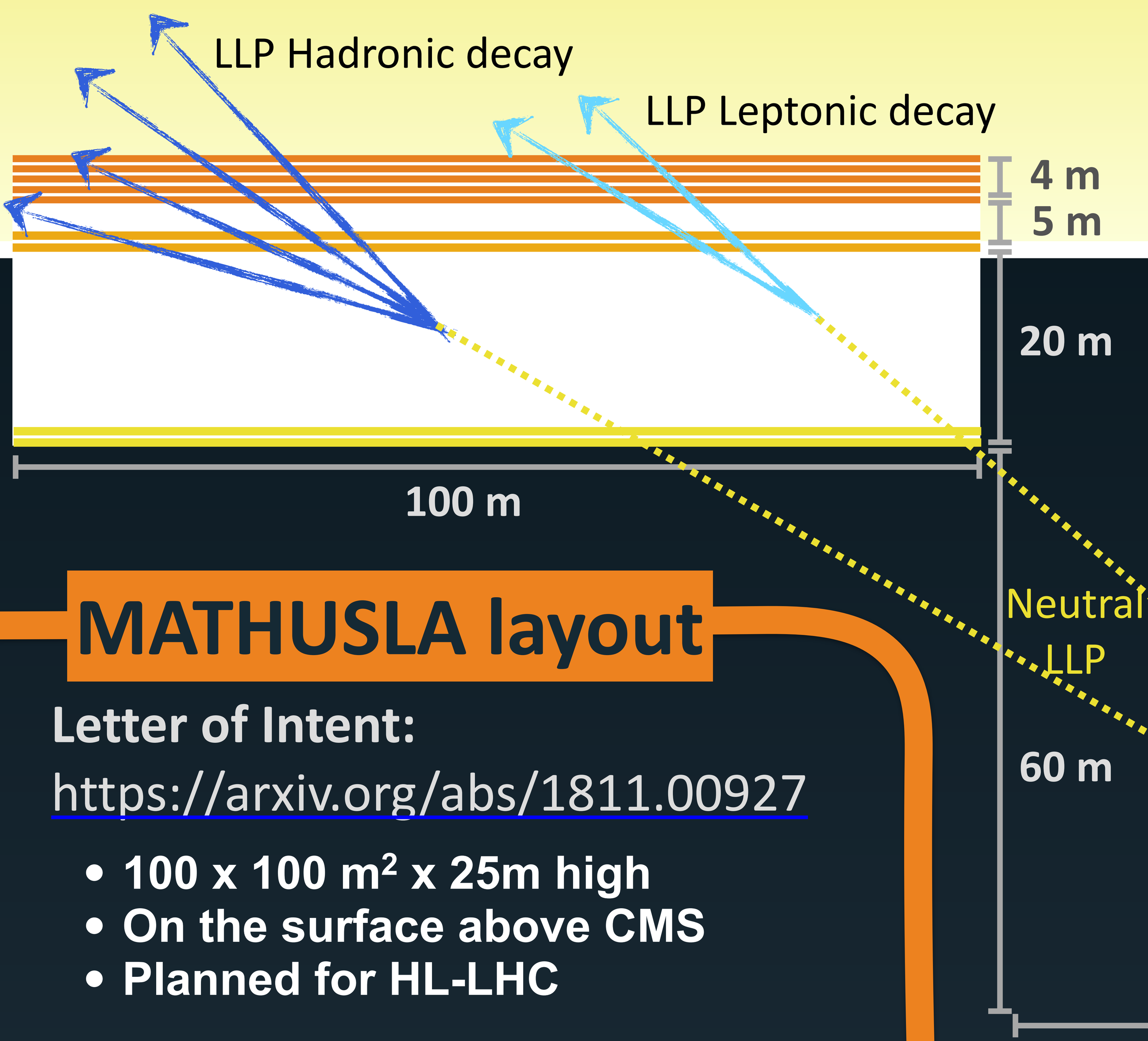
