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# The upgraded photon tagging facility at the MAX IV Laboratory

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ABSTRACT

A description is given of the upgraded photon tagging facility at the MAX IV Laboratory. Two magnetic spectrometers are used to momentum analyze post-bremsstrahlung electrons. The tagged photon range extends from 10 to 180 MeV with an energy resolution of about 300 keV. The system has been operated at rates up to $4\times10^6$ photons s$^{-1}$ MeV $^{-1}$. Different diagnostic tools are described as well as the experimental program.



## 1. Introduction

The photon tagging technique is employed at several laboratories [1–5] since it provides a method to obtain detailed and accurate information about nucleon and nuclear properties and reactions. The energy of individual post-bremsstrahlung electrons from a thin radiator is measured along the focal plane of a magnetic spectrometer. The photon energy, $E_\gamma$, is obtained as the difference between the energies of the incoming, $E_e$, and residual, $E'_e$, electrons. The photon energy resolution is mainly determined by the width of the individual components of the focal plane detectors, e.g. an array of plastic scintillators. A time coincidence between a reaction product X and a focal plane detector element is used to obtain the photon energy. The normalization is given by the number of electrons in a given bin corrected for the tagging efficiency. The photon tagging technique is well suited for electron accelerators with modest intensities, i.e. less than 100 nA, however, the technique requires a beam with high duty factor due to the coincidence requirements.

The MAX IV Laboratory is a National Facility placed in Lund, Sweden. At present the laboratory consists of a common injector to three electron storage rings: MAX I (550 MeV), MAX II (1.5 GeV) and MAX III (700 MeV), with the maximum energies given within the parentheses. The injector is based on two linear accelerators,

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each with a nominal energy of 125 MeV, and a recirculator resulting in maximum electron energy of 500 MeV. These three rings are used for the production of synchrotron radiation from dipole magnets and insertion devices (undulators and wigglers). The MAX I ring may also be used as a pulse stretcher for energies below 250 MeV. The nuclear physics program at the MAX IV Laboratory began at this ring in 1987, at that time the injector was a 100 MeV race track microtron [6–9]. In connection with the replacement of the microtron and the inclusion of the MAX III ring, the nuclear physics part of MAX I [10], the beam transport system and the experimental cave were upgraded to accommodate an electron beam of 250 MeV. The commissioning of the upgraded tagged photon facility began in 2005 and the experimental program started in 2006.

## 2. Beam transport system

The electron beam from the linac system has a pulse width of about 200 ns with a repetition rate of 10 Hz. This beam arrives at an angle of 30° with respect to the plane of MAX I and is bent into the plane by the septum magnet.

When the injection is finished, the electrons are driven towards the third order betatron tune resonance, used for extraction, by increasing their amplitudes with an amplitude-controlled RF ferrite kicker magnet [10] working at fixed frequency, close to the horizontal betatron frequency. The amplitude of the kicker is slowly ramped over the 100 ms extraction period. A thin electrostatic extraction septum in combination with the magnetic septum magnet is used to bring the electrons toward the experimental area situated in the basement below the MAX I ring.

The beam transport system from the ring to the basement is the same as the system previously used [9]. The 30° magnetic septum magnet is followed by five quadrupoles (Q1–Q5) symmetrically positioned around the center of the section, where Q3 is situated. The quadrupole power supplies are connected into three families (Q1 and Q5, Q2 and Q4 and Q3). This section also contains two pairs of horizontal and vertical steering magnets, and finally a 30° magnet that makes the beam parallel with the basement floor. The energy of the primary electron beam $E_e$ is determined by the currents in the two 30° dipole magnets. The difference between the two values differs by less than 0.4% and the mean value is used for the determination of $E_e$. A 50°, see Figs. 1 and 2, dipole magnet bends the beam in a direction that optimizes the usable size of the experimental area. The last part of the beam transport system contains two steering magnets, one horizontal and one vertical. The electron beam may interact with radiators at two positions, each in front of a magnetic spectrometer (see below), and finally the non-interacting electrons are dumped in a Faraday cup, see Fig. 2.

