



PIERRE  
AUGER  
OBSERVATORY



BERGISCHE  
UNIVERSITÄT  
WUPPERTAL

# PAO IN ACME: ARCHIVE EXPANSION & NEUTRINO SEARCH FOLLOW-UP SYSTEM

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## ASTROCOLIBIRI WORKSHOP

12-10-2026

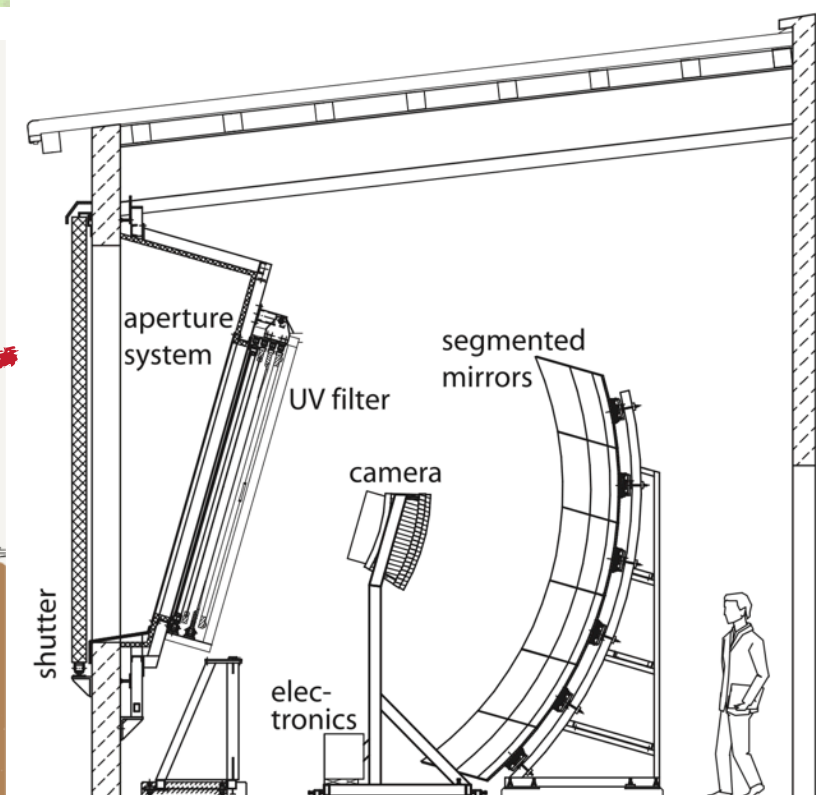
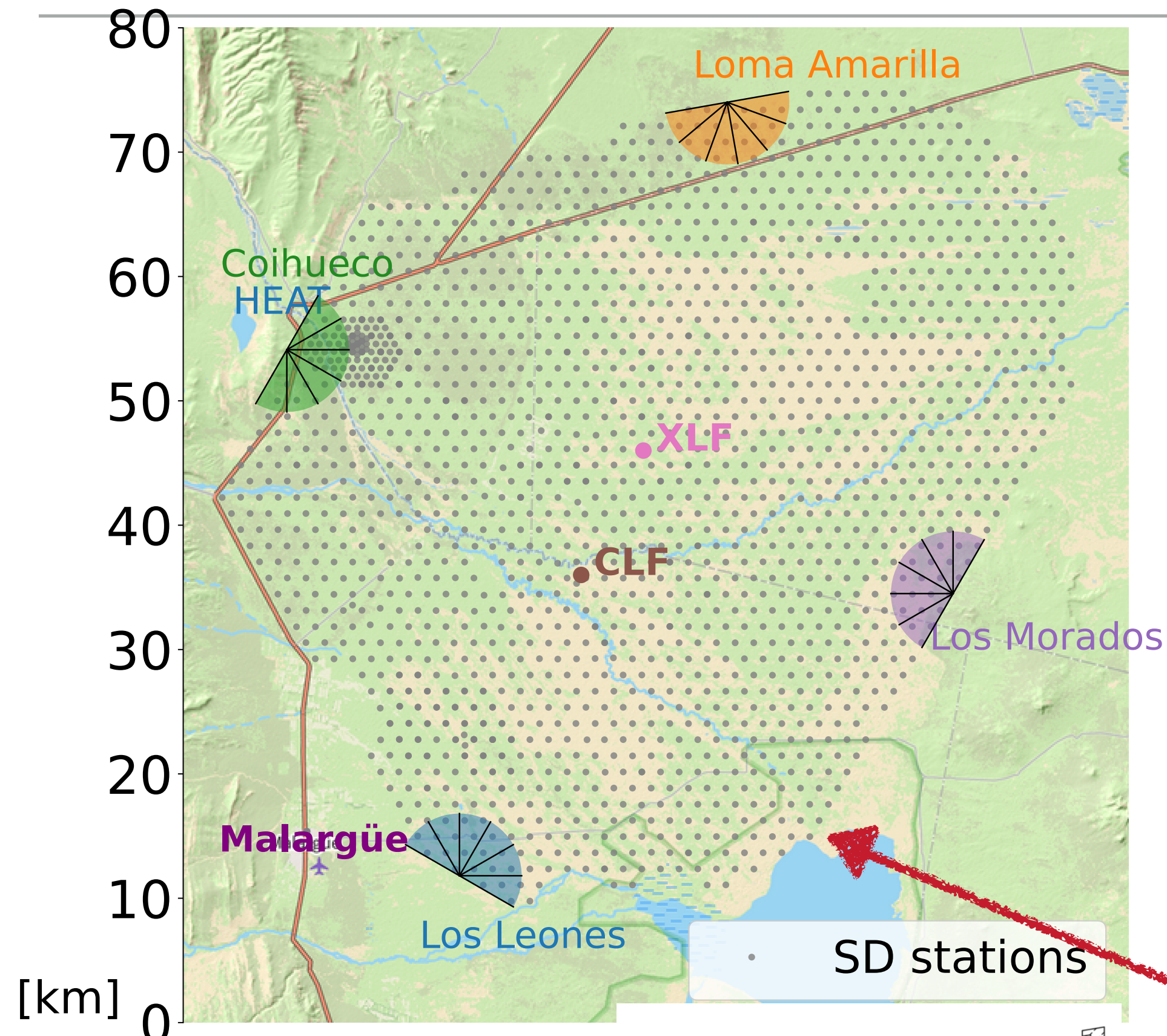
**SRIJAN SEHGAL**

