Project submitted for the base funding of Artem Alikhanyan National Laboratory (ANL)

Principal Investigator: Amur Margaryan

TITLE: Fission and fragmentation of nuclei with real and virtual photon beams

Division, group: Department of Experimental Physics, ANL in collaboration with MAX-lab, Lund, Sweden; Hampton University, USA; Tohoku University, Japan; Saclay, CEA, France; University of West Virginia, WVA, USA.

DURATION: 3 years

Estimated total cost of the project (US $) **170,000**

Including:

Payments to Individual Participants	**96,000**
Equipment	**24,000**
Materials	**5,000**
Other Direct Costs	**30,000**
Travel	**15,000**

PROBLEM:

The problems during the realization of the Project can be divided in two categories: experimental studies and methodic studies. Experimental studies related to the following approved experiments at MAX-lab Sweden and Jlab, USA:

1) Photofission of heavy actinide nuclei, MAX-lab Experiment 04-08, 2004;
2) Photo-fission studies of nuclei by virtual photon tagging at MAX-lab, MAX-lab Experiment 08-04, 2008;
3) Study of light hypernuclei by pionic decay at JLab, JLab Proposal: PR-10-001, 2010.

It included also study of experimental possibilities of performing measurements of cross sections of the ^{12}C photodisintegration into three alpha particles at ANL.

Methodic studies related to the developing, manufacturing and investigating of a new radio frequency, RF phototube and dedicated detectors based on low-pressure MWPC technique, for low-energy protons, deuterons and alpha particles for nuclear studies with astrophysical interest and for one and two proton emission spectroscopy applications.

OBJECTIVES:

In the first experiment [1] the total photofission cross section of U-238 and Np-237 will be measured in the energy range 50-200 MeV. The goal of these measurements are motivated by results from early experiments that show distinct differences in the fissility of these targets and partly distinctly higher values of total cross sections than given by the “universal curve” of photon absorption on nuclei ([1] and references therein).

The second experiment [2] will provide detailed measurements of the photo-fission cross section, including fragment mass and velocity distributions, for U-238, Th-232 and Bi-209 nuclei in the energy range 60-200 MeV. We are planning to use a new fission fragment detector system and exploit a virtual tagging technique at MAX-lab, which previously was used at YerPhI.

The third experiment [3] is a program of novel systematic studies of light hypernuclei at JLab using the pionic weak 2-body decay. The experiment aims to determine structural properties, such as binding energies, lifetimes, production mechanism, charge symmetry breaking effects in mirror pairs, and in-medium effects on electric and magnetic properties of hypernuclei.

We are planning to investigate possibilities of measuring cross section of the $^{12}C(\gamma,3\alpha)$ reaction near threshold by using 50 MeV bremsstrahlung photon beam of YerPhI linear injector and active target based on 3 Torr heptane (C_7H_{16}) filled low-pressure MWPCs and Si detectors. By using MWPCs and Si detectors, trajectory, velocity, ionization energy loss (dE/dx) and energy (E) of produced charged particles will be measured. The threshold energy for detection of alpha particles is ~100 keV. The position of the interaction point will be determined within error of about 1 mm, rms. The effective masses of the 3α resonance states and consequently energy of interacted photon will be determined with in error of about 200 keV. These studies aims to provide better data with decreased statistical and systematic errors and resolve conflicting data in this reaction, which plays a crucial role in stellar helium burning and in cluster structure of the ^{12}C nucleus.

The activities related to methodic studies included R&D of super bandwidth (~50 GHz) and super stable (10 fs/hrs) photon detector [4-6]. We are planning to develop the prototype sample and produce of sample RF phototube with a few ps temporal resolutions for detection of single photons in collaboration with manufacturing company.

The next topic of methodic studies related to the dedicated detectors for near threshold photodisintegration of ^{12}C and ^{16}O nuclei with astrophysical interest and for one or two proton emission spectroscopy of exotic nuclei, e.g. ^{18}Ne, based on low-pressure MWPC technique [7]. The detection threshold of this technique e.g. for alpha particles, can be decreased to be equal 100 keV which is crucial for studying photodisintegration process of ^{12}C and ^{16}O nuclei with astrophysical interest. The prototype devices will be developed, constructed and tested in lab and at electron-photon beams.

4. Scope of Activities

Task 1: Methodic Studies: Low-pressure MWPC technique

Task description and main milestones	Participating Institutions
1.1 Assembling of the alpha and Fission Fragment, FF detectors. 1.2 Design and assembling of the test experimental setup (vacuum technique, electronic equipment, Data acquisition system). 1.3 Test of the alpha and FF detector at lab by using Cf-252. 1.4 Design, construction and assembling of the test experimental setup (vacuum technique, electronic equipment) at ANL. 1.5 Methodic studies at ANL and at MAX-lab. 1.6 Monte Carlo simulations and preparation of a new proposals.	Yerevan Physics Institute MAX-lab, Lund, Sweden

Description of deliverables	
1	Reports.
2	Publications.
3	Device assemblies.

Task 2: Methodic Studies: RF phototube

Task description and main milestones	Participating Institutions
2.1 Design, construction and assembling of the test experimental set-up (RF technique, electronic equipment, vacuum technique, electron gun, picosecond laser and etc). 2.2 Design, construction, assembling and testing of front-end electronics. 2.3 Design, construction, assembling and testing of prototype RF phototubes with thermo-electron source. 2.4 Design, construction, assembling and testing of prototype RF deflectors. 2.5 Test of RF phototube with thermal photoelectrons and optimization of parameters.	Yerevan Physics Institute Saclay, SEA, France Photek, www.photek.com MAX-lab, Lund, Sweden Tohoku University, Japan University of WVA, USA

2.6 Manufacturing of the RF deflector. 2.7 Manufacturing of the RF phototube. 2.8 Test of the RF phototube. 2.9 Monte Carlo simulations and preparation of a new proposals.	
Description of deliverables	
1	Device assembly.
2	Reports.
3	Publications.

Task 3: Experimental Studies

Task description and main milestones	Participating Institutions
3.1 Design and assembling of the experimental set-ups at YerPhI and at MAX-lab photon beams (vacuum technique, electronic equipment, Data acquisition system). 3.2 Test of the alpha and FF detectors at photon beams. 3.3 Study of experimental conditions at YerPhI linear accelerator. 3.4 Measurements of photo-fission cross sections of U-238 and Np-237 nuclei in the energy range 60-200 MeV at MAX-lab. 3.5 Design and assembling of the experimental set-up at MAX-lab electron beams (vacuum technique, electronic equipment, Data acquisition system). 3.6 Test of the FF detector at electron beams. 3.7 Design and assembling of the virtual tagging system at MAX-lab electron beams. 3.8 Measurements of fission cross sections of U-238, Th-232, Bi-209 nuclei in the energy range 60-200 MeV by using virtual photon tagging technique. 3.9 Data analyzing and preparation of materials for publications. 3.10 Delayed pion spectroscopy of nuclear matter. 3.11 Tagged weak pi method. 3.12 Preparation of a new proposal.	Yerevan Physics Institute MAX-lab, Lund, Sweden Tohoku University Hampton University

Description of deliverables	
1	Device assembly.
2	Reports.
3	Publications.

