A LOW BACKGROUND MICROMEGAS DETECTOR FOR THE CAST EXPERIMENT

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A low background Micromegas detector has been operating on the CAST experiment at CERN for the search of solar axions during the first phase of the experiment (2002-2004). The detector operated efficiently and achieved a very low level of background rejection (5×10^{-5} counts keV^{-1}cm^{-2}s^{-1}) thanks to its good spatial and energy resolution as well as the low radioactivity materials used in the construction of the detector. For the second phase of the experiment (2005-2007), the detector will be upgraded by adding a shielding and including focusing optics. These improvements should allow for a background rejection better than two orders of magnitude.

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1. Introduction

The CAST (Cern Axion Solar Telescope) collaboration is using a decommissioned LHC dipole magnet to convert solar axions into detectable x-ray photons. Axions are light pseudoscalar particles that arise in the context of the Peccei-Quinn[1] solution to the strong CP problem and can be Dark Matter candidates[2]. Stars could produce axions via the Primakoff conversion of the plasma photons. The CAST experiment aims to track the Sun in order to detect solar axions. The detection principle is based on the coupling of an incoming axion to a virtual photon provided by the transverse field of an intense dipole magnet, being transformed into a real, detectable photon that carries the energy and the momentum of the original axion. The axion to photon conversion probability is proportional to the square of the transverse field of the magnet and to the active length of the magnet. Using an LHC magnet (9 T and 9.26 m long) improves the sensitivity by a factor 100 compared to previous experiments. A more detailed description of the principle of the experiment can be found in Zioutas *et al.*[3].

For the first phase of the experiment, 2002-2004, three different types of detectors have been developed to detect the x-rays originated by the conversion of the axions inside the vacuum of the magnet: a time projection chamber (TPC), a CCD and a Micromegas detector. The CCD detector has been working in conjunction with a mirror system to focus x-rays coming out of the magnet bores improving its signal to background ratio. The analysis of the data collected during 2003 shows no excess of signal over background and has resulted in the most restrictive experimental limit on the coupling constant of axions to photons[4]. The CAST second phase, 2005-2007, will allow us to scan axion masses greater than 0.02 eV/c^2. This is made possible by filling the magnet bore with a buffer gas (^{4}He or ^{3}He) allowing the photon to acquire an effective mass. During 2005 a He gas system has been designed and constructed, allowing systematic changes of the He pressure. Cold polypropylene windows have been installed in the magnet bore to minimize the thermal coupling between the cold bore and the outside of the magnet.

2. Performance of the Micromegas detector during phase I

2.1. *Description*

The Micromegas detector is a double gap chamber. It consists of a conversion gap separated from an amplification gap by a gauze-light electroformed conducting micromesh. A full description of the detection principle can be

found in Giomataris *et al.*[5]. For CAST, the conversion gap is 20 (30) mm thick and the amplification gap used was of 50 (100) μm in the 2003 (2004) data taking. The gas mixture is 95 % Argon and 5 % Isobutane. The field applied to the amplification gap is about 40 times higher than the conversion field. The charge is collected on a two dimensional readout by means of X and Y strips of 350 μm pitch.The mechanical pieces of the detector are of Plexiglas because of its low natural radioactivity to limit as much as possible the inherent background of the detector. The Micromegas detector, which operates at atmospheric pressure, is interfaced with the LHC magnet by two thin vacuum windows. These two windows, made of polypropylene, act as a buffer for the pressure gradient and at the same time they need to maximize the x-ray transmission in the energy range of interest for the axion search. The integrated x-ray efficiency of the detector in the solar axion energy spectrum (1-8 keV) is of 73 % taking into account the loss in transmission due to the thin windows as well as the conversion efficiency of the gas.

2.2. *Results*

The detector has run successfully during the first phase of the experiment. The Micromegas detector records tracking data at sunrise, and during the rest of the day background data is taken. The detector is calibrated daily using a ^{55}Fe source. The energy resolution at 6 keV is 20 % (FWHM). Tracking and background data have been analysed. Signal events (photons with a mean energy of 2-8 keV) have a well defined signature giving a typical cluster in the read out strips and a typical pulse in the micromesh. Background events, coming from cosmic rays and natural radioactivity, give out a bigger cluster in the strips, and the pulse shape in the micromesh is very different favouring an efficient rejection based on the micromesh pulse shape and on the cluster topology.

