EXPERIMENTAL PHYSICS DIVISION (EPD) OF THE YEREVAN PHYSICS INSTITUTE (SUMMARY 2009-2014)

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Program of scientific activity EPD for period 2009-2014

During 1970-1991 years the Yerevan synchrotron operated productively and many scientific results have been obtained in the energies range up to 4,5 GeV, including: the study of hadronic properties of photons in reaction of π- meson photoproduction on nuclei, structures of nucleon resonances in multi-polarization experiments, structure and characteristics of a nuclear matter, study of properties of X-ray transition radiation and radiation of relativistic electrons at channeling in monocrystals etc.

In 1980, academician H.Vartapetian (Deputy Director of YerPhI in 1974-1993) with group of his colleagues has been awarded by State prize of Arm. SSR for outstanding contribution and remarkable scientific results obtained at YerPhI's synchrotron. .

Since 1991 because of an energy crisis in Armenia the accelerator has been stopped. However, its maintenance continues till now and short- time experiments are periodically performed.

Last two experiments have been carried out in 1998 (deuteron photodisintegration by polarized photons) together with LHE JINR and in 2005 (direct measurement of coherent bremsstrahlung (CB) polarization in GeV energy range) together with USA – scientist.

Measurement of the cross-section asymmetry of deuteron photodisintegration process by linearly polarized photons (cited 11 times) was oriented to understand the mechanism of exclusive photonuclear process in the region of early scaling (E = 1,4- 2,0 GeV). The data obtained for asymmetry Σ contradict to model of quark-gluon degrees of freedom with hadron helisity conservation (HHC). Up to now there are only Yerevan data for the cross section asymmetry Σ .

Experimental study of photon beam polarimetry based on e^+e^- pair production in an amorphous target (cited 3 times) – the linear polarization of photon beam at peak energy of 1,0 GeV has been measured using azimuthal asymmetry of incoherent e^+e^- pair production in an amorphous target with precision of σ = 0,06. The polarization value was in good agreement with the value computed from CB spectral shape analysis.

The proposed program consists of two parts. One part concerns the planned investigations on the basis of Yerevan synchrotron and its linear injector, another is focused on continuation of researches within the frames of existing international collaborations with TJNAF, CERN, DESY, HESS, JINR, IHEP.

Now the Experimental Physics Division consists of 104 people including 5 Doctors and 37 Candidates of Science, funded by 7 research budget themes of RA . Division also involves 4 postgraduate students. During the last 5 years of research EPD published 165 articles outside of collaborations at total number of 370, including collaborations. Also six researchers from EPD defended their Candidate`s (PhD) thesis and one thesis for a Doctor`s degree.

Proposed experiments on synchrotron during 2009-2014:

The experiments is presented according to priorities.

1. **Direct measurement of polarization P_γ of coherent bremsstrahlung (CB) photon beam with precision of σ = 0,02 in the process of e^+e^- pair production in an amorphous target.**

The high precision of the photon's beam linear polarization is necessary for the precise experimental studies not only at YerPhI but also in other laboratories around the world where CB beams are being exploited, in particular at TJNAF (USA) (see for example the project GlueX on the study of the quantum numbers of the exotic meson resonances).

It is planned to complete an experiment carried out in 2005 achieving the precision of σ = 0,02 by mean of systematic uncertainty decrease. The ongoing Monte Carlo simulations allow to

investigate an influence of several important experimental uncertainties on the value of measured asymmetry.

For preparation of experimental setup 1 month is required including hardware(vacuum, pumps, tests of pair spectrometer, remote control system, etc.) and software.

The funding expenses for this experiment at maximal energy setting of synchrotron to 3,0 GeV and including accelerator operation, is about $150K (55,5 mln.drams), to cover the electricity cost and additional payment to personnel for 24h maintenance of equipment and shifts.

***Influence of acoustic waves on the coherent electron-positron pair production in the quartz monocrystal** (in cooperation with IAPP , NAS of Armenia) - byproduct

It is proposed for the first time an experimental study of the acoustic waves influence on the process of electron-positron pair production in a single quartz crystal at photon energy 3,0 GeV. Calculations of the cross-section of pair production have shown the possible increase of electron-positron pairs yield more than 2 times for the few energy ranges. in the presence of the hypersonic excitation in the crystal.

