Long-term Studies of Sgr A* with H.E.S.S.

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on behalf of the H.E.S.S. collaboration

H.E.S.S.

Introduction to H.E.S.S.

Cherenkov telescopes located in Namibia

H.E.S.S. I:
- four 12m telescopes from 2003 – 2012
- 960 pixels, each of size 0.16°
- Field of view : 5°
- Energy threshold around 100 GeV

H.E.S.S. II:
- a 28m telescope added to the centre
  of the array in 2012
- 2048 pixels, each of size 0.067°
- Field of view : 3.6°
- Aim to significantly reduce the energy
 threshold (below 100 GeV)
→ overlap with Fermi -LAT in spectra

The Galactic Center viewed by H.E.S.S.

- 2004 – 2005
- livetime: 55 hrs
- two point sources detected:
  pulsar wind nebula G0.9+0.1 and
  HESS J1745-290
- diffuse emission is seen when point sources
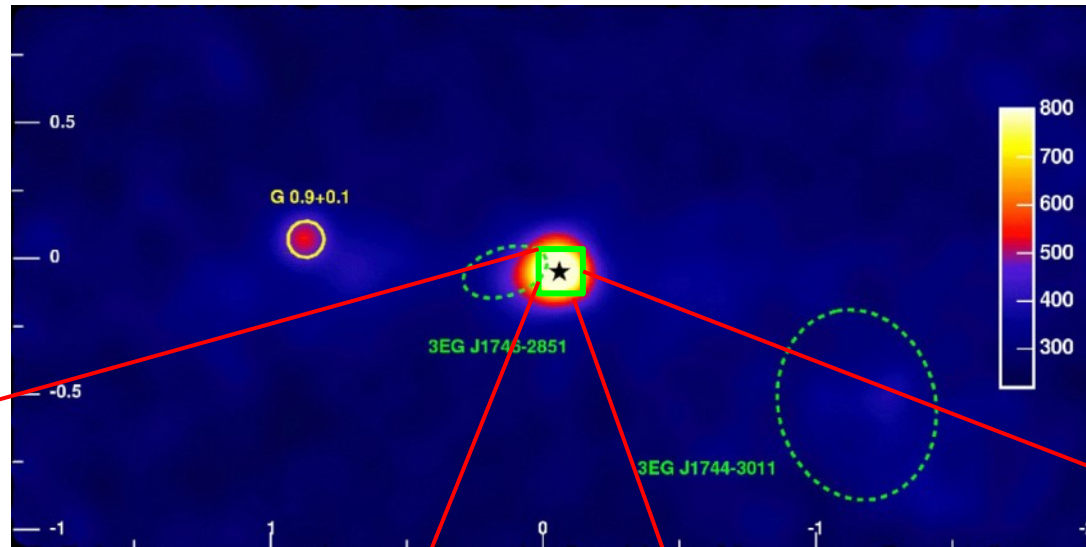 are subtracted
  → powerful cosmic ray accelerator

Two bright point-like sources:
➢ HESS J1745-290 : unidentified
➢ G 0.9+0.1 : SNR/PWN association

Aharonian et al. Nature04467 (2006)
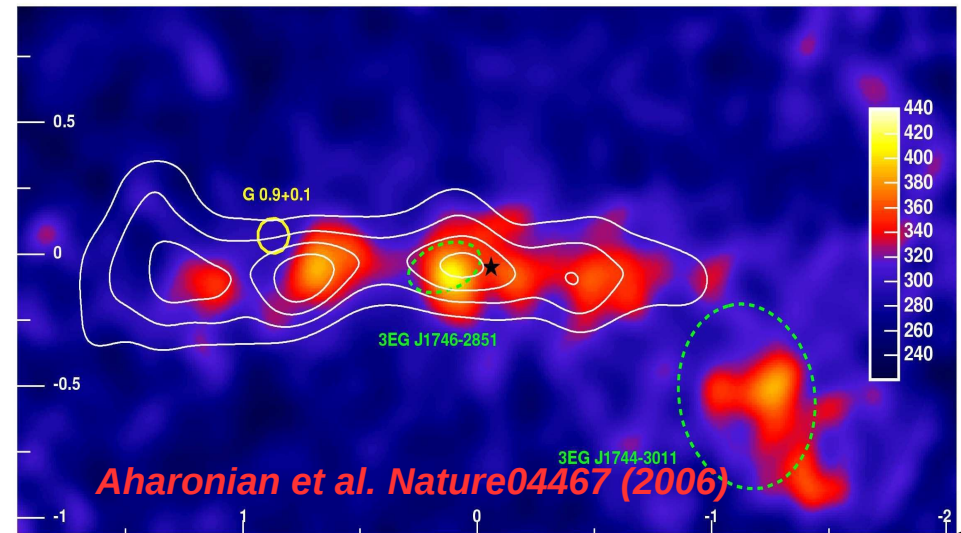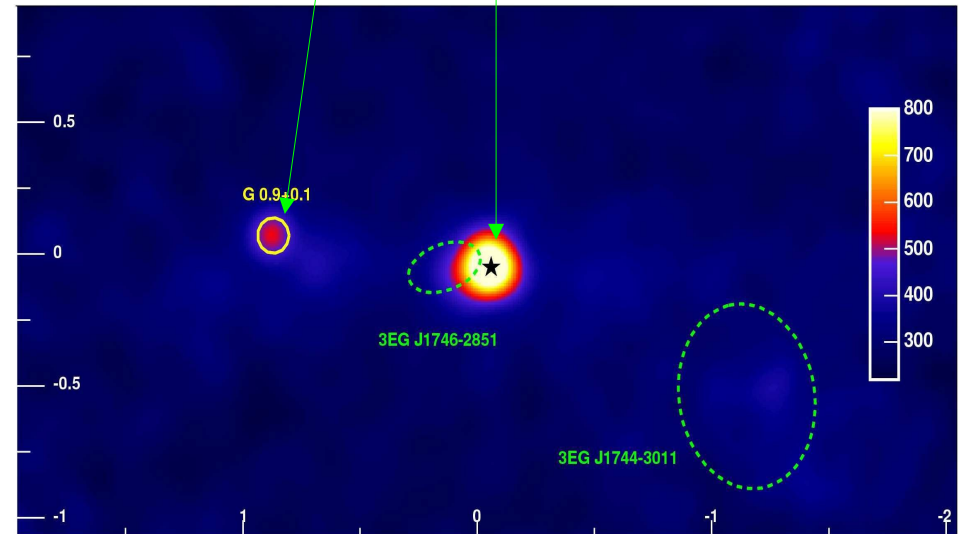
Possible Counterparts of HESS J1745-290

