Touschek Polarization Lifetime Experiment Planning

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Experiment Planning

0.5% lifetime measurement will be sufficient to measure the transverse beam polarization and to detect the $\gamma G = 16$ depolarizing resonance, the presence of which would indicate that polarization is preserved and the resonance reduces it.

Because of this connection to the beam energy (the resonance is at a beam energy of 7049.86 MeV) the resonance can be used to precisely calibrate the beam energy by performing an energy scan.

Goals of Experiment:

- Verify spin-transport through the injector chain is understood and preserves the polarization magnitude and direction.
- Verify polarization is preserved upon storage of the electron bunches in the HER, determine the polarization lifetime and map out the topology around the $\gamma G = 16$ spin resonance.
- If possible, to detect and quantify the effect of the beam-beam interaction on the polarization lifetime and develop mitigation strategies.
- If beam-beam effects are detectable, quantify the effect on polarization in terms of the beam-beam parameter – could be valuable input to helping SuperKEKB improve luminosity

High-level Run Plan

Anticipate 3 days to match the beam from the new source to the injection linac, verifying the beam transport and capture into the linac and acceleration, and that the measured beam parameters are as expected.

Once the beam is stored in the HER, the beam-lifetime measurement (bunch-by-bunch or in groups) will be verified and lifetime data taken under specific conditions to allow separating Touschek lifetime from beam-gas lifetime, and the time needed to get a better-than 0.5% lifetime measurement will be re-established.

Four days for the resonance scan—from 7000 MeV to 7100 MeV in 10-MeV steps—incl. refinement steps in energy to detect synchrotron satellites and increase accuracy of the resonance energy. The ability and efficiency of ramping the energy of the HER will set the duration needed for each energy point.

Nominally the resonance is expected at 7049.86 MeV. Assuming run proceeds reasonably smoothly to this point, plan to inject positron beam into LER and study the effect of the beam-beam interaction on polarization.

Step	Duration (d)	Task	Outcome
1	1	Turn on source and magnet	Beam in transport line
2	1	Accelerate electrons	Beam at 7 GeV
3	1	HER injection	Beam stored
4	1	Initial Measurements	Separate Touschek and b-g lifetime
5	1	Set ring to lowest energy (7 GeV)	Initial point on ramp
6	4	Ramp ring in steps to 7.1 GeV	Production measurements
7	5	Beam-beam effect measurements	Parametrize change in resonance behaviour vs beam-beam

Preparation Planning

The experiment will be prepared in detail using modeling of the beam transport and spin-tracking in the HER to precisely locate the resonance in beam energy, taking into account the beam orbit and possible uncompensated solenoidal field components from the detector.
(use Bmad and other tools capable of modeling spin dynamics)
This will feed back into the planning of the experimental details.

The depolarizing-resonance spectrum will be modeled in sufficient detail to be able to predict polarization lifetime using the DKM formula.

If the synchrotron satellites are detectable, measuring their offset in energy will help cross-check the measurement since the synchrotron tune is known.

Anticipated Results:

- Measurement of polarization lifetime achievable in the HER

- Measurement of the Sokolov-Ternov (de-)polarization time constant

- Energy calibration of the HER to an accuracy of 1 MeV or better

- Potential assessment of the beam-beam parameter by measuring the effect of beam-beam on polarization lifetime

Experiment Run Plan Proposal

SuperKEKB Polarization experiment	
Initial State	Source installed and all under vacuum. Laser tested and ready. Well characterized cathode installed. Well characterized e^- beam properties.
Resonance:	γG=16: 7050 MeV (nominal) Sync. Satellites: ± 12.34 MeV
Expt. Plan	Initial coarse scan 7000 -> 7100 MeV in 10 MeV steps Refine with 5 MeV interleaving steps to identify synchrotron satellites. 2 data-taking coasts for <0.5% lifetime accuracy each. Optional: add LER beam, observe resonance shift with LER intensity

