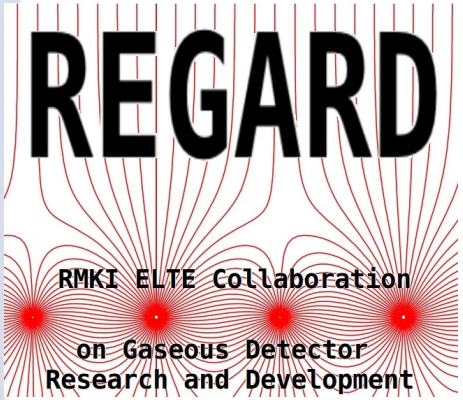
Single electron avalanches in GEM



Gábor Kiss for the REGARD group
Eötvös Loránd University &
Wigner RCP, Budapest

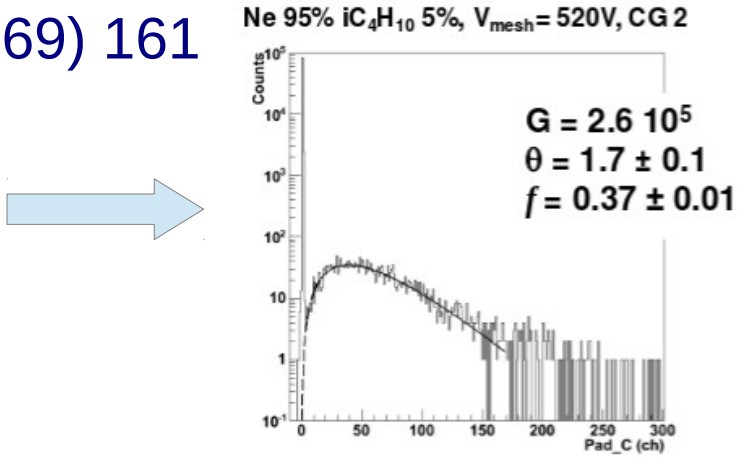
RD51 Collaboration Meeting CERN,
June 19, 2014

Outline

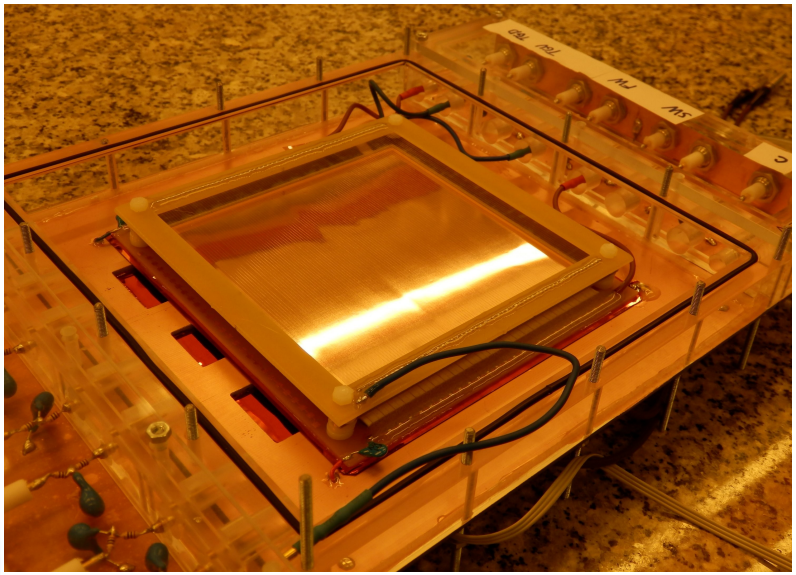
- Motivation
- Detector concept and measurement setup
- ADC nonlinearity calibration
- Single electron avalanche distributions in different gases
- Single electron spectra
  - Direct measurement and Fourier methode
- Summary and outlook

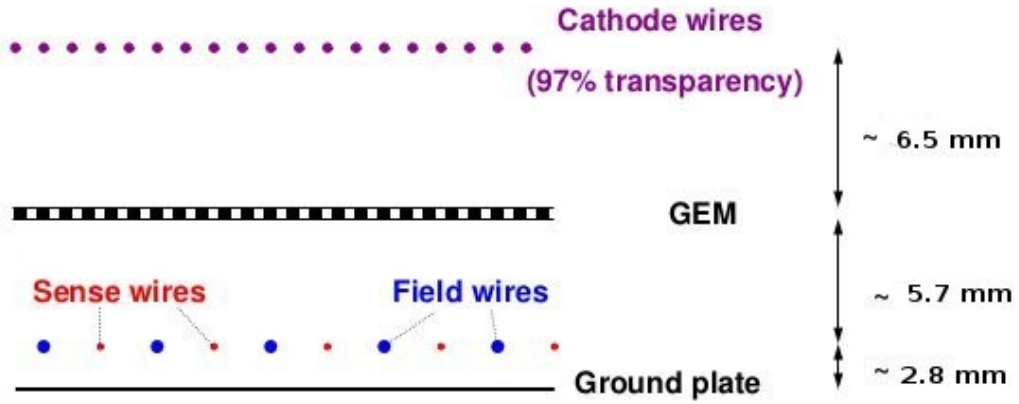
Motivation

- Avalanche fluctuation contributes to energy resolution
- Relevant in single photon counters (RICH)
- Gain fluctuation in MWPC:
  Alkhazov: NIM 89 (1970) 155, NIM 75 (1969) 161
- „New results on gas gain fluctuations in a Micromegas detector”
  (T. Zerguerras, RD51 Collab Meeting in Zaragoza, 2013)
- GEM gains are relatively low
  → hard to measure on a single GEM

