

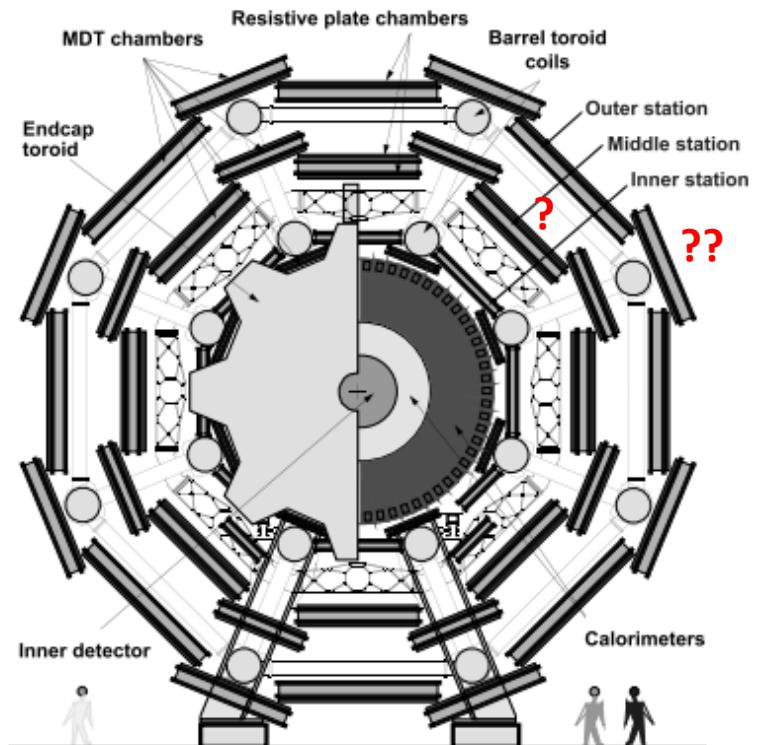
Topic #5: New subdetectors for enhanced LLP sensitivity

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New ideas in detecting long-lived particles at the LHC

LBNL

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<https://indico.physics.lbl.gov/indico/event/633/>



NEW YORK UNIVERSITY

Introduction

Author: *Haas Andrew Colton* w/ help from D. Curtin!

The long shutdown before HL-LHC running presents an opportunity to install additional (modest in scale) subdetectors or detector enhancements to one or more LHC experiments, that could significantly enhance the sensitivity to LLP, either by increasing efficiencies or rejecting background. (They may also aid other physics object reconstruction at the detectors, as a side-benefit.) An example may be active punch-through veto layers on the outside of a calorimeter, to reduce the main background to displaced decays in the muon system (see <https://arxiv.org/abs/1203.1303>). We could study the amount and type of shielding / detectors necessary to reject such backgrounds sufficiently, and estimate the impact on the sensitivity of the search. We could also consider other new ideas for new subdetectors.

Idea 1: veto layer to enhance single-DV search in ATLAS MS

- some additional scintillator (?) to detect charged particle punch-through between central calorimeter and muon system

Idea 1': (cheap) calorimeter layer to “ “ “

- roughly measure the energy of particles from candidate DV decay, to distinguish from backgrounds

