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

H Poon, A Viana, R D Parsons, M Holler, J King,
V Lefranc, E Moulin, F Brun, N Chakraborty

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 2002 – 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

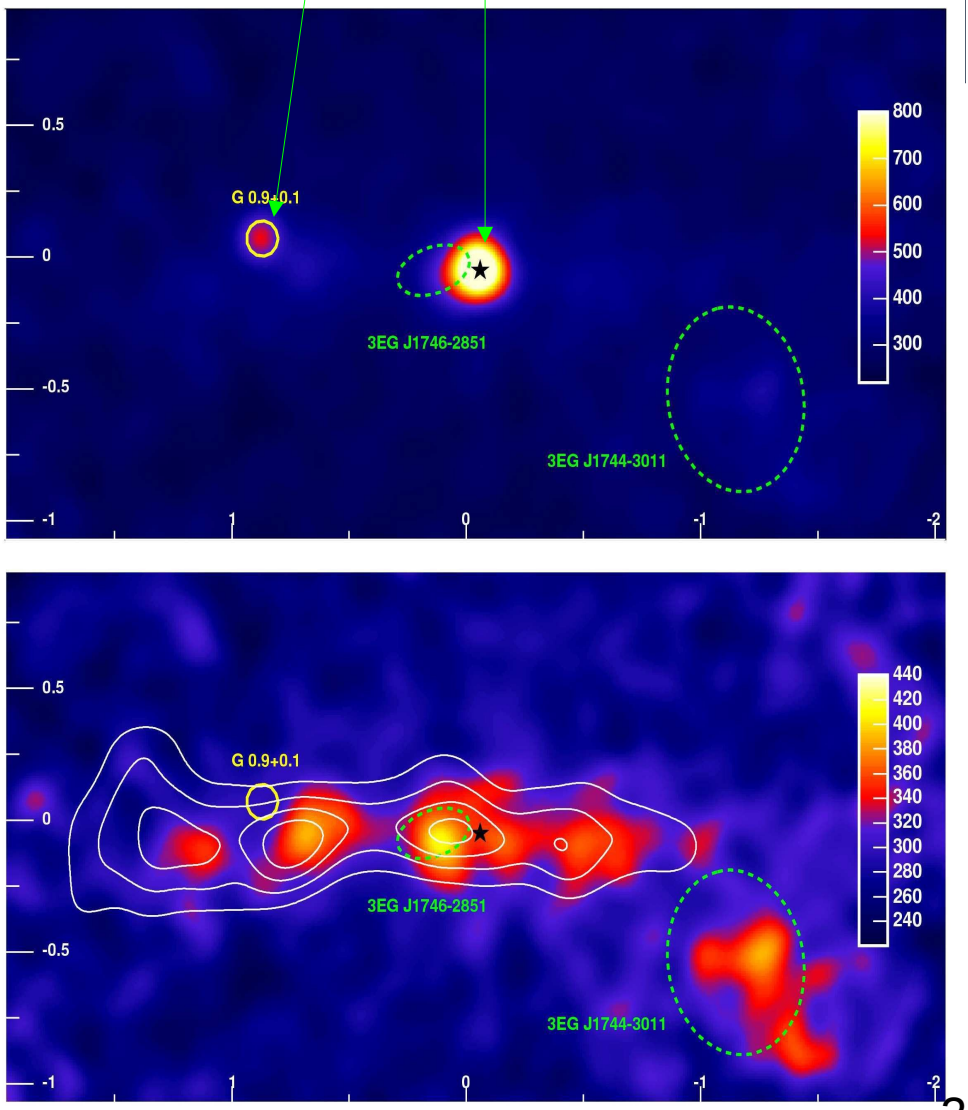
The Galactic Center viewed by H.E.S.S.

- bright and complex region for the GC

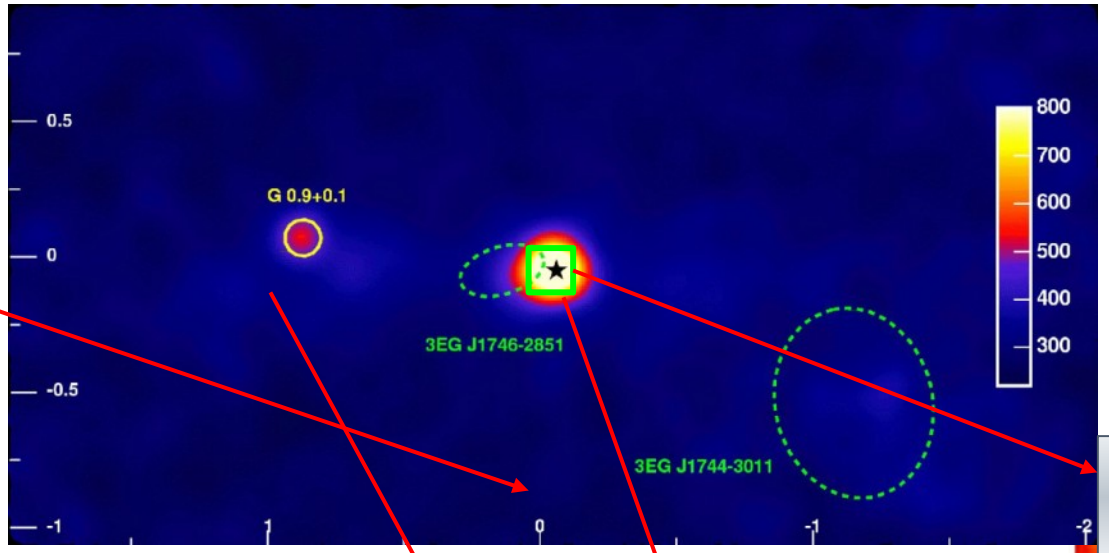
- pulsar wind nebula G0.9+0.1 and HESS J1745-290

- diffuse emission is seen when point sources are subtracted
→ powerful cosmic ray accelerator

