

MATHUSLA

Status and Prospects for an Optimised Geometry

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on behalf of the MATHUSLA Collaboration

Physics Beyond Collider Annual Workshop

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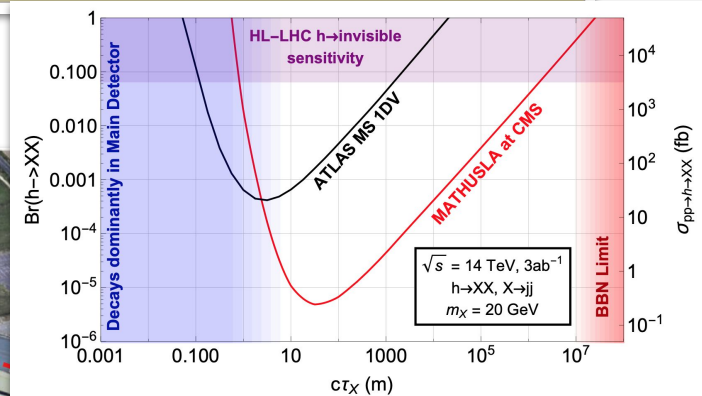
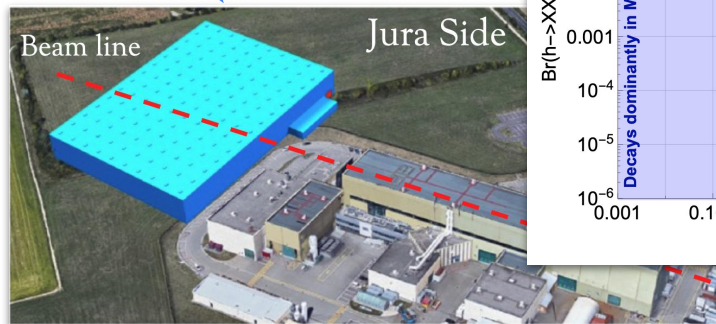
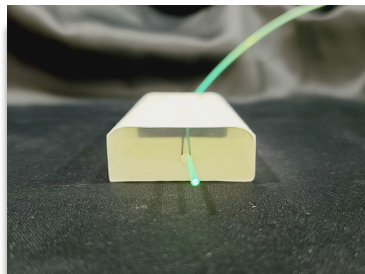
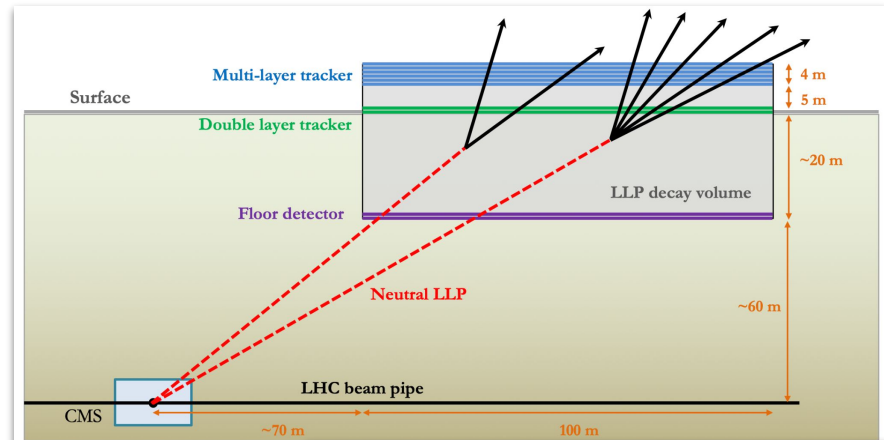
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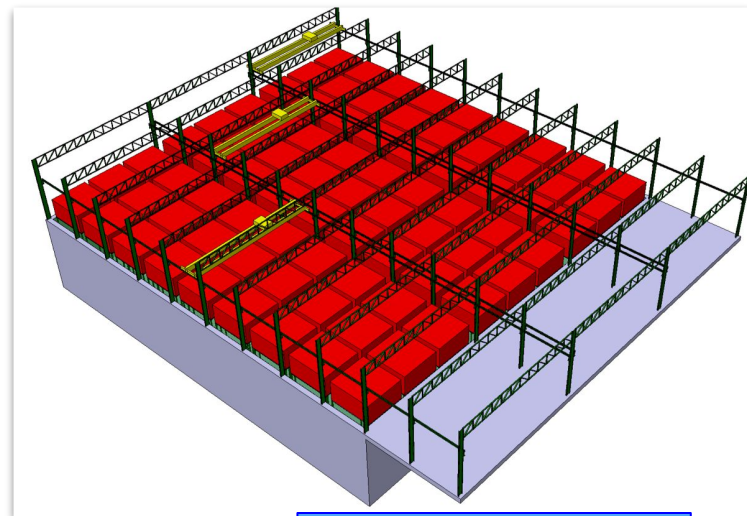
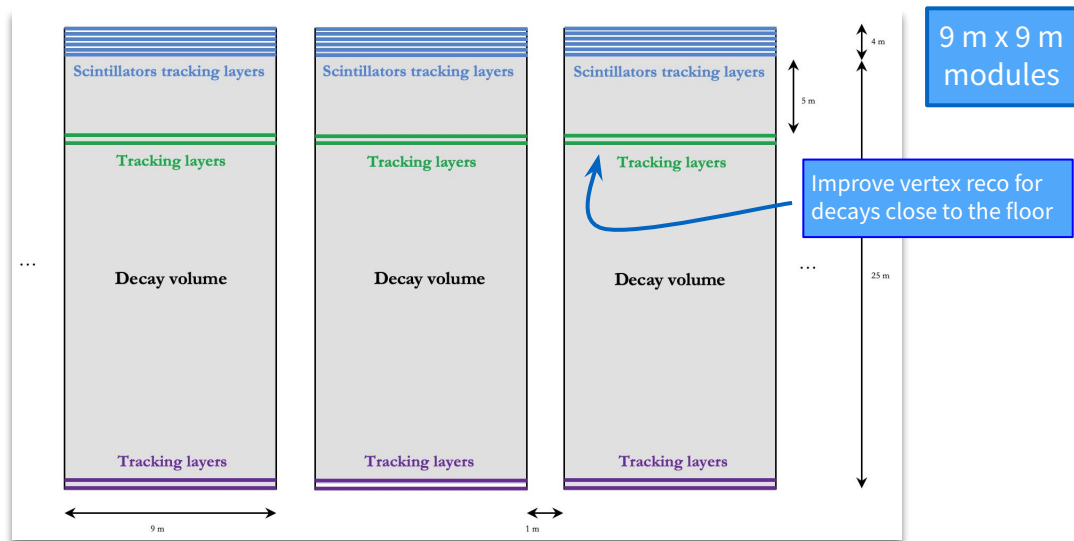
Original Design Recap - 1

