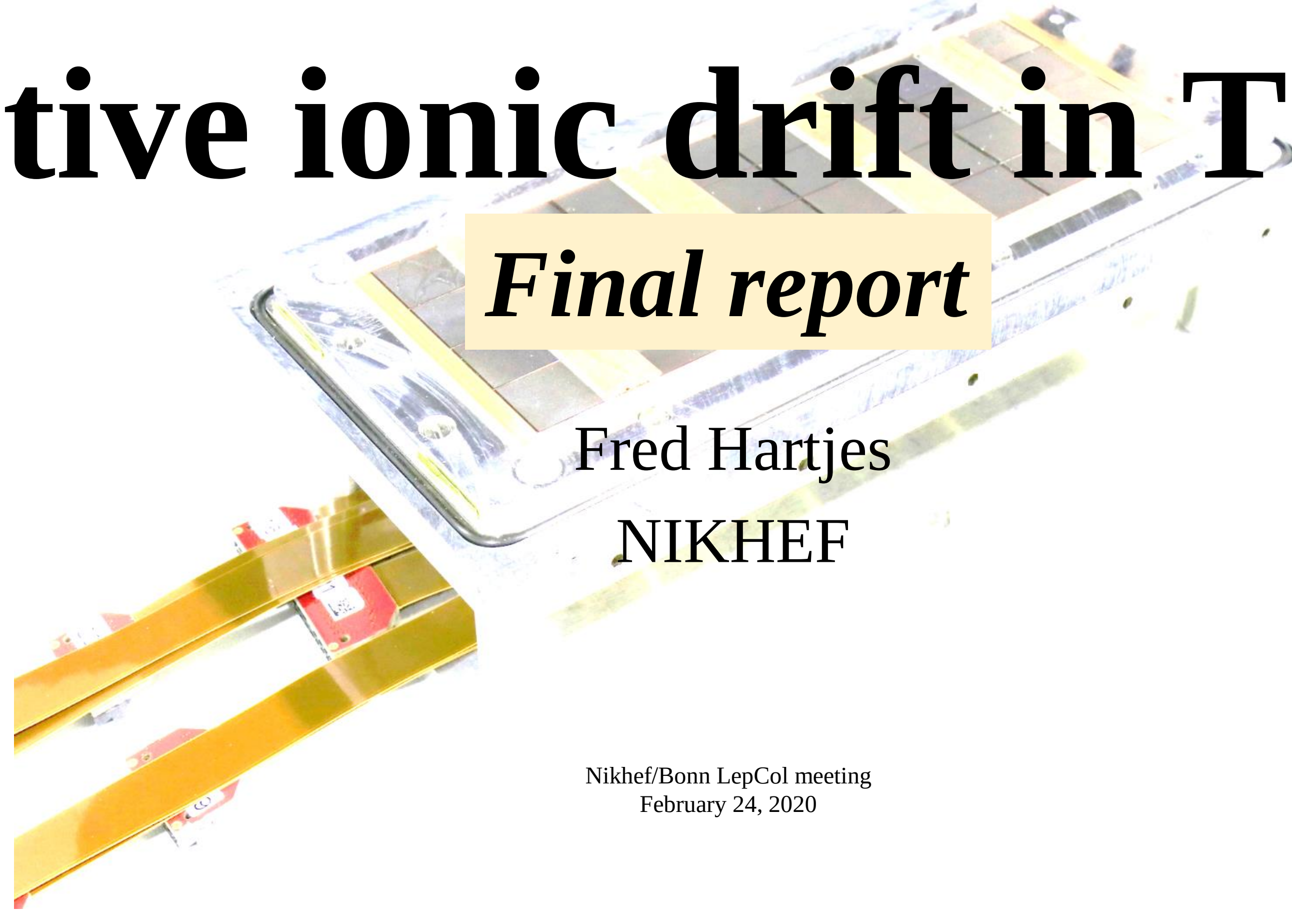
Positive ionic drift in T2K gas

Final report



Fred Hartjes

NIKHEF

Nikhef/Bonn LepCol meeting
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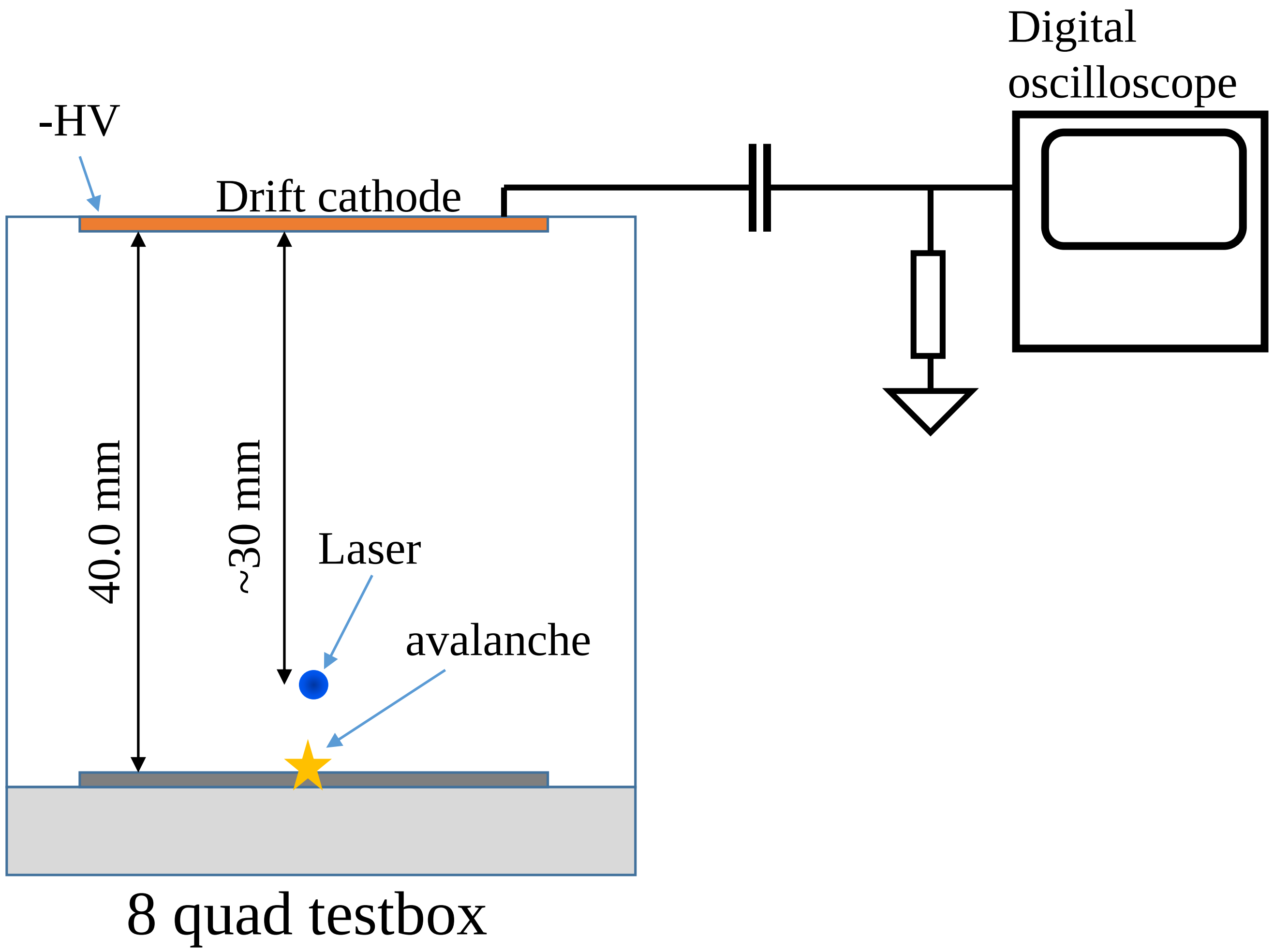
Setup for measuring positive ion drift

- Drift cathode used as an antenna
- Ions from the laser beam instantaneously induce charge on drift cathode
- Ions move towards the drift cathode, generating an induction current
  - Current terminated at arrival at the drift cathode
- In addition ions leaking through the grid during the avalanche induce charge as well

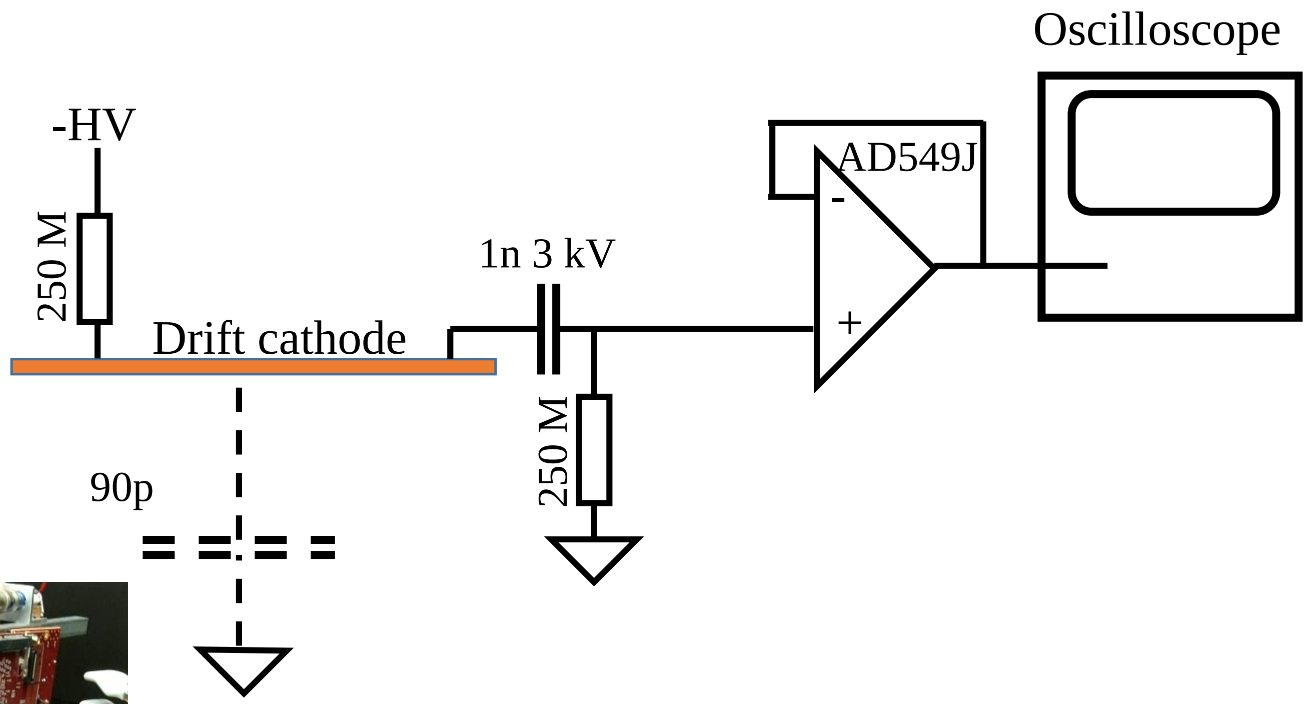
- Measurements triggered by laser diode
  - On the scope **averaged over 32 triggers**

