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Experimental study of an Impact-Parameter Optical Discriminator

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Abstract

An optical discriminator, sensitive to the impact parameter has been tested in a particle beam. The device is based on the detection of Cherenkov light produced and trapped in a thin spherical crystal shell viewed by a fast photodetector. The detector is only sensitive to charged particles with a non-zero impact parameter relative to the centre of the crystal sphere. A prototype using a LiF crystal has been tested and the experimental results are in agreement with expectations. We outline the foreseen developments in order to use such a detector for a fast selection of B events in fixed-target experiments at proton accelerators. We also discuss the use of the detector as presently conceived for the fast selection of strange particles.

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1 Introduction

Up to now CP violation has only been observed in the $K^0-\bar{K}^0$ system. An additional measurement of this effect in the $B^0-\bar{B}^0$ system will allow checking of the internal consistency of the Standard Model which describes the CP violation by the phase of the CKM matrix [1]. Such a study requires the production of a large amount of B events.

At future hadron machines [Large Hadron Collider (LHC), Superconducting Super Collider (SSC)] the b-quark production will be large enough to ensure in one year the detection and tagging of more than 10^3 rare $B^0(\bar{B}^0)$ decays into CP eigenstates such as $B^0(\bar{B}^0) \rightarrow J/\psi K_s^0$ or $B^0(\bar{B}^0) \rightarrow \pi^+\pi^-$. This is the case for hadron colliders as well as for high-energy fixed-target experiments. In spite of a lower b-production cross-section, a fixed-target experiment has the following advantages compared with a collider experiment [2]: multiplicities are smaller, particles are more energetic and, provided that the size of the target is small, the primary vertex is precisely localized.

For example, at the LHC, a luminosity of $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ can be achieved using a small jet target [3], the longitudinal size of which is $\sigma = 1 \text{ mm}$, the transverse dimension ($75 \mu\text{m}$ both in x and y) of the interaction region being given by the beam itself. However, the ratio of the b-production cross-section to the total cross-section is 10^{-5} and the event rate is expected to be 70 MHz. The time between two interactions (15 ns) is too short for a first selection based on, say, a silicon microvertex detector, unless sophisticated processing is used (pipe-line and parallel processors). However, if the rate is reduced by a factor of 100, the average time between two selected interactions is $1.5 \mu\text{s}$, which allows the operation of a second-level trigger based on real-time processing of the silicon microvertex detector looking for a secondary vertex.

Therefore, an efficient and fast first-level selection of the events in a very high background environment is mandatory. The optical discriminator, described hereafter, we believe solves this problem. The idea is to use the Cherenkov light emitted by charged particles crossing a spherical crystal shell and retain those having a sizeable impact parameter with respect to the centre of the sphere where the target is located [4].

In this paper, we present the experimental results obtained with a prototype. We discuss improvements that will allow us to select B events. We also consider small modifications of the present prototype with which one can achieve a good sensitivity for strange-particle selection.

2 The Principle of the Optical Discriminator

In this detector, particles with zero impact parameter produce no detected light, whereas those with a small impact parameter will be seen. The principle of the Optical Discriminator (OD) is illustrated in Fig. 1.

The radiator is a thin crystal with a refractive index n_1 . It is shaped as a shell limited by two concentric spheres surrounded by a medium of refractive index n_2 . A charged particle emerging from the target (the geometric centre of the spheres) generates Cherenkov light. Most of it is refracted out of the crystal; the small reflected part is rapidly attenuated before reaching the photodetector, owing to multiple reflections in the crystal shell. For particles produced off the centre of the device with a non-zero impact parameter, the above refraction condition will not be met any more. A sizeable fraction of the Cherenkov light produced in the crystal is totally reflected, trapped by total internal

Figure 1: The principle of the optical discriminator: a particle with zero impact parameter (a) produces Cherenkov light refracted through the outer surface of the crystal, whereas for a particle with a non-zero impact parameter (b), part of the Cherenkov light is internally reflected and trapped.

reflection, and reaches the crystal edge with negligible losses. The light collection at the exit can be optimized by an appropriate choice of the edge cut angle Ω .

