Sensitivity of the Proposed ANUBIS Experiment to BSM LLPs at the LHC

Toby Satterthwaite on behalf of the ANUBIS Collaboration
SLAC National Accelerator Laboratory
Stanford University

Twelfth Workshop of the LLP Community, 3 November 2022

What changes would you make to increase discovery potential of LLPs?

More time to analyze data?

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A dedicated detector for LLPs?

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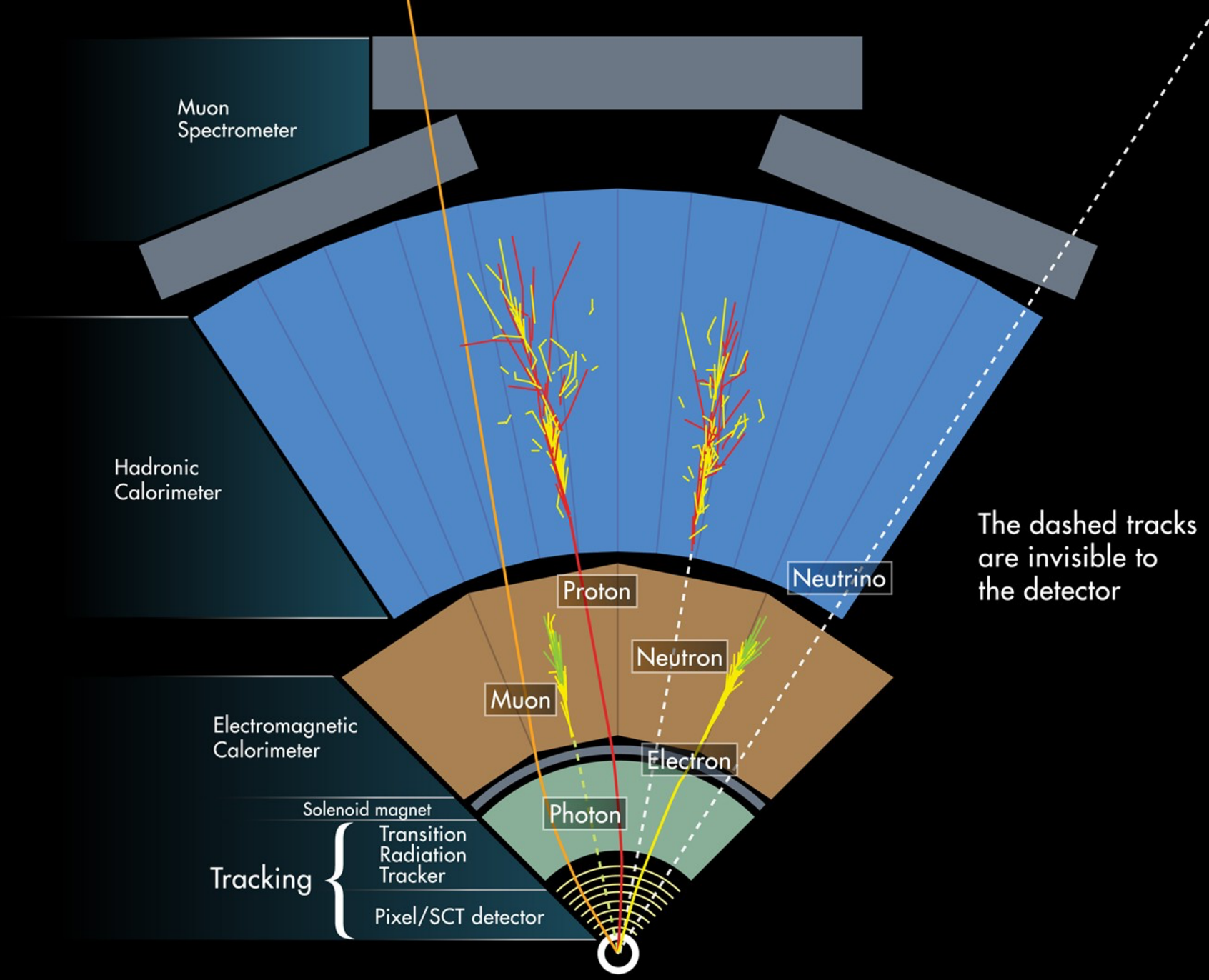
What changes would you make to increase discovery potential of LLPs?

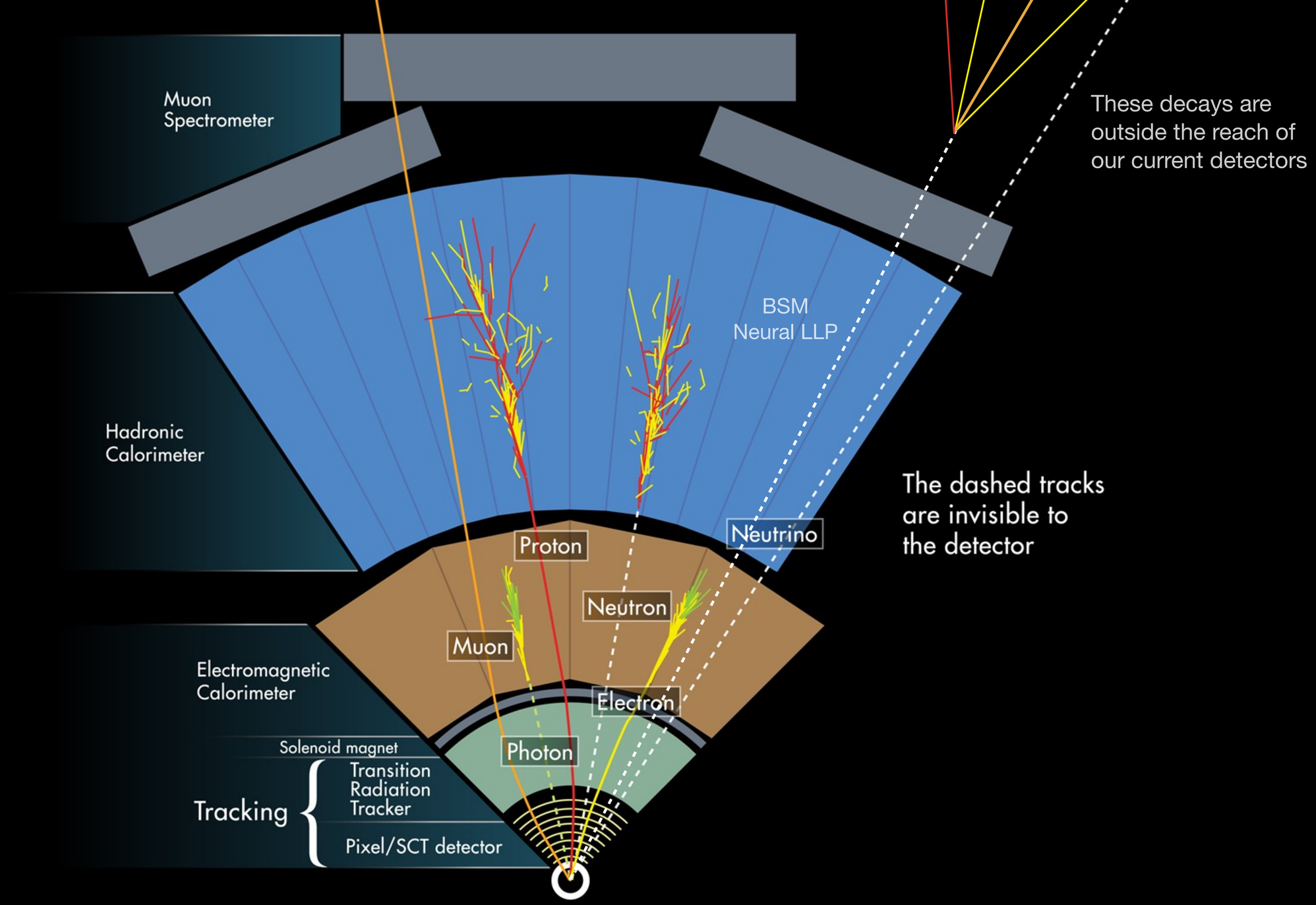
A dedicated detector for LLPs?

Higher branching ratios of production?

