Neutrino Search with ToO:
Analysis, ICRC proceedings, and Journal Paper

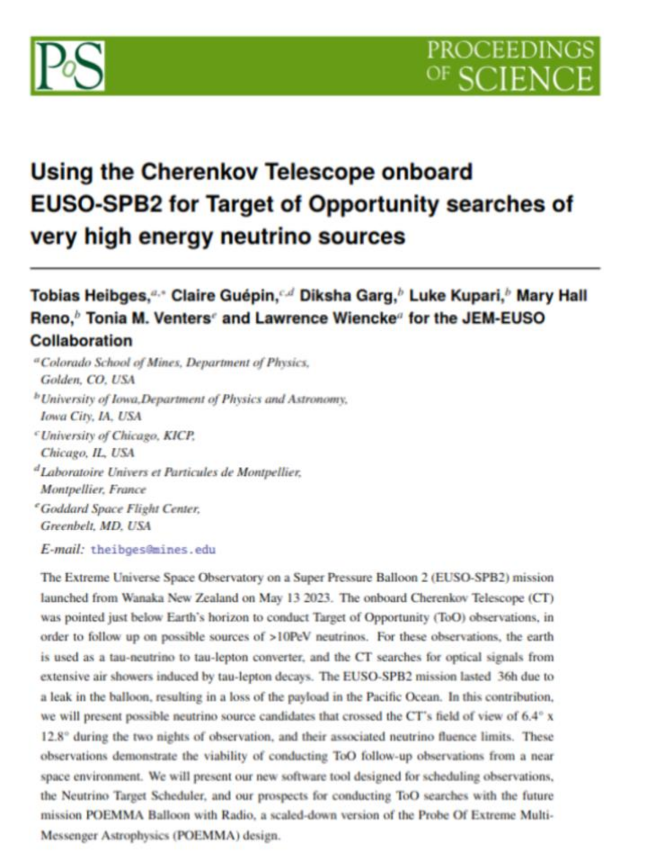
Tobias Heibges

37th JEM-EUSO Collaboration Meeting

PHYSICS
COLORADO SCHOOL OF MINES

ICRC Proceedings / Journal Paper

- Proceedings are mostly written
- Analysis mostly complete
- Journal paper will be extension of ICRC proceedings



PoS PROCEEDINGS OF SCIENCE

Using the Cherenkov Telescope onboard EUSO-SPB2 for Target of Opportunity searches of very high energy neutrino sources

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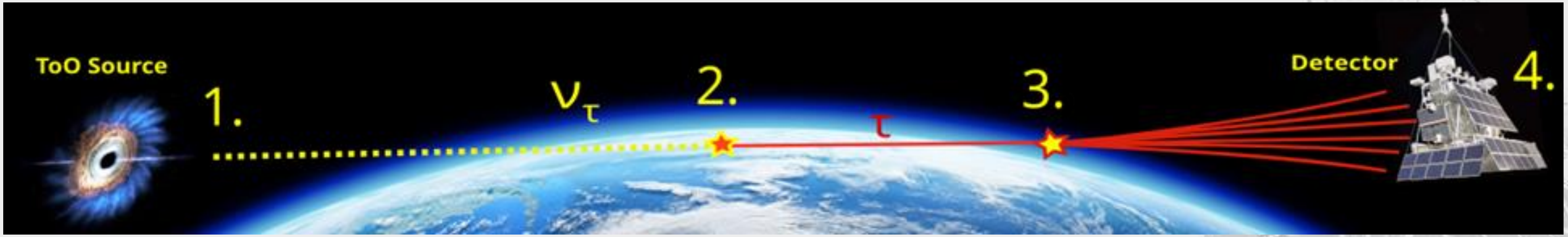
The Extreme Universe Space Observatory on a Super Pressure Balloon 2 (EUSO-SPB2) mission launched from Wanaka New Zealand on May 13 2023. The onboard Cherenkov Telescope (CT) was pointed just below Earth's horizon to conduct Target of Opportunity (ToO) observations, in order to follow up on possible sources of >10PeV neutrinos. For these observations, the earth is used as a tau-neutrino to tau-lepton converter, and the CT searches for optical signals from extensive air showers induced by tau-lepton decays. The EUSO-SPB2 mission lasted 36h due to a leak in the balloon, resulting in a loss of the payload in the Pacific Ocean. In this contribution, we will present possible neutrino source candidates that crossed the CT's field of view of 6.4° x 12.8° during the two nights of observation, and their associated neutrino fluence limits. These observations demonstrate the viability of conducting ToO follow-up observations from a near space environment. We will present our new software tool designed for scheduling observations, the Neutrino Target Scheduler, and our prospects for conducting ToO searches with the future mission POEMMA Balloon with Radio, a scaled-down version of the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) design.

Earth Skimming Technique



1. Neutrino source crosses through detector FoV

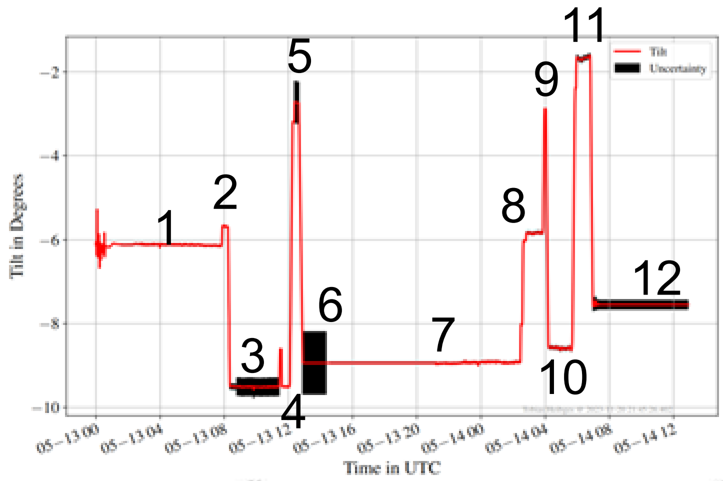
2. A **ν_τ** interacts and **produces a τ**

3. The **τ decays and produces an EAS**.

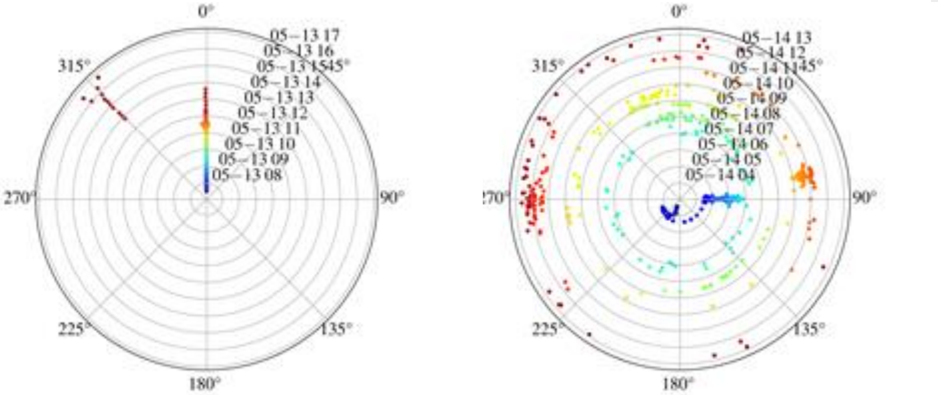
4. Detector triggers on Cherenkov **signal**

CT Flight Operations

Night 1				
Begin Time	**End Time**	**Telescope Status**	**Tilt**	**Pointing**
06:25:00	08:01:00	Commissioning	-	-
08:01:00	08:12:00	Observations	-5.8°	0.0°
08:12:00	08:23:00	Tilting/Observations	-5.8° to -9.62°	0.0°
08:15:00	08:35:00	Commissioning	-9.62°	0.0°
08:38:00	11:24:00	Observations	-9.62°	0.0°
11:25:00	12:02:00	Observations	-8.62°	0.0°
12:03:00	12:26:00	Tilting/Observations	-8.62° to -2.69°	0.0°
12:26:00	12:42:00	Observations	-2.69°	0.0°
12:43:00	12:55:00	Tilting/Observations	-2.69° to -9.69°	0.0°
12:55:00	13:39:00	Observations	-9.69°	0.0°
13:40:00	13:52:00	Observations	-9.69°	315.0°
13:52:00	-	Shutters Closed	-5.8°	315.0°
Night 2				
Begin Time	**End Time**	**Telescope Status**	**Tilt**	**Pointing**
05:37:00	05:40:00	Observations	-8.6°	0.0°
05:40:00	05:58:00	Tilting/Observations	-8.6° to -1.68°	0.0°
05:58:00	06:46:00	Observations	-1.68°	Spinning
06:47:00	07:02:00	Tilting/Observations	-1.68° to -7.6°	Spinning
07:02:00	07:10:00	Observations	-7.6°	Spinning
07:10:00	09:24:00	Troubleshooting	-7.6°	Spinning
09:10:00	12:40:00	Observations	-7.6°	Spinning
12:40:00	-	Shutters Closed	-7.6°	Spinning

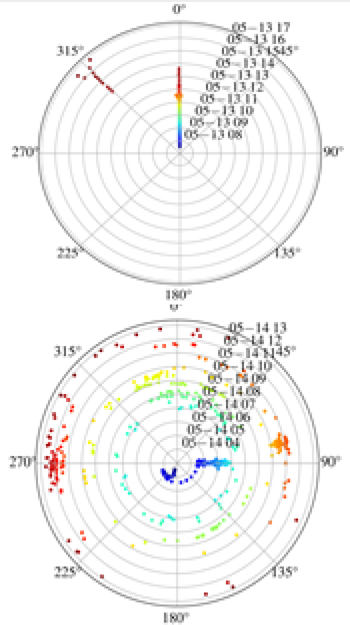


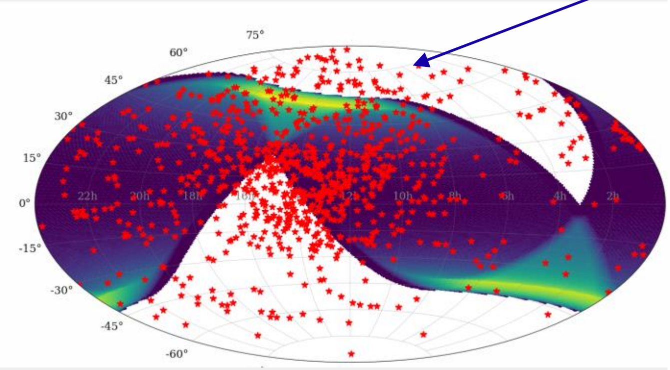
Mask	Uncertainty
Mask 1	0.7023°
Mask 2	0.0068°
Mask 3	0.1110°
Mask 4	0.3852°
Mask 5	1.4843°
Mask 6	1.3288°
Mask 7	0.0161°
Mask 8	0.0341°
Mask 9	0.0396°
Mask 10	0.0393°
Mask 11	0.1432°
Mask 12	2.2192°

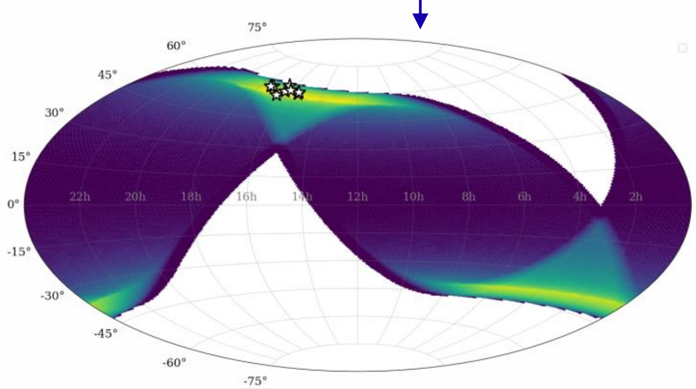


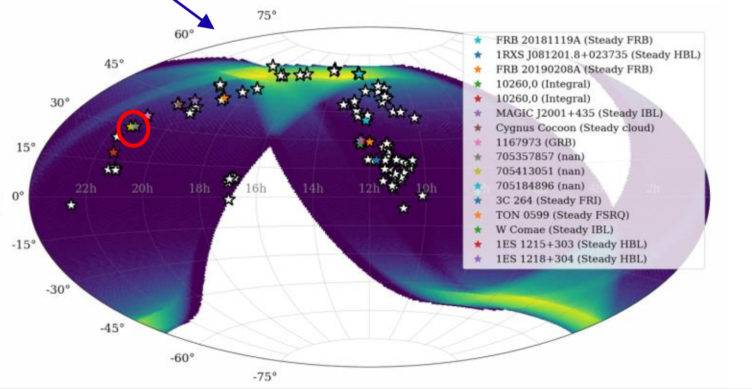
ToO Sources Candidates

Alert system	Total number of sources	Recent sources following the prioritization scheme	Sources in the Field of View night 1	Sources in the Field of View night 2
GCN	12965	56	0	6
TNS	151658	736	(7)	(72)
Steady	121	121	0	10
Other	24	8	0	0
Total	164768	922	(7)	88



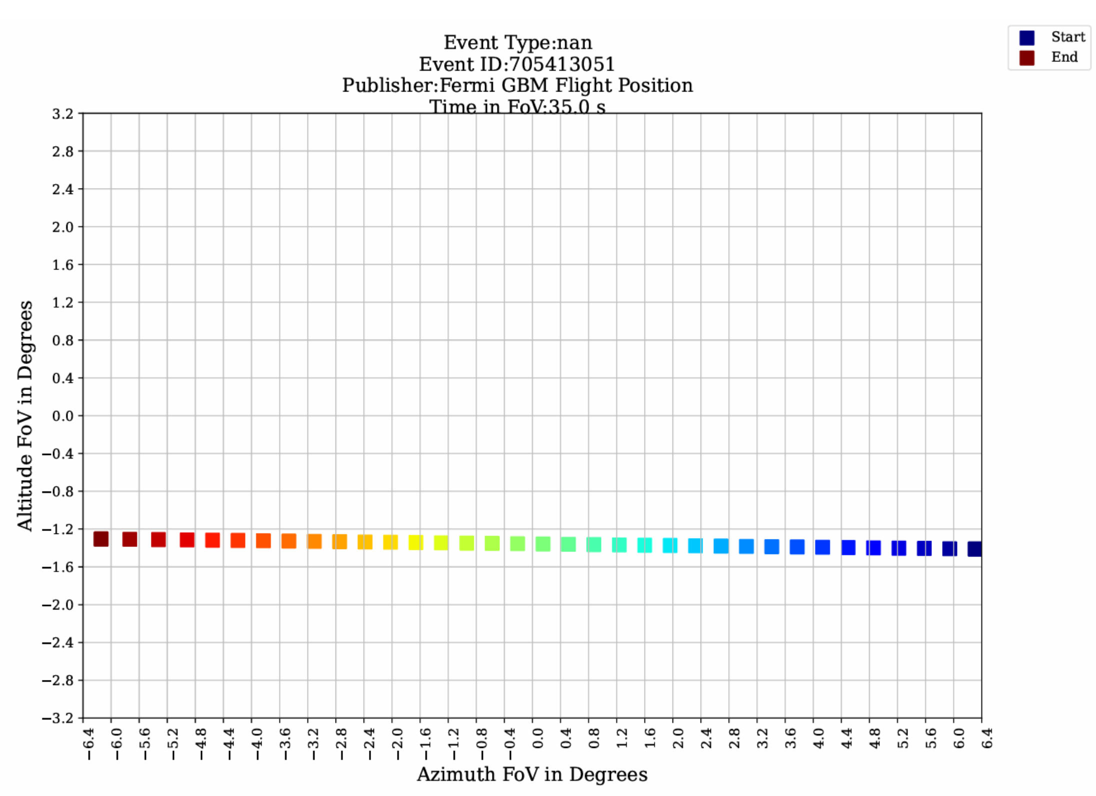






Example ToO Source

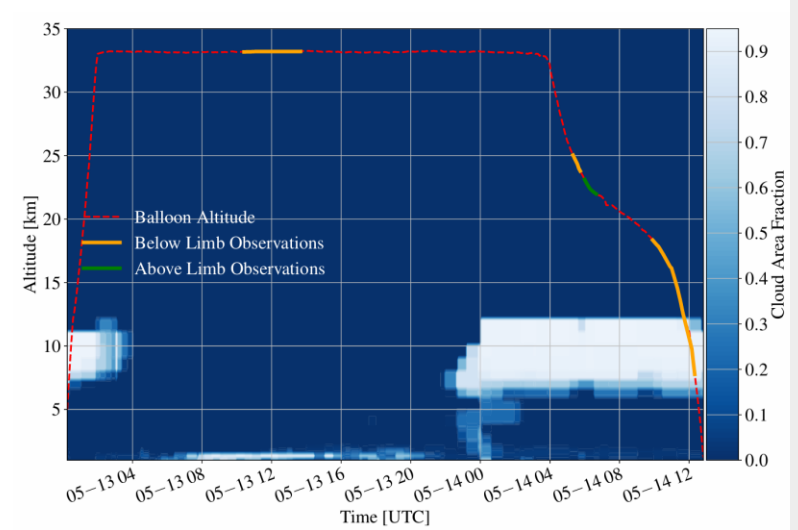
- Example source chosen:
  - Fermi 705413051 alert
  - GRB 230510A
- Observed at:
  - 12:04:06.93 on 10 May 2023
  - RA: 318, DEC: 34
  - T90: 144s
- Total time in the FoV:
  - 35s



Flight Cloud Coverage

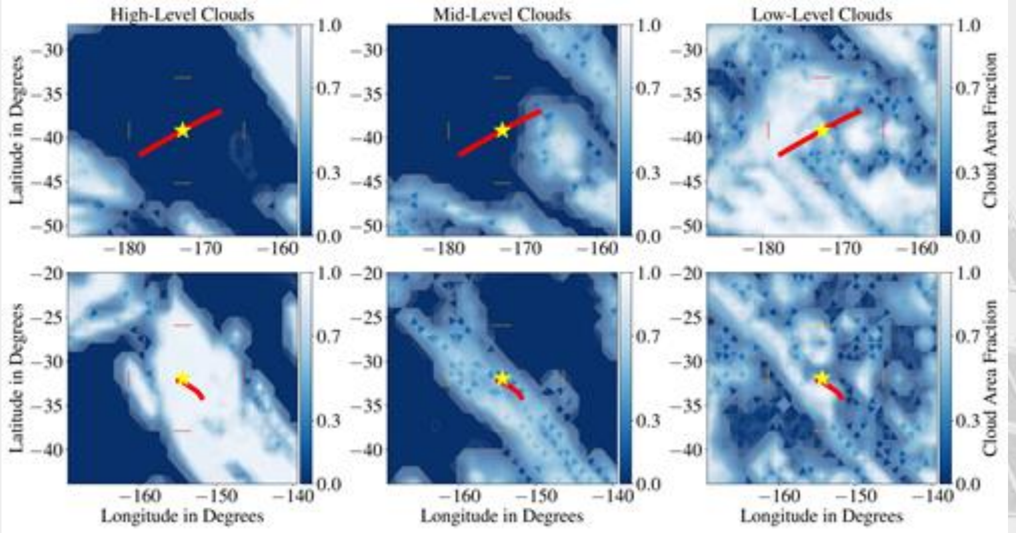
- Assumed homogenous cloud cover
  - Night 1: low-level (2km)
  - Night 2: high-level (12km)

- Clouds impact neutrino acceptance
  - Need light creation above clouds
  - Requirement on Energy and tau decay location

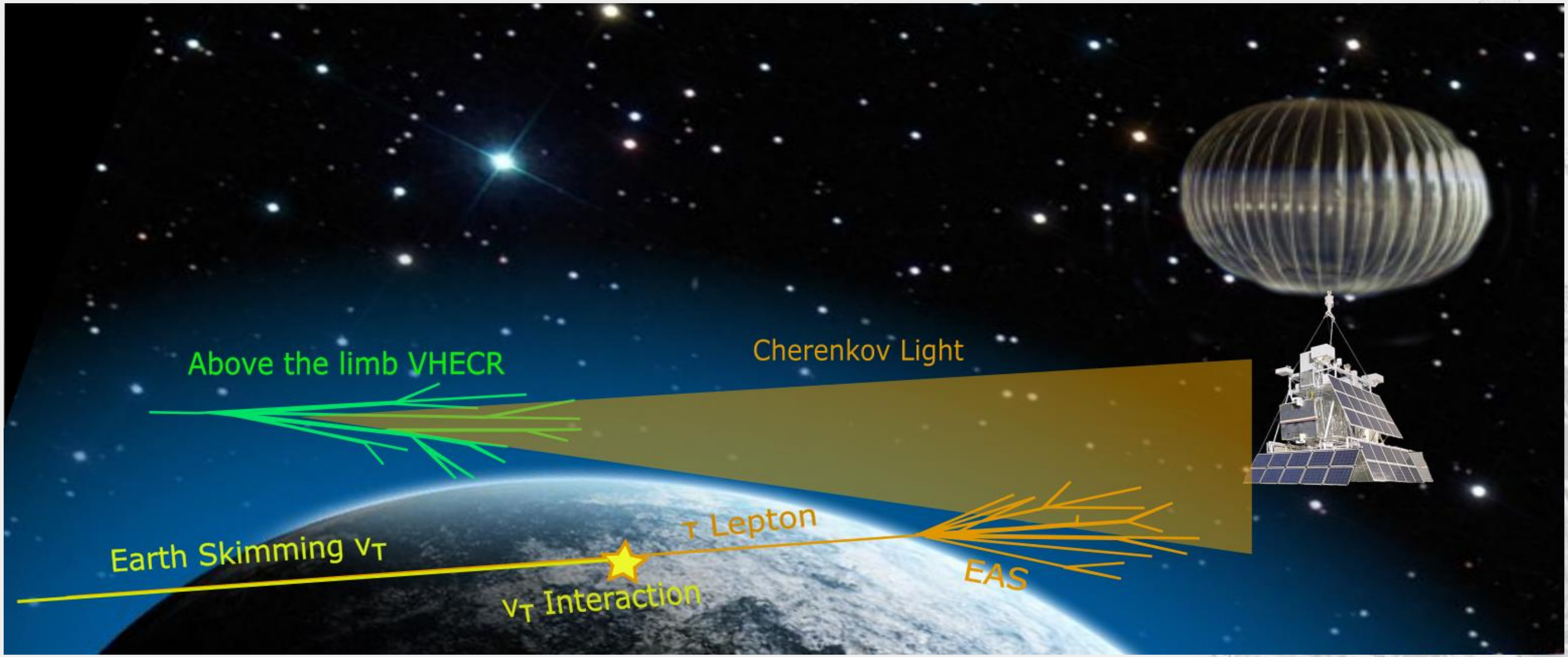


Night 1

Night 2



General CT Simulation Chain



Cosmic Ray / Neutrino Geometry Sampling → EAS / Neutrino Simulation → EAS Cherenkov Light Simulation (EASCherSim) → Detector Simulation

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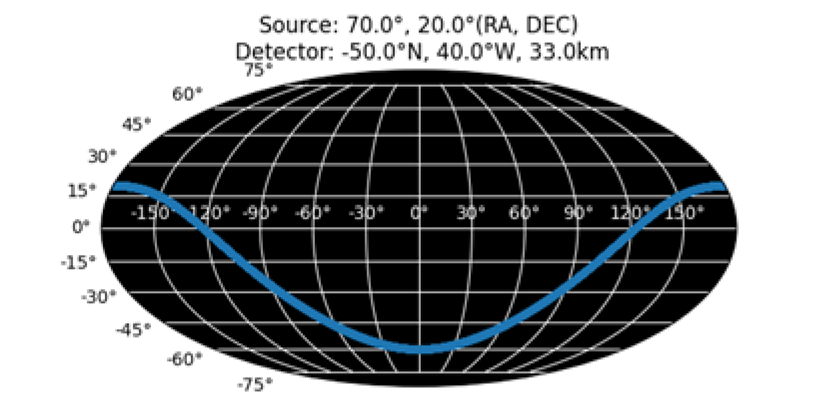
NUTS (Neutrino Target Scheduler)

- Collects alerts from alert networks
  - **GCN** (Uniform alert messages): GRBs, neutrinos, GW, …
  - **TNS** (Machine readable): SN, TDEs, FRB,…
  - **ATels** (Human radable): AGN/Balzar Flares, …
- Calculate position of source in sky based on detector location
  - Flight logs, Constant position, kml file predictions from CSBF
- During Astronomical night calculates when a source would be in observable band (0-6.4deg from limb)
- Select subset of sources based on prioritization scheme
  - Relative distance to source
  - Relative occurrence rate
  - Time source is in FoV



Source Type	Priority
Galactic transient	1
Binary neutron star mergers	2
Tidal disruption events	3
Flaring blazar or active galactic nuclei	4
Gamma-ray bursts	5
Supernovae outside of the galaxy	6
Other transients	7
Steady sources	8

