Design and Simulation of Beam-Background Monitors in the Vicinity of the Electromagnetic Calorimeter for the Belle II Experiment

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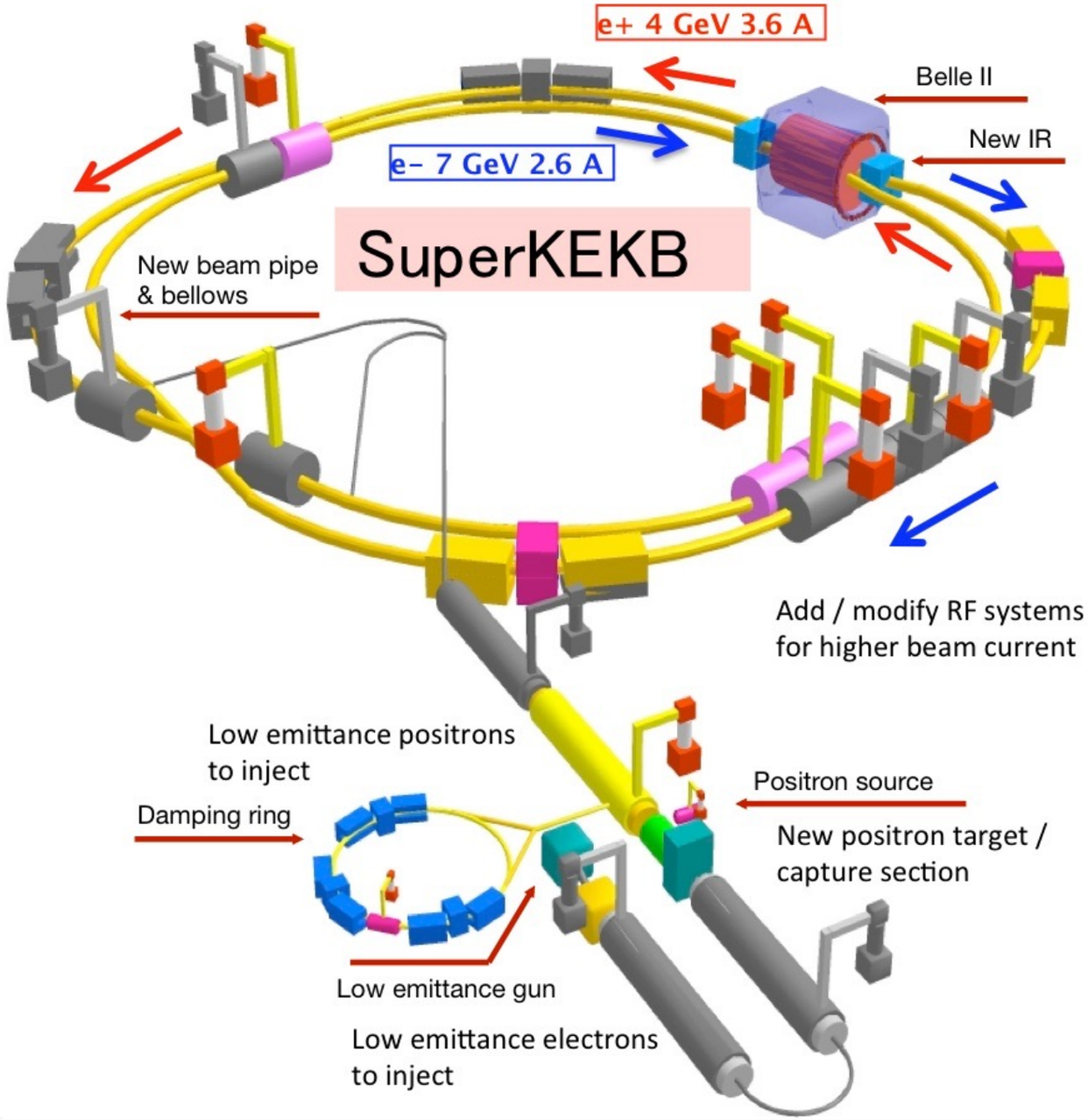
Belle II experiment and SuperKEKB

- Electron - positron collider located at KEK Laboratory in Tsukuba, Japan
- High Energy electron ring (HER) - **7 GeV**
- Low Energy positron ring (LER) - **4 GeV**
- Collisions at the center of mass energy 10.58 GeV ⇒ **Y(4S)** resonance



- Successor to the KEKB collider
- “Nano-beam” and continuous injection scheme
- Design integrated luminosity $50\ ab^{-1}$
- Design instantaneous luminosity $8 \cdot 10^{35}\ cm^{-2}s^{-1}$

2 times larger

$$L = \frac{\gamma_\pm}{2er_e}\left(\frac{I_\pm \xi_{y\pm}}{\beta^*_{y\pm}}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