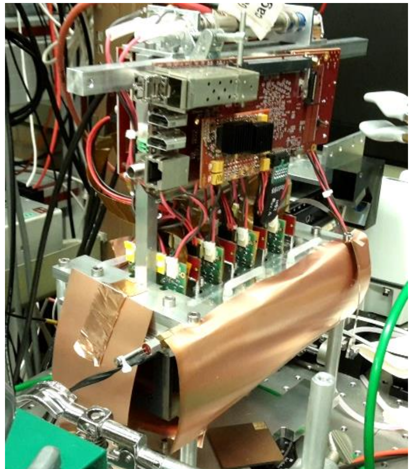


Instabilities/ noise reduced/cancelled

Setup of the charge signal collection

- Filters on control line and output of drift field HV supply
- LabVIEW communication with HV supplies had to be stopped during data taking
- Remaining micro discharges at drift cathode
- Reducing 50 Hz pickup
- Laser instability 20 – 30% rms





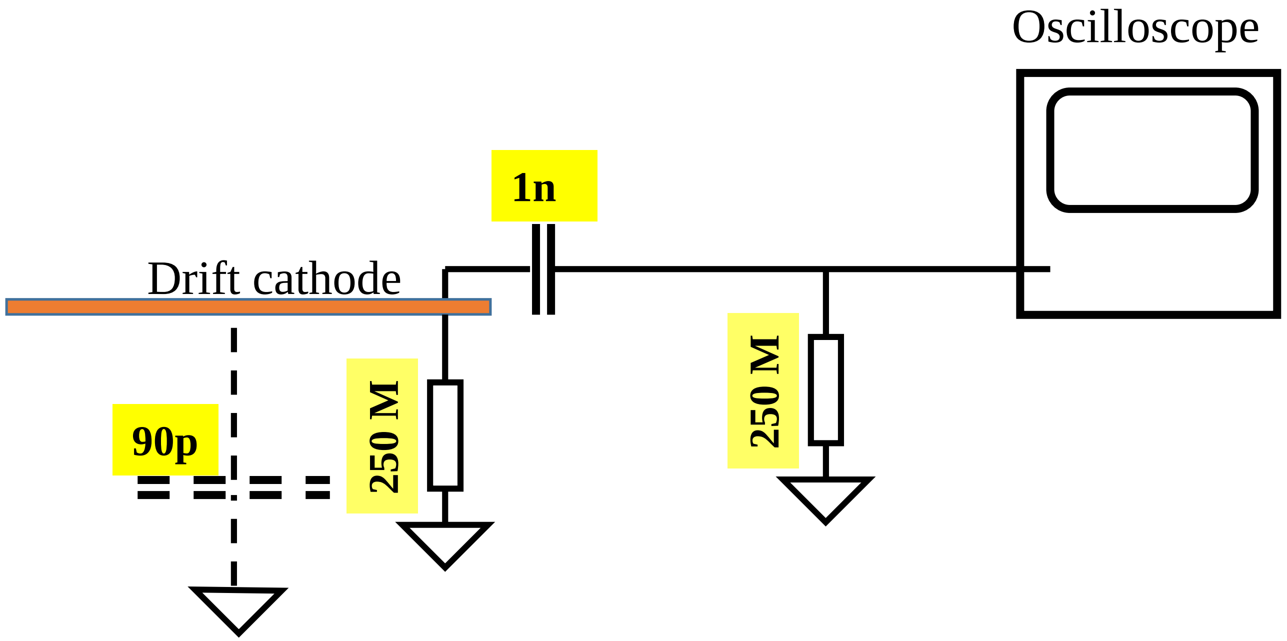
Best scope sensitivity 1 mV/div
- Signal was often clipped at 0.5 mV/div

Averaging over 32 laser shots

Simplified electronic circuit

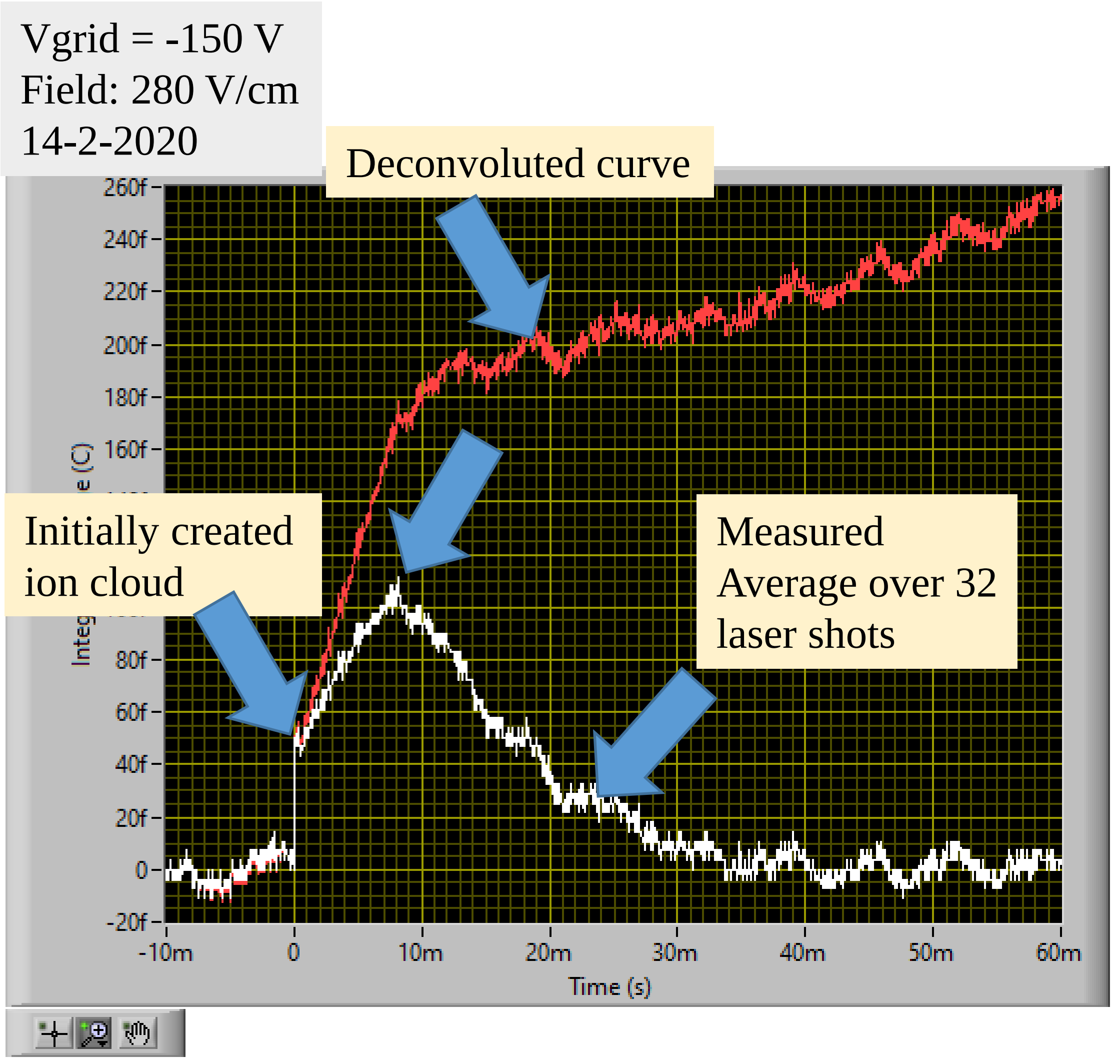
- Circuit values measured with test pulse
  - Through 1 pF and 100 MOhm
- Parasitic capacity of drift cathode, Lemo cable, electronics measured as 89.5 pF
- RC time 10 +/- 0.5 ms

- We get an ideal integrator curve by deconvolution of the measured curve from the RC time constant
  - Also taking into account the voltage change on 1 nF coupling capacitor



Primary ionization by laser

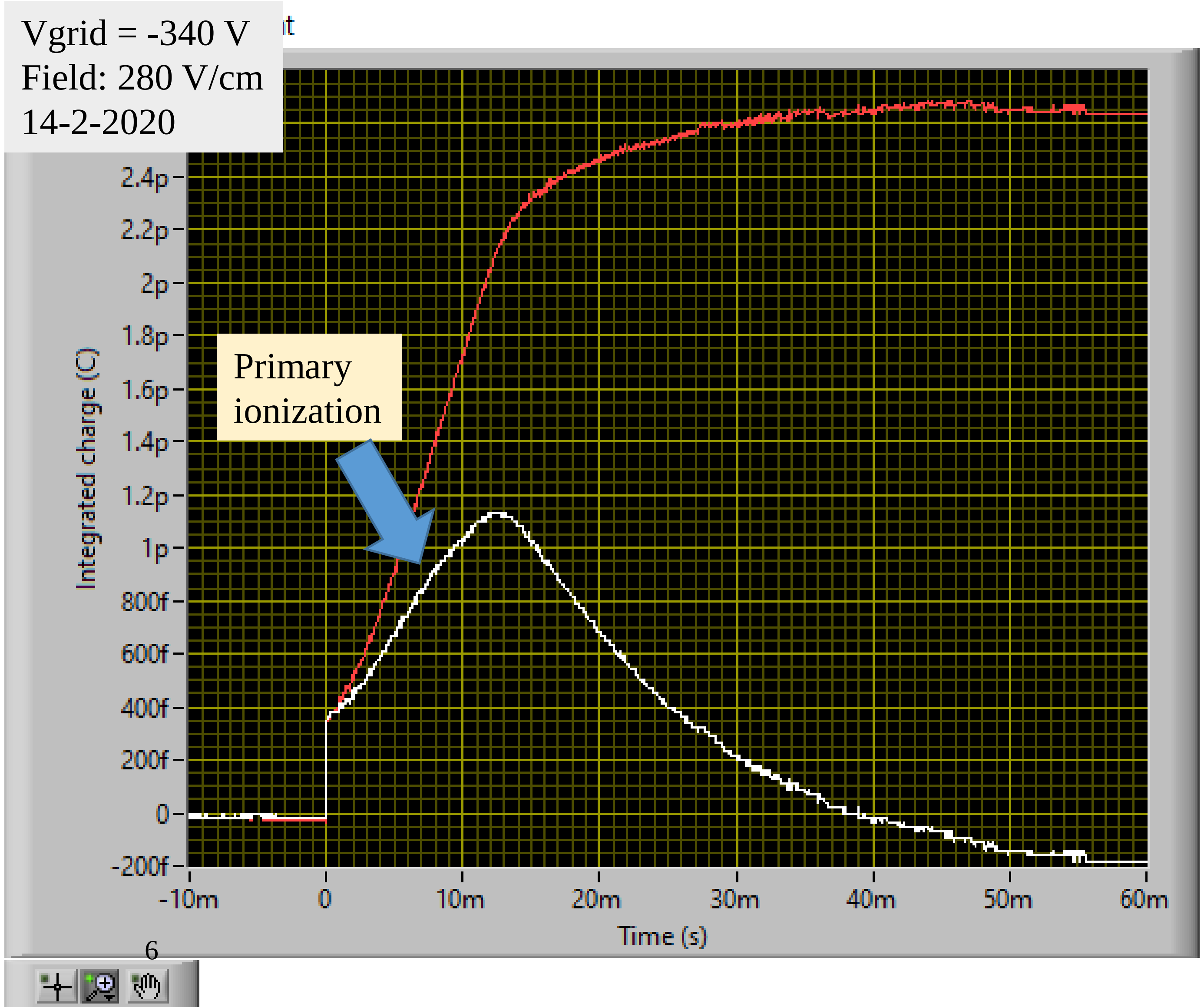
- Vgrid = -150V => no gas gain
- Ionizing **exclusively** TMPD (N, N, N', N' - Tetramethyl-1,4-phenylendiamin)
  - In the chamber gas as a pollution in the ppb level
- Laser beam at about 30 mm from the drift cathode
- Note the **sharp** bend when the ions are collected by the drift cathode
- Initial drift time 8 ms
  - => velocity ~3.8 m/s
  - **But possible tail of slow ions**
  - Phenomenon hard to measure because of instabilities on the charge signal
  - **Measurement with blocked laser has been subtracted**
- Integrated charge 200 - 260 fC
  - **=> 1.25 - 1.6 M ions**
  - Above the 8 grids: 129 – 167 fC
  - **=> ~ 6.7 – 8.8 electrons entering each hole**



