



ASTRI-1: Early data and performance highlights

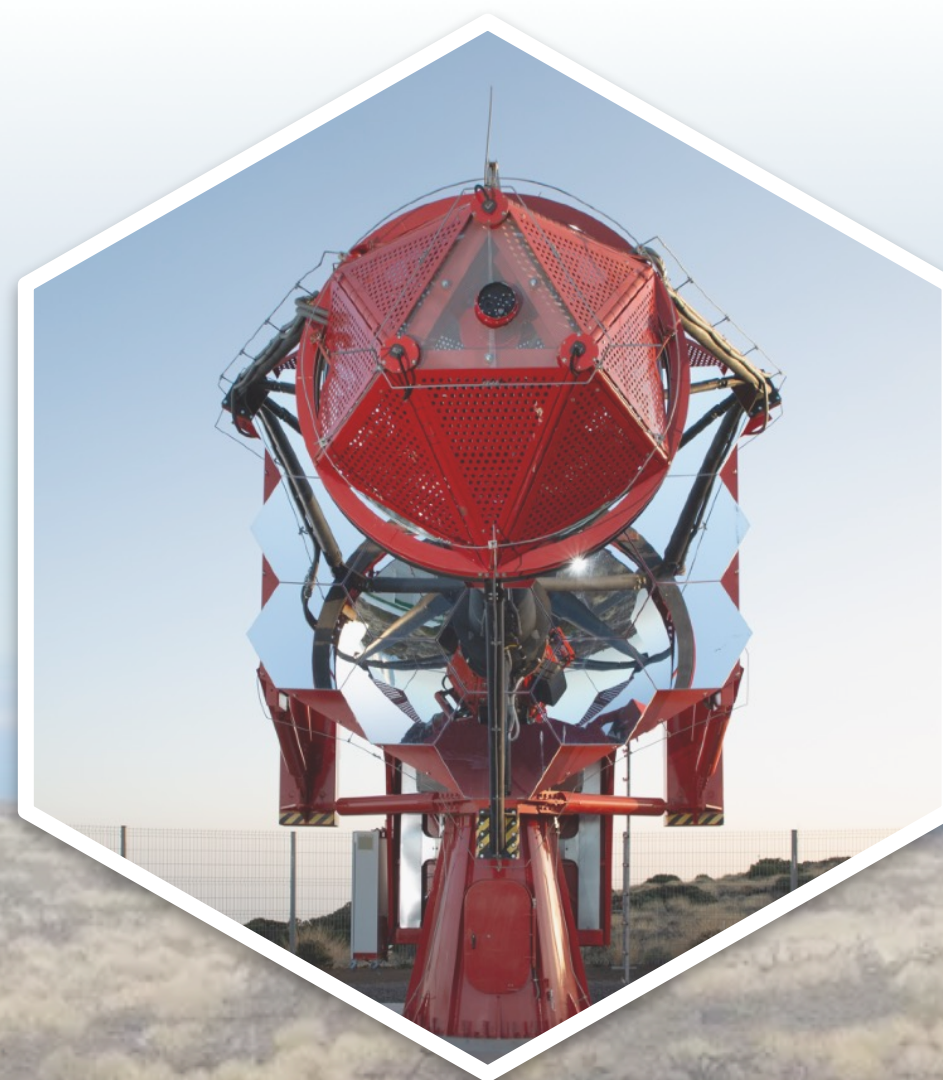
Silvia Crestan

for the ASTRI Project





ASTROFISICA CON SPECCHI A TECNOLOGIA REPLICANTE ITALIANA
ASTROPHYSICS WITH MIRRORS WITH ITALIAN REPLICATING TECHNOLOGY
帶有意大利复制技术的镜子天体物理学



ASTRI Project

2010

2014

2024

2026



Develop and deploy an innovative end-to-end prototype and an array of Cherenkov telescopes based on new technology for energies 1-100 TeV

ASTRI-Horn
Prototype



ASTRI-1



ASTRI Mini Array



ASTRI-1 basement

Astronomy & Astrophysics manuscript no. aa
February 4, 2020

First detection of the Crab Nebula at TeV energies with a Cherenkov telescope in a dual-mirror Schwarzschild-Couder configuration: the ASTRI-Horn telescope

S. Lombardi^{1,2,*}, O. Catalano^{3,*}, S. Scuderi^{4,*}, L. A. Antonelli^{1,2}, G. Pareschi⁵, E. Antolini⁶, L. Arrabito⁷, ...

PS PROCEEDINGS OF SCIENCE

ASTRI-1: Early data and performance highlights

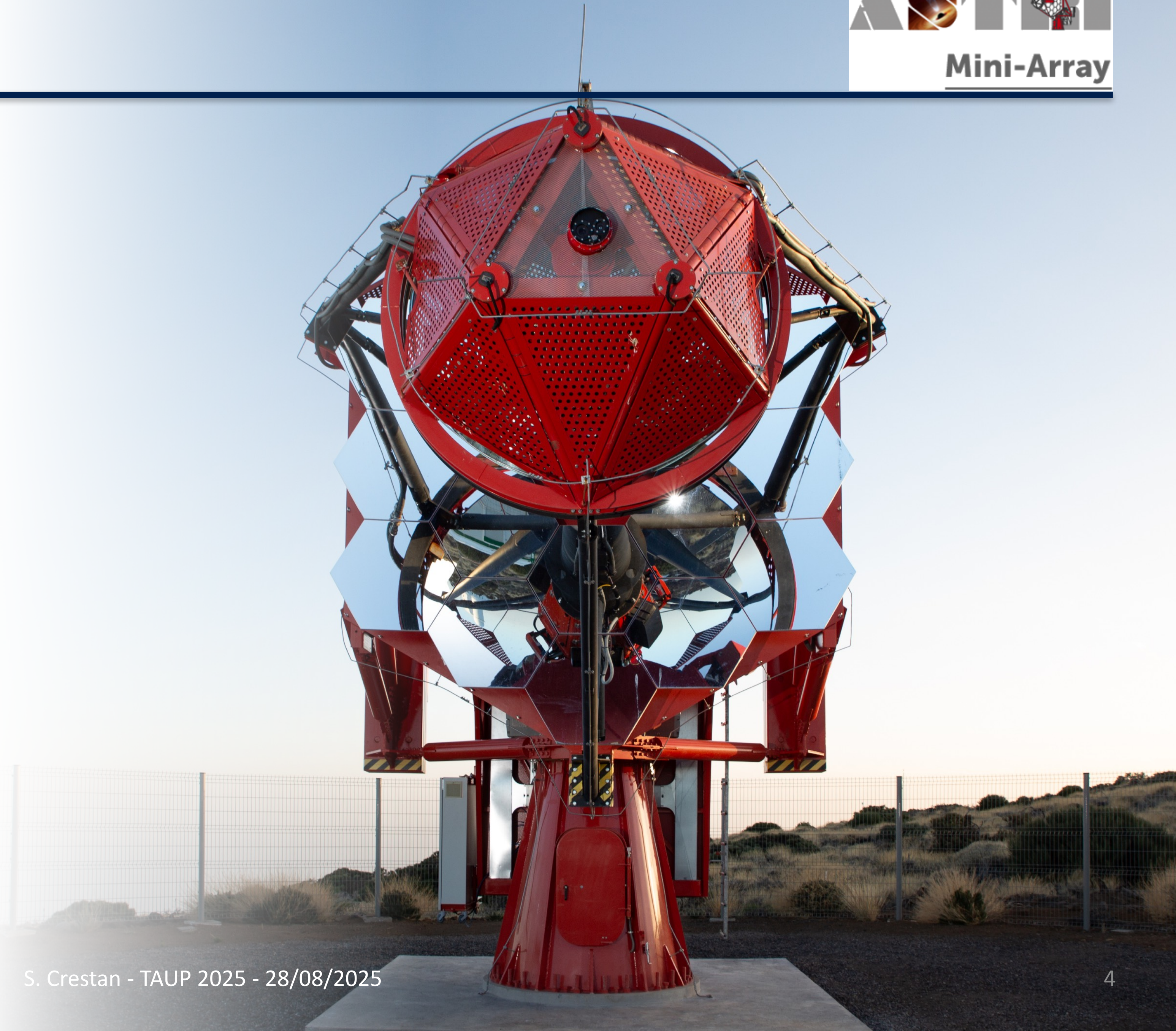
S. Crestan,^a S. Lombardi,^{b,c} L. Barrios,^d C. Bigongiari,^b A. Bonollo,^{e,f,a} P. Bruno,^g A. Bulgarelli,^h M. Corpora,ⁱ E. Fedorova,^h S. Germani,^j A. Giuliani,^a S. Iovenitti,^k V. La Parola,^g G. Leto,^g F. Lo Gerfo,ⁱ F. Lucarelli,^{h,c} T. Mineo,ⁱ E. Molina,^d D. Mollica,ⁱ G. Pareschi,^k V. Pastore,^h F. Pintore,ⁱ M. Rigoselli,^{k,a} F. G. Saturni,^b P. Sangiorgi, S. Scuderi,^a G. Sottile,ⁱ G. Tosti^j for the ASTRI Project[†]

PoS ICRC2025

ASTRI Telescopes



- **Dual-mirror optical layout**
 - First time for Cherenkov telescopes
 - Schwarzschild-Couder optical design
 - Optimal PSF across the entire FoV
- **Silicon photo-multipliers camera**
 - Small pixel-size (0.19°)
 - Can work during moonlight condition
- **Wide FoV ($>10^\circ$)**
 - Important for surveys and multi-target fields
 - Important for extended sources
 - Serendipity sources
- **Expected performance**
 - Energy threshold ~ 1 TeV
 - Energy resolution $< 25\%$
 - Angular resolution $< 0.25^\circ$
 - Sensitivity ~ 1 Crab @ 5σ in few hours



ASTRI Site

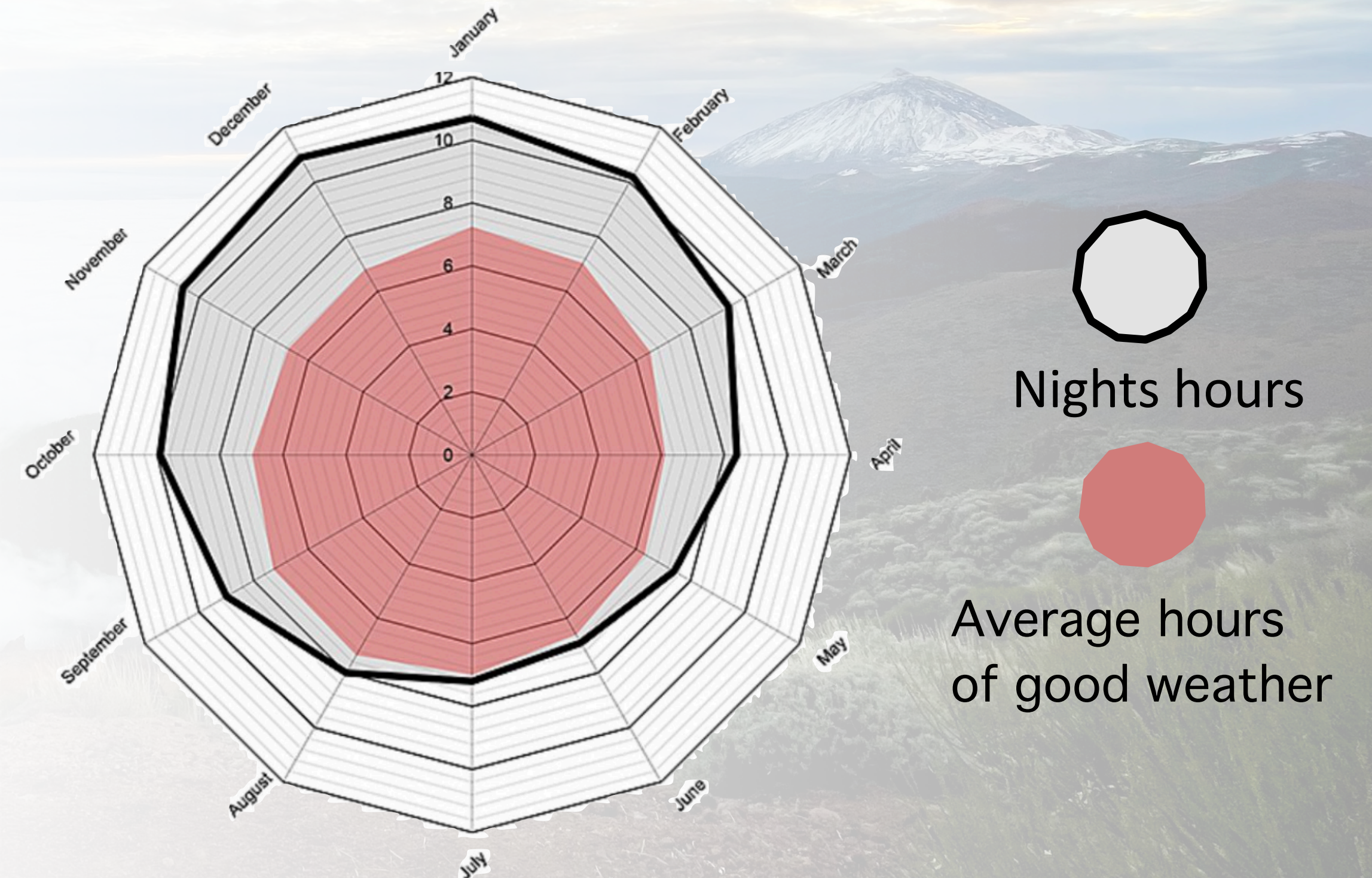
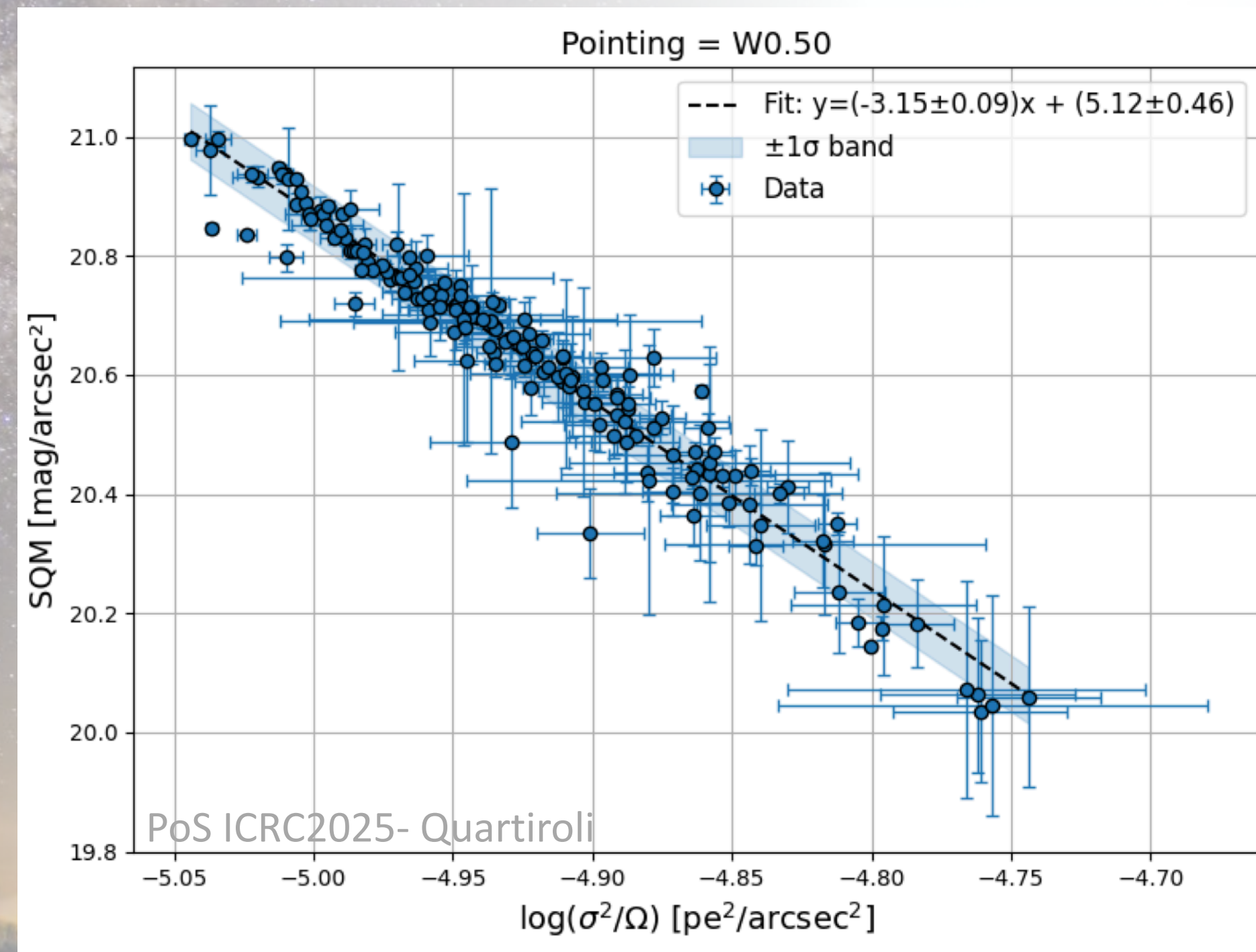
- Dark night sky: Dry air and minimal light pollution create optimal darkness
- Minimal cloud coverage: Teide's high altitude keeps it above the inversion layer, reducing cloud interference



ASTRI Site

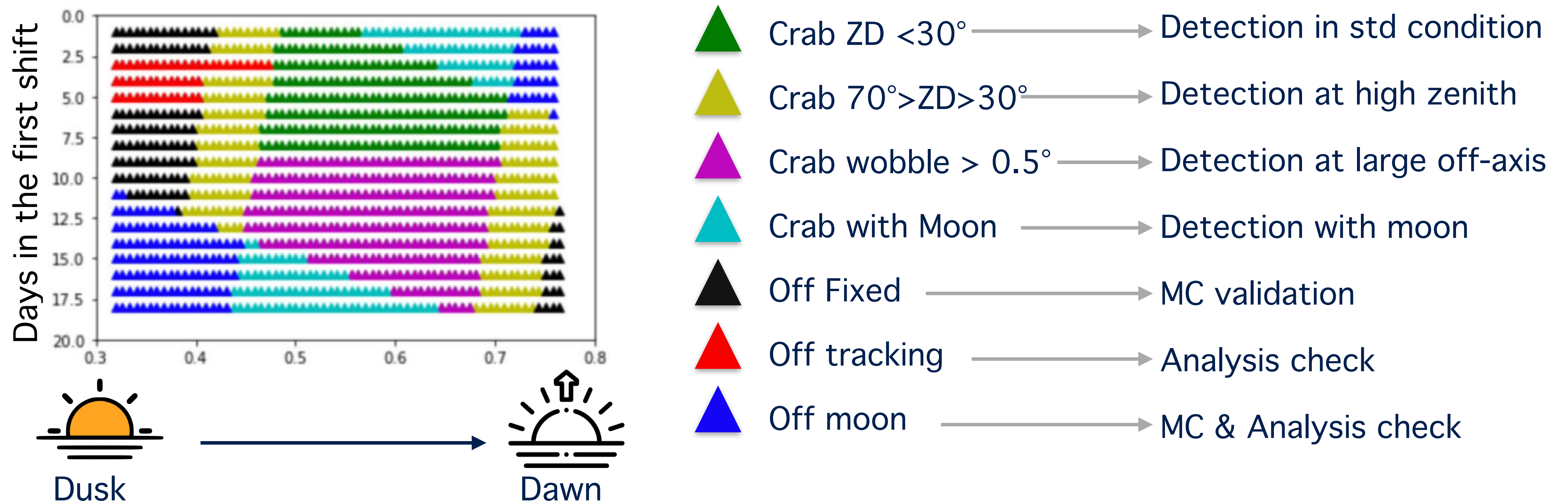


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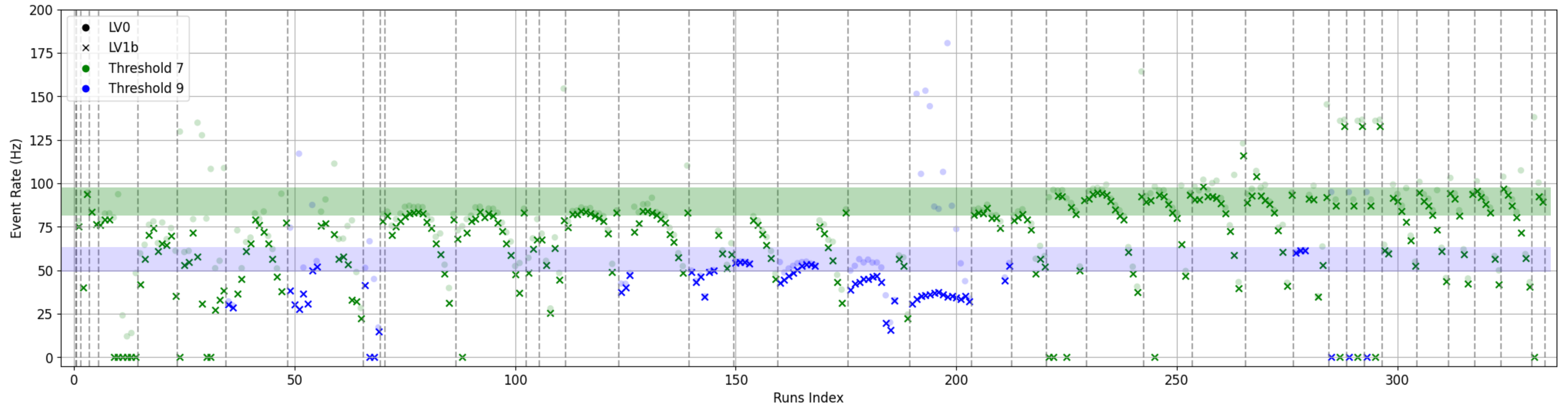


