ENERGY DEPENDENT MEASUREMENTS OF GAMMA AND NEUTRON DOSE AT ANKA

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Abstract

Gamma and neutron radiation dose rates around an electron storage ring are proportional to the number of lost particles in a certain time. They are depending on beam energy, current, lifetime and operating conditions of the storage ring.

The online area monitoring network of ANKA makes it possible to measure the radiation from the decaying beam at eight stations distributed over the ANKA hall. Measurements of the ambient dose at beam energies from 800 MeV to 2.5 GeV show higher dose rates around and in the forward direction of insertion devices and other devices with restricted horizontal or vertical aperture.

INTRODUCTION

ANKA is a 2.5 GeV ramped electron storage ring with a 500 MeV injector. It can be operated at all energies from 500 MeV to 2.5 GeV. An online dose measurement system offers the opportunity to measure and document the gamma and neutron ambient radiation dose every minute. [1, 2]. Gamma dose rates of 2.5 GeV beams, which could not be explained with electron losses only, encouraged the investigation of the beam size and the gamma spectrum in the ANKA hall.

DOSE RATE AND BEAM SIZE DEPENDING ON THE BEAM ENERGY

Special machine shifts were dedicated to the systematic investigation of the radiation dose from the operation of the storage ring at different beam energies and gap sizes of a superconducting in-vacuum undulator [3].

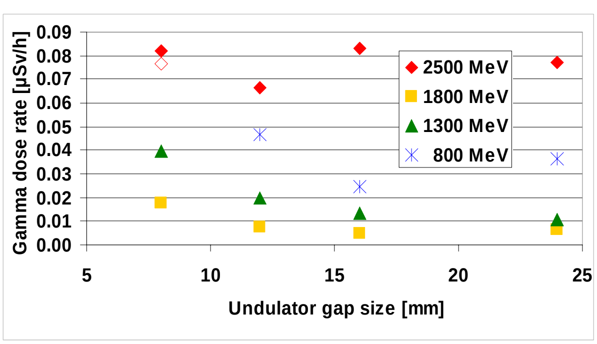

Figure 1: Normalized gamma dose rate vs. undulator gap size.

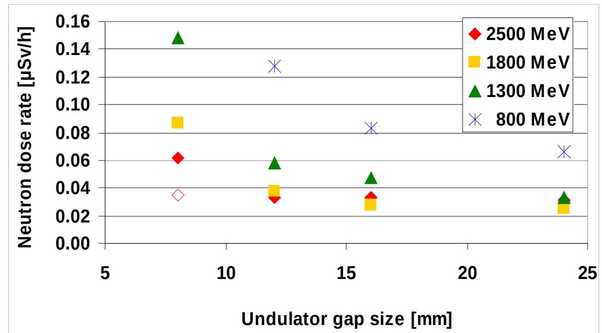

Figure 2: Normalized neutron dose rate vs. undulator gap size.

Fig. 1 and 2 show gamma and neutron dose rates at different gap sizes of the undulator measured by the monitor station next to the undulator. They are normalized with the beam current, which is set equal 1 mA. The dose rate is increasing with decreasing gap width due to the increasing electron losses at small apertures. It is higher for lower beam energies, except the gamma dose rate from 2.5 GeV beams, because higher beam energies are stabilizing the beam orbit and the beam is smaller at higher beam energies.

Fig. 3 shows the vertical beam size measured with a camera in a diagnostic beam line for different beam energies and currents. It starts with 70-80 µm for 800 MeV and 1.3 GeV beams, decreases to 65-70 µm for 1.8 GeV beams and 55-60 µm for 2.5 GeV beams. The smallest beam size of 53 µm is achieved at 2.5 GeV with low beta optics.

