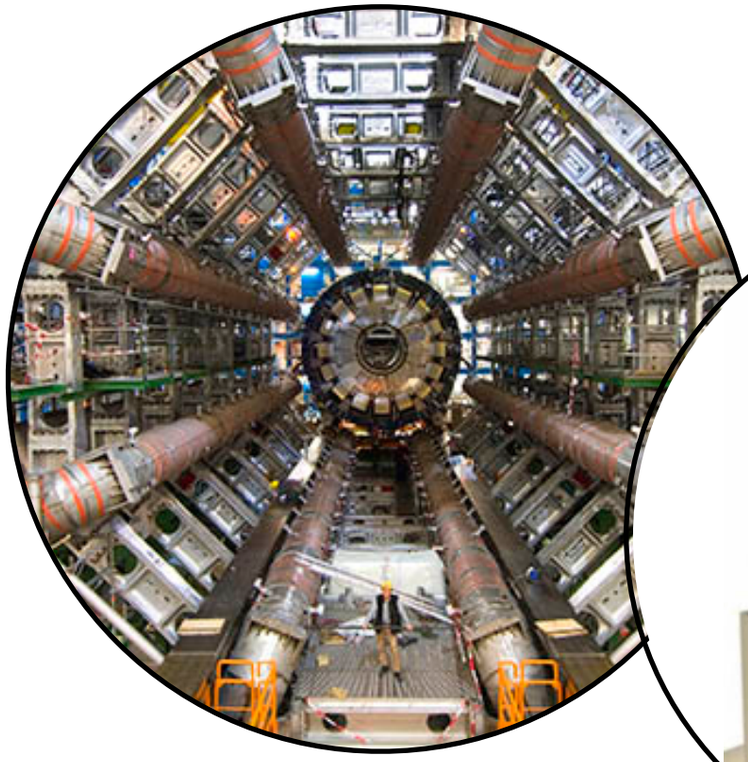

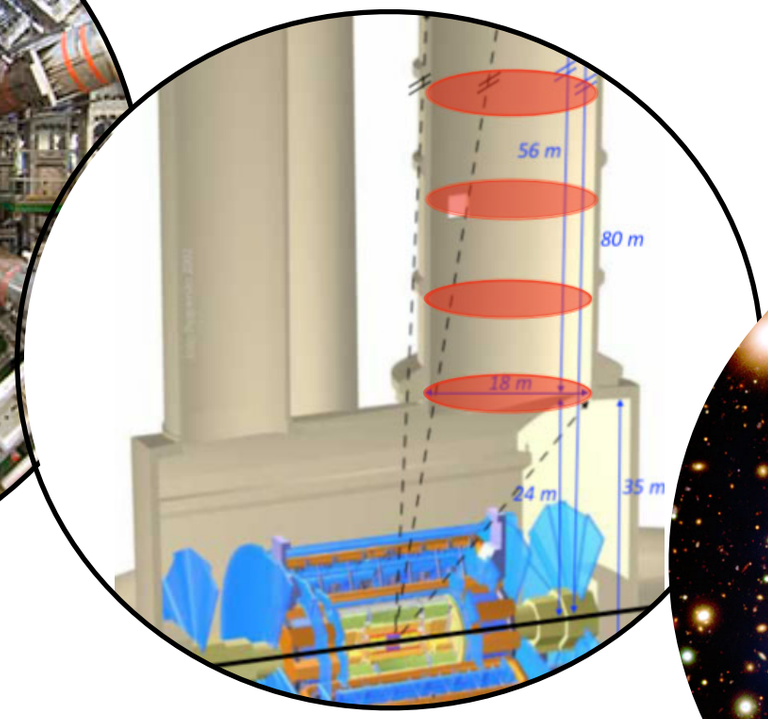

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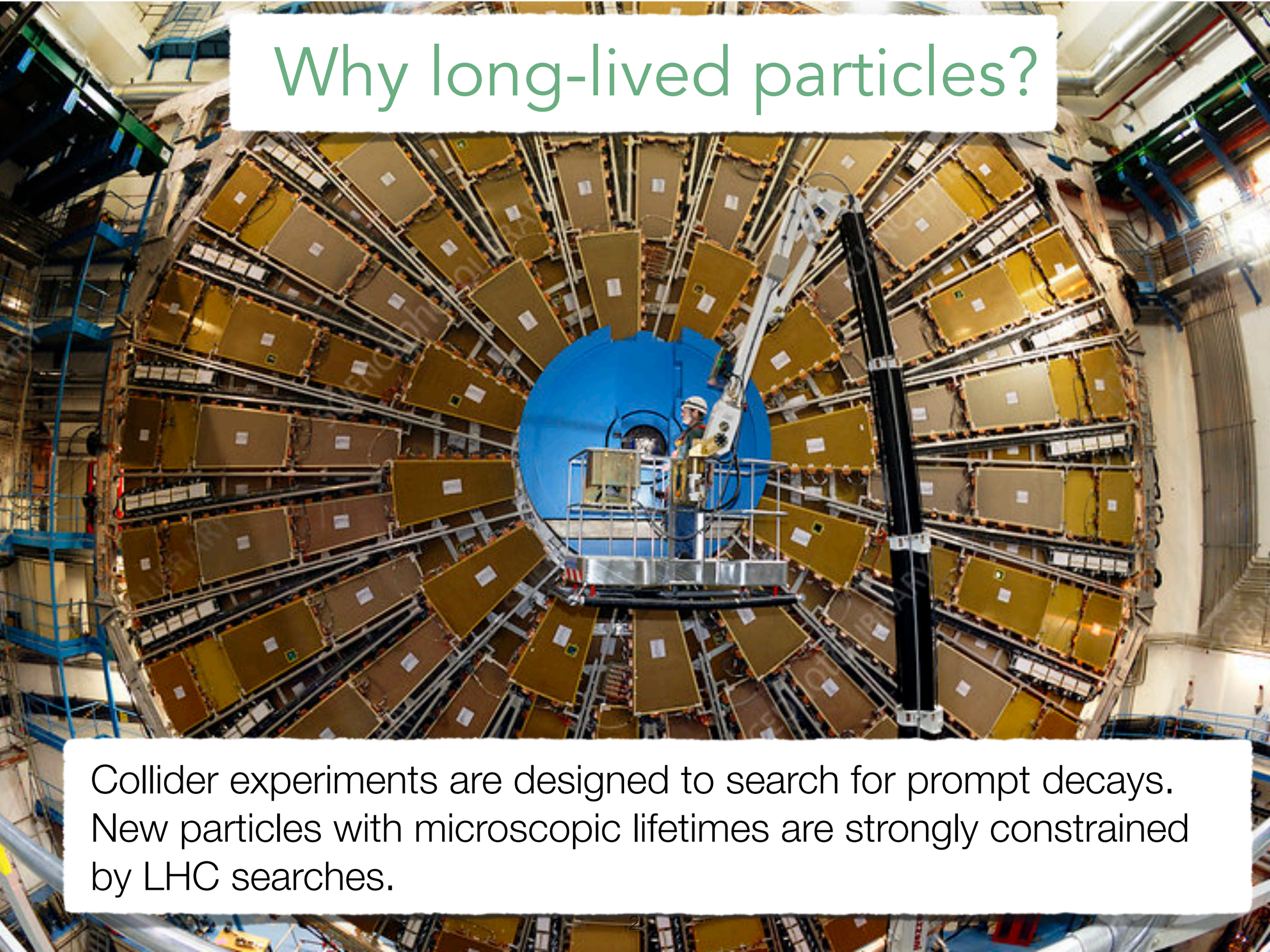
AN Underground **B**elayed **I**n-**S**haft search experiment

Martin Bauer • Oleg Brandt • Lawrence Lee • Christian Ohm

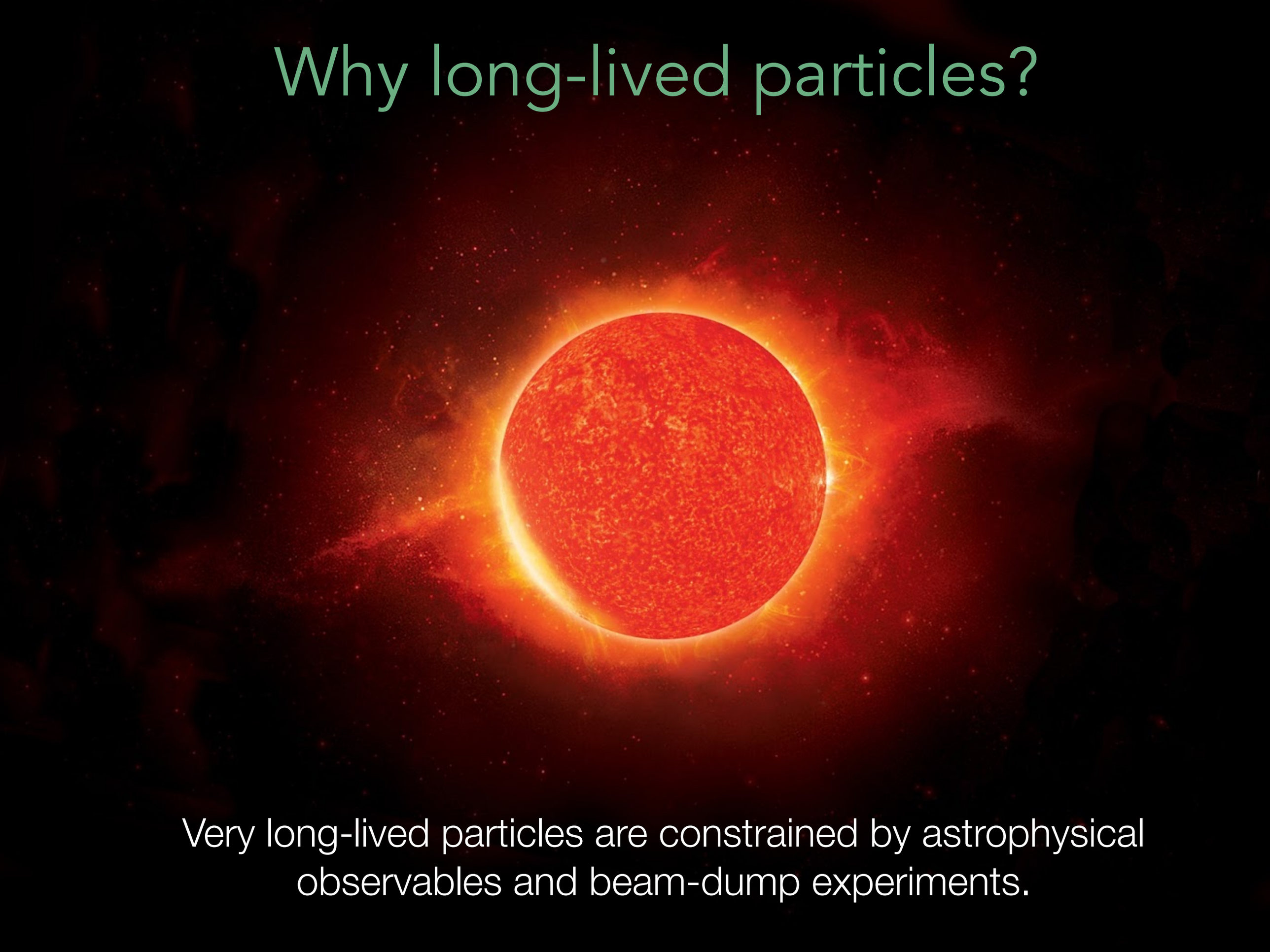
SHiP collaboration meeting 30.10.2019

Why long-lived particles?



