



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

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



# 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  $0.16^\circ$
- Field of view :  $5^\circ$
- 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  $0.067^\circ$
  - Field of view :  $3.6^\circ$
  - Aim to significantly reduce the energy threshold (below 100 GeV)
- overlap with Fermi -LAT in spectra

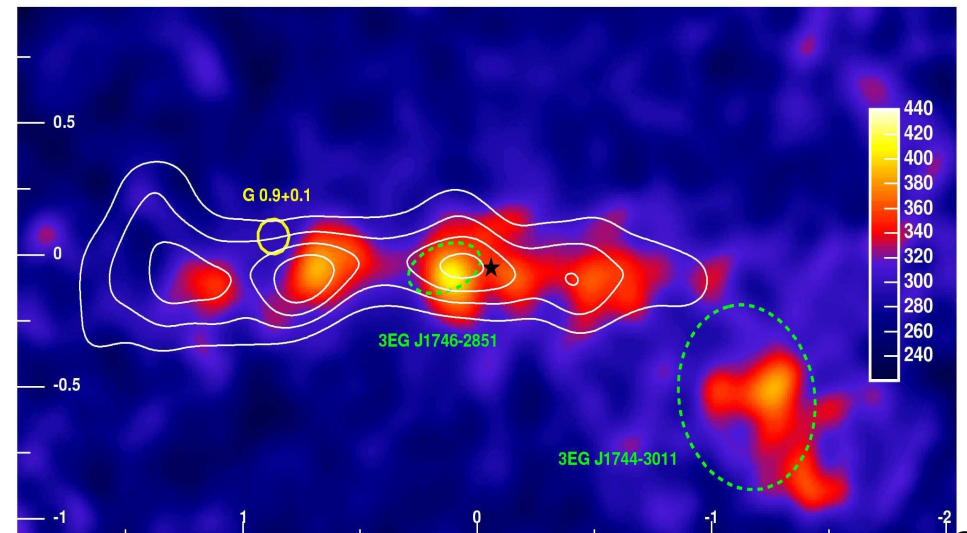
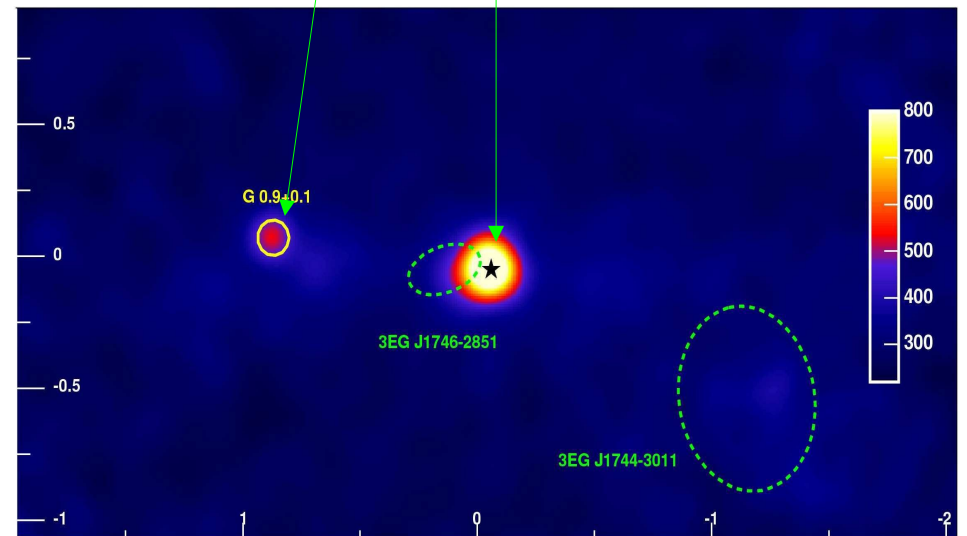


# The Galactic Center viewed by H.E.S.S.

- 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

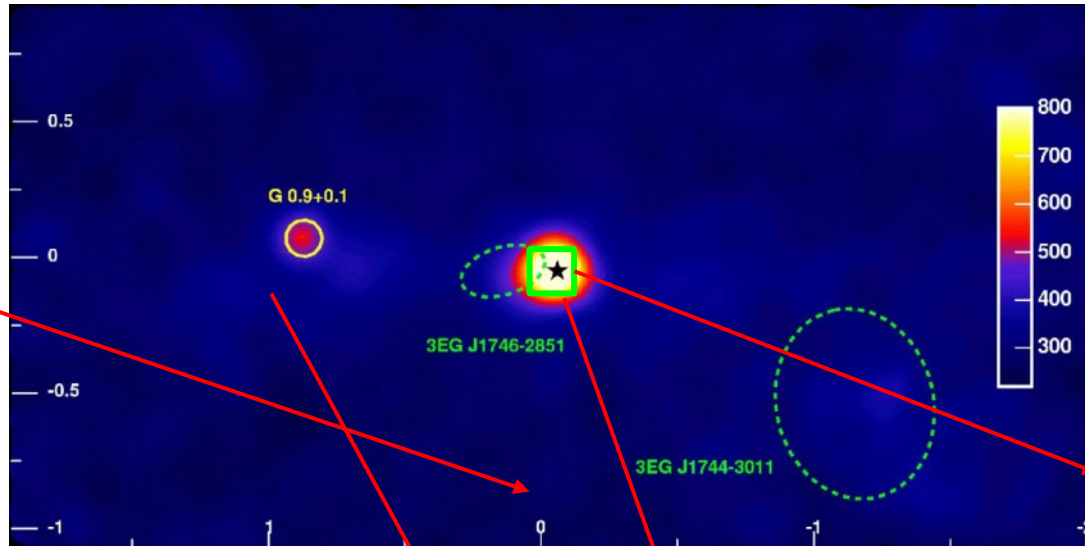
## Two bright point-like sources:

- HESS J1745-290 : unidentified
- G 0.9+0.1 : SNR/PWN association



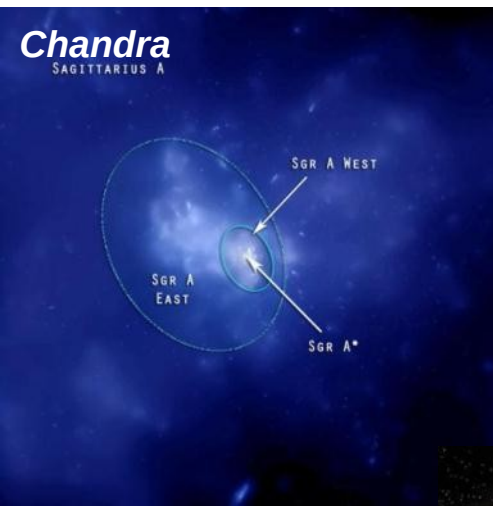


# Possible Counterparts of HESS J1745-290



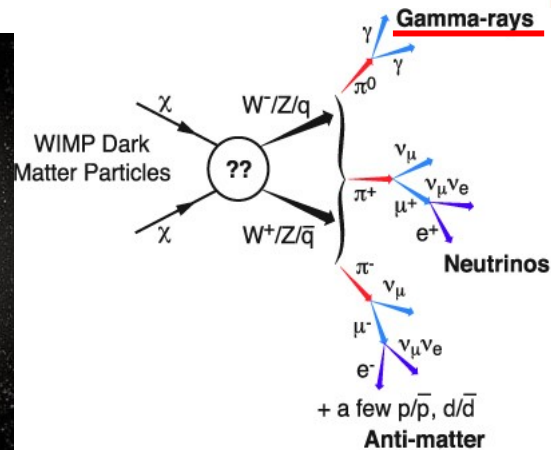
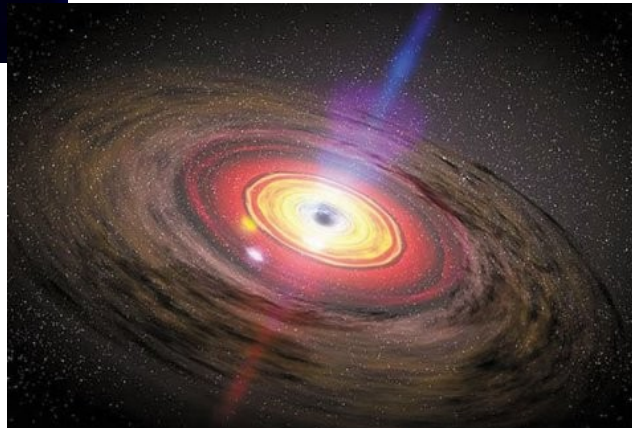
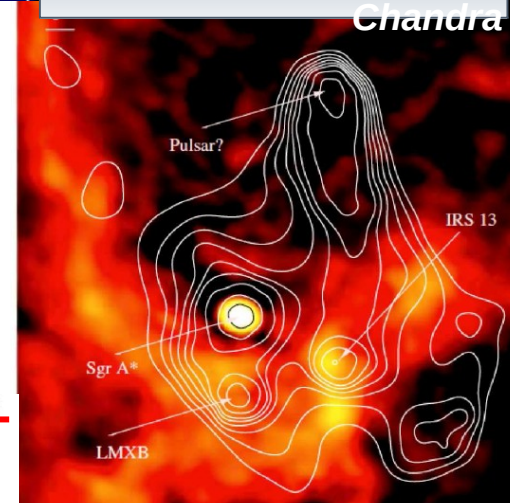
SNR Sgr A East

PWN G359.95-0.04



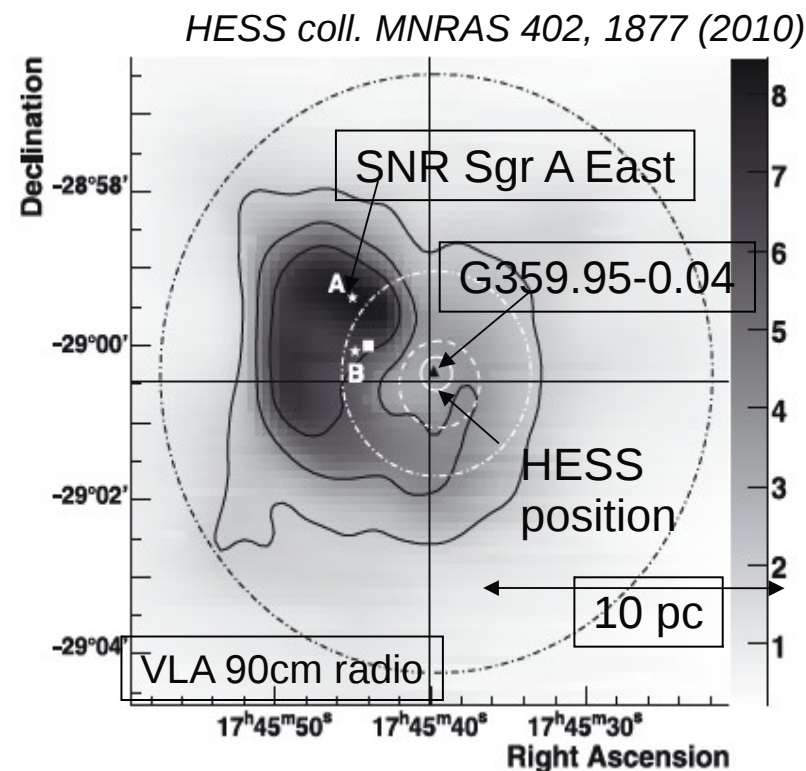
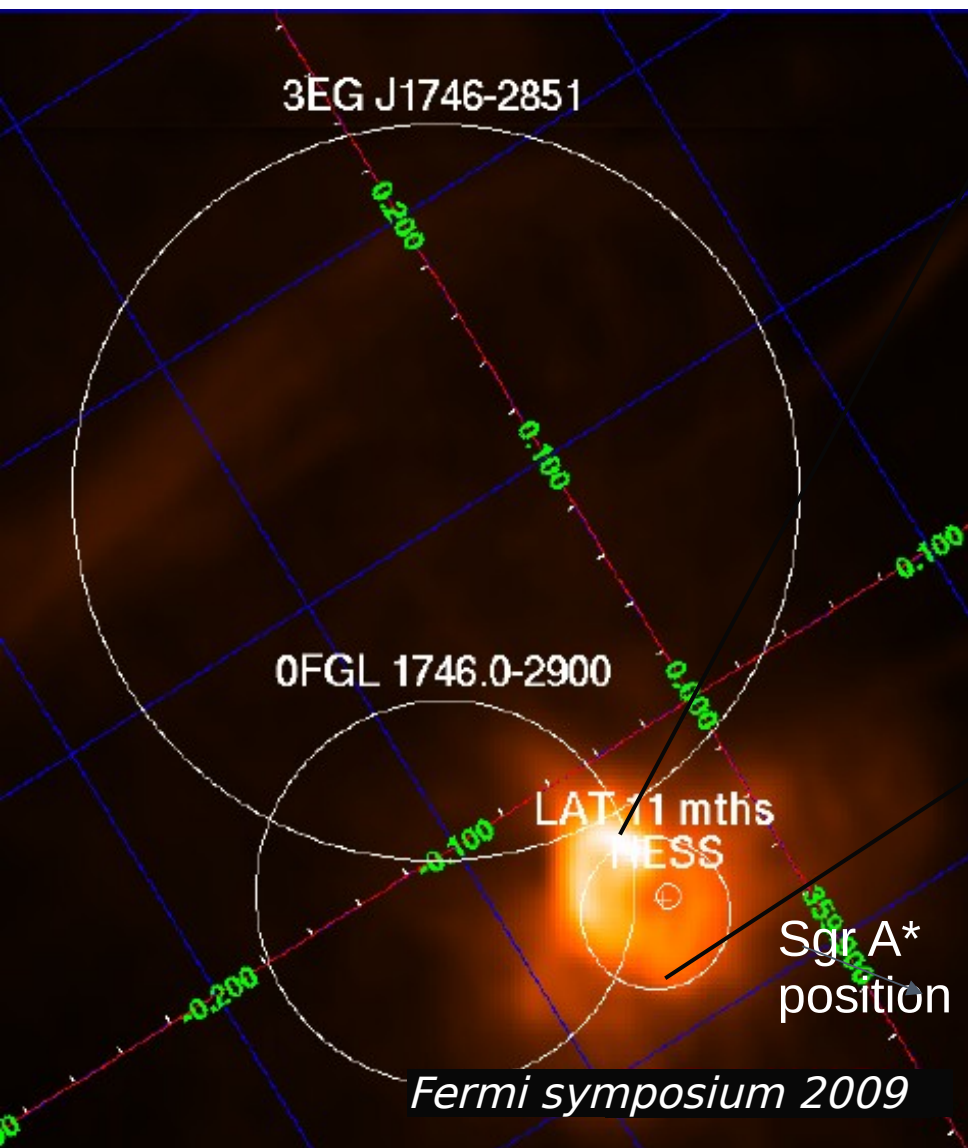
SMBH Sgr A\*

