Single-electron response and energy resolution of a Micromegas detector

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Energy resolution in gaseous detectors

Two contributions:

- Primary ionisation fluctuations

→ can be quantified by the **Fano factor (values : 0.1 up to 0.4)**

- Gas gain fluctuations during the multiplication process

Two probability distributions:

- **Exponential (Furry distribution)**
- **Polya (generalisation proposed by Byrne) :**

$$P(Q) = C_0 \frac{(1+\theta)^{1+\theta}}{\Gamma(1+\theta)} \left(\frac{Q}{\bar{Q}}\right)^{\theta} \exp\left[-(1+\theta)\frac{Q}{\bar{Q}}\right]$$

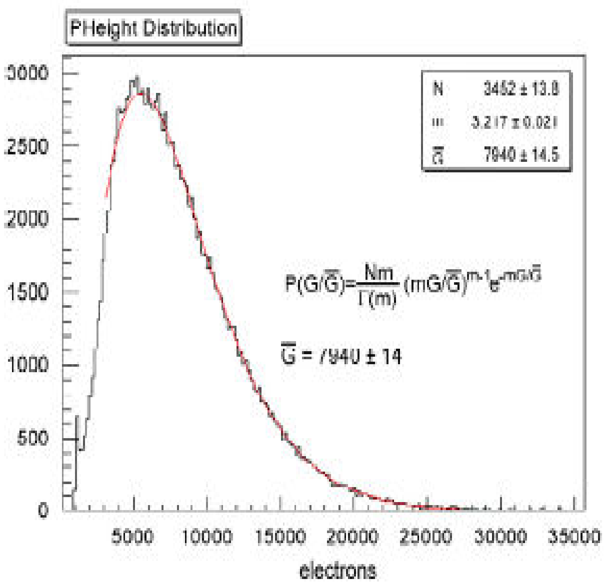
θ: parameter of the Polya, related to the relative gain variance f by : $f = 1/(1+\theta)$

→ Measurement of the **Single-Electron Response (SER)** is a direct method to determine gas gain fluctuations.

SER in single GEM

Ne 50% DME 50%
Gain: 7.9 10^3

Polya distribution

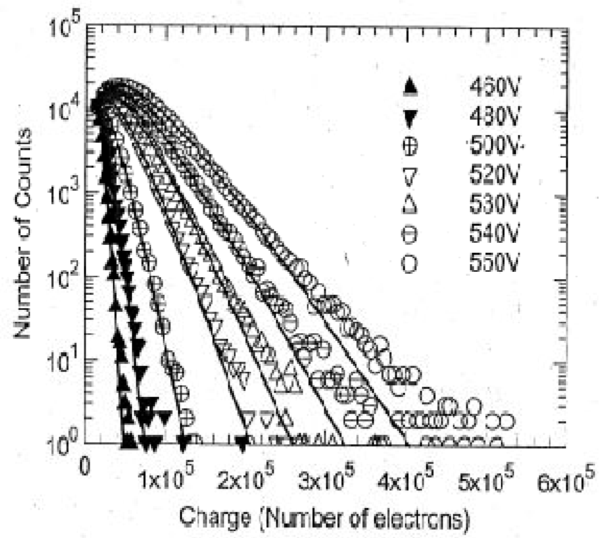


$\theta = 2.2 \longrightarrow f = 0.31$

R. Bellazzini et al., NIM A 581 (2007) 246

GEM-MIGAS in GEM mode
He 85% iC_4H_{10} 15%
Gains of a few 10^4

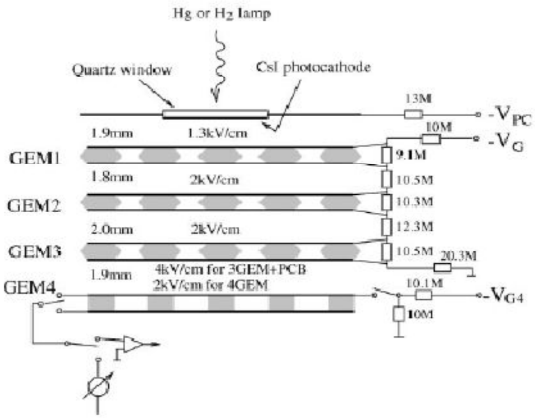
Polya distribution



$1.4 \leq \theta \leq 2.5 \longrightarrow 0.3 \leq f \leq 0.4$

Jamil A. Mir et al, IEEE Trans. Nucl. Sci. NS-55 (2008) 2334.