Motivation from single LLP decay study

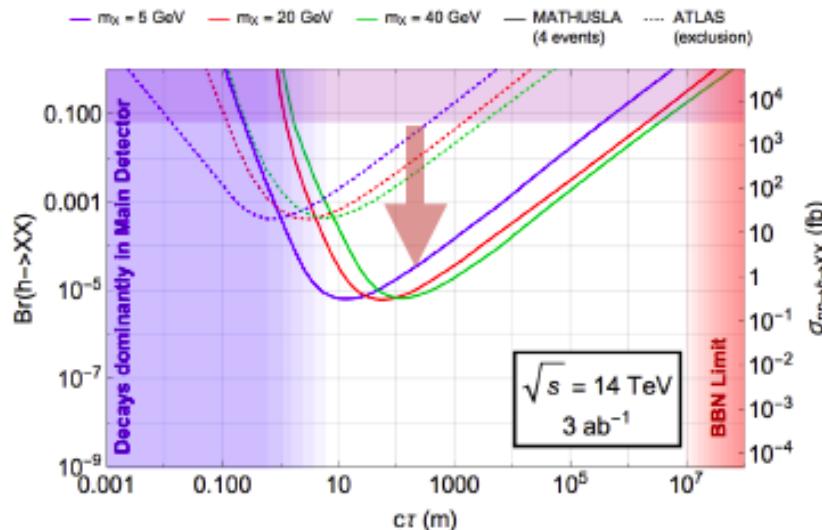
... from D. Curtin

To effectively probe long lifetime regime of LLPs, the search may only require a single LLP decay, otherwise huge acceptance penalty.

ATLAS Muon System can trigger on single LLPs, but it suffers from $O(100\text{fb})$ of punchthrough and other backgrounds, despite being shielded by the **HCAL active veto** (1605.02742).

This was the whole reason for the MATHUSLA proposal (1606.06298).

MATHUSLA has similar geometric acceptance for single LLP decay as ATLAS. If a single LLP decay could be probed without background, you could enhance sensitivities of ATLAS by a factor of 1000!



→ if we could get a BG rejection of 10^{-6} in the ATLAS Muon system somehow, we could reach the background-free regime and increase sensitivity by 1000!

First steps

Was punch-through the main background to single DV in muon system?

Is the punch-through that fails the “hadronic isolation” very different from average punch-through?

We should talk to Henry and other people on analysis.

Action: look at old studies, discuss, ... ?

Punch-through, a mysterious tail

What does punch-through look like?

Jets with lots of neutrals?

