JLab PAC12 Proposal Cover Sheet

This document must be received by close of business Thursday, June 26, 1997

Jefferson Lab
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(Choose one)

[x] New Proposal Title: Study of the generation and decay of fissioning hypernuclei

[ ] Update Experiment Number:

[ ] Letter-of-Intent Title:

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Experimental Hall: A Days Requested for Approval: 2

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Receipt Date: 6/25/97 97-004

By:

LAB RESOURCES LIST

JLab Proposal No.: ____________________ Date ____________________

(For JLab ULO use only.)

List below significant resources — both equipment and human — that you are requesting from Jefferson Lab in support of mounting and executing the proposed experiment. Do not include items that will be routinely supplied to all running experiments such as the base equipment for the hall and technical support for routine operation, installation, and maintenance.

Major Installations *(either your equip. or new equip. requested from JLab)*

target chamber, vacuum valve,

vacuum pump, detector, target

New Support Structures:

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets:

Power Supplies:

Targets: solid targets Al, Bi

Detectors:

Electronics:

Computer Hardware:

Other:

Other:

HAZARD IDENTIFICATION CHECKLIST

JLab Proposal No.: ______________________________ Date: ________________
(For CEBAF User Liaison Office use only.)

Check all items for which there is an anticipated need.

Cryogenics _____ beamline magnets _____ analysis magnets _____ target type: __________ flow rate: __________ capacity: __________	**Electrical Equipment** _____ cryo/electrical devices _____ capacitor banks _____ high voltage _____ exposed equipment	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: ____________________ ____________________ ____________________ ____________________
Pressure Vessels _____ inside diameter _____ operating pressure _____ window material _____ window thickness	**Flammable Gas or Liquids** type: __________ flow rate: __________ capacity: __________ **Drift Chambers** type: __________ flow rate: __________ capacity: __________	**Other Target Materials** ___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) ___ Other (list below) 209Bi, 27Al ____________________
Vacuum Vessels _____ inside diameter _____ operating pressure _____ window material _____ window thickness	**Radioactive Sources** _____ permanent installation _____ temporary use type: __________ strength: __________	**Large Mech. Structure/System** _____ lifting devices _____ motion controllers _____ scaffolding or _____ elevated platforms
Lasers type: __________ wattage: __________ class: __________ Installation: _____ permanent _____ temporary Use: _____ calibration _____ alignment	**Hazardous Materials** ___ cyanide plating materials ___ scintillation oil (from) ___ PCBs ___ methane ___ TMAE ___ TEA ___ photographic developers ___ other (list below) ____________________ ____________________	**General:** Experiment Class: _____ Base Equipment _____ Temp. Mod. to Base Equip. _____ Permanent Mod. to Base Equipment __X__ Major New Apparatus Other: __________ __________

BEAM REQUIREMENTS LIST

Lab Proposal No.: ______________________ Date: ______________

Hall: A　　Anticipated Run Date: ______________　　PAC Approved Days: __________

Spokesperson: Yu.M.Ranyuk, J.D.T.Arruda-Neto　　Hall Liaison: Kees de Jager
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List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition No.	Beam Energy (MeV)	Mean Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Material Thickness (mg/cm²)	Est. Beam-On Time for Cond. No. (hours)
1	2400	30		$^{209}Bi + ^{27}Al$	0.1+2.7	12
2	2400	30		^{27}Al	2.7	12
3	800	30		^{27}Al	2.7	12

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Other energies should be arranged with the Hall Leader before listing.

Proposal to the Jefferson Laboratory PAC-12

STUDY OF THE GENERATION AND DECAY OF FISSIONING HYPERNUCLEI

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August 3, 1997

Abstract

We propose the delay fission investigation which will be the indication of the hypernuclear production and decay within the atomic masses region near 200. The aim of the experiment is to measure the hypernuclei electroproduction cross section and Λ-hyperon lifetime inside of a heavy nucleus.

Proposed measurements demand the utilization of high energy electron beam facility with low angular emittance and high current. Other parameters such as high duty factor and compact beam spot dimensions at the target are also required. Actually these beam characteristics are offered by Jefferson Laboratory only.

Despite the fact that hypernuclear physics has about 40 years of history, the experimental investigations have been made predominantly for hypernuclei within atomic mass number ≤ 20. Available data are rather scarce and have large uncertainties. This is due to the tremendous difficulty in the hypernuclei production and subsequently - due to the detection and identifying problems of their decay products. Only two heavy hypernuclei - $^{209}Bi_\Lambda$ and $^{238}U_\Lambda$ have been experimentally observed and their lifetimes were measured with very low accuracy.