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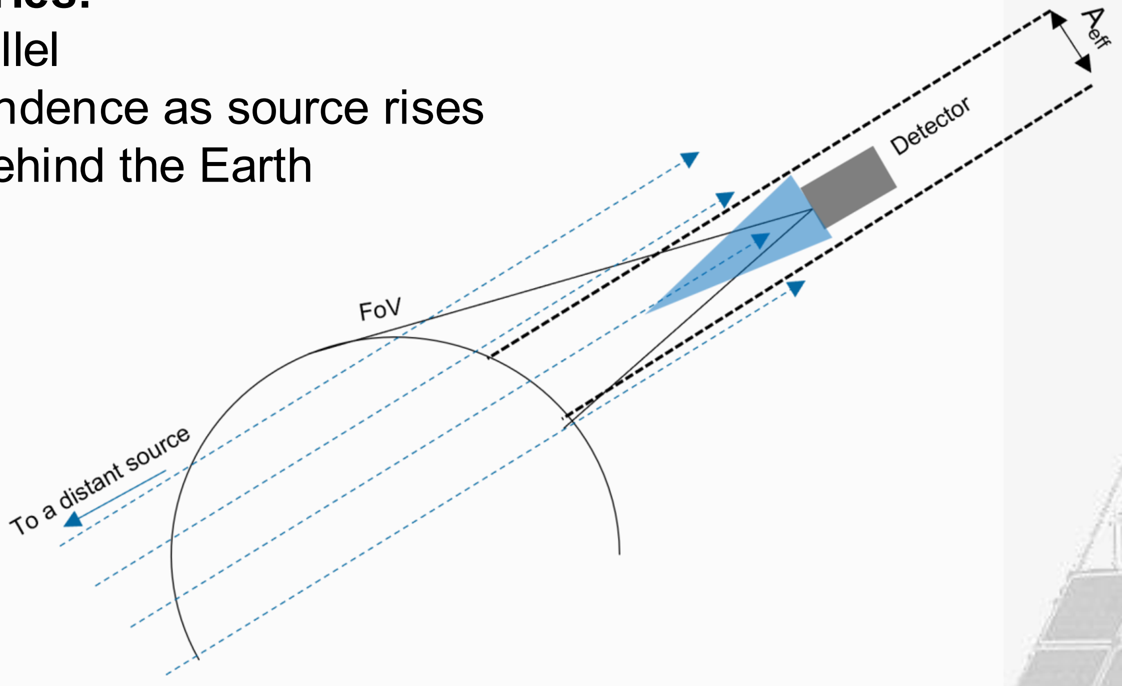
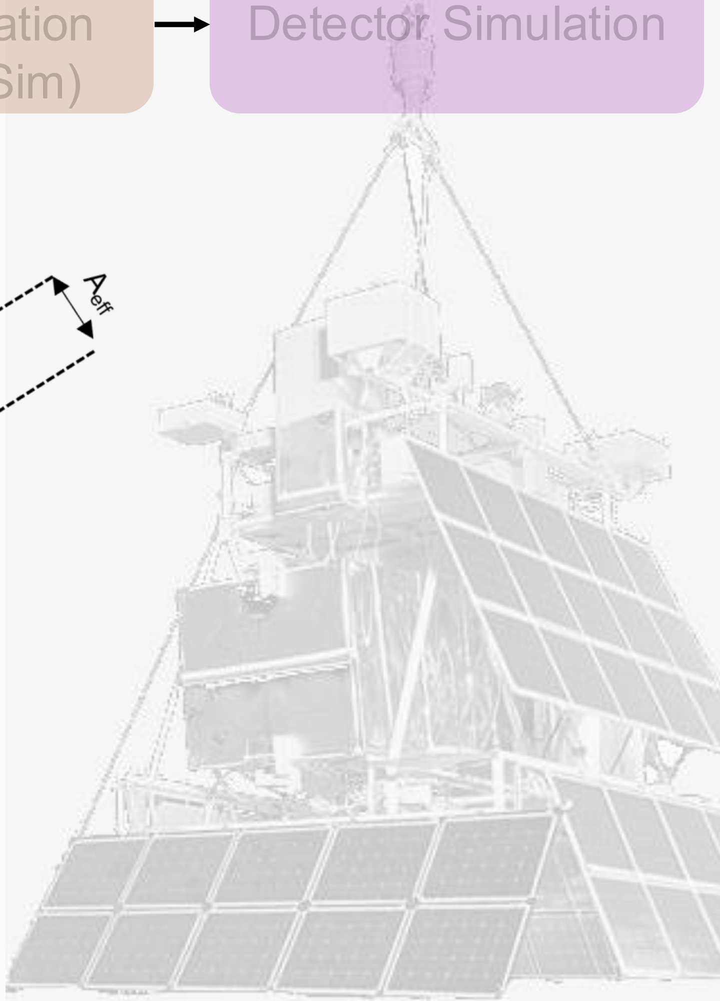
ToO Geometries:

- Quasi parallel
- Time dependence as source rises and sets behind the Earth





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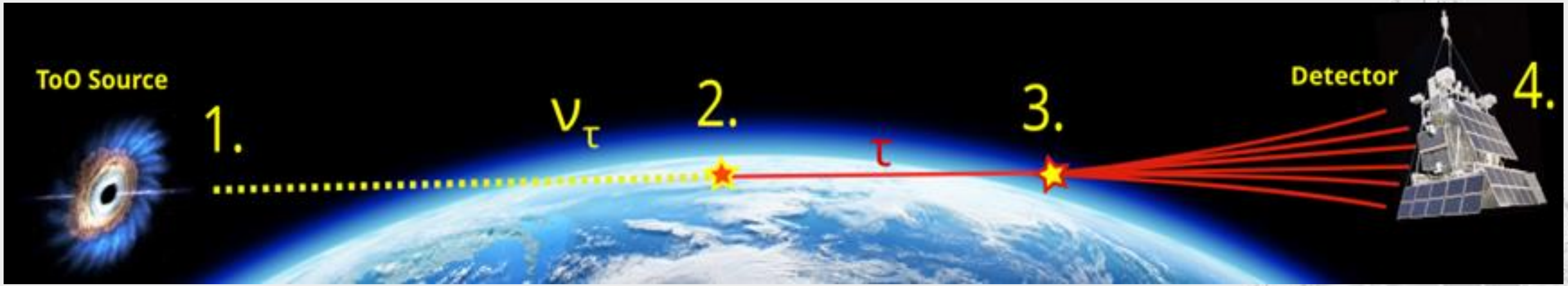

Neutrino Simulation (NuSpaceSim)

2. Samples ν_τ interaction and τ propagations in the Earth to estimate P_{exit} based on NuPyProp/NuLeptonSim tables
3. Samples τ probability based on exponential decay and produces EAS
4. Uses NuSpaceSim internal EAS model or samples EASCherSim shower library

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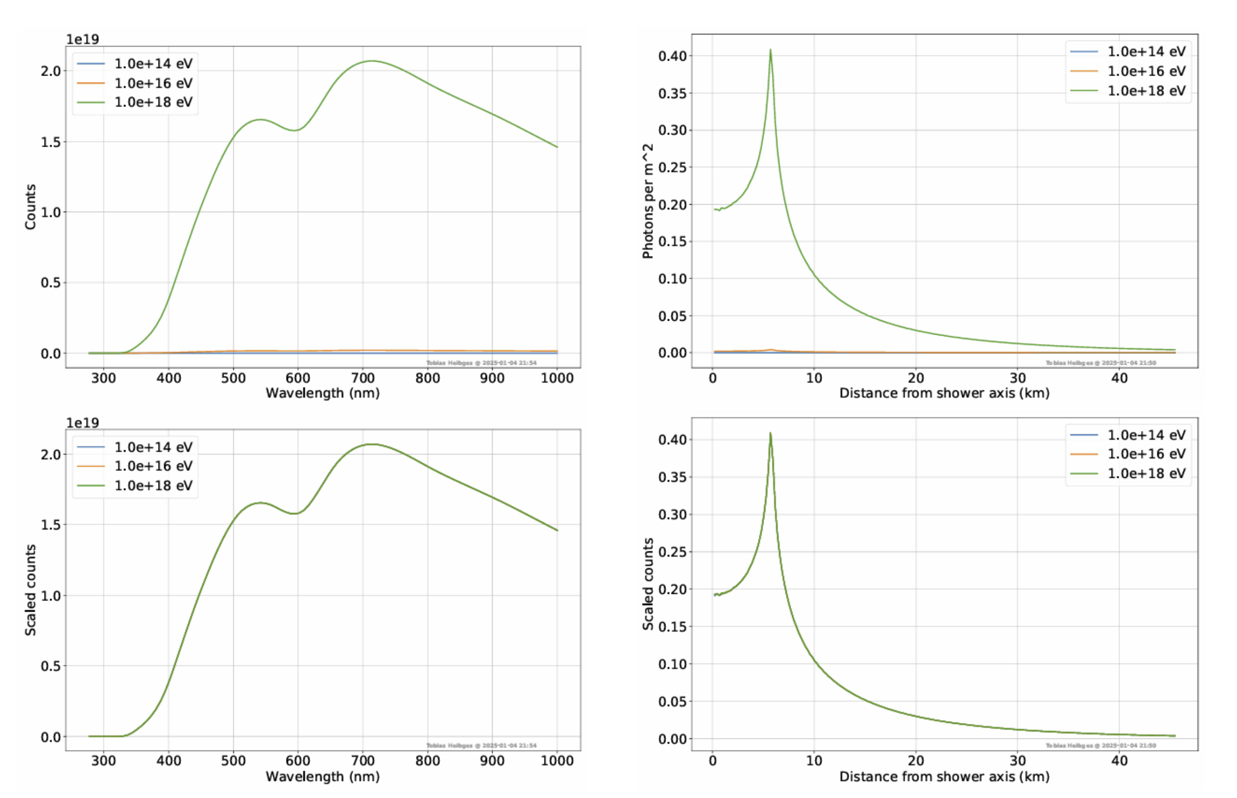

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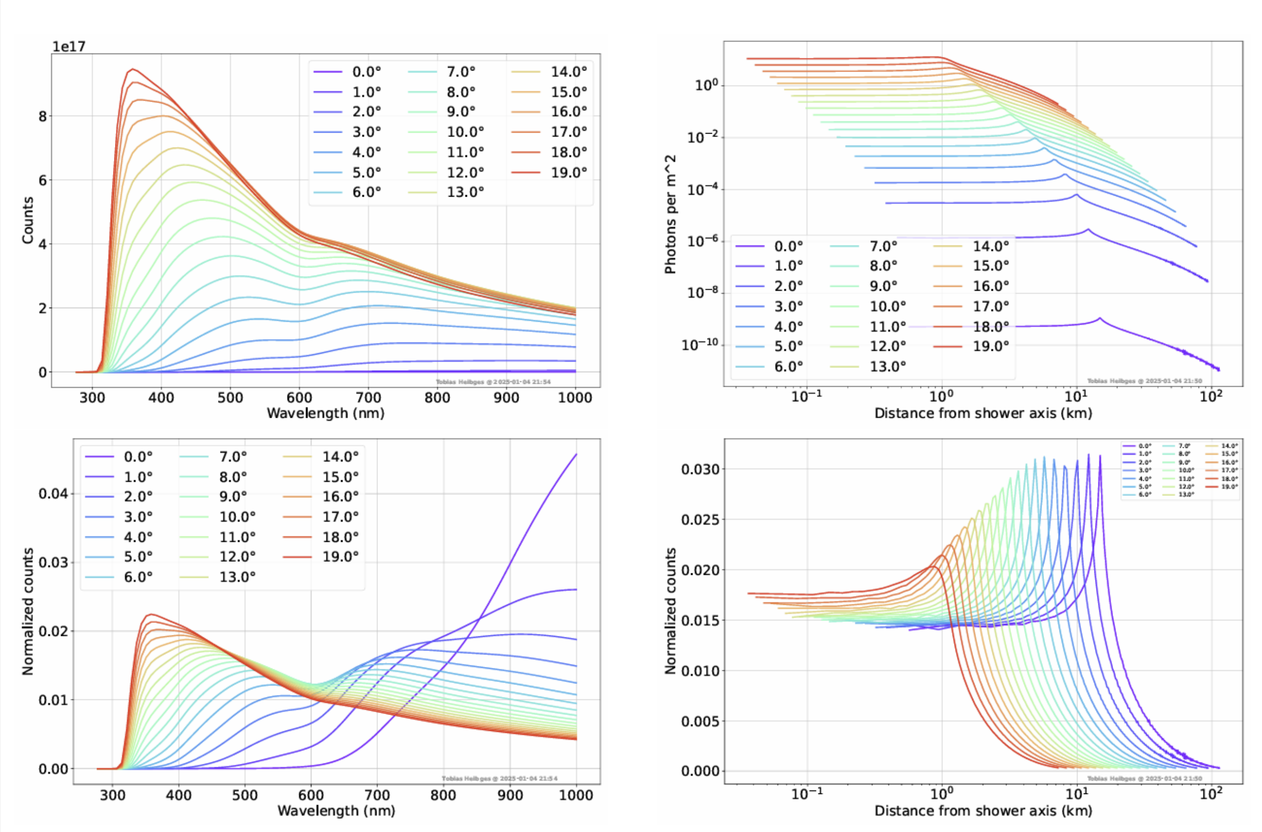

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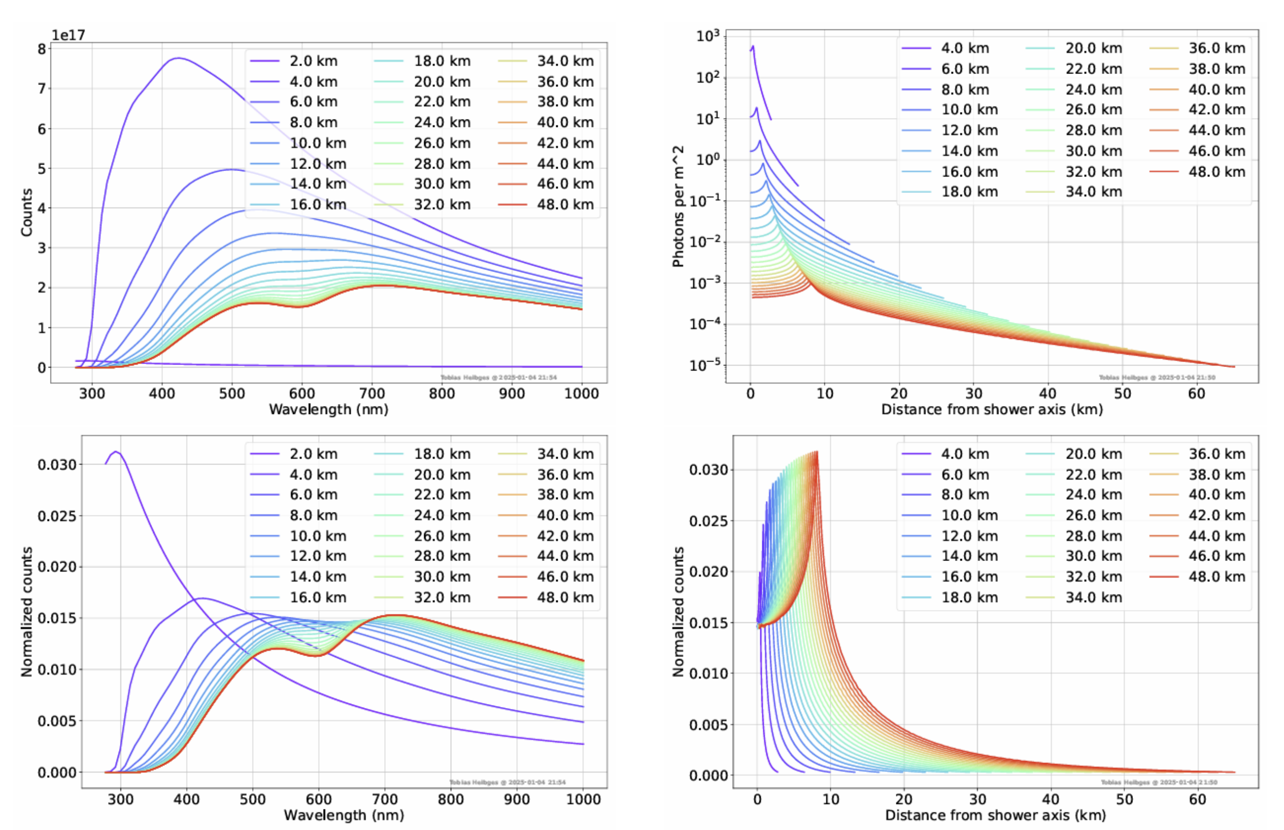

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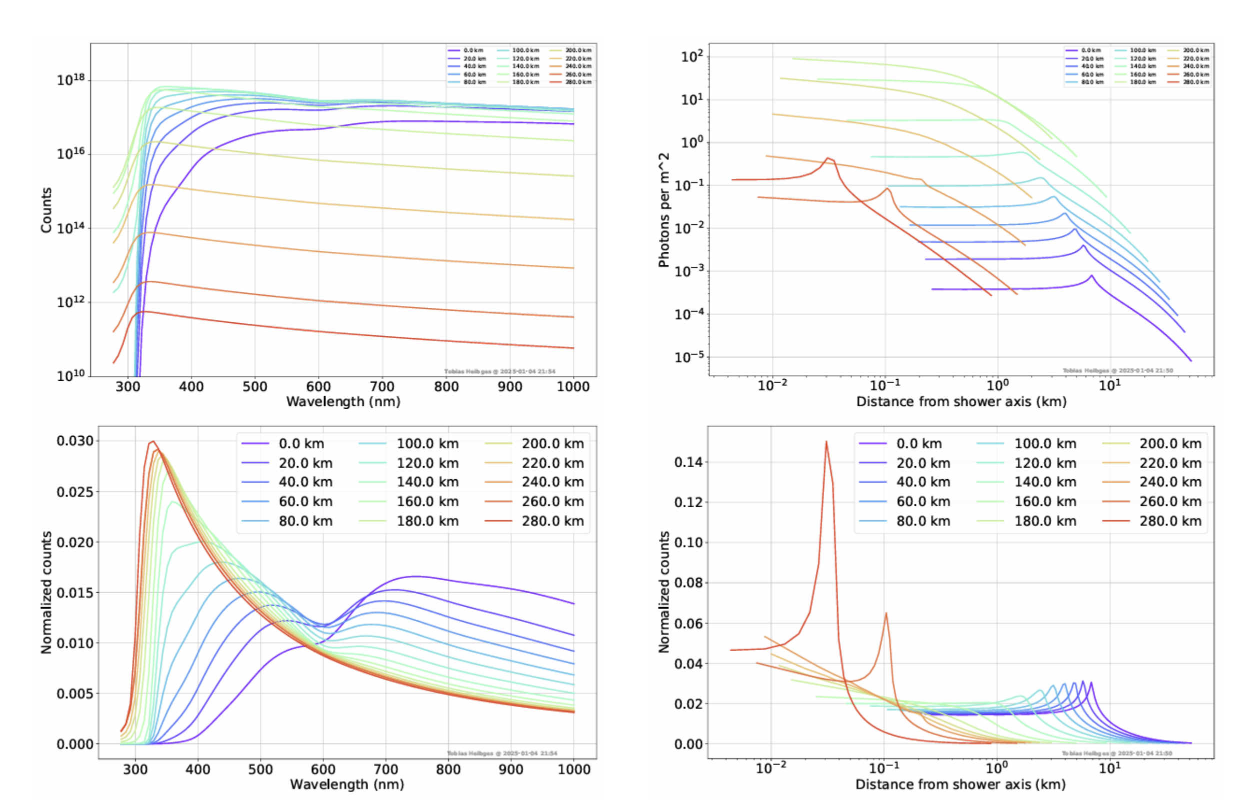

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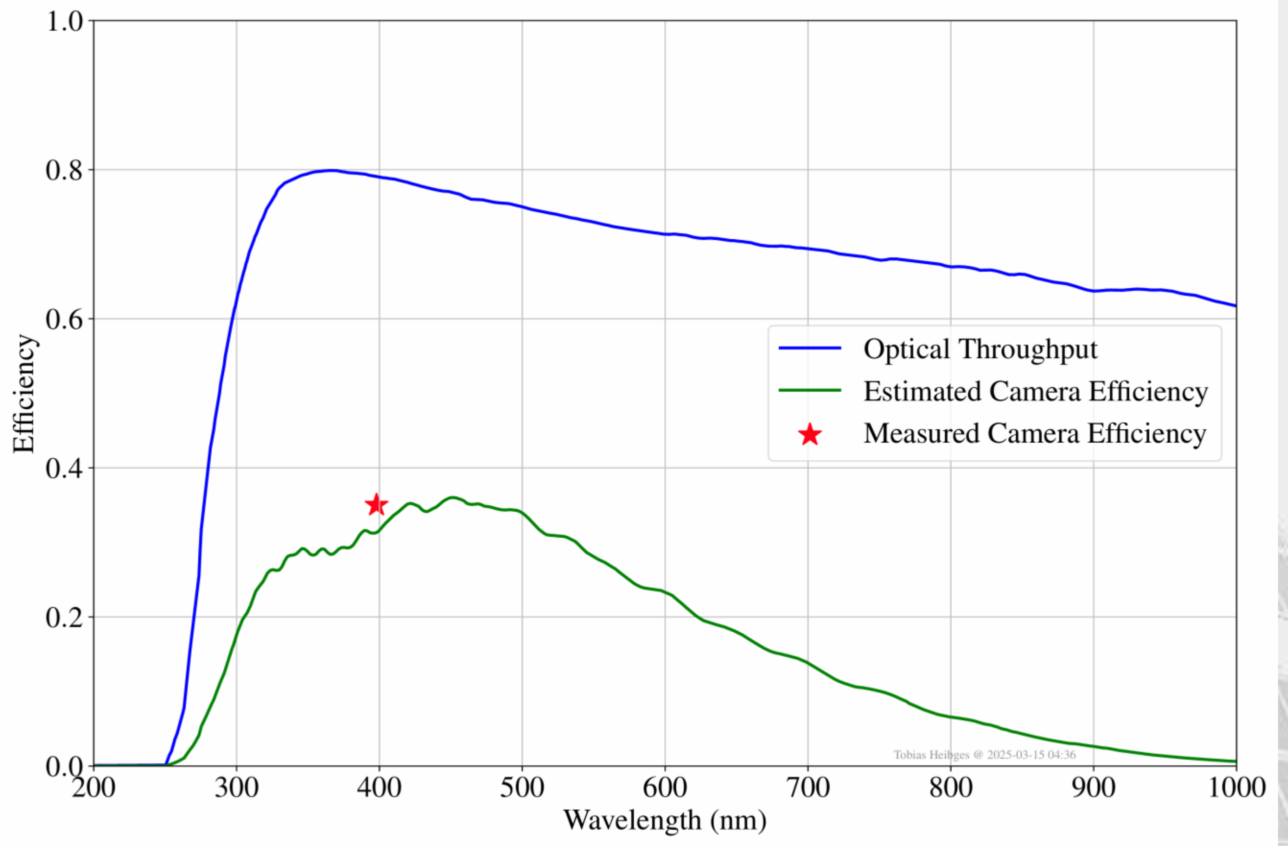
Simplified model includes:

1. ACP throughput
2. Mirror reflectivity
3. SiPM efficiency
4. Gap estimation

Close to absolute calibration efficiency measured in the field



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In depth detector simulation OffLine:

1. Optics simulation (GEANT 4)
2. Photon PE conversion
3. Background simulation
4. Optical cross-talk
5. Bi-focal trigger
6. Signal pile up
7. Output pulse shaping
8. Digitization

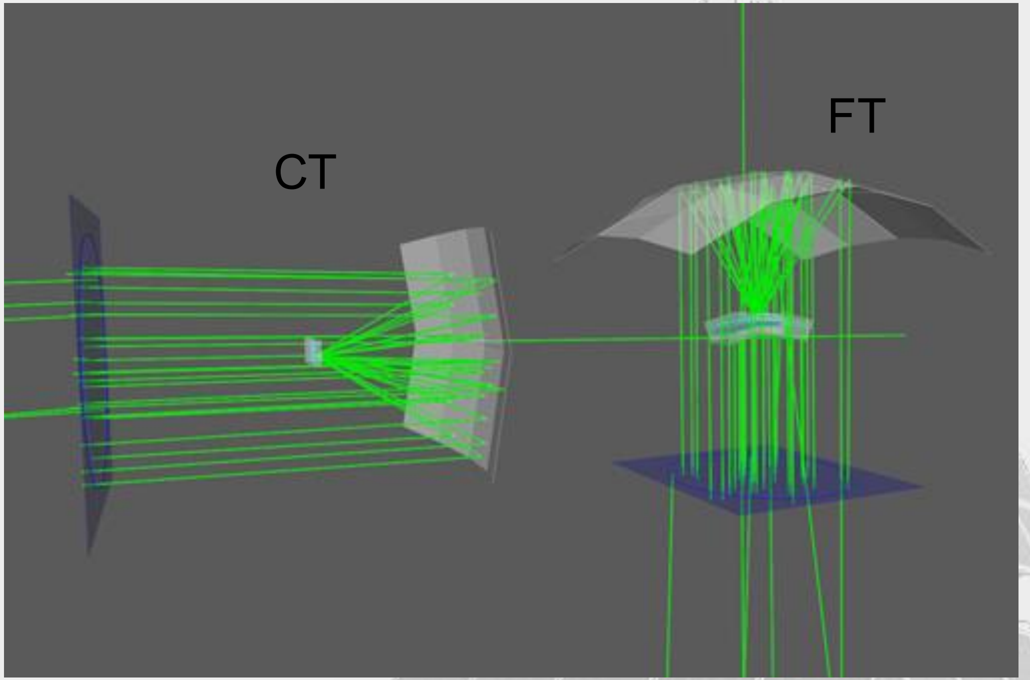
Result: Can not reproduce camera response accurately

- Event by event level
- Derived quantities like trigger rate

Lack of calibration data / understanding of instrument

Only use parts that can be verified: 1, 2

Need a different approach to estimate the camera response

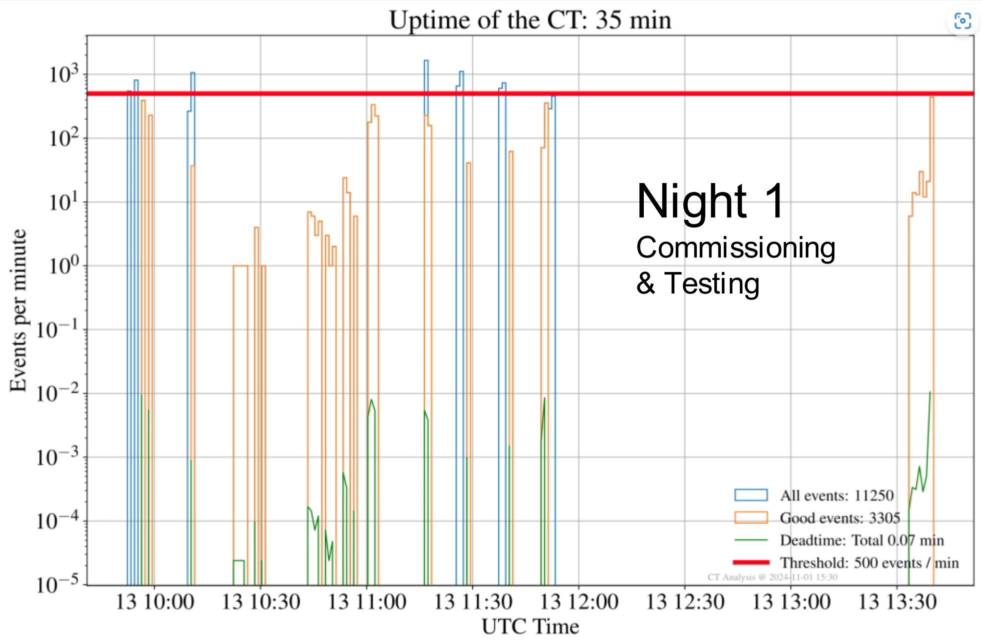


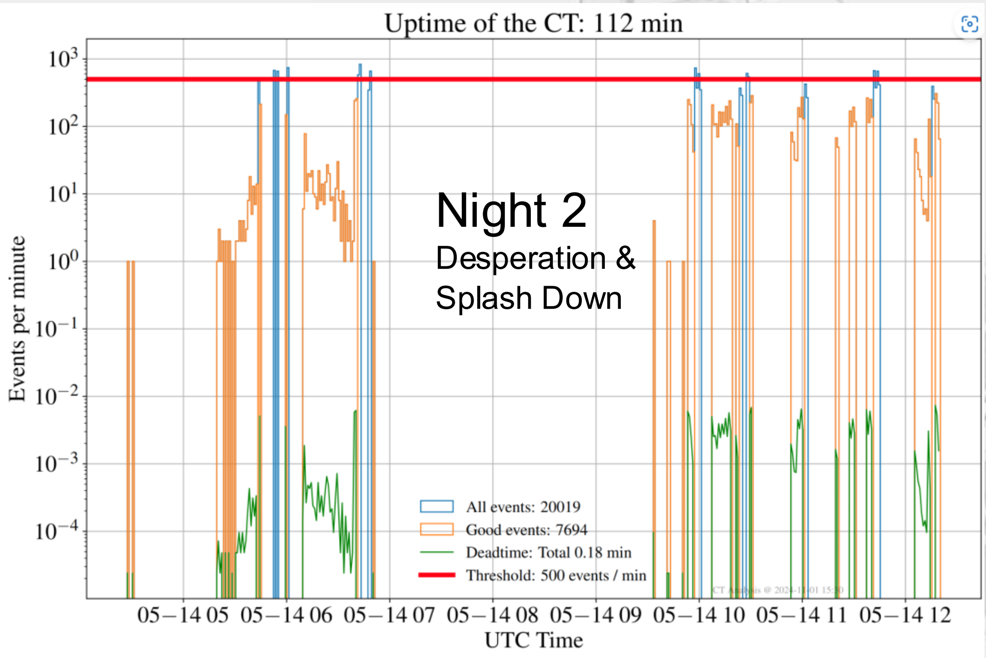
→ Can we rely purely on data?

