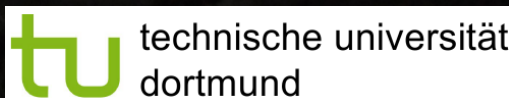


# FACT – Systematic Study of Blazar Flux States at TeV Energies



Daniela Dorner, for the FACT Collaboration





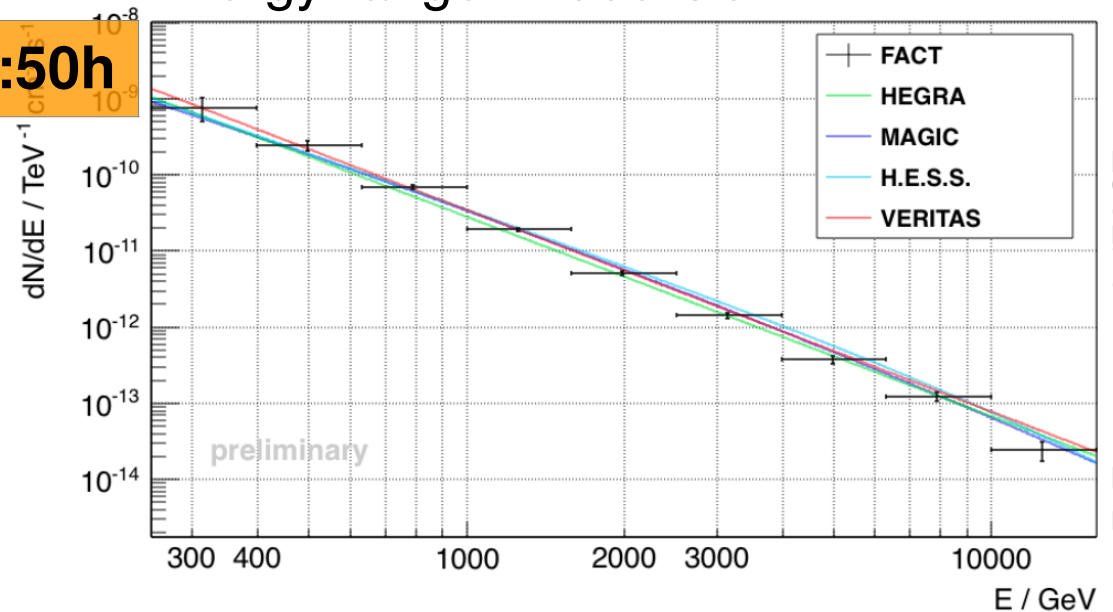
# First G-APD Cherenkov Telescope

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



Photo: Thomas Krähenbühl

- Operational since Oct 2011
- 9.5 m<sup>2</sup> mirror area
- Camera: Silicon based photosensors (SiPM), 4.5° FoV, 1440 pixels à 0.11°
- 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*



# Unbiased Long-Term Monitoring



- Using silicon-based photosensors
  - Excellent and stable performance
  - Observations during bright ambient light
- Robotic operation
  - Maximized data taking efficiency
- **Maximizing duty cycle** of FACT
- **Minimizing gaps** in light curves
- Observing strategy: **Unbiased long-term monitoring** of small source sample [mostly blazars]

> 90%

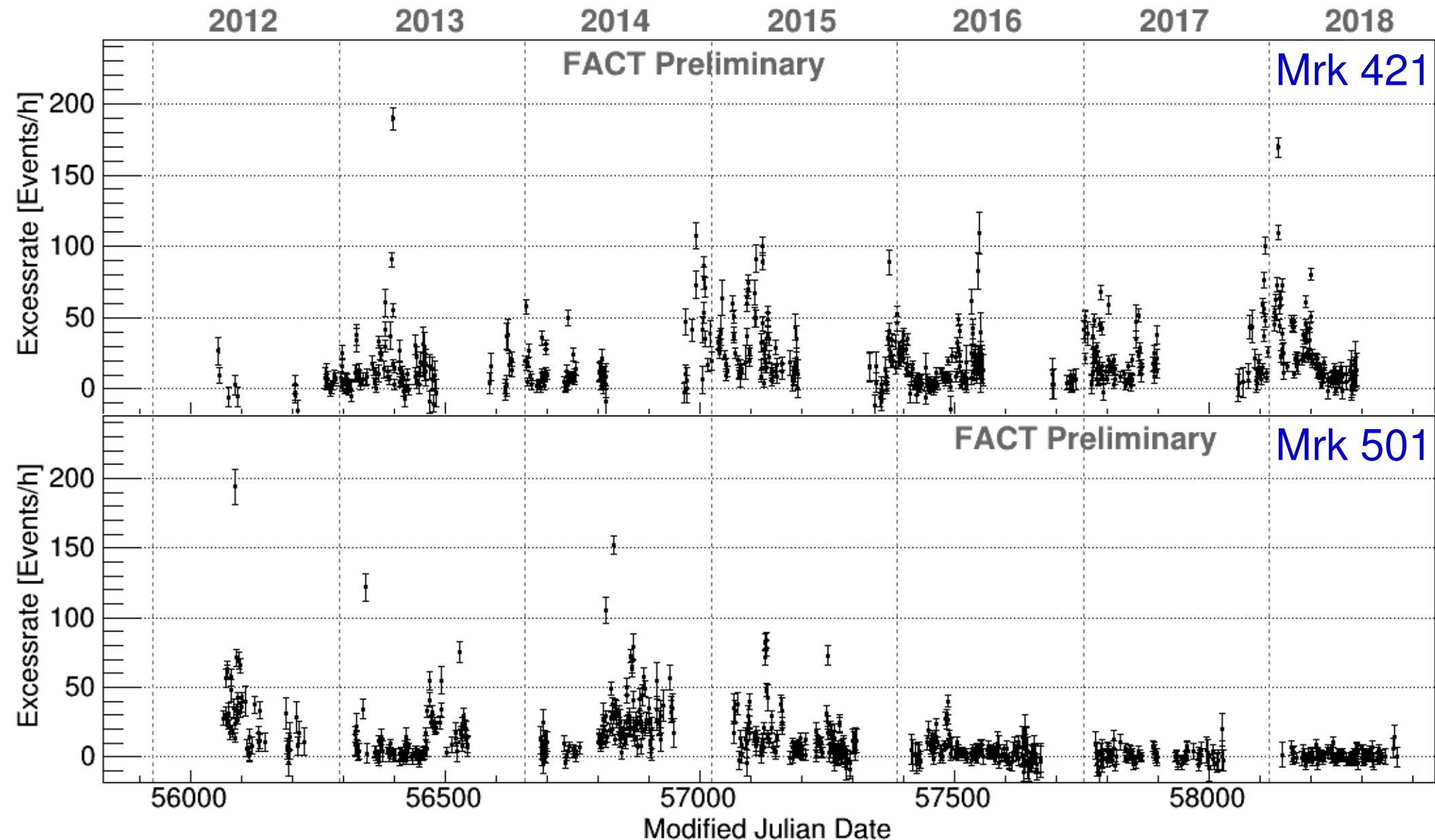
importance of unbiased monitoring: see Tue 10:10h

> 11'700 hours of physics data

Photo: Daniela Dorner



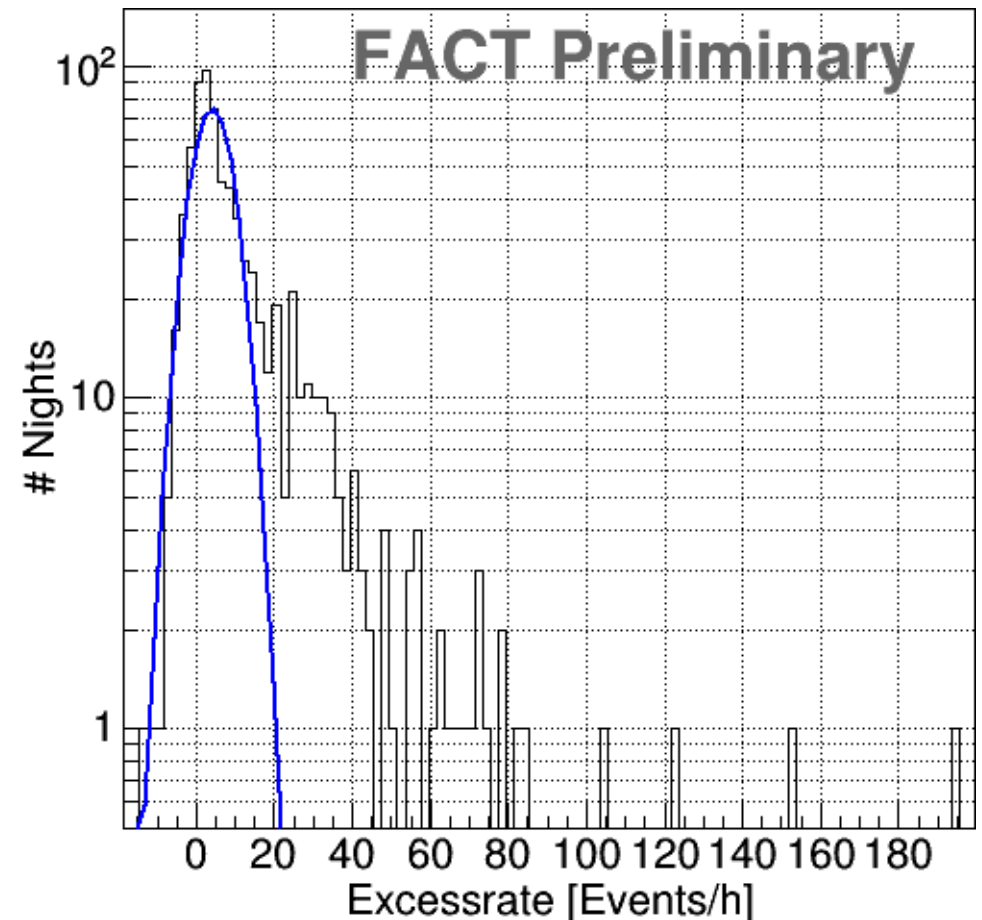
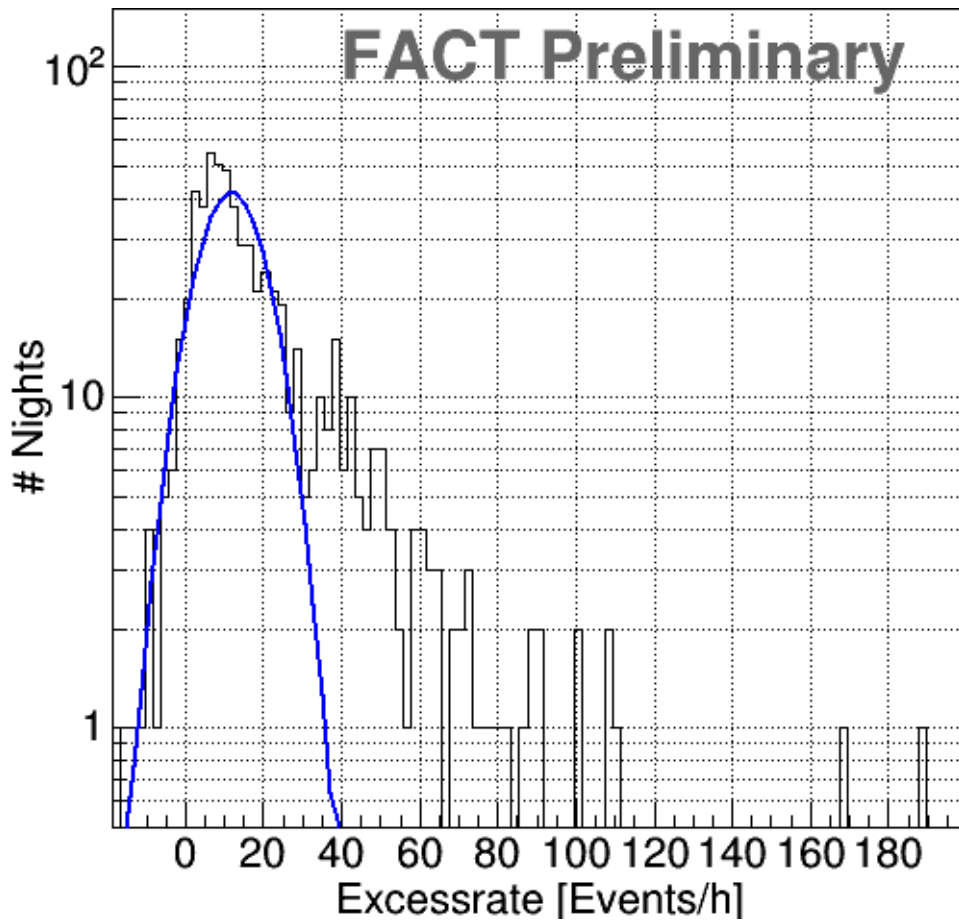
# Unbiased Long-Term Monitoring



