Exploring the Lifetime Frontier:
Searching for LLPs with MATHUSLA

AUDREY KVAM on behalf of the MATHUSLA collaboration

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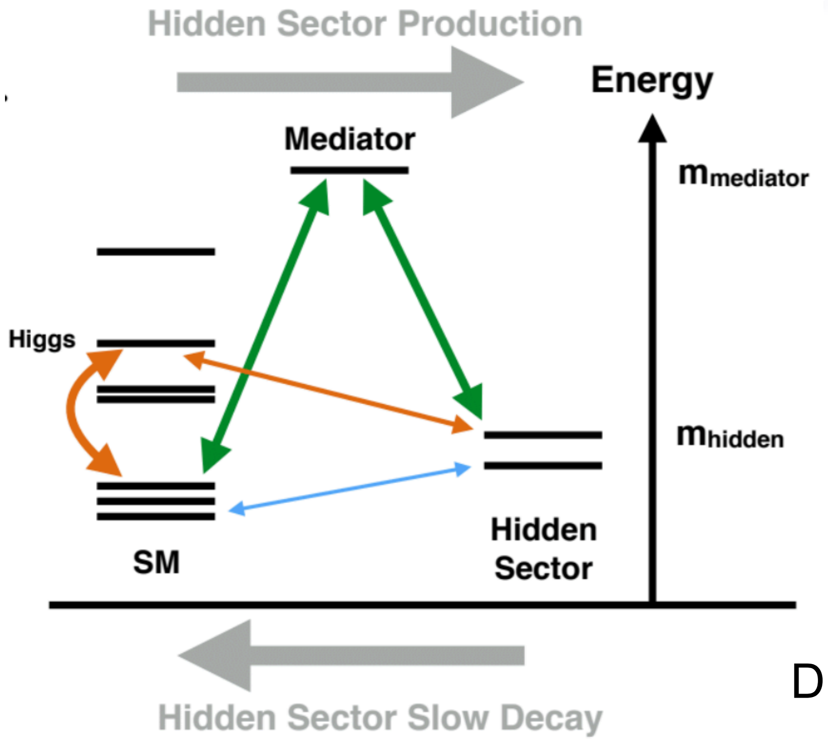
MATHUSLA

Motivation

- Neutral, weakly coupled, long lived particles (LLPs) are generic and highly motivated in many BSM models (Hidden Valley, Stealth SUSY, 2HDM, baryogenesis models…)

- LLPs occur naturally in coupling to a hidden sector (HS) via small scalar (Higgs) or vector (gamma, Z) portal couplings

- Possible lifetimes range from $\mathcal{O}$(mm) to $\mathcal{O}$(km), with an upper bound of $10^7 - 10^8$ m provided by Big Bang Nucleosynthesis (BBN) with a few caveats

