

Status of the CODEX-b experiment

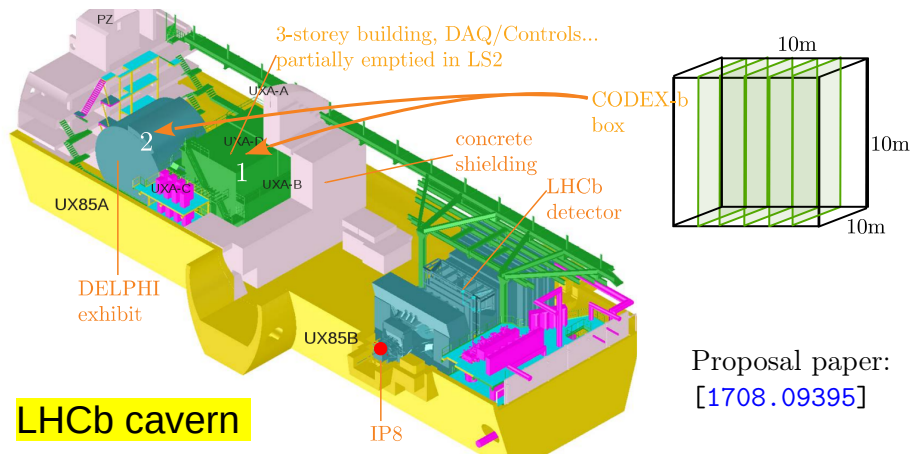
Biplab Dey



Eötvös Loránd
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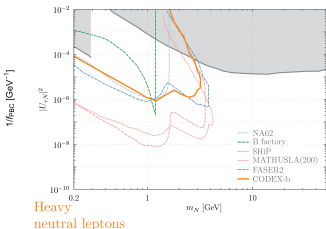
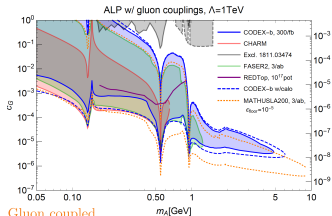
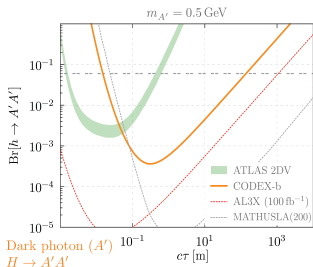
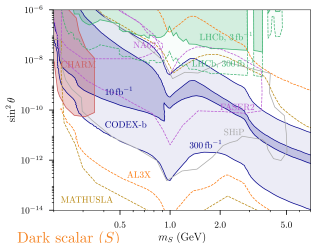
LLP9 workshop (virtual)

CODEX-B: A TRANSVERSE LLP DETECTOR AT LHCb



- 10^3 m^3 tracker box behind a 3.2 m thick shield placed transverse to LHCb. Integrated with LHCb triggerless DAQ.
- Nominal location: counting room (“1”). Or, DELPHI exhibit (“2”) area.

WIDE PHYSICS REACH IN HL-LHC ERA



- Optimized for **GeV-scale** $c\tau \sim 25$ m neutral LLPs produced by **heavy intermediate** objects (Higgs) \Rightarrow transverse detector.

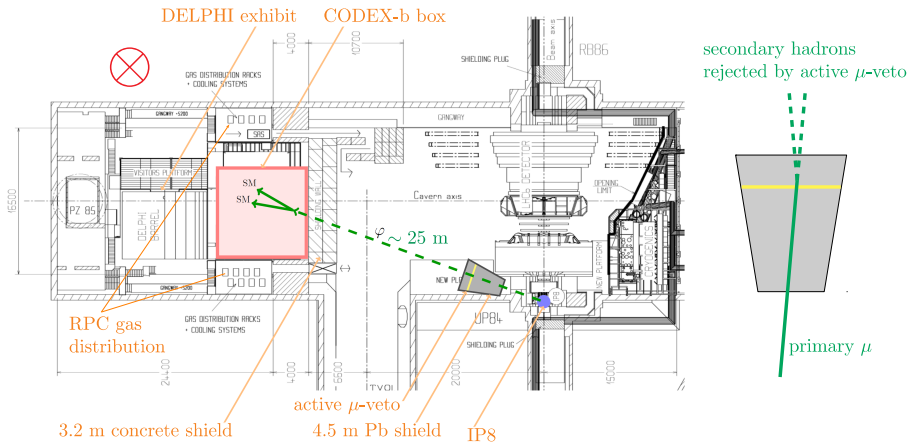
- See our Expression of Interest ([1911.00481](#)) for further details.

