

# Next Generation Triggers: SM & BSM benchmarks

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# Introduction

- The **Next Generation Triggers (NGT)** project aims at getting more physics out of the HL-LHC data.
- Task 1.6: *New Physics scenarios and Standard Model properties as trigger benchmarks*
- Identify SM measurements and BSM scenarios which can be improved with the expected triggering improvements.
- What is not triggered on is lost forever. What could we be missing?

**New ideas are very welcome!**

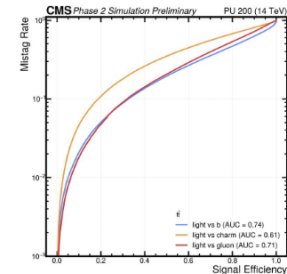
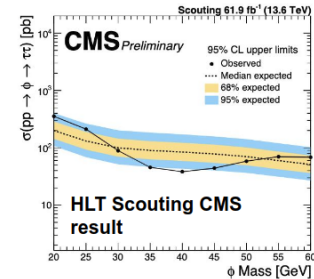
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# Trigger improvements

- Multiple, soft final states

## First prototype analyses: low-mass resonances

- Investigating low mass narrow resonances decaying into  $\mu\mu$ ,  $ee$ ,  $\tau\tau$ ,  $\gamma\gamma$ ,  $qq/bb$  being explored
  - **Soft final state**, not selected efficiently by the standard L1 Trigger
  - **Small signal yield**, but visible as **narrow peak over smooth background**
  - Too large “irreducible” backgrounds
    - **X $\rightarrow\tau\tau$  further expand HLT Scouting acceptance (CMS-EXO-24-012)**
      - see how far we can push low  $p_T$   $\tau$  reco with ML-algo on PF candidates in Scouting, current L1T tau reco NN-based target focusing on high  $p_T$  for  $H \rightarrow \tau\tau$
    - **Investigating di-jets resonances to extend further HLT Scouting reach**
      - any two L1T PUPPI jets ( $\sim 90\%$  efficient for  $p_T > 30$  GeV in  $t\bar{t}$ )
      - exploit L1T PUPPI jets reconstruction quality: flavour tagging, large radius jets
      - can improve further in Scouting with: jet  $p_T$  regression (as offline for b-jets), more complex tagging algorithm



# Trigger improvements

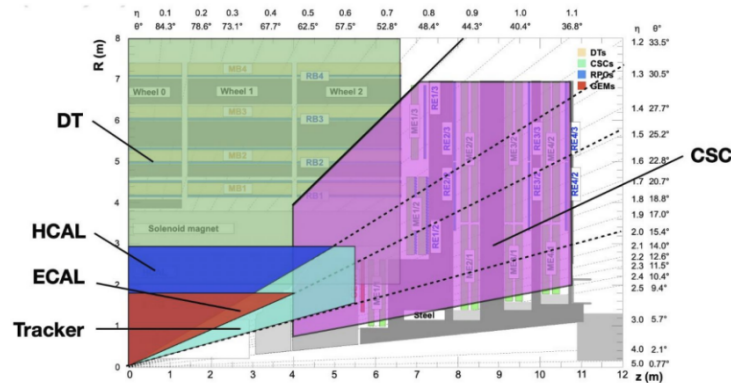
- Track information

## New LLP Triggers in Run 3: Track-based

- As a result of long-standing developments, in Run(2)3 large suit of triggers dedicated to LLPs
  - mostly in prompt/parking, only a dedicated displaced muon reconstruction for Di-muon stream in Scouting

- Multiple triggers using different detectors to effectively cover a large range of final states and LLP lifetimes

- Track-based: Available at HLT
- Calo-based:
  - ECAL timing available at HLT
  - Displaced/delayed jets in HCAL available at L1T & HLT
- Muon-based:
  - Displaced muon triggers available at L1T & HLT
  - Muon detector showers in DTs available at HLT
  - Muon detector showers in CSCs available in L1T & HLT



Run-3 LLP Trigger paper coming soon (EPS)

# | What have we been doing?

**July 4th Workshop:** *BSM benchmarks for next-generation triggers*

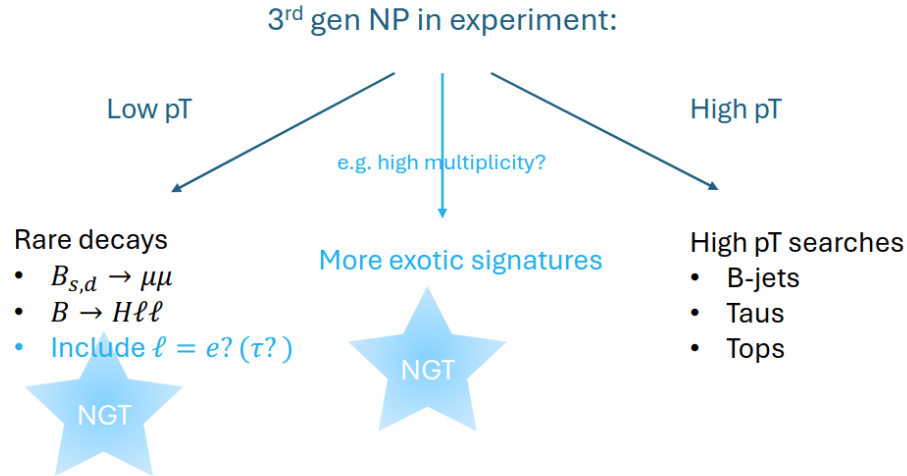
## **September 18th Meeting**

- First steps towards identifying interesting BSM directions
- Goal is to become a regular meeting

