The Belle II Simulation Library

The Belle II Simulation Group

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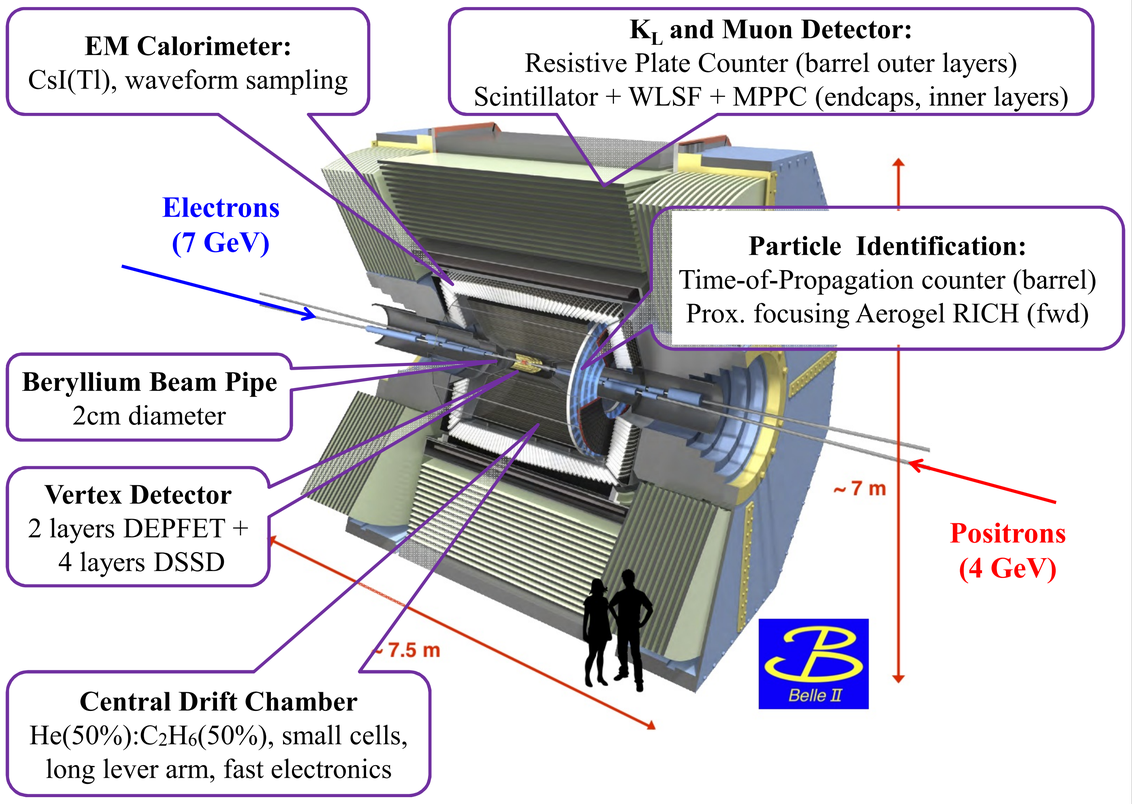
The Belle II Detector



Simulation of New Physics: Magnetic Monopole

The simulation of ionizations (dE/dx) inside the Belle II detector

- Magnetic monopoles do not have electric charge. Therefore, the $1/\beta^2$ term should be dropped from the Bethe ionization equation. This decreases the amount of ionization by magnetic monopoles.
- The original Geant4 monopole code has been enhanced with QED and Bloch corrections for the Belle II simulation.

Y. Kazama et al., Phys. Rev. D15 (1977) 2287-2299
S.P. Ahlen, Phys. Rev. D17 (1978) 229-233

Improvement in Calorimeter Simulation

Calorimeter simulations include recently developed techniques that allow for the dE/dx dependent CsI(Tl) scintillation response as modelled in [1].

- MC vs data agreement is improved in hadronic showers.
- This allows for pulse shape discrimination simulations.

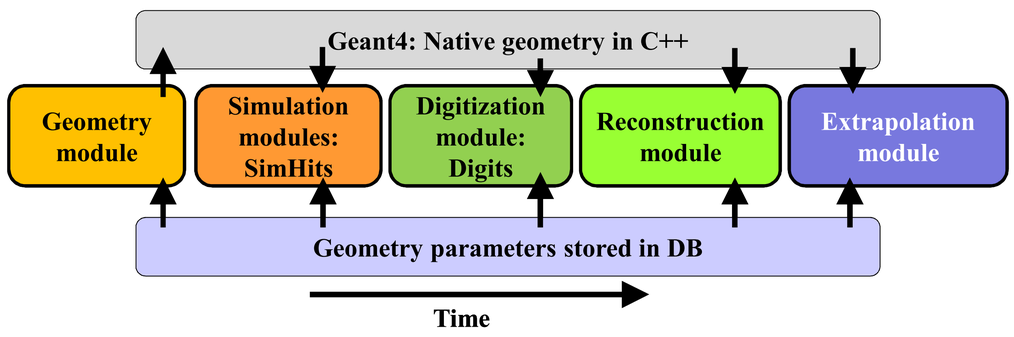
[1] S. Longo and J. M. Roney JINST 13 (2018) P03018

