

The discrimination capabilities of Micromegas detectors at low energy

F.J. Iguaz

on behalf of

IRFU/CEA-Saclay: E. Ferrer-Ribas, J. Galán, I. Giomataris, J.P. Mols,
T. Papaevangelou

CERN & Univ. Thessaloniki: T. Vafeiadis

Dogus University: C. Yildiz

Univ. Zaragoza: T. Dafni, J.A. García, I. Irastorza, A. Rodríguez, A. Tomás

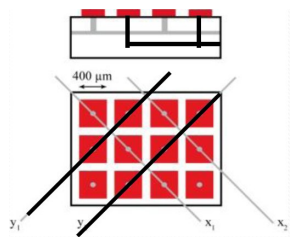
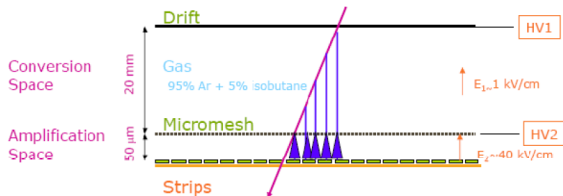
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Micromegas technology

Micromegas: A Micro-Pattern Gas Chamber detector



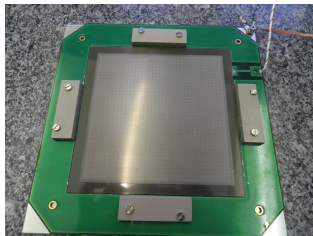
I. Giomataris (1996)

A thin metallic grid and an anode plane, separated by insulated pillars. They define a very little amplification gap (20-300 μm).

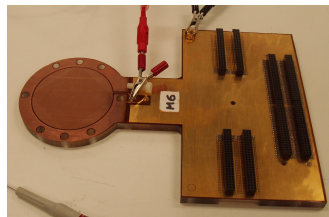
Good properties: High granularity, good energy and time resolution, stable, easy construction, little mass and radiopure.

Micromegas technology

Micromegas: The bulk and microbulk technologies



Bulk MIMAC detector



Microbulk CAST detector

Bulk: I. Giomataris et al., *Nucl. Instrum. Meth. A* **560** (2006) 405

The pillars are attached to a woven mesh and to the readout plane. Mesh thickness $30\mu\text{m}$, gap $128\text{-}256\mu\text{m}$.

Microbulk: S. Adriamonje et al., *JINST* **5** (2010) P02001

The pillars are constructed by chemical processing on a kapton foil, to which the mesh and the readout plane are attached. Gap $25\text{-}50\mu\text{m}$.

CAST: an axion experiment

The axion and the helioscope principle



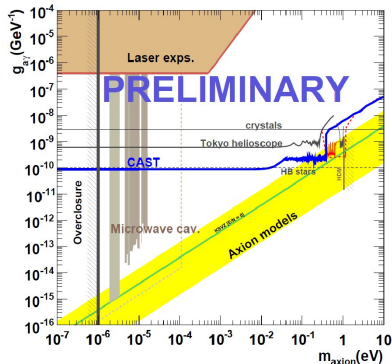
- Axion is a particle proposed to explain the non CP violation in strong interactions (Peccei & Quinn, 1977 and Weinberg & Wilczek, 1978).
- Helioscope principle: "Axions produced in the Sun's core could be reconverted to x-rays inside an intense magnetic field" P. Sikivie, *Phys. Rev. Lett.* **51** (1983) 1415.
- CAST uses a LHC dipole magnet (9.3 m length, 9 Teslas) to detect solar axions. 10 years of operation!!!
- Solar tracking possible during sunrise and sunset (2 x 1.5 h/day).
- X-ray detectors: 3 Micromegas and 1 CCD.
- Range of interest: 1-8 keV. Low background level needed.

CAST: an axion experiment

General results

CAST experimental limit dominates in most of the favoured parameter space.

- For $m_a < 0.02$ eV:
 $g_{a\gamma\gamma} < 0.88 \times 10^{-10} \text{ GeV}^{-1}$
 JCAP04(2007)010
 PRL (2005) 94, 121301.
- For $m_a < 0.39$ eV:
 $g_{a\gamma\gamma} < 2.2 \times 10^{-10} \text{ GeV}^{-1}$
 JCAP 0902:008,2009.



