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MICROMEGAS for Rare Event Searches

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Recently, micropattern detectors and in particular micromegas are receiving much attention from the community of rare event searches. The main features that make these detectors rather promising for this field of research are summarised and the latest results on the development of micromegas towards this direction are described in the context of axion searches in the CAST experiment but also their possible application to double beta decay searches.

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1. Introduction

Since its conception in 1996, the MICROMEsh GAseous Structure (micromegas)[1] has had many and diversified applications, exhibiting very good performances. Some of these characteristics, in particular the stability in operation, high spatial, energy and time resolution make micromegas very attractive for the field of rare event searches (axions, WIMP, double beta decay)[2] because of the capability to reconstruct quite accurately the topology of a low energy event. In the present paper, we discuss their performances in the CAST (the CERN Axion Solar Telescope) [3, 4, 5] experiment as well as first results useful for double beta decay searches.

2. Micromegas searching for Axions

The first application of micromegas in the field of rare events searches has been in the context of the CAST Experiment [6]. CAST is looking for axions coming from the sun, via their conversion into x-rays, with the help of a 9 m long, powerful (9 T) decommissioned LHC test magnet[1]. The magnet is mounted on a platform allowing a movement of $\pm 8^\circ$ vertically and $\pm 40^\circ$ horizontally. This allows tracking of the Sun during about 1.5h at sunrise and the same time interval at sunset. X-rays from the converted axions are expected to appear only during the 'sun tracking', forming an excess on the spectrum of the background taken during the rest of the day. Low background detectors have been constructed, optimised for the energy region of interest, 1 to 10 keV, among them micromegas.

Micromegas detectors have been sitting in one of the four apertures of the dipole magnet since late 2002, looking for 'sunrise' axions. These prototypes were the first to have used a 2-dimensional strip readout. Due to their remarkable stability of operation and high rejection capability, they reached very low background levels even unshielded. In 2007, during the preparation of the experiment's upgrade, the detector at the sunrise was upgraded as well. Moreover, the old Time Projection Chamber (TPC) covering the 'sunset' side of the experiment was replaced by two new micromegas.

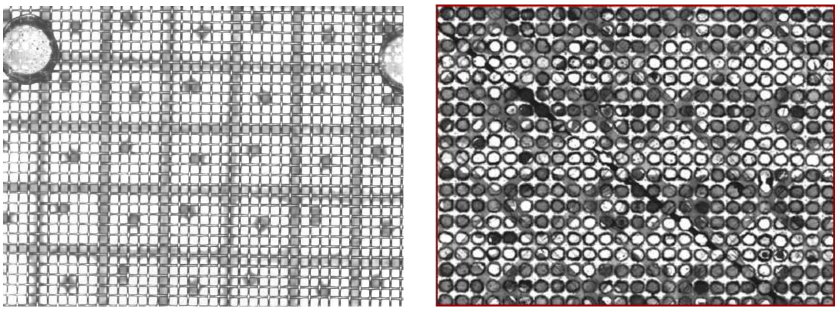

Figure 1: Pictures of a bulk (left) and microbulk (right) detectors taken with a microscope. In both arrangements one can distinguish the 400 μm readout pads. On the top side of the bulk configuration two pillars are visible. These pillars help maintain the gap between the micromesh and the readout plane, and they are absent in the picture of the microbulk.

[1] See proceedings of this conference on the CAST experiment

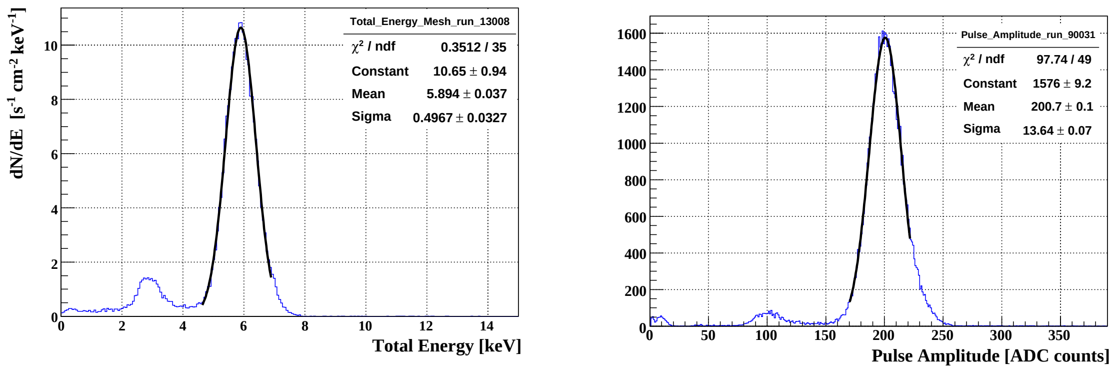

Figure 2: Energy resolution of one of the CAST bulk detectors (left), better than 20% FWHM and a microbulk (right) better than 14% FWHM, measured with an ^{55}Fe source (5.9 keV).