**FOR THE PIERRE AUGER COLLABORATION**

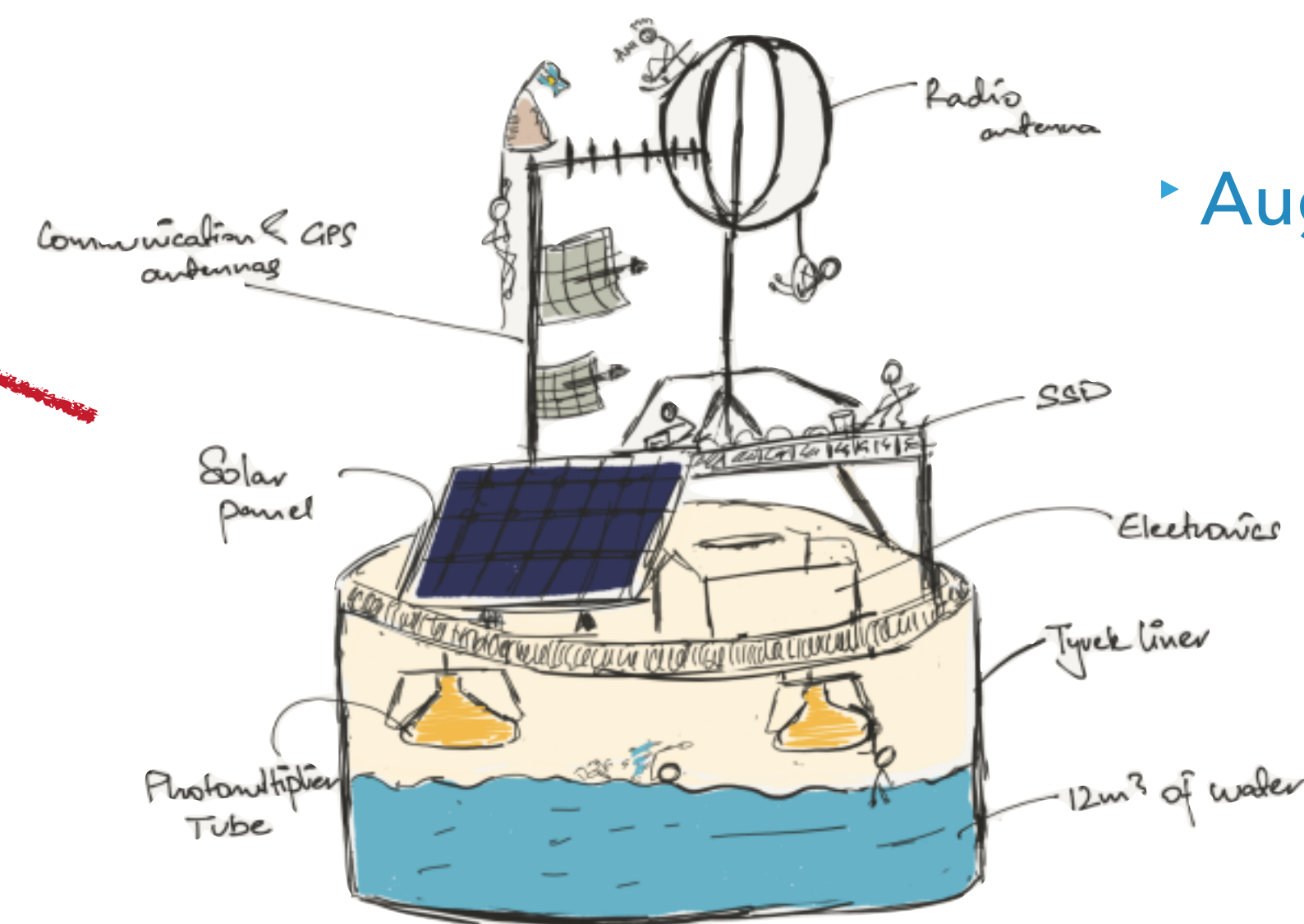


Funded by  
the European Union

[sehgal@uni-wuppertal.de](mailto:sehgal@uni-wuppertal.de)



- Largest cosmic ray detector  $\sim 3000 \text{ km}^2$
- Surface Detector (SD) SD-1500 & SD-750
  - 1660 water Cherenkov stations
  - Detects EAS via secondary particles at ground
- Fluorescence Detector (FD)
  - 4 sites with 27 telescopes
  - Measures longitude development via fluorescence
- Duty Cycle - SD  $\sim 100\%$ , FD  $\sim 15\%$



- AugerPrime upgrade operational

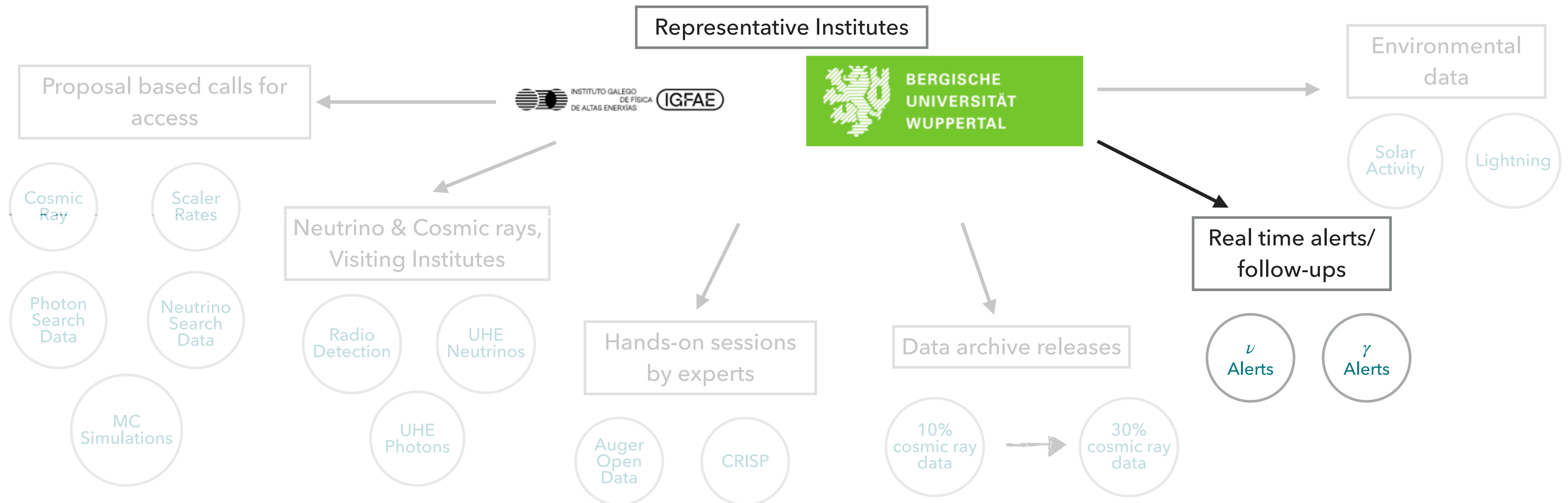
- Increases detection capability
- Potential for increasing neutrino sensitivity
- And much more .....

