CEBAF Program Advisory Committee Ten Proposal Cover Sheet

This document must be received by close of business on Tuesday, December 19, 1995 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

(Choose one)

☒ **New Proposal Title:** Direct Measurement of the Lifetime of Heavy Hypernuclei at CEBAF

☐ **Update Experiment Number:**

☐ **Letter-of-Intent Title:**

Contact Person

7860

Name: Amur Margarian, Liguang Tang

Institution: Yerevan Phys. Inst., Hampton University

Address: Alikhanian Brothers' st. 2

Address:

City, State ZIP/Country: Yerevan, Armenia, 375036

Phone: Hampton **FAX:** University

E-Mail → Internet: Margarian@vx1.yerphi.am, Tangl@CEBAF.GOV

Experimental Hall: C **Days Requested for Approval:** 14

CEBAF Use Only

Receipt Date: 12/19/95 PR 95-002

By: gp

HAZARD IDENTIFICATION CHECKLIST

EBAF Experiment: ______________________ Date: ______________

Check all items for which there is an anticipated need—do not check items that are part of the CEBAF standard experiment (HRSE, HRSH, CLAS, HMS, SOS in standard configurations).

Cryogenics
- ______ beamline magnets
- ______ analysis magnets
- ______ target
- ______ drift chambers
- ______ other

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

(incl. target)

type: ______________

flow rate: ______________

capacity: ______________

Other Target Materials
- ___ Beryllium (Be)
- ___ Lithium (Li)
- ___ Mercury (Hg)
- ___ Lead (Pb)
- ___ Tungsten (W)
- ___ Uranium (U)
- ___ Other (list below)

^{209}Bi, ^{197}Au

____

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
- ______ other

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)

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Notes:

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BEAM REQUIREMENTS LIST

3AF Proposal No.:________________________________ Date: ____________________
(For CEBAF User Liaison Office use only.)

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 #	Beam Energy (MeV)	Beam Current (µA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm²)
1	1645	10-15		^{209}Bi	≤40mg/cm²
2	1645	10-15		^{197}Au	≤40mg/cm²

e beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are), 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following ditional values of E_{Linac} will become available: E_{Linac} = 400, 500, 600, 700, 900, 1000, 1100, and 1200 MeV. The sequence and ning of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

LAB RESOURCES REQUIREMENTS LIST

CEBAF Proposal No.: ____________________ Date: ____________________
(For CEBAF User Liaison Office use only.)

List below significant resources — both equipment and human — that you are requesting *from CEBAF* 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 CEBAF)*

New Support Structures:

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets: SOS-spectrometer quadrupole and dipole

Power Supplies:

Targets: Solid targets Au, Bi

Detectors: SOS-spectrometer a tector paskage for K

Electronics: Standard Hall C ele ronic plus ~400chann amplifier and delay for LP

Computer Hardware:

Other:

Other

Proposal to the CEBAF PAC10

12.18.95 *(CEBAF HALL C)*

DIRECT MEASUREMENT OF THE LIFETIME OF HEAVY HYPERNUCLEI AT *CEBAF*

Ts.A. Amatuni, G.L. Bayatian, K.Sh. Egiyan, N.K. Grigorian,
S.G. Knyazian, A.T. Margarian (cospokesperson), Yu.L. Margarian,
G.G. Marikian, H.G. Mkrtchyan, L.K. Parlakian,
G.S. Vartanian, and V.O. Tadevosyan

Yerevan Physics Institute
Alikhanian Brothers St.2, 375036 Yerevan, Armenia

K. Assamagan, O.K. Baker, T. Eden, P. Gueye,
C. Keppel and L. Tang (cospokesperson)

Department of Physics, Hampton University, Hampton, VA 23668, USA

R. Carlini, R. Ent, H. Fenker, D. Mack, S. Majewski,
J. Mitchell, E.A.J.M. Offermann, S. Wood, W. Vulcan, C. Yan

CEBAF, 12000 Jefferson Ave, Newport News, VA 23606, USA

P. Markowitz

Florida International University, Miami, FL 33199, USA

B. Barakat, M. Elaasar, K. Johnston, and N. Zotov

Department of Physics, Louisiana Tech. University, Ruston, La, USA

E. Oset

Departmento de Fisica Teorica and IFIC, Centro Mixto Universidad
de Valencia CSIC, 46100 Burjassot (Valencia), Spain

J. Arrington

California Institute of Technology, Pasadena, CA, USA

Sh. Beedoe

Physics Department, North Carolina A&T State University, NC, USA

ABSTRACT

The lifetime of very light Λ hypernuclei is dominantly determined by mesonic decay. As the mass of the hypernucleus increases, the nonmesonic decay rate increases while the mesonic decay rate decreases rapidly due to Pauli suppression of the low momentum final state nucleons. The nonmesonic Λ decay, a strangeness changing weak interaction, takes place only in the nuclear medium, and provides a unique opportunity to investigate the weak four-fermion vertex. In general, it is believed that the lifetime of the Λ hypernuclei is a decreasing function of the mass number A. However, the effective YN interaction range may lead to a situation where additional nucleons may have no effect on the lifetime of the hypernuclei.

In spite of the great physics interest in the decay of hypernuclei, the available data are scarce and have large uncertainties. This is due to the tremendous difficulty in producing Λ hypernuclei and of subsequently detecting their decay products. Many of the measurements are based on limited statistics and are predominantly for hypernuclei with an atomic number $A \leq 16$. Only a few heavy hypernuclei (such as $^{209}Bi_\Lambda$ and $^{238}U_\Lambda$) have been experimentally observed and their lifetimes were measured with very low accuracy (~100%). New precise measurements of heavy hypernuclei lifetimes and the A dependence of the lifetimes are therefore needed.

Since both the electron and K^+ are particles that interact weakly, electroproduction (photoproduction) of hypernuclei provides a low distortion means of investigating the fundamental interactions between nucleons, lambdas and sigmas. We propose to carry out a measurement of the lifetimes of the heavy Λ hypernuclei $^{197}Au_\Lambda$ and $^{209}Bi_\Lambda$ produced in the (γ, K^+) reaction using virtual photons from forward scattering of unobserved outgoing electrons.

Kaons will be detected at small angles (~12.5^o) in the kinematical region corresponding to the high energy part of the photon spectrum (to keep hypernuclear excitation energies as low as possible). A Low-Pressure Multiwire Proportional Chamber ($LPMWPC$) which is only sensitive to the fission products with Z much higher than α particles will be utilized to detect the so-called delayed fission fragments produced by the decay of heavy hypernuclei. Such delayed fission accompanied with kaon production is a signal for hypernuclear decay.

The lifetime of the produced hypernuclei will be measured directly from the time delay between the $CEBAF$ electron beam pulses (which will be tagged by detecting K^+ mesons) and, the nuclear fission fragments. Nuclear targets with an effective thickness ~(20 - 40)mg/cm^2 will be used. The existing parameters of the $CEBAF$ electron beam, the Hall C SOS magnetic spectrometer, and a $LPMWPC$ will allow measurements of hypernuclear lifetimes with an accuracy of ~ 20ps which were impossible to achieve with low luminosity K^- and antiproton beams, or with electron (photon) beams having a low duty factor.

1. INTRODUCTION

A hypernucleus is a many body system composed of nonstrange nucleons and one or more strange baryons. The presence of the strangeness degree of freedom in a hypernucleus adds a new dimension in the evolving picture of nuclear physics. Such a system provides a laboratory in which properties in the ΛN interaction in the nuclear medium may be explored. The lifetime of heavy Λ hypernuclei is an especially interesting subject from the viewpoint of the weak-decay mechanism of the Λ in a nucleus.

High precision measurements of hypernuclear lifetimes and their A dependence may provide valuable constraints in for attempts to understand many fundamental issues in hypernuclear physics. Such open issues include the effective YN interaction range (which is directly associated with the role and the strength of the vector meson exchange interaction); $\Lambda N \rightarrow \Sigma N$ conversion; and the ΛNN three body interaction (interesting due to lack of one pion exchange). At the quark level, Pauli blocking may lead to an observable deviation from the expected A dependance of the hypernuclear lifetime using conventional hadronic models, especially in the very high A ($A \geq 50$) region.

A free Λ decays with a well-known lifetime almost exclusively via the mesonic channel: $\Lambda \rightarrow N + \pi$, whose decay width has been well determined. The nonmesonic decay,

$$\Lambda + N \rightarrow N + N$$

a strangeness changing weak interaction, takes place only in the nuclear medium and provides a unique opportunity to investigate the purely hadronic weak interaction. Since for heavier nuclei, the momentum of the final state nucleon from mesonic decay is below the nuclear Fermi momentum while that from nonmesonic decay is above. It is commonly believed that only the lifetime of very light Λ hypernuclei are dominantly determined by the mesonic decay. As the mass of the hypernucleus increases, the nonmesonic decay rate increases while the mesonic decay rate decreases rapidly due to the Pauli suppression of the low momentum final state nucleon. Thus, in general, it is believed that the lifetime of Λ hypernuclei is a decreasing function of the mass number A. However, the effective YN interaction range may change the lifetime, i.e. additional nucleons may appear to have no effect on the lifetime of the hypernuclei.

At the quark level, if one requires that the u and d quarks in the Λ be antisymmetrized with the nonstrange quarks in the neighboring nucleons, then observable effects such as isospin mixing in hypernuclei or modification of the

$$\Lambda \rightarrow \pi + N$$

weak decay rate in the nuclear medium may occur. The effect is particularly interesting and may appear in heavy hypernuclei where significant new physics may appear. The partial widths of different decay modes, as well as the A dependence of their parameters, are subjects of many theoretical models[1−17].

