Status and Limits of DORIS II

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Abstract: DORIS first came into operation in 1973 as a double ring. Later on it was rebuilt as a single ring, and the maximum energy was increased from 3.5 GeV to 5.6 GeV. The experience with the double ring is briefly described, and that with the single ring in more detail. Emphasis is put on those topics which are important for the design of future storage ring colliders. - DORIS II is also operating as a source for synchrotron radiation. But this aspect is not treated here.

Introduction: The designs of future storage rings for J/Φ, Tau- and B-Meson physics which would yield a factor of 10 and more luminosity than those operating now are currently being discussed. The attainment of this target will be possible only if all the experience gained from the old rings is transferred to the new ones. The experience with DORIS is described in the following.

Some Characteristics of DORIS: The name DORIS originates from double ring storage. When the collider came into operation in 1973, 2 rings were put on top of each other with a crossing in the vertical plane[1]. The idea was to reduce the beam-beam effect by using many (up to 480) low intensity bunches and to avoid unwanted bunch crossings. A further advantage of the double ring scheme was, and is, that independent control of each beam is possible.

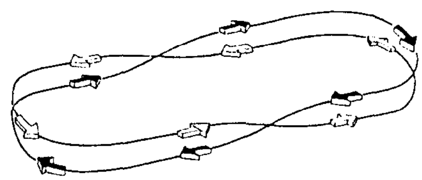

Fig. 1 The original DORIS double ring concept

A luminosity greater than 10^{33} cm^{-2} sec^{-1} was expected at about 2 GeV. The maximum energy should be 3.5 GeV. However, it turned out very soon, that the maximum tolerable tune shift was only ξ_z .009 (instead of the assumed ξ_z =

.025) due to the vertical crossing angle[2] and that the maximum currents per beam were limited to about 300 mA by beam instabilities. As a result the luminosity never exceeded a few 10^{30} cm^{-2} sec^{-1}.

After the discovery of the Y-resonances DORIS was rebuilt as a single ring-single bunch machine and named DORIS II[3]. The aim was to increase the energy to 5.6 GeV and to obtain a luminosity greater than 10^{31} cm^{-2} sec^{-1} with currents of about 30 mA. To achieve this, 1.2 MWatt of rf-power were installed, the gaps of the magnets were reduced and a mini-β-scheme was introduced. Some vertical bending was kept so as to prevent the synchrotron radiation from the last horizontal bending magnet from illuminating the interaction points. As Fig. 2 shows, the synchrotron radiation is absorbed by the tilted part of the vacuum chamber. The synchrotron radiation from the

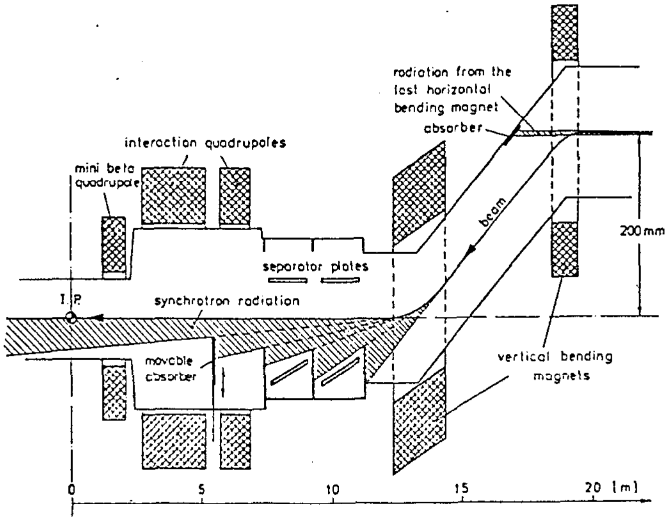

Fig. 2 Vertical bending

weak vertical bend is kept away from the detector by a movable absorber which reduces the background by roughly a factor of 5. Originally, electrostatic separators were used for separating the beams during injection. But since the injection rates are high, even with colliding beams, the separators are no longer needed and have been removed because the vacuum feedthroughs too often began to leak as a result of overheating by higher mode losses.