IMPACT:

1. Photo-fission cross sections of actinides in the energy range of 60-200 MeV.

In the case of the heavy actinides, the total photofission cross section has been thought to be good approximation to the total photoabsorption cross section at photon energies well above the giant dipole resonance region. This allows one to study the effect of the nuclear medium on the processes, such as baryon resonance formation and propagation within the interior of the nucleus. Specifically for the case of ^{238}U, the experimental measurements and theoretical calculations have suggested that the photofission probability is consistent with unity for photon energies larger than about 40 MeV [8, 9]. The comparison of the total photofission cross section per nucleon for the uranium nuclei with the total photoabsorption cross section per nucleon for nuclei from Be to Pb in the Δ resonance region (from approximately 200 MeV to 450 MeV photon energy) shows a similar shape and strength for these cross sections, known as a "universal curve", indicating that the photoabsorption process can be described by an incoherent total volume absorption mechanism [10, 11]. However, this conclusion is in part based on the assumption that the photofission probability of uranium is close to unity [12]. But the most recent results using monochromatic photons [13-19] show some discrepancies in the cross sections per nucleon for ^{235}U and ^{238}U and the so-called "Universal Curve" in the Δ-resonance region.

The most important discrepancy reported previously appears in the results of the measurement of the relative photofission probability of ^{237}Np compared with ^{238}U from 60 MeV to 240 MeV photon energy [20, 21]. In this measurement the photofission probability of ^{237}Np appears to be between 20% and 30% larger than that of ^{238}U, so that the photofission probability for the latter isotope could be at most 0.8. Recently the total photofission cross sections for the actinide nuclei ^{232}Th, ^{233}U, ^{235}U, ^{238}U and ^{237}Np have been measured from 68 to 264 MeV [22] using tagged photons at the Saskatchewan Accelerator Laboratory as well as in the energy range 0.17-3.84 GeV [23] using the photon tagging facility in Hall B at Jefferson Lab. In these experiments, production of the FF has been detected by means of parallel-plate avalanche detectors. The results of these last measurements show that the fission probability for ^{238}U is 20% lower than that for ^{237}Np.

This result clearly calls into question the concept of the "Universal Curve", has serious implications for the inferred total photo-absorption cross-section strengths in the Δ-resonance region, and demonstrates the need for a new investigations [24, 25].

The lack of direct measurements of the total photo-absorption cross sections for actinide isotopes, together with the discrepancies mentioned above, makes it very important to measure precisely the absolute and relative photofission cross sections for ^{237}Np and ^{238}U nuclei.

2. Photo-excitation mechanism of nuclei in the energy range of 60-200 MeV.

The excitation of nuclei by electromagnetic probes such as real photons (γ-quanta) or virtual photons (inelastic electron scattering) offers attractive features for the study of nuclear phenomena over a broad range of excitation energies. The use of photons in the study of fission of highly excited nuclei is advantageous, since photons are very effective, due to their volume absorption, in heating nucleus, transferring at the same time, relatively low angular momentum to the struck nucleus. In the intermediate and high energy ($E_\gamma \geq 40$ MeV) region the gamma-nucleus reaction has been currently explored in the framework of a two-step interaction models [26-32]. In this approach, firstly a rapid intranuclear cascade, INC, develops through binary intranuclear collisions. During the second stage of the reaction, the excited residual nucleus slowly reaches its final state through a competition between the fission and the particle–evaporation process. The two-step picture clearly assumes that fission is a relatively slow process which samples the target residues only after they have lost a large fraction of their excitation energy. Therefore, the fission of a heavy nuclear system provides an excellent tool for studying the both stages of a complex, high-energy nuclear reaction. Coulomb energy systematics give a clear indication for the binary fission process while fragment angular correlations and mass and energy distributions can be used to estimate average quantities such as linear momentum transfer and mean mass and excitation energy of the fissioning system.

The investigations of photofission of heavy nuclei at intermediate (40-140 MeV) energy range is very convenient because the primary photoexcitation process is well understood. However even in the quasideuteron region of photoexcitation, where the photoabsorption mechanism is a simple one, different INC approaches predict quite different values for excitation energies [28]. These features indicate necessity for precise measurement of more complete set of experimental parameters, to develop proper theoretical approach for both stages of the INC.

In this respect, interesting possibilities are offered by the measurement of mass-energy-momentum distributions of fission fragments, FF, with monochromatic photons, to investigate the excitation energy dependence of mass distributions comparing the data taken at different photon energy E_γ [29]. In fact such experimental data allow to study in a clean way the thermal effects, in particular the excitation energy dependence of the fission barrier [27]. Even precise measurements of the photofission cross sections of preactinide nuclei such as Au and Pb by monochromatic photons in the energy range 40-200 MeV can help checking existing theoretical approaches [32].

To date current experimental studies have concentrated on total photofission cross section measurements of the heavy actinides. The FF's mass-energy-momentum distributions have up to now only been determined in a few experiments with $E_\gamma \geq 40$ MeV monochromatic photons. The mass of FFs was indirectly determined [33, 34] for actinide targets. Therefore, more data with precise mass-energy-momentum distributions of FF, measured directly and by monochromatic photons, highly desirable for targets in a wide range of mass.

We propose to carry out zero degree electro-fission studies [35-37] by using the MAX-lab tagged photon system in combination with large acceptance FF detector [7] and to perform high statistic and precise measurements of nearly complete FF parameters, such as mass, velocities and folding angles, for nuclei in a wide mass range $50 \leq A \leq 240$. The parameters of the INC as well as the influence of shell and collective effects on the level density and the decay widths of nuclei which have different excitation energies and deformations [26, 38] will be determined by using these correlations and analyzing the high statistic experimental data. Such an experiment is like a microscope through which we can have a close look at the nature of excited nuclear matter.

3. Study of light hypernuclei by pionic decay

The binding energies of the Λ particle in the nuclear ground state give one of the basic pieces of information on the Λ-nucleus interaction. Most of the observed hypernuclear decays take place from the ground states, because the electromagnetic interactions or Auger neutron emission process are generally faster than the weak decay of the Λ particle. The binding energy of Λ in the ground state is defined by:

$$B_\Lambda(g.s.) = M_{core} + M_\Lambda - M_{HY}\ .$$

The mass M_{core} is merely the mass of the nucleus that is left in the ground state after the Λ particle is removed. The binding energies, B_Λ, have been measured in emulsion for a wide range of light ($3 \leq A \leq 15$) hypernuclei (see [3] and references therein). These have been made exclusively from weak π^--mesonic decays. The precise values of the binding energies of Λ in the few-baryon systems provide filters through which one can look at particular aspects of the YN interaction, and one of the primary goals in hypernuclear physics is to extract information about YN interactions through precise calculations of few-body systems such as ${}^3_\Lambda H, {}^4_\Lambda H, and\, {}^4_\Lambda He$.

A new, counter experiment [3], aims to determine structural properties, such as binding energies, lifetimes, production mechanism, charge symmetry breaking effects in mirror pairs, and in-medium effects on electric and magnetic properties of a light ($A \leq 15$) mass range of hypernuclei, again exploring weak π^--mesonic decays of hypernuclei.

4. Photo-disintegration of ^{12}C into three alpha particles near threshold.

The $^{12}C(\gamma, 2\alpha)\ ^4He$ reaction is interesting in connection with 3α reaction, which plays a crucial role in stellar helium burning [39-42]. In the centre of stars where the temperature is high enough, three α-particles (helium nuclei) are able to combine to form ^{12}C because of a resonant reaction leading to a nuclear excited state. Stars with masses greater than ~0.5 times that of the Sun will at some point in their lives have a central temperature high enough for this reaction to proceed. Although the reaction rate is of critical significance for determining elemental abundances in the Universe, and for determining the size of the iron core of a star just before it goes supernova, it has hitherto been insufficiently determined.

