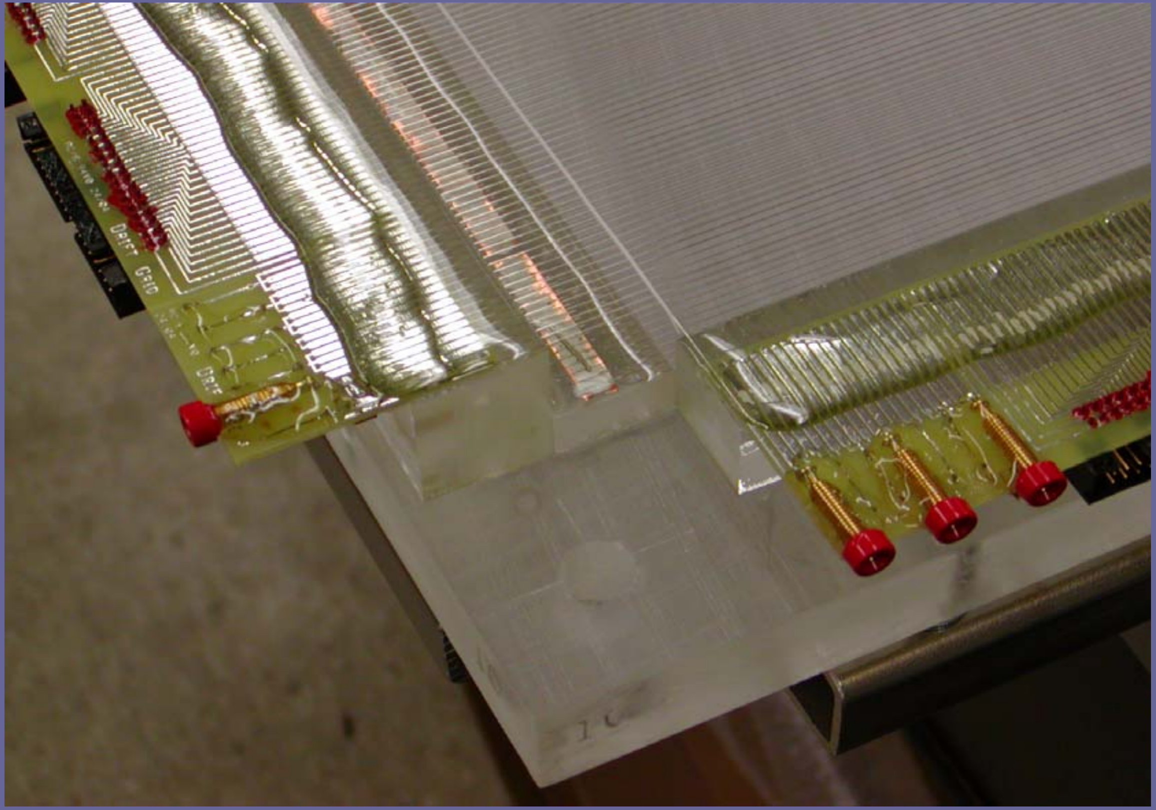
First operation of bulk micromegas in low pressure negative ion drift gas mixtures for dark matter searches

Why look for alternative readout options for DRIFT style detectors?

Maximum spatial resolution perpendicular to the MWPC anode wires is limited to the wire separation (2 mm for DRIFT IIa) which for mechanical and electrostatic reasons cannot be reduced below approximately 1mm.



Since WIMP range decreases with increasing target pressure, this places a restriction on the maximum pressure and target mass feasible without losing directional information.

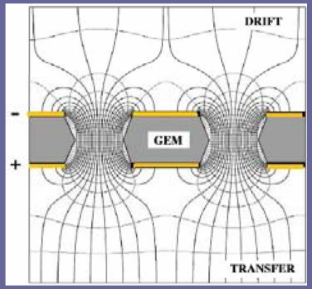
New readout technology with increased spatial resolution would allow improved sensitivity through the use of increased pressure and/or more accurate reconstruction of tracks. The latest evolution of charge readout devices – the Bulk Micromegas - may potentially provide this improvement in spatial resolution, and offers a more robust, adaptable, and lower cost alternative to MWPCs.

Charge readout devices

Micropattern charge amplification devices have evolved to become a possible replacement for MWPCs with improved spatial resolution, high radiopurity, flexible read-out configuration and high rate capability.

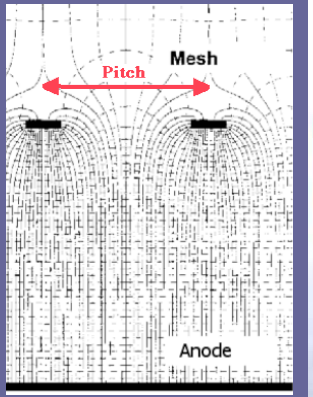
Gas Electron Multipliers

A 50µm kapton sheet with 5µm Cu layers on the top and bottom surfaces through which holes have been etched. Due to the presence of dielectric at the holes, GEMs are vulnerable to damage caused by breakdown limiting the maximum gain. GEMs can be stacked to increase the gain albeit at the cost of resolution and positional sensitivity.



