

# Future long-lived particle experiments

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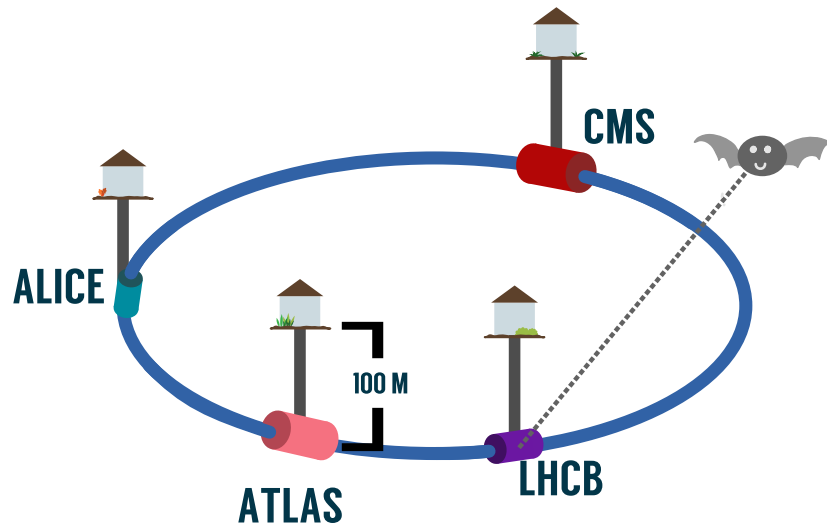
Heather Russell, CERN