Observation time

As per recommendation from the GT group time periods with more than **500events/min** are considered over triggered and are remove

	Observation Time (min)	Events Recorded
Night 1	$50 \rightarrow 35$	$11250 \rightarrow 3305$
Night 2	$136 \rightarrow 112$	$20019 \rightarrow 7694$
Night 2 above limb	$41 \rightarrow 21$	$5537 \rightarrow 1043$
Night 2 below limb	$95 \rightarrow 78$	$14482 \rightarrow 6651$





Trigger Threshold Estimation

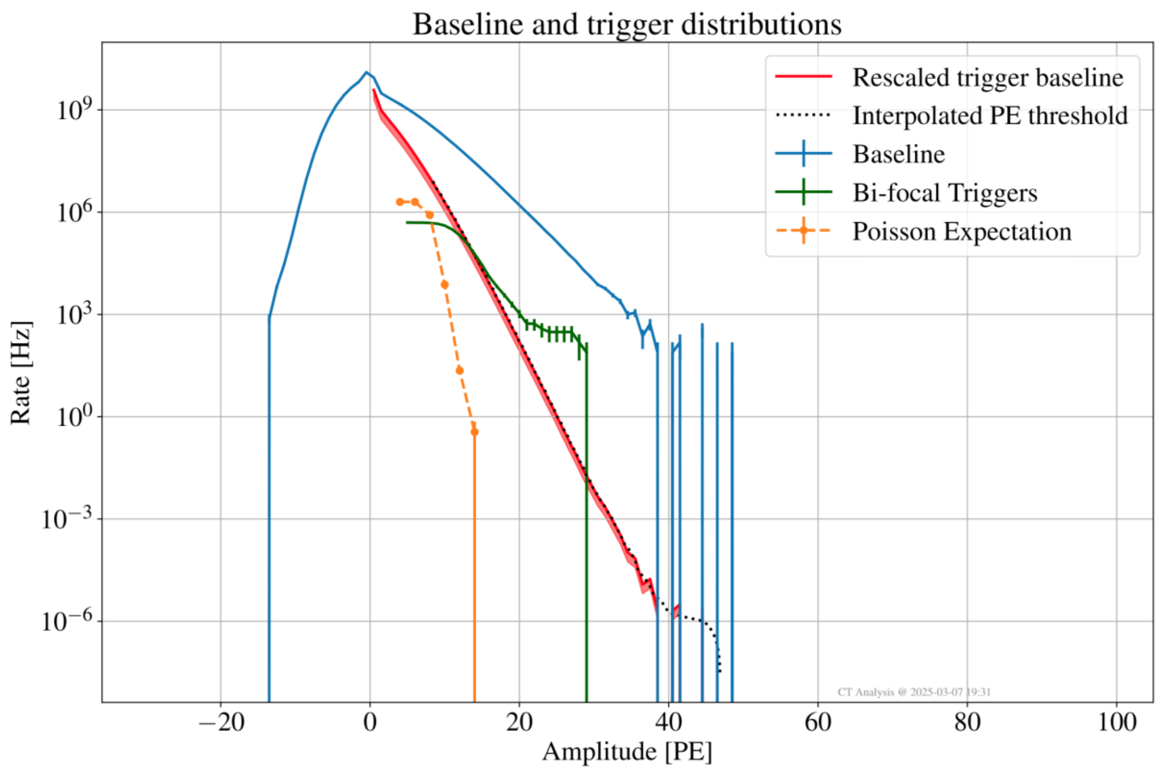
Baseline distribution can be used to estimate Bi-Focal trigger rate for a trigger threshold "a"

$$P_{\text{trigger}} = (2 \cdot n_{\text{timebins}} - 1) \cdot n_{\text{bifocal partners}} \cdot n_{\text{pixels}} \cdot P(x > a)^2$$

Comparison with triggers found in baseline shown

- Saturation at low PE values because only one trigger can be found in 2us
- Most high PE baseline triggers can be identified as 'bad'-events by eye but the algorithm does not catch them

Background rate threshold of 1E-7 Hz



Observation Period	PE threshold	Top BP threshold	Bottom BP threshold
Night 1	67	64	66
Night 2 above the limb	53	34	53
Night 2 below the limb	47	47	44

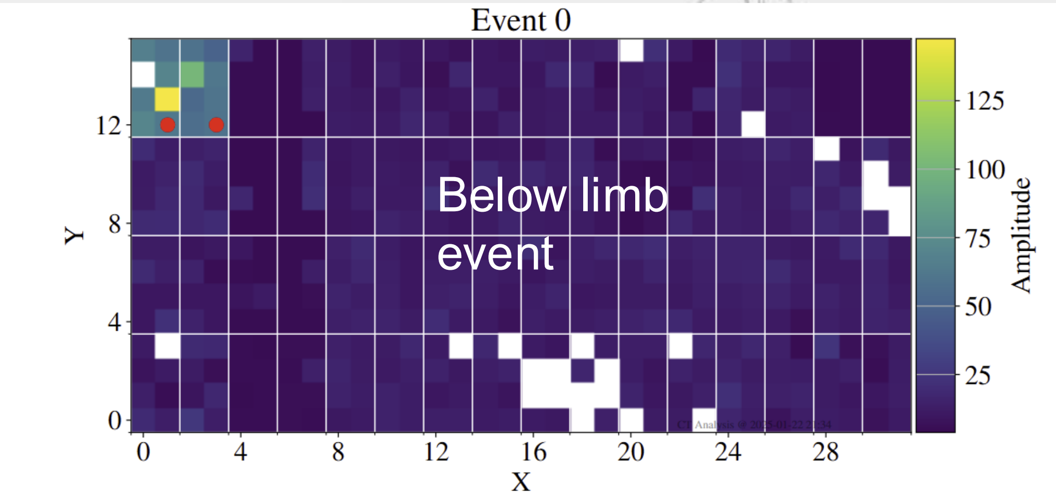
Signal classification

C0: Event triggered off cross-talk

C1: Event is within 2 pixels of an over-triggered pixel or in a separate SiPM matrix

C2: Event is on the edge row of pixels

P: Passing event. The event is by itself, with the camera fully operational.



Observation period	Total number of passing events	C0	C1	C2	P
Night 1 below the limb	0	0	0	0	0
Night 2 above the limb	8	2	1	3	2
Night 2 below the limb	1	0	1	0	0

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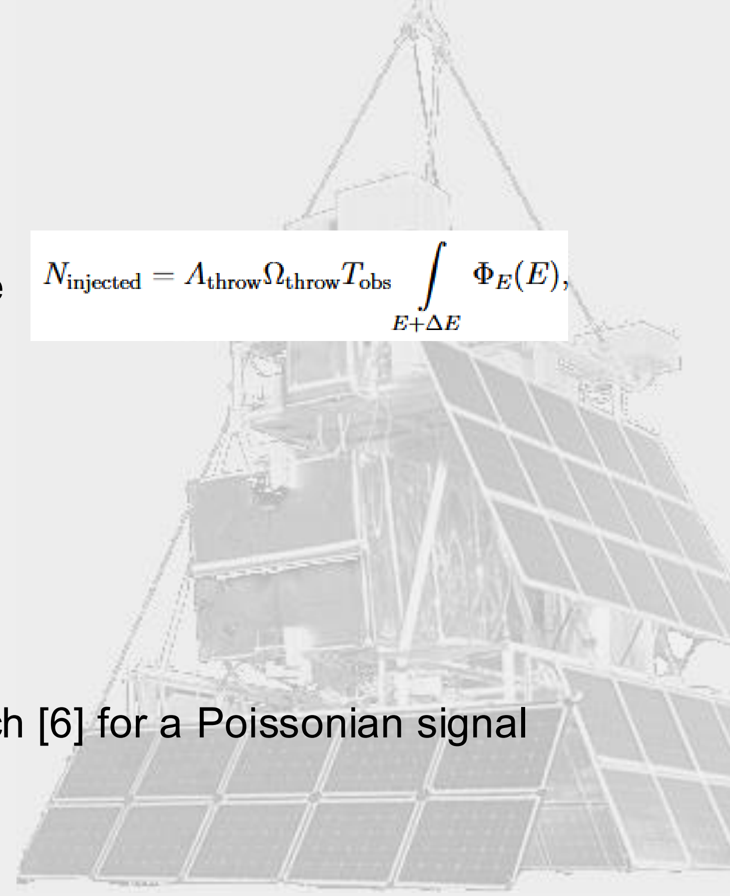


Acceptance can be numerically approximated by $\mathcal{A}(E) = \frac{n_{\text{accepted}}}{n_{\text{thrown}}}$

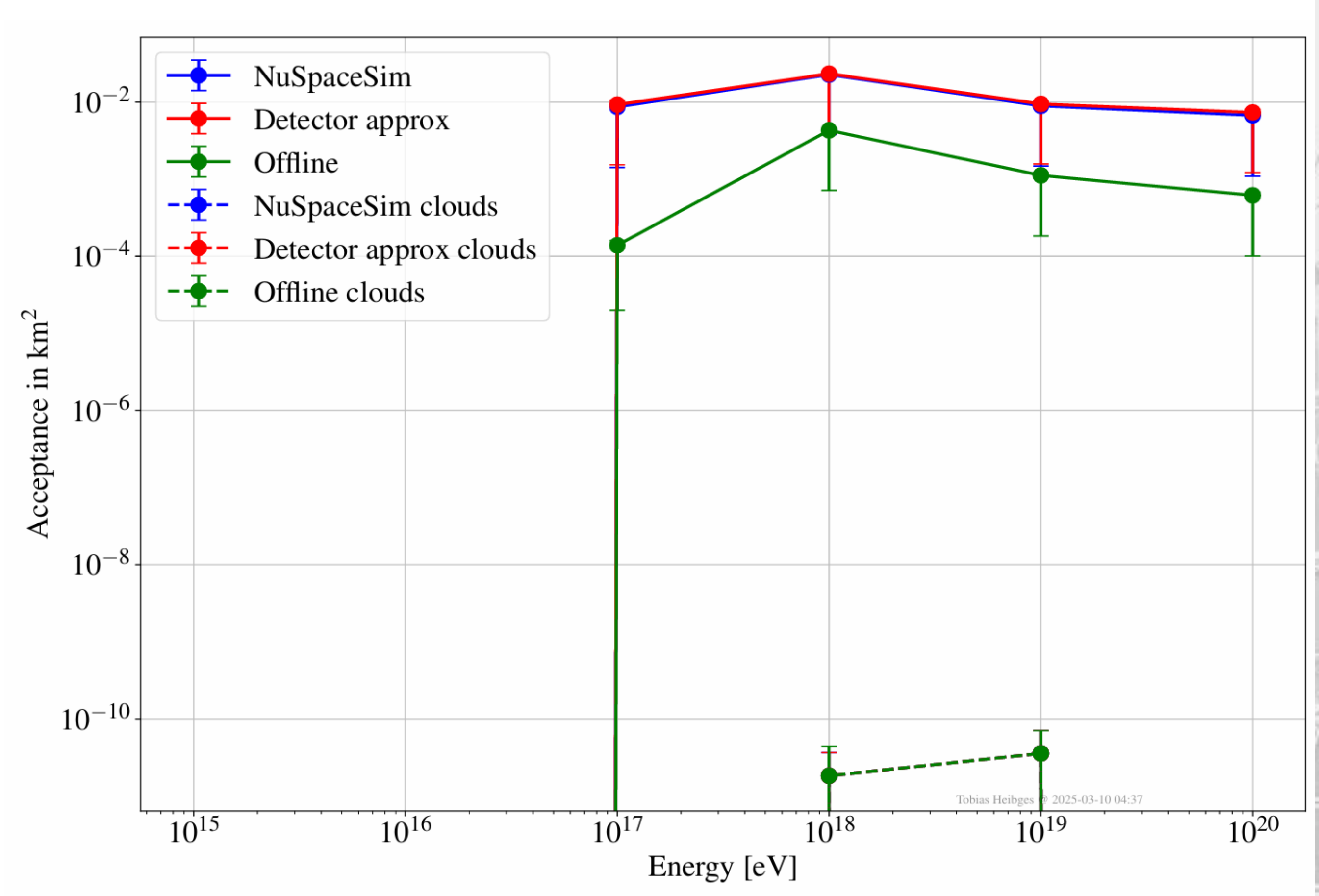
The **number of expected events** is then $N = \int \mathcal{A}(E) N_{\text{injected}}(E)\, dE$ where $N_{\text{injected}} = A_{\text{throw}} \Omega_{\text{throw}} T_{\text{obs}} \int\limits_{E+\Delta E} \Phi_E(E),$

A **Sensitivity Limit** can be calculated using

$$\mathcal{S}_i(E) = \frac{N_{\text{exp}} \cdot 3}{\ln(10) \cdot E \int\limits_{t_0}^{t_0+T} dt\, \mathcal{A}_i(E,t)}.$$

Assuming no signal and no background the Feldmann Cousins approach [6] for a Poissonian signal distribution implies $\mathbf{N_{exp}=2.44}$ for a **90% upper confidence limit**

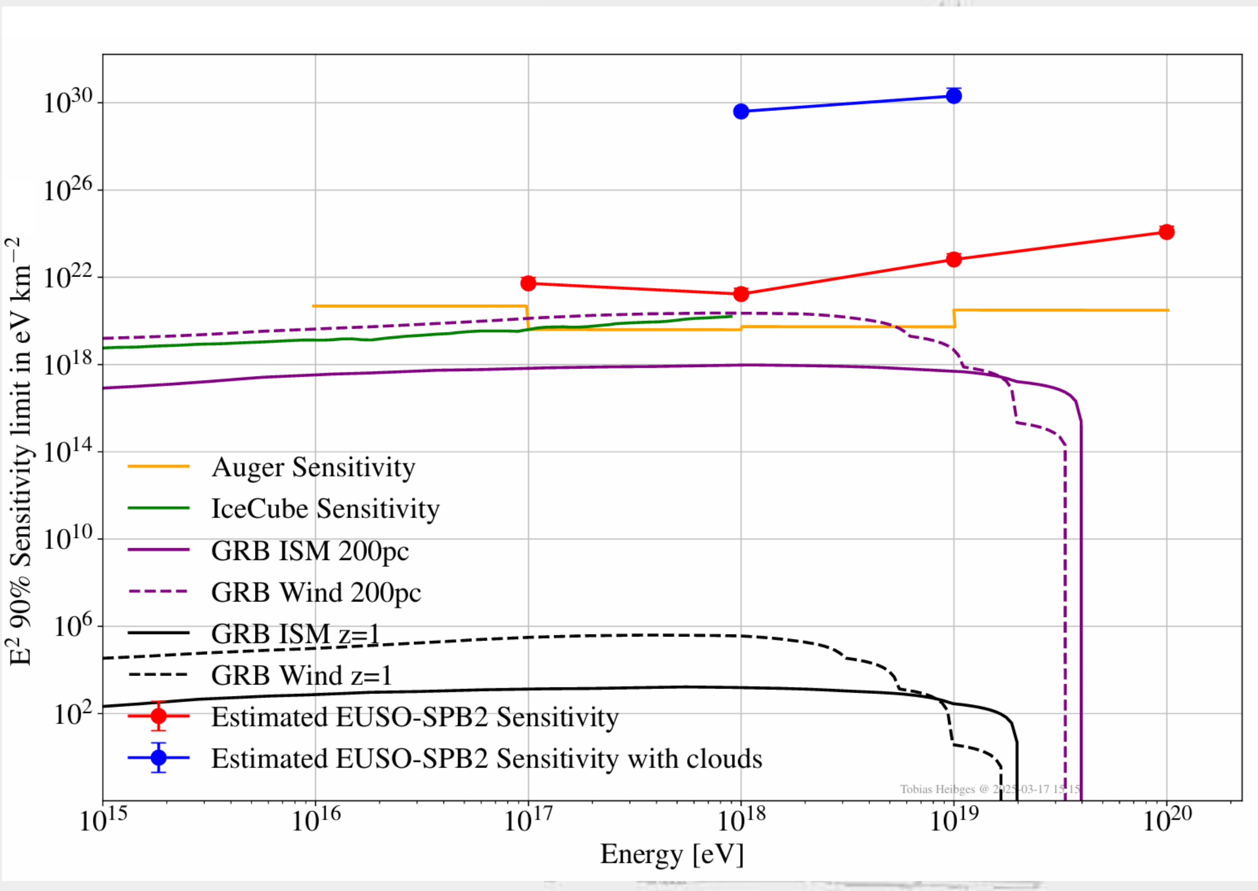
ToO Source Acceptance- GRB 230510A



ToO Source Sensitivity- GRB 230510A

- Comparison of CT Sensitivity with other experiments
- Overlayed is a GRB fluence model for a distance of
  - 200pc
  - Redshift z=1 (~6.7Gpc)
- Expected number of events in 35s at z=1 (~6.7Gpc)

$$
\begin{aligned}
N_{\nu,1,\text{clouds}} &= 2.9^{+4.0}_{-2.1} \cdot 10^{-26} \\
N_{\nu,2,\text{clouds}} &= 6.6^{+9.4}_{-4.6} \cdot 10^{-24} \\
N_{\nu,1,\text{no clouds}} &= 8.6^{+1.2}_{-7.4} \cdot 10^{-18} \\
N_{\nu,2,\text{no clouds}} &= 2.0^{-2.6}_{-1.7} \cdot 10^{-15}.
\end{aligned}
$$



ICRC Proceedings / Journal Paper

- Proceedings are mostly written
- Analysis mostly complete
    - Needs to be cross checked
    - Change units to standard units
    - Rerun more statistics
- Journal paper will be extension of ICRC proceedings
    - Include different sources
    - Projection using SuperBit/Simulated trajectories
    - Fit measured light curve with power law
    - Will include fluence weighting by measured light curve

PoS PROCEEDINGS OF SCIENCE

Using the Cherenkov Telescope onboard EUSO-SPB2 for Target of Opportunity searches of very high energy neutrino sources

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Thank you!

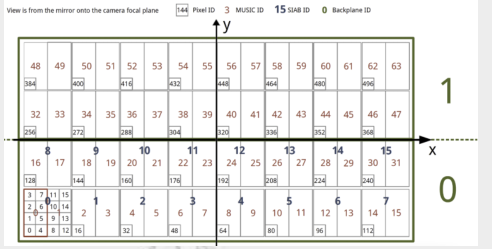
Camera Characterization

Backplane discrepancy

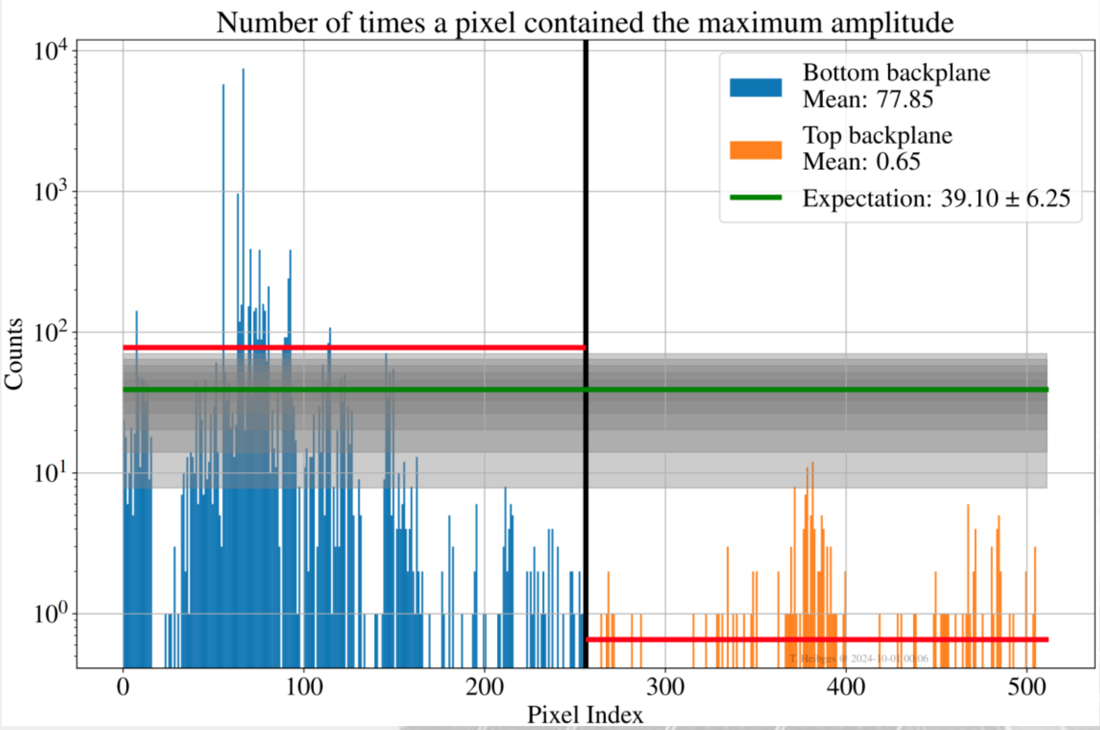
- Number of times a pixels contains the larges peak in the event
- Dominated by a few pixels
- Large discrepancy between top and bottom of camera
  - Expectation Poissonian distribution with mean:

$$\mu = \frac{N_{events}}{N_{pixels}}$$

  - Difference between top and bottom >5σ
- Separate treatment of the backplanes
  - Pixels that contain more triggers than 5σ from expectation are flagged as overtriggering



