Astrophysics

Astroparticles

1) Search for Dark Matter and Solar Axions at the Sierra Grande Underground Laboratory,
2) ^{54}Mn and ^{144}Pm as Cosmic-Ray Chronometers.

This group is devoted to theoretical and experimental research in areas in the frontiers between nuclear physics, particle physics and astrophysics. Specifically we conducted a series of experiments at the Sierra Grande Underground Laboratory with the aim of search and identification of cold dark matter candidates (such as WIMPs = weakly interacting massive particles) existing in the Milky Way and axions created in the Sun.

Results: The Sierra Grande Laboratory, built in May 1994 in a tunnel (at a depth of 380 m) of the iron mine HIPARSA in the province of Rio Negro, is the first and unique underground facility in South America. An ultralow background germanium detector of 1.033 kg was setup. A lead shielding made of archaeological material (2000 years old) and contemporary bricks surrounds the detector and protects against the local natural radioactivity in the mine. Since the beginning of its operation in June 1994, the experiment extended over a period of 1142 days almost without interruption until the end of 1997, with a total effective running exposure of 804 days. The analysis of the data was focused in the possible identification of cold dark matter candidates by using three methods: exclusion plots, and diurnal and annual modulation of the expected signal. By proposing a novel technique, the same set of data was also used to search for solar axions using the single crystal germanium detector. This technique exploits the coherent Primakoff conversion of axions into photons when their angle of incidence satisfies a Bragg condition with a given crystalline plane. This area of research was extended to other topics of astrophysics. In particular, in collaboration with the Nuclear Astrophysics group from the Lawrence Berkeley National Laboratory, a series of experiments were performed to determine the β-decay half-life of ^{54}Mn and ^{144}Pm which are needed to employ these isotopes as cosmic-ray chronometers.

Galactic confinement time of iron-group cosmic rays derived from the ^{54}Mn chronometer

K. Zaerpoor, Y.D. Chan, D.E. Di Gregorio, M.R. Dragowsky, M.M. Hindi, M.C.P. Isaac, K.S. Krane, R.M. Larimer, A.O. Macchiavelli, R.W. MacLeod, P. Miocinovic and E.B. Norman.

The β-decay half-life of 54Mn is needed to employ this isotope as a cosmic ray chronometer. We have determined the partial half-life of 54Mn for positron emission by counting a highly purified 35-μCi source of 54Mn in GAMMASHPERE to search for the astrophysically interesting β+ decay branch through the observation of coincident positron-annihilation γ-rays. A careful analysis of 97 hours of source counting and 61 hours of background shows a net signal of 24 ± 10 back-to-back 511-511 keV coincident events. Based on this result, the branch for this decay mode is (2.2 ± 0.9) x 10 –7 %. The implications of this result for the 54Mn cosmic-ray chronometer problem are discussed.

** Phys. Rev. Lett.* ***70*** *(1997) 4306.*

Cold dark matter identification. Diurnal modulation reexamined

F. Hasenbalg, D. Abriola, J.I. Collar, D.E. Di Gregorio, A.O. Gattone, C.K. Guérard and H. Huck

We report on new estimates of the modulation expected in semiconductor detectors due to the eclipsing of dark matter particles in the Earth. We reevaluate the theoretical modulation significances and discuss the differences found with previous calculations. We find that a significantly larger statistics than previously estimated is needed to achieve the same level of sensitivity in the modulated signal.

** Phys.Rev. D* ***55*** *(1997) 7350.*

Cosmic-ray half-life of ^{144}Pm

K. Zaerpoor, Y.D. Chan, D.E. Di Gregorio, M.R. Dragowsky, M.M. Hindi, M.C.P. Isaac, K.S. Krane, R.M. Larimer, A.O. Macchiavelli, R.W. MacLeod, P. Miocinovic, and E.B. Norman.