The hypernuclei lifetime is a fundamental quantity. Its knowledge is required to verify different concepts of the nuclear structure and hadron interaction. The investigation of hyperon decay in nuclei may provide the information about the influence of nuclear media on weak Λ-hyperon decay, quark structure of hypernuclear system and so on. One of the problems still existing is the search for long-lived hypernuclei whose existence may be due to the delaied decay of a Λ-hyperon in the strong intranuclear electromagnetic fields. It was predicted by Salam and Strathdee in connection with the expected symmetry restoration in such circumstances.

The delay fission cross section caused by hypernuclei production is about $(2.5 \pm 1.0) \times 10^{-5}$ of prompt fission cross section. The lifetime of delay fission is some picoseconds.

We propose to carry out the measurements of electroproduction cross sections for $^{197}Au_\Lambda$, $^{209}Bi_\Lambda$ and $^{238}U_\Lambda$ in the electron energy range $1-2GeV$ and their lifetime determination.

The measurements will be performed using the recoil-distance technique in projectile modification and solid state fission fragment detectors.

The Kharkiv members of this collaboration have good experience in this field of investigation, while the Sao Paulo group has long time developed solid state fission fragment detectors technique.

In principle, the aim of our proposal is very similar to the proposal of E95-002 [16]. But we have to stress that proposed method is very different. In this case our experimental data may complement others by E95-002 and could be used for the comparison and more deep analysis. Anyway, actually such measurements could be performed only at Jefferson Laboratory and to check the reproducibility of experimental results it is possible only here. We believe that using this way the final answer about heavy hypernuclei formation and their lifetime could be found.

1 MOTIVATION

Generally the induced fission of heavy nuclear system is considered to be an excellent method to study the latter stages of complex nuclear reactions. The fission process could be initiated by the transfer of energy and momentum to a target nucleus from a nuclear or electromagnetic probe. Then the resultant excited system may emit pre-equilibrium particles prior to formation of a thermalized compound nucleus. The compound nucleus evaporates particles and/or undergo fission, depending on the final thermalized value of excitation energy and angular momentum of the system. The use of real or virtual photons as initial probe has several advantages in comparison with others. The primary advantage is that electromagnetic interaction is well known and calculable. The photon can transfer significant energy to the target nucleus with a relatively small transfer of linear and angular momenta. And at last, we can say that photon (real or virtual) has equal probability to interact with any nucleon within entire nuclear volume.

The photo- and electrofission phenomena is the subject of intensive investigation at the present time [1, 2, 3, 4].

The main aims of the research are the following:

1. *Prompt fission.* For actinide nuclei, with a low fission barrier, the photofission cross sections are very close to the total photoabsorption cross section [4, 5]. For the case of ^{238}U, experimental measurements and theoretical calculations have suggested that the photofission probability is consistent with unity for photon energies higher than 40 or $50MeV$ [2, 6]. However, even the most recent results using monochromatic photons [7, 8] exhibit some discrepancies in the cross sections per nucleon as for ^{235}U and ^{238}U, as between these two isotopes and so-called *"universal curve"* in the Δ-resonance region. These discrepancies are nearly within the systematic uncertainties of the experiments. But if they are indeed real, it could be inconsistent with the predictions based on incoherent total volume absorption. This complicates the assumption that the photofission probability for transuranium nuclei is equal to unity at these energies.

   Another interesting problem appears in the results of recent measurements of the relative photofission probability of ^{237}Np compared with ^{238}U above $100MeV$ [5, 6]. The photofission probability for ^{237}Np appears to be 30% bigger than for ^{238}U. In this case the photofission probability for ^{238}U, as well as that for ^{235}U, must be less than 1. Its preliminary estimation gives approximately 0.7. Such a result would have some serious implications for the inferred total photoabsorption cross-section strengths in the Δ-resonance region.

   The photofission cross sections for W, Au and Ta appear to show a large peak near the pion-production threshold [9]. The similar result was deduced from electrofission experiments. Since the photofission cross section is a smoothly varying function of the excitation of the compound nucleus, this structure has been interpreted as arising directly from a quasideutron pion reabsorption mechanism. To explain this phenomena the precise measurements of prompt fission cross sections have to be done for preactinide nuclei at the energy region close to discovered maximum (near $200 - 250MeV$).

   These two examples of present problems with prompt photo- and electrofission data demand further accurate measurements of fission cross sections. And two proposals at this area were approved recently to be performed in Jefferson Laboratory.

2. *Delay fission.* Another direction of induced nuclear fission investigation is the study of delay fission. Here we are going to discourse not isomer form fission, but the delay fission caused by hyperon formation inside the nucleus and its further decay. In other words, we propose to study the production of heavy hypernuclei and their decay through fission channel. We propose to go further in our previous investigations of delay fission phenomena induced by electrons with energy above $1GeV$ with the aim to study the effects of the nuclear medium influence on the Λ-hyperon formation process, its decay and its propagation within the interior of the nucleus.