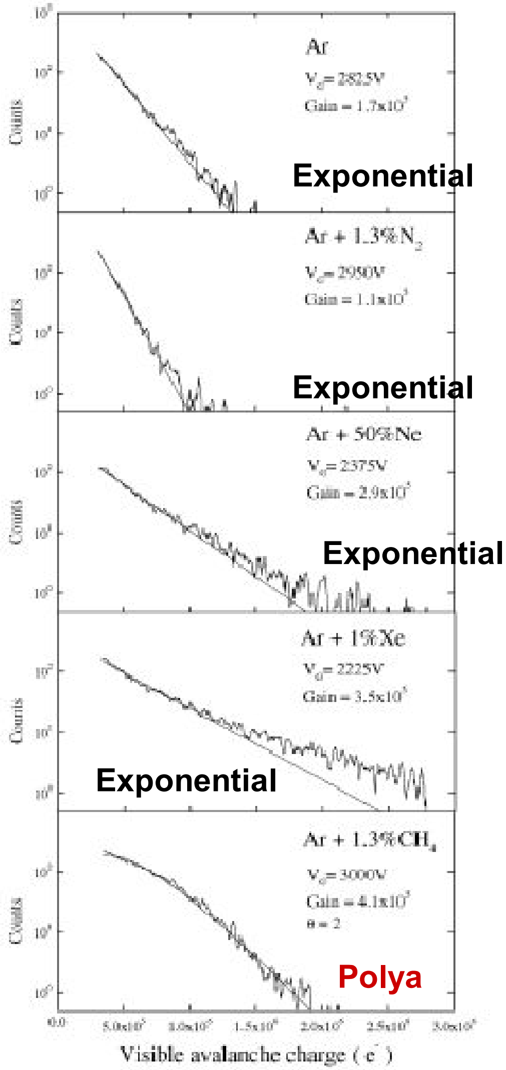
SER in stack of GEMs



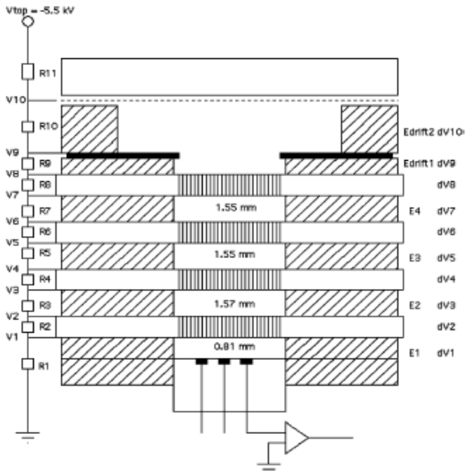
A.Buzulutskov et al., NIM A 443 (2000) 164.

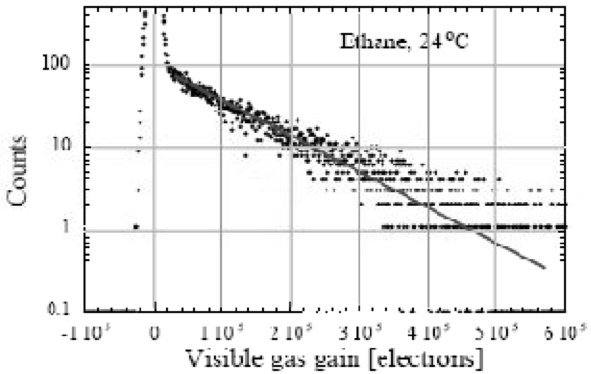
3GEM +PCB

Gains of a few 10^5



4 GEMs





J. Va'vra and A. Sharma, NIM A 478 (2002) 235.

SER in Micromegas

Micromegas:

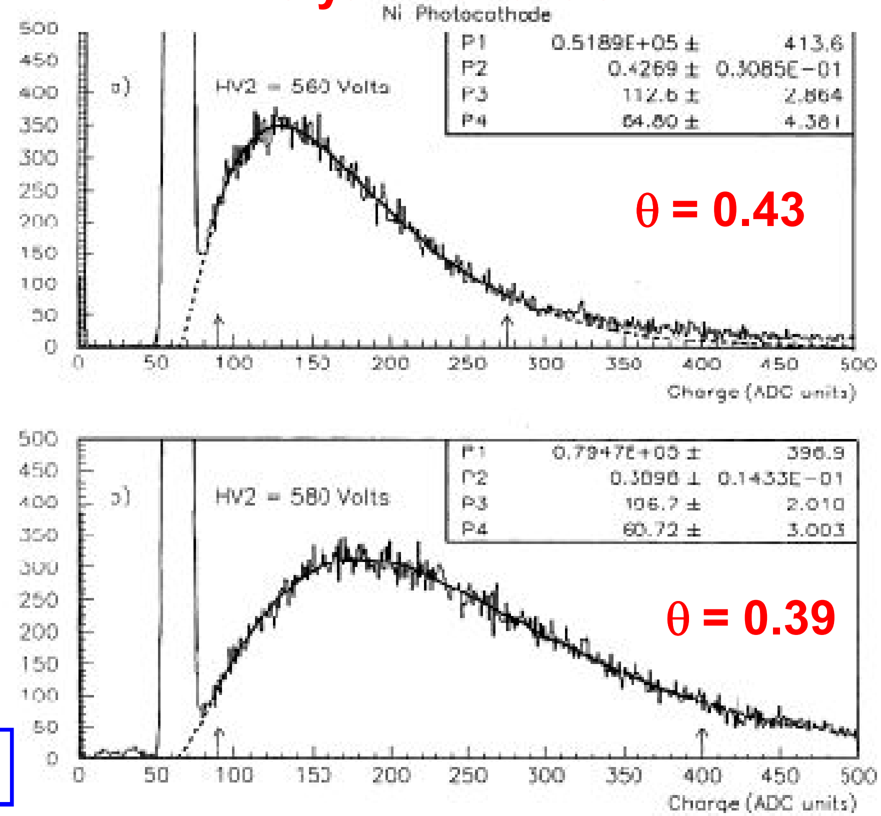
Conversion zone: 5 mm
Amplification gap: 100 µm

He 90% iC_4H_{10} 10%

Gain ≈ 10^6
(Electronic noise: 4 10^4 e^- RMS)

