An Auxiliary ATLAS Detector to Enhance the Detection of Long Lived Particles - The First Steps

ADAM - Auxiliary Detector above the ATLAS Muon detector

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Outline

1. Motivation and Detector Description
2. Example Physics Use Cases
3. Decays in Flight
4. Trapped LLPs
5. Cosmic Multi-Muons
6. Simulation
7. Summary/Conclusion

Motivation and Detector Description

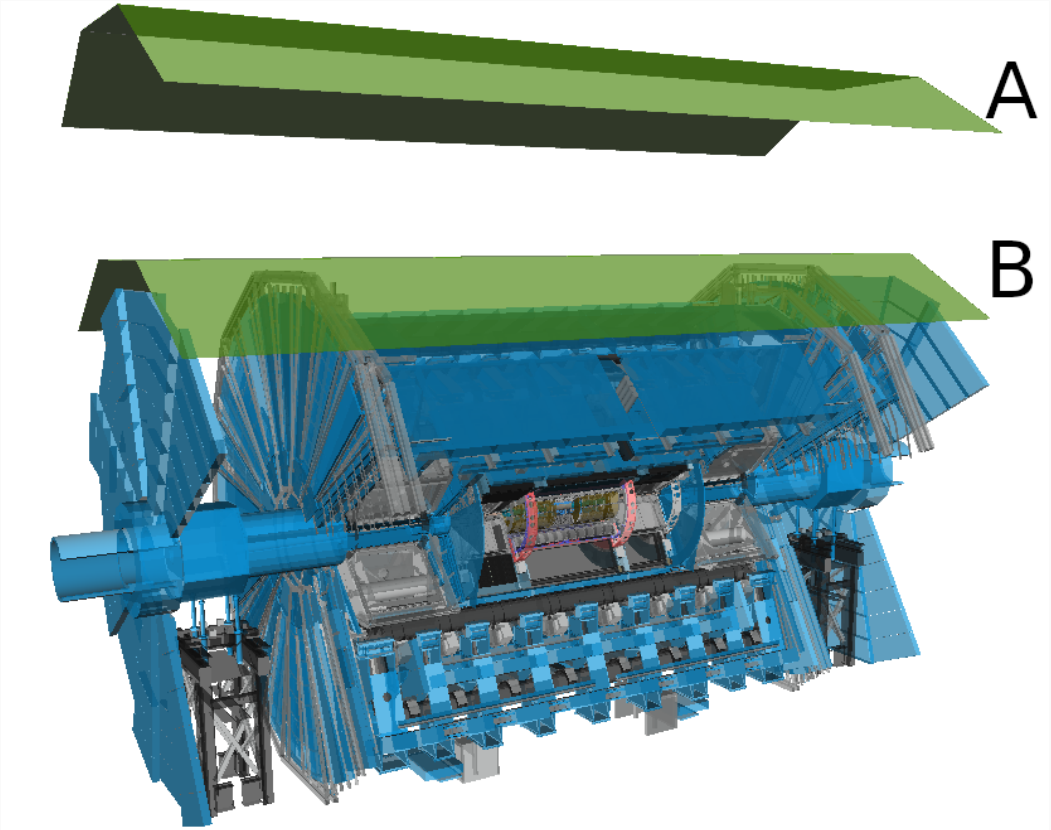
Motivation

Why build a new detector?

Higgs discovery completes standard model, but open questions remain.

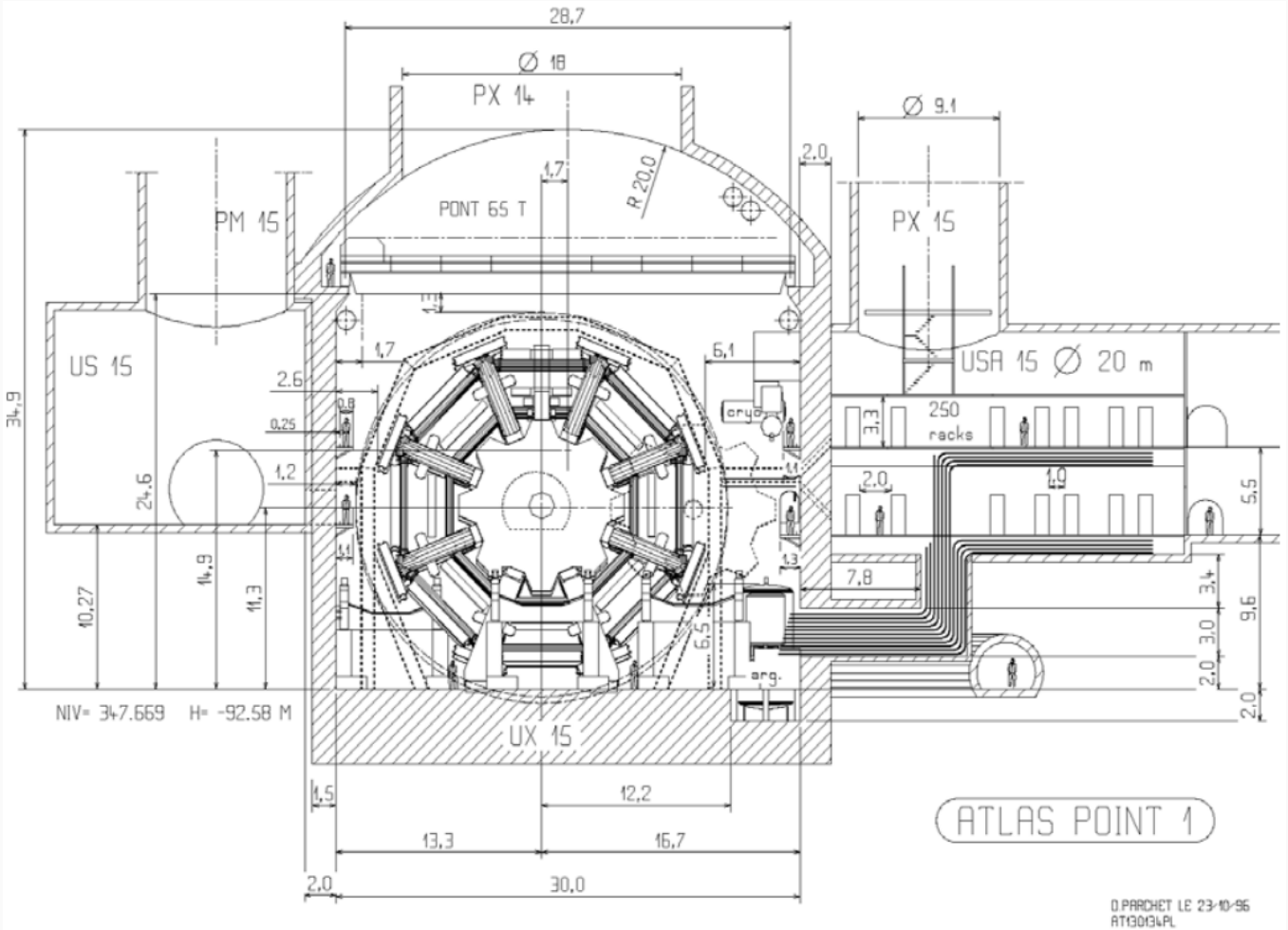
So far, no signs of new physics. This is an attempt to help maximize the physics reach of ATLAS in the arena of new physics.

