

Detection of highly extended gamma-ray emission around the Geminga pulsar by H.E.S.S.

A. Mitchell (ETH, MPIK), S. Caroff (LAPP),
J. Hinton (MPIK), L. Mohrmann (ECAP)

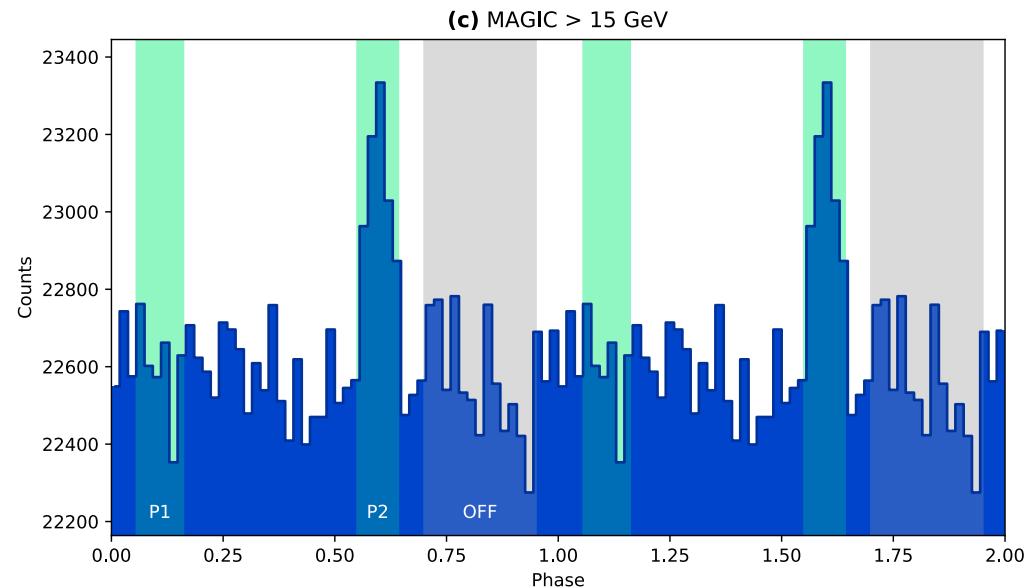
ICRC 2021

Discussion: 20/07/21 (18:00 CEST)



The Geminga Pulsar

- Radio quiet pulsar:
strong gamma-ray and weak radio pulsed emission
- One of the first gamma-ray pulsars detected (SAS-2, COS-B, EGRET)
- One of four pulsars with VHE pulsed emission detected by IACTs
(Crab, Vela, PSR B1706-44)
- Nearby $d \sim 250$ pc
- Older and lower luminosity:
age = 342 kyr,
 $\dot{E} = 3.26 \times 10^{34}$ erg /s
- Pulsars are copious lepton producers – nearby pulsars could help explain positron excess



