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A. Esposito, M. Pelliccioni and A. Rindi: RADIATION DOSES AT
AN ELECTRON AND POSITRON LINAC AND STORAGE RING.

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The INFN National Laboratory of Frascati (Italy) makes use of an high energy Linac for different physics experiments and for feeding an electron-positron storage ring (ADONE).

For radiation protection purposes we have performed a series of gamma dose measurements during the running of the accelerators along the Linac beam line and the concrete tunnel that covers the Linac as well as along the storage ring.

Generalities.

The Linac, whose total length is 80 m, is composed of 12 accelerating sections where the electrons or positrons are accelerated up to an energy of about 440 MeV and 360 MeV respectively. The Linac consists of a first high intensity section, the first 4 accelerating sections, where electrons are accelerated up to about 80 MeV reaching intensities up to 1A; at that point of the beam line an electron-to-positron converter can be introduced. It is made either of a high duty cycle target consisting of a cylinder of copper 13 mm thick, used for experiments with positrons, or of an high efficiency target made of tungsten 4 mm thick used for generating positrons to be injected into the ring. In the second part of the Linac the electrons or positrons are either accelerated to the maximum energy and directed toward the experimental facilities or accelerated to the energy needed for the injection into the storage ring (about 300 MeV). The pulse length can be varied between about 0.01 μ s and 4 μ s; repetition rates up to 200 Hz can be achieved. The maximum duty-cycle of the beam is 6×10^{-4} ($6 \times 10^{-2}\%$). At the upper energies, maximum currents of 100 mA for e^- and 500 μ A e^+ can be achieved. The electrons and positrons can be injected into the storage ring. It consists of a torus of about

16 m radius where the e^- and e^+ are further accelerated in opposite directions by two accelerating cavities up to 1,5 GeV and are let to collide. The average intensity of each beam is 100 mA (i. e. 2×10^{11} particles). Luminosities up $10^{34} \text{ cm}^{-2} \text{ hr}^{-1}$ have been reached. Typical injection currents at the entrance of the ring are 25 mA for the e^- and 100 μA for the e^+ at 1 Hz.

The Measurements.

Harshaw TLD 700 LiF thermoluminescence dosimeters were used for the measurements. A ^{60}Co source was used for the calibration.

a) Measurements in the Linac. We measured the gamma-ray doses along the beam line: the dosimeters were installed as close as possible to the vacuum chamber, between the accelerating sections. At corresponding locations dosimeters were put on the walls of the concrete tunnel enclosing the Linac (1 m and 2 m from the vacuum chamber respectively).

Fig. 1 shows a map of the Linac indicating the position of the detectors.

Fig. 2 line A shows the results of a measurement made with the Linac accelerating 45 mA of e^- to 271 MeV into the storage ring. The data of Fig. 2 line B were taken with the Linac accelerating 65 mA of e^- to 294 MeV into the storage ring. In both cases about 5 mA of beam were lost in the Linac, as indicated by beam monitors at the input and at the output of the Linac; pulse length was $4 \mu\text{s}$ and frequency 1,5 Hz.

In Fig. 3 we show the results of measurements performed with the Linac accelerating 280 mA of e^- at 80 MeV into the converter and then accelerating 150 μA of e^+ into the storage ring.

By comparing Fig. 2 A and B we see that the electron losses vary from one run to the other even when the accelerating conditions are about the same. This can be due to the fact that during the routine operation of the Linac the operators do not control the beam leakages provided they have the desired intensity and energy at the end of the Linac.

Fig. 3 shows, as expected, a high dose rate peak at the converter and a different leakage distribution along the beam line as compared with Fig. 2. The dose rates at the end of the Linac are much higher for the e^- case than for the e^+ case due to the difference between beam intensities.

Fig. 4 A and B show the dose rates at the walls of the tunnel at positions symmetrical to the positions of the measure -

ments along the vacuum chamber (Curve A for the e^- beam conditions of Fig. 2 A and curve B for the e^+ beam of Fig. 3).

As expected, the differences in the dose rates for the two cases at the converter region and at the end of the Linac are emphasized.

At two positions along the Linac, measurements were performed on a line perpendicular to the beam line when accelerating e^- (Fig. 5). One can see that the variation of the dose rate with the distance from the beam line follows roughly a $1/r$ law (dotted lines).