The ADAM detector



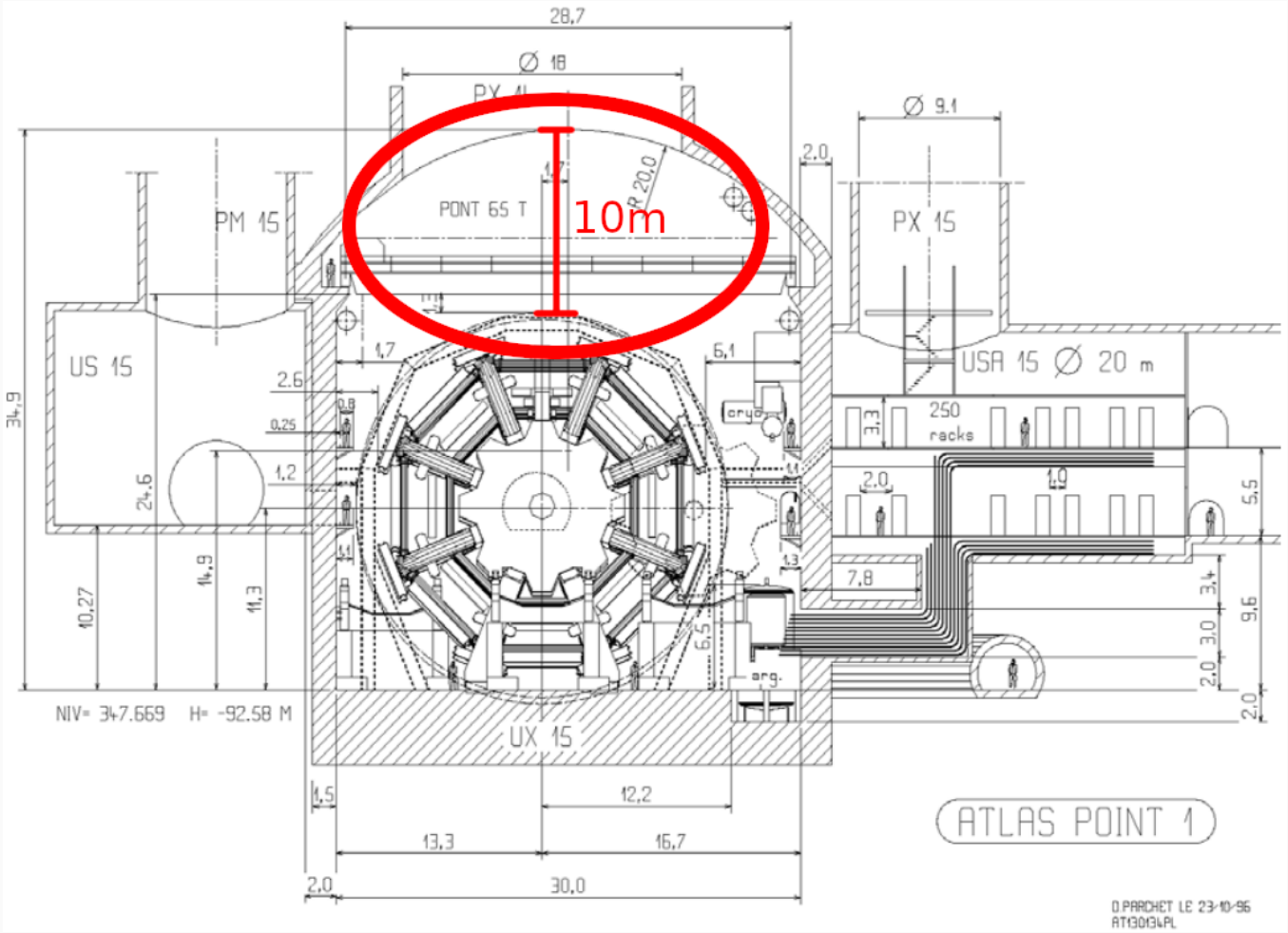
Two scintillating panels (green), the top A layer would rest on the ceiling of the ATLAS cavern, while the bottom B layer would straddle the existing ATLAS infrastructure. This would allow us to resolve upward vs downward travelling particles.

ATLAS UX15 Cavern



Schematic drawing of ATLAS and the UX15 Cavern. There is approximately 10m of space above ATLAS.

ATLAS UX15 Cavern



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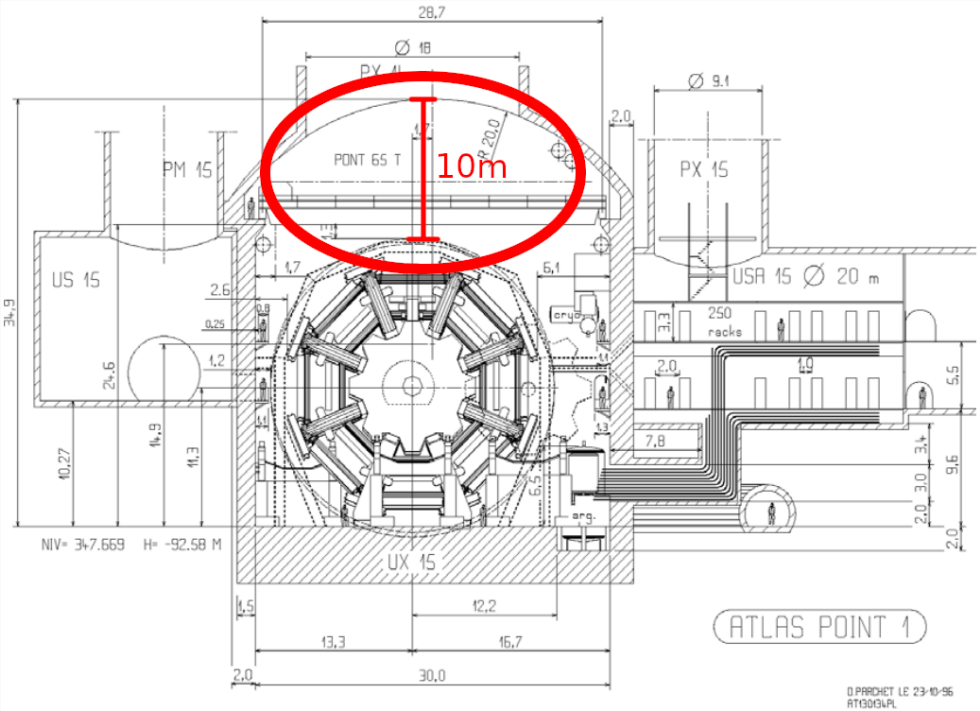
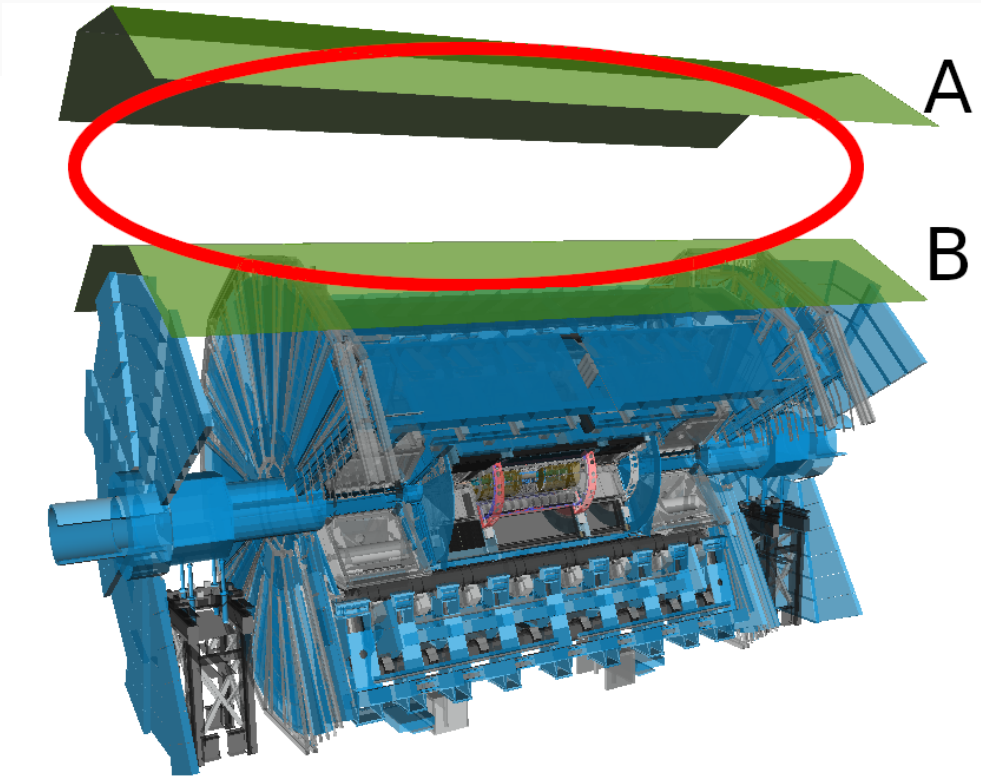
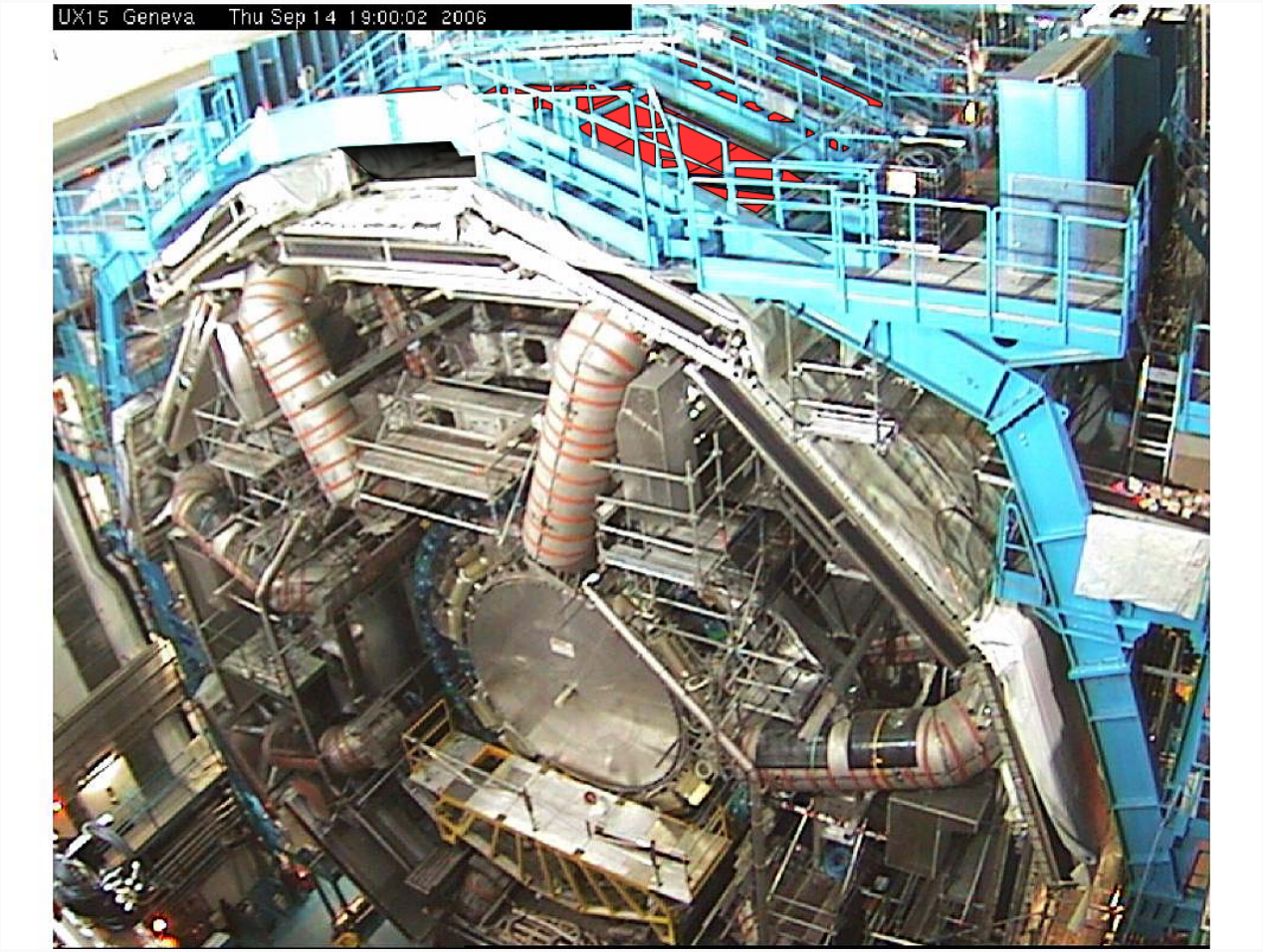


