# INVESTIGATION OF MACHINE OPERATION AND RELATED RADIATION DOSE AT THE ANKA STORAGE RING

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*Abstract*

A new online network for radiation dose measurements offers the opportunity to register the dose rate at the ANKA storage ring every minute. The network consists of six mobile and two stationary monitors with a gamma and a neutron detector and a central computer. The analysis of the dose rate shows a strong correlation between beam energy, beam current, machine parameters and dose rate.

## INTRODUCTION

ANKA is the synchrotron light source of the research centre Karlsruhe in Germany. It is a 2.5 GeV ramped electron storage ring with a 500 MeV injector [1]. The storage ring can be operated at any energy from 500 MeV to 2.5 GeV. It is surrounded by a 3 m high and 80 cm thick concrete shielding wall. During operation of the storage ring all parts above 3 m are not accessible, except the stairs to the control room and the rooms in the first floor of the extension of the ANKA hall.

## DOSE MEASURING EQUIPMENT

During the commissioning of the ANKA storage ring we found out, that we can operate the facility with less than 1 mSv radiation dose per year (2000 working hours) in the at machine operation accessible parts of the ANKA hall. This gave us the opportunity to detect the personnel dose by area monitoring (Fig.1).

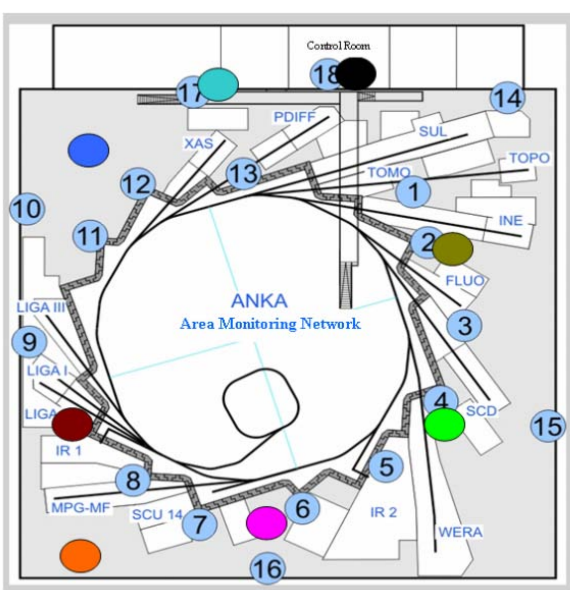


Figure 1: Area Monitoring Network

We installed an area monitoring network with two fixed monitor stations at the gallery in the first floor and the control room and six mobile monitors mounted on carts, which can be connected with the central computer at 16 interface boxes all over the hall. Every station consists of a gamma ion-chamber and a neutron counter with local data processing electronics, a monitor interface and a beacon for alarms (Fig. 2).

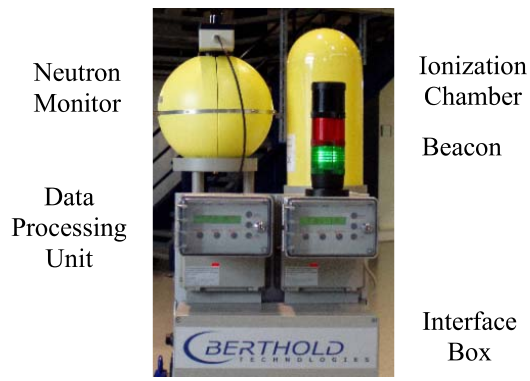


Figure 2: Mobile dose monitor.

The gamma ionization chamber probe consists of a high pressure ionization chamber and a current to frequency converter. The measurement range of the probe is 50 nSv/h to 75 Sv/h, the energy range is 45 keV to 10 MeV. The 45 keV limit is due to the steel chamber.

The neutron probe is a REM counter for high energy neutrons measuring ambient dose equivalent with a $^3$He tube centred in a moderating polyethylene sphere. Our version of the probe has a 10 mm thick external spherical lead layer for neutrons with energies up to 500 MeV. A prototype of that monitor has been calibrated at the CERF at CERN in Geneva/Switzerland [2].