Ion measurement at working point

- Mainly ions leaking through the grid

- Measurement is polluted by two phenomena
  - Signal of the ions from the primary ionization
  - Cross talk from the grids onto the drift cathode

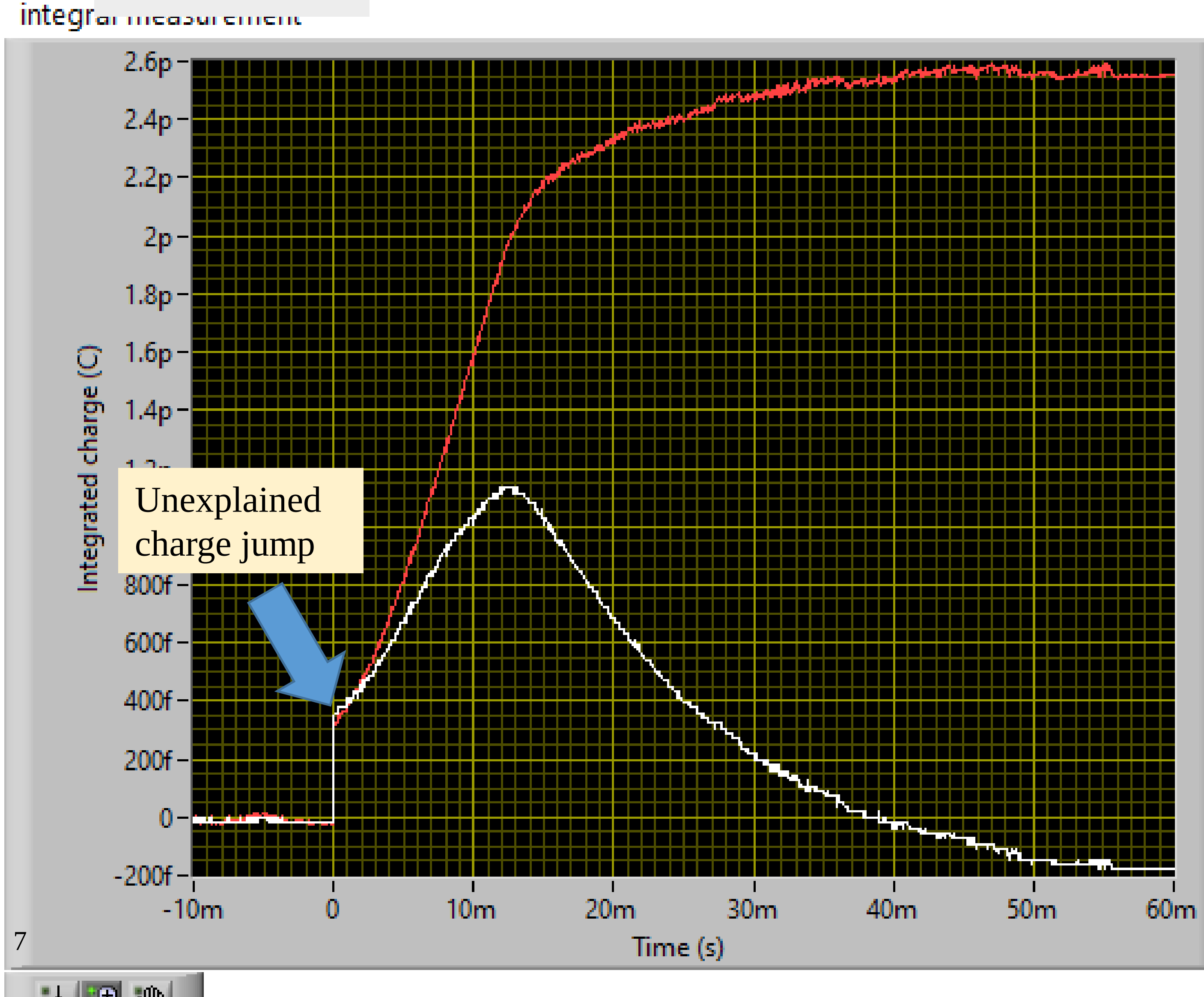


Primary ionization subtracted

Vgrid = -340 V
Field: 280 V/cm
14-2-2020

- Sudden charge jump at laser firing
- Ions starting drifting from the grid should not induce an immediate charge

- **Unexplained charge jump of ~ 350 fC**



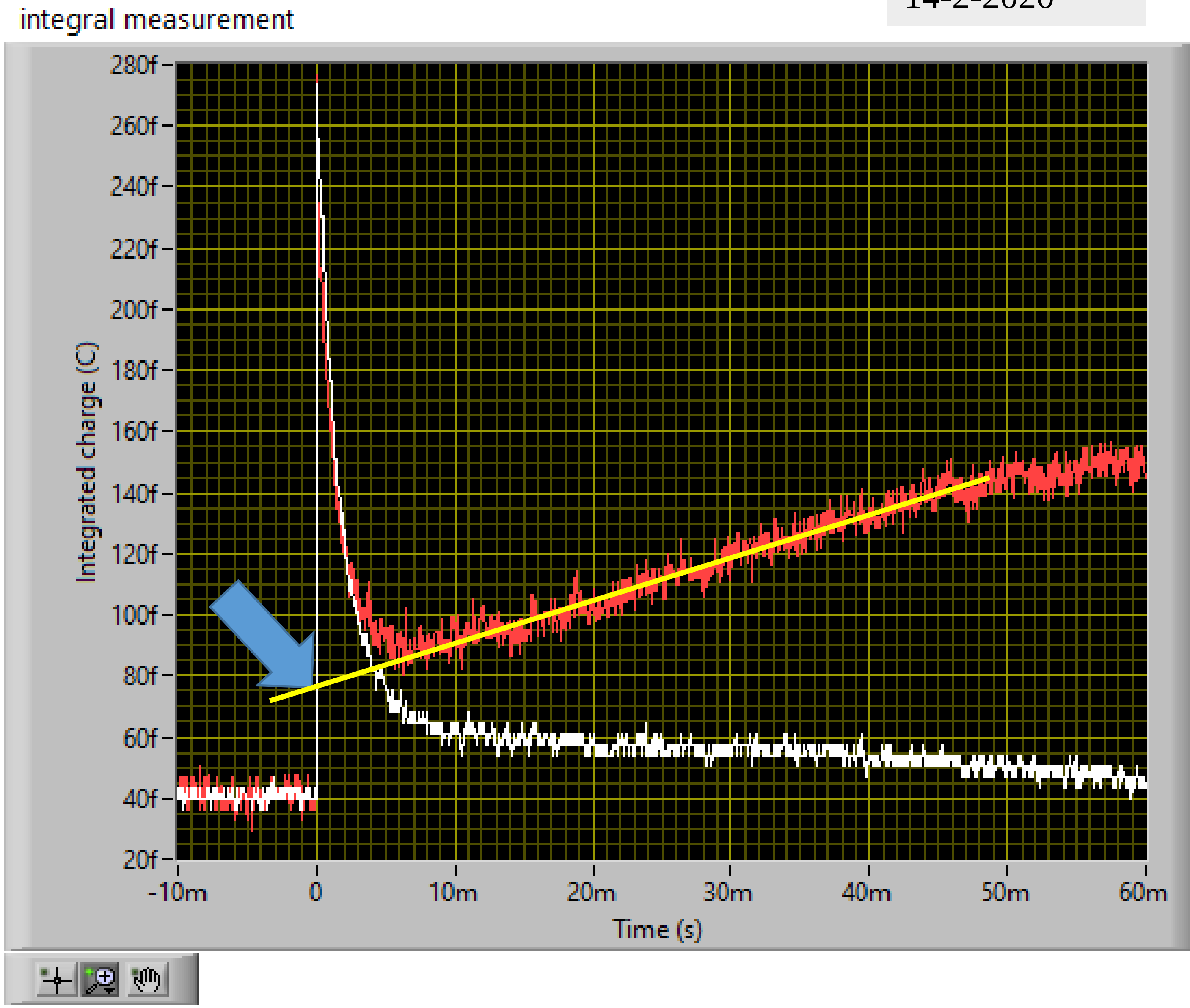
Test with extremely low drift field

Vgrid = -340 V
Field: 15 V/cm
14-2-2020

- Drift field 15V/cm
- Primary ionization subtracted

- Sudden jump of the integrated charge curve mostly cancelled after 5 ms
  - Time constant does not correspond to the system time constant (10 ms)
  - Source of the rapid charge rise: **cross talk** by the eight grids under the laser beam to the drift cathode
  - After that slow rise due to the slow ionic drift

