

LLPs From Exotic Higgs Decays Using Faraway Sub-detectors

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University of Cincinnati

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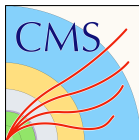


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- 1 Introduction and Motivation
- 2 HS Higgs to LLPs With CalRatio at ATLAS
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- 4 Anomaly Detection in LHCb Muon System
- 5 Conclusions

→ **Why do we care about exotic Higgs decays?**

- Experimental constraints on SM Higgs BR leaves room for “invisible” decays
- Small natural width of SM Higgs makes it natural proponent for BSM theories
- Higgs serves as a portal to hidden-sector neutral matter

→ “Invisible” decays of the Higgs can manifest as long-lived particles

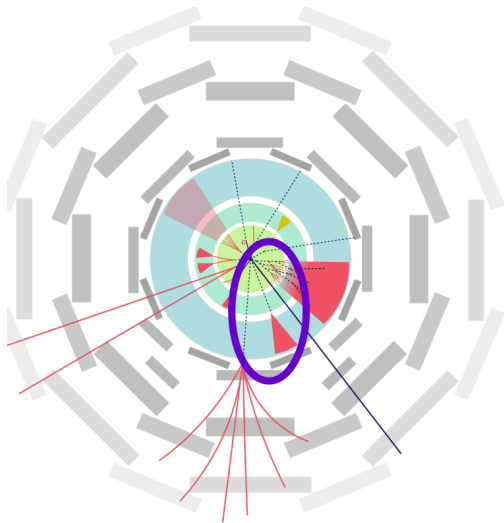
Use unconventional signatures to search for LLPs!!

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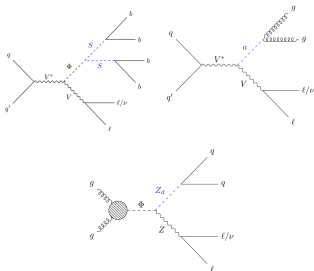
$HS \rightarrow SS$ Using CalRatio

JHEP11 (2024) 036; ATL-DAQ-SLIDE-2020-110

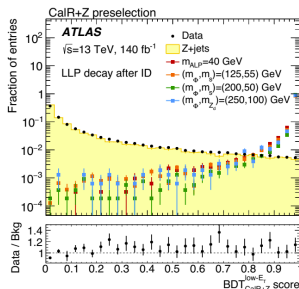
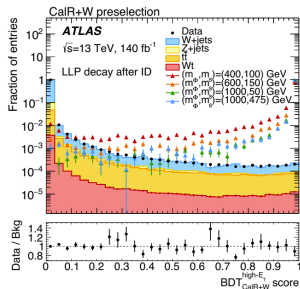
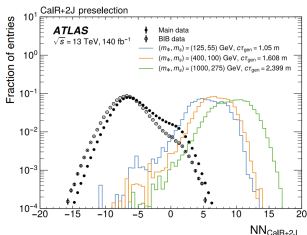


→ Neutral long-lived particles leave displaced jets: **CalRatio!**

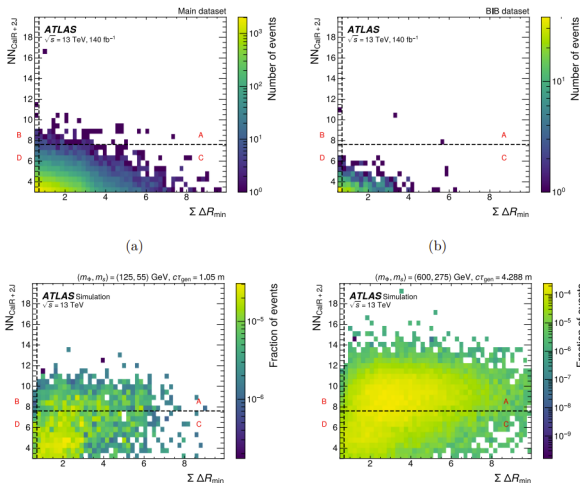
ML For Multiple Signal Modes



Utilize BDTs and NNs targeting different BSM modes

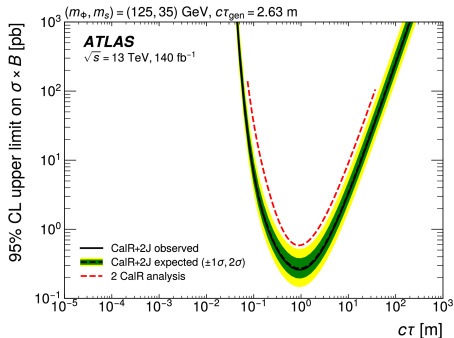
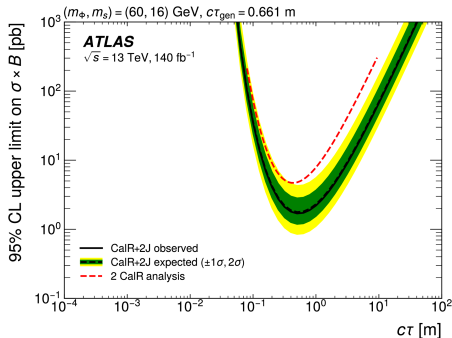


