

Highlights of the FACT Monitoring Program



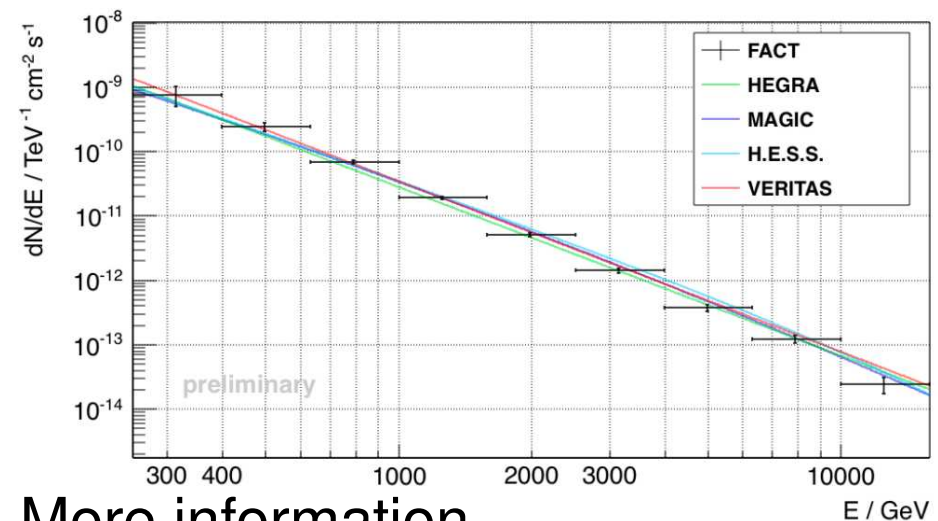
Daniela Dorner for the FACT Collaboration



First G-APD Cherenkov Telescope

2200 m a.s.l., Observatorio
del Roque de los Muchachos,
La Palma

- Operational since Oct 2011
- 9.5 m² mirror area
- Camera: Silicon based photosensors (SiPM), 4.5° FoV, 1440 pixels à 0.11°
- Imaging Air-Cherenkov Technique
- Energy range: > 300 GeV



F. Temme et al. (FACT
Collaboration), ICRC 2015

- More information
H Anderhub et al 2013 JINST 8 P06008
A Biland et al 2014 JINST 9 P10012

Photo: Thomas Krähenbühl

FACT – Ideal Monitoring Telescope



- Gain of SiPMs: no degradation when exposed to bright light
→ **Observations during strong moon light possible**
- SiPMs robust and stable
→ Stable telescope performance
→ Robotic operation
<https://www.fact-project.org/smartfact>
→ High data taking efficiency
- **More complete data sample**
→ Maximized duty cycle
→ Minimized gaps
→ Denser light curve
- FACT Observation Strategy
→ **Unbiased Monitoring**

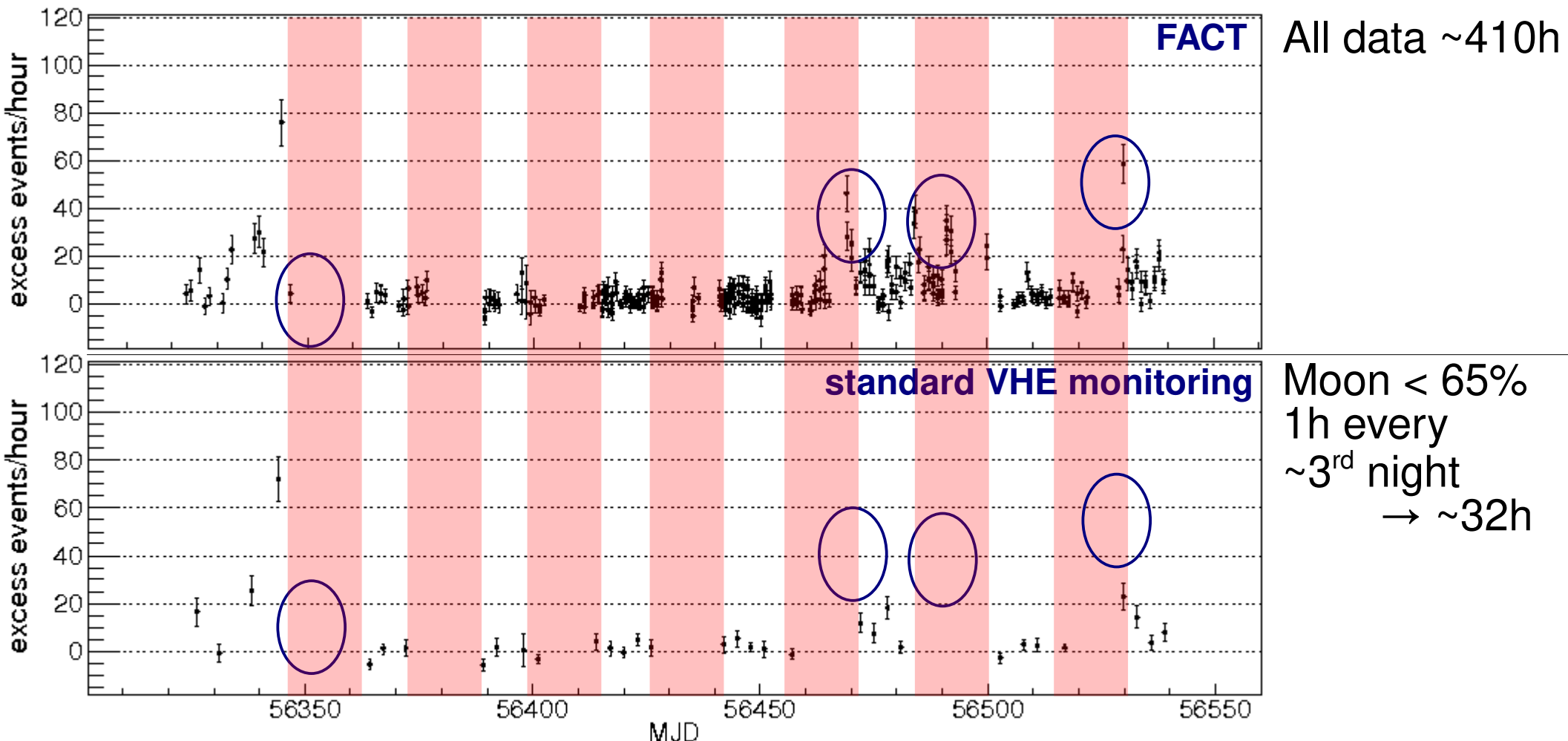


Up to 2400 h/year

Unbiased Monitoring

FACT monitoring strategy
→ Unbiased observation

Mrk 501 (2013) 1-hour-binning



Standard VHE: Follow-up of flares → bias toward high fluxes

Observations

- Total amount of **physics data** in 8 years:
> 14'900 hours
- Open data policy
 - Crab raw data sample
 - Quick look analysis results
 - Schedule public
 - FACT as instrument for teaching & student projects

ID760
**Schleicher et al.
this conference**

<u>Source</u>	<u>Time[h]</u>
Mrk 501	2993.84
Mrk 421	3196.49
1ES 1959+650	2230.76
Crab	2386.43
1ES 2344+51.4	1975.72
1H0323+342	1179.28
PKS 0736+01	151.43
V404 Cyg	71.46
TeV J2032+4130	64.79
1ES 1218+304	35.21
IC 310	42.59
IceCubeEHE20171106b	15.64
H 1426+428	13.25
PG 1553+113	14.13
PKS 2155-304	10.55
TOMAS2345736	11.46
TOMAS2445523	9.72
2FHL J0326.0-1644	11.61
M87	9.98
AMON20160218	4.33



Source Sample

- Bright TeV blazars
- Crab Nebula as standard candle at VHE
- Multi-wavelength campaign on various VHE sources
- Follow-up of multi-wavelength and multi-messenger alerts

<u>Source</u>	<u>Time[h]</u>
Mrk 501	2993.84
Mrk 421	3196.49
1ES 1959+650	2230.76
Crab	2386.43
1ES 2344+51.4	1975.72
1H0323+342	1179.28
PKS 0736+01	151.43
V404 Cyg	71.46
TeV J2032+4130	64.79
1ES 1218+304	35.21
IC 310	42.59
IceCubeEHE20171106b	15.64
H 1426+428	13.25
PG 1553+113	14.13
PKS 2155-304	10.55
TOMAS2345736	11.46
TOMAS2445523	9.72
2FHL J0326.0-1644	11.61
M87	9.98
AMON20160218	4.33

