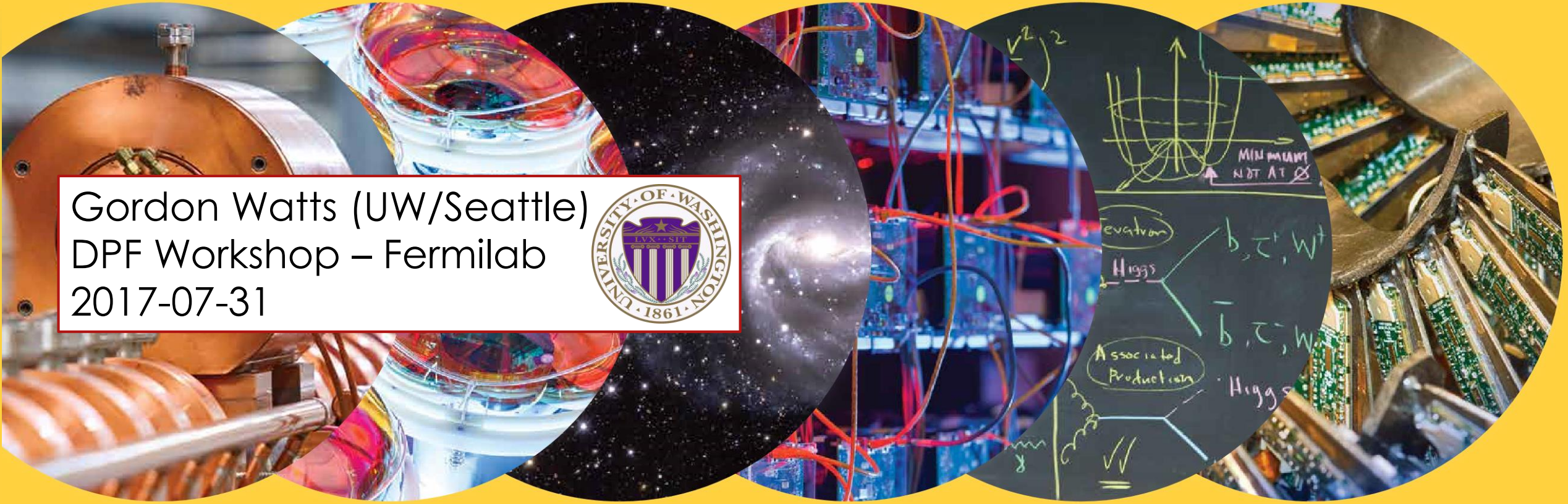
MATLASA



Gordon Watts (UW/Seattle)
DPF Workshop – Fermilab
2017-07-31

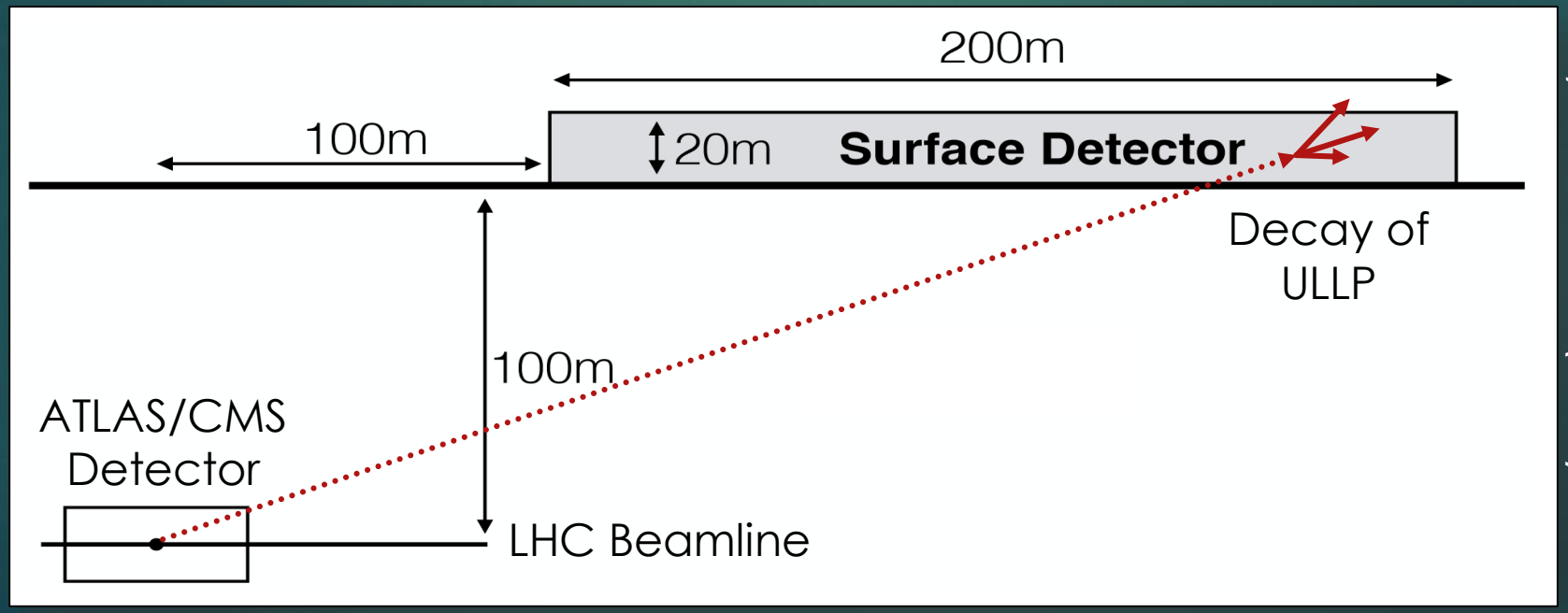
The MATHUSLA Detector

MAssive Timing Hodoscope for Ultra Stable

To search for ultra long-lived neutral particles (ULLPs)

Decay very far from the interaction point ($c\tau \sim 10^7$ m)

Do not interact with SM particles



Phys.Lett. B767 (2017) 29-36

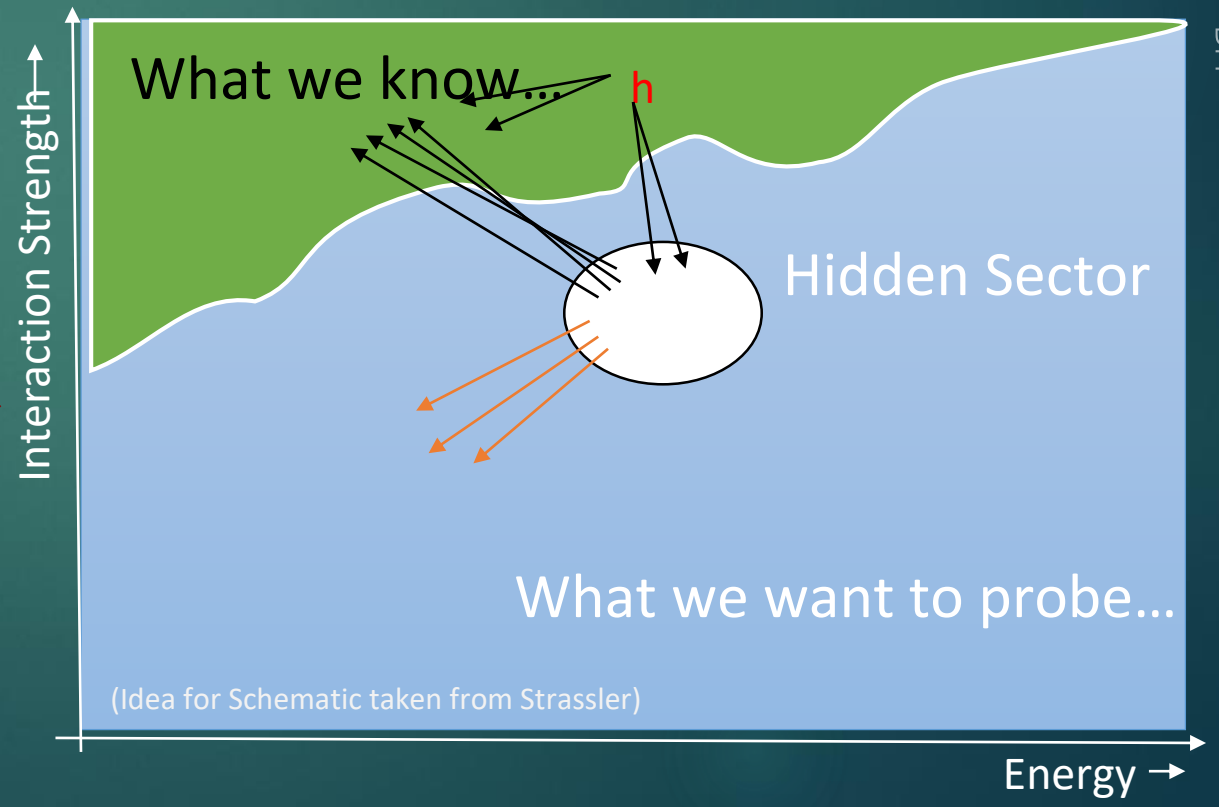
Why Search for Long Lived Particles?

