



Long Lived Particle Searches with

FASER

Ansh Desai ☺

On Behalf of the FASER^{⚙️} Collaboration

Lepton Photon August 27th 2025

The *FASER* Collaboration



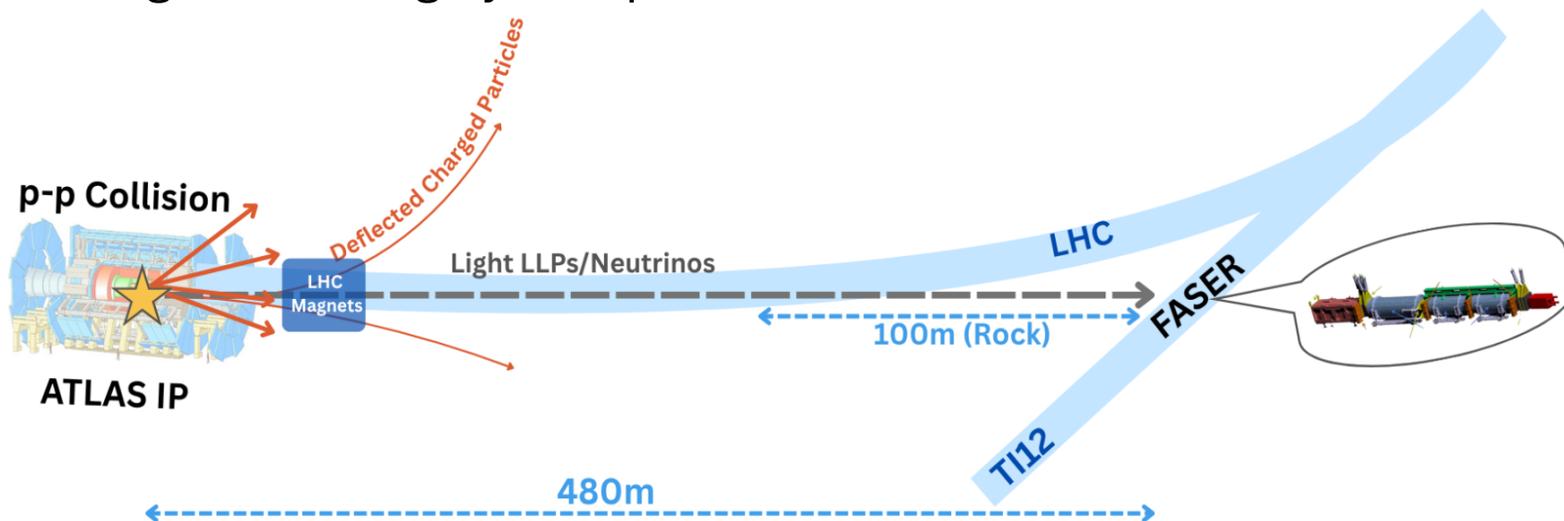
107 collaborators
27 institutions
11 countries

Supported by



FASER

The LHC produces an intense and collimated beam of high energy particles (light hadrons) in the far forward region that largely escape the ATLAS Detector



Low collision background due to 100m of rock + LHC magnets, mostly see muons ($1/\text{cm}^2/\text{s}$)

FASER was purposefully designed to exploit the large forward production rate to:

Search for light long lived particles (particularly dark sector mediators)

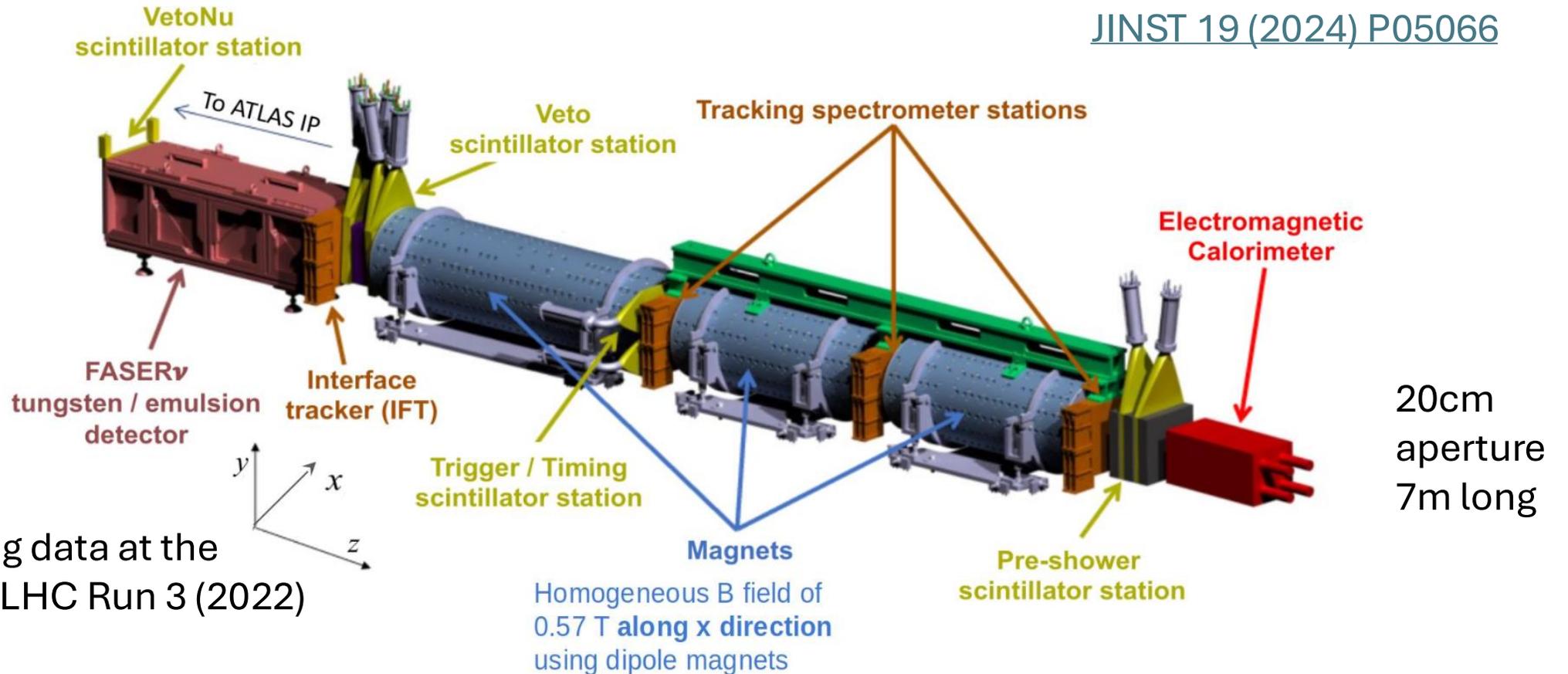
(this talk)

Study high energy neutrinos produced in colliders

(see talk by Yuxiao Wang on 8/25)

The **FASER** Detector

[JINST 19 \(2024\) P05066](#)



Started taking data at the beginning of LHC Run 3 (2022)

So far we've collected >97% of delivered luminosity (215 fb⁻¹)



Calorimeter

Preshower

Tracking spectrometer

Decay volume

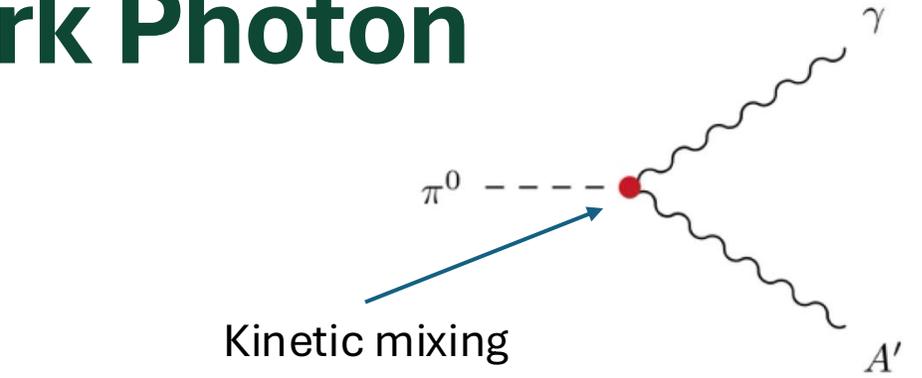
Veto IFT

To ATLAS

FASERnu

BSM Searches: Dark Photon

- The dark photon (A') is a common benchmark for hidden sector models
- Extension of SM -- massive U(1) gauge boson with kinetic mixing (ϵ) with the SM photon
- FASER is most sensitive to small $\epsilon \sim \text{MeV}$ scale dark photons produced in light meson decays
- For $2m_e < m_{A'} < 2m_\mu$ the A' decays only into e^+e^- pairs – which are easy to detect!



