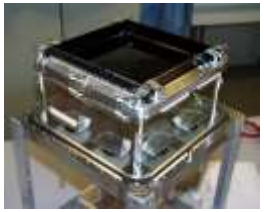
The MSGC Task in WP9 (Damien Roulier & Bruno Guérard)

Goal: 2D, high resolution (<=1 mm), high counting rate (> MWPC), sensitive area → 200 mm x 200 mm (reflectometers)

Solution studied: MSGC / Charge Division along the strips (called MSGC-CD)

MWPC counting rate limit:1 MHz global (coinc), 50 kHz/ channel (pile-up); 1 kHz/mm2 local (space charge)
Limitation for reflectometry = space charge + pile-up (the last one can be reduced by tilting the wires by 45° / beam slit)

MSGC-CD: Readout strips perpendicular to the neutron slit to be imaged → NO pile-up
Remaining limitation = space charge → MSGCs are better than MWPCs (in theory)

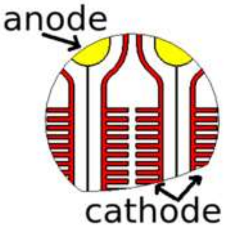


Previous studies (before SINE2020)

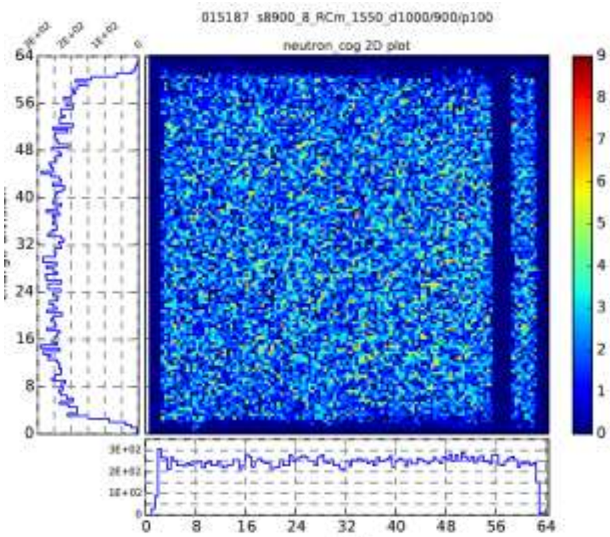
1/ Charge division along anodes + virtual cathode (cathode are on the rear side) at a pitch of 3 mm
Connectics provided by spring contact probes
2 problems: substrate charging up + Anode electrical resistance is too high (30 kOhm / 20 cm for Chromium strips) → Requires long shaping time amplifiers (goes against counting rate capability)

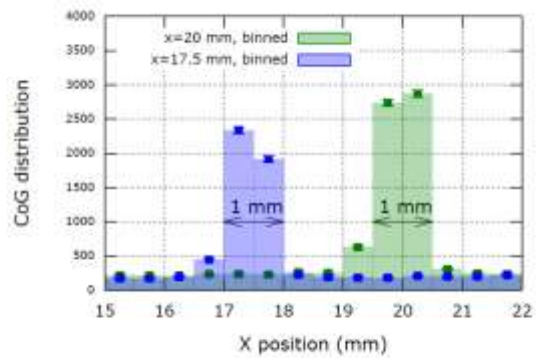
2/ Charge division along anodes coated with Aluminium + standard cathodes at a pitch of 3 mm
Aluminium deteriorates rapidely with CF4. It should work with Ar-CO2, but it was prefered to develop a solution without Aluminium coating to reduce the constraints of MSGC fabrication

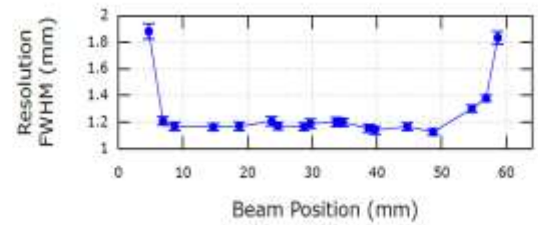
SINE2020
Charge division along Chromium cathodes at a pitch of 1 mm
Challenges: wire bonding of the anodes, fine pitch cathode connector
Difficulties : MSGC production quality, Image deformation due to Ion Backflow, space charge effect



