

# BEYOND THE STANDARD MODEL AT FASER

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on behalf of the FASER Collaboration

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# BSM Models

## Dark Photon

Portal to the dark sector

$$\mathcal{L} \supset \frac{1}{2} m_{A'}^2 A'^2 - \epsilon e \sum_f q_f A'^\mu \bar{f} \gamma_\mu f$$

**Mass:**  $m_{A'} \sim \text{MeV} - \text{GeV}$

**Coupling:**  $\epsilon \sim 10^{-6} - 10^{-3}$

**Production:** SM meson decay & dark bremsstrahlung

**Decay:** Various, but  $A' \rightarrow e^+ e^-$  most interesting for FASER sensitivity

## Axion-like particles (ALPs)

Broad category of models, solution to strong CP problem. Can be extended to include DM candidates or mediators. One example *ALP-W*:

$$\mathcal{L} \supset -\frac{1}{2} m_a^2 a^2 - \frac{1}{4} g_{aWW} a_W W^{a,\mu\nu} \tilde{W}_{\mu\nu}^a$$

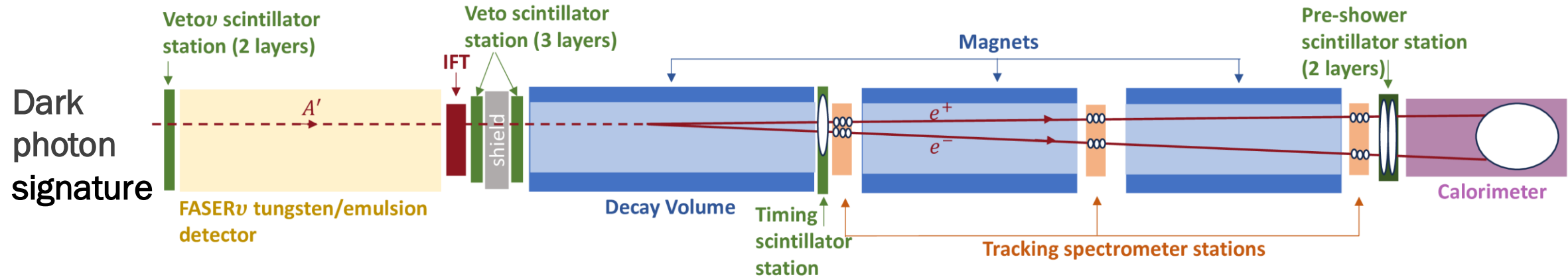
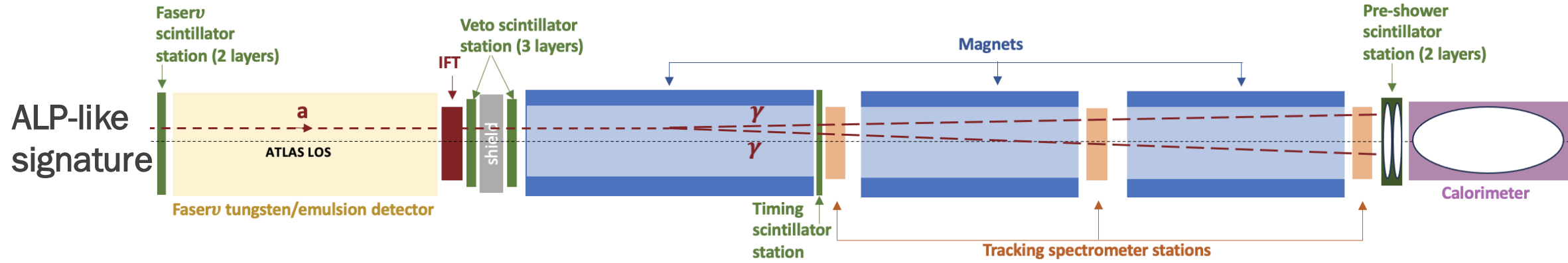
**Mass:**  $m_a \sim 50 - 500 \text{ MeV}$

**Coupling:**  $g_{aWW} \sim 10^{-5} - 10^{-3} \text{ GeV}^{-1}$

**Production:**  $B$  &  $k$  meson decay

**Decay:** Dominant decay mode is  $a \rightarrow \gamma\gamma$  at FASER

# Long lived particle signatures at FASER



\*Detector shown in 2022-24 configuration. In 2025 we added a new pixel based [preshower](#) to help separate closely spaced photons.

# Backgrounds

- **Neutrino interactions in detector material**
  - *Largest background, modelled in Monte-Carlo and validated against data*
- **Veto inefficiency**
  - *Negligible, each veto plane has very high efficiency as measured in data*
- **Neutral hadrons**
  - *Heavily suppressed, neutral hadrons produced in rock in front of FASER must traverse 8 interaction lengths and deposit  $> 500$  GeV in calorimeter.*
- **Large angle muons which miss the veto**
  - *Negligible, determined using simulation and data*
- **Non-collision events**
  - *Negligible, cosmic background determined using data taken when there was no beam. Background from beam interactions with gas or beampipe studied by looking at events which do not correspond to colliding bunches at ATLAS*

