Overview on recent PICOSEC-Micromegas developments and performance tests

@

RD51 Miniweek
Feb. 2020

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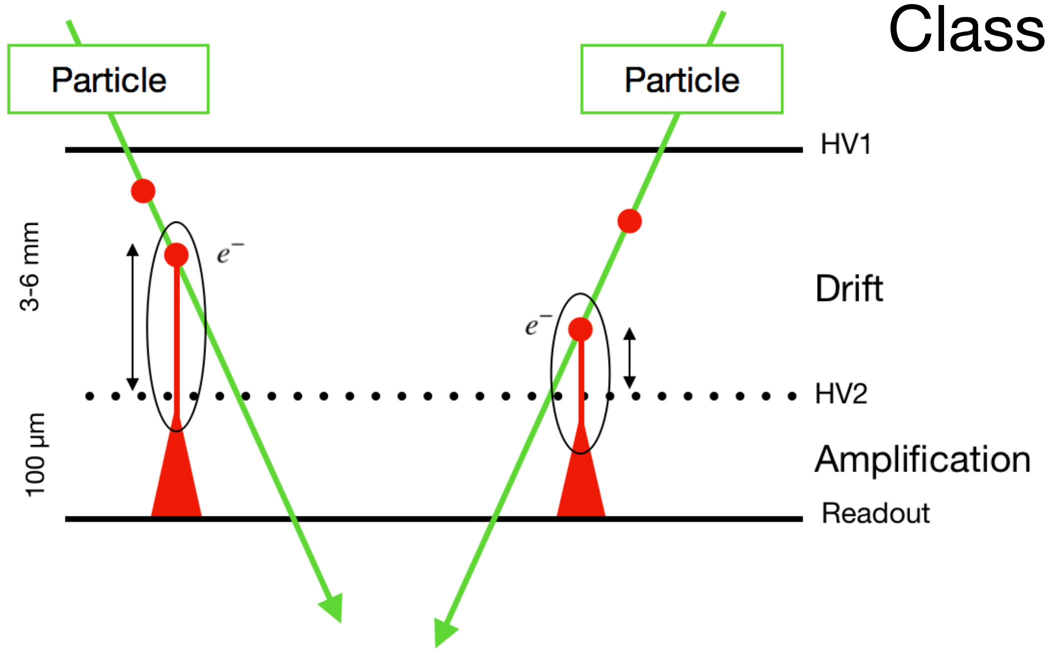
11.02.2020

PICOSEC Micromegas



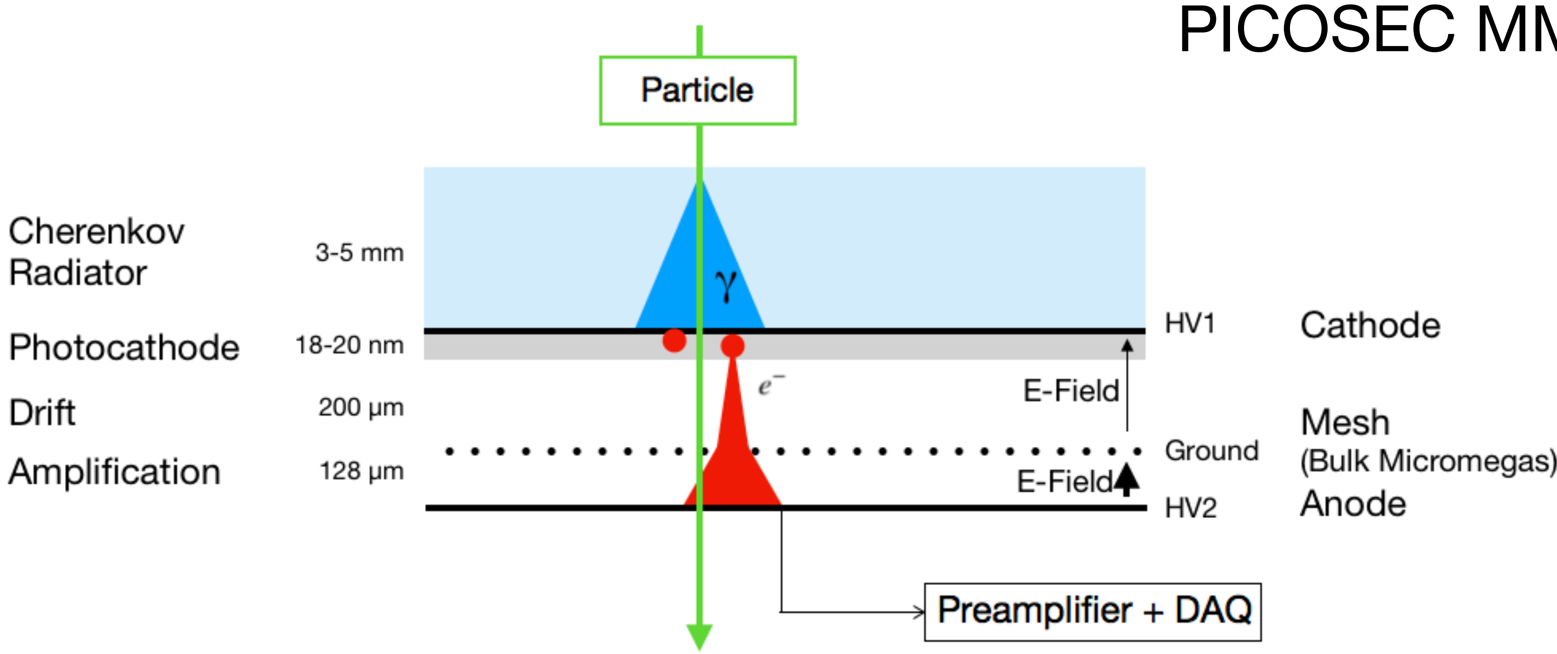
Classical MM

- Different position of ionisation clusters at direct gas ionisation
- Inevitable signal arrival time jitter due to drift velocity and average ionisation lenght

$$\sigma_t = \frac{\sigma_I}{v_d} = \frac{355\ \mu m}{84\ \frac{\mu m}{ns}} \approx 4\, ns$$

Estimated time jitter for COMPASS Micromegas

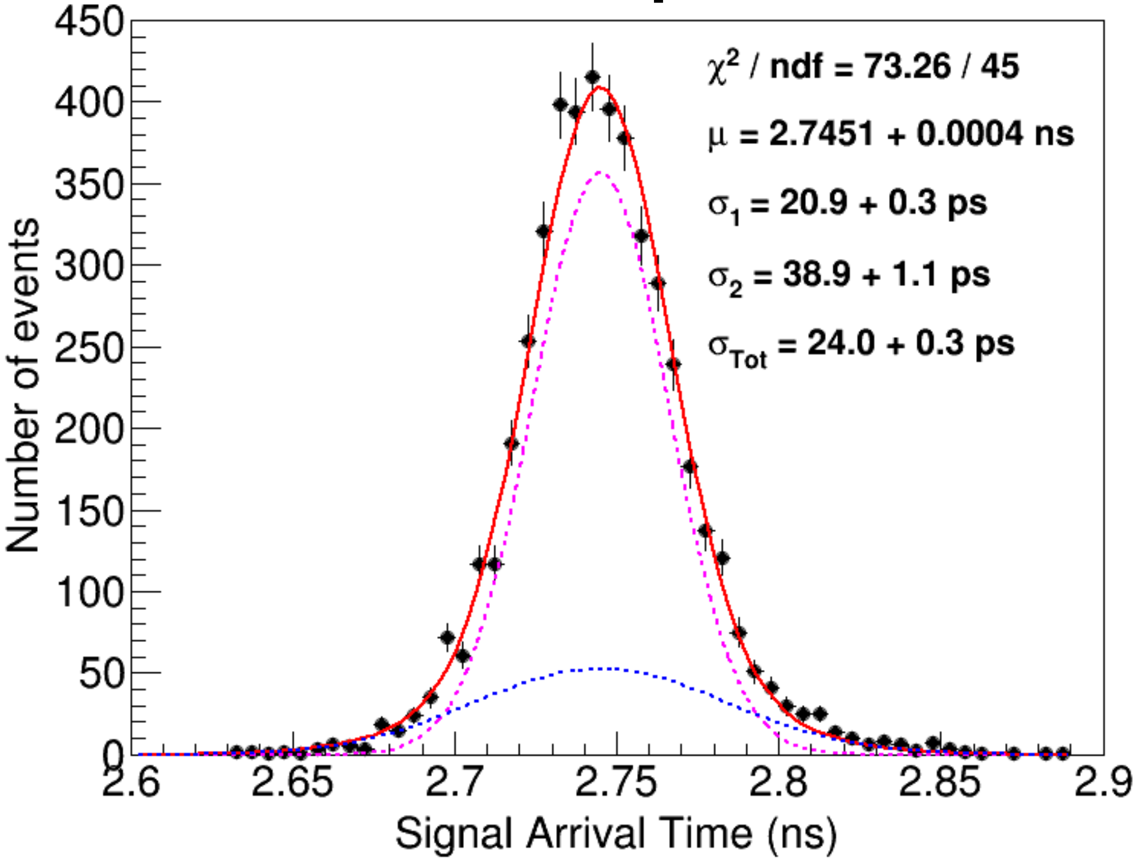
PICOSEC MM



- Particle produce Cherenkov radiation
- Electrons are emitted by the radiation in a photocathode
- All primary ionised electrons are localised on the photocathode
- Due to high electric field, time jitter before first amplification minimised

Previous Development

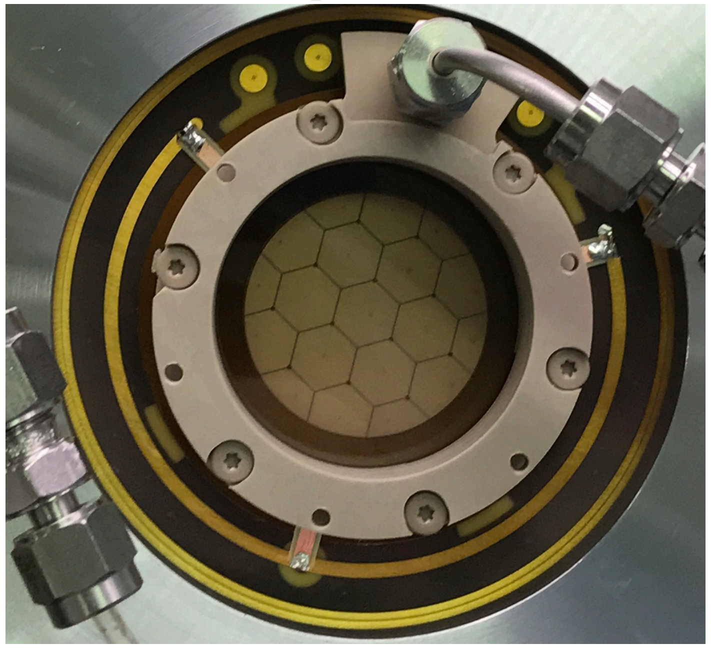
Time Resolution ~24 ps in muon beam



Different photocathode materials tested

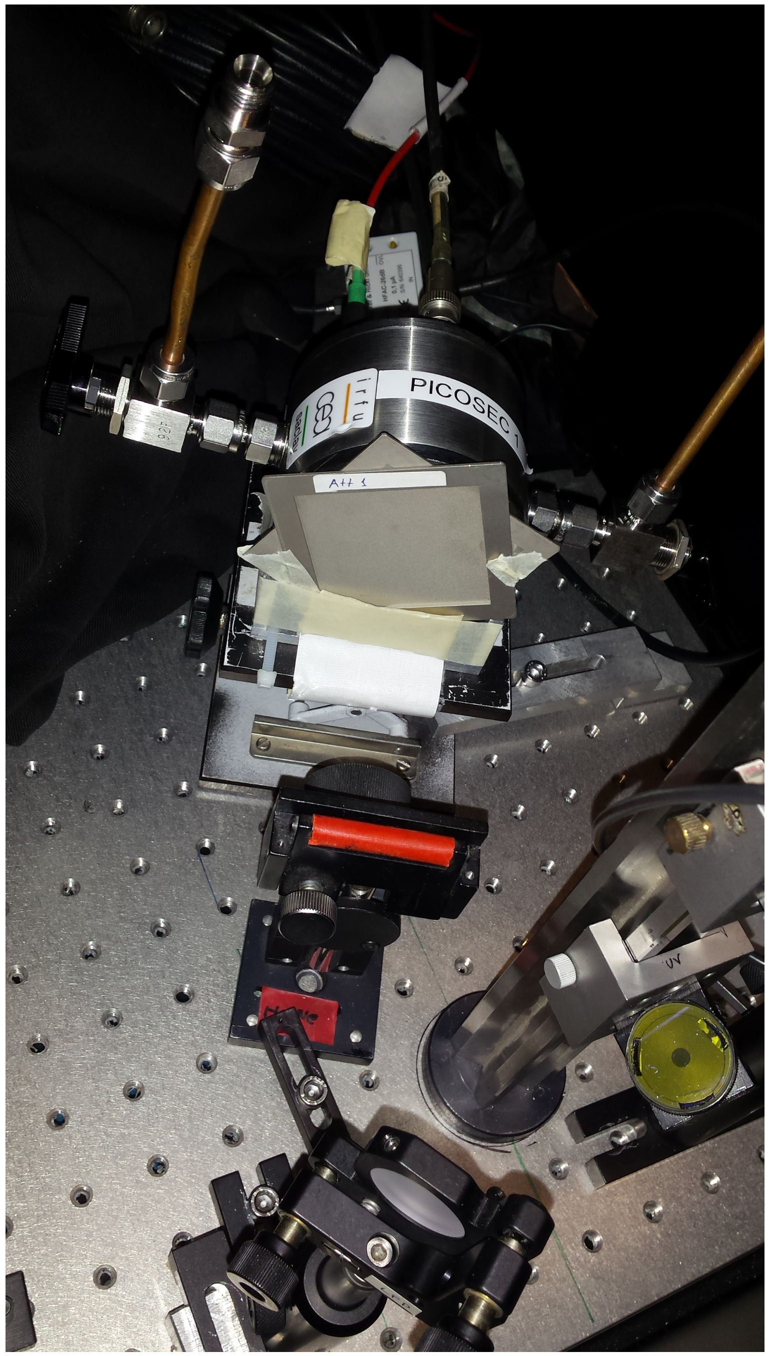
Thickness of DLC film (nm)	Npe/per muon	Detection efficiency for muons
1	Bad	Bad
2.5	3.7	97%
5	3.4	94%
7.5	2.2	70%
10	1.7	68%
5 nm Cr + 18 nm CsI	7.4	100%

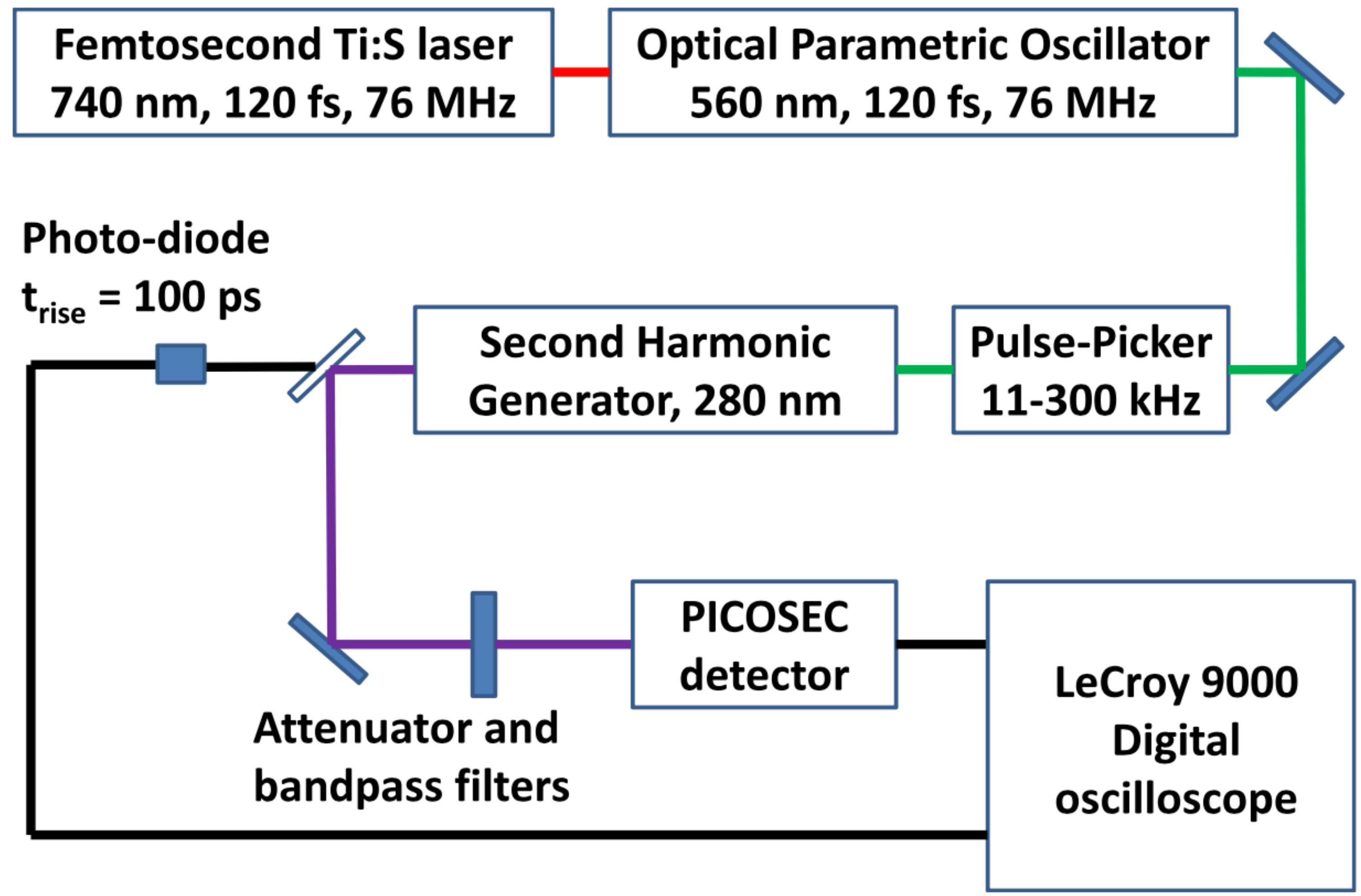
First Multipad Detector



- Fast Timing for High-Rate Environments with Micromegas, EPJ Web of Conferences **174**, 02002 (2018), doi: 10.1051/epjconf/201817402002
- PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector, Nucl. Instrum. Meth. **A903** (2018) 317-325. doi:10.1016/j.nima.2018.04.033.
- Charged particle timing at sub-25 picosecond precision: The PICOSEC detection concept, Nucl. Instrum. Meth. **A936** (2019) 515-518. doi:10.1016/j.nima.2018.08.070.
- Precise charged particle timing with the PICOSEC detector, AIP Conference Proceedings **2075**, 080009 (2019); doi: 10.1063/1.5091210
- PICOSEC-Micromegas: Robustness measurements and study of differentphotocathode materials, J. Phys.: Conf. Ser. **1312** (2019) 012012 ; doi: 10.1088/1742-6596/1312/1/012012

