Results from monitoring TeV blazars with HAWC

Robert J. Lauer for the HAWC collaboration

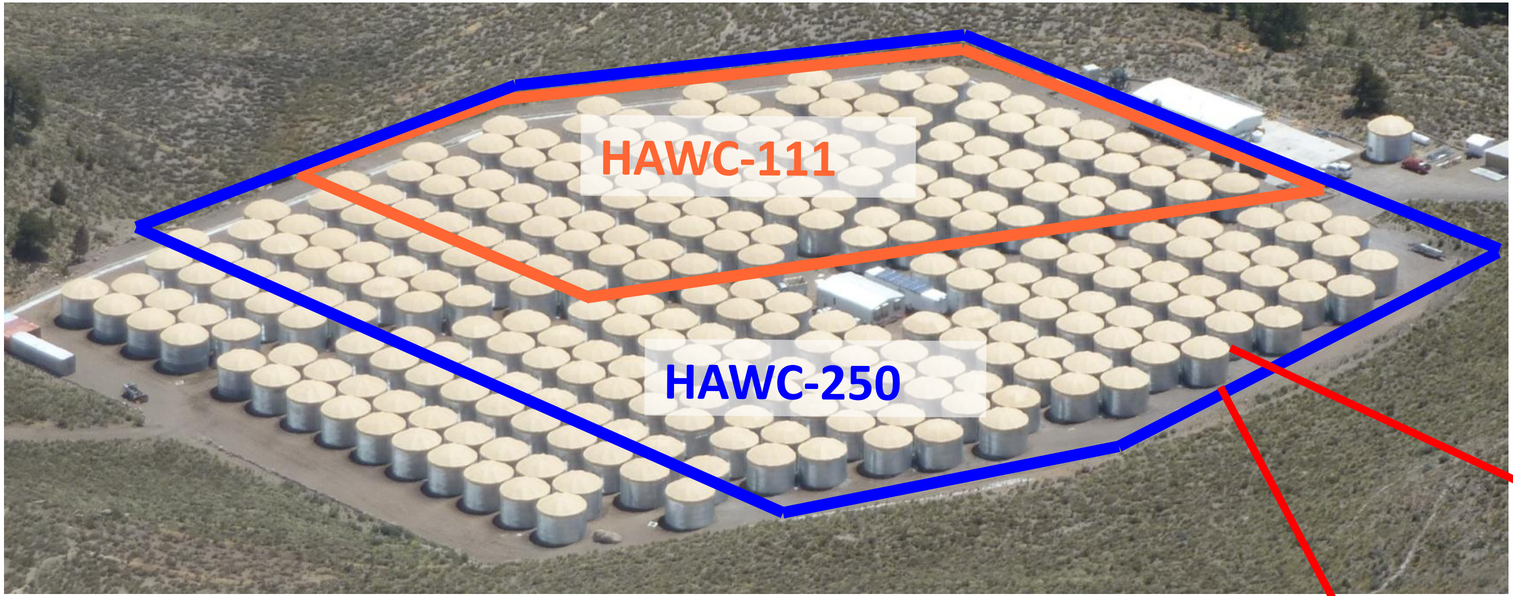
HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

