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PROPOSAL FOR RF TIMING OF DELAYED FRAGMENTS AND RECOIL NUCLEI IN THE PICOSECOND RANGE

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ABSTRACT

Principles of a picosecond time measurement method is proposed which is based on microwave properties of beams from electron accelerators or from possible remodulated external beams from synchrotrons. Conventional RF resonators (RFR) are used which operate at the same frequency as the microwave structure of the accelerated beams and driven by the same master oscillator which modulates the beam. For example, the 500 MHz microwave structure at TJNAF corresponds to a 2 ns difference between RF beam buckets; accelerated electrons are time structured and correspondingly have a 1.67 ps time spread for every 2 ns interval.

Secondary electrons produced in interactions of the incident beam, or from promptly produced charged particles, originate with this time structure. The time scale of the secondary electrons from decay processes (delayed fission, recoils from delayed decays, etc.) lay between two bunches.

An RFR is placed at the end of an isochronous secondary- electron transport system, providing circular scanning of accelerated secondary-electrons. Secondary electrons which are promptly produced are timed and used as a reference calibration.

Other observed, secondary-electrons arriving at different times than this reference ones are deflected differently and displayed on the position sensitive detector, with a radius about a few centimeters. From the determination of the center of gravity for the secondary-electron swarm, with a precision of about 0.1 mm, a few psecond resolution can be reached at TJNAF. A rich hypernuclear and nuclear program can be performed using this technique alone or in combination with other existing devices.

INTRODUCTION

One inherent value of microwave properties of electron beams from TJNAF (Yerevan Synchrotron and others) is the availability of a fine time structure, which makes possible timing measurements with psecond resolution. The timing spread of these beams is determined by the microwave phase bite producing RF buckets of a few pseconds in duration, which are separated in time by the period of the modulator frequency. The timing resolution made available by these beams is far beyond the capability of conventional particle detectors; therefore, to take advantage of the available timing resolution, the applied particle detector system must also be used with a microwave technique.

Previously, the resonant microwave cavity was used as a deflecting system to investigate structure of the electron bunches in a linear accelerator[1] and microtron[2]. In these papers, a 2ps time resolution was reported.

Johanson and Alvager[3] suggested to use the method for measuring nuclear short half-lives in the ps and sub-picosecond range. Nuclear lifetimes in the range of 10-100 ps had been measured previously [4-9]. In these investigations, a beam of charged particles is swept acrossed a slit using a high frequency field, producing beam pulses of short duration of about 20 ps. Nuclei in a target situated behind this slit are coulomb excited and decay by emission of conversion electrons. These internally converted electrons are then allowed to escape the cavity. The decay time is determined by analyzing the energy of the emerging conversion electrons, which are a function of the microwave signal phase at the decay time.

An RF timing technique based on the use of a conventional RF separator (RFS) was employed by Guiragossian et al. [10]. The technique was used in an experiment to search for changes in the velocity of light with high energy photons using the SLAC accelerator facility to provide a flight path of about 1 km for 15 GeV photons. In this application, the RFS had been operated at the same frequency as the microwave structure of the beam; by driving the separator with the same muster oscillator which modulated the beam, picosecond resolution for time-of-flight was achieved.

In this paper we show that the RF technique can be employed for the timing of delayed recoils or fragments at electron accelerators (TJNAF, Yerevan Synchrotron, and others) with picosecond resolution. Such a method opens new opportunities for the investigation of hypernuclei and fissioning isomers at electron accelerators.

METHOD.

Electron beams with a fine time microstructure in interactions with a target will produce secondary particles. This secondary particles which are produced promptly, originate with the same time structure as that of the incident beam. Some of the secondaries which had been produced in decays (hypernuclei, fission isomers, etc.) are delayed. Passing through the target surface with an incident electron beam, prompt and delayed secondaries produce secondary electrons in proportion with their energy loss in matter the mean number of which ranges from about 10-1000 for each recoil nucleus or fission fragment. For relativistic particles this number is of the order 1 or smaller. The secondary electrons are emitted with a large angular spread, but with energies mainly on the order of a few electron volts. These electrons are emitted from a thickness on the order of 10^{-5}cm, and the time scale of the process is less than 0.1 ps. Therefore, these secondary electrons originate with the same time structure as that of the incident beam or secondary particles, and has long been used as a timing device in time of flight mass identification of nuclear fragments [9].