The Basic Structure of basf2 (The Belle II Software System)

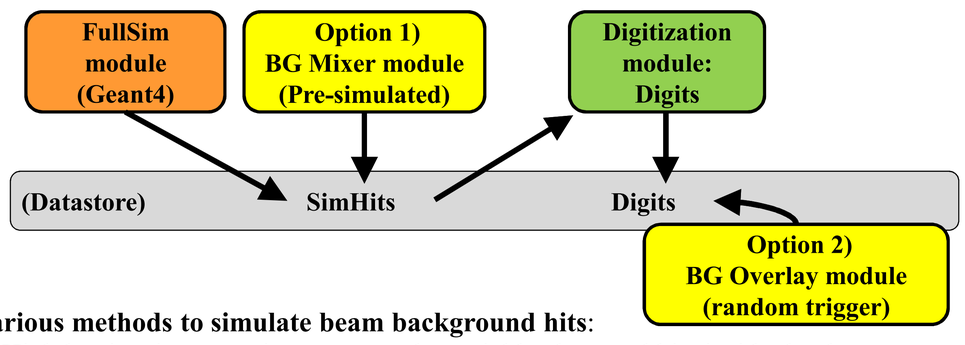
The Belle II software is written in C++ mostly. The scripts are handled by Python.

- A basf2 event is created by a user defined chain of modules on a path.
- The core simulation module is an interface to Geant4 v 10.1.2.

Example: Order of basf2 Modules per Event



Mixing of Beam Background Hits



Various methods to simulate beam background hits:

- High luminosity operation creates substantial background hits inside the detector.
- Option 1) Pre-simulated beam background hits:
  Radiative Bhabha, Touschek scattering, beam-gas interactions, two-photon QED.
- Option 2) The background overlay scheme using random trigger events. This option consumes much less computing resources than Option 1.
- We also study machine learning based background generation & simulation strategy. Please check the presentation by James Kahn on "Selective background Monte Carlo simulation" and the poster by Matej Srebre on "Pixel detector background simulation using generative adversarial networks at Belle II."

Projects to Optimize Simulation Library
Step 1: Geant4 Physics List

The popular physics list input for Geant4, FTFP_BERT, is optimized for the LHC experiments.

- Collaboration with the Geant4 experts is ongoing to replace FTFP_BERT with a tailored physics list for Belle II.
- The main objective is improving the CPU performance while preserving the physics details. Improving hadron shower shape is included in the objectives, too.
- The Electromagnetic (EM) standard will be replaced by EM option 1. Compared to the standard, option 1 has the characteristics of
  - The hadronic processes are weighted more toward the Bertini cascade. Belle II operates at lower energy than the LHC experiments.
  - Options for optical photons are added. (note: Belle II is already using the optical photon package provided by Geant4.)
  - Options for High Precision Neutron Model will be added later, to study neutron background near the beamline.
- The validation of the new physics list will start soon. CPU performance and physics details will be compared between two physics list,. with emphases on
  1. Shower shapes.
  2. Detector responses to electrons and pions.
  3. Visible energy.
  4. Effects generated by switching from EM standard to EM option 1.
  5. Effects generated by switching from FTFP_BERT to new model combination.

Step 2: Geant4 Version Upgrade

The Geant4 will be upgraded from version 10.1.2 to version 10.5

- This will allow to use various geometry options provided by Geant4 since v. 10.4.
- A separate validation project will be conducted to understand version 10.5 in depth.

Summary and Future Plan

- Geant4 is the core of the Belle II simulation library, *FullSim*.
- The library has been stable and is ready for Phase III of SuperKEKB/Belle II.
- We are pursuing optimization of the simulation library for better performances. The ambitious luminosity schedule of SuperKEKB will produce peta-scale data sets, which will burden the system much. This project (a new physics list, upgrade) will be the main objective of next basf2 version, release 4.
- Machine learning technologies are being investigated to enhance the performance of background event generation and simulation.

Acknowledgments

Doris Y Kim is supported by the National Research Foundation of Korea (NRF) Grant No. 2016R1D1A1B02012900 and No. 2016K1A3A7A0900560. This author also thanks Korea Institute of Science and Technology Information (KISTI) GSDC and KRONET/GLORIAD for the computing resources and technical supports.