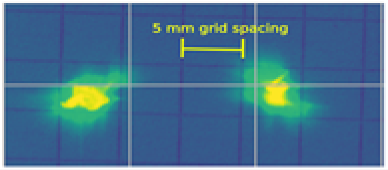
Night 2 above limb

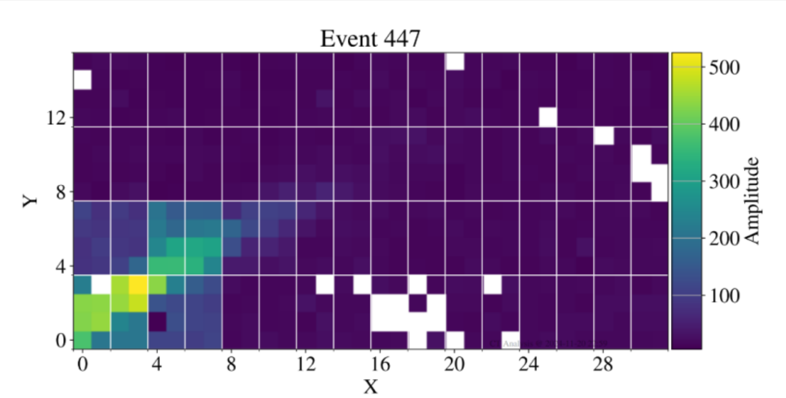


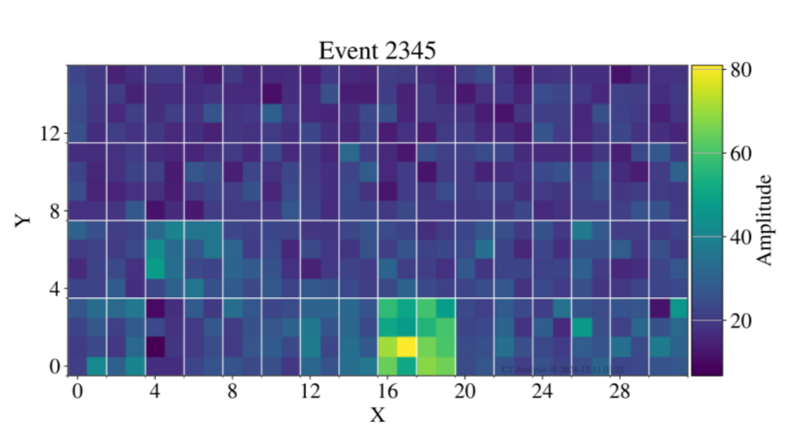
Event Criteria

To select signatures that look like EAS signatures

1. The event has to have **two bifocal spots each above the PE-threshold**
2. The triggering pixels are **not overtriggering**
3. The peak occurs in the **same 10ns timebin**





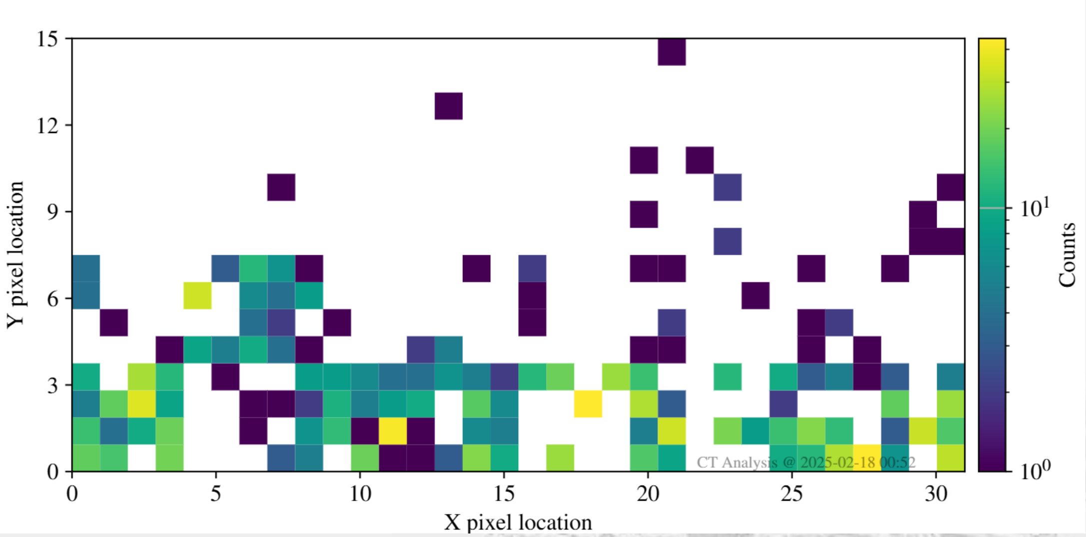


Observation Period	Number of events before	Number of events cut	Number of events after
Night 1	3305	2148	66
Night 2	7694	4135	66
Night 2 above the limb	1043	568	53
Night 2 below the limb	6651	3567	44

Overtriggering pixels

- Dominated by a few pixels
- Large discrepancy between top and bottom of camera
  - Expectation Poissonian distribution with mean: Nevents/Npixels
  - Difference between top and bottom >5sigma
- Separate treatment of the backplanes
  - Pixels that contain more triggers than 5sigma from expectation are flagged as overtriggering

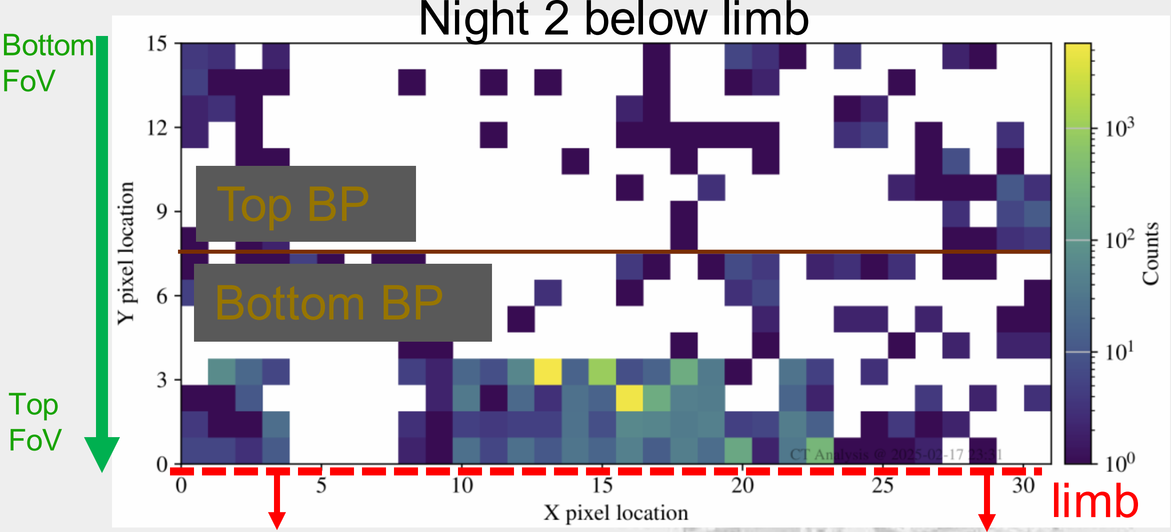
Night 2 above limb

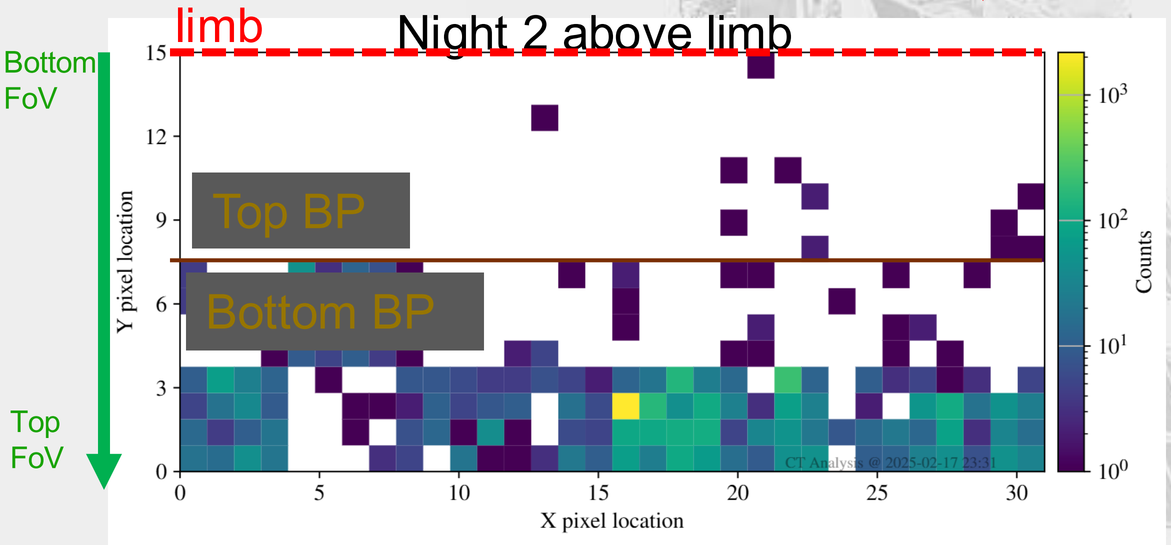


	Number of masked pixels	Top BP	Bottom BP	Camera fraction
Night 1	37	24	13	7.2%
Night 2	23	8	15	4.5%

Trigger Overview

- Number of times a pixels contains the larges peak in the event
- Dominated by a few pixels
- Large discrepancy between top and bottom of camera
  - Expectation Poissonian distribution with mean:
    $$\mu = \frac{N_{events}}{N_{pixels}}$$
  - Difference between top and bottom >5σ
- Separate treatment of the backplanes
  - Pixels that contain more triggers than 5σ from expectation are flagged as overtriggering

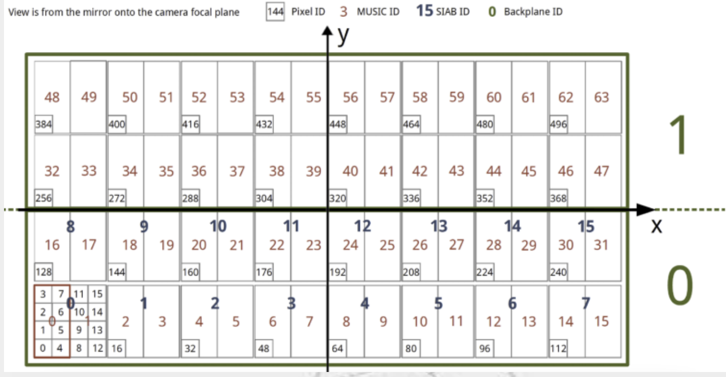




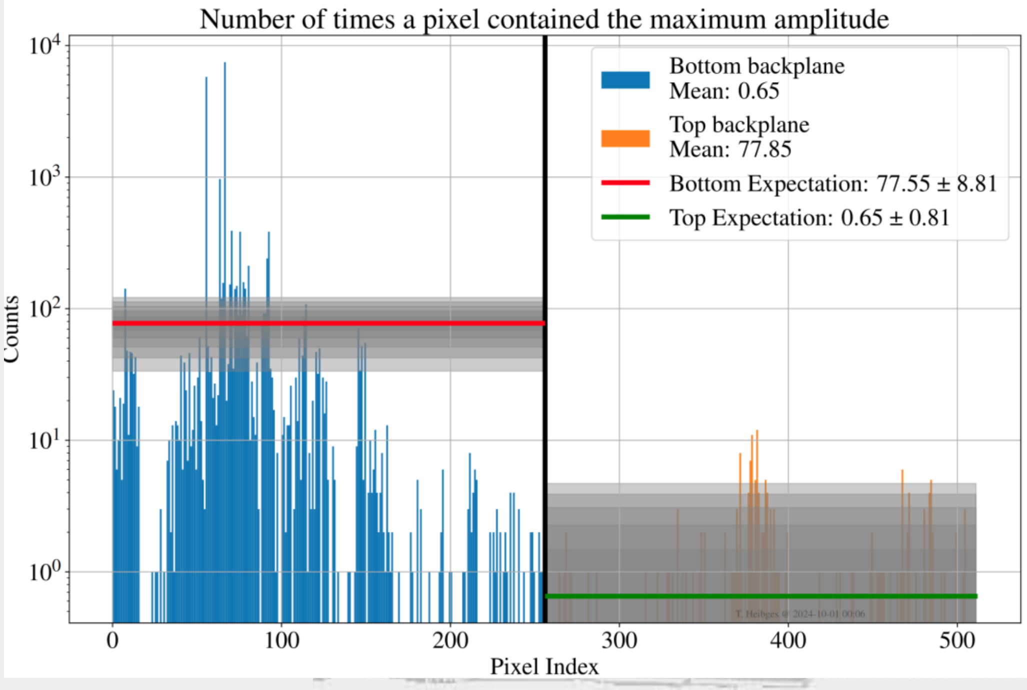
Overtriggering pixels

- Number of times a pixels contains the larges peak in the event
- Dominated by a few pixels
- Large discrepancy between top and bottom of camera
- Separate treatment of the backplanes
  - Expected number of counts:
    $$\mu = \frac{N_{events}}{N_{pixels}}$$
  - Pixels more than 5σ from expectation are flagged as overtriggering

	Number of masked pixels	Top BP	Bottom BP	Camera fraction
Night 1	37	24	13	7.2%
Night 2	23	8	15	4.5%



Night 2 above limb

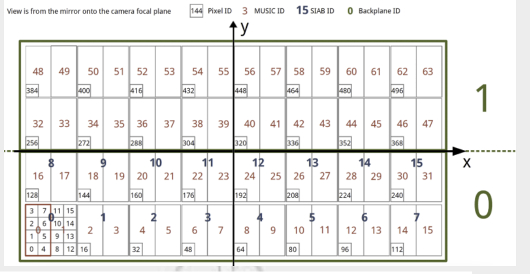


Overtriggering pixels

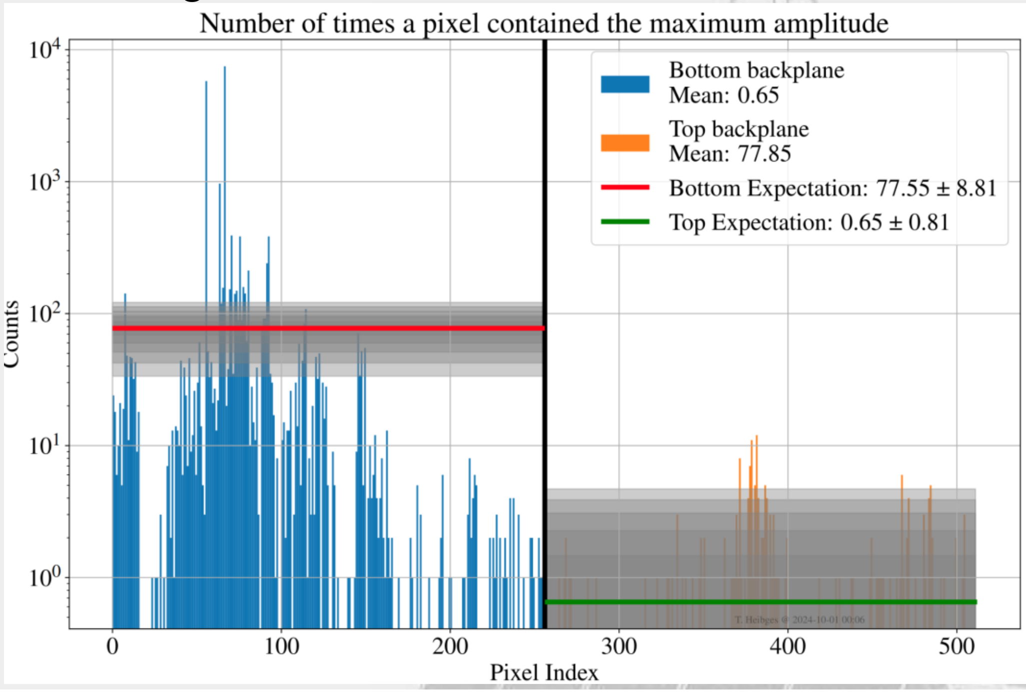
- Number of times a pixels contains the larges peak in the event
- Dominated by a few pixels
- Large discrepancy between top and bottom of camera
  - Expectation Poissonian distribution with mean:

$$\mu = \frac{N_{events}}{N_{pixels}}$$

  - Difference between top and bottom >5σ
- Separate treatment of the backplanes
  - Pixels that contain more triggers than 5σ from expectation are flagged as overtriggering



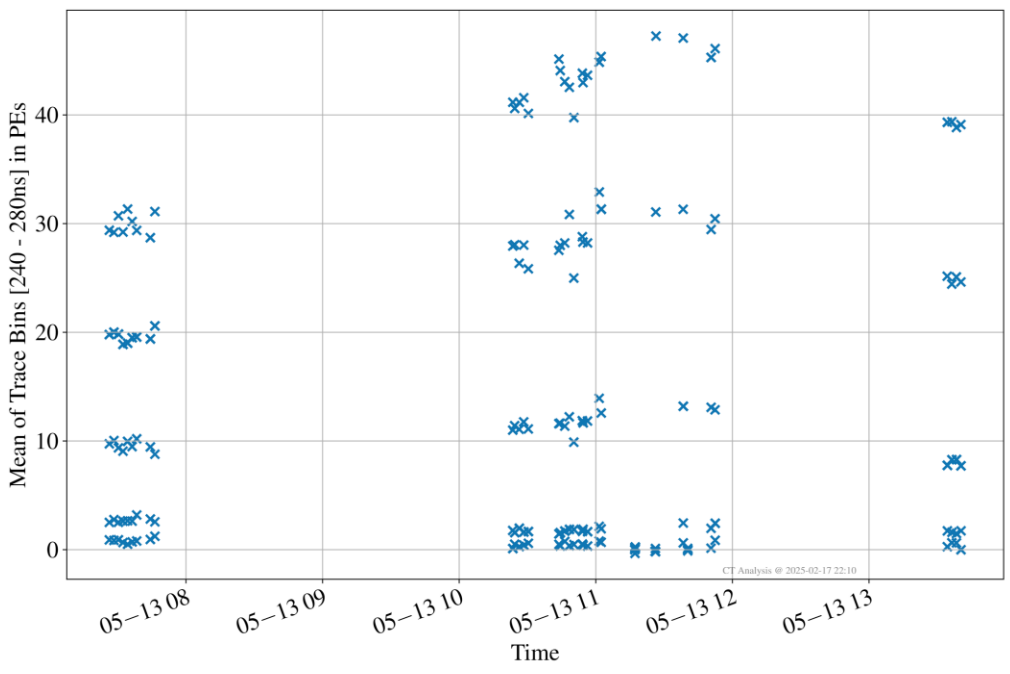
Night 2 above limb

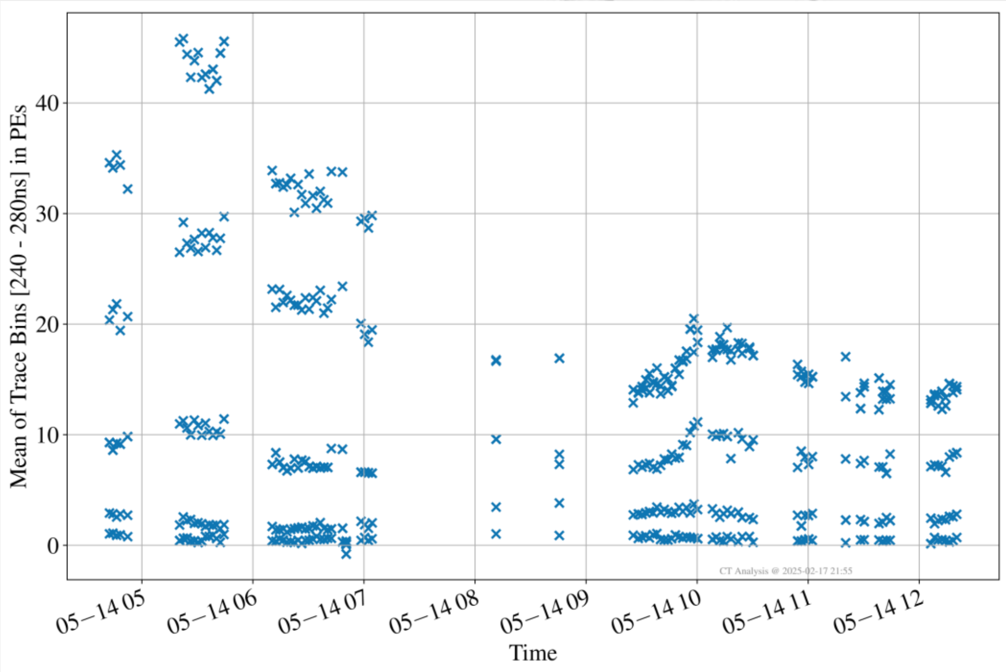


	Number of masked pixels	Top BP	Bottom BP	Camera fraction
Night 1	37	24	13	7.2%
Night 2	23	8	15	4.5%

System Monitoring

- Calibrated Health-LED
  - Flashes at 5 different intensities
- Average values around the central peak

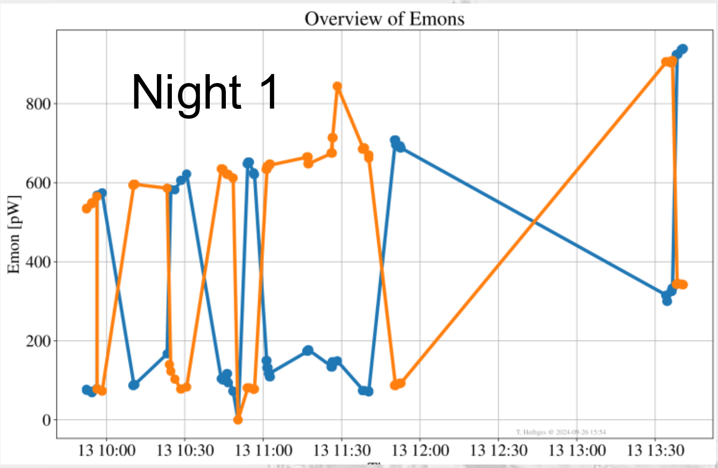


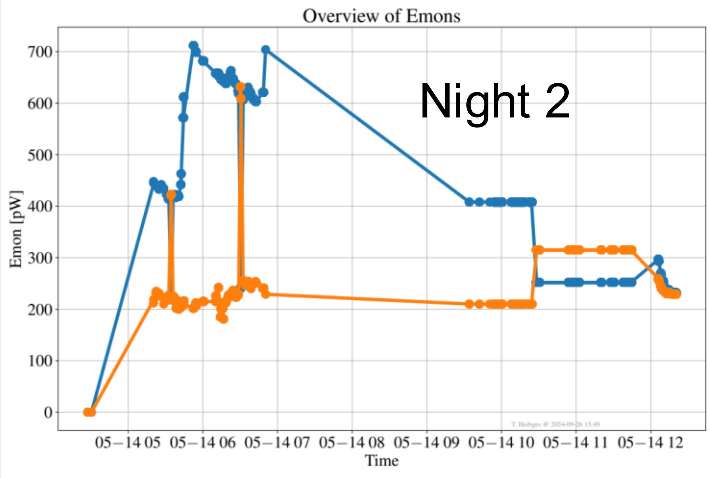


Observation Conditions

System	Acceptable range	Status during flight
HVPS	40-44V	✓
LVPS	24-26V	✓
CoBo Temp	<60C	✓
SiPM Temp	<30C (<25C preferred)	✓
EMONs	<300 pW (<100pW preferred)	x

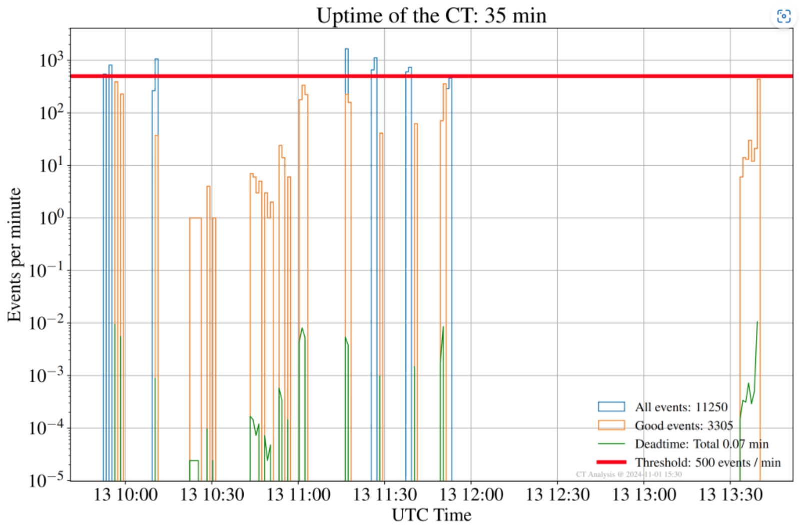
- Two EMONs mounted above and below the camera
- No clear labeling of EMON1 and EMON2
- 2 Scenarios:
  - One side of the camera sees significantly more light than the other
  - One of the EMONs is malfunctioning

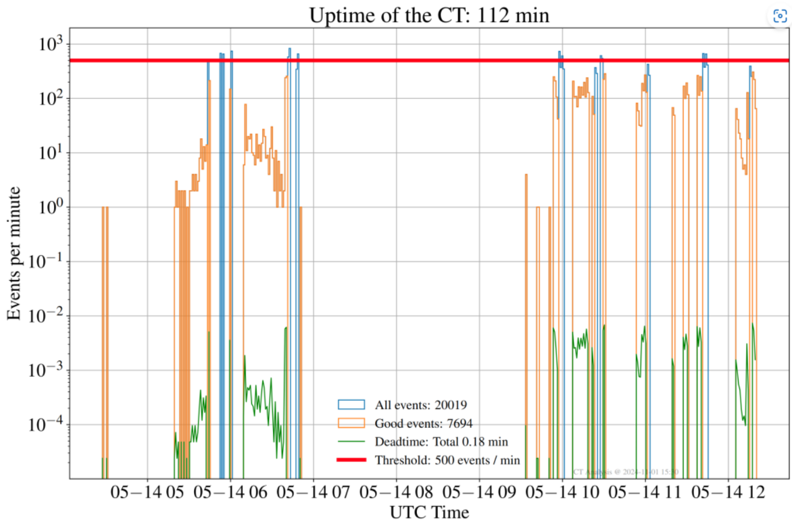




Observation time

- Commissioning and testing lead to frequent on-off changes
- As per recommendation from the GT group time periods with more than **500events/min** are considered over triggered and are remove
- Nominal dead-time of 1.44ms per event

