Glasgow, Edinburgh, Mainz (GEM) Tagging System

J.D. Kellie, I. Anthony, S.J. Hall, I.J.D. MacGregor, A. McPherson, P.J. Thorley (Glasgow), F. Zettl (Mainz).

The GEM tagging spectrometer system [1] was designed to make best use of the 100% DC MAMI-A beam for doing photoreaction experiments. As the location available for the spectrometer was in the Magnet Hall a non standard design was necessary so that the tagging magnet system could also act as electron beam handling system when the beam was required in Hall 2. This location also offered the possibility of parasitic operation in conjunction with experiments in Hall 2.

The design chosen is shown in fig. 2.1. The spectrometer for residual bremsstrahlung electrons is of the QDD type and there are two extra magnets for beam handling. This system gives a fairly large momentum acceptance range (2:1) and just four magnet settings are needed to achieve a tagged photon energy range of 80-174 MeV using a 180 MeV incident beam. Undegraded electrons exit down the normal beam handling line towards Hall 2 and are normally dumped in a Faraday cup at the far end of the Magnet Hall. Tagged photon energies below 80 MeV are possible either by using lower incident electron energy or by dumping the main beam near the focal plane. Both techniques have been used successfully. The former method allowed energies down to ~50 MeV to be tagged at full intensity while the latter method enabled tagged photons down to ~5 MeV to be used albeit at low intensity.

The focal plane was equipped with an array of 92 overlapping plastic scintillators. The array was read out into 12 TDC's. Gamma-ray and neutron background was reduced by requiring a coincidence between two neighbouring scintillators. The resolving time for all channels is <0.8 ns FWHM and the system operated successfully at total counting rates $>5\times10^7$/sec. With the number of TDC's available it was found to be unprofitable to run at rates higher than this because of the increasingly large corrections required for random coincidences and for multiple hits in the focal plane.

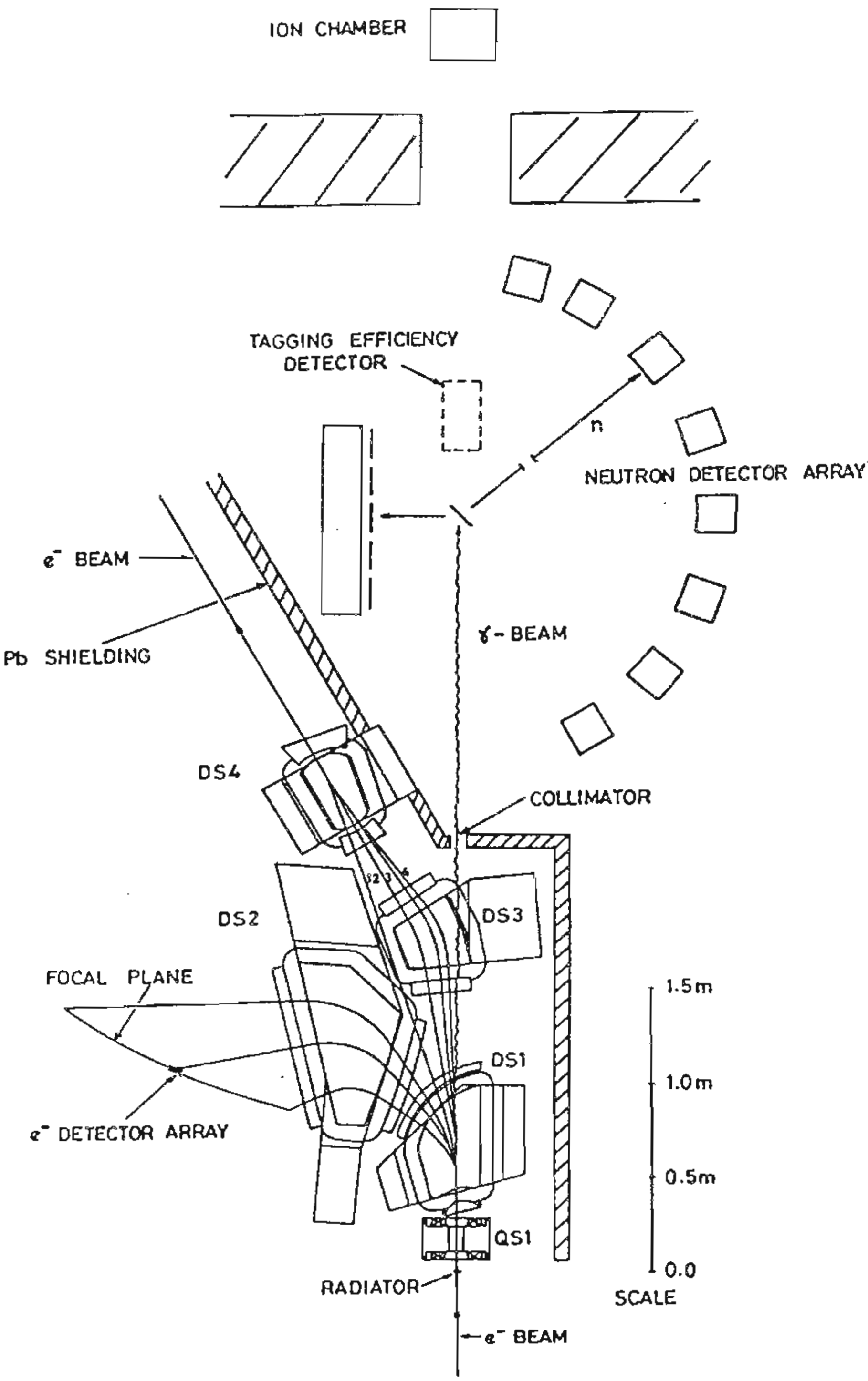
ION CHAMBER
TAGGING EFFICIENCY DETECTOR
n
NEUTRON DETECTOR ARRAY
e⁻ BEAM
Pb SHIELDING
γ - BEAM
DS4
COLLIMATOR
DS2
DS3
FOCAL PLANE
1.5m
DS1
1.0m
e⁻ DETECTOR ARRAY
0.5m
QS1
0.0
RADIATOR
SCALE
e⁻ BEAM

