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RADIATION PROTECTION ASPECTS OF THE DECOMMISSIONING OF THE LINAC–ADONE STORAGE RING

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Introduction

An $e^+ e^-$ collider, christened DAΦNE (Double Anular Φ factory for Nice Experiments), optimized for operation at a total energy of 1020 MeV, is under construction at the Frascati National Laboratories (LNF) of the National Institute of Nuclear Physics (INFN). The new machine will be placed into the existing buildings which in the past housed the Linac-Adone complex, which definitively ceased operation April 26th 1993 and was at once decommissioned.

The Linac-Adone complex has operated without stopping up to the 26th of April 1993 except for the ordinary maintenance periods.

It was composed by a Linac, capable of accelerating 100 mA of e^- beam peak current to 400 MeV and 1 mA of e^+ beam peak current to 365 MeV, in operation since 1964, and by an e^+e^- storage ring capable of storing $2x10^{11}$ particles per beam at 1500 MeV, in operation since 1967.

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Radiation safety standard and criteria for unrestricted release adopted at LNF

The objectives of radiation safety for the Linac-Adone decommissioning were:
- limitation of personal doses;
- control of radioactive materials either for reuse or for disposal;
- prevention of dispersion of radioactive material during handling and transportation to the final destination.

The limits for personal doses and radioactive material were taken from the recommendations of the Italian National Agency of Environment Protection (1) and from the law in force on the safety and health protection for workers and population against the danger of ionizing radiation field (2), as follows:
- the reference dose for people working in decommissioning areas was 15 mSv/y;
- a limit for unrestricted release for β–γ emitters was set at 1 kBq/m^2 for surface contamination and 0.1 kBq/kg for mass activity.

Decommissioning organization and classification of materials

In view of the rather low values of induced radioactivity no problems were expected as regards personal doses.

The biggest concern as regards radiation protection was the dispersion of radioactive materials outside the decommissioning area. A priori each machine item or component was considered radioactive until the contrary was proven.

At the exit of the Linac tunnel and the Adone storage ring area all materials were checked with the hand-held instruments: on non-radioactive materials a green adhesive tape was applied while the radioactive material was marked with a black trefoil on yellow background. Materials, whose radioactivity neither exceeded the clearance levels above mentioned nor made them a radioactive substances according to the law, were considered non-radioactive and were released completely free.

For instance all materials coming from control rooms, counting rooms or areas outside the accelerator's shielding or placed very far from primary or secondary beams were considered belonging to this category. Anyway, in case of doubt, samples were taken for gamma ray quantitative spectrometry measurements.

The radioactive materials which remained at LNF for reuse were stored in special areas at the disposal of every experimental group and finally those items intended for disposal were transported and stored into LNF radioactive waste area.

During the decommissioning two people of the radiation protection staff were permanently on the work site.

The personal doses for external radiation were monitored using pocket electronic dosimeters and a couple of TLD individual dosimeters (from an external company and from LNF service). Special clothes including overshoes were worn and in addition proper breathing masks were used during dusty operations in order to prevent any internal contamination. It needs to be stressed nevertheless that in the case of the LNF machine and in general in the case of high energy accelerators, the radiological risk for people involved in decommissioning was due pratically only to the external radiation, being in fact neglegible or absent surface contamination. The risk, very low actually, of internal contamination was connected to very particular and rare operations like sawing, cutting or cleaning.

Following the previous classification, all materials were divided into categories like "iron", "steel", "aluminium", "copper" etc., cut into pieces and compressed, if possible, to form easy to stock cubes.

Smaller metallic pieces (screws, connectors, pieces of cables, steel plates, etc.) were collected and put into baskets of about one cubic meter each. Special iron galvanized drums were used to store some cooling water coming from Linac beam dumps.

Each cube, drum or basket was marked with an adhesive tape with a radioactive material symbol on which the gamma dose rate was reported.

Preliminary measurements

Following the shut down of the Linac-Adone complex, the Health Physics Service carried out many measurements to find out the amount of dose rate along e^+e^- beam lines, the specific activity in dust, in cooling water and in metallic components of the machine, in order to obtain useful information for planning the decommissioning itself.

Gamma dose rates, using CaF2 TLD dosimeters (bulb dosimeter mod. 4040 by Harshaw) and a Victoreen ionization chamber mod. 450 P, were measured along e^+e^- beam lines at the distance of about 30 cm from the machine. The results obtained, shown in Figures 1, 2, 3, stress that the dose rate values are higher than the background only near the positron converter and the final part of the e^- beam line before beam dump.

Liquid samples, collected from the primary cooling circuit of the machine supplied with aqueduct water and from the secondary circuit supplied with distilled or demineralized water show (Tab.I) an appreciable concentration of H-3, as expected, in cooling water of beam dumps.