Other results

- High energy axions: x-ray calorimeter, *JCAP* (2010) 1003:032.
- 14.4 keV axions, TPC data: *JCAP* (2009) 0912:002.
- Low energy axions, PMT/APD data: arXiv:0809.4581.

CAST: an axion experiment

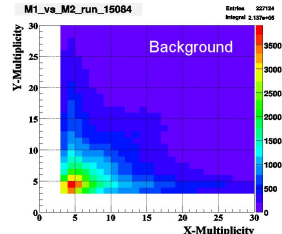
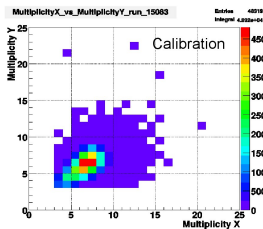
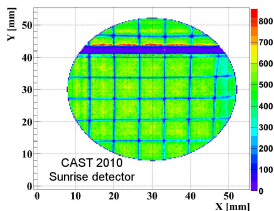
Micromegas detectors in CAST



- 3 Micromegas microbulk detectors installed. Readout: 106×106 strips, $550\mu\text{m}$ pitch. Gas: Ar + 2.3% Isobutane at 1.44 bar.
- Mesh pulses are digitized by a MATAcq board suited for acquisition of fast analog signals.
- The strips charge is integrated by gassiplex electronics.
- Shielding: 5 mm copper, 25 mm lead and 15-20 cm polyethylene.
- The inner volume is fluxed with nitrogen to remove Radon.
- References: *J. Phys. Conf. Ser.* **179** (2009) 012015.

CAST: an axion experiment

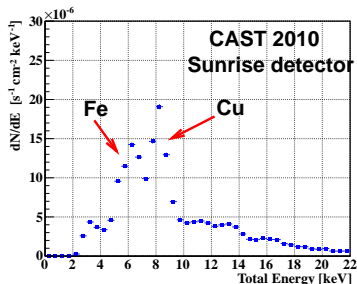
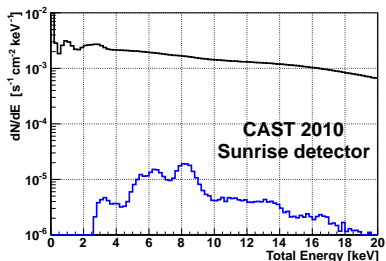
Discrimination of low energy x-rays and background



- The full area of the detector is calibrated with an ^{55}Fe x-rays source.
- From the calibration data, several parameters are defined to use in the background run to select x-rays events:
- Strips: Clusters, multiplicity and width.
- Mesh: Risetime, width, amplitude and integral.
- These parameters show an excellent dicrimination performance.

CAST: an axion experiment

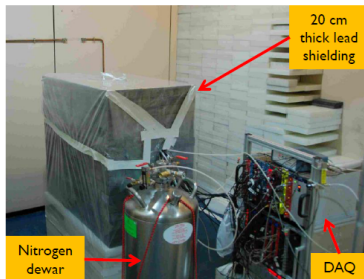
Results



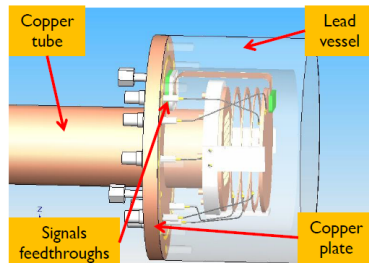
- Muons are efficiently rejected by the offline analysis
- External radiation is stopped by the shielding (25 mm lead, Cd, 5mm Copper, polyethylene + Nitrogen flow), except from its front part.
- Under these conditions the background should be determined by the fluorescence lines of near materials (Copper at 8 keV, Iron at 6 keV).

