A status update on CODEX-b

@ Searching for long-lived particles at the LHC (Amsterdam)
10/23/2018

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based on 1708.09395 with V. Gligorov, M. Papucci, D. Robinson
18xx.xxxxx with J. Evans, H. Ramani, D. Robinson
+ a lot of great work from LHCb colleagues
Lifetime frontier

Mass

10^{-3} 10^{-2} 10^{-1} 1 10^{\text{GeV}} 10^{\text{TeV}}

coupling / c \tau^{-1}

Already discovered/excluded

ATLAS / CMS

LHCb

(HIGHLY oversimplified!)
Lifetime frontier

Already discovered/excluded

ATLAS / CMS

Luminosity
Upgrades (trigger!)
Analysis improvements

(HIGHLY oversimplified!)
Lifetime frontier

![Diagram showing the mass-coupling frontier with regions labeled as already discovered/excluded, ATLAS/CMS, LHCb, and MATHUSLA, SHiP, CODEX-b, FASER, MiliQan, AL3X.](image)

- **Already discovered/excluded**
- **ATLAS / CMS**
  - Luminosity Upgrades (trigger!)
  - Analysis improvements
- **LHCb**
- **MATHUSLA, SHiP, CODEX-b, FASER, MiliQan, AL3X**

(HIGHERLY oversimplified!)
LHCb Cavern

Shielded space: 10m x 10m x 10m (20m x 10m x 10m if DELPHI is removed) roughly 25m from IP
CODEX-b

UXA shield

Pb shield

IP8

shield veto

GAS DISTRIBUTION RACKS
+ COOLING SYSTEMS

DELPHI

CODEX-b box

SM

SM
Background calibration

- Measured charged flux at different points in UX85A
- Good amount of data: 50k hits in 17 days (results for later day)
- Use to calibrate background simulation

By Biplab Dey, Heinrich Schindler, Victor Coco, Raphael Dumps and Jongho Lee*

* CERN summer student
CODEX-b simulation framework

Implemented in DD4hep package
https://dd4hep.web.cern.ch/dd4hep/

- Veto cone
  - Two Pb absorbers
  - Active layer (Si)

- Concrete wall (3.2 m)

- CODEX-b detector

Tested with muon particle gun

By Biplab Dey, Markus Frank, Ben Couturier and Jongho Lee
Minimal geometry for tracking

Face station (6x)
- 6 silicon* layers on each surface
- 4 cm inter layer distance

Inner station (5x)
- 3 silicon* layers on each surface
- 4 cm inter layer distance

* proxy for RPC’s in the simulation
Test on min bias events

Sanity checks

- Most hits from low $e^{-}$/brem
- Mostly muons from $\pi / K$ decays

(with shield removed, no hits with shield present)
Next simulation steps (ongoing)

- Import CODEX-b simulation into LHCb simulation (GAUSS)
- Simulation of background campaign
- Simulation with shield, huge statistics needed
- $B \rightarrow K \ X$ signal sample
- Tracking (almost done)
- Replace Si with RPC modules

For more info, see Biplab’s talk: [https://indico.cern.ch/event/743635/contributions/3151747/attachments/1737333/2810385/Implications_CODEXb_sim_Biplab.pdf](https://indico.cern.ch/event/743635/contributions/3151747/attachments/1737333/2810385/Implications_CODEXb_sim_Biplab.pdf)
Benchmark signal models

Rather than using full models, benchmark according to simplified production portals

Maximum production rate + boost distribution

Aiming for theory paper toward end of the year: 18xx.xxxxx with J. Evans, SK, H. Ramani, D. Robinson

Working on “Physics Beyond Colliders” (PBC) report
Benchmark signal models

Rather than using full models, benchmark according to simplified production portals

Maximum production rate + boost distribution

Production modes:

• Higgs decays: dark photon model, hidden valley models
• Z decays: neutralino’s, inelastic dark matter
• B decays: Higgs mixed scalar, heavy neutral leptons, axion-like particle (ALP)
• D decays: heavy neutral leptons
• QCD hadronization: axion-like particle (ALP)

Aiming for theory paper toward end of the year: 18xx.xxxxx with J. Evans, SK, H. Ramani, D. Robinson

Working on “Physics Beyond Colliders” (PBC) report
For low masses, ATLAS/CMS are background limited, CODEX-b and MATHUSLA have an edge.
Exotic Z decays

R-parity violating neutralino’s

J. C. Helo, M. Hirsch and Z. S. Wang: 1803.02212
Exotic B decays

Model: \[ \mathcal{L} \supset \mu \varphi H H^\dagger + \frac{\lambda}{2} \varphi^2 H^\dagger H \]

With \( \lambda = 0 \)

Production
Exotic B + Higgs decays

Model: \[ \mathcal{L} \supset \mu \varphi H H^\dagger + \frac{\lambda}{2} \varphi^2 H^\dagger H \]

With \( \lambda = 1.6 \times 10^{-3} \)
\[ \text{Br}(h \to 2\varphi) \approx 0.01 \]

Production

(FASER reach somewhat underestimated here)
Exotic D decays: Heavy neutral leptons

- **Production:** any SM decay with neutrinos (c, b, τ, W & Z decays)

- **Decay:** Mix back to off-shell SM neutrino (N→3ν, N→ℓ hadrons, N→νℓℓ)

Example: $U_{eN}$

$|U_{μN}|^2$ and $|U_{τN}|^2$ in the back-up material

18xx.xxxx: J. Evans, SK, H. Ramani D. Robinson

See also: Heo, Hirsch, Wang: 1803.02212
Moving forward

Ongoing work on theory side: finishing benchmark models
(back-up slides, see also upcoming PBC report)

Ongoing work on the LHCb side

- Background data analysis
- Detector design and simulation
- On track for a detector paper in Spring 2019
Team

Theory: J. Evans, SK, M. Papucci, H. Ramani, D. Robinson

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

Support from LHCb computing & simulation:
M. Frank, B. Couturier, D. Muller, G. Corti

Still growing, and we welcome new collaborators!
Back-up
More general models

Reach

Complementary reach compared to main LHCb detector

(Branching ratio to muons is irrelevant for CODEX-b)
Hidden glueballs (Neutral Naturalness)

Production: exotic Higgs decay

Decay: through Higgs mixing:

Lifetime very strong function of glueball mass: $cT \sim m_0^{-7}$

ATLAS / CMS pay double penalty at low mass:

- Backgrounds go up
- Requiring a second displaced vertex kills the signal rate
Heavy neutral leptons

- **Production:** any SM decay with neutrinos (c, b, τ, W & Z decays)

- **Decay:** Mix back to off-shell SM neutrino (N→3ν, N→ℓ hadrons, N→νℓℓ)

Example: $U_{μN}$
Heavy neutral leptons

- **Production:** any SM decay with neutrinos (c, b, τ, W & Z decays)
- **Decay:** Mix back to off-shell SM neutrino (N→3ν, N→ℓ hadrons, N→νℓ ℓ)

Example: UTN

18xx.xxxxx: J. Evans, SK, M. Papucci, H. Ramani D. Robinson

see also: Heo, Hirsch, Wang: 1803.02212