A high precision hypernuclear lifetime measurement for varied target masses is indeed necessary and important. The present status of the experimental and theoretical investigations of hypernuclear physics has been reviewed by B.F.Gibson and E.V.Hungerford (see Ref.[18]), and they conclude, " The physics of hypernuclei is new and different, and the challenge to understand it beckons". The available experimental data are scarce and have large uncertainties. The experiments have only been done with low beam intensity and at low duty factor machines. The low luminosity and duty factor have limited the statistical precision using conventional techniques. Experimentally, uncertainties in beam timing, the low efficiency and large timing uncertainties in detecting the final state neutrons has limited the systematic uncertainty; the emulsion data, though subject to good energy resolution, have suffered similarly from low statistics (see more discussion in next section).

We propose to carry out at the ($CEBAF$), in Hall C, a direct measurement of the lifetimes of heavy Λ hypernuclei with a precision which is not feasible using K^- or antiproton beams. Since both the electron and K^+ are particles that interact weakly, electroproduction (photoproduction) of hypernuclei provides a low distortion means of investigating the fundamental interactions between nucleons and hyperons. More importantly, the fine beam micro structure at $CEBAF$ provides beam timing of nearly zero width. Low-pressure proportional chambers, which are sensitive only to fission products with Z much higher than the α particles, will be used to detect the so-called delayed fission fragments produced by the decay of heavy hypernuclei. Experimentally it has been proven that such delayed fission predominantly occurs with hypernuclear decay.

The fission detector has not only excellent timing resolution but is also capable of reconstructing the fragment trajectory and velocity. This will allow to minimize the timing uncertainties due to geometry and the momentum spread. By making a coincidence between the kaon and the delayed fission within the kinematic range corresponding to $E \leq 50$MeV in the hypernuclear excitation energy, the hypernuclear lifetime can be measured directly. The kaon timing will be used to reconstruct the appropriate beam bucket, which in turn will determine the fission timing. The accuracy of this lifetime measurement can be about 20ps (with a high signal to noise ratio). A detailed description is given in the following sections.

2. SCIENTIFIC JUSTIFICATION

Because of strangeness conservation, kaon photoproduction (electroproduction) entails strange baryon (Λ, Σ) production and for nuclear targets this provides an excellent opportunity to study hypernuclei. The decay modes and widths (lifetimes) of hypernuclei are directly connected to the effective YN interaction range.

The free Λ-hyperon lifetime is determined by its π -mesonic decay:

$$\tau_\Lambda = \hbar/\Gamma_\Lambda = 2.63 \times 10^{-10}\,\text{sec},$$

$$\Gamma_\Lambda = \Gamma_{\pi^-} + \Gamma_{\pi^0}$$

$$\Lambda \rightarrow p + \pi^- + 37.8 \text{ MeV } (64.2\%)$$

$$\Lambda \rightarrow n + \pi^0 + 41.1 \text{ MeV } (35.8\%).$$

This decay mode is characterized by a small pion (nucleon) momentum, $q_0 \simeq$100 MeV/c, which is smaller than the typical nuclear Fermi momentum ($k_f \simeq$ 280MeV/c). In the heavy hypernuclei therefore the π-mesonic decay mode tends to be suppressed by the Pauli exclusion principle acting on the created nucleon.

On the other hand, nonmesonic weak decays take place only in the nuclear medium, since via a two-body weak interaction with a nucleon:

$$\Lambda + n \rightarrow n + n + 176\text{MeV}$$

$$\Lambda + p \rightarrow n + p + 176\text{MeV}$$

The 176MeV energy release in both of the neutron stimulated and proton stimulated decay corresponds to a final-state nucleon momentum on the order of 400MeV/c. Because this is well above the nuclear Fermi momentum, the nonmesonic decay modes dominate in all but the lightest hypernuclei.

The relative contributions of these two extremely different decay modes of the Λ in nuclear matter can depend on A, hence hypernuclear lifetimes can have an observable A dependence. For light hypernuclei, the mesonic channel plays a dominant role. The lifetime of light hypernuclei may decrease as A increases due to opening of the s - shell levels (for example from ^4He to ^6Li) which can contain a final-state nucleon from mesonic decay. This effect is enhanced due to increased phase space. If this additional phase space will increase the mesonic rate faster than the non mesonic rate decreases (due to a reduced nuclei density) shorter lifetimes for the light hypernuclei are expected.

For the heavier hypernuclei the contribution from this channel is believed to be vanishing small, and the nonmesonic decay channel becomes dominant. Hence, the lifetime of heavy hypernuclei can depend strongly on the behavior of this nonmesonic decay mode. In turn this nonmesonic decay mode in nuclear matter is strongly related to the effective ΛN interaction range.

In this simple and naive picture, one would expect that the hypernyclear lifetime is smaller than the lifetime of a free Λ. The lifetime should decrease slowly as the atomic number increases (due to the suppression of the mesonic decay channel). At large enough mass number A, the lifetime of the hypernuclei should be completely dominated by the nonmesonic decay. Hence, the behavior of the hypernuclear lifetime versus the atomic number A will depend strongly on the character of the ΛN interaction. If the ΛN interaction has a very short effective range (relative to the nuclear size), then one should observe a saturation effect in the A dependence of hypernuclear lifetime. Most importantly, such a saturation effect will strongly appear in the region of heavy hypernuclear, where explicit quark effects may also appear which could effect on the A dependence. The partial width of the different decay mode channels, as well as the A dependence of their parameters have been predicted by many theoretical models[1-17].

A critical review of the different approaches can be found in Ref.[17]. Here it is shown that the mesonic width is highly sensitive to modification of the pion properties in the medium. The Λ-width in the medium, or inversely the lifetime, can vary with of order 30% for $A \sim 200$, depending on the assumption mode in the models of Ref.[17].

The lifetime of a Λ particle in a very heavy nucleus is additionally an interesting subject from the viewpoint of the hypothesis of Kirzhnitz,Linde[19]; Salam, Strathdee[20] and Bychkov[21]. A weak charged current contains not only the pure d and s quark states, but also their combinations with the Cabibbo mixing[22]. The switching off of this mixture occurs abruptly when the external temperature, magnetic or electric fields attain a critical value. Therefore, the surface hypernuclear states in their hypothesis could have a much longer lifetimes than the volume hypernuclear states.

2a. CURRENT EXPERIMENTAL STATUS

In spite of great theoretical interest there are scarce data because, experiments with conventional techniques can not be done without great technical difficulties. These problems are associated with the large timing uncertainties when using low duty factor beams. Large effects from low detection efficiency and timing uncertainties in detecting of neutral particles (mainly neutrons) have also contributed to the overall lifetime measurement uncertainties of all previous experiments. Detection of the charged final state particles (pions and protons) could also not be effective due to severe nuclear distortions and ionization energy losses when the target thickness becomes large. Thus, all existing data including those from decay width measurements have poor accuracy, and many of them have poor statistics (a few tens of counts). The observed Λ hypernuclear lifetimes, $\tau({}^A_\Lambda Z) = \hbar/\Gamma_{tot}({}^A_\Lambda Z)$, are shown in Fig.1.

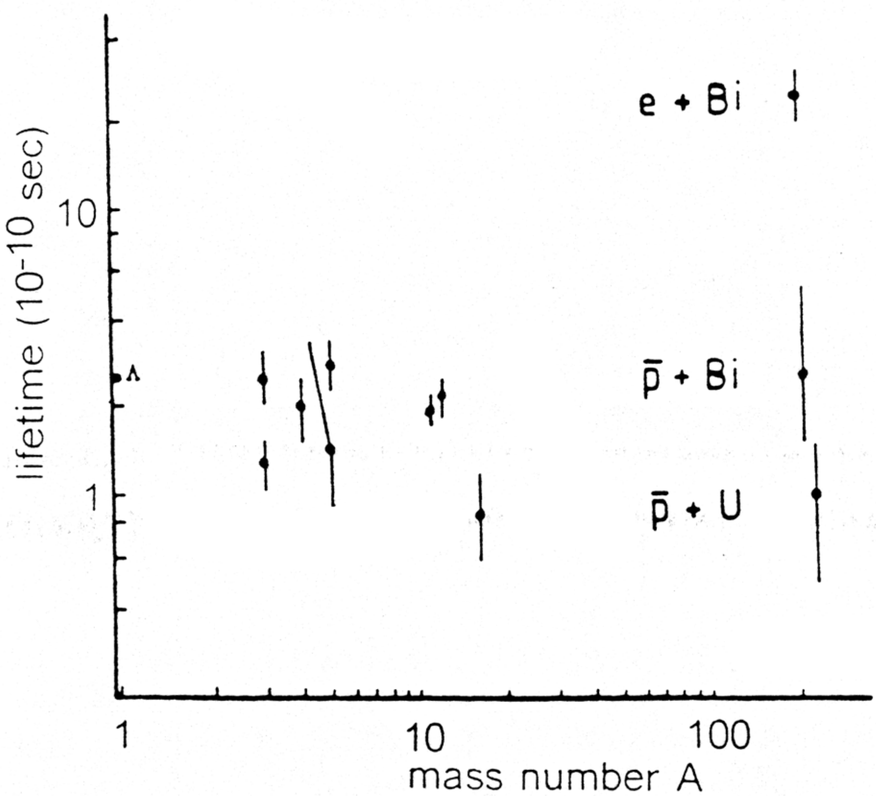


Fig.1 The observed lifetimes of the Λ hypernuclei
The experimental data are from Ref.[23,24].