The indicated energy of accelerator E_e = 3.0 GeV corresponds to maximal energy of electrons.

This experiment doesn't need in especial expenses, as the experimental setup remains almost the same as compared to a previous experiment. Only ultrasound generator will be added and second target replaced. So it is planned to perform this experiment immediately after previous one without accelerator stop. All the funding expenses should be covered by IAPP.

2. Investigation of cluster structure of light nuclei H, He, Li and Be isotopes in three - body final states disintegration processes in the energy range 50-250 MeV using photon beams of Yerevan synchrotron.

It is proposed to investigate the cluster structure of the excited states of nuclei produced in the photodisintegration reactions on ^{6}Li, ^{7}Li and ^{9}Be targets, with three bodies final state (clusters and nucleons) using non-polarized and linearly polarized photon beams.

The analysis of the experimental data with the use of Dalitz diagrams allows to investigate 22 cluster structures of 11 isotopes (^{3}H, ^{4}H, ^{3}He, ^{4}He, ^{5}He, ^{6}He, ^{5}Li, ^{6}Li, ^{7}Li, ^{8}Be, ^{9}Be) in seven reactions of photodisintegration with the above-mentioned targets.

The structure of the excited states of these light nuclei is a subject of increasing interest and is widely discussed in the modern theoretical analyses, that corresponds to a possible existence and manifestation of cluster structure inside of these nuclei. An advantage of three particle final state reactions as compared with ones of two particle final state $\gamma+A \rightarrow 1+2$ is the possibility to investigate not only two cluster structure of excited state of the stable targets: ^{6}Li, ^{7}Li, ^{9}Be, but also an excited states of the unstable isotopes: ^{3}H, ^{4}H, ^{5}He, ^{6}He, ^{5}Li and ^{8}Be, according to a scheme $\gamma + A \rightarrow (1,2)^* + 3$ with the formation and subsequent decay of the excited state $(1,2)^* \rightarrow 1+2$ etc.

For realization of the coincidence experiments with γ-beam in the energy range of 50-250 MeV the new non-acceleration mode of synchrotron with electron energy 50-75 MeV and low energy acceleration mode with energy 100- 300 MeV will be developed and used for the first time. The extracted photon beam should have a good time stretching (> 2-3 msec).

To achieve this low energy mode of acceleration, 1 month is foreseen with planned expenses app. 5,5 mln.dram (15 k $).

Concerning a detection system it is planned to find an optimal solution for the type, structure and required precision using detailed Monte Carlo simulations of the investigated processes including the capability of the particle identification – p, d, t, ^{3}He, α.

These detectors is necessary either to buy, or to find in other centres on the basis of cooperation. Now we have begun the negotiations with JINR.

3.Test the efficiency of experimental setup for precise measurement of binding energies of lightest hypernuclei ${}^{3}_{\Lambda}H$, ${}^{4}_{\Lambda}H$ by pionic decay

It is proposed to curry-out an experimental research of pionic decay of lightest Λ-hypernuclei at the internal beam of electron synchrotron operating at energy 1.5-2.0GeV and applying the combination of recoil-distance technique and low-energy nuclear fragment detector based on low pressure MWPC and solid state detectors.

At a first, it is necessary to test an operational possibility of experimental setup at the high radiation background of the working synchrotron and induced electro-technical and RF noises. An expected cost for the detection system and low-energy nuclear fragment detector as well as the infrastructure design and construction is estimated to be app. 18,5 mln.dram(50 k $).There is some hope to transform one of the existing magnets into high-resolution pion spectrometer (HπS) with relative momentum resolution 10^{-3}, but that is the next stage of apparatus construction.

Proposed experiments at linear accelerator LUE-75 (injector) during 2009-2014:

1. Spectroscopy of neutron-rich nuclides .

The possible development of YerPhI's experimental nuclear and particle physics program might be also based on the use of small accelerator. It is intended to use known ISOL technology exploiting the fission of U-238 nuclei by accelerated particles for generation of low energy radio-isotope beams (RIB) and subtraction of selected fragments through their thermo-diffusion from heated up to 2300 C target. The proposal is now prepared with a motivation of the physics program of investigations.

The main aim of the proposal is to provide a minimal functioning of YerPhI's own experimental base and that is very important..