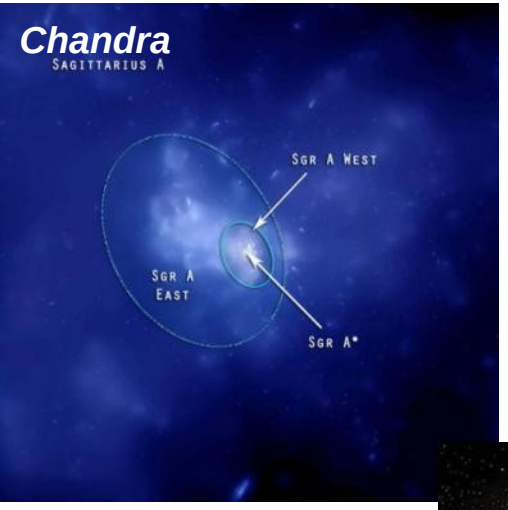
Two bright point-like sources:
- HESS J1745-290 : unidentified
- G 0.9+0.1 : SNR/PWN association



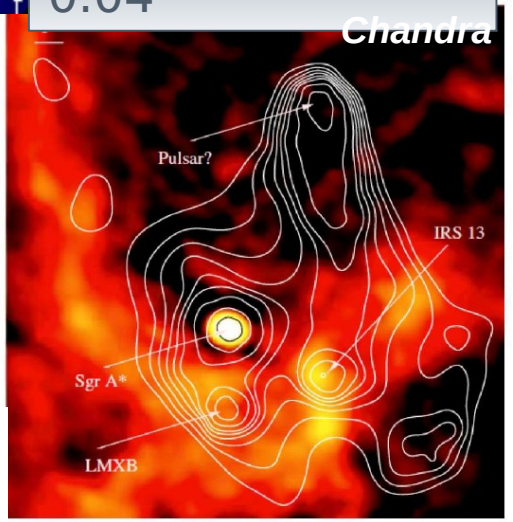
Possible Counterparts of HESS J1745-290



SNR Sgr A East

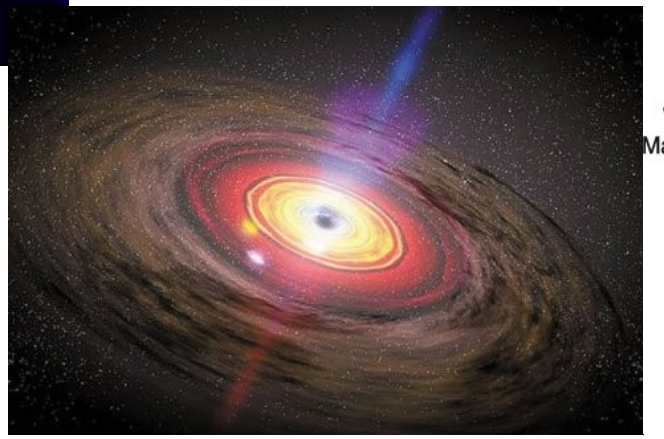


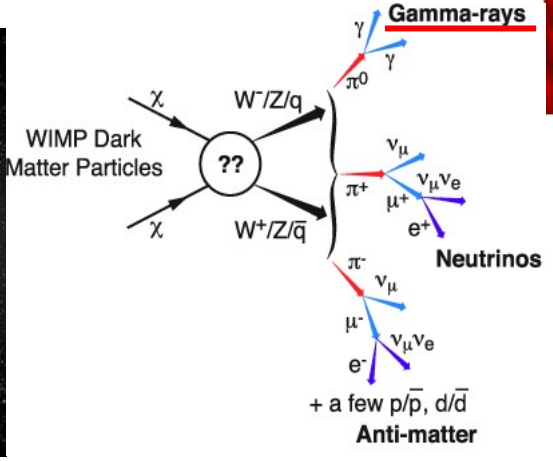
PWN G359.95-0.04



SMBH Sgr A*

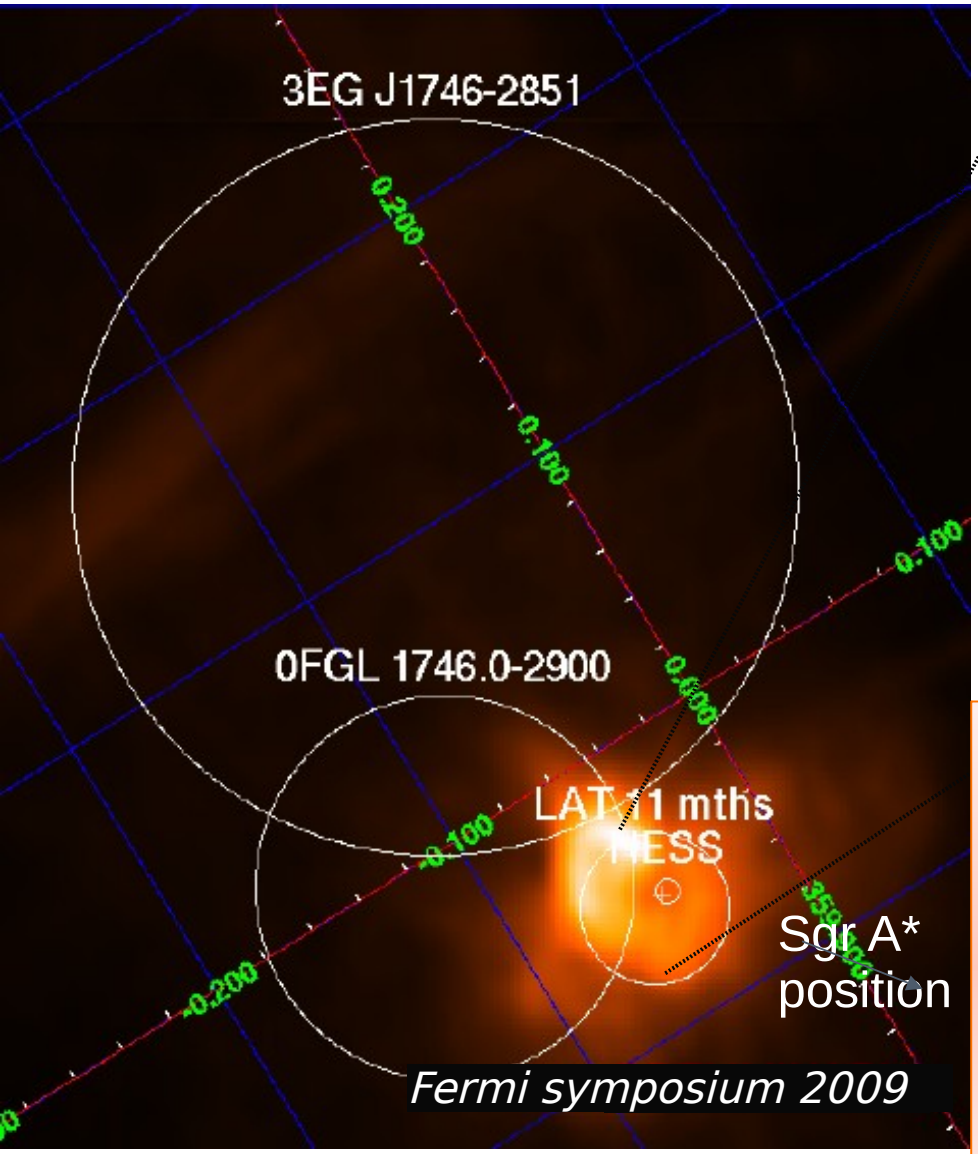
Dark Matter?