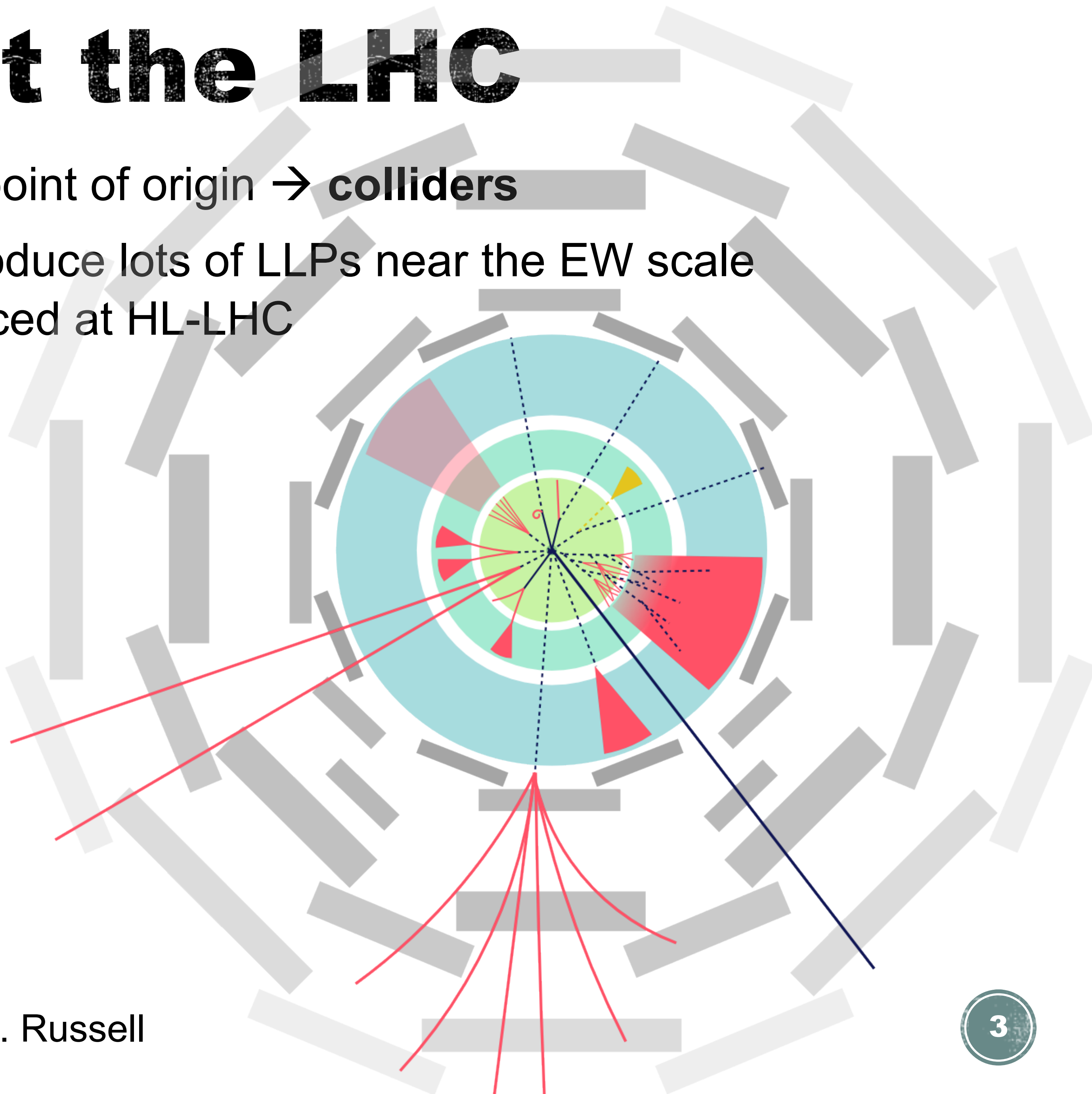


D. Curtin

LLP Searches at the LHC

- To reliably identify LLPs, must know the point of origin → **colliders**
- The LHC is the only machine that can produce lots of LLPs near the EW scale
  - ~1.5 x 10^8 Higgs bosons will be produced at HL-LHC
- Current LHC searches limited by
  - Detector size and geometry
  - Large backgrounds
    - Large QCD jet production
    - Pile-up problems
    - Beam halo issues
    - Etc

What would a background-free detector look like…?



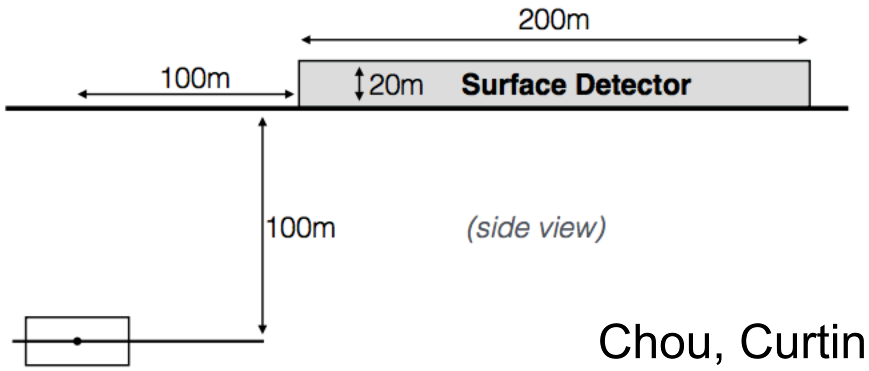
H. Russell

MATHUSLA

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

Dedicated surface detector sensitive to neutral LLPs with lifetimes up to the BBN limit, for the HL-LHC

Large, air-filled, located on surface above and offset from ATLAS or CMS interaction points



Chou, Curtin, Lubatti
1606.06298

Observed exotic Higgs decays:

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

$\epsilon_{\mathrm{geometric}}$ ~ geometrical acceptance along ULLP

b is the Lorentz boost of the ULLP

L ~ size of the detector along the ULLP direction

→ Need $L \sim 20\,m,\ \epsilon_{\mathrm{geometric}} \sim 10\%$

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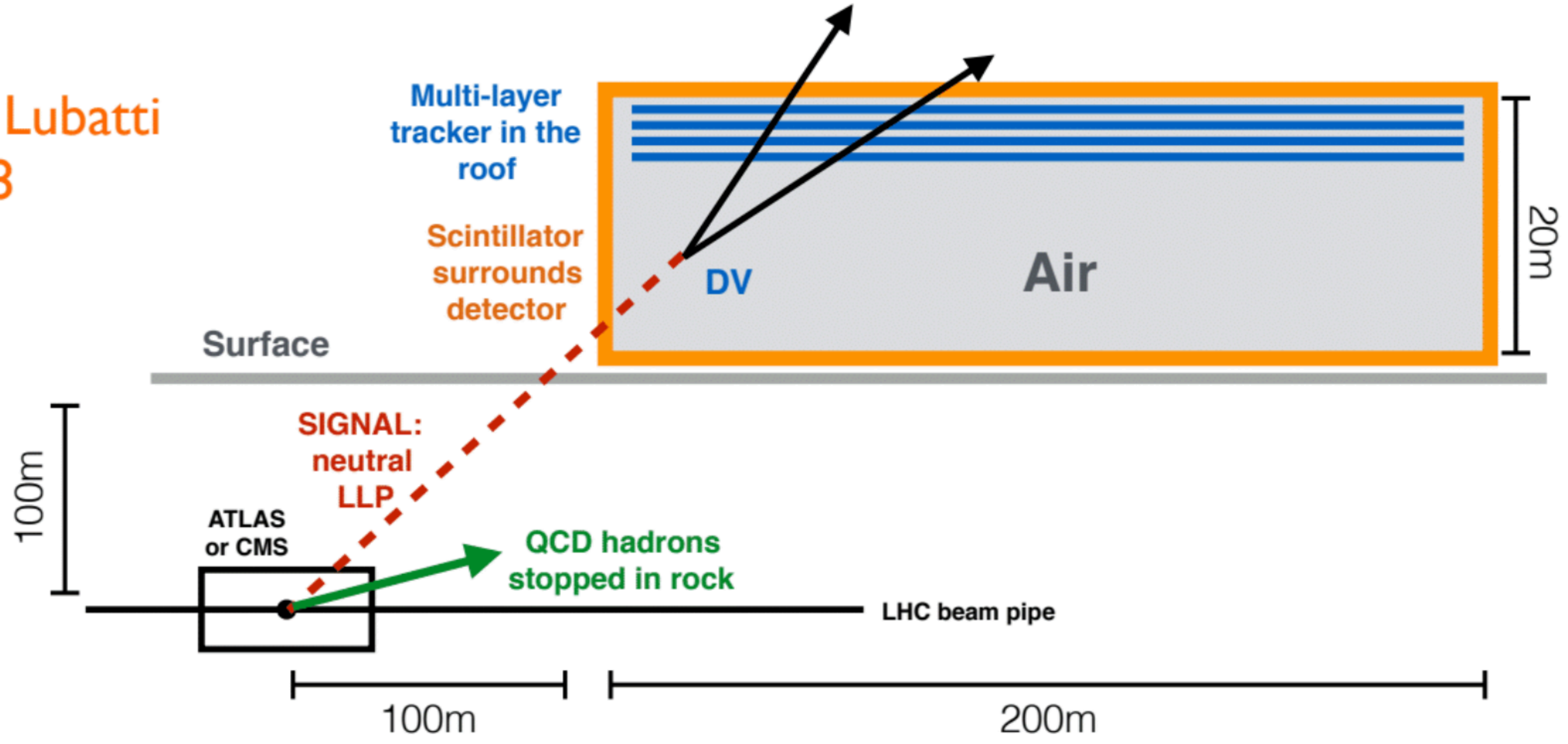
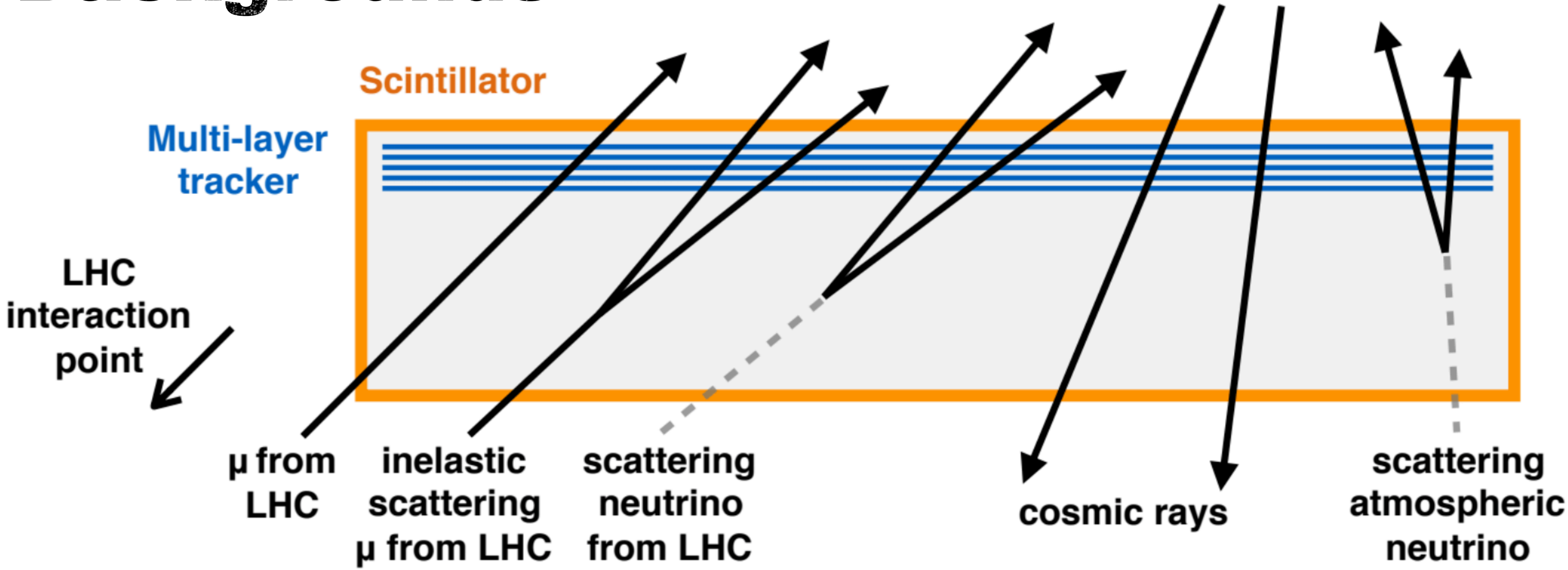