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

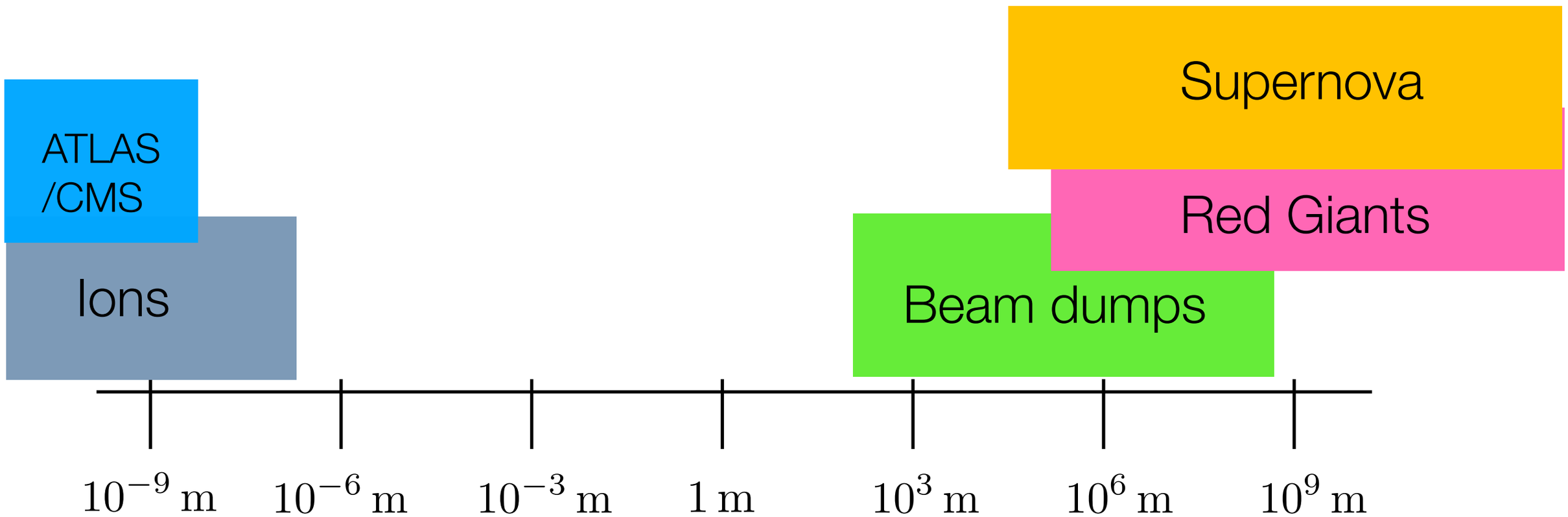
Why long-lived particles?



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

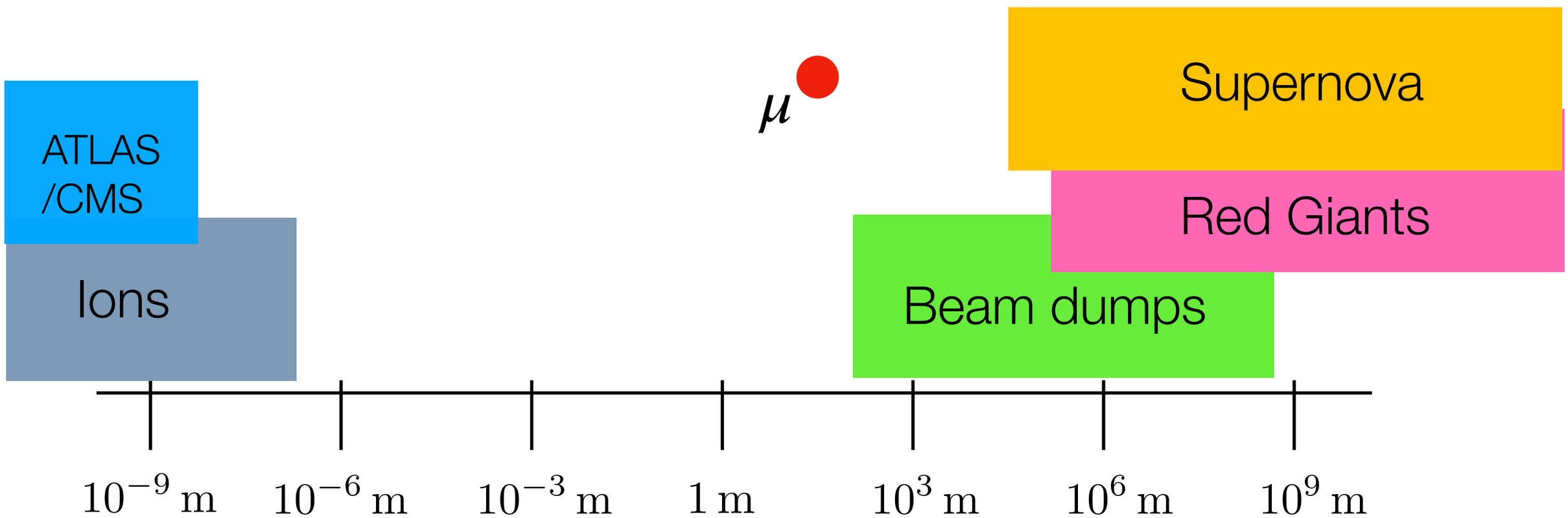


Constrains new Physics with sizable interactions with the SM

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)

Where to look for long-lived particles?

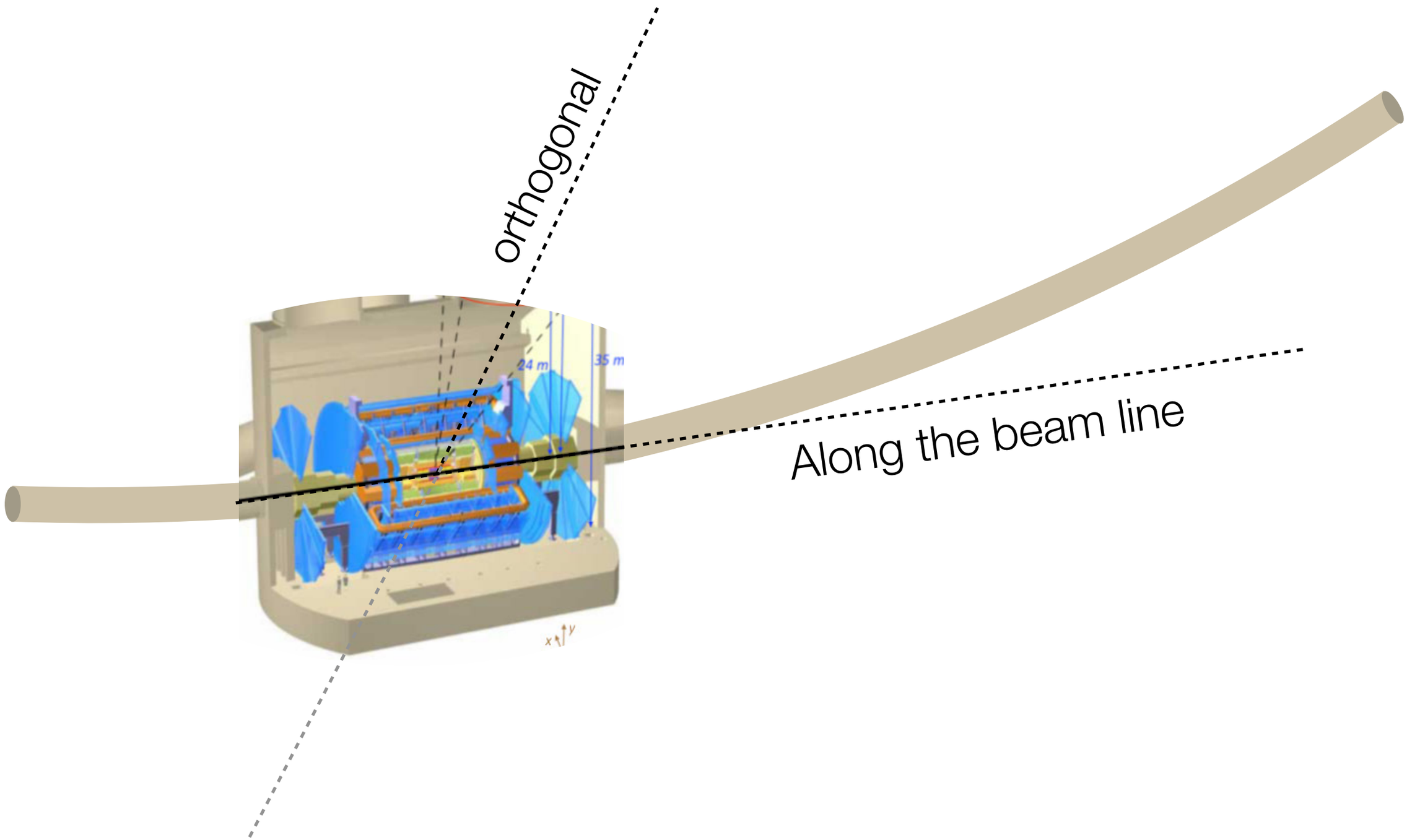
There are two different search strategies:

- 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?