Dark Matter
Dark Energy
Hierarchy Problem
Matter/Anti-Matter Asymmetry

Motivated searches for new physics

Many extensions to the SM contain LLP

- Hidden Valley
- StealthSUSY
- Baryogenisis Models
- 2 Higgs Doublet Models
- Hidden Sector Models

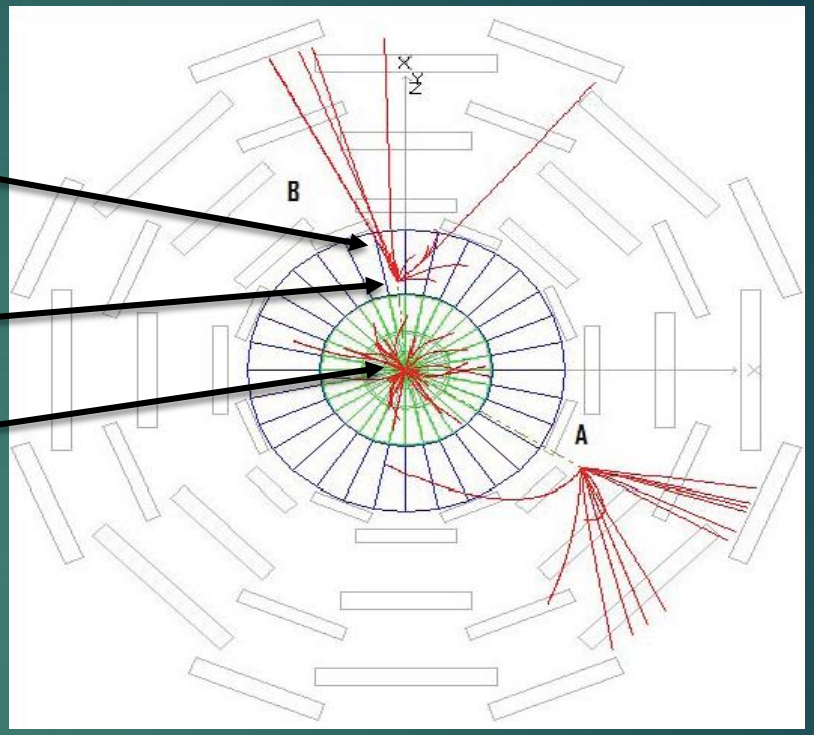


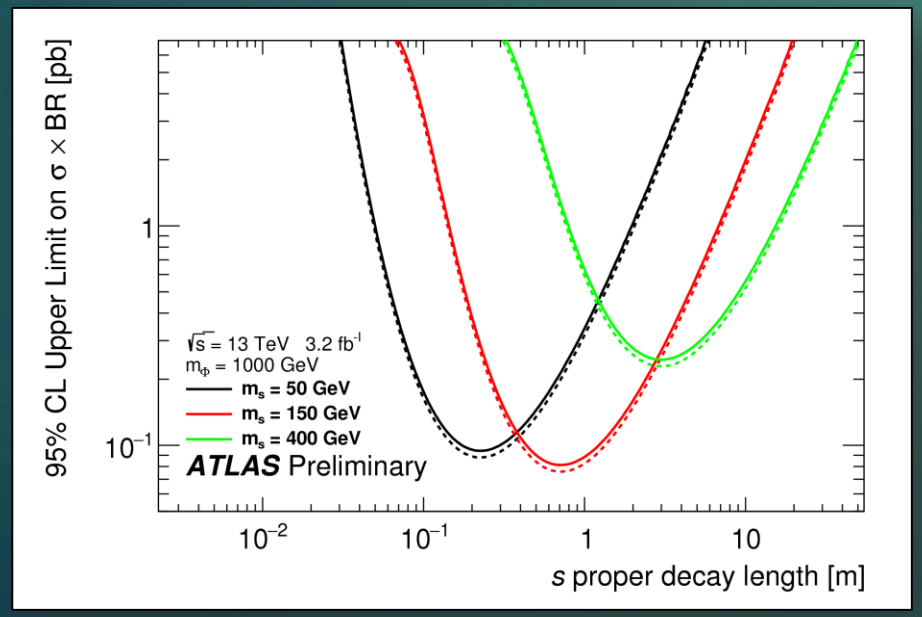
Current Searches

Specialized triggers and analysis methods re-purpose ATLAS to select the decays and reject background

LLP decays in the ATLAS Calorimeters

LLP is produced

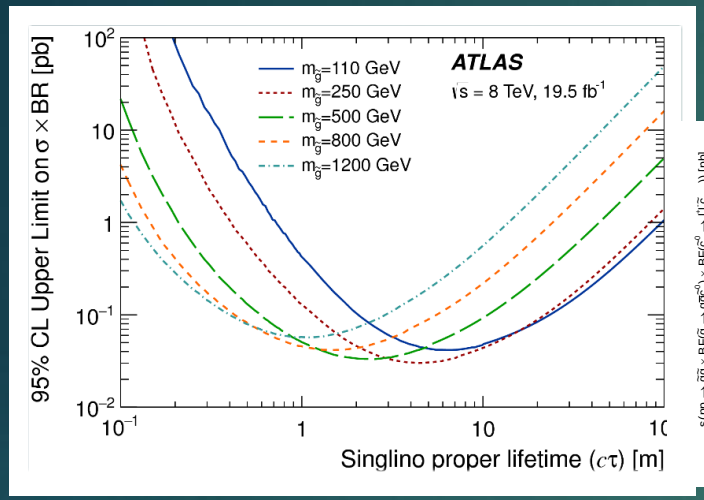


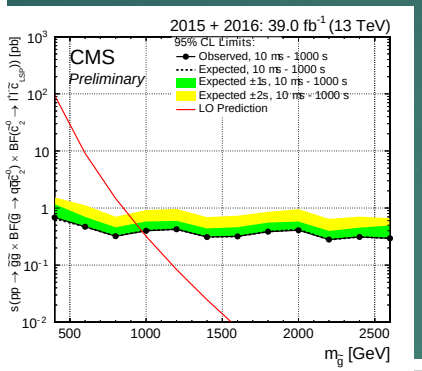


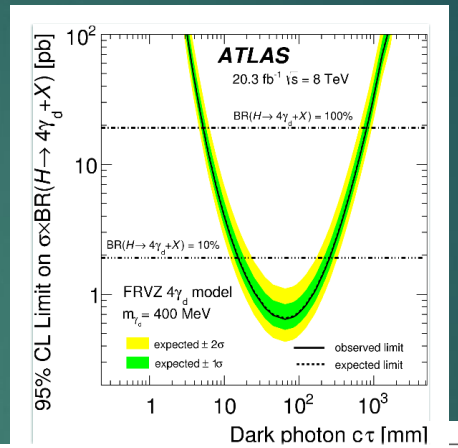
Backgrounds typically QCD, cosmics, cavern background, etc. depending on the analysis.

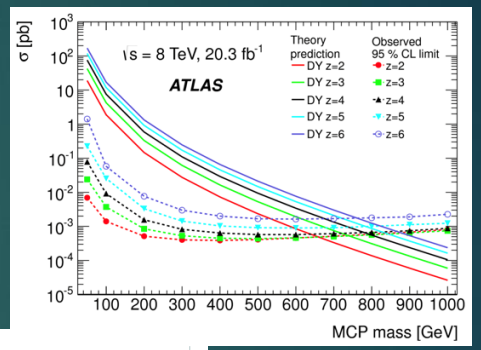
Rarely background free!

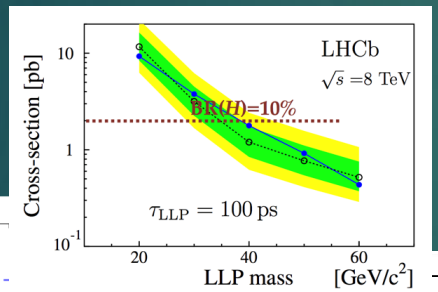
LHC Experiments have been busy!