Scintillators + RPCs = robust, well understood technologies: could be ready for HL-LHC

Backgrounds

D. Curtin



In principle all of the most relevant backgrounds can be vetoed from geometry and/or timing of DV final states

Achievable limits: LLP production in exotic Higgs decays

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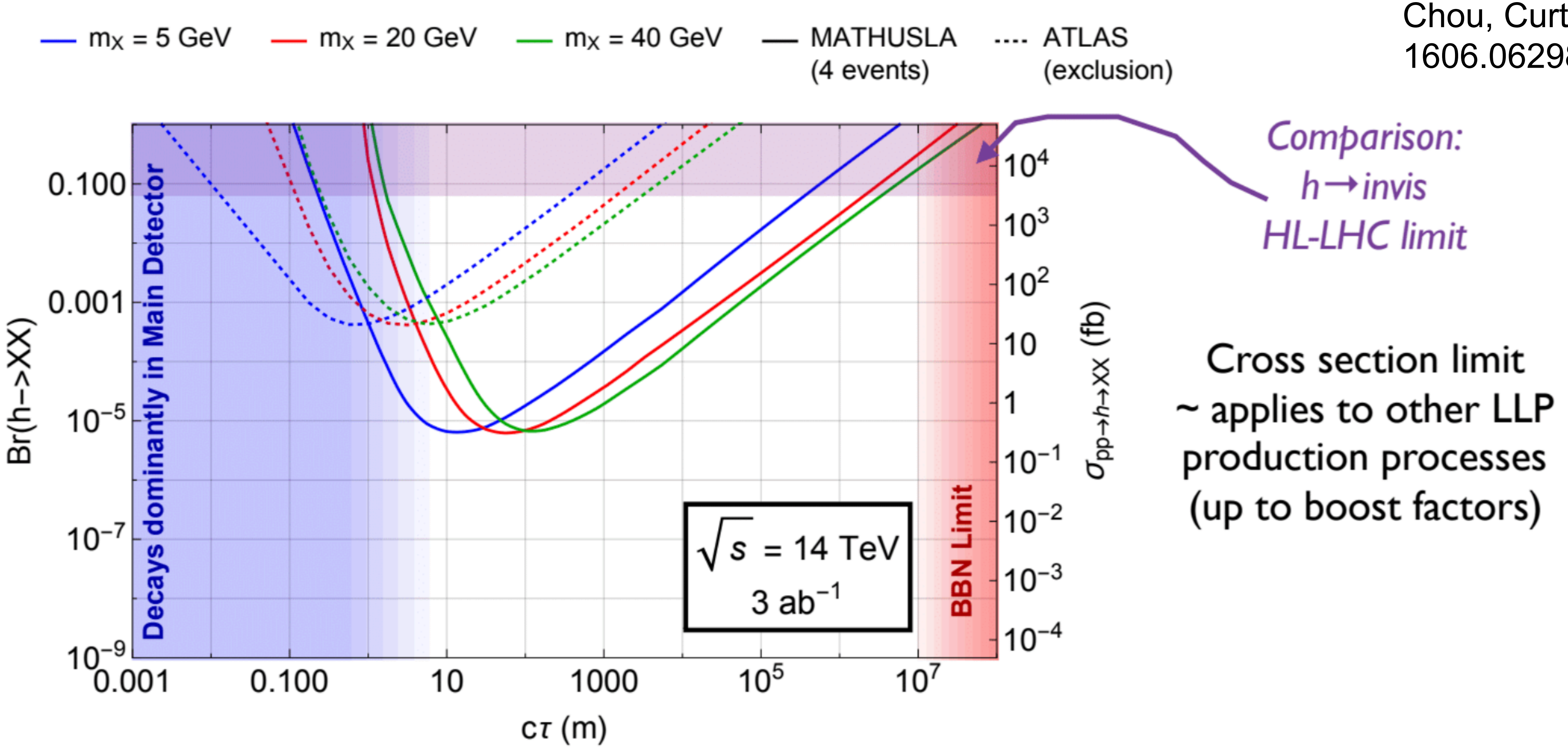