Fig. 3 shows the layout near the interaction point for the ARGUS-detector.

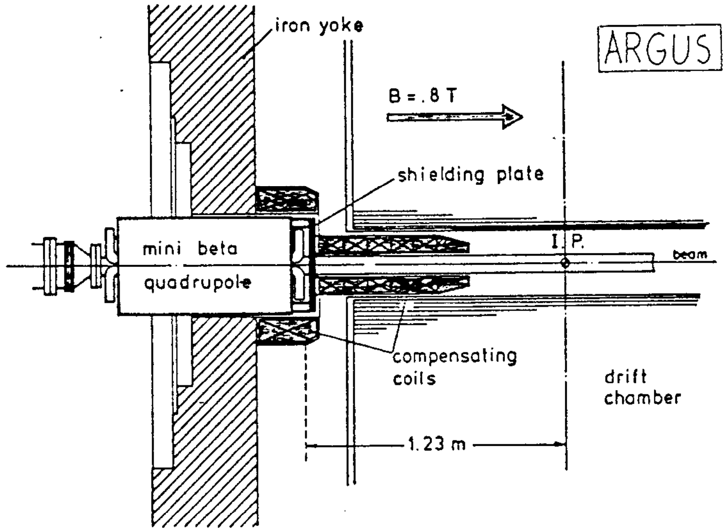

Fig. 3 Layout near the interaction point

The mini-beta- quadrupole generating the vertical waist is supported by the iron yoke. It is shielded from the .8 T of ARGUS by a compensating coil and an iron plate. Other compensating coils in front of the quadrupole make $\int B dl$ vanish along the beam axis. The advantage of this scheme is that it can be handled easily, the disadvantage is that a lot of chromaticity is created due to the comparatively long distance of 1.23 m between the interaction point and the quadrupole.

At present there is no particle detector installed at the second interaction point. So a small vacuum pipe with an inner diameter of 37 mm could be tested there. The test was successful both from the point of view of machine operation and background. A vertex chamber with similar dimensions will therefore be used at ARGUS.

The optical properties at the interaction points are summarized in table 1.

Table 1 Optical properties at the interaction points

	theoretical	measured
β_z^*	.04 m	.05 m
β_x^*	.63 m	.64 m
D_x^*	- .39 m	-
D_z^*	- .004 m	-

The non vanishing horizontal dispersion D^*_x is unwanted but tolerated. With this optics it is possible to obtain a horizontal emittance smaller than the acceptance for all energies.

Luminosity and its Limitations: Fig. 4 shows the luminosity versus current at 5.3 GeV. The measurements were recorded during 10 days of a normal ARGUS run. For each point Bhabba counts were taken over a period of 15 min. The current here is the average over this time. The luminosity is still increasing with current, but less than quadratically. The scattering of the points is much larger than would be expected if only statistics were involved. There are two reasons: a) the luminosity is sensitively dependent on the vertical orbit, and this was not constant over the 10 days. b) Sometimes the beams only partly overlapped due to a vertical instability.

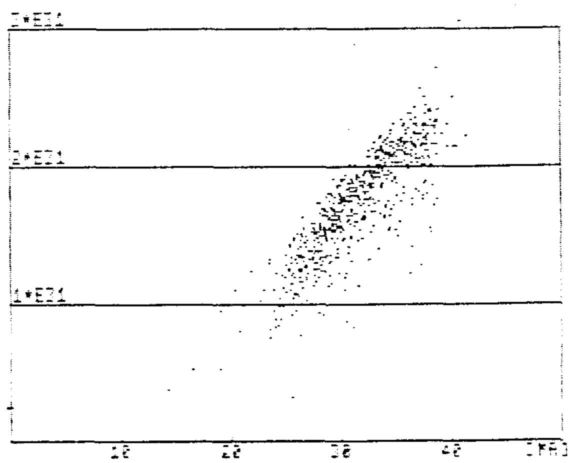

Fig. 4   Luminosity versus current

The specific luminosity (Fig. 5) decreases by factor of $\sim$ 1.7 if the currents change from 25 mA to 42 mA.

