Polarimetry studies at SuperKEKB summary of recent activity at IJCLab

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Conceptual design

- A summary of the conceptual studies performed for the laser system and the scattered photon detector has been published recently
- A summary of the results is inserted in the current CDR draft

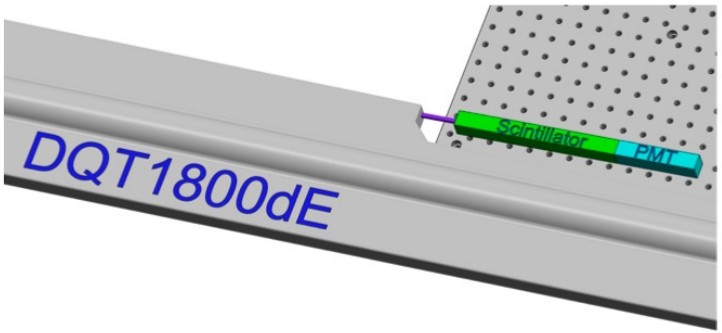

Figure 4. Drawing of the modified beam pipe for the insertion of the photon calorimeter in the SuperKEKB ring.

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Conceptual study of a Compton polarimeter for the upgrade of the SuperKEKB collider with a polarized electron beam

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Abstract: The physics scope of the Belle II experiment currently acquiring data at the SuperKEKB collider will expand with a polarized electron beam upgrade, as recently proposed. Among the required elements for this upgrade, a real time diagnosis of the polarization is necessary to ensure it is large for all bunches in the accelerator during its regular operation. This will be realized by inserting a Compton polarimeter in the accelerator. Its conceptual design is described and no show-stopper for its integration has been identified. An estimation of the sensitivity of the polarimeter is made by means of toy Monte-Carlo studies. The proposed design accounts for the constraint to preserve the performance of the SuperKEKB accelerator and to cope with the short time separation of successive bunches. We show that the polarimeter will measure for each bunch the polarization within five minutes with a statistical precision below 1% and systematic uncertainties below 0.5%. It has the capability of providing this information online on a similar timescale. This work paves the way towards future implementation of real-time Compton polarimetry in several future projects.

Keywords: Accelerator Subsystems and Technologies; Beam-line instrumentation (beam position and profile monitors, beam-intensity monitors, bunch length monitors); Instrumentation for particle accelerators and storage rings - high energy (linear accelerators, synchrotrons)

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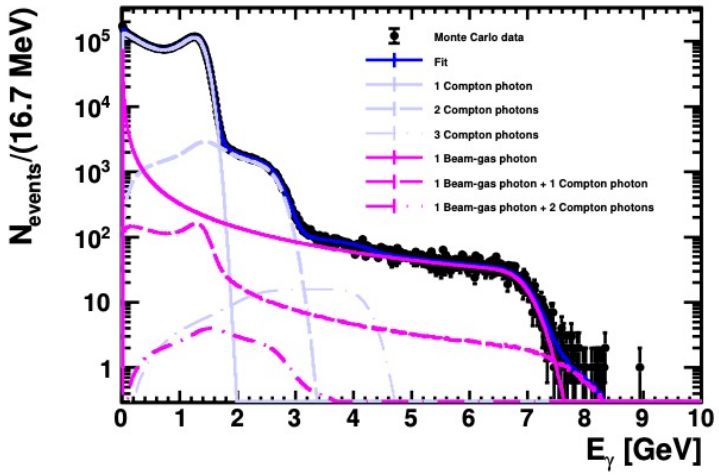
Main results



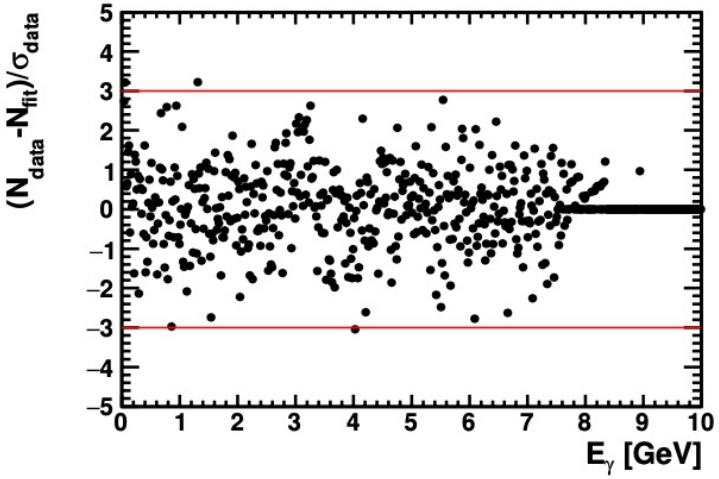


Table 4. Systematic uncertainties on the extraction of P_z, see text for details. Background modeling and absolute knowledge of the laser polarization dominates.

Source	Uncertainty on P_z(%)
Laser beam polarization	0.30
Backgrounds	0.16
Fit procedure	0.080
Beam energy	0.050
Spatial misalignment	0.015
Angular misalignment	0.015
Longitudinal misalignment	0.015
Transverse electron beam polarization	0.015
Total	0.35

Open points

- Systematic uncertainty related to beam transport from Compton IP to Belle 2 IP
- Prototype photon detector → French National Research Agency call for funding, answer in Spring.
- Laser synchronization → possible solution found with relevant KEKB expert, relevant tests may be performed in the coming year at IJCLab and then possibly at KEK on longer timescale.

Touschek polarimetry

Also Natochii, Roney, Zhou

- A summary conceptual document has been prepared (work reported previously already).

