DESY 1977 - A MULTI-PURPOSE PARTICLE ACCELERATOR

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From 1964 until the end of 1976, the total operating time of DESY has been approximately 78ooo hours, out of which 6631o h were scheduled for high energy physics prime time. Out of these 6631o hours, 6935 hours were unscheduled breakdown or machine set up time. This corresponds to an operating efficiency of 9o %. Furthermore, these numbers illustrate that DESY has indeed met the original design goal: to serve as an efficient particle source for high energy physics. In order to reduce set up time, maintenance and test shifts are only scheduled every 1o weeks with 8 weeks of uninterrupted operation time inbetween.

Accelerator improvement programs in the years from 1964 to 1973 were primarily aimed at meeting the needs of the research groups using photon, electron and positron beams in experimental halls I and II (3). High electron intensities and good stability were achieved by improving the 4o MeV e^- injector linac, and by adding a 4oo MeV Linac. With the original 4o MeV linac, which now is a 55 MeV-Linac, DESY reached the intensities it was designed for (10^{11}ppp); with the larger Linac, more than five times this intensity has been accelerated at maximum. 4o-5o mA average circulating electron current (which corresponds to $3 \cdot 10^{11}$ ppp or $1.5 \cdot 10^{13}$ pps) are routinely accelerated for certain experiments. In addition to 3 main photon beams generated on internal targets, two external electron/positron beams are available. Those beams are generated by exciting the 1/3 horizontal resonance at the maximum energy of the synchrotron cycle. A quadrupole and a sextupole with a well controlled current pulse are required for this

purpose. Furthermore, the "macroscopic duty factor" of the synchrotron was brought up from .9 msec out of 2o msec to 3msec out of 2o msec ($\hat{=}$ 15 %!) by "flat topping" the synchrotron magnet current. During this time, the energy variation is smaller than $\pm$ o.25 % of $\Delta E/E$.

A smooth square shaped spillout during flat top time for photon beams as well as for the external electron beams is accomplished with self-adjusting feed back loops. The DESY machine data relevant for high energy physics users are compiled in fig. 1.

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max. energy	7.5 GeV
pulse rep. rate	50 ppsec
max. macroscopic duty factor	15.4 %
resolution $\Delta E/E$ (used for definition of duty factor)	$\pm$ 0.25 %
internal electron beam	80 mA average or $5 \cdot 10^{11}$ ppp or $2{,}5 \cdot 10^{13}$ ppsec or 5 μA equ. dc
internal positron beam	0.8 mA average or $5 \cdot 10^{9}$ ppp or $2{,}5 \cdot 10^{11}$ ppsec or $5 \cdot 10^{9}$ A
external electron beam, slow extraction:	
energy range	1 to 7.25 GeV
max. intensity (at 25 mA av. circulating beam)	10^{11} ppp or $5 \cdot 10^{12}$ ppsec
beam emittance	$\varepsilon_z \approx 0.1 \cdot \pi \cdot$ mm $\cdot$ mrad $\varepsilon_r \approx 0.5 \cdot \pi \cdot$ mm $\cdot$ mrad
extraction efficiency	$50\% < \eta < 85\%$
extraction time (for $\frac{\Delta E}{E} = \pm 0.25\%$)	0.3 msec $< t_e <$ 3.1 msec
external positron beam, slow extraction:	$2 \cdot 10^{9}$ ppp or 10^{11} ppsec
number of beams	2 external e^+/e^- beams (also simultaneously) 3 photon beams 3 converted photon beams for test purposes 2 synchrotron radiation beams