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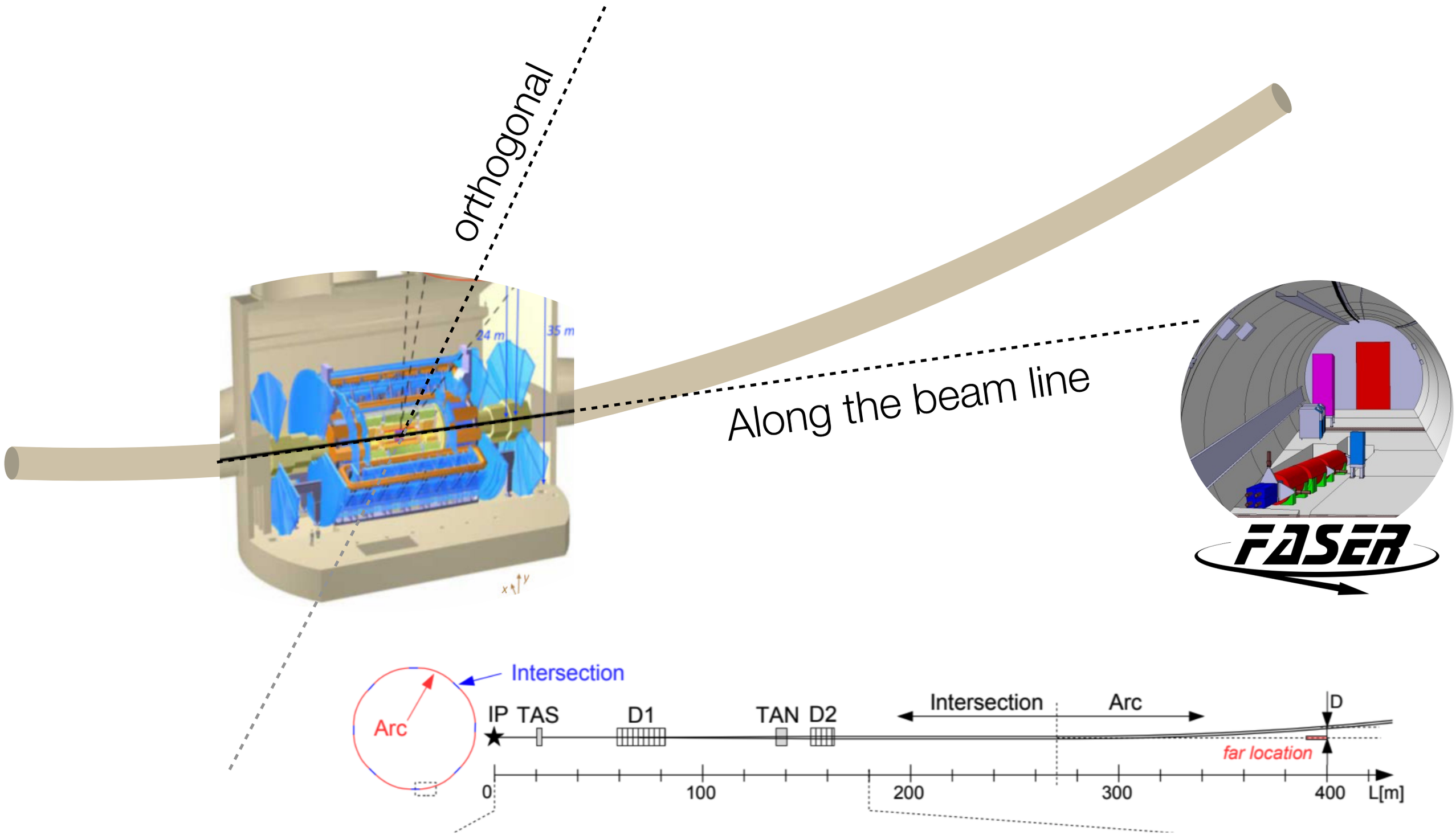
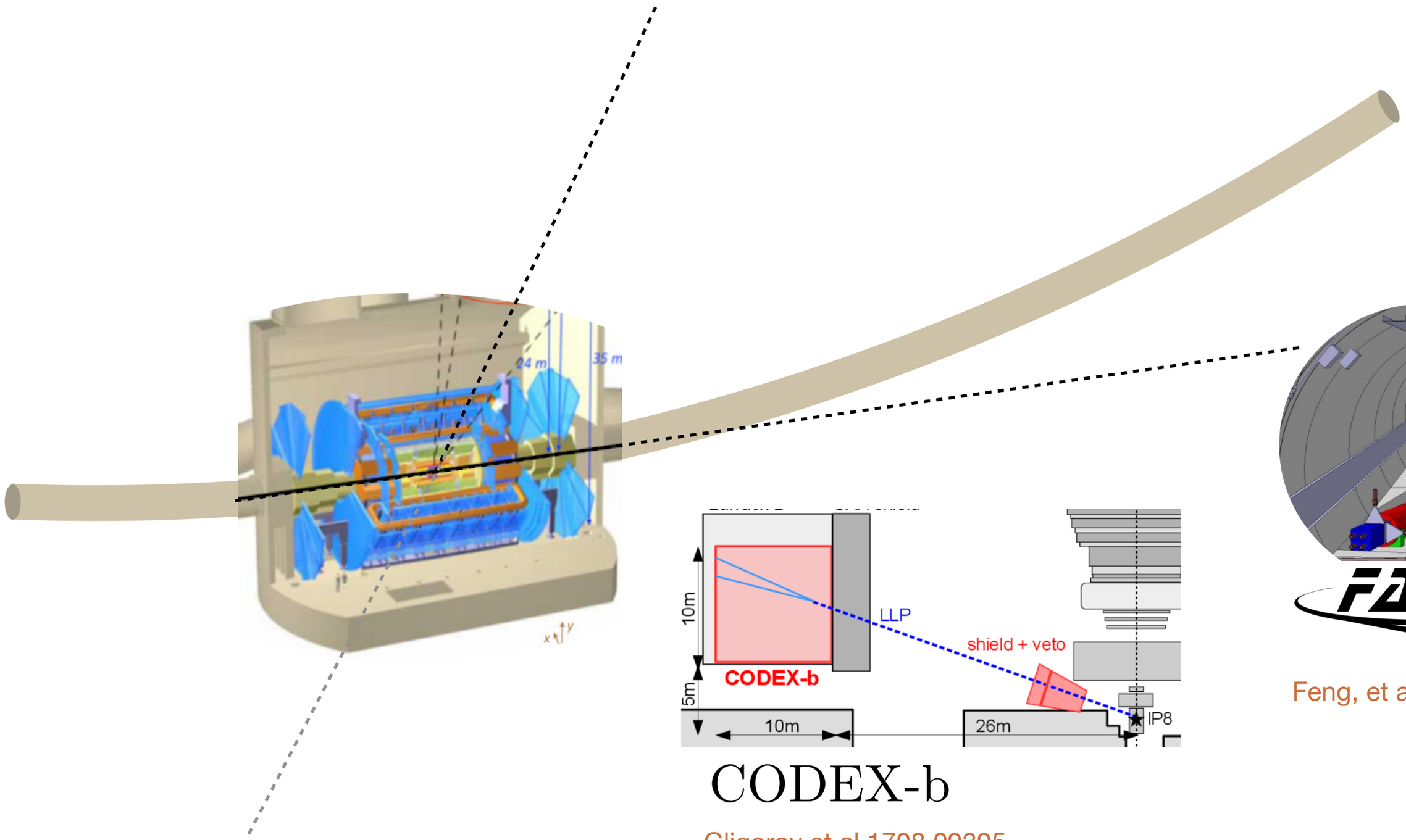
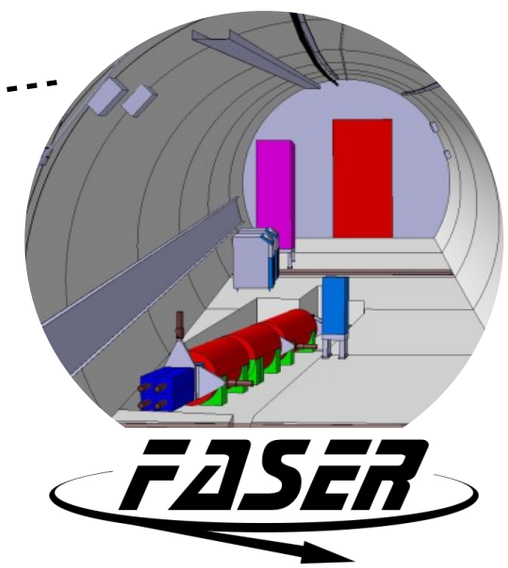


Where to look for long-lived particles?



