CODEXb: status and plans

COmpact Detector for EXotics at LHCb

[1708.09395]

Biplab Dey

on behalf of the CODEX-b WG

Physics Beyond Colliders Workshop, CERN
LHCb perspective

- Complementarity between ATLAS/CMS and LHCb: luminosity, acceptance, triggers, lifetime reach.

- Our best tracks originate inside the VeLo ($L \sim 20\text{cm}$). Longer lifetimes are challenging. CODEX-$b$ to extend to much larger $c\tau$. 
DAQ racks in UXA-D move to surface for Run 3. Space available.

- Shielded, underground, $10 \times 10 \times 10$ m box, around 25 m from IP.
- Instrument with tracking layers $\Rightarrow$ CODEX-b
If DELPHI is removed, access to even $20 \times 10 \times 10$ m box.

Angular acceptance $\sim 1\%$. 
Background flux in UX85A cavern

- Understanding background rates critical for reach studies.
- Supervised a CERN summer student [Jongho Lee] to measure charged flux at different points in UX85A
- Used scintillators from Herschel detector in LHCb
- Very successful campaign: \(~50K\) triggers in 17 days
- Calibrate simulation employing these measurements
Herschel scintillators and setup

- Plastic scintillators w/ lightguides wrapped in Al foil, coupled to Hamamatsu R1828-01 PMT’s
- $30 \times 30 \text{ cm}^2$ area and 2 cm thickness.

- Tested with cosmics on surface. $\sim 100\%$ efficient for MIP’s
- Can’t measure energy deposit though.
Background measurement campaign

**Test bench assembly in VeloLab**

- Upright iron stand, scintillators horizontally separated by $\sim 11$ cm.
- NIM crate + LeCroy WR scope for DAQ.
- Coincidence trigger in 5 ns window (no spillover effects)
Four measurement positions on D3 platform

- $0^\circ$ (1) to beam line
- $0^\circ$ (2) and $90^\circ$ (3) to beam line
- $0^\circ$ (4) to beam line
- $0^\circ$ (5) and $45^\circ$ (6) to beam line
Equipment setup on D3

- Shield wall
- DAQ racks

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CODEX-\textit{b} status and plans
Jan 16\textsuperscript{th}, 2019
Equipment setup on D3 (cntd.)

Delphi

DAQ rack

Shield wall

DAQ racks
GLOBAL SNAPSHOT OF THE DATA

- Measurement campaign spanning **17 days** in July-Aug. **52036** triggers.
- **6 positions/configurations** on D3 marked in blue and green, alternatingly:

25\(^{th}\) July

10\(^{th}\) Aug

<table>
<thead>
<tr>
<th>Detector positions</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
</table>

**Lumi rate**

MD, no beam till ~ 30\(^{th}\)
**Detailed features: background rate w/o beam**

- **Ambient** background hit rate between fills or in MD, **without beam.**

<table>
<thead>
<tr>
<th>Position</th>
<th>Description</th>
<th>Hit rate [mHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>shield, right corner,</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>shield, center,</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>shield, center, ⊥ to beam</td>
<td>2.26 ± 0.03</td>
</tr>
<tr>
<td>P4</td>
<td>shield, left corner,</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>shield + D3 racks, center,</td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>shield + D3 racks, center, 45° to beam</td>
<td>2.22 ± 0.02</td>
</tr>
</tbody>
</table>

- Pretty consistent, ~2 mHz, across all positions and essentially negligible
## Specific features rate during stable beam

