# A UV laser test bench for micro-pattern gaseous detectors

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## Motivation

Techniques for the characterization of micro-pattern gaseous detectors (MPGDs) involving X-rays and cosmic muons are not suitable for devices with thin gas volumes or made entirely of resistive electrodes, like the Fast Timing MPGD (FTM). Lasers are a viable alternative for their flexible application in both high-power and single-electron regimes and allow to test thin gas stuctures.

An optical setup made of an UV laser has been developed and tested with a Time Projection GEM (TPG) prototype and proved useful for measurements of gain, space position and electron drift velocity.

## Laser specifications

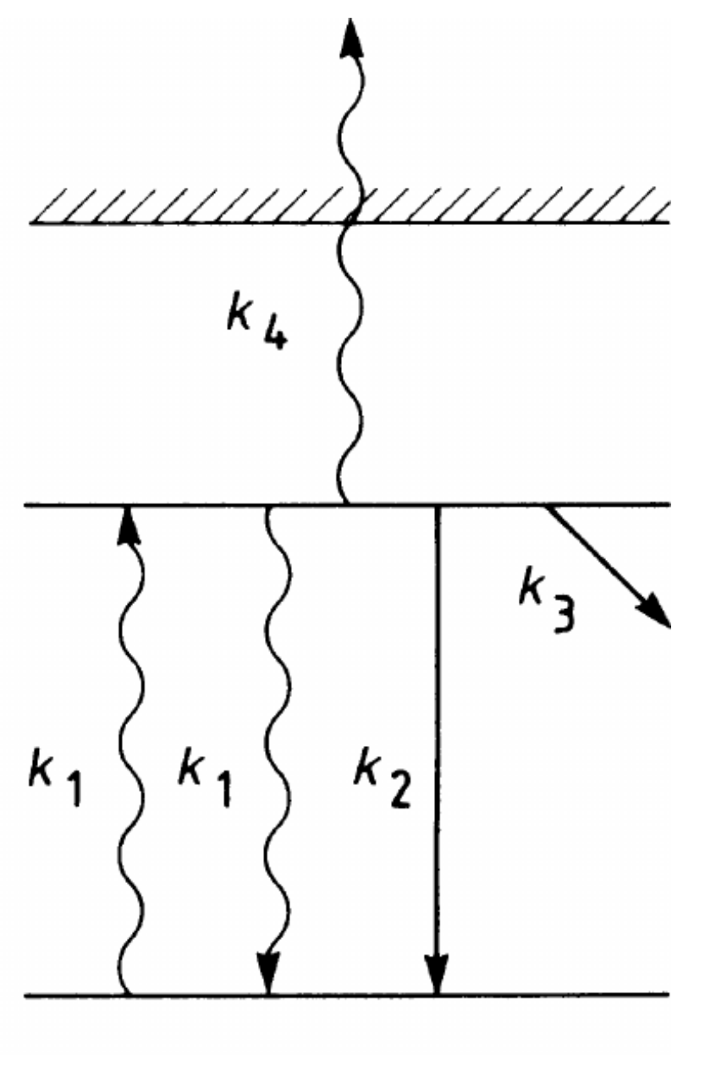
Laser rays ionize impurities in the detector gas mixtures by multi-photon absorption. The rate density for n-photon ionization is

$$\frac{R}{V} = N\,\sigma^{(n)}\,\phi^{n},$$

where $\phi$ is the laser beam flux and $\sigma^{(n)}$ is the n-photon cross-section. Two-photon ionization dominates at low intensities and $\sigma^{(2)} = \sigma_{excitation} \times \sigma_{ionization}$.

Table: Specifications of the CryLaS FQSS266-50 laser.

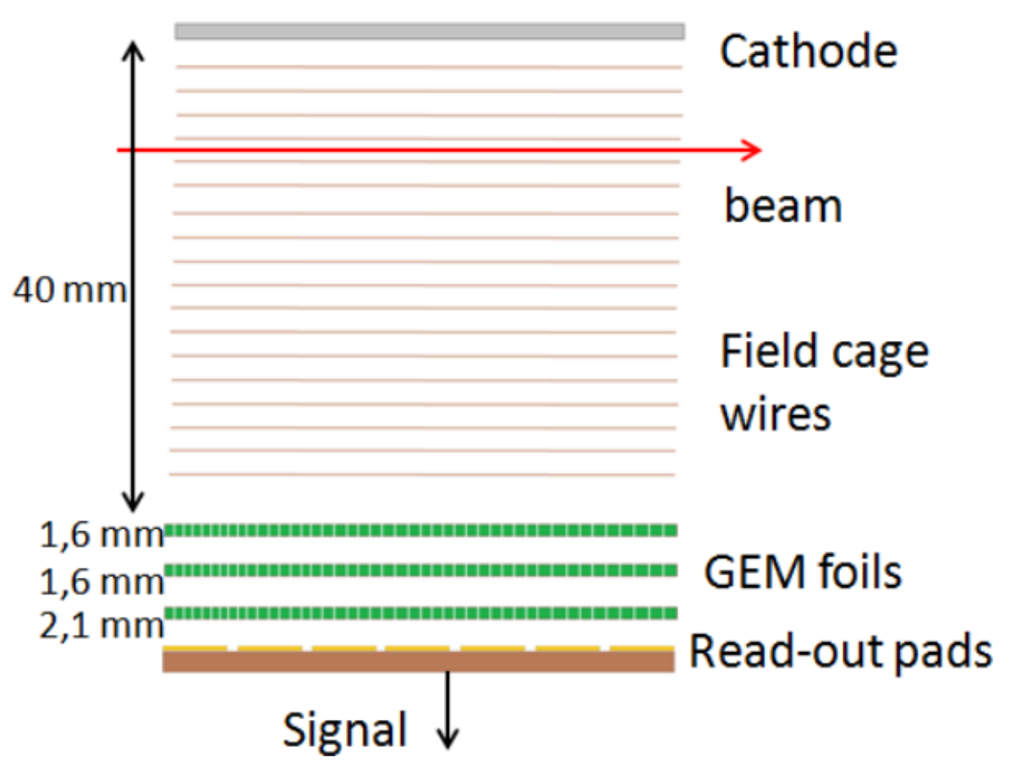
| Pulse energy | Waist radius | Wavelength | Pulse duration | Spatial mode |
|---|---|---|---|---|
| 51 µJ | 400 µm | 266 nm/4.7 eV | 1 ns FWHM | $TEM_{00}$ |
| can provide a MIP-like energy deposit | low angular divergence | two-photon ionization of hydrocarbons | lower than the TPG time resolution | gaussian beam quality <1.5 |

