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SYNCHROTRON RADIATION FROM THE LOW-BETA QUADRUPOLES SCATTERED BACK TOWARD THE SHORT INSERTION OF LEP

R. Del Fabbro
INFN, Sezione di Pisa, Pisa, Italy

ABSTRACT

By Montecarlo calculation the synchrotron radiation produced by the LEP beam in the low-beta quadrupoles is evaluated.

This radiation is simulated to scatter back along the beam pipe toward the short insertion of LEP in the mini-beta version.

The back photon flux reaching the experimental insertion is calculated and the corresponding energy and delay time spectra are given as well as the azimuthal distribution.

It results that the back scattered radiation from the low-beta quadrupoles don't appear to be dangerous, mainly because the bulk of this radiation is delayed more than 200 nsec with respect to the crossing time.

On the contrary ~~one suspects that~~ the back radiation coming from the quadrupoles upstream the short insertion could be a more serious source of background.

1. - INTRODUCTION

The synchrotron radiation produced by the e^+e^- colliding beam passing through the magnetic components of a storage ring is considered a source of background for those tracking detectors, which for experimental purpose have to be located very close to the beam.

In this note it is investigated how serious can be the background of the synchrotron radiation coming from the low-beta quadrupoles and scattered back toward the short insertion of LEP in the mini-beta version as proposed(1) at Villars in the "General Meeting of LEP".

The problem of the synchrotron radiation background around the experimental insertions has been studied since the 1976 by the early STUDY GROUP ON LEP. Hoffmann and Wiik calculated(2) the direct synchrotron radiation coming from the dipoles and quadrupoles.

From these studies it appeared clear that the experimental insertions must be shielded by collimators from the synchrotron radiation.

In the present note I refer to the collimator configuration as recently proposed by Burn(3) in order to shield the experimental insertion by the radiation coming from the full bending and 10% bending dipoles.

In his talk at Villars K. Potter(4) on the base of Leistam's calculations pointed out the necessity of setting up masks in the low-beta quadrupoles region in order to stop the back synchrotron radiation coming from the quadrupoles.

In fact, nevertheless the bulk of this radiation is closely confined in the beam region, in a long path this photon flux hits the pipe wall and a fraction of it scatters back toward the experimental insertion.

This back radiation, which is strongly dependent on the pipe size and shape around the experimental insertion as well as on the collimator configuration, reaches the experimental insertion delayed with respect to the crossing time by an amount depending on the distance of the back collision from the crossing point.

The Section 2 is devoted to study the synchrotron radiation direclty produced in the quadrupoles QS1 and QS2. In the Section 3 the back photon fluxes are calculated. In the Section 4 the Montecarlo results are given and the energy spectra, the delay spectra and the azimuthal distributions of the effective back photon fluxes in the experimental insertion are provided.

At last in the Section 5 some conclusive remarks are given on the contribution to the back scattering radiation from the upstream quadrupoles QS3, ... QS8 in comparison with the contribution from QS1 and QS2.

2. - FLUX OF PHOTONS RADIATED IN THE QS1 AND QS2 QUADRUPOLES

This Section is devoted to calculated the yield of photons radiated by the LEP electron beam passing through the QS1 and the doublet of QS2 quadrupoles. (See in the sketch of Fig. 1 the LEP lattice around the short insertion).

In the Section 4 of Ref. (5) an analogous calculation is reported on the power emitted by the electron beam in the approximation of the vanishing vertical dimension of the electron beam, i.e. neglecting the vertical betatron oscillations.

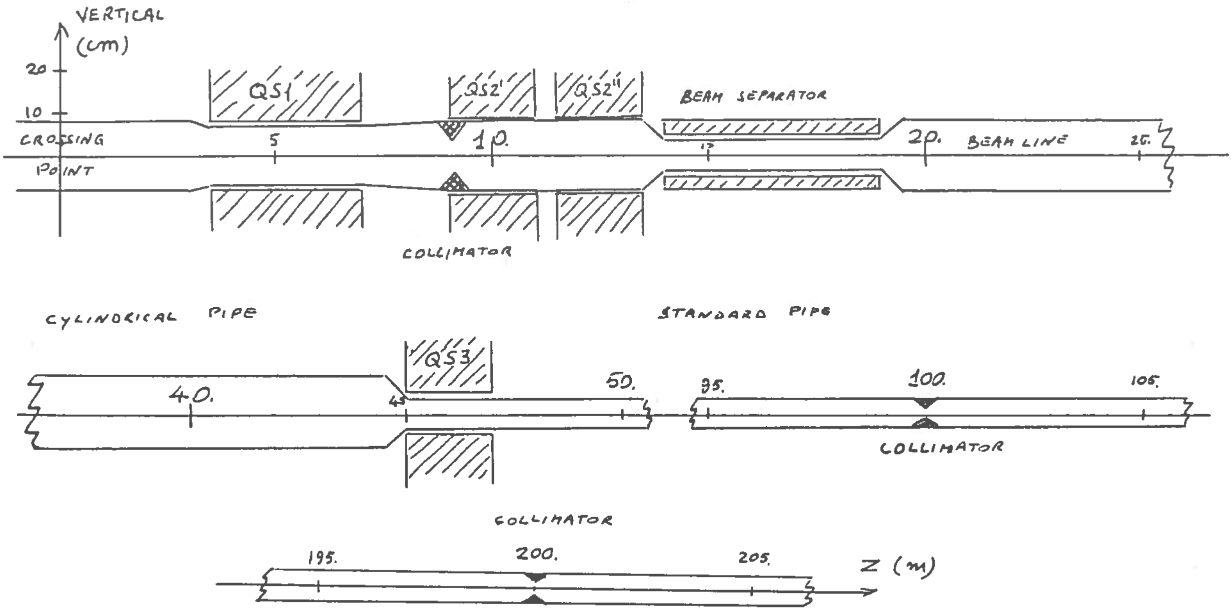

FIG. 1 - LEP lattice around the short insertion.

