)	~ 2% with the collimation at the medium beam currents I = 0.2 – 2 μA
Vacuum	10^{-6} Torr

- Unique in region: electron beam with energies up to 75 MeV.
- Provides electrons in the large limits of beam currents 10^{-18}-10^{-5}A.
- Extremely low intensities: ~ 10-20 e/s.

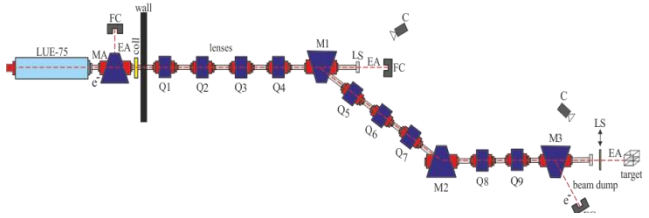
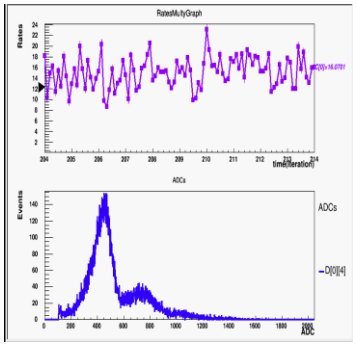


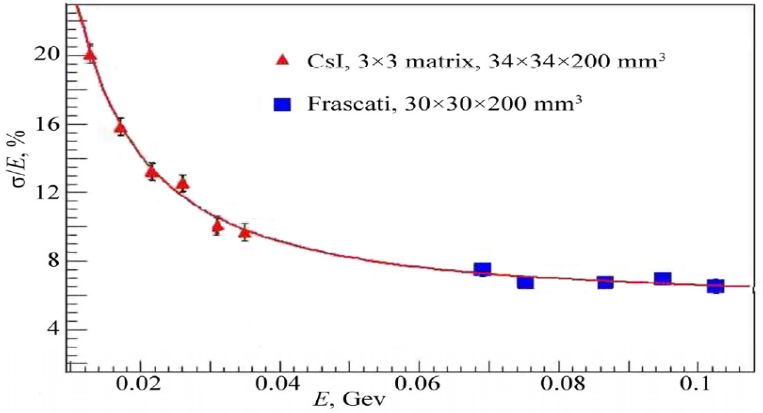
Diagram of the beam transport path with parallel transfer.

Since 2014, active cooperation has been resumed between JINR and AANL (YerPhI) on the basis of the linear electron accelerator LUE-75 ЛИУЭ-75.

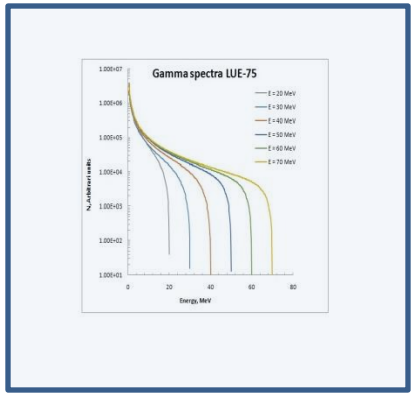


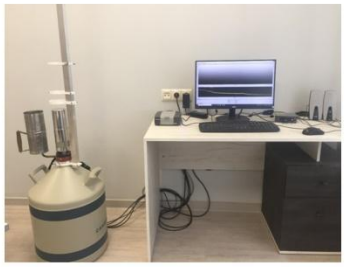
Upper ray – the line for reading single events; Bottom – the distribution of the events; Hump on the right corresponds to the intensity of the two electron events.

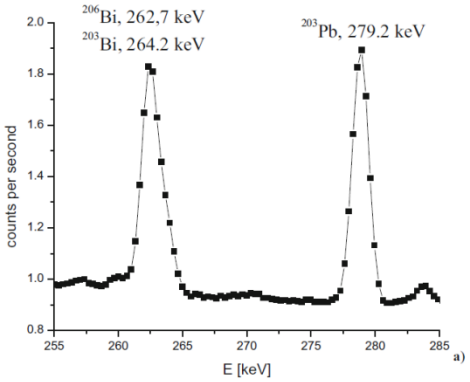
This circumstance served as an incentive to carry out reconstruction work to increase the energy of the LUE to 75 MeV and obtain ultra-low intensity beams. Joint work between JINR (LNP) and AANL (EPD) was successfully carried out in 2014-2019 with these unique beams - several tens of electrons per second - on testing a matrix of CsI crystals, which served as a prototype of the electromagnetic calorimeter of the Mu2e experiment (Fermilab)..