# Flux Distributions

Mrk 421

Mrk 501



Nightly Binning

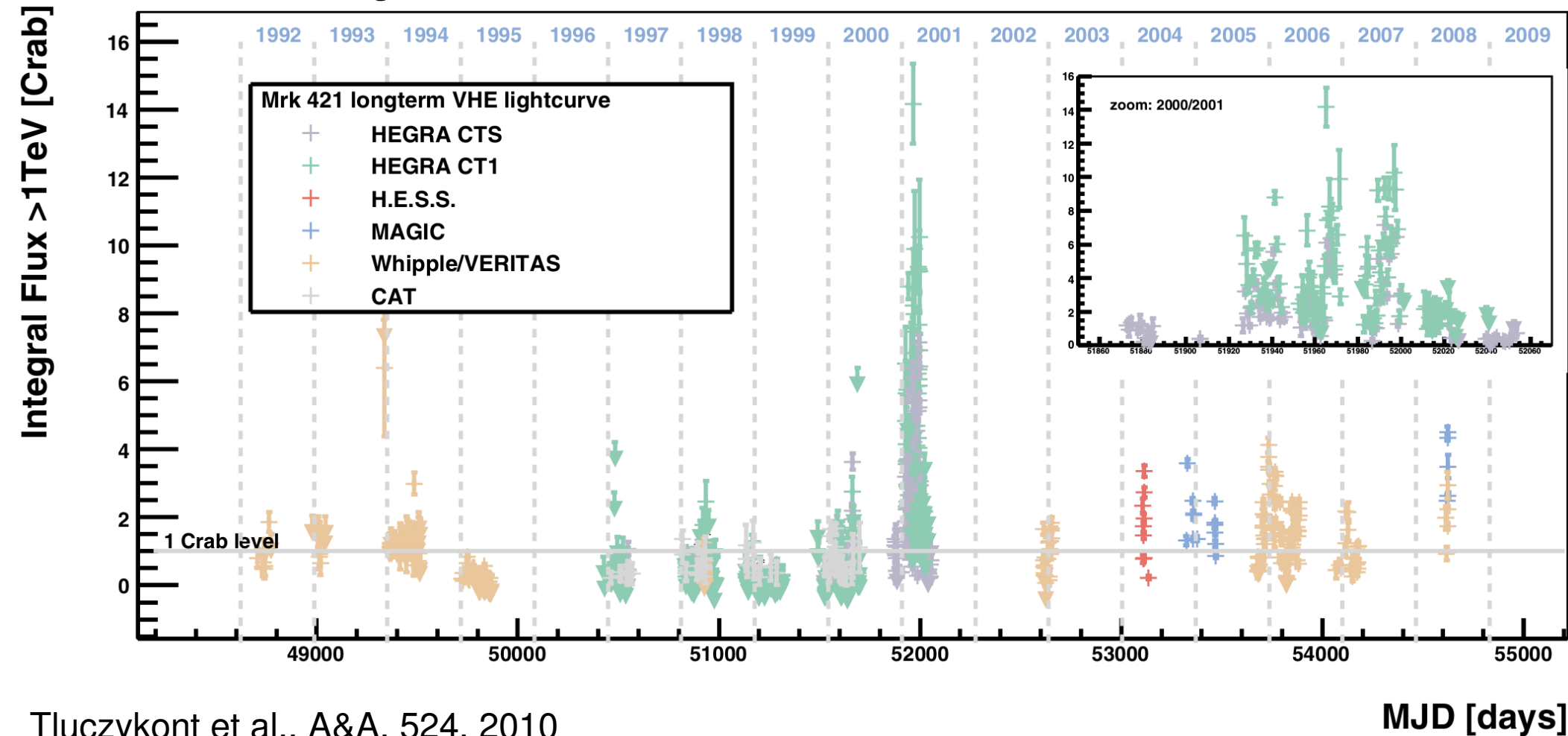
# What to learn from flux distributions?

- Evolution of flux states in blazars
- Is there a steady state of the source?
  - When is the source active?
  - What is the duty cycle of a blazar?



# What to learn from flux distributions?

## Historical light curve of Mrk 421

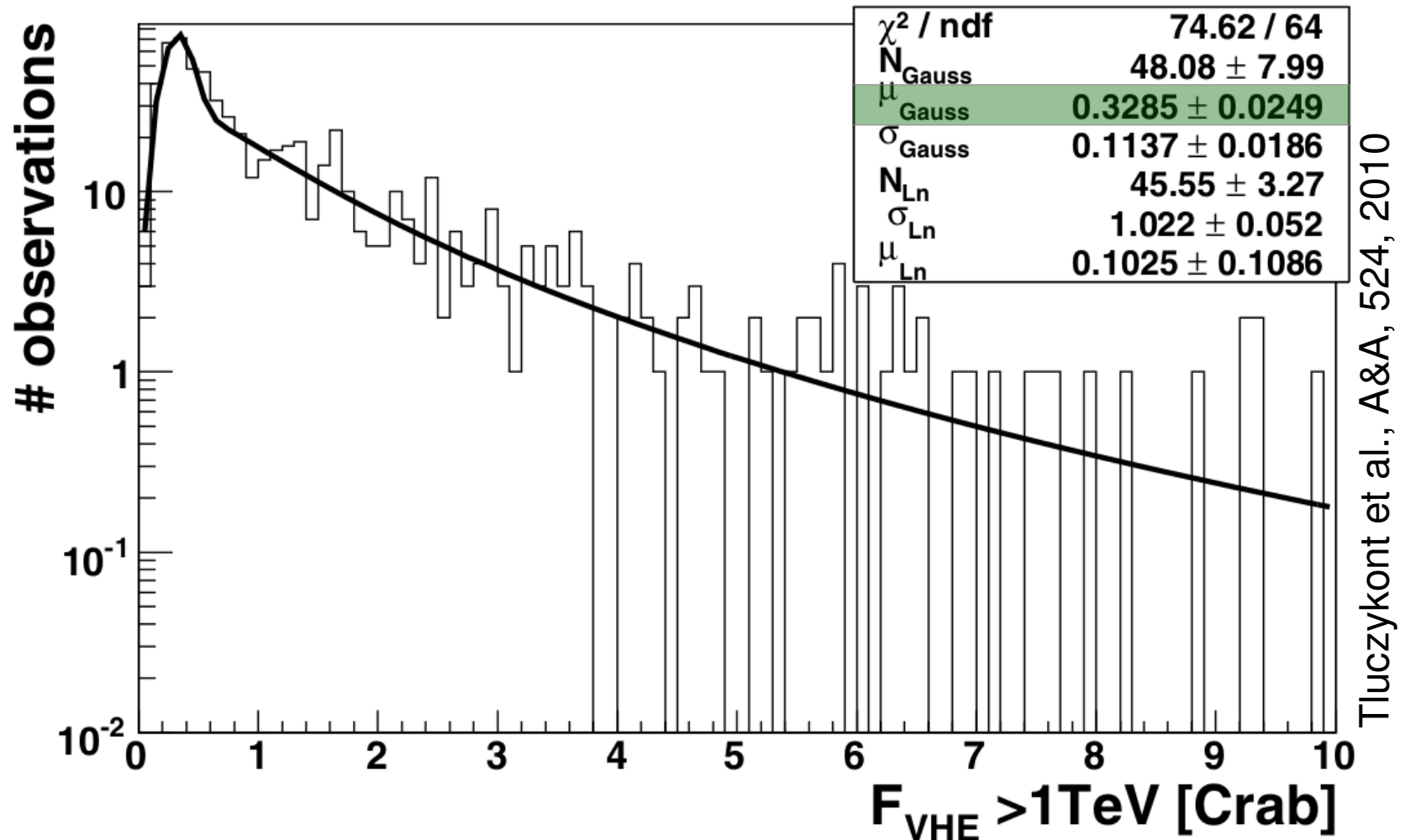


Gluczykont et al., A&A, 524, 2010

MJD [days]



