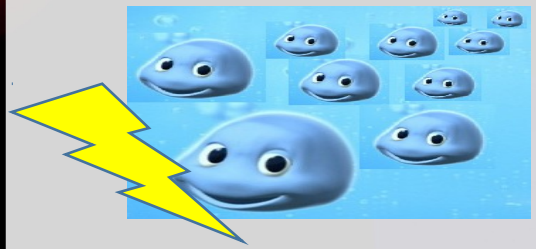
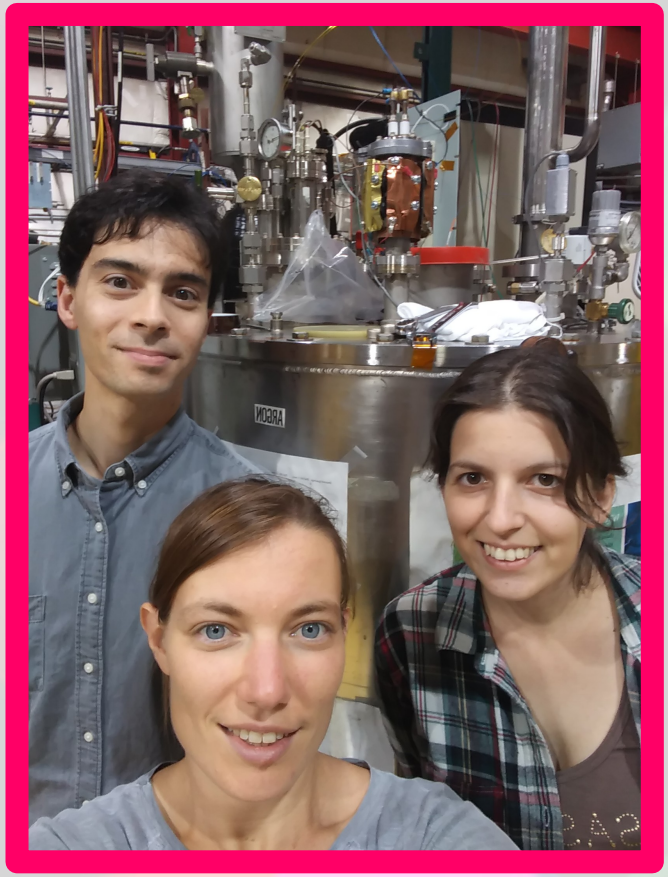

Fermilab
LArCADe:
Liquid Argon Charge Amplification Devices
Student: Sara Leardini
Supervisors: Dr David Caratelli,
Dr Angela Fava

# The project - goal

**Purpose: single-phase TPC with stable electron amplification in liquid argon (LAr)**



**Amplification → low energy threshold experiments (neutrino coherent scattering, DM...)**



**VS DUAL PHASE:**

- **Better spatial resolution**
- **No liquid ↔ gas interface**

# The project - overview

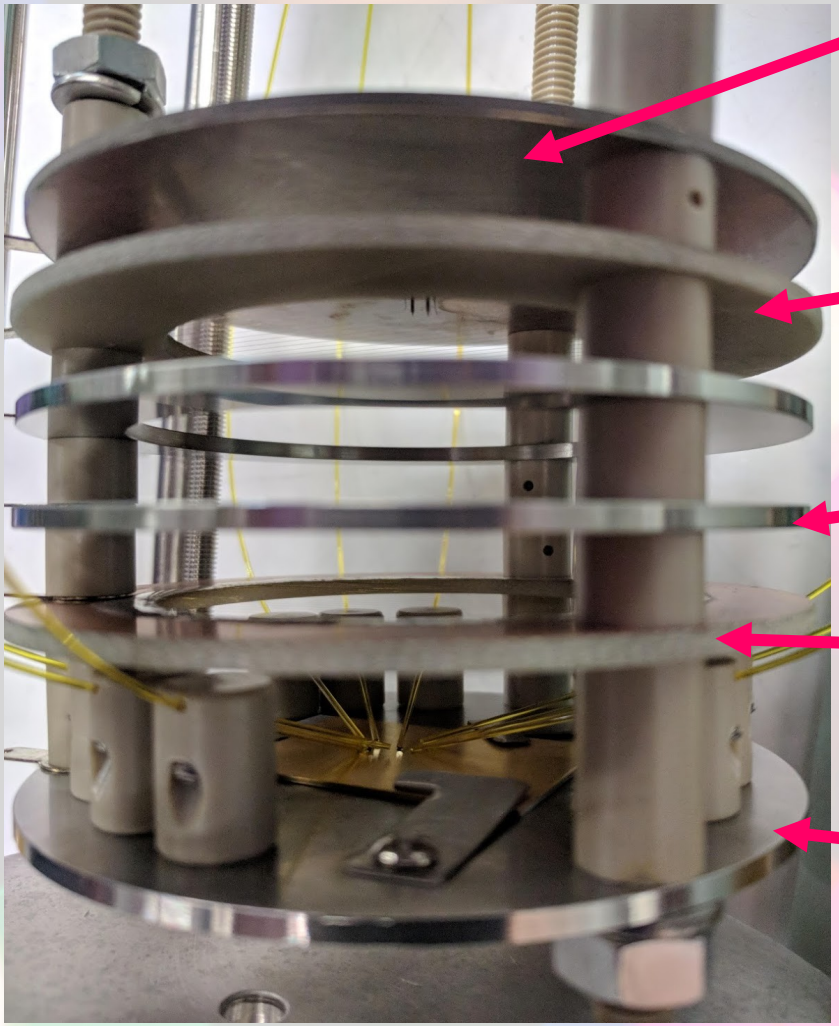

TASKS:

- Hardware:
  - setup installation and preparation
  - operation of detector @ PAB

- Simulation:
  - reproduction of a simplified version of the experimental setup

- Data analysis:
  - study of data collected @ PAB
  - study of data produced with the simulation

