The FIDIAS project: development of a Micromegas TPC for low energy heavy ions detection

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on behalf of

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Index

Full reconstruction of low energy heavy ions

Motivations: why a TPC?

- TPCs are widely used in high energy physics
  - Good tracking capabilities (3D reconstruction)
  - Precise momentum measurements
  - High multiplicty events
  - Good energy resolution
  - Large surface coverage (high detection efficiency)
  - Low material budget (radiation hardness)
- Rarely used in low energy physics (heavy ions)
  - Active target technique (inverse kinematic reactions)
  - High detection efficiency and full angular coverage (low cross section reactions)
  - Very compact setup and easy coupling with other detectors

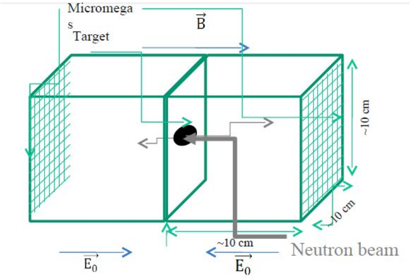
Full reconstruction of low energy heavy ions

Physics cases for a TPC

- Nuclear fission characterization.
  - Measurement of fission fragments mass, charge and TKE.
  - Neutron induced fission (thermal, resonance and fast regions).
  - Gamma induced fission.
- α-capture reactions relevant to stellar nucleosynthesis.
  - Study of p-process puzzle.
  - Few data available on reaction cross sections.
  - Well established programm (ex. ^{78}Kr (α, γ) ^{82}Sr at GANIL-Lise III).
  - Measurement of $(\alpha$,p),(α,γ), $(\alpha$,n) and their inverse.
- Measurement of the stopping force (STF) of heavy and super-heavy elements.
  - Relevant topic for nuclear physics and radiochemistry.
  - Development of physical pre-separation between target and collection chamber.
  - Interest in validating and improving STF calculation methods.

Full reconstruction of low energy heavy ions

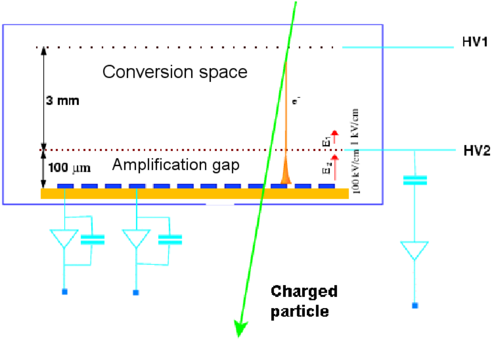
FIDIAS: FIssion Detector at the Interface with AStrophysics



- TPC: full angular coverage, portability and radiation hardness.
- Micromegas: high space resolution, high rate, low material budget.
- Use of FEE developped at IRFU (applied in T2K, MIMAC, CAST. . .).
- Use of Helium gas as the most suitable for both physics cases.
- Status: Tests of prototypes and simulation

Full reconstruction of low energy heavy ions

Micromegas: A Micro-Pattern Gas Chamber detector



I. Giomataris (1992)

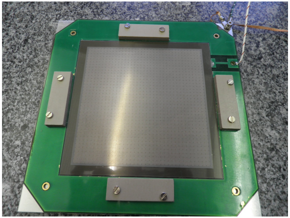
A thin metallic grid and an anode plane, separated by insulated pillars. They define a very little amplification gap (20-300μm).

- Good properties: High granularity, good energy and time resolution, stable, easy construction, little mass and radiopure.
- The two actual technologies (bulk and microbulk) have improved their features as the mesh and the anode plane are built in a single piece.