The most important resonance in ^{12}C for astrophysics is situated 7.65 MeV above the ground state, and has spin and parity 0^+ [43]. Hoyle suggested this resonance in 1953 in order to reproduce the observed abundances of ^{12}C and ^{16}O, respectively the fourth and third most abundant nuclear species in the Universe [44]. This so-called Hoyle resonance was soon discovered experimentally [45], and its properties were established [46] on the basis of a measurement of α-particles emitted in the β-decay of ^{12}B. In 1956 it was predicted [47] to have the structure of a linear chain of three α-particles, and it was further conjectured that there had to be another resonance at 9–10 MeV with spin-parity 2^+. A resonance was found soon after [48] at 10.1 MeV with a very large width of 3 MeV, but its spin-parity could only be determined as 0^+ or 2^+. The past half-century has brought little clarification to this problem, but the 2^+ resonance (at 9.1 MeV with Γ = 0.56 MeV, Γ_γ = 0.2 eV) is still included in the current NACRE (Nuclear Astrophysics Compilation of Reaction Rates) compilation of astrophysical reaction rates [42], where it enhances the 3α ^{12}C reaction rate by more than an order of magnitude for temperatures above 10^9 K. The $^{12}C^*$ states fed by the β-decay of ^{12}B and ^{12}N nuclei has studied recently with improved methodic [49, 50]. These investigations find a dominant resonance at energy of ~11 MeV, but do not confirm the presence of a resonance at 9.1 MeV. The same collaboration has studied the $^{10}B(^3He,p\alpha\alpha\alpha)$ reaction at 2.45 MeV aiming to gain more complementary information on the $^{12}C^*$ that may be of relevance in the triple-alpha process responsible for helium burning in stars. They have identified the 3^- 9.64 MeV state and 1^- 10.8 MeV state [51].

Although the Hoyle resonance dominates the triple reaction rate at the most relevant astrophysical temperatures of 10^8 K< T< 2.0*10^9 K, at higher temperatures other natural parity states such as 0^+,1^-, 2^+, and 3^- may play a more dominant role [41]. Therefore, by studying the break-up of the three alphas from $^{12}C^*$, populated by means of different reactions we can gain more information on resonances near the triple alpha threshold (7.275 MeV) which may help clarify the rate of ^{12}C production at high temperatures [40, 41] as well as cluster structure of the ^{12}C nucleus [52-55]. The results of photodisintegration of a carbon nucleus into three alpha particles are interesting also for the studies of the mechanism of interaction of the electromagnetic radiation with nucleus [56].

5. Methodic studies

5.1 Radio frequency phototube

At present the photon detection is carried out with solid state devices, vacuum photomultiplier tubes (PMTs) or hybrid photon detectors (HPDs). These instruments also provide fast time information necessary in different fields of science and engineering. In the high energy particle physics and nuclear physics experiments the time precision limit for the current systems consisting of particle detectors based on PMTs or HPDs and common nanosecond electronics (amplifiers, discriminators, logic units and time-to-digital converters) is about 100 ps (FWHM). However, it is well known that timing systems based on radio frequency (RF) fields can provide time resolution on the order of ~ several ps or better. Streak cameras, based on similar principles, provided ps temporal resolution but they provide integral or slow information and they have not found so far wide application, including in the field of elementary particle and nuclear physics experiments.

Nevertheless, the RF timing technique as well as the streak cameras did not find wide application in the past, including elementary particle physics and nuclear physics experiments, medical and other applications. This is mainly connected to the fact that commercially available streak cameras provide slow or averaged time information.

The basic principle of the RF timing technique or streak camera’s operation is the conversion of the time domain information into spatial one by means of RF fields. Recently we have developed a compact 500 MHz circular sweep RF deflector for keV energy electrons. The sensitivity of this new RF deflector is an order of magnitude higher than the sensitivity of RF deflectors used previously. Such a compact and sensitive high frequency RF deflector for keV energy electrons can find wide application in different photo-electronic devices. We have demonstrated the operational principles of an RF phototube [4, 5], based on the 500 MHz RF circular sweep deflector. Such a photon detector combines advantages of a vacuum photomultiplier tube, PMT, and a circular scan streak camera. This kind of phototube is capable of detecting optical signals and providing nanosecond signals, like fast PMT, for future event by event processing of each photoelectron with better than 20 ps resolution. In addition combination of the radiofrequency phototube and optical clock or femtosecond optical frequency comb generator results a new high resolution (~20 ps for single photons), high rate (≥

1 MHz) and highly stable (10 fs/hrs), H^3, time measuring technique [6].

These developments have made it possible to create a new photon detection device, RF phototube and a new- H^3 timing system, which could extend range of the time-correlated single photon counting, TCSPC, technique, [57], into the subpicosecond domain. Possible fields of application include precise measurements in fundamental physics [58] and in high energy elementary particle and nuclear physics experiments [59-62]. The radio frequency phototube and H^3 timing system have a great potential in medical applications such as diffuse optical tomography, fluorescence lifetime imaging and time-of-flight positron emission tomography [63].

The main goal of this proposal is to develop the prototype sample and produce of sample RF phototubes in collaboration with manufacturing company and test it in lab and in real experimental conditions.

We are planning to investigate possible applications of the RF phototube and new timing technique in different fields of science and technology, including:

a) H^3 timing system;
b) Cherenkov and scintillator time-of-flight detectors for high energy physics applications;
c) γ-ray and neutron scintillator spectrometers for nuclear physics and biomedical applications and etc;
d) Medical applications.

5.2 Low-energy recoil detector

We are planning to develop, construct and investigate detectors for low-energy protons, deuterons and more heavy particles based on low-pressure MWPC technique for dedicated nuclear studies with astrophysical interest and for one and two proton emission spectroscopy applications.

As an example of possible application of the proposed technique we would like to focus on the photodisintegration of ^{12}C nucleus into three α-particles. The photodisintegration of carbon into three α-particles was investigated in the past by using photon beams and different experimental technique such as photo-emulsion technique [64-67], time projection chamber [68], time projection chamber with optical readout system [69], and diffusion chamber placed in the 1.5 T magnetic field [70]. Obtained experimental results are very contradictory and only the data obtained with diffusion chamber have some results in the energy region lower than 10 MeV. The chamber was filled with a mixture of methane (CH_4) and helium in the proportion 1:7 at the pressure near to the atmospheric one. The threshold of α-particle registration is (~300 keV) due to the low density of the target. For other cases the threshold of α-particle registration is ~ 1 MeV. It was demonstrated that the events in the energy region lower than 10 MeV observed in diffusion chamber is related to the low energy (< 1 MeV) α-particles [70].

The experimental setup based on heptanes (C_7H_{16}) filled low-pressure MWPCs with the pressure of about 3 Torr and Si detectors is ideally suited for investigating 3α resonance states produced in photon carbon interactions. By using MWPCs and Si detectors, position, time, ionization energy loss (dE/dx) and energy (E) of produced charged particles will be measured. The threshold energy for detection of alpha particles is ~100 keV. The position of the interaction point will be determined within error of about 1 mm, rms. This will allow reconstructing the energy of the charged-particles at the interaction point within error ~1%, carry out their identification and determining the effective masses of the 3α resonance states with in error of about 200 keV.

For one and two proton emission spectroscopy applications we are planning to study operation of the low-pressure MWPCs by using different working gases. As a nice example we can consider one and two proton emission spectroscopy from Ne-18 [71]. The high rate capabilities of the detector system based on the low-pressure MWPCs filled with Ne-20 can be used as target as well. Then excited states of the ^{18}Ne can be produced by using 50 MeV photon beams. The detection system allows measuring the energies and directions of emitted protons therefore allowing separating two body decay events from the successive three body decays (see more discussion in [71]).