At YerPhI there is a good detector's base , including the rectangular crystals of NaJ(Tl) for build-up the segmented γ-detection modules and big Ge(Li) detector for precise spectrometry. There is also enough Camac apparatus for data handling and new ultra-low noise amplifiers and linear electronics is constructed and used.

The module of the target: container and target itself should be ordered. The ionization chamber, magnetic mass-separator and vacuum system is necessary to construct at YerPhI using some components and possibilities of YerPhI's mechanical workshop.

The total preliminary cost of the project is evaluated to be app. 37 mln.dram (100 k$).

2. High energy electron radiation in crystalline structures

The high energy electrons radiation was intensively investigated in the past at YerPhI. **P**arametric **X**-**R**ay (PXR) radiation, which is the diffraction of pseudo-photons accompanying the high energy charged particles, was predicted in YerPhI by M.Ter-Mikaelian. An experimental discovery of PXR in multi-GeV region was first done at YerPhI. In this experiment the PXR intensity's increase more than 3 times was observed under influence of ultrasonic waves while theory predicts less than 1% (R.Avakian et al., Radiation Effects and Defeacts in Solids 117, 17-22, 1991; Phys. Lett. A152, 297, 1991). According to the theory for the high energy electrons (above 200 MeV) the contribution of the **T**ransition **R**adiation (TR). in the PXR geometry (Bragg diffraction), known as **D**iffracted **T**ransition **R**adiation (DTR) could be essential. The following investigations are planned to carry out on:

- the intensity of PXR at the electrons energy 50-70 MeV, where the contribution of DTR is negligible;

- the increase of PXR intensity under influence of ultrasonic wave for the electron energy 50-70 MeV;
- the intensity of PXR for the high and low Z crystals and on the nanotubes;
- the intensity of channeling radiation in different crystals.

The use of the Bragg diffraction on the second crystal allows to reflect the monochromatic photons from the broad spectrum of channeling radiation onto two Bragg angles. It is important to compare intensity of monochoramatized channeling radiation with PXR intensity to clarify, which is the more intense monochromatic source of photons from the mentioned types of radiation.

The experimental realization of this program in the direct beam of the linear accelerator with the energy 50-70 MeV may meet a difficulties of high electromagnetic and neutron background in the experimental hall. The solution is to turn the electron beam by 120^0 and direct it into the low background hall. The construction of magnetic optics line and of corresponding infrastructure need in funding at the level of app. 3,7 mln.dram (10 k$).Another alternative is in the use of the stretcher regime of synchrotron with the energies 75 MeV and 300 MeV and to foresee either to work with circulating internal beam or to extract the electron beam to the experimental hall.

Investigation of rare physical processes in the low – background laboratory

The low-background laboratory of YerPhI is located at the depth of 660 of water equivalent (240 m underground) in Yerevan salt mine. The main current activity is in the study of conditions for preparing of competitive experiment on the WIMPs (Relic Weakly Interacting Massive Particles) search. For this purpose the R&D works on the threshold energy decrease for NaI(Tl) scintillator detectors comparing to one of DAMA experiment (< 2 KeV) there are planned. In the case of success there is a possibility to construct the full scale experimental setup on the base of existing several hundreds kilograms of NaI(Tl) crystals). Another task of activity is in testing of the salt mine suitability for the detection of ultra-high energy (UHE) neutrinos through their radio Cherenkov signature (Askarian method).

Participation in international collaborations with TJNAF, CERN, DESY, HESS, JINR

TJNAF

In 1990's, when YerPhI's synchrotron in practice was unable to deliver electron beam of required intensity and quality because of financial and electricity shortages and technical problems, an opportunity to continue electroproduction program became only possible in a framework of collaboration with one of the best accelerator centers in the world, TJNAF. Last activities (during 2004-2008) carried out by three YerPhI groups (for Hall A,B,C) included a wide range of experiments with the goal to study the quark structure of hadrons, their production and interaction mechanisms. YerPhI groups in collaboration with other groups in JLab carried out an experimental studies of electromagnetic form-factors of proton, neutron and pion, short range correlations of nucleons, quark-hadron duality, real and virtual Compton scattering. YerPhI groups made a valuable contribution in the construction and development of detectors at JLab, proposed and carried out experiments.