THE UNIVERSITY of NEW MEXICO

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

ICRC 2015
The Hague,
The Netherlands
August 5, 2015

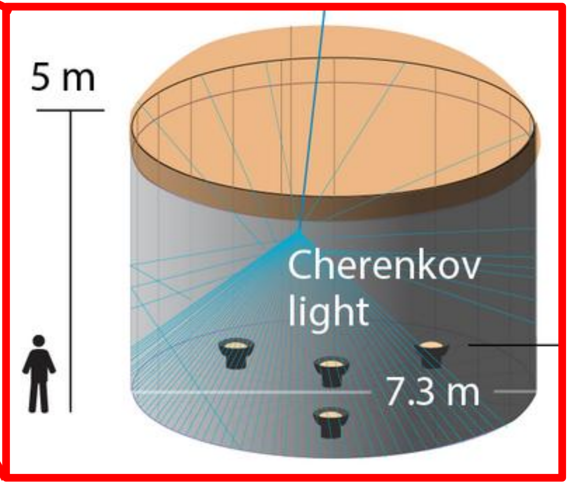
The HAWC array



Ongoing **data taking during construction:**

111 WCDs operated **since Aug. 2013,**

250 since Nov. 2014

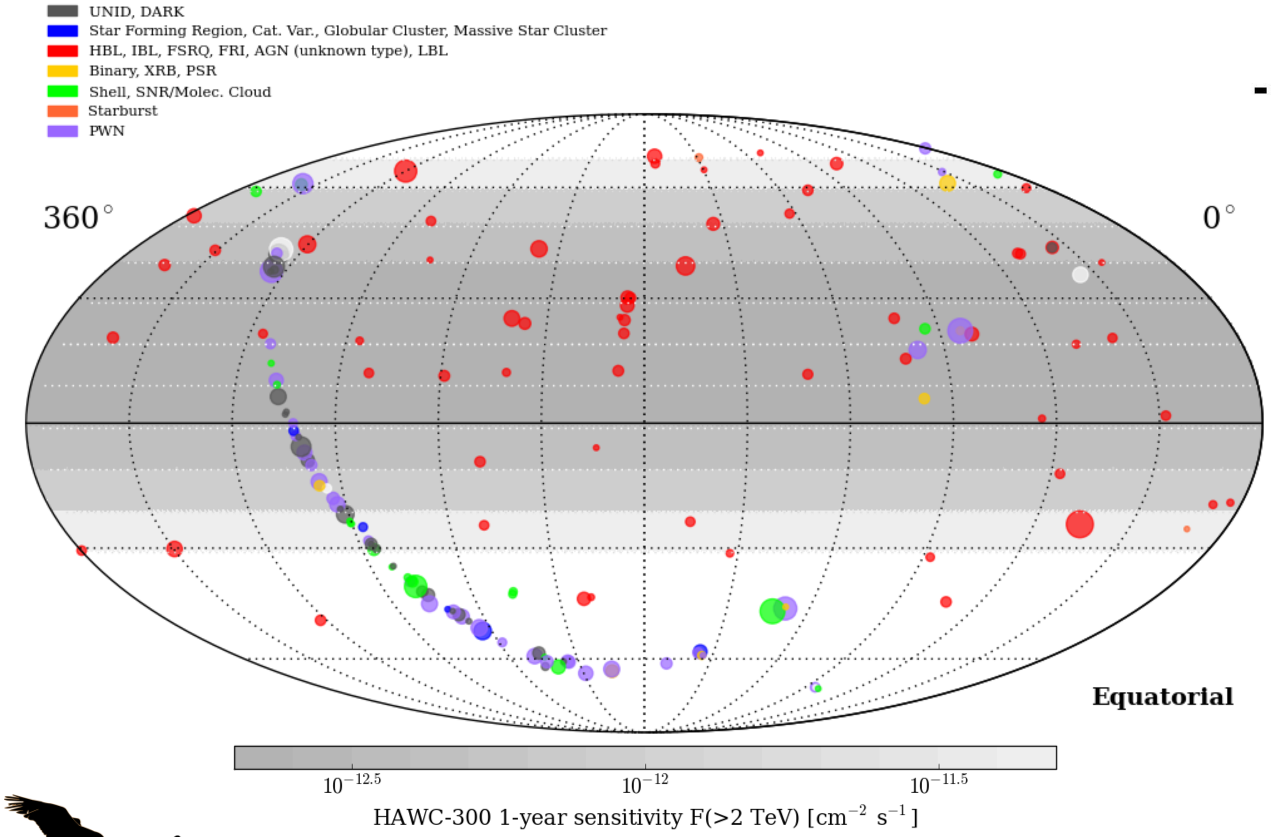


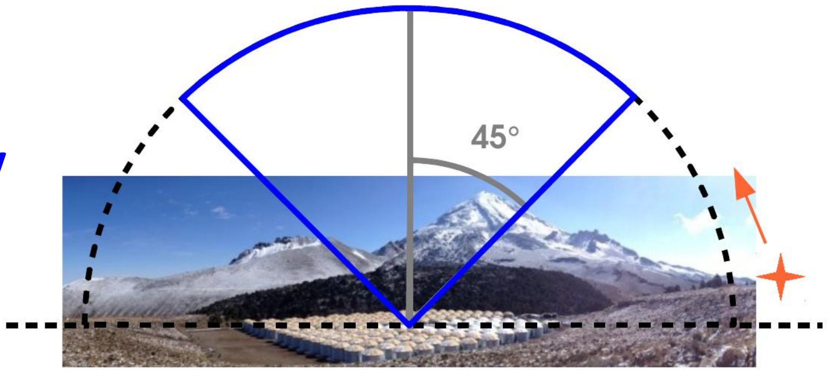
- **22,000 m^2** water Cherenkov detector (WCD) array
- **300 WCDs** at completion (March 2015)
- **188,000 liters** of purified water **per WCD**
- **4 PMTs per WCD** (3x 8” from Milagro + one high QE)