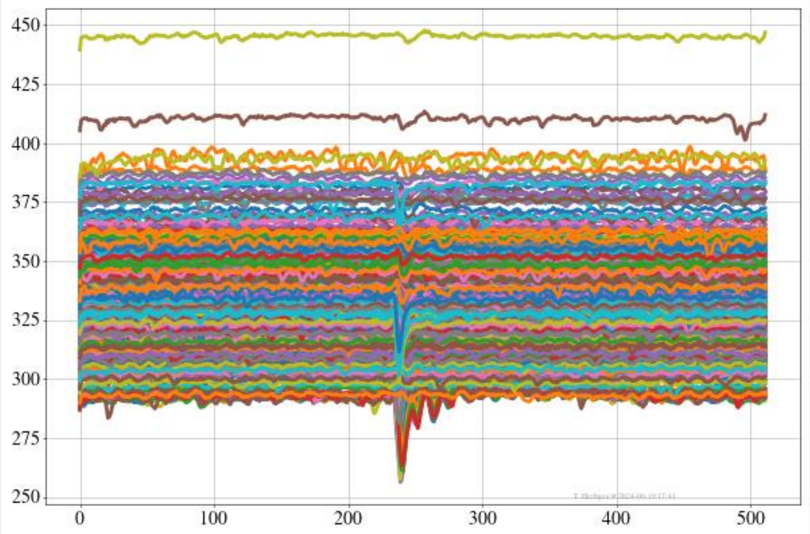


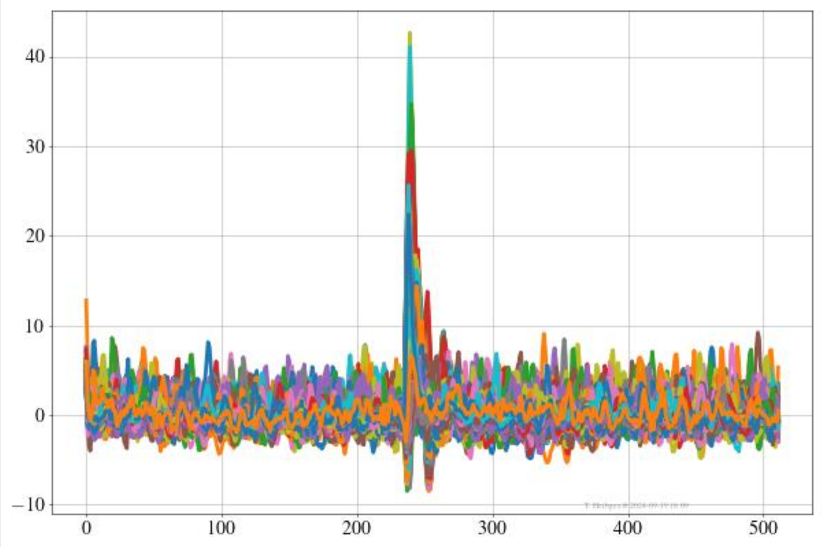


	Observation Time (min)	Events Recorded
Night 1	50 → 35	11250 → 3305
Night 2	136 → 112	20019 → 7694
Night 2 above limb	41 → 21	5537 → 1043
Night 2 below limb	95 → 78	14482 → 6651

Data Calibration

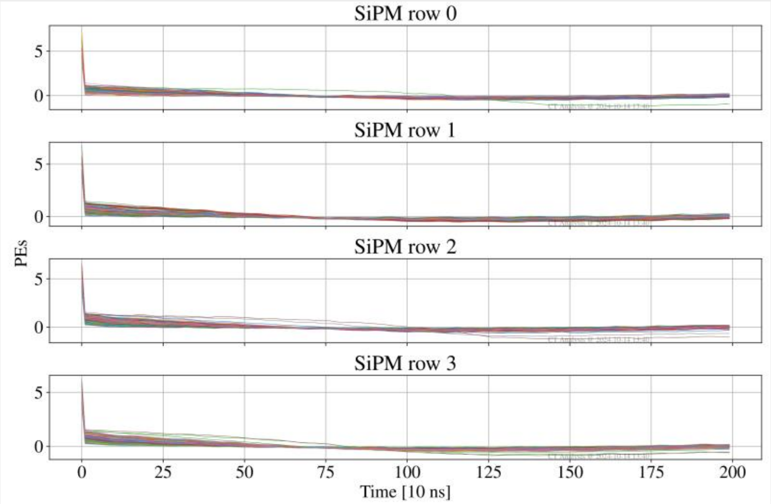
- Calibration performed by GT-team
- Compensates for
  - Temperature of SiPMs
  - Voltage settings
- Based on peak offset from baseline

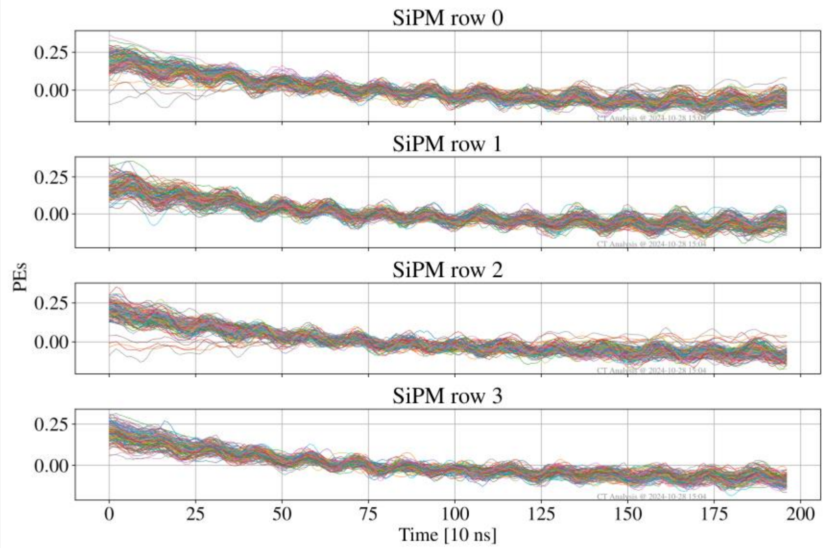




Baseline distribution

- Baseline defined as the 200 time bins before the main peak of the trace
- Should be free of ringing and other artifacts
- Unphysical peak in the first 4 time bins
- Ringing and general trend unexplained





Baseline distribution

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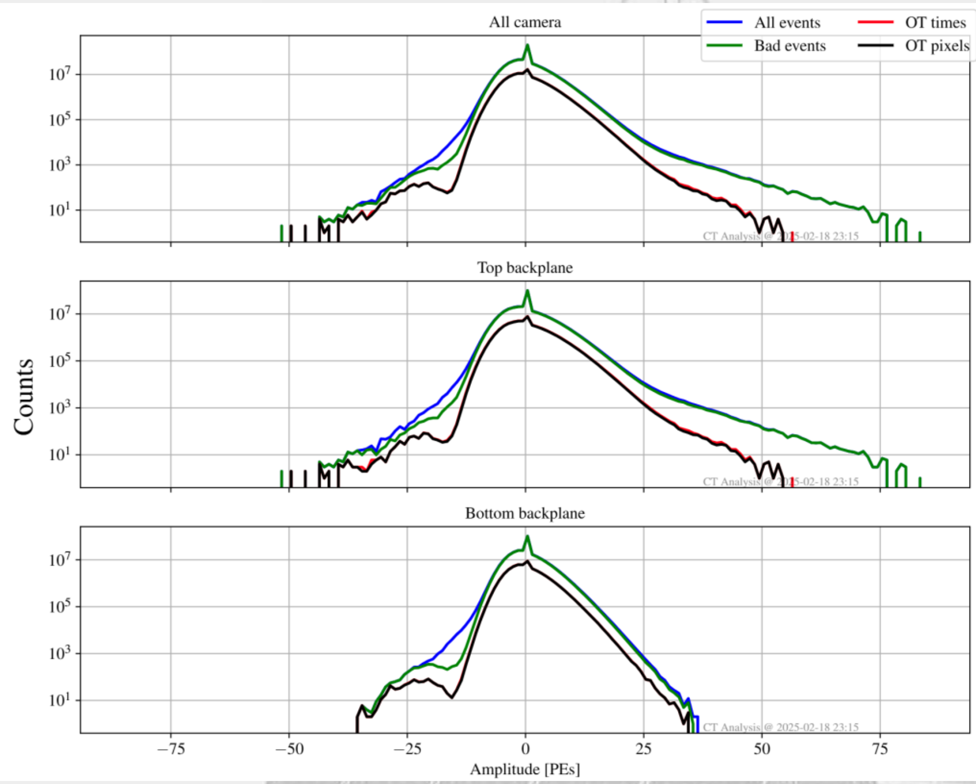
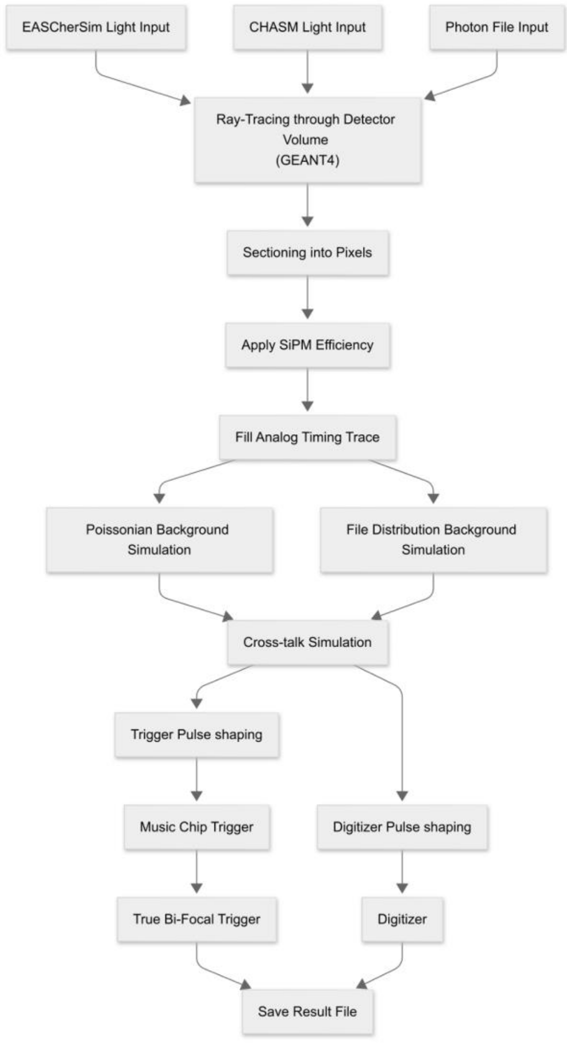


Detector Simulation

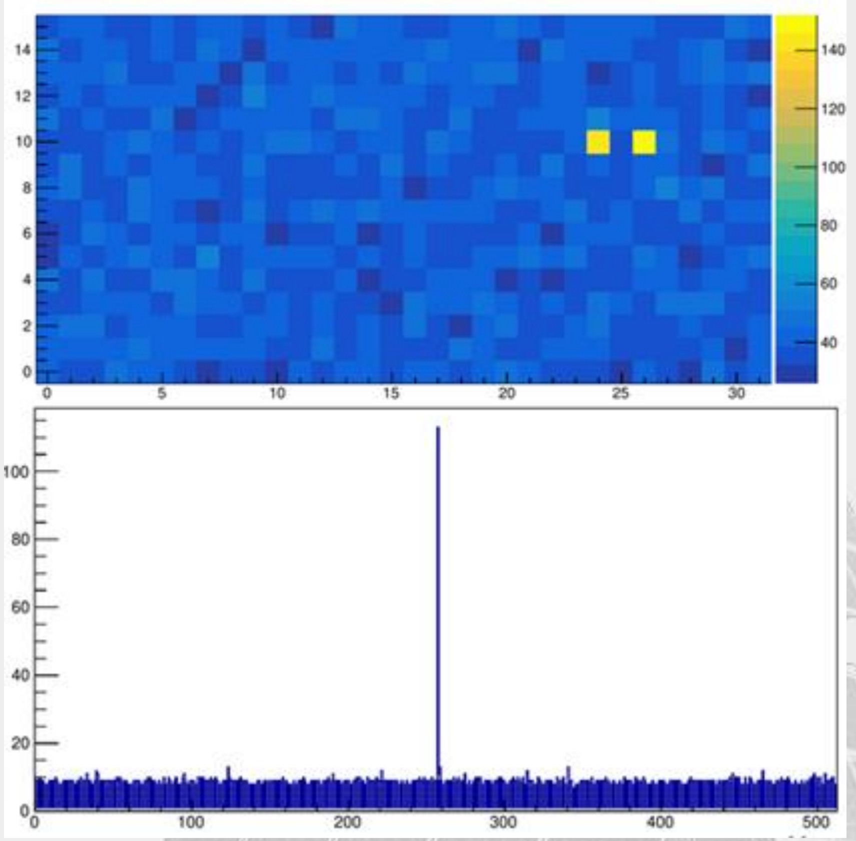
Detector Response - OffLine

- Optics simulation (GEANT 4)
- Photon to photoelectron conversion
- Background simulation
- Optical cross-talk
- Bi-focal trigger logic with 50ns coincidence window
  - Hardware and Software trigger to detect true bi-focal events
- Signal pile up
  - Minimum resolvable signal 30ns
- Output pulse shaping
  - Based on delta function input combined with cross-talk
  - Does not fully recover edge cases
- Digitization saturation
- To be cross checked against
  - Data, GT Simulation chain, Lab tests



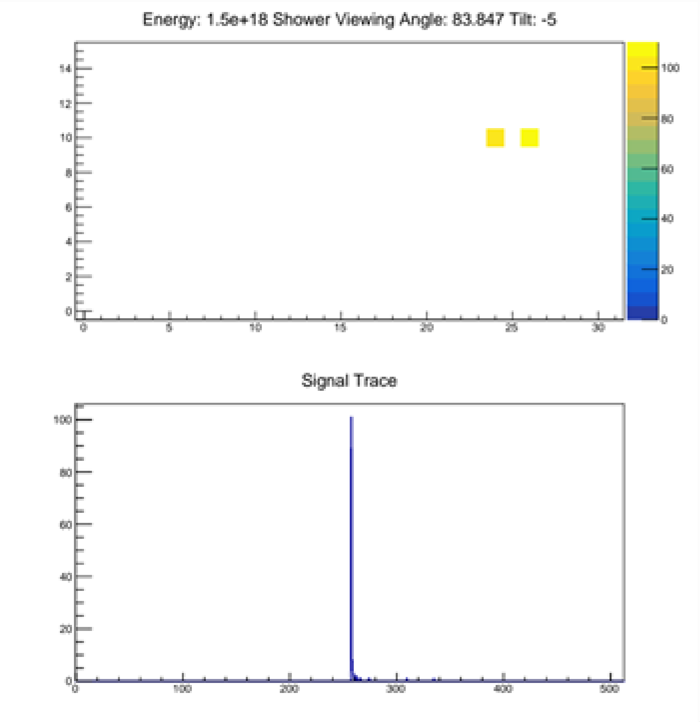
Detector Response - Background simulation

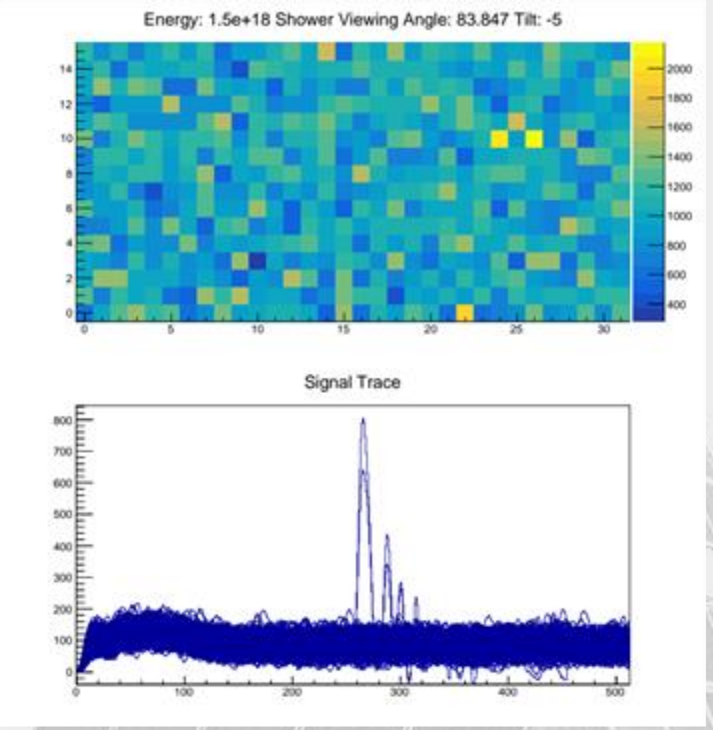
- Based on estimated night sky background measurements from SPB2
- PE rate of ~180MHz
- Implemented in OffLine by sampling from Poisson distribution with a mean of 1.8PE per digitization bin



Detector Response - Pile Up and Pulse Shaping

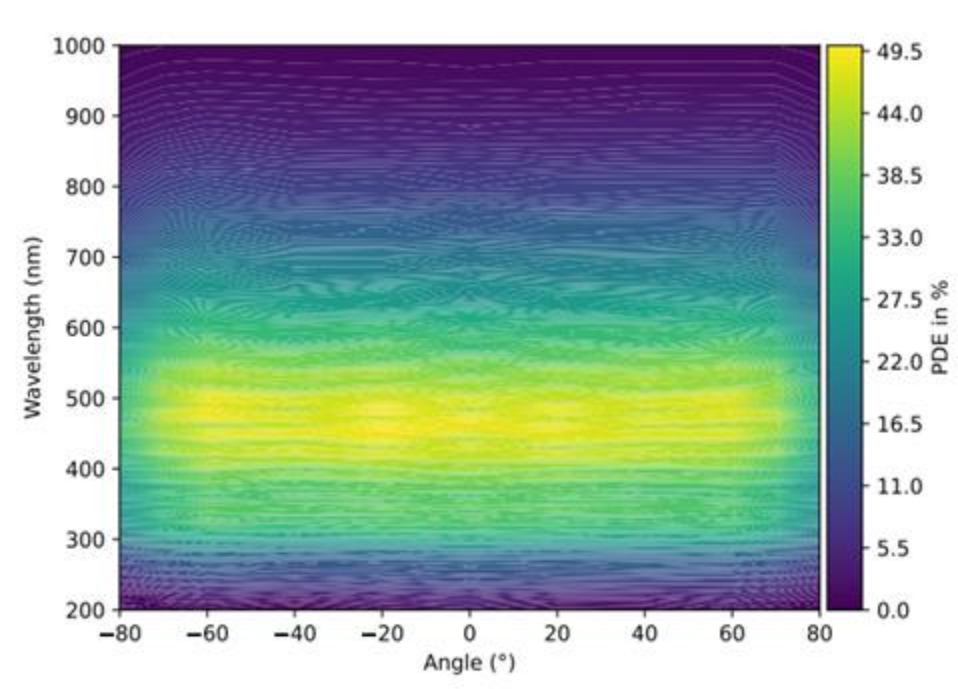
- Pile up:
  - Minimum pulse shape resolution of 30ns
  - 30ns sliding window
- Pulse shaping:
  - 1ps laser response curves for different input PEs
  - Pick closest trace in PEs

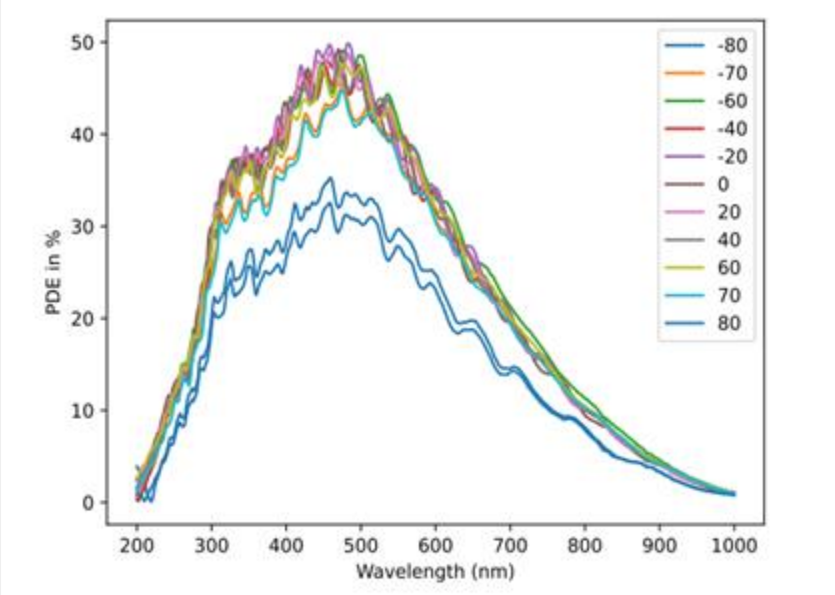




Detector Response - Photons to Photoelectrons

- Photon detection efficiency (PDE):
  - Peak around 480 nm
  - Range 200nm to 1000nm
  - Constant with incoming angles of -60° to 60°
  - PDE was applied to the incoming photons in OffLine



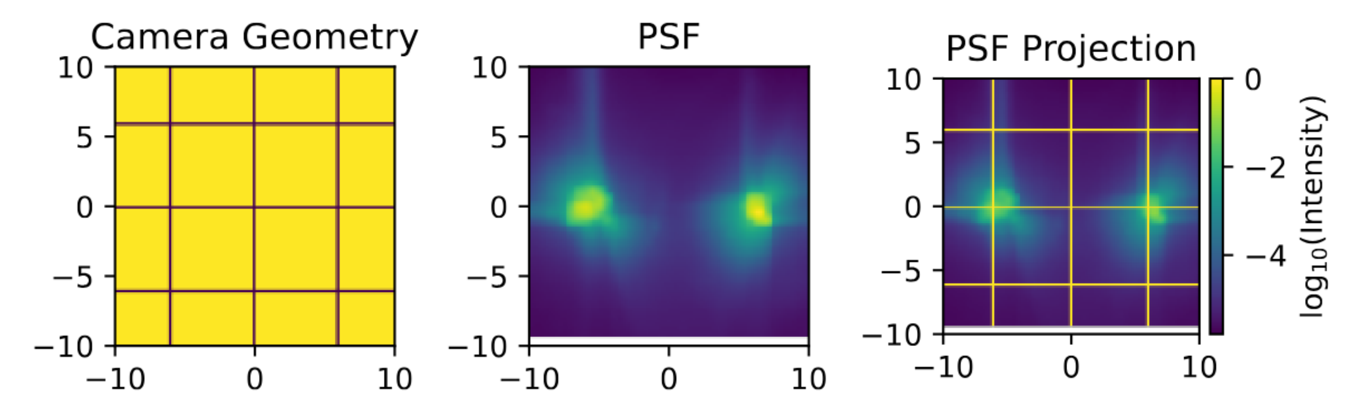


Detector Response – Simplified model

Wavelength dependent PE-threshold

Includes:

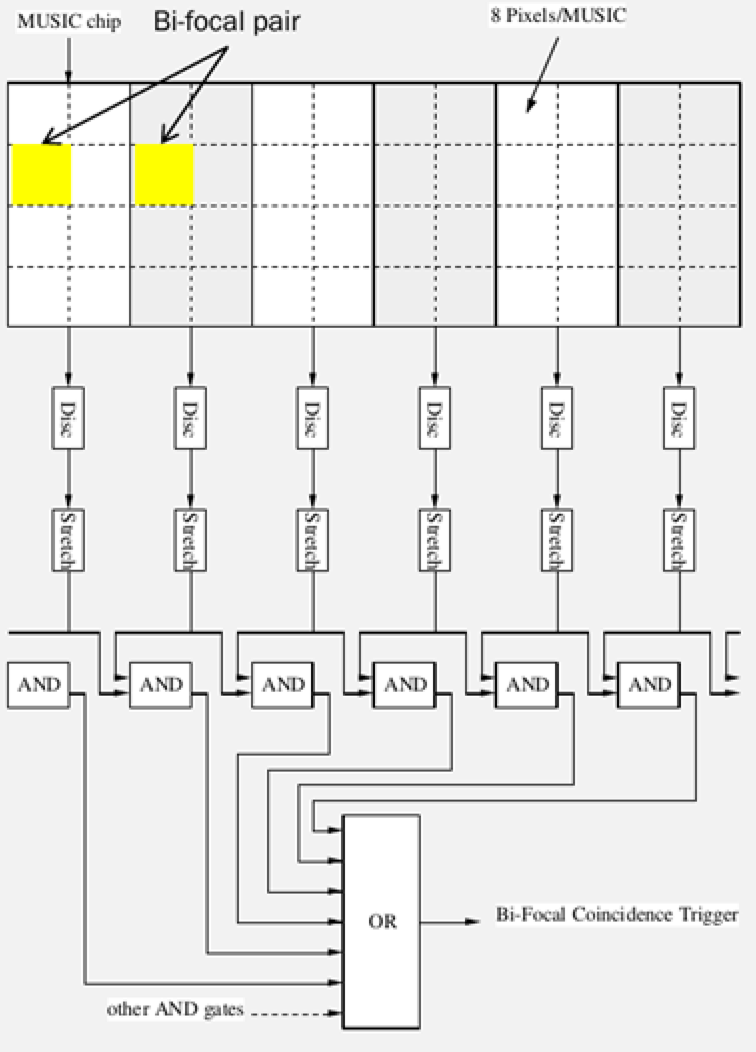
- ACP through put
- Mirror reflectivity
- SiPM efficiency
- Gap estimation



Close to absolute calibration efficiency measured in the field

Detector Response - Trigger

- Hardware Trigger
  - Coincident signal between two neighboring music chips within 50ns.
  - Does not mean a bifocal pair...
- Software Trigger
  - Requires that two triggering pixels are a bifocal pair.
- Implemented by Diksha Garg

