Proposal for Experiment to Measure Transverse Polarization Lifetime in SuperKEKB

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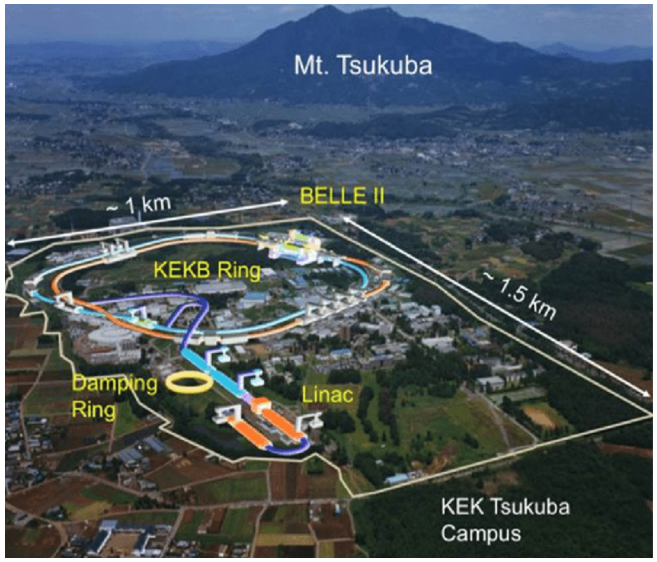
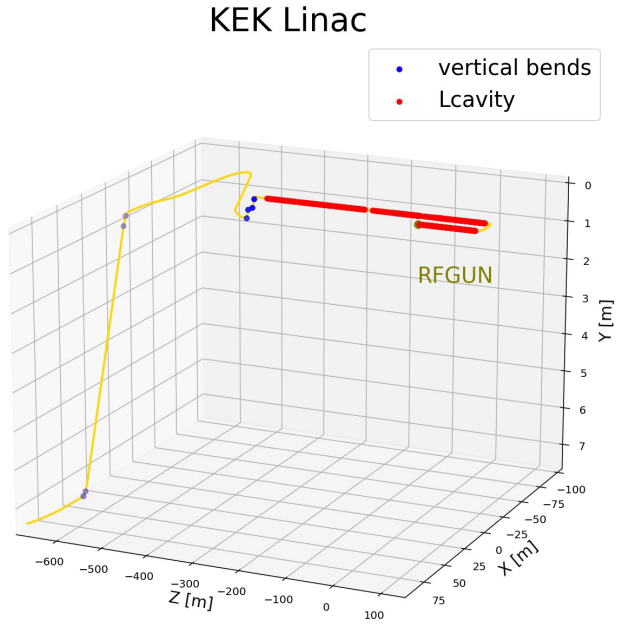
Chiral Belle Session
B2GM KEK

KEK Injection Linac polarization BMAD studies

Y. Peng's (UVictoria)

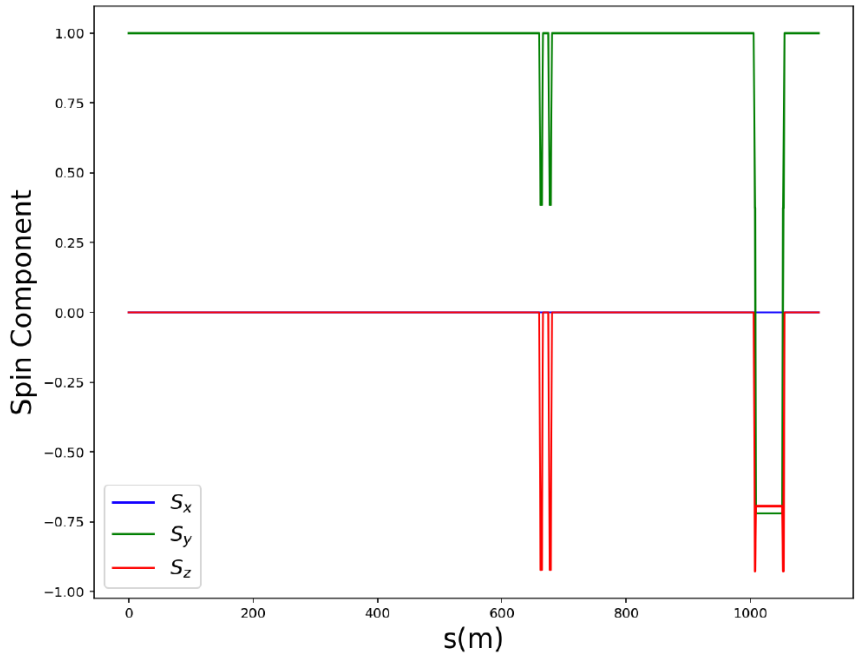




Need transversely polarized beam at the injection point of the e- storage ring (High Energy Ring -HER)