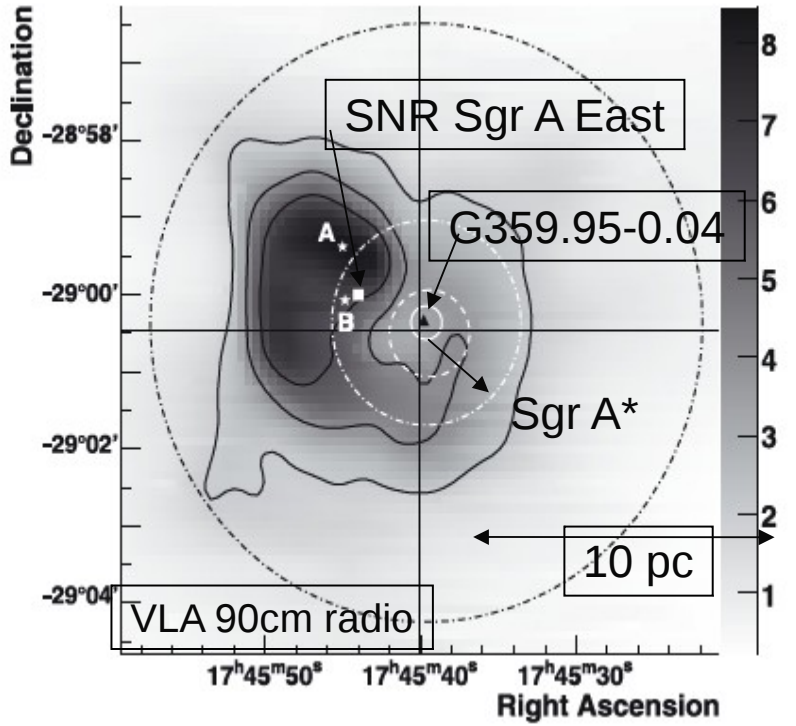


Position of HESS J1745-290

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



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*)

Spectra of HESS J1745-290

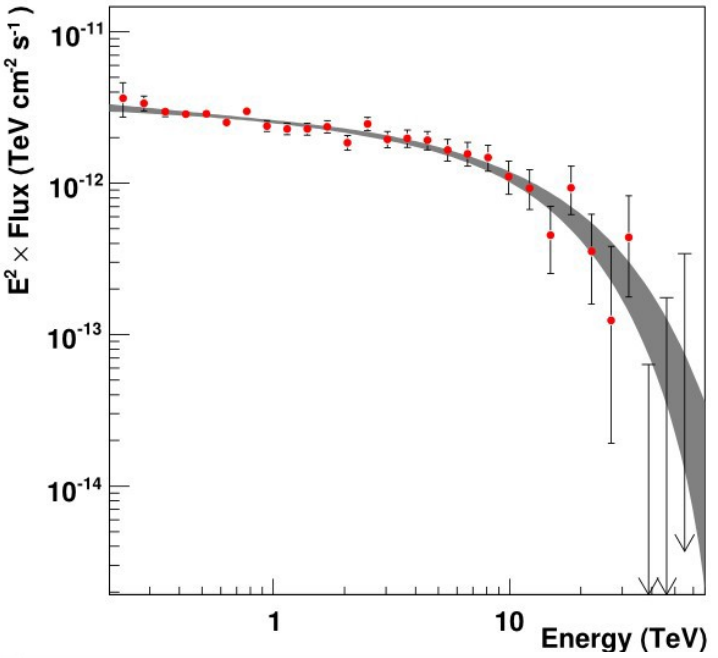
- 2004-2006 data: 93h live-time of observation and gamma energy:
- 160 GeV < E < 70 TeV

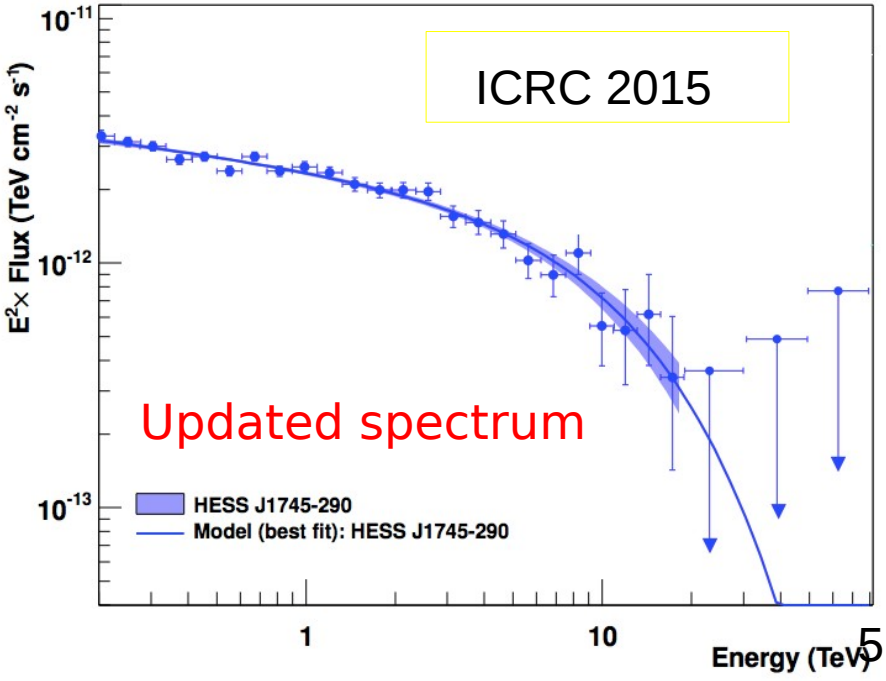
- Best fit: Power law with exponential cutoff
- Ecut ~ 15 TeV