It is worthwhile to note that the values of τ_Λ reported in Fig.1 were obtained by quite different techniques. In the low mass region, many of the measurements were based on very limited statistics, such as the ${}^{16}_{\Lambda}O$ lifetime measurement (which had only 22 events). The values for the light hypernuclei ($A \leq 5$) are from old bubble chamber and emulsion experiments, and a new measurement for ${}^{5}_{\Lambda}He$ is from a counter experiment performed at the Brookhaven National Lab AGS [24]. The values for $9 \leq A \leq 12$ were also given by this last experiment. The lifetime for ${}^{16}_{\Lambda}O$ was measured by an unusual technique of bombarding a polyethylene target with a relativistic ${}^{16}O$ beam [25].

Even with these rather inaccurate measurements, one can still see some of the effects discussed above. It seems that the lifetime of the light hypernuclei is slowly decreasing as a function of the atomic number. In the region of $A \leq 16$ the lifetime appears to be a factor of $\sim$1.5 shorter than that of a free Λ. Essentially, there is no reliable data above $A = 16$. A few more recent measurements at very high A values (${}^{209}Bi$ and ${}^{238}U$) with large error bars provide no clues in resolving the standing A dependence issues.

The same character of the A dependence can be seen in the data for the ratios of the nonmesonic decay rate Γ_{nm} to the π^- decay rate (see Fig.2). Again as above, no data is available for values of $A \geq 16$ where significant new physics may possibly appear.

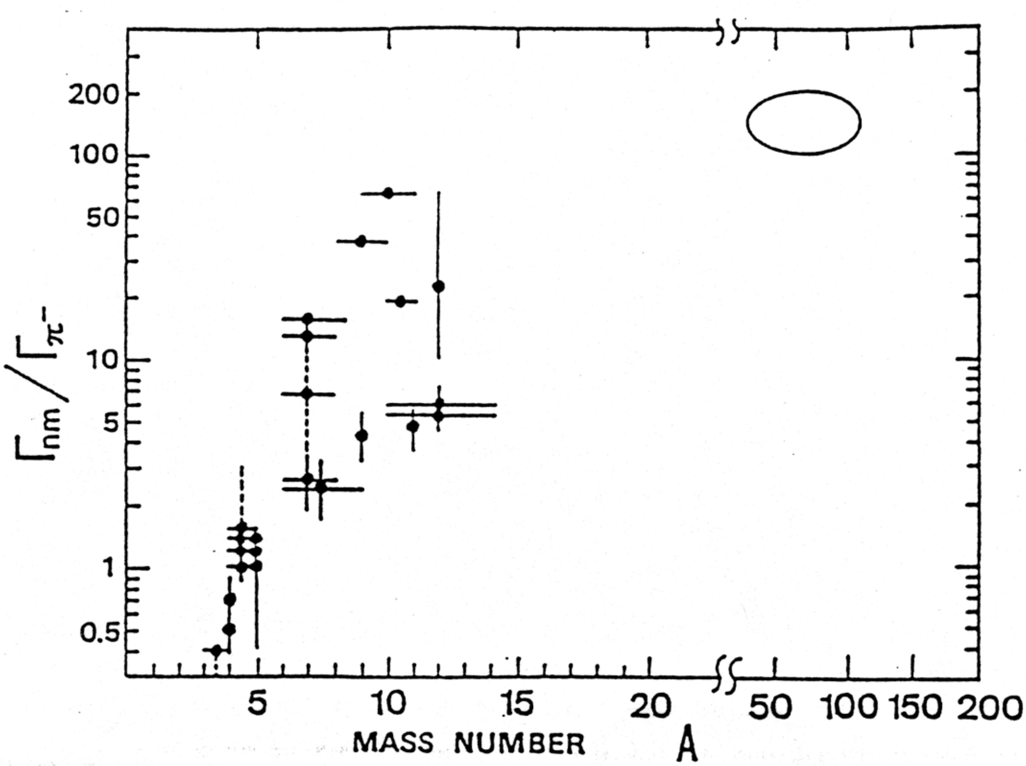


Fig.2 An illustration of the experimental ratios of the nonmesonic decay rate to the π^- decay rate

2b. HYPERNUCLEI TIME DELAYED FISSION

A new technique of detecting hypernuclear fission fragments and utilizing the excellent *CEBAF* beam character with simultaneous kaon detection (associated with Λ production) provides an excellent opportunity for measurement of the hypernuclear lifetimes and their A dependence in a particularly interesting region with very good accuracy. The fission detection technique has been successfully applied in nuclear fission studies and has proved to be very effective and insensitive to the high radiation background. A detailed technical discussion and features of device can be found in the section below on experimental setup for our proposed lifetime measurement at *CEBAF* Hall C. Here, we will give a little more physics background on the hypernuclear fission process.

A mesonic decay into a pion and nucleon may be described in terms of the exchange of a W boson between quarks as shown in Fig.3(a). The quark and meson exchange diagrams for the weak nonmesonic decays of the Λ hyperon where two nucleons are produced are shown in Fig.3(b) and Fig.3(c).

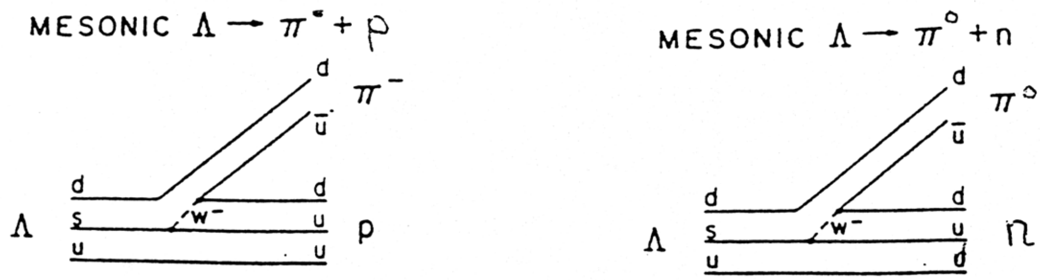
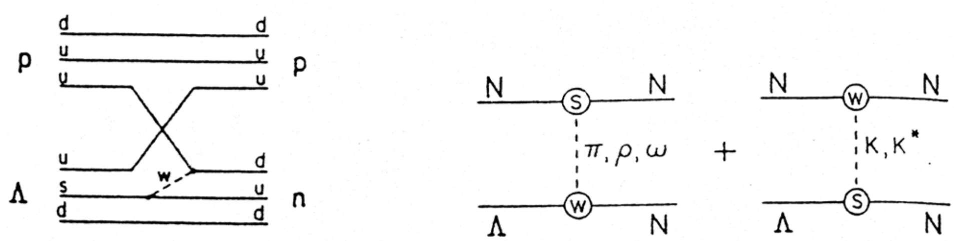


Fig.3(a) The mesonic mode diagram for Λ decay

b)



c)

Fig.3(b.c) Quark and mesonic exchange diagrams for weak nonmesonic decays of Λ hyperon

Theoretically it has been pointed out that the total nonmesonic (nm) decay rate, $\Gamma_{nm}=\Gamma_{np} + \Gamma_{nn}$, appears to be relatively insensitive to the details of the weak interaction models employed. In contrast, the Γ_{np}/Γ_{nn} ratio appears to be directly related to the specific meson exchange components (π, ρ, K ,...) of the Hamiltonian and sensitive to the question of whether the ΔI=1/2 rule holds for nonmesonic decay.

The mesonic decay of free hyperons occurs with isospin changes of 1/2 and 3/2. In a naive theory, the $(V - A)$ Hamiltonian description of $\Lambda \rightarrow \pi N$ transition implies equal ΔI=1/2 and ΔI=3/2 strength. However, it is experimentally well known, from both free hyperon decay and kaon decay, that the ΔI=1/2 amplitude is enhanced by an order of magnitude over the ΔI=3/2 (about of factor of twenty in the case of $\Lambda \rightarrow \pi N$). The nature of this empirical ΔI=1/2 rule is not understood.

In the ΛN interaction, a π cannot be exchanged, and there is no OPE dominant force such as in the nucleon-nucleon interaction. The absence of direct OPE force in ΛN ensures, that information regarding the short range properties of the baryon-baryon interaction can be obtained in Λ hypernuclei.

In the nuclear medium, the pionic decay modes are considered to be severely inhibited by Pauli blocking of the final-state nucleons and is strongly suppressed as the mass number of the hypernuclei increases. Furthermore, in s-shell hypernuclei the variety of open channels has a dramatic effect upon the π^-/π^0 ratio. In nuclei the $\Gamma_{\pi^-}/\Gamma_{\pi^0}$ ratio is predicted to range from $\sim$ 0.1 up to $\sim$ 1.5 (due to the selective character of

π^- and π^0 decay in the nuclear medium). For the range $40 \leq A \leq 100$, the ratio $\Gamma_{nm}/\Gamma_{\pi^-}$ lies in the range of 120 to 180. In other words, pionic decay is less than 1% of the weak decay transition. Since the energy liberated in the nonmesonic decay of the lambda is $\sim$ 176MeV, the residual nucleus can undergo fission with a high probability. Experimentally it has been found that time-delayed fission only appears near or above the hyperon production threshold. Also, nuclear fission which is unrelated to hypernuclear production appears to occur on a time scale more than three orders of magnitude shorter than the lifetime of the hyperon. Thus, the lifetime of the delayed fission is directly related to the lifetime of hypernucleus. Detection of nuclear fission fragments in coincidence with a kaon can be associated with hypernuclear production with an efficiency close to 100% (for example for preactinide nuclei). Therefore, the lifetime of the produced hypernuclei can be measured directly from the time delay between K^+ meson production (or corresponding to beam bunches) and fission fragment detection.