Dedicated detector sensitive to neutral LLP with lifetime up to BBN

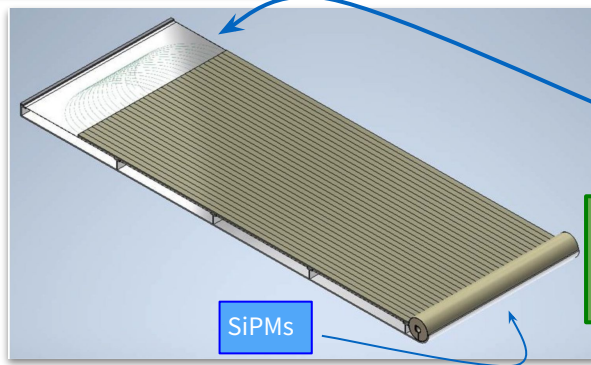
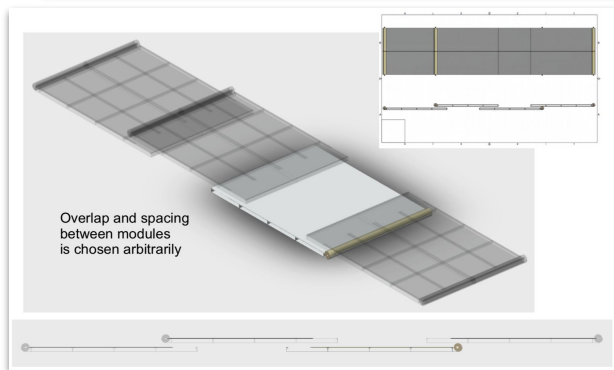
- Proposed a **large area surface detector** located above CMS
 - Robust tracking + excellent background rejection**
 - Floor detectors to reject interactions occurring near the surface
 - Extruded scintillators + SiPMs** (good time/space resolution)



Original Design Recap - 2



Detector + assembling area



U-readout:
two bars connected at one end (every N-bars). Info read by SiPM only on one side of the bar

Tests proved we can reach timing resolution of **~0.54 ns** (i.e. 9 cm RMS position resolution) well within MATHUSLA requirement. **Worst case light-yield: 29 PE**