*9<sup>th</sup> Edition of the Large Hadron Collider Physics Conference*

8 June 2021

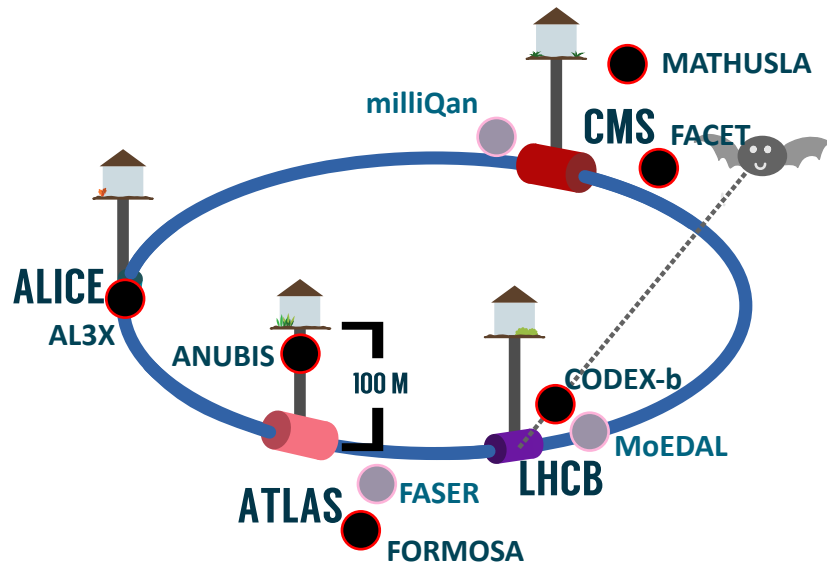


# Overview of LLPs @ the LHC

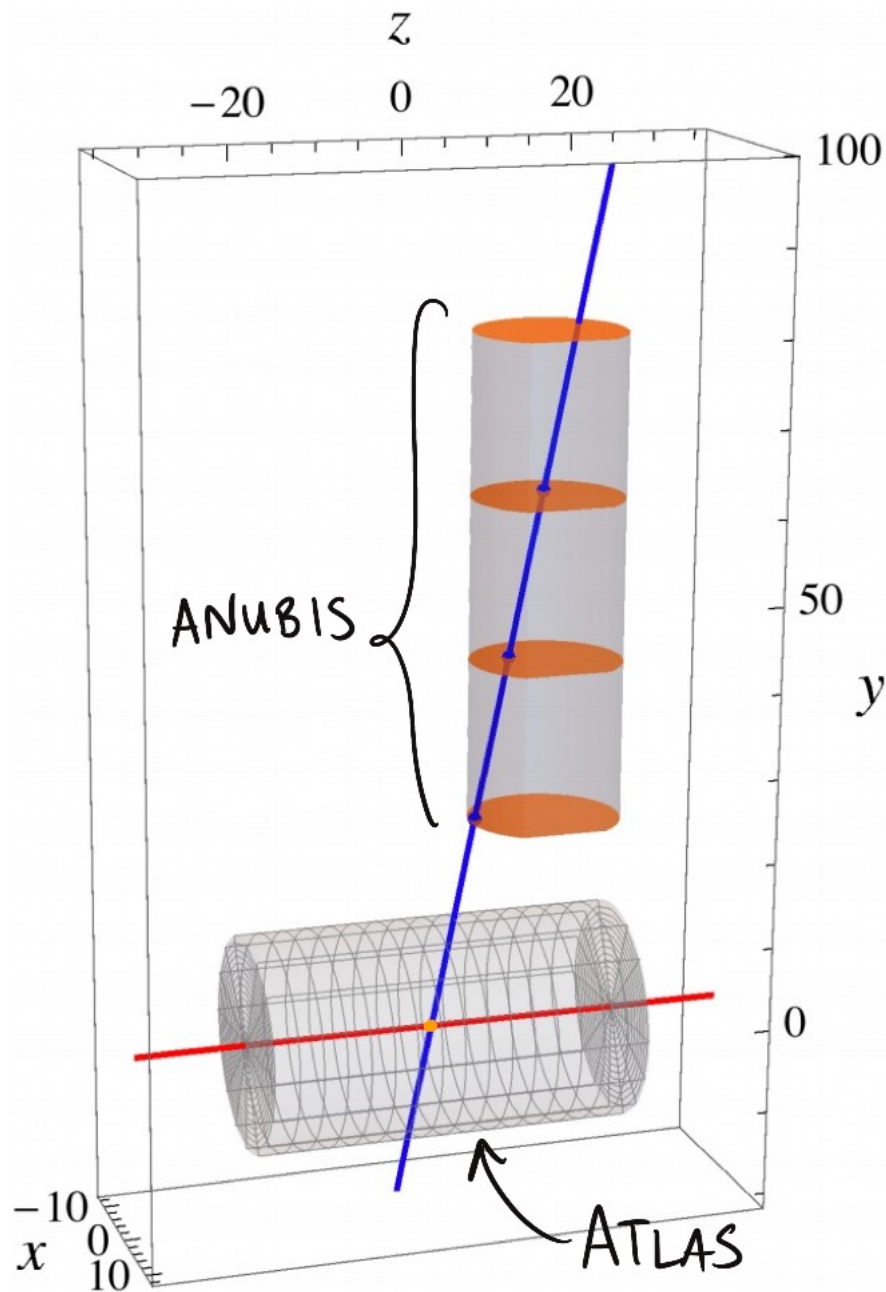


Neutral, long-lived particles with sufficiently long lifetimes could escape the standard detectors before decaying

# Overview of LLPs @ the LHC



Dedicated experiments will increase sensitivity to LLPs by having **large decay volumes** and being **farther displaced** from the interaction point



# ANUBIS

LLPs from IP1 (ATLAS)

Below ground: inside  
access shaft above  
ATLAS



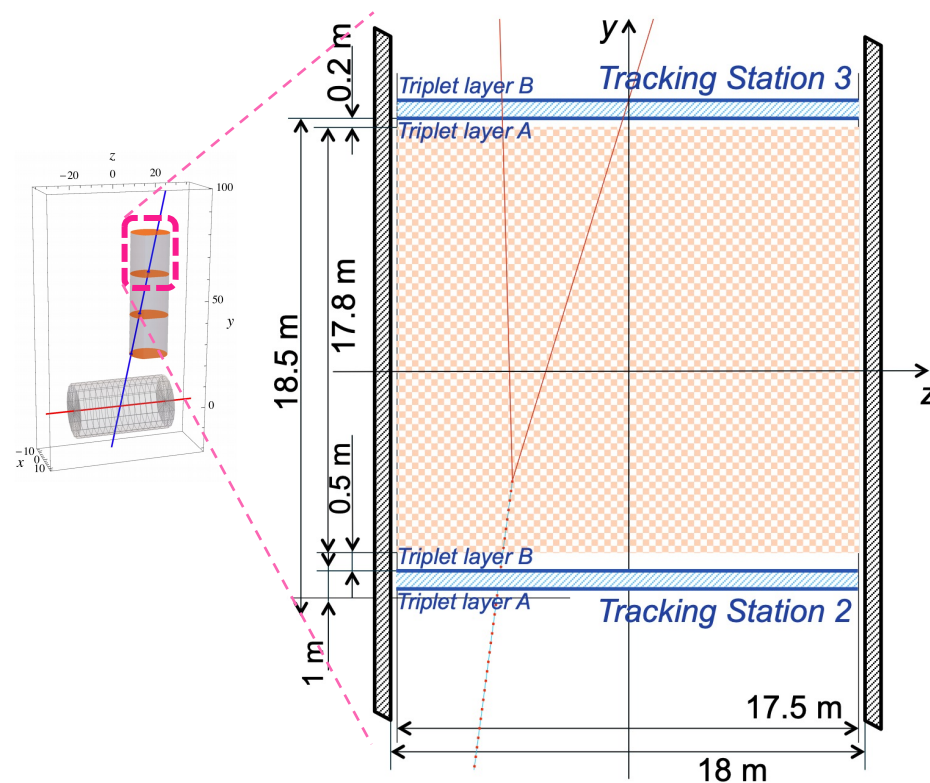
ATLAS has an 18m wide access shaft (PX14) located **directly above the detector**: suspend **four tracking stations** (2 x 3 layers each) within the 56 m high shaft

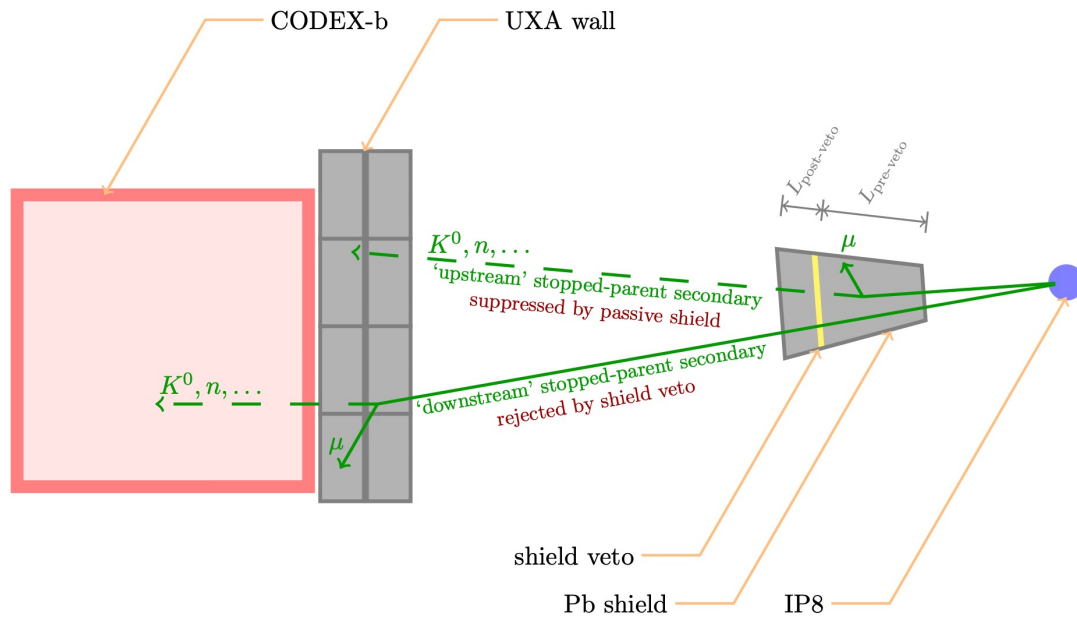
Trigger ATLAS using ANUBIS

ATLAS can be used as an active veto of SM activity

Tracking stations same RPC technology as new ATLAS layers, with additional material for showering