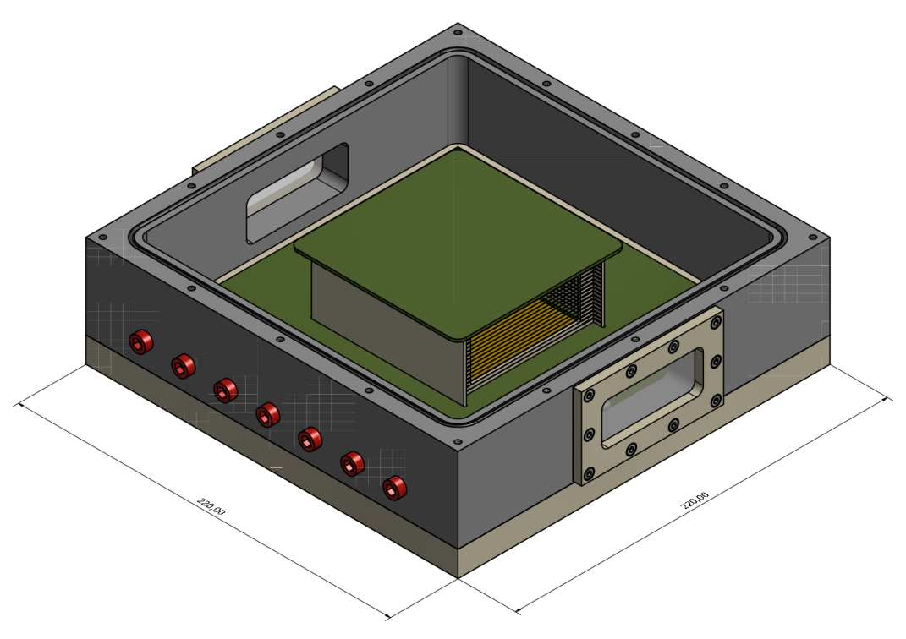


Two-photon ionization scheme.

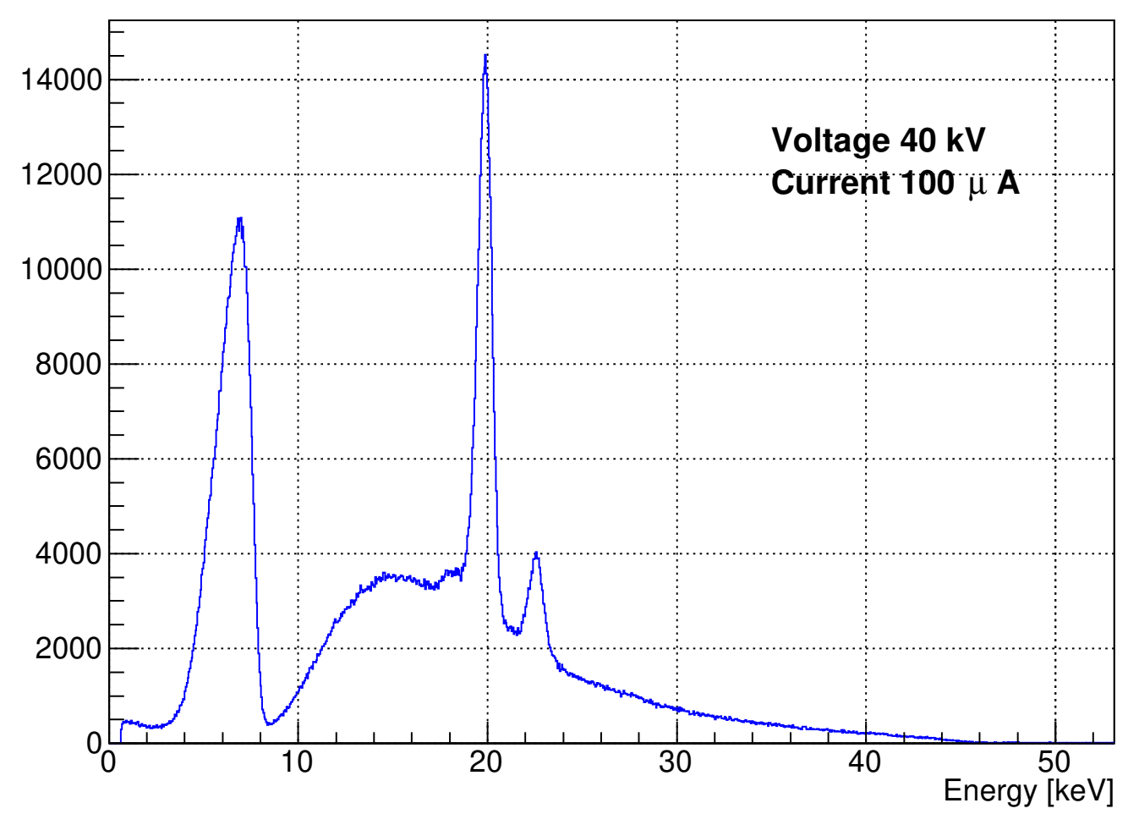
## Validation of the Time Projection GEM

The TPG protoype is a triple-GEM chamber with a drift gap of 40 mm, two 1.6 mm transfer gaps and a 2.1 mm induction gap. The beam enters the drift gap from a mylar window and the signal is read from a 4-ASIC board on two rows of 60 pads (each of 6 × 2 mm$^2$).