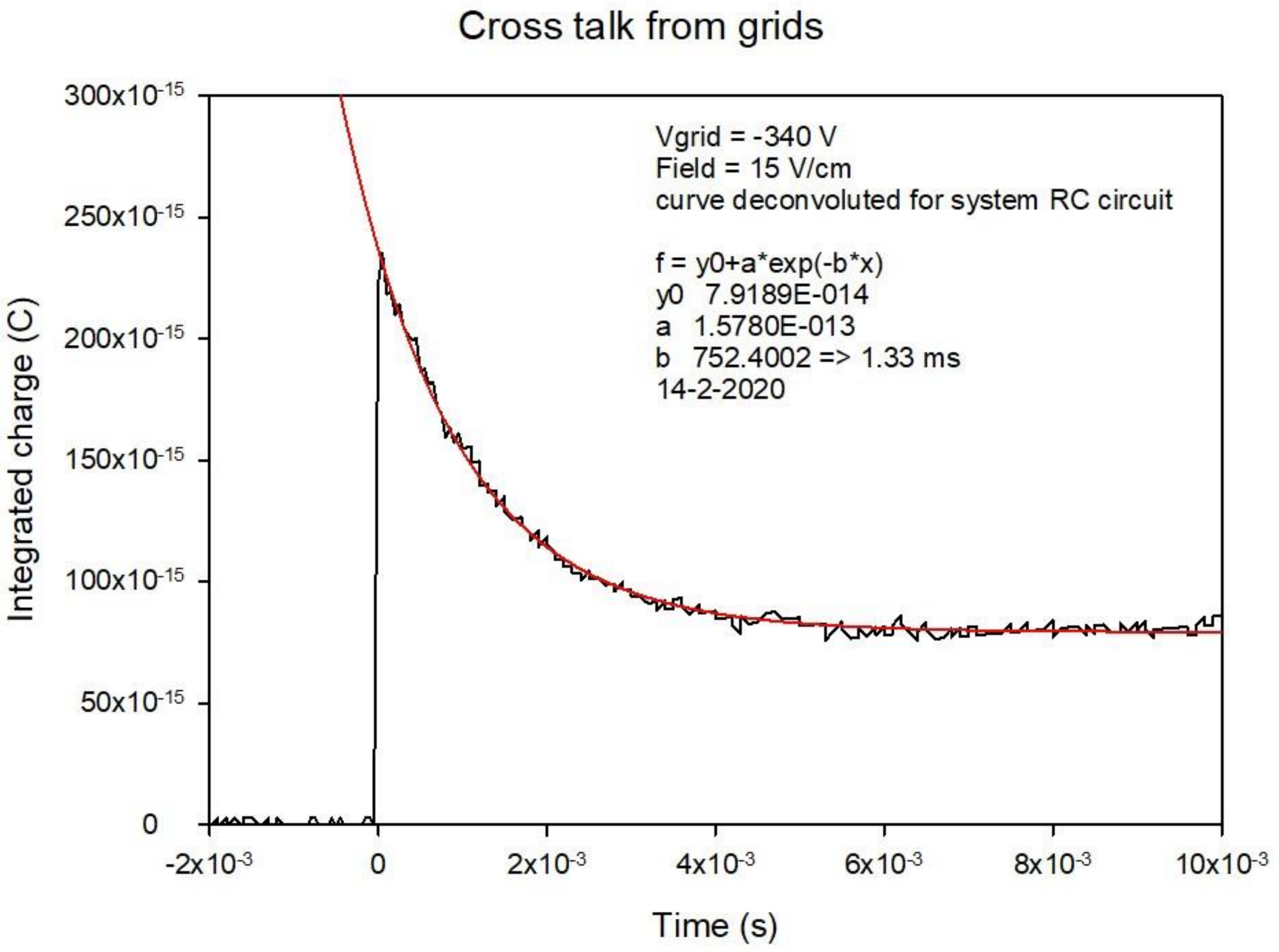
- Small part of the initial peak charge remains
  - ~ **75 fC** (1 fC = 6242 e-)



Time constant of the charge jump

- T_{RC} **= 1.33 ms**

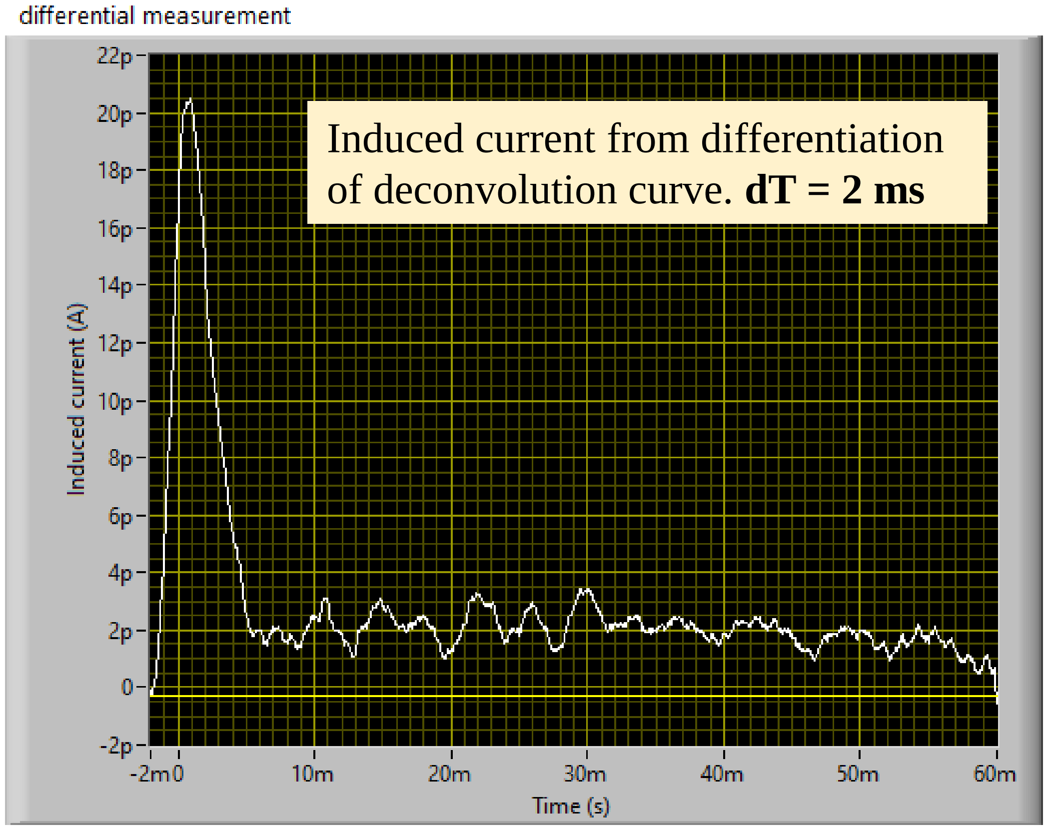
- Each of the 8 involved grids has a supply resistor of 100MΩ
  - => C_{grid} **= 13.3 pF** for a single grid