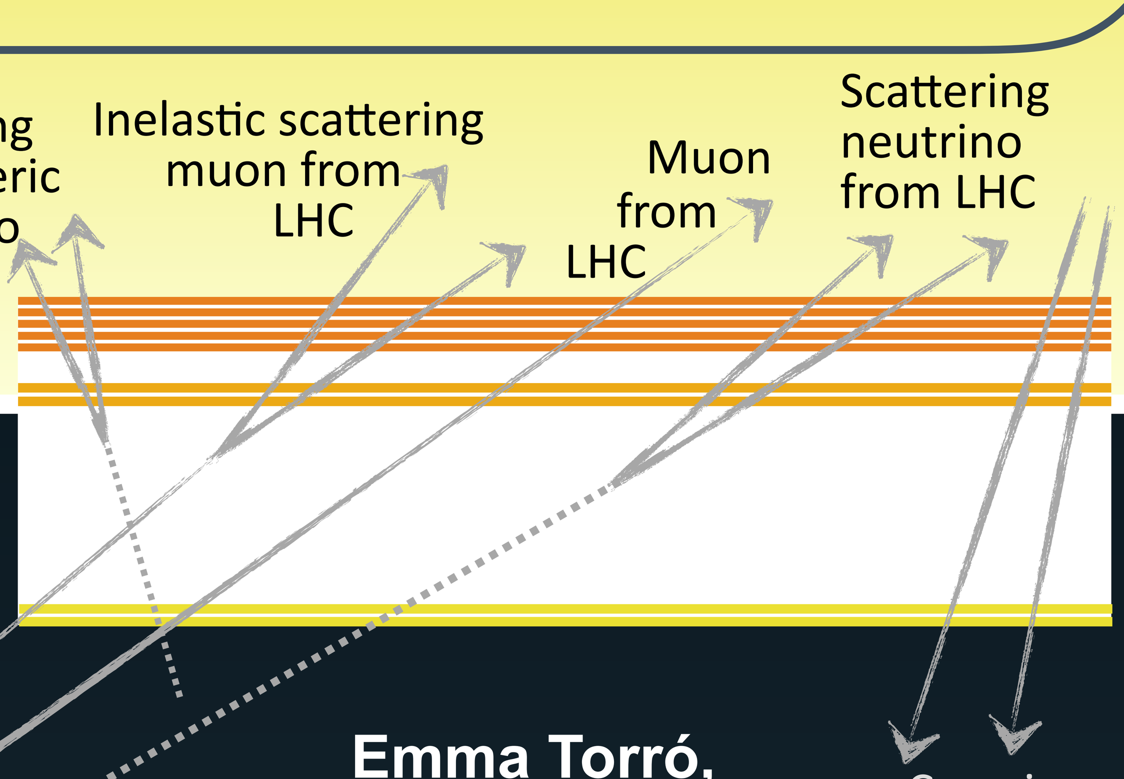
Why Long-lived particle experiments?