A 180° bend in a homogenous magnetic field as shown in Fig.1 will be used for transportation of the secondary electron swarm [10] for RF analysis. It is well known from the principle of the cyclotron that such a bend is isochronous both with respect to position and energy [11]. There is also a one-to-one focus with respect to position and initial angle. However, the flight time depends on the initial angle in the plane of the bend as seen in Fig.1. The secondary electrons are emitted with a large angular spread and with energies on the order of only a few electron volts. We will accelerate them to about 20 keV, thereby greatly reducing their angular dispersion. The acceleration is accomplished with a high transmission wire harp oriented so that the individual wires are parallel to the plane of the 180° bend. Thus the nonuniform electric field due to the spacing of the wires does not introduce angular dispersion in the plane of the bend, thereby preserving the time resolution. Finally, any residual angular dispersion in the bend plane is reduced by the use of the collimator located at the 90° position of the bend. As seen in Fig.1, at the position of such a collimator, the normal trajectories which have equal path length, cross over, while any remaining off-angle rays hit the collimator. The estimated time-of-flight of the secondary electron swarm from the target to the RF system is of the order of 1 ns, and less than 1 ps in width. The spatial size of the swarm at the end of transportation is about 0.5 mm. The energy of the electrons after the acceleration is near 20 keV; hence, the minimal time dispersion is of the order of 5 ps. It is assumed that center of the gravity of this distribution can be determined to high precision with the anticipated 0.5 ps time resolution.

ANALYSIS OF THE RF SYSTEM.

Passing through RF cavities, charged particles change their direction or energy as a function of the relative phase of oscillations in the cavity. This had been used in previous papers for the RF timing with picosecond ranges. In this paper, we will consider the oscilloscopic method of RF timing [1,2]. The RF deflecting system consists of two RF resonant cavities, where the electric fields are perpendicular to each other and to the velocity of the electron swarm. The thickness of these cavities are about 1 mm providing effective deflection and precise phase resolution of secondary electron swarms. Power feeds the resonators from accelerator wave-guides by means of a coaxial line. Spatial phase shifters will be used for adjusting the entire system.

A position sensitive detector will be located a few centimeters after the RF deflecting system. The electron swarm after each resonator, deflects to the direction of electric field and results in a circular pattern. We suggest to use a scintillator foil with a thickness on the order of 10 micrometers, with fiber optics and position sensitive PMTs; for example, XP4702 [12] for the determination of the position of the center of gravity for the deflected electron swarm. Determining the position of the electron swarm with the accuracy of 0.1 mm is achievable with picosecond resolution at TJNAF. All secondary electrons from incident electrons, or from promptly produced secondaries, traverse the RF deflecting system in the same phase, deflected in the same angle and located in the same place on the detector and will be used as reference calibration. Secondary electrons from delayed fragments or recoiling nuclei deflect differently as a function of the relative phase of oscillations in the cavity.

One inherent value of the above method is the expected low insensitivity to relativistic particles, gamma and neutron backgrounds.

In conclusion picosecond RF timing of delayed fragments and recoil nuclei can be performed at TJNAF and other electron accelerators based on the microstructure of the incident beam and isochronous transport system for secondary electrons.

New HYPernuclear and nuclear Program at Electron Accelerators (HYPPEA)

Picosecond RF timing of delayed fragments or recoil nuclei opens unprecedented opportunities for the investigation of hypernuclei and fissioning isomers at electron accelerators, like those at

TJNAF or Yerevan Synchrotron. This new technique can work in coincidence with other existing devices (magnetic spectrometers, etc). Picosecond time resolution allows for the unambiguous recording of a delayed process connected to the formation of hypernuclei, fissioning isomers, etc. RF timing alone or in combination with a recoil distance technique, based on low pressure multiwire proportional chambers (see Fig.1), allows for the first time an electronic recording of the production of doubly strange hypernuclei.

The following physical program based on this new technique can be suggested for electron accelerators (TJNAF, Yerevan, and others).

HYPERNUCLEAR PROGRAM

-The measurement of the hypernuclear lifetimes in the wide range of mass with sub-picosecond resolutions.
-Investigation of the decay channels.
-Gamma spectroscopy of hypernuclei.
-New

NUCLEAR PROGRAM

-Sensitive search for new fissioning isomers with lifetimes in the range of 10^{-9} - 10^{-13} s.
-Investigation of the decay channels of the shape isomers.
-Gamma spectroscopy of the shape isomers.
-The measurement of the optical anisotropy of the shape isomers.

