Monitoring Beam Backgrounds at Belle II with Scintillator Detectors

Helena Pikhartova

Supervisor: Steven Robertson

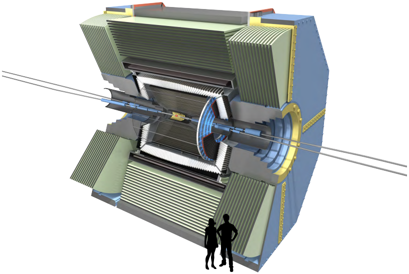
McGill University

May 29, 2017

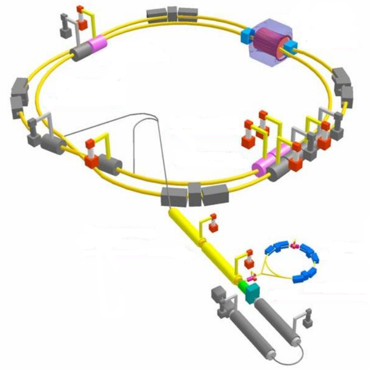
Belle II Experiment Overview

- B-factory experiment, planned start of operation at the end of 2018
- International High Energy Physics experiment in Japan
- Plan to achieve instantaneous luminosity of L= $8\mathrm{x}10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Belle II detector



SuperKEKB



Belle II Upgrade & Beam Background

Design parameters for the SuperKEKB operation compared to the KEKB design and achieved parameters:

Beam Parameters	KEKB achieved		SuperKEKB design	
	LER	HER	LER	HER
Energy [GeV]	3.5	8.0	4.0	7.01
Beam current - I [A]	1.64	1.19	3.6	2.62
Vertical beam-beam parameter - ξ_y	0.129	0.090	0.087	0.081
Beta function at interaction point - β_y^* [mm]	5.9	5.9	0.27	0.30
Vertical beam size at interaction point - σ_y^* [nm]	940	940	48	60
Horizontal beam size at interaction point - σ_x^* [μm]	147	170	10	10
Beam lifetime [min]	200	133	10	10
Luminosity [10^{34} cm^{-2} s^{-1}]	2.108		80	

The luminosity can be expressed as:

$$L = \frac{\gamma_\pm}{2er_e}(1 + \frac{\sigma_y^*}{\sigma_x^*})(\frac{I_\pm \xi_{y\pm}}{\beta_y^*})(\frac{R_L}{R_{\xi_{y\pm}}})$$

e = electron charge

γ = Lorentz factor

r_e = radius of electron

R = reduction factor

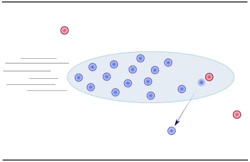
With higher beam currents and smaller beam size, beam background will increase significantly.

Negative effects of beam background:

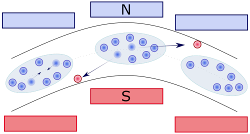
- On detector: radiation damage, increased occupancy
- On physics analyses: reduced signal to background ratio

Beam Background at Belle II

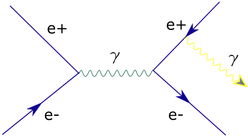
Interaction that produces occupancy in the detector that originates from a source other than a e^+e^- physics collision at the interaction point



Beam-Gas interaction



Touschek effect



Radiative Bhabha

Sources of background:

- Injection into storage rings
- Bending/focusing the beam
- Intra-bunch effects

Types of background:

- Beam-Gas induced background (Beam-gas radiation, Touschek effect)
- Luminosity induced background (Radiative Bhabha)
- Injection background

Belle II commissioning and background monitoring

Three phase of commissioning:

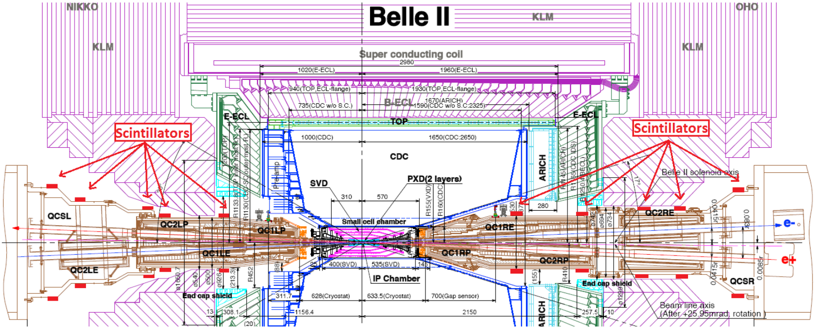
- Phase 1 - Commissioning of SuperKEKB, first turns (spring 2016)
- Phase 2 - Belle II detector without vertex detectors, first collisions (spring 2018)
- Phase 3 - Full Belle II detector operation (end of 2018)

The purpose of the commissioning is:

- Identify all major sources of background
- Predict radiation dose for Belle II detector components
- Collect data to improve the accuracy of background simulations

Scintillation Array Beam Background Monitor

Array of detectors for monitoring beam background.



Location:

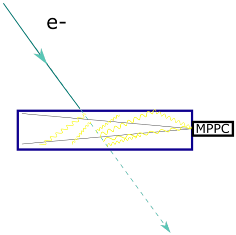
- Beam background monitors around QCS (final focusing quadrupole magnets and cryostat)
- Between 1 and 4 m from interaction point

Goals:

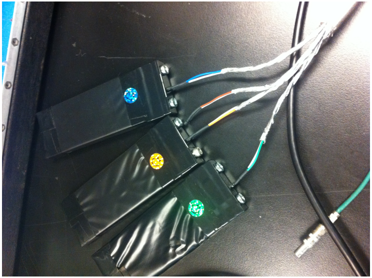
- Real time injection background
- Measurement of background hit rates
- Luminosity monitoring

Scintillator Detectors

- The passage of charged particles generates light by fluorescence in the plastic scintillators
- Scintillation light collected by multi-pixel photon counters (MPPC)
  - Photon-counting device using multiple APD (avalanche photodiode) pixels operating in Geiger mode
- Installation of 40 detectors around the QCS

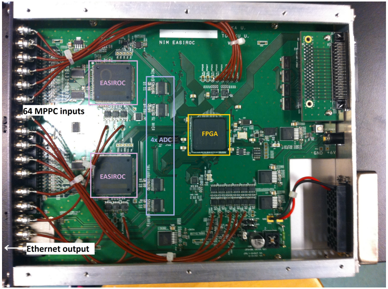


Production of scintillation light.

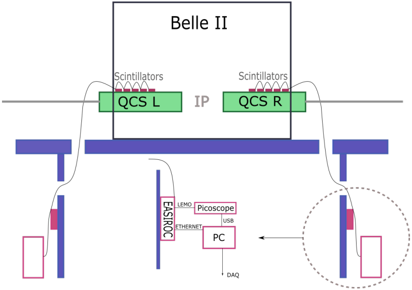


Scintillator detectors.

Readout of Scintillator Detectors



EASIROC NIM board.
Callier, S., Taille, C. D., Martin-Chassard, G., & Raux, L. (2012). EASIROC, an Easy & Versatile ReadOut Device for SiPM. Physics Procedia, 37, 1569 — 1576. doi:10.1016/j.phpro.2012.02.486.



Planned readout path.