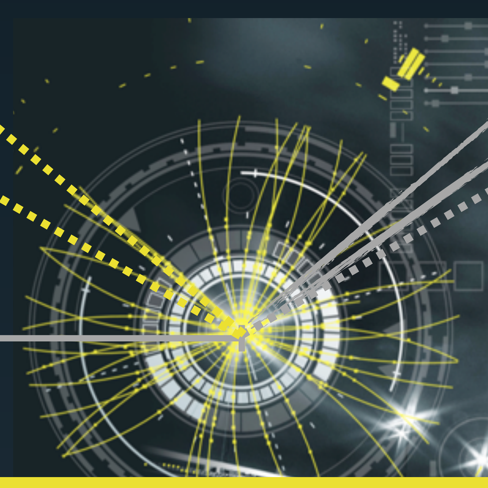
- Many Beyond the Standard Model predict new long-lived particles (LLPs)
- **The HL-LHC era required an enormous investment. Its potential must be fully exploited!**
- The LHC experiments have wide programs to search for LLPs, but searches are limited by triggers, large backgrounds, the size of the detector, etc.

Dark sectors · RPV SUSY · Baryogenesis · Neutral Naturalness · GMSB SUSY · Discrete symmetries · Neutrino masses

Exploring the lifetime frontier with the proposed MATHUSLA detector







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LHCP2020 May 25-30, 2020 Online

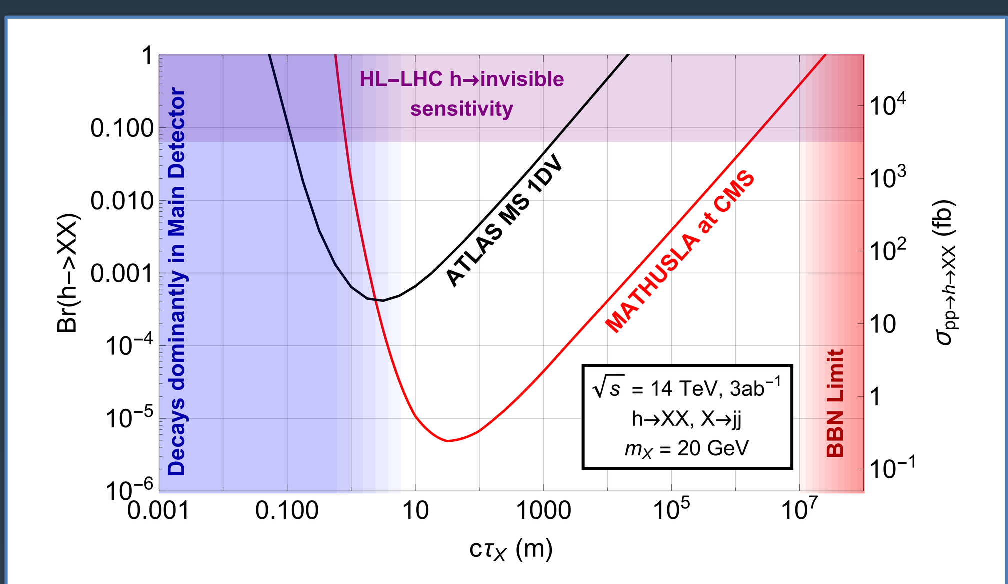
MAsive **T**iming **H**odoscope for **U**ltra **S**table neutra**L** p**A**rticles

MATHUSLA layout

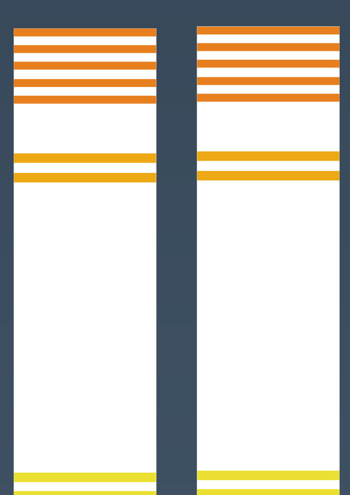
Letter of Intent:
https://arxiv.org/abs/1811.00927

- **100 x 100 m² x 25m high**
- **On the surface above CMS**
- **Planned for HL-LHC**

- Aim for zero background in analysis
- The sensitivity of this design is similar to that of the original benchmark (200 x 200 m² x 20m), by bringing the detector closer to the Interaction Point:
  - vertically: excavating 20m
  - horizontally: placing the detector at 70m instead of 100m

