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Dark Matter search with Fermi

E. Bonamente
Università di Perugia - Perugia, Italy
INFN, Sezione di Perugia - Perugia, Italy

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Summary. — The Fermi mission is a gamma-ray telescope operating since 2008. One of its goals is the indirect search of Dark Matter (DM) in the Universe. Emission yielded from annihilating DM particles is supposed to produce a characteristic gamma-ray spectrum that could be observed in several astrophysical sites. Results and status updates for different DM searches with Fermi data will be presented.

PACS 95.35.+d – Dark matter (stellar, interstellar, galactic, and cosmological).

1. – The Fermi Space Telescope

The Fermi Space Telescope is an international mission with approximately 400 members from 5 different countries, France, Italy, Japan, Sweden and the United States. The satellite has been launched on June 11, 2008, and now it is in its third year of data taking. It is performing very well, with low degradation rate for silicon strips, and passed the record of 100 billion triggers.

It is composed by two instruments, the Gamma-ray Burst Monitor [1] (GBM), which is an array of crystals, disposed around the spacecraft, designed to measure the energy emission of bursts occurring in the energy range from 8 keV up to 40 MeV, and the Large Area Telescope [2] (LAT), made by an array of 4×4 towers, each one having a converting-tracker and an electromagnetic calorimeter, surrounded by tiles of scintillators. The energy range of the LAT goes from 30 MeV up to > 300 GeV, producing an overall energy coverage of more than 7 energy decades for the Fermi Telescope. It is able to observe the gamma-ray emission with unprecedented performances in terms of spatial resolution (0.1 degrees, $E > 10$ GeV) and sensitivity ($3 \cdot 10^{-9}$ ph $\cdot$ cm^{-2} s^{-1}, $E > 100$ MeV), covering the unexplored region above 10 GeV. The satellite is orbiting at an altitude of ~ 550 km, with a period of 90 minutes. The LAT has been designed with a very compact aspect ratio, resulting in a broad field of view (2.4 sr), corresponding approximately to the 20% of the sky. These two characteristics allow one to have a uniform exposure coverage of the sky every 2 orbits.

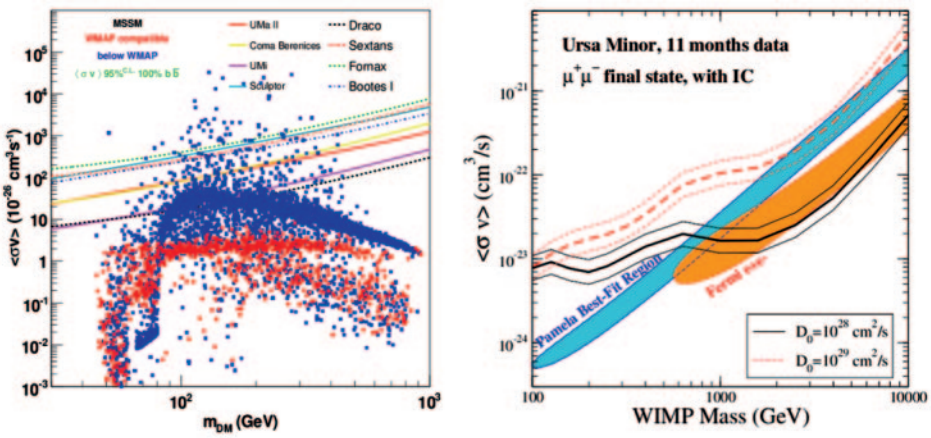

Fig. 1. – Left: 95% CL upper limits on the annihilation rate from dSph analysis for the $b/\bar{b}$ channel. Right: 95% CL upper limits on the annihilation rate from dSph analysis for the μ^+/μ^- channel.

2. – Active DM searches

DM annihilation is supposed to take place in several astrophysical sources and its products to be revealed by modern instruments. This search for DM is called indirect, since it is not based on the direct interaction of a DM particle in the detector, but on the observation of its products. Fermi represents the leading instrument to search for the gamma-ray signature yielded by DM annihilation in the MeV–GeV energy scale, the benefit of studying the photon emission being that of knowing the position of the source in the sky.

The first site of interest is the Galactic Halo. Here the DM component, peaking at energies from 10 to 100 GeV, have been added to the model defined for the fit and tested against the null hypothesis. Using data from the first 21 months of observations, the preliminary result is that there is no evidence for a DM component at 3σ CL. Upper limits on the annihilation rate suggest that, for DM annihilating into the μ^+/μ^- channel, the excess seen by Pamela and Fermi in the e^+/e^- spectrum cannot be attributed to DM.