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

$$L = c\beta\tau\gamma \approx (80 \text{ m}) \left[\frac{10^{-5}}{\epsilon} \right]^2 \left[\frac{E_{A'}}{\text{TeV}} \right] \left[\frac{100 \text{ MeV}}{m_{A'}} \right]^2$$

Decay length scales inversely with mixing and mass

BSM Searches: Dark Photon Signal

Event Selection

$\approx 50\%$ signal efficiency

In time with LHC Collision

No signal in veto scintillators

Signal in downstream scintillators

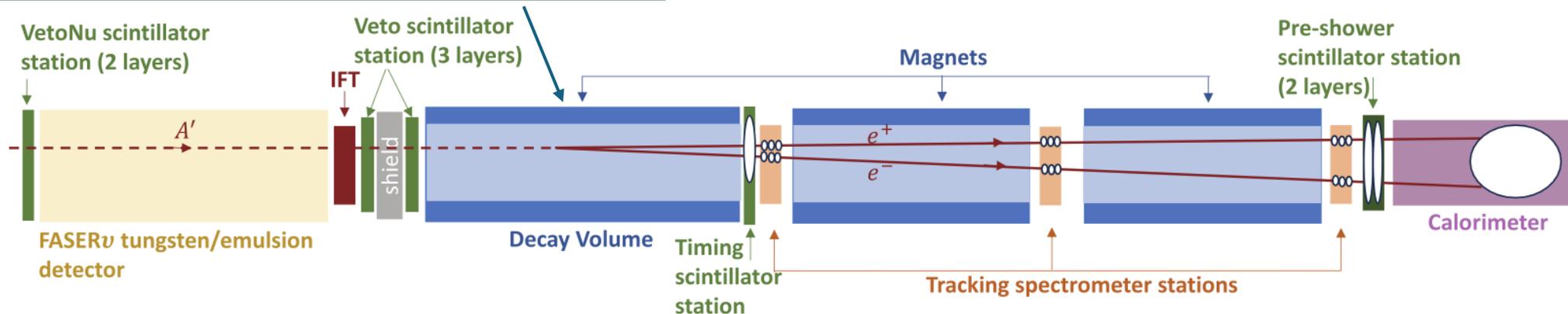
Two good opposite sign tracks within fiducial volume ($r < 95\text{mm}$)

Calorimeter energy $> 500\text{ GeV}$

Systematics

Source	Value	Effect on signal yield
Signal Generator	$\frac{0.15+(E_{A'}/4\text{ TeV})^3}{1+(E_{A'}/4\text{ TeV})^3}$	15-65% (15-45%)
Luminosity	2.2%	2.2%
MC Statistics	$\sqrt{\sum W^2}$	1-3% (1-2%)
Track Momentum Scale	5%	$< 0.5\%$
Track Momentum Resolution	5%	$< 0.5\%$
Single Track Efficiency	3%	3%
Two-track Efficiency	7%	7%
Calorimeter Energy Scale	6%	0-8% ($< 1\%$)

Acceptance is 1.5m long decay volume



BSM Searches: Dark Photon Backgrounds

Background Sources

Beam / cosmic background ~ negligible, suppressed by timing cuts

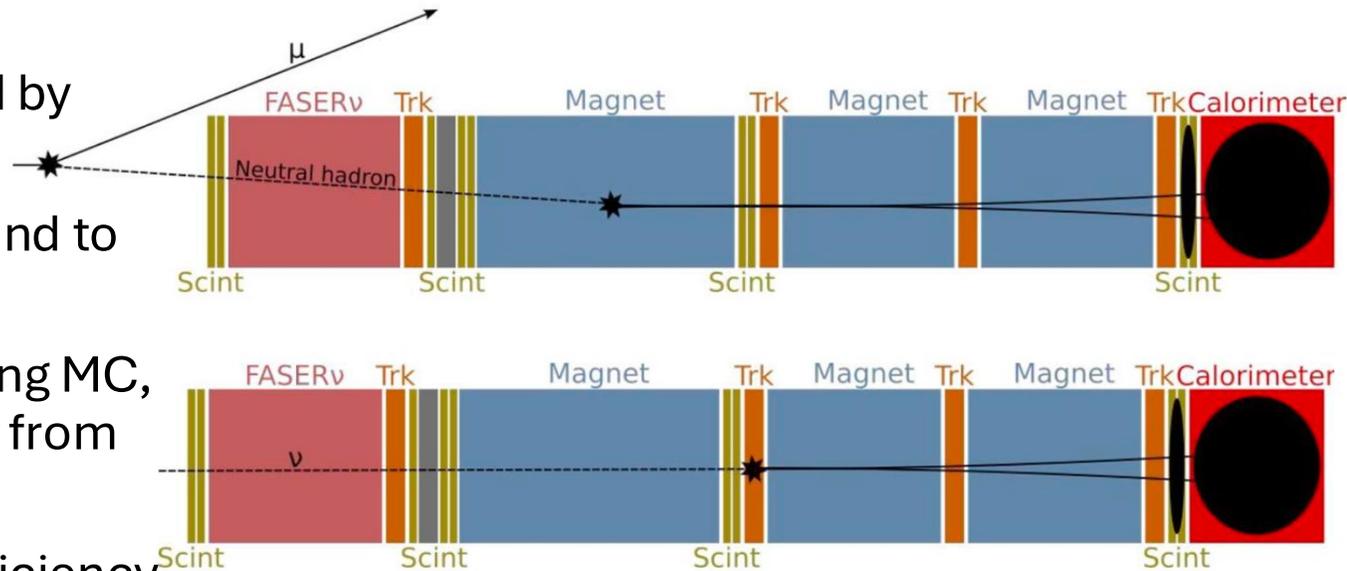
Large angle muons ~ negligible, suppressed by track quality cuts

Neutral Hadrons ~ data driven estimate, found to be $\sim 8 * 10^{-4}$ (100% uncertainty assigned)

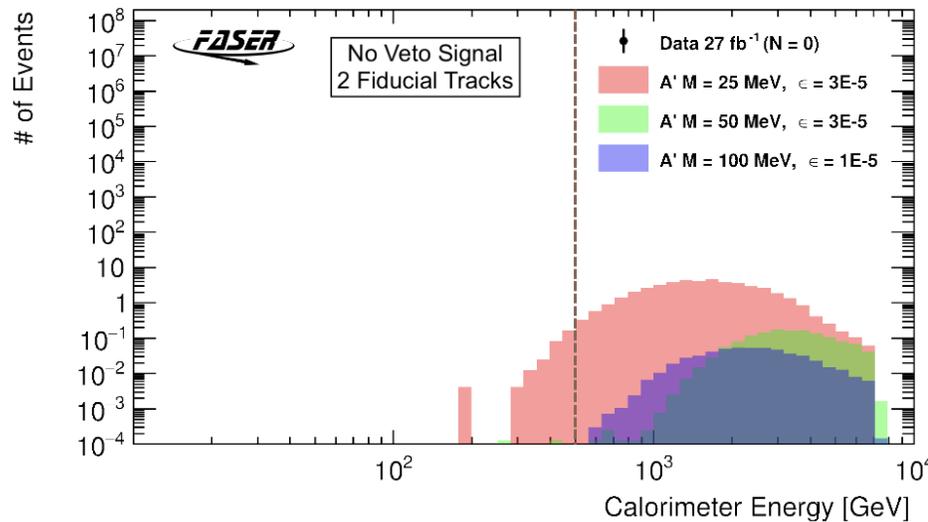
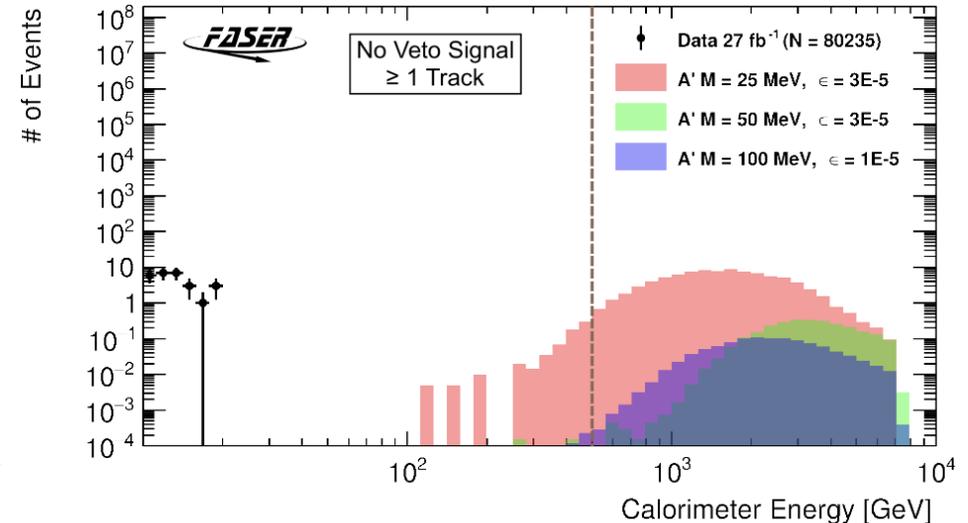
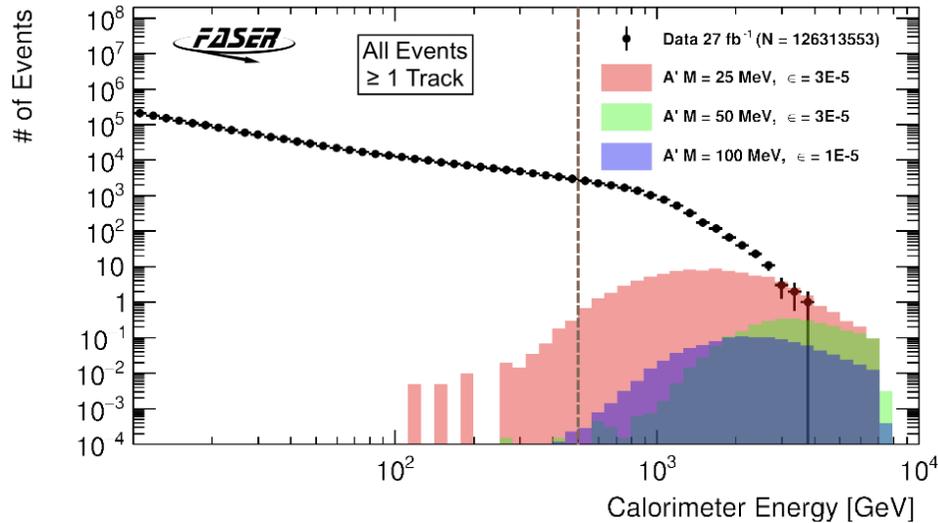
Neutrinos ~ estimated to be $\sim 1.5 * 10^{-3}$ using MC, suppressed by energy cut (127% uncertainty from modeling)

