University of Louisville
ThinkIR: The University of Louisville's Institutional Repository

Undergraduate Arts and Research Showcase | Undergraduate Research

2020

Validation of Geant4 upgrade to model response from muons passing through the KLM detector at the Belle II experiment.

Stephen C Temple
stephen.temple@louisville.edu

Swagato Banerjee Ph.D
swagato.banerjee@louisville.edu

David N. Brown Ph.D
david.brown@louisville.edu

Validation of Geant4 upgrade to model response from muons passing through the KLM detector at the Belle II experiment.

Stephen Temple
Prof. Swagato Banerjee, Prof. David N. Brown
Department of Physics & Astronomy
University of Louisville

Abstract

The KLM detector or K^0_L- Muon Detector is equipped on the outermost layer of the Belle II detector structure. The detector is designed to detect the K_L mesons and muons above 600 MeV/c with high efficiency. The barrel shaped region around the intersection point covers a polar angular range of 45° to 125° while the forward and backward end caps extend this range to 20° to 155°. With the upgraded Geant4 model we observe the effectiveness of the new model.

Introduction

The KLM detector is the outermost sub-detector in the Belle II experiment [1,2,3] shown in figure 1. The purpose of this detector is to detect K_L^0 mesons and measure the momentum of muons. It is made up of alternating sandwiches of 4.7 cm thick iron slabs and active detector elements located outside the superconducting solenoid.

Figure 2 shows that he KLM detector has two parts [4] - Barrel KLM (BKLM) and Endcap KLM (EKLM). The BKLM is coaxial to the beam axis. The EKLM is located at the two ends of the Belle II detector, perpendicular to the beam axis, and made up of scintillators.

