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Search for supersymmetric dark matter with GLAST

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Abstract. The detection of exotic cosmic rays due to pair annihilation of dark matter particles in the Milky Way halo is a viable technique to search for supersymmetric dark matter candidates. The study of the spectrum of gamma-rays, antiprotons and positrons offers good possibilities to perform this search in a significant portion of the Minimal Supersymmetric Standard Model parameter space. In particular, the EGRET team has seen a convincing signal for a strong excess of emission from the Galactic center that has no simple explanation with standard processes. We will review the limits achievable with the experiment GLAST taking into accounts the LEP results and we will compare this method with the antiproton and positrons experiments, and direct detection underground experiments.

PACS. 95.55.Ka Gamma-ray telescopes – 95.35.+d Dark matter

GLAST [1] is a next generation high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy band extending from 20 MeV to more than 300 GeV. The principal instrument of the GLAST mission is the Large Area Telescope (LAT) that is being developed jointly by NASA and the US Dept. of Energy (DOE) as a mission involving an international collaboration of particle physics and astrophysics communities from 26 institutions in the United States, Italy, Japan, France and Germany. The main scientific objects are the study of all gamma ray sources such as blazars, gamma-ray bursts, supernova remnants, pulsars, diffuse radiation, and unidentified high-energy sources. Many years of refinement has led to the configuration of the apparatus, formed by 4x4 array of identical towers, each formed by: • Si-strip Tracker Detectors and converters arranged in 18 XY tracking planes for the measurement of the photon direction. • Segmented array of CsI(Tl) crystals for the measurement of the photon energy. • Segmented Anticoincidence Detector (ACD). Positrons and electrons from pair-converted photons, are tracked through the silicon and tungsten of the tracker with the goal to find the best one or two trajectories, depending on the incident energy. Multiple scattering is the key to this analysis, in that it is the dominant error contribution below a few GeV. A Kalman filter technique is used in the tracker to account for this effect. It basically follows trajectories, accounting for energy-dependent error introduced by material in the tracker and predicting a cone in which to look for hits to associate in the next layer. The Tracker provides the principal trigger for the LAT, converts the gamma rays into electron-positron pairs, and measures the direction of the incident gamma ray from the charged-particle tracks. The main characteristics of the detector, extensively studied with Monte Carlo and beam tests, are an energy range between 20 MeV and 300 GeV, a field of view of ~ 3 sr, an energy resolution of $\sim 5\%$ at 1 GeV, a point source sensitivity of 2x10^{-9} (ph cm^{-2} s^{-1}) at 0.1 GeV, an event deadtime of 20 μs and a peak effective area of 10000 cm^2, for a required power of 600 W and a payload weight of 3000 Kg. A more detailed description of the main GLAST parameters can be found in [2]. GLAST could be of particular interest for the search of dark matter candidates. If dark matter is made by the lightest supersymmetric particles (neutralinos), they would have non-relativistic velocities; hence the neutralino annihilation into two γ's and a γ and a Z as final states can give rise to mono-energetic γ-rays with $E_\gamma = M_\chi$ and $E'_\gamma = M_\chi\ (1 - m_z^2/4M_\chi^2)$. All the others annihilation process will give also π^0 that that will decay in a continuum gamma-ray flux (for a review see Bergström [3]; a list of other recent analyses on this topic includes Bergström et al. [5,6], Bertone et al. [7], Hooper et al. [8], Merritt et al. [9], Ullio et al. [10], Boer et al. [11]).

The key problem is to separate the two different (standard and exotic) contributions

As most photons are produced in the hadronization and decay of π^0s, the shape of the photon spectrum is always peaked at half the mass of the pion, about 70 MeV, and it is symmetric around it on a logarithmic scale (sometimes this feature is called the "π^0 bump"). The same is