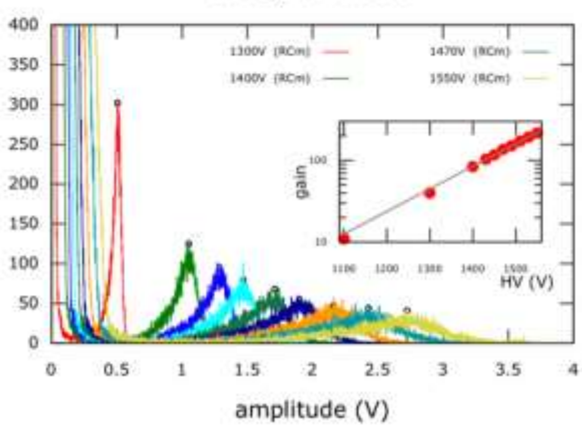
Results presented at the last meeting

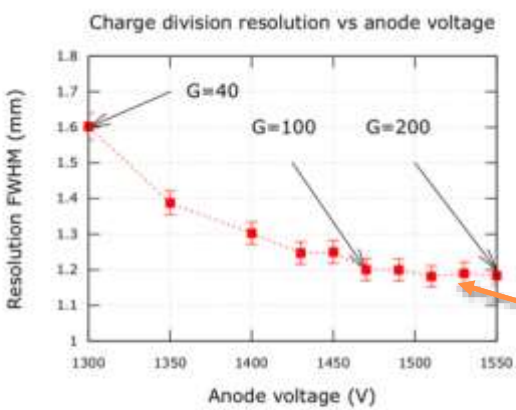






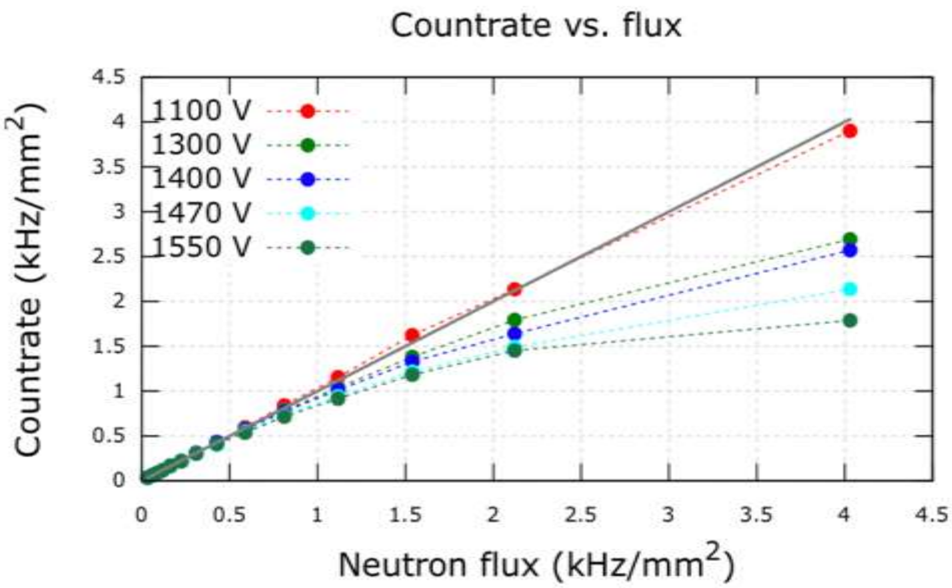
3 bar CF_4 + 2 bar ^{3}He, drift=-1000V
charge on anodes

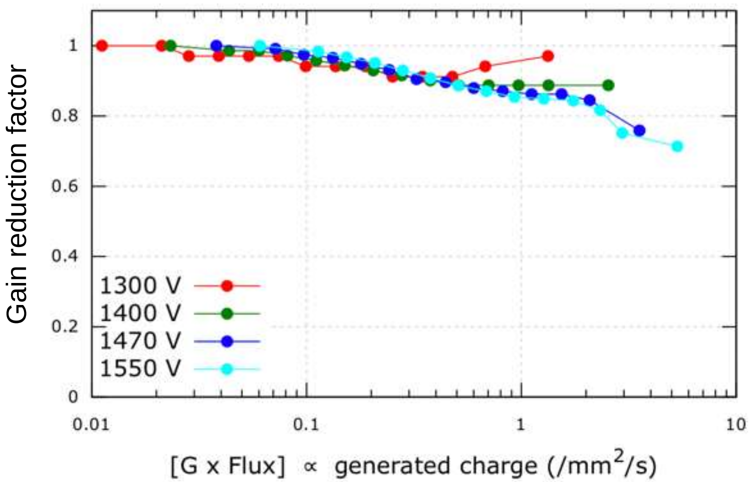




- Mechanical design
- Spatial resolution close to 1 mm
- Spatial uniformity
- Gamma discrimination
- Counting rate ?

4 bar of CF4 would be better





Counting rate limit (@10% counting deviation)
0.5 kHz/mm^2 at 1550 V (Gain 230)
1 kHz/mm^2 at 1470 V (Gain 140)
> 4 kHz/mm^2 at 1100 V (Gain 12)

1470 V OK to achieve 1.2 mm FWHM along the strips (charge division)
1100 V is sufficient for 1mm perpendicular to the strips (C.O.G.)

