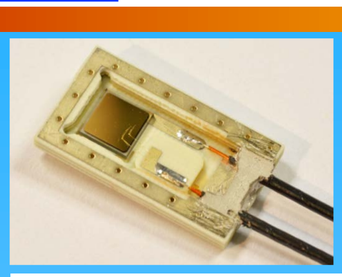
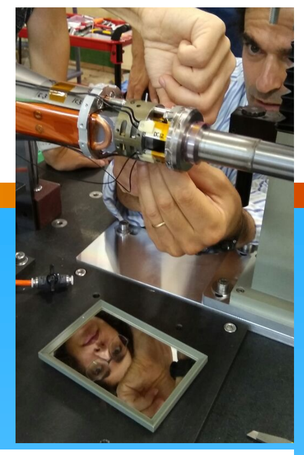
UNIVERSITÀ DEGLI STUDI DI TRIESTE
Dipartimento di Fisica
Department of Physics

Istituto Nazionale
di Fisica Nucleare
Sezione di Trieste

First experience with the Belle II radiation monitoring based on diamonds





Lorenzo Vitale on behalf of Belle-II SVD collaboration

INFN and Univ. Trieste, ITALY

Abstract

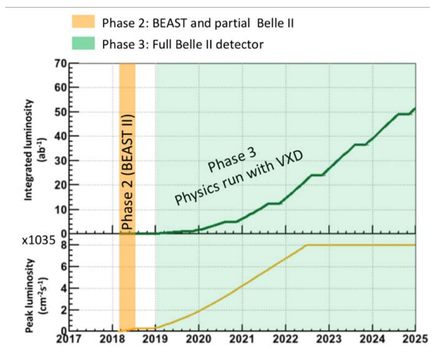
The Belle II detector at the SuperKEKB e+e- collider is undergoing first commissioning with beams until mid 2018. The outer detector is complete and only an azimuthal portion of the silicon vertex detector is installed.
A radiation monitoring and beam abort system is essential for safe operation of the Belle II detector, given the unprecedented luminosity planned for SuperKEKB.
Belle II will employ 20 single-crystal, CVD diamond sensors, appropriately installed in close to the beam and to the tracking volume.
The diamond current will be continuously sampled at 10 Hz to record the average radiation dose accumulated through the life of the experiment, and recursively sampled at 100 kHz to monitor the instantaneous radiation rate and to deliver a fast abort signal if sudden radiation spikes occur.
We report the status, and first measurements with beams, of a preliminary configuration of the system based on the eight innermost diamond sensors, installed directly on the beam pipe and read by the final readout system.

Radiation environment

SuperKEKB asymmetric e^+e^- collider

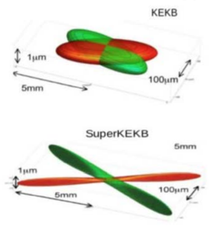
Design luminosity $8\times10^{35}\ cm^{-2}s^{-1}$ → 40 × KEKB!

with ≳ beam currents, ≪ beams size at interaction



Phase 2 = Commissioning
Phase 3 = Physics

HER = High Energy Ring
LER = Low Energy Ring



⇒ severe beam-induced bkg & radiation doses

Mainly **e^+, e^-, γ,** from:

e^+e^- pair production in γγ scattering,

Radiative Bhabha, Touschek,

Off-momentum particles from beam-gas,

Synchrotron radiation.

Radiation monitoring

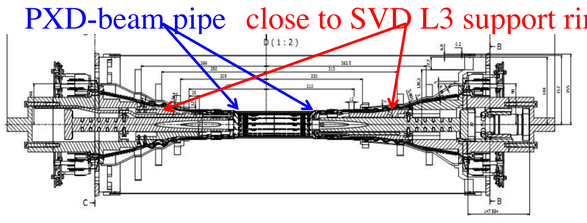
Belle II vertex detector (VXD):

- **PXD**: pixel detector, 2 layers of DEPFET pixels
- **SVD:** silicon-strip vertex detector, 4 layers of double-sided silicon strips

Monitoring: 20 diamonds

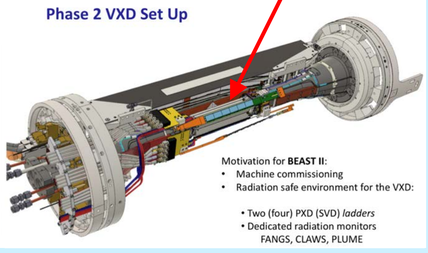
4 + 4 sensors 6 + 6 sensors

PXD-beam pipe close to SVD L3 support rings



During Phase 2: horizontal sector of VXD

- 8 diamonds around beam pipe (as for physics)
- Other dedicated detectors for background studies