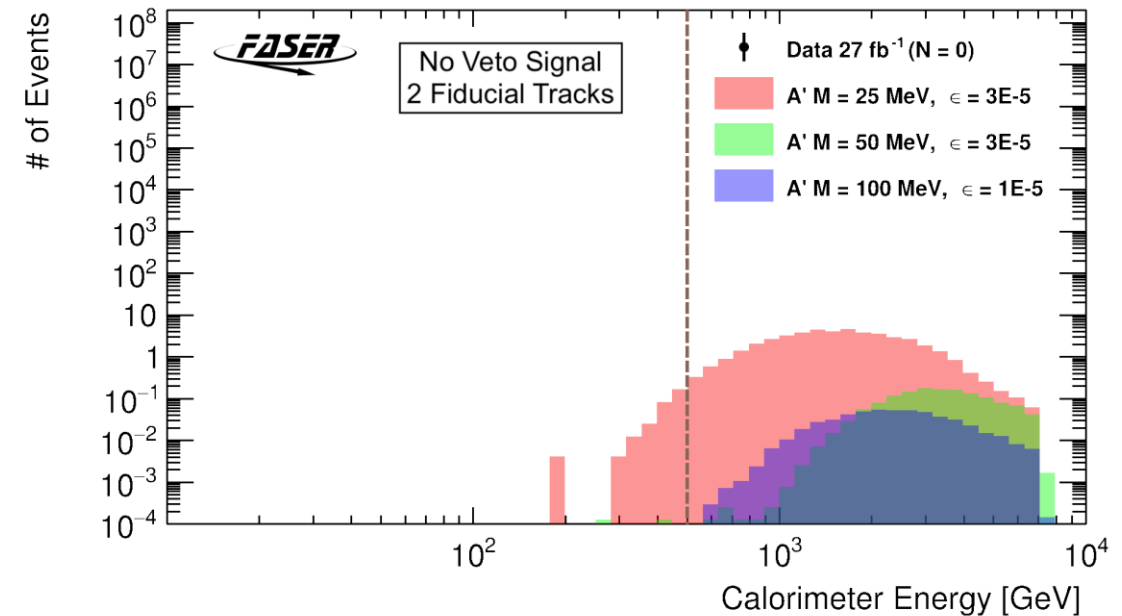
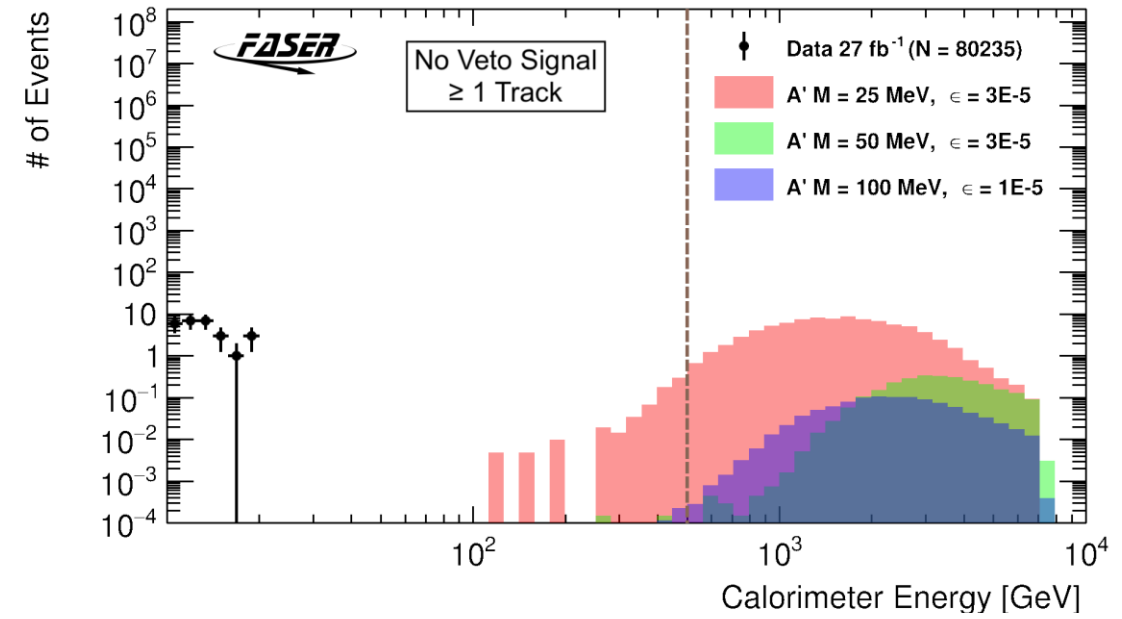
# Dark Photon Analysis

## Selection cuts:

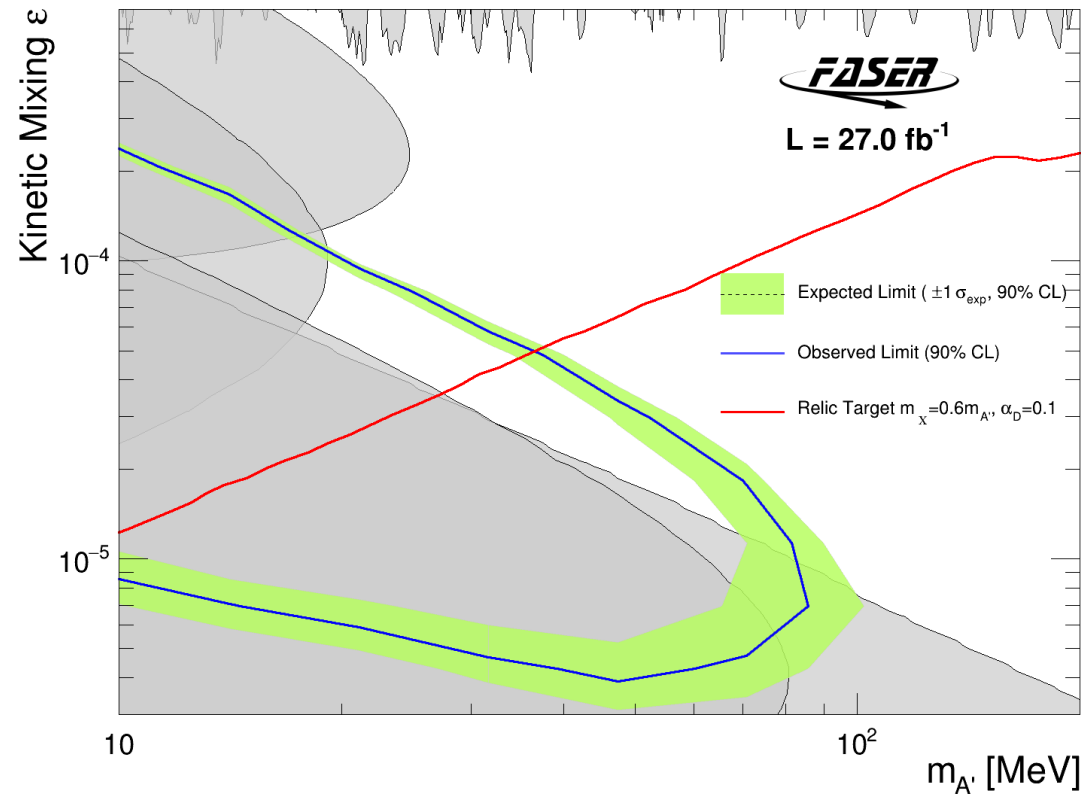
2022 dataset:  $27.0 \text{ fb}^{-1}$

- Event time corresponds to colliding bunches at ATLAS
- No signal in any veto scintillators
  - Required to be  $< \frac{1}{2}$  MIP signal
- Signal in downstream scintillators
  - Required to be  $\geq 2$  MIPs
- Two well reconstructed tracks in fiducial volume
- Calorimeter energy  $> 500 \text{ GeV}$