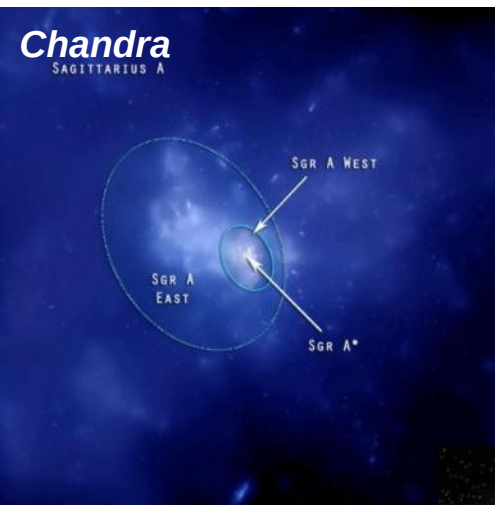SNR Sgr A East

Chandra
SAGITTARIUS A
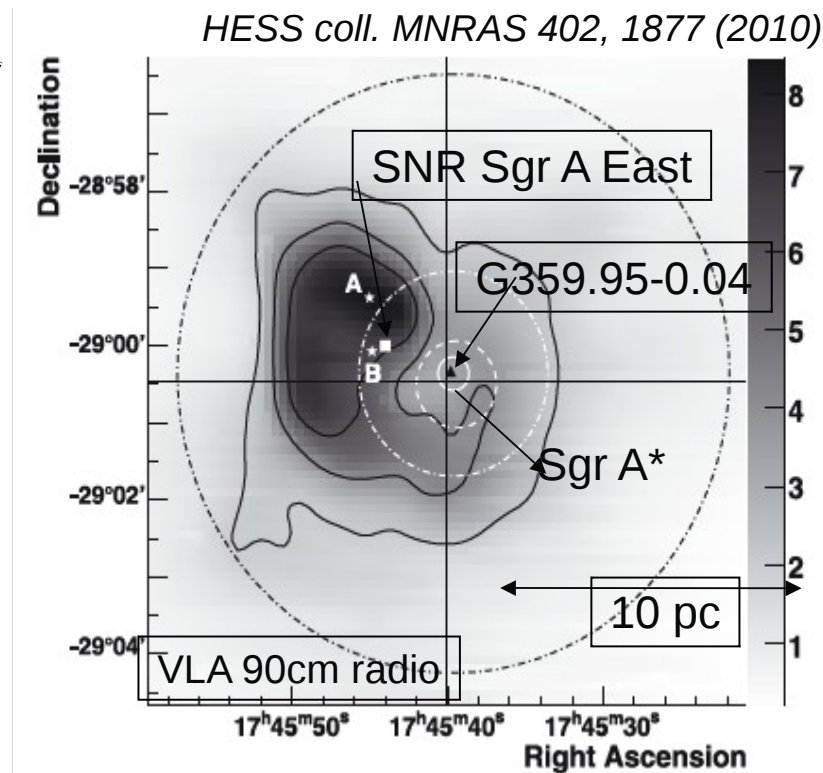
PWN G359.95-0.04

Chandra

SMBH Sgr A*   Dark Matter?

3
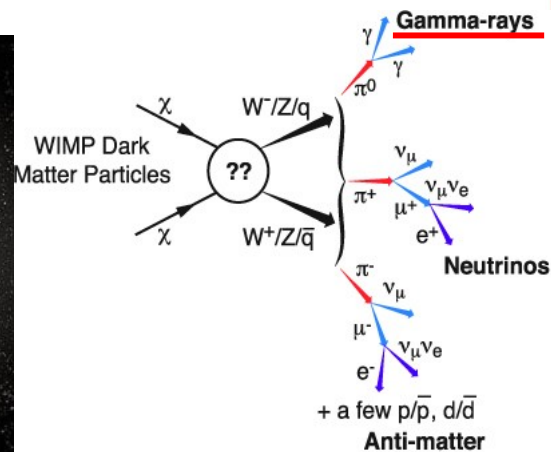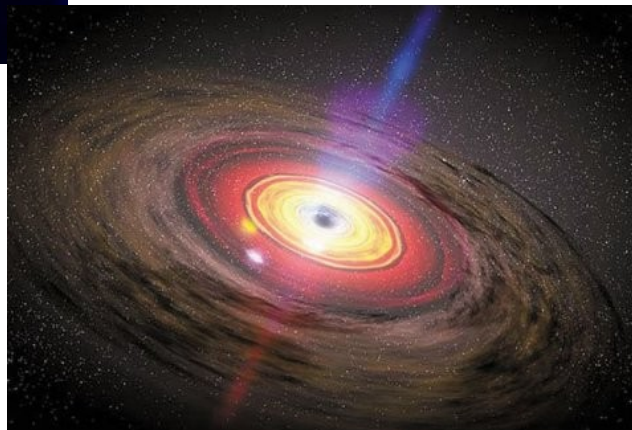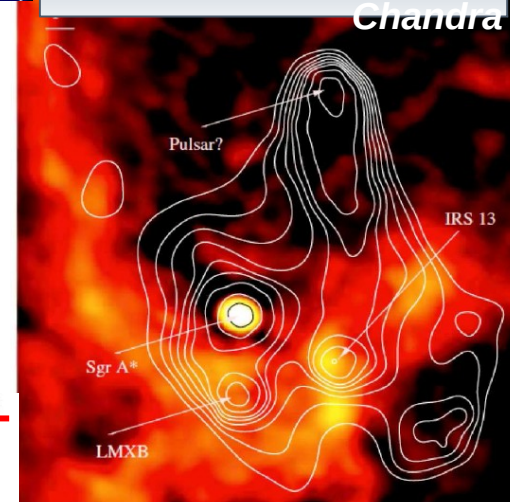
Position of HESS J1745-290 (2004 -2006)

HESS improved pointing analysis : 30''->6''

Fermi symposium 2009

HESS coll. MNRAS 402, 1877 (2010)
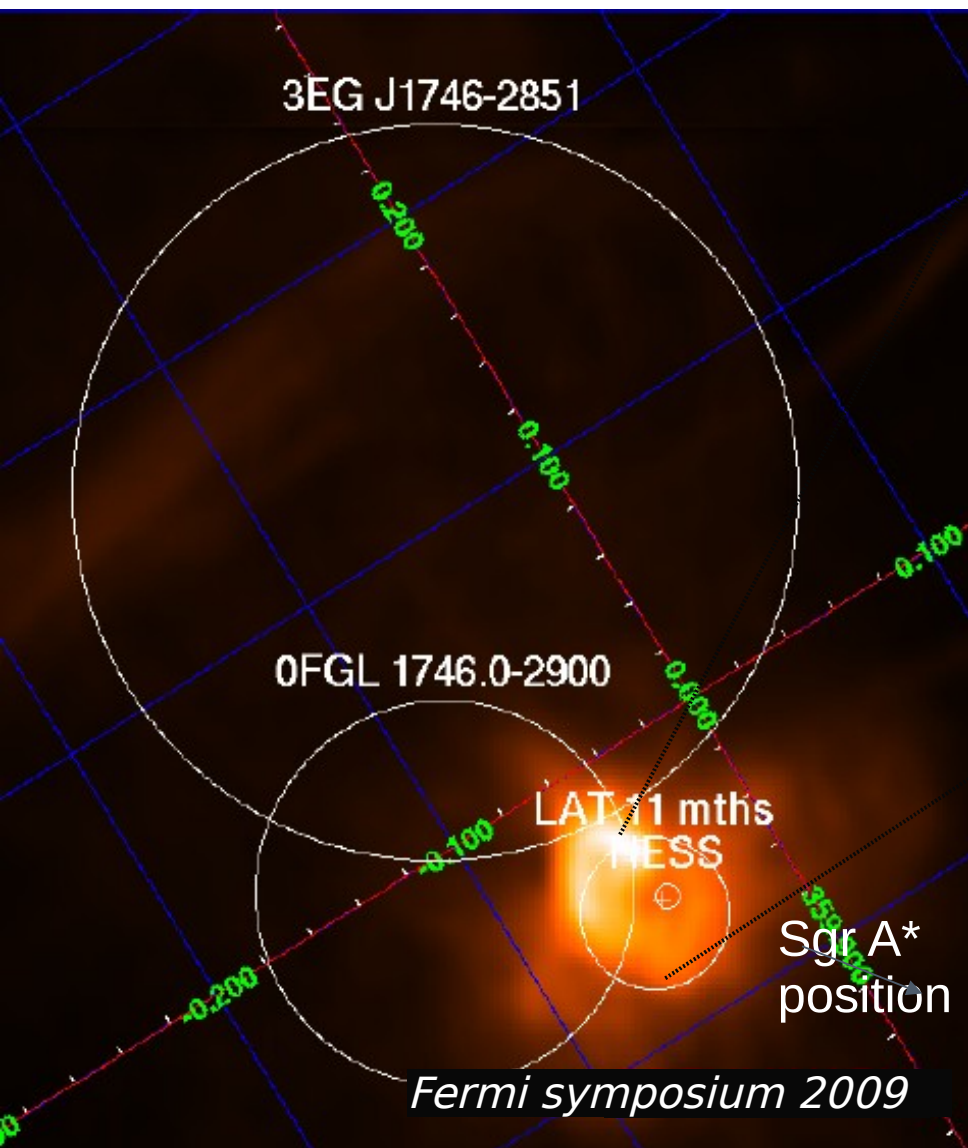
- ➢ position:
  l=359°56'41.1''± 6.4''± 6''
  b=-0°2'39.2'' ± 5.9'' ±6''
- ➢ centroid emission located at 7''±12'' from Sgr A*
- ➢ Sgr A East excluded at the 7σ C.L.
- ➢ G359.95-0.04 and Sgr A* still inside error bars (8.7'' from Sgr A*)

