Light dark matter searches at FASER

https://faser.web.cern.ch

Andrea Coccaro on behalf of the FASER collaboration
LDMA 2025 International Workshop
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Physics prospects

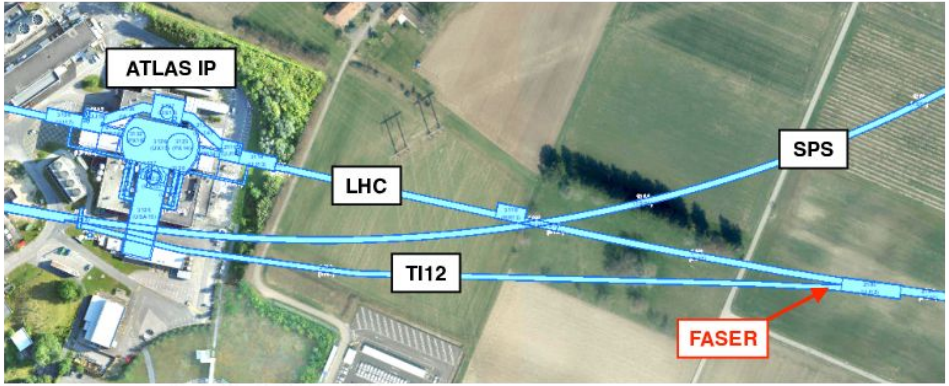
Experiments at the LHC focus on heavy, strongly interacting particles by looking at the transverse plane. In absence of signals of new physics at the TeV scale, the initial paradigm broadened

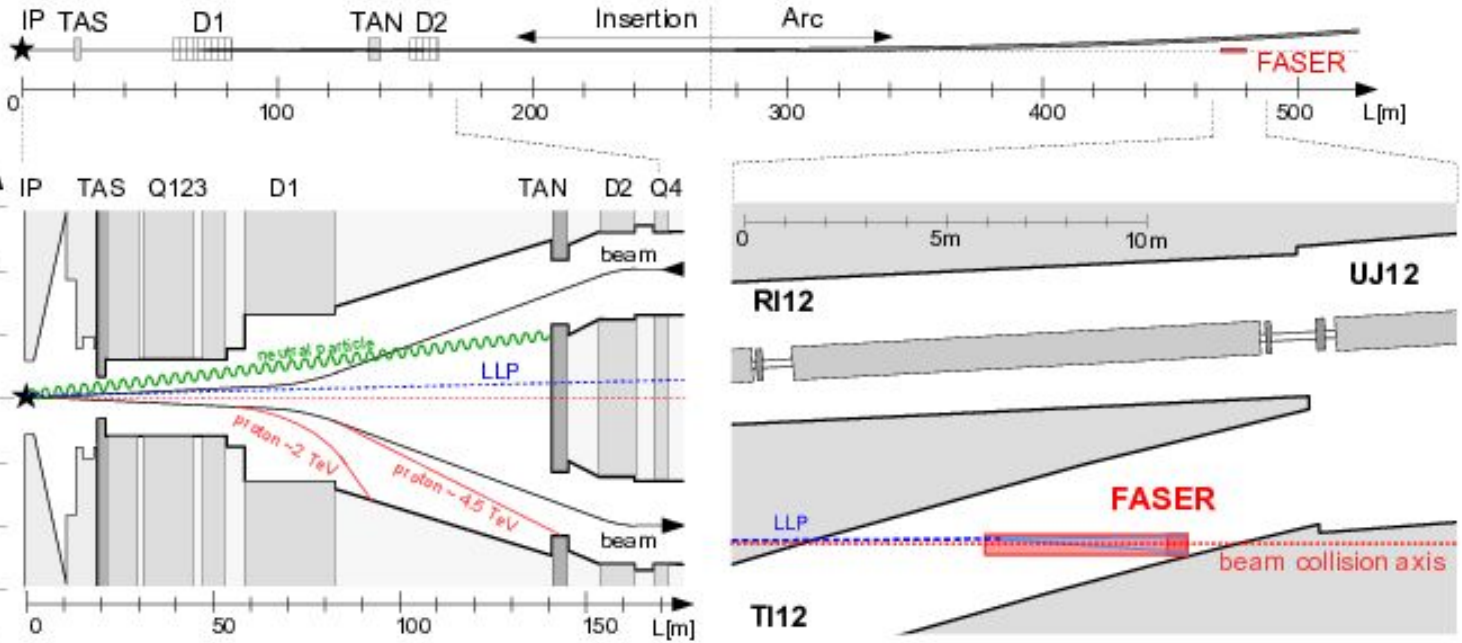
- Using existing experiments / with new triggers, or new reconstruction techniques, with displaced objects, with analysis with trigger-level quantities, etc.
- Proposing new experiments / to complement the coverage of existing experiments, mainly towards longer lifetimes and lower masses