J. Derré et al., NIM A 449 (2000), 314.

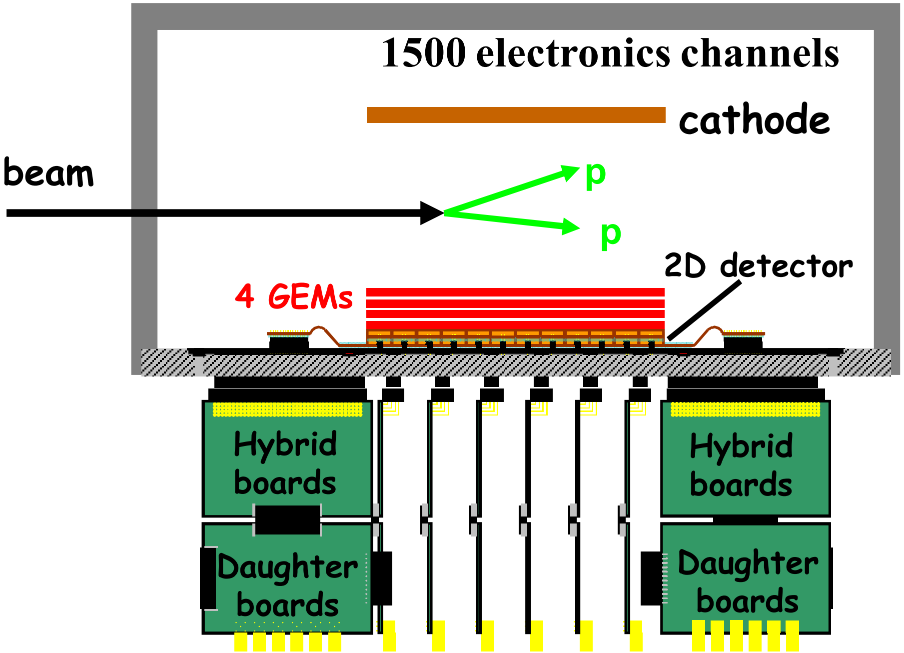
Polya distribution



→ $f \approx 0.7$

MPGD: new detectors for Nuclear Physics

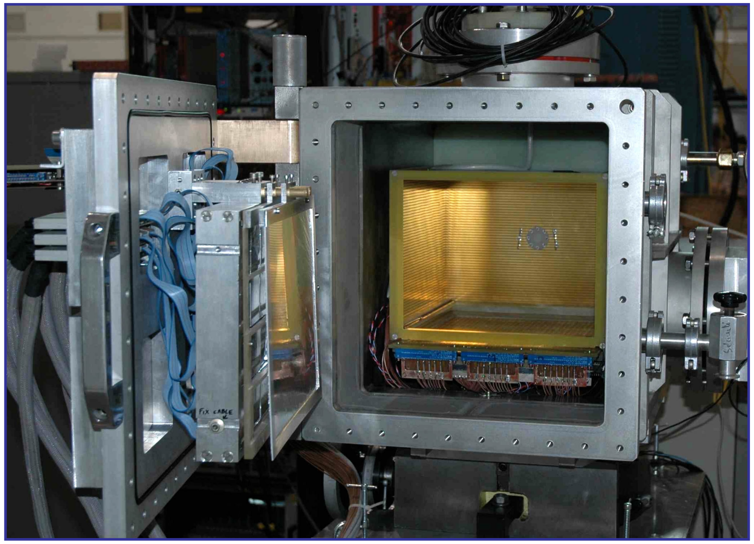
TPC for detection of 2p radioactivity



Implantation in the gas volume
Gas: P10 from 0.5 up to 1.03 atm
X-Y detector
Z by time projection
3D tracks of the 2 protons

B. Blank et al., NIM B 266 (2008) 4606

MAYA @ GANIL, France



TPC principle
Gas : target and detection medium
3D reconstruction of nuclear reactions
MWPC for the amplification

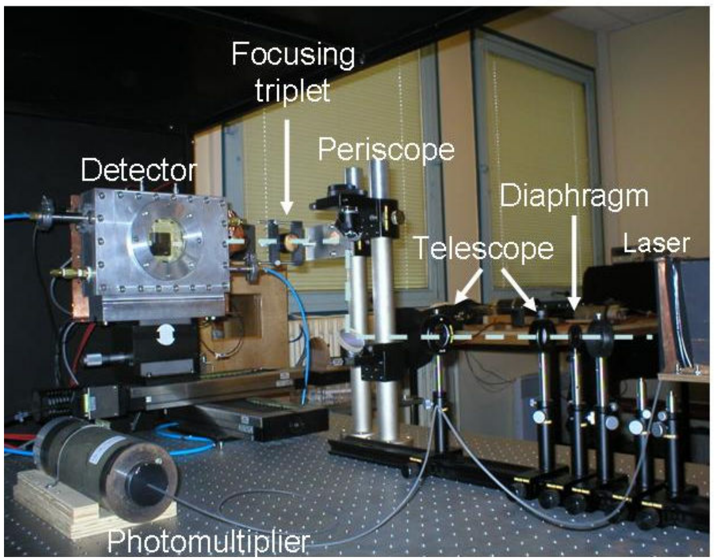
C.E. Demonchy et al., NIM A 573 (2007) 145