The second target is represented by DM subhalos, structures of high-density DM orbitating inside the Galactic Halo [3]. Dwarf spheroidal galaxies (dSph) are very high mass-to-light ratio objects, hence DM dominated. 14 dSph have been analyzed, without any evidence for gamma-ray emission. Upper limits on the annihilation rate confirm the non-DM interpretation of the electron escess (μ^+/μ^- channel) and begin to constrain on some DM scenarios for the $b/\bar{b}$ channel (fig. 1).

Gamma-ray emission has been searched also from 6 bright galaxy clusters [4]. No detection has been made with 11 months of data, and usual upper limits on σv confirm results from dSph analysis (fig. 2).

The diffuse isotropic gamma-ray emission, that is in part given by known unresolved sources, has been fitted including a DM contribute [5]. Its spectrum is consistent with a power law (index $= -2.41 \pm 0.05$), with no space for a DM component (fig. 3).

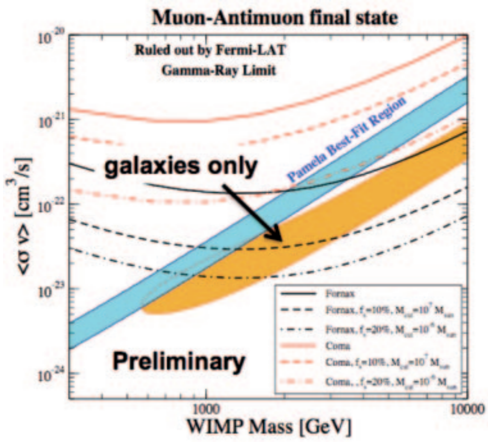

Fig. 2. – 95% CL upper limits on the annihilation rate from Galaxy Clusters analysis for the μ^+/μ^- channel.

Finally also the direct annihilation of DM into a photon pair (*i.e.* line emission) has been searched through the Galaxy in the range 30–200 GeV [6]. A line contribute (fig. 4) has been added to the fit, without any detection.

3. – Conclusions

Results on the search for DM with Fermi from the first two years of operation have been presented. The data analysis did not produce any detection. Interesting limits on DM properties have been set, especially the interpretation of the electron cosmic-ray excess as non-DM. Future works will take great benefits of higher statistics (the mission has been projected to take data for up to 8 years more) and better understanding of instrument response function and in general an improved background modelization.

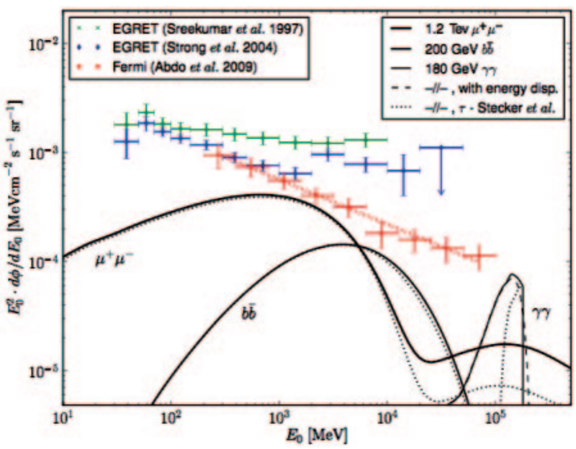

Fig. 3. – Diffuse isotropic background as seen by Fermi and by EGRET. The EGRET excess is not confirmed and there is no evidence for a DM component.

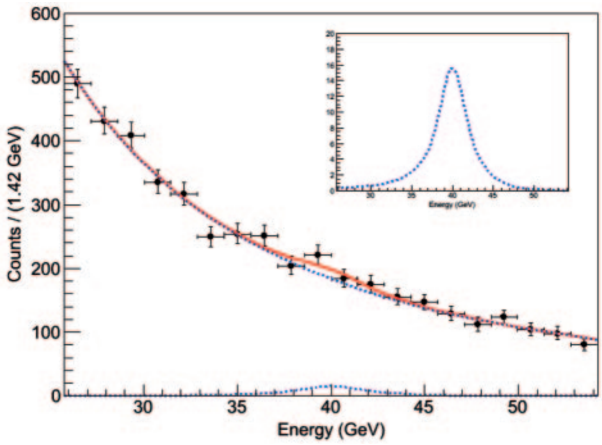

Fig. 4. – (Colour on-line) Example of the fit for line search in the gamma spectrum. The upper dotted line is the background, the lower dotted line is the signal, and the red line is the best fit (signal+bg).

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