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RESULTS ON DARK MATTER BY DAMA/LIBRA AT GRAN SASSO

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DAMA/LIBRA is running at the Gran Sasso National Laboratory of the I.N.F.N. The data collected in the first six annual cycle have already been released. The cumulative exposure – including that of the former DAMA/NaI experiment (0.29 t · yr) – is now 1.17 t · yr, corresponding to 13 annual cycles; this exposure is orders of magnitude larger than the exposures typically collected in the field. The data further confirm the model independent evidence of the presence of Dark Matter (DM) particles in the galactic halo on the basis of the DM annual modulation signature (8.9 σ C.L. for the cumulative exposure). In particular, the modulation amplitude of the *single-hit* events in the (2 - 6) keV energy interval measured in NaI(Tl) target is (0.0116 ± 0.0013) cpd/kg/keV, the measured phase is (146 ± 7) days and the measured period is (0.999 ± 0.002) yr, values well in agreement with those expected for the DM particles. Various related arguments are addressed.
Keywords: dark matter, experiment DAMA/NaI, DAMA/LIBRA.

Introduction

DAMA is an observatory for rare processes located deep underground at the Gran Sasso National Laboratory of the I.N.F.N. It is based on the development and use of low background scintillators [1 - 19]. Profiting of the low background features of the realized set-ups, many rare processes are investigated (see also other presentations in this conference).

In particular, DAMA/LIBRA is investigating the presence of Dark Matter (DM) particles in the galactic halo by exploiting the model independent DM annual modulation signature [20]. In fact, as a consequence of its annual revolution around the Sun, which is moving in the Galaxy travelling with respect to the Local Standard of Rest towards the star Vega near the constellation of Hercules, the Earth should be crossed by a larger flux of Dark Matter particles around ≈ 2nd June (when the Earth orbital velocity is summed to the one of the solar system with respect to the Galaxy) and by a smaller one around ≈ 2nd December (when the two velocities are subtracted). It is worth noting that the DM annual modulation signature has a different origin and peculiarities than the seasons on the Earth and than effects correlated with seasons (consider, for example, the expected value of the phase as well as the other requirements listed below). This signature offers an efficient model independent signature, able to test a large number of DM candidates, a large interval of cross sections and of halo densities.

The DM annual modulation signature is very distinctive since the corresponding signal must simultaneously satisfy all the following requirements: the rate must contain a component modulated according to a cosine function (1) with one year period (2) and a phase that peaks roughly around ≈ 2nd June (3); this modulation must only be found in a well-defined low energy range, where DM particle induced events can be present (4); it must apply only to those events in which just one detector of many actually "fires" (*single-hit* events), since the DM particle multi-interaction probability is negligible (5); the modulation amplitude in the region of maximal sensitivity must be ≈ 7 % for usually adopted halo distributions (6), but it can be larger in case of some possible scenarios such as e.g. those in Refs. [21 - 22]. Only systematic effects or side reactions able to fulfill these requirements and to account for the whole observed modulation amplitude could mimic this signature; thus, no other effect investigated so far in the field of rare processes offers a so stringent and unambiguous signature.

† Deceased.

The DAMA/LIBRA set-up, whose description, radiopurity and main features are discussed in details in Ref. [16], has been firstly upgraded in September/October 2008 [19]. We just remind that the sensitive part of this set-up is made of 25 highly radiopure NaI(Tl) crystal scintillators (5-rows by 5-columns matrix) having 9.70 kg mass each one. In each detector two 10 cm long special quartz light guides act also as optical windows on the two end faces of the crystal and are coupled to two low background photomultipliers working in coincidence at single photoelectron level. The detectors are housed in a sealed low-radioactive copper box installed in the center of a low-radioactive Cu/Pb/Cd-foils/polyethylene/paraffin shield; moreover, about 1 m concrete (made from the Gran Sasso rock material) almost fully surrounds (mostly outside the barrack) this passive shield, acting as a further neutron moderator. A threefold-level sealing system excludes the detectors from the environmental air of the underground laboratory [16]. A hardware/software system to monitor the running conditions is operative and self-controlled computer processes automatically control several parameters and manage alarms. Moreover: i) the light response ranges from 5.5 to 7.5 photoelectrons/keV, depending on the detector; ii) the hardware threshold of each PMT is at single photoelectron (each detector is equipped with two low background photomultipliers working in coincidence); iii) energy calibration with X-rays/γ sources are regularly carried out down to few keV; iv) the software energy threshold of the experiment is 2 keV electron equivalent (hereafter keV); v) both *single-hit* events (where just one of the detectors fires) and *multiple-hit* events (where more than one detector fires) are acquired; v) the data are collected up to the MeV region despite the optimization is performed for the lower one. For the radiopurity, the procedures and further details see Refs. [16, 17, 19].