- spectral index ~ 2.2

- Updated spectrum
- data: 2004 – 2012
- livetime: 220 hrs
- compatible with 2009 paper:
- Best fit: power law with exponential cutoff
- spectral index ~ 2.1
- Ecut ~ 11 TeV

Aharonian et al. A&A 503, 817 *(2009)*

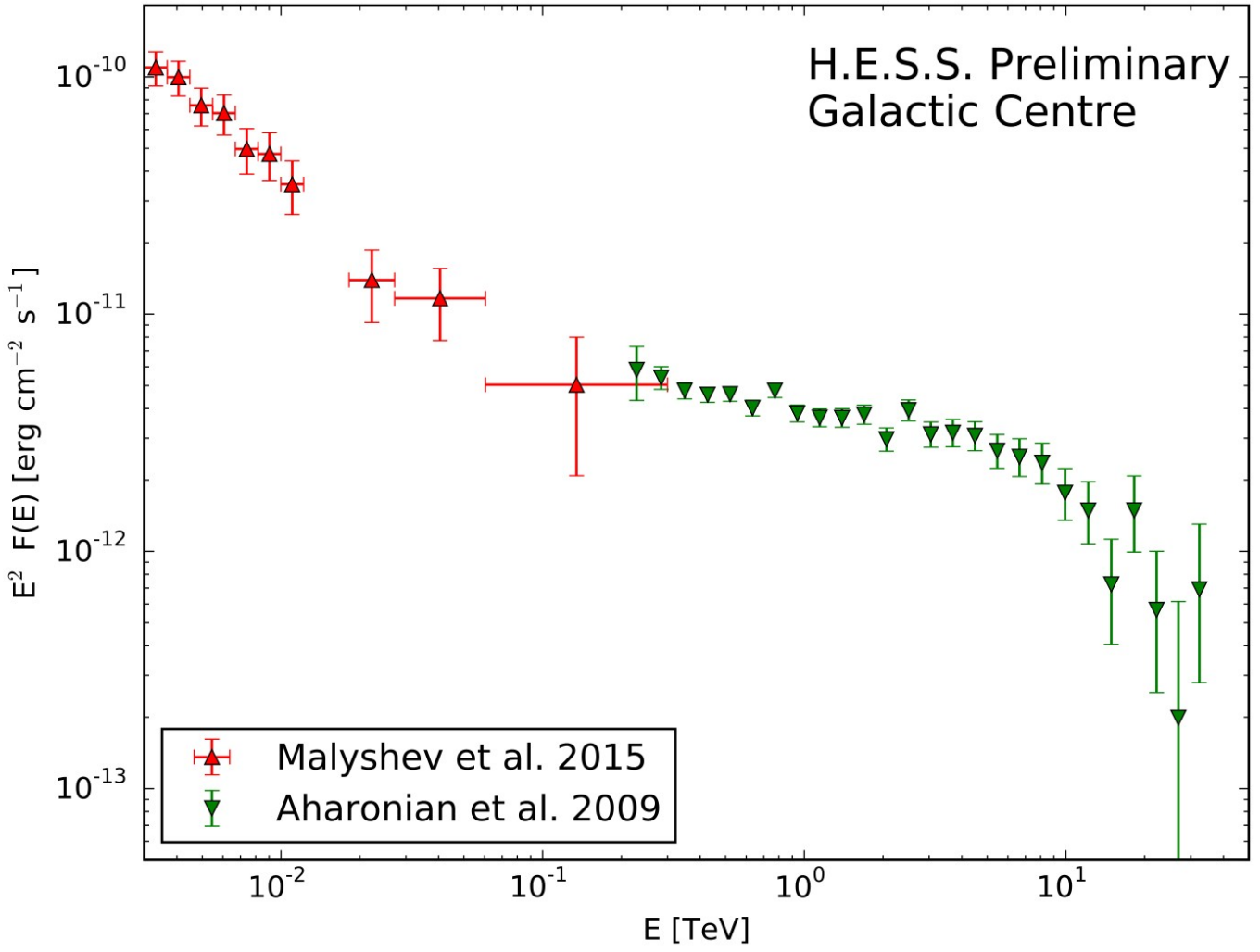




SLIDES ON HESS-II RESULTS

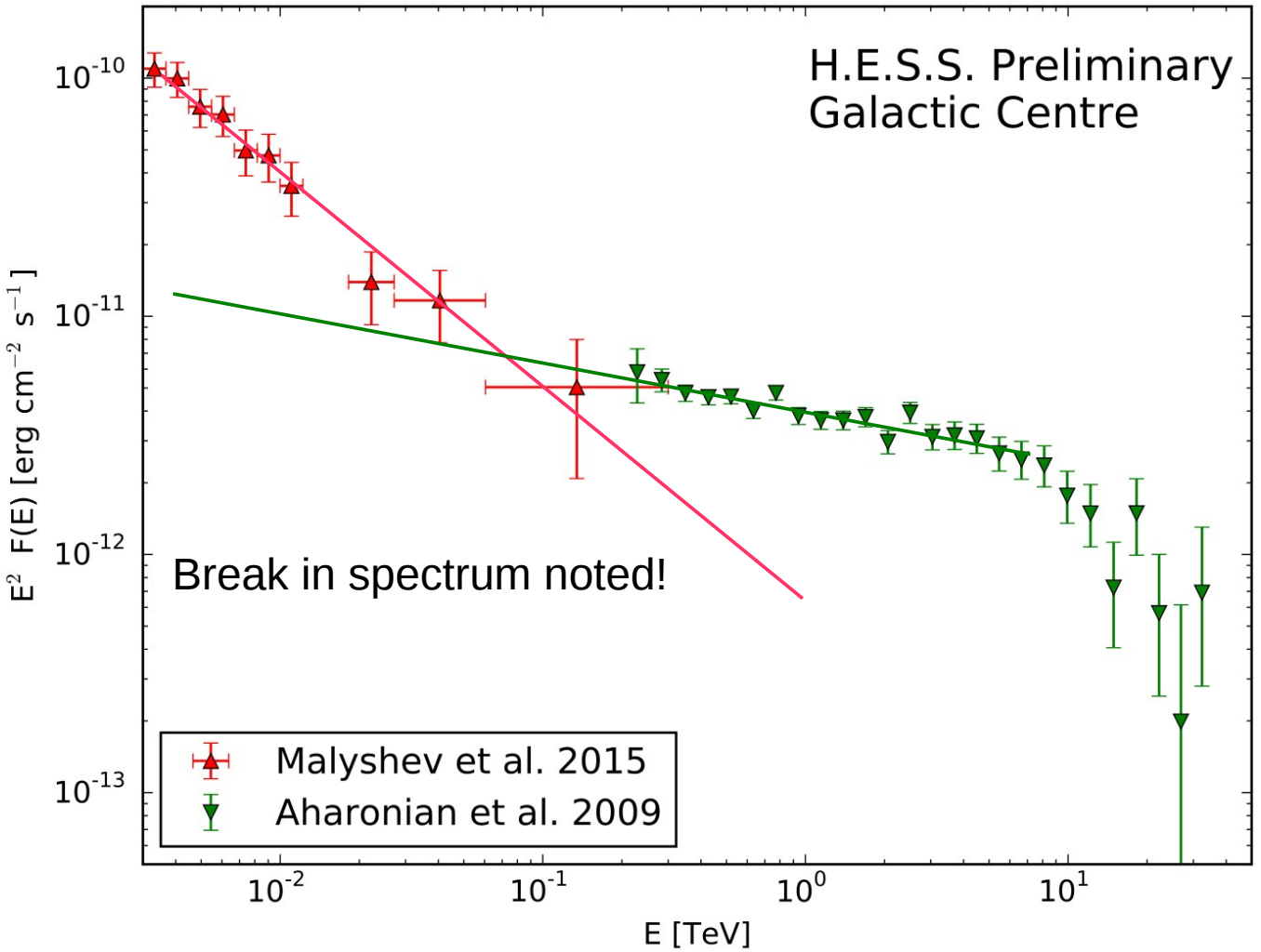
GC Spectra

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



GC Spectra

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



GC Spectrum (H.E.S.S. II)

(ICRC 2015/ arxiv:1509.03425)