Tabella I – Measured specific activity in water of Linac-Adone–Leale cooling circuits.

Radionuclides	Co-58	Co-60	H-3
Cooling circuits	(Bq/l)	(Bq/l)	(Bq/l)
Linac-Adone primary cooling circuit			3.1±1.3
Linac secondary cooling circuit (5350 l)		1.47±0.07	21.9±1.6
Wiggler secondary cooling circuit (5500 l)		2.00±0.08	21.7±1.6
Adone secondary cooling circuit (5900 l)			20.8±1.6
Leale primary cooling circuit			18.8±1.7
Leale secondary cooling circuit S2 (1500 l)			30.8±1.8
Leale secondary cooling circuit S3 (1000 l)			7.4±1.6
Linac beam dump 1 cooling circuit (2000 l)		0.27±0.03	3.5E04±43
Linac beam dump 2 cooling circuit (6000 l)		1.38±0.06	3.4E04±42

In order to obtain useful information on possible contamination of areas involved in the decommissioning air and floor samples were taken: gamma spectrometric measurements show that no γ lines different from background were stressed in air samples and that only traces of Na-22, Mn-54, Co-57, Co-60, Ba-133, Cs-134, Cs-137 Eu-152, Eu-154, were found in dust samples. Further gamma ray spectrometries, performed in site at the location shown in Figure 4 and reported in Table II show clearly that residual radioactivity, was basically found near components in which beams were lost such as the positron converter, collimators, bending magnets or beam dumps.

Tabella II – In situ Linac-Adone-Leale gamma spectrometry.

Radionuclides	Co-56	Co-57	Co-58	Co-60	Cr-51	Eu-152	Na-22	Mn-54	Zn-65
Energy (keV)	847	122	810	1172	320	1408	1275	835	1115
Measurement position									
Along the Linac	(cps)	(cps)	(cps)	(cps)	(cps)	(cps)	(cps)	(cps)	(cps)
Linac 1		81		9.7				0.73	
Linac 2		192		52		4.2	11	22.7	2.37
Linac 3				1.85					
Linac 4	0.7	5.26		6.4				3.17	
Linac 5	2	19.7		5.9				4	
Along the Linac-Leale									
Leale 1									
Leale 2				0.35				0.08	
Leale 3				7.4		8.5		4	
Leale 4				48			2.7	1.76	
Leale 5		28		132		0.43	7.6	34	
Leale 6				83		16	5.3	18	
Leale 7				99		14	39	14	
Leale 8									
Along the Linac-Adone									
Transfer line 1				0.005				0.04	
Transfer line 2		12		0.06				0.62	
Transfer line 3				0.05				0.34	
Transfer line 4				0.03				0.36	
Transfer line 5		36		0.17				2	
Transfer line 6				0.034				0.16	
Transfer line 7				0.03				0.18	
Transfer line 8		60		0.54				11	
Transfer line 9		0.19		10				1.2	
Transfer line 10		43		0.2				8.7	
Transfer line 11				0.04				0.16	
Adone storage ring 1	0.46	19	1.1	0.4	4.6	0.22		9.4	0.09
Adone storage ring 2		0.037	0.045	0.035	0.11			0.5	
Adone storage ring 3	0.04	2.2	0.06		0.2				
Adone storage ring 4								0.7	
Adone storage ring 5				0.031					
Adone storage ring 6								0.05	
Adone storage ring 7									
Adone storage ring 8									
Adone storage ring 9									
Adone storage ring 10									

Dismantling of the machine elements and final cleaning

On the basis of the results of the preliminary measurements the decommissioning program, the handling and transportation of materials began and were completed in 3 months without particular protections for people involved except the use of personal dosimeters and disposable dresses used in dusty operations.

During the dismantling the following instruments were used for in the field measurements:

- two portable HpGe EG&G spectrometric systems;
- two environmental Reuter Stokes ionization chambers;
- a Victoreen 450 P ionization chamber;
- a Victoreen Frisker connected with a pancake probe;
- other useful monitors.

Two HpGe spectrometric systems in network with a 486 IBM PC were used for the quantitative analysis of samples.

Materials coming from Linac, including the 12 accelerator sections, the magnetic structures, the vacuum pipe line, the Linac-Adone transfer lines and 43 baskets, filled with remaining materials, were transported to the storage area without any quantitative measurements.

On the basis of the γ rate measurements it was clear that the most part of the materials had a concentration values higher than the clearance levels while the remaining ones not voluminous but very numerous, would have paralized uselessly all Health Physics Service γ ray spectrometric systems. More accurate measurements are foreseen for the future.

In Table III are reported, for instance, the results of the measurements carried out on the most radioactive parts of the accelerator.

Tabella III – Qualitative gamma–rays spectrometry on Linac components.