On the contrary in the present calculation of the photon yield both radial and vertical betatron oscillations of the beam are taken into account.

The number of photons emitted in the time and length unit of the radiating electron trajectory is given by the expression:

$$\frac{d^2N}{dt\,ds} = \left(\frac{dp}{ds}\right) \frac{1}{E_c} \int f(\xi)\, \frac{d\xi}{\xi} \qquad (\mathrm{sec}^{-1}, \mathrm{m}^{-1}) \qquad (1)$$

where (dp/ds) is the power emitted in the unit of trajectory length, E_c is the critical energy $f(\xi)$ is the normalized spectral function ($\int_0^\infty f(\xi) d\xi = 1$).

In the quadrupole case the (dp/ds) and E_c can be described by the following expressions:

$$\left(\frac{dp}{ds}\right) = 14.09\, I\, E_b^4\, K^2\, y^2 \qquad (\mathrm{w}, \mathrm{m}^{-1}) \qquad (2)$$

$$E_c = 2.2\, E_b^3\, K\, y \qquad (\mathrm{keV}) \qquad (3)$$

Being K the quadrupole constant (in m^{-2}) and y the distance (in m) of the considered radiating point from the quadrupolar axis; I is the beam current (in mA) and E the beam energy (in GeV).

The spectral function $f(\xi)$ (ξ being the photon energy in the critical energy unit) is shown in Fig. 2, it is a pure algebric function of its argument, which can be expressed by the formula:

$$f(\xi) = \frac{9\sqrt{3}}{8\pi}\, \xi \int_\xi^\infty K_{5/3}(\bar{\xi})\, d\bar{\xi}$$

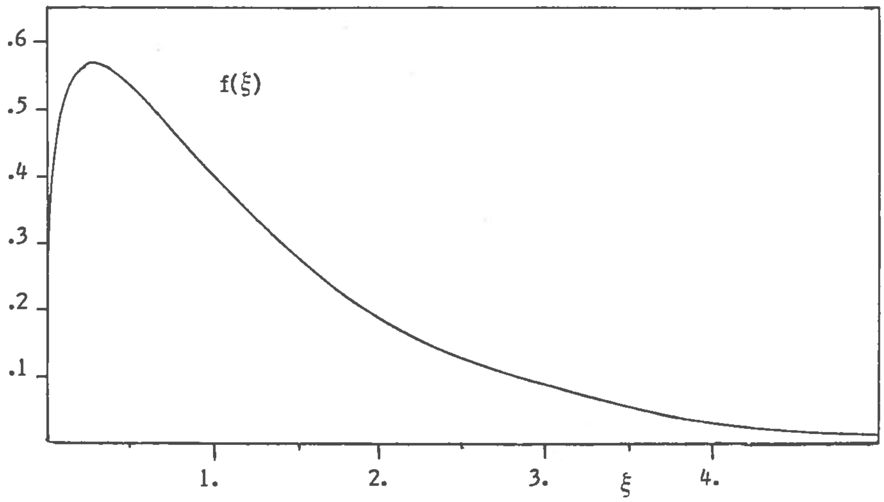

FIG. 2 - Spectral function of the synchrotron radiation.

where $K_{5/3}$ is a modified Bessel function (see for instance the Sand's paper: "The physics of electron storage ring. An introduction"). This spectral function can be fairly well described by the following analytical functions for different regions of the ξ parameter:

$$f(\xi) = 1.3\ \xi^{1/3} \qquad \text{for } \xi < 0.05$$

$$f(\xi) = (0.77\ e^{-\xi/1.75} - 0.34\ e^{-\xi/0.15})\ e^{-\xi^2/10} \qquad \text{for } 0.05 < \xi < 2.5 \tag{4}$$

$$f(\xi) = 0.78\ \xi^{1/2}\ e^{-\xi} \qquad \text{for } \xi > 2.5$$

being these expressions approximated at a precision of few percent.

The formula (1) can be rewritten taking into account the expressions (2) and (3) as follows:

$$\frac{d^2N}{dt\ ds} = 4.10^{16}\ I\ E_b\ K\ y \int f(\xi)\ \frac{d\xi}{\xi}\ ) \qquad (sec^{-1}, m^{-1}) \tag{5}$$

By the expression (5) I am able to write the following quantity:

$$4.10^{12}\ I\ E_b\ K\ y\ l \int_{\Delta\xi} f(\xi)\ \frac{d\xi}{\xi} \tag{6}$$

which expresses in a single bunch crossing the number of photon in the energy range $\Delta\xi$ radiated by an electron in the trajectory element of length l and located at a distance y from the quadrupolar axis. (Note that the bunch crossing frequency in LEP has been supposed to be 10 KHz).

In order to know the total photon flux, one needs to compute the contribution (6) for all electrons of the beam.

To do that means to consider the distributions of the betatron oscillation amplitudes both in the radial and vertical directions. The radial and vertical oscillations are supposed to be completely uncoupled.

If by X(Y) I indicate the radial (vertical) coordinate, the number of electrons in the radial range $\frac{x_o}{\sigma_x}, \frac{x_o}{\sigma_x} + d\frac{x_o}{\sigma_x}$ and in the vertical range $\frac{y_o}{\sigma_y}, \frac{y_o}{\sigma_y}\ d\frac{y_o}{\sigma_y}$ is:

$$d^2 H = d\frac{x_o}{\sigma_x}\ e^{-\frac{1}{2}\left(\frac{x_o}{\sigma_x}\right)^2} \frac{x_o}{\sigma_x}\ d\frac{y_o}{\sigma_y}\ e^{-\frac{1}{2}\left(\frac{y_o}{\sigma_y}\right)^2} \frac{y_o}{\sigma_y} \qquad (7)$$

where $x_o(y_o)$ is the amplitude of the radial (vertical) phase space ellipse and $\sigma_x(\sigma_y)$ the corresponding radial (vertical) spatial standard deviation (see for more details the discussion in the Ref. (5)).

