# THE BYPASS PROJECT AT DORIS II

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## Abstract

DORIS II is used for high energy physics and for the production of synchrotron radiation. The lack of suitable straight sections for the installation of wigglers or undulators led to the idea of bypassing the one interaction point that is no longer needed. The bypass provides space for 7 additional insertion devices and allows colliding beam operation too. Therefore the bypass can also be used for parasitic synchrotron radiation experiments during high energy physics runs. A description of the bypass is presented.


## Introduction

Synchrotron radiation (SR) is used for experiments covering a very wide field, including medicine, biology, chemistry and physics. The intensity can be greatly improved if special magnets like undulators and wigglers are added to the normal bending magnets. The design of future storage rings dedicated to SR allows many of these devices to be installed. Their installation at operating rings like DORIS II [1, 2] leads in general to difficulties since they may be rather long and since there are no corresponding long straight sections in the existing magnet lattice. The way out is to change the lattice. This is what we plan to do (see Fig. 1). Operation with colliding beams must not suffer from this change.

## Layout of the Bypass

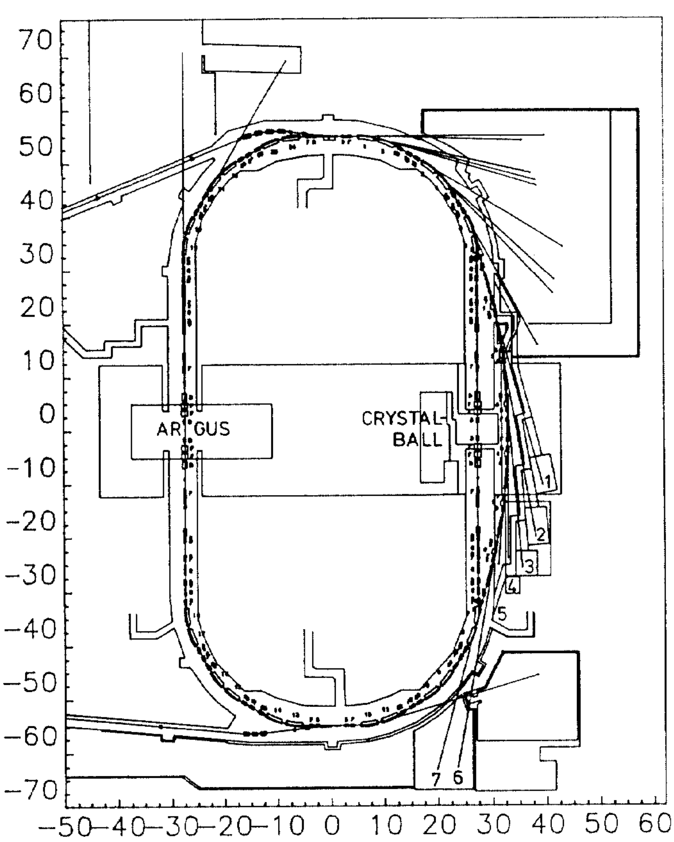


Fig. 1 Layout of DORIS II including the bypass

## General Layout and DORIS III

The general layout of DORIS II including the planned bypass with 7 new beam lines, 3 existing beam lines from wigglers and 28 from bending magnets is shown in Fig. 1. The bypass and the bypassed low beta section of DORIS II, where until 1987 the CRYSTAL BALL detector had been installed, could be supplied alternately with beam. The original section, however, will be replaced by the bypass. The other low beta section will continue to be employed for the ARGUS experiment. This scheme is called DORIS III. Because the "bypass" will be used during high energy physics runs for parasitic SR experiments, the time available for these experiments will at least be doubled. To permit this, the bypass must be able to handle two counterrotating beams. The last magnets in the arcs must be removed to accomodate the bypass. The "lost" bending power will be distributed between six smaller magnets. So 7 straight sections are supplied, useful for wigglers and undulators. Each of them is limited in length to about 4 m by quadrupoles and sextupoles.