In order to test the possibility of using ^{144}Pm as a clock to measure the mean cosmic-ray confinement time in the Galaxy, we counted a highly purified 1.4 μCi source of this isotope in GAMMASHEPERE and searched for its astrophysically interesting β+ decay branch through the observation of coincident positron-annihilation γ-rays in coincidence with the characteristic 697-keV γ-ray. Analysis of 57 h of source and 15 h of background shows no net signal and results in an upper limit of 3.7 of 511-511-697 keV coincident events. From this result we establish a 90 % confidence level upper limit on the branch for this decay mode to be 7.4 x 10 –6 %. The implications of this result for the ^{144}Pm cosmic-ray problem are discussed.

** Phys. Rev. C **57** (1998) 2046.*

Theory for the direct detection of solar axions by coherent primakoff conversion in germanium detectors

R.J. Creswick, F.T. Avignone, H. A. Farach, J.I. Collar, A.O. Gattone, S. Nussinov and K. Zioutas.

It is assumed that axion-like Nambu Goldstone bosons exist and are created in the sun by Primakoff conversion of photons in the Coulomb fields of nuclei. Detection rates are calculated in germanium detectors due to the coherent conversion of axions to photons in the lattice when the incident angle fulfills the Bragg condition for a given crystalline plane. The rates are correlated with the relative positions of the sun and detector yielding a definite recognizable sub-diurnal temporal pattern. A major experiment is proposed based on a large detector array.

** Phys. Lett. B **427** (1998) 235.*

Experimental search for solar axions

A.O. Gattone, D. Abriola, F.T. Avignone, R.L. Brodzinski, J.I. Collar, R. J. Creswick, D.E. Di Gregorio, H. A. Farach, C. K. Guérard, F. Hasenbalg, H. Huck, H.S. Miley, A. Morales, J. Morales, S. Nussinov, A. Ortiz de Solórzano, J.H. Reeves, J. A. Villar, and K. Zioutas.

A new technique has been used to search for solar axions using a single crystal germanium detector. It exploits the coherent conversion of axions into photons when their angle of incidence satisfies a Bragg condition with a crystalline plane. The analysis of approximately 1.94 kg·yr of data from the 1 kg DEMOS detector in Sierra Grande, Argentina, yields a new laboratory bound on axion-photon coupling of $\gamma\gamma < 2.7 \times 10\text{-}9$ GeV-1 independent of axion mass up to ≈ 1 keV.

*Nucl. Phys. B **70** (Proc. Suppl.) (1998) 59.*

Experimental search for solar axions via coherent primakoff conversion in a germanium spectrometer

F.T. Avignone III, D. Abriola, R.L. Brodzinski, J.I. Collar, R.J. Creswick, D.E. Di Gregorio, H.A. Farach, A.O. Gattone, C.K. Guérard, F. Hasenbalg, H. Huck, H.S. Miley, A. Morales, J. Morales, S. Nussinov, A. Ortiz de Solorzano, J.H. Reeves, J. Villar and K. Zioutas.

Results are reported of an experimental search for the unique, rapidly varying temporal pattern of solar axions converting into photons via the Primakoff effect in a single crystal germanium detector when axions are incident at a Bragg angle with a crystalline plane. The analysis of 1.94 kg·yr of data from the 1 kg DEMOS detector in Sierra Grande, Argentina, yields a new laboratory bound by an axion-photon coupling of $\gamma\gamma < 2.7 \times 10\text{-}9$ GeV-1 , independent of axion mass up to ≈ 1 keV.

** Phys. Rev. Lett. **81** (1998) 5068.*

Search for annual modulation of dark-matter signals with a germanium spectrometer at the Sierra Grande laboratory

D. Abriola, F.T. Avignone III, R.L. Brodzinski, J.I. Collar, D.E. Di Gregorio, H.A. Farach, E. García, A.O. Gattone, C. Guerard, F. Hasenbalg, H. Huck, H.S. Miley, A. Morales, J. Morales, A. Ortiz de Solórzano, J. Puimedón, J.H. Reeves, A. Salinas, M.L. Sarsa, and J.A. Villar.

Results of a search for dark-matter induced annual modulation using 830.5 kg·days of data collected at the Sierra Grande underground laboratory with a germanium detector are presented. The analysis of the data does not show any indication of seasonal effects.