   Any nuclear reaction, where the strange particle appears, can be used for hypernuclei production, i.e. to create nuclei with a heavy hyperon inside. The hyperon decay inside the nucleus causes nuclear excitation followed by hadron emission or nuclear fission. The observation of delay fission events could be used for identification of hypernucleus production.

   One of the fundamental characteristics of hypernucleus is its lifetime, which is necessary to know in order to verify different predictions concerning nuclear structure and nuclear interactions. The available lifetimes are very close to the lifetime of free Λ-particles. It is therefore of great interest to measure the lifetime of heavier hypernuclei, especially for $A > 200$ where according the theory predictions it will increase.

A traditional tool for the Λ-particle generation is the strangeness exchange reaction:

$$K + N = \Lambda + \pi$$

The (K, π) reaction on nuclear has commonly been used to study spectroscopic properties of hypernuclear states.

Besides, the possible hypernuclei production can be attained due to electromagnetic interactions:

$$\gamma + N = K + \Lambda,$$

i.e., one can use real or virtual (electron beam) photons to produce strange particles and study hypernuclei properties.

The lifetime of a free Λ-particle is $\tau = 2.63 \times 10^{-10} sec$ and the main decay mode is:

$$\Lambda \to N + \pi \, (> 99\%)$$

$$\Lambda \to p + \pi^- + 37.8 MeV \, (64.2\%)$$

$$\Lambda \to n + \pi^o + 41.1 MeV \, (35.8\%)$$

with energy release about $176 MeV$ including the pion rest mass. This decay mode is characterized by small nucleon momentum, $q_o \approx 100 MeV/c$, which is smaller than typical nuclear Fermi momentum ($kf \approx 280 MeV/c$). For the lightest nuclei the hypernuclei decay looks as pion emission ($\Lambda \to N + \pi$). For the heavier hypernuclei therefore the π-mesonic decay mode tends to be suppressed by the Pauli exclusion principle acting on the created nucleon.

For nuclei with $A > 5$, nonmesonic decay is favored in the nuclear medium ($\Lambda + N \to 2N$):

$$\Lambda + n \to n + n$$

$$\Lambda + p \to n + p$$

The liberated energy in this case is about $160 MeV$, so the residual heavy nucleus may easily undergo fission.

The energy release in nonmesonic decay corresponds to a final state nucleon momentum on the order of $400 MeV/c$. Because this is well above nuclear Fermi momentum, the nonmesonic decay modes with two nucleon emission dominate in $A > 5$ hypernuclei.

One of the most probable decay channels of heavy hypernuclei with $A > 200$ is the nuclear fission which can be used for identification of hypernuclei production. The advancement in such studies toward heavier hypernuclei, particularly their lifetime measurements, presents an undoubted interest.

The aim of proposed experiment is lifetime and cross section measurements for delayed fission caused by Λ-particle decay.

The result which shall be obtained can be compared with theoretical predictions. In general, the difference between the predictions of various models is associated with the mechanism of weak interaction between the Λ-hyperon and nucleon at short distances. The author of Ref. [10] assumed that at short distances hyperon and nucleon form a bag filled with quarks. Than the weak interaction of quarks occurs via exchange by W or Z bosons. In another model [11] the role of a mediator in the weak interaction at short distances is played by meson.

According to the hybrid quark-baryon model the heavy hypernuclei lifetime is expected to be three times shorter than that for free Λ-hyperon. At the same time the ρ-meson exchange model predicts the hypernuclei lifetime equal to that for the free Λ-hyperon [12].

An attempt to explain the existence of long-living hypernuclei components in the region close to bismuth mass number was made in [13] on the basis of the model where the potential well for heavy hypernuclei has a minimum at the surface of the nucleus. Then the wave function of the Λ-hyperon in the ground state must be concentrated in the nuclear surface region. Author [13] predicted the lifetimes of excited heavy hypernuclei to be 2.2 times longer than those for the ground states. This increasing of the lifetime is a result of the lower nuclear density close to the nuclear surface [14].

Another present interesting problem is the search for long-lived hypernuclei whose existence may be due to the delayed decay of a Λ-hyperon in strong intranuclear electromagnetic field, or in other words - due to restoration of spontaneously broken symmetry of weak and electromagnetic interactions under extreme conditions [15].

Similar heavy fissile hypernuclear lifetimes measurements was proposed by Tang et al [16] and recently approved by $CEBAF\ PAC10$ (proposal E95-002).

In principle, the aim of our proposal is the same as in [16] but the proposed method is very different. In such a way our experimental data may complement others by E95-002 and could be used for the comparison and more deep theoretical analysis. Anyway, actually such measurements could be performed only at Jefferson Laboratory and to check the reproducibility of experimental results it is possible only here. We believe that two proposed different experimental methods lead to the same final aim to give the answer about the mechanism of heavy hypernuclei formation and their lifetime.