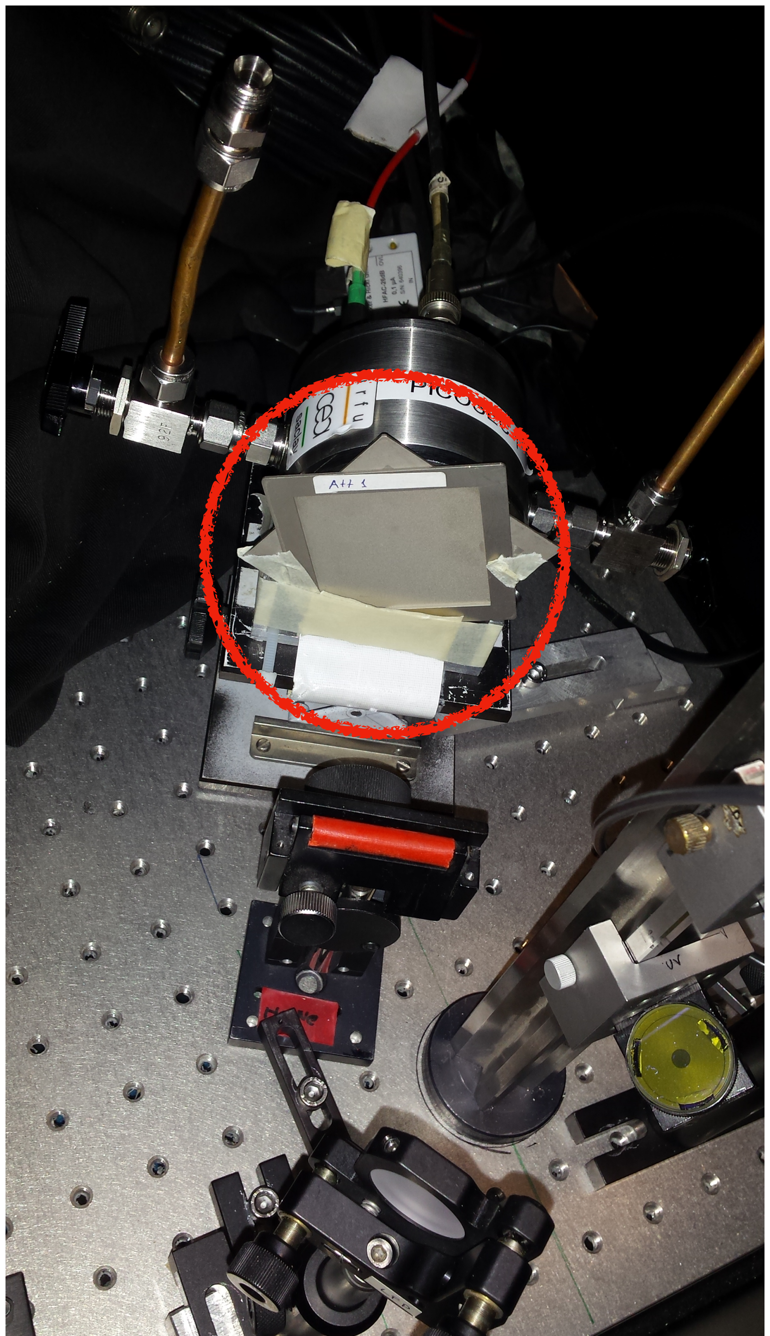
Clean measurements with a Laser



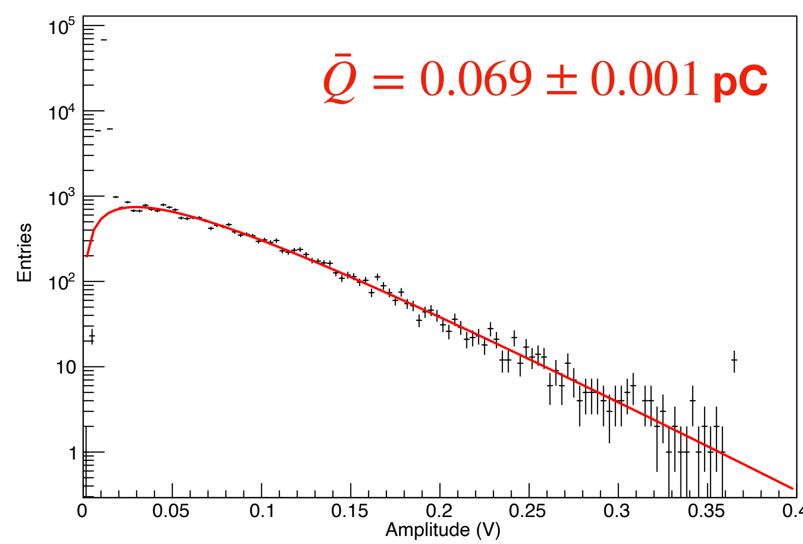


- Pulsed laser at IRAMIS Facility (CEA Saclay)
- 267 - 288 nm Wavelengths
- Repetition rate up to 500 kHz
- Laser intensity attenuated to study single photoelectron emission

Light attenuation for 1 p.e. measurements with attenuators



- Mean signal size is determined by a Polya fit
- 1 p.e. condition: additional attenuators (factor 4) are not changing the mean signal size



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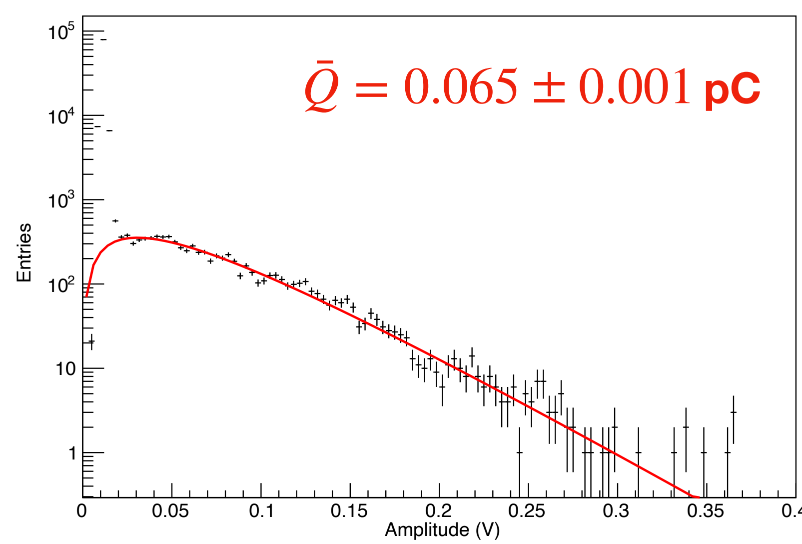
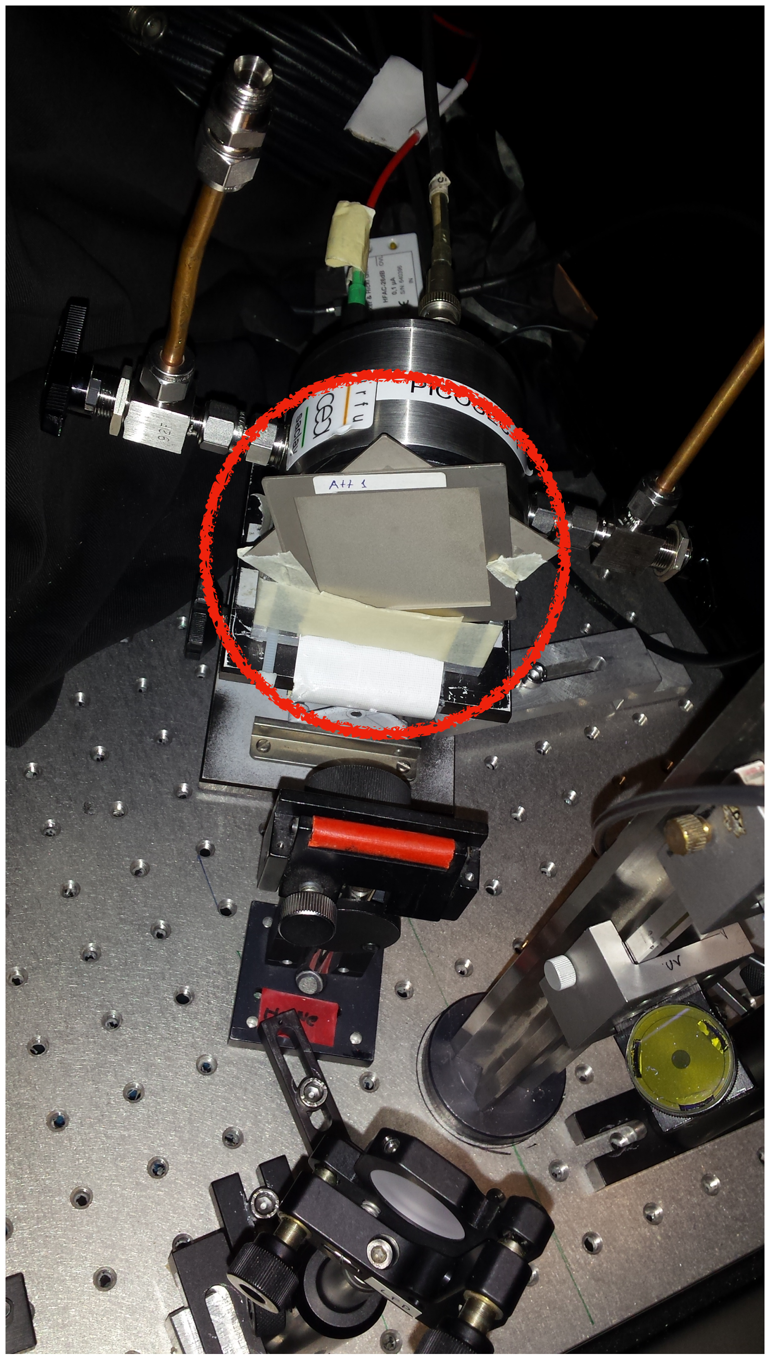
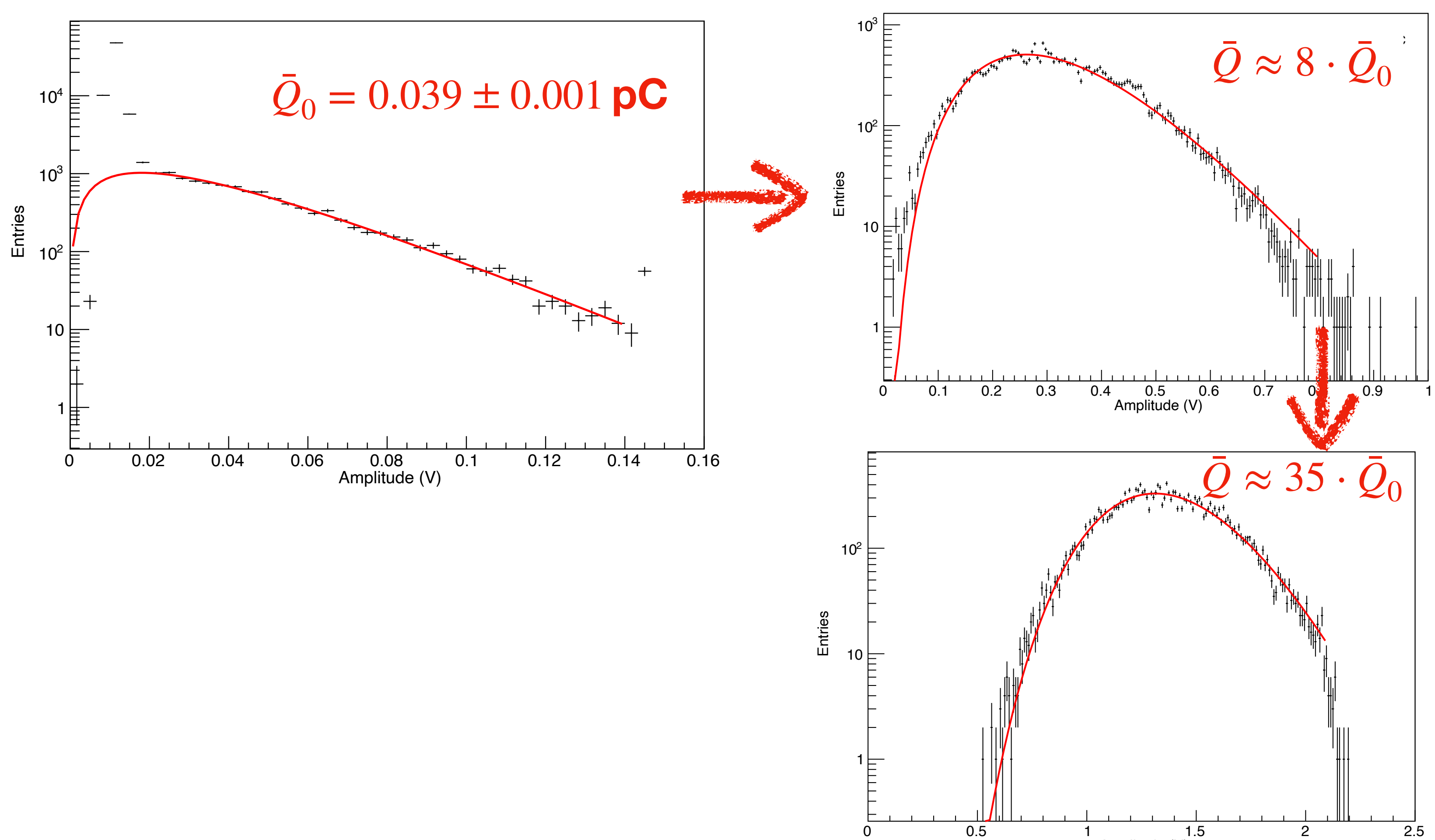


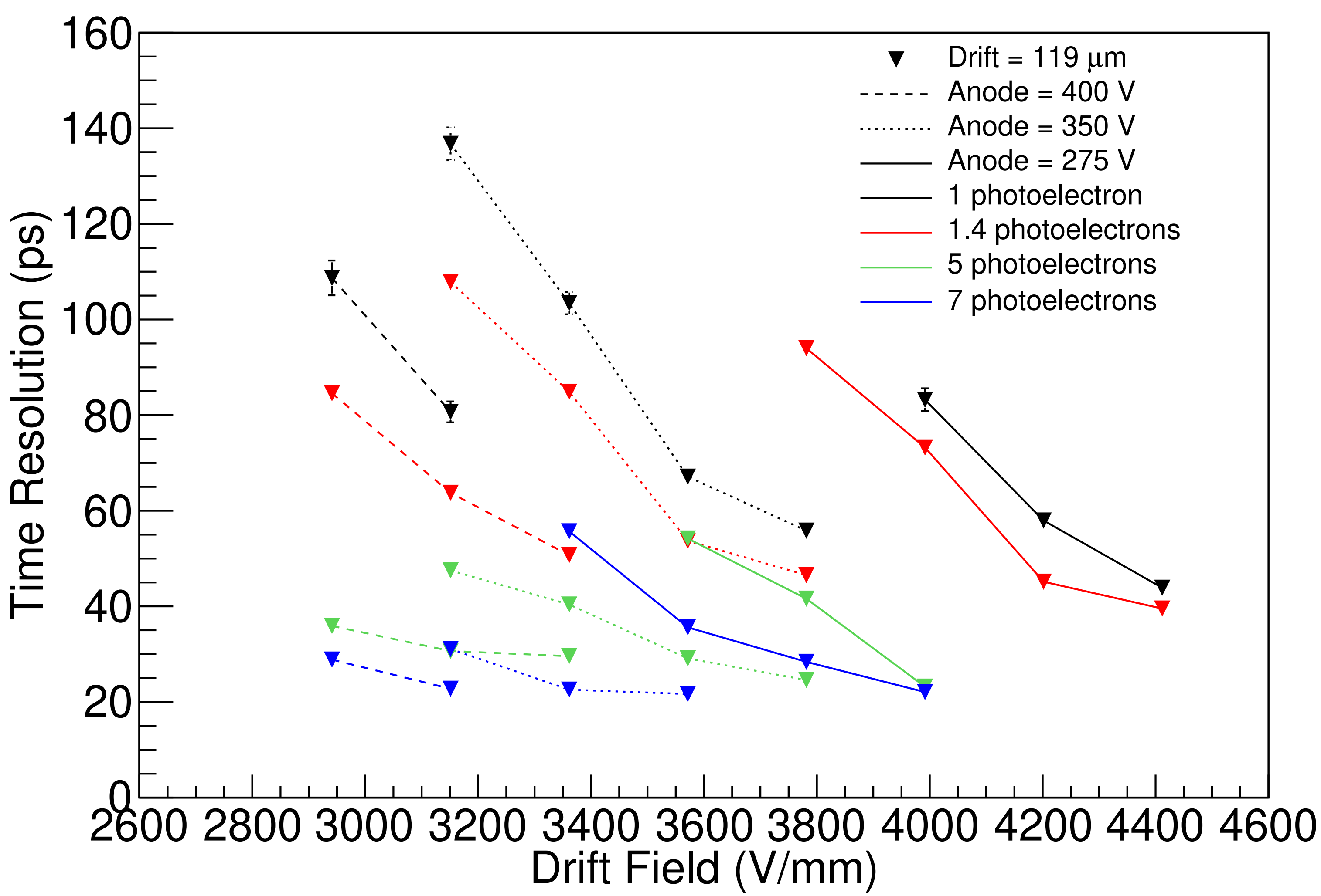
Removing attenuators for many p.e.



