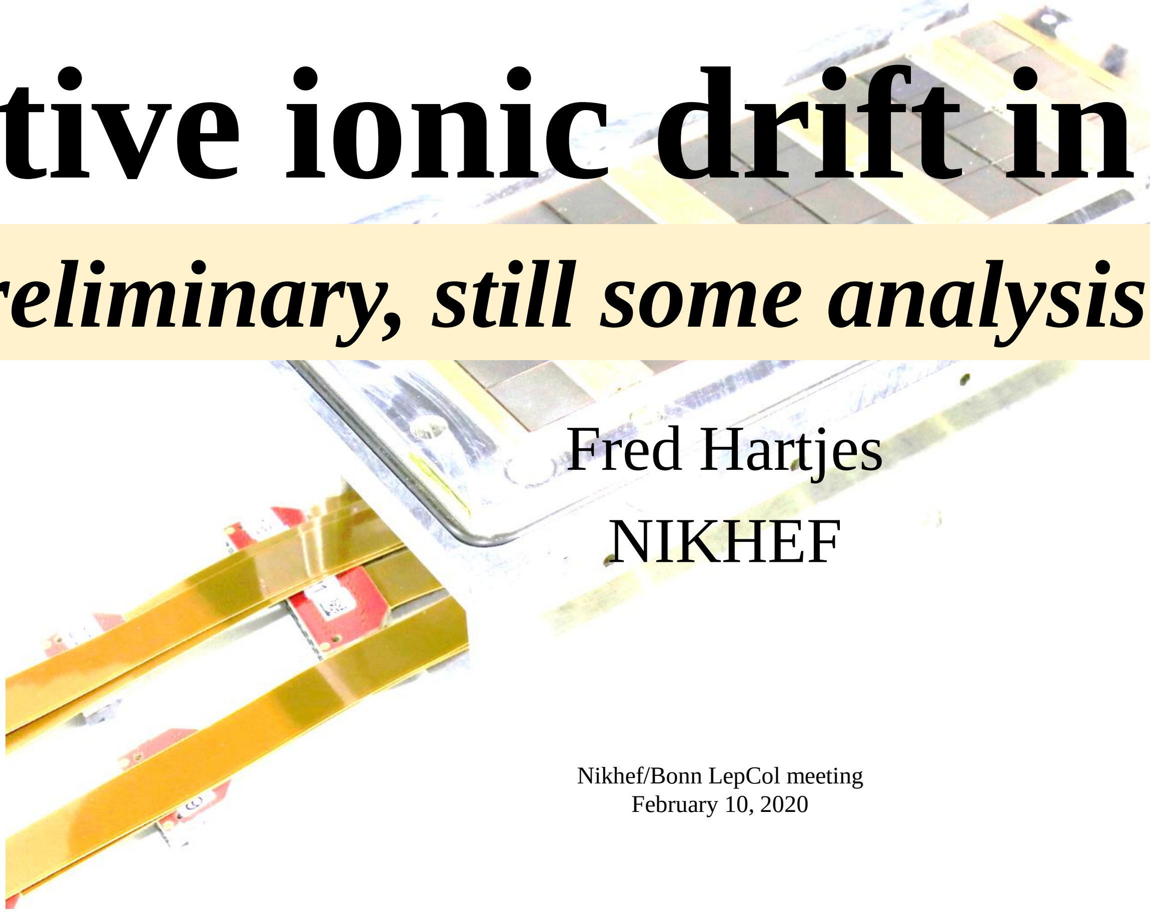
Positive ionic drift in T2K gas

Preliminary, still some analysis ongoing



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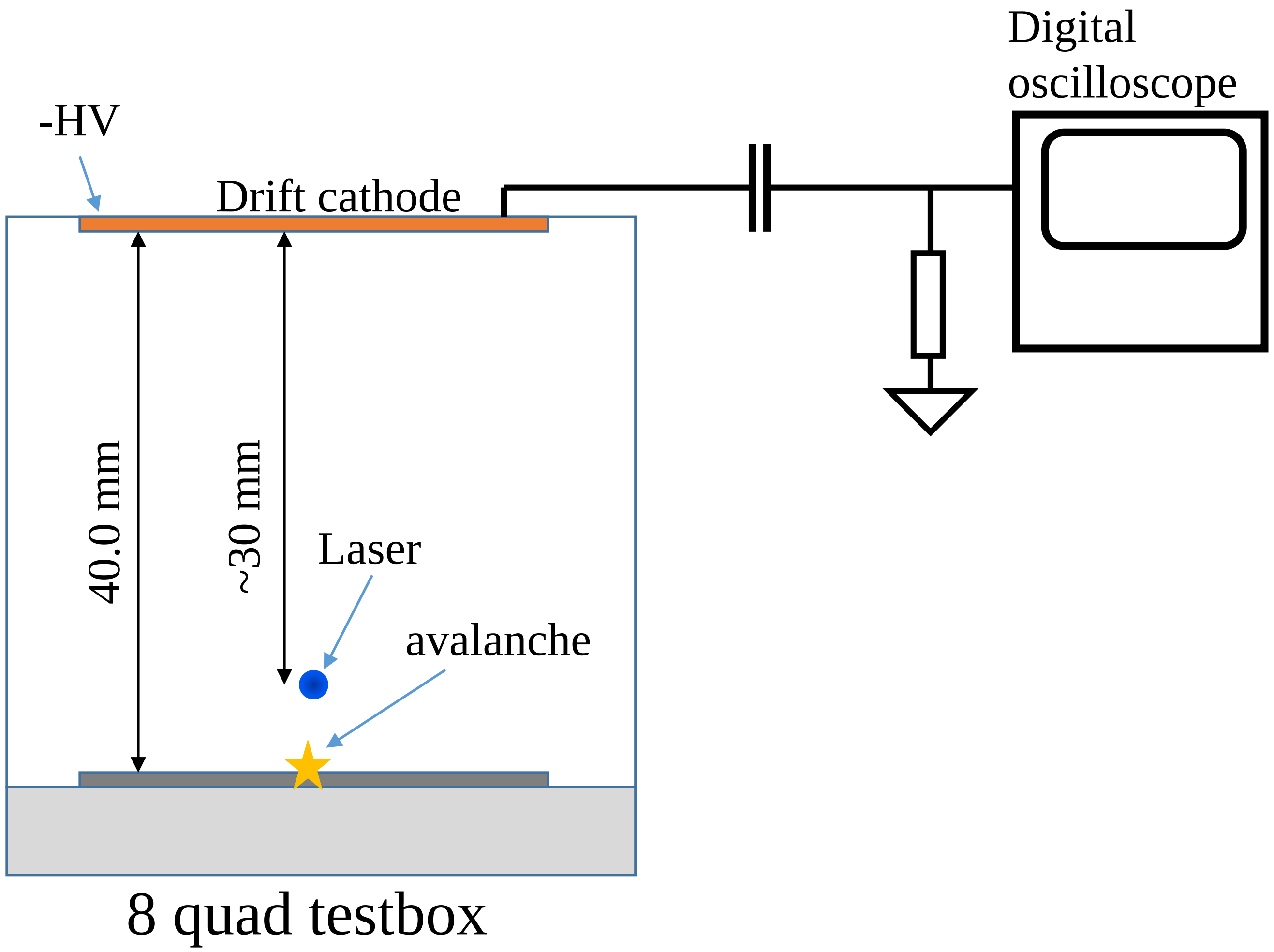
Setup for measuring positive ion drift

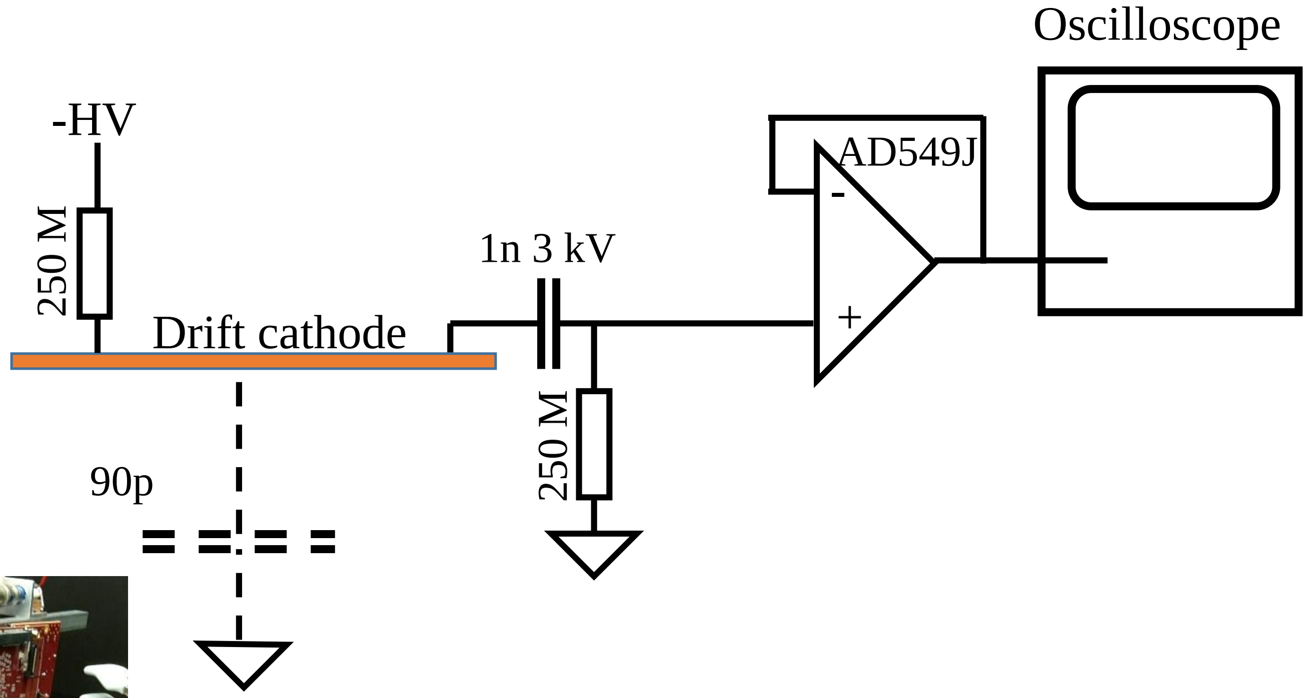
- Ions from the laser beam instantaneously induce charge on drift cathode
- In addition ions leaking through the grid during the avalanche induce charge as well
- Ions move towards the drift cathode, generating an induction current
  - Current terminated at arrival at the drift cathode
- Measurements reliably triggered by laser diode
- On the scope **averaged over 32 triggers**