20 times smaller

40-fold increase in instantaneous luminosity compared to KEKB

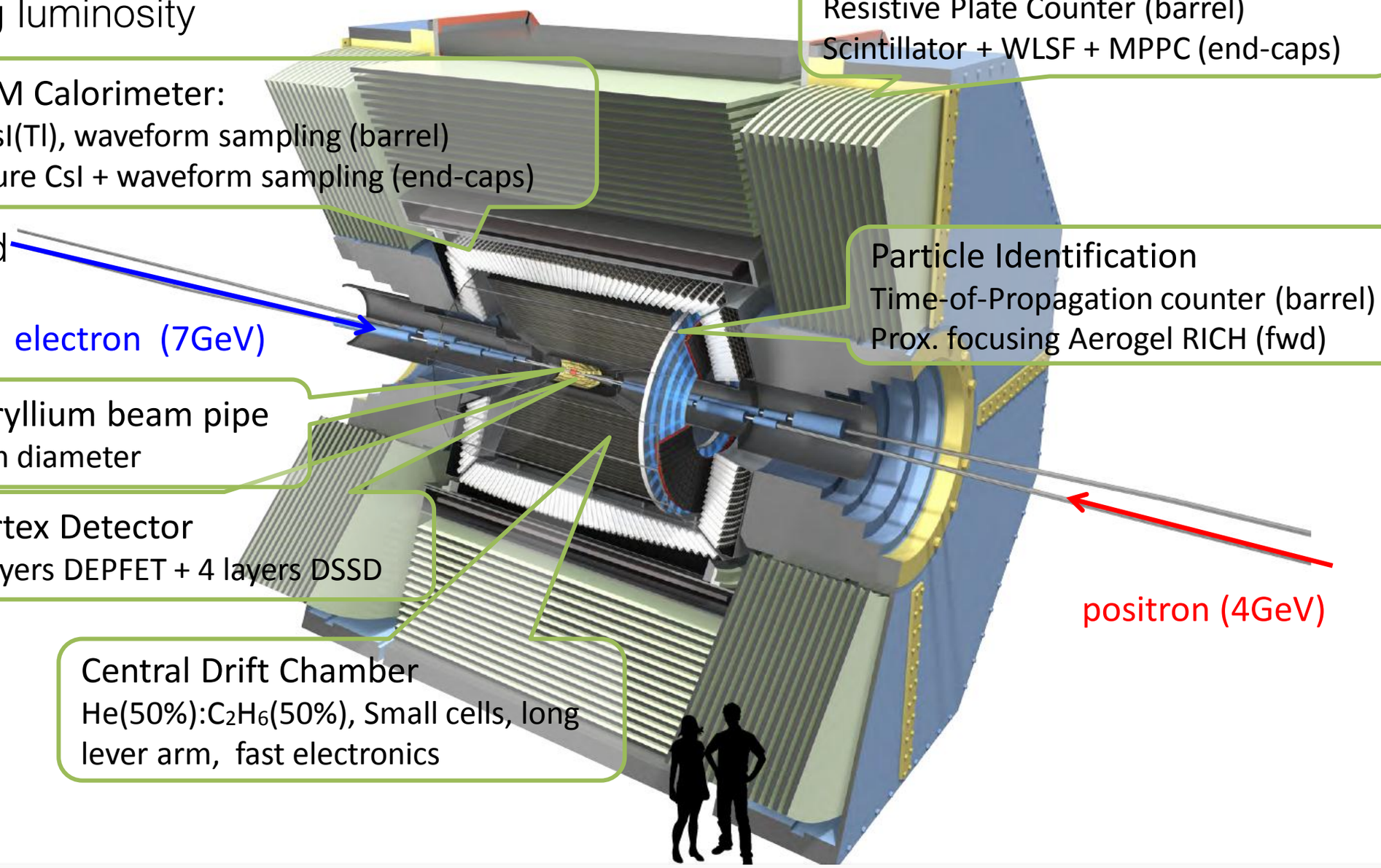
Belle II experiment and SuperKEKB

- Belle experiment ran from 1999 to 2010
- Important discoveries including first observation of CP violation in the neutral B meson system

Belle II Detector

- All sub-detector components upgraded to match the new record-breaking luminosity

- Physics goals:
  - New Physics beyond Standard Model
- Sensitivity to:
  - SUSY
  - charged Higgs
  - dark photon

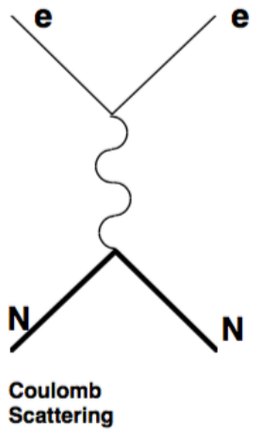


Beam backgrounds at SuperKEKB

- Deterioration of detector resolution, damage to detector components
- Expected ~40-fold increase in beam backgrounds compared to KEKB
- Scattered e^-/e^+ hit the beam-pipe and create electromagnetic showers and neutrons
- Simulations used to get an estimate of background rates in each sub-detector