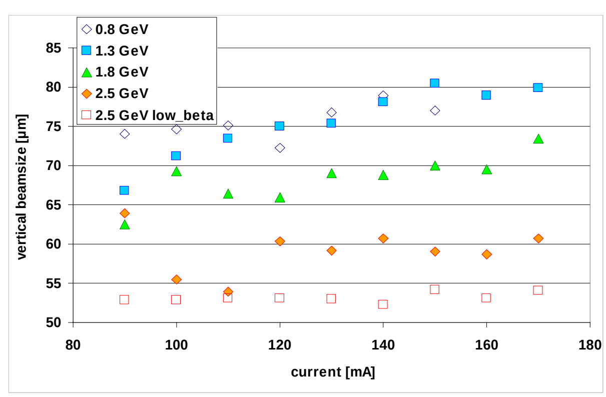

Figure 3: Vertical beam size vs. beam current and energy.

As shown in Fig. 1 the gamma dose rate of 2.5 GeV beams is higher as expected, if electron losses are the only reason for high dose rates, and it is almost not changing with the undulator gap size. Therefore a machine shift

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was dedicated to the measurement of radiation dose, beam size and gamma spectra at different beam energies.

The storage ring was filled with 180 mA. The beam was ramped to 1.6 GeV. At 1.6 GeV the ramping was stopped and the vertical beam size and gamma spectra were measured. Afterwards the storage ring was ramped in steps to 2.5 GeV with stops at 1.8, 2, 2.2, 2.3 and 2.4 GeV for the measurement of gamma spectra at these energies. Beam size and radiation dose were monitored continuously. Fig. 4 shows beam current, energy and lifetime.

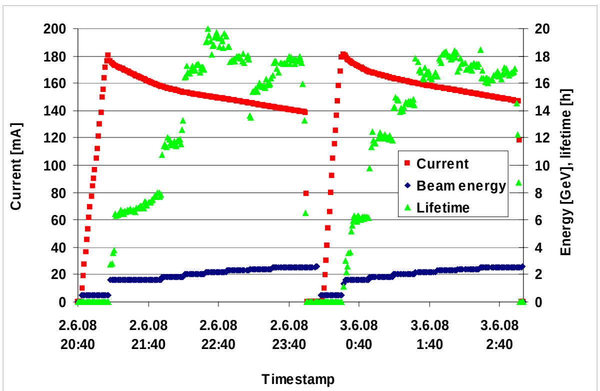

Figure 4: Special machine shift for gamma spectra.

Fig. 5 shows beam size, beam energy and current of one fill. The beam size decreases continuously with decreasing current and increasing beam energy with a jump at 2.5 GeV due to the machine optics. Near 2.5 GeV the machine optics is changing from 100 nm optics to 50 nm optics.

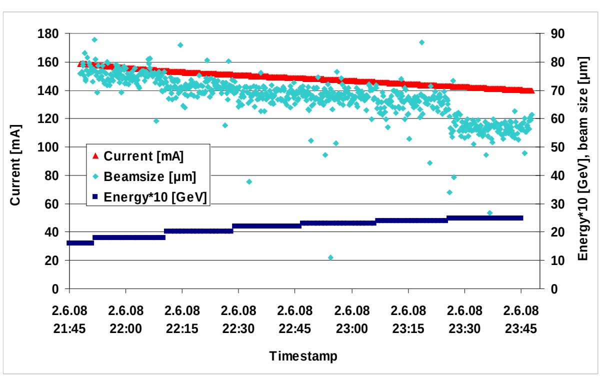

Figure 5: Beam size measured at various beam energies.

Fig. 6 and 7 show the related gamma and neutron radiation dose rates. The highest dose rates are measured from beam dumps and during injection. The neutron dose rate is almost constant after ramping to 1.6 GeV, whereas the gamma dose rate is increasing at beam energies higher than 2 GeV.