For a constant Electric field in the drift gap, the variation of the Gain depends on G_0* neutron Flux

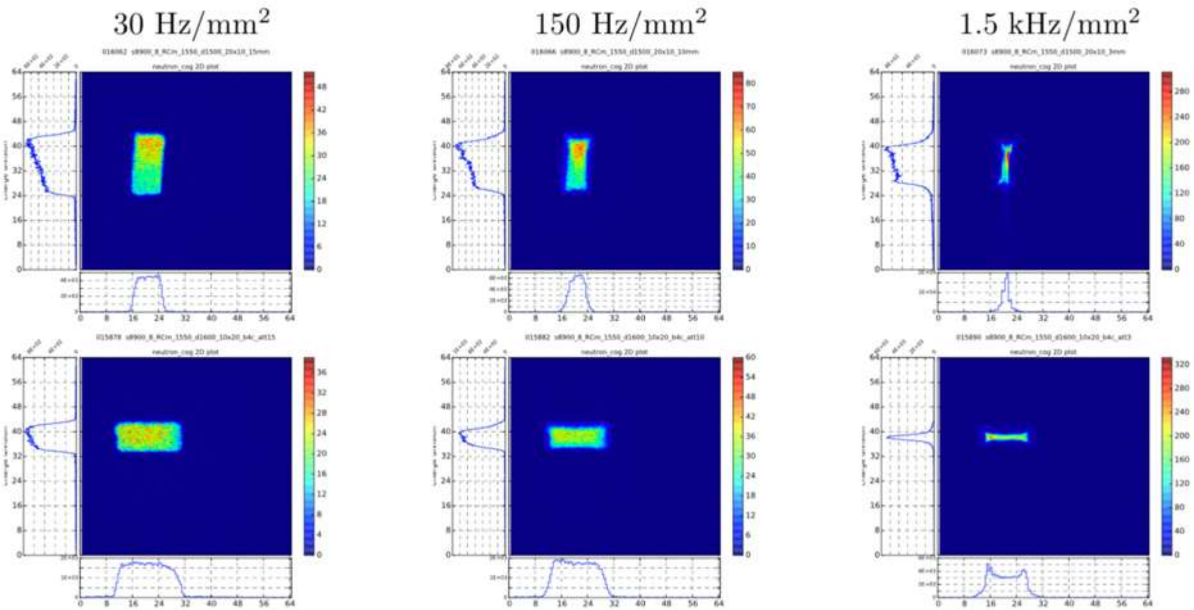
, with G_0 being the Gain at low flux (no space charge effect)

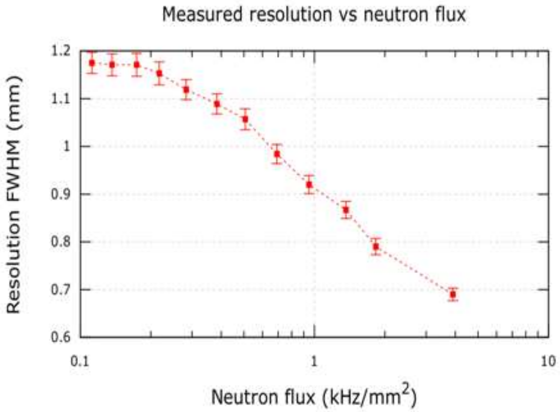
The reduction of the Gain at high neutron flux is attributed to the Electric Field screening induced by secondary ions in the amplification region.

Reducing the gain G_0 of the MSGC by a factor of X allows increasing the counting rate by the same factor X

Image distortion versus rate

Above 150 Hz at Van = 1550 V, the image of a rectangular masks is shrinked in both directions.
We can characterize the image distortion by measuring the shrinking factor