Core
monitoring
sample

Source Sample

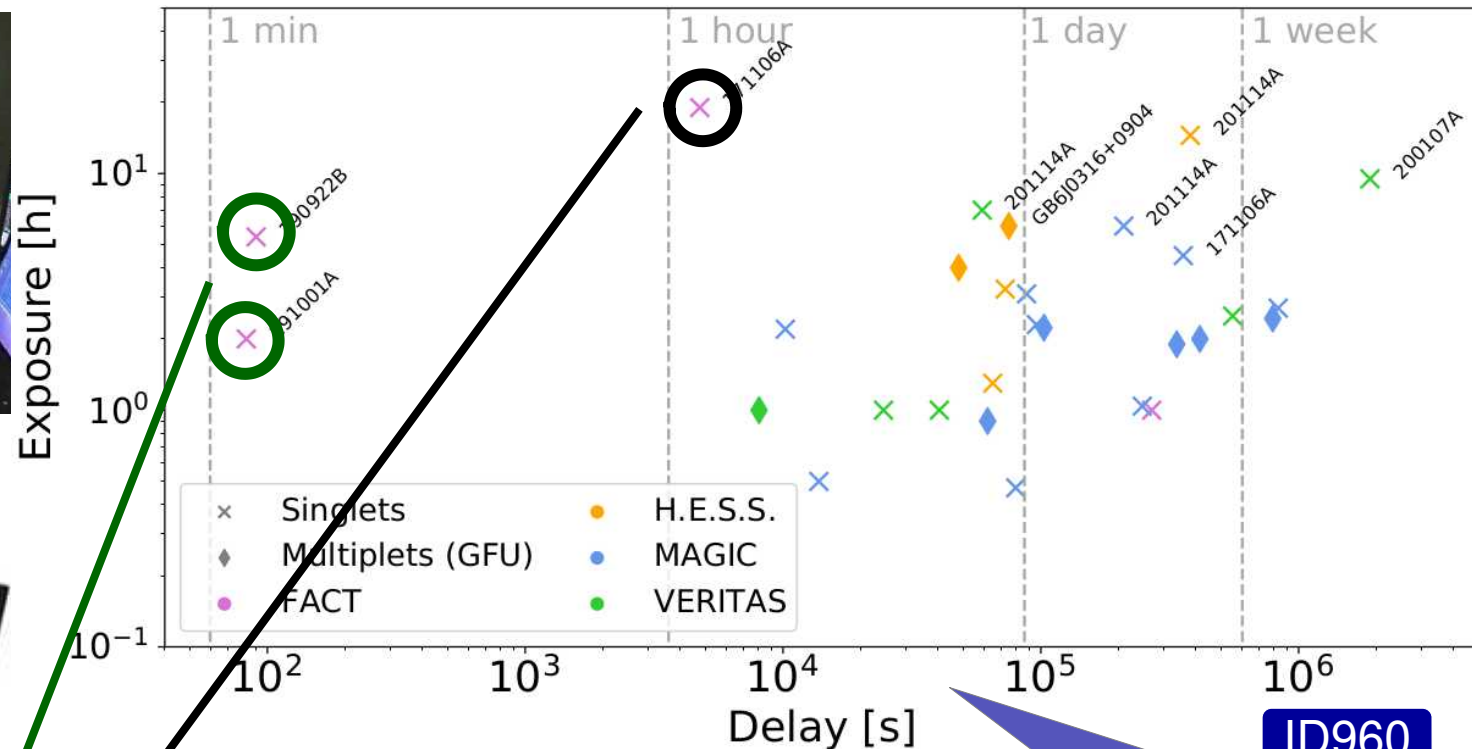
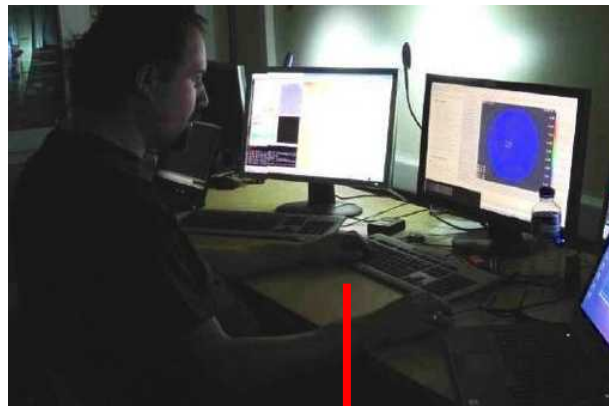
- Bright TeV blazars
- Crab Nebula as standard candle at VHE
- Multi-wavelength campaign on various VHE sources
- Follow-up of multi-wavelength and multi-messenger alerts

<u>Source</u>	<u>Time[h]</u>
Mrk 501	2993.84
Mrk 421	3196.49
1ES 1959+650	2230.76
Crab	2386.43
1ES 2344+51.4	1975.72
1H0323+342	1179.28
PKS 0736+01	151.43
V404 Cyg	71.46
TeV J2032+4130	64.79
1ES 1218+304	35.21
IC 310	42.59
IceCubeEHE20171106b	15.64
H 1426+428	13.25
PG 1553+113	14.13
PKS 2155-304	10.55
TOMAS2345736	11.46
TOMAS2445523	9.72
2FHL J0326.0-1644	11.61
M87	9.98
AMON20160218	4.33

ID960

Satalecka et al.
this conference

Follow-up of Neutrino Alerts



ID960
Satalecka et al.
this conference

2011: start of operation

2012: remote operation without data-taking crew onsite

2017: automatic operation with manual scheduling of follow-up observations

2019: automatic scheduling activated for follow-up observations

2020: no operation (problem in DAQ electronics, repair delayed due to SARS-CoV-2)

June 2021: back to operation, waiting for alerts

MWL and ToO Activities

- Multi-Messenger:
AMON Network
- Multi-Wavelength (MWL)
Projects: [joint with]
 - Mrk 501 Jun 2012 [MAGIC, MWL]
 - Mrk 501 Jun 2014 [H.E.S.S.]
 - Mrk 501 Jul 2014 [MAGIC, MWL]
 - Mrk 421 2015/2016 [MAGIC, MWL]
 - 1ES 1959+650 2015-19 [MAGIC, MWL]
 - Mrk 421 Dec 2015 [X-ray ToO]
 - 1ES 2344+51.4 [MAGIC, MWL]
 - Mrk 421 Jan 2018 [MAGIC, HAWC]
 - Mrk 421 Jan 2019 [AstroSAT, WEBT]
 - Mrk 421 Jun 2019 [X-ray ToO]

Gokus et al.
this conference

- MWL Observations
triggered by FACT
- Target-of-Opportunity (ToO)
campaigns with
X-ray satellites