- Mean signal size is determined by a Polya fit
- 1 p.e. condition: additional attenuators are not changing the mean signal size
- Multi p.e. conditions: removing one attenuator after an other resulting in higher mean signal size

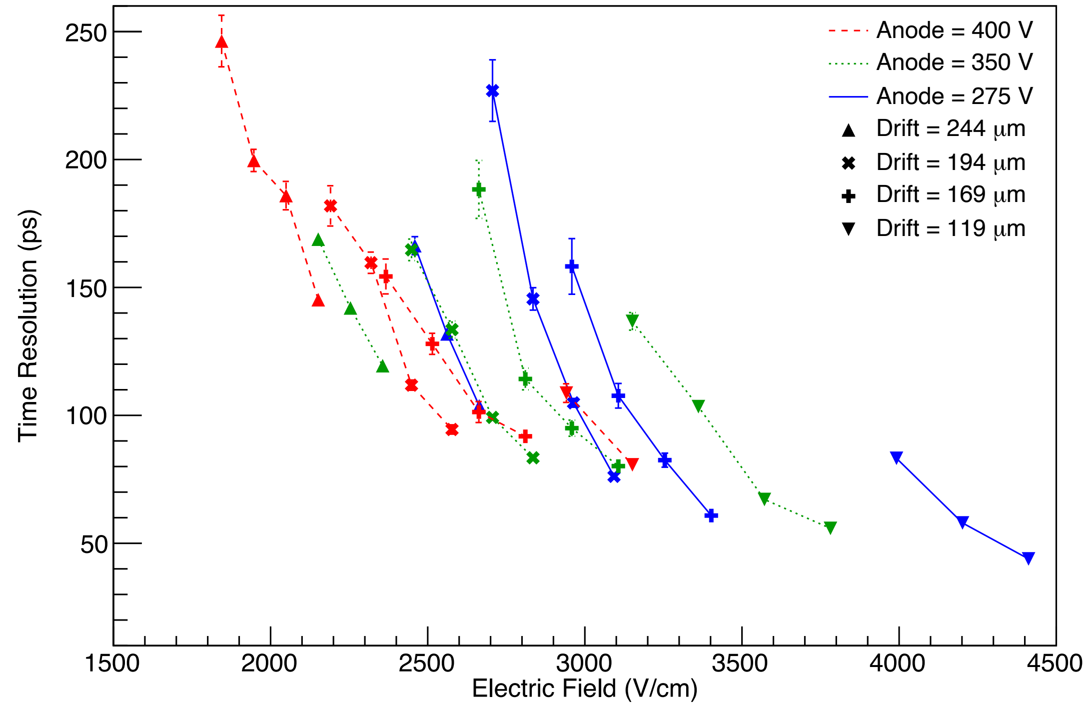


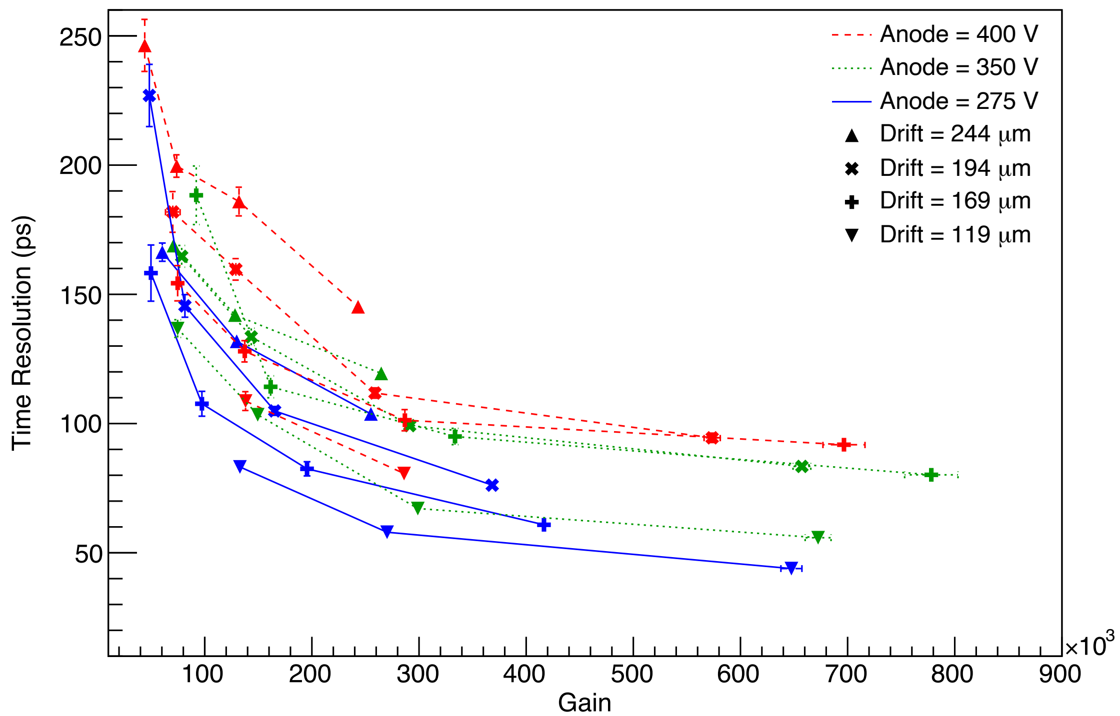
Time resolution improves with drift field and number of p.e.



- Drift field scan performed for several drift distance and p.e. settings
- Time resolution improves with higher drift field
- Smaller drift gaps allow higher electric fields
- Time Resolution improves for many p.e.

Time resolution improves with higher field in a shorter drift gap





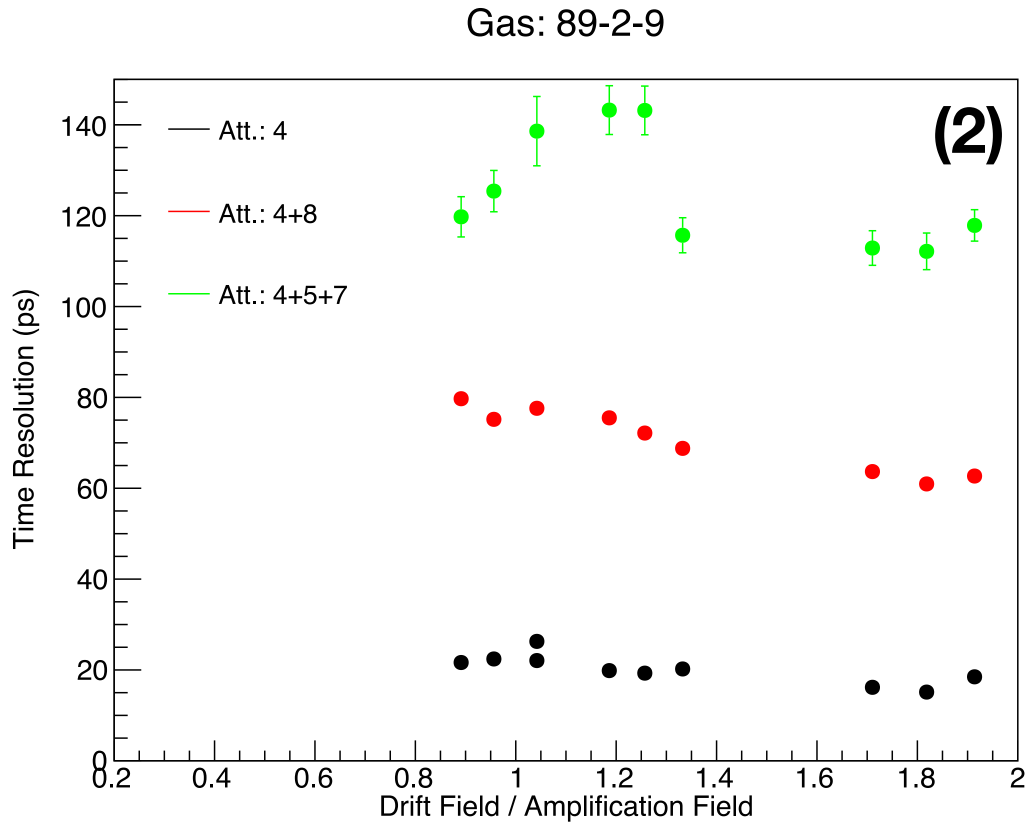
1 p.e.; Anode: 128 μm

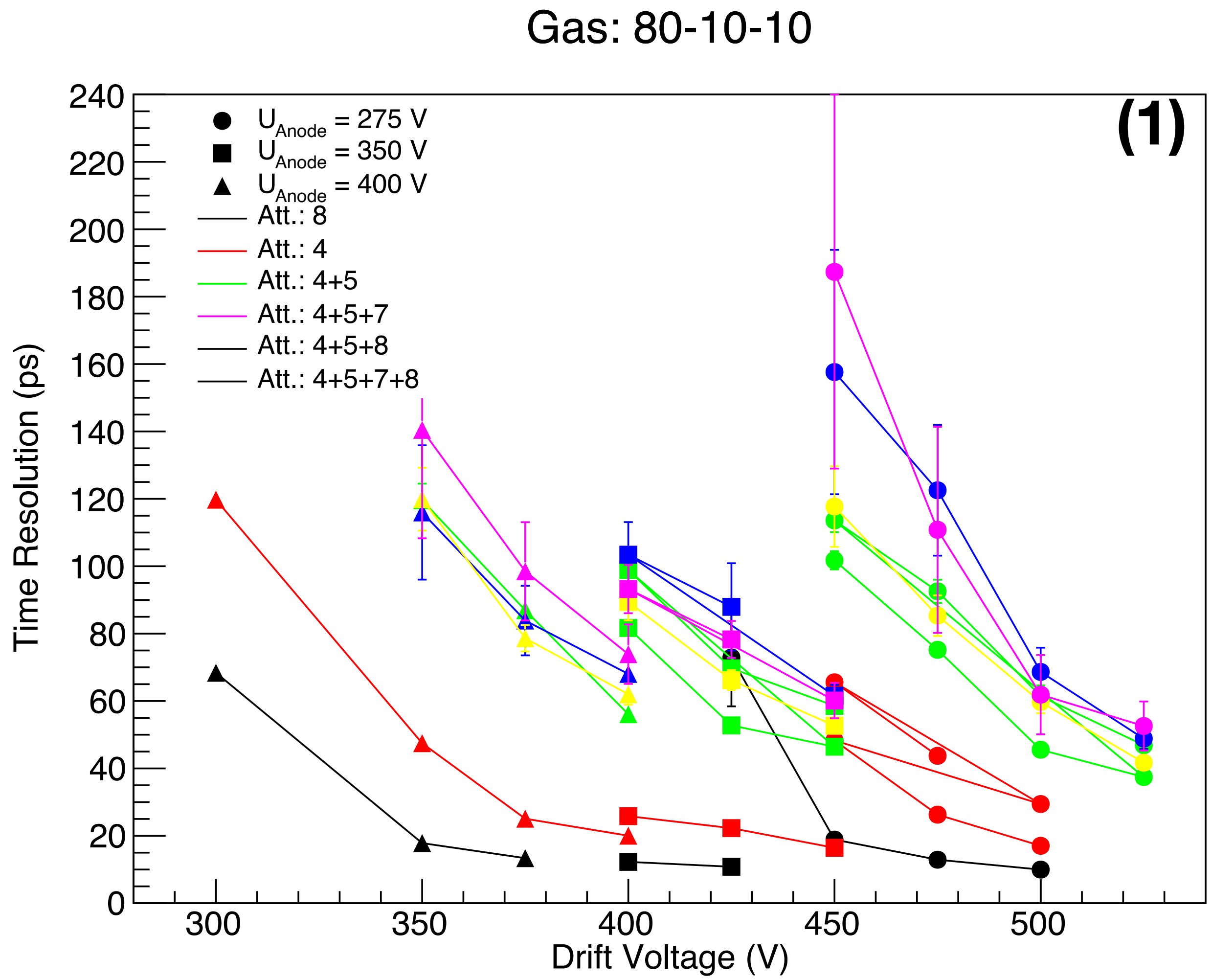
- Time resolution improves with electric field
- Time resolution < 50 ps at 1 p.e. is possible with preamplification larger than amplification
- Smaller drift gap has better performance at same gain
  - Shorter drift time of the first electron before starting an avalanche gives a better time resolution

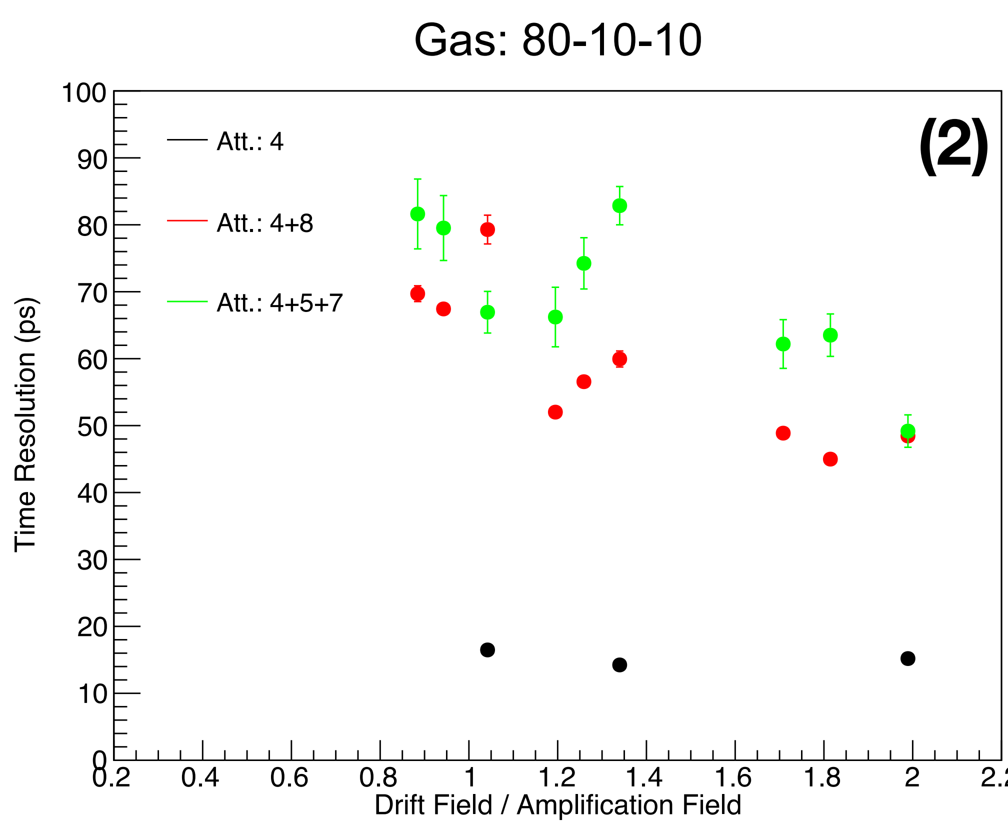
Gas mixture measurements

- Up to now all measurements done with „COMPASS gas mixture“
  - 80 % Neon : 10 % Ethane : 10 % CF_4
- Understand impact of the gas mixture on PICOSEC-Micromegas
  - Longitudinal diffusion may not be dominating factor
  - Higher total gain may improve the resolution
  - Similar gain at lower field can give technical advantages

- Two methodes of field scan:
  1. Keep fixed amplification field and variate drift field
  2. Keep gain constant and change field ratio
- Higher overall gain and higher drift field improves time resolution for all gases
- Measured different Neon-Ethane(-CF4) mixtures
  - Only Neon-CF4 too instable without quencher
  - Compas Gas (80-10-10) best performing





