

Long-lived particles from the prompt side using **CONTUR**

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[arXiv:2407.18710](https://arxiv.org/abs/2407.18710) - Accepted by JHEP





01

Overview & long-lived particles

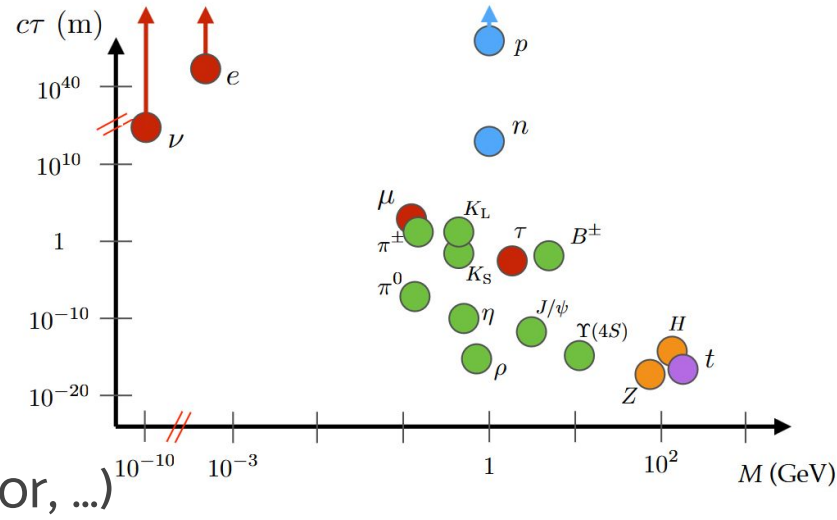


Overview

- Constrain NP models featuring LLPs using **prompt** measurements
- Modification of the **CONTUR** workflow to account for:
 - LLP that decay **early enough** to be considered prompt
 - **Recoil** of LLPs against prompt systems
- New constraints on LLP models: **complementary** to direct searches

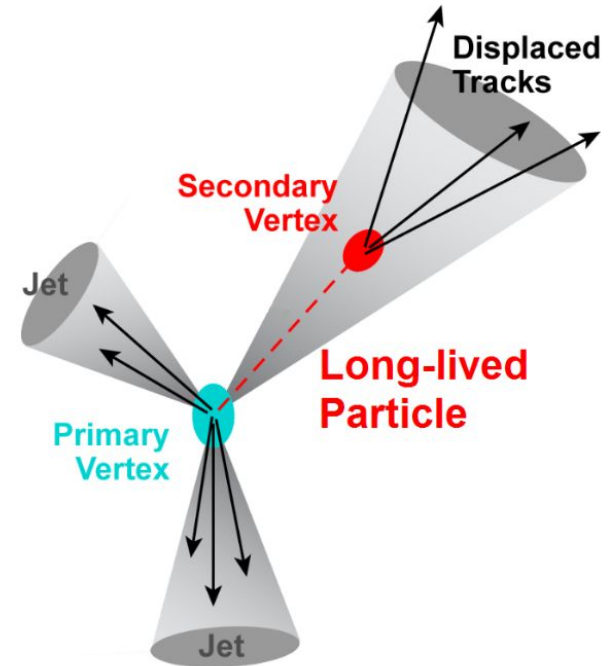
Long-lived particles

- **Blind spot** of the LHC
- Good theoretical **credentials**
- Long lifetime \sim small width:
 - Small **matrix element** (small coupling, heavy virtual mediator, ...)
 - **Phase space** (small mass difference between parent/daughter particles)



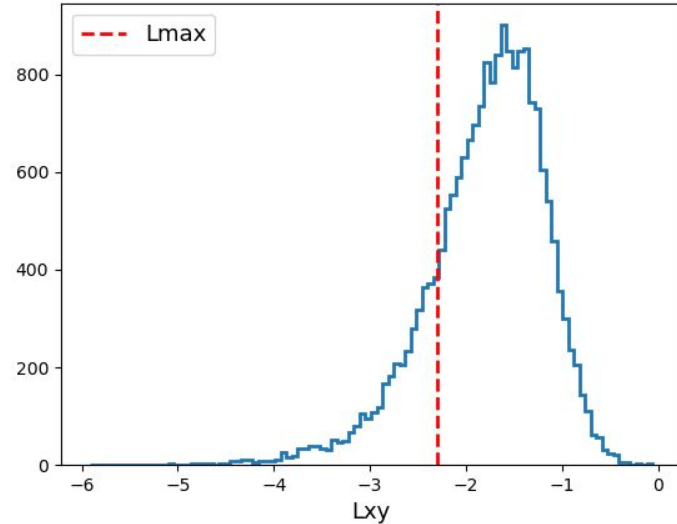
Long-lived particles

- Recent **interest** in LLP searches: constraints on σ vs. $c\tau$
- **Low-lifetime** regime ill-covered (2^{ry} vertices, SM bkg, ...)
- Sensitivity drops at **large lifetimes**
- CONTUR **not** usable for LLP signatures:
analyses in RIVET assume **prompt**
behaviour
- **Wrong** estimate of the signal



Long-lived particles

- Detector corrections would not account for **lost** jets/tracks due to **displaced** starting point
- Data might resemble detector **noise** (hence thrown away)



- **Not** all parameter space regions need to be **avoided**: regions where LLPs can decay promptly in large numbers can still give meaningful constraints

Our method

- Prompt LHC measurements can **constrain** LLP production:
 - Some **fraction** of LLPs will have prompt behaviour
 - Effect of the **recoil** of the LLP on the prompt particle's p_T
- Application to benchmark **LLP** models: single/pair production, leptonic/hadronic decay, charged/neutral
- Comparison with **existing** searches
- Estimation of **HL-LHC** constraints (scaling stat/syst uncertainties by \sqrt{L})