Due to the availabilities of the excellent beam characteristics at $CEBAF$ and the high efficiency and excellent timing resolution in the fission fragment detection technique, it is possible to carry out a direct measurement of the lifetime of heavy hypernuclei produced in the (γ, K^+) reaction, using virtual photons from forward scattering of the unobserved outgoing electrons. In the (γ, K) reaction the small momentum transfer and generally the higher cross section is obtained when the angle between the photon and the kaon is small. Hence, one must place the kaon spectrometer at forward angles to maintain a reasonable cross section. In $CEBAF$ Hall C, kaons will be detected with the SOS magnetic spectrometer placed at a small angle ($\sim 12.5^o$) which is in the kinematic region corresponding to the production of low lying hypernuclear states in the energy range of $E_{ex} \leq$ 50MeV. The fission fragments will be detected in a low-pressure multiwire proportional chamber $(LPMWPC)$[26–30]. A chamber such as this haw been successfully applied in nuclear fission studies. The unique time structure of the $CEBAF$ beam (1.67ps bunch width and $\sim$ 2ns bunch spacing) will provide the time-zero information, and is very suitable for the hypernuclei lifetime measurements in the range of (0.1-1.0)ns. Therefore, we believe that the existing parameters of the $CEBAF$ electron beam, the Hall C's SOS magnetic spectrometer's, and the $LPMWPC$ will allow us to make a hypernuclear lifetime measurements with a high accuracy ($\sim$ 20ps) which has been impossible to achieve in K^-, antiproton, or electron (photon) beams with a low duty factor.

3. EXPERIMENTAL SETUP

The Experimental layout is shown in Fig.4.

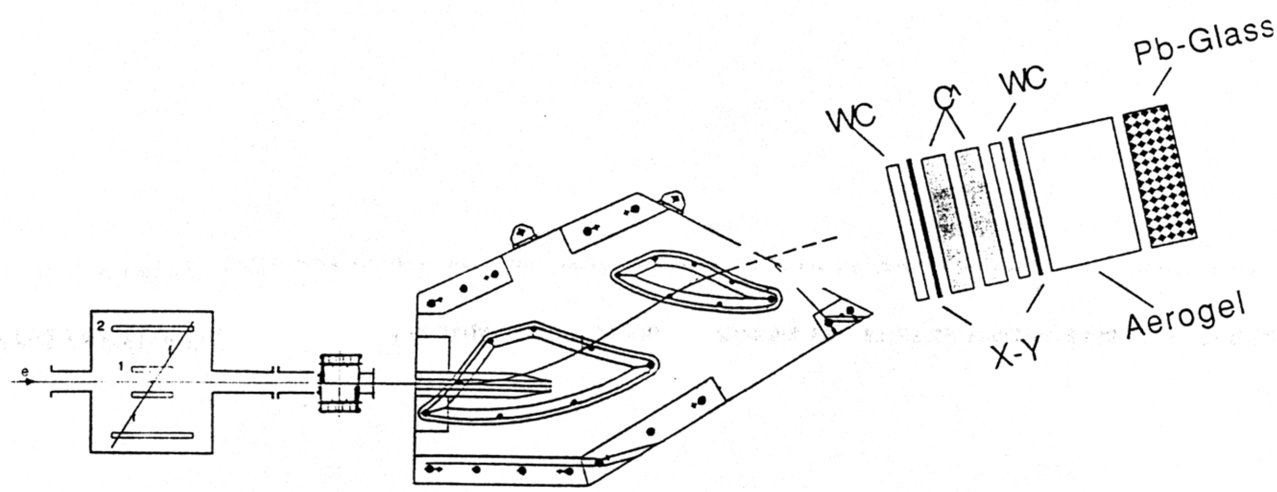


Fig.4 Schematic representation of the experimental setup
(not to scale)

The electron beam passing through the nuclear target will produce K^+ mesons on the bound protons due to the $\gamma^v P \rightarrow K^+\Lambda$ reaction (as well as π^+, P and e^+ from background reactions). With some probability, the electron beam interaction with the heavy nuclear targets will induce nuclear fission. But only hypernuclear formation and subsequent decay can be associated with the observed delayed fission fragments. In this case the time interval between kaon production and the delayed fission fragments can be directly interpreted as the lifetime of the hypernuclei.

The Hall C Short Orbit Spectrometer (SOS), with its relatively large angular acceptance ($\sim$ 10msr) and good momentum resolution ($\sim$ 0.1%), was specially constructed for the detection of low momentum and short lifetime hadrons [31]. It will be very convenient for K^+ detection in this experiment. The K^+ mesons will be detected at the smallest possible angle ($\sim$ 12.5^o relative to the incoming electron beam). The kinematic range to the reaction $\gamma^v P \rightarrow K^+\Lambda$ (on nuclear targets) has been chosen to correspond to a low nuclear excitation energies (E_{ex} $\leq$50MeV).

Low-pressure multiwire proportional chambers ($LPMWPC$) will be used for detection of the nuclear fission fragments. The $LPMWPC$ as a fragment detector is best suited for photo-fission and electro-fission experiments. Its main advantages include: a) good timing resolution (σ $\leq$50ps), b) high efficiency for fission fragment detection ($\sim$ 100%), c) an extreme insensitivity to γ and neutron backgrounds and good discrimination between α-particles and fragments, d) negligible radiation damage by αs and fission fragments, e) good position resolution ($FWHM$ $\sim$ 100μm), f) high rate capability (operates at count rates up to $10^5/mm^2$), and g) high angular acceptance and availability in different sizes and shapes. A coincidence between a kaon in the SOS and a fission fragment in the $LPMWPC$ will determine an online trigger. The lifetime of the hypernucleus will be determined by a detailed offline analysis.

3a. THE FISSION FRAGMENT DETECTOR

The nuclear fission fragment detection will be done with two low-pressure multiwire proportional chambers ($LPMWPC$). The proposed design of $LPMWPC$ is shown in (Fig.5).

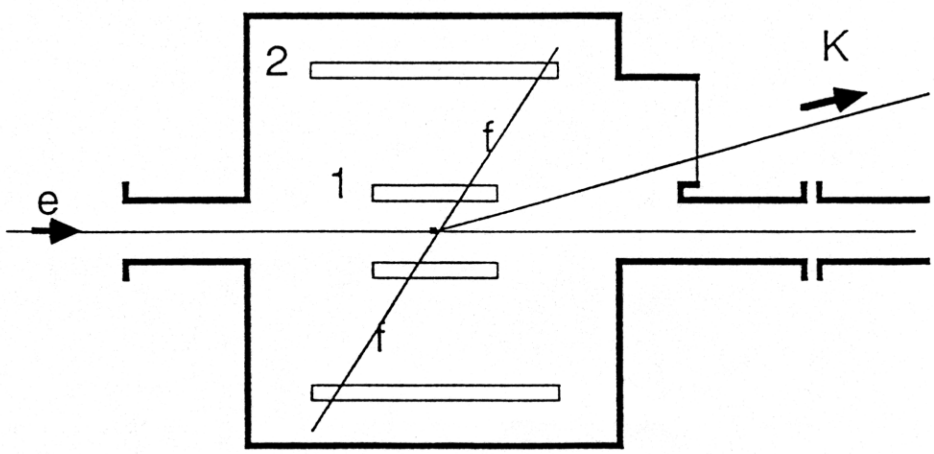


Fig.5 The schematic sketch of the target box and fragment detector

The active volume of the $LPMWPC$ detectors will be isolated from the volume of the scattering chamber by $\sim$ 0.5$-$1.0$\mu m Al$-coated polypropylene window. At this thickness the dispersion of the fragment velocities will be negligible. The scattering chamber will be operated at a pressure of $\sim$ 10^{-4}Torr. The detector will be filled with isobutane (C_4H_{10}) gas and operated at a pressure of $\sim$ 3Torr. It has been shown that pure hydrocarbons are best suited for low-pressure gas-filled counters[26–29]. The high density of this gas yields high primary ionization which is important for precise timing measurements. The pressure inside the detector volume will be kept constant by a special control system, because, pressure variations during long runs must be less than $\sim$ 1%.

The first layer of the $LPMWPC$ chamber ($\sim$ 5.0 $\times$ 5.0cm^2) will be placed parallel to the electron beam at a distance of $\sim$2-3cm away. The second layer (10 $\times$ 10cm^2) will be at a distance of $\sim$7-10cm behind the first. Each layer of the chamber consist of one anode plane and two cathode planes. The anode planes will be constructed from gold-plated 10μm diameter tungsten wires with a spacing of 1mm. The cathode plane which faces the target will consist of a set of $\sim 50\mu m$ gold-plated tungsten wires also with 1mm wire spacing. The distance between the anode and cathode planes will be ~3mm.

The signals from the $LPMWPC$ anodes and cathodes will be used for time and position measurements respectively. This information will be used to reconstruct the fragment trajectories and avoid the fragment travel time uncertainties due to velocity and path length dispersion. The position determination will be obtained by the measurement of the induced charge on the cathode wires (~ 350 channels) which will be connected to the commercially made delay lines. For timing measurement the anode signals (~ 350 channels) will be used through amplifiers that will have very good timing characteristics. The information from the chambers will be used for the reconstruction of the fission fragment angle with an accuracy of $\sim 5mr$. The time-of-flight of the fragments between the detector planes will be obtained with fast timing signals with ~50ps accuracy. In addition, signals from each layer will be used for an independent estimation of the delayed fission time relative to beam pulses tagged by a coincident arrival of kaons in the SOS.

The operation mechanism of the low-pressure multiwire proportional chamber is similar to a regular multiwire proportional chamber ($MWPC$) and a multi step chamber (MSC). The operation is characterized by a fast electron collection time (signal rise time ~2-3ns) and a high gain ($\sim 10^5 - 10^6$), resulting in excellent timing[26–30] and spatial resolution characteristics. Typical time resolution for a larger size, position sensitive detector of this type is on the order of a hundred ps with a position resolution of about hundred μm. Such low-pressure avalanche detectors have been successfully used in nuclear fission experiments using antiproton [23], and photon and electron beams [32,33]. For example, the active uranium targets have been used in the photo-fission and electro-fission experiments [32] performed at the Yerevan electron synchrotron. In these experiments, the registration of only one fragment by the $LPMWPC$'s permitted a background suppression of relativistic particles, γ and neutrons by a factor of more than 10^6 times, and was able to distinctly separate the delayed fission fragments from the fragmentation of heavy nuclei due to the absorption of real or virtual photons.