# THE ASTROPHYSICS CENTRE FOR MULTI-MESSENGER STUDIES IN EUROPE

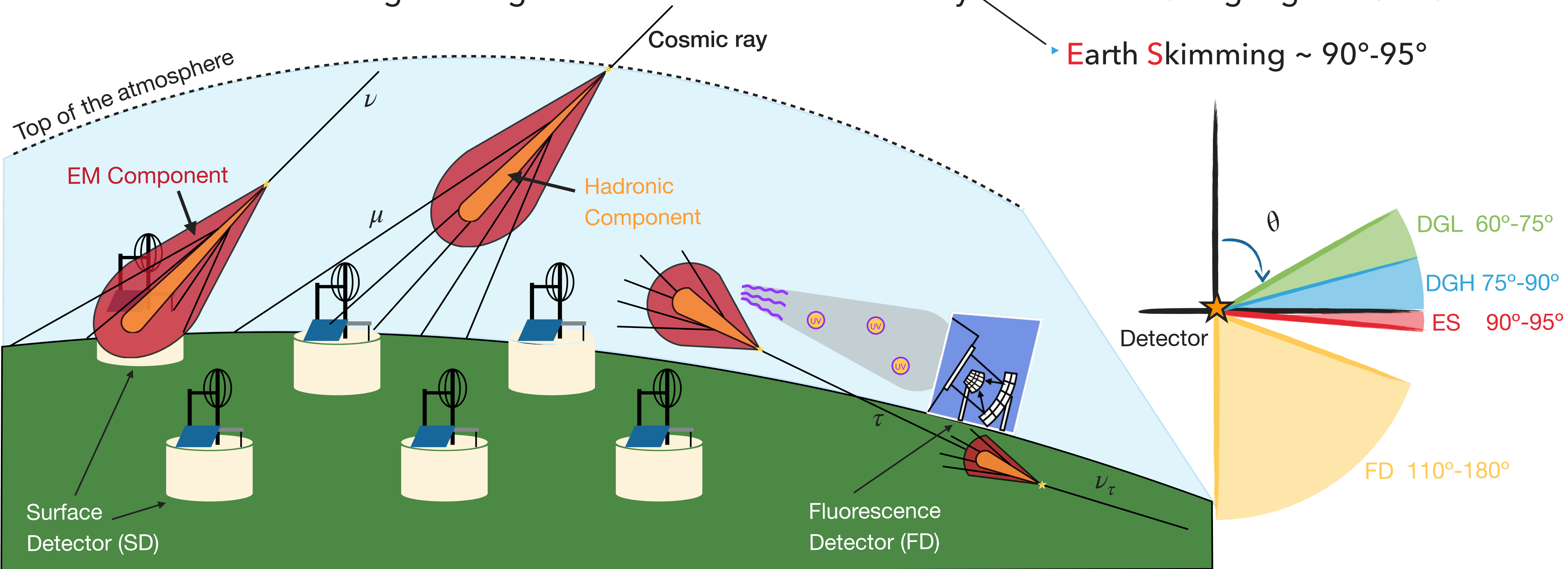


- ▶ Initiative to offer better access to the best research infrastructures
- ▶ Funded under the EU Horizon Europe Research and Innovation Programme till 2028
- ▶ ~41 institutes (BUW + USC/IGFAE), 12 infrastructures (Auger)

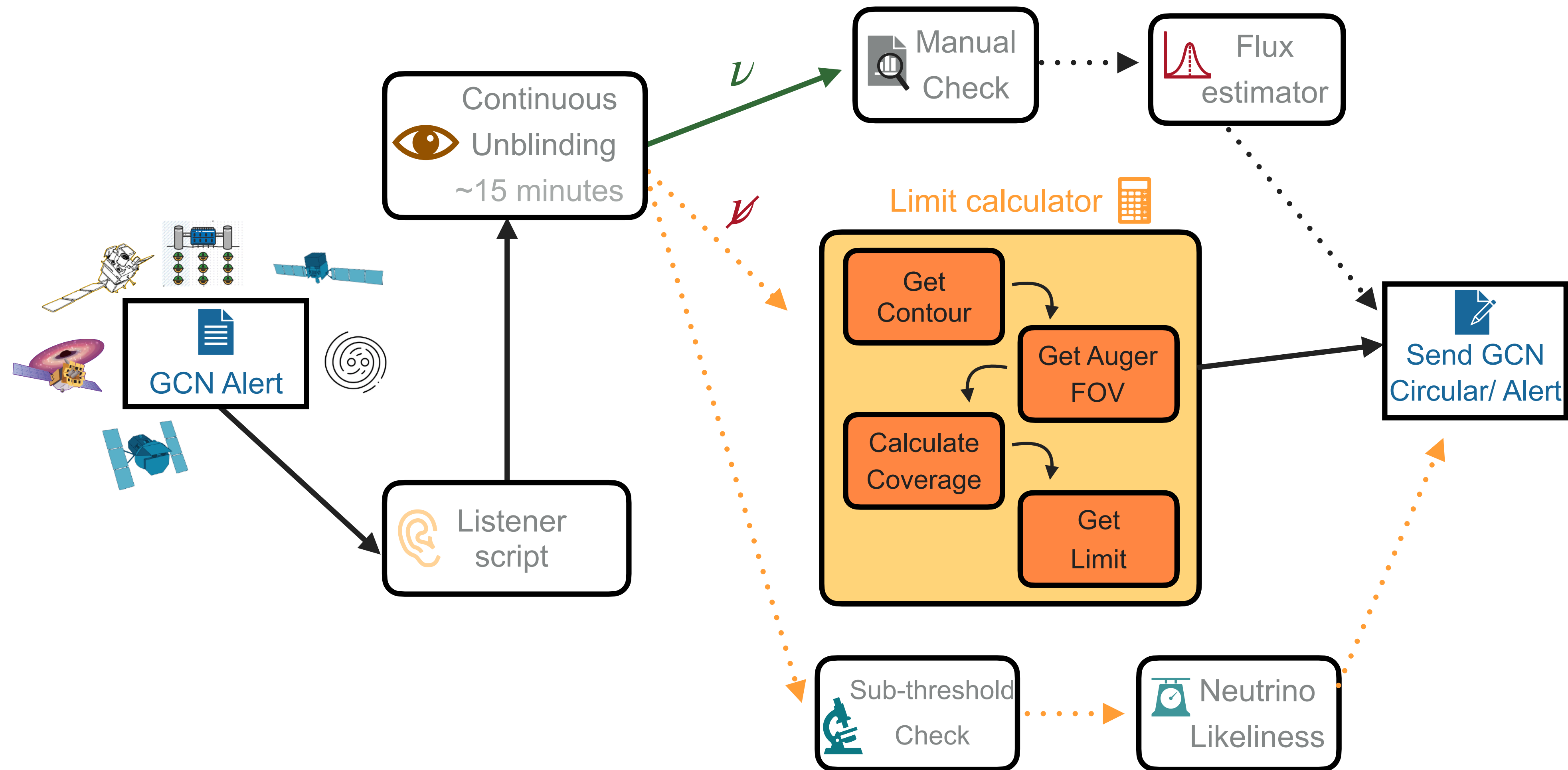
<https://www.acme-astro.eu/>



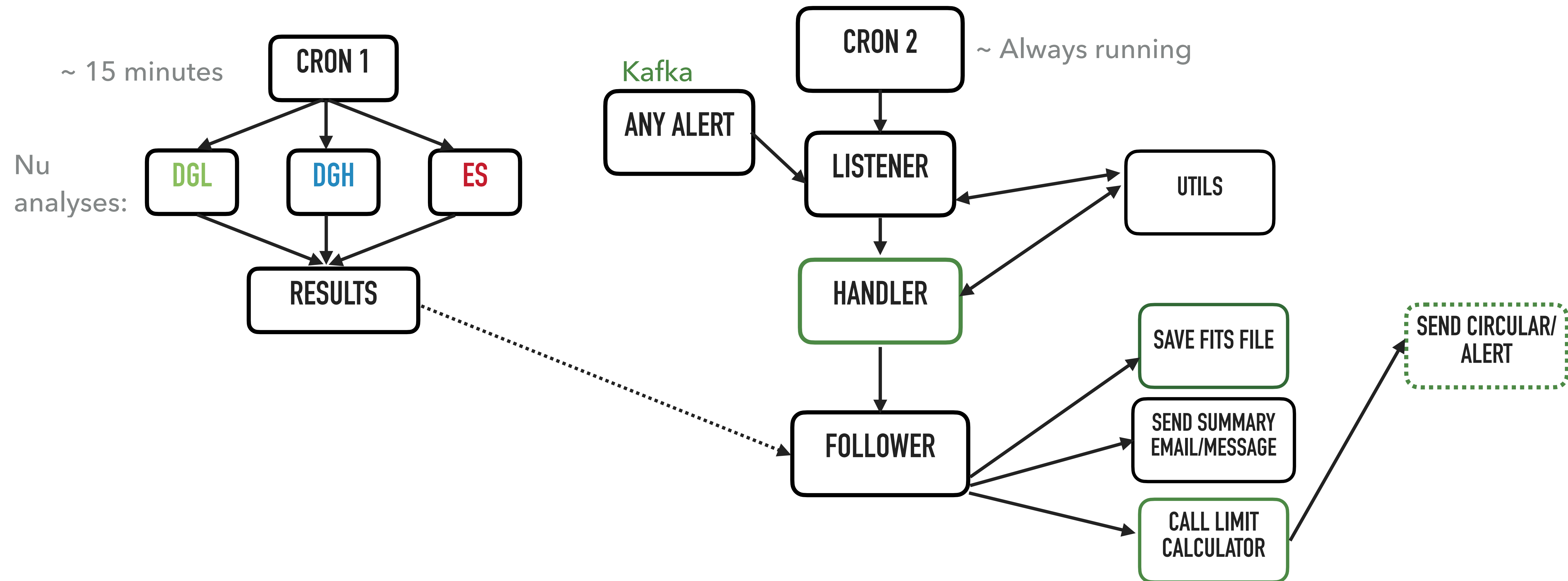
- ▶ Neutrinos can be detected at the Pierre Auger Observatory indirectly via Extensive Air Showers (EASs)
- ▶ UHECR main background, higher separation  $> 60^\circ$  zenith angle ( $\theta$ )
- ▶ Divided into **three** angular ranges to maximise search efficiency
  - ▶ Down **G**oing **L**ow  $\sim 60^\circ$ - $75^\circ$
  - ▶ Down **G**oing **H**igh  $\sim 75^\circ$ - $90^\circ$
  - ▶ Earth **S**kimming  $\sim 90^\circ$ - $95^\circ$