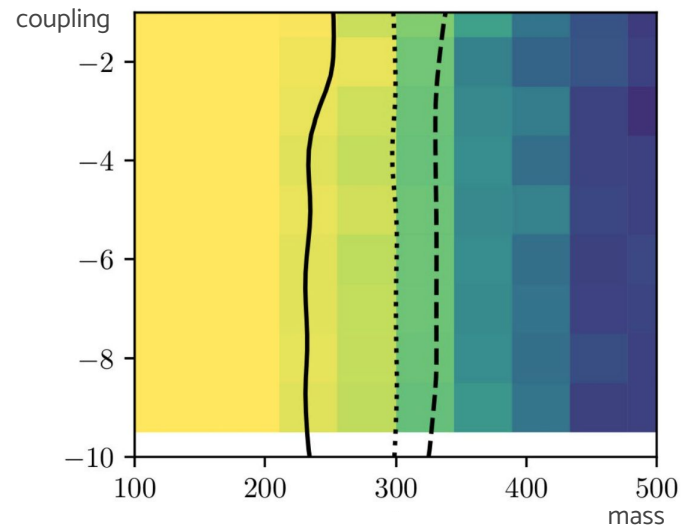
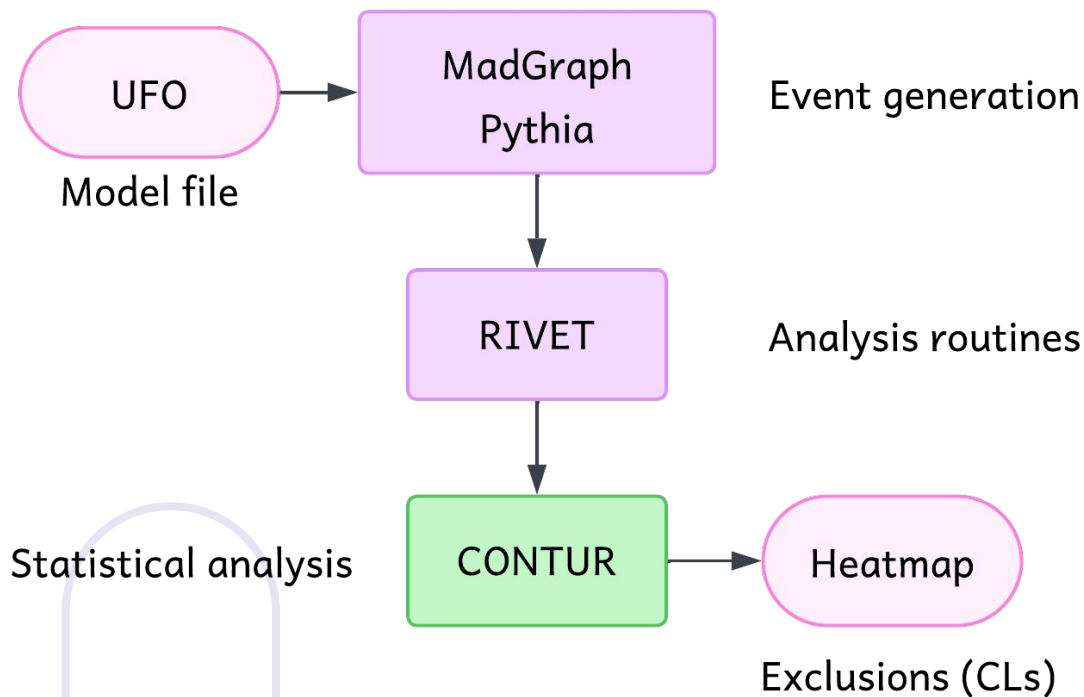


02

Adapting CONTUR to LLP topologies



Standard CONTUR workflow



[arXiv:2102.04377](https://arxiv.org/abs/2102.04377)

Adapting workflow

LLP lab-frame **decay length** determined by the MCEG. Prompt threshold: **5 mm** (max d_o cut in primary tracking)

- a) Decay **early** enough ~ prompt
- b) Decay **within** detector volume ~ noise
- c) (Heavy) **charged** particle decays **outside** the detector ~ problematic reconstruction
- d) **Neutral** particle decays **outside** the detector ~ missing energy

3 regimes of sensitivity

Low lifetime:

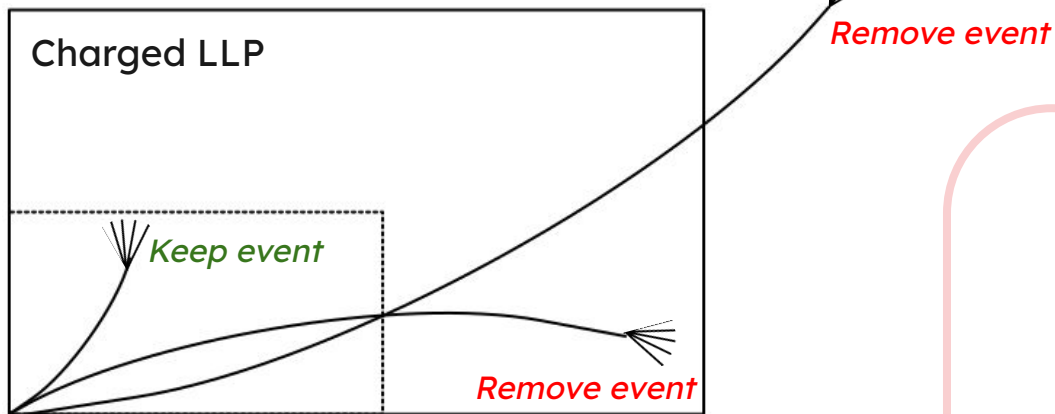
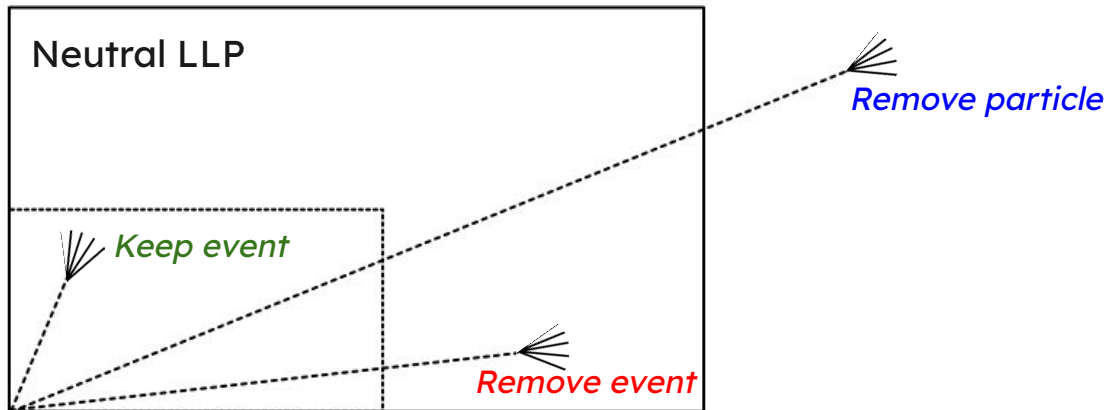
extrapolation of the prompt sensitivity

Long lifetime:

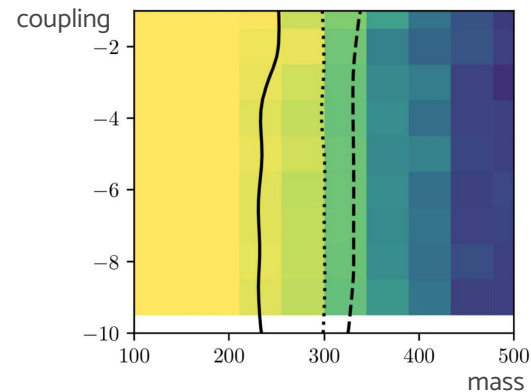
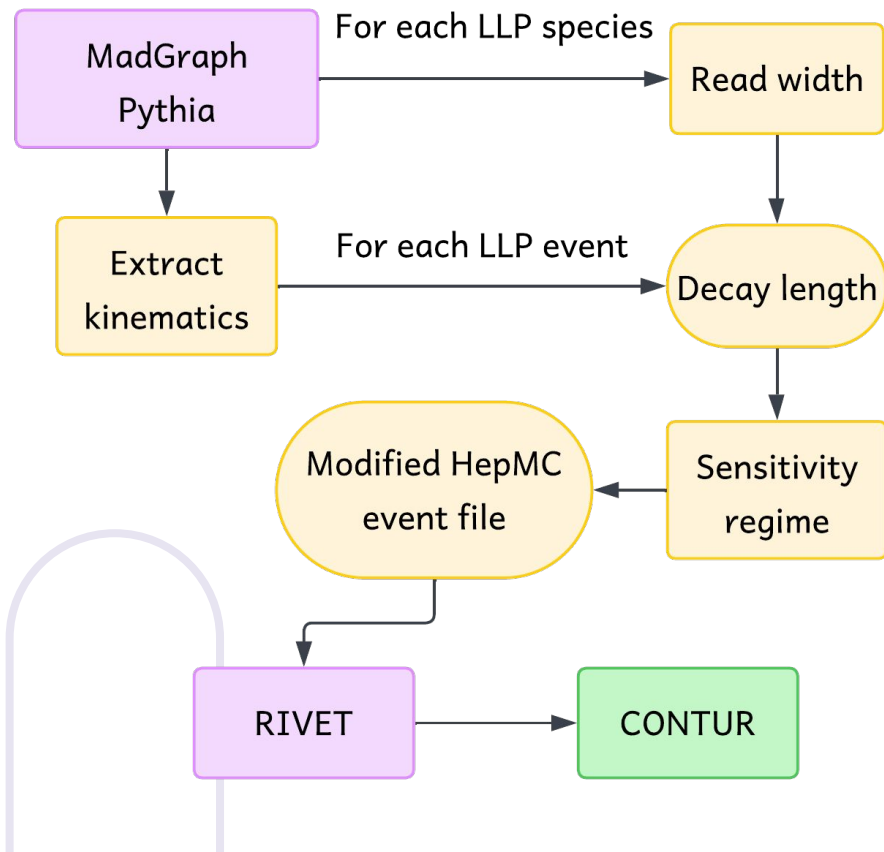
neutral LLP can yield to a recoil effect on the p_T of prompt particles which they are produced with

Intermediate regime:

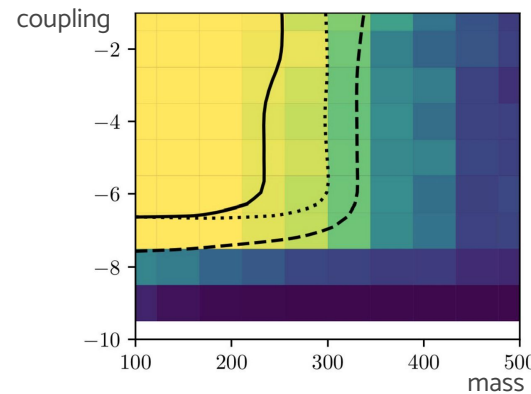
dip in sensitivity, regime which direct searches are designed to probe



Modified CONTUR workflow



After accounting for LLP signatures





03

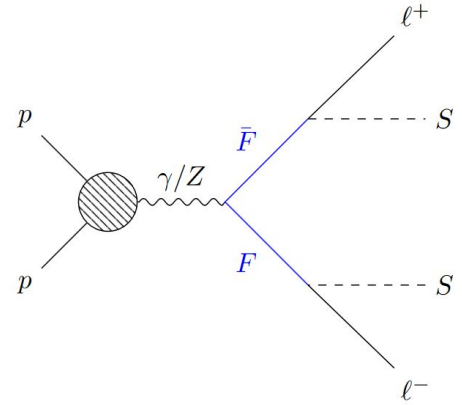
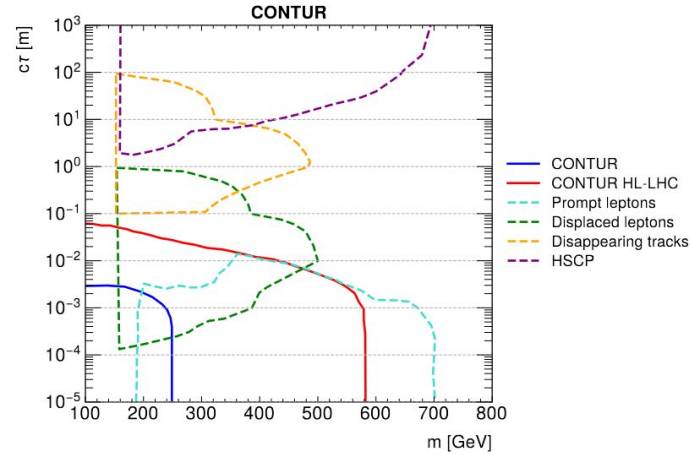
Results & existing searches



Results

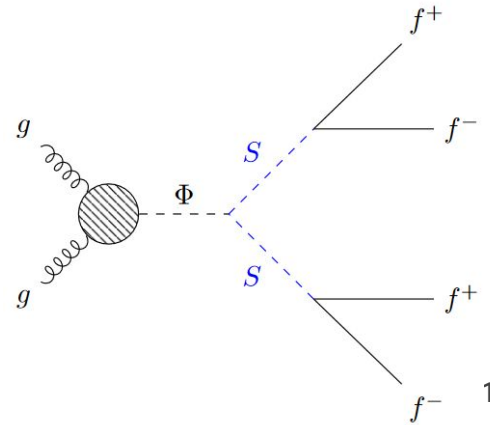
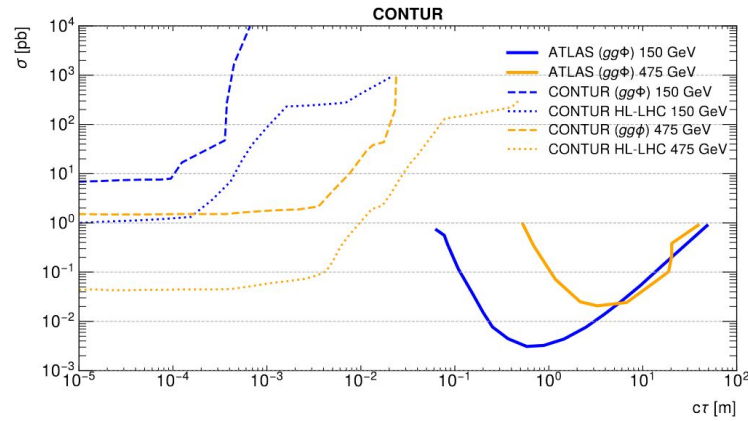
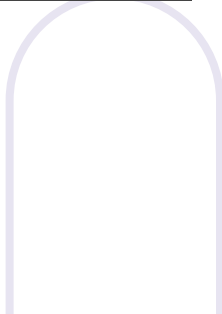
Feebly interacting DM:

[arXiv:1811.05478](https://arxiv.org/abs/1811.05478)



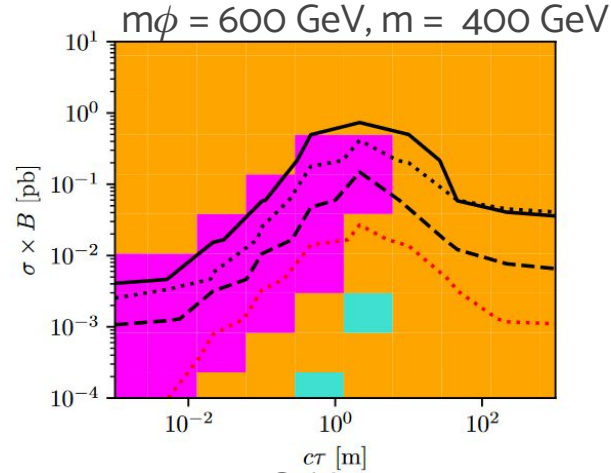
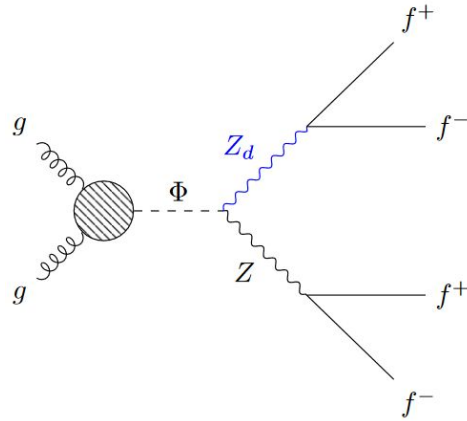
Hidden sector:

[arXiv:1312.4992](https://arxiv.org/abs/1312.4992)

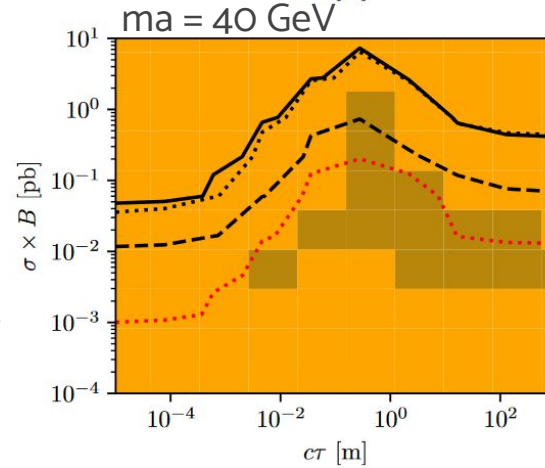
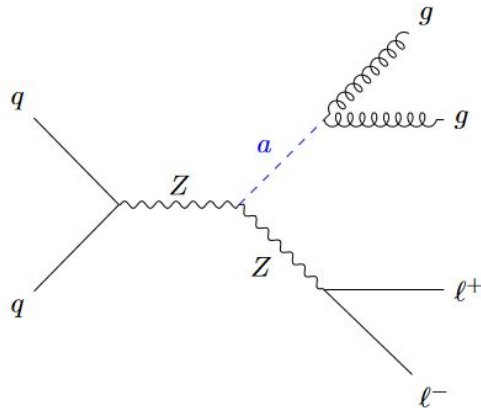


Results

Dark photon:
[arXiv:1203.2947](https://arxiv.org/abs/1203.2947)

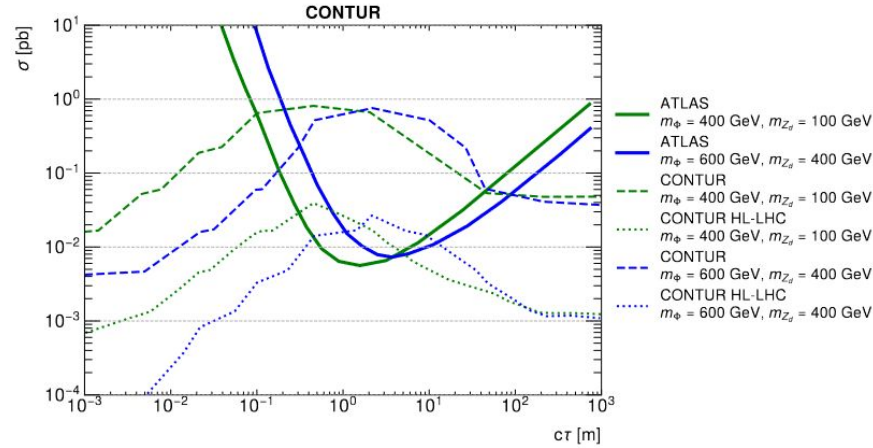
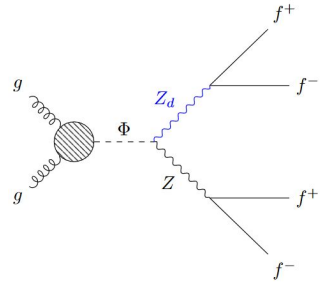


Photophobic ALPs:
[arXiv:1701.05379](https://arxiv.org/abs/1701.05379)

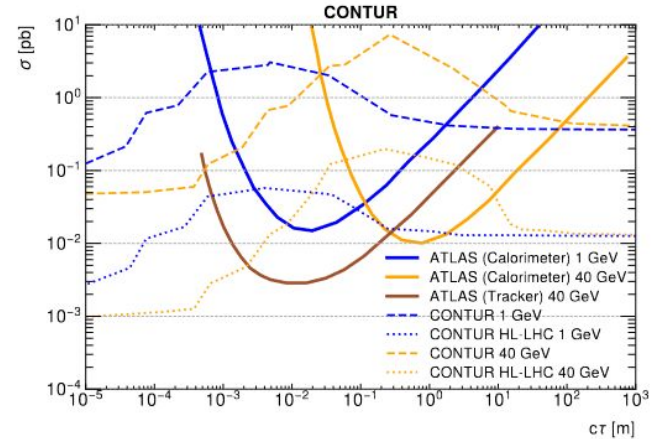
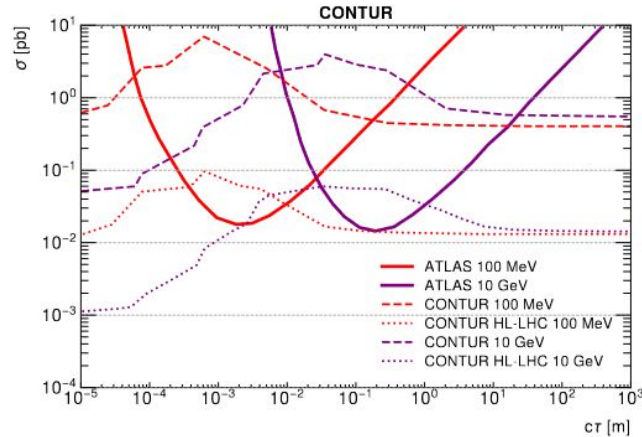
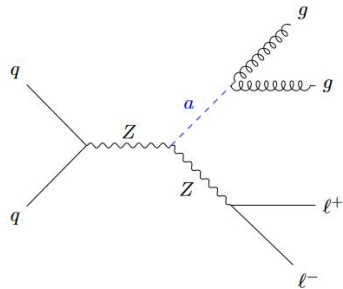