This equipment has worked with high stability without any encountered problems in beams of ~1.7-1.9GeV energy, low duty factors ($\leq 1\%$), and high intensity photon ($10^9\gamma/s$) or electron ($10^7 e/s$) beams passing directly through the active portion of the $LPMWPC$ detector. The detection efficiency of α particles in these experiments was on the order of $\leq 10^{-3}$, while the detection efficiency of fission fragments was practically 100%. In another experiment the effective separation of the fission fragments from the high level relativistic particle background was observed. Detailed description of some of these experiments and of the $LPMWPC$ detector used can be found in Ref.[32,34]. A detector of this type was applied in the electro-fission experiment using $^{236}U(e,e'f)$ reaction at the University of Illinois[33] with a beam current up to $8\mu A$ (the maximum attainable by accelerator) and worked reliably without any problems.

The fine time structure of the $CEBAF$ beam (1.67ps bunch width and ~2ns bunch spacing)[31] can be used to provide the time-zero arrival information and will be very suitable for lifetime measurements employing this technique in the range 0.1-1.0ns. As is illustrated in Fig.6, time resolution of the $LPMWPC$ of $\leq$100ps ($FWHM$) can be obtained.

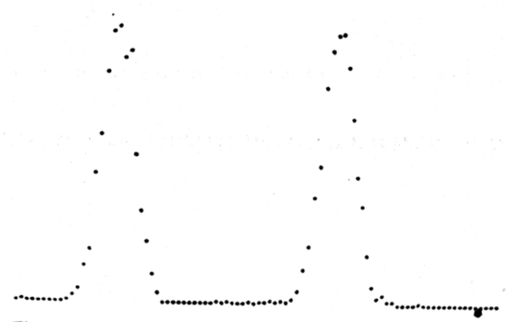


Fig. 2. Time resolution of an 80×100 mm^2 MWPC, measured with 100 MeV ^{58}Ni ions against a surface barrier detector. $p = 1.6$ Torr, hv = 470 V. The two peaks are 1 ns apart. fwhm = 170 ps. Intrinsic time resolution: 130 ps (fwhm).

Fig.6 An illustration of obtainable time resolution of low-pressure MWC
Experimental data from Ref.[26]

It is expected that the time resolution in this proposed *CEBAF* experiment can be improved to 20-30ps when the reaction vertex is determined with a precision of $\leq 200\mu m$ and timing of the fission fragments are measured relative to the tagged electron beam pulses in coincidence with (K^+).

Since nuclear prompt fission follows the act of interaction of the initial particle with target after about 10^{-18}sec, the fission nucleus remains in the target. As a result, in this case the fragments are emitted from the target plane. On the other hand, hypernuclei with lifetimes of the order of $\sim 10^{-10}$sec can leave the target and decay at some distance from the target plane (typically this distance will be of the order of $\geq$2mm).

Due to a small beam spot size, in the proposed *CEBAF* experiment we will be able to detect both delayed fission fragments with high efficiency by defining the fission decay point away from the target. The measurement of timing and geometrical parameters of both fragments will be used to reconstruct their decay vertex, trajectory angles and their velocities. This information will be also used to obtain fragment masses with an accuracy defined by the kaon spectrometer which will be sufficient to subtract multifragment and low mass fragments background.

3b. KAON DETECTION WITH THE *SOS*

The detection of K^+ mesons in this experiment will be done with the *SOS* spectrometer. K^+ mesons from the reaction $\gamma^v P \to K^+\Lambda$ will be detected at a minimum angle of $\theta_K \simeq 12.5^o$. The angular and momentum acceptance of the *SOS* spectrometer ($\Delta\Omega \sim 10msr$ and $\Delta P/P \sim \pm 20\%$) and its optical length (~10m) are suitable for this experiment. The detector package will be setup for K^+ detection and will be similar to the configuration for the approved Hall C K^+ form-factor experiment[35] and the light hypernuclei electroproduction experiments[36,37].

In the case of monochromatic γ-quanta with fixed K^+ kinematics kaon production will be associated only with the production of Λs. In our case (without detection of the scattered electrons) for the virtual photons with a continuous energy spectrum, the hypernuclear states cannot be resolved. However, if the set kaon momentum close to the maximum momentum possible for this kinematics, then we will be able to suppress the contribution from other K^+ production channels (like quasi-free K^+ production).

A tabulation of threshold values for kaon photo-production from a nucleon with a kaon emitted at P_K =1.2GeV/c and $\theta_K = 12.5^o$ are presented in Table 1.

TABLE 1
Threshold for K^+ photoproduction reaction
$\theta \simeq 12.5^o$ and P_K =1200MeV/c

REACTION	Gamma Threshold (GeV/c)
$\gamma p \to K\Lambda$	1.55
$\gamma p \to K\Sigma$	1.67
$\gamma p \to K^*(892)\Lambda$	1.87
$\gamma p \to K\Lambda(1405)$	2.00
$\gamma p \to K^*(892)\Sigma$	2.02
$\gamma p \to K\Lambda(1520)$	2.20
$\gamma p \to \Phi(1020)P$	2.30

The proposed experiment will detect only kaons and fission fragments. This allows reconstruction of the energy spectrum of initial photons with an accuracy determined by the detected kaon momentum and the spectrometer angular byte. The energy spectrum will reflect excited hypernuclear states. Hence, the experimentally measured lifetimes determined by all of statistics will be mean lifetime measurements for ground and also for all possible excitation states. It is well known from experimental results that excitation energies has strong influence on hypernuclear lifetimes. For example, the lifetime for ^6Li drops from 256±20psec for the ground state region down to 160±20psec at excitation energy ~30MeV.

The SOS spectrometer has a momentum resolution of $\sim 0.1\%$, and $\sim 10\%$ momentum acceptance will be used. With this momentum acceptance, we will be able to separate several hypernuclear excitation energy regions. Three different energy regions will be of interest for this experiment, and they are:

i) $E_{ex} \leq$5.0MeV which corresponds to the production of hypernuclear ground states with the help of virtual photons with energies $E_\gamma \geq E_\gamma{}^{max}-$5.0MeV, where $E_\gamma{}^{max}$ is equal to the energy of incident electron.

ii) $E_{ex} \leq$25.0MeV which corresponds to the production of hypernuclear ground and low lying excited states with the help of photons with energies $E_\gamma \geq E_\gamma{}^{max}-$25.0MeV.

iii) $E_{ex} \leq$50.0MeV which corresponds to the production of hypernuclear ground, excited states, and quasi-free production of Λ particles with the help of photons with energies $E_\gamma \geq E_\gamma{}^{max}-$50.0MeV.

Such separation in three distinctly different regions will help us to identify the contributions from various excited states in lifetime measurement.

The SOS spectrometer detector package consists of two wire chambers followed by an $X-Y$ scintillator hodoscope, two lucite cherenkov detectors, another $X-Y$ hodoscope, an aerogel detector, and finally a Pb -glass shower counter.

Particle identification is important, particularly for kaon separation from pion, proton, and positron backgrounds. This configuration of the SOS spectrometer will allow us to have a high efficiency K^+ detection ($\sim$ 95%) and an effective rejection of backgrounds from the e^+, π^+, and Ps. In the on-line analysis the rejection factor will be: $\geq 2\times 10^4$ for e^+, $\geq 2\times 10^2$ for π^+, and ≥ 20 for P. In the off-line analysis these factors will be improved by $\sim$ 100 times by using more effective thresholds for the detectors and information from TOF system.

3c. THE TARGETS

Initially two nuclear targets (^{197}Au and ^{209}Bi) and late three more (^{64}Cu, ^{195}Pt, and ^{238}U) with an effective thickness of up to $\sim 40mg/cm^2$ (a thin $\sim 2mg/cm^2$ target located at a low grazing angle with respect to incident beam) will be used.

The power loss in the $40mg/cm^2$ target for a $10\mu A$ electron beam will be $\sim$ 0.5W. For a beam spot size $S \sim (0.1\times 0.5)mm^2 \simeq 5\times 10^{-4}mm^2$, the power density will be $P/S \sim 1.0kW/cm^2$. At very high intensity the raster/deraster system will be used. To keep the ratio of accidental background to signal (for the proposed targets) at the same level ($\sim$ 5%), we will use different beam currents I for targets of different atomic numbers A (see Table 2).

TABLE 2

Target	Cu	Pt	Au	Bi	U
Beam current (μA)	7 - 10	10 - 15	15 -25	20 - 30	2 - 5
Ratio Accident/True	0.04 - 0.05	0.05	0.03 - 0.05	0.04 - 0.05	0.05
Detect. numb. hypernucl/day	100 - 150	30 - 50	75 - 130	400 - 500	500 - 1000

3d. THE BEAM ENERGY AND CURRENT

Standard Hall C beamline hardware will be used which includes the raster/deraster system, beam position and beam current monitors. A standard *CEBAF* accelerator two-pass beam with an energy ~1.65GeV will be used. At this energy, combined with kaon kinematics for the *SOS*, the E_γ will be chosen just below the Σ production threshold so that other kaon production channels can be avoided. The beam intensity will be in the range of (10-30)μA ($\sim 6 \times 10^{13} - 2 \times 10^{14} e/s$).

To carry out the physics program mentioned above, we will need approximately 50 days of *CEBAF* beam at a current of $\leq 10 - 30\mu A$. We would like to complete this program in two phases.