ASTRI-1: Data taking

- Overall we collected more than 250 hours of scientific data in 43 days



ASTRI-1: Crab 2024-2025

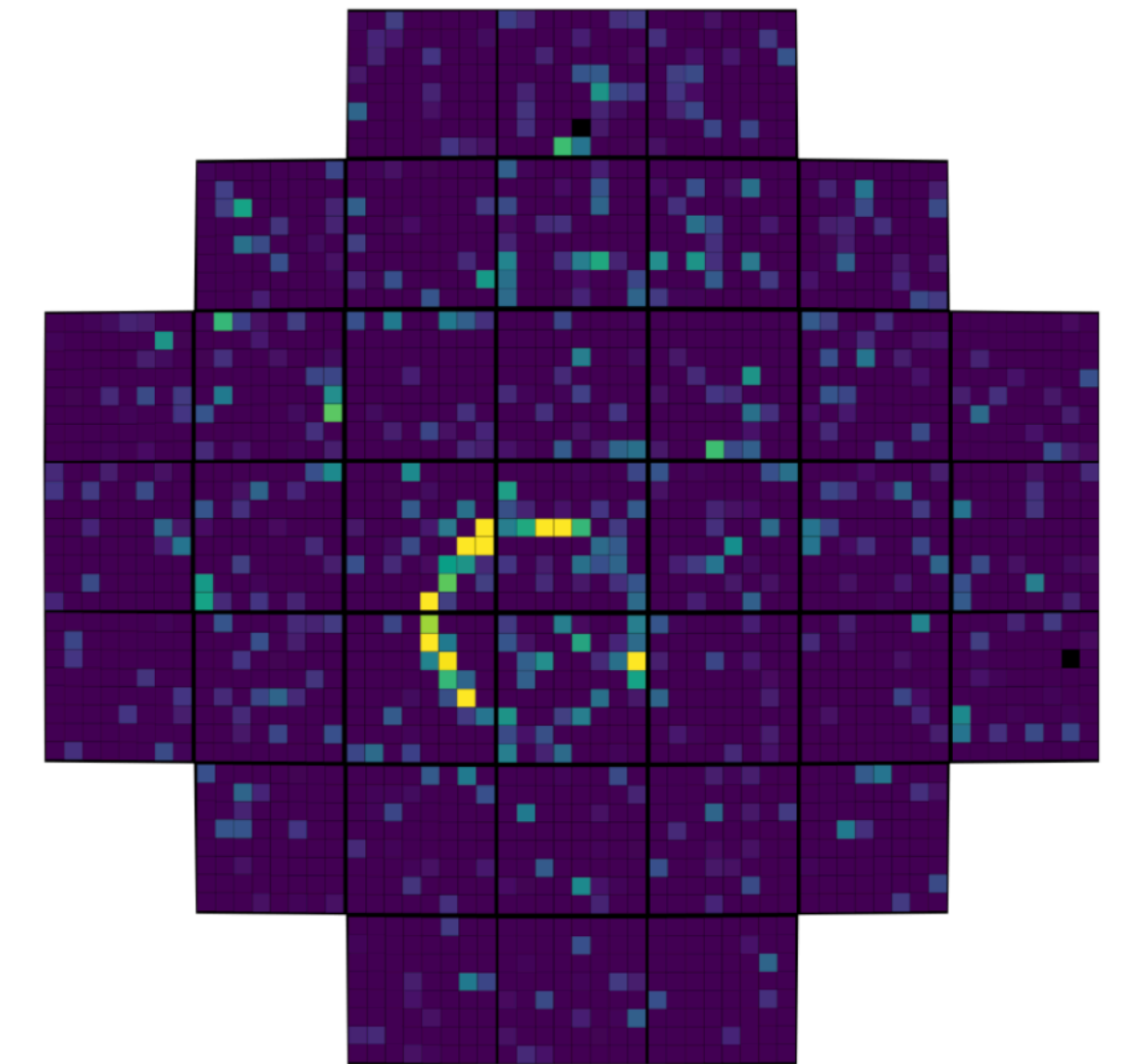
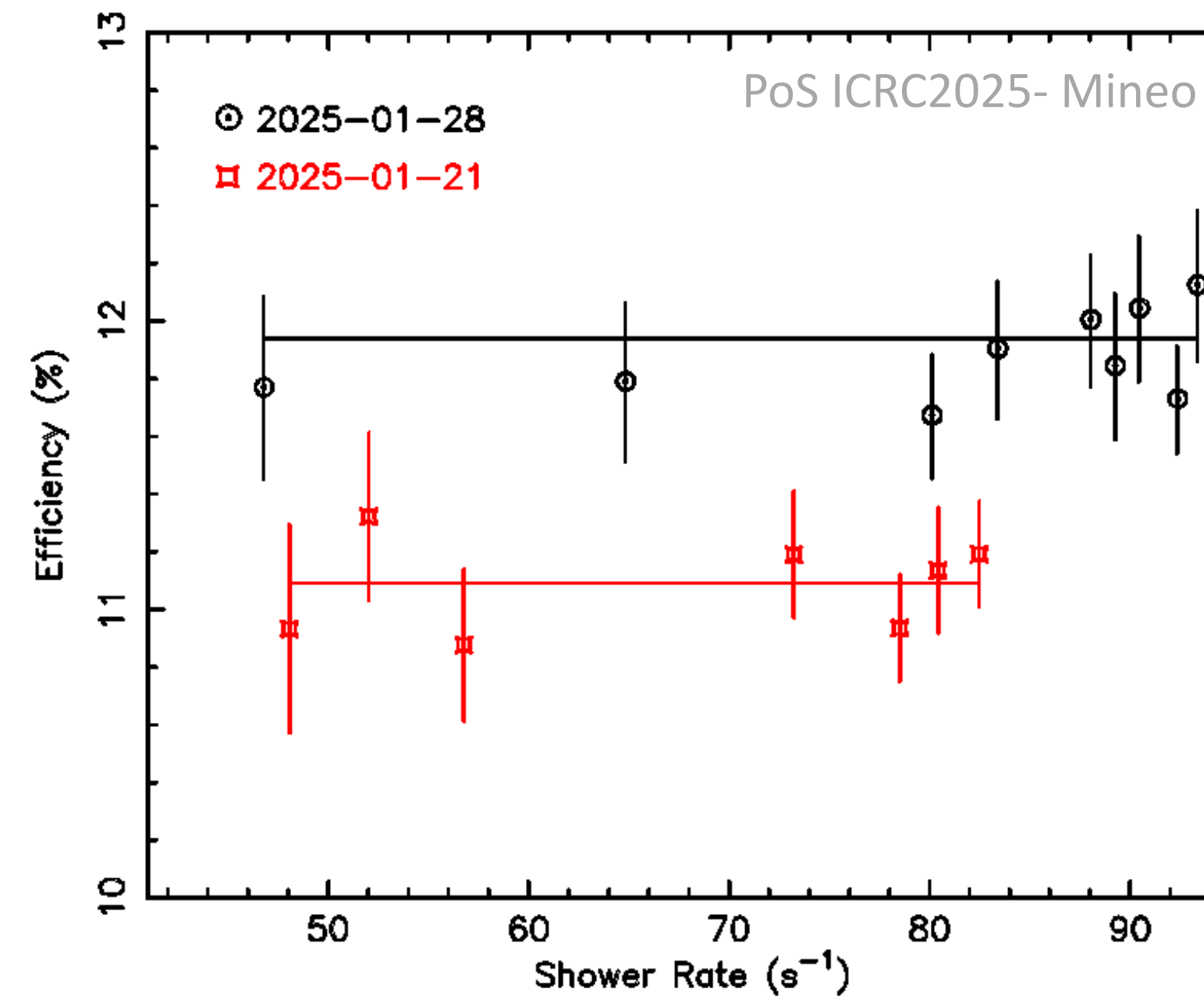
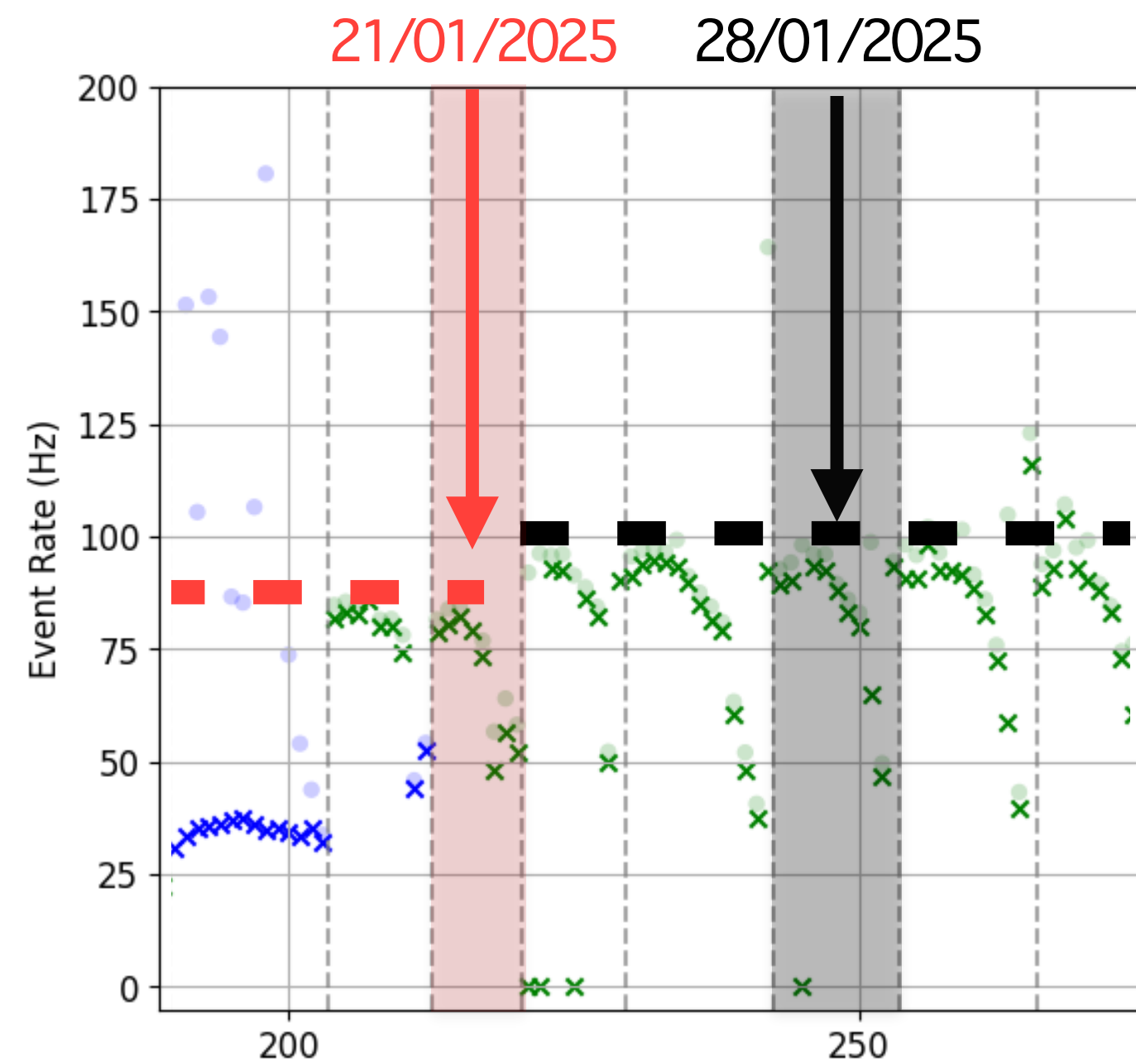


Discriminator threshold set to 7 or 9 pe

$$\frac{S}{N} (@th \text{ pe}) \leq 10^{-3}$$

- Rate after cleaning ($ZD < 30^\circ$):
 - Dark nights: 80-95 Hz
 - Moonlight nights: 50-60 Hz

ASTRI-1: Crab 2024-2025



- Rate increases (~10%) after 21/01/2025 → Suggest a change in the system response or operating conditions
- Muons ring analysis indicate +5% efficiency → Likely due to rain washing calima dust off the mirrors

ASTRI-1: Data Quality

- Rate stability: Relative srt.dev of cleaned event rate $< 10\%$
-> Filters out runs affected by some instability
- Background level: Median variance < 6 p.e.²
-> Ensures dark-sky conditions
- Star count in FoV: $> 75\%$ of the expected stars
-> Lower values indicate poor weather

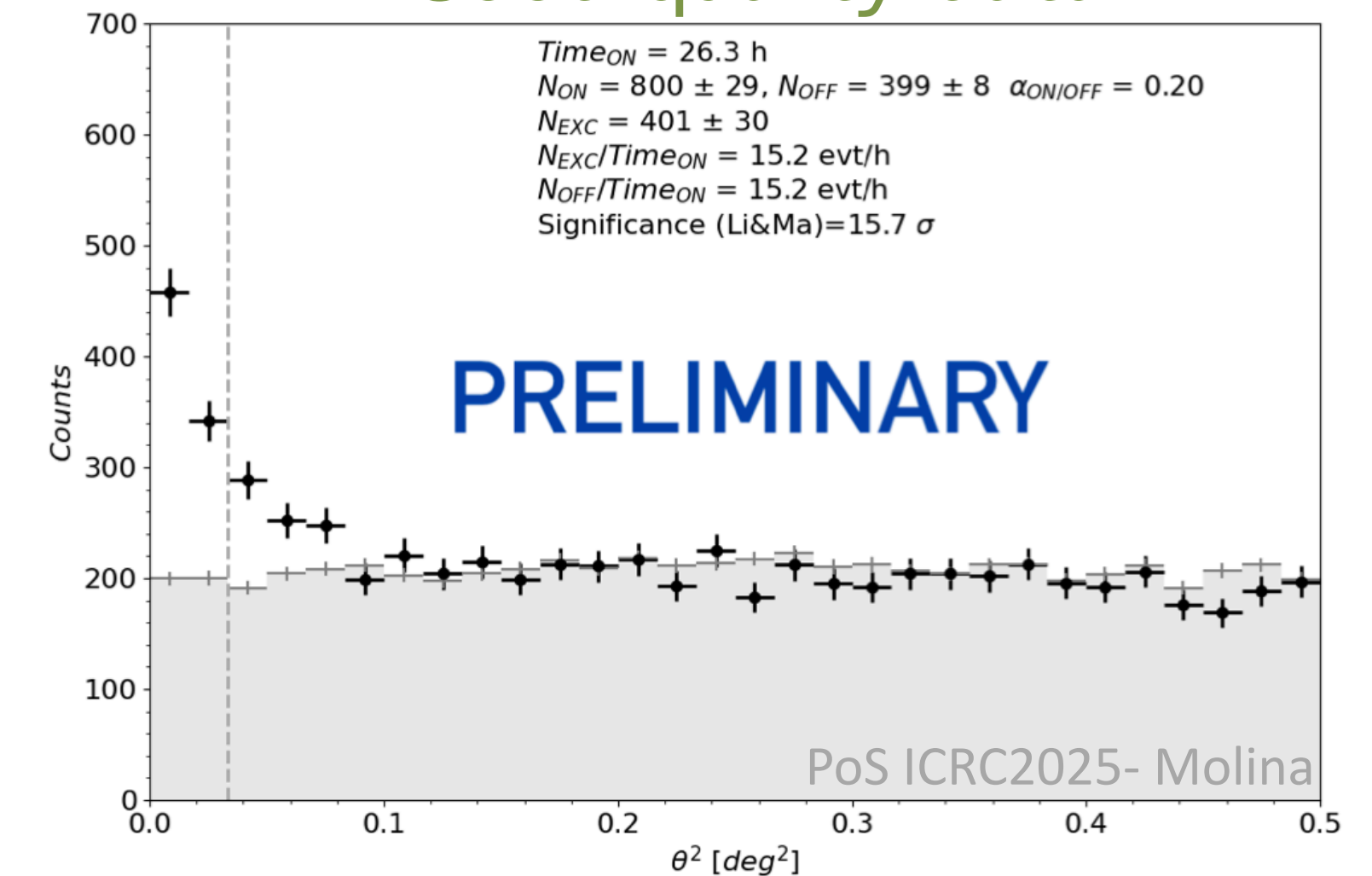
Results:

Good Data: $15.7 \sigma - 15.2 \pm 1.1$ events/h

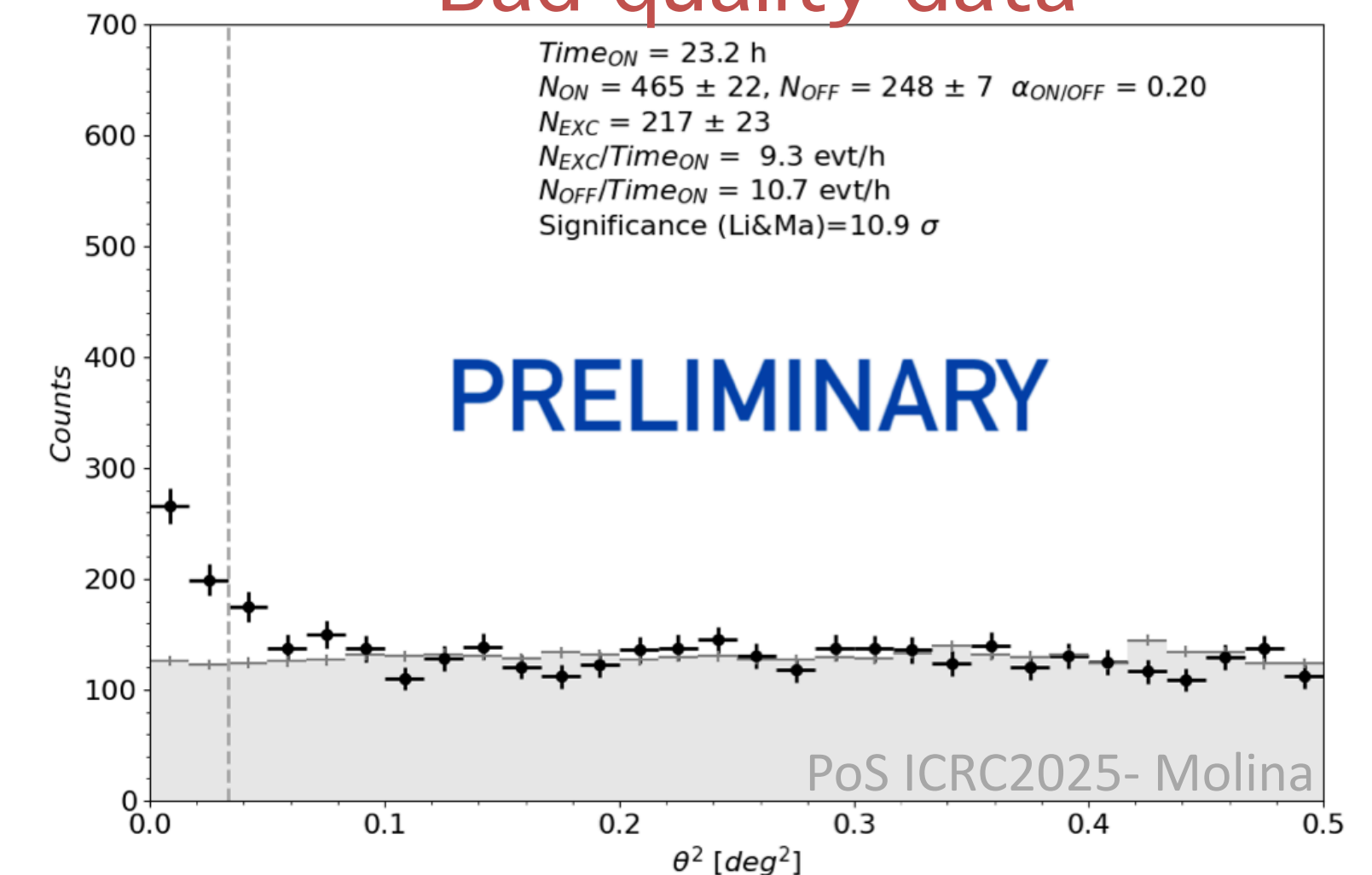
Bad Data: $10.9 \sigma - 9.3 \pm 1.0$ events/h