DAMA/LIBRA results

Several analyses on the model-independent DM annual modulation signature have been performed (see Refs. [17, 19] and references therein); here just few arguments are mentioned. In particular, Fig. 1 shows the time behaviour of the experimental residual rates of the *single-hit* events collected by DAMA/LIBRA in the (2 - 6) keV energy interval [17, 19]. The superimposed curve is the cosinusoidal function: $A \cos \omega(t - t_0)$ with a period $T = 2\pi/\omega = 1$ yr and with a phase $t_0 = 152.5$ day (June 2nd), and modulation amplitude, A, obtained by best fit over the seven cycles of DAMA/NaI [4, 5] and the six cycles of DAMA/LIBRA data. When the period and the phase parameters are also released in the fit, values well compatible with those expected for a DM particle induced effect are obtained for the cumulative exposure [19]: $A = (0.0116 \pm 0.0013)$ cpd/kg/keV, $T = (0.999 \pm 0.002)$ yr and $t_0 = (146 \pm 7)$ day in the cumulative (2 - 6) keV energy interval. Summarizing, the analysis of the *single-hit* residual rate favours the presence of a modulated cosine-like behaviour with proper features at 8.9 σ C.L. [19].

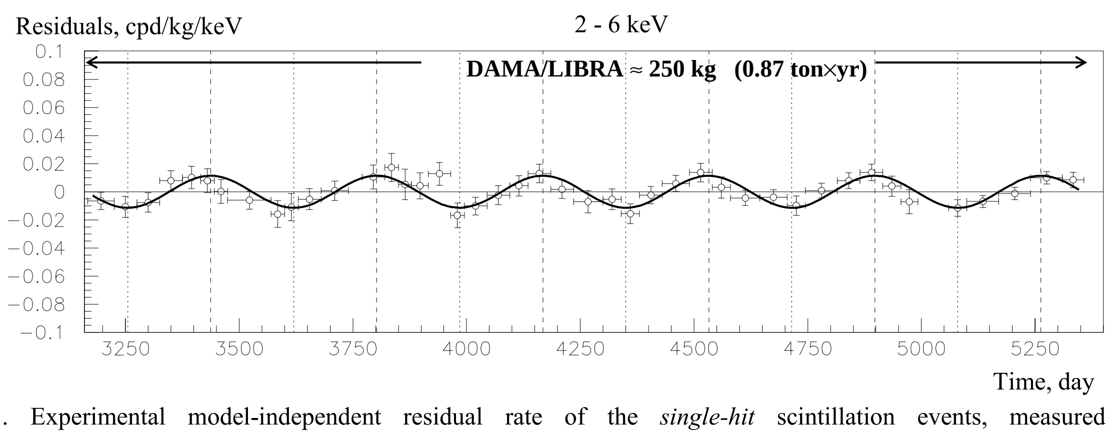

Fig. 1. Experimental model-independent residual rate of the *single-hit* scintillation events, measured by DAMA/LIBRA,1,2,3,4,5,6 in the (2 - 6) keV energy intervals as a function of the time. The experimental points present the errors as vertical bars and the associated time bin width as horizontal bars. The superimposed curves are the cosinusoidal functions behaviors $A \cos \omega (t - t_0)$ with a period $T = 2\pi/\omega = 1$ yr, with a phase $t_0 = 152.5$ day (June 2nd) and with modulation amplitudes, A, equal to the central values obtained by best fit over the whole data including also the exposure previously collected by the former DAMA/NaI experiment (1.17 t · yr). The dashed vertical lines correspond to the maximum expected for the DM signal (June 2nd), while the dotted vertical lines correspond to the minimum [19].