- ▶ A basic real-time neutrino search follow-up system **active**, being upgraded to be **more robust**
- ▶ High energy gamma, neutrino and Gravitational Wave follow-ups have been **implemented**
- ▶ Sub-threshold checks and alert publishing is being explored



- Two parallel cron jobs running at the Observatory
- One implements neutrino analysis on data every 15 minutes
- Other listens to all GCN alerts and then checks if any neutrino was found in the most current analysis result file, allows follows up depending on alerts



📖 Loading credentials:

Kafka listener started...

First 100 chars: b'{"alert\_type":

"PRELIMINARY",

"time\_created": "2026-05-08T11:01:01Z",

"superevent\_id":"MS260508g", '

✅ **MS260508g passes FAR cut threshold: FAR=1/348050.03 years**

🇺🇸 **Classification - P(BNS): 1.0 | P(NSBH): 0.0 |**

**P(BBH): 0.0 | P(Terr): 0.0**

🇺🇸 **Properties - P(HasNS): 1.0 | P(HasRemnant):**

**1.0 | P(HasMassGap): 0.0**

📁 Unpacking embedded sky map

📁 Successfully extracted map directly to: fitsFiles/

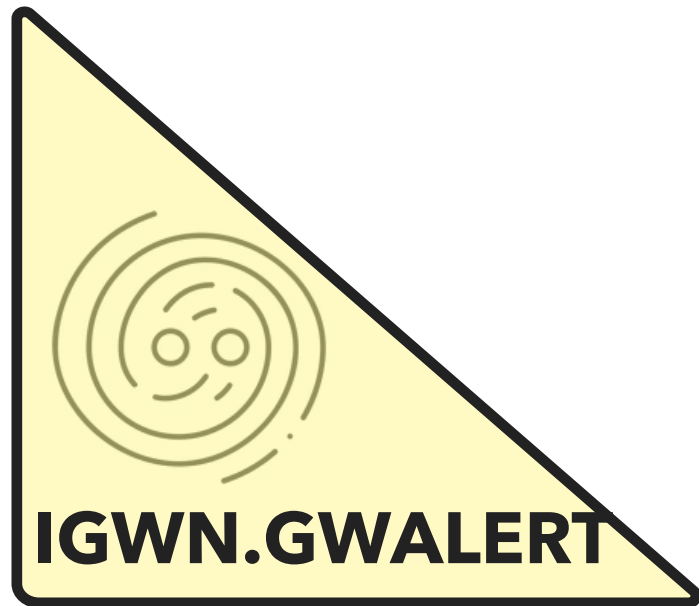
MS260508g.fits.gz

✓ Follower spawned: call(['python3', '

follower.py', 'GW', 'fitsFiles/

MS260508g.fits.gz'])

✓ Email sent



**gcn.classic.text.FERMI\_GBM\_ALERT**

Kafka listener started...

Alert received: 1

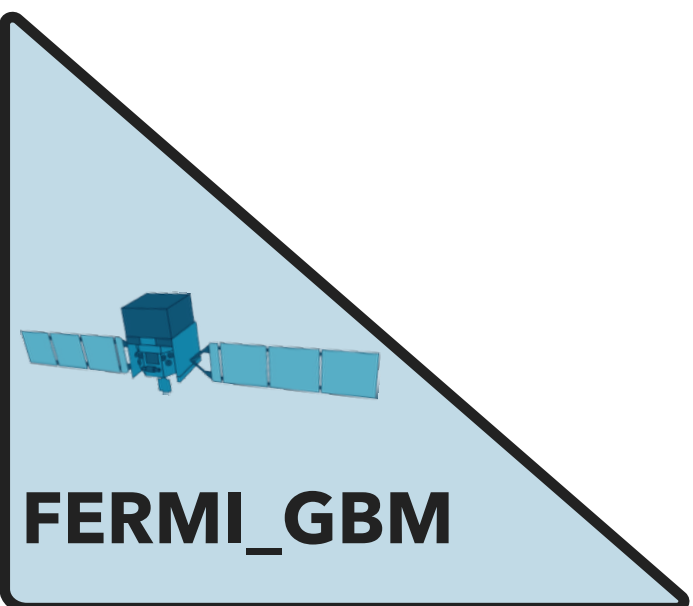
✉ Received message #1 on topic: gcn.classic.text.FERMI\_GBM\_ALERT

📡 GCN TEXT ALERT PARSED | Topic: gcn.classic.text.FERMI\_GBM\_ALERT  
ID: 800351945 | Start: Wed 13 May 26 07:59:05 UT | End: Wed 13 May 26  
07:59:05 UT + 7200s (Fallback)