The detailed geometry of Cherenkov emission is shown in Fig. 2. A particle with a velocity β generates Cherenkov light at an angle given by

$$\cos \theta_c = \frac{1}{\beta n_1} . \quad (1)$$

The number of emitted photons in an interval ΔE is

$$N = \frac{\alpha}{\hbar c} \ell_0 \Delta E \sin^2 \theta_c , \quad (2)$$

where ℓ_0 is the path length of the particle inside the crystal shell. A photon emitted at a distance ρ from the centre O of the crystal shell reaches the outer face of radius R at point P with an incidence angle ω given by

$$\cos \omega = \frac{1}{R} \sqrt{R^2 - \rho^2 + \left(b \sin \theta_c \cos \phi_c + \cos \theta_c \sqrt{\rho^2 - b^2} \right)^2} , \quad (3)$$

where b is the impact parameter of the particle relative to the centre O , ϕ_c the azimuthal angle around the particle direction, such that $\phi_c = 0$ along $\vec{b}$ (see Fig. 2). The total reflection limit at the point P is

$$\cos \omega_{\text{lim}} = \sqrt{1 - \left(\frac{n_2}{n_1} \right)^2} . \quad (4)$$

Figure 2: Cherenkov light emission and transmission in the crystal. For a LiF crystal the collecting edge is cut at $\Omega = 45^\circ$.

To avoid the detection of particles coming from the target, i.e. with $b = 0$, ω has to be smaller than ω_{lim} ; thus the refraction indices have to satisfy the following condition:

$$\frac{\rho^2}{R^2} < \frac{(n_2\beta)^2}{(n_1\beta)^2 - 1} \quad (5)$$

for any ρ , in particular for its maximum value $\rho = R$, which means that

$$n_1^2 - n_2^2 < \frac{1}{\beta^2} . \quad (6)$$

Let us define the quantity ε by

$$n_1^2 - n_2^2 = 1 - \varepsilon . \quad (7)$$

The relation (6) is equivalent to

$$\varepsilon > -1/(\beta\gamma)^2 . \quad (8)$$

For relativistic particles, the condition on the indices becomes

$$\varepsilon > 0 . \quad (9)$$

Only relativistic particles will be considered hereafter, since the above condition (9) is sufficient to reject primary non-relativistic particles as well. When a single crystal is used in air or vacuum, $n_2 = 1$, and n_1 has to be close to, but lower than, $\sqrt{2}$.

The choice of ε will determine the minimum impact parameter b_{min} which will be the threshold of the device [from Eqs. (3) and (4)]:

$$b_{\text{min}} = \frac{R}{n_1^2} \left(n_2 - \sqrt{n_1^2 - n_2^2} \sqrt{n_1^2 - 1} \right) . \quad (10)$$

Figure 3: Probability for a Cherenkov photon to be trapped, as a function of the depth ρ where it was produced inside the crystal and of the impact parameter b of the incident charged particle. Two values of the refractive index are considered.

A useful approximation of this formula for small ε is

$$b_{min} = \varepsilon R / 2n_2 . \quad (11)$$

The incidence angle θ_{min} of the track at the external face is given by

$$\theta_{min} = \frac{b_{min}}{R} \quad (12)$$

and depends only on the refractive indices. The right hand side of Eq. (10), or ε , can take negative values. In this case b_{min} and θ_{min} take unphysical values, which only indicate the optical properties of the two materials. From relation (3), one sees that, for a given impact parameter b , the incidence angle ω is maximum when $\rho = R$ and $\cos \phi_c = -1$. This means that most of the photons trapped in the crystal shell:

- a) travel in a plane containing the centre of the spheres and emerge in the hemisphere opposite to the one containing the impact parameter $\vec{b}$ ($\phi_c = 180^\circ$);
- b) are emitted when the particle is close to the exit face of the shell ($\rho \approx R$) because the incidence angle on the exit surface is larger; the useful track length ℓ , i.e. the distance along which the track emits Cherenkov light, which can be caught, is related to the impact parameter b by

$$\ell = (b - b_{min}) / \sqrt{n_1^2 - 1} \quad (13)$$

and hence, the impact parameter for which the useful length becomes maximum, equal to the total depth d of the device, is

$$b_0 = b_{min} + d \times \sqrt{n_1^2 - 1} . \quad (14)$$

Figure 4: Refractive indices as a function of the photon energy or wavelength for crystal LiF (black solid line) and MgF₂, which is birefringent (grey solid line for ordinary ray, dashed line for extraordinary ray).

The process is illustrated in Fig. 3, where the probability for a photon to be internally reflected and trapped is plotted as a function of the impact parameter of the incident particle and its depth of creation inside the crystal. The photon signal rises from a minimum impact parameter, b_{min} , up to b_0 and then saturates. Thus the thickness d of the crystal to use is related to the range of interesting impact parameters that we want to explore: for the charged decay products of the B mesons, for instance, whose mean impact parameter is about $600 \mu\text{m}$, we can choose d such that the corresponding b_0 is equal to a few times $600 \mu\text{m}$ (a crystal a few millimetres thick in this case).