Dark Matter?



# Position of HESS J1745-290

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

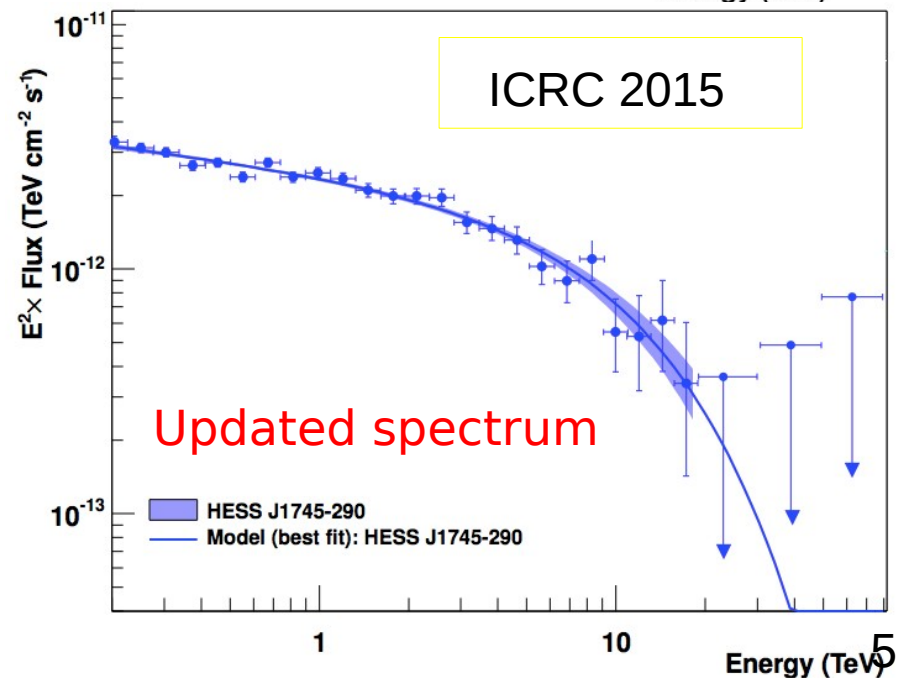
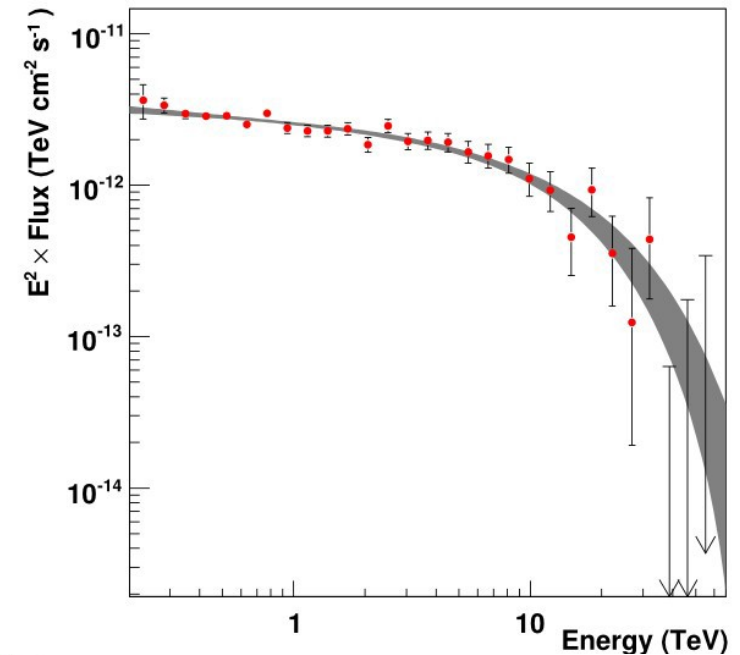


- position:
  - $l=359^{\circ}56'41.1'' \pm 6.4'' \pm 6''$
  - $b=-0^{\circ}2'39.2'' \pm 5.9'' \pm 6''$
- centroid emission located at  $7'' \pm 12''$  from Sgr A\*
- Sgr A East excluded at the  $7\sigma$  C.L.
- G359.95-0.04 and Sgr A\* still inside error bars ( $8.7''$  from Sgr A\*)