2 PREVIOUS MEASUREMENTS

Few experiments searches of the hypernuclei production and their decay through the fission channel have already been done. One from them was performed by Polikanov's group with low energy antiproton beam at *CERN* (*LEAR*) [17]. Another measurement has been done with the electron beam in Kharkiv [18].

Both experiments indicate an existence of delay fission, which could be treated as a hypernuclei decay.

In both measurements the same experimental technique was used for hypernuclei decay fragments detecting and further lifetime reconstruction. This method has been well developed in studies of fissile shape isomers where it permits to analyze the lifetimes up to 10^{-10} sec. Described technique consist of the recoil range distance reconstruction from the target surface to the fission point inside the experimental vacuum chamber [19].

The lifetime value obtained in *CERN* experiment from the analysis of the recoil range hypernuclei distribution for *Bi* target is:

$$\tau_{Bi} = (2.40 \pm 0.06) \times 10^{-10} sec,$$

The same for *U* target is:

$$\tau_{U} = (1.0 \pm 0.5) \times 10^{-10} sec$$

One can conclude that in Polikanov's experiment with antiprotons the observed lifetime of the hypernuclei within the mass number close to *U* and *Bi* region are practically the same. More over they are close to the lifetime of the free Λ-hyperon.

The investigations performed in Kharkiv has also shown the occurrence of the delay fission. The recoil-distance method with modernized detector placement in the experimental vacuum chamber was employed with an aim to reconstruct directly the range distribution of the fissile hypernuclei formed in a *Bi* target irradiated with $1.2 GeV$ electrons. It gave us the possibility to improve significantly the spatial resolution. The result of fission fragment track distribution density measurements in mica detector are shown in the Fig.1 [20].

The distribution has an exponential character. It is clearly pronounced two lifetime periods of *Bi* hypernucleus with the mean values $\tau_1 = (0.8 \pm 0.15) \times 10^{-10} sec$ and $\tau_2 = (1.5 \pm 0.4) \times 10^{-9} sec$. The analysis was performed assuming the recoil hypernuclei momentum $0.6 GeV/c$.

So the Kharkiv experiment with electron beam showed two periods of hypernuclear decay: (*i*) short or *"normal"*, which is similar to the result of Polikanov's group, and (*ii*) long or *"anomalous"* which one is by an order of magnitude greater than the short one. This second result appeared to be contradictory with *CERN* experiment.

Therefore, we propose to repeat the measurements with the electron beam at better conditions than it was possible at Kharkiv. Large beam spot cross section (few millimeters) and bad long time stability of the Kharkiv linac did not allow us to perform precise measurements, to

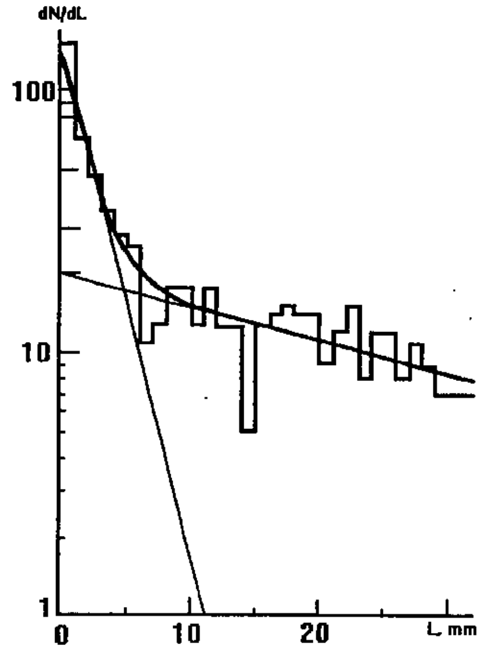

Figure 1: Track density distribution on detector in experiment [20]. Histogram - experimental data, curve - sum of two exponents shifted by least square method calculations

collect sufficiently big statistics and to get the final reliable enough results. The continuation of measurements at Jefferson Laboratory is very desirable.

3 EXPERIMENTAL TECHNIQUE

Traditional method of hypernuclei lifetime measurements is based on the determination of hypernuclei recoil range distances. In [16] the hypernuclei lifetime will be determined as time interval between K meson and fission fragment detection. Experimental time resolution has to be near to $20 - 30ps$.

We propose to use recoil range measurement method.

The hypernuclei l average recoil momentum is near to $0.6GeV/c$ [21] and range distance in vacuum for *"normal"* lifetime is near to $0.1mm$. The lifetime will be determined by measuring the range of the fissile recoil nuclei from the target and the point of their decay (fission). Such short distances as $0.1mm$ can be measured by so-called projectile method.

A schematic view of proposed experimental set-up is shown in Fig.2.