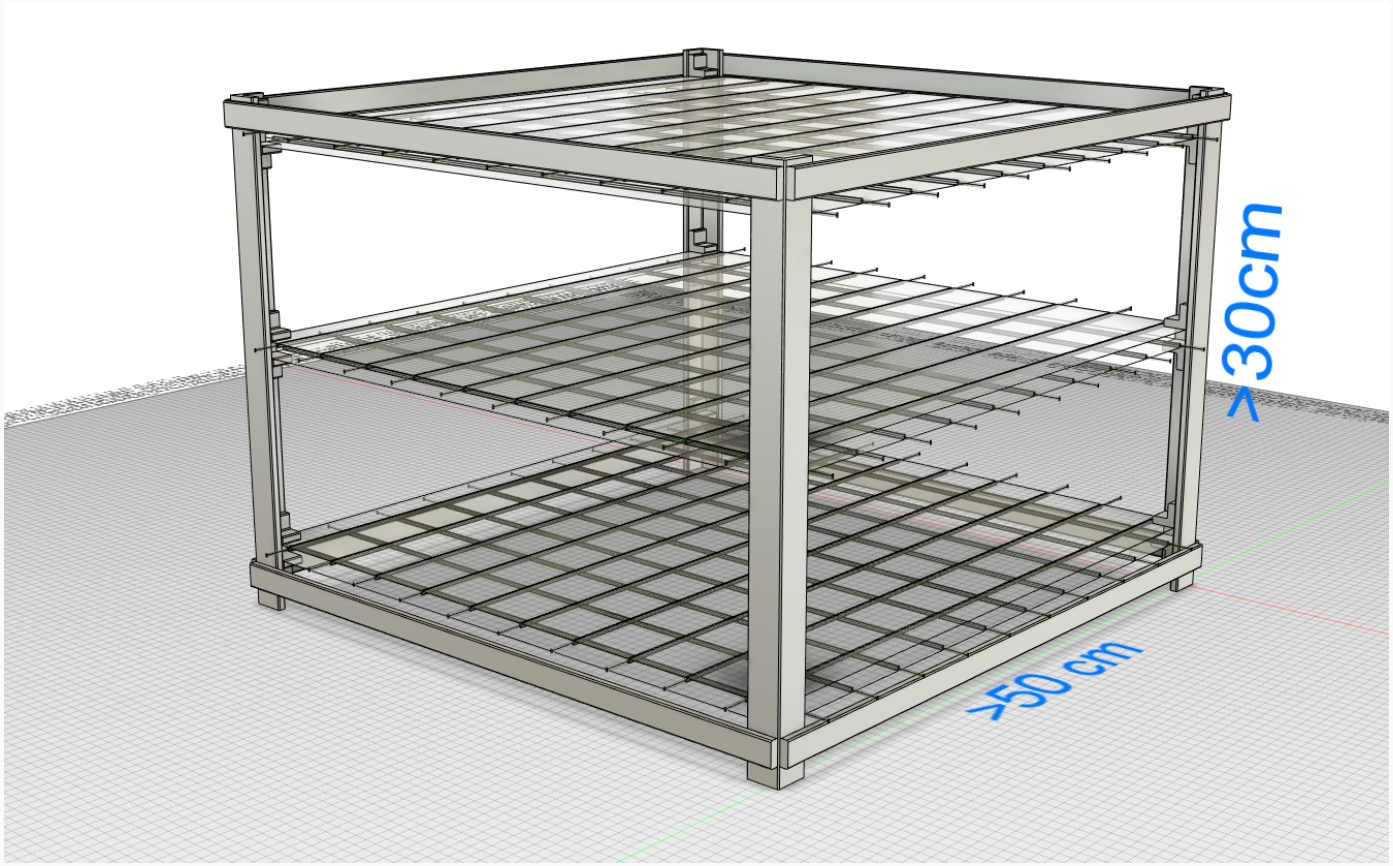


ATLAS - A TOP VIEW



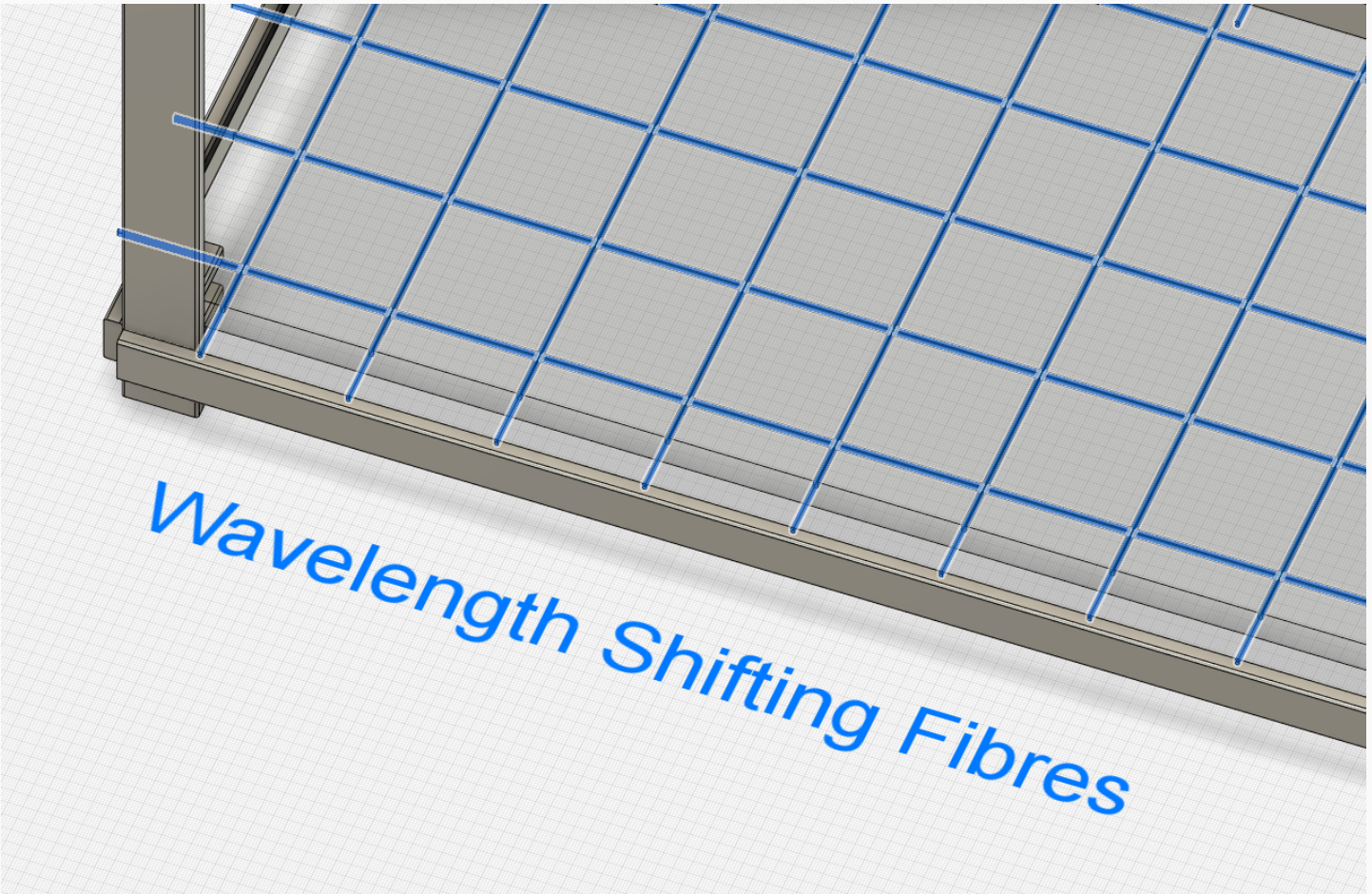
This picture shows of the top of ATLAS, red highlighted areas show candidate zones for scintillating panels.