Spectrum of HESS J1745-290 (2004 - 2006)

- Livetime: 93h

- 160 GeV < E < 70 TeV

- Best fit: Power law with exponential cutoff

- Ecut ~ 15 TeV

- spectral index ~ 2.2
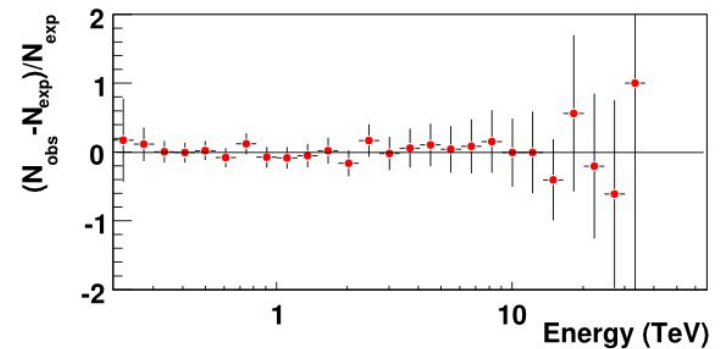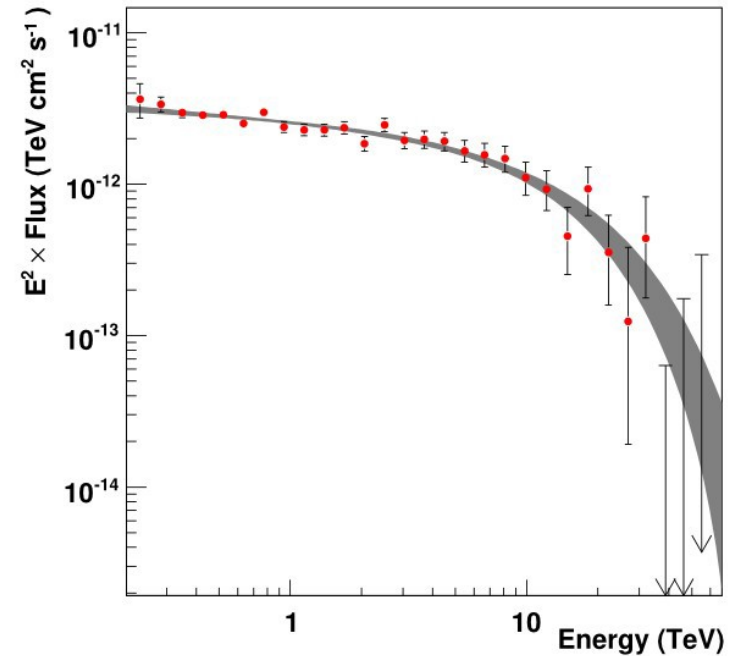
Spectrum of HESS J1745-290
(Full H.E.S.S. I dataset)

- data: 2004 – 2012

- livetime: 220 hrs

- compatible with 2009 paper

- Best fit: power law with exponential cutoff

- spectral index ~ 2.1

- Ecut ~ 11 TeV

Updated spectrum
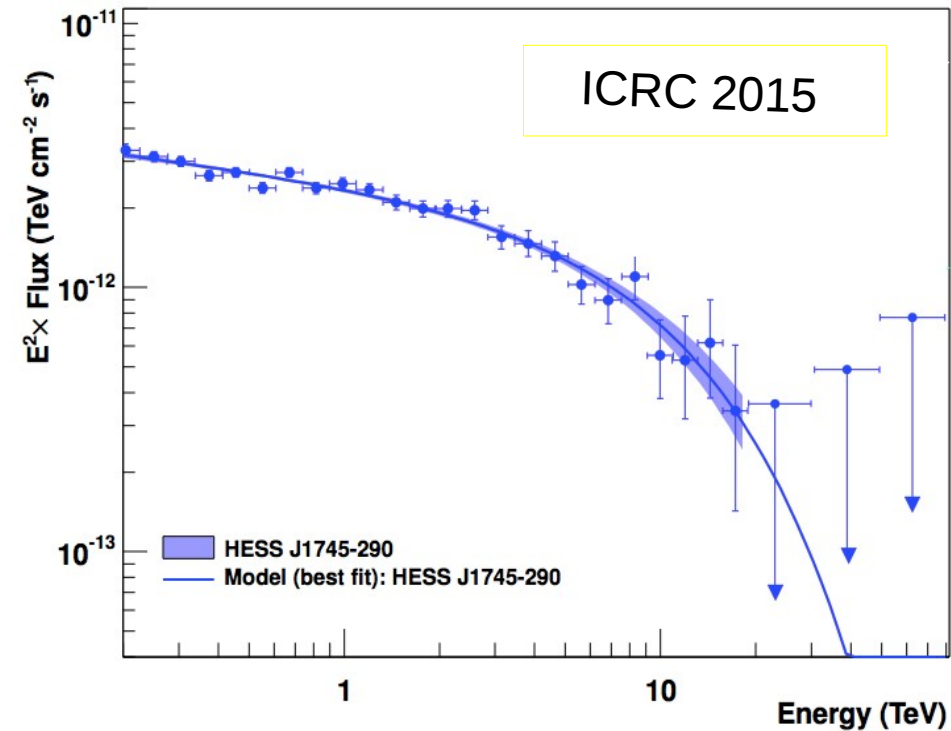
ICRC 2015

HESS-II RESULTS

GC Spectra

- Old H.E.S.S. + Fermi Lat Specturm

GC Spectra

- Old H.E.S.S. + Fermi Lat Specturm

HESS II Observations

- 2013 – early 2014
- Livetime: 58.6 hrs
- Mean zenith: 22 degrees
- Mean offset: 0.5 degree