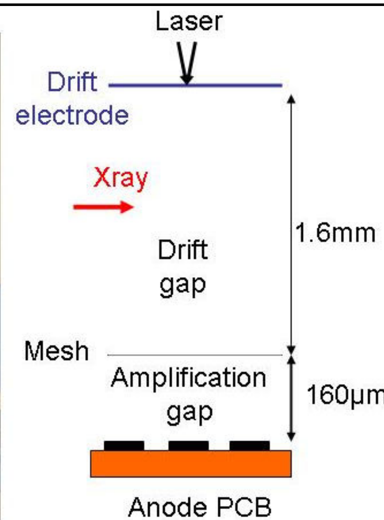
→ R&D ACTive TARget detector:
MPGD for amplification
Pressure: 100 mbars up to 2bars

Study with a laser test bench @ Orsay

- **Production of an intensity and position monitored electron source using a 337 nm wavelength laser**
- **Focused laser beam size ≤ 100 µm**

→ *T. Zerguerras et al. , NIM A 581 (2007) 258*





Drift electrode: Quartz window with a 0.5 nm thick Ni-Cr layer

Mesh: 333lpi Buckbee-Mears©
70% optical transmission
Nickel

Measurements with a set of 9 pads (3*3), size of 4*4mm^2

Ne 95% iC_4H_{10} 5% @ 1 bar

Drift field: 1kV/cm

Electronics:

Pads: Gassiplex chips (noise: 2 000 e$^-$ RMS)
Mesh: gain 100 voltage amplifier

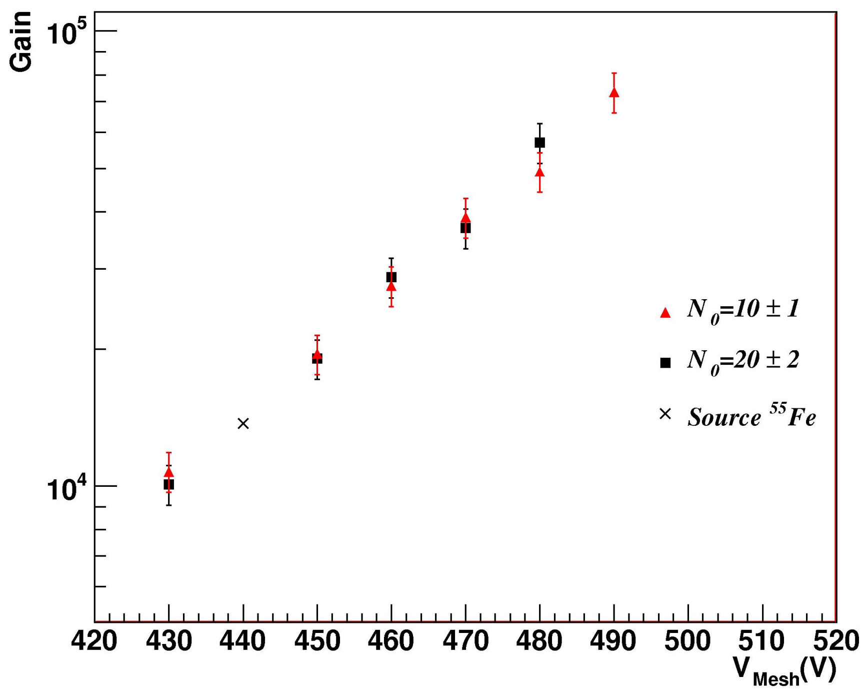
Trigger:

- Mesh signal in ^{55}Fe source mode.
- Photonis© XP2282B photomultiplier anode signal in laser mode

Gas gain calibration

Method:

- Measurement with the ^{55}Fe source @ 440V.
- Gain calibration curve completed with the laser, for two values of the number of primary electrons N_0 .