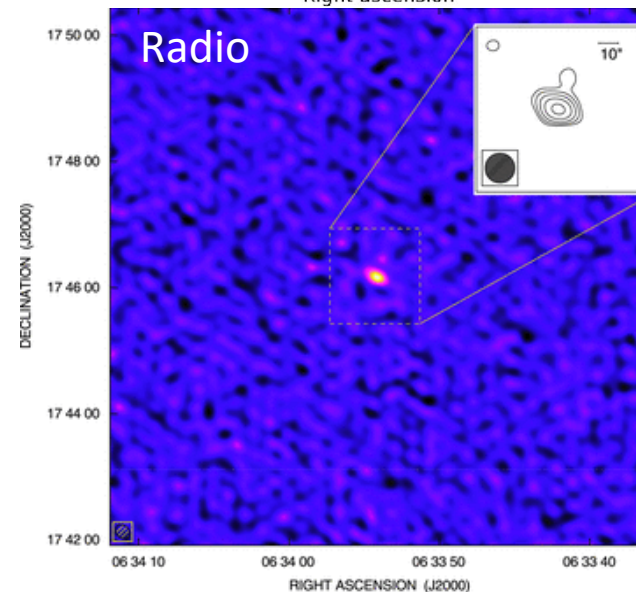
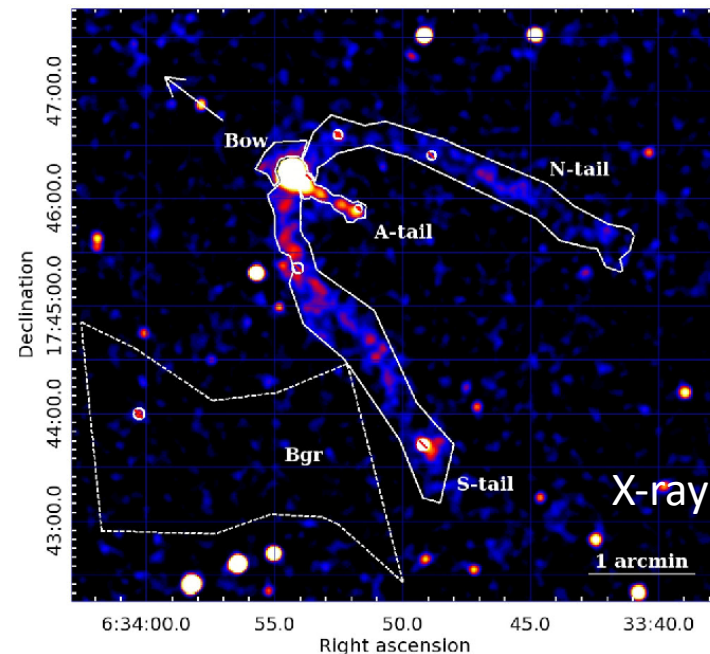
MAGIC collaboration, A&A 643, L14 (2020)

Searches for extended emission

- Previous searches for extended emission in gamma-ray and radio
- X-ray and Radio PWN confirmed (on arcsecond – arcminute scales)
- Detection of extended gamma-ray emission around Geminga found by Milagro & HAWC
- Challenging for IACTs due to large scale emission

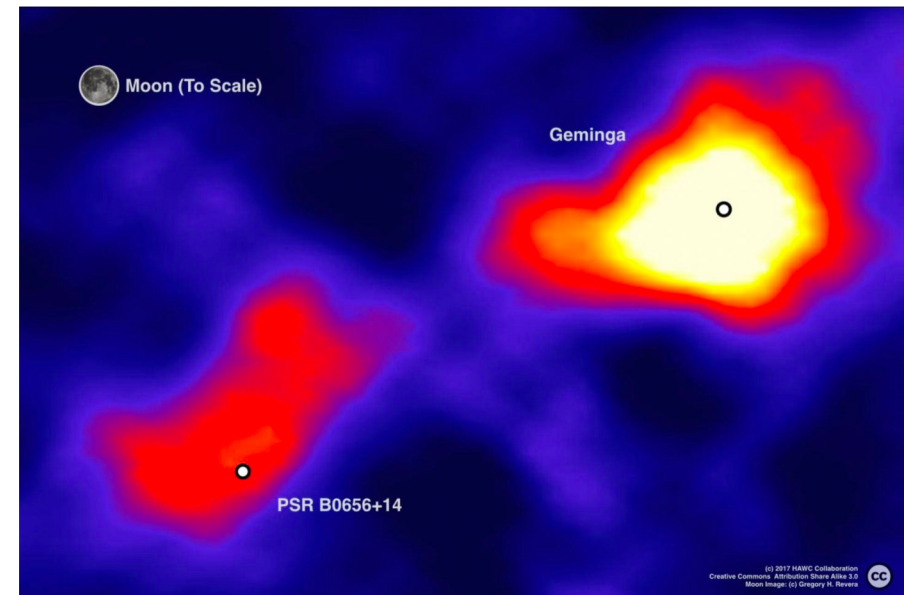
Posselt et al, ApJ 835, 66 (2017)

Pellizzoni et al, MNRAS Lett. 416, L45 (2011)