# Upper Limit on Integral Baseline Flux



Upper limit on integral baseline flux: 0.33 CU



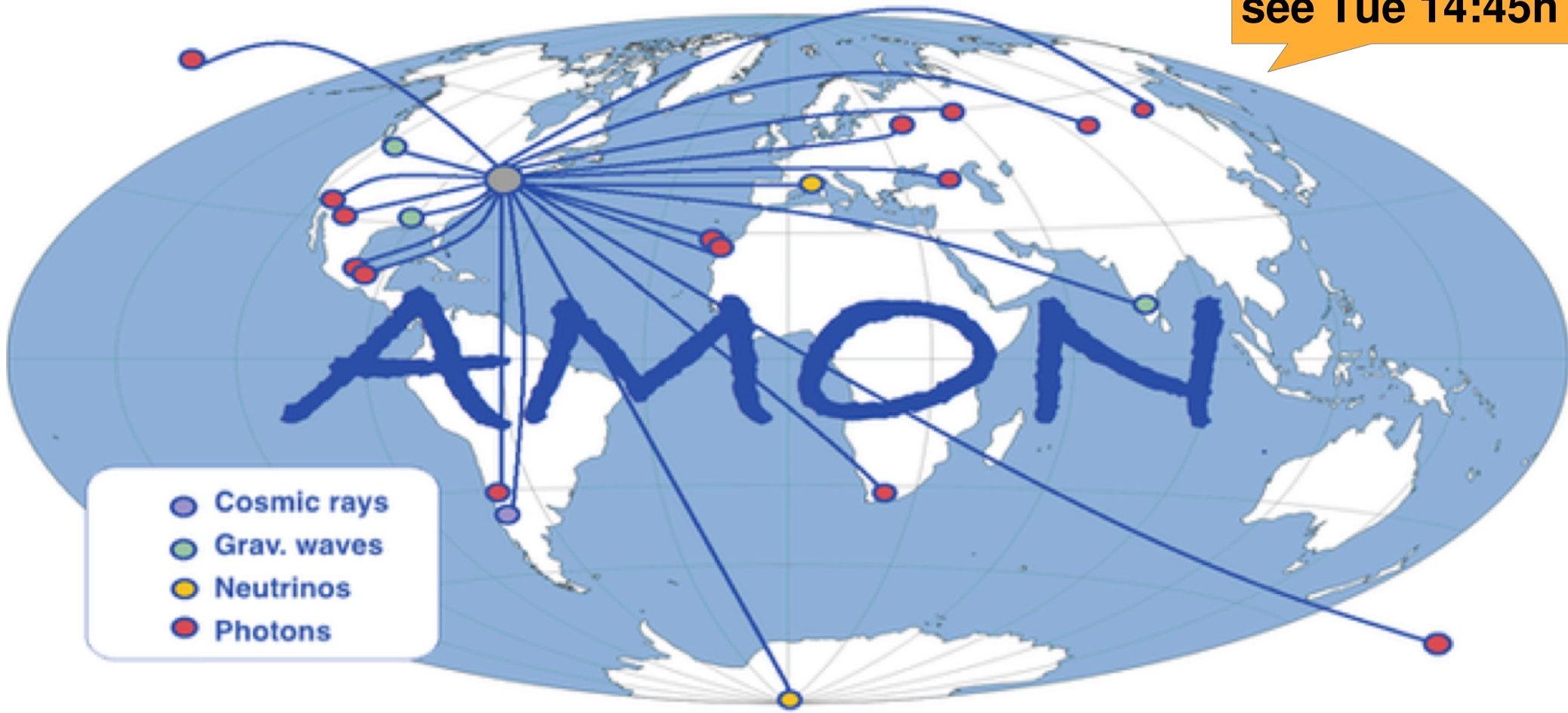
# What to learn from flux distributions?

- Evolution of flux states in blazars
- Is there a steady state of the source?
  - When is the source active?
  - What is the duty cycle of a blazar?
- Multi-wavelength and multi-messenger studies
  - When to alert other instruments?



# Astrophysical Multi-Messenger Observatory Network

see Tue 14:45h

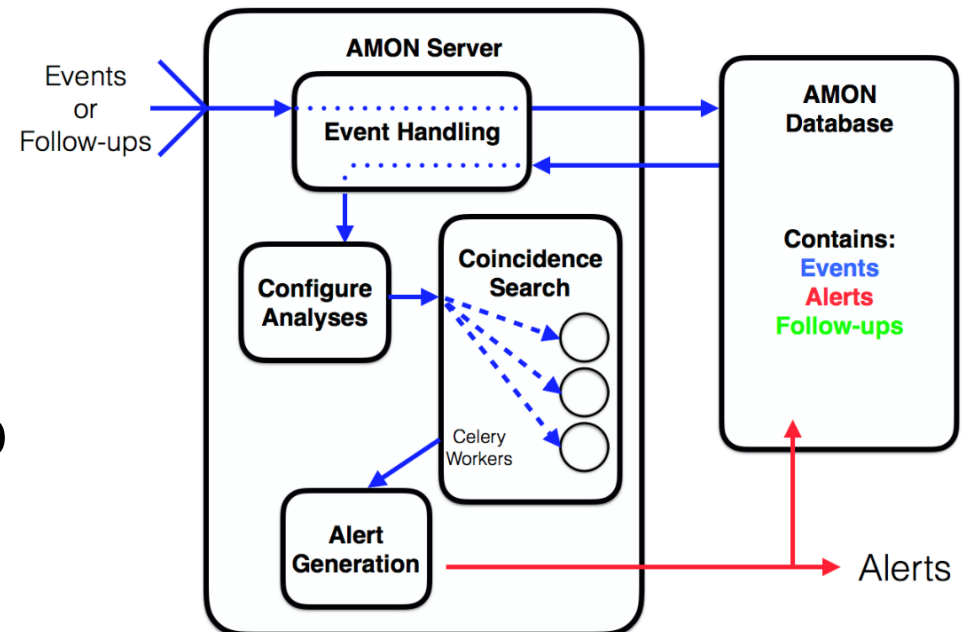
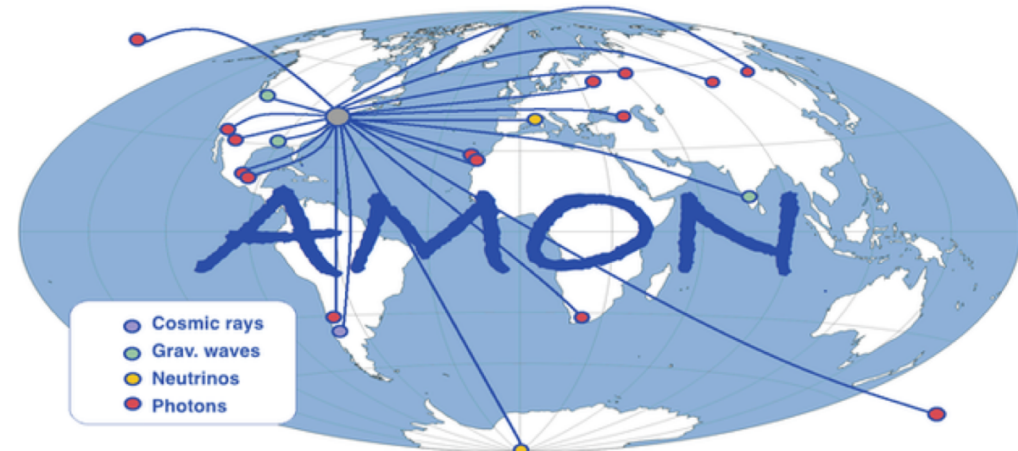


AMON links high-energy astrophysical observatories into a single virtual system



# AMON – Connecting Observatories

- Searches for coincident signals
  - Archival
  - Real-time
- Real-time sharing of **sub-threshold data** between multi-messenger observatories
- Prompt **distribution of electronic alerts** to follow-up observations



# FACT Contribution in AMON



Photo: Daniela Dorner

- Archival analysis:  
Long-term light curves ideal to study multi-messenger correlation [e.g. Kintscher et al. PoS(ICRC2017) 969]
- Realtime alerts:
  - Provide
    - gamma-ray alerts
    - sub-threshold data
  - Follow up alerts
    - other messengers e.g. neutrino
    - multi-messenger coincidence