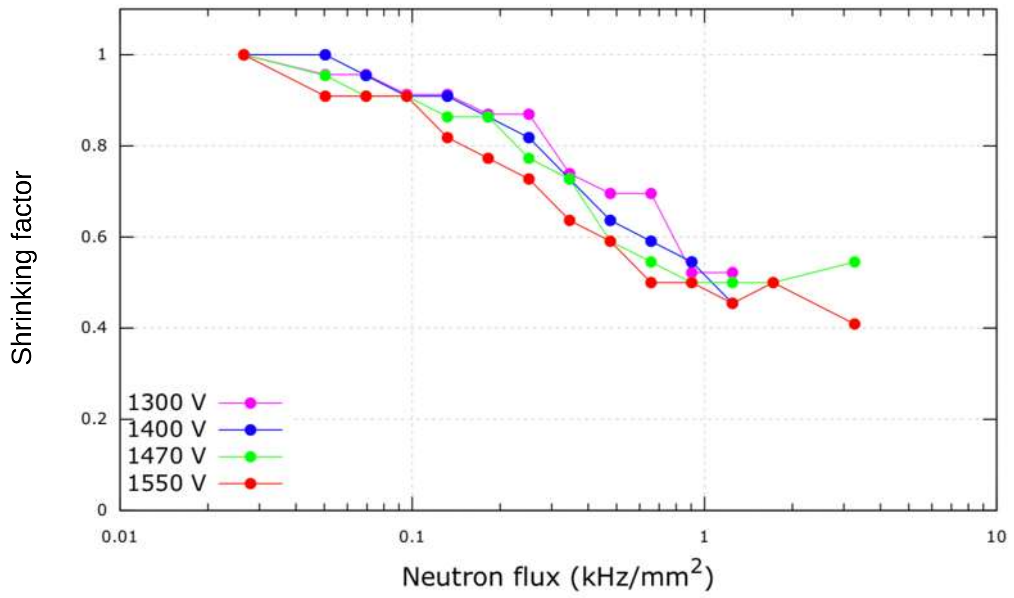
We first observed the effect of image distortion when measuring the spatial resolution: At high rate, it was 2 times better than the expected resolution imposed by the stopping power of the gas !

The common definition of the counting rate limit (= 10% counting deviation) does not take Image distortion into account.

This effect, attributed to positive ions in the conversion gap, has been described for X-ray MWPCs (see for exemple M. W. Trow, A. C. Bento, A. Smith, NIMA A 348 (1994) 232-236), but to our knowledge, not for neutrons.

Given the experimental conditions on reflectometers (intense local irradition), it is crucial to characterize all types of gas detectors for image distortion.
The maximum acceptable distortion, and the method to measure it, remain to be defined.
The spatial resolution measurement shouldn't be affected by this effect.

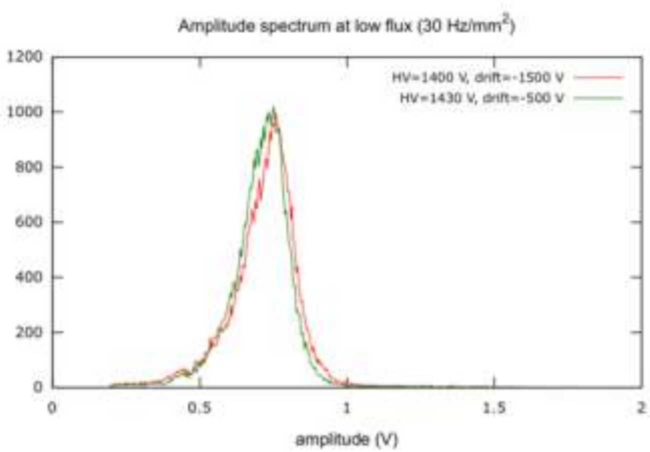
Image distortion versus neutron Flux



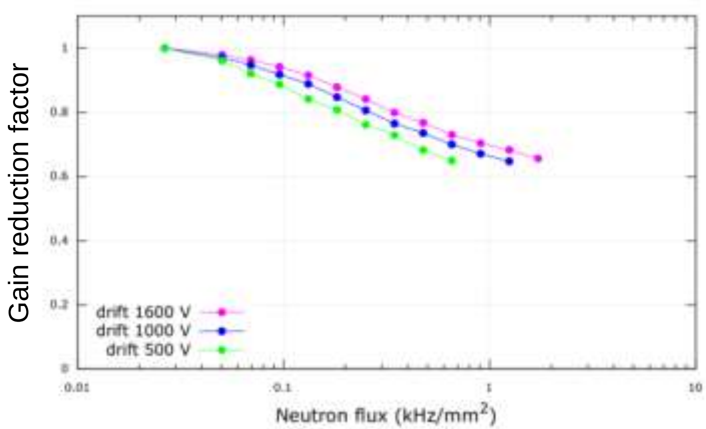
The image distortion increases (the shrinking factor decreases) with the Neutron flux, and with G_0.
The effect of the neutron flux is about 5 times stronger than the effect of G_0.