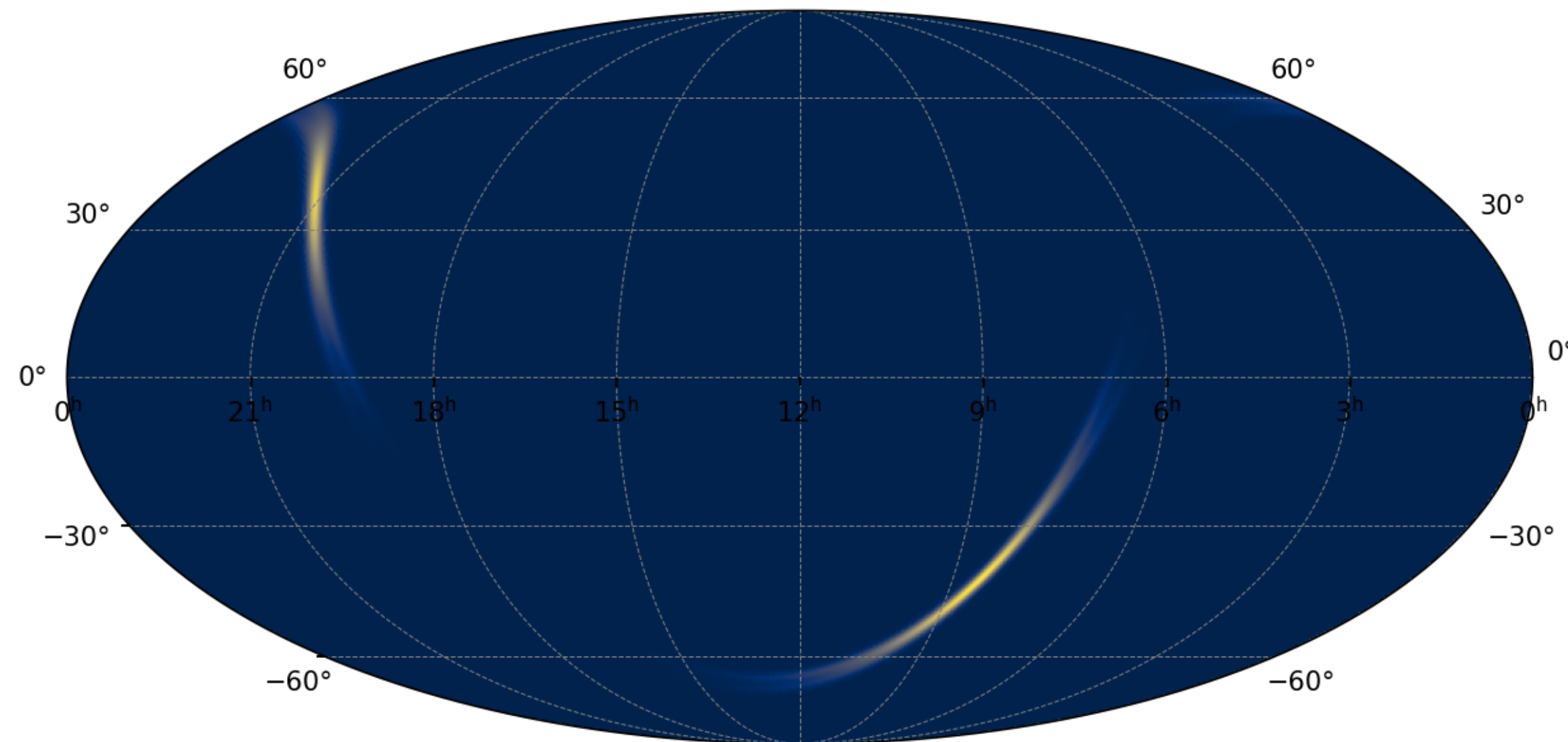
🚀 **SUCCESS: Launching follower for 800351945**

✓ Follower spawned: call(['python3', 'follower.py', 'TIME', 'Wed 13  
May 26 07:59:05 UT', 'Wed 13 May 26

✓ Email sent



## Step 1: Calculate 90% CL contour

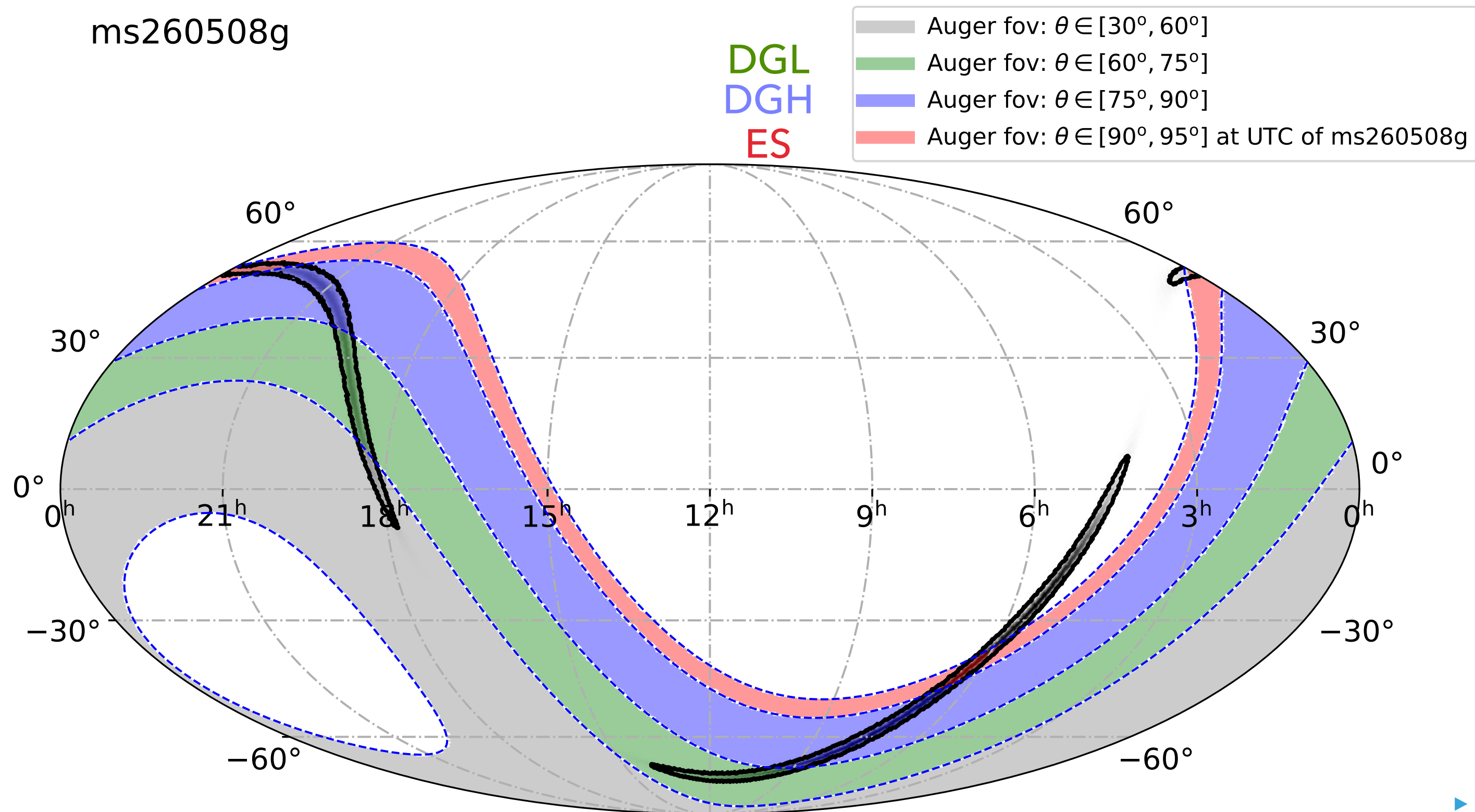


Ms260508g

- ▶ Obtain the localization probability from FITS file
- ▶ Choose highest pixels and define lobes across the contour after HEALPIX ring indexing
- ▶ Split lobes
- ▶ **Update:** Works Multi order FITS

