Technical Design Report

B E A S T

B*ackground* **E***xorcism for* **a** **St***able BELLE Experiment*

Commissioning Detector for the KEK-B Factory

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Contents

1 Introduction

For the success of Belle experiment it is imperative that we start taking physics data no later than January 1999. The KEK-B beam commissioning will start in the Fall of 1998, and therefore there is no substantial time gap between the completion of KEK-B accelerator commissioning and commencement of Belle detector commissioning. It is quite possible that both the commissionings will be done in parallel on the same beam.

Accelerator commissioning involves (1) laying down all the electro-magnetic elements, vacuum pipe etc.. and then (2) getting the beams to run eventually at their design parameters. Part-1 is a straightforward task in progress, and will be completed in the summer of 1998. Part-2 will start in the Fall 1998. We are not sure how long it will really take to bring the beam to design current and emittance, although it is likely that it will happen by early Jan 1999.

At the beginning of the experiment the Belle detector needs to sit on the beam for a while, getting tuned up. The main foreseeable trouble for Belle is the beam background, which can be large enough to cripple any meaningful data acquisition. An important goal, therefore, is to understand and reduce the beam background during the accelerator commissioning phase (part-2 in last paragraph) with some expendable detector system, without damaging the real Belle detector.

In this note, we discuss different Belle commissioning strategies, designs and plans.

In the first section we reproduce K. Oide's plan for KEKB commissioning. Strategies for a commissioning detector are described in next three sections. Sixth and seventh sections address simulation and proposed beam background experiments. Rest of the note addresses manpower and communication issues.

2 KEK-B Commissioning Plan

The following commissioning plan has been prepared by K. Oide of KEK (1/28/1998).

2.1 Linac, Beam Transport

Dec 1997 : The new e^- Linac was commissioned up to 1.5 GeV, 10-13 nC(design = 10 nC)/bunch, single bunch/pulse.
Repetition : 5 Hz (design = 50 Hz)
100% transmission from 19 MeV to 1.5 GeV.
Reasonably good quality of the beam.
Improvements are needed for further stability.

Mar 1998 : Commissioning of J-Arc and AR injection.

May - June 1998 : Full commissioning of 3.5 GeV e^+ and 8 GeV e^-, including a part of beam transport to KEKB.

2.2 Commissioning before Belle

2.2.1 Initial storage to enable degassing of vacuum chamber

This will take 27 shifts/ring, with 1 shift = 8 hours.

- flat optics (minimum chromaticity, moderate tunes). RF, sextupoles off.
- Injection kicker = single turn mode (1 mA, 1 bunch/ring).

    one turn, looking at button signals of the beam position monitors(BPM), loss monitors, single pass BPMs (2).
    a few hundred turns by manual orbit/quadrupole/energy correction(1).

- RF, sext(2-6 family correction) on. (1 mA, 1 bunch/ring).

    observation of synchrotron light.
    extend the stotage time until BPM can measure the closed orbit(1).
    primary closed orbit correction(2).

- Injection kicker = storage mode (10 mA, 20 bunches/ring)

    x, y, z tunes, dispersion, chromaticity measurement(3).
    determination of path length and ring energy(1).
    basic behaviour of rf system, adjustment of station phases, etc.(6).
    adjustment of timing/balance kickers.
    measurement of injection efficiency/ optimum injection orbit/phase(2).
    survey of optimum tunes(2).
    observation of beam size by synchrotron light(2).
    measurement of bunch length(2).
    commissioning of the bucket section system(1).
    commissioning of the beam abort system(2).

2.2.2 Toward the low-β optics

This will take at least 104 shifts/ring.

- Lattice - BPM diagnostics

    checking function/resolution of all BPMs by 3(4) BPM method (6).
    measurement of steering-BPM response(3).
    beam-BPM mapping(6).
    commissioning of local bump generator(1).
    calibration of quadrupole strengths by π-bump(6).

determination of center of sextupoles by π-bump/K-modulation methods(12).

commissioning of sextupole movers(6).

determination of BPM offset by quad-BPM response(6).

advanced orbit correction(6).

measurement of β functions at all quads (3).

correction of x-y coupling(3).

re-measurement of main parameters after update of the database and model(6).

- Dynamic aperture

  measurement of higher order chromaticities/ dispersions(2).

  damping of coherent oscillations(3).

  measurement of the dynamic aperture(3).

- Emittance ratio

  reduction of emittance ratio, down to less than 1% by local bump, etc.., looking at the synchrotron light interferometer(6).

- Beam lifetime

  observation of correlation between the lifetime and intensity/beam sizes/vacuum pressure (2 + anytime).

- Stability of orbit and beam-size(3 + anytime)

  record/log as frequently as possible.

  correlation between room/water temperatures, etc..

- Commissioning of wigglers/chicanes (3)

  observation of damping times/emittances.

- Low-β optics

  achieve the design β functions at IP by monitoring/controlling optics/tunes/orbits/ emittance/dynamic aperture/lifetime/injection efficiency. May be done step by step if necessary(9).

  optimize the working conditions (9).

  comparison between low/high currents (3).

2.2.3 Storing high current

This requires at least 56 shifts/ring, starting from 100 mA to the design current.

observation of single bunch instabilities(2).

storage with various bunch patterns(3+).

study of vacuum pressure system (3+any).

behaviour of rf systems at high current : power/voltage/loading/heating/reflection/transient/stability.. (12+).

commissioning of bunch by bunch feedback/monitor system (6).

observation of heating at various components(3+).

observation/suppression of coupled bunch instability (9).

dependencies on machine parameters (6).

fast-ion/photo-electron instabilities (FII/PEI). Chioce of the bunch-gap. Clearing solenoid (12).

2.2.4 Collision of beams

This requires minimum 33 shifts, starting from 10 mA to design current.

finding out the collision orbit/rf phase (3).

commissioning of the collision feedback system (6).

observation of beam-beam tune shift(3).

observation of luminosity and its dependence on parameters (9).

stabilities (3+).

observation of beam backgrounds, tuning by masks (3).

observation/control of beam tails (6).

3 Experimental Goals of Commissioning Detector

From the collective experience at CESR and PEP-I which were discussed during the beam-background workshop [2] at Hawaii (March 1997), we have an agenda of the studies that should be carried out with the commissioning detector (BEAST).

Dose Measurements : We must measure the integrated and instantaneous doses at the locations of the sensitive detector components. These include the CsI crystals, the silicon vertex detector and the central drift chamber.

Establishing Figures of Merit for accelerator tuning : An important goal of the commissioning detector is to develop empirical quantities that the machine operators can tune on. In CLEO, such a number, called the "Cinabro number", is a linear combination of the Level-0 trigger rate and the rate on a inner wire chamber layer. This number is sent to the accelerator operator. Injection into CESR is not complete until the Cinabro number is below the acceptable threshold. In the BEAST detector, no trigger will be available. However, we can obtain a signal based on the rates in the diodes and proportional tubes to send to the accelerator control room. We must also develop a final figure of merit for tuning when the final BELLE detector is ready to take data.

Movable Masks : We should measure the background rates as a function of aperture of the movable masks. This will tell test the reliability of our accelerator model and verify the effectiveness of the moveable masks.

Injection vs. Steady State : For several reasons, backgrounds will not normally scale with emittance for steady state operation and injection. Model calculations of doses during injection are difficult and unreliable. In general, the emittance is much larger and the machine optics during injection differ from the optics in steady state operation. For the case of the CLEO II and CLEO II.5 interaction regions, the integrated injection dose was comparable to the dose integrated during steady state running[2]. Thus backgrounds during injection need to be studied carefully.