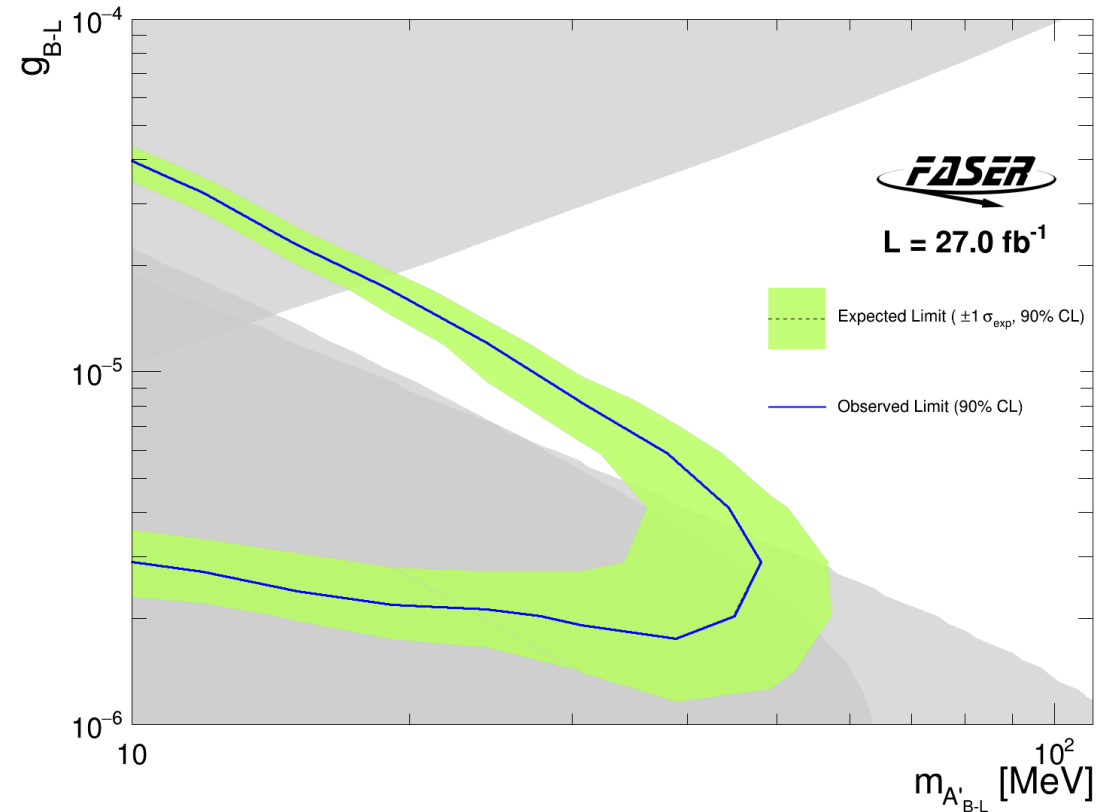
Zero observed events passing selection



# Dark Photon Analysis



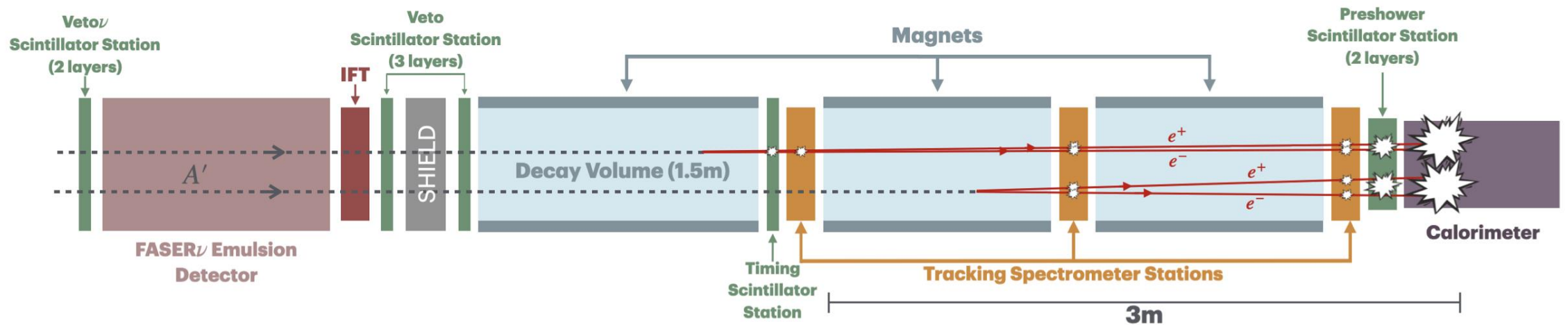
Search for Dark Photons with the FASER detector at the LHC:  
[arXiv: 2308.05587](https://arxiv.org/abs/2308.05587)



Reinterpretation in an alternative model  
 The gauge boson  $A'_{B-L}$  which arises  
 under  $U(1)_{B-L}$  symmetry

# Dark Photon future

- New analysis with 2022, 2023 and 2024 datasets (**6.5x more data!**)
- New signal regions targeting one track and track segment events (**2.5x better signal efficiency!**)
- Not quite ready for this conference – but expect public results soon!



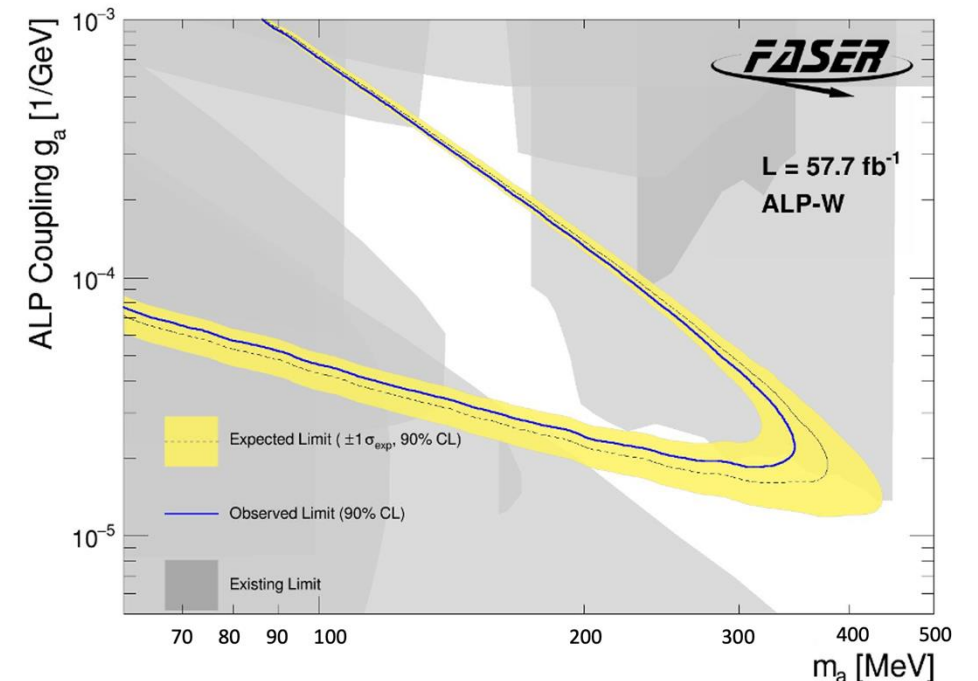
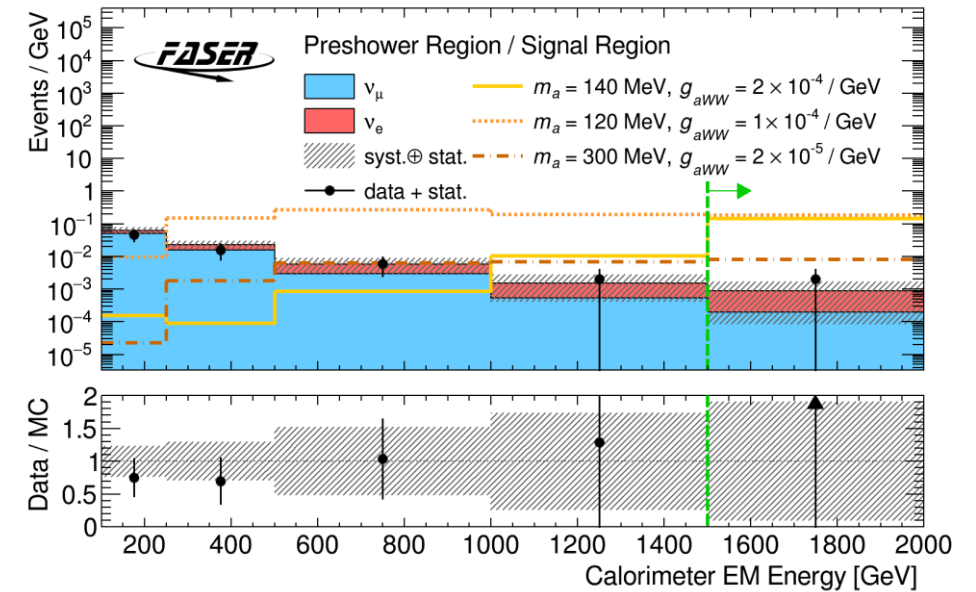
# ALPs Analysis

