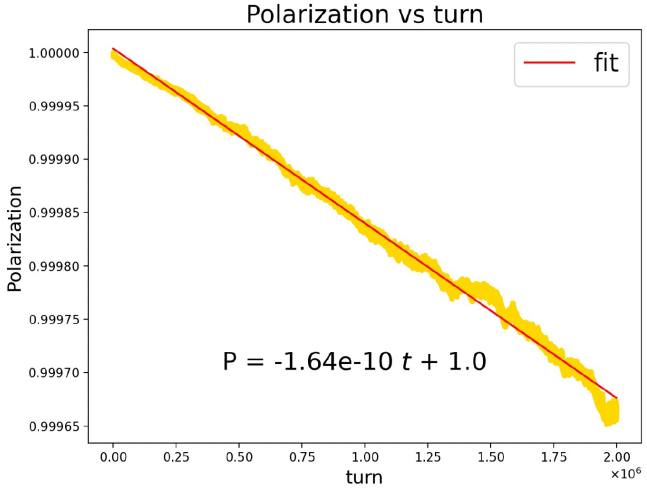
Touschek Polarization Lifetime Experiment Planning

Michael Roney (U Victoria)

2 Feb 2026

Touschek Polarization Experiment

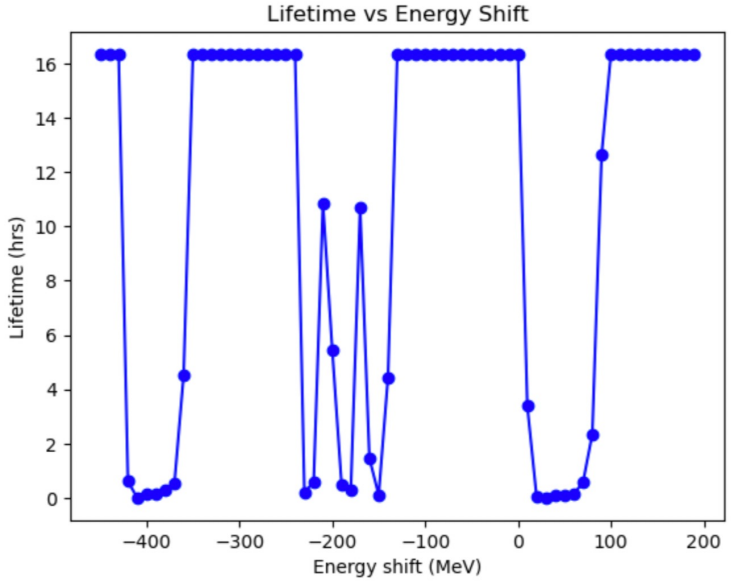
Study of Spin lifetime for the HER



- Tracking 100 particle for 2M turns in the SuperKEKB HER at the design energy: 7.00729GeV
- Lifetime~17hrs

Yuhao Peng (UVictoria)

Study of Spin lifetime for the HER



- Design Energy: 7.00729GeV
- The energy is shifted from the designed energy with 10 MeV as step
- Tracking 100 particle for 20000 turns in the SuperKEKB HER

Yuhao Peng (UVictoria)

Experiment Planning

0.5% lifetime measurement will be sufficient to measure the transverse beam polarization and to detect the γG = 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:

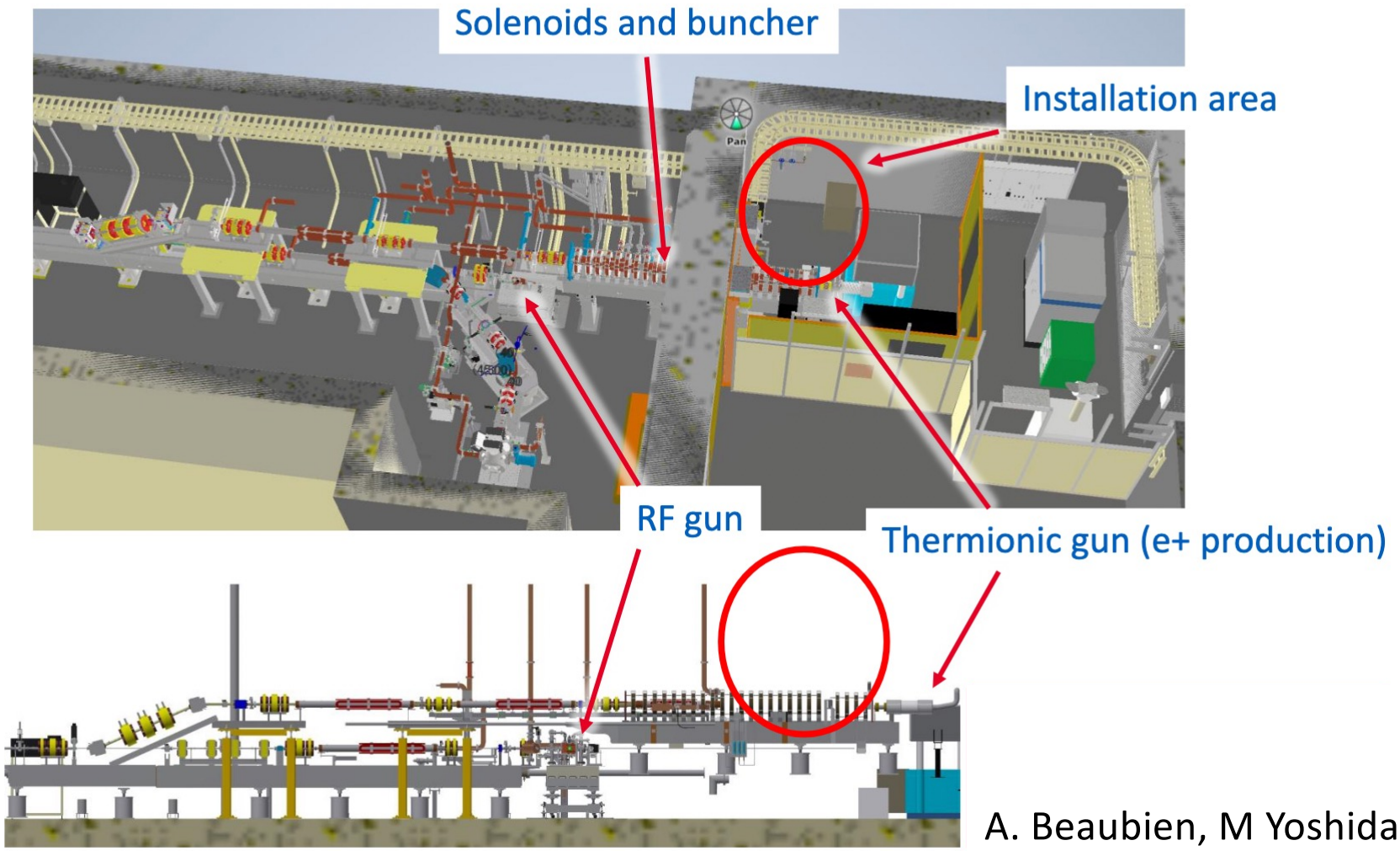
- Verify spin-transport through the injector chain is understood and preserves the polarization magnitude and direction.
- Verify polarization is preserved upon storage of the electron bunches in the HER, determine the polarization lifetime and map out the topology around the γG = 16 spin resonance.
- 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
- Starting to investigate how the polarization probe of beam-beam parameter compares with other methods of measuring it

R&D Work

- Develop the temporary polarized source (M. Yoshida, A. Beaubien, Z. Liptak)
  - Design
  - Construction
  - Installation and testing in lab with Mott polarimeter
- Polarized Source line development
  - Source
  - Wein filter
  - Merger
- Integration into source room
  - Address solenoid fields in bunchers