Separate Backgrounds for e^+ and e^- : We need to measure backgrounds for e^- and e^+ single beams separately. As noted in the contributions of Henderson [4] and Cinabro's [5] papers, a difference in these two rates was the signature of the original CLEO II background problem, which was finally traced to a misalignment that allowed a distant SR source to make a single bounce into the central beam pipe. In the case of KEK-B, the expected ratio of backgrounds from e^- and e^+ is also known.

1-beam vs. 2-beams : The background with 2-beams may not be the sum of the single beam backgrounds. This has been observed at PEP-I (MAC experiment) and at BEPC. In these cases, the effect was attributed to tails in the beam distribution.

Dependence on Beam Current : Background rates are normally proportional to I^n, with $1 < n < 2$, depending on how well baked the beam-pipe is. In steady state operation, the synchrotron radiation component is proportional to I, while the particle background is proportional to I^2. Thus measuring the dependence of background on beam current can determine the relative importance of SR and charged particle backgrounds[5].

Pressure Bumps : Pressure bump tests involves regulating the vacuum at a certain section in the accelerator (e.g. by introducing calibrated leaks), and then measuring the background as a function of vacuum pressure. As shown in section (xxx), the sources of particle background are localized in z, the coordinate along the beam line. Therefore, increases in the vacuum pressure at critical locations will produce predictable increases in detector background. These pressure bump tests check our understanding of the magnetic elements and particle backgrounds. Similar tests have been carried at CESR Phase II and have revealed significant flaws in the background simulation[4].

Quadrupole and Sextupole off-axis : Our simulation shows that background may severely change when quadrupoles and sextupoles are off the axis(see

Fig. 5). By intentionally changing the axes (making the fields move by changing currents in coils) such effects can be studied. In CESR Phase II, an offset was deliberately introduced in a quadrupole adjacent to the interaction region to dramatically increase the SR component of the background and check the background model.

4 Simulation - Expected Beam Background

4.1 Radial Dose

Some parts of the commissioning detector, such as the barrel CsI counters, may get damaged if the radiation is excessive. We therefore need an estimation of the dose that will be accumulated at various points in the detector as a function of beam current and emittance. We studied four cases :

1. **Runtime :** $\epsilon_x = 1.8 \times 10^{-8}$, $\epsilon_y = 3.6 \times 10^{-10}$, $I_{e^+} = 2.6$ Amp, $I_{e^-} = 1.1$ Amp, Vacuum = 1 nTorr.

2. **Commissioning Runtime :** $\epsilon_x, \epsilon_y = 10\times$ respective runtime emittances, $I_{e^\pm} = 500$ mA each, Vacuum = 10 nTorr.

3. **Injection :** $\epsilon_x = 1.3 \times 10^{-5}$, $\epsilon_y = 1.3 \times 10^{-6}$, Same current as runtime, but only one bunch out of 5000 is assumed to be *hot*, *i.e.*, at injection emittance, the rest are at runtime emittance. Vacuum = 1 nTorr.

4. **Commissioning Injection :** Same emittance as injection time, Current is 500 mA each, but only one bunch out of 5000 is assumed to be *hot*, *i.e.*, at injection emittance, the rest are at runtime emittance. Vacuum = 10 nTorr.

Radial dose, averaged over all ϕ-angles and z-positions is given in Fig 1. Azimuthal, or ϕ distribution is shown in Fig 2. z-distribution is rather uniform at large radial distances, but as will be shown later in this section, source distribution in z is highly non-uniform.

It is estimated that during commissioning phase, the CsI counters will get on average a few Rads of irradiation per month in the worst case. We are safe, since CsI is radiation hard upto about 200 Rad dose.

4.2 Particle Rates

Drawing on the results from our recent Belle Notes [6, 7], and adding some back of the envelope calculation, we estimate the flux of photons and charged particles. In Fig. 3, we show the z- and E(or p_T) distribution of γ's and charged particles entering the Belle detector in 4 ms. Cut on E_γ is 100 keV and on p_T for charged particles is 100 keV/c. We used KEK-B run-time parameters, which are given in Table. 1.

Using these plots, we calculate the fluxes and get the following equations (in Hz/z-distance in cm/ϕ in radian) :

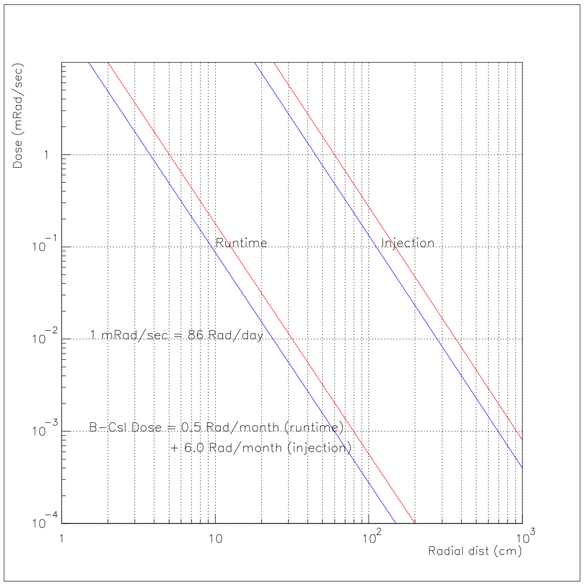

Figure 1: Absorbed dose as a function of radial distance for the BELLE detector. Please see the text for assumed parameters and explanations.

$$\mathrm{Rate}_\gamma = \frac{1.7}{2\pi} 10^{\frac{0.07}{E} - 0.14} \ \mathrm{Hz/cm/rad} \tag{1}$$

$$\mathrm{Rate}_{\mathrm{charged}} = \frac{1.7}{2\pi} 10^{\frac{0.03}{p_T} - 0.22} \ \mathrm{Hz/cm/rad} \tag{2}$$

where E and p_T are in GeV and GeV/c, respectively.

Using these equations, and scaling for different beam currents, vacuum and emittance, one can calculate the sensitivity and size of different counters in the commissioning detector.

Of course, the beam conditions and even the IR geometry for the commissioning detector may be radically different from what we assumed, but at least we have a starting point.

4.3 Origin of Spent Electrons

It is important to know where the majority of spent particles that hit[2] the detector originate in the length of the beam pipe. That will let us decide where to put masks. We plot in Fig. 4 the z-position of scattering of these particles off the beam-gas. Fig. 4(a),(b),(c) and (d) give z-position distribution of the origin

[2]This study was done with Decay Turtle, without Geant. If the spent particle is more that 2 cm away from the IP at the vertical plane containing the IP ($r > 2$ cm), then we call it a “hit” in the detector.

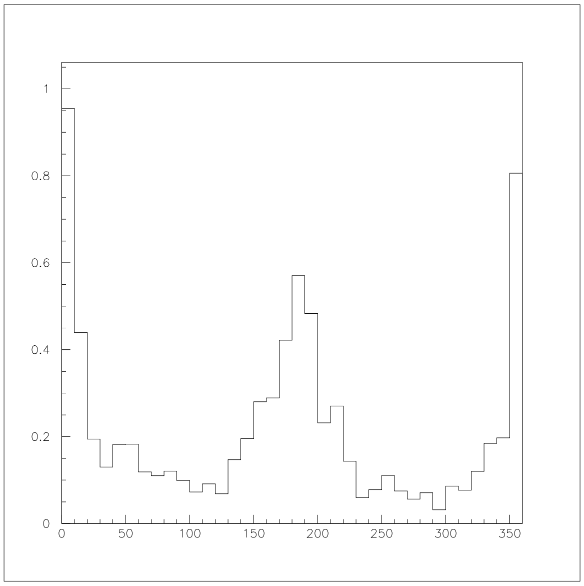

Figure 2: Absorbed dose distribution as a function of azimuthal angle, ϕ for the BELLE CsI detector. Vertical axis has arbitrary units, horizontal axis is in degrees.

of hitting particles for e^+ Bremsstrahlung, e^+ Coulomb, e^- Bremsstrahlung and e^- Coulomb scattering processes, respectively. BELLE detector is situated at the right-most end of each of these plots. For comparing the position with corresponding beam-elements, beam-line plots are given at the bottom of these histograms in the same figure. It is observed that while Coulomb scattered e^+/e^- come from nearby regions of BELLE, Bremsstrahlungs come from all over the straight section.

