# Development of PhotoNeutron Target for 30 MeV RF Electron Linac

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A 30 MeV, 3 kW on-axis coupled cavity RF Electron linac is being designed, developed at BARC and will be installed at Vizag . It will be used as a neutron generator and will produce ~ $10^{12}$-$10^{13}$ n/sec. The design of the 94 cell RF structure, rf system, modulator for the electron gun and the Neutron generation target is in the advanced design stage This Accelerator can be used as a Prototype to study the Production of Medical Radioisotopes, Neutron rich Radioactive Nuclei, Energy Driver, Transmutation of Radioactive Waste, to study Electron beam based Nuclear physics including photonuclear reactions and target optimization for photoneutron production. In This paper the study of the target design is discussed.

Neutrons can be produced by electron beams through photonuclear reactions. The total neutron production is composed of two parts: (1) photonuclear reactions via bremsstrahlung, and (2) electroproduction via virtual photons (NCRP 79). In general, the cross sections of electroproduction are expected to be of the order of the fine structure constant, a ~ 1/137, times the cross sections of photonuclear reactions. The neutron yield produced by electroproduction may become important only when the target is thin and the bremsstrahlung yield is low.

GDR neutrons are produced by photons with energies from approximately 7 to 40 MeV. The GDR neutron yields are proportional to the product of the length l of the material traversed by photons of each energy (the photon track-length) and the GDR photoneutron cross section. Two formulas for the differential photon track length are based on Approximations A and B of analytical shower theory (Rossi 1952), where the former includes only the pair production and bremsstrahlung processes and the latter additionally includes ionization losses. The GDR neutron yields are calculated by integrating, over the photon energy spectra generated by electrons, the product of the differential photon track length and the published GDR photoneutron cross sections.

It has also been observed that, most of the energy from the electromagnetic cascade initiated by the electron in a thick target is absorbed, so that neutron yields no longer increase with target thickness. These neutron yields reach saturation when the target thickness is greater than about 7 or 10 radiation lengths.

The GDR neutron yield per incident electron can be determined analytically for each photoneutron reaction, using :

$$Y_{GDR} = \frac{6.023x10^{-4}\rho f N_n}{AE_0}\int_{E_{th}}^{E_{max}} \sigma_{GDR}(k)\left(\frac{dl}{dk}\right) dk$$

Where, $Y_{GDR}$ = GDR neutron yield (neutron electron$^{-1}$ MeV$^{-1}$); $\rho$ = density of target (g cm$^{-3}$); f = isotope fractional abundance; $N_n$ = no. of neutrons produced per photoneutron reaction; A = atomic weight (g mol$^{-1}$); Eo = electron energy (MeV); $\sigma_{GDR}(k)$ = photoneutron cross section (mb); dl/dk = differential photon track length (cm MeV$^{-1}$); k = photon energy (MeV): $E_{th}$ = threshold energy of the reaction (MeV); and $E_{max}$ = upper limit energy of the reaction or the electron energy when upper limit energy of the reaction is larger than the electron energy (MeV).

The expression for dl/dk is given by :

$$\frac{dl}{dk} = 0.572\,\frac{X_0 E_0}{k^2}$$

Where $X_0$ is the radiation length of the target material in cm. The graph has been plotted for various energies from 10 -30 MeV and beam poer of ~ 1 kW. From the above equation, the neutron yield or 30 MeV, 3 kW with Tungsten as a Target has been evaluated and comes out to be ~ $4 \times 10^{12}$ neutrons/sec.

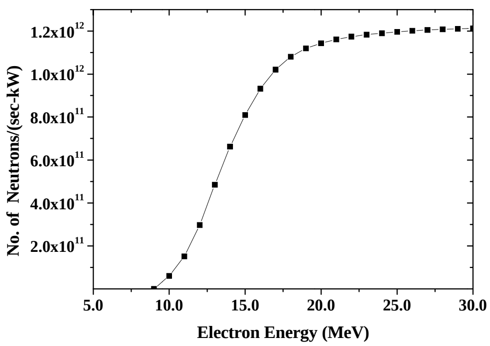


Fig.1 : Neutron yield $sec^{-1}$ $kW^{-1}$ for various energy of electron beam

The prototype photoneutron target has been made from a solid piece of tungsten-copper alloy (75% W and 25% Cu). It is 70 mm in diameter and 60 mm long. It has been brazed to one side a stainless steel CF150 “Conflat” flange using Ag-Cu Eutectic brazing alloy at 820 $^{0}$c. The brazed assembly has been tested upto ~ $10^{-6}$ mbar which was an ultimate vacuum of the pump and He-leak tested upto ~ $5 \times 10^{-10}$ mbar-lit/sec. The assembly is shown in fig. 2 and 3 . With a total beam power of about 3 kW, the face of the target, which is inside the vacuum beam port, will heat up to several hundred $^{0}$C. This heat will be conducted throughout the massive target (> 6 kg) and will be dissipated from its much lower temperature surface by natural circulation of water. The cooling jacket is under fabrication.

Further calculations for Thermal Analysis as well as analysis with FLUKA will be carried out. In addition, various materials and combinations to improve the neutron yield will be studied.

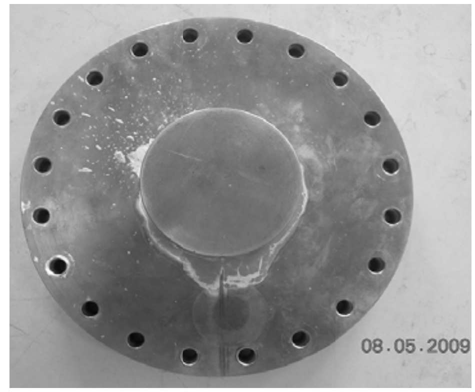


Fig. 2. : Top View of the photoneutron Target

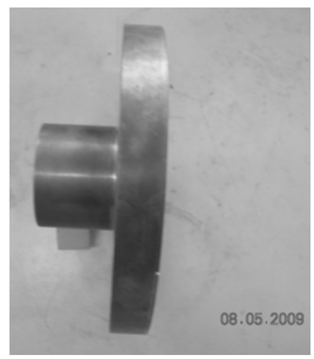


Fig. 3. : Side view of the photoneutron Target.

References :

[1]. Giant Dipole resonance Neutron yields produced by electrons as function of Target material and thickness . X. Mao et. al. SLAC-PUB-6628.
[2]. Calculations of Neutron yields Released by Electrons Incident on Selected Materials., WP Swanson , SLAC-PUB-2042.