*See **HAWC Highlight talk, J. Pretz, Aug. 5, 17:30***

HAWC field of view

~2 sr instantaneous FoV: scans 2/3 of the sky each day



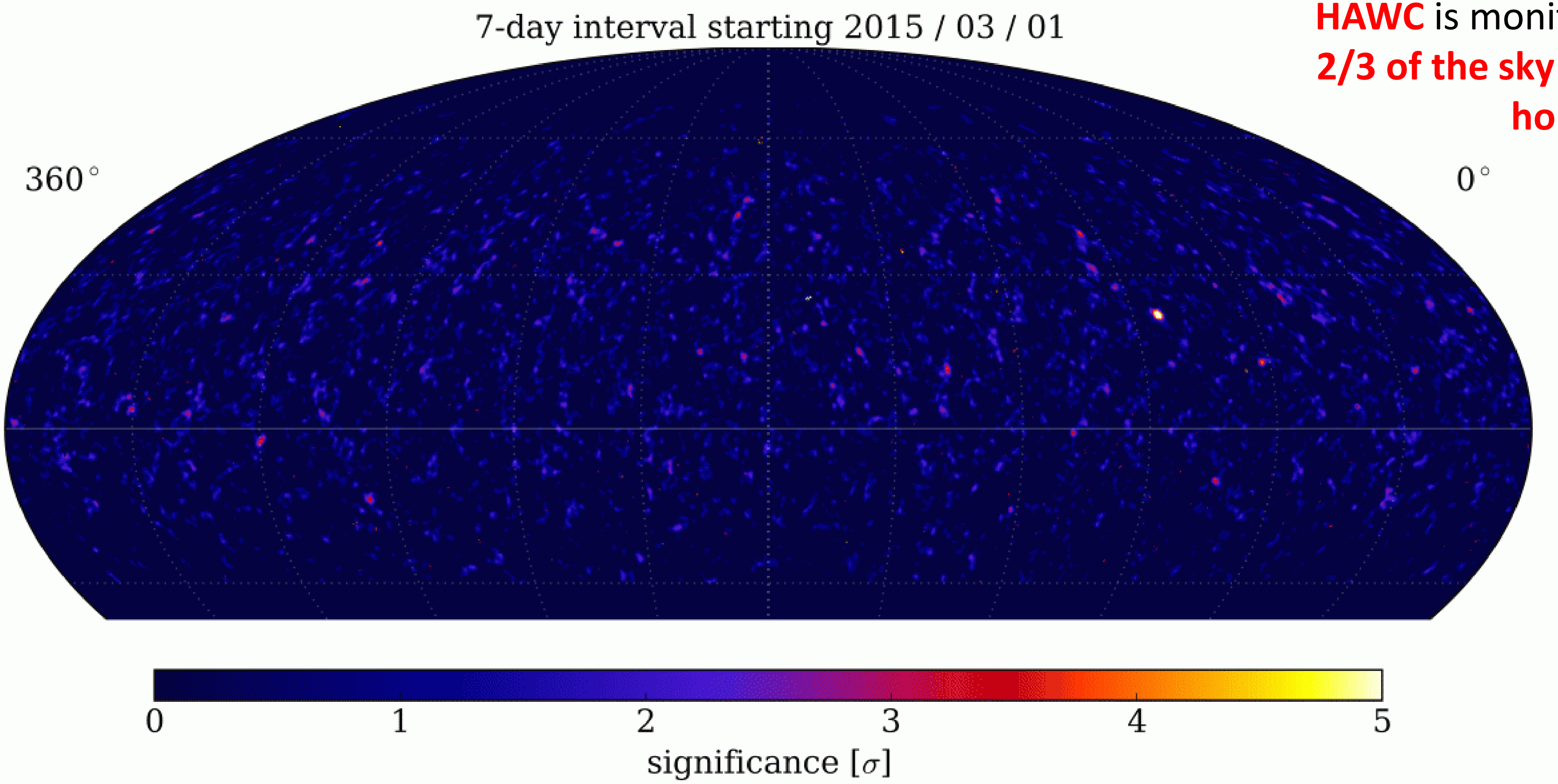


Maximum transit time: ~6 h for sources with peak elevation near zenith (e.g. Crab Nebula)

IACTs have **limited duty cycle** and usually **only 1 source per observation.**

HAWC can **monitor most of the ~60 known TeV-emitting Active Galactic Nuclei** (AGN)

TeV Monitoring of Active Galactic Nuclei



HAWC is monitoring **over 2/3 of the sky for up to 6 hours** per day

HAWC significance map for March 2015, 7-days per frame, shifted by 1 day

Physics from AGN Monitoring

AGN studies with unbiased flare data:

- **Flaring duty cycle** → acceleration mechanism
- **Orphan flare search** → leptonic vs. hadronic acceleration
- **Flare alerts** → trigger multi-wavelength follow-ups

See also: ***Blazar Alerts with the HAWC Online Flare Monitor***
T. Weisgarber, I. Wisher, ICRC 2015, # 732

Cosmological features illuminated by bright flare emission:

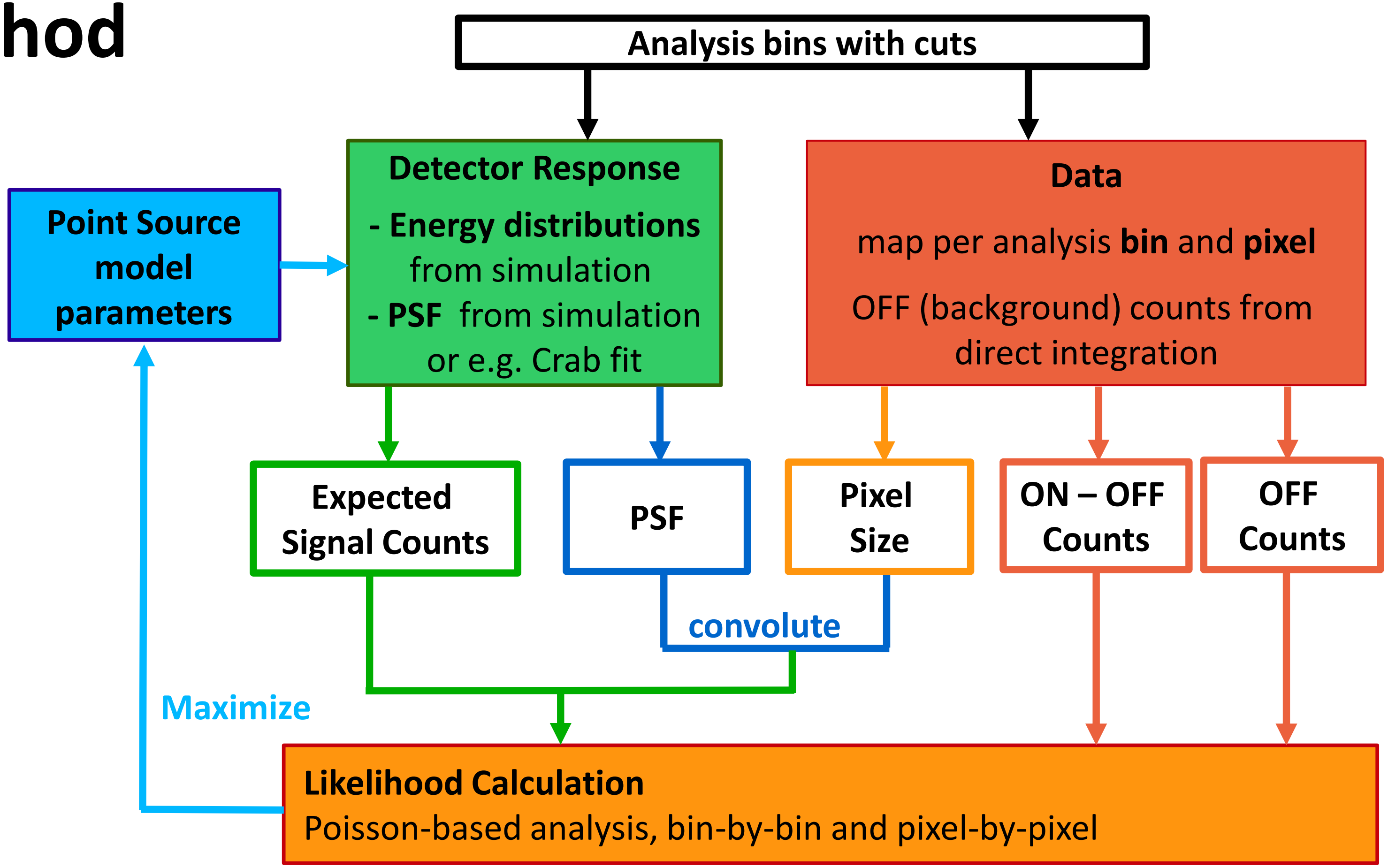
- **Extra-galactic Background Light** (EBL) studies:
  TeV cut-off due to absorption, probing evolution of infrared emission
- **Axion-like dark matter** searches:
  reduced γ-absorption due to conversion to/from axion-like particles
- **Inter-galactic magnetic field**:
  search for delayed emission at lower energies after strong flares

Likelihood Method

Poisson statistics facilitate analysis
for small signal
counts in **intervals**
of ≥1 source transit