In general, improving vacuum near the detector as much as possible and installing masks in the linear region would help reduce the background.

4.4 Effect of Mis-aligned Optics

It is not to be expected that all the beam elements will be aligned properly at the beginning of the experiment. Therefore we have estimated the effect of small mis-alignments of optical elements on beam backgrounds. Typically, as long as the beam elements are not off by more than 2 mm from the designed beam-line, the backgrounds from different sources do not exceed by more than 50% from their normal values. As an example. we show the effects of shifts $(\Delta x, \Delta y)$ of closest and farthest quadrupoles to BELLE in the LER on background rates. Factor by which the background increases is plotted as a function of Δx and Δy in Fig. 5. Shifting of closest quad to BELLE yields Fig. 5(a), and (b) represents

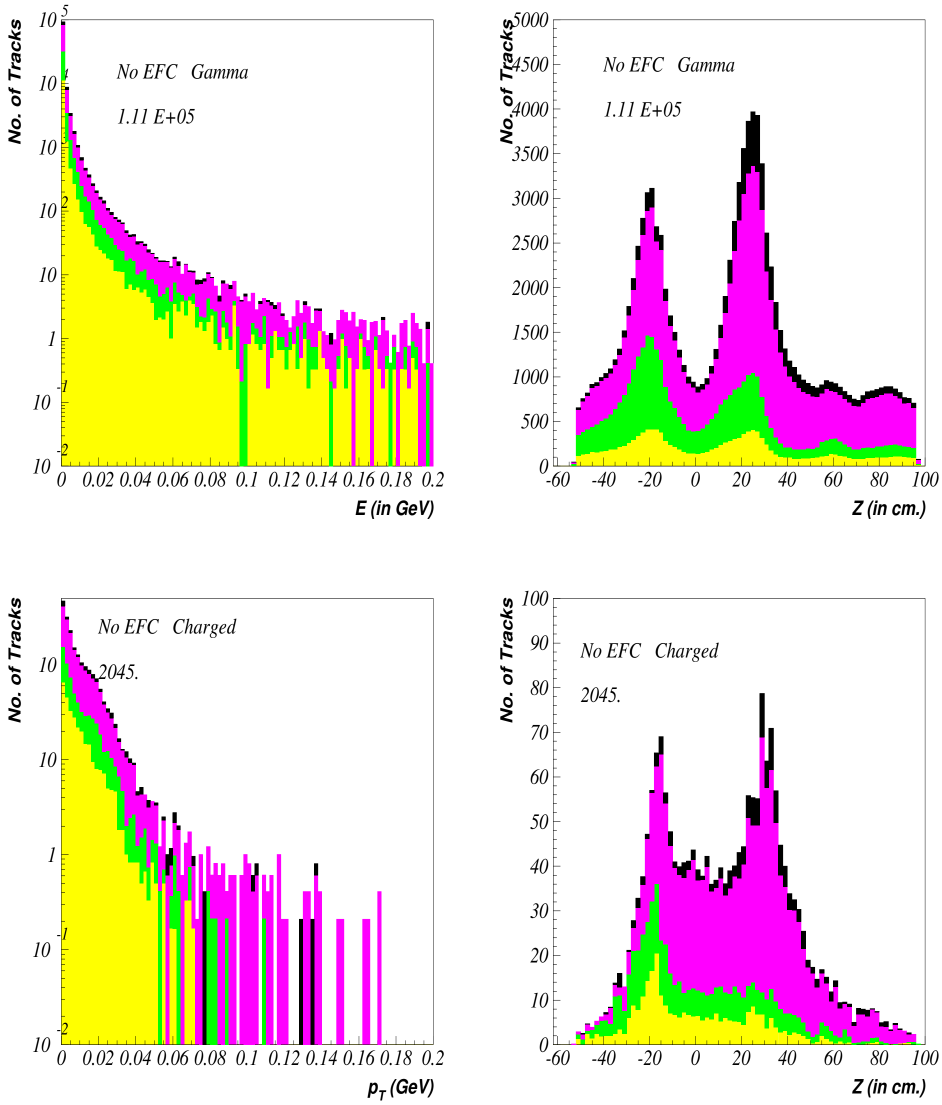

Figure 3: Charged tracks and γ's entering the Belle detector volume in 4 ms. For these histograms, $E_\gamma > 100$ keV, and $p_{T charged} > 100$ keV/c. Peaks in the z_γ distribution come from the tungsten masks placed inside the beam-pipe, which serve as "photon amplifiers", in Steve Olsen's language.

shifting of the farthest quad from BELLE in the straight section, both in LER.

