Experimental determination of GEM avalanche multiplicity distribution

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Outline

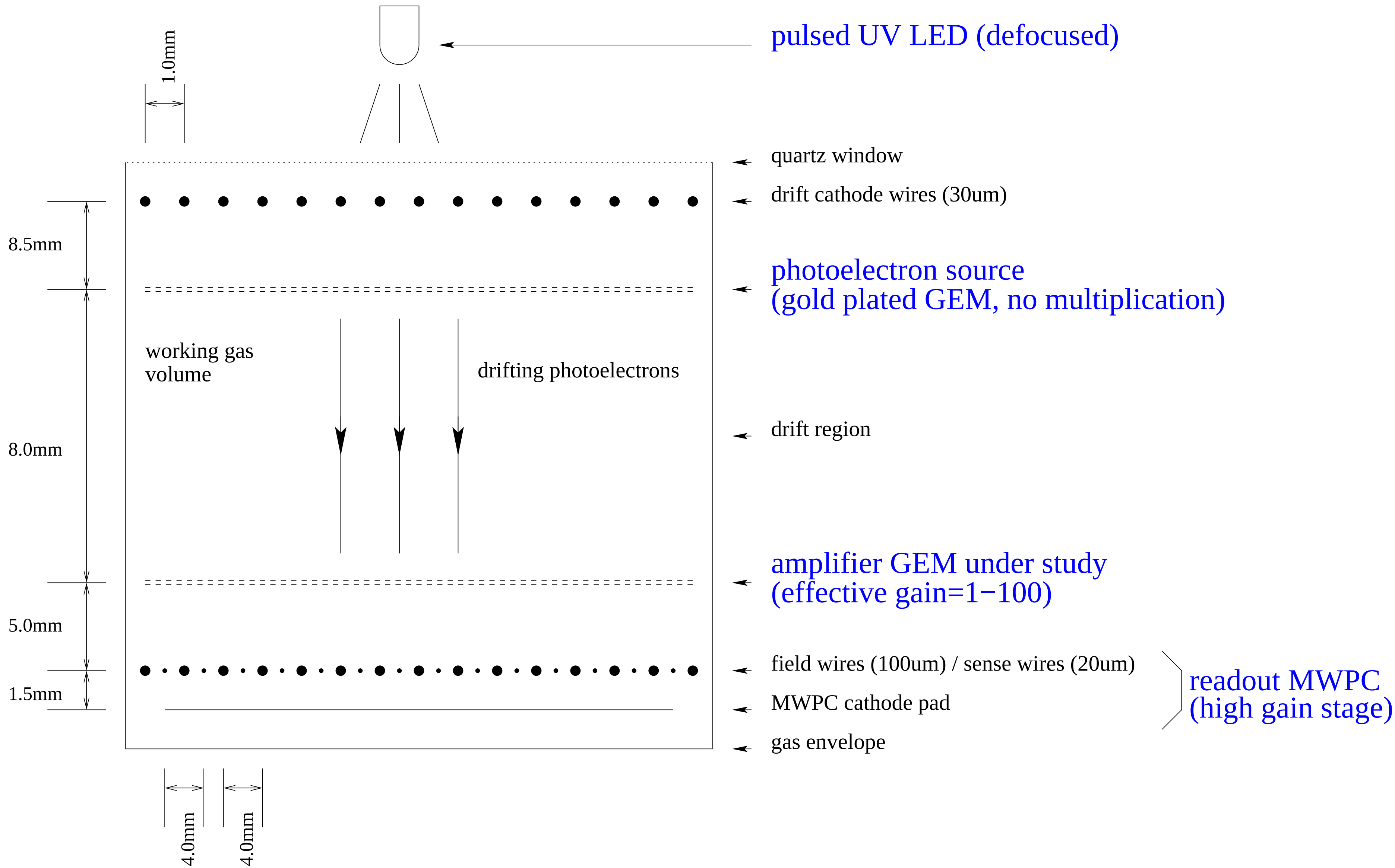
- Introduction
- Experimental setup
- Corrections for systematic effects
- Preliminary results
- Summary

Introduction

- Experimental determination of GEM avalanche multiplicity distribution (gain fluctuations) is an important ingredient for understanding energy resolution.
- Contrary to the case of MWPCs, when the number of avalanche generations is large, strong deviation from the exponential (geometric) distribution is qualitatively expected.
- Studies addressing gain fluctuations in case of Micromegas have been already performed, e.g by T.Zerguerras et al. (NIM **A608** 397, see also talk by T.Zerguerras at RD51 Collab.Meeting at Zaragoza 5-6th July 2013).
- Our aim is to quantitatively determine GEM avalanche multiplicity distribution, in a wide range of effective gains (1-100), with a special emphasis on the low multiplicity tail (deviation from exponential).
- Once determined, can be used in detector design simulations.