FASER aims at searching for light and weakly-interacting particles

- By looking at the very-forward region at a distance where known background is highly suppressed
- With a dedicated, low-budget detector placed in the TI12 side tunnel at the LHC

FASER location

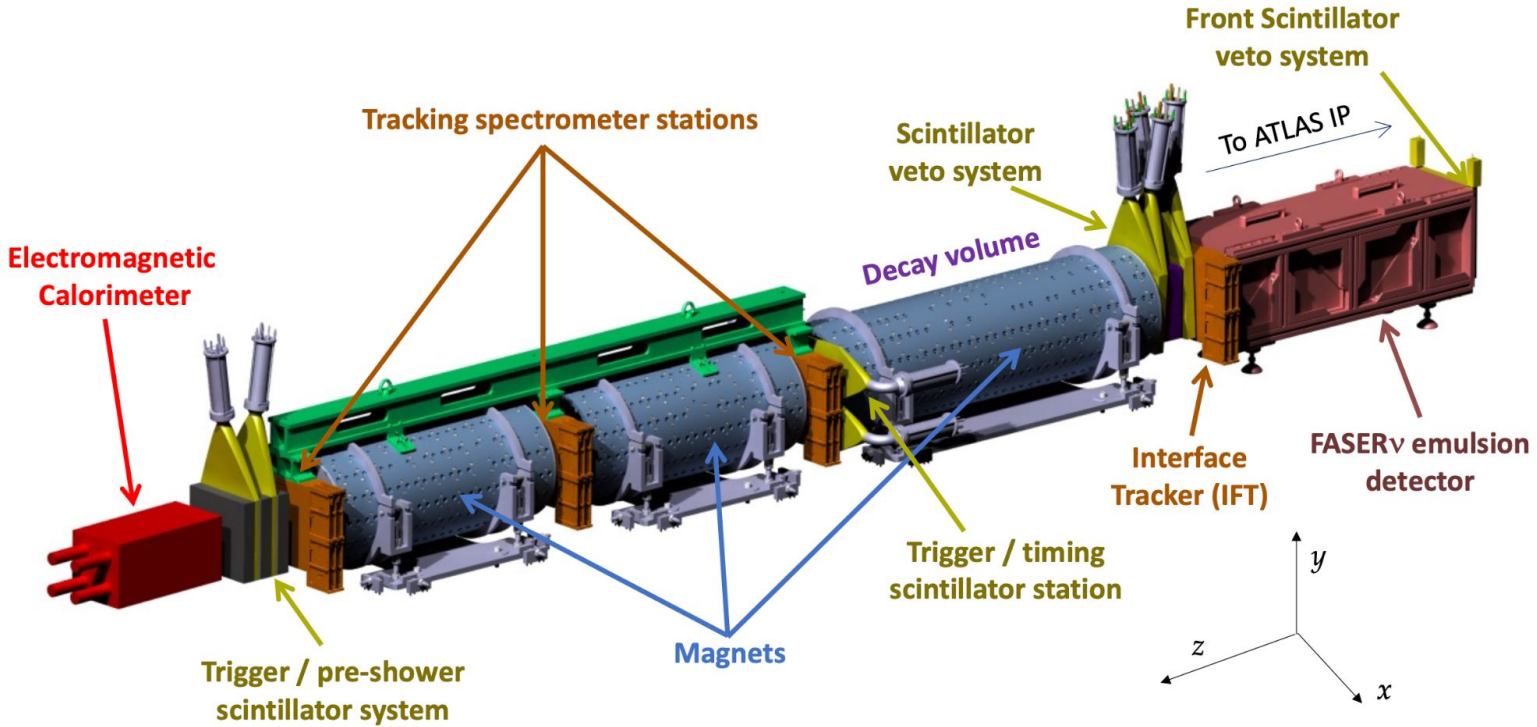