# LArCADe experimental apparatus



Anode

Anode grid

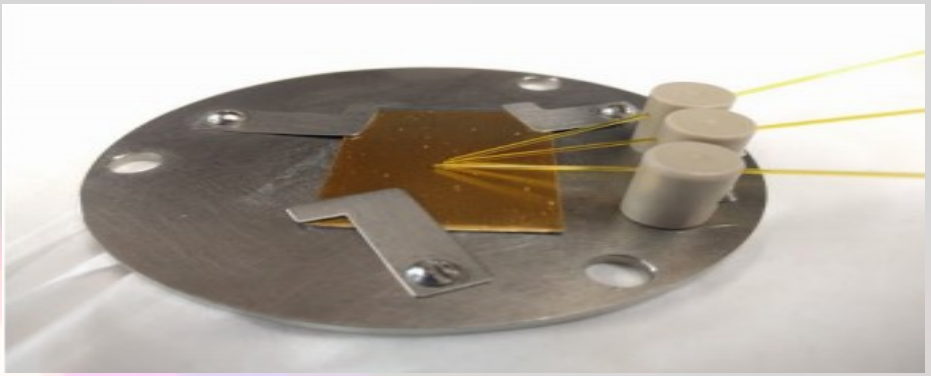
Rings →
make E field uniform

Cathode grid

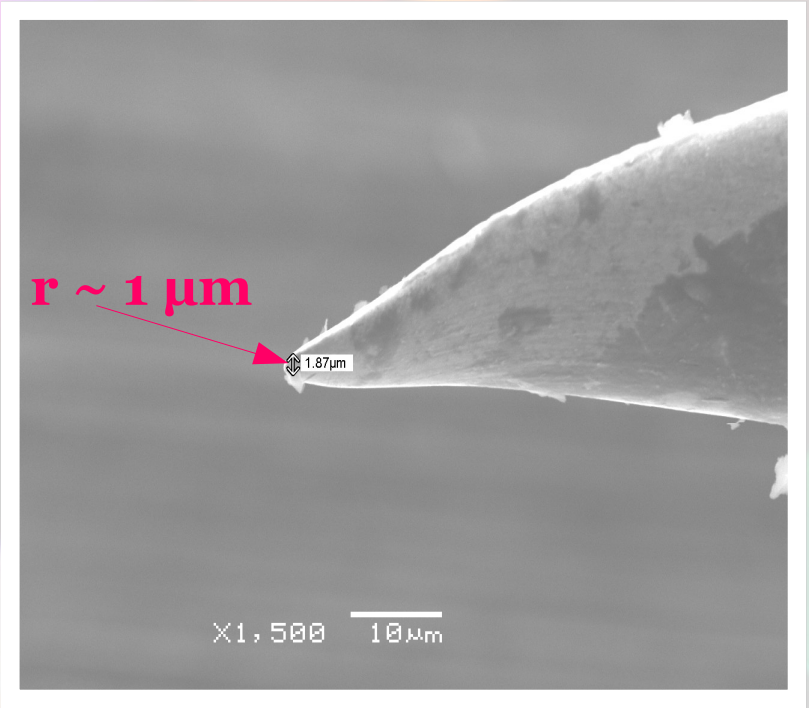
Cathode

# LArCADe: experimental apparatus

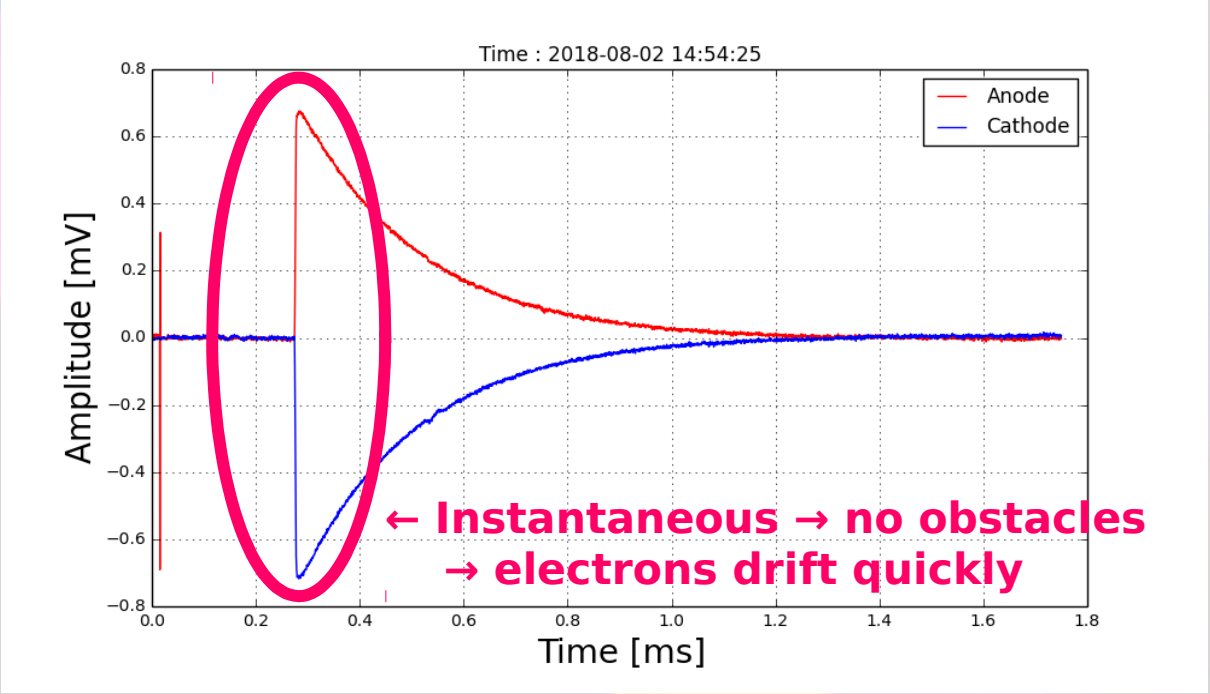
**9 optical fibers → photoelectric effect**
**→ extract electrons from cathode**



**IDEA → put small tips on the anode**
**→ increase E field locally**



# First data taking




## Studies in vacuum:

**→ measure signal on the anode and on the cathode with one optical fiber at once**

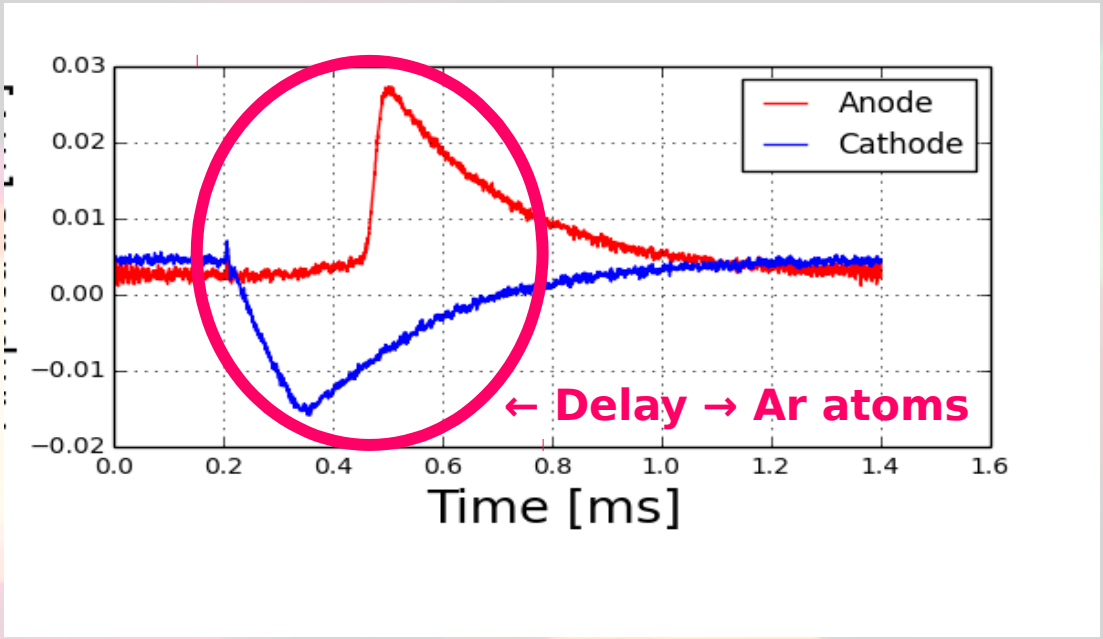
## Behaviour of apparatus in gas:

**Experimental apparatus in gaseous Ar → measure signal on anode and on cathode changing voltages (also 3 different values of pressure, 2, 7 and 15 psi)**