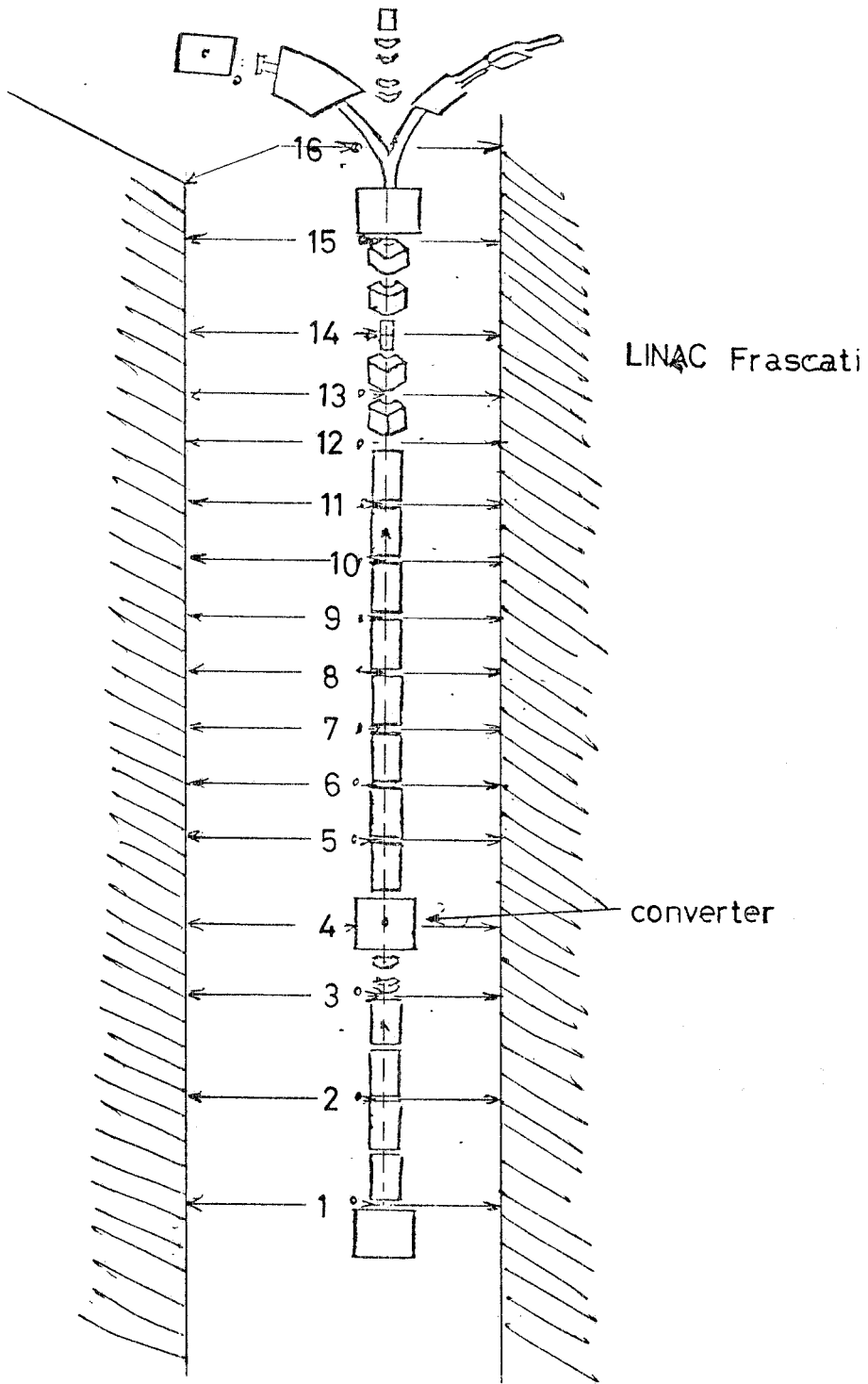
A measurement of absorption into a polyethylene phantom was performed close to the converter area when accelerating e^+ . The results are shown in Fig. 6 Curve A.

Assuming a $1/r$ variation of the dose with the distance from the vacuum chamber also under these machine conditions and subtracting that contribution from the absorption curve A, one obtains the curve B of Fig. 6. This operation is not strictly correct because we do not know the exact shape of the variation with the distance and the contribution due to the back-scattering from the wall: however we think it is correct to infer that the attenuation inside the phantom is very small i. e. the gamma rays generated at 90° at the converter are quite energetic.

b) Measurements in the storage ring. In Fig. 7 we show a map of the storage ring with the indication of the measurement points. The dosimeters were installed as close as possible to the vacuum chamber: given also the curvature of the ring, one can assume that the dose at the detector is representative of the leakage at the measurement point. The dosimeters were left in position for different lengths of time (several days) during which the beams were injected and "lost" into the ring several times. We do not have an indication of the total number of e^- and e^+ that were injected and lost into the ring during these periods. The number of injections was used as a parameter; it is not strictly correct because, due to imperfect machine conditions, different injection times may be required before reaching the desired stable current and energy in the ring.