YerPhI groups (for the next 2009- 2014) will actively participate and contribute in development and construction of many detection systems for experiments at 12 GeV: electron spectrometer BigBite, hadron spectrometer Super BigBite, photon spectrometer BigCal, Preshower calorimeter for the upgraded CLAS12 detector, aerogel detector and SHMS spectrometer. Besides this YerPhI groups will participate in many experiments, proposed also by themselves. They will participate effectively in data taking, analysis and interpretations of series of experiments planed at JLab: (Hall A)- measurement of neutron magnetic form factor in large range of Q^2 with greatly reduced systematic uncertainties, (Hall B)- will continue physics analysis of CLAS data from the exclusive d(e, e'p)n reaction to study events in the range of Short Range Correlations (SRC), support ongoing 6 GeV physics program, and participate in the development of the physics program for 12 GeV upgrade, (Hall C)- initiate new proposal to

carry out the measurements of the ratios of longitudinal and transverse components of pion electroproduction cross section $R = \sigma_L/\sigma_T$ in deep inelastic region at 12 GeV , continue a transverse momentum studies in semi-inclusive pion and kaon electroproduction using 8.8 and 12 GeV and measurement of the charged pion form factor for Q^2= 1,6- 6,0 $(GeV/c)^2$.

CERN

YerPhI has a traditional relations with CERN. In the past many Armenian physicists participated in several experiments at CERN: WA69, WA56, NA22, NA43, NA50 and NA60. In 1994 Cooperation Agreement between Government of the Republic of Armenia and CERN on further development of scientific and technical cooperation in high-energy physics was signed.

Since 1995, the **YerPhI/High Energy Nuclear Physics group** participates in the realization of the heavy-ion physics program at the CERN in the framework of international collaborations NA50 and NA60 at the SPS-CERN.

Detailed experimental data are obtained on the production of Φ meson and charmonium states J/ ψ and ψ' (via their decay into $\mu^+\mu^-$) in Pb–Pb and In–In collisions at 158 A GeV incident energy. For the first time, an evidence for the emission of thermal dimuons is obtained and the spectral function of ρ meson (decaying into $\mu^+\mu^-$) is measured. The obtained experimental data indicate on the creation of a dense, hot matter (in particular, a new state of matter - quark-gluon plasma) in head-head heavy-ion collisions.

Participation in the LHC (ATLAS, ALICE,CMS) experiments

At present our scientists are successfully participating in the LHC experiments (ATLAS, CMS, ALICE). Despite a lack of financial support, YerPhI has contributed visibly to all three experiments. Armenian groups of physicists and engineers actively participated in the detectors design, prototyping and construction, software development as well as in test beam data taking and analysis.

ATLAS/YerPhI group has been participating in Tile Hadron Calorimeter of ATLAS experiment since 1994. YerPhI group made valuable contribution in the design and construction of 7 robots for high- precision cutting of WLS fiber bundles, in development and construction of 10300 magnetic shields for PMT and in construction of bronze radiation shielding components. One of the main achievement in data analysis is the detailed study of the hadrons(proton, pion) shower profiles and their leakage for TileCal, used for GEANT4 simulation and precise energy. reconstruction . The PhD thesis was defended on this subject in 2007. The group continues participation in hardware-software works for detector's electronics maintenance and on-line monitoring.

ALICE/YerPhI group has been participating in the development and construction activities for ALICE since 1996. YerPhI group made valuable contribution in design, development, construction and installation of the Geometry Monitoring System for Muon Spectrometer (GMS), development of the software for analysis of the alignment of the optical components of GMS and participation of ALICE detector performance studies. Group manufactured in YerPhI and installed at CERN of a 4.7 tons Aluminium Ring as a supplementary absorber for radiation protection in ALICE detector. ALICE group is strongly involved in the development of Grid technology and has already implemented AliEn(ALICE Grid environment) locally. In 2006, the group has deployed the middleware of EGEE (Enabling Grid for E-science) international project, allowing thus integration of YerPhI in the largest in the world Grid/e-Science infrastructure and the YerPhI site has been officially certified as production site of EGEE/WLCG.