# Spectra of HESS J1745-290

- 2004-2006 data: 93h live-time of observation and gamma energy:
- $160 \text{ GeV} < E < 70 \text{ TeV}$
- Best fit: Power law with exponential cutoff
- $E_{\text{cut}} \sim 15 \text{ TeV}$
- spectral index  $\sim 2.2$
- **Updated spectrum**
- data: 2004 - 2012
- livetime: 220 hrs
- compatible with 2009 paper:
- Best fit: power law with exponential cutoff
- spectral index  $\sim 2.1$
- $E_{\text{cut}} \sim 11 \text{ TeV}$

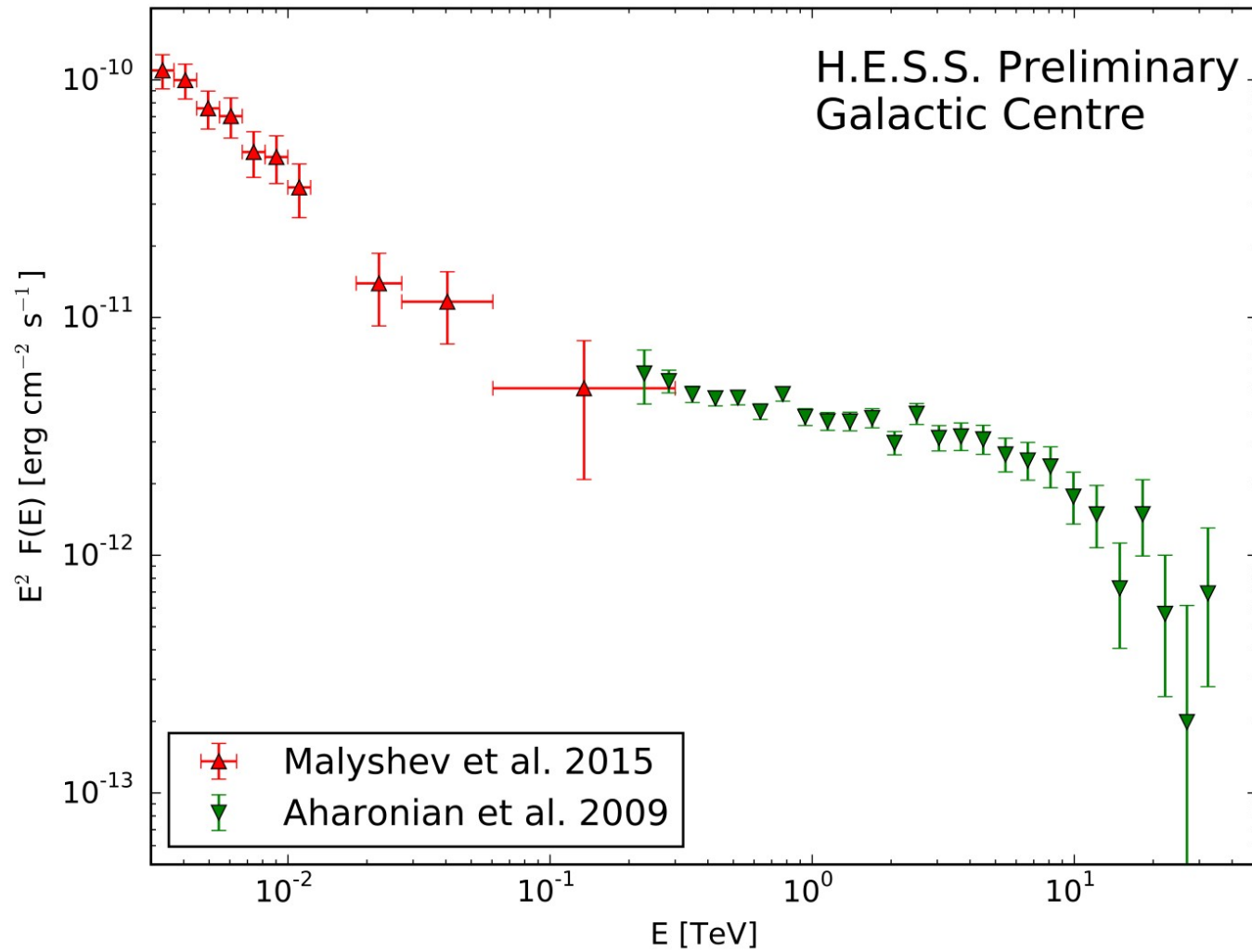
Aharonian et al. A&A 503, 817 (2009)