Veto Inefficiency ~ negligible due to high efficiency (10^{-5} per layer)

Total Background Estimate: $\approx 10^{-3}$ events

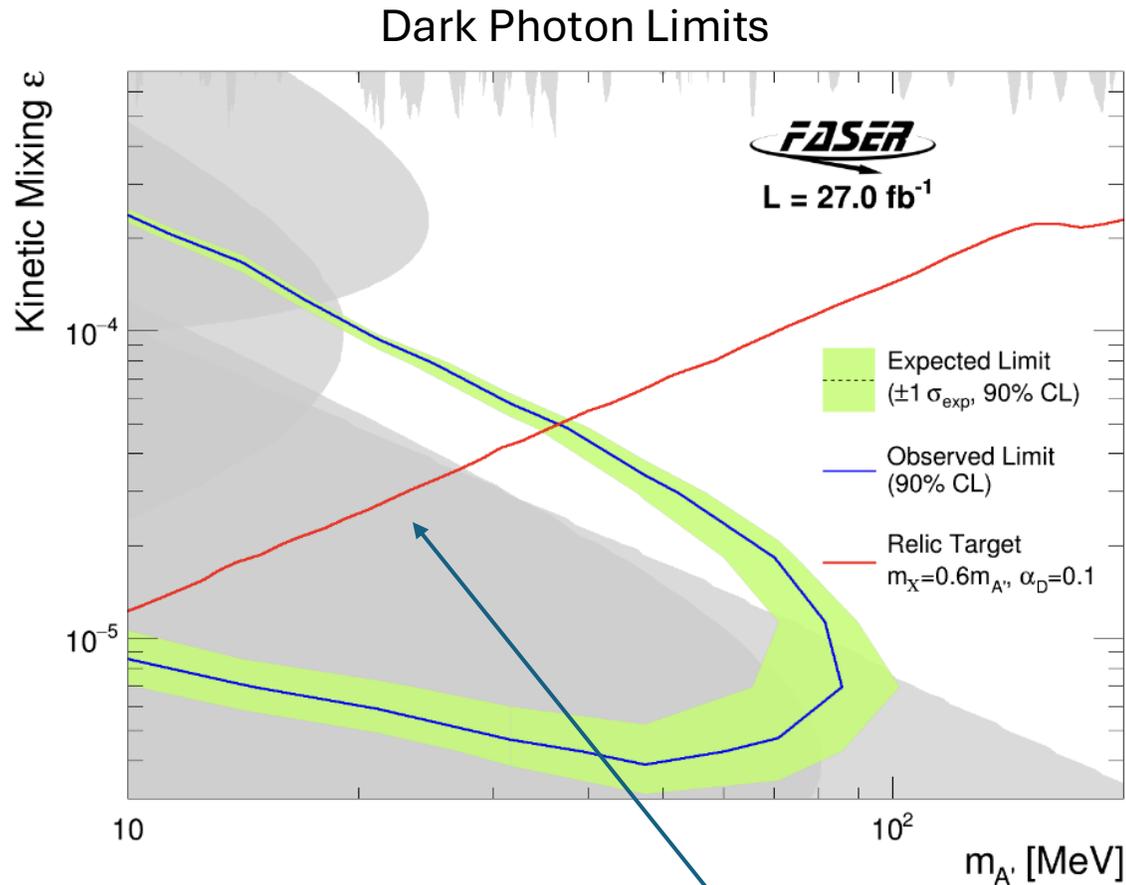


BSM Searches: Dark Photon Data

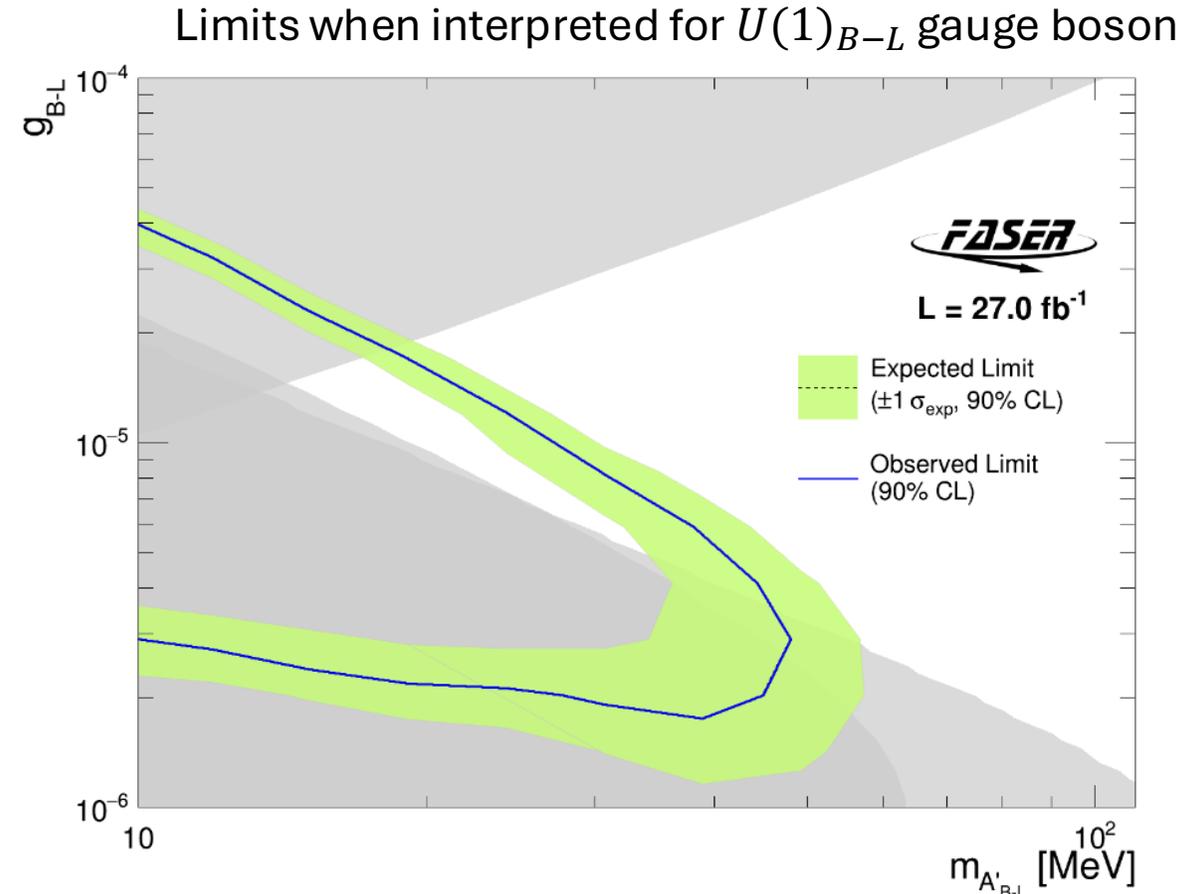


No events seen in 27 fb^{-1}

BSM Searches: Dark Photon Limits



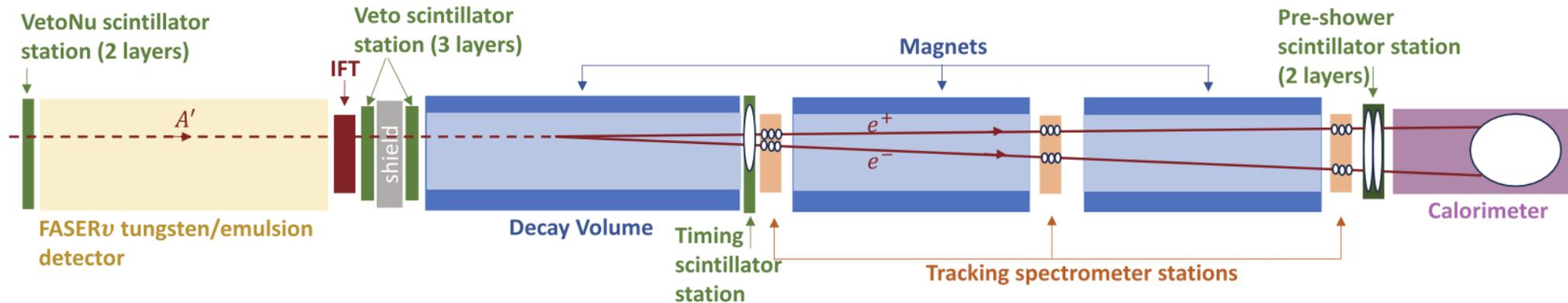
Red line is region motivated by DM thermal relic density



[PLB 848 \(2024\) 138378](#)

BSM Searches: Dark Photon: What's Next?

Coming soon: second Dark Photon analysis using $\geq 190\text{fb}^{-1}$ ($>7\times$ more data!)