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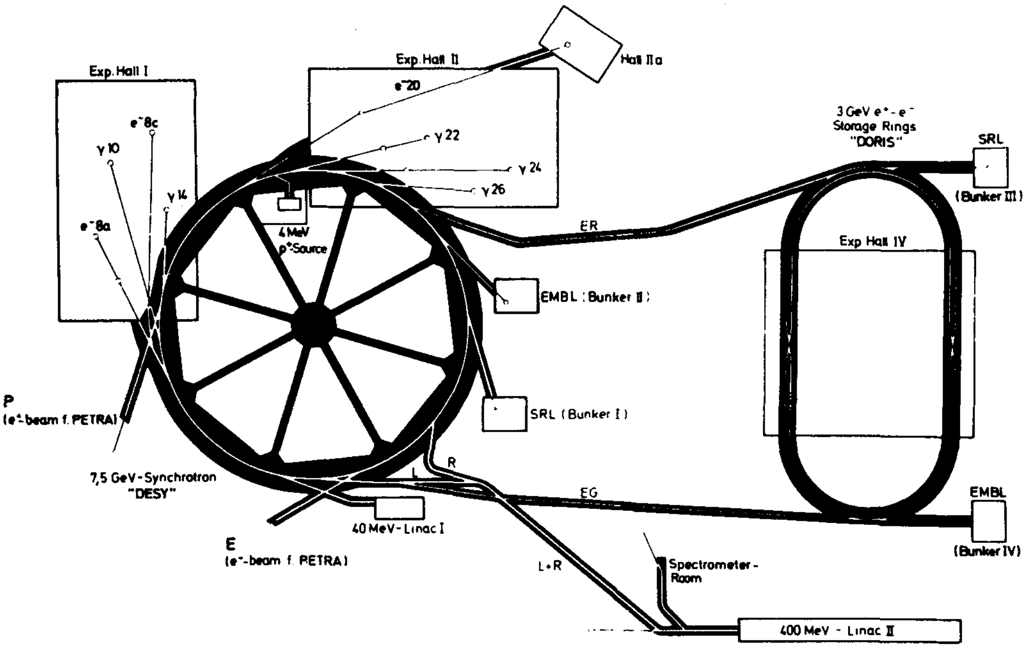
Fig.1 DESY machine data as relevant for high energy physics users

Parallel to high energy physics, the DESY synchrotron radiation is used via two beam lines, one for a laboratory with 2o user groups mainly interested in solid state physics, atomic physics, molecular physics, and applied physics, the other one for the EMBL-Laboratory interested in molecular biology.

In 1973, two new beam lines using single turn extraction from DESY, had to be set up to deliver electrons and positrons up to 5 GeV for DORIS. In 1976, the two 7 GeV transfer systems connecting PETRA to DESY **were added. Since the orbit time of DESY is approximately 1 μsec, single turn extraction requires fast kickers. They have to be especially fast if the extraction of all circulating 5oo MHz bunches is required. The harmonic number of DESY is 528, the injection kicker** leaves a gap of 10 ÷ 20 % in ring filling, thus a maximum of about 450 bunches can be extracted. In case of the DORIS e^+/e^- beams, the full aperture kickers will kick the particles into the gap of a septum magnet.

At higher energies, an additional beam bump will move the closed orbit as close as possible to the septum current strip in order to minimize the kicker amplitude. In case of PETRA beams, a beam bump moves the single bunch then circulating in DESY into the gap of a C-type kicker located in the inner side of the ring.