– 2013: *XMM-Newton* / *Swift*

– 2015/6: *INTEGRAL* / *Swift*

– Ongoing: *INTEGRAL*, *Swift*
and *XMM-Newton*

11 Atels

101 alerts since March 2014

Successful ToO Dec 2015

Successful ToO June 2019

ID869



MoU & MWL partners

Swift-XRT

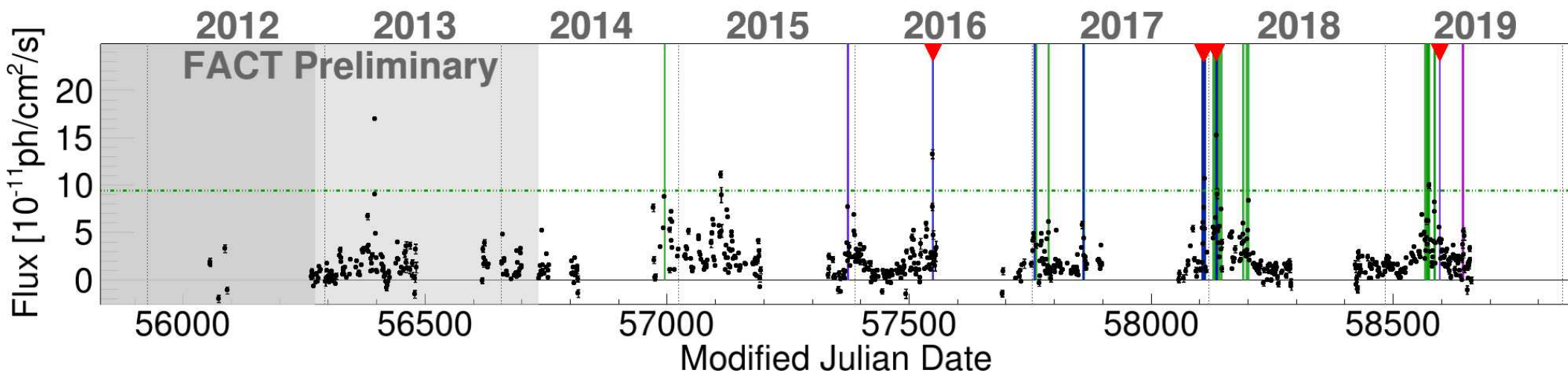
INTEGRAL

XMM-Newton

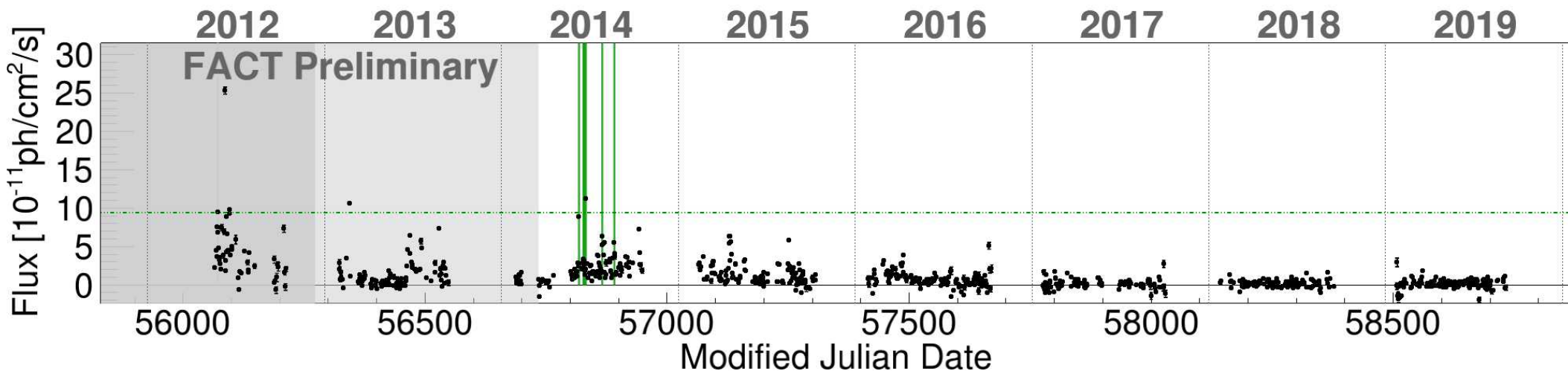
ATels

8 Years of Monitoring

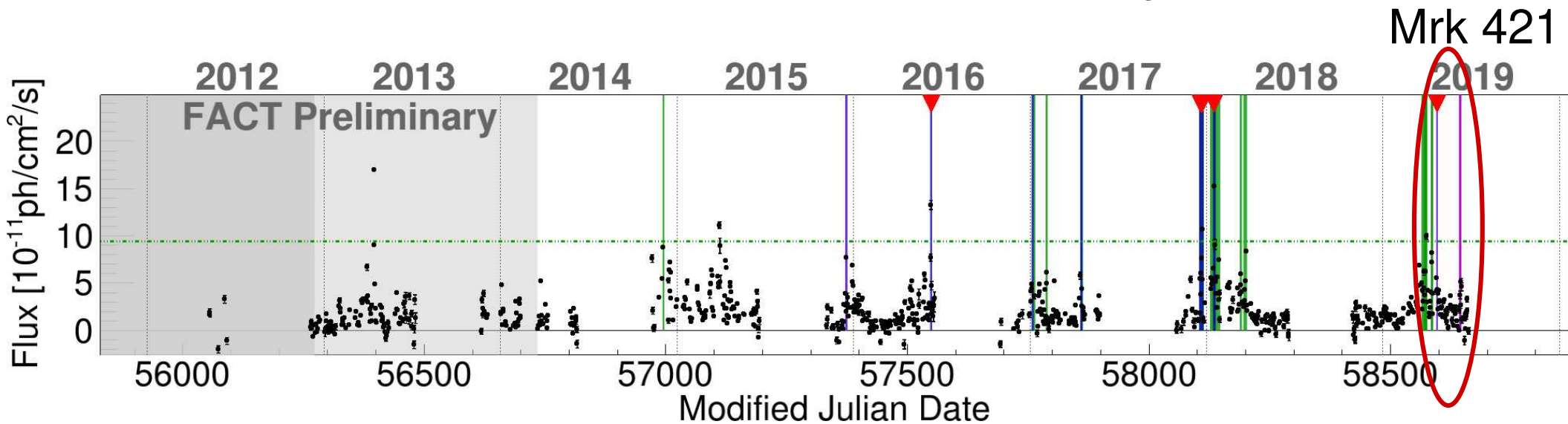
Mrk 421



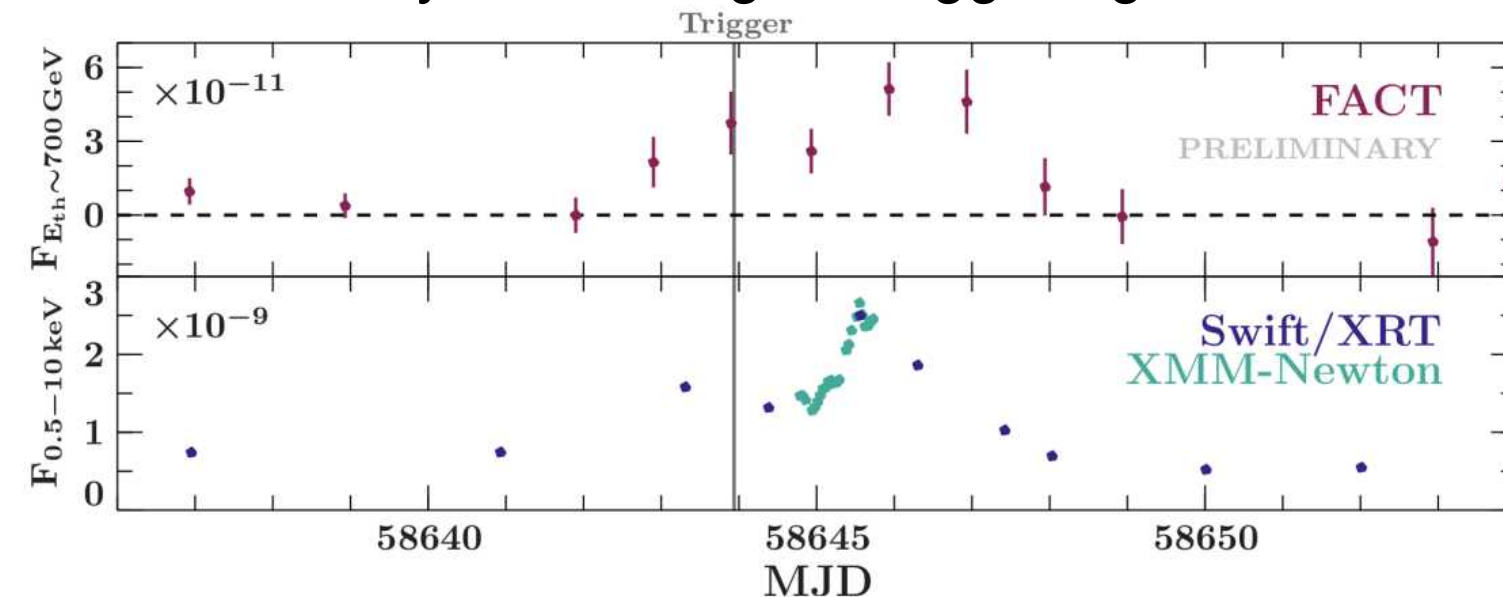
Mrk 501



FACT: Results from > 8 years



TeV + X-ray monitoring → Triggering XMM-Newton and INTEGRAL



ID869
Gokus et al.
this conference

MoU & MWL partners

Swift-XRT

INTEGRAL

XMM-Newton

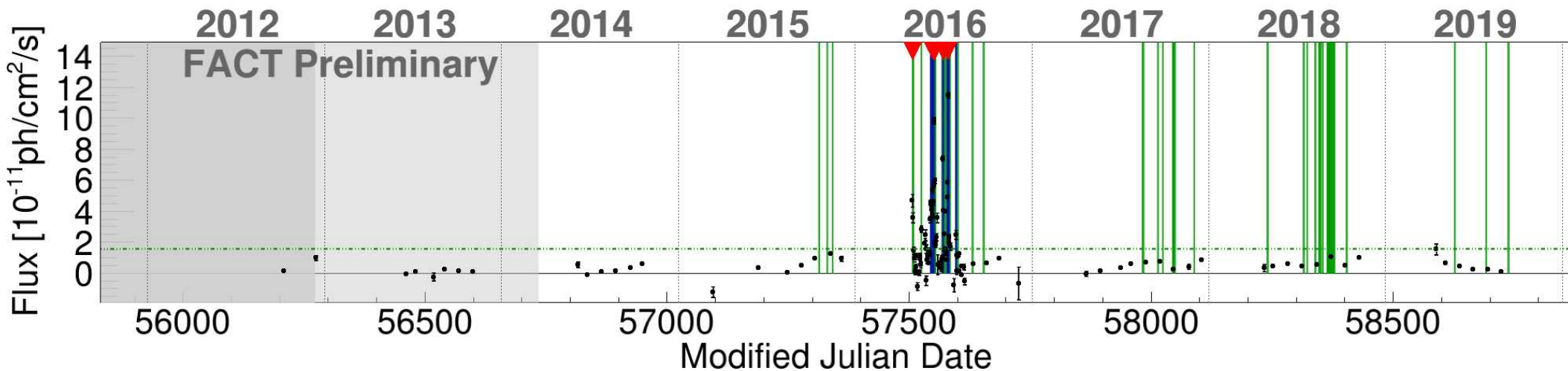
ATels

ID858

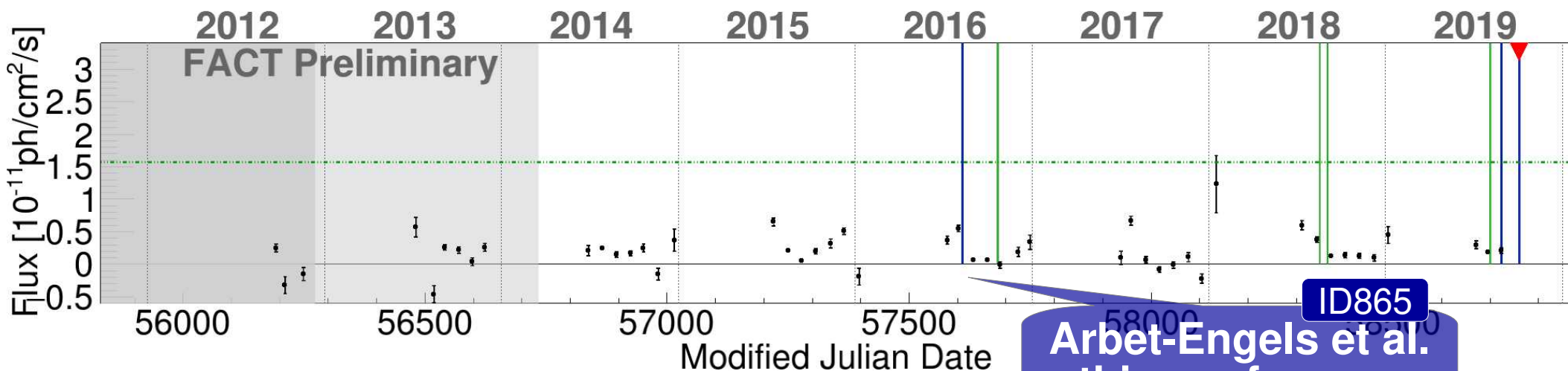
8 Years of Monitoring

Sakurai et al.
this conference

1ES 1959+650