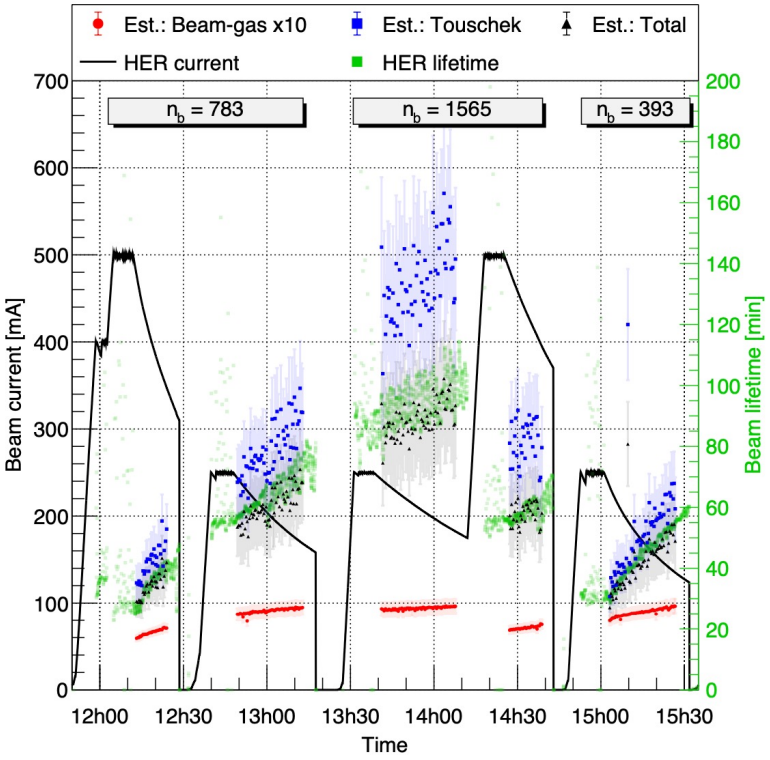


Figure 5: Estimated (Est.) beam lifetime during dedicated beam loss studies in May 2020 using fit results listed in Table 1.

$$\frac{\Delta I}{\Delta t} = B \times I\bar{P}_{\text{eff.}} + T \times \frac{I^2}{n_{\text{b}}\sigma_{\text{x}}\sigma_{\text{y}}\sigma_{\text{z}}}$$

A Touschek polarimeter for SuperKEKB

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Institute name in English, Town, Country

Abstract
A stages approach is considered for an upgrade of the SuperKEKB accelerator with a polarized electron beam. In this context the usefulness of a measurement of the beam polarization by means of its Touschek lifetime is investigated here.

Keywords
Touschek lifetime; beam polarization

1 Introduction

An upgrade of the SuperKEKB accelerator with polarized electron beams would enhance the physics reach of the Belle II experiment by otherwise impossible measurements of electroweak asymmetries and tau-vertex as its g-2 [1]. The first step consists in demonstrating that the required current of polarized electron beam can be produced, transported in the linac to the main SuperKEKB ring and stored for a long enough time without loss of vertical polarization. The next stage would consist in actually implementing modifications to the main SuperKEKB ring by inserting spin rotators and a Compton polarimeter to ensure and optimize a longitudinal polarization at the Belle II interaction point. In order to minimize modifications to the main ring prior a demonstration that significantly polarized electron bunches can be stored in SuperKEKB, it is of interest to find a simple, possibly non invasive technique to diagnose the beam polarization in SuperKEKB. We investigate here the possibility to do so by means of Touschek lifetime measurements.

This document is organized as follows. First we introduce the dependence of the Touschek lifetime as a function of beam polarization. We investigate its impact for the SuperKEKB ring. In a second section, we investigate the present status of Touschek lifetime measurements in the SuperKEKB ring that are presently made in the context of beam background diagnostics for the Belle II experiment. We finally list the needs for a meaningful polarization measurement at SuperKEKB.

2 Touschek lifetime and polarization

Touschek described the lifetime of electrons in AdA (accumulation ring) in 1963 [2], as a result of Moeller scattering in between electrons of a beam in a ring. Right after, Baier and Khoze pointed out that the Touschek lifetime is sensitive to polarization [3]. It was then used in the VEPP-2M ring to measure depolarization, and in turn the beam energy, by measuring the counting rate of scattered electrons [4]. It allowed to realize a first precision mass measurement of the J/Psi, that was continuously improved until it reached a few parts per million accuracy on the beam energy measurement at VEPP-4M [5]. Since then it has been continuously used by the accelerator physics community to measure beam polarization, also at the most modern synchrotron light sources, see for instance [6–8] and is planned to be used at FCC-ee too [9].

In order to quantitatively investigate the effect of beam polarization on the Touschek lifetime at SuperKEKB we follow the formalism developed in Ref. [9–11], where a flat beam approximation is being used. It is obtained after calculations that the ratio of Touschek lifetimes with and without polarization reads

$$\frac{\tau_T(P=0)}{\tau_T(P)} = 1 + \frac{< \tilde{F}(\xi) >_s}{< \tilde{C}(\xi) >_s} P^2, \quad (1)$$

- A. Natochii revisited his analysis for beam background
  - → Touschek relative contribution to lifetime known to ~0.5%
  - → ~3% uncertainty on $|\vec{P}|$

Open points

- Need to know momentum acceptance →how to calibrate ?
- Would be wise to consider storage of polarized and unpolarized bunches in the beam → bunch/bunch beam size monitor needed, and information kept.

Summary/next steps

- Conceptual design is ready
- Prototype photon calorimeter critically needed to operate at 250MHz ← critically funding dependent
- Practical validation of synchronization concept expected within a year at IJCLab, then possibly at KEK (TBC)
- Still some remaining important open points on the feasibility of the Touschek polarimetry to be investigated and discussed with KEKB colleagues.