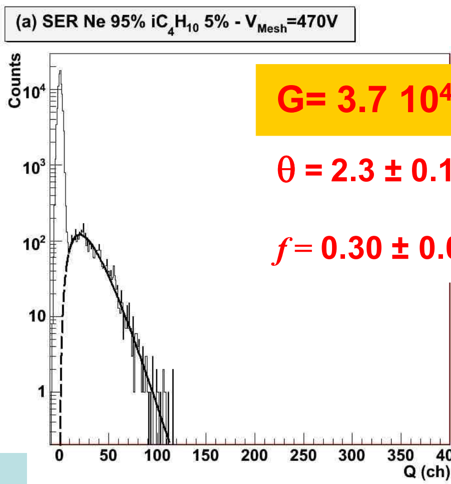


Single-electron response

Laser intensity light attenuated by a factor of 2 000.
Rate of non-zero events: 7%
Measurement on the central pad

Polya distribution adjusted on data

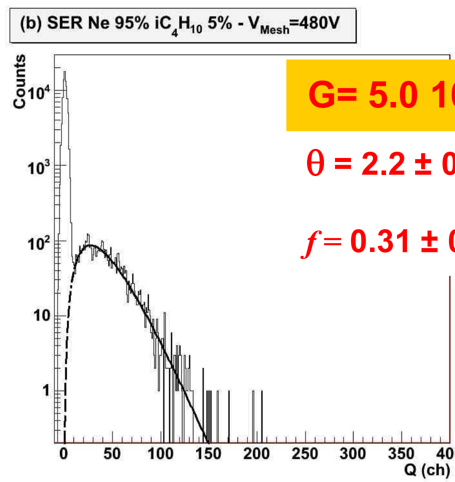
V_{Mesh} <500V



G= 3.7 10^4

θ = 2.3 ± 0.1

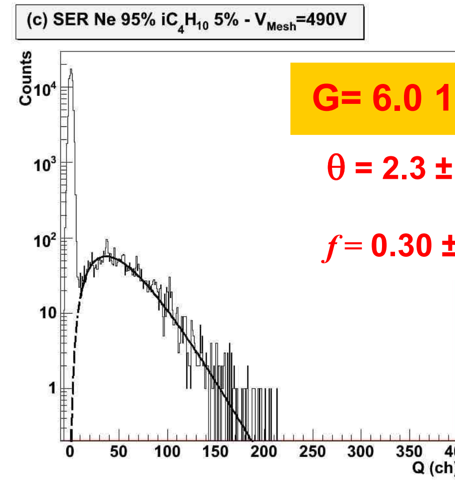
f = 0.30 ± 0.01



G= 5.0 10^4

θ = 2.2 ± 0.1

f = 0.31 ± 0.01

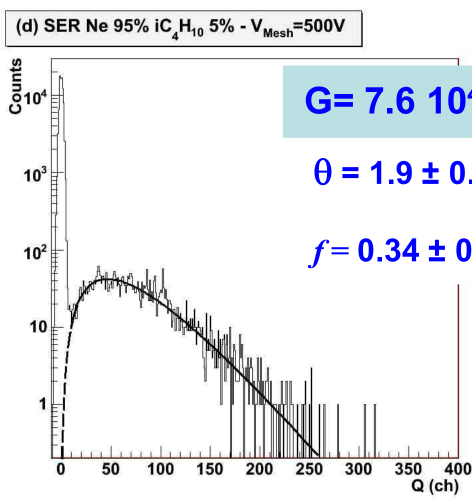


G= 6.0 10^4

θ = 2.3 ± 0.1

f = 0.30 ± 0.01

$V_{Mesh} \geq$ 500V



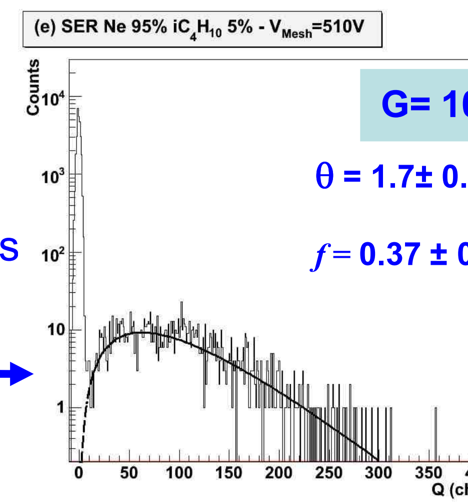
G= 7.6 10^4

θ = 1.9 ± 0.1

f = 0.34 ± 0.01

- Gain 10-15% lower than expected from gain calibration curve extrapolation.
- Relative gain variance increases