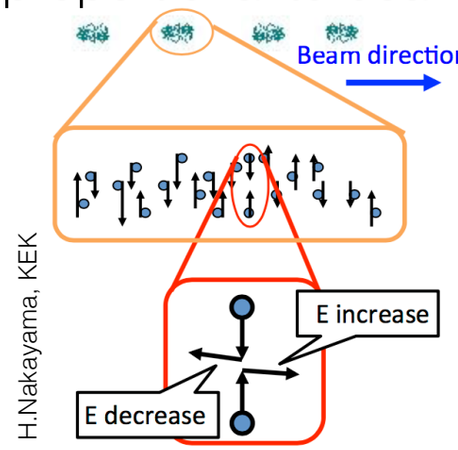
Beam-gas interactions

- Coulomb scattering of beam particles off of residual gas
- Bremsstrahlung
- Proportional to beam current



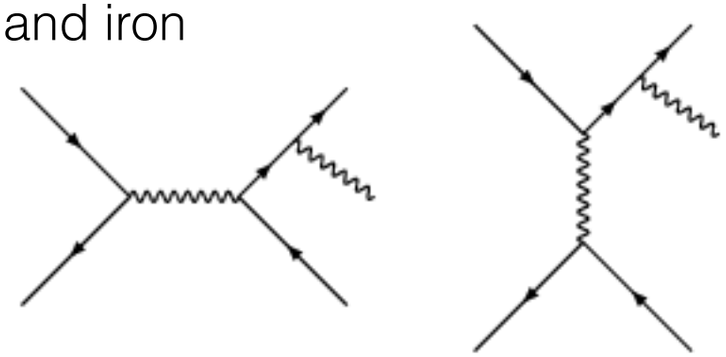
Touschek scattering

- Intra-beam scattering
- Scattering rate inversely proportional to beam size, proportional to beam current



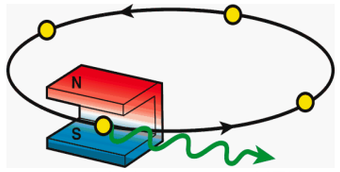
Luminosity backgrounds

- e^-e^+ Bhabha scattering
- Followed by photon emission
- Rate proportional to luminosity
- Neutrons copiously produced in a photo-nuclear reaction of photons and iron



Synchrotron radiation

- Collimators and shielding prevent scattered particles from reaching the detector



H.Nakayama, KEK

Injection background

- New particles injected every 100 ns
- Newly injected particles interact with existing beam particles
- Hard to simulate