→ 63% improvements

Good quality data



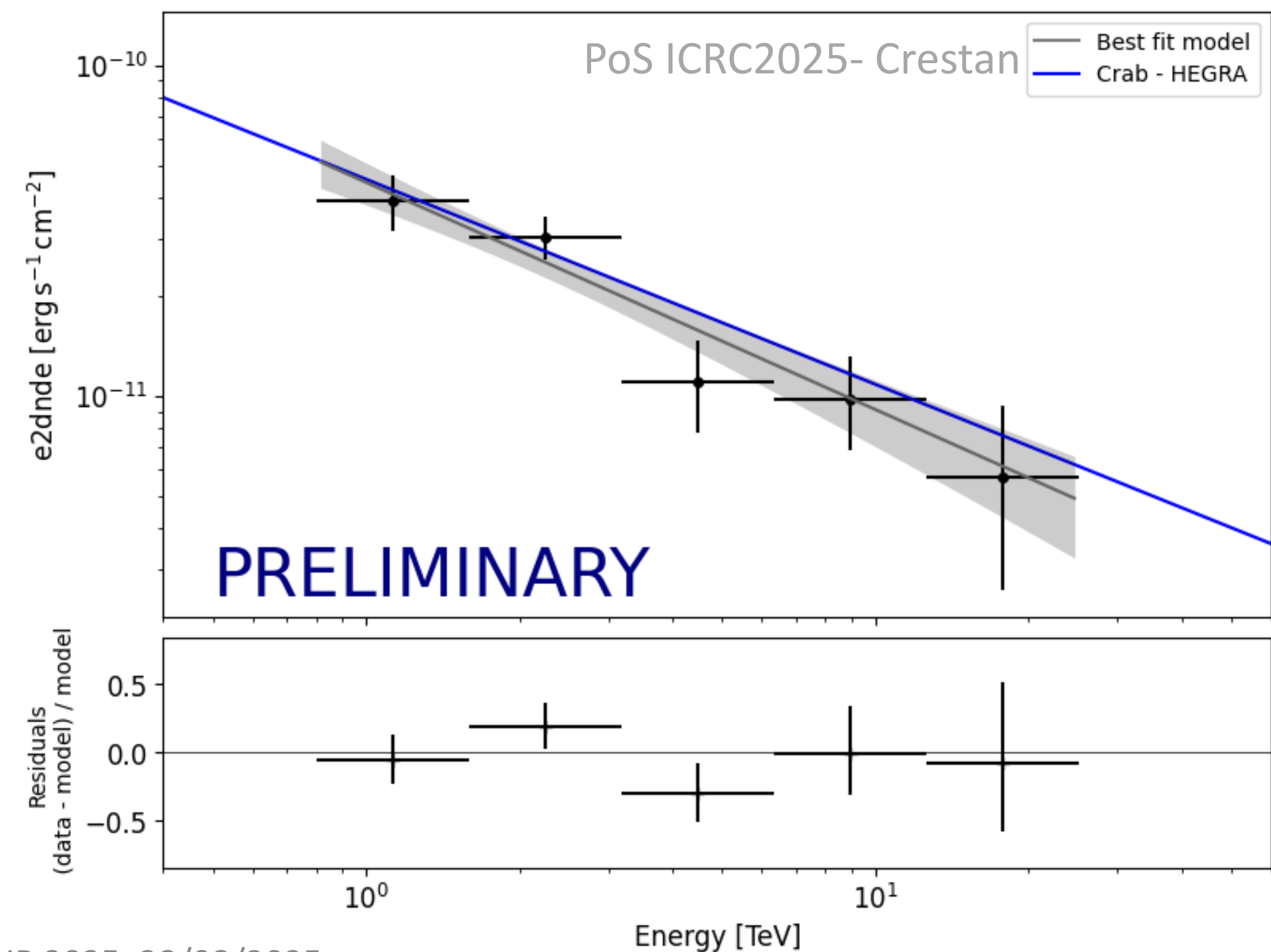
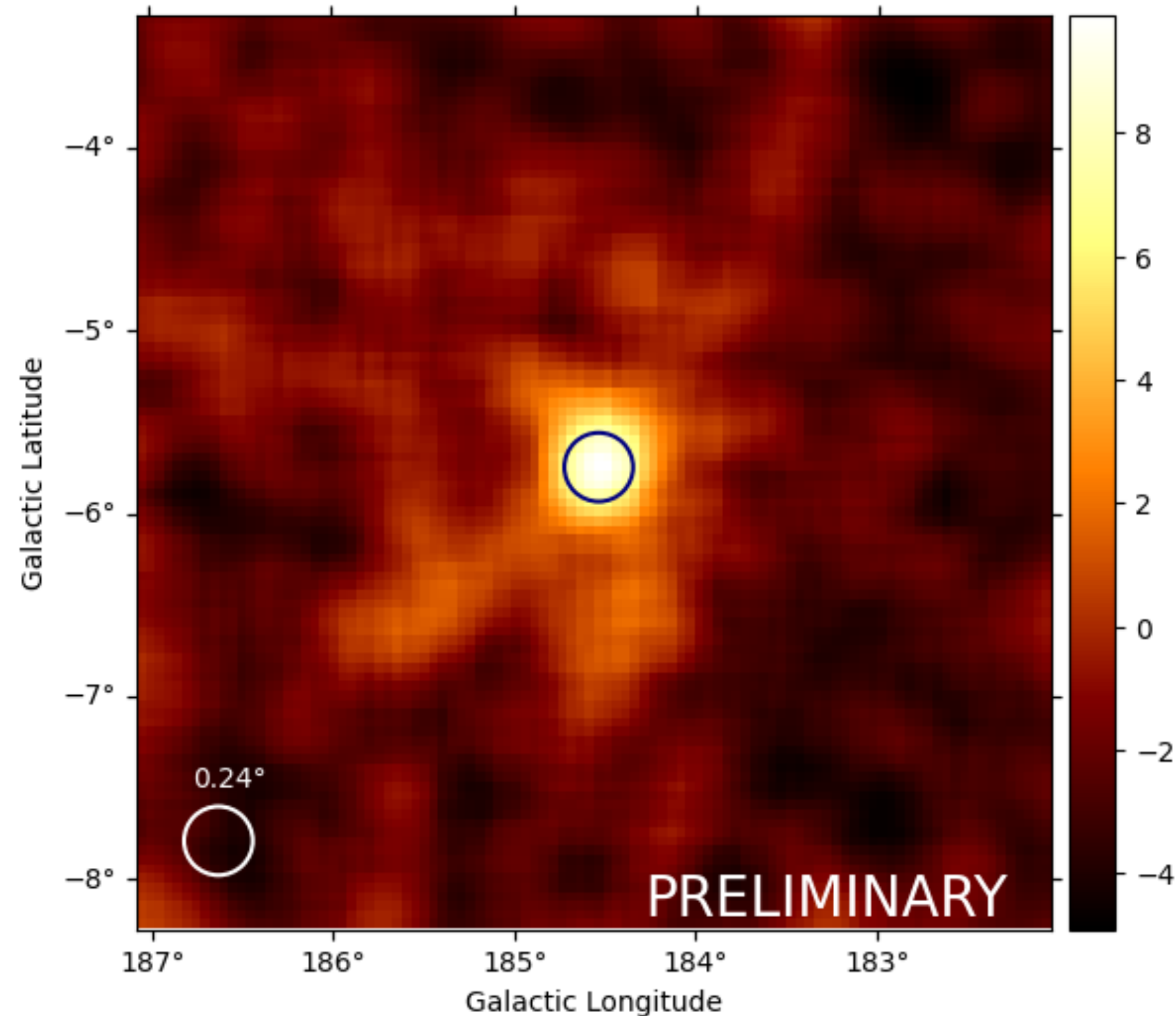
Bad quality data



ASTRI-1: Crab Spectrum

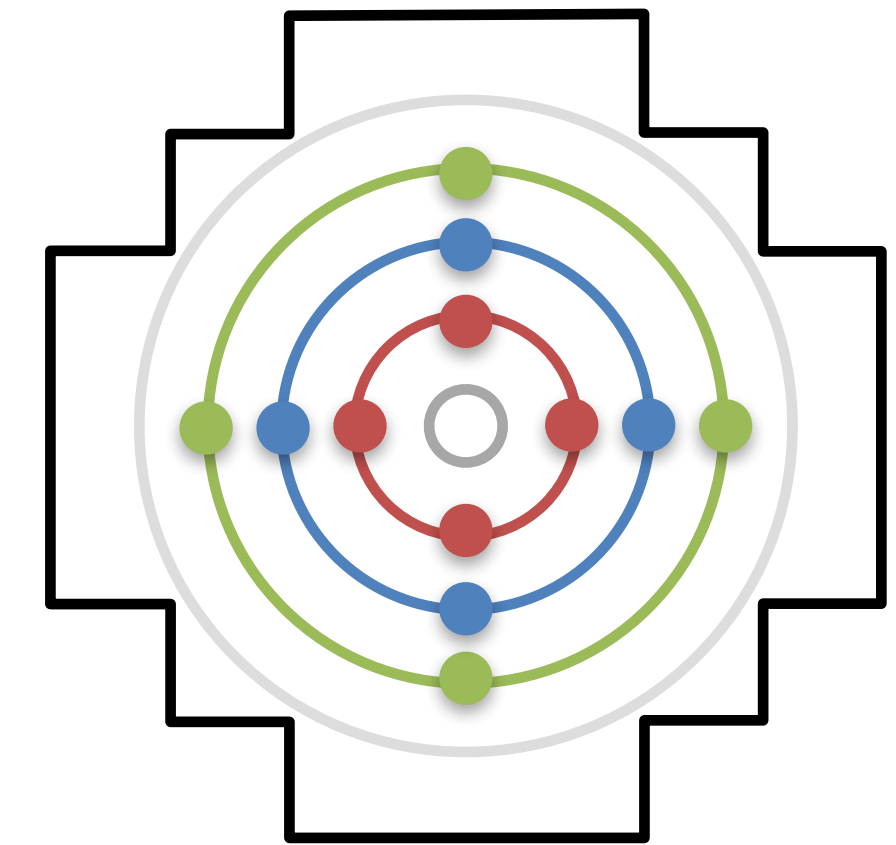
- Subsample of ~ 9 h of Crab data
- Detection at $\sim 10\sigma$
- RA/DEC = 83.65° , 22.05°
- 0.03° away from the position of Crab Nebula

- Power-law fit in 1-30 TeV energy range:
Index = 2.68 ± 0.13 , $N = 3.7 \pm 0.5 \text{ TeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1}$
- There is a good agreement!
- Spectral points up to ~ 20 TeV in 9 h



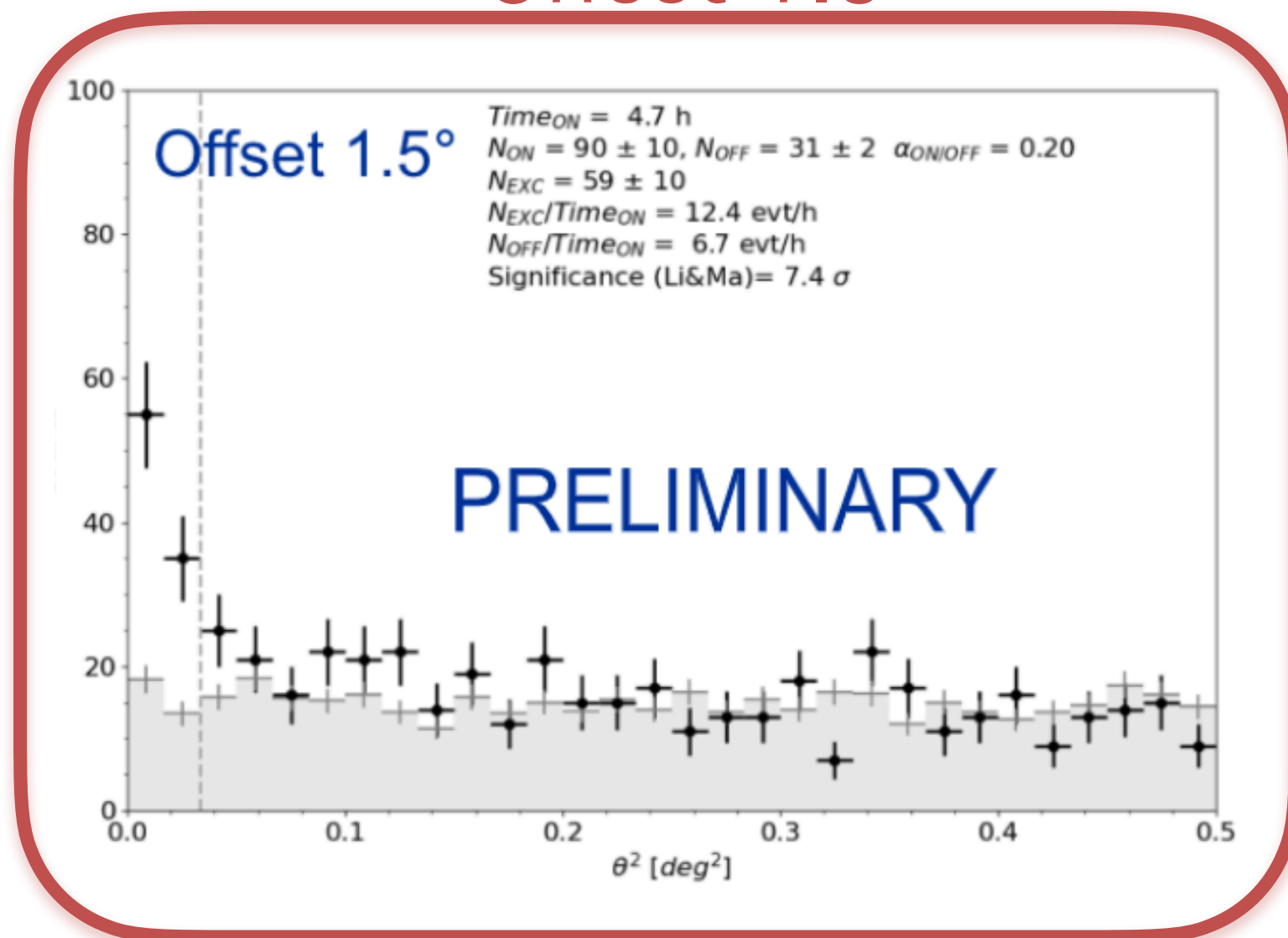
ASTRI-1: Off-axis performance

- MC available (p, He, γ):
 - Zenith = 20° , Azimuth = 180° , tailored for Offset 0.5°
- Data selection:
 - Runs passing data quality criteria with $ZD < 30^\circ$ (tailored for Offset 0.5°)
 - $SIZE > 150$ pe, $LEAKAGE < 0.1$, $GAMMANESS > 0.85$
- Clear detection at all considered offsets