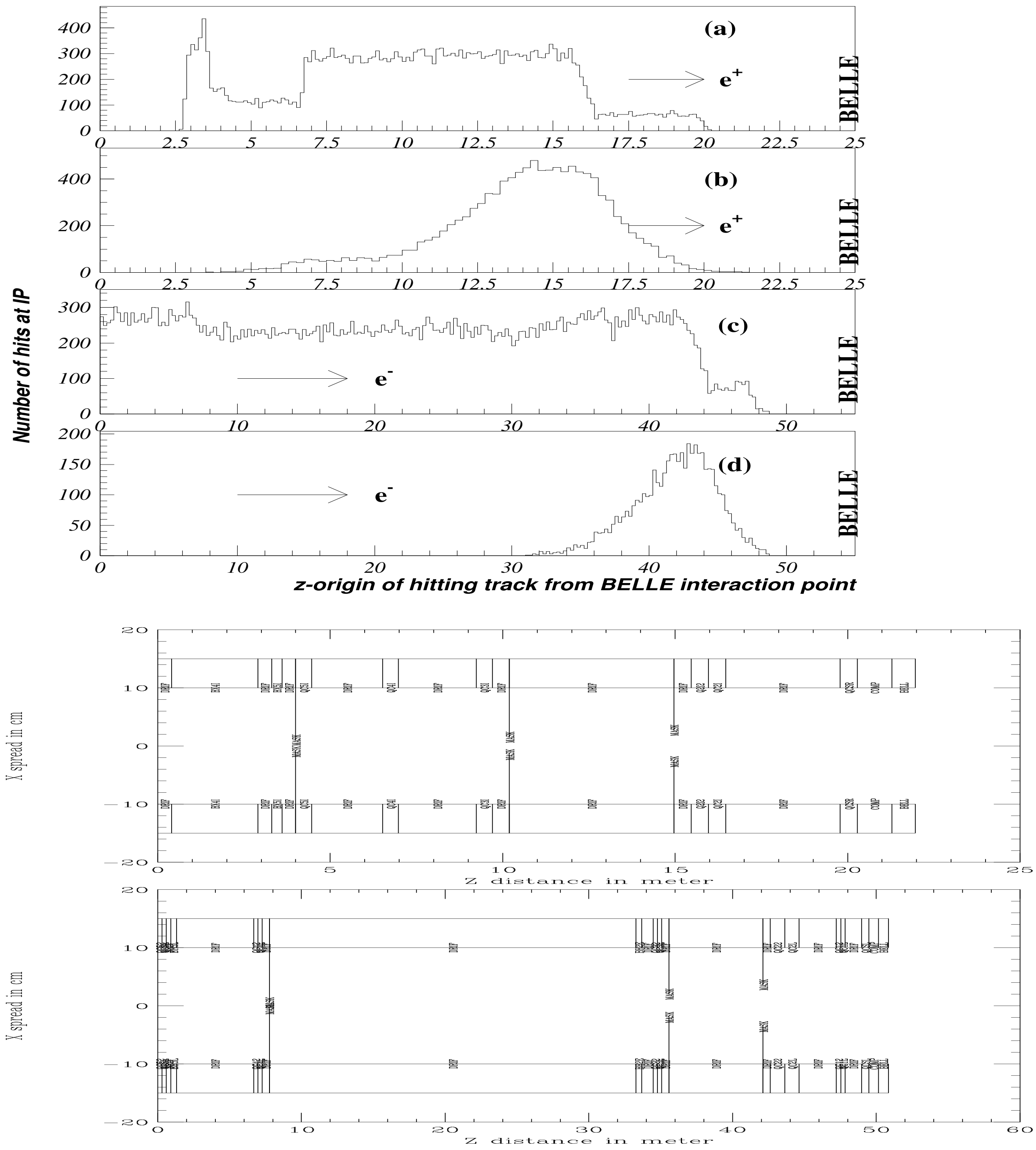

Figure 4: Distribution of z-origin of hitting spent beam particles along the beam-line. (a) e^+ Bremsstrahlung, (b) e^+ Coulomb, (c) e^- Bremsstrahlung and (d) e^- Coulomb scattering processes. Pictures of beam elements of LER and HER are given at the bottom as maps.

Vacuum	1 nanotorr
Beam pipe	Aluminum
e^+ current	2.6 ampere
e^- current	1.1 ampere
Luminosity	$10^{34}\text{cm}^{-2}\text{s}^{-1}$
ϵ_x	1.8×10^{-8} meter
ϵ_y	3.6×10^{-10} meter
β_x	0.33 meter at IP
β_y	0.01 meter at IP

Table 1: Accelerator parameters with which the background events were generated.

5 Design of the Commissioning Detector

5.1 Non-vulnerable Belle

It was *tentatively* agreed by the BELLE group at the general meeting of March 1998, that BELLE detector without SVD and Endcap CsI would not be vulnerable to bad beam conditions, and therefore may be rolled in for the beam commissioning. This also precludes the roll-in of endcap ACC. For reasons of radiation damage and scheduling, EFC will not be installed either.

There are some concerns about any possible damage to the barrel CsI. Simulation results have been reported elsewhere in this report to show that such damage would be small, and in the event of large background, one can always lower the beam current and rectify the problem before going into high current adventures.

We will call this partial BELLE (SVD,CDC,BACC,TOF,BECL,MAG,KLM) the *non-vulnerable BELLE*. It will be augmented with some simple additional detectors - generally called commissioning detectors, that will go in places of SVD, EFC and Endcap. These detectors are described in detail in the following sections.

5.2 Commissioning BELLE

The central commissioning detector will consist of four quadrants for easy mounting and dismounting. The $r-\phi$ and $x-z$ views are shown in Figs. 6 and 7, respectively.

Each of the quadrants will be mounted on the end-ring of the CDC. Proportional tubes, sandwich and monitor diodes, SVD ladder, and TLDs or MOSFETs will reside in each quadrant except the top one, which will be used mostly for SVD ladders.

On the face of each cryostat, we will put partial EFCs, which consists of four blocks of 3 x 3 BGO crystals, as shown in Fig. 8. They will be matched the the lab frame to have maximum acceptance for Bhabha events. When the beams

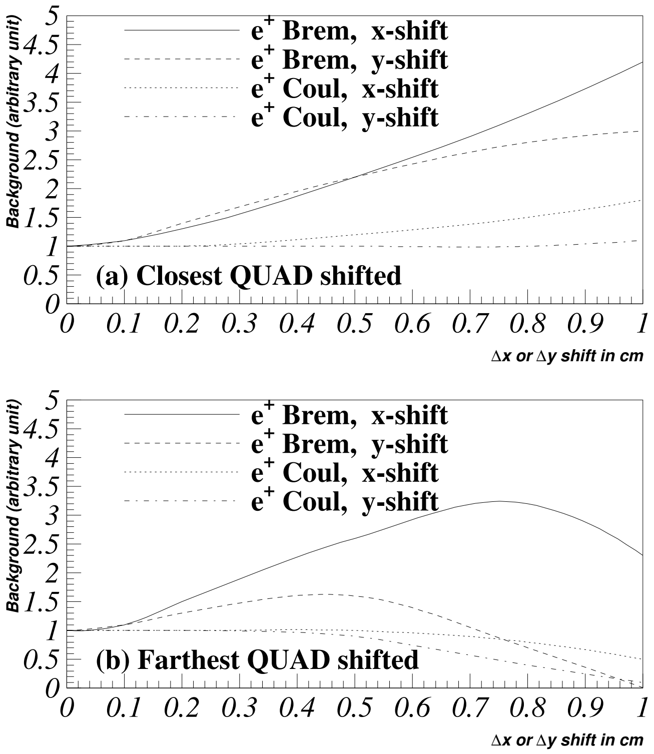

Figure 5: Increase by factor in background hit rate as a function of x- or y-shift in quadrupoles for LER; (a) when nearest quadrupole from BELLE is shifted, (b) when farthest quadrupole is shifted.

collide, this will be the first detector to observe the Bhabhas, and therefore give direct information about the luminosity.

5.3 Proportional Chambers

Proportional chambers are being made at UH. A prototype has already been made and tested. Aluminum tubes will hold negative high voltage, and 50 μm gold-plated tungsten wires will serve as the anode. Basic circuit of the measurement is given in Fig. 9. The DC current is measured by looking at the impedance across the high voltage source. Signal from wires can be amplified