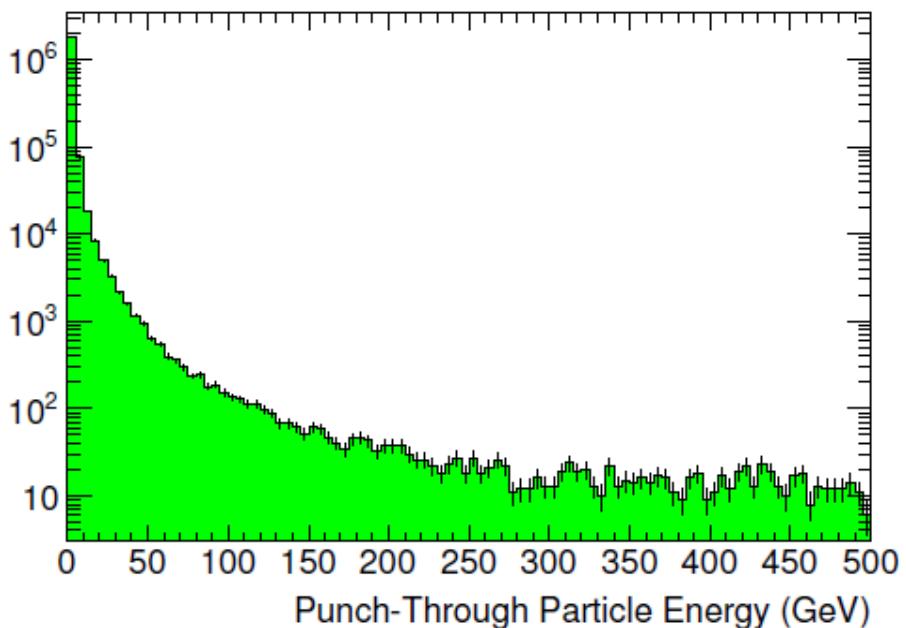
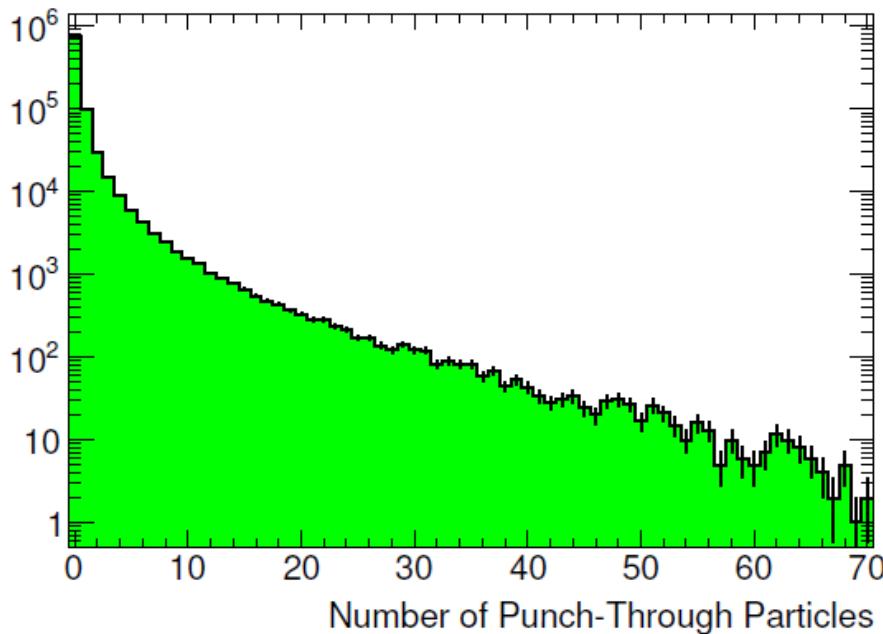
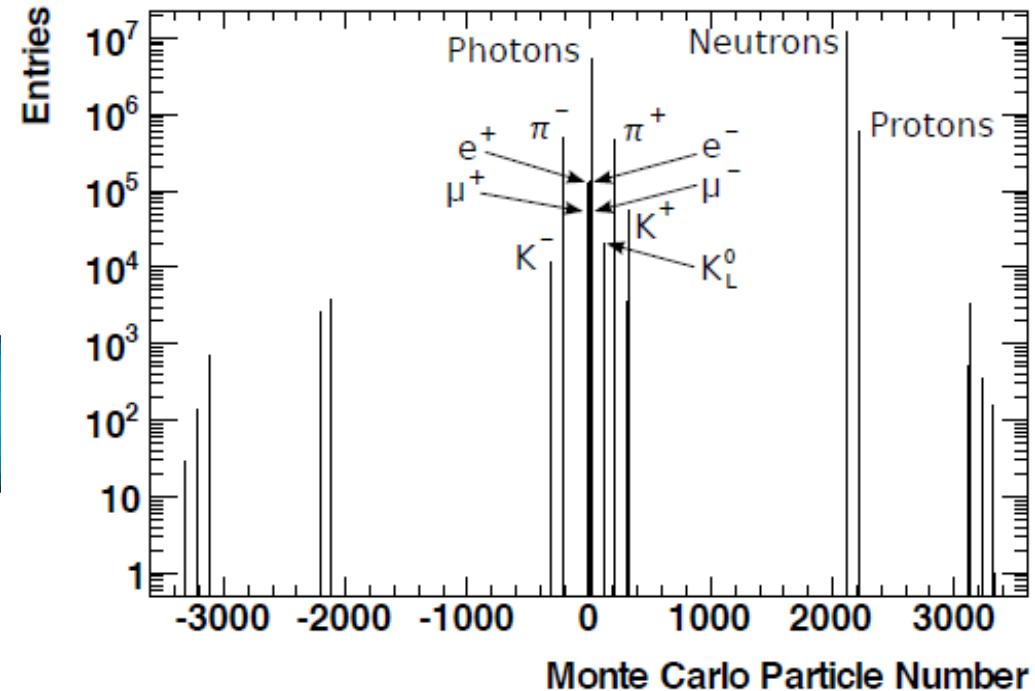