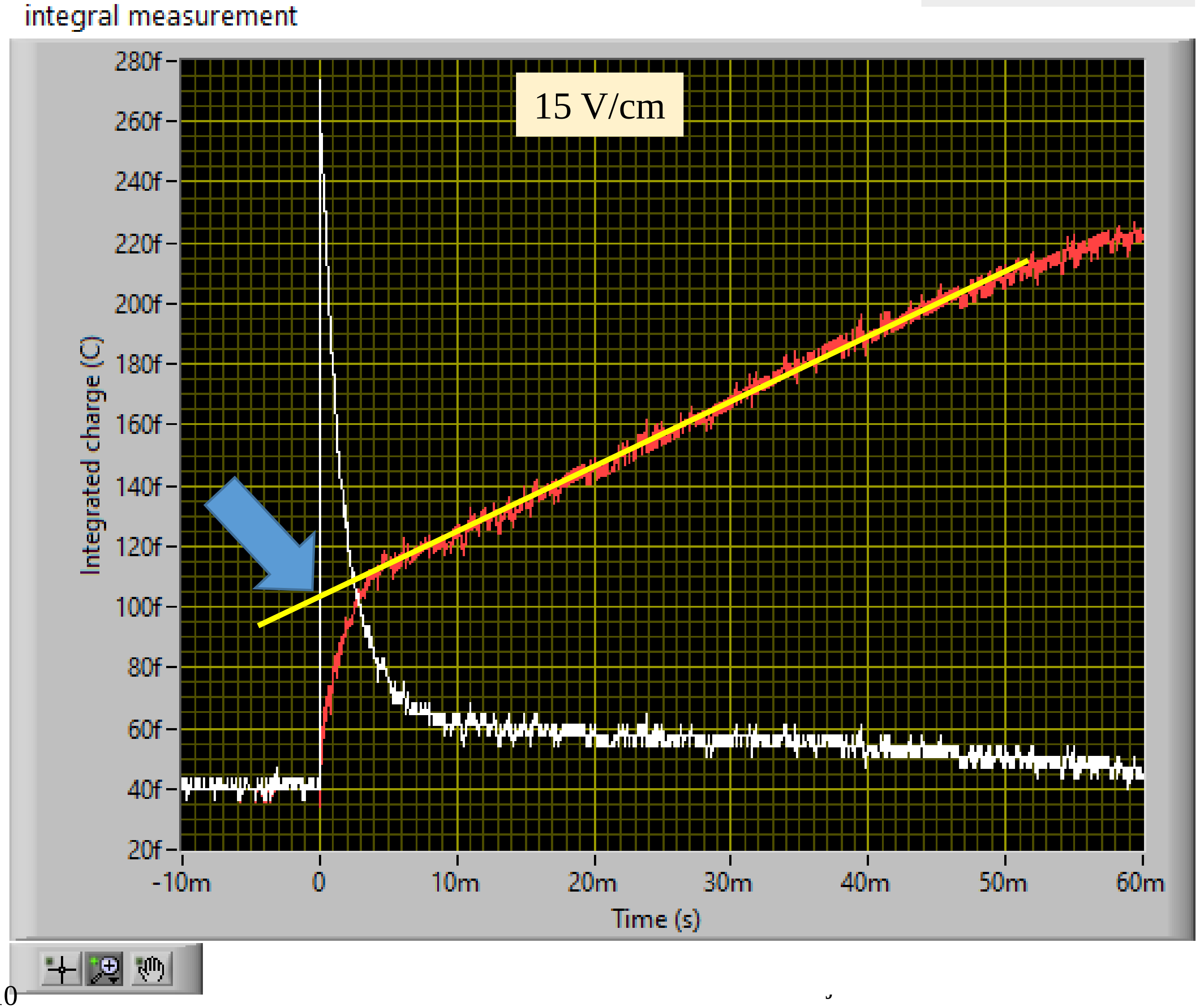


Low field measurement with cross talk compensated

Vgrid = -340 V
Field: 15 V/cm
14-2-2020

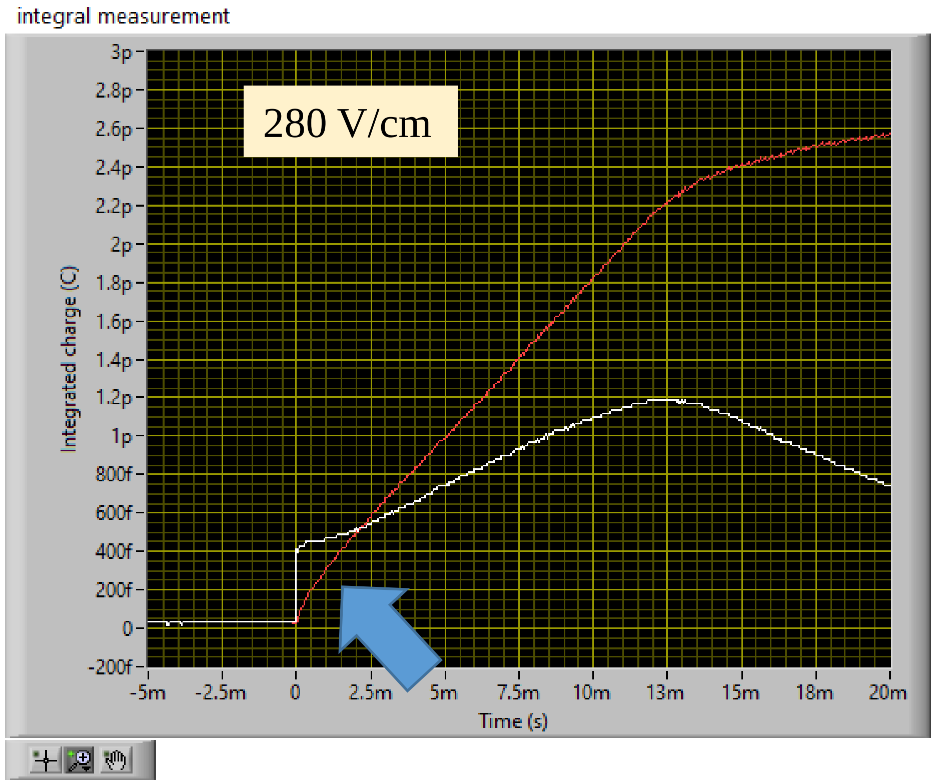
- Current peak at the beginning remains
  - Cannot be compensated by cross talk correction
  - **Here ~ 60 fC** (1 fC = 6242 e-)
- Peak is 4 ms wide, NOT a delta function
- Peter effect??





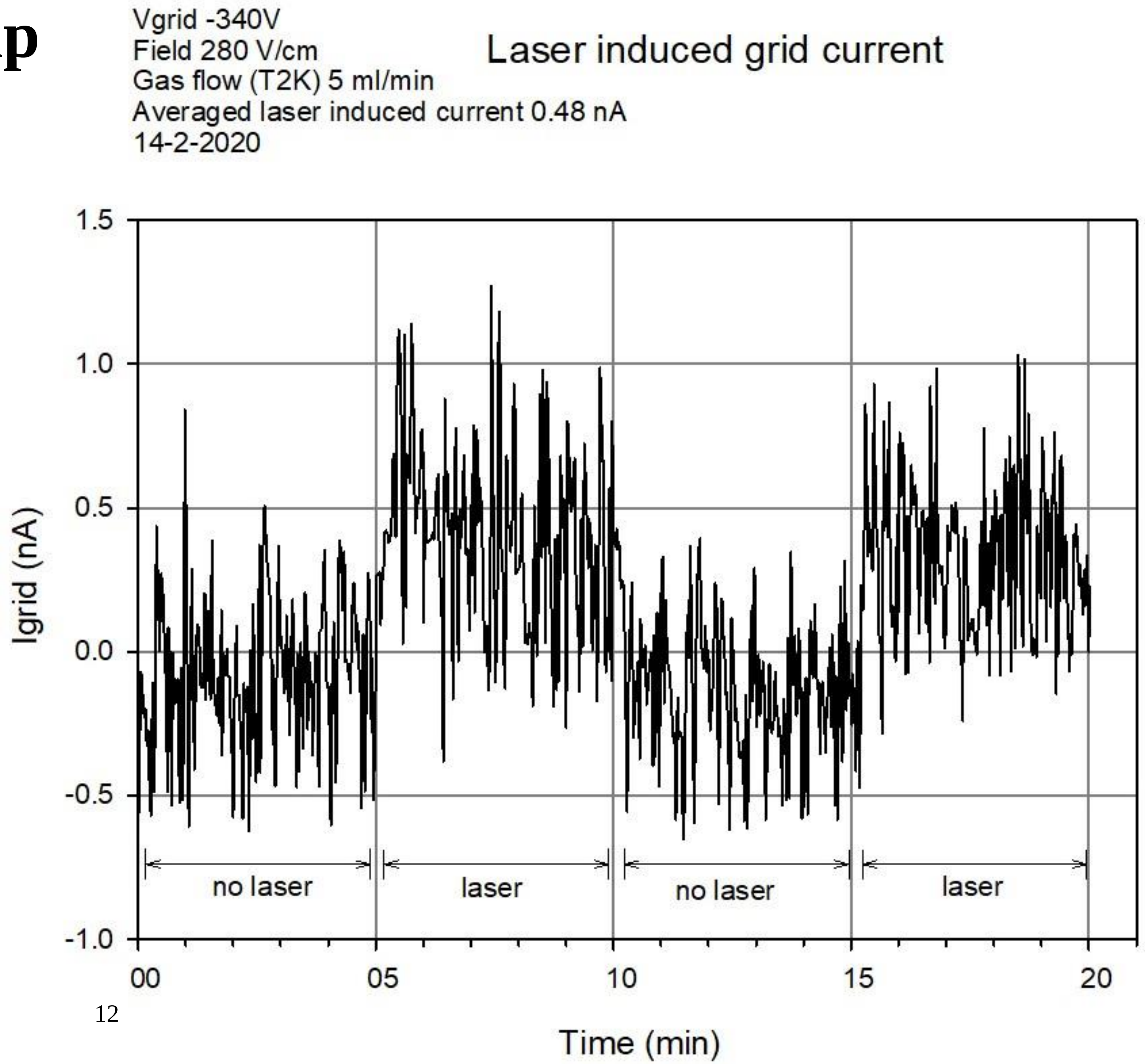
Induced ionic current at working point

- Current corrected for grids cross talk
  - TRC = 1.5 ms
- Same peak as for the low field measurement
- It has a duration of ~ 1.5 ms



How big is the voltage jump on the grids?

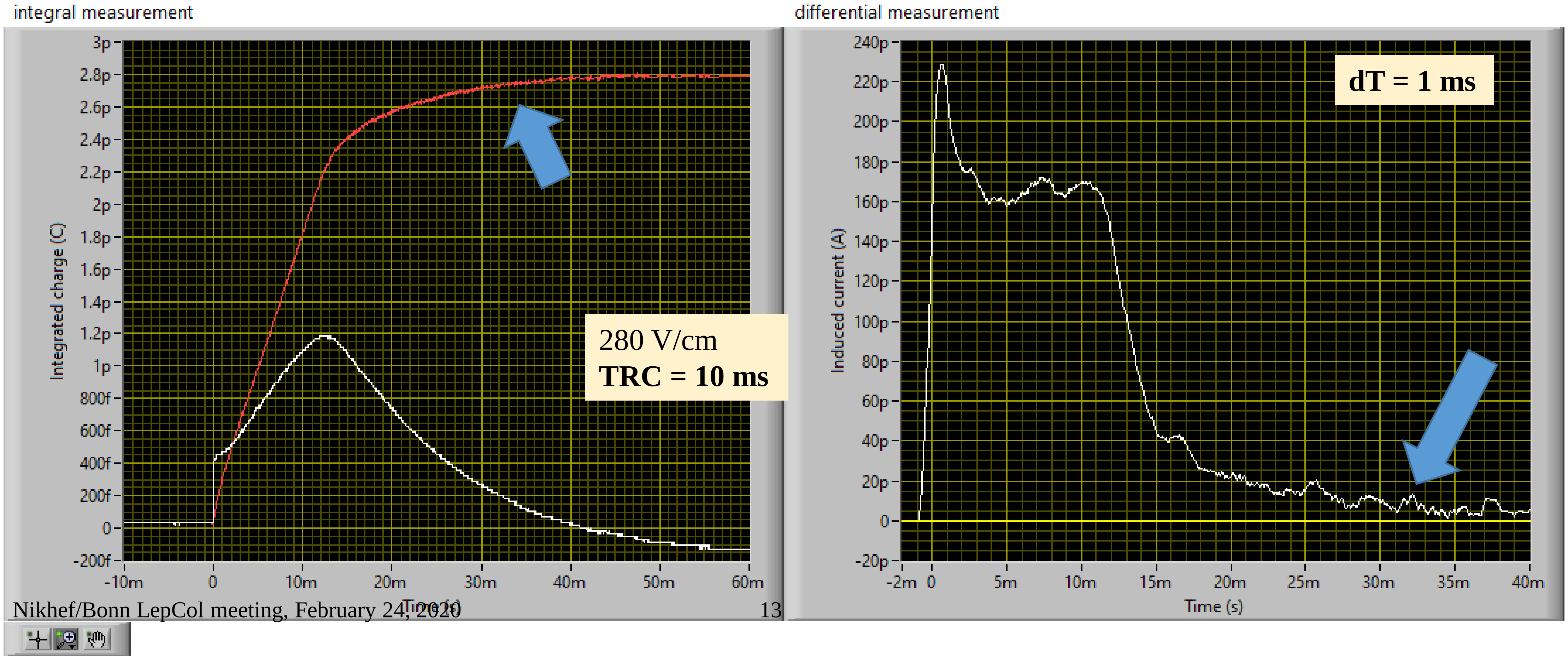
- The grid supply current induced by the laser beam can be measured
  - 0.48 nA
- Laser frequency: 2.68 Hz
  - **=> 180 pC per laser pulse**
- Total grid capacity: 8 x 13.3 = 106 pF
- **=> voltage jump on grids 1.7 V**
- Induced charge: 350 fC
- **=> parasitic capacity between 8 grids and drift cathode: 0.2 pF**



Ionic current at work point

- Tail of slow ions with drift times between 15 and 30 ms
- From deconvolution using **TRC = 10 ms**
  - System time constant measured using test pulses through 1 pF capacitor and 100 MΩ resistor