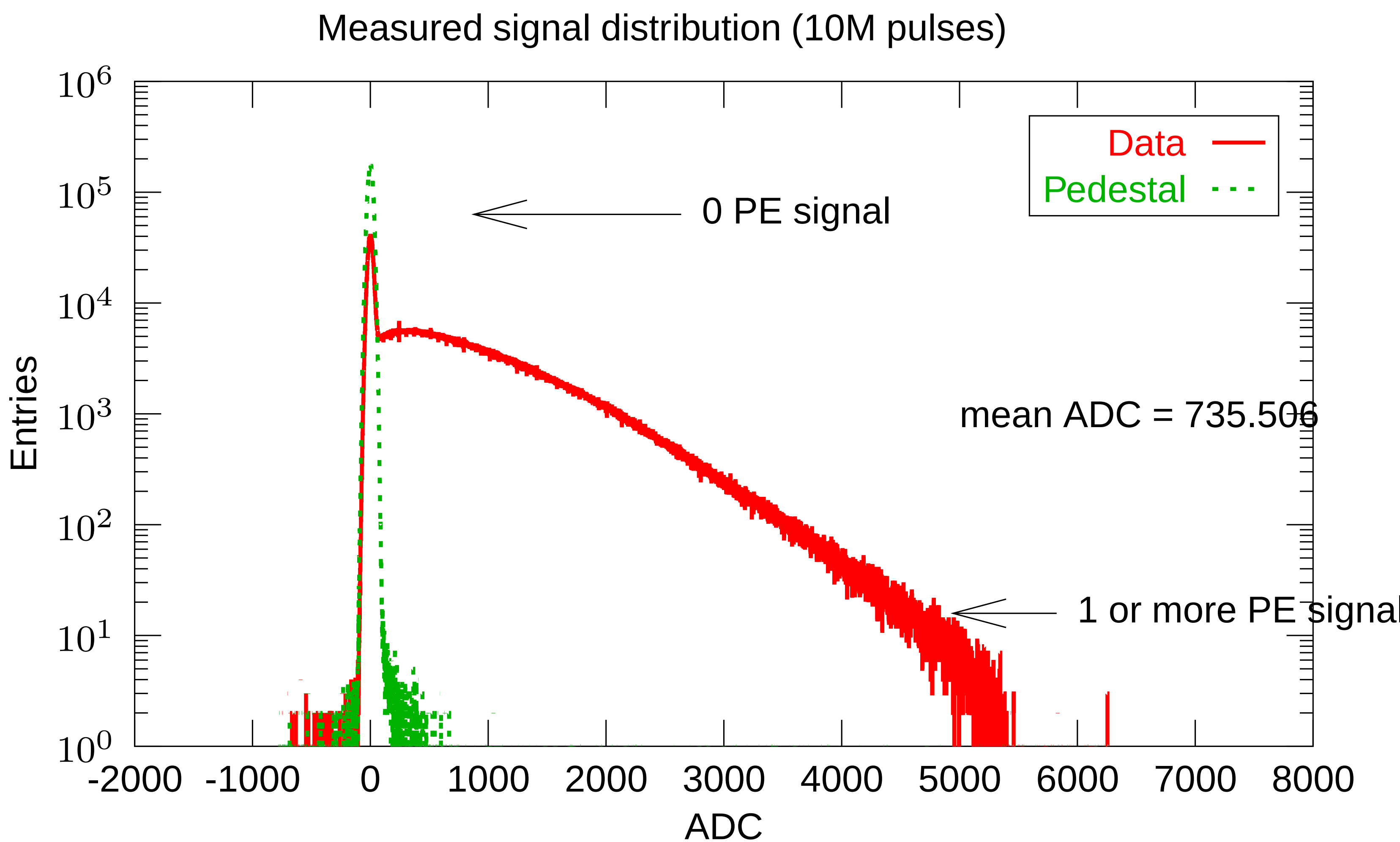
Experimental setup

- Defocused pulsed UV LED used to extract photoelectrons (PEs) from surface of gold plated classic GEM.
- These PEs were transferred to the reverse side, providing a source of laminarly drifting PEs.
- Electron multiplication takes place in a subsequent classic GEM (effective gain 1-100).
- Multiplied electrons enter into an MWPC amplifier region to enhance their signal.
- Electronic FEE amplifier detects the MWPC-amplified signal from sense wires.


pulsed UV LED (defocused)
1.0mm
quartz window
drift cathode wires (30um)
8.5mm
photoelectron source
(gold plated GEM, no multiplication)
working gas
volume
drifting photoelectrons
drift region
8.0mm
amplifier GEM under study
(effective gain=1−100)
5.0mm
field wires (100um) / sense wires (20um)
readout MWPC
(high gain stage)
1.5mm
MWPC cathode pad
gas envelope
4.0mm
4.0mm

- FEE and LED electronics from the Leopard project (NIM **A694** 16).
- MWPC design based on CCC concept (NIM **A648** 163, NIM **A698** 11).
- Due to fast recording, statistics of 10M pulses were recorded for each setting. (Negligible statistical errors, systematics dominated measurement.)
- Various working gases – Ar(80)CO_2(20), CH_4(100), Ne(90)CO_2(10) – were studied.