CMS/YerPhI group has been participating in CMS experiment via RDMS (Russia and Dubna Member States) since 1995. YerPhI group participated in Preshower detector construction and has made the following contribution:development of the technology of thick film printing on a ceramic PCB with various metallic pastes and laser cutting technique and large-scale production (5000 units) of the ceramic PCBs. The financial contribution of Armenia has made 90 kCHF. Group participated also in physics analysis and investigated the structure of hard double Pomeron exchange processes in proton – proton collisions at the LHC energy. The postgraduate student participated in CMS working group "Detector Performance Group (HCAL)" and tested

the CMS Endcap (HE) calibration on the basis of CMS CRUZET(Cosmic Runs at Zero Tesla), CRAFT (Cosmic Runs at Four Tesla) and Beam Halo LHC data.

Participation of YerPhI groups in LHC physics program and data analysis for 2009- 2014

ATLAS group is now making the steps toward the involvement in JetEtmiss working group activity (during low luminosity period of LHC) as a general tool for many physical programs having in mind a future participation in the data analysis within exotics phenomenon discovery program, such as the TeV scale graviton and micro-black holes excitation.

ALICE/YerPhI group will be involved mainly in the analysis of light ρ, ω and φ vector resonances production in *pp* and Lead-Lead collisions. Participation in the studies of the production of the family of heavy-flavour resonances (J/Ψ, Υ and higher-lying resonances) in $\mu^+\mu^-$ channel is foreseen. The group will continue development of the components for ALICE data handling framework. It is planned to deploy the ALICE data analysis software, called Aliroot, on the YerPhI local Grid cluster. The development of software for monitoring of the position of Tracking Chambers of Muon Spectrometer on the base of the GMS data will be completed and the software will be integrated in the Aliroot.

CMS group will investigate Hard Diffractive Interactions of pp with $\mu^+\mu^-$ or γ-Jet production for studying parton structure of Pomeron and diffractive structure function $F_2^D(x,t,Q^2,\xi)$.

Goal is the separation of hard and soft parton (quark- antiquark) and hard and soft parton (gluons) contributions in Pomeron. For examination of factorization the data of cross-section in QCD, SPE(single) and DPE(double Pomeron exchange) processes in same kinematical range will be selected. Group has skills of work with CMSSW program and will participate in data taking and physics analysis.

Some problems connecting with CERN-LHC collaborations. Activity of three groups will be connected with analysis of experimental data. Therefore is important to create an analysis center at YerPhI with high-speed communication line and developed a GRID infrastructures at YerPhI. Other problem is corresponds with M&O payments in the level of 10 kCHF/author (for inclusion in authors lists) and expenses for the working visits to CERN. For this point there is a needs to achieve the corresponding RA governmental decision.

DESY

HERMES/YerPhI group has actively participating in construction and tuning of the HERMES facility since 1993. The group has played essential role in construction of electromagnetic calorimeter, especially in providing of high quality lead glass blocks. Last activities carried out by YerPhI group includes wide range of experiments with the goal to study the spin structure functions of nucleons in inclusive, semi-inclusive and exclusive processes in deep-inelastic lepton scattering and hadronization in nuclear medium. It should be noted that N. Akopov together with few scientists from Dubna (including famous S. Gerasimov) was awarded two times:-in 2005 for generalized GDH integral measurements at HERMES N. Akopov has got the First Scientific Prize of JINR, and - in 2008 for series of measurements of g1 structure function N. Akopov has got the Second Scientific Prize of JINR.

HERMES/YerPhI group plans for the next 3-4 years.

HERMES has collected the richest in the world sample of electroproduction data obtained on different nuclear targets: D, He, Ne , Kr and Xe. Group will investigate: the hadronization phenomenon in nuclear medium; charged pions, kaons and protons multiplicities on hydrogen and deuterium targets; color transparency phenomenon in electroproduction of exclusive rho mesons on different nuclear targets like neon, krypton and xenon. Also will continue the DVCS analysis.

H1/YerPhI group is H1 collaboration member since July 1999. YerPhI group at H1 has involved primary in hardware development, support and maintenance and later on in data physical analysis. During the period from 2004 to first half of 2007 (HERA shutdown) group was fully responsible for Time-of-Flight (TOF) system. The main efforts of the group are focused on the analysis of following processes: Jet Production at Low Q2 in DIS (strong coupling constant $\alpha_s(M_Z$ extracted)) and Measurement of Leading Neutron Production in DIS

(pion structure function F2).