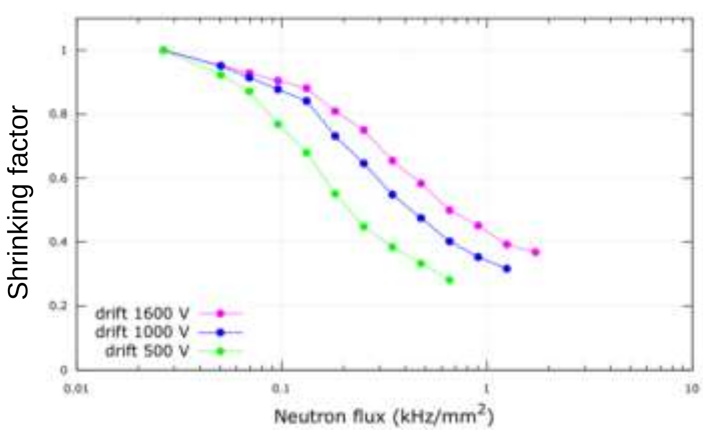
It can be understood as if the image distortion would be dominated by the primary ions back flow, and as if secondary ions produced in the avalanche would contribute in a less extent.

Influence of the electric field E_{field} in the drift region



Measurements were performed at V_{drift} = -1500V and -500 V for the same value of G_0 = 88





Increasing the drift field produces similar effects like decreasing the neutron flux:
the gain stability is slightly improved, and the image distortion is significantly reduced

Effect of the Ion Back Flow current produced by secondary ions flowing toward the drift gap (or drift current)

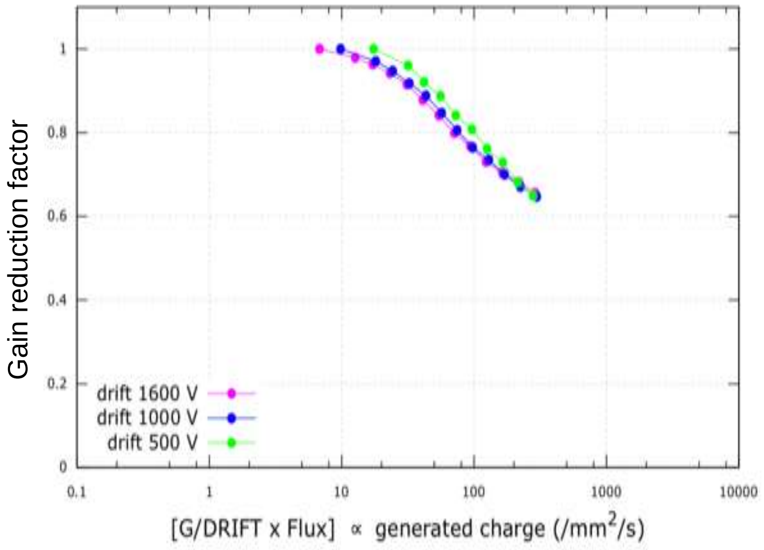
The drift current is proportional to the gain divided by the Ion mobility G/Dfrift, multiplied by the Flux.

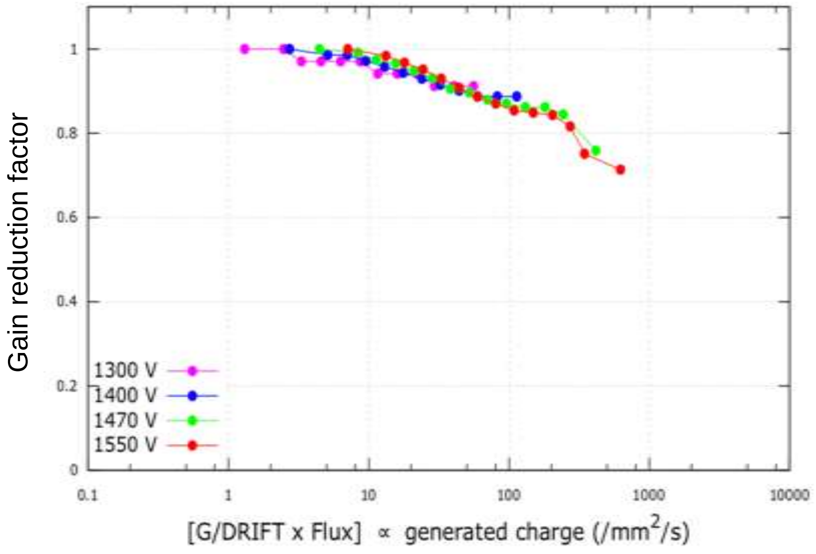
This parameter should have a direct impact on the space charge effect in the amplification region.

This is the case as demonstrated in the 2 following Figures

- left: the gain variation is ploted for 3 different values of the drift field at G_0 constant
- Right: the gain variation is ploted for 4 different values of G_0 at constant drift field

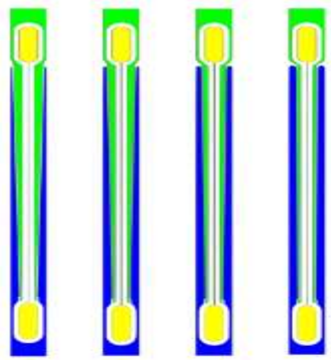
The gain variation depends only on the drift current, whatever are G_0, E_{drift}, and Flux.
Hence the screening effect induced by the secondary ions is directly correlated to the drift current.



