

Dark Photon Search at FASER

Particle Physics Annual Meeting 2026

Pawan

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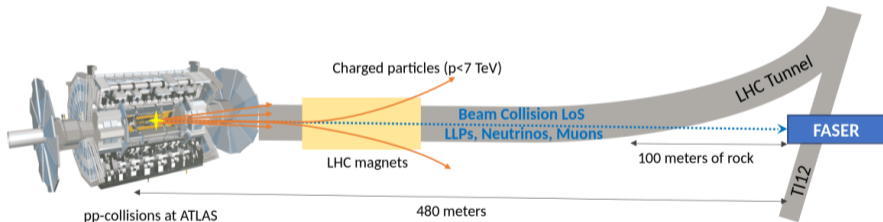


Particle Physics

FASER Experiment

ForwArd Search ExpeRiment (FASER) is a small inexpensive experiment designed to search for light, weakly-interacting particles produced in the forward direction at the LHC.

- ❖ FASER is located 480 meters downstream of the ATLAS Interaction Point (IP1)
- ❖ Positioned along the beam collision axis ($\eta > 8.8$)
- ❖ Majority of SM particles that can reach FASER are neutrinos and high-energy muons



- ❖ FASER Physics Program
 - ❖ Search for LLPs
 - ❖ Studying collider neutrinos

FASER Detector

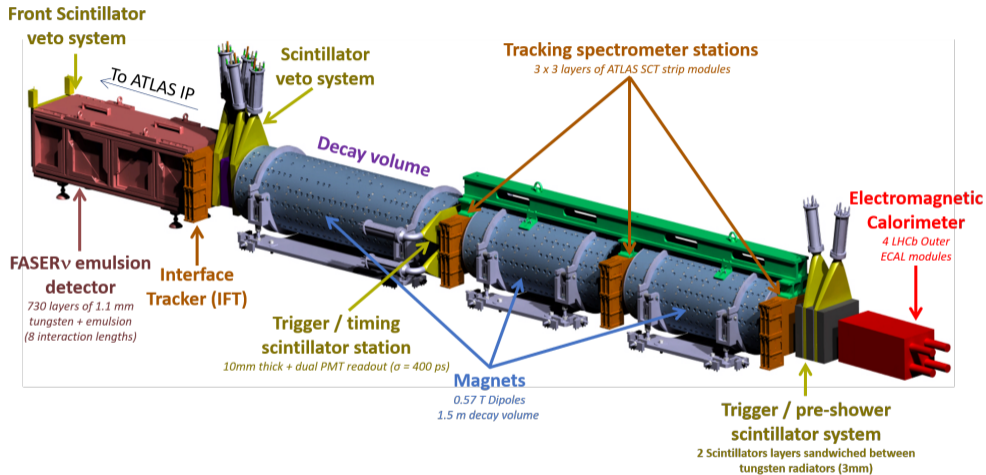
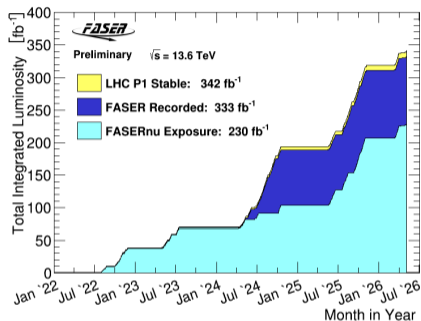


Figure: FASER Detector Schematic [2207.11427].

FASER Operations

- ❖ Data taking since 2022
- ❖ 333 fb^{-1} total recorded (2022-2026)
- ❖ Efficient data taking with $>97\%$ of delivered luminosity recorded
- ❖ Analyses have used up to 177 fb^{-1} of data so far (2022-2024)

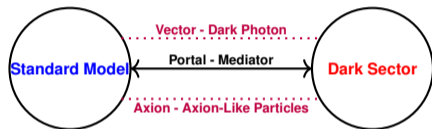


Contributions to Operations

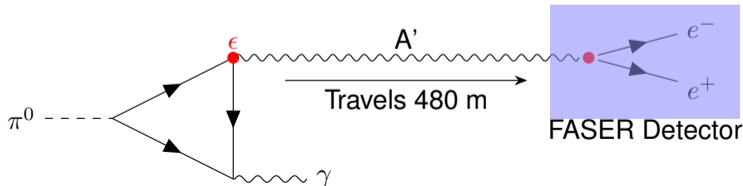
- ❖ Monte Carlo production of BSM samples for analyses
- ❖ Monitoring and Run manager shifts
- ❖ Contributing to offline software with an emphasis on tracking (in backup)

Analysis Focus : Dark Photons

- Dark matter may consist of as-yet undiscovered particles and forces, potentially forming an extended Dark Sector beyond the Standard Model.
- The Dark Photon can arise when a dark sector containing a U(1) gauge symmetry kinetically mixes (ϵ) with the Standard Model photon through the Vector Portal.

