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REPORT OF THE INFN - GROUP 2 STRATOSPHERIC BALLOONS WORKING GROUP

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Abstract

In 2011 a working group dedicated to the study of the physics opportunities offered by stratospheric balloons has been formed within the INFN "Commissione II" (Astroparticle physics). The Working Group has been mandated to investigate the role that future balloon-borne experiments can play in the next 5-10 years and the scientific and technological issues that can be addressed with this technique without resorting to space-based experiments. This report summarizes the findings of the working group and its recommendations.

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Introduction

Stratospheric balloons offer a fast and cheap access to near space, essential to prepare space missions and to get important scientific results. Looking at an historical development of “science” achieved by means of balloon borne instruments, we can set the starting date of astroparticle physics at the beginning of the last century, when Herman Hess in 1907 demonstrated the extraterrestrial nature of cosmic rays, using a balloon borne instrument. Skipping the whole balloon history, well reported for people interested to read further in the site ***stratocat****.com.ar/indexe.html* and restricting ourselves for now to the Italian situation, we can resume it very briefly: after a pioneering activity performed from Cagliari Elmas airport with small balloons (about 10000 cubic meters volume) by the group led by Edoardo Amaldi, in 1957, with the goal to study “strange” particles in the atmosphere by means of photographic emulsions, CNR started a systematic balloon activity from a Stratospheric Balloon Base located in Milo, Trapani. This was continued by the ASI (Italian Space Agency), The Base in the past has been very active with launches performed by a French team in collaboration with ASI, with launches lasting up to 24 hours from Trapani to Spain, starting in the seventies from an idea of Livio Scarsi, and through the nineneties. Then, with the advent of a new need for longer duration at float, the interest for shorter duration flights became less and less, and the Base was unable to setup a complete facility for Long Duration Balloon (LDB) flights from polar regions, despite of the efforts of several University members. However, the technical feasibility of such flights from Svalbard islands has been demonstrated with the circumpolar flight of a small payload (PEGASO, 2006, fig.1) and the launch of a heavy payload from Longyearbyen (SORA, 2009, fig.2).

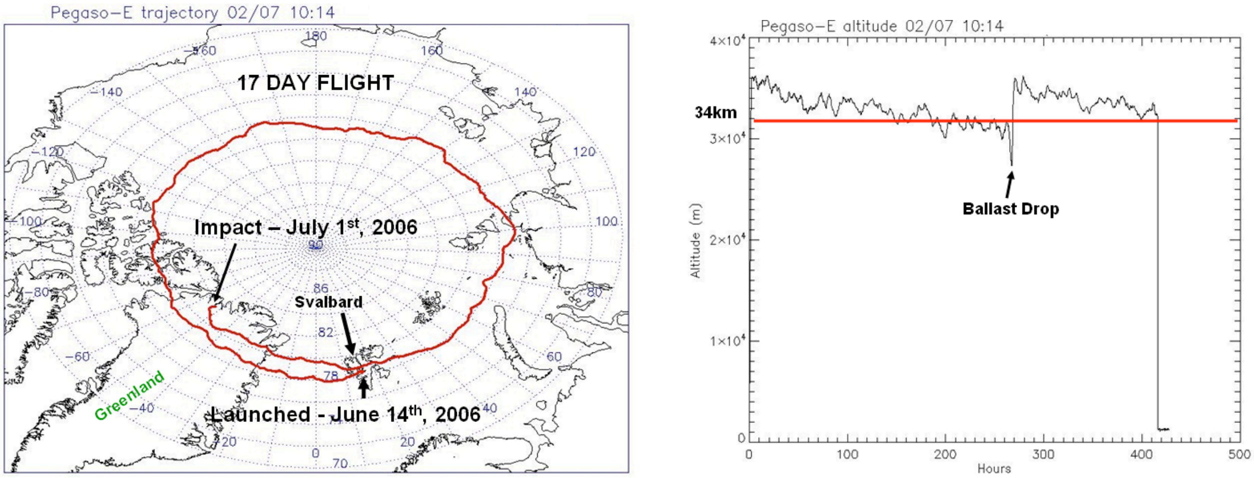

Fig. 1: The first circumpolar flight launched from Longyearbyen (Svalbard) by ASI, INGV, Dipartimento di Fisica Sapienza, ISTAR, in 2006. Left: ground path. Right: payload altitude vs. time.

Recently the Balloon Base of Trapani Milo has been closed, and the interested scientists are worried about the possibility to continue their on-going and forthcoming research in different fields, ranging from cosmology to particle physics to biology and atmospheric physics. This community is quite wide, as testified by the Workshop held in Rome in June 2008 (proceedings available at http://sait.oat.ts.astro.it/MSAIt790308/index.html).

During the last year we have repeatedly discussed, within the scientific community, about the common goals and common developments that could bring, if well organized, to important achievements in science and technology, confirming the leading role of Italy in the international scenario.

Fig.2: Launch of the SORA payload (ASI + ISTAR) from the Longyerbyen airport (July 1st, 2009).

The discussion has involved both the scientific and technological return and the operational apparatus and organization, looking at the success accomplished in other Countries, first of all the USA, in the field of stratospheric balloon activities. In the US the activities are divided between NASA as a funding agency, New Mexico State University, and CSBF, as operators, managed by the New Mexico State University.

In the past few months these ideas and discussions brought us to form a Balloon Working Group, (BWG), composed of members of INFN and of the Phys Dept. of the University of Rome La Sapienza, with experience in both science and logistical organization for balloon launches and related activities. A non negligible source of concern for the organization of arctic balloon launches is the procedure for obtaining the permission for flight over Russia from Russian authorities: on this respect, Italy enjoys a privileged position , given the good diplomatic relations between the two countries.