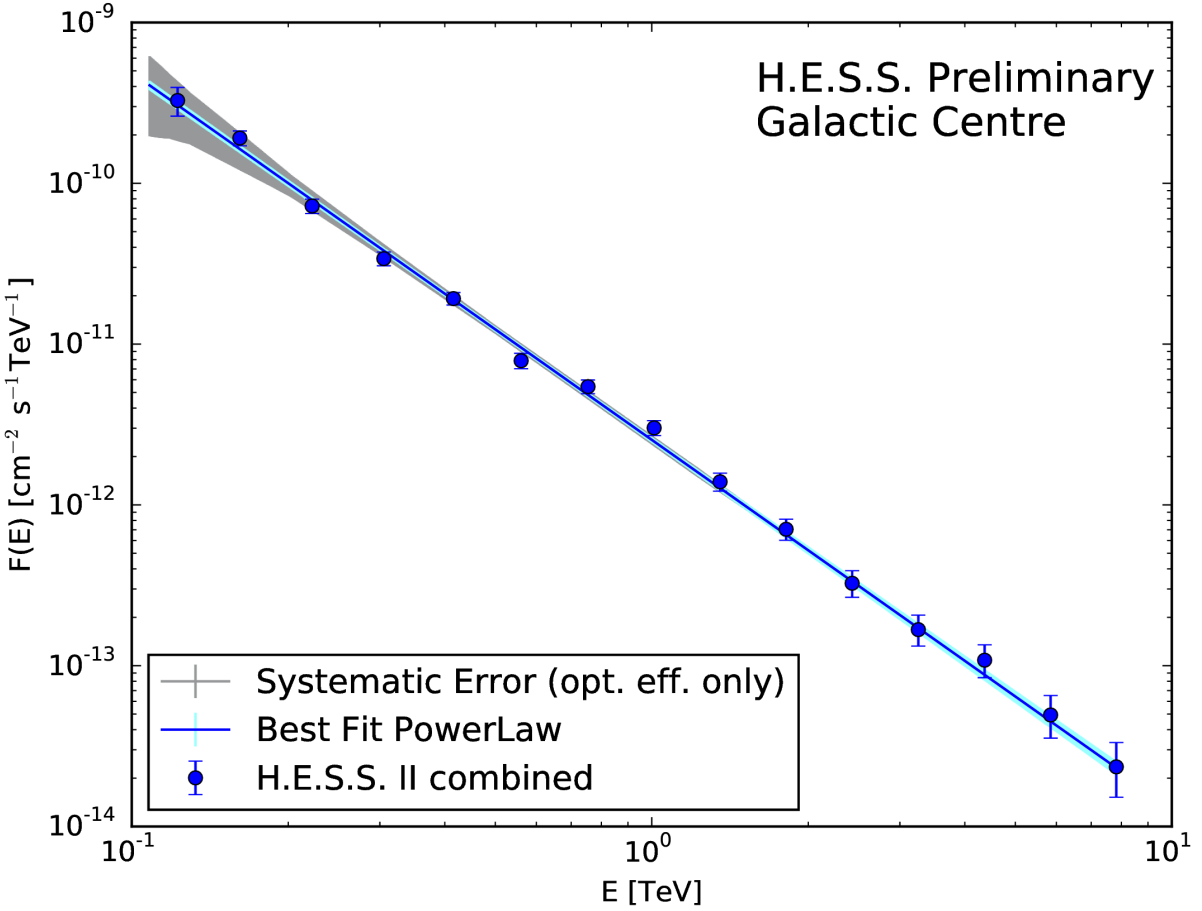
- Power-law fit acceptable

- Index: 2.28 ± 0.04

- Flux (1 TeV): 2.54±0.1 x 10-12 cm-2s-1TeV-1

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

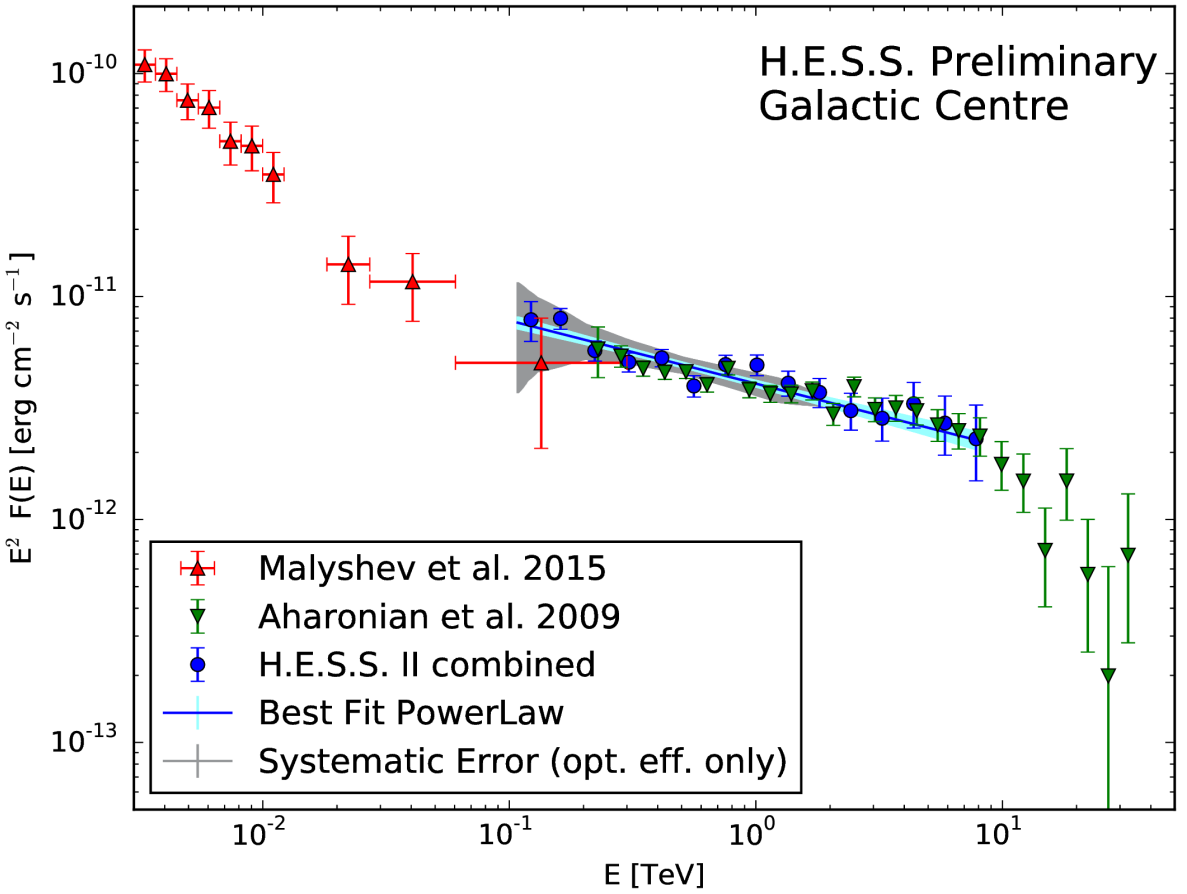
- No high energy cut-off seen due to low statistics