Improved signal acceptance and analysis strategies!



We are studying:

Using the acceptance of the entire detector (3.5m)

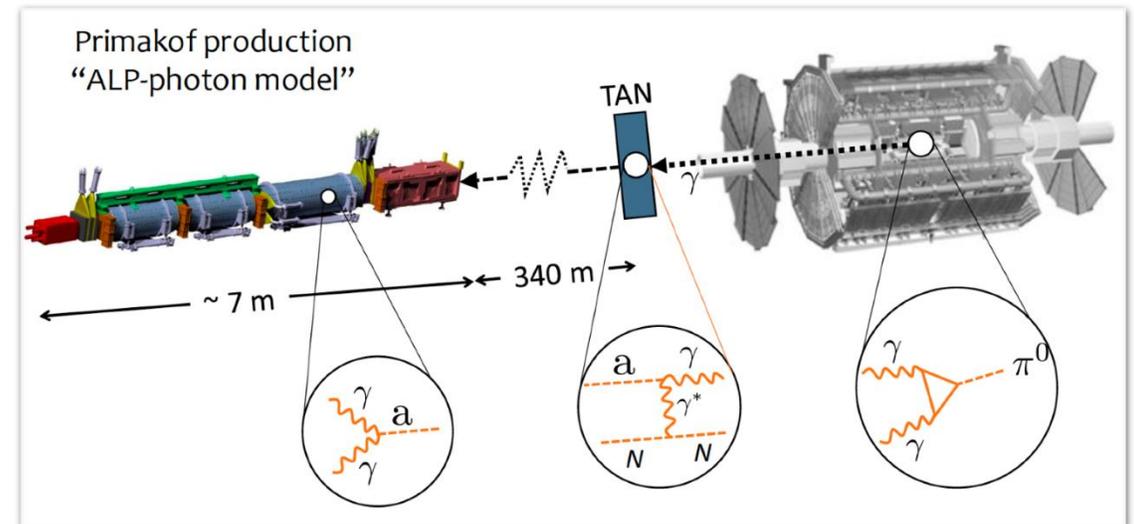
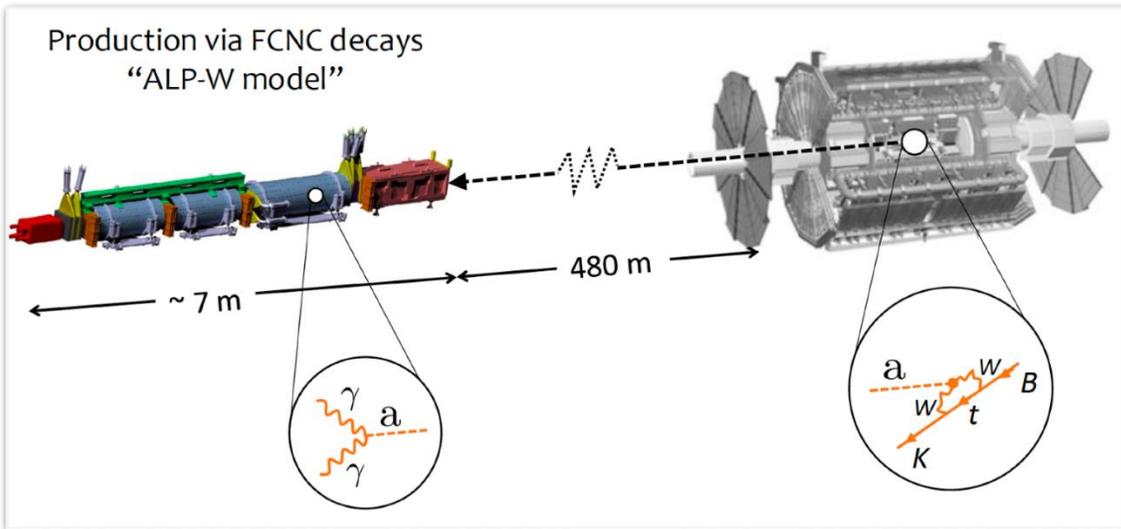
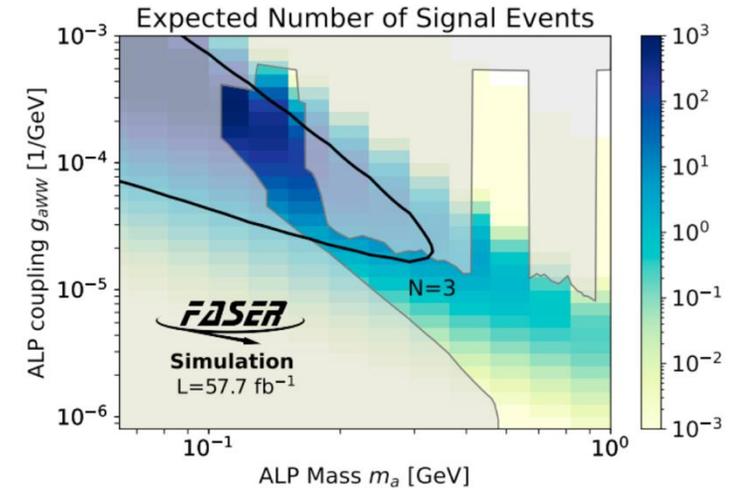
Understanding the largest source of inefficiency (requiring ≥ 2 tracks)

BSM Searches: Axion-Like-Particles (ALPs)

ALPs are another popular BSM search target

FASER is sensitive to several ALPs models, mostly produced by B^0 , B^\pm meson decays