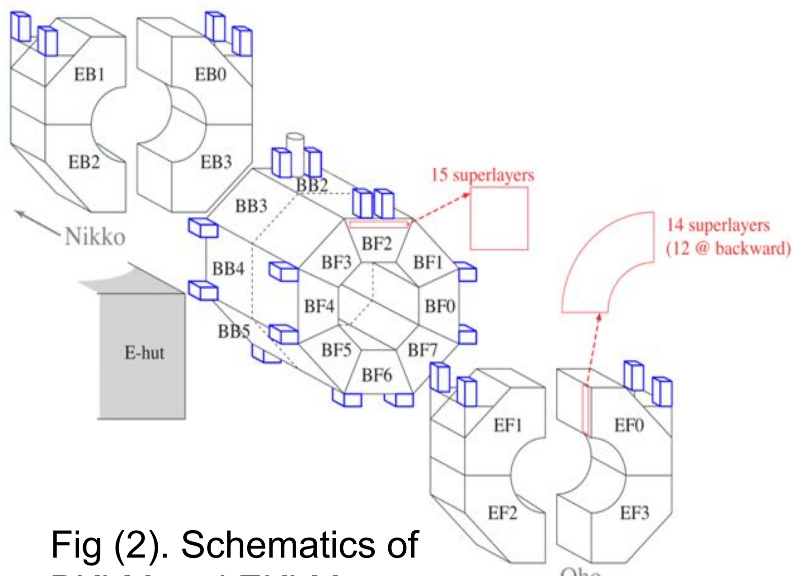
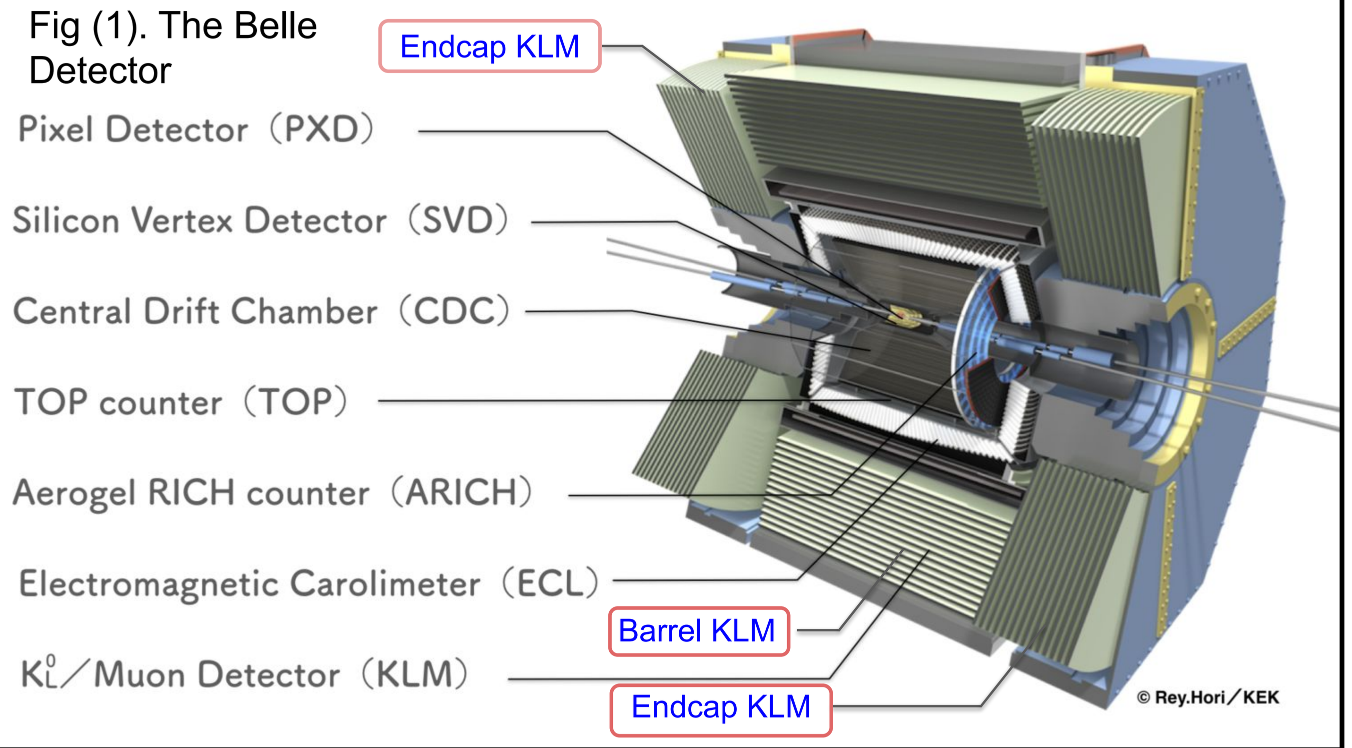


Fig (2). Schematics of BKLM and EKLM

Fig (1). The Belle Detector



Structure of KLM

The main structure of the KLM detector is comprised of both the barrel and endcaps. The barrel is divided into forward and backward halves, there are 8 sectors called "octants" in each half of the barrel configuration. Each of these 8 sectors contains 13 of the superlayer double gap RPC modules and 2 layers of scintillators[1,3].

The RPC modules have a gas gap contained between the high voltage (HV) layers that is comprised of non-flammable gas mixture of 62% HFC-134a, 30% Argon, and 8% butane-silver [2]. A discharge in either gas gap induces signals on both of the orthogonal external copper-strip planes. Figure 3 shows a RPC superlayer, used in the BKLM. Passage of a muon is recorded as hits in these Z and ϕ-strips of the RPC's in the BKLM.

While the endcaps of the structure are divided into 4 sectors dubbed "quadrants", 14 layers are present in the forward configuration and 12 are present in the backward configuration[2]. The scintillator can be seen to the right in figure 4.