The same data of Fig. 1 have also been investigated by a Fourier analysis, obtaining a clear peak corresponding to a period of 1 year [19]; this analysis in other energy region shows instead only aliasing peaks. Moreover, while in the (2 - 6) keV *single-hit* residuals a clear modulation is present, it is absent at energies just above [19]. Moreover, in order to verify absence of annual modulation in other energy regions and, thus, to also verify the absence of any significant background modulation, the energy distribution measured during the data taking periods in energy regions not of interest for DM detection has also been investigated. In fact, the background in the lowest energy region is essentially due to "Compton" electrons, X-rays and/or Auger electrons, muon induced events, etc., which are strictly correlated with the events in the higher energy part of the spectrum; thus, if a modulation detected in the lowest energy region was due to a modulation of the background (rather than to a signal), an equal or larger modulation in the higher energy regions would be present. The data analyses have allowed the exclusion of a background modulation in the whole energy spectrum at a level much lower than the effect found in the lowest energy region for the *single-hit* events [19].

A further relevant investigation has been performed by applying the same hardware and software procedures, used to acquire and to analyse the *single-hit* residual rate, to the *multiple-hits* one. In fact, since the probability that a DM particle interacts in more than one detector is negligible, a DM signal can be present just in the *single-hit* residual rate. Thus, this allows the test of the background behaviour in the same energy interval of the observed positive effect. In particular, Fig. 2 shows the residual rates of the *single-hit* events measured over the six DAMA/LIBRA annual cycles, as collected in a single annual cycle, together with the residual rates of the *multiple-hits* events, in the same energy interval.

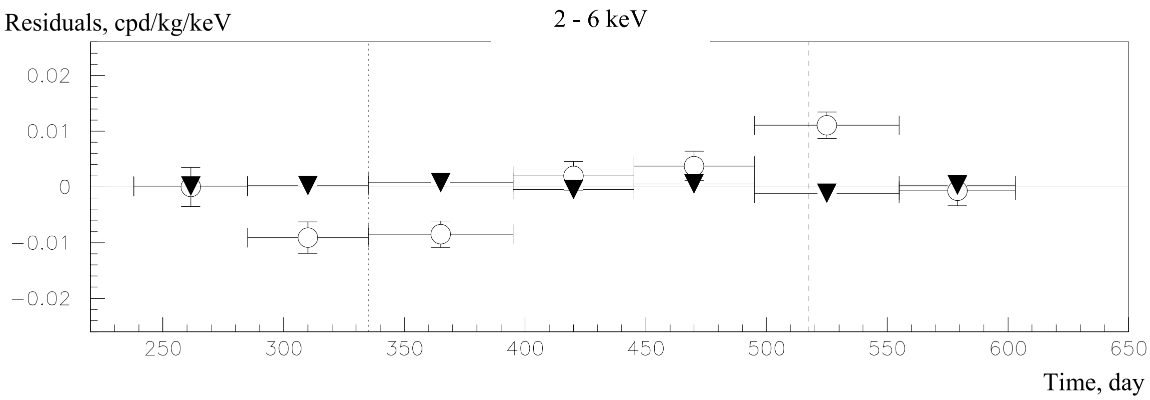

Fig. 2. Experimental residual rates over the six DAMA/LIBRA annual cycles for *single-hit* events (open circles) (class of events to which DM events belong) and for *multiple-hits* events (filled triangles) (class of events to which DM events do not belong), in the energy interval (2 - 6) keV [19]. They have been obtained by considering for each class of events the data as collected in a single annual cycle and by using in both cases the same identical hardware and the same identical software procedures. The initial time of the scale is taken on August 7-th. The experimental points present the errors as vertical bars and the associated time bin width as horizontal bars. Analogous results were obtained for the DAMA/NaI data [5].