We propose a new set of detectors further from the IP to detect decays of neutral LLPs



T. Satterthwaite



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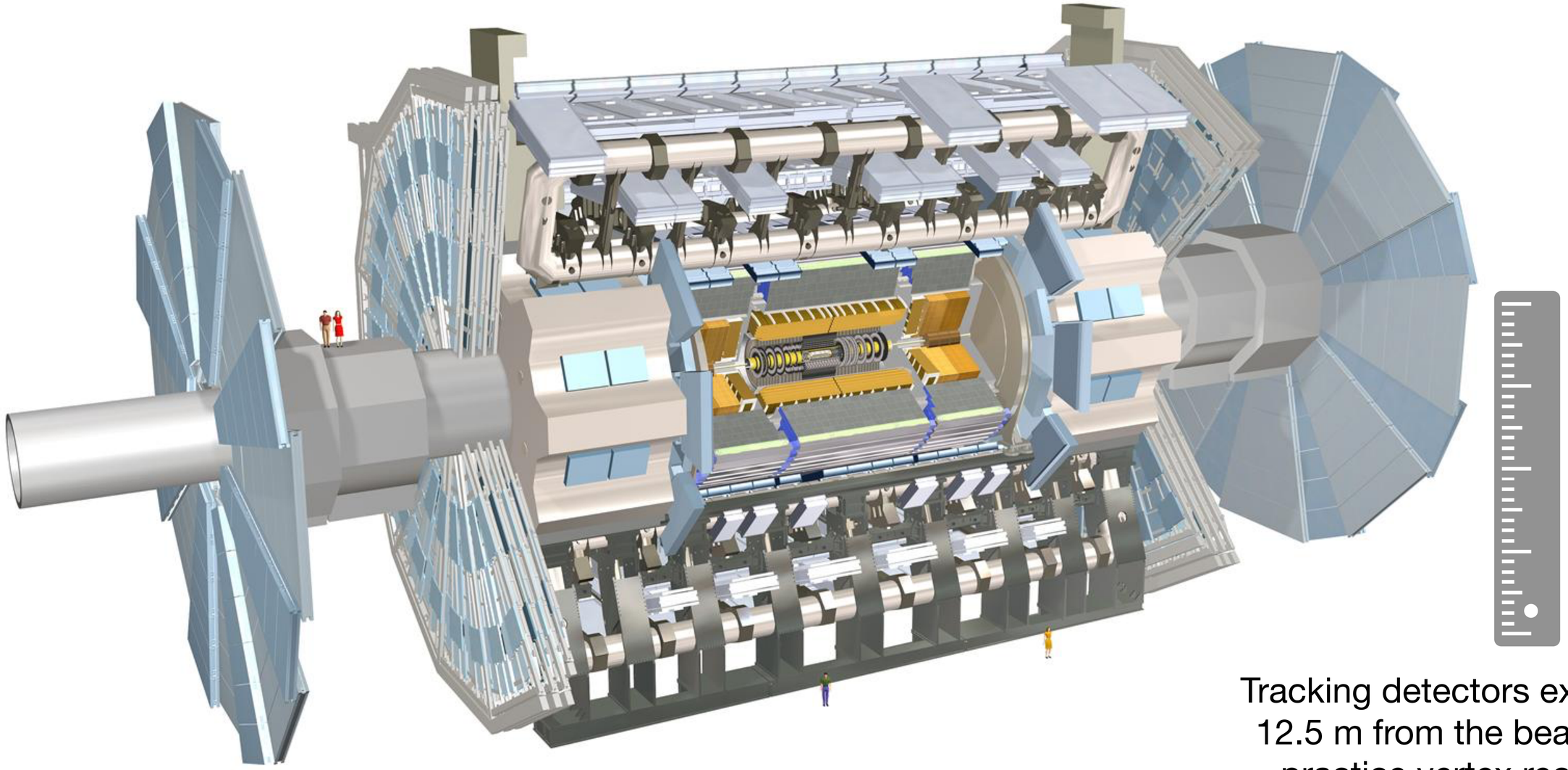
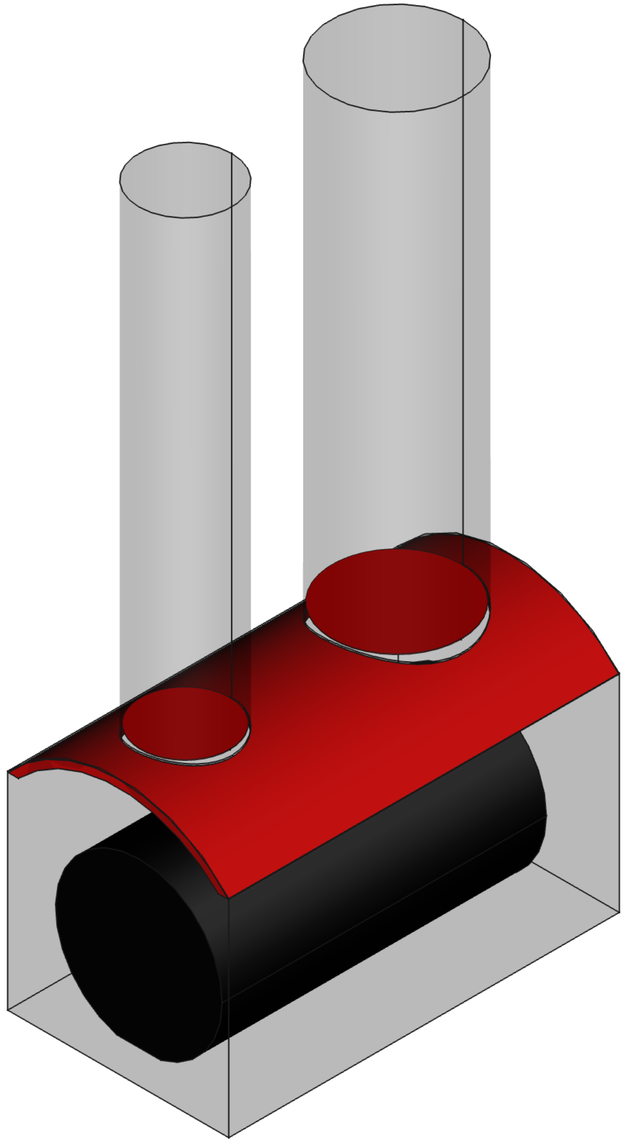


Tracking detectors extend to about 12.5 m from the beam line, but in practice vertex reconstruction efficiency drops off after about 7.5 m*

*Phys. Rev. D 99, 052005



The ANUBIS project proposes installing a new set of RPC detectors along the ceiling of the ATLAS Experiment's cavern

Image courtesy of O. Valentino

The project alternatively proposes installing detectors along the PX14 service shaft

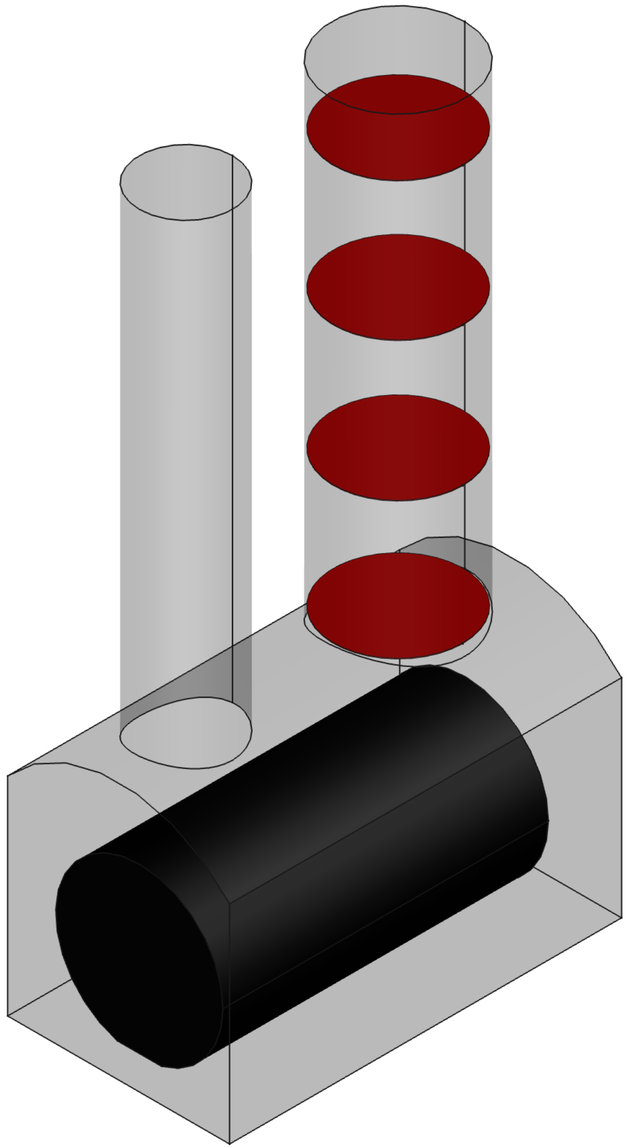


Image courtesy of O. Valentino

Outline

Signal at ANUBIS

How sensitive would ANUBIS be to decays of BSM LLPs?