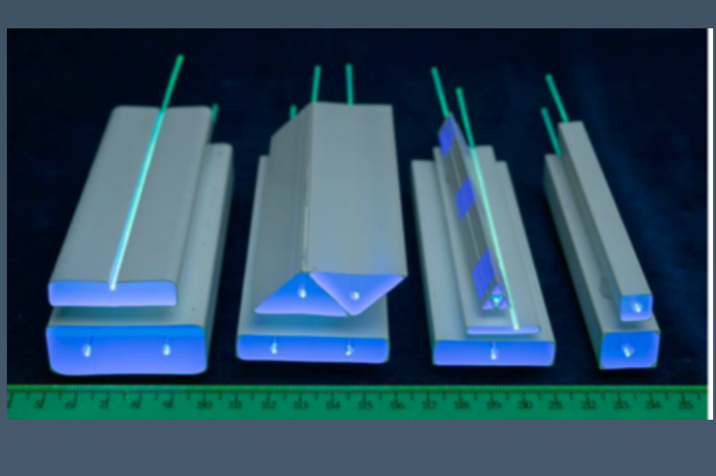


- Total **decay volume** height of 25 m
- Three sets of tracking detectors:
  - **Floor detectors**: two layers, to flag incoming charged particles from the LHC
  - Two sets of detectors to track LLP decay products:



  - **Top detectors**: five layers with 1m-spacing, above the decay volume. Also used for trigger
  - **Intermediate detectors**: two layers, 5m below the top detectors to optimize performance

- Plan to use extruded scintillators for tracking with wavelength shifting (WLS) fibers.



- Fiber read out on both ends using SiPM
- Time difference gives longitudinal position

The MATHUSLA Test Stand

https://arxiv.org/abs/2005.02018
Submitted to NIM

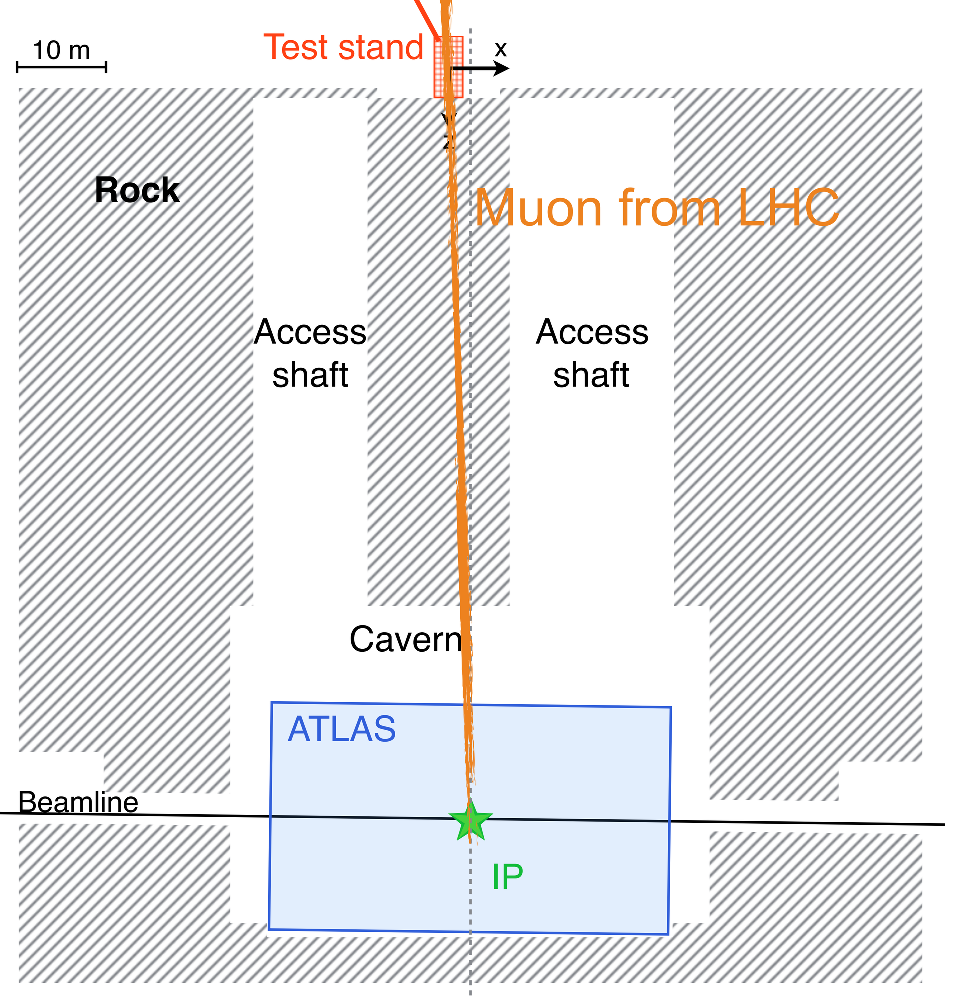
The test stand results confirm the background assumptions in the MATHUSLA proposal and give confidence in the MATHUSLA projected physics reach.