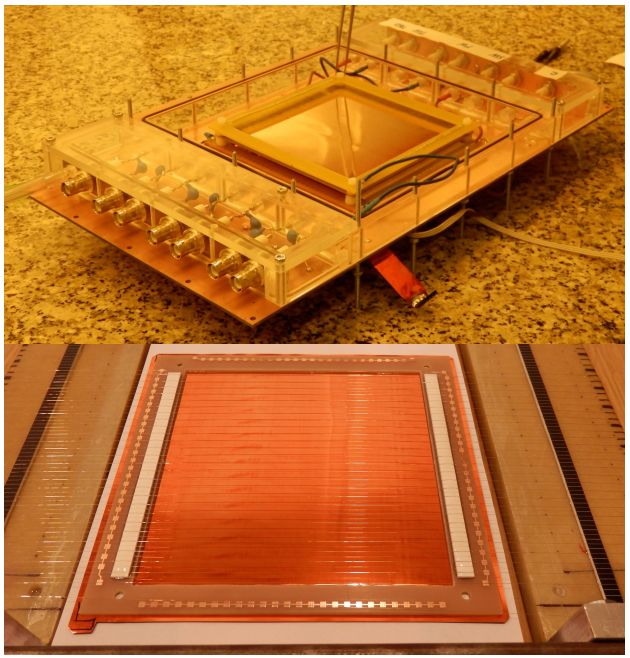


Detector concept

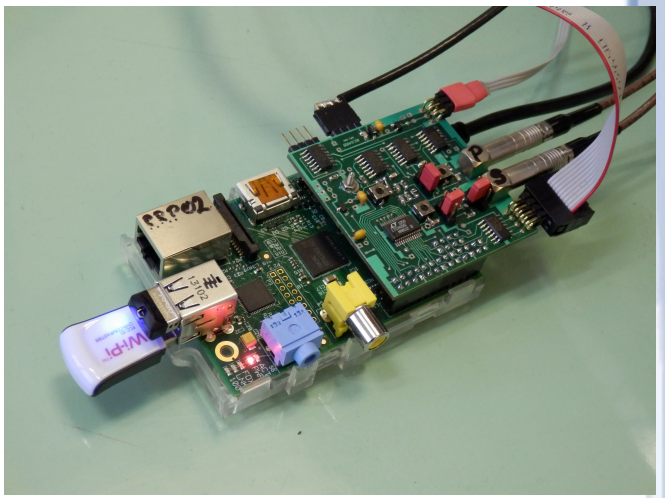




- Measurement principle: single PE induced by pulsed UV
- GEM+CCC (wire chamber)
- Standard GEM made @ CERN
  (50/70μm diameters, 140μm pitch, 50μm thick)
- Standard CCC with 21μm and 100μm wires