# Realtime-Alerts from FACT

- Alerts based on automatic quick-look analysis

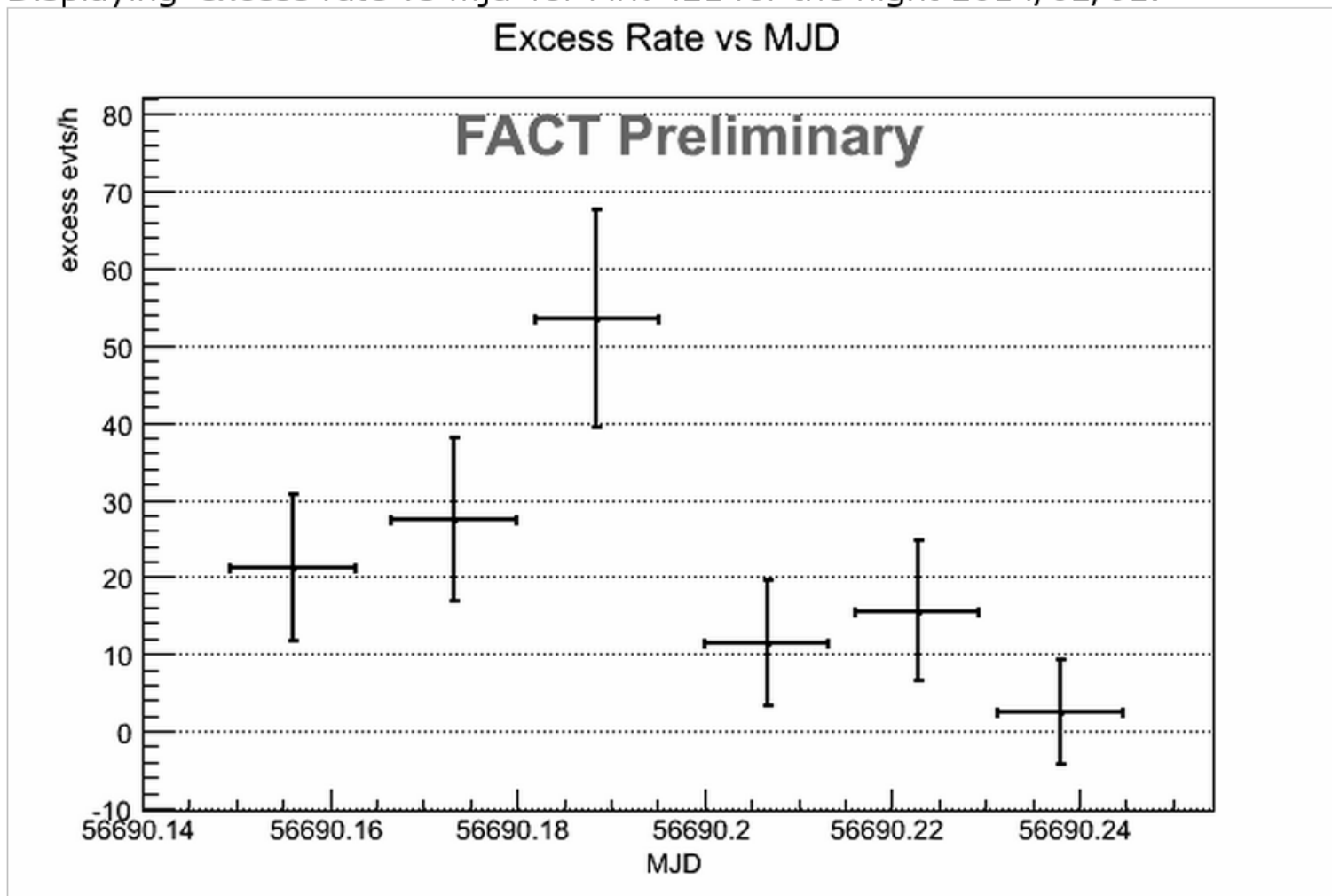


# FACT Quick Look Analysis

Select date    source

Select time binning  and range

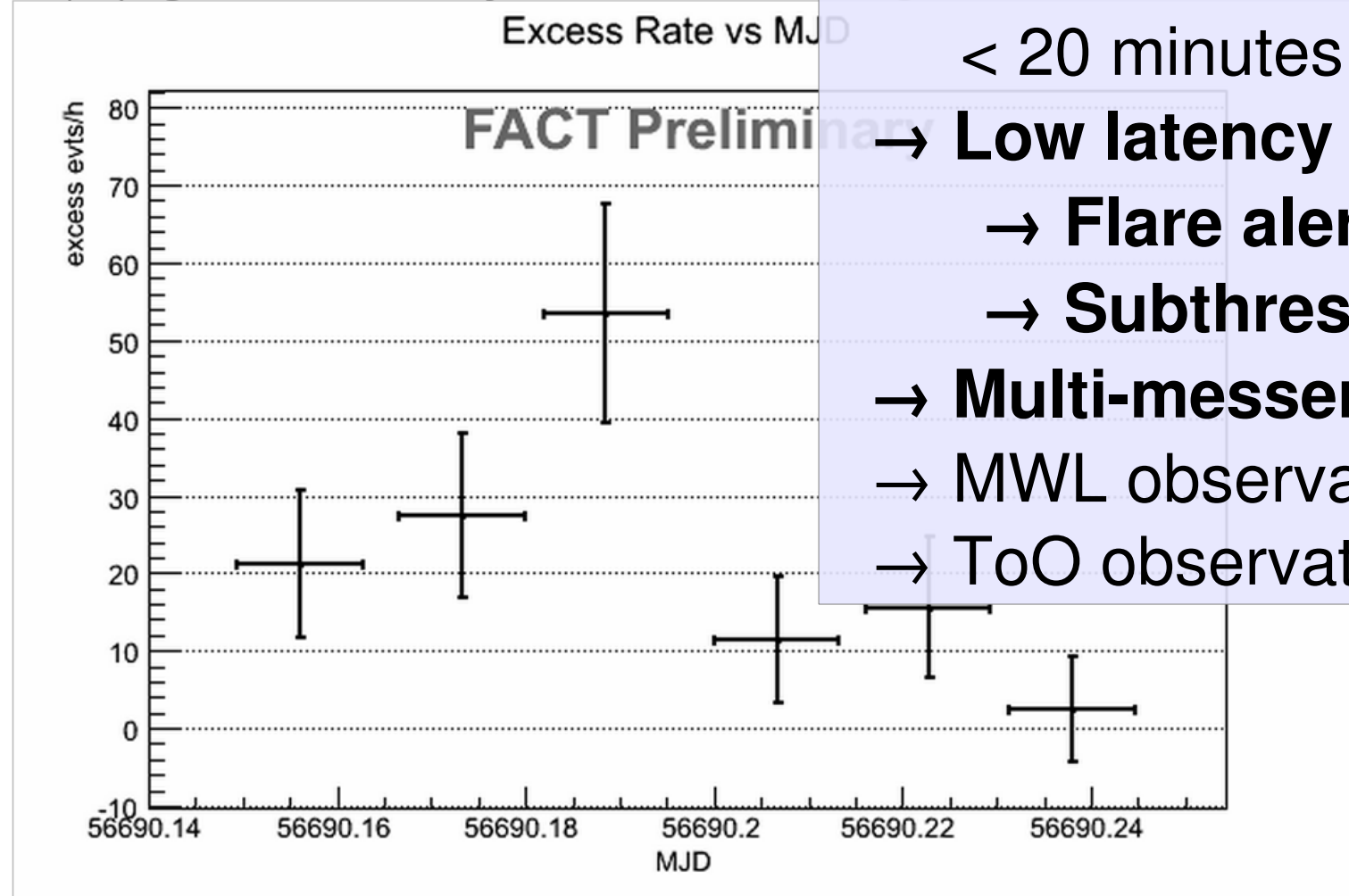
Displaying 'excess rate vs mjd' for Mrk 421 for the night 2014/02/01.



## FACT Quick Look Analysis

Select date    source   
Select time binning  and range

Displaying 'excess rate vs mjd' for Mrk 421 for the night



**Results publicly available**

**Fast processing**

→ Excess rates within  
< 20 minutes

→ **Low latency**

→ **Flare alerts**

→ **Subthreshold data**

→ **Multi-messenger correlation**

→ MWL observations

→ ToO observations

# Realtime-Alerts from FACT

- Alerts based on automatic quick-look analysis
- Since March 2014:
  - **88 alerts** (to gamma-ray community)
  - **9 Astronomer's telegrams**
  - **2 GCN circulars** (as follow-up of AMON alerts)





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- Trigger thresholds for alerts to the gamma-ray community:
  - Mrk 421, Mrk 521: 3 Crab Units
  - other blazars: 0.5 Crab Units

Since March 2017  
alerts automatically  
sent to AMON



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Criteria for  
sub-threshold  
trigger to AMON?



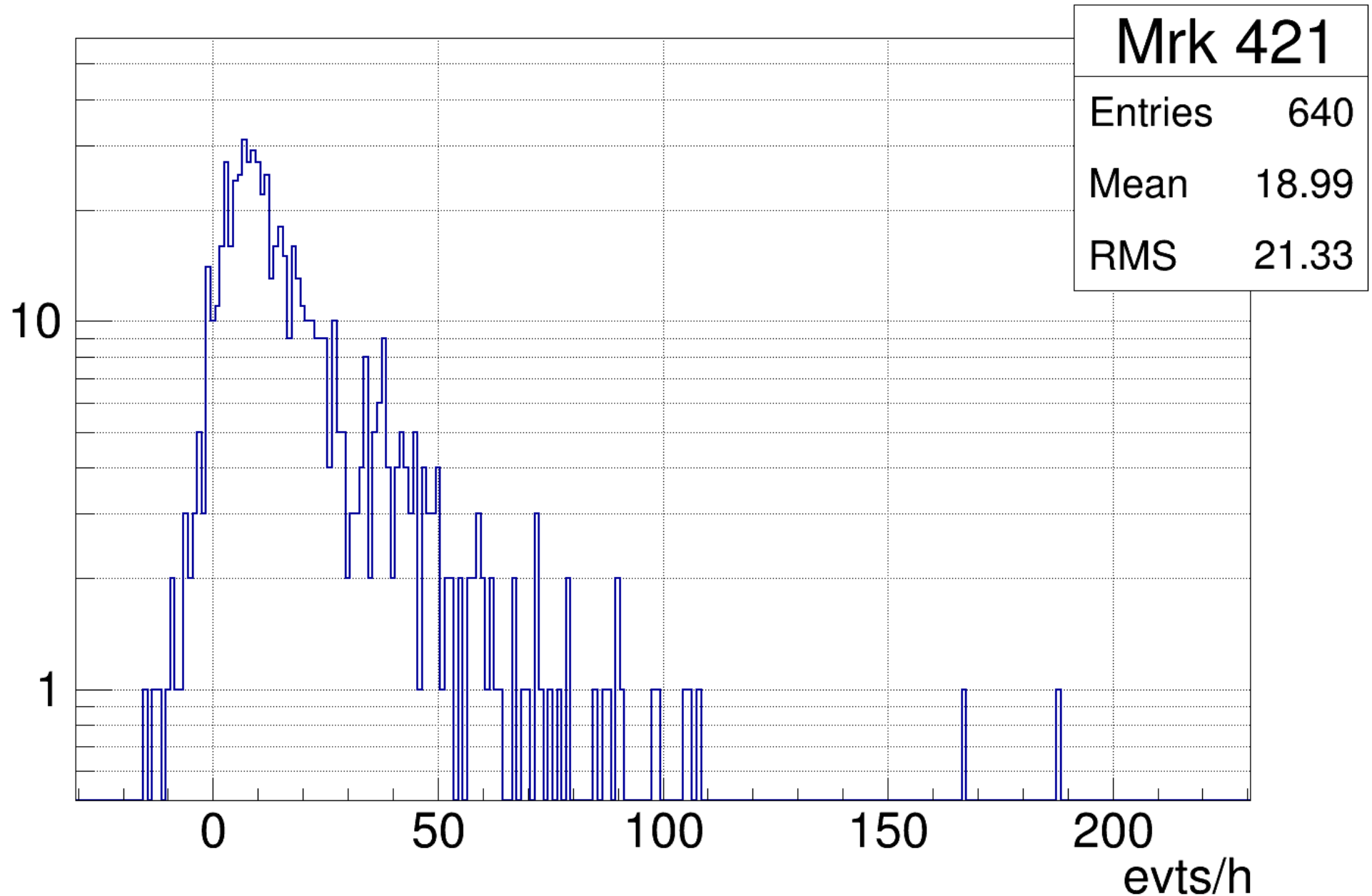
# Trigger Criteria and Limits

- When is the source active?