3 orders of magnitude better than ATLAS search for single DV in MS

MATHUSLA Test Stand

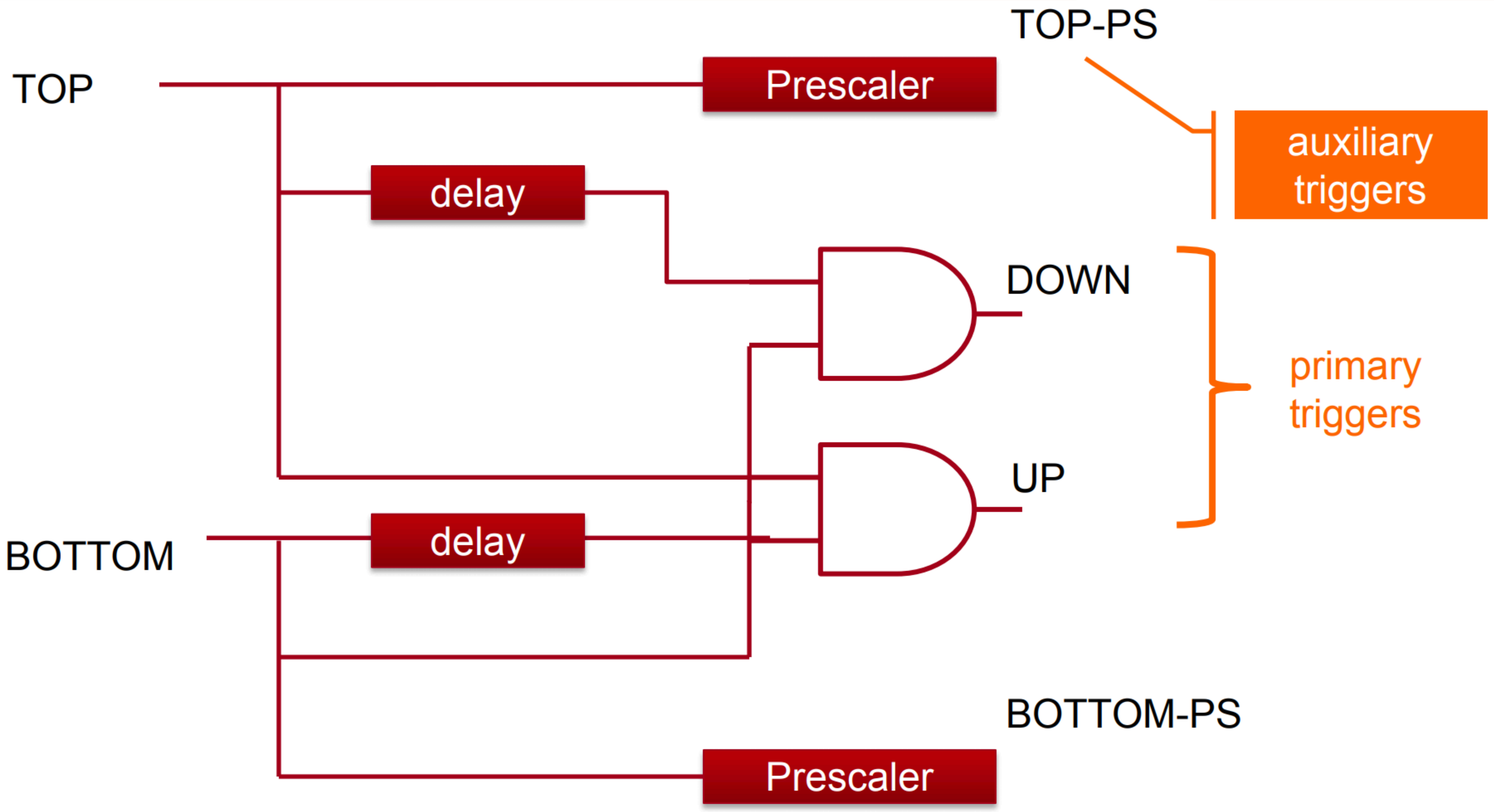
Need to validate design, quantify background rates from LHC

- Scintillators from Tevatron D0 provided by Dmitri Denisov
- RPCs from ARGO provided by University of Tor Vergata (Rome) by Rinaldo Santonico
- Built hardware-based trigger
- Developed DAQ and monitoring systems
- Constructing detector in B175 and at P1/P5
- Take data in November 2017 before shutdown