Micromegas

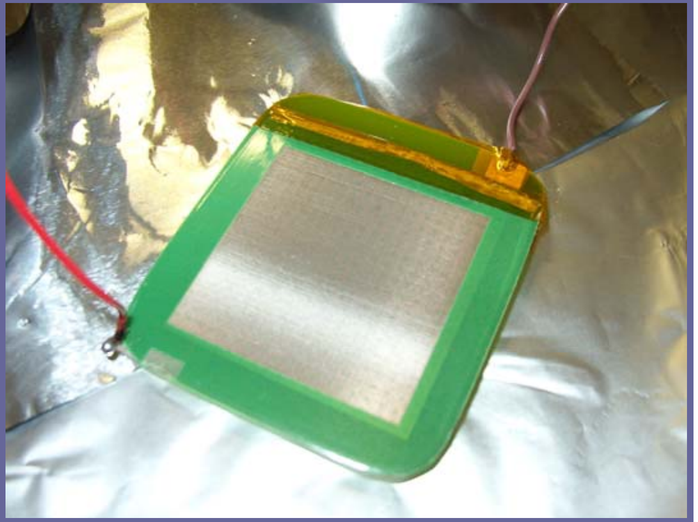
A thin perforated Cu foil or micromesh, typically 5µm thick with, for instance, 25µm diameter holes at a 50µm pitch, supported at a constant distance of 25-100µm below an anode plane by insulating kapton cylindrical pillars in a square matrix. Micromegas provides increased spatial resolution, higher gain and better robustness compared to GEMs.



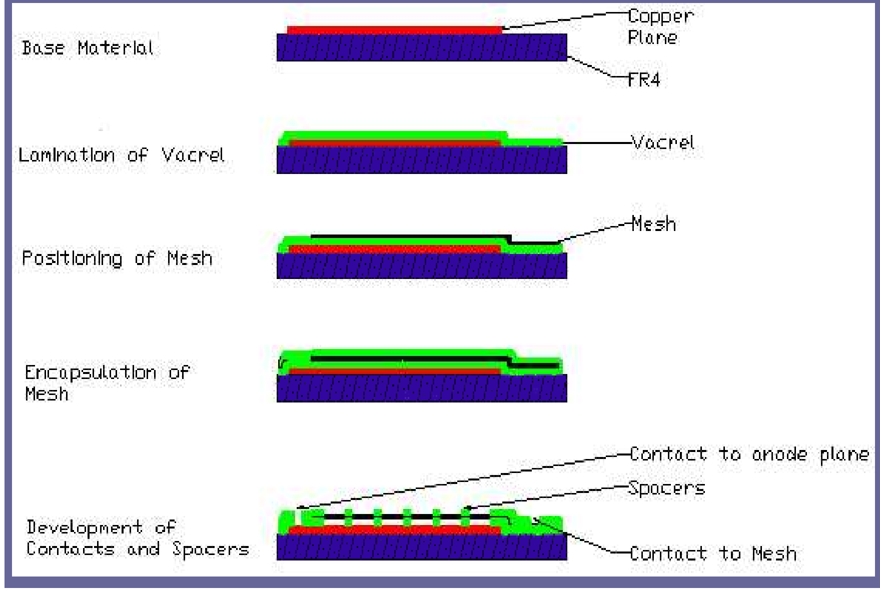
However the Cu foil is easily damaged and the method by which the anode is pressed into contact with the micromesh can result in a lack of parallelism. In addition typical detector applications require charge readout devices to cover a large area, be robust, reliable, cheap and simple to mass produce. For these reasons the second generation **bulk micromegas** was developed.

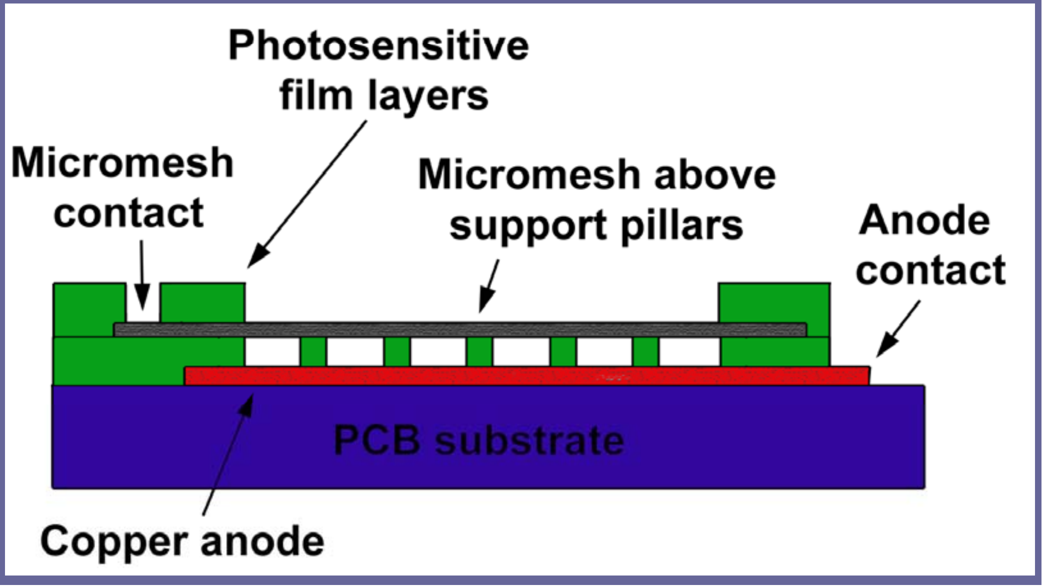
Bulk Micromegas

The method of fabrication is based on standard PCB technology and can be extended to very large area detectors manufactured by industry. A woven wire mesh is used instead of the standard electroformed micromesh foil. This significantly reduces the costs and processing time, and greatly increases the mechanical strength with regard to stretching and handling. The copper PCB anode, a photo-resistive film of appropriate thickness and the cloth mesh under tension are laminated together at high temperature prior to photolithographic etching of the film to produce cylindrical spacer pillars. A final layer of photo-resistive film is then applied to define an active volume and pacify the edges of the device.