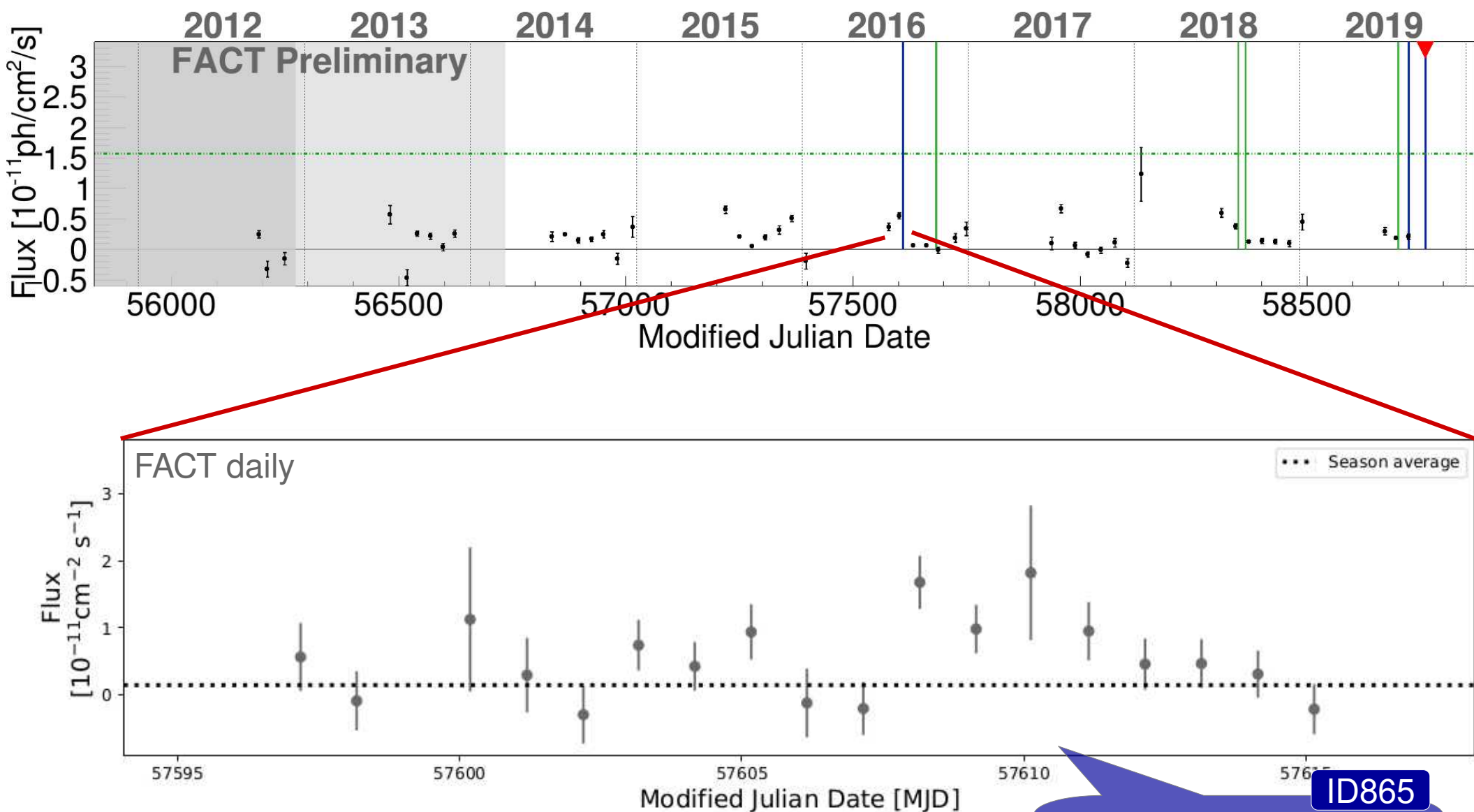
1ES 2344+51.4



ID865

Arbet-Engels et al.
this conference

1ES 2344+51.4



V. A. Acciari et al. (MAGIC, FACT, others), MNRAS 498, 3 (2020)

ICRC 2021, Dr. Daniela Dorner

ID865

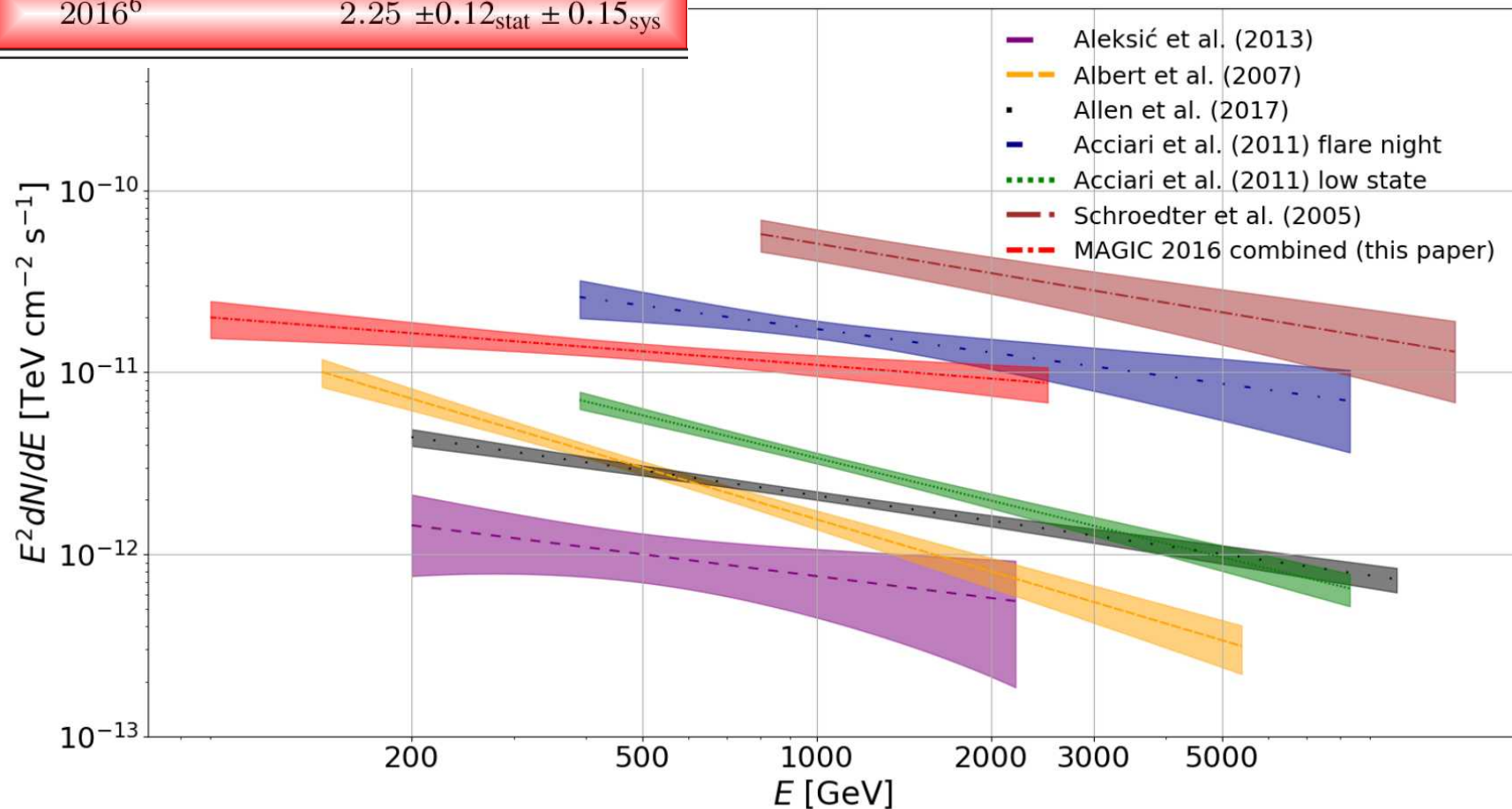
Arbet-Engels et al.
this conference

	Epoch ^b	Γ (observed spectrum)
Whipple	1995 ¹	$2.54 \pm 0.17_{\text{stat}} \pm 0.07_{\text{sys}}$
MAGIC	2007 ²	$2.95 \pm 0.12_{\text{stat}} \pm 0.2_{\text{sys}}$
VERITAS	2007–2008 ³ (low state)	$2.78 \pm 0.09_{\text{stat}} \pm 0.15_{\text{sys}}$
	2007–2008 ³ (flare)	$2.43 \pm 0.22_{\text{stat}} \pm 0.2_{\text{sys}}$
MAGIC	2008 ⁴	$2.4 \pm 0.4_{\text{stat}} \pm 0.2_{\text{sys}}$
VERITAS	2007–2015 ⁵	$2.46 \pm 0.06_{\text{stat}} \pm 0.2_{\text{sys}}$
MAGIC	2016 ⁶	$2.25 \pm 0.12_{\text{stat}} \pm 0.15_{\text{sys}}$