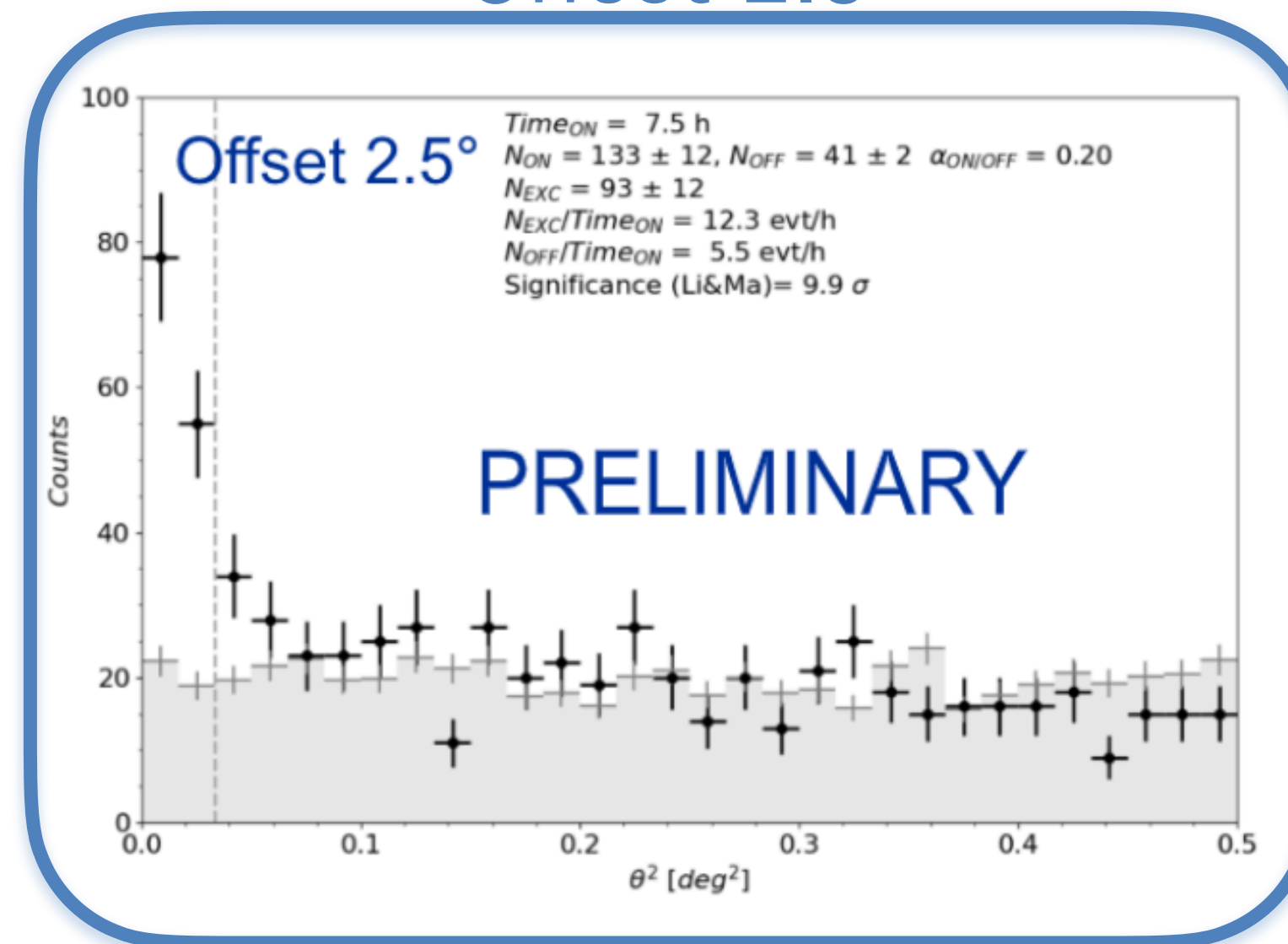


PoS ICRC2025- Crestan

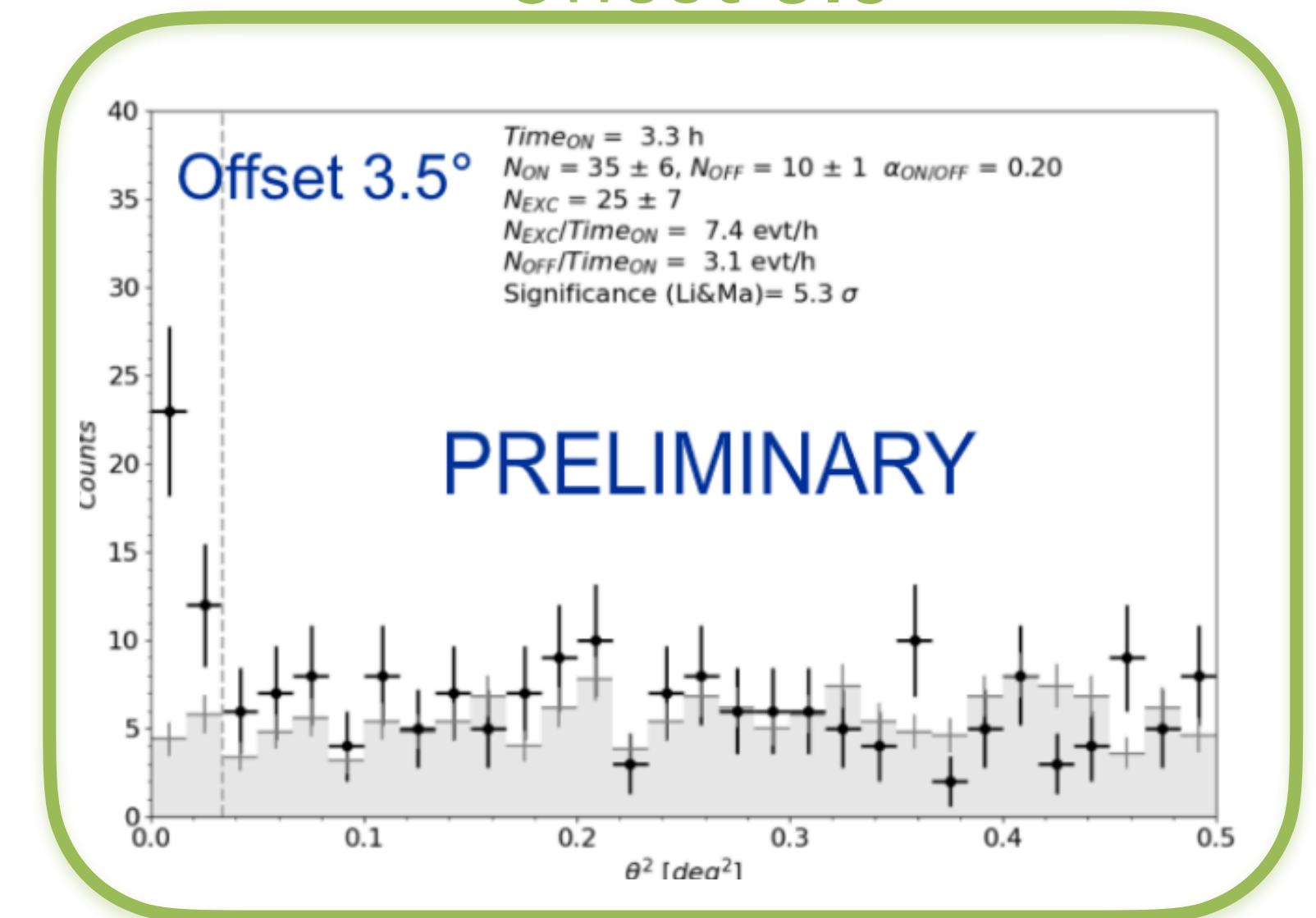
Offset 1.5°



Offset 2.5°

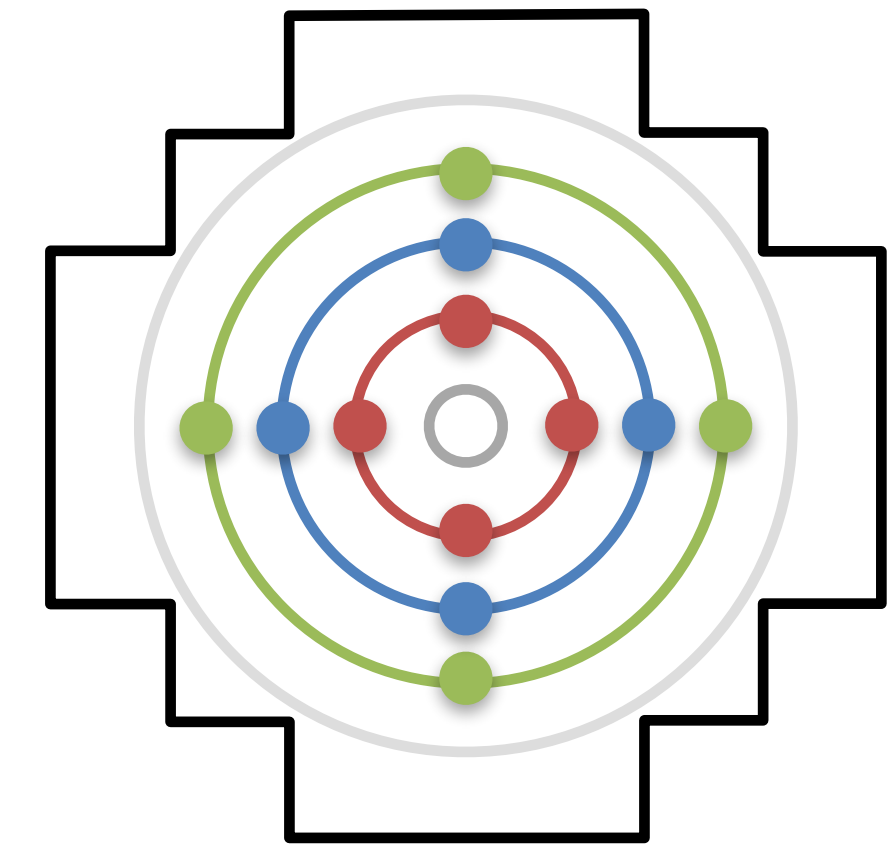


Offset 3.5°



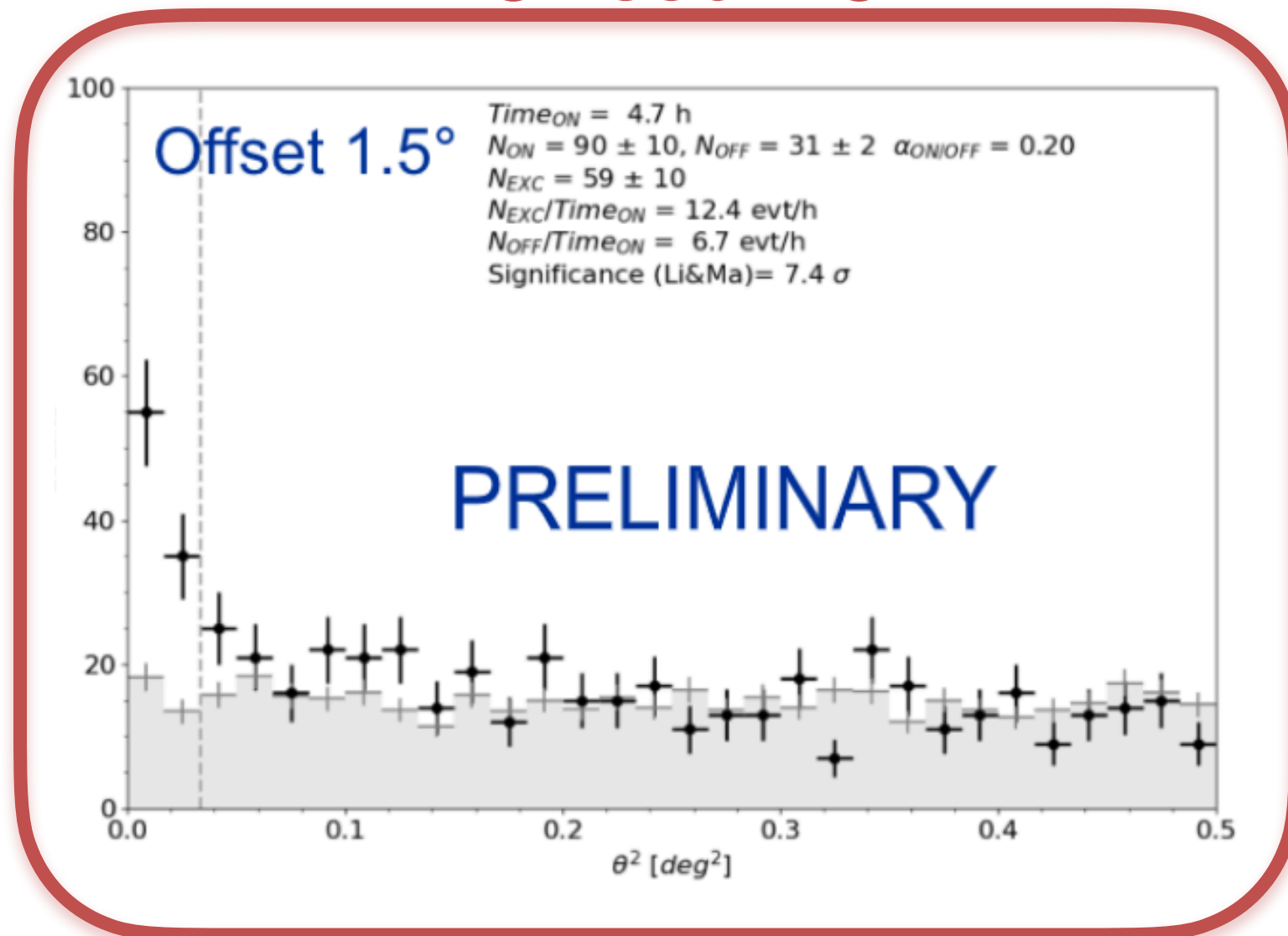
ASTRI-1: Off-axis performance

- Excess Rate:
 - @0.5° → 13.5 ± 1.0 events/h
 - @1.5° → 12.4 ± 2.1 events/h
 - @2.5° → 12.3 ± 1.6 events/h
 - @3.5° → 7.4 ± 1.8 events/h
- Results: Flat acceptance up to 2.5° and decreases by ~40% at 3.5°

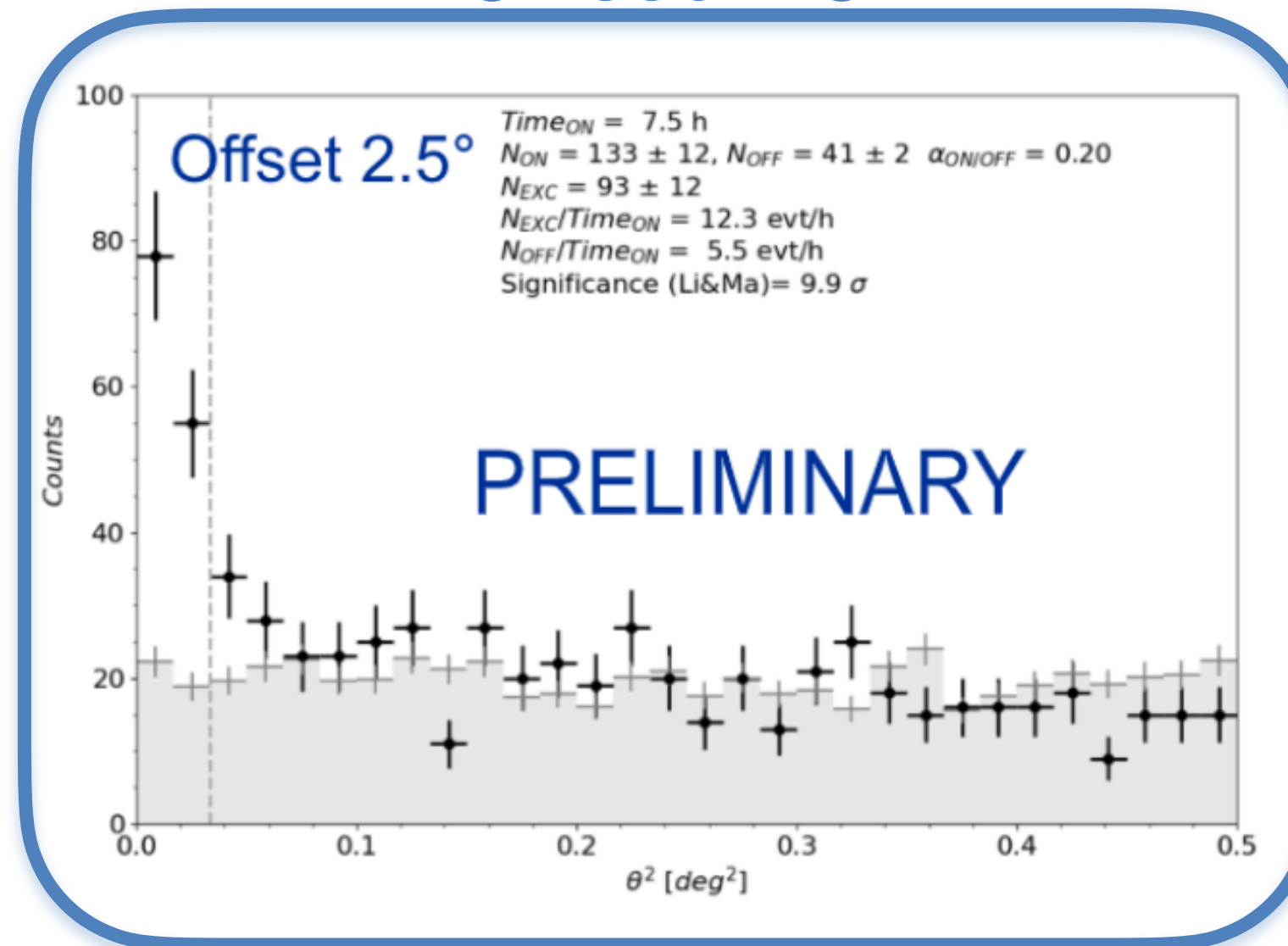


PoS ICRC2025- Crestan

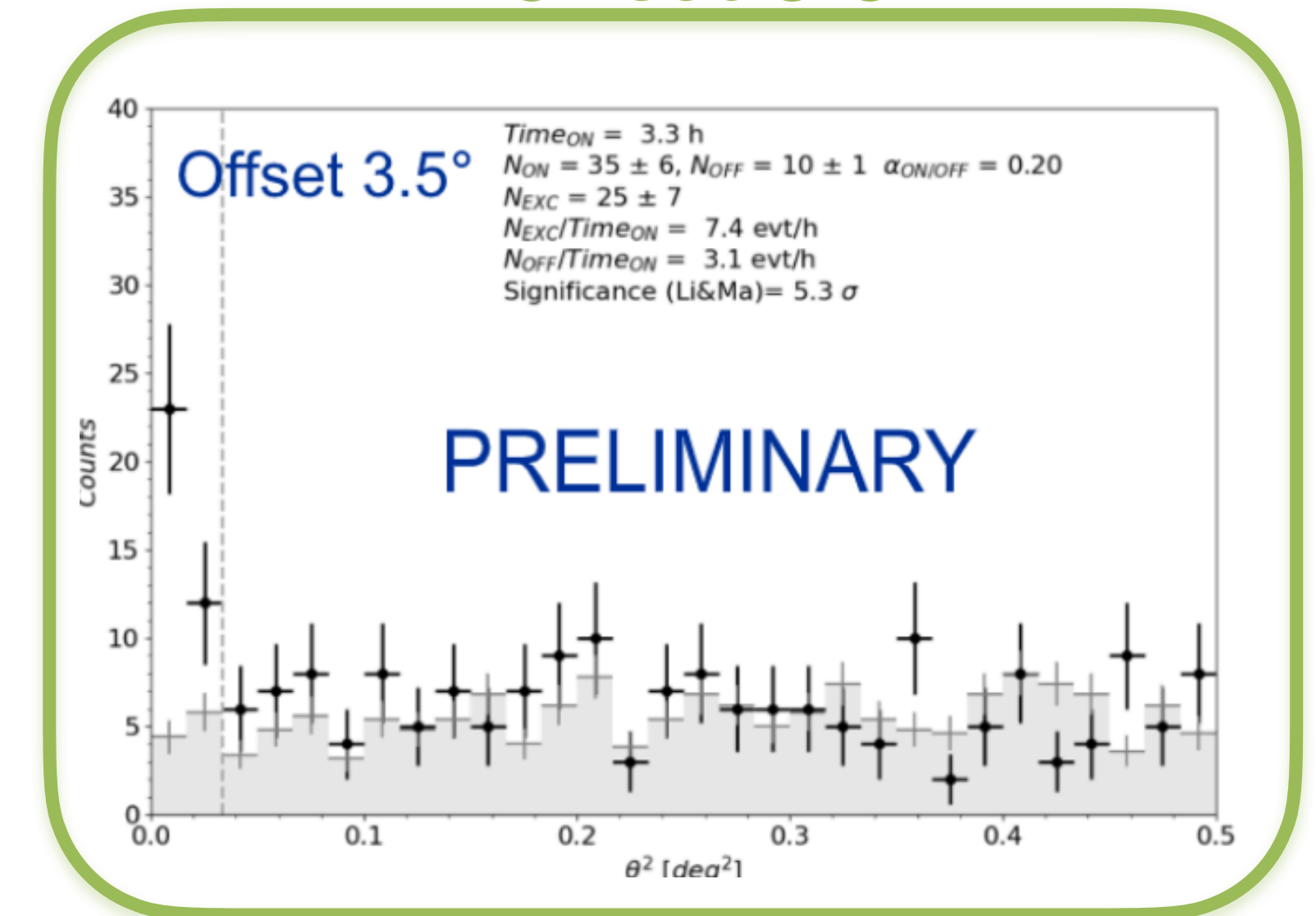
Offset 1.5°



Offset 2.5°

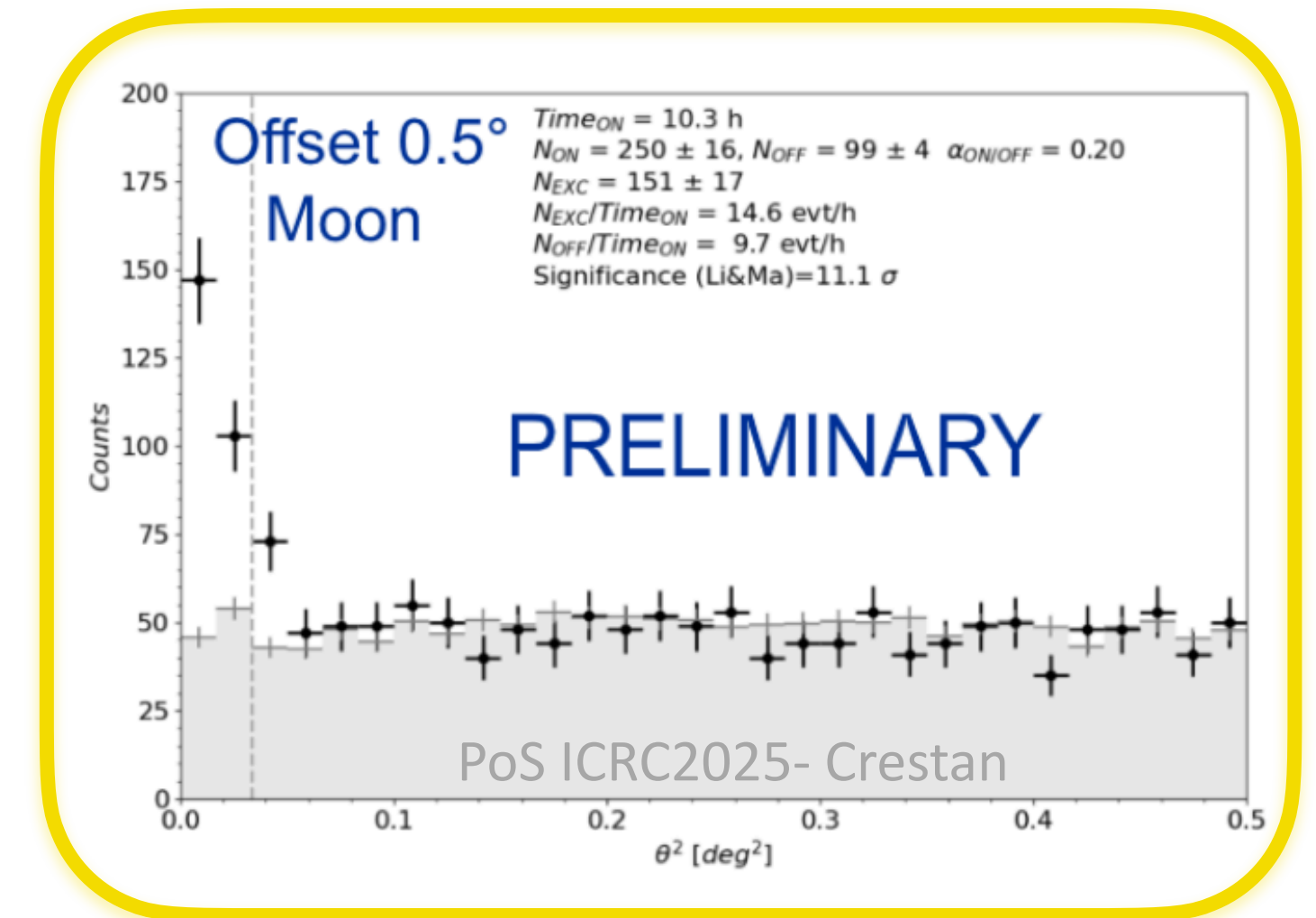


Offset 3.5°



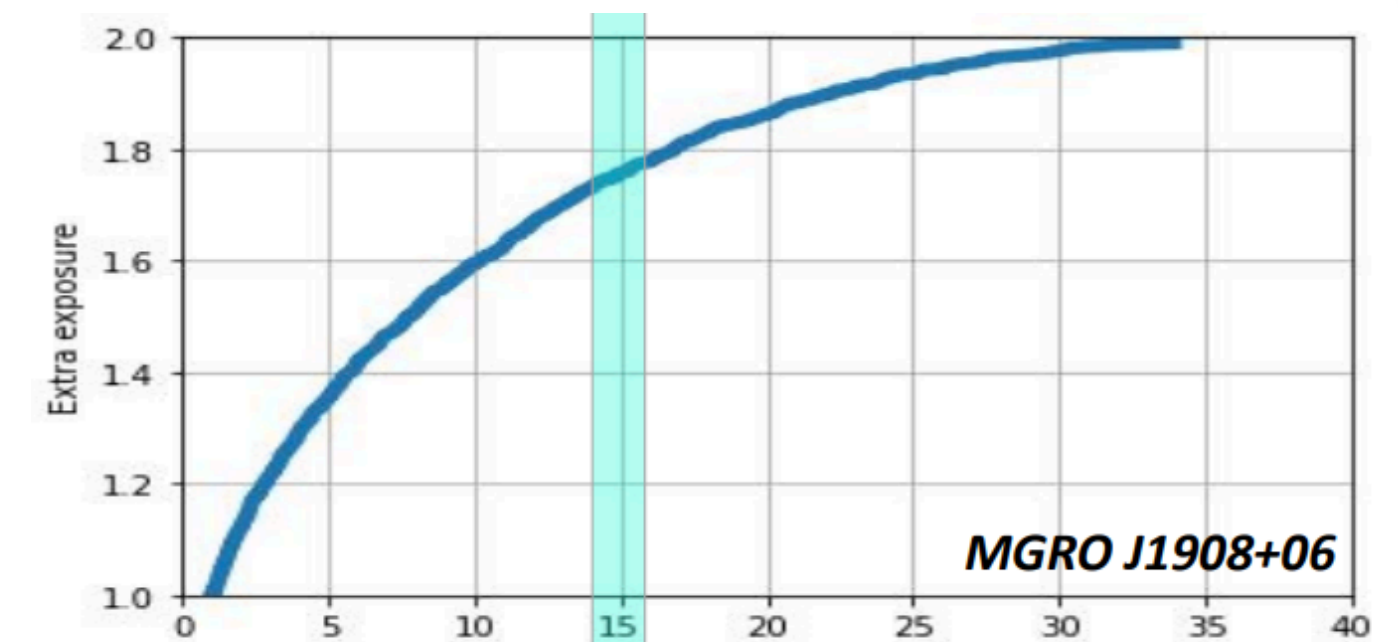
ASTRI-1: Observation with Moon

- MC available (p, He, γ):
 - Zenith = 20° , Azimuth = 180° , tailored for Dark & Offset 0.5°
- Data selection:
 - Runs passing data quality criteria with $ZD < 30^\circ$ & Offset 0.5°
 - Moon phase up to $\sim 70\%$
 - $SIZE > 150$ pe, $LEAKAGE < 0.1$, $GAMMANESS > 0.85$
- Excess rate: 14.6 ± 2.1 events /h
- Results: we can extend our observing time by a factor ~ 1.5 -2 at medium and high energy



Moonless Night Hours	1565 h
Fraction of clear nights (cloud coverage <20%)	0.79
Fractional loss due to bad weather	0.04
Fractional loss due to "Calima"	0.07
Average Annual Observation Time	1104 h

