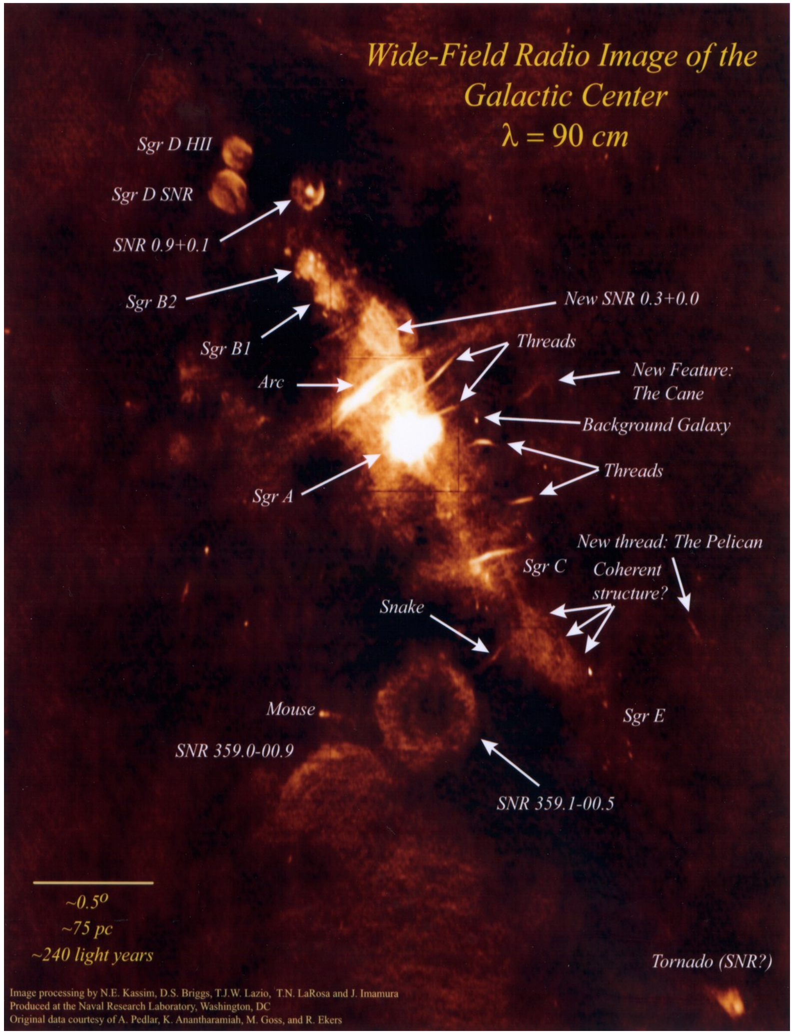
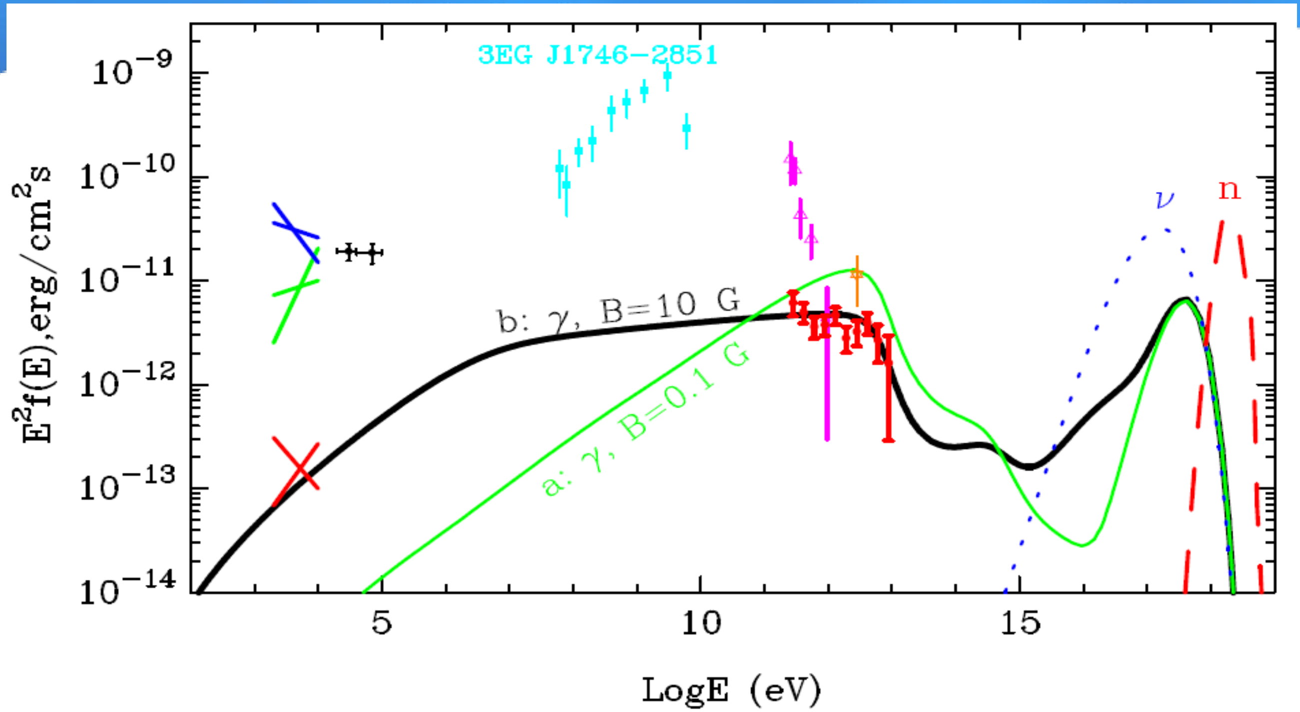
Origin of the gamma-ray emission from the Galactic Centre



D. Malyshev
M.Chernyakova
A.Neronov
R.Walter

28th Texas Symposium on Relativistic Astrophysics, December 17th, 2015

Pre-FERMI observations of GC



TeVs – HESS and significantly different results of CANGAROO
GeVs – EGRET source 3EG 1746-2851 – weakly reliable due to poor angular resolution
X-rays – quiscent and flaring states with flux difference in serveral orders of magnitude.