1ES 2344+51.4

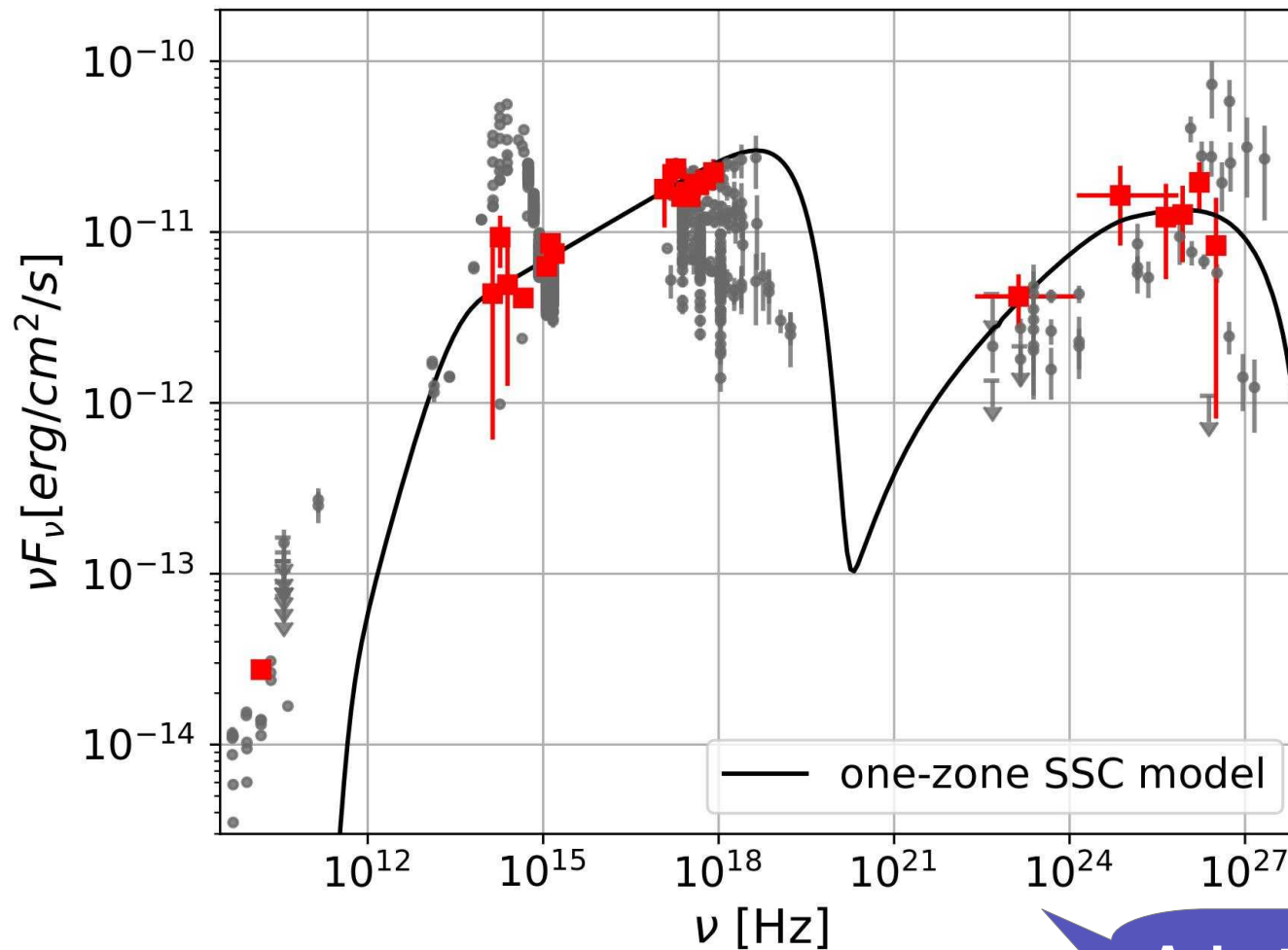
ID865

Arbet-Engels et al.
this conference



V. A. Acciari et al. (MAGIC, FACT, others), MNRAS 498, 3 (2020)

1ES 2344+51.4 an Intermittent Extreme Blazar

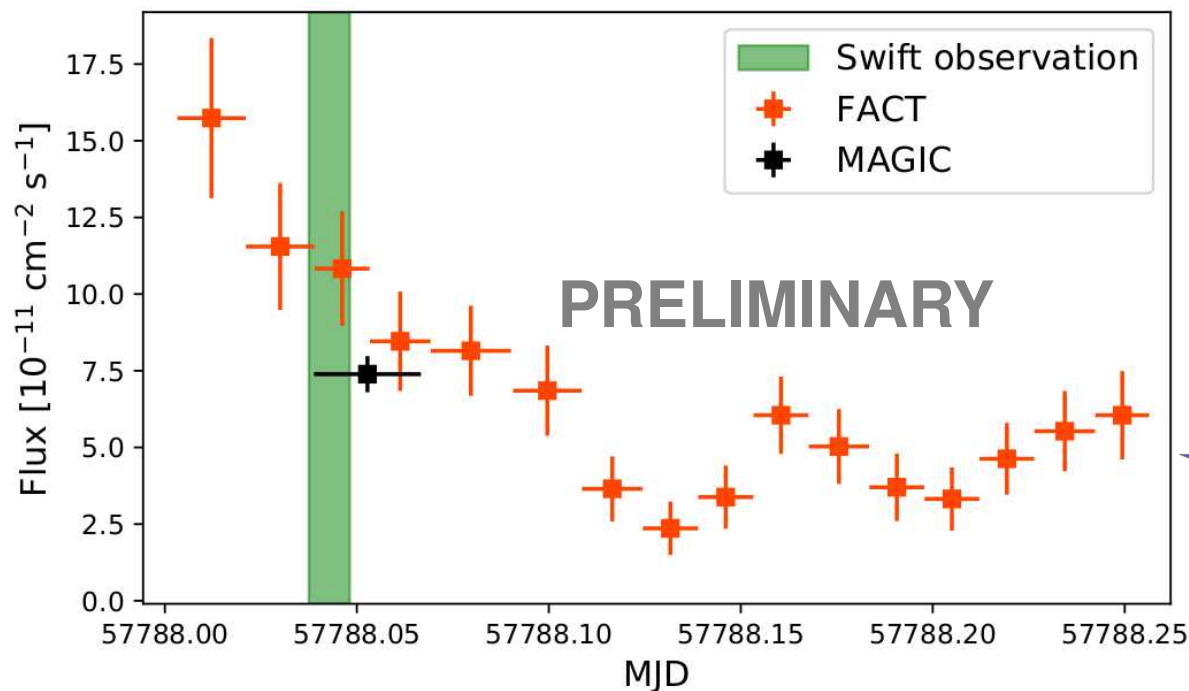
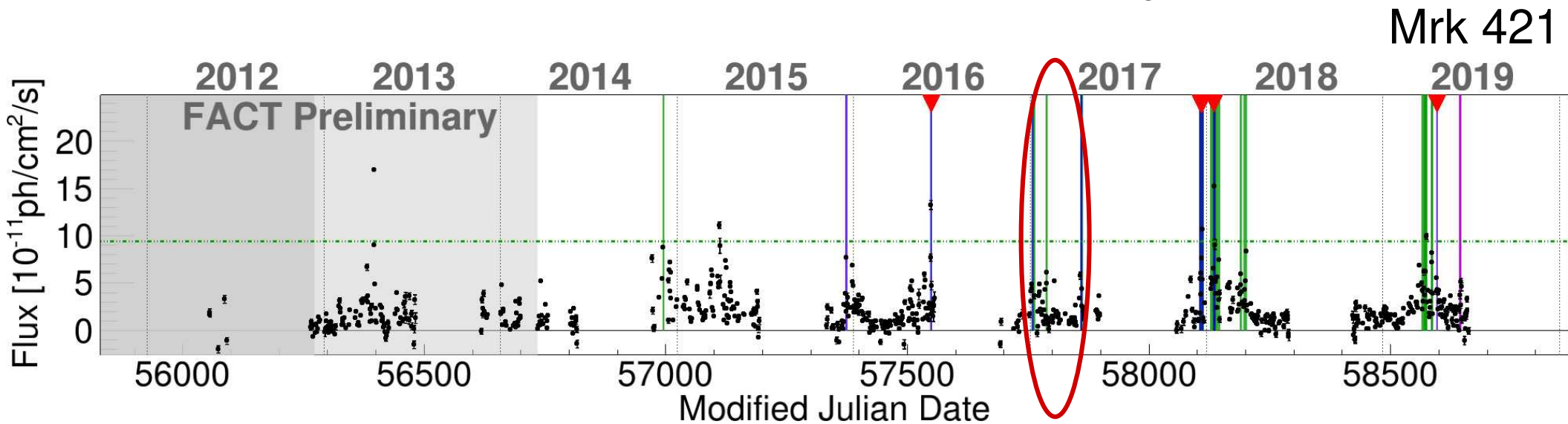


ID865

Arbet-Engels et al.
this conference

V. A. Acciari et al. (MAGIC, FACT, others), MNRAS 498, 3 (2020)

FACT: Results from > 8 years



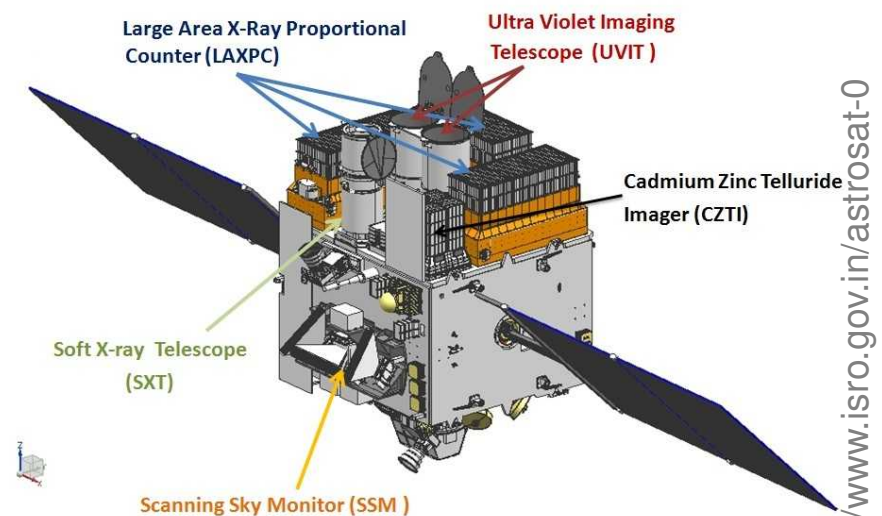
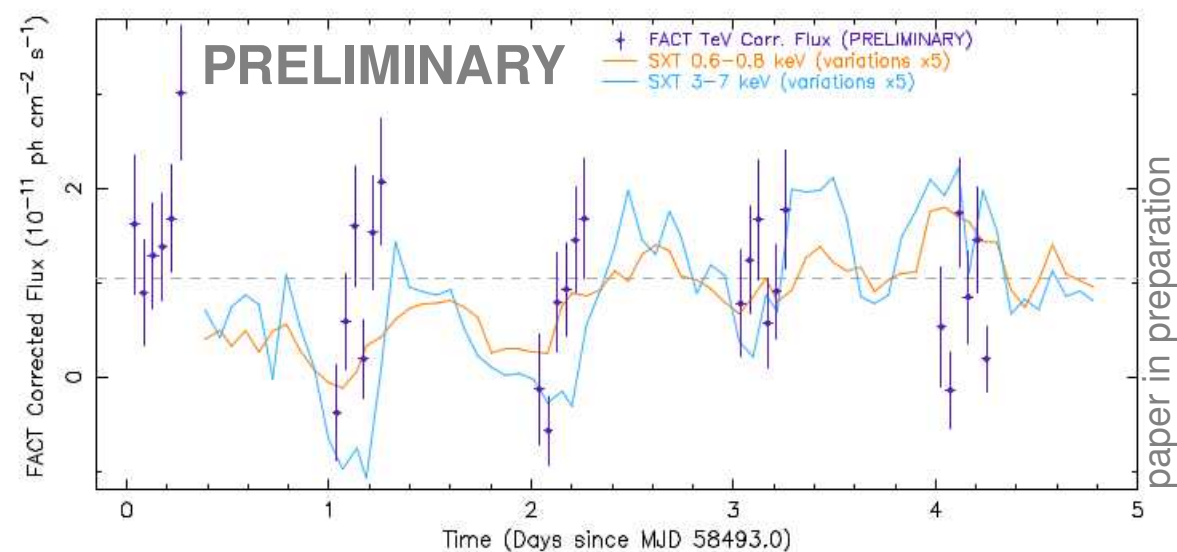
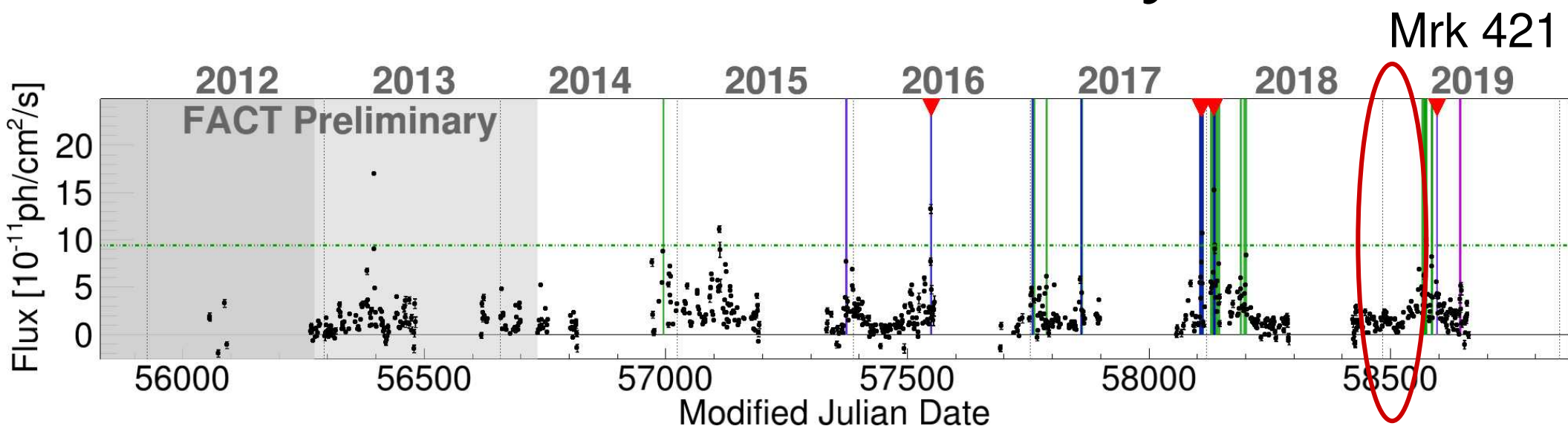
MWL campaign:
- NuStar observations
- outburst in Feb 2017