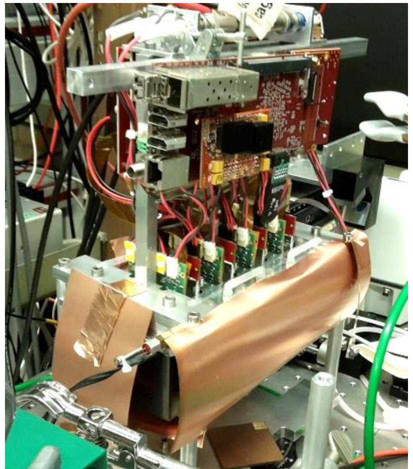


Setup of the charge signal collection

Instabilities/ noise from:

- Drift field HV supply
  - => heavy RC filters at input and outlet
  - Outlet filter has time constant of 2.2 s
- LabVIEW communication with HV supplies
  - Interrupted during data taking
- Micro discharges at drift cathode
  - Strong dependence on magnitude drift field
  - Cannot be solved easily
- 50 Hz pickup
  - Shielding testbox
- Laser instability 20 – 30% rms





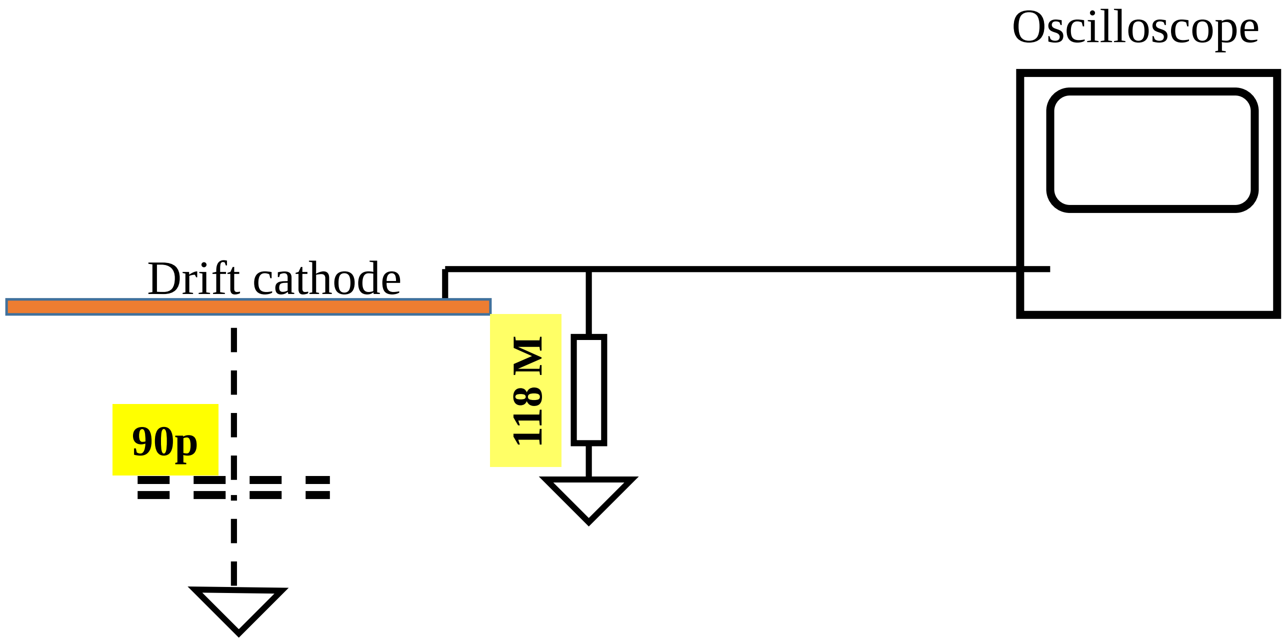
Best scope sensitivity 1 mV/div
- Signal was often clipped at 0.5 mV/div