See also framework description:

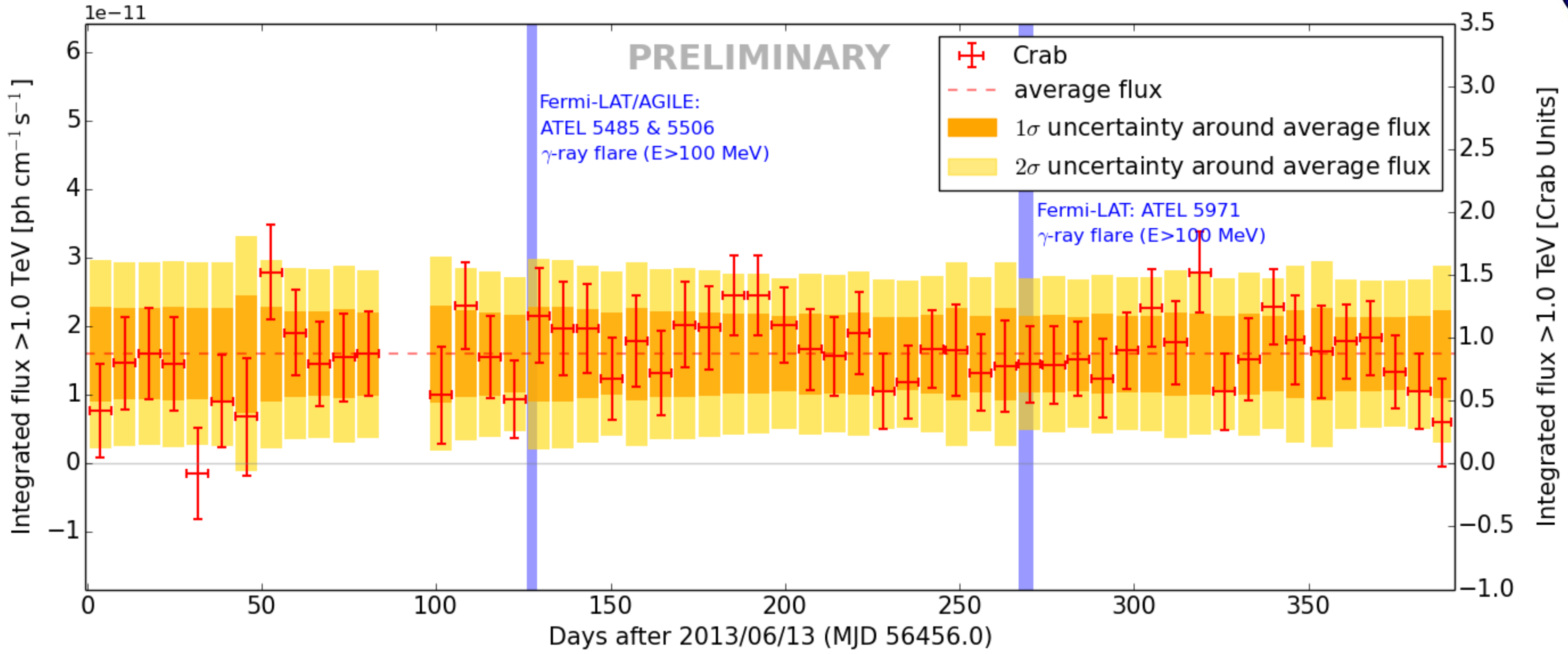
A high-level analysis framework for HAWC
P. Younk, R.L., et al.
ICRC 2015, #238

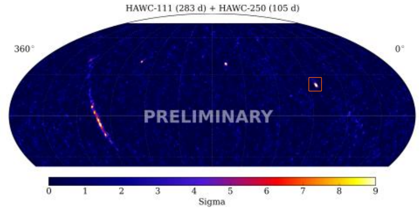


$$\mathcal{L}_S\left(\{F_0, s, c\}|\vec{N}\right) = \prod_b \prod_p P(N_{b,p}, S_{b,p} + B_{b,p})$$

Poisson probability

The Crab nebula in early HAWC data





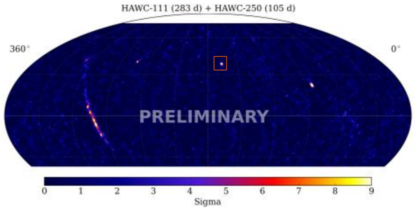
HAWC-111 data from **June 13, 2013 to July 9, 2014**, binned in 7-day intervals.