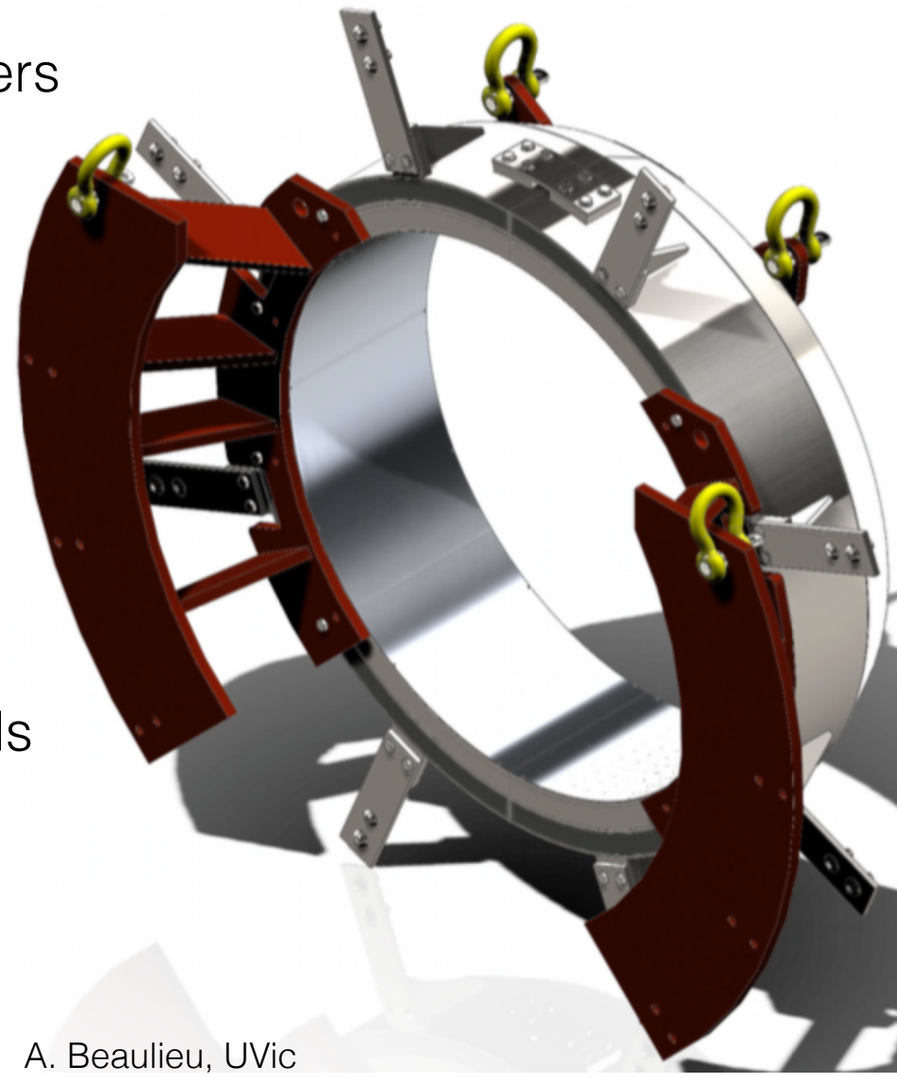
Beam-background monitors near ECL

- Background monitors needed to ensure safe operation of electromagnetic calorimeter (ECL)
- Live feedback to SuperKEKB control room about the background conditions in the detector
- Belle used a scintillation detector attached to ECL backward shield

- New ECL endcap shield design at Belle II
- High density polyethylene (HDPE) + stainless steel layers

neutrons

γ/e± showers



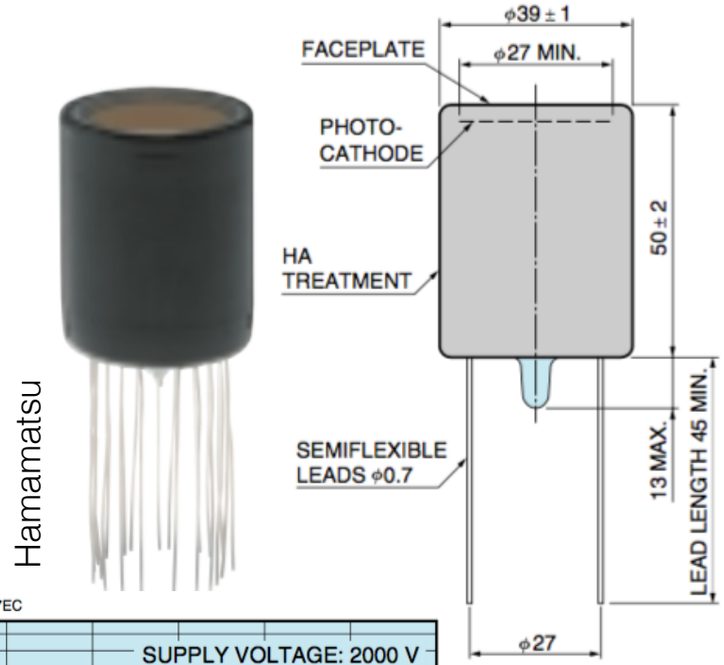
- **Proposal**: make recesses in HDPE layer which would enclose the scintillation-detector based beam-background monitors
- **Needs**:
  - Fast timing for observing the injection backgrounds
  - Wide energy range
  - High radiation hardness

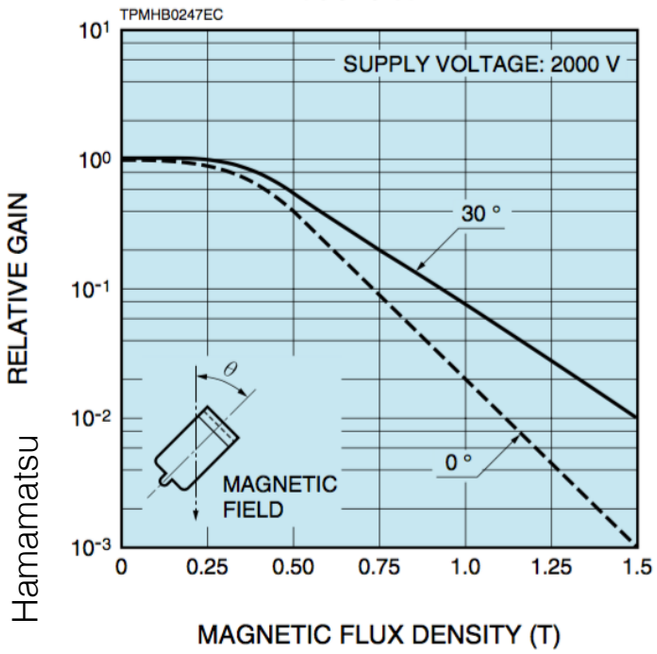
A. Beaulieu, UVic

Beam-background monitors: design

Hamamatsu R7761-70 Photomultiplier

- suitable for operation in high magnetic field
- peak wavelength 420 nm
- gain 10^4 at 1.5 T
- compact design, 39 mm diameter