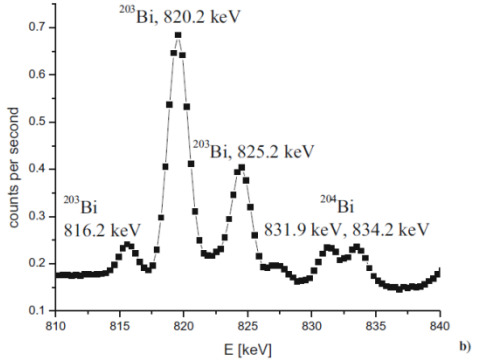
Electron Linear Accelerator LUE – 75







- 29.10.-05.11.2022 a meeting and joint discussion was organized with the delegation of the JINR and the University of Novi Sad. The goal was to get acquainted with the equipment of AANL and explore the possibility of joint work. Organizers: H. Torosyan, H. Marukyan, A. Hakobyan. A protocol was signed. Future joint work was also discussed



AANL – JINR – University of Novi Sad November 2022

2023	User, Responsible for the experiments
April	EPD – L. Poghosyan
April	JINR – Dubna Russia, University of Noviy Sad (Serbia)
August	EPD – L. Poghosyan
August	EPD – N. Margaryan
December	EPD – L. Poghosyan, APRD – E. Alexanyan

- A number of experiments were performed during 2023. Most of them are within the framework of the projects approved by the RA Ministry of ESCS Higher Education & Science Committee.
- 3 papers are published in J. Contemporary Physics, J. Applied Radiation and Isotopes, Eur. Phys. J A.

Period 2012-2022**: 35 published papers, 4 proceedings of conferences** related the LUE-75

Cyclotron - C18/18

Proton beam:

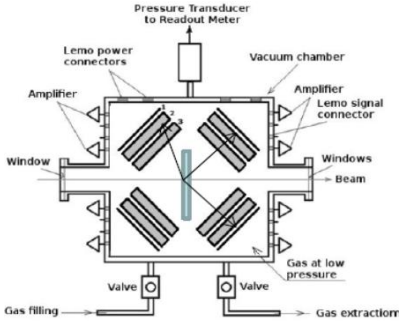
Energy → 18 MeV

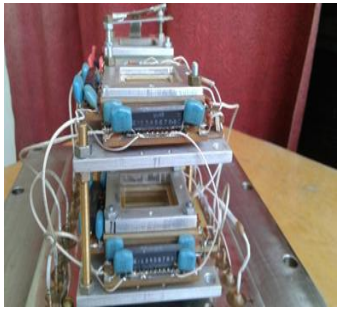
Current → up to 150 μA

Current and planned investigations:

- Measurement of cross sections of (p,γ), (p,n) reactions presumably related to stellar nucleosynthesis of proton-rich nuclei (so called p-nuclei), data analysis.
- Measurement of cross sections of disintegration reactions and fission of actinide nuclei presumably influencing the heavy nuclide abundances in the stellar nucleosynthesis, accepted in Phys. Rev. C.
- Measurement of cross sections of poorly studied (p, α) reactions, experiment.
- Measurement of cross sections of production of isomeric states, published in NIM B.
- Measurement of cross sections of medical radioisotope production, published in NIMB.
- Neutron beam formation at cyclotron C18/18.
- Investigations concerning the radiation resistance of materials.

Low Energy Nuclear Interaction Chamber

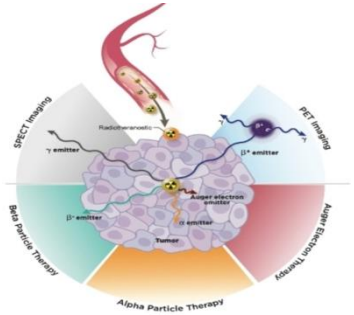


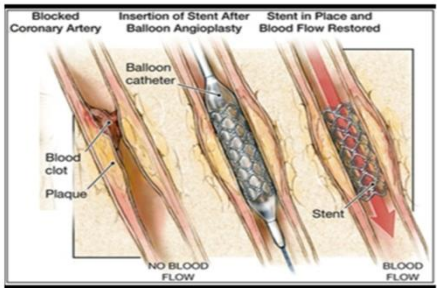


- Preliminary study of LPMWPC with C18/18 proton beam

Applications:

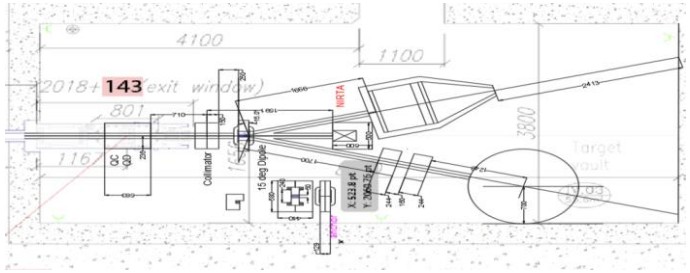
- Specific activity estimation for isotope ^{186}Re, paper submitted to Nucl. Phys.. A.
- Production of ^{124}Sb for coating the coronary stents, theoretical calculations done.
- Production of theranostic isotopes of Tb, published in J. Contemporary. Physics.



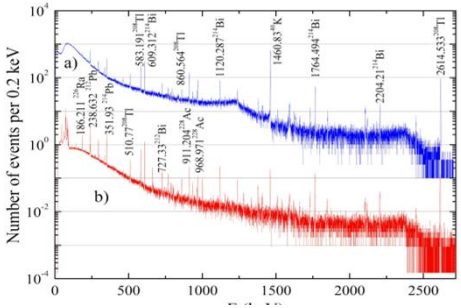


Future program :

- A proposal for the upgrade of external beam delivery system of the Yerevan proton cyclotron was prepared; Cooperation with professor G.P.A. Berg from the University of Notre Dame (USA)
- Submitted for modernization of research infrastructure announced by SC of the Ministry of ESCS of RA: was rejected.



Low Background Laboratory



Number of background events in the HPGe detector normalized to 1 hr in ground-based measurements (a) and in the underground measurement with protection (b).

Avan salt mine underground laboratory

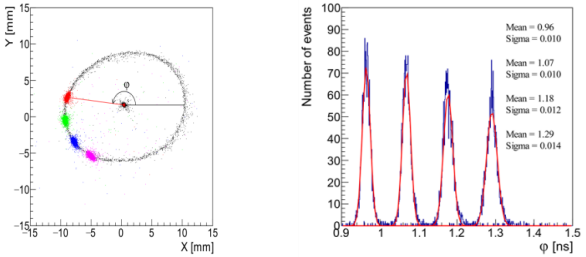
- The laboratory was founded by initiative of G. Flerov and Yu. Oganessian: the aim was to search for nuclei from the "Island of stability" in the natural samples.
- The further substantial development of laboratory was performed for double-beta decay experiment, which was carried out together with ITEP (Moscow).
- The first observation of two-neutrino double beta decay of ^{76}Ge was made, estimation of the half- life of this process was done (~10^{21} years), and the most stringent lower limit (for that time) on half-life of neutrinoless double beta-decay for this germanium isotope was set.
- As the result of more than three decades exertions the appropriate infrastructure (including, for example, the data transmission from experimental setups, placed there, to the YerPhI's web page in real time) have been provided.

- Investigation of (p, γ) , (p, n), (p,α) reactions.
- Investigations of photon-induced multinucleon and fission reactions.
- Photoactivation analysis of alloys and minerals aiming at the diagnostics for toxic elements.
- Supernova "archeology": searching for long-lived radionuclides (^{244}Pu, ^{247}Cm etc) in salt layers.
- Search for spontaneous fission rare modes of Cf and Pu isotopes.
- High energy (>150 GeV) cosmic muons monitoring.
- Investigation of applicability of Askarian method for the ultra-high energy neutrino detection in Avan salt mine.
- Applied tasks: dating of archaeological samples, earthquake forecast.

- New technology for quantitative identification of heavy metals in the environment and in mining industry. Experiments on LUE-75, published in J Contemporary Physics.
- A special purity germanium HPGe GCD-20180 detector was purchased at the expense of thematic funding.

Methodic Developments

Radio-Frequency Photo Multiplier Tube (RFPMT)



(left) phase/time distributions of the 500 MHz scanned fixed phase photoelectrons, (right) 2D images of anode hit positions

A. Margaryan et al., "An RF timer of electrons and photons with the potential to reach picosecond precision", NIM A 1038 (2022) 166926.