In order to have a good sensitivity to very small impact parameters, θ_{min} must be as small as possible (positive). On the other hand, in order to avoid background from minimum bias tracks coming from the optical centre and giving a signal through multiple Fresnel reflections, a lower limit to θ_{min} must also be required.

So far, we have not considered chromatic dispersion. In fact $n, \epsilon, \theta_{min}$, and b_{min} are λ -dependent. This chromaticity has to be minimized. The slower the variation of θ_{min} with λ , the wider the bandwidth of the produced Cherenkov light in which θ_{min} has the required value and the larger the number of photons on the photodetector. Unfortunately,

Figure 5: The experimental set-up: the LiF crystal, the ellipsoidal mirror, and the photomultiplier inside the vessel and the two fibre crosses outside.

such a quasi-achromatic behaviour cannot be obtained with a single medium ($n_1 \simeq \sqrt{2}$ and $n_2 = 1$): θ_{min} and b_{min} vary with the wavelength (chromatic aberration). The effective b_{min} is obtained by convolution over the bandwidth of useful Cherenkov light. However, if the crystal is constructed with a core of a high index material (n_1) and a cladding of an appropriate lower index material (n_2), the wavelength dispersion of the core material may be balanced by the dispersion of the cladding material giving an achromatic pair.

In this experiment we have been concerned with testing the principle of the detector. Therefore we have chosen the simplest case of a single medium. The most important requirement for the crystal is that its refractive index must be close to, but not exceed, $\sqrt{2}$ for the largest bandwidth of the radiated Cherenkov light. This is well satisfied by the LiF and MgF_2 media (see Fig. 4) for wavelengths above 270 and 220 nm respectively, although MgF_2 monocrystals exhibit an important birefringent behaviour.

The edge-cut angle which optimizes, in this case, light collection is 45° with respect to the tangent plane; the photons produced in the crystal, and internally reflected, exit with an angular distribution peaked at the normal to the edge. The outgoing photons appear to come from a virtual source located on the crystal axis. Large impact parameters introduce a defocalization as exit angles with respect to the normal increase with

increasing impact parameter.

We have tested such an OD device using a LiF crystal in a particle beam at the CERN PS.

Figure 6: The Pulse-height distribution from the UV lamp. The peak at zero photoelectrons is divided by 10.

3 The experimental set-up

The experimental set-up is shown in Fig. 5. The main components are: a LiF crystal, an ellipsoidal mirror, and a photomultiplier. The LiF spherical shell was shaped and delivered by the firm Quartz et Silice. The crystal shell has a thickness of 3 mm, a diameter of 60 mm, and a spherical radius of 100 mm. The reflectivity of the mirror was roughly measured in the UV range. It lies between 0.4 and 0.6. Placing the virtual source, from which the photons appear to come, at the first focus of the mirror, the light is focused on a photomultiplier whose photocathode is placed at the second focus. The photomultiplier has a 2 in. diameter quartz window [5] and is mounted at an angle of 7.5° to the beam axis. Diaphragms of variable sizes and filters can be mounted in front of the photocathode. Choosing suitable filters we can let through only those Cherenkov photons for which the wavelength corresponds to a refractive index lower than $\sqrt{2}$. Two filters were used, cutting wavelengths shorter than 280 nm and 305 nm (Fig. 7). All the

above components are mounted on a 20 mm thick aluminium plate. An aluminium cover ensures the light tightness of the system. Two thin 100 μm circular aluminium windows, upstream and downstream, are used to minimize nuclear interactions, radiations, and multiple scattering effects of the beam. The whole system is mounted on a moving table which allows a scan in the horizontal plane transverse to the beam (x) with a precision of 50 μm .

The set-up was installed in the CERN PS test beam T9 providing 8 GeV/ c momentum pions. The particle trajectory is reconstructed with two drift chambers, each equipped with x - y planes and having a spatial resolution of 150 μm ; they are mounted upstream and downstream of the OD system. Each plane has six cells of 2.5 cm drift space between a double sense wire and a single cathode wire. Double tracks in the same cell are not resolved. Close to each drift chamber, a pair of crossed, 2.5 mm diameter scintillator fibres are mounted on the support plate. They have been mechanically placed along the axis of the system to determine precisely the relative position of the chambers in this system. The chambers were triggered by a hodoscope consisting of two $3 \times 3 \text{ cm}^2$ plastic scintillators placed upstream of the set-up. The size of the beam was sufficiently small to use, after alignment, only the central drift cell of each chamber plane. For each trigger the Pulse height of the photomultiplier is recorded in a standard Lecroy 2249W CAMAC ADC. The data acquisition and on-line analysis was controlled by a Macintosh computer. Events were written onto a disk and transferred, when necessary, via Ethernet to the central computing system at CERN.

