When LEP and Tevatron combined with WMAP and XENON100 shed light on the nature of Dark Matter

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Recently, several astrophysical data or would-be signals has been observed in different dark-matter oriented experiments. In each case, one could fit the data at the price of specific nature of the coupling between the Standard Model (SM) particles and a light Dark Matter candidate: hadrophobic (INTEGRAL, PAMELA) or leptonophobic (WMAP Haze, dijet anomalies of CDF, FERMI Galactic Center observation). In this work, we show that when one takes into account the more recent LEP and Tevatron analysis, a light thermal fermionic Dark Matter ($\lesssim 10$ GeV) that couples to electrons is mainly ruled out if one combines the analysis with WMAP constraints. We also study the special case of scalar dark matter, using a mono–photon events simulation to constrain the coupling of dark matter to electron.

I. INTRODUCTION

Very recently, the CDF collaboration announced the observation of an excess of events which include a lepton (electron or muon), missing transverse energy, and two jets [1]. Many studies have been done since then motivating the existence of light dark matter candidates (see e.g., [2]). Some authors [3] interpreted this excess by the introduction of a new gauge boson with sizable couplings to quarks, but with no or highly suppressed couplings to leptons (a leptonophobic dark boson). Dark matter experiments had also given some hints for signals in direct or indirect detection modes. On one hand, some hadrophobic dark matter candidates were proposed in [4–6] to explain the DAMA [7] and CoGENT [8] signals in direct or indirect detection modes. On the other hand, some authors showed that a light dark matter could at the same time explain these direct detection signals and the excess of emission observed by the Fermi Gamma Ray Space telescope [11] and the CDF signal if it annihilate predominantly into hadronic states. There was also cosmic rays excess measured in PAMELA or INTEGRAL [12] which needed hadrophobic dark matter. In each case the nature of the couplings of the dark matter with the Standard Model particles is fundamental in any kind of discoveries. Recently, the authors of [13] used the mono–photon events at LEP to constrain the nature of the dark matter couplings, concluding that a dark matter with mass $\lesssim 10$ GeV with charged-leptonic couplings generates a too low annihilation rate to avoid the over–closure of the Universe. In this work, we compute the rate of hadronic coupling needed to reconciliate the LEP analysis with a thermal dark matter hypothesis and respect WMAP upper bound constraint. In section II, we will review the models and type of couplings we have studied. We give our result in the case of contact operator for a fermionic candidate in section IIIA, and consider a scalar case in section IIIB. For the later, we ran a simulation of events at DELPHI experiment [14] in order to constraint the operator suppression scale, in the same fashion as is done in the literature for the fermionic DM. We then implement the constraints from the mono–jet event of Tevatron and XENON100 in the analysis in section IV before concluding in section V.

II. THE MODELS

We begin with the case of a fermionic WIMP, and study the 4 types of interactions consistent with the requirement of Lorentz invariance and strongly constrained by LEP analysis. This enables us to describe the interaction between WIMPs and standard model fermions in terms of an effective field theory, in which we keep only terms of an effective field theory, in which we keep only

\begin{align}
&\frac{1}{\Lambda_t} \equiv \sqrt{g_l^2} \frac{1}{\Lambda} ; \quad \frac{1}{\Lambda_h} \equiv \sqrt{g_h} \frac{1}{\Lambda} \\
&\text{Vector : } \mathcal{L}_V = \sum_i \frac{g_i^l}{\Lambda^2} (\bar{l}^i \gamma^\mu l^i)(\bar{\chi} \gamma^\mu \chi) + \sum_i \frac{g_i^h}{\Lambda^2} (\bar{q}^i \gamma^\mu q^i)(\bar{\chi} \gamma^\mu \chi) \\
&\text{Scalar, s – channel : } \mathcal{L}_S = \sum_i \frac{g_i^l}{\Lambda^2} (\bar{l}^i l^i)(\bar{\chi} \chi) + \sum_i \frac{g_i^h}{\Lambda^2} (\bar{q}^i q^i)(\bar{\chi} \chi) 
\end{align}

\[\text{(1)}\]