The BWG has studied accurately the white papers written both in Italy (see 1st balloon workshop) and in United States (LCANS….etc. see http://www.findpdf.us/details-705651.pdf?nasa-balloon-community-workshop) besides gathering information on different groups operating in the field of stratospheric balloon experiments (SBE hereafter).

We have identified several common interest areas, in technological, scientific, organizational fields, among several University groups already cooperating (besides La Sapienza: Milano, Naples, Bologna….) and INFN, INAF, CNR, INGV. These groups are strongly interested in developing and in launching, in the coming 3 to 5 years, several payloads, of various sizes, and embracing different branches of physics, engineering, and biological/medical related fields. Some of the instruments are precursors of, or complement, more ambitious space missions, and some of them are self standing and will bring to results not achievable from ground. The time schedule for the individuated activities is from 1 year to 10 years from now.

So we believe that it is important to build a consortium between the interested parties, to coordinate the activities and to manage the required services, using the already existing synergies between different programs in order to better use the available funding. The activities will be involving personnel of the interested groups, and we will also perform operations abroad where needed.

1. Current Experiments

Modern stratospheric balloon flights for science are long duration (few days to few weeks), allowing for long integrations and different tests for systematic effects. Circumpolar flights are used, either in Antarctica in the southern hemisphere (NASA-NSBF launches from McMurdo three payloads every year) or from the Svalbard islands in the northern hemisphere, where the group of La Sapienza has proposed and carried out with ASI and ISTAR a Long Duration Stratospheric Balloons project.

Here is a list of current experiment taking advantage of long duration flights opportunities.

Fig. 3: The OLIMPO payload, with the ground shield removed to show the 2.6 m Cassegrain telescope. The neutrino mass measurement described below must be made with an even larger telescope (4m).

OLIMPO: is a mm-wave telescope with a primary mirror 2.6 meters diameter, dedicated to the study of clusters of galaxies via the Sunyaev Zel'dovich (SZ) effect (inverse Compton scattering of CMB photons in the hot ionised intergalactic medium in clusters). This experiment has the potential to discover distant clusters (the SZ effect does not dilute with distance) and use them as probes of the evolution of the universe and of dark matter, and study the peripheral region of nearby clusters, which are almost invisible in X-rays and optically, and carry information about the distribution of normal and dark matter. In addition to these aspects, the technology developments achieved with OLIMPO are also of common interest for INFN and INAF, since this will be the largest telescope ever launched on a balloon, and an important step towards achieving the high angular resolution needed for CMB experiments optimised for constraining neutrino masses (see below) from the stratosphere. From this point of view, this experiment is propaedeutic to several future balloon missions, and can give technical/experimental information in a short timescale. A 3 to 5 year launching plan is foreseen for this instrumentation; the first launch is planned for May 2012. The PI institution is Dipartimento di Fisica, La Sapienza, Roma (S. Masi).

BOOMERANG-FG: is 1.3m mm-wave telescope with polarimetric capabilities, covering the 140 and 350 GHz bands with arrays of Cold Electron Bolometer (CEB) detectors. The observations will map the polarization state of galactic foreground emission, with deeper integration and lower systematic effects when compared to Planck. The experiment has, in fact, a cryogenic polarization modulator, which is missing in Planck. An accurate measurement of the polarization of the foregrounds is mandatory to clean the future CMB polarization surveys devoted to the detection of the B-modes of polarization generated during the inflation process, in the very early universe. BOOMERanG provides the opportunity to test in space a polarization modulator, which is considered mandatory for the next generation of space-based CMB measurements, like COrE and CMBPOL. The launch is planned one year after the launch of OLIMPO. The PI institution is Dipartimento di Fisica, La Sapienza, Roma (P. de Bernardis).

LSPE: recently approved by ASI, this instrument will map CMB polarization at large angular scales, so will be flown during the arctic night (the forecast for the flight at the moment is December 2014). LSPE is built by a nation-wide collaboration (Roma Firenze Bologna Milano), with additional contributions from UK (Manchester Oxford) and US (JPL) , and includes both bolometric and coherent detectors. It will cover the spectral region between 40 and 270 GHz, with sub-degree angular resolution, and with advanced polarization modulation techniques. It promises to measure CMB polarization at large angular scales with exquisite sensitivity and control of systematic effects. The target is the B-mode of CMB polarization that is in the end an indirect study of the cosmic inflation phenomenon, at energies > 10^{19} GeV. Given the energy-scale involved in the inflation process, the attainable indications from such an instrument are not only important for cosmology, but also for fundamental physics at extremely high energies, unreachable with any accelerator on earth. Propedeutic to LSPE is BOOMERanG-FG (see above). The PI institution is Dipartimento di Fisica, La Sapienza, Roma (P. de Bernardis) for the payload in general and for the high frequency instrument; Dipartimento di Fisica, Università di Milano (M. Bersanelli) for the low-frequency instrument.

DUSTER / VESUVIO is a series of small payloads (weight range 35 to 50 Kg), aimed at collecting small dust particles of both terrestrial and interplanetary / interstellar origin. The samplers will be launched on an LDB during various seasons. There is a strong interest in flying this next June (2011) and next October (correlation with Draconides) from the Svalbards. This collaboration is led by Parthenope University (A.Rotundi, V.Della Corte, P. Palumbo).

NISBA is a small infrared detector to be flown at night (winter launch LDB from polar regions) in order to monitor the infrared sky background in the lowest background window 2.4-2.6 μm. The study of sky darkness at balloon altitude in this window is in view of a future large (3-4 m primary) balloon-borne payload for deep surveys of galaxies, to be flown before the launch of JWST, scheduled by Nasa for 2014. The weight of NISBA is below 25 kg. NISBA is developed by Osservatorio Astronomico di Roma (INAF, E. Giallongo, F. Pedichini).