Source for Touschek Polarization Experiment

Source Room Available Area



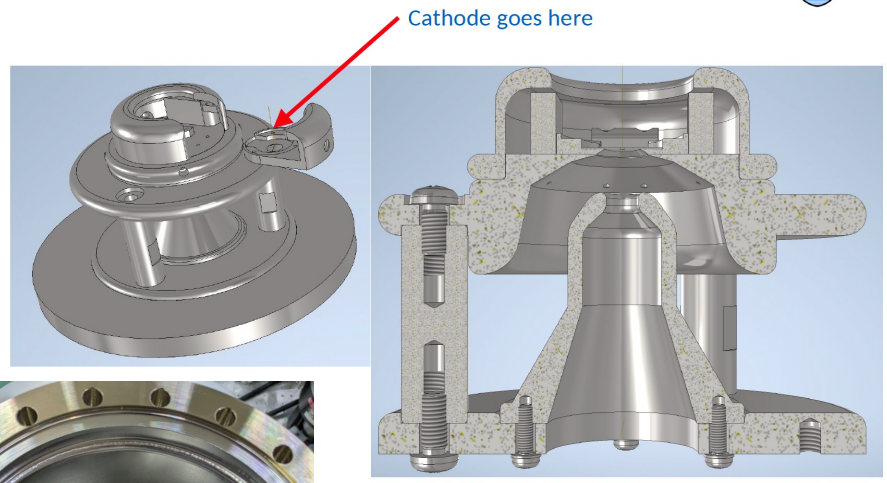
A. Beaubien, M Yoshida

GaAs Polarized Source for Touschek Polarization Experiment

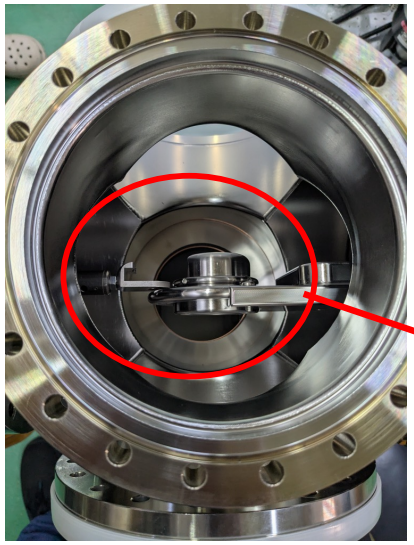
U.of Victoria PhD student Alexandre Beaubien was stationed at KEK for 11 months with EPECR KEK-TRIUMF Scholarship

- Working with Mitsuhiro Yoshida (KEK) to implement source

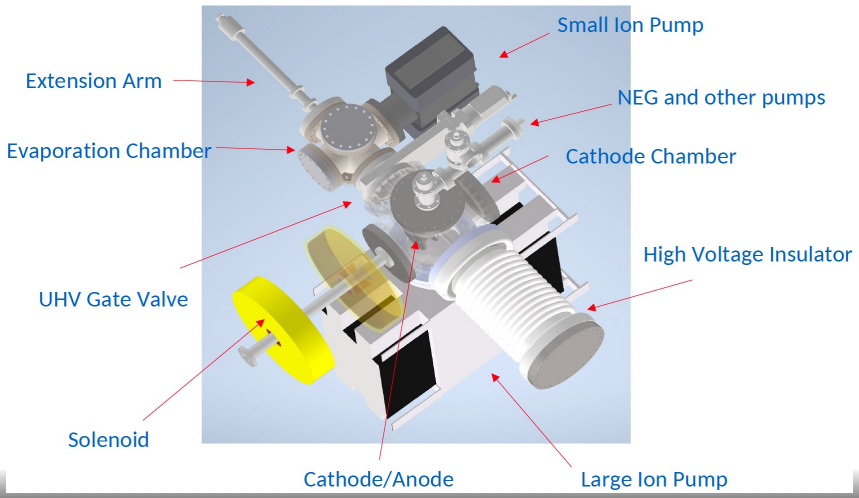
Cathode & Anode



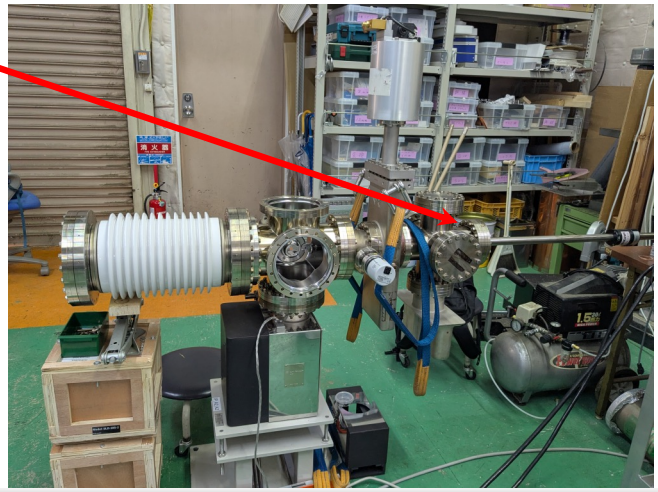
Adapted from a design by N. Yamamoto; Redesigned in part for low emittance at 200keV using Inventor