Material	Dose equivalent rate (μGy/h)	122 keV Co-57 (cps)	321 keV Cr-51 (cps)	810 keV Co-58 (cps)	835 keV Mn-54 (cps)	846 keV Co-56 (cps)	1275 keV Na-22 (cps)	1332 keV Co-60 (cps)
Linac section n°4 at contact	1.5	28	4	2	12	1		36
Linac section n°5 at 1 m of distance	750	21			39		1	154
Linac section n°6 at contact	1.7				0.8			
Linac section n°7 at 10 cm of distance	2	1.5			1			23
Linac section n°8 at 1 m of distance	14					0.08		20
Linac section n°9 at contact	0.3	3.5	0.3	0.2	3			18
Linac section n°10 at contact	0.8	13	0.9		8			58
Linac section n°11 at contact	2	3			1.6			10
Linac section n°12	1	59		3	35	1.		101
Bending magnet n°1 at contact	11	12	0.6	0.2	8	0.4		7
Bending magnet n°2 at contact	0.3	1.7			1.7			1.6
Pulsed magnet at 50 cm of distance	30	0.6			2			54
positron converter target at 50 cm of distance	230	8			4		1	170
positron converter flange at 1 m of distance	500	137		1.7	127		197	12

Dose rate measurements carried out with a Reuter Stokes mod RSS112 during the cleaning of the Linac area from the remaining dust and reported in Figure 5, have shown appreciable values in the positron converter area with a maximum of 3 μSv/h.

A quantitative γ spectrometry measurement of a concrete sample, collected from a wall of the positron converter area, stressed the presence of Eu-152, Co-60, Cs-134, Eu-154 (Table IV), due to the concrete activation (n, γ) of the Linac walls (3).

The decommissioning of the Adone area has caused many problems due to the big volumes and weights involved and to the very low value for unrestricted release. The Adone storage ring was formed of 12 identical sectors, each one composed by a straight section, a bending magnet, and a couple of quadrupoles for a total weight of about 35 ton/sector and the concrete shielding weighted about 800 tons. In situ γ spectrometry measurements were carried out on each part of the sectors in order to collect a sample from the most radioactive area. Anyway, the final destination of materials was determined on the basis of quantitative results.

All materials coming from Adone were released free except a few vacuum chamber.

Tabella IV – Residual radioactivity in the concrete walls.

Radionuclides	Measured radioactivity (Bq/g)
Be-7	0.020 ± 0.002
Mn-54	0.0020 ± 0.0003
Co-57	<0.0017
Co-58	0.0045 ± 0.0001
Co-60	0.420 ± 0.001
Ba-133	0.0090± 0.0005
Cs-134	0.160 ± 0.005
Cs-137	0.003± 0.0003
Eu-152	1.10 ± 0.03
Eu-154	0.130 ± 0.004

Some results of the quantitative analysis, carried out on the most representative magnetic elements and vacuum chamber of the storage ring (Figure 6), are reported in Table V. The measurements stress the presence of Mn-54 in the iron of a few bending magnets and Co-60 in the inox steel of a few vacuum chambers, where beams usually were lost (near injection devices).

Tabella V – Quantitative gamma-rays spectrometry on some representative Adone components.

Radionuclide mass activity	Co-57 (Bq/g)	Co-60 (Bq/g)	Mn-54 (Bq/g)
Sample collected from			
Quadrupol 5		0.022± 0.002	
Quadrupol 11		0.0092 ± 0.00103	0.0022 ± 0.0006
Quadrupol 15		0.0072 ± 0.0007	
Quadrupol 17		0.011 ± 0.001	
Quadrupol 42			0.0042 ± 0.0004
Quadrupol 43		0.00085 ± 0.00007	0.022 ± 0.002
Quadrupol 44			0.033 ± 0.003
Quadrupol 48			0.0220 ± 0.0003
Bending magnet 2		0.0080 ± 0.0007	
Bending magnet 11			0.0070 ± 0.0008
vacuum chamber of quadrupol 35	0.0017 ± 0.0003	0.0140 ± 0.0015	0.0033 ± 0.0008
vacuum chamber of quadrupol 37	0.11 ± 0.02	0.0650 ± 0.0063	0.11 ± 0.01
vacuum chamber of bending magnet 2	0.011 ± 0.001	0.017 ± 0.002	0.014 ± 0.002
vacuum chamber of quadrupol 42	1.50 ± 0.12	0.20 ± 0.02	1.20± 0.10
vacuum chamber of quadrupol 40	0.20 ± 0.02	0.092 ± 0.009	0.280 ± 0.025
vacuum chamber of quadrupol 43	4.70 ± 0.40	2.14 ± 0.30	9.70± 0.80

Conclusion

The decommissioning of the whole Linac-Adone complex, including radiation protection measurements, has been completed in 6 months.