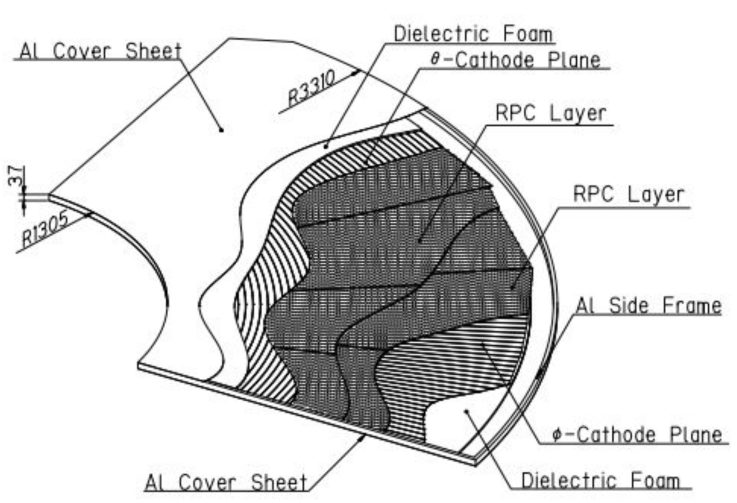


Fig (3). RPC Breakdown[2]

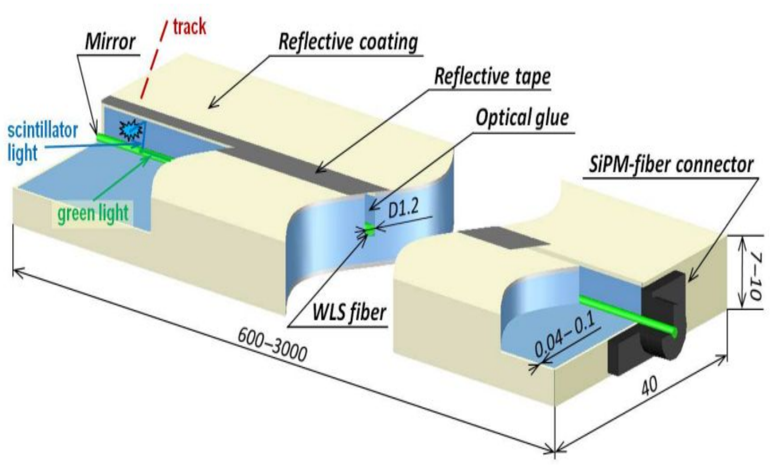


Fig (4). Scintillator Breakdown

Geant4 Optimization for basf2

Geant4 is a set of software tools for simulation of the passage of particles through matter[5]. In the case of this project the particles that pass through the KLM detector, are namely muons and K_L^0 mesons. The default description of the list of the physical processes, known as the PhysicsList, was optimized for the experiments at the Large Hadron Collider, operating at a much larger energy scale.[6] The Belle II experiment optimized this list using a custom made optimization of physical processes as appropriate to the scale of the center-of-mass energy to produce what is called as the Belle2 PhysicsList.
This Belle2 PhysicsList speeds up the CPU requirements of the Geant4 simulation by as much as 25%[6]. Our goal is to validate that the performance of the KLM simulation is not compromised while using this optimized Belle2 PhysicsList. In the BKLM, consecutive hits on the double-gap RPC layers are combined to form BKLMHit2ds.
Figures 5 and 6 below show that for both the default and the new PhyicsLists, the simulation reproduces the expected distributions of the occupancy of the Z-strip and Phi-strip numbers of these BKLMHit2ds.