Micromegas used in for all tests

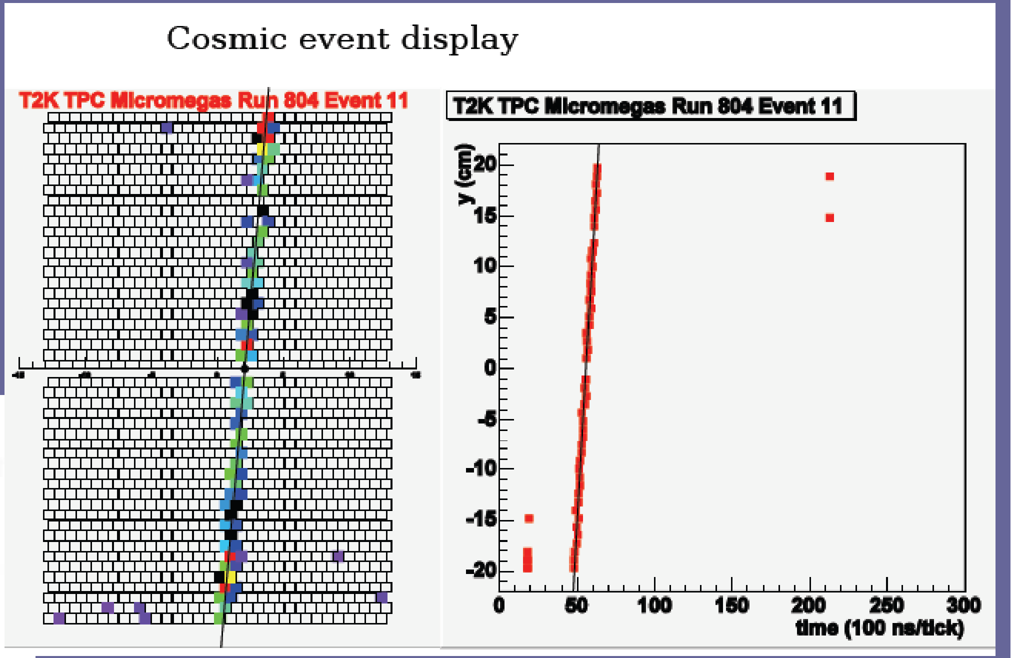


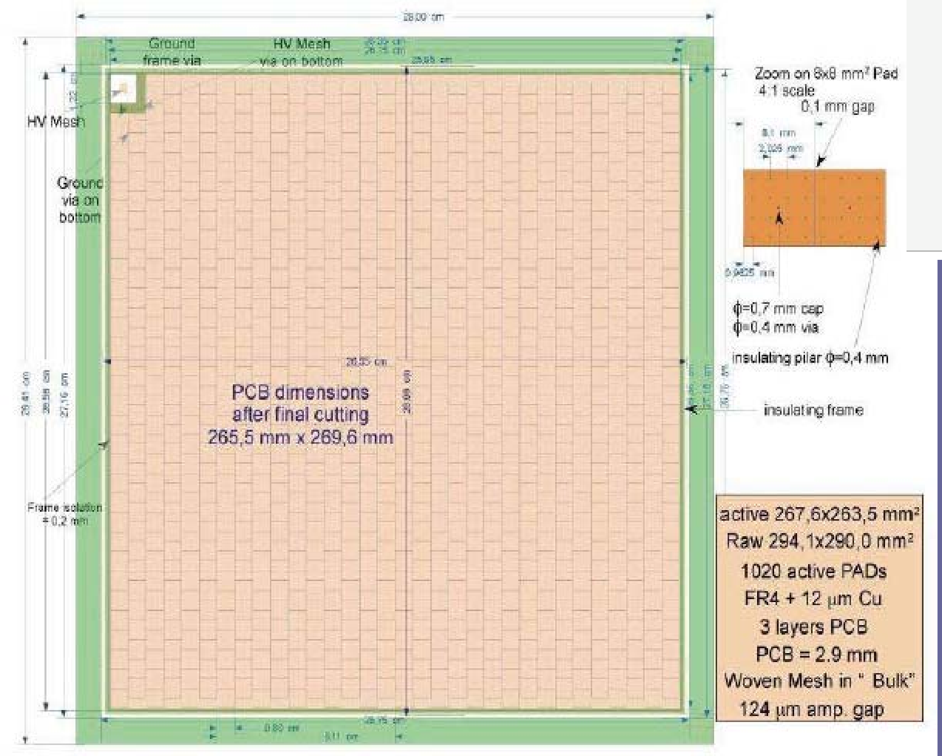


Bulk Micromegas in T2K

Micromegas are successfully used in a range of experiments such as COMPASS, NA48, CAST, in the CENBG neutron beam, and are currently under review for use in the future Linear Collider. Bulk micromegas will be used in HELLAZ and NOSTOS, and has been selected as the readout for the TPCs in the ND280 of T2K.