## Selection cuts:

2022/23 dataset:  $57.7 \text{ fb}^{-1}$

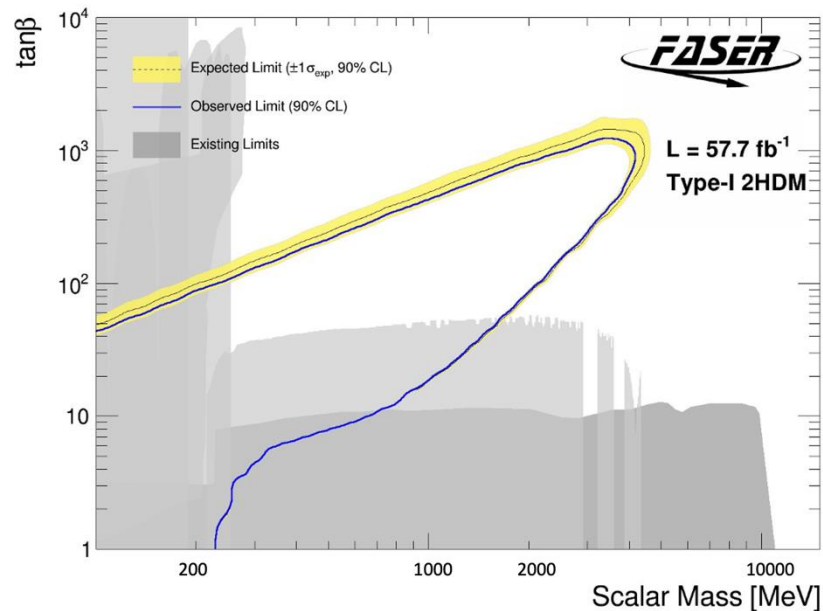
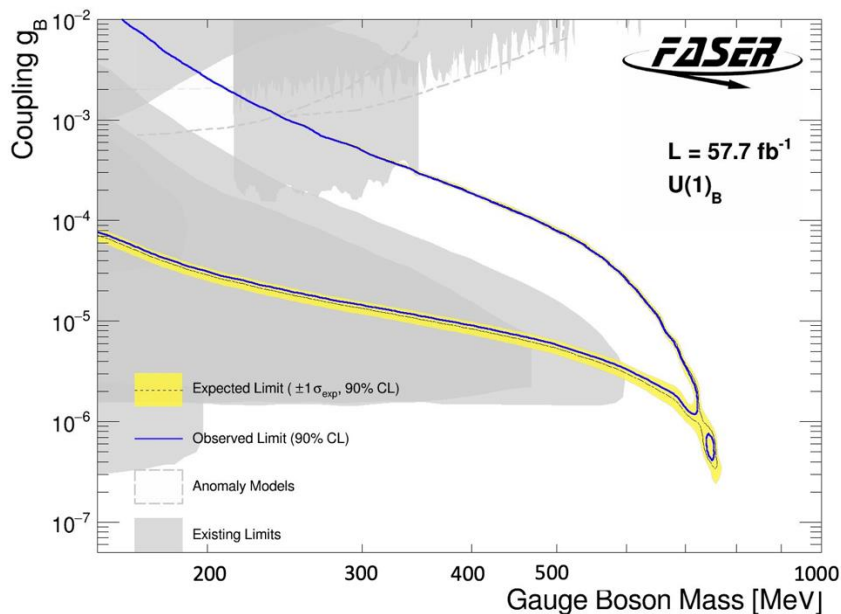
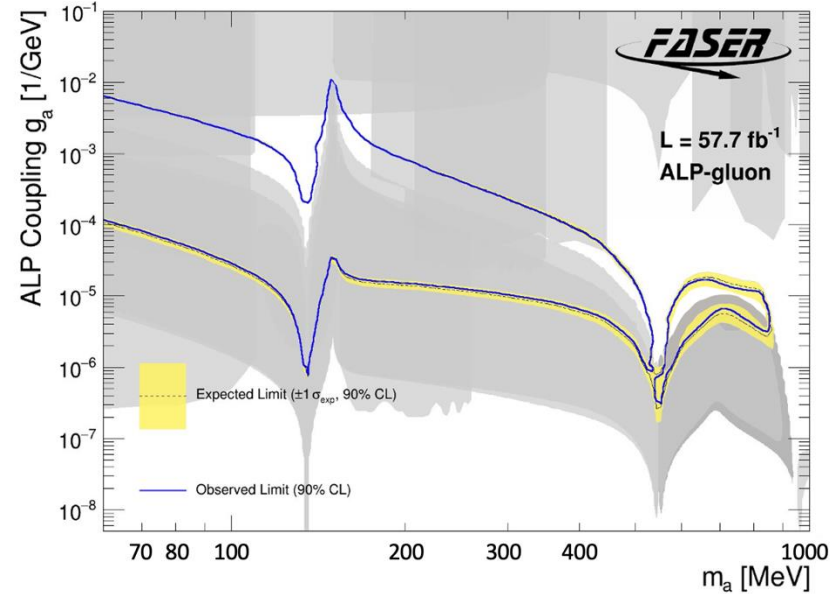
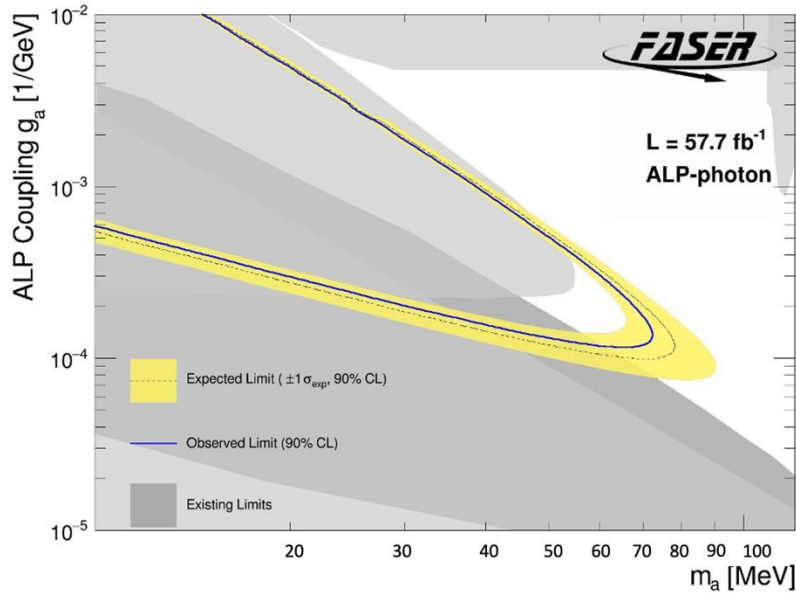
- Event time corresponds to colliding bunches at ATLAS
- No signal in any veto or timing scintillators
  - Required to be  $< \frac{1}{2}$  MIP signal
- Ratio of charge in 1<sup>st</sup>/2<sup>nd</sup> preshower layers  $> 4.5$ 
  - Photons shower in preshower material hence release more energy in 2<sup>nd</sup> layer. Mitigates background from neutrinos interacting in calorimeter
- Signal in 2<sup>nd</sup> preshower layer
  - Required to be  $> 10$  MIPs
- Calorimeter energy  $> 1.5 \text{ TeV}$