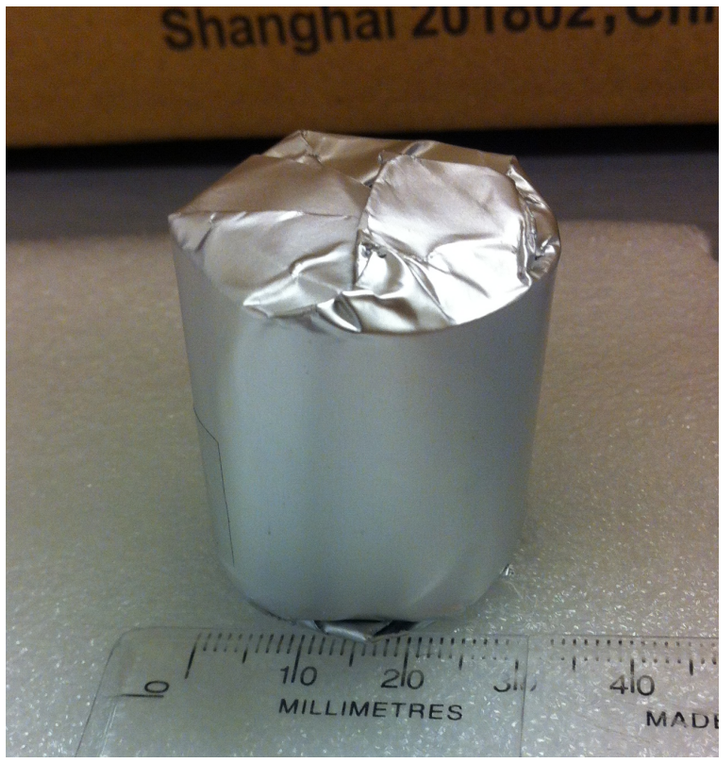




LYSO crystal

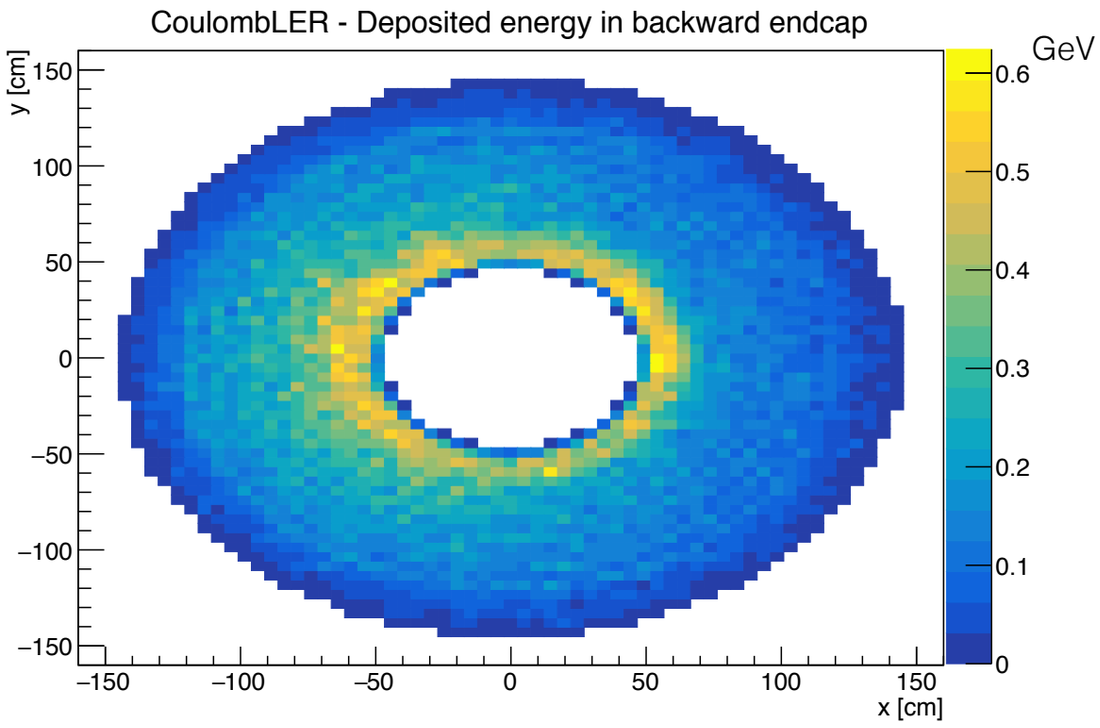
- wavelength of emission maximum at 420 nm
- short decay time of 40 ns
  →well matches the beam top-up time of 100 ns
- high light yield of 32000 photons/MeV
- radiation length of 1.14 cm
- good radiation hardness
- radioactive isotope ^{176}Lu