Planning to install a demonstrator for Run 3





# CODEX-b

LLPs from IP8 (LHCb)

Below ground

(inside LHCb's old DAQ room and/or DELPHI cavern)



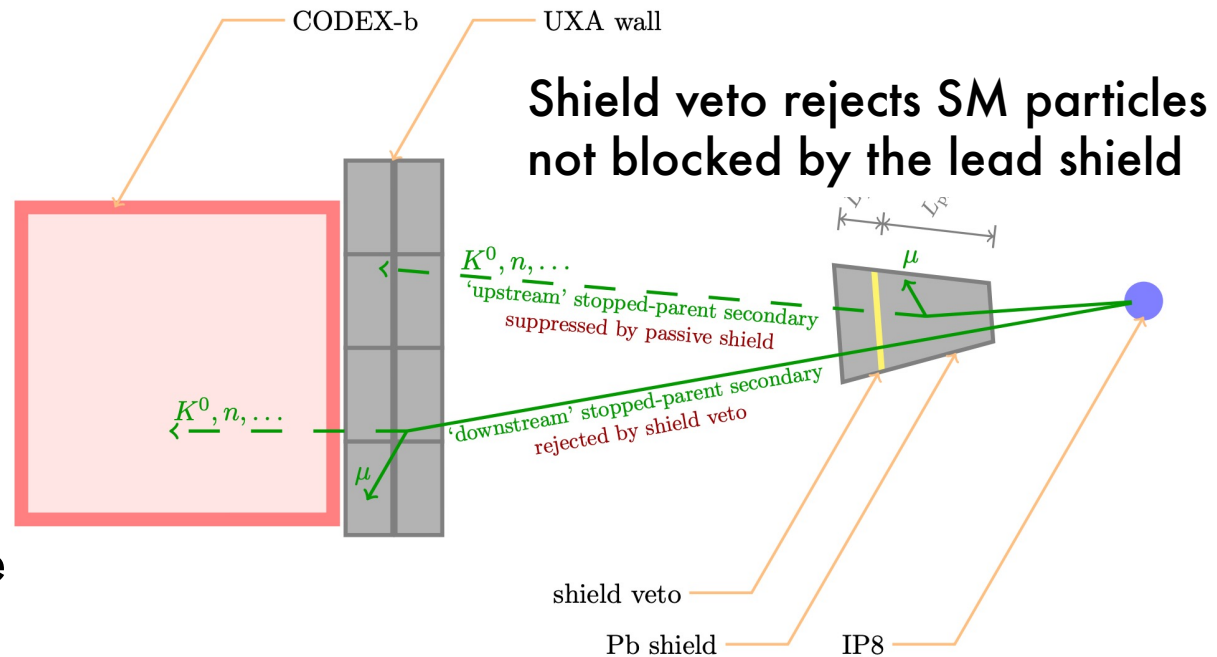
Detailed update @ Quarks (today!)

## Detector located underground, 25 metres from the LHCb IP

Tracking with new-RPCs,  
like ANUBIS

6 layers on each wall to  
reconstruct LLP decay  
vertex

10x10x10 m<sup>3</sup> fiducial  
volume has large lifetime  
acceptance

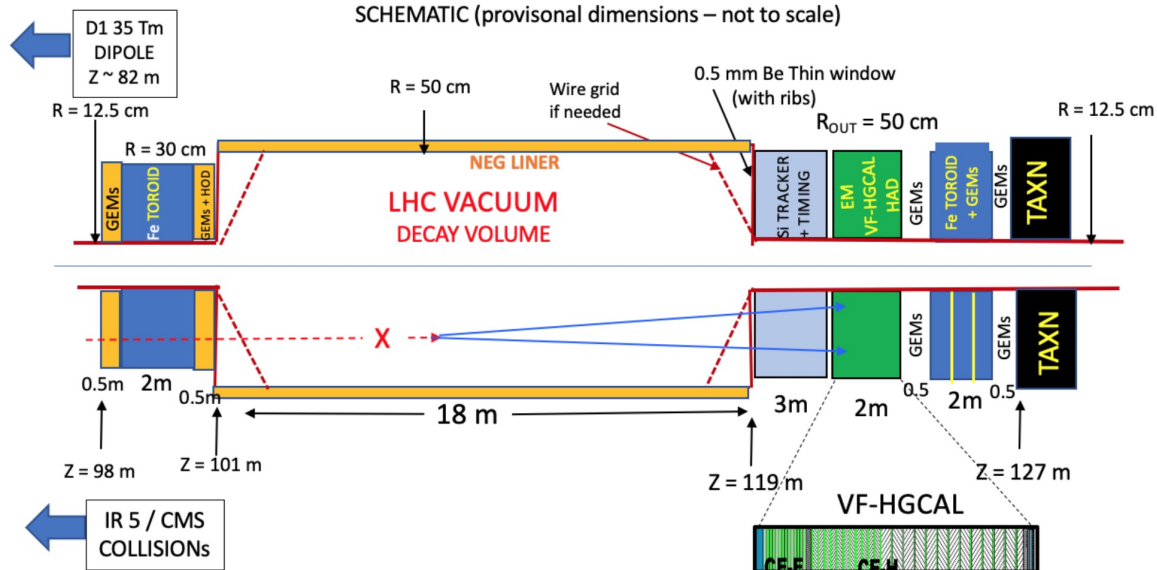


Targeting low-mass LLPs produced transversely and decaying to charged particles

*addition of calorimetry or other material layers for photon ID is being considered*