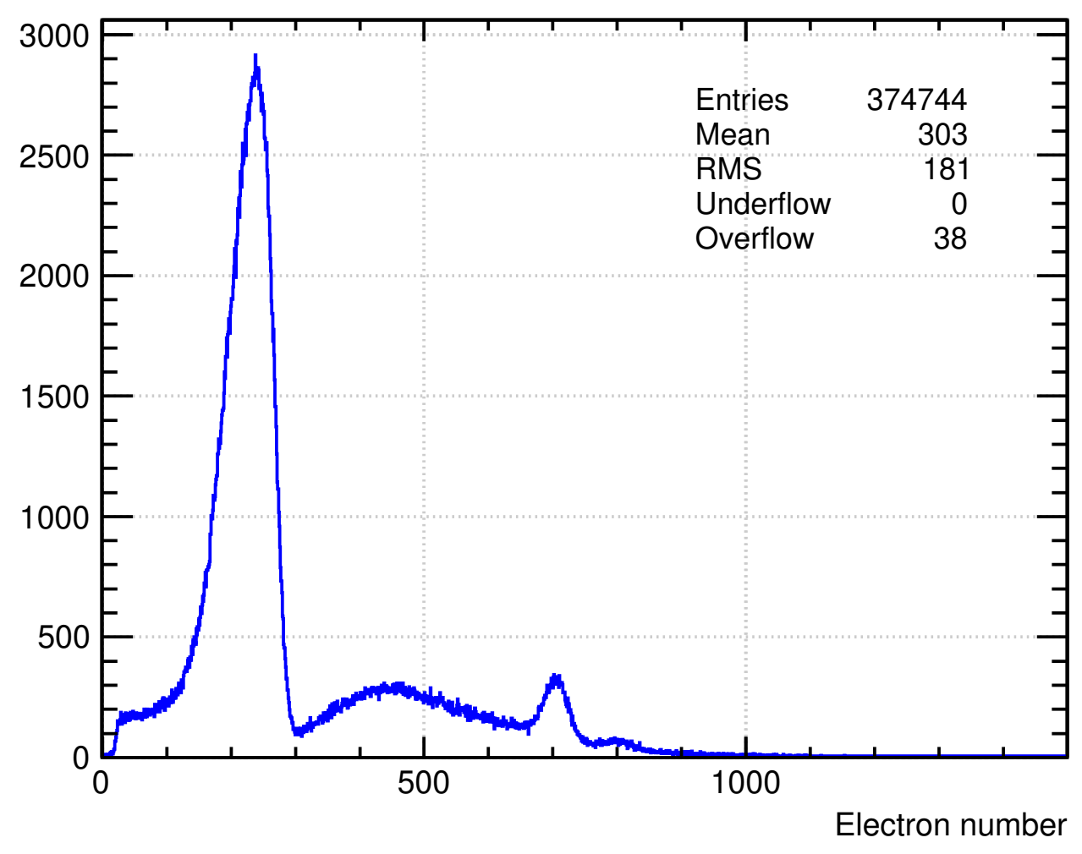




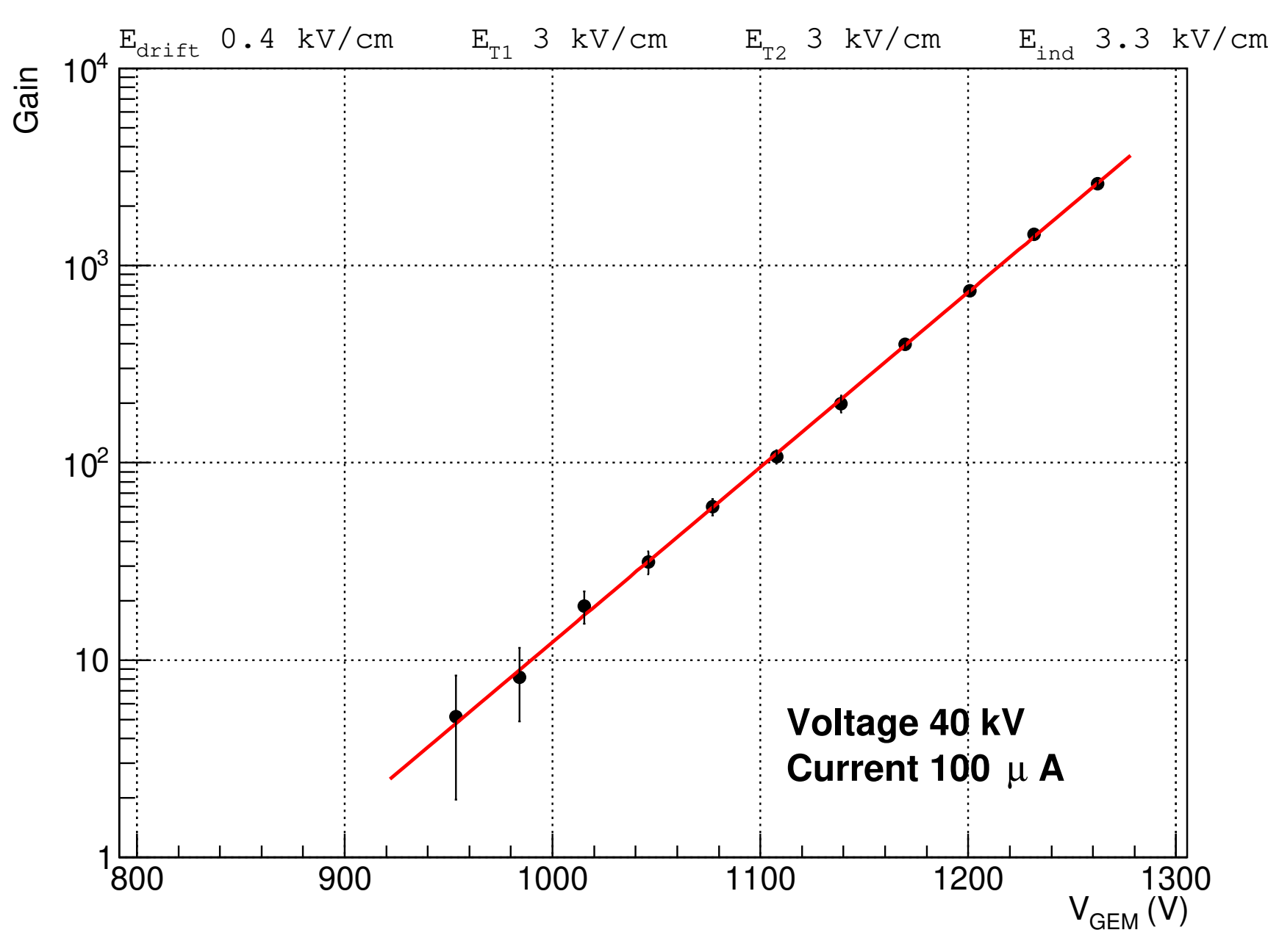
**TPG gain calibration.** The effective gain is the ratio $\frac{i_{anode}}{i_{primary}}$. The anodic current is read by a picoammeter, while the collection efficiency is too low to read the primary ionization curent; $i_{primary}$ is estimated by the signal rate.