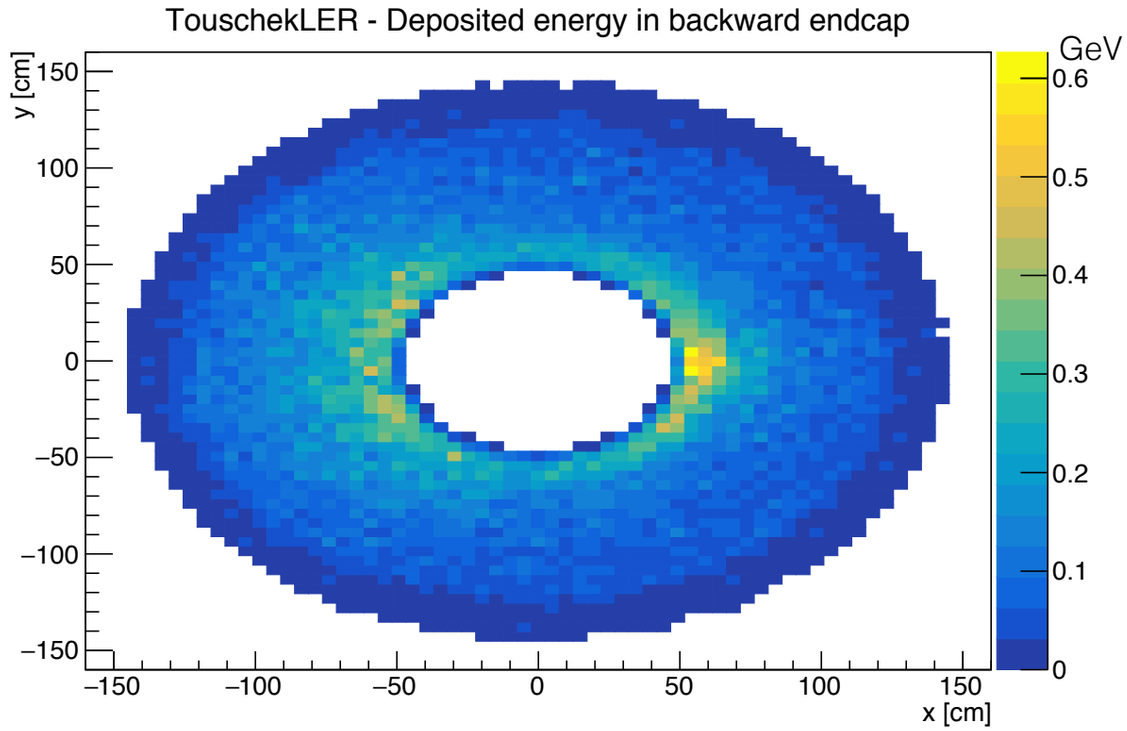
→ 30×30 mm cylindrical crystals

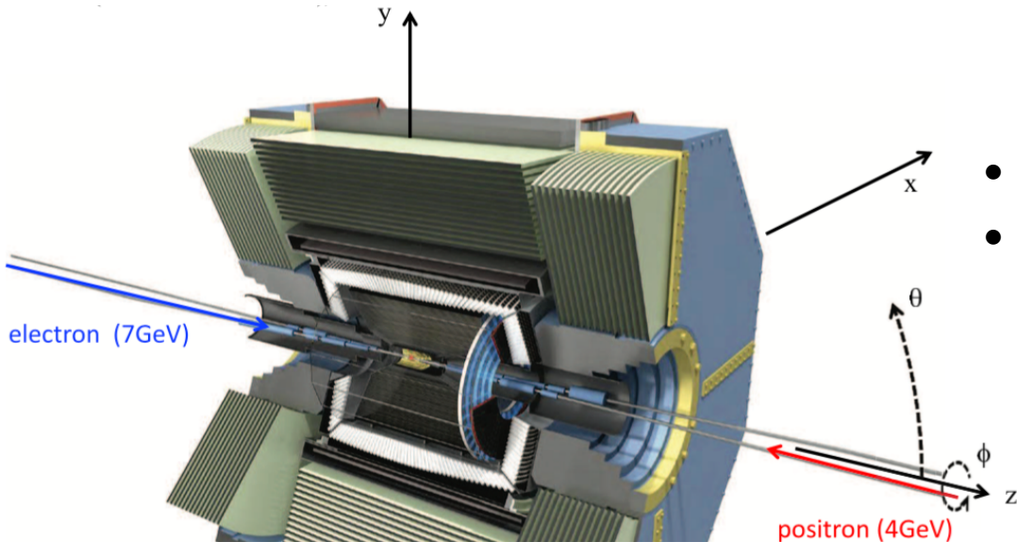


ECL background simulation

- Looking at the ECL background simulation to determine the hit distribution and average energy deposition and hit frequency
- Interval of energy per hit on the order of 1 keV - 100 MeV