CAST: an axion experiment

Next steps



The M10 detector in the LSC

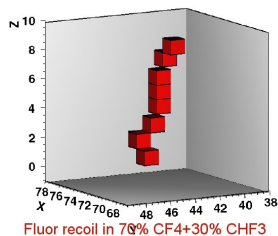
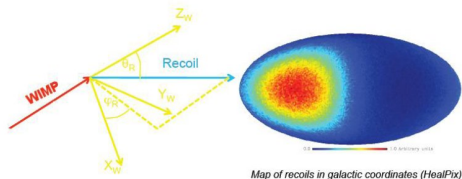


Design by J.P. Mols (IRFU-Saclay)

- A Micromegas CAST-like detector has been installed at the LSC to find its ultimate background level and check the effect of different shieldings (see A. Tomás talk of 10th June, Gaseous Detectors).
- Based on these results and simulations, a new Micromegas detector is being developed. It will contain several improvements (shielding, drift field, materials, T2K electronics) to reduce the background level.

MIMAC: a dark matter experiment

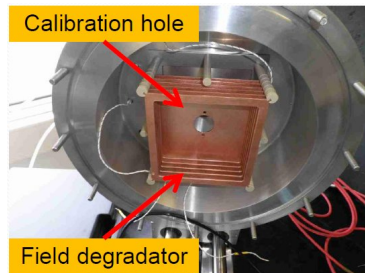
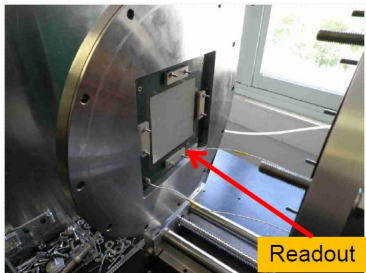
The MIMAC project



- If the halo of WIMPs come from a specific direction in the space, the recoil's direction distribution will have a clear spot.
- Advantage: A TPC with a highly segmented readout could reconstruct a little nuclear track (some mm) and little energy (some keV).
- Drawback: Some events per year are expected, which requires big masses.
- Main results up to now: Reconstruction of tracks of nuclear recoils of ⁴He and ⁹F of few keVs and the measurement of quenching factor.
- Latest reference: D.Santos *et al.*, arXiv 1102.3265v1.

MIMAC: a dark matter experiment

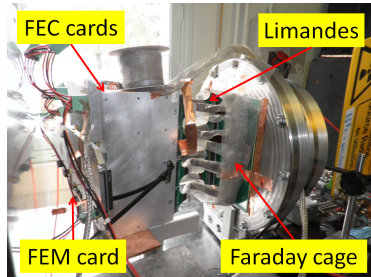
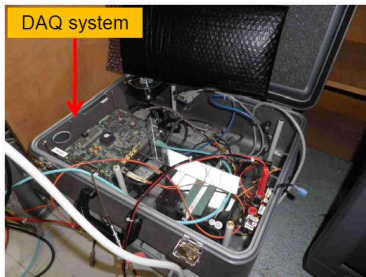
The MIMAC $10 \times 10 \text{ cm}^2$ setup



- The readout is a $10 \times 10 \text{ cm}^2$ 2D bulk detector ($424 \mu\text{m}$ pitch).
- Tested in a dedicated TPC, with two gas entrances, an iso-KF25 valve for pumping and four SHV feedthroughs for voltages.
- A field degrader (made of peek bars, squared copper rings and resistors of $33 \text{ M}\Omega$) creates an uniform electrical field in a drift distance of 6 cm.
- F.J. Iguaz *et al.*, Micromegas detector developments for Dark Matter directional detection with MIMAC, accepted in JINST, arXiv:1105:2056.

MIMAC: a dark matter experiment

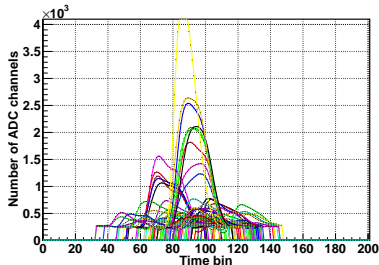
The T2K electronics



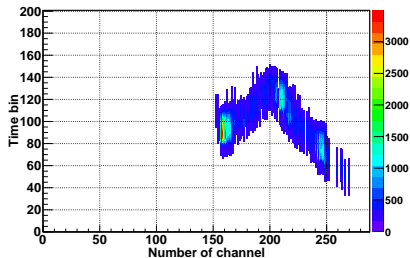
- The strip signals are extracted with 8 flat cables to 2 FEM cards. Each card has 4 ASIC chips, which amplify and shape the signals.
- A FEM card reads the two FECs and send the data to the DAQ system.
- An external trigger is generated with the mesh amplifier output.
- References: P. Baron *et al.*, *IEEE Nucl. Sci. Symp. Conf. Rec.* **55** (2008) 1744; D. Calvet *et al.*, *16th IEEE NPSS real time conference*, 2009, Beijing (China).