Averaging over 32 laser shots

Simplified electronic circuit

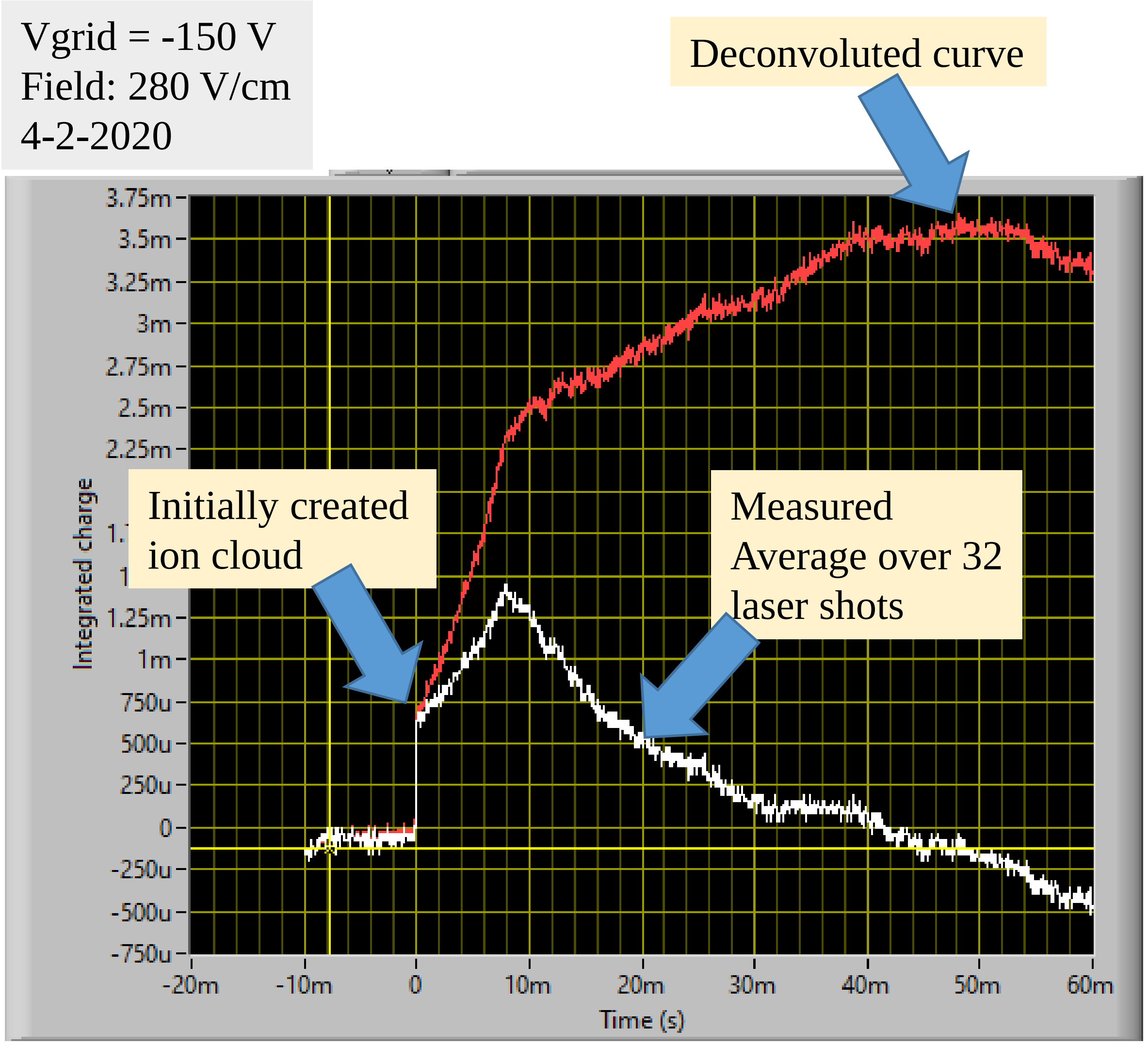
- Values measured with test pulse
  - Through 1 pF and 100 MOhm
- Parasitic capacity of drift cathode, Lemo cable, electronics measured as 89.5 pF
- RC time 10 +/- 0.5 ms

- We get the ideal integrator curve by deconvolution of the measured curve from the RC time constant
  - But for better deconvolution also the voltage change on 1 nF coupling capacitor had to be taken into account