The photon yield is calculated by the Montecarlo method, so a finite number of electrons from the distribution (7) is required. In doing that I have choosen an integrated form of the expression (7) in bins of one half standard deviation:

$$H_{n,m} = \int_{\frac{x_o}{\sigma_x} - \Delta\frac{x_o}{\sigma_x} = \frac{n}{2} - \frac{1}{4}}^{\frac{x_o}{\sigma_x} + \Delta\frac{x_o}{\sigma_x} = \frac{n}{2} + \frac{1}{4}} d\frac{x_o}{\sigma_x} e^{-\frac{1}{2}\left(\frac{x_o}{\sigma_x}\right)^2} \frac{x_o}{\sigma_x} \int_{\frac{y_o}{\sigma_y} - \Delta\frac{y_o}{\sigma_y} = \frac{m}{2} - \frac{1}{4}}^{\frac{y_o}{\sigma_y} + \Delta\frac{y_o}{\sigma_y} = \frac{m}{2} + \frac{1}{4}} d\frac{y_o}{\sigma_y} e^{-\frac{1}{2}\left(\frac{y_o}{\sigma_y}\right)^2} \frac{y_o}{\sigma_y} \qquad (8)$$

where $x_o/\sigma_x = n/2$, $\Delta x_o/\sigma_x = 1/4$ (n=1,2...N) and $y_o/\sigma_y = m/2$, $\Delta y_o/\sigma_y = 1/4$ (m=1,2...M).

One can express the number of photons in the energy range ΔE emitted by all electrons of the beam in the element l of trajectory length:

$$N(\Delta E) = 4.10^{12} I\, E_b\, K\, l \sum_{n,m=1}^{N,M} \left\langle \int_{\Delta\xi} f\ (\xi)\frac{d\xi}{\xi} \right\rangle_{n,m} \langle y \rangle_{n,m} H_{n,m} \qquad (9)$$

where $\langle y \rangle_{n,m}$ is the averaged value of the radiating electron distance from the quadrupolar axis. This value is averaged on many possible electron trajectories corresponding to different points randomly distributed on the phase space radial and vertical ellipses, whose half-axes are fixed by the values of m and n:

$$x_o = \sigma_x\, n/2 \qquad\qquad y_o = \sigma_y\, m/2$$

$$x'_o = \frac{\sigma_x}{\beta^*_x}\, n/2 \qquad\qquad y'_o = \frac{\sigma_y}{\beta^*_y}\, m/2$$

being $x'_o(y'_o)$ the angular oscillation amplitudes and β^*_x (β^*_y) the radial (vertical) beta function taken in the crossing point. In fact in the Montecarlo simulation the electron trajectory is choosen in the crossing point (the values of σ_x and σ_y refer to the beam spatial distribution in the crossing point), then electron trajectory is calculated back through the optical elements of the machine up to the considered radiating point.

It is worth while to point out that the integral $\int_{\Delta\xi} f(\xi)d\xi/\xi$ is not a fixed quantity, but varies trajectory by trajectory depending on n and m through E_c, which is a function of y.

That is why one must calculate the expression (9) for many trajectories and take the everage values.

From the calculation it results that a power of 95. Watt is radiated per crossing by an electron beam of 5.7 mA in current and 50. GeV in energy (these values correspond to the forseen phase I of LEP).

This power is radiated in the quadrupole QS1 of quadrupolar constant K=0.1188 m^2 and in the doublet QS2' and QS2" of quadrupolar constant K=0.042 m^2.

The calculation refers to an electron bunch simulated up to 5 standard deviations both in the radial and vertical direction (N=M=10).

The mean values in the expression (9) have been averaged on 30 different electron trajectories randomly choosen on the phase space ellipses.

The power distribution has been projected in the vertical and radial standard deviation parameters and the results are plotted in the Fig. 3a and 3b respectively.

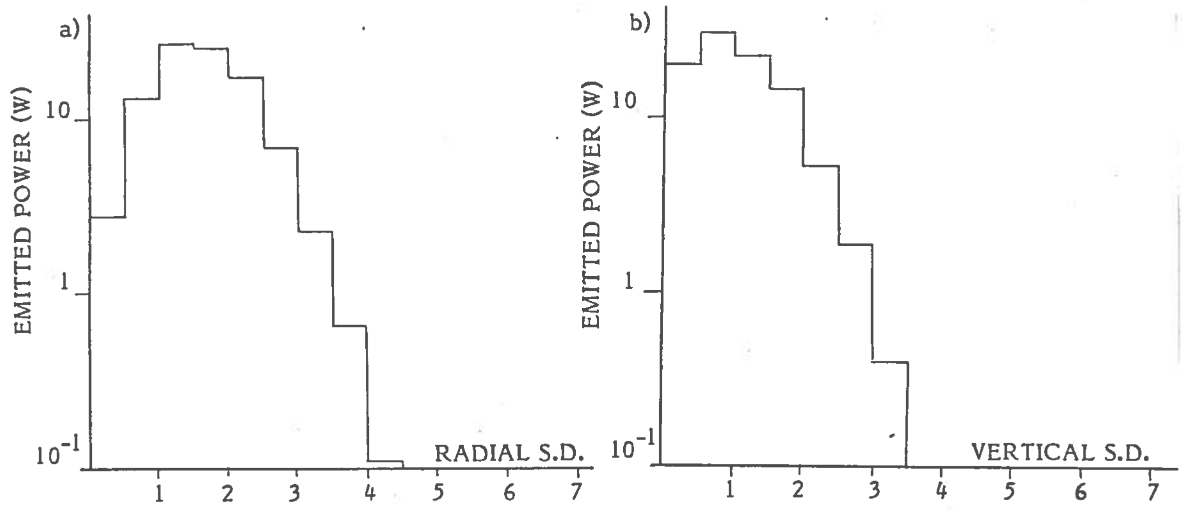

FIG. 3 - Emitted power distribution. a) Radial projection. b) Vertical projection.