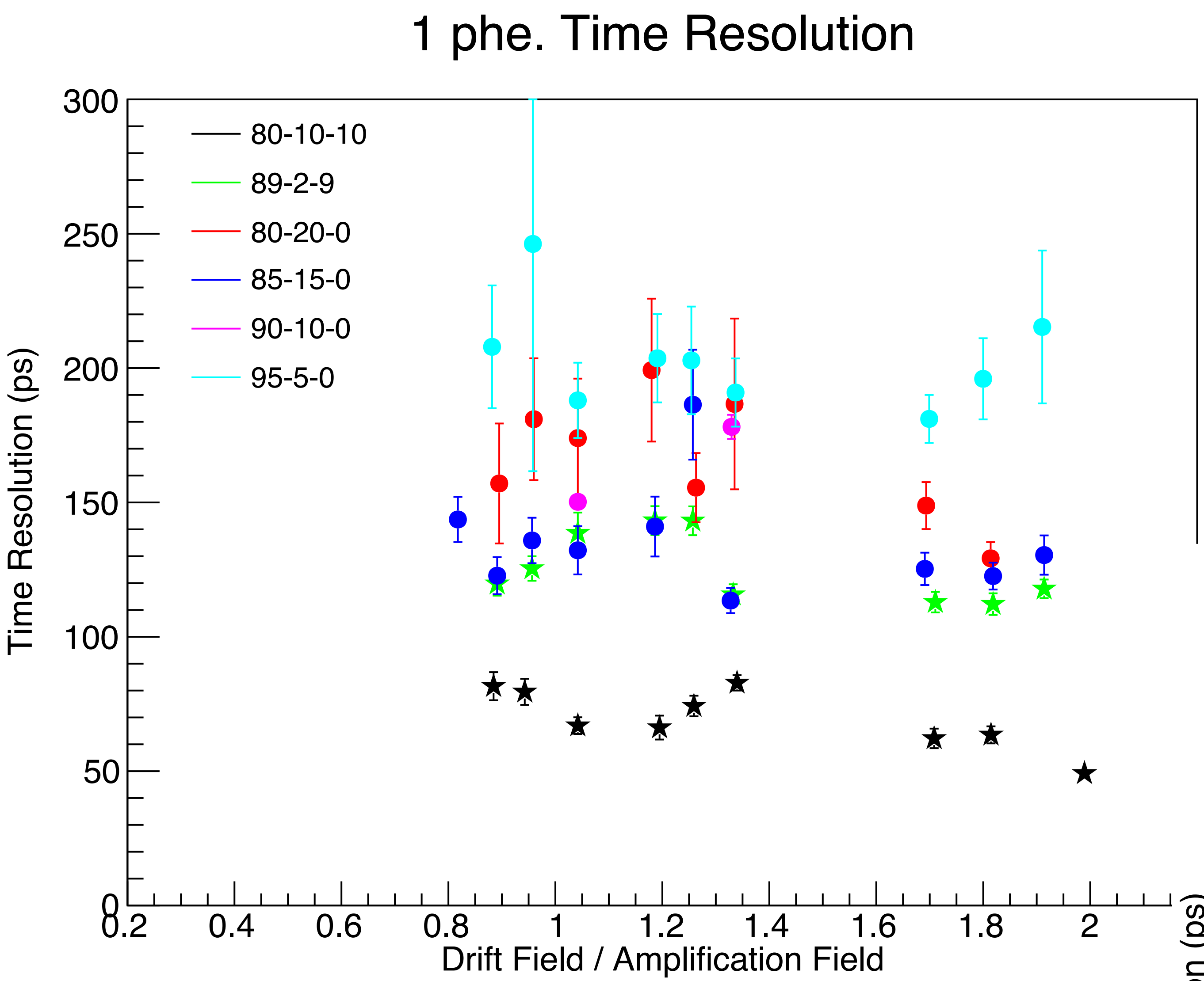


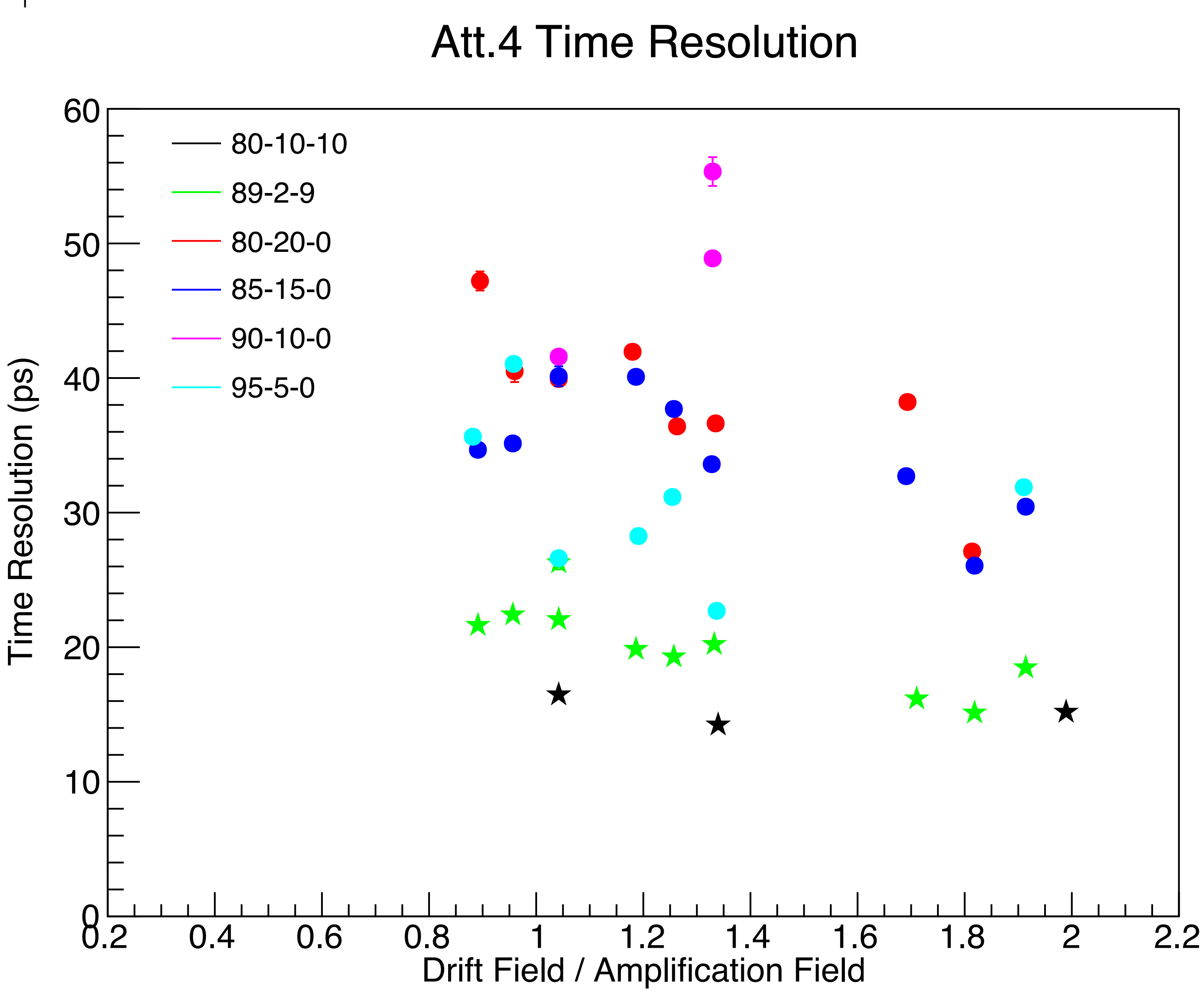
Best time resolution for 1 p.e.

Gas mixture (Neon-Ethane-CF4)	U_{Amp} (V)	U_{Drift} (V)	echarge (pC)	amplitude (mV)	$\sigma_{tres.}$ (ps)
80-10-10	275	525	8.58 ± 0.13	166.3 ± 0.2	43.89 ± 1.00
89-2-9	255	445	1.69 ± 0.01	31.56 ± 0.44	112.15 ± 4.03
80-20-0	270	470	0.54 ± 0.01	21.61 ± 0.18	129.21 ± 6.03
85-15-0	310	395	0.74 ± 0.01	22.83 ± 0.21	113.48 ± 4.66
90-10-0	340	340	0.82 ± 0.01	20.72 ± 0.09	150.23 ± 3.17
95-5-0	230	375	1.13 ± 0.01	22.98 ± 0.16	181.09 ± 8.91

- Ethane+CF4 allows higher electric fields and thus better time resolution
- Improvement with Ethane: less gain but narrower signal at higher field
- Optimum mixture of only Neon-Ethane reached at 85-15

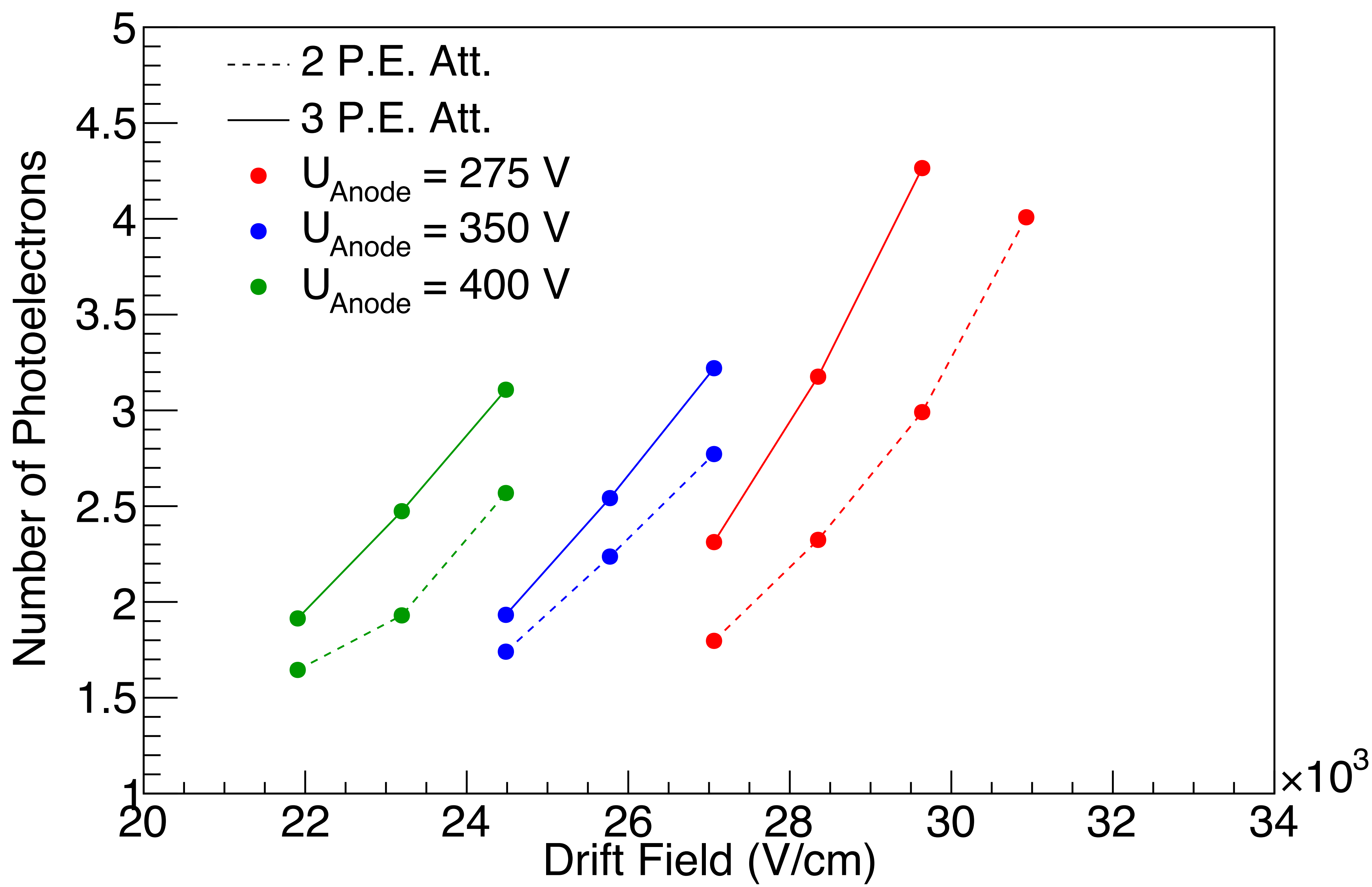
- Ne-Ethane-CF4 can hold higher voltage -> better gain-> better resolution
- Ne-Ethane-CF4 improves with higher drift field
- Ne-Ethane worsens at too high Drift/ Amplificatio ratios
- Ne-Ethane of 85-15 provides best Ne-Ethane performance





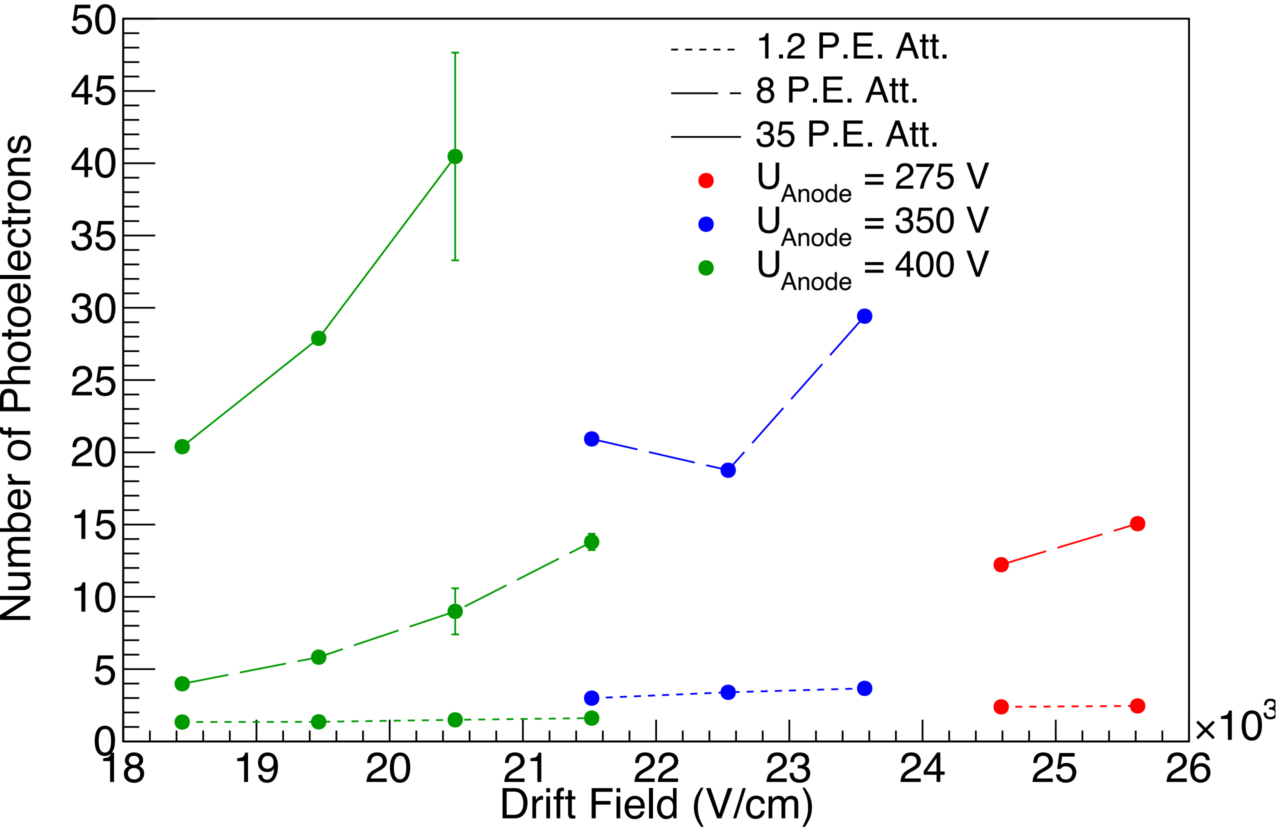
N.p.e. depending on the field?

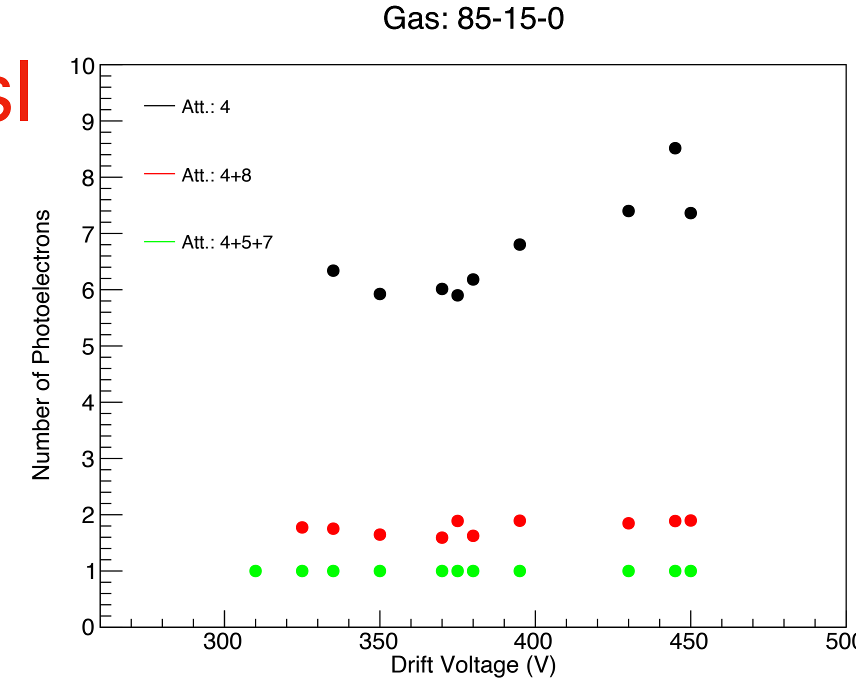
N.p.e. rises at constant light and higher drift field

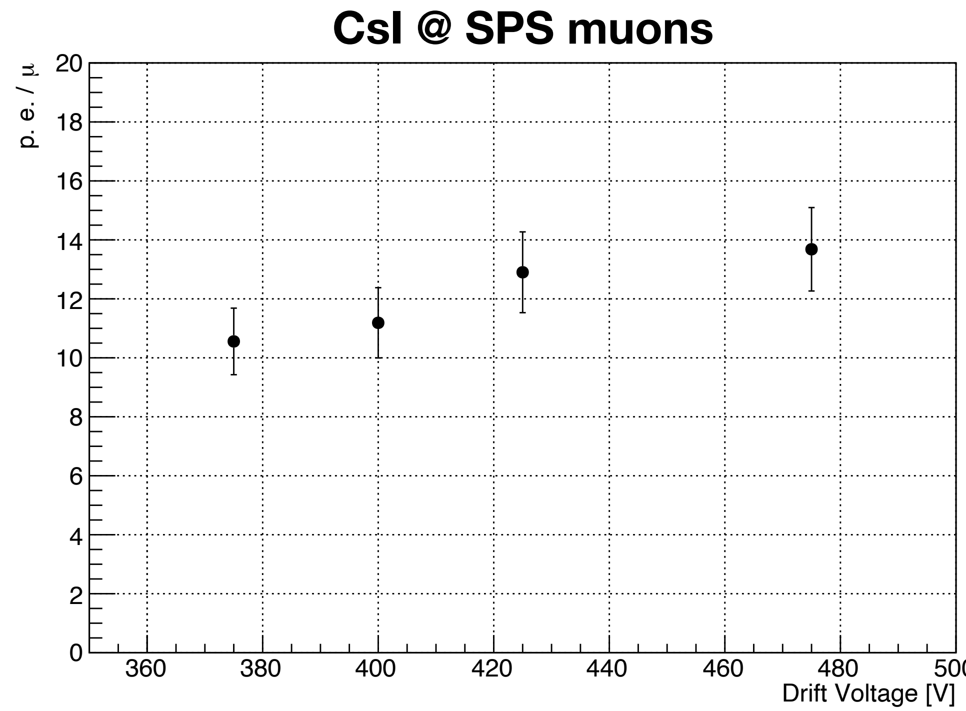


Effect is stronger at more light

- At single p.e. conditions not noticeable
- Same beahviour at all gas mixtures
- Same effect with muons and CsI