Amplitude distribution from direct measurement for typical data (PE yield $\approx 1.5/$ event):



Corrections for systematic effects

In this simple experimental setup several detection distortion effects can occur.

- *Multi-PE contributions* must be disentangled whenever large PE yield (ν) is used to enhance signal-to-background ratio.
  That can be done in mathematical way!

  If f were the distribution of amplitude response of the system for a single injected PE

  $$g = \sum_{n=0}^{\infty} f^{(n\text{-fold convolution})}\, P_\nu(n)$$

  would be the measured signal distribution of the full system.
  Here P_ν is the Poisson distribution of PE yield.

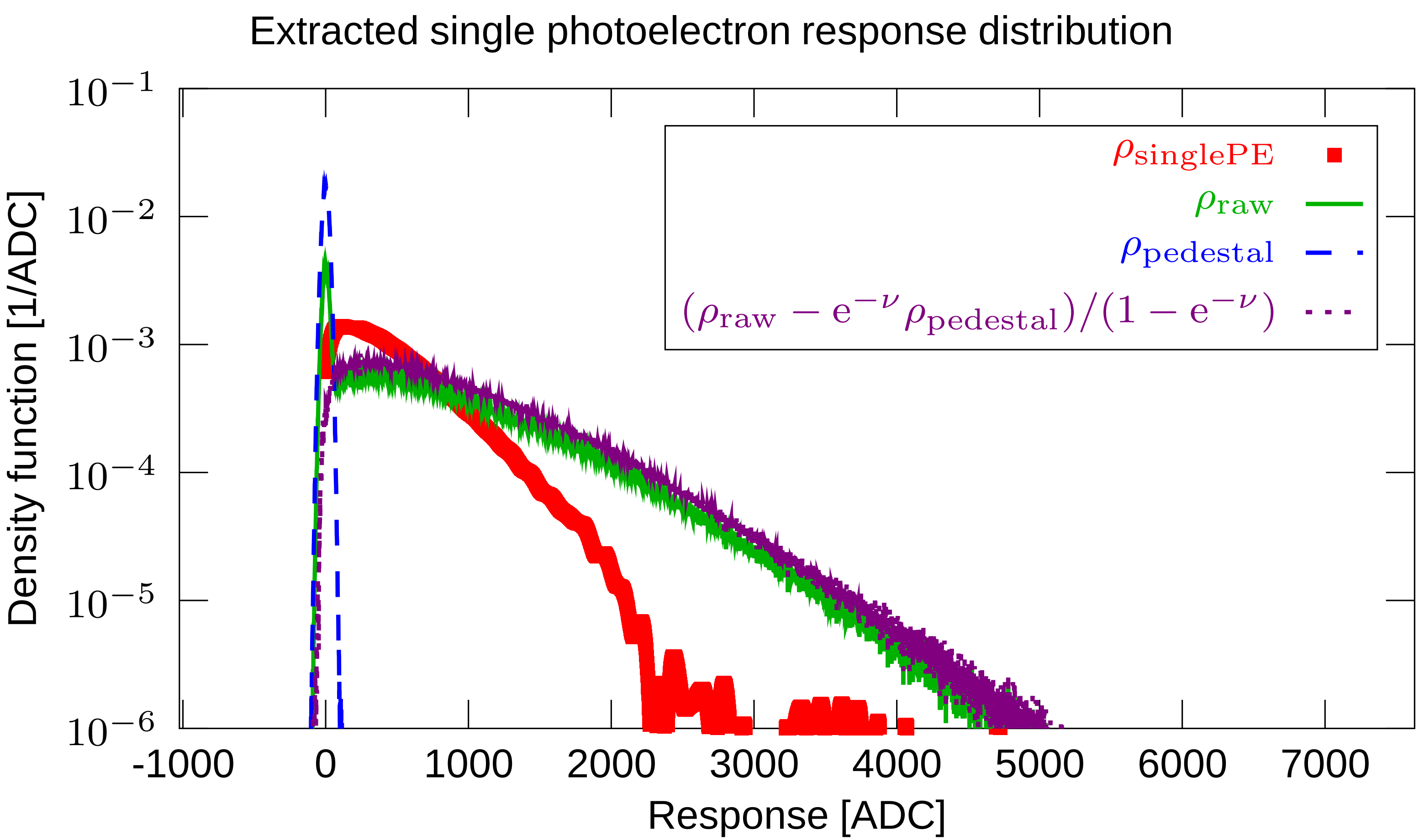
  In Fourier space this composite distribution simplifies to