Full reconstruction of low energy heavy ions

The Micromegas bulk technology

T2K detector

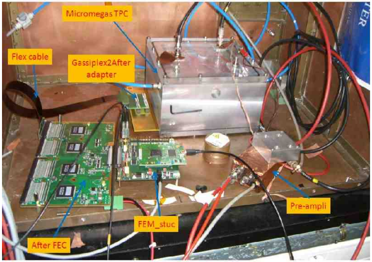


MIMAC 10x10 detector

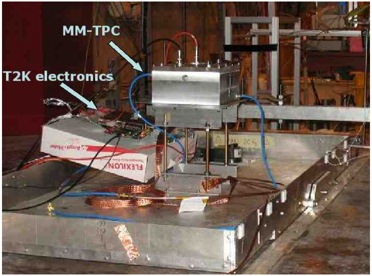
I. Giomataris et al., *Nucl. Instrum. Meth. A* 560 (2006) 405

- The pillars are attached to a woven mesh and to the readout plane. Typical mesh thickness 30μm. Gaps 128 or 256μm.
- Good properties: Uniformity, robustness, lower capacity, easy fabrication, small surrounding dead region, large area detectors and mass production.
- Limitations: Energy resolution (15% FWHM at 6 keV), more sensitive to pressure variations.

FIDIAS prototype
First prototype



Micromegas TPC prototype at Saclay

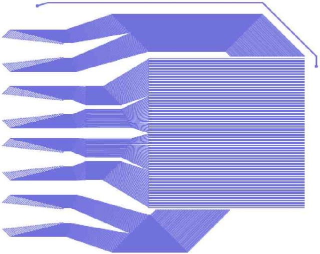


Micromegas TPC prototype at Goliath

- First prototype was a 1D Micromegas bulk (96 strips, 250 μm pitch).
- It was characterized with ^{55}Fe, ^{109}Cd and ^{252}Cf in Ar+10%iC_4H_{10}.
- It was also tested at the Goliath magnet of ^{4}H beam line.

FIDIAS prototype

Setup description: A new 2D Micromegas detector



Micromegas board design

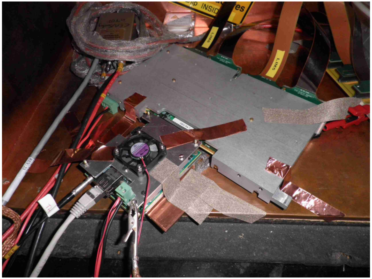
Drift cage

- The TPC consists in a field shaper cage and a Micromegas bulk readout.
- The drift field cage (by Demokritos) creates a uniform field for 8 cm.
- The chamber is equiped with all BNC connectors and gas inputs required.
- The detector is a 2D Micromegas bulk (2 x 144 strips, 128μm-thick gap, Enri connectors) designed at Saclay and built by Rui's lab at CERN.

FIDIAS prototype

T2K electronics

General setup view

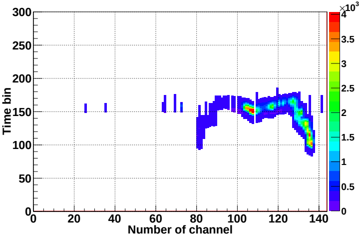


T2K electronics

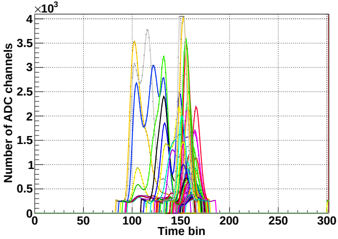
- The strip signals are extracted with 4 flat cables to a FEC card. They are then sent to a FEM card, which sends the data to the computer.
- An external trigger is generated with the mesh pulse, using the bipolar signal of the amplifier, a FAN IN/ OUT and a NIM-TTL converter.
- References: P. Baron *et al.*, *IEEE Nucl. Sci. Symp. Conf. Rec.* **55** (2008) 1744; D. Calvet *et al.*, *16th IEEE NPSS*, 2009, Beijing (China).