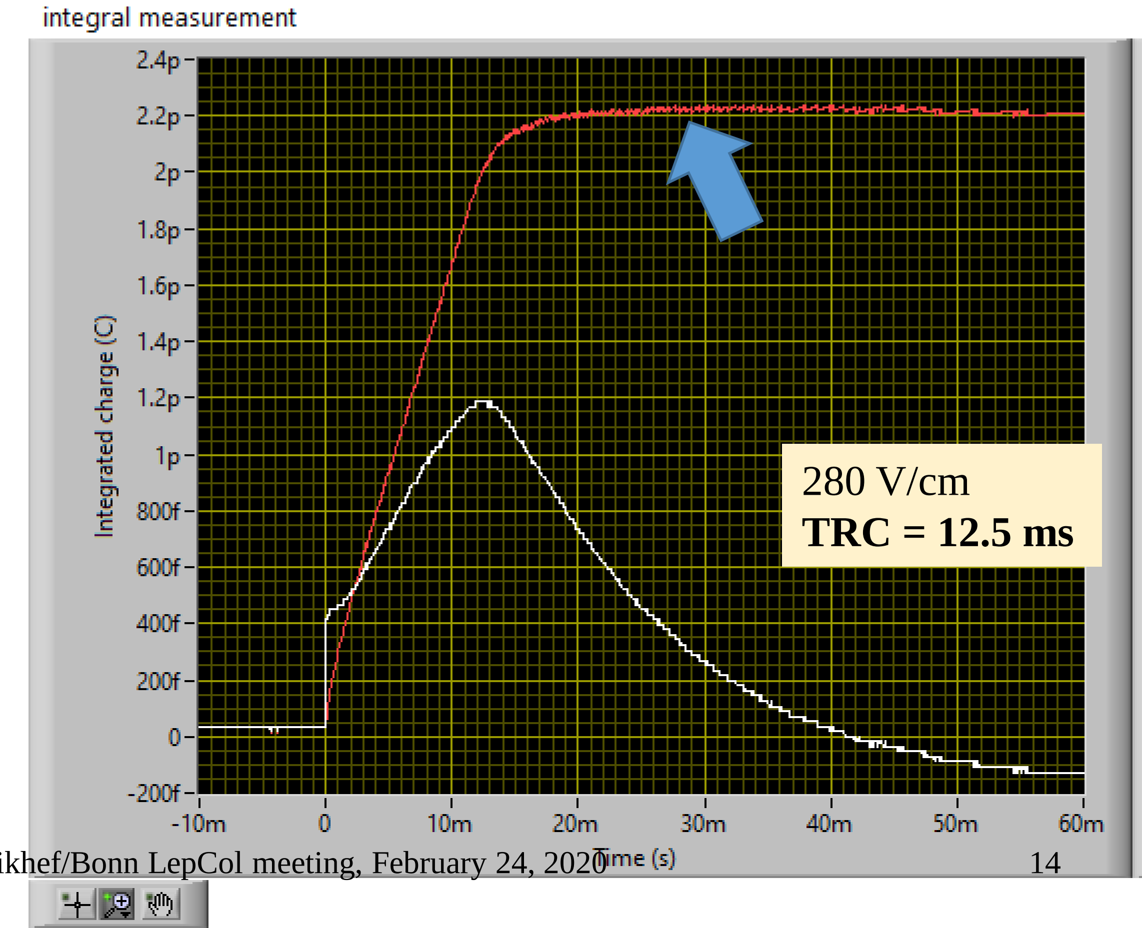
Vgrid = -340 V
Field: 280 V/cm
14-2-2020

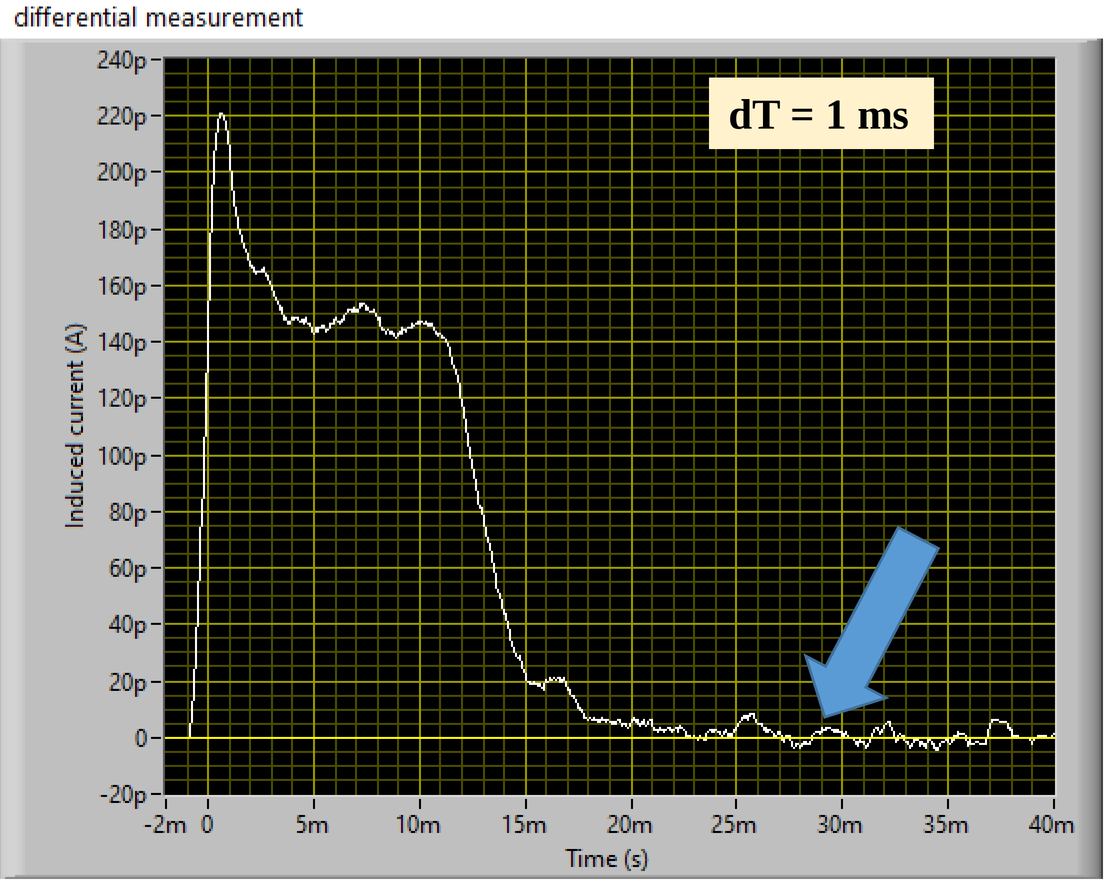


Deconvolution for other time constant

- Tail of slow ions has disappeared using **TRC = 12.5 ms**
  - So are these slow ions really there or has the system time constant been wrongly measured?

Vgrid = -340 V
Field: 280 V/cm
14-2-2020



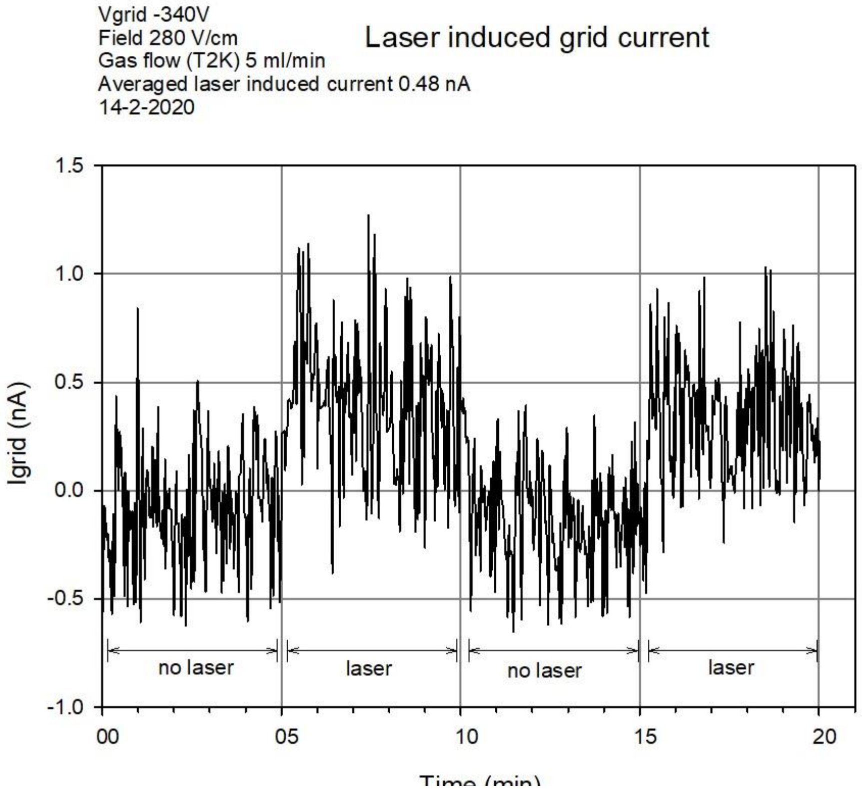


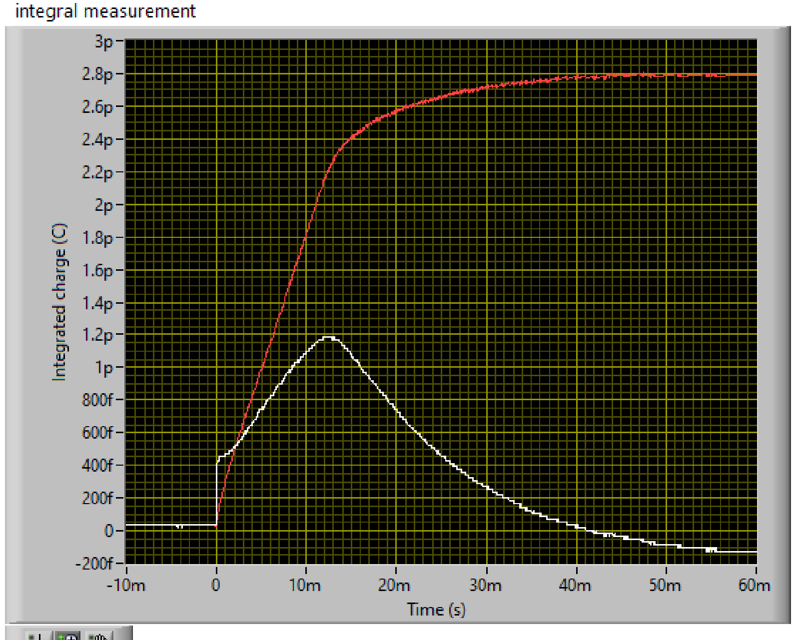
Grid leakage and gas gain

- Total avalanche charge per laser shot = 180 pC
- Induced charge on drift cathode = 2.8 pC
  - Subtract primary ionization (0.2 pC)