## Step 2: Compute Field of View

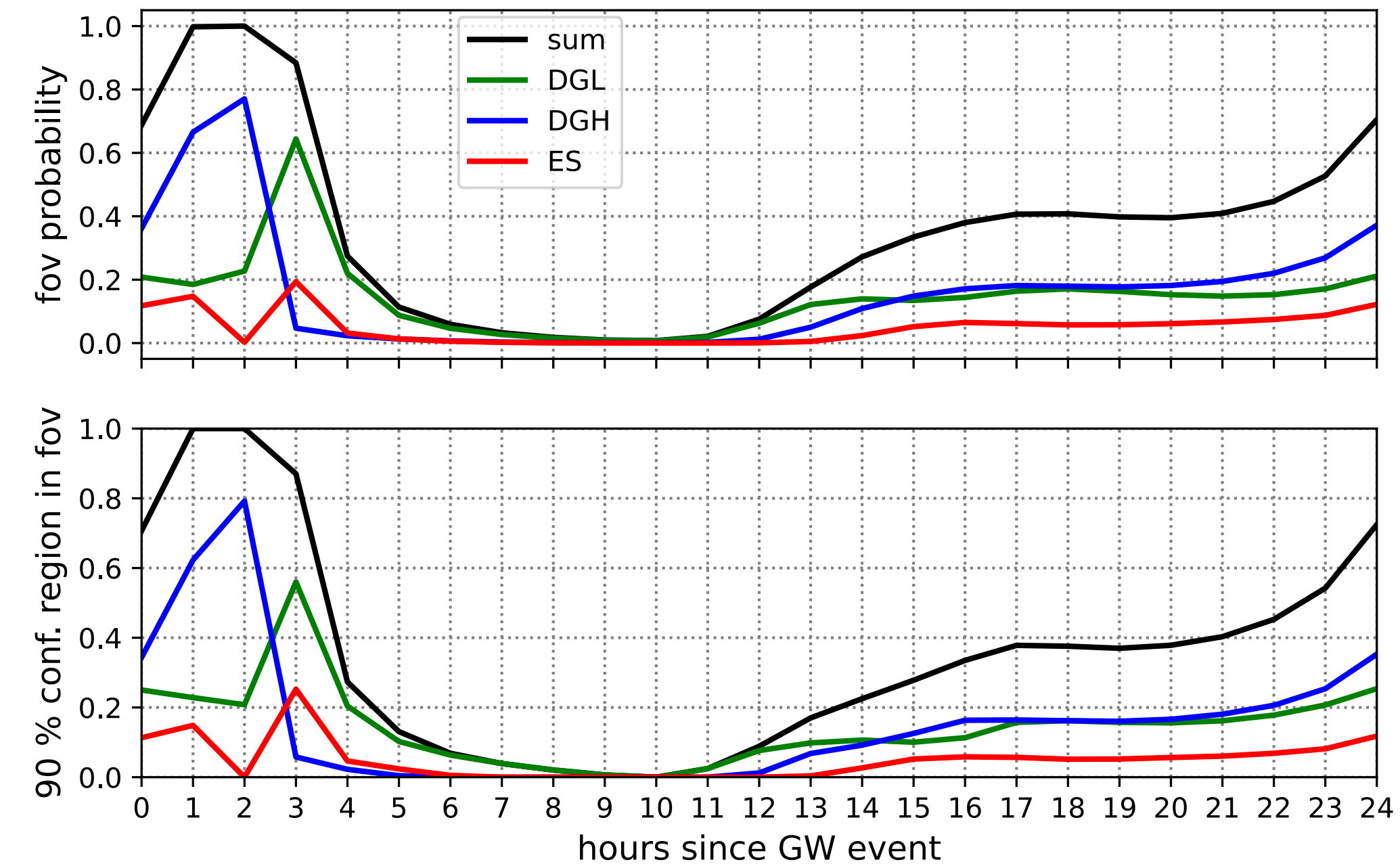
ms260508g



- Obtain FoV for neutrino channels

## Step 3: Calculate Coverage

2026-05-08



- Scan FITS file every 4 min during 24h
- Calculate start and end times of max probability
- Calculate probability to be in FoV

Get  
Limit

► One-day fluence limit for a point source

► Assumptions:

- Normal operating status of SD-1500
- $\nu$  flux  $\propto E^{-2}$

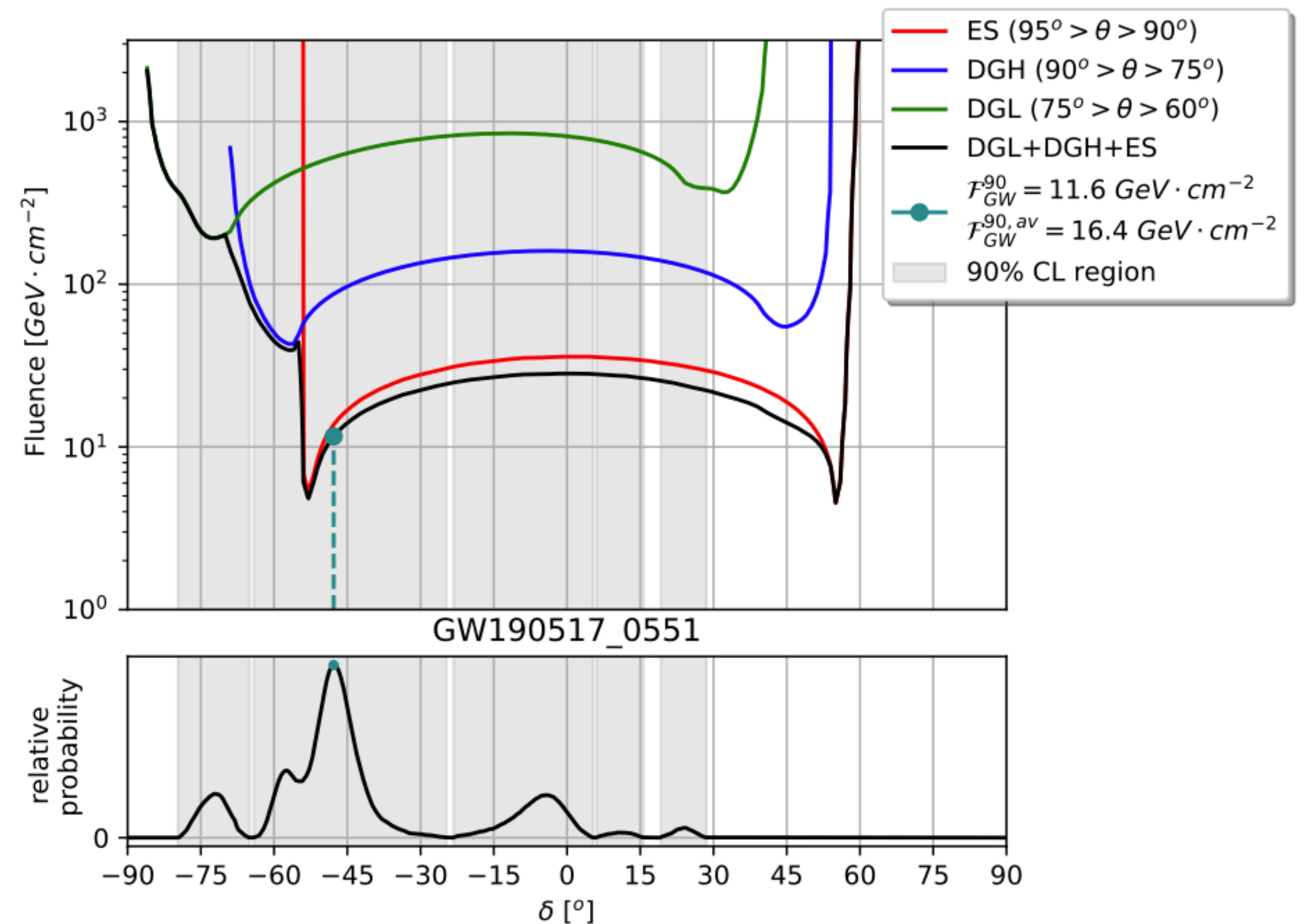
► Currently,

$$\phi_0^{90}(\delta) = \frac{2.39}{\int_{E_\nu} (E_\nu/1\text{GeV})^{-2} \epsilon_{\text{tot}}(E_\nu, \delta) dE_\nu}$$

$$F_{90}(\delta) = \phi_0^{90}(\delta) T_{\text{day}} 1\text{GeV}^2$$

- **Update:** Implemented a new method to correct for partially contained sources