300x600mm bulk micromegas have already been produced, and 267 x 263mm bulk micromegas with 1020 pad readout has been successfully operated at Saclay.


Cosmic event display



Slides taken from:-
Large Bulk Micromegas detectors for TPC applications
F.Pierre CEA/Saclay DAPNIA
IPRD'06 Siena

(http://www.bo.infn.it/sminiato/sm06/paper/061002p/pierre.pdf)

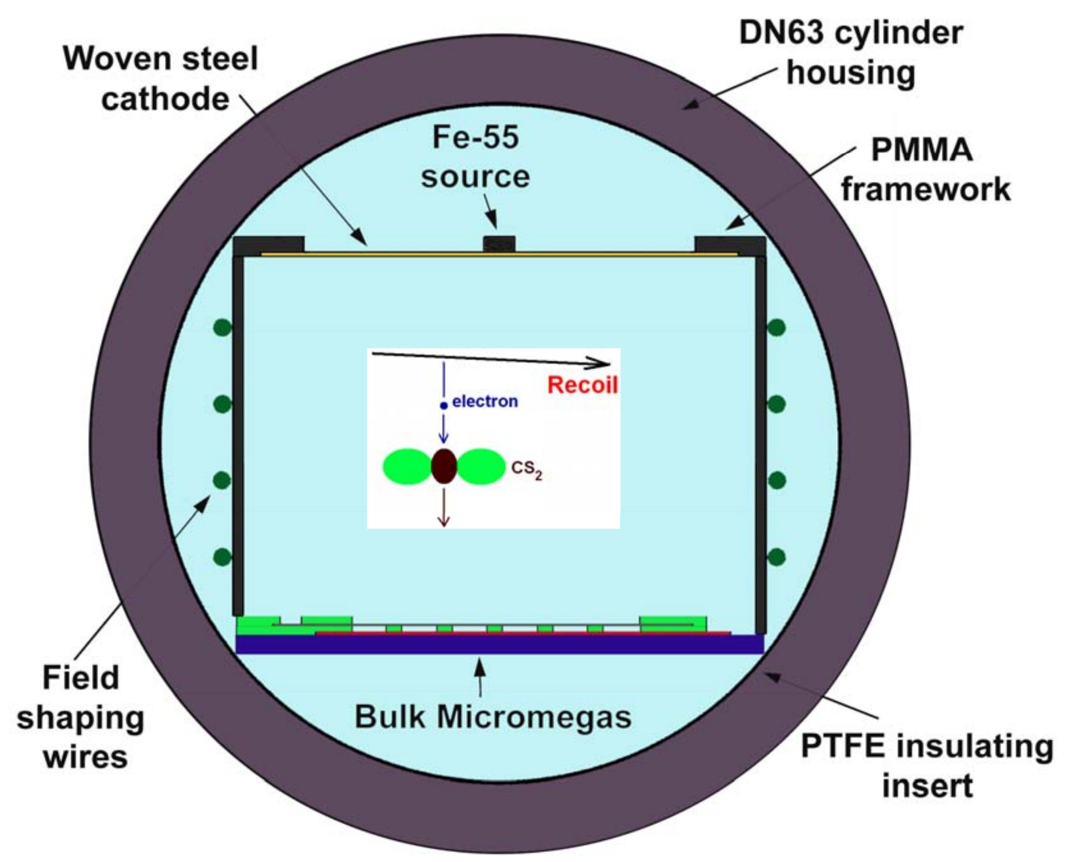
First operation of bulk micromegas in low pressure CS_2

Experimental details

Tests were performed using a bulk micromegas with active area of 36 × 36 mm, made from stainless steel cloth of 19µm diameter wire interwoven in an orthogonal mesh at a 500d.p.i. pitch separated from a Cu anode by 75µm high, 400µm diameter insulating pillars in a 2mm square matrix.

The mesh was grounded and the amplification field was controlled at the anode using a Bertan 1755P high voltage supply with an 8µA trip.

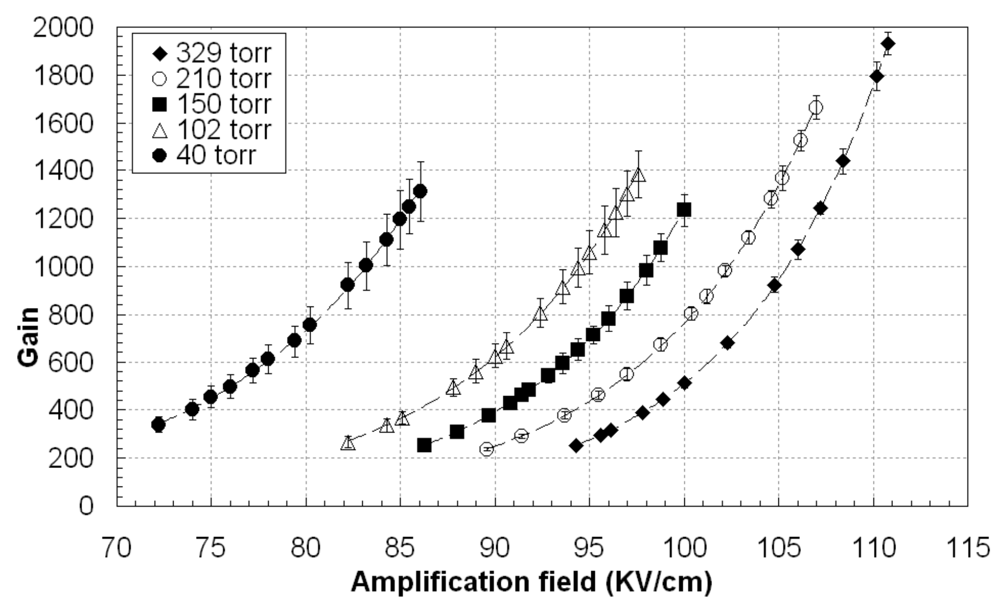
The signal, read from the anode, was decoupled from the high voltage line through a 247pF capacitor and passed through an Amptek A250 preamplifier, an Ortec 570 shaping amplifier, to a Lecroy 9350A digital oscilloscope linked via GPIB cable to a DAQ computer.