The initial beam is passing through the experimental target, deposited on the basket thick enough to absorb the fission fragments. The target diameter is smaller than the basket diameter. The target plane on Fig.2 delimits two areas on the detectors: downstream and upstream.

Since prompt fission of nuclei occurs after about $10^{-18}sec$, the fissile nuclei remain practically at the target. As a result, the fragments are emitted from the target plane, and those direct towards the upstream hemisphere will be stopped in the target basket and will not be recorded in the detector. On the other hand, hypernuclei with lifetimes of the order $10^{-10}sec$ can leave

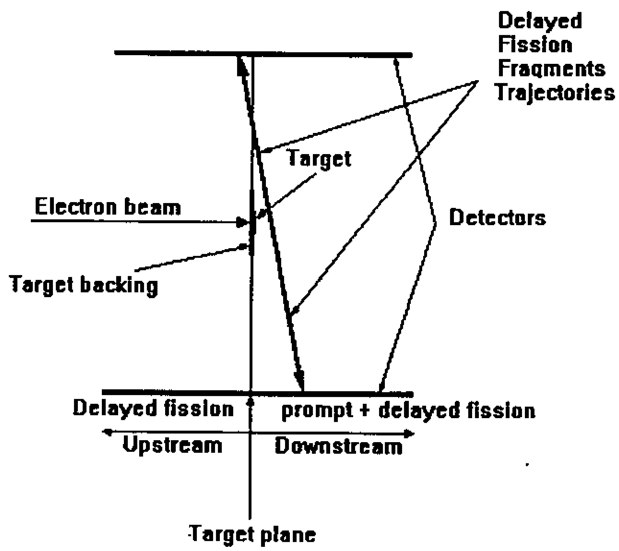

Figure 2: Principle of the recoil-distance method

the target and undergo the decay (fission) at some distance from the target plane. Some fragments produced in this decay are emitted towards the upstream hemisphere, shadowed by the target basket, and will hit the detector. Prompt fission fragments are registered only in the downstream area of detectors. In the detectors situated in the upstream (shadow) area only delayed fission fragments can be recorded.

The distribution of the recorded fragment position in the shadow area of the detector depends on the lifetime of the hypernuclei and their velocity.

Using the position sensitive detectors, situated in the upstream hemisphere it is possible to measure the integral hypernuclei recoil distance distribution.

- *The beam.* Proposed experiment we have an intention to perform using the electron beam (virtual photons). In this case it is possible to realize the pointlike geometry with the aim to increase the recoil-range resolution accuracy of the measurements. Small beam spot cross section at the target will make better the fission detector efficiency as well without to increase the magnificent factor of the experimental chamber.

- *The target.* As a target we propose to use pure isotopic layers of ^{238}U (uranium), ^{209}Bi (bismuth) and ^{197}Au (gold) nuclei, which previously have been used in the experiments. The big advantage is that Bi and Au in comparison with U nuclei have no fission isomers and have rather high fissility (Bi - 11% and Au - 2%). These isotopes are easily available for the target preparation as well. Bismuth, unfortunately, has too low melting point which is equal $544.3K$.

  The target layer with $0.3mm$ in diameter has to be deposited on an aluminum basket. The target diameter is defined by the electron beam spot cross section and has to be as small as possible.

  The target thickness is determined by the hypernuclei recoil range in the target material. We choose it about $0.1\mu m$ which allows the 70% of hypernuclei to recoil out. The target has to be flat within $10\mu m$ to define perfectly the edges and to have a clear target plane projection on the detector plane. This last requirement could be solved without difficulty.

- *Detectors.* For hypernuclei fission fragment detection it is required the position sensitive detectors. As the first step of measurements we propose to use cylindrical solid state detectors such as mica with radius $25mm$ and width $25mm$. This material possess extremely high spatial resolution of fission fragments tracks which we need to perform further reconstruction of recoil distribution function and lifetime.

- *Background estimation.* Because the cross section of heavy hypernuclei production is very small, it is very important for the proposed experiment to control the background level.

  We can expect few sources of background.

  1. Prompt fission of the target nuclei. Prompt fission cross section is 4×10^4 times larger than for delay fission and part of prompt fission fragments can reach the shadow area of the detector by rescattering at the edge of the target supporting basket.
  2. Prompt fission of uranium contamination of internal surface of experimental fission chamber induced by scattered electrons and random neutrons. To prevent the contribution of this background component it is necessary to cover internal chamber surface by uraniumless (and thoriumless) material.
  3. Prompt fission of uranium contamination of the detector material.

One of the possibilities to control this component of the background is delay fission cross-section measurements at the electron beam energy below the hypernuclei production threshold.

Another control method is to install simultaneously with the main basket-target system another turned to the opposite beam direction as it is shown on Fig.3.