References:

[1] J.-O. Adler, A. Margaryan, spokespersons, Photofission of heavy actinide nuclei at MAX-lab, MAX-lab Experiment 008, 2004.

[2] K. Hansen, A. Margaryan, spokespersons, Photofission Studies of Nuclei by Virtual Photon Tagging at MAX-lab, MAX-lab Experiment 08-04, 2008.

[3] L. Tang, A. Margaryan, L. Yuan, S.N. Nakamura, J. Reinhold, F. Garibaldi, J. LeRose, spokespersons, Study of Light Hypernuclei by pionic Decay at JLab, JLab Proposal: PR-10-001, 2010.

[4] A. Margarayn, R. Carlini, R. Ent et al., Radiofrequency Picosecond Phototube, Nucl. Instr. and Meth. A566 (2006) 321.

[5] Amur Margaryan, Karlen Gynashyan, Osamu Hashimoto, Stanislaw Majewski, Liguang Tang, Radio Frequency Phototube, Docket 1963 (JSA)/I.D. 1225, U.S. Patent Application Serial No. 12/660,966, Filed: March 8, 2010.

[6] A. Margaryan, Radio frequency phototube and optical clock: high resolution, high rate and highly stable single photon timing technique, Symposium on Radiation Measurements and

Applications, SORMA XII, Ann Arbor, University of Michigan, USA, 2010, article in press, doi:10.1016/j.nima.2010.08.122.

[7] A. Margaryan et al., Armenian Journal of Physics, 3 (4) (2010) 282.

[8] H. Ries et al., Phys. Lett. 139B (1984) 254.

[9] A. Lepretre et al., Nucl. Phys. A472 (1987) 533.

[10] J. Ahrens, Nucl. Phys. A446 (1985) 229c.

[11] M. MacCormick, et al., Phys. Rev. 55C (1997) 1033.

[12] Th. Frommhold et al., Phys. Lett. 127B (1983) 331.

[13] E. A. Arakelyan et al., Yad. Fiz. V.49 (1989) 1651.

[14] E. A. Arakelyan et al., Yad. Fiz. V.49 (1989) 1253.

[15] E. A. Arakelyan et al., Yad. Fiz. V.52 (1990) 1387.

[16] Th. Frommhold et al., Z. Phys. A350 (1994) 249.

[17] N. Bianchi et al., Phys. Lett. B299 (1993) 219.

[18] J. Ahrens et al., Phys. Lett. B146 (1984) 303.

[19] K. Hansen et al., Phys. Rev. 41C (1990) 1619.

[20] A. S. Iljinov et al., Nucl. Phys. A539 (1992) 263.

[21] Ya. Kezerashvili et al., JETP Lett. 40 (1984) 1271.

[22] J. C. Sanabria et al., Phys. Rev. C61 (2000) 034604.

[23] C. Cetina et al., Phys. Rev. Lett., v.84, n. 25 (2000) 5740.

[24] I. A. Pshenichnov et al., arXiv:nucl-th/0303070.

[25] V.G. Nedorezov, A.A. Turinge, Yu. M. Shatunov, Physics-Uspekhi **47** (4) (2004) 341.

[26] V. S. Barashenkov et al., Nucl. Phys. A231 (1974) 462.

[27] A. S. Iljinov et al., Yad. Fiz. 32 (1980) 322, (Sov. J. Nucl. Phys. 32 (1980) 166.

[28] T. E. Rodrigues et al., Phys. Rev. C 69, 064611 (2004) 064611.

[29] V. Lucherini et al., Preprint LNF-90/019 (R), Frascati, 1990.

[30] A. Deppman et al., Phys. Rev. Lett. V. 87, n. 18, (2001) 182701-1.

[31] L. A. Pshenichnov, et al., Arxiv preprint nucl-th/0303070, 2003.

[32] S. G. Mashnik et al., J. Nucl. Radiochem. Sci. Vol. 6, No. 2 pp A1-A19 (2005).

[33] D. I. Ivanov et al., Sov. J. Nucl. Phys. 55 (1992) 506.

[34] Th. Frommhold et al., Z. Phys. A 350, (1994) 249.

[35] C. E. Hyde-Wright, W. Bertozzi, J. M. Finn, Electron Scattering at 0°: A Photon Tagging Technique, 1985 Summer Workshop, CEBAF, Newport News, Virginia.

[36] E. A. Arakelyan et al., Sov. J. Nucl. Phys. 49, 1022 (1989).

[37] O. Hashimoto, H. Tamura, Progress in Particle and Nuclear Physics, **57**, 564 (2005).

[38] A. S. Iljinov et al., Nucl. Phys. A 543 (1992) 517.

[39] W. A. Fowler, Rev. Mod. Phys. 56 (1984) 149.

[40] G. Wallerstein, et al., Rev. Mod. Phys. 69 (1997) 995.

[41] L. R. Buchmann and C. A. Barnes, Nucl. Phys., A 777 (2006) 254.

[42] C. Angulo, et al., Nucl. Phys. A 656, (1999) 3.

[43] F. Ajzenberg-Selove, Nucl. Phys, A 506 (1990) 1.

[44] F. Hoyle, D. N. F. Dunbar, W. A. Wenzel, and A. Whaling, Phys. Rev. 92 (1953) 1095.

[45] D. N. F. Dunbar, et al., Phys. Rev. 92 (1953) 649.

[46] C. W. Cook, W. A. Fowler, et al., Phys. Rev. 107 (1957) 508.

[47] H. Morinaga, Phys. Rev. 101 (1956) 254.

[48] C. W. Cook, W. A. Fowler, et al., Phys. Rev. 111 (1958) 567.

[49] H.O.U. Fynbo *et al.*, Phys. Rev. Lett. 91 (2003) 82502.

[50] H.O.U. Fynbo *et al.*, Nature 433 (2005) 137.

[51] Martin Alcorta et al., Nuclei in the Cosmos – IX , 25-30 June 2006, PoS (NIC-IX)067.

[52] R. Alvarez-Rodriguez et al., Eur. Phys J. A 31 303 (2007) 303.

[53] Yoshiko Kanada-En'yo, Phys.Rev.C75 (2007) 024302.

[54] Y. Kanada-En'yo, Prog.Theor.Phys.117, (2007) 655; ibid.121 (2009) 895.

[55] Y. Kanada-En'yo et al., Eur. Phys. J. A25 (2005) 305.

[56] R. I. Dzhibuty, R. Ya. Kezarashvily, N. I. Shibitidze, Proceedings of the 7 th Seminar Electromagnetic Interactions of Nuclei at Low and Medium Energies, Moscow, p. 248, 1988.

[57] W. Becker, Advanced Time-Correlated Single Photon Counting Technique, Springer Series in CHEMICAL PHYSICS, 81, 2005.

[58] A. Margaryan, OPTICAL CLOCK, RADIO FREQUENCY TIMING TECHNIQUE AND A NEW EARTH-BOUNDED GRAVITATIONAL REDSHIFT EXPERIMENT, Armenian Journal of Physics, v. 3, issue1, p.33, 2010.

[59] A. Margaryan, Radio Frequency Phototube, Optical Clock and Precise Measurements in Nuclear Physics, arXiv: 0910.3011, 2009.

[60] A. Margaryan, O. Hashimoto, S. Majewski, L. Tang, RF Cherenkov picosecond timing technique for high energy physics applications, Nucl. Instr. and Meth. A595 (2008) 274. A. Margaryan, Gas time-of-flight Cherenkov detector with RF phototube for FP420, Cracow, 2010.