THE ADAM DETECTOR - AN INDIVIDUAL CELL



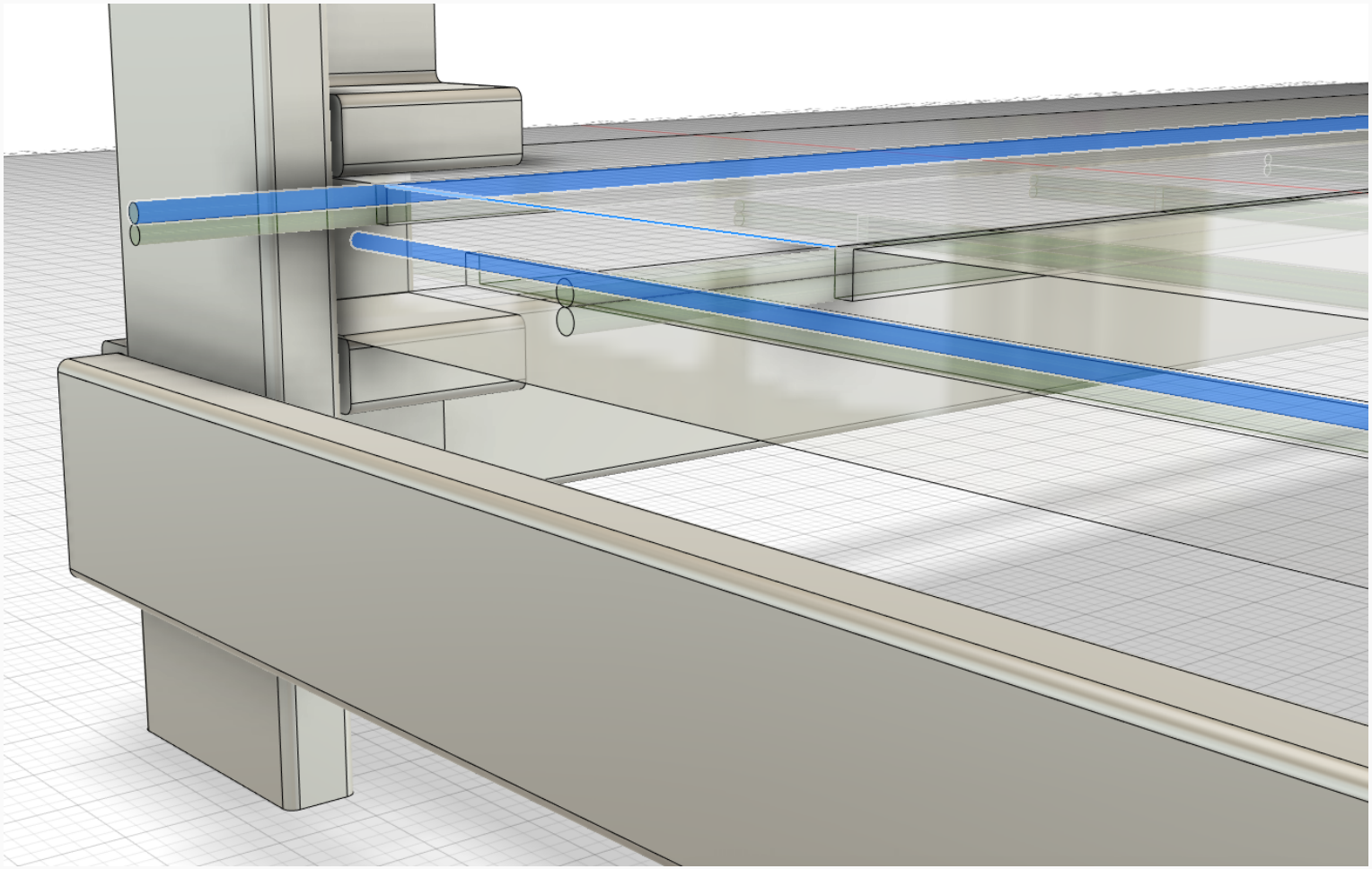
CAD drawing of an individual scintillating unit. This unit is designed to make a spatial measurements of a muon track and determine whether it is upward or downward moving.

The ADAM detector - XY channel pattern



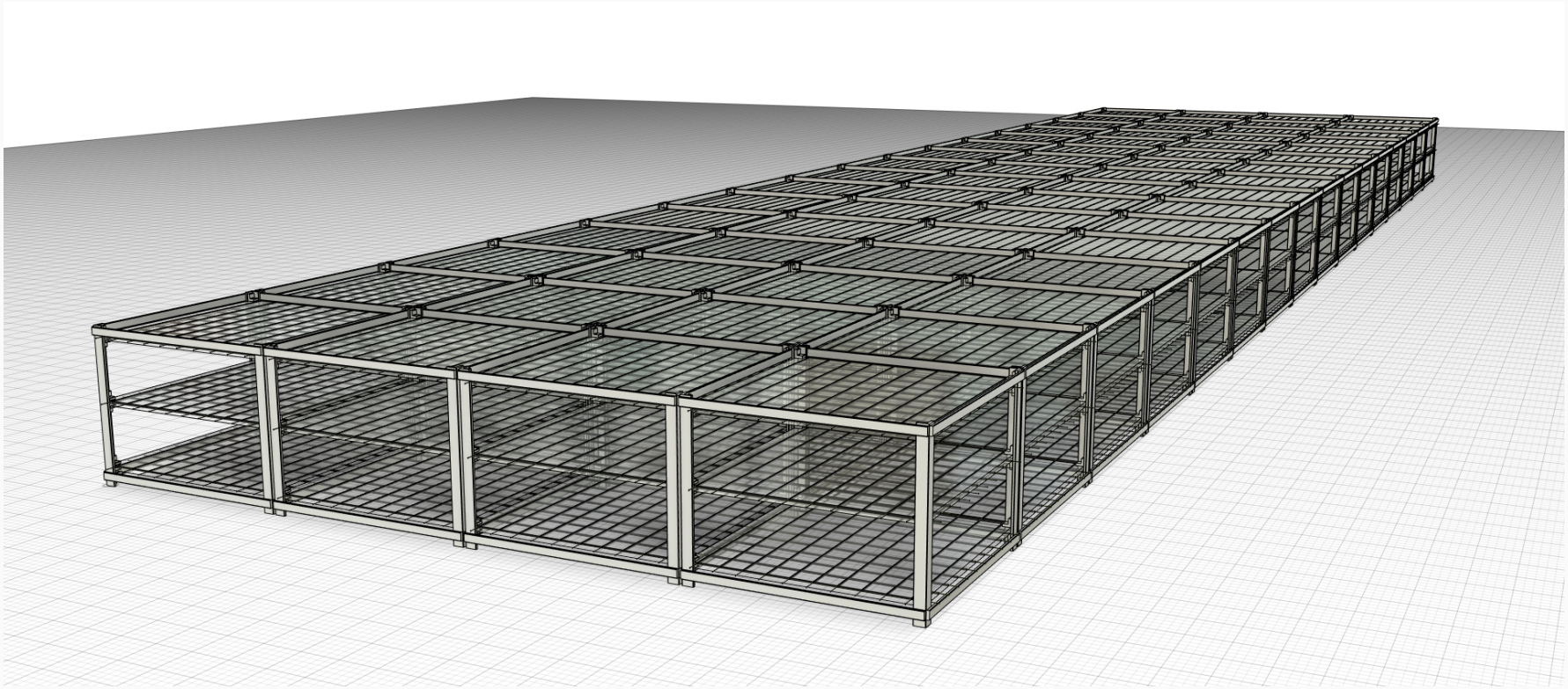
Close up of the X-Y patterned wavelength shifting fibres, which will have a 1-5cm pitch and will be read out by silicon photomultipliers.

THE ADAM DETECTOR - CLOSE UP



2 fibres are highlighted in blue to illustrate the fibres resting in channels cut in the top and bottom of the scintillator panel.