In all tests calibration was performed using an Fe-55 source. For each pressure, the amplification field was increased for a constant drift field until sparking occurred, defined here as one breakdown taking place every 10 seconds and of intensity 8µA or more.

First operation of bulk micromegas in low pressure CS_2

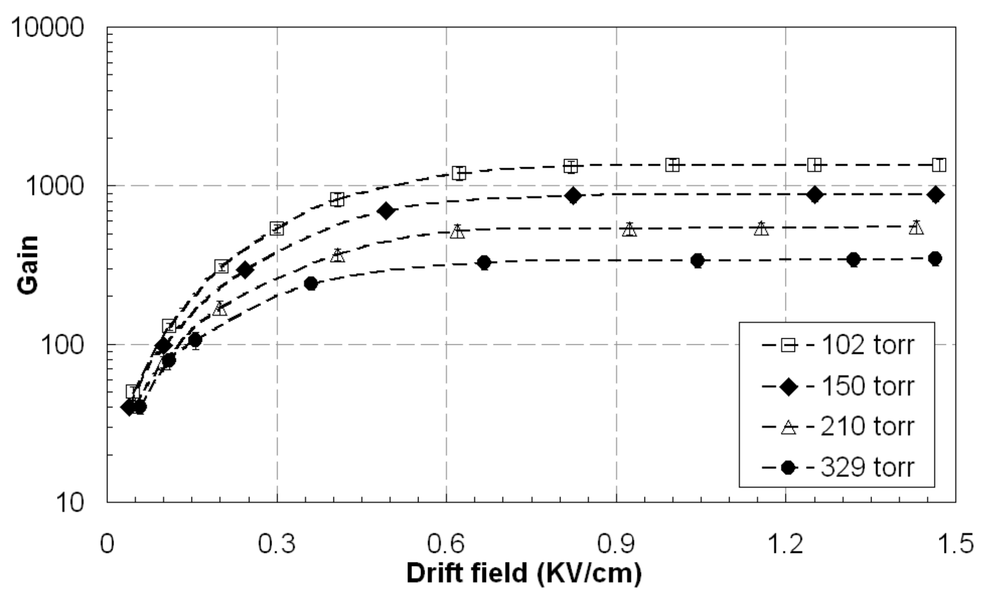
Gain in pure CS_2 at fixed 1KV/cm drift field



A maximum gain of 1300 ± 120 was measured in 40 torr vapour with an energy resolution of 22%. Although this is similar to the gain from the MWPC, optimisation of the mesh pitch, hole size, and pillar height will improve this figure.

NB. Pad or strip readout at the anode could allow higher pressures to be used with associated improvements in gain.

Gain in pure CS_2 at fixed 97KV/cm amplification field

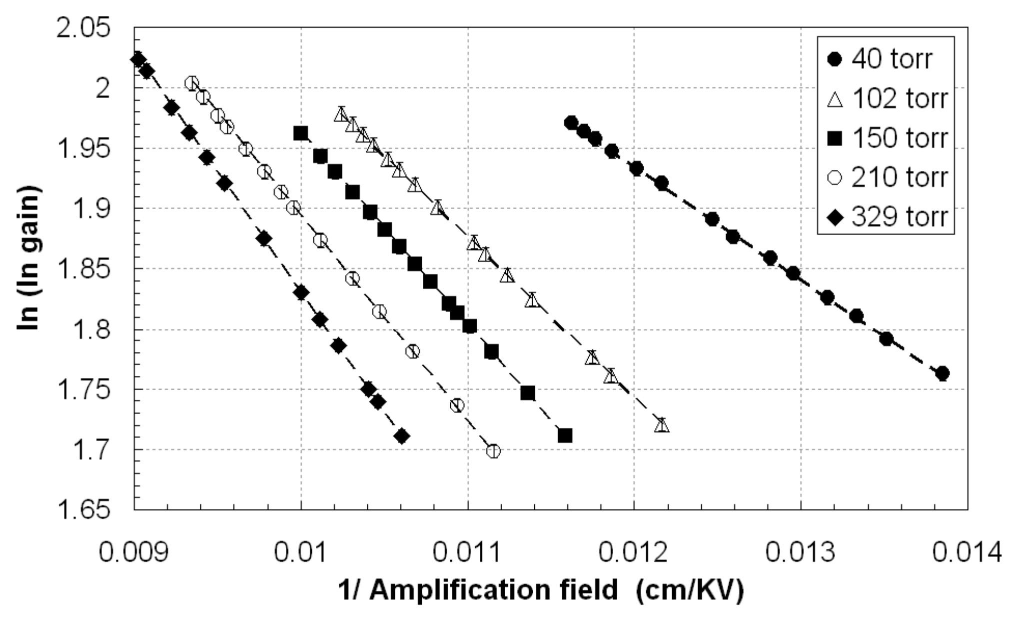


For a constant amplification field, increasing the drift field provides a measure of the field intensity required to ensure maximum charge collection at the anode.