[61] A. Margaryan, RF picosecond timing technique and new possibilities for hypernuclear studies. The European Physical Journal A- Hadrons and Nuclei, V. 33, N3 (2007), p. 47.

[62] A. Margaryan, L. Tang, S. Majewski, O. Hashimoto, V. Likhachev, Auger Neutron Spectroscopy of Nuclear Matter at CEBAF, JLab Letter of Intent: LOI-00-101, 2000.

[63] A. Margaryan, V. Kakoyan, S. Knyazyan, Time-of-flight positron emission tomography with radiofrequency phototube, Workshop on Timing Detectors, Cracow, 2010.

[64] F. K. Goward and J. J. Wilkins, Proc. R. Soc. Lond. A 217 (1953) 357.

[65] V. N. Maikov, Zh. Eksper. Teor. Fiz. 34 (1958) 1406; Sov. Phys. JETP 7 (1958) 973.

[66] A. Murakami, J. Phys. Soc. Japan 28 (1970) 1.

[67] E. A. Kotikov er al., Izv. Rossiiskoi Akademii Nauk, Ser. Fiz. 66 (2004) 455.

[68] Tatsushi Shima, Nuclei in the Cosmos-IX, 25-30 June 2006, PoS (NIC-IX) 176.

[69] M. Gai et al., TUNL XLVIII, 99, 2008-2009.

[70] S.N. Afanas'ev, et al., № 5. *Series:* Nuclear Physics Investigations (44), p. 14-18, 2004.

[71] G. Raciti et. al., 9th International Conference on Clustering Aspects of Nuclear Structure and Dynamics, Journal of Physics, Conference Series 111 (2008) 012049.

Personnel Commitments

Name	Scientific Title	Function in project
Margaryan Amur	Ph.D.	Project Manager
Ajvazyan Robert		Methodic Studies
Gounashyan Karlen	Ph.D.	Experimental Studies, RF Deflector
Grigoryan Nersik	Ph.D.	Experimental investigations, Vacuum Technique
Kakoyan Vanik	Ph.D.	Data analysis, Monte Carlo
Kavalov Ruben	Ph.D.	Experimental investigations, Vacuum Technique
Knyazyan Svetlana	Ph.D.	Data analysis, Monte Carlo
Vardanyan Henrik	Ph.D.	Experimental investigations, Electronic Equipment
Zhamkochyan Simon*	Ph.D.	Experimental investigations, Monte Carlo

*Younger than 35 year.

Equipment

Equipment description	**Cost (US $)**
PIN-diodes	5,000
PC	1,000
RF equipment	9,000
Vacuum equipment	9,000
Total **24,000**	

Materials

Materials description	Cost (US $)
Supplies	5,000

Other Direct Costs

Direct cost description	Cost (US $)
Manufacturing of pilot RF phototube	25,00
Manufacturing of the amplifiers	2,000
Manufacturing of pilot RF deflectors	2,000
Machine shop expenses	1,000

Travel costs (US $)

CIS travel	International travel	Total
	15,000	15,000

Technical Approach and Methodology

6. Low-pressure MWPC system for the detection of alpha particles and fission fragments

A fission-fragment detection system, FFD, was designed and built in order to measure the absolute photofission cross sections for the actinides ^{238}U and ^{237}Np at MAX-lab tagged photon beam within statistical and systematic error less than 3% [1]. The FFD should have capability operate with tagged photon beam and separate unambiguously binary photofission events from background reactions, e.g. from fragmentation reactions. Our FFD is based on low-pressure multi-wire proportional chamber (LPMWPC) techniques, the properties of which are suited for these goals. The history of LPMWPC techniques and its applications are enlightened in [7] (and references therein). The FFD is displayed schematically in Fig. 1.

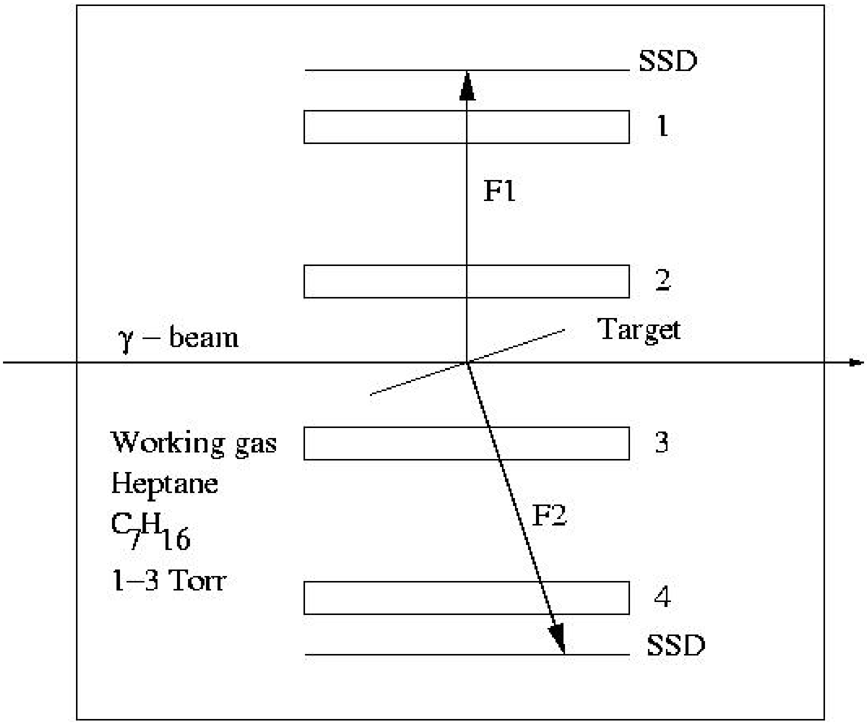

Fig. 1. A schematic sketch of the fission fragment detector.

It consists of four windowless LPMWPC units, which form two symmetric arms placed above and below the central beam. The chambers have an active area of 12×12 cm^2. The inner chambers have a separation distance of 3 cm from the anode plane to the central beam. The outer chambers are located 8 cm away from the central beam. The solid state detectors will be mounted just behind outer chambers and will provide only pulse height information for evaluation of the energy of fission fragments. Each arm provides about 2.5 sr of solid angle coverage and measures the time-of-flight (TOF) as well as the fragment trajectory and energy. The target is located at the center of the two arms. When a photofission event occurs, two fission fragments are emitted in opposite directions, go through the FFD and are registered. The assembly of the windowless LPMWPC system and experimental target is placed in a cylindrical vacuum chamber. There are two windows for the incoming beam and outgoing particles. The operational gas is a Heptane at about 3 Torr pressure.

In Fig. 2 the structure of the LPMWPC unit is illustrated schematically. It consists of five electrodes made of wire planes. The central electrode is a wire-anode plane from which the time signal is extracted. The anode is placed between two cathode wire planes which have their wires oriented at an angle of 90 degrees with respect to each other. The active area of the chamber is 12×12 cm^2. The positive signals induced on the cathodes are used for (*x*, *y*) position readout, one coordinate from each cathode plane. The two outer wire planes function as either guard planes against electrons from ionization taking place outside of the chamber region, or additional electrodes to form the double-step gas amplification. Due to the large active area, a passive mean timing was made in grouping the anode wires to minimize position dependence of the time resolution.