We will then consider the set of operators

\begin{align}
&\text{Vector : } \mathcal{L}_V = \sum_i \frac{g_i^l}{\Lambda^2} (\bar{l}^i \gamma^\mu l^i)(\bar{\chi} \gamma^\mu \chi) + \sum_i \frac{g_i^h}{\Lambda^2} (\bar{q}^i \gamma^\mu q^i)(\bar{\chi} \gamma^\mu \chi) \\
&\text{Scalar, s – channel : } \mathcal{L}_S = \sum_i \frac{g_i^l}{\Lambda^2} (\bar{l}^i l^i)(\bar{\chi} \chi) + \sum_i \frac{g_i^h}{\Lambda^2} (\bar{q}^i q^i)(\bar{\chi} \chi) 
\end{align}
Axial : \[ \mathcal{L}_A = \sum_i \frac{g_i^A}{\Lambda^2} (\bar{f} \gamma^\mu \gamma^5 f)(\bar{\chi} \gamma^\mu \gamma^5 \chi) + \sum_i \frac{g_h^A}{\Lambda^2} (\bar{q} \gamma^\mu \gamma^5 q)(\bar{\chi} \gamma^\mu \gamma^5 \chi) \]

Scalar, t– channel \[ \mathcal{L}_t = \sum_i \frac{g_i^A}{\Lambda^2} (\bar{f} \gamma^5 f)(\bar{\chi} \gamma^5 \chi) + \sum_i \frac{g_h^A}{\Lambda^2} (\bar{q} \gamma^5 q)(\bar{\chi} \gamma^5 \chi) \]

\( \chi \) being the DM candidate. Throughout this paper, we will assume that the dark matter particle \( \chi \) is a Dirac fermion (except in section IIIIB, where we consider a real scalar DM candidate). A vectorial interaction is motivated by the exchange of a \( Z'_\mu \) whereas scalar interaction is motivated by Higgs-portal like models [16].

We will consider 3 kinds of models which could be representative of UV completion:

- Electrophilic couplings (model A): \( g_l^e = g_e \), \( g_l^{i=\mu,\tau,\nu_i} = 0 \)
- Charged lepton couplings (model B) : \( g_l^{i=e,\mu,\tau} = g_l \), \( g_l^{i=\nu_i} = 0 \)
- Universal lepton couplings (model C) : \( g_l^{i=e,\mu,\tau,\nu_i} = g_l \)

As we are interested in the ratio of the hadronic to the leptonic final states in the DM annihilation, we will consider without loss of generality an universal generation/family coupling in the hadronic sector: \( g_h^{i=u,d,c,s,t,b} = g_h \). Note that we assumed lepton flavor to be conserved in the dark matter interaction.

Recently, the authors of [13] made an analysis with relatively little model dependance, by pair production of pair of dark matter particles in association with a hard photon. The LEP experiments have searched for anomalous mono–photon events in their data sets, but have found no discrepancy from the prediction of the standard model. They used the mono–photon spectrum from the DELPHI experiment to place upper bound to 1/\( \Lambda_\chi^2 \) = \( g_e/\Lambda^2 \). We reproduce interpolated functions of this result in Fig.(1). We then translated this limit on \( \Lambda_\chi \) to a limit on the ratio of hadronic to leptonic channel, \( \text{Br}_{h}/\text{Br}_{l} \), taking into account the relic density constraints.

III. CONSTRAINTS FROM THE THERMAL RELIC TO THE HADRONIC BRANCHING RATIO

A. The fermionic case

The LEP lower bound on the scale \( \Lambda_\chi = \Lambda/\sqrt{g_e} \) can be converted in a upper bound to the dark matter annihilation into \( e^+e^- \) (case A), into charged leptons pair (case B) or into general leptons pair (case C). Moreover, if dark matter is a thermal relic, asking for the density to respect the upper bound given by WMAP [18] \( \Omega_\chi h^2 \lesssim 0.1 \), one needs to impose \( \langle \sigma v \rangle \gtrsim 3 \times 10^{-26} \text{cm}^2/\text{s} \simeq 1 \) pb to avoid an overclosed universe (but letting for the possibility of having another dark matter candidate). We computed the annihilation cross section which is given for a final state with particles masses \( m_4, m_4 \) by

\[
\frac{d\sigma_t}{dt} = \frac{|\mathcal{A}_t|^2}{64\pi^2 s} \sqrt{s - 2m_4^2 - 2m_3^2 + \frac{(m_3^2 - m_2^2)^2}{s}} \sqrt{s - 4m_3^2} \tag{3}
\]