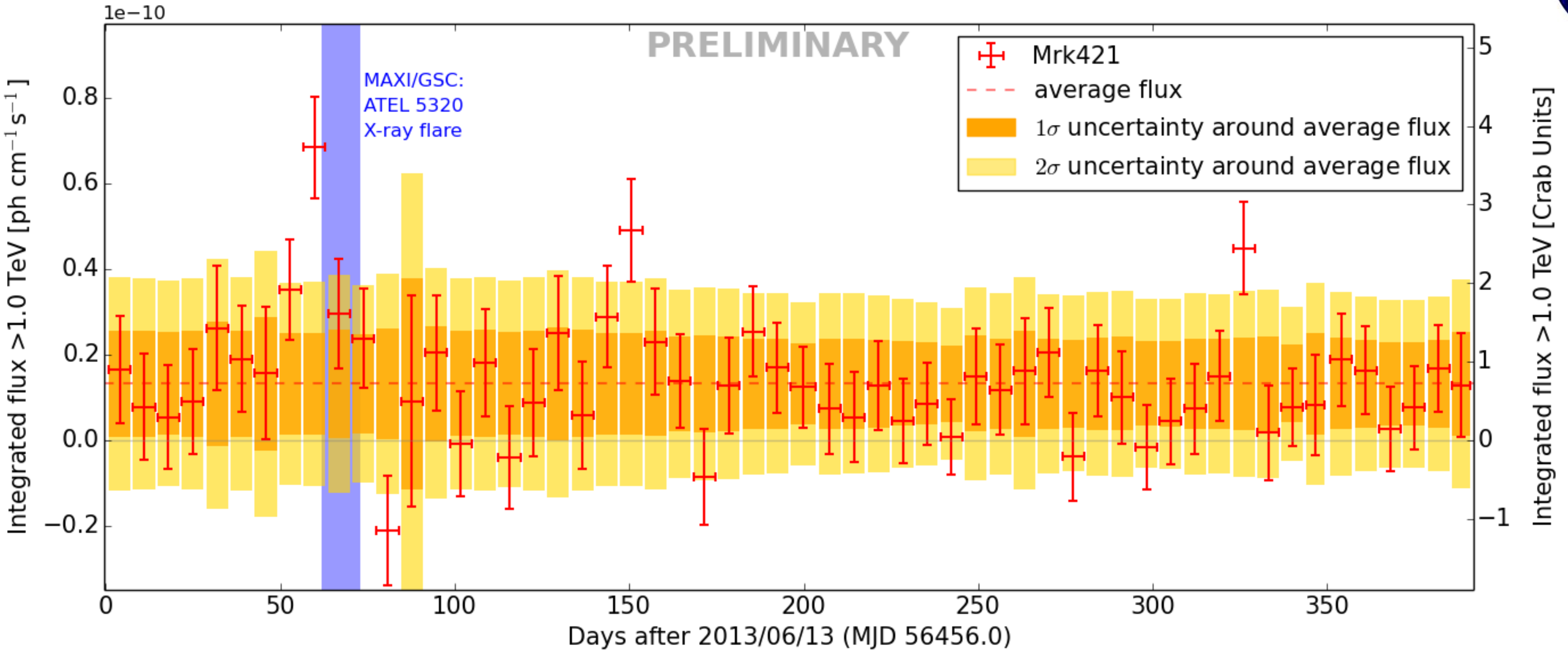
Fit with fixed spectral shape: simple power law, index 2.63 .

Consistent with being a steady source.

Average flux consistent with TeV flux measured by IACTs.

Mrk 421 flux light curve



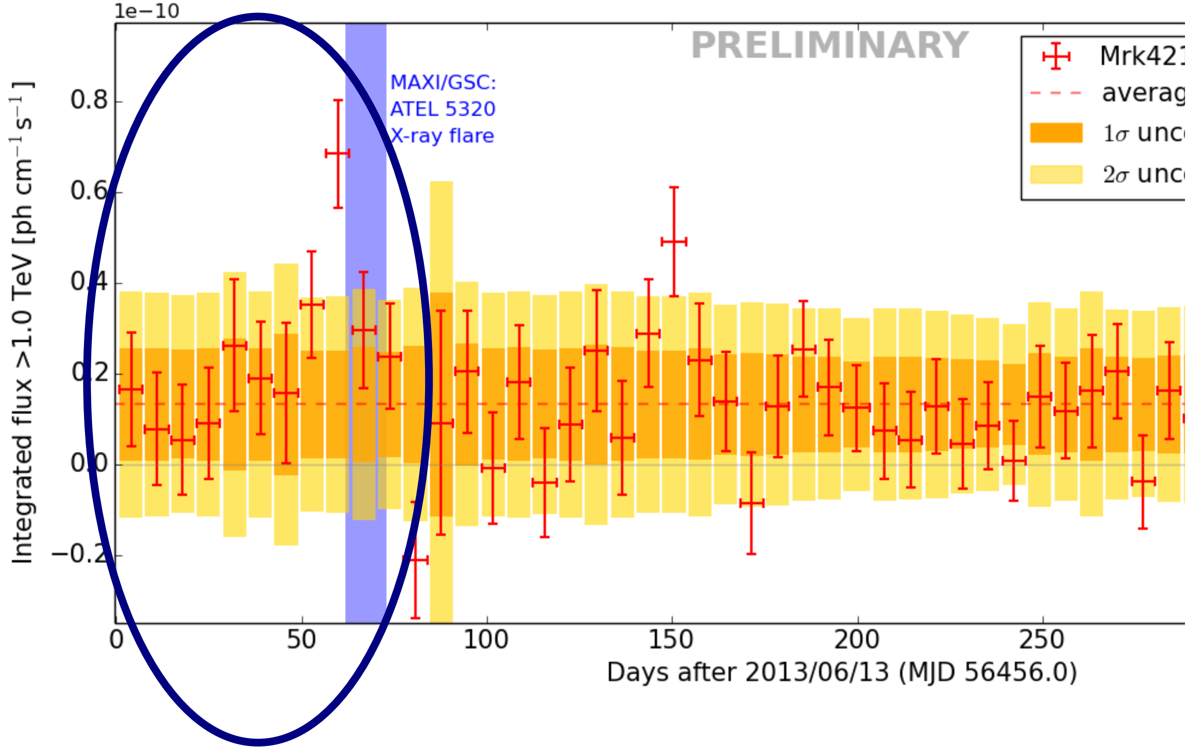


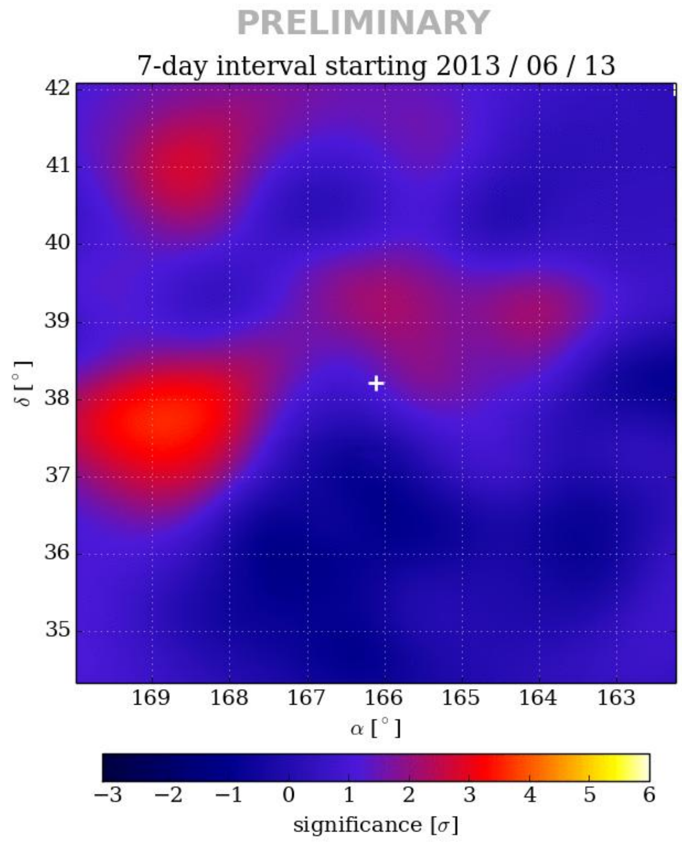
HAWC-111 data from **June 13, 2013 to July 9, 2014**, binned in 7-day intervals.

Fit with fixed spectral shape: power law index 2.2, cut-off 5 TeV.

Highest flux coincides with onset of X-ray flare (MAXI/GSC, 2-4 keV, ATEL 5320).
HAWC-only probability of this excess assuming a steady flux: 1.4×10^{-5} .

Mrk 421 flux light curve

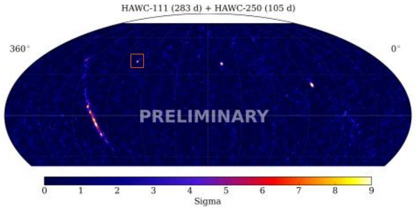


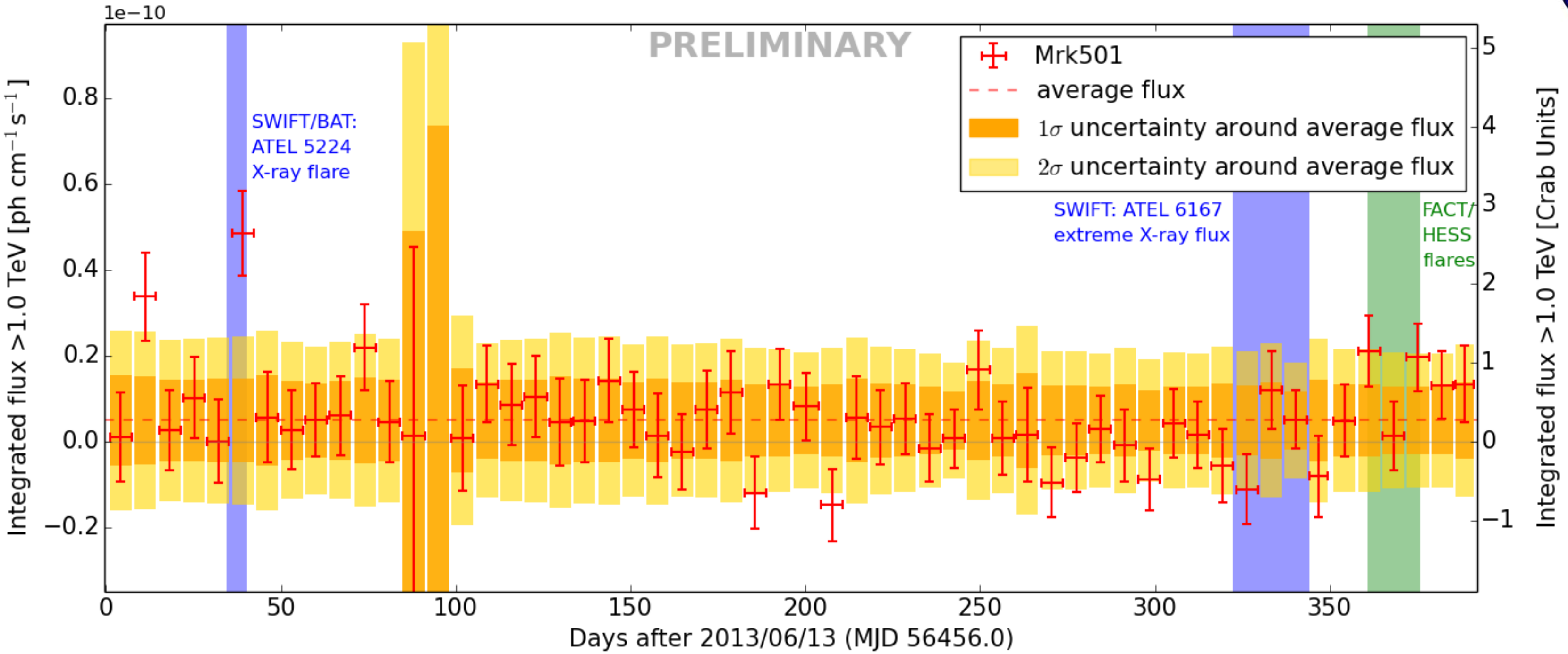


Highest flux coincides with onset of X-ray flare (MAXI/GSC, 2-4 keV, ATEL 5320).

HAWC-only probability of this excess assuming a steady flux: $1.4\mathrm{x}10^{-5}$.

Mrk 501 flux light curve





HAWC-111 data from **June 13, 2013 to July 9, 2014**, binned in 7-day intervals.

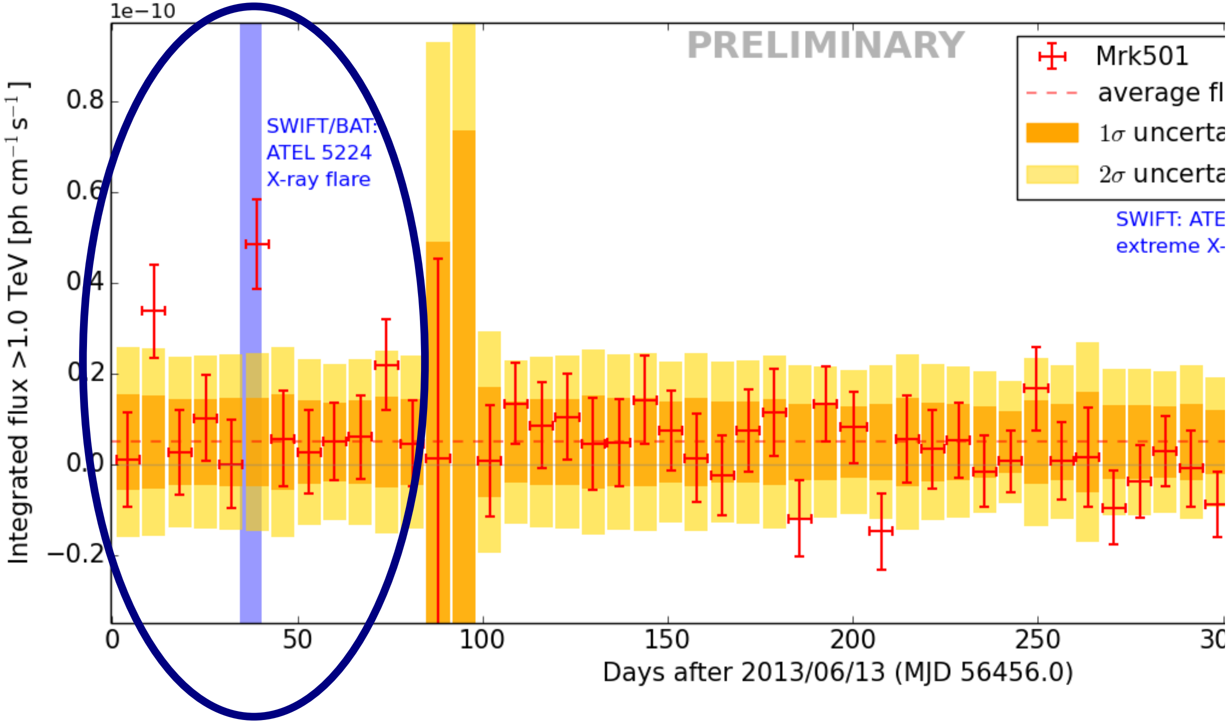
Fit with fixed spectral shape: simple power law, index 2.8 .

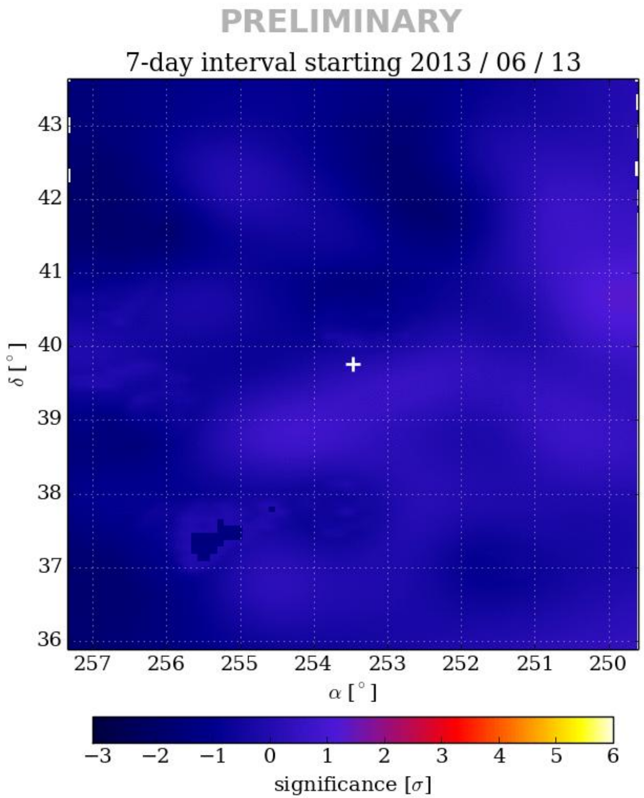
Highest flux coincides with onset of X-ray flare (SWIFT/BAT, 15-50 keV, ATEL 5320).

HAWC-only probability of this excess assuming a steady flux: 1.9×10^{-4} .

No significant features in weekly HAWC fluxes during later X-ray flare, nor during June 2014 TeV flares (FACT, H.E.S.S., ATEL 6268, flare durations < 1 day).

Mrk 501 flux light curve





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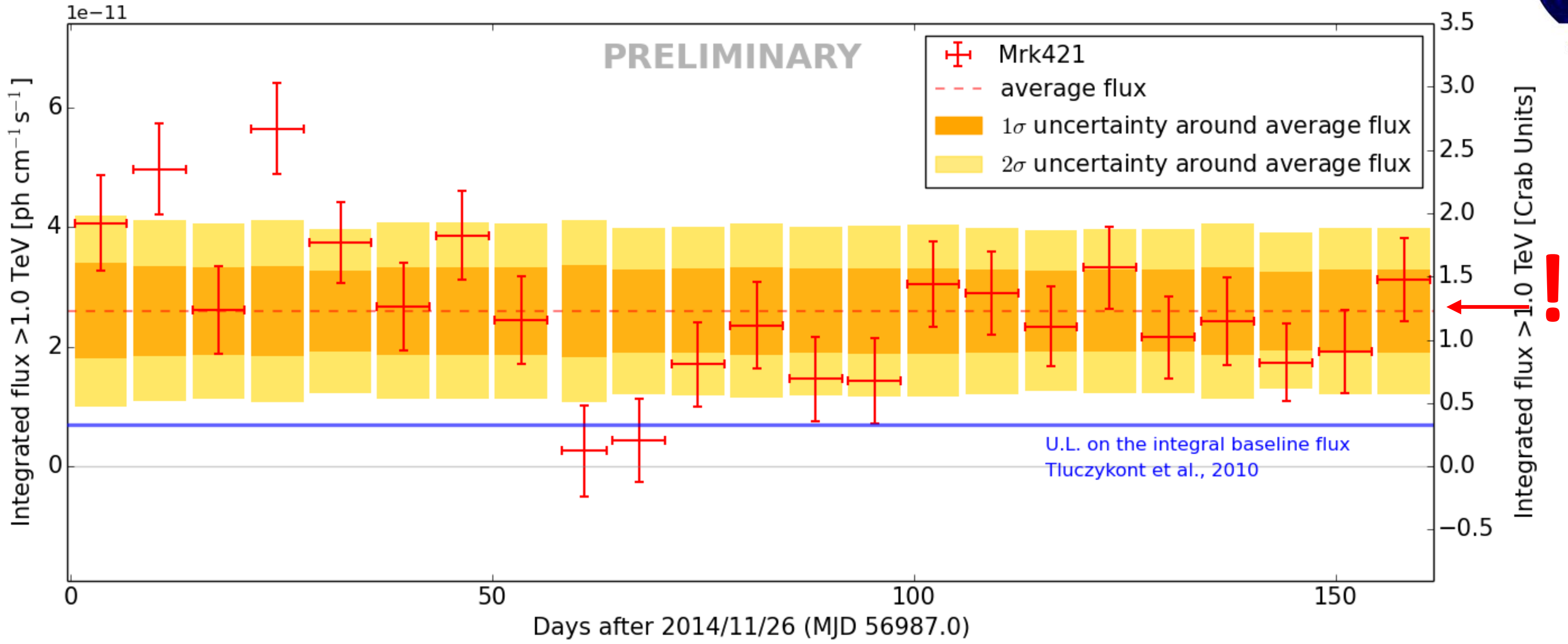
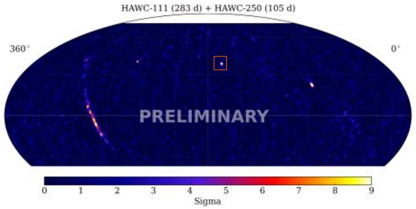
First look at HAWC-250: Mrk 421





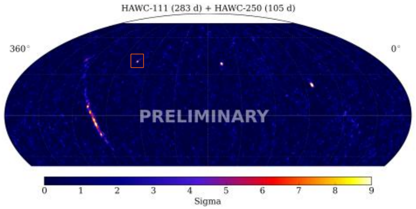
HAWC-250 data from **Nov. 26, 2014 to May 6, 2015**, binned in 7-day intervals.

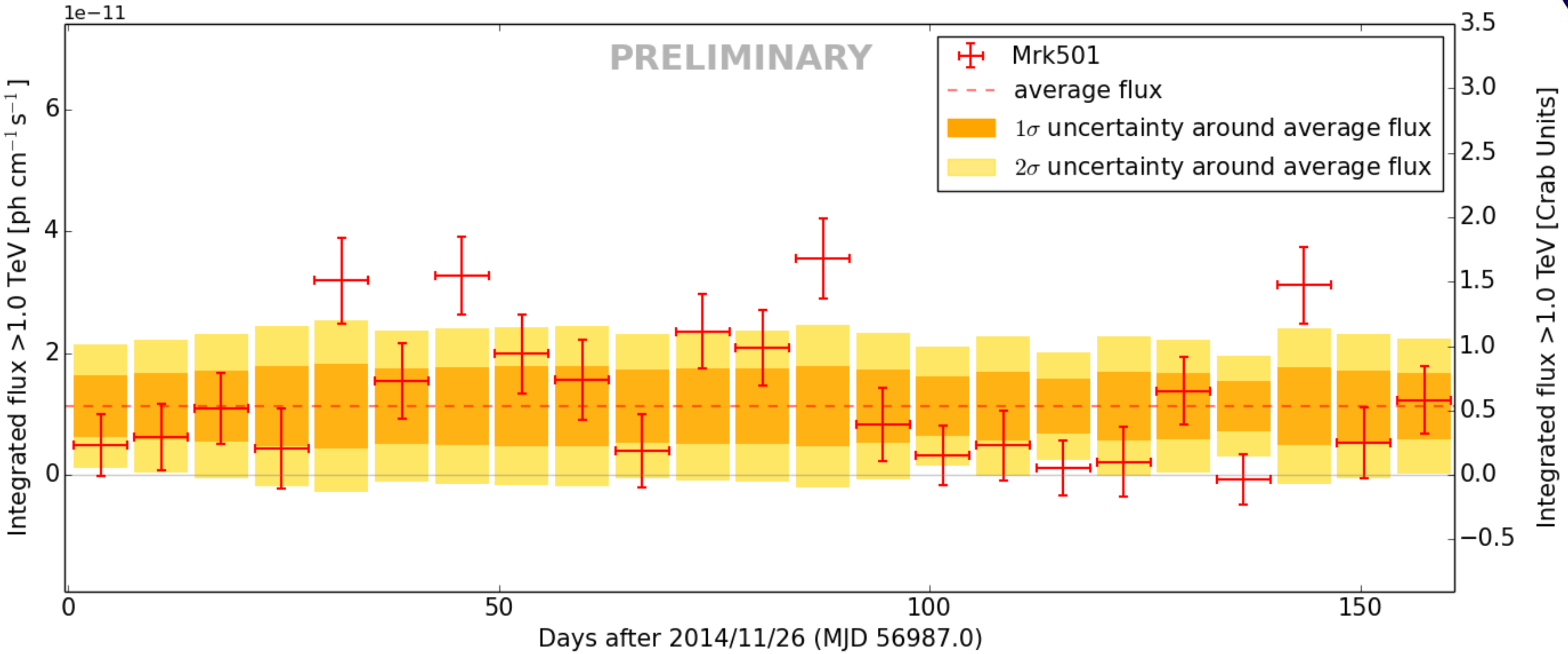
Fit with fixed spectral shape: power law index 2.2, cut-off 5 TeV.

Average flux larger than 1 Crab Unit (normalized to HAWC integrated Crab flux)

Very high flux states observed in December 2014, analysis in progress.

First look at HAWC-250: Mrk 501





HAWC-250 data from **Nov. 26, 2014 to May 6, 2015**, binned in 7-day intervals.

Fit with fixed spectral shape: simple power law, index 2.8 .

Several high flux states observed, further analysis in progress.

Summary & Outlook

- **HAWC** has started to **survey and monitor 2/3 of the sky.**
- **Weekly flux light curves** for Mrk 421 and Mrk 501 **show flares**: Water Cherenkov technique ready for flare monitoring.
- A **likelihood** analysis method provides **daily flux measurements of AGN** and other objects.
- **Joint multi-wavelength analyses** in preparation, see poster on **3ML software** (still on display today)

The Multi-Mission Maximum Likelihood Framework (3ML), *G. Vianello, R.L. et al., ICRC 2015, #238*