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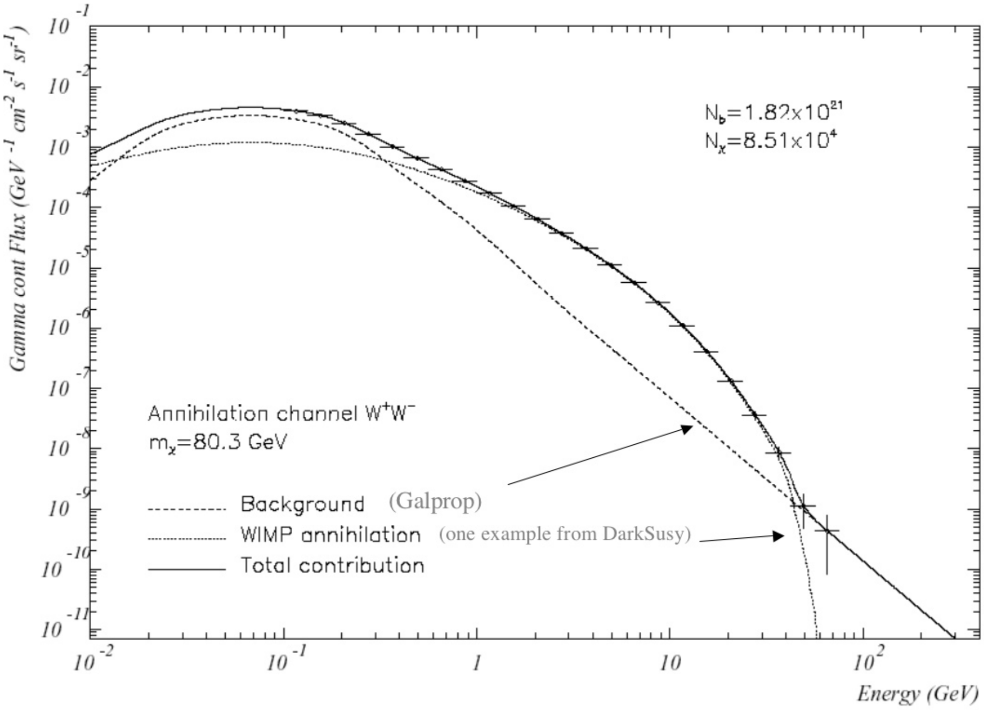

Fig. 1. The total photon spectrum from the galactic center from standard propagation models and from one neutralino annihilation models and the kind of statistical errors that it is expected in three years with GLAST

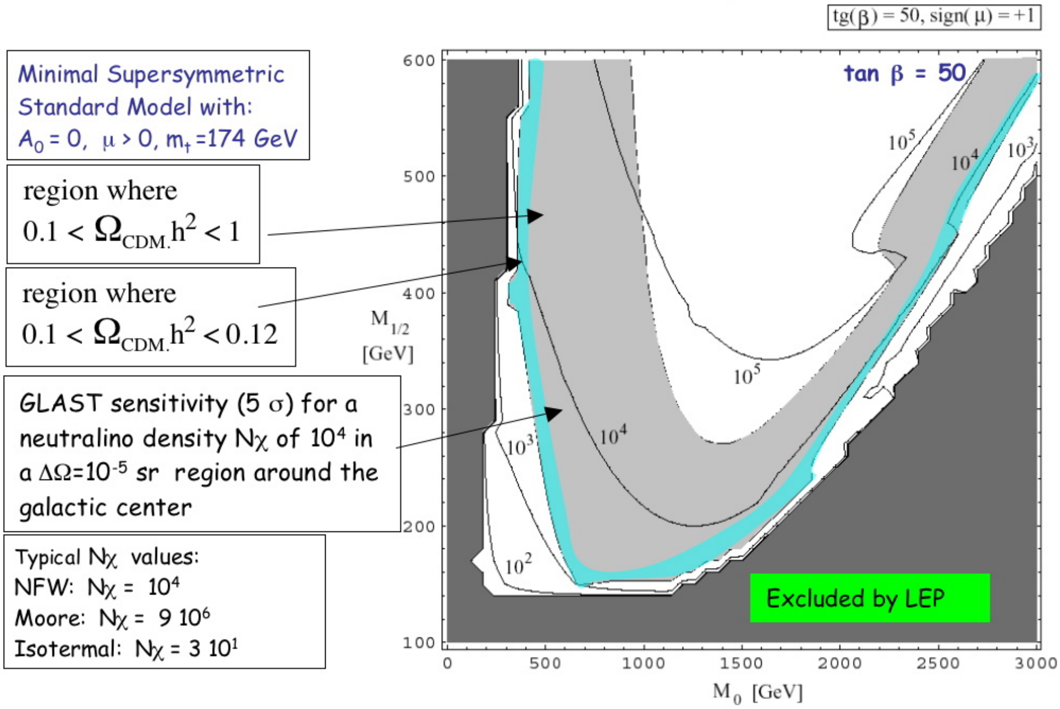

Fig. 2. Contour plot in the mSUGRA $(m_0, m_{1/2})$ plane, for the value of the normalization factor N_χ, that allows the detection of the neutralino γ ray signal, with GLAST. The light shaded region corresponds to $0.1 \leq \Omega_\chi h^2 \leq 1$, while the dark shaded one corresponds to models that are excluded either by LEP bounds violations or because the neutralino is not the lightest supersimmetric particle