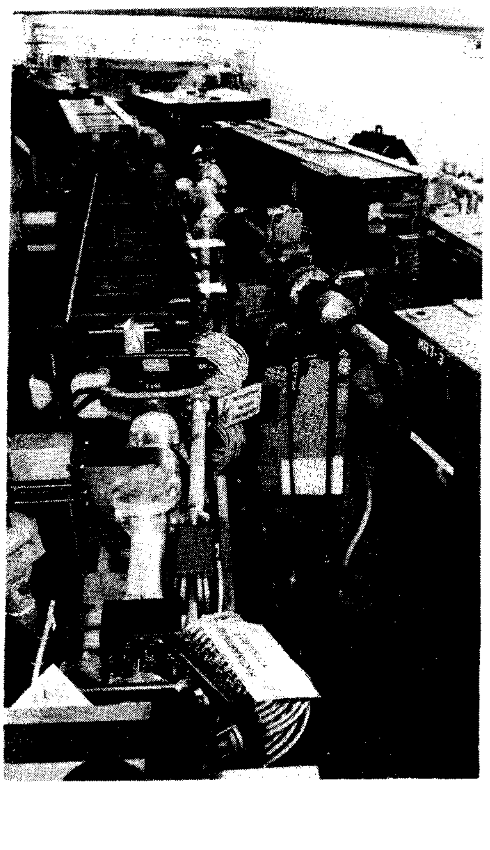


Fig. 2 Layout of DESY beams

Fig. 3 View of DESY target area I with one photon beam and two electron beam runs for exp. hall I, and the PETRA e$^+$ beam crossing the other three beams.

This kicker then deflects the particles into a septum. More detailed information on PETRA injection can be found in another paper in these proceedings (1).

DESY, DORIS and PETRA use the same radiofrequency of 500 MHz. This is helpful not only in that the same klystron type is used in DESY and DORIS (and, in a more powerful high efficiency version in PETRA, too), but it also facilitates the particle transfer between the machines, since no rebunching is needed. 5oo MHz -

bunching starts as early in the process as in the injection systems of the linacs, where 5oo MHz choppers or buncher cavities are in use. These are frequency and phase locked to the 3ooo MHz linac S-band systems. For most experiments with photon and electron beams, DESY normally requires all 5oo MHz-bunches available on the circumference of DESY. For reasons which are explained in another paper of this conference (2), DORIS sometimes requires 24o, 12o, or 3o equally spaced bunches besides the normal 48o bunch operation, and even single bunch operation will be necessary in the near future. The 24o-bunch mode is achieved in DORIS itself by injecting twice in the 12o bunch mode and adjusting the bunch trigger appropriately. All other bunch order patterns including single bunches are produced by additional chopper or "fast sweeper" systems in the linac injection sections, or in the beam transport between linac and synchrotron. For PETRA, DESY has to deliver single e^- and e^+ bunches. e^- bunches will be injected into DESY directly from one of the linacs. e^+ bunches are reinjected from DORIS at 2 GeV, and accelerated to 7 GeV. However, if operating as intermediate storage ring for positron accumulation, DORIS is filled with 3o equally spread bunches at 2 GeV.

External e^-/e^+ - beams for DORIS and PETRA, single turn extraction:

e^- for DORIS, 480 500 MHz-bunches:	0,5 GeV < E < 5 GeV max. rep. rate 12,5 pps * $5 \cdot 10^{10}$ ppp * * (≙ 8 mA peak current)
e^+ for DORIS, 480 500 MHz-bunches:	0,5 GeV < E < 5 GeV max. rep. rate 50 pps $6 \cdot 10^{9}$ ppp (≙ 1,2 mA peak current)
120 500 MHz-bunches	$4 \cdot 10^{9}$ ppp
30 500 MHz-bunches	$1 \cdot 10^{9}$ ppp
e^- for PETRA (500 MHz single bunch)	5 GeV < E < 7 GeV max. rep. rate 10 pps * * $5 \cdot 10^{9}$ ppp (Linac II) $1 \cdot 10^{9}$ ppp (Linac I)
e^+ for PETRA (500 MHz single bunch)	5 GeV < E < 7 GeV max. rep. rate 10 pps * * max. $2 \cdot 10^{7}$ ppp (Linac II) $2 \cdot 10^{9}$ ppp (DORIS)

* Limited by radiation safety requirements of DORIS

** PETRA damping time

Fig. 4 Data of the DESY single turn extracted beams for DORIS and PETRA

In addition to 5oo MHz-synchronisation, also the different orbit times of the three circular machines must be taken into account, since the harmonic numbers of DESY, DORIS and PETRA are 528, 48o and 384o, respectively.
Finally, the triggers which are coherent with the rf-structure of the circulating particles, must be gated with the triggers defining the momentary energy of the synchrotron magnet cycle.