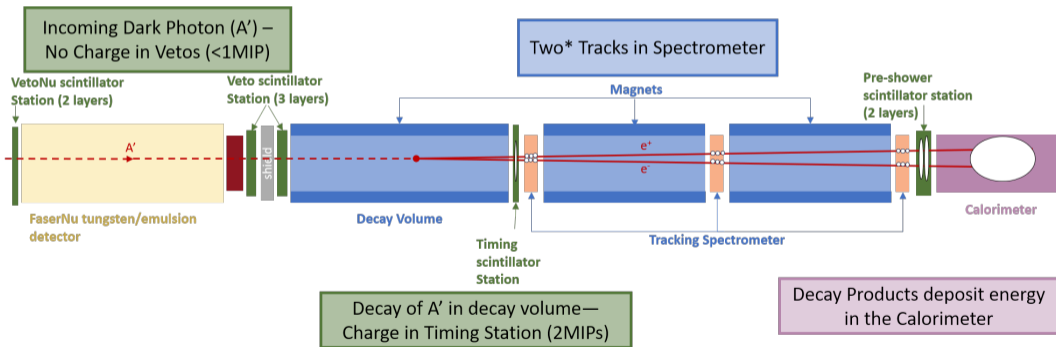


- At FASER Dark Photon are dominantly produced through meson decays.
- They can then be detected through their decays to SM particles in FASER.



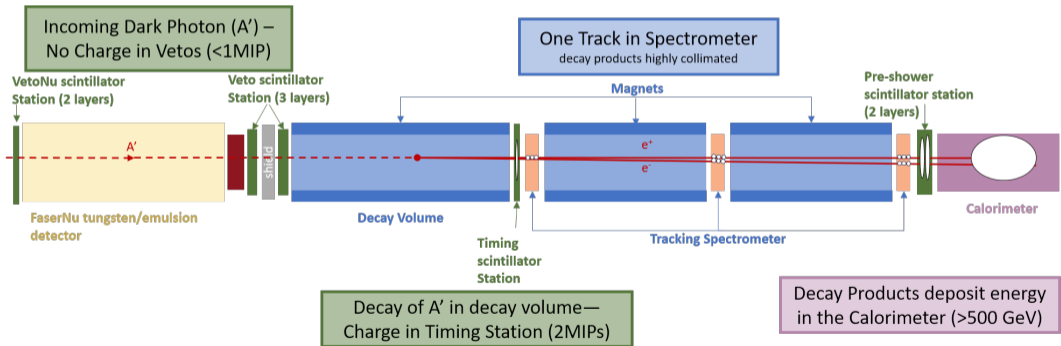
Dark Photon Analysis (LLPs with Tracks)

- ❖ Three signal regions have been defined for the Dark Photon search
 - ❖ Two Track SR – used in previous Dark Photon Search



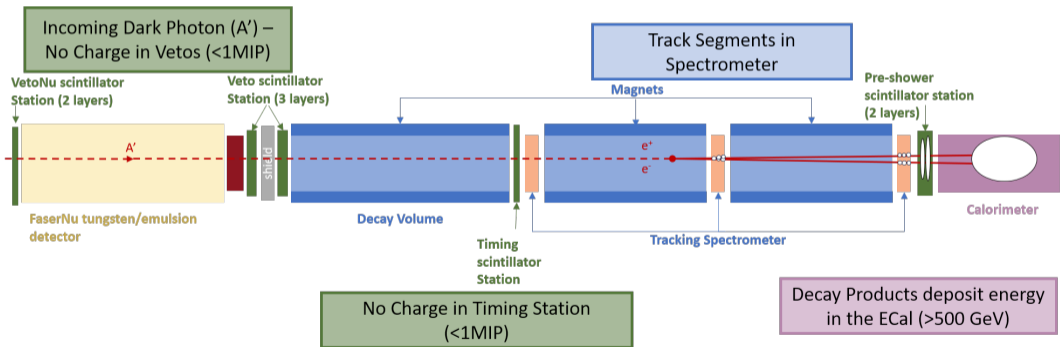
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 - ❖ Segment SR – targets decays occurring downstream of the decay volume



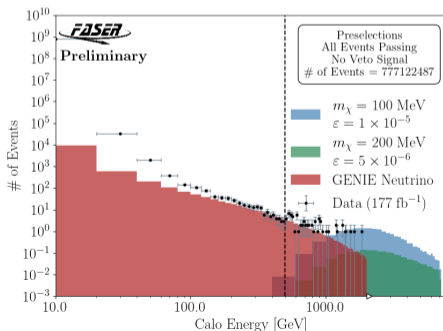
Contributions to the Analysis

- Neutrinos form the dominant background for this search
 - Modeled using Monte Carlo simulations