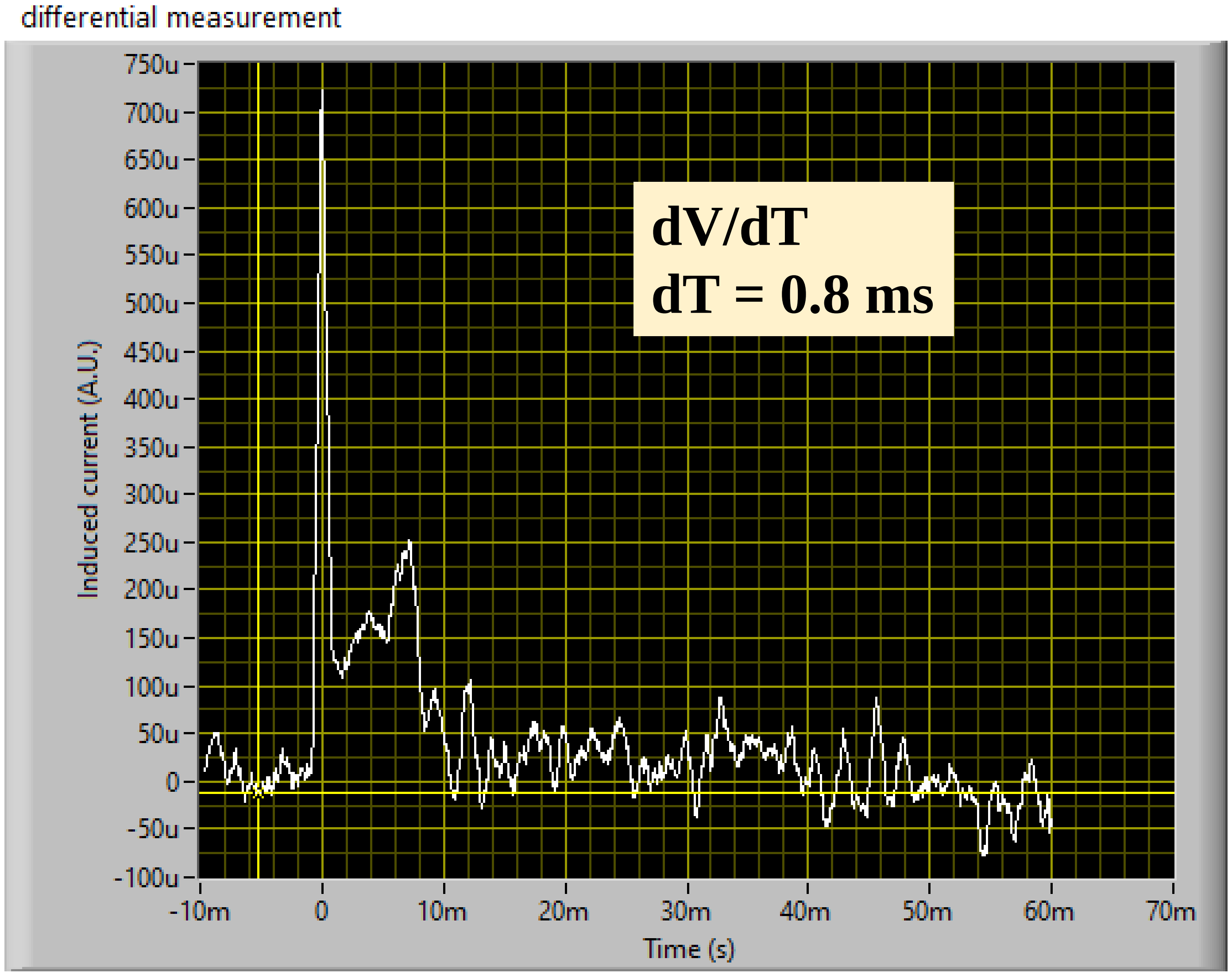
Primary ionization by laser

- 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 up to 40 ms**
    - Phenomenon hard to measure because of instabilities on the charge signal
    - **Measurement with blocked laser has been subtracted**
- Integrated charge 2.5 - 3.5 mV across 90 pF => **225 - 315 fC**
    - **=> 1.4 - 2.0 M ions**
    - **=> ~ 40 - 60 electrons entering each hole**



Differentiated deconvolution curve of primary ionization

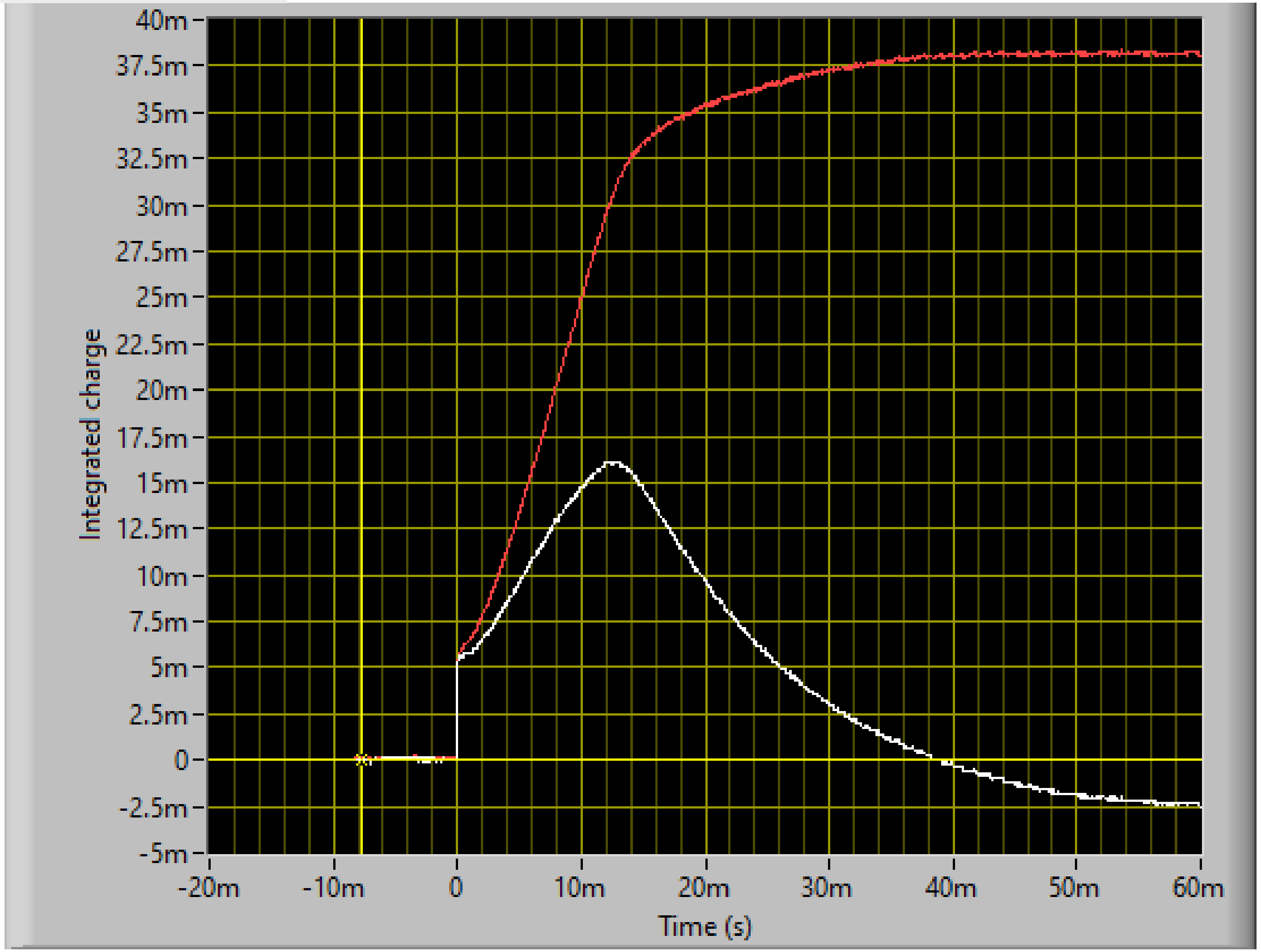
- Tail of slow ions between 8 and 40 ms may be present
- Note that this is only relevant for the laser measurements