A clear modulation is present in the *single-hit* events, while the fitted modulation amplitude of the *multiple-hits* residual rate is well compatible with zero [19]. Similar results were previously obtained also for the DAMA/NaI case [5]. Thus, again evidence of annual modulation with proper features, as required by the DM annual modulation signature, is present in the *single-hit* residuals (events class to which the DM particle induced events belong), while it is absent in the *multiple-hits* residual rate (event class to which only background events belong). Since the same identical hardware and the same identical software procedures have been used to analyze the two classes of events, the obtained result offers an additional strong support for the presence of DM particles in the galactic halo further excluding any side effect either from hardware or from software procedures or from background.

The annual modulation present at low energy has also been analyzed by depicting the differential modulation amplitudes, $S_{m,k}$, as a function of the energy (the k index identifies the energy interval); the $S_{m,k}$ is the modulation amplitude of the modulated part of the signal obtained by maximum likelihood method over the data, considering T = 1 yr and t_0 = 152.5 day. The $S_{m,k}$ values are reported as function of the energy in Ref. [19]. It has been also verified that the measured modulation amplitudes are statistically well distributed in all the crystals, annual cycles and energy bins; these and other discussions can be found in Ref. [19]. It is also interesting the results of the analysis performed by releasing the assumption of a phase $t_0 = 152.5$ day in the procedure of maximum likelihood to evaluate the modulation amplitudes from the data of the seven annual cycles of DAMA/NaI and the six annual cycles of DAMA/LIBRA. In this case alternatively the signal is written as: $S_{0,k} + S_{m,k} \cos \omega(t - t_0) + Z_{m,k} \sin \omega(t - t_0) = S_{0,k} + Y_{m,k} \cos \omega(t - t^*)$ where $S_{0,k}$ is the constant part of the signal in k-th energy interval. Obviously, for signals induced by DM particles one would expect: i) $Z_{m,k} \approx 0$ (because of the orthogonality between the cosine and the sine functions); ii) $S_{m,k} \approx Y_{m,k}$; iii) $t^* \approx t_0 = 152.5$ day. In fact, these conditions hold for most of the dark halo models; however, it is worth noting that slight differences in the phase can be expected in case of possible contributions from non-thermalized DM components [7, 23]. The 2σ contours in the plane (S_m, Z_m) for the (2 - 6) keV and (6 - 14) keV energy intervals and those in the plane (Y_m, t^*) are reported in Fig. 3.