CODEx- $\beta$  demonstrator will be installed during Run 3: 2x2x2 m<sup>3</sup> and integrated with LHCb; full detector for Run 5

# FORWARD MULTIPARTICLE SPECTROMETER SCHEMATIC (provisional dimensions – not to scale)



# FACET

LLPs from IP5 (CMS)

Forward detector

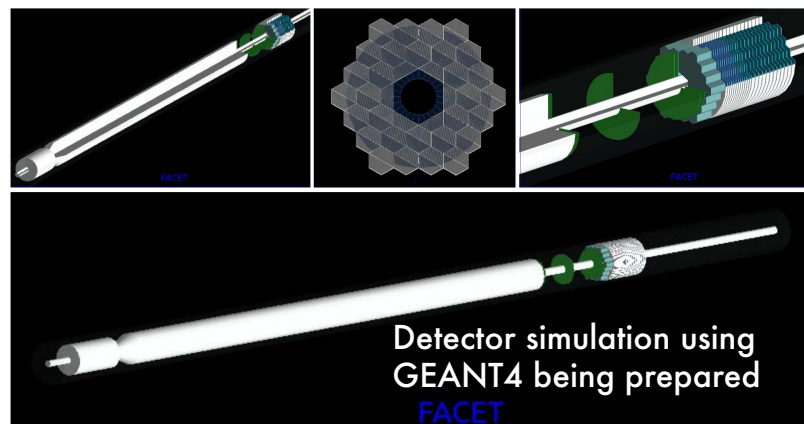
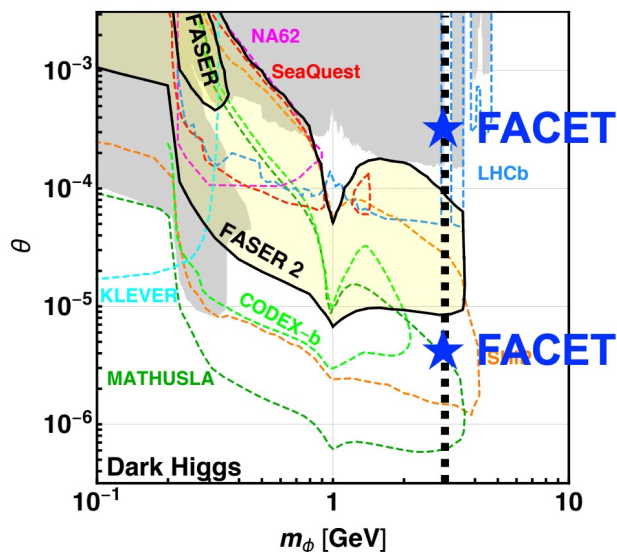


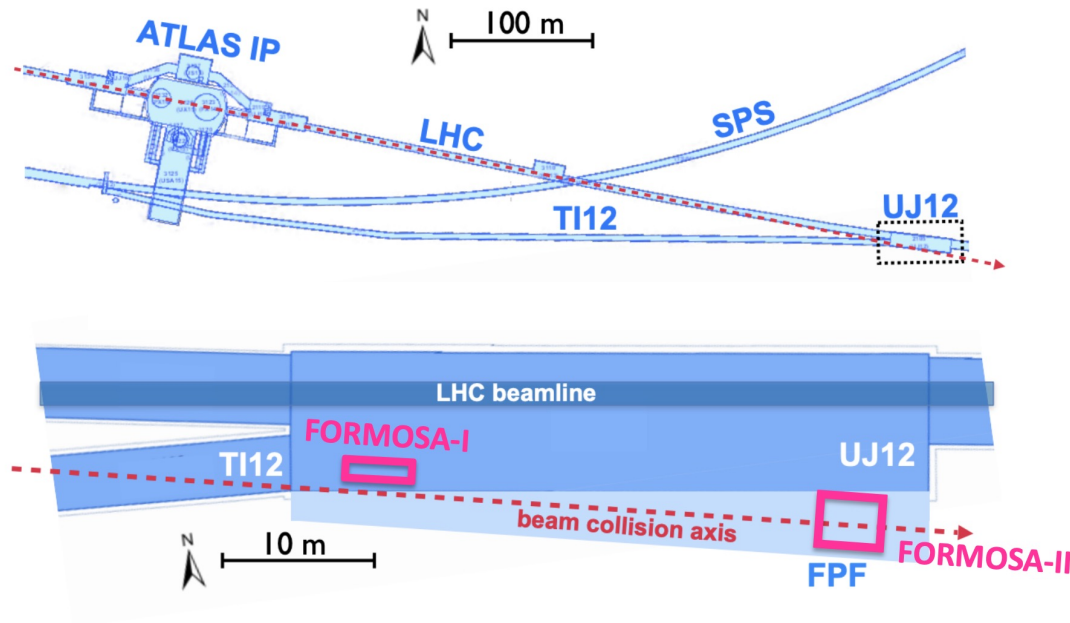
**F**orward-**A**perture **C**MS **E**x**T**ension: detector  $\sim 100$  m from CMS IP with  $\sim 20$  m long decay volume, coverage in  $6 < \eta < 8$

Much **closer** to the IP and much **larger decay volume** than FASER  
( $z_{\text{FASER}} = 480$  m – complementary)

Targeting letter of intent this summer and installation for HL-LHC (Run4)