A ZERO SM BACKGROUND EXPERIMENT

- Reducing **SM backgrounds** to $\lesssim \mathcal{O}(1)$ over entire 300/fb during HL-LHC @ LHCb is the key.
- Detailed simulations ([1911.00481](#), [1708.09395](#)): combination of shields, and active/topological vetoes will achieve this.
- Most relevant backgrounds:
 - Primary/secondary muons punching through concrete+Pb shield (\Rightarrow active veto layers on CODEX-b face)
 - Primary neutrons/ $\pi^\pm/K^\pm/K_L^0$ (\Rightarrow additional Pb shielding)
- Additional potential sources:
 - LHC machine-induced background (dedicated LbMIB tool)
 - Thermal neutrons (hard to simulate)
 - Neutrinos (very low xsection).

ACTIVE VETO FOR SHIELD-INDUCED SECONDARIES

- Around 25λ ($\sim 4.5\text{m}$) additional Pb shielding for hadrons. But the shield itself generates (neutral) **secondary hadrons** from slowed down muons.
- Dedicated **active μ -veto** for secondaries.

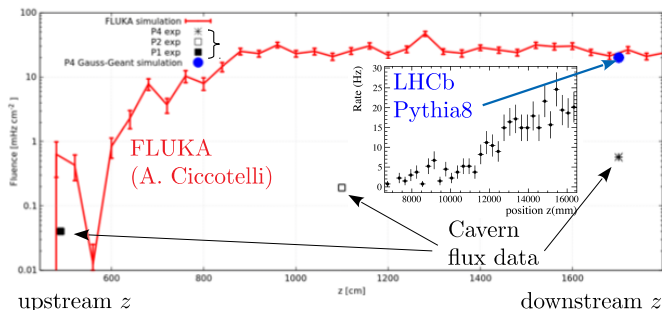


ESTIMATES FROM Geant4+Pythia8 STUDY (1911.00481)

BG species	Particle yields			Net yield
	Net ($E_{\text{kin}}^{\text{neutral}} > 0.4 \text{ GeV}$)	Shield veto rejection (total)	Shield veto rejection ($\pm/0$ correlation)	
γ	0.54 ± 0.12	$(8.06 \pm 0.60) \times 10^4$	$(2.62 \pm 1.03) \times 10^3$	-
n	58.10 ± 4.63	$(4.59 \pm 0.15) \times 10^5$	$(3.44 \pm 0.51) \times 10^4$	-
$n (> 0.8 \text{ GeV})$	2.78 ± 0.25	$(1.03 \pm 0.06) \times 10^5$	$(7.45 \pm 1.92) \times 10^3$	$\lesssim 1$
\bar{n} (no cut)	$(3.24 \pm 0.72) \times 10^{-3}$	34.40 ± 25.80	$(7.12 \pm 2.19) \times 10^{-2}$	$\ll 1$
K_L^0	0.49 ± 0.05	$(1.94 \pm 0.74) \times 10^3$	54.40 ± 19.20	$\lesssim 0.1$
K_S^0	$(6.33 \pm 1.39) \times 10^{-3}$	93.90 ± 45.80	0.74 ± 0.19	$\ll 1$
$\nu + \bar{\nu}$	$(5.69 \pm 0.00) \times 10^{13}$	$(7.35 \pm 0.12) \times 10^6$	$(7.31 \pm 0.11) \times 10^6$	-
p^\pm	$(2.07 \pm 0.26) \times 10^2$	$(9.24 \pm 0.36) \times 10^5$	$(9.24 \pm 0.36) \times 10^5$	-
e^\pm	$(4.53 \pm 0.02) \times 10^3$	$(4.38 \pm 0.02) \times 10^7$	$(4.38 \pm 0.02) \times 10^7$	-
π^+	34.70 ± 2.27	$(2.96 \pm 0.20) \times 10^5$	$(2.96 \pm 0.20) \times 10^5$	-
π^-	31.40 ± 2.12	$(2.68 \pm 0.19) \times 10^5$	$(2.68 \pm 0.19) \times 10^5$	-
K^+	0.83 ± 0.30	$(3.08 \pm 1.24) \times 10^3$	$(3.08 \pm 1.24) \times 10^3$	-
K^-	0.23 ± 0.12	$(1.12 \pm 0.63) \times 10^3$	$(1.12 \pm 0.63) \times 10^3$	-
μ^+	$(1.04 \pm 0.00) \times 10^6$	$(1.04 \pm 0.00) \times 10^{10}$	$(1.04 \pm 0.00) \times 10^{10}$	-
μ^-	$(8.07 \pm 0.01) \times 10^5$	$(8.07 \pm 0.01) \times 10^9$	$(8.07 \pm 0.01) \times 10^9$	-