Besides these scientific experiments (and many others which were mentioned during the 2008 balloons workshop in Rome), there is a growing interest from Universities, both in Europe and in the United States, in involving students to develop their own project (technological or scientific or both) to be flown on a balloon as a "piggy back" on a bigger experiment gondola or as a standalone on a small size balloon. An example of what could be done easily in Italy is what Prof. Guzik is doing in the USA at Louisiana State University, or what is done in Kiruna with the program called BEXUS. An INFN (Group V) student's experiment has been funded to celebrate the Hess experiment on cosmic rays (Panareo, Lecce): it will be hosted on the OLIMPO gondola next year.

2. New Experiments of interest for INFN

2.1 Searches for Neutrino Mass

CMB observations can be used to constrain neutrino masses and hierarchies in a way effective and complementary to direct searches. This is of utmost interest for INFN. Here we describe the scientific drivers for this experiment and a possible implementation.

2.1.1 Direct Searches

The best known technology for Direct Searches of neutrino mass is fully exploited in the KATRIN experiment, which makes use of the largest source of Tritium and the biggest magnetic spectrometer ever built in the world. KATRIN experiment has been designed in order to have an energy resolution of 0.9 eV and to control the systematic uncertainties due to a measurement of molecular gas source at level of 0.2 eV. The experiment is expected to start taking data in 2013.
The present main spectrometer has a diameter of 10 m and a length of 23m at a pressure of 10^{-11} mbar. Further advancements of this technology are difficult, if not unrealistic, because of the increase of the spectrometer sizes with the energy resolution and the precision which is required for the B and E fields.

Recently, a new proposal has been made with the aims to overcome these limitations in which the beta energy measurement is made by means of the detection of its EM cyclotron radiation. But this will requires high B fields with homogeneity at level of 1 ppm. Furthermore, the loss of kinetic energy in EM radiation is not negligible and needs sophisticated signal analysis in the time domain in radio frequency band.

Drawbacks like external sources of systematic effects, complicate detector calibration of the energy scale, huge radioactive sources and large size apparatus can be avoided by using calorimetric spectroscopy with Low Temperature Detectors.

Low Temperature Detectors have to be considered a young technology mainly in the field of applications to the high precision beta spectroscopy for direct mass measurements.
In principle, the known phenomenology of these devices at mK temperatures allows to design high spectral resolution (0.1-0.3 eV) and reasonably fast detector (100ns) in the keV energy band. These could be considered "realistic" reaches in the next future.

However, in the last decade only a small area of the "phase space" of the phenomenology of these detectors have been practically investigated, mainly due to limited human resources and the needs of high interdisciplinary approach. Only few groups are currently working intensively on these specific goals, therefore the advancements are not fast enough.

Presently, two main technologies have achieved 1-2 eV energy resolution and 100 ns timing resolution: the so called TES Microcalorimeter, which has been developed since the '90s, and the Magnetic Calorimeter, the newest, since it has been developed in the last decade.

Low Q beta decaying isotopes under consideration are 187-Re (β^- , Q=2.45 keV, $t_{1/2}= 4\times10^{10}$ y) and 163-Ho (E.C., Q=2.3-1.8 keV, $t_{1/2}= 4.5\times10^{3}$ y). They provide sufficiently "clean" decaying processes to which the usual and well known kinematical method at the end-point of the spectra can be applied. Lower Q value isotopes (like ^{115}In) have excited decay with low branching ratio, so are not usable.

A crucial issue that affects largely the detector performance is the integration method of the isotopes in the detector itself, which is based on available techniques: crystal bonding, implantation, etc. It is clear that a large effort is needed for investigating new and efficient methods for embedding the source in the detectors, for achieving the required performance for large bolometer arrays.

Within the present framework of knowledge and technical achievements the 0.1 eV region should be covered in the time scale of 3-5 years with 0.5 Kg mass of ^{187}Re in 10^4-10^5 detectors, or 50μg of ^{163}Ho in 10^3-10^4 detectors. The two measurements have different systematics and in principle an experiment with both isotopes should be done, even if the ^{163}Ho presently appears the most appealing.

The recent progresses in LTDs have not found fundamental limitations for further improvement. As an example a reduction of a factor ten in operating temperature (100mK to 10 mK) should allow to increase further the spectral resolution in Metallic Calorimeters. Therefore, future sensitivities down to 0.01 eV are not excluded for direct neutrino mass searches in the coming decade, but they must be demonstrated with intensive investigations to achieve fast progress in detector and readout technology.

2.1.2 Measuring Neutrino Masses with the CMB

In this section we present what we consider the 3 major scientific goals, of great interest for the astro-particle physics community, that could be achieved with a high resolution survey of the CMB anisotropy and polarization with wide sky coverage:

a) a new constraint on the neutrino absolute mass scale
b) a determination of the number of relativistic degrees of freedom in the primordial universe (i.e. sterile neutrinos)
c) an independent bound of the primordial Helium abundance.

In what follows we include also forecasts, assuming the Planck CMB survey [Tauber et al., A&A 520 (2010) A1] , expected to deliver data by 2013 and the Euclid satellite galaxy survey [see e.g. Refregier, et al. , arXiv:1001.0061, 2010] still on phase of discussion but that, if launched by 2017, should deliver data around 2020. Note that a balloon-borne survey might produce data in 4 years, i.e. in 2015. We will name this experiment SUPEROLIMPO for the time being, given the similarity of the instrument to the OLIMPO payload, and the required substantial increase of telescope size and detectors number. The unique feature of SuperOLIMPO will be the very high angular resolution (comparing to forthcoming experiments, the resolution would be a factor 10 better than SPIDER and a factor 3 better than EBEX) combined to the ability to cover large angular scales using night-time flights.