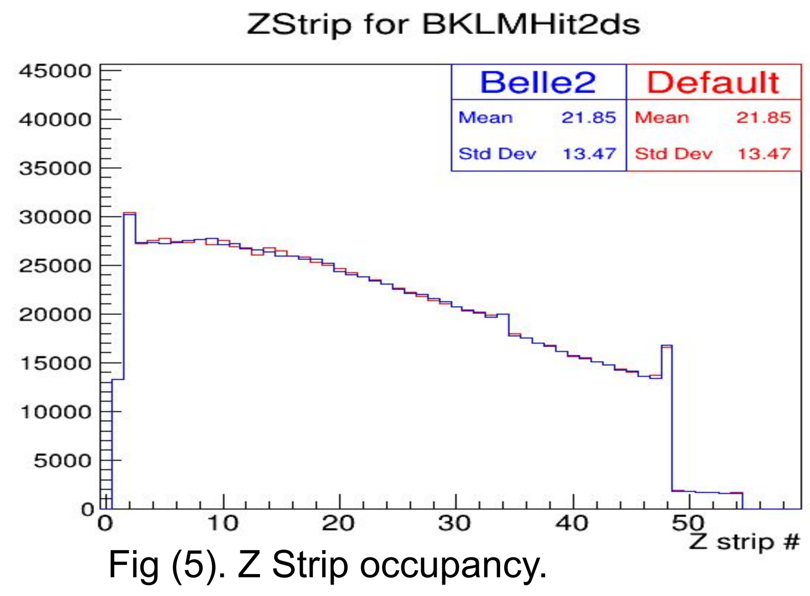


Fig (5). Z Strip occupancy.

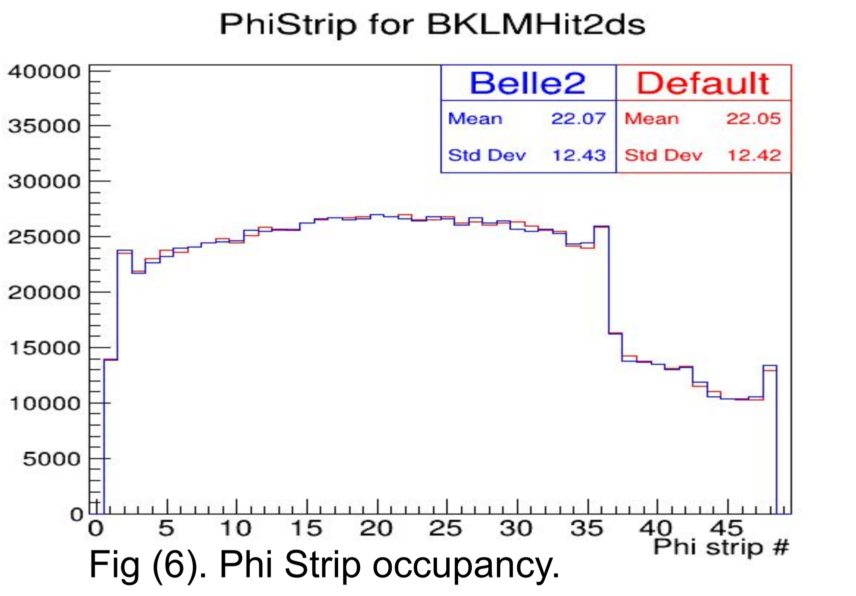


Fig (6). Phi Strip occupancy.

Summary and additional plots -

Below are additional figures showing the performance of simulation in different regions of BKLM and EKLM. Figures 7 and 8 show the distribution of energy deposition and layer occupancy of the BKLMHit2ds respectively. Figure 9 shows the timing distribution of the hits in the RPC in the BKLM. Figure 10 shows the timing distributions of the scintillators in the BKLM; Figure 11 shows the same timing distributions of the scintillators in the EKLM.
These findings lead us to suggest the implementation of the Belle2 PhysicsList as an effective refinement of the present defaults in the Geant4 software. The update showed that for the KLM detector that it was a near perfect mirror of the previous list. While these developments are still ongoing these results have yielded a positive result for the detector and we plan to move forward with further improvements.
This project could not have been completed without the extensive effort and guidance of Dr. Swagato Banerjee and Dr. David Brown. A special thanks goes to Dustyn Hoffer, Dominic Smith, Nate Riche, and the rest of the UofL HEP group for their continued support.

