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Abstract

A low background Micromegas detector was operating at the sunrise side of the CAST (CERN Axion Solar Telescope) experiment during the previous data taking periods (2002-2006). This detector, constructed of low radioactivity materials, operated efficiently and achieved a background level, $5 \cdot 10^{-5} keV^{-1} cm^{-2} s^{-1}$, in the 2-7 keV region. This performance was accomplished by exploiting the spatial and energy resolution of the detector as well as the time information contained in the pulse shape of the events. During the second phase of the experiment, the detector at the sunrise was replaced and upgraded by including a shielding. Moreover the old TPC covering the sunset side of the experiment was replaced by two new Micromegas detectors. These detectors belong to the newest generation of Micromegas detectors: 'bulk' and 'microbulk'. Performances and advantages will be presented.

Key words: CAST, Micromegas, gaseous detector, x-ray, photon, detector

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1 Introduction.

The CAST Collaboration is using a decommissioned LHC dipole magnet to convert solar axions into detectable photons. Axions are light pseudoscalar particles that were introduced to solve the strong CP violation problem[1] and could be a Dark Matter candidate[2]. The CAST experiment aims to detect solar axions by tracking the Sun, where axions could be produced via the Primakoff effect with the plasma photons. The detection principle is based on the coupling of an incoming axion to a virtual photon, provided by a transverse magnetic field (8.8 T). The incoming axion is thus being transformed into a real, detectable photon that carries the energy and the momentum of the original axion.

The expected axion signal is in the x-ray energy range and an important factor to achieve good signal to noise ratio and improve in discovery potential is the usage of low background x-ray detectors. During the previous

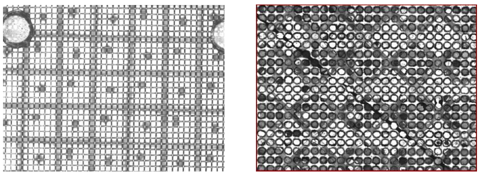

Fig. 1. Microscope pictures for bulk and microbulk detectors with 400 μm pads patterns. Bulk detector on the left (two mesh pillars observed at the top) and microbulk detector on the right (only micromesh holes without pillars).

phases of CAST, 3 different detectors were covering the 4 magnet bore ends. An x-ray telescope focusing in a CCD, together with a Micromegas detector in the sunrise side, and a TPC (Time Projection Chamber) in the sunset side.

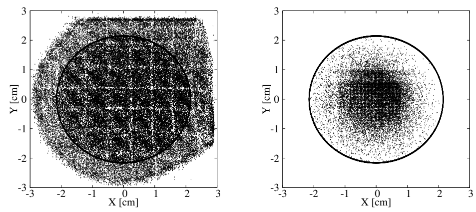

Fig. 2. Detector calibration hitmap taken with an iron source. On the left, sunrise bulk detector (frontal shinning). On the right, sunset microbulk detector (back shinning through plexiglass perforated hole).

These three detectors have run successfully in the previous phases of the experiment (2002-2006) exploring the parameter space of the axion to photon coupling constant for axion masses up to 0.39 eV/c^2[3,4].

During the last ongoing data taking period CAST will be sensitive to higher axion masses, up to 1.2 eV/c^2.

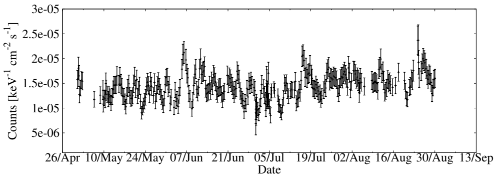

Fig. 3. Background rate evolution for the Bulk sunset detector during the last data taking period.

2 Micromegas performance during last data taking.

During 2007, CAST was in an upgrade phase preparing for the new coming He^3 phase. This period was used to improve the Micromegas sunrise detector control/monitor system and for the replacement of the sunset TPC chamber by new Micromegas detectors.

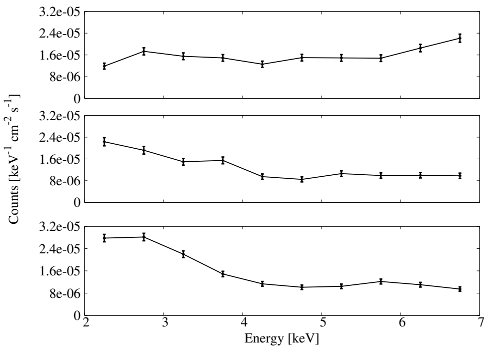

Fig. 4. Mean background energy spectrum for each CAST Micromegas detector. Sunrise bulk (B4) on bottom, Sunrise microbulk (M6) on top and Sunset bulk (B3) in the middle.

The latest generation of Micromegas detectors (see figure 1) designed in CEA Saclay were prepared for

CAST. Two different technologies, bulk[5] and microbulk, were built and tested to fulfill the CAST needs and improve signal sensitivity from previous phases.

The new sunrise shielding improved the background level of the detector by more than a factor 3. The sunset detectors replacing the *TPC* detector improved the background rejection by more than a factor 15.

These new detectors are showing good stability and performance (see figures 2 and 3).