4 Calibration

A hydrogen pulsed lamp with a CaF_2 window is used as a source of UV photons for on-line calibration. The emitted light is guided through an optical fibre to a position facing the photomultiplier. A set of attenuators can reduce the light down to the operating level of a single photoelectron (p.e.).

Calibration runs were performed to determine the gain and the single photoelectron response of the photomultiplier. The Pulse-height distribution for an average of 1.5 p.e. per pulse of the UV lamp is shown in Fig. 6. It exhibits clear peaks corresponding to 1, 2, ... p.e. This distribution can be well fitted with a series of Gaussian peaks, the positions and widths of which are correlated, and an exponential background which reproduces the pedestal tail. The χ^2 per degree of freedom for the fit is 1.4. The non-linearity of the photomultiplier has been evaluated to be about 3% between two peaks. The resolution for the single p.e. peak is $\sigma = (0.28 \pm 0.03)$ p.e. In the fit, the areas under the peaks were left free: we found that these areas do follow a Poisson distribution. In the region between the pedestal and the single p.e. peak, the contribution of the Gaussian peak and that of the decaying exponential were chosen randomly once the sum of their contributions had been determined. The same procedure is applied for the analysis of the data.

5 Experimental results

The particle impact parameter is measured by reconstructing the track with the two drift chambers. A first filtering of the data is performed by requiring only one hit per wire plane. This constraint rejects most of the background, such as pile-up, and electromagnetic or hadronic showers. Wrong track reconstruction can only occur when two particles cross

Figure 7: Quantum efficiency of the photomultiplier (dashed line, right scale), the LiF θ_{min} angle (solid line, left scale), and the measured filter transmission (right scale): filter of 280 nm (dark gray line) and filter of 305 nm (light gray line).

the same central cell during the drift-time in this cell. The rate has been lowered to less than 4000 incident particles during a 350 ms spill so that the probability of getting two particles in the central cell is kept below 1%. A second filtering of the data consists in cutting the tails of the angular beam profile. This removes part of the scattered particles. The beam defined by the trigger hodoscope allows the scan of impact parameters in the range of 10 mm. To reach higher values of impact parameters, the main vessel was moved in the horizontal plane (x -direction). Taking into account the spatial resolution of the chambers, the resolution on the impact parameter is $250 \mu\text{m}$.

In spite of a careful mechanical alignment of the crystal axis, with the fibre crosses, small deviations cannot be avoided. Fortunately, these deviations can be determined from the data themselves, since the signal delivered by the crystal has to be minimum for particles going through the centre of the sphere. Indeed, near the centre, the efficiency of the device is minimum (see Fig.8). We have fitted the distribution of the amplitude, given as a function of the transverse coordinates x and y , by a paraboloid of revolution. This allowed us to determine the centre with a precision of $\pm 50 \mu\text{m}$. We found that the coordinates of the centre are $x = -0.620 \pm 0.05 \text{ mm}$ and $y = +0.015 \pm 0.05 \text{ mm}$. Since

Figure 8: $x - y$ impact in the crystal of tracks giving a signal of more than 2 p.e..

mechanical adjustments have been performed with about 0.1 mm precision, we can only interpret the x shift as resulting from a slight tilt of the crystal.

The distribution of the amplitude of the signal in p.e. units, after correction for the right position of the crystal, is shown in Fig. 9, as a function of the impact parameter b ; the sign attributed to b is that of the vertical y (Fig. 9a) or horizontal x (Fig. 9b) coordinate of $\vec{b}$. It can be seen that the response is symmetric with respect to the horizontal plane (Fig. 9a) but not to the vertical one (Fig. 9b). This x asymmetry is due to the angle of the mirror axis with respect to that of the crystal (7.5°). The background due to the scintillation of the air inside the vessel during the passage of the particles has been subtracted: it was measured in dedicated runs by hiding the crystal from the photomultiplier and was found to be (0.030 ± 0.008) p.e. This background is trivial, since it depends on the light readout system and can otherwise be shielded or suppressed by operating in vacuum or in an appropriate gas.