The detection of the absolute mass scale of the neutrino is one of the major goals of experimental particle physics. However, cosmology could provide an earlier, albeit model-dependent, detection. CMB power spectra are sensitive to a total variation in neutrino mass eigenstates Σm_ν [see e.g. Ma and Bertschinger, Astrophys. J., 455, 7 (1995); Ichikawa et al., Phys. Rev. D 71 (2005) 043001 ; Abazajian, K., & Dodelson, S., Physical Review Letters, 91, (2003) 041301] but can't discriminate between the mass of a single neutrino flavour (see e.g. A. Slosar, Phys. Rev. D 73, 123501 (2006)] because of degeneracies with other parameters.

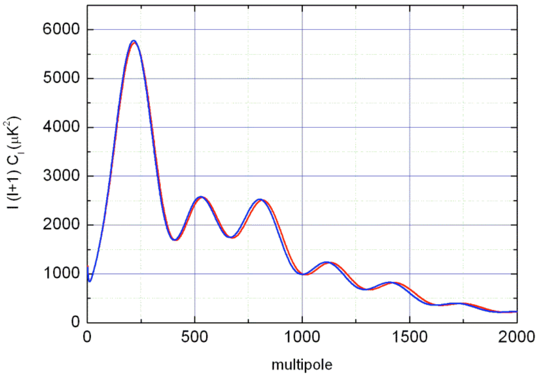

Fig.4: The tiny effect of massive neutrinos on the power spectrum of CMB anisotropy (blue: no neutrinos, red: N_ν=3, Σm_ν=0.65 eV). Precision measurements are already achieved routinely, and constrain the sum of neutrino masses to a fraction of eV.

Inclusion of massive neutrinos increases the anisotropy at small scales because the decreased perturbation growth contributes to the photon energy density fluctuation. Moreover, gravitational lensing leads to smoothing of the acoustic peaks and enhancement of power on the damping tail of the power spectrum; the amount of lensing is also connected to the neutrino mass [see e.g. Kaplinghat, et al., Phys. Rev. Lett. 91 (2003) 241301].

Current oscillation experiments provide essentially two mass differences for the neutrino mass eigenstates: $\Delta m^2_{solar} \sim 8 \times 10^{-5}$ eV^2 and $\Delta m^2_{atm} \sim 2.5 \times 10^{-3}$ eV^2 [see e.g. Fogli et al., Phys. Rev. D 78 (2008) 033010 and references therein]. An inverted hierarchy in the neutrino mass eigenstates predicts a lower limit to the total neutrino mass of about $\Sigma m_\nu >= 0.10$ eV while a direct hierarchy predicts $\Sigma m_\nu >= 0.05$ eV. The goal for CMB experiments is therefore to have a sensitivity better than $\Sigma m_\nu < 0.10$ eV for possibly ruling out the inverted hierarchy and better than <= 0.05 eV for a definitive detection of neutrino mass.

As we can see from Table 1 the expected sensitivity from Planck and Planck+SuperOlimpo is sufficient to find the neutrino mass in the inverted hierarchy case, while the inclusion of data from a future galaxy survey as the one expected by the Euclid Proposal (to be available around 2020) could possibly also measure it in the direct hierarchy case. In particular, the combination of SuperOlimpo data with Planck is expected to improve the bound on the neutrino mass by a factor of about 3 while further inclusion of data from galaxy surveys can improve it by a factor of more than 5.

Parameter uncertainty	Planck	Planck +SuperOlimpo	Planck +SO+Euclid
$\sigma(\sum m_\nu)$	< 0.28 eV	< 0.09 eV (3.1)	< 0.05 eV (5.6)

TABLE I. errors on cosmological parameters in the case of massive neutrinos. The numbers in brackets show the improvement factor σ_{Planck}/σ respect to the Planck experiment. The entries for $\sigma(\sum m_\nu)$ are upper limits (<) at 95% c.l..

These limits are better than those expected from future laboratory experiments. The expected upper limit expected from the KATRIN beta decay experiment is $\Sigma m_\nu < 0.2$ eV at 90% c.l., which roughly translates to an upper limit of $\Sigma m_\nu < 0.48$ eV at one standard deviation [see Kristiansen and Elgaroy, JCAP 0801 (2008) 007]. Planck+SuperOlimpo will explore the same energy scale but with higher accuracy, providing a great opportunity for confirming or anticipating a mass detection from KATRIN.

Planck+SuperOlimpo will also falsify or confirm at high confidence level the claim of detection of the absolute scale of the neutrino mass from the Heidelberg-Moscow neutrinoless double beta decay experiment with a effective electron neutrino mass in the range $0.2 \text{ eV} < m_{\nu e} < 0.6$ eV at 99.73 % c.l. [Klapdor-Kleingrothaus, et al. , Phys. Lett. B 586 (2004) 198].

Future double beta decay experiments such as MARE [Monfardini et al. 2006, Nuclear Instruments and Methods in Physics Research A, 559, 346] should sample, together with KATRIN, mass scales of the order of $m_{\nu e} \sim 0.2$eV. These experiments, if combined with Planck and Planck+SuperOlimpo constraints could provide extremely valuable information on neutrino physics. For example, a CMB detection of a neutrino mass not confirmed by double beta decay experiments would rule out neutrinos as majorana-like particles.

Future Constraints on Extra Neutrinos

The three neutrino scenario is a minimal scheme, and there is no fundamental symmetry in nature forcing a definite number of right-handed (sterile) neutrino species, as those are allowed in the Standard Model fermion content.