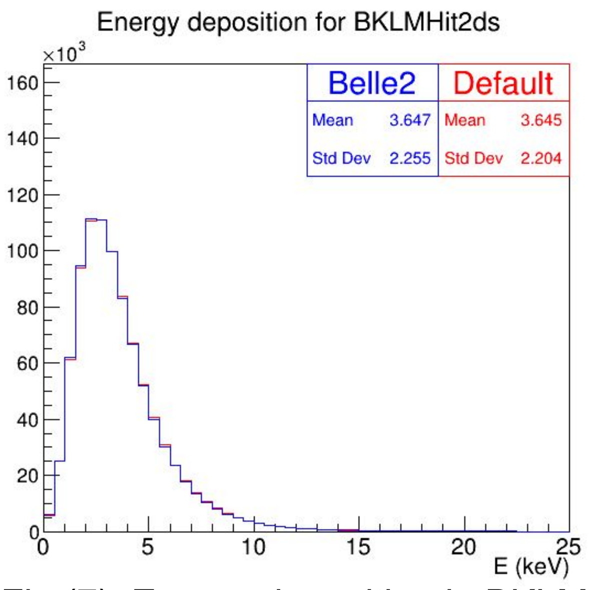


Fig (7). Energy deposition in BKLM

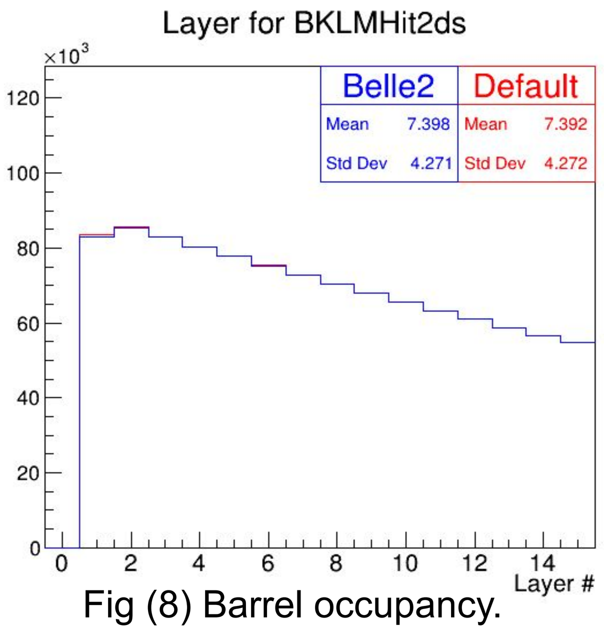


Fig (8) Barrel occupancy.