Initial simulations showing good sensitivity





# FORMOSA

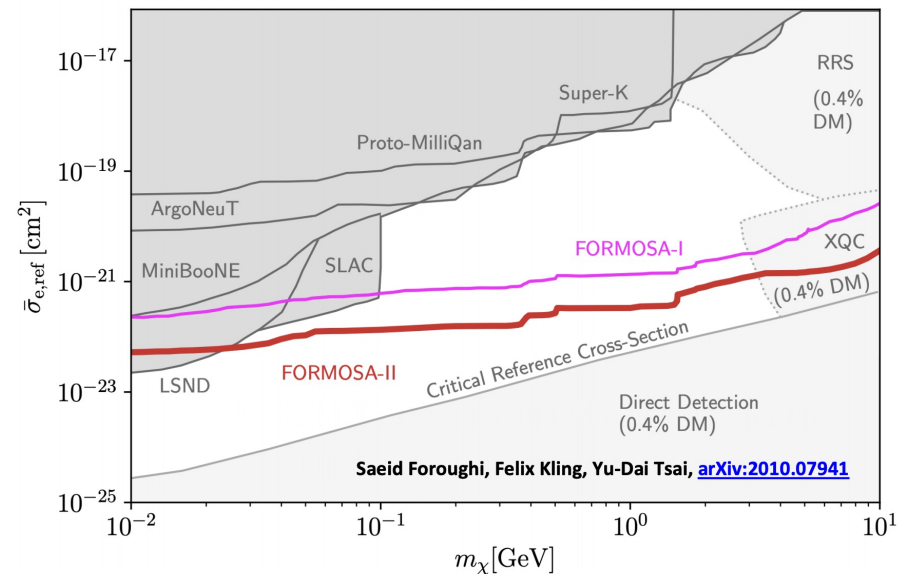
millicharged LLPs from  
IP1 (ATLAS)

Forward detector

## FORward MicrOcharge SeArch

Increased reach for both mass and charge, especially for strongly interacting dark matter

Similar detector technology to milliQan (scintillator bars coupled to PMTs)



Propose to start in Run 3 by moving the milliQan demonstrator



Growing collaboration: institutes from Canada, US, Mexico, Chile, Bolivia, Italy, Israel ...

Detailed update @ Quarks (today!)  
Scintillator development @ Fermilab

100 9m x 9m modules

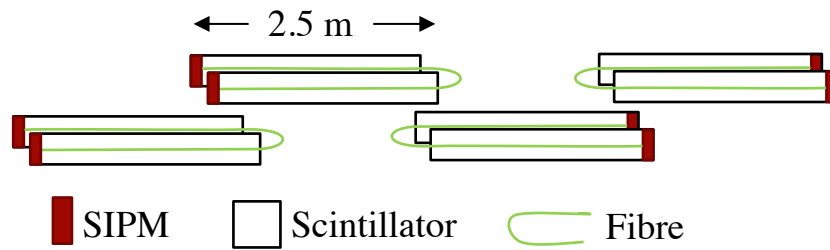
9 layers:

2 on floor = active veto

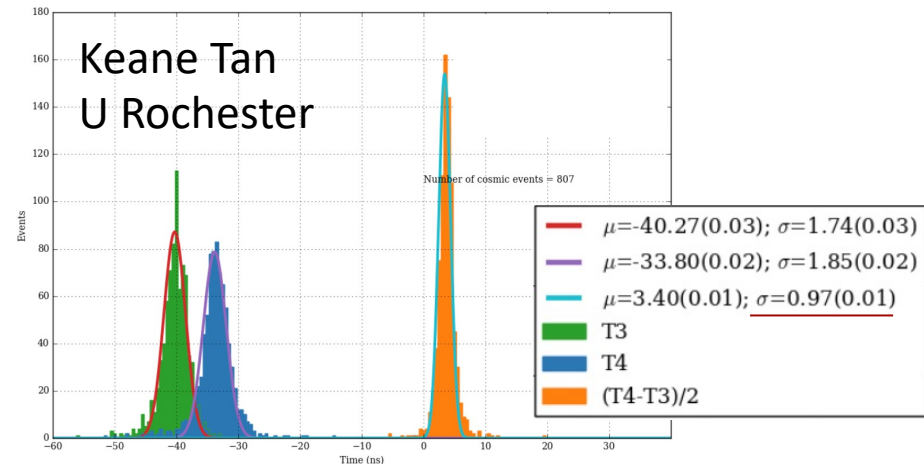
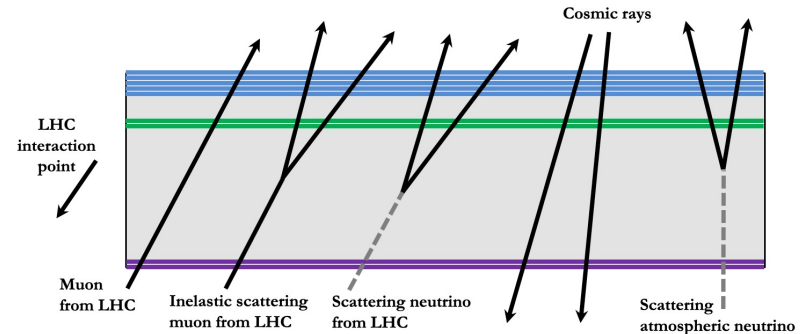
2 intermediate (tracking)

5 on top (tracking + trigger)

Tracking with overlapping long (4x2.5m) plastic scintillator bars, wavelength-shifting fibres, and SIPMs