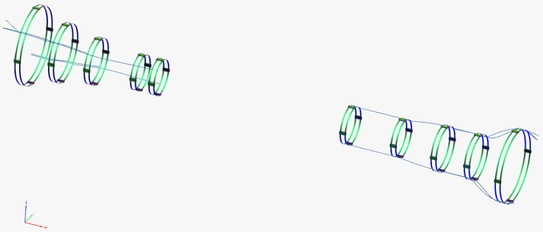
- The EASIROC board reads out the scintillation monitors and provides the supply bias voltage
- Up to 64 MPPCs handled by one board

- 2 EASIROC modules (BWD/FWD) regions
- Cable length more than 30 m between scintillator sensor and DAQ room

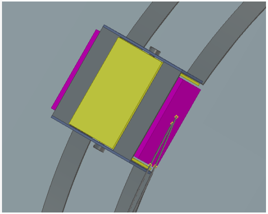
Real-time monitoring in the control room, recorded by DAQ for offline analysis

Cabling and Attachment

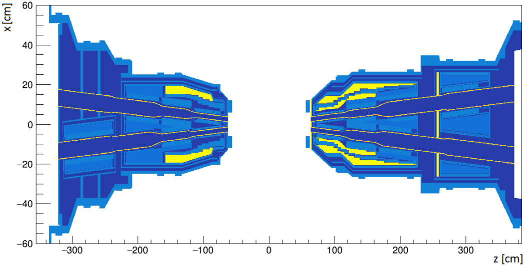
- Final positions of scintillators with design of attachment



CAD drawing of the scintillator attachment system.



Detail of scintillator.



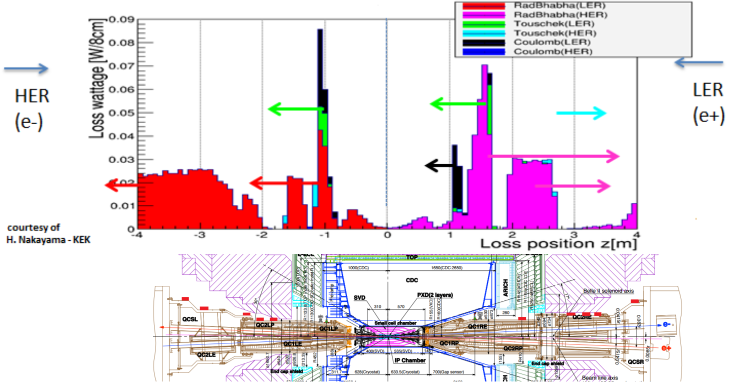
Material profile image of QCSs with scintillator positions.

← XZ cross section of QCS with heavy metal shielding visible (yellow)

Simulation

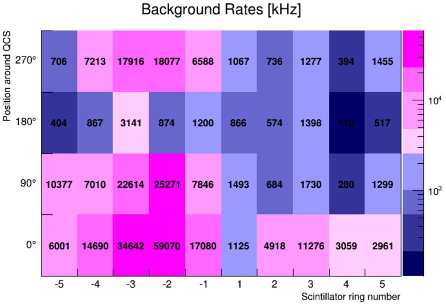
- Belle II simulates beam background using Monte Carlo methods and the Geant4 toolkit
- Possible to determine positions and energies of particles coming out of beam background events

Background loss distribution near interaction point:

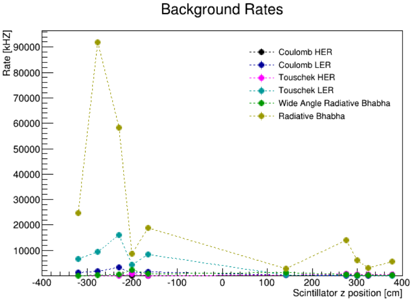


Simulation of Scintillator Rates

- Goal of simulation is to predict sensitivity to individual types of background
- Preliminary results of the simulated background rates for each scintillator sensor:



Background rate for each scintillator detector.



Rate as a function of position along the beam pipe.

- Data taking will provide scalar rates from each of the detectors

Schedule and Future Plans

- Spring 2017:
  - Completion of attachment design
  - Test installation of the monitors →

- Before start of Phase 2:
  - Feedback setup for Belle II/SuperKEKB control rooms
  - Installation

Conclusion

- Scintillator detectors
  - Beam background monitors
  - Near the interaction point of the Belle II detector
- Will provide feedback to the detector and accelerator control rooms
  - Live monitoring
  - Allow adjustments of collimator settings while running

Thank you!