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



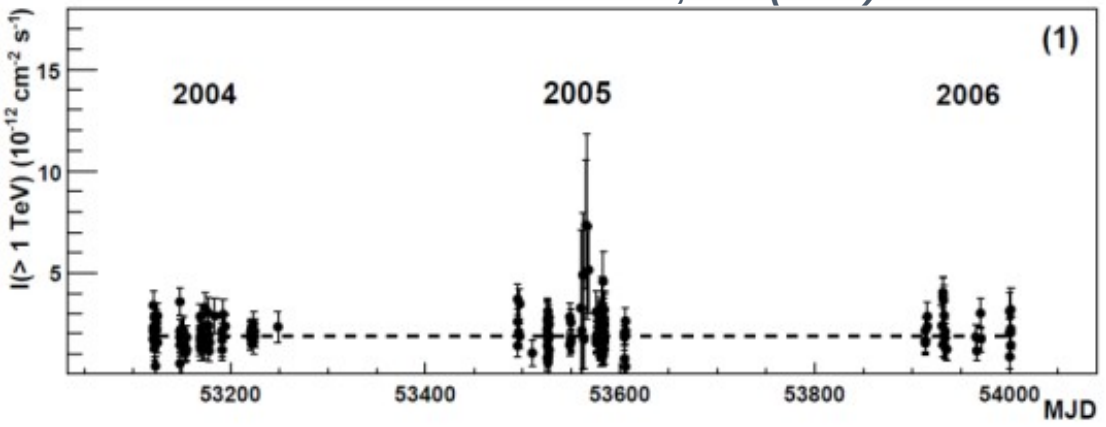
Variability Study of HESS J1745-290

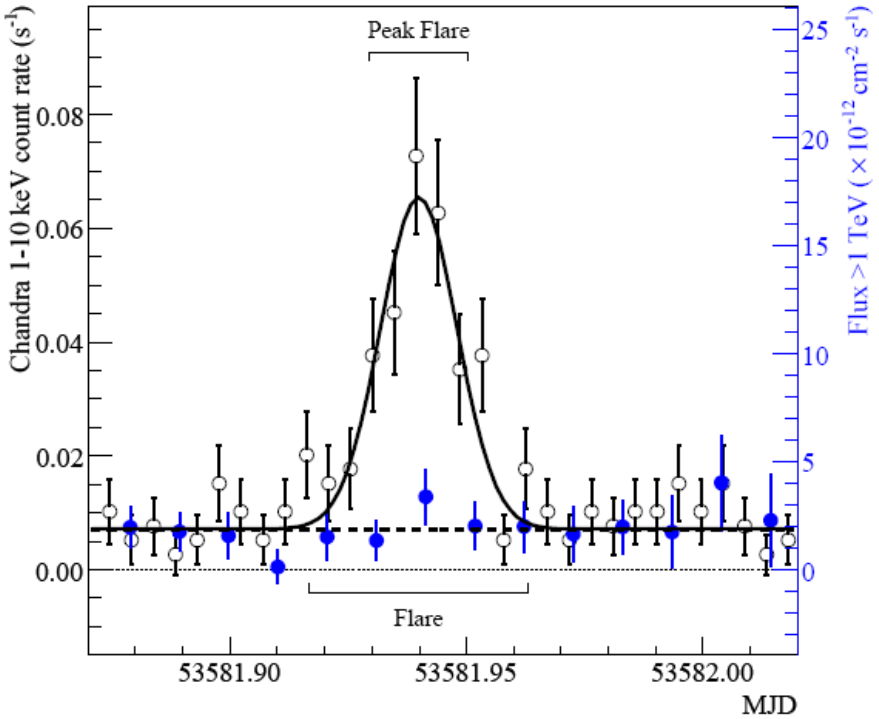
- No signs variability in VHE lightcurve observed based on 93 hours of data