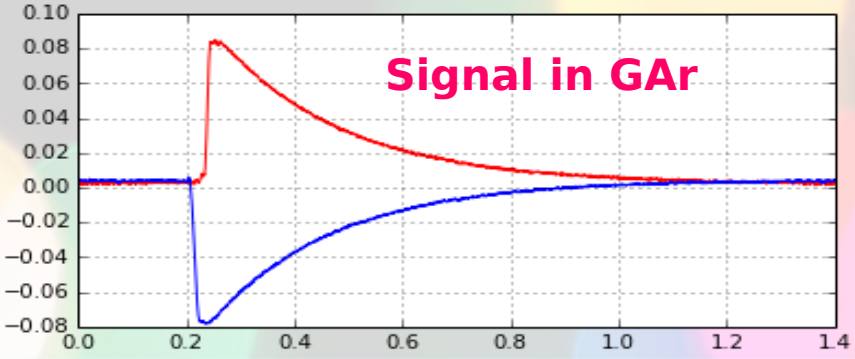
# First data taking

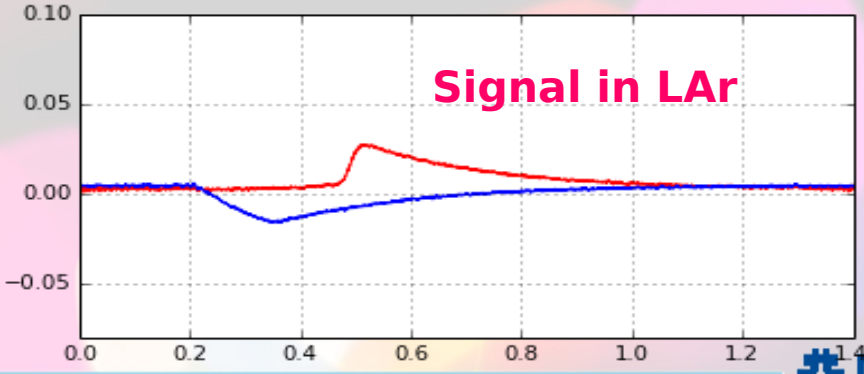

Picture by Ronald P Davis

## Measurements with LAr!

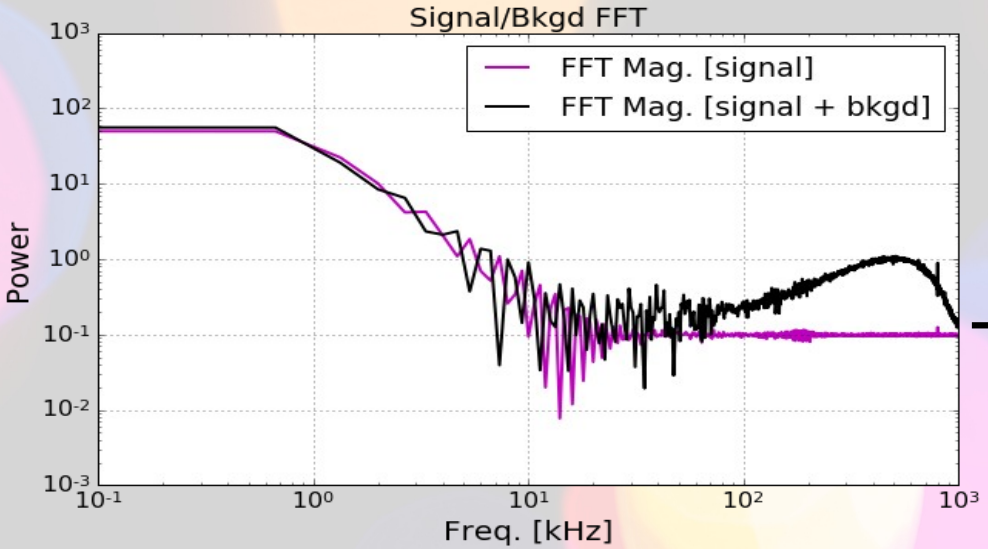



**Measure signal on anode and on cathode changing voltages**

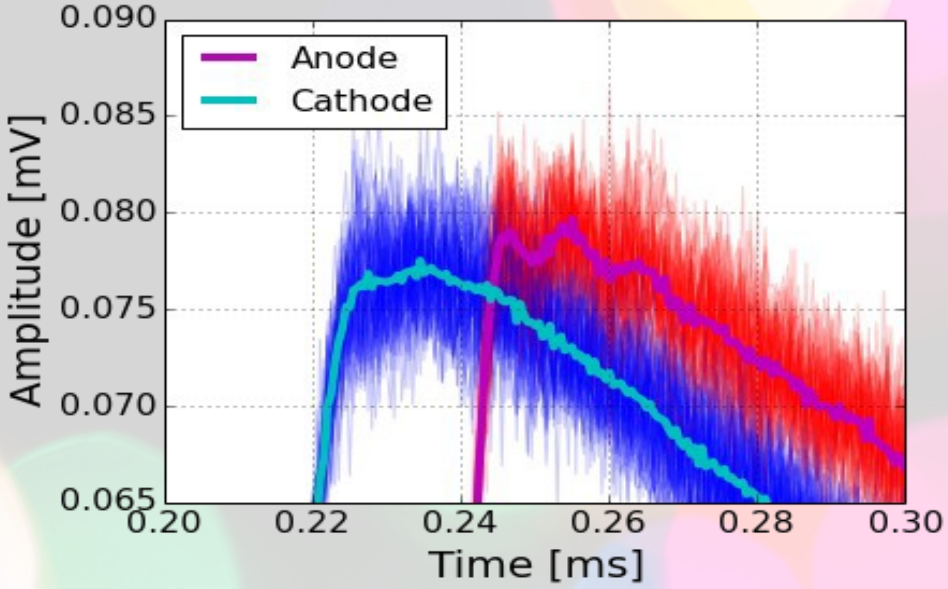


# First data taking – data analysis

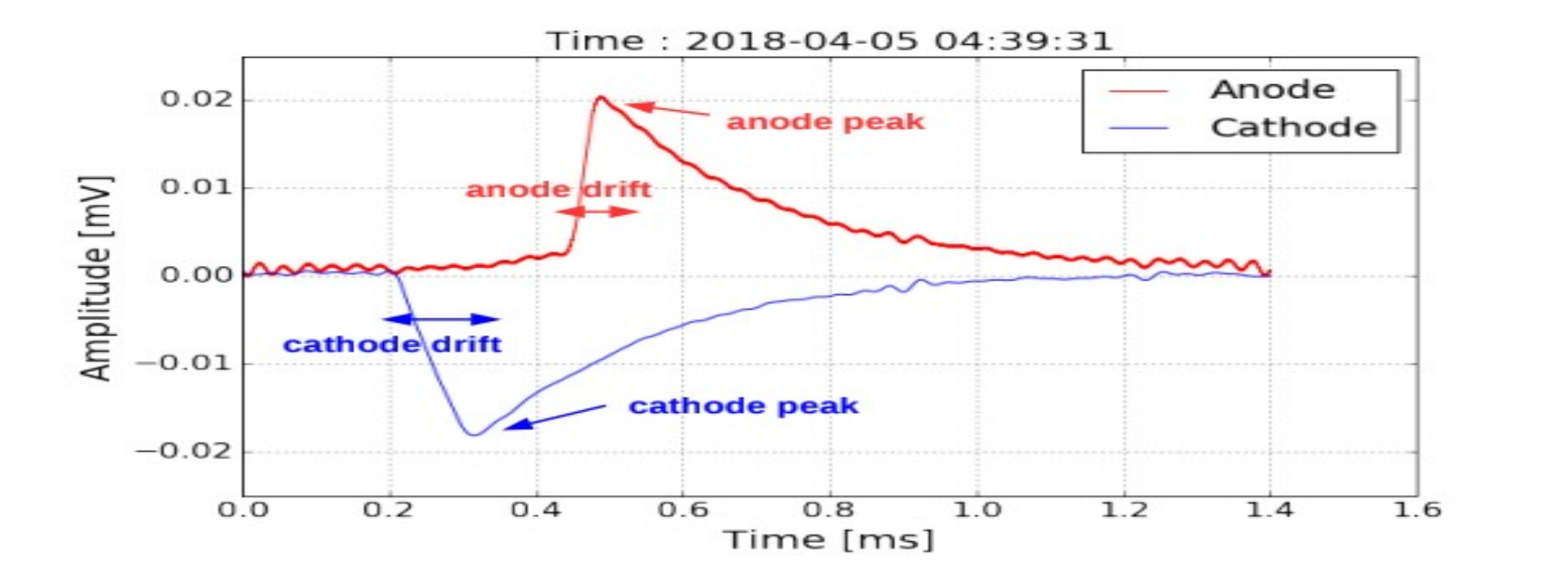



**Fourier transform of signals**
**→ noise @ high frequencies**
**→ remove frequencies > 20 kHz**




**50 waveforms**
**each measurement**
**→ average waveform**

# First data taking – data analysis




**Calculate parameters:**

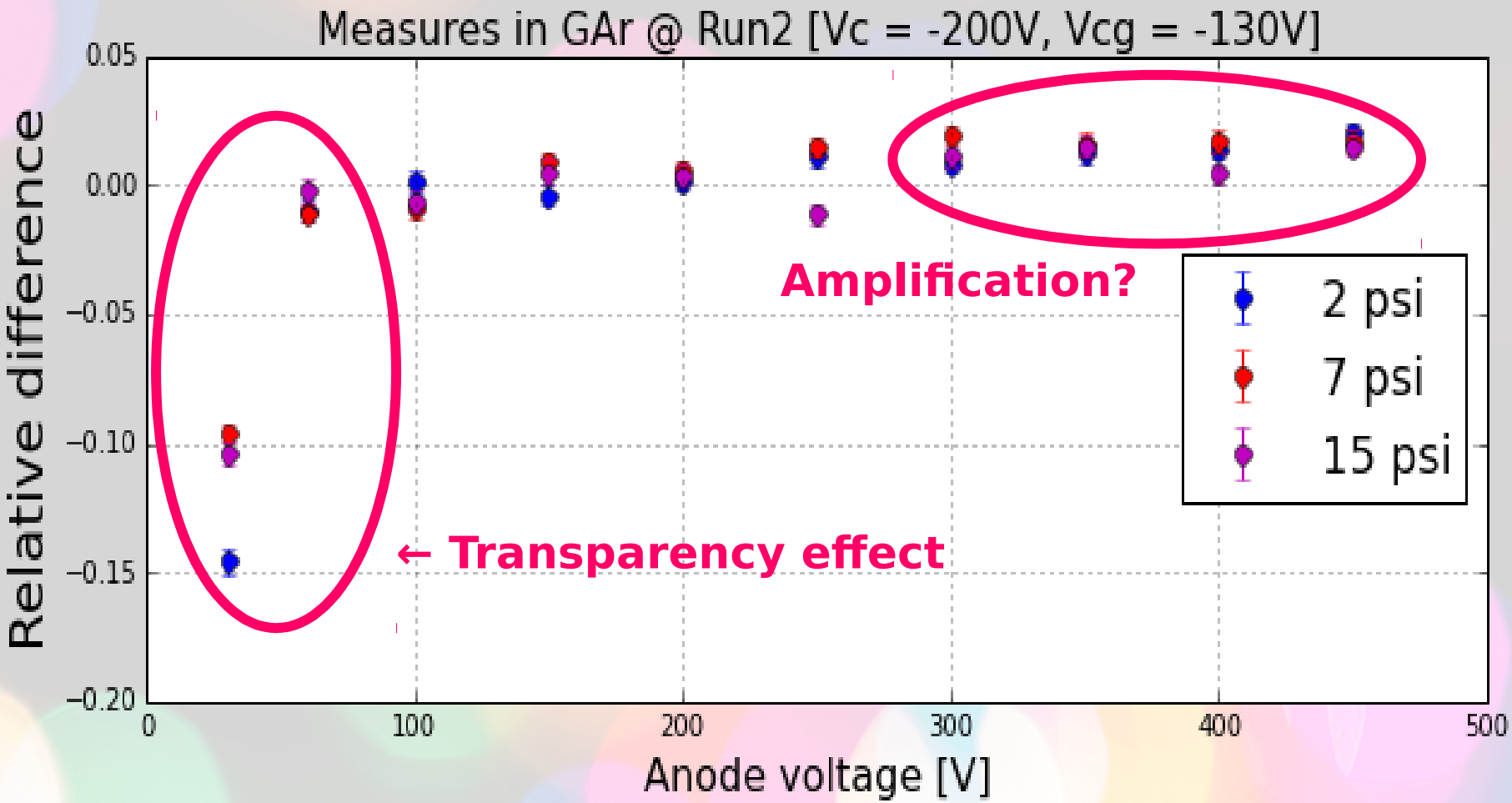