ID834

Arbet-Engels et al.
this conference

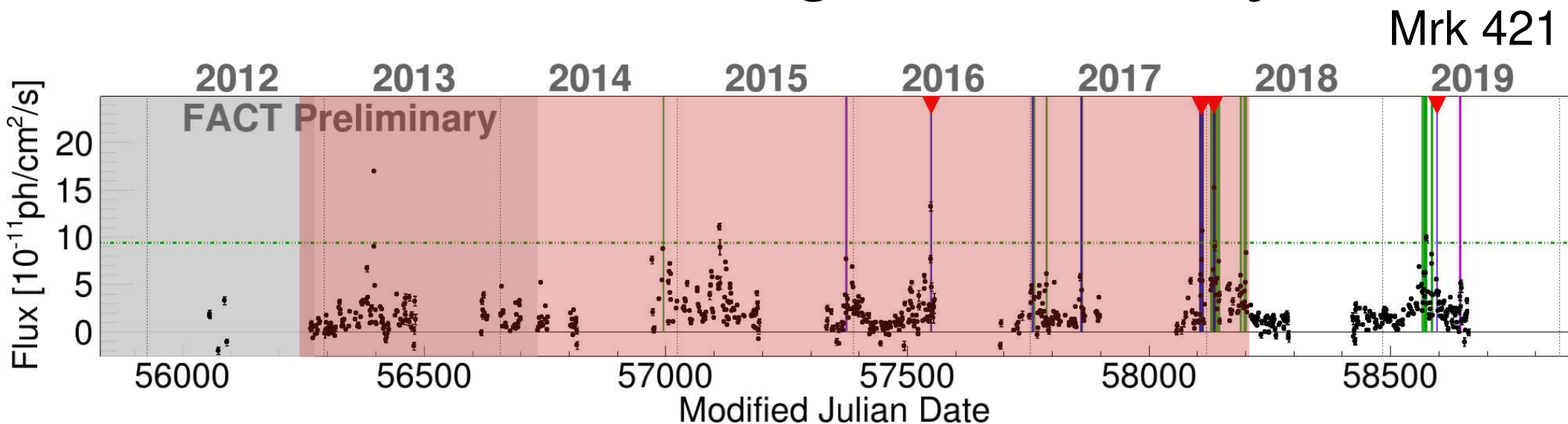
paper accepted in A&A

FACT: Results from > 8 years



Joint campaign with AstroSAT and WEBT: Jan 2019

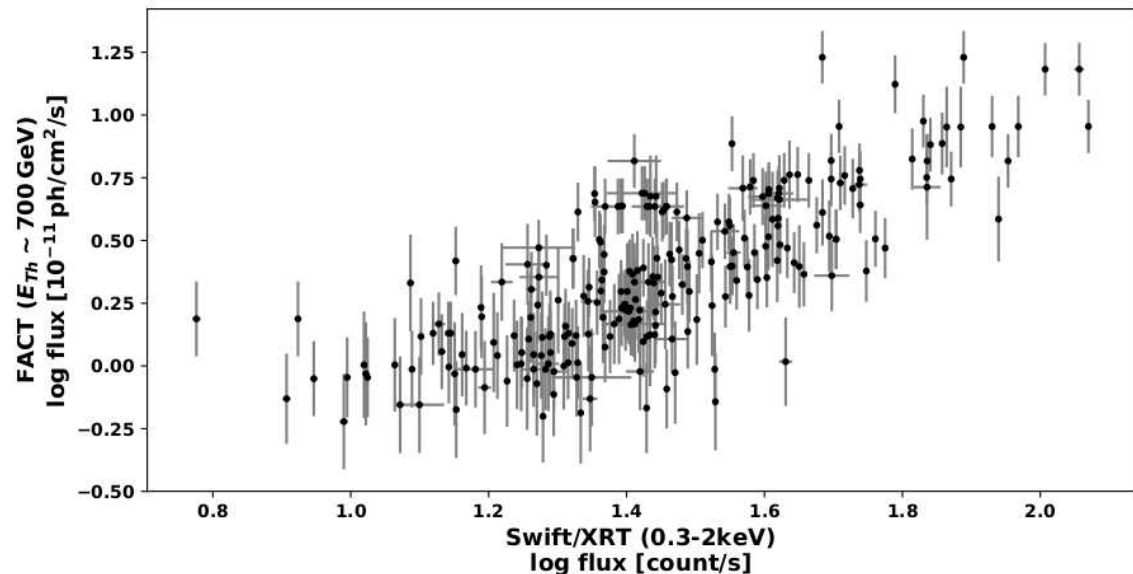
Mrk 421: Long-term Study



Data sample: 5.5 years
Dec 2012 – April 2018
*FACT, Fermi-LAT, Swift-BAT,
Swift-XRT, Swift-UVOT,
OVRO, optical*

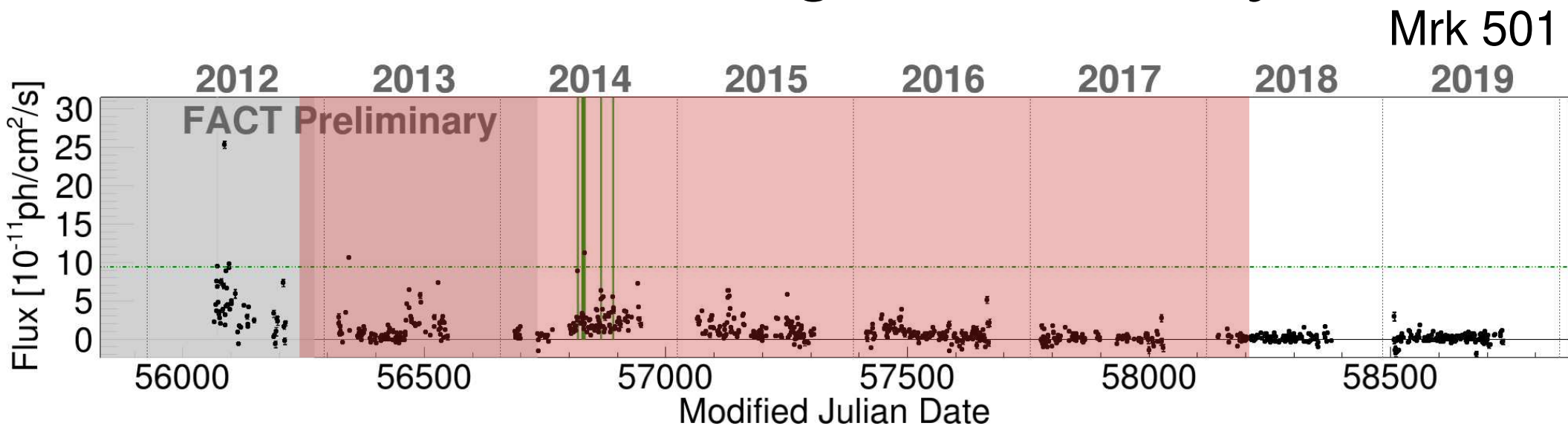
ID808

**Slusar et al.
this conference**



Arbet-Engels et al. (FACT Coll.), A&A, 647, 2021

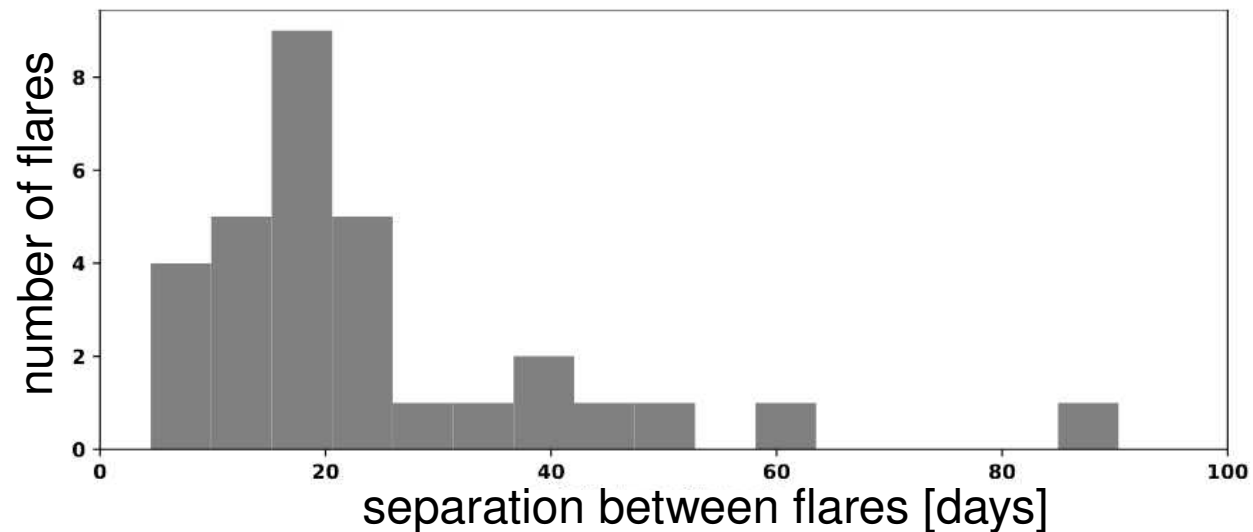
Mrk 501: Long-term Study



Data sample: 5.5 years
Dec 2012 – April 2018
*FACT, Fermi-LAT, Swift-BAT,
Swift-XRT, Swift-UVOT,
OVRO, optical*