RF PMT – picosecond resolution timing detector with THz bandwidth

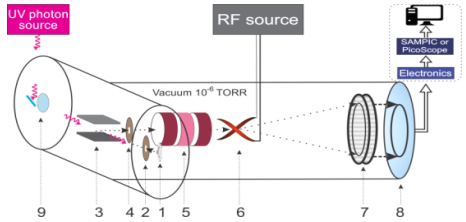
Applications include:

HEP (bunch length detection, TOF measurements, particle ID)

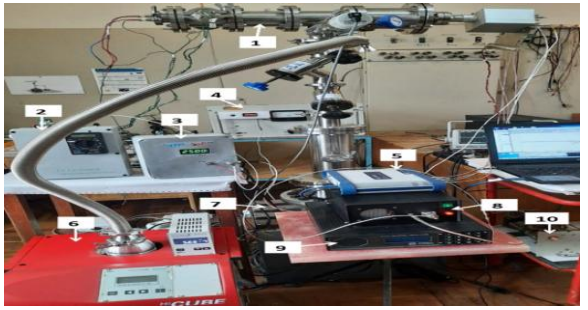
Medical Imaging (PET, DOT, Fluorescence Lifetime Imaging)

United States Patent No: US 8,507,838 B2

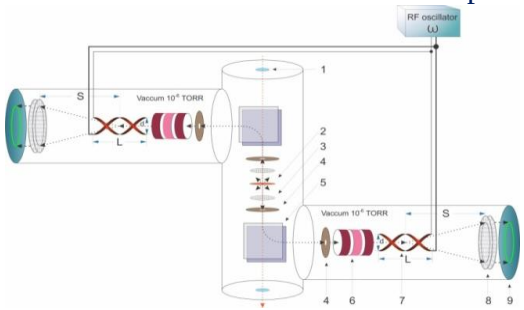
A. Aprahamian, A. Margaryan, V. Kakoyan et al., "Advanced Radio Frequency Timing AppaRATus (ARARAT) Technique and Applications", Universal Journal of Lasers, Optics, Photonics & Sensors (UJLOPS), 2 (2022) 3.



Picosecond precision RF timing processor/sensor for studying the lifetime of quantum states of nanostructures.



General view of the RF Timer and the test experimental setup.



Precise measurements of the lifetimes of heavy hypernuclei.

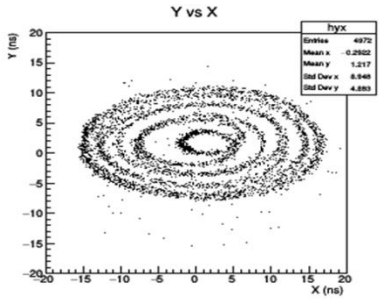
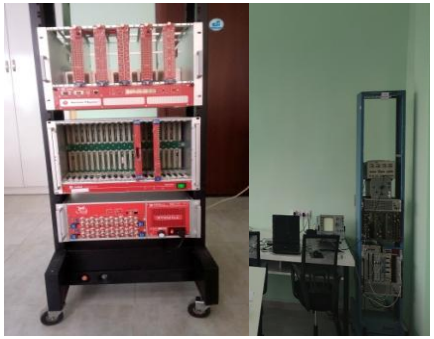
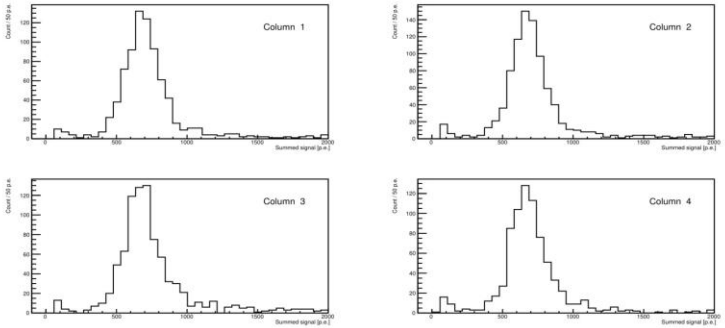


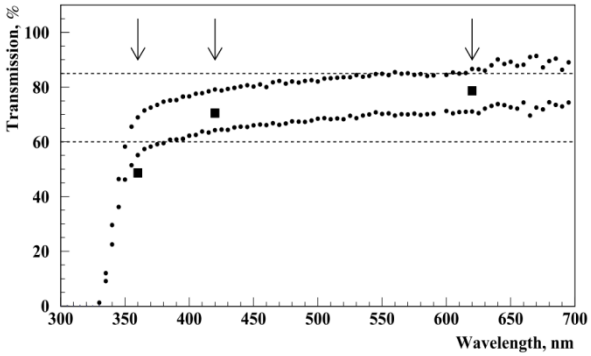
Image of scanned photoelectrons for two simultaneous RF fields of 500 MHz and 550 MHz.