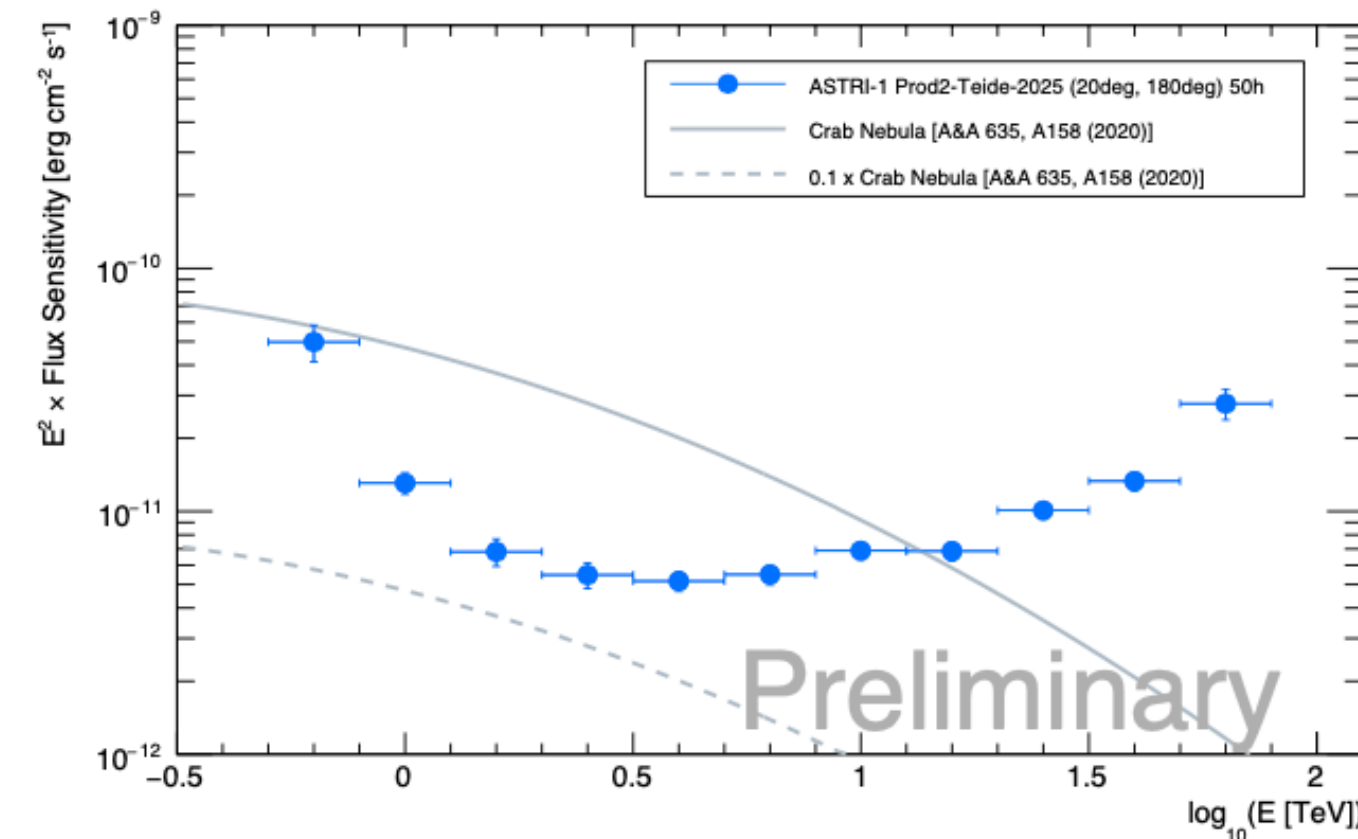
Setting 15 NSB as a limit
→ Average annual observing time : 1900h



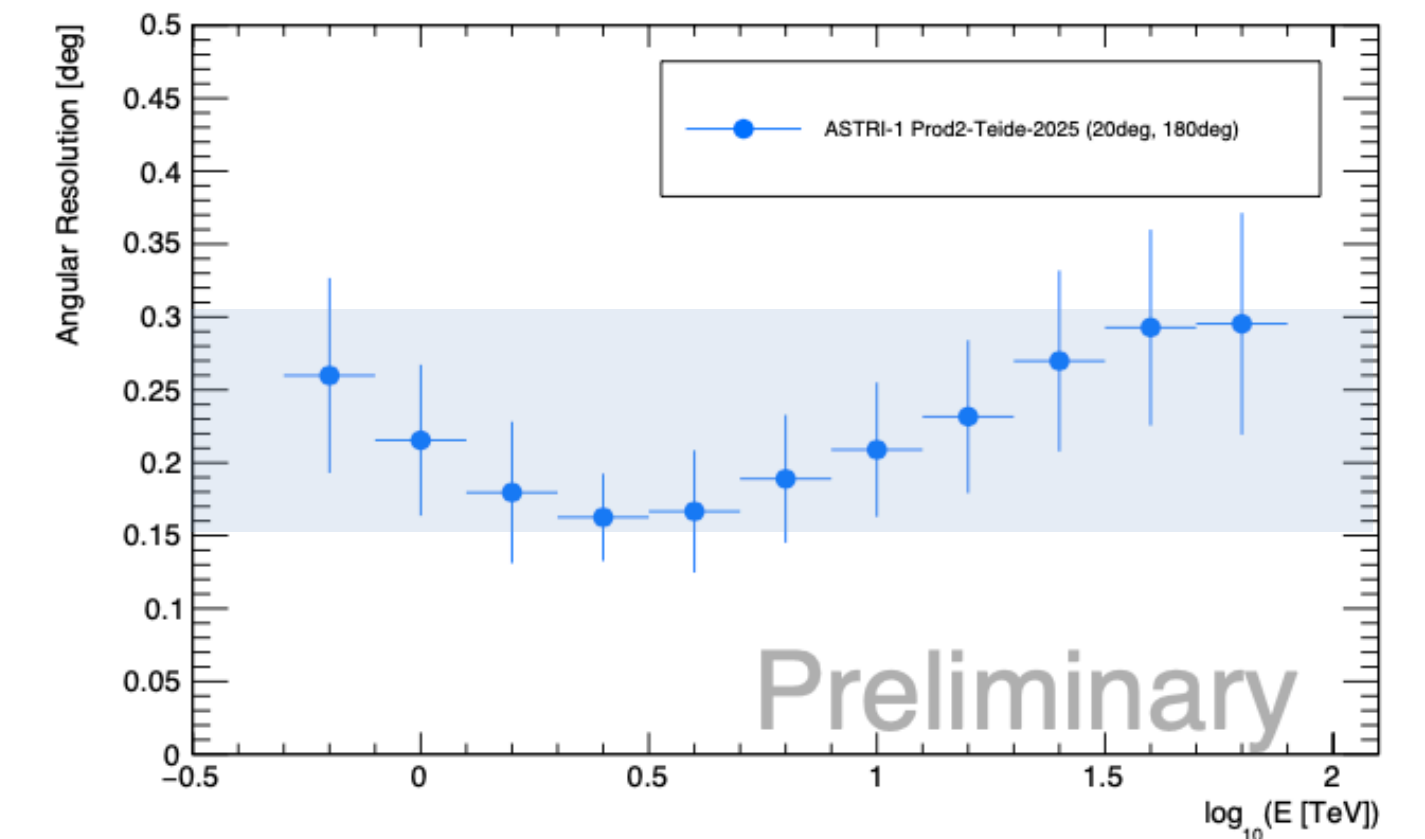
ASTRI-1: Performance

PoS ICRC2025- Crestan

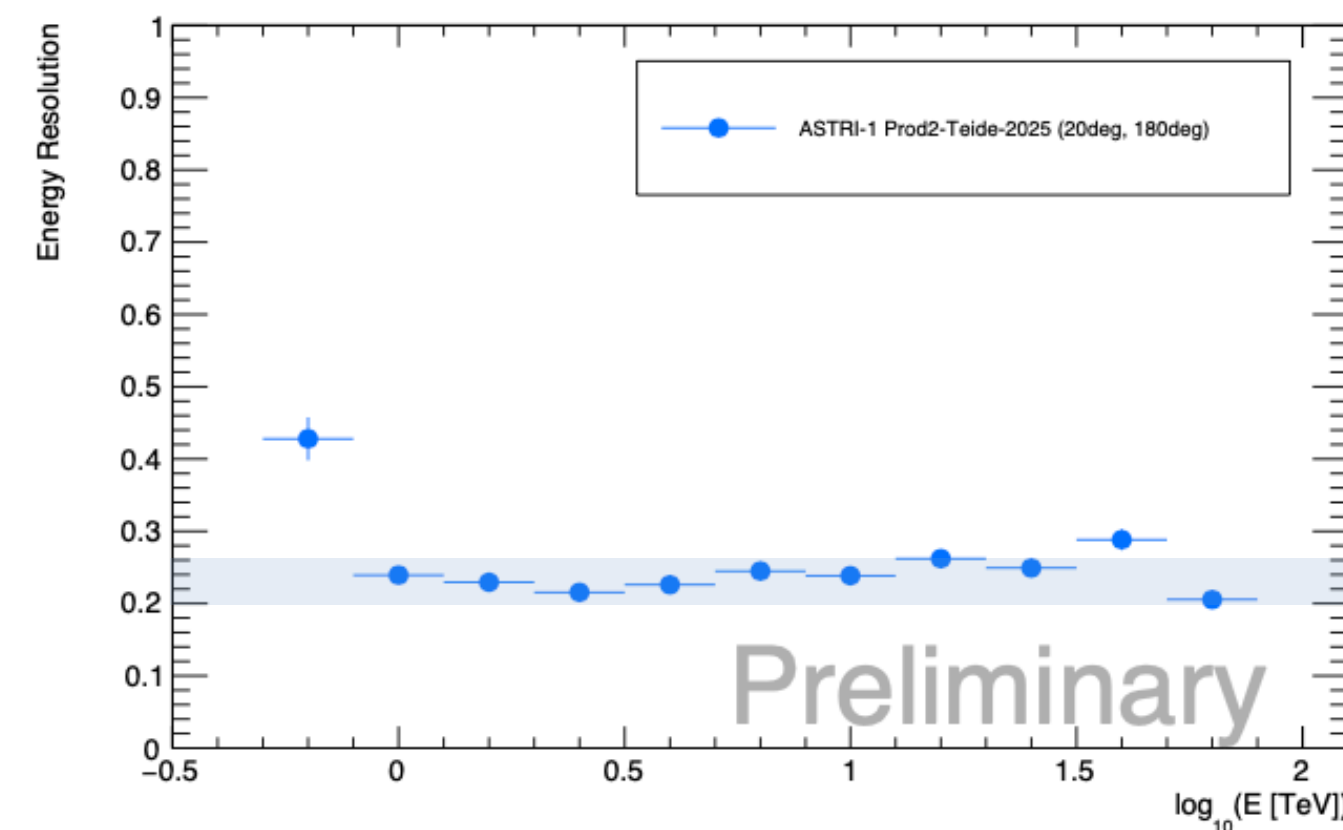
SENSITIVITY



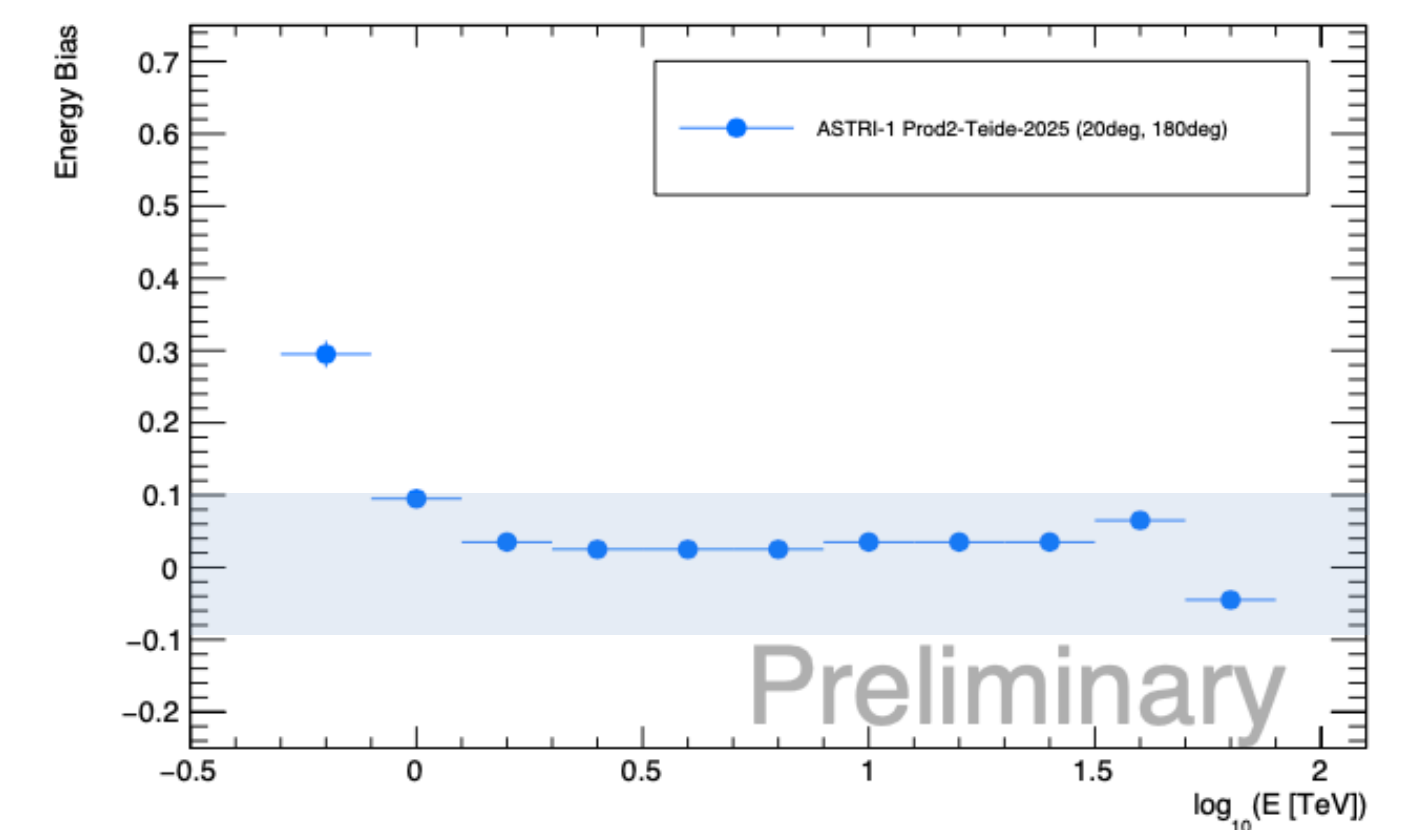
ANGULAR RESOLUTION



ENERGY RESOLUTION



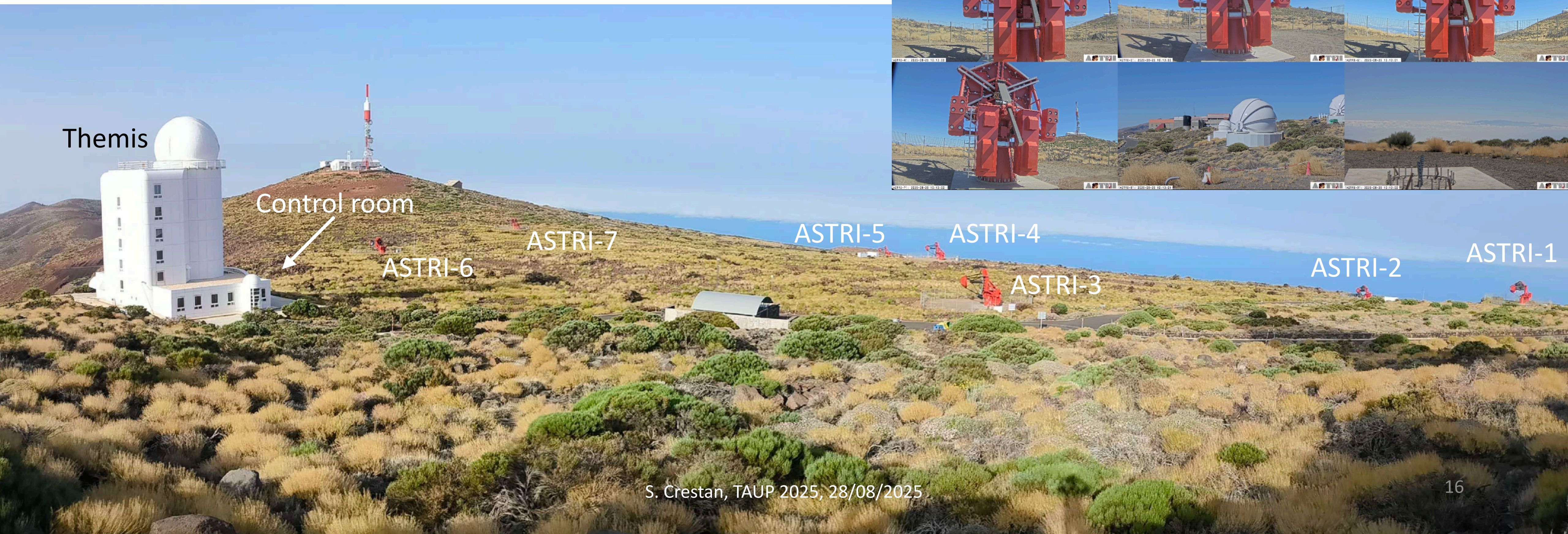
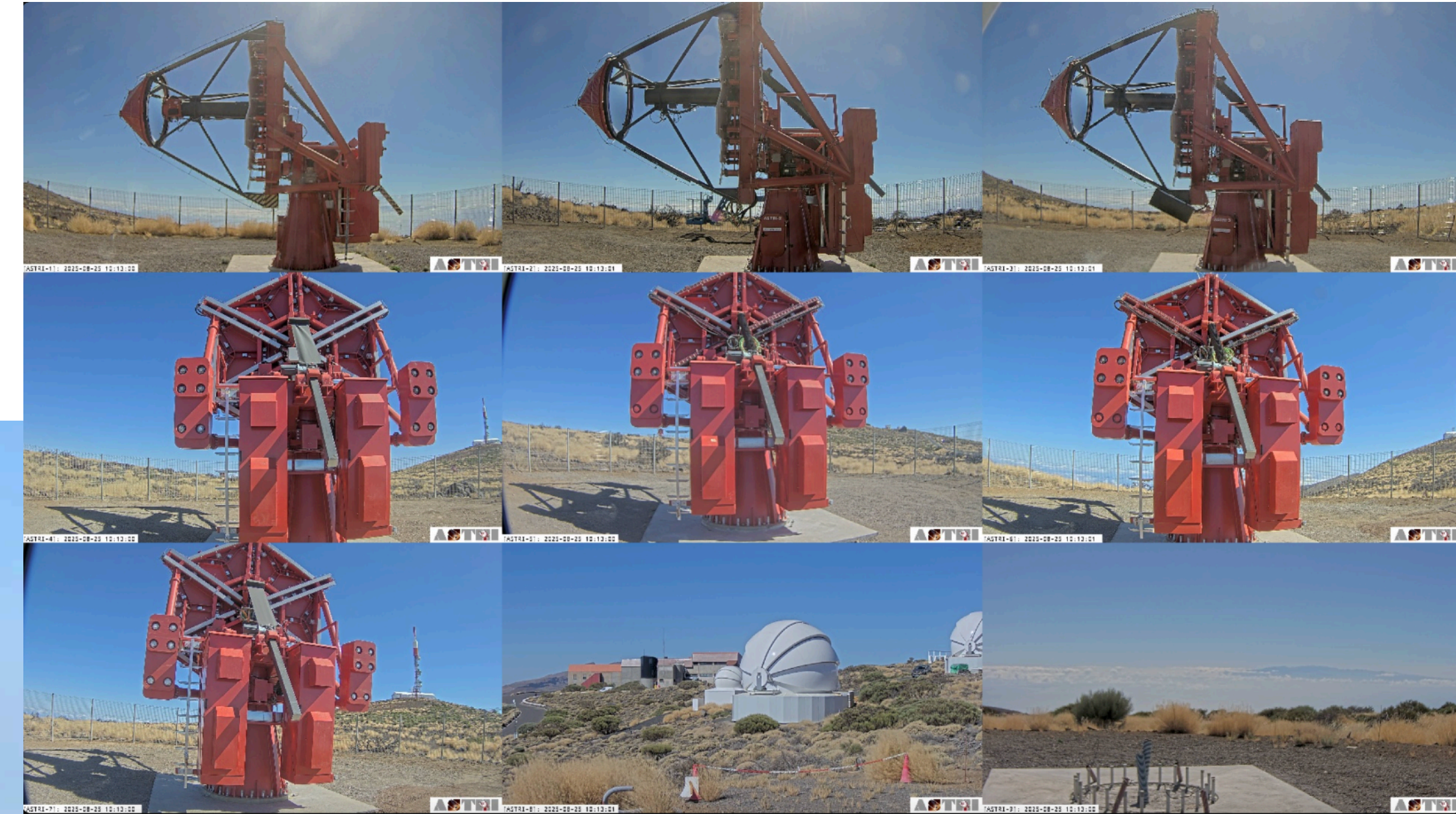
ENERGY BIAS



- MC available (p, He, γ):
 - Zenith = 20°, Azimuth = 180°, tailored for Dark & Offset 0.5°
- Sensitivity: @2TeV (~ 0.25 Crab)
- Energy Threshold ~ 1 TeV
- Angular resolution: 0.15°- 0.3°
- Energy resolution: 20 - 25%
- Energy bias: <10%

ASTRI Mini Array Status

- 7 out of 9 telescopes fully assembled
- Remaining 2 telescopes to be delivered next year
- Second camera scheduled for installation next month
- Subsequent cameras to be deployed in the following months



ASTRI Science: Overview

Origin of Cosmic Rays

- PeVatrons
- CRs Acceleration and Propagation
- Pulsar Wind Nebulae and TeV Halos

Fundamental Physics

- Intergalactic fields
- Blazars
- LIV, ALP and DM

Transient Follow-Up

Non gamma-ray science

The ASTRI Mini-Array of Cherenkov Telescopes at the Observatorio del Teide

S. Scuderi^{a,*}, A. Giuliani^a, G. Pareschi^b, G. Tosti^c, O. Catalano^f, E. Amato^g, L.A. Antonelli^h, J. Becerra González^m, G. Bellasai^d, C. Bigongiari^h, B. Biondo^f, M. Boettcherⁿ, G. Bonanno^d, P. Bruno^d, A. Bulgarelli^e, R. Canestrari^f, M. Capalbi^f, M. Cardillo^k, V. Conforti^e, G. Contino^f, M. Corpora^f, A. Costa^d, G. Cusumano^f, A. D'Ai^g, E. de Gouveia Dal Pinoⁱ, R. Della Ceca^b, E. Escribano Rodríguez^o, D. Falceta-Goncalves^s, C. Fermino^l, M. Fiori^{h,g}, V. Fioretti^e, M. Fiorini^a, S. Galante^g, R. Ginetti^g, S. Ince^g, L. Lesi^g, M.C. Lillo^g, G. Morlino^g, F. Pintore^g, G. Rosi^g, G. Sotgiu^g, L. Zanello^g