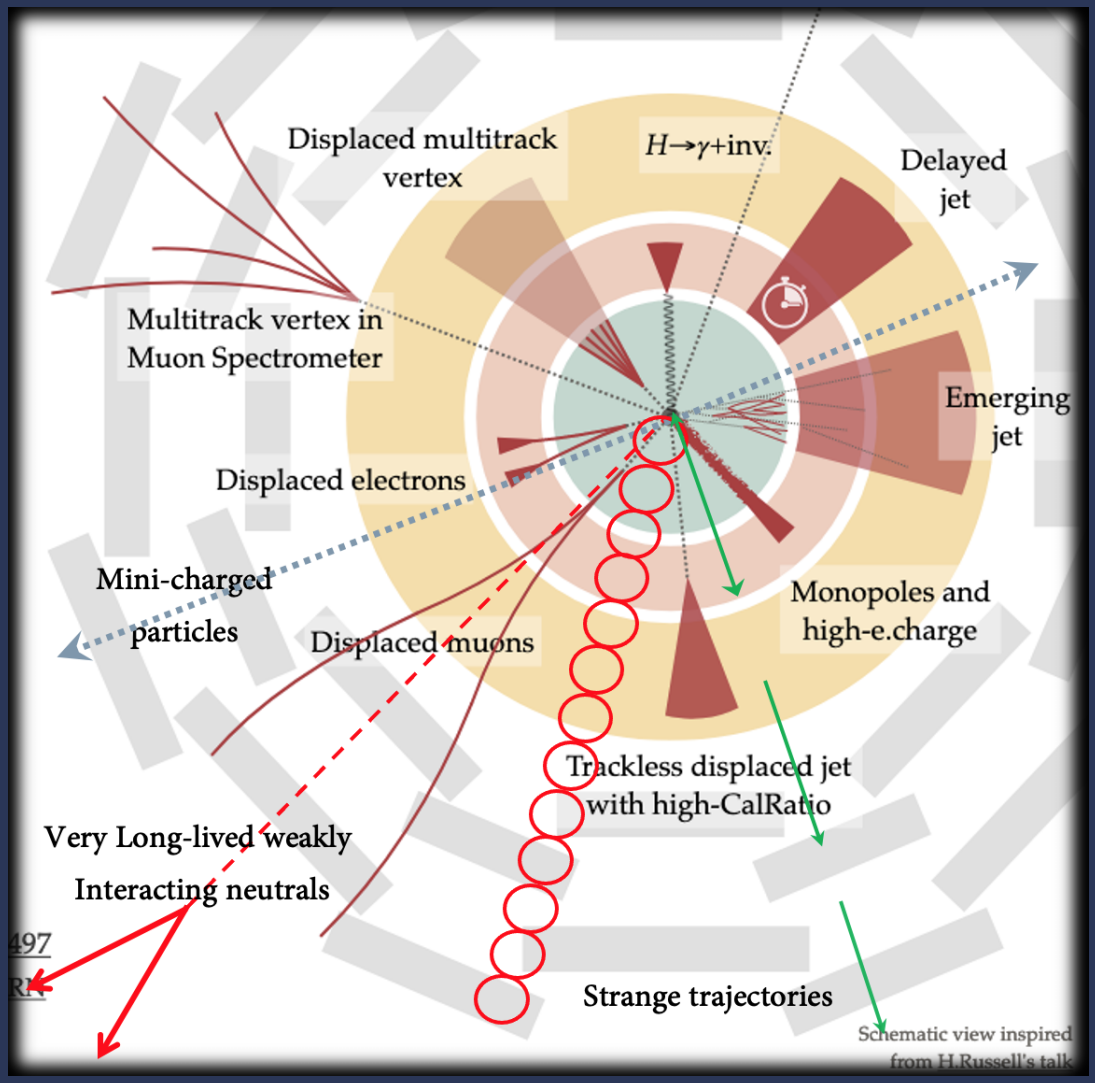
THE ADAM DETECTOR - AN ARRAY OF CELLS



CAD Drawing of multiple cells joined forming a main detector panel.

Example Physics Use Cases

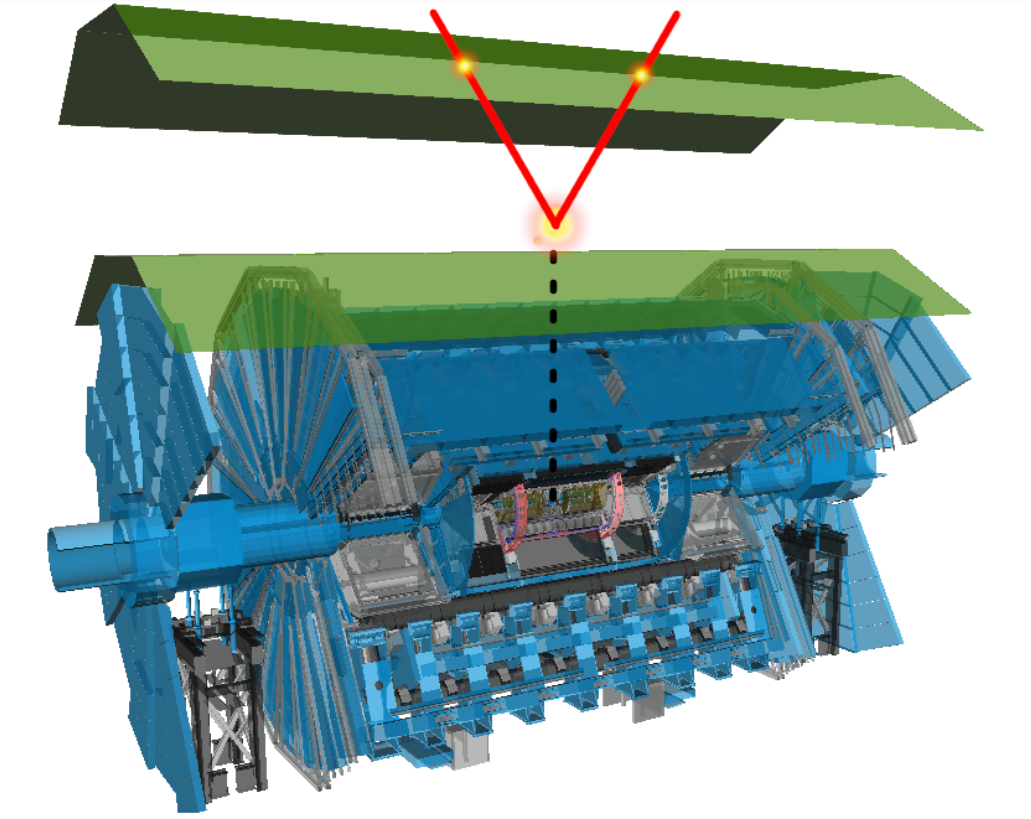
EXAMPLE PHYSICS USE CASES



A diagram of potential new physics signatures *[Credit: H Russell]*.

Decays in Flight

Decays in Flight



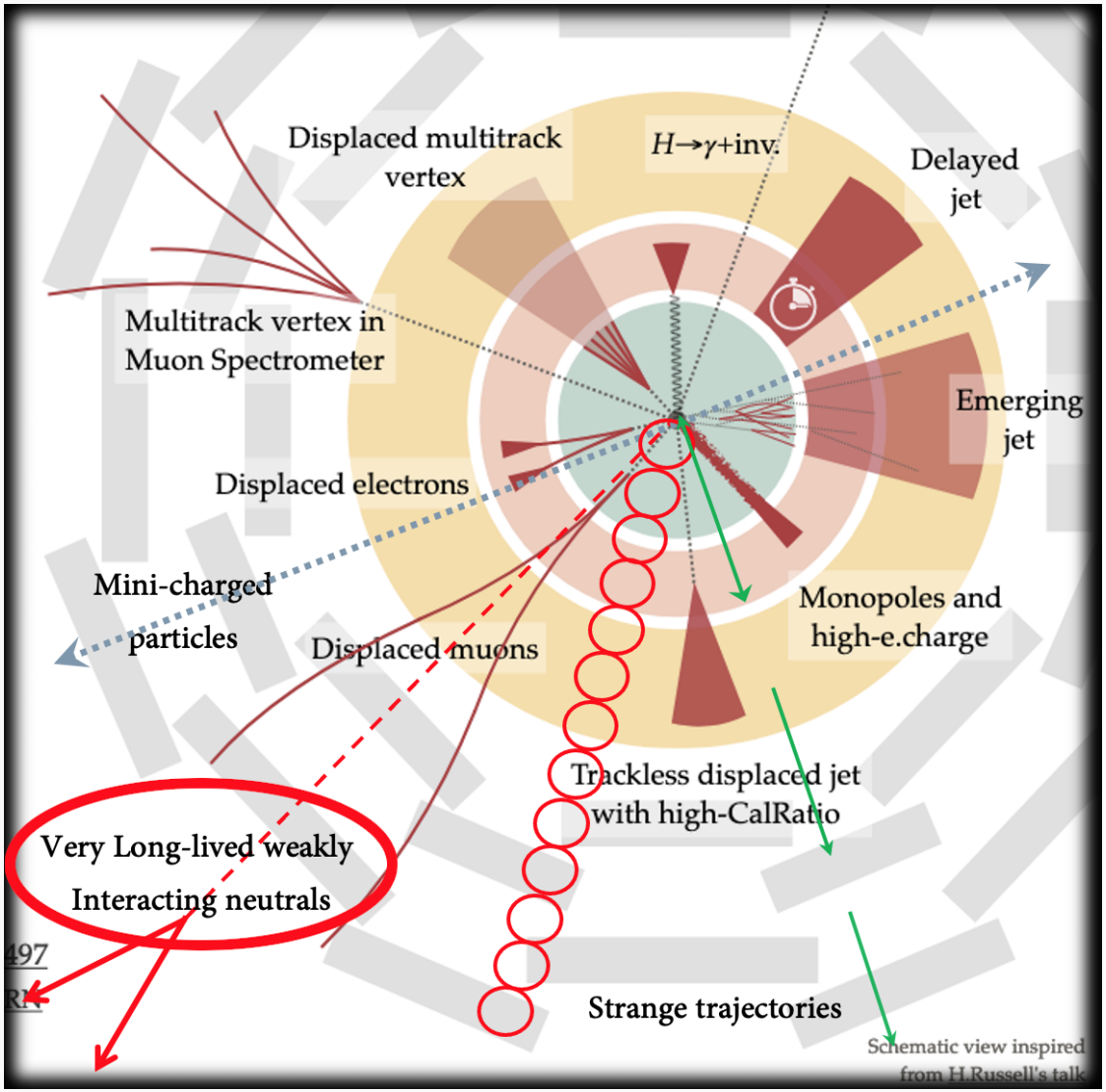
A neutral particle (black) traverses ATLAS and the lower layer of ADAM undetected, the decay products (red) then interact with the top layer. The lower layer is used as a veto against charged particles from the IP.