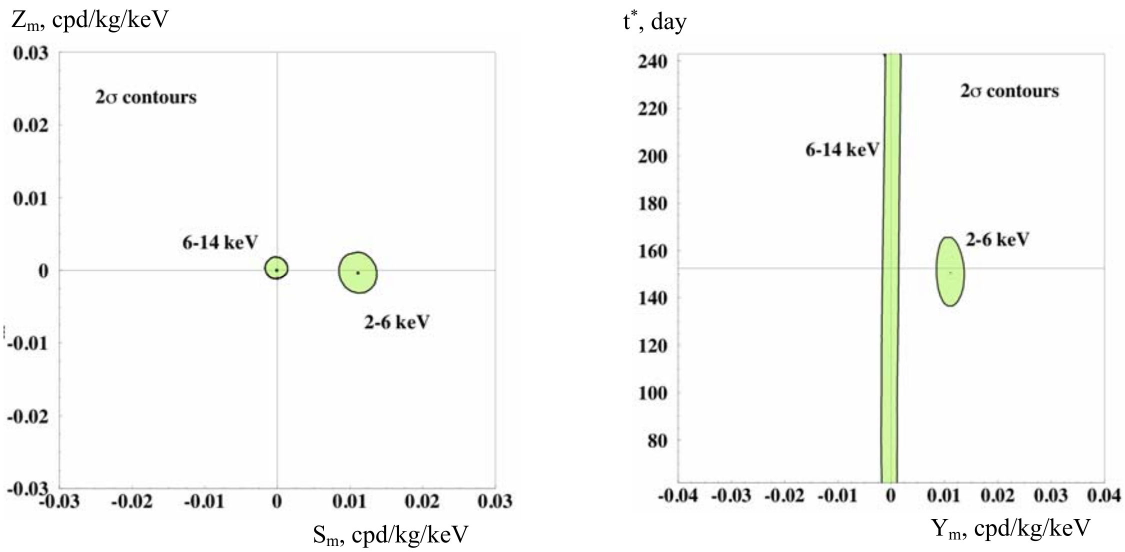

Fig. 3. 2σ contours in the plane (S_m, Z_m) (left) and in the plane (Y_m, t*) (right) for the (2 - 6) keV and (6 - 14) keV energy intervals. The contours have been obtained by the maximum likelihood method, considering the cumulative exposure of 1.17 t · yr. Modulation amplitude is present in the lower energy intervals and the phase agrees with that expected for DM induced signals. For details see Ref. [19].

The best fit values for the (2 - 6) keV energy interval are (1 σ errors):
$S_m = (0.0111 \pm 0.0013)$ cpd/kg/keV;
$Z_m = -(0.0004 \pm 0.0014)$ cpd/kg/keV;
$Y_m = (0.0111 \pm 0.0013)$ cpd/kg/keV;
$t^* = (150.5 \pm 7.0)$ day; while, e.g., for the (6 - 14) keV energy interval (also shown there) are:
$S_m = -(0.0001 \pm 0.0008)$ cpd/kg/keV;
$Z_m = (0.0002 \pm 0.0005)$ cpd/kg/keV;
$Y_m = -(0.0001 \pm \pm 0.0008)$ cpd/kg/keV
and t^* obviously not determined. These results confirm those achieved by other kinds of analyses. In particular, a modulation amplitude is present in the lower energy intervals for single hit events and the period and the phase agree with those expected for DM induced signals. For more detailed discussions see Ref. [19]. Both the data of DAMA/LIBRA and of DAMA/NaI fulfill all the requirements of the DM annual modulation signature.

As previously done for DAMA/NaI [4, 5] careful investigations on absence of any significant systematics or side reaction effect in DAMA/LIBRA have been quantitatively carried out and reported in details in Ref. [17] and some other arguments have also been addressed in Refs. [24, 25]. No systematics or side reactions able to mimic the signature (that is, able to account for the measured modulation amplitude and simultaneously satisfy all the requirements of the signature) has been found or suggested by anyone over more than a decade. For detailed quantitative discussions on all the related topics and for results see Refs. [17, 19] and Refs. therein.

Comments

As regards the corollary investigation on the nature of the DM candidate particle(s) and related astrophysical, nuclear and particle physics scenarios, it has been shown - already on the basis of the DAMA/NaI result - that the obtained model independent evidence can be compatible with a wide set of possibilities. The model dependent analyses performed with the previous DAMA/NaI results can be further addressed with the present cumulative data of DAMA/NaI and DAMA/LIBRA. Many candidates and scenarios can be investigated; as e.g.:

a) the case of low and high mass WIMP candidates with spin-independent (SI), spin-dependent (SD) and mixed SI&SD couplings [4, 5]. This analysis has also been extended in Ref. [7] considering possible contribution arising from a non thermalized DM particle component in the dark halo: in particular, the Sagittarius Dwarf Elliptical Galaxy (SagDEG) has been considered;

b) the role of the electromagnetic contribution produced in the interaction of the WIMP with target nuclei [8], showing that this effect can have appreciable impact in the DM direct searches when interpreted in terms of WIMP candidates, with particular regard for the WIMP of low mass [8];

c) WIMP candidates with preferred SI inelastic scattering [4, 26] in many model frameworks (see e.g. Ref. [4]);

d) light (~keV mass) bosonic candidates, either with pseudo-scalar or with scalar coupling [6]. For these candidates, the direct detection process is based on the total conversion - in the target - of the mass of the absorbed bosonic particle into electromagnetic radiation. Thus, in this case the recoil of the target nucleus is negligible and it is not involved in the detection process (therefore, signals from these light bosonic DM candidates are lost in experiments applying procedures for the rejection of the electromagnetic contribution to the counting rate);