YerPhI-H1 group activities during 2009-2011.
Based on world data on jet production and DIS, the group starts a new analysis on parton distribution function (pdf) and multijets (four and more) production at Low Q^2 . These data give a good opportunity to investigate the tasks for future physics at LHC.

Very high energy gamma-ray astrophysics

High energy gamma ray astronomy researches began in YerPhI in mid 80ies with the creation of Gamma Ray Astronomy group led by F. Aharonian in Experimental Physics Division (under the leadership of academician H. Vartapetian). In 1985, for the first time in the world, the group designed and started to construct a system of Imaging Atmospheric Cherenkov Telescopes (IACT) for the ANI experiment on the mount of Aragats. The first IACT of the system was installed at the Nor Amberd station in the early 90ies, but the collapse of the Soviet Union stopped the experiment. Scientists of YerPhI's group together with O. Alkoffer from Kiel University proposed to install the same system of IACTs as part of the HEGRA (High Energy Gamma Ray Astronomy) on the Canary island of La Palma, Spain. In 1992 the first HEGRA telescope measured the gamma rays from Crab Nebula. The YerPhI's group participated in all stages of HEGRA experiment, namely in the design and construction of telescopes and cameras, in the data taking (shifts), in the data analysis as well as in the theoretical works on the high energy gamma-ray astrophysics.

YerPhI /HESS group- HESS (High Energy Stereoscopic System) was built in 2001-2003 by the international collaborations with the participation of YerPhI's group (one of the initiators was F. Aharonian). HESS is an array of four imaging atmospheric Cherenkov telescopes installed at an altitude of 1800 m above sea level in the Khomas Highland of Namibia. The members of YerPhI's group participated in several stages of HESS experiment, namely in the construction of telescopes, in the determination of response function and main characteristics of the system and in the investigation of methods of experimental data analysis. YerPhI provided a 400 high-quality mirrors and developed a mirror protective coating technology (with Galaktika). Group developed a Monte-Carlo program for the calculations of optical response of IACT and mathematical methods for the data analysis. It should be noted that the members of group: A.Akhperjanian and V.Sahakian as well as F.Aharonian (from MPIK, Heidelberg) were awarded in 2005 by President's Prize of Republic of Armenia for the outstanding contribution to physics research within the framework of the HEGRA and HESS collaborations. The HESS collaboration has won the European Union Descartes Research Prize for 2006 as a world first in the field of gamma astronomy.

HESS group activities during 2009-2014. Group will actively participate in construction of the new large telescope of HESS-II collaboration and in the new established CTA (Cherenkov Telescope Array) project as well. CTA stands for an initiative to build the next generation ground - based gamma-ray instrument. These activities include: development of the new protective coating technology (with Galaktika) for the HESS and HESS II mirrors in order to provide high reflectivity coefficient (in order of 80%); participation in the shifts (if corresponding funding will be available); participation in the experimental data analysis; participation in the works within the framework of CTA project.

Participation YerPhI/High Energy Nuclear Physics group in collaboration with IHEP (Serpukhov) and JINR (Dubna)

IHEP

The group performed a systematical study of the neutrino production of hadrons and hadronic resonances on nuclei, using the data from the SKAT propane-freon bubble chamber exposed to a neutrino beam at the Serpukhov accelerator. These investigations provide a valuable information on the space-time pattern of the quark string fragmentation and the hadron formation.

Planed investigations for the period of 2009-2014

In the framework of the SKAT Collaboration at the **IHEP** (Serpukhov) the group will continue researches on the production of hadronic resonances in neutrinonuclear reactions and the nuclear medium influence on the production of hadrons and hadronic systems at $3 < E_{\upsilon} < 30$ GeV .

In the framework of BECQUEREL Collaboration at the **JINR** (Dubna) the group will investigate the dissociation of light nuclei (including non-stable and exotic ones) in nuclear track emulsion at the energy range of a few GeV per nucleon, with the purpose to infer information on the cluster structure of nuclei and mechanisms of nuclear fission reactions – the inverse reactions to the multiparticle fusion which can occur in the cosmic nucleosynthesis.