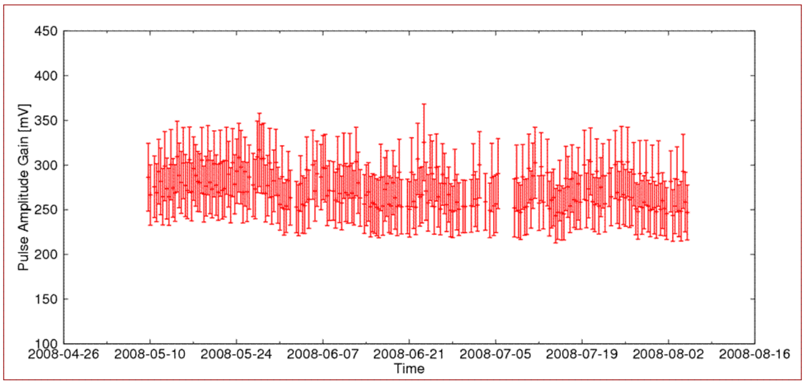

Figure 3: Stability of the gain of the bulk detector during the last data taking period.

At the sunrise side, a complete new detector line was designed, constructed and installed. It takes into account the possibility to add x-ray focusing optics in front of the detector, with the aim to increase the signal-to-background ratio significantly and therefore the discovery potential of the experiment. The new line implied a new detector design, which allows for an external shielding composed of copper, lead, cadmium and polyethylene, the inner part of which is flushed with nitrogen. It also allows for a better calibration of the detector with the help of two sources (one meant for the optics) located along the line. The new line is equipped with a new Bulk detector, and has been taking data since February 2008, when the ^{3}He phase of CAST started.

At the sunset part of the magnet a bulk and a microbulk [7], were mounted and covered with the (modified) old TPC shielding. These two technologies represent the second generation of the micromegas detectors (figure 1). The difference they present with respect to the conventional one, is that the micromesh and the readout plane are built as one entity, defining the amplification gap quite homogeneously (within some microns). The novelty of the microbulk detectors is the absence of pillars, the whole detector being constructed out of a thin kapton foil doubly clad with copper; it reaches very high energy resolution (less than 15% at FWHM at 5.9 keV) but is delicate because of the way it is manufactured. On the other hand, bulks are more robust, although the energy resolution achieved with this type of detectors is predestined to be worse (around 20% at FWHM at 5.9 keV) owing to the thickness of the micromesh used.

All three detectors are being operated with a gas mixture of Ar-Isobutane 2,3% at 1.44 bar, which is non-flammable and provides an overall efficiency of better than 75%. Until August 2008, the detectors have shown good gain stability and a very good energy resolution, characteristic of their type (figures 2,3). The presence of the shielding has helped to decrease the level of background almost a factor 3 compared to the old sunrise detectors. The levels of background reached are for all three, better than 2×10^{-5} counts^{-1}s^{-1}keV^{-1}cm^{-2}.

3. Micromegas and double beta decay

The micromegas structures are known to provide a very stable amplification factor. This is due to the particular geometry of the avalanche, which makes it rather insensitive to the amplification gap and other external parameters like temperature and pressure [8]. The latest development of the micromegas detectors mentioned in the previous section, enhance this feature due to the improved homogeneity these readouts present. This characteristic combined with the very good energy resolution achieved open the way for the application of the micromegas in other rare event searches, such as the double beta decay experiments. The observable in such an experiment is the energy carried by the two β. In all cases the disintegration with 2ν is present and gives a continuum in the energy spectrum. However, in the absence of ν (if neutrinos are Majorana particles) only a very narrow peak is expected around the $Q_{\beta\beta}$ value. The neutrinoless double beta decay $0\nu\beta\beta$ process has not been detected so far, and yet its observation holds many answers to fundamental questions like the nature of neutrinos (through their non-appearance) and the neutrino mass (through the measurement or limit of the process' half life).