Decays in Flight

Possible Scenarios

Several BSM models allow very long lived neutral particles with $c\tau > 10m$. For example:

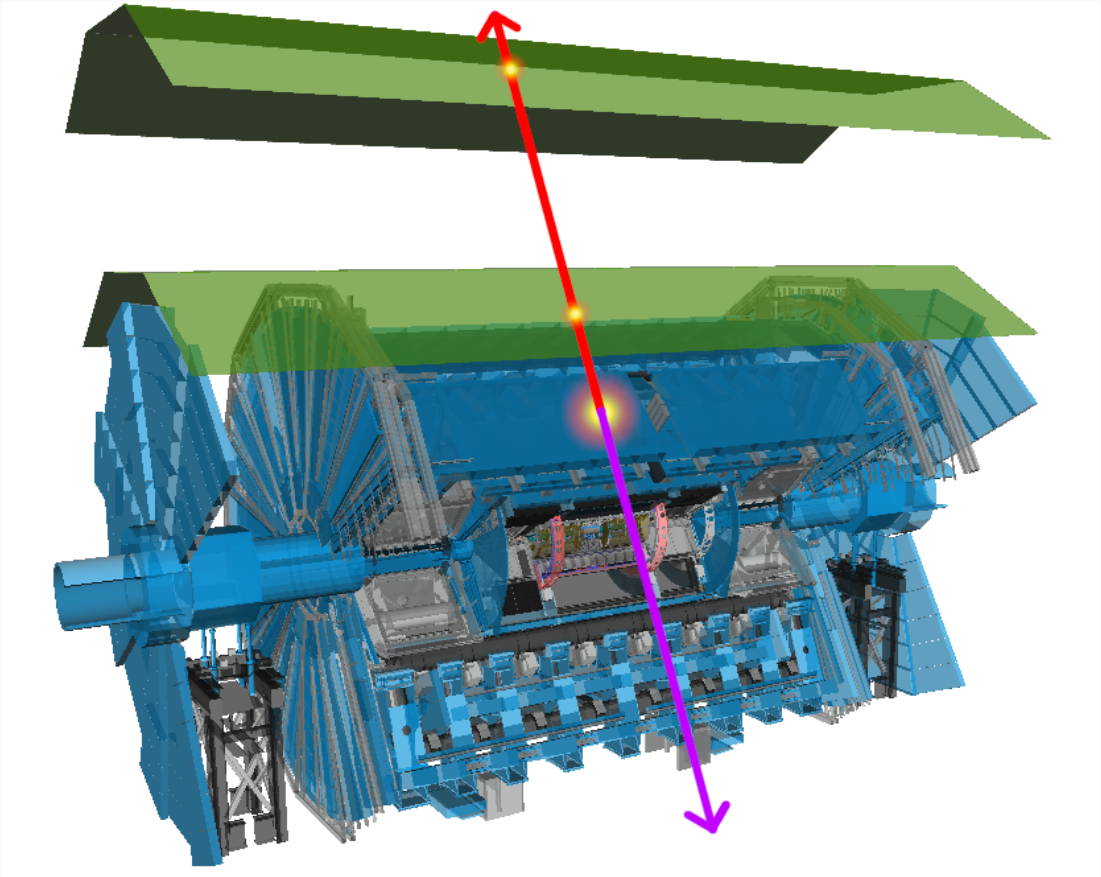
- Supersymmetry - Neutralino NLSP $\tilde{\chi}_1^0$
- Dark sector B decays - $B \to X\varphi \to X\mu\mu$



References:
J. High Energ. Phys. 2010, 67 (2010)
Phys. Rev. D 97, 015023, (2018)

Trapped LLPs

Very Long Lived Particles



Very long lived trapped charged particles that are stopped inside the ATLAS detector (calorimetry), and then at some later time decay (red/purple).

Trapped Long Lived Particles

Possible scenarios

MSSM models can allow for very long lived particles, that range up to over 10 years [1]. For example massive, ionizing, charged sleptons which would come to rest and wait to decay.

Similarly, other SUSY models predict heavy gluinos or squarks that hadronize to form R-Hadrons which could exhibit the same behaviour [2].

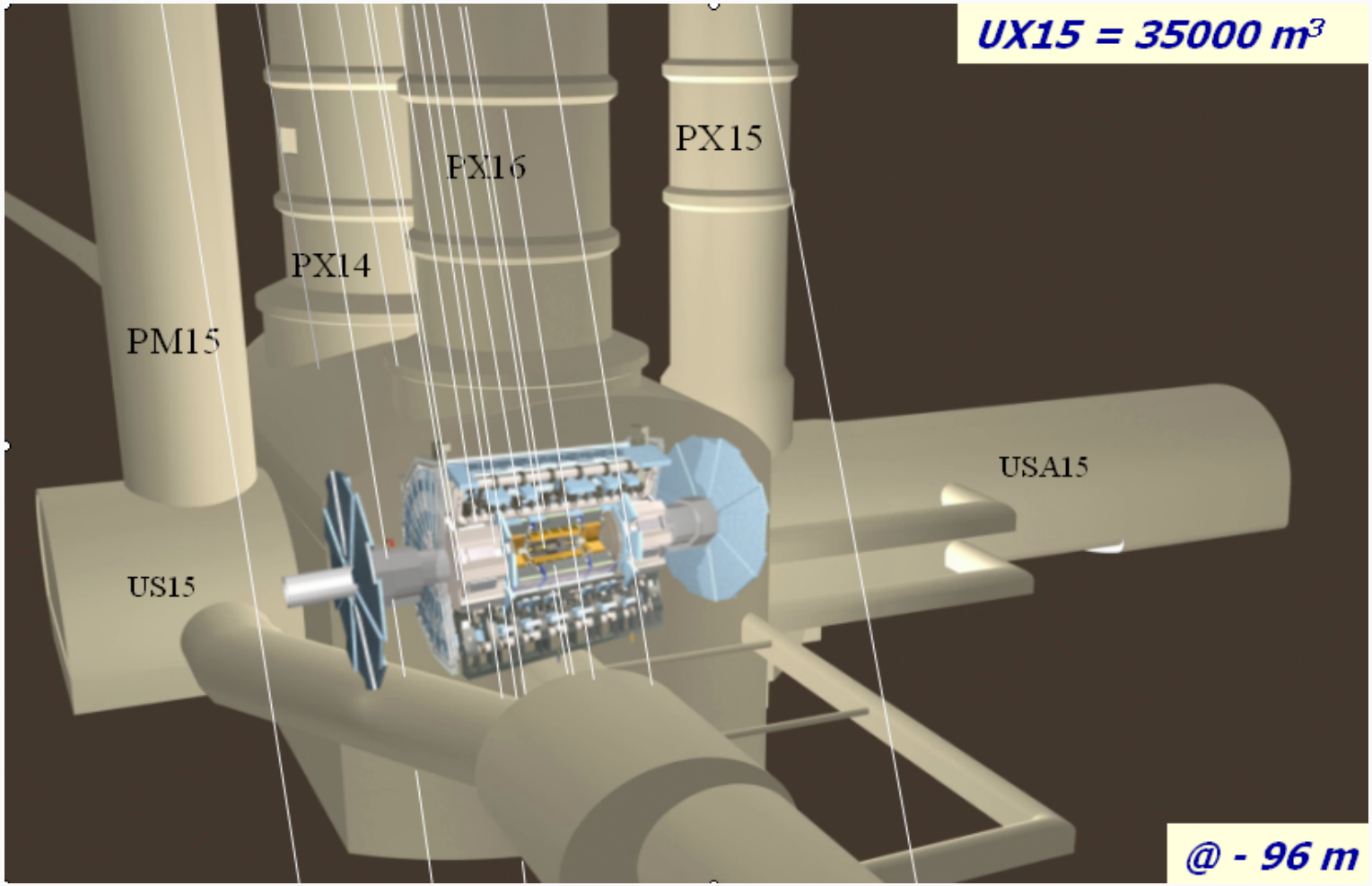
ADAM could be used to detect the decay and measure the lifetime of very long lived exotics while the LHC beam is off (during year end shutdown and technical stops)

References:
[1] J. High Energ. Phys. 2015, 1–24 (2015)

[2] Phys. Rev. D, 88, 112003 (2013)