The total number of the radiated photons in the energy range from 100.0 eV to 200.0 MeV turns out to be 3×10^{12} photons per crossing.

The energy spectrum of the emitted radiation is shown in Fig. 4.

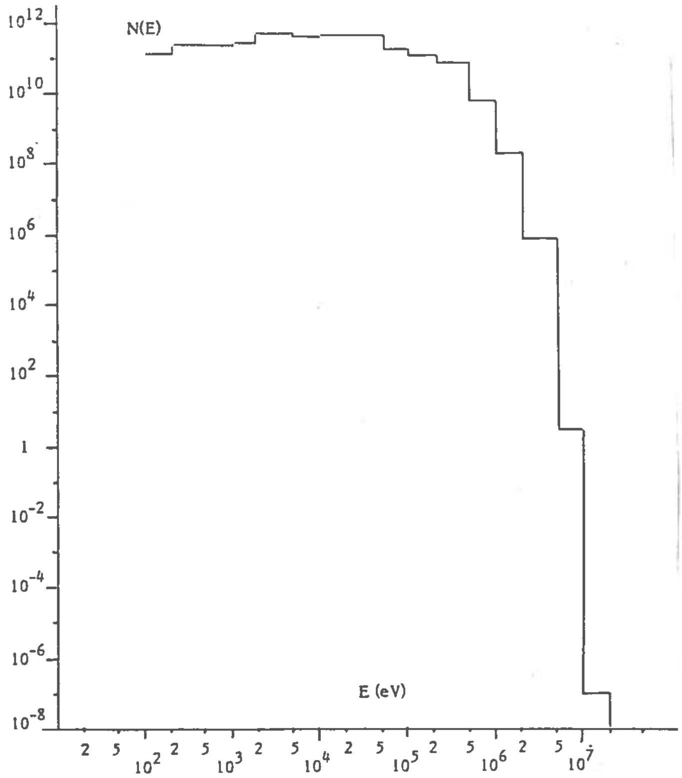

FIG. 4 - Energy spectrum of the emitted radiation.

3. - BACK SCATTERED RADIATION

The bulk of the synchrotron radiation emitted in the QS1 and QS2 quadrupoles is produced in small angular range. Therefore the radiation travels for a long path into the beam pipe before hitting the pipe wall at a distance from the crossing point, which can be variable but no more than about 280.0 m due to the beam pipe curvature.

Actually a fraction of this radiation may scatter back toward the experimental insertion.

A photon flux of energy E reaching the aluminium wall of the beam pipe is reduced by a factor $e^{-\mu(E).x}$ after crossing a path of length x. In a successive infinitesimal layer dx a photon can undergo a Compton collision and scatter back in the real solid angle $d\Omega$ with a probability given by the following expression:

$$d^2P = Zn = \left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E) \; e^{-\mu(E)x} \; dx \, d\Omega \qquad (10)$$

where n is the number of atoms in the volume unit and Z is the atomic number.

Since one is interested to the back radiation, the involved diffusion angles one has to consider are $\pi-\delta$, where δ is of the order of few mradiants. Therefore one is allowed to put $\cos\theta=-1$ in the Klein-Nishina formula obtaining the back Compton cross section:

$$\left(\frac{d\sigma}{d\Omega}\right)^{\text{Compton}}_{\text{Back}} (E) = r_e^2 \, \frac{1 + \dfrac{(2E/m_e)^2}{2(1+2E/m_e)}}{(1+2E/m_e)^2} \tag{11}$$

where r_e is the classical radius and m_e the mass of the electron.

In the Compton collision a photon of energy $\bar{E}$ is emitted:

$$\bar{E} = \frac{E}{1+E(1-\cos\theta)/m_e} \simeq \frac{E}{1+2E/m_e}$$

where the last expression in the above formula is referred to the back diffused photons.

In the Fig. 5 the back Compton cross section in the Thompson limit unit and the back photon energy are shown as function of the incoming photon energy.