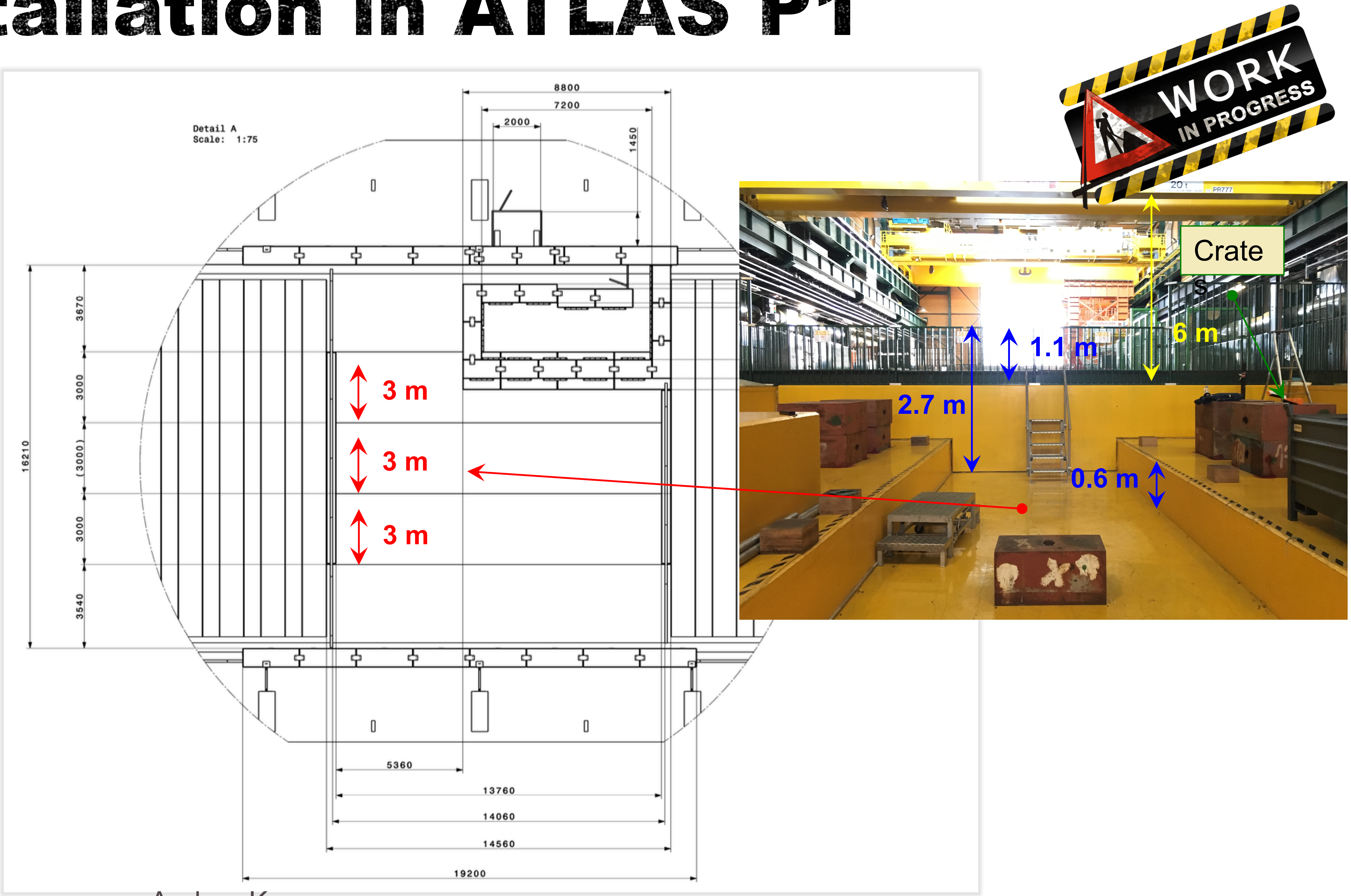
MATHUSLA Test Stand

- Two scintillator layers
- Three layers of 4 RPCs each, two in x-coordinate and two in y-coordinate
- 5 m tall, 2.5 m by 2.8 m surface area
- ~1.5 ns resolution for scintillators, ~1 ns resolution for RPCs
- TDC and ADC information for each scintillator
- RPCs have readout system from ARGO which includes TDC information