With gas gain ~ 2000

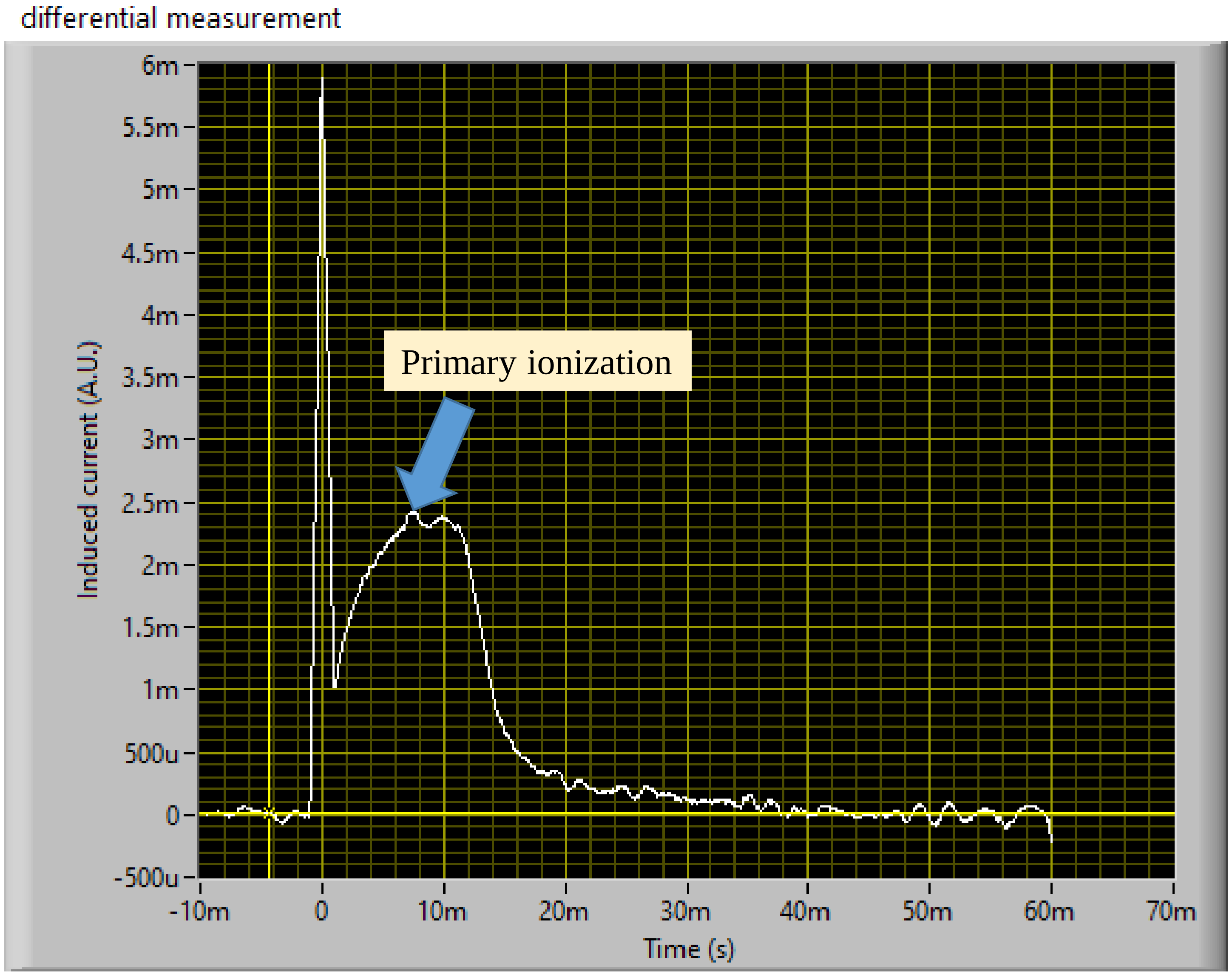
- Gas: T2K
- Primary ionization: about 60 e-/hole
  - Gain may be still proportional
  - To be verified
- Integrated charge: 38 mV across 90 pF
  - **=> 3.4 pC**
  - **=> 21 M ions**
  - Note the **soft** bend when the ions are collected by the drift cathode
  - => various types of ions are involved
- Bend starting at 12 ms
  - Ending at about 22 ms
- => drift velocity 1.8 – 3.3 m/s