Spectrum of the X-ray gun with a 25 µm copper filter measured with a spectrometer.



Simulated spectrum of the primary electrons created by the X-ray tube in the TPG gas.



Gain curve of the TPG obtained with the X-ray gun.

The gain measured with the X-ray gun is not compatible with the gain curves of other triple GEM chambers of the CMS GE1/1 sector operated at the same voltages.

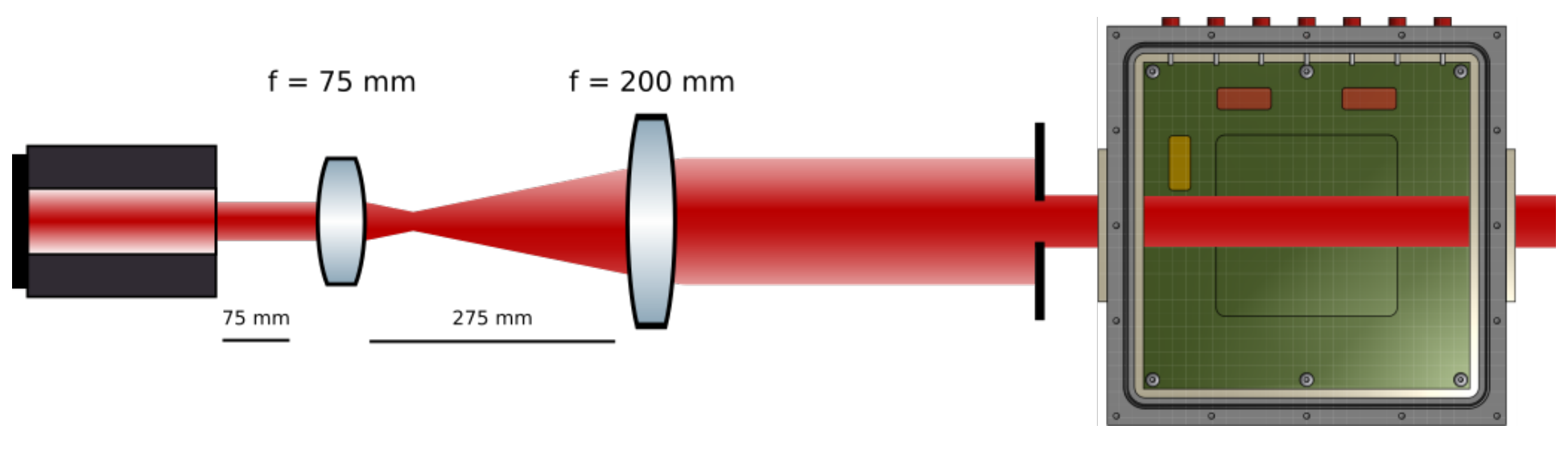
**Difficulties in the gain measurements** due to

non-monochromatic spectrum with no thick copper conversion electrode;

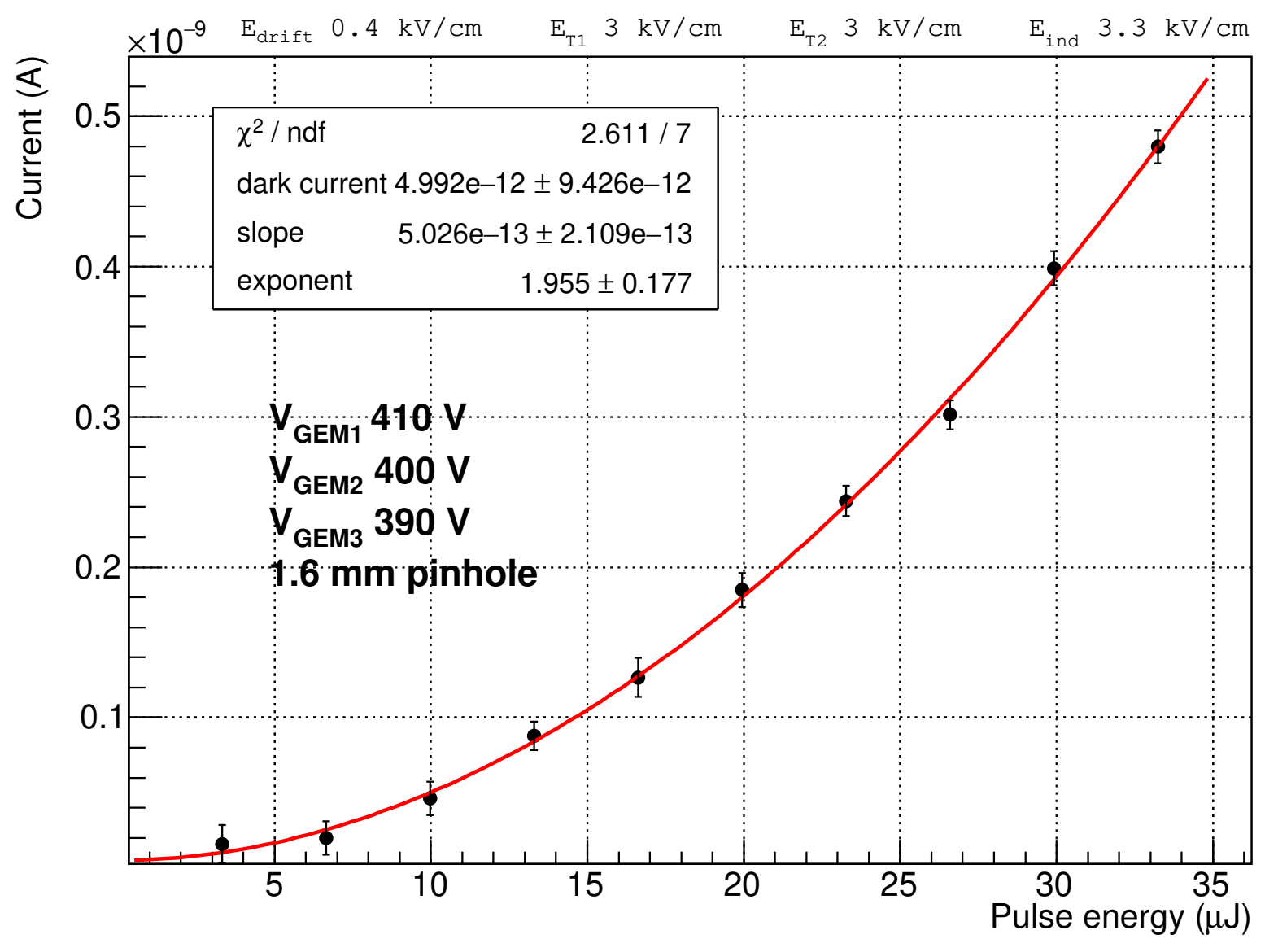
small active region with respect to the total gas volume.