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

=> 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)

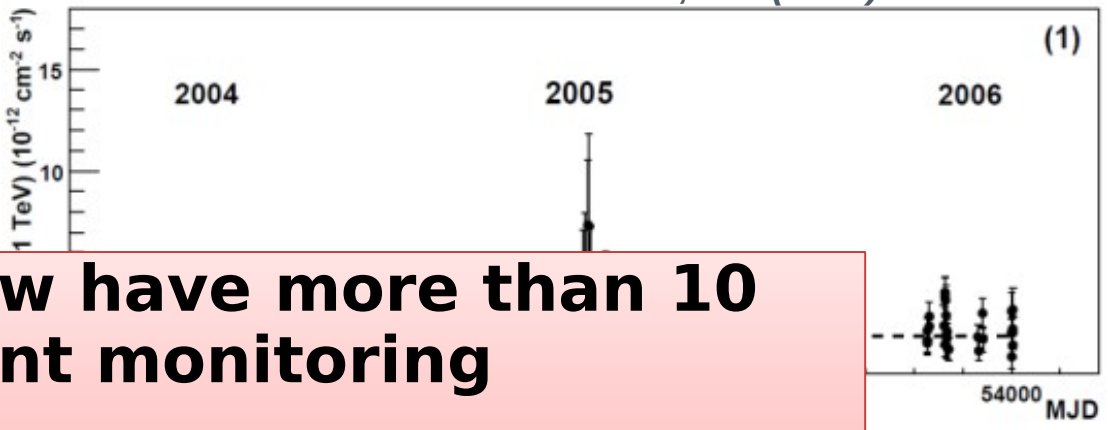
Variability Study of HESS J1745-290

- 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 det
  - 1-10 keV
  - 1600s duratior
  - 9x quiescent l
- No increase of
  (factor 2 increa
  99%CL)

=> disfavours
and TeV emiss
with the same

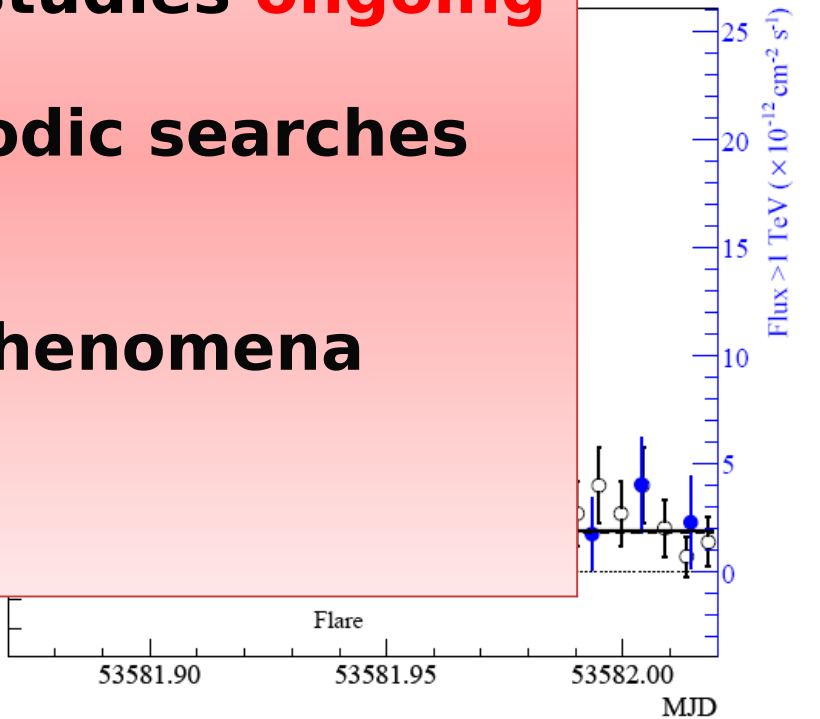
Aharonian et al. A&A 503, 817 *(2009)*



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!



HESS Coll, A&A 492, L25 (2008)

Conclusion

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 phenomona
- 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)