H.E.S.S. Preliminary
Galactic Centre

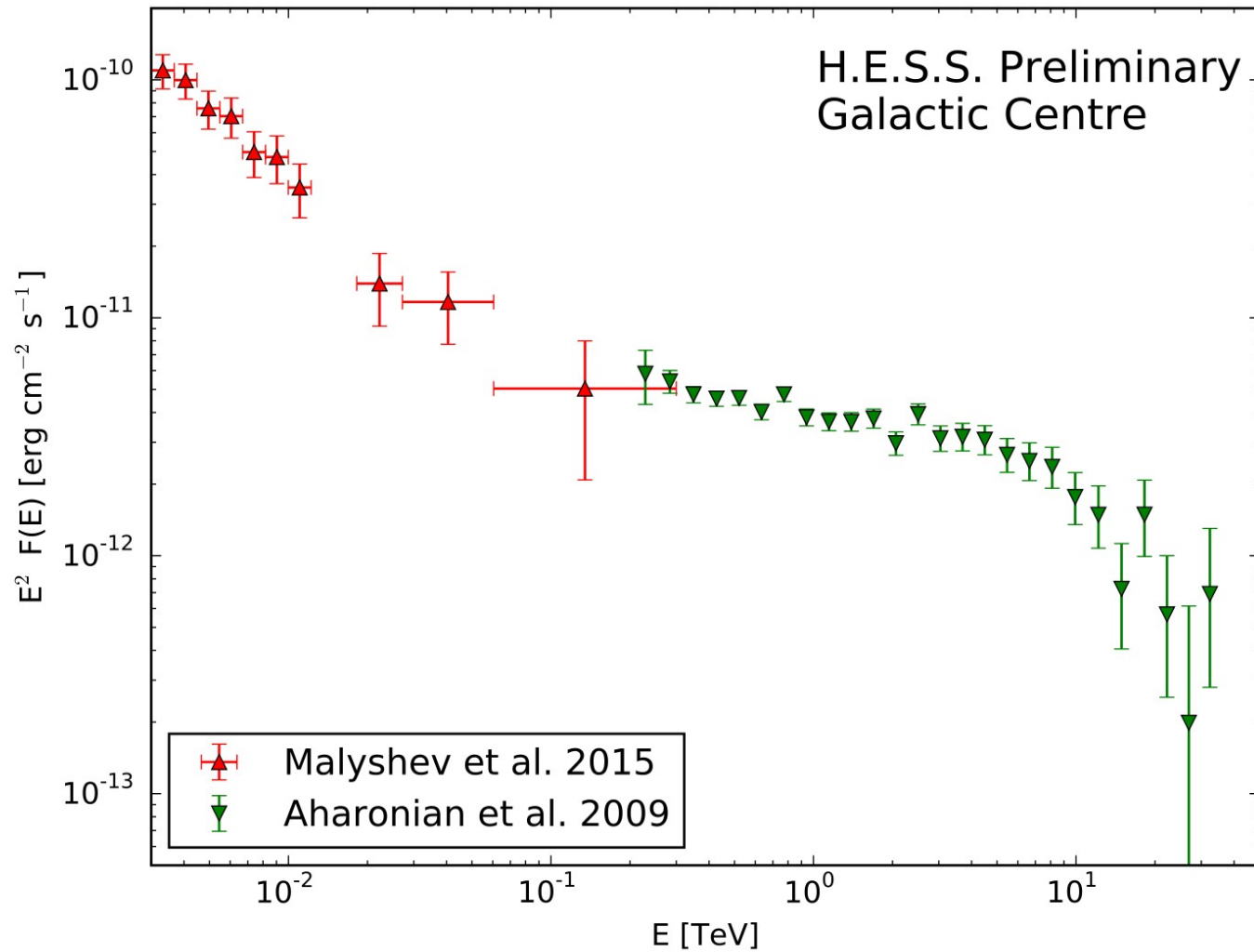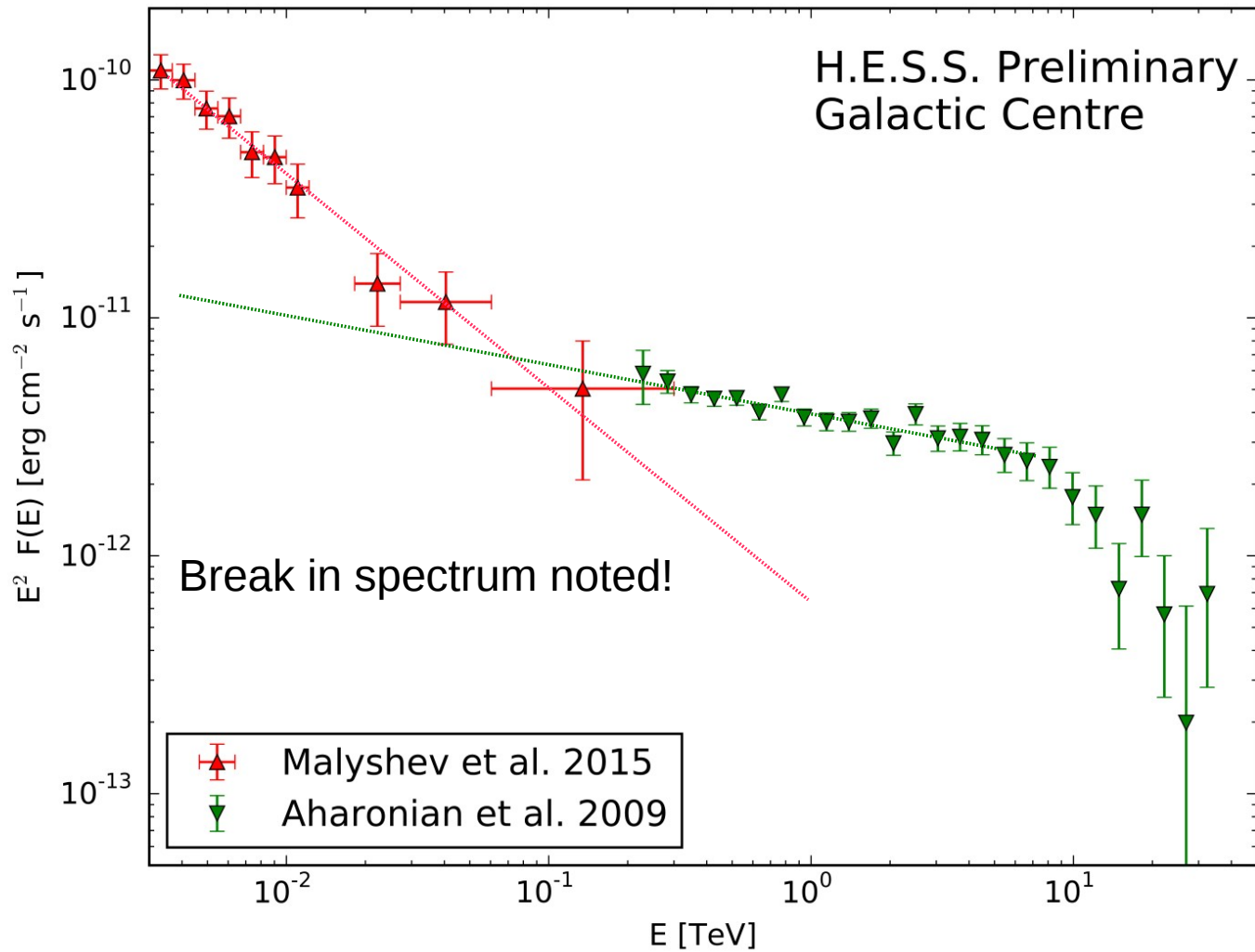58.6 hours
40σ detection
3739.5 excess events