One observed events passing selection



# ALPs Analysis

Shining Light on the Dark Sector: Search for Axion-like Particles and Other New Physics in Photonic Final States with FASER:  
[arXiv: 2410.10363](https://arxiv.org/abs/2410.10363)



Reinterpretation in the context of multiple BSM LLP models proposed by theorists:

- ALP-photon
- ALP-gluon
- $U(1)_B$  Gauge Boson
- Type-I two Higgs doublet scalar & Up-phillic scalar

[arXiv:2201.01788](https://arxiv.org/abs/2201.01788)

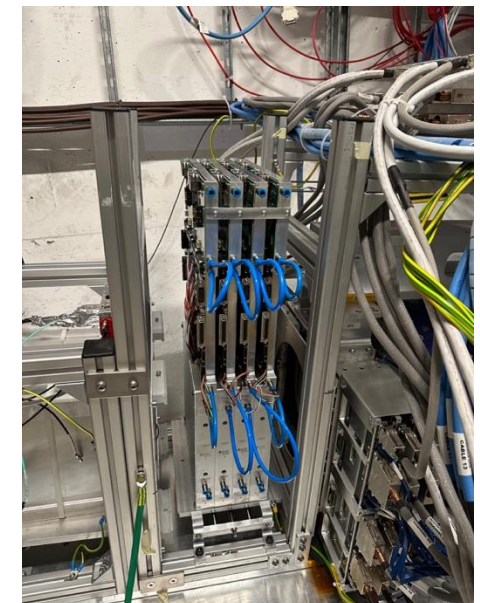
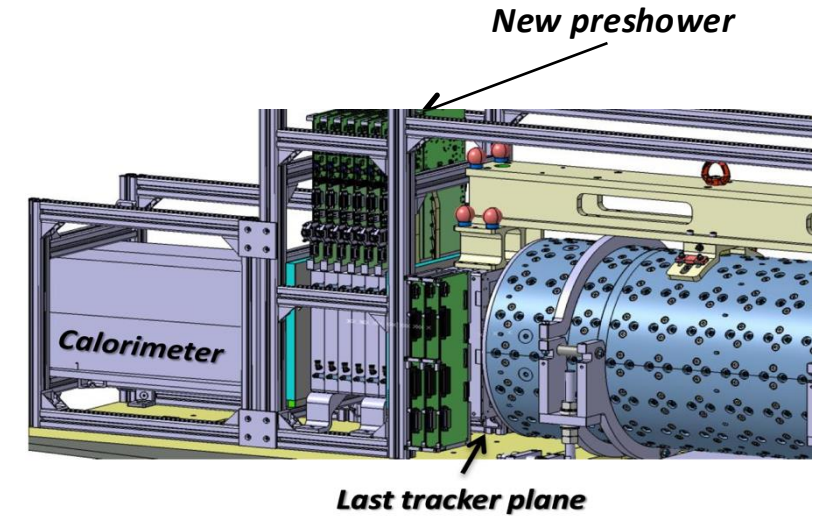
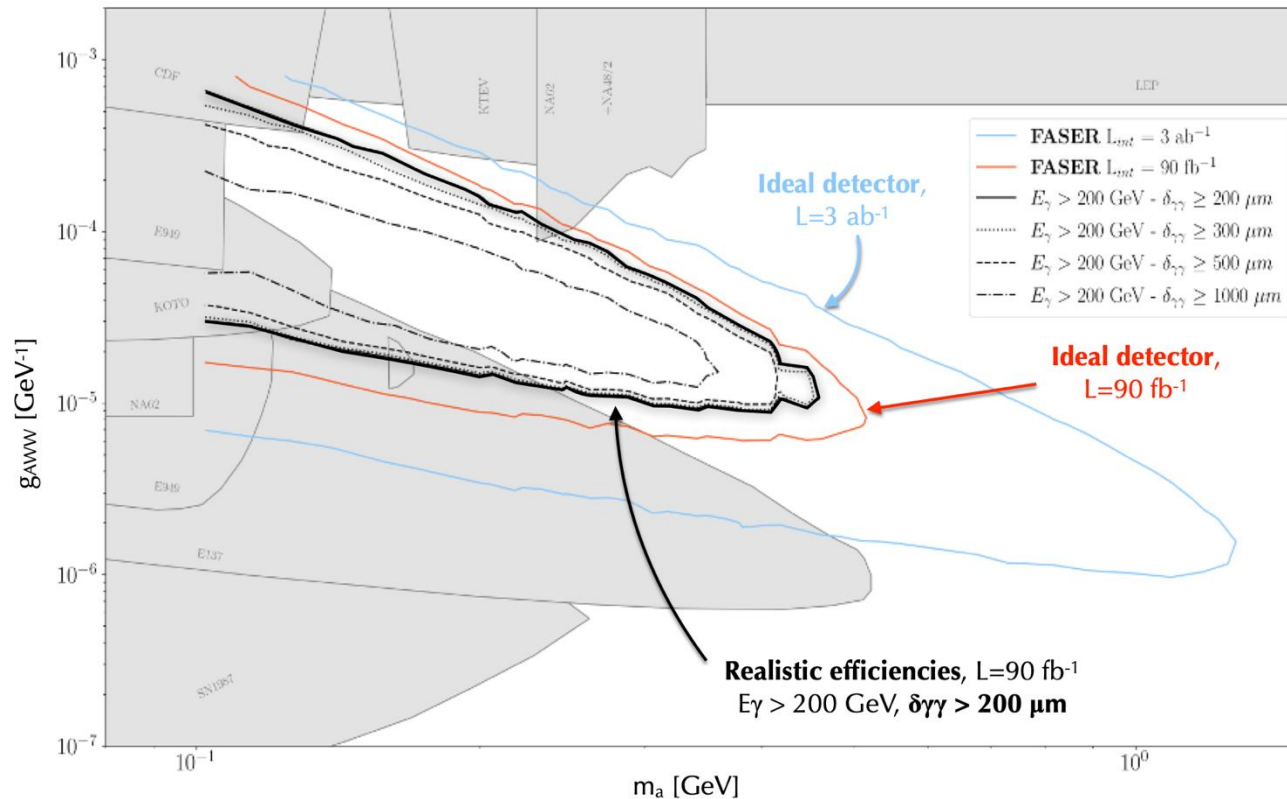
[arXiv:2212.06186](https://arxiv.org/abs/2212.06186)