MIMAC: a dark matter experiment

The event reconstruction



Strips pulses

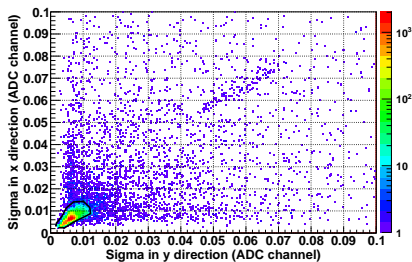


The reconstructed 2D view

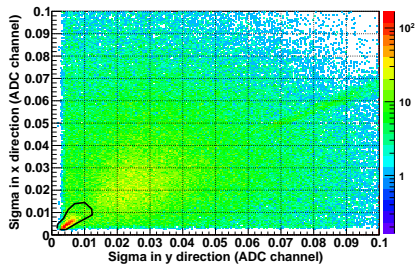
- The XY and YZ projections of each event are reconstructed with the pulse height in each time bin. The shaping time works as an extra diffusion.
- Different types of events observed: photons, muons, alphas.

MIMAC: a dark matter experiment

A first step towards a directional detector



^{55}Fe calibration run

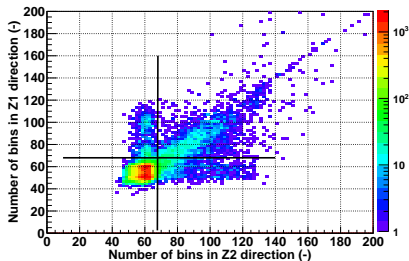


Background run

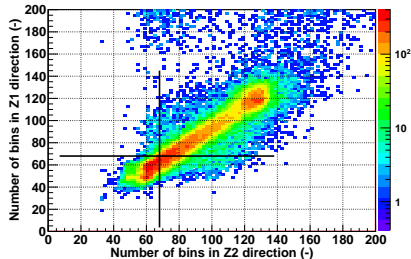
- In Dark Matter, the main objective is the neutron detection and the rejection of the other types of backgrounds.
- Study of the low energy photon background(2-10 keV), rejecting events with large topologies (muons, gammas).
- CAST analysis algorithms, adding the temporal information.
- Next steps consist in the neutron selection decreasing the TPC pressure.

MIMAC: a dark matter experiment

Description of the analysis



^{55}Fe calibration run

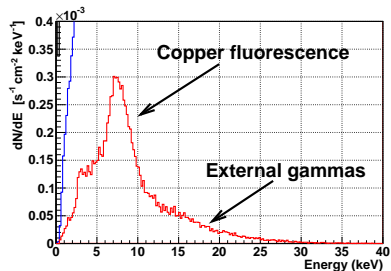
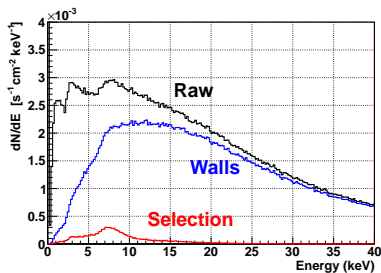


Background run

- In each spatial direction, the following parameters are calculated: charge, mean position, width and number of strips activated.
- The analysis has been then extended to the temporal direction using the amplitudes of the strips pulses in each temporal bin.
- The total event charge is just the sum of the charge of both projections.