JHEAP, 2022, 35, 52

ASTRI Mini-Array Core Science at the *Observatorio del Teide*

S. Vercellone^{a,*}, C. Bigongiari^b, A. Burtovoi^c, M. Cardillo^d, O. Catalano^e, A. Franceschini^f, S. Lombardi^{h,g}, L. Nava^a, F. Pintore^e, A. Stamerra^b, F. Tavecchio^a, L. Zampieri^h, R. Alves Batistaⁱ, E. Amato^{c,j}, L. A. Antonelli^{b,g}, C. Arcaro^{h,k}, J. Becerra González^{l,m}, G. Bonnoli^d, G. Brunettiⁿ, A. A. Compagnino^e, S. Crestan^{o,p}, A. D'Ai^e, M. Fiori^{h,f}, G. Galante^g, E. M. de Gouveia Dal Pino^q, J. G. Green^b, A. Lamastra^{b,g}, M. Landoni^a, F. Lucarelli^a, G. Morlino^g, B. Olmi^{e,c}, E. Peretti^s, G. Piano^d, G. Ponti^{a,t}, E. Poretti^{u,v}, P. Romano^a, F. G. Saturni^{h,g}, S. Scuderi^o, A. Tutone^b, G. Umana^v, L. A. Accosta-Pulido^{l,m}, P. Barai^g, A. Bonanno^v, G. Bonanno^v, P. Bruno^v

JHEAP, 2022, 35, 1

Galactic Observatory Science with the ASTRI Mini-Array at the *Observatorio del Teide*

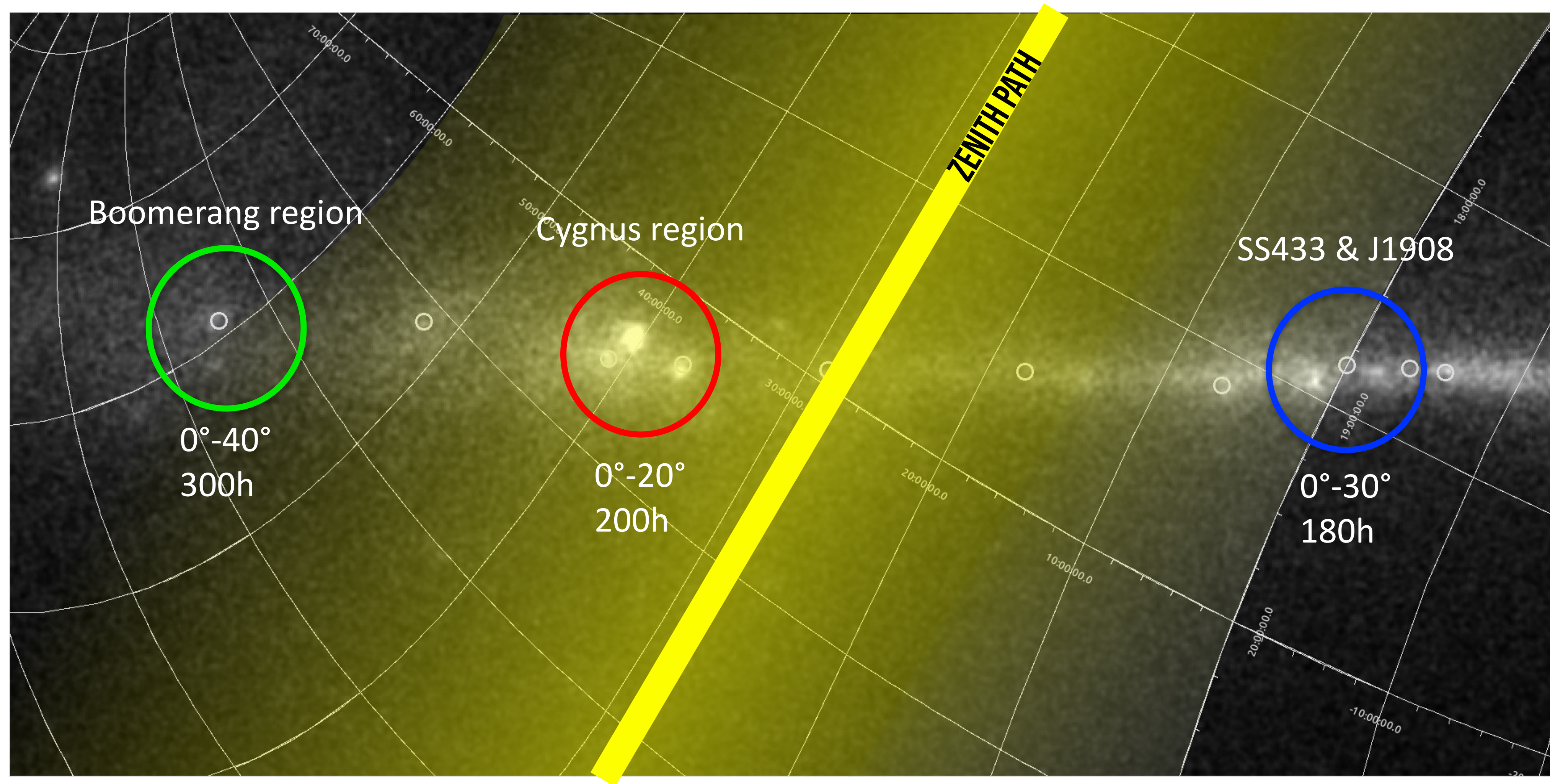
A. D'Ai^{a,*}, E. Amato^b, A. Burtovoi^b, A. A. Compagnino^a, M. Fiori^c, A. Giuliani^d, N. La Parola^e, G. Naletto^f, P. Sangiorgio^g, N. Żywulak^h, A. Palombara^d, A. Paizis^d, G. Piano^e, F. G. Saturni^{i,g}, A. Tutone^{a,h}, A. S. Crestan^d, G. Cusumano^a, M. Della Valle^{ij}, M. Del Santo^a, A. La S. Lombardi^{i,g}, S. Mereghetti^d, G. Morlino^b, F. Pintore^a, P. Romano^a, S. Vercellone^a, A. Antonelli^h, C. Arcaro^l, C. Bigongiari^f, M. Böettcher^m, P. Brunoⁿ, A. Bulgarelli^o, V. Conforti^o, A. Costaⁿ, E. de Gouveia Dal Pino^q, J. G. Green^b, A. Lamastra^{b,g}, M. Landoni^a, F. Lucarelli^a, G. Morlino^g, B. Olmi^{e,c}, E. Peretti^s, G. Piano^d, G. Ponti^{a,t}, E. Poretti^{u,v}, P. Romano^a, F. G. Saturni^{h,g}, S. Scuderi^o, A. Tutone^b, G. Umana^v, L. A. Accosta-Pulido^{l,m}, P. Barai^g, A. Bonanno^v, G. Bonanno^v, P. Bruno^v

JHEAP, 2022, 35, 39

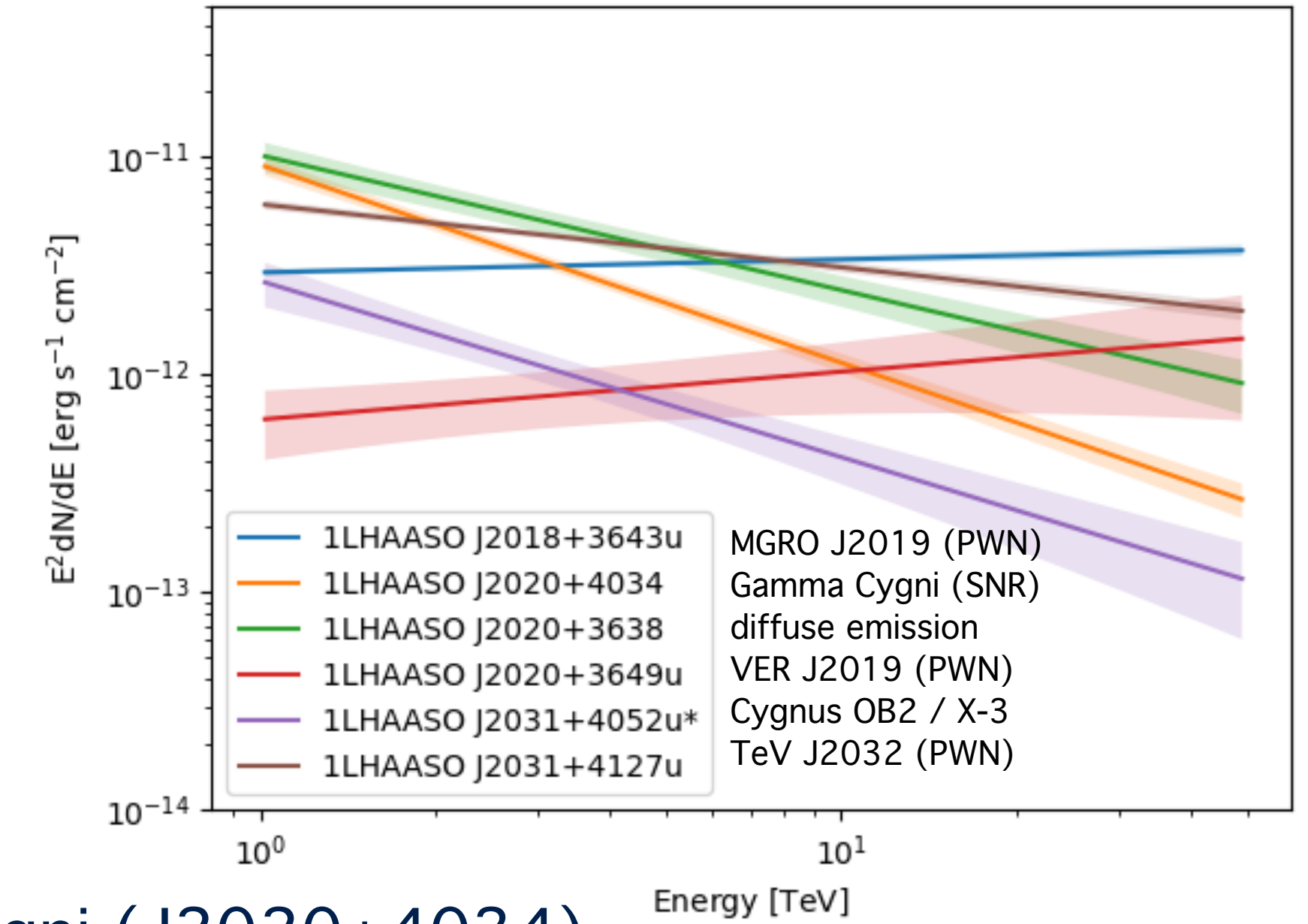
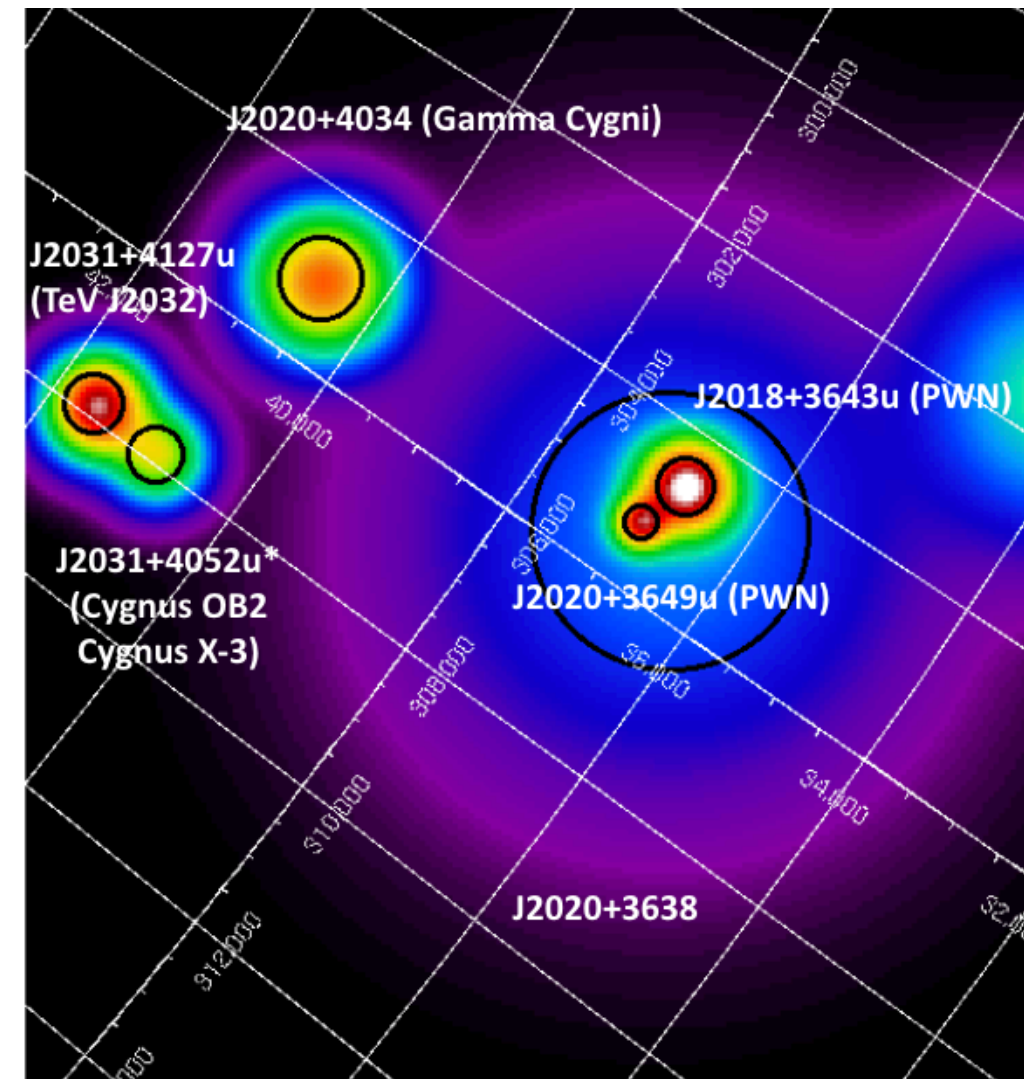
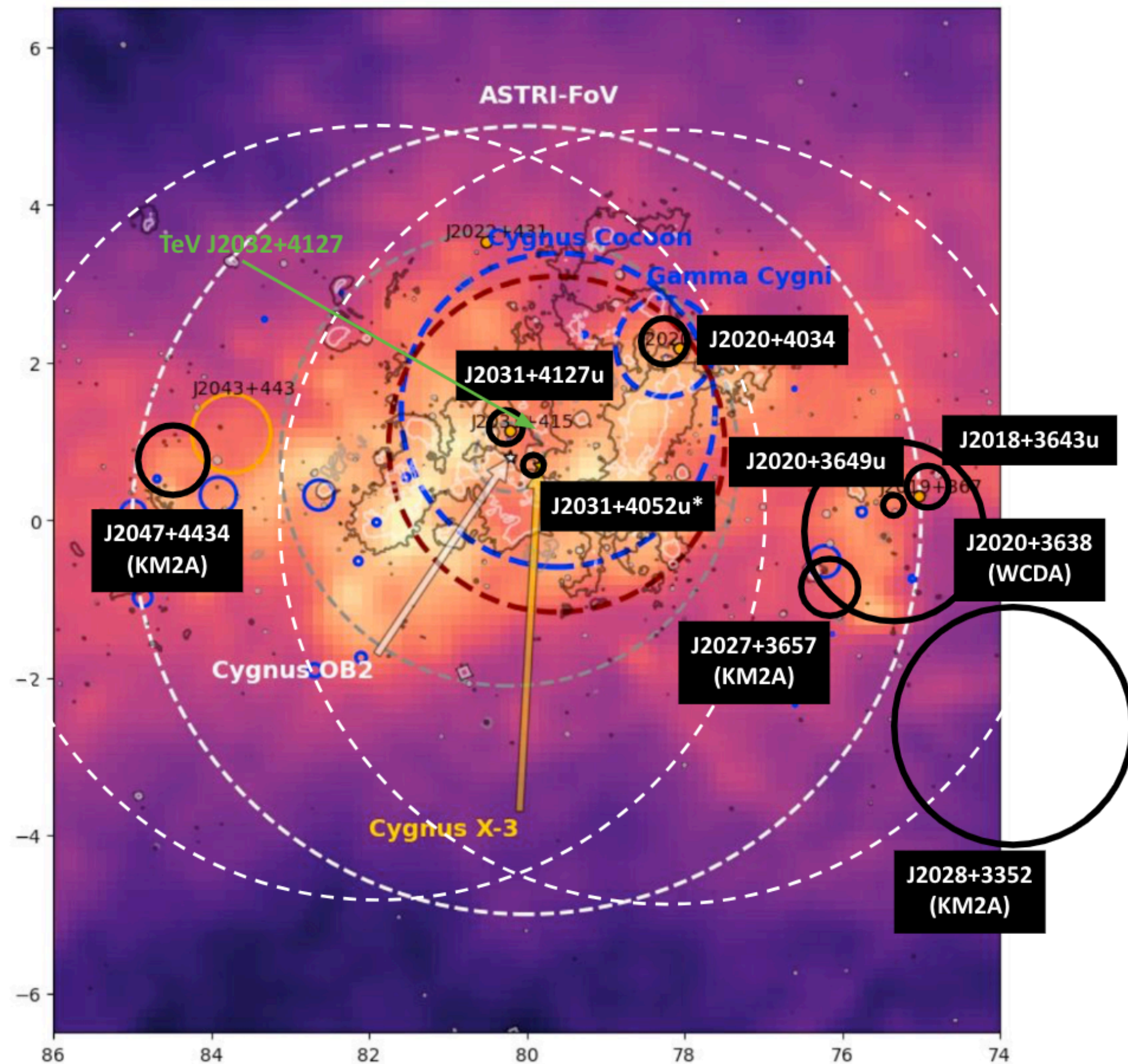
Extragalactic Observatory Science with the ASTRI Mini-Array at the *Observatorio del Teide*

F. G. Saturni^{a,b,*}, C. H. E. Arcaro^{c,d,e,f}, B. Balmaverde^g, J. Becerra González^{h,i}, A. Caccianiga^j, M. Capalbi^k, A. Lamastra^a, S. Lombardi^{a,b}, F. Lucarelli^{a,b}, R. Alves Batista^l, L. A. Antonelli^{a,b}, E. M. de Gouveia Dal Pino^m, R. Della Ceca^j, J. G. Green^{a,b}, S. Vercelloneⁿ, A. Wolter^j, E. Amato^o, C. Bigongiari^{a,b}, A. Bulgarelli^r, M. Cardillo^s, V. Conforti^r, A. Costa^q, G. Cusumano^k, V. Fioretti^r, S. Germaniⁱ, A. Ghedina^u, V. Giordano^q, A. Giuliani^v, F. Incardona^q, A. La Barbera^k, G. Leto^q, F. Longo^{w,x}, G. Morlino^o, B. Olmi^y, N. Parmiggiani^r, P. Romanoⁿ, G. Romeo^q, A. Stamerra^a, G. Tagliaferriⁿ, V. Testa^a, G. Tosti^{l,t}, P. A. Caraveo^v and G. Pareschiⁿ