Models with one additional ~ 1 eV massive sterile neutrino, i.e. the so called (3+1) models, were introduced to explain LSND short baseline (SBL) antineutrino data [Aguilar et al., Phys. Rev. D 64, 112007 (2001)] by means of neutrino oscillations. A much better fit to SBL appearance data and, to a lesser extent, to disappearance data, is provided by models with two sterile neutrinos (3+2)

[Sorel, et al., Phys. Rev. D 70, 073004 (2004); Karagiorgi et al. Phys. Rev. D 75, 013011 (2007), ibid. D 80, 099902 (2009)] which can also explain both the MiniBooNE neutrino [Aguilar-Arevalo et al. Phys. Rev. Lett. 98, 231801 (2007)] and antineutrino data [Aguilar-Arevalo et al., Phys. Rev. Lett. 103, 111801 (2009)] if CP violation is allowed [Karagiorgi et al., Phys. Rev. D 80, 073001 (2009)]. CP violation can even occur in (3+1) scenarios with only one relevant mass squared difference in the presence of non standard neutrino interactions (NSI). Therefore, the (3+1) NSI model can also nicely explain current data [Akhmedov & Schwetz, JHEP 1010 (2010) 115].

An additional background of relativistic (and non-interacting) particles can be parametrized by introducing an effective number of neutrino species N_v^{eff}. This additional background changes the CMB anisotropies through time variations of the gravitational potential at recombination, due to the presence of this non-negligible relativistic component (the so-called early Integrated Sachs Wolfe effect). The main consequence is an increase in the small-scale CMB anisotropy [see e.g. Bowen et al., Mon. Not. Roy. Astron. Soc. 334, 760 (2002)].

Cosmological probes have been extensively used to set bounds on the the relativistic energy density of the universe in terms of the effective number of neutrinos N_v^{eff} [see, for instance, Reid et al., JCAP 1001, 003 (2010); Hamann et al., JCAP 1007, 022 (2010); Mangano et al., JCAP 0703, 006 (2007); Hamann et al. JCAP 0708, 021 (2007)]. Currently, WMAP, SDSSII-BAO and HST data provide a 68\% CL range $N_v^{eff} = 4.34 \pm 0.87$ [Komatsu et al. Astrophys .J. Suppl. 192, 18 (2011)] in the assumption of a ΛCDM universe.

In Table II we report the constraints achievable on this parameter with Planck, Planck+SuperOlimpo and Planck+SuperOlimpo+Euclid.

Parameter uncertainty	Planck	Planck +SuperOlimpo	Planck +SO+Euclid
$\sigma(N_\nu^{\rm eff})$	0.18	0.044 (4.1)	0.034 (5.3)

TABLE II. 68% c.l. errors on cosmological parameters in the case of extra background of relativistic particles $N_\nu^{\rm eff}$. The numbers in brackets show the improvement factor σ_{Planck}/σ respect to the Planck experiment.

As we can see, combining SuperOlimpo with Planck will improve the constraint on N_v^{eff} by a factor of ~ 4 while the inclusion of a Euclid-like galaxy survey could improve it by a factor of ~5. As we can see, the constraints on N_v^{eff} comes mainly from CMB anisotropies and adding galaxy survey data, while useful, has a smaller impact with respect to the neutrino mass case.

SuperOlimpo can provide constraints that could give valuable information on the physics of neutrino decoupling from the photon-baryon primordial plasma. As it is well known, the standard value of neutrino parameters $N_v^{eff} = 3$ should be increased to $N_v^{eff} = 3.046$ due to an additional contribution from a partial heating of neutrinos during the electron-positron annihilations [see e.g. Mangano et al. Phys. Lett. B 534 (2002) 8]. This effect, expected from standard physics, could be observed by the SuperOLimpo experiment, albeit at just one standard deviation. However, the presence of non standard neutrino-electron interactions (NSI) may enhance the entropy transfer from electron-positron pairs into neutrinos instead of photons, up to a value of $N_v^{eff} = 3.12$ [Mangano et al., Nucl. Phys. B 756 (2006) 100]

Future Constraints on Helium Abundance

As recently shown by several authors [Trotta & Hansen, Phys. Rev. D 69, 023509 (2004); Ichikawa et al. Phys. Rev. D 78 (2008) 043509; Hamann et al. 2008, JCAP, 3, 4] the small scale CMB anisotropy spectrum can provide a powerful method for accurately determining the primordial ^{4}He abundance. While standard BBN, assuming a value of the baryon-photon ratio of $\eta=(6.19\pm0.15)\times 10^{-10}$ as measured by CMB data, predicts a primordial helium mass fraction $Y_p=0.2487\pm0.0002$, current observational measurements prefer a larger value of $Y_p=0.2561\pm0.0108$ [Aver et al. JCAP 1005 (2010) 003] and $Y_p=0.2565 \pm0.001$ (stat.) ±0.005 (syst.) [Izotov & Thuan, Astrophys. J. 710, L67 (2010)]. Having an independent, reliable, way to measure primordial Helium abundance with the same precision it is therefore of crucial importance to test the BBN scenario.

As we can see from Table IV, the Planck satellite mission alone will marginally reach this accuracy. On the other hand, SuperOlimpo has the potential of reaching a better precision than current astrophysical measurements. This will open a new window of research for testing systematics in current primordial helium determinations.

Parameter uncertainty	Planck	Planck +SuperOlimpo		Planck +SO+Euclid	
$\sigma(Y_p)$	0.010	0.0033	(3.0)	0.0025	(4.0)

TABLE III. 68% c.l. errors on cosmological parameters in the case of helium abundance. The numbers in brackets show the improvement factor σ_{Planck}/σ respect to the Planck experiment.

It is important to note that the Helium abundance in the BBN scenario is a growing function of N_{eff} and the baryon density. A change in $\Delta N_{eff} \sim 1$ could produce a ~ 5% variation in Y_p that could be measurable by Planck or Planck+Superolimpo.

2.2.3 Instrument and mission requirements

All the results in the previous section have been obtained assuming to be able to build an instrument with 1000 CMB detectors with high throughput, all in the focal plane of a balloon-borne 4m telescope with polarimetric capabilities.