The continuous survey carried out by the Health Physics Service (1 physicist and two technicians) has obtained two important aims:

1) the movement of the activated material to the area of storage has been carried out avoiding any loss;
2) people involved in decommissioning have received doses, no higher than the background.

References

1. Indirizzi di radioprotezione per l'allontanamento incondizionato dagli impianti nucleari di materiali solidi debolmente attivati e/o contaminati ENEA-DISP-CCPR documento L 85/01 del 26/5/96
2. Decreto del Presidente della Repubblica 13 febbraio 1964, n°185, Sicurezza degli impianti e protezione sanitaria dei lavoratori e delle popolazioni contro i pericoli delle radiazioni ionizzanti derivanti dall'impiego pacifico dell'energia nucleare. Supplemento ordinario alla Gazzetta Ufficiale n°95 del 16 aprile 1964
3. Itsumasa Urube, Katsuhei Kobayashi, Yoshiaki Fujita, Tadashi Tsujimoto and Jin Guangchuang, Health Physics Vol. 60, N° 4 (April), pp 587-591

Dose equivalent rate from residual radioactivity

Measurements performed along the Linac at the shut-down using a Victoreen monitor model 450 P background 0.1 μSv/h

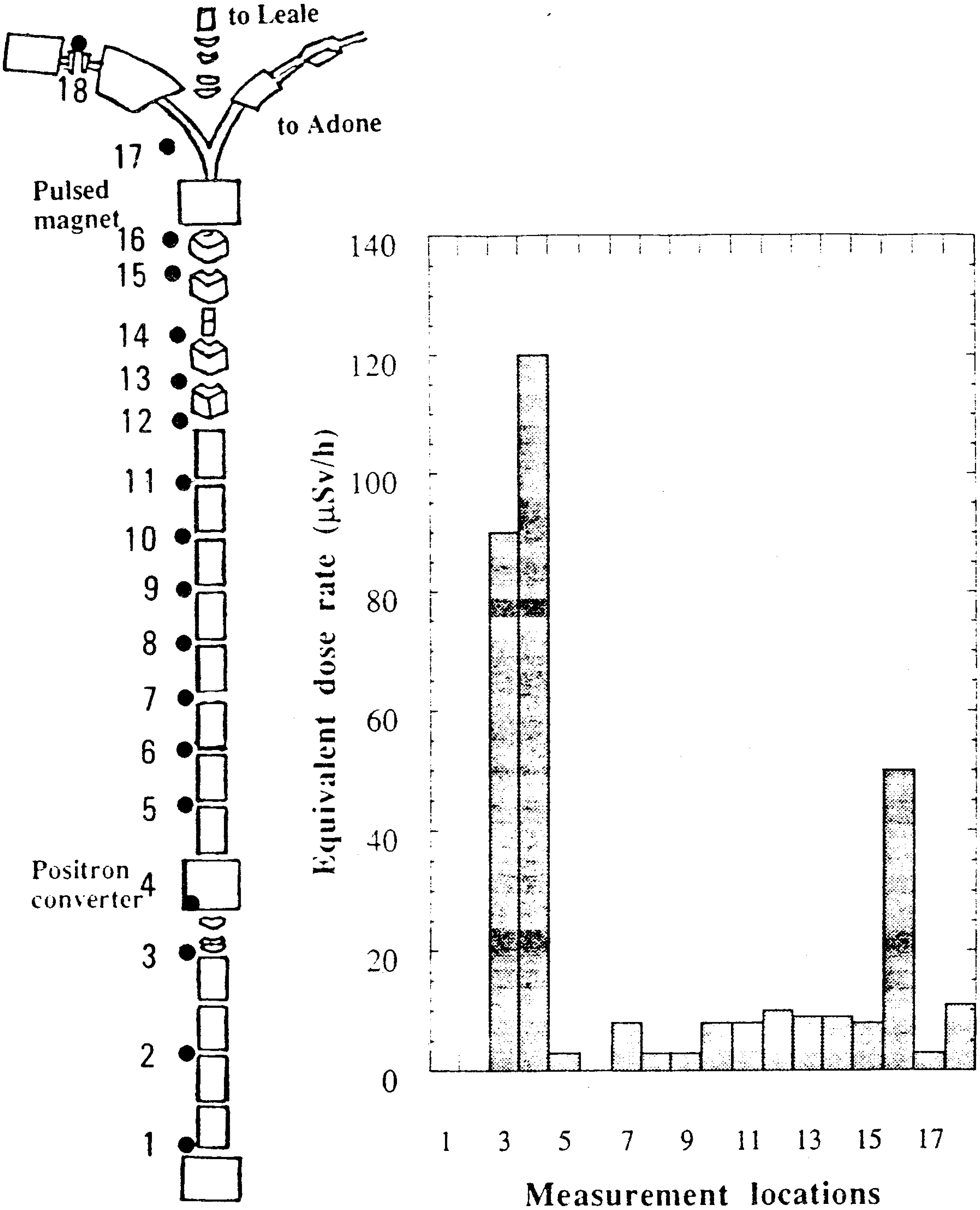

Figure 1

Dose equivalent rate from residual radioactivity

Measurements performed along the positron beam line at the shut-down using a CaF_2 TLD dosimeters