arXiv:2207.11427

JINST 19 P05066

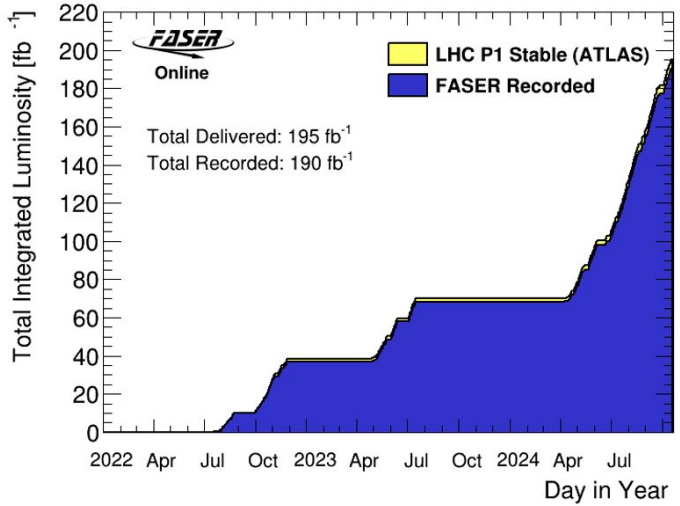
Detector Layout

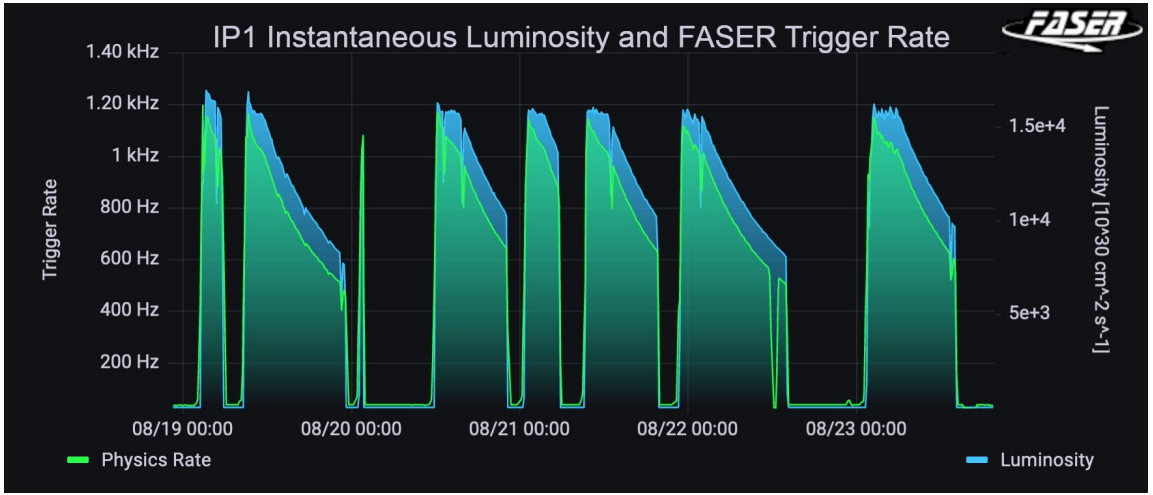


~7m length with 20 cm aperture (η>9.1) and a ~1.5 m magnetized decay volume

Operations and data-taking

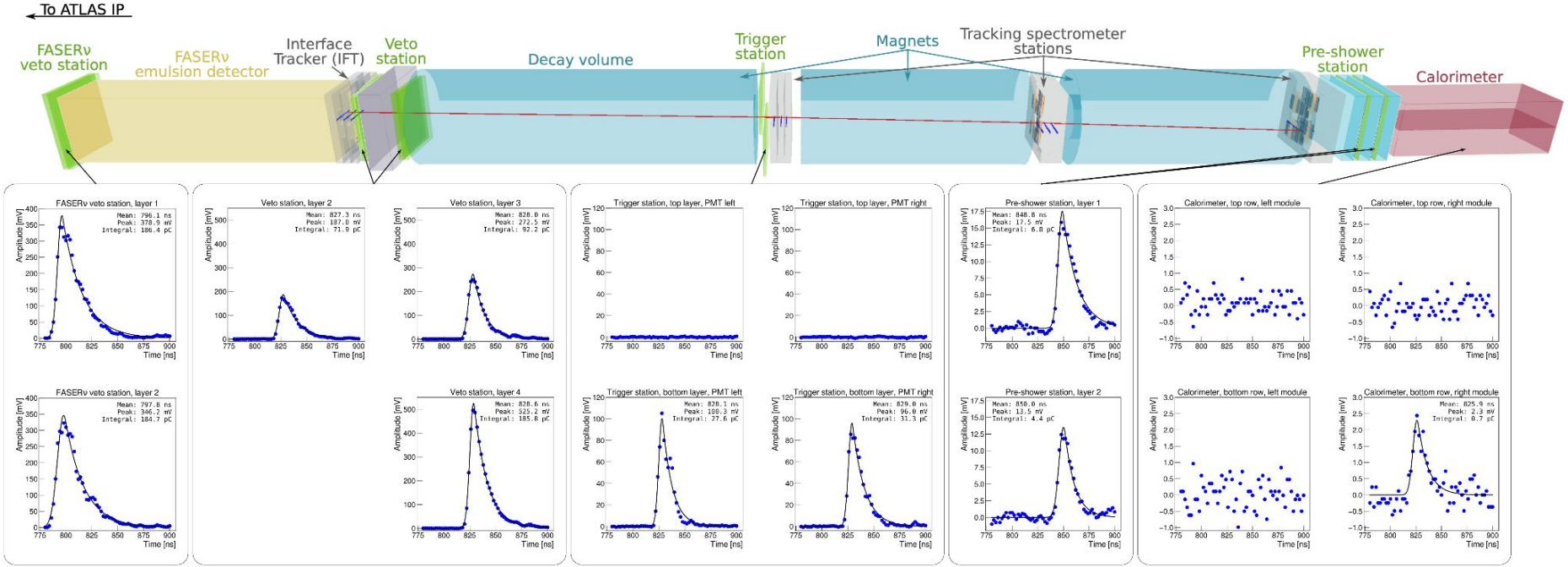
- Smooth operations since July 2022