Fig. 2.1

Although the intrinsic resolution of the spectrometer is ~10^{-3} in practice the resolution was set by the focal plane detector array, but was always better than 0.5 MeV. The tagger resolution was nevertheless sufficiently good for all the experiments undertaken and was usually very much better than the resolution of the reaction product detectors.

In order to reduce the photon beam spot to a manageable size (~4 cm dia) a collimator was installed between the Bremsstrahlung target and the photonuclear target (fig. 2.1). This resulted in the fraction of tagged photons reaching the target (ε) being less than unity. A large scintillating glass detector could be inserted in the photon beam (fig. 2.1) in order to measure ε. It was found that the value of ε was rather unstable unless the incident electron beam was aligned accurately along the collimator axis, and a photographic method was developed to do this. Once a suitable "recipe" for positioning the electron beam had been worked out it was possible to set up fairly quickly. The value of ε was reproducible to $\pm 0.5\%$ and agreed reasonably well with a Monte Carlo calculation which took account of multiple scattering in the radiator. A shielded ion chamber downstream of the target was used to check for drifts and the ratio of ion chamber current to the count rate in the focal plane and was found to be very sensitive to small instabilities in electron beam position. Owing to the excellent stability of the MAMI beam corrections were only required about once every 2 or 3 hours.

The tagging spectrometer design envisaged the possibility of using the system in two other ways.

a) To provide linearly polarised tagged photons. The polarisation of off-axis photons can be enhanced if the degraded electrons are restricted in vertical angle. The spectrometer was designed to have approximately point to parallel focusing in the non-bend plane. Hence the electron displacement at the focal plane perpendicular to the mid-plane gives information about the vertical angle and hence about the photon polarisation. From α particle tests [1] it was estimated that a photon polarisation between 30 and 60% was achievable, but these predictions were not tested.

b) Parasitic mode. A series of tests were carried out to assess the feasibility of using the spectrometer in a parasitic mode of operation. This was done by replacing the normal 25μm Al foil radiator with a 20μm thick Ni wire and increasing the electron beam current until typical counting rates of a few times 10^7 were observed from the focal plane detectors. The quality of the electron beam was assessed by noting if any deterioration occurred in data being recorded using the electron scattering facility in Hall 2.

The results were very encouraging since it was found that the on-line spectra recorded in a short test both with the tagging system and in Hall 2 appeared to show no significant degredation compared to similar spectra recorded with dedicated beam. Unfortunately more extensive tests of parasitic operation were not possible and the facility was not used in this mode over an extended period.

Undoubtedly both the above features would have been valuable if the system had been in operation longer. In fact the pressure of 'standard' experiments severely restricted the ability to develop both.

In use over a period of three and a half years and some 2500 hours of beam time the original standards of time resolution, count rate capability and background rejection were sustained with not more than an annual gain check on the channel elements. The photomultipliers now exhibit signs of ageing but still have some useful life left. No electronic component requires replacement.

The tagging spectrometer system was used for many different experiments (see below and contributions from Mainz, Giessen, Edinburgh and RPI). It operated reliably, stably and without failure for lengthy periods and must be judged successful by any criteria.

[1] J.D. Kellie, I. Anthony, S.J. Hall, I.J.D. MacGregor, A. McPherson, P.J. Thorley, S.L. Wan and F. Zettl. Nucl. Inst. Meth. A241 (1985) 153.