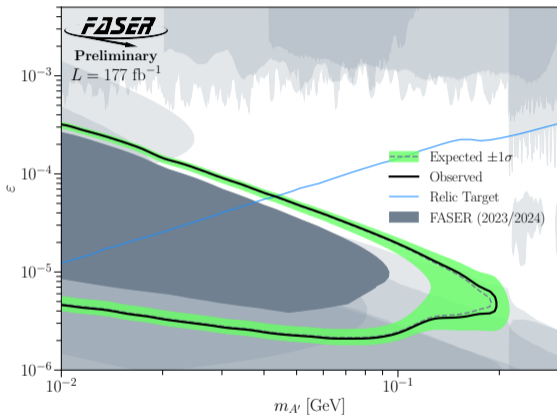
Source	Segment SR	One-Track SR	Two-Track SR
Neutrinos	$0.025^{+0.014}_{-0.014}$	$0.050^{+0.024}_{-0.039}$	$0.018^{+0.007}_{-0.016}$

Table: Background contributions in different signal regions.

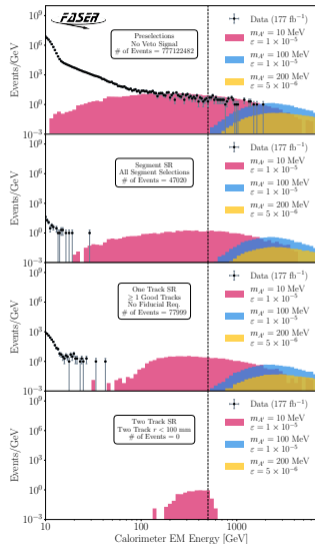
- Studied signal efficiencies and systematic uncertainties
- Statistical analysis and limit setting
 - Limit setting using ATLAS's HistFitter framework [1410.1280].
 - Largely developed by Liverpool group, led by Dr. John Anders.
 - Also being used by other LLP analyses in FASER



Results from FASER



❑ No events observed in any of the signal regions. New exclusions! [CERN-FASER-CONF-2026-001].



Summary and Outlook

- ❖ Currently contributing to FASER Operations and Analysis
 - ❖ Neutrino background for Dark Photon Search
 - ❖ Statistical analysis and limit settings
 - ❖ Monte Carlo Production for BSM analyses
 - ❖ Run Manager and Monitoring Shifts
- ❖ LTA ends this autumn
 - ❖ will be based at RAL for the next year
- ❖ Future work includes:
 - ❖ Optimization of the tracking software
 - ❖ Further interpretations of the Dark Photon Search
 - Focus on low energy final states (LLP $\rightarrow \mu\mu$ or $\pi\pi$)
 - ❖ Expecting paper this summer

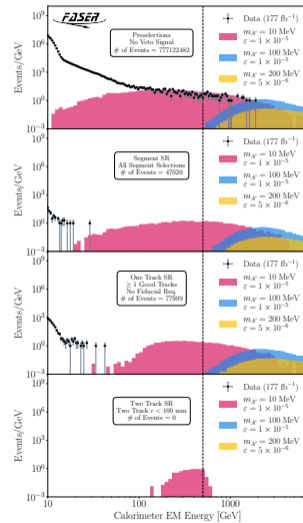
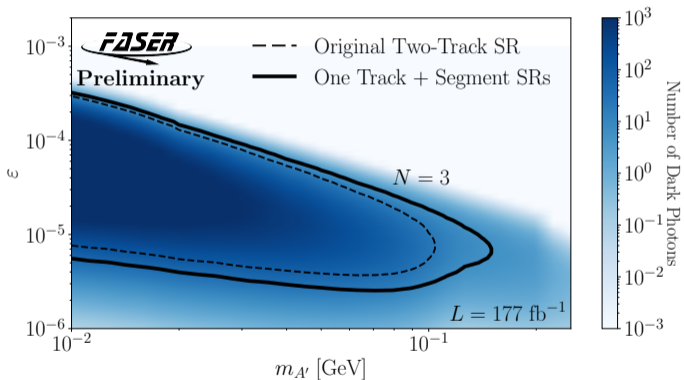
Thank you!