HAWC detection of extended TeV emission

- HAWC confirms Milagro excess
- Extended emission on $\sim 2^\circ$ scale
- Low diffusion coefficient inferred by HAWC from radial profile of emission
- Would imply Geminga is not local positron source if representative of intervening ISM
- Cool too quickly to reach Earth



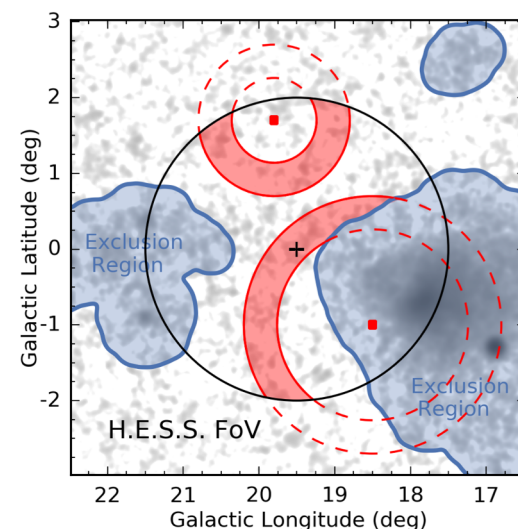
RA-Dec, HAWC collaboration 2017

- CT1-4: operational since 2004
- 108m² mirror area
- 5° field-of-view
- CT5: constructed in 2012
- 614m² mirror area
- 3.2° field-of-view
- 50 GeV – 50 TeV range
(c.f. HAWC ~ 1 – 100 TeV)
- ~0.1° angular resolution
(c.f. HAWC ~0.2° - 1°)



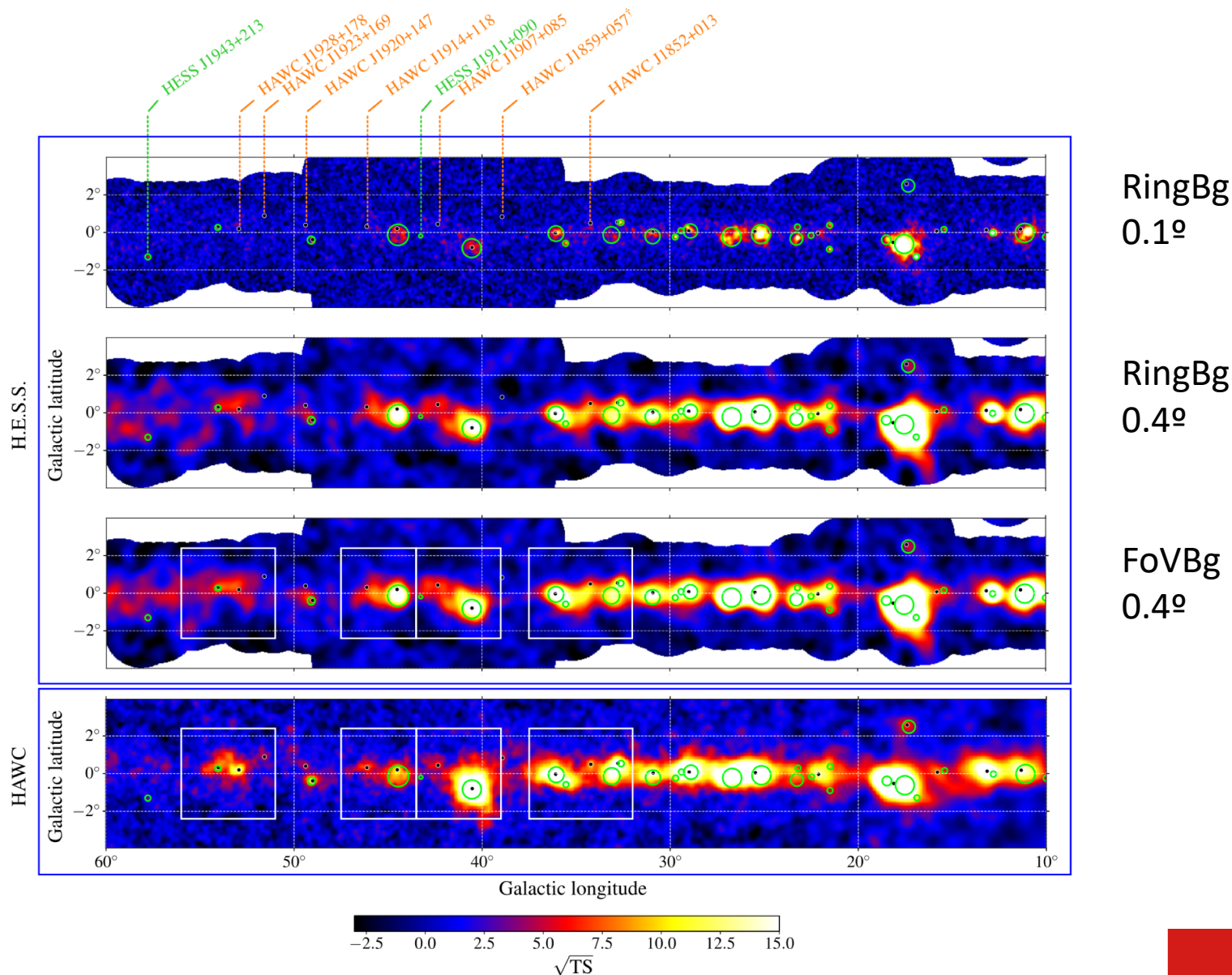
HAWC - H.E.S.S. analysis comparison study