JHEAP, 2022, 35, 91

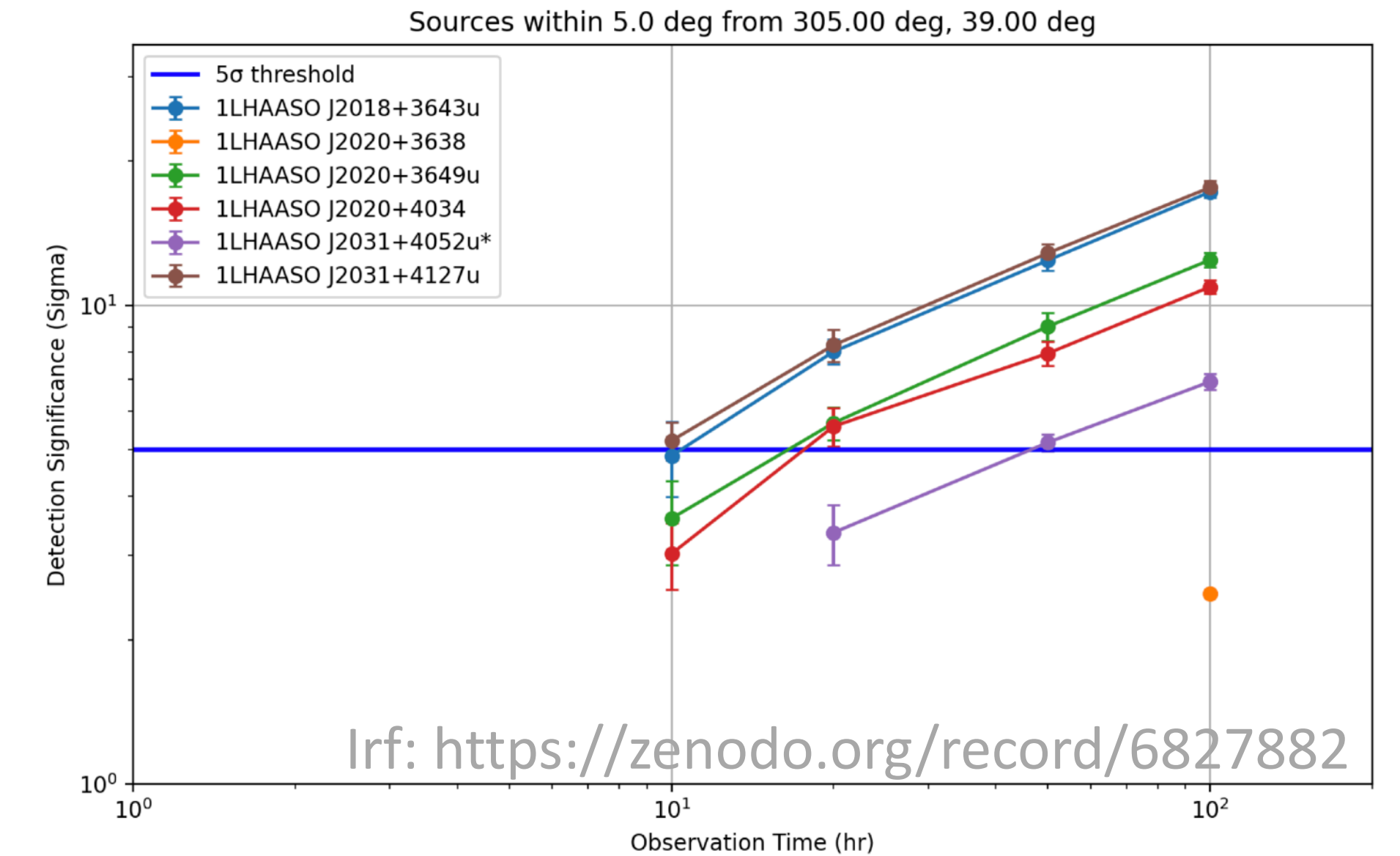
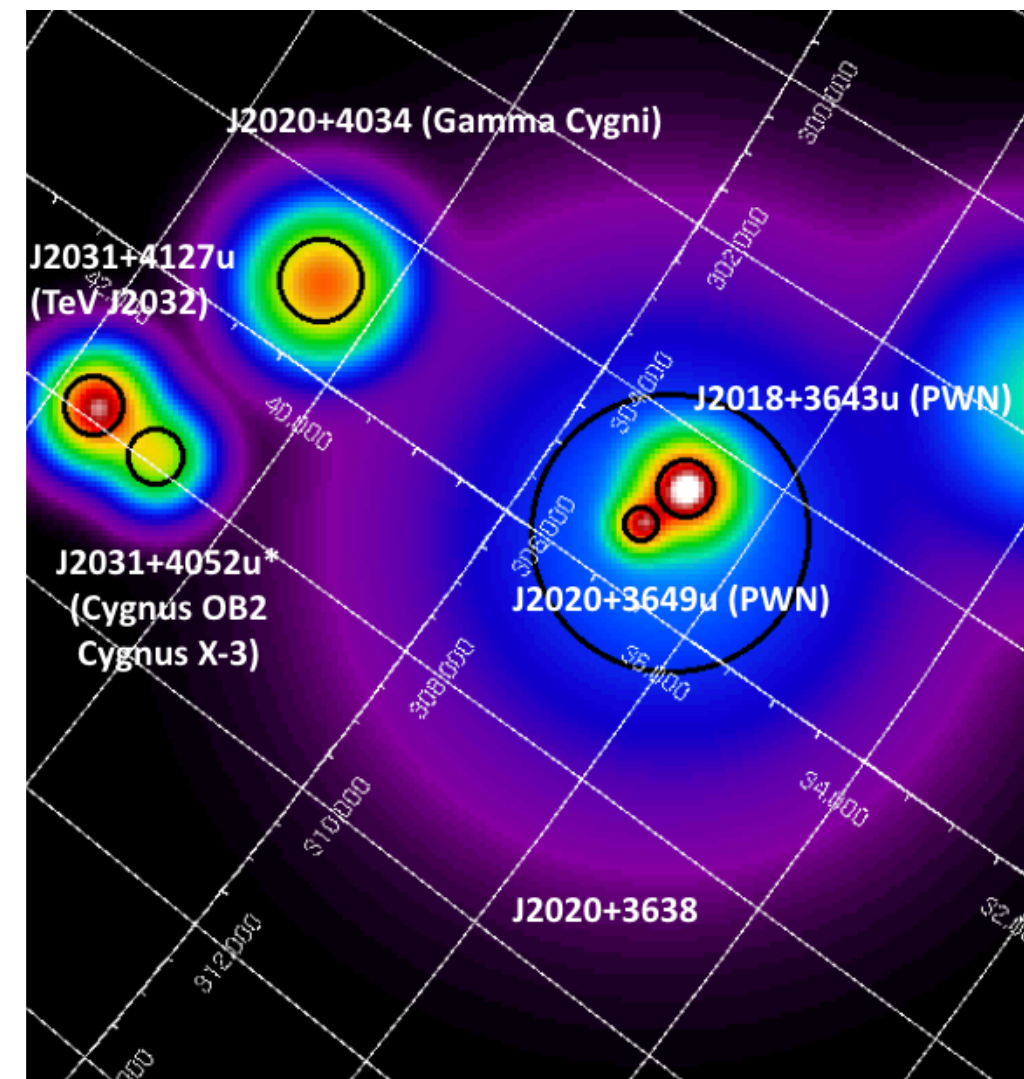
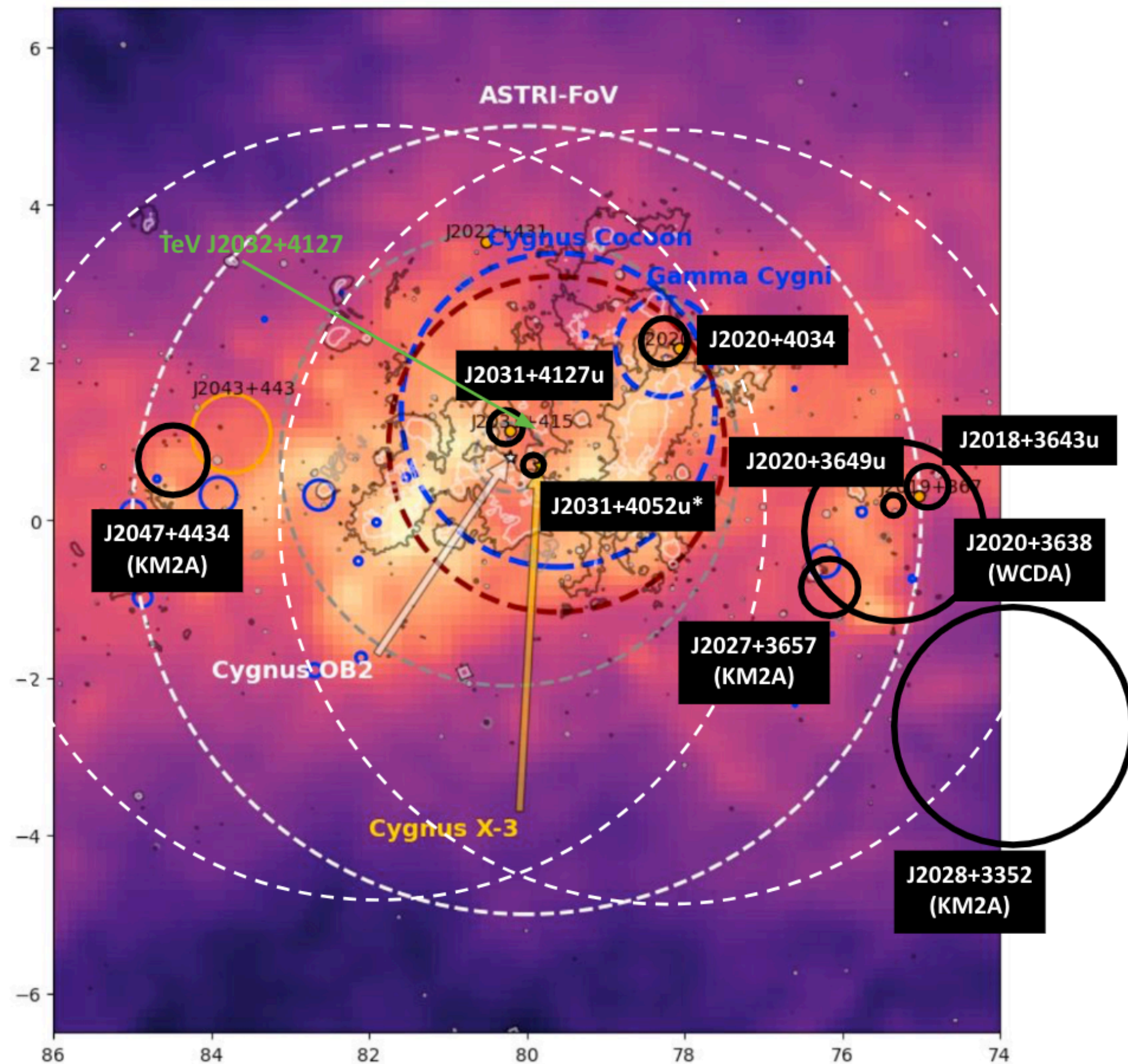


Cygnus Region



- SNRs: Gamma Cygni (J2020+4034)
- PWNe: TeV J2032+4130 (J2031+4127u)
MGRO J2019+37 (J2018+3643u)
VER J2019+368 (J2020+3649u)
- YMSCs: Cygnus OB2 (J2031+4052u*)
Berkeley 86 & 87
- MicroQ: Cygnus X-3 (J2031+4052u*)

Cygnus Region



- SNRs: Gamma Cygni (J2020+4034)
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MGRO J2019+37 (J2018+3643u)
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Berkeley 86 & 87
- MicroQ: Cygnus X-3 (J2031+4052u*)

Conclusions

- First observational campaign: over 200 hours of data collected in multiple observational configurations — a successful run with promising results
- Crab spectrum up to 20 TeV with 9 hours of observation, consistent with other experiments
- Off-axis performance confirms ASTRI's potential for multi-target observations
- ASTRI-1 performs well under moonlight, enabling a potential doubling of observing time
- Key performance: angular resolution $< 0.25^\circ$, energy resolution 20–25%, energy bias $< 10\%$
- Next steps: improvement of the single-telescope pipeline and simulations to support full deployment of the ASTRI Mini-Array and get ready for the stereo observations in autumn.



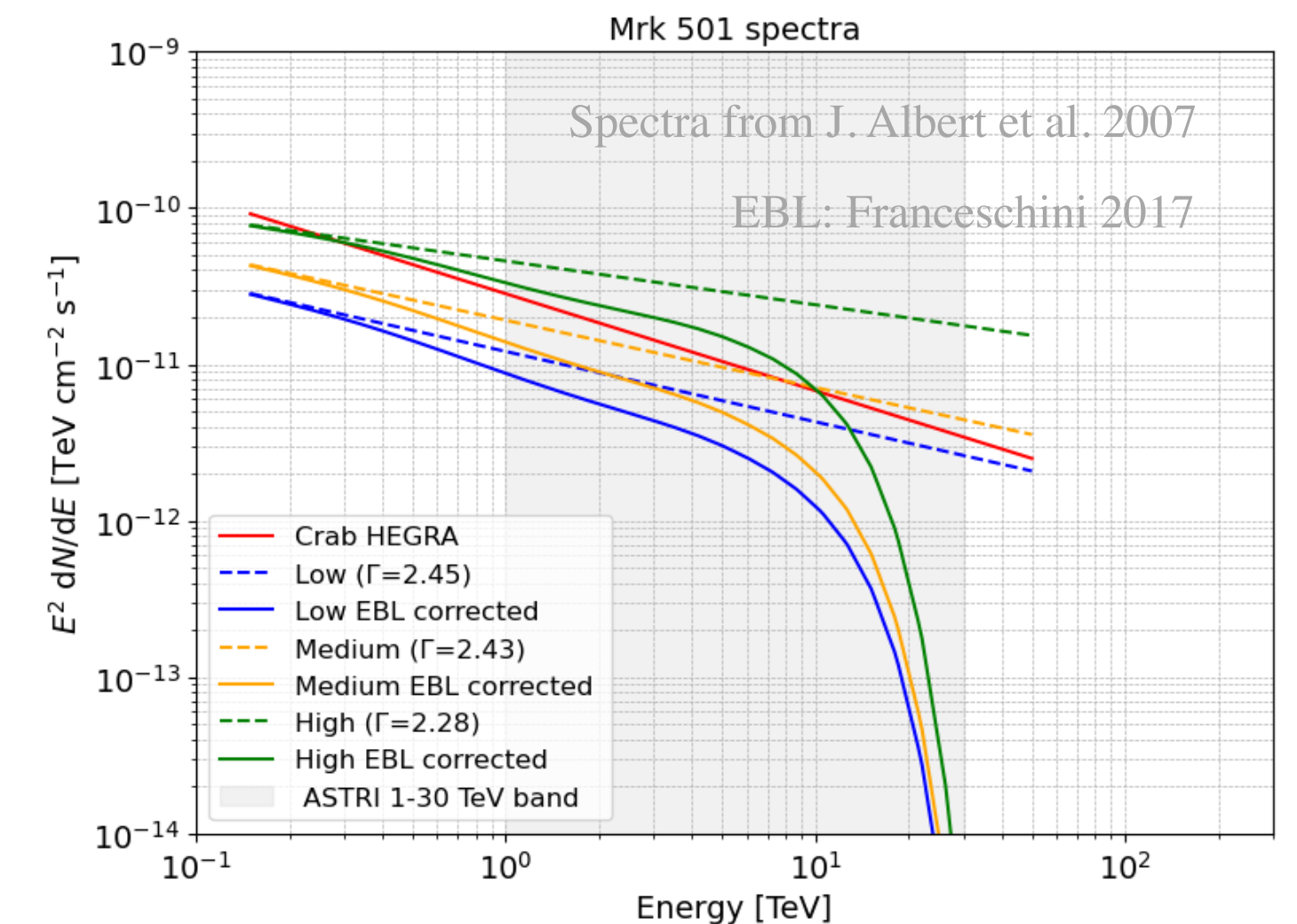
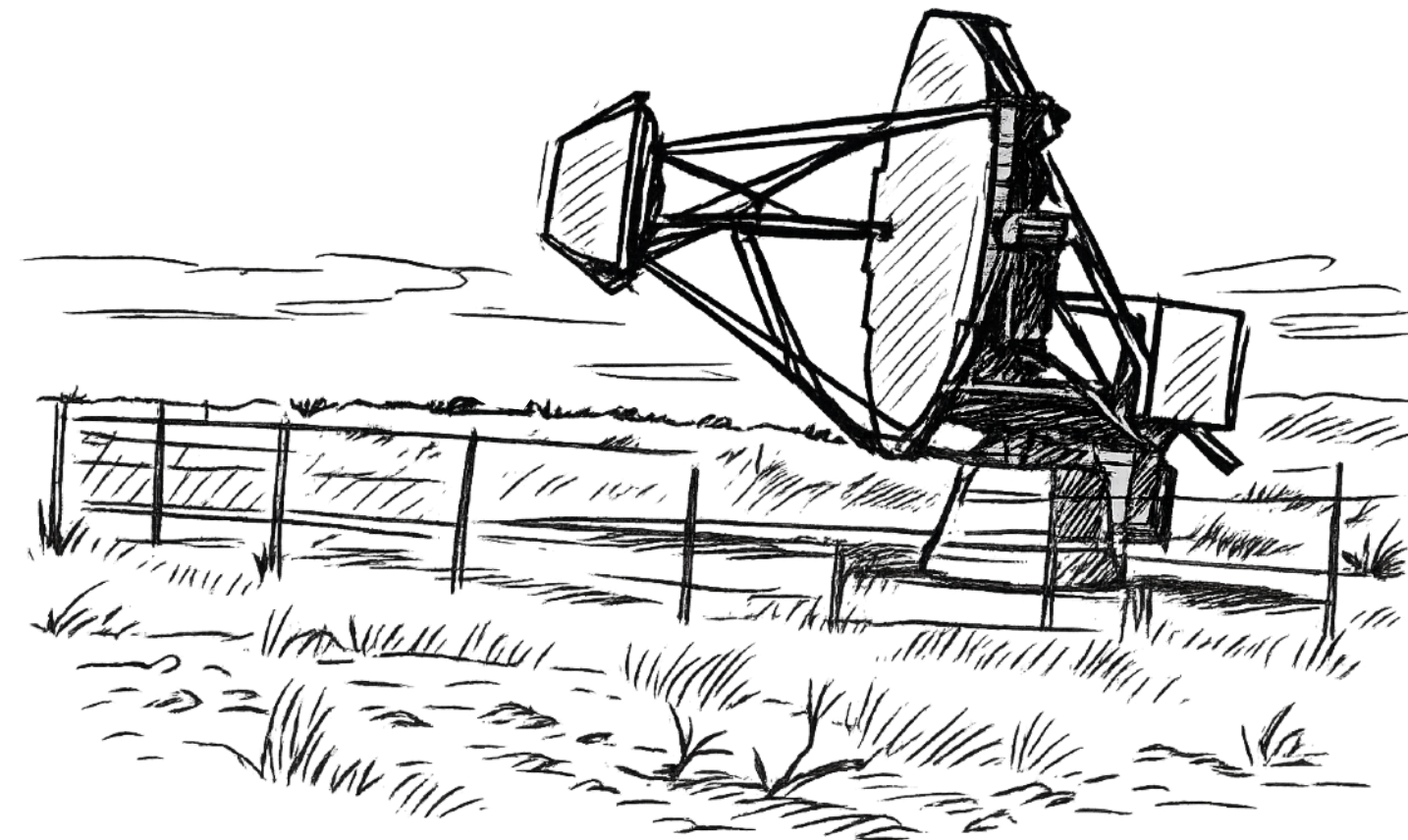
BACK-UP SLIDE



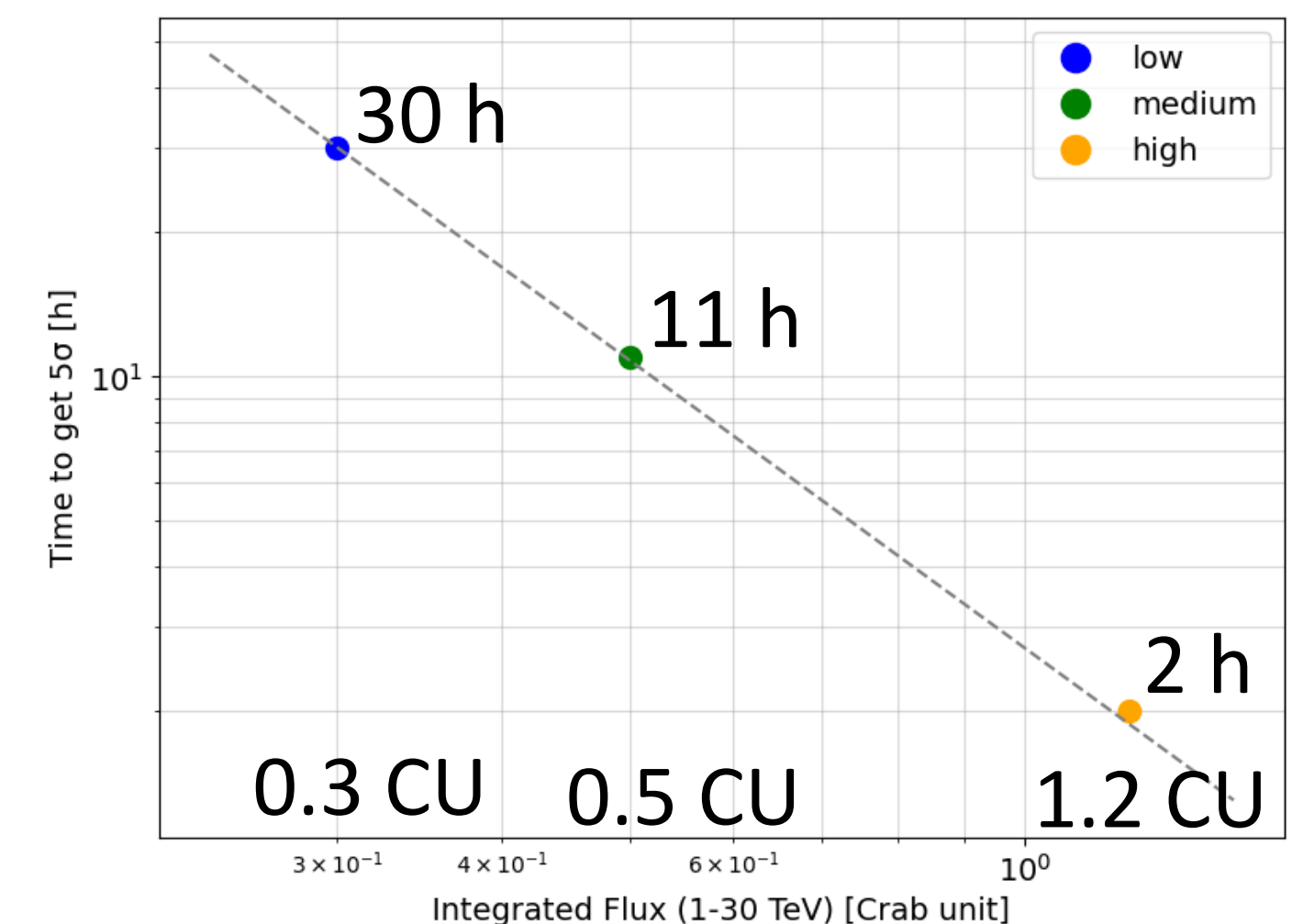
BACK-UP SLIDE

ASTRI Very Early Science

- This summer (ongoing): blazar monitoring campaign
- Sensitivity estimates based on Crab observations
- Detection estimates for 1 telescope:
 - ~30 h (low state, 0.3 CU)
 - ~11 h (medium state, 0.5 CU)
 - ~2 h (high state, 1.2 CU)
- Analysis still ongoing
- Joint observing program with Swift