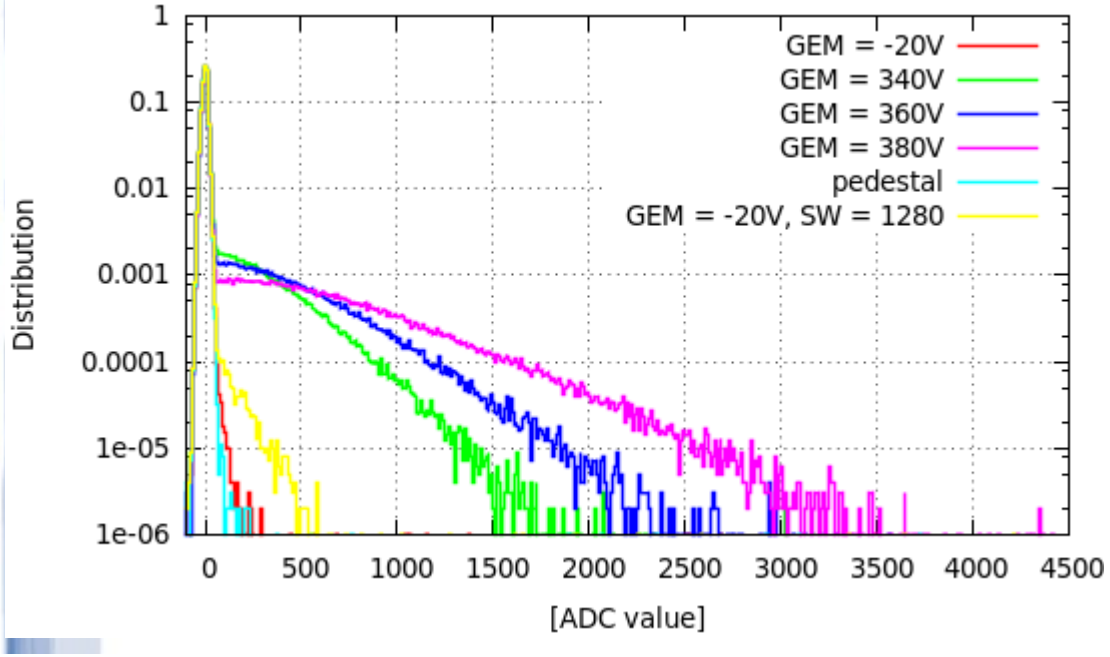


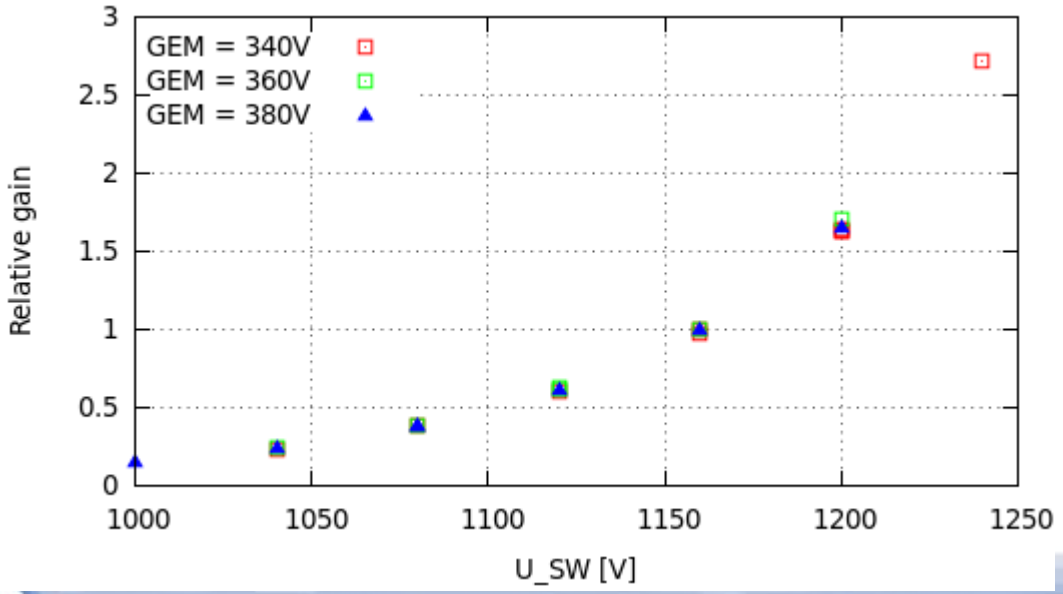
Measurement setup



- Ar-CO_2 (80:20), Ne-CO_2 (90:10), CH_4
- Pulsed UV LED source (SETI UVTOP 240)
  - Intensity tuned to have <<1 PE/event
- Signal from connected sense wires
- DAQ: 12bit ADC controlled by a RaspberryPi
- Leopard-style non-focused LED
  - see G. Hamar's „The Leopard system” talk (RD51 Common Project Status Report, 02/2014)
- Data taking @ 20kHz to avoid signal overlapping
- 1M events per run

Pulse height distribution

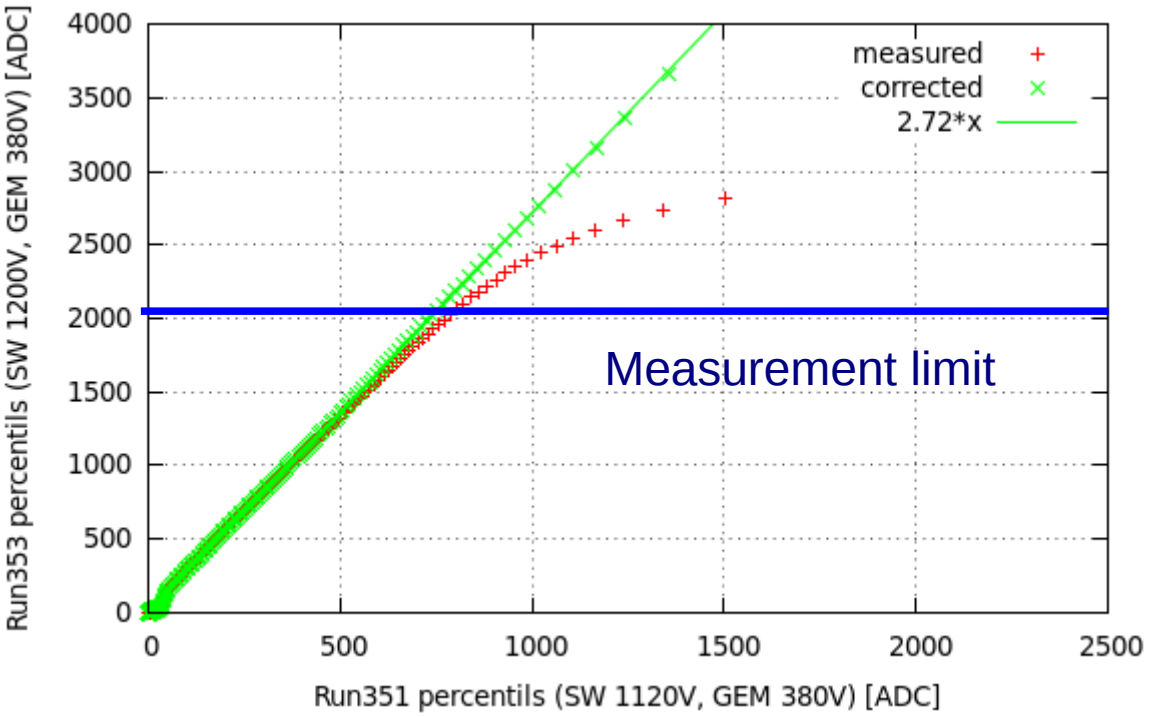




- 2 amplification stages:
  - GEM (10-50)
  - Wires (10^3 - $4*10^4$)
- Single PE distributions at different voltage setups
- Distribution is dominated by the first amplification stage
- Exponential distribution for wire gain
- Clearly not exponential for GEM
- Factorization of Wire and GEM gains
- Electronics linearity?

ADC nonlinearity correction

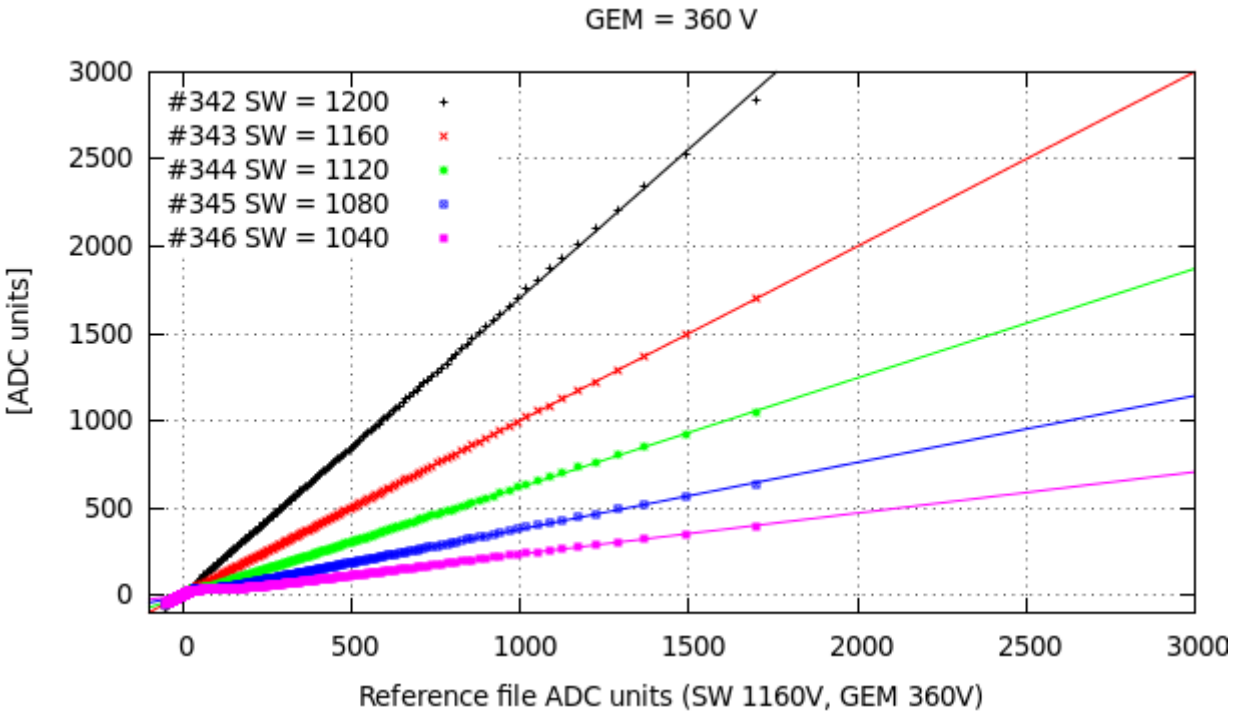
- **Need for high effective dynamic range**