θ^2 (deg^2)
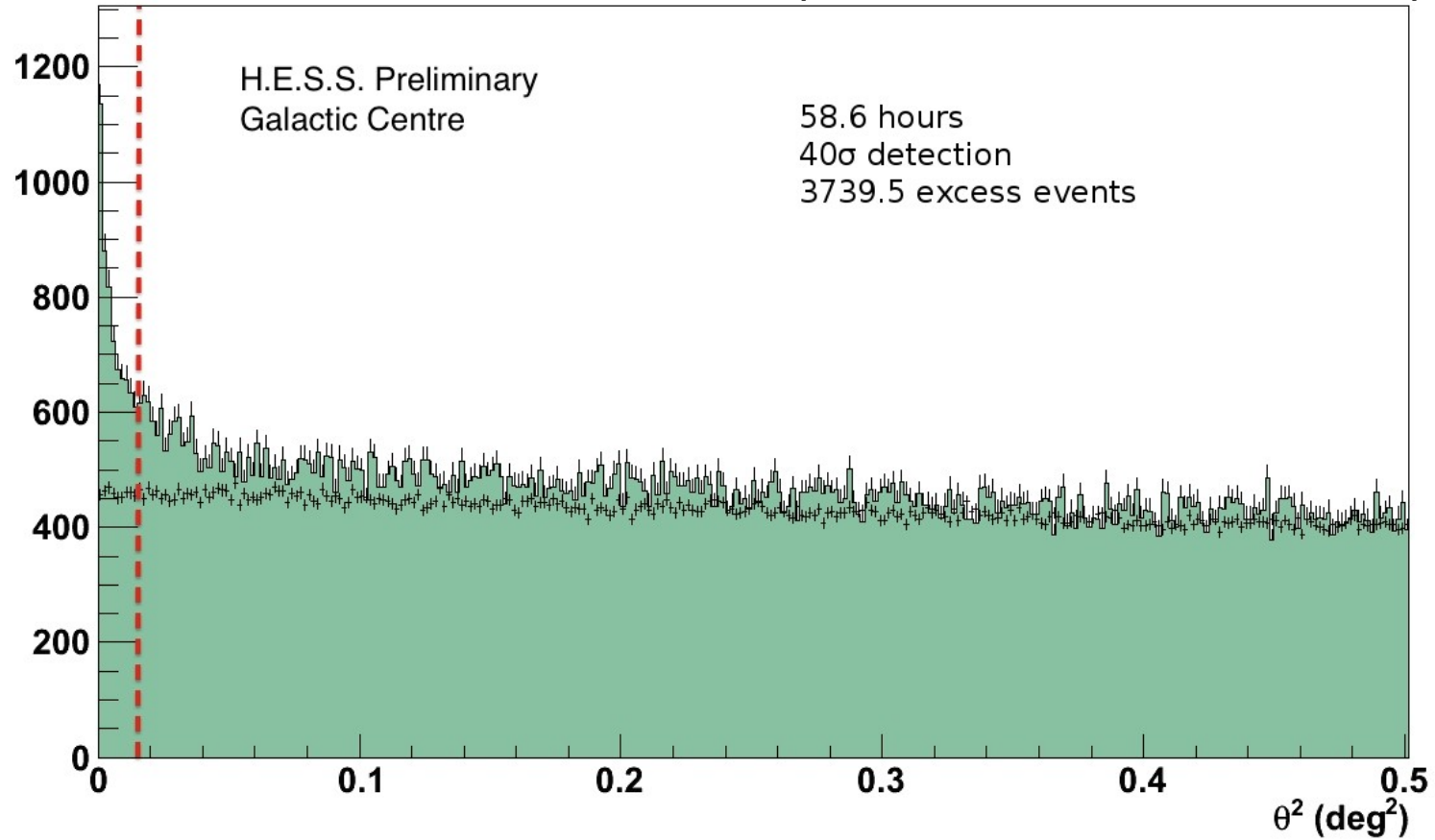
GC Spectrum (H.E.S.S. II)

(ICRC 2015/ arxiv:1509.03425)

- Power-law fit acceptable

- Index: 2.28 ± 0.04

- Flux (1 TeV): $2.54 \pm 0.1 \times 10^{-12}$ $cm^{-2}s^{-1}TeV^{-1}$

- Well compatible with previously published spectrum (Aharonian et al. 2009)

- No high energy cut-off seen due to low statistics

H.E.S.S. Preliminary
Galactic Centre

Legend:
— Systematic Error (opt. eff. only)
— Best Fit PowerLaw
● H.E.S.S. II combined

Y-axis: $F(E)$ $[cm^{-2}\ s^{-1}\ TeV^{-1}]$
X-axis: E [TeV]
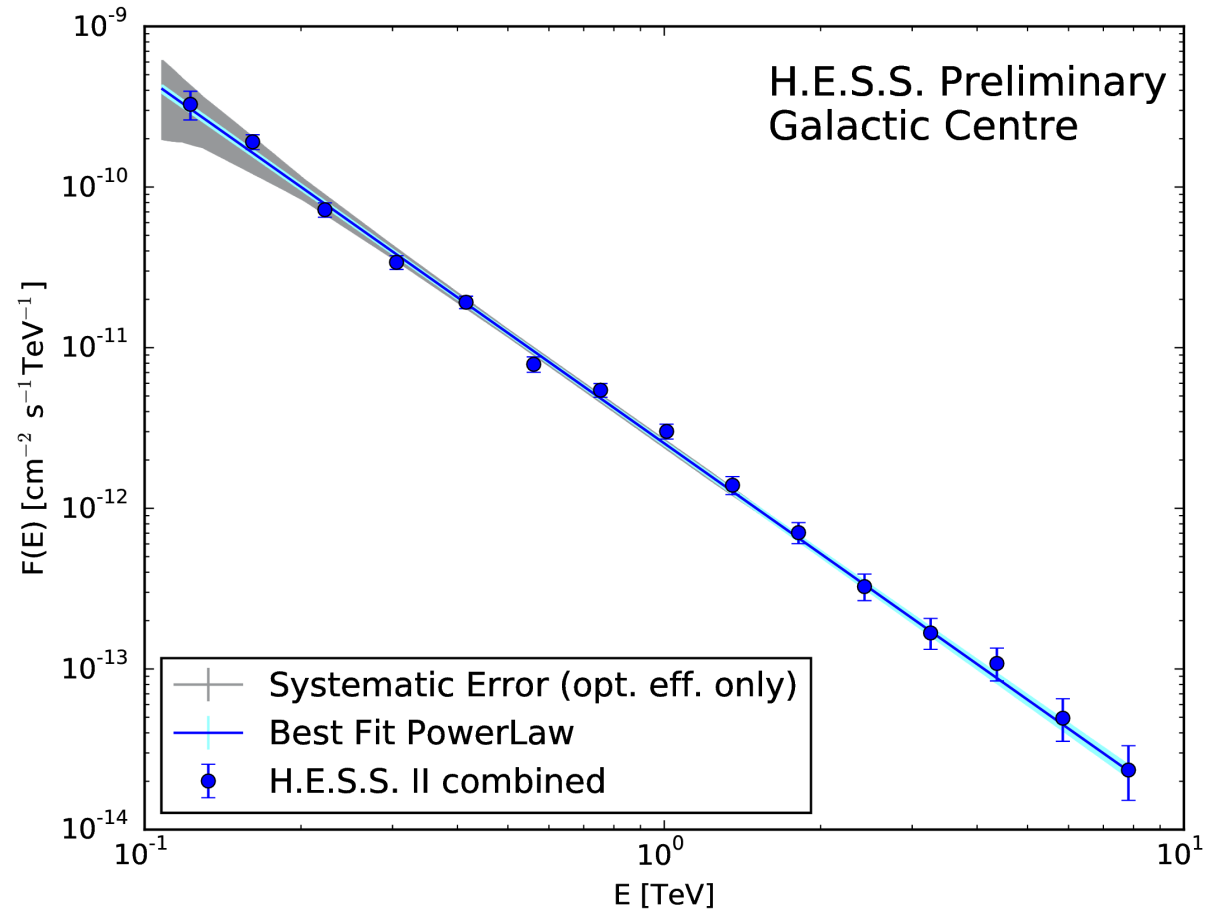
Spectral Energy Distribution