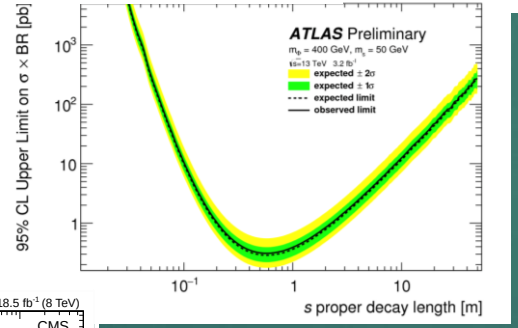


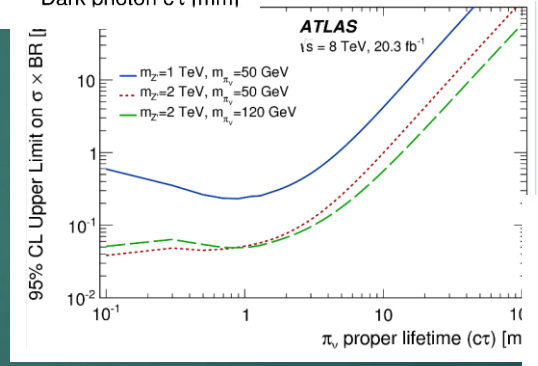


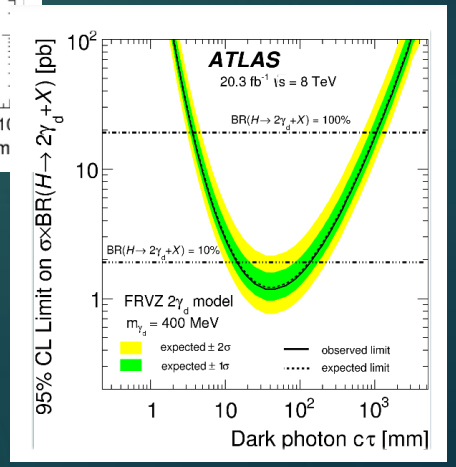


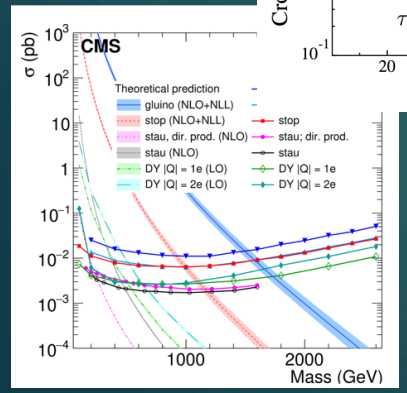


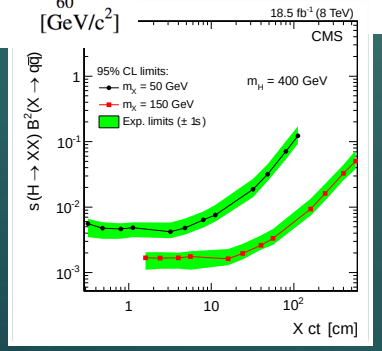


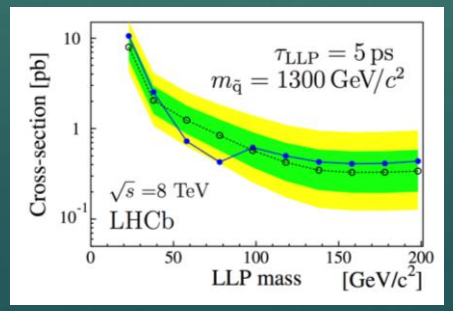




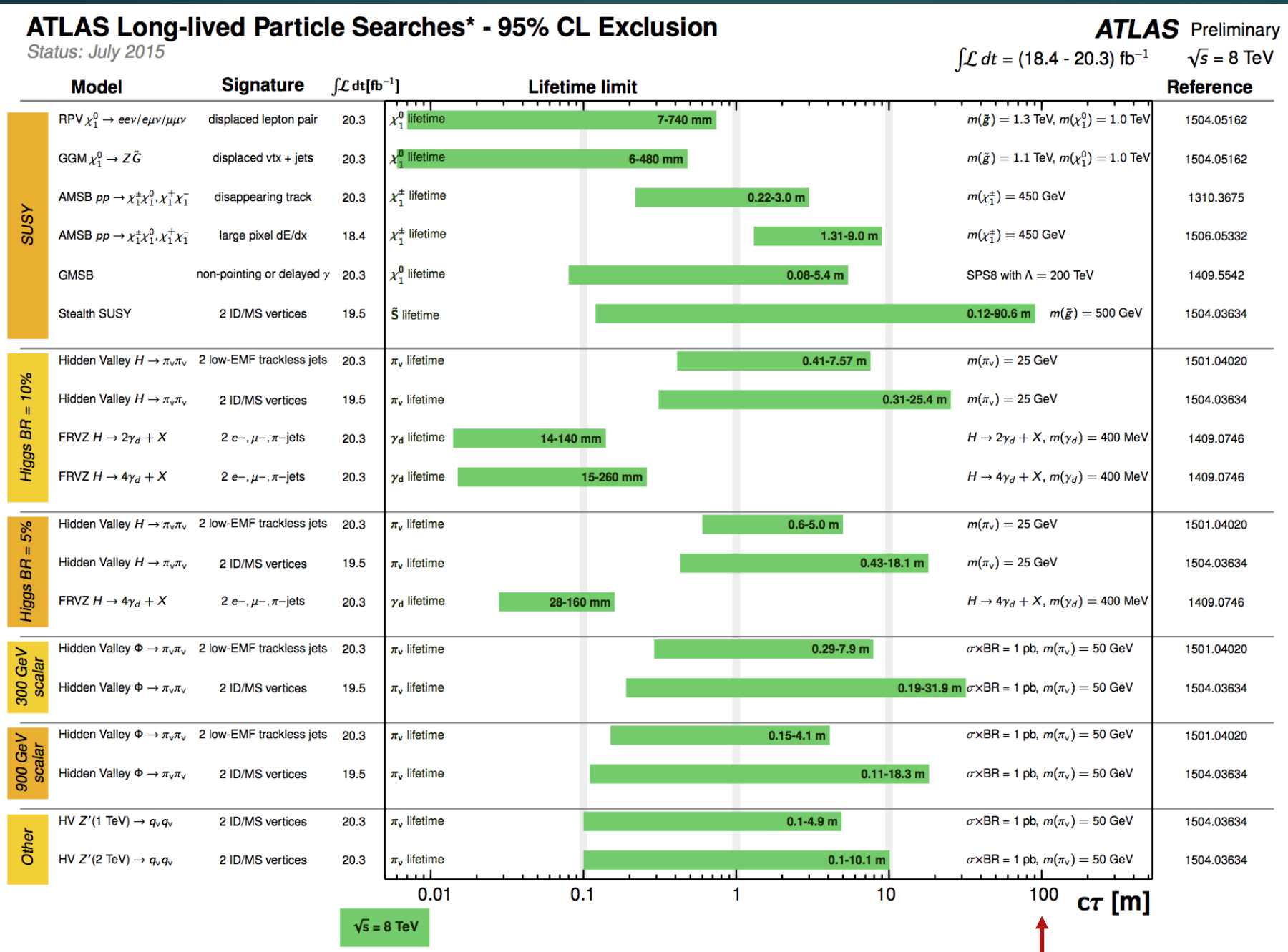








Life Time Coverage Is Restricted



Run 3+4?

