Development of a ^{3}He based microstrip gas chamber (MSGC) with a novel 2D readout

The individual cathode charge division readout
SINE2020 WP9.3

J.C. Buffet, J.F. Clergeau, S. Cuccaro, B. Guerard, J. Pentenero, and D. Roulier

ILL

May, 16th 2018

SINE2020 WP 9.3

Needs

- 2D detector for reflectometry
- 1 mm$\times$1 mm resolution
- high counting rate

Microstrips

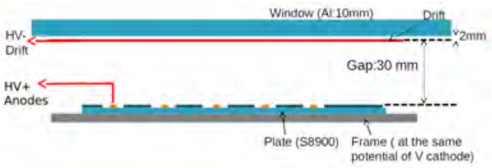
- Capable of high counting rate

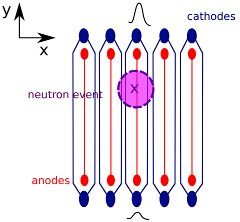
  10 kHz/"pixel" expected
- short anode-anode and anode-cathode distance ($\neq$ MWPC)
- parallel reading

  charge division along the strips (Y)
- Novelty : reading of cathodes

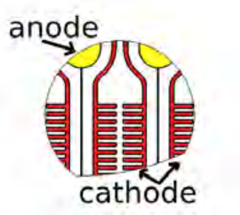
  tunable resistance for charge division, shorter RC

MSGC64 prototype

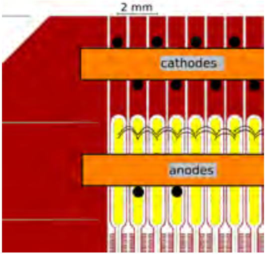


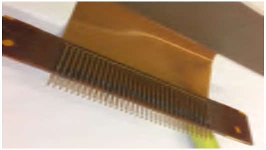


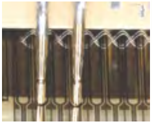
- 64 anodes and cathodes 1 mm periodicity in X
  64 mm$\times$64 mm detection area
- comb design on cathodes
- Charge division on cathodes $R = 1.25\ \mathrm{k}\Omega$
- Schott S8900 substrate
- plates made by IMT (Greifensee, CH)



Connectics







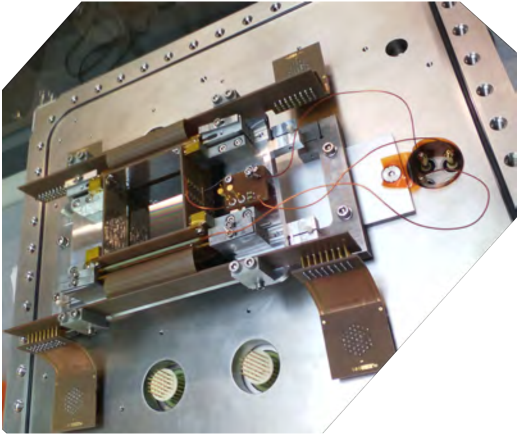
Cathodes

- 0.8 mm pads
- flexible PCB with spring probes (Ø0.53 mm)
- every 2 mm on each side of the connector $\rightarrow$ every 1 mm on the MSGC.

Anodes

- 0.5 mm pads, 150 μm away from cathode strips $\rightarrow$ different connectics needed
- wedge bonding Ø33 μm diameter Al wire
- 4 spring probes to supply HV
- tested @PTA Minatec (Grenoble), performed @STFC Interconnect

Setup



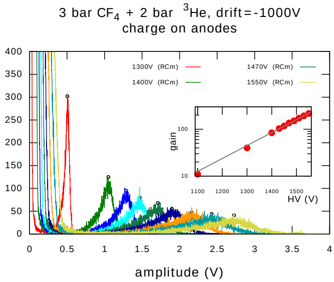
- up to 5 bar pressure vessel
- possibility to mount a larger plate ($\sim$ 200 mm$\times$200 mm)
- (2×4) 37 pins HV feedthroughs
- drift electrode on the entrance window

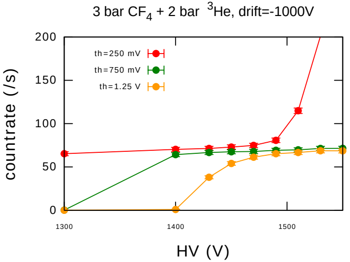
Setup

- 3 bar CF_4 (up to 1 mm resolution), 2 bar ^3He
- Drift from -1000 V to -1600 V
- cathodes to ground, individual readout
- charge division amplifiers $\sim$ 2 V/pC, 1 μs

  CAEN V1740 electronics with ILL DPP Firmware and readout software, under implementation on all the ILL instruments equiped with Position Sensitive Proportional Counter Tubes.