- > 97% of delivered data collected corresponding to ~190/fb
- All detector components working as expected
- Lightweight operations with two remote shifters and no control room





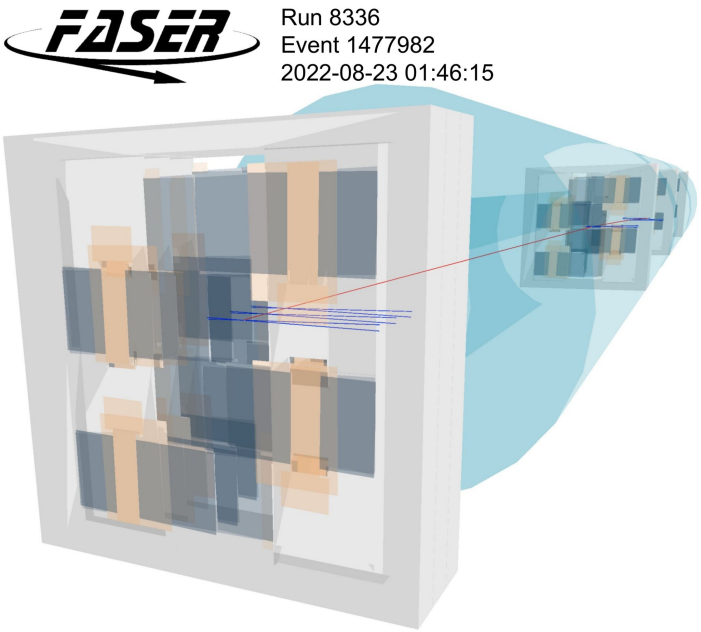
Event display

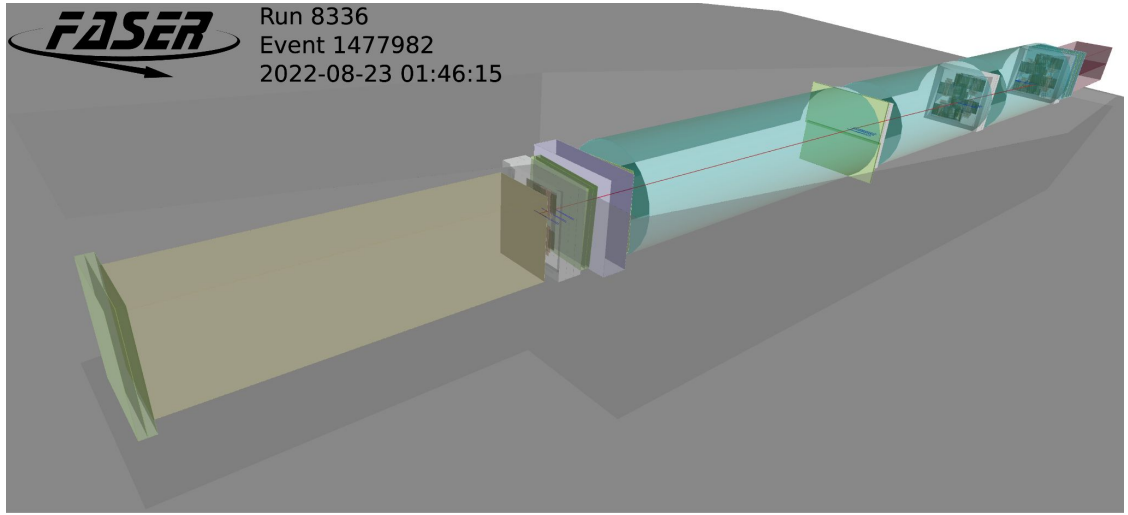
Run 8336
Event 1477982
2022-08-23 01:46:15