Backup

Dark Photon Selection

Selection	Description
Data Quality Selections	
Stable Beams Colliding BCID No Timing Scintillator Saturation Preshower0 Charge < 1250 pC	Require period of stable beam delivered to LHC Event corresponds to a colliding bunch Ensure no saturation of the timing scintillator layers Ensure no saturation of the preshower station
One Plus Track Signal Region	
Veto ν Charge < 40 pC Veto Charge < 40 pC Timing Charge > 70pC Preshower scintillators > 2.5 pC ≥ 1 Good Track \geq One Track $r \leq 95$ mm throughout detector Calorimeter Energy > 500 GeV	No signal in Veto ν scintillators Require no signal in Veto scintillators 2 MIPs in timing layer Require signal in downstream scintillators At least one good track Enforcing fiduciality High energy event
Segment Region	
== 0 Tracks Veto ν Charge < 40 pC Veto Charge < 40 pC Timing Charge < 25 pC ≥ 2 Segments in Tracking Station 2 OR Station 3 All Segments < 95mm at St2 and St3 All Segment Angles < 0.02 radians Calorimeter Energy > 500 GeV	No tracks, to enforce orthogonality No signal in Veto ν scintillators Require no signal in Veto scintillators Require no signal in Timing scintillators Evidence of tracking Select only fiducial segments Ensure only straight segments High energy event (sum of all four channels)
Two Track Signal Region*	
Raw Veto ν Charge < 40 pC Raw Veto Charge < 40 pC Timing Charge > 70pC Preshower scintillators > 2.5 pC == 2 Good Tracks 2 Tracks with $r \leq 95$ mm throughout detector Calorimeter Energy < 500 GeV	No signal in Veto ν scintillators Require no signal in Veto scintillators 2 MIPs in timing layer Require signal in downstream scintillators Exactly two good tracks Enforcing fiducial requirement for both tracks Enforcing orthogonality with one plus track signal region

Dark Photon SRs



Dark Photon Systematics

Source	Value	Effect on Signal Yield
Dark Photon Generation (from mesons)	15%	15% (8%)
Dark Photon Generation (from dark Bremsstrahlung)	22%	22% (40%)
Luminosity	1.9%	1.9%
Momentum Scale	5%	<0.5%
Momentum Resolution	5%	<0.5%
Single Track Efficiency	0.47%	0.47%
Two Track Efficiency	~1% (3.5%)	~1% (3.5%)
Segment Efficiency	6.07%	6.07%
Calo Energy Scale	5.46%	3% (11%)

Table: Summary of systematic uncertainties in the two signal regions. The numbers in parenthesis indicate the effect on the signals within the parameter space for which this analysis is sensitive.

Four Station Tracking

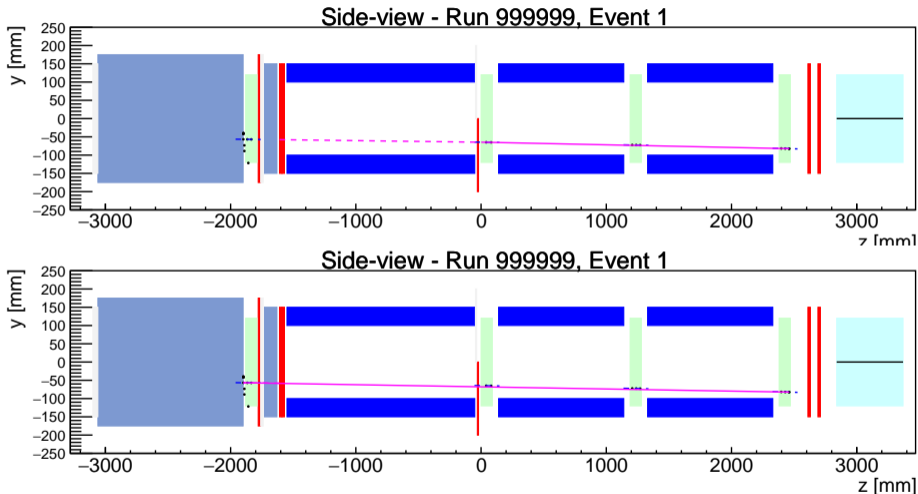


Figure: Previously the clusters in the IFT were unused for the tracking (see top figure). The bottom figure shows how they are now included in the tracking.

Four Station Tracking Performance

Selection	Pass	All	Eff. (%)	Cum. Eff. (%)
Four Station Tracking				
At least one long track	4671	5000	93.42	93.42
Track w/ hits in station 0	4543	4671	97.26	90.86
Three Station Tracking				
At least one long track	4733	5000	94.66	94.66

Table: Performance of the tracking algorithms on a MC sample of 100 GeV muons.

- ❖ While the performance seems reasonable for a first pass.
 - ❖ 1% loss of tracks in the four station tracking
 - ❖ 3 % of tracks in four station tracking are still reconstructed as three station tracks
- ❖ Further work needed to estimate the performance on data.