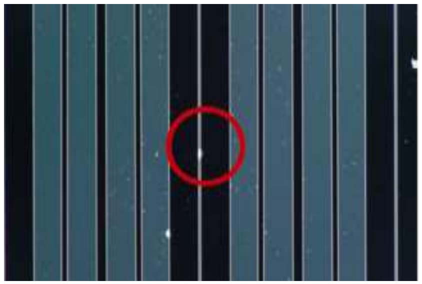


Where are we now ?

1/ Operating the MSGC at lower G_0 to reduce the drift current allows to increase the max counting rate
→ A higher cathode resistance is needed



Development of a new MSGC layout with triangular electrodes for capacitive charge division.
A prototype containing 4 different types of electrodes is in fabrication.

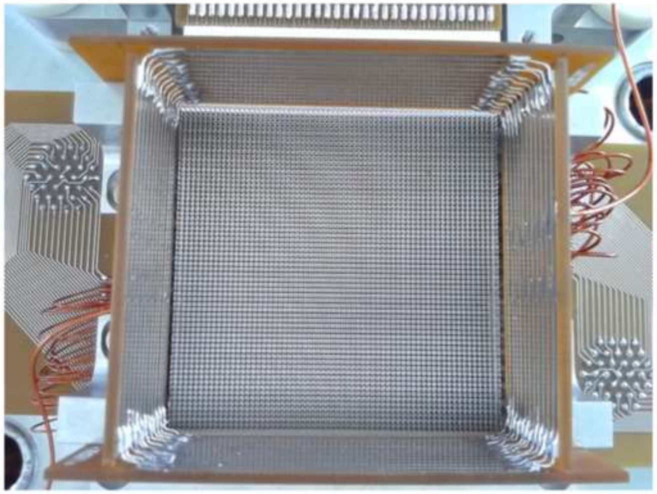


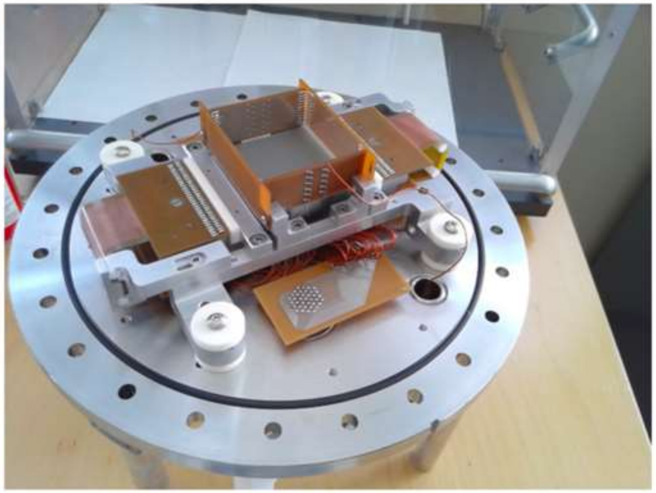
We rejected the MSGC samples from IMT two times because of insufficient quality
Should we continue with IMT or find an other supplier ?
The difficulty to find a good MSGC supplier seems to be again of actuality
What is the feedback from other labs ?

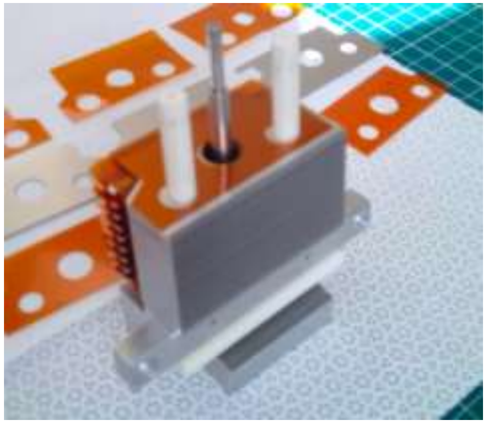
Increasing the cathode resistance from 1 kOhm to 10 kOhm might be simpler than using triangular electrodes

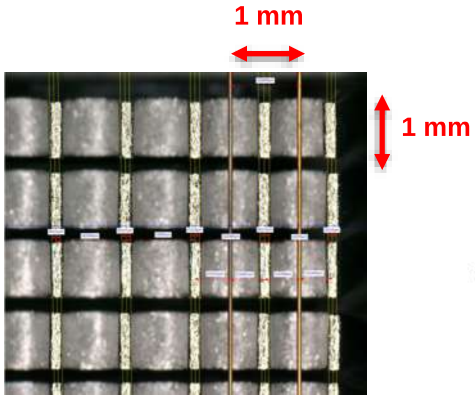
2/ Need to reduce the primary ion back flow to avoid image distortion
(reducing the amplification gain does not help a lot)
→ Faster gas / higher drift field.

