Studies of Polarized Photofission

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Introduction

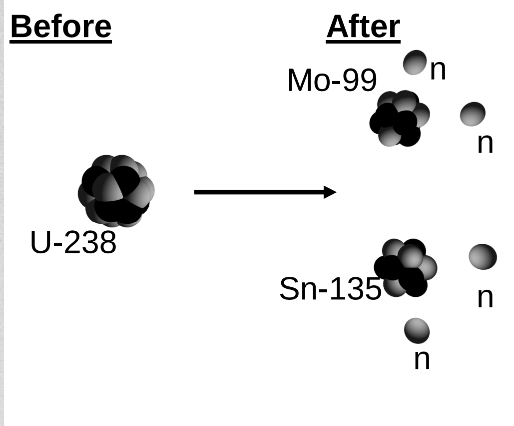
It has long been known that the nuclear fragments resulting from photon induced fission of heavy nuclei are emitted anisotropically when measured with respect to the incident photon direction. The first such measurement, performed with unpolarized photons was done in 1956 by Sommerfeld [1] who showed that the angular distribution depends on the polar angle theta. The introduction of linear photon polarization breaks the azimuthal symmetry by imposing a preferred direction in space perpendicular to the incident photon beam, which was shown in 1982 by Winhold [2] with the measurement of fission fragments from the polarized photofission of thorium.

For linearly polarized photons and considering only electric dipole (E1) transitions, the photofission of an even-even nucleus gives the angular distribution of the fission fragments

$$W(\theta,\phi) = A_0 + A_2(P_2(\cos\theta)) + P_\gamma f_2(1,1)\cos 2\phi P_2^2(\cos\theta)$$

The angular distribution coefficients A_0 and A_2 depend on the transition state (J,K), where *K* is the projection of the total spin J on the symmetry axis of the deformed nucleus. For J = 1, K = 0, we have $A_0 = 1/2$, $A_2 = -1/2$ and for J = 1, K = 1, we have $A_0 = 1/2$, $A_2 = 1/4$. P_γ is the photon polarization, and $f_2(1,1) = 3 \sin^2\theta$. θ is the polar angle with respect to the beam and ϕ is the azimuthal angle ($\phi = 0$ parallel to the electric field vector and $\phi = \pi/2$ perpendicular to E). The asymmetries for fragments emitted parallel and perpendicular to the polarization vector are large even for relatively low polarization.

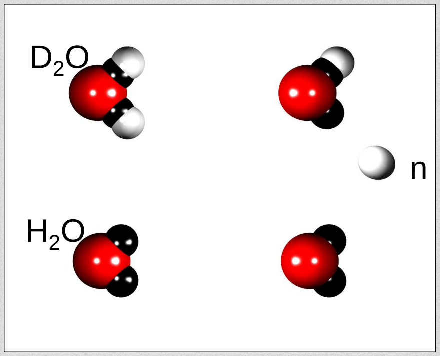
For any target thicker than a few mg/cm^2, of course, the fission fragments are not detectable. The question we wish to address concerns whether or not the angular asymmetry in the fission fragments is manifest in the angular distribution of the prompt neutrons which they emit, thus providing a possible signature for the presence of photofission. Such a technique exploits the unique kinematics of the fission process in conjunction with the relative penetrability of the fission neutrons.

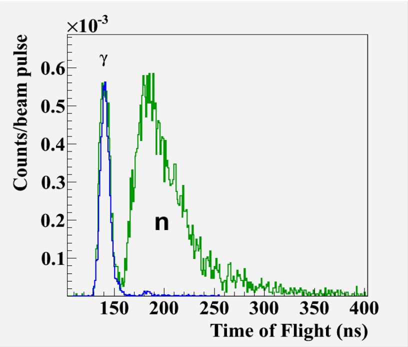


Preliminary Measurements

A low energy electron accelerator can produce 80 mA peak currents which can intersect a radiator target to produce bremsstrahlung photons. The bremsstrahlung photons enter an experimental cell through a collimator configured to select off axis polarized photons. A target (H_2O/D_2O), in the experimental cell, is positioned in the path of the polarized photons. Two neutron sensitive scintillators are placed at 90 degrees to the incident photon beam and in the same plane as a 20 cm long target. A NaI crystal optically coupled to a photomultiplier tube (PMT) was placed off the beamline axis at the end of the experimental cell to monitor the incident photon flux.