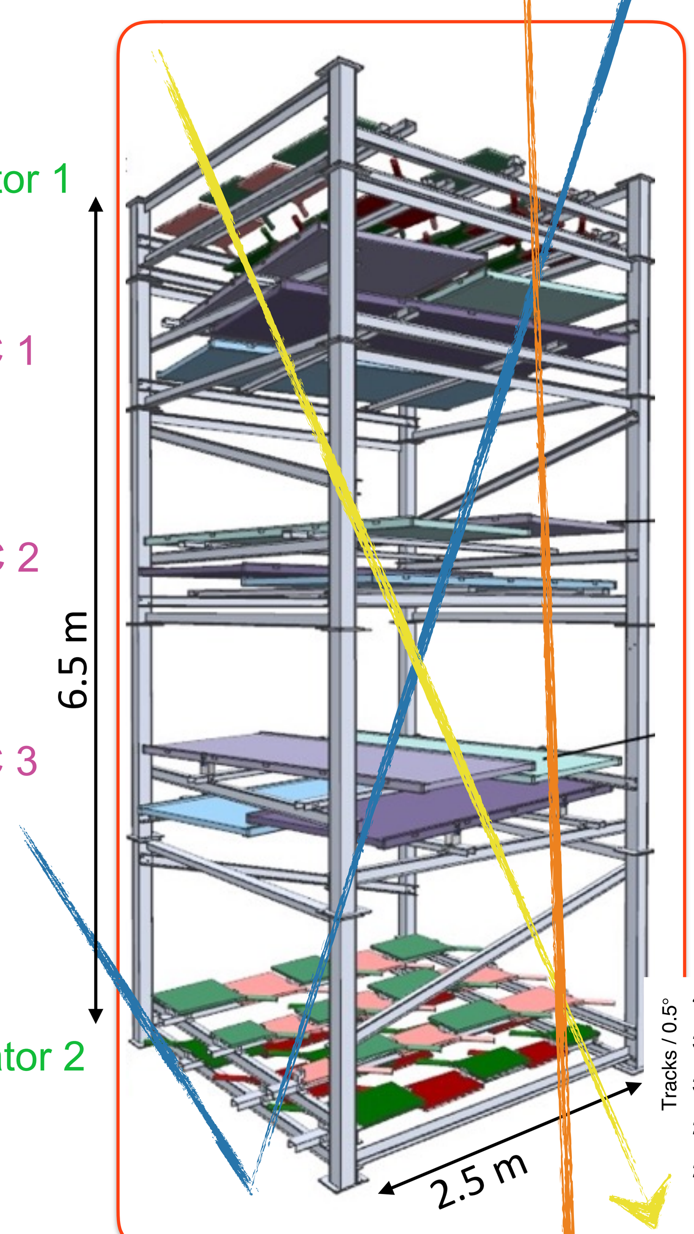
1 The MATHUSLA Test Stand is a small-scale experiment, built on the surface above the ATLAS detector

- It collected data during 2018, both with LHC pp collisions and when the LHC was not colliding protons.