Rescoping MATHUSLA after P5

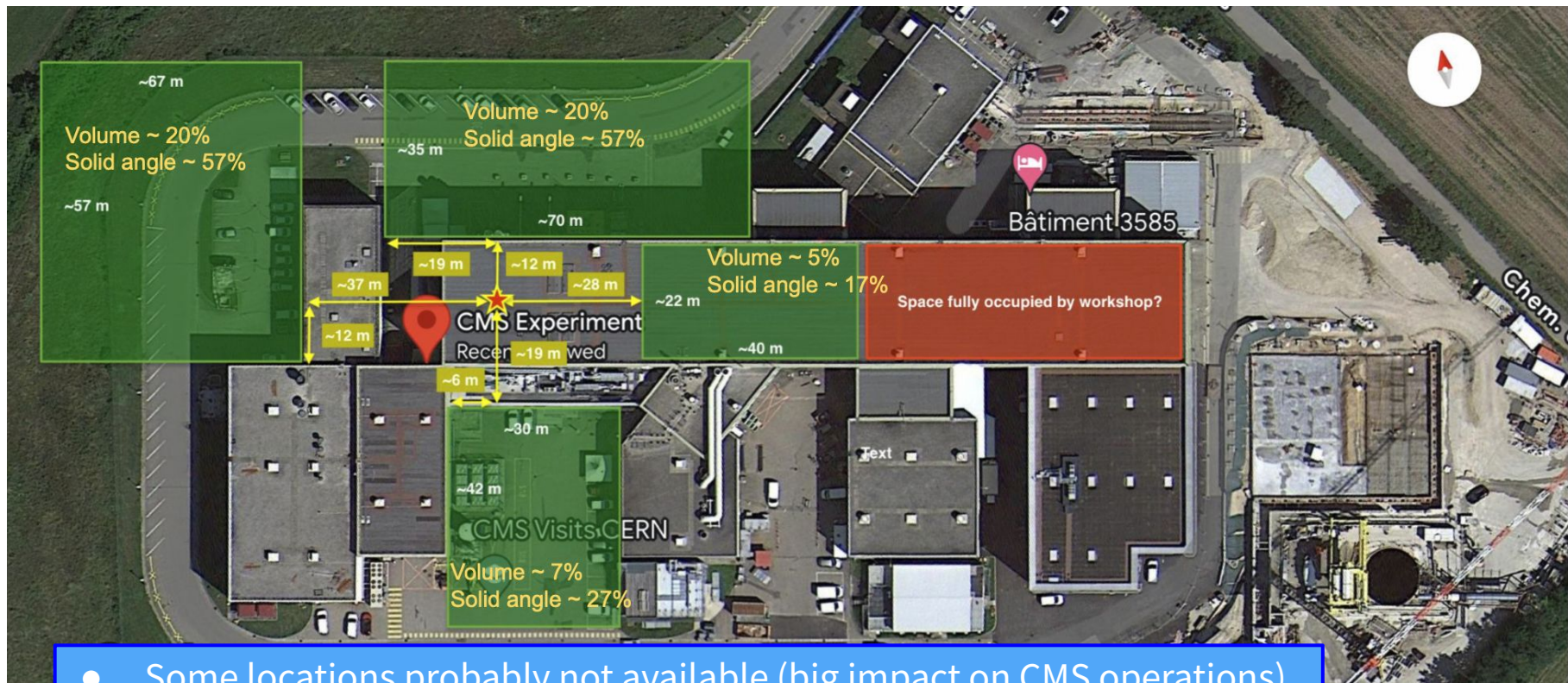
- P5 not recommended DOE to fund MATHUSLA at its full 100 m x 100 m scale
- MATHUSLA can do leading LLP searches (hadronic decays in the 10-100 GeV range) with a reduced size
 - Need to rescope the detector to make it affordable
- Investigated the possibility of housing a MATHUSLA-like detector in existing buildings near ATLAS and CMS
 - Still ongoing discussion (expected more concrete conclusions in the coming months)
- Lot of work done over the past 3 months (many studies are still ongoing)
 - **Today we want to present a preliminary layout**

New Geometrical DRAFT Proposal - Overview

Attribute	Pre-P5 benchmark	New proposal	Comment
Position	Near CMS, ~ centered on beamline	Same	Wall closest to IP is at same place on surface
Area	100 m x 100 m	40 m x 40 m	
Excavation	About 20 m below grade	NONE	Huge reduction in infrastructure costs
Modularity	9x9 m ² modules, 1 m gap	Probably the same - TBC	
Number of tracking layers	6 (ceiling) + 2 (mid) = 8	4 (ceiling) - TBC	Detailed GEANT studies ongoing
Vertical sensor layer layout	2 in floor, 2 in middle, 6 in ceiling	2 in floor, 4 in ceiling (mid TBC)	Detailed GEANT studies ongoing
Tracker installation	Crane assemblies above tracker	Space-optimised solutions under studies with engineers	Height is now at premium due to max building height of 17 m at CMS and no excavation
Height of decay volume	25 m	~12 m	
Total Decay volume	250,000 m ³	~20,000 m³	We can roughly expect new proposal to have 1/10 the signal sensitivity as the old big one (TBC)