The groups of Rome Sapienza, Genova and Perugia, have already in hands key technologies to build such an experiment: OLIMPO is a nice precursor, and the developments of Kinetic Inductance Detectors by the RIC experiment (group 5) and of spider-web bolometers as an ASI technology activity have qualified these groups to propose such an ambitious experiment. Several other groups in the INFN are potentially interested in contributing technologies, analysis and theory.

The study done up to now will have to be further implemented for the part taking into account the local foregrounds, observed with very high accuracy by Planck and by Herschel and now available to be used further, and the systematic and instrumental effects.
This part will have to be studied together with the interested parties in the collaboration, by the experimental cosmology group of the Phys. Dept. of La Sapienza directed by prof. Paolo de

Bernardis. Another task to be fulfilled will be the careful study of the hardware to be built by the collaboration, and the method and performance of the needed precise calibrations, both in lab and in flight.

Due to the size of the telescope and to the needed characteristic of a winter polar flight (darkness is required to obtain a wide sky coverage), such an experiment needs several test flights with smaller balloons and payloads, to validate the launches in that extreme environmental conditions and the retrieval methods, besides some of the needed subsystems to be used later on the big payload.

The time scale for these test flights during the night is 3 to 4 years, and they can be still used to perform some technological and scientific test for small payloads, also involving tests for private industries on materials and power supplies to be flown and used during the nights (new lithium batteries, fuel cells, thermal protections, etc..)

To this experiment, to be launched on a 4 to 5 years scale of time from kick off, we need to add for the short time range (1 to 3 years from now) the experiments already funded by ASI (OLIMPO, BOOMERanG, LSPE).

2.3 Astroparticle Measurements

Another synergy is represented by the scientific study of cosmic rays, and X rays, in ultra long duration flights, made possible by recent developments on new materials to build superpressure balloons, and pressurised balloon high altitude stabilized platforms. These structures will allow to keep a payload at float for several months in a row, to increase integration times by large factors, if compared to conventional and long duration balloon flights.

Proposed payloads as PEBS, DbarSUSY, eTeV, GAPS, for which it is mandatory a polar flight LDB because of the geomagnetic cut, represent a clear example of the potential inside the planned polar LDB flights for astroparticle physics, and could largely benefit from a launch facility under Italian control at Svalbard. The following paragraphs will review astroparticle physics measurements on balloons which are complementary to the space experiments currently running or in preparation.

2.3.1 Low energy anti-deuteron as a probe of dark matter in space.

Surely the understanding of the nature of the dark matter is one of the most intriguing questions of current cosmology. The most likely particle physics candidate for dark matter is the neutralino, expected in MSSM [S. P. Martin, arXiv:hep-ph/9709356v5 (2008)]. Many theory models exist, to predict which would be the most likely signature of neutralino annihilation: it is generally thought that anti-protons, positrons or anti-deuterons are sensitive probes for neutralino detection. In particular, detection of slow anti-deuterons ($T<1$ GeV/n) would be hardly explained by other indirect mechanisms for secondary production, while dark matter models predict a relatively high anti-deuteron flux in this energy range (see Fig.1)[Donato, Fornengo, Salati Phys. Rev. D 62, 043003 (2000)]. Thus, at low energies, anti-deuteron detection is effectively a background free signature of dark matter.

This search has been performed up to now, or proposed to be carried out, essentially by space borne experiments or balloons for long duration flights.
At present, the best limits on anti-deuteron in space have been set by the BESS-Polar experiment [H. Fuke et al., Phys. Rev. Lett. 95, 081101 (2005)], a joint project of Japanese and US scientists, in a long duration flight in Antarctica.
The design concept of the BESS-Polar spectrometer [Yoshida, T., et al., Adv. Space res., 33-10, 1755, 2004] is typical of experiments for antimatter search in space. A tracking system put in a thin superconducting solenoid measures the curvature of the trajectory of the incident particles. Time-of-flight plastic scintillation paddles are mounted at the top and the bottom of the spectrometer, in order to measure the velocity and the energy deposit of the incident particles.
A silica-aerogel Cherenkov counter is also utilized as a redundant particle identifier. Aerogel is needed to reduce the weight of the payload to meet the requirements of long duration flights over Antarctica, and also to reduce material thickness in the payload, in order to measure antiprotons and anti-deuteron at the lowest possible energy.

GAPS (General Antiparticle Spectrometer) is a proposed experiment to search for the anti-deuteron particle in the cosmic rays [Ph. von Doetinchem et al. arXiv: 1012.0273v1 (2010); J. E. Koglin et al, Proc 30th ICRC 2007, Vol. 4 (HE part 1), pages 769-772]. Initially configured as a long-duration balloon experiment, it will detect anti-deuterons with an effectively background-free method. Anti-deuterons will be captured in the GAPS target material, resulting in an exotic atom in an excited state. This exotic atom will then quickly decay, producing X-rays of precisely defined energies and a correlated pion signature from nuclear annihilation. The method of detection uses a time-of-flight (TOF) system, which tags candidate events and particle velocities, and ten 3x3 m^2 planes of Si(Li) detectors, which serve as the target material and tracking detector. The Si(Li) detectors provide both excellent X-ray energy resolution and good particle tracking. The GAPS method has already been successfully tested in an accelerator environment at KEK in 2004 and 2005. A prototype flight of a portion of the instrument is planned for 2011. This prototype balloon flight will lead to a full balloon experiment that is expected to be ready to fly over Antarctica by 2014.

The cited Collaborations, involved in anti-deuteron search in space, have faced challenges which physicists and technicians in INFN are ready to deal with, so is possible to plan an Italian participation to a new project in this field if the scientific interest is confirmed.