## Step 5: Calculate Fluence limit

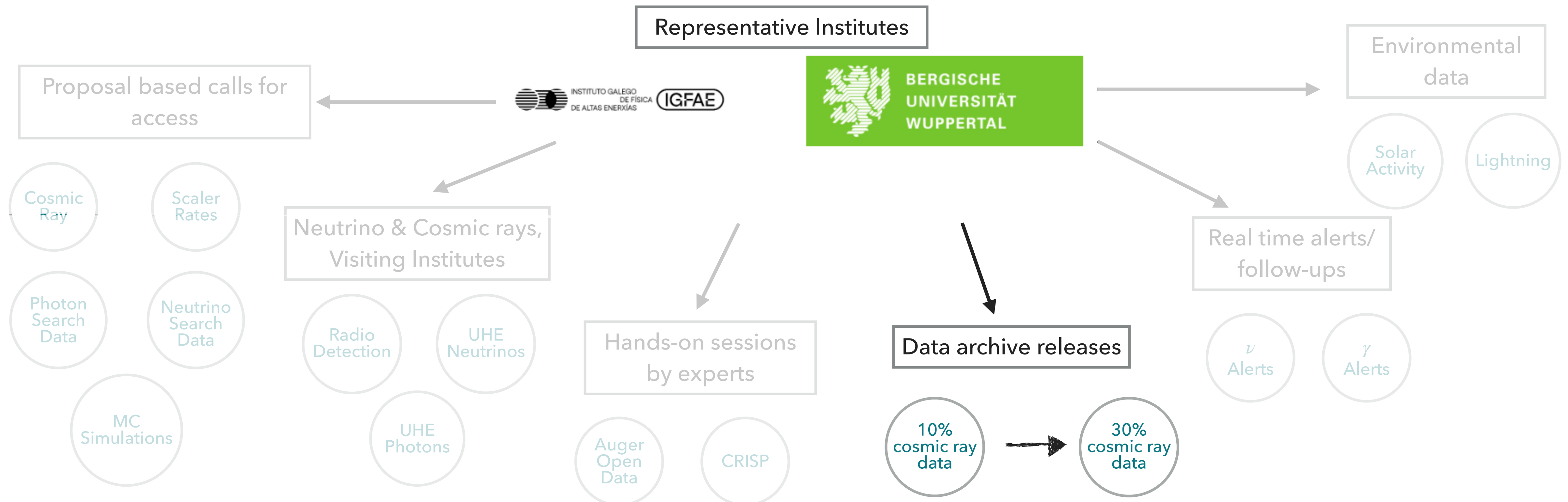


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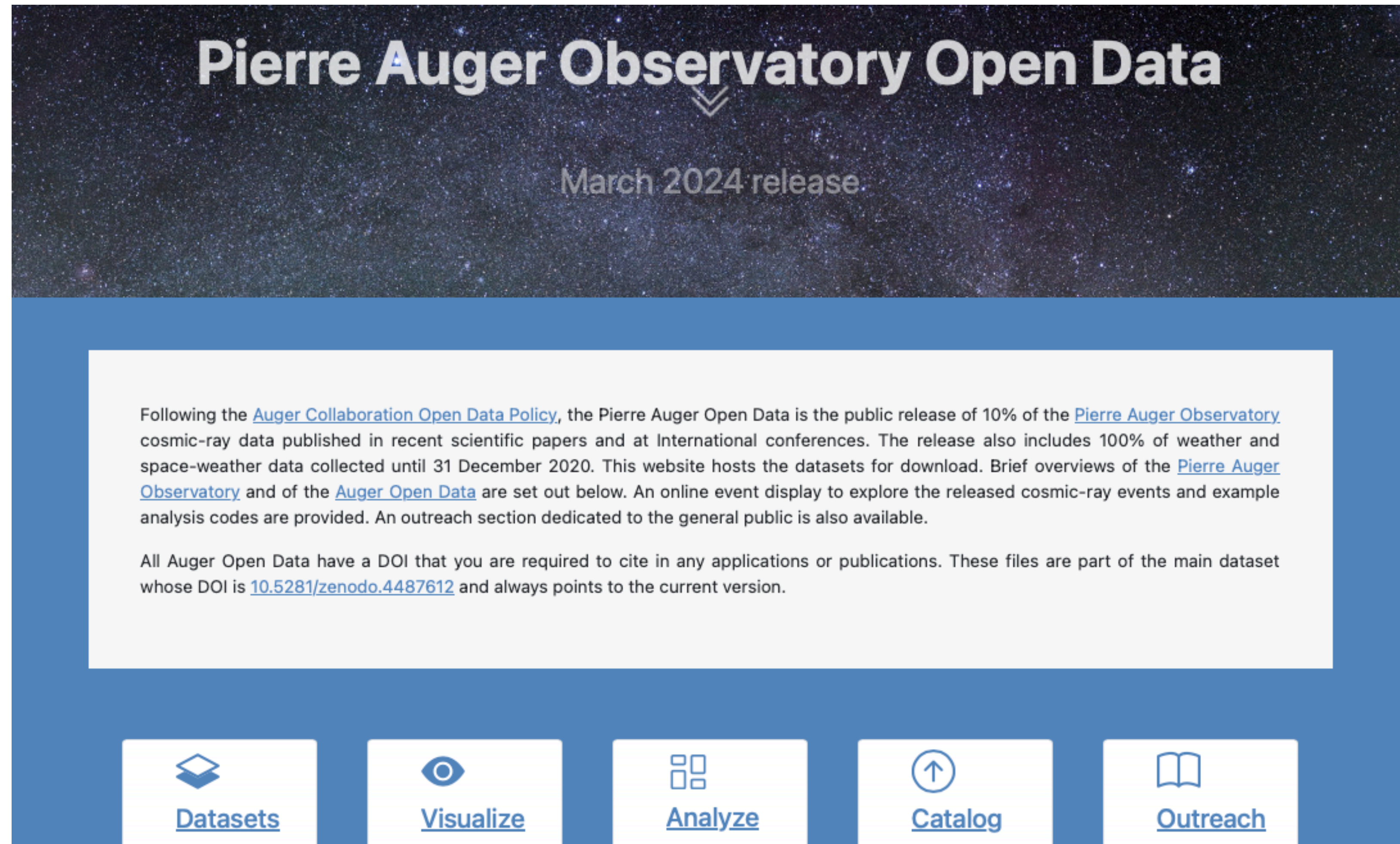


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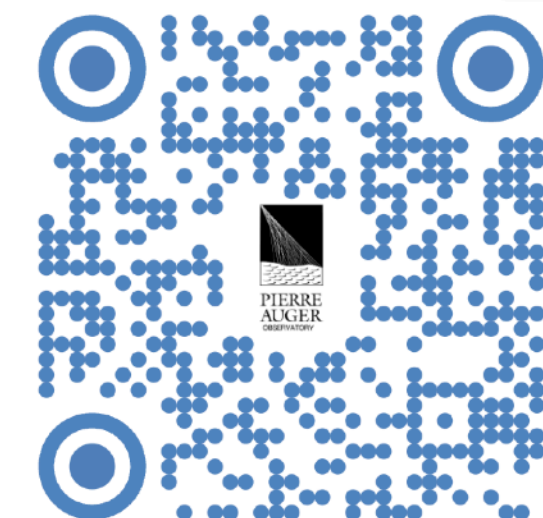


- ▶ Have been releasing data since 2007
  - ▶ The Pierre Auger Observatory Public Event Browser
  - ▶ 1% of data released for educational purposes
- ▶ The Open Data Portal set up in 2021
  - ▶ Based on the [FAIR](#) principles
  - ▶ Consists of :
    - ▶ [Detailed explanation](#) of detectors and the sample
    - ▶ [Close-to-raw data \(JSON\)](#) and [event level info \(CSV\)](#)
    - ▶ Online [2-D and 3-D visualization tools](#)
    - ▶ [Analysis examples \(Python\)](#)
    - ▶ [100 highest-energy events](#) as a catalog
    - ▶ Engaging [outreach](#) section
  - ▶ Regular releases with latency