# Flux Distributions Revisted

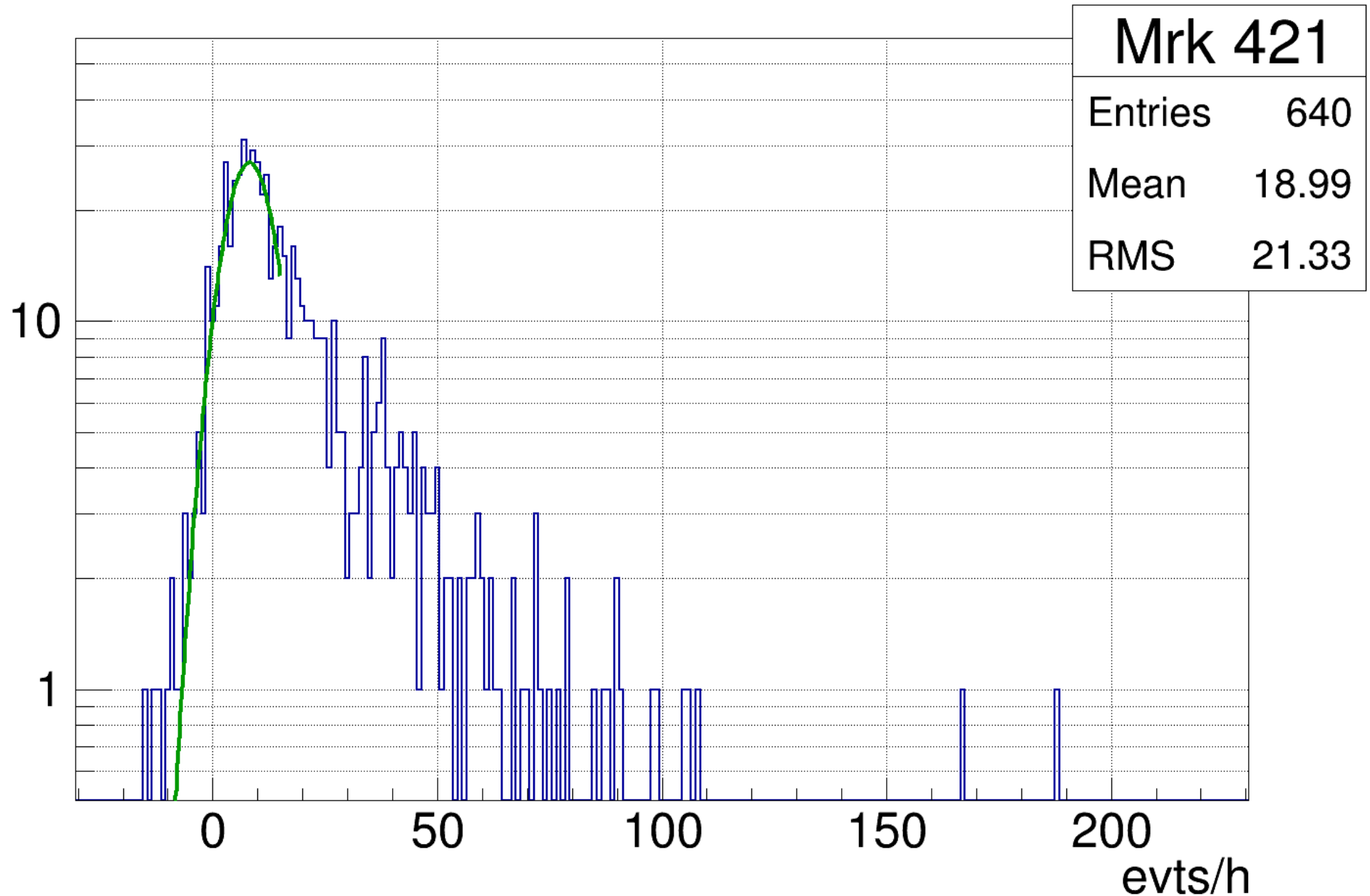
counts





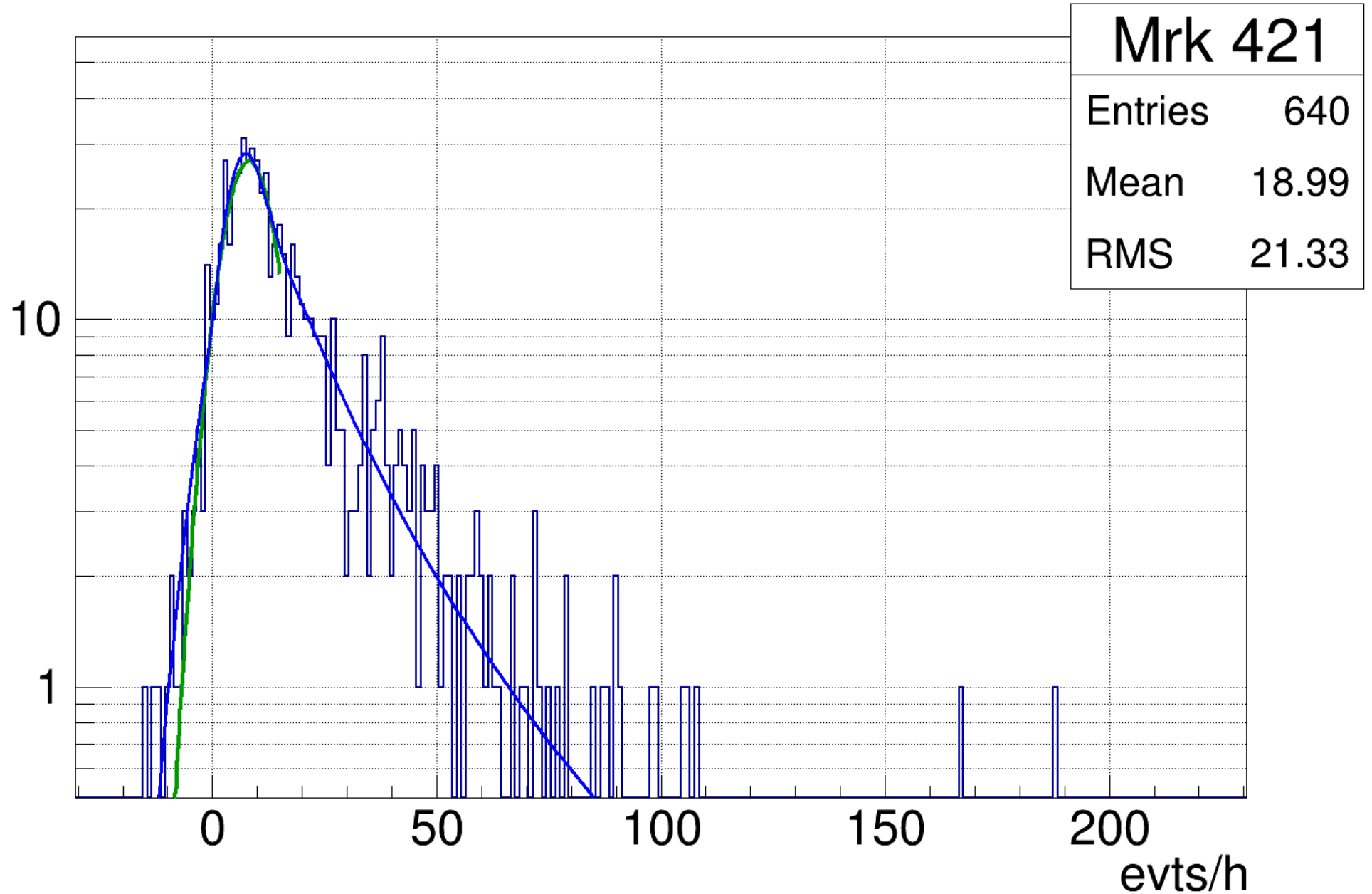
# Flux Distributions Revisted

counts



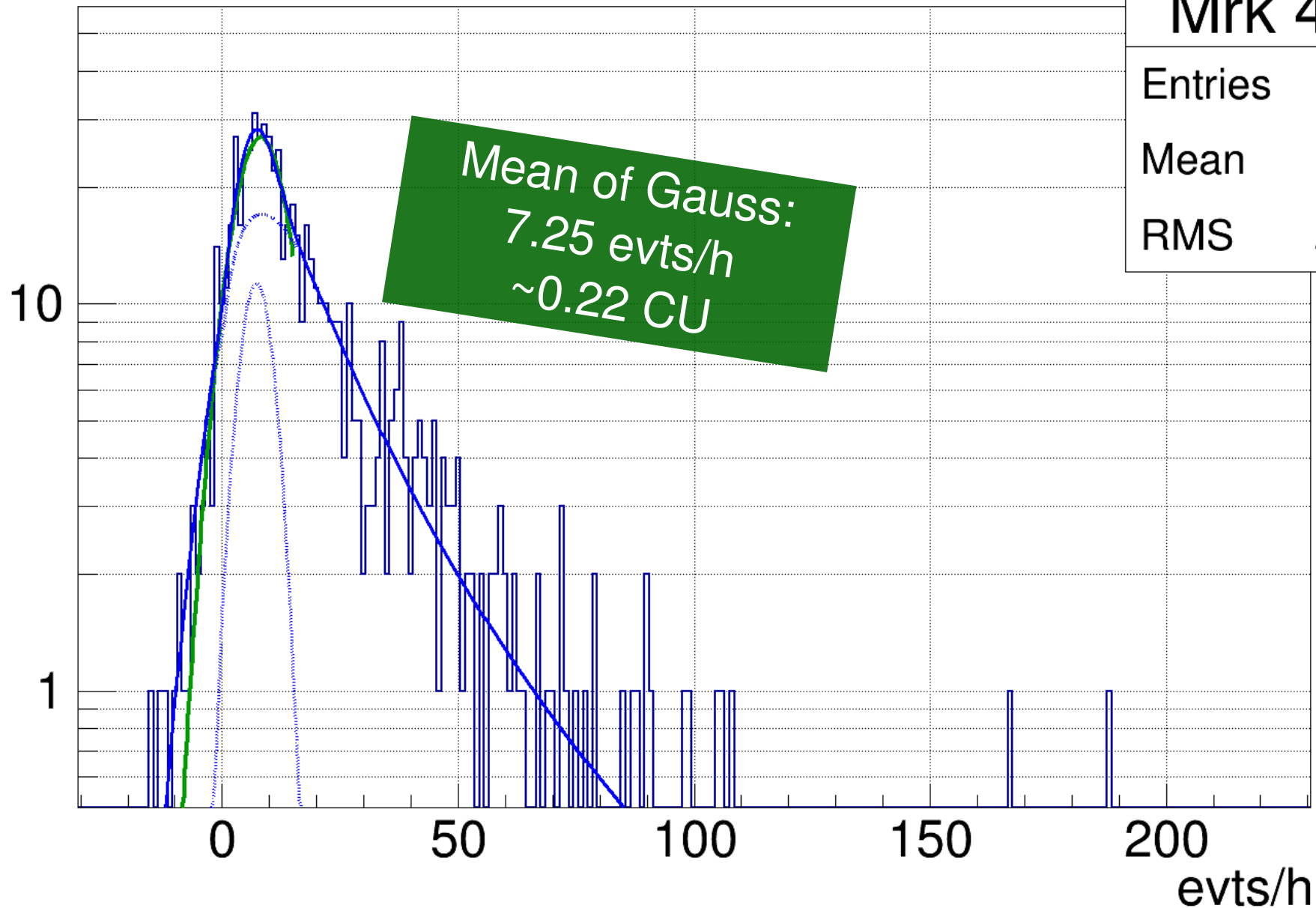
# Flux Distributions Revisted

counts



# Flux Distributions Revisted

counts



Mrk 421

Entries 640

Mean 18.99

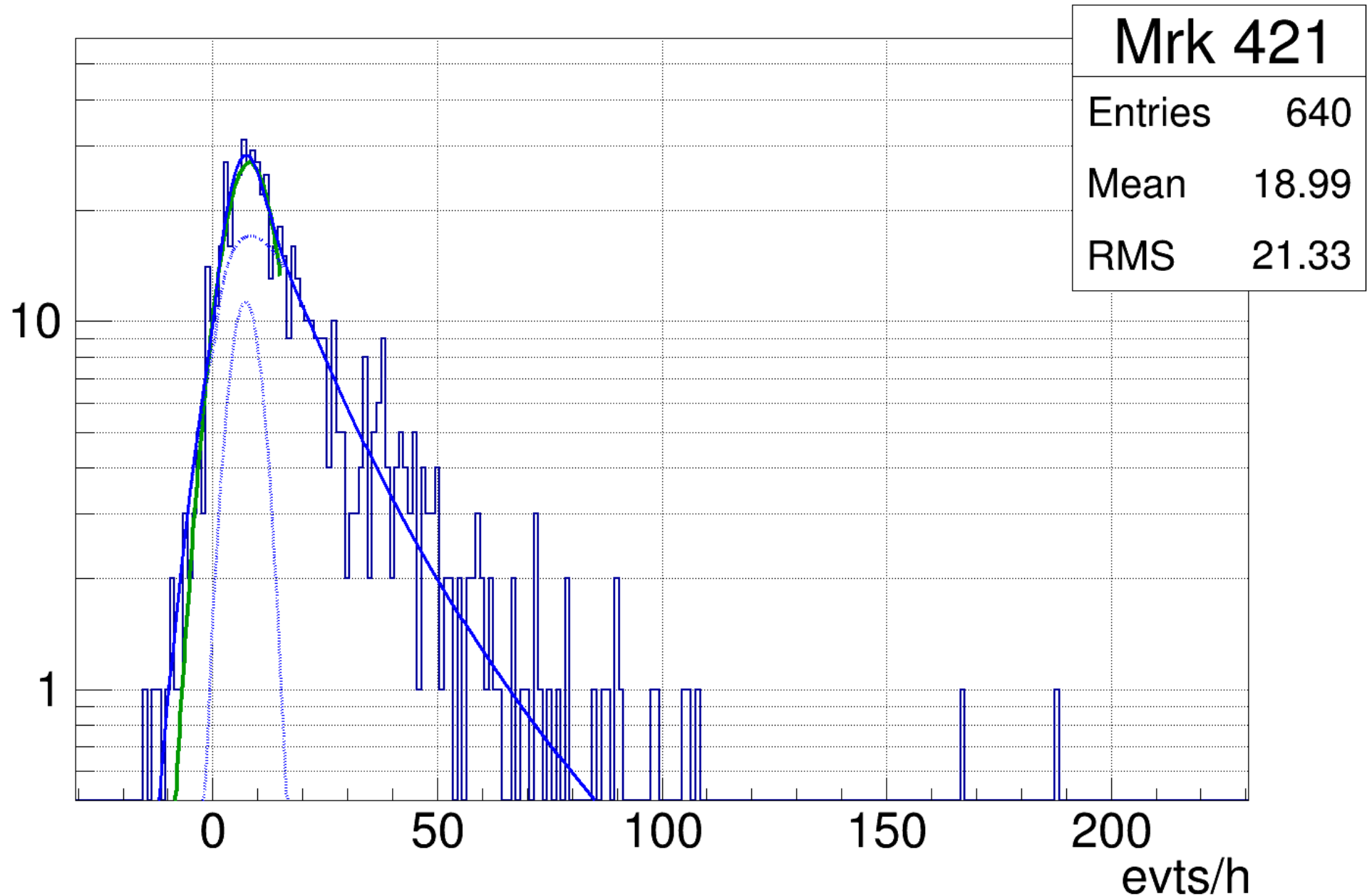
RMS 21.33

Mean of Gauss:  
7.25 evts/h  
~0.22 CU



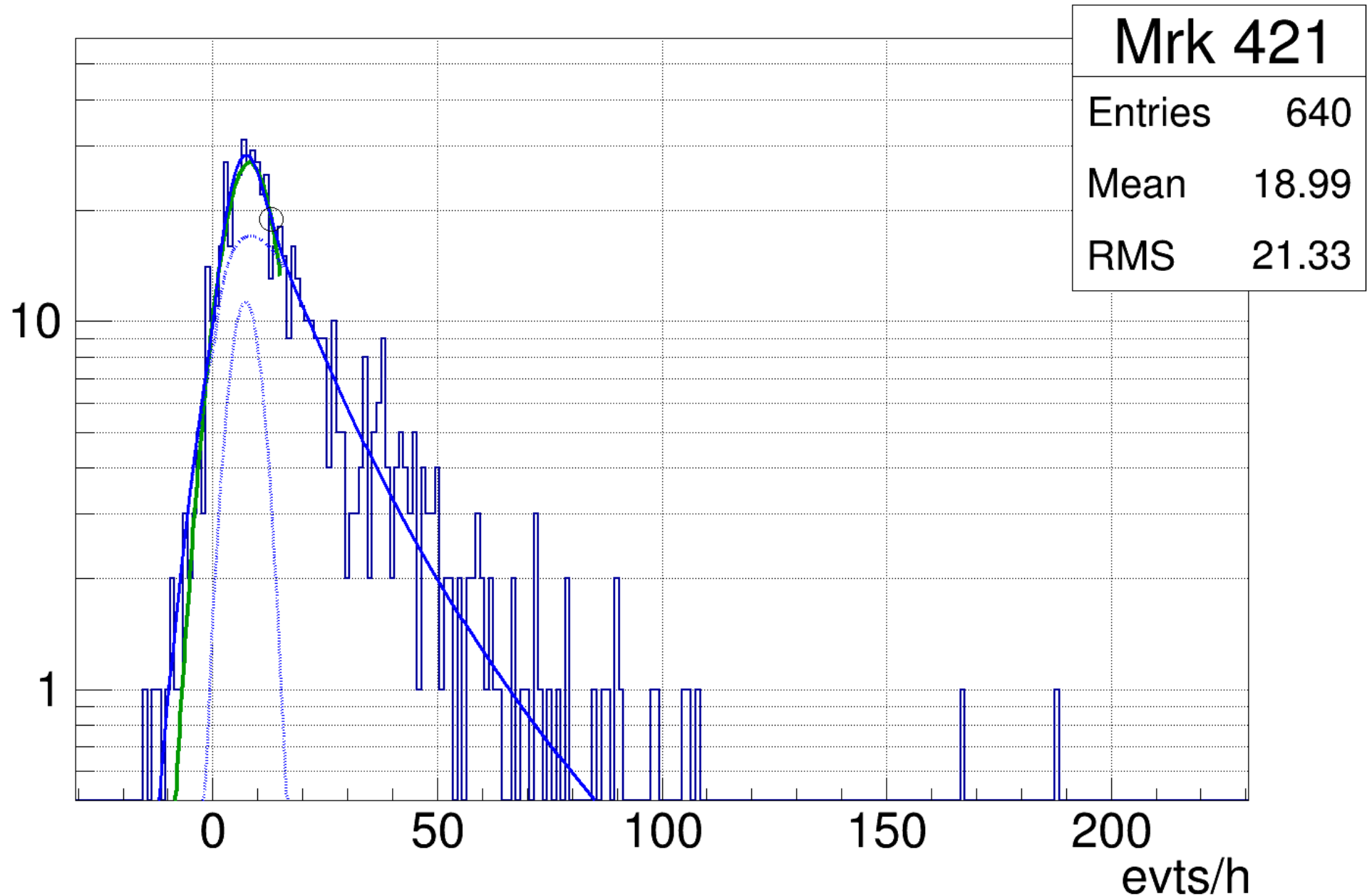
# Flux Distributions Revisted

counts



# Flux Distributions Revisted

counts



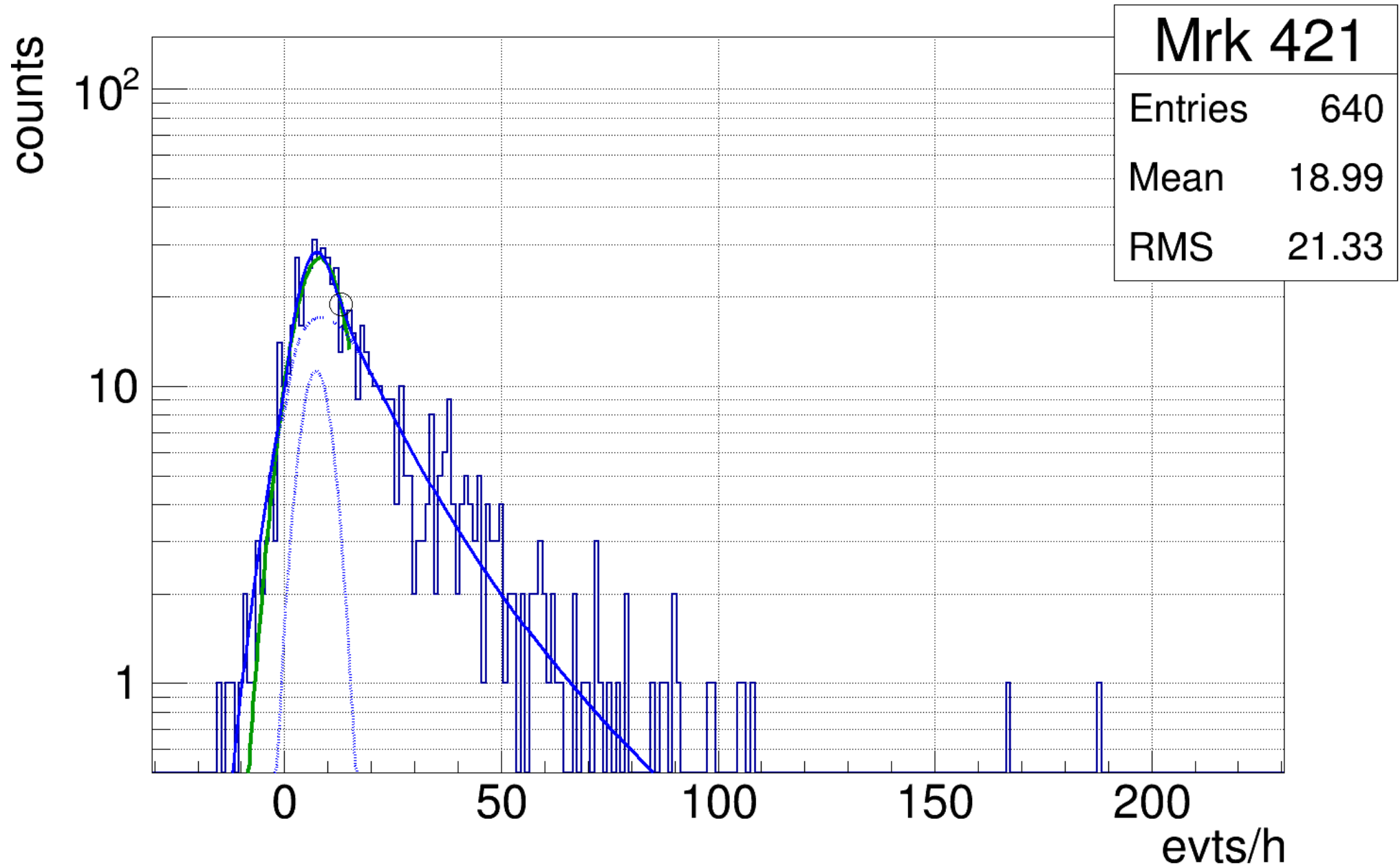
# Trigger Criteria and Limits

- When is the source active?
- Assuming a steady state of the source  
→ Fit a gaussian distribution
- Other flux states: Log-Normal Distribution
- Define Trigger Limit as point where flux distribution deviates from gaussian distribution
- Is that realistic?  
Does it trigger the cases of interest for AMON?
- Other approaches are being tested and discussed

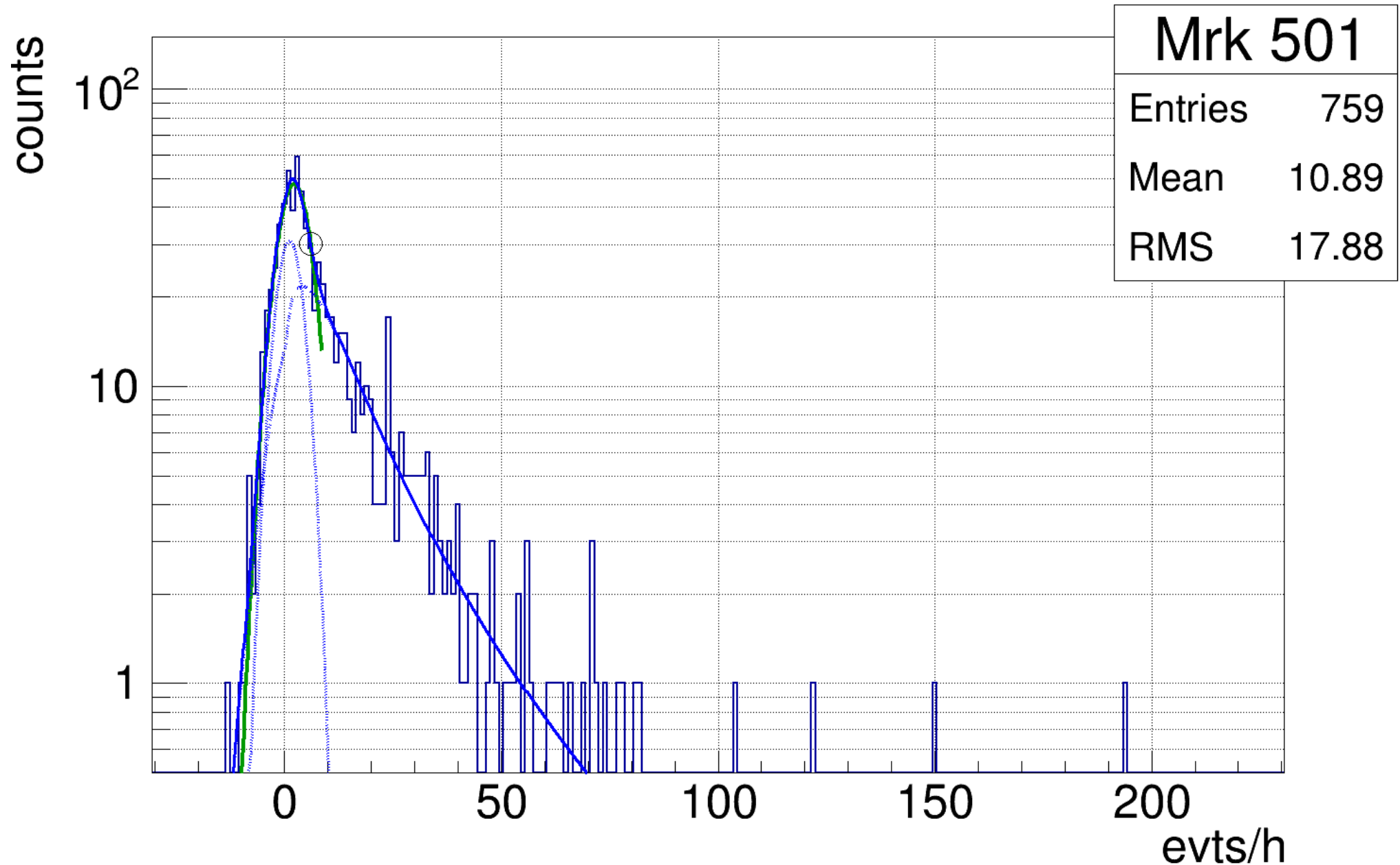




# Flux Distributions Revisted

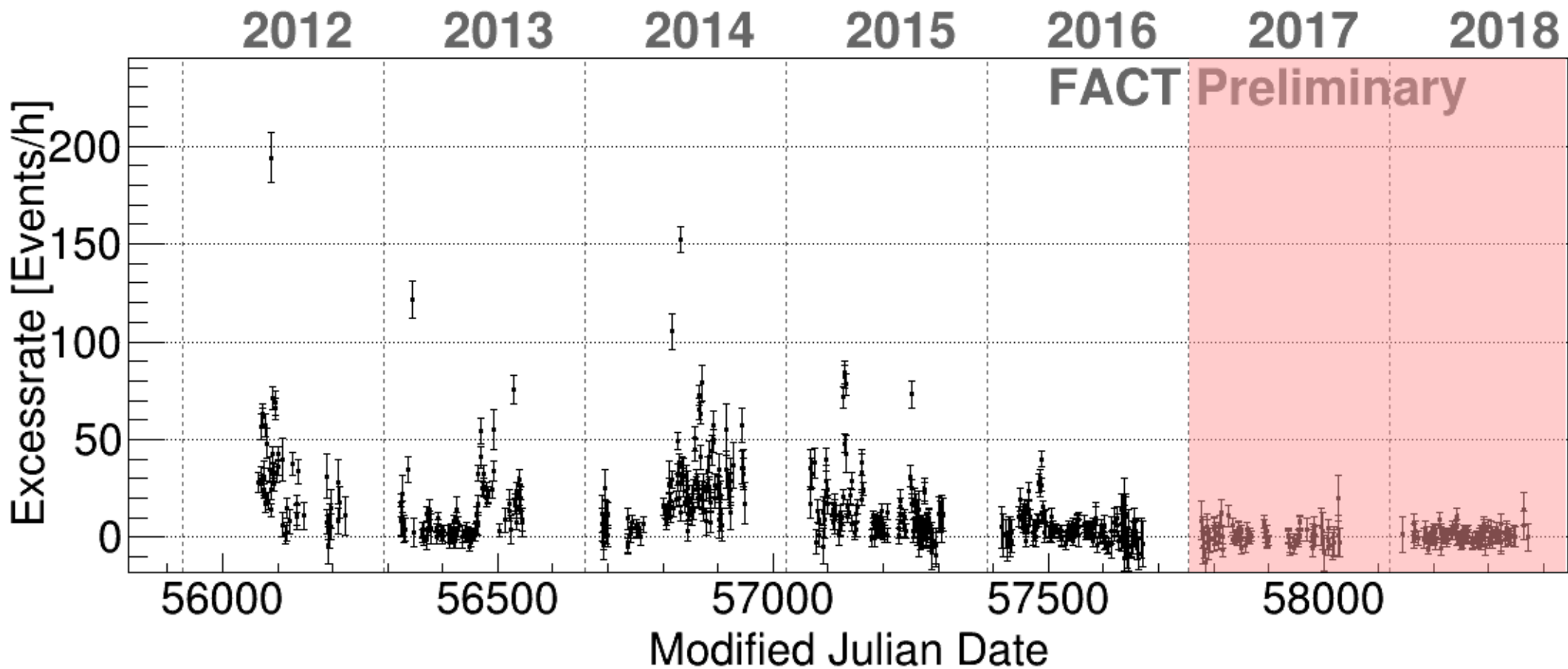


# Flux Distributions Revisted



# Low State of Mrk 501

- Very low flux in 2017/18



# Low State of Mrk 501

- Very low flux in 2017/18
- Determination of the quiescent state limited by detector sensitivity



# Low State of Mrk 501

- Very low flux in 2017/18
- Determination of the quiescent state limited by detector sensitivity

- Analysis Mrk 501

data 2017/18:

Average flux:

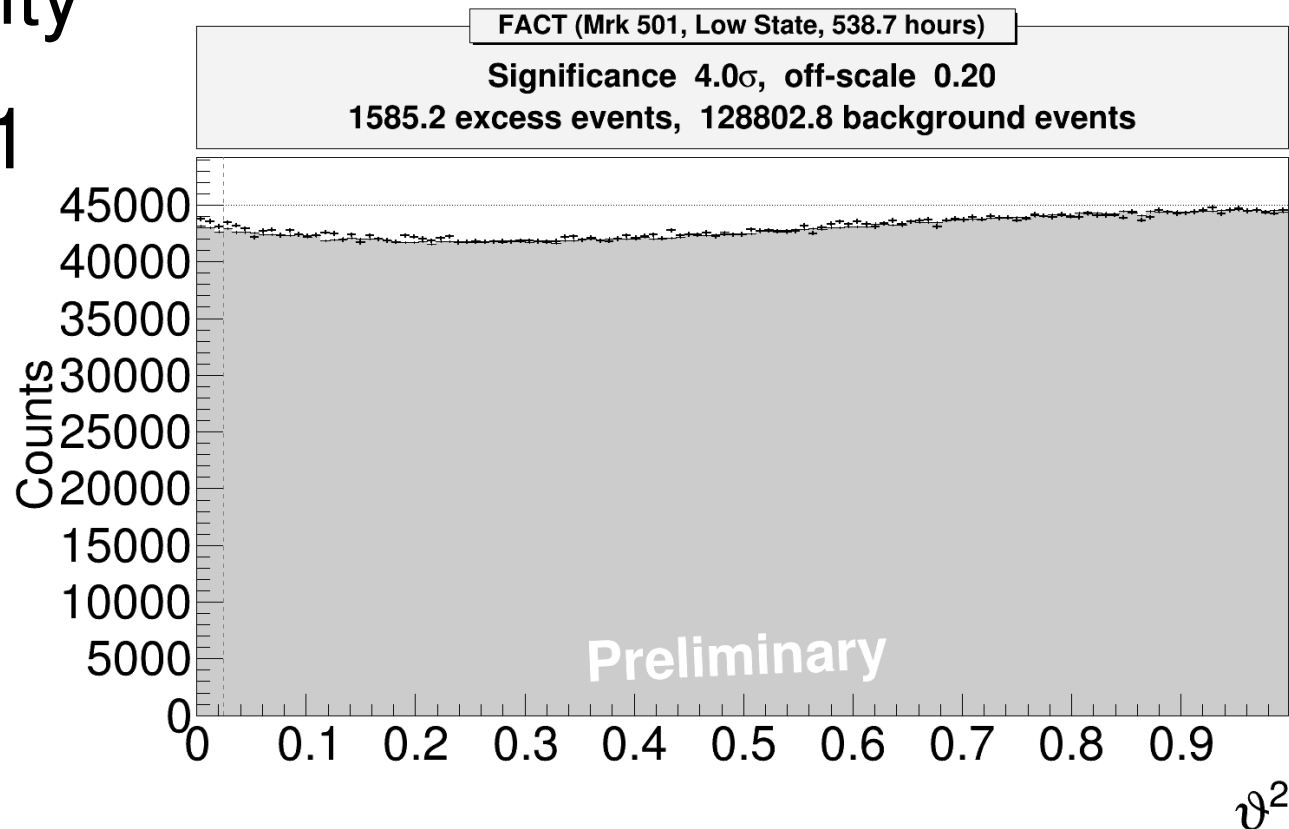
2.9 evts/h

→ **0.09 CU**

UL (99%CL):

4.7 evts/h

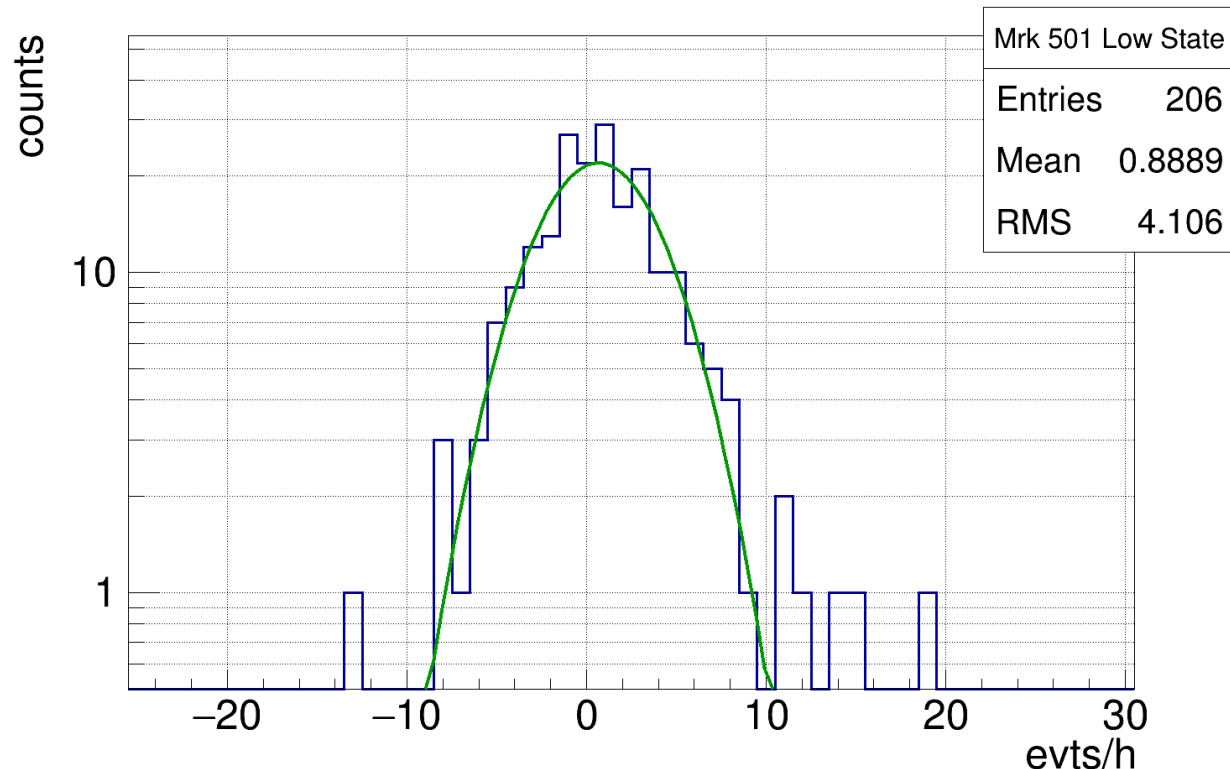
→ **0.15 CU**



# Low State of Mrk 501

- Very low flux in 2017/18
- Determination of the quiescent state limited by detector sensitivity
- Analysis Mrk 501 data 2017/18:
- Flux distribution of 2017/18:

Mean gauss:  
0.66 evts/h  
→ **0.021 CU**





# Low State of Mrk 501

- Very low flux in 2017/18
  - in  $> 500$  hours at limit of detection
  - average flux: 0.09 CU
  - UL (99%CL): 0.15 CU
- **Average flux over two years  $< 0.15$  CU**
- Flux distribution of 2017/18:
  - **Upper limit for baseline flux: 0.02 CU**
- Low state also in X-rays in the last two years



# Summary and Outlook

- FACT: Evaluation of blazar flux states at TeV energies
  - New UL for baseline flux for Mrk 421: 0.22 CU
  - Very low state of Mrk 501
    - Flux over two years < 0.15 CU
    - New UL for baseline flux: 0.02 CU
- FACT in AMON:
  - Different triggering strategies being evaluated
  - Sub-threshold data will be sent automatically