Scraper measurements indicate that the relative beam height is enlarged more than the beam width. The ratio is $\Delta h/h : \Delta w/w \sim 4$. At maximum currents the aperture limit is reached.

The linear tune shift ξ_z (Fig. 6) can be calculated from the specific luminosity if the beam height is small compared to the beam width (for DORIS II 30 μ vs 600 μ). ξ_z increases linearly with current up to 25 mA. The maximum

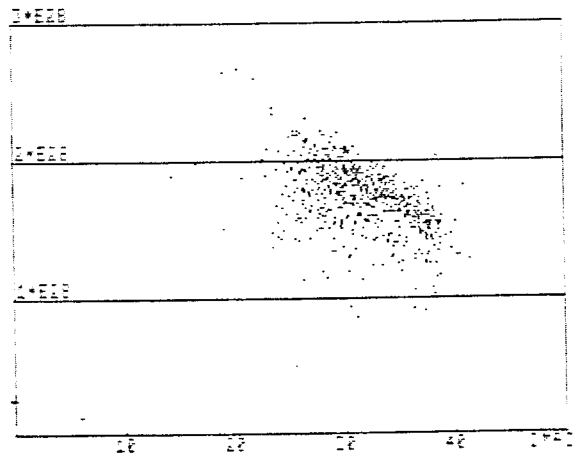

Fig. 5 Specific luminosity versus current

value obtained is ξ_{zmax} = .028.

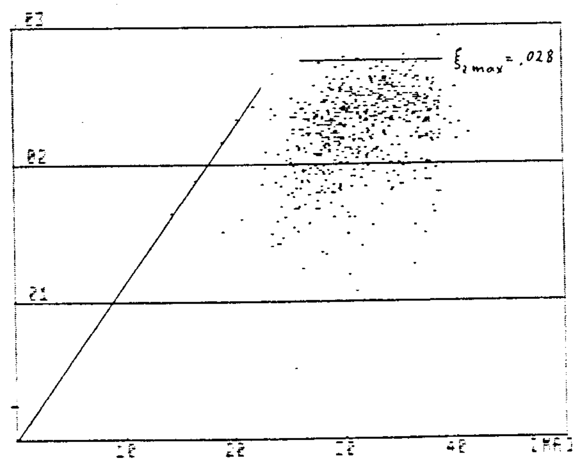

Fig. 6 Tuneshift ξ_z versus current

Fig. 7 shows the development in time of a single fill. The injection up to more than 40 mA per beam is finished within 1 to 2 minutes. The lifetime at the beginning of this run is about 2 h and for other runs very often below 1 h. It depends very critically on the working point. Changes of $\pm$ .001 may decrease the lifetime by a factor of 2. At the highest currents the lifetime is determined by the aperture of the ring as scraper measurements prove. Sometimes both beams have a reduced lifetime (indicated by arrows in Fig.7).

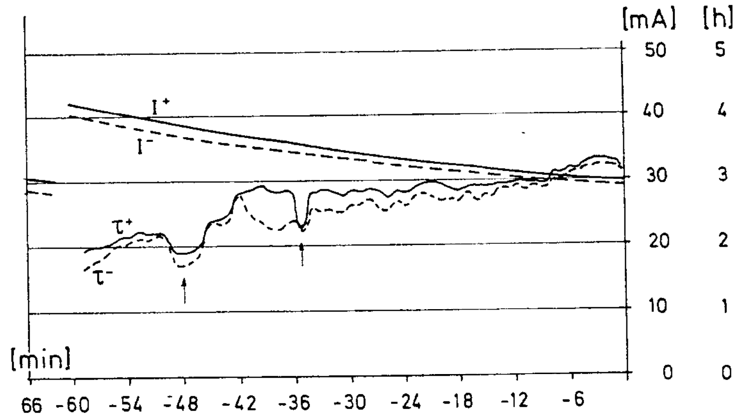

Fig. 7 Current and lifetime versus time

This can be improved only by adding more positrons and by no other machine parameter. This is more and more frequent as the e^--beam becomes stronger and is interpreted as being due to the presence of ions. If electrons only are stored the lifetime may change from 5 h to .5 h and vice versa within minutes. To avoid the effects of ions, more positrons than electrons are stored in general.

