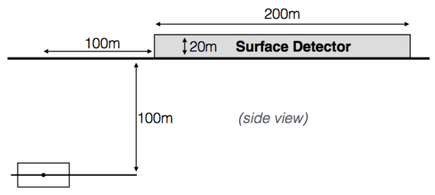
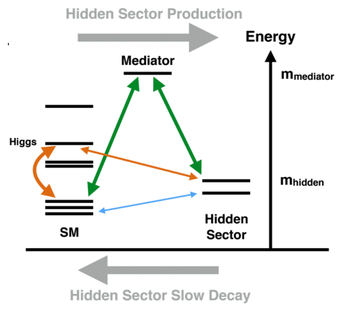
Ultra long-lived particles searches with MATHUSLA

Giovanni Marsella on behalf of The MATHUSLA Collaboration
14th Pisa Meeting on Advanced Detectors 2018

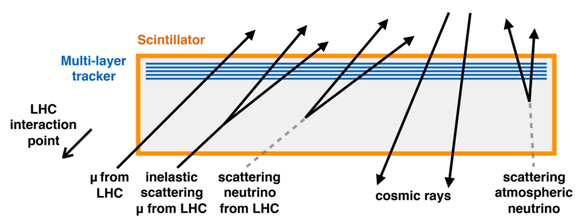
The MATHUSLA (**MA**ssive **T**iming **H**odoscope for **U**ltra-**S**table Neutra**L** P**A**rticles) detector is proposed to be built at CERN on the surface above and slightly displaced from the CMS or ATLAS IP to search for ultra-long-lived particles at the HL-LHC.





Long-lived particles are generic to many BSM models, including Neutral Naturalness, Hidden Valleys, various SUSY theories, models of dark matter, explanations for matter- antimatter asymmetry, and models that generate neutrino mass.

MATHUSLA would search for long-lived particles in an extremely low-background environment.



Theory White Paper

Collaboration of more than 70 theorists

Aiming to publish mid 2018

Detecting Ultra-Long-Lived Particles: The MATHUSLA Physics Case

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Letter of Intent

The Physics Beyond Colliders (PBC) CERN Working Group (http://pbc.web.cern.ch/) decided to expand its scope and include external detector proposals for the LHC, like MATHUSLA, milliQan, Codex-b, Faser, etc, in its study and evaluation.
Our plan is to prepare a MATHUSLA letter of intent (LOI) to be ready near the middle of 2018.
The physics case white paper will provide the necessary theory input. This LOI will also provide input for the PBC report.

Simulation

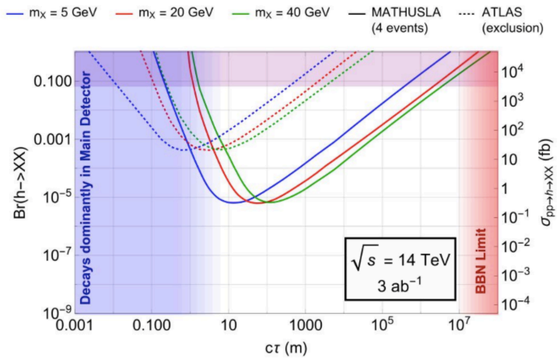
- Ongoing work on simulating signal and background for MATHUSLA
  - MadGraph/Pythia for generating signal events and incoming muons from LHC collisions
  - GENIE for simulating neutrino scattering
  - CORSIKA for cosmic ray simulation
  - Simulating detector response in Geant4
- Because geometric coverage is not 100%, idea is to get spectrum of particles (muons, neutrinos) coming from LHC collisions in MadGraph/Pythia, then create a "particle gun" directly in G4 to send into detector simulation

Estimated sensitivity

Aiming to reduce background events over the entire HL-LHC run to *O*(1)

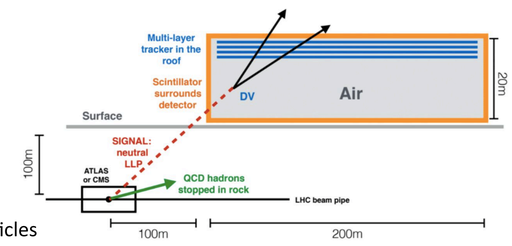
⇒ Sensitive to *O*(1) signal events!

Plot shows predicted sensitivity to exotic Higgs decays to ULLPs from requiring 4 signal events



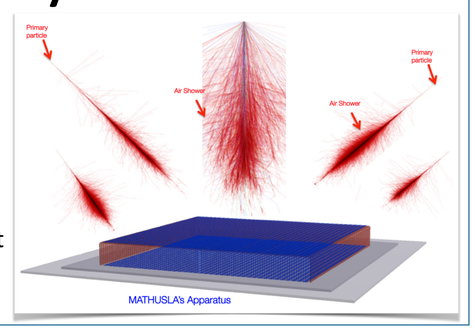
The Detector

- Considering two robust, well-understood technologies:
  - Scintillator planes:
    - Covering entire boundary of detector volume
    - Used for triggering and rejecting incoming SM particles
  - 5 RPC layers placed horizontally near top of the volume:
    - Tracking, vertex reconstruction, rejection of downward-traveling particles (cosmic ray muons)
  - The ~1 ns and ~1 cm resolutions expected to be needed for tracking and background rejection are very attainable, have been proven with the above in existing detectors
  - Could replace scintillators with all RPCs ⇒ single technology detector
- Can be built as several smaller modules (e.g., 20 m × 20 m × 20 m)
  - Would streamline deployment, improve flexibility to funding availability, allow placing modules above both ATLAS and CMS



Cosmic Rays

Upshot: MATHUSLA could be a very powerful cosmic ray instrument with unique capabilities within the ecosystem of CR experiments.
Articulating & understanding this completely separate CR physics case will take a lot more study, but it seems clear that this can represent a "guaranteed physics return" (both "SM" and possibly "BSM") on the investment to build MATHUSLA.