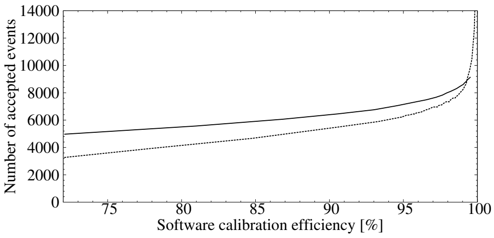

Fig. 5. Neural network rejection (dashed line) versus Standard Multivariate efficiency (solid line).

The quality of data and the posterior data analysis are fundamental in achieving a low background level. Background rejection has been studied comparing different statistical methods: sequential, standard multivariate method and SOFM (Self Organized Feature Maps) from neural networks methods.

In this paper, the modified standard multivariate analysis is used to find the background levels (see table attached), the software signal efficiency used was 75%, value to be improved by using more sophisticated statistical methods. The background spectrum for each detector is appreciated in figure 4).

Background levels ($keV^{-1}cm^{-2}s^{-1}$)	
Sunrise (B4)	$1.20 \cdot 10^{-5}$
Sunset (B3)	$1.42 \cdot 10^{-5}$
Sunset (M6)	$1.76 \cdot 10^{-5}$

Actually, work is in progress for the background rejection provided by neural networks. Preliminary results show much better signal efficiency for the same background discrimination efficiency (figure 5).

3 Detectors characterization

Bulk and microbulk detectors are being characterized in CEA Saclay for a better understanding of their behavior under different conditions: evolution with pressure, isobutane concentration, drift voltage and mesh voltage.

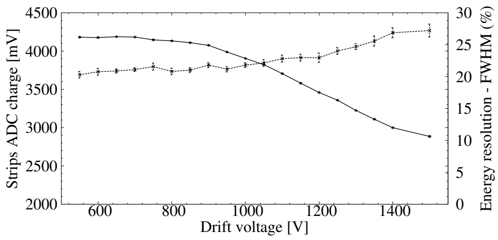

Fig. 6. Dependency of charge collected by the strips clustering and the drift voltage. Conditions are : 1.4 *bar* of Argon + 2.5% isobutane.

Results of these measurements for a bulk detector are presented in this paper (see figures 6, 7 and 8).

Cluster size and pulse parameters depend on these settings and they could play a role in the improvement of background discrimination.

An x-ray finger is placed in the sunset side to crosscheck the x-ray tele-

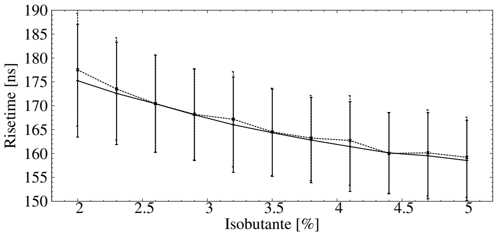

Fig. 7. Evolution of risetime with isobutane concentration.

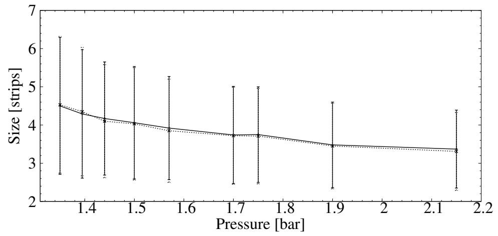

Fig. 8. Evolution of cluster size with detector's pressure.

scope alignment. When these telescope alignment measurements are going on, the sunset microbulk is able to see, through walls scattering, an x-ray spectrum that covers all the energy range of the detector. These measurements were exploited to characterize the detector's parameters relation with energy.

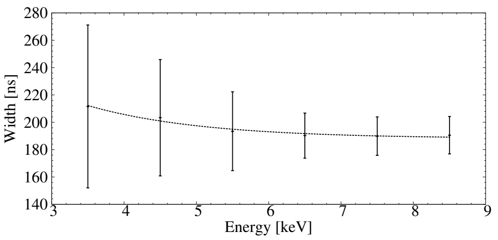

Fig. 9. Pulse width dependence on x-ray energy.

Pulse and cluster parameters show a smooth dependence with energy that can be parametrized and introduced in a posterior discrimination analysis (see figures 9 and 10).

4 Conclusions and prospects

Micromegas detectors have shown good performance and stability during the long data taking period of the CAST experiment. The background measured with each detector have a comparable level rate.

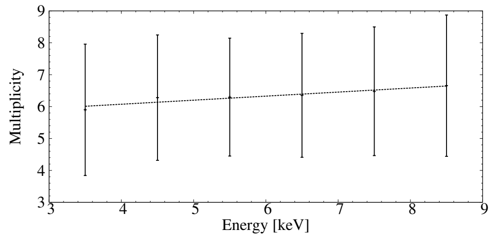

Fig. 10. Cluster multiplicity dependence with x-ray energy.

New spare detectors are available for further testing and characterization. Background measurements are carried out in the *Canfranc Underground Laboratory* to complete a more detailed detector description. Some extra energy characterization and efficiency measurements will be done in x-ray facilities.

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