Spin motion in the KEK Injection Linac

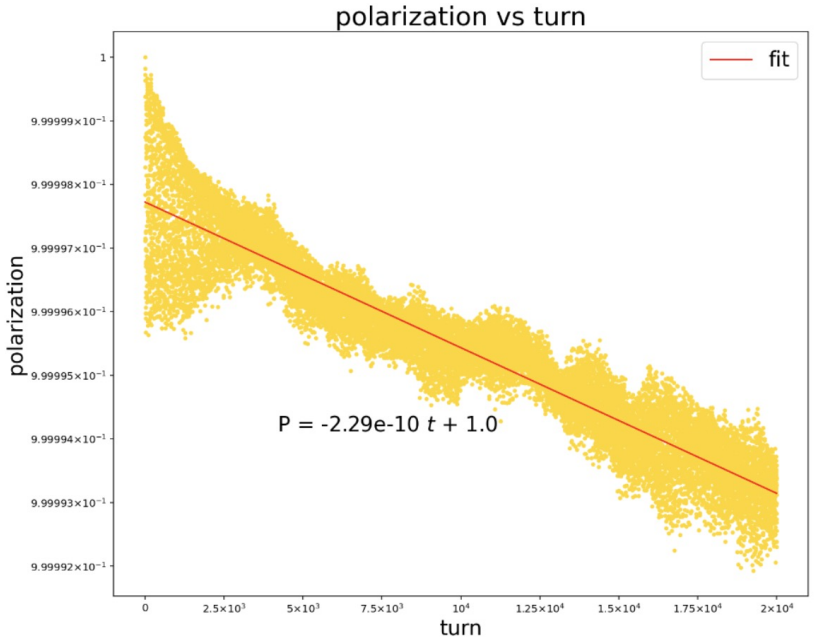
Y. Peng's (UVictoria)



These spin tracking using BMAD show if the electron starts with vertical spin (0,1,0) at the source, after all the vertical beam motion,
it will end up with a vertical spin at the injection point, as desired.

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

Touschek lifetime have been to study transverse polarization

- Touschek described the lifetime of electrons in AdA (’accumulation ring’) in 1963 (Bernardini et al., Phys. Rev. Lett 10 (1963) 407)
- Baier & Khoze, pointed out that Touschek lifetime is sensitive to polarization (At. Energ. 25 (1968) 440)
- It was then use in the VEPP-2M ring to measure depolarization (and thus beam energy): Derbenev Part. Acc. 8 (1978) 115
  - Measuring the counting rate of scattered electrons
- Ex: Allowed first precision mass measurement of J/Psi (3096.93+-0.09 MeV) then superseded in 1993 (E760)
- Continously improved at VEPP-4M (KEDR at VEPP-4M: 3096.900 ± 0.002 ± 0.006 MeV): Phys. Lett 96B (1980) 214; Blinov et al., proc. of EPAC (2002) 1954

From
Farah MAWAS
Aurélien MARTENS
Slides at Feb
Chiral Belle meeting

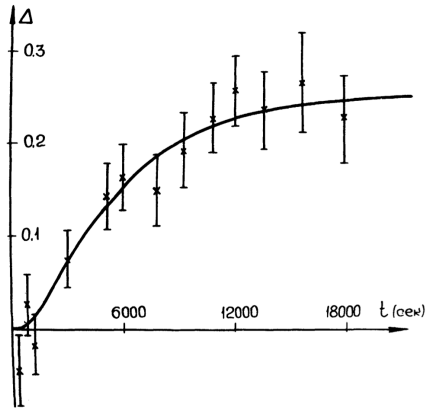


FIGURE 5 The jump in the counting rate during depolarization versus time from the beginning of a polarization cycle.