In Fig. 8 we show the results of measurements for two different periods and different number of injections: curve A refers to measurements performed in November 1977 during 50 injections and curve B to measurements performed in January 1978 during 74 injections. They show that, with the exception of a few typical leakage points like the deflectors

and the accelerator cavities, the other leakages vary from one period to the other and, as expected, the intensity of the leakage is not related to the number of injections.



Electron LINAC

FIG. 1 - Map of the Linac.

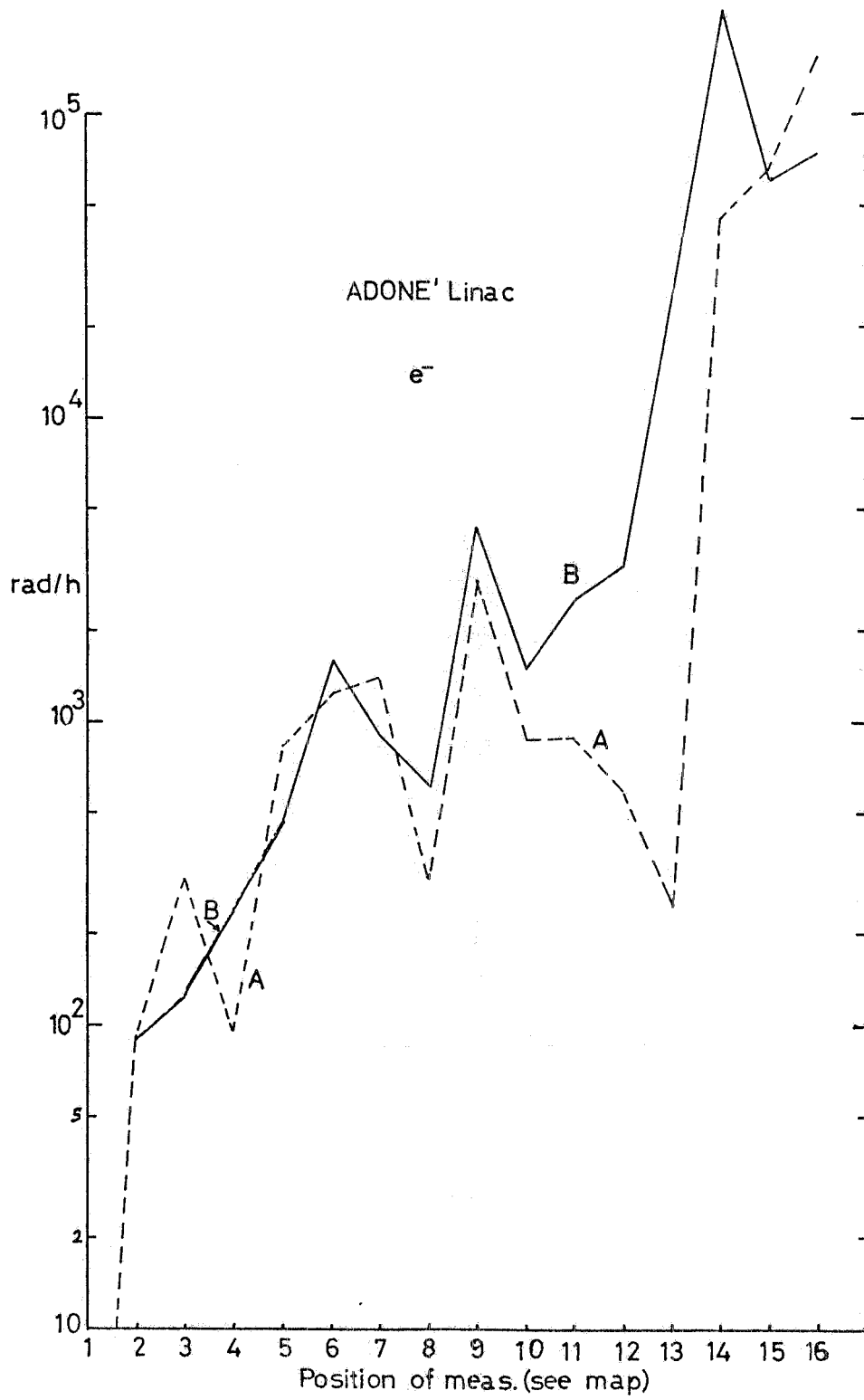


FIG. 2 - Dose rates in the Linac Tunnel for acceleration of e^- (A: $i=45$ mA, $E=271$ MeV; B: $i=65$ mA, $E=294$ MeV).