<table>
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<tr>
<th>Position</th>
<th>Description</th>
<th>Hit rate [mHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>shield, right corner, $\parallel$ to beam</td>
<td>$38.99 \pm 0.99$</td>
</tr>
<tr>
<td>P2</td>
<td>shield, center, $\parallel$ to beam</td>
<td>$167.10 \pm 1.43$</td>
</tr>
<tr>
<td>P3</td>
<td>shield, center, $\perp$ to beam</td>
<td>$82.81 \pm 1.55$</td>
</tr>
<tr>
<td>P4</td>
<td>shield, left corner, $\parallel$ to beam</td>
<td>$517.45 \pm 3.52$</td>
</tr>
<tr>
<td>P5</td>
<td>shield + D3 racks, center, $\parallel$ to beam</td>
<td>$73.58 \pm 1.18$</td>
</tr>
<tr>
<td>P6</td>
<td>shield + D3 racks, center, $45^\circ$ to beam</td>
<td>$15.71 \pm 0.33$</td>
</tr>
</tbody>
</table>

- Maximal rate at P4, $\sim 0.5$ Hz during beam. Calibrate simulation.
- Clear $\eta$ dependence: $P1 \Rightarrow P2 \Rightarrow P4$. Rate higher at higher $\eta$.
- The D3 racks definitely add some shielding as well (hard to simulate).
**Minimal geometry for tracking**

- Resistive plate chambers (RPC’s)
- 6 RPC layers at 4 cm intervals on each box face with 1 cm granularity

- 5 equally spaced triplets along the depth to minimize distance between reconstructed vertex and 1st measurement. $\epsilon_{\text{tracking}} \sim O(1)$.

- 50-100 ps timing from RPC’s foreseen for mass reconstruction
Detector geometry using DD4hep package

- Veto cone
  - Two Pb absorbers
  - Active Si shield layer
- Concrete shield wall
  - 3.2 m thickness
  - Block most particles from $pp$ collisions
- CODEX-b box
  - Consists of two types of stations: inner and face.
**CODEXb box volume: details**

- Nominal geometry from 1708.09395. Replace RPC’s by simple Silicon layers as sensitive element

  - **Inner station (x5)**
    - Silicon tracker
    - 3 layers of $10 \times 10 \ m^2$ size and 2 cm thickness
    - Inter-layer distance is 4 cm

  - **Face station (x6)**
    - Silicon tracker
    - 6 layers of $10 \times 10 \ m^2$ size and 2 cm thickness
    - Inter-layer distance is 4 cm
**Sample Minbias Event**

- 13 TeV minbias events with existing shield removed

- Simulation running on the grid within LHCb framework (Gauss).
**η DEPENDENCE IN SIMULATION**

- Simulation reproduces the higher activity seen in data.
- \( P_1 \Rightarrow P_4 \), at higher \( \eta \) (larger \( z \)) has higher hits.

- MCHits seen in all the layers.
Machine Induced Background (MIB) sources

- CODEX-\(b\) is essentially a zero background experiment
- **Background** induced by the LHC machine has to be considered carefully, especially during HL-LHC
- Relevant sources for IP8/LHCb: beam-gas interactions, IR7 Betatron Cleaning, IR3 momentum cleaning, IP1 ATLAS elastic interactions
- LbMIB: tool within Gauss to simulate this background
- We do see MIB hits in CODEX-\(b\) volume. Can we veto them with tracking.
Summary and next steps

- Critical steps achieved since 2017 proposal paper
  - Background flux directly measured in cavern, for calibration
  - Include detector within the official LHCb simulation
  - Measurement simulation mature (final results not today).
    Normalizations have to be done correctly.

- Next important steps
  - Tracking, including timing information on the hits.
  - Simplistic Si layers used. Move to realistic RPC’s and/or Calorimeters

- LHCb Internal-Note for the measurement campaign being prepared
CODEX-b: who we are

- **Theory colleagues:**
  - S. Knapen, M. Papucci, D. Robinson, H. Ramani, J. Evans, ...

- **LHCb physicists:**
  - J. Lee, V. Coco, B. Dey, R. Dumps, V. Gligorov, H. Schindler,
  - P. Ilten, X. Vidal + many others...

- **Support from LHCb computing and simulation:**
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- **Growing collaboration...you’re very welcome to join!!!**
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*Thanks!*