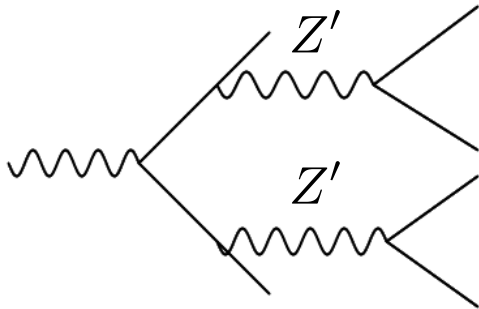
# What are we looking for?

## Flavour non-universal new physics

- 3<sup>rd</sup> generation-philic NP can explain **flavour puzzle**, but not only:
  - Weaker direct search bounds → more natural solutions to **hierarchy problem**
  - Flavour **anomalies**



# Light $Z'$



- Multiple objects coming from a light resonance, around 10 GeV
- Couple only to third generation? Avoids other bounds

**A  $Z'$  from a gauged  $U(1)_{(B-L)_3}$  could serve as a good benchmark**

Arises naturally in more complete flavour models, e.g. flavour deconstruction

# | Light $Z'$

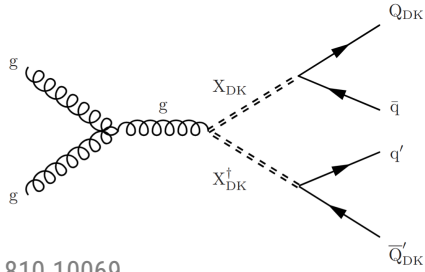
- **Why TH?**

- *Models to explain flavour hierarchies*
- *3rd-generation-philic physics is motivated*

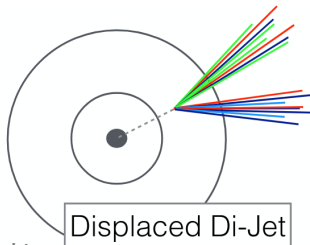
- **Why NGT?**

- Soft leptons
- Multiple low-mass resonances – b-jets and taus

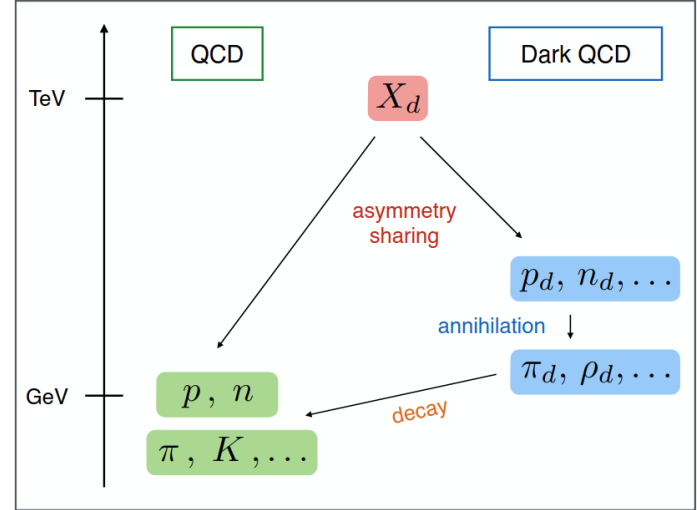
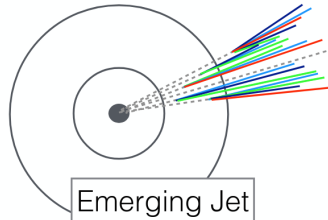
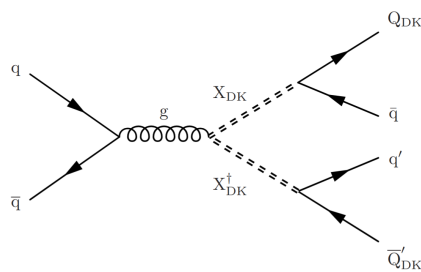
# Dark QCD-like sectors



CMS, 1810.10069



Schwaller, Stolarski,  
Weiler 1502.05409



## Dark pion lifetime

$$c\tau \approx 80 \text{ mm} \left( \frac{1}{\kappa^4} \right) \left( \frac{2 \text{ GeV}}{f_{\pi_{\text{DK}}}} \right)^2 \left( \frac{100 \text{ MeV}}{m_{\text{down}}} \right)^2 \left( \frac{2 \text{ GeV}}{m_{\pi_{\text{DK}}}} \right) \left( \frac{m_{X_{\text{DK}}}}{1 \text{ TeV}} \right)^4$$