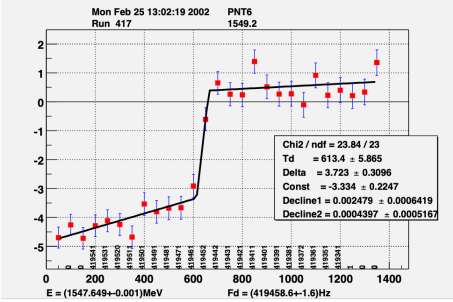


Figure 6: The jump ΔS during the scan of the depolarizer frequency. Abscissa is the time in seconds.

A slightly more modern use

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- Used at :
  - HIgS (DUKE): NIMA 614 (2010) 339
  - SOLEIL, NIMA 697 (2013) 1
  - Diamond Light Source, PRAB22 (2019) 122801
  - Based on expressions given in NIMA 554 (2005) 85
  - Also proposed for FCCee: arXiv1909.12245

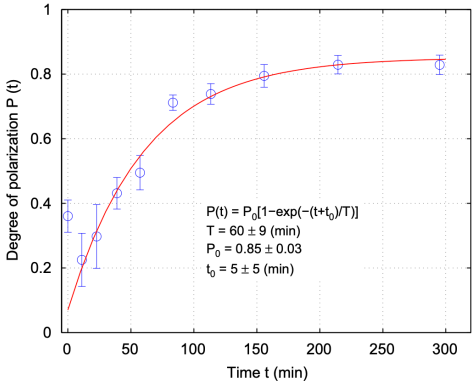

Fig. 6. The build-up process of the electron beam polarization $P(t)$. The solid line is the exponential fit of the data. The fitting model as well as the fit results are also shown in the plot.

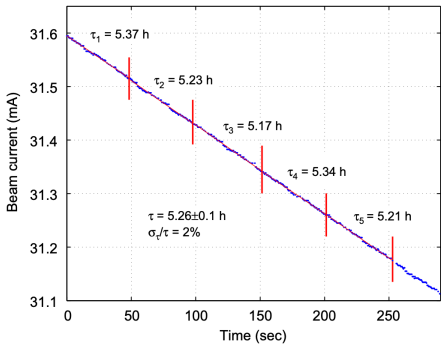

Fig. 4. Illustration of beam lifetime determination around the current of 31 mA of the first run.

$$C(\epsilon) = \epsilon \int_{\epsilon}^{\infty} \frac{1}{u^2} \left\{ \left(\frac{u}{\epsilon}\right) - \frac{1}{2} \ln\left(\frac{u}{\epsilon}\right) - 1 \right\} e^{-u}\, du$$

$$F(\epsilon) = \frac{\epsilon}{2} \int_{\epsilon}^{\infty} \frac{1}{u^2} \ln\left(\frac{u}{\epsilon}\right) e^{-u}\, du$$