Increasing the strength of the drift field resulted in improved gain and energy resolution, although above 1KV/cm the effect significantly reduced.

First operation of bulk micromegas in low pressure CS_2

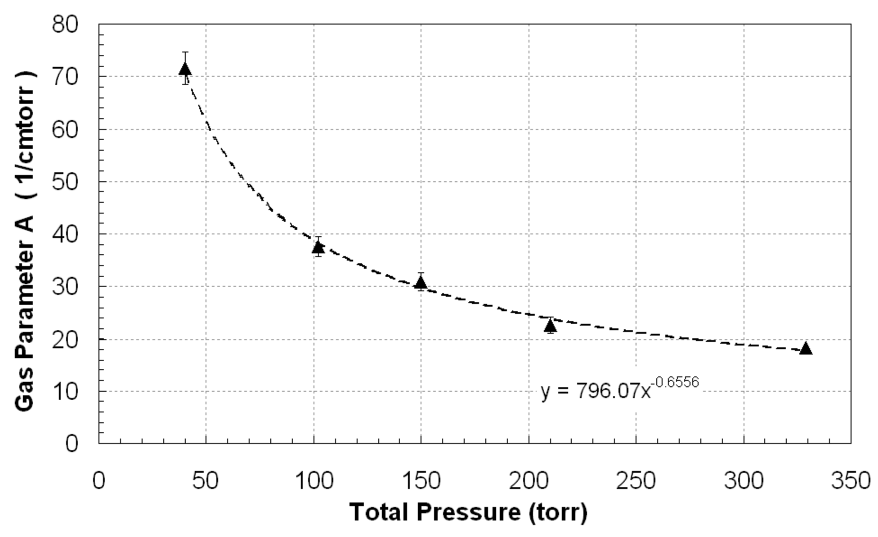
Characterisation of performance via measurement of A and B gas parameters

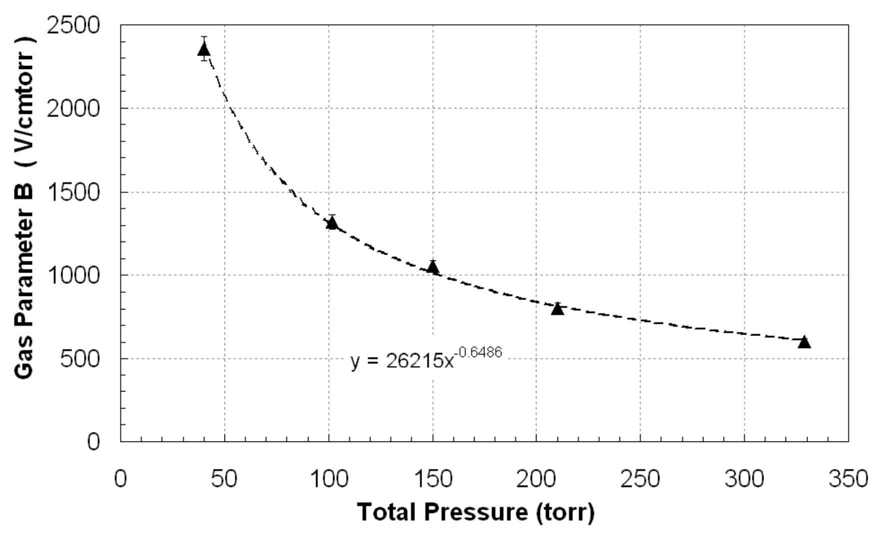


The electron multiplication process in bulk micromegas can be described by a combination of the Townsend coefficient and the Rose Korff formula such that:

$$\ln(\ln(\mathrm{Gain})) = \ln(A\,P\,d) - (B\,P / E)$$

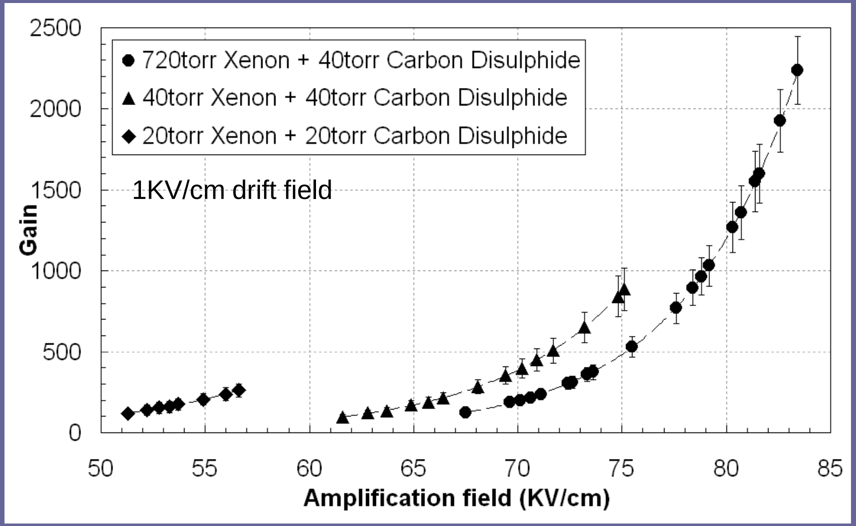
where A and B are gas parameters, P is the pressure, d is the separation, and E is the amplification field between the plates. Plotting the double log against the reciprocal of the amplification field allows A and B for each pressure to be deduced graphically.