NB: Fibres join non-adjacent bars



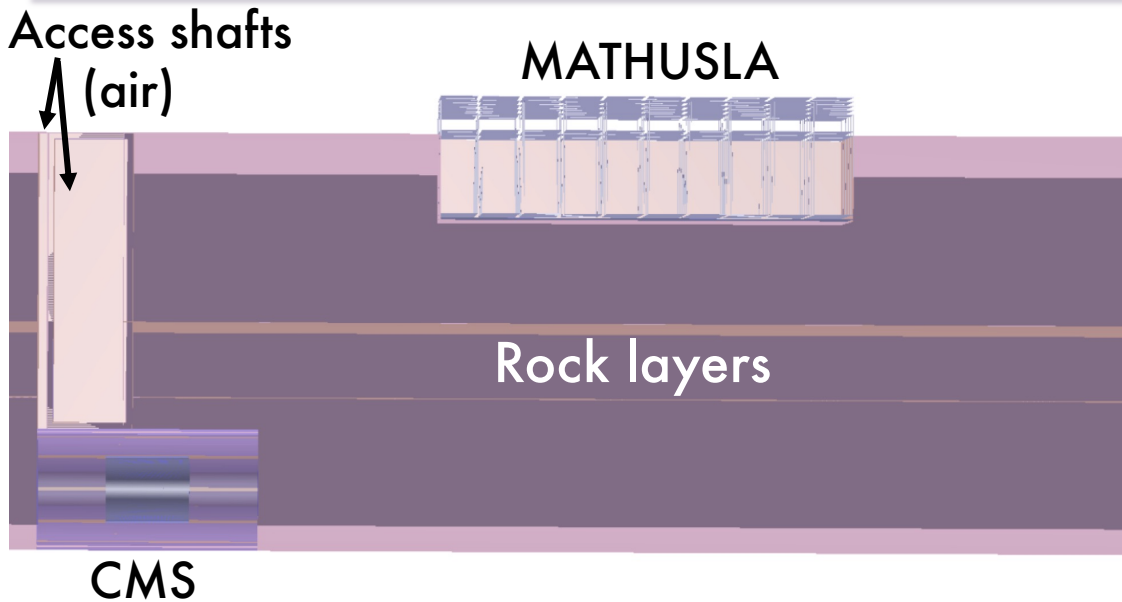
Extensive study of scintillators underway: **1 ns timing resolution** recently demonstrated with cosmic data

Detailed update @ Quarks (today!)  
Scintillator development @ Fermilab

Detector and surrounding area simulated using GEANT4

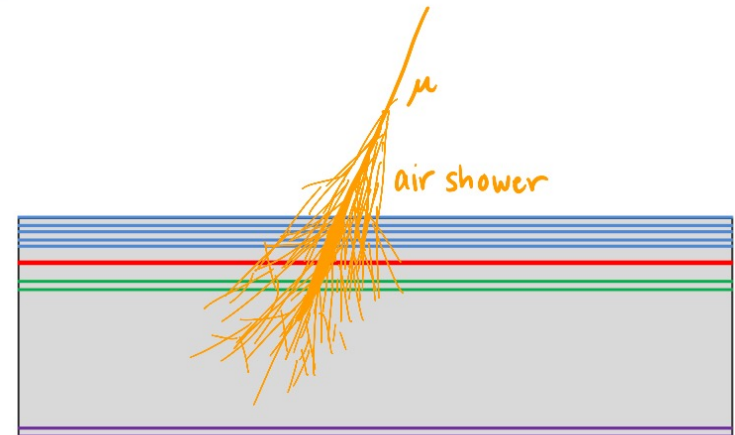
- rock from geological survey
- cylindrical CMS with  $\lambda = 10$

Allowing for detailed efficiency and reconstruction studies

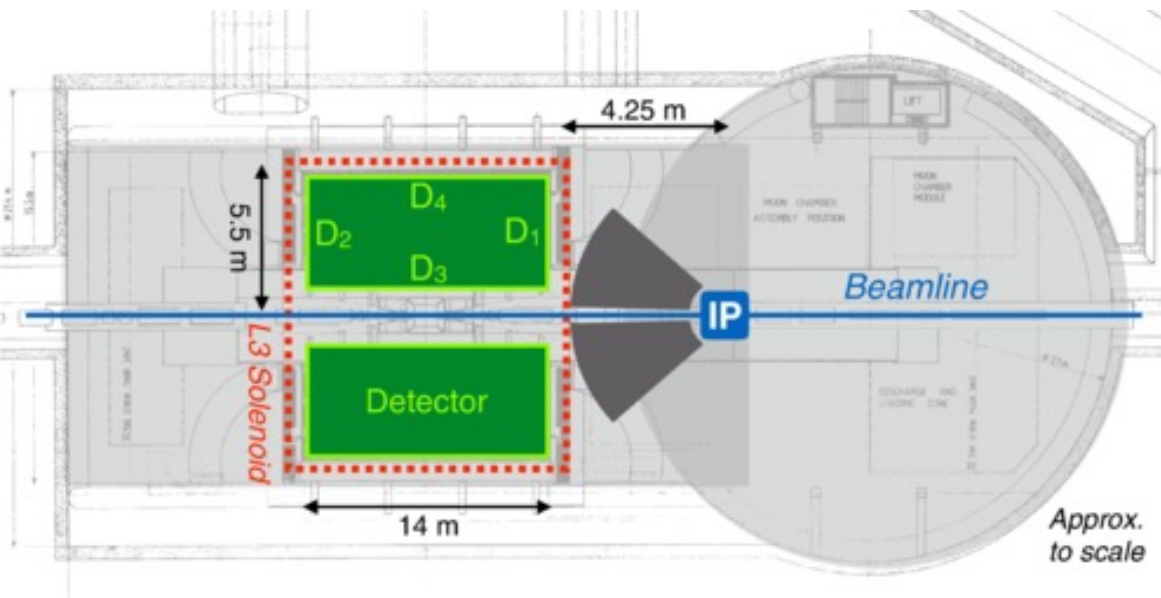


Detector also functions as a cosmic ray air shower observatory

Additional **RPC layer** would enhance sensitivity to extended air showers  
(*less saturation*)



Cosmic Update @ LLP Workshop  
Paper coming soon!