Treating EGRET points as upper limits – no reason to expect something interesting in GeV range.

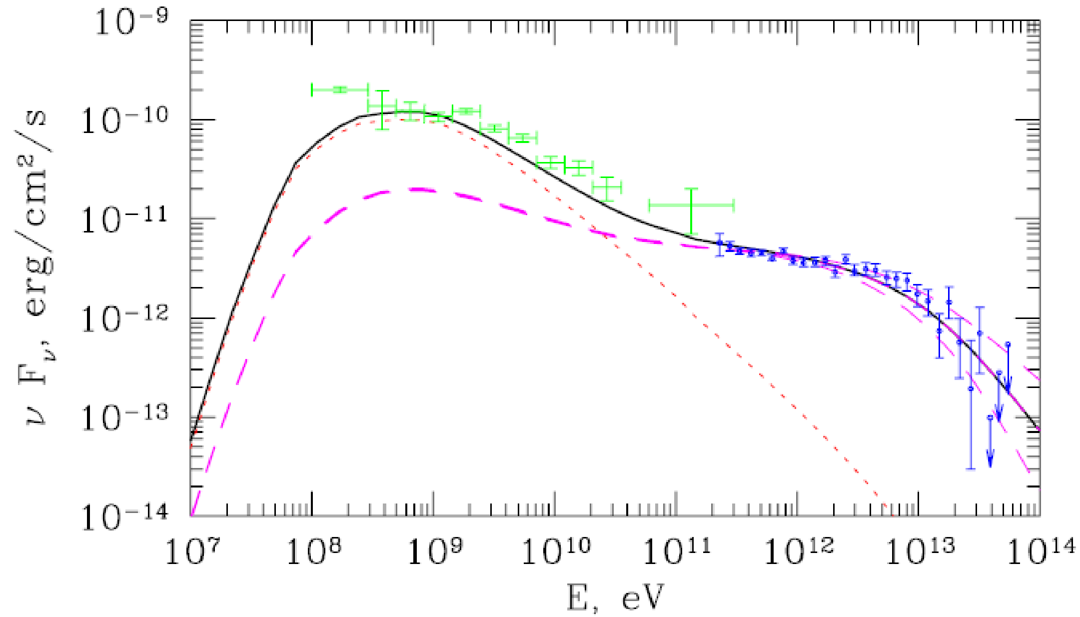
HESS observations of GC

Despite the fact that the GC TeV gamma-ray source is a point-like object for the HESS (Aharonian et al., 2004), the 0.07° PSF of the instrument and the extremely crowded and complex nature of the region does not allow the unambiguous identification of the source(s) of gamma-ray emission.

However, it is possible to place the center-of-gravity of the TeV point source within the central 6" of the Galaxy(Acero et al. 2010), leaving only a handful of possible sources:

- the central black hole itself, Sgr A* (Aharonian & Neronov 2005),
- a plerion discovered within the central few arcseconds (Hinton & Aharonian 2007)
- a putative “black hole plerion” produced by the wind from Sgr A* (Atoyan & Dermer 2004),
- the diffuse10 pc region surrounding Sgr A* (Aharonian & Neronov 2005; Ballantyne et al. 2007, 2010).