Test stand trigger



Installation in ATLAS P1



MATHUSLA Theory White Paper

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

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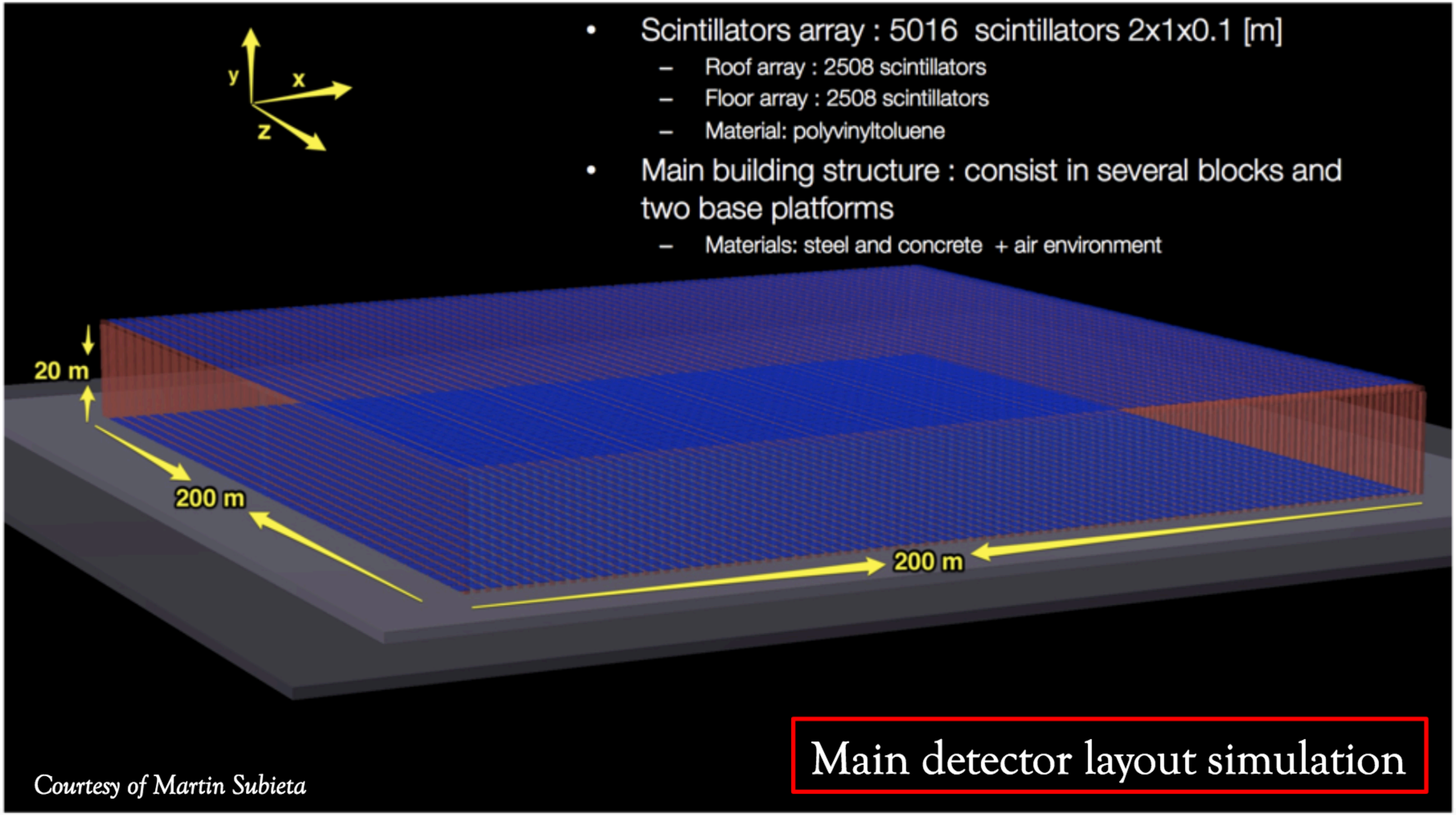
Collaborative report from 70+ theorists

