

Background measurements and simulation for CODEX-b

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Abstract

Include abstract here.

1 List of changes between versions

- 2 ● version 1
3 – Start version.
4 ● version 1.01
5 – Add figures in each section and rewrite.
6 ● version 1.02
7 – Add contents at each section.

1 Introduction and motivation

This is the reference [1]

“The results shown are unofficial and have not been formally approved by the LHCb collaboration”

1.1 Motivations

There is no clear observation of new physics (NP) at the LHC as yet. The NP portal is considered in weakly coupled sector with long lifetime. The long lifetimes are very generic in any theory with multiple mass scales, broken symmetries and so on. Standard Model (SM) is a good example since it contains low mass particles with long lifetime such as electron, neutrino, proton and neutron. There are several experiments for searching longlived particles (**LLPs**). Likewise we introduce a new detector to measure **LLPs** based on high luminosity large hadron collider (HL-LHC).

1.2 Compact Detector for Exotics at LHCb

The Compact Detector for Exotics at LHCb (CODEX-b) was proposed to observe weakly coupled **LLPs** in LHCb cavern. Since ATLAS and CMS focused on high p_T and large QCD backgrounds and restricted lifetime of LHCb, current detectors can miss signals from weakly coupled **LLPs**. By following the fig. 1, the DAQ racks will be moved to the surface before run 3 and the CODEX-b will be placed at the site with 10 X 10 X 10 m size. The CODEX-b apart 25 m from the impact point 8. If the DELPHI is removed, the size can be expanded to 20 X 10 X 10 m.

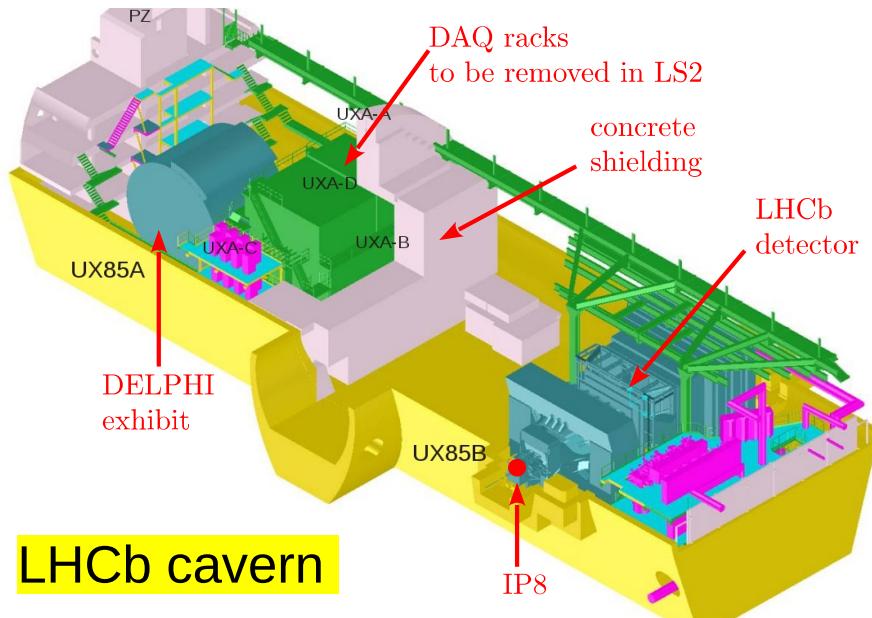


Figure 1: Schematic plot of LHCb cavern

28 2 Measurement

29 2.1 Test-bench

30 We used Herschel detector. For PMT, model: R1828-01 Because, it has high anode current
31 upper limit, wide range of gain variation, fast time response to fit in 25 ns, large entry
32 window to increase light yield, good single electron separation. The test-bench includes
33 cosmic stand, scope with extended functions (auto save waveforms, coincidence logic),
34 high voltage power supplies (1.5 kV, bias 350 V), current-voltage meter, laptop to remote
35 connect to scope.