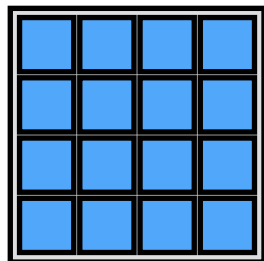
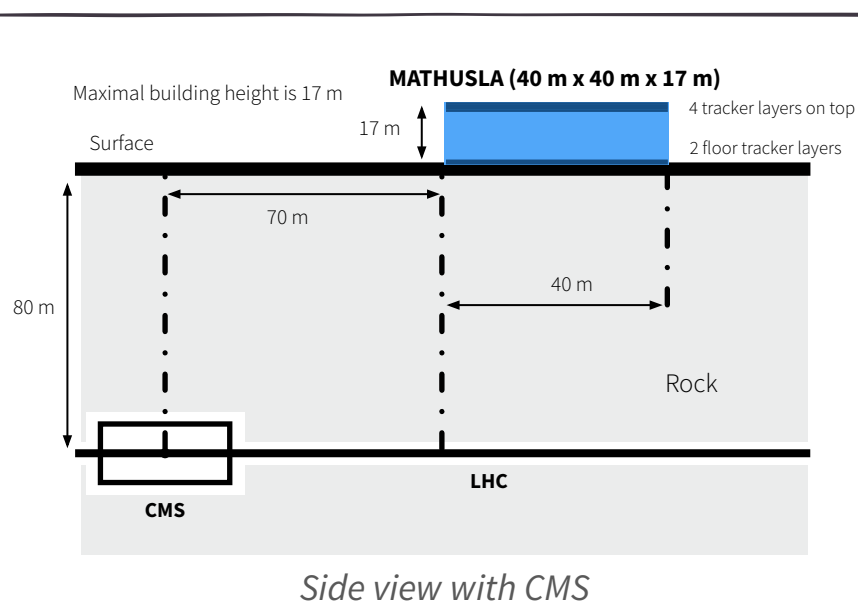
Goal to reduce both infrastructure and detector costs to roughly 1/10 of original design

New Geometrical DRAFT Proposal - CMS Site

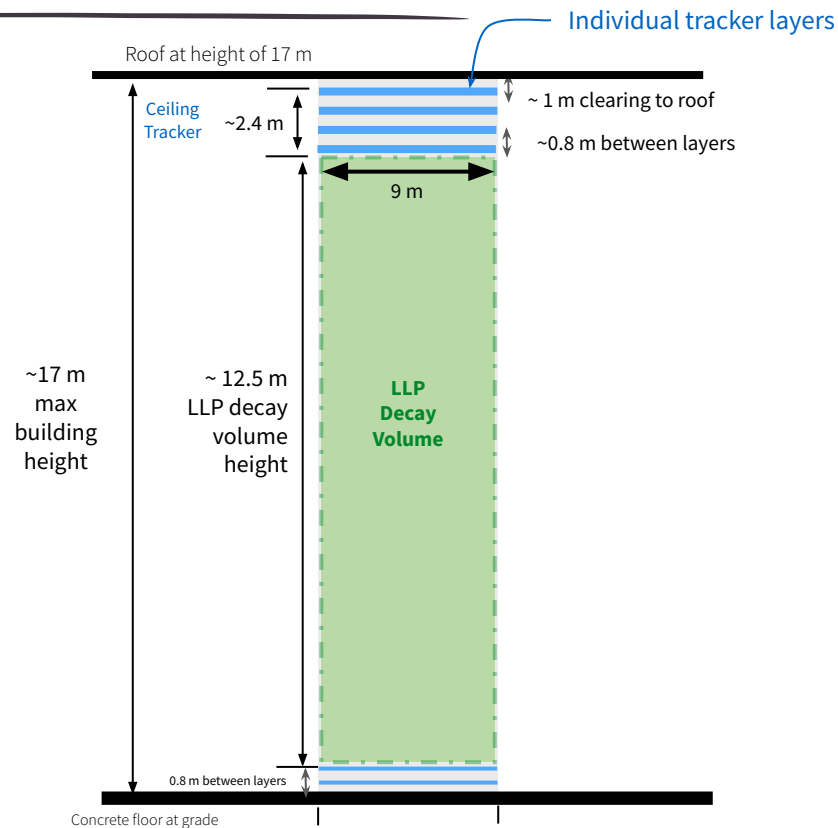


- Some locations probably not available (big impact on CMS operations)
- Discussion with CMS still ongoing