- HV $+1300$ V$\rightarrow$ $+1550$ V on anodes (gain 40-200), global readout (amplifier $\sim$ 3 V/pC, 0.8 μs)

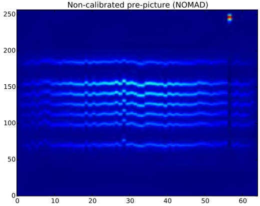




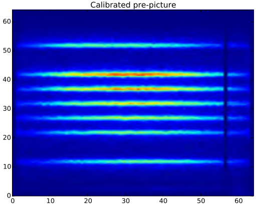
Charge Division Calibration

Individual channel calibration with a mask

- Piecewise linear function between slit positions
- Compensation of the resistance differences of the strips
- Compensation of bad probes contacts
- Compensation of gain differences of individual amplifiers



⇒



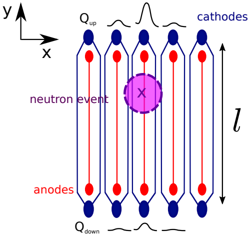
Data treatment

Microstrip $\neq$ Tubes (multiplicity!) $\Rightarrow$ Processing data off-line

($\Rightarrow$ possibility to compare differents algorithms with the same data set)

A clustered event is defined as a group of simultaneous active contiguous channels

- X (perpendicular to the strips): CoG with the total charge on each strip $\rightarrow$ Left-Right overbinning
- Y (parallel to the strips): the charge division algorithm is applied to Q_{up} and Q_{down}

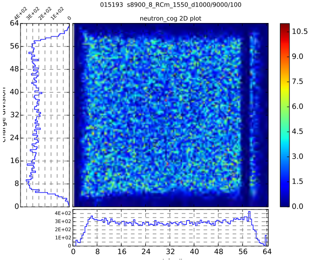


$$y = l \frac{Q_{up}}{Q_{up} + Q_{down}}$$

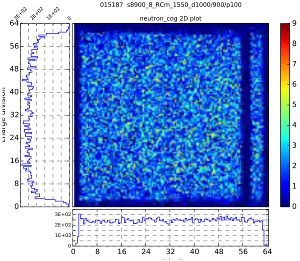
Uniformity

With AmBe source

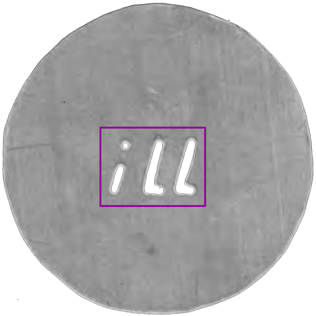
No drift compensation

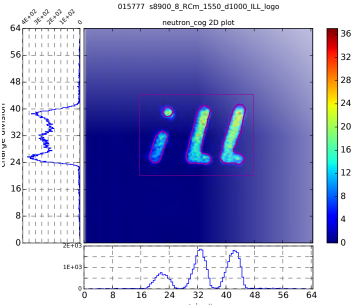


With drift compensation



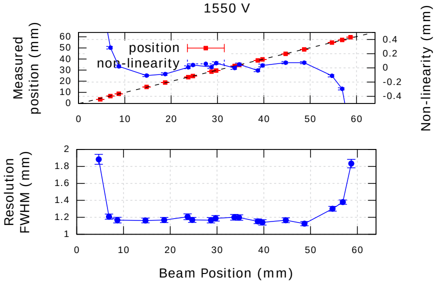
Measurements with neutron beam

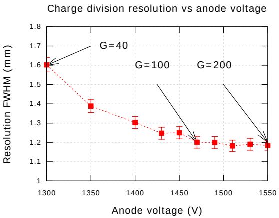




Resolution with charge division

Scanning the Y direction with a horizontally collimated beam (0.5 mm slit)