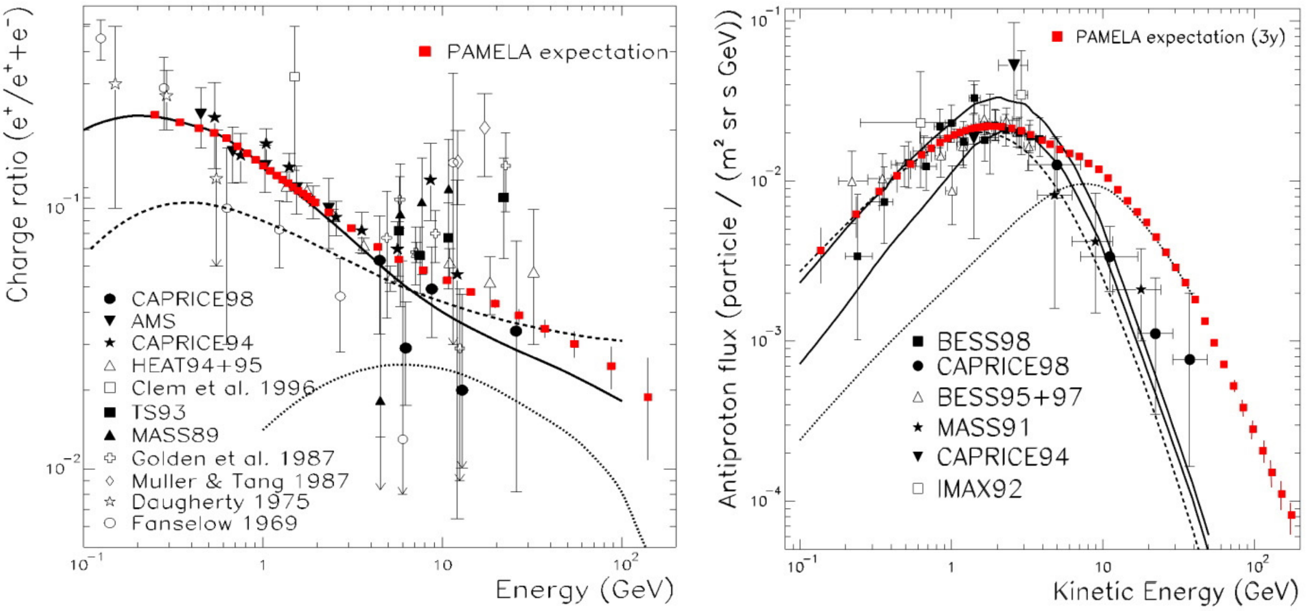

Fig. 3. Distortion of the secondary positron fraction (*on the left*) and secondary antiproton flux (*on the right*) induced by a signal from a heavy neutralino. The PAMELA expectations in the case of exotic contributions are shown by red squares. For the experimental results and standard theoretical predictions see [12]

true for the background, but still it may be possible to tell signal from background: the signal arises in processes which have all the same energy scale, i.e. $2M_\chi$, therefore the WIMP induced flux, contrary to the background, is spectral index free and shows a sharp cutoff when E_γ approches the WIMP mass. Figure 1 shows the typical spectral shape of the background flux due to the interaction of primary cosmic rays with the interstellar medium and of the spectral shape from one neutralino annihilation model. From the figure one can see that GLAST will have the needed statistical, angular and energetic accuracy to distinguish the two kinds of spectral shape. Figure 2 shows the GLAST capability to probe the supersymmetric dark matter hypothesis [4]. The figure shows in the $(m_0, m_{\frac{1}{2}})$ plane, the iso-contour regions for the minimum allowed value of the neutralino density in a $\Delta\Omega = 10^{-5} sr$ region around the galactic center. The density depends on the halo shape of the neutralino distribution, that is still matter of debate and can vary from a value of $N_\chi = 3 \times 10^1$ for an isothermic profile up to $N_\chi = 10^4$ for a NFW profile. In the figure it can be seen that GLAST can explore a good portion of the supersymmetric parameter space if the halo has a Moore (or steeper) profile.

This effort will be complementary to a similar search for neutralinos looking with cosmic-ray experiments like the next space experiments PAMELA[12] and AMS[13] at the distortion of the secondary positron fraction [14] and secondary antiproton flux [15] induced by a signal from a heavy neutralino. As an example, the expected data from the experiment PAMELA in the annihilation scenario for three years of operation are shown by squares in Fig. 3 for both the positron and antiproton fluxes.

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