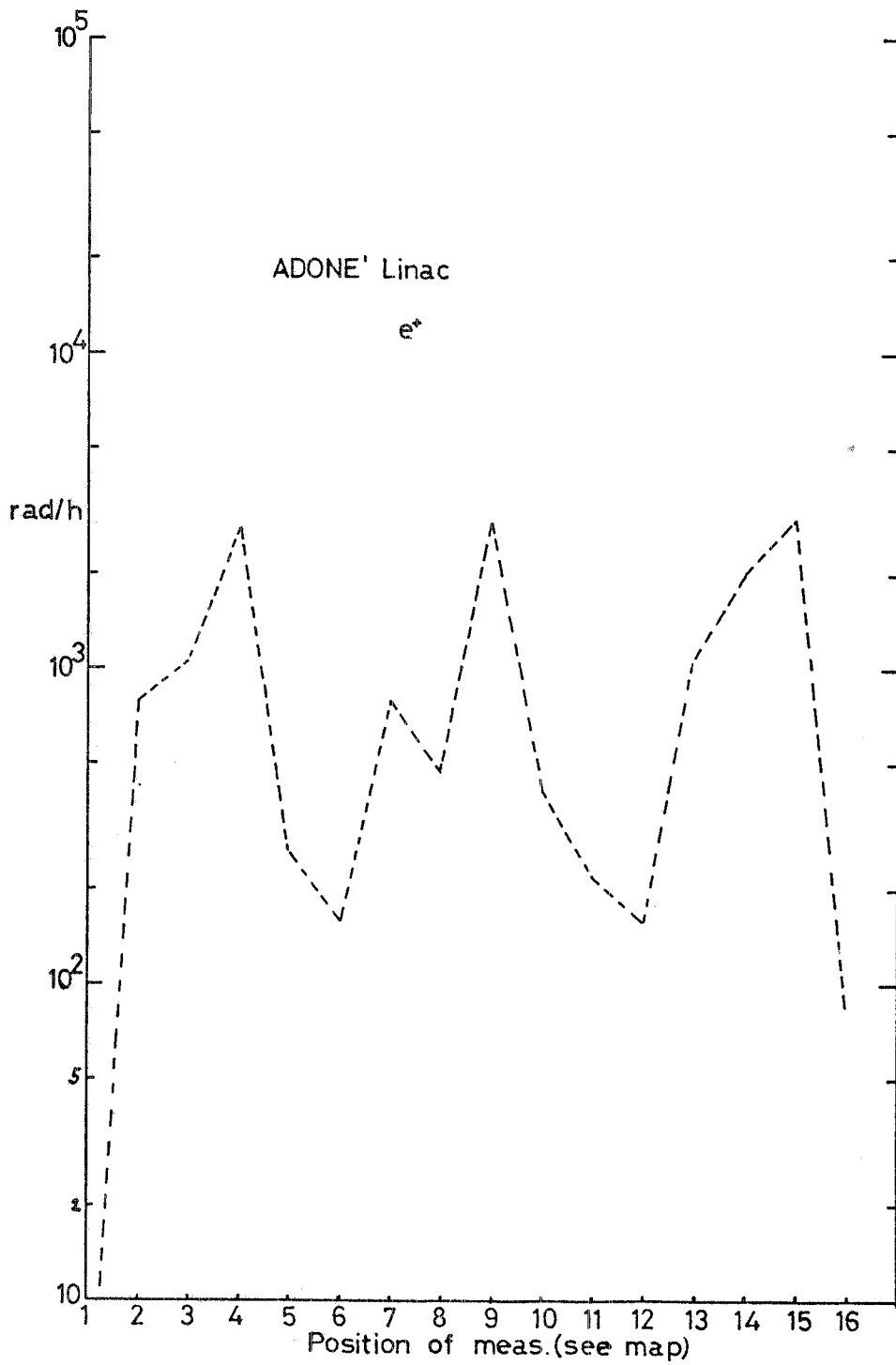


FIG. 3 - Dose rates in the Linac Tunnel for acceleration of e⁺ (i = 280 mA, E = 8 MeV into the converter; i = 150 μ A, E = 300 MeV into the storage ring).