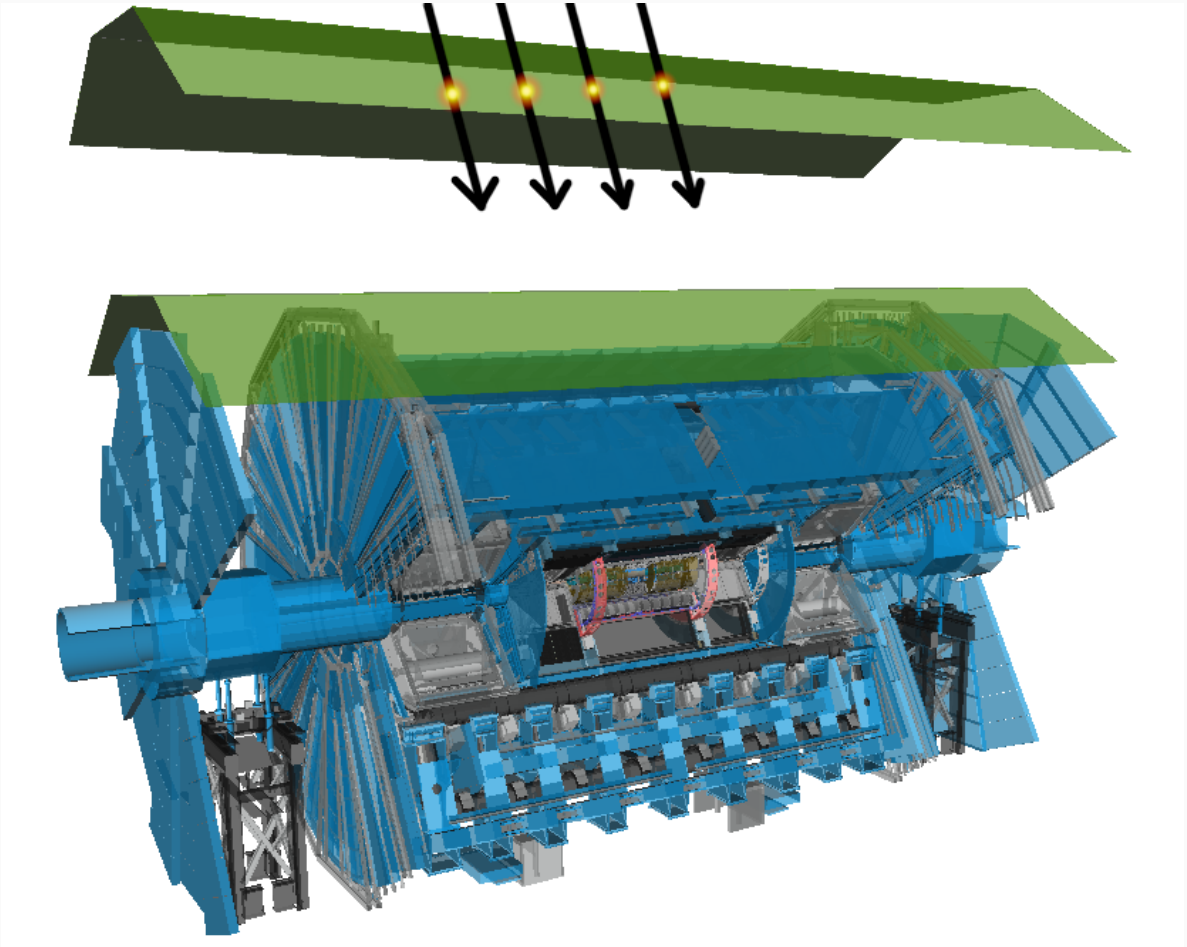
Cosmic Multi-Muons

Cosmic Multi-Muons



Cosmic ray muons penetrate the ATLAS overburden and can enter the detector.

Cosmic Multi-Muons



ADAM can be used with ATLAS to study multi-muon events (muon bundles).

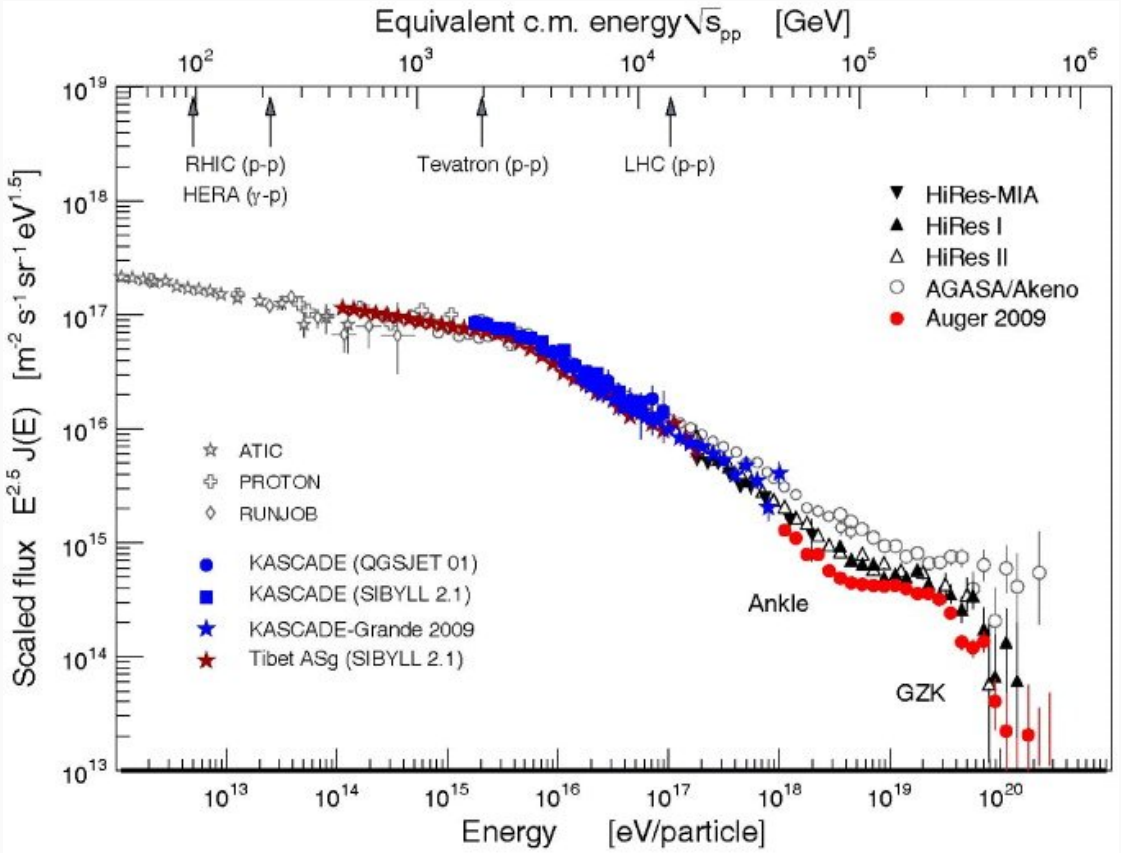
Cosmic Multi-Muons

ATLAS as comic muon detector

High energy cosmic muons penetrate the earth far enough to reach ATLAS.

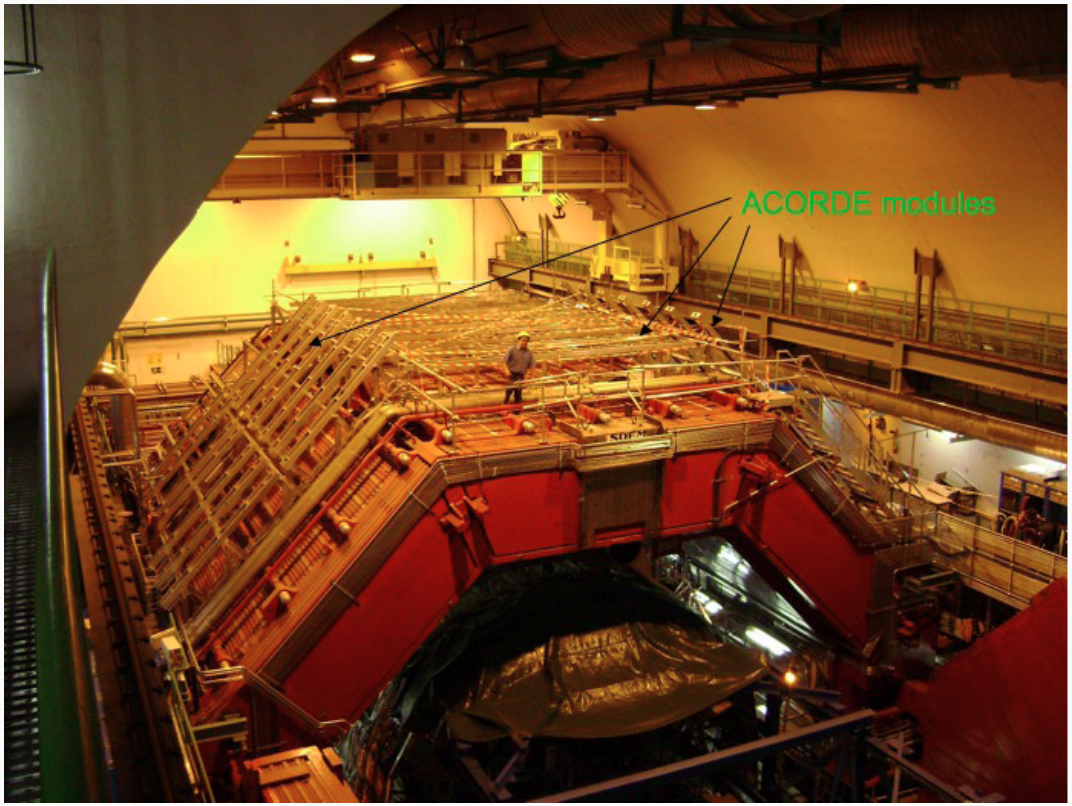
We are investigating the use of ADAM together with ATLAS to study cosmic muons, at intermediate depth.