   Figure 1 shows the energy spectra for background events for 2003 and 2004 data. In these plots, a flat background is observed with a superimposed peak at 8 keV. This peak has been identified as the copper fluorescence peak coming from the detector materials (micromesh and readout strips). Thanks to the upgrading of the detector in 2004 and the elimination of residual cross-talk between strips, the background rejection was improved of a factor 3 with respect to 2003, achieving a level of 5×10^{-5} counts keV^{-1}cm^{-2}s^{-1}. The combined analysis of the three CAST detectors for the 2003 data has resulted in a limit on the coupling constant of photon
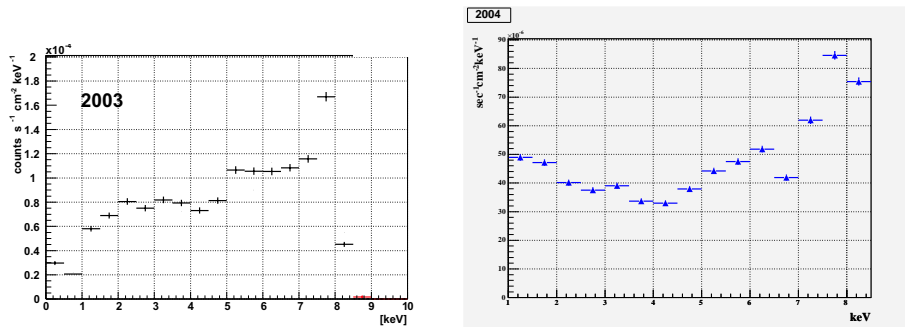
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Figure 1.   Background spectra for the 2003 and 2004 data.

to axions[4]. This limit, 1.16×10^{-10} GeV^{-1} for $m_a < 0.02$ eV, improves the existing experimental limit by a factor 6. The 2004 combined analysis should allow us to extract a limit close to the theoretical bound coming from astrophysical considerations.

3. The new Micromegas line for phase II

During the transformation of the magnet for phase II, the Micromegas group has been designing an upgraded Micromegas detector surrounded by a shielding and coupled to an x-ray optic, as shown in Figure 2. This new line should be installed at the CAST experiment during spring 2006. These upgrades will improve significantly the performance of the detector. First, the x-ray optic, a concentrator with a 1.3 m focal length and 47 mm diameter, will allow us to increase the signal to noise ratio by a factor ~ 100 by focusing the photon flux in a 2 mm spot. This concentrator will consist of 14 nested polycarbonate shells, each 125 mm long and coated with iridium. The optic will transmit $\sim 36\%$ of the 0.5-10 keV flux emerging from the magnet bore. Second, the shielding, composed of copper, lead, cadmium, nitrogen and polyethylene, is expected to reduce the background by a factor of 4. Third, by changing the gas of the chamber from Argon to Xenon, the photon conversion probability can be improved by at least $\sim 10\%$. The new detector will be running with the same electronics and acquisition developed for phase I. First tests of a prototype of the detector have started. The complete line, with the integrated optics, is expected to be operational for characterisation tests and calibration at the PANTER x-ray test facility in Munich beginning of 2006. Recent developments on

the integration of Micromegas with pixel CMOS readout[6], may lead to an ultimate upgrade of the detector for the 2007 data taking to profit of the spatial and energy resolution of pixel sensors.
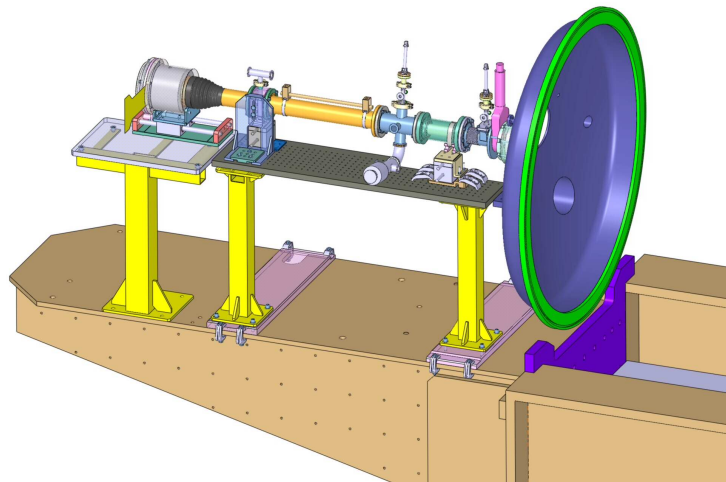

Figure 2.   The new Micromegas line consisting of a new detector with integrated x-rays optics and shielding.

4. Conclusions

A low background Micromegas detector has been operating at the CAST experiment achieving a remarkable background rejection (5×10^{-5} counts keV^{-1}cm^{-2}s^{-1}). For the CAST second phase, an upgraded Micromegas detector with integrated x-ray optics and shielding will be installed at the experiment during spring 2006. These improvements should lead to a reduction of the background level by at least two orders of magnitude.

Acknowledgments

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