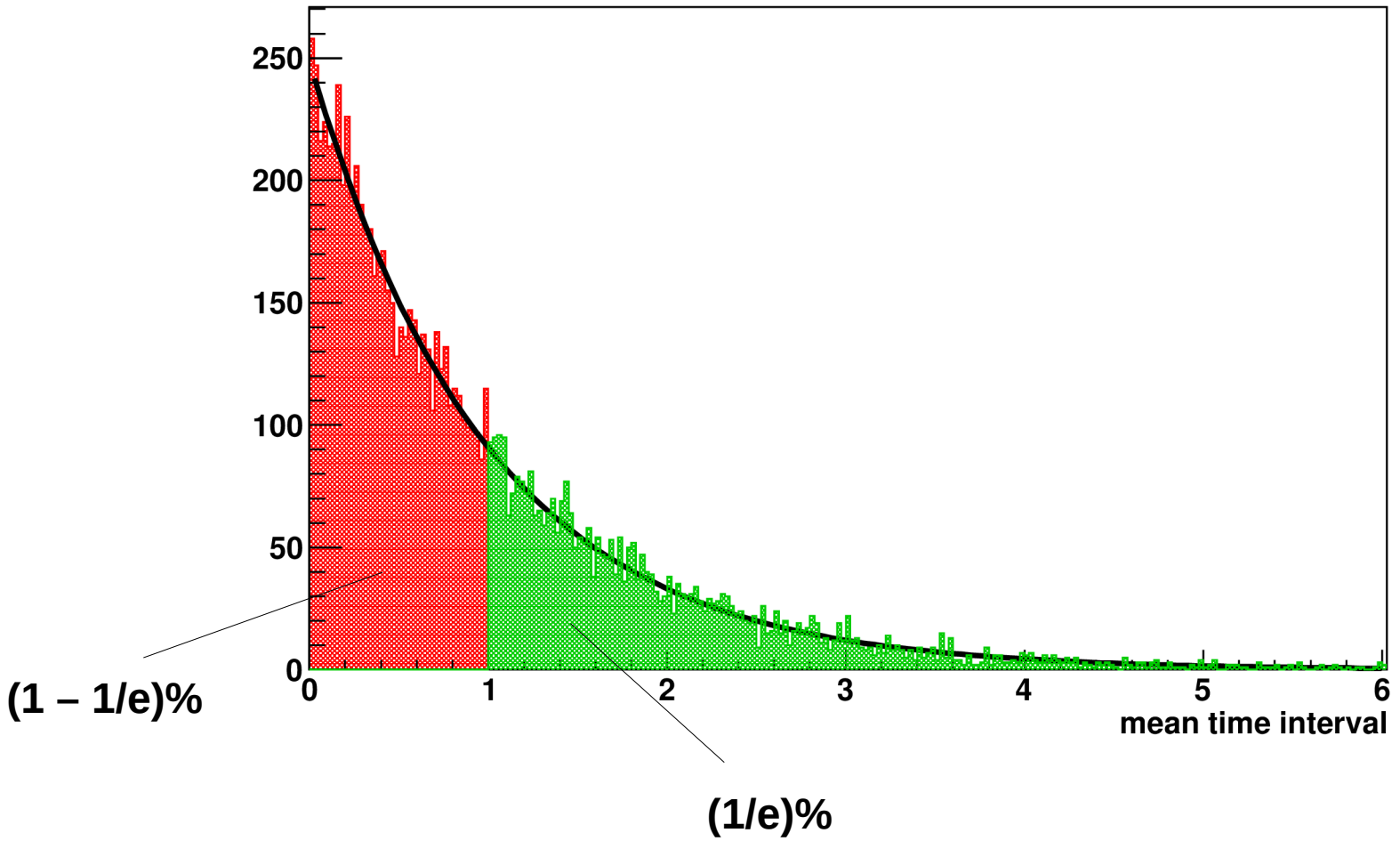
- check for deviation from Poisson statistics according to time intervals

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



Exp test Estimator

- M estimator

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

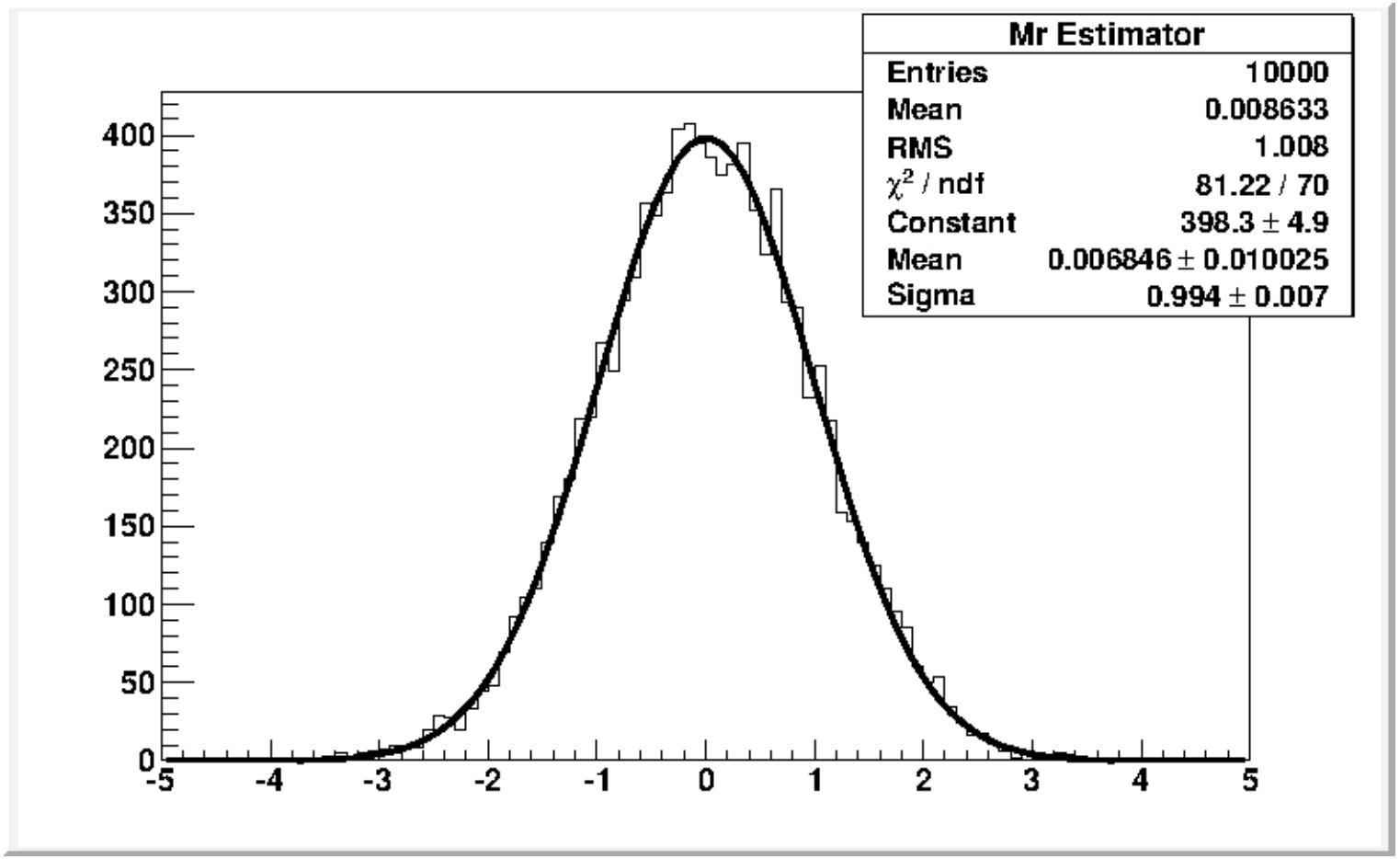
- where C* = mean time interval
- - for periodic distribution: M ~ 0
- - for Poisson distribution: M ~ 1/e
- - for burst-like distribution: M > 1/e

- 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