  $$G = \exp\left(-\nu\left(1 - F\right)\right)$$

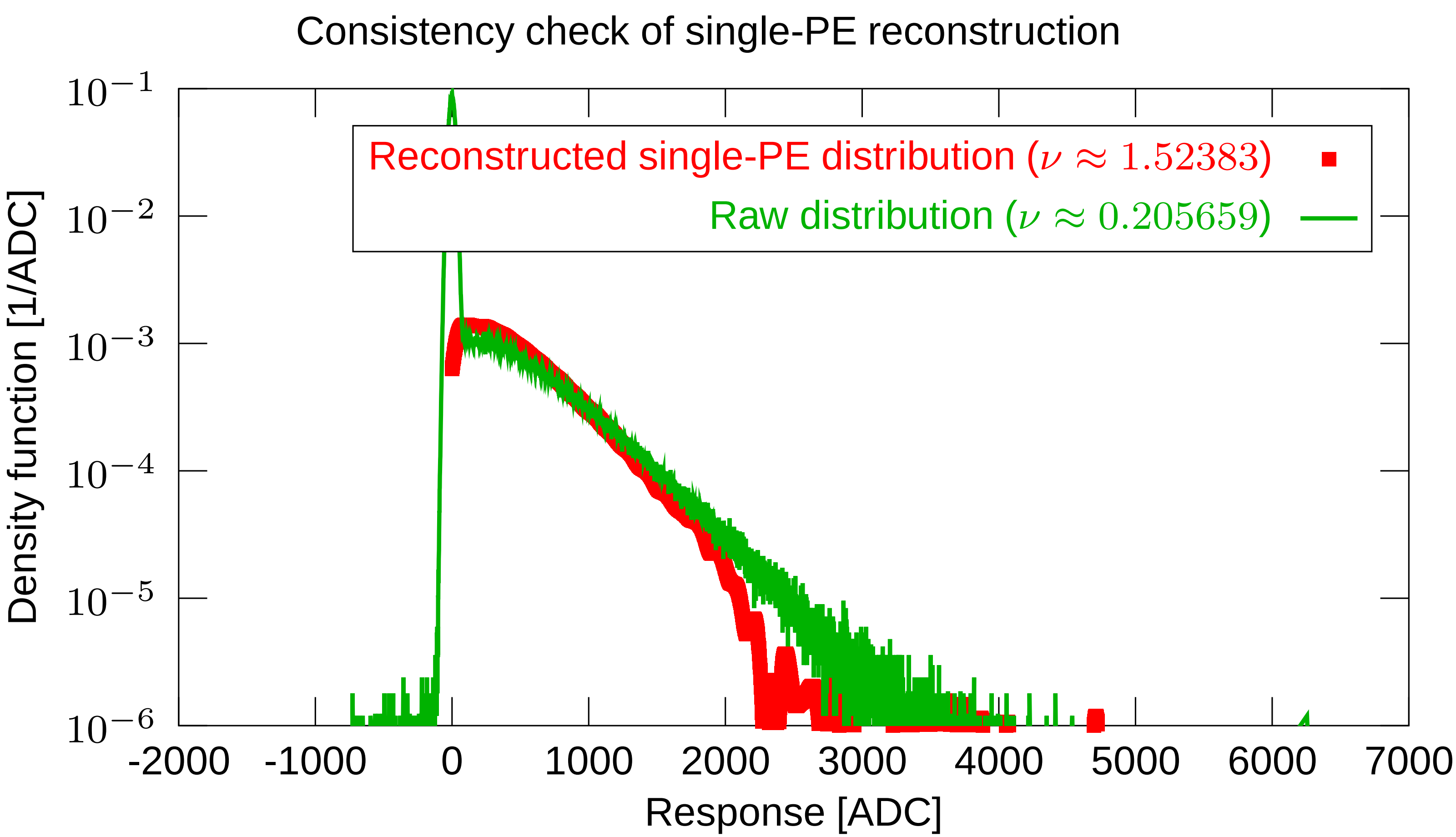
  where F,G is Fourier transform of f,g.

  Asymptotic value of G determines PE yield ν, and given ν the Fourier transform F of f can be reconstructed from G. Thus f can be reconstructed from measured g.

Amplitude distribution after single-PE reconstruction (PE yield ≈ 1.5):



Consistency with the low PE yield (≈ 0.2) measurements:



Correction to naive measurement is not large but visible.

Method provides clean measurement of the low amplitude region.

- *MWPC response function* must be unfolded, whenever small number of electrons is to be counted.
This can be done in mathematical way!