Diamond sensors

Radiation-hard single-crystal Chemical Vapour Deposition diamond sensors 4.5x4.5x0.5 mm^3 mounted in a compact and shielded package 18x12x3.1 mm^3

8 now in use for Phase 2

20 for Phase 3:

12 already installed, 8 in June 2018

Characterization and calibration

0 – "dark" I-V <1 pA up to 500V & I-V with light exposure

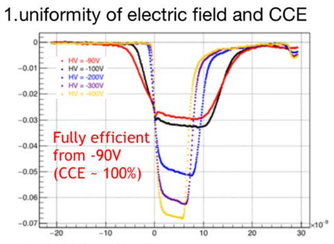
1 – TCT transient current technique with α source for charge collection efficiency (CCE)

2 – β source vs distance + FLUKA simulation

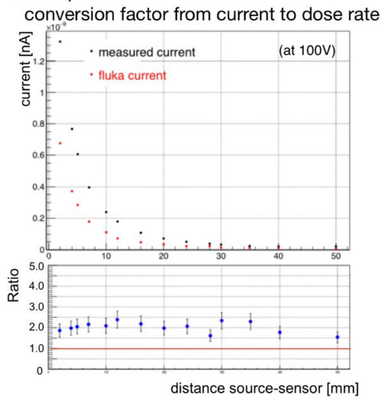
3 – Long time > 1×10^5s stability with β souce

4 – Radiochromic films comparison

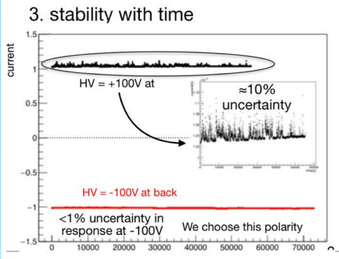
1.uniformity of electric field and CCE



2. comparison with fluka simulation –> conversion factor from current to dose rate



3. stability with time



4. Comparative test with radiochromic films in collaboration with F. Di Capua

Main goals:

→ **1 Fast beam-abort** signal to SuperKEKB in conditions potentially damaging for VXD sensors, Front End electronics and other components.

→ **2 Real time monitoring of dose rate**

→ **3 Integrated dose**

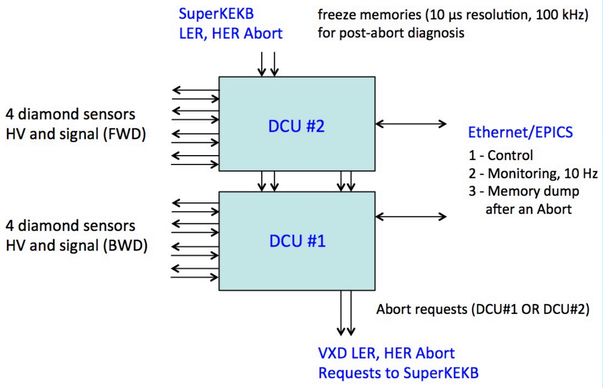
Electronics

In collaboration with Elettra-Sincrotrone S.C.p.A. Trieste.

Trans-impedance amplifiers. 16 bit ADC oversampling at 50 MHz. FPGA sums 500 samples and performs operations at 100 kHz.
Data displayed at 10 Hz.
High Voltage individually supplied to sensors.
Three selectable current digitization ranges.

	range	10 Hz	100 kHz
1	±10 nA	0.003 mRad/s - 100 mRad/s	0.3 mRad/s - 100 mRad/s
2	±1 μA	0.3 mRad/s - 10 Rad/s	30 mRad/s - 10 Rad/s
3	±1 mA	0.3 Rad/s - 10 kRad/s	30 Rad/s - 10 kRad/s

2 Diamond Control Units (DCU)



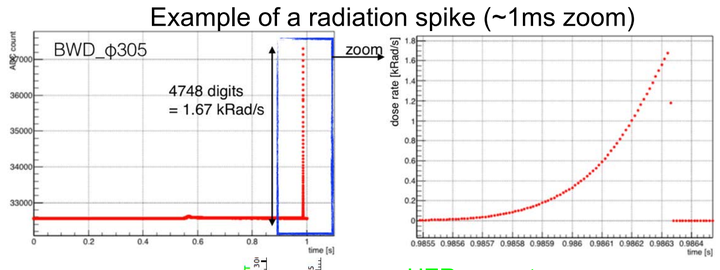
Preliminary Phase 2 results

Radiation system always operational.