## Choice of the Harmonic Number

Obviously the closed orbit must be longer for DORIS III than for DORIS II. The harmonic number is changed from 480 to 482. With this layout sufficient place can be provided within the existing buildings for all but two experiments at the bypass, and most of the existing ports for SR can remain in their position (see Fig. 1). Because the harmonic number is changed, the synchronisation between the preaccelerators and DORIS III must also be changed. The same applies to the triggering for time resolved measurements. For these measurements at present 4 bunches are employed, spaced evenly around the ring. Such an even spacing is possible for a harmonic number of 480, but not for 482.

## Two Counterroating Beams in the Bypass

If two beams are counterrotating in the bypass, there is an unwanted interaction point. The beams must be either separated or suitably focussed at this place. The first method cannot be applied, because there is no room for the installation of separators. Moreover the aperture in the bypass is too small. With respect to the second method it is expected from linear tune shift calculations that the effect of one beam acting on the other remains the same for two interaction points as long as the ratio $\beta_x^*/\beta_z^*$ is the same ($\beta_{x,z}^*$ horizontal resp. vertical amplitude function at the interaction point). Tracking calculations confirm this expectation [3]. It is not necessary therefore to install a mini-β-scheme in the bypass with the usual drawbacks concerning chromaticity and dynamic aperture. Nevertheless the constraint on the beta ratio leads to an optics that is less well suited for SR experiments during high energy physics runs than one would wish. This will be discussed in the next chapter on optics. During dedicated SR runs this drawback does not apply. The SR from the second beam cannot be used and must be absorbed in special parts of the vacuum chamber.

## Vacuum Chamber with Variable Vertical Cross Section

Some of the insertion devices yield good performance with respect to brightness and energy of the emitted SR only if the magnet gap is small. So for the X-ray-undulator (see Table 1) a gap of 11 mm is necessary. Therefore, the free aperture will not be larger than 9 mm. Although this device is placed where the vertical amplitude function is small ($\beta_z \sim 5$ m), the acceptance is reduced by this small aperture. Nevertheless a good beam life time can be expected under normal conditions with one beam, since the half aperture is still large enough for 10 $\sigma_z$. But for high energy physics runs vertical beam widening must be taken into account. Therefore a reduction of the acceptance cannot be tolerated. The wayout is to use either different vacuum chambers under different running conditions or better, to use a chamber with variable vertical cross section. Such a chamber is being developped. It will be similar to that used at the SSRL at Stanford [4].

Rf-requirements

At DORIS III dedicated synchrotron radiation runs are intended at an energy of 4.5 GeV and a stored current of 100 mA. Six 500 MHz cavities of the 5-cell PETRA-type and 650 kW rf-power are sufficient under these conditions. 12 cavities and 1400 kW rf-power are needed for high energy physics runs at 5.3 GeV with currents of 2x70 mA. Since the sites for cavities in the bypassed part of DORIS II are no longer available, nearly all of them have to be installed in the straight sections near ARGUS (see Fig. 1). Instead of 12 cavities of the PETRA-type 4 superconducting 4-cell cavities could be used. But their coupling windows have to withstand a power of about 200 kW, and it is difficult to shield their cold parts from synchrotron radiation.

## Optics

Design Considerations

The horizontal emittance of the particle beam must be as small as possible to obtain a SR beam with large brightness [6]. For the present magnetic lattice of DORIS II the emittance has already been minimized and is $2\times10^{-8}$ $\pi$ radm at 1 GeV. Smaller values are possible only if the lattice in the arc is changed. But then the peak energy is lowered and most of the existing ports for SR have to be shifted. This is not tolerable. Therefore a further reduction of the horizontal emittance will not be attempted. The properties of a SR beam depend also on the amplitude function at the source of the photons. Since the same beam line may be used by different experiments, it is difficult to define optimum values for them. Nevertheless there are some common features. So for a wiggler small horizontal and large vertical amplitude functions are wanted, whereas just the opposite holds for an undulator [5]. To get optimum conditions an individual compromise between different requirements has to be found for each insertion device.

Linear Optics

The compromise accepted for an optics to be used in the bypass during dedicated SR runs is shown in Fig. 2.