How does this compare to existing and approved future detectors?

Background at ANUBIS

What sources of background could be expected at ANUBIS?

How can our prototype detector help understand this background?

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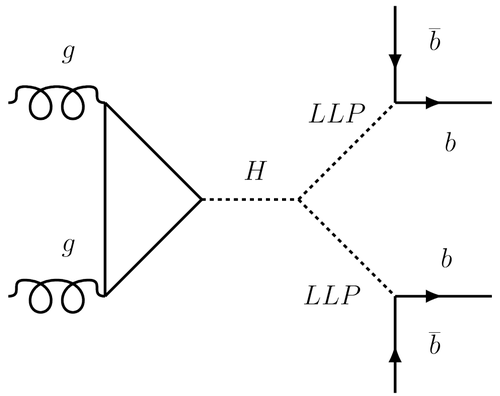
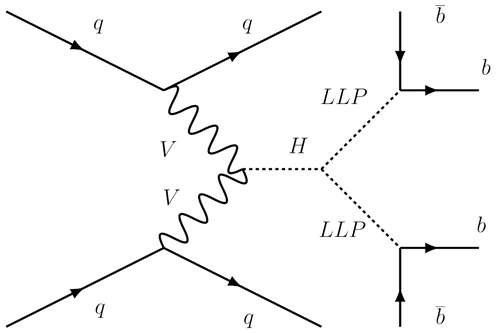
Signal studies
Benchmark models



Gluon fusion



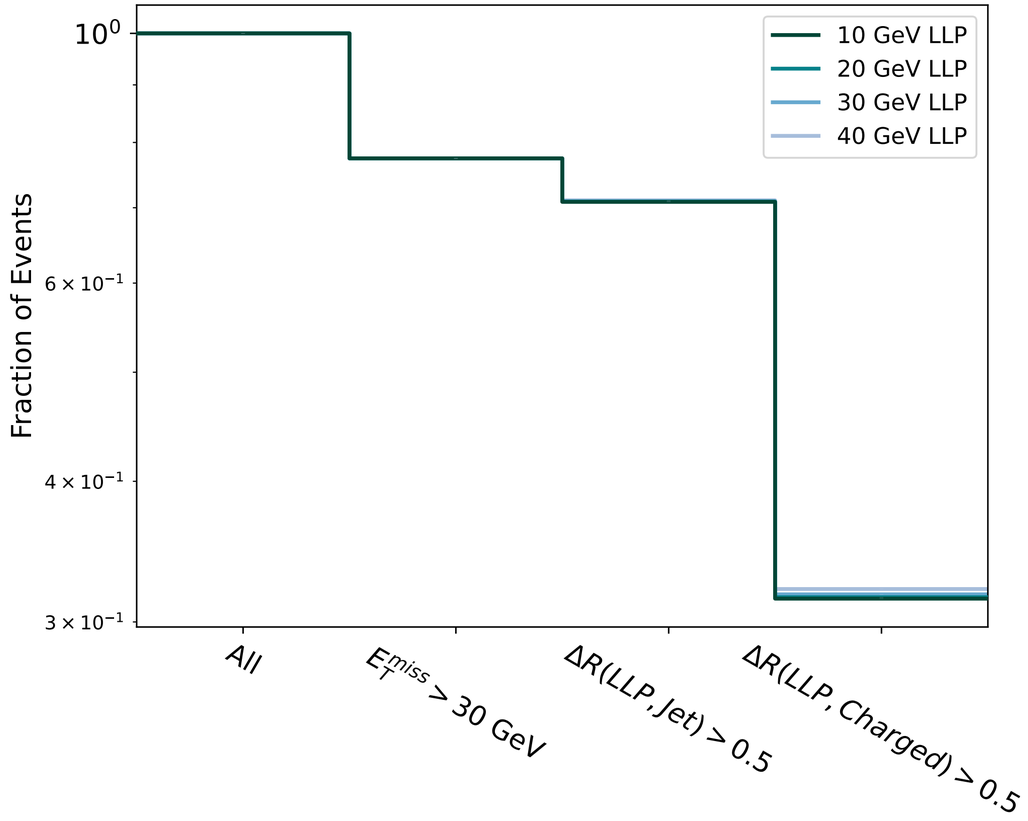
Vector boson fusion

We focus on a pair-produced Higgs-portal scalar particle which decays into a $b\bar{b}$ pair as a benchmark model — though this extends to mediators above the EW scale

Pythia8 and PowHeg were used to generate MC simulations of these LLP decays using ggF and VBF Higgs-production files provided by ATLAS

$\mathcal{O}(10^8)$ events were generated for each of $m_{\text{LLP}} = 10, 20, 30, 40$ GeV

Signal studies
Benchmark models

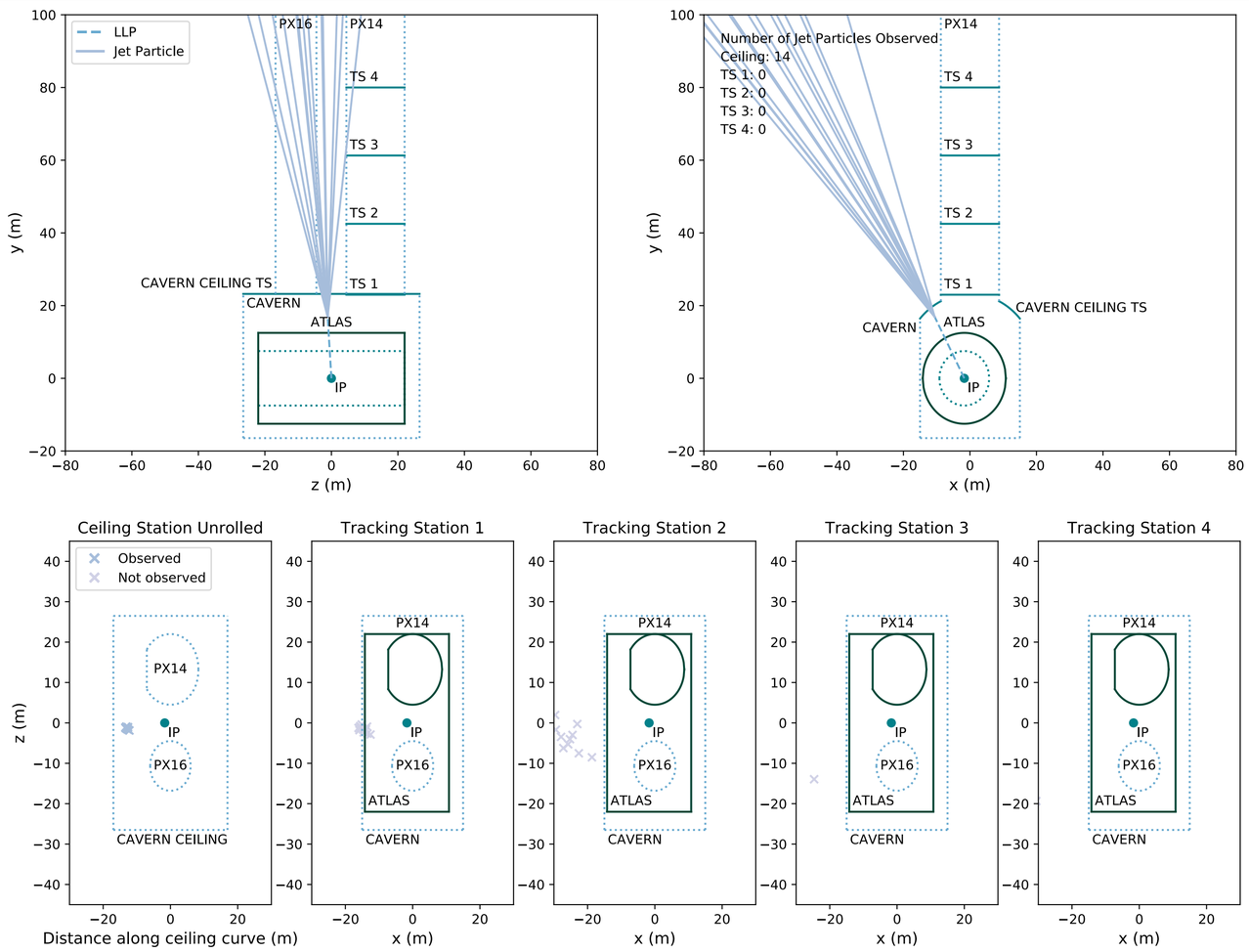


Cuts are applied on E_T^{miss} and isolation from nearby charged particles and reconstructed jets to suppress background