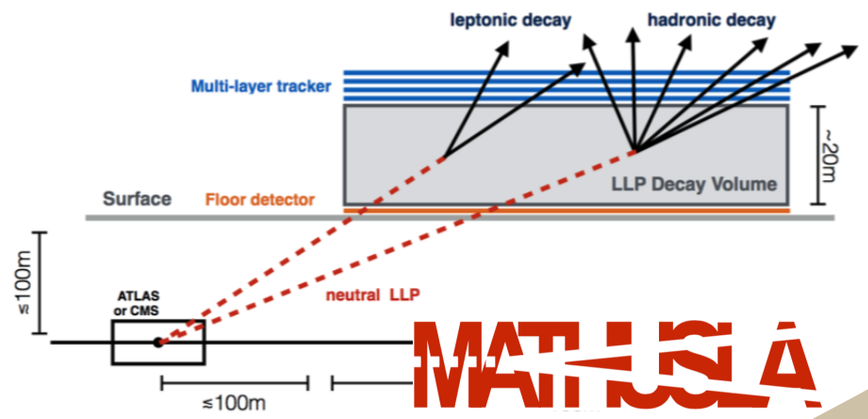
CODEX-b

Gligorov et al 1708.09395

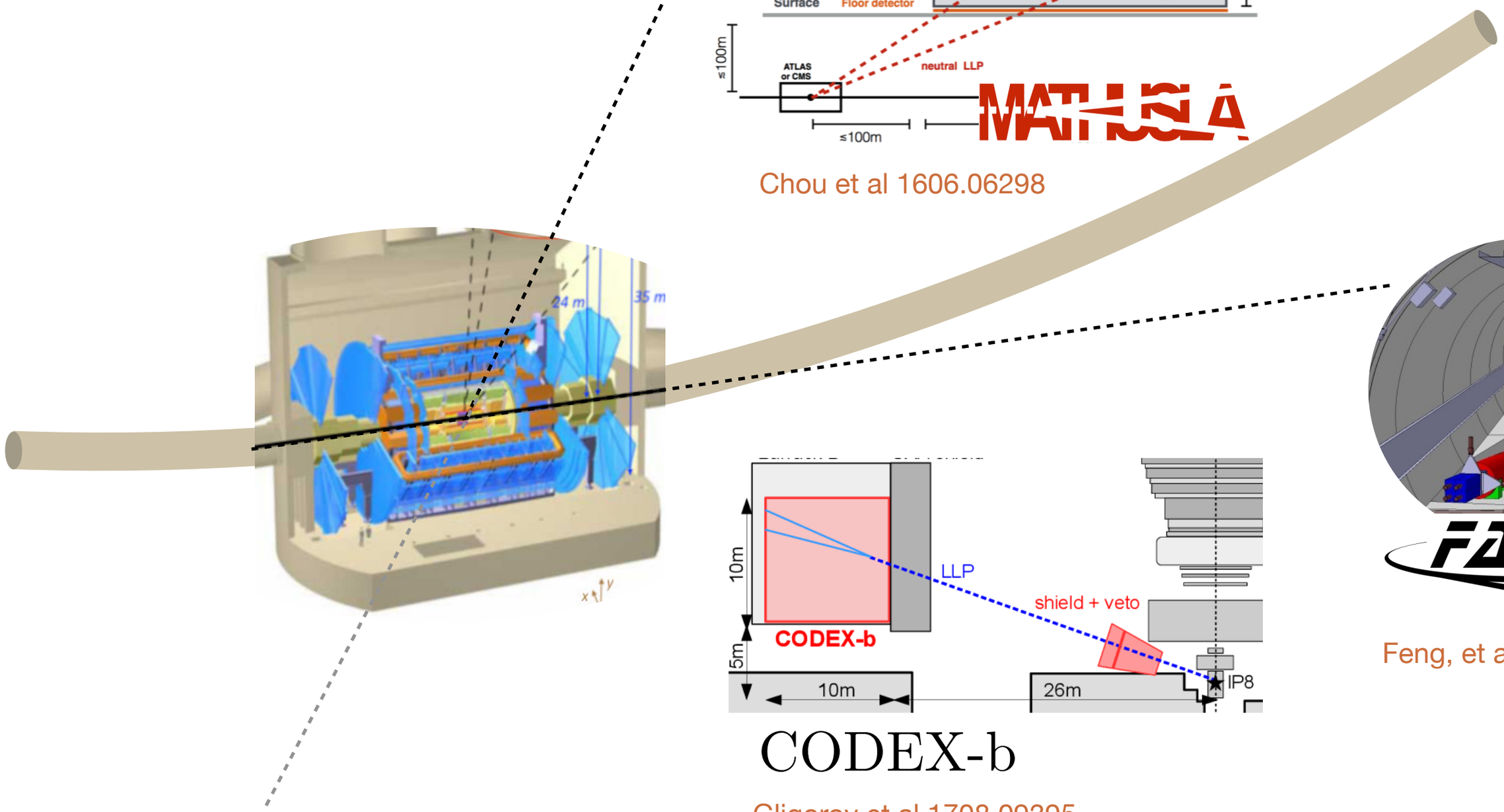


Feng, et al 1710.09387

Where to look for long-lived particles?

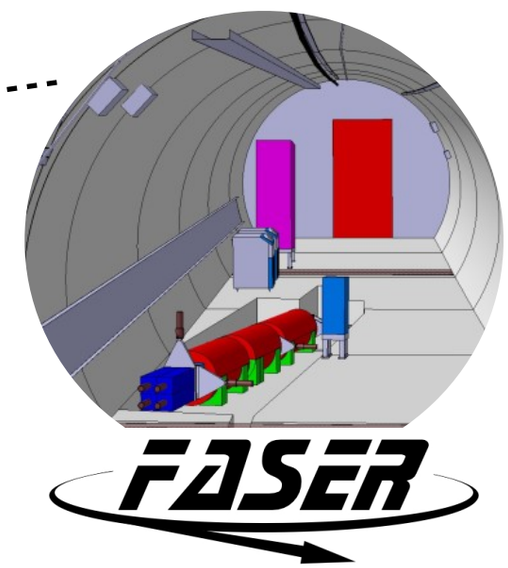


Chou et al 1606.06298



CODEX-b

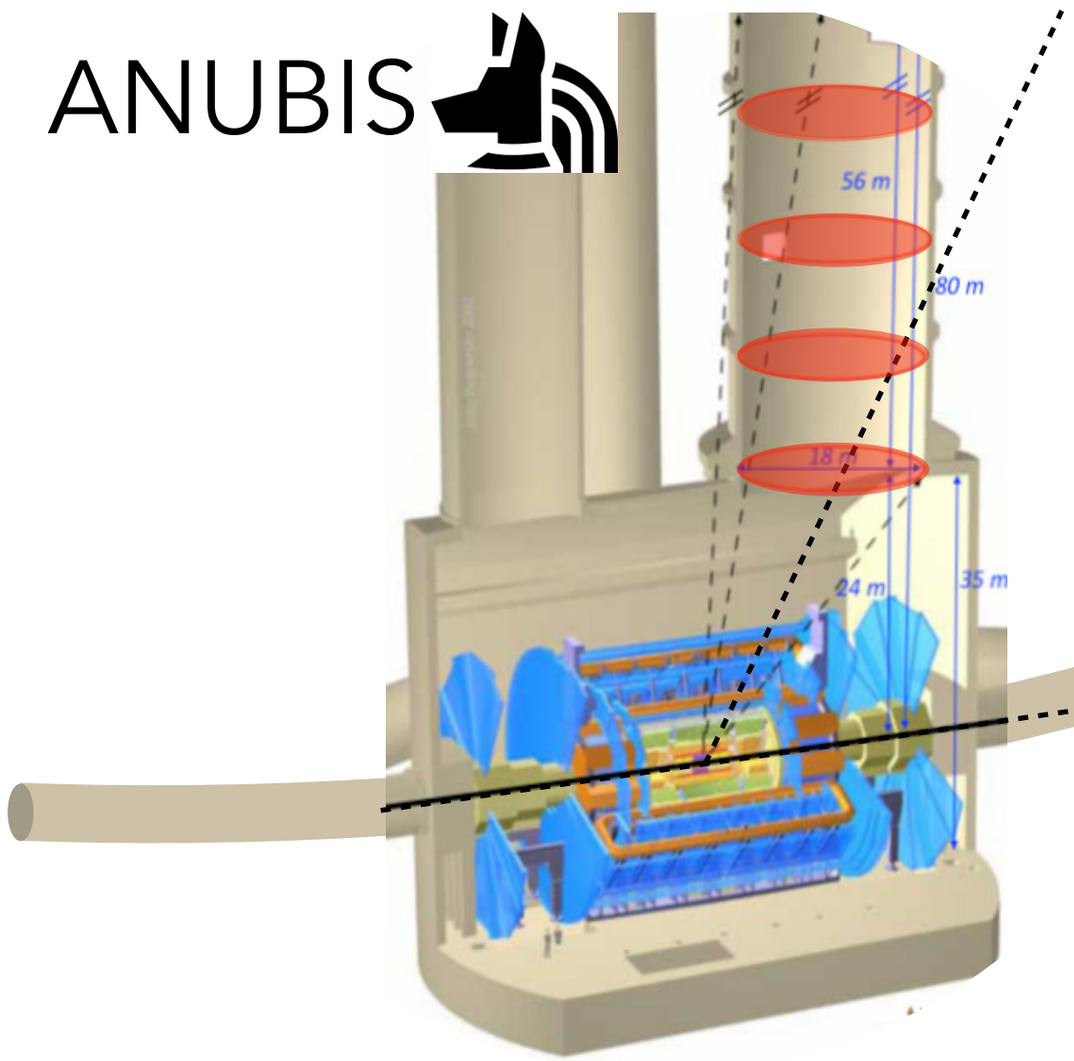
Gligorov et al 1708.09395

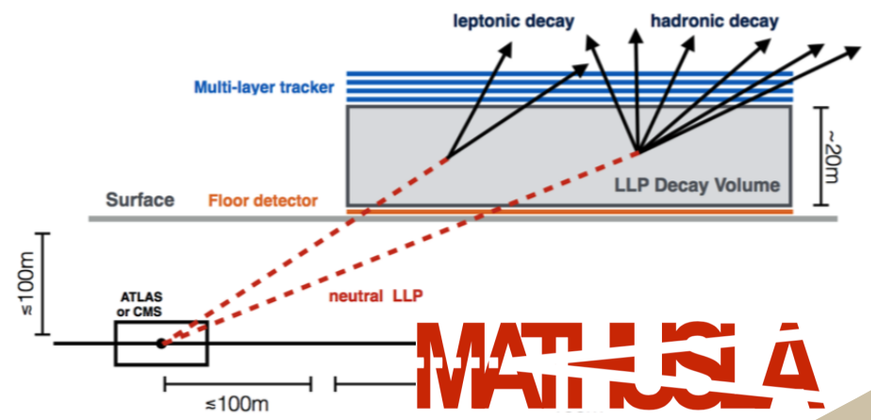


Feng, et al 1710.09387

Where to look for long-lived particles?