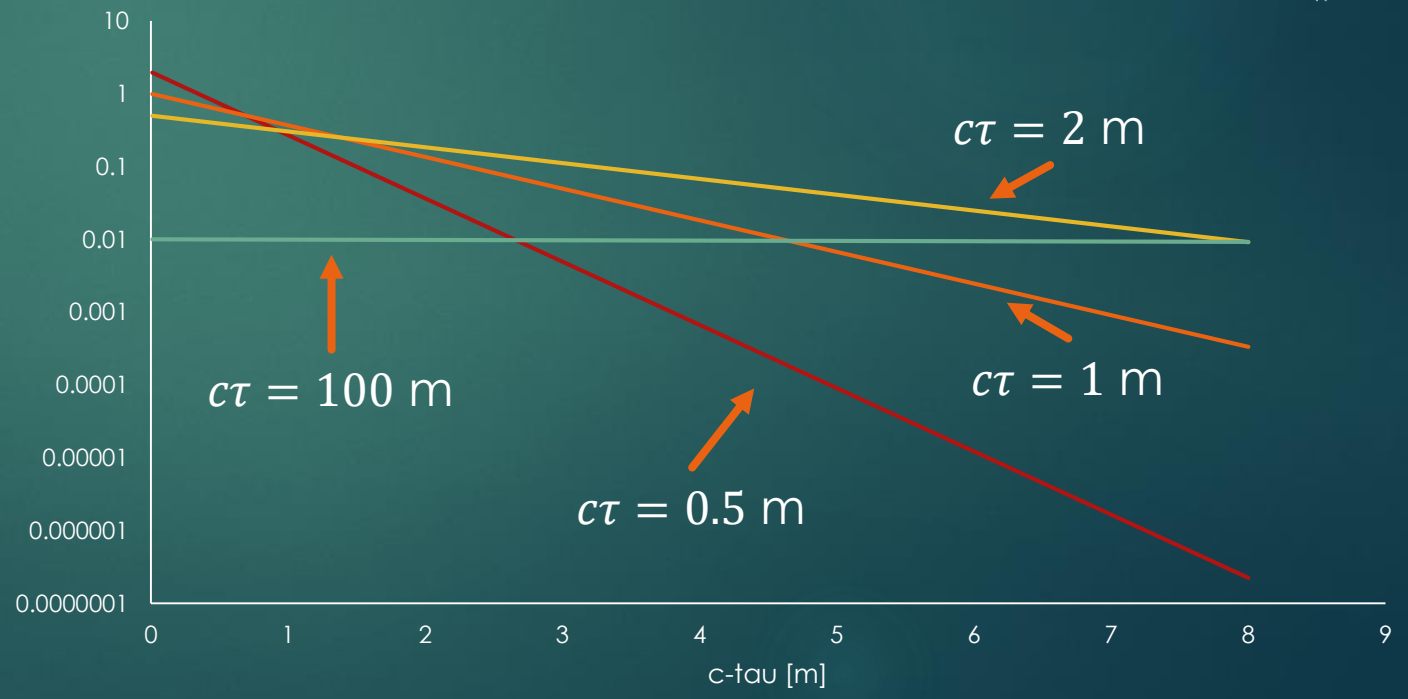
Much Longer Lifetimes Are Possible

Big Bang Nucleosynthesis

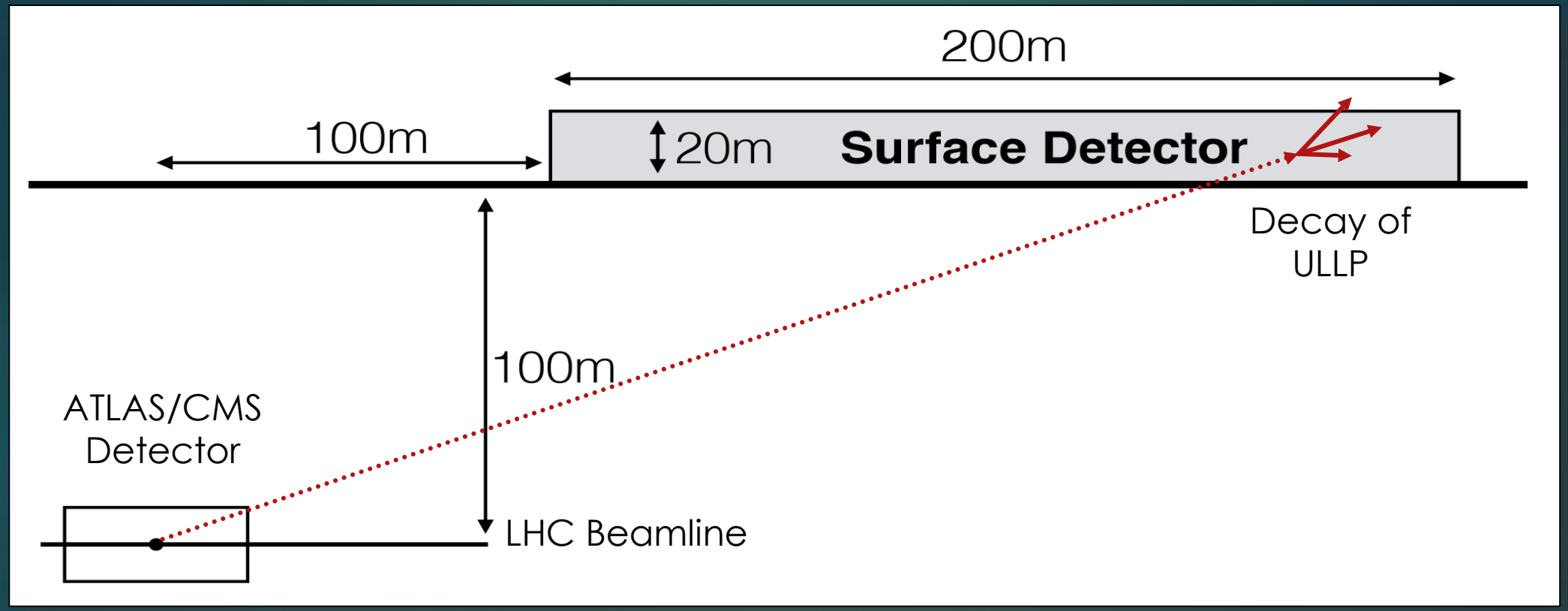
- Defines the upper limit on the lifetime
- Approximately 0.1 seconds (10^7 or 10^8 m)
- Limit comes from the n/p ratio
- Robust against most variations and is considered conservative

arXiv: 1706.01920

Conclusions: to access these long lifetimes we need a detector really far away, with no background



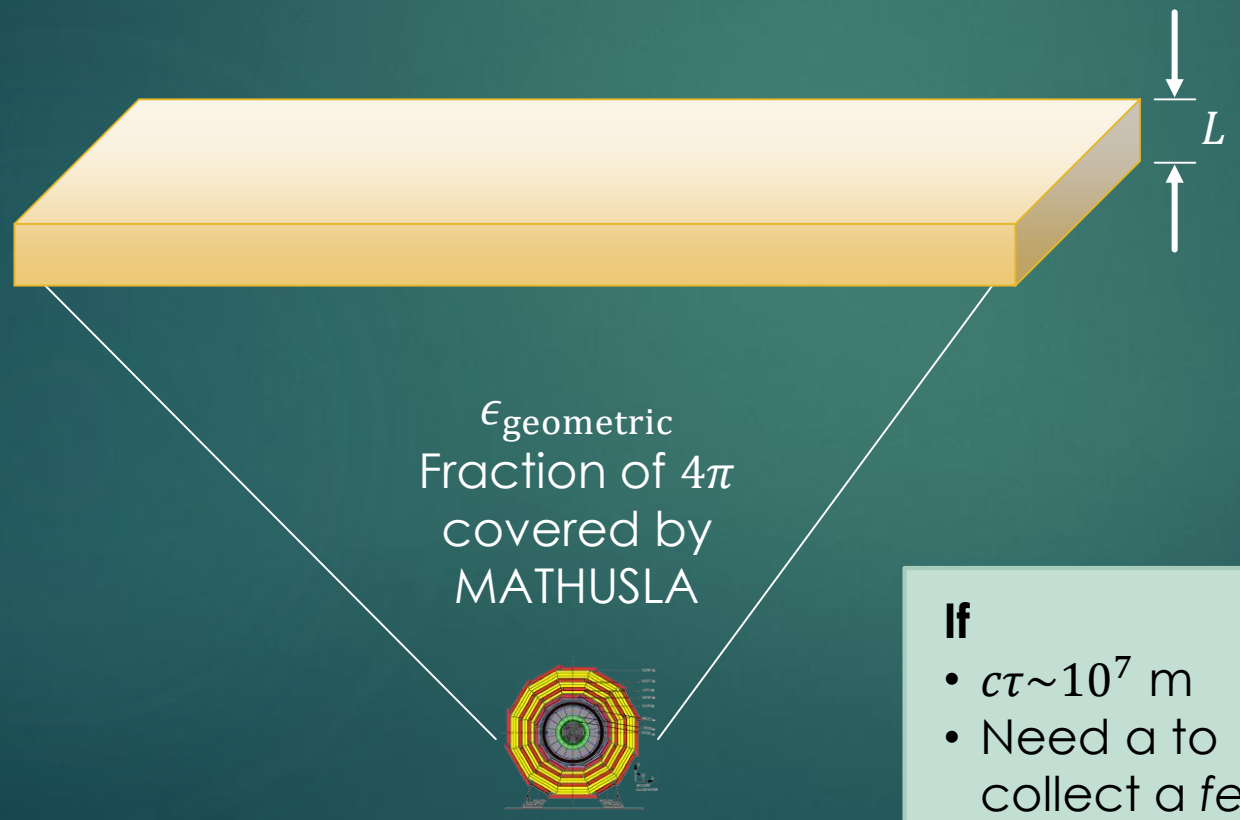
MATHUSLA Overview



Surface Detector size is determined by acceptance!