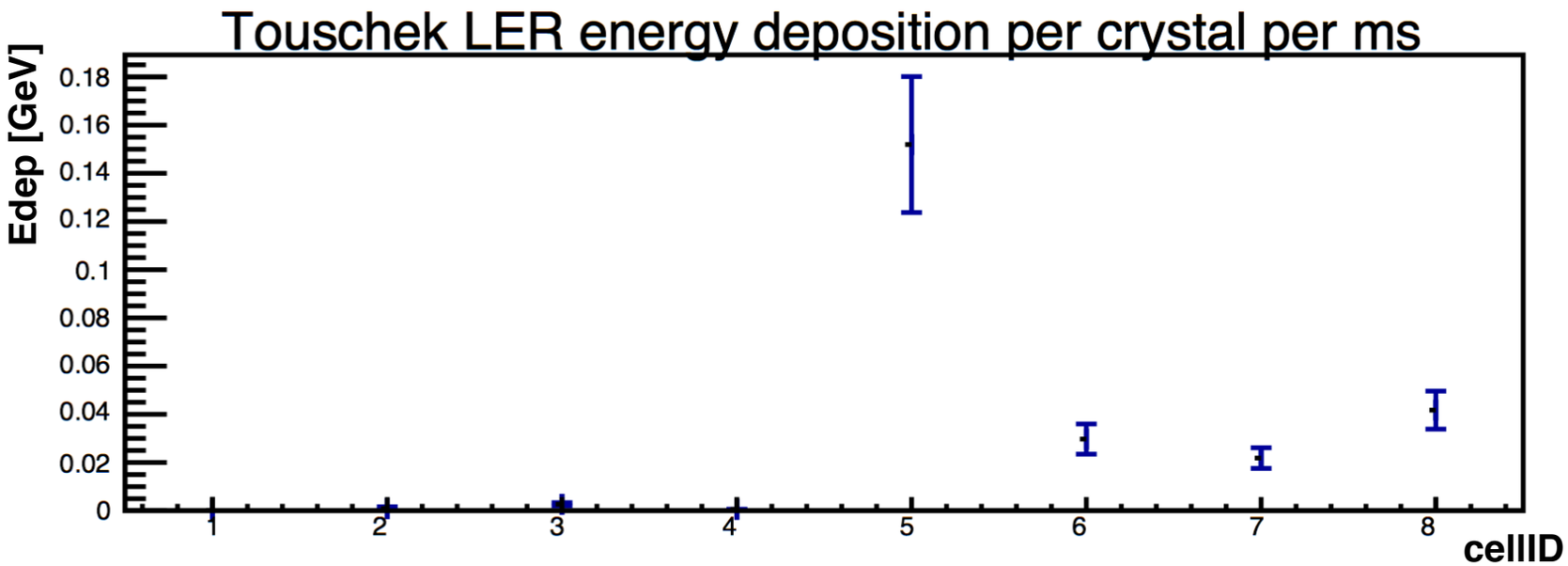


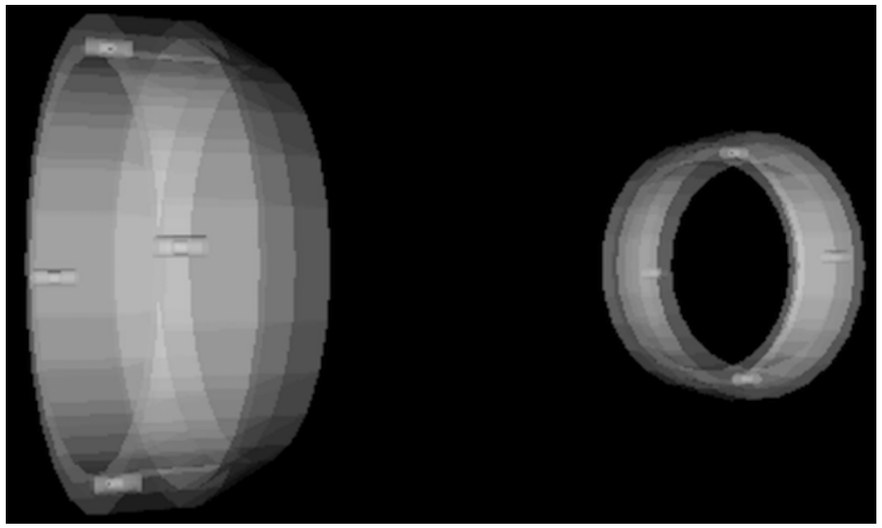




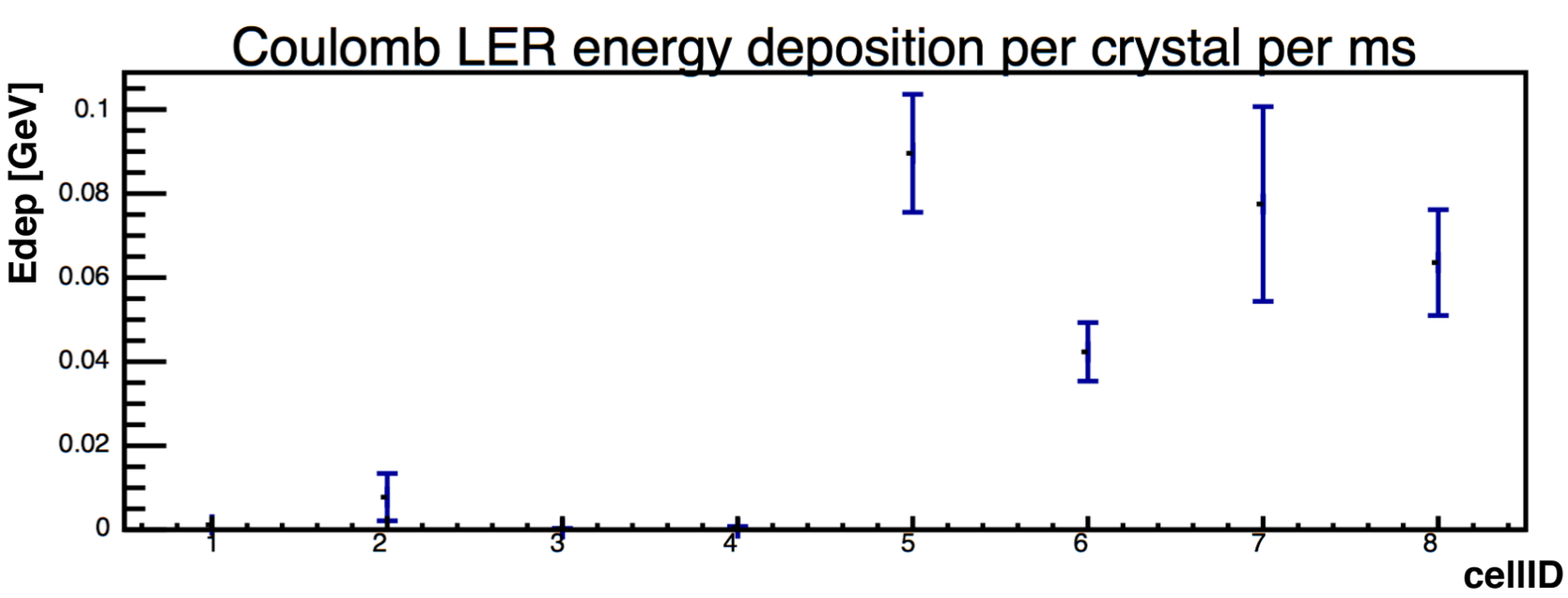
- 8 detectors in total
- ϕ = {0, 90, 180, 270} degree in forward and backward shield

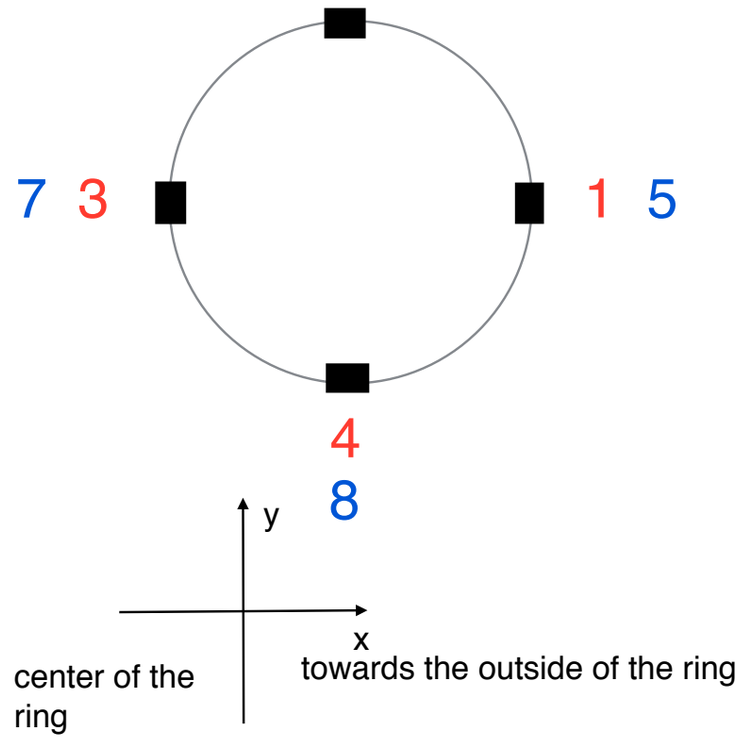
Beam-background monitors: simulation





Background monitors included in the Belle II simulation





Beam-background monitors: next steps

- Read-out system being designed by Université de Montréal
- Lab tests starting in couple of weeks
- Installation in summer 2017
- Phase 2 data taking starting in February 2018
- Monitors stay active during phase 3 data taking, starting December 2018