This maintains ~30% of signal events across simulated mass points

Signal studies

Decay scenarios

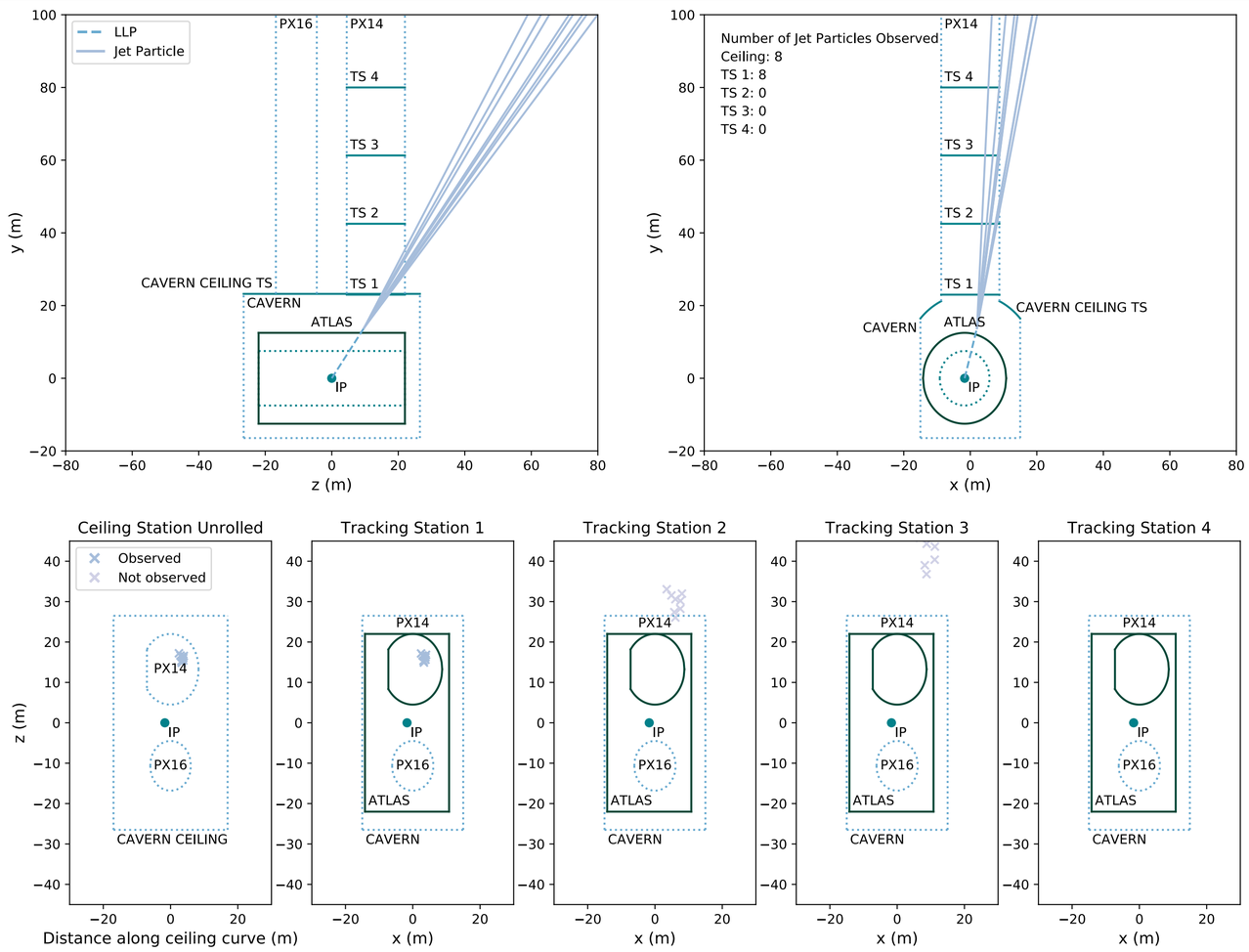


ANUBIS would be sensitive to “in-cavern” decays: those which occur between ATLAS’ vertexing limit (~7.5 m) and ANUBIS’ tracking stations

To observe an LLP decay we want at least two of the ensuing charged jet particles to intersect at least one tracking station

Signal studies

Decay scenarios

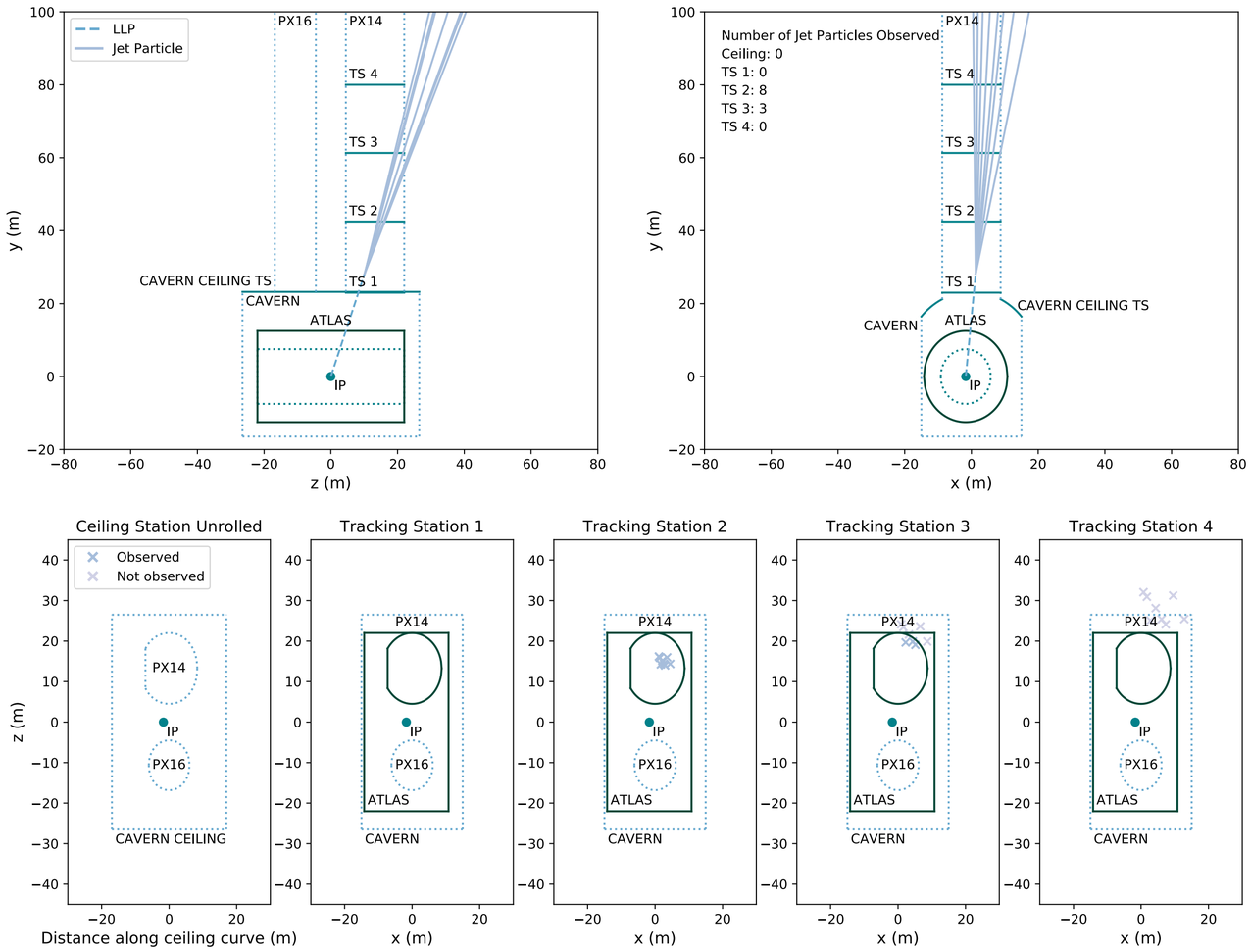


ANUBIS would be sensitive to “in-cavern” decays: those which occur between ATLAS’ vertexing limit (~7.5 m) and ANUBIS’ tracking stations

This decay scenario could be observed by either the proposed ceiling or PX14 shaft versions of ANUBIS