Advanced Detector Laboratory

Advanced Center of Detector Technology at AANL







The basis for the creation of an advanced detector laboratory

- The idea of Advanced Center of Detector Technology (ACDT) was proposed by scientists of experimental physics division participating in international collaborations.
- The AANL teams participated in both the leading scientific experiments and the creation of the equipment needed for their performance, in particular at TJNAF CEBAF, at DESY and at CERN.
- The creation and furnishing of the ACDT started in 2020 with the support of the AANL leadership and direct financial support of PIERIS fund.
- ACDT provides real conditions in AANL for prototyping and construction of modern detectors for high energy particle physics. It essentially improves our position and level of our contribution in international collaborations, facilitate our on-site methodological research and enable the construction of state-of-the-art experimental equipment.
- It serves also to educate and train our students and young scientists.

Future plans

- The AANL - EIC collaboration group built a prototype of $PbWO_4$ crystal based electromagnetic calorimeter and study it performance at AANL, involving more young scientists, educate and train them and prepare them for serious research in such a field, both in the AANL and for participation in international collaborations.
- ACDT is equipped with necessary tools allows to perform detailed studies of optical properties of various crystals currently used in calorimetry around the world as well as develop, build and test prototypes here on site.
- Study the radiation hardness of crystals, irradiating them with electron (LUE-75) and proton (Cyclotron C18/18) beams at AANL.
- We hope to attract our collaborating foreign scientists to join our work here and educate young people, give opportunity for students to do their master and thesis work. Jan Broulin (from Prague, Czech Republic) and Sasha Ayiryan (from Dubna, Russia) started calibrating their silicon pixelized detector in the advanced detector laboratory. The detector is from Medipix. MOU is signed.

Material Science, nanostructures and nanomaterials

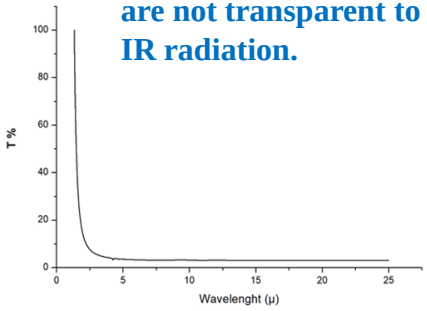
Class 1000 (ISO 6) Cleanroom

1000-class “clean room” for data recording in material sciences, verifying the super-accurate performance of new detectors, developing clean electronics for the environment

PECVD system

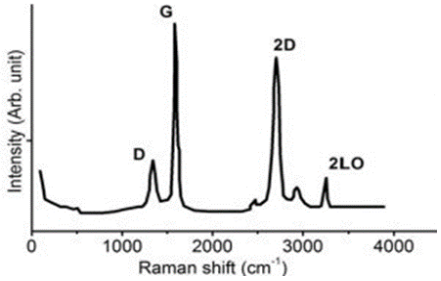
Fourier transform Infrared spectrometer (Cary 630 FTIR)

The tunable doped layers of graphene are not transparent to IR radiation.



Canon mask aligner PLA-501 FA

Raman spectrum of few layer turbostratic graphene.



Narek Margaryan is involved in research of the local "Clean room" laboratory at the University of Notre Dame (USA).

The newly created laboratory was equipped with PCVD system, FTIR spectrometer, spin coater and data-metric equipment.

Summary

- Experiments on electron linear accelerator LUE-75: YerPhI groups, YSU, JINR & UNS, new proposals ….
  2023 - 5 papers published, 2012-2022 -35 published papers & 4 proceedings.

- Experiments on proton cyclotron C18/18. Theoretical calculations, Data analysis, 2 papers published, others submitted or are in preparation.

- Methodic developments. RF-Timer with ps resolution, Patent,

- Advanced Center of Detector Technology, train young scientists & eduacate students.

- Material sciences: Clean room; graphene, nanostructures and nanomaterials. Chitosan.


Thank you