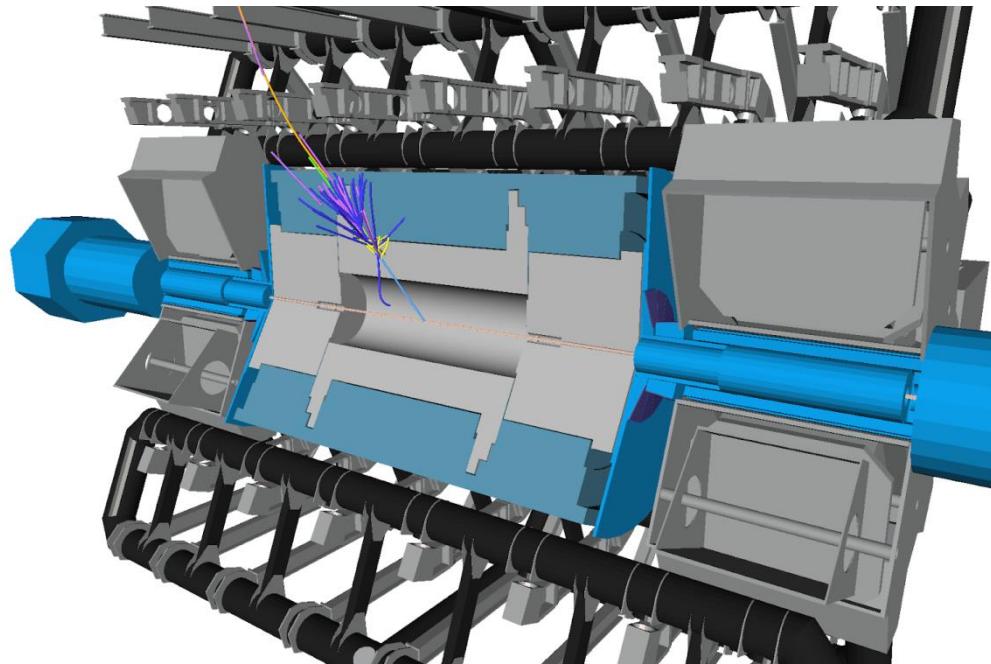
Or depositing energy in cracks/dead regions?