# **SLIDES ON HESS-II RESULTS**

# GC Spectra

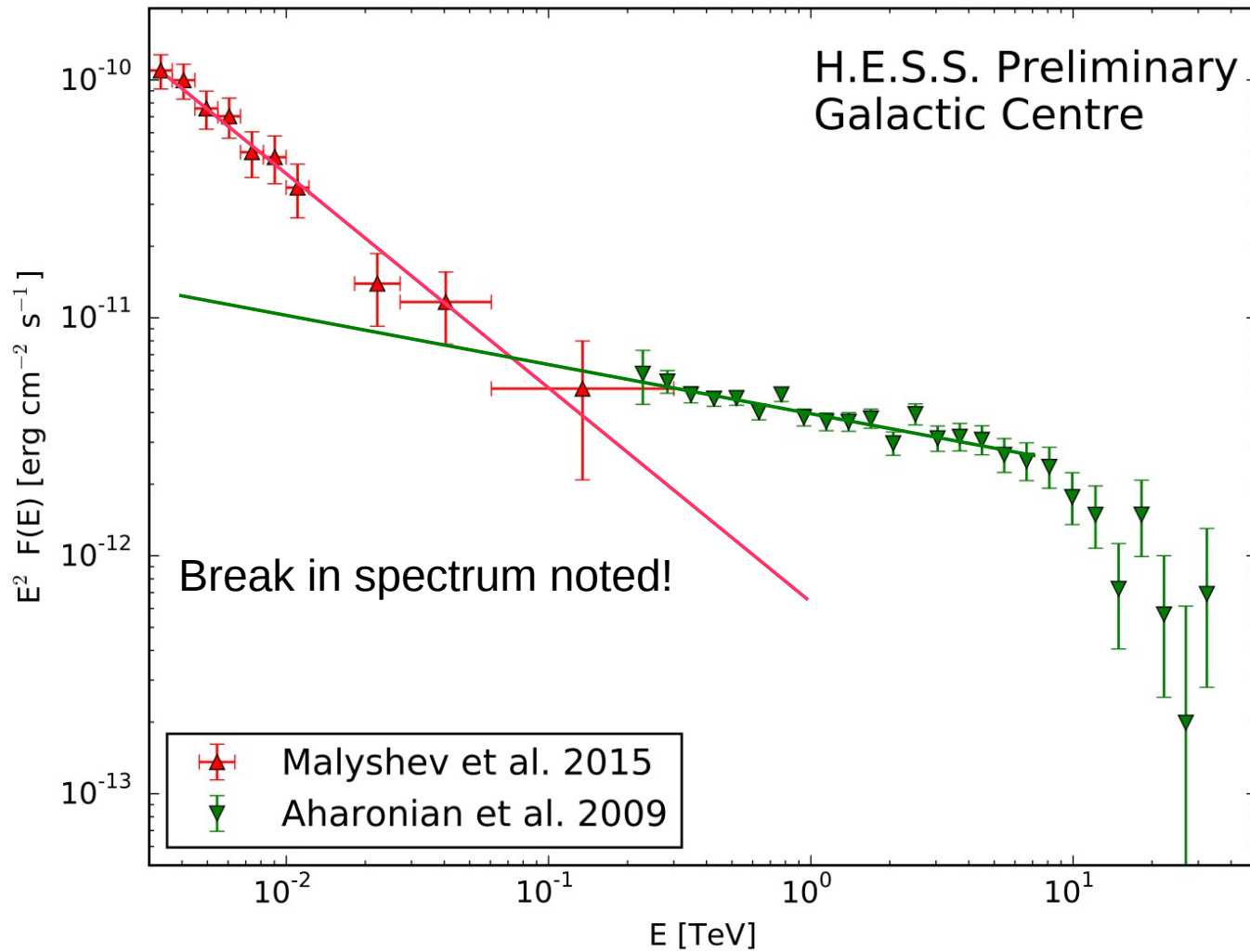
- Old H.E.S.S. + Fermi Lat Spectrum





# GC Spectra

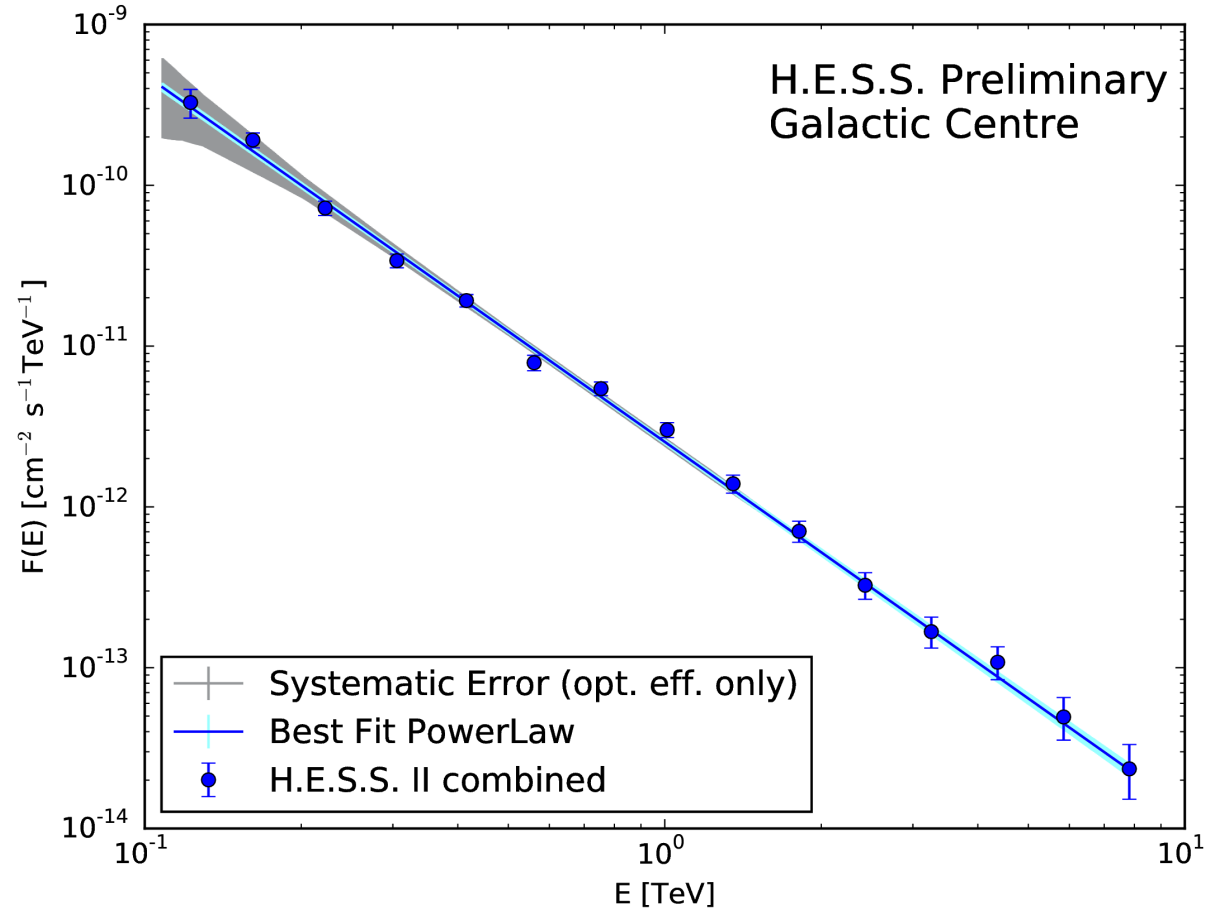
- Old H.E.S.S. + Fermi Lat Spectrum



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

(ICRC 2015/ arxiv:1509.03425)

- Power-law fit acceptable
- Index:  $2.28 \pm 0.04$
- Flux (1 TeV):  $2.54 \pm 0.1 \times 10^{-12}$  cm<sup>-2</sup>s<sup>-1</sup>TeV<sup>-1</sup>
- Well compatible with previously published spectrum (Aharonian et al. 2009)
- No high energy cut-off seen due to low statistics