If p were the GEM multiplicity distribution

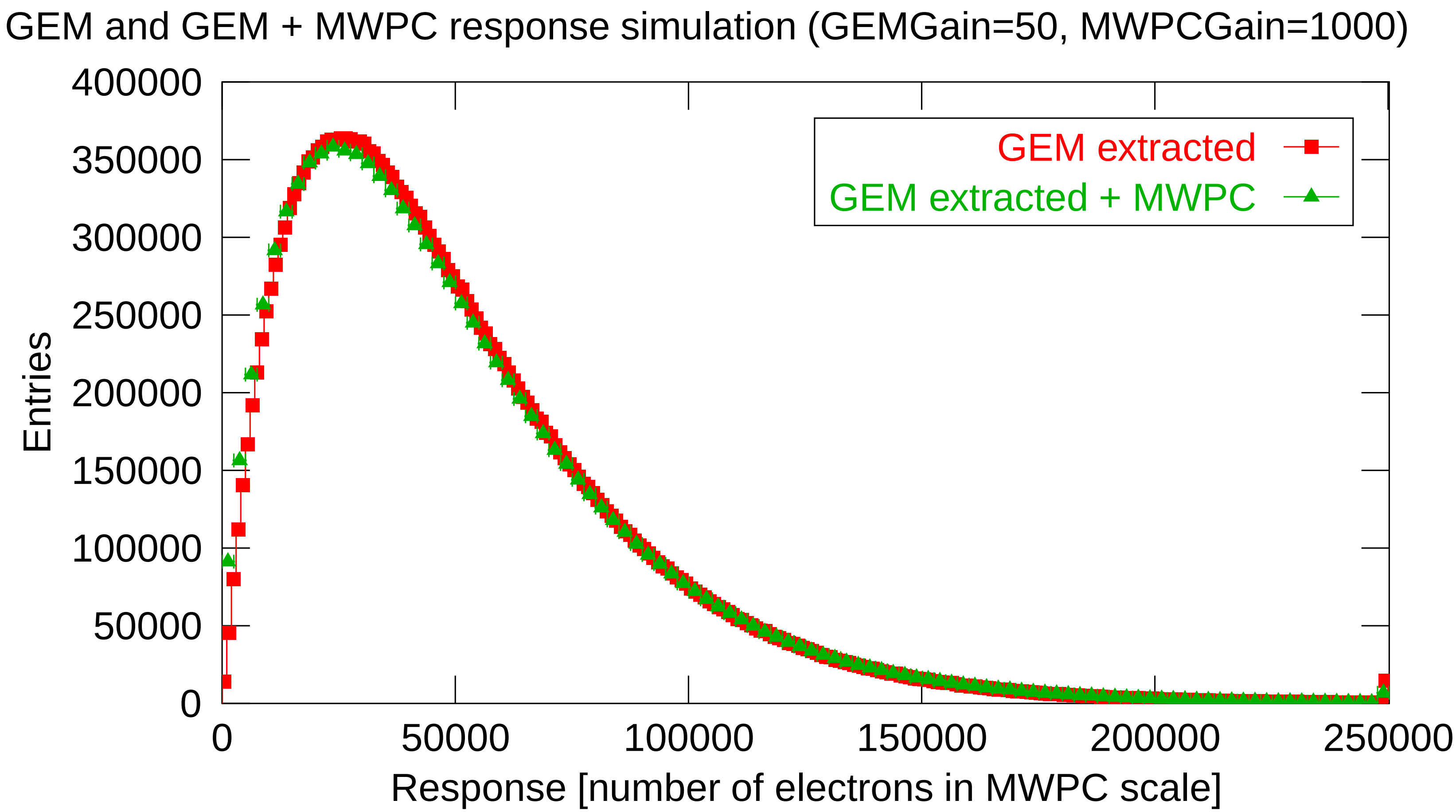
$$f = \sum_{k=0}^{\infty} \mathrm{e}_{\gamma}^{(k\text{-fold convolution})}\; p(k)$$

would be the measured MWPC response.
Here e_{γ} is the exponential distribution with slope γ (MWPC response with gain γ).

Determination of p is an unfolding problem.