Signal studies

Decay scenarios



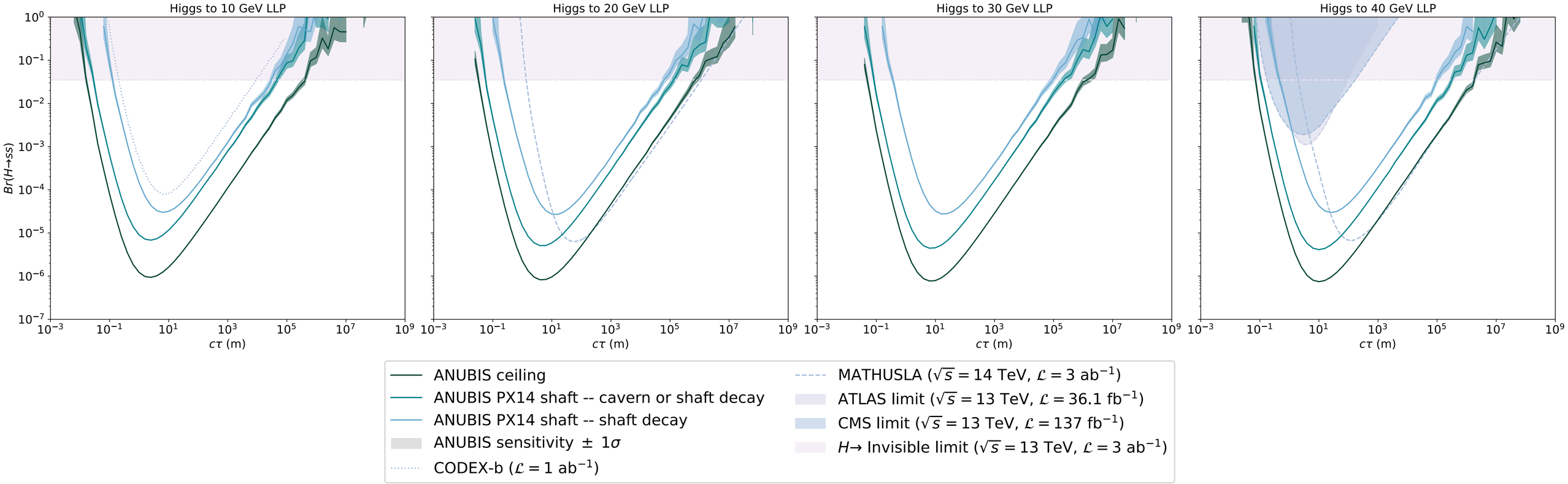
PX14 shaft ANUBIS could also be sensitive to “in-shaft” decays: those which occur within the service shaft

This decay scenario uses ANUBIS’ first tracking station to help discriminate against background events

To what branching ratios of BSM LLP production would ANUBIS have the sensitivity to claim detection at HL-LHC conditions ($\mathscr{L} = 3$ ab^{-1})?

Signal studies

Sensitivity to various mass points

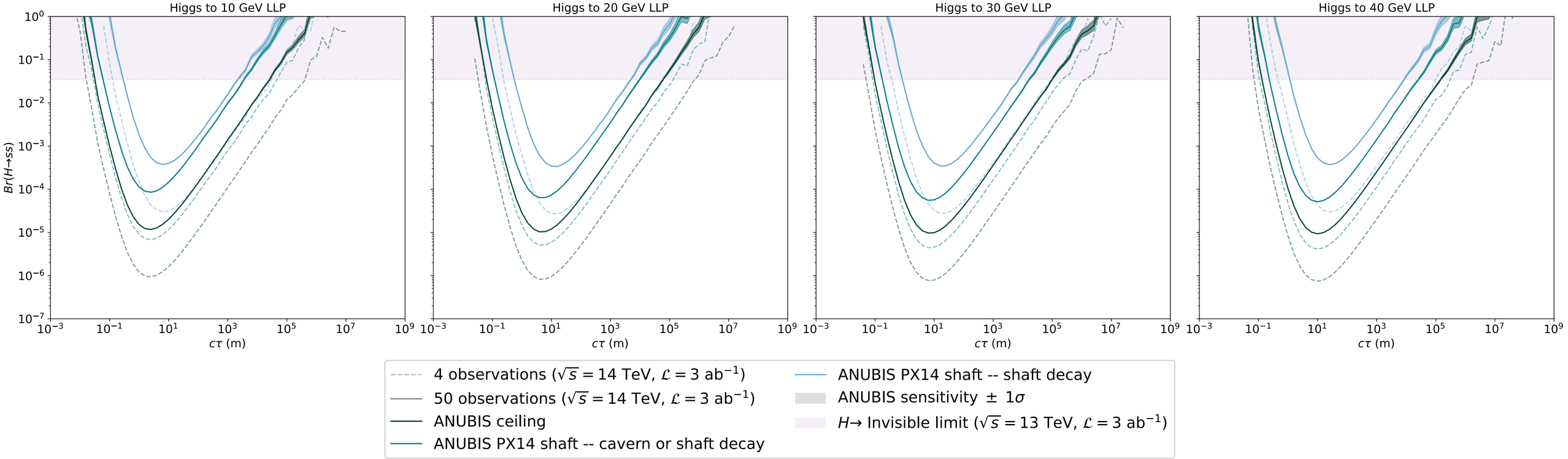


ANUBIS' sensitivity shows a significant improvement over ATLAS and CMS' existing capabilities *assuming no background and searching for 4 signal events*

More details: CERN-THESIS-2022-169

Signal studies

Sensitivity to various mass points

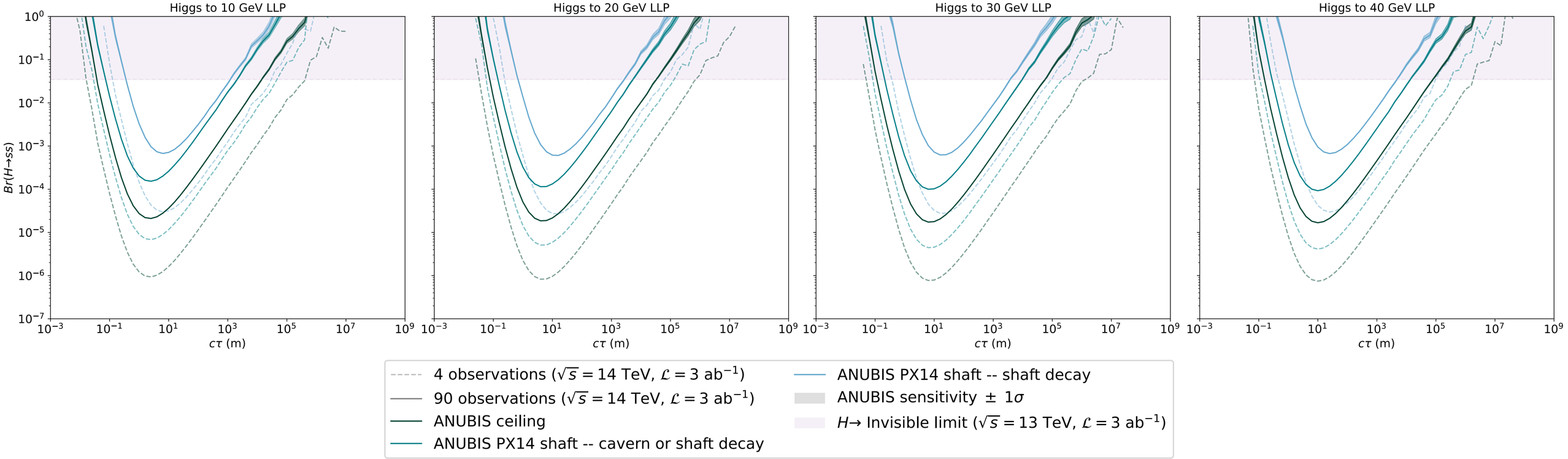


ANUBIS' sensitivity still shows a significant improvement *when searching for 50 signal events*

More details: CERN-THESIS-2022-169

Signal studies

Sensitivity to various mass points



ANUBIS' sensitivity still shows a significant improvement *when searching for 90 signal events*