First operation of bulk micromegas in CS_2 : xenon blends

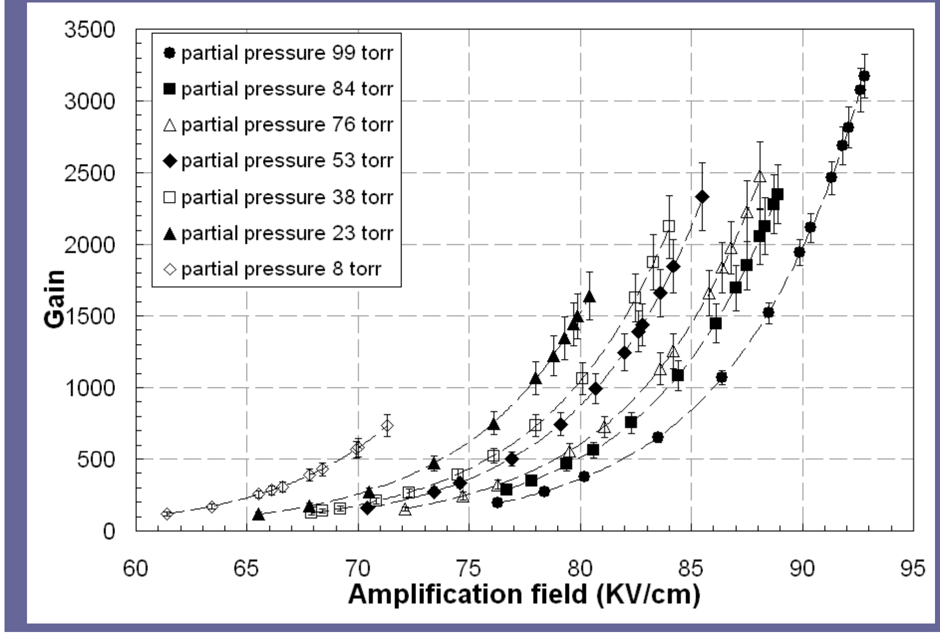
Xe and CS_2 at varied partial and total pressures

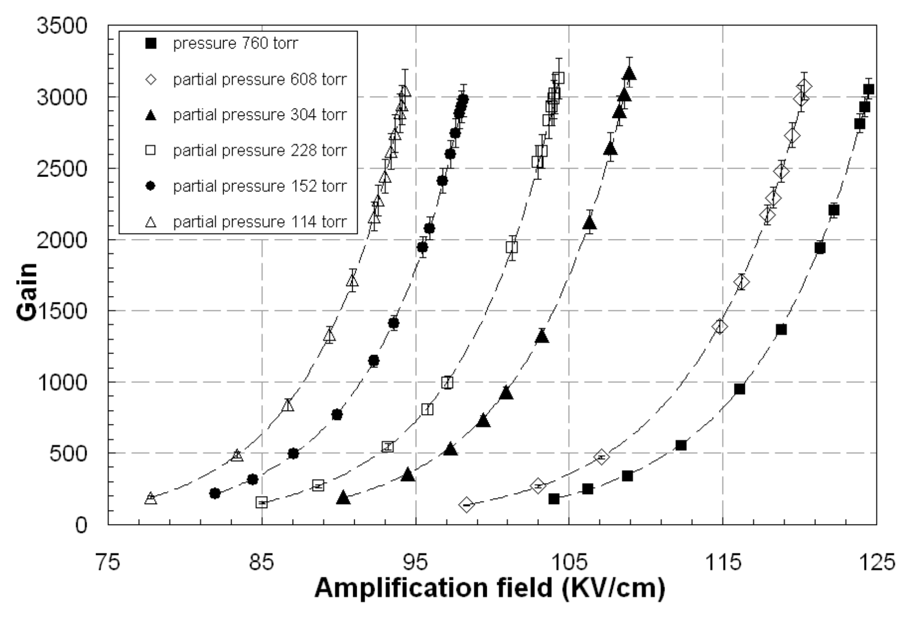


The low atomic mass of CS_2 limits both the target mass and sensitivity. Incorporation of a significant content of a second, heavy atomic mass, gas nuclei that is better kinematically matched to the favoured range of WIMP masses yet does not disturb the negative ion operation would be beneficial.