Figure 2: Test-bench photo

36 2.2 Trigger

37 We used simple 2x fold coincidence and a distance between two scintillators 2 cm. For
38 this measurement, a discrimination (scope) threshold set as 30 mV. When first scintillator
39 receive a signal and the other scintillator also receives a signal in 5 ns, scope counts.
40 The scope automatically saved two waveforms from each scintillator and the number of
41 minimum ionizing particles (mip) counted during the run.



Figure 3: Trigger setup using coincidence occurrence of two signals in 5 ns.

42 2.3 Detail Configuration

43 The background measurement was taken at the LHCb cavern on D3 platform. The
 44 equipment had been set at 3 positions between DAQ racks and the concrete shield wall
 45 and the position between the DELPHI and DAQ racks. We basically placed the scintillator
 46 stand parallel to the beam line but also rotated 45° and perpendicular to the beam line.
 47 Fig 4. shows positions and configurations of measurement.

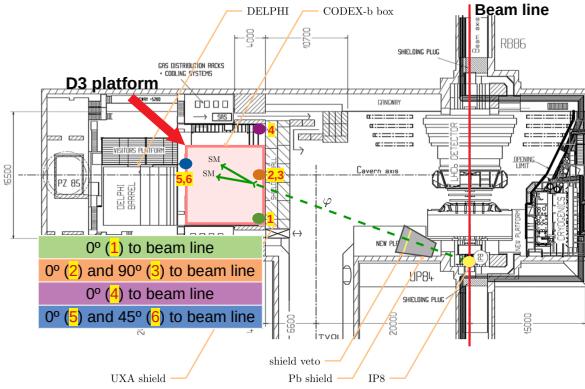


Figure 4: Four measurement positions at the LHCb cavern

48 2.4 Results

49 The measurement campaign spanning 17 days in July-Aug 2018. The scope performed
 50 52036 triggers during the run. The LHCb lumi rate was stable during the measurement.
 51 There was no beam until July 30th because of machine development and power cut happened
 52 during measurement.

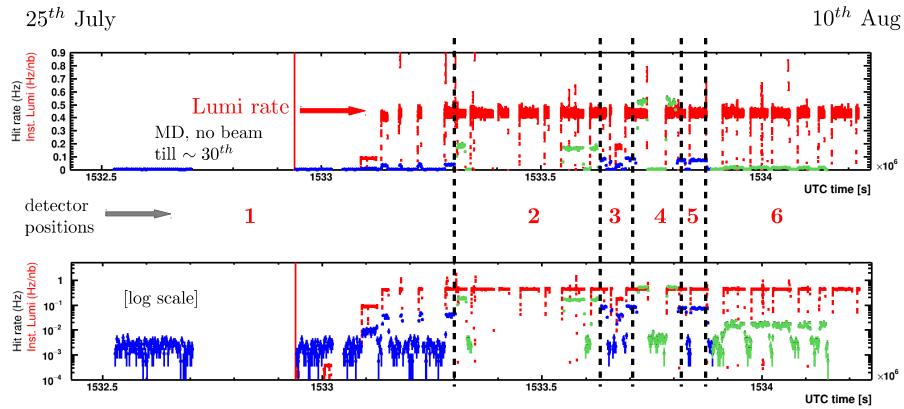


Figure 5: Hit rate plots during the run based on 6 positions/configurations linear and log scale. Red dots mean the lumi rate of LHCb, blue and green dots mean hit rates.

53 Below tables are shown hit rate based on measurement position and configuration.
 54 The rate of pp collisions is 25 MHz. First table is about ambient background hit rate
 55 between fills and in MD without beam.