If you have a favourite model that you would like probed, we can do it **IF** you provide a **FORESEE** implementation

# Projected ALP sensitivity with new silicon preshower

New high precision monolithic pixel detector installed at the end of the spectrometer

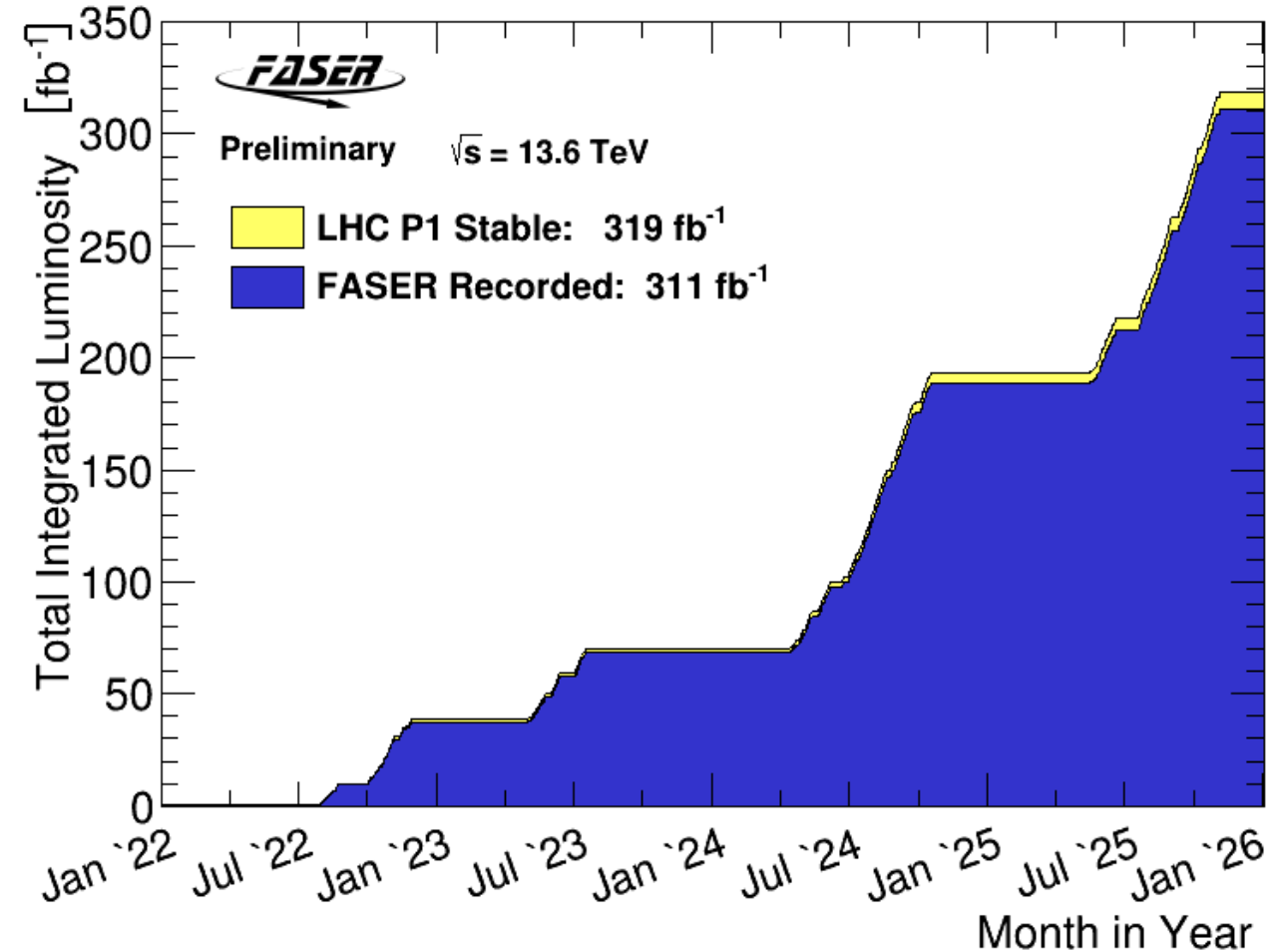
- Installed and commissioned in 2025
- Can resolve closely spaced photons up to  $200 \mu\text{m}$



# Outlook



- Wide range of BSM models that can be probed by FASER without the need for a dedicated analysis for each model
- FASER run very well so far, and we have even more data to analyse!
  - *New iterations with more luminosity, improved analysis techniques and new detector hardware in progress!*
- Lots of exciting results to come in 2026 – **stay tuned!**



Acknowledgements:





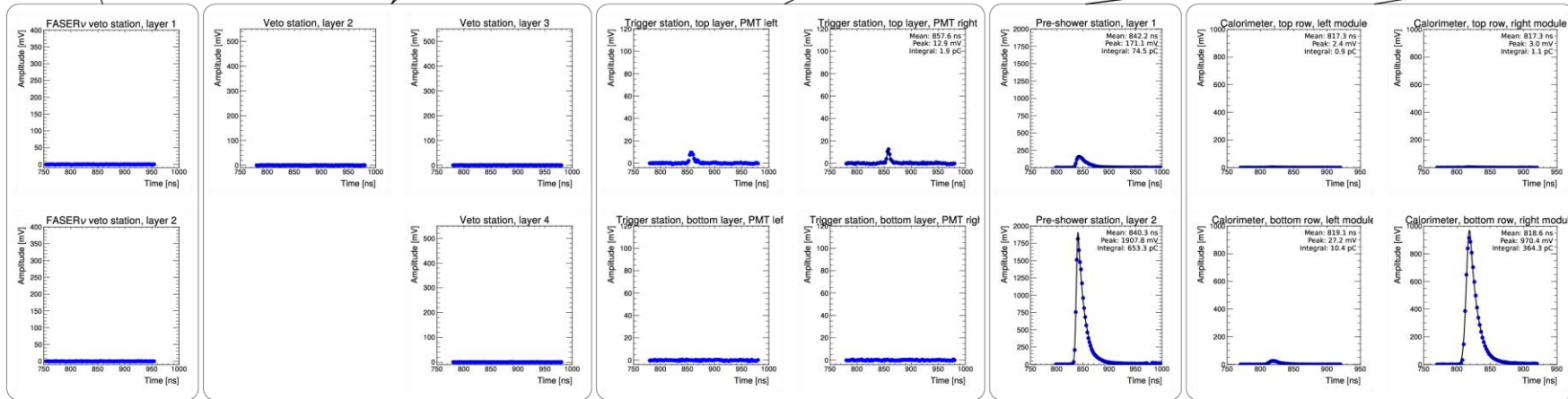
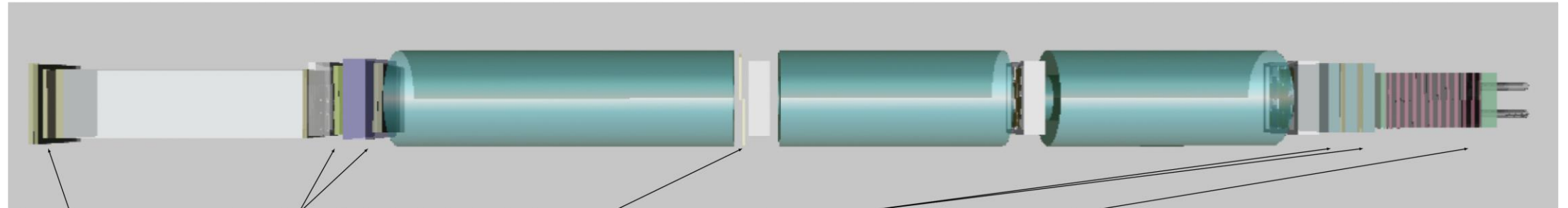
BACKUP



# The 'Alprino' Event

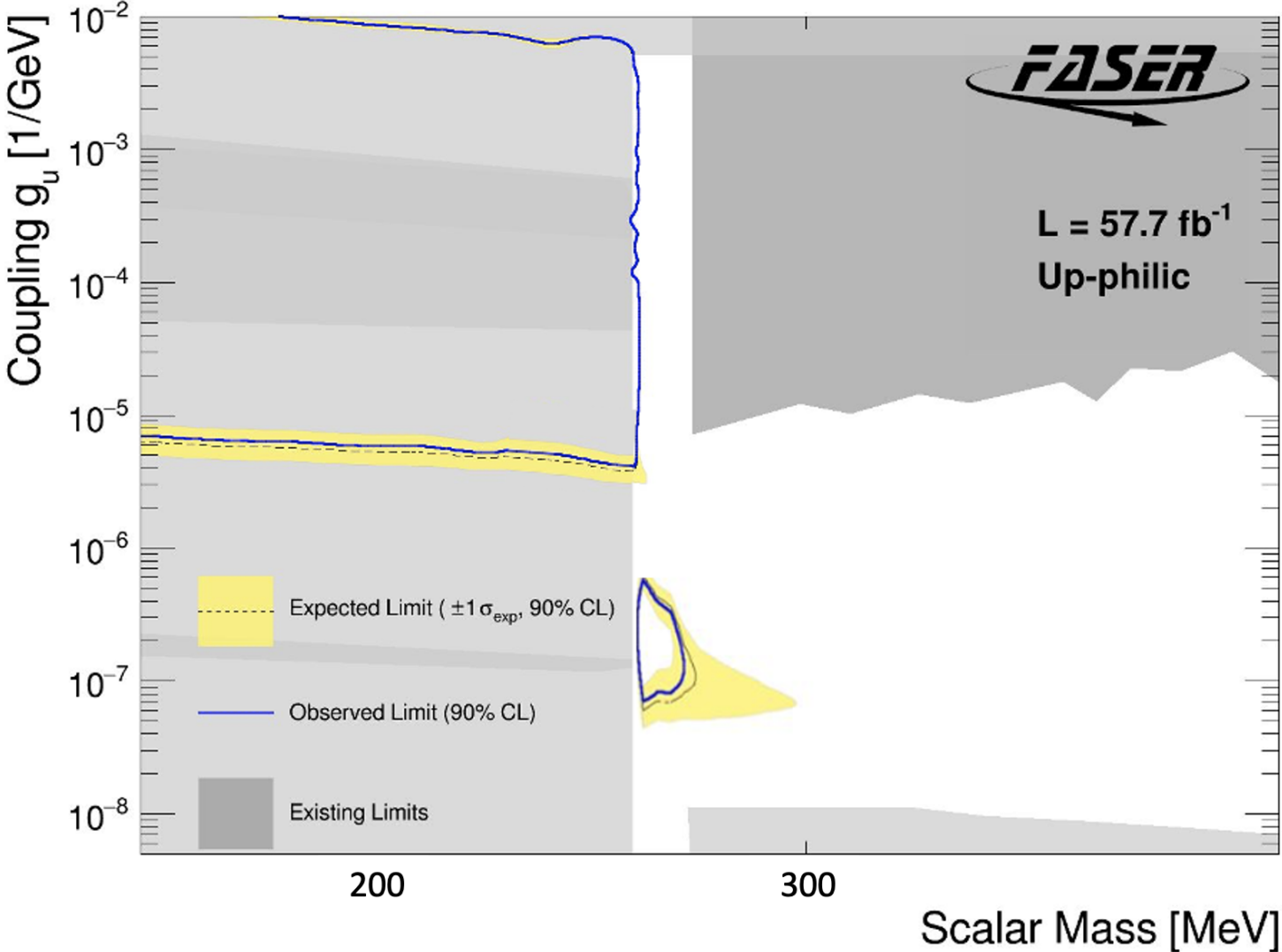


Run 8834  
Event 44421456  
2022-10-13 16:09:44

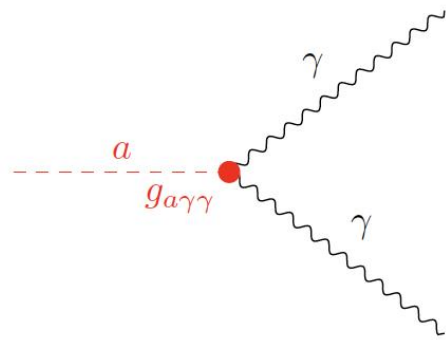


The one 1.6 TeV event in the ALP analysis SR, this event is consistent with an electron neutrino interaction

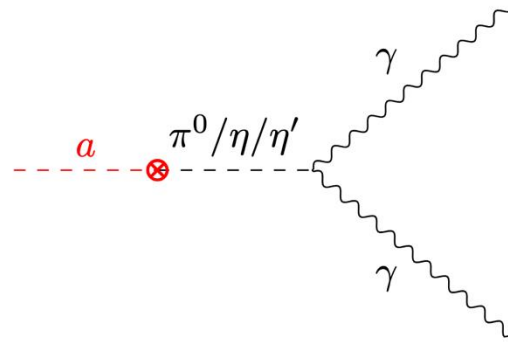
# ALPs analysis Up-philic interpretation