FIDIAS prototype

The event reconstruction with T2K electronics



XZ view of the event

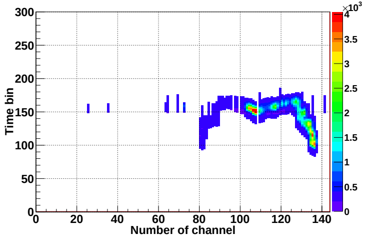


Pulses recorded in ASIC0

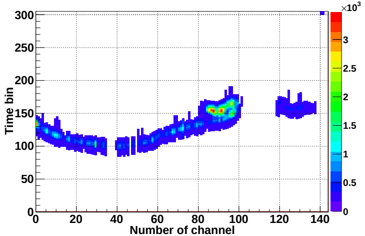
- The XY and YZ projections of each event are reconstructed with the pulse height in each time bin (20 ns). The shaping time (100 ns) works as an extra diffusion of the event.
- Low noise due to a much better grounding than in former tests.
- Different events observed: electron, muons, alphas and fission fragments.
- The example is an electron (note the final charge accumulation).

FIDIAS prototype

The event reconstruction



XZ view of the event

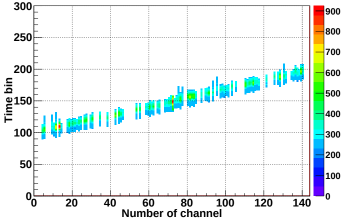


YZ view of the event

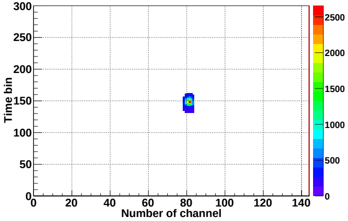
- The XY and YZ projections of each event are reconstructed with the pulse height in each time bin (20 ns). The shaping time (100 ns) works as an extra diffusion of the event.
- Low noise due to a better grounding than in former tests.
- Different events observed: electron, muons, alphas and fission fragments.
- The example is an electron (note the final charge accumulation).