Polarized Electron Gun



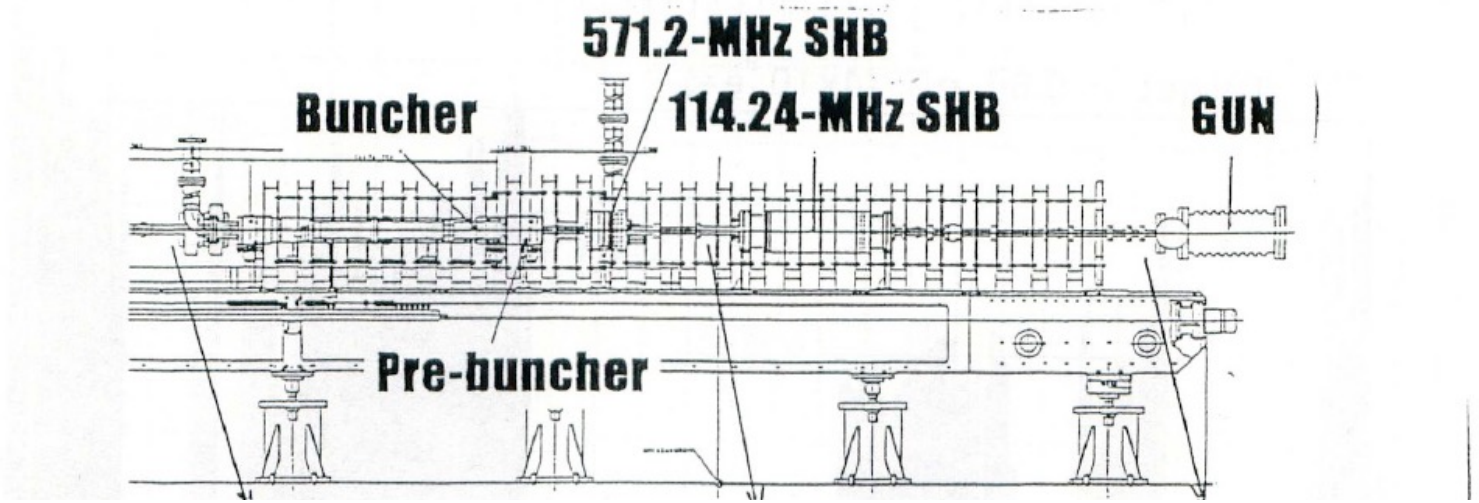
In Lab 4 at KEK

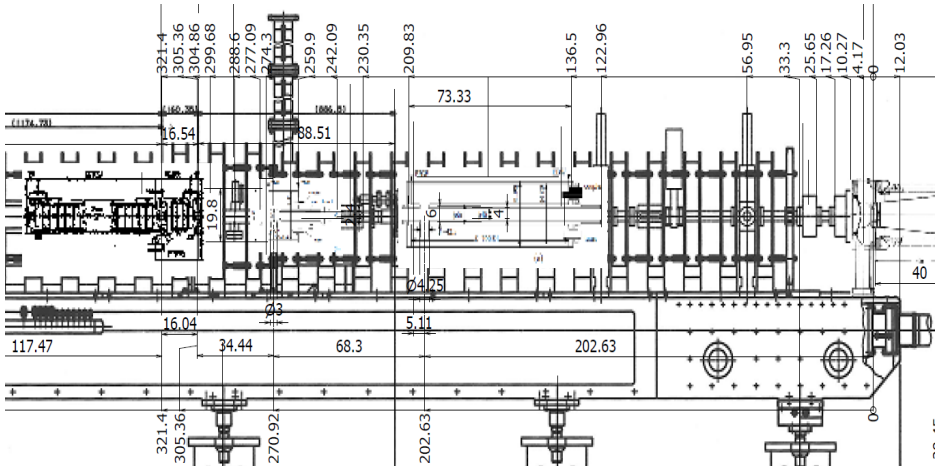


Source anode delivered To KEK in October 2025

Merge Line

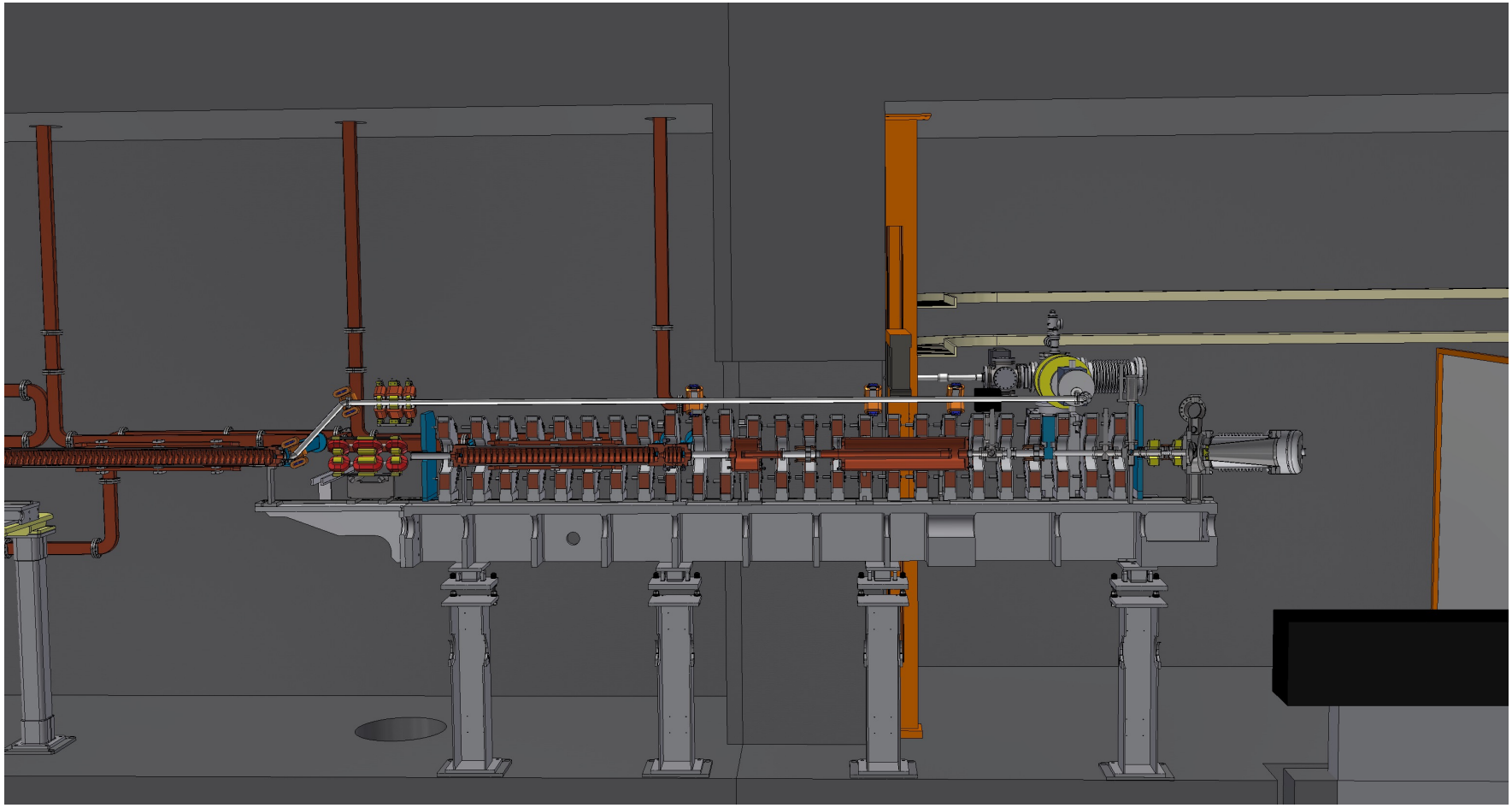
Pre-injector





M. Yoshida

Considering New Merger Line Concept



Developing the Merger Line is on the CRITIAL PATH –
need this in place to complete submitting proposal to EB
(EB provides the first level of approval)

Further Preparations for Touschek Polarization Experiment

Background Group –

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

Andrii Natochii (BNL)

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

Will want to repeat these studies in 2026 running period

- Connect with MDI Beam Background group

High-level Run Plan (Uli Wienands)

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

(Uli Wienands)

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 (Uli Wienands)

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 (Uli Wienands)