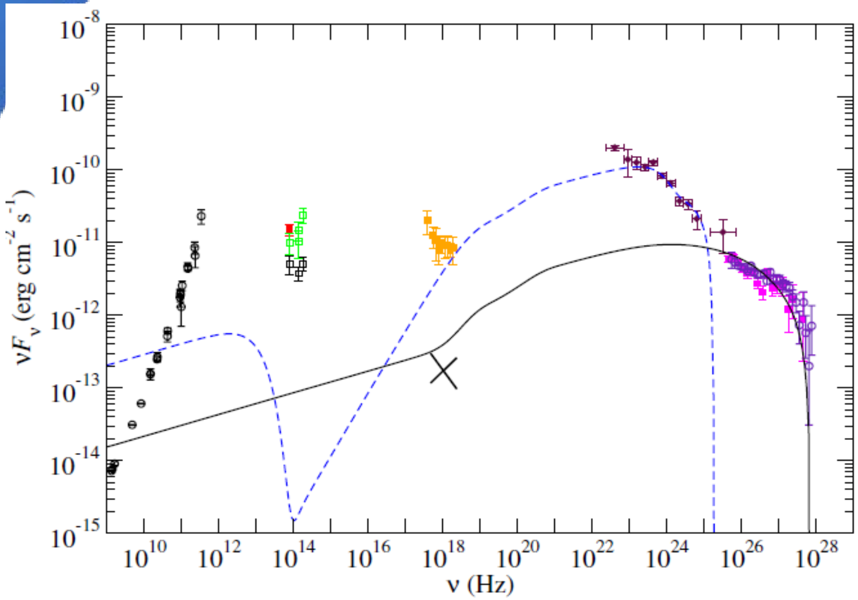
Fermi/LAT observations of GC

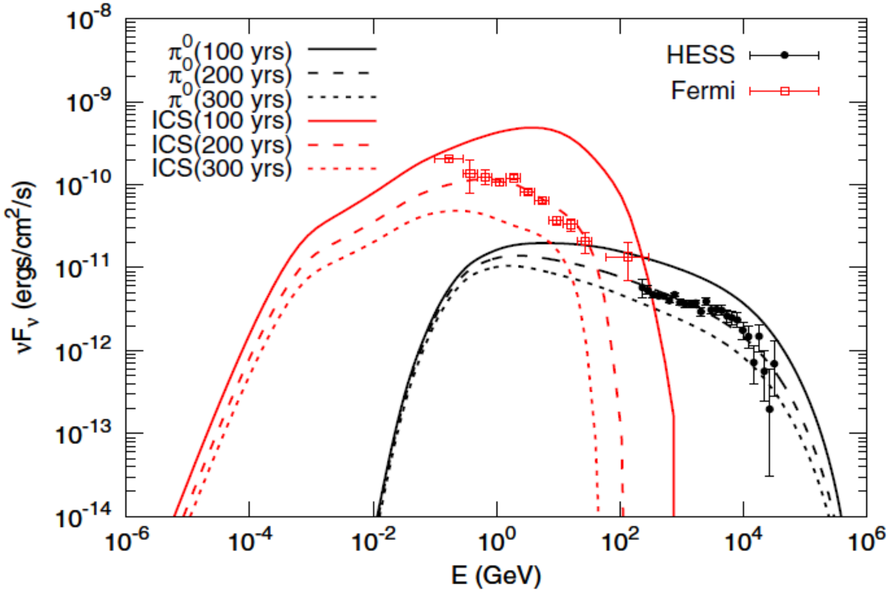


The first results of *Fermi* observations of the GC were presented by J.Cohen-Tanugi on behalf of *Fermi* -LAT collaboration during the 2009 *Fermi* Symposium (11 month).

In 2010 Chernyakova et al. analyzed 25 months of the data. On the base of 1FGL catalog they presented the updated GC spectrum and propose a model of diffusion of CRs in GC ambient medium which allowed to explain the observed spectrum.

Fermi/LAT observations of GC

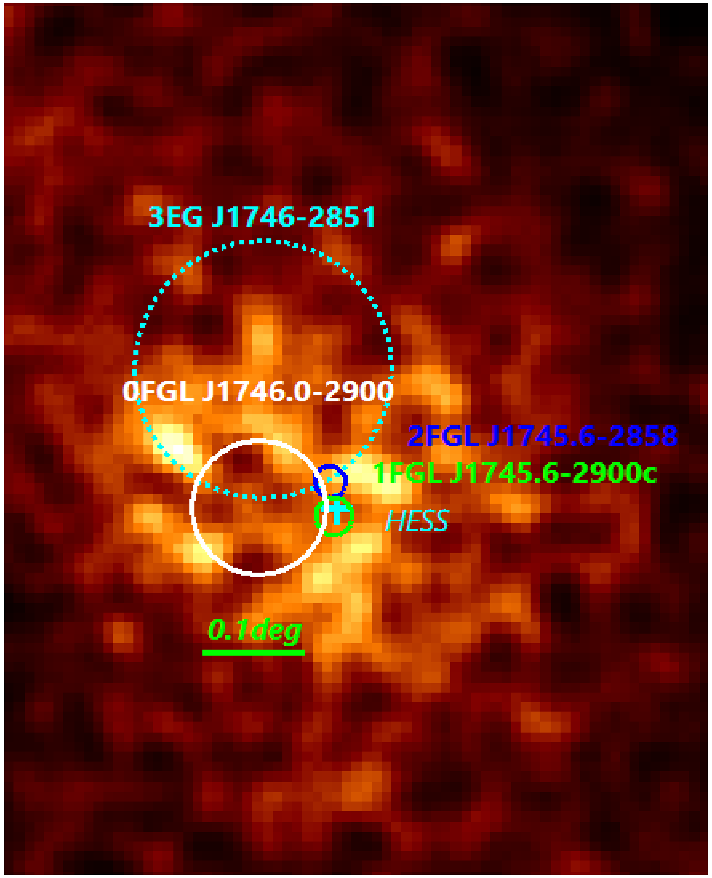




Leptonic (e.g. Hinton & Aharonian 2007, Kusunose 2012) and hybrid (Guo 2013) models were also proposed in order to explain the observed GC spectrum.