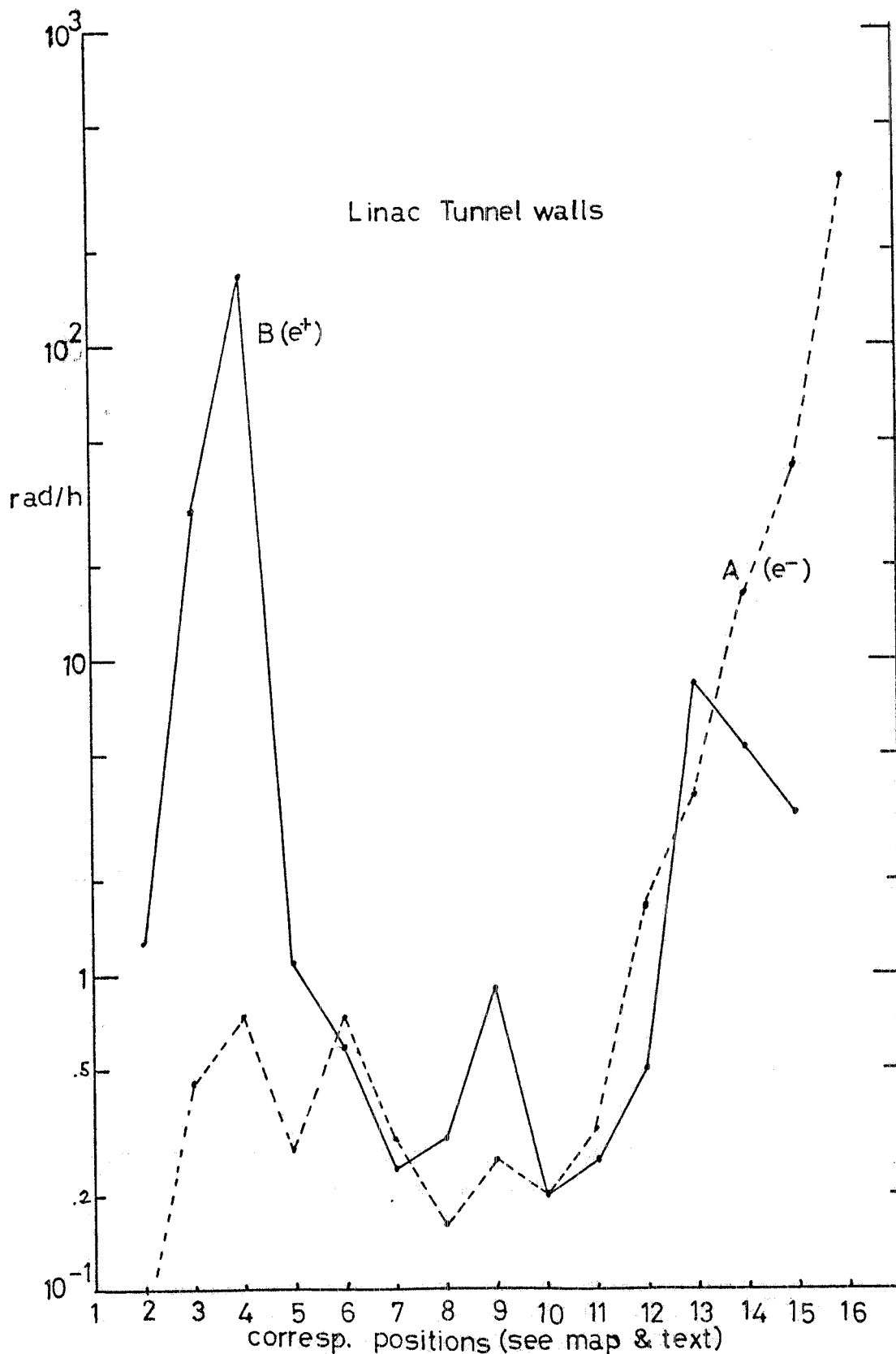


FIG. 4 - Dose rates along the walls of the Linac Tunnel for acceleration of e^+ and e^- .