A. Phase One.

The phase one measurement would be the measurement of the Λ hypernuclear lifetime for the two nuclei *Bi* and *Au* with an accuracy of ~30ps. These two nuclei have atomic numbers that are very close in value, however, their nuclear fission probabilities are very different. This measurement would require 14 days of beam time.

B. Phase Two.

Upon successful completion of the first phase run, we propose to measure the rest of the above mentioned targets. We hope that in this stage we can improve the accuracy of the lifetime measurement for Bi_Λ and Au_Λ to $\leq$20ps. In addition, we will measure Λ hypernuclear lifetimes of the *Cu*, *Pt* and *U* targets with an accuracy of ~20-30ps also.

4. BACKGROUNDS, COUNTING RATES AND BEAM TIME REQUEST

4a. BACKGROUNDS

Results of the estimated counting rates and the signal to background ratios for all of the targets are presented in Table 3.

TABLE 3

The counting rate and signal/background for proposed targets

	Cu	Pt	Au	Bi	U
Z	29	78	79	83	92
A	64	195	197	209	238
Number of nuclear (10**20 /40mg.cm**{-2})	9.2	1.2	1.2	1.1	1.0
e-fission cross section (mb)	0.012	0.027	0.048	0.260	7.000
Fissibilities	0.02	0.01	0.02	0.10	1.00
Hypernucl. product.cross section (10**{-30}cm**2)	0.73	2.00	2.00	2.10	2.30
Prompt fission rate (10**5 c/s)	6.8	2.0	3.3	1.8	4.0
Prompt fissi.robability per bunch	0.0014	0.0005	0.0007	0.0036	0.0800
Hypernucl. prod. with det. K (10**{-2} /s)	8.4	3.0	3.0	3.0	3.0
Delayed fission rate (10**{-3}/s) in coincid. with K	1.68	0.30	0.60	3.0	30.0
Delayed fisson rate (count/day) in coincid. with K	150	26	52	260	2600
The ratio of Accident/True count	0.07	0.05	0.035	0.036	0.080

More detailed explanation and calculation will be discussed in next section.

The main source of background in hypernuclear experiments are the quasi-free production of the Λ and Σ hyperons (see, e.g.[9]). The detection of the delayed fission fragments in coincidence with K^+ is the effective suppression of these channels. Nevertheless, some contributions from this channel as well as from other possible backgrounds can give contributions to the single arm rates and, hence, contributions in the real and accidental coincidence rates.

4b. COUNTING RATES

The singles rate in the kaon arm consists of photoproduction of K^+, π^+, protons, and the mostly from e^+ Each of these rates has been estimated and the results are shown in detail below.

- Singles rate of real kaons.

The real kaon singles rate R_K at the kinematics of this experiment, will be mainly due to quasi-free Λ production. For the setup of this experiment the kaon photoproduction rate at a beam current of $\sim 10\mu A$ using the parameters for the SOS spectrometer system is calculated to be:

$$R_K = N_{nucl} \times d\sigma/d\Omega \times \Delta\Omega \times N_\gamma{}^*$$

where the spectrometer angular acceptance is $\Delta\Omega = 10msr$ and the number of nuclei on the target is $N_{nucl} = \rho \times t/A \times N_A = 0.04g/cm^2/A \times 6 \times 10^{23}g^{-1} = 2.4/A \times 10^{22}nucl/cm^2$. For the Bi target the number is $N_{nucl} \simeq 1.2 \times 10^{20}$. The flux of virtual photons at 0^o may be determined from the expression, $N_\gamma{}^* \simeq 0.015 \times N_e \times dE/E$. At an energy of E=1645MeV and a dE=120MeV (using $\sim$ 10% momentum byte) we will have $N_\gamma{}^* \simeq 0.015 \times 6 \times 10^{13} \times 0.073 \simeq 6.6 \times 10^{10}\gamma/s$. For K^+ photoproduction on protons at an energy of $E_e \sim$1600MeV/c, $\theta_K \sim 12.5^o$, and P_K =1200MeV/c the differential cross sections are $d\sigma/d\Omega_K \sim 0.5 \times 10^{-30}cm^2/sr$. On the nuclear targets with the same equivalent thickness, the kaon rate will be $\sim Z \times R_K$ ($Z = 83$ for the Bi nuclei).

The rate of K^+ which will be detected in the SOS from the Bi target will be $R_K{}^* \simeq 83 \times R_K \times \epsilon_K \times \epsilon_T \times \epsilon_d$, where $\epsilon_K \simeq 0.4$ - the kaon survival efficiency (decay factor) at P_K=1200MeV/c and SOS spectrometer length ~10m; $\epsilon_T \simeq 0.8$ - the tracking efficiency; and $\epsilon_d \simeq 0.95$ - the kaon detection efficiency.

Then the real kaon counting rate in the SOS spectrometer from the Bi target for these conditions will be: $R_K{}^* = 83 \times 6.6 \times 10^{10} \times 1.2 \times 10^{20} \times 0.5 \times 10^{-30} \times 10 \times 10^{-3} \times 0.4 \times 0.8 \times 0.95 \simeq$1.0 Kaon/s.

- Single rate from P and π^+.

To estimate the rate from protons and pions we have used the $eA \rightarrow hx$ reaction cross sections calculated for ^{12}C with the "EPC" program[38]. The cross sections calculated at E_e =1600MeV, P_{SOS} =1200MeV/c, and $\theta_{SOS} = 12.5^o$ are:

$d\sigma/d\Omega dp \sim 0.10 \times 10^{-1}\mu b/MeV/c$ - for protons,

$d\sigma/d\Omega dp \sim 0.77 \times 10^{-2}\mu b/MeV/c$ - for the π^+.

For the Bi target estimation the value of the ^{12}C cross section was increased by the factor $k = A_{Bi}/A_C$. For the same beam intensity, target thickness, and the same SOS parameters, the proton and pion rate is $N_P \sim 13p/s$ and $N_\pi \sim 9.7\pi^+/s$, respectively. Contributions of the protons and pions in the on-line trigger will be negligible ($\leq 1.0s^-$) due to the trigger rejection factor and the extremely small rate.

- Rate from e^+.

With the spectrometer located at small angles the singles rate from positrons N_{e^+} will dominate. For an estimation of the N_{e^+} rate, we used the same cross section for $eA \rightarrow e^+e^-$ reaction as used in Ref.[37] which is given by:

$d\sigma/d\Omega dp \sim 6\mu b/MeV \cdot sr$.

The positron rate in the SOS for an electron beam intensity of $6 \times 10^{13}e/s$, solid angle of the SOS spectrometer of $\sim 10msr$, a momentum of P_{SOS} =1200MeV/c, and a target thickness of $\sim 40mg/cm^2$ is calculated to be: $N_{e^+} \sim 7.5 \times 10^5s^{-1}$.

However, this rate will be effectively rejected because the detection efficiency of the on-line trigger will be $\sim 6 \times 10^{-5}$. Therefore, the resulting singles rate in the trigger due to positrons will be $\sim 45e^+/s$. Hence, the total singles rate of the kaon arm in the on-line trigger level can be ${R_{SOS}}^{tot} \leq 50s^{-1}$.

- Single rate in the $LPMWPC$

For a 40 mg/cm^2 Bi target at an incident beam flux of $\sim 6 \times 10^{13} e/s$ ($\sim 10\mu A$) with an electrofisson cross section value of $\sim 260\mu b$ the total mean rate for nuclear fission fragments is calculated to be $R_f \sim 1.2 \times 10^{20} \times 260 \times 10^{-30} \times 6 \times 10^{13} \sim 1.9 \times 10^6 s^{-1}$. The rate of fission in the effective solid angle of the $LPMWPC$ will be ${R_f}^* \sim 0.7 \times 1.9 \times 10^6 \sim 1.3 \times 10^6 s^{-1}$.

With an on-line coincidence resolving window of about 30ns, the accidental coincidence rate between the kaon arm and the fission fragment detector can be on the level of $R_{Accident} \sim 2 \times \tau \times {R_K}^{\times} R_f \simeq 2 \times 30ns \times 10^{-9} \times 1.0 \times 1.3 \times 10^6 \sim 8.0 \times 10^{-2} s^{-1}$. In offline analysis, this accidental rate will be reduced at least by a factor of ~400-700 (due to a factor of $\sim 20 - 25$ from improved offline time analysis, and a factor of $\sim 20 - 30$ from constraining the fragments geometric and kinematic parameters). Hence, the accidental to true ratio in offline analysis will be achieved on the level ~ 0.04.

A potential problem for the operation of $LPMWPC$ at small distances from the electron beam and the target is the abundance of low energy (~10KeV or less with our geometry) electrons from Moller scattering on the target nuclei. These low ionizing particles will produce signals below the electronics threshold and will not be processed any further. However, at high beam currents (high count rates) they can still affect the detector response. Large numbers of these small signals can produce space charge effect in the chamber lowering the electric field and thereby reducing the detector gain[33]. To suppress this effect so that the chamber can be operated at small distances from high intensity beams, different technical solutions can be used. For example, one can apply a low (~0.5Tesla) magnetic field around the target by using a Helmholtz solenoidal coil.

In this proposed $CEBAF$ experiment, we plan to use an additional shielding electrodes between the target and the detector. A thin Al-polypropylene window with an applied electric potential will effectively collect such low energy electrons. The relatively high energy fission fragments (velocity $\sim 10^{10}$mm/s) will penetrate the active part of detector without serious deviation from their initial direction. With this simple technique or by using the magnetic filter, we will be able to suppress the electrons from Moller scattering at least by a factor of 10-20 and make the operation of the $LPMWPC$ possible with the high intensity beam at $CEBAF$.