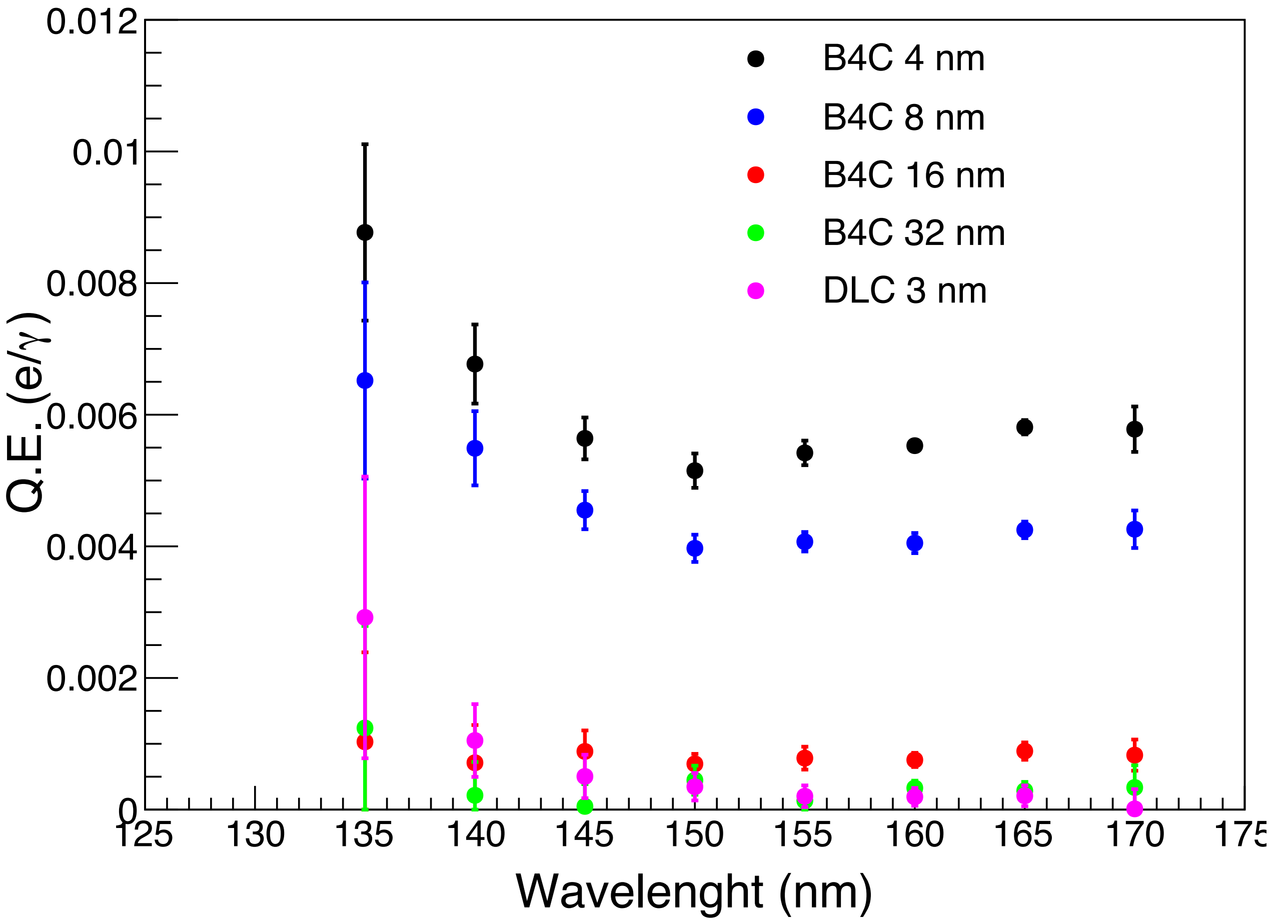


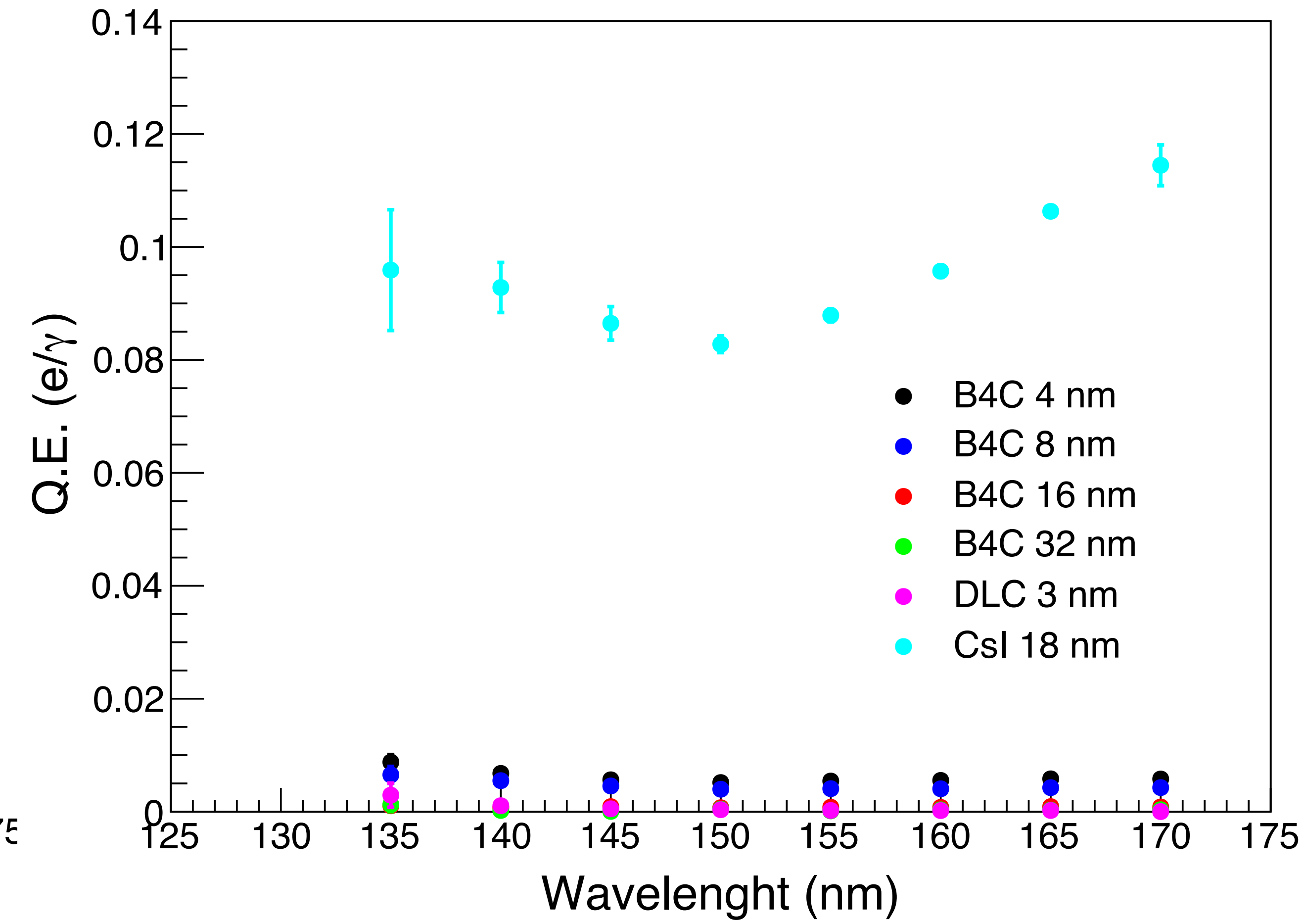




B4C promising photocathode material

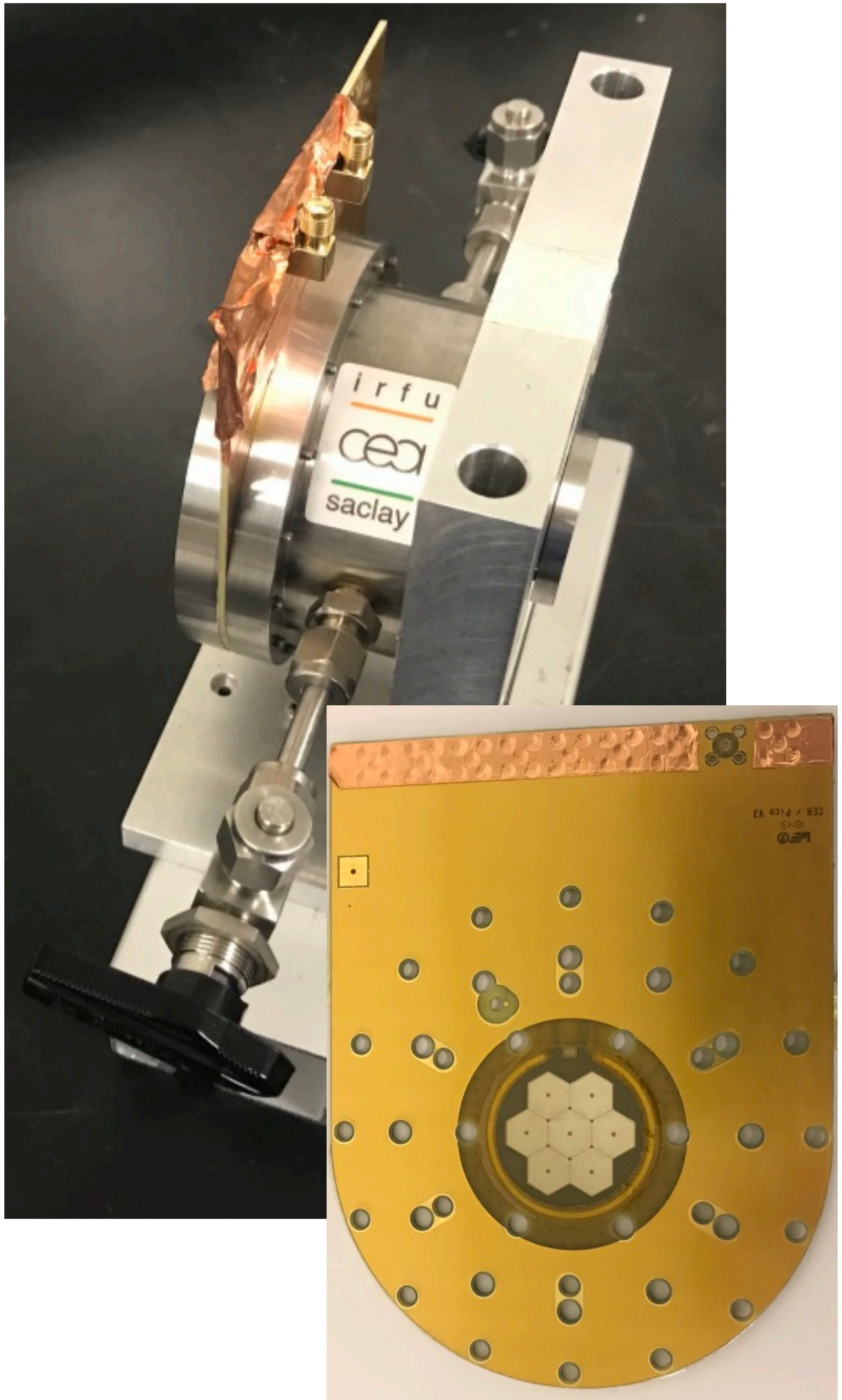
- Test of photocathodes in the ASSET chamber at CERN
  - More in Martas talk and the DLC sessions
- B4C 5 times higher q.e. compared to DLC
- CsI 10x higher q.e.
- DLC/B4C is maybe a secondary emitter?
  - In the muon beam: CsI 7-11 phe.; DLC 3-4 phe.
  - In the laser: only few signals from DLC



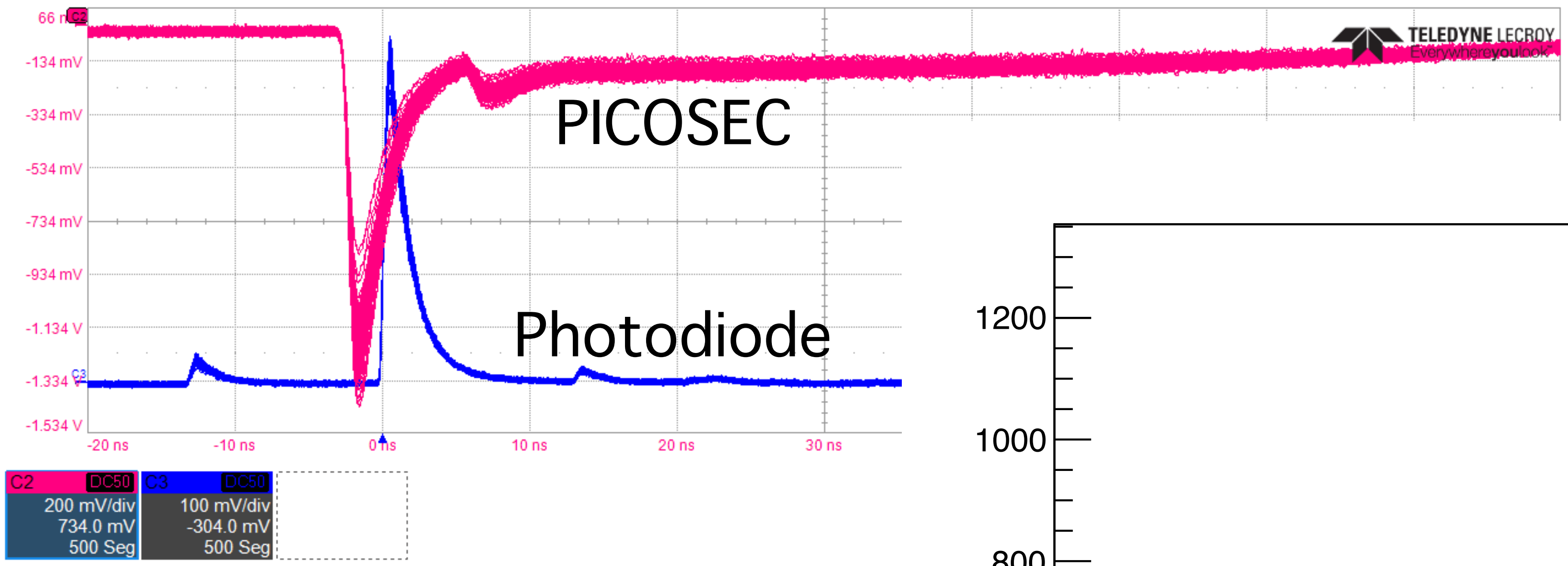


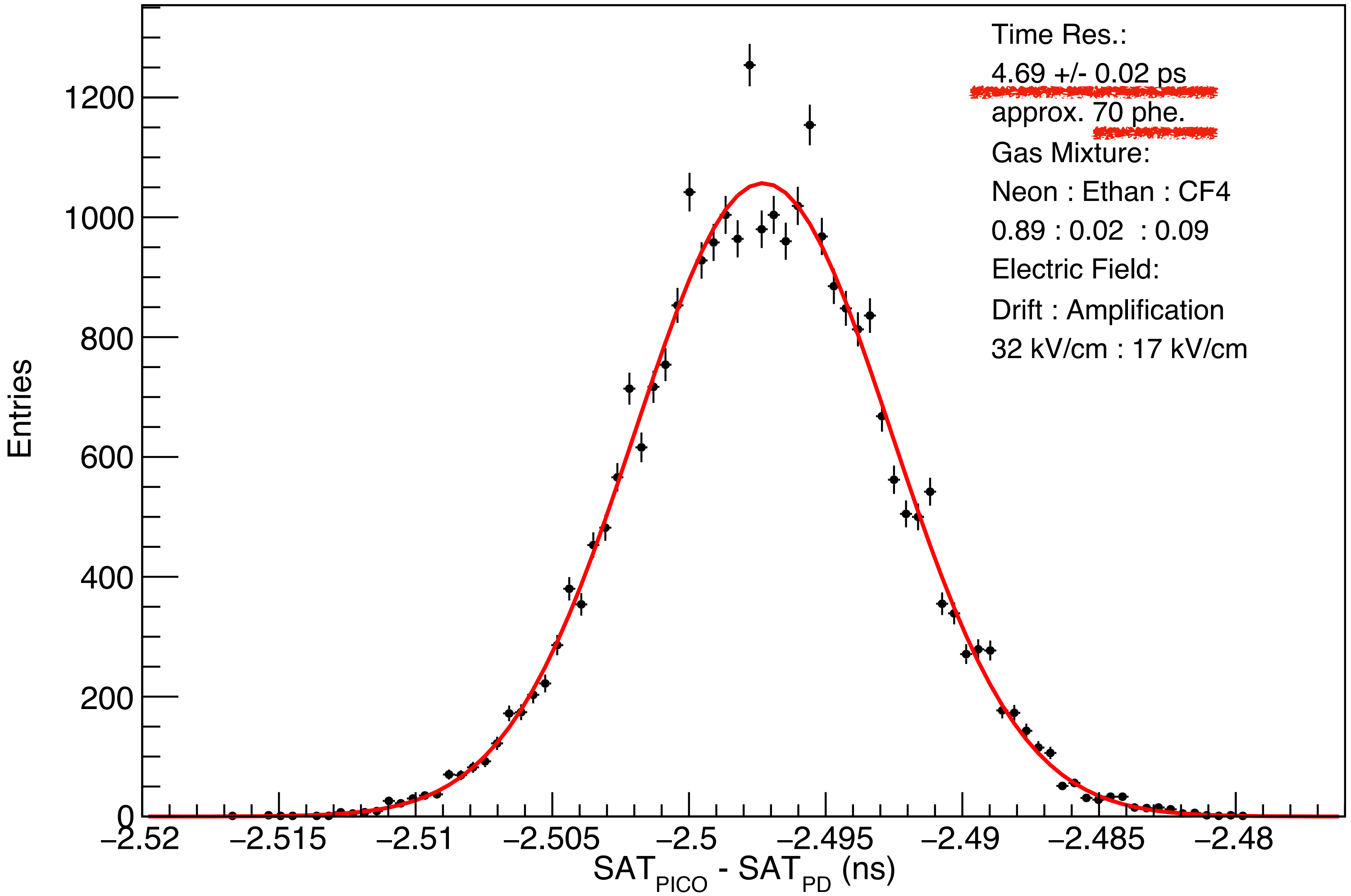
What is next …

- Research for photocathode materials (DLC, B4C, secondary emitter, nano diamonds, …)
  ➡ Only few p.e. needed for target time Resolution when <50 ps @ 1 p.e.
  - Irradiation and Q.E. measurements at USTC
  - ASSET chamber at CERN
  - Beam test for secondary emitter
- Production of a resistive multipad Picosec chamber
  ➡ Beam time May 2020 at PSI πE1
- (Embedded) electronics for segmented readout



What is possible with a lot of light: <5 ps @ ~70 phe.