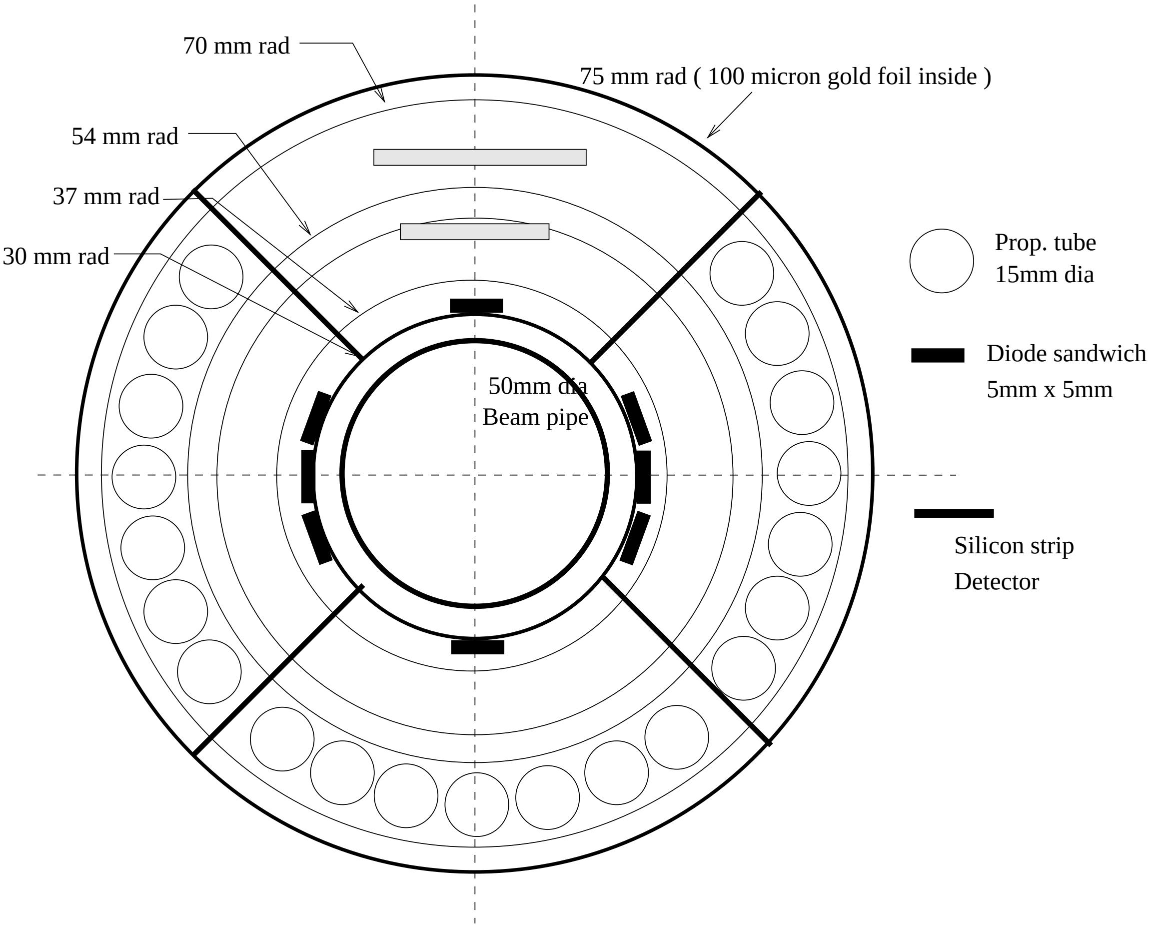

Figure 6: $r\phi$-view of commissioning detector between beampipe and CDC.

to measure any characteristic X-ray spectrum.

5.4 Sandwich Diodes

Diodes in coincidence have been used in many experiments to separate synchrotron background from spent-electron background in CESR and PEP-II. The basic idea is shown in Fig. 5.4. Individual rates of the diodes will give us (γ + charged) rate, whereas coincidence will provide charged particle rate. Synchrotron vs. charged particle discrimination of 100 or better is achievable with this design. UH group is now making such diodes, and a few prototypes will be tested at KEK in April/May 98.

Temperature calibration of dark current has been already done. Dose calibration will be performed in May 1998 at Hawaii Irradiation Institute at UH.

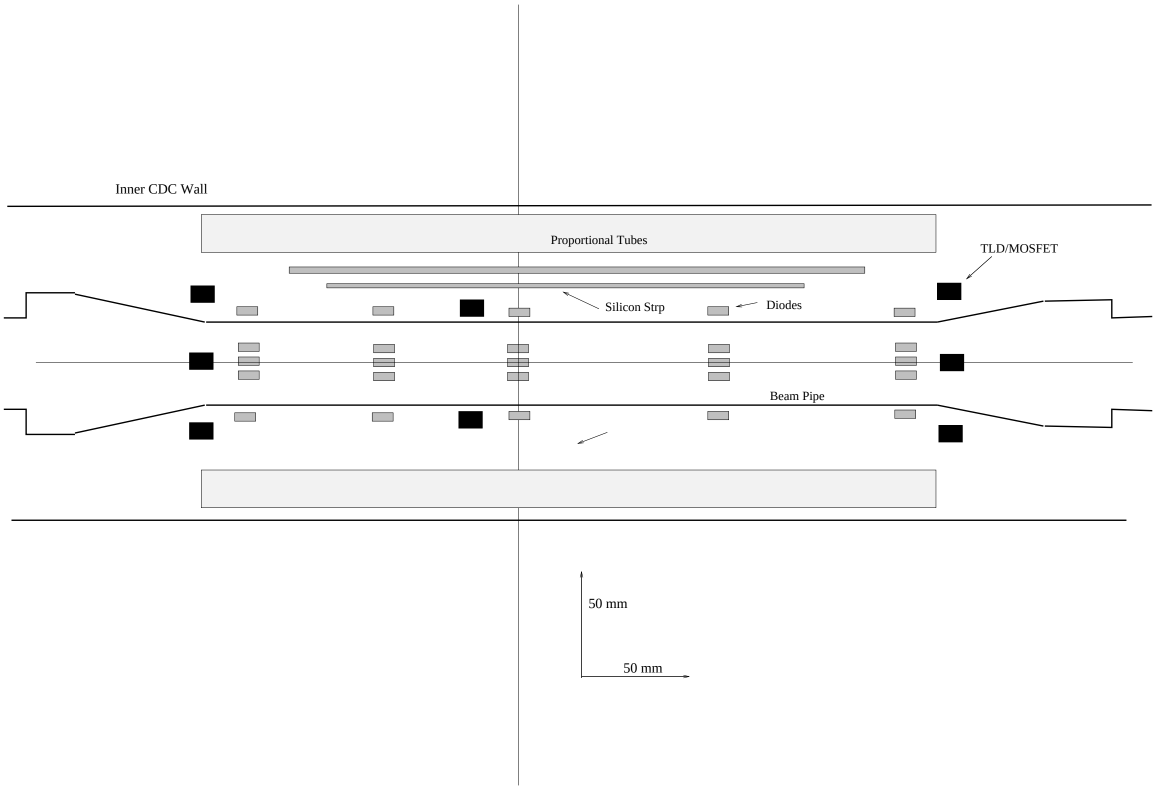

Figure 7: xz-view of commissioning detector between beampipe and CDC.

Figure 8: Partial EFC to be mounted on each cryostat.

5.5 Monitor Diodes

The diodes that where developed at the university of Sydney for use in the SVD detector will be placed in “BEAST”. It is envisaged that they will serve to complement the sandwich diodes being developed for charged particle/gamma seperation. It is also seen as benificial for there long term use in the SVD detector where they will act as a fast beam dump trigger that they be fully exercised and debugged. Unlike the sandwich diodes, they will not have the ability to seperate the charged particles from gammas, but will measure the total flux.

The system employs pin diodes operating in an unbiased mode feeding an operational amplifier supplying an output voltage normally sitting at a level of a few tens of millivolts with the ability to range up to 10 Volts in an almost linear dependence.

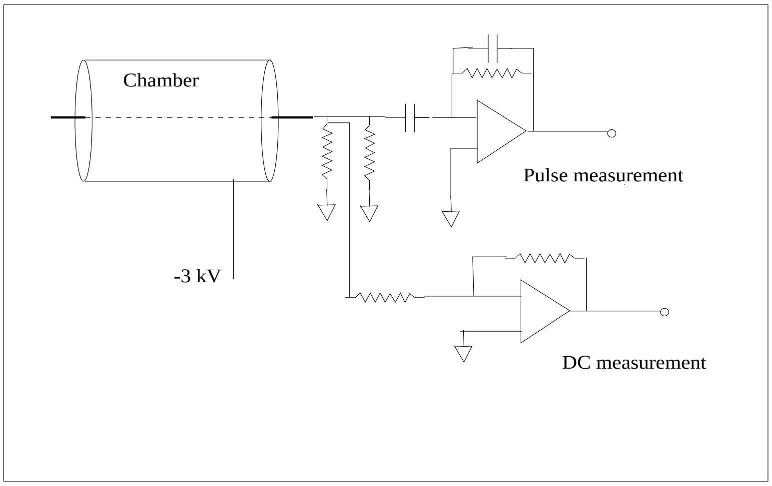

Figure 9: Circuit schematics for proportional tubes.