New Geometrical DRAFT Proposal - Details 1

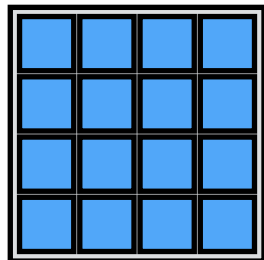
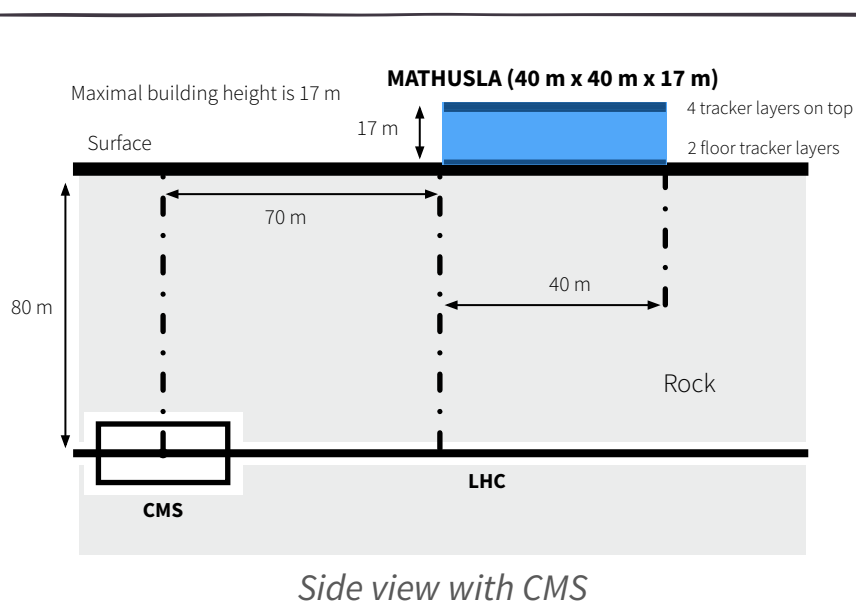


*Top view of MATHUSLA only:
sensors divided into ~ 9 m x 9 m
area modules with ~1 m gap*

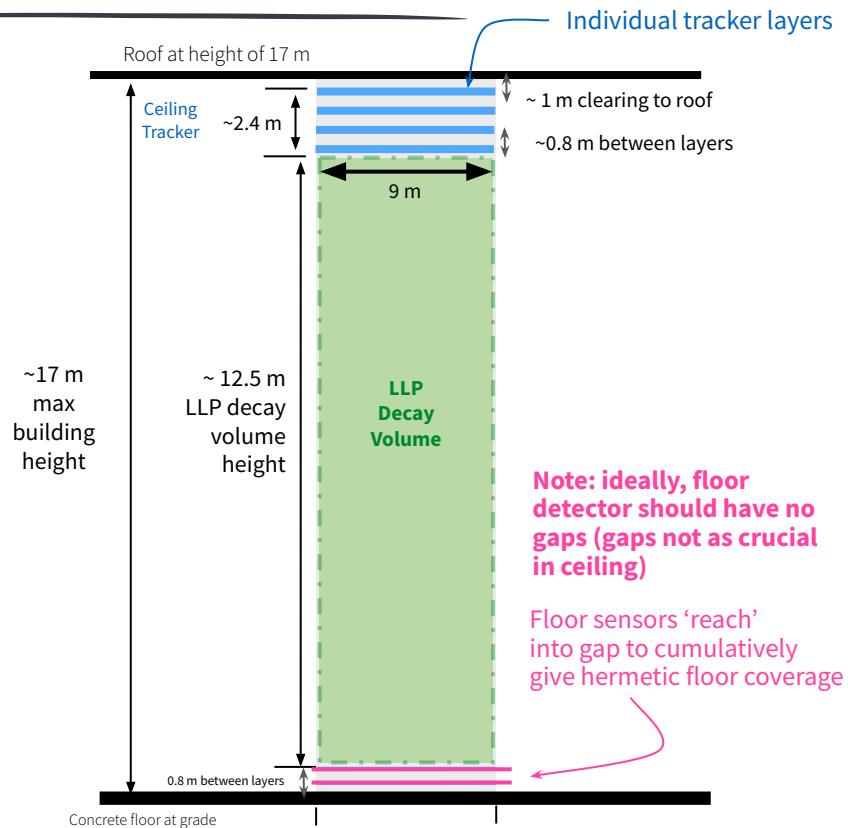


Vertical structure detail (not showing any mechanical supports etc) for a single 9 m x 9 m sensor module