Vgrid = -340 V
Field: 280 V/cm
4-2-2020



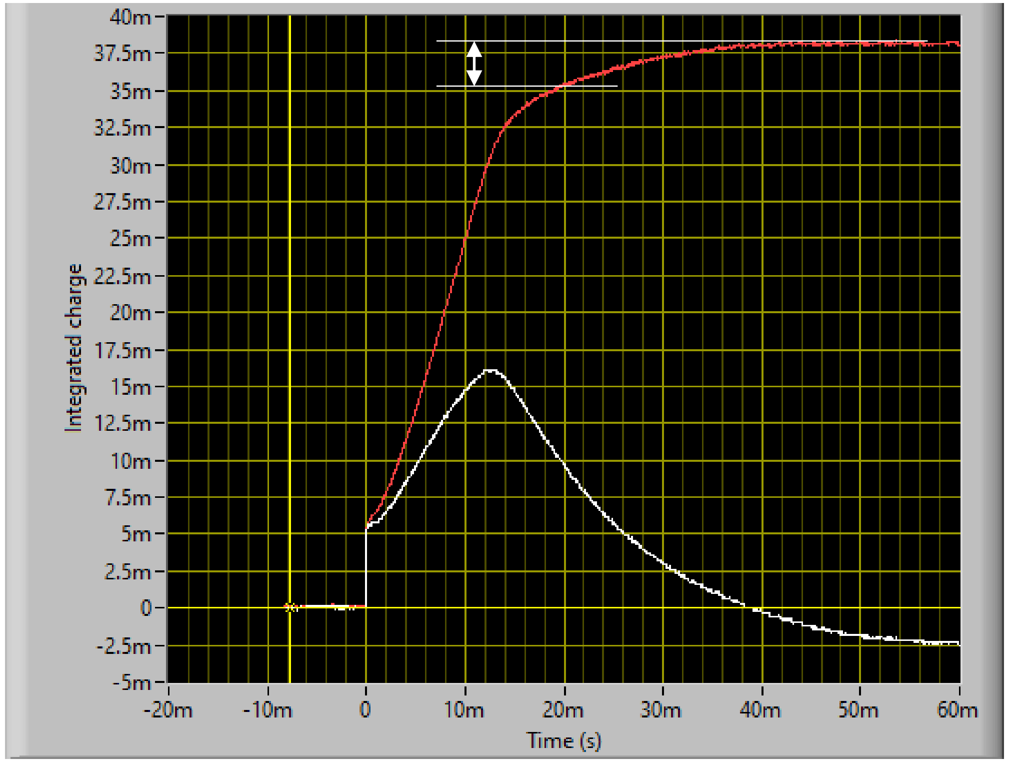
Differentiated curve

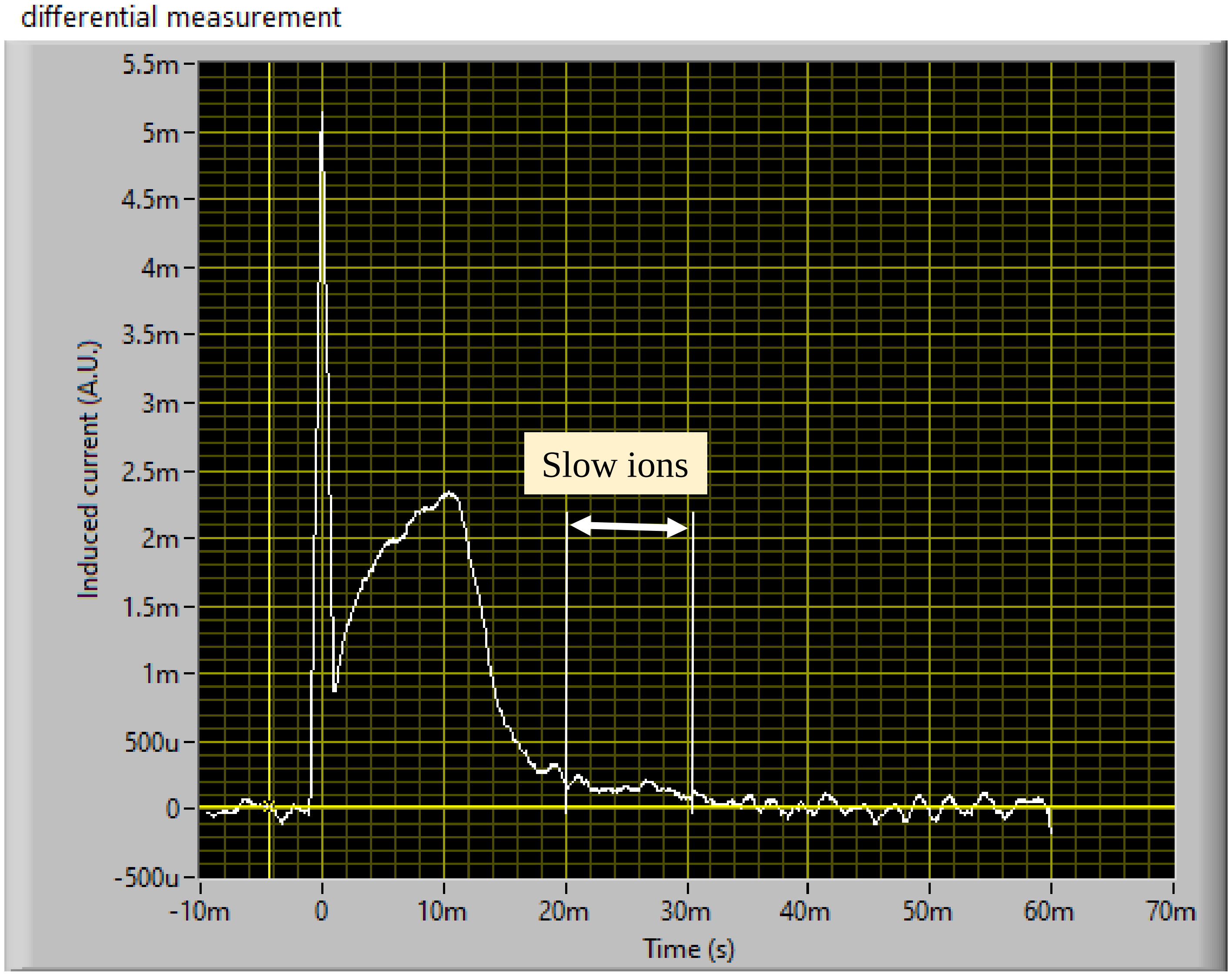
- dT = 1 ms
- The sharp bend of the primary ionization is well visible