## 3. Tagging spectrometers

For a given electron energy the bremsstrahlung spectrum resulting from the interaction with a thin radiator, e.g. a metal foil, contains energies from zero to $E_e$. The residual electron energy $E'_e$ is determined by a magnetic spectrometer and the photon energy, $E_\gamma$ is obtained from the equation $E_\gamma = E_e - E'_e$. At the laboratory we have access to two magnetic spectrometers kindly donated by the Saskatchewan Accelerator Laboratory (SAL) after the close down of the nuclear physics activities at that facility. The two spectrometers, one called the main tagger (MT) and the other the end point tagger (ET), are shown in Figs. 1 and 2. Compared to the setup at SAL, the ET has been flipped in order to be able to shield the focal plane detectors from the forward direction of the electron beam from MAX I. With these two spectrometers presently it is possible to obtain tagged photon energies from 10 to 180 MeV.

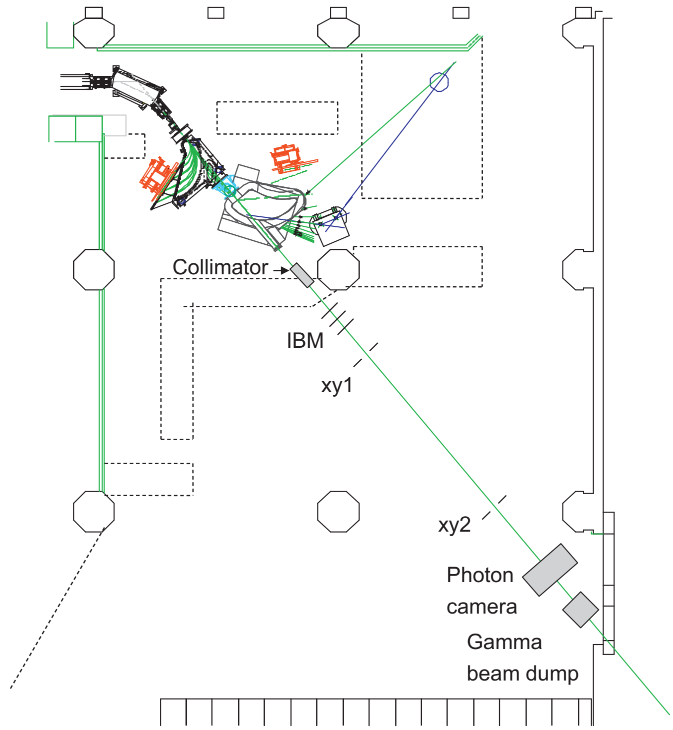


**Fig. 1.** An overview of the experimental area. The shielding walls are shown as dashed lines. The various components of the beam transport system, the tagging spectrometers, beam dumps and diagnostic equipment are described in the text. These components are also shown in Fig. 1.

### 3.1. The main tagger

The so called main tagger (MT) is described in detail in [11]. The spectrometer has a "clam-shell" design with a single, gradient field dipole with flat pole faces tilted to form a wedge-shaped gap. The spectrometer was modified so that the bend angle of the central momentum $P_0$ is about 110° with a parallel-to-point optics in the vertical plane. The maximum central momentum is 200 MeV/$c$ and the momentum acceptance is $\pm 40\%$. The characteristics are given in detail in Table 1 in [11]. The focal plane is flat over the range 0.8–1.4$P_0$ but curved over the range 0.6–0.8$P_0$. The vacuum window consists of 0.5 mm stainless steel with holes for the residual electrons and the primary electron beam. The residual electrons pass a 125 μm thick Kapton foil glued to the stainless steel plate with Araldite 2013. The primary electron beam exits the vacuum chamber through 25 μm stainless steel window glued to the plate with epoxy.

The original radiator chamber, see Fig. 3, contains a horizontally rotating disc with 9 radiator positions. In the "normal" position, the radiator is situated inside the magnetic field 6.55 cm from the vacuum flange (position 1). The spectrometer is designed also to function as a small angle spectrometer, and in this case the radiator is moved back 18.85 cm from the vacuum flange. This moves the focal plane position towards the exit edge of the spectrometer (position 2). A new vacuum chamber was built to house a goniometer with five radiator positions, the central one occupied by a thin diamond used to produce coherent bremsstrahlung (see below). The diamond is positioned 26.5 cm from the vacuum flange, and the focal plane is moved even further towards the exit of the magnet (position 3). The locations of the focal planes, see Fig. 4, were calculated using field maps measured at MAX-lab. The location of positions 1 and 2 is also shown in Fig. 2. The new vacuum chamber is also used for the original SAL wheel, in which case the goniometer is removed.