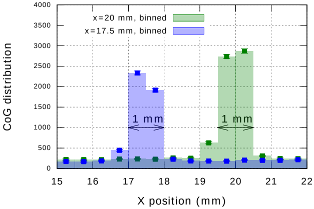


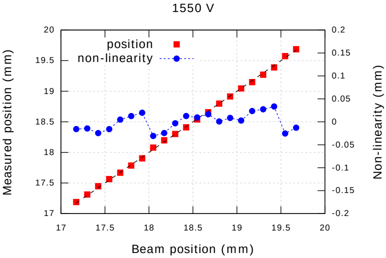


- Non-linearity $\pm 100\ \mu$m
- Resolution better than 1.2 mm in the inner area of the detector
- Resolution still good at lower gain (1.6 mm at gain ~ 40)

Resolution with CoG

Scanning the X direction every 0.125 mm with a vertically collimated beam

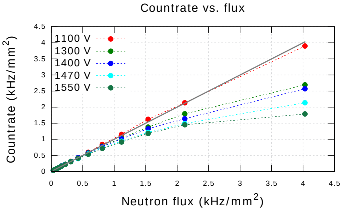


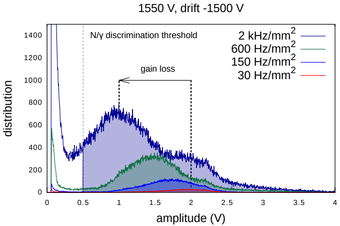


- 0.5 mm re-binning
- Non-linearity $\pm 30\ \mu$m
- 1 mm resolution ($\geq$ 76% of events in 2 bins $\Leftrightarrow$ FWHM)

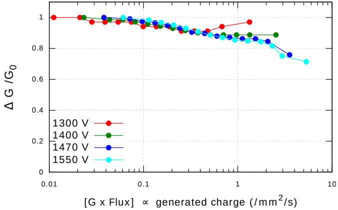
Countrate capability

Irradiation on a 10×20 mm^2 B_4C hole on the detector window, w/o several layers of attenuator (plexiglas)





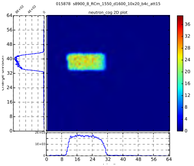
- early countrate loss at gain > 40
- collected charge is reduced at high flux
- space-charge effect
- happens instantly (< 1 s)



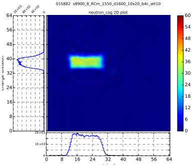
Geometrical effects

1550 V, drift −1500 V

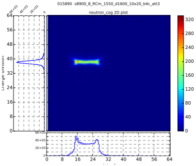
30 Hz/mm^2



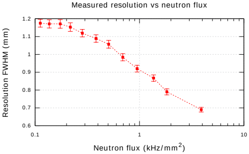
150 Hz/mm^2



1.5 kHz/mm^2



- At high flux, charges concentrated in the middle of the slit (orientation-independant)
- Appears at low flux
- Falsifies resolution measurements



Conclusion and prospects

- Good resolution results (up to 1 mm$\times$1.2 mm) : charge division on cathode works!
- Unexpected countrate issue at high gain : strong space charge effect (substrate or gas ?)
  $\Rightarrow$ To be determined
- Plans to make a larger plate (200 mm$\times$200 mm) with 128 strips are on hold

Thank you

Expected anodes and cathodes resistances

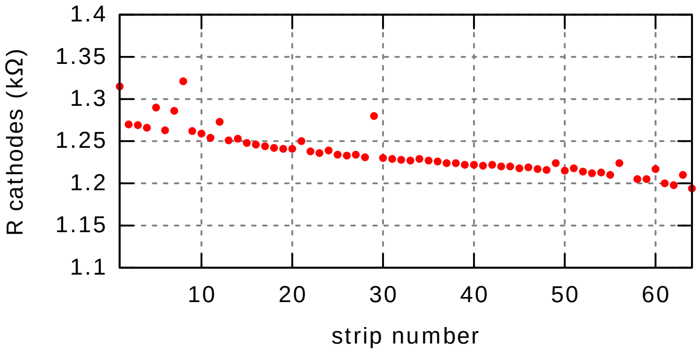
- length $l = 7.65$ cm
- thickness $t = 200$ nm
- anodes width $w_a = 10\ \mu$m
- cathodes width $w_c = 50\ \mu$m
- $R_s = 2.6\ \Omega/\square$