FIDIAS prototype

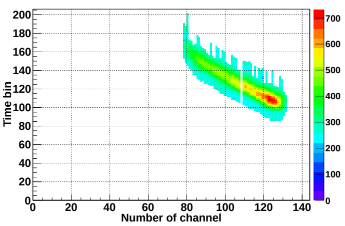
Different types of events observed



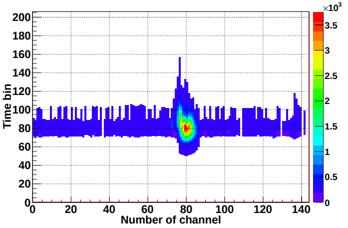
Muon crossing the chamber



6 keV x-ray



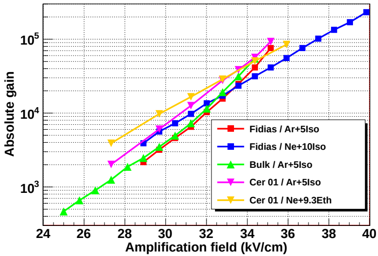
^{252}Cf alpha



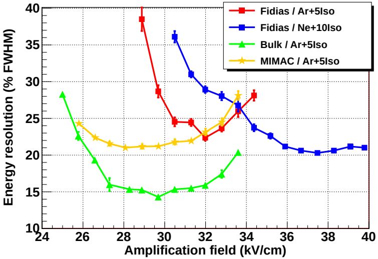
^{252}Cf fission fragment

Tests with Fidias prototype

Characterization with the ^{55}Fe source



Gain vs the amplification field

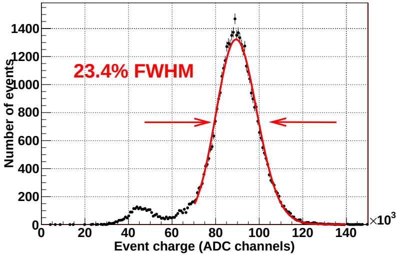


Energy resolution vs amplification field

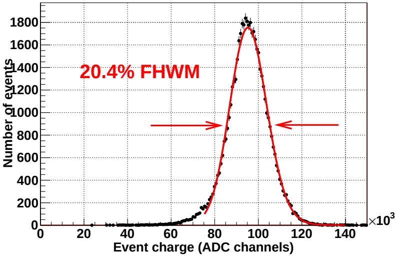
- The bulk detector was calibrated with a ^{55}Fe source to generate the gain curve, to study the energy resolution and the activate surface.
- The spectra were generated by the mesh pulses (Amplifier + MCA).
- Gains up to 7×10^4 and 2×10^5 and energy resolutions at 5.9 keV of 23.6 and 20.6% FWHM are respectively obtained in Ar+5%iC_4H_{10} and Ne+10%iC_4H_{10}. The gain curves follow the expected tendencies.

Tests with Fidias prototype

Characterization with the ^{55}Fe source



^{55}Fe spectrum in Ar+5%iC_4H_{10}

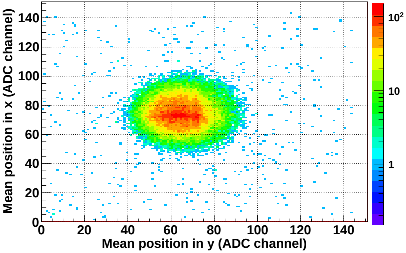


^{55}Fe spectrum in Ne+10%iC_4H_{10}

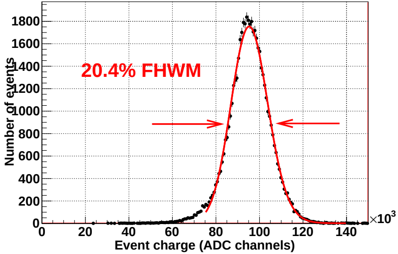
- The same spectra were then generated by the charge induced in the strips. The energy resolutions obtained (23.4 and 20.4% FWHM) are similar to those obtained with the mesh pulses (23.6 and 20.6% FWHM).
- No missing strip was observed by calibrations.

Tests with Fidias prototype

Characterization with the ^{55}Fe source



Mean position of x-rays events



^{55}Fe spectrum in Ne+10%iC_4H_{10}

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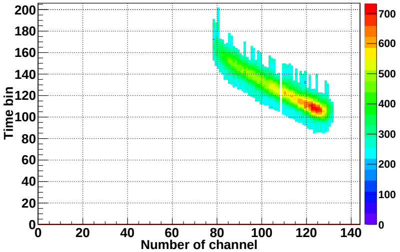
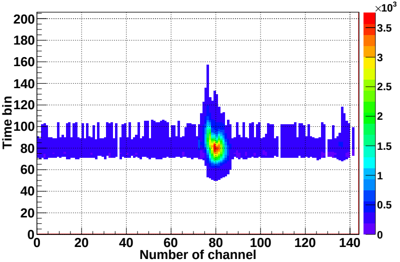
- No missing strip was observed by calibrations.

Tests with Fidias prototype

Characterization with the ^{252}Cf source



Alpha event of ^{252}Cf

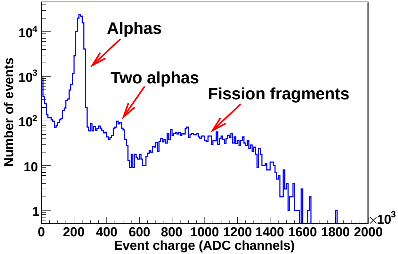


Fission fragment of ^{252}Cf

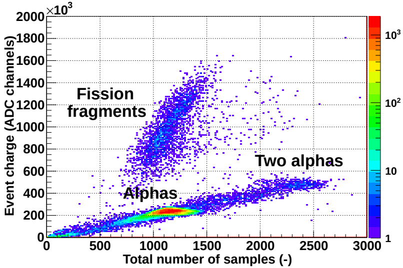
- The detector was characterized in Ar+5%iC_4H_{10} with ^{252}Cf (96.91% αs of 6 MeV and 3.09% fission fragments of $90 < A < 160$ and 1 MeV/A).
- Fission fragments can be distinguished from alphas by their shorter range.
- However, they saturate the electronics at a gain ≈ 16.
- To get a good discriminating parameter, the number of samples was calculated increasing the strip threshold from 250 to 350 ADC.