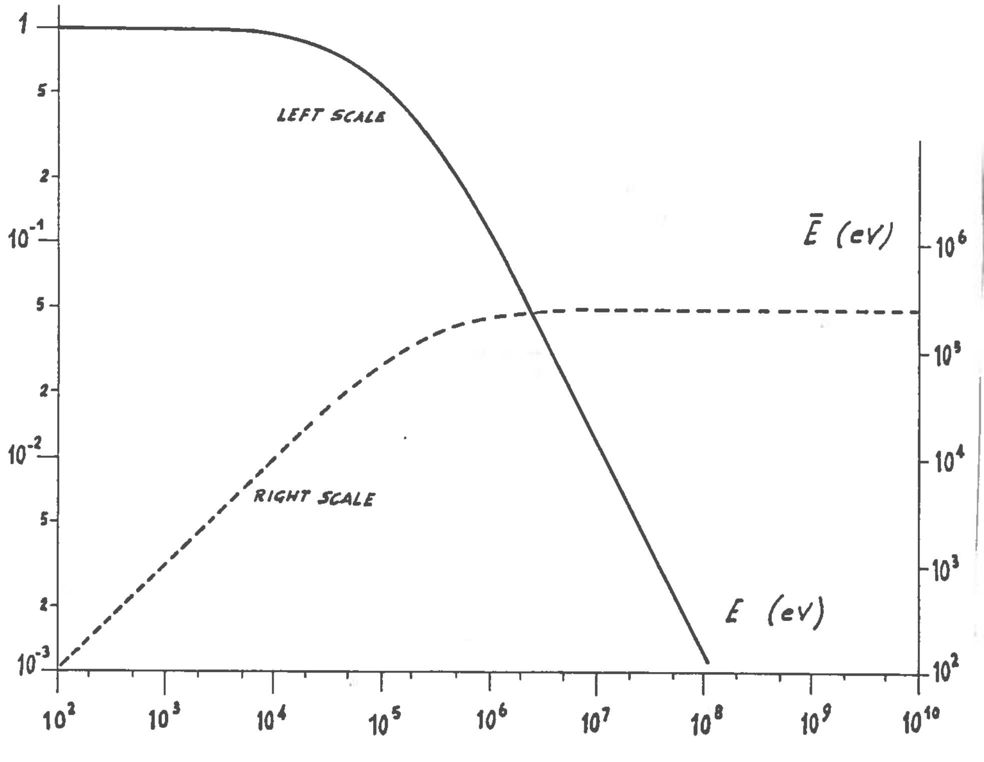

FIG. 5 - Back Compton cross section and diffused photon energy.

The photon of energy $\bar{E}$ can emerge back from the pipe wall with a probability $e^{-\mu(\bar{E})x}$. Therefore the total differential probability that an incoming photon produces a back photon emerging from the pipe wall in the solid angle $d\Omega$ can be written:

$$d^2P = n\,Z\left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E)\; e^{-\left[\mu(E)+\mu(\bar{E})\right]x}\, dx\, d\Omega$$

or after an integration in the x parameter:

$$\left(\frac{dP}{d\Omega}\right) = n\,Z\left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E)\;\frac{1-e^{-\left[\mu(E)+\mu(\bar{E})\right]\bar{x}}}{\mu(E)+\mu(\bar{E})}$$

where $\bar{x}$ is the maximum thickness in aluminum.

The thickness $\bar{x}$ crossed by the incoming photon, in general under a grazing angle, is large enough that the exponential term can be neglected with a good approximation:

$$\left(\frac{dP}{d\Omega}\right)_{Back} \simeq n\,Z\left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E)\;\frac{1}{(\mu(E)+\mu(\bar{E}))} \qquad (12)$$

The expression (12) is plotted in the Fig. 6 versus the incoming photon energy in the case that the target material be aluminum.

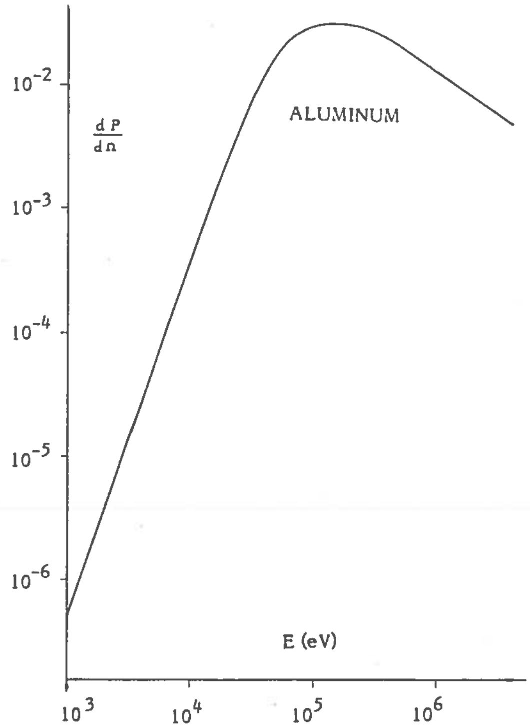

FIG. 6 - Back scattering probability in aluminum versus the photon energy.

The number of photons scattered back in the solid angle unit can be given by the following expression:

$$d\left(\frac{dN}{d\Omega}\right) = dN(E)\; n\,Z\left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E)\;\frac{1}{(\mu(E)+\mu(\bar{E}))} \qquad (13)$$

where the number of the incoming photons dN(E), is the differential of the expression (9):

$$dN(E) = 4.10^{12} I\, E_b\, K\, l\, \frac{dE}{E} \sum_{n,m=1}^{N,M} \langle f(\xi) \rangle_{n,m} \langle y \rangle_{n,m} H_{n,m}$$

by an integration of the expression (9) on the photon energy E one obtains the total number of photons scattered back in the solid angle unit per crossing:

$$\left(\frac{dN}{d\Omega}\right)_{Back} = 4.10^{12}\, I\, K\, l\, n\, Z \sum_{n,m=1}^{N,M} \int \frac{dE}{E} \frac{\left(\frac{d\sigma}{d\Omega}\right)^{Compton}_{Back}(E)}{\mu(E) + \mu(\bar{E})} \langle f(\xi) \rangle_{n,m} \langle y \rangle_{n,m} H_{n,m} \qquad (14)$$

The expression (14) has been calculated by the Montecarlo program and it is plotted in the Fig. 7 versus the back photon energy $\bar{E}$ in the range from 100.0 eV to $m_e/2$=255.0 keV, which is the maximum energy allowed to the back photons.