Unquenched photon effect



G= 10^5

θ = 1.7± 0.1

f = 0.37 ± 0.01

Energy resolution with the laser

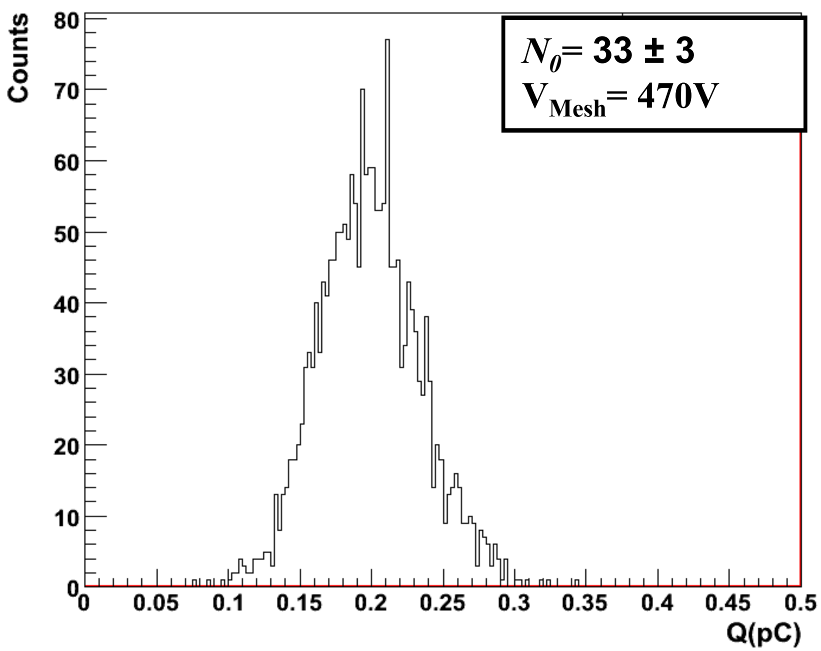
V_{Mesh} < 500V

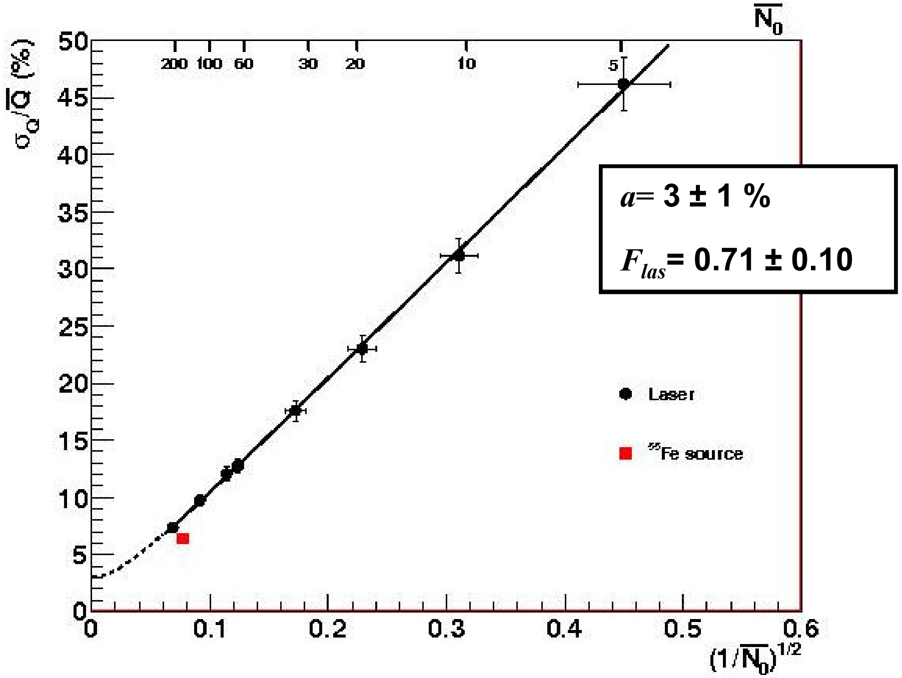
Measurement on the central pad

$$\frac{\sigma_Q}{\overline{Q}} = \sqrt{a^2 + \frac{f + F_{las}}{\overline{N_0}}}$$

a **: related to the energy resolution of the laser**

F_{las} : effective Fano factor associated with the electron emission from the metal.





