SYNCHROTRON RADIATION MASKING ON ASYMMETRIC 6.5 x 4.3-GEV B-FACTORY

V.E. Blinov, V.A. Lebedev, A.V. Matveev,
V.A. Tayursky, and A.A. Zholents

Institute of Nuclear Physics, 630090 Novosibirsk, USSR

Abstract

We studied a synchrotron radiation background rate in the recently proposed project of the asymmetric 6.5 GeV on 4.3 GeV B-Factory with monochromatization. An applied method is Monte-Carlo simulations of the absorption and reradiation of photons in the primary masks, secondary masks shaded primary masks and so on. With the proposed masked scheme we obtained the acceptable background level in the silicon vertex chamber about 8 10^6 photons/sec.

I. INTRODUCTION

B-Factory is a well known name for a collider with high luminosity, good vertex resolution, and high average current. Luminosity requirements are reduced by having a moving center of mass, which implies unequal beam energies (6.5 GeV on 4.3 GeV in this study). The difference of the beam energies opens a possibility of a fast orbit separation by having magnetic fields close to the interaction point (IP). It is considered as a major factor for a luminosity improvement.

At the same time a synchrotron radiation (SR) in the separation magnets produces powerful x rays in the dangerous vicinity of a small, thin beampipe of the vertex chamber. Therefore a sophisticated masking design is required to fulfill a condition of a high luminosity with a good vertex resolution at the acceptable background level.

Another important issue very close related to the SR masking design is the heat loads on various beampipes, masks, and surfaces. Possible problem areas are high SR power densities and HOM heating of the beampipe.

In this paper we present a design of SR masking system for a project of a B-Factory with monochromatization. A description of the project can be find elsewhere [1-3]. Among all beam parameters we will emphasize here only on the very small emittances: $5\cdot10^{-9}$ m·rad for high energy beam (HEB) and $4\cdot10^{-9}$ m·rad for low energy beam (LEB) in horizontal plane and $2.5\cdot10^{-10}$ m·rad for HEB and LEB in the vertical plane, which is a distinctive feature of all monochromatic projects [4]. It means that the vertical beam size and divergence near the IP are very small. This fact plays an important role in our proposal for SR masking.

II. MASK DESIGN

A schematic drawing of our SR masking scheme is shown in Fig.1. There are two projections here, because the beam orbits don't lie in plane. The horizontal projection is mirror symmetrical relative to central line while the vertical one is symmetrical relative to the IP.

The separation of the LEB and HEB orbits begins in the bending magnet. Then it is continued in the quadrupole lens. The bending magnet on the left side is tilted on the angle of 22° and has the following vertical and horizontal components of the magnetic field: B_y = 4 kG, B_x = 1.6 kG. The bending magnet on the right side is tilted in the opposite direction on the same angle and has the magnetic field with the components B_y = 4 kG, B_x = -1.6 kG. Both lenses have equal gradient of -2.8 kG/cm. They are placed offset with small vertical and horizontal slopes, so the LEB

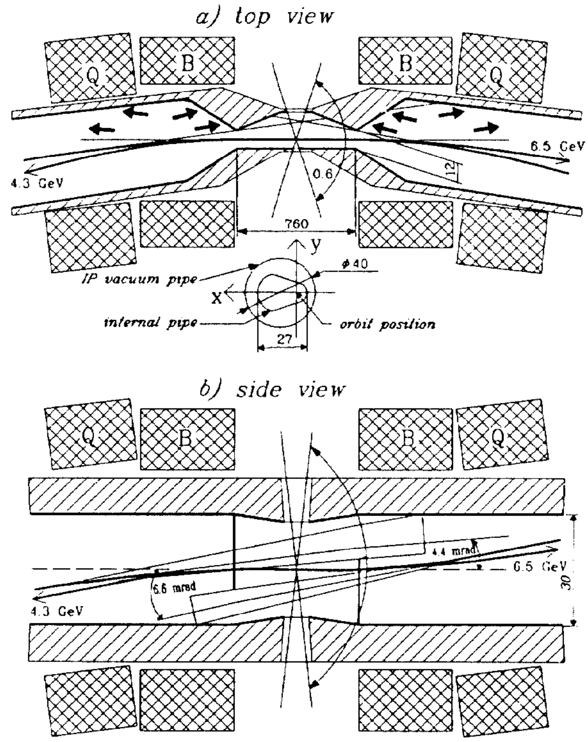

Fig.1. A schematic drawing of the SR masking system.

orbit lies in the middle plane of the lenses. The position of the central axis of each lens and its horizontal slope are chosen in a such way that the LEB passes the lenses in the approximately constant magnetic field of 2.9 kG.

At the same time the HEB is shifted to the lens center as it moves along the lens, so the magnetic field on its trajectory is gradually reduced. It helps us to choice a position of the mask edge in the place, where the incident SR from the HEB is emitted in the relatively low magnetic field of 1.3 kG.