Data-Driven Background Estimates



Primary backgrounds from V+jets/multijets
 → Data-driven estimate using ABCD

Limits on Multiple Interpretations



No excess in observed events

→ Numerous interpretations used to set limits

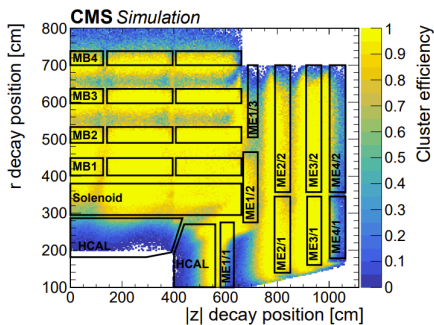
Improvement over previous analysis

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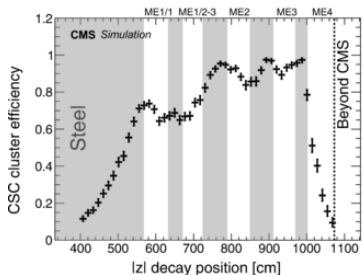
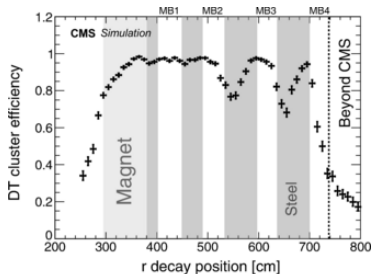
$H \rightarrow$ LLP Using Muon Systems

PRD 110, 032007



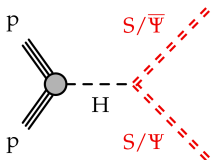
→ Utilize CMS detector as shielding wall

Use muon system as sampling calorimeters
for LLP showers

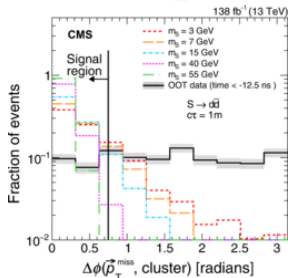
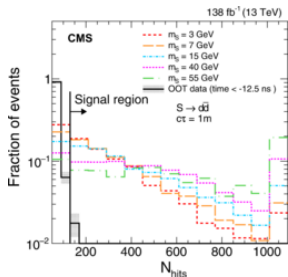
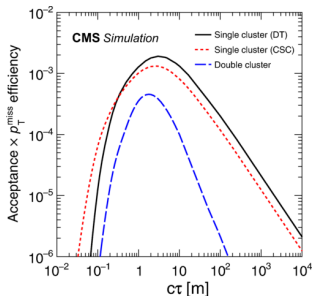


Model-Independent Signal Extraction

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Analysis approach allows for model-independent selection



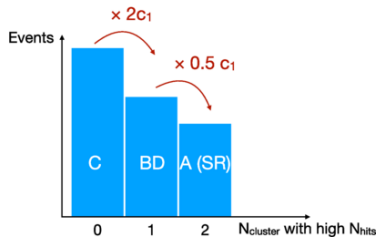
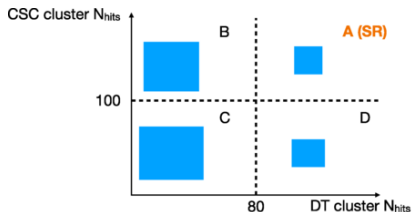
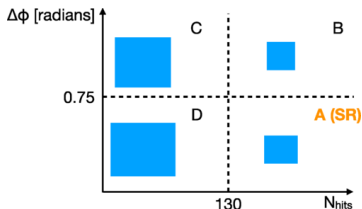
Data-Driven Background Estimates

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SM Background estimates taken from data-driven ABCD method, depending on cluster selection type

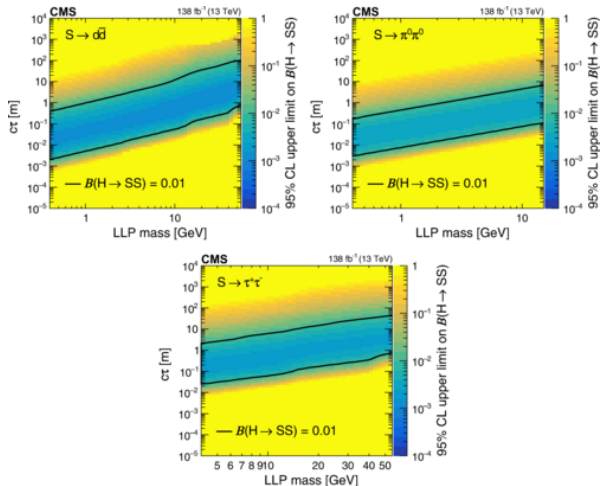
Backgrounds primarily from:

- ① punch-through jets
- ② bremsstrahlung muons
- ③ isolated hadrons



Limits on Multiple Interpretations

PRD 110, 032007



No excess in observed events

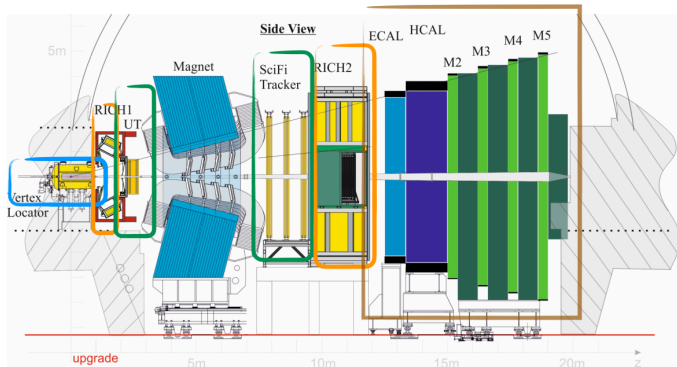
→ Numerous interpretations used to set limits

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$H \rightarrow AA$ Using Muon Showers

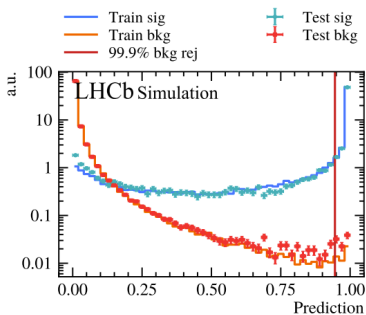
LHCb-FIGURE-2024-015



→ Long-Lived BSM particles could have decay lengths $O(10\text{m})$
 Use muon chambers as sampling calorimeters for anomaly detection

Classical Search Approach – Neural Network

LHCb-FIGURE-2024-015



Neural Networks require defined
signal model:

$$H \rightarrow AA \rightarrow 4\tau ;$$

$$\tau \rightarrow \pi\pi\pi$$

→ **Limitations!**

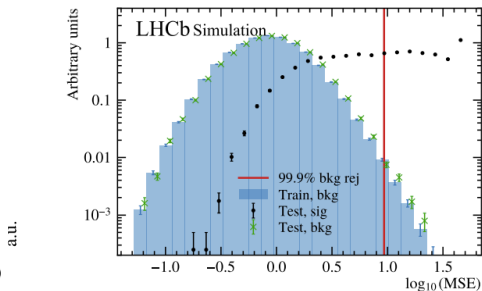
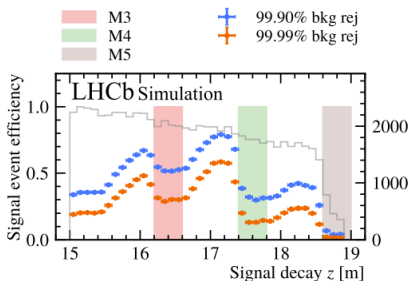
What if reality is different than the
model used to train?

Background-Only Training – Auto Encoders

LHCb-FIGURE-2024-015

Auto Encoders serve as classifiers
only training on the
background-only hypothesis

Versatile!



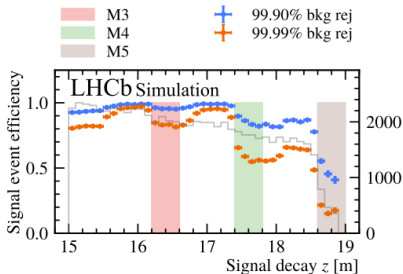
↑ Separation of signal (anything **not** expected) from background (data) comes from minimization of reconstruction error

Penalizing Performance – Normalised Auto Encoders

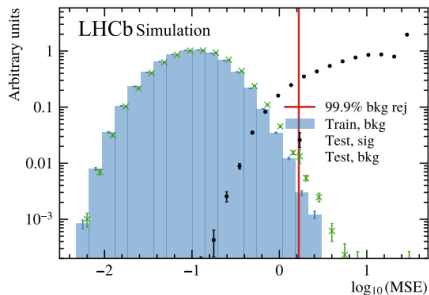
LHCb-FIGURE-2024-015

Auto Encoders can be too good at reconstructing **Anything**, like our anomalies..

Normalised Auto Encoders!



Constructed by sampling reconstructible space outside of min-bias concentration



← ↑ Significant improvement in performance

→ Limitations!

Need stable detector performance, or need to retrain classifier

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Conclusions

→ Current SM measurements leave significant room for Higgs decays to “invisible” BSM particles

- LHC experiments are making use of unconventional detector signatures to search for Higgs decaying to LLPs
- Analysis approaches focus on model-independent selections, allowing for multiple interpretations
- Pushing ground on ML front to apply anomalous detection to these unconventional searches

BACKUP