## ANKA OPERATION

### *User Operation*

The ANKA storage ring can be operated at any energy from 500 MeV to 2.5 GeV. For normal user operation we have two injections per day, one in the morning and one in the evening. We inject about 200 mA at 500 MeV, ramp the beam to 2.5 GeV, let it decay until the next injection, dump the remaining beam, prepare the machine for the new injection and inject again. Fig. 3-5 show two days of user operation and screen dumps of the total dose rate (sum of gamma and neutron dose rate) and the integrated dose. The values include the dose from natural background radiation.

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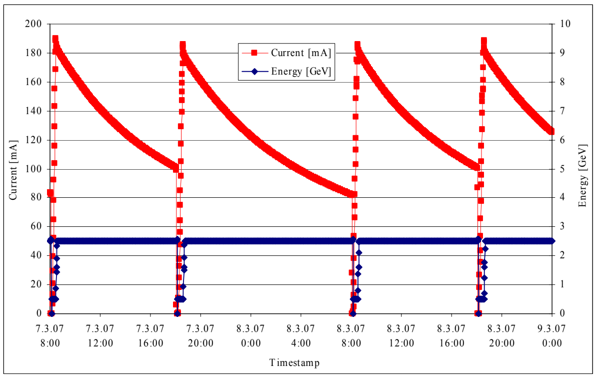


Figure 3: User operation, current [mA], energy [GeV].

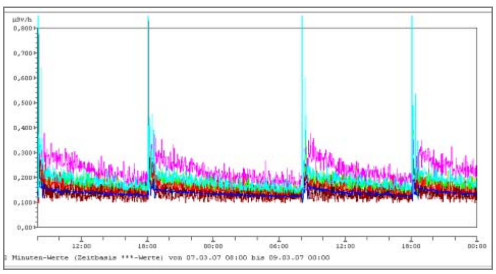

Figure 4: Dose rate [µSv/h].

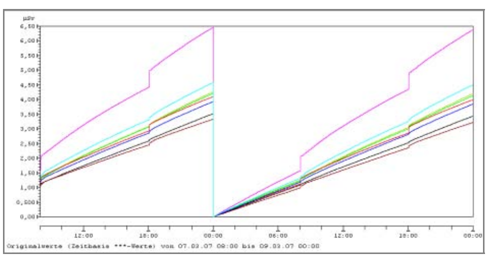

Figure 5: Integrated dose per day [µSv].

The highest dose rate starts at about 300 nSv/h for a 180 mA beam right after ramping the beam and it ends at about 150 nSv/h before dumping about 80 mA. Dose and dose rate are not corrected for natural background radiation. The natural background at machine off is about 90 to 100 nSv/h.

The integrated dose per day starts at midnight. It has steps from beam dumps and injections. The highest values are measured at station 6, which stands next to a straight section with a superconducting undulator. Before the undulator is a scraper chamber installed that protects it against the synchrotron radiation of the upstream dipole. The control system closes the inner horizontal scraper at about 2.4 GeV. The horizontal scraper becomes the smallest horizontal aperture in the storage ring and the beam gets lost at the smallest aperture.

The integration of the total dose for a beam shift from 8:00am to 6:00pm gives about 7% dose from the injection of 190 mA, 1 % from ramping, 80 % from the decay to 100 mA and 13 % from the beam dump. The value for the beam dump goes up to 25 % in the forward direction of the superconducting undulator.

## *Machine Shifts*

The beam dump causes a not negligible part of the radiation in the ANKA hall. A special machine shift dedicated to radiation dose caused by beam dumps is shown in Figures 6 and 7.

Figure 6 shows the injection of a certain amount of current, the ramping to 2.5 or 1.8 GeV, the decay of the beam for about 30 minutes and the beam dump.

Figure 7 shows the related integrated dose, including the natural background (maximum dose 8.7 µSv).