Overall Design

$$N_{obs} \sim N_h \cdot Br(h \rightarrow ULLP \rightarrow SM) \cdot \epsilon_{\text{geometric}} \cdot \frac{L}{bc\tau}$$



$c\tau$ – Lifetime of ULLP

b – kinematic constant: $\frac{m_h}{m_h - n \cdot m_X}$

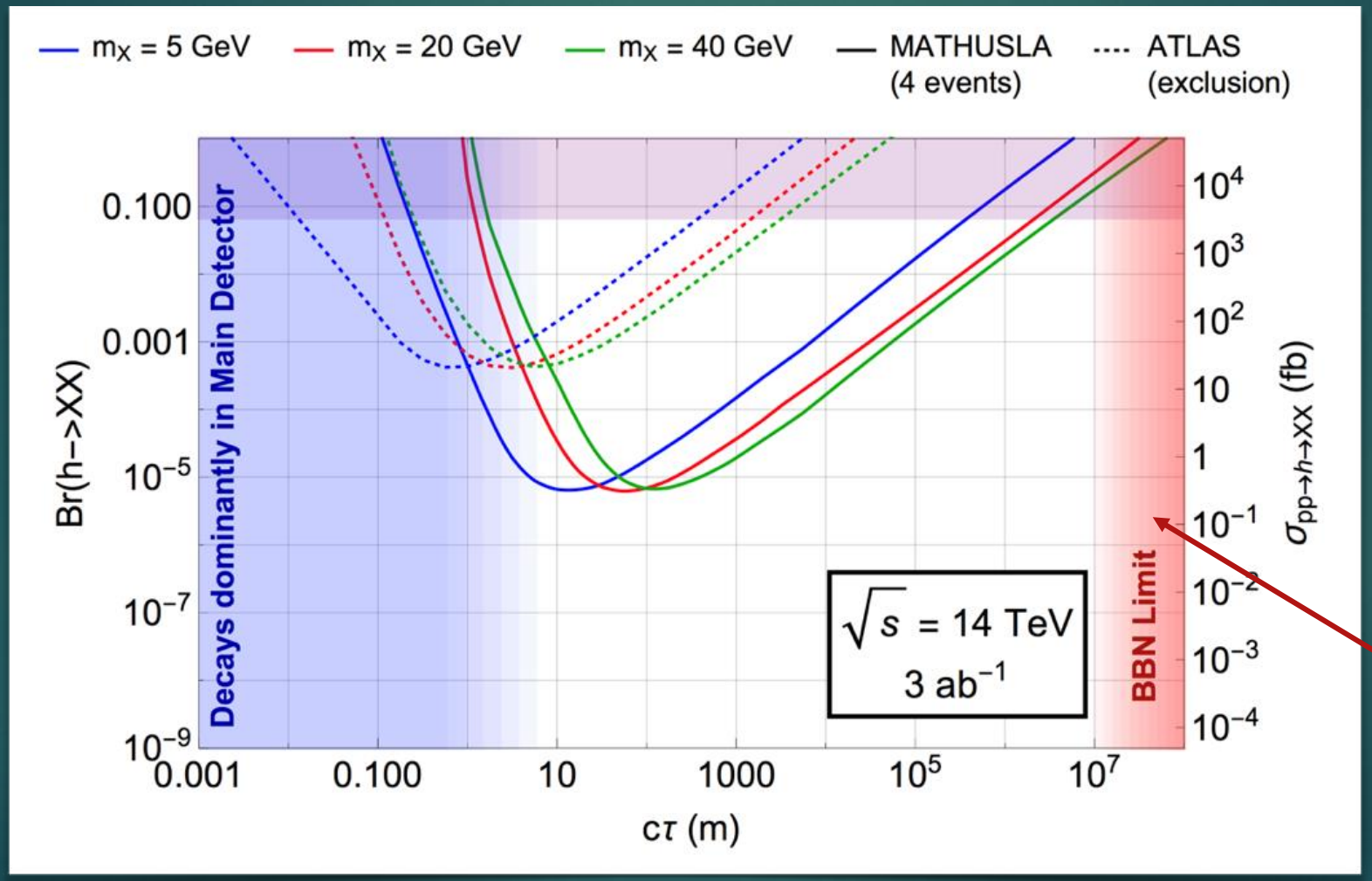
(less than 3 for 2 body decay with $m_X \sim 20$ GeV)

N_h - 1.5×10^8 during HL-LHC

If
- $c\tau \sim 10^7$ m
- Need a to collect a *few*

Then
- $L = 20$ m
- $\epsilon_{geometric} = 10\%$

What Is The Sensitivity?

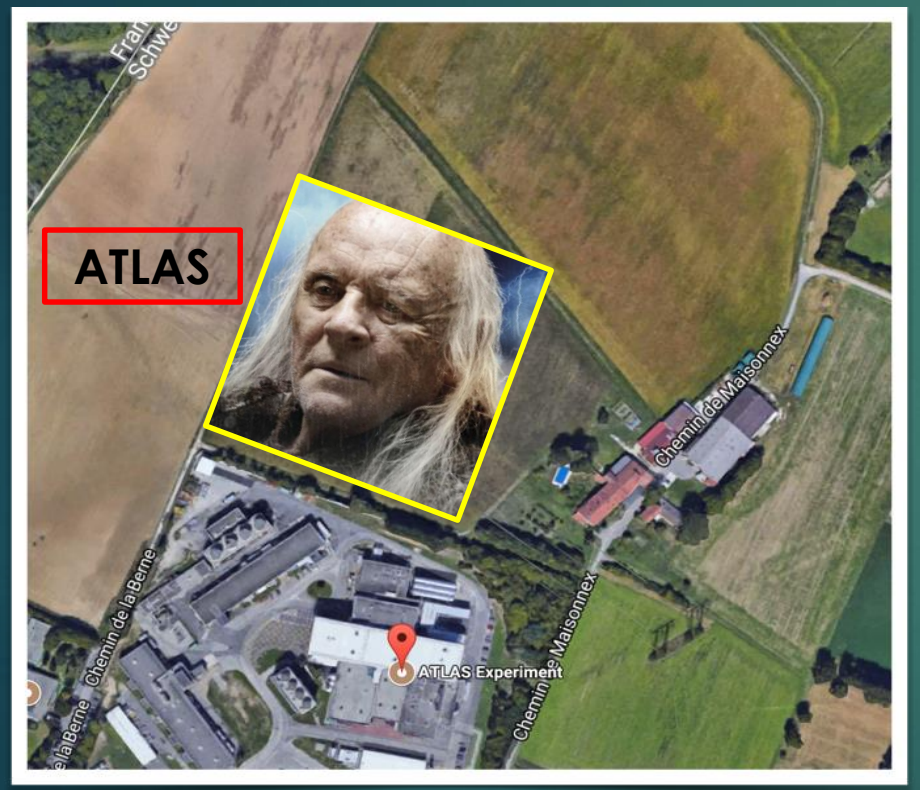


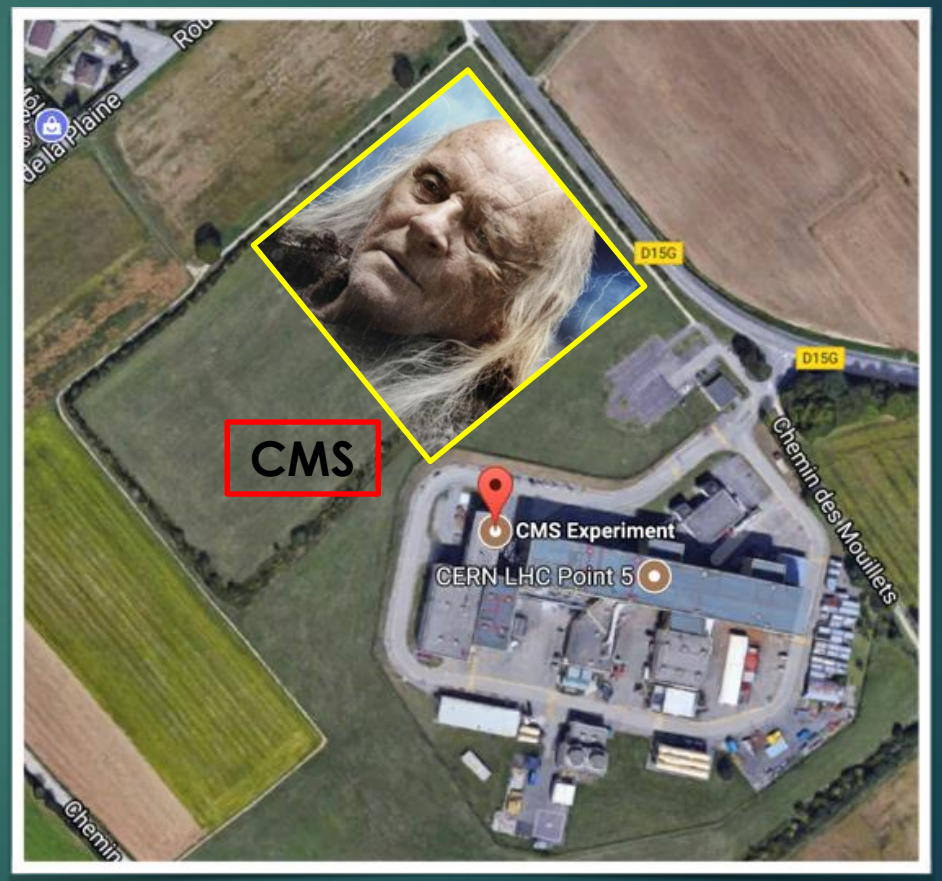
Some sensitivity at the BBN limit

That is big?