- The break can be connected
  with H.E.S.S. II data

Note!
Spectrum extracted in different ways
H.E.S.S aperture photometry
Fermi-LAT Full region model

H.E.S.S. Preliminary
Galactic Centre

Legend:
- Malyshev et al. 2015
- Aharonian et al. 2009
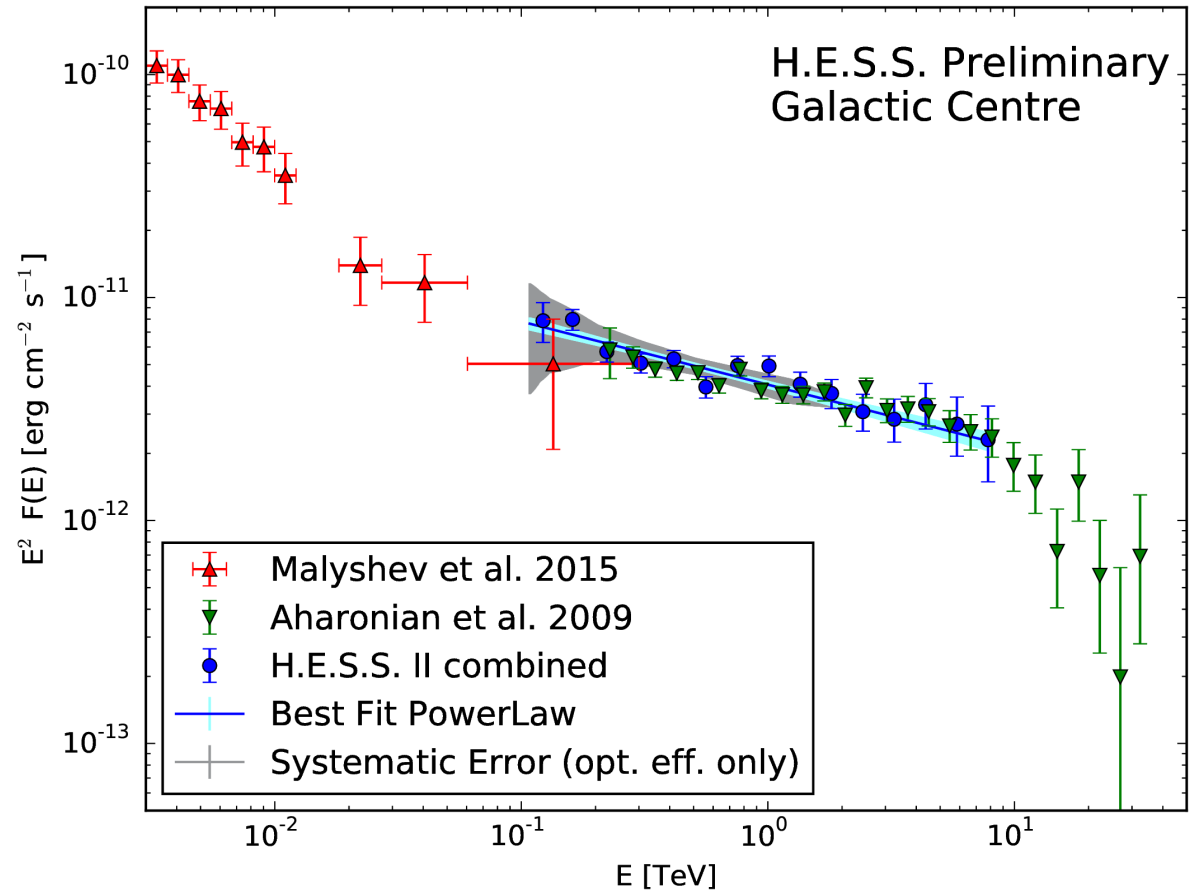- H.E.S.S. II combined
- Best Fit PowerLaw
- Systematic Error (opt. eff. only)

Axes: $E^2\,F(E)$ [erg cm^{-2} s^{-1}] vs E [TeV]

Variability Study of HESS J1745-290

- No signs variability in VHE lightcurve observed based on 93 hours of data

- Simultaneous H.E.S.S. and Chandra observations in 2005
- X-ray flare detected
  - 1-10 keV
  - 1600s duration
  - 9x quiescent level
- <u>No increase of gamma flux >1 TeV (factor 2 increase excluded at 99%CL)</u>

=> disfavours scenarios where keV and TeV emission are associated with the same parent population