## Primary ionization with the laser

The number of primary electrons created by a laser beam pulse is estimated by interpolation with the signal rate curve at different pulse energies.

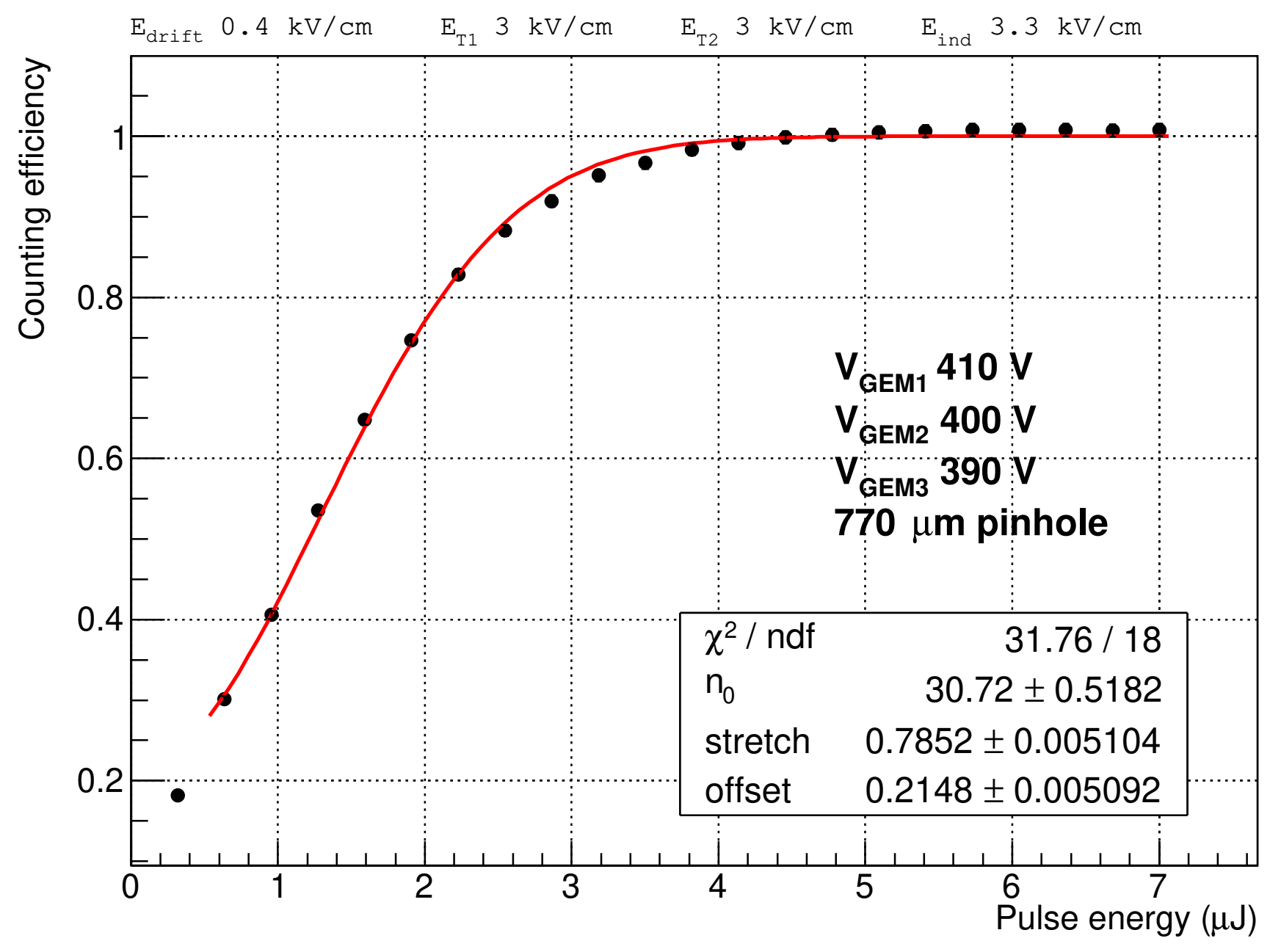


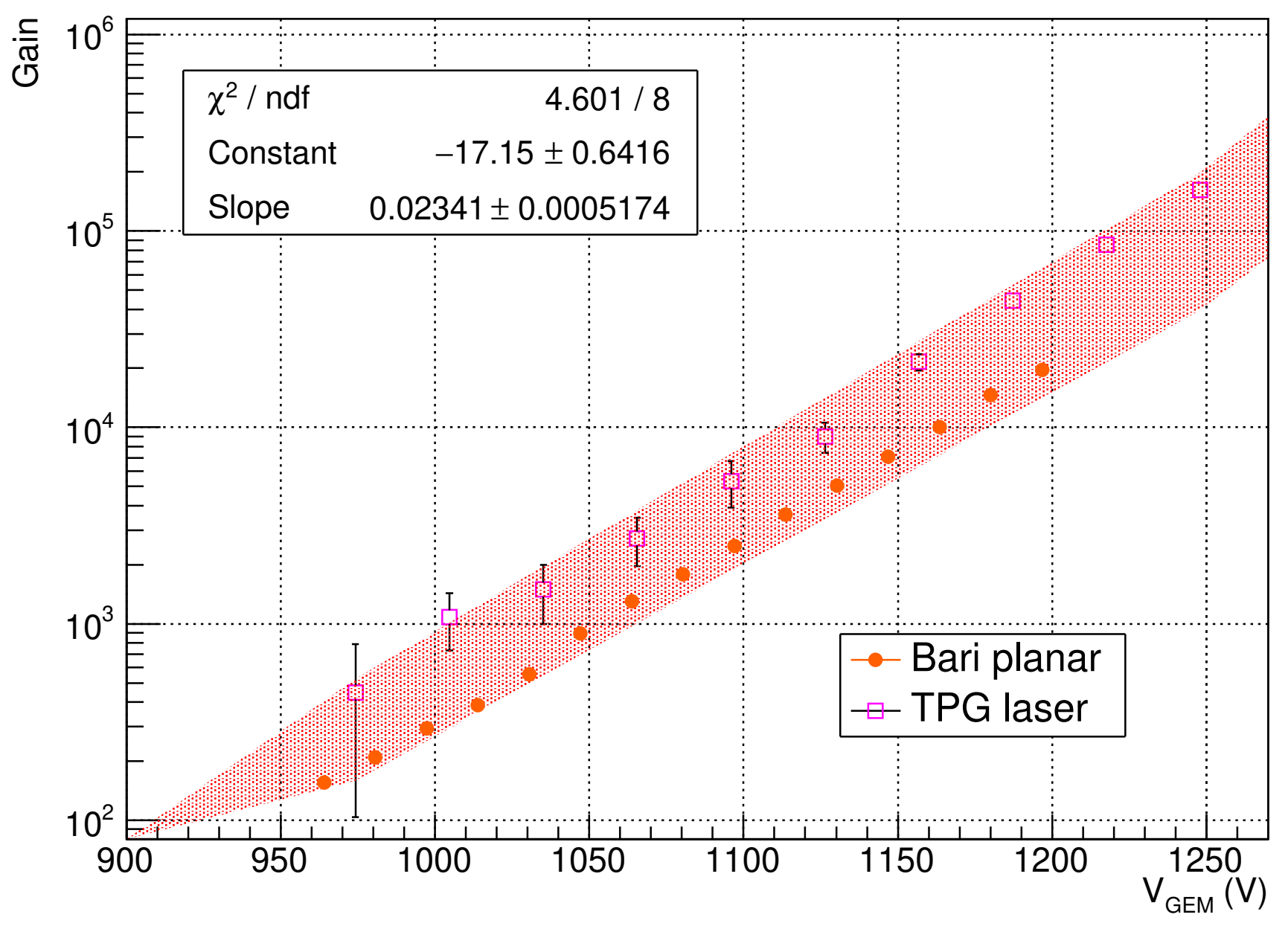
**Low intensity collimated setup** made by a 2f-2f beam expander (magnification 3.75); a pinhole cuts the external part of the wavefront to allow for a sampling at still lower beam energy. The beam radius in the detector (with no pinhole) is 1.5 mm.