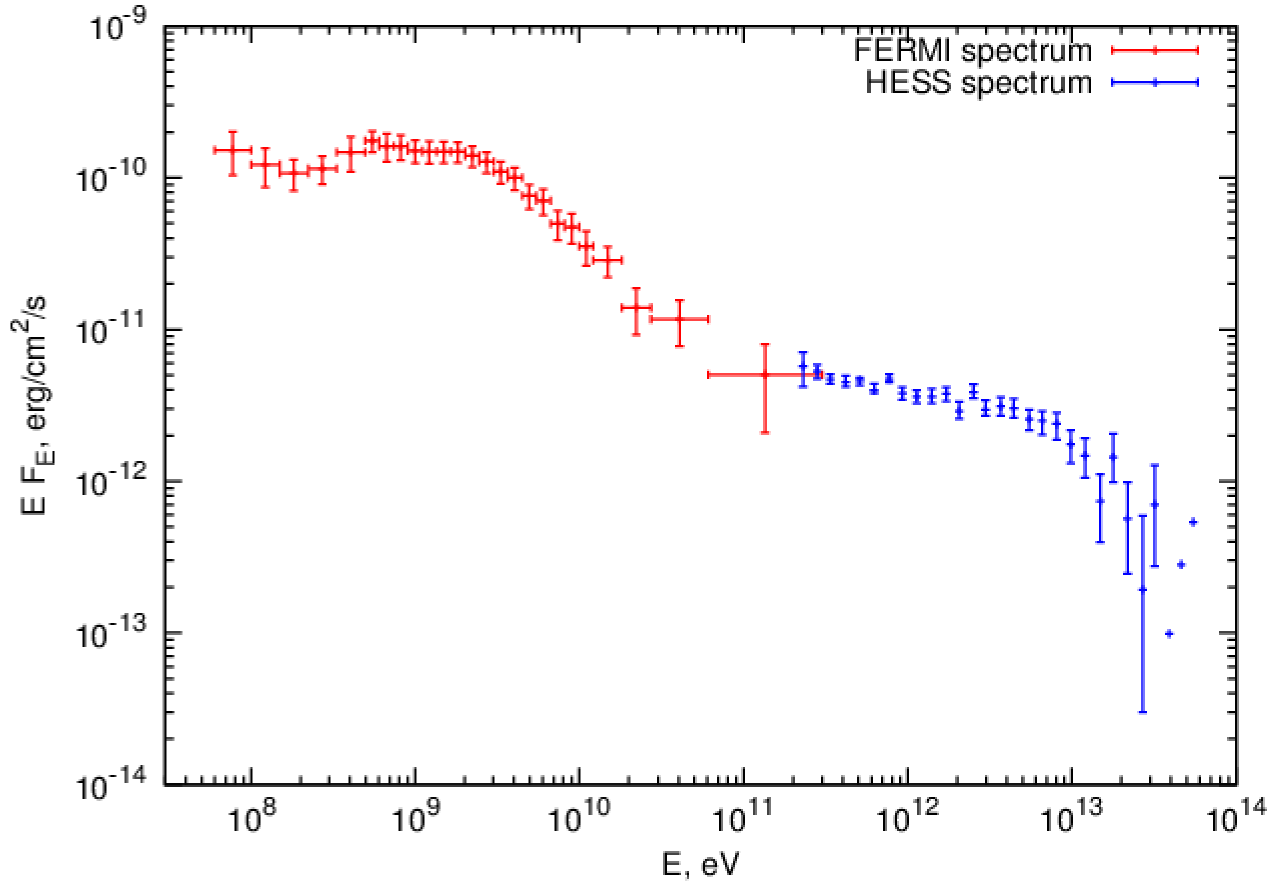
In works of Hooper (2010), Abazajan (2014), Ajello (2015) the authors argue on diffuse nature of GC FERMI/LAT source (at least at certain energies), that can be a signature of DM decay.

FERMI/LAT overview



Complicate data analysis:

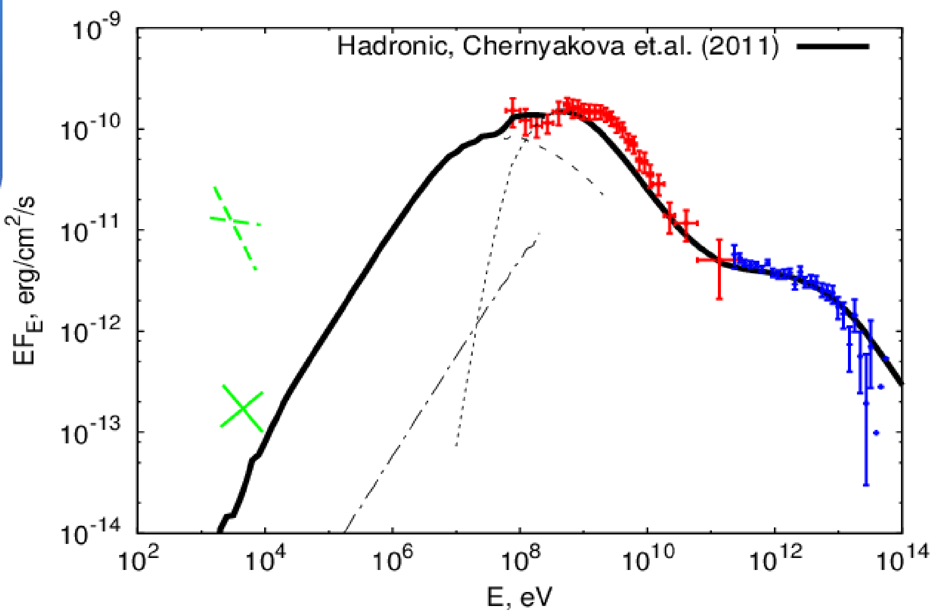
- Source's characteristics depend on the diffuse background model used for the analysis.
- Some diffuse regions (like gas clouds regions) can be confused with point sources.
- Concetration of sources in the galactic central region creates confusion. It is difficult to distinguish between point sources and diffuse emission.
- The determination of flux/spectrum of the source is accomplished with a fitting procedure. In crowded region it can converge to false local minimum or produce degenerate results.

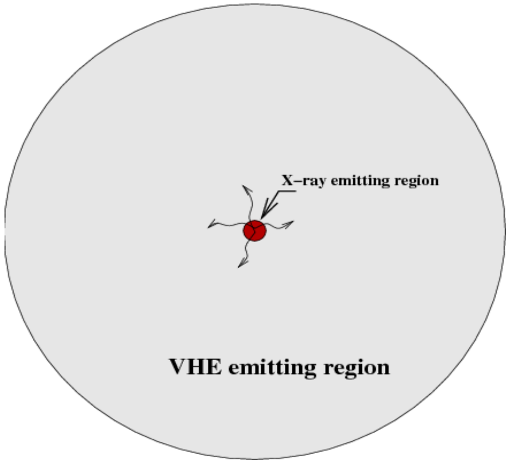


The results of the modelling below are based on 76 months of FERMI/LAT data (Malyshev et al., 2015). The analysis considered all 2/3FGL sources and several choises for the diffuse background model.