with \( \text{I=V, S, A, t} \). We then substitute \( s \simeq 4m_4^2 + m_3^2 v^2 \) in Eq.(3) and expanding in powers of the relative velocity between two annihilating WIMPs up to order \( v^2 \) for each type of couplings. We find

\[
\sigma_I^2 v = g_l^2 \sum_{l=e,\mu,\tau,\nu} \sigma_{l,l}^2 v + c g_h^2 \sum_{h=u,d,c,s,t,b} \sigma_{l,h}^2 v \tag{4}
\]

where \( \text{I=V, S, A, t} \) represents the nature of the coupling (vectorial, scalar, axial or t-scalar) and \( \text{J=V, A, B, C} \) the type of coupling (electronic, charged leptonic or universal leptonic), \( c \) the color factor and

\[
\sigma_{l,k}^2 v = \sigma_{l,k}^2 v \times \theta_k^2 (m_\chi) \tag{5}
\]

1 in the absence of resonances or coannihilation.
\[ \theta_{J=A,B,C}^{l=\mu,e,\tau}(m_{\chi}) = \Theta_H(m_{\chi} - m_h) \]
\[ \theta_{e}^{A}(m_{\chi}) = \Theta_H(m_{\chi} - m_e), \quad \theta_{l=\mu,e,\tau}^{A}(m_{\chi}) = 0 \]
\[ \theta_{e}^{B}(m_{\chi}) = \Theta_H(m_{\chi} - m_l), \quad \theta_{l=\mu,e,\tau}^{B}(m_{\chi}) = 0 \]
\[ \theta_{e}^{C}(m_{\chi}) = \Theta_H(m_{\chi} - m_e) \]
\[ \Theta_H \text{ being the classical heaviside function (} \Theta_H(x) = 1 \text{ if } x > 0, \text{ and 0 otherwise) and } \sigma_{l,k} \text{ is given by:} \]
\[ \sigma_{v,k} = 4g_{L}(24m_{\chi}^2 + m_{k}^2) + \frac{8m_{\chi}^4 - 4m_{\chi}^2m_{k}^2 + 5m_{k}^4}{m_{\chi}^2 - m_l^2}v^2 \]
\[ \sigma_{s,k} = 24g_{L}(m_{\chi}^2 - m_{k}^2)v^2 \]
\[ \sigma_{A,k} = 4g_{L}(24m_{k}^2 + \frac{8m_{\chi}^4 - 22m_{\chi}^2m_{k}^2 + 17m_{k}^4}{m_{\chi}^2 - m_k^2}v^2) \]
\[ \sigma_{t,k} = g_{L}(24(m_{\chi} + m_k)^2 + \frac{(m_{\chi} + m_k)^2(8m_{\chi}^2 - 16m_{\chi}m_k + 11m_k^2)}{m_{\chi}^2 - m_k^2}v^2) \]

with \( g_{L} = \sqrt{1-m_e^2/m_{\chi}^2} \).

The LEP constraint on \( \Lambda_c = \Lambda/\sqrt{g_e} \) gives a maximum value for the leptonic annihilation cross section \( \sigma_{l}^{\text{max}} \) for each type of couplings we considered (A, B and C, see Fig. 1). This maximum value of the leptonic cross–section give a lower bound on \( \Omega_h h^2 \) : one thus can calculate the hadronic contribution needed to satisfy WMAP upper bound limit (\( \Omega_h h^2 \lesssim 0.1 \)) corresponding to the thermal condition \( \sigma v \gtrsim 3 \times 10^{-26}\text{cm}^3/\text{s} \). This can be summarize by:

\[ \sigma_{l}^{\text{max}} + \sigma_{h}^{\text{max}} v \gtrsim 3 \times 10^{-26}\text{cm}^3/\text{s} \approx 2.5 \times 10^{-9} \text{GeV}^{-2} \]  

(7)

As an example, we can analytically evaluate the order of magnitude for the hadronic branching ratio \( B_{rn}/B_{rt} \) we expect for a dark matter mass \( m_{\chi} \approx 5 \text{ GeV} \) in the case of an electronic (case A) vector–like coupling (\( \mathcal{L}_V \)). We combined the condition given in Eq. (7) to the value of \( \sigma_{v} v \) computed through Eq. (6) with the value of \( \Lambda_c \) obtained by LEP (see Fig. 1): \( \Lambda_c^{\text{max}} \approx 480 \text{ GeV} \) for \( m_{\chi} \approx 5 \text{ GeV} \). Neglecting \( m_l,h \ll m_{\chi} \), in the electronic–type coupling, one can simplify \( \sigma_{v} v \approx \frac{m_{\chi}^4}{m_{\chi}^2} (1 + B_{rn}/B_{rt}) \gtrsim 2.5 \times 10^{-9} \) which gives \( B_{rn}/B_{rt} \gtrsim \frac{\Lambda_c^{\text{max}}}{m_{\chi}} 2.5 \times 10^{-9} \approx 16 \).