ID808

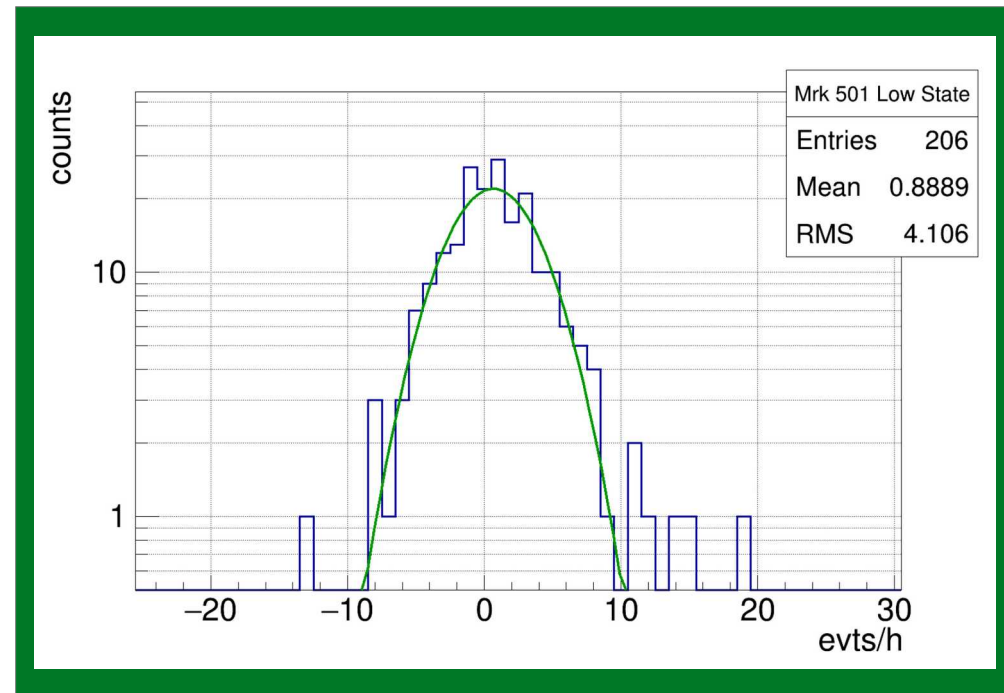
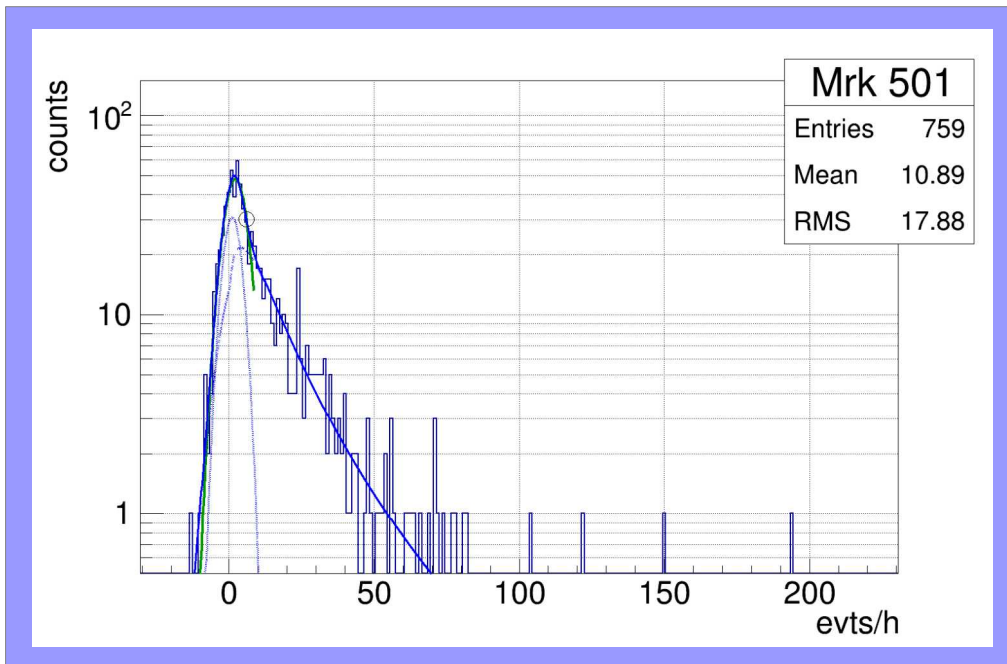
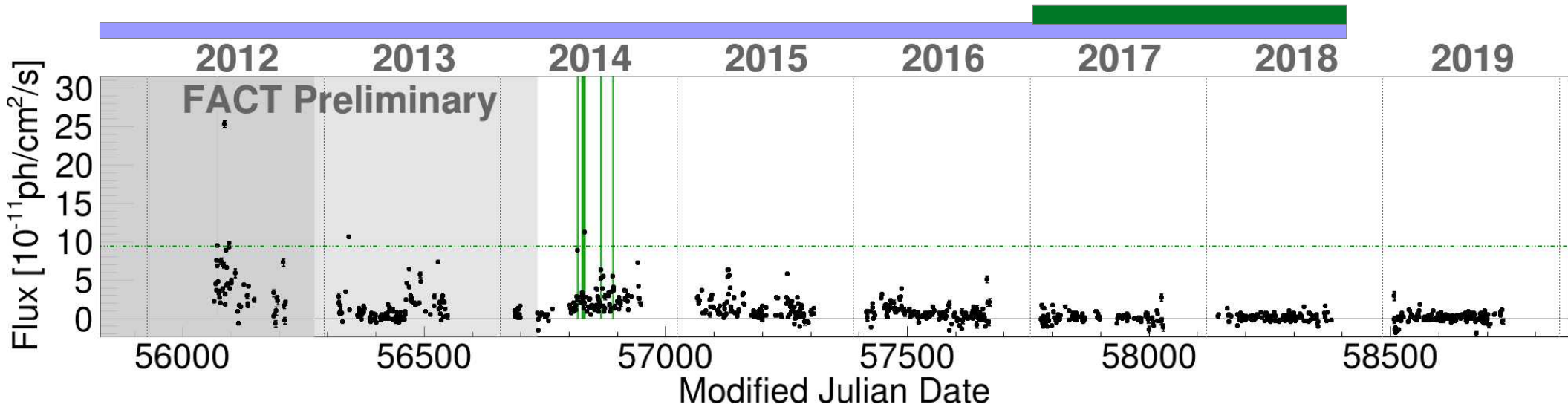
Sliusar et al.
this conference



→ compatible with Lense-Thirring
accretion disk precession

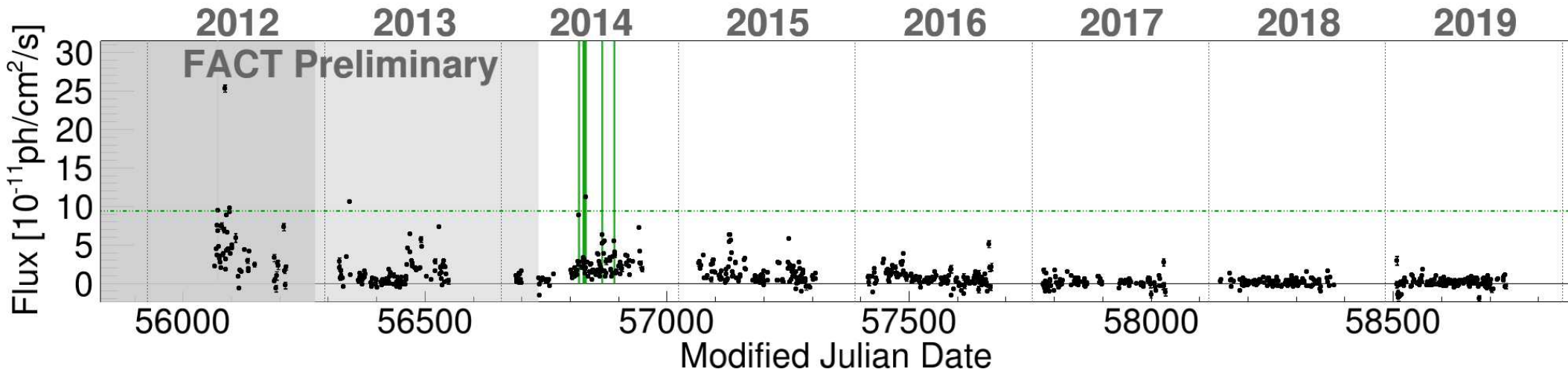
paper in preparation

Mrk 501: Historical Low State

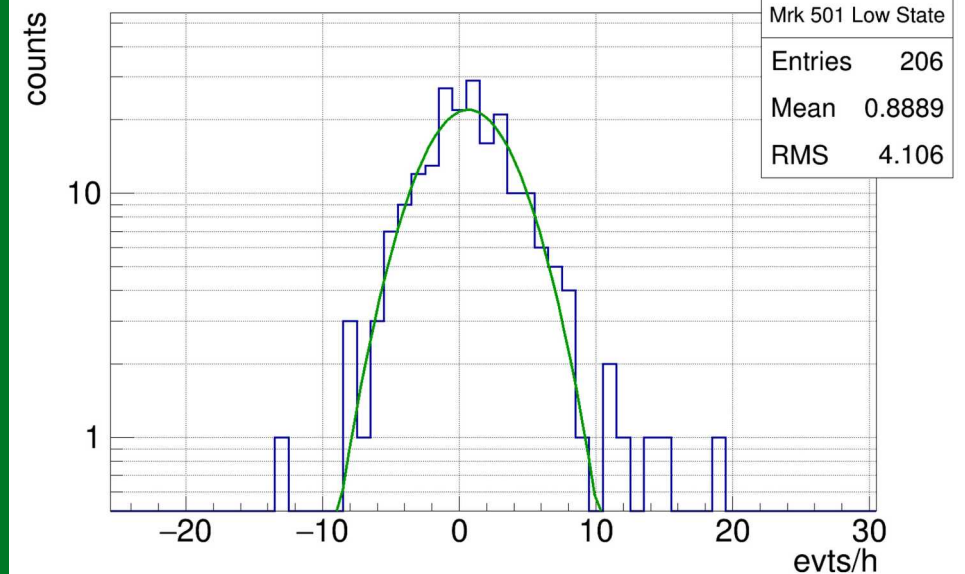


D. Dorner et al. (FACT Collaboration), Galaxies 2019, 7(2), 57

Mrk 501: Historical Low State



Steady state flux:
Upper limit:
2% of flux of the Crab
Nebula @TeV energies



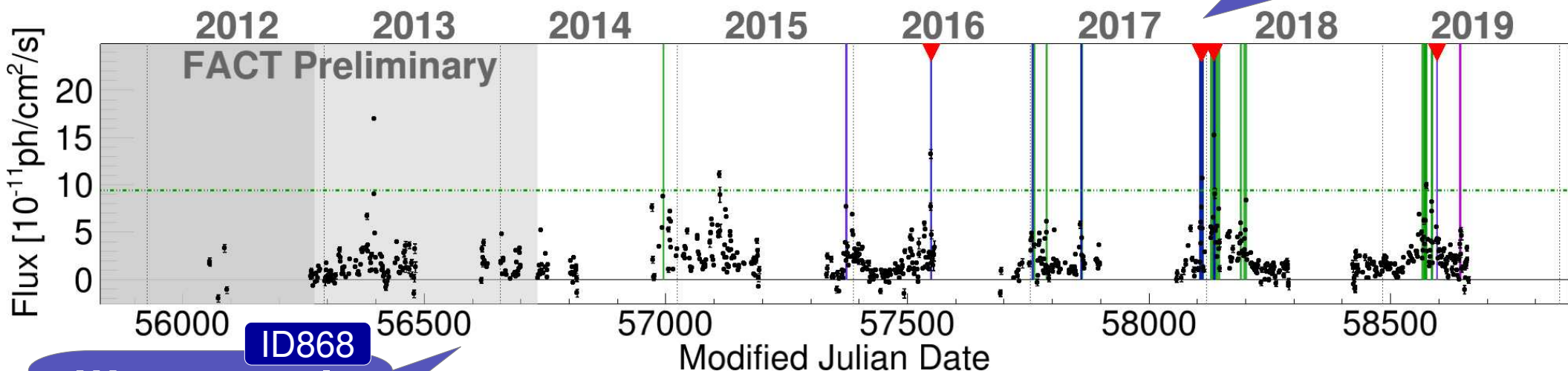
D. Dorner et al. (FACT Collaboration), Galaxies 2019, 7(2), 57