Collision event with a 21.9 GeV muon traversing the entire detector

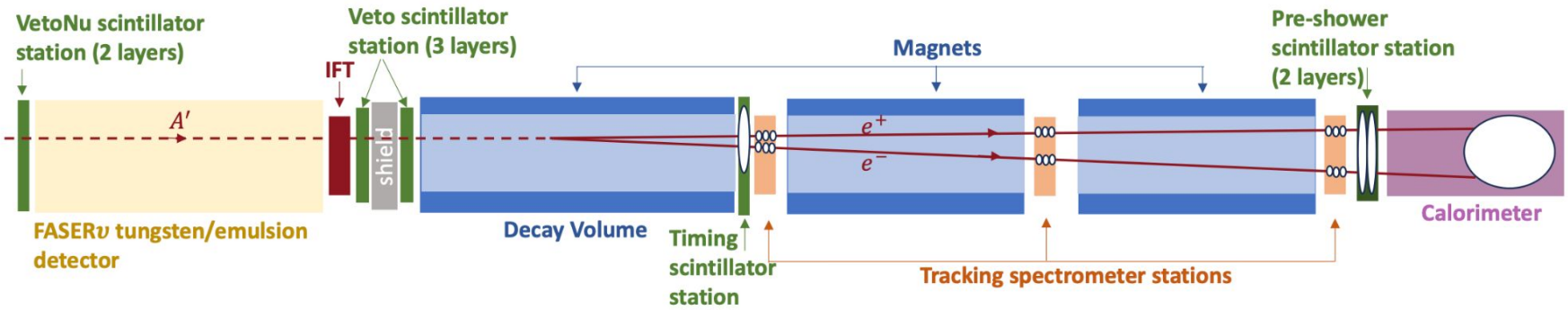
Event display





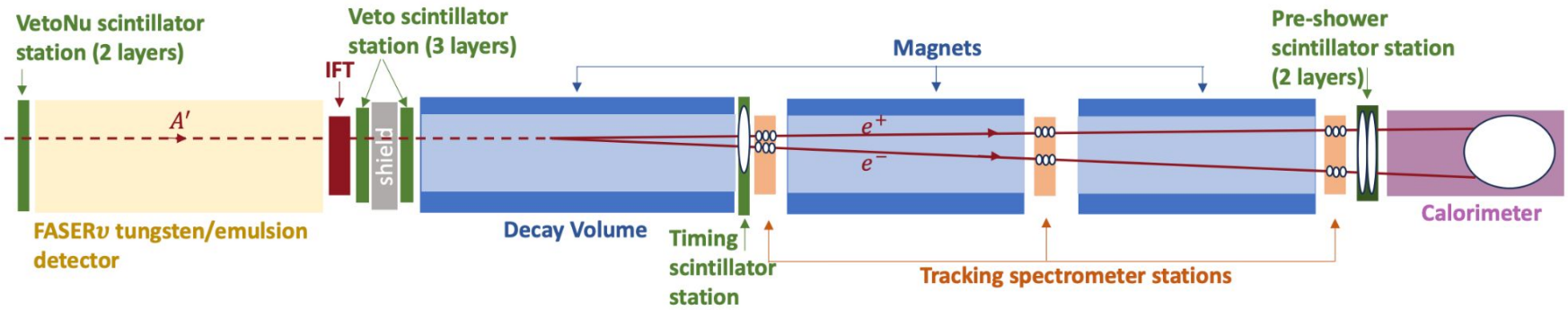
Collision event with a 21.9 GeV muon traversing the entire detector

Which physics?



- Huge number of light mesons in the forward direction
  - ~10% of pions in the FASER acceptance, covering ~10^{-6} of solid angle
- Scintillators for vetoing charged particles coming from IP1
- Emulsion detector for neutrino physics
- Timing scintillators for triggering
- Tracking detectors within dipole magnetic field
- Calorimeters

Which analysis?