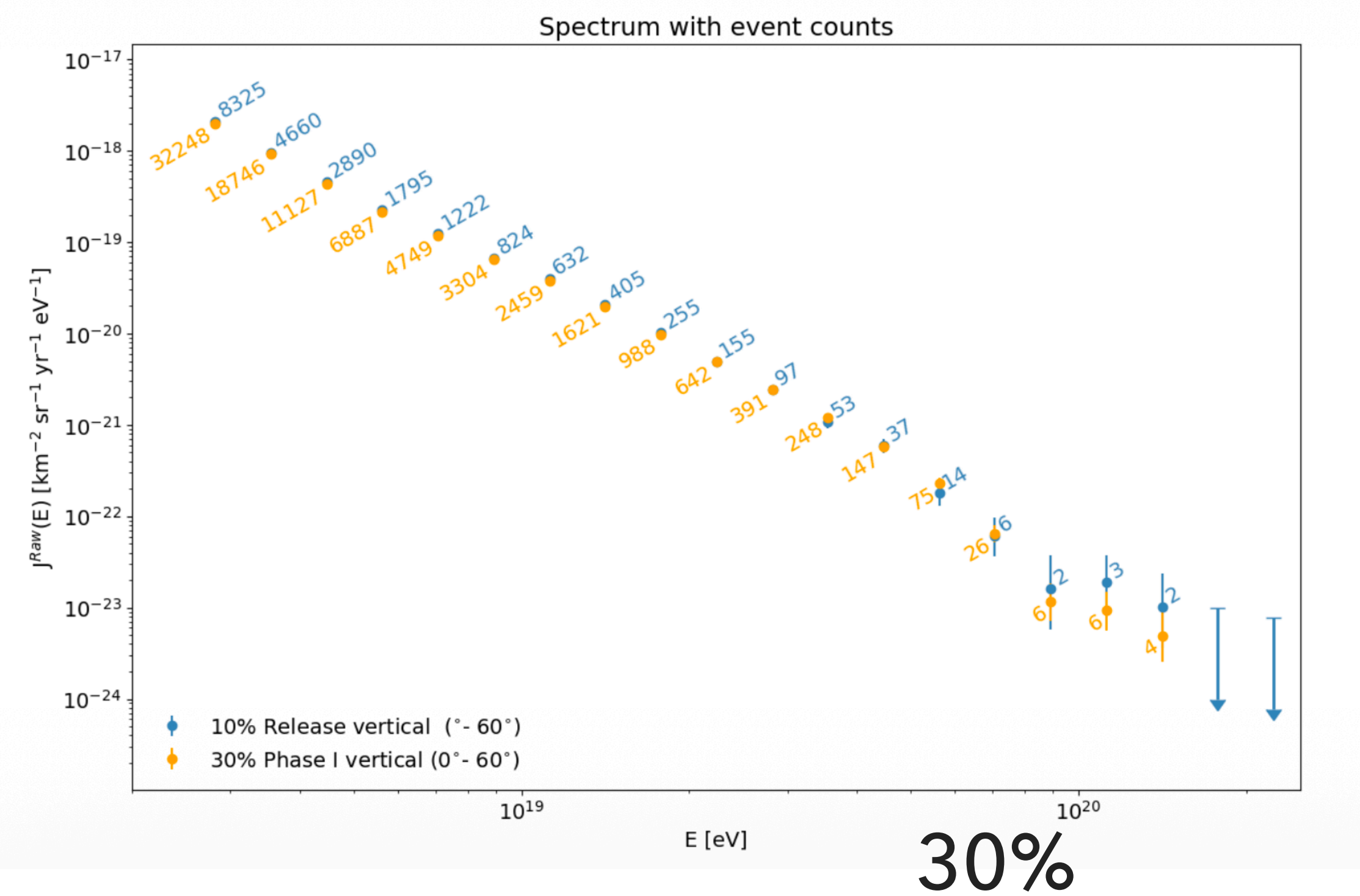


The screenshot shows the homepage of the Pierre Auger Observatory Open Data portal. The header features the title "Pierre Auger Observatory Open Data" in large white letters against a dark, starry background, with a downward arrow icon and the text "March 2024 release" below it. The main content area is a white box with blue text explaining the data release policy, mentioning the Auger Collaboration Open Data Policy and the public release of 10% of the Pierre Auger Observatory cosmic-ray data. It also includes a DOI for the data: [10.5281/zenodo.4487612](https://doi.org/10.5281/zenodo.4487612). At the bottom, there is a navigation bar with five icons and labels: "Datasets" (book icon), "Visualize" (eye icon), "Analyze" (grid icon), "Catalog" (up arrow icon), and "Outreach" (book icon).

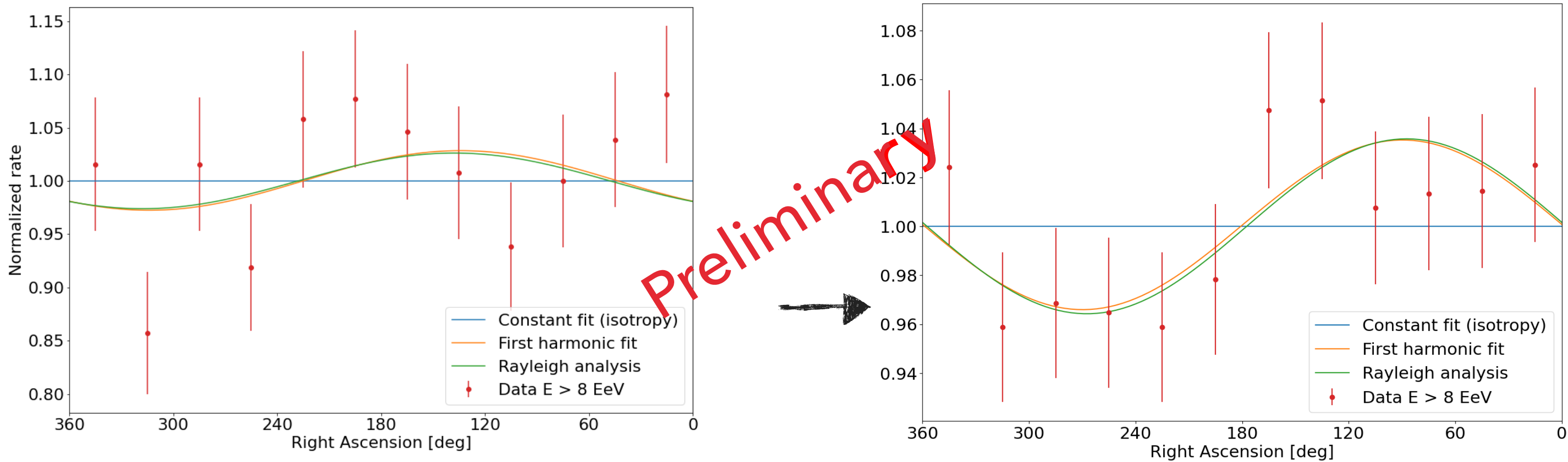
▶ <https://opendata.auger.org/>



- ▶ Working on increasing the fraction from 10% -> 30%
  - ▶ Data Period: 2004-2022
    - ▶ 30% events with SD-1500 and hybrid (SD+FD) events
    - ▶ Zenith 0°-60°, E > 2.5 EeV
    - ▶ Zenith 60°-80°, E > 4EeV
- ▶ Exposure > 30,000 km<sup>2</sup> sr yr
- ▶ Updated analysis notebooks



Release by 2027



- ▶ ACME offers a unique opportunity to provide **better access** to multi-messenger observatories
- ▶ The real-time alert system is being **improved** and extended
- ▶ The open archive is being regularly increased with the next release offering **30%** of all recorded cosmic ray data
- ▶ The Pierre Auger Observatory plans to have **yearly proposal calls** to provide access
- ▶ **Visits** to institutions are also provided for skill development