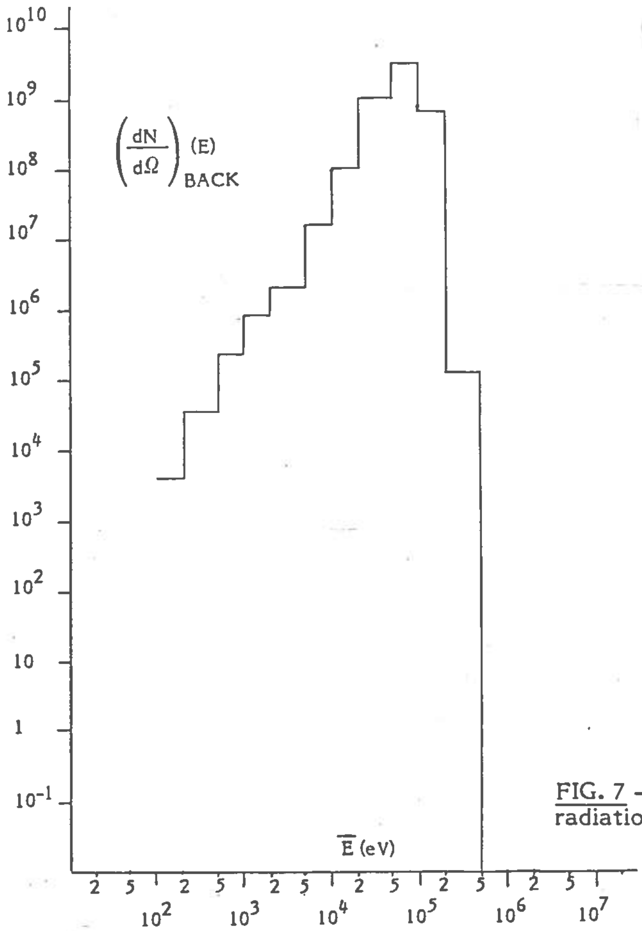

FIG. 7 - Energy spectrum of the back scattered radiation.

4. - BACK PHOTON FLUXES IN THE SHORT INSERTION

In this section the back photon flux reaching the experimental insertion is studied. Since the back photon flux in the solid angle unit has been calculated in the previous section, one can evaluate the effective photon flux in the short insertion through the knowledge of the solid angles involved.

These angles depend on the collision points and these in turn depend on the beam pipe shape and on the collimators position inside the pipe.

Looking in the Fig. 1 at the sketch of the LEP lattice (6) around the short insertion, the beam pipe appears to be cylindrical (16 cm in diameter) up to the QS3 quadrupole (45 m far from the crossing point (C.P.)). In this point the cylindrical shape is changed in the shape of the storage ring standard pipe.

In the cylindrical part two changes are present in the beam pipe. The first one is a diameter reduction at 14 cm in the QS1 region and the second one behind the QS2 doublet is a box shaped insertion 5 m long and 7x16 cm^2 in cross section. This insertion is due to the beam separator housing. Inside the beam pipe three different collimators are present [(3)]. The first one is 9 m away from the C.P. and gets an inner circular aperture 8 cm in diameter. The second one is 100 m away from the C.P. and has a squared aperture 3x3 cm^2. The third one is 200 m away from the C.P. and gets a rectangular aperture 7x3 cm^2.

The beam pipe begins to be bent 250 m away from the C.P., and about 30 behind this point the passage of an internal straight line is completely closed.

The cross section of the beam pipe in different points and the encumbrance of collimators are shown in Fig. 8.

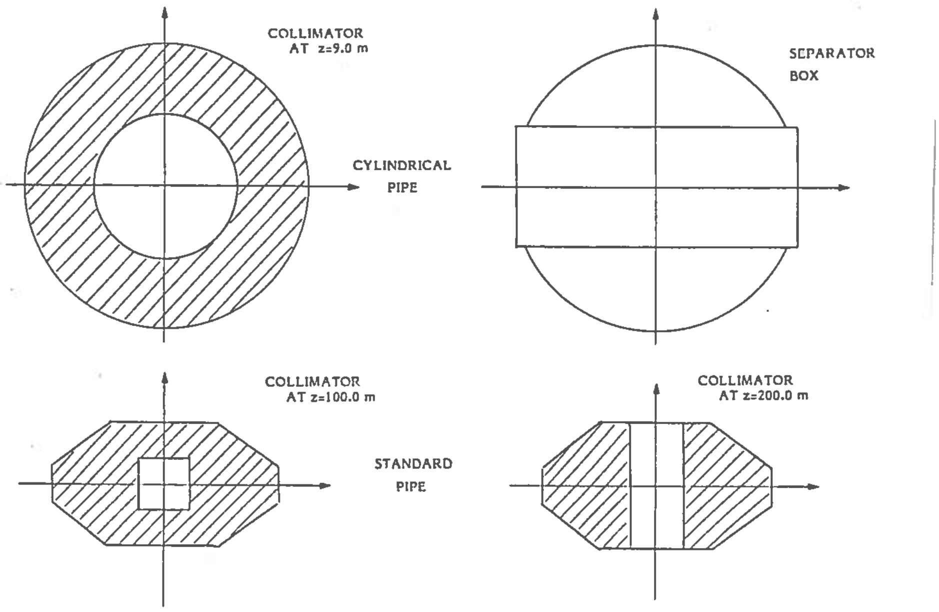

FIG. 8 - LEP beam pipe cross sections.

Along the beam pipe direction the collimators get a wedge shape, that is due to the requirement of obtaining a smooth change in the pipe impedence.

The Montecarlo calculation takes into account all described features of the beam pipe. For each radiating element of the electron trajectory the program finds the point where the emitted radiation is scattered backward. This point is taken as master point, from which the internal apertures of all collimators encountered back toward the short insertion are projected in the transverse plane at the C.P..

By definition the region of this plane common to all projected apertures is the area effectively crossed by the photon flux starting from the master point and reaching the experimental insertion. The delay time of this back radiation is also calculated and registered in bins 100 nsec. wide.

In order to study the back photon flux as a function of the distance from the electron beam, in the program two photon yields are calculated in the C.P.. These yields are relative to the photon flux outside a disk 5 cm and 8 cm in radius respectively. In this calculation any absorption effect of the pipe wall has not taken into account, i.e. the pipe wall in the short insertion region has been considered perfectly transparent. Coerently with the incident radiation the lower cut in the back photon spectrum results to be 100 eV. The total number of photon out a disk 5 cm in radius turns out to be 1.4×10^5 per crossing; the number out a disk 8 cm in radius results to be 2.6×10^2 per crossing. The energy spectra of these photons are shown in Fig. 9 distinghuished as case A and B respectively. One can see from these spectra that the main contribution is provided by photons in the energy from 20 to 200 keV.