Our approach to the design of the SR masking scheme is based on the idea of the vertical separation of the SR fans emitted by HEB and LEB in the vicinity of the IP. Two masks with slits at different vertical position are placed symmetrically with respect to the IP. X ray approaching the IP is primary absorbed by the mask before the IP (whose slit lies above or below of horizontal plane). Then the remaining part of x ray which passes through the aperture of first mask can through the slit of the second mask. Thus, this radiation is absorbed far from the IP (see, Fig.1).

The heights of masks and slits depend critically on the beam halo distribution. It is a well known fact that the beam-beam effects extend vertical beam tails to many sigma. Today, it seems to be impossible to accurately predict the population of particles in the halo in a future machine. Therefore we applied to previous experiences. A collection of data from different e^+e^- storage rings [5] shows that in most cases the limiting vertical aperture lies in 20-25 sigma during the luminosity runs. This means that with movable distant masks we can simply cut the tails over

0-7803-0135-8/91$01.00 ©IEEE

25 sigma. Therefore, we choose the heights of our masks to shadow geometrically the vertex chamber from the direct SR emitted by beams with vertical tails extended up to ±25 sigma. The remaining place in the aperture is used for slits. They allow to through x ray emitted by tails in the beam angular distribution extended up to +25 and -12 angular sigma for the HEB and +12 and -25 angular sigma for the LEB (the vertical size of x rays inside slits is mainly determined by the tails in the beam angular distribution). We didn't manage to through all photons and therefore about 10^{-5} photons emitted by the HEB in the angle of 11.5 mrad and 10^{-5} photons emitted by the LEB in the angle of 15.5 mrad impinge masks from the IP side. We employ the term *residual* for these photons (For an estimation of the particle population between 12 and 25 sigma we used the data obtained on PEP [6]).

Another important problem is screening the reradiation from the mask edge (*tip scattering*). For a solution of this problem we decided to continue the mask with narrow beam aperture up to the internal IP beampipe.

The described above SR masking scheme is obviously a very sensitive to the stability of the beam orbit relative to the masks and the IP beampipe. Allowed orbit deviations are less than one sigma. But it is not a lack of the proposal. There is another important reason to have the high stability of the orbit. It is beam-beam effects that require the orbit stability about 0.2-0.3 sigma. Therefore an existence of a good orbit feedback is implied in our design.

III. MONTE-CARLO SIMULATION

We simulate the SR background in the vertex chamber by the program **EMSH** [7] which is capable to calculate the photoelectric effect, fluorescence from K, L shells, Rayleigh and Compton scattering.

In the described above masking scheme most SR photons can reach the IP beampipe after three or more intermediate scattering or reradiations. We will show below that every interaction with the mask material results in a significant reduction of the photon flux. A total factor for three interactions is about 10^{-8}. But in some cases of our scheme the IP beampipe remains open for photons after the second scattering. Fortunately it hasn't severe effects because takes place mainly in the very small solid angle about 10^{-4} sr. Only *tip scattered* radiation can reach the IP beampipe in the relatively large solid angle of 10^{-1} sr.

A proper choice of the mask coating is one of the problem for the optimization in competition between absorption and reradiation. We found the silver in our case of multiple photon-material interactions as the best choice. For example, it is better than aluminum and copper in 25 and 250 times respectively. Histograms in the Fig.2 show x ray energy spectrum after the first, second and third interaction with silver. The forth histogram shows the energy spectrum of photons penetrating through the internal IP beampipe. This beampipe is made from beryllium of 0.5 mm thickness coated inside by the aluminum layer of 0.15 mm thickness (0.3% of the radiation length for total beampipe). It is placed inside the vacuum and is intended for several goals. One of them is to cut a high peak of the silver fluorescence line at 3.5 keV.

Another subject for the optimization is the choice of the material on the mask edge. If the primary photon hits the mask close to the edge there is a certain probability for scattering and fluorescence photons to leave the mask through the side wall. This *tip scattering* effect was calculated for different materials and the tungsten was chosen as the most appropriate material. Similar conclusion was made earlier in Ref.8.

The SR photons become real background when they are detected by the vertex chamber. We considered silicon

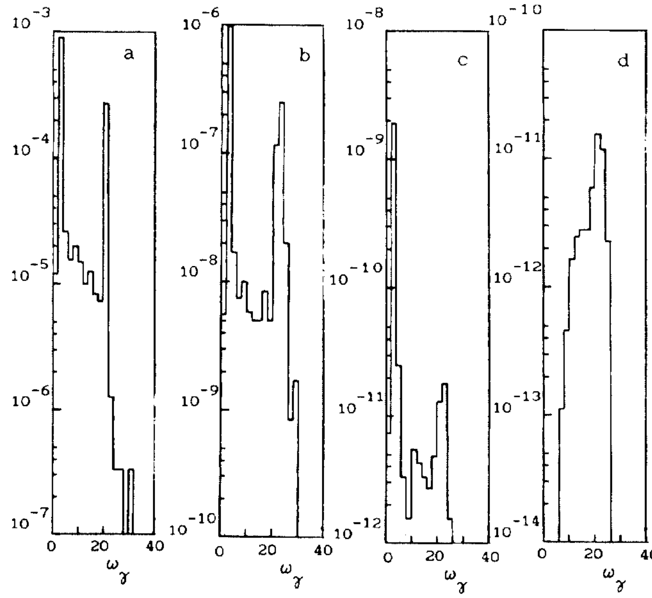

Fig.2. Histograms of the energy spectrum of photons after the first (a), second (b) and third (c) interaction with the mask coated by the silver layer of 0.5 mm thickness in places where the primary radiation is absorbed and 0.15 mm thikness in other places. The forth histogram (d) shows the energy spectrum of photons penetrating the internal IP beampipe. The normalization is made on one incident photon. The SR source is the HEB in the field of 3 kG.