This corresponds to a 94% annihilation rate to hadronic states. Of course, we ran the analysis with the complete formulation for the cross sections and the results are shown in Fig. 2. One can see that whatever is the nature of the coupling (electronic, charged-leptonic or universal leptonic), a dark matter of mass \( m_{\chi} \approx 10 \text{ GeV} \) has a very strong hadronic component in its annihilation final state, in the case of scalar and axial interactions (above 90%). On the other hand, for vector and t-scalar interactions, the nature of the coupling plays an important role, being an hadronic component as large as 80% in one case (electronic coupling), or a 0% (i.e. no need of hadronic channel) in other case (universal leptonic), for a vector interaction for example. These behaviors can be understood from expressions (6), where the scalar
and axial interactions are suppressed by the velocity and the leptonic masses, respectively. As a consequence one needs a much larger hadronic contribution to ensure a relic abundance below the WMAP limit and avoid the over–closure of the Universe. However for the vector and t-scalar interactions there is no such suppression, so leading to possible large contributions coming only from the leptonic couplings.

We also observe that, paradoxically, the more electrophilic are the dark matter couplings (model A), the more hadrophilic it should also be. Indeed, because there are no possibility to fulfill the relic abundance constraints with charged lepton or neutrino channels and the hadronic final states become thus the dominant ones. In the charged leptonic and universal leptonic models (B and C), there exists a threshold mass with a null hadronic branching ratio: this corresponds to the mass for which the hadronic components of the annihilation rate are not anymore necessary (but can be present) to fulfill the relic density constraints. The leptonic channels are sufficient to avoid the relic overabundance for a DM mass above this threshold.

B. Scalar case

We also checked the case of a scalar dark matter. It could not be obvious at the first sight that we can apply the same analysis. In fact, we need to introduce a new scale $\Lambda_S$. We will consider a real scalar dark matter, which is produced via the following scalar-type effective operator:

$$L^S = \frac{g_e}{\Lambda_S} \chi \bar{e} e.$$ (8)

In an analogous procedure as the one done above for a fermionic candidate, we derive limits on the suppression scale $\Lambda_S/g_e$ from mono-photon signals in the DELPHI experiment at LEP. We used MadGraph/MadEvent to simulate the distribution of number of events with photon energy $E_\gamma$. The background process $e^+e^- \rightarrow \gamma \nu\bar{\nu}$ was taken directly from the simulation done by [14]. On the other hand, the signal process $e^+e^- \rightarrow \gamma \chi \chi$ was studied assuming the following kinematical cuts: $E_\gamma > 6$ GeV, and a photon rapidity $y_\gamma > 2.5$. We realize that these constraints are less restrictive than in the fermionic case, so in principle the bounds on $\Lambda_S$ could be different if using those more rigorous cuts. To quantify this difference, we reproduced the bounds on $\Lambda_e$ coming from a signal due to a fermionic dark matter, and a vector-like effective operator, and compare it directly with the result shown in Fig[1]. The result, shown in Fig[2] top, is a $\chi^2$/d.o.f. $= 5.12/8$, which means a small difference of our case with respect to the more correct result of [14]. We include as an example of a scalar dark matter signal, the simulation done by [13]. On the other hand, the fermionic candidate, we derive limits on the suppression scale $\Lambda_S/g_e$ from mono-photon signals in the DELPHI experiment [14], at a 90% C.L. For reference, the resulting limits on $\Lambda/\sqrt{s}$ (fermionic dark matter) coming from a vector-like effective operator, using the same cuts as before, are shown (dashed-green), to be compared with the correspondent result shown in Fig[1] here in (dotted-blue). (bottom) Distribution of photon energies in single-photon events at DELPHI. The histogram shows the signal+background coming from a hypothetical scalar dark matter, as in (8), with mass $m_\chi = 10$ GeV, and a suppression scale $\Lambda_S/g_e = 300$ GeV. See body text.
We thus observe that if we define $\Lambda_S \equiv \Lambda^2/\sqrt{2\sigma}$ we can deduce the lower limit on $\Lambda_S$ from the lower limit on $\Lambda$ (see Fig.1). If imposing $\sigma^P \approx \sigma^P$, taking a dark matter candidate with mass of 10 GeV, we deduce from the above expressions the lower bound $\Lambda_S \gtrsim 815$ GeV. However from Fig.3 we obtained $\Lambda_S \gtrsim 520$ GeV, which implies that in fact $\sigma^P \approx 2.55\sigma^P$.