Some investigations of this program (lifetime measurements, study of decay channels, gamma spectroscopy) can be performed at internal beams of Yerevan Electron Synchrotron.

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REFERENCES

1.L.E. Tzopp, Radio Engineering and Electron Physics,4(1959)1936
2.V.P.Bykov, Soviet Physics JETP,v13,n6(1961)1169
3.B.Johanson and T.Alvager, Nucl.Instr.Meth.3(1958)49
4.A.E.Blougrund,Y.Dar,G.Goldring, Phys.Rev. v.120, n4(1960)1328
5.G.Goldring,Nucl.Instr.Meth.,11(1961)29
6.A.E.Blougrund et al.,Nucl.Phys.,45(1963)54
7.A.E.Blougrund et al.,Nucl.Phys.,69(1965)423
8.I. Ben-Zvi et al.,Nucl.Phys.,A117(1968)625
9.I. Ben-Zvi et al.,Nucl.Phys.,A135(1969)153
10.Z.G.T. Guiragossian et al.,IEEE Trans.Nucl.Sci. 20(1973)994
11.A.M.Zibelman et al.,Nucl.Instr.Meth.,141(1977)439
12.G.Comby and R.Meunier, Nucl.Instr.Meth.,A269(1988)246

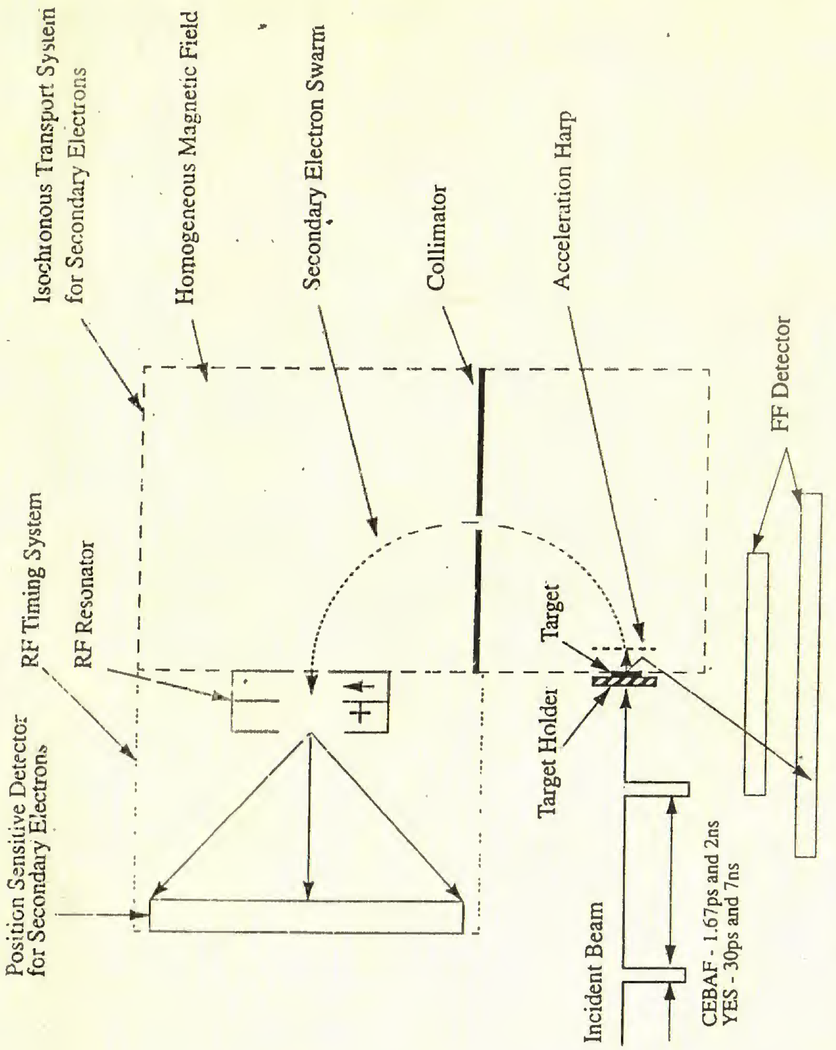

Fig.1. The Principal Scheme of RF Timing for Delayed Recoils or Fragments.
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