and gas vertex chambers and simulated the probability of SR photon detections versus their energy. At the energy of 20 keV (a peak of the distribution in Fig.2.d) it is 100% for silicon chamber, composed from three layers of silicon of 0.35 mm thickness, and 7% for gas chamber [9].

The final expectation for SR background in the silicon vertex chamber is presented in Table 1. Here the contributions of all possible ways for photons to arrive in the vertex chamber are detailed. Predictions are made for HEB with the current of 0.7 A. The LEB contributes into the background on the order of magnitude smaller.

Table 1. Summary of SR backgrounds for silicon vertex chamber.

Beam	Current (A)	1 (γ/sec)	2 (γ/sec)	3 (γ/sec)	4 (γ/sec)	total (γ/sec)
HEB	0.7	$3.9\cdot10^{4}$	$1.7\cdot10^{6}$	$9.8\cdot10^{4}$	$6\cdot10^{6}$	$8\cdot10^{6}$

Item 1 shows contributions of the way with three scattering or reradiation.

Item 2 shows contributions of the way with two scattering or reradiation in a small solid angle of 10^{-4}sr.

Item 3 shows contributions of *tip scattering*.

Item 4 shows contributions of the *residual* x rays. The LEB is also taken into account here.

Backgrounds for the gas vertex chamber are on the order of magnitude lower.

IV. HEAT LOADS

Three types of heat loads are important to take into account in the design of the SR masking system. They are SR heating of masks, image currents and HOM heating of the IP beampipe. Fortunately all of them need a common approach in the design. It consists in providing of gentle tapering transitions to a small mask aperture (30 mrad tapers in our case). One goal of transitions is to spread high SR power densities. With such masks we distributed the absorption about 4 kW radiation of HEB and about 2.5 kW radiation of LEB along water cooled mask surfaces with linear densities of 125 W/cm and 85 W/cm correspondingly.

Another goal of tapers consists in the reduction of a loss parameter of transitions. We didn't figure out exact places of energy deposition by HOMs, which is not easy. Instead we used all means to prevent the energy deposition on the IP beampipe. We placed the end of the transition in 38 cm from the IP, so the low frequencies HOMs are rapidly attenuated propagated down the beampipe. Then we shielded a relatively large cavity composed by the IP beampipe and the mask walls by the internal beampipe of a smaller size (see Fig.1). Finally we coated a part of cooled surfaces close to the IP by a ferrite layer to intend here the energy deposition of HOMs.

Heat loads from image currents are also absorbed by the internal beampipe. A design of the internal beampipe [10] is made to allow a relatively high temperature rise.

V. COMMENTS

It seems to be the conventional wisdom to begin the B-Factory run with beam experiments. One of them has to be devoted to the test of the SR masking system. During this test a particle population in tails and orbit stability should be figured out. In case of smaller tail expansions then considered above the diameter of the IP beampipe can be diminished and it should be increased in the vice versa case.

Acknowledgements. We would like to thank A.Bondar, A.Chilingarov, S.Mankov, A.Onuchin, L.Romanov, V.Telnov, Yu.Tikhonov, A.Vlasov for useful discussions.

VI. REFERENCES

[1] A.Zholents, AIP Conf. Proc., v.214, New York, 1990, p.592.

[2] A.Dubrovin, A.Vlasov, A.Zholents, Annals of the New York Academy of Sciences, v.619, 1991, p.193.

[3] A.Dubrovin, A.Zholents, "A Combined Symmetric and Asymmetric B-Factory with Monochromatization", in Proc. of this conf.

[4] A.Dubrovin, A.Garren, A.Zholents, AIP Conf. Proc., v.214, New York, 1990, p.347.

[5] J.T.Seeman, Lect. Notes in Phys., v.247, Springer Verlag, 1985, p.121.

[6] M.K.Sullivan, Synchrotron Radiation Background in the MAC and TPC Vertex Chambers, UC-IIRPA-88-01, May 1988.

[7] V.A.Tayrsky, Preprint INP 89-16, Novosibirsk, 1989.

[8] A.P.Onuchin, Ju.A.Tikhonov, Preprint INP 77-77, Novosibirsk, 1977.

[9] T.Tauchi *et al.*, Estimation of Beam Backgrounds for the TOPAZ Vertex Chamber, KEK Preprint 89-83, September 1989.