200 m × 200 m

($\epsilon_{geometric}$~10%)



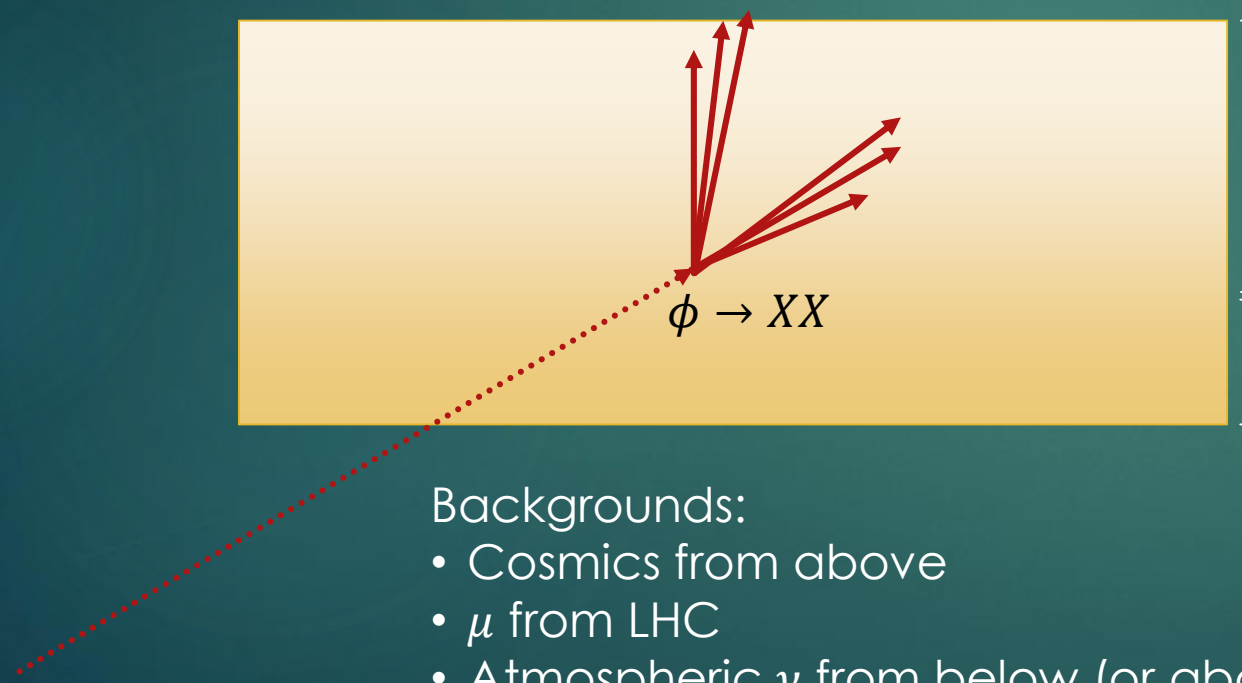


Perhaps easier at CMS as they have unused land already owned by CERN

Detector Design

Internal design motivated by the differences between signal and background!

Goal is very high efficiency and almost zero background



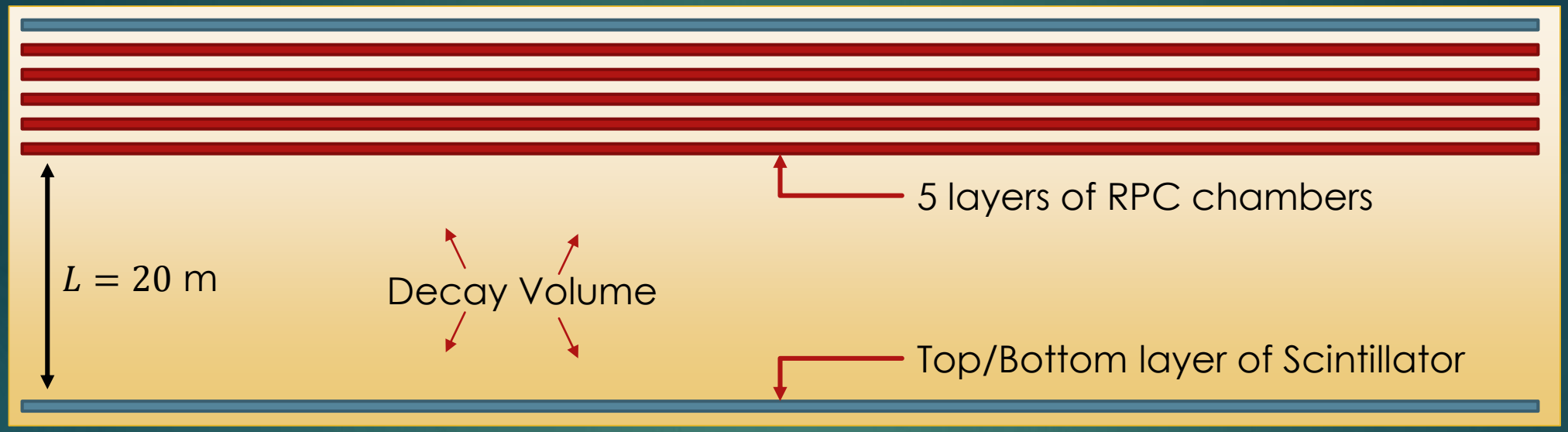
Two jets of charged (and neutral) particles
Point back along direction of ϕ
Point back to LHC interaction Point

No Interaction

Backgrounds:

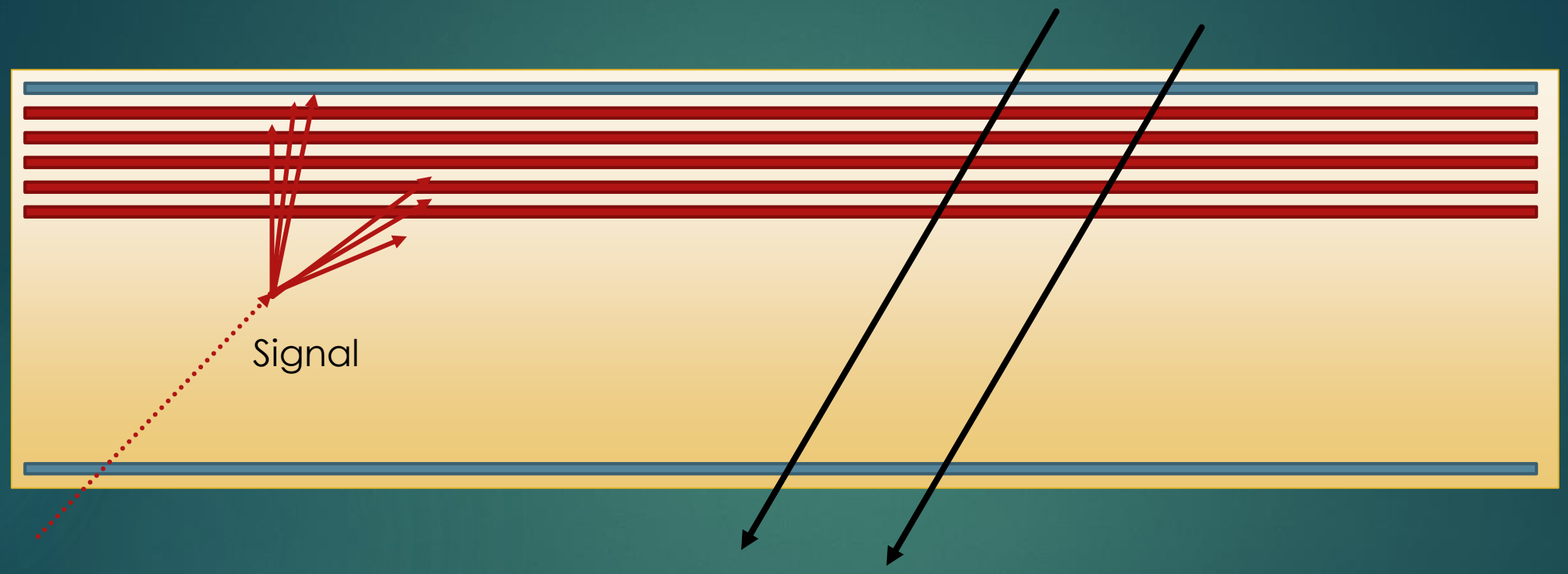
- Cosmics from above
- μ from LHC
- Atmospheric ν from below (or above)
- ν from LHC

Detector Design



Scintillator	Precise timing. ~ 80ns to cross top to bottom	Differentiate between upward and downward going Assure decay happened inside decay volume.
Resistive Plate Chambers	"Cheap" tracking chambers Decent timing	Pointing back to origin of particle