- Expected rate for hypernuclear production

The hypernuclear production cross section is expected to be approximately 5% of the kaon production cross section, therefore, the cross section is given by the formula $\sim 0.05 \times d\sigma/d\Omega_K$. The fission probability for Bi nuclei after nonmesonic decay of the hypernucleus is $P_f = 0.1$. The fission fragment detector solid angle in the $LPMWPC$ is assumed to be $\Delta\Omega \cong 1.4 \times \pi \cdot sr$. Given the above data, then the rate of detected hypernuclei will be:

$R_{Hyprnucl} = R_K^* \times 0.05 \times 0.1 \times 0.7 \sim 3.5 \times 10^{-3} s^{-1}$.

The delayed fission (hypernuclei) count will be ~ 260-300 counts/day.

The ratio of the the accidental background to true signal coincidence will be $\leq 4\%$. The estimated values for the true signal coincidence and the true signal/background ratio for all of the proposed targets are presented in Table 3. For the estimations, we used the probabilities of 0.1 for Pt and 1.0 for U [39]. For the other nuclear electrofission cross sections as well as the fission probabilities of hypernuclei after nonmesonic decay were estimated by the photofission data at $E_\gamma \sim$1GeV[40].

4c. FISSION AS A FILTER FOR THE STUDY OF HEAVY HYPERNUCLEI

As a result of the initial particle interaction with the targets a nuclear reaction can take place. Some portion of the nuclear reactions will occur after a short time of $\leq 10^{-18}$s[42,45] and this is called "prompt fission". However, some of the nuclear fissions occur at a relatively long time between the original interaction and the fission process. This is the "delayed fission" process and is considered to be associated with the weak decay of heavy hypernuclei.

It is well known that due to nuclear fission two (binary) or more fragments can be produced. About 80% of delayed fission is binary mode. Experimentally it is observed that delayed fission is dominated by the symmetric mode. Additionally, at low excitation energies ($E_{ex} \leq$100MeV), the heavy nuclei fragment mass distribution peaks at $m_f \sim M/2$ with $\Delta M/M \leq 30\%$, (FWHM).

Results from two experiments were reported concerning delayed fissions induced by 1.2GeV electrons [42] and stopped antiprotons on heavy nuclear targets[41,43]. In case of light hypernuclei the mesonic decay of the $\Lambda \rightarrow N + \pi$ dominates, however, the heavy hypernuclei decay via the weak interaction

$$\Lambda + N \rightarrow N + N.$$

The energy liberated in this case is $\sim$ 176MeV which is enough to cause the residual nucleus to undergo fission. If the other possible sources of delayed fission are negligible, then the lifetime for delayed fission can be interpreted as the lifetime of the hypernuclei decay.

In a Kharkov experiment perfórmed at an electron energy of E_e =1200MeV the cross section for delayed fission was observed to be $6.5 \pm 1.0 \times 10^{-33} cm^2$[41]. In this experiment the ratio of the cross sections of the delayed to the prompt electrofission was found to be $(2.5 \pm 1.0)10^{-5}$. A similar level of 10^{-5} of delayed to prompt fission was observed in an experiment on the interaction of bremsstrahlung quanta with a maximum energy of 1.66GeV with ^{235}U nuclei [34]. The Kharkov experiments were carried out at an electron energy of 700MeV which is below the threshold for photoproduction of the Λ particle and delayed fission was not observed (the cross section is less than $\sim 10^{-34} cm^2$). This indicates that the fragments observed at E_e =1200MeV arise as a consequence of the fission of hypernuclei. The simultaneous detection of the fission fragments and the formation particles can result in elimination the of the background reactions to $\geq$ 90%.

A possible formation of heavy hypernuclear in the (γ, K^+) reactions[44] (as well as with stopped antiproton's[45]) can be a multistep process. Some of the quasi-free hyperons do not fly away. As a result of the rescattering process the Λ or Σ can be brought back to form a "bound" hypernucleus. The efficiency of these multistep processes was estimated to be 10 – 20%. About 80 – 90% of the quasi-free process claims that not only the pion and the kaon, but also the hyperon is in free space. In this case the possible excitation energies of the residual nuclei are much lower, and, as a result the probability of nuclear fission is very low (see Fig.7).

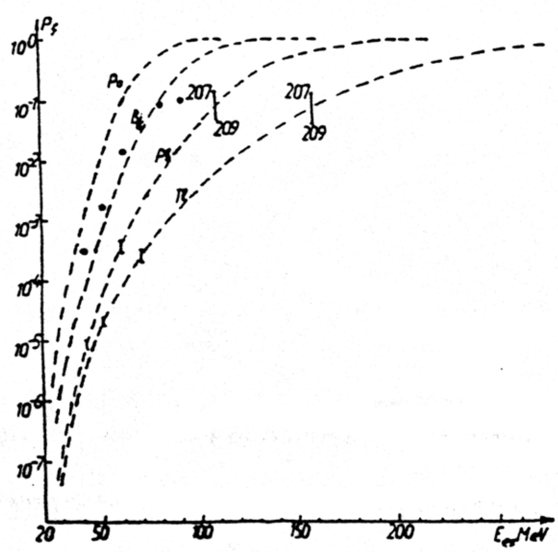


Fig.7 Nuclear fissibility plotted against excitation energy

Therefore, about 10% of the kaons in the kinematic range corresponding to the production of the hypernuclear low lying states and about 1% of the quasi-free production of the Λ -hyperon will be associated with the delayed fission process.

The calculations were performed in the framework of a statistical model[46–48]. Here, for comparison, the experimental values of the fissibilities for Bi in photofission experiments are shown[49]. For each photon energy the excitation energy of the nucleus was defined by the Monte Carlo Cascade program. The strong dependence of the fission probabilities on the excitation energy can be used as a tag for differentiating the reactions with high and low values of the excitation energy. Therefore, the simultaneous detection of the fission fragments with kaons in the (γ, K^+) reactions can be used as a tag for the formation and subsequent decay of heavy hypernuclei. The signal to background ratio in the kinematic region corresponding to the low lying hypernuclei states can be about 100.

4d. BEAM REQUEST

For completion of the first phase of our proposal we are asking for two weeks of *CEBAF* beam time or $\sim$ 350 hours. A standard *CEBAF* two-pass beam with energy of 1.65GeV and intensity of $\sim 10 - 30\mu A$ is required. Estimated beam intensity and time request for the first phase proposal are presented in Table 4.

TABLE 4
Beam time request

Target	I(μA)	Ratio Accident. to True	Number of Hypernucl. per day	Time request (hour)	Expect. accuracy
Au	8 - 10	0.07	40 - 50	220	10 %
Bi	8 - 10	0.07	200 - 260	80	8 - 10%

*** In addition about 35 hours for control measurements.**

TOTAL : Beam time request : 335 hours (about 14 days)

This stage will be devoted to a test of all methodological problems and a measurement of the Λ hypernuclear lifetimes for the *Bi* and *Au* nuclei with an accuracy of $\sim$30ps. The methodological problems to be studied are investigations of the real parameters for the *LPMWPC* with the *CEBAF* high intensity beam, all backgrounds associated with this type of experiment, and particularly the possibility of the operation of the *LPMWPC* at high beam currents of $\geq 15\mu A$ or higher and at small distances from the beam, investigations of potential radiation damage effects on the parameters of detectors, and time resolutions for fragment detection utilizing the *CEBAF* beam bunch structure. In addition, we will need about one week of unrestricted beam access in Hall C for installation of the *LPMWPC*.

5. SUMMARY

There are real possibilities of using this detector technique in other *CEBAF* experiments. This type of device would be very useful as a recoil nucleus detector in electroproduction and photo/electrofission experiments on light and heavy nuclei. The *LPMWPC* can be successfully used with the *CEBAF* high intensity beam and with its unique parameters one should be able to achieve lifetime measurements with a resolution better than 50ps. The time structure of the *CEBAF* beam (1.67ps bunch width and $\sim$2ns bunch spacing) can provide the time-zero information and is very suitable for life time measurements in the range (0.1-1.0)ns. The shape and centroid of the time resolution for the experimental setup can be monitored continuously with the help of the existing prompt fission. This will make systematic errors easier to be identified and controlled.

Delayed fission with detection of a strange meson could be very useful for investigation of the Σ hypernuclear structures. The Σ hypernuclear structures reported so far appear only in the continuum where the large quasi-free background causes a problem in the search for possible narrow states. This new technique will effectively suppress this quasi-free background. The simultaneous detection of the fission fragments with kaons in the (γ, K^+) reactions can be used as a tag for the formation and decay of heavy hypernuclei. The signal to background ratio in the kinematic region corresponding to the low lying preactinide hypernuclei states will be $\sim$100:1.

Taking high statistical data has not been possible with earlier machines. It is possible at *CEBAF* to have 10^3 events for just a few days of running for a 1.65GeV incident flux of $6 \times 10^{13} e/s$ and determine the τ_Λ with a precision $\leq$20ps.

This technique can be successfully employed with kaon, pion and electron-photon beams. In the case of kaon and pion beams, one must use multisection active targets[46] to compensate for the low intensity of the beams. However, even with the help of the multisection active targets it will be difficult to obtain time resolutions on the order of $\sim$ 100ps. Therefore, the high-intensity and continuous electron beam available at *CEBAF* is very suitable.