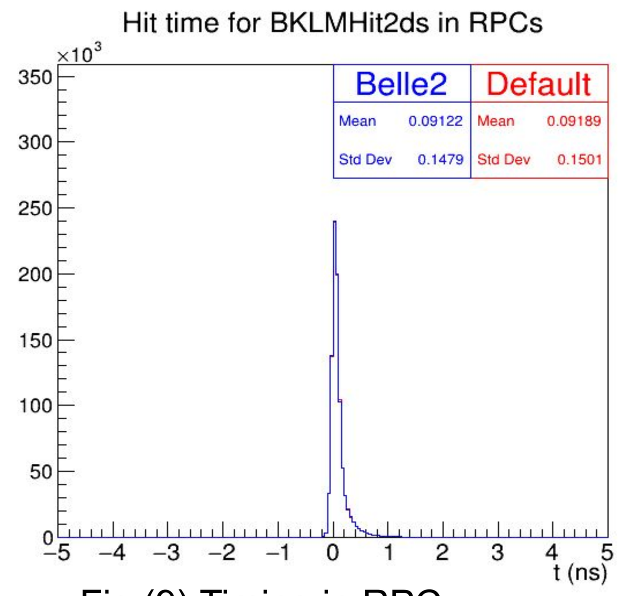


Fig (9).Timing in RPC

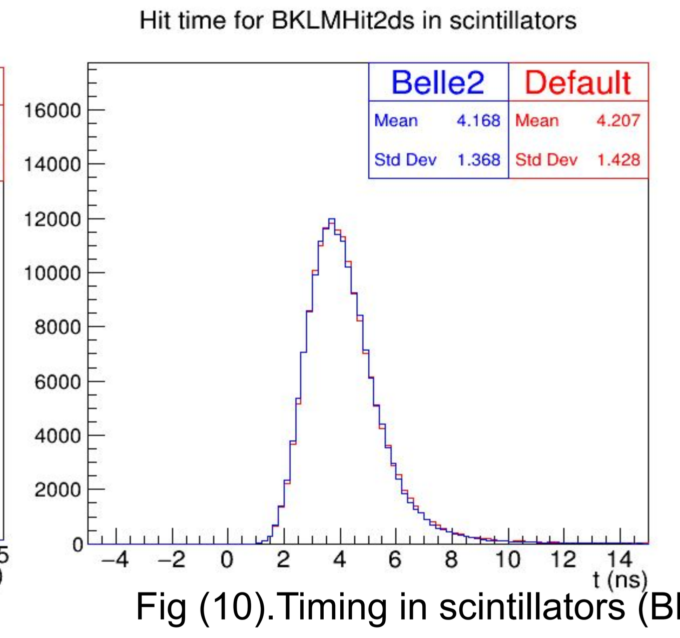


Fig (10).Timing in scintillators (BKLM)

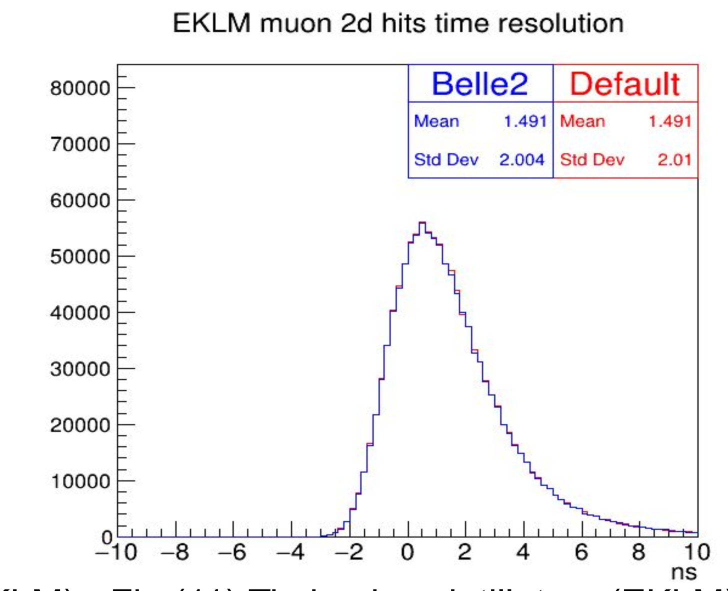


Fig (11).Timing in scintillators (EKLM)

References

1. "Belle II Technical Design Report", T. Abe, et. al., [Belle II collaboration], arXiv: 1011.0352 [physics.ins-det].
2. "The Physics of the B Factories", A.J. Bevan, et. al. [BaBar and Belle Collaborations] Eur. Phys. J. C74 (2014) 3026, arXiv:1406.6311 [hep-ex].
3. "The Belle II Physics Book," E.Kou et. al., [Belle II Collaboration], Prog. Theor. Exp. Phys.2019, no. 12, 123C01, Erratum:Prog. Theor. Exp. Phys.2020, no. 2, 029201, arXiv:1808.10567 [hep-ex].
4. "A scintillator based endcap K-Long and muon detector for the Belle II experiment," T. Aushev et. al. [Belle II collaboration], Nucl. Instrum. Meth. A789, 134 (2015), arXiv:1406.3267 [physics.ins-det].
5. "Recent Developments in Geant4", J. Allison et al. [Geant4 collaboration], Nucl. Instrum. Meth. A 835 (2016) 186-225.
6. "Validating the Belle2 PhysicsList", D. Hofer, S. Banerjee, D.N. Brown, A. Pathak, Poster in Undergrad Research Showcase, UofL.