In the Fig. 10 the time spectra of the two considered photon fluxes are shown. One may observe that the bulk of the back radiation reaches the experimental insertion 200 nsec after crossing time. The straight line in the figure refers to the vertical scale on the right side and represents the line of

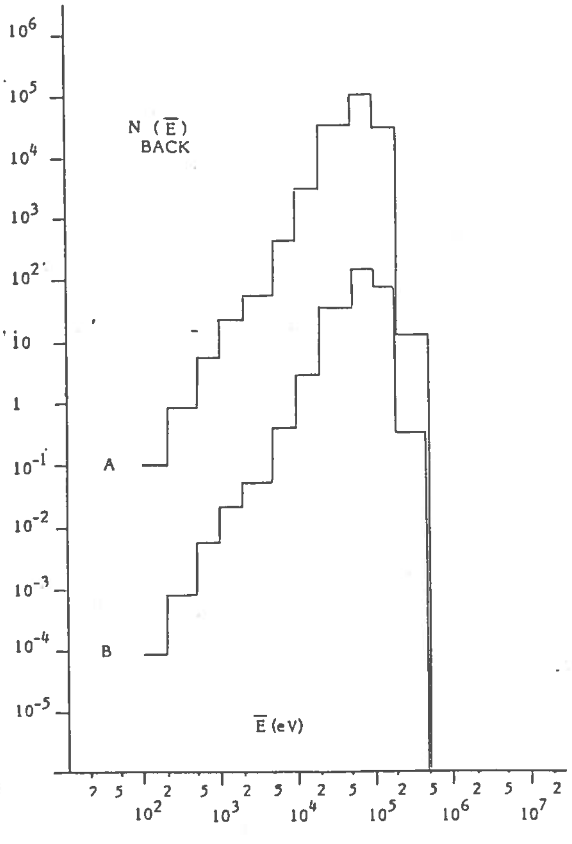

FIG. 9 - Energy spectra of photon fluxes in the short insertion.

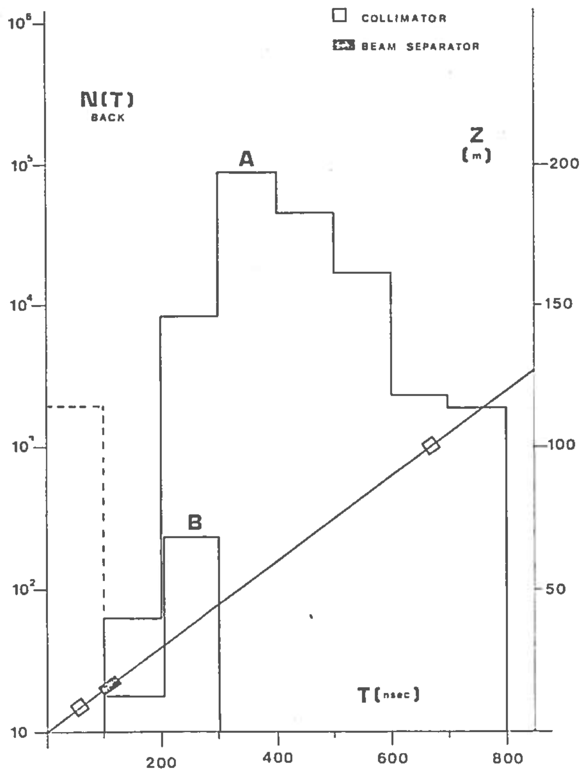

FIG. 10 - Delay spectra of the photon fluxes in the short insertion.

the light velocity. On this line the points corresponding to the first and second collimators are marked. It results that the first collimator does not produce any back scattered flux and that the synchrotron radiation hitting the pipe wall at a distance from the C.P. larger than 120 m is unable to diffuse radiation reaching back the experimental insertion.

An additional information coming from the Montecarlo calculation is the azimuthal distribution of the back radiation. This information can be useful in design vertex detectors located very close to the beam. The distribution of the back radiation versus the azimuthal angle in the crossing point is shown in the polar plots of Fig.s 11 and 12 for the case A and B respectively. In the figures the back photon yields per crossing in logarithmic scale are reported in bins of 15 degrees each. In each figure two histograms are given: the higher one is the total and the lower one the partial yield relative to the radiation coming in the first 200 nsec after the crossing time.

From the common behaviour of all these histograms it results that the region around the vertical direction is less contaminated than the other ones by the back synchrotron radiation.

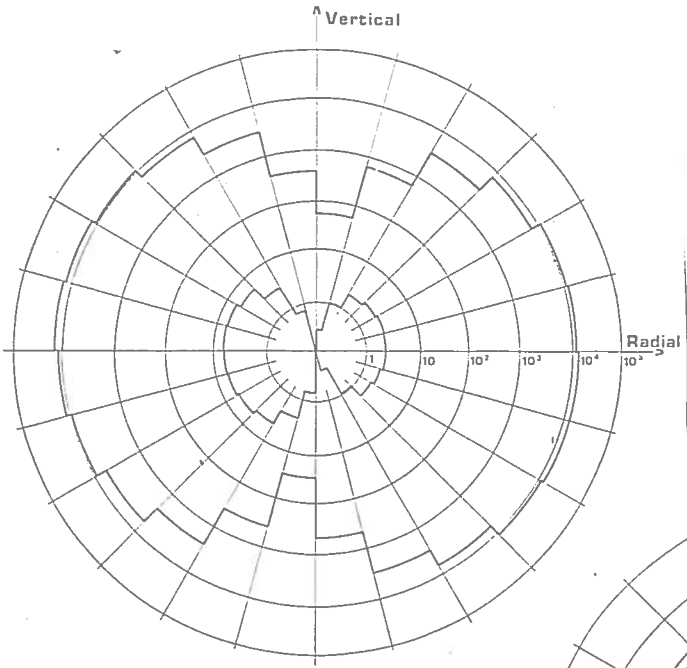

FIG. 11 - Azimuthal spectra of photon fluxes in the short insertion. Case A.