Energy resolution with a ^{55}Fe source

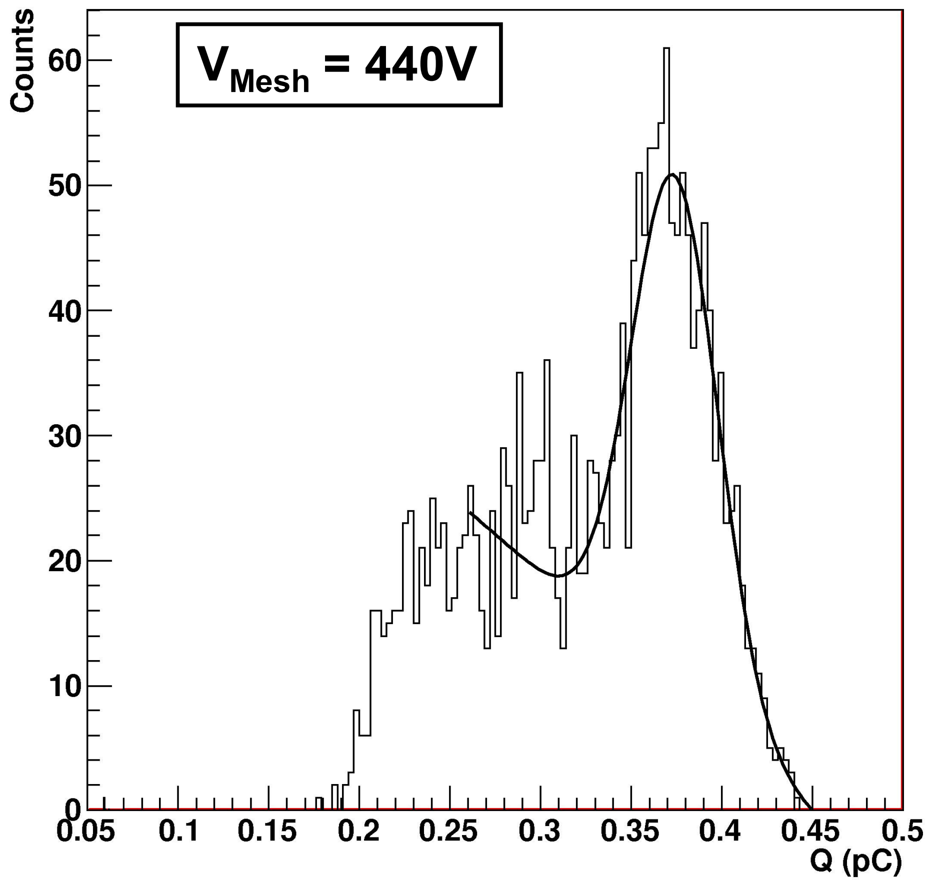
$$\frac{\sigma_Q}{\overline{Q}} = \sqrt{(f+F)\frac{W}{\varepsilon}}$$

Selection of events with a signal induced only on the central pad

→ Very low counting rate (10 events per minute)

Energy resolution: 6.4% RMS

Upper limit on the Fano factor deduced: $F \leq 0.37$



Conclusions

- **Gas gain fluctuations in MPGDs are lower than in MWPC (0.7) for the same gain values.**

- **The present experimental method can be used for all kind of MPGDs and allows direct SER measurements down to gains of a few 10^4.**
  It could help provide experimental data for simulation software improvement (see R. Veenhof's talk @MPGD 2009)

- **Study of the energy resolution as a function of the primary number of electrons can be performed.**

- **From the relative gain variance *f* deduced from the SER, the Fano factor can be estimated.**

→ **Present work to be published in NIM A.**

Perspectives:

- Spatial resolution

- Gas gain fluctuations for different pressures and in other gas mixtures