2 Composed of two scintillator planes for triggering, and three double-layers of RPCs between them.

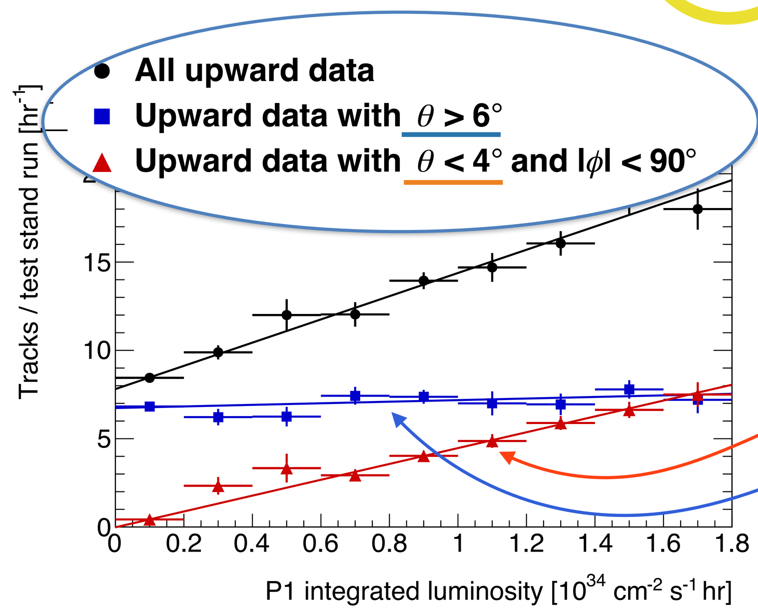
- Tracks were reconstructed using scintillator and RPC information.
- Upward and downward directions were distinguished with timing





3 The goal was to measure the rate of:

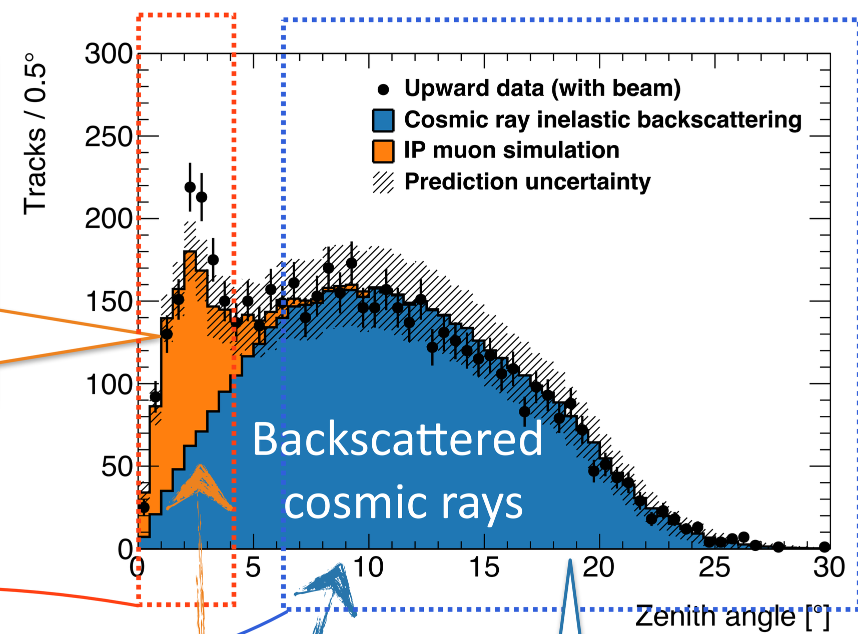
- muons from LHC pp collisions reaching the surface
  - the rate of muons from the IP scales linearly with luminosity
  - it is consistent with Monte Carlo simulated rates from decays of W and Z bosons and b- and c-quark jet
- inelastic backscattering from cosmic rays
  - can create upward-going tracks
  - rate of upward-going tracks at large zenith angles is constant with luminosity
  - it is consistent with Monte Carlo simulated rates



- Rate of IP muon tracks per (10^{34} cm^{-2} s^{-1} hr):
- Measured: 5.7 ± 0.7
- Predicted: 4.8 ± 0.5

4

Significantly narrower angular distribution determined by the small solid angle subtended by the test stand



Wide angular distribution consistent with the downward cosmics as both are determined by geometric acceptance