More details: CERN-THESIS-2022-169

Signal studies

Comparison to existing and proposed technology

Mass $c\tau$	10 GeV 3 m	10 GeV 100 m	40 GeV 10 m	40 GeV 100 m
ATLAS Experiment $\mathscr{L} = 36.1$ fb^{-1}	—	—	1.9 x 10^{-3}	3.7 x 10^{-2}
CODEX-b $\mathscr{L} = 1$ ab^{-1}	1.2 x 10^{-4}	4.2 x 10^{-4}	—	—
MATHUSLA $\mathscr{L} = 3$ ab^{-1}	—	—	2.6 x 10^{-4}	6.9 x 10^{-6}
ANUBIS ceiling $\mathscr{L} = 3$ ab^{-1}	9.4 x 10^{-7}	1.2 x 10^{-5}	7.4 x 10^{-7}	2.4 x 10^{-6}
ANUBIS PX14 shaft — cavern or shaft decay	6.8 x 10^{-6}	8.3 x 10^{-5}	4.1 x 10^{-6}	1.3 x 10^{-5}
ANUBIS PX14 shaft — shaft decay	4.3 x 10^{-5}	1.4 x 10^{-4}	4.2 x 10^{-5}	4.8 x 10^{-5}

When searching for four observations (no background), ANUBIS shows a significant improvement over existing and approved future detectors

Uses a recent results from ATLAS and CMS and available projections from CODEX-b and MATHUSLA

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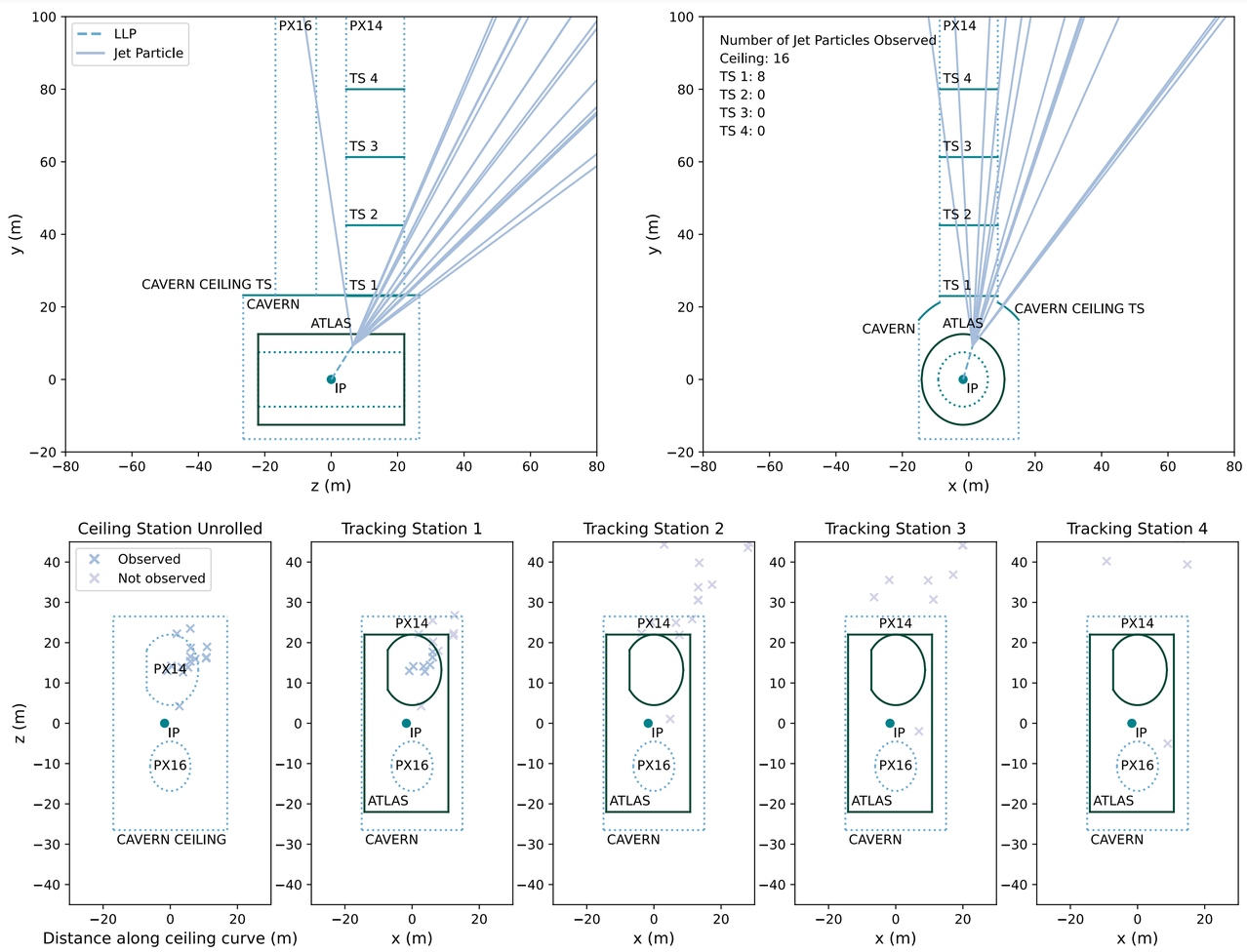
How can our prototype detector help understand this background?

Background studies

Sources of background

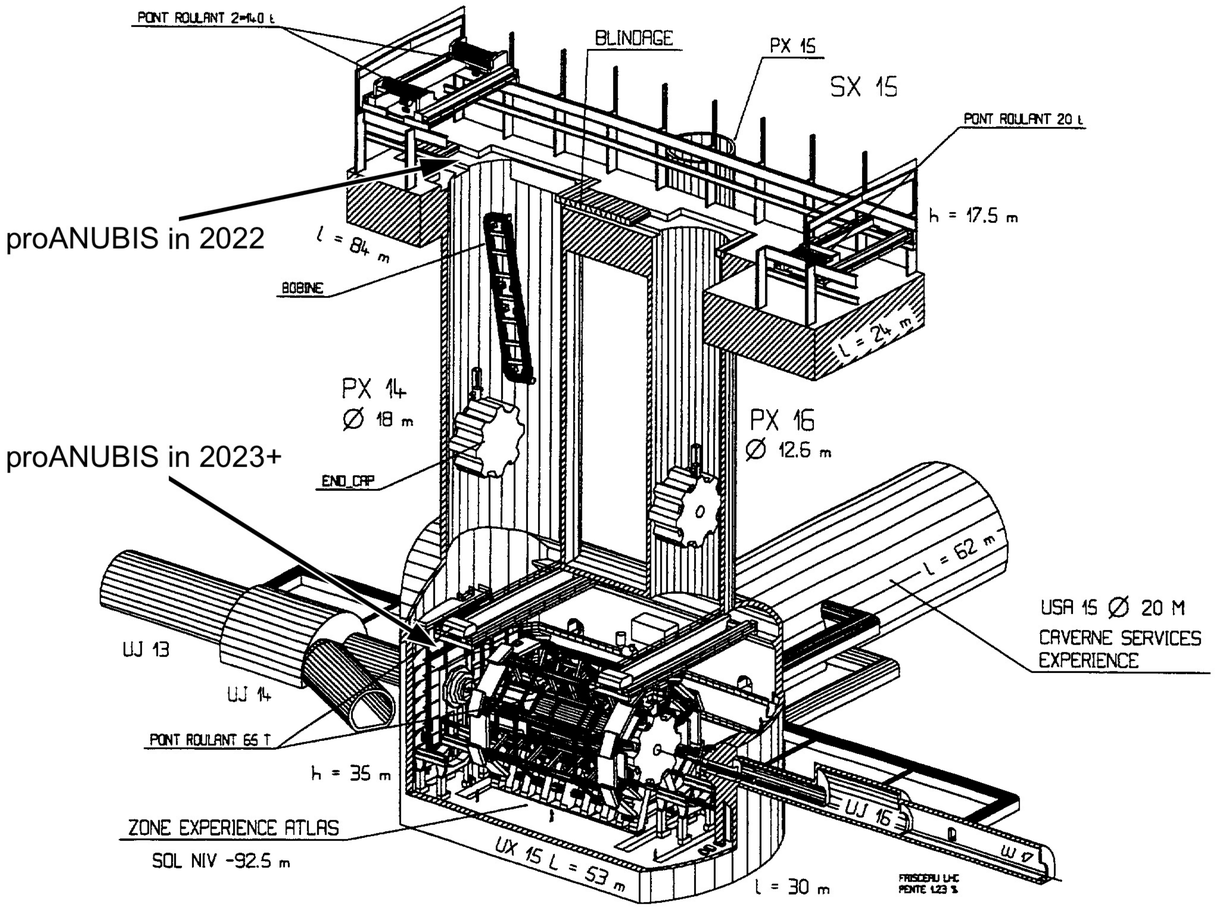


Like any experiment, ANUBIS will have to contend with signals which mimic those of BSM LLPs

We expect that interactions involving n^0 and K_L^0 will be the dominant sources of background