The absence of low-energy cut-off up to 60 MeV requires some modification of hadronic models (see below)

Hadronic model, Chernyakova et. al. 2011





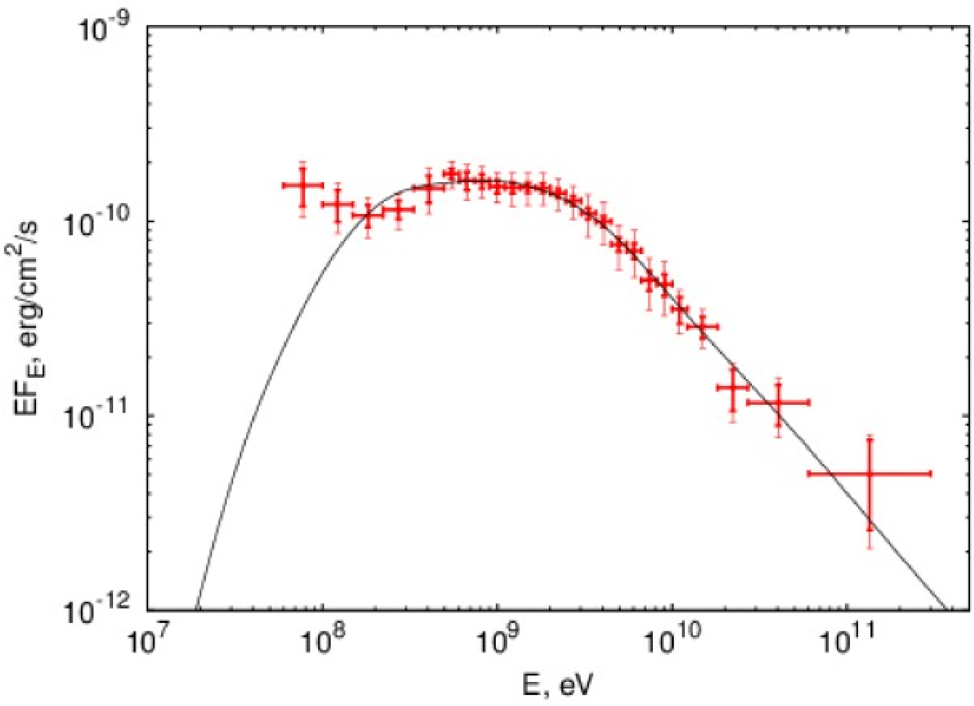
X-ray and low-energy emission come from the central object.

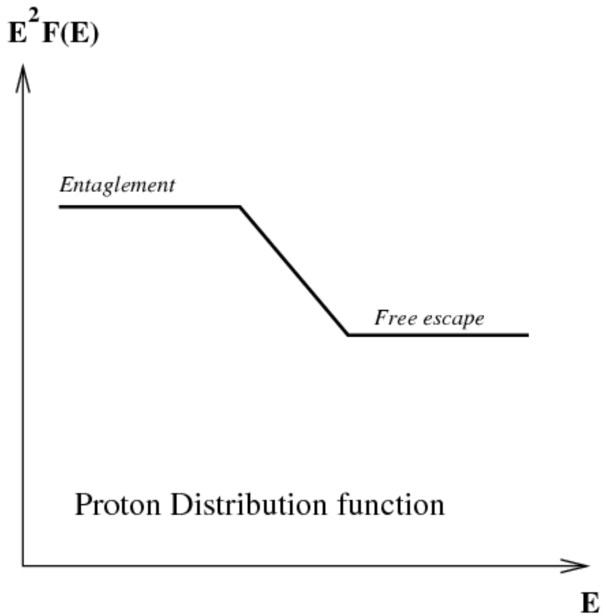
The same central object is a source of high energy protons and electrons.

As proposed in Aharonian & Neronov (2005), a significant fraction of the protons accelerated near the black hole may enter the surrounding gaseous environment and initiate VHE gamma-ray emission through neutral pion production and subsequent decay.

The diffusion of protons is described by relativistic (Jutner) analog of transport equation → no super-luminal particles.

Hadronic model, Chernyakova et. al. 2011





Diffusion coefficient is the (power law) function of energy → diffusion times are different at low and high energies.

At high (TeV) energies protons move almost with the speed of light and thus their number in the cloud remain constant.

At low (GeV) energies due to diffusion protons are entangled and their number in the cloud grows with time.

The shape of the spectrum is the same at low and high energies and similar to injected from central source (~E^{-2}).

The photon spectrum from pp collisions looks similar to proton spectrum.

~100MeV cutoff in photon spectrum is un-avoidable due to cutoff in p-p crossection.