How many charged particles with reasonable momentum?

Lots of info in [here...](#) basically GEANT does a fine job of modeling punch-through, and it's a dribble of 1-few charged hadrons, with p peaking near \sim few GeV and falling off exponentially. Rate is $\sim 10^{-2}$ for 100 GeV p charged hadrons!

And [this](#) is from ATLAS work on simulating (approximately, and quickly) punch-through.

Punch-through, a mysterious tail



Options for a punch-through veto layer

What are the options for this veto-layer sub-detector?

Dictated largely by the nature of the background.

Would detecting ≥ 1 charged particle at the calorimeter exit near the DV with reasonable momentum be enough?

Action: design a straw-person detector that could detect these charged particles with reasonable granularity and timing. Is scintillator best?

Action: For various detector options, what are the BG-rates due to cavern background, etc. How much do corresponding fake vetoes reduce signal rate?

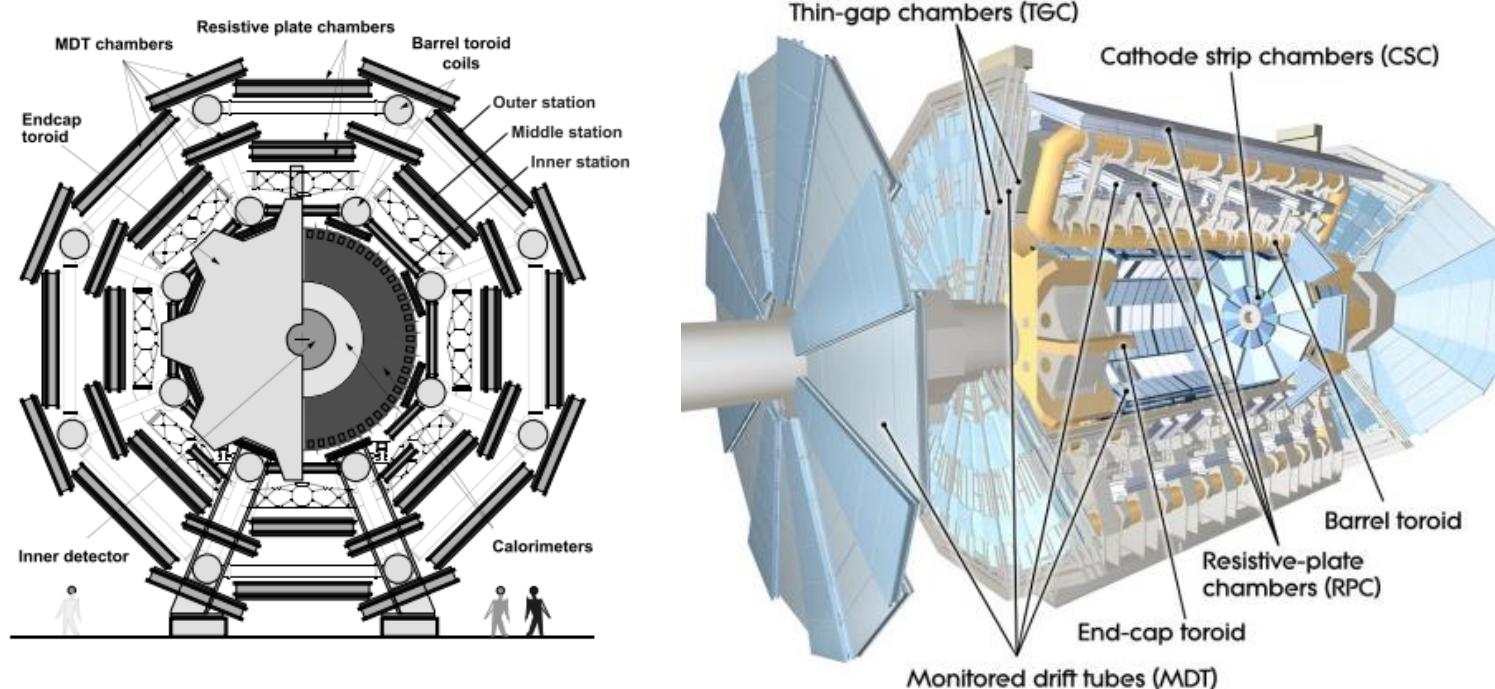
<http://cdsweb.cern.ch/record/1457509/files/ATL-MUON-PROC-2012-005.pdf>

Where could this go?

Is this an insane idea?

Is there room to put stuff between calorimeter and muon system?

Places in eta/phi where more difficult, others where things could fit?



Action: look at schematics of existing muon system and
“parameterize” the regions that can be enhanced.

https://www.nikhef.nl/pub/services/biblio/theses_pdf/thesis_J_Snuverink.pdf

Action: estimate the negative effects on the muon momentum resolution from additional material / multiple scattering.

A calorimeter layer instead / in addition ?

... from D. Curtin

Maybe a calorimeter layer on the outside of the muon system for additional info on signal could greatly aid background rejection?

Where on the detector is there room for this, and hence geometrically what fraction of detector could be thusly enhanced?

Action: look at schematics of existing muon system and “parameterize” the regions that can be enhanced.

Action: given punch-through (and other background?) characteristics, how much would measuring the event energy in the muon system help?

Other

Idea 2: Novel detectors for external LLP detectors?

- There are several detector ideas on the market already, which we could discuss how to improve / expand for more general LLP coverage
- Could also discuss completely new detector ideas

Idea 3: Audience suggestions?

- You've likely already thought of things we haven't!

Outcome here: Fun little paper examining this as an upgrade possibility?
It would have to be fleshed out with some significant studies to really be credible, but in principle yes. It could become a serious proposal.