With these bounds on $\Lambda_S$, one could in principle try to deduce bounds on the amount of hadronic channel from DM annihilation, as we did above for the fermionic case. The expression for the annihilation cross-section $\sigma^S_S$ of a scalar DM with a scalar interaction, into an electron-positron pair is:

$$\sigma^S_{S,e} \equiv g^2_{S,e} \sigma^S_{S,e} \simeq \frac{g^2_{S,e}}{4\pi\Lambda^2_S} \left(1 - \frac{m^2_S}{m^2_{\gamma}}\right)^{3/2} + \frac{g^2_{e}}{32\pi\Lambda^2_S} v^2.$$ (10)

Unfortunately, this single channel already gives, for $510 \lesssim \Lambda_S/g^2 \lesssim 520$GeV and $1 \lesssim m_\chi \lesssim 20$GeV (as in Fig.3) a cross-section $\sigma^S_S \simeq 10^{-22}$cm$^2$/s, with negligible dependence on $m_\chi$. Being $\sigma^S_S \gtrsim 3 \times 10^{-26}$, there is in principle no need for hadronic channel. We conclude that LEP bounds are insufficient to constrain the nature of couplings in the case of scalar DM. A similar conclusion holds for the Tevatron bounds, if considering the total cross-section

$$\sigma^S = g^2 \sum_{l=e,\mu,\tau,\nu} \tilde{\sigma}^S_{S,l} v + c^2 g^4_{h} \sum_{h=u,d,c,s,t,b} \tilde{\sigma}^S_{S,h} v$$ (11)

and the lower limits shown in Fig.4. It turns out that the scale $\Lambda_S/g^2$ above which $\sigma^S_S v$ starts to be of the order of the thermal relic one, is around 5 TeV. So in principle the LHC would be able to constrain the nature of couplings and interactions of a scalar DM candidate.

IV. COMPLEMENTARITY WITH OTHER EXPERIMENTS

A. Fitting with WMAP

To run a more precise analysis, we decided to implement the contact coupling lagrangian into CompHEP and micromegas 21 for the different type of interactions (vectorial, scalar and axial) in the fermionic DM case. We then applied the last 5$ \sigma$ constraint on the relic density from WMAP experiment 18, $\Omega_{WMAP} h^2 = 0.1123 \pm 0.00175$ and ran a scan on the parameter space of the model ($\Lambda_i$, $\Lambda_h$, $m_\chi$) keeping only the points respecting both astrophysical and accelerator constraints. We can understand easily that in order to respect WMAP upper bounds, the hadronic contribution depends on the type of interactions. After a look at Fig.2 we decided to consider the most and the less conservative cases, which are the universal-leptonic coupling for vector-like interaction, and the electronic coupling for scalar-like interaction, respectively. The results are shown in Figs.5 and 6. We see that WMAP forbids a dark matter with hadrophilic couplings $(g_h/g_e \gtrsim 10)$ of $m_\chi \gtrsim 5$ GeV for a vector interaction, and $m_\chi \gtrsim 10$ GeV for a scalar interaction. For such values of hadronic couplings, $\Omega h^2 \lesssim \Omega_{WMAP} h^2$. When combined with LEP analysis, a large part of the parameter space with small $g_h/g_e$ is excluded because of the non–observation of mono–jet events at LEP (which implies an upper bound on $g_e$). Whereas it excludes a broad region of the parameter space for a dark matter mass $m_\chi \lesssim 11$ GeV in the vectorial case (in total agreement with Fig.6 of 13) it completely exclude leptophilic $(g_h/g_e \lesssim 0.1)$ dark matter with the scalar-like interaction. Combining these limits with the recent Tevatron analysis restricted even further the parameter space.