New Geometrical DRAFT Proposal - Details 2

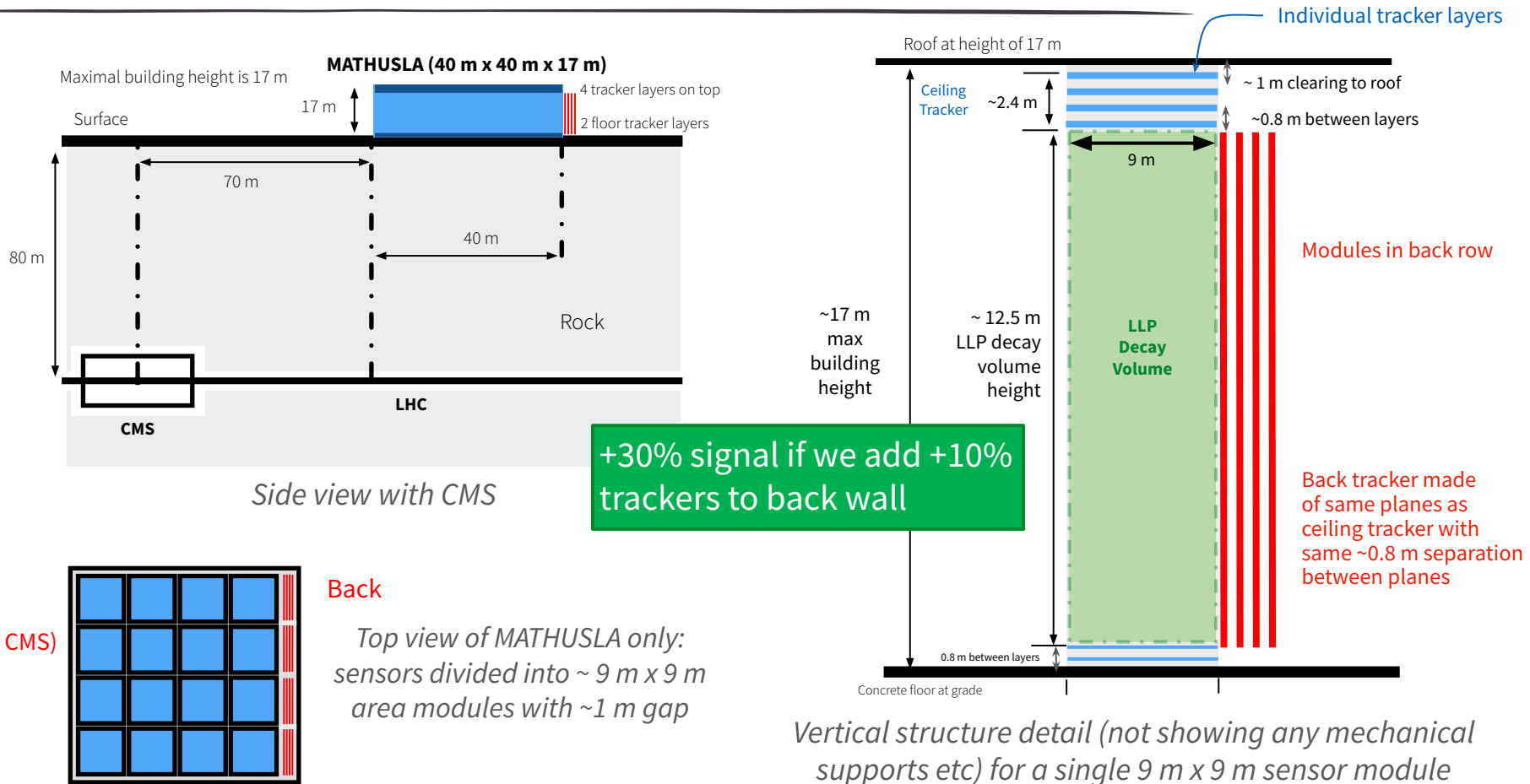


*Top view of MATHUSLA only:
sensors divided into ~ 9 m x 9 m
area modules with ~1 m gap*



Vertical structure detail (not showing any mechanical supports etc) for a single 9 m x 9 m sensor module