e) electron interacting DM candidates [10], i.e. DM candidates which can have dominant coupling with the lepton sector of the ordinary matter. These DM particles can be directly detected only through their interaction with electrons, while they are lost by experiments based on the rejection of the electromagnetic component of the counting rate [10];

f) Light DM candidate (LDM) particles [11] considering inelastic scattering channels either on the electron or on the nucleus target. As result of the interaction a lighter particle is produced and the target (either nucleus or electrons) recoils releasing detectable signal in suitable detectors;

g) inclusion of the known channeling effect on NaI(Tl) crystals in some model dependent analyses described above [9];

h) etc.

Some related arguments and some template examples of DM expectations in different scenarios superimposed to the experimental modulation amplitudes are given in the Appendix and in Fig. 21 of Ref. [17]. They show that at the present level of sensitivity the experimental modulation amplitudes are well compatible with different-in-shape behaviours. Many other interpretations of the annual modulation results are available in literature (as e.g. [21, 27 - 34], etc.); many others are open.

Comparisons

It is worth recalling that no other experiment exists, whose result can be directly compared in a model-independent way with those by DAMA/NaI and DAMA/LIBRA, and that - more in general - results obtained with different target materials and/or different approaches cannot be directly compared among them in a model-independent way. This is in particular due to the existing experimental and theoretical uncertainties, not last e.g. how many kinds of dark matter particles can exist in the Universe*, the nature, the interaction types, the different nuclear and/or atomic correlated aspects, the unknown right halo model, the right DM density, etc. as well as the uncertainties on the values of each one of the many involved experimental and theoretical parameter/assumption/approximation used in the calculations.

Moreover, some experimental aspects of some techniques used in the field have also to be addressed, see e.g. [4, 25, 36 - 38]. For example, as regards the recent model dependent CDMS-II result [39], the real knowledge and control of the "physical" energy threshold, of the energy scale, of the Y scale, of the sensitive volumes, of the all efficiencies, the uncertainties related to the phonon position correction (that requires to apply a look-up table to correct the variation), the uncertainties related on the stability with time of all these quantities and of all the acceptance windows used in the analysis, etc. are questionable. Moreover, detectors were excluded in the analysis, significant part of the exposure was rejected and, thus, after many cuts, only 9 % of the total exposure survives. As regards the recent model dependent XENON-100 result [40], we remind that several experimental aspects of the technique used by XENON-100 (and by the other experiments using liquid noble gases) have to be addressed (for a review see Ref. [36]); here we just remind the low light response, which would prevent to reach low energy threshold – on the contrary of what is claimed – and good energy resolutions, the known and unknown uncertainties related to the many applied cuts, the disuniformity of the light collection, which implies knotty and huge corrections, the long term stability of such set-ups,

* In fact, it is worth noting that, considering the richness in particles of the visible matter which is less than 1 % of the Universe density, one could also expect that the particle part of the Dark Matter in the Universe may also be multi-component.

the uncertainties related to the energy scale (the calibrations are made by gamma rays at energies much larger than the energies of interest), the unlinearity of the energy scale, which requires to make assumptions introducing further systematics, etc.. Moreover, the possibility that XENON-100 and, therefore, every experiment based on Xenon target could be sensitive to low-mass WIMPs has been confuted e.g. in Refs. [36, 38]. In addition to the criticisms reported above on experimental aspects, a single (of the many possible) arbitrary set of astrophysical, nuclear and particle Physics assumptions are considered by that experiment in their model dependent results, and without accounting any of the many existing experimental and theoretical uncertainties. It is worth noting that the implications of the DAMA model independent results are generally presented in an incorrect/partial/not-updated way; see also some talks in this Conference. Another relevant argument is the methodological robustness [41]. In particular, the general considerations on comparisons reported in Appendix A of Ref. [17] still hold. Hence, claims for contradiction have no scientific basis. On the other hand, whatever possible “positive” result has to be interpreted and a large room of compatibility with DAMA annual modulation evidence is present.