Leptonic model, Malyshev et al., 2015

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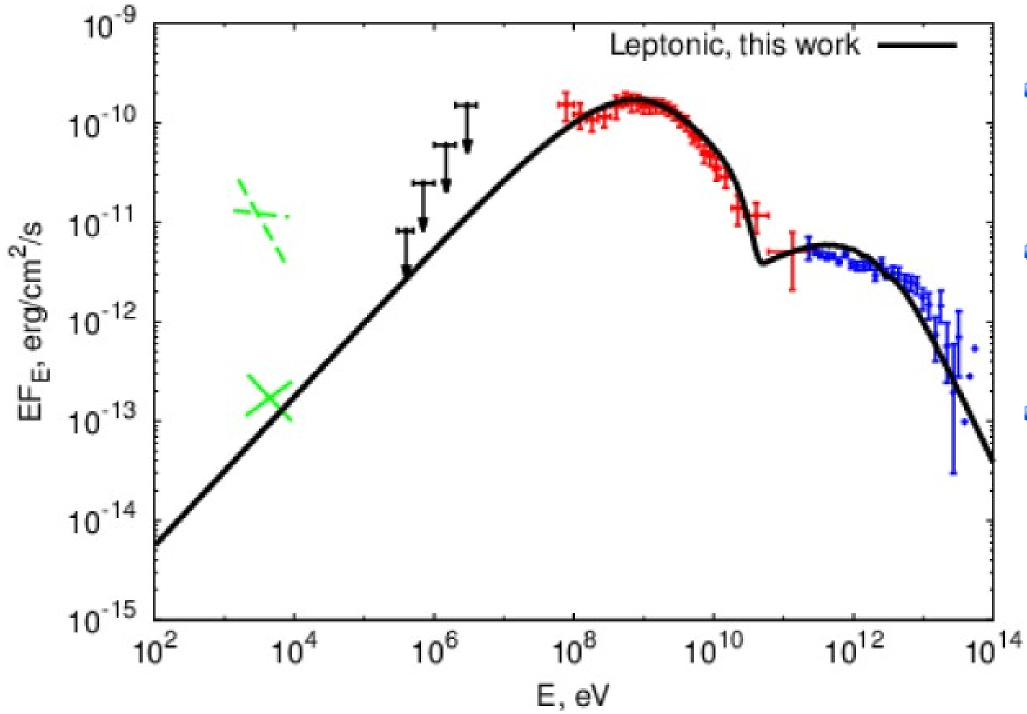
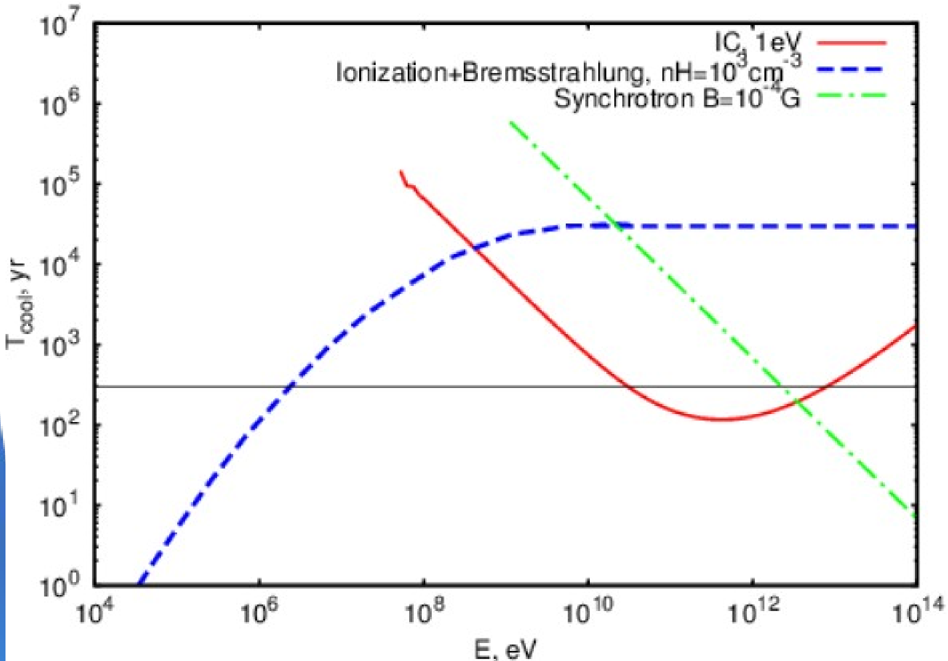




- Non-thermal electrons were supplied by a flare of Sgr A* ~300yrs ago with the powerlaw spectrum of index ~-1.5
- After the flare GC luminosity decreased by ~$2x10^4$ times

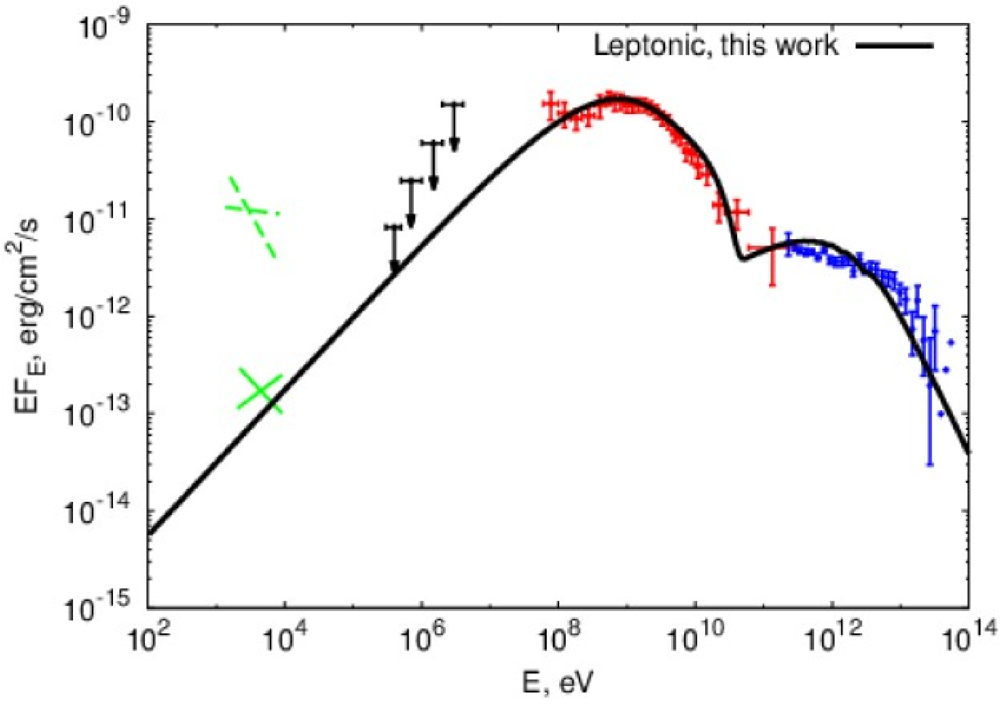
- Electrons propagate through a medium with the density of about $10^3 cm^{-3}$, through the soft photon field with the density $5x10^4$ eV/cm^3 at 0.3-3 eV and magnetic field of order 10-1000 muG