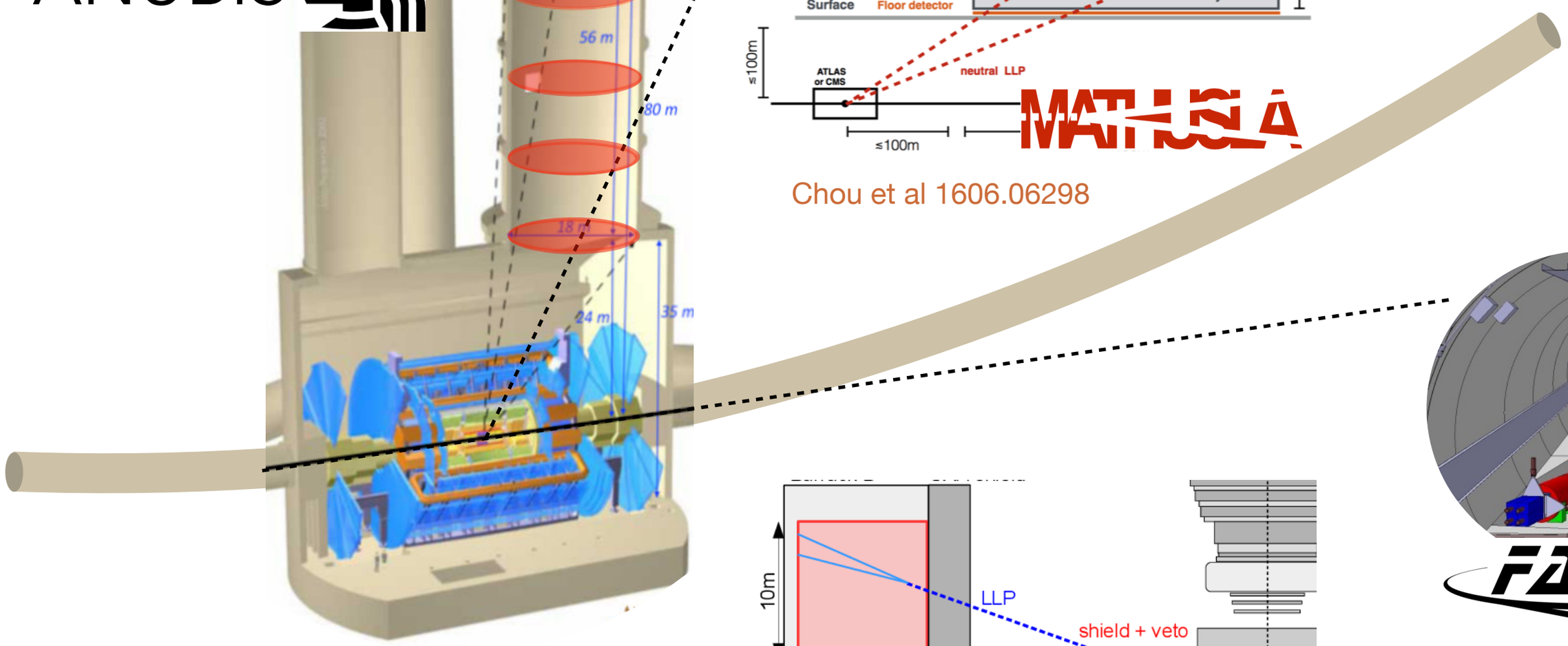
ANUBIS

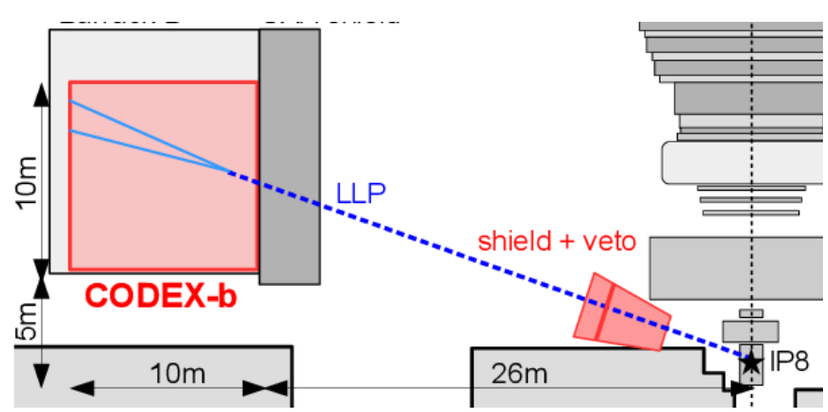




MATHUSLA

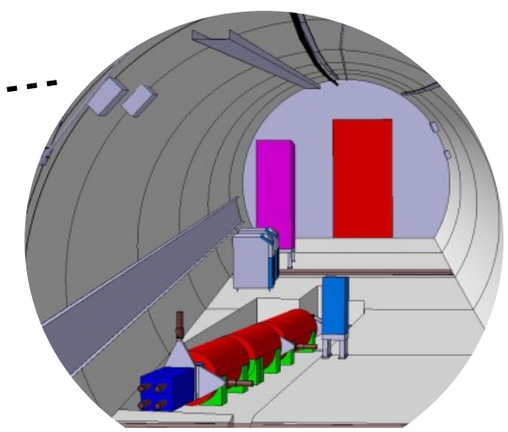
Chou et al 1606.06298





CODEX-b

Gligorov et al 1708.09395



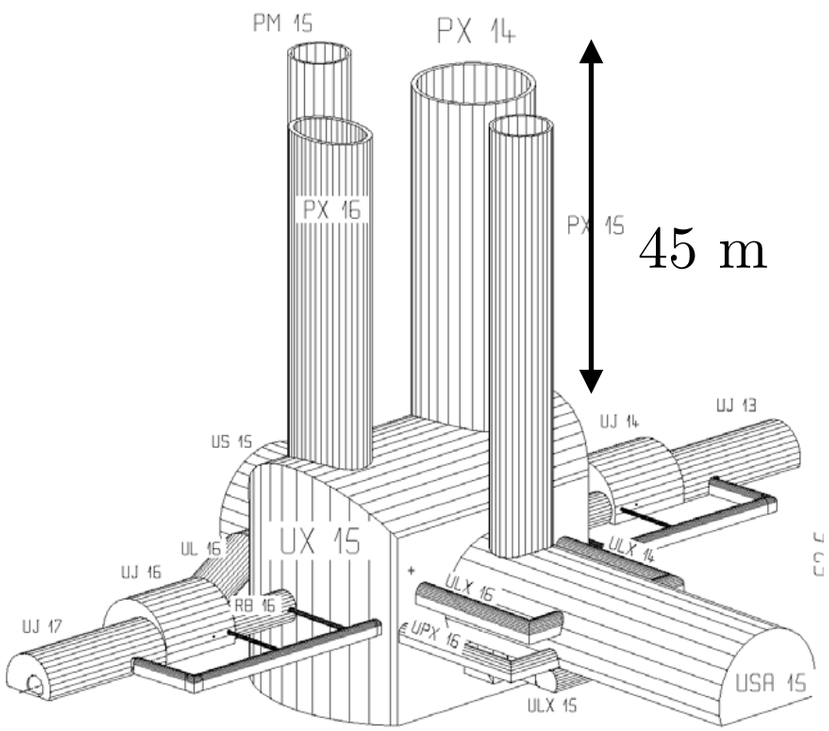
FASER

Feng, et al 1710.09387

We propose to instrument the ATLAS service shaft.

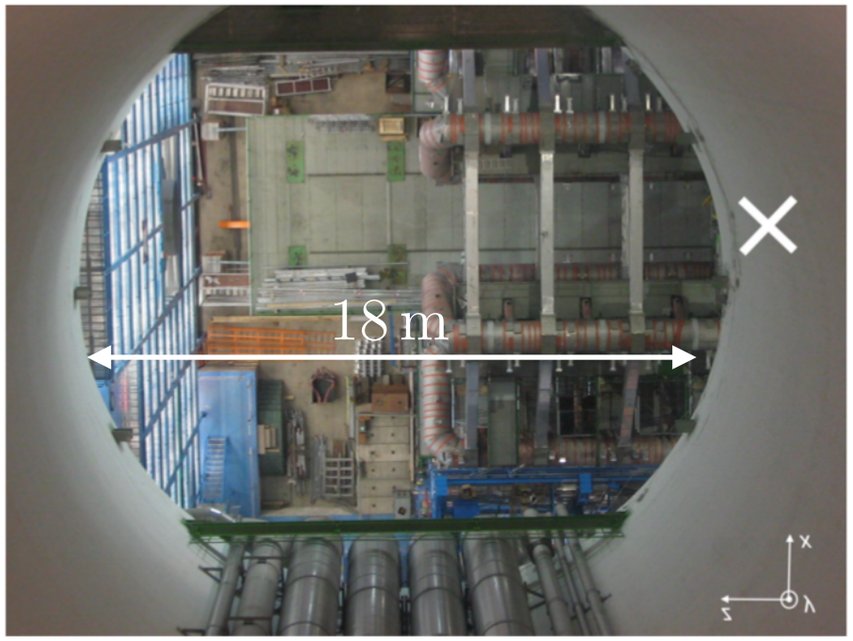
MB, Brandt, Lee, Ohm 1909.13022

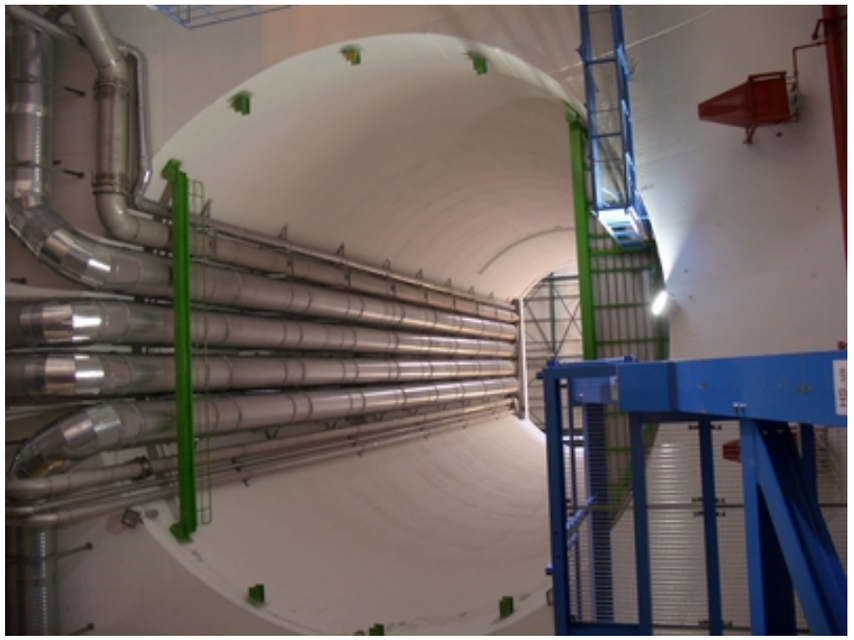
ANUBIS



cranes can support up to 270 t

- Existing geometry allows for minimal civil engineering costs
- projective decay volume optimises acceptance for different lifetimes





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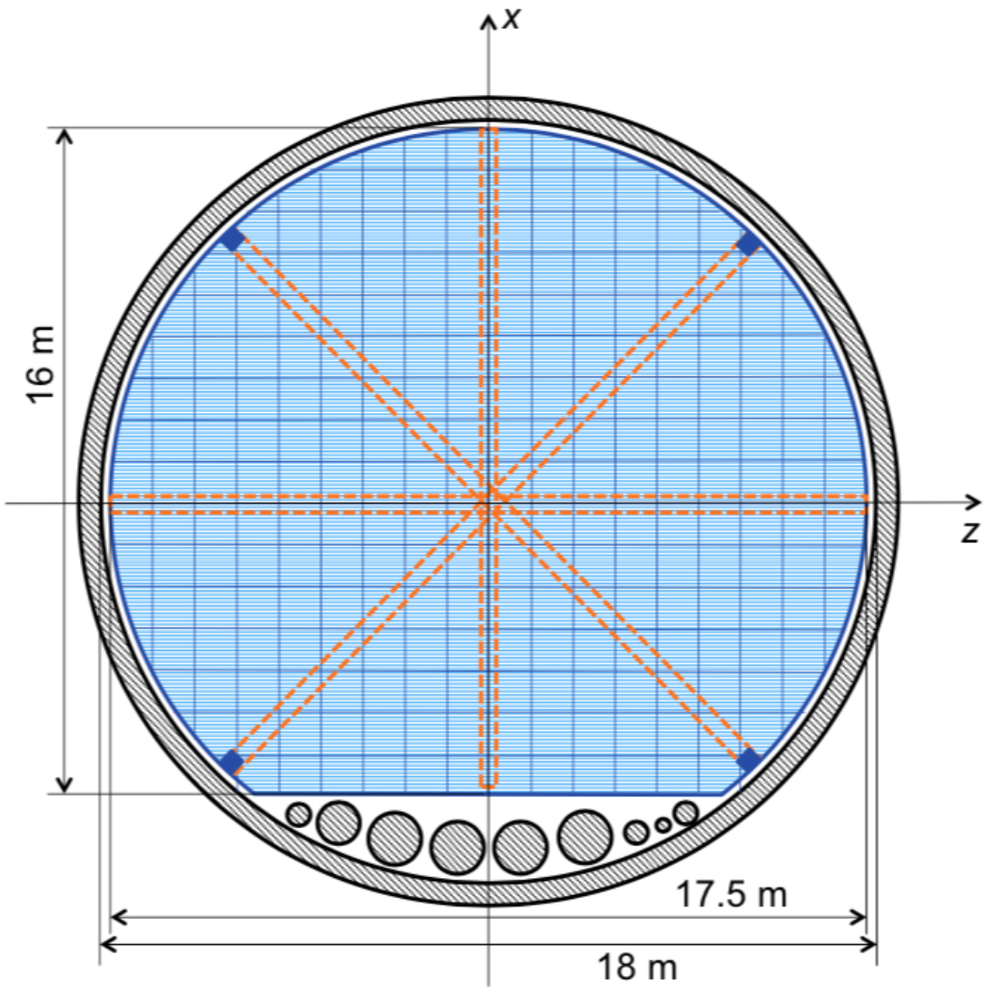