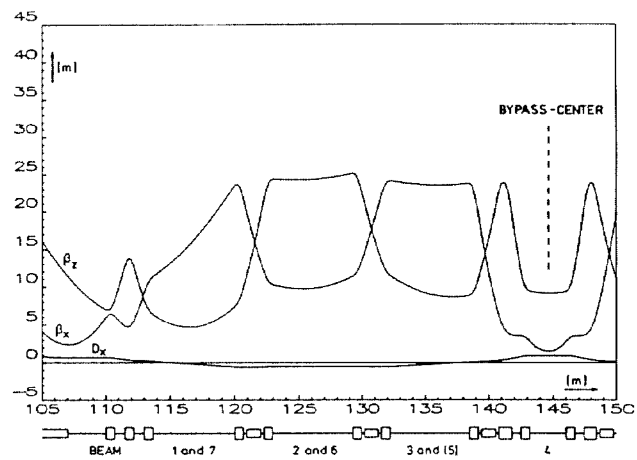


Fig. 2 Bypass optics for dedicated SR runs

The arrangement is mechanically and electrically symmetric to an axis connecting the two interaction points (see Fig. 1). The optical properties in the old part of DORIS II are preserved. Fundamentally the focussing in the bypass has a doublet structure. But near the symmetry point two more quadrupoles had to be added to allow an almost arbitrary ratio $\beta_x^*/\beta_z^*$ during high energy physics runs. For this reason at this position there is place only for a device of about 2.5 m length. Four of the seven straight sections (see Fig. 2) are supplied with large $\beta_x$ ($\sim$ 25 m) and small $\beta_z$ ($\sim$ 6 m). They are suitable for undulators. The other three are more appropriate for wigglers. In table 1 the attributes of the different devices at the different places are described [5] together with some properties of the particle beam. The numbers refer to 4.5 GeV, the chosen particle energy for dedicated SR runs.

| Insertion in straight section | 1 and 7 | 2 and 6 | 3 and (5) | 4 | Unit |
|---|---|---|---|---|---|
| Type of insertion | X-ray undulator | X-ray wiggler | XUV undulator | X-ray wiggler | |
| Wiggler parameter K | 1.61 | 7.1 | 4.0 | 17.1 | |
| Max. angular orbit deflection $K/\gamma$ | .19 | .80 | .46 | 1.9 | [mrad] |
| Critical engergy | 7.4 | 13.1 | 5.5 | 9.4 | [keV] |
| Energy of emitted photons | 8.0 | - | 0.2-1.0 | - | [keV] |
| Emitted power | 15.5 | 35.5 | 8.4 | 24.6 | [Watt/mA] |
| Max. magnetic field | .55 | .97 | .41 | .7 | [Tesla] |
| Height of the magnetic gap | 11 | 20 | 30 | 30 | [mm] |
| Length of the device | 4 | 3 | 4 | 2.5 | [m] |
| Number of periods | 127 | 37 | 37 | 12 | |
| Particle beam width $\sigma_x$ | 2.6 | 2.1 | 3.1 | 1.4 | [mm] |
| " " height $\sigma_z$ | .26 | .54 | .34 | .35 | [mm] |
| Hor. angular envelope $\sigma'_x$ | .22 | .20 | .13 | .53 | [mrad] |
| Vert. " " $\sigma'_z$ | .050 | .022 | .037 | .037 | [mrad] |

Table 1 Properties of some insertion devices

The optics that is to be used during high energy physics runs is shown in Fig. 3. At the interaction point in the bypass the ratio of the amplitude functions $\beta_x^*/\beta_z^*$ has been changed from about .15 to about 20. To achieve this, less favourable amplitude functions have to be tolerated especially for beam lines 3 and 5. Nevertheless most users are expected to take considerable advantage of parasitic SR runs. The big change in the ratio $\beta_x^*/\beta_z^*$ demonstrates the flexibility of the magnet lattice. Although there are in general only 2 quadrupoles between adjacent insertion devices very different solutions for the optics can be found.