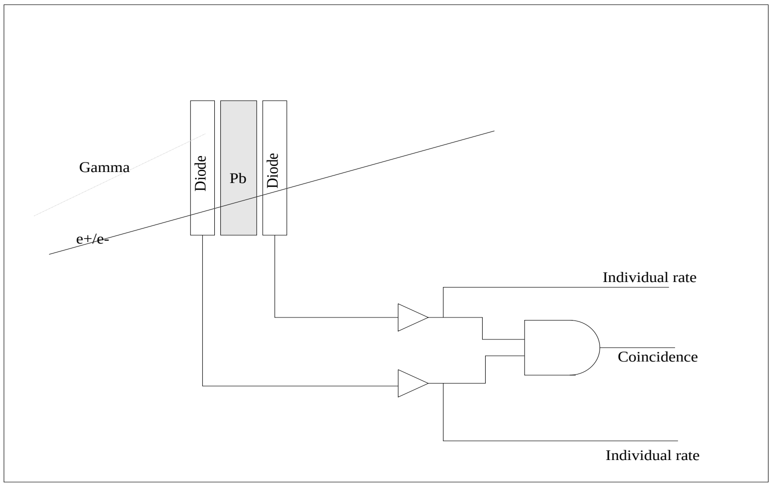

Figure 10: Schematics for diode sandwich.

5.5.1 Detector Details

The PIN diodes are Hamamatsu S3590-08 with a sensitive area of $1cm^2$ and a thickness of 300 microns. The amplifier is a Burr Brown operational amplifier type OPA 129 with a 1 GigaOhm resistor both in the feedback loop and connecting the non-inverting input to ground. Having the matching resistors makes the unit far more stable against temperature fluctuations as variations in leakage current will be cancelled. Each unit is mounted in an individual brass box with a 0.1mm aluminium window. Four leads are required for each unit, +15V, -15V, ground, and output signal voltage.

5.6 Linearity of Response

Figure 11 shows the result of tests with a 1 millicurie ^{90}Sr source for a varying seperation. As can be seen the response shows the expected R^{-2} dependence over the range from about 10 millivolts up to almost 10 volts. There is obvious saturation as the output approaches the value of the supply voltage of the amplifier. Within the normal expected running conditions of KEKB within the SVD the ambient operating voltage is expected to be around 50millivolts allowing the radiation levels in the commissioning to be greater than this by at least two orders of magnitude before saturation is reached.

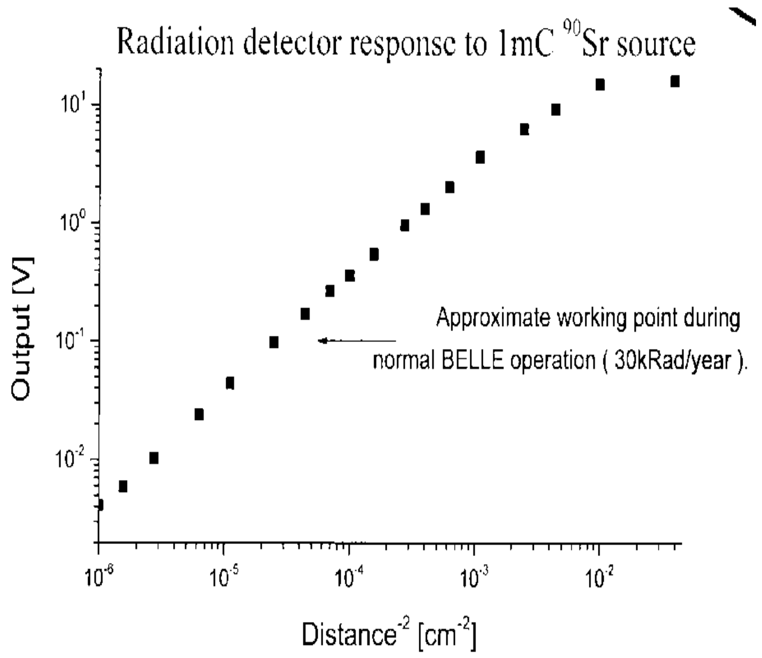

Figure 11: Radiation detector response to ^{90}Sr source.

5.7 Silicon Strip Detector

One important purpose of BEAST is to make a reliable measurement of the radiation level and judge whether the it is low enough for installing SVD and end cap detectors.

We concluded that it is valuable to install some SVD ladders in BEAST for the following reasons;

1. The SVD system is debugged outside the BELLE structure but it is hard to know the real operating environment. By installing a part of SVD in the BELLE structure, external electric noises, common mode base-line shifts would be experienced. We could learn how to avoid these noises and their effect to physics output could be estimated.

2. The hit rate or the occupancy has been carefully studied by a Monte-Carlo simulation. By using a real SVD, we can check the validity of the simulation and relationship between radiation monitors.

3. The radiation-dose measurement by a MOSFET is essentially a measurement of its radiation damage. Since we operate both MOSTFET sensors and SVD simultaneously, we could tell the damage to SVD readout system without a precise calibration.

4. At some stage of accelerator commissioning, it is planned to take a small amount of data ($\sim 10\ \mathrm{pb}^{-1}$). If SVD is still alive, we would take data and the data will be useful to test the data reduction process.

5. The leakage current of DSSDs is a function of radiation level, operation temperature and radiation damage. The current could be used for estimating the environment and invoking warning signal.

5.7.1 Mechanics

In BEAST we will install just two ladders. They do not have to be perfect mechanically nor electrically. The support mechanics should be simple since they are not intended for physics analysis. However, by adopting an adequate support system the $10\ \mathrm{pb}^{-1}$ data could be used as a good practice of the physics analysis.

Cooling system will also be omitted and the support system should have enough heat conductivity and capacity. The thermistor on the SVD hybrid will prevent dangerous treatment.

5.7.2 Electronics

In the SVD group, the commissioning detector is understood as an indispensable step of the SVD system test. Therefore the VA1 readout chips will be operated by the real repeater system and online data acquisition system. Therefore, the readout electronics in the electronics-hut should also be ready by the time of the commissioning of KEKB.

5.7.3 Data Reduction

Since we do not expect physics signal, the algnment between two ladders is not a main issue. A simple analysis will be enough to estimate the occupancy and energy spectrum. By comparing the result of two ladders it might be possible to separate neutral and charged component in the SVD region. The data should be compared with the result of proportional tubes, fast-response radiation monitors.