New Geometrical DRAFT Proposal - Details 3



Simulation and Track Reconstruction

- Conducted full GEANT track and vertex reconstruction studies for old 100 m geometry
 - Closely reproduced signal acceptances of purely geometric FastSim ([2308.05860](#))
- **Reconstruction studies are currently being repeated for the new geometry**
- GEANT studies of backgrounds ongoing
 - Don't expect backgrounds to be an issue for the primary physics case (high-multiplicity DVs)

Civil Engineer Studies

Working with Canadian engineering support to develop CDR-level engineering concepts for the new detector geometry

- For simplicity, assume MATHUSLA housed in a **“standard aircraft-hangar” 17 m tall**
 - Standard templates are available
 - Crucial input: thickness of the roof to span 40 m, with the detector starting just below the roof
- Design a support structure for the detector layers that likely uses much **less steel than original estimate**
- Study **conceptual engineering design for the whole detector**
 - How to join and support scintillator bars into a sub-plane, then a 9 m x 9 m plane, then how to arrange and attach/install those in the superstructure
- Examine how to install vertical detector planes in the back wall (if added)

MATHUSLA (new) Test Stand (UVic)

Small scale prototype MATHUSLA module

- 4 layers of scintillators
- 32 WLSF connected to 64 SiPM array
- Orientation rotated by layer

DAQ

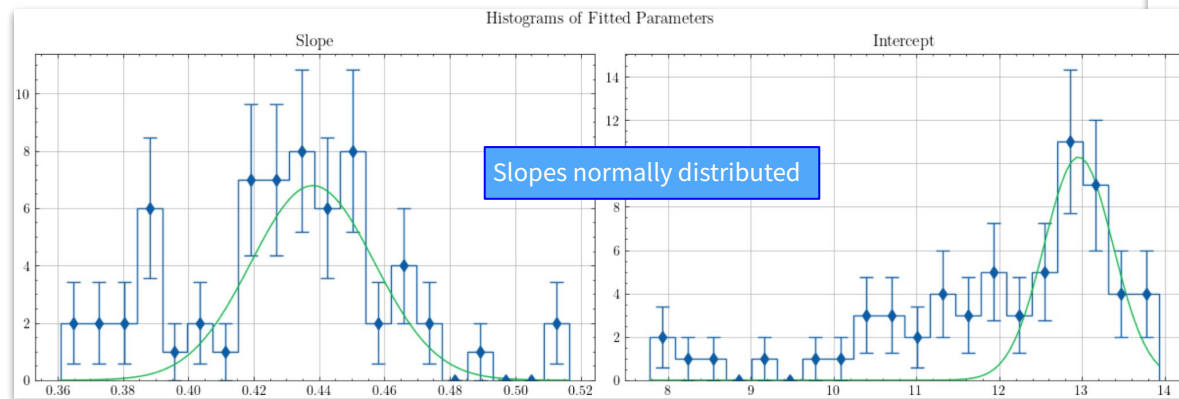
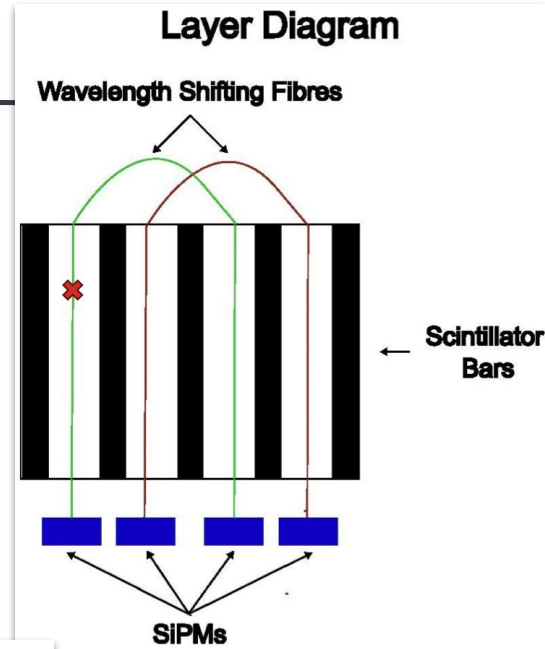
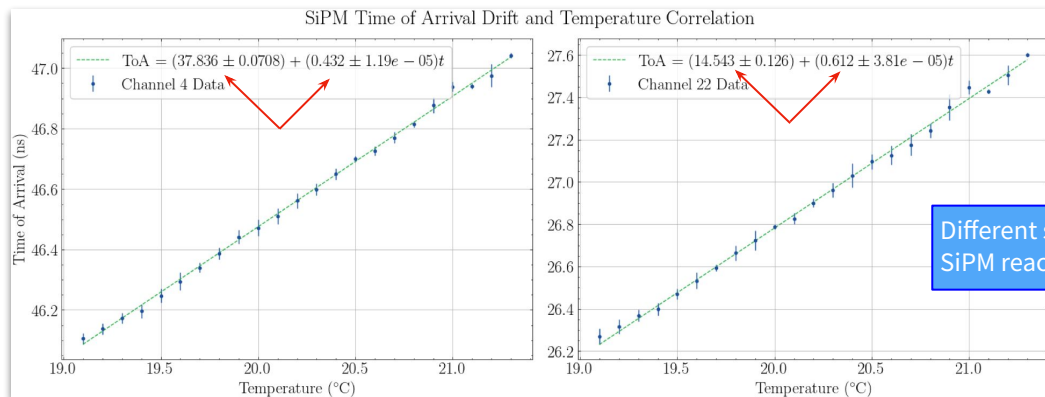
- CAEN Janus on ubuntu machine
- 1 min data collection loop
- OR64 Trigger
- 300 ns timing window
- Writes ~230 MB/min in binary format (converted into 7MB ROOT file)