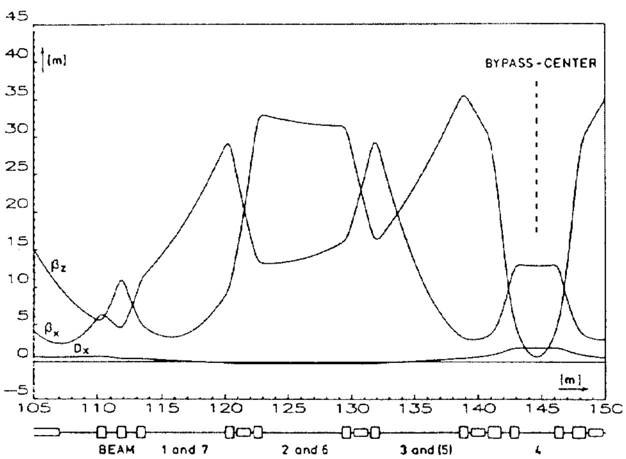


Fig. 3 Bypass optics for parasitic SR runs

The influence of the wigglers and undulators on the linear optics is small. The reason is that the absolute value of the magnetic field at 4.5 GeV integrated over the bending magnets is about 6 times larger than that integrated over the insertions. Due to edge focussing the betatron tune is changed by less than .04 which can be corrected easily. The change in momentum spread and emittance is roughly 1 % only.

## Chromaticity Corrections and Dynamical Aperture

Like in most electron storage rings, the nonlinear dynamics in DORIS III is governed by sextupole magnets and not by field errors. Substituting the CRYSTAL BALL low beta insert by the bypass has mainly two consequences if nonlinear dynamics is considered. Firstly, the linear chromaticity of the luminosity optics is reduced from $\xi_{x/z}$ = -20/-21 to -16/-15. Therefore its compensation by sextupoles is done by weaker fields than before. This is expected to positively affect nonlinear acceptance. This statement holds all the more for the SR optics with linear chromaticities as small as $\xi_{x/z}$ = -12/-6.5. Secondly, on the other hand, with the new DORIS lattice the superperiodicity of 2 and the mirror symmetry with respect to the centers of the arcs is replaced by mirror symmetry with respect to the centers of the straight sections only (see Fig. 1). Reduction of superperiodicity by a factor of 2 results in twice as many intrinsic resonances, however. Tracking calculations have been performed using the RACETRACK tracking code [7]. 16 particles have been distributed elliptically in the x/z phase space with the emittance ratio of $\varepsilon_z/\varepsilon_x$ = 0.1. Closed orbit errors of 1 mm rms horizontally as well as vertically have been introduced. 2000 tracking turns have been performed, corresponding to about one transverse damping time at

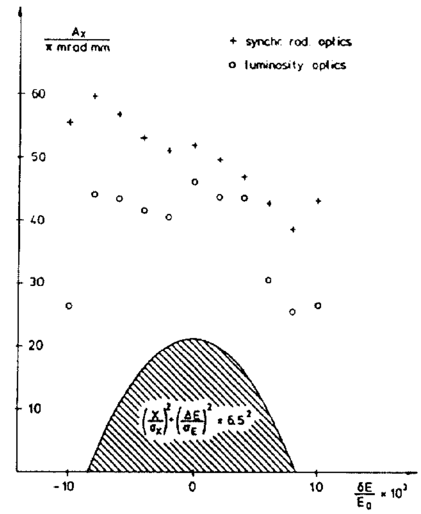


Fig. 4 Hor. acceptance vs momentum deviation

5.3 GeV. Four sextupole families have been used so far, compensating the linear chromaticity and - in some extent - the off-energy beta beat. It is seen from Fig. 4 that the resulting acceptance is generous for the SR optics. For Luminosity operation there is still sufficient space for the beam, the size of which at 5.3 GeV is indicated in Fig. 4 too. For the latter small emittance coupling and 6.5 σ have been assumed. Tracking calculations for the old DORIS II luminosity optics result in somewhat worse acceptance conditions (not displayed in Fig. 4). Knowing that this optics had been used in DORIS for many years, this fact supports our optimistic interpretation of tracking results for the new DORIS luminosity optics.


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