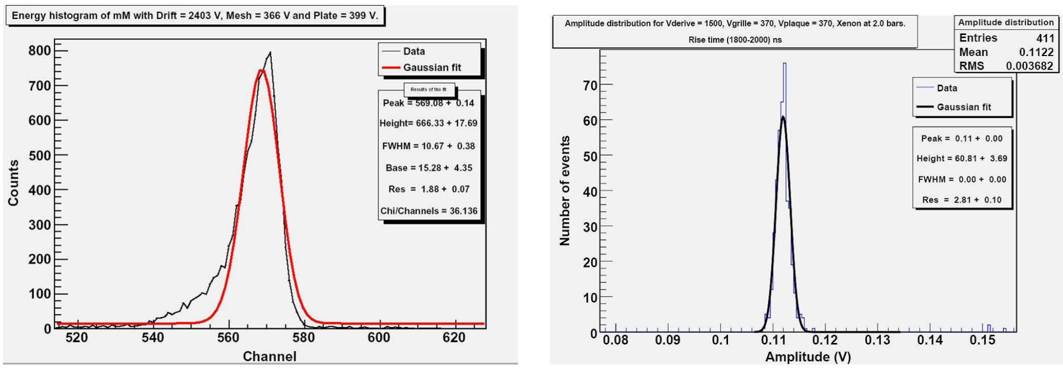

Figure 4: Energy spectra obtained with an ^{241}Am source, which emits alphas of 5.5 MeV, in Ar- 5% Isobutane at 4.75 bar (left) and pure Xenon at 2 bar (right). Preliminary results indicate resolutions better than 2% and 2.8% at FWHM respectively.

A new experiment NEutrino Xenon Experiment (NEXT) has been proposed, with the aim to define all technical aspects of a 100 kg Xenon gas TPC and eventually build it, while at the same time assessing whether a ton scale detector is feasible or not. In this context, we are currently exploring the possibility to use micromegas as readout. Taking advantage of the high granularity, very good energy and spatial resolution this technology offers, one could reconstruct the event with quite an accuracy, presenting a rather powerful background discrimination tool.

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The key feature for such an experiment is the energy resolution at the $Q_{\beta\beta}$ value of Xe, which is 2.48 MeV. With the help of the HELLAZ setup, several measurements of energy resolution have been made. The setup consists of a small (2l) TPC [9] with the readout of a microbulk detector. An ^{241}Am source, which emits alpha particles of 5.5 MeV, was introduced in the gas volume. The first measurements of the gain and energy resolution with the detector were made in several mixtures of Ar with quenchers like isobutane (iC_4H_{10}) or CH_4, in a pressure range of 2 to 4 bar. The best resolution obtained so far with those mixtures was with 2% FWHM at 5.5 MeV when at 4.75 bar. Tests were also performed with pure Xe up until 4 bar (figure 4). Preliminary results show an energy resolution at 4 bar of 4.5% FWHM at 5.5 MeV, opening the way for promising results in the next attempts. Improvements in the gas system have been done and more measurements with the source are ongoing. Measurements with monochromatic electrons at the MeV range will be used in the near future.

4. Conclusion

This short report has shown how micromegas detectors are related to rare event searches. The first item has reported on the long standing performance of micromegas detectors in the CAST experiment since 2003. A small description of the very new technologies has been given and how they are proving to be stable and reliable detectors. Using one of these types, a microbulk detector, the energy resolution has been measured in argon-isobutane mixtures and in pure xenon. These preliminary results proclaim that the possible application of the micromegas in double beta decay searches is rather promising.

References

[1] Y. Giomataris, Ph. Rebourgeard, J. P. Robert and G. Charpak, *MICROMEGAS: a high-granularity position-sensitive gaseous detector for high particle-flux environments*, *NIMA* **376** (1996) 29-35.

[2] J. L. Collar and I. Giomataris, *Possible low-background applications of Micromegas detector technology*, *NIMA* **471** (2000) 254-259.

[3] K. Zioutas et al., *First Results From the CERN Axion Solar Telescope*, *PRL* **94** (2005) 121301.

[4] S. Andriamonje et al., *An improved limit on the axion-photon coupling from the CAST experiment*, *JCAP* **04** (2007) 010.

[5] K. Zioutas et al., *Probing eV-scale axions with CAST*, `arXiv:0810.4482`, submitted to JCAP.

[6] P. Abbon et al., *The Micromegas detector of the CAST experiment*, *NJP* **9** (2007) 170.

[7] I. Giomataris et al., *Micromegas in a bulk*, *NIMA* **560** (2006) 405-408 [`physics/0501003`].

[8] Y. Giomataris, *Development and prospects of the new gaseous detector 'Micromegas*, *NIMA* **419** (1998) 239-250.

[9] P. Salin, P. Gorodetzky, J. Dolbeau and T. Patzak, *Status report on high-pressure TPC*, *NIMA* **535** (2004) 253-259.