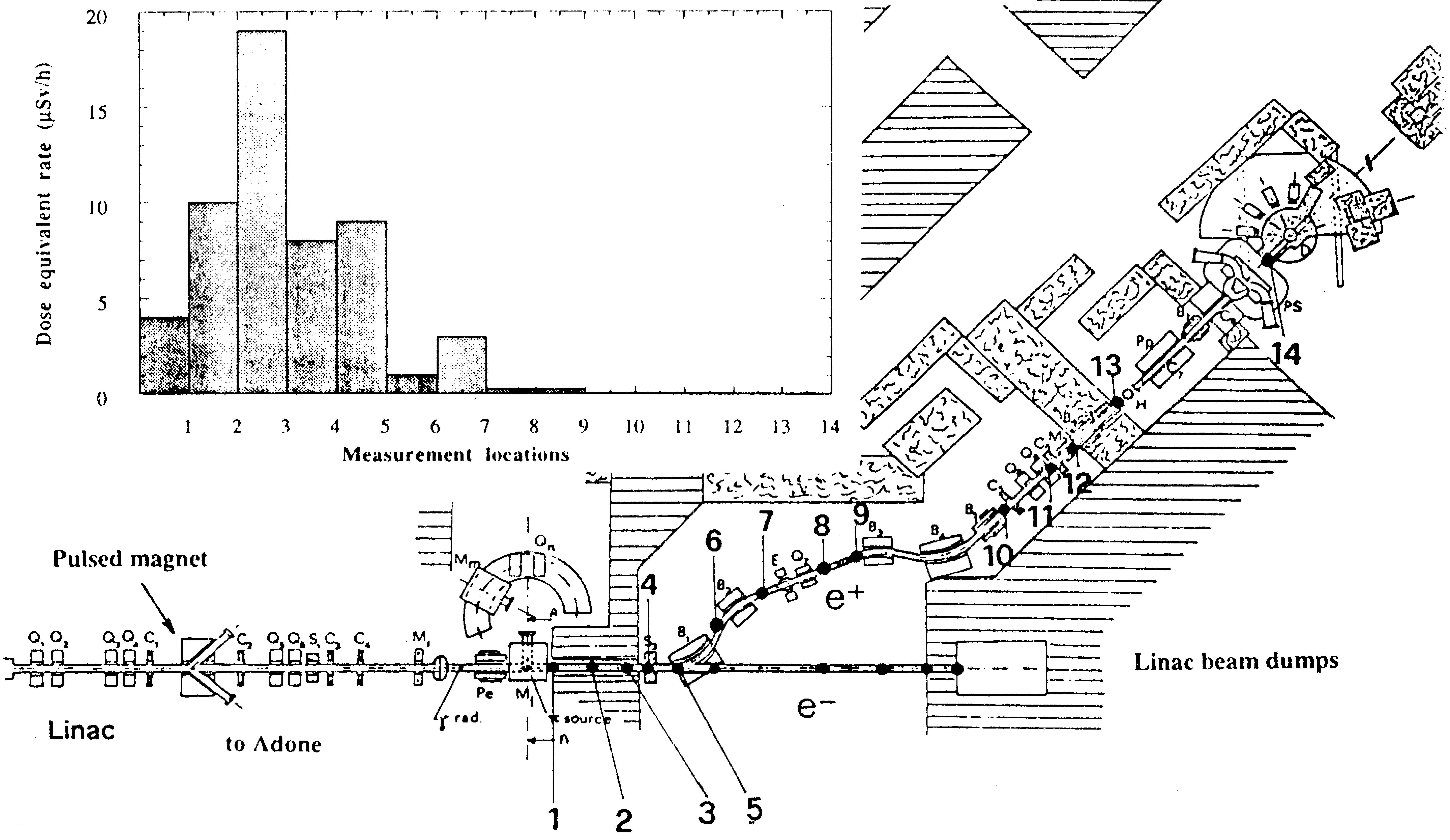

Figure 2

Dose equivalent rate from residual radioactivity

Measurements performed along the electron beam line at the shut-down using a CaF_2 TLD dosimeters