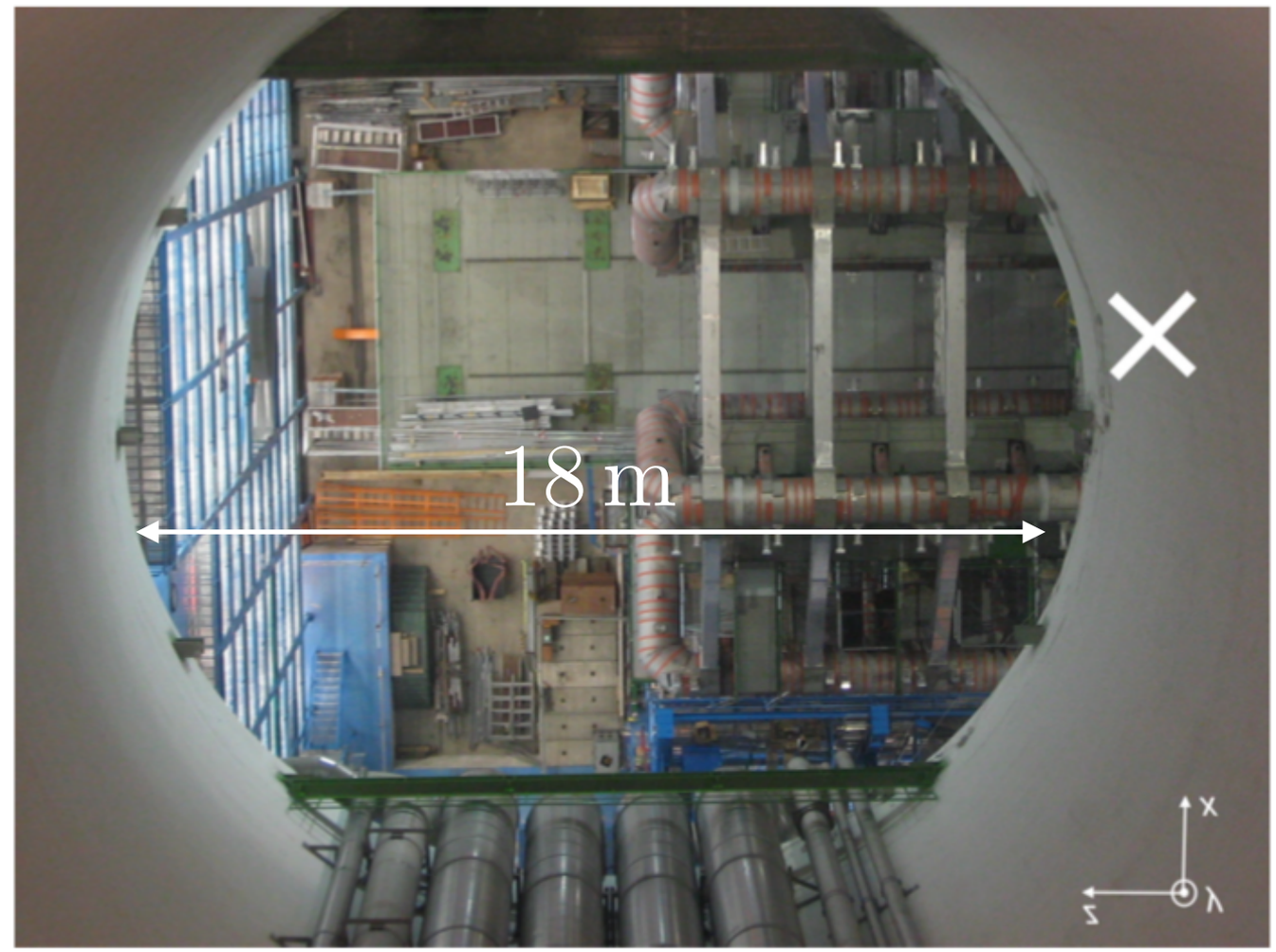

Current proposal: Four evenly spaced tracking stations with a cross-sectional area of 230 m^2 each.

Parameter	Specification
Time resolution	$\delta t \lesssim 0.5$ ns
Angular resolution	$\delta\alpha \lesssim 0.01$ rad
Spatial resolution	$\delta x, \delta z \lesssim 0.5$ cm
Per-layer hit efficiency	$\varepsilon \gtrsim 98\%$

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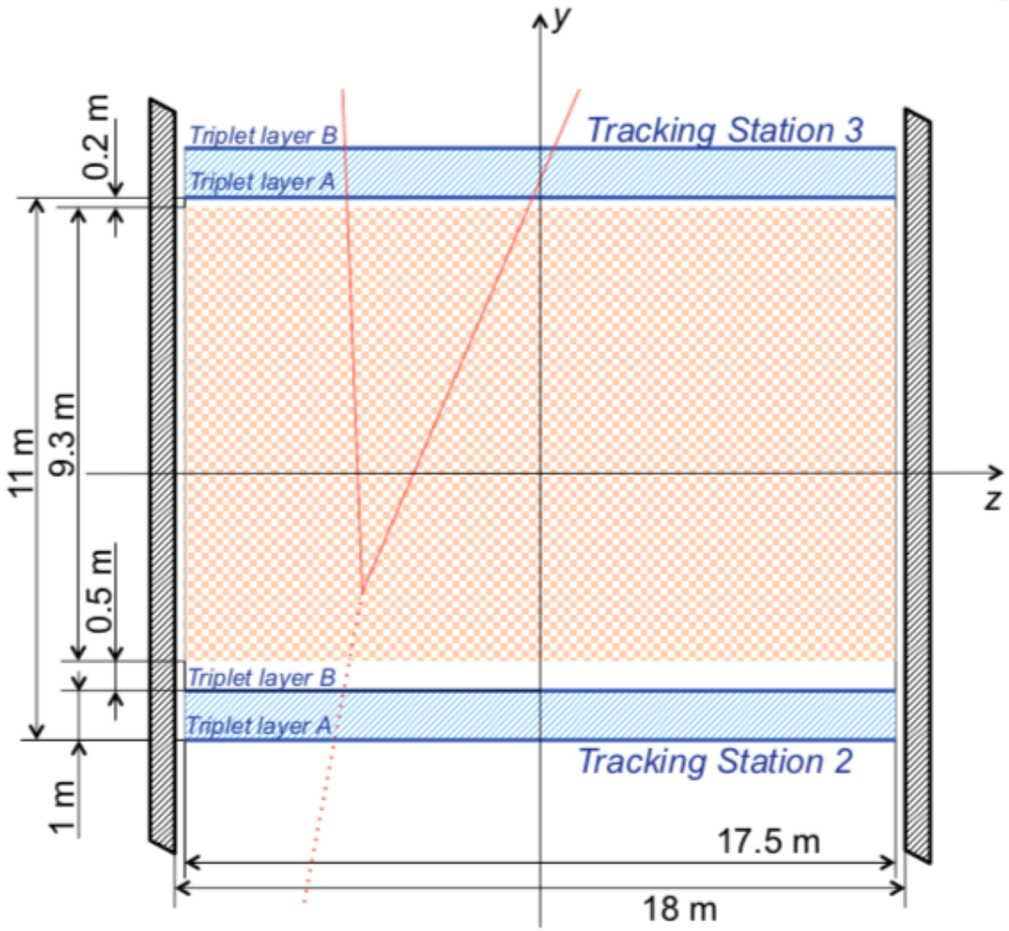

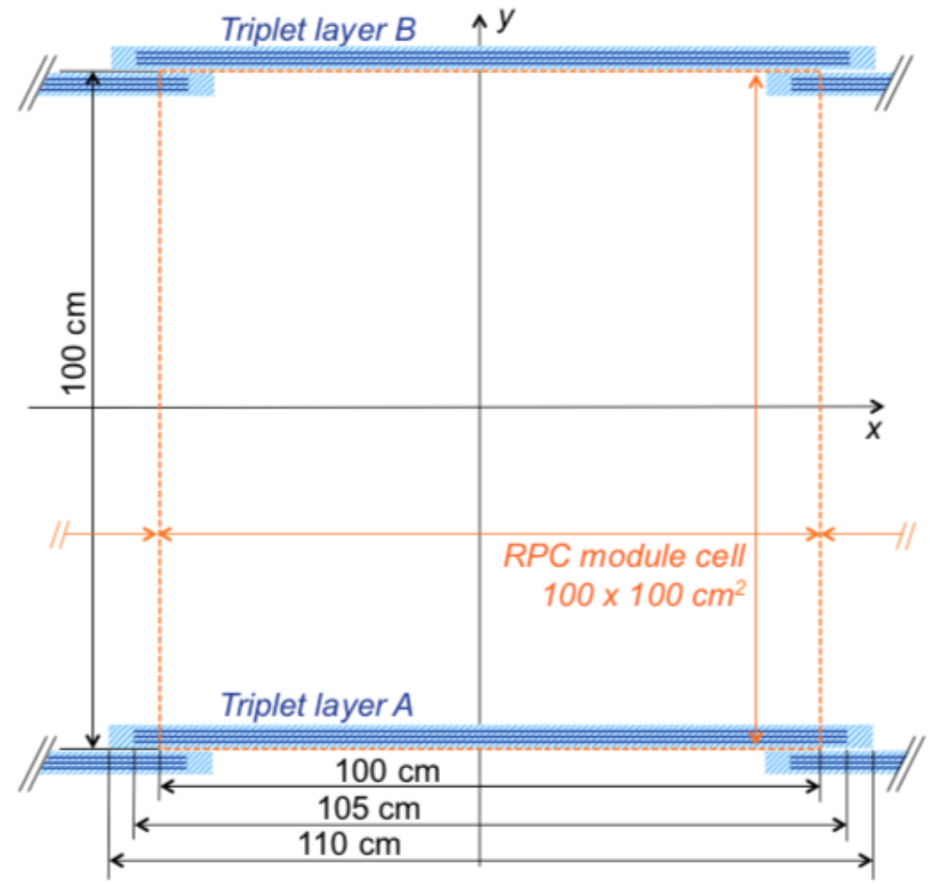

- Resistive Plate Chamber technology; ANUBIS performance specifications met by ATLAS BIS-78 prototype (to be installed in ongoing upgrade): triplet of layers with 0.4 ns time resolution, 0.1 cm spatial resolution