In this case all recoil nuclei, emitted in forward direction from the target installed in reversible part of chamber, will be absorbed in the supporting aluminium basket and their fission fragments will not reach the detector surface. The shadow part of the direct detector will detect effect + background fission fragments. The shadow part of reversible detector will detect only background fragments. And the difference between two detectors contributions will give pure effect.

Good control experiments require to vary the basket radius, when the track density distribution on detector will indicate the adequate response.

4 THEORY AND MONTE-CARLO SIMULATION

The electrofission cross section formally is:

$$\sigma_{\sigma f}\left(E_{\sigma}\right)=\int_0^{E_e} dE_{\gamma}\sigma_{\gamma f}\left(E_{\gamma}\right)N_{\sigma}\left(E_{\sigma},E_{\gamma}\right)/E_{\gamma} \tag{1}$$

where $\sigma_{\gamma f}$ is real photon fission cross section, E_{γ} is the virtual photon energy, E_e - the electron energy, N_e - the virtual photon spectra. Thus, to evaluate the electrofission cross

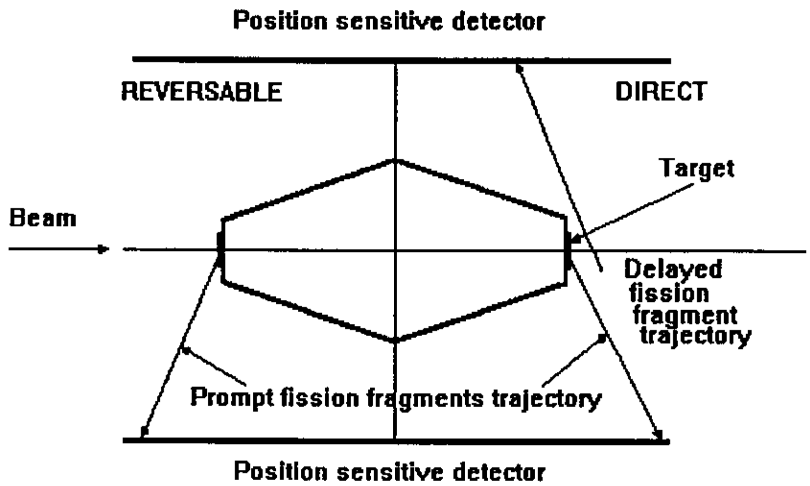

Figure 3: Experimental layout for detecting delay fission fragments with simultaneous background measurements

sections it is necessary to know the photofission cross sections versus excitation energy and the virtual photon spectra intensity as well.

The high energy photonuclear reaction is a very complex cascade type process with many particles involved. Such processes are usually calculated by means of intranuclear-cascade Monte-Carlo models, in which the nucleus is assumed to be Fermi gas of neutrons and protons. High energy photonuclear interaction is usually considered as a three-stage process [21, 22].

1. In the first rapid photoabsorption stage, the incident photon with energy E_γ interacts with independent intranuclear nucleon or *"quasydeutron"* par:

   (a) Quasydeuteron absorption is described by Levinger theory [23]:

   $$\gamma + pn \rightarrow p + n$$

   (b) Δ-isobar or one pion photoproduction ($E_\gamma > 140MeV$) by:

   $$\gamma + N \rightarrow N + \pi$$

   (c) $\Delta\pi$ or a double pion production ($E_\gamma > 300MeV$) by:

   $$\gamma + N \rightarrow \Delta + \pi \rightarrow N + \pi + \pi$$

   (d) ρ , ω , η mesons production, for $E_\gamma > 1GeV$

   (e) Λ , Σ baryons production, for $E_\gamma > 1GeV$

   All these elementary processes are well known for free nucleons and their differential cross sections are used in photonuclear reactions calculations.

2. Second rapid stage of photonuclear interaction is intranuclear cascade generated by secondary particles produced during the first photoabsorption stage inside the nuclei where the photon was absorbed. This cascade also may be simulated by a Monte-Carlo code, using experimental values for the cross sections and angular distributions of the individual NN, πN, ΛN interactions. Some of the cascade particles could escape from the nucleus, carrying away some part of the photon energy. Those, with energies below the threshold to escape, remain in the nucleus and account for the excitation energy E^*. As a result, for a given photon energy the simulation code generates the A_c, Z_c and E^* distributions.
3. In the third slow stage, the compound nuclei dispose their excitation energy by gamma-ray or particles emission, or undergoing fission. Therefore, for highly exited heavy nuclei, the de-excitation process reduces to a competition between fission and particle emission. The emitted particles are mostly neutrons. But emission of protons, deuterons, tritons and alpha particles is also possible.