**- from peak → difference between anode and cathode signal → charge @anode - charge @cathode**

**- from drift time → correction for convolution of amplifier response:**

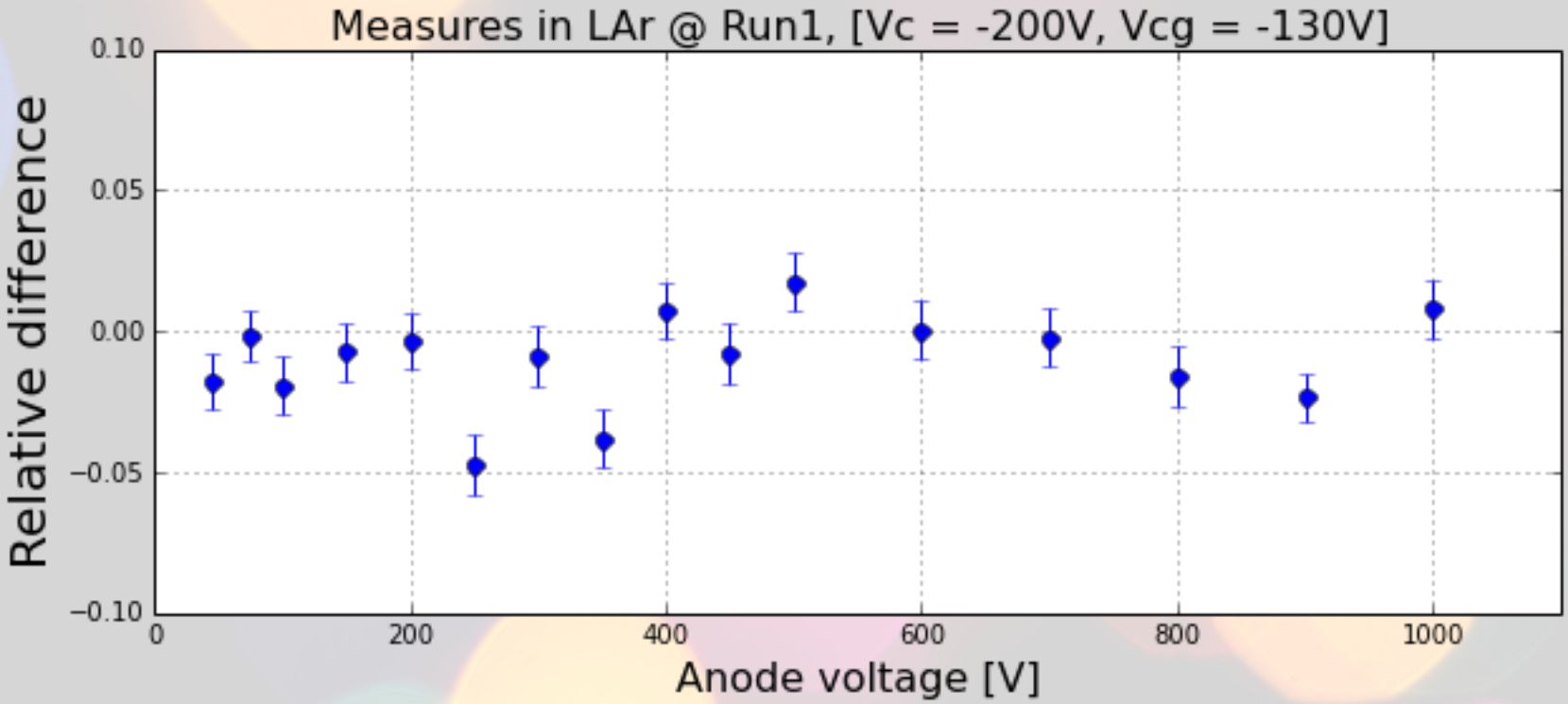
**(1 - exp($t_{drift}$ /RC )) * RC/ ($t_{drift}$), RC=240 µs**

# First data taking – results

## Signals in gas



# First data taking – results for LAr




**Tried also fit rising part to detect small amplifications**

**No amplification seen**

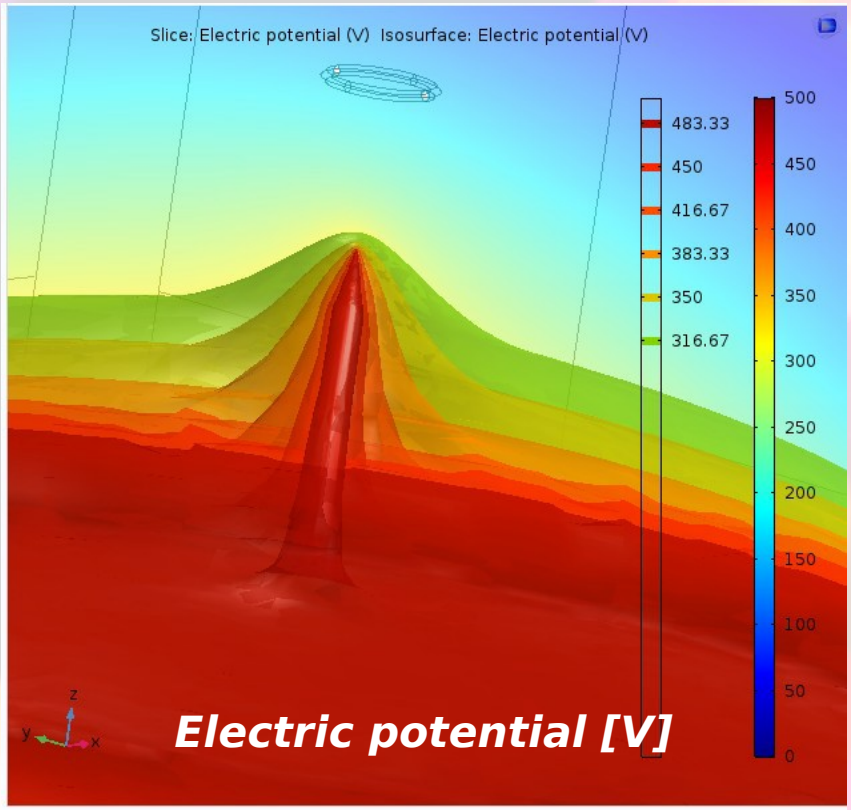
# Questions after data analysis

- **Are tips good enough?**
- **Do we reach high enough E fields?**
- **How many electrons are reaching tips?**