Results

Dark photon:



Photophobic ALPs:



Summary

- Probed **LLP** models using **CONTUR** (+ HL-LHC projection)
- New **constraints** on 4 popular LLP models
- Various **nature** of LLPs: charged/neutral,
signly-/pair-produced, leptonically/hadronically decaying
- Relevant **sensitivity** for very **short**/very **long** lifetimes
- Pave the way for **new** constraints **methods** on LLPs

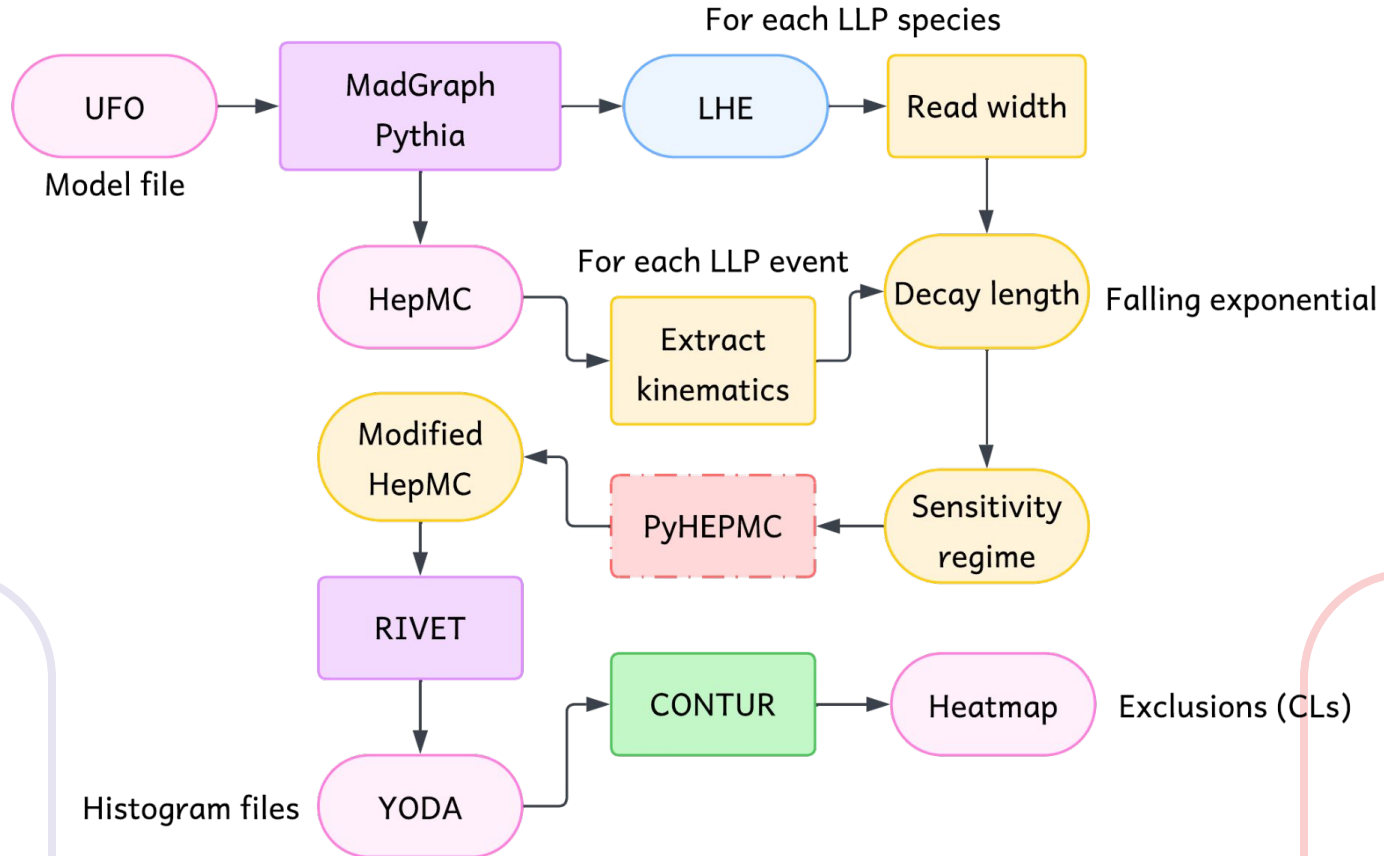
Thank you for your attention !



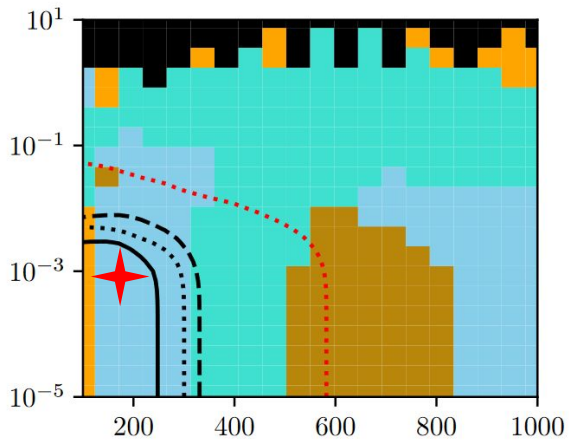
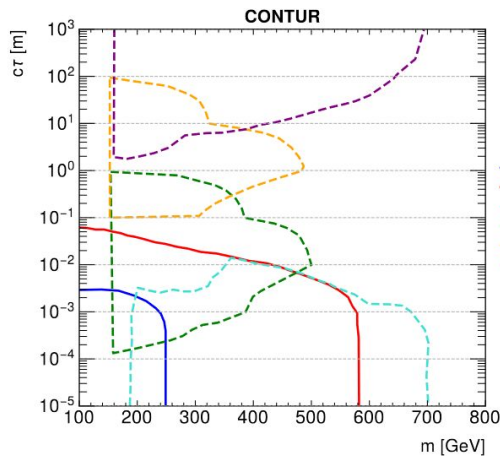
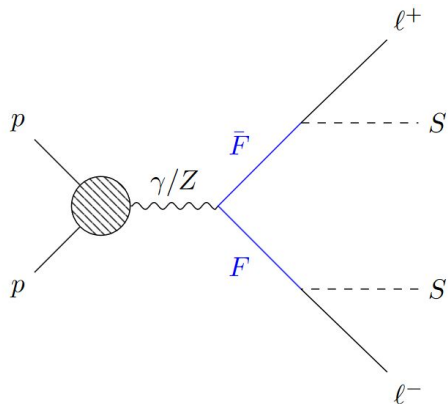
BACKUP