A prototype detector will measure the rates of these events in this new region

Background studies
proANUBIS location

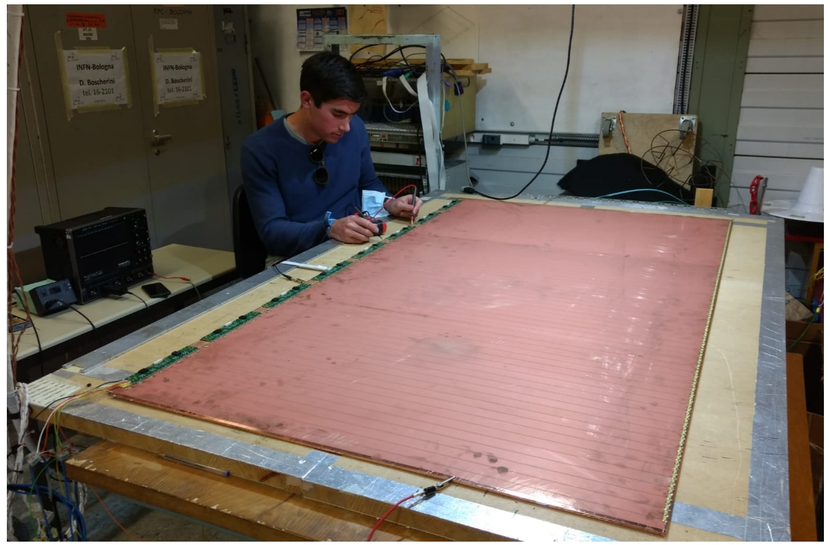


A 180 cm x 100 cm x 100 cm BIS78 RPC triplet dubbed proANUBIS is being commissioned to measure background rates in the cavern

The detector will soon be installed atop the concrete beams above the PX14 service shaft

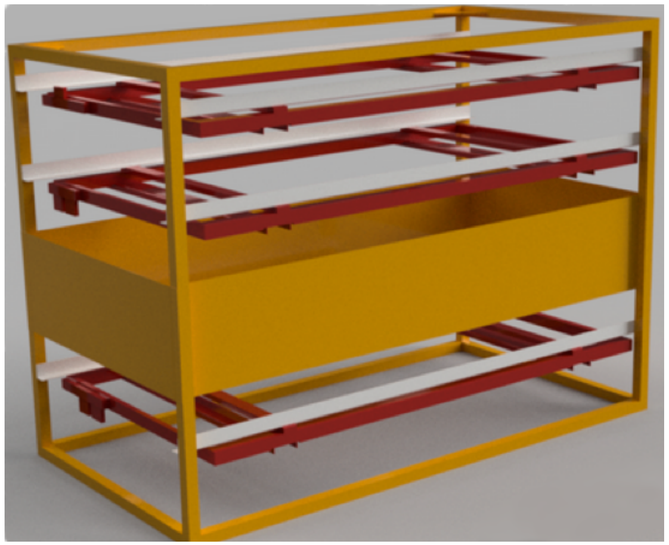
proANUBIS will be moved to the 12th floor gantry in the ATLAS cavern in 2023 (confirmed by ATLAS TC)

Background studies
proANUBIS construction



Installation of front-end electronics

Completed panels after passing testing procedures

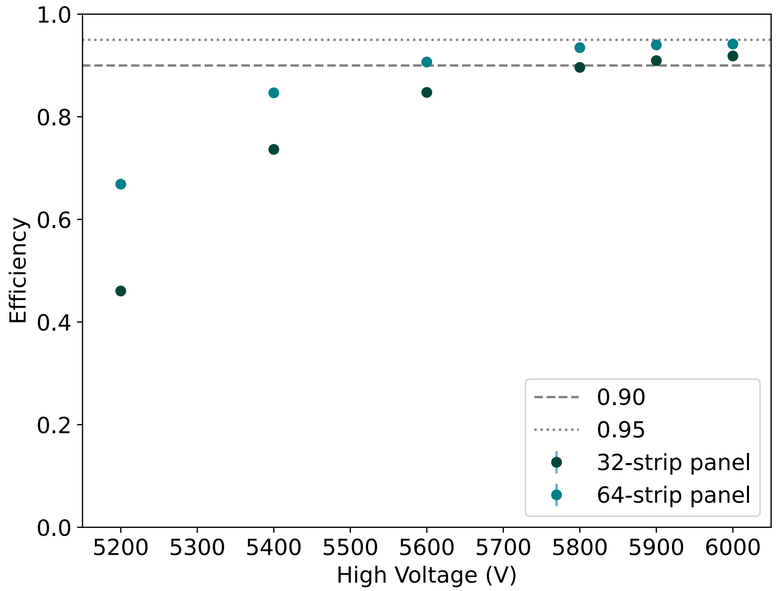


Mechanical frame to house detector

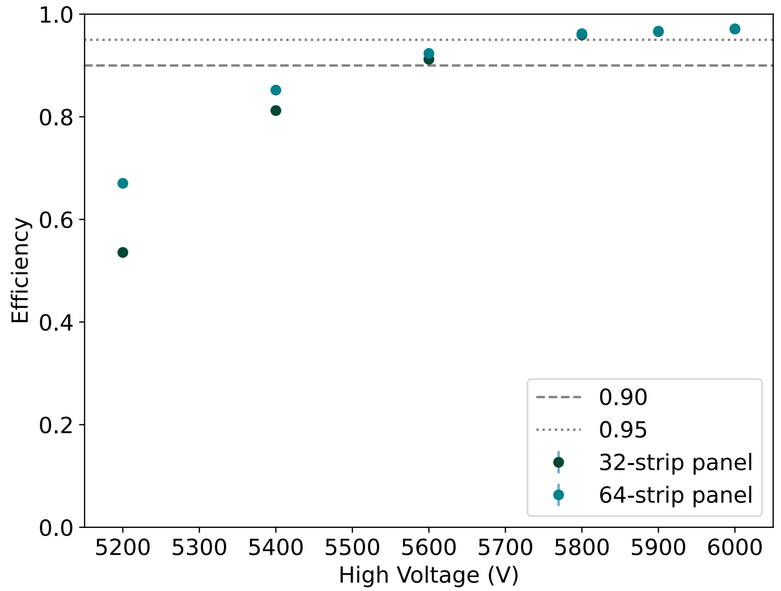
Thank you to the many members of the ATLAS RPC team who guided us as we constructed the BIS78 RPC detectors!