Once produced, the ALP decays into two high energy photons



BSM Searches: ALP Signal + Backgrounds

Event Selection

In time with LHC Collision

No signal in veto or timing scintillators

EM-like signal in Preshower

Calorimeter energy > 1.5 TeV

Largest uncertainty on signal comes from theoretical modeling $\sim 60\%$

$\approx 75\%$ signal efficiency

Backgrounds

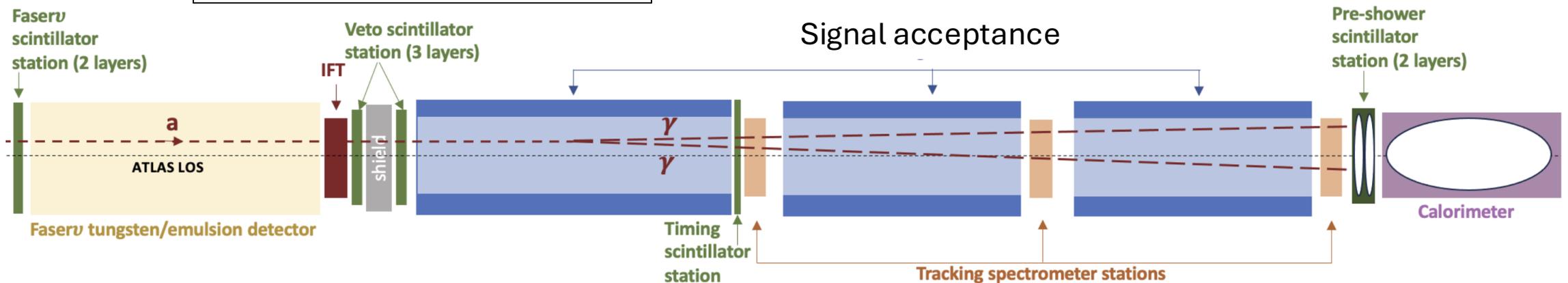
Neutral hadrons

Large-angle muons

Cosmic/Beam Background

Neutrinos

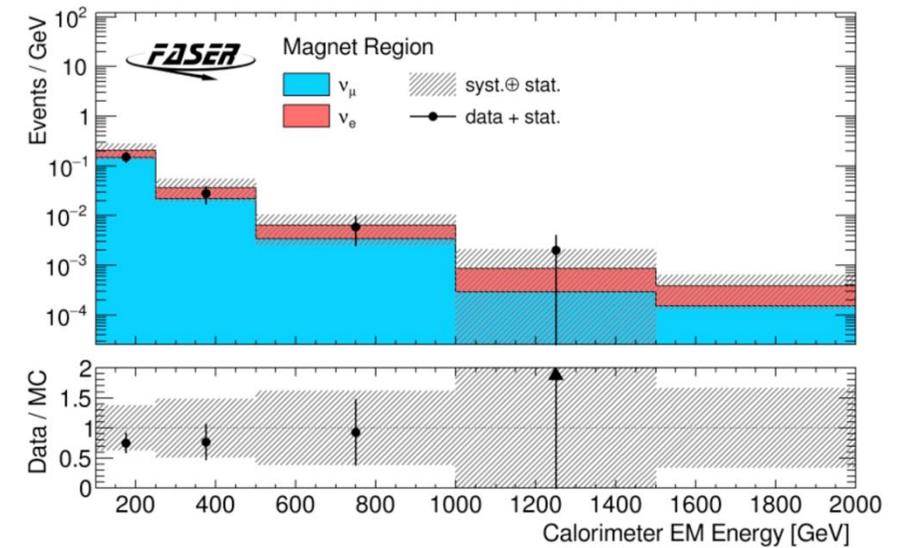
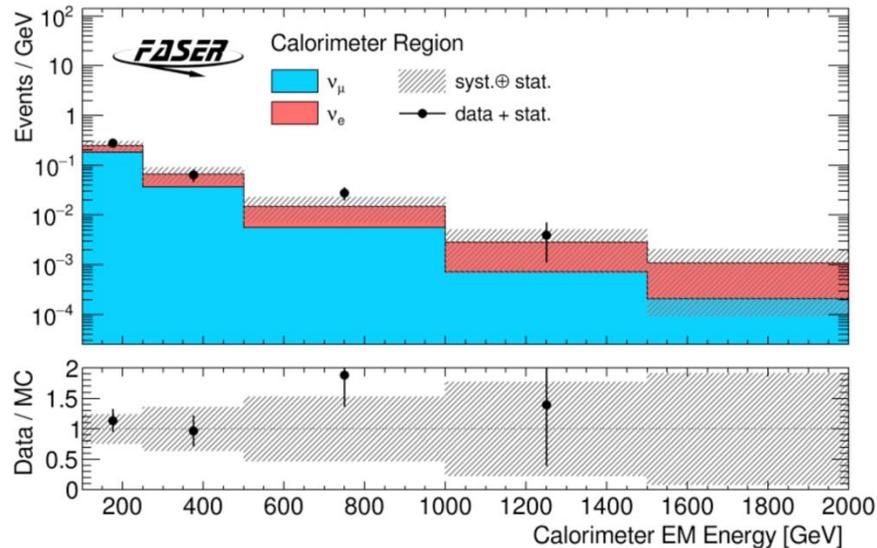
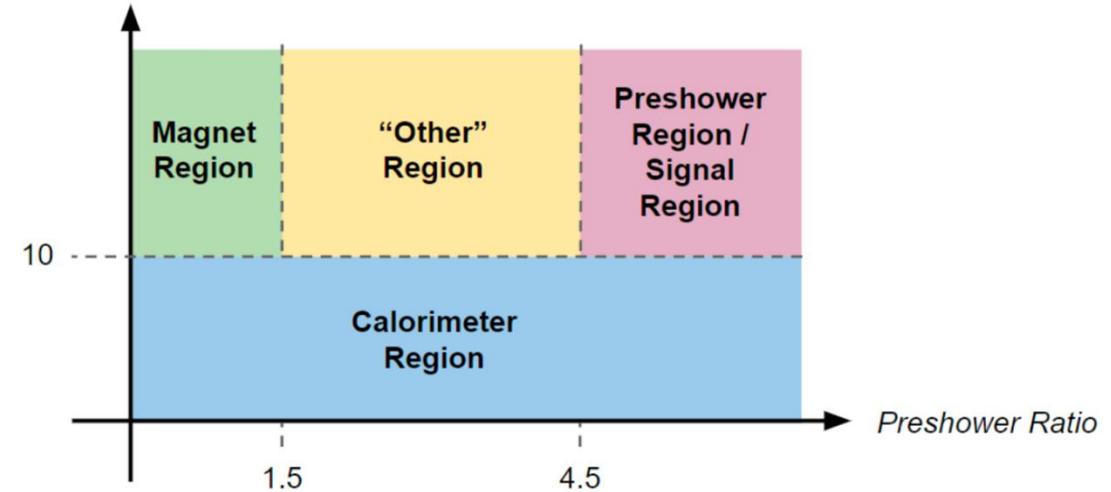
All backgrounds except neutrinos negligible



BSM Searches: ALPs Neutrino Backgrounds

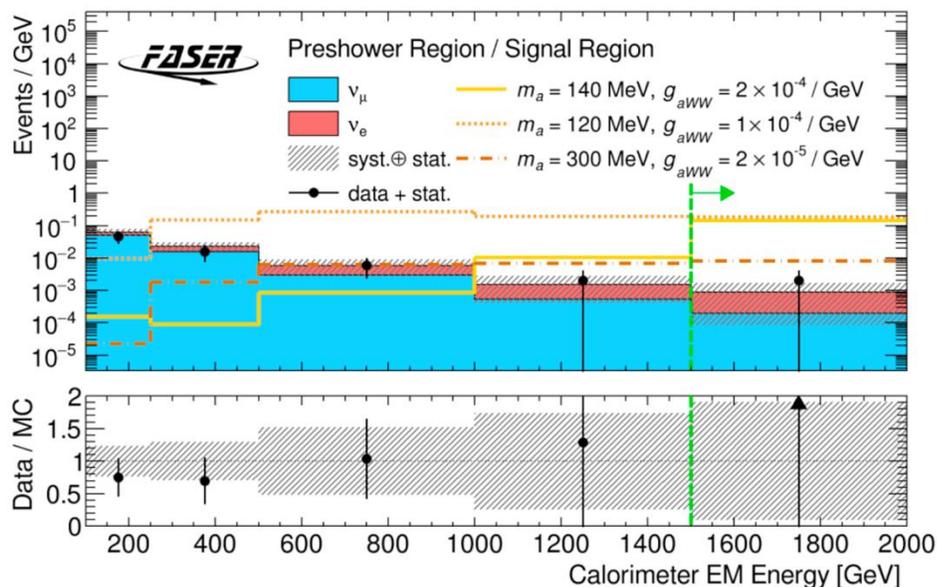
- Largest background comes from neutrinos interacting in the preshower or the calorimeter
- Expected 0.44 ± 0.39 background events from MC modeling (see [PRD 110, \(2014\) 012009](#))
- Validated by isolating different neutrino interaction regions with preshower ratio