- A small effect in the measured region
- Same GEM gain
- Nth Percentil vs. Nth percentil:
- Slope
  → relative gain

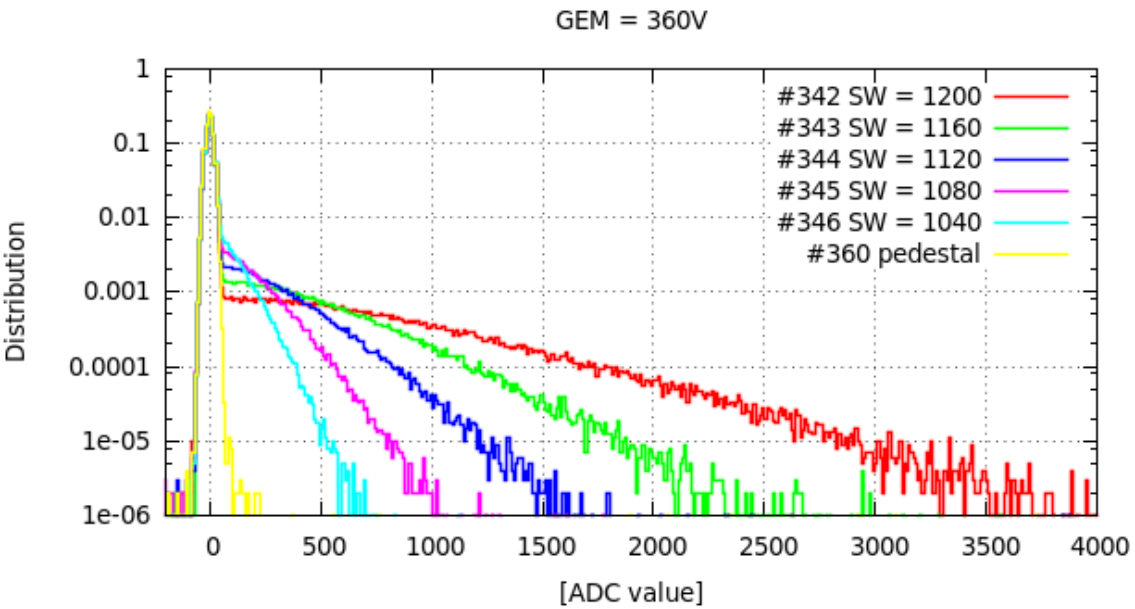
- Corrected ADC values = f(measured ADC values)
  where f(x) is polynomial