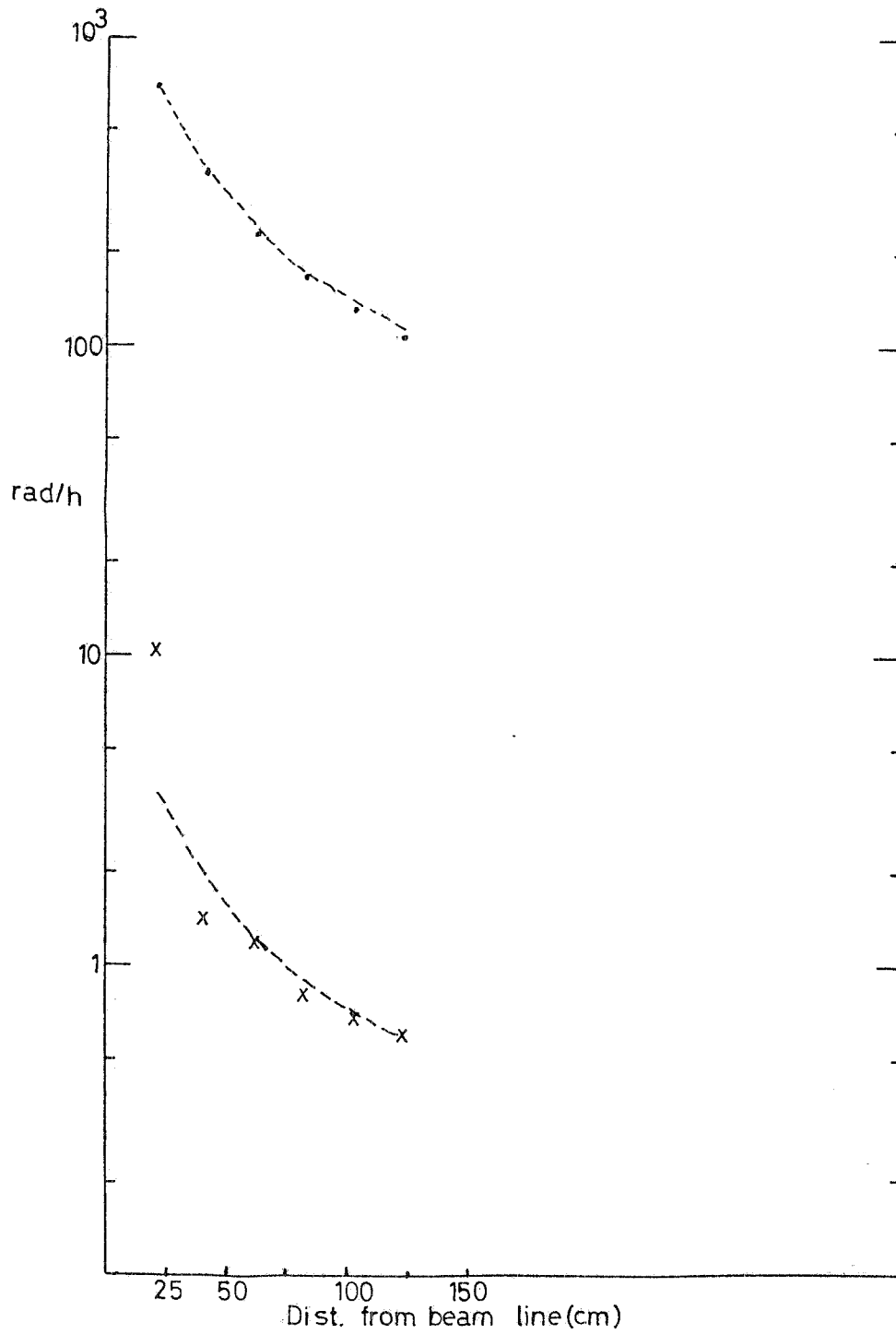


FIG. 5 - Dose rate inside the Linac Tunnel as function of the distance from the beam line (top: at the converter; bottom at the end of the Linac).