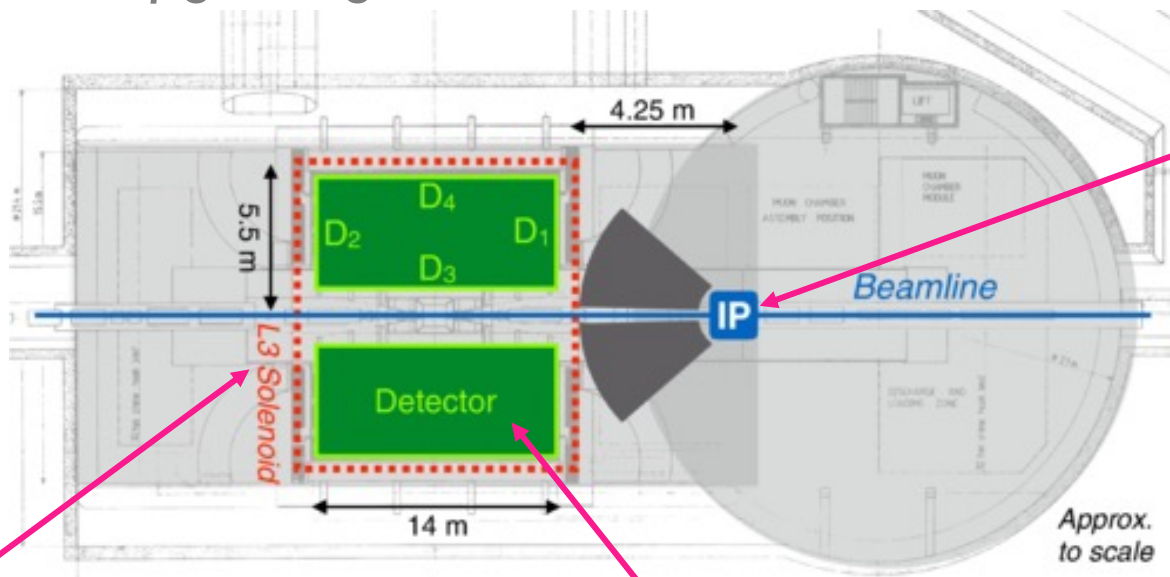
# AL3X

LLPs from IP2 (ALICE)

Only if ALICE ends their physics program before the end of HL-LHC

In the very unlikely event\* ALICE finishes their physics program before the end of HL-LHC: **cavern and magnet** could be used for LLP searches

→ Requires upgrading IP2 to run at the nominal LHC luminosity



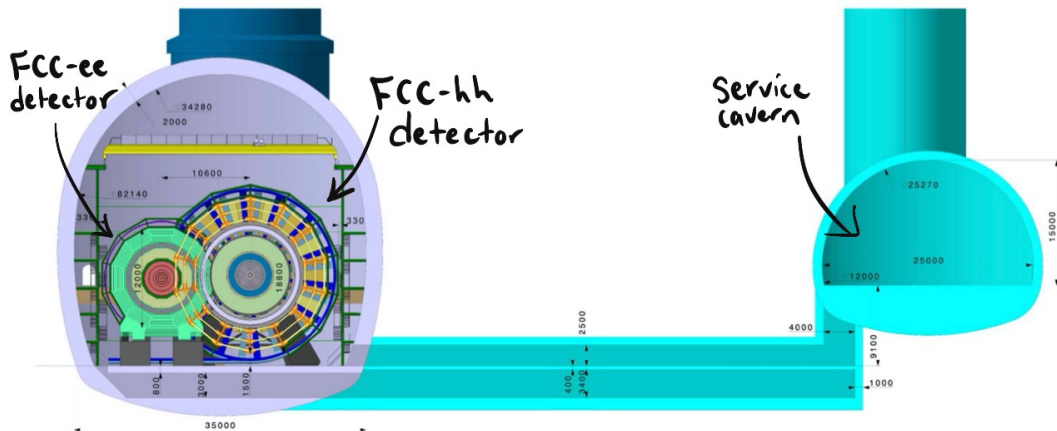
Move IP2  
**outside** of the  
**magnet** so  
LLPs can  
travel before  
decaying

Using the **existing magnet** would allow for both position and momentum determination

Could reuse the ALICE TPC (smaller than the **detector** drawn here)

\*consider this a case study in how existing detectors could be reused for LLP searches, not an active proposal





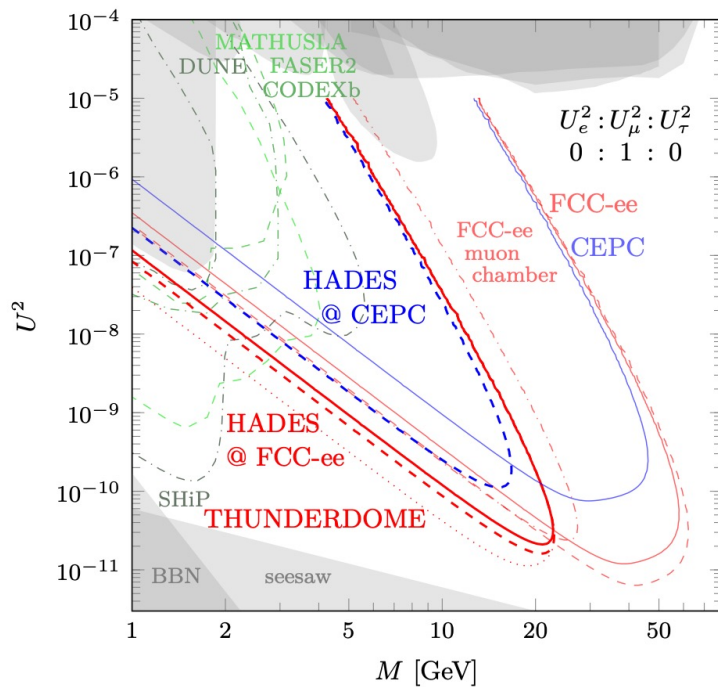
# HADES

LLPs of the future  
(FCC or CEPC)