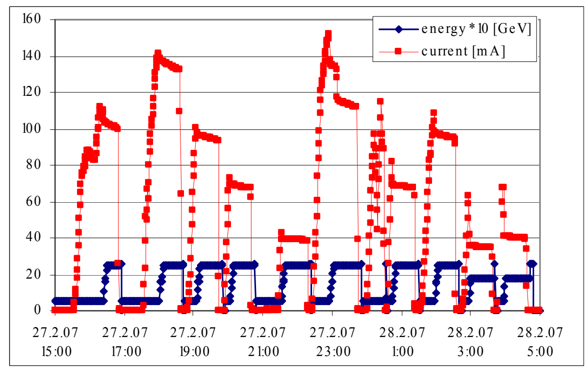


Figure 6: Machine shift, current [mA], energy [GeV].

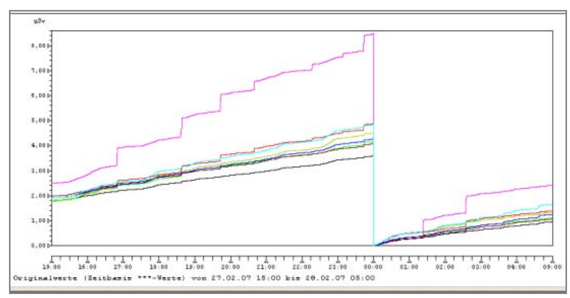

Figure 7: Machine shift. Integrated total dose.

The ANKA storage ring has two operational insertion devices. A superconducting in-vacuum undulator with a period length of 14 mm and 100 periods in the long straight section next to station 6 and a 2 m long permanent magnet wiggler with a period length of 74 mm in the long straight section parallel to the gallery. The vertical aperture of the wiggler vacuum chamber is 16 mm.

The wiggler gap is usually closed to 25 mm for the commissioning of the wiggler beam line. The undulator gap is variable in steps from 20 mm to 16, 12 and 8 mm. Machine operation with 8 mm undulator gap requires a special low beta optics. The wiggler gap size was 25 mm for all measurements.

For beam dumps at user operation the beam shutters in the beam line front ends are closed and the undulator gap is open. For these special machine shifts the front end shutters were closed all the time, but the undulator gap was kept at the given gap size for the beam dumps.

 

Figure 8 shows the integrated gamma dose vs the dumped charge for 2.5 GeV beams and 20 mm undulator gap. The radiation dose is a linear function of the amount of dumped charge. The highest doses were measured by the monitor stations 6 and 7, next to the undulator and in the forward direction of the undulator.

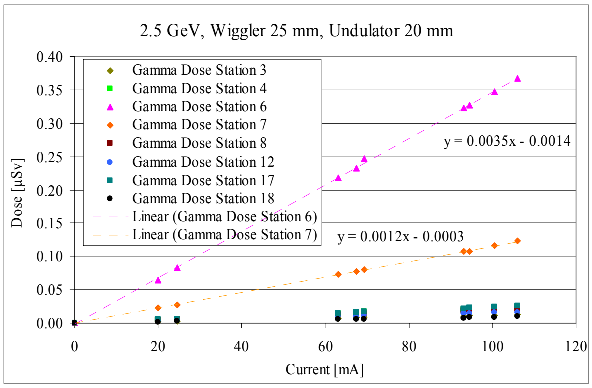


Figure 8: Integrated gamma dose vs dumped current.

Measurements of the radiation doses with an older area monitoring network showed that the distribution of the dose in the ANKA hall depends on the machine optics [3]. The sum of the dose over all monitor stations is a constant depending on the energy of the beam and on the amount of dumped beam.

Figure 9 shows the sum of the gamma dose over all monitor stations for dumped 2.5 GeV beams, 25 mm wiggler gap and 20 mm undulator gap.