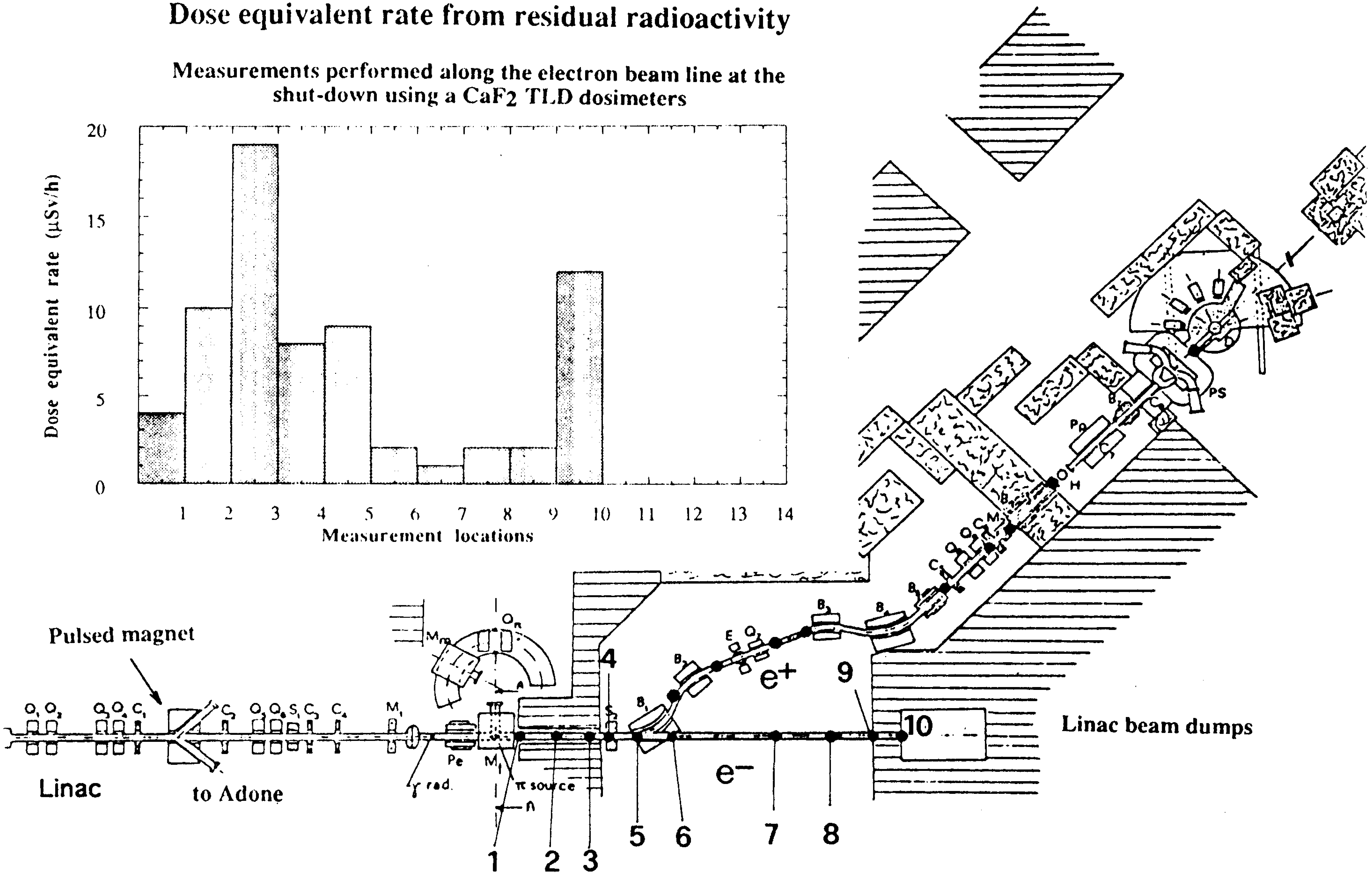

Figure 3

Linac-Adone-Leale Layout

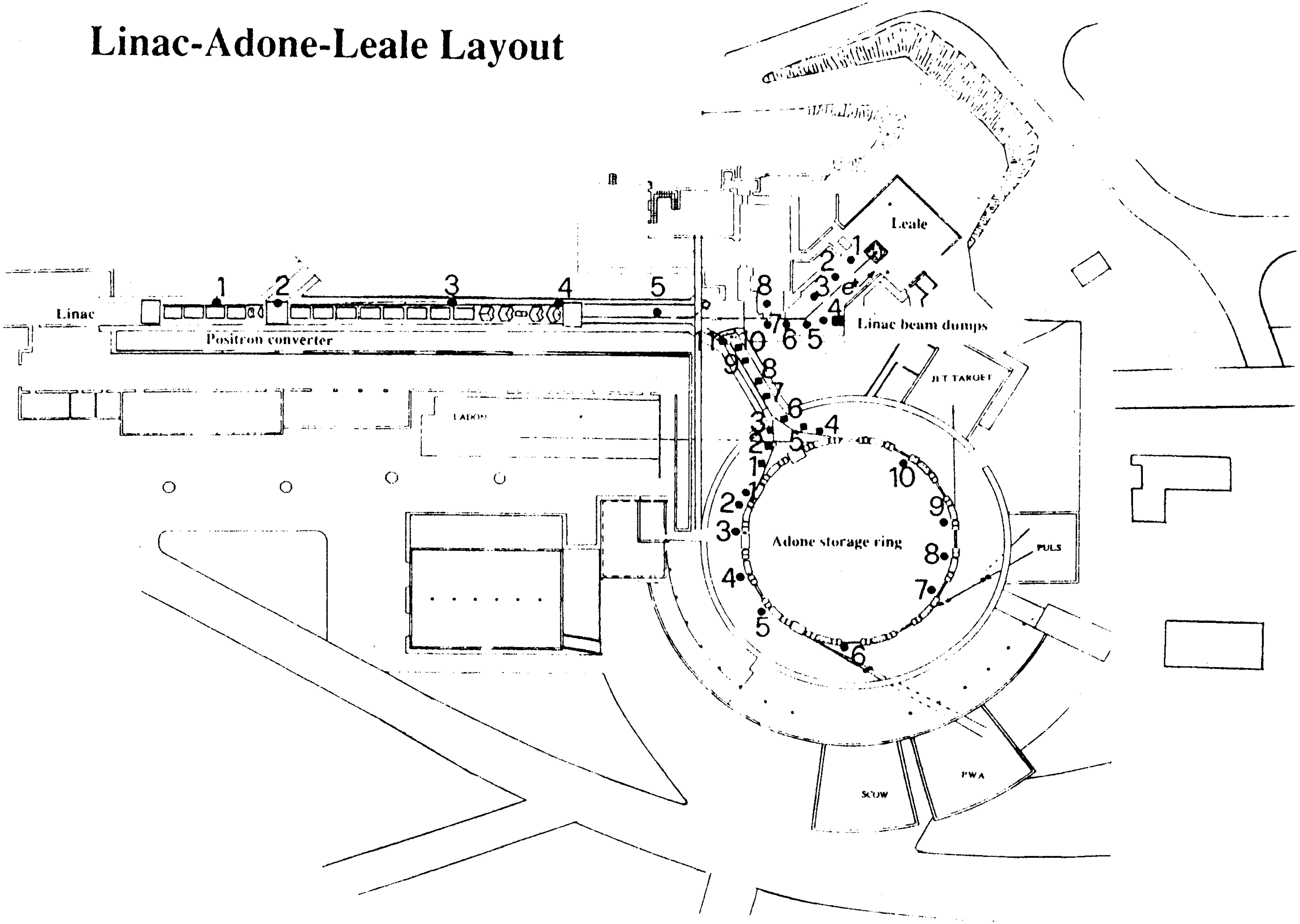

Figure 4

Dose equivalent rate from residual radioactivity (μSv/h)

Measurements performed along the tunnel of the Linac at the end of the decommissioning, using an high pressure ion chamber Reuter Stokes model RSS112.