Detailed workflow

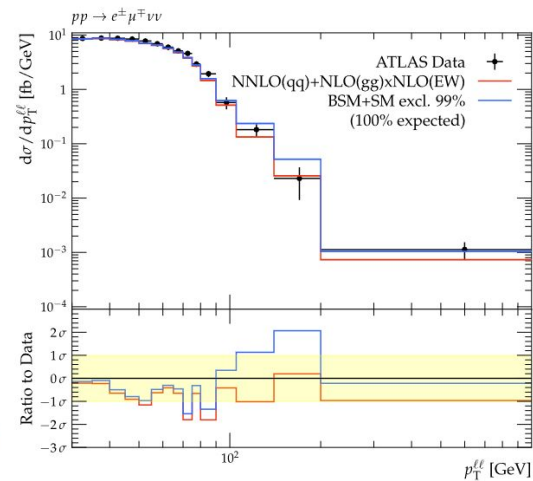


Feebly interacting DM



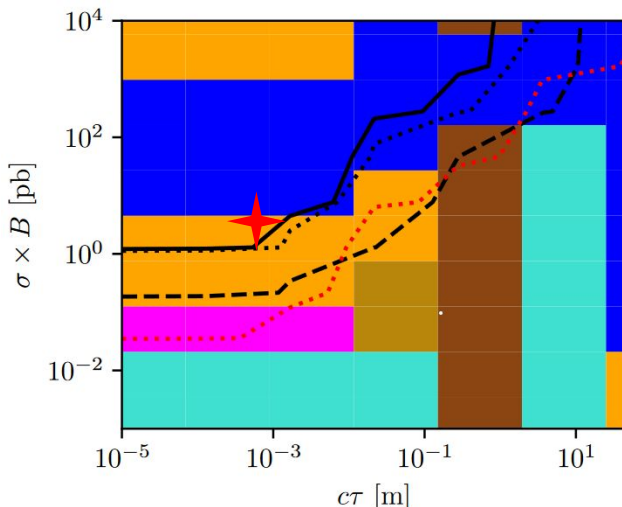
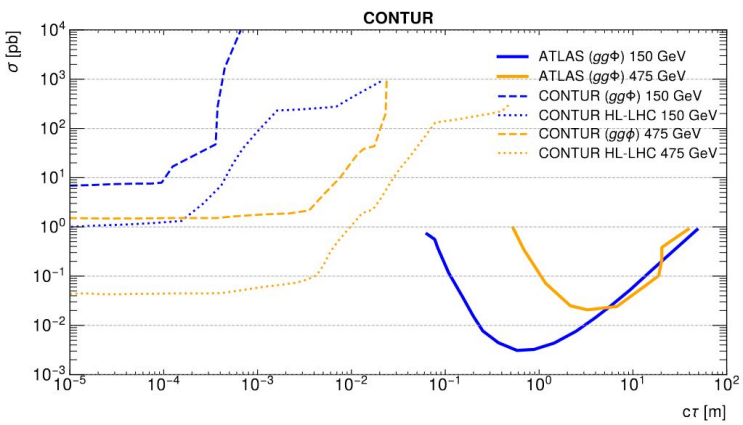
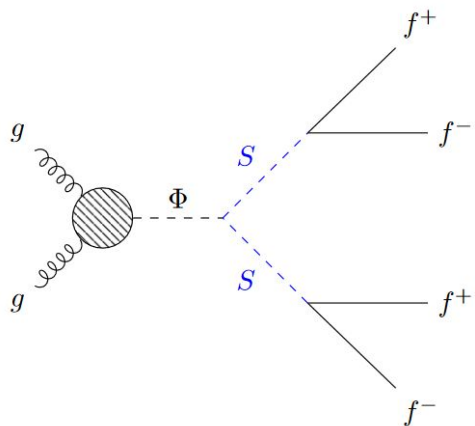
No data
 $\ell_1\ell_2 + E_T^{\text{miss}} + \text{jet}$ [49]
 $\ell_1\ell_2 + E_T^{\text{miss}}$ [50]
 $\ell + E_T^{\text{miss}} + \text{jet}$
 $\ell^+\ell^- + \text{jet}$ [51]
 $\ell^+\ell^-\gamma$