In particular, a few years ago, the DbarSUSY experiment (AntiDeuteron Supersimmetry Spectrometer) [R.Battiston and S.Schael, Mem. S.A.It. Vol. 79, 834 (2008)] was proposed by INFN/ASI (I), together with Aachen (RWTH)(D), Moscow State University (Ru). It consists of large acceptance (1.8 m^2 sr) spectrometer with a permanent magnet with scintillating fiber read by SiPM, a TOF system and a solid state RICH. Its goal is to measure rigidity (R) and sign of charge in the spectrometer, energy loss (dE/dx) and velocity (β) in the ToF and RICH, to do particle id by mass reconstruction: $m=Rz/\beta\sqrt{(1-\beta^2)}$. The project was proposed for ULD Balloon in 2008 as a part of a program to search for indirect evidence for Dark Matter in Cosmic Rays, using long duration balloon from the ASI base at the Svalbard Island, extending the sensitivity of space borne experiments like AMS-02, PAMELA and LDB like BESS (see Fig. 2 for a comparison between results and perspectives).

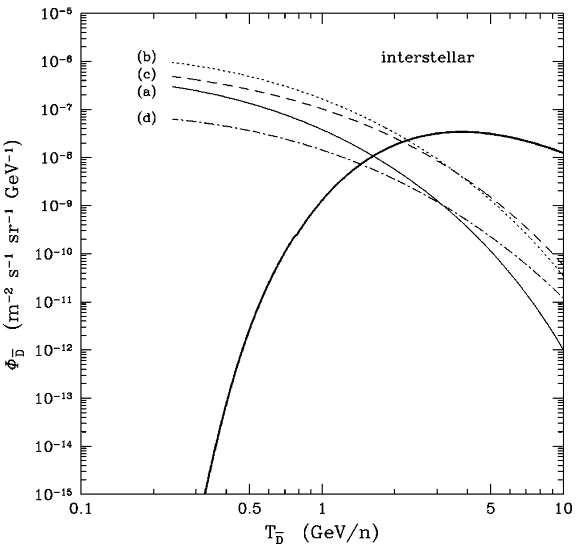

Fig. 5. The IS flux of secondary anti-deuterons (heavier Solid Curve) decreases at low energy whereas the energy spectrum of the anti-deuterons from supersymmetric origin tends to flatten. (a,b,c,d are 4 choices in the supersymmetric parameter space)

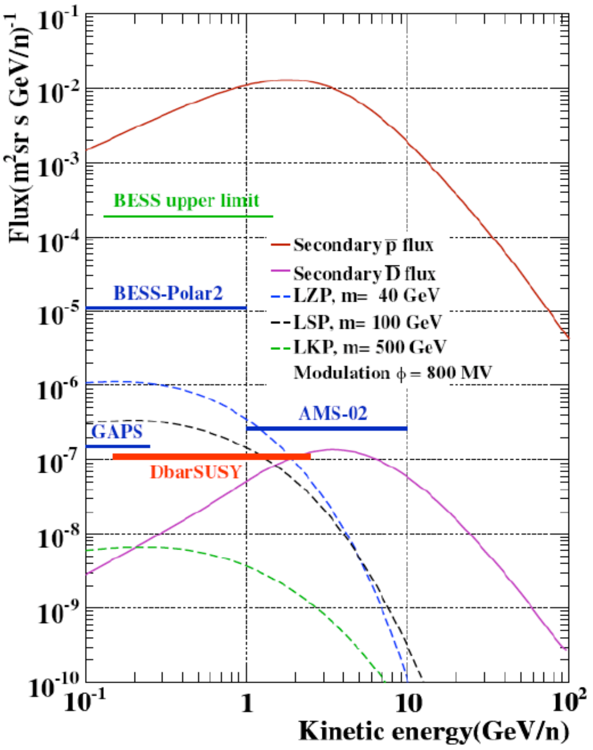

Fig. 6. Upper limits of anti-deuteron flux measured or estimated by space experiments.

3. State of the art in the world.

A comprehensive review of the various launched experiments or to be launched by CSBF is reported in the attached document called NASA balloon roadmap (attachment 1).

The Italian situation at June 2008 is instead extrapolated from the 1st workshop dedicated entirely to balloon activities and experiments (not much changed since then). This workshop has brought to the writing of a white paper included in the proceedings of the workshop (volume Mem. S. A. It., **79**, 2008) with endorsement of the CTS (ASI), and to the writing from the CTS of a call for proposals for balloon experiments open to the whole scientific community (attachment 2).

4. Common Technologies and Methods:

Detectors (transition edge superconductors, TES and kinetic inductance detectors KID): the RIC project (group V INFN, in collaboration with Fondazione Bruno Kessler Trento,FBK) has demonstrated the feasibility of detectors mosaics based on the kinetic inductance phenomenon.
Such kind of arrays would be ideal, once optimized and installed in the focal plane of the balloon borne neutrino mass experiment (see e.g. Calvo et al. 2010, Exp. Astron. 28: 185–194). The same sensors are potentially very useful for the direct measurement of the neutrino mass (see e.g. MARE experiment etc.). An analogous situation is present when considering the status of the TES used as bolometers and as microcalorimeters: they can be used by a variety of experiments both at ground

and in space and the readout electronics is most of the times the same. Once optimised for use in Space and before mounting the sensors at the focal plane of space borne experiments, the detector arrays need to be tested extensively on LDB missions, even in the version of membrane mounted prototypes (the scientific scenario including all the possible problems to be encountered in a space mission has been detailed analysed by Masi et al. Astronomy and Astrophysics, 519, A24, 2010).

A similar reasoning can be applied to the new high Tc superconducting magnets: MgB2. Or even YBCO, the use of these materials would facilitate the development and tests of cryocoolers both in suborbital missions and in satellite missions. These technological developments are mandatory for the development of high Tc superconducting magnet based spectrometers, but also for the development and tests of magnetic shields for protection of astronauts to be sent in space in future human interplanetary exploration travels. All these shields need an extensive testing at stratospheric balloon altitude, before being used in space.