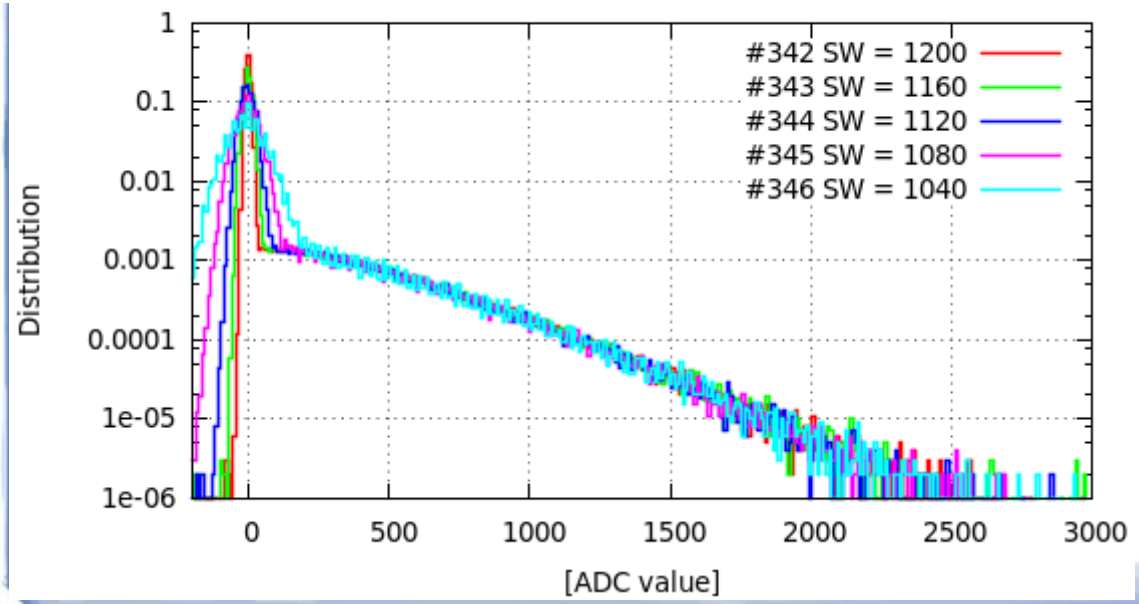
ADC nonlinearity correction



- Successfull correction over the whole range

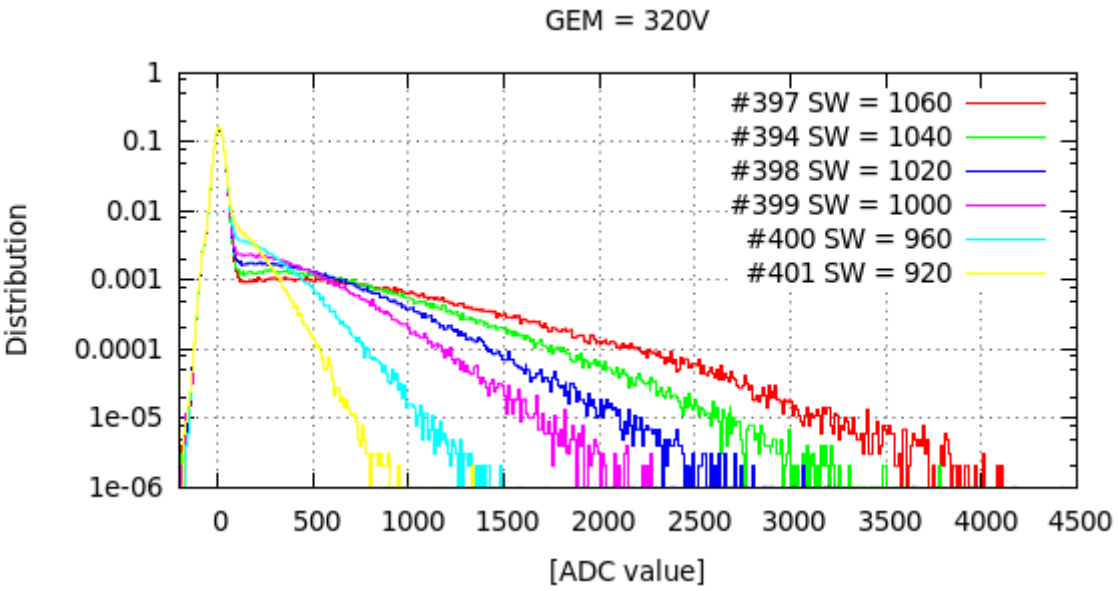
Avalanche distribution in Ar-CO_2

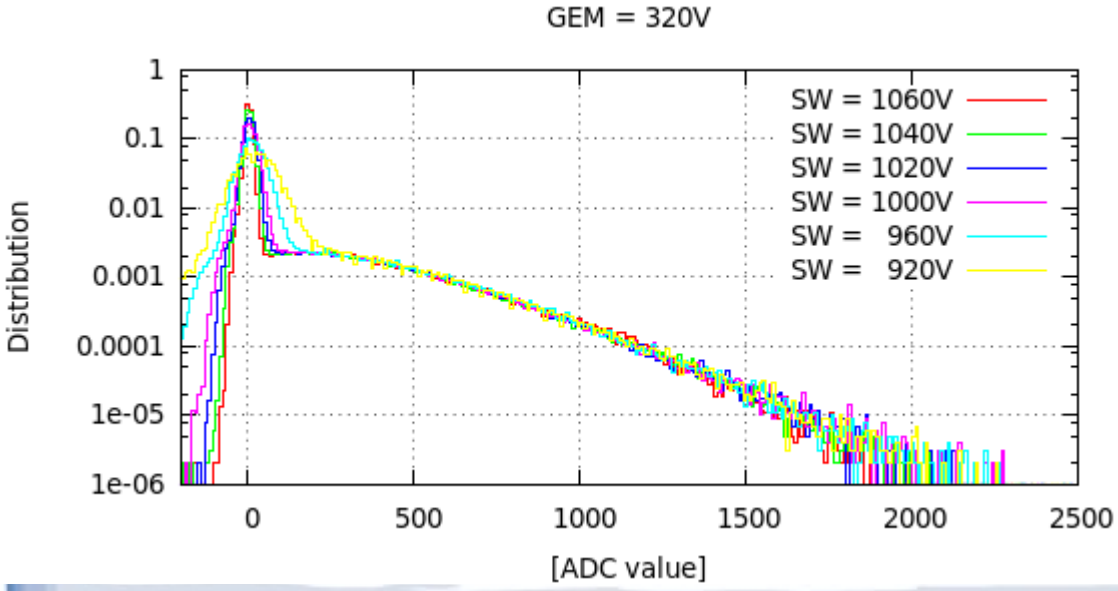




- U_{GEM} = 360V (gain: ~15)
- The gain on the wires does not change the shape of the avalanche distribution
- Similar results for other GEM gains (10-50)