Data collected during three years have been analyzed for distinctive features of annual modulation of the signal induced by WIMP dark matter candidates. The main motivation for this analysis was the recent suggestion (by the DAMA collaboration) that a yearly modulation signal could not be rejected at the 90 % confidence level when

analyzing data obtained with a high-mass low-background scintillator detector. In our work, two different analyses of the data were performed. First, the statistical distribution of modulation-significance variables (expected from an experiment running under the conditions of Sierra Grande) was compared with the same variables obtained from the data. Second, the data were analyzed in energy bins as an independent check of the first result and to allow for the possibility of a crossover in the expected signal. In both cases no statistically significant deviation from the null result was found, which could support the hypothesis that the data contain a modulated component. Finally, a plot was presented to be able to compare our results to those of the DAMA collaboration.

** Astropart. Phys.* ***10*** *(1999) 133.*

Solar Axion Experiments Using Coherent Primakoff Conversion in Single Crystals

F.T. Avignone III, D. Abriola, R.L. Brodzinski, J.I. Collar, R.J. Creswick, D.E. Di Gregorio, H.A. Farach, A.O. Gattone, C.K. Guerard, F. Hasenbalg, H. Huck, H.S. Miley, A. Morales, J. Morales, S. Nussinov, A. Ortiz de Solorzano, J.H. Reeves, J. Villar, and K. Zioutas

The results of a 1.94 kg·yr pilot search for solar axions with an ultralow background Ge detector are reviewed. The detection method is based on Bragg-coherent Primakoff conversion of axions into photons when the momentum vectors of the axion and photon satisfy the Bragg condition. The theory of the experiment are presented for Ge and TeO2 crystals. Future prospects of large volume experiments are discussed.

** Nuclear Instruments & Methods in Physical Research A 425 (1999) 480*

A decommissioned LHC model magnet as an axion telescope

K. Zioutas, C.E. Aalseth, D. Abriola, F.T. Avignone III, R.L. Brodzinski, J.I. Collar, R.J. Creswick, D.E. Di Gregorio, H.A. Farach, A.O. Gattone, C.K. Guerard, F. Hasenbalg, M. Hasinoff, H. Huck, A. Liolios, H.S. Miley, A. Morales, J. Morales, D. Nikas, S. Nussinov, A. Ortiz, E. Savvidis, S. Scopel, P.Sievers, J.A. Villar, L. Walckiers

The 8.4 T, 10 m long transverse magnetic field of a twin aperture LHC bending magnetcan be utilized as a macroscopic coherent solar axion-to-photon converter. Numerical calculations show that the integrated time of alignment with the Sun would be 33 days/yr with the magnet on a tracking table capable of $\pm 5^{\circ}$ in the vertical direction and $\pm 40^{\circ}$ in the horizontal direction. The existing lower bound on the axion-to-photon coupling constant can be improved by a factor between 30 and 100 in 3 yr, i.e., $g_{a\gamma\gamma} \leq 9 \times 10^{-11}$ GeV^{-1} for axion mass ≤ 1 eV. This value falls within the existing open axion mass window. The same set-up can simultaneously search for low- and high-energy celestial axions, or axion-like particles, scanning the sky as the Earth rotates and orbits the Sun.

** Nuclear Instruments & Methods in Physical Research A* ***425*** *(1999) 480.*

Pierre Auger Project

The Pierre Auger Project consists of two similar observatories over an area of 3,000 km2 each, in order to study ultra energetic cosmic rays coming from outer space with the larger energies known in nature. There will be a observatory in each hemisphere as to have an ample sky coverage, one to be built in the Province of Mendoza – Argentina and the other in the State of Utah – USA. The Observatories consist of fluorescence telescopes and water tank detectors, in order to measure the longitudinal and transverse shower profiles, respectively.

The Tandar Auger Group has been working in the management, water detector systems, detector simulations, site infrastructure, solar power, bacteria growth in water, water temperature monitoring, and administration. We have done a wide spectrum of tasks leading to the Observatory ground-breaking ceremony on March 17th, 1999.