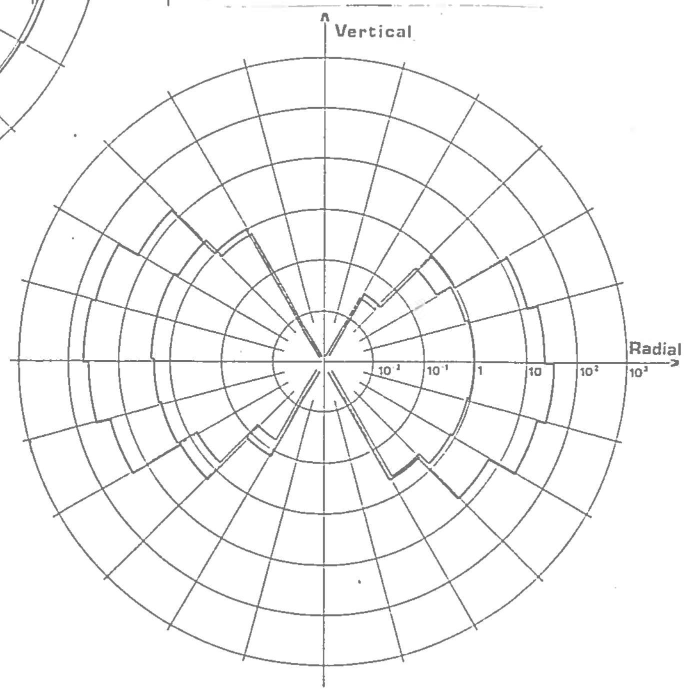

FIG. 12 - Azimuthal spectra of photon fluxes in the short insertion. Case B.

5. - CONCLUSIONS

Before getting some optimistic conclusions about the synchrotron background for those vertex detectors, which one hopes to put near the beam as close as possible, let me do some considerations on the contribution[2] to back scattering due to the radiation coming from the upstream quadrupoles QS3,...QS8.

For the simplicity sake let me discuss this point in the hypothesis that the collimators get a sharp stop-no-stop performance, that the photons are radiated on the beam line and that the contribution of the photon scattering on the pipe wall be negligible.

One can see that the collimator located 9 m far from the C.P. gives shape to a 8 cm wide beam of photons produced in the quadrupoles QS3, QS4 and QS5. In fact the beam of photons produced in the others farer quadrupoles gets a smaller size by the collimator located at 100 m away from the C.P.. Actually not all photons coming from the QS3, QS4 and QS5 quadrupoles can pass through the aperture of the collimator symmetrically localetd with respect to the C.P.. But those photons, which are in a well defined angular range, are scattered back and a fraction can reach the experimental insertion 54 nsec after the crossing time.

That appears to be dangerous, because this delay is well in the read-out time of a standard tracking detector. Let me try to give an order of magnitude of this photon flux. According to the Ref. (2) the considered quadrupoles show an equal gaussian angular distribution of the emitted radiation with a standard deviation of 0.2 mradiants. Therefore the fraction of photons hitting the second collimator will be:

$$\frac{1}{\sqrt{2\pi}\,\sigma}\int_{\alpha_1}^{\alpha_2} d\alpha\, e^{-\frac{1}{2}\left(\frac{\alpha}{\sigma}\right)^2} \qquad (15)$$

where $\alpha_{1,2} = \frac{R}{D \pm 9}$, being R=4 cm the aperture radius of the collimator and D the distance of the quadrupole from the C.P.. In the Table I for each quadrupole is given the values of D, α_1, α_2 and of the expression (15).

TABLE I

QUADRUPOLE	D (m)	α_1 (mrad)	α_2 (mrad)	$\frac{1}{\sqrt{2\pi}\,\sigma}\int_{\alpha_1}^{\alpha_2} dx\, e^{-\frac{1}{2}\left(\frac{R}{\sigma}\right)^2}$
QS3	45.0	0.74	1.11	$1.1\ 10^{-4}$
QS4	100.0	0.37	0.44	$1.8\ 10^{-3}$
QS5	136.0	0.28	0.31	$2.0\ 10^{-2}$

One can see that the main contribution is given by the quadrupole QS5. If I assume that the mean back scattering probability in copper is $1x10^{-3}$ and that the solid angle involved toward the experimental insertion is $1x10^{-4}$ sterad, I get an overall reflection factor of $2x10^{-9}$. Since the total number per crossing radiated in the quadrupole is of the order of $1x10^{-12}$ one expects a back photon flux of about $2x10^{-3}$ per crossing in the experimental insertion.

In the Fig. 10 this photon level is represented by the dashed line in the first channel. In conclusion one can say that the back photon flux coming from the radiation produced in the QS1 and QS2 quadrupoles in a mini-beta configuration appears to be not dangerous especially thanks to the delay time distribution. On the contrary one suspects a dangerous contribution from the quadrupole QS5. It seems to me that a next step on the subject of this note must be a carefull investigation on this point.

ACKNOWLEDGEMENTS

Thanks are due to T. Taylor and K. Potter for updated informations on the mini-beta lattice and on background and collimator disegn. I acknowledge the kindness of B. Roudeau in letting me know the preliminary version of his work on the same subject of this paper.

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(6) This lattice structure is not the definitive one, but only the present version as given to me by T. Taylor and K. Plotter.
~~(7) I have to thank G.P. Murtas for having focused my attention on this point.~~