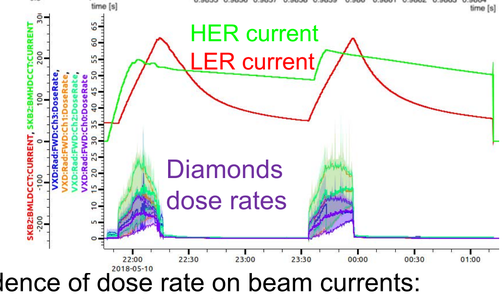
All ranges used to accommodate goals 1 2 3.

- One DCU for fast abort threshold: 1rad in 1ms
- The other DCU usually set to the highest sensitivity range for background studies in different beam conditions

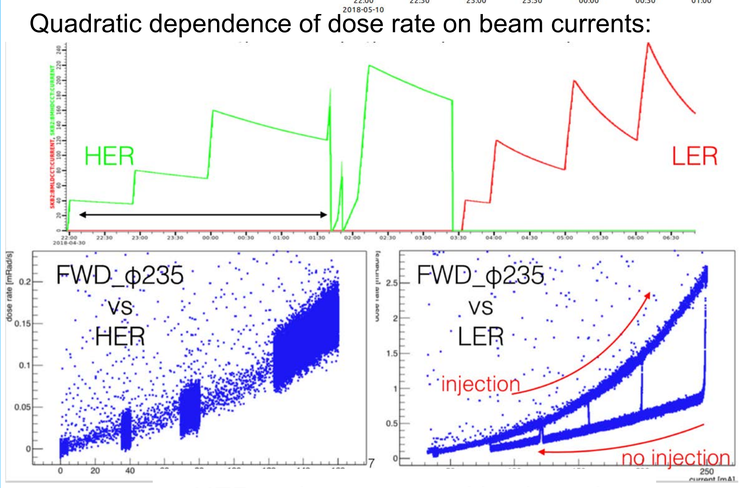
Example of a radiation spike (~1ms zoom)



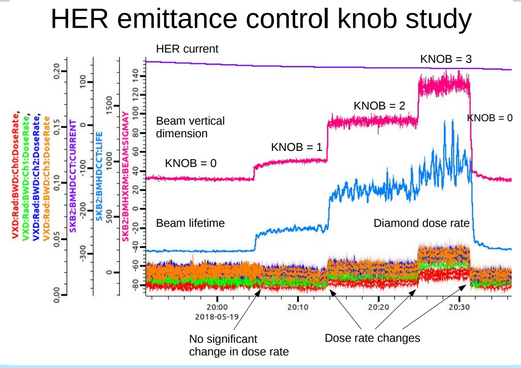
Example of injection background



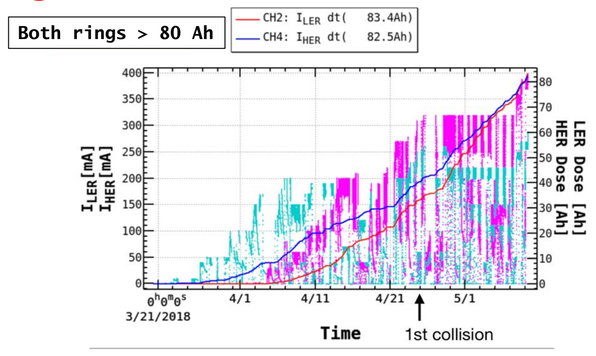
Quadratic dependence of dose rate on beam currents:

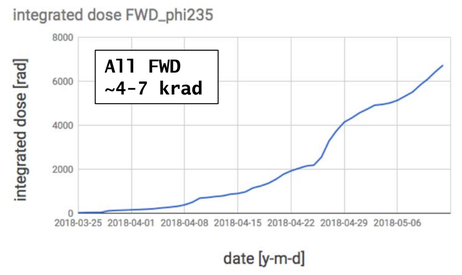


HER emittance control knob study



Integrated beam currents and doses





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