CODEX-b: status and plans

COmpact Detector for EXotics at LHCb

[1708.09395]

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for the CODEX-b WG

LLP workshop, 29th May 2019, CERN
Reminder: the CODEX-b proposal at Point 8

- 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 RPC tracking layers ⇒ CODEX-b
If DELPHI is removed, access to even $20 \times 10 \times 10$ m box.

Angular acceptance $\sim 1\%$. 
Physics reach: global snapshot

- **CODEX-b**: complementary with other proposals with competitive reach/$ in all four portals
  - Scalar portal $\rightarrow$ Dark Higgs/scalars
  - Neutrino portal $\rightarrow$ Heavy Neutral Leptons
  - Pseudoscalar portal $\rightarrow$ Axion-like particles
  - Vector portal $\rightarrow$ Dark photon

- Some snapshots...
  (see Gaia F.’s epic ESPP slides as well)
Physics reach

Scalar sector

**Higgs-scalar mixing**

- Minimal extension of Higgs sector: \( \mathcal{L} \sim \mu \varphi HH^\dagger + \frac{\lambda}{2} \varphi^2 HH^\dagger \)

- Scalar singlet w/ Higgs-\( \varphi \) mixing angle \( \theta \ll 1 \). \( c\tau \propto 1/\theta^2 \)

- Run1 LHCb has searched in \( B \to K^{(*)} \varphi \to \mu^+\mu^- \). CODEX-b nicely complement in the longer lifetime regime. *Tag with LHCb events.*

- Many more modes if \( \lambda \neq 0 \). (eg. Higgs\( \to \varphi\varphi \)). Unique coverage

\[
\begin{align*}
\lambda = 0: \\
\lambda = 1.6 \times 10^{-3}:
\end{align*}
\]

[plots: S. Knapen]

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Heavy Neutral Leptons (HNLs)

- Neutrinos oscillate and therefore have masses $\Rightarrow$ not in SM.
- RH Majorana HNL mass terms: $\mathcal{L} \sim YN(H \cdot L) + \bar{N}MN$
  
  $m_{\text{Dirac}} \sim Y\langle \nu \rangle_H \ll M_N$. Active-sterile mixing angle: $U \sim \frac{m_{\text{Dirac}}}{M_N} \ll 1$. $m_\nu \sim U^2 M_N \sim 0$

- Production/decay similar to neutrinos folded with $U_{\ell N}$
- Single HNL coupling either to $e/\mu/\tau$:

  - $e$:

  - $\mu$:

  - $\tau$:

[plots: D. Robinson]
Dark photons via exotic Higgs decays

- $A'$-$\gamma$ mixing + coupling to Higgs: $\mathcal{L} \supset \epsilon F'_{\mu\nu} B^{\mu\nu} + y h F'_{\mu\nu} F'_{\mu\nu}$
- Short $c\tau$ region: $D^*$ decays + inclusive $A' \rightarrow \mu^+ \mu^-$ at LHCb.
- Longer lifetimes: CODEX-b does better than ATLAS disp. dijet searches (proj. to HL-LHC)

[plots: S. Knapen]
ALPS/Dark glueballs: placeholder

More reach plots coming soon, in preparation for EOI...
Reminder: baseline tracking geometry

- Resistive Plate Chambers (RPC’s) – fast, precise, cheap for large area
- 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. $\epsilon_{\text{tracking}} \sim \mathcal{O}(1)$.
- 50-100 ps timing from RPC’s foreseen for mass reconstruction
Detector hardware proposals

**Hardware proposals**

- Discussions with experts within and outside LHCb earlier this year.

- **Electronics** must be easily integrable within the upgrade LHCb R/O.

- Re-use of current LHCb muon (MWPC) M1 station chambers considered.

- RPC technology + expertise from **ATLAS Muon Upgrade** as baseline.

- LHCb online experts confirm **ATLAS RPC board** that talks to FELIX (ATLAS Upgrade R/O), can talk to the **LHCb TELL40** board (LHCb Upgrade R/O) ⇒ critical!
RPC’s from ATLAS Muon Upgrade

- BIS78 Phase I (LS2) new RPC’s: 1mm gas gap, 1.2mm bakelite electrodes, 25 mm strips ($\sigma \sim 1$ cm w/ charge-centroid analysis)
- Environment-friendly gas, 6.5kV w/ new FE, $\sigma_t \sim 0.4 \text{ ns}/\text{singlet}$

- R&D on BI Phase II RPC’s for HL-LHC based on BIS78
- 20mm strips, $3 \times 0.5 \text{m}^2$ pads
- Perfect timing for CODEX-b in LS3!
Demonstrator for Run 3

- Our USP: tag CODEX-b event with LHCb activity.

- $2 \times 2 \times 2 \text{ m}^3$ demonstrator for Run 3 $\Rightarrow 1/25$ of full detector

- 6 faces $+$ 1 inner station $\Rightarrow$ 14 BIS78 triplet chambers.

- Enough space already in D1 area of the cavern once DAQ racks shifted out before EOY.

- Main goal: reconstruct $K^0_L$’s in the volume from IP8 during 2021-23.
Managerial issues for demonstrator

- CODEX-b mini-workshop in March’19 at CERN.
- LHCb management recommended for an EOI targeting LHCb week in September’19.
- Part of LHCb U2 physics case [1808.08865]
- ATLAS RPC group needs formal “blessing” from ATLAS management.
- Ongoing discussions with LPHNE engineers/technicians for mechanics and chamber construction.
- Overall cost for demonstrator expected around sub-200K Euro.
**Word on simulation/tracking activities**

- We’re a zero-background experiment. Scattering/shielding from cavern infrastructure is important.
- CODEX-b volume is outside LHCb acceptance, not fully realistic in current simulation.
- Data-driven validation of background levels + tracking studies ongoing (not for today).
Summary and looking ahead

- Slow but steady progress on several fronts – hardware, simulation, theory.
- We’ve a concrete plan for baseline hardware using ATLAS Upgrade RPC’s.
- Focusing on installing demonstrator by end-2021 – collect data over Run3.
- Working towards an EOI in Fall’19 for review within LHCb.
List of collaborators

- Theorists: D. Robinson, S. Knapen, M. Papucci, H. Ramani, J. Evans


- Helpful discussions with computing/sim/detector experts: M. Frank, G. Corti, B. Couturier, D. Muller, G. Aielli and R. Cardarelli (ATLAS RPC), A. Cardini, M. Palutan, N. Neufeld, R. Lindner, and others

- Very much open to the LLP community to join us!