A Monte Carlo program has been developed to simulate the observed signal. The following physical processes for the optics have been taken into account: polarization of the generated Cherenkov light, Fresnel reflections and refractions, index chromaticity $\varepsilon(\lambda)$ of the LiF crystal, mirror collection with a mean reflectivity of 0.4, measured filter transmission and quantum efficiency of the photomultiplier (Fig. 7). The agreement with

Figure 9: Amplitude of the signal as a function of the signed impact parameter, with a 40 mm diaphragm, data (crosses) and Monte Carlo (line).

the Monte Carlo simulation is good and the behaviour of the device well understood. As expected, the signal rises to 1.6 p.e. at an impact parameter of 7 mm, then goes down for larger values of b . The fall at large impact parameters is due to the cut-off imposed by a 40 mm diaphragm in front of the photomultiplier. With a smaller diaphragm, i.e. of 20 mm, the fall occurs at a lower value of b . This can be seen in Fig.10, where the signal versus b for both 20 and 40 mm diaphragms is shown. Rejection of large impact parameters can thus be achieved by adjusting the diameter of the diaphragm. This is an additional good property of the OD, as closing the window will reduce the background due to delta rays and nuclear interactions. If optical fibres are used, instead of a mirror for light readout, the same pleasant feature is encountered, owing to the optical fibre aperture. Figure 10 also shows the effect of cutting short wavelengths: the dip at very small values of b is due to the cut-off of shorter wavelength Cherenkov light induced by the filter.

At zero impact parameter the observed signal is not zero. This is due to two kinds of sources:

- i) Processes that take place in the crystal and may still be present in future B experiments (or other future experiments where the OD would be installed). These processes would contaminate impact parameter discrimination; this is why we already consider

Figure 10: Amplitude of the signal as a function of the impact parameter with and without filter and with two different diaphragms.

here their contribution as inherent background. Such processes are delta rays and nuclear interactions generated by the particle inside the crystal and propagation of unwanted photons through multiple Fresnel reflections down to the exit edge of the crystal.

- ii) Effects that are associated with our test-beam measurement and the set-up excluding the crystal (external background). Since the signal is small, tiny effects of this second kind may strongly affect the estimate of the first type of background. Such effects are photons from outside sources as well as biases due to track selection and reconstruction.

All sources of photons related to the beam and having an origin outside the crystal have thus to be removed or precisely measured. We recall that the gas scintillation is already subtracted out. Other unknown sources may still remain. For example, a variation with the beam position of the background at zero impact parameter has been observed. This is not yet understood and is not shown here.

Set-up related biases that have not yet been precisely evaluated are: wrong impact parameters due to tracking errors; multiple scattering inside the vessel; possible misalignments of the different components of the optical system; the production of sec-

ondary particles upstream of the crystal, giving two particles in the same drift chamber cell, of which only one is detected; the chamber hit multiplicity cut; and the cut in the angular beam profile.

The observed value of (0.04 ± 0.02) p.e. has to be considered as a first estimate of the crystal-induced inherent background. Studies are being pursued for a more precise determination.

The contamination of the inherent background, in B-meson research, will depend on the threshold imposed on the signal. Simulation studies are under way and show that contamination can be suppressed by coincidence techniques.

Figure 11 shows the efficiency per particle of the device as a function of impact parameter with a threshold set at 1 p.e. and Fig. 12 gives the efficiencies at impact parameters of 1 and 10 mm as a function of the threshold value.

Figure 11: Efficiency with a threshold at 1 p.e. as a function of impact parameter, obtained with a filter of 305 nm and a diaphragm of 40 mm.

By improving the quality of the mirror, we can increase the maximum signal to the level of 3 p.e. per particle. Additional improvements to increase both the collected signal and the sensitivity at low impact parameters are discussed in the next section.

Figure 12: Efficiencies at impact parameters of 1 mm (a) and 10 mm (b) as a function of the threshold [p.e].

6 Perspectives

The experimental results obtained are in agreement with expectations and demonstrate the ability of the OD to reject small impact parameters. A first application of such a device with an increased radius for the spherical crystal can be considered: it can provide a fast trigger for K_s^0 or hyperon selection. As an example, a MgF_2 crystal with 200 mm radius and 2 mm thick could be suitable for K_s^0 ($c\tau = 2.675$ cm), Σ^+ (2.40), Ω^- (2.46). However, the presently obtained threshold is too high and its rise too smooth for a direct application as a B-event selector.