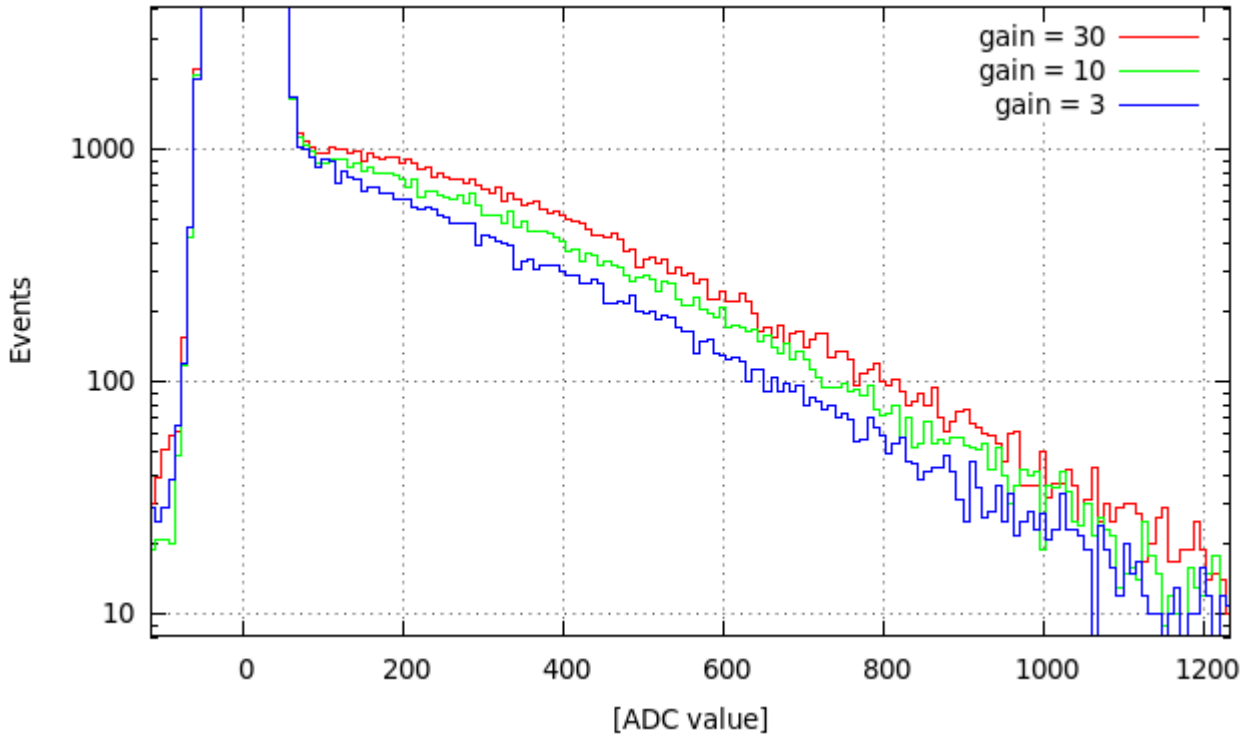
Avalanche distribution in Ne-CO_2





- Similar results in Ne-CO_2
- GEM Gain: ~15
- Note: even stronger non-exponential shape!

Avalanche distribution in methane



Extracting single electron response in GEM

Measured signal:

(1) Poisson statistics of PE

(2) Avalanche fluctuation in GEM

(3) Extraction from GEM

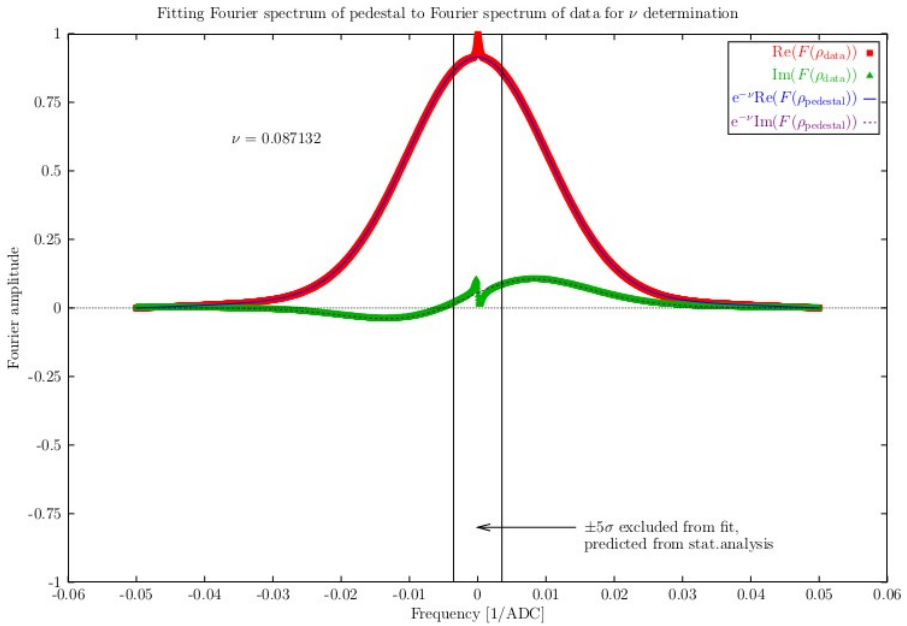
(4) Avalanche on MWPC

} → Large effective GEM gain supresses the distortions

PE Poisson statistics unfolding (A. László)

$$g = n * \sum_{k=0}^{\infty} f^{*(k)} P_\nu(k), \quad \text{Fourier transformation} \rightarrow \quad G = N \sum_{k=0}^{\infty} F^k P_\nu(k),$$

- g: measured probability distribution function
- n: electronic noise distribution (easily measurable with a pedestal run)
- **f: unknown single electron avalanche response distribution**
- P_v (k): per trigger PE emission with expectation value v (Poisson)



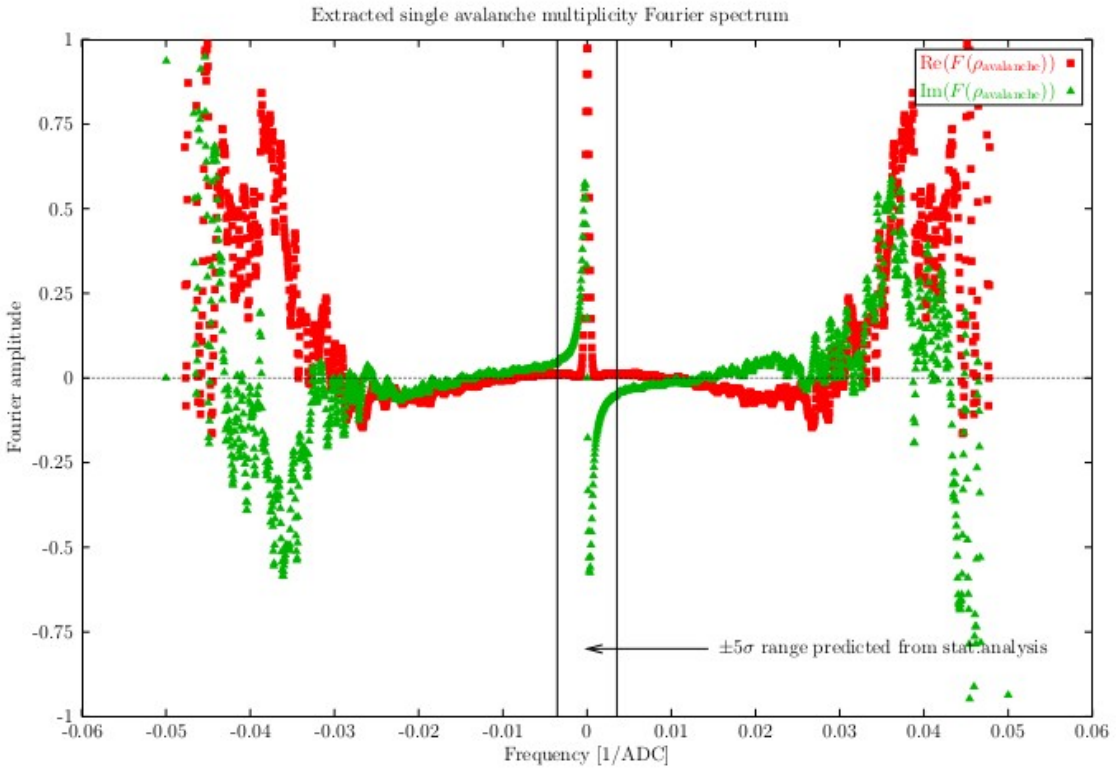
$$G = N \sum_{k=0}^{\infty} F^k \frac{\nu^k}{k!} \mathrm{e}^{-\nu} = N \exp\left(\nu\left(F-1\right)\right).$$