**→ took steps to better understand experiment**

# Simulations with COMSOL

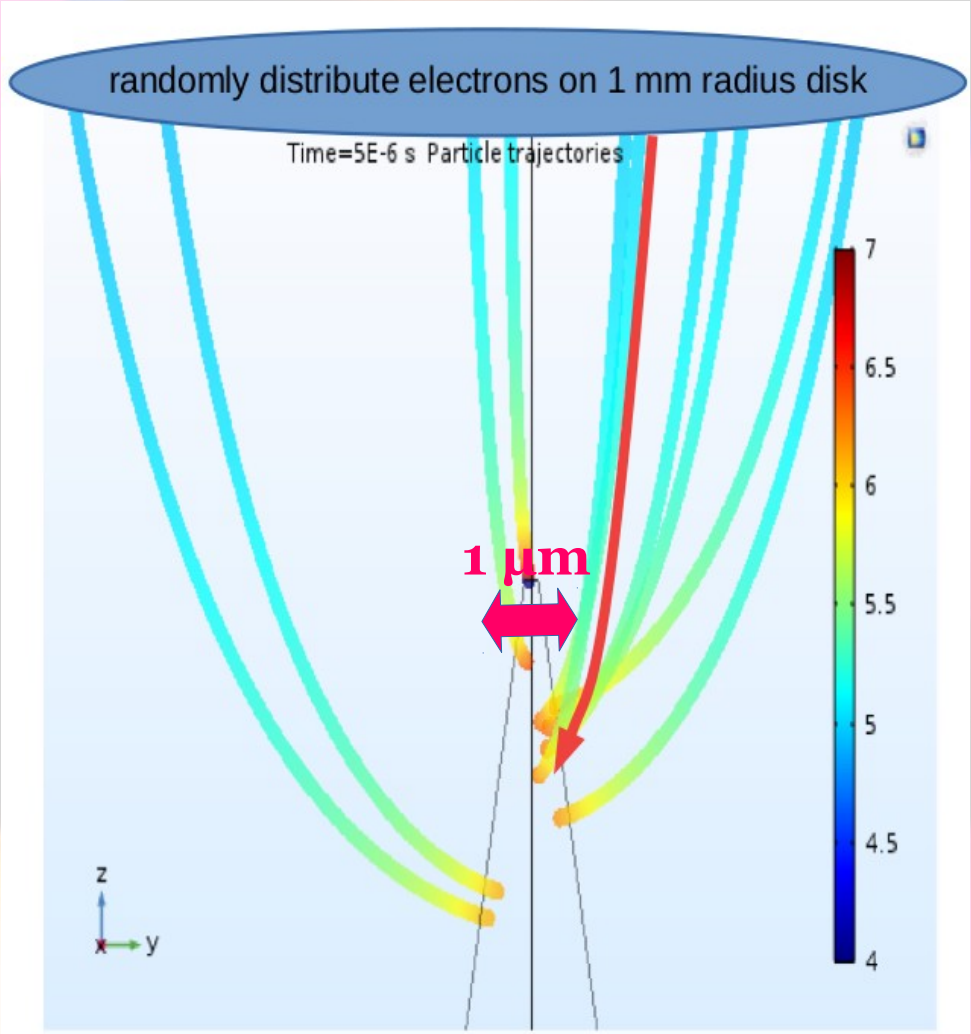
**Goal: Measure gain amplification factor in gas**
**Compare simulation with data**




**First step: simulated anode (with tip) + anode grid**

**Second step: simulate electric potential**

# Simulations with COMSOL




**Third step: simulate particle trajectories**

**Final step: calculate amplification analytically**

M represents the multiplication factor. In the general case of a non-uniform electric field, $\alpha = \alpha(x)$, Eq. (23) has to be modified in the following way:

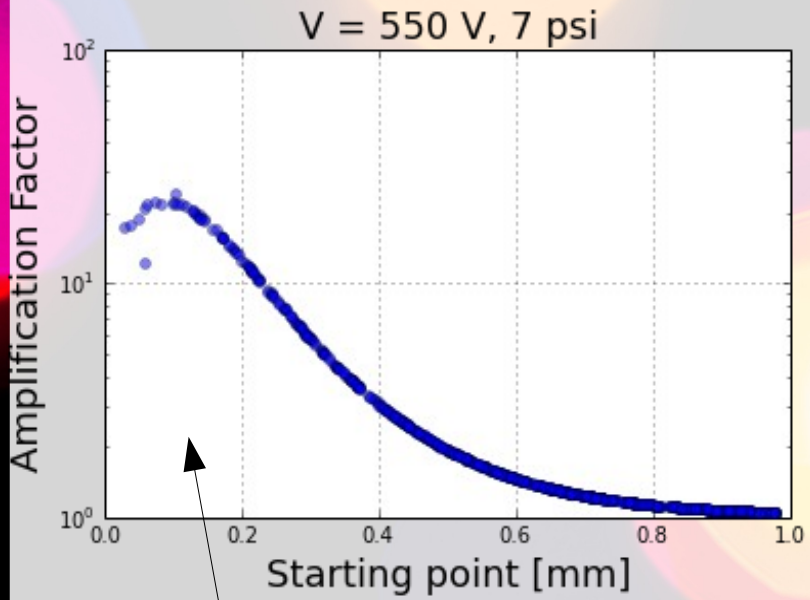
$$M = \exp\left[\int_{x_1}^{x_2} \alpha(x)\, dx\right]. \qquad (24)$$