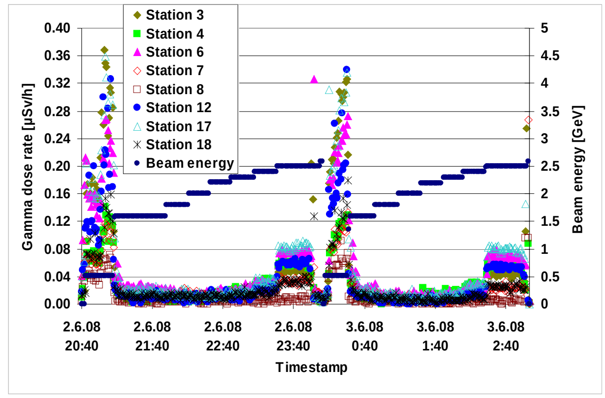

Figure 6: Gamma dose rate measured at special shift.

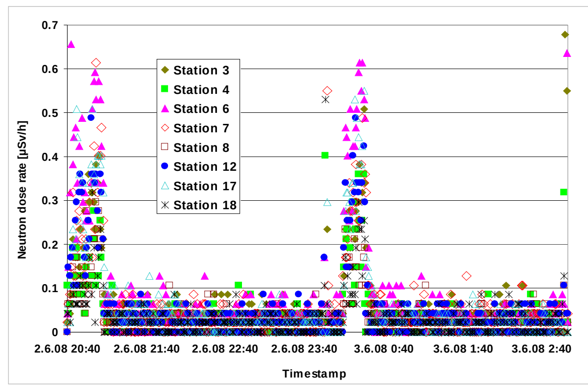

Figure 7: Neutron dose rate measured at special shift.

ENERGY DEPENDENT GAMMA SPECTRA

Gamma spectra were measured with a handheld spectrometer. The detector of the spectrometer is a 38 mm long NaI(Tl) crystal with a diameter of 30 mm. The measuring range is 25 keV to 3 MeV. It is calibrated with an internal Cs-137 source. The data are stored in 1024 channels.

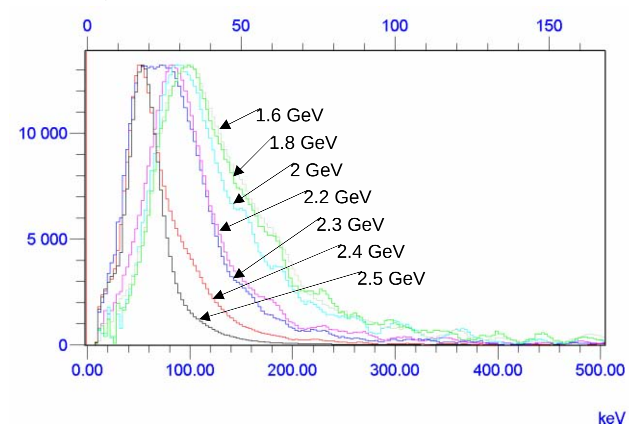

Figure 8: Measured gamma spectra scaled to the same height of the main peak.

Fig. 8 shows the gamma spectra after the subtraction of a background spectrum, which was measured several times, when the storage ring was empty. The spectra are scaled to the same height of the main peak. The lower horizontal scale shows the photon energy in keV. The upper horizontal scale shows the channel numbers of the spectrometer. The vertical scale shows net counts in 10 minutes of the 2.5 GeV spectrum.

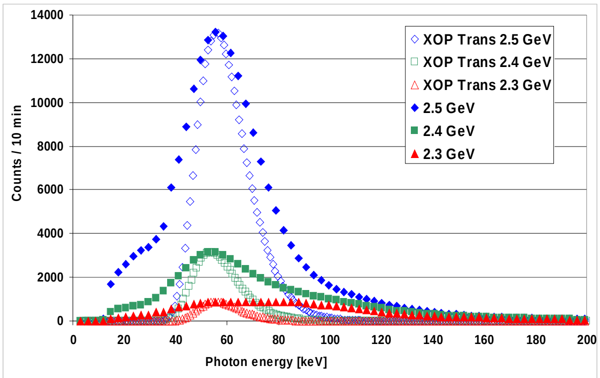

Figure 9: Measured gamma spectra and calculated synchrotron radiation spectra.