$$F = \frac{1}{\nu} \ln\left(\frac{G}{N}\right) + 1$$

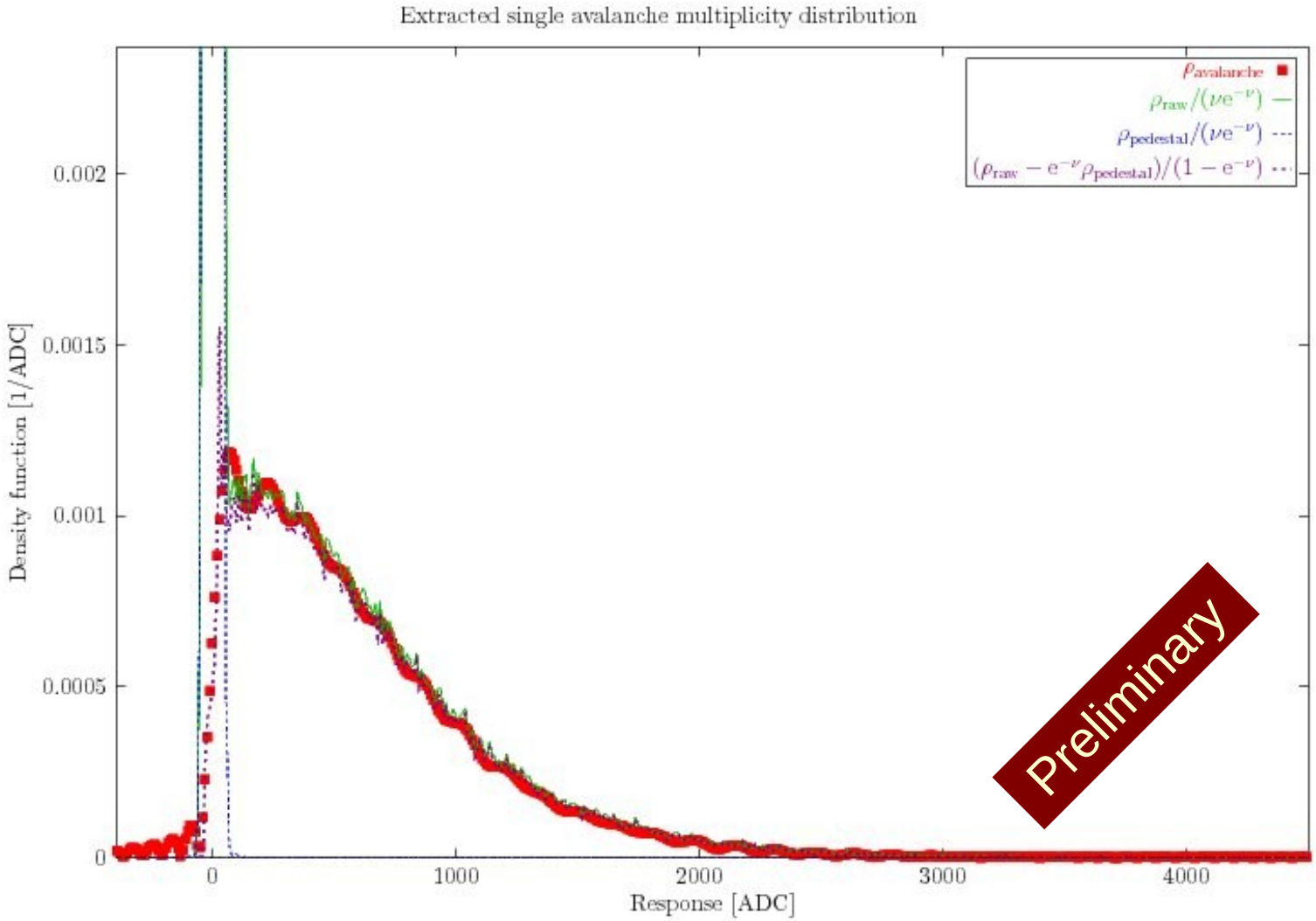
where: $G \approx N \exp\left(-\nu\right)$ (for large frequencies).