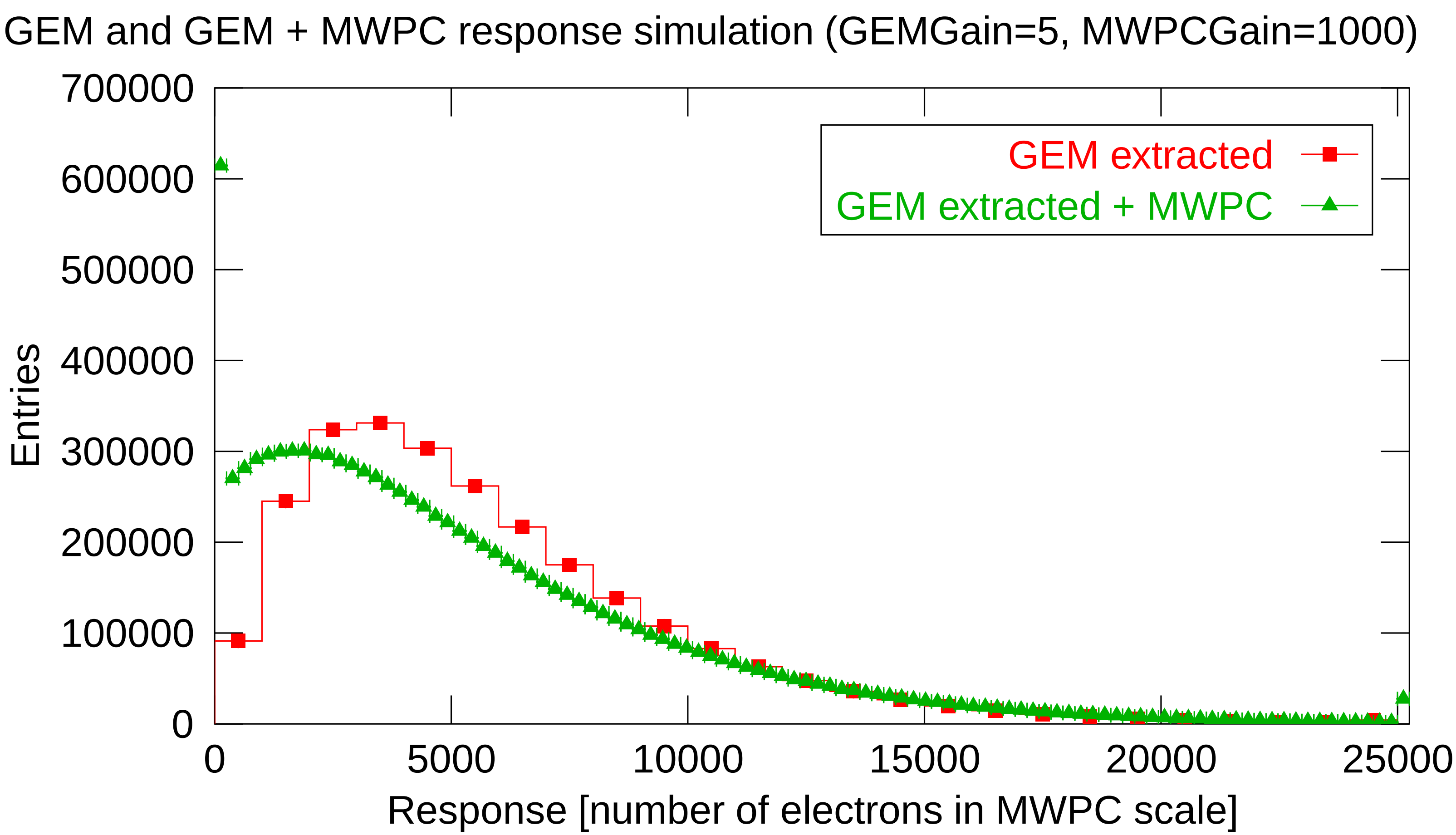
Remark: if p were geometric distribution, f would be exponential (analytically seen).

Simulation of MWPC response to a hypothetical GEM multiplicity distribution p:



At larger GEM effective gains (≈ 50), MWPC does not make large shape distortions.

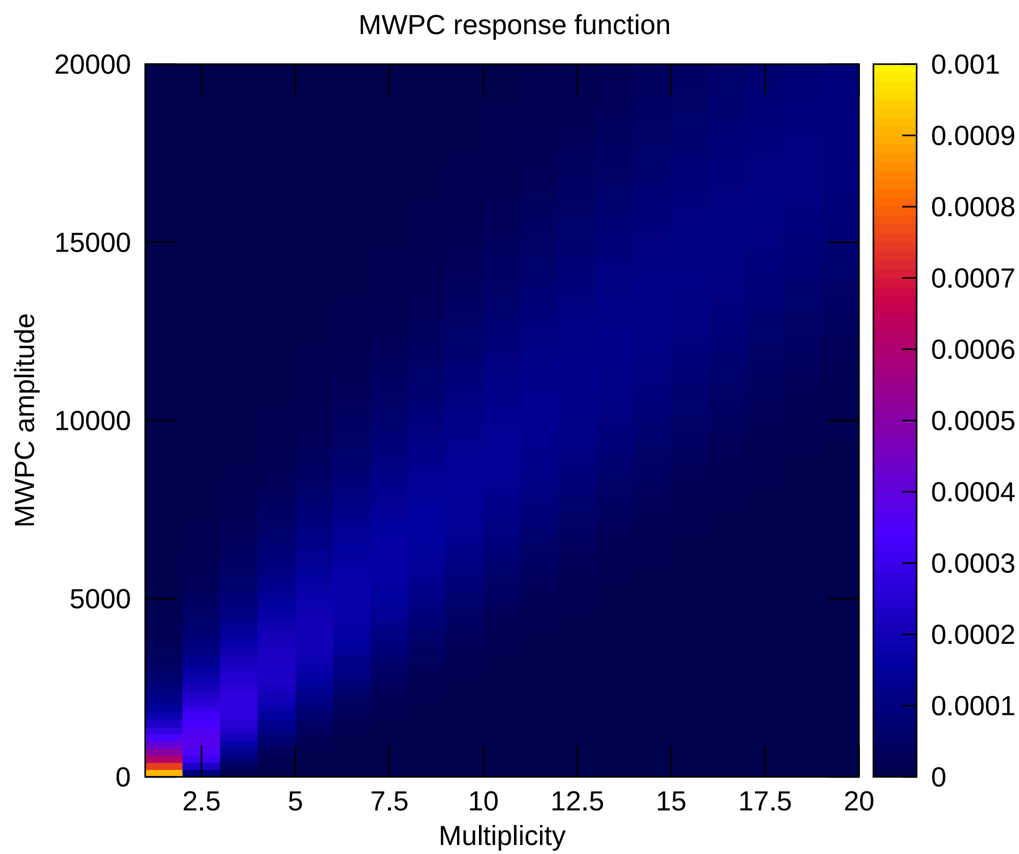
Simulation of MWPC response to a hypothetical GEM multiplicity distribution p:



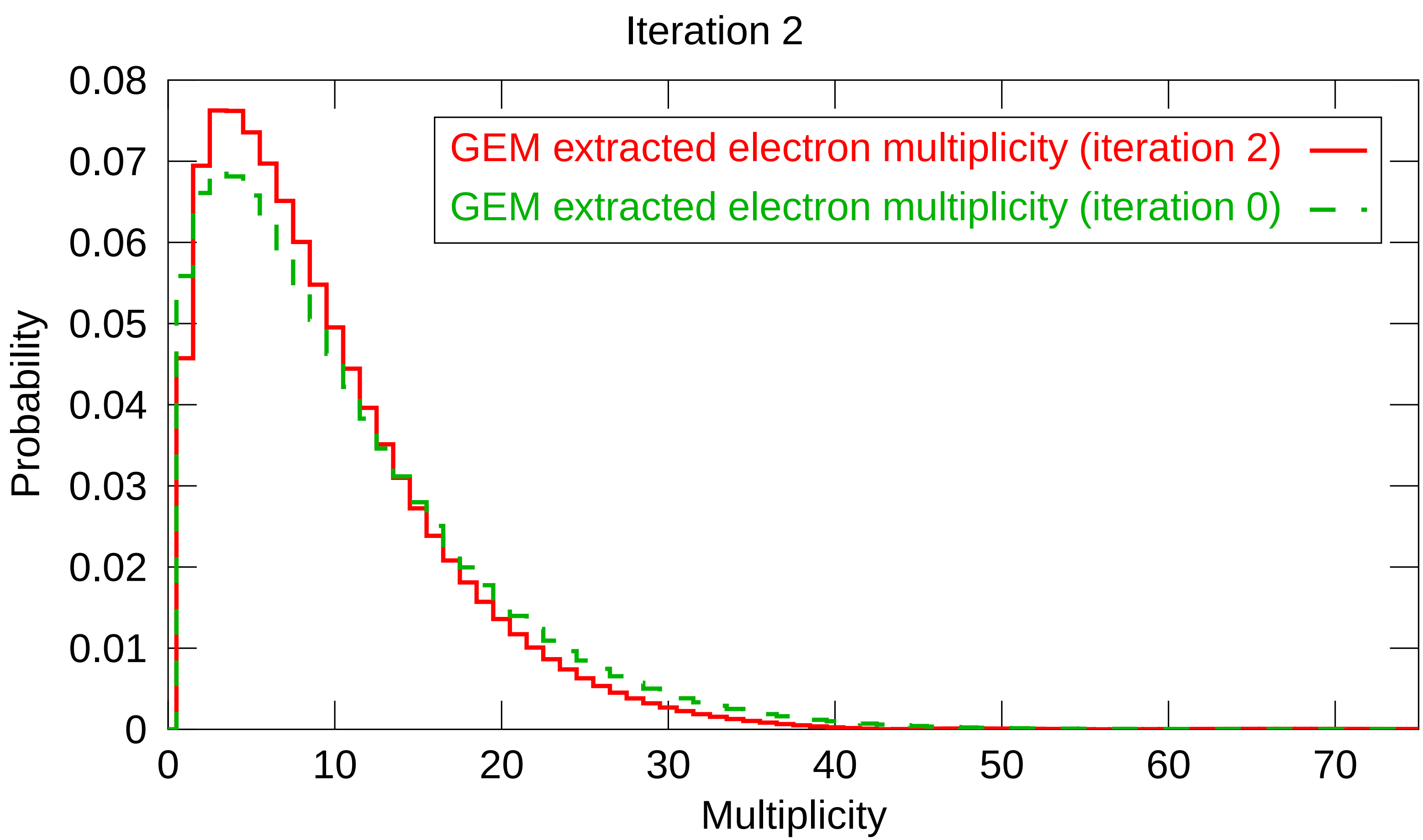
Seemingly even at this low GEM effective gain (≈ 5), response may be still extracted!