$$\frac{\alpha}{P} = A\, e^{-BP/E}$$

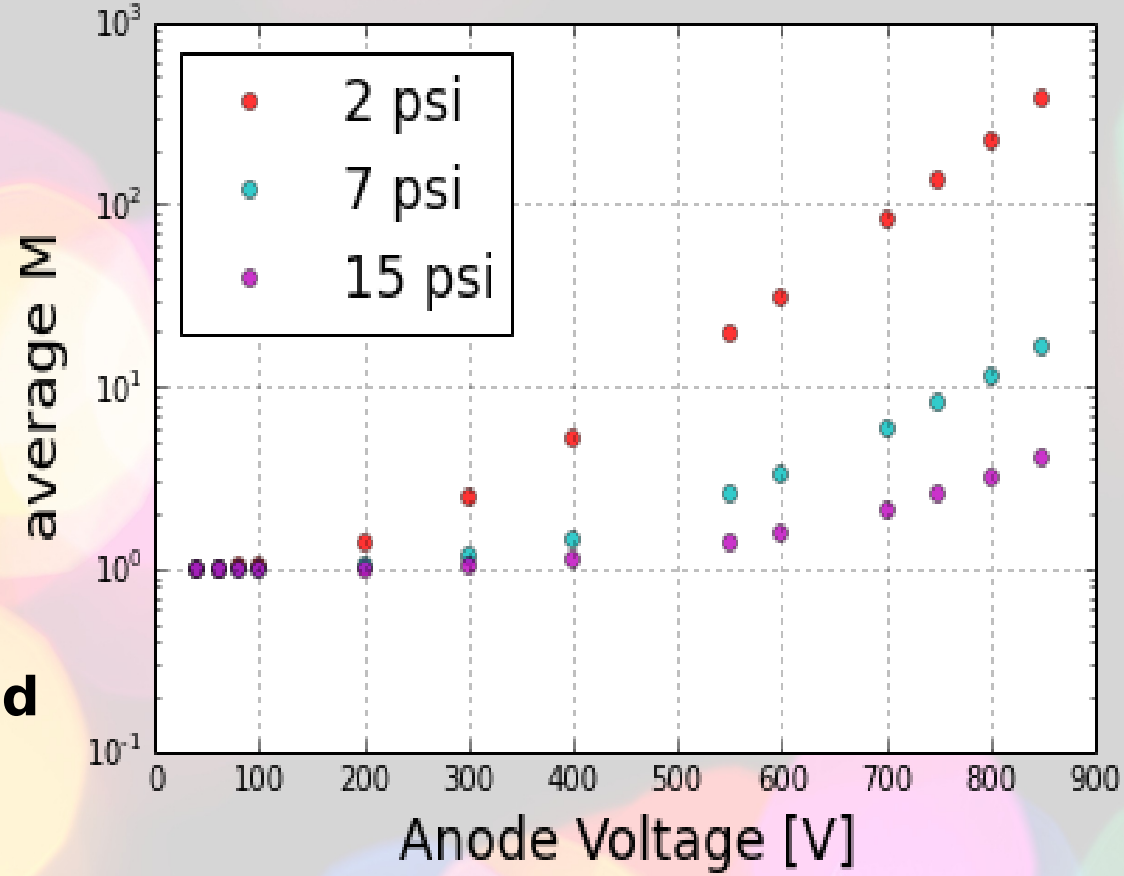
α = Townsend coeff.
→ Inverse of ionization mean free path.