PICOSEC

Micromegas

Backup

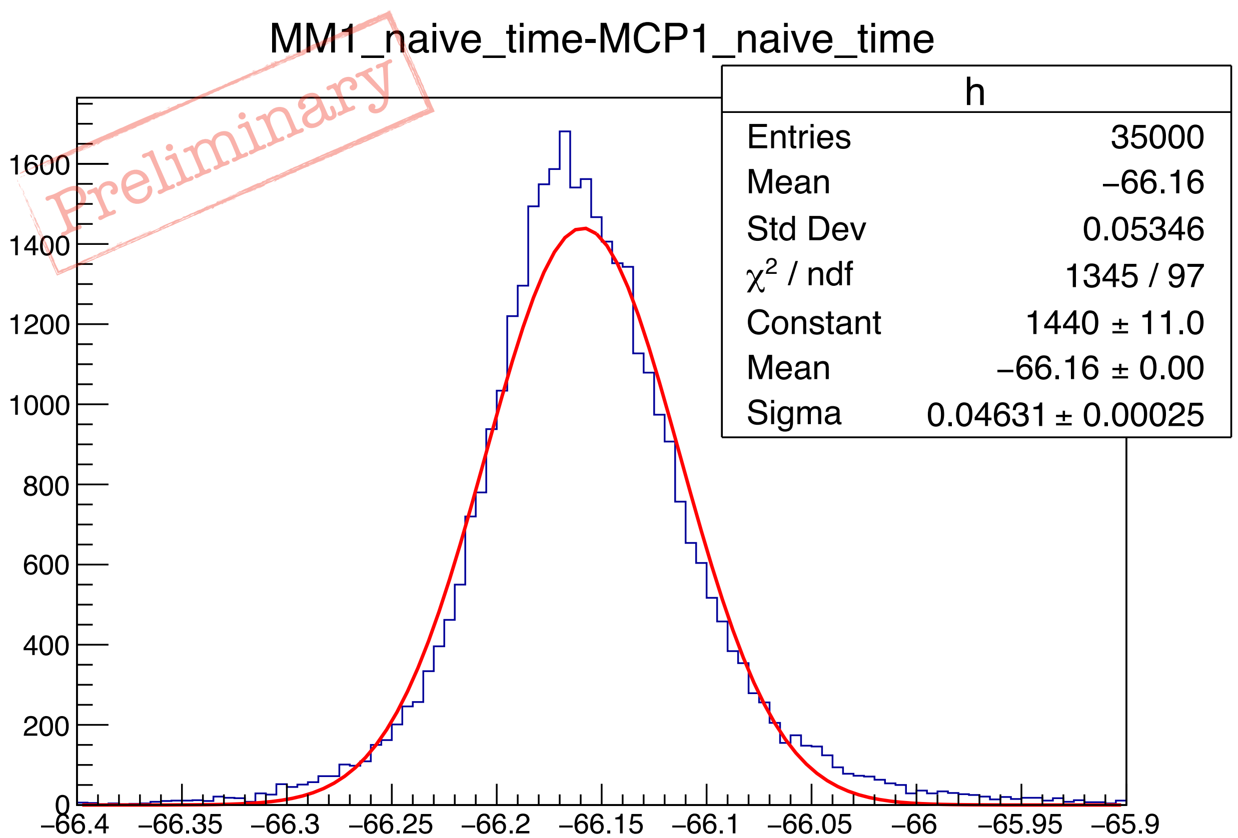
New Amplifier Tested

PICOSEC Amplifier „ATHR N3“

CIVIDEC „C2HV0177“

Anode: 275 V
Drift: 600 V
Drift gap: 194 µm
4 photoelectrons

ATHR N3



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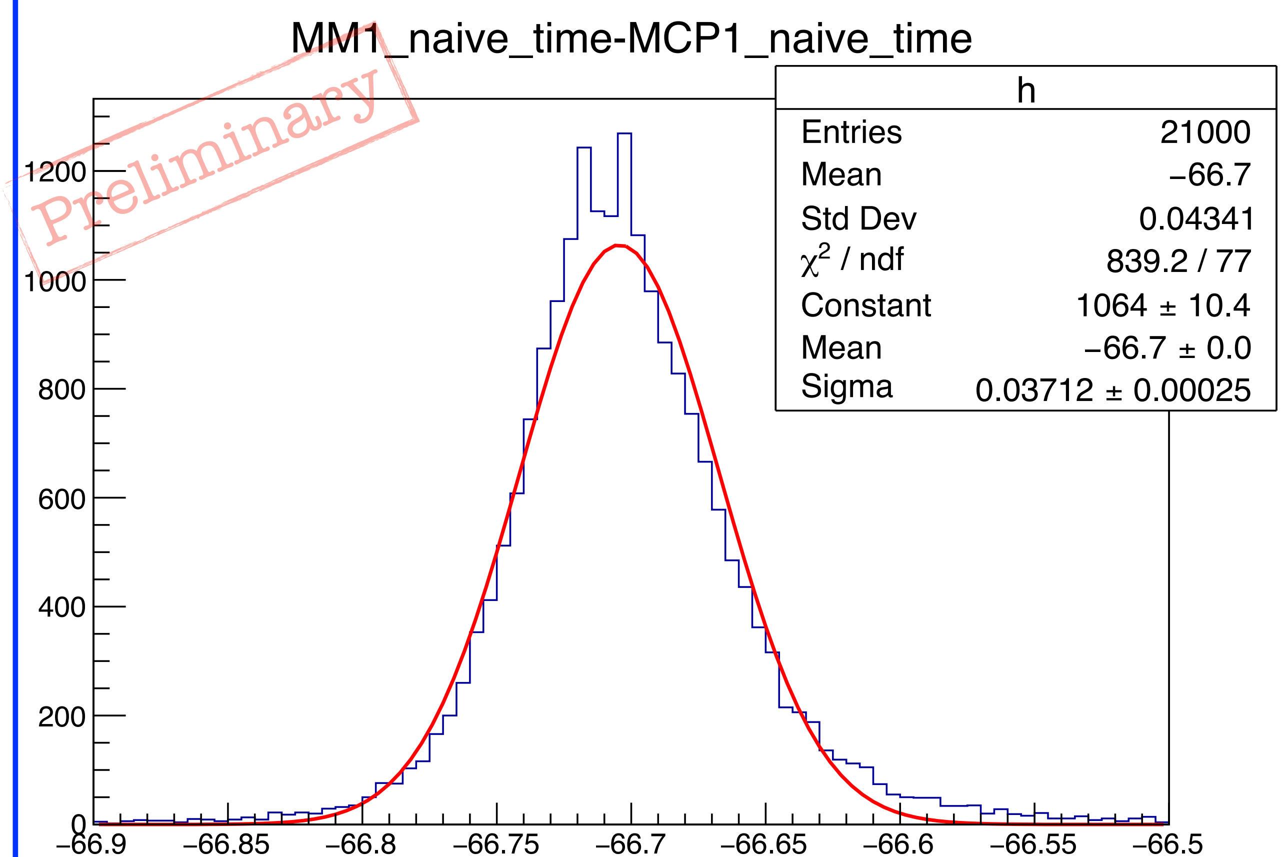
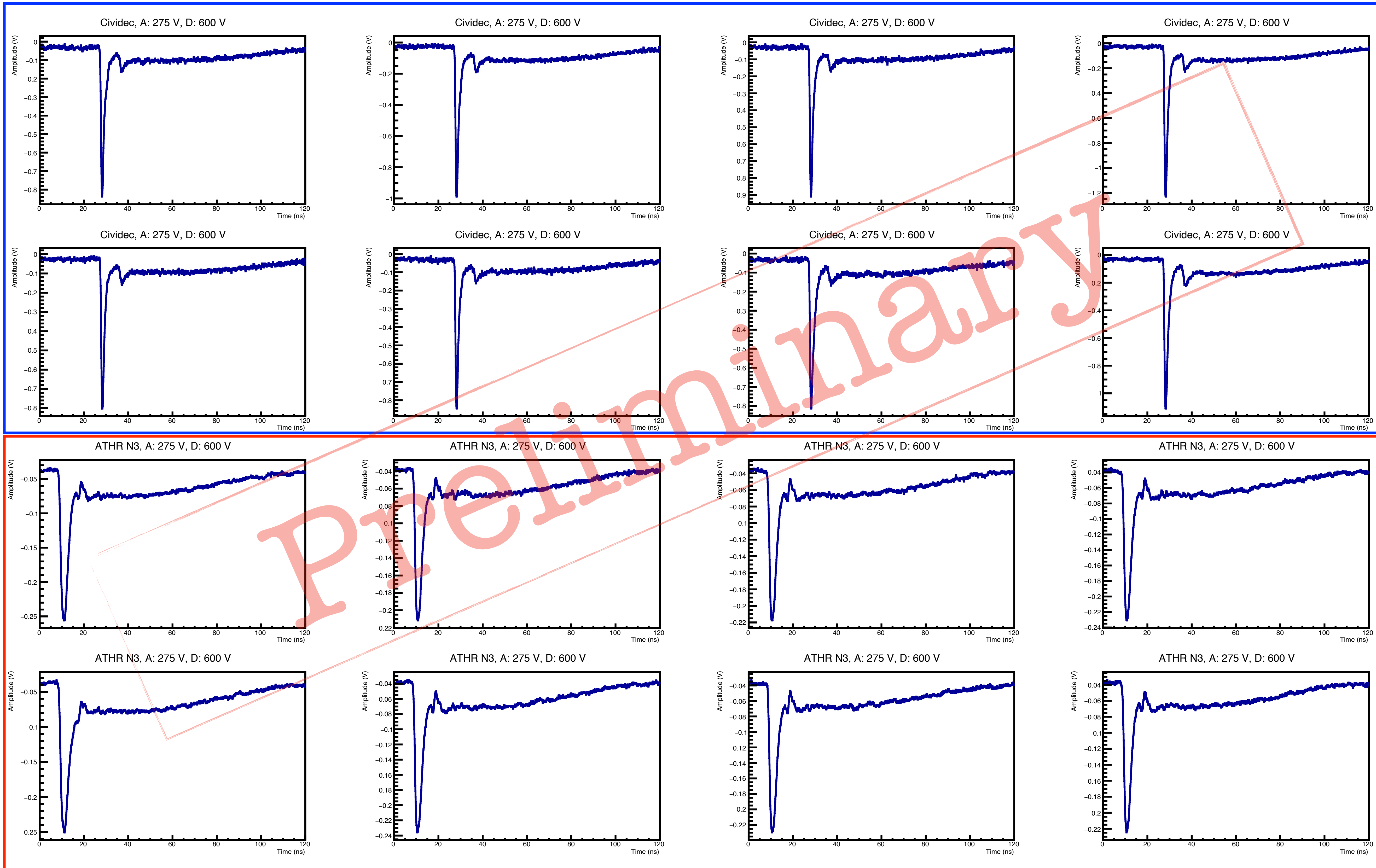
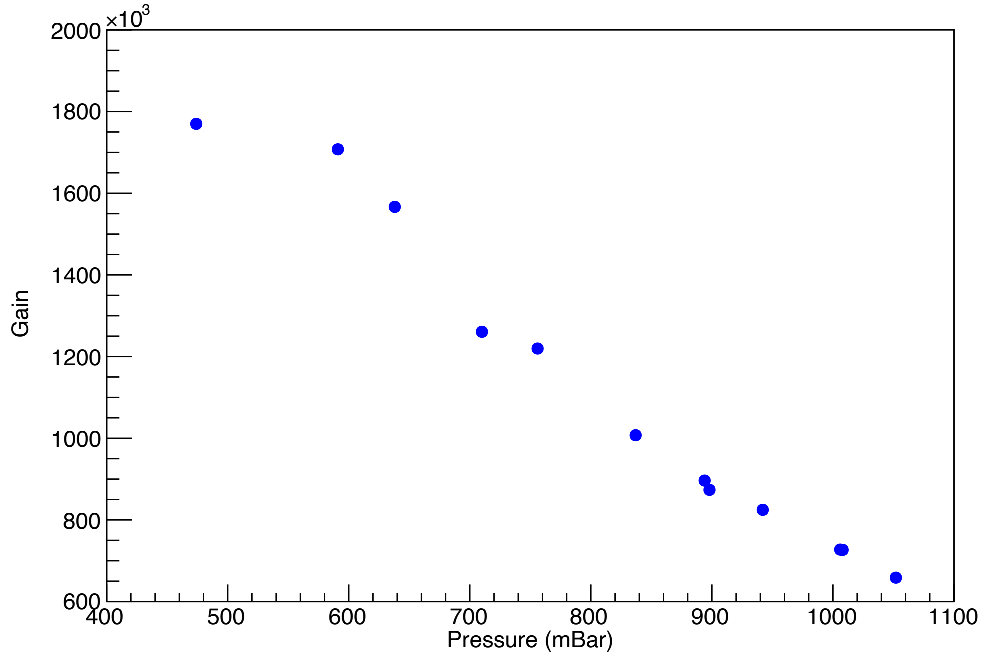


Comparison of selected waveforms

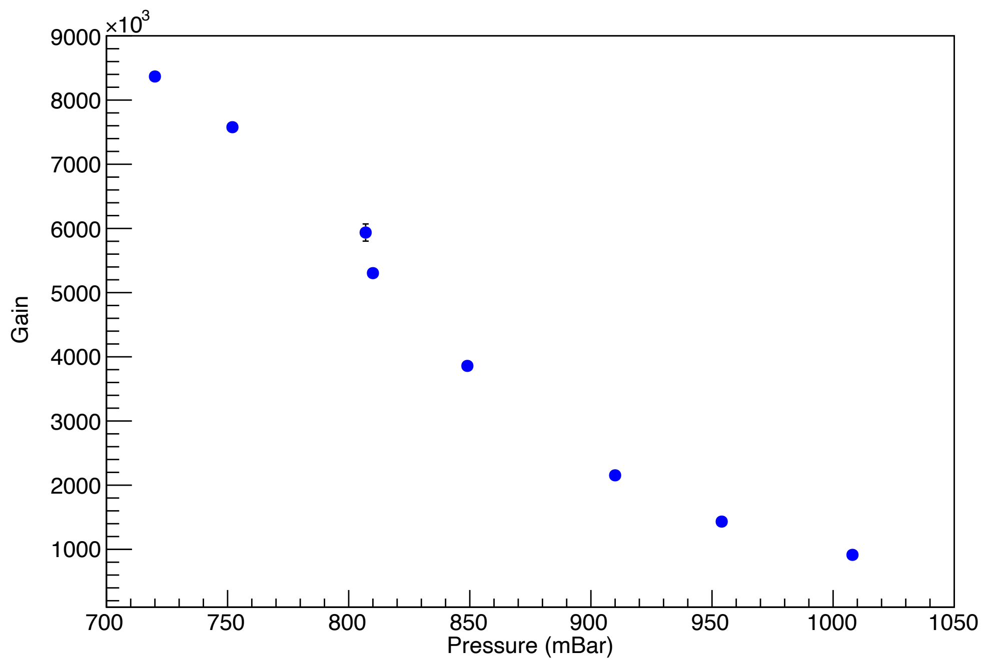


Gain rises and saturates at lower pressure

Anode 500 V; Drift 100 V

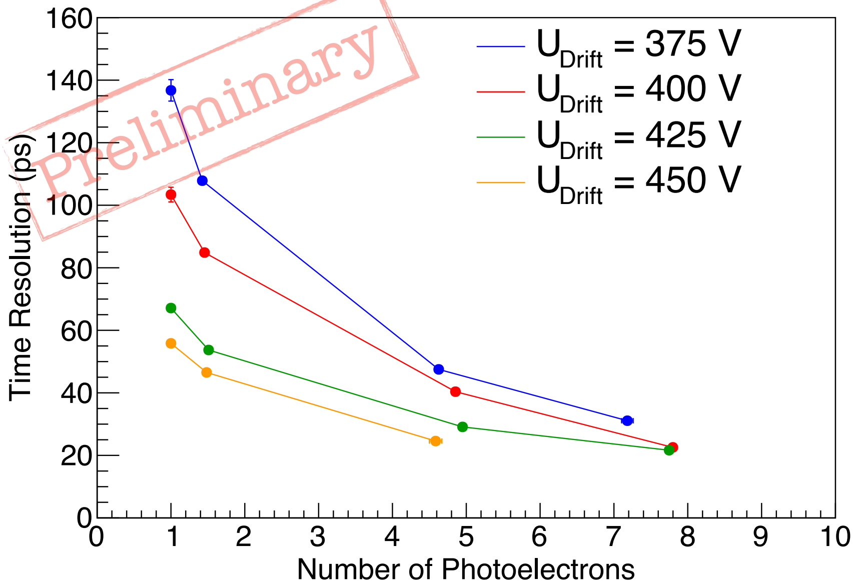


Anode 275 V; Drift 450 V

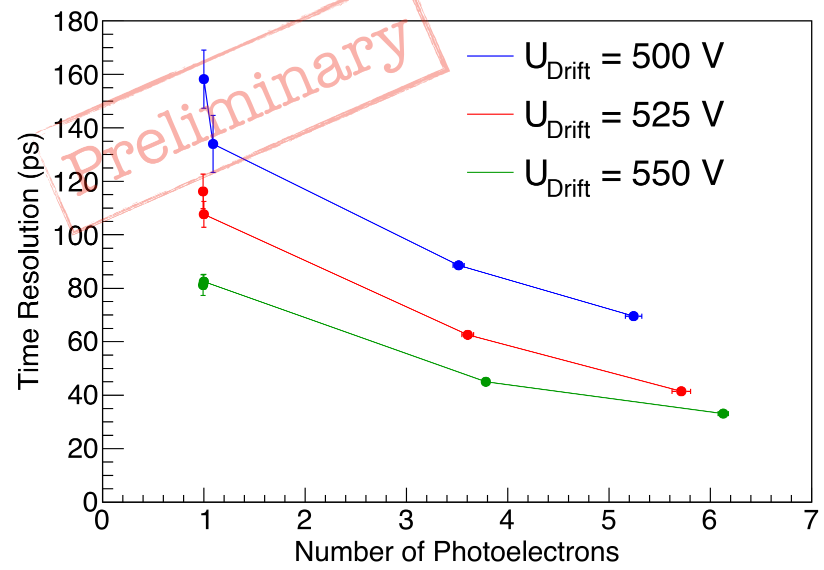


- Measurement done for COMPASS gas only
- Gain saturates at lower pressure
- Natural atmospheric pressure fluctuation can affect gain and thus time resolution
- Time resolution measurements at different gas pressures are planned