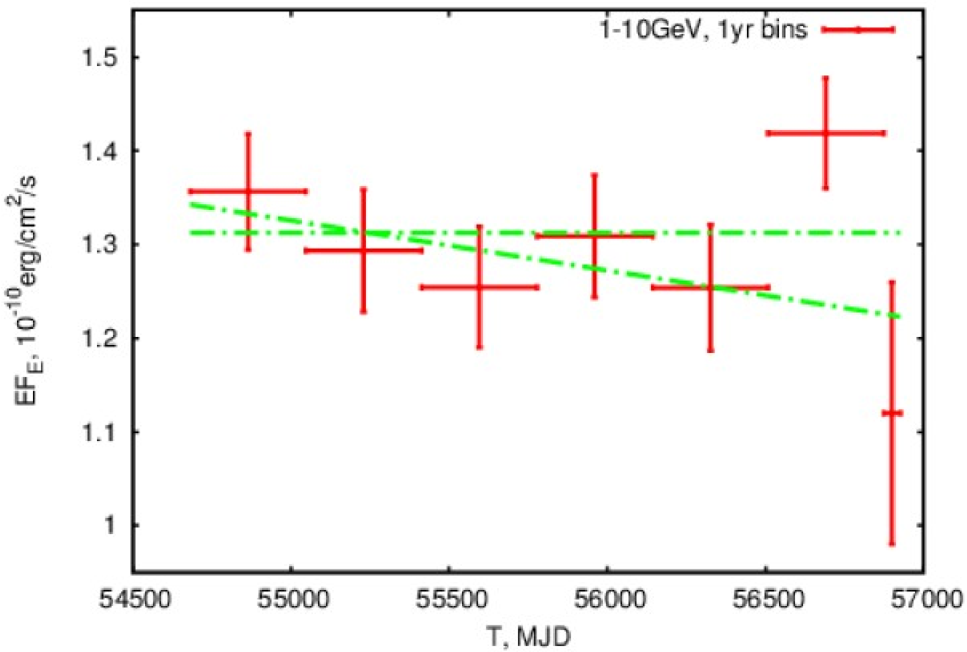
- The main energy-loss channels are ionisation, bremsstrahlung, inverse Compton (IC), and synchrotron

- Observed GeV bump – IC scattering of injected electrons. TeV part – from «quiescent electrons»

- Slow decrease of VHE flux expected

Leptonic model, Malyshev et al., 2015





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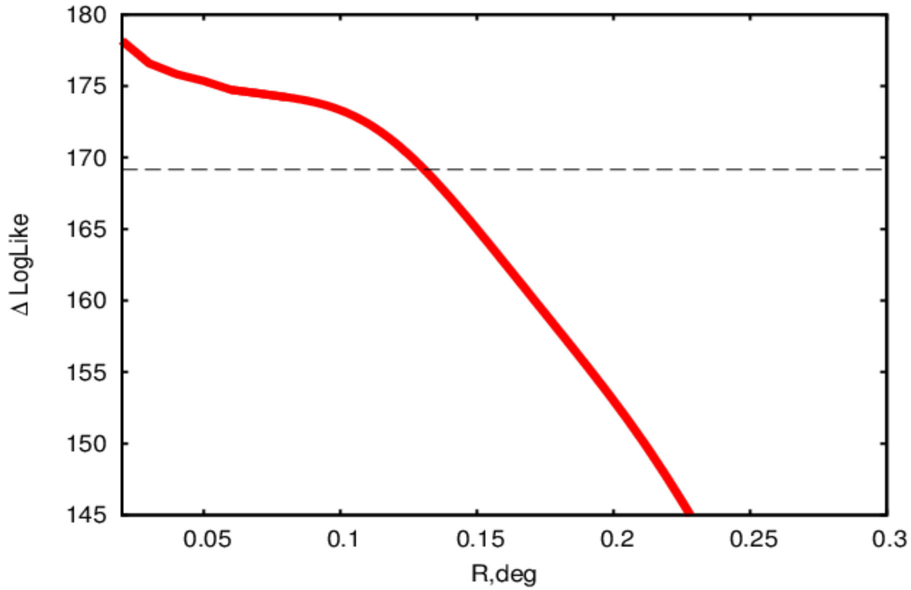
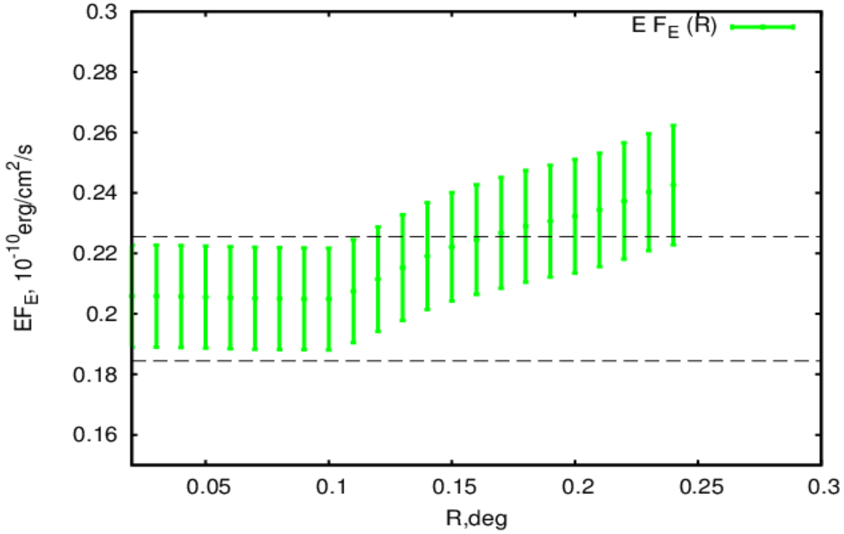
- The main energy-loss channels are ionisation, bremsstrahlung, inverse Compton (IC), and synchrotron
- Observed GeV bump – IC scattering of injected electrons. TeV part – from «quiescent electrons»
- Slow decrease of VHE (>1 GeV) flux expected