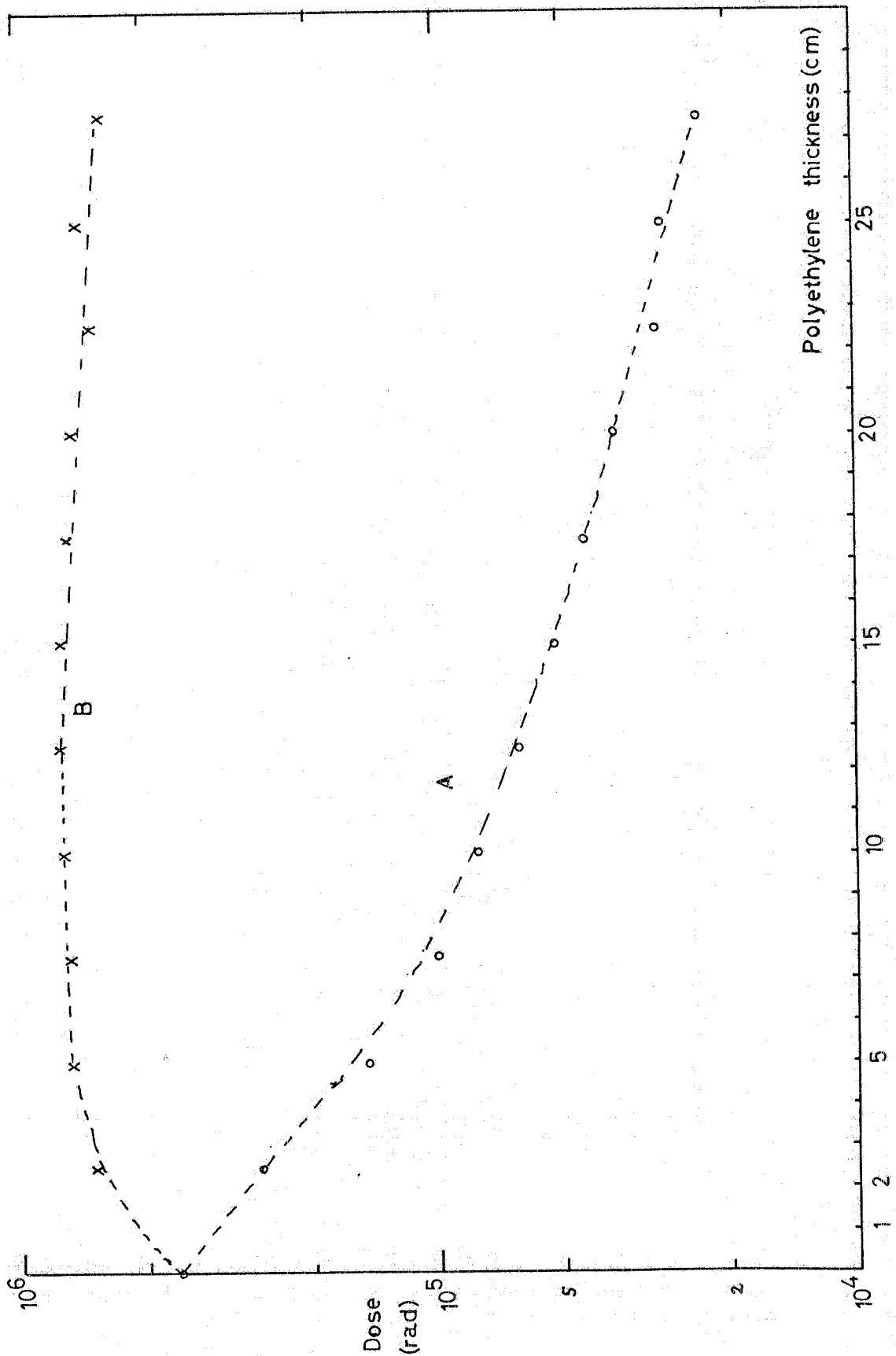


FIG. 6 - Dose trasmission through a polyethylene phantom inside the Tunnel of the Linac.