*CERN 77-09, F. Sauli*

# Simulations with COMSOL



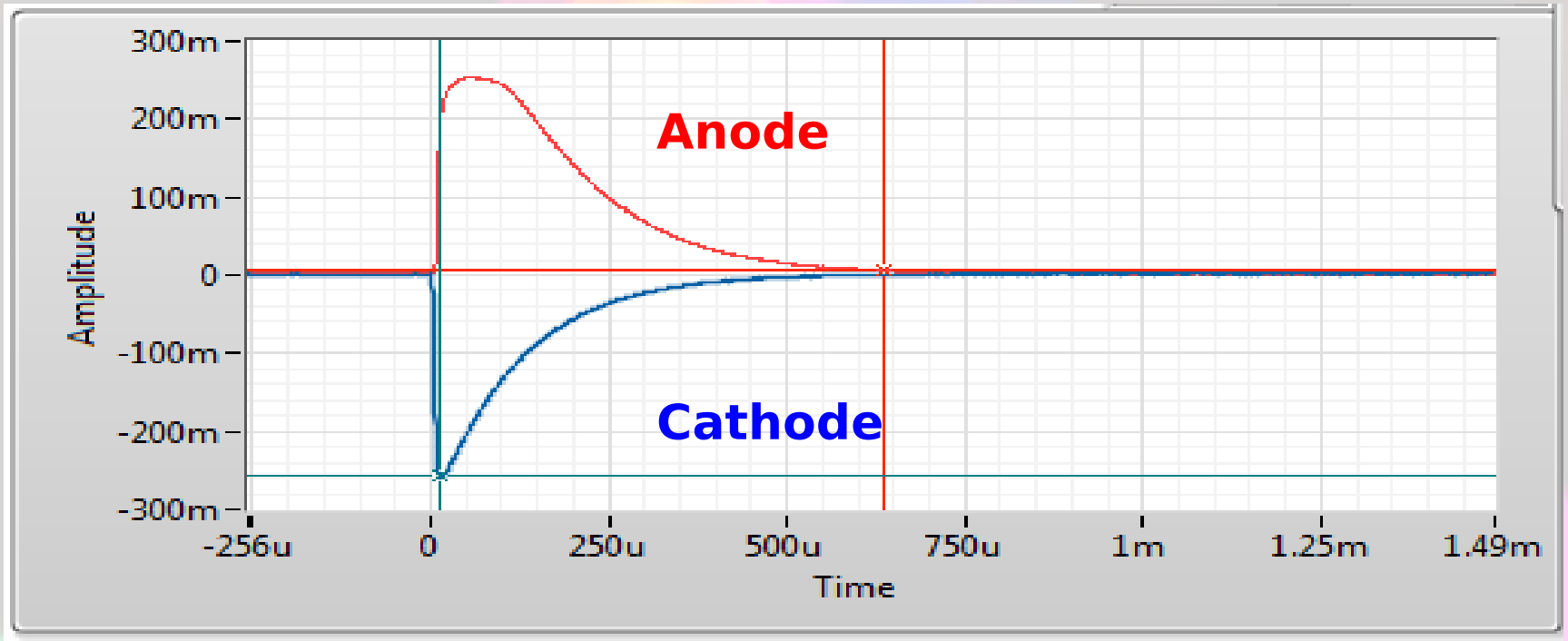

**Example of multiplication factor trend with distance**




**Multiplication factor M higher for lower pressures**
**→ Consistent with analytical trend of M**

# Second data taking

**Broadening of anode signal →**
**Different data analysis approach →**
**Integral of the waveforms**

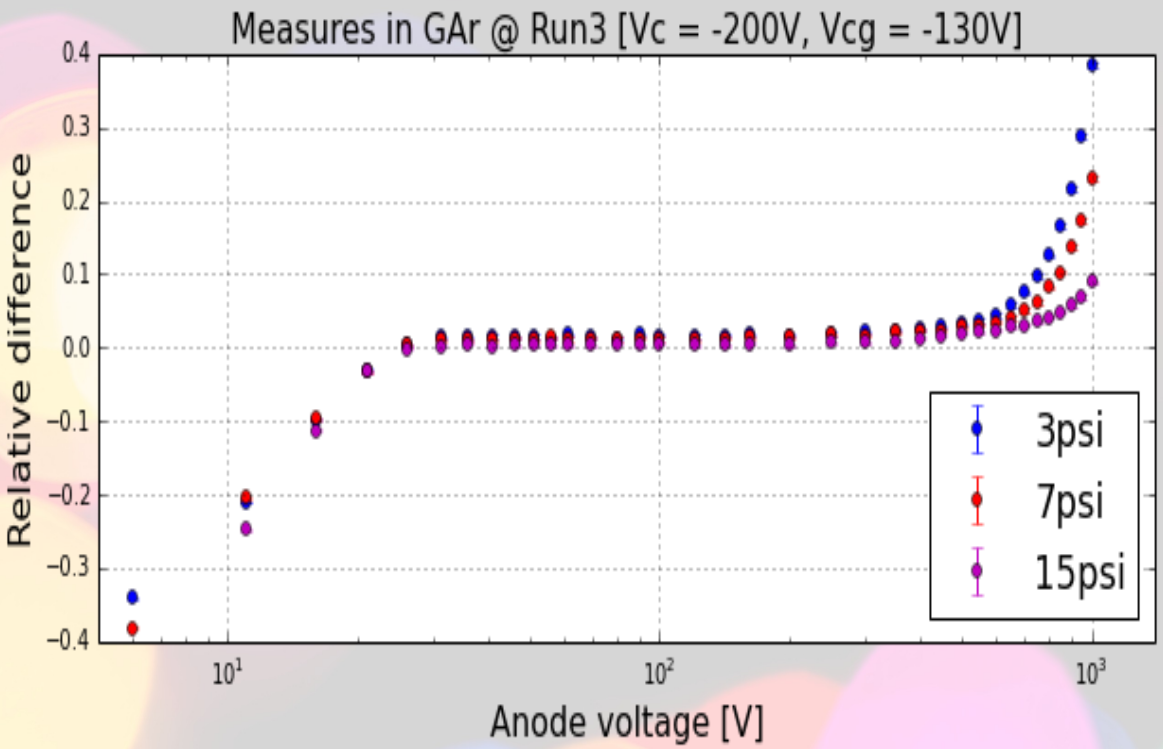



**(Physical reason still to be figured out...)**

# Second data taking

**- Checked experimental apparatus + new run only in gas**
**- Rotated grids 60 degrees**

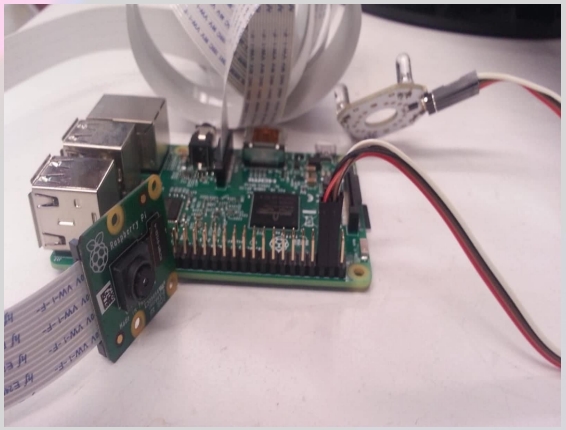


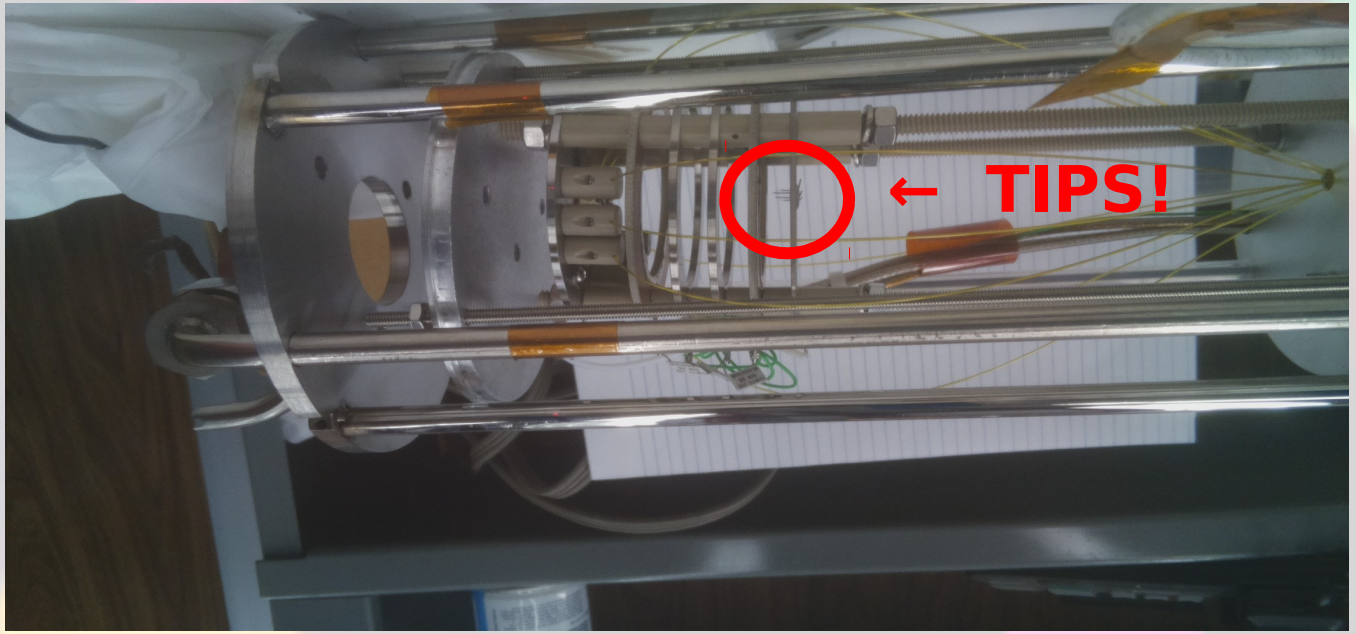



**-similar trend as simulation**
**- much smaller amplification possibly due to the fraction of electrons reaching the tip**

# Setup of camera

**Set up Raspberry Pi camera to monitor tips**






**- Measurements with light and dark (+LEDs) @ different distances**
**- Strong electric field near tips → formation of bubbles of hot argon → observe them with the camera during measures**

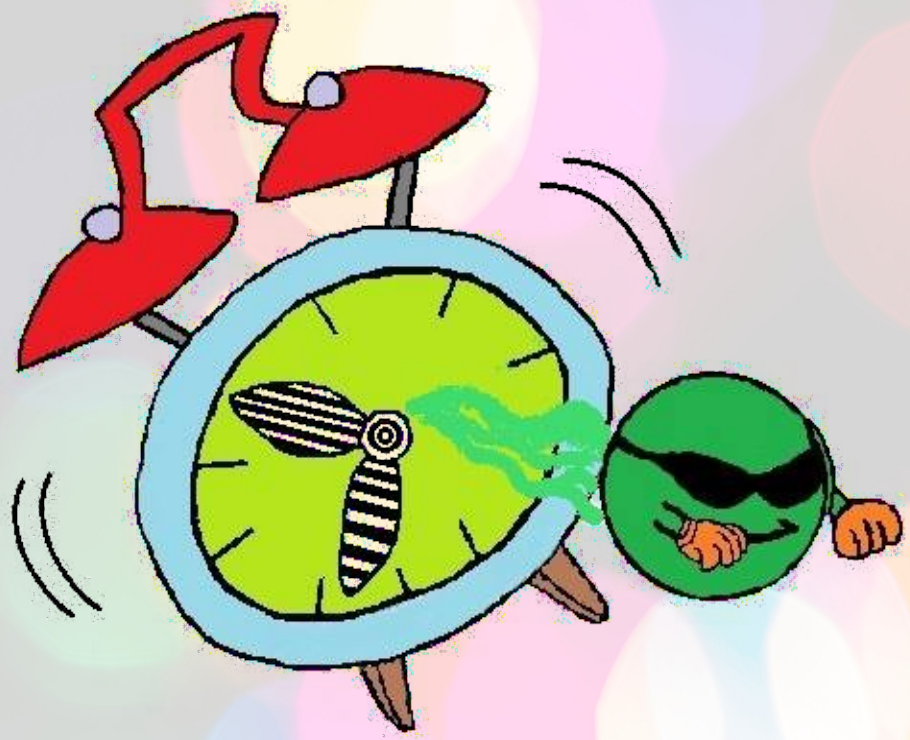
# Conclusions and future developments

**- Observed amplification in GAr**
**- Not observed amplification in LAr**
**- Simulations and new run helped the understanding of the experiment**