A program of technical development of the device has started, to obtain a high efficiency in B-meson pairs and a strong rejection factor against unwanted minimum bias events [6, 7]. A first way to lower the impact parameter threshold of the device was mentioned in Section 2: θ_{min} should be small for the largest possible bandwidth of the Cherenkov light. We have investigated various optical materials: crystals, glasses, etc. [8]. Standard optical glasses have indices greater than 1.46 and are not suitable in such a design. Other materials whose indices are not too far from $\sqrt{2}$, could be used if doped. We mention the possibility of doping of LiF or MgF_2 to bring the useful bandwidth into a lower dispersion region, or of CaF_2 in order to lower its index value.

Another solution could be to replace the air or vacuum surrounding the crystal by a liquid or a gas under pressure, to reach the threshold condition for optical materials with indices slightly over $\sqrt{2}$; CaF_2 is again a good candidate and in that case the pressure might be a convenient parameter to monitor the indices constraint (6).

A complementary possibility is to use the reflection threshold condition on the inner surface of the crystal instead of on the outer one. In that case the formulae of Section 2 are slightly modified and the effective b_{min} is decreased by a quantity depending on the crystal thickness.

Figure 13: θ_{min} as a function of the photon energy or wavelength for a sapphire crystal coated with silica.

Nevertheless, a 2-layer design, a core coated with a cladding, appeared to be more promising, a compensation being possible between the wavelength dispersions of the core and the cladding material. The use of such a pair of indices enlarges the wavelength region where the quantity ε is small and therefore it is possible to decrease the impact parameter threshold. The external surface of the cladding has to be absorbent in order to dump the light refracted at the core/cladding interface, which would otherwise be reflected at the air (or vacuum)/cladding interface. We are concentrating our efforts on a reliable and radiation-hard pair of materials: sapphire (Al_2O_3), coated with a layer of about $2 \mu\text{m}$ of silica (SiO_2). As shown in Fig. 13, the required condition (9) on ε (and hence on θ_{min}) is

satisfied for the bulk materials between 600 and 1000 nm. The possibility of extending it to the UV region and to diminish the variations of θ_{min} is under investigation in collaboration with the LETI laboratories [9]. Other pairs of materials, such as Al_2O_3 -KCl or LiCl-NaF, have also been considered.

A further improvement of the signal at small impact parameters can be obtained by splitting the total thickness of the device into four or five such 2-layer elements. For small impact parameters the number of detected photons begins to increase almost linearly with the number of slices. This is due to the fact that only photons emitted close to the exit face contribute to the signal (Fig. 3). An optical trigger based on this idea of multilayers is under study.

Another way to improve the efficiency is to increase the quantum yield of the photodetector. Reflection-type photomultipliers are expected to give higher quantum efficiency ($\approx 45\%$) to be compared with 25% efficiency of the transmission ones used in this set-up. However, the entrance windows of reflection-type photomultipliers are still too small. Silicon avalanche photodiodes have a quantum efficiency close to unity, but their gain is limited at the level of a few hundreds and they are not at the moment available as single photon detectors.

A new development concerning visible-light photon counters (VLPCs) seems to be promising, as quantum efficiency is optimum (80%) in the range from 400 to 800 nm [10] where ϵ is appropriate in the case of the pair sapphire-silica. These devices exhibit fast response (< 5 ns), and can operate at high rates. At nominal operation conditions the gain is 3×10^4 and the resolution for single photons is excellent. The device operates at 6.5 K where the dark noise is quite low, i.e. 5×10^3 counts per second. For the OD project low temperature is not an obstacle, since light signals can be guided using optical fibres to the cryostat which lies far from the interaction point. A test of the OD with VLPC read-out is in preparation.

7 Conclusions

Experimental results from the tests with a full Optical Discriminator are very encouraging and demonstrate the feasibility of such a device as a fast Impact Parameter Detector, which could be used as a first-level trigger. Its simplest configuration could be a one-channel device. The collected signal as a function of the particle impact parameter exhibits the shape expected by the Monte Carlo simulation program.

The device is insensitive to very small and very large impact parameters. The sensitivity thresholds can be controlled and tuned. This allows selection of the desirable impact parameter window and considerable rejection of background from delta rays, nuclear interactions produced in the crystal, and other large impact parameter processes. The use of existing technologies, such as the new generation of avalanche photodetectors (VLPCs) and the multilayer shell based on sapphire coated with doped silica should allow us to reach the characteristics necessary for an efficient B-meson decay detection with low background. Minor changes in the design of the present prototype can open up a new experimental approach to the study of rare strange particle decays.

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