$mF = 147 \text{ GeV}, c\tau = 0.0008 \text{ m}$

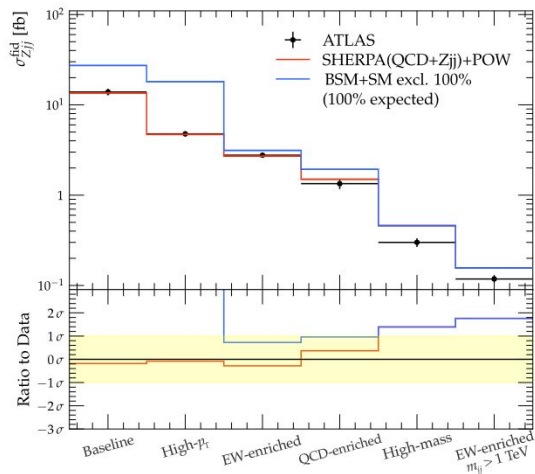


Hidden sector

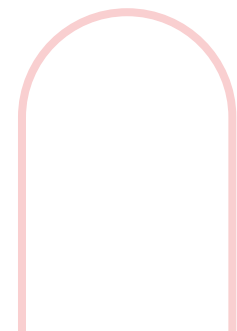
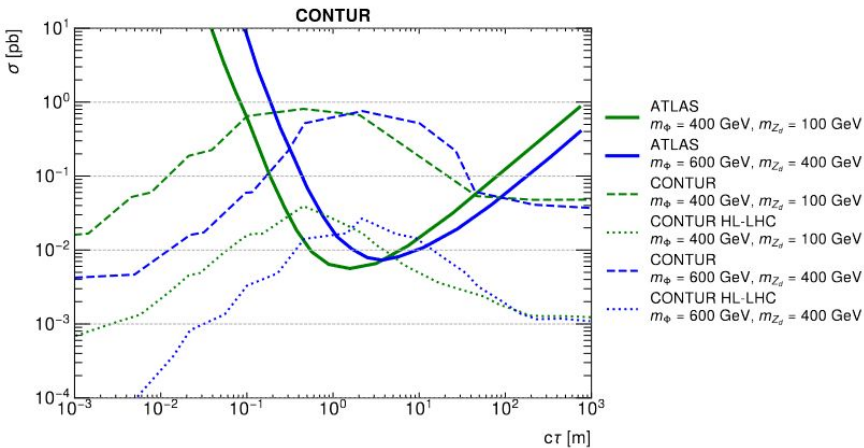
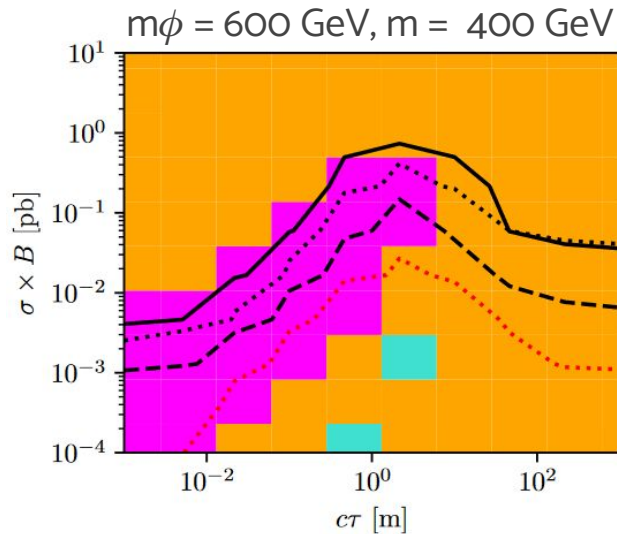
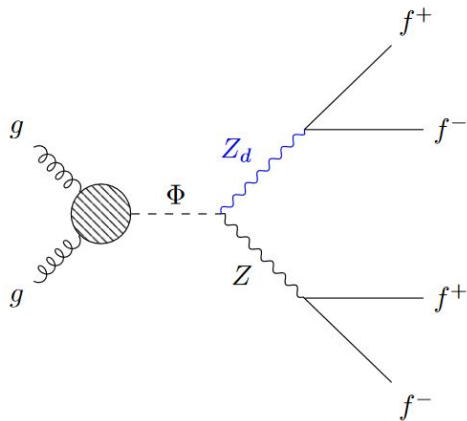
$m\phi = 1000 \text{ GeV}$, $m_S = 475 \text{ GeV}$, $c\tau = 0.00031 \text{ m}$, $\sigma = 2.15 \text{ pb}$



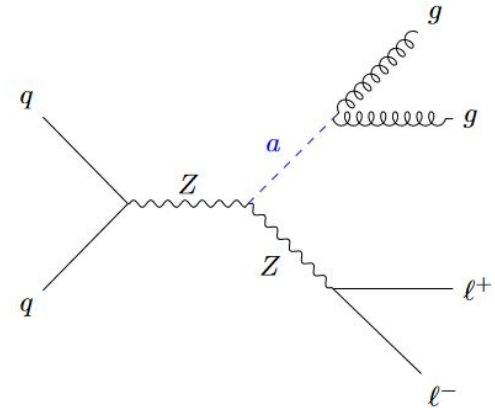
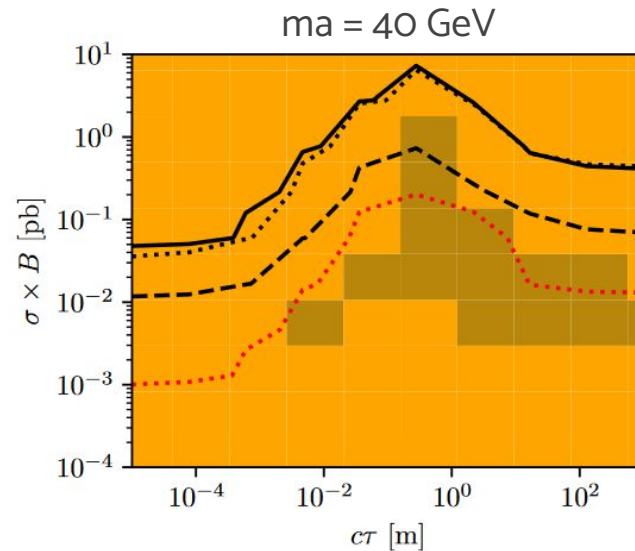
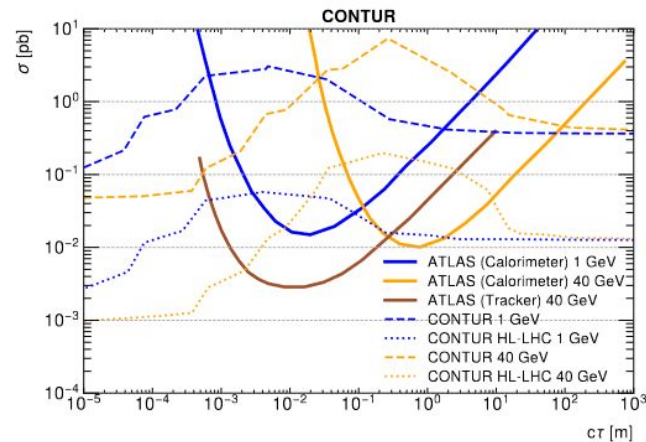
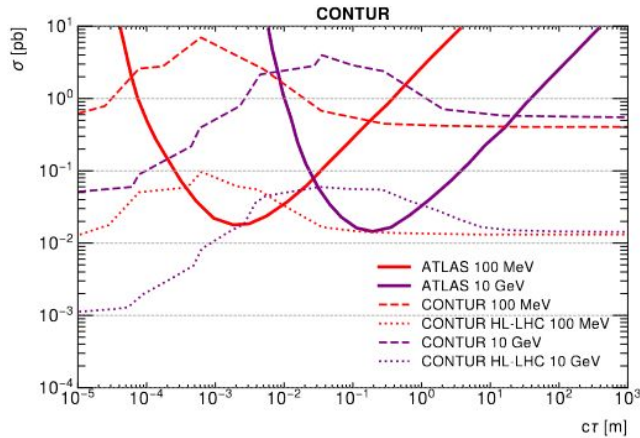
- $l_1 l_2 + E_T^{\text{miss}} + \text{jet}$ [58, 59]
- $4l$ [60]
- $l^+ l^- + \text{jet}$ [51, 61]
- $l + E_T^{\text{miss}} + \text{jet}$ [62–65]
- hadronic $t\bar{t}$ [66, 67]
- $l^+ l^- \gamma$ [68]