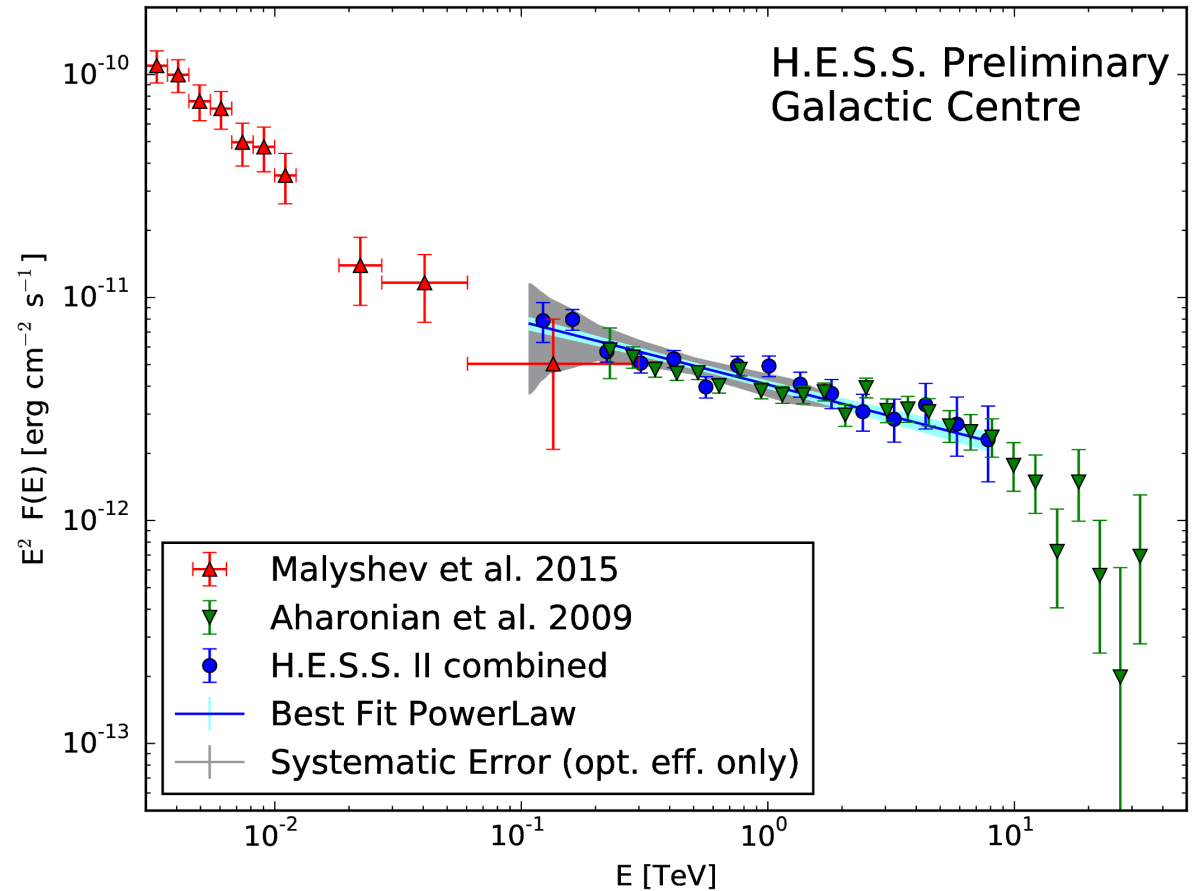


# Spectral Energy Distribution

- 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

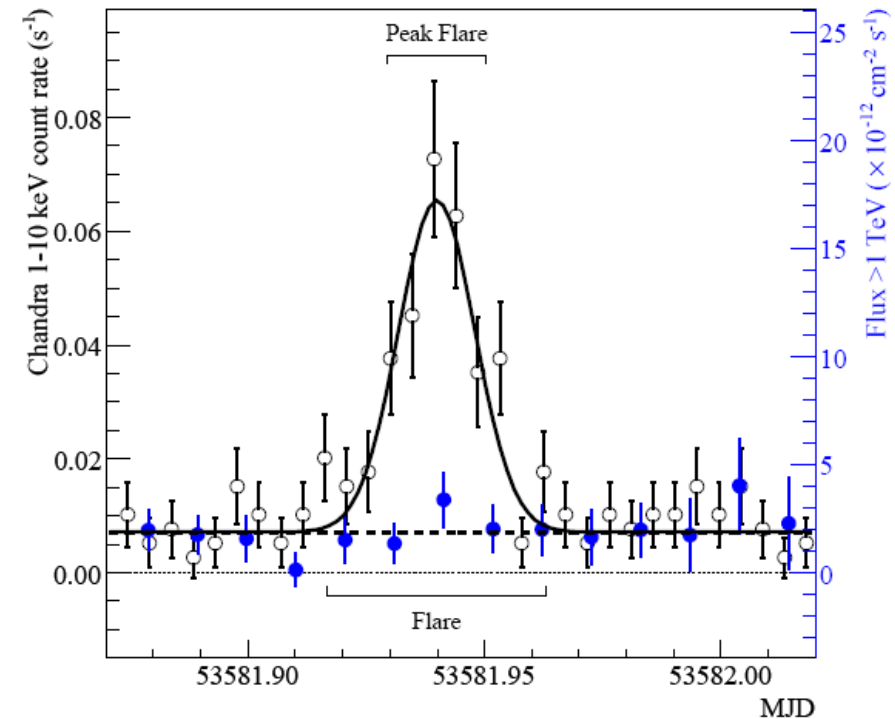
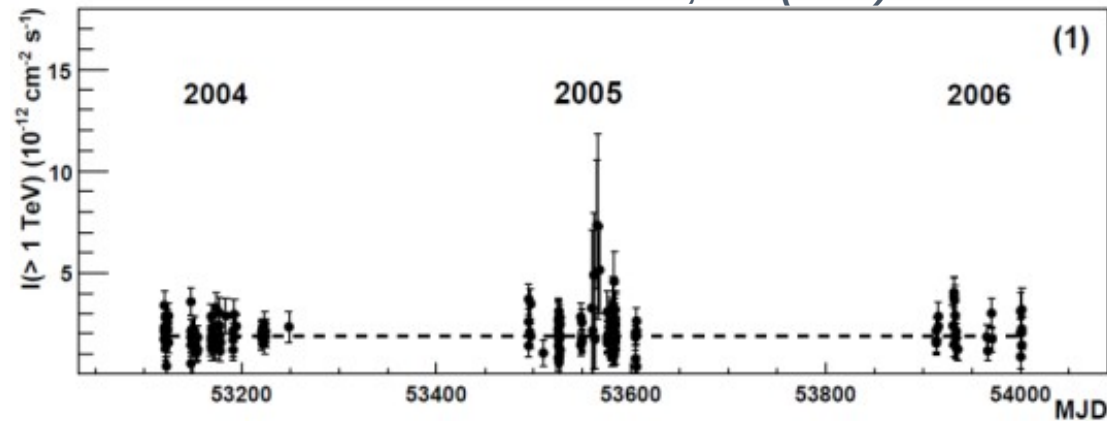