Fig. 9 shows gamma spectra measured at 2.3, 2.4 and 2.5 GeV and calculated synchrotron radiation spectra for the same energies. The spectra were calculated with XOP [4]. A 2 mm thick steel filter was assumed, because the vacuum chambers are made of this material. The vertical scale shows counts in 10 minutes from the measured spectra. The calculated spectra were scaled to the peak height of the measured spectra.

A shoulder in the low energy range of the measured 2.5 GeV spectrum indicates a second line. This line was identified by subtracting a fitted 2.5 GeV spectrum from the measured spectrum (see Fig. 10). The criteria for the fit were to keep the shape of the transmission spectrum that was calculated with XOP and the line width of the measured peak, because the peaks of the measured spectra are broadened by multiple scattering and the sensitivity of the spectrometer.

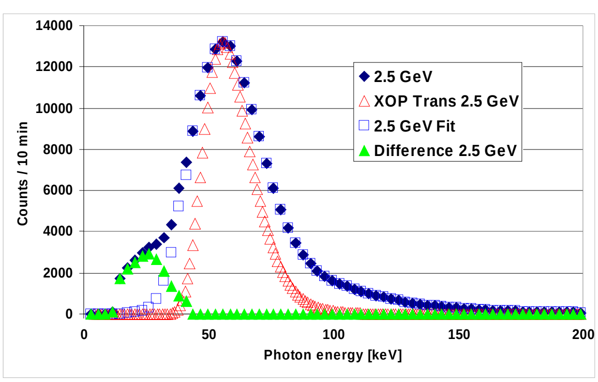

Figure 10: Gamma spectrum measured at 2.5 GeV and transmission spectrum fit.

Fig. 11 and 12 show the same calculations for the 2.4 and 2.3 GeV spectra. The fitting parameters of the calculated spectra were taken from the 2.5 GeV fit. The green triangles are indicating the two resulting peaks after the subtraction of the synchrotron radiation peak from the original spectrum. The high energy peak is the bremsstrahlung peak that becomes broader at lower beam energies.

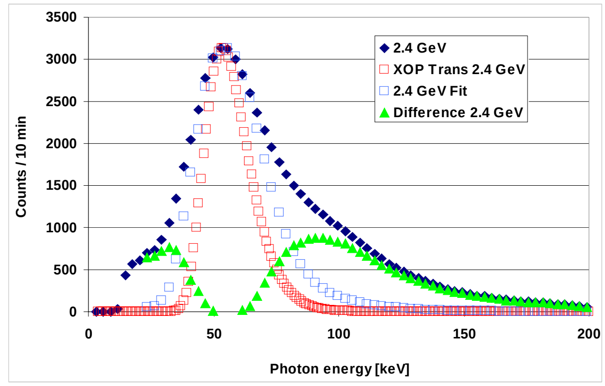

Figure 11: Gamma spectrum measured at 2.4 GeV and transmission spectrum fit.

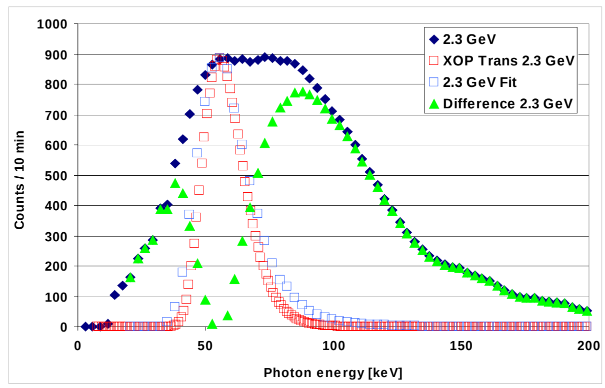

Figure 12: Gamma spectrum measured at 2.3 GeV and transmission spectrum fit.

CONCLUSION

The high gamma dose rates measured for 2.5 GeV beams as shown in Fig. 1 result from the rapidly growing synchrotron radiation of high energy beams. They don't depend on the undulator gap size, because the vertical beam size is decreasing with the beam energy and the machine optics used for 2.5 GeV beams causes less electron losses in the insertion devices.

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