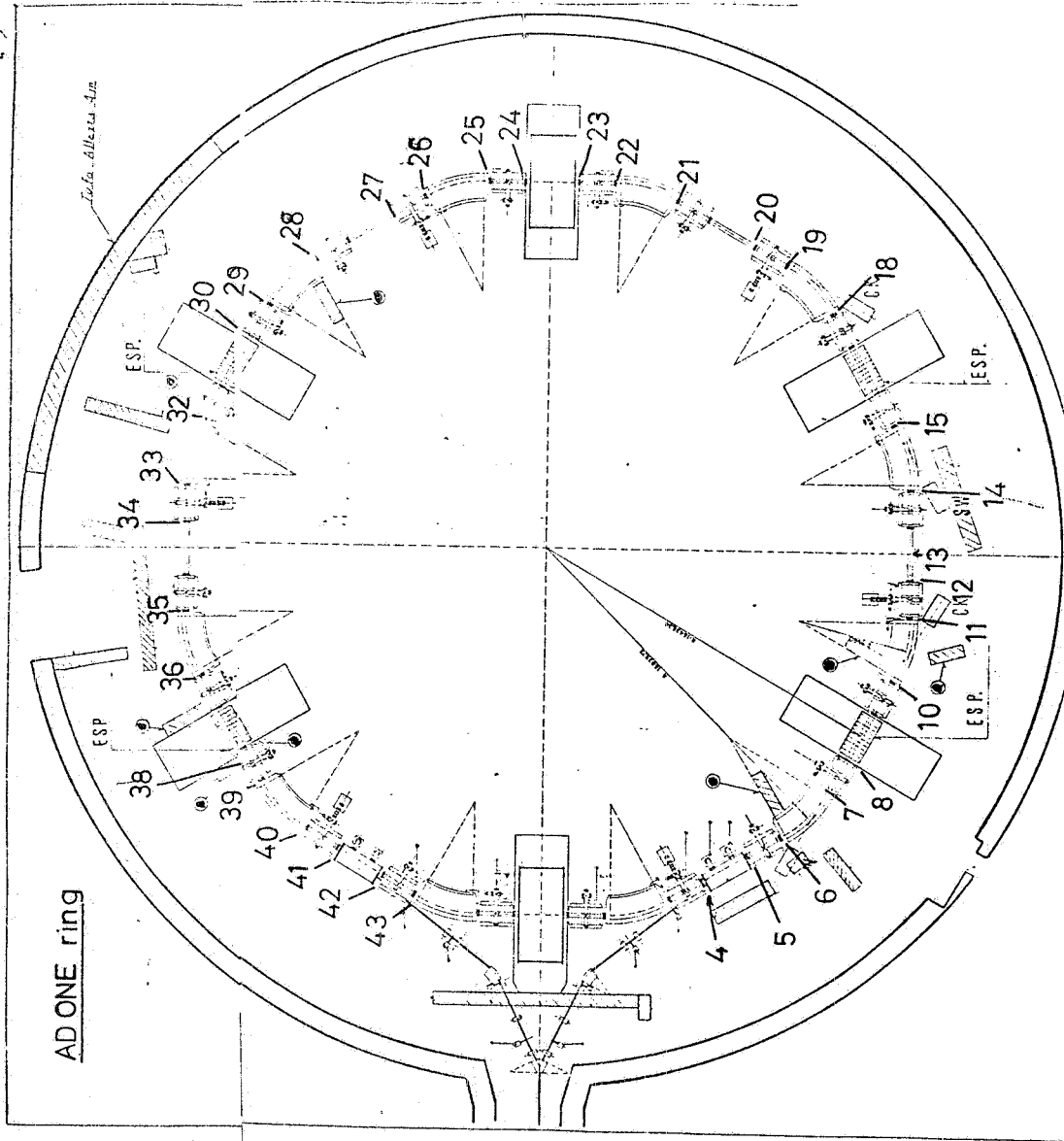


FIG. 7 - Map of the storage ring Adone.

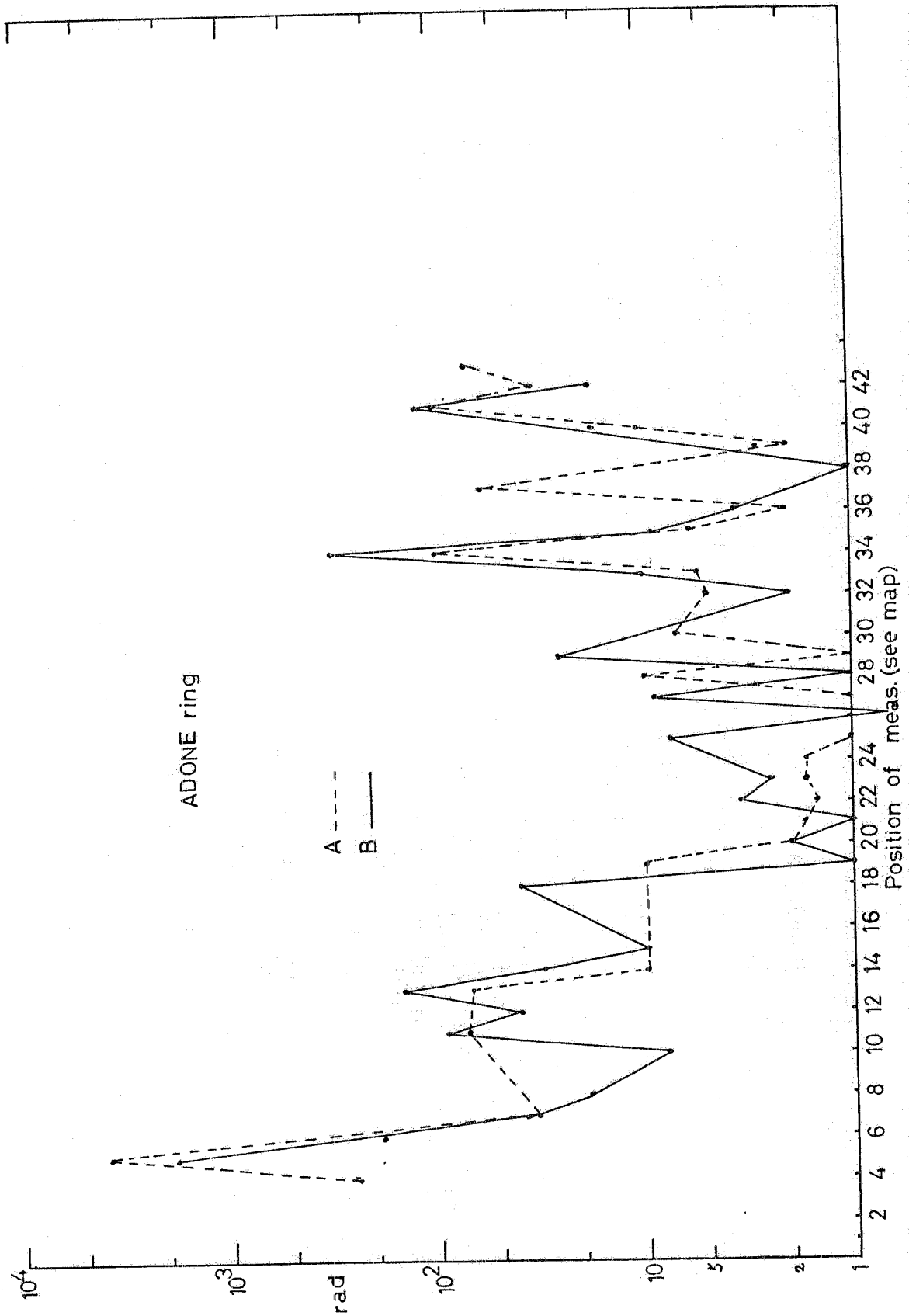


FIG. 8 - Doses measured along the storage ring (A: doses accumulated in 50 injections; B: doses accumulated in 78 injection).

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