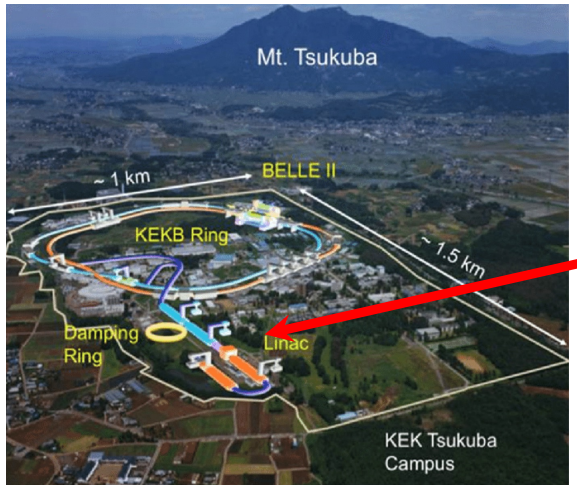
Step	Duration (d)	Task	Expected Outcome
1	1	Turn on Source and switching magnet	Beam in transport line
		• Turn on HV and laser and verify source produces e^- • Turn on switching magnet to correct polarity & STDZ. • Verify beam makes it through the switching magnet. • Steer beam on axis and towards linac 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
4a		• Standard injection tuning.	
	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	
7		• 4 additional steps to id. synchrotron satellites.	
	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?

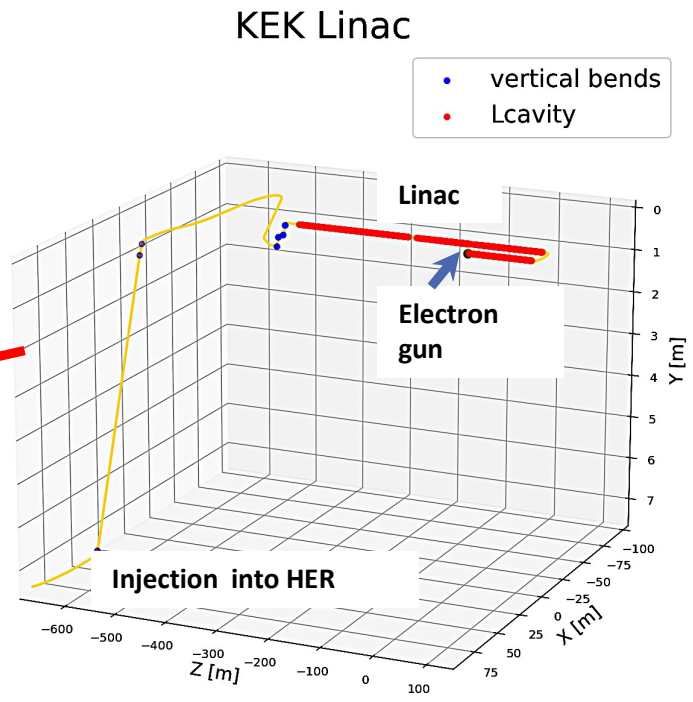
Additional Slides

Touschek Polarization Lifetime Experiment

Proposing to put LTT studies to the test with data in a dedicated experiment with TRANSVERSE polarized beam to validate polarization lifetime