5.8 Passive Radiation Dosimeter

To measure the absolute integrated radiation dose experienced by the detector during the commissioning of KEK-B passive radiation dosimeters shall be used. These will be used in conjunction with the MOSFET system (see next section). Due to the availability of space they will serve as a reliable, independent cross check of the MOSFET and diode systems, though they will only be measured after the commissioning has finished and not be of use during the lifetime of the "BEAST". Due to the high doses predicted, it is expected that Thermo Luminesent Detectors(TLD) will saturate (less than 1000 Rad) and not be of use. To gain the most sensitivity over a wide range of doseages ew intend upon using three different passive dosimeteric devices. These will be Cobalt glass, CR39 plastic and Alanine molded with polystyrene. Both Cobalt glass and CR39 are a transparent material that as they are damaged by radiation turn opaque, with the Cobalt glass turning black as a function of exposure and the CR39 turning a dark brown. The measurement of the exposed samples is performed by simply measuring the absorption of light in the sample at a set frequency. The polystyrene molded Alanine is an organic compound that when damaged by radiation causes electron bond breaking which results in the formation of unpaired electrons in the molecule, known as "free radicals". The number of free radicals is proportional to the amount of radiation to which a sample is exposed. The density of free radicals in the substance can be measured using Electron Spin Resonance (ESR). ESR is identical to NMR expect that the frequencies used probe electrons not the nucleus. The sample is place in a uniform magnetic field that causes the splitting in energy levels of electrons with a net angular momentum (ie. unpaired electrons). The sample is exposed to an orthogonal low-amplitude high-frequency field which is typically of the order of microwaves, to excite the electrons. The Amplitude of the decay frequency of the excited electrons is proportional to the density of excited electrons. The range of response of Alanine is 10^2 - 10^7 Rad, linear to 5×10^6 Rad, $\pm$ 1% 10^4 - 10^7Rad, $\pm$ 2% 10^2 - 10^4Rad. Dose response depends on temperature during irradiation $0.29\%/^oC$ at 25^oC (-40^oC , 50^oC). So for a total exposure of 100kRad and a temperature fluctation of 10^oC during irradiation would lead to a reading error of roughly 3.9%. It should be noted that the "BEAST" will be instrumented with RTD temperature monitors and so the estimation of error due to temperature fluctuations should be well understood.

The radiation safety division at KEK has experience with all these devices and the facilities to perform the measurement.

5.9 MOSFET

The principle of the operation of the MOSFET detector is shown in Figure(12). Under ionizing irradiation electrons and holes will be created in the silicon oxide, which has a normal thickness of 0.1-1.5 microns. Part of this charge will recombine, while another part (holes) will be captured on the traps in the SiO_2 close to the $SiO_2 - Si$ interface. The created charge will change the electric field in the channel of the transistor and as a result change the current between source and drain. The most convenient characteristic for measurement is the threshold voltage ΔV_{th} under constant current conditions.

The advantage of such systems are

- Simple readout.
- Possibility to work on passive and active modes.
- Threshold voltage shift is proportional to accumulated dose.
- Small size (typically less than $1 \times 1mm^2$).
- Readout current is large enough to feed long cables without noise problems and preamplifiers.
- One cable is enough to readout in passive mode.

The MOSFET detector most accurately reflects radiation damage in CMOS electronics and passivated oxide strip detectors. Figure(13) shows the response of two types MOSFET detectors in passive and active modes. In the active mode the response of the MOSFET detectors becomes almost linear. The applied voltage on the gate during the irradiation will reduce the recombination of charges in SiO_2 and more holes will be trapped. Figure(14) shows the change in threshold voltage of a typical commercial "radiation-soft" MOSFET transistor in active mode which would be suitable for monitoring integrated radiation fields up to 30kRad(SiO_2). The oxide thickness is about 0.1 microns.

5.9.1 Temperature dependence of the response

From a study of the temperature dependence of the response it was shown that the temperature change during irradiation did not effect the sensitivity of the MOSFET. The most important factor of possible error in dose measurement is the temperature dependence of the threshold voltage. We have investigated the temperature dependence of current-voltage characteristics of MOSFETs manufactured of high purity silicon. The threshold voltage of these detectors was the same, independent of geometry. The two MOSFETs were different only in channel width. The temperature dependence of I-V characteristics clearly shows a temperature stable point , ie. where V_{th} is independent of temperature. For this MOSFET detector it was about 35 microamp and V_{th} was about minus

6.9V. Figure(15) shows the temperature dependence of ΔV_{th} vs. temperature for two readout currents, 30 and 40 microamps. It is clear that both gradients $\Delta V_{th}/\Delta T$ have different sign - thus showing that the thermostable point is between these curves. From this measurement it is clear that the temperature instability coefficient was less than 1 mV/degree near the stability point. For an oxide thickness of 0.2 microns the expected sensitivity in passive mode is 0.1mV/Rad(Si) which means an error of 10 Rad/degree. With an expected dose of the order of KRads, temperature effects are not important.

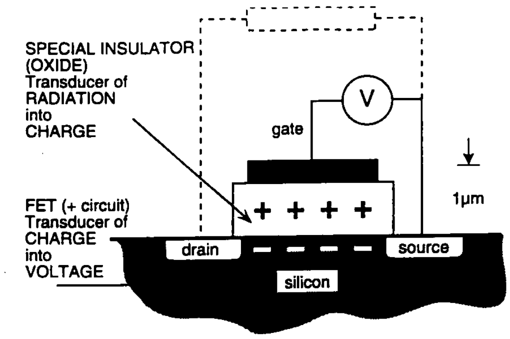

Fig. 1 Principle of the RADFET chip

Figure 12: Principle of MOSFET use for doseage measurements

5.10 Partial EFC

A partial EFC detector is being prepared for the October commissioning. It consists of four 3X3 BGO matrices at four ϕ locations of 0, 90, 180, and 270 degrees in the forward and the backward hemispheres. The arrangement of the crystals is shown in Fig. 16 The matrices in the forward are taken from the innermost three layers of θ segmentations. The matrices in the backward are taken from the outermost three layers of θ segmentations. The arragement makes it possible to detect two particles of Bhabha events in the detector. The readout electronics system is the same as the one which will be used in the full detector. The system worked fine in the beam test of March, 1998.

5.11 CsI Gamma Counters

For the purpose of the Commissioning Detector we decided to use the eight full size detectors (four for the forward and four for the backward calorimeters). In addition we will make four small detectors based on pure CsI crystals with Fine Mesh PMT (FM-PMT) readout. That kind of detector will be necessary for measuring the spectrum of the low energy particles. According the MC simulation, we expect that maximum counting rate corresponds to the photons of energy about 0.5 MeV. The pure CsI crystals have less light output, 3–5

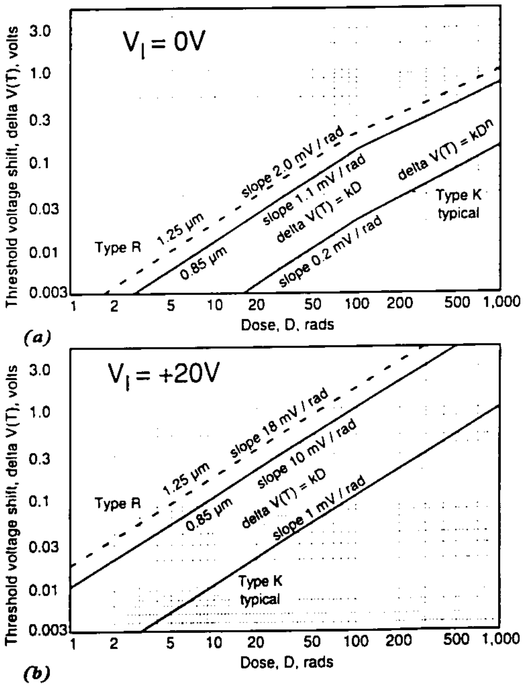

Fig. 2 Nominal response of the TOT501 RADFET for two bias modes
(a) zero bias during irradiation (V_I=0)
(b) positive bias during irradiation (V_I=+20V)