Dark-photon search

- No signal in veto scintillators
- Two opposite-charge tracks
- Calorimeter energy deposit

arXiv:2308.05587

Phys. Lett. B 848 (2024) 138378

Axion-like Particles search

- No spoiler, more in Noshin's talk!

arXiv:2410.10363

JHEP 01 (2025) 199

Dark photon search

Analysis ingredients

- 2022 dataset corresponding to 27/fb
- <0.5 MIPS in veto scintillators
- >2 MIPS in timing and pre-shower scintillators
- Two reconstructed tracks with
  - Chi2/nDOF <25
  - >12 associated hits
  - >20 GeV momentum
- >500 GeV in EM calorimeter

Background sources

- Veto scintillators inefficiencies
  - Estimated in being negligible
- Large-angle muons entering in the active detector
  - Estimated in being negligible
- Non-collision events
  - Estimated in being negligible
- Neutral hadrons
  - $(8.4 +/- 11.9)\times10^{-4}$ expected events
- Neutrinos
  - $(1.5 +/- 2.4)\times10^{-4}$ expected events

Dark photon search

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Robust and relatively simple analysis (with blind strategy)

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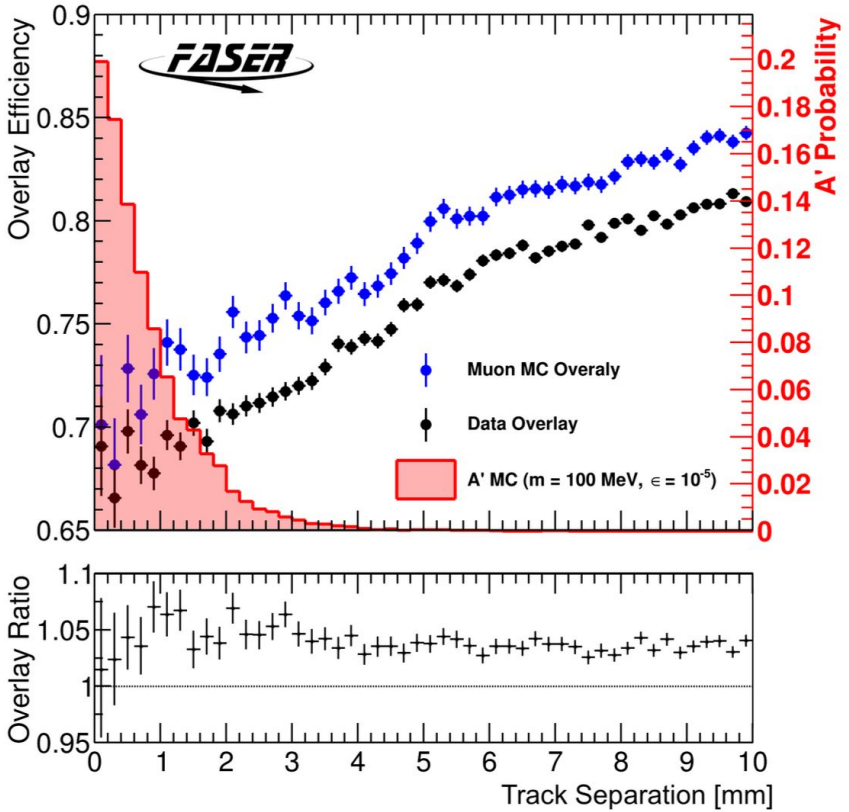
Background-free analysis

