



# ICRC

The Astroparticle Physics Conference

34<sup>th</sup> International Cosmic Ray Conference

July 30 - August 6, 2015

The Hague, The Netherlands

# Observations of the Crab Nebula with Early HAWC Data



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for the HAWC Collaboration

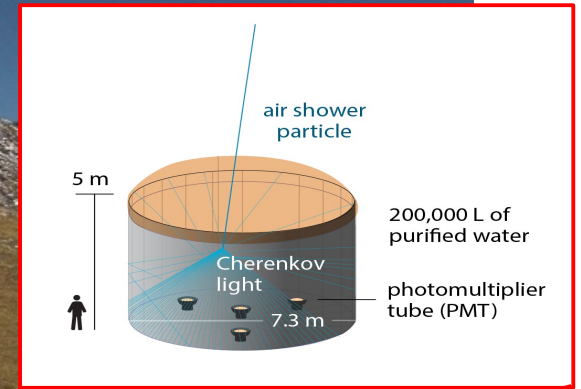


# Outline

- HAWC introduction.
- Crab Nebula observations.
- Crab Nebula time variability.
- HAWC  $5\sigma$  differential sensitivity.
- Conclusions.

# HAWC Gamma-Ray Observatory

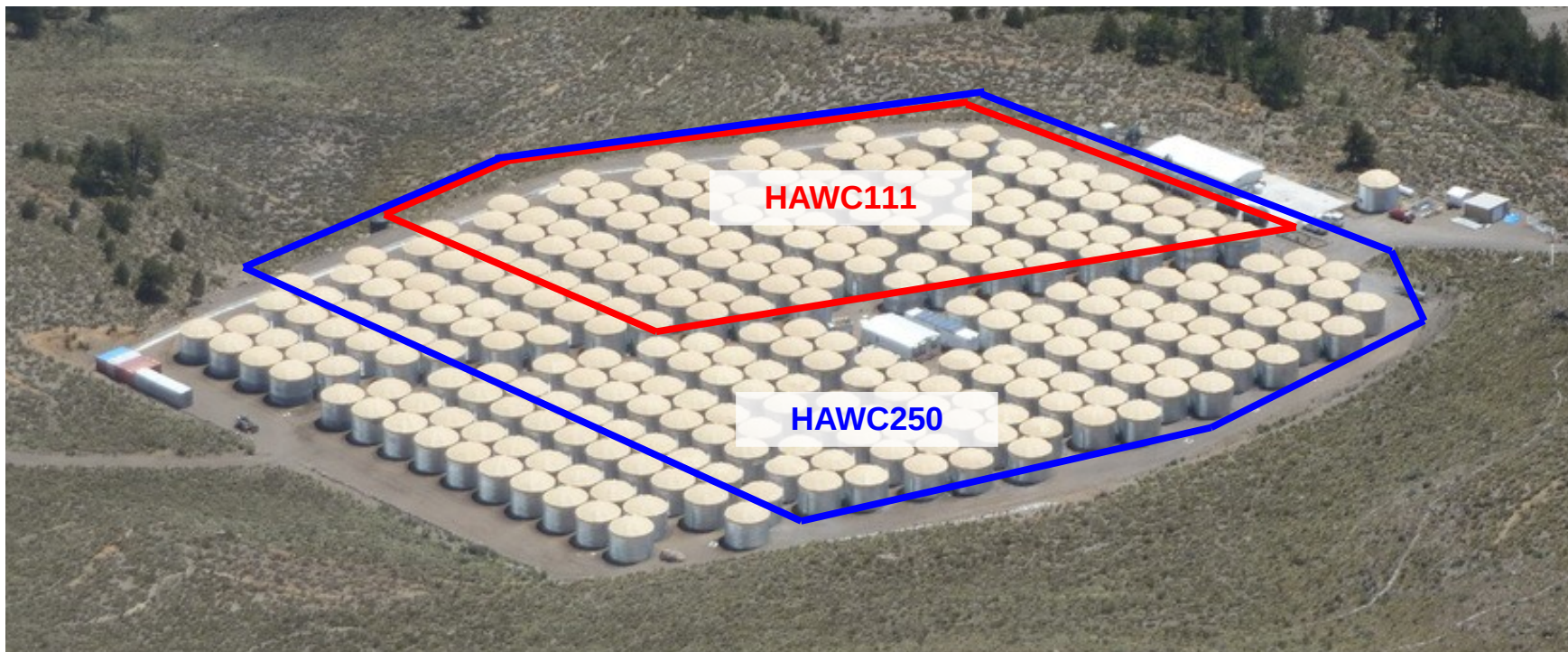
**Location:** Sierra Negra, Mexico (19° N)  
**Altitude:** 4100 m a.s.l.  
**Instrumented area:** 22,000 m<sup>2</sup>  
**Detectors:** 300 WCDs (4 PMTs each)  
**Field of view:** 2sr instantaneous, 8sr daily



More details in A. Smith (#397)  
poster 1 GA, July 30<sup>th</sup> 3.30pm

**Inaugurated on Mar 20<sup>th</sup> 2015**

# Data Sets

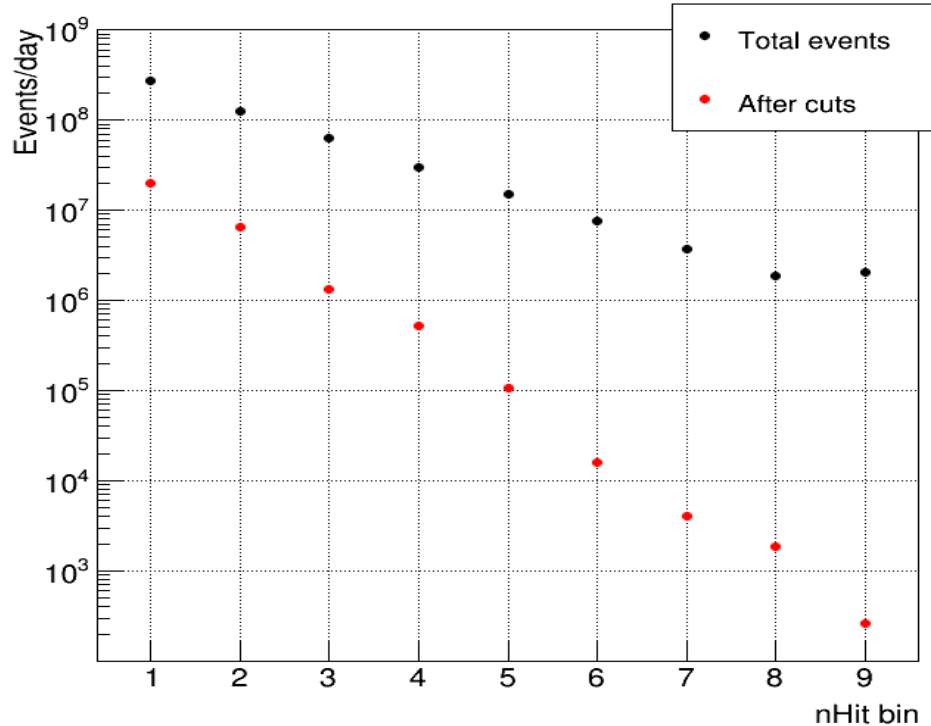


**HAWC111:** Aug 2<sup>nd</sup> 2013 – Jul 7<sup>th</sup> 2014 (106 - 133 WCDs)

**HAWC250:** Nov 26<sup>th</sup> 2014 – May 6<sup>th</sup> 2015 (247 - 293 WCDs)

# Data Selection

HAWC250



- Divide the data in 9 analysis bins (nHit bins) based on the % of PMTs triggered in an event.
- First bin is defined for a given passing rate (5 kHz for HAWC250).
- The following bins are defined to decrease the rate by a factor 2.
- Apply G/H cuts, optimized on data to maximize the Crab significance:

Current HAWC G/H separation:

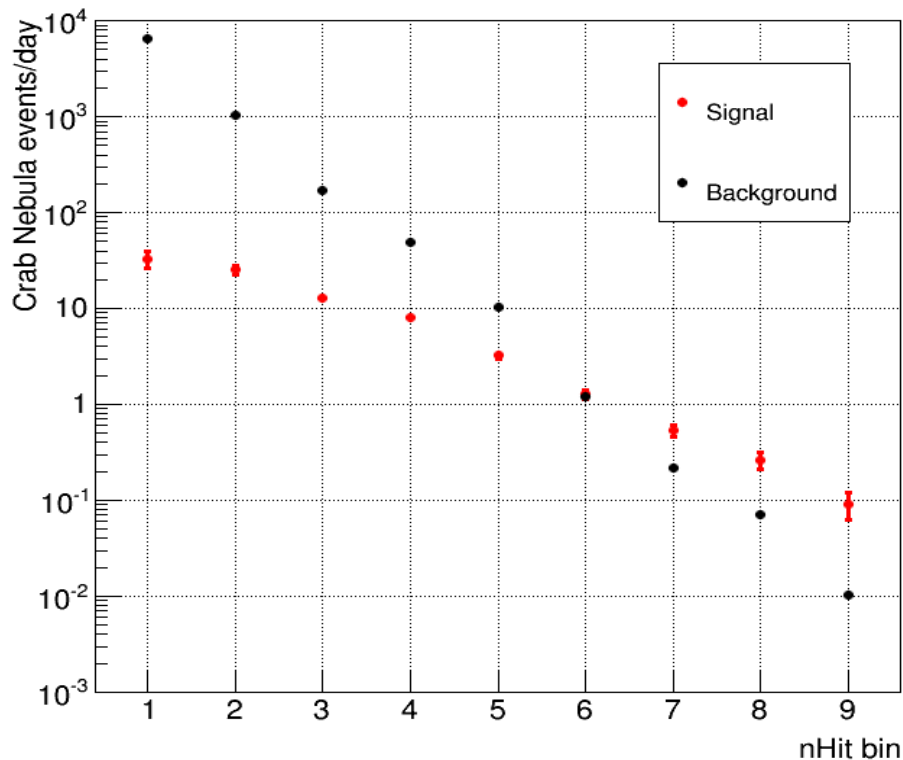
**A. Smith (#397) poster 1 GA, July 30<sup>th</sup> 3.30pm**

**BIN 1: 7-10%, ~0.6 TeV**

**BIN 9: 84-100%, ~25 TeV**

# Data Selection

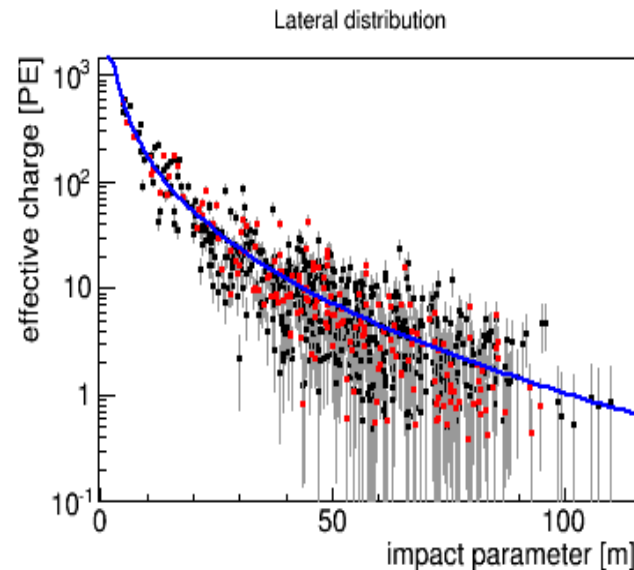
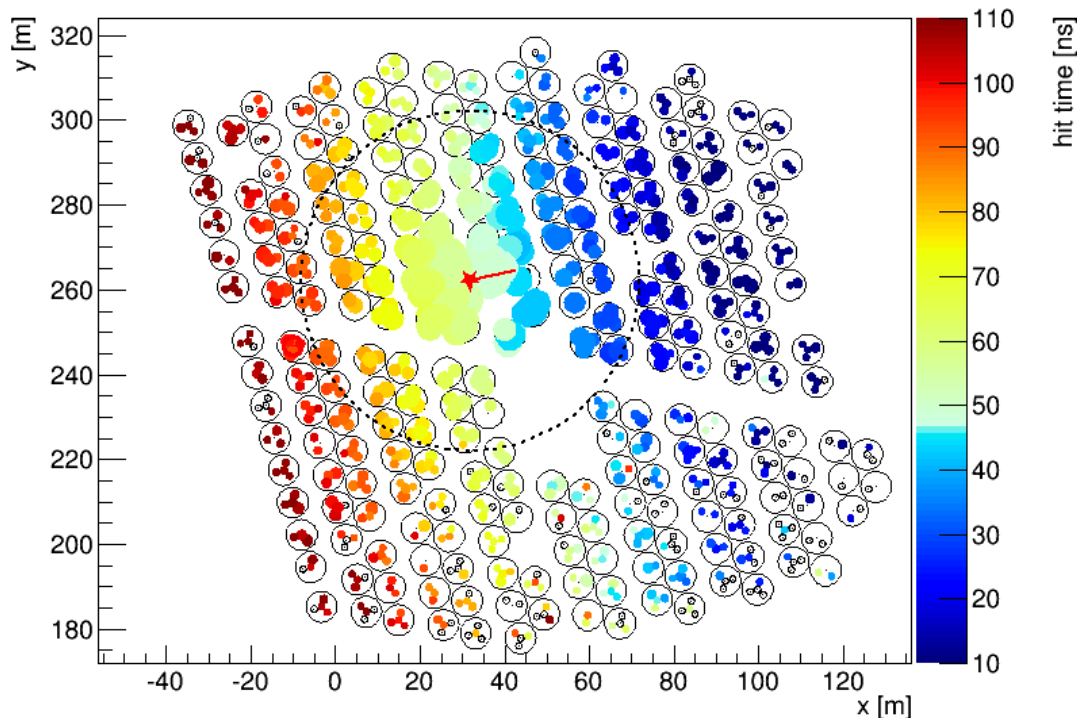
## HAWC250



- For the **Crab Nebula** analysis we use circular angular bins (a.k.a. top-hat).
- We estimate the background using the direct integration technique:  
**Astrophys. J. 595 (2003) 803-811**
- The signal is defined as the excess over the background.
- Almost 10:1 (signal:back) in bin 9.

# Gamma-Like Event

HAWC250, nHit bin9

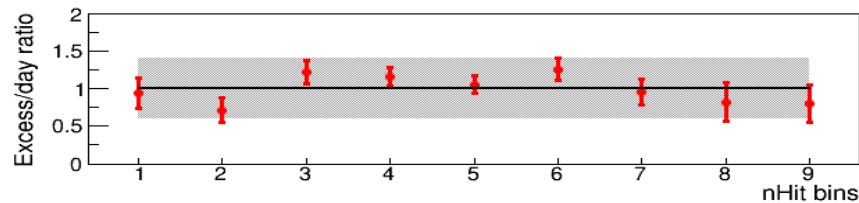
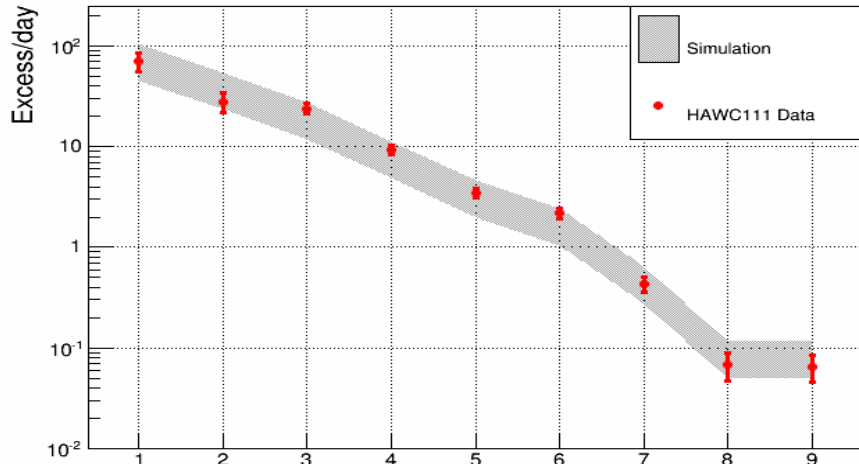


ICRC contributions on G/H separation:  
- Z. Hampel-Arias (#829)  
poster 2 GA, Aug 1<sup>st</sup> 3.30pm  
- T. Capistrán (#692)  
poster 3 GA, Aug 4<sup>th</sup> 3.30pm

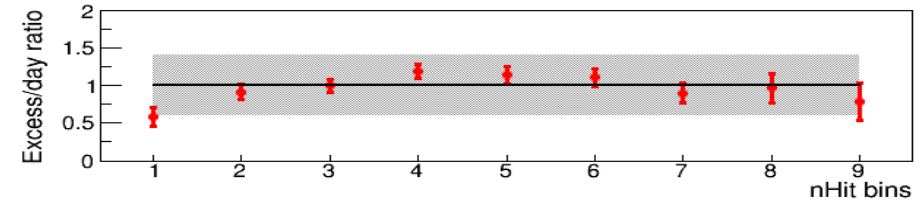
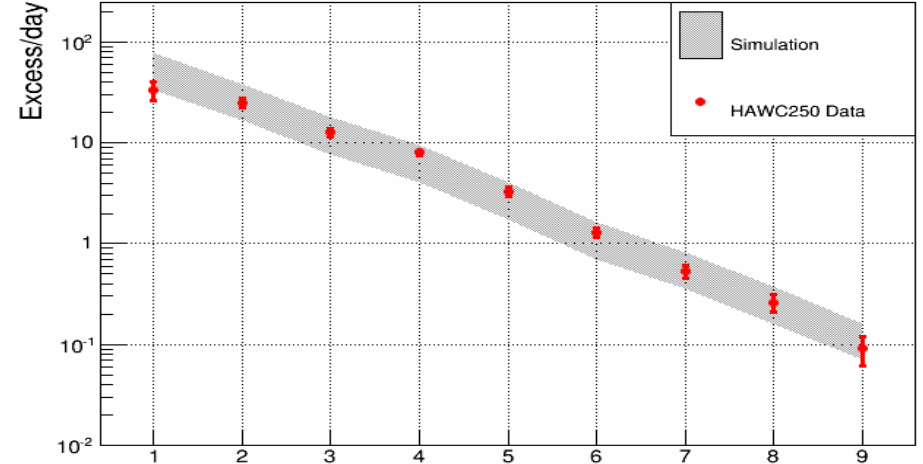
- Event reconstructed within  $0.4^\circ$  of the Crab Nebula.

# Signal from the Crab Nebula

HAWC111 (283 days)



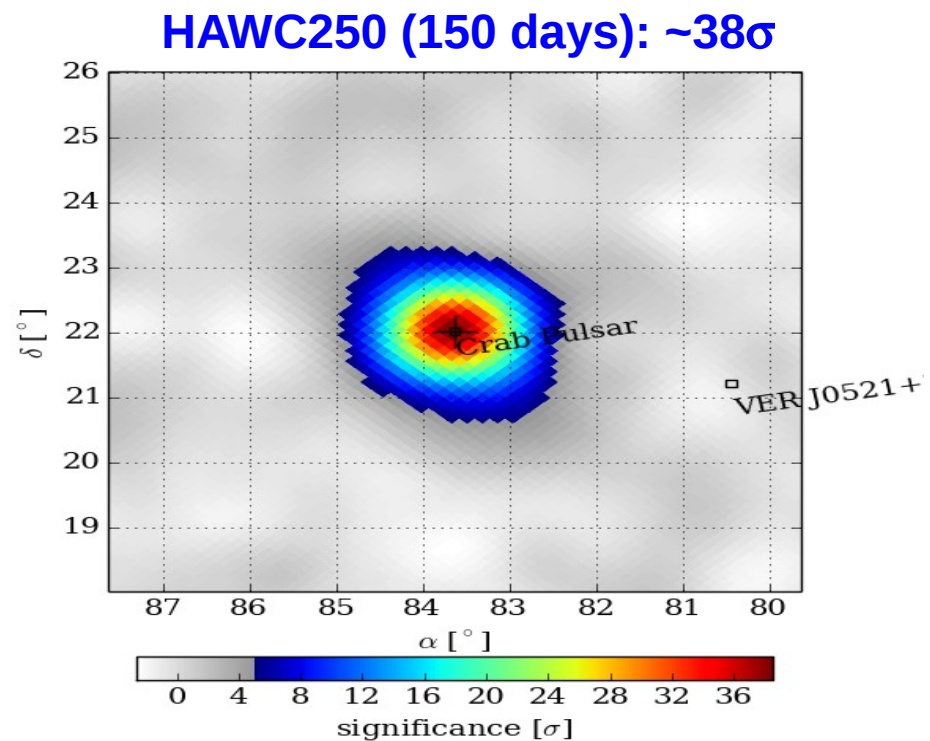
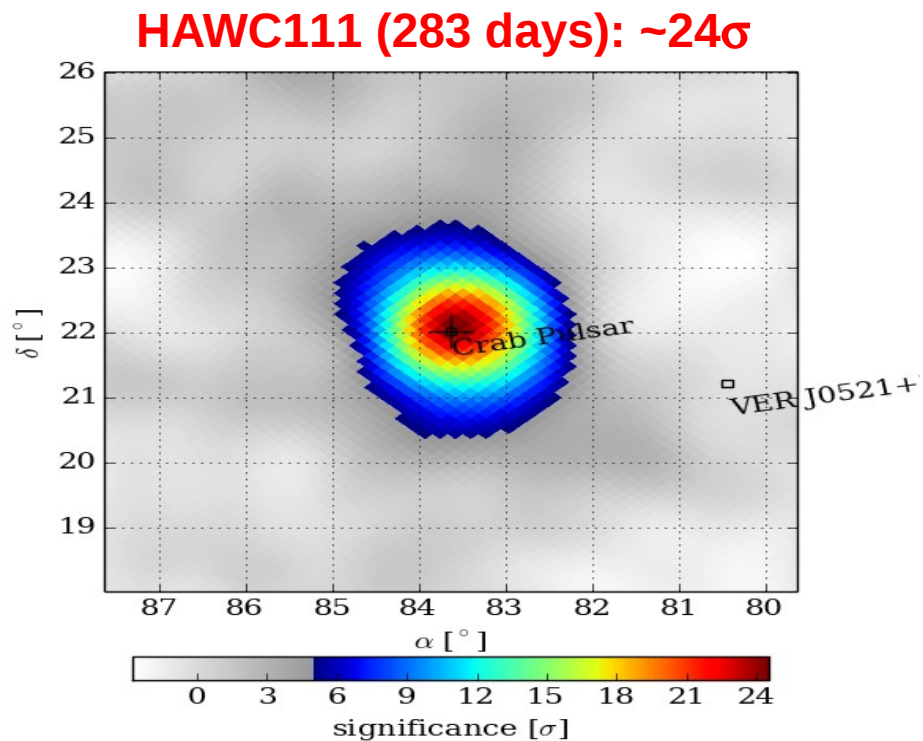
HAWC250 (150 days)



- Data errors statistical only. Simulation systematic uncertainty 40%.

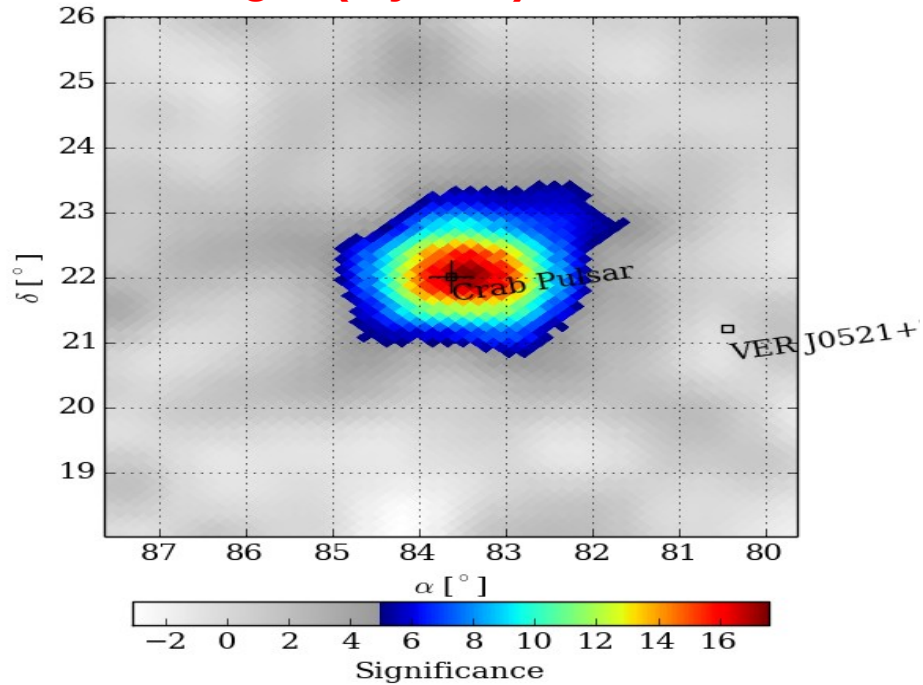


# Detection of the Crab Nebula

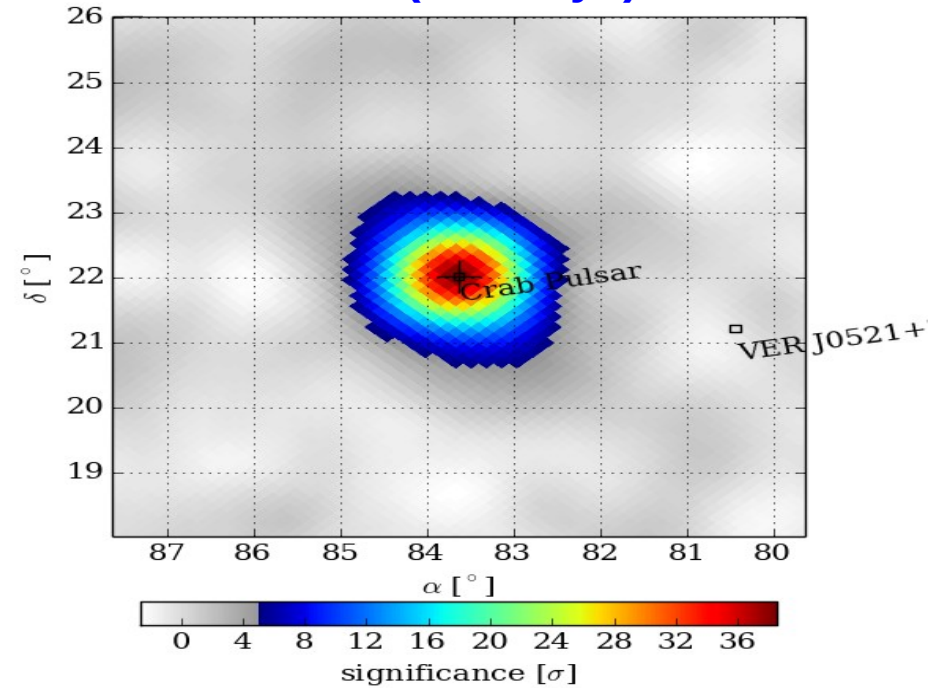


# HAWC vs Milagro

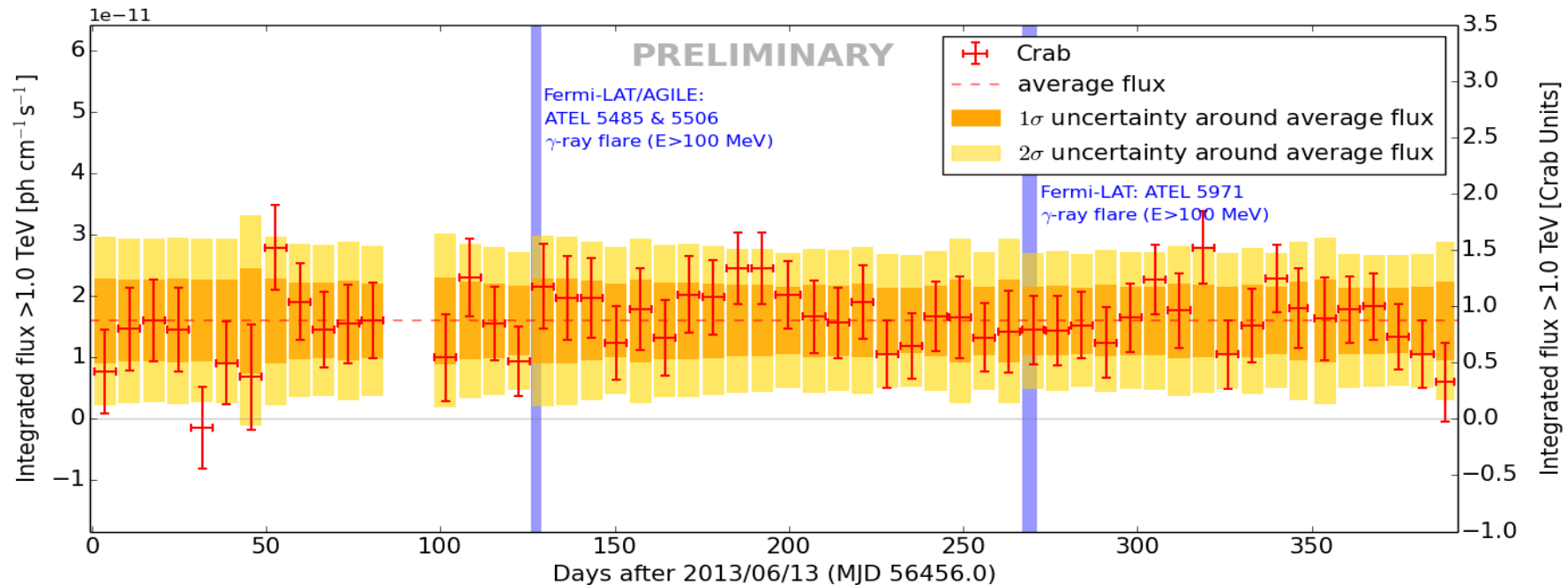
Milagro (8 years):  $\sim 17\sigma$



HAWC250 (150 days):  $\sim 38\sigma$

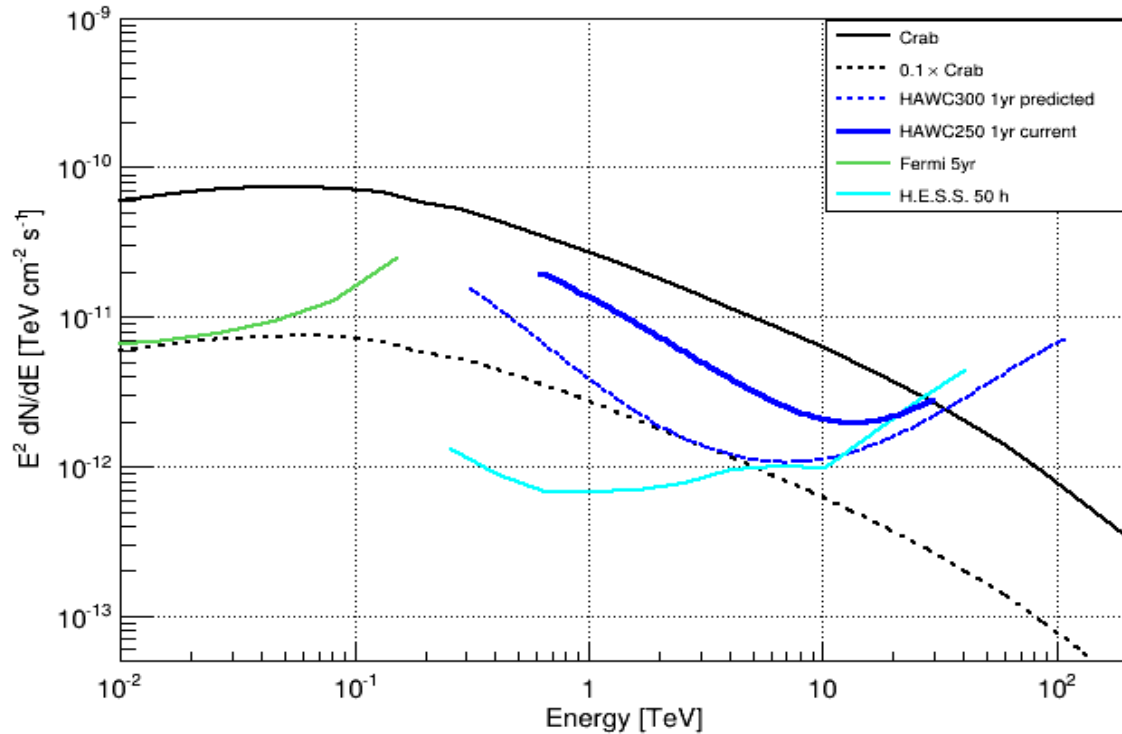


# Time Variability



- Measured flux in 7 days intervals between Jun 13<sup>th</sup> 2013 to Jul 9<sup>th</sup> 2014 (**HAWC111**).
- No evidence for the Crab Nebula emitting significantly higher w.r.t. its quiescent flux.

# HAWC Differential Sensitivity ( $5\sigma$ )



- We use a simulated Crab-like source at  $\text{dec}=35^\circ$  to estimate the sensitivity.
- Incoming improvements on the G/H separation and calibration, together with a better understanding of our detector response are expected to recover the predicted sensitivity.

Predicted HAWC sensitivity: Astropart. Phys. **50-52** (2013) 26-32

# Conclusions

- The Crab Nebula has been detected with high significance ( $>20\sigma$ ) in each of the two HAWC datasets.
- There is no evidence for Crab Nebula TeV flares in the HAWC111 period.
- Incoming improvements (G/H separation, better calibration, detector response) are expected to enhance the present detector sensitivity by more than a factor 2.