PE Poisson statistics unfolding

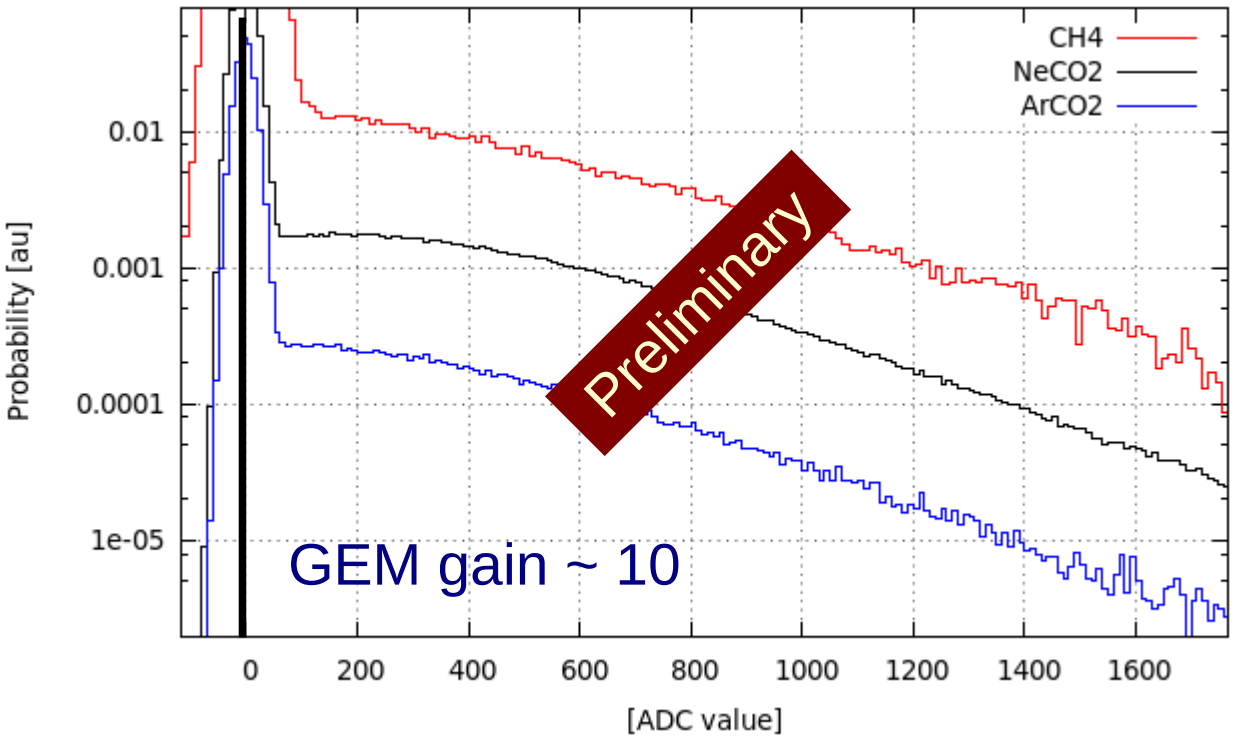
- Fourier spectrum of the signal (pedestal extracted)



Single avalanche response



Avalanche distributions



Summary

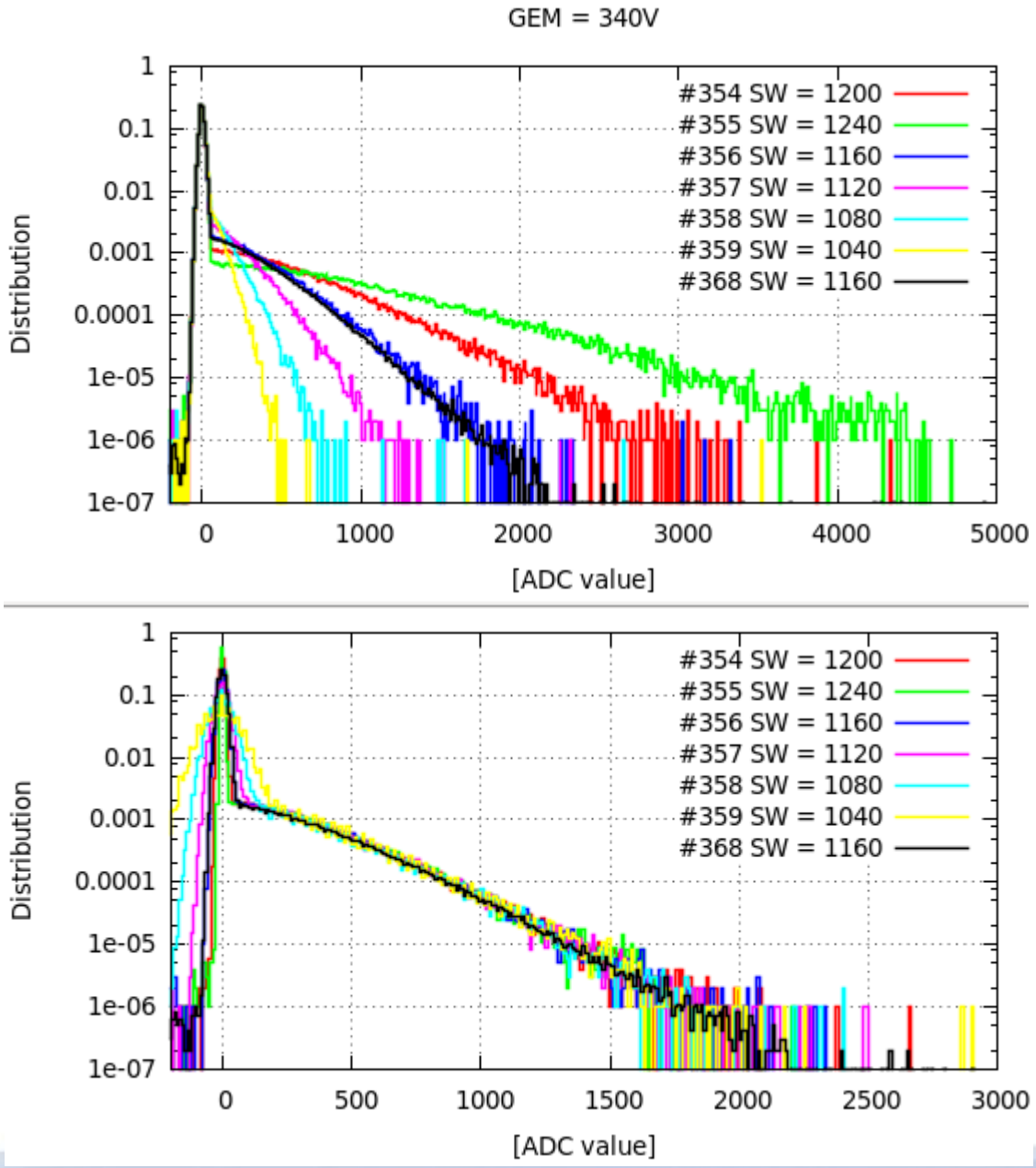
- Single PE distributions with a GEM+CCC detector has been measured
  - Separation of the 2 amplification stages
  - Evidence for non-exponential distribution
- Method for determining single PE avalanche distribution in GEM

Further plans

- Investigation of different gas mixtures
- Detailed comparison to microscopic simulation
- Measurements on Thick GEM

Backup

Avalanche distribution in Ar-CO_2



Avalanche distribution in Ar-CO_2