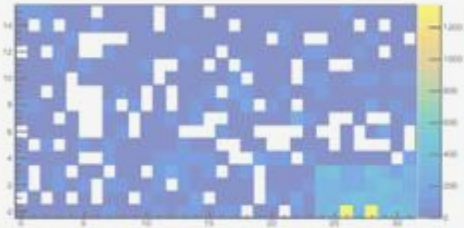


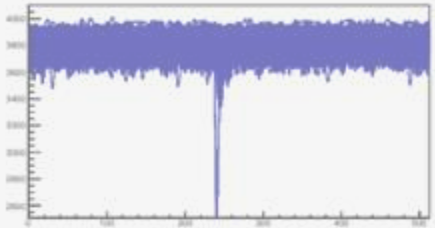
Above the limb Cosmic Rays

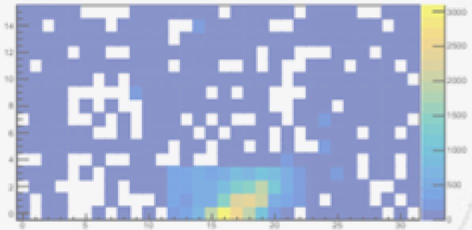
First pass at signal searches:

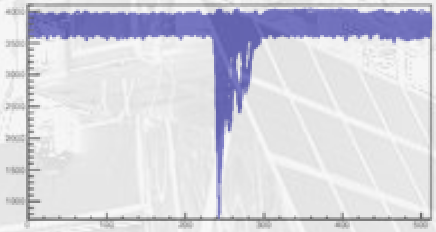
- Only high amplitude events (>800 ADC counts)
- Several CR candidates while looking above the limb
- Some unidentified signals

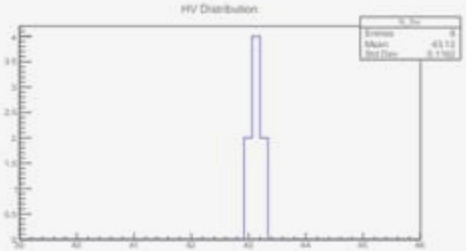
	Night 1	Night 2
Event type	**Number**	**Number**
Cosmic Ray Candidates	15	19
Extended events	20	5
Up-going extended events	1	0
Health LED or Bad Events	170	16
Total	205	57



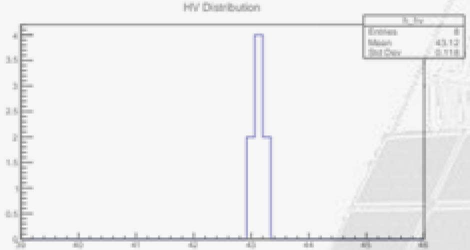








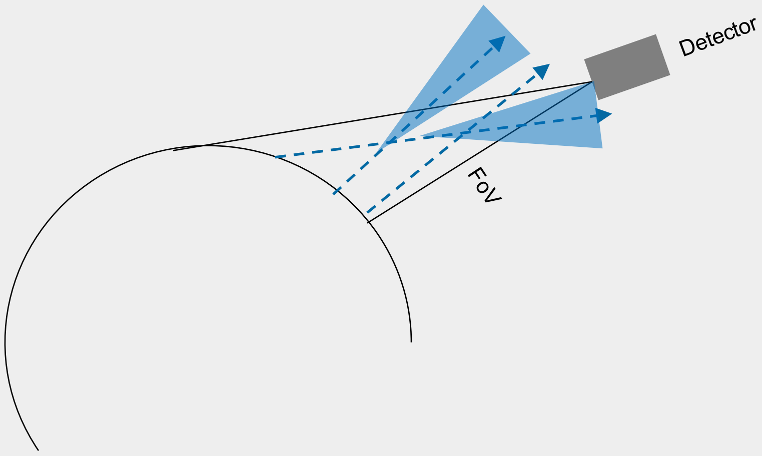
Event Time: 168404535111060734
Event Number: 4479
Lat: -31.963
Long: -154.322
Alt: 22281
Emon1: 663
Emon2: 230
Tilt: -1.73
LVPS Voltage: 26
LVPS Cur: 3650

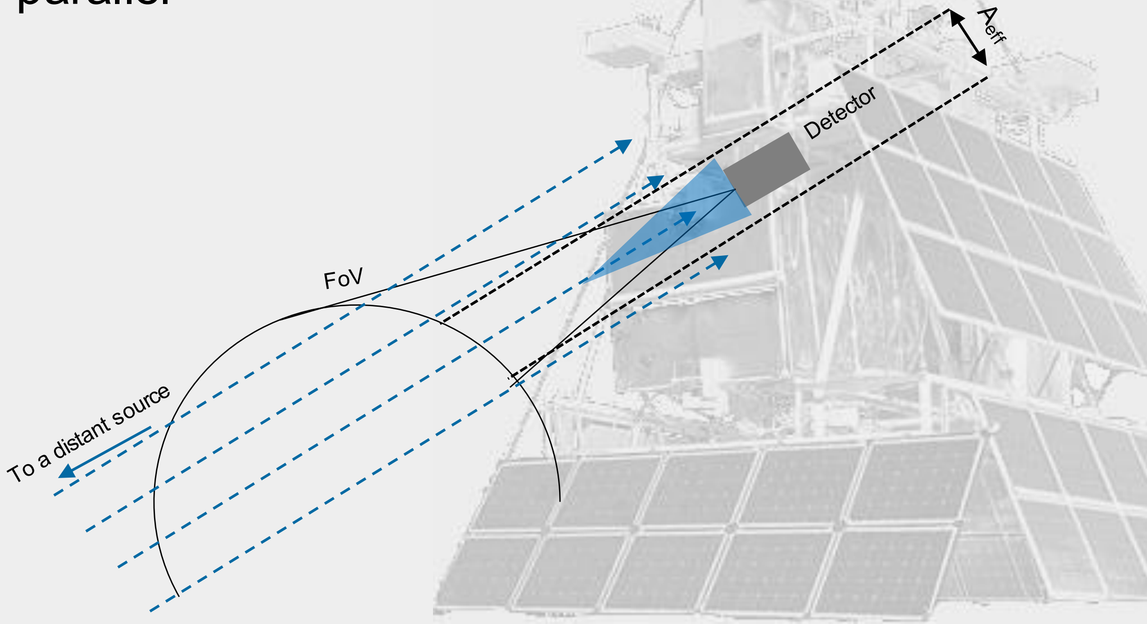


Event Time: 168404594926816226
Event Number: 14532
Lat: -32.007
Long: -154.34
Alt: 22055
Emon1: 607
Emon2: 256
Tilt: -1.73
LVPS Voltage: 26
LVPS Cur: 3639

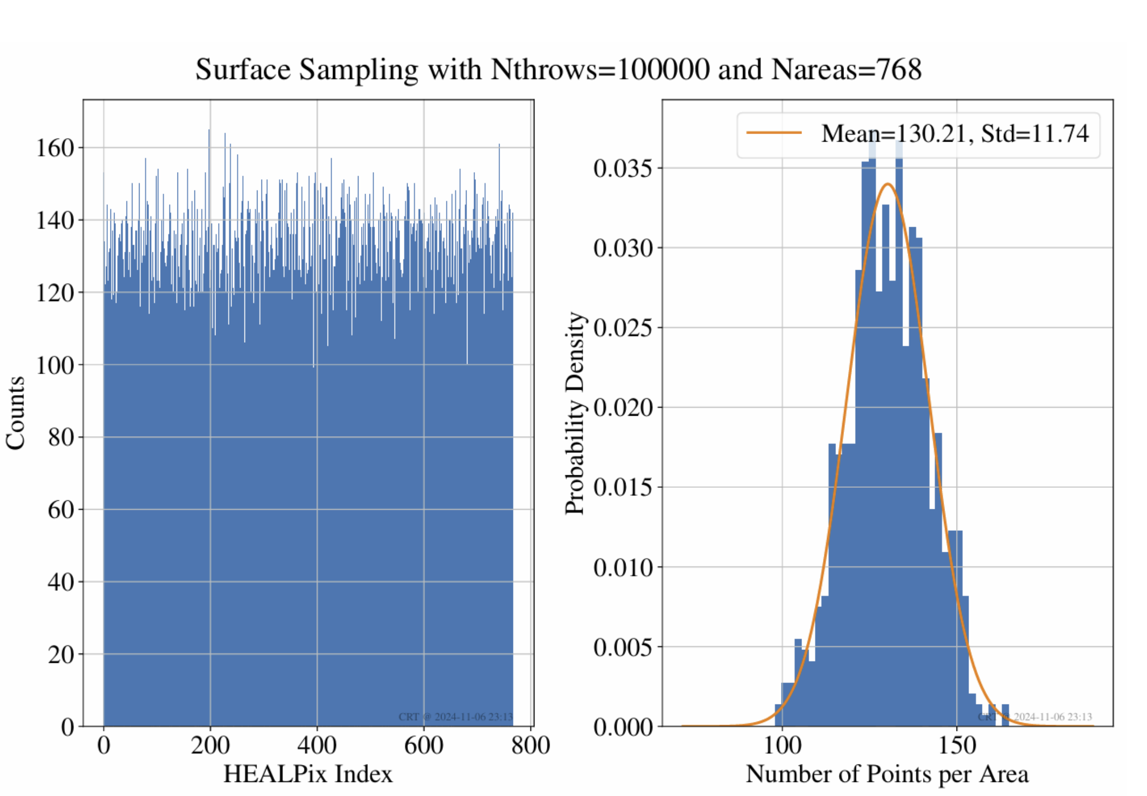
Cosmic Ray / Neutrino Geometry Sampling → EAS / Neutrino Simulation → EAS Cherenkov Light Simulation (EASCherSim) → Detector Simulation

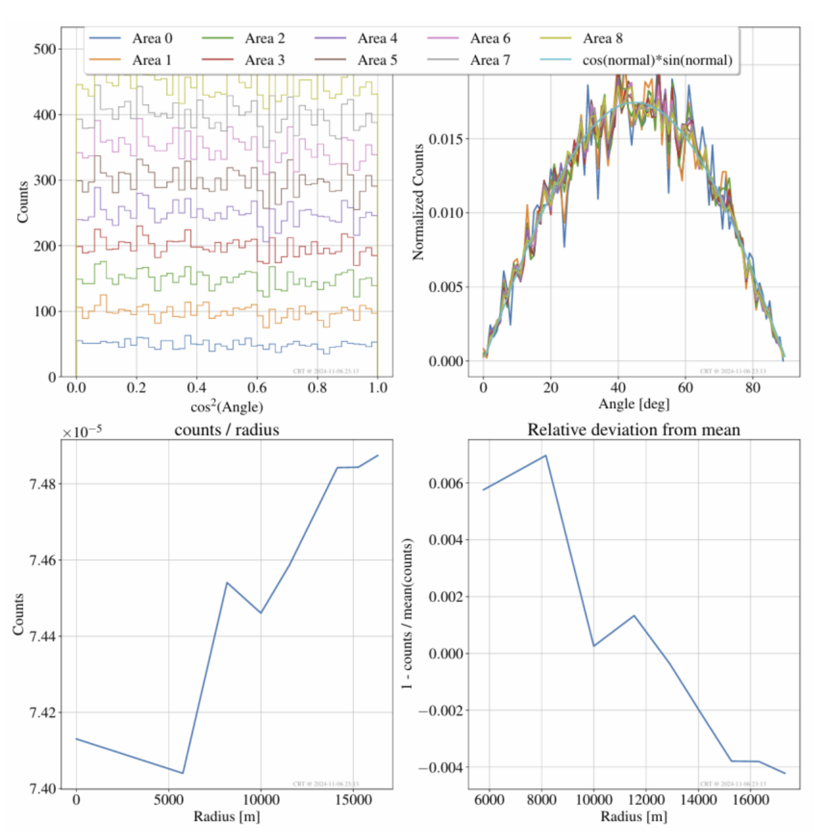
Geometries:
- **CRs:** Isotropic and homogenous
- **Diffuse neutrinos:** Isotropic and homogenous
- **ToO neutrinos:** Quasi parallel



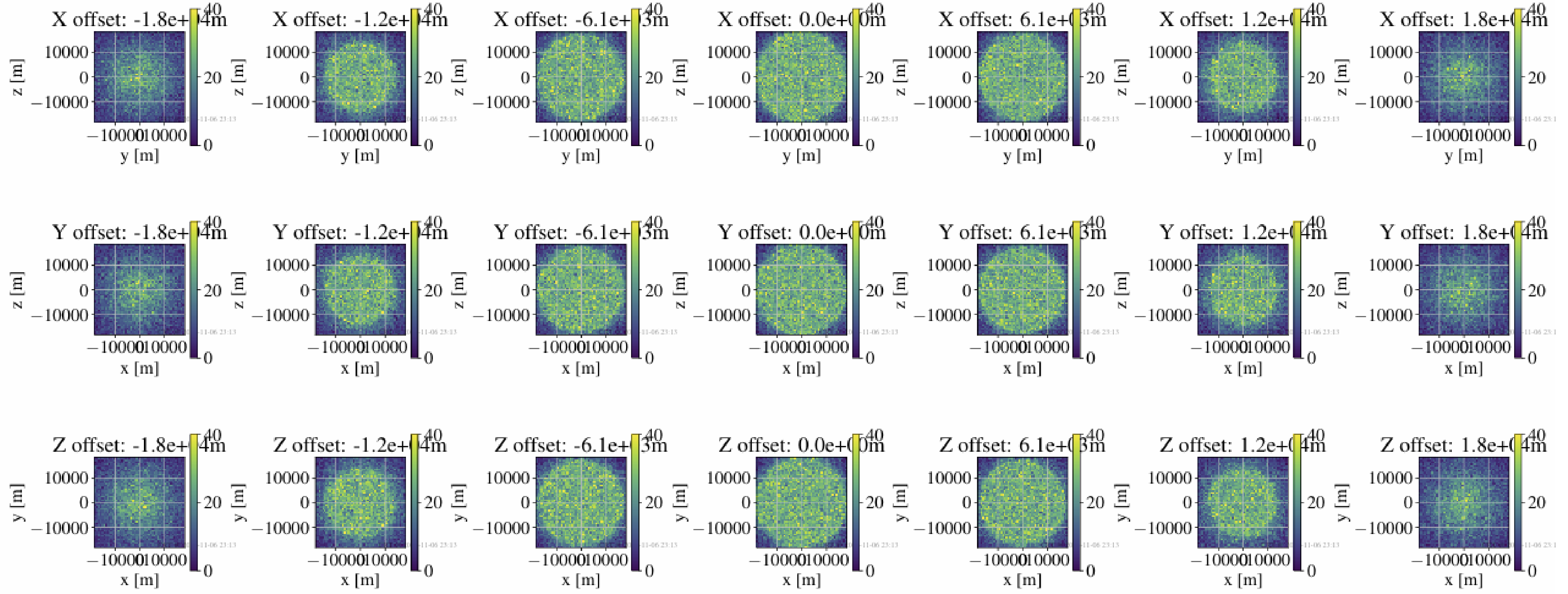


Cosmic Ray / Neutrino Geometry Sampling → EAS / Neutrino Simulation → EAS Cherenkov Light Simulation (EASCherSim) → Detector Simulation



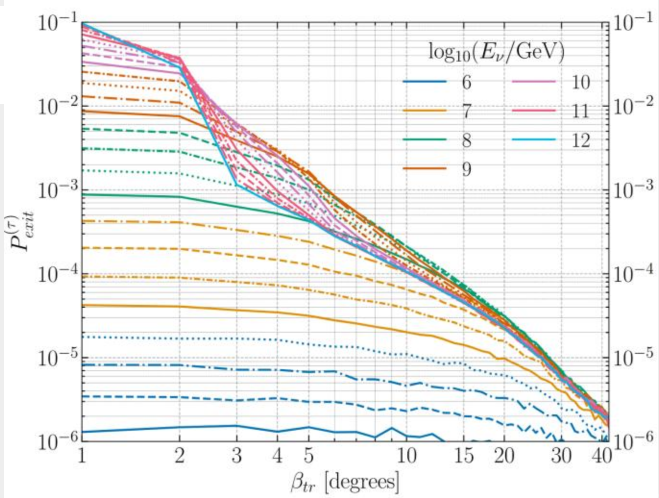


Cosmic Ray / Neutrino Geometry Sampling → EAS / Neutrino Simulation → EAS Cherenkov Light Simulation (EASCherSim) → Detector Simulation

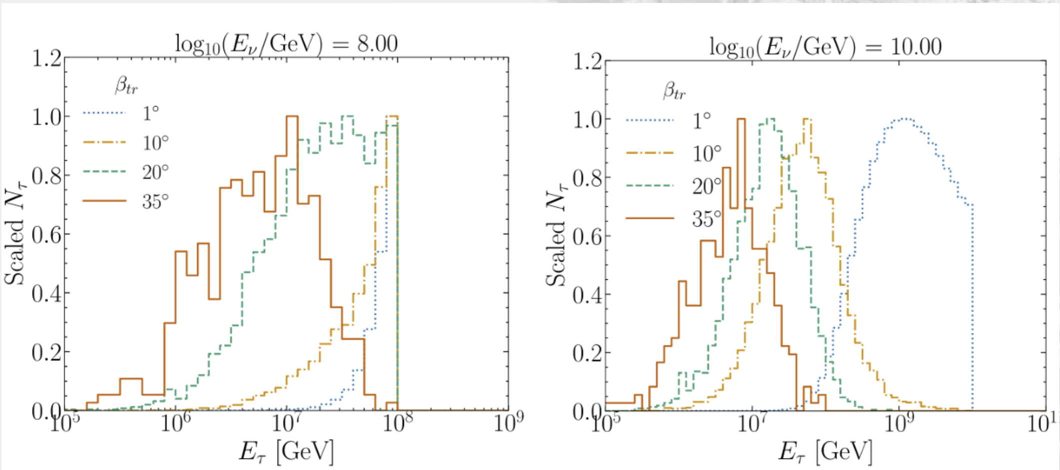


NuSpaceSim

Diksha Garg et al. Neutrino propagation in the Earth and emerging charged leptons with nuPyProp. JCAP, 01:041, 2023. doi: 10.1088/1475-7516/2023/01/041.

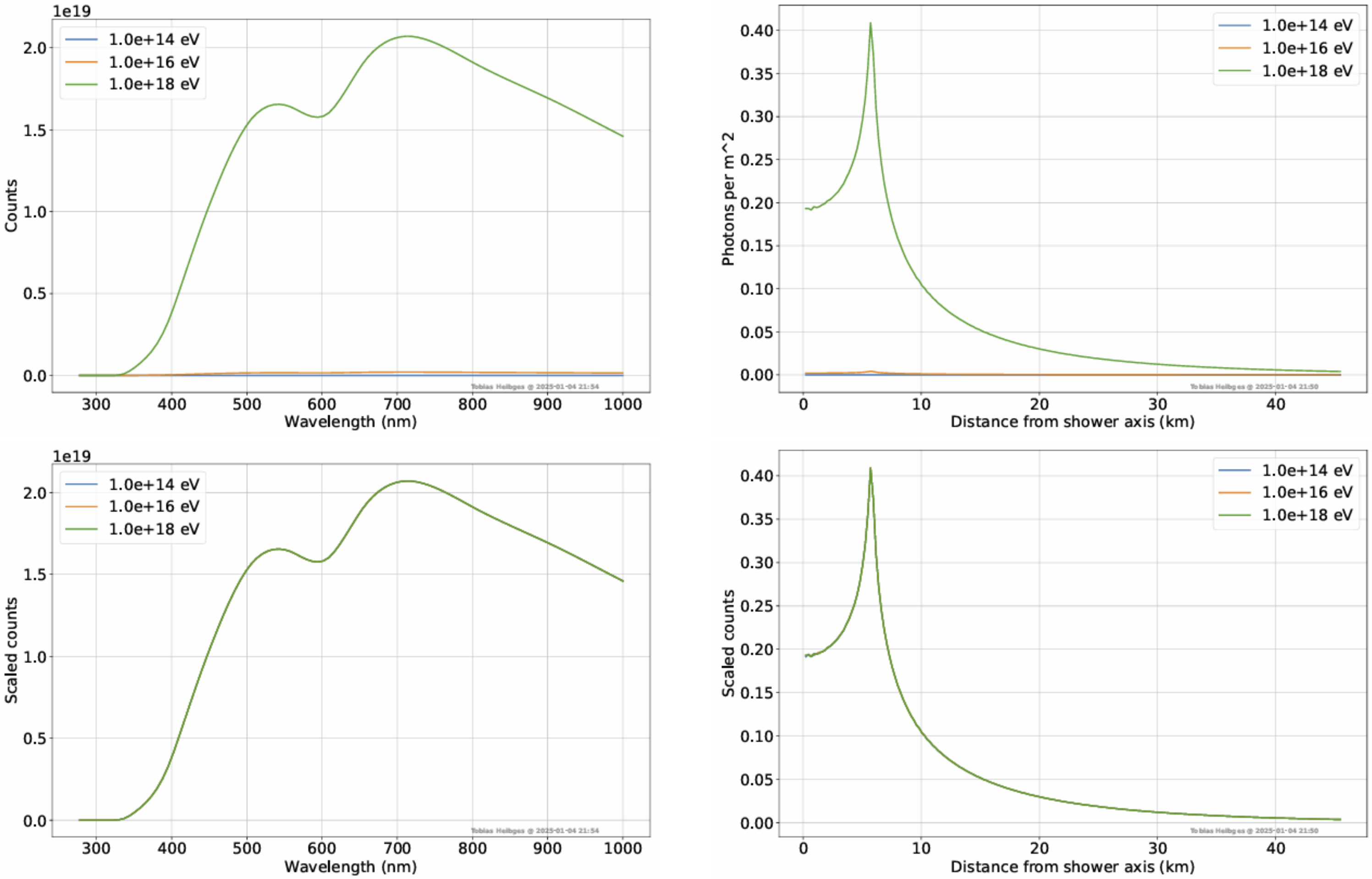


- Monte Carlo Simulation tool for Earth skimming neutrino searches from above
- Designed for diffuse neutrinos
- Calculates:
  - Neutrino Interaction probability
  - Earth emergence probability
  - Tau-lepton decay location
  - Airshower profile
  - Cherenkov light production
  - Cherenkov light at a detector