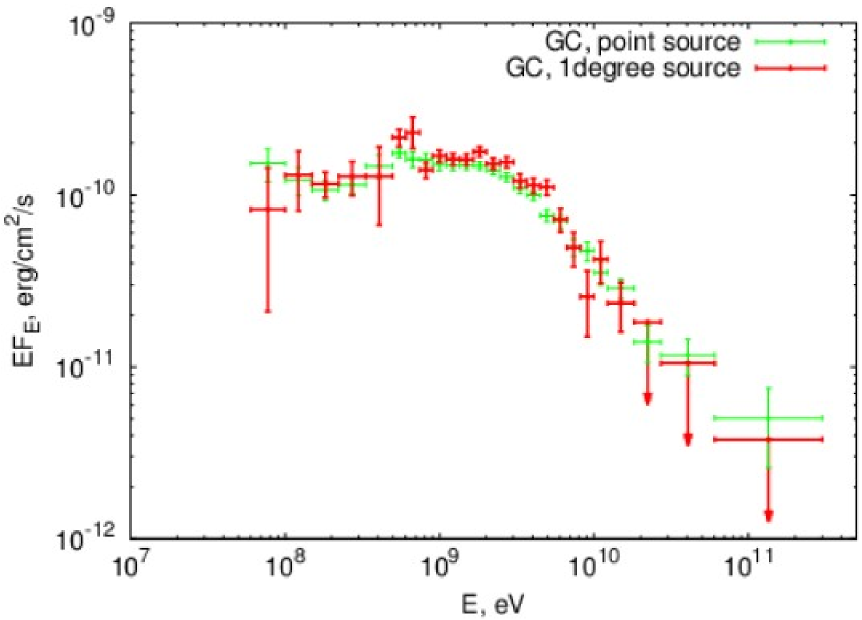
Morphology of the Galactic Center

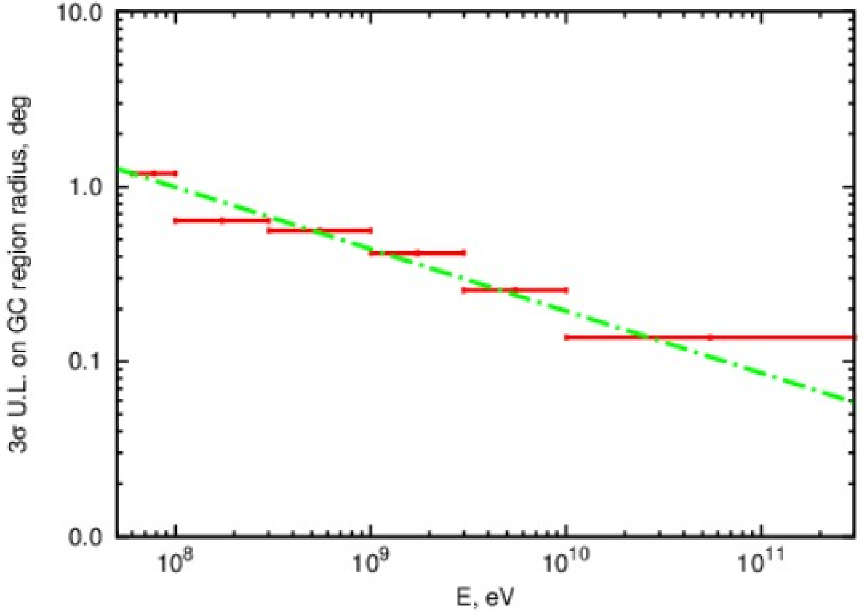




- To discriminate between point- and diffuse- morphologies proposed in the literature we model GC as a disk of certain radius and investigate the dependance of the detection significance on the disk size.
- We perform simulations at 0.06-300 GeV energies
- The decrease of the TS by 9 corresponds to 3sigma c.r. upper limit on the source's size
- We studied how the flux attributed to the GC is changing with the increase of the source's size.

Morphology of the Galactic Center





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Conclusions

- We present the spectrum of the Galactic Center from the analysis of 74 months of FERMI/LAT data, taking into account all 3FGL sources. Low-energy (60-100MeV) results are also presented.

- Both, hadronic and leptonic models describe the data reasonably well.
  Low (60 MeV) energy detection of the GC can indicate the presense of low-energy leptonic component in hadronic model or give a preference to pure leptonic model.

- Slow decrease of 10-100 GeV is expecting for the leptonic model case

- We do not see the diffuse morphology of the Galactic Center and put upper limits on its size. At all energies the size of the GC does not exceed 1^{o}