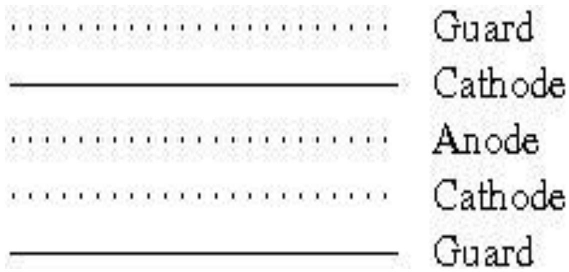

Fig. 2. Schematic diagram of the structure of LPMWPC.

The LPMWPC system can be operated in single as well as double step operational modes. In the case of the single step operational mode the typical potentials applied to the anode, cathode and guard planes are about +400, -100 and 0 V respectively and the resulting signals from the FF have about 200-300 mV amplitudes, while signals from α-particles are less than the amplitudes of electronic noise of the preamplifier which is about or less than 5 mV.

In the case of the double step operational mode the typical potentials applied to the anode, cathode and guard planes are about +300 V, 0 V and -300 V respectively and the resulting signals from the FF are about 1.0 -1.5 V, while signals from α-particles are in the range 12-20 mV, well above the electronic noise of the detector.

Typical values of the time and position resolutions (FWHM) are about or less than 300 ps and 1 mm consequently for fission fragments. The energy loss spectrum of α-particles and fission fragments in the LPMWPCs, which are very useful and needed for a correct threshold adjustment of the timing discriminators in photofission experiments to minimize the systematic error, was studied at MAX-lab by using α-particles and fission fragments from a ^{252}Cf source. The pulse height distribution of the signals generated by α-particles, has a typical Landau distribution shape with ~ 60% FWHM, while the pulse height distribution of signals generated by FFs differs from Gaussian shape. It has long tails at both low and high energy sides. The average pulse height ratio of the signals generated by α-particles and FFs is about 1/80 and close to the theoretical value 1/88. In previous measurements, which were carried out mainly by using parallel plate avalanche chambers (PPACs), this ratio lay in the range from 1/5 to 1/35 (see [7] for details). Such a big differences between measured and theoretically expected values was explained by space charge effects, which decreases the pulse heights produced by the strongly ionizing fission fragments in PPACs. The results obtained at MAX-lab demonstrate that in contrast to PPACs space charge effects play minor role in LPMWPs. Such a linear response of the technique in a wide dynamic range from alpha particles to FFs is an important property for unambiguous detection of FFs and therefore for precise measurements of photofission cross sections at MAXlab. Meanwhile the technique can be used for detection of low energy recoils such as ^{3}He and ^{4}He.

Recent studies at ANL demonstrated that gas amplification can be increased of about order of magnitude by increasing distance between wire planes and proper selection of operation regimes. Therefore the LPMWPC technique can be used for detection of low energy protons and deuterons as well. We are planning to study operation of LPMWPC with Neon, Argon and Xenon gases at low pressure, aiming to develop active targets for fission and fragmentation studies with real and virtual photon beams. In particular we are planning to investigate possibilities of two proton emission studies of the excited Ne-18 nuclei [71] by using Ne-20 filled LPMWPC technique as an active target. It is assumed that energetically allowed excited states of Ne-18 will be produced in photon Ne-20 interactions.

The activities during the realization of the Project can be divided into the following stages.

1) Design, construction and assembling of the test experimental set-up at MAX-lab, which includes vacuum chamber, readout electronics and data acquisition system.

2) Assembling of the FF detector at MAX-lab and investigation of their parameters in lab by using spontaneous source of FF, Cf-252.

3) Design, construction and assembling of the experimental setup at MAX-lab, which includes tagged photon system, readout electronics and data acquisition system.

4) Experimental studies and performing of measurements at MAX-lab at with real and virtual tagging technique.

5) Data analysis and preparation of results for publication.

6) Design, construction and assembling of the test experimental set-up at ANL, which includes vacuum chamber, readout electronics and data acquisition system.

7) Assembling of the detector system based on low-pressure MWPCs at ANL and investigation of their parameters by using different gases (Neon, Argon, and Xenon) and spontaneous source of FF and alpha particles, Cf-252.

8) Data analysis and preparation of results for publication, preparation of a new proposals.

7. Radio frequency phototube: design feature

7.1 Radio frequency phototube with point size photocathode

The general layout of the proposed phototube for point-size photocathode is shown in Fig. 1.

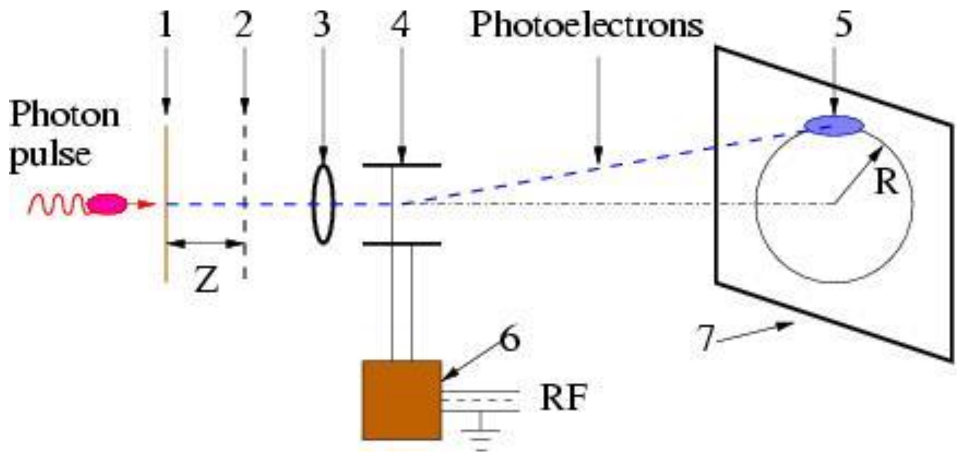

Figure 1: The schematic layout of the RF phototube with point-size photocathode.
1- photo-cathode, 2- electron transparent electrode, 3- electrostatic lens, 4- RF deflector, 5- image of photo electrons, 6- $\lambda/4$ coaxial RF cavity, 7- SE detector.

The primary photon pulse hits the photocathode (1) and produces photo-electrons (PEs). These electrons are accelerated by a voltage V applied between the photocathode and an electron transparent electrode (2). The electrostatic lens (3) then focuses the electrons onto the screen (7) at the far end of the tube, were the secondary electron (SE) detector is placed. The time structure of the produced PE bunch is identical to that of the light pulse. Along the way the electrons are deflected by the circular sweep RF deflection system, consisting of electrodes (4) and $\lambda/4$ coaxial RF cavity (6), which operates at 500 MHz and forms a circle on the screen, where the time structure of the input photon signal is transferred into spatial PE image (5) and detected. In this way the timing error sources are minimized, because PEs is timed before the necessary further signal amplification and processing.

The internal time resolution of the system which is determined by physical time resolution of the photocathode and electron tube is of the order of ~2 ps.

Technical time resolution of the electron tube is determined by the electron transit time dispersion and in a carefully designed system is of the order of ~1 ps.

To scan circularly 2.5 keV electrons, dedicated RF deflecting system at a frequency of $f = 500$MHz have been developed. The sensitivity of this new and compact RF deflector is about 1 mm/V or 0.1 $rad/W^{1/2}$ and is an order of magnitude higher than the sensitivities of the RF deflectors used previously. About 1 W (on 50 Ω) RF power at 500 MHz has been used to scan the 2.5 keV electron beam circularly and to reach 2 cm radius or 20 ps technical time resolution for 1 mm beam spot size.