Position	Description	Hit rate [mHz]
P1	shield, right corner, \parallel to beam	1.99 ± 0.07
P2	shield, center, \parallel to beam	2.76 ± 0.03
P3	shield, center, \perp to beam	2.26 ± 0.03
P4	shield, left corner, \parallel to beam	3.11 ± 0.03
P5	shield + D3 racks, center, \parallel to beam	1.95 ± 0.03
P6	shield + D3 racks, center, 45° to beam	2.22 ± 0.02

Table 1: Pure background hit rates based on each configuration

Position	Description	Hit rate [mHz]
P1	shield, right corner, \parallel to beam	38.99 ± 0.99
P2	shield, center, \parallel to beam	167.10 ± 1.43
P3	shield, center, \perp to beam	82.81 ± 1.55
P4	shield, left corner, \parallel to beam	517.45 ± 3.52
P5	shield + D3 racks, center, \parallel to beam	73.58 ± 1.18
P6	shield + D3 racks, center, 45° to beam	15.71 ± 0.33

Table 2: Average hit rates during the stable beam measured by the Herschel detector

56 The average hit rate of each position and configuration is 2 mHz. It is indicated that
 57 background can be negligible. However, during stable beam, hit rate increases a large. By
 58 moving position from P1 to P2, from P2 to P4, we found that hit rate depends on η . Also,
 59 DAQ racks add some shielding effect based on the hit rates of P5 and P6.

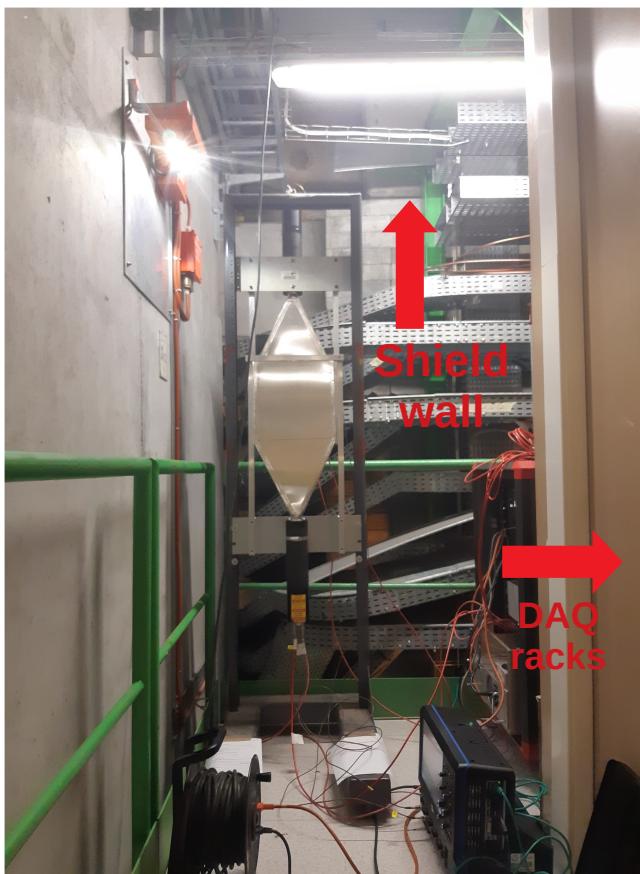


Figure 6: Photos from each position at D3 platform

60 3 Simulation

61 3.1 Detector Description for High Energy Physics

62 We used Detector Description for High Energy Physics (DD4hep) standalone version.
63 DD4hep is a software framework to provide overall detector description for experiments.
64 It offers a consistent description through a single source of detector information for
65 simulation, reconstruction, analysis, etc. Additionally, DD4hep being developed for high
66 luminosity large hadron collider (HL-LHC) detector simulation. During the internship,
67 we built the geometry of CODEX-b constructing hierarchy system. We designed concrete
68 shield wall to block particles from particle gun or MC and herschel detector since we used
69 as a scintillator for our measurement. For validation μ particle gun and minbias event
70 had been used. We also checked energy deposits and positions of CODEX-b hits.