Based on the three-stage description of the photofission process, its cross section can be writen as:

$$\sigma_{\gamma f}\left(E_\gamma\right) = \Sigma_i \Sigma_{A_c} \Sigma_{Z_c} \sigma\prime_{CN}\left(A_c, Z_c, E^*\right) w_f\left(A_c, Z_c, E^*\right) dE^* \tag{2}$$

where i denotes the channel of photoabsorption, $\sigma\prime_{CN}$ is the cross section of the compound nucleus with A_c mass number formation in i-th reaction channel, Z_c is the number of protons, E^*- nuclear excitation energy and w_f is probability for compound nucleus to undergo fission during the transition (relaxation) to the ground state.

In the case of hypernuclei production the cross section equations 2 could be sufficiently simplified as soon as we have taken into account only one initial photoabsorption process which leads to the Λ-particle production on intranuclear nucleons [24]. We reproduce here the main results of our calculations.

The hypernuclei photoproduction cross section can be writen as:

$$\sigma_\Lambda = \sigma_0 \times A \times h \tag{3}$$

Here σ_0 - is the total Λ-hyperon production cross section (for example, - the $(\gamma p \to K\Lambda)$ - reaction) on a single nucleon. This value is about $2 \times 10^{-30}\ cm^2$ in the photon energy range between 1 and 2 GeV [25]. A is the mass number of the nucleus, i.e. $\sigma_0 \times A$ is the total cross section for Λ-production at the nucleus, h is the probability coefficient for produced Λ-hyperon to be absorbed by the same nucleus. The h value was calculated by the Monte-Carlo code and it appeared to be 5% for a hyperon binding energy of $30MeV$ [24]. It can be easily found that the hypernuclei photoproduction cross section is $\sigma_{\gamma\Lambda} = -2 \times 10^{-29} cm^2$ for a mass number close to 200 and photon energy range $1 - 2GeV$. The same calculation of electroproduction cross section gives $\sigma_{e\Lambda} = -4 \times 10^{-31} cm^2$ for electron energy range $E_e = 1 - 2GeV$.

If one takes into account that the electrofissility of bismuth nuclei is about 10% within this range of initial electron energy, than the cross section for the delay fission process could be estimated to be $\sigma_{ef}(del) = 4 \times 10^{-32} cm^2$. The cross section for prompt electrofission on bismuth at $E_e = 1 - 2GeV$ is about $3 \times 10^{-28} cm^2$ [26].

The measured and calculated values of prompt and delay electrofission cross sections for bismuth are presented in the Table 1.

So, in the Kharkiv experiment we have observed both the short-period delay fission with the cross section close to the calculated one, and the long-period delay fission with the lifetime by a factor of 10 bigger. The cross section of this second channel is by a factor 10 smaller than for short period delay fission.

Table 1. Experimental and calculated cross-section (cm^2) for bismuth fission by electrons with energy of $1.2 GeV$ [18, 20, 24, 26].

	Prompt fission	Delayed fission	
		Short period	Long period
Experiment	2.6×10^{-28}	$(5.5 \pm 0.2) \times 10^{-32}$	$(6.5 \pm 0.2) \times 10^{-33}$
Calculation		4×10^{-32}	

5 THE DETECTION EFFICIENCY AND REACTION YIELDS EVALUATION

Hypernuclei yield is estimated by:

$$Y = \sigma N I_b \varepsilon t \tag{4}$$

σ - cross section of delay electrofission (fissioning hypernuclei electroproduction);
N - target thickness;
I_b - electron beam current;
ε - fragment detection efficiency;
t - irradiation time.

Evaluations of using parameters are given in the Table 2.

Table 2. The parameters used in exposure estimation calculations.

	Au	Bi	U
Z	79	83	92
A	197	209	238
σ ($10^{-32} cm^2$) for *"normal"* lifetime	0.75	4.0	45.5
$N \times 10^{17}$ ($atoms/cm^2$)	2.99	2.81	2.48
target thickness, $\mu g/cm^2$	98	98	98

The fragments detection efficiency depends on target support (basket) radius and hypernuclear average lifetime. We calculated the detection efficiency for three values of hypernuclear average lifetimes: $\tau = 0.8 \times 10^{-10} sec$, $1.5 \times 10^{-10} sec$ and $2.63 \times 10^{-10} sec$. The first two values are taken from the previous Kharkiv experiment and the last one is a free Λ-hyperon lifetime. The results of efficiency calculation are presented in Table 3.

Table 3. Calculated detection efficiency as function of the hypernuclei average lifetime and the target basket radius.

$\tau \times (10^{-10} sec)$	R=3mm	R=0.5mm
0.8	0.226	-
15	0.013	0.0482
2.63	0.0686	0.162

The efficiency calculation was made by Monte-Carlo simulation method for two different values of the basket radius $R = 1mm$ and $R = 3mm$. Geometry of detection with $1mm$ basket radius is good for investigation of short lifetime hypernuclei and $3mm$ is suitable for investigation of long life hypernuclei.