As is demonstrated in Fig. 8 DORIS II can be operated rather smoothly.

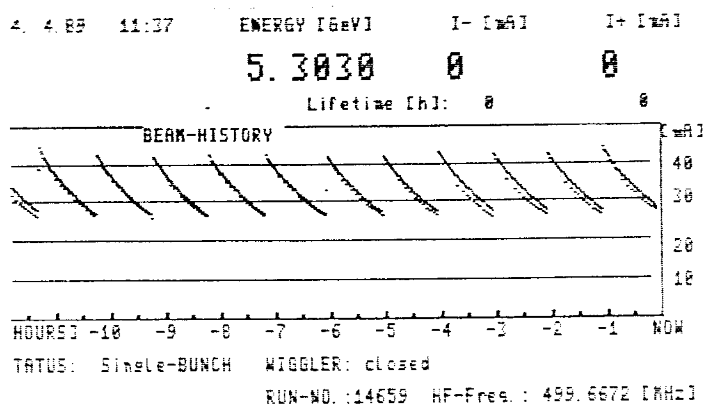

Fig. 8 Luminosity runs at DORIS II

Nevertheless the performance is critically dependent on some parameters, and some tuning is nearly always necessary. There is a new fill roughly every hour.

The following best values have been obtained at an energy of 5.3 GeV

current	2x42 mA
luminosity	1880 $(nb)^{-1}$/day
peak luminosity	3.3×10^{31} cm^{-2} sec^{-1}
maximum tune shift	.028

The performance is limited by the maximum tune shift ξ_z and by the aperture of the ring in both planes. But other limits lurk nearby:

- rf power. The installed 1200 kW supplied to 11 five-cell cavities are just sufficient for a lifetime of 1 to 2 hours at the highest currents. A reduction by about 50 kW also reduces the lifetime.
- vertical instability. Due to beam-beam interaction there are two eigenfrequencies of the betatron oscillations. The lower mode is stabilized by the smallband transverse feedback. At the upper one a weak vertical instability sometimes is observed which decreases the luminosity but increases the lifetime.
- higher order mode losses lead to overheating of the vacuum chamber and then to leaks. Some chambers have already been changed sucessfully. Weak points are now the feedthroughs at the kicker magnets.

Conclusions: Future storage rings designed for a luminosity greater than 10^{33} cm^{-2} sec^{-1} will use currents of about 500 mA per beam in about 15 bunches. From the DORIS-experience all this will be possible only if attention is paid to some important points:

- A very effective injection scheme is needed. The scheme well fitted to DORIS would not be sufficient because it would lead to a fillingtime of about 20 minutes (at DORIS II 1 to 2 minutes).
- The spurious modes in the cavities must be damped heavily to avoid beam instabilities.
- In addition, a powerful feedback system must be supplied. It must be able to handle the splitting of the betatron frequencies due to beam-beam interaction.

- Overheating of the vacuum chamber by higher order mode losses or synchrotron radiation has to be avoided by using a smooth design and effective cooling.
- The beams must collide head on because the maximum tune shift may become small otherwise.
- A good orbit control is needed to obtain small beam dimensions.
- A vertical deflection may be used to reduce the background at least from synchrotron radiation.
- Ion clearing must be provided for the e^--part of the double ring.

References:

1) DESY Storage Ring Group, DORIS, Present Status and Future Plans, Proc. of the 9th Int. Conf. on High Energy Accel. Stanford 1974

2) A. Piwinski, Proc. of the 1977 Part. Acc. Conf., Chicago

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