# Dark QCD-like sectors

- **Why TH?**

- *Dark matter model*
- *Efforts towards simulation of dark confining sectors*

- **Why NGT?**

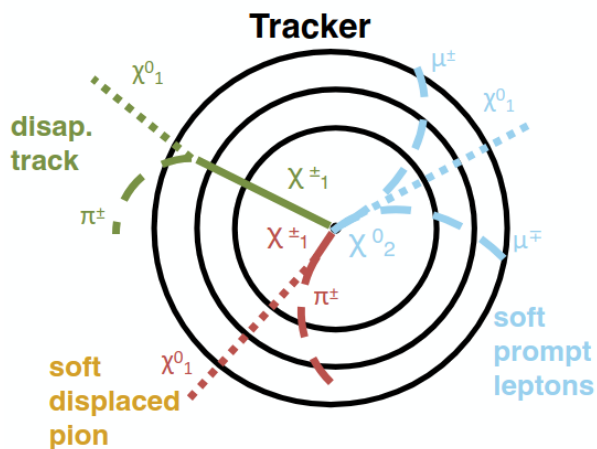
- Combining track information with HT triggers to test lighter mediators

# Long-lived particles (LLPs)

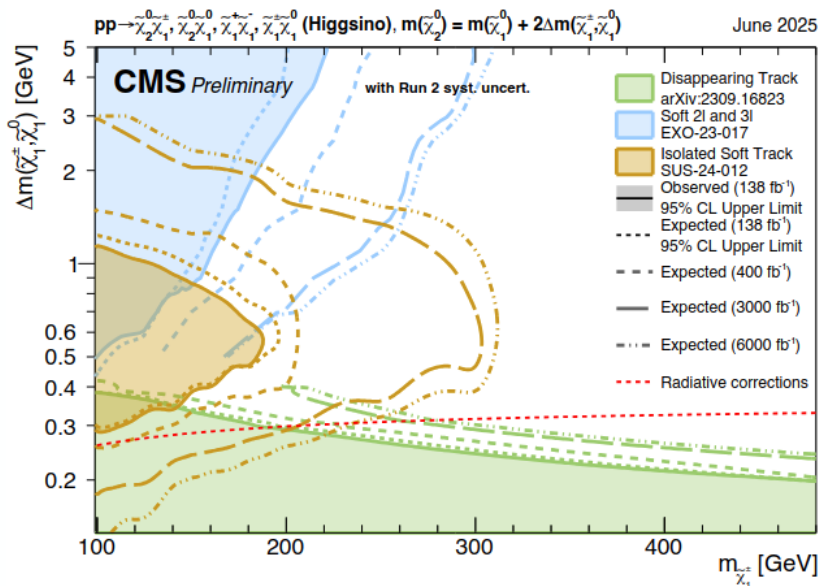
## Compressed mass spectra:

- SUSY
- Non-minimal Composite Higgs Models
- Dark sectors
- Co-annihilating WIMPs
- (Your input)

# Long-lived particles



Cornering natural SUSY using ultra-soft signatures at CMS, talk by Sam Bein, LHC Seminar – 1st July 2025



[CMS:EXO/EXO-23-017]

A good framework which covers NGT improvements: tracking and soft leptons

# Long-lived particles

## ■ Why TH?

- *Minimal dark matter model - Higgsino*
- *More complex compressed spectra - non-minimal Composite Higgs models*

## ■ Why NGT?

- Current triggers based on MET/soft PT
- Using track information

# Anomaly detection

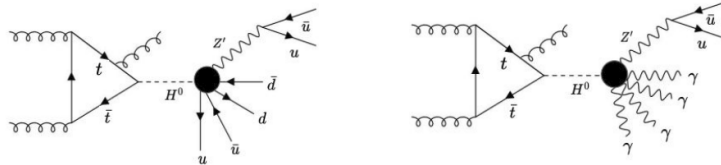
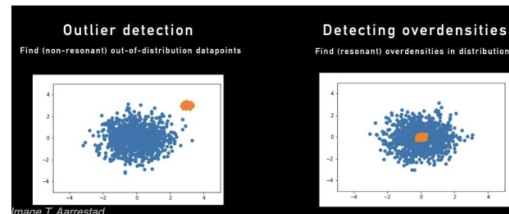
## Sensitivity of AD Triggers (?)

- Assumptions for AD with Autoencoder

- Anomalies are **rare** in training set
- Anomalies are **out-of-distribution**
- Anomalies are **detectable in input objects**

- Physics analysis of AXOL1TL data

- Analysis with an anomaly detection trigger has never done before, lots of technology to develop. On-going: characterization of trigger performance in 2024 data on SM candles (J/ψ/Z peak, etc...)
- **Start simple, bump hunt** in di-object invariant mass spectra with AXOL1TL data as in [ATLAS offline search](#)
  - Expect increased acceptance for events with a resonance produced in association with additional objects
  - **Question for theorists:** Examples of well-motivated models for such final states?



# | Other directions?

- Decay chains from non-minimal sectors
- SUEPS, Quirks, etc
- Vector boson fusion
- Anomaly detection
- (...)

**Community input is essential to make the most out of the  
Next Gen Triggers project**

# Thanks

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