- **=> Ion leakage through grid at working point (280 V/cm, -340 V grid): 1.45%**

- **=> Gas gain 1075 – 1400** @ Vgrid = -340 V
  - Using *only* the primary charge above the grids
    - 129 -167 fC
  - Possible saturation effects (7 – 9 electrons entering each hole during ~ 100 ns)
  - Ionic drift time over 50 μm at -340 V grid is 50 ns
    - So fresh electrons entering the gap when still positive ions from the previous avalanche are present

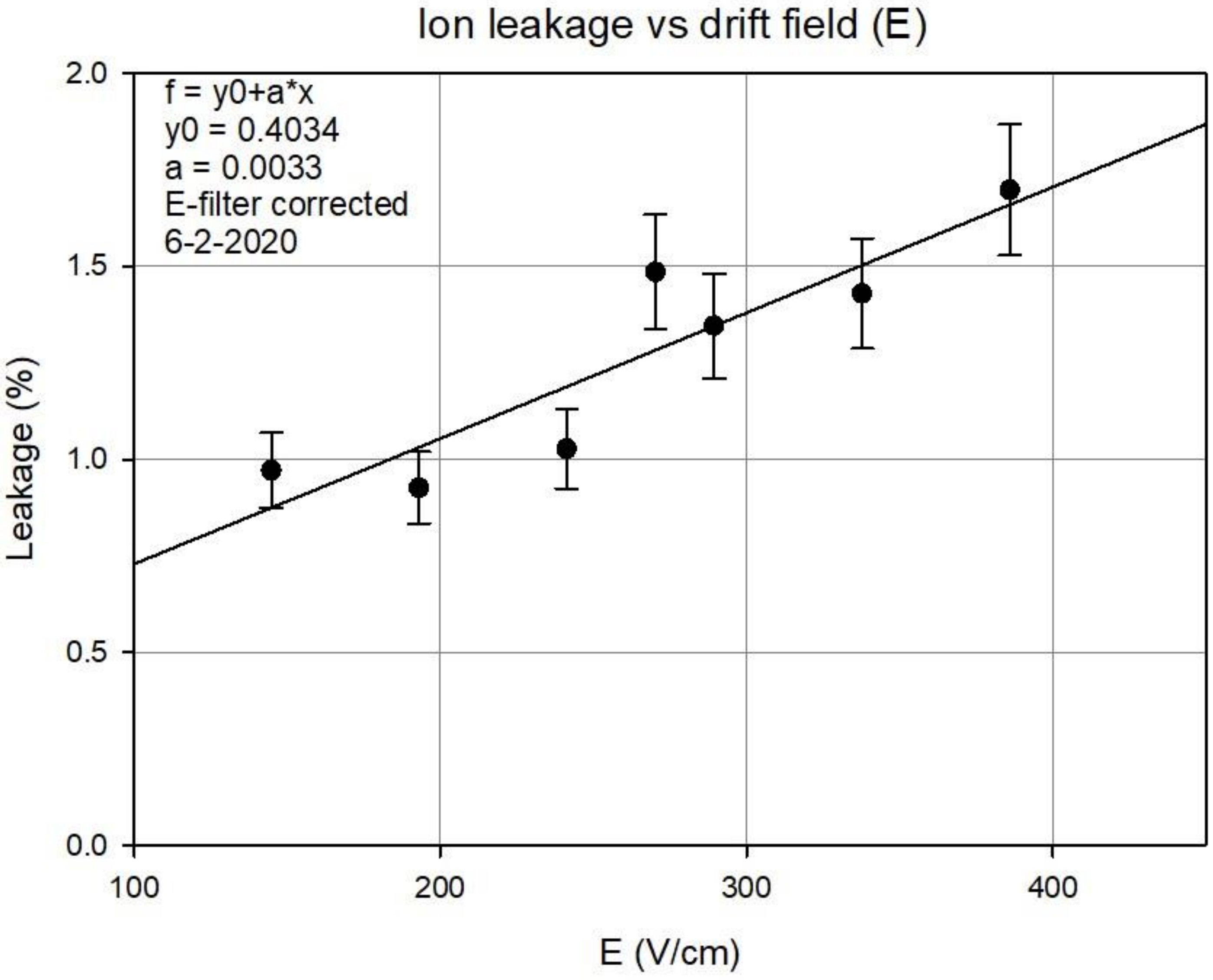




Leakage for different drift fields

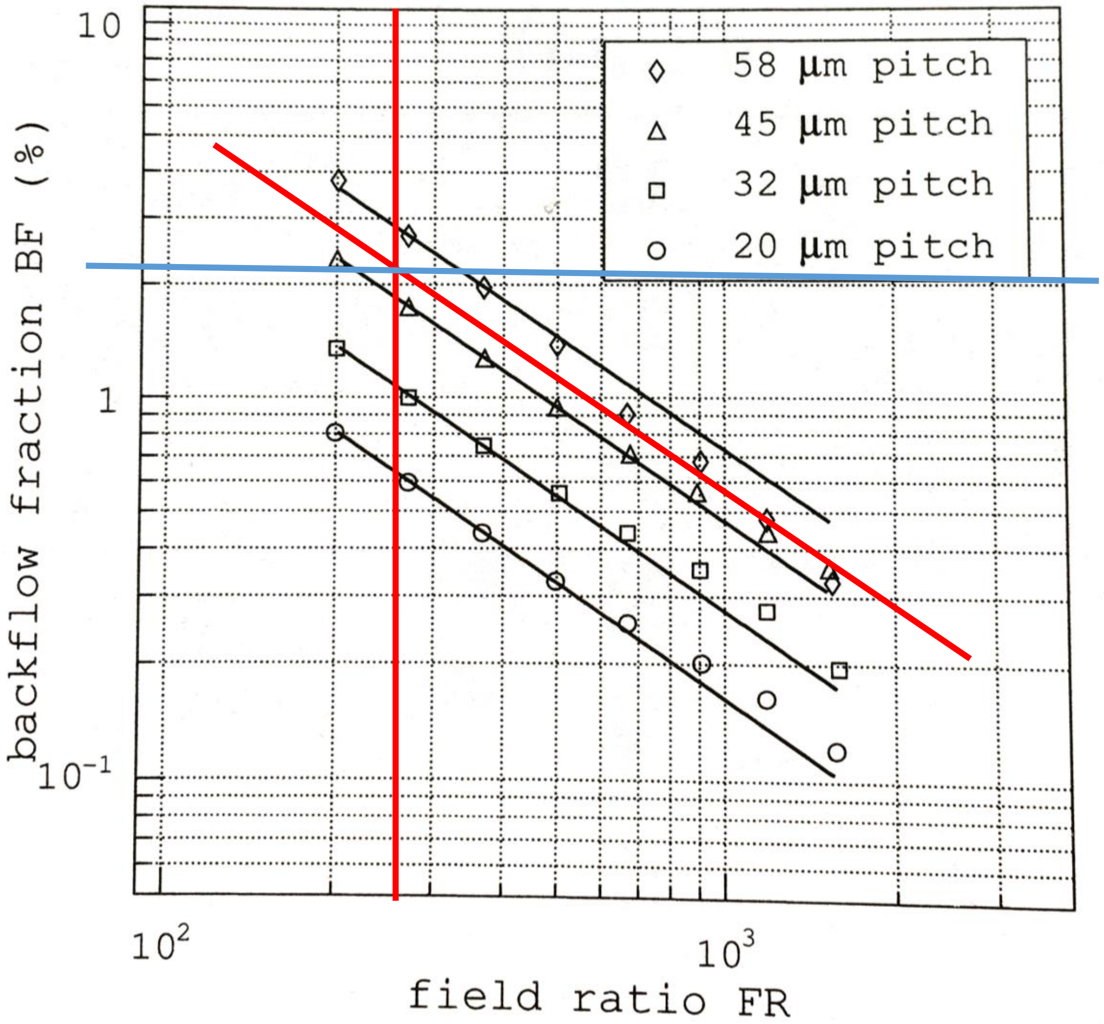
- Leakage rising with field strength from <1.0 to 1.7 %
- Accuracy affected by instabilities

- The 1.45% value was measured a few hours before the other measurements
- The fit suggests rather 1.3%



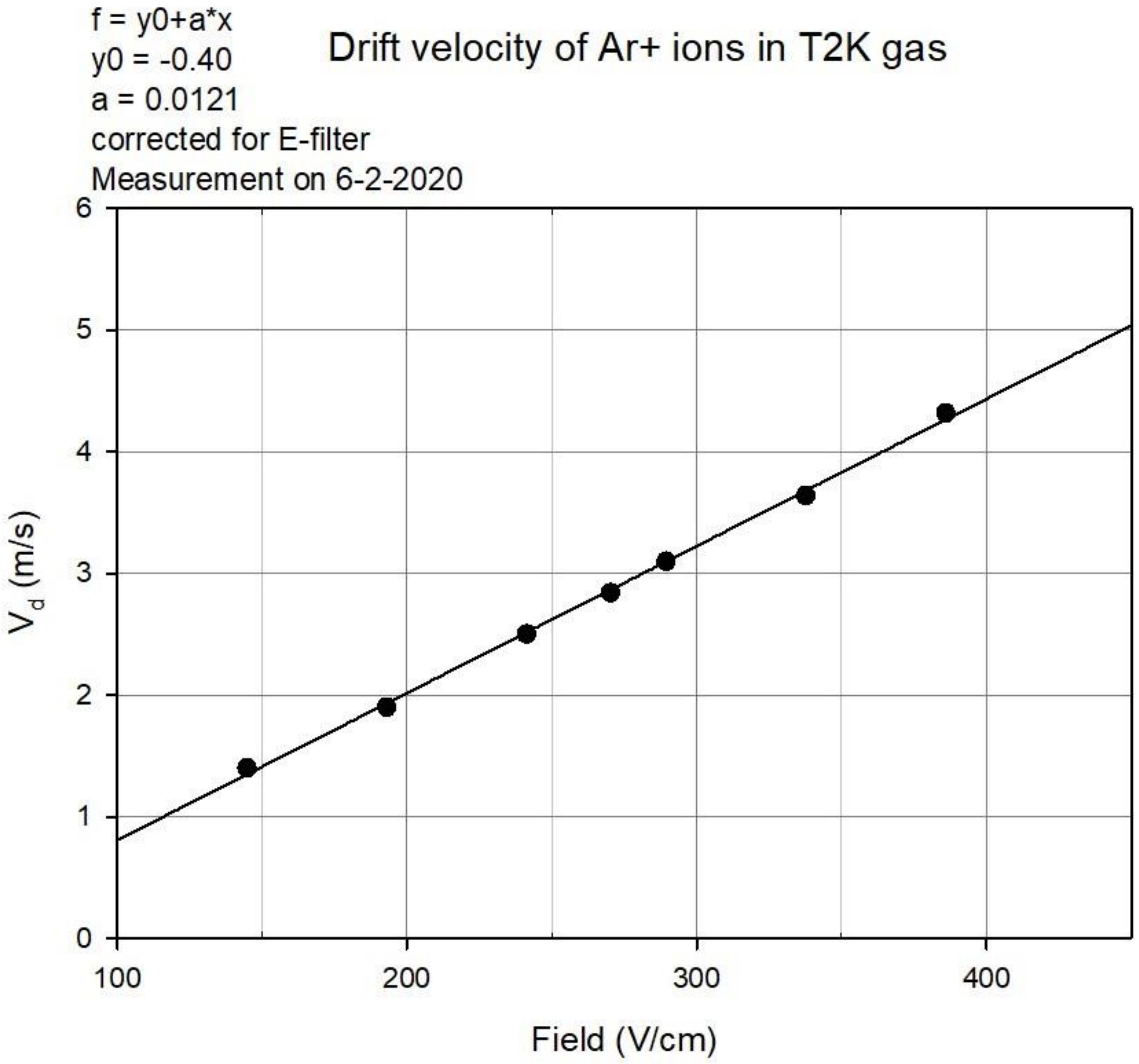
Comparing leakage fraction with Chefdeville