Inject transversely polarized beam at the HER injection point

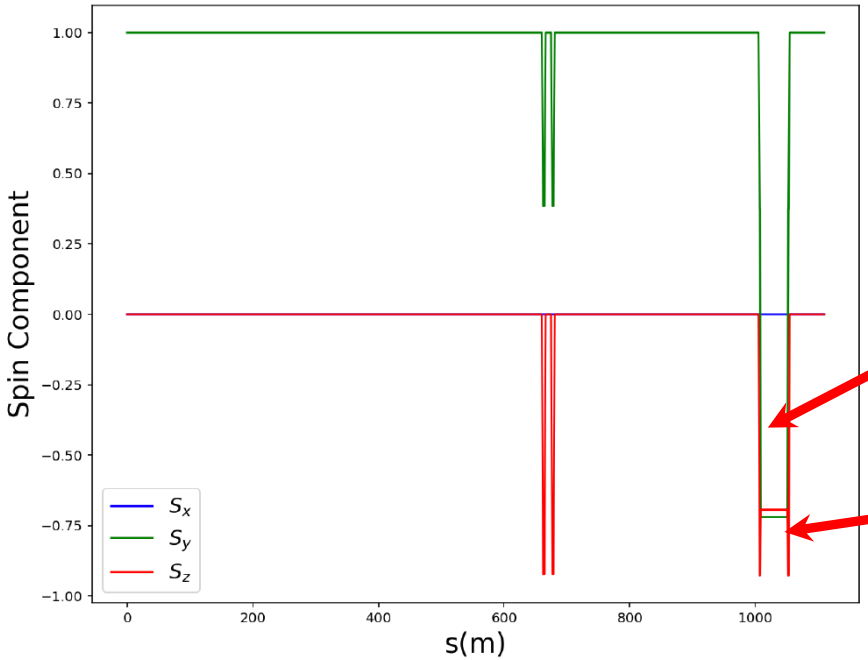




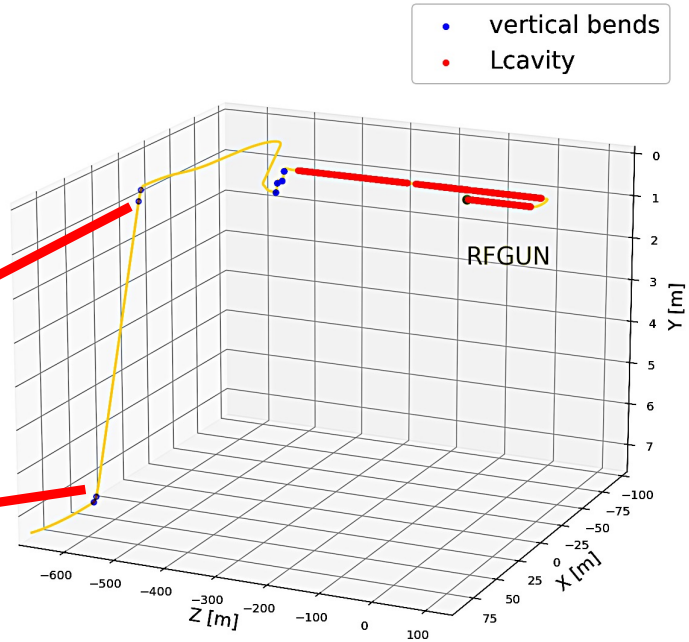
KEK Injection Linac polarization Bmad studies

Spin motion in the KEK Injection Linac

Y. Peng (UVic)



KEK Linac

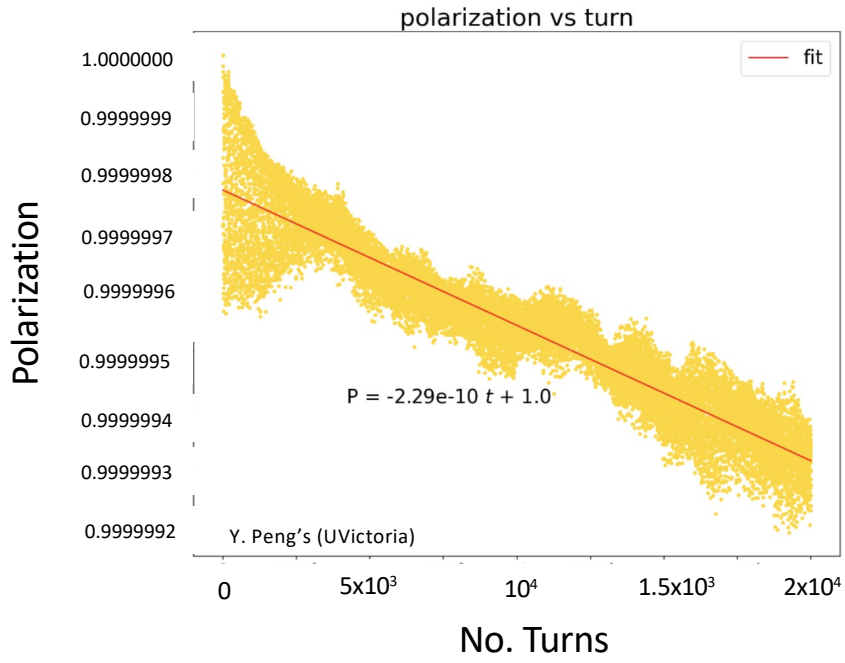


These spin tracking using BMAD show if the electron starts with vertical spin (0,1,0) at the source, after all the vertical beam motion,
it will end up with a vertical spin at the injection point, as desired.