CHARGED FLUX IN CODEX-B AREA

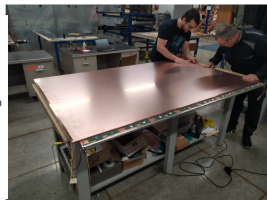
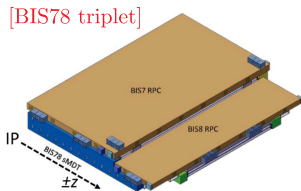
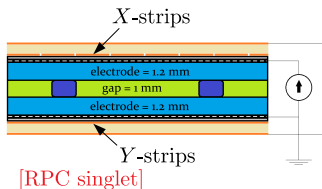
- Measured **charged MIP flux** along \hat{z} (beam-direction) just behind the shield wall in summer 2018 during Run 2 ([1912.03846](#)).
- Excellent agreement between LHCb and CERN-FLUKA simulation (both normalization and z -profile).



- Cavern **data** reproduces the z -profile, but sees **lower** rate. Further checks planned in Run 3 (more later).

BASELINE DETECTOR TECHNOLOGY: ATLAS RPCs

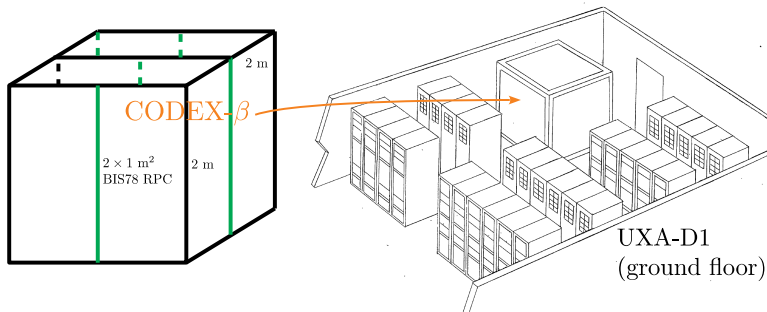
- Resistive Plate Chambers (RPCs) offer **cost-effective** baseline for a large-area tracker as CODEX-b.
- New generation of **BIS78** triplet RPCs from ATLAS muon **phase-I Upgrade**. Reliable QC due to established ATLAS production line.
- Chamber spatial resolution ~ 2 mm (charge-centroid) in X - Y strips; timing resolution $\sim 400/\sqrt{3} \sim 230$ ps.



- Synergy with R&D (\Rightarrow see RPC 2020 [talk](#) by Y. Sun) for phase II BI RPCs + electronics for CODEX-b + future LLP detectors.

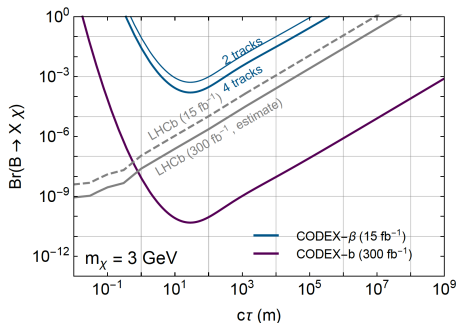
CODEX- β : PILOT RUN DURING RUN 3

- CODEX- β : $2 \times 2 \times 2$ m³ box to be placed in (already emptied) ground floor barrack space for **Run 3**.
- **14 BIS78** chambers to be used. Hardware cost around 150k€ (funding secured!)



CODEX- β : PHYSICS CASE

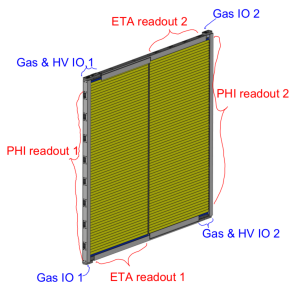
- Primary goal is to integrate with **LHCb online**, reconstruct K_L^0 and measure **background** rates.
- Competitive sensitivity to $b \rightarrow s\chi(\rightarrow \text{hadrons})$ as well.



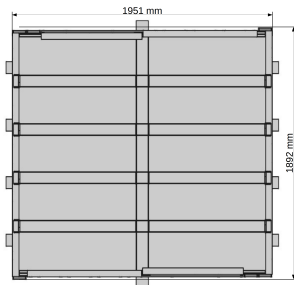
CODEX- β PREPARATIONS

- Steady progress towards TDR preparation for LHCb Technical Board within this year.
- Technical drawings for mechanical support, gas/power supply designs ongoing (D. Northacker).