71 3.2 Simulation geometry

72 First geometry is the CODEX-b. CODEX-b consists of two parts face station and inner
73 station. Based on the paper, face station has 6 resistive plate chambers (RPCs) layers
74 at 4 cm intervals with 1 cm granularity. The size of each layer is $10 \times 10 m^2$ and the
75 thickness is 2 cm. In this simulation we had been implemented layers as a tracker instead
76 of RPCs. Inner station also has same configuration except number of layers. It will be
77 equally spaced with triplets along the depth to minimize distance between reconstructed
78 vertex and 1st measurement.

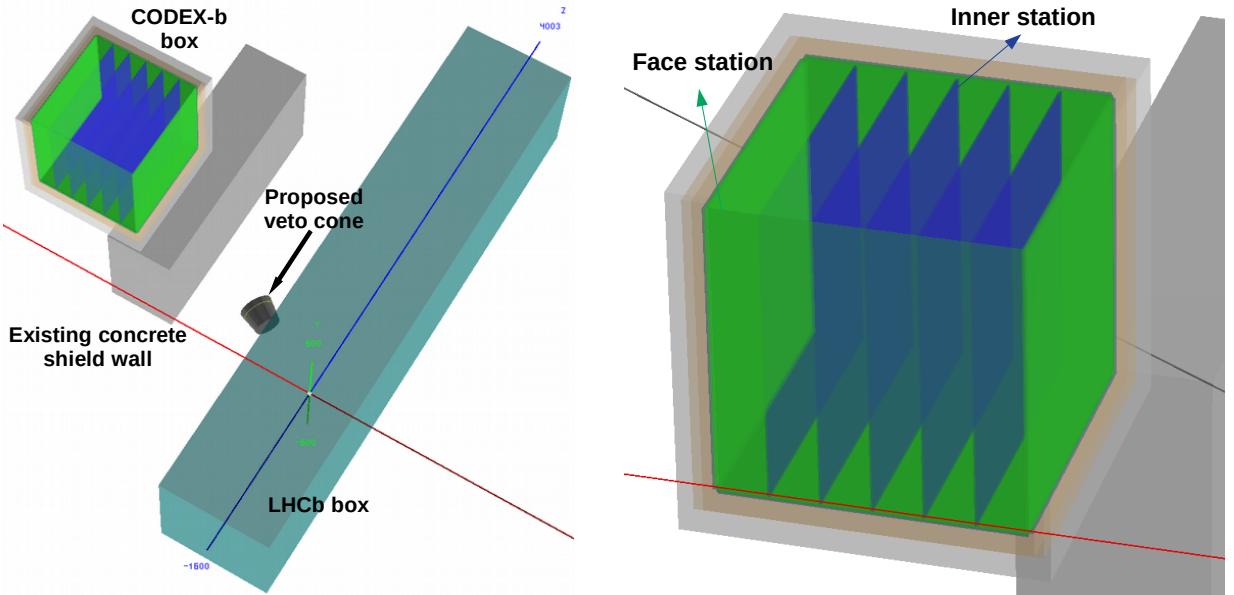


Figure 7: Wide view of CODEX-b simulation geometry

79 We also created a concrete shield wall with 3.2 m thickness. It was placed just front
80 of CODEX-b box. Between the LHCb box and the concrete wall, there is a proposed veto
81 cone. It contains two lead absorber and one active silicon layer.

82 Second geometry was consists of two scintillator plates which is the same as our
83 measurement configurations. The material of scintillator was

84 3.3 Simulation status

85 We designed two different detectors based on the paper and the measurement, the former
86 is the CODEX-b and the latter is a scintillator. Both were tested with μ particle gun
87 with 1 TeV and the minimum bias events generated from the standalone Gauss.