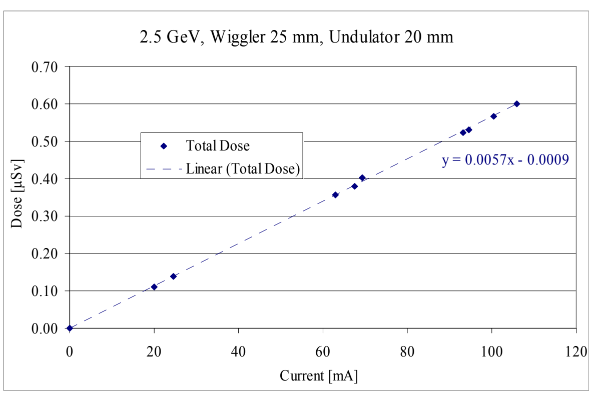


Figure 9: Gamma dose from beam dumps at 2.5 GeV. Sum over all monitor stations.

Measurements of beam dump related gamma or neutron doses at 500 MeV, 800 MeV, 1.3 GeV and 1.8 GeV showed the same behaviour.

Figure 10 shows neutron doses from beam dumps at 1.8 GeV with 12 mm undulator gap. The most obvious fact is, that the highest radiation doses at 1.8 GeV are measured in the forward direction of the injection septum, indicated by the blue points.

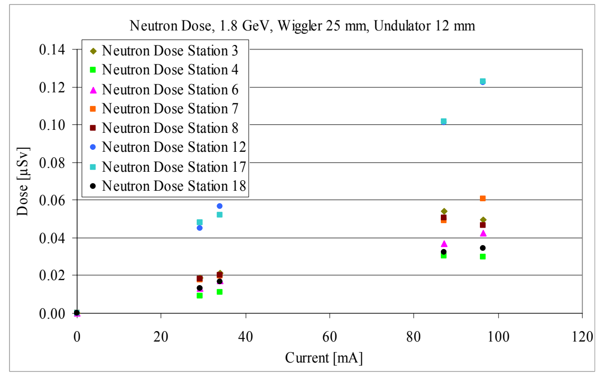


Figure 10: Neutron dose from beam dumps at 1.8 GeV. Undulator gap size 12 mm.

The distribution of the radiation dose from a certain amount of current varies with the energy of the beam. But the sum of all doses in the ANKA hall should depend on the amount of dumped beam current and the energy of the beam.

Figure 11 shows the sum of all measured doses per station at 2.5 GeV and 20 mm undulator gap divided by the current.

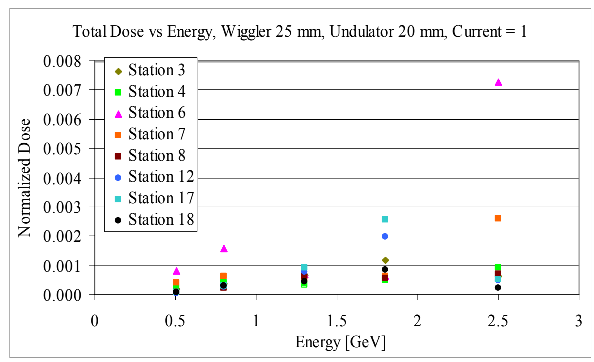


Figure 11: Normalized total dose vs energy.

The sum of all doses per energy goes quadratic with the energy.

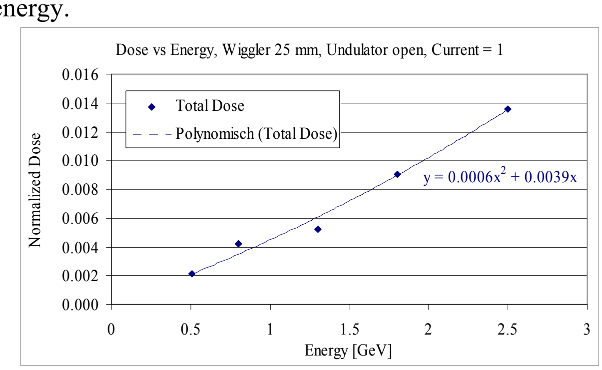


Figure 12: Normalized total dose from beam dumps. Sum over all radiation monitors.

## REFERENCES

[1] http://www.fzk.de/ANKA
[2] A. Klett et al., Radsynch'04, SPring-8, Japan, 2004
[3] I. Birkel et al., Proceedings of the EPAC'2006, pp. 3323-3325