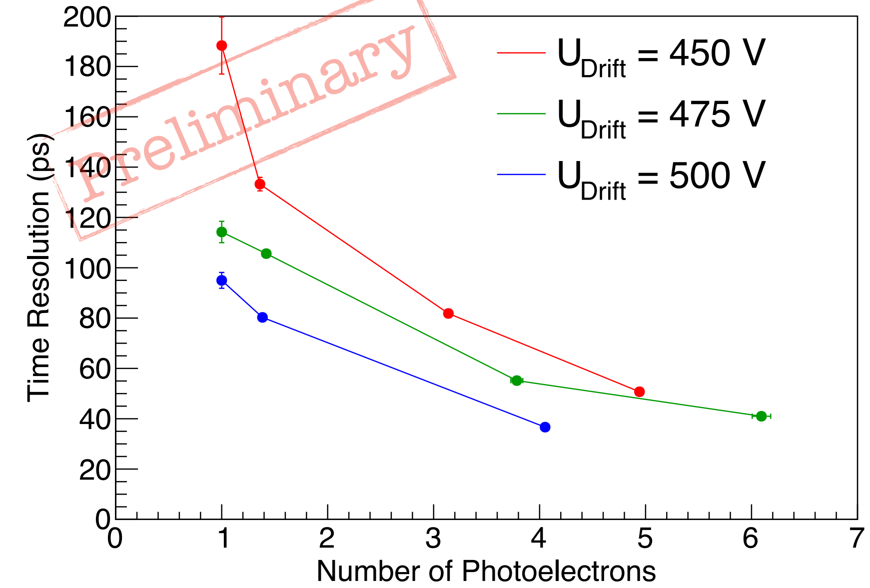
119 μm; Anode 350 V



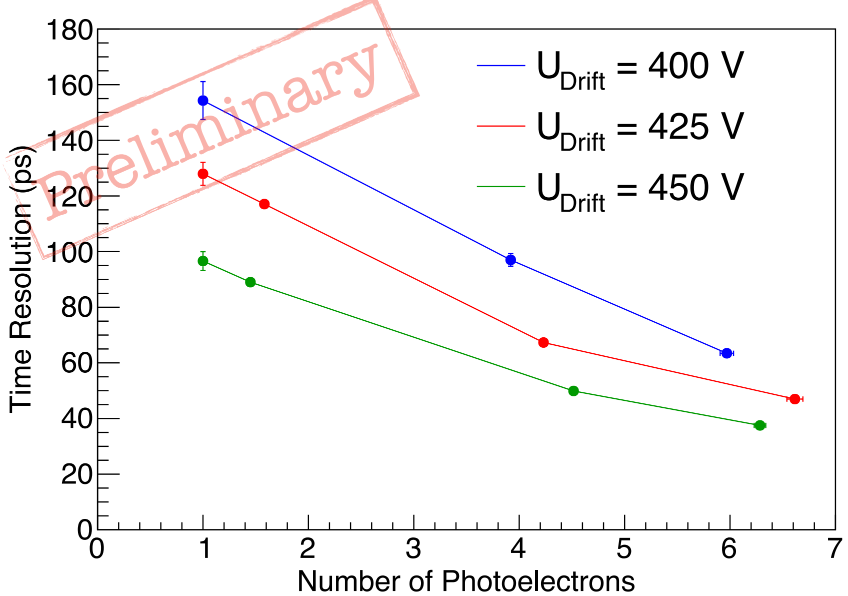
169 μm; Anode 275 V



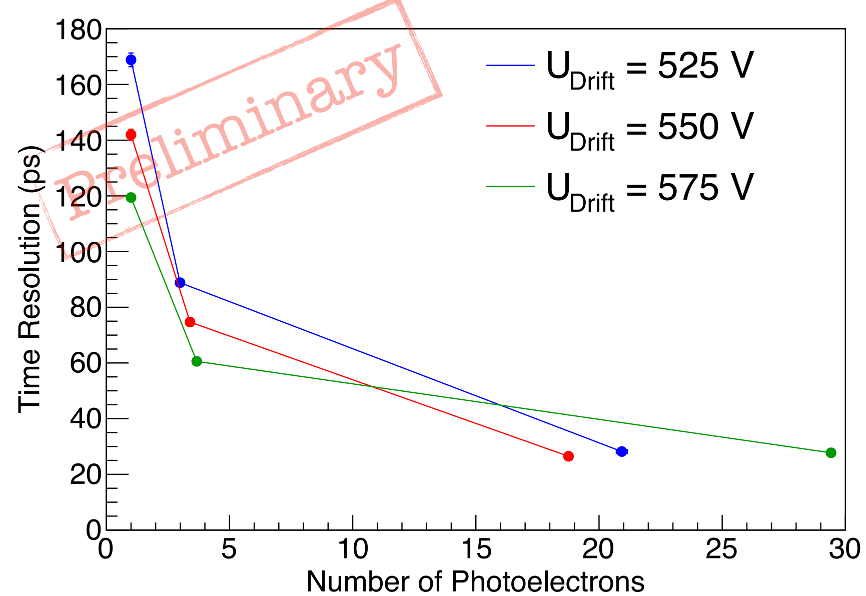
169 μm; Anode 350 V



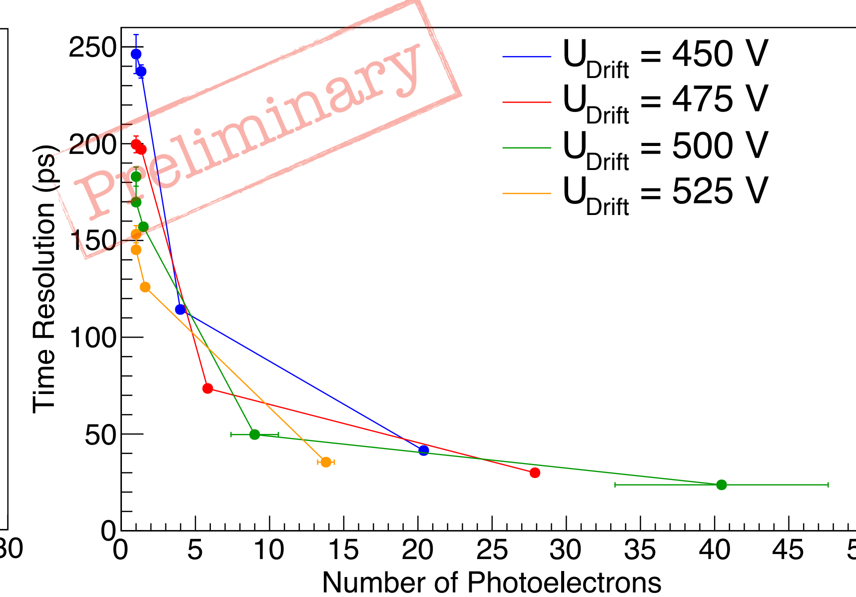
169 μm; Anode 400 V



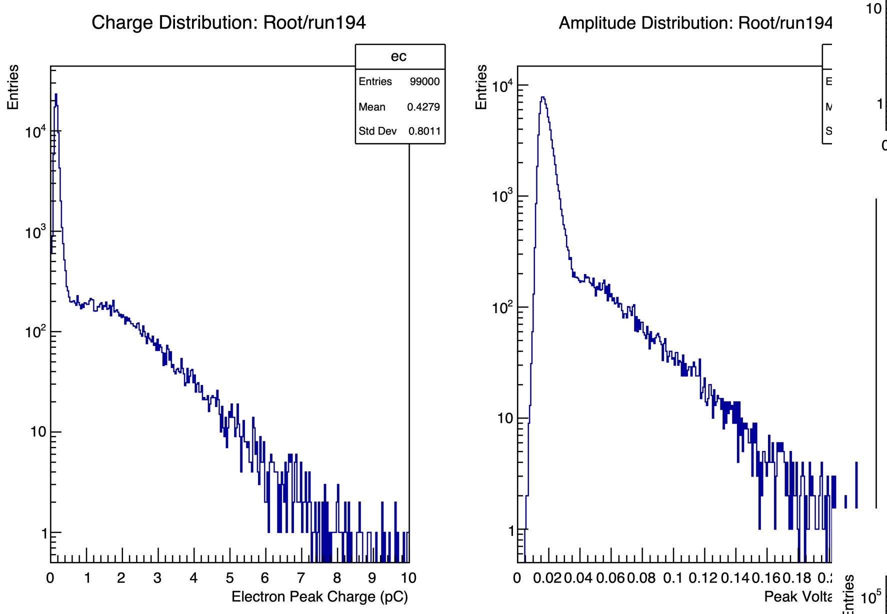
244 μm; Anode 350 V



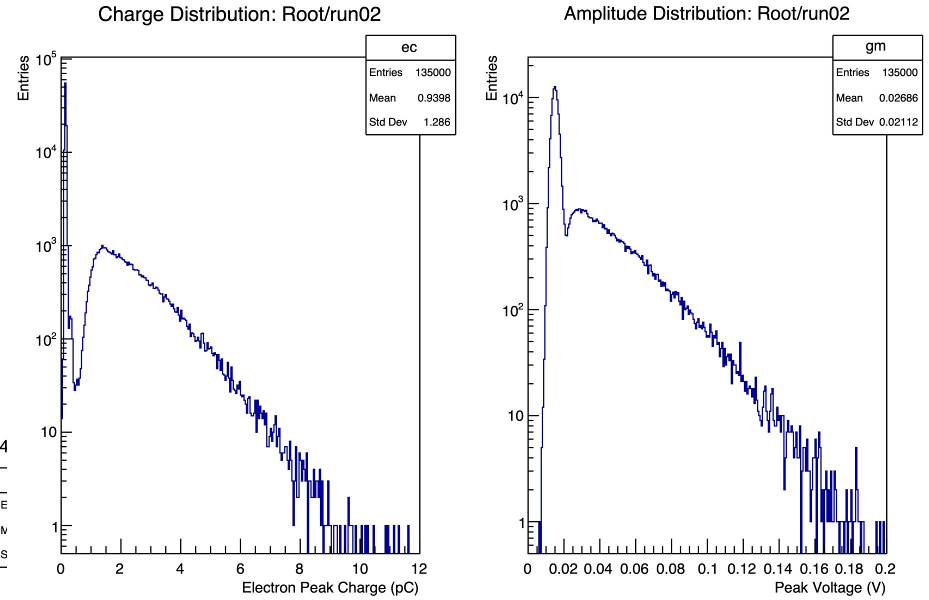
244 μm; Anode 400V



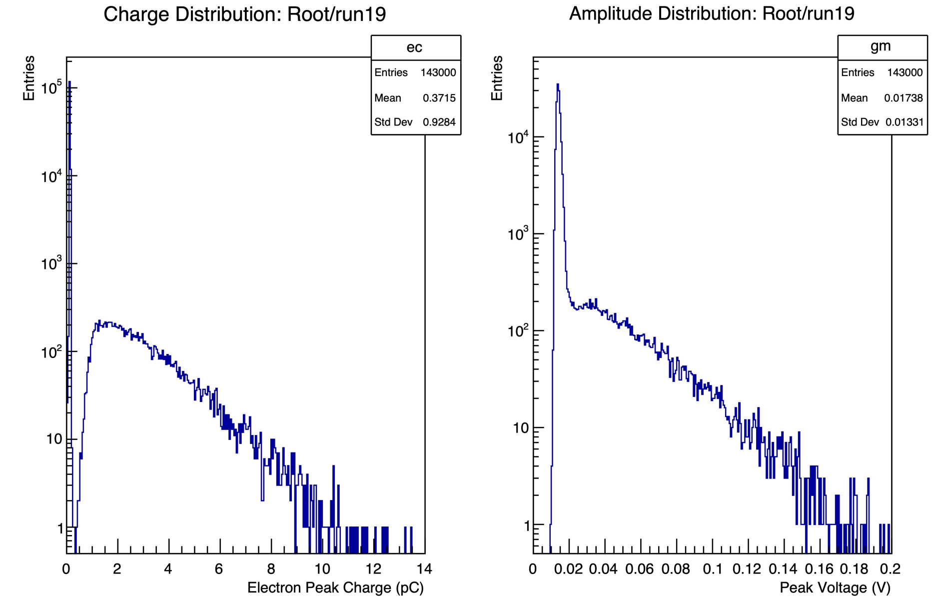
COMPASS GAS
A:350V D:500V



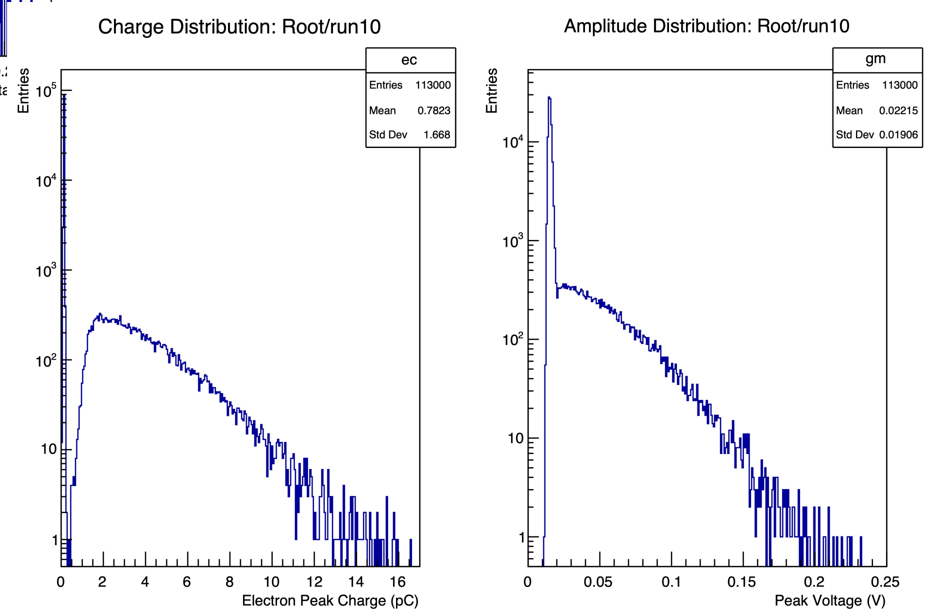
Ne 80%
A:350V D:575V



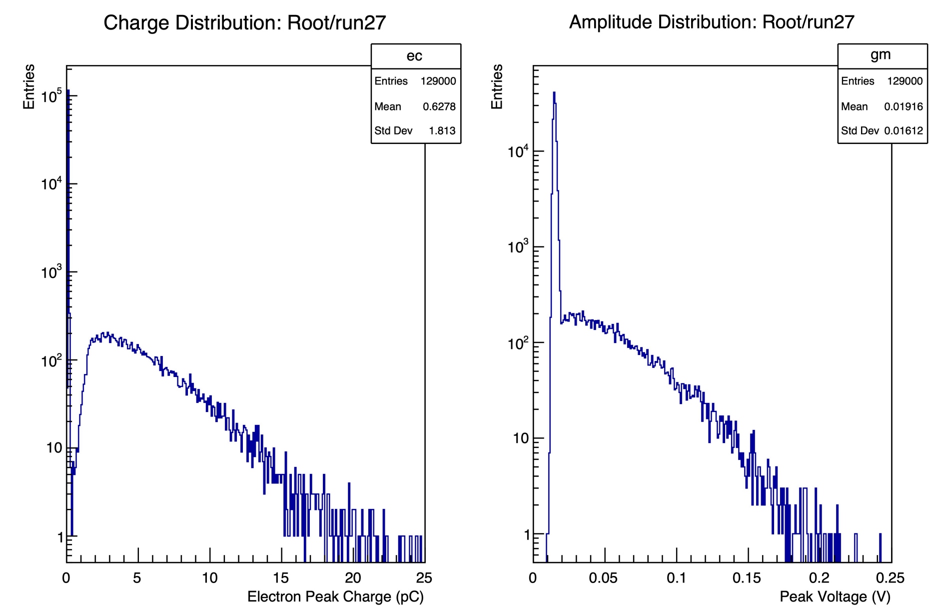
Ne 85%
A:350V D:495V



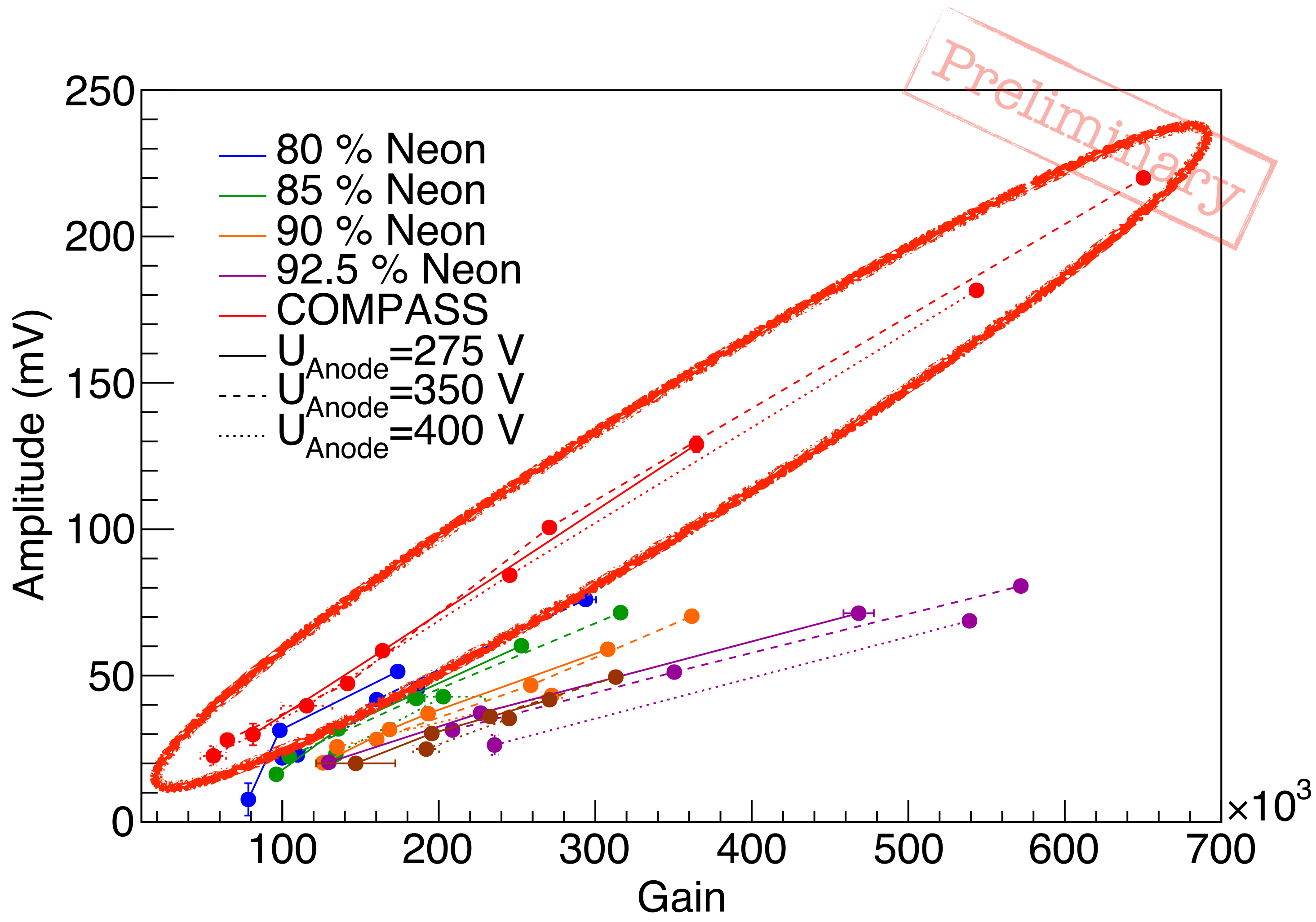
Ne 90%
A:350V D:425V



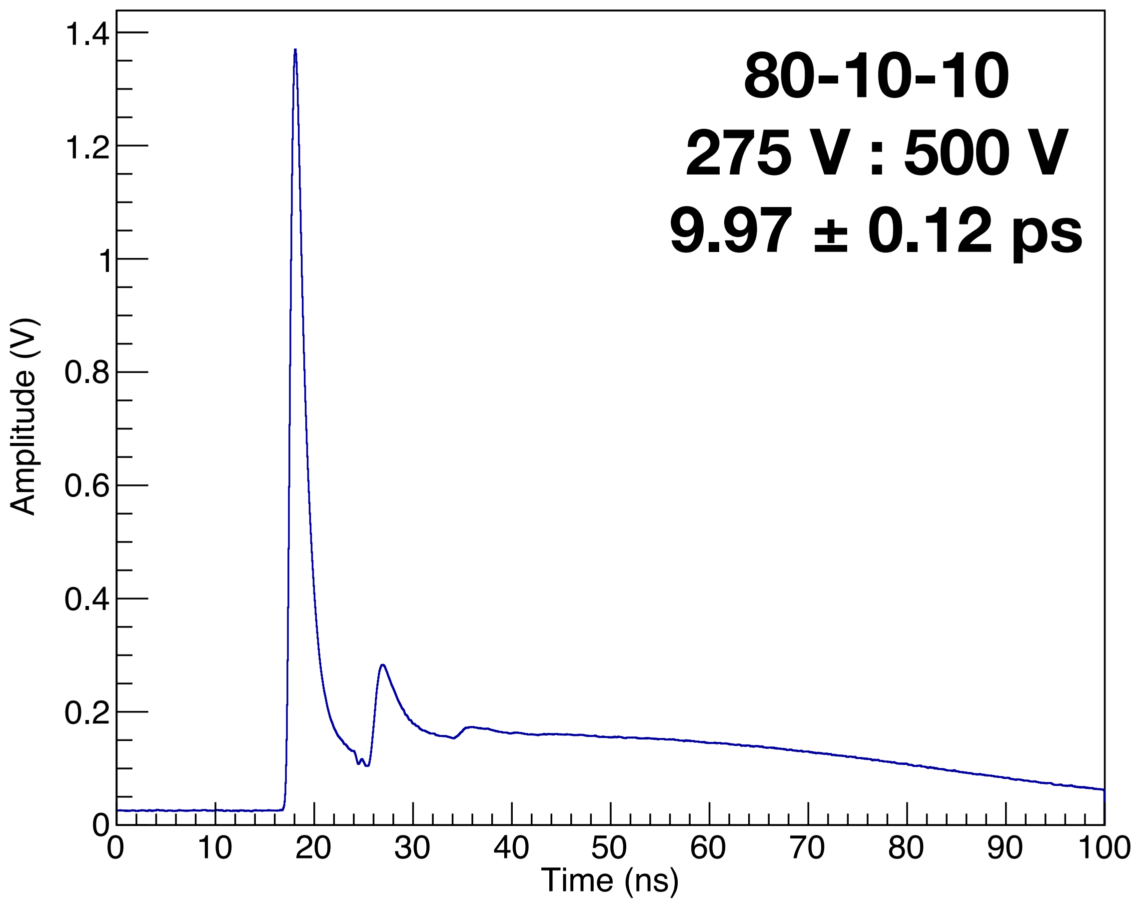
Ne 92.5%
A:350V D:390V

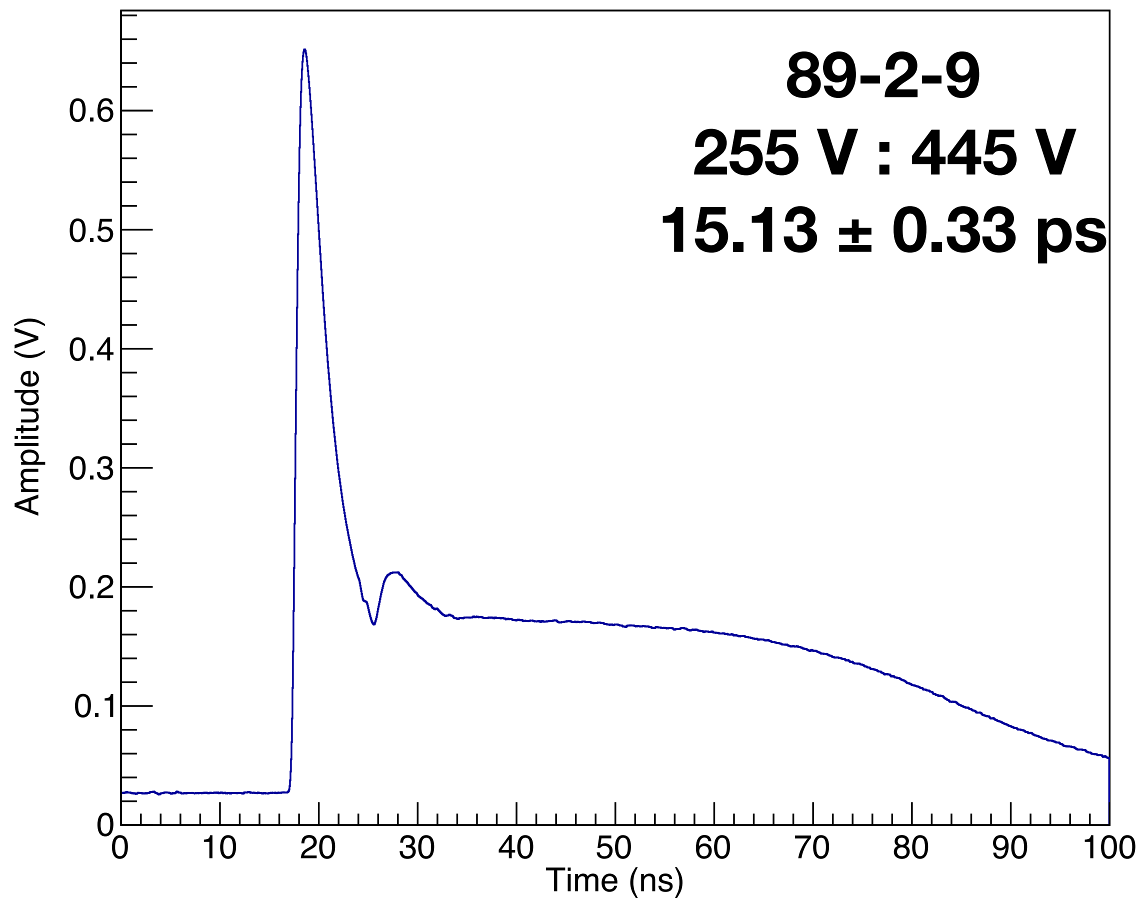


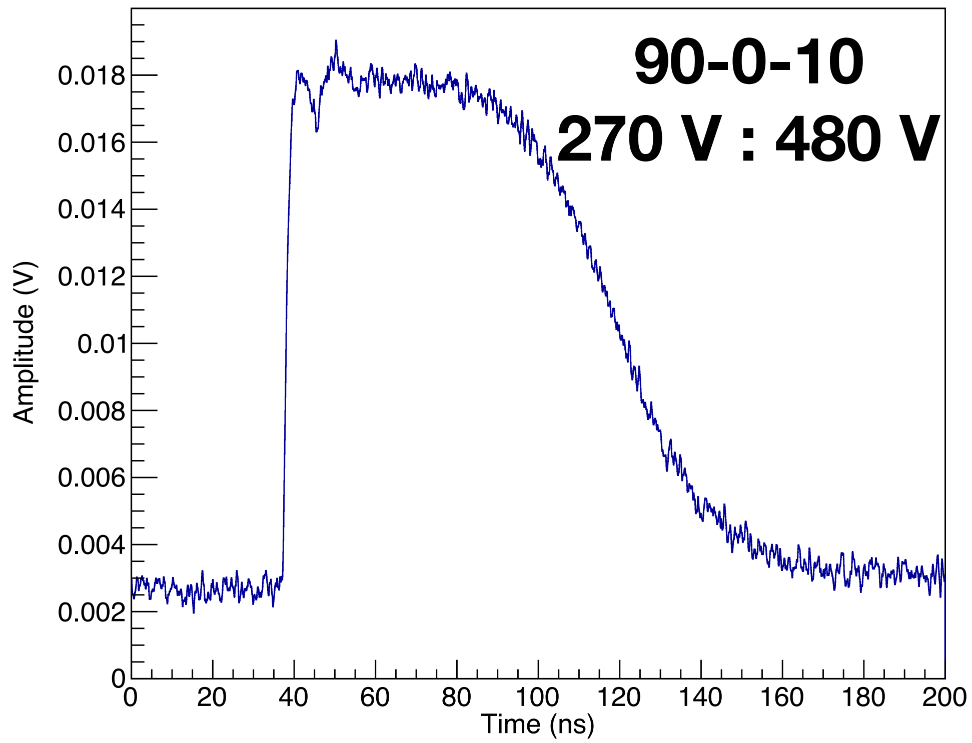
Amplitude vs. gain ratio gives hint about signal shape