This arrangement could be used to study the composition of the cosmic ray spectrum at the "knee".



Reference: Progress in Particle and Nuclear Physics, 63, 2, 293-338, 2009

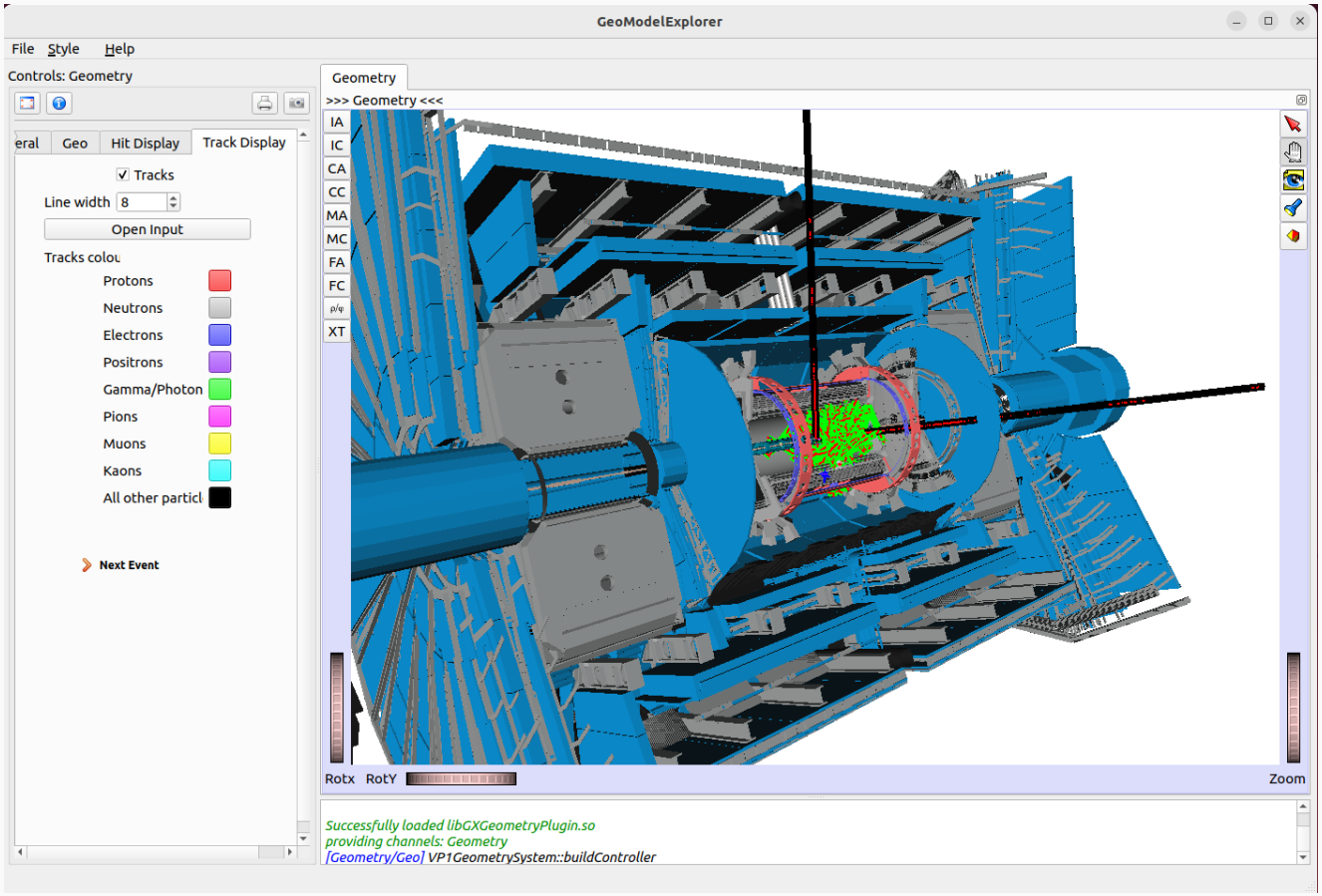
A SIMILAR COSMIC MUON DETECTOR - ACORDE



The ACORDE detector is a scintillating cosmic muon detector designed to study multi-muon events, but has a significantly smaller area of muon chambers than the ADAM-ATLAS detector would. ACORDE is placed above the ALICE magnet.

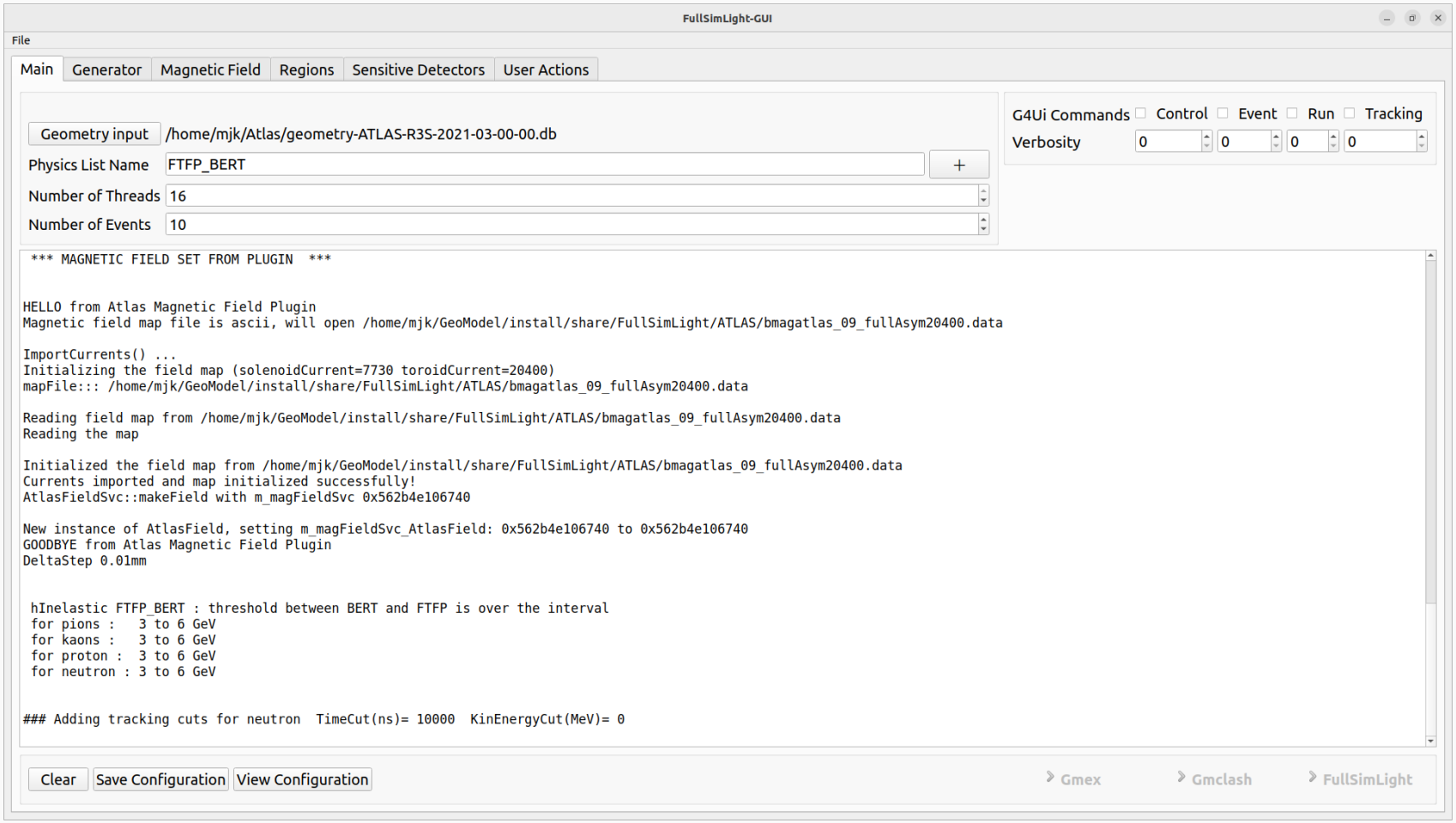
Simulation

GeoModel



GeoModelExplorer: visualization software for GDML or SQlite geometry files. Based on Athena software but has been ported out and is "detector agnostic." (https://geomodel.web.cern.ch/home/)

FullSimLight



An image of the FullSimLight GUI. FullSimLight reads GDML or .db format geometry files and imports the geometry to GEANT4. FSL can transport events from Pythia directly and from HEPMC files.

Summary/Conclusion

Conclusion

We hope to investigate ADAM's ability to expand the physics reach of ATLAS

- 10m decay volume above ATLAS for neutral LLP decays
- Beam off detector for trapped, charged, VLLP decay detection
- Possibility to study cosmic muons? Muon bundles?
- Highly cost effective technology
- Investigate the use of timing