Now, remembering that long-period fission cross section is smaller by a factor of 10 than the short period delay fission cross section, it is interesting to note that in the case $R = 3mm$ it has about a factor of 10 larger geometrical efficiency. That is the reason why we choose basket radius $R = 3mm$.

Table 4. The target irradiation exposure estimation for electron beam current $I_0 = 10\mu A$, initial electron energy $1 - 2GeV$ per 1000 detected fragments for the *"normal"* period delay fission. Exposure time T is given in hours. $R = 3mm$.

Target	Au	Bi	U
T (hours)	153	31	3

6 HEATING UP OF THE TARGET

The target layer with the thickness about $0.1\mu m$ will be deposited on the target aluminum supporting basket with thickness 50 or $30\mu m$. In this case we can expect that target layer temperature will be equal to aluminum basket temperature. Considering mentioned above initial electron energy we estimate the ionizing electron losses to be in average $2MeV/(g/cm^2)$. Using the aluminum supporting basket with a density of $2.7g/cm^3$ we calculated that this electron will deposit about 0.027 MeV in a $50\mu m$ of aluminium support or about $0.016MeV$ in the case of $30\mu m$ basket thickness. The deposited power is presented in Table 5.

The basket temperature grow estimation during the electron beam irradiation could be done using the following formula [26]:

$$\Delta T = \frac{Q \ln (R_b/R_0)}{2\pi\lambda d} \tag{5}$$

where:
λ is the thermal conductivity constant = 2.09 $W/(cmK)$
R_b is the beam spot radius = $0.05mm$
R_0 is the target basket radius = $3mm$
d is the target basket thickness = $30\mu m$
Q is the deposited power.
The results of aluminium basket heating analysis are presented in Table 6.
Table 5. Power deposition in mW in basket $50\mu m$ and $30\mu m$

Beam current (μA)	$50\mu m$	$30\mu m$
1	27	16
10	270	160
50	1350	800
100	2700	1600

Table 6. Basket heating up for different beam currents.

beam current (μA)	ΔT ($T = 300K$)
1	1.6
10	16
30	48
50	90
100	160

The melting temperature for Bi is $544K$. The adequate temperatures for Au and U are much higher. It is seen that proposed experiment may be done with electron beam current up to $100\mu A$.

7 RUN PLAN AND BEAM TIME ESTIMATE

We propose to make this experiment in Hall A by using separate vacuum chamber which has to be situated behind the Hall A scattering chamber as it is shown on Fig. 4.

We propose as a first step of experiment to continue the measurements that have begun at Kharkiv with Bi target. The experiment should be done with an electron energy of $2.4GeV$ and a beam current $30\mu A$, the subthreshold measurements should be at $E = 0.8GeV$. Evaluations of the yield, based on the results of Kharkiv experiments, give 0.1 counts per second at a current of $1\mu A$, target thickness of $0.1\mu m$ and a registration efficiency of 13%. Beam time estimation is presented in Table 7.

Table 7. Beam time estimation for electron energy $0.8 - 2.4GeV$, beam current $30\mu A$, target basket radius $R = 3mm$ (per 1000 detected delay fission fragments at the shadow area of detector).

	Electron beam energy (GeV)	Beam current (μA)	Time (hours)
Measurement of effect	2.4	30	12
Background measurement without Bi	2.4	30	12
Background measurement with Bi	0.8	30	12
Total time	-	-	36

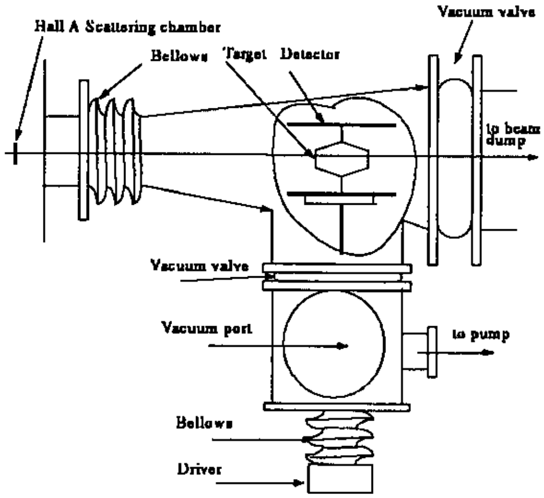

Figure 4: Experimental layout in the Hall A

8 COLLABORATION BACKGROUND AND RESPONSIBILITIES

The experimental equipment, including vacuum chamber, target supporting basket, detector holders, etc., will be prepared by the Brazilian group of participants with the engagement of visiting scientists from Ukraine. Further chemical development of solid state detectors supposed to be done at Sao Paulo University as well.

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