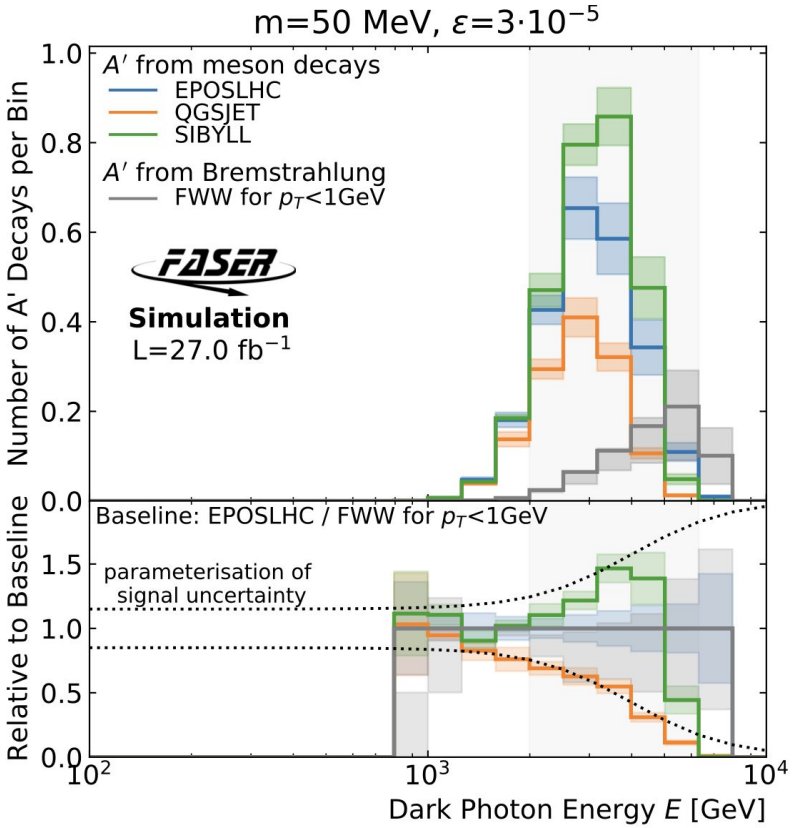
Track reconstruction efficiency for close-by tracks

Overlay technique for both muon simulation and data to study the track reconstruction efficiency for close-by tracks.

Typical separation from signal-candidate events depends on dark-photon kinematics.



Systematic uncertainties

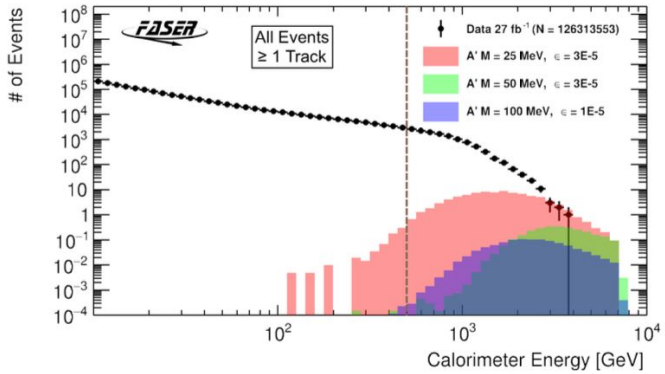


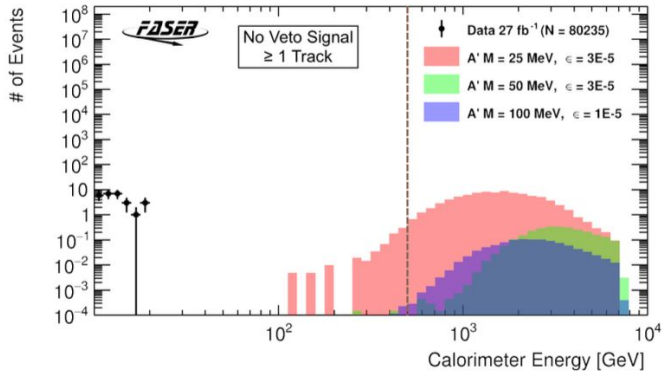
Source	Value	Effect on signal yield
Signal Generator	$\frac{0.15+(E_{A'}/4\text{TeV})^3}{1+(E_{A'}/4\text{TeV})^3}$	15-65% (15-45%)
Luminosity	2.2%	2.2%
MC Statistics	$\sqrt{\sum W^2}$	1-3% (1-2%)
Track Momentum Scale	5%	< 0.5%
Track Momentum Resolution	5%	< 0.5%
Single Track Efficiency	3%	3%
Two-track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

Systematic uncertainties on the expected signal yields largely dominated by signal model generation

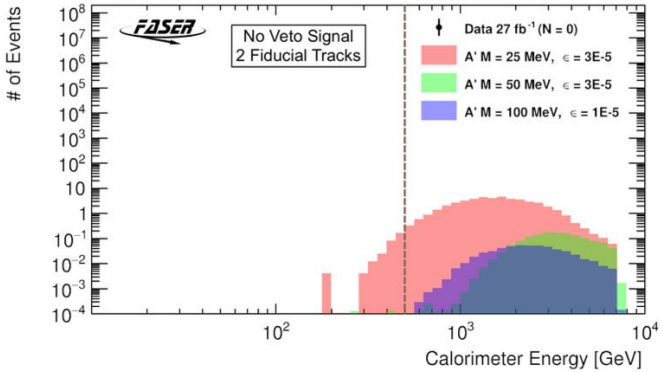
Very forward generation of SM particles validated with forward measurement by LHCf