Figure 13: Threshold voltage vs. Doseage for both zero and positive bias

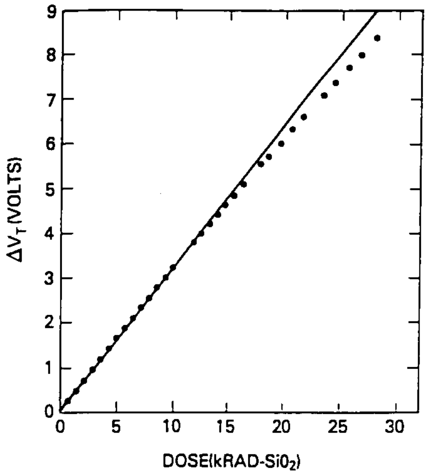

Figure 14: MOSFET threshold voltage vs. Dose

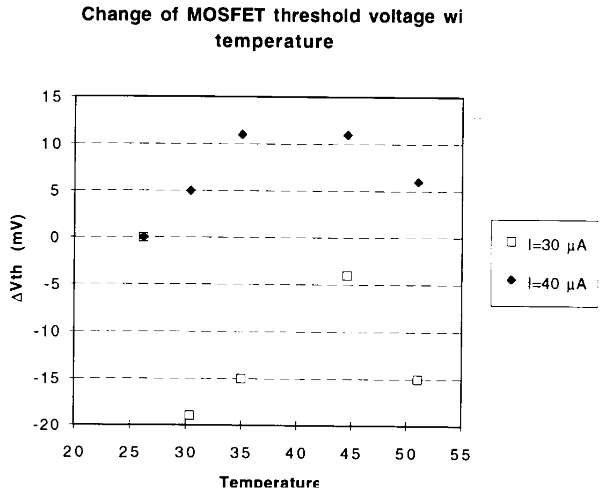

Figure 15:

times less in comparison with CsI(Tl), but decay time is much shorter, 10-20 nsec. To have a low as possible threshold for photons, we prefer to use the 2-inch FM-PMT's which can work in the high magnetic field. Finally we hope to have a counting rate capability up to 1 MHz, the noise level less than 50 keV, energy threshold less than 100 KeV and energy resolution better than 20% for 500 keV photons. The crystals will be supported by the Al frame, as it shown in Fig.XXX . Full size detectors should be shielded by 3–5 cm thick layer of lead in order to reproduce the self shielding effect of the calorimeter crystals.

6 Data Acquisition

6.1 Retrieving Accelerator Parameters

As we take data with the commissioning detector, all the accelerator parameters need to be logged synchronously. We need this data for making predictions with our accelerator models, and match with observation. Clearly, the accelerator group will log this data, and it is a matter of establishing a method to retrieve such files, and synchronize them with the data that we log with the commissioning detector.

This is mostly a software and perhaps a bit of networking work, and needs to be done by somebody who is stationed at KEK.

6.2 Data Logging

The commissioning experiment is short-lived, and we have to take as much useful data as possible when the beam is on - typically this would be about 2 months - or about 150 shifts.

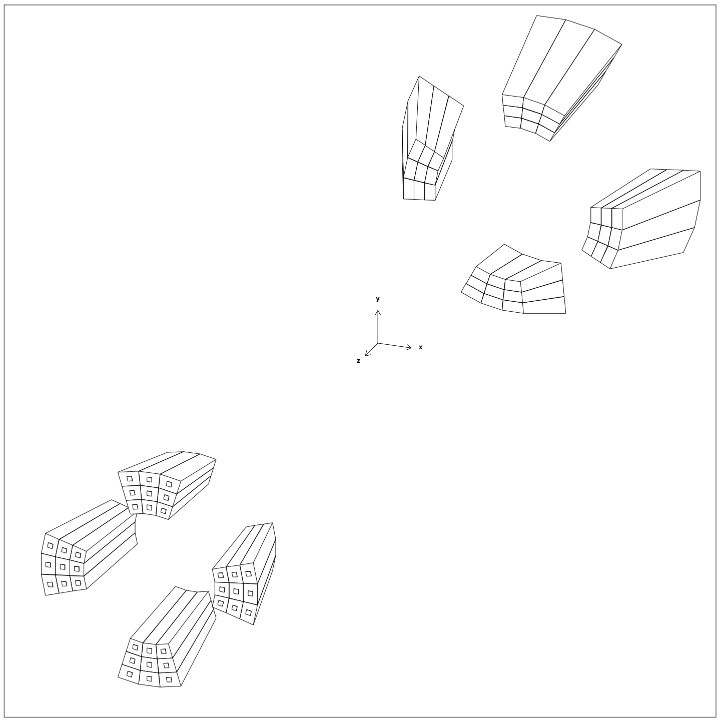

Figure 16: Schematics of the partial EFC. The quadrants will be installed on the face of the cryostat of the compensating solenoid.

Therefore no adventure on DAQ is permissible. We would like to keep the system as simple as possible. We are planning on doing the DAQ with our laptop Pentium PC, with CAMAC GPIB, and instantly analyze the data with LabView. All these are available at Melbourne, Sydney and Hawaii labs. The philosophy is to just take the working system down to KEK, and start taking data.

Most of the detectors will be read out with NIM/CAMAC modules.

7 Manpower, Resources and Schedule

Four PhD scientists (Tom Browder, Steve Olsen, Mike Peters and Saroj Sahu) are working part time on the design and construction of this detector. Two students (Casey Law and Sanjay Swain), with the help of the above, will be working full time on its construction and testing during the summer of 1998. Adequate enginnering support is available at the machine shop at University of

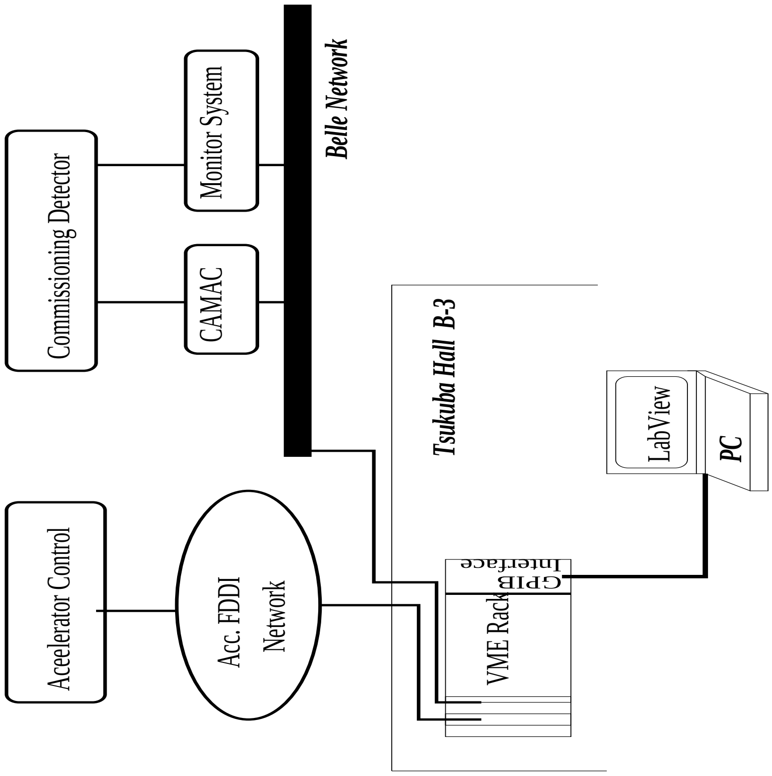

Figure 17: Schematic of DAQ and acclerator-detector communication. All lines are bidirectionaL data/command.

Hawaii.

Significant help is anticipated from the Novosibirsk group, which would provide crystal counters; the Australia group, which is already making radiation monitors for SVD; and from the Taiwan group, which will provide the BGO counters.

We plan to finish the fabrication by the end of June 1998, and ship it to KEK after that.

Some of us (who wouldn't want to !) will be there at the time of comissioning to operate this detector, do the data analysis, and consult with the accelerator physicists.

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