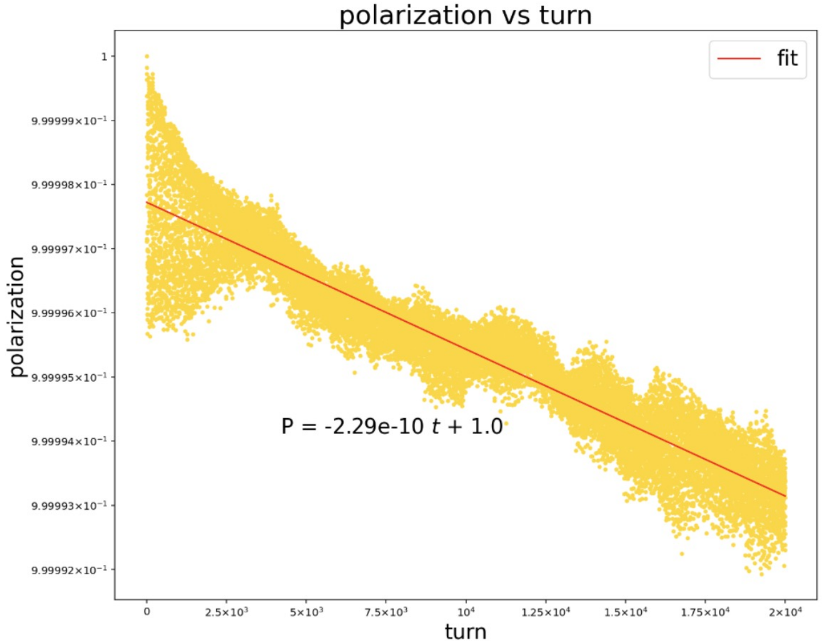
Experiment Run Plan Proposal

Step	Duration (d)	Task	Expected Outcome
1	1	Turn on Source and switching magnet	Beam in transport line
		• Turn on HV and laser and verify source produces e^- • Turn on switching magnet to correct polarity & STDZ. • Verify beam makes it through the switching magnet. • Steer beam on axis and towards linac entrance. Parameters are source HV and vertical steering. • Characterize beam sizes and charge. Tune up if needed. • Verify polarization switch w/o beam property changes	
2	1	Accelerate electrons	Beam at 7 GeV
		• Inject into Linac. Verify acceptance. • Measure and center timing curve. • Steer beam through linac as needed. • Once beam is through linac assess beam loss. • Tune up beam as required. Ideally, only the launch conditions need tuning.	
3	1	HER injection	Beam passes into HER and stores
		• Standard injection tuning.	
4a	0.5	Prepare beam for measurements	Stored beam with desired intensity and bunch pattern
4b	0.5	Initial beam lifetime measurement	verify time needed for <= 0.5% lifetime data.
		• Constant bunch current, vary total current • Constant total current, vary bunch current	These are to separate Touschek from beam-gas scattering.
		• I would want to take data for at least twice the minimum length	
		• Run half the ring with spin-up, half with spin-down and see if S-T time constant can be extracted.	
5	1	Ramp ring to lowest energy point (7000 MeV)	Stored beam and lifetime after STDZ.
		Procedure depends on how KEK does this.	
6	4	Ramp ring in suitable steps	measure lifetime at each step.
		• 10 steps in 10-MeV increments 1o 7100 MeV to find resonance	
		• 4 additional steps to id. synchrotron satellites.	
7	5	Try assessing beam-beam effect on spin	
		Resonance scan with LER in collision	Look for movement of resonance
		Resonance scan with LER without collisions	Look for absence of movement of resonance
		Same with different LER bunch charge	Does any effect scale with LER intensity?