Unbiased Data Sample for Systematic Studies

ID879

Iotov et al.
this conference

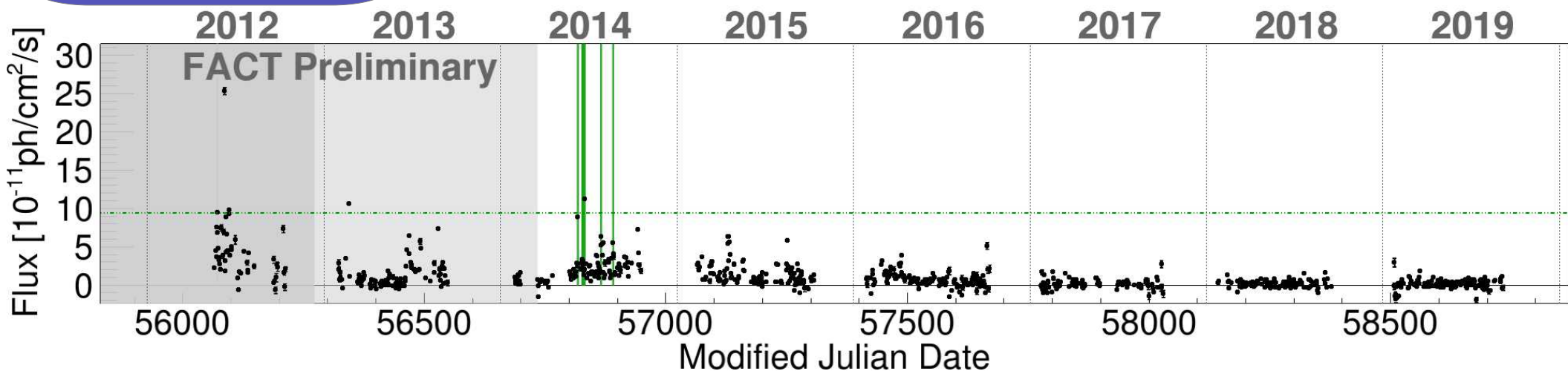
Mrk 421



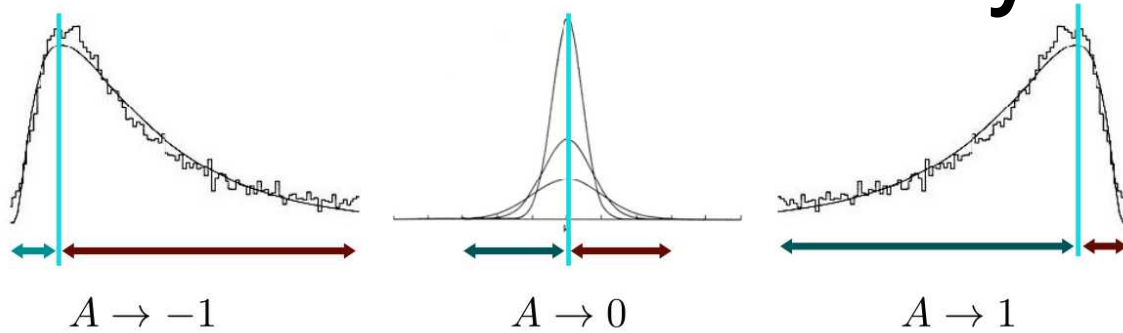
ID868

Wagner et al.
this conference

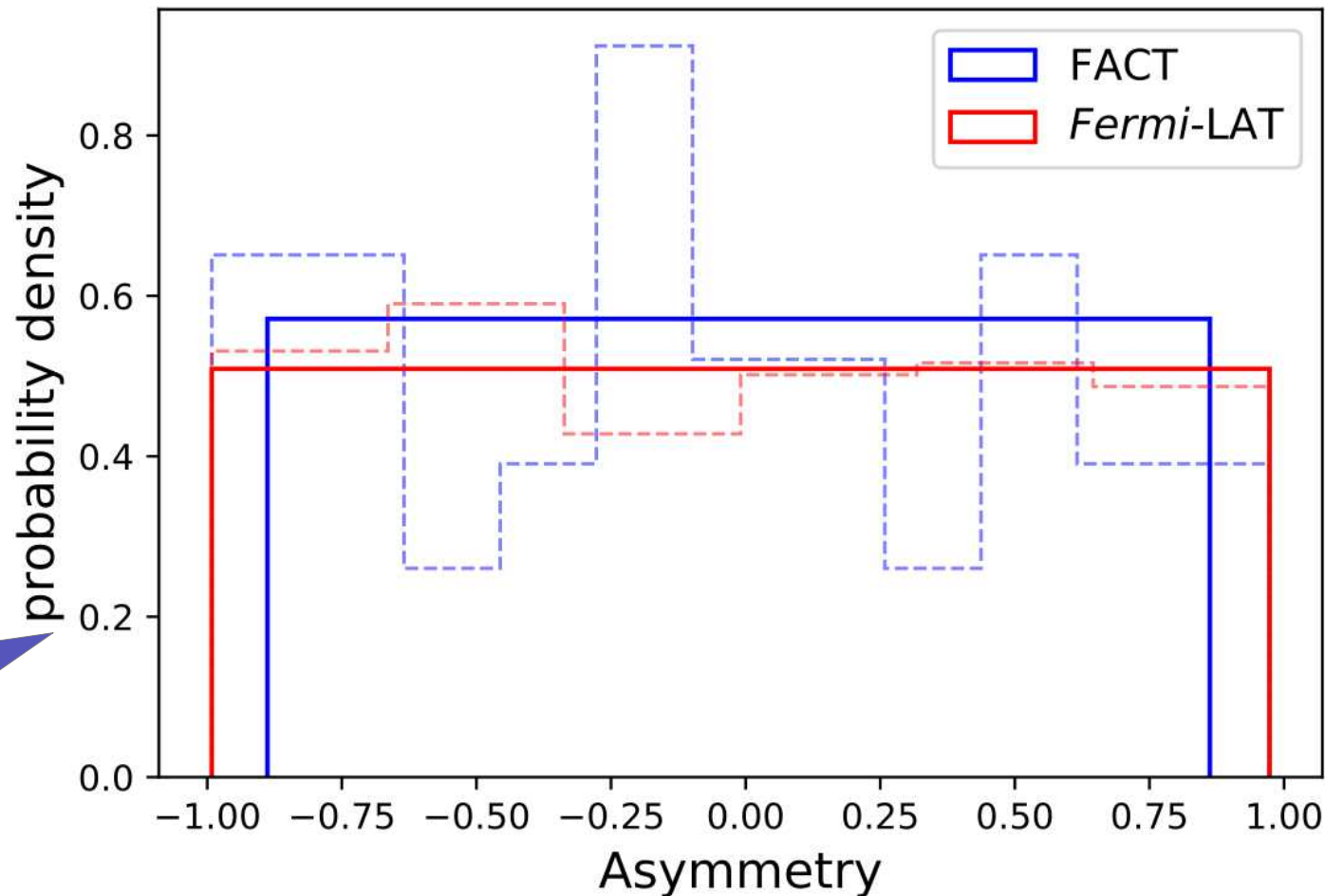
Mrk 501



Flare Asymmetry



$$A = \frac{t_{rise} - t_{decay}}{t_{rise} + t_{decay}}$$

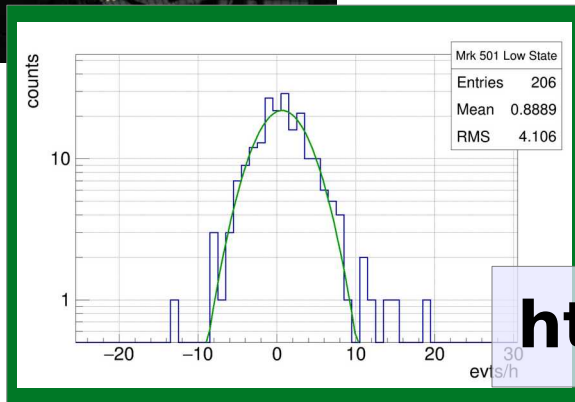
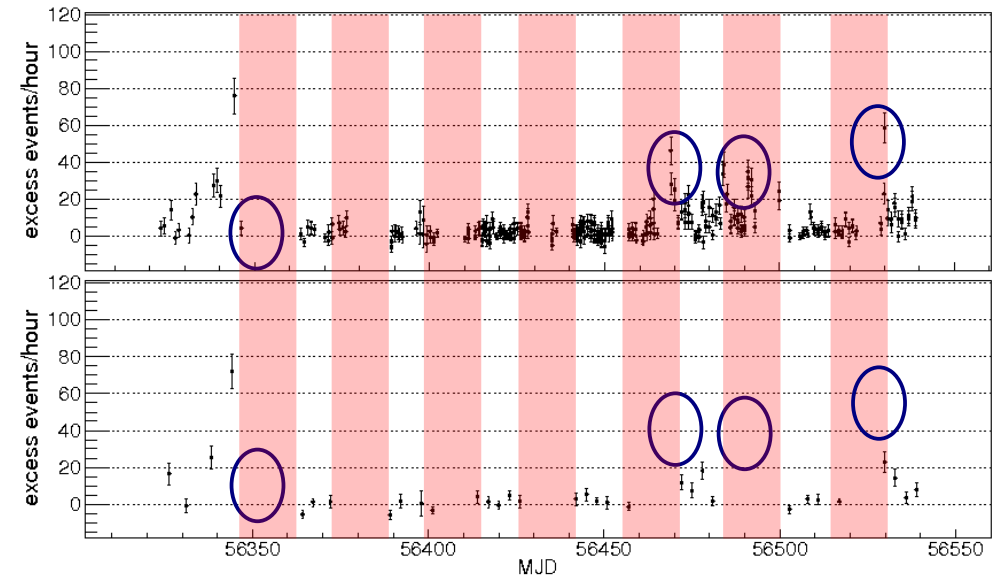
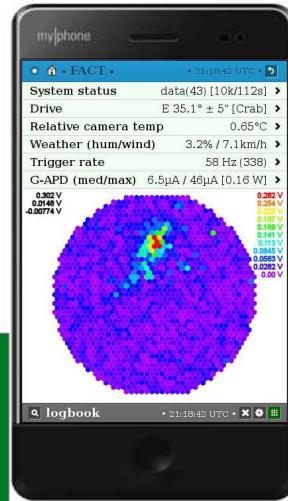
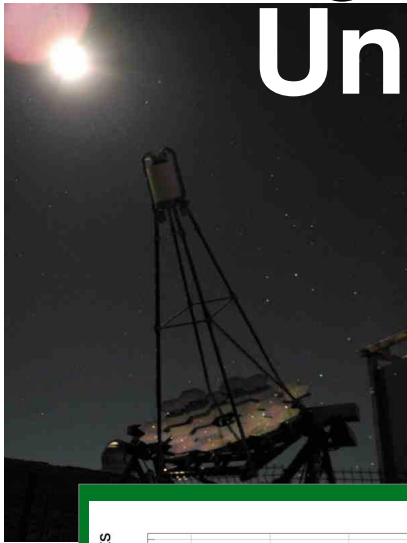


ID868

Wagner et al.
this conference

Long-term Studies @TeV Energies

Unbiased Monitoring & ToO



<http://www.fact-project.org/monitoring>

