1) Title

Prompt Fission Neutron Investigation with Frisch-gridded Twin Back-to-back Ionization Chamber.

2) Introduction

Modern models consider the nuclear fission process as a result of competition between the attractive nuclear and the repulsive coulomb forces. At normal conditions the for majority of heavy nuclei balance between the coulomb and the nuclear forces makes the nuclei stable. The nuclear surface performs complicated motion, consisting of elongations and contractions. When the excitation energy of nuclei increase by external influence the amplitude of surface motion increase and at very long elongations when the nuclear forces became not strong enough to prevent the disintegration, the nucleus splits usually into two parts of comparable mass. Nuclear shell effects make preferable asymmetric scission with the fragments mass ratio about 1.5. One of the main characteristic of fission, therefore, is the fission fragment (FF) mass and kinetic energy distribution. The initial excitation energies of the fragments convey information about the shape of the fissioning nuclear immediately before the scission. The information about excitation energy of the fragments can be concluded from simultaneous measurement of the fission fragment kinetic energies, masses and prompt fission neutron (PFN) emission kinematics.

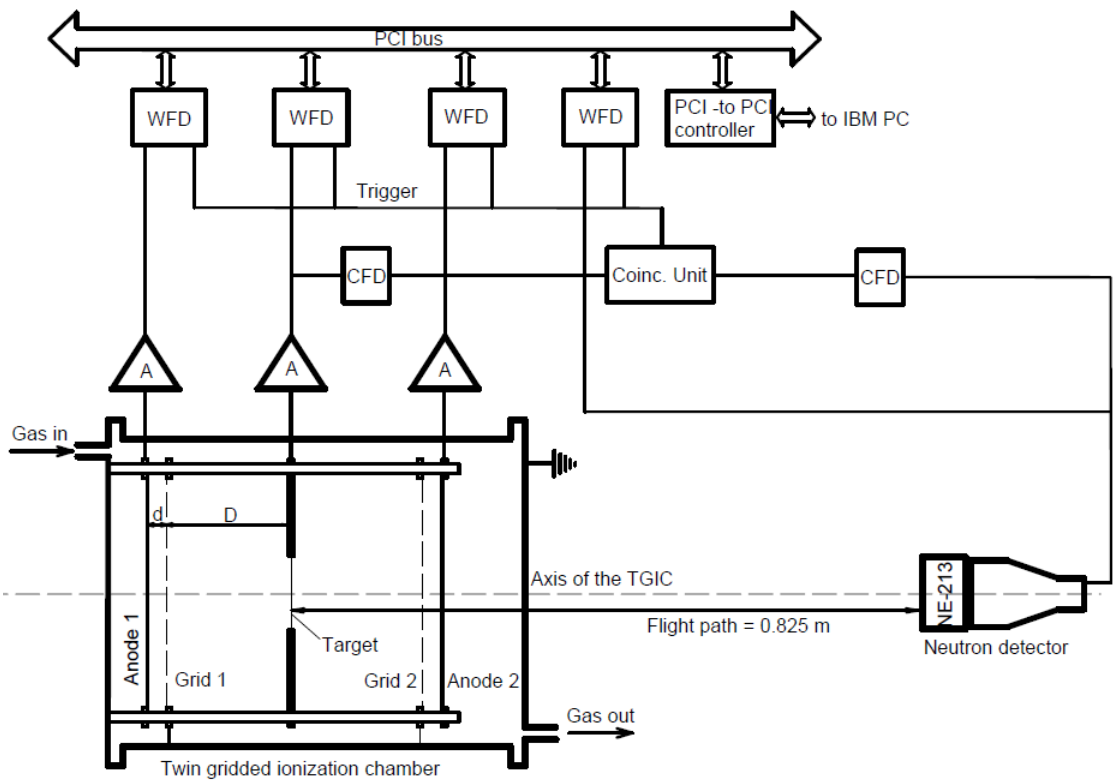

Fig. 1 Sketch of the experimental setup for PFN investigation.

Fig 2. Photograph of twin back-to-back ionization chamber with 235U target mounted on the common cathode.