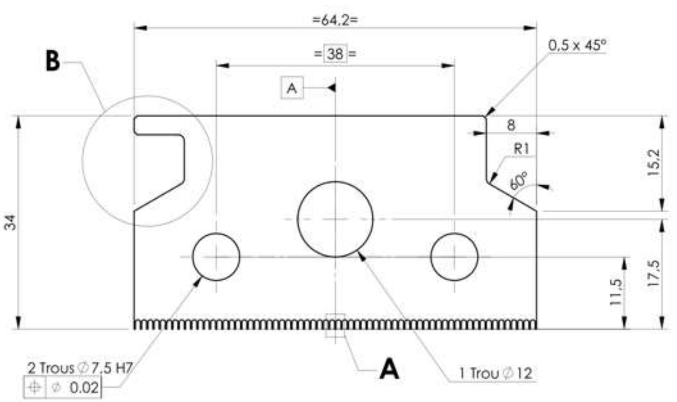
As a plan B, we applied the trench-MWPC technique (introduced for the XtremeD project) to SINE2020

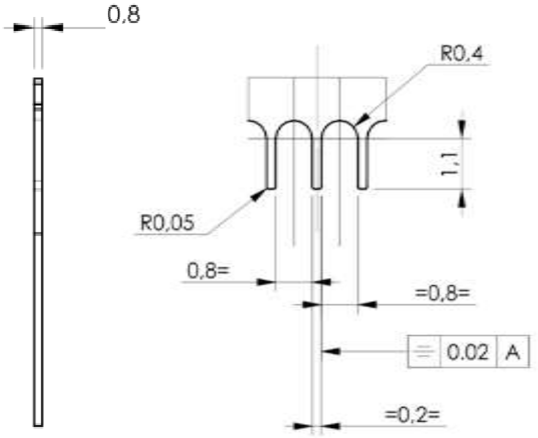






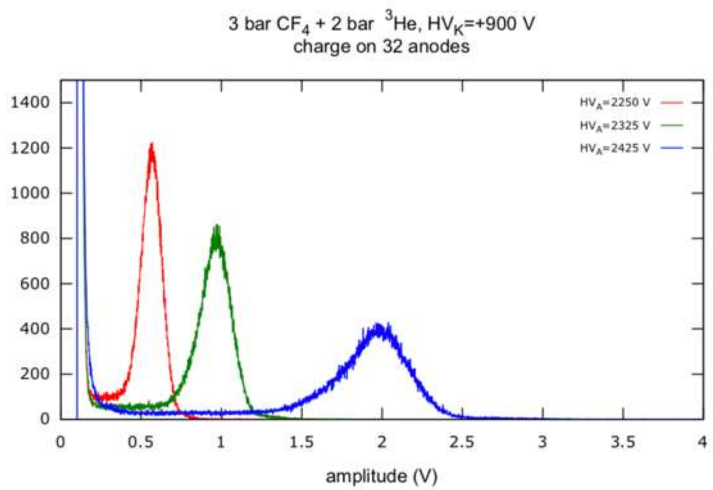


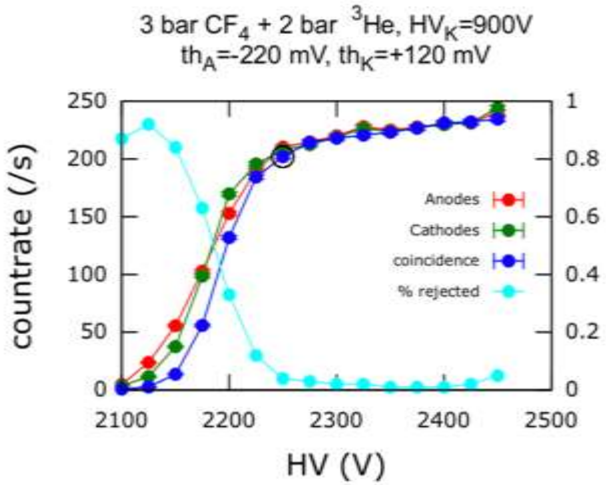




Wire pitch = 1 mm
Stainless steel blades, 0.8 mm thick, mounted at a pitch of 1 mm.
fabricated (acceptation ratio = 100%) by Watajet (contact: stefano.volpi@watajet.com)