Aharonian et al. A&A 503, 817 (2009)
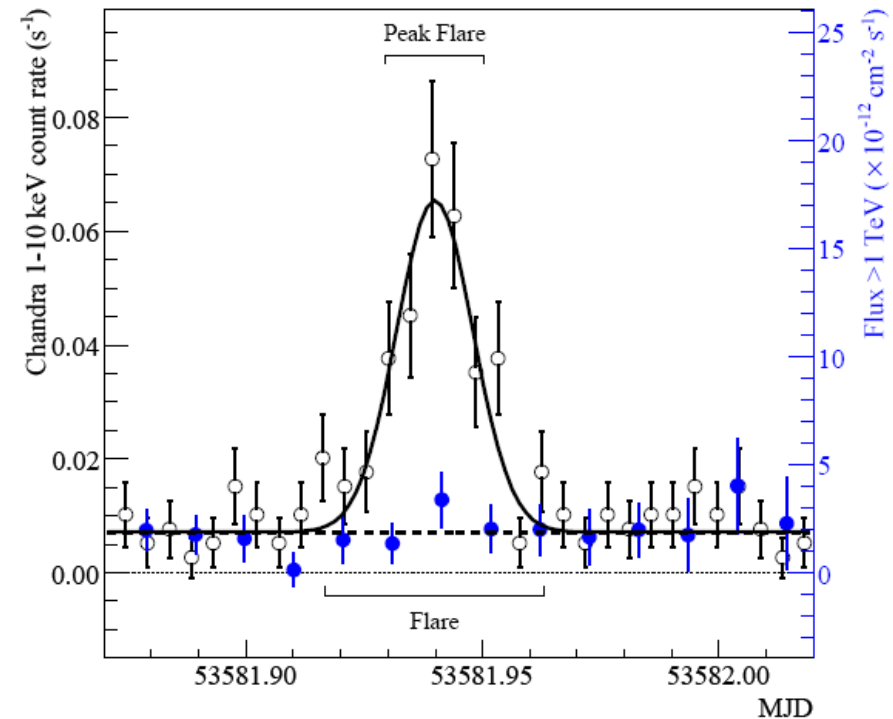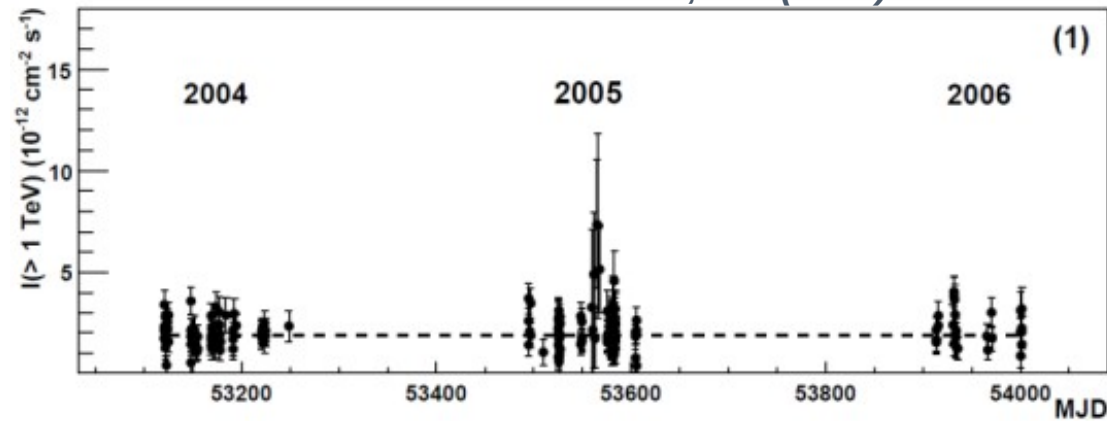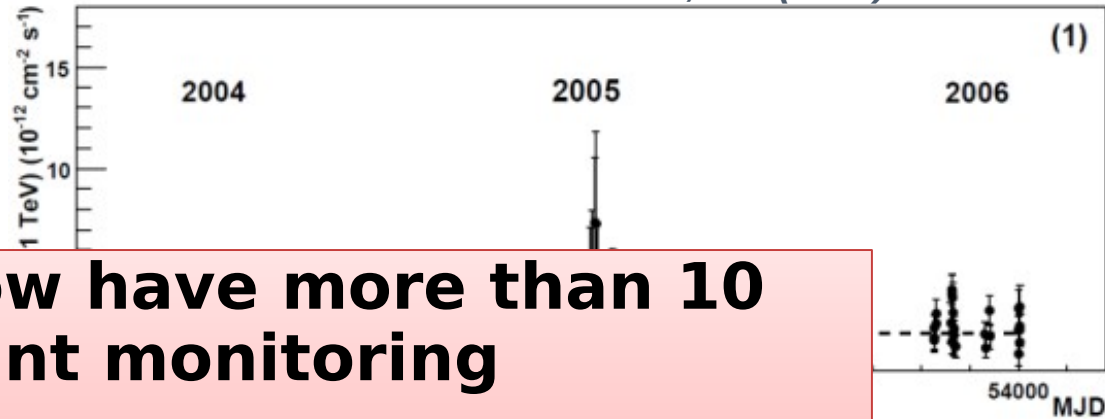
HESS Coll, A&A 492, L25 (2008)

Variability Study of HESS J1745-290

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  - 1-10 keV
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- No increase of
  (factor 2 increa
  99%CL)

=> disfavours
and TeV emiss
with the same
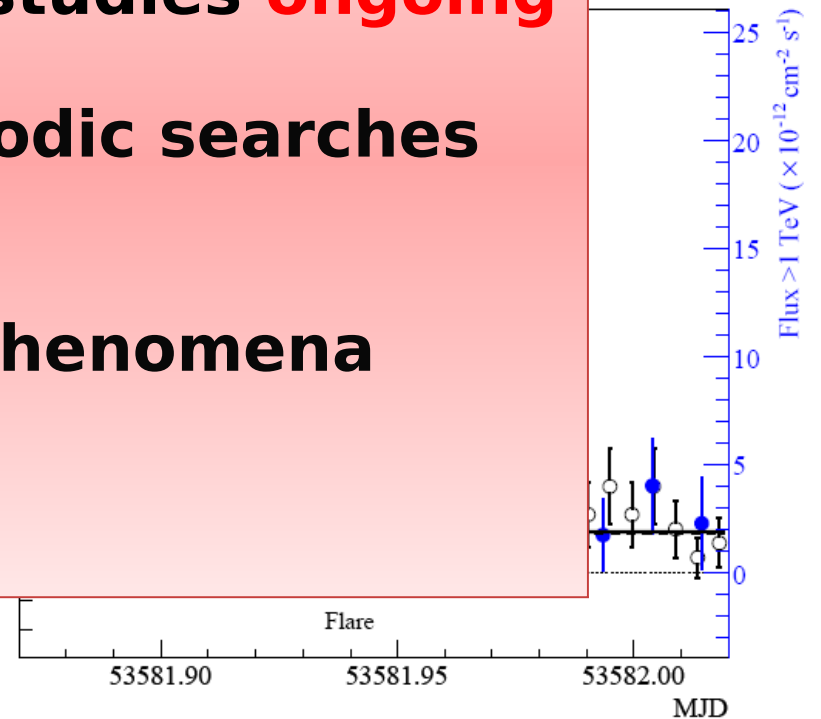
However we now have more than 10 years of constant monitoring

- **long-term variability studies ongoing**

- **short-term quasi-periodic searches ongoing**

- **search for transient phenomena ongoing**

Stay tuned!

Flare

53581.90   53581.95   53582.00
MJD

Summary

- H.E.S.S. has monitored the GC (HESS J 1745-290) for > 10 years
Spectrum:
- updated spectrum compatible with previous results
- Observation of Galactic Center with the H.E.S.S. II array have been made down to almost 100 GeV
- Spectrum well fit by a power-law, seems to smoothly continue from spectrum seen
  in HESS I
- Threshold not yet low enough to fully describe spectral break
- Investigations into the systematic uncertainties are still underway, should allow us to reduce the energy threshold and the systematic error band size

Variability Study:
- Long-term and short-term variability study ongoing to search for transient and periodic phenomena
- Different tests implemented already