# Variability Study of HESS J1745-290

- 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)

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

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



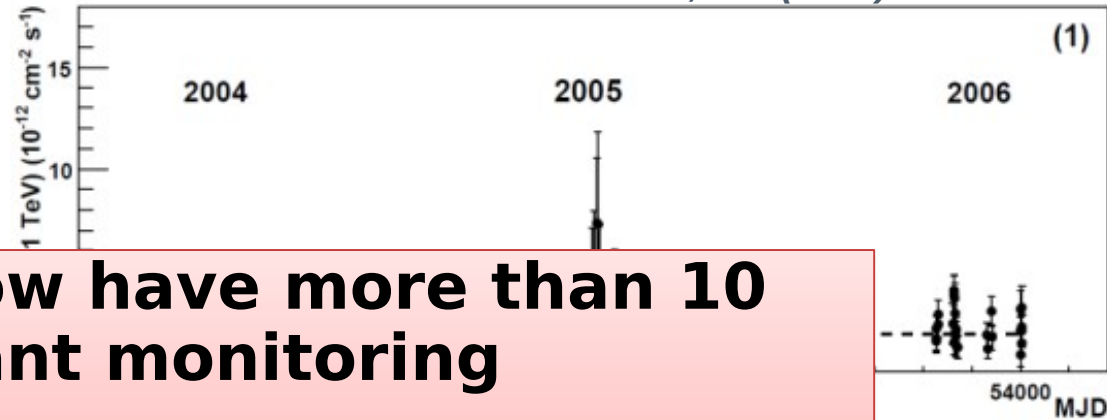
HESS Coll, A&A 492, L25 (2008)



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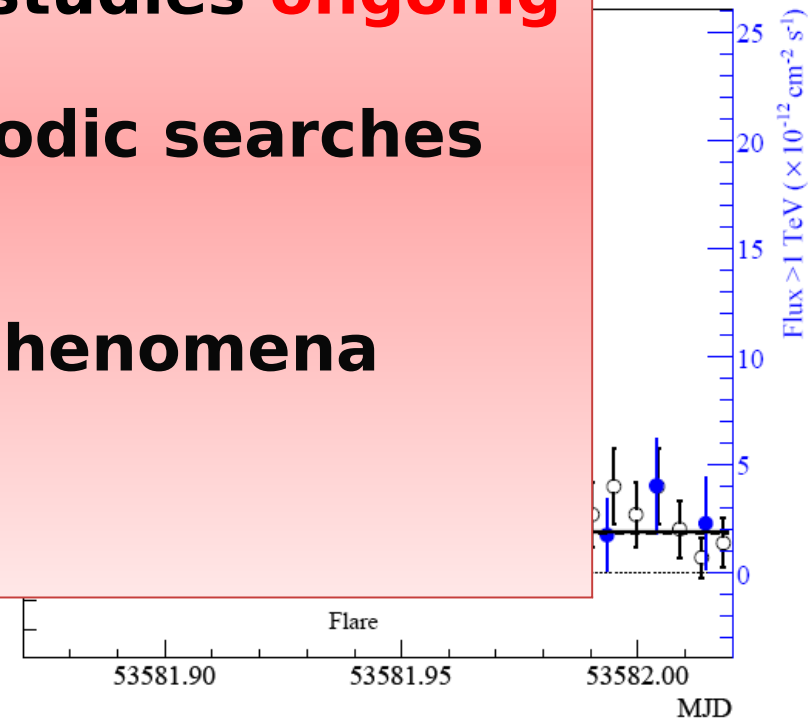


**However we now have more than 10 years of constant monitoring**

- **long-term variability studies ongoing**
- **short-term quasi-periodic searches ongoing**
- **search for transient phenomena ongoing**

**Stay tuned!**

=> disfavour  
and TeV emiss  
with the same



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 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