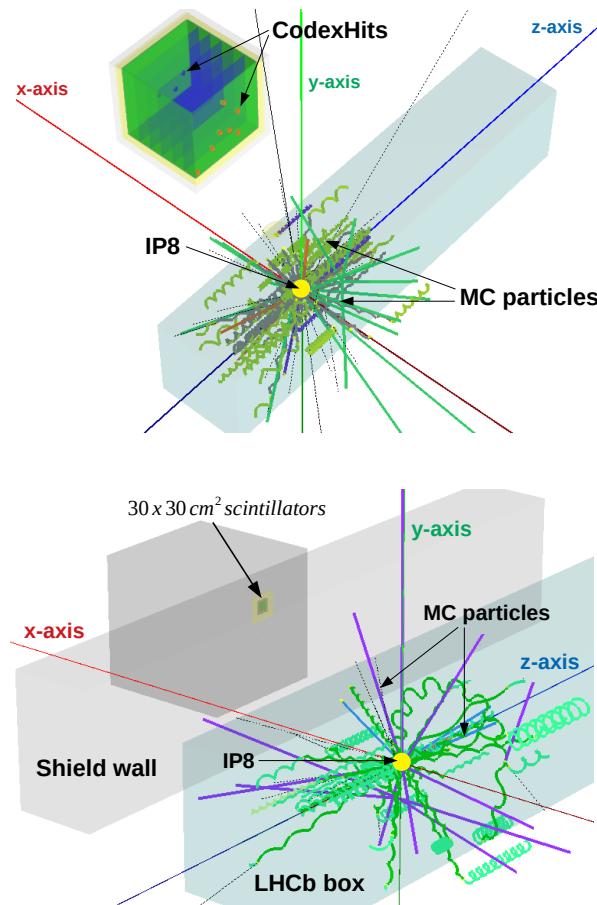


Figure 8: Validation of the CODEX-b simulation by removing the concrete shield wall with minimum bias events

88 To check hits on the layers of the CODEX-b, we removed the concrete wall. Fig
89 8 upper plot is shown the results. Also we recovered the concrete wall and changed
90 CODEX-b geometry to two scintillator plates and tested with minbias events. Following
91 the lower plot of Fig 8, there is no hit on the scintillators. Because its size is too small to
92 measure hits and the concrete wall blocks particles from collisions.

93 4 Summary

94 It was a very successful measurement campaign at D3 platform. We measured hit rates of
95 mip based on 2x fold coincidence trigger using Herschel detector and scope. We could
96 also manage run and data by remote connect to scope. The average hit rates in the stable
97 beam condition is much higher than the average hit rates of pure background. Based
98 on this result, we can ignore pure background. The background rate just behind the
99 concrete shield wall around 0.5 Hz over 900 cm^2 size scintillators. Also the hit rates have
100 η dependence when moving far from the impact point. The D3 racks behave like a shield
101 from the P5 and P6 results but it is difficult to simulate because of complicated structure.

102 About the simulation, DD4hep had been used to design CODEX-b and background
103 measurement campaign. Built a hierarchy system to implement a bundle of 6 silicon
104 layers (these layers are planned to change to RPC layers) and a triplet bundle. Reminding
105 that CODEX-b geometry is a final version. Detail information about components of
106 designed CODEX-b using DD4hep is following. The layer runs as a tracker which measure
107 hit position of particles and the size is $10 \times 10 \text{ m}^2$ with 2 cm thickness. Using similar
108 hierarchy system, background measurement campaign geometry had been made. The size
109 of scintillator plate is $30 \times 30 \text{ cm}^2$ and 2 cm thickness. The distance of them is 2 cm. Veto
110 cone and concrete shield wall were generated using DD4hep.

111 All geometries were tested with μ particle gun with and without concrete shield wall.

₁₁₂ **References**

- ₁₁₃ [1] V. V. Gligorov, S. Knapen, M. Papucci, and D. J. Robinson, *Searching for Long-lived Particles: A Compact Detector for Exotics at LHCb*, Phys. Rev. **D97** (2018) 015023,
₁₁₄ [arXiv:1708.09395](https://arxiv.org/abs/1708.09395).
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