Analysis results

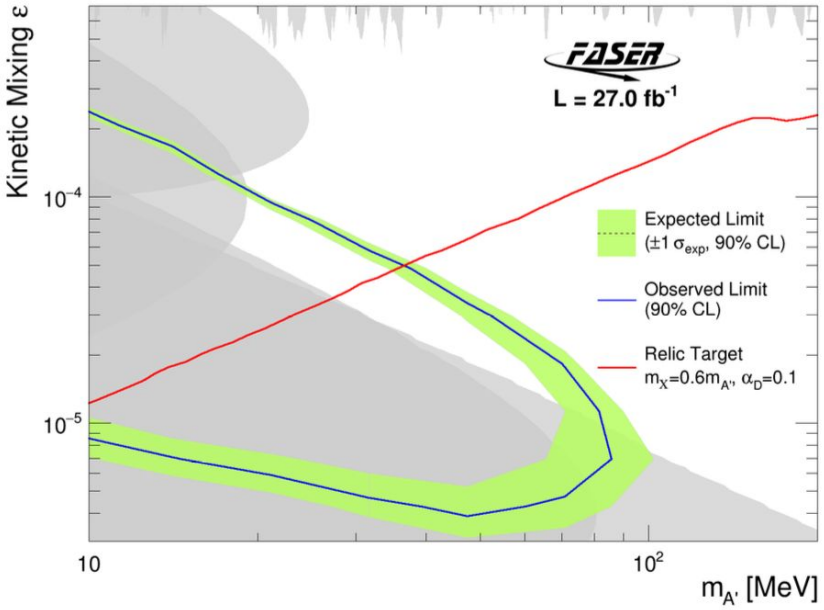


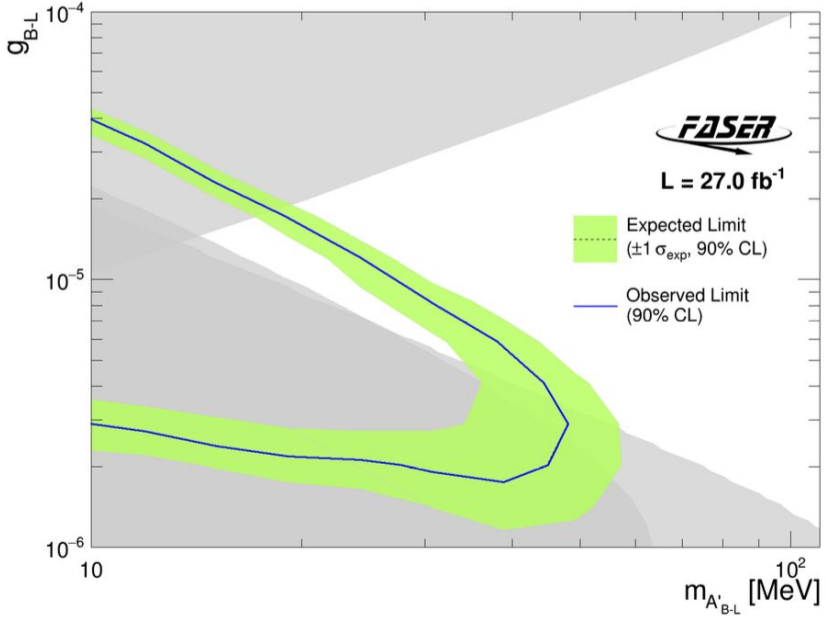


Calorimeter energy distribution for all events with at least one track (upper-left), with no signal in veto stations and at least one track (upper-right) and in the signal region (bottom)



Exclusion limits





- Blue | 90% CI exclusion contours for the dark-photon and the B-L gauge boson scenarios
- Gray | Previously excluded regions
- Red | Cosmologically favoured parameter space

Summary

- FASER is a small experiment at the LHC
  - Designed for detecting light and weakly-interacting particles
  - Complemented by a dedicated detector for neutrino physics
- FASER is installed and beautifully taking data
  - A large dataset currently being analysed
  - Newly pre-shower detector installed increasing the physics reach of the experiment
  - Run-4 operations approved and proposal for a FASER-2 experiment at the Forward Physics Facility submitted (arXiv:2203.05090)
- FASER is producing interesting physics results
  - Neutrino physics at colliders, not covered here
  - BSM searches probing uncharted territories and complementing the LHC physics program

The Collaboration

107 members from 27 institutions and 11 countries

International laboratory covered by a cooperation agreement with CERN