As regards the indirect detection searches, it does not exist a biunivocal correspondence between the observables in the direct and indirect experiments. However, if possible excesses in the positron to electron flux ratio and in the γ rays flux with respect to a modelling of the background contribution, which is expected from the considered sources, might be interpreted - under some assumptions - in terms of Dark Matter, this would also be not in conflict with the effect observed by DAMA experiments. It is worth noting that different possibilities either considering different background modelling or accounting for other kinds of sources can also explain the indirect observations [42].

Finally, as regards the accelerator searches for new particles beyond the Standard Model of particle Physics, it is worth noting that they can demonstrate the existence of some of the possible DM candidates, but cannot credit that a certain particle is the DM solution or the "single" DM solution. Moreover, DM candidates and scenarios exist (even e.g. for the neutralino candidate) on which accelerators cannot give any information. It is also worth noting that for every candidate (including the neutralino) there exist various different possibilities for the theoretical aspects. Nevertheless, the results from accelerators will give outstanding and crucial complementary information in the field.

DAMA/LIBRA upgrades

The first upgrade of the DAMA/LIBRA set-up has been performed during September 2008, and the shield has been opened in HP Nitrogen atmosphere. This has allowed the increase of the exposed mass since one detector has been recovered by replacing a broken PMT and a new optimization of some PMTs and HVs. A total replacement of the transient digitizers with new ones, having better performances, has also been realized and a new DAQ with optical fiber has been installed and put in operation. The data taking has been restarted on October 2008.

The model independent results achieved by the DAMA/LIBRA set-up has pointed out the relevance to lower the energy threshold of the experiment below 2 keV; thus, the replacement of all the PMTs with new ones having higher quantum efficiency has been planned; this will also improve - as evident - other significant experimental aspects.

A larger exposure collected by DAMA/LIBRA (or by a possible future DAMA/1ton) and the lowering of the 2 keV energy threshold will further improve: i) the experimental sensitivity; ii) the corollary information on the nature of the DM candidate particle(s) and on the various related astrophysical, nuclear and particle physics scenarios. It will also allow the investigation of other DM features, of second order effects and of several rare processes other than DM- with high sensitivity. In particular, some of the many topics - not yet well known at present and which can affect whatever model dependent result and comparison - are: i) the velocity and spatial distribution of the Dark Matter particles in the galactic halo; ii) the effects induced on the Dark Matter particles distribution in the galactic halo by contributions from satellite galaxies tidal streams; iii) the effects induced on the Dark Matter particles distribution in the galactic halo by the possible existence of caustics; iv) the detection of possible "solar wakes" (the gravitational focusing effect of the Sun on the Dark Matter particle of a stream); v) the investigation of possible diurnal effects; vi) the study of possible structures as clumpiness with small scale size; vii) the coupling(s) of the Dark Matter particle with the ^{23}Na and ^{127}I and its nature; viii) the scaling laws and cross sections; etc.

It is worth noting that ultra-low background NaI(Tl) scintillators can also offer the possibility to achieve significant results on several other rare processes as already done e.g. by the former DAMA/NaI apparatus [12] and just started with DAMA/LIBRA [18].

Finally, we mention that a third generation R&D effort towards a possible NaI(Tl) ton set-up, DAMA proposed in 1996, has been funded by I.N.F.N. and is in progress.

Conclusions

The results of DAMA/NaI and DAMA/LIBRA (cumulative exposure 1.17 t · yr) a peculiar annual modulation of the *single-hit* events in the (2 - 6) keV energy region satisfying the many requests of the DM annual modulation signature. In fact, as required by the DM annual modulation signature: 1) the *single-hit* events show a clear cosine-like modulation as expected for the DM signal; 2) the measured period is equal to (0.999 ± 0.002) yr well compatible with the 1 yr period as expected for the DM signal; 3) the measured phase (146 ± 7) days is well compatible with the roughly ≈152.5 days expected for the DM signal; 4) the modulation is present only in the low energy (2 - 6) keV interval and not in other higher energy regions, consistently with expectation for the DM signal; 5) the modulation is present only in the *single-hit* events, while it is absent in the *multiple-hit* ones as expected for the DM signal; 6) the measured modulation amplitude in NaI(Tl) of the *single-hit* events in the (2 - 6) keV energy interval is: (0.0116 ± ± 0.0013) cpd/kg/keV (8.9 σ C.L.). No systematic or side processes able to simultaneously satisfy all the many peculiarities of the signature and to account for the whole measured modulation amplitude is available. Further work is in progress.