$$P(t) \approx \sqrt{\frac{1}{A} \frac{I(t)\tau(P) - I_0\tau(0)}{I(t)\tau(P)}}$$

$$A = \frac{\langle aF(\epsilon) \rangle}{\langle aC(\epsilon) \rangle}$$

$$\epsilon = \left(\frac{\Delta p_m / p_0}{\gamma \sigma_{x'}} \right)^2$$

$$a = \frac{\sqrt{\pi} c r_e^2}{\gamma^3 V \sigma_{x'} (\Delta p_m / p_0)^2}$$

For SuperKEKB

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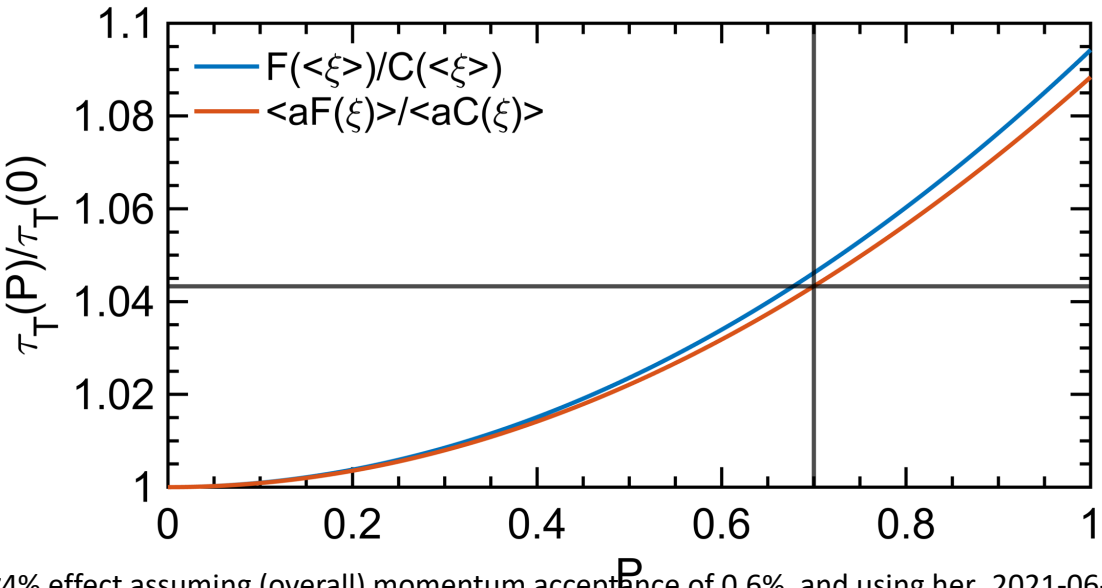

- It is ~4% effect assuming (overall) momentum acceptance of 0.6%, and using her_2021-06-09_231636.388_MeasOpt
- This is likely observable in SuperKEKB
- May need to inject both polarized and unpolarized beams in the ring and measure bunch/bunch intensity with time to minimize systematics (feasbile according to Demin)
- Maybe F/C factor could be calibrated by comparing measurements with various momentum acceptances ? (linked to RF voltage ?)

Touschek Lifetime Studies - Andrii Natochii

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

Dominant uncertainties are:

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

Touschek-Polarization Lifetime Studies Draft Proposal

Dedicate time at the end of the 2024 running period (December 2024) if possible to setup the injection of transversely polarized beam into HER (n-days)

Then run the machine for two days and measure Touschek Lifetime in the HER

In a series of runs each of 2 hours in (>3 Toushek lifetimes).

Each run will have alternating polarization states:

PolRun 1: ZERO polarization

PolRun 2: UP transverse polarization

PolRun 3: ZERO polarization

PolRun 4: DOWN polarization

PolRun 5: ZERO polarization

PolRun 6: UP transverse polarization

PolRun 7: ZERO polarization

PolRun 8: DOWN polarization

Perform these studies both with HER and LER in collision and then with a single HER beam to measured the magnitude of beam-beam depolarizing effects

Touschek-Polarization Lifetime Studies Draft Proposal

Draft Proposal Outline of Hardware Requirements:

- Polarized source – can use sources developed for ILC , since we are not running for long periods of time, or EIC
- Wien Filter after the source to make the polarization transverse
- Source switch to enable the polarized source to be utilized with minimal disruption to existing SuperKEKB source and will minimal time to activate the polarized source
- other …

Touschek-Polarization Lifetime Studies Draft Proposal

With EB endorsement, we will consult KEK source experts prepare a full and complete list and establish costs and realistic timelines, including R&D on Wien Filter, etc, before construction, commissioning an installation of polarized source

- Does Mitsuhiro Yoshida-san already have something close to being usable?
- Engage KEK team – Makoto Tobiyama-san, Mika Masuzawa-san, Yoshida-san

Develop schedule for completing R&D and execution of studies and determine if Dec 2024 is possible

Consider requirements to calibrate the HER beam energy via resonant depolarization using this hardware and Toushcek measurement

Touschek-Polarization Lifetime Studies Draft Proposal

Consider requesting US-Japan Funds for the associated hardware costs required for this Touschek-Polarization lifetime study in SuperKEKB in a single application that would include spin rotator R&D at BNL and source R&D work at Hiroshima University

(At BNL, next steps towards design of prototype of dipole+solenoid+skew-quads overlapping field magnet)