Estimates for 1 telescope



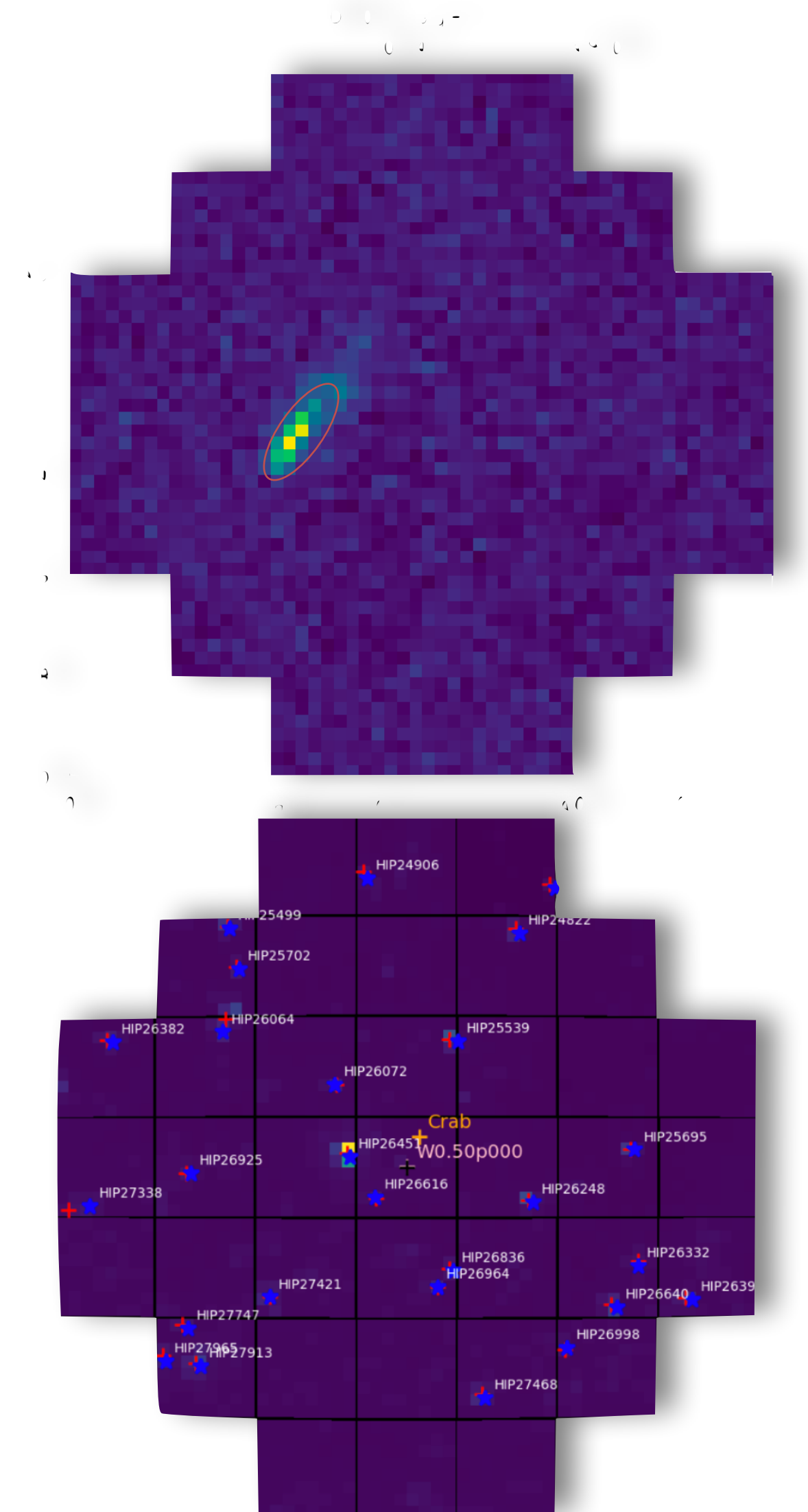
Flares in bright TeV blazars with *Swift* and the ASTRI Mini-Array

S. Vercellone, P. Romano, G. Bonnoli, G. Pareschi, F. Tavecchio (INAF/OAB)

J. Becerra González (IAC), A. Giuliani (INAF/IASFMI), M. Capalbi, S. Lombardi (INAF/OAR)

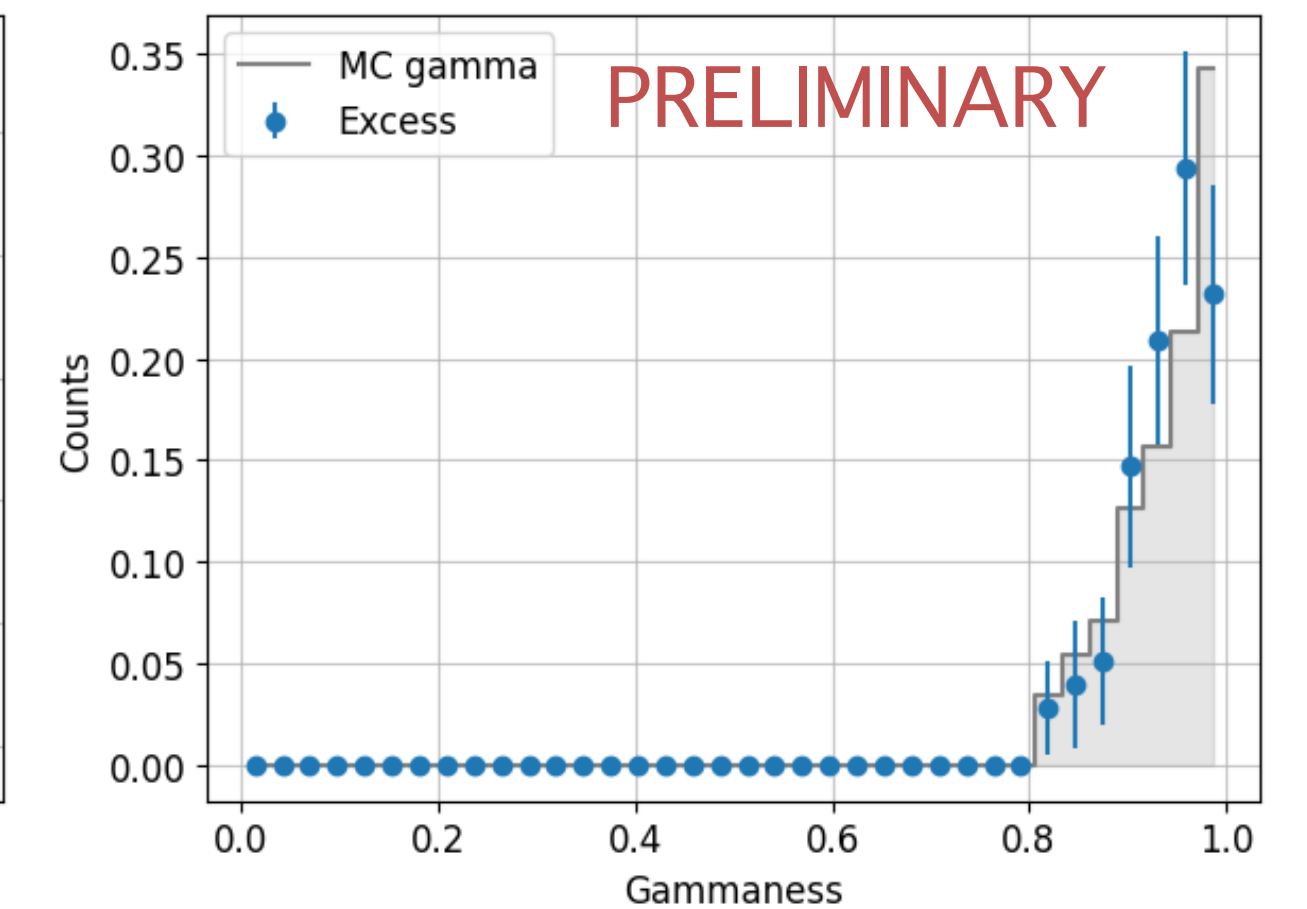
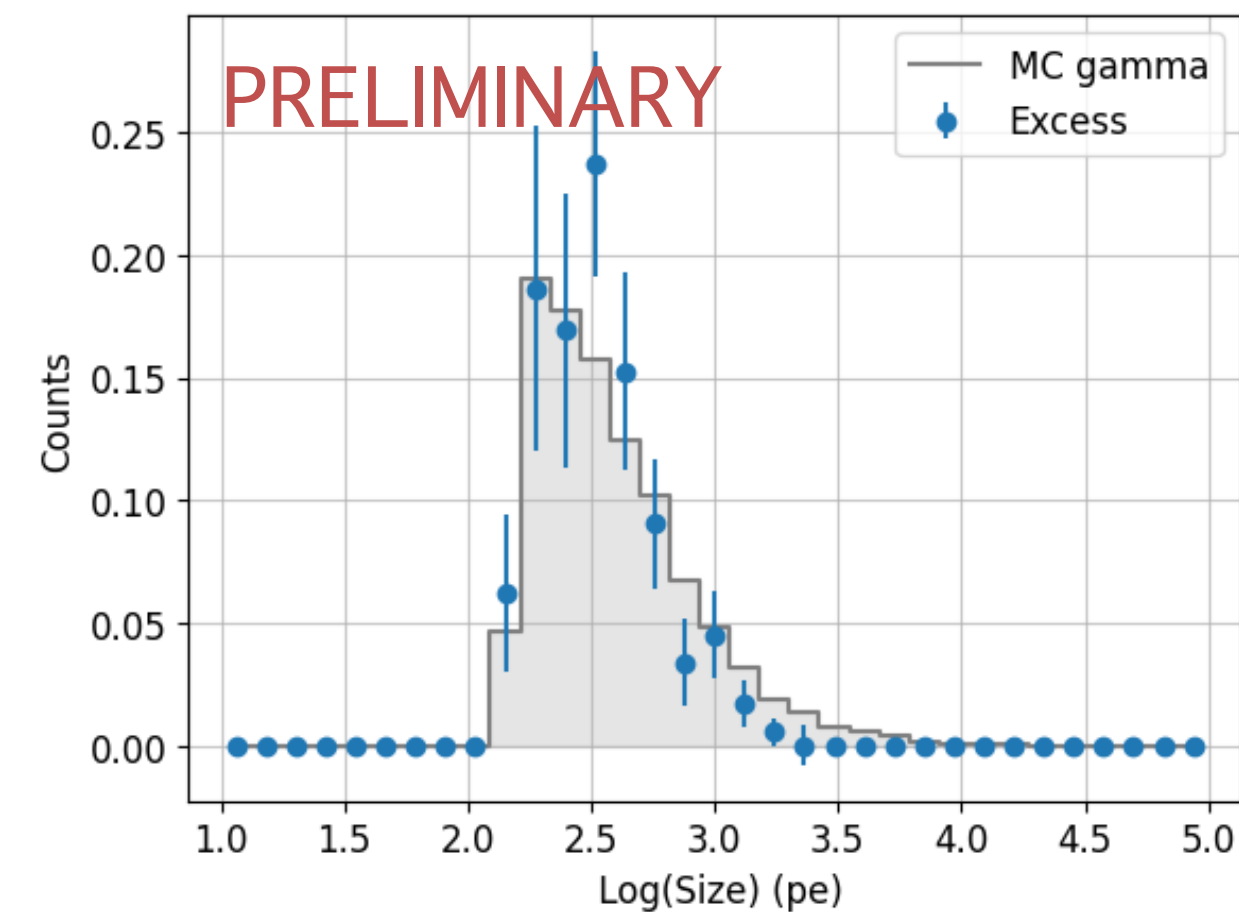
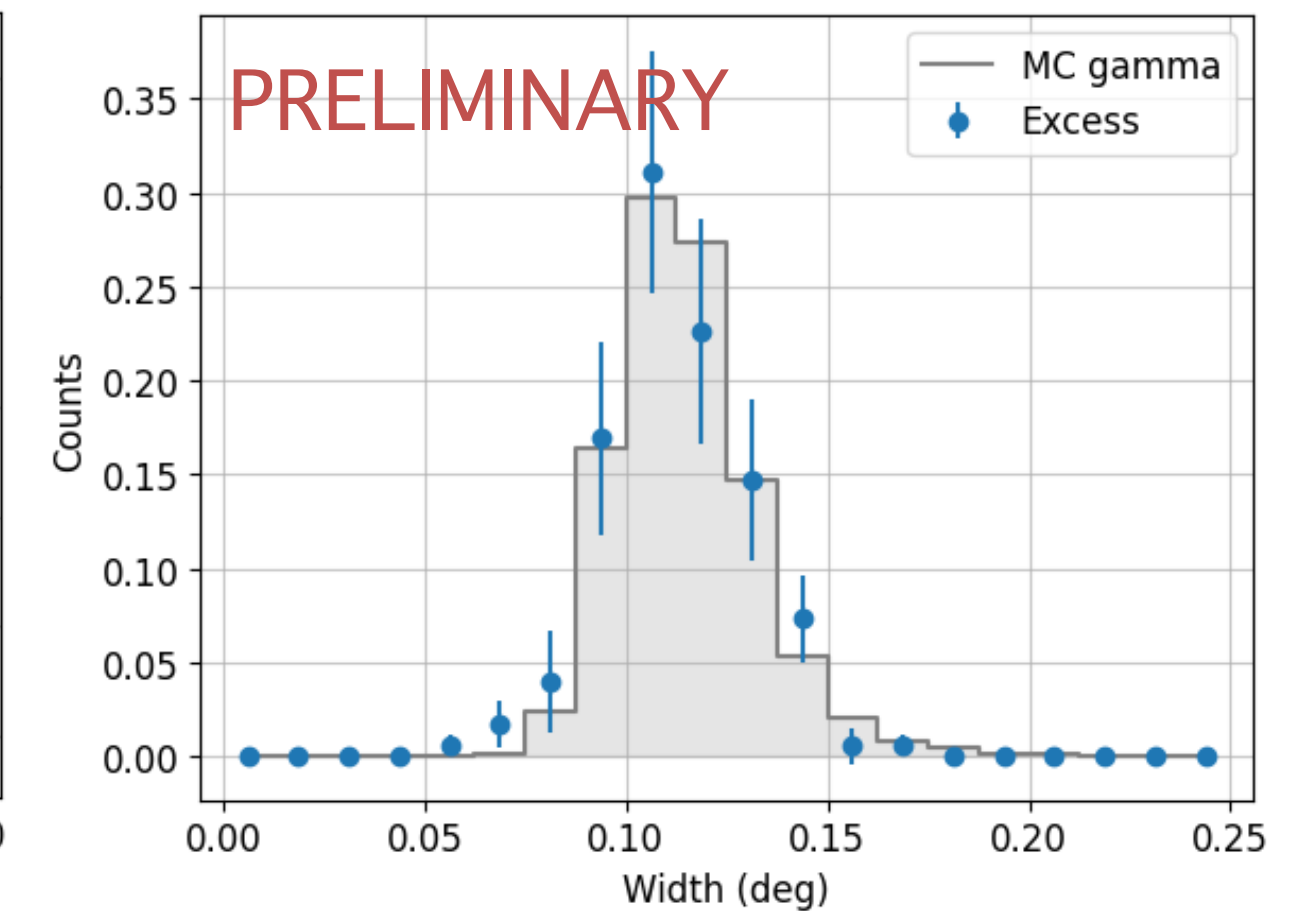
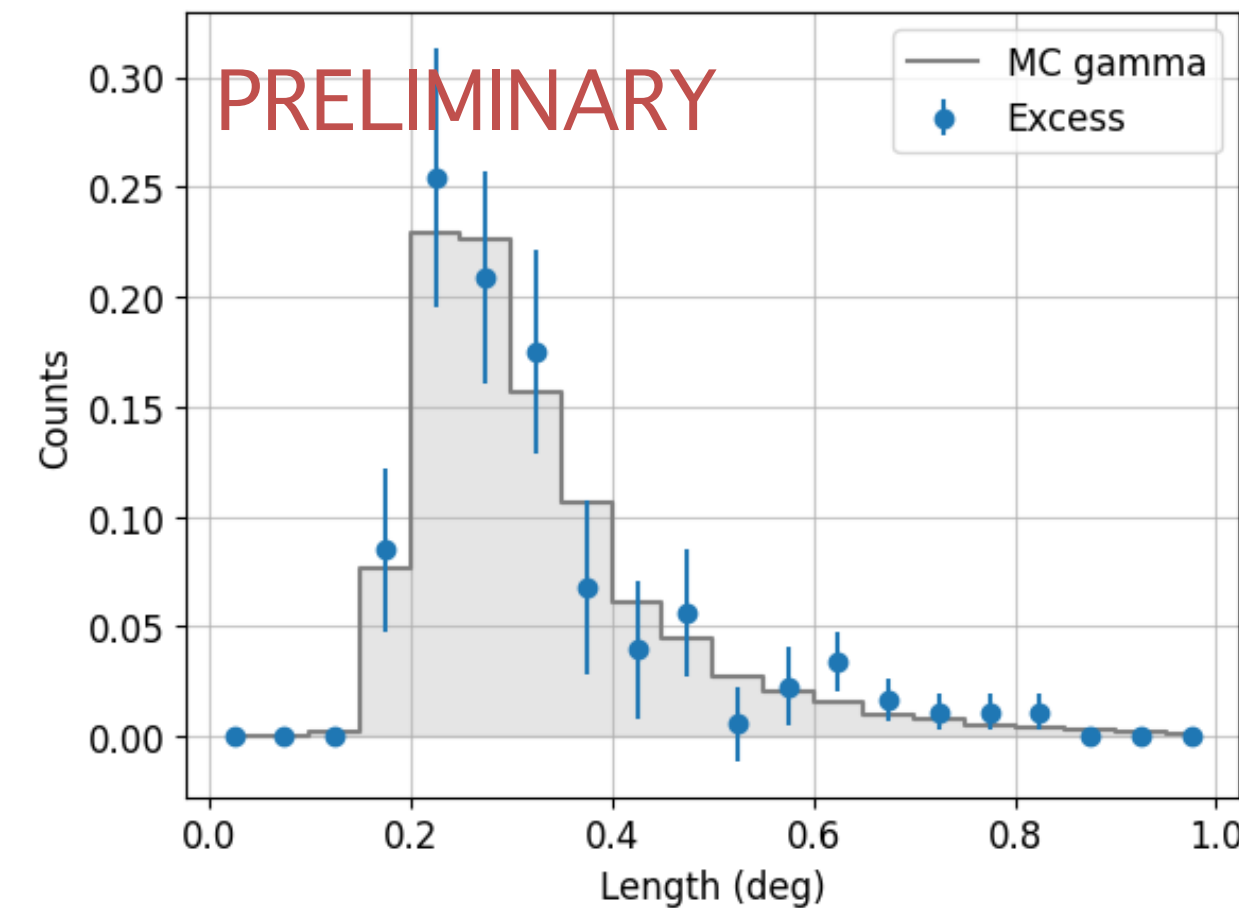
ASTRI-1: Data Analysis (Not Optimized)

- Lv0 Calibration:
 - Standard procedure
 - Cleaning/Parameterization: relative cleaning 4.0-2.0
- Lv1 reconstruction:
 - Quality cuts: ($\text{SIZE} > 50$, $\text{LEAKAGE} < 0.1$, $\text{NUMISLAND} < 2$) (i.e. basically none)
 - Pointlike-srcindep approach (Random Forest for g/h, energy, arrival direction)
 - Pointing and source position calculation from astrometry of VARIANCE data (without PMC information)
- Lv2 reconstruction:
 - No additional Random Forests
- Lv3 Event-list and IRF generation
- Lv4/5: Analysis with Gammapy



ASTRI-1: MC and real data comparison

- MC gamma available:
 - Zenith = 20° , Azimuth = 180°
 - Data selection:
 - Runs passing data quality criteria with $ZD < 30^\circ$ and offset 0.5°
 - $SIZE > 150$ pe, $LEAKAGE < 0.1$
 - Parameters considered:
 - SIZE, WIDTH, LENGTH, GAMMANESS
- Good Agreement: MC gamma events reproduce well real Crab excesses



General: Status of the ASTRI Mini-Array Gamma-Ray Experiment - (G. Pareschi et al.) - **TALK**

Science

Classification of Unidentified Extended LHAASO Sources based on their Gamma-Ray Morphology - (A. Bonollo et al.) - **TALK**

Studying SNR-MC interactions as galactic PeVatrons in the era of CTAO and ASTRI Mini-Array - (A. Sunny et al.) - **PO2**

Unveiling TeV halos among unidentified extended sources - (M. Rigoselli et al.) - **PO2**

The Stereo Event Builder of the ASTRI Mini-Array - (S. Germani et al.) - **PO1**

Data Processing &
Simulation

New time-based parameters to enhance g/h discrimination for the ASTRI Mini-Array event reconstruction - (V. La Parola et al.) - **TALK**

The Data Handling System of the ASTRI Mini-Array project - (F. Lucarelli et al.) - **PO1**

To cut or not to cut: Data-quality evaluation for the ASTRI Mini-Array - (E. Molina et al.) - **PO1**

Renewed performance of the ASTRI Mini-Array at the Observatorio del Teide - (F. Pintore et al.) - **PO2**

Advances in the Simulation System of the ASTRI Project - (F.G. Saturni et al.) - **PO2**

iactsim: a CUDA-accelareted Python simulation framework for Imaging Atmospheric Cherenkov Telescopes - (D. Mollica et al.) - **PO2**

Calibration

Calibration of the ASTRI-1 Cherenkov camera - (D. Mollica et al.) - **PO2**

Using muon rings for the optical calibration of ASTRI-1 telescope: preliminary results - (T. Mineo et al.) - **PO2**

Night sky background at the ASTRI Mini-Array site: correlation between the SQM and ASTRI-1 variance data - (C. Quartiroli et al.) - **PO2**

Measurement and monitoring of the ASTRI Mini-Array pointing accuracy - (S. Iovenitti et al.) - **PO2**

The ASTRI Mini-Array calibration software - (D. Mollica et al.) - **PO2**

AIV: The Product Assurance and AIV strategy from the ASTRI Mini-Array project to the SST Project - (N. La Palombara et al.) - **PO2** 27