Negligible MWPC distortion effect for large number of electrons extracted from GEM.
Pronounced MWPC distortion effect for low number of electrons extracted from GEM.

Possible to solve the problem in mathematical way: JPCS **368** 012043, `arXiv:1404.2787`.
This involves an iterative unfolding, where the actual response matrix is of the form:

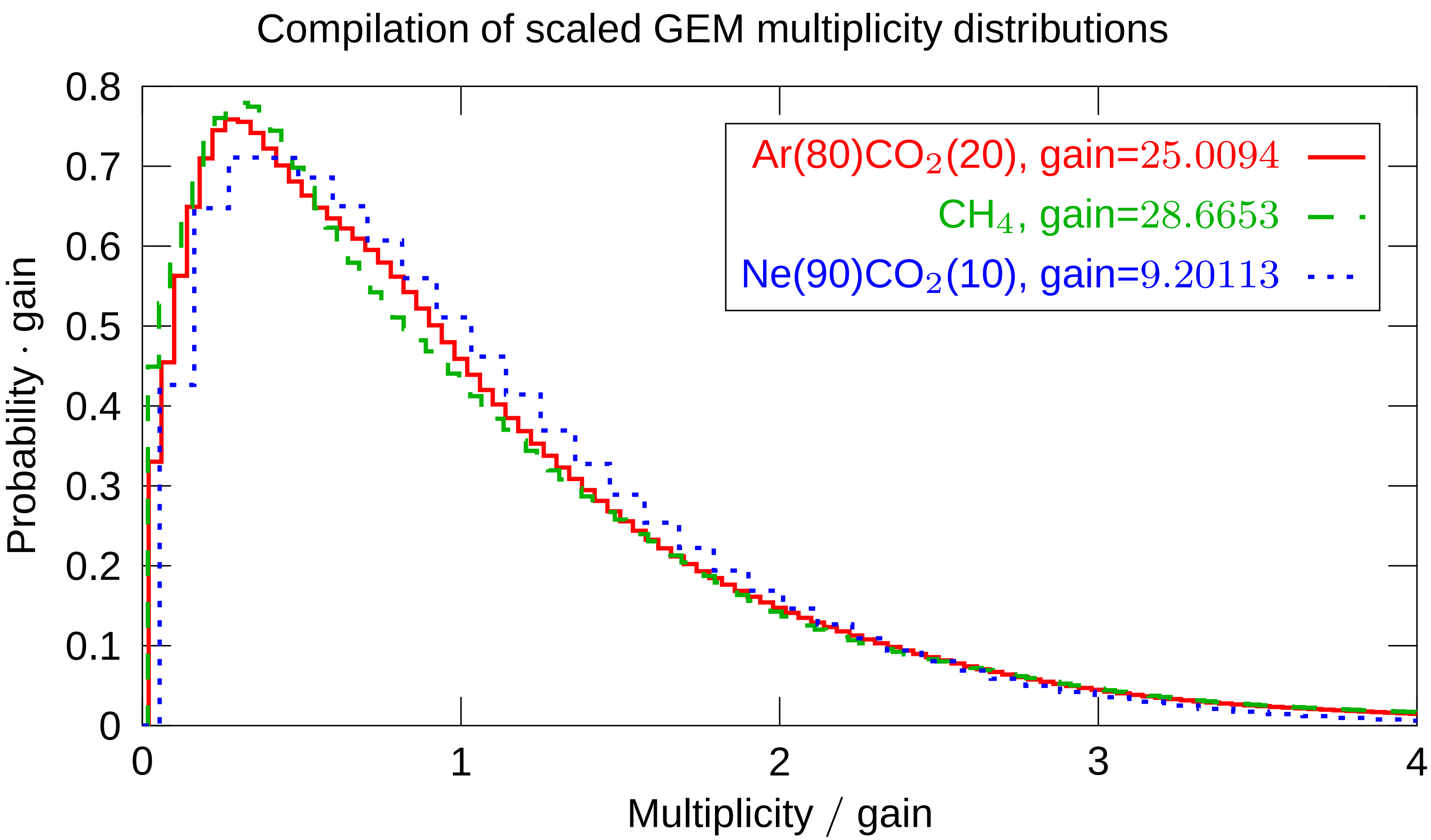


Iteration converges quite fast for the MWPC unfolding problem.



Example result in Ne(90)CO2(10), with GEM net effective gain of 9.2.

Preliminary results



Preliminary results show that shape of GEM multiplicity distribution is approximately independent of working gas and the effective gain.

Summary

- An experimental setup and methodology was developed for determination of the multiplicity distribution of GEM-multiplied electrons.
- Apparatus and methodology was designed specially for the coverage of wide ranges of effective gain (1-100) as well as for direct measurement of the low multiplicity tail of the distribution.
- Experimentally measured multiplicity distribution shows deviation from exponential at low multiplicities.
- Preliminary results on universal properties of the shape of the multiplicity distribution in different gases and at different GEM effective gains.