BACKUP SLIDES

An Introduction to Transient Tests

- a set of statistical tests based on photon arrival times rather than flux
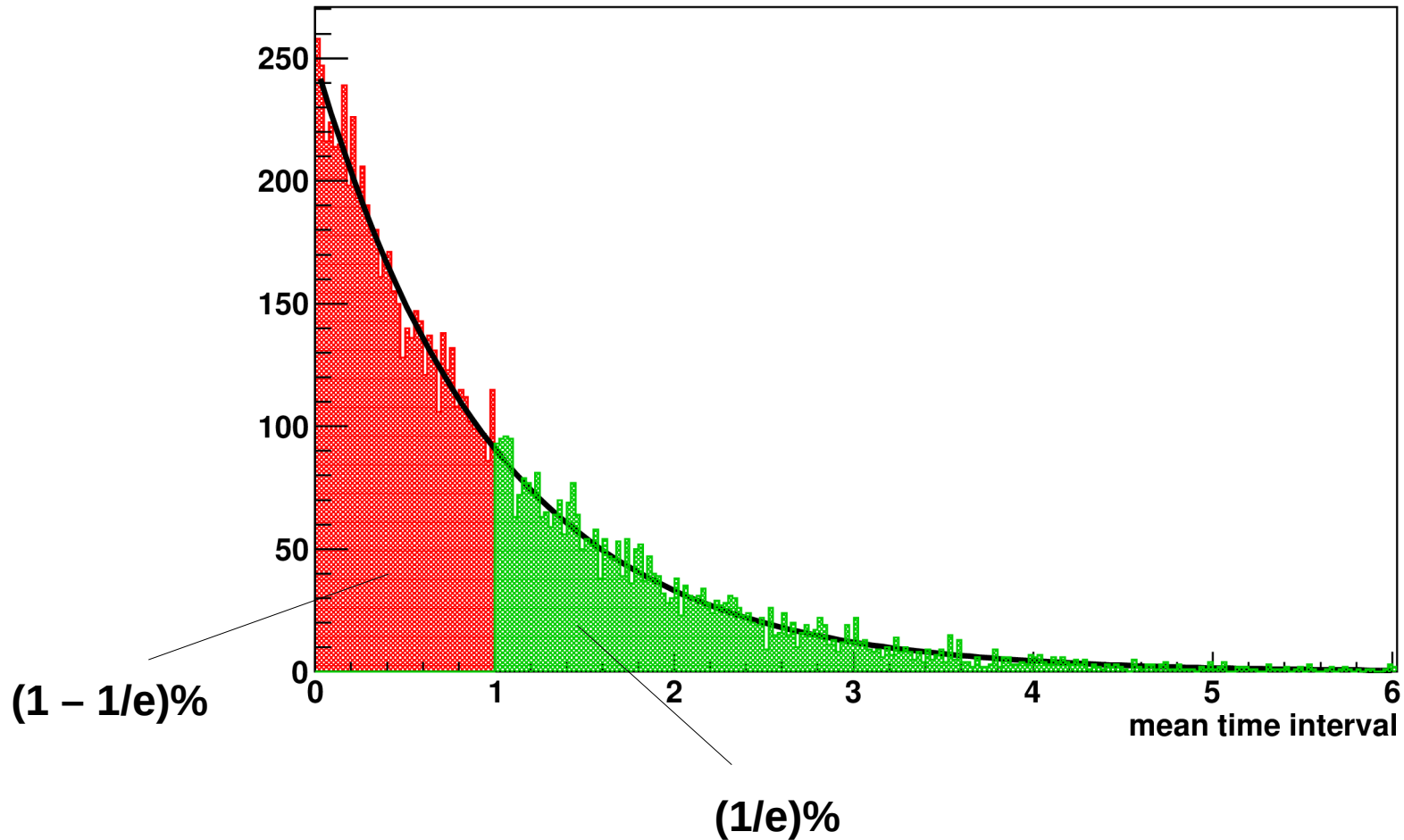
 - Tests included:

 Exp test (Prahl 1999)
   - check for deviation from Poisson statistics according to time   intervals

 Cumulative Sum test (Brun 2011)
   - check for deviation from the mean value according to time intervals

Exp test

From Prahl (1999)

Time interval distribution of 10000 simulated events following Poisson distribution with a mean interval = 1

(1 − 1/e)%

(1/e)%

mean time interval

Exp test Estimator

- M estimator

$$M = \frac{1}{N} \sum_{\Delta T_i < C^*} \left(1 - \frac{\Delta T_i}{C^*}\right)$$

- where C* = mean time interval
- - for periodic distribution: M ~ 0
- - for Poisson distribution: M ~ 1/e
- - for burst-like distribution: M > 1/e
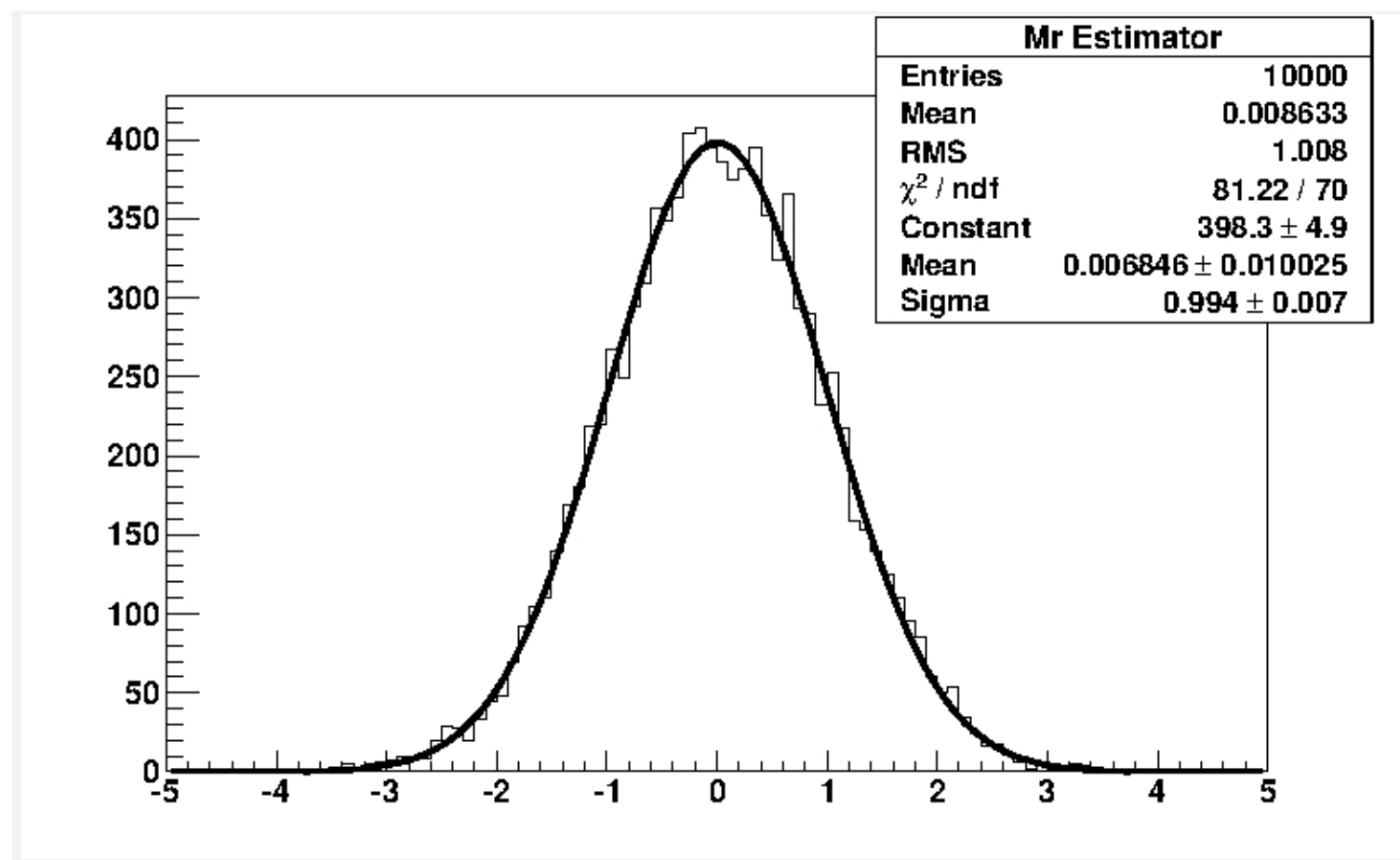
- Normalized M estimator (Mr estimator)
- - corresponding to a normal distribution for Poisson statistics

$$M_r = \frac{M - (1/e - \alpha/N)}{\beta/\sqrt{N}}$$

Exp test

- 10000 simulations performed for 1000 events following Poisson statistics
- an Mr value for each simulation
- distribution corresponds to normal distribution

Cumulative Sum Test

$$\chi_i = \sum_{k=1}^{i} (\Delta T_k - <\Delta T>)$$

- Xi = cusum value;   <ΔT> = mean time interval;
- ΔTk = individual time interval
- In a burst, ΔTk <   <ΔT> → Xi gets small
- otherwise → fluctuation

Cusumulative Sum Test

- - Simulation of 10000 events following Poisson statistics
- → fluctuation