Additional Slides

Transverse polarization survival rate in HER

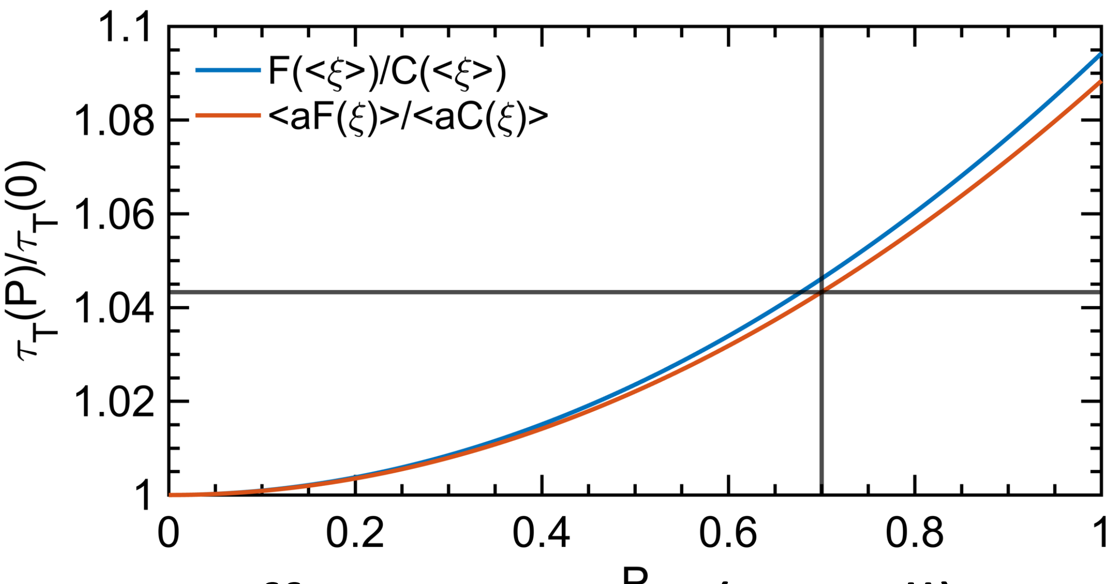
Y. Peng's (UVictoria)



- Tracking 100 particles for 20000 turns in the HER with BMAD
- This study estimates polarization lifetime > 10 hours

For SuperKEKB

From
Farah MAWAS
Aurélien MARTENS
Slides at Feb
Chiral Belle meeting



- It is ~4% effect assuming (overall) momentum acceptance of 0.6%, and using her_2021-06-09_231636.388_MeasOpt

Touschek Lifetime Studies

Andrii Natochii (BNL) Presentation this B2GM

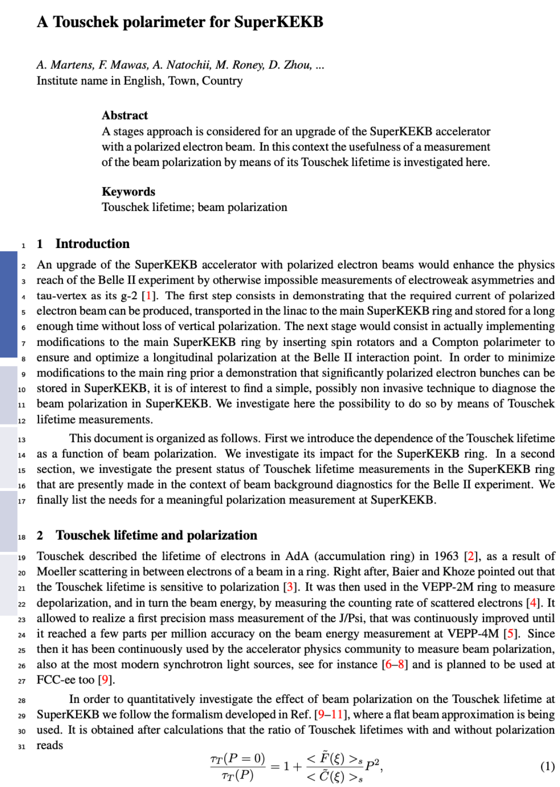
Background Group Data –

the Touschek Lifetime in the HER has been measured at the few per-mil level – sufficient for measuring polarization effects which are at the 4% level

Described in current draft of Chiral Belle CDR

Period	Experimental Touschek Lifetime (minutes)	Ratio of Experimental to SAD Simulation lifetimes
May 2020	37.929 ± 0.057 (0.15%)	0.642 ± 0.002
June 2020	33.656 ± 0.064 (0.19%)	0.746 ± 0.005
June2021	27.93 ± 0.10. (0.36%)	0.601 ± 0.003
December 2021	24.107 ± 0.079 (0.33%)	0.519 ± 0.002

(see Andrii Natochii presentation in this B2GM)



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

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