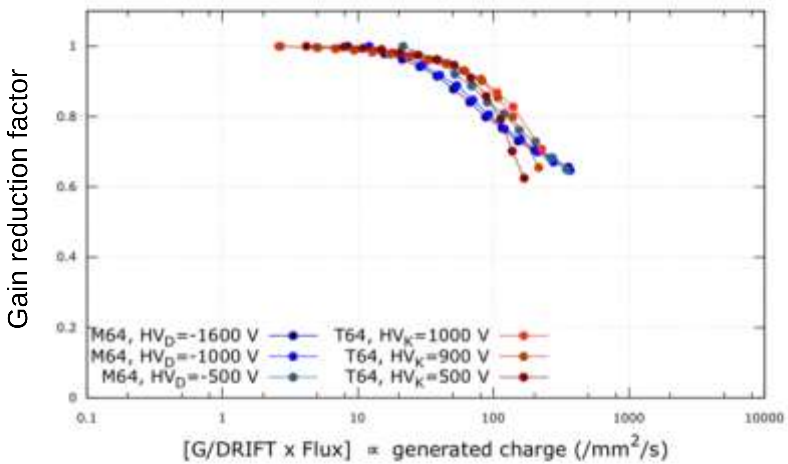
Preliminary results with the trench64 MWPC



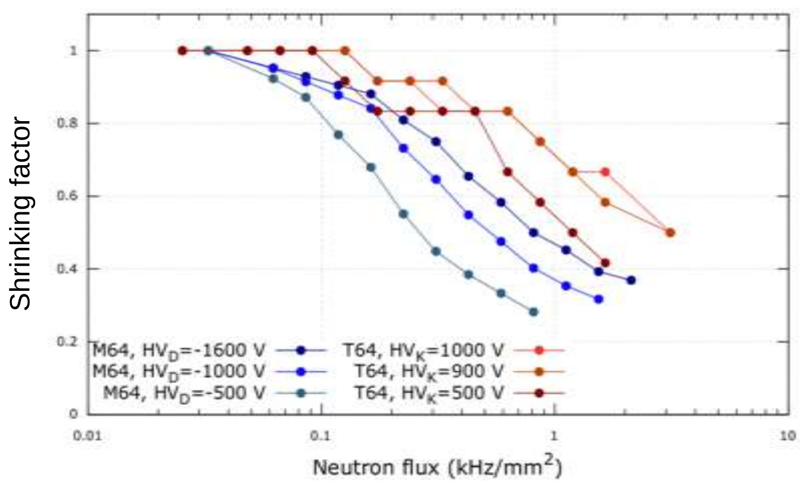


The detector was not equiped with a drift electrodes as it should be, hence the drift field was limited by the maximum voltage we could apply on the cathode blades (+900 V)

Preliminary results with the trench64 MWPC



The trench MWPC shows a similar dependance of the gain versus « (G_0 / Ion mobility) * Flux »
Since it is operated at a gain 10 times lower than the MSGC, we can expect a local counting rate 10 times higher (10 kHz/mm^2 instead of 1 kHz) at similar drift field (provided signal pile up does not contribute)



Even considering the higher drift field in the MSGC, the image distortion is smaller with the trench-MWPC.
A possible explanation for this result might be that primary ions are collected on the trench cathode more efficiently than on the MSGC cathodes. Further measurements are needed to support this theory.

Independant measurements with other prototypes (trench and standard MWPC) have demonstrated a lower image distortion with the trench-MWPC compared to the standard MWPC.

Conclusion

We succesfully studied a 2D MSGC, and measured a spatial resolution close to 1 mm in both directions.

The usual way of quantifying the counting rate capability of a detector is
R_{max} = maximum counting rate with < 10% counting deviation

The measured local counting rate is 1 kHz/mm^2 , 5 times < specification

We observed that an **image deformation** starts to occur at R_{max} / 10

This image deformation is attributed to the IBF (Ion Back Flow) which induces a distortion of the the Electric Field lines inside the conversion gap. This effect exists in a similar way for MSGCs and MWPCs. It was not reported for neutrons before.

Prospects

To reduce the amplification gain, electrodes with **higher electrical resistance** could be used. It will require amplifiers with longer shaping time. The signal pile-up will remain acceptable for reflectometers with irradiation perpendicular to the strips. A gain of 2 or 3 in counting rate can be expected from this change.

Furthermore, the IBF will be efficiently reduced, as well as the electron collection time, by increasing the electric field in the drift gap. This can be done in two ways:
1/ reducing the conversion gap of 3 cm, which is not optimum, to 1.5 cm, and
2/ increasing the voltage on the drift electrode (limited today by design) by a factor 2.
The overall expected improvement factor is around 10

The first Oed Prize has been presented during the MPGD2019 conference in La Rochelle to Rui de Oliveira (CERN)

The trench-MWPC is an interesting alternative which might provide comparable performance

30 years after their introduction by Anton Oed at the ILL, MSGCs are still improving