We are mounting a three water detector array at the Centro Atómico Constituyentes. These detectors are in a 1:1 scale to the Observatory detectors and consist in 12 tons water tanks with three 8” photomultiplier tubes to collect the charge deposited by the Cherenkov light produced by impinging shower particles. We will measure cosmic showers with energies 1015 – 1016 eV. We also collaborated installing two water tanks at the Observatory site in order to analyze the water thermal behavior, and doing the data analysis.

Several works were performed in relation with the site infrastructure. Fifty-eight out of a 108 contracts were signed with landowners to allow Auger to install the detectors in their properties and do their maintenance.

The first telecommunication tower, 40 m high, was built at the Los Leones hill, 15 km away from the city of Malargüe.

The Environmental Impact study was performed and has been submitted to the government of Mendoza for approval.

We have finished with the architectural project for the Los Leones fluorescence detector building and the complete Central Station buildings and services and we are now ready to call for a construction bidding. These buildings consists in:

Fluorescence Detector at Los Leones hill. It consists of 6 rooms were the telescopes and their electronics will be placed, a data acquisition room, an optic calibration laboratory, a workshop, a small kitchen and a bathroom (Fig.1).

Central Station at the City of Malargüe. It consists of an office building, a workshop, dormitories, parking lot, and tank storage place (Fig.2).

The Office Building (Fig. 3) has a control and data acquisition room, offices, meeting rooms, reception, visitor's center, small cafeteria, etc. The Workshop (Fig. 4) is mainly intended for assembly of water tank detectors. It has an electronic workshop, an optic calibration laboratory, an ultra pure water plant location, an storage room, a mechanical workshop, a lunch area and services. The Dormitories are displayed in Fig. 5 and this building has 10 two-bed dormitories, a common room, a kitchen, a lunch and a washing areas.

We expect to have and Engineering Array, consisting in 40 fully installed water tanks, a telescope at Los Leones, telecommunication and main buildings finished and operational by the end of 2001.

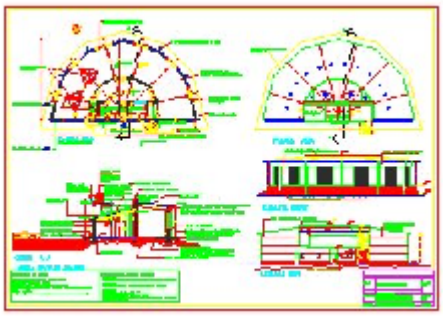

Figure 1

Figure 2

Figure 3

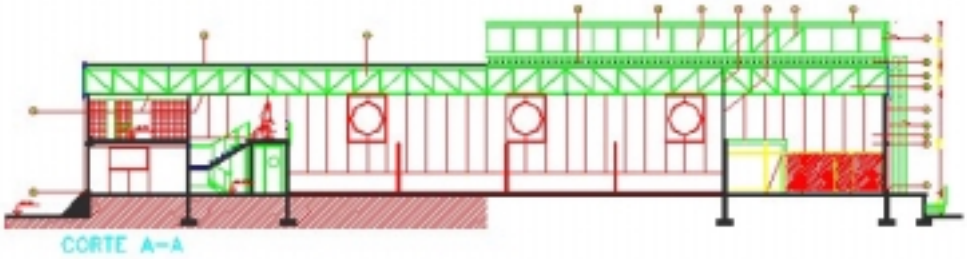

Figure 4

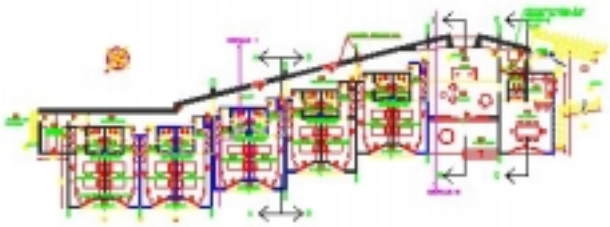

Figure 5