Anodes

$R_a = R_s \frac{l}{w_a} = 20\ \mathrm{k}\Omega$

Cathodes (approx. no comb pattern)

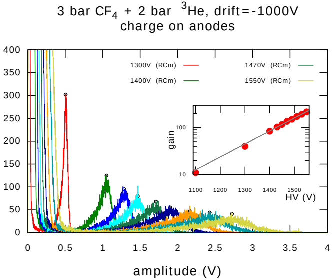
$R_c // R_c = \frac{1}{2} R_s \frac{l}{w_c} = 2\ \mathrm{k}\Omega$

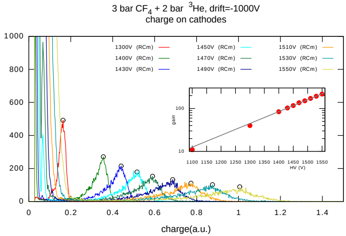


Electronics for charge division

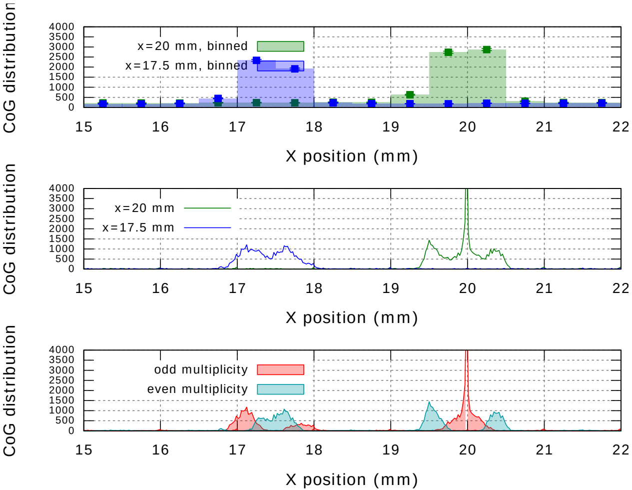
- CAEN V1740 digitizer boards (64 channels=32 tubes/strips) with ILL DPP Firmware and readout software
- amplifiers with 4^{th} order Gaussian filter function, baseline correction circuit
- under implementation on all the ILL instruments equiped with Position Sensitive Proportional Counter Tubes.

- input is 12 bits unsigned data, the output is 16 bits unsigned data.
- real-time : $s_n(t)=ch_{up}(t)+ch_{down}(t)$
- real-time : if $s_n(t)$>threshold, find max and save event (s_n, ch_{up} and 48 bit timestamp)


3 bar CF4 + 2 bar 3He, drift=-1000V
charge on anodes
1300V (RCm)
1400V (RCm)
1470V (RCm)
1550V (RCm)
gain
HV (V)
amplitude (V)


3 bar CF4 + 2 bar 3He, drift=-1000V
charge on cathodes
1300V (RCm)
1400V (RCm)
1430V (RCm)
1450V (RCm)
1470V (RCm)
1490V (RCm)
1510V (RCm)
1530V (RCm)
1550V (RCm)
charge(a.u.)

Resolution CoG

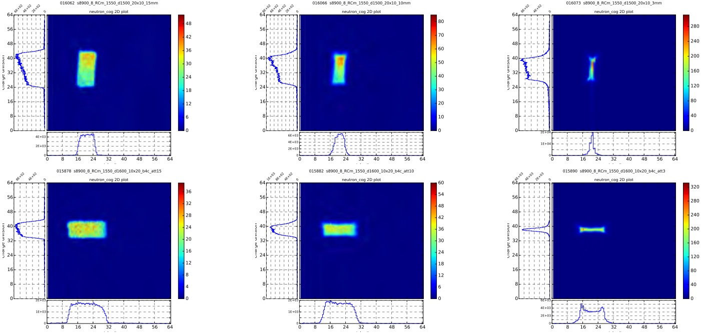


Non-gaussian distribution, with peaks depending on the multiplicity of events (odd/even)

Geometrical effects

1550 V, drift −1500 V

30 Hz/mm^2	150 Hz/mm^2	1.5 kHz/mm^2



Geometrical effects

- At high flux, charges concentrated in the middle of the slit.
- Appears at low flux
- Huge effect
- Falsifies resolution measurements