The combined operation of the two linacs, DESY and DORIS is fully automatized on a cycle sharing basis, the cycle time being 2o msec, since the DESY repetition rate is 5o Hz. For the DORIS operator, calling for electrons or positrons is a push button operation. If he pushes the two buttons simultaneously, in a given example the sequence of DESY machine cycles may be as follows:

cycle No. 1: electrons and/or photons at e.g. 7.2 GeV maximum energy during 2-3 msec flat top time for one or more of the beam end stations in exp. halls I or II, electrons for all possible buckets on the DESY circumference from Linac I at 55 MeV.

cycle No. 2: positrons at 2.2 GeV, single turn extraction, for DORIS, every fourth 5oo MHZ bucket on the DESY circumference filled with 3oo MeV positrons from Linac II.

cycle No. 3: electrons for DORIS, single turn extraction at 2.2 GeV, every fourth 5oo MHz bucket on the DESY circumference filled at 55 MeV from Linac I.

cycle No. 4: positrons for DORIS, as in cycle No. 2

cycle No. 5: identical with cycle No. 1

As soon as the DORIS operator after some 5 minutes stops injection by means of his two push buttons, all machine cycles are automatically available for exp. halls I/II with Linac I-electrons. Refilling DORIS normally occurs every 2÷3 hours.

The machine cycles for halls I/II can be further split up, either in another cycle-sharing mode between e.g. photon and electron beams, or by sharing the intensity in the same machine cycle e.g. between to slowly extracted electron beams. In addition to the main user beams, normally 1 to 3 test beams for halls I/II are generated in parallel by means of very thin carbon fiber targets positioned on the DESY closed orbit. The photon beams thus produced all the way up the acceleration cycle, are converted to e^+/e^- beams outside the synchrotron and then transferred to end-stations in halls I/II. The fiber is thin enough not to disturb the main user.

It is evident, that such complex combined operation of several accelerators including the beam transport systems in between the machines is impossible without extensive use of process computers. For this reason, computers were incoporated in both the 3oo MeV linac and the synchrotron along with the long term machine improvement programs.

While filling DORIS, as described above, is merely a parasitic process with respect to operation in halls I/II, filling of PETRA will temporarely interrupt high energy physics experiments not only in DORIS but also in DESY. This interruption is presently estimated to take 2o ÷3o% of the machine time. To avoid this loss for DORIS and its users (colliding beam experiments as well as synchrotron radiation experiments), construction of a small 4oo MeV storage ring especially for the purpose of positron single bunch accumulation is under consideration. This little ring just fits in the linac II spectrometer room. It will be filled multiturn with positrons from linacII at a rate of 5o Hz. The positrons will be accumulated in a single bunch. This high intensity bunch then will be further compressed using a second, higher rf in the small storage ring, until the bunch length fits into a 5oo MHz bucket of DESY, into which this bunch then will be extracted or be injected, respectively.

Finally, another option of DESY should be mentioned here.

In 1972/73 it was felt that it would be desirable to store protons in DORIS to serve as a target for both electron and positron beams. It was expected that such an accomplishment would be useful both for physics directly and for studies of machine problems associated with a large e/p colliding beam facility. As a first step, it was decided to inject protons into DESY in order to accelerate them to 2 to 4 GeV/c (transition energy of DESY is 5.4 GeV/c).

As a proton source, a 4 MeV NEC electrostatic accelerator was installed. For rf acceleration parts of a PPA drift tube/cavity unit were integrated into a DESY built system. The magnet circuit was modified to enable a 2 sec-"ramp" as required in proton machines.

Protons were successfully injected into DESY and accelerated up to approx. 200 MeV/c. At this stage, the project had to be discontinued temporarily because of priority for PETRA activities, and before further steps like improving the synchrotron vacuum system (as originally planned) and modifications for the proton rf-system could be accomplished.

REFERENCES

(1) A. Febel et al.: PETRA-Injection-System, in these proceedings

(2) K. Wille: DORIS, A Status Report, in these proceedings

(3) H. Kumpfert: Recent progress in the Performance of the DESY Electron Synchrotron, 1973 Particle Accelerator Conference, S.F., March 1973, (IEE-Transactions); pp. 231-235.