Second Preshower Layer nMIP

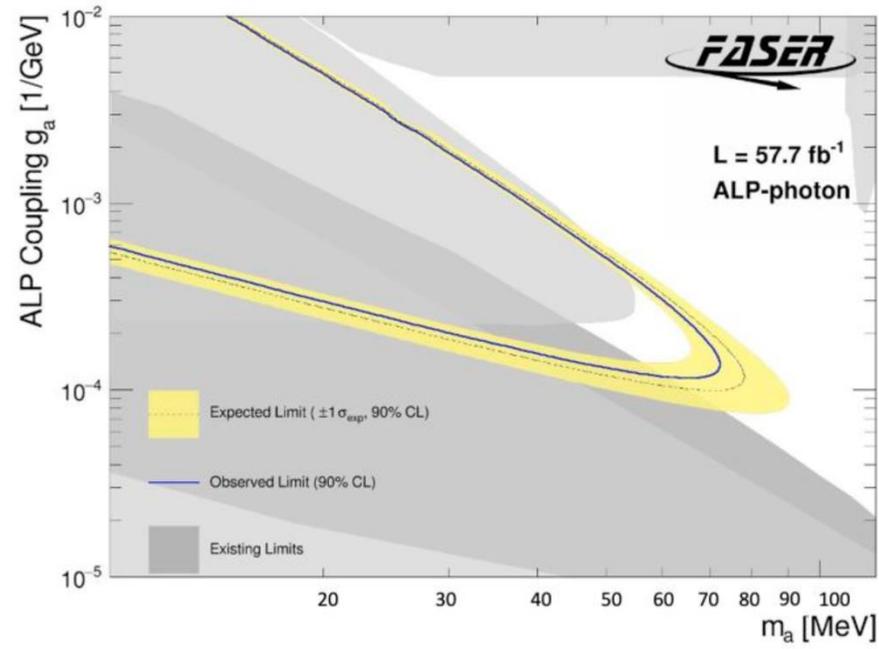
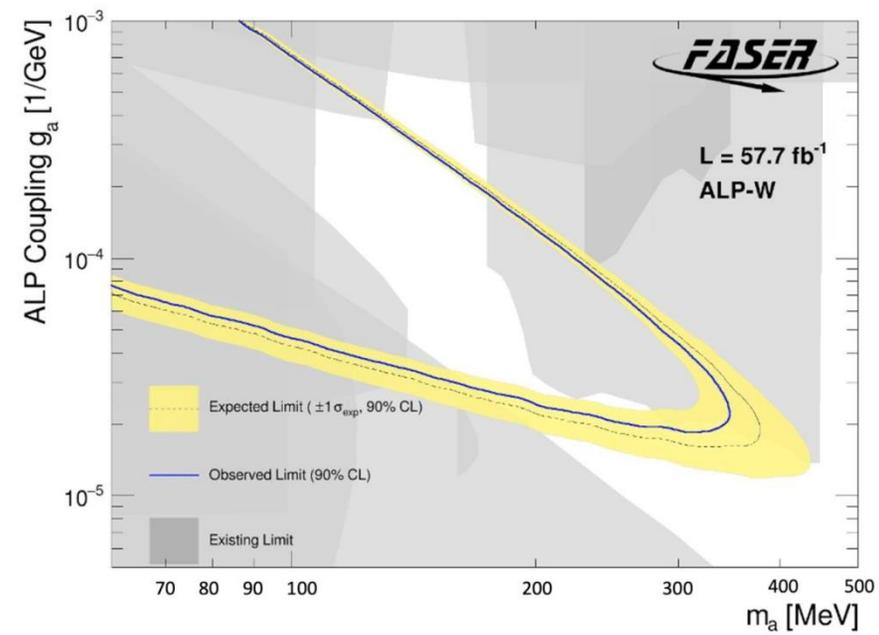


BSM Searches: ALPs Results

- **1 observed event**, compatible with background estimation
- World leading constraints in unexplored regions!
- ALP-W and ALP-photon shown here, but more models/interpretations in backup!



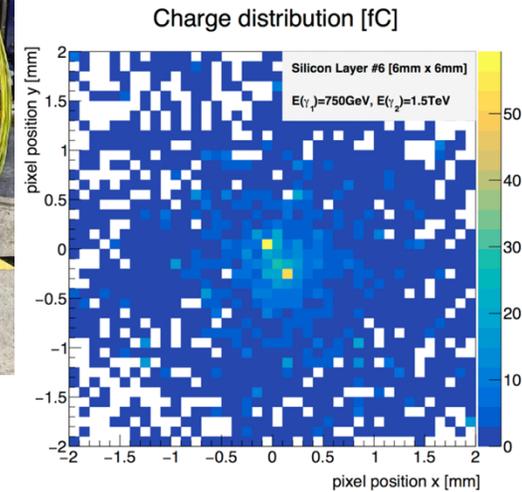
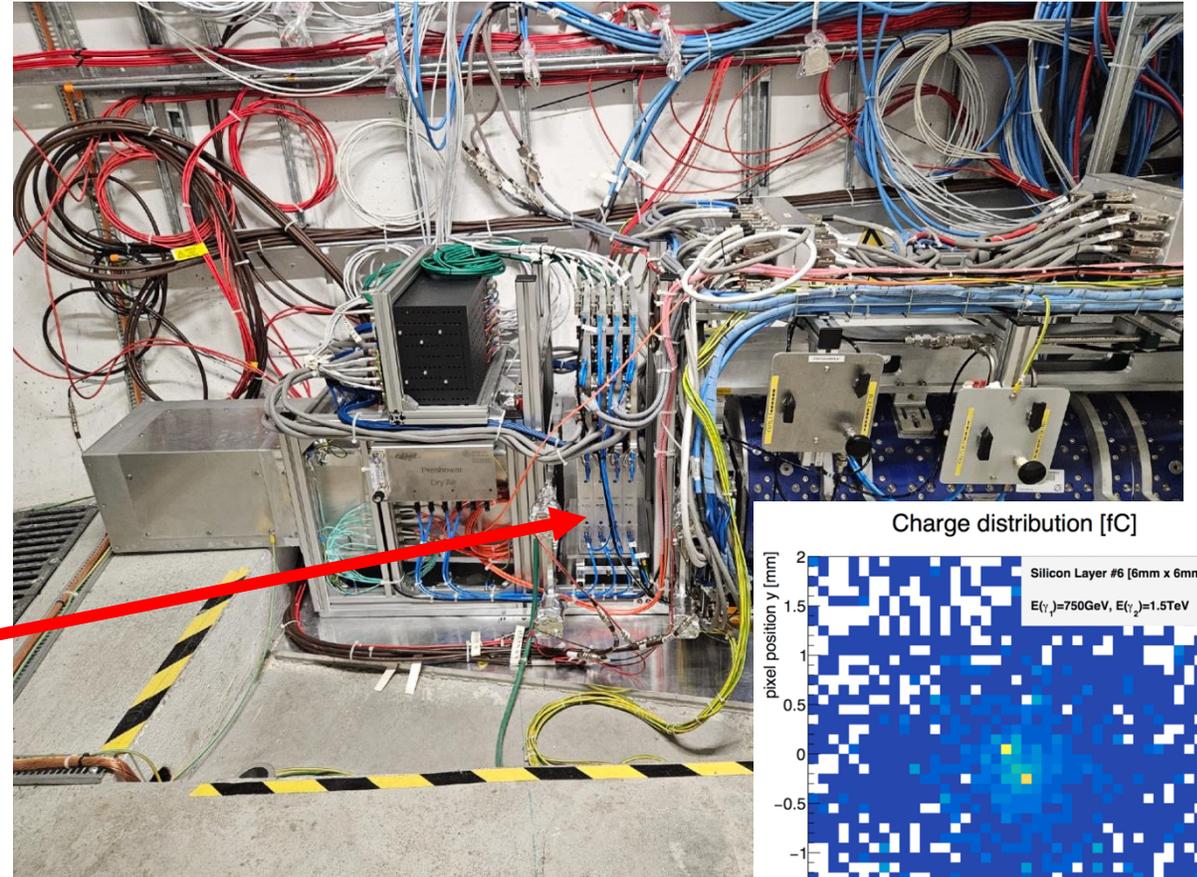
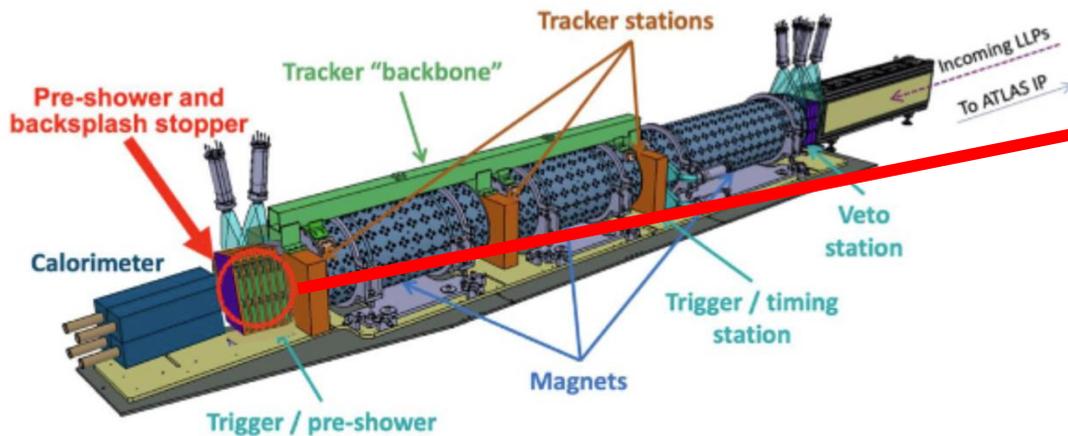
JHEP 01 2025 199



What's Next For *FASER* ?