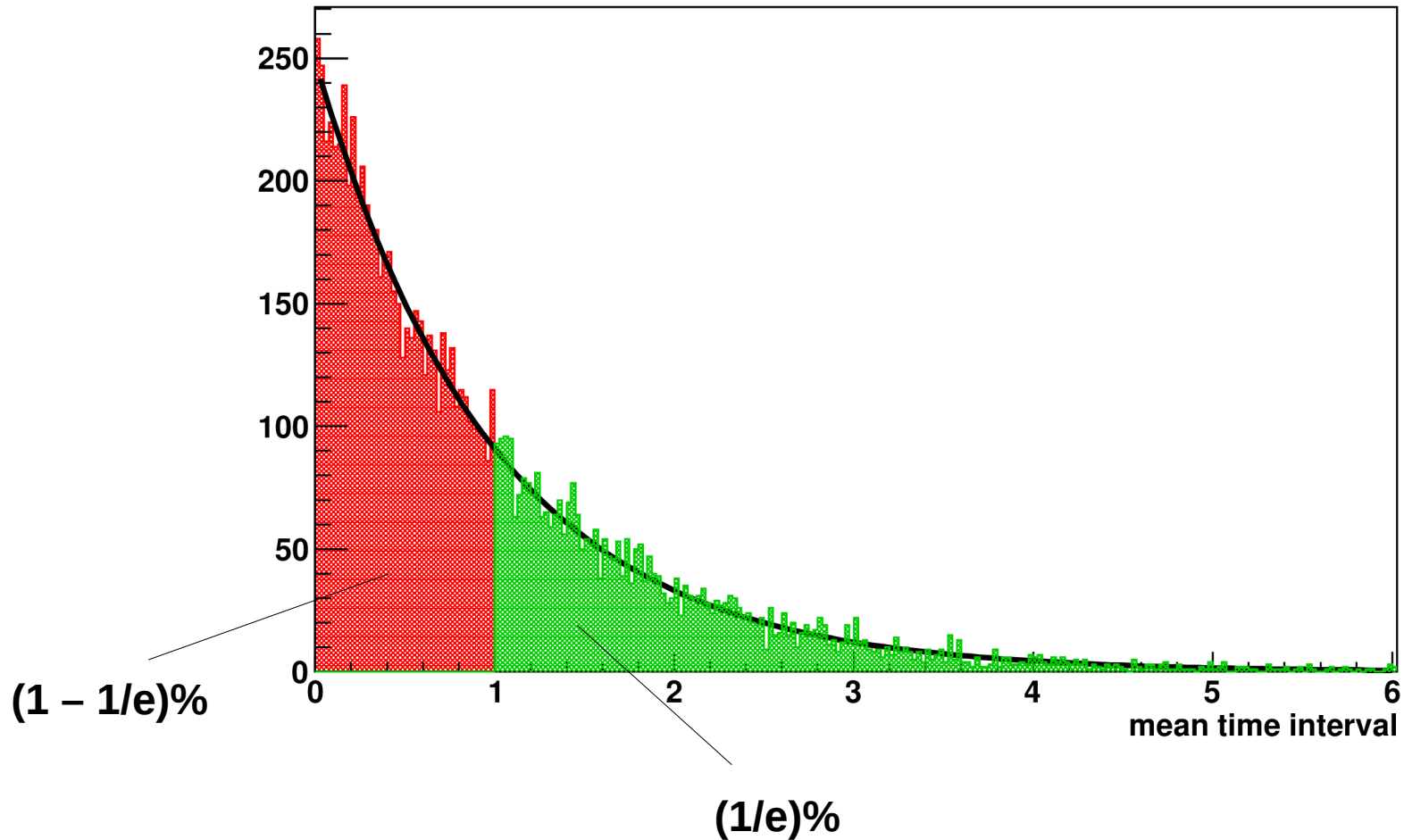
## **Cumulative Sum test (Brun 2011)**

- 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



# Exp test Estimator

- M estimator

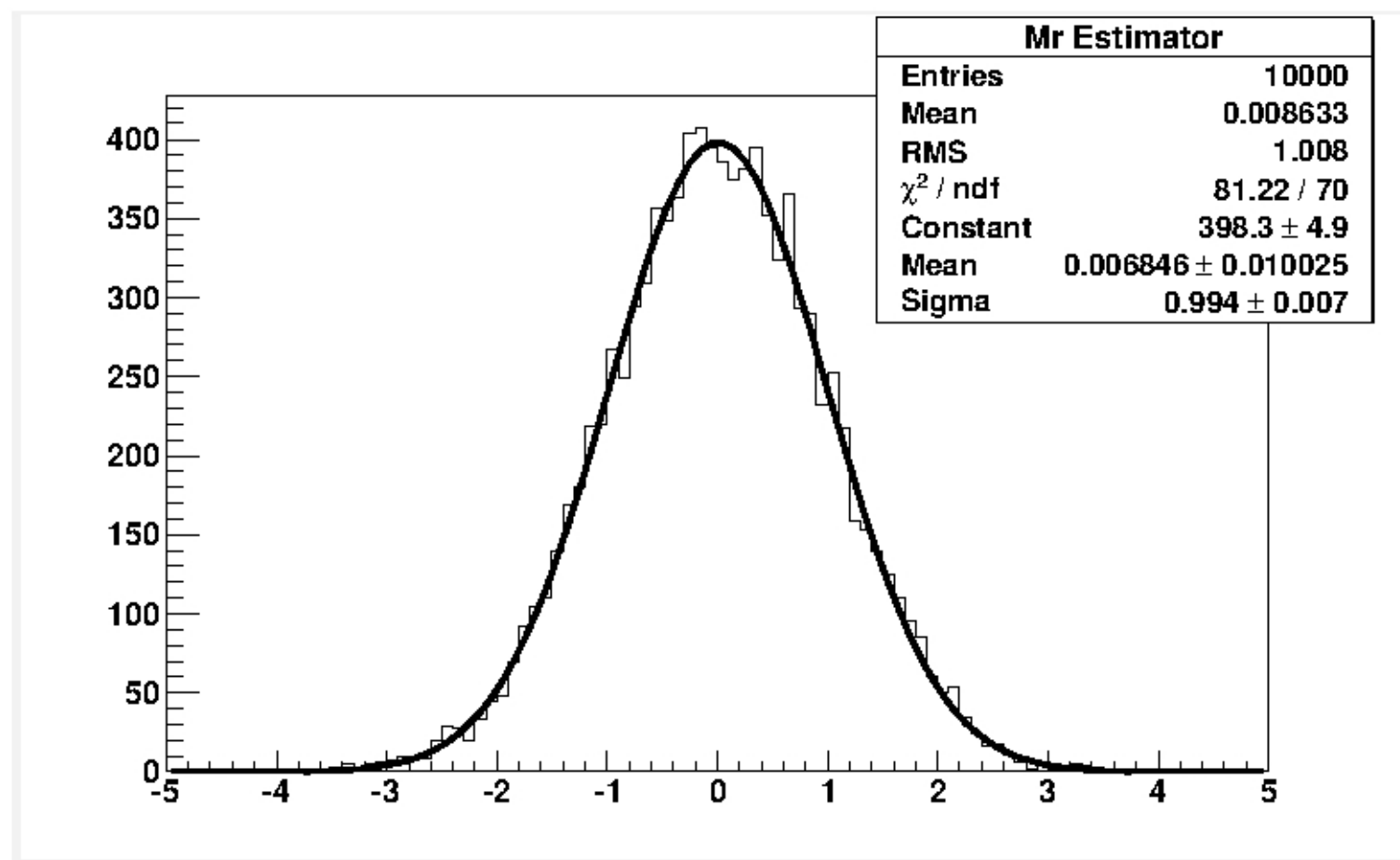
$$M = \frac{1}{N} \sum_{\Delta T_i < C^*} \left(1 - \frac{\Delta T_i}{C^*}\right)$$

- where  $C^*$  = mean time interval
- - for periodic distribution:  $M \sim 0$
- - for Poisson distribution:  $M \sim 1/e$
- - 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

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

- $\chi_i$  = cusum value;  $\langle \Delta T \rangle$  = mean time interval;
- $\Delta T_k$  = individual time interval
- In a burst,  $\Delta T_k < \langle \Delta T \rangle \rightarrow \chi_i$  gets small
- otherwise  $\rightarrow$  fluctuation



# Cusumulative Sum Test

- Simulation of 10000 events following Poisson statistics
- fluctuation