Aiming for early 2018

BACKUP

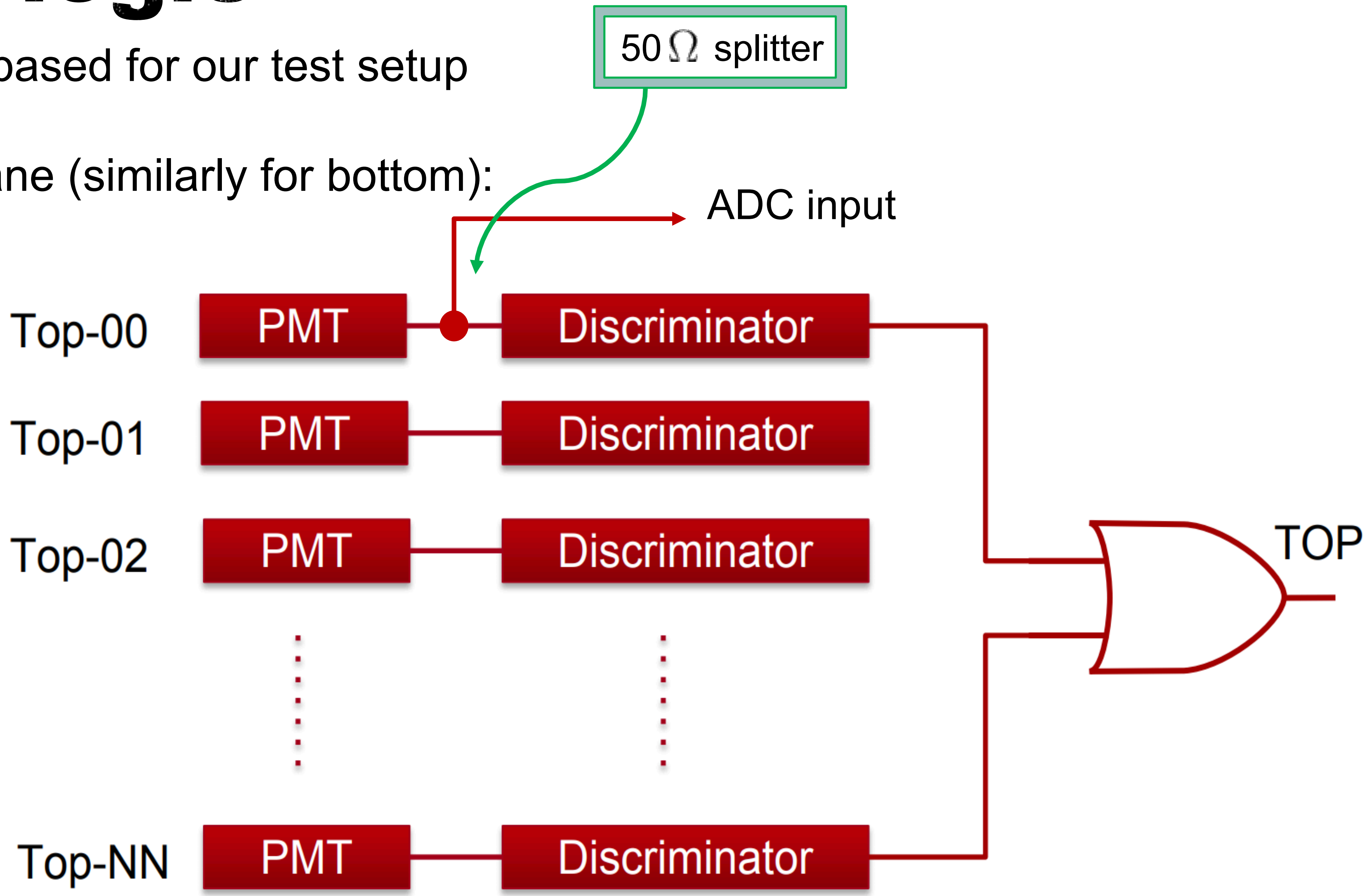


Scintillators array : 5016 scintillators 2x1x0.1 [m]
Roof array : 2508 scintillators
Floor array : 2508 scintillators
Material: polyvinyltoluene
Main building structure : consist in several blocks and two base platforms
Materials: steel and concrete + air environment
y
x
z
20 m
200 m
200 m
Main detector layout simulation
Courtesy of Martin Subieta

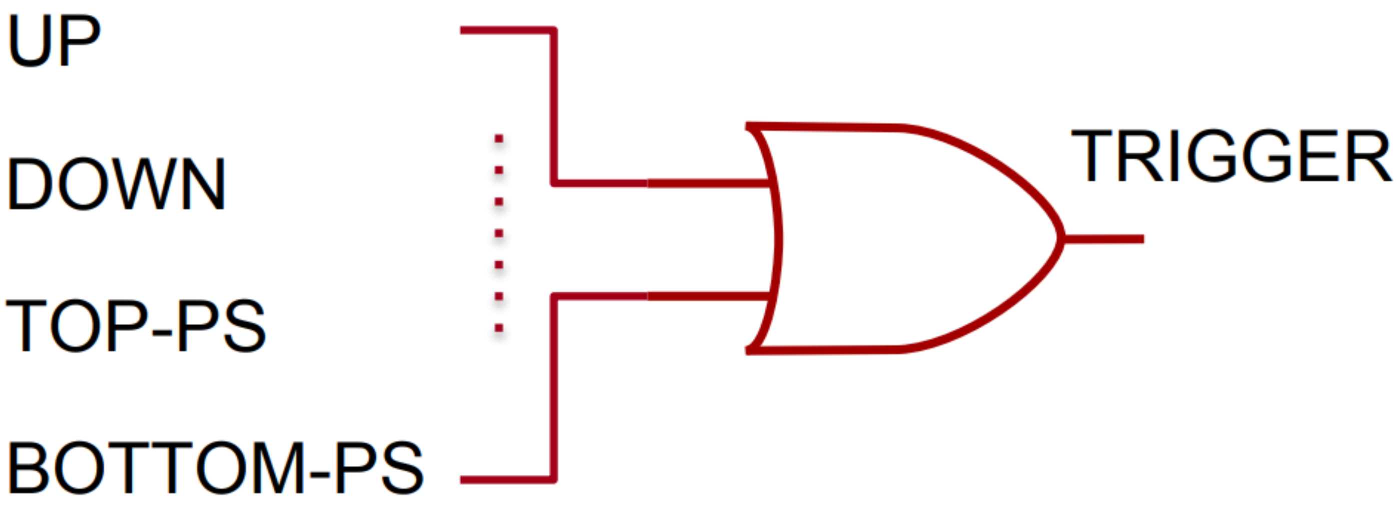
Trigger logic

Purely hardware-based for our test setup

Top scintillator plane (similarly for bottom):



Trigger logic



➢ Final trigger provides gate for ADC, common stop for TDC, and gate for RPC Local Station