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AN Underground Belayed In-Shaft search experiment

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Why long-lived particles?

Collider experiments are designed to search for prompt decays. New particles with microscopic lifetimes are strongly constrained by LHC searches.
Why long-lived particles?

Very long-lived particles are constrained by astrophysical observables and beam-dump experiments.
Why long-lived particles?

For particles with “intermediate lifetimes” there exists a sensitivity gap.

Constrains new Physics with sizable interactions with the SM

Constrains new Physics with no (tiny) interactions with the SM (almost stable)
Why long-lived particles?

This is not a small class of exotic theories. Muons are “collider-stable” (as is the $K_L$, $n$).

Constrains new Physics with sizable interactions with the SM

Constrains new Physics with no (tiny) interactions with the SM (almost stable)
There are two different search strategies:

- Search for very weakly coupled light particles with high statistics
- Search for particles in the decays of heavy states (the Higgs, new heavy mediators)

With respect to the LHC this corresponds to two different measurement regions

- Measurements along the beam line
- Measurements orthogonal to the beam line
Where to look for long-lived particles?

Orthogonal

Along the beam line
Where to look for long-lived particles?

Along the beam line orthogonally
Where to look for long-lived particles?

CODEX-b

Gligorov et al 1708.09395

Feng, et al 1710.09387
Where to look for long-lived particles?

- Feng, et al. 1710.09387
- Gligorov et al. 1708.09395
- Chou et al. 1606.06298

**CODEX-b**

Gligorov et al. 1708.09395

Feng, et al. 1710.09387
Where to look for long-lived particles?

We propose to instrument the ATLAS service shaft.

MB, Brandt, Lee, Ohm 1909.13022

Chou et al 1606.06298

Feng, et al 1710.09387

Gligorov et al 1708.09395

Gligorov et al 1708.09395
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• Existing geometry allows for minimal civil engineering costs

• Projective decay volume optimises acceptance for different lifetimes

Crane can support up to 270 t
Current proposal: Four evenly spaced tracking stations with a cross-sectional area of 230 m\(^2\) each.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Time resolution</td>
<td>$\delta t \lesssim 0.5$ ns</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>$\delta \alpha \lesssim 0.01$ rad</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>$\delta x, \delta z \lesssim 0.5$ cm</td>
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<tr>
<td>Per-layer hit efficiency</td>
<td>$\varepsilon \gtrsim 98%$</td>
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• Resistive Plate Chamber technology; ANUBIS performance specifications met by ATLAS BIS-78 prototype (to be installed in ongoing upgrade): triplet of layers with 0.4 ns time resolution, 0.1 cm spatial resolution

• $2.3 \times 10^3$ m$^3$ instrumented volume at 3.1k€/m$^2$ results in costs of 7.2 M€ (total < 10M€, scales with m$^2$). Each tracking station weighs 230 m$^2 \times 51$ kg/m$^2 \sim 30$ tons
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It should be possible to dramatically reduce backgrounds. The ATLAS detector serves

• as a passive shield (the calorimeters account for ~10 nuclear interaction length)

• and as an active veto. High-\(p_T\) neutral particles typically come with energetic jets.

Additional shielding is provided by several meters of rock between the interaction point and the tracking stations - useful as control region. Cosmic backgrounds can be vetoed using timing and directional requirements.
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Sensitivity study for exotic Higgs decays

\[ \mathcal{L} = \lambda s^2 H^\dagger H \quad h \rightarrow ss, s \rightarrow \text{SM SM} \]

ATLAS searched for displaced vertices in the muon spectrometer.

ATLAS 1811.07370
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Sensitivity study for exotic Higgs decays

\[ \mathcal{L} = \lambda s^2 H^\dagger H \quad h \rightarrow ss, s \rightarrow \text{SM SM} \]

We simulated the signal with madgraph and require the LLPs to penetrate at least 1 (2) tracking stations.

We consider an optimistic scenario (requiring 4+ events- similar to MATHUSLA) and a conservative scenario (requiring 50+ events- similar to ATLAS MS measurement).
Sensitivity study for exotic Higgs decays

\[ \mathcal{L} = \lambda s^2 H^\dagger H \quad h \rightarrow ss, s \rightarrow \text{SM SM} \]

- The MATHUSLA estimate assumes 200x200x20m^3 decay volume
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Sensitivity study for exotic Higgs decays

\[ \mathcal{L} = \lambda s^2 H^\dagger H \quad h \rightarrow ss, s \rightarrow \text{SM SM} \]

- The MATHUSLA estimate assumes 200x200x20m^3 decay volume
Conclusions

• **AN Underground Belayed In-Shaft** search experiment is a cost-effective (< 10M€) alternative to optimise the LHC reach searching for LLPs produced orthogonal to the beam direction.

• The existing geometry and infrastructure minimises civil engineering.

• ANUBIS physics reach is comparable to CODEX-b and MATHUSLA.

• We propose to construct two 1x1m2 prototypes to be suspended at the top and bottom of the PX14 shaft during Run III.