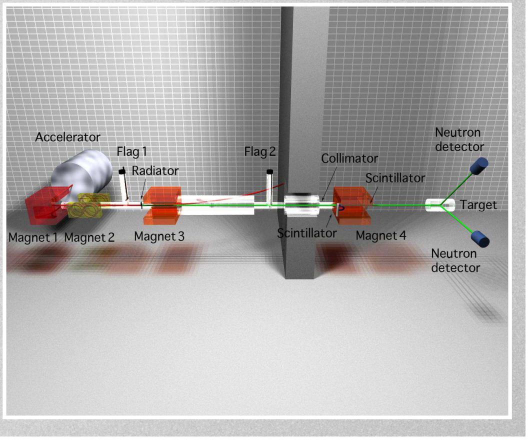
After polarized photons hit the target, both neutrons and photons are emitted and detected by the scintillator detectors. A typical time of flight spectrum is shown on the right with green line representing D_2O (both photon and neutron peaks are present) and blue one representing H_2O (virtually no neutron are detected). Preliminary results demonstrated the possibility of measuring the asymmetry?





Conclusions and Outlook

The possibility of obtaining polarized photons and measuring asymmetries was proved in the preliminary measurements. We propose to optimize our polarized beamline and construct a polarimeter to measure its performance. It consists of a pulsed electron accelerator delivering electrons which are bent 90 degrees in the horizontal plane. In order to change the photon polarization state, the electrons are then bent up or down in the vertical plane before they strike a Ti bremsstrahlung converter. The bremsstrahlung photons propagate down the beamline in a cone with a characteristic opening angle of m_e/E_{beam} radians. A fixed collimator is placed downstream of the bremsstrahlung radiator and is offset in the horizontal plane. This collimator selects bremsstrahlung photons which are off axis from the primary electron beam, and therefore are linearly polarized 45 degrees with respect to the horizontal, with an orientation depending upon the angle of incidence of the electron beam on the bremsstrahlung radiator. Between the radiator and the collimator, a magnet deflects charged particles in the horizontal plane away from the photon collimator. The photons exit the vacuum via a thin window at the downstream edge of the collimator on the downstream side of a concrete wall. This window serves as a thin converter for a pair spectrometer luminosity monitor which is used for relative normalization of the photon flux in the two polarization states. The yields of the electron-positron pairs will be directly proportional to the photon flux at a photon energy given by the position of the plastic scintillator detectors and the pair spectrometer magnetic field setting, thus providing a relative flux normalization between the two polarizations states. The pair converter thickness, electron and positron detector size and position, and magnetic field setting are chosen to provide electron-positron coincidences for about one out of every ten beam pulses in order to minimize accidental coincidences. Electron-positron timing distributions will be recorded in a time to digital converter.



Pulsed electron accelerator	3-16 MeV, 80mA peak current, 25 ns mean pulse width, 1 kHz
Magnet 2 (up-down)	Gamma polarization selector
Magnet 3 (left-right)	Electron sweep
Radiator	Titanium, 10^{-3} radiation length (0.3 micron)
Pair spectrometer	Pair converter – kapton window, 0.25 mm, Magnet 4 – 35T, 20cm; Scintillators – BC-?
Target	Plastic bottle with D_2O/H_2O
Neutron detectors	BC-420

References

[1] Sommerfeld, Atombau un Spektrallinien, Vol. II, Ch. 7, 1967; R.M.Laszewski et al, NIM 228,334 (1985)
[2] Winhold and Halpern, Phys. Rev. 103, 4, 990 (1956)