- Recent dedicated effort in understanding analysis differences
- Explored common Galactic plane
- Ring Background:
fixed offset from test position, estimate from data outside exclusion regions
- Field-of-View Background:
use acceptance map for background estimation, assuming radial symmetry
- On-Off Background:
treat entire field of view as On; background estimated from Off data taken from empty sky regions (under similar conditions)



H.E.S.S. Collaboration,
A&A 612, (2018) A1

HAWC - H.E.S.S. analysis comparison study



H.E.S.S. Observations 2006-2008, 2019

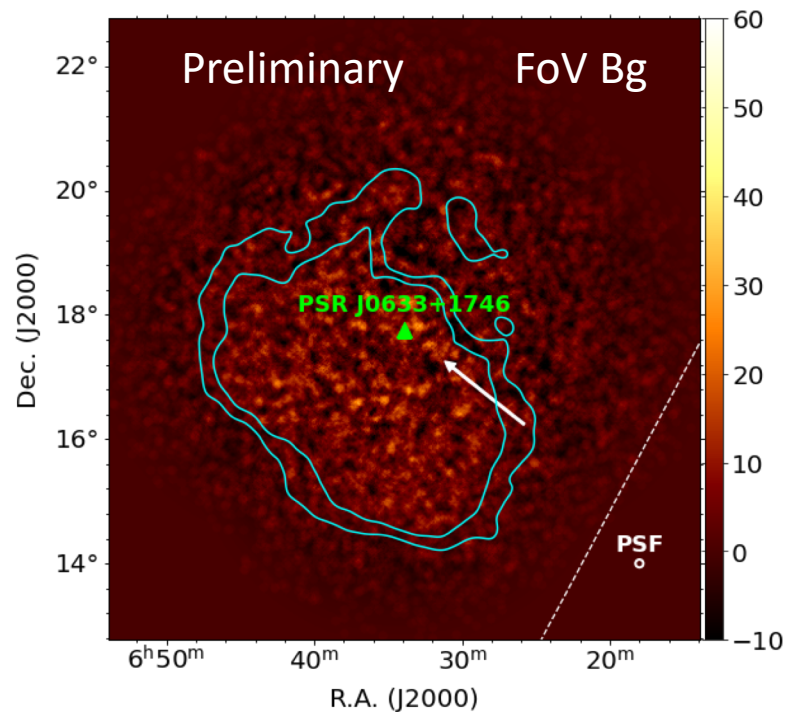
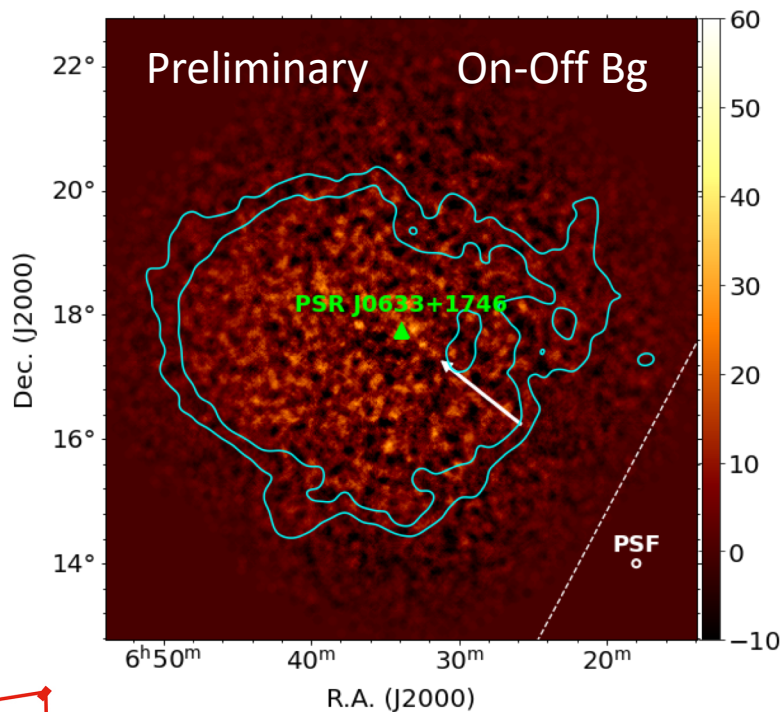
- Data taken in 2006 and 2008
- 0.5° and 0.7° wobble offset
- 14.2 hours total livetime
- Observations with CT1-4