Background studies

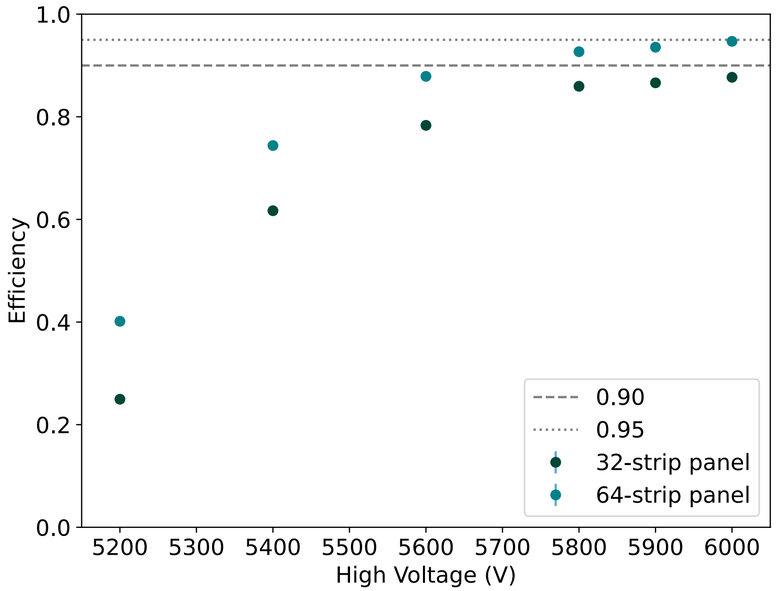
proANUBIS commissioning



Bottom singlet



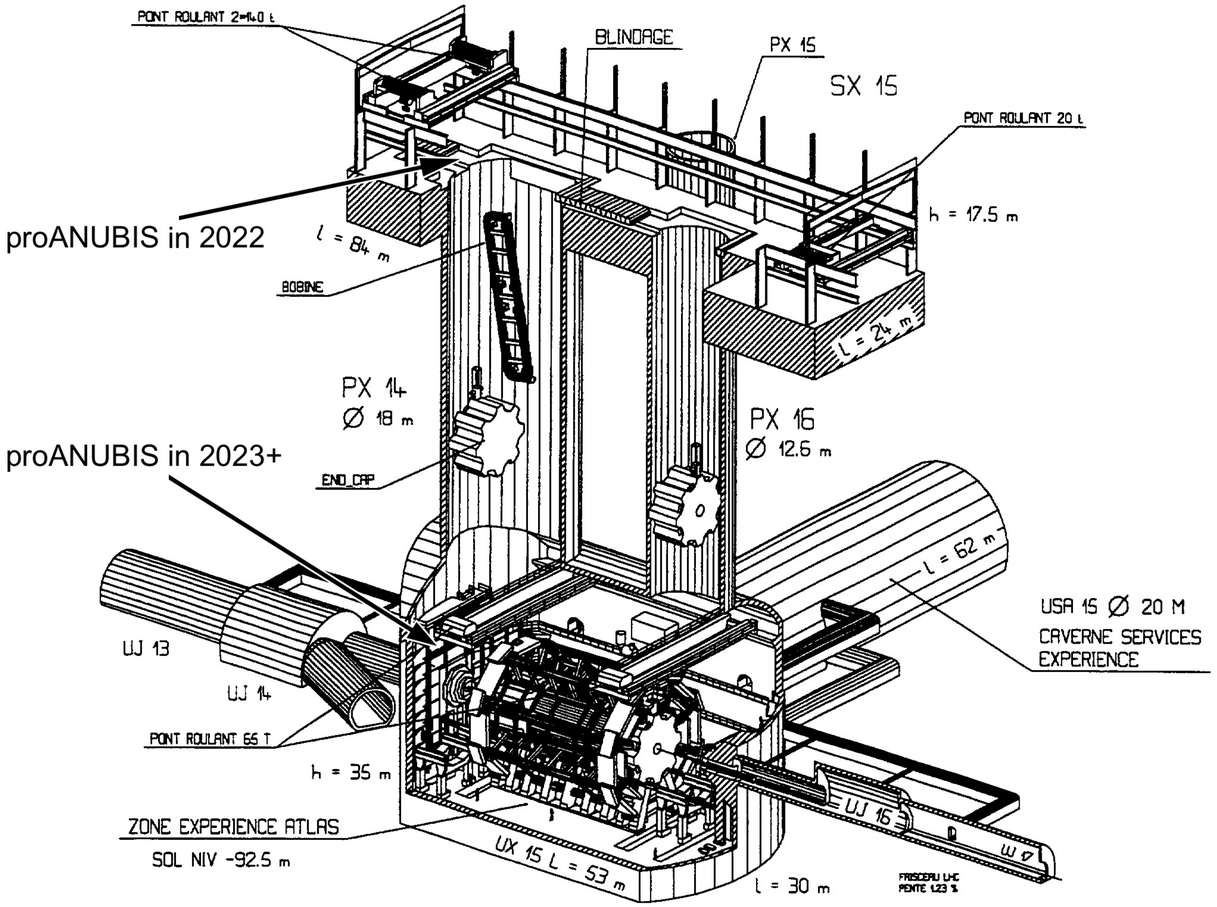
Middle singlet



Top singlet

The first triplet to be commissioned shows high efficiency, though more testing will be undertaken as commissioning continues

Background studies
proANUBIS methodology



After installation, proANUBIS will synchronize with ATLAS using reconstructions of muons from the interaction point

proANUBIS will be able to measure the flux of punch-through jets and secondary interactions

proANUBIS will allow us to cross-check Geant4 simulations and potentially identify new sources of background

Outlook

MC simulations show that ANUBIS' sensitivity would radically improve on that of ATLAS' existing detectors, and match or exceed that of approved future detectors

proANUBIS will soon provide data for understanding the background events with which ANUBIS will have to contend

Interested in contributing to our effort? Please reach out!

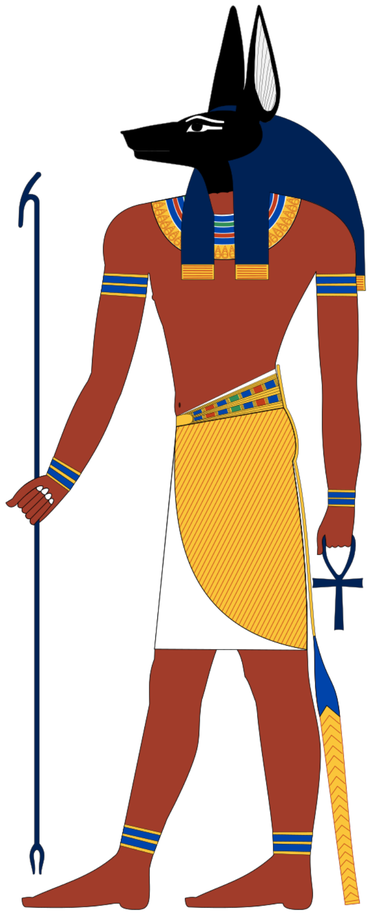
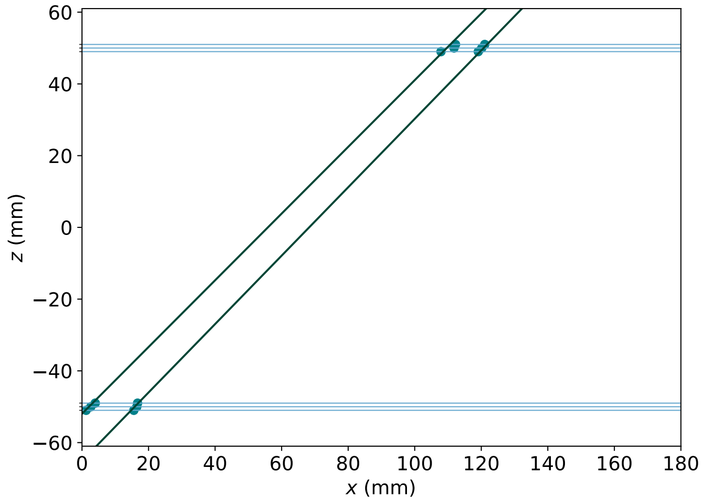


Image source: Wikimedia Commons

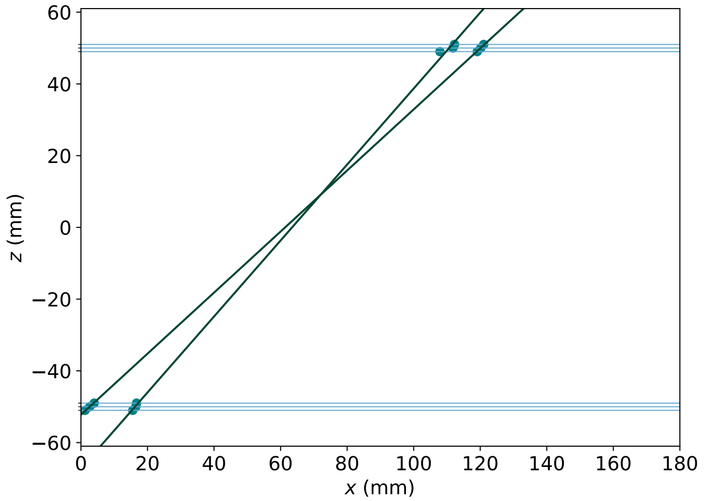
Backup

Background studies

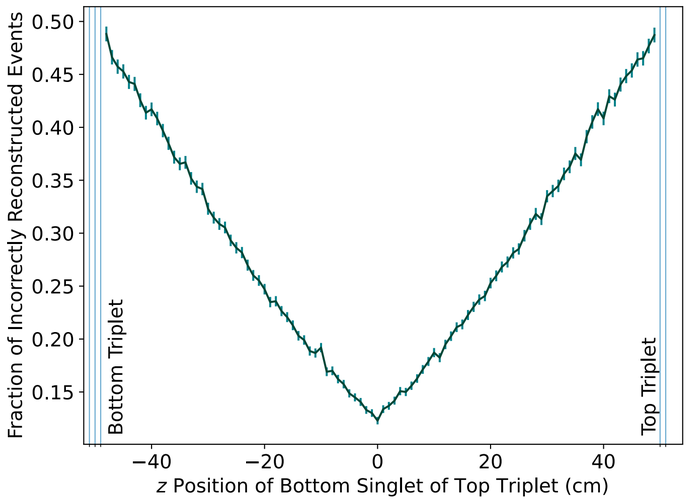
proANUBIS layout



Correctly reconstructed track



Incorrectly reconstructed track



Toy MC simulation results

In order to help disambiguate between tracks which pass close to each other through proANUBIS, one singlet will be offset to the middle of the detector

Simulations show that this will help reconstruct the correct tracks given expected hit uncertainty