The detection of the PEs is accomplished with a position sensitive detector based on a dual, chevron type micro-channel plates, MCPs. Thus, signals from such a device can be processed by using common nanosecond-time electronics (amplifiers, discriminators, logic units, analog-to-digital converters and etc.), and time resolution better than 20 ps can be achieved for single PE. Position determination can be performed in two basic architectures:

1) Direct readout: array of small (~1 mm^2) pixels, with one readout channel per pixel. The position resolution in this case is about or better than the size of readout cell.
2) Interpolating readout**:** position sensor is designed in such a way that measurement of several signals (amplitudes or times) on neighboring electrodes defines event position. The position resolution limit for both cases (amplitude or times) is $\Delta x/x \sim 10^{-3}$.

The RF phototube with direct readout scheme such as an array of small (~1 mm^2) pixels with one readout channel per pixel can be used as an optical waveform ultrafast digitization device. In this case the RF phototube operates as a 50 GHz sampling optoscope and can be used as an optical waveform fast digitization device in the nanosecond and subnanosecond domain with ~2 ps internal timing resolution.

7.2 Radio frequency phototube with large size photocathode

The general layout of the RF phototube with large-size photocathode, which is needed in high energy elementary particle physics and nuclear physics experiments, is shown in Fig. 2. We propose to use “spherical-capacitor” type immersion lens. It implies a configuration consisting of two concentric spheres of which the outer one is a photocathode (1) and the inner one is an electron transparent electrode (2). This configuration has a number of advantages, e.g., the possibility of having high accelerating field near the photocathode, between photocathode (1) and electrode (2), form a perfect crossover outside of this electric field and a complete lack of transit time dispersions in the crossover for electrons with equal initial energies. The transmission dynode (3), e.g. fine mesh or thin cooper-beryllium alloy (coating Al_2O_3) is placed in the crossover. In a tube with similar structure and with 40 mm diameter photocathode about 10 ps (FWHM) temporal resolution can be achieved.

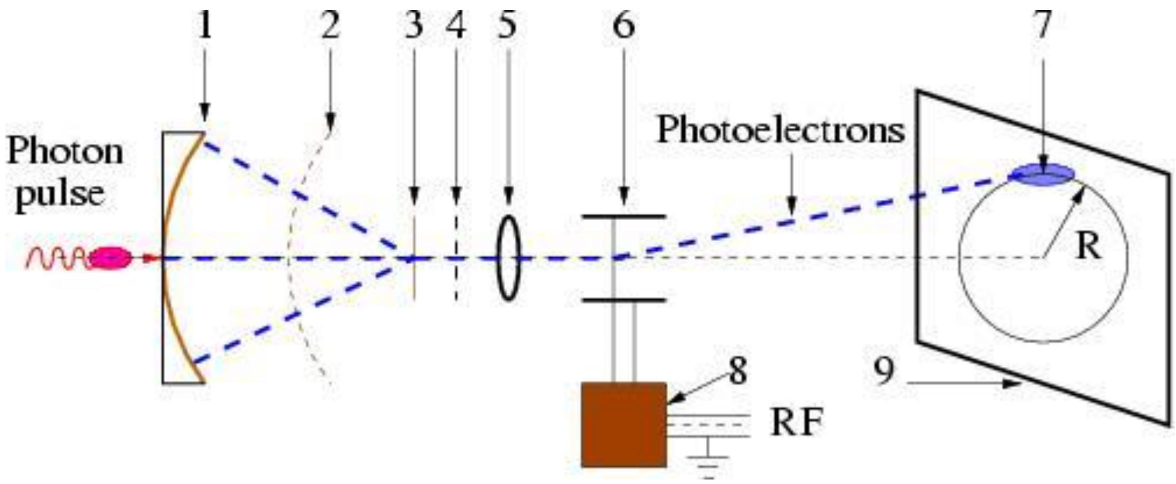

Figure 2: The schematic layout of the RF phototube with large size photocathode.

1- photo cathode, 2- electron transparent electrode, 3- transmission dynode, 4- accelerating electrode, 5-electrostatic lens, 6- RF deflection electrodes, 7- image of PEs, 8- $\lambda/4$ RF coaxial cavity, 9- SE detector.

The activities during the realization of the Project can be divided into the following stages.

9) Design, construction and assembling of the test experimental set-up, which includes vacuum chamber, electron gun, position sensitive detector, readout electronics and data acquisition system.

10) Design and construction the prototype RF deflectors. Investigation and optimization of their parameters by using developed experimental setup and dedicated Monte Carlo codes.

11) Design and construction of the prototype RF phototube by manufacturing company, e.g. by Photek, which include design, simulations, experimental tests and manufacturing of prototype samples.

12) Investigation and optimization of parameters of the prototype RF phototube by using proper pulsed photon sources e.g. at MAX-lab, Sweden or Tohoku University, Japan.

Design and construction the prototype RF phototube, studies of its parameters, preparation of publications and new projects will be the main result of this proposal.

Appendix: additional information related to the Project activities is enclosed.

Proposal 2008-04

Photo-fission studies of nuclei by virtual photon tagging at MAX-lab.
Presented by Amour Margaryan.

The proposed experiment would provide detailed measurements of the photo-fission cross section, including fragment mass and velocity distributions, for a range of nuclei. The proposal will use a new fission fragment detector system and exploit a virtual tagging technique, both of which are new to the MAX facility. The PAC is positive to this experiment and feels that the study of the fission process in such detail will provide new information to challenge theoretical understanding of these reactions.
The PAC views the proposed fission fragment detector system as an important development and strongly supports its construction. We would expect that the development, proof and siting of the detector would necessitate additional time. This was not requested in the proposal but could be adequately provided by discretionary test time from the facility management.
The virtual-photon tagging technique offers new opportunities in terms of achievable tagged photon flux. The PAC encourages the development of this technique at MAX-lab, including more detailed studies of the expected properties of the virtual photon flux than presented in the proposal.

Beam time recommendation: 41 shifts

Proposal 8: Photofission of heavy actinide nuclei

It is proposed to measure the total photofission cross section of several heavy actinides. These measurements are motivated by results from earlier experiments that show distinct differences in the fissility of these targets and partly distinctly higher values of total cross sections than given by the "universal curve" of photon absorption on nuclei. This effect, if correct, is not understood. The PAC cautions that special care is needed in the production of the targets and recommends initially measurements only on ^{238}U and ^{237}Np. The idea of measuring $e^+ e^-$ pairs accompanying the process has no theoretical footing. Therefore, if it were done, extra beam-time should not be used for it, and a better method than proposed to measure the pairs should be applied, for example, a method with a magnetic field.

The proposal is rated B.
1 week of beam time is recommended.

Proposal: LOI-00-101

Title: Auger Neutron Spectroscopy of Nuclear Matter at CEBAF

Spokesperson: A. Margaryan

This proposal is to perform precise spectroscopy of the deeply bound, single-particle levels in heavy hypernuclei. A tremendous improvement in precision is sought by measurement of the neutron decays between single particle states in neighboring hypernuclei, in analogy to the Auger process. Successful determination, with high energy resolution, of the 1s, 1d, 1f, 2p, 1g, 2d and 1h states in a heavy nucleus would truly be a major step in nuclear physics.

The measurements rely upon a novel RF timing system, as well as a new approach to neutron time-of-flight measurement using ^{235}U foils backed by low pressure MWPC's to detect the ^{235}U fission fragments. Design, development, and successful implementation of these systems represents a significant amount of R&D work. The rate of background neutrons will be extremely high. The proponents plan to control the background via timing cuts, but the signal to background is likely to still be small.

Extensive Monte Carlo studies or in-beam tests of backgrounds and approaches to reject them would be necessary to establish the feasibility of making the measurements. The PAC remained unconvinced that the stated energy resolutions would be achievable.