New Preshower Detector!

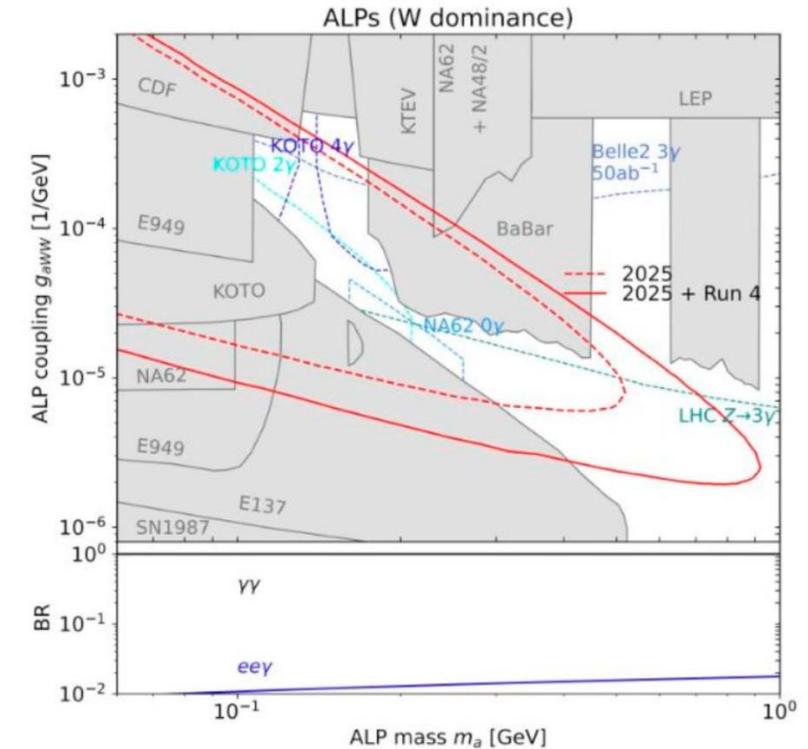
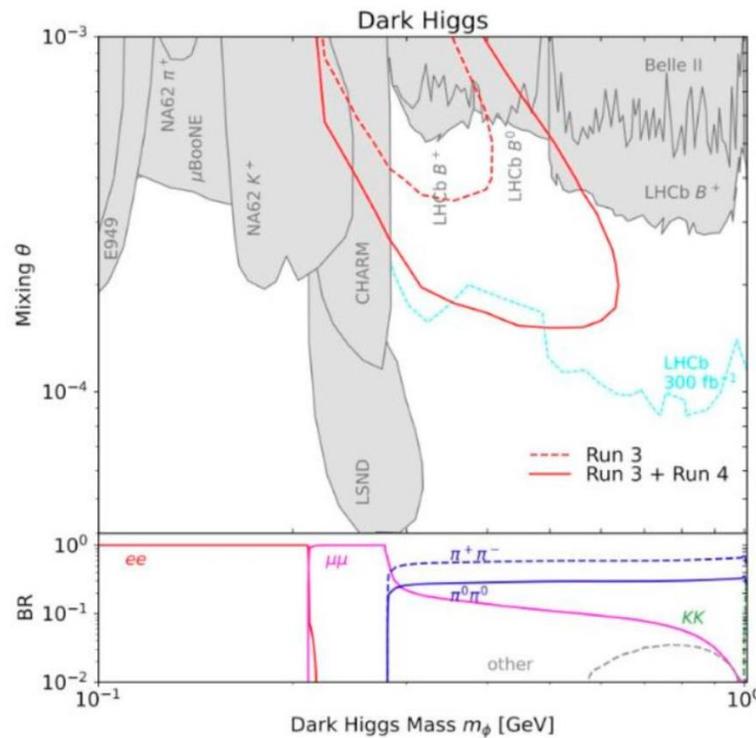
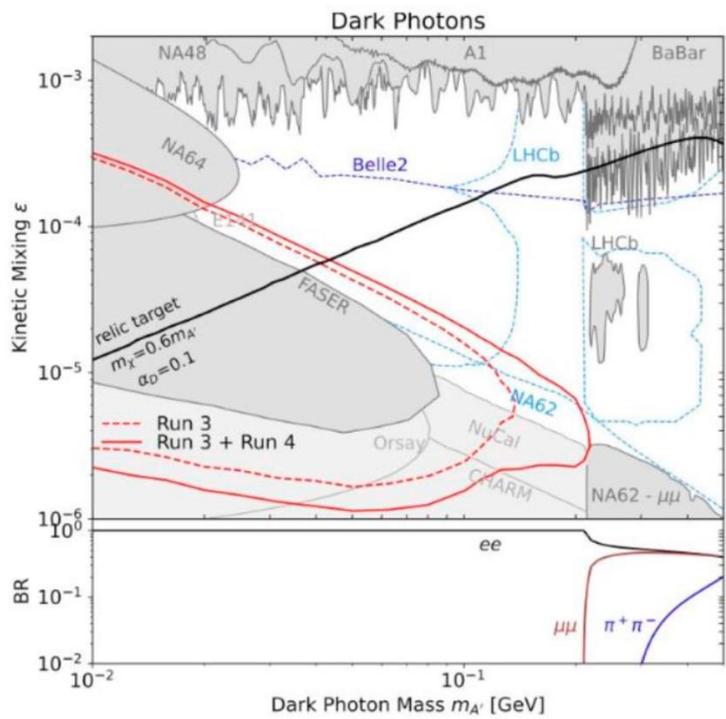
- New high-granularity tungsten-silicon pixel preshower detector installed in February of this year
- Enable distinguishing between very close ($\sim 0.2\text{mm}$) spaced photons
- Will improve ALPs sensitivity!



FASER @ HL-LHC

[Run 4 request info](#)

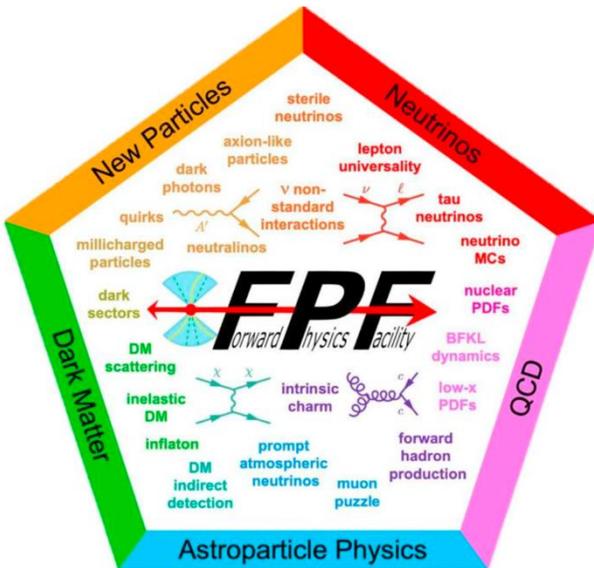
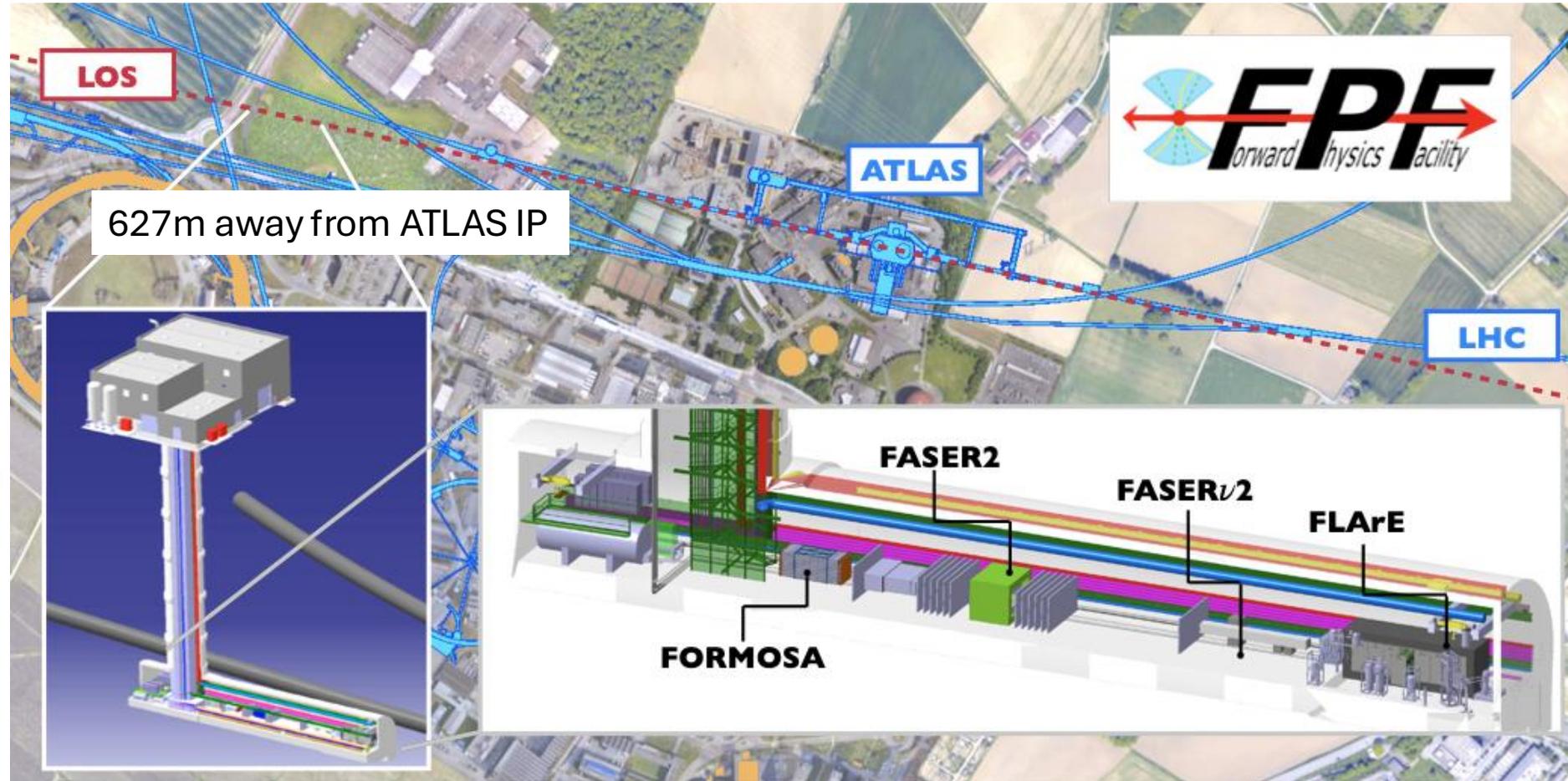
We are approved to run in Run 4 — expecting close to 680 fb^{-1}
 Increased statistics will make us sensitive to lots of dark sector physics!