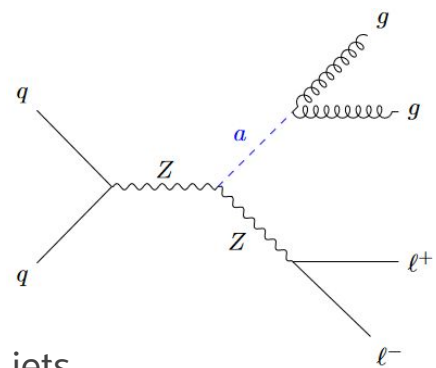
Dark photon



Photophobic ALPs

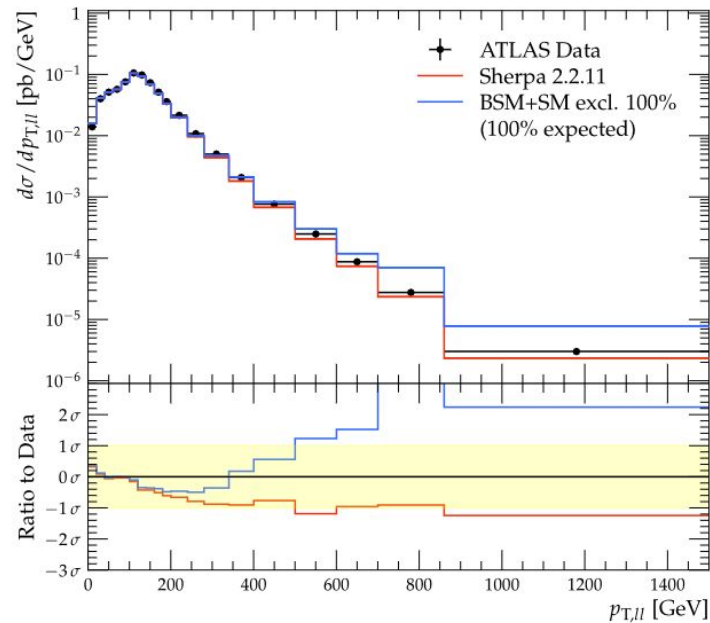
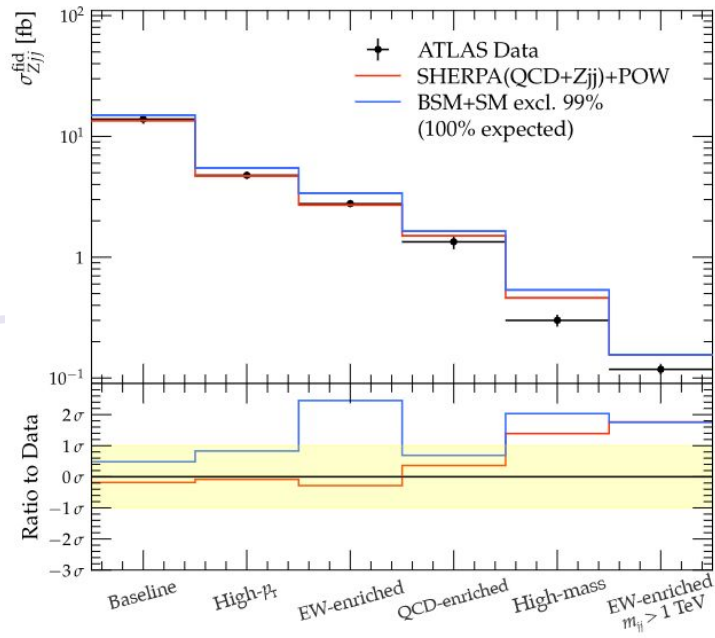


Photophobic ALPs

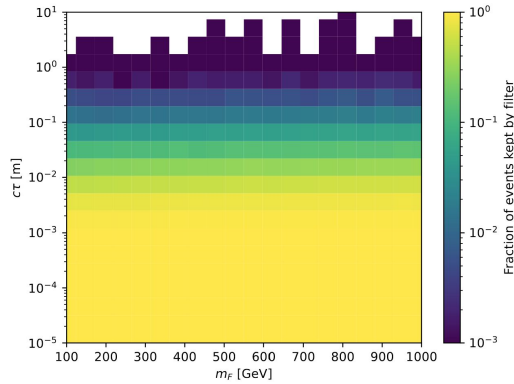


$c\tau = 0.1 \text{ mm} - \text{dijets} + Z$

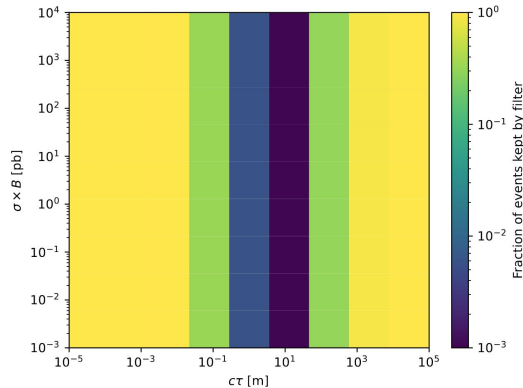
$c\tau = 100 \text{ m} - Z + \text{high } p_T \text{ jets}$



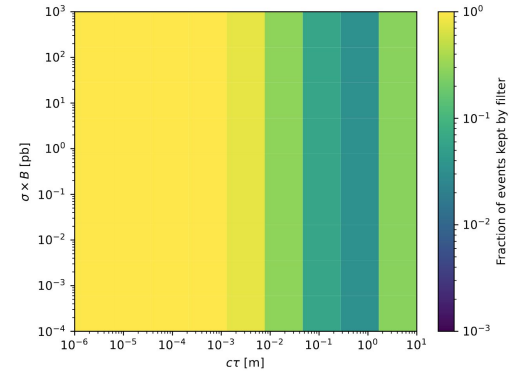
Events kept by the filter



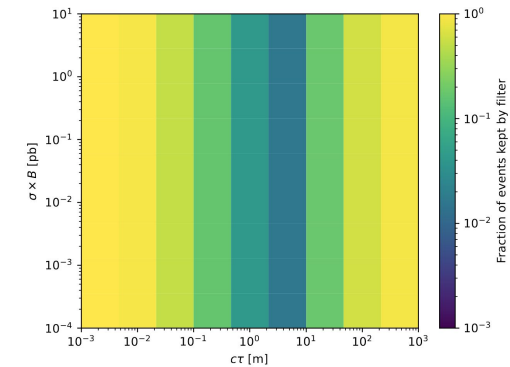
(a) FIMP



(b) HS $m_\Phi = 1000$ GeV, $m_S = 475$ GeV



(c) Axion-like particle $m_{ALP} = 10$ GeV



(d) Dark photon $m_\Phi = 600$ GeV, $m_{Z_d} = 400$ GeV