**The anode current** vs pulse energy is proportional to the first ionization rate. The fit is compatible with a quadratic dependence (**1.96 ± 0.18**), confirming the dominance of two-photon ionization.

The TPG cannot be operated to read the single-electron signal induced by the laser because the noise overcomes the response of the ASIC preamplifier.





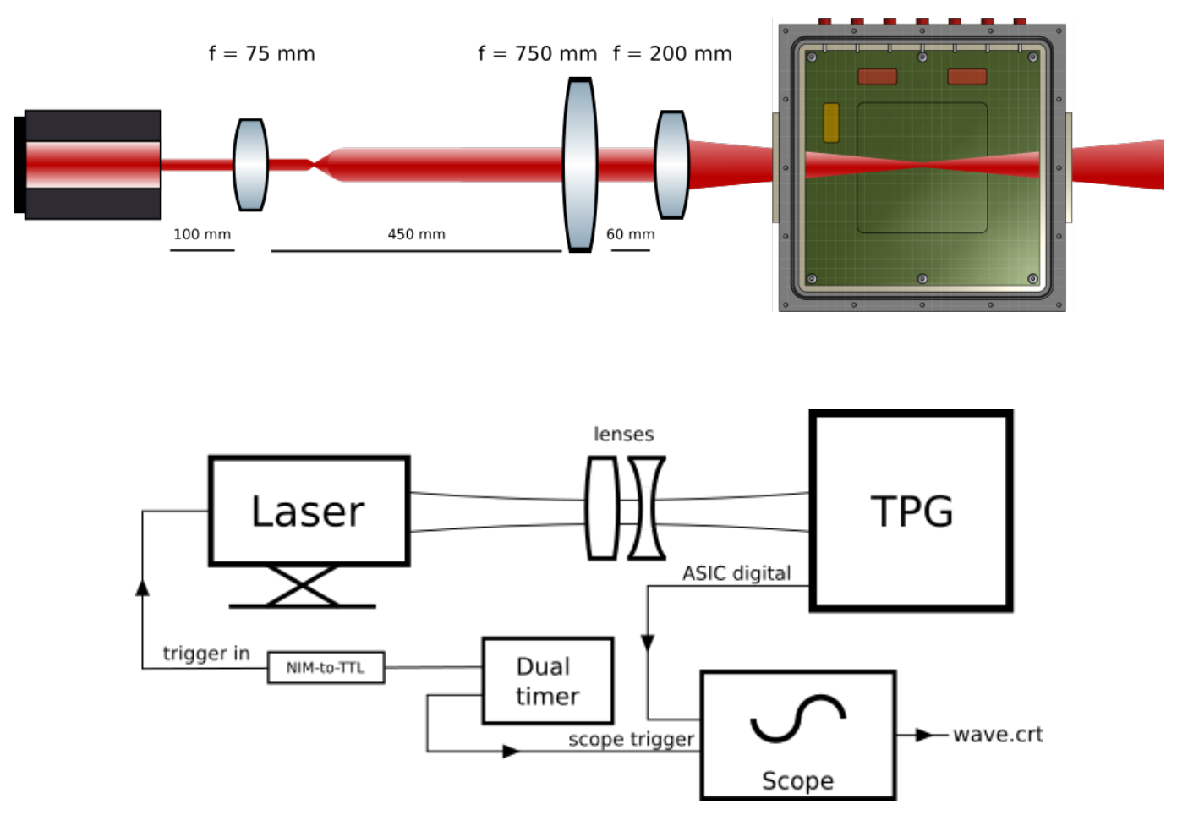
The **counting efficiency** is plotted against the pulse energy. The fitting function is