Future: FASER2 @ Forward Physics Facility

EPJC 85 (2025) 4, 450

FPF is a dedicated facility for forward physics—neutrino science, LLPs, DM...



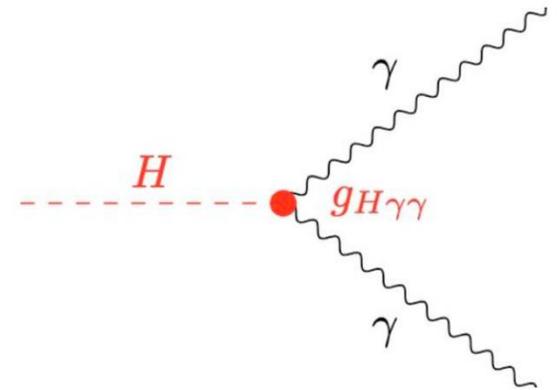
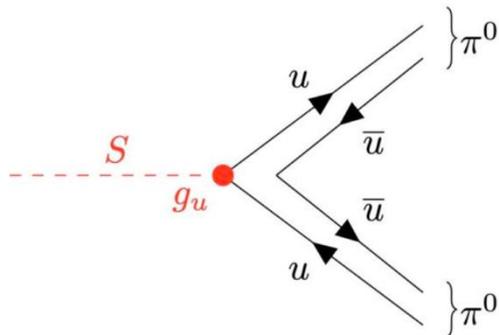
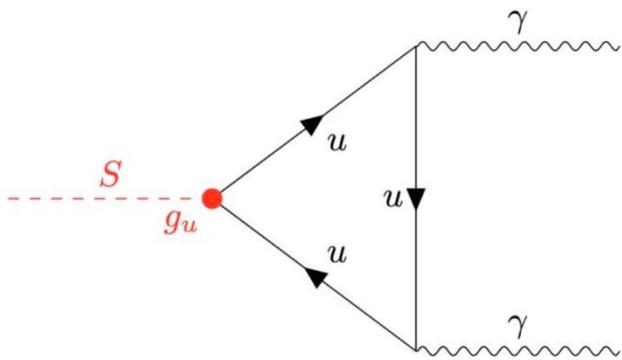
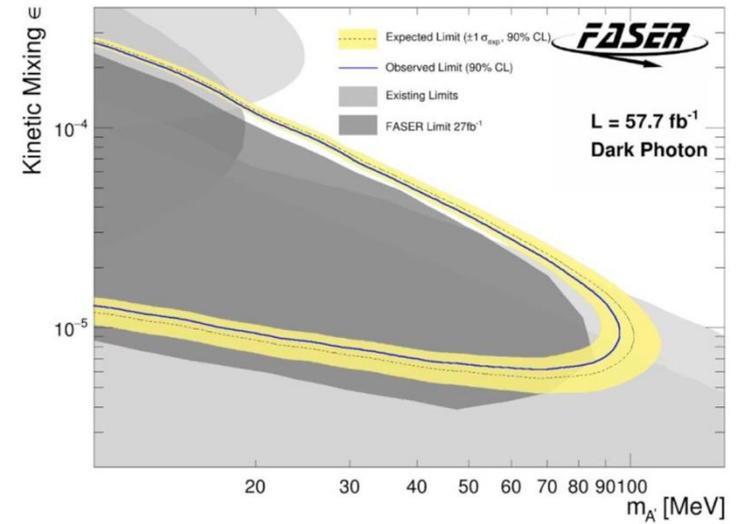
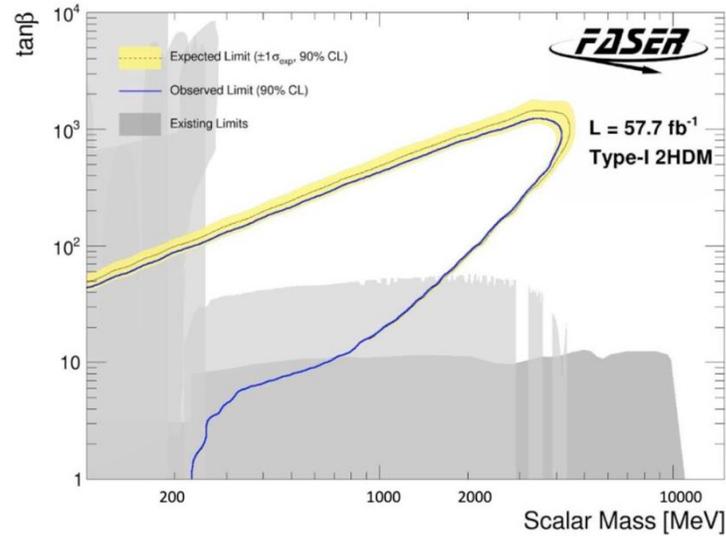
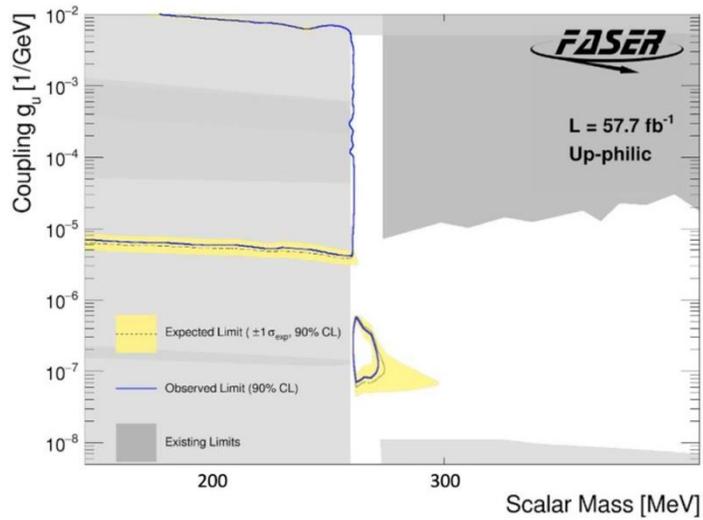
Summary

- FASER has world leading limits for **dark photons** (27 fb^{-1}) and **ALPs** (57.7 fb^{-1}) search
- Current analyses ongoing: studying neutrinos and a second dark photon analysis with improved signal acceptance
- Preshower upgrade earlier this year (Feb 2025) to enhance future ALPs sensitivity
- FASER is approved for Run 4 — expecting 680 fb^{-1}
- The Forward Physics Facility hosting 4 detectors, including FASER2 is under discussion -- will provide significant sensitivity for dark sector physics!

Thanks for your attention :D

Backup

BSM Searches: More ALPs Interpretations



BSM Searches: More ALPs Interpretations