MIMAC: a dark matter experiment

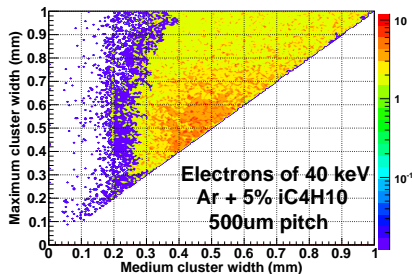
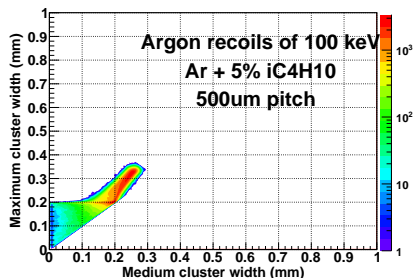
Analysis results



- The background factor rejection is a factor 10 between 2 and 10 keV.
- For only strips criteria, this factor is 8.6 for both energy ranges.
- The signal efficiency is respectively 78% and 87% at 3 and 6 keV.
- The final background spectrum is dominated by the environmental gammas and the copper fluorescence line at 8 keV.

A directional dark matter experiment

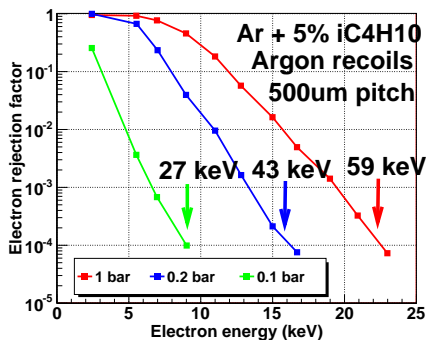
Future: Neutron and gamma discrimination



- Micromegas detectors are able to reject the gamma background and select with a high efficiency nuclear recoils.
- First studies: A. Tomás in the conference CYGNUS 2007.
- Simulated argon recoils (10-100 keV) and electrons (2-40 keV) in a $20 \times 20 \times 20 \text{ cm}^3$ TPC filled with Ar+5%iC₄H₁₀ at different pressures.
- The cluster width of nuclear recoils is a key parameter to reject the gamma background in directional experiments.

A directional dark matter experiment

Future: Neutron and gamma discrimination



- The cluster width is more efficient if the gas pressure is reduced, as nuclear recoils of lower energies can be selected.
- The width of nuclear recoils remains almost constant. In contrast, the width of electrons increase dramatically.
- Next step: To detect the head-tail of nuclear recoils.

Conclusions

- Micromegas detectors are applied in Dark Matter experiments due to its good discrimination capabilities for low energy events.
- In the CAST experiment, three microbulk detectors are installed since 2007. Muons are efficiently rejected by the offline analysis and the background is mainly determined by the fluorescence lines of near materials.
- A CAST detector has been installed in the LSC to find its ultimate background level. A new design is being developed based on these results, with several improvements.
- A $10 \times 10 \text{ cm}^2$ readout has been completely validated with the T2K electronics. Low energy photons (2-10 keV) have been selected rejecting events with large topologies. In the near future, its capability to select neutrons at low pressure will be studied.
- We acknowledge the ANR-07-BLANC.0255-03 funding.

Back-up slides.

Micromegas technology

Micromegas: The bulk and microbulk technologies

Bulk: I. Giomataris et al., *Nucl. Instrum. Meth. A* **560** (2006) 405

- The pillars are attached to a woven mesh and to the readout plane. Typical mesh thickness $30\mu\text{m}$, gap $128\mu\text{m}$.
- Good properties: Uniformity, robustness, lower capacity, easy fabrication, small surrounding dead region, large area detectors and mass production.
- Limitations: Energy resolution (16% FWHM at 6 keV), more sensitive to pressure variations.

Microbulk: S. Adriamonte et al., *JINST* **5** (2010) P02001

- The pillars are constructed by chemical processing on a kapton foil, to which the mesh and the readout plane are attached.
- Good properties: Excellent energy resolution (10% FWHM at 6 keV), low intrinsic background, better particle recognition, low mass, flexible structure and stable gain during long periods.
- Limitations: Large area detectors and mass production.