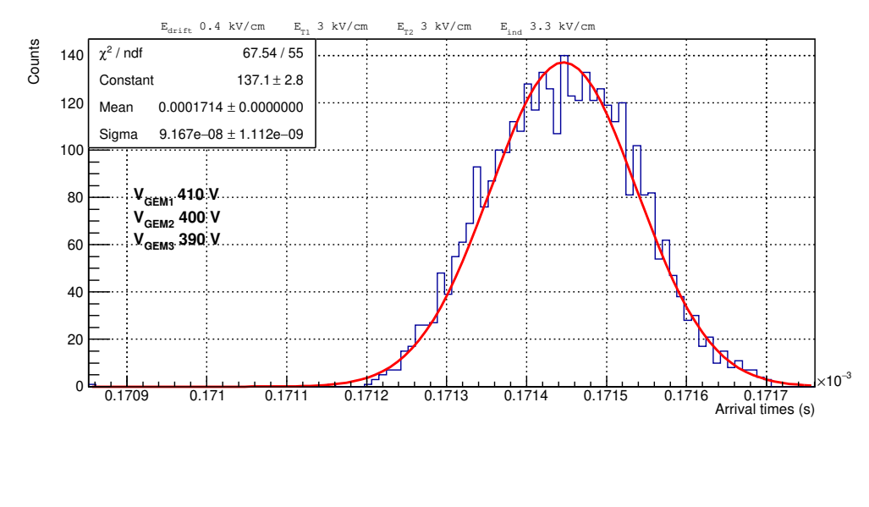
$$\epsilon = 1 - \sum_{n=0}^{n_{th}} \frac{\exp\left[n_0(E/E_0)^2\right]}{n!}\, n_0^n (E/E_0)^{2n},$$

obtained by assuming Poisson fluctuations on the laser ionization. Fixing $E_0$ at 10 µJ, the fit gives $n_0 = 30.7 \pm 0.5$ electrons created by a pulse of 10 µJ.

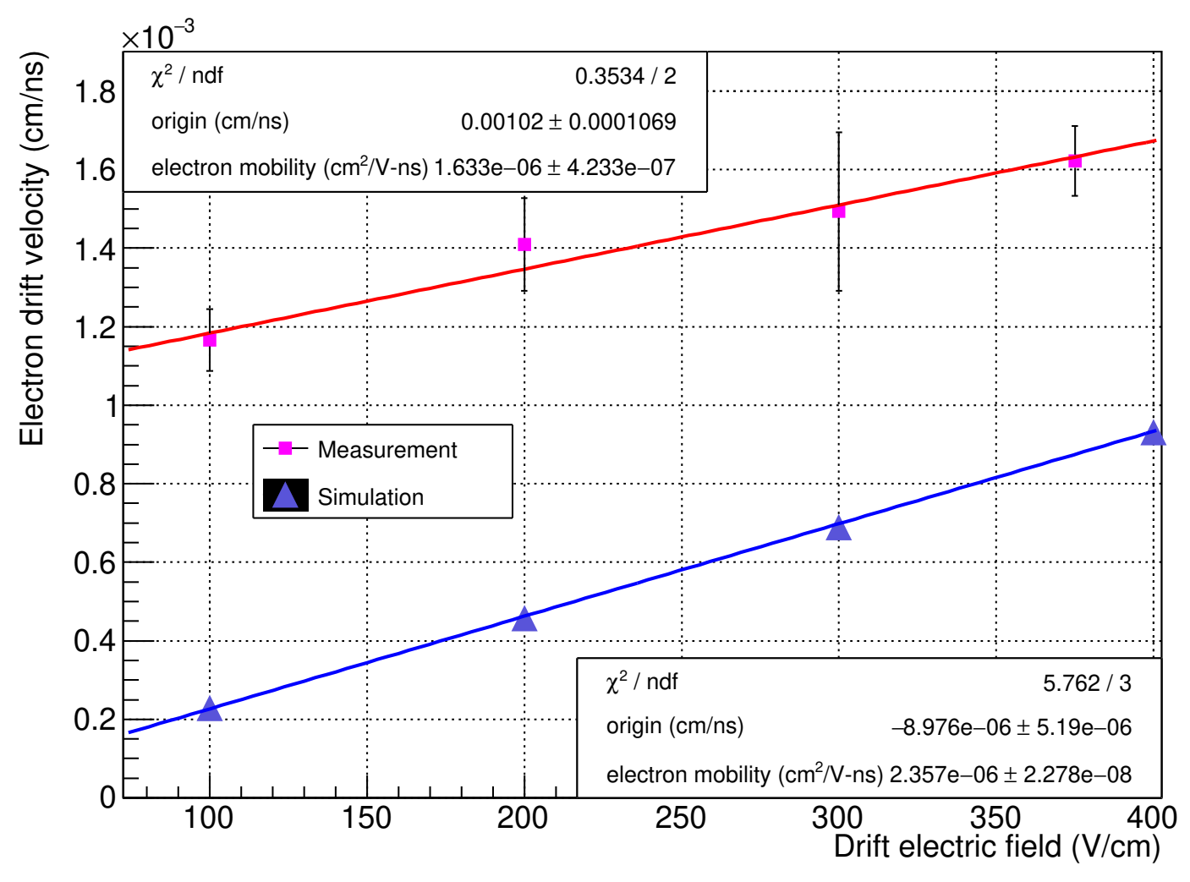
**The gain curve** obtained with the laser is compatible with the results of GE1/1 detectors. Since the ionization current cannot be measured in the TPG due to the small collection efficiency at low GEM voltages, conclusive proof will come from direct primary current measurements on the FTM.