Cosmic Muon Background

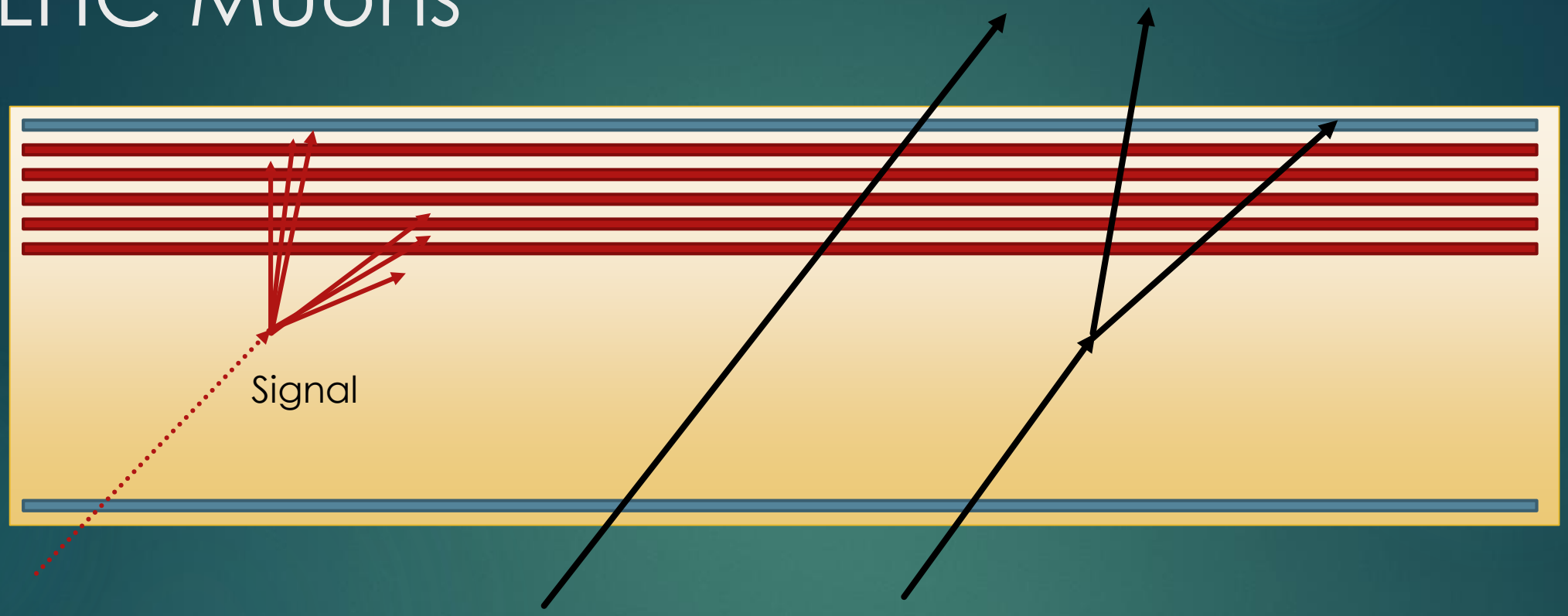


10 MHz rate (over $200^2\ m^2$)

- Downward traveling
- No vertex
- Hits bottom scintillator

Multiple ways to reject this background
Main worry: combinatorics with another background

LHC Muons

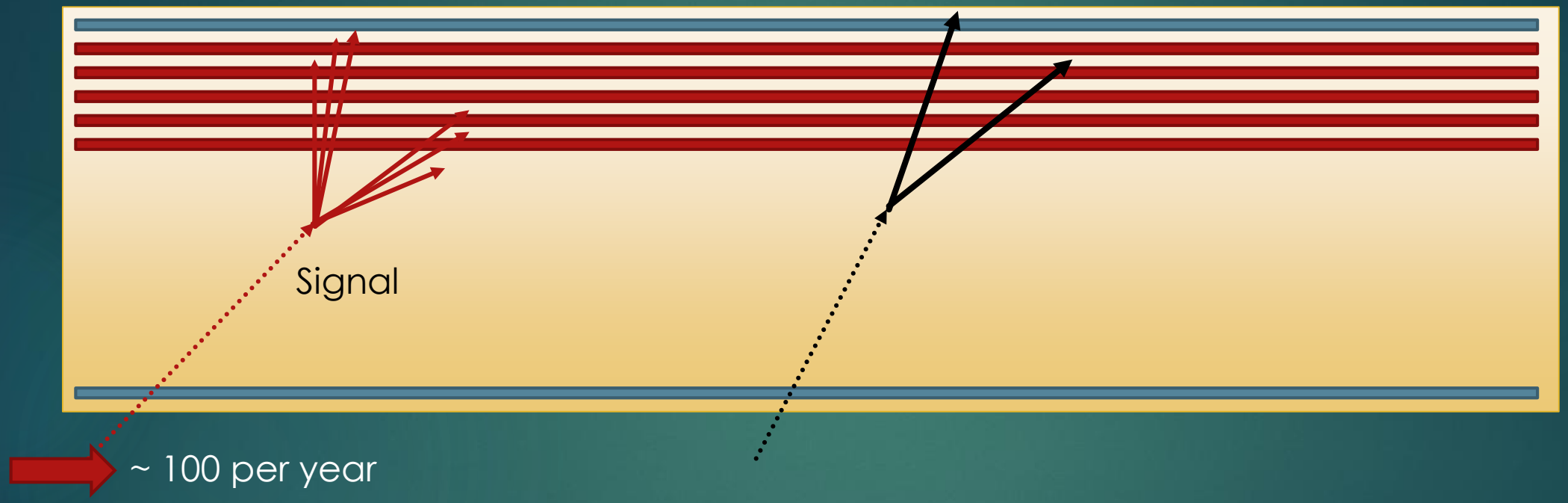


Rate from HL-LHC is ~ 10 Hz

- Muons must have p ~ 70 GeV to penetrate rock
- Some lack vertex
- Vertex-track multiplicity

} Bottom scintillator-plane efficiency crucial

Upward Going Cosmic Neutrinos

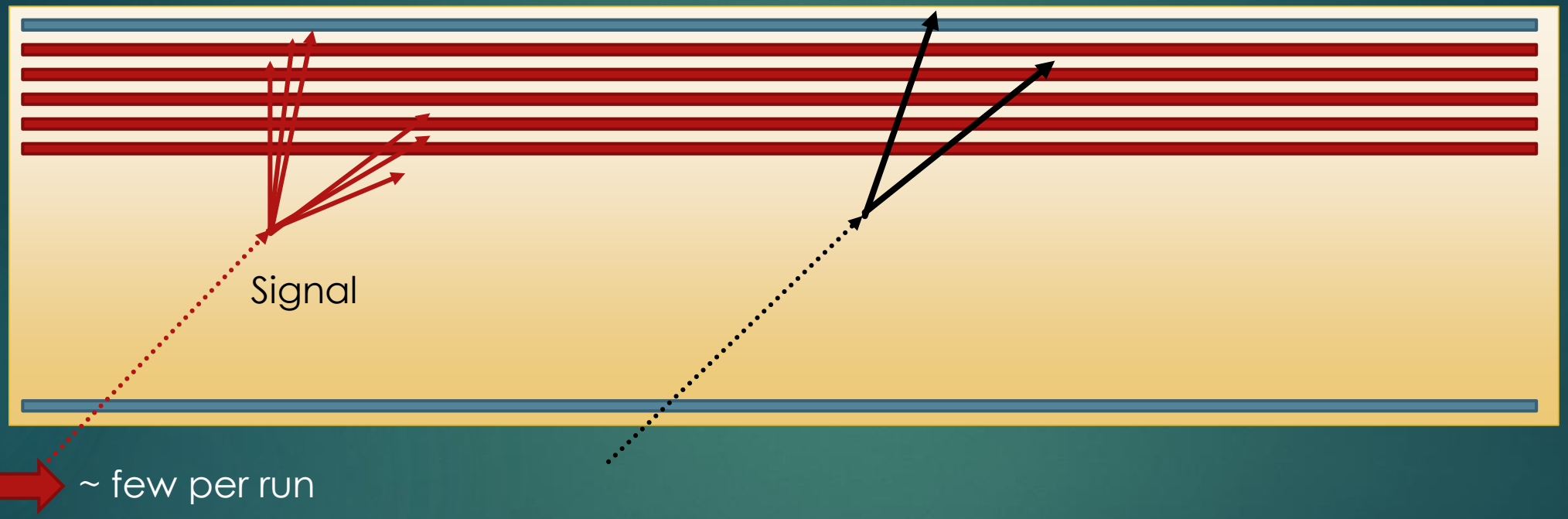


~ 100 per year

- For muons above 300 MeV
- Does not point back to detector
- For some forms of signal this may be irreducible
- Combinatorics with cosmic ray

Will have to be carefully measured when LHC is turned off

LHC Neutrinos



~ few per run

- Does point back to detector
- Vertex-track multiplicity
- Combinatorics with cosmic ray