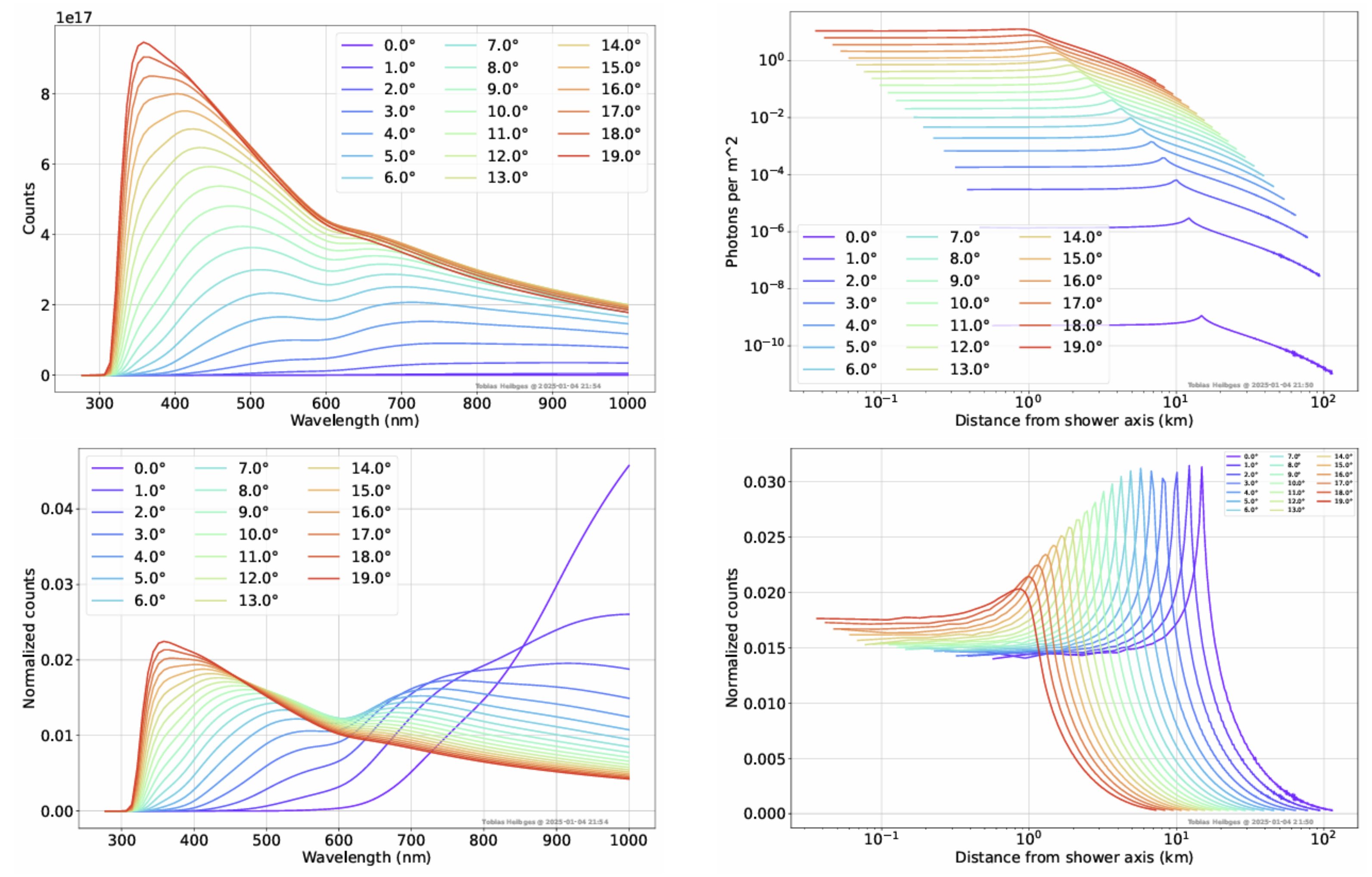


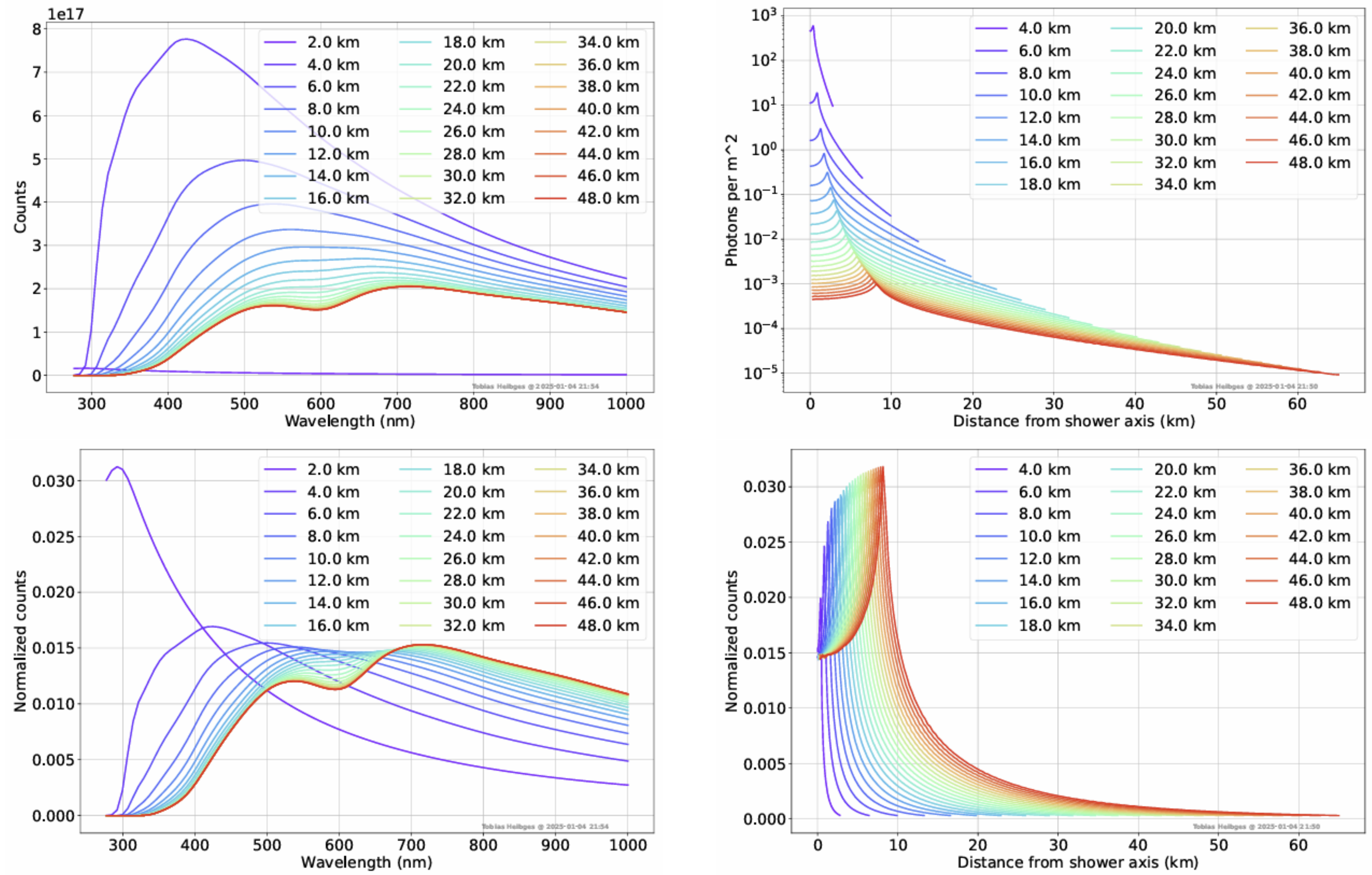
Diksha Garg et al. Neutrino propagation in the Earth and emerging charged leptons with nuPyProp. JCAP, 01:041, 2023. doi: 10.1088/1475-7516/2023/01/041.

Shower Library

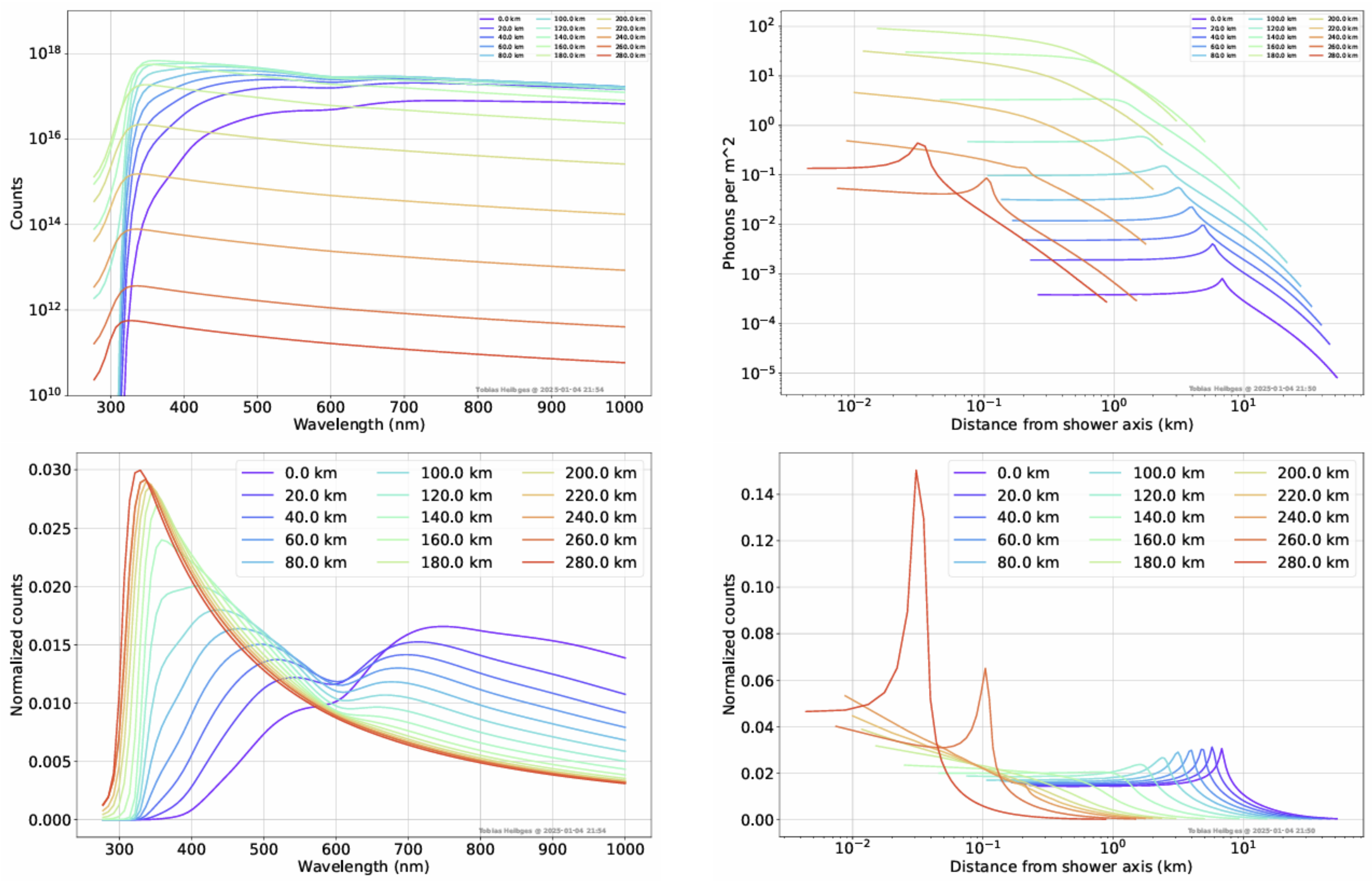


1e19
Counts
Wavelength (nm)
300
400
500
600
700
800
900
1000
0.0
0.5
1.0
1.5
2.0
1.0e+14 eV
1.0e+16 eV
1.0e+18 eV
Photons per m^2
Distance from shower axis (km)
0
10
20
30
40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
1e19
Scaled counts
Wavelength (nm)
Scaled counts
Distance from shower axis (km)

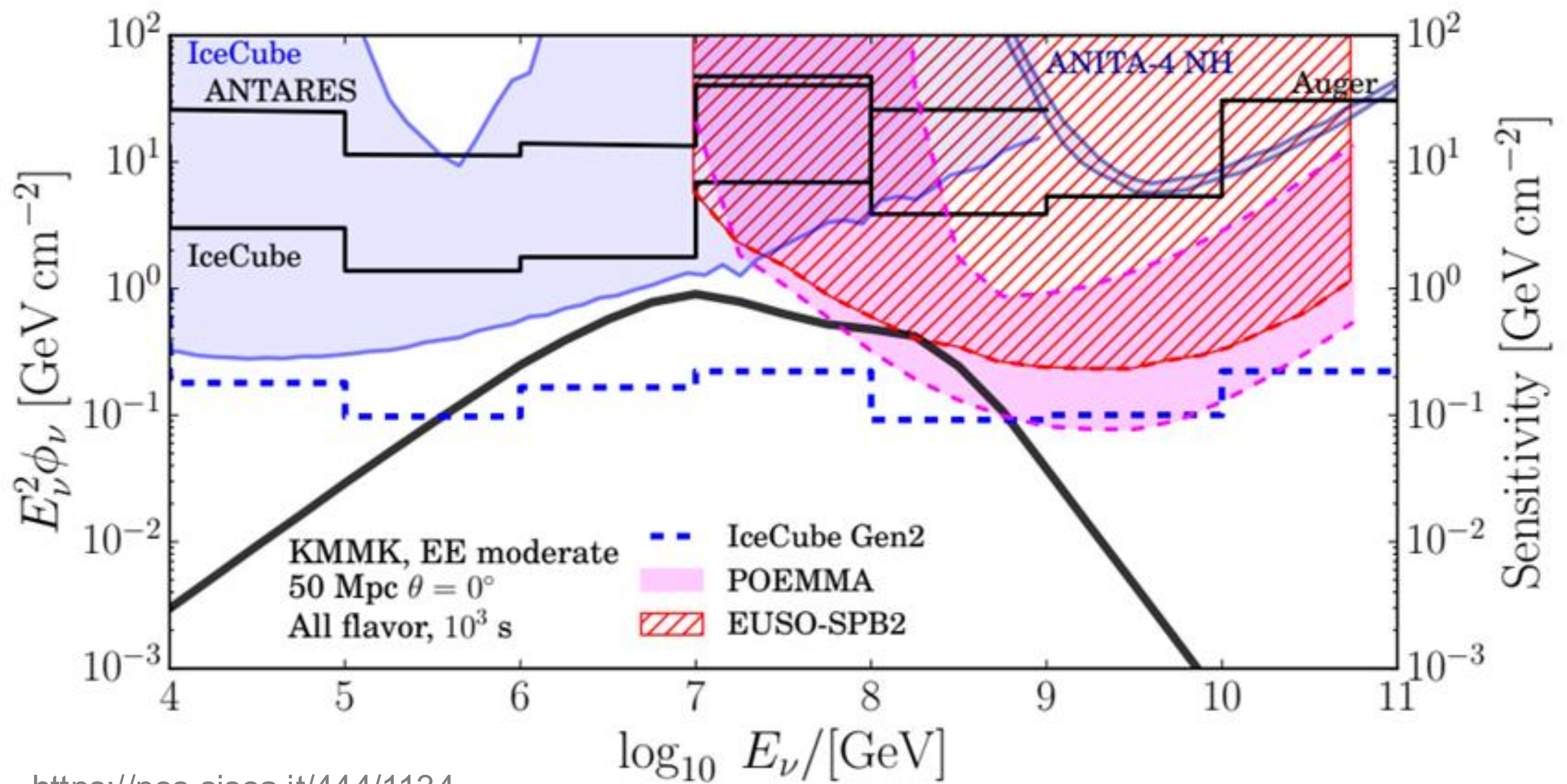

1e17
Counts
Wavelength (nm)
Photons per m^2
Distance from shower axis (km)
Normalized counts
Wavelength (nm)
Normalized counts
Distance from shower axis (km)
0.0° 1.0° 2.0° 3.0° 4.0° 5.0° 6.0° 7.0° 8.0° 9.0° 10.0° 11.0° 12.0° 13.0° 14.0° 15.0° 16.0° 17.0° 18.0° 19.0°



1e17
Counts
Wavelength (nm)
2.0 km
4.0 km
6.0 km
8.0 km
10.0 km
12.0 km
14.0 km
16.0 km
18.0 km
20.0 km
22.0 km
24.0 km
26.0 km
28.0 km
30.0 km
32.0 km
34.0 km
36.0 km
38.0 km
40.0 km
42.0 km
44.0 km
46.0 km
48.0 km
Photons per m^2
Distance from shower axis (km)
Normalized counts
Wavelength (nm)
Normalized counts
Distance from shower axis (km)

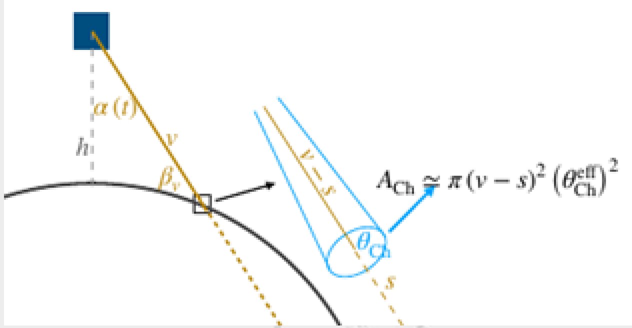

Counts
Wavelength (nm)
Photons per m^2
Distance from shower axis (km)
Normalized counts
Wavelength (nm)
0.0 km
20.0 km
40.0 km
60.0 km
80.0 km
100.0 km
120.0 km
140.0 km
160.0 km
180.0 km
200.0 km
220.0 km
240.0 km
260.0 km
280.0 km
Normalized counts
Distance from shower axis (km)

Sensitivity Expectation



https://pos.sissa.it/444/1134

Sensitivity Calculation



The sensitivity is given by:

$$\mathcal{F}_{\rangle} = \frac{2.44}{\ln(10) \cdot E_{\nu_i} \cdot \mathcal{A}(E_{\nu_i})}$$

Where the effective area is:

$$\mathcal{A}(E_{\nu_\tau}) = \frac{1}{T} \int_{t_0}^{t_0+T} dt \mathcal{A}(t, E_{\nu_\tau})$$

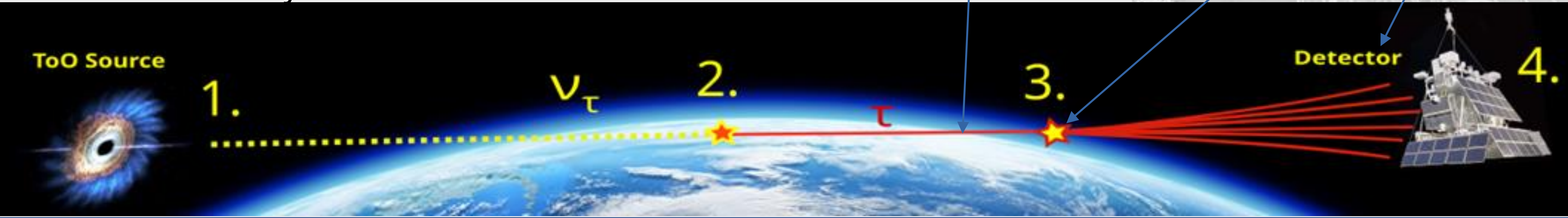
And changes as the source moves in the sky

The effective area is given by this:

$$\mathcal{A}(t, E_{\nu_\tau}) = \int ds \quad P_{\rm obs}(t, E_{\nu_\tau}, \beta, s) A_{cc}(s).$$

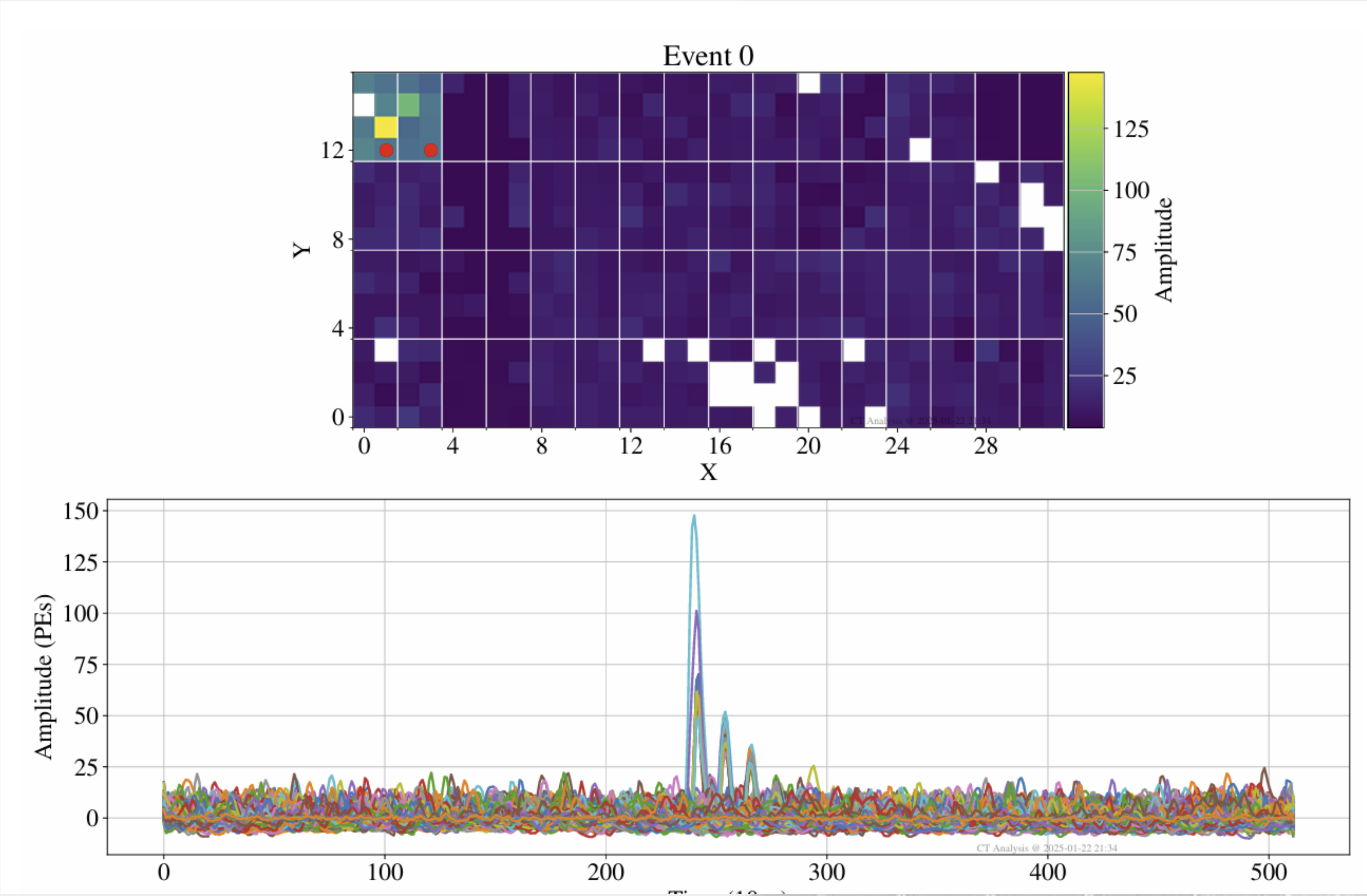
And the probability of observation is:

$$P_{\rm obs} = \int dE_\tau \quad p_{\rm exit}(E_\tau | E_{\nu_\tau}, \beta) p_{\rm decay}(s, E_\tau) p_{\rm detect}$$