3) Experimental Setup

A convenient way to study of PFN emission in spontaneous or neutron-induced fission is to use a traditional twin back-to-back ionization chamber (see Fig.1,2), with two chambers sharing a common cathode [2]. The cathode is made from a thin conductive foil and at the same time serves as backing for the fissile deposit. For binary fission events the two complementary FF are simultaneously detected in two independent chambers. Free electrons released by FF deceleration are induced pulses on the chambers anodes and on the common cathode during drift along the applied externally electric field. The pulse height in each chamber was proportional to corresponding FF kinetic energy release and the FF pulse shape conveys information on the FF angle (Θ) in respect to the electric field applied in the direction of the normal to the cathode plane. From the correlated energies obtained in the above double-energy (2E) experiment, FF masses and velocities may be found [2-4]. If the point fissile target located on the common cathode's centre and the fast neutron detector (ND) was positioned at the certain distance along the normal to the target, then the angle between FF and the PFN emission would be equal to Θ. The PFN velocity may be determined from the known flight path and the measured time delay between cathode and ND pulses. Measured FF and PFN velocity vectors then may be used to reconstruct the PFN emission kinematics. The PFN multiplicity distributions in respect to FF kinetic energy release and mass split may be reconstructed by comparison of two sets of FF measurements. In the first experiment fission fragment mass and kinetic energy release should be evaluated from the measurement independent from ND. In the second experiment FF mass and kinetic energy release should be evaluated for the FF coincided with ND. The obtained experimental results are of great demand for theoretical models of fission process development. When the chamber equipped by the anodes composed of the delta strips then the chamber gains position sensitivity. There various principles could be implemented to obtain the position information using ionization chamber. The most simple and popular method based on making up the anode from the strips. Then the ionization charge divided between strips and could be measured if the strips equipped with individual pulse processing electronics. Another way to organize the pulse processing relies on connecting the strips serially making up the chain, on which the ionization charge induced pulses could travel to both ends. In that case only two sets of electronic apparatus can be used for position information analysis. In our team we using both approaches to get position information about charged particles.

4. Main expected achievements
Student working for this projects will be able to get acquainted (under supervisor control) with one or all listed below skills:

modern experiment planning and management,
fission fragment spectroscopy,
alpha particle spectroscopy,
prompt fission neutron detection,
neutron-gamma separation using pulse shape analysis,
PFN energy measurement with time-of-flight technique,
digitization implemented to nuclear detectors, data acquisition software and hardware,
data analysis methods and software, nuclear electronics for experiment organization.
During real measurement student(s) will be able to:
perform measurements of charged particle spectra with ionization chamber (simple or position sensitive) and waveform digitizer,
perform analysis of measurement,
perform data analysis of PFN emission on neutron induced fission of 235U(n,f) experiment acquired during 2016 run of IBR-2 pulsed reactor,
student(s) will perform (or participate in) measurement and data analysis of neutron-gamma separation of PuBe neutron source using waveform digitizers (12 bit 250 MSample/second),
students (upon their will) can learn digital pulse processing algorithms theory and application,
students will be get acquainted with basic principles of position sensitive detector design,
students will be involved in experiments with position sensitive detectors and data analysis,
students will be able to gain basic knowledge about cross-correlation (with Fourier chopper) technique applied to time-of-flight measurements with thermal neutron,
students will be given introduction to cryptographic methods applied to data transmission in open networks,
students can study graphic data encryption/decryption to prevent privacy breach (movies, photographic images),
basic theory and applications of image processing theory and applications

5. Requirements

Student(s) expected to have basic knowledge of experimental nuclear physics or engineering in the framework of university course of nuclear physics, university level in mathematics, very desirable the basic knowledge of computer programming.

6. Recommended literature

1. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (available for free in Internet)
2. C. Budtz-Jørgensen and H.-H. Knitter , *Nucl. Phys.*, A490, 307 (1988).
3. C. Wagemans, The Nuclear Fission Process, Boca Raton: Boca Raton, 1991.
4. Sh. Zeynalov, O.V. Zeynalova, b, F.-J. Hambsch, S. Oberstedt, Physics Procedia Volume 31, 2012, pp 132–140

7. The Number of Students

Up to five person

Supervisors

Shakir Zeinalov, Senior Scientist at FLNP, PhD in nuclear physics.

Olga Sidorova, Senior Scientist at FLNP, PhD in mathematical physics