Primary ionization subtracted

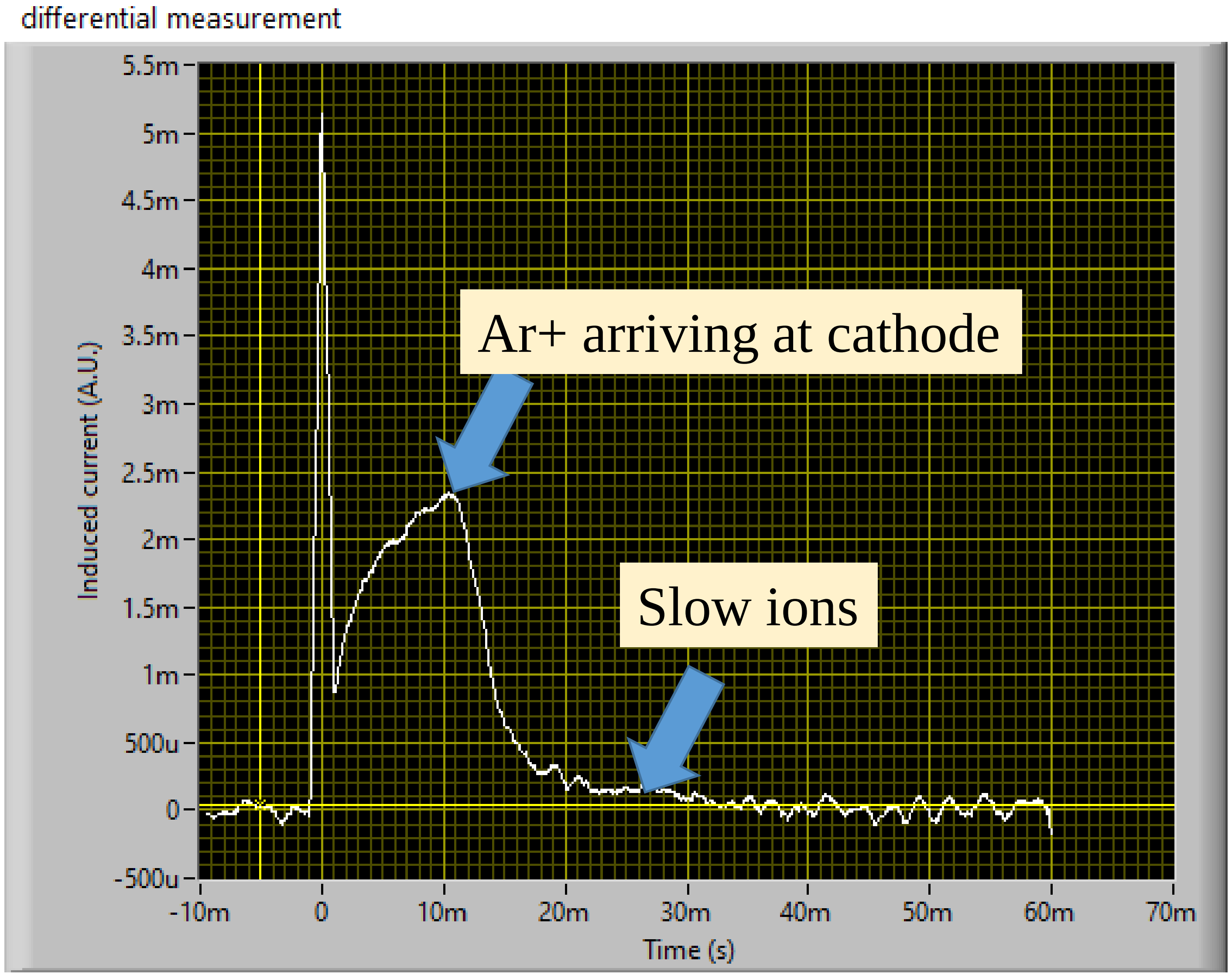
- **A slow ion** tail runs until ~ 30 ms
- This corresponds to 3 mV => 0.27 pC or 1.7 M of 21 M ions
  - About **8% of the total charge**
- Drift time main phenomenon: 12.5 ms
  - => velocity 3.1 m/s
- Drift time slow ions: 12.5 to 30 ms
  - => velocity 1.3 – 3.1 m/s





Nature of the peaks