Parameter	Specification
Time resolution	$\delta t \lesssim 0.5$ ns
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Per-layer hit efficiency	$\varepsilon \gtrsim 98\%$

- 2.3×10^3 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 x 51 kg/m^2 ~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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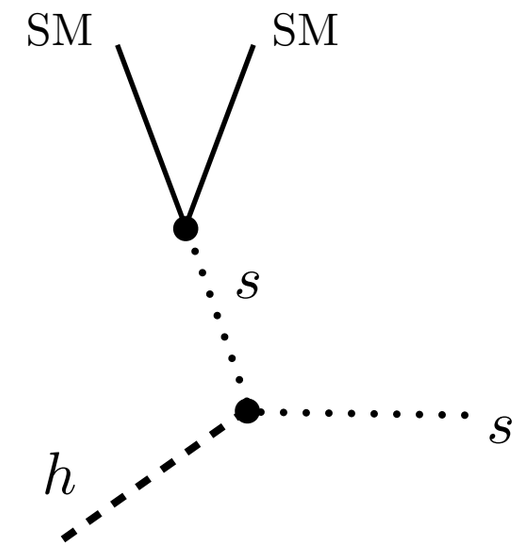
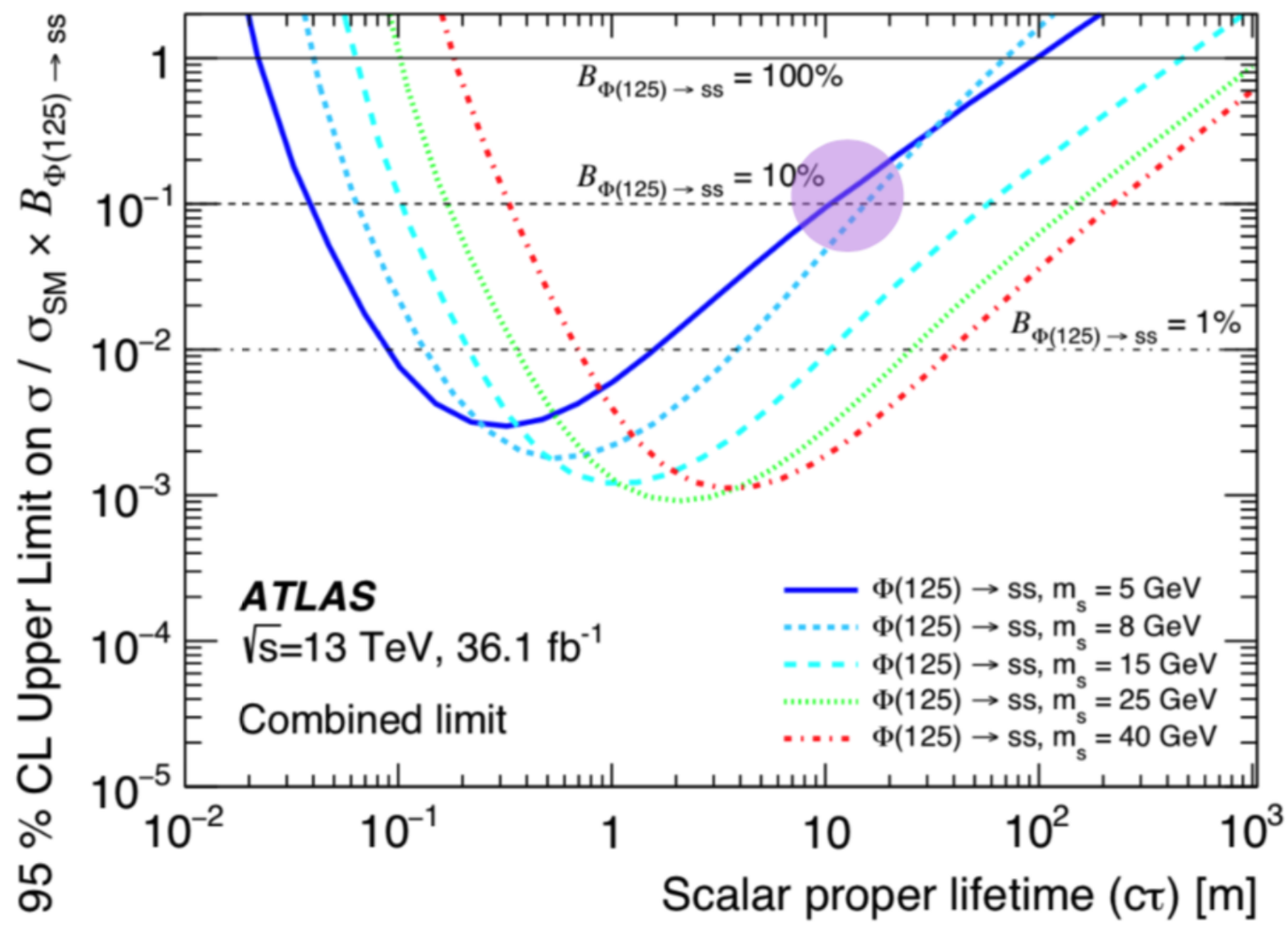


Sensitivity study for exotic Higgs decays

$$\mathcal{L} = \lambda s^2 H^\dagger H \qquad h \to ss, s \to \mathrm{SM}\,\mathrm{SM}$$

ATLAS searched for displaced vertices in the muon spectrometer.

ATLAS 1811.07370



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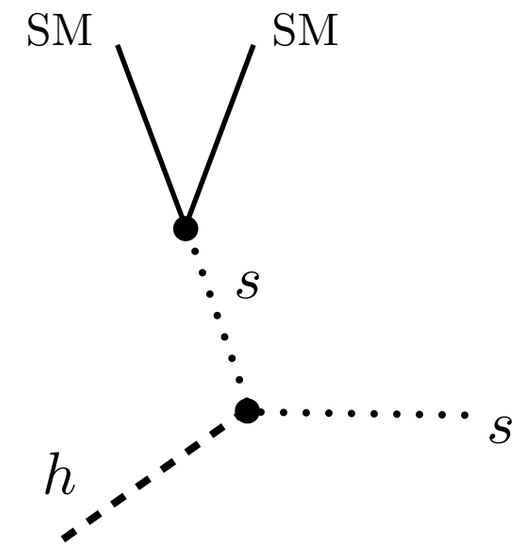

Sensitivity study for exotic Higgs decays

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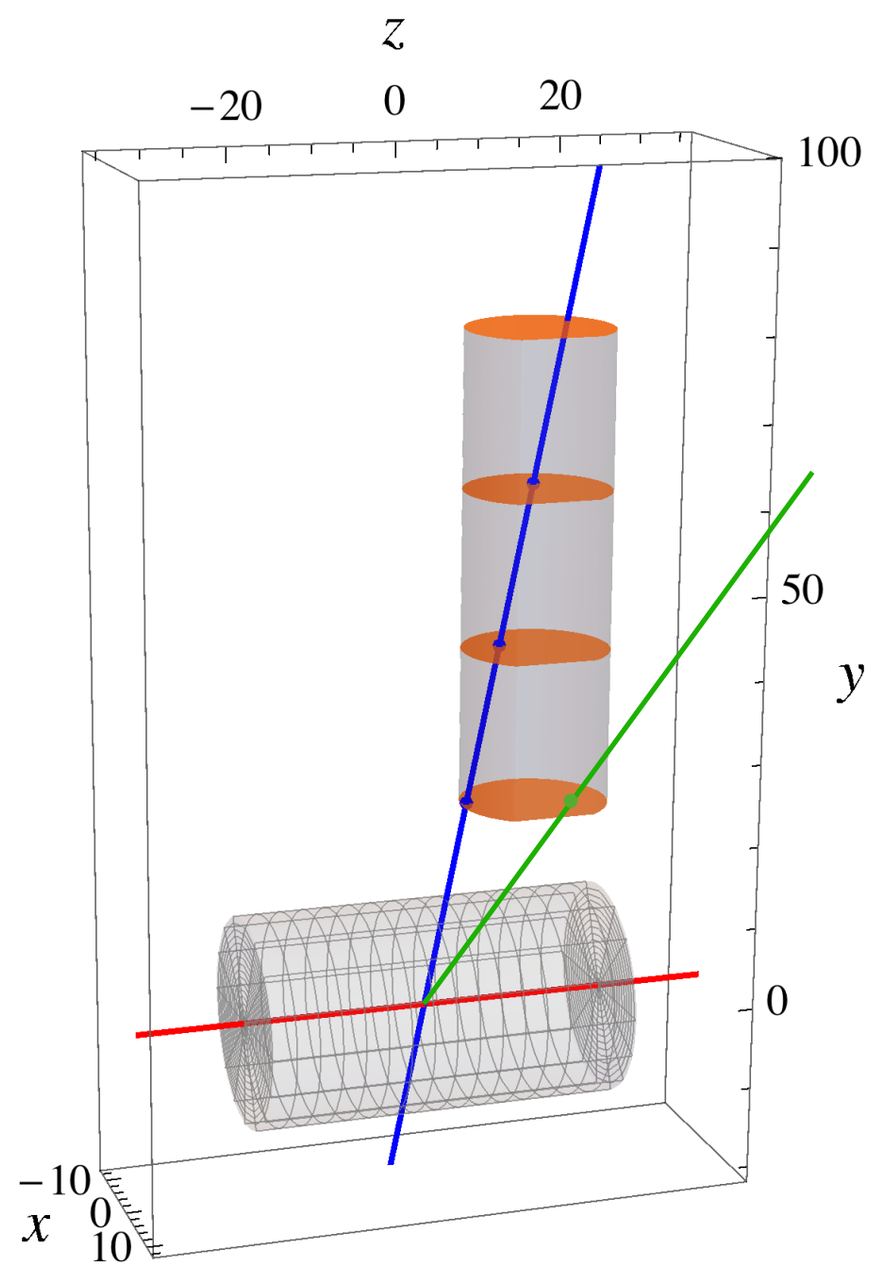
We simulated the signal with madgraph and require the LLPs to penetrate at least 1 (2) tracking stations.

We consider an optimistic scenario (requiring 4+ events- similar to MATHUSLA) and a conservative scenario (requiring 50+ events- similar to ATLAS MS measurement).