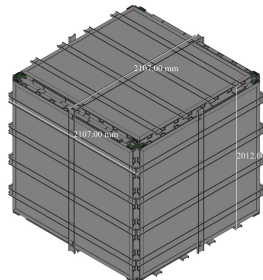
RPC support (single plane)



Outer support (single plane)



Full box

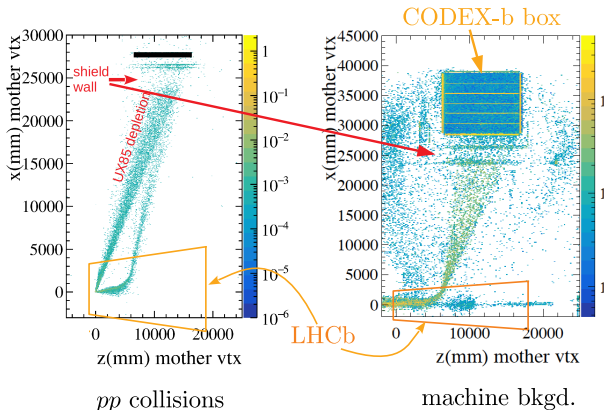


CODEX- β : R/O ELECTRONICS FOR RUN 3

- Run 3 onwards, triggerless DAQ @ 30MHz inelastic rate for LHCb.
- CODEX- β effectively acts as a sub-detector of LHCb. Hits sent to eventbuilder farm on the surface \Rightarrow **HLT lines for LHCb**.
- **DCT** \Rightarrow FPGA board collects RPC signals. Performs TDC and ships to LHCb PCIe40 via lpGBT @ around 0.5kHz estimated rate.
- One DCT per RPC \rightarrow 14 DCTs for full CODEX- β . Optimization needed for full CODEX-b (daisy chain RPCs).
- DCT time resolution is $\sim 800/\sqrt{12} \sim$ **230 ps**. Matches well with RPC time res.

FURTHER BACKGROUND CONSIDERATIONS

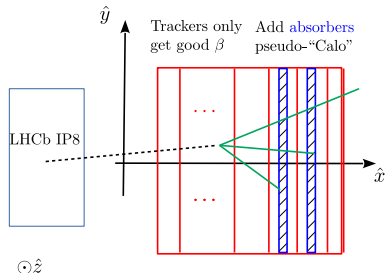
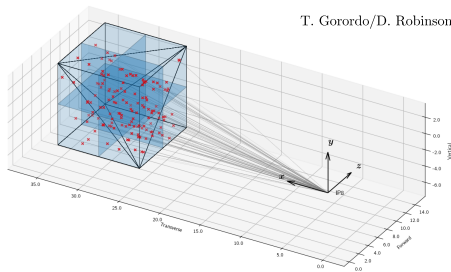
- Additional RadMon unit to be placed in CODEX- β area for Run 3 to monitor hadron backgrounds (thanks to Giuseppe Lerner).
- In discussion with LHCb lumi group as well as CERN radiation group to include CODEX-b area for Run 3 beam condition MIB studies.



- MIB will be small wrt flux from inelastic pp collisions, but needs to be calibrated properly.

OTHER ONGOING ACTIVITIES AND IDEAS

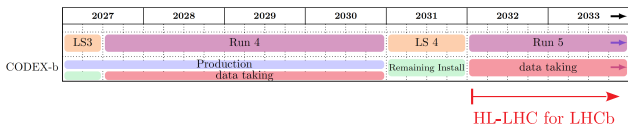
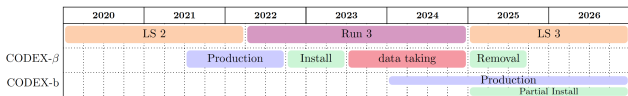
T. Gorordo/D. Robinson



- Simulation framework for fast geometry optimization.
- Inclusion of RPC detector response in full LHCb sim framework.
- LHCb HLT lines for CODEX-b.
- Calorimetry for CODEX-b would significantly enhance the physics reach (eg. $ALP \rightarrow \gamma\gamma$)
- Absorber or pre-shower layers can also perform some PID (eg. e/γ separation)

TOWARDS THE FULL CODEX-B DETECTOR

- **CODEX- β** during Run 3 will give us critical **experience**.
- For Run 4, full UXA-D (barrack) will not be available. Partial install of CODEX-b might be possible in UXA-D1 (ground floor).
- Depends on requirements from LHCb Upgrade II sub-detector requirements (TDR in ~ 2025).



- Tentative schedule.
- Note: HL-LHC for LHCb starts only from Run 5.

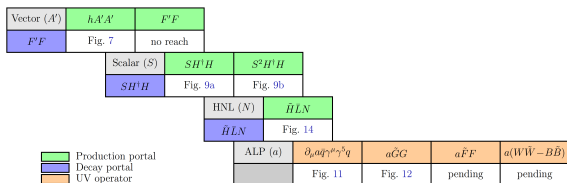
CONCLUSION AND OUTLOOK

Growing collaboration (16 institutes)

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 S. Lopez Solino

- CODEX- β is progressing well.
- CODEX-b offers excellent physics reach/€



- CODEX-b: total cost ~ 10 M€

The HL-LHC program needs a dedicated transverse LLP detector!