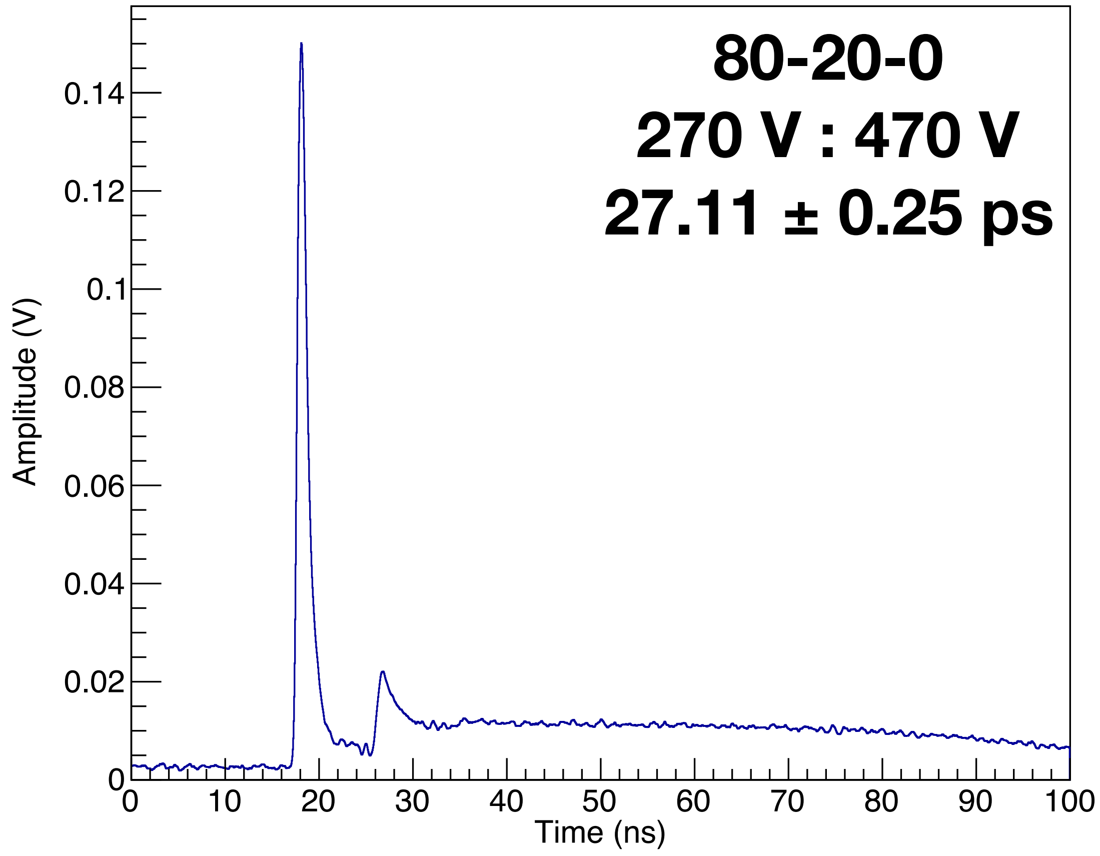


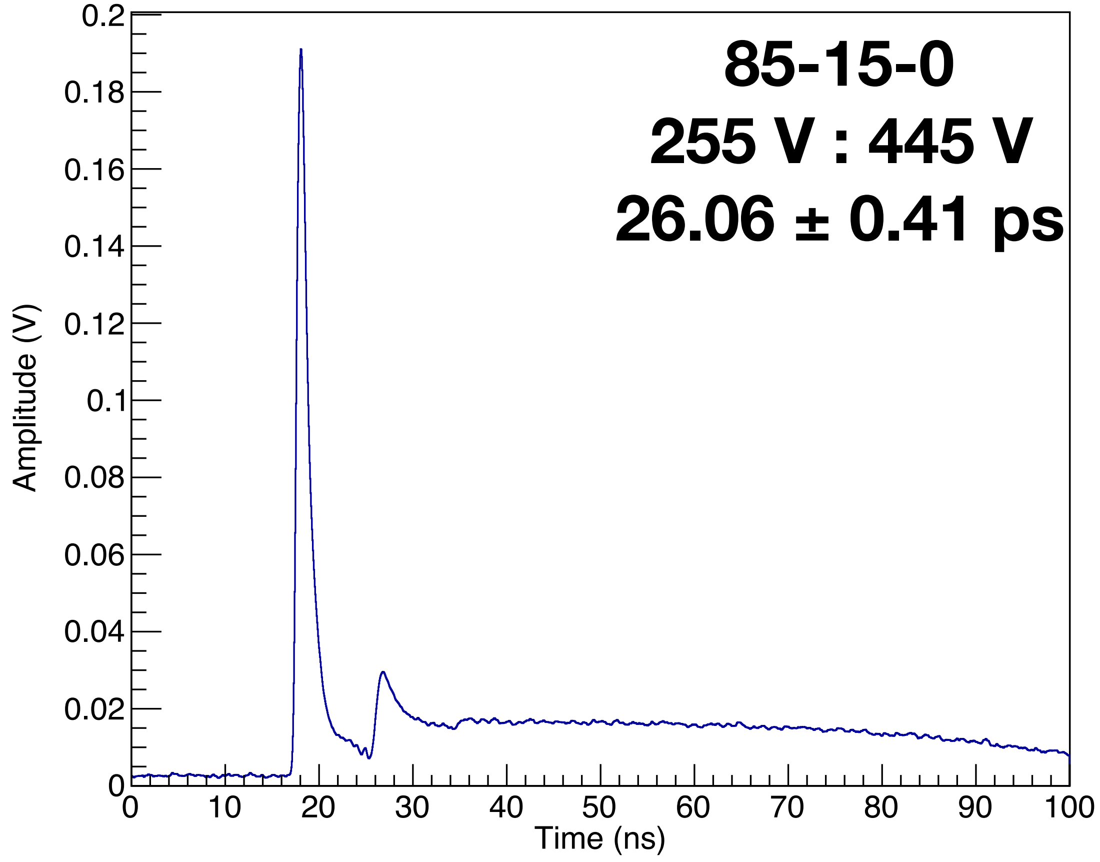
- Sharper electron peaks have higher amplitude at the same signal charge
- COMPASS gas mixture signals are given steeper rising edges than the other mixtures
- Probably better time resolution
- To be verified in the Laser

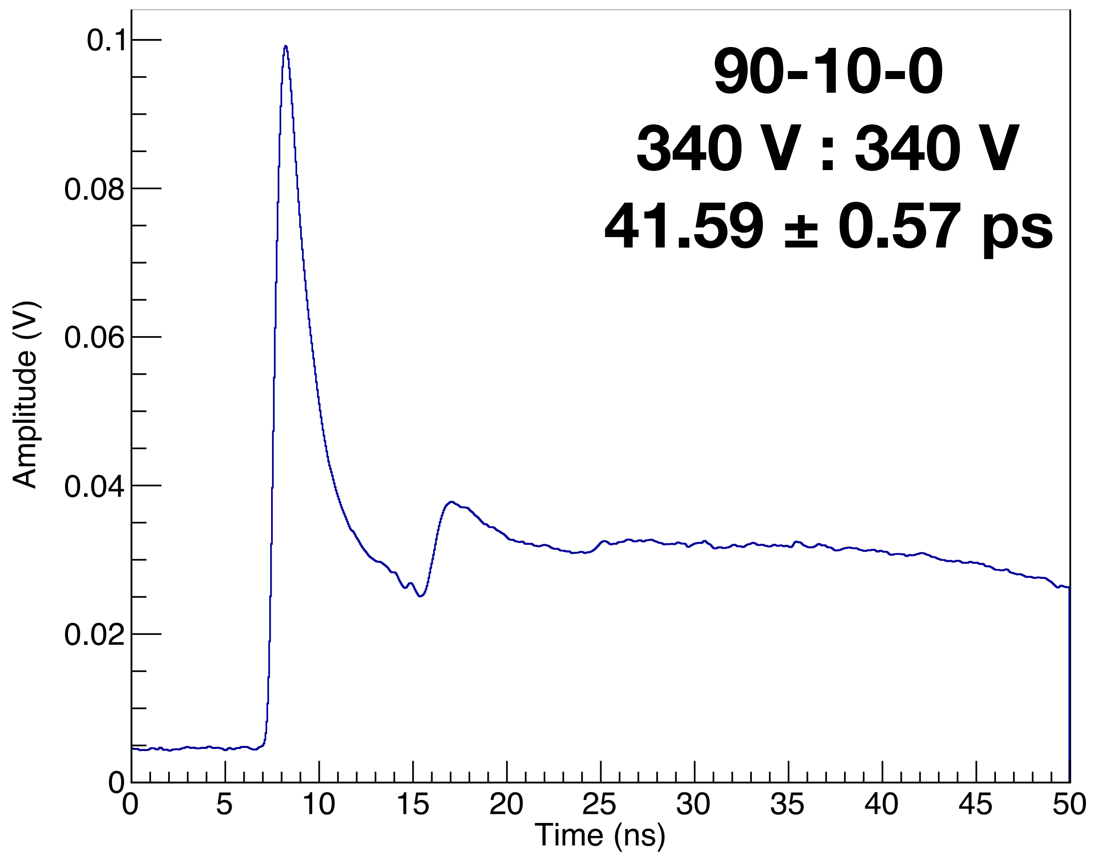

80-10-10
275 V : 500 V
9.97 ± 0.12 ps
Amplitude (V)
Time (ns)

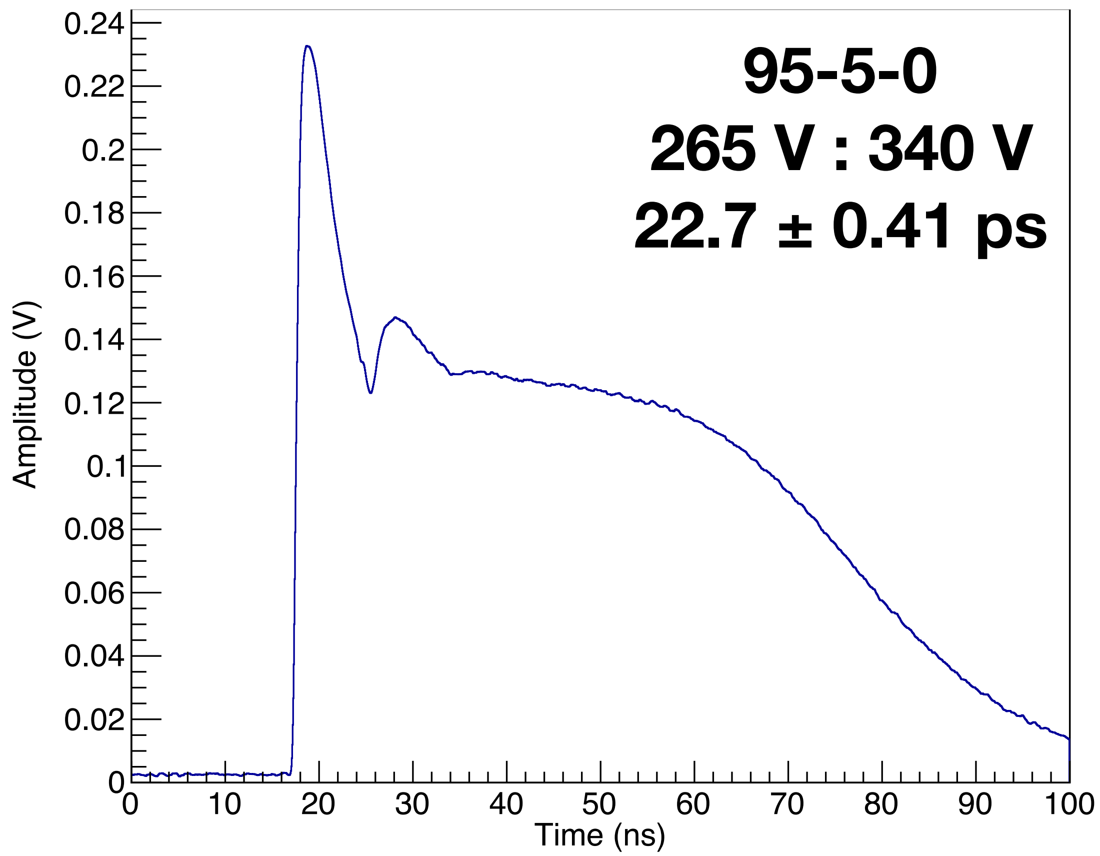

89-2-9
255 V : 445 V
15.13 ± 0.33 ps
Amplitude (V)
Time (ns)


90-0-10
270 V : 480 V
Amplitude (V)
Time (ns)


80-20-0
270 V : 470 V
27.11 ± 0.25 ps
Amplitude (V)
Time (ns)


85-15-0
255 V : 445 V
26.06 ± 0.41 ps
Amplitude (V)
Time (ns)


90-10-0
340 V : 340 V
41.59 ± 0.57 ps
Amplitude (V)
Time (ns)


95-5-0
265 V : 340 V
22.7 ± 0.41 ps
Amplitude (V)
Time (ns)