Tests with Fidias prototype

Characterization with the ^{252}Cf source



Energy spectrum of ^{252}Cf in Ar+5%iC_4H_{10} with T2K

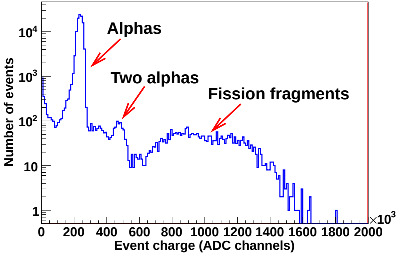


Charge vs number of samples activated

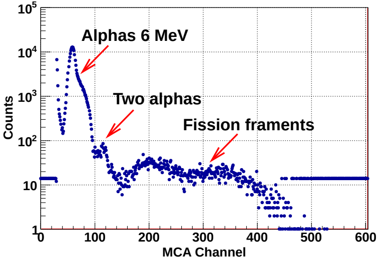
- Fission fragments are clearly separated from alphas when the dependence of the number of samples with the event charge is plotted.
- However, the energy spectrum of fission fragments could not be reproduced, possibly due to the saturation of the electronics.

Tests with Fidias prototype

Characterization with the ^{252}Cf source



Energy spectrum of ^{252}Cf in $Ar+5\%iC_4H_{10}$ with T2K



Energy spectrum of ^{252}Cf in $Ar+5\%iC_4H_{10}$ with MCA

- Fission fragments are clearly separated from alphas when the dependence of the number of samples with the event charge is plotted.
- However, the energy spectrum of fission fragments could not be exactly reproduced, possibly due to the electronics' saturation.

Conclusions

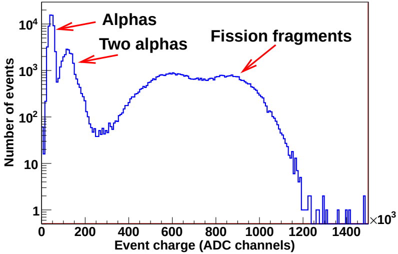
Summary

- A 2D Micromegas bulk detector has been built as a prototype for low energy heavy ions detection. Applications: Fission, Astrophysics and Super-heavy Elements Chemistry.
- The detector has been characterized in argon and neon-isobutane mixtures, respectively showing a gain up to 7×10^4 and 2×10^5 and an energy resolution of 23.6 and 20.6% FWHM at 5.9 keV.
- The T2K electronics has been successfully used to reconstruct the topology of events and to discriminate fission fragments from alphas.

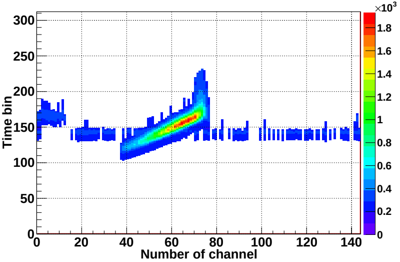
Outlook

- The detector will be again tested in argon-isobutane mixtures at low gain with the ^{252}Cf to avoid the electronics saturation.
- Tests in neon-isobutane were made last week at low gain conditions (no saturation) with a clear increase of FF range.
- Test in helium-isobutane mixtures are planned to increase even more the range and to make a isotopic separation of fragments.

Conclusions



Energy spectrum of ^{252}Cf in Ne+5%iC_4H_{10} with T2K



Fission fragment of ^{252}Cf in Ne+5%iC_4H_{10}

Outlook

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