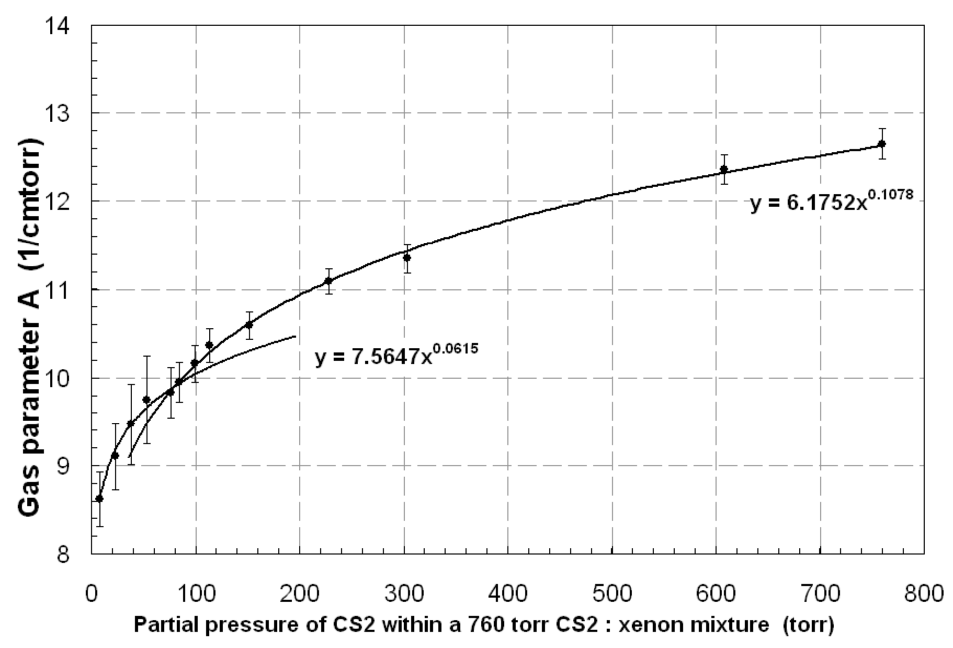
The high density, purity and atomic number of xenon (A=131) make this gas a natural choice for a WIMP scattering target with enhanced sensitivity to spin-independent cross-sections.

At constant total pressure of 760 torr, the partial pressure of CS_2 in the Xe:CS_2 blend is varied





First operation of bulk micromegas in CS_2 : xenon blends



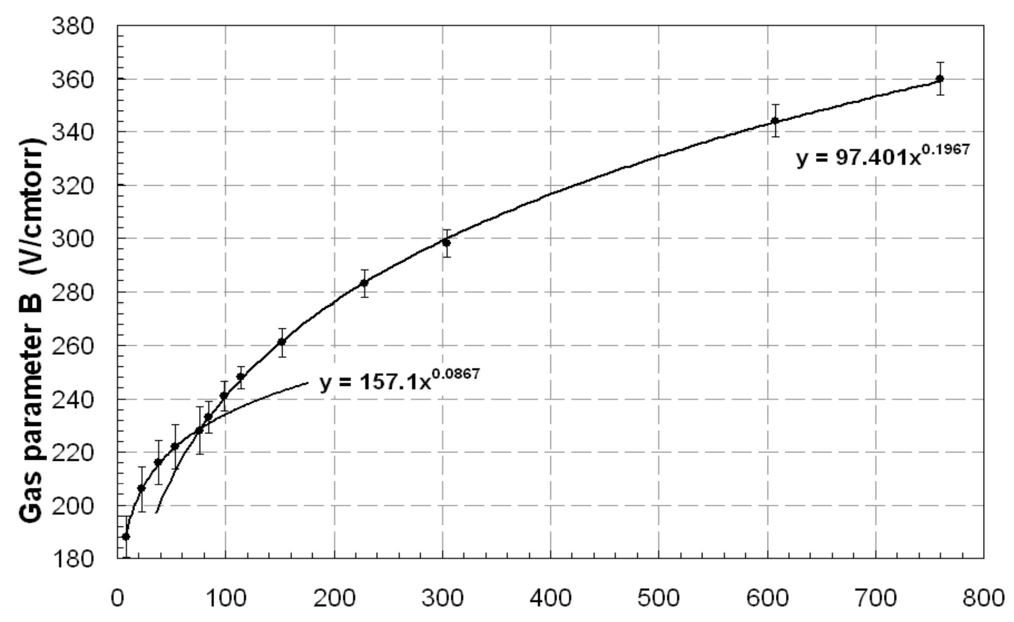
Use of gas parameters to identify transition from electron drift to negative ion drift

Key benefit of NID: Free electrons produced in the drift volume are quickly attached to CS_2 gas molecules to form negative ions that are drifted towards the MWPCs, undergoing significantly less diffusion, and achieving higher spatial resolution, due to the mass matching of the drifting ions with the gas molecules, than would occur in the case of free drifting electrons.

As before, the A and B gas parameters for the CS_2 : xenon blends were determined graphically using the Townsend coefficient and the Rose Korff formula.

Plotting A and B against partial pressure of CS_2 reveals a deviation at 80 torr CS_2 : 680 torr xenon, suggested to be the point at which electron drift is superseded by negative ion drift within the test chamber.

At 760 torr total pressure, this imposes a limit on the proportion of xenon within the blend.



Conclusions

- Successful and stable operation of a bulk micromegas micro-pattern charge readout device has been demonstrated in pure CS_2 vapour and xenon : CS_2 blends for the first time over a range of pressures, achieving high gain and good energy resolution. This is a key step opening prospects for use of bulk micromegas readout for large volume negative ion TPCs without magnets, such as proposed for directional dark matter detectors and other rare event applications.

- The fundamental benefit envisaged following replacement of the MWPCs in favour of bulk micromegas is an increase in the spatial resolution of the sense plane technology over large areas (>1m^2). For dark matter TPCs this would mean higher pressures and therefore greater target masses per module.

- Improved spatial resolution can only be achieved following development and assessment of a suitable segmented readout plane. A multi-strip anode readout plane will be constructed in readiness for processing into a bulk micromegas for this purpose and for evaluation of its performance compared with the multi-wire systems that it may replace. This will be the subject of a future report.