Considering the relevance to lower the software energy threshold of the experiment, in order to improve the performance and the sensitivity of the experiment and to allow a highly precise determination of all the DM modulation parameters and deeper corollary information on the nature of the DM particle(s) and on the various related astrophysical, nuclear and particle Physics scenarios, the replacement of all the PMTs with new ones with higher quantum efficiency has been planned and work is in progress. DAMA/LIBRA will also study second order effects and several other rare processes as done by the former DAMA/NaI apparatus in the past [12] and by itself so far [18].

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РЕЗУЛЬТАТИ ДОСЛІДЖЕННЯ ТЕМНОЇ МАТЕРІЇ В ЕКСПЕРИМЕНТІ DAMA/LIBRA В ГРАН САССО

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Експеримент DAMA/LIBRA проходить у Національній лабораторії Гран Сассо Національного інституту ядерної фізики (Італія). Проаналізовано дані, отримані за перші шість річних циклів. Сумарна експозиція, включаючи дані попереднього експерименту DAMA/NaI (0,29 т · рік), дорівнює зараз 1,17 т · рік, що відповідає 13 річним циклам; ця експозиція на порядки перевищує експозиції, типові для експериментів з дослідження темної матерії (ТМ). Дані продовжують підтверджувати модельно незалежне свідчення про присутність частинок ТМ у галактичному гало на основі річних модуляцій ТМ (8,9 σ довірча ймовірність для сумарної експозиції). Зокрема, амплітуда модуляцій для *одиночних* подій в енергетичному інтервалі (2 - 6) кеВ у детекторах NaI(Tl) є (0,0116 ± 0,0013) відліків/доба/кг/кеВ, виміряна фаза дорівнює (146 ± 7) діб і виміряний період є (0,999 ± 0,002) років; ці значення добре узгоджуються з очікуваними для частинок ТМ. Обговорюються різноманітні проблеми, пов'язані з даними спостереженнями.

Ключові слова: темна матерія, експеримент DAMA/NaI, DAMA/LIBRA.

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ ТЕМНОЙ МАТЕРИИ В ЭКСПЕРИМЕНТЕ DAMA/LIBRA В ГРАН САССО

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Эксперимент DAMA/LIBRA проходит в Национальной лаборатории Гран Сассо Национального института ядерной физики (Италия). Проанализированы данные, полученные за первые шесть годовых циклов. Суммарная экспозиция, включая данные предшествующего эксперимента DAMA/NaI (0,29 т · год), равна сейчас 1,17 т · год, что соответствует 13 годовым циклам; эта экспозиция на порядки превышает экспозиции, типичные для экспериментов по исследованиям темной материи (ТМ). Данные продолжают подтверждать модельно независимое свидетельство о присутствии частиц ТМ в галактическом гало на основе годовых модуляций ТМ (8,9 σ доверительная вероятность для суммарной экспозиции). В частности, амплитуда модуляций для *одиночных* событий в энергетическом интервале (2 - 6) кэВ в детекторах NaI(Tl) равна (0,0116 ± ± 0,0013) отсчетов/сут/кг/кэВ, измеренная фаза равна (146 ± 7) сут и измеренный период равен (0,999 ± ± 0,002) лет; эти значения находятся в хорошем согласии с ожидаемыми для частиц ТМ. Обсуждаются различные проблемы, связанные с данными наблюдениями.

Ключевые слова: темная материя, эксперимент DAMA/NaI, DAMA/LIBRA.

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