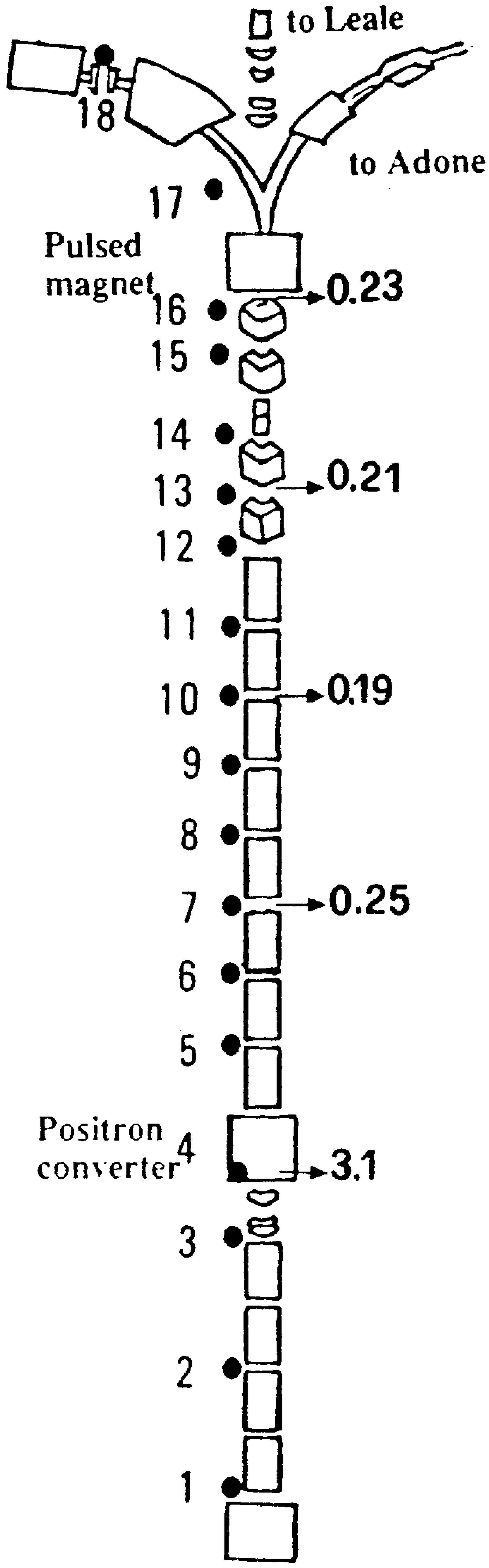

Figure 5

Adone e+ e- storage ring layout

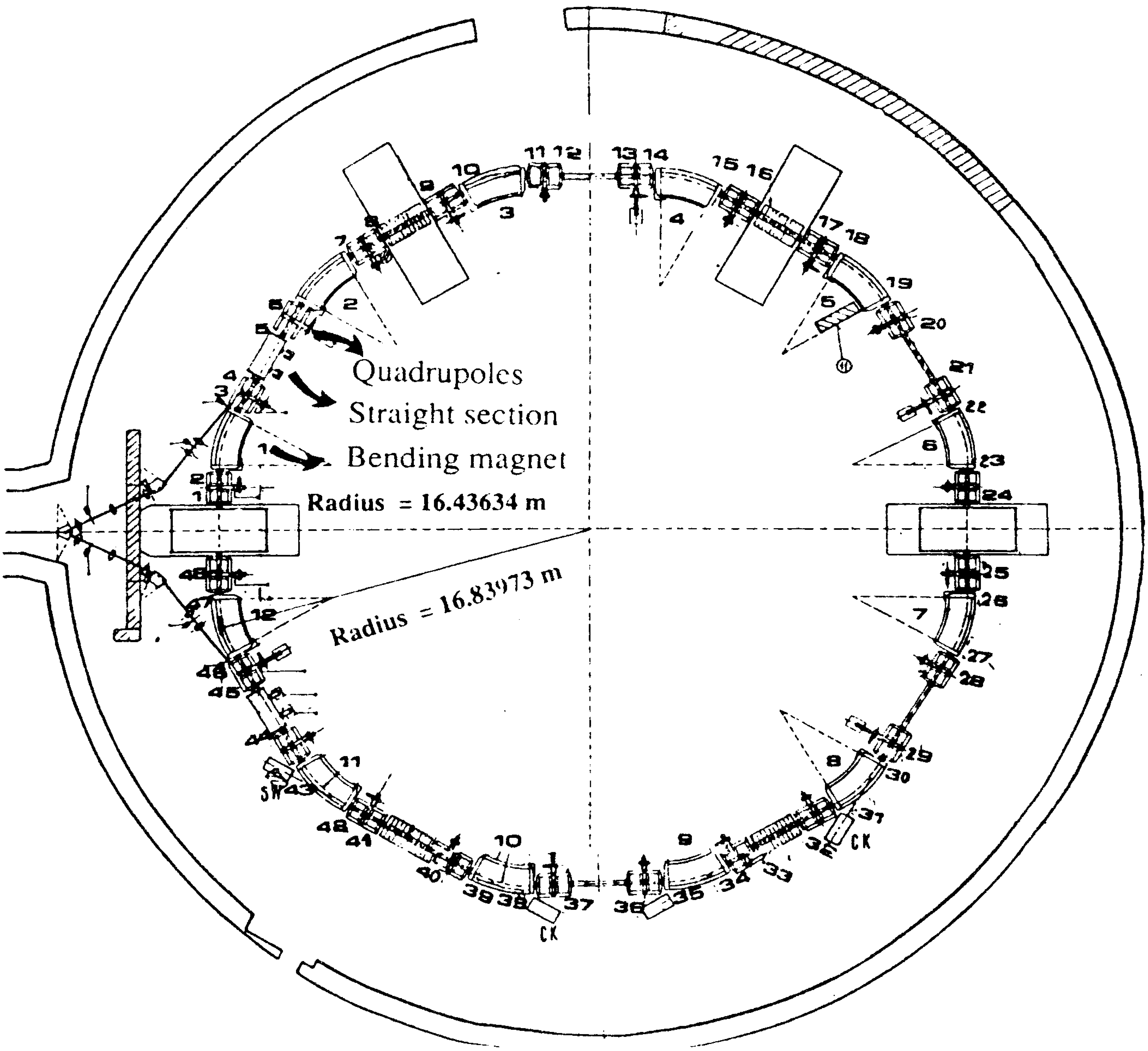

Figure 6