This will need further study, but is a very small background

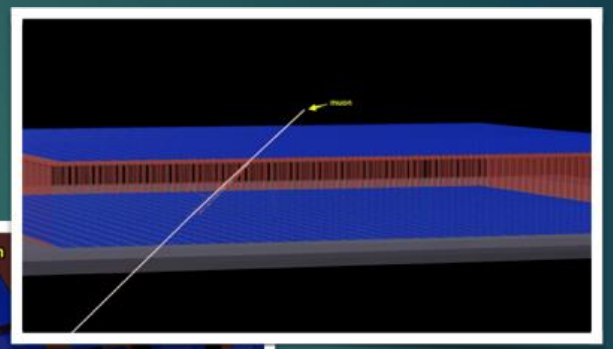
Anchoring The Background Estimates

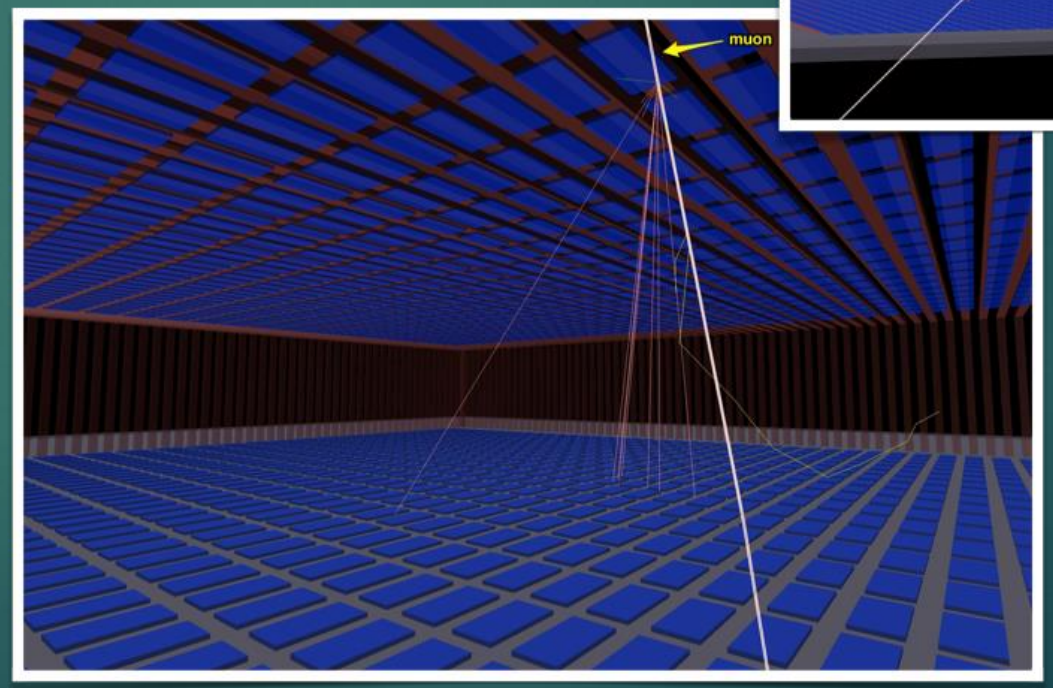
We are developing a GEANT-4 simulation to better understand these backgrounds

And a fast simulation to aid in detector design

We need some way to anchor these simulations in reality, however

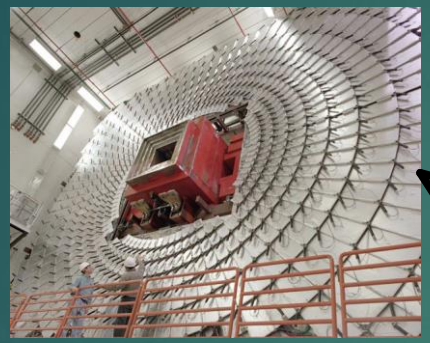
→ Test Stand



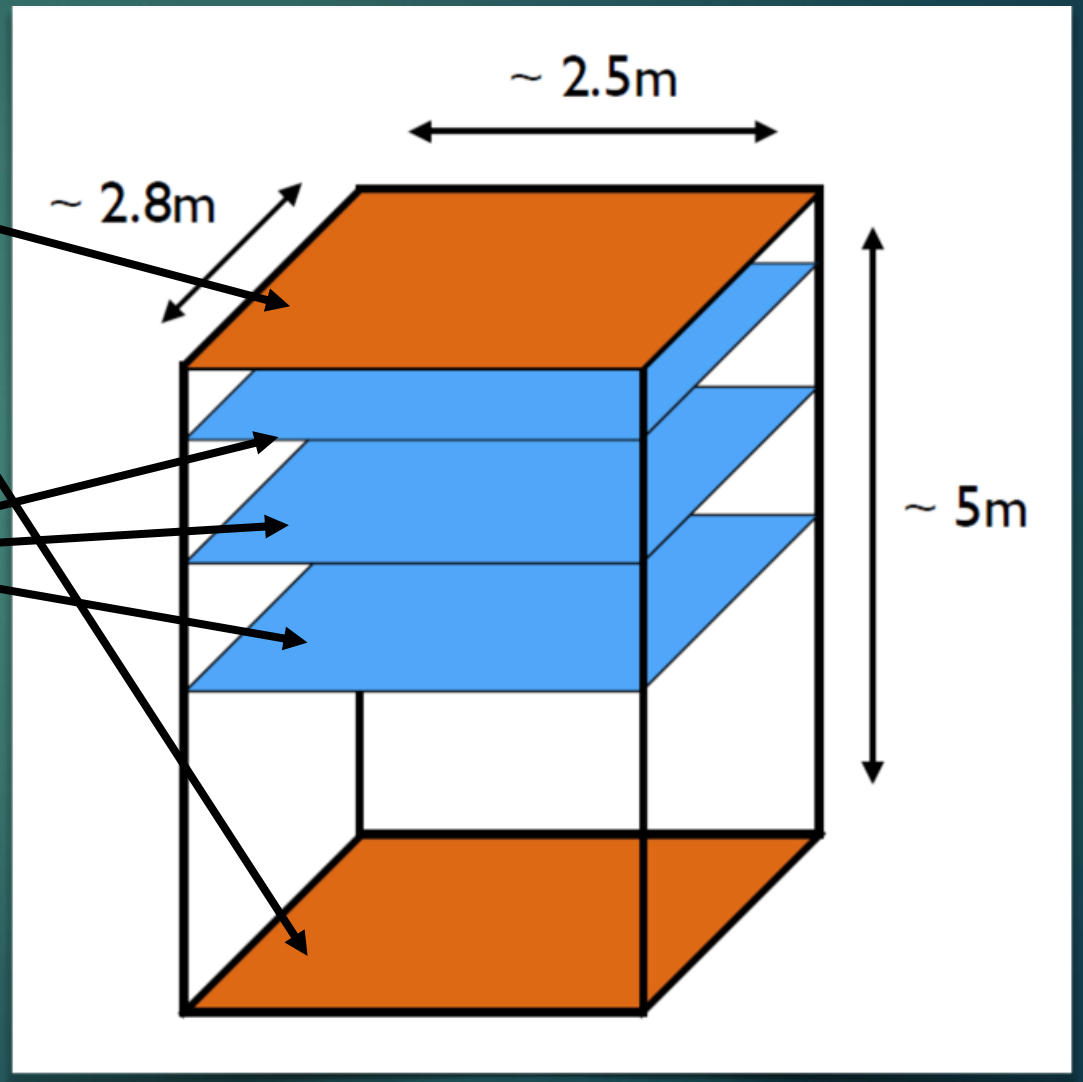


The MATHUSLA Test Stand

Repurpose DØ forward muon scintillator paddles (thanks, DØ!)



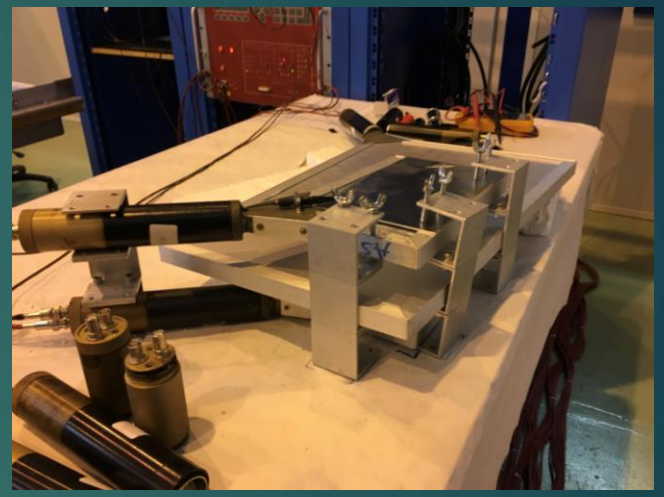
Repurpose RPC's from the Argo cosmic ray experiment



Place test stand in ATLAS assembly building (P1)

Test Stand Status

Status
- Scintillator is being tested & characterized at CERN
- RPC's will arrive any week now
- Support structures completing design/safety
- Aim to run in the fall of 2017 until winter shutdown



Goals
- Develop background rejection algorithms
- Understand algorithm performance in relation to full MATHLUSA design simulation
- Trigger: proposed to have only upward and downward going scintillator pair
    - The goal is not to hunt for signal with such a small $\epsilon_{gometric}$
- Create an LOI with a well understood background estimation

Collaboration

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Conclusion

- A novel idea to cover the complete phase space for neutral decaying ultra long lived particles
  - Takes advantage of field's investment in the LHC
- Large Surface Detector – close to 200 × 200 m
- Composed of
  - Top and bottom scintillator planes to record direction and if particles are thru-and-thru
  - 5 layers of RPC's to reconstruct secondary vertex
- Low background requirements will make detector design and quality control important
- Other interesting physics – like cosmic ray bundles – being explored
- Always looking for new people