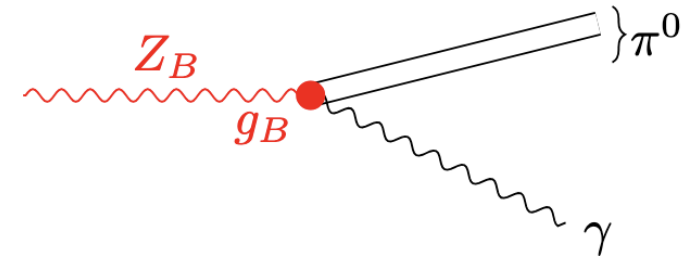
# ALP Decay Modes



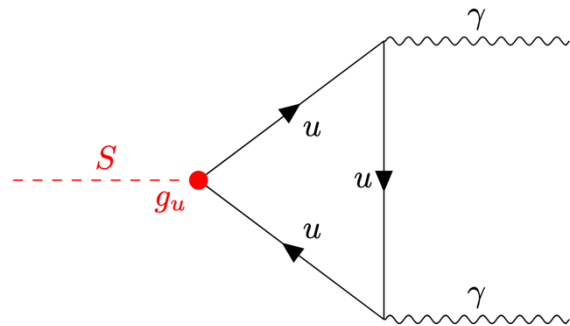
ALP-Photon



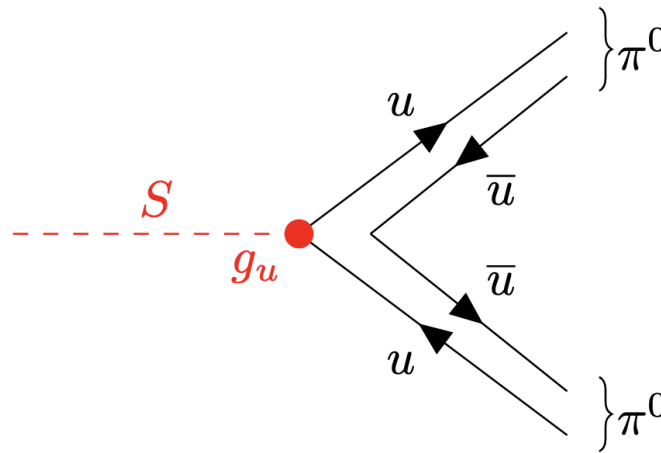
ALP-Gluon



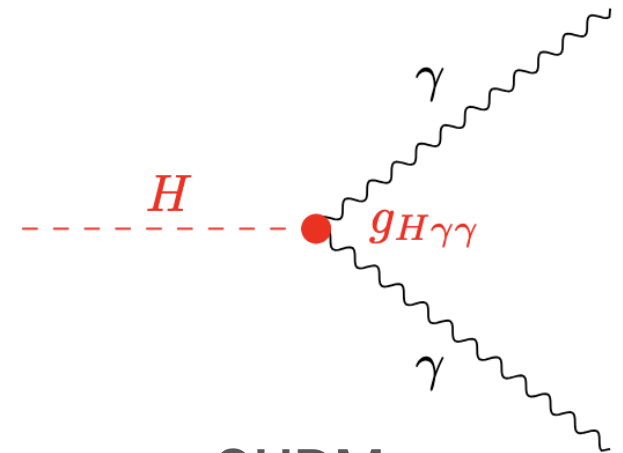
$U(1)_B$



Up-philic

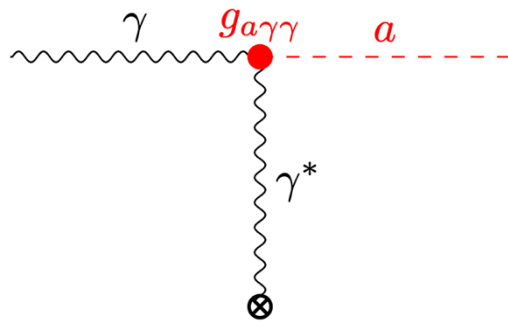


Up-philic



2HDM

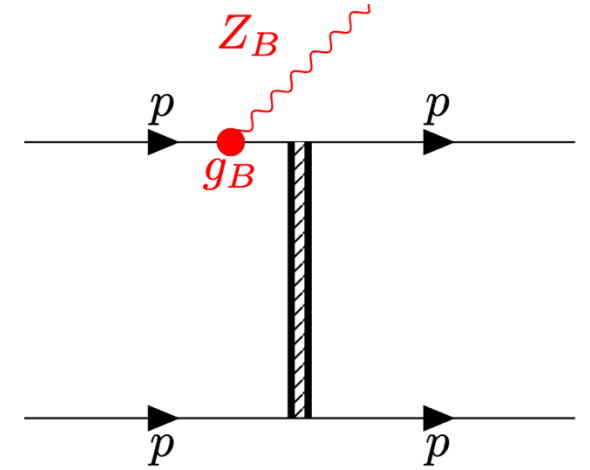
# ALP Production Modes



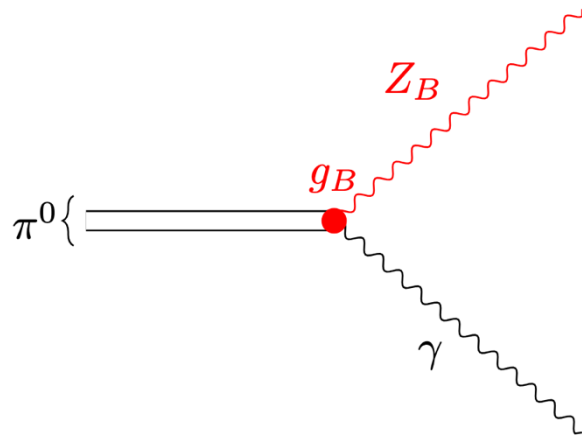
ALP-Photon



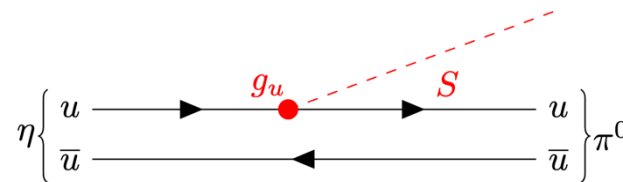
ALP-Gluon



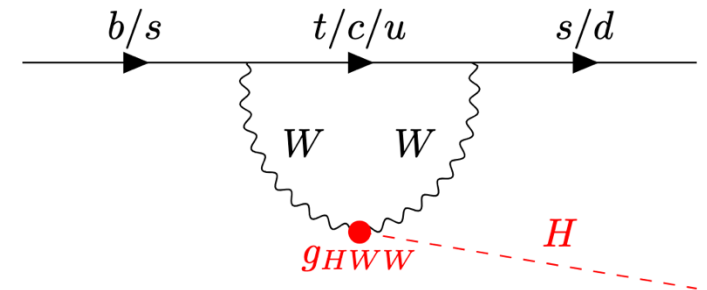
$U(1)_B$



Up-philic



Up-philic



2HDM