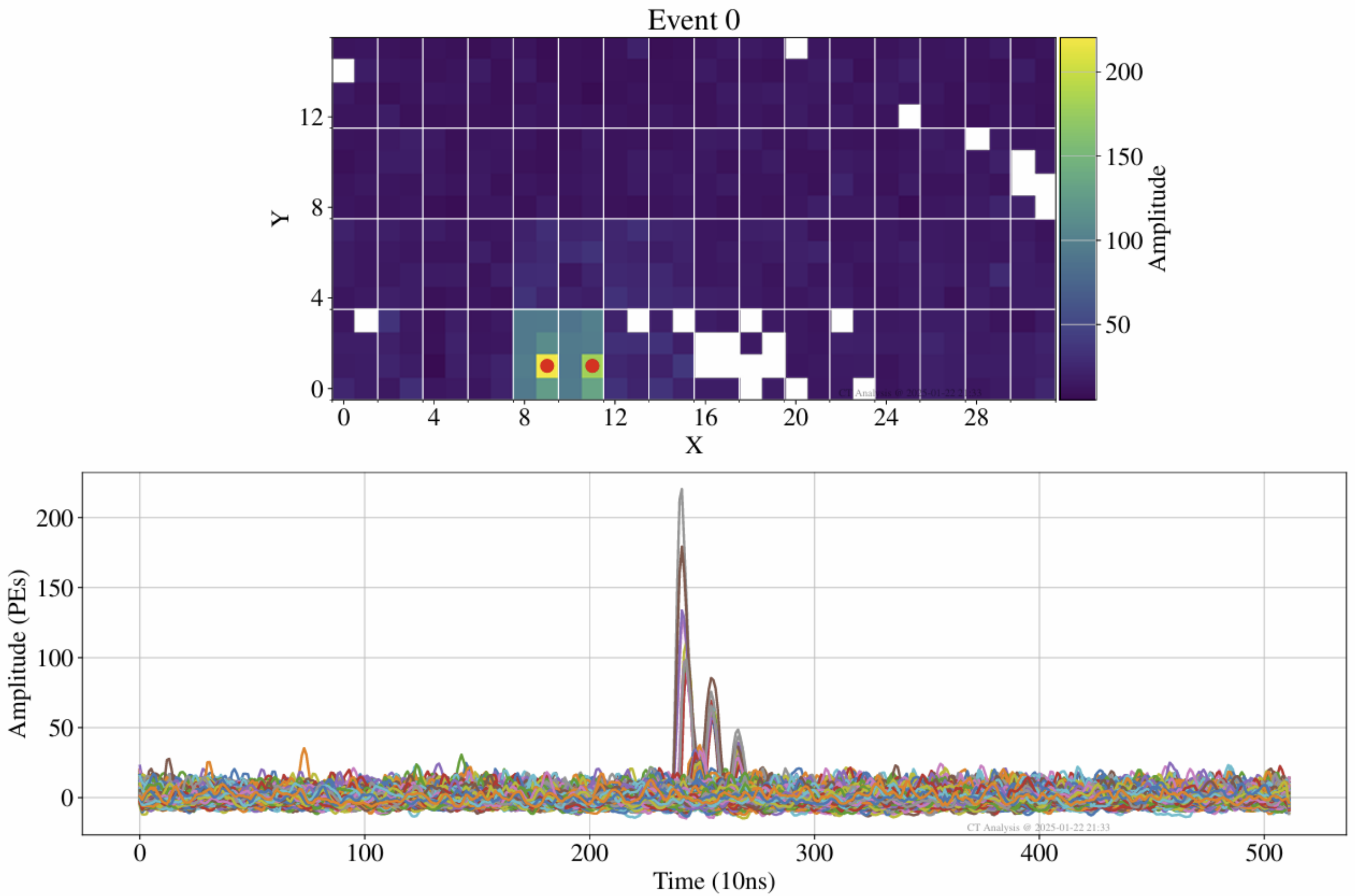


Passing Events

Below limb

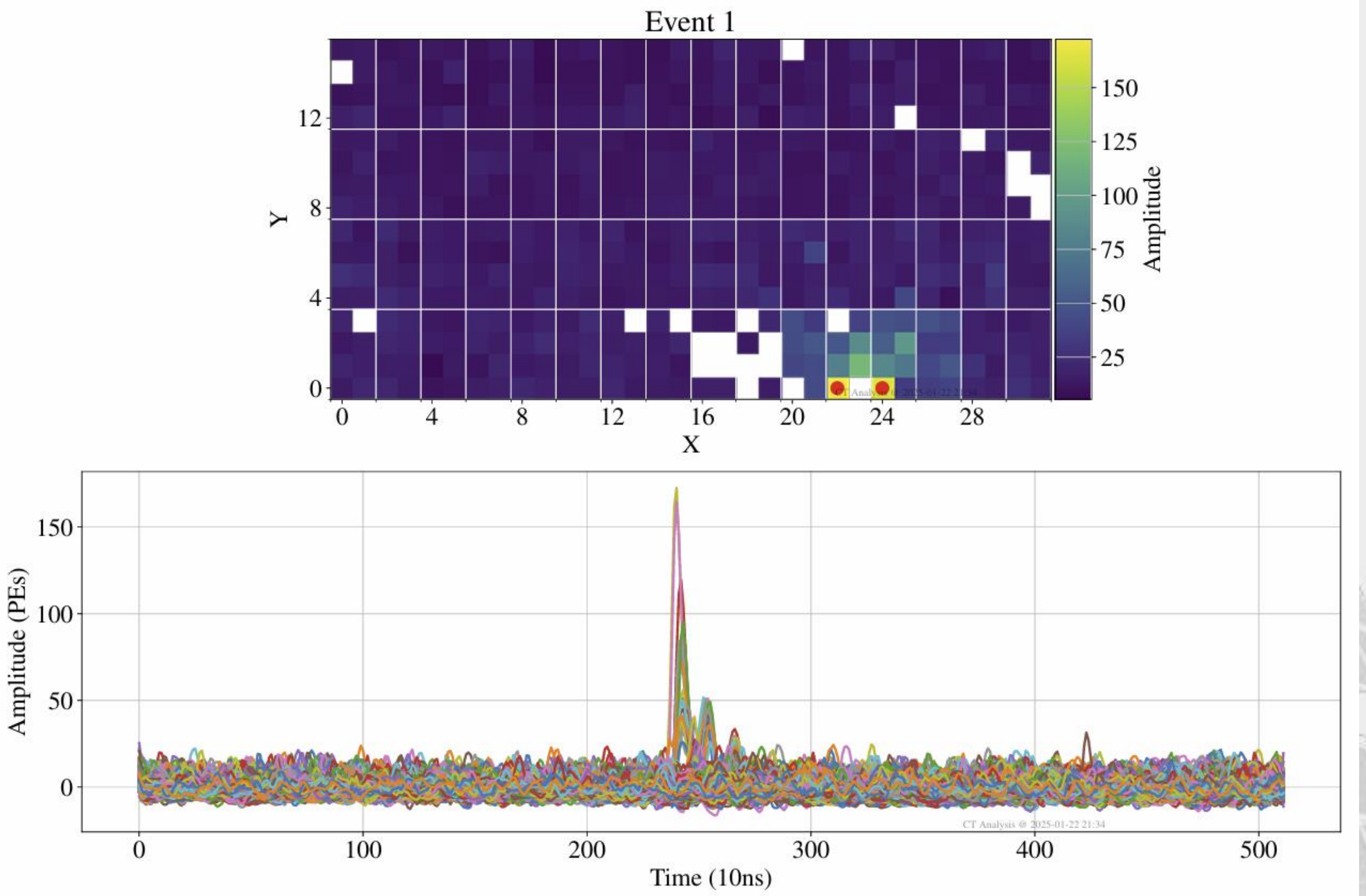


Above limb

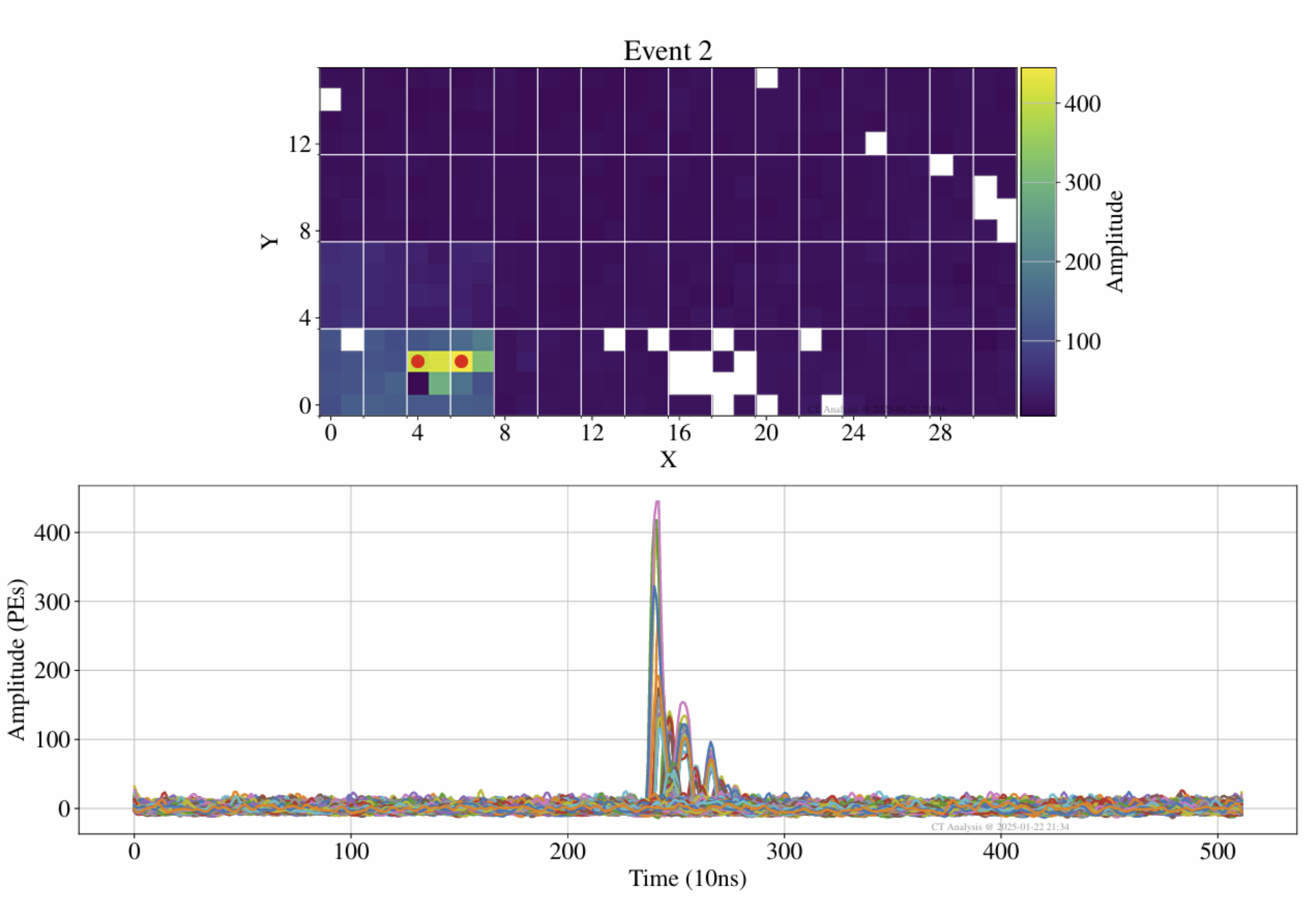


Event 0
Y
X
Amplitude
Amplitude (PEs)
Time (10ns)
CT Analysis @ 2025-01-22 21:33

Above limb

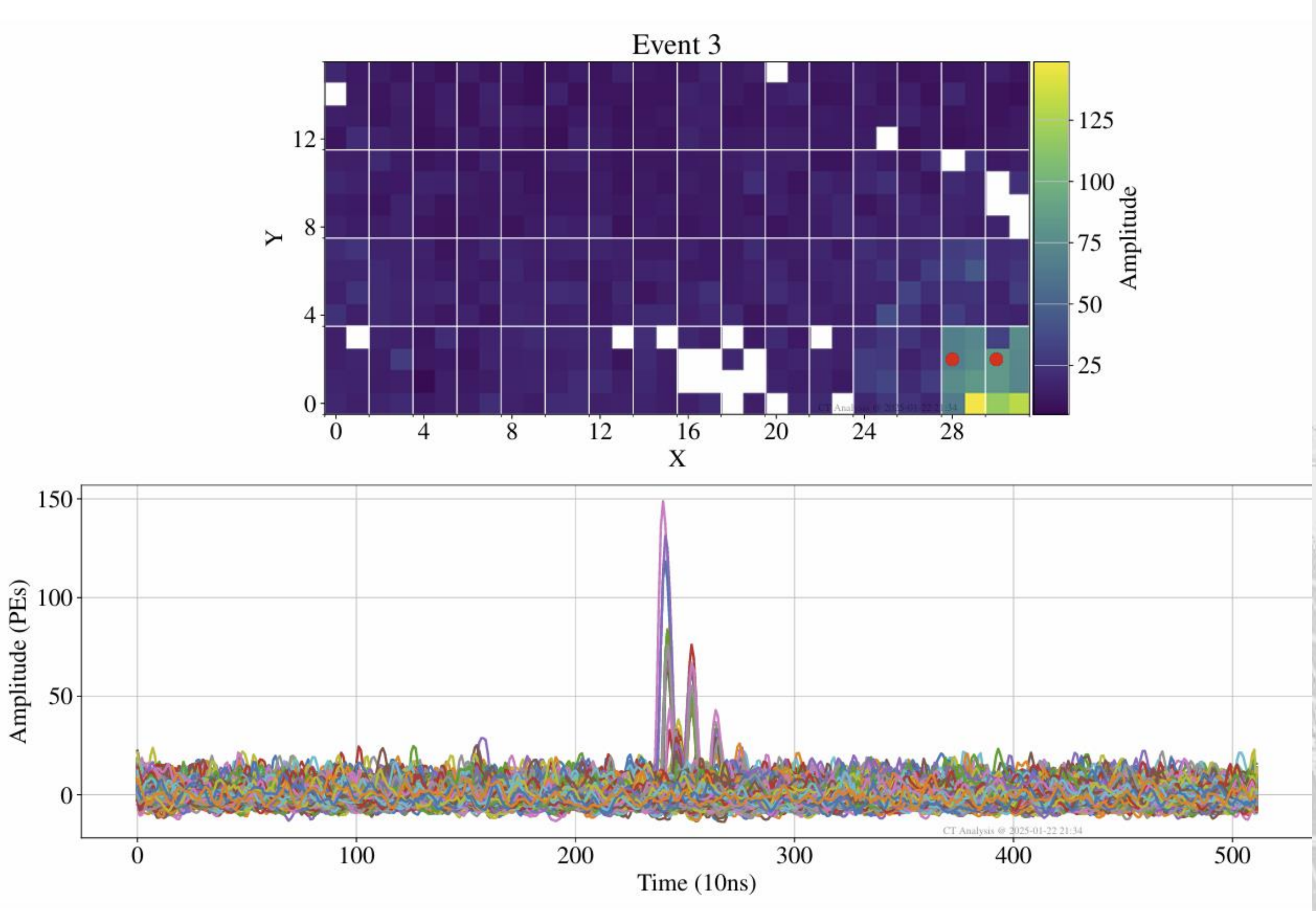

Event 1
Y
X
Amplitude
CT Analysis @ 2025-01-22 21:34
Amplitude (PEs)
Time (10ns)
CT Analysis @ 2025-01-22 21:34

Above limb



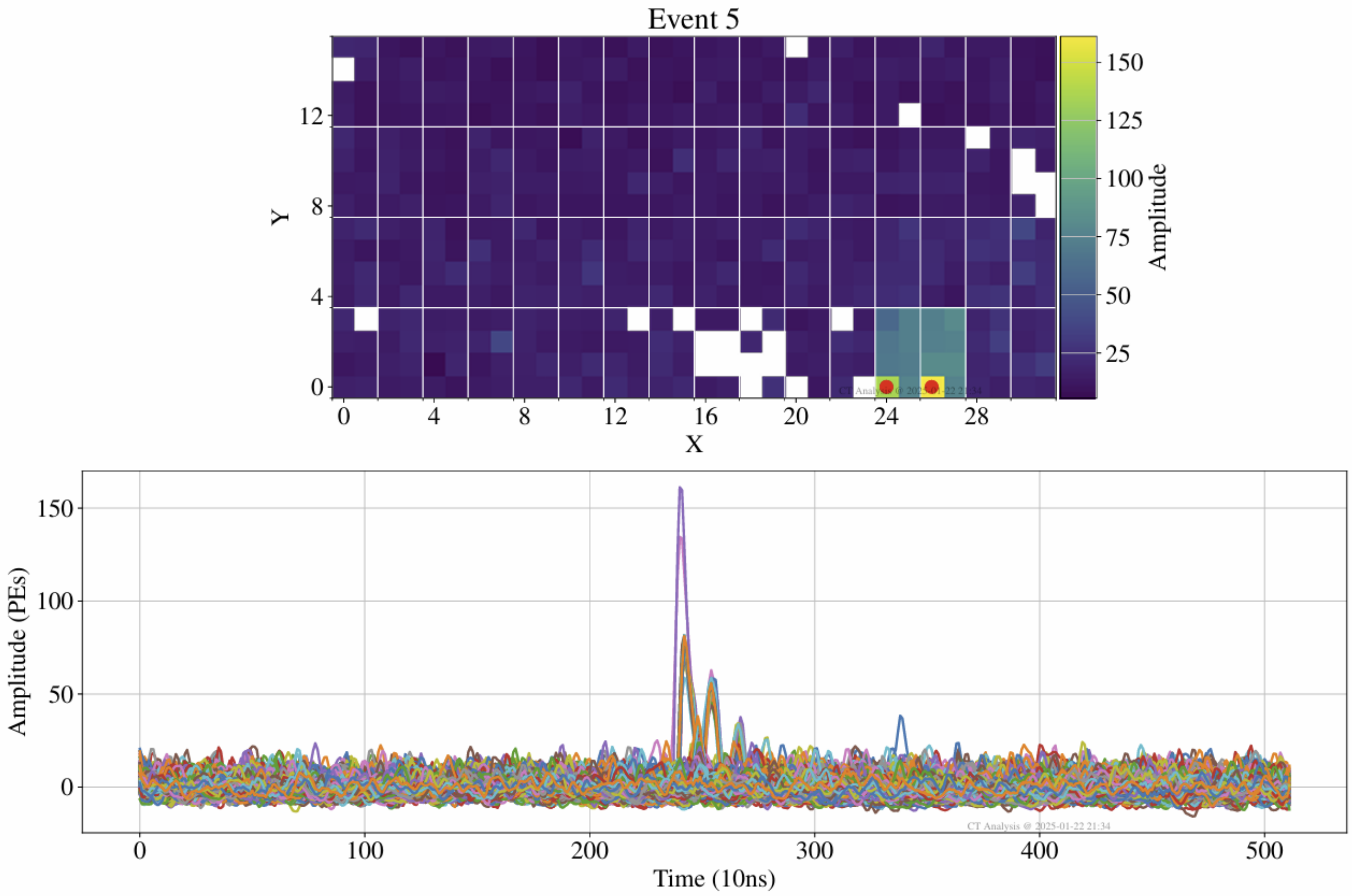
Event 2
Y
X
Amplitude
0
4
8
12
16
20
24
28
100
200
300
400
Amplitude (PEs)
Time (10ns)
500

Above limb

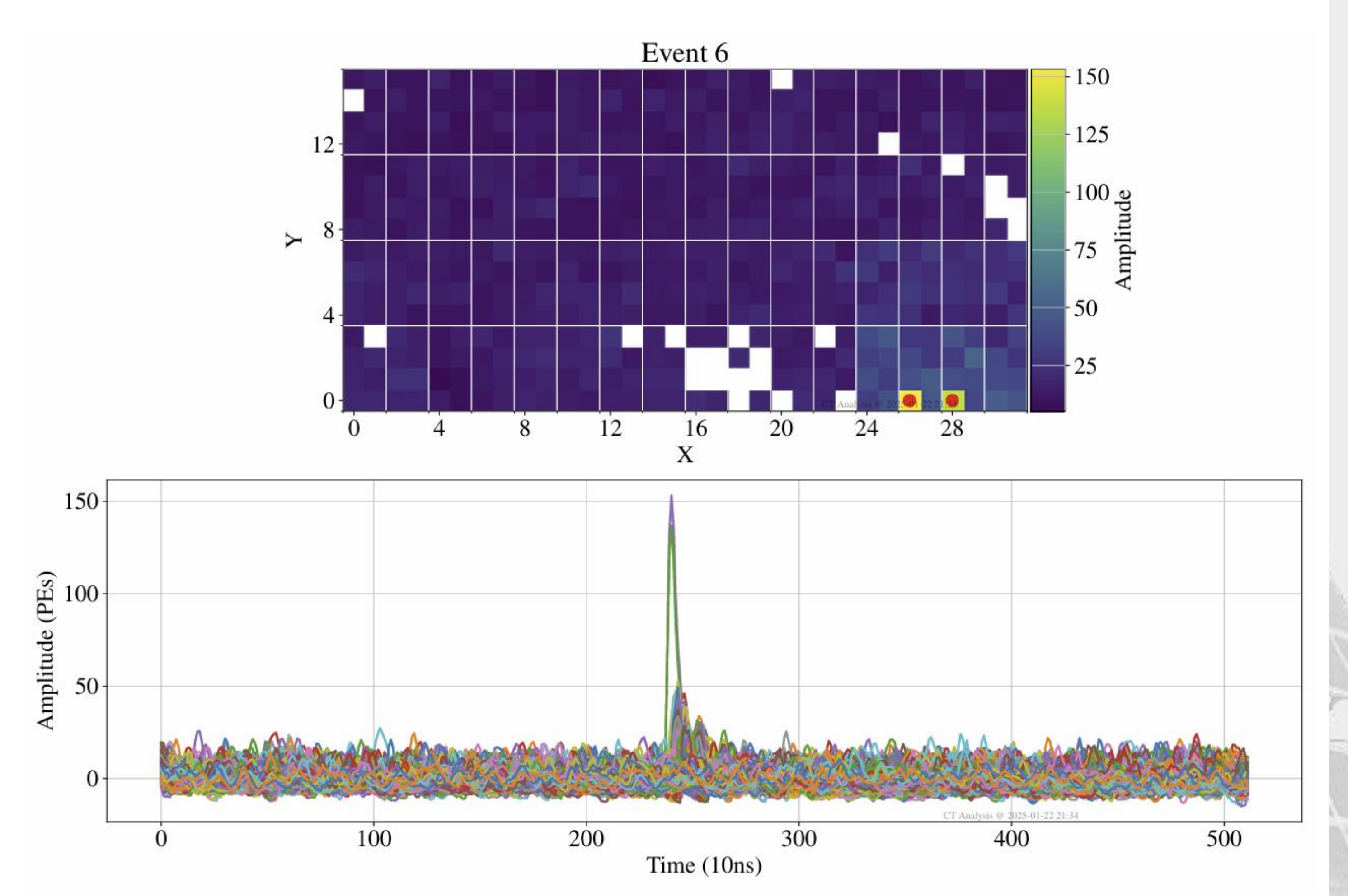


Event 3
Y
X
Amplitude
125
100
75
50
25
0
4
8
12
16
20
24
28
Amplitude (PEs)
Time (10ns)
150
100
50
0
200
300
400
500

Above limb

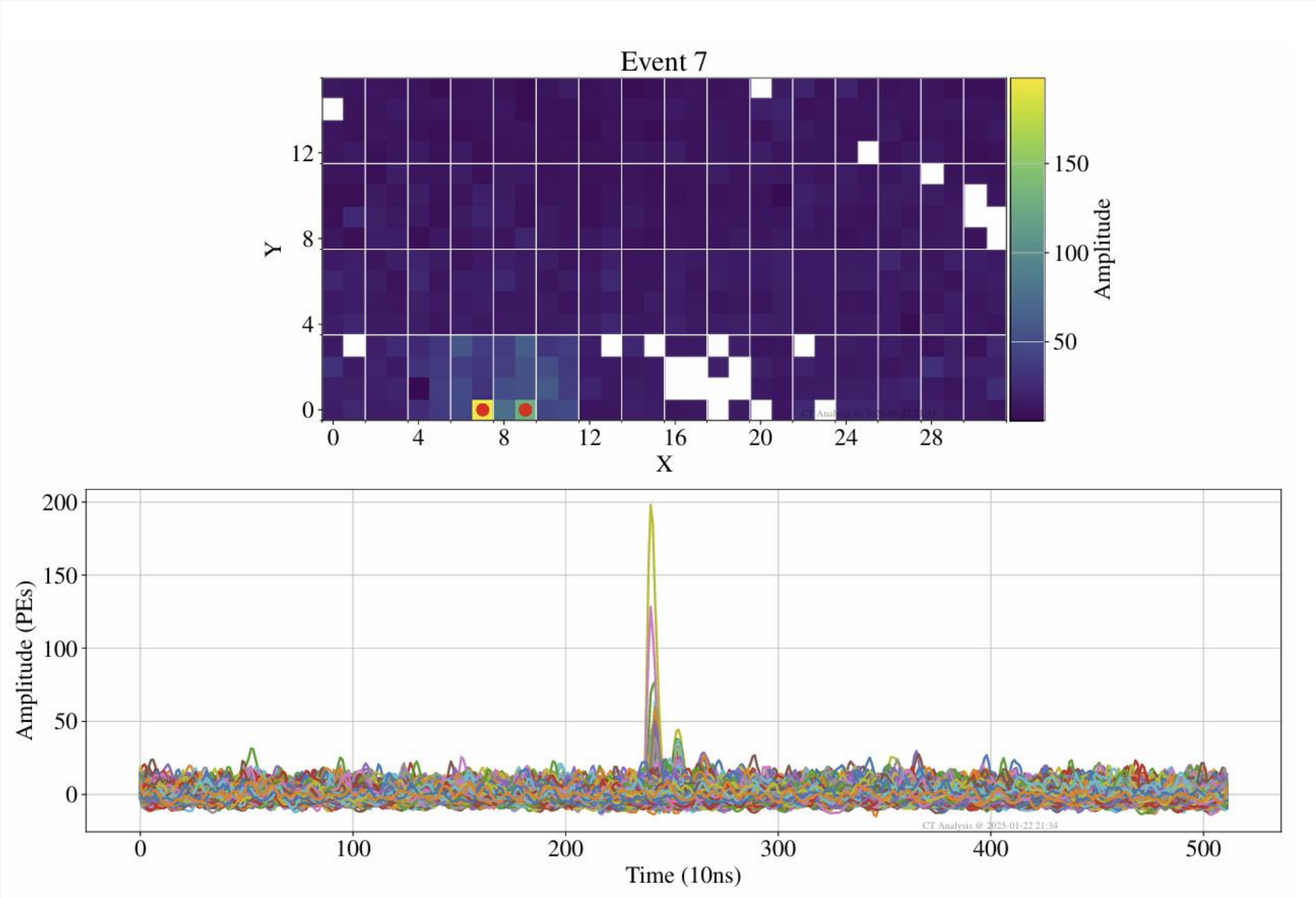


Above limb

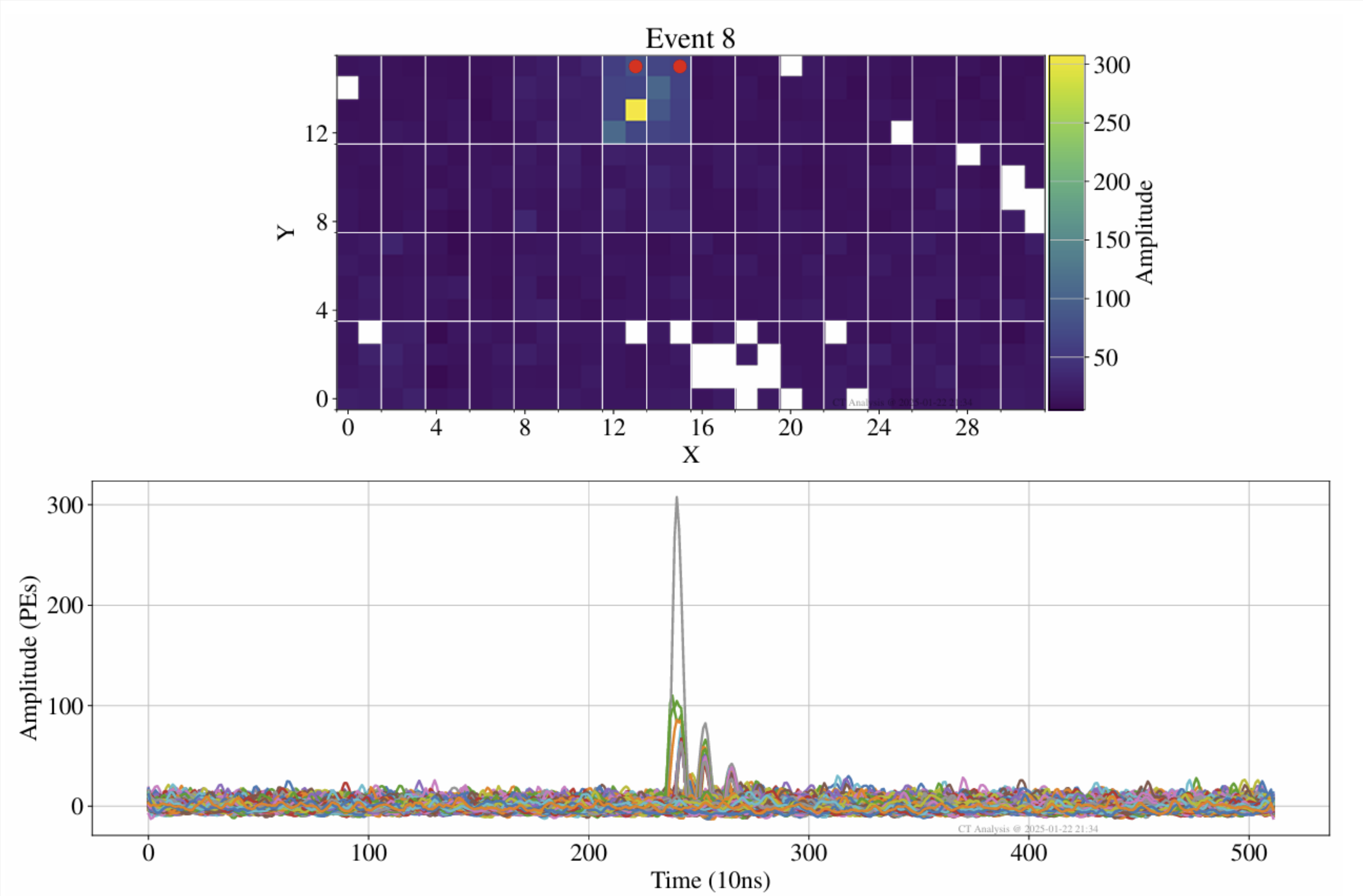


Event 6
Y
X
Amplitude
0
4
8
12
16
20
24
28
150
125
100
75
50
25
Amplitude (PEs)
Time (10ns)
0
100
200
300
400
500

Above limb



Above limb



Event 8
Y
X
Amplitude
300
250
200
150
100
50
Amplitude (PEs)
Time (10ns)

References

Citations

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