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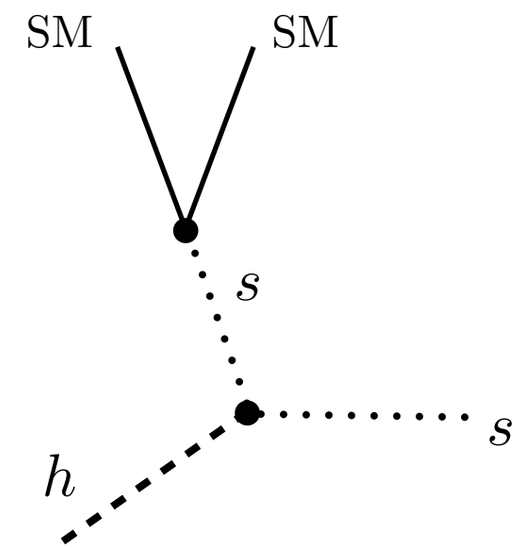

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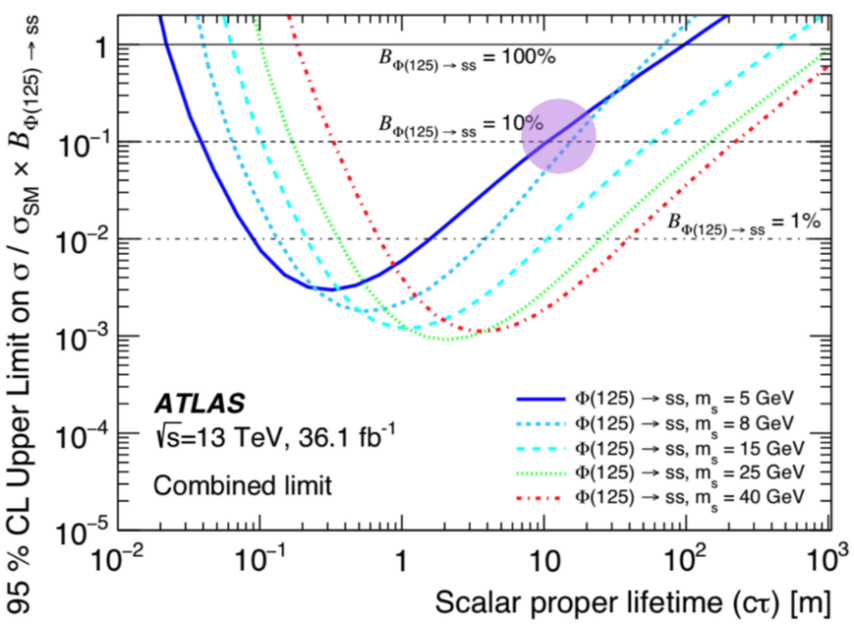
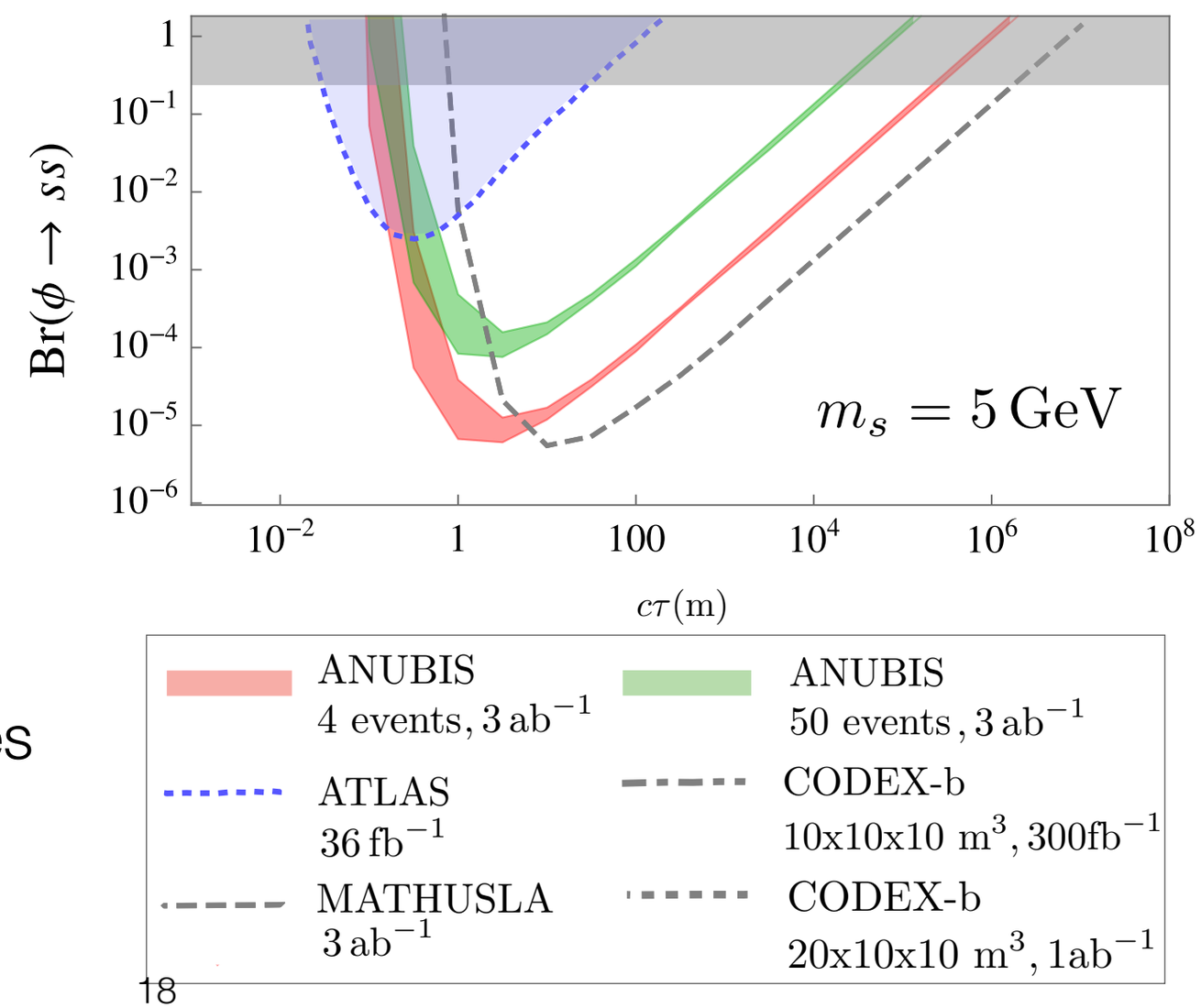
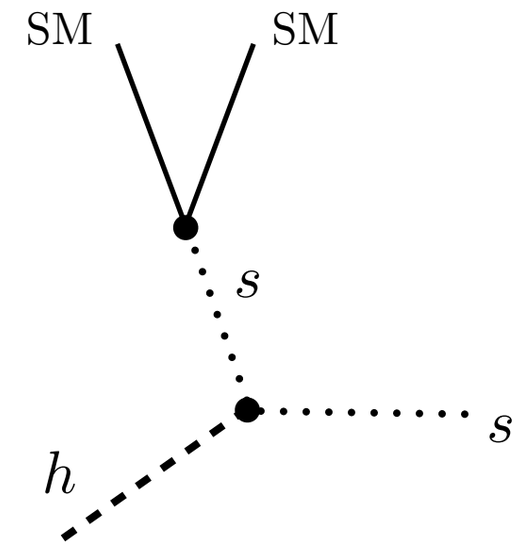




- The MATHUSLA estimate assumes 200x200x20m^3 decay volume

ANUBIS



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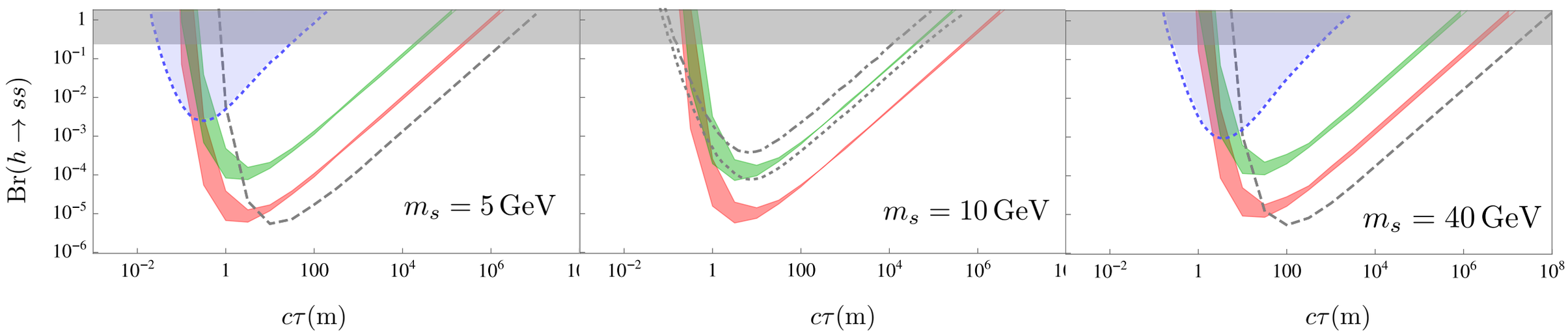

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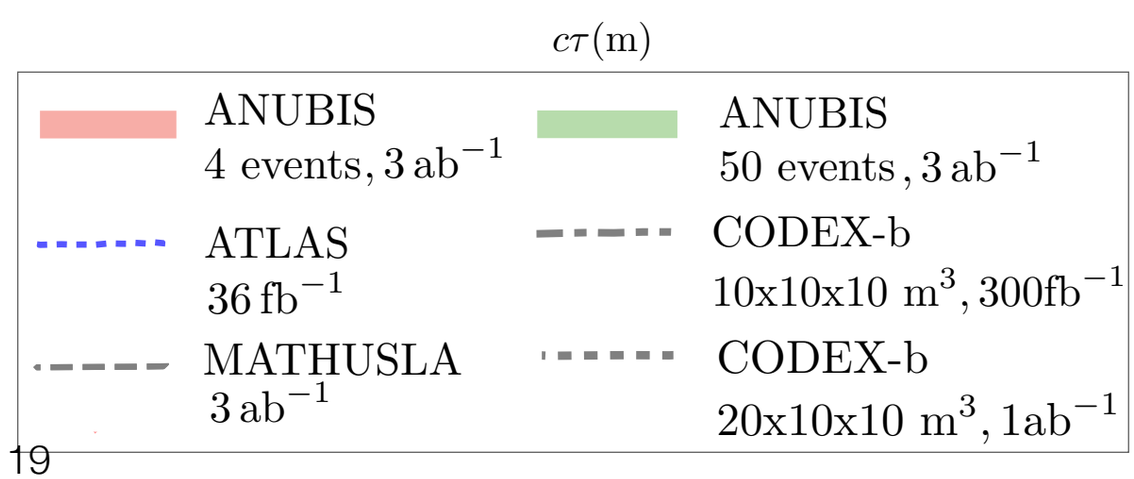

Conclusions

- **AN U**nderground **B**elayed **I**n-**S**haft 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