Allow also small scale testing of instrumentation

MATHUSLA (new) Test Stand (UVic)

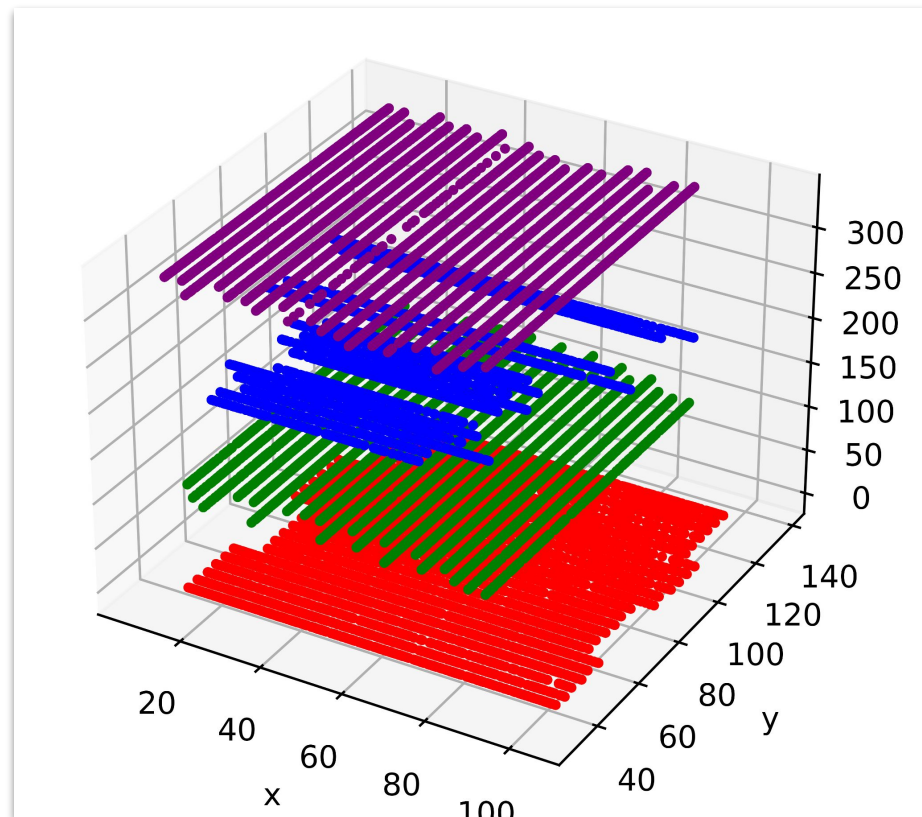
Temperature - Time of Arrival correlation studies



MATHUSLA (new) Test Stand (UVic)

- Analysis selection
 - Hits have Δt consistent with being inside a scintillator bar
 - Each event has at least one hit in each layer
 - ± 5 cm linear gaussian smear applied
- Selects 1623 events (~ 0.02 Hz)

Ongoing work on track reconstruction
and trigger selection



Conclusions

- Following P5 outcome, we are studying a new layout with a smaller size (less detector layers) and fully on the surface
- Exploring alternative locations (closer to the IP) in both ATLAS and CMS areas
- Detailed simulations are ongoing to compute the new layout sensitivities
- Working with Canadian engineers to develop a detailed engineering concept for this detector geometry (will then work with CERN civil engineers to finalize the design)
- Good progress with the small scale prototype developed with Canadian fundings