MIMAC: a dark matter experiment

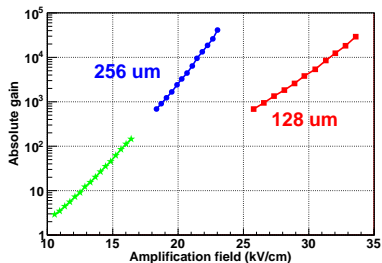
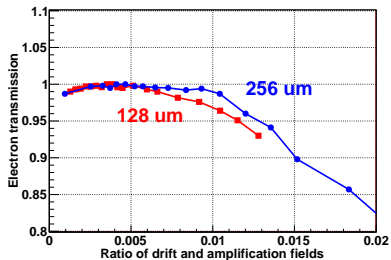
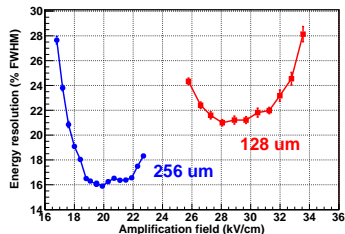
General references

- J. Billard, F. Mayet and D. Santos, Phys. Rev. D 82 (2010) 055011, arXiv:1006.3513.
- J. Billard, F. Mayet, J.F. Macias-Perez, D. Santos, Phys. Lett. B 691 (2010) 156-162, arXiv:0911.4086.
- J.P. Richer, *et al.*, NIMA 620 (2010) 470, arXiv:0912.0186.
- O. Bourrion *et al.*, NIMA 662 (2010) 207, arXiv:1006.1335.

MIMAC: a dark matter experiment

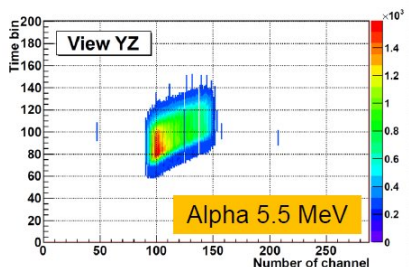
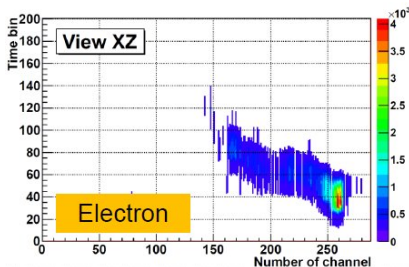
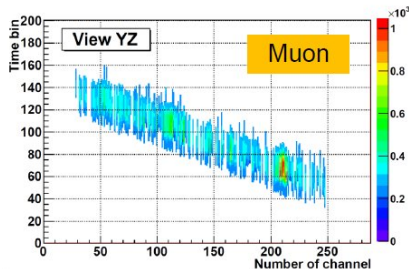
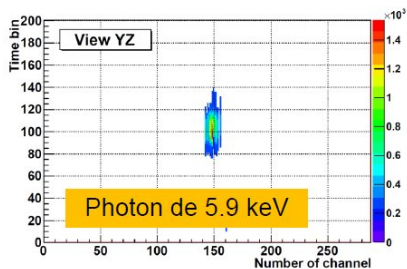
Characterization of the $10 \times 10 \text{ cm}^2$ readouts

- The two detectors of $256 \mu\text{m}$ gap thickness showed a better energy resolution than those of $128 \mu\text{m}$.
- A larger distance gap distance probably reduces the influence of strips and mesh uniformities in the amplification process.



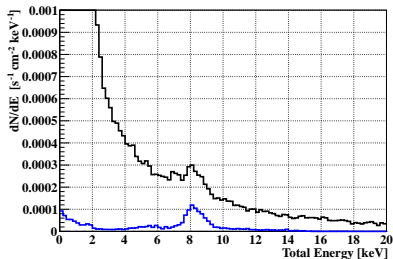
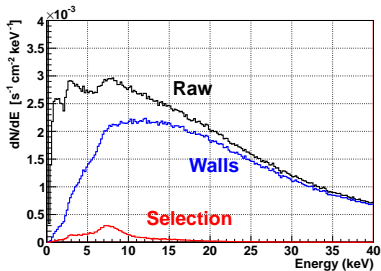
MIMAC: a dark matter experiment

Some examples of reconstructed events



MIMAC: a dark matter experiment

A comparison of MIMAC and CAST rejection factors



- The rejection factor of MIMAC detector (8.6) is clearly better than for CAST detector (3) in the same shielding conditions.
- The signal efficiency (respectively 78% and 87% at 3 and 6 keV) is a bit better than for CAST detector (respectively 68% and 78%).
- This results motivates the application of T2K electronics in CAST experiment and the study of neutron and gamma discrimination in Micromegas detectors.