We believe that using the Hall C, *SOS* spectrometer, the collaboration has the strength and commitment to successfully carry out this measurement. Hampton University has an approved proposal to measure $(e, e'K^+)$ reaction for the determination of F_{K^+} and will use the *SOS* spectrometer with the same configuration as we are proposing for kaon detection. Most of the members of this collaboration have long time experience in this physics region and will be able to resolve many technological and scientific problems. The Yerevan group has experience in construction and maintenance of *LPMWPC* detector. Additionally, CEBAF Detector Group is ready to provide assistance in all stages of design, construction, testing and installation of the chambers. Each institution has built hardware for the Hall C spectrometers. Hampton University has completed wire chambers for *HMS*. The Yerevan Physics Institute has built the Lead-glass shower counters for both the *HMS* and the *SOS* spectrometers. The *CEBAF* staff scientists will assist in this project and will be responsible for the electronics, data acquisition and beamline hardware.

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APPENDIX

Estimation of experimental errors

As was mentioned the accidental coincidence mainly due from "prompt" electrofission. In the case of incident electron beam flux $6 \times 10^{13} e/s$ the signal/background (from accidental "prompt" fission) ratio expected to be $\leq 4\%$ if $E_{ex} \leq 50$MeV.

The accidental coincidence level between $LPMWPC$ and SOS spectrometer will be monitored continuously by the measurement of the coincidence rate between SOS and other electron bunches. For estimation of backgrounds from the other physics process the measurements at the kinematic below the kaon production can be done.

Let us discuss more why we can achieve more accuracy for hypernuclei lifetime measurement at $CEBAF$.

Main problems for all early experiments was: very low level for statistics (in early experiments they was detected only about several tens hypernuclei) and difficulty to achieve good timing resolution between the detected kaons and products of Λ decay. In addition of this in all of early experiments no way to match this time with a good precision using a beam time distribution.

First problem was connected with low intensity of kaon and antiproton beams and with difficulty to have coincidence experiment (for detection of decay products) in low duty factor beam.

The second problem was directly connected with lifetime measurement, which in practice was determined time difference between produced kaons (start time) and hypernuclei decay products (stop time). In these previous experiments time resolution (or accuracy for lifetime) of measurements included contribution from each arm. But each of them can give in practice at least ~100-200ps (in best case).

In our Hall C experiment we can as "start" use signal from $CEBAF$ accelerator. Detection of kaons and its time relative to the beam bunch will determine which bunch will be connected with kaon (Λ hyperon) production. Distance between bunches about 2ns, and time resolution in kaon arm (better than 200ps) will give us chance to resolved this problem.

As it's followed from Fig.8 we already achieved such time measurement level in Hall C.

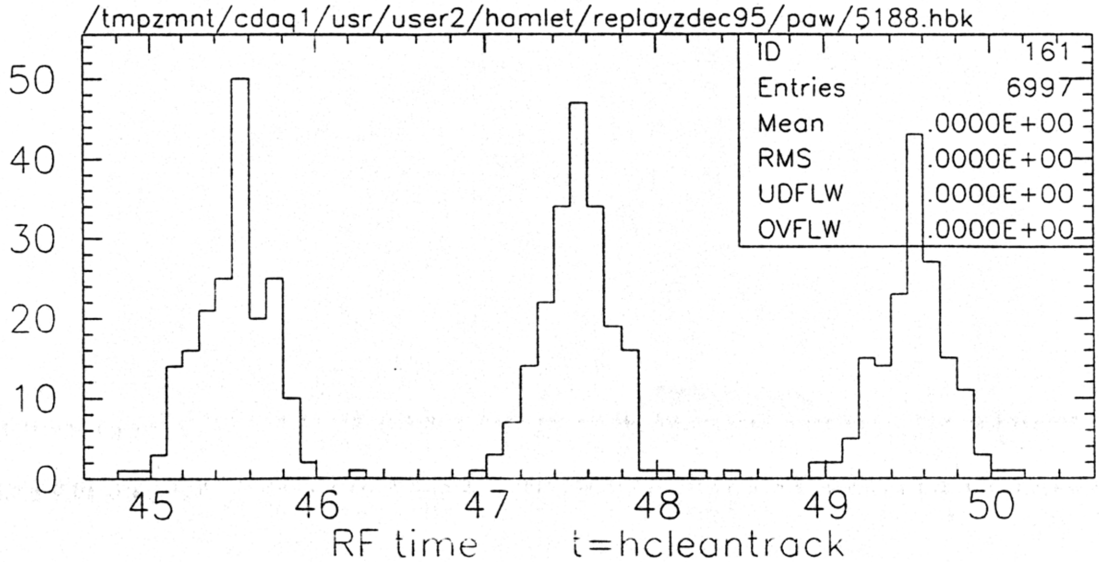

Fig.8 Bunch structure $CEBAF$ beam tagged by SOS spectrometer

Therefore, because $CEBAF$ beam bunch have only 1.67ps width, all time measurement accuracy will determined by time resolution of $LPMWPC$ (detector for delayed fission products).

The velocity of fragments (~1cm/ns) has a wide dispersion (~ 30%) due to fragments mass distributions. But high coordinate and time resolution of detectors will allowed to reconstruct fission fragments angle and make very precise all corrections in the off-line analysis.

The shape and centroid of the time resolution function of the experimental setup will be monitored continuously by the help of "prompt" fission, the rate of which is about $10^6 sec^{-1}$ for incident electron flux

$6 \times 10^{13} e/s$.

The expected time distribution of events following an exponential decay obtained by Monte Carlo simulation with instrumental total time resolution σ =200ps and 100ps are presented in Fig.9 and Fig.10. Total number of events - 10^4.

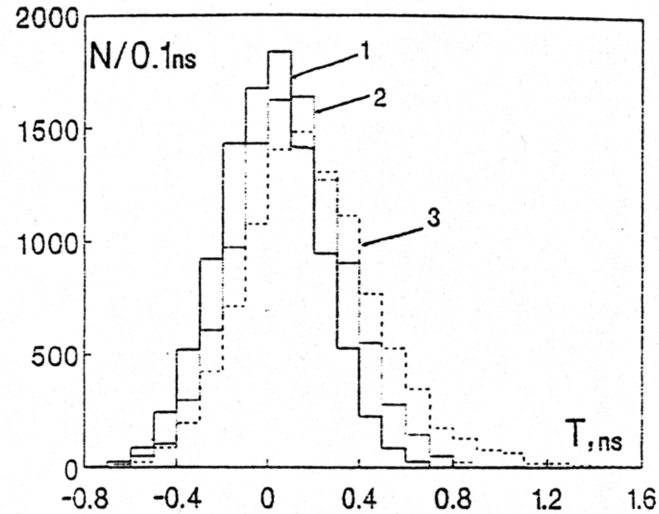

Fig.9 Time distribution between K^+ meson's and fission fragments at τ_Λ : 1 - 0.0ps; 2 - 100ps; 3 - 200ps

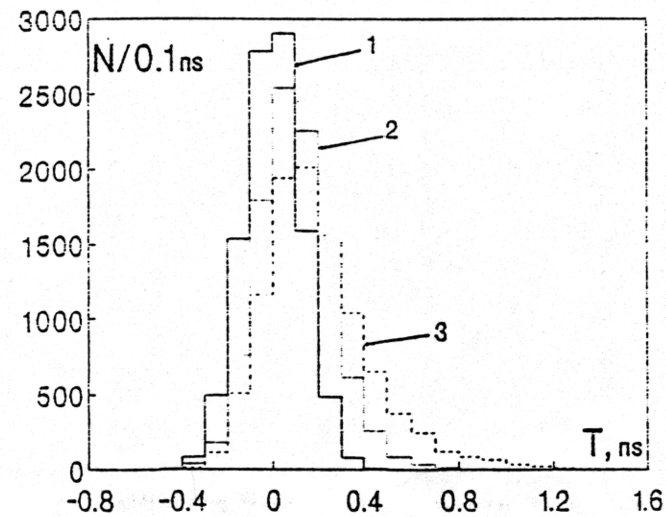

Fig.10 Same than Fig.9, but with σ =130ps

The "prompt" event distribution ($\tau_\Lambda = 0$) is also shown for comparison. For estimation for what we will expect in worst case the instrumental total time resolution (σ) is 220ps (Fig.9) and 130ps (Fig.10) was considered, respectively.

Fitting the Monte Carlo lifetime spectrum presented in Fig.10 by the convolution of the resolution function with an exponential decay using a fitting algorithm based on Gaussian statistics, 98.35±1.5ps and 198±2.3ps lifetimes with an effective χ^2 per degree of freedom of 0.5 and 0.9 respectively can be extracted.

Therefore, one needs $\sim 10^3$ events for the determination of hypernuclei lifetimes with a good precision ($\leq 5\%$).

The measurement of the delay time distributions of the fission fragments in coincidence with K^+ mesons in these energetic regions alow us to measure the lifetimes of the hypernuclei weak decay from ground, ground plus excited, and ground and excited plus hypernuclear states.

The estimated background conditions at $CEBAF$, the characteristics of $LPMWPC$'s; and the time structure of the $CEBAF$ beam allows us to conclude that the $CEBAF$ is a very suitable lab for this experiment.

Detection of K^+ mesons in SOS spectrometer at minimum angle relative to the beam direction ($\sim 12.5^0$) and at maximum possible momentum for Λ production, will fixed maximum kinetic energy of hyperon or upper level of excitation energy for hypernuclei

$E_{ex} = E_0 - (E_k + E_\lambda)$. As its followed from this, in this case $E_{ex} \leq E_0 + (E_K + M_\Lambda)$.

If E_{ex} $\leq$50MeV (which we can fixed by detection of kaon) then Λ will have very low energy (or momentum) in nuclei and probability of nuclei fission $\leq 0.1\%$ (see Fig.7).

In this case $\sim$ 100% delayed fission of nuclei will connected with hypernuclei.

Quasifree Λ production can give contribution in nuclear delayed fission (due to secondary interactions) in the waste case on the level of $\leq 10\%zz$.

There are no any significant contribution in the accuracy of measurements due to fission fragments mass or energy distribution. The mass division is binary and approximately symmetric.