Time Period	Exposure	Zenith angle
Nov 2006	7.7 hours	42.2°
Jan-Feb 2008	6.5 hours	42.0°
Jan-Mar 2019	27.2 hours	43.5°

- No significant excess seen at the time
- Re-analysis applying lessons learnt from HAWC-H.E.S.S. analysis comparison study
 - Detection of extended emission around the Geminga pulsar
- Observations in 2019 at large wobble offset $\pm 1.6^\circ$
- Analysis using CT1-4 only (5° field-of-view, cf. 3.2° for CT5)

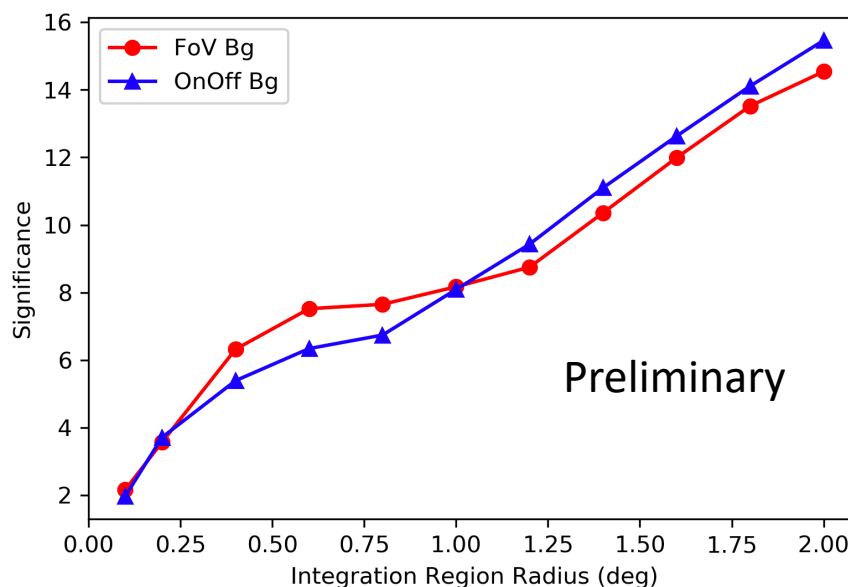
H.E.S.S. detection of extended TeV emission: 2019