B. Tevatron constraints

Last year, the authors of 21, 22 made a similar analysis searching for mono–jet events for the Tevatron. These non–discovery of any events of this kind can be translated into a lower bound on $\Lambda_h \equiv \Lambda/\sqrt{g_h}$ which depend on the nature of the coupling and is represented in Fig.4. Contrarily to the LEP analysis, the center of mass energy does not limit the lower bound on $\Lambda_h$ for $m_\chi \lesssim 100$ GeV. We have only plotted the limit on the up-type coupling, which is the one we used through the paper to stay as conservative as possible (limits of down or charm–type couplings on $\Lambda_h$ are a factor 3 and 10 lower respectively 21). We can easily understand how the Tevatron constraint imply some strong tensions when combined with WMAP and LEP analysis. Indeed, to reconcile LEP constraints with WMAP we needed to increase the hadronic contribution (and thus, the coupling to quarks) in the annihilation process. This then enters in conflict with the limit from the non-observation of mono-jet excess at Tevatron. To keep the logic of the work and keep
FIG. 5. Hadronic ratio coupling for the annihilation of dark matter as function of the dark matter mass in the case of universal leptonic couplings for a vector–like interaction after a scan on $\Lambda_e$ and $\Lambda_h$. After applying the constraint of WMAP (top) mono–jet events from LEP (top) and Tevatron (bottom) we observe that no point of the parameter space respects both constraints (see the text for details). After applying the constraint of mono–jet events from LEP (top) and Tevatron (bottom) we observe that no point of the parameter space respects both constraints (see the text for details).

FIG. 6. Hadronic ratio coupling for the annihilation of dark matter as function of the dark matter mass in the case of electronic couplings for a scalar–like interaction after a scan on $\Lambda_e$ and $\Lambda_h$. After applying the constraint of mono–jet events from LEP (top) and Tevatron (bottom) we observe that no point of the parameter space respects both constraints (see the text for details).

Recently, the XENON100 collaboration has released several analysis claiming for no detection signal of dark matter $[23]$. Their results are by far the more constraining one in the field of direct detection experiments. One can easily understand that XENON100 is adding new

C. XENON100 constraint
tensions when combined with WMAP, LEP and Tevatron bounds. Indeed, the hadronic branching fraction required to avoid the overproduction of dark matter in the early universe could enter in conflict not only with Tevatron results but also with XENON100 exclusion limits. Indeed, whereas the s-channel dark matter production \( q q \to \chi \chi g \) is the process constraining \( \Lambda_h \) at Tevatron, the nuclear recoil gives bound to \( \Lambda_h \) (and thus \( g_h/g_e \)) through the t-channel process \( q q \to \chi q \). As we can see in Fig.6 XENON100 restrict even a larger part of the parameter space for \( m_\chi \gtrsim 6 \) GeV (which would not have been the case if we took into account the previous XENON100 analysis \[24\]). Whereas the scalar–like interaction is already excluded without the XENON100 data, dark matter with vector–like coupling to the SM still survives in a narrow hadrophilic region of the parameter space with light dark matter \[4\] and another region definitively hadophobic for \( m_\chi \gtrsim 12 \) GeV.

V. CONCLUSION AND PROSPECT

Recently, several astrophysical data or would-be signals has been observed in different dark-matter oriented experiments. In each case, one could fit the data at the price of specific nature of the coupling between the Standard Model (SM) particles and a light Dark Matter candidate: hadrophilic or leptophilic. We computed the rate of hadronic coupling needed to respect WMAP combined with the LEP and Tevatron constraints from mono-jet events. We showed that a light fermionic dark matter (\( \lesssim 10 \) GeV) is mainly excluded whatever is its type of interaction, whereas heavier candidates (\( \gtrsim 20 \) GeV) should be largely hadrophobic for vectorial interaction, but excluded for scalar one. We also studied the special case of scalar dark matter, using the mono–photon events to constraint the coupling of dark matter to electron with a complete simulation of DELPHI events and showed that LEP and Tevatron are not able to restrict the couplings. One of the main consequences is that models with light leptophilic couplings, explaining INTEGRAL data or constraints from synchrotron radiations are excluded by Tevatron/LEP analysis. One possibility to escape such strong conclusion would be to suppose that DM has no electronic coupling. In this case, LEP limits do not apply. Moreover, if at the same time the hadronic coupling is only to the bottom or charm quark, Tevatron XENON100 bounds are not applicable too. However such unnatural construction should be excluded by FERMI last analysis of dwarf galaxies \[27\].

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