**PLANS FOR THE FUTURE:**

**- Run with anode covered except tips**
**- Run with camera**
**- Run with smaller 100 nm tips**

# THANKS FOR YOUR ATTENTION!

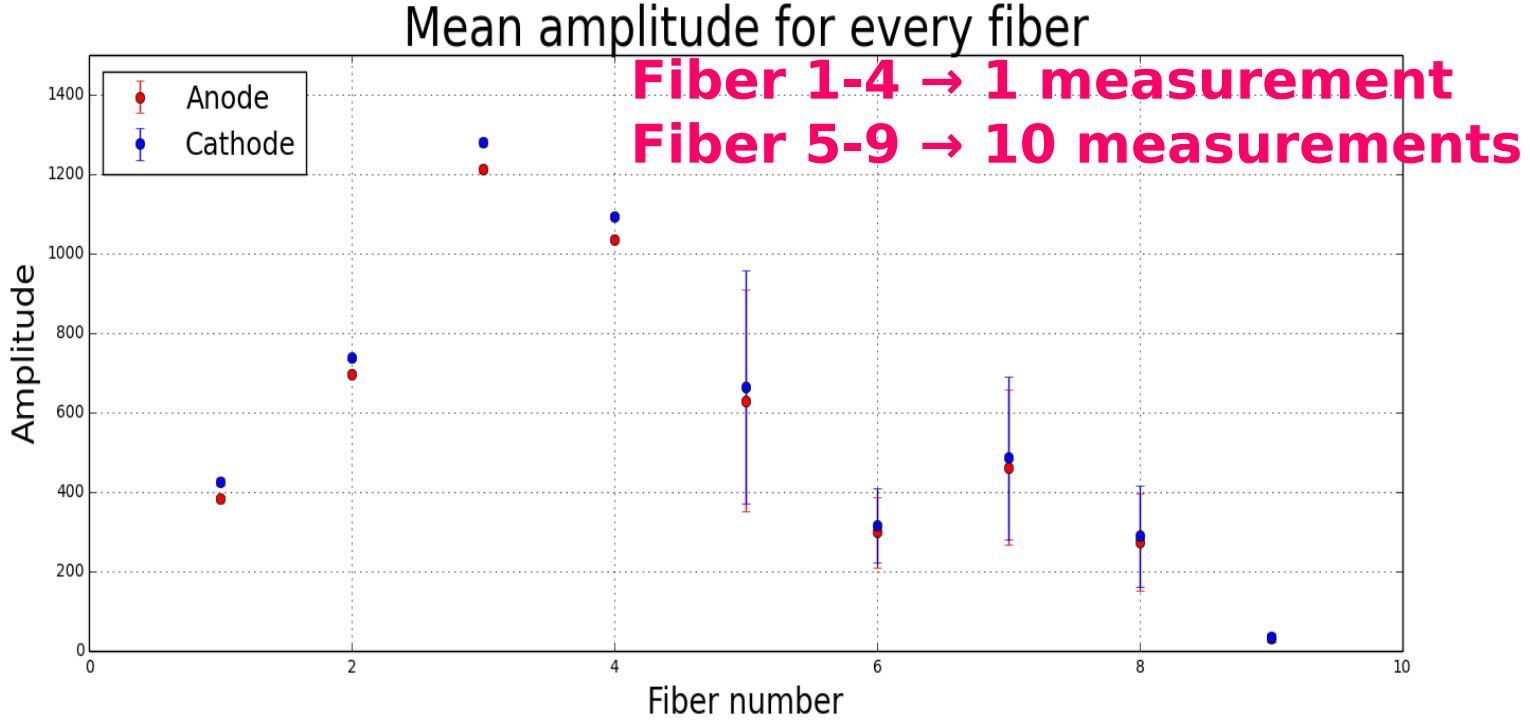


# Backup slides


iStock.com/AnatoliYakovenko

# First data taking – data analysis

## Behaviour of fibers (measures in vacuum)

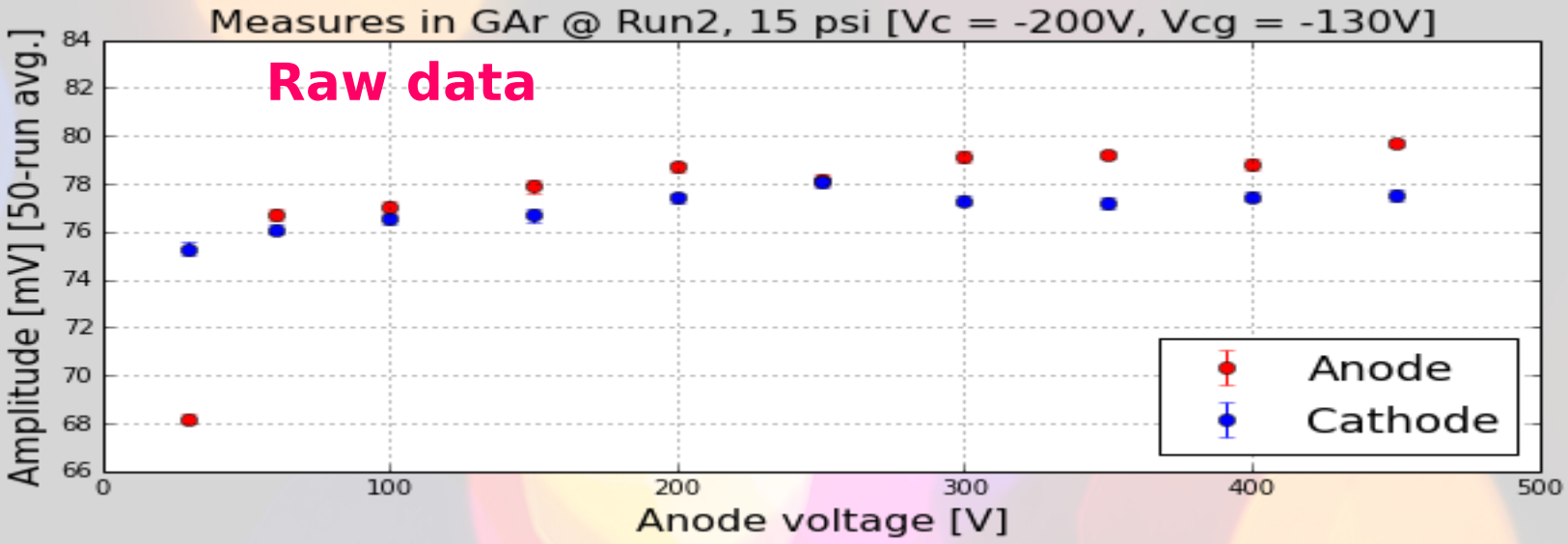


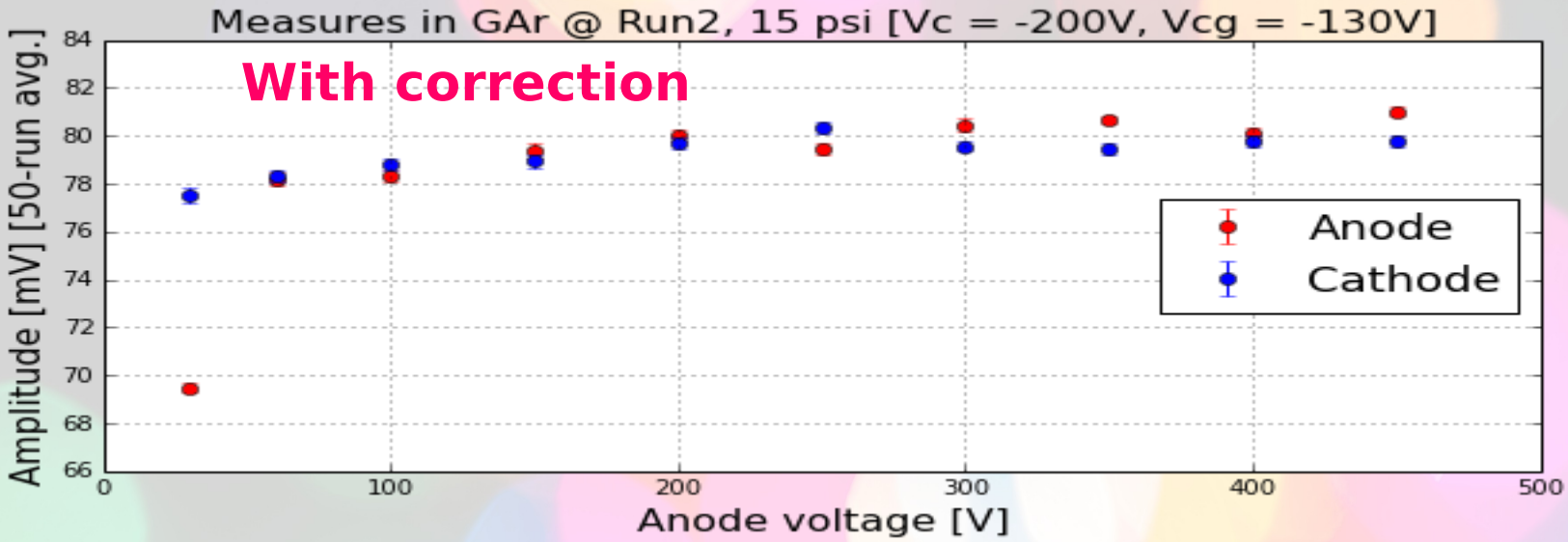

**Fiber 1-4 → 1 measurement**

**Fiber 5-9 → 10 measurements**

**Systematic fluctuations in fiber response → intrinsic variations, not due to position with respect to tips**

# First data taking – data analysis



# Expected multiplication factor

**At lower pressures larger mean free path → can obtain enough energy to ionize at lower fields.**

**At higher pressures more difficult to obtain enough energy, but once threshold is reached more ions produced per unit distance.**