- For our working point (280 V/cm, -340 V grid and 50 μm grid gap) => **Field ratio = 252**
- Chefdeville => leakage **~ 2.2 %**
- This measurement: **1.3 – 1.45%**



Ar+ drift velocity vs drift field

- Not valid for low fields
  - Curve does not pass X, Y = 0, 0
- Linear fit may not be correct
  - Mobility gets smaller at low fields

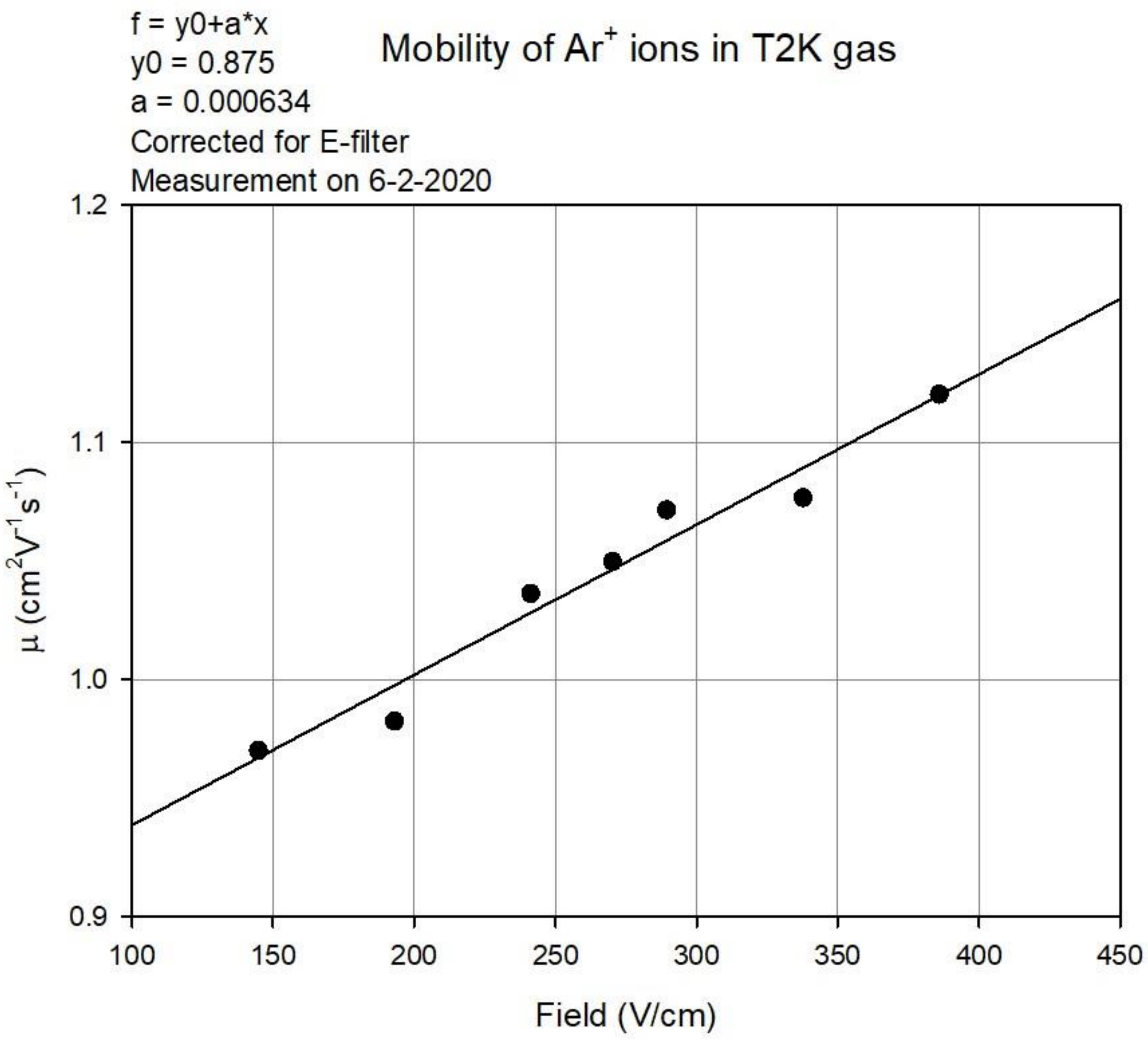


Ionic mobility vs drift field

- Assuming the main peak originates from Ar+ ions

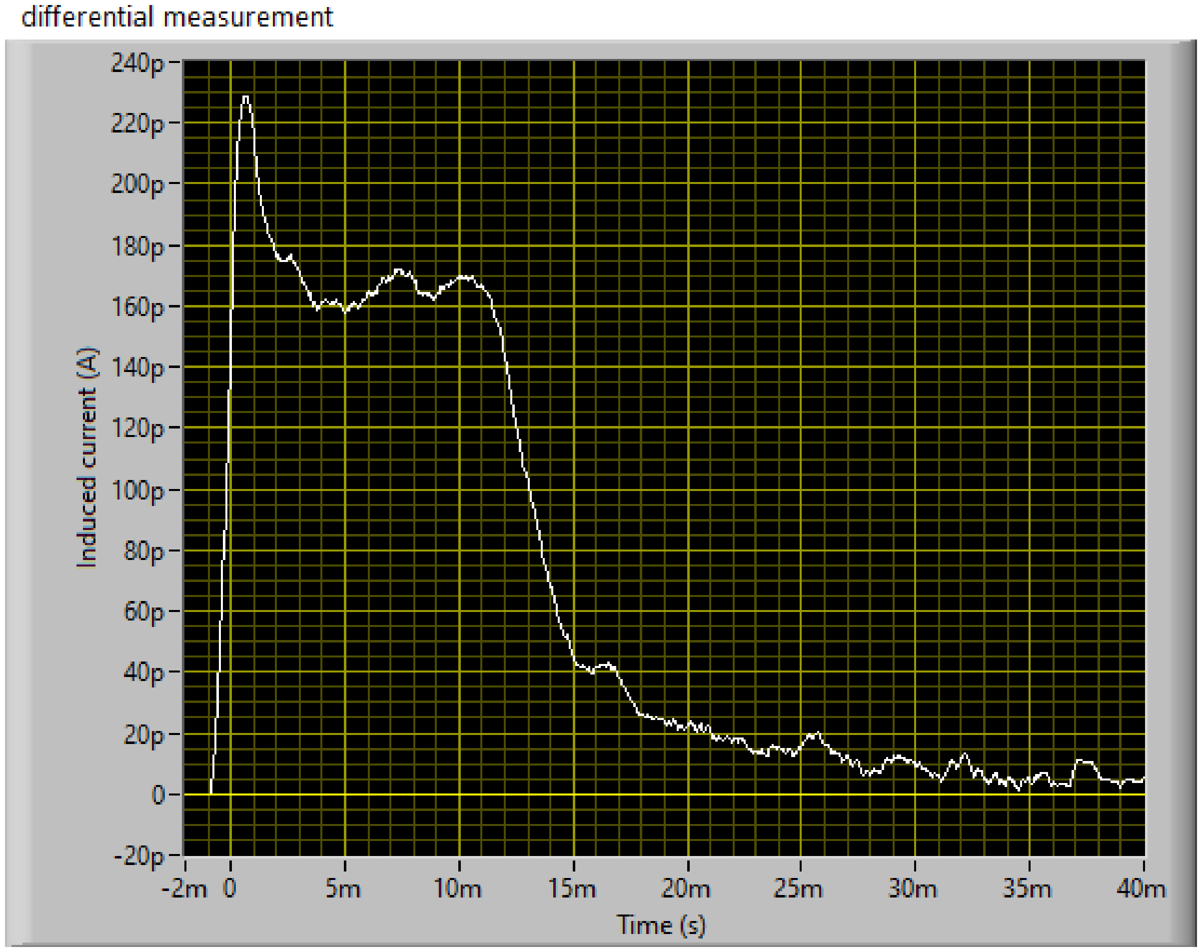
- Literature (Ar+ ions in Ar) (Madson, Hornstein 1967, 1951)
- ~ 1.3 – 1.5 $cm^2V^{-1}s^{-1}$ measured in 20 – 25 kV/cm range

- For mobility = 1.5 we get for the ionic drift time across the amplification gap of 50 um: ~ 50 ns



Summary positive ion measurements

- 8-quad testbox has not been designed for ionic measurements
  - Additional analysis is required to extract the physical phenomena
- Using the drift cathode as an antenna the leakage current of positive ions through the grid could well be measured
  - Disturbing effects from electronic noise, cross talk from the grids, laser instability could be minimized by shielding, filtering, offline compensation and averaging
- The leakage fraction of ions through the grid at the working point was measured considerably lower than earlier (Chefdeville)
- Some additional ions (0.11% of the avalanche charge) generated during the first few ms
  - Peter effect?



Summary positive ion measurements cntd

- Uncertainty of time constant of the measuring system
  - 10 ms measured with test pulses => reliable
  - 12.5 ms removes tail of slow ions
  - Are the slow ions there or not??

- Measured gas gain at -340 V grid possibly too small (1075 - 1400)
  - Possible saturation effects because of the extremely high primary ionization
    - Electrons entering the amplification gap when positive ions are still present
    - To be verified with ToT measurement

- Unattenuated laser pulse gives significant voltage drop on the grids (1.7 V)
  - => Cross talk to drift cathode