Planned FCC-ee detector cavern is much larger than necessary

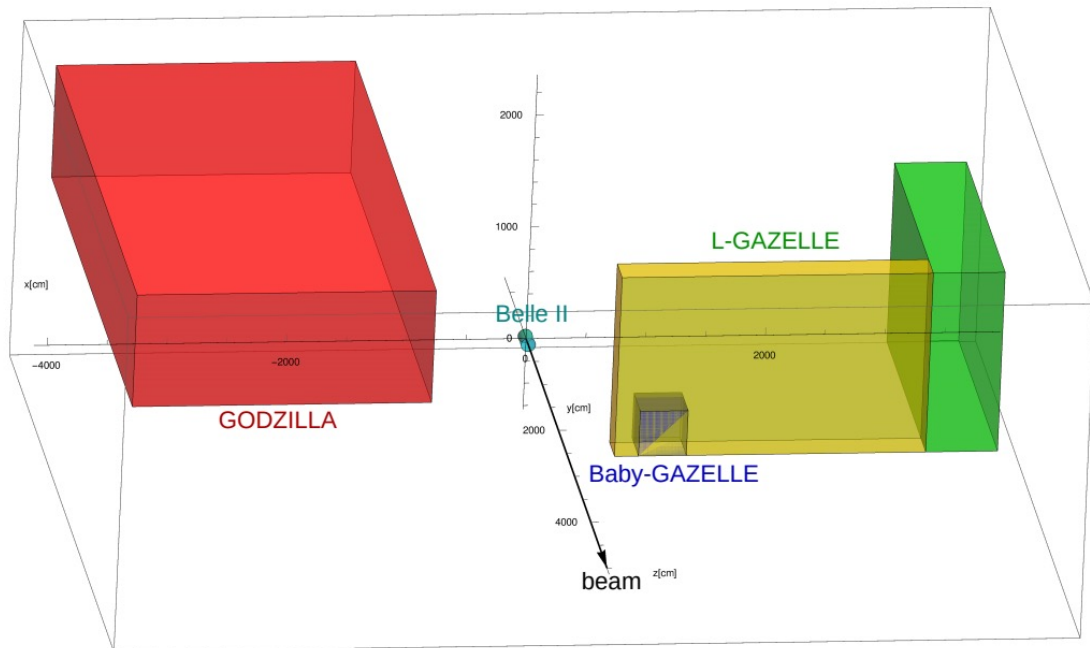


Cover the walls with layers of scintillators



- ➔ Can achieve near  $4\pi$  coverage
- ➔ FCC-ee detector available as an active veto
- ➔ Sensitive to a unique area of phase space

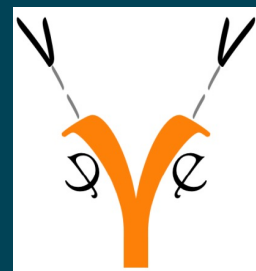
THUNDERDOME = Totally Hyper-UNrealistic DEtectoR in a huge DOME



# GAZELLE

LLPs @ SuperKEKB

Three proposed  
configurations around  
for LLPs from collisions in  
Belle-II



Initial proposal: arXiv:2105.12962

Update @ LLP Workshop

# Summary and conclusions

Future experiments will be sensitive to large swaths of phase space

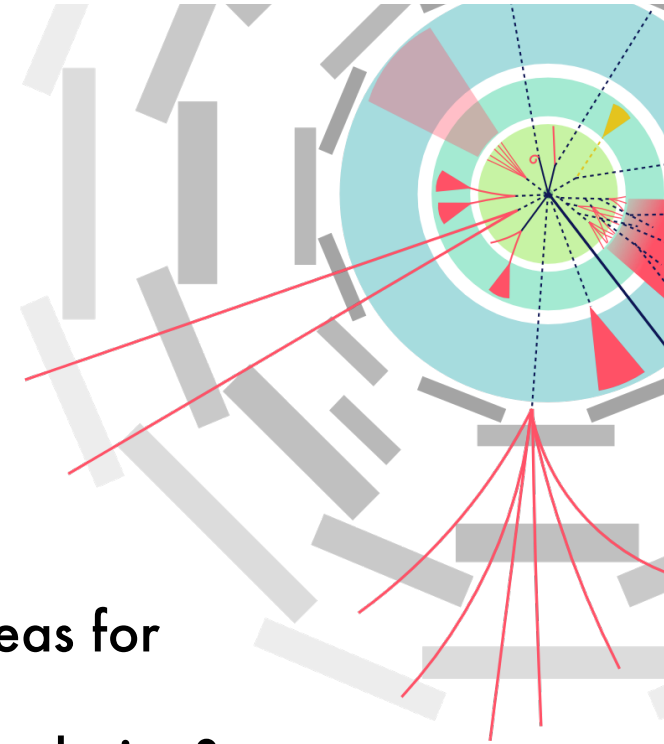
Many ideas for dedicated long-lived particle detectors – and new ones still being formed

Most current proposed experiments are aiming for data collection during HL-LHC

Now is an excellent time to start brainstorming ideas for FCC-ee/hh:

- can we work LLPs better into the baseline design?
- can we repurpose parts of current detectors?

(why not both?)



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If you're interested in learning more, join the LLP working group workshops (twice per year). More information on the website:  
<https://longlivedparticles.web.cern.ch/>