Furthermore, the PAC was concerned about energy spreading in the low-lying levels because of coupling to the many other occupied states. It must be demonstrated that this effect is sufficiently small that the sharp energy spectra expected from the decay neutrons remain well separated. Furthermore, the full spectrum of states from the parent and all daughters following the transitions must be studied.

Letter of Intent: LOI-07-001

Title: Study of Hypernuclei by Pionic Decay at JLab

Spokespersons: A. Margaryan, O. Hashimoto, S. Majewski, L. Tang

Motivation: This Letter of Intent describes a potential program of systematic studies of light hypernuclei at JLab using pionic decay. The Project aims at determination of structural properties, such as binding energies, lifetimes, production mechanism, and in-medium effects on electric and magnetic properties. The highlights of the proposed program include (i) precision measurements of binding energies of hypernuclei (100 keV resolution; to be compared with a current resolution ~700 keV); (ii) Studies of exotic, extremely rich halo hypernuclei such as $^{8}H_{\Lambda}$; (iii) Measurements of electromagnetic rates (and moments) using a "tagged-weak pi-method." If successful, the program described in the LOI has a potential to move JLab into the field of precision hypernuclear spectroscopy that is essential for making an impact on modern shell-model- and ab-initio calculations. To this end, the group intends to utilize the high-resolution kaon spectrometer (HKS) in Hall C, develop a high-resolution magnetic spectrometer for hypernuclear decayed pions (HπS), and develop a Cherenkov picosecond timing technique based on the recently proposed RF picosecond phototubes.

Measurement and Feasibility: As suggested by the TAC report, there are a number of potentially serious experimental issues with rates, resolutions, and backgrounds that need to be addressed by comprehensive simulations.

Issues: The above issues will need to be adequately addressed if this letter of intent is to proceed to a full proposal.

Recommendation: The physics motivations of this Letter of Intent are strong and the PAC encourages the proponents to develop this into a full proposal.

Proposal: PR-08-012

Scientific Rating: A-

Title: Study of Light Hypernuclei by Pionic Decay at JLab

Spokespersons: L. Tang, A. Margaryan, L. Yuan, S.N. Nakamura, J. Reinhold

Motivation: This proposal, complementary to the approved experiment E05-115, describes a potential program of novel systematic studies of light hypernuclei at JLab using pionic decay. The project aims at determination of structural properties, such as binding energies, lifetimes, production mechanism, and in-medium effects on electric and magnetic properties of hypernuclei. The highlights of the proposed program include (i) high precision measurements of binding energies of hypernuclei (55 keV resolution; to be compared with current resolution ~500 keV); (ii) Studies of exotic, extremely rich halo hypernuclei such as $^{6}H_{\Lambda}$; (iii) Measurements of electromagnetic rates (and moments) using a "tagged-weak π-method"; (iv) Studies of production of neutron-rich hypernuclei by means of multifragmentation. This program has a potential to move JLab into the field of precision hypernuclear spectroscopy that is essential for making an impact on modern shell-model and ab-initio calculations of hypernuclei. To this end, the group intends to use the recently developed high-resolution kaon spectrometer (HKS) for tagging strangeness production and use the existing Enge spectrometer as a high-resolution magnetic spectrometer for pions from hypernuclear decay (HπS).

Measurement and Feasibility: This is a large installation experiment, requiring installation of the HKS spectrometer, the Enge spectrometer and a splitter magnet. The incoming beam would be re-chicaned by using the beamline designed and built for E05-115, changing the incline angle from 14 degrees to 8.2 degrees. The experiment would use two targets, ^{7}Li and ^{12}C. According to the PAC report, there are a number of experimental issues with rates, precision in pion momentum, background, and Li target. However, all these comments were addressed by the proponents.

Issues: The PAC was convinced that this is an outstanding experiment with very high impact that should be pursued. Nevertheless, for the success of this new program it is important to demonstrate that the proposed measurements can be performed without major issues. The PAC believes that a test study of the production mechanism, following the completion of PR-08-002, is necessary. For the test, the use of the HES spectrometer instead of the Enge spectrometer is suggested.

Recommendation: Conditionally approve: C3 for 5 days in Hall C, if a meaningful test is feasible.

Proposal: PR12-10-001

Title: Study of light hypernuclei by pionic decay at JLab

Spokespersons: L. Tang, A. Margaryan, L. Yuan, S.N. Nakamura, J. Reinhold, F. Garibaldi, J. LeRose

Motivation:

This proposal describes a potential program of novel systematic studies of light hypernuclei at JLab using the pionic weak 2-body decay. The project aims to determine structural properties, such as binding energies, lifetimes, production mechanism, charge symmetry breaking (CSB) effects in mirror pairs, and in-medium effects on electric and magnetic properties of hypernuclei. The highlights of the proposed program include:

(i) High precision measurements of binding energies of hypernuclear ground and isomeric states

(ii) Studies of exotic, extremely rich halo hypernuclei such as superheavy hydrogen ^{6}H;

(iii) Measurements of electromagnetic rates (and moments);

(iv) Studies of the production of neutron-rich hypernuclei by means of multi-fragmentation; and

(v) CSB studies in mirror pairs.

This program has the potential to move JLab into the field of precision hypernuclear spectroscopy that is essential for making an impact on modern shell-model and *ab-initio* calculations of hypernuclei. In this proposal, the collaboration asks to transfer the previously approved 5 days test beam (E08-012) from Hall C to Hall A to carry out a feasibility test run with a ^{7}Li target.

Measurement and Feasibility:

The proponents want to use the seemingly only possible experimental installation available before the shut-down for the accelerator upgrade to perform the test measurement, which is possible in Hall A, using the HRS (for K) and the Enge split pole (for π^-). This implies only a moderate set-up effort, while the final equipment will involve a large installation.

Issues:

The PAC is convinced that this is an outstanding program with very high impact that should be pursued. Nevertheless, for the success of this new program it is important to demonstrate that the proposed measurements can be performed without major issues. The PAC believes that a test study of the production mechanism is necessary.

Recommendation: Conditional Approval.

Transfer the previously approved 5 days test beam (E08-012) from Hall C to Hall A so that the feasibility test-run with a ^{7}Li target can be carried out.

Dr. A. Margaryan
Alikhanian National Center
Yerevan, Armenia

NANYANG TECHNOLOGICAL UNIVERSITY

Prof. Gagik Gurzadyan
Nanyang Technological University
Division of Physics and Applied Physics
21, Nanyang Link, SPMS-PAP-03-11
Singapore 637371

Tel: +65 6513 7405 off
+65 6513 8496 lab 20
+65 6513 849 lab 16
Email: gurzadyan@ntu.edu.sg
http://www3.ntu.edu.sg/home/gurzadyan/

Dear Dr. Margaryan,

I am delighted to learn about your work on the design of a radio frequency phototube, its patent application in US and projects for its production. If the stated parameters, i.e. time resolution better than 20 ps for individual photons, high rate, over 1 MHz, and stability of 10 fs/hrs, will be reached, then I can state, that your phototube will be indeed a useful device in hundreds, and even thousands laboratories worldwide and will find applications in fluorescence imaging (FLIM) merged to the confocal microscope. The latter indeed will attract interest of biomedical research community. I will be strongly interested to get such a phototube for the research in our laboratory in the systems of time-correlated single photon counting of fluorescence.

Thus, as an interested person, I believe that you'll successfully accomplish the production of such a useful device.

With all my best wishes

Gagik Gurzadyan   27 July 2010, Singapore