KEK Injection Linac polarization Bmad studies

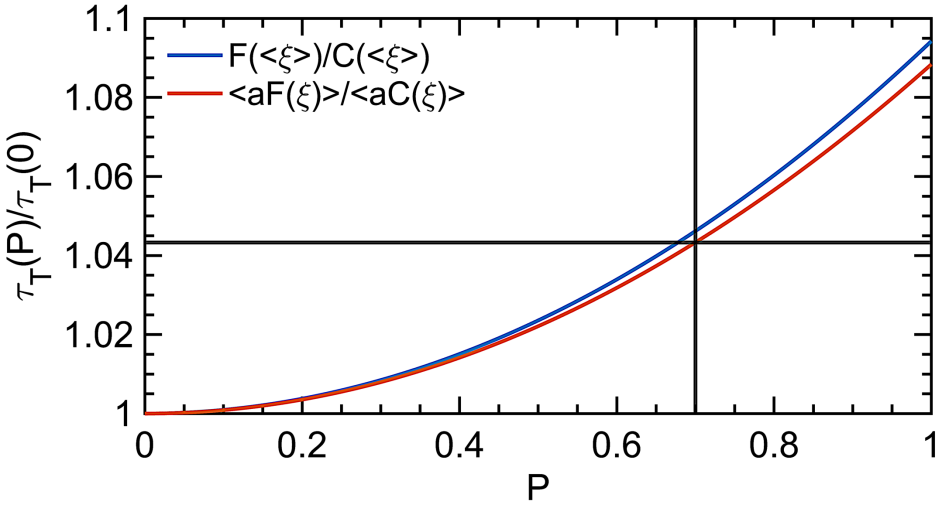
Inject transversely polarized beam at the HER injection point

Transverse polarization survival rate in HER



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

Touschek Lifetime Dependence on e- polarization



For 70% polarization this is a ~4% effect assuming (overall) momentum acceptance of 0.6%

Touschek lifetime measurements already performed in HER with required precision

Touschek Lifetime Studies

from Andrii Natochii (BNL)

Belle II Background Group

Beam current as a function of beam lifetime

$$I = I_0 \times e^{-\frac{t}{\tau}}$$

lifetime

Heuristic fit formula for beam losses

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

ring average effective residual gas pressure seen by the beam

# of bunches in the ring

bunch volume

Heuristic fit formula

Bunch length
[H.Ikeda, KEK, private communication (2021)]

$$\begin{cases} \sigma_{\mathrm{z}}^{\mathrm{LER}}[\mathrm{mm}] = 5.4466 + 1.7642 \times \frac{I^{\mathrm{LER}}[\mathrm{mA}]}{n_{\mathrm{b}}^{\mathrm{LER}}} \\ \sigma_{\mathrm{z}}^{\mathrm{HER}}[\mathrm{mm}] = 6.0211 + 1.3711 \times \frac{I^{\mathrm{HER}}[\mathrm{mA}]}{n_{\mathrm{b}}^{\mathrm{HER}}} \end{cases}$$

More information in https://arxiv.org/pdf/2302.01566

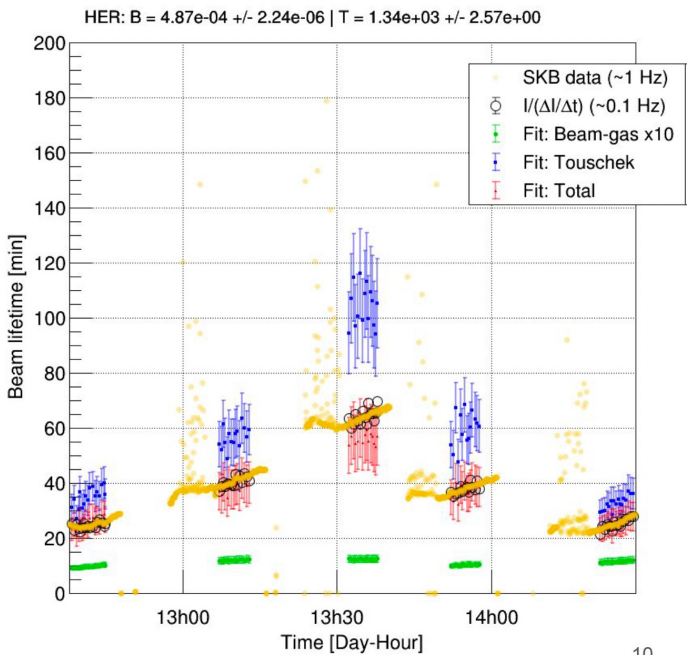
See also: Qingyuan Liu presentation at eeFACT2025 : “SuperKEKB/Belle II background studies update”

Touschek Lifetime Studies

from Andrii Natochii (BNL)

Example of data and results of heuristic fit for HER

Beam lifetime estimation for June 2020



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The Touschek Lifetime in the HER has been measured at the few per-mil level (statistical) – sufficient for seeing changes in lifetime from polarization effects, which are at the 4% level