5. Logistics and operations overview:

The best modus operandi is according to us an agreement between associated groups belonging to the different institutions, really interested in the use, for scientific and technological applications, of the LDB services. The groups will share expert personnel available and will give the logistics support (machine shops, technical projects and administrative offices and personnel) in order to be able to manage the entire process of the LDB campaigns.

The consortium should be available for the entire scientific and industrial community, and should have a specific contract from ASI to perform the activities, with a budget depending on the number of launches to be done each year. The plan is extended, and the contract as well, for a minimum period of 3 to a maximum period of 10 years, in a similar way as it is done abroad, in order to give the consortium the time to plan well the activities and to make efficient use of the money, and to be competitive with the available organizations in Europe and in USA.

The subcontract to the expert personnel to be used to perform the campaign, from organization, integration, launch and recovery, must be done on a yearly basis, in order to get the maximum advantage from such a contract for our community.

In order to form an Italian team and also for safety reasons, we will require that the expert instructs at least 2 persons to be used as crew chief and campaign manager in case of any problem even physical that might occur to the expert.

Each year there will be a pre-campaign initiation conference, for the selection of the payloads, with one back up payload at least, in case one team will not be ready, with a pre-campaign conference (PCC) for the selected projects, which will have to fill in advance the flight application, sent each year by September 30th to the possible interested groups, with the PCC in November, and a final review by February. The go – no-go will be on April 2nd. Each campaign during the summer will be prepared by the team and science personnel, which will be on site in May, for a June launch, and in June, for a July launch.

The interested parties, which could be available for putting in the field experts as subcontractors and technicians expert in electronics and mechanics, are mainly:

INFN laboratori nazionali di Frascati,
INFN sezione di Roma,

INFN sezione di Perugia,
INFN sezione di Genova
Dipartimento di Fisica, La Sapienza, (Roma)
Univ. Parthenope (Naples),
Univ. Milano,
CRAS,
INAF-IASF Roma,
INAF Osservatorio di Roma,
INGV Roma.

Once the technical staff has been identified, such personnel will be trained to be part of a launch team, (for a few years) under the direction of ISTAR (Peterzen) who coordinated for Italy the launches of POP, SORA, DUSTER, PEGASO from Svalbard. The goal is to form a team with the ability to perform the complete series of operations from the campaign organization, to the telemetry optimization and use, to the launch and recovery operations, and to have more than one single person with such skills, in order to fulfil all the needs of the scientific community in Italy.

The breeds of professionals that are needed are the following:

- 1 coordinator of the launch activities and campaign manager
- 2 mechanics technicians for rigging (assembling the flight trains and for launch operations)
- 1 engineer, expert in electronics or electronics technician expert in operating and troubleshooting of tele-commands and telemetry systems (TC and TM).
- 2 technicians in electronics for interface and test of TM and TC
- All this personnel will be based in Rome and Frascati, as the equipment will be hosted in Rome (TM system) or in Frascati or/and at the URBE Airport (launch equipment).

Sites available for LDB in Svalbard:

Longyearbyen has a civil aviation airport, fenced and reachable on a daily basis with commercial flights. On the airfield have been performed more than 14 small balloon launches, starting in 2003: among these the long duration SORA (1.6 ton), DUSTER (65 kg) and PEGASO (30 kg). Lab and integration hangars can be rent (see letter from the AVINOR airport Director attached). For the previous campaigns ASI has given funds to Andoya Racket Range for the logistics, but it is possible for the future to make a direct agreement (saving at least 40%) with the airport management to have an efficient and economic logistics for the campaign. In Longyearbyen there are hotels, hardware shops and machine shops, including the UNIS (University of Svalbard) one, and it is possible to lease the 70 tons crane adapted by Peterzen during the past years for the big payloads launches. Our Department has besides this the use on a yearly base (with a symbolic charge for the use of the facilities and maintenance of equipment, light, heaters, machine shop, bedrooms, electron ics shop, internet a reserve lab storage and use) at the new auroral observatory (mine 7 hill), where it will be installed the line of sight telemetry station, needed to monitor the ascent and the high bit rate data from the experiment during the 1st 24-48 hours of flight.

The other option that we have used for the winter (night) flight, is the airport of Ny-Alesund, reachable from Longyearbyen with a 20 minutes flight twice a week (small airplane). In Ny-Alesund the Base Dirigibile Italia used by CNR is present and they have hosted us for the launch campaign of the POP experiment (a small payload 3Kg weight for the test of the circumpolar currents during the arctic winter). The airport is not fenced and the runaway is much tighter than the LYR airport one. This second site is then to be used only for small size launches, and we choose it for the next winter testing campaign for night launches, to continue monitoring the currents to choose the best time in the winter to retrieve the payloads in the future. It cannot be used, at least at the moment, for bigger payloads.

6. **Recommendations:**

- Several key science issues of interest for INFN can be efficiently investigated using stratospheric balloons.
    - In particular, INFN should support balloon borne experiment devoted to cosmological searches for neutrino mass and astroparticle physics, as well as the related instrumentation development.
- These also represent a very good test-bench for instrumentation to be flown on satellites.
- For these reasons INFN should become an active promoter of a Consortium to be setup as soon as possible to operate stratospheric balloons in synergy with ASI.
- Direct interaction between the Consortium and ASI should be started as soon as possible, in order to
    - get control on the instrumentation from Trapani and Longyearbyen
    - instruct technical personnel
    - test and optimize the on-site equipment
    - restart the organization of the logistics in Longyearbyen
    - attract old and new users.
    - restate the need for an agreement with Russia for overflight permission, and possibly help ASI to finalize it.
    - finalize agreements with polar nations (Greenland, Canada, Russia) to deploy intermediate ground stations for data-dump along the circumpolar path.