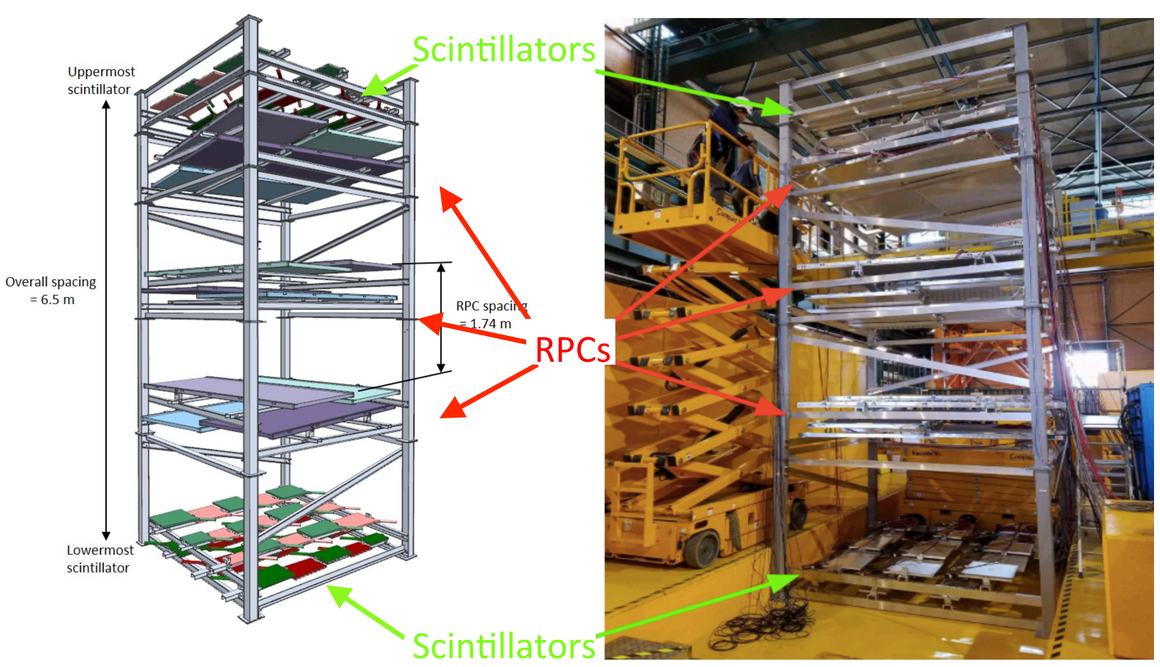


MATHUSLA test-stand

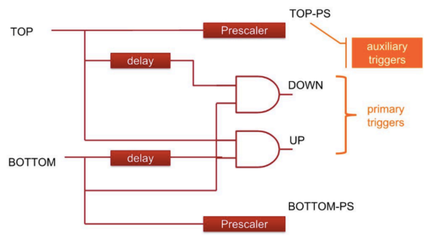
Each layer has 2 RPCs aligned in the "x" direction and 2 in the "y" direction

Size 2.5 m x 2.5 m x 6.5 m

DAQ includes:
TDC and ADC information for scintillators
TDC and pad/strip ID for RPCs



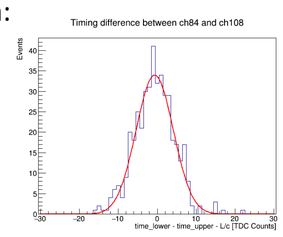
59 scintillators borrowed from D0 experiment used to form top and bottom layers of structure
12 RPCs borrowed from ARGO experiment used to form middle 3 layers with 4 RPCs per layer: 10 pads per RPC and 8 strips per pad
4 triggers:
Upwards going particle
Downwards going particle
Prescaled signal from top layer
Prescaled signal from bottom layer

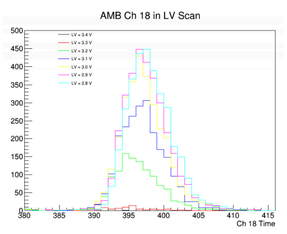


Signal from top (bottom) layer is logical OR of all scintillators in top (bottom) layer
Data taken at P1 and the H8 beamline, with beams off and on

Performance and Data Analysis

- Ongoing analysis of test stand data:
  - Writing analysis framework
  - Starting tracking
  - Optimizing RPC voltage settings
  - Timing calibration





Efficiency vs Threshold

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