## Timing measurements on the TPG



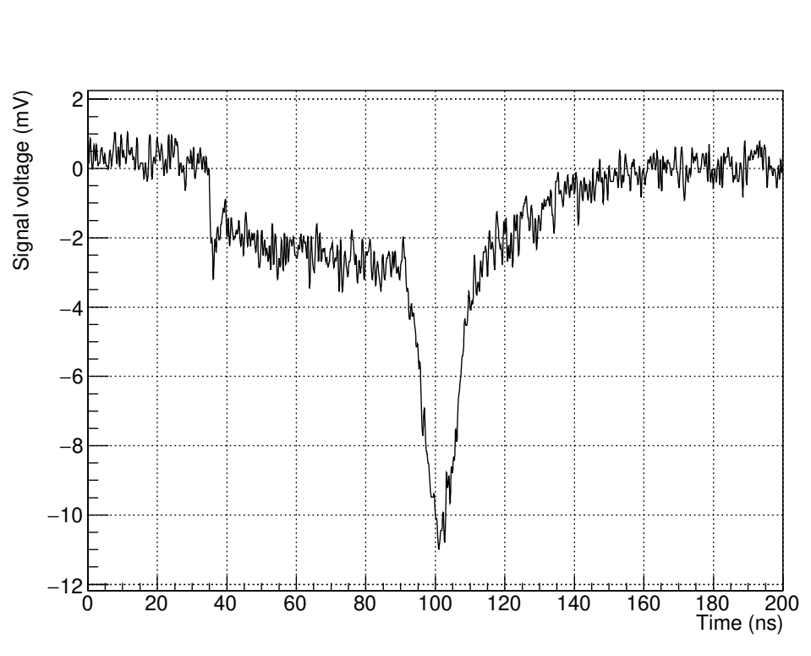


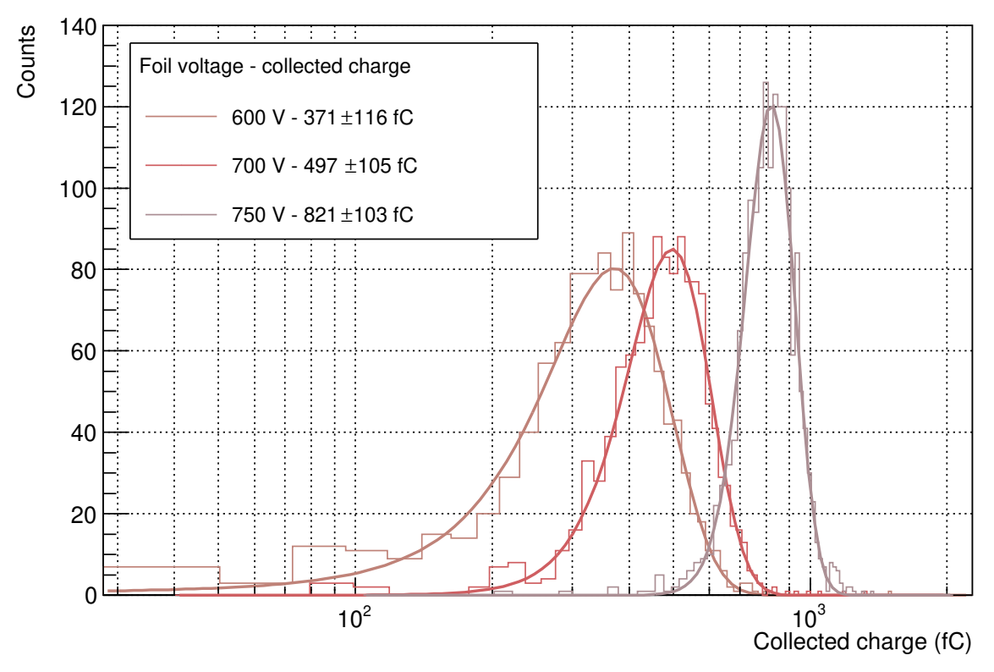
**The electron drift velocity** in the TPG is measured from the average arrival times of the ASIC digital signals with respect to the external laser trigger (controlled by a dual timer at 100 Hz repetition rate). The laser is focused to 23.4 µm in the drift gap and acts as a point-like electron source; the primary ionization position is moved along the z-axis by a millimetric stage.



The **time resolution** measured is $(92 \pm 1)$ ns; the time fluctuations on the whole apparatus may be dominated by laser timing accuracy. The **electron mobility** is $(1.63 \pm 0.42) \times 10^{-6}\,\mathrm{cm^2/V \cdot ns}$, compatible with the `Magboltz` calculation.

## Preliminary FTM test





The **two-stage FTM prototype** has a 5 mm thick drift gap followed by a 50 µm GEM foil. The drift electric field is set to 2 kV/cm and the voltage difference on the foil is raised from 600 to 750 V. The laser beam is focused inside the bottom stage and the signal is read with a 40 dB CIVIDEC amplifier.

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