- Confirm detection in an independent dataset
- Centred on pulsar: 1° radius integration region
- Two background methods: On-Off and field-of-view (FoV)
 - ~ 8 sigma detection with both methods



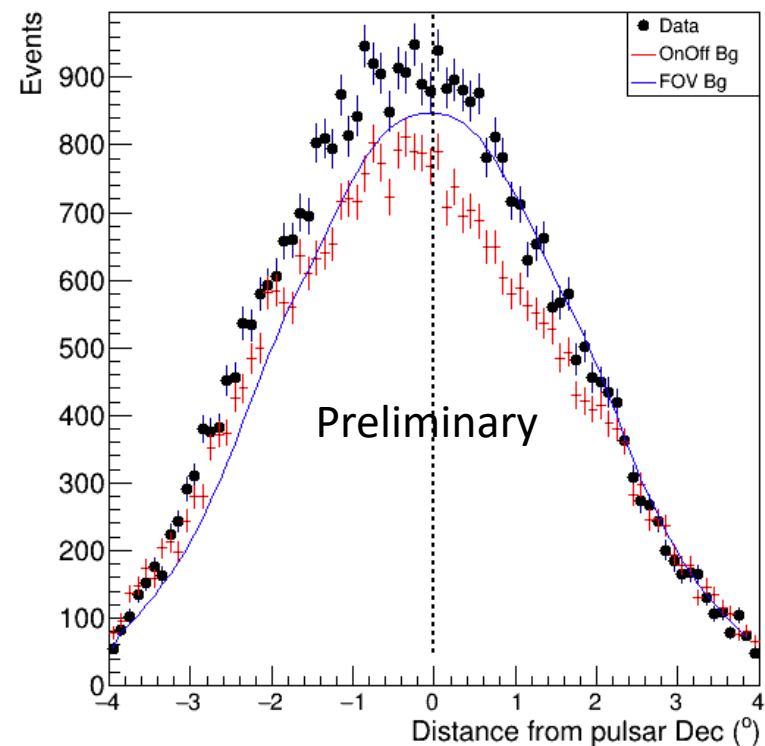
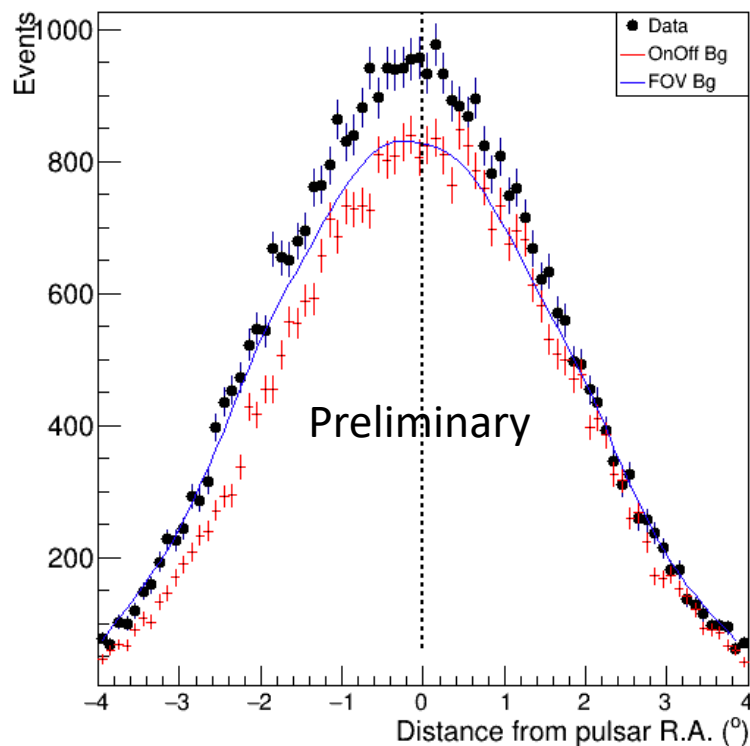
Integration region radius

- Significance increases with increasing radius
- Curve does not flatten
- True extent $> 2^\circ$ radius
- Likely that significant emission continues to fill the field of view
- Compared to previous searches with IACTs, H.E.S.S. now probes much larger angular scale



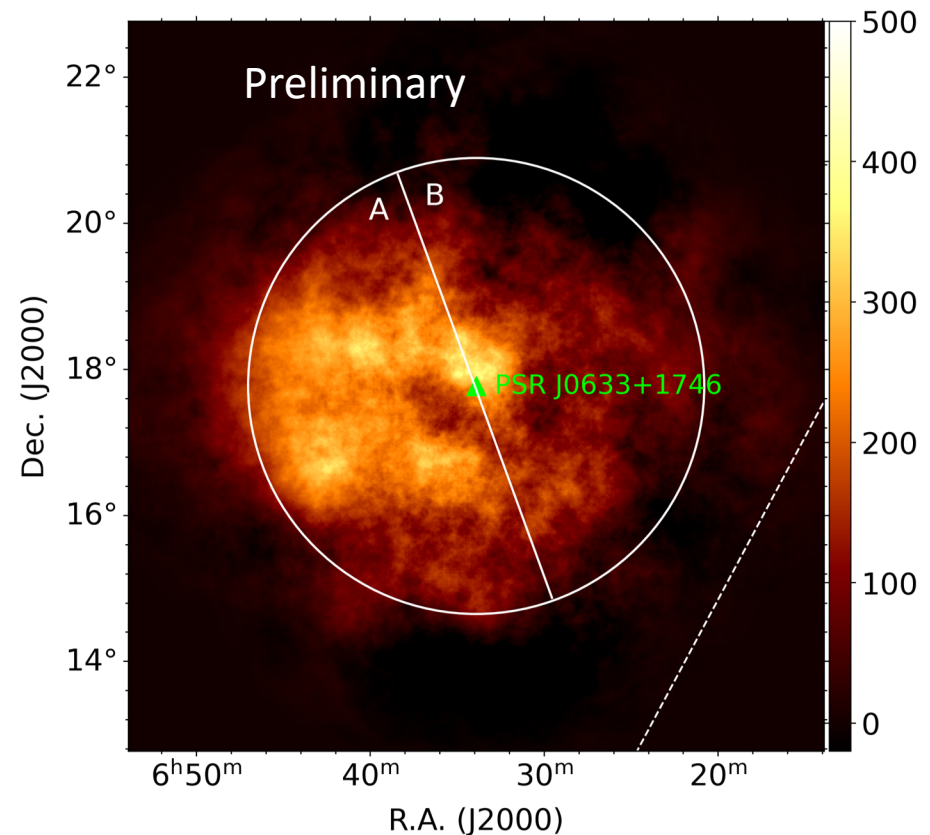
Slice Profiles

- Emission projected onto R.A. and Dec axes
- Compared to background estimation from two methods
- Clear excess – also clear discrepancies



Asymmetric emission?

- There appears to be an asymmetry to the emission
- Form Azimuthal profile and find major axis $\sim 110^\circ$
(averaged over the independent analyses; On-Off and FoV background)
- Split region along minor axis
- Compare ratio of the two sides
- Find emission at least $\sim 40\%$ brighter on side A than side B



This slide is available in the video recording

This slide is available in the video recording

Outlook

- Detecting large, extended sources with IACTs is challenging, but possible
- True emission extent likely larger than H.E.S.S. field-of-view
→ even with large wobble offset
- TeV gamma-ray emission appears to be asymmetric
- Good IACT energy resolution – spectral analysis from inner 1° of pulsar
- Analysis results with the 2019 dataset confirm the detection in archival data
- A diffusion model applied to the morphological and spectral results will be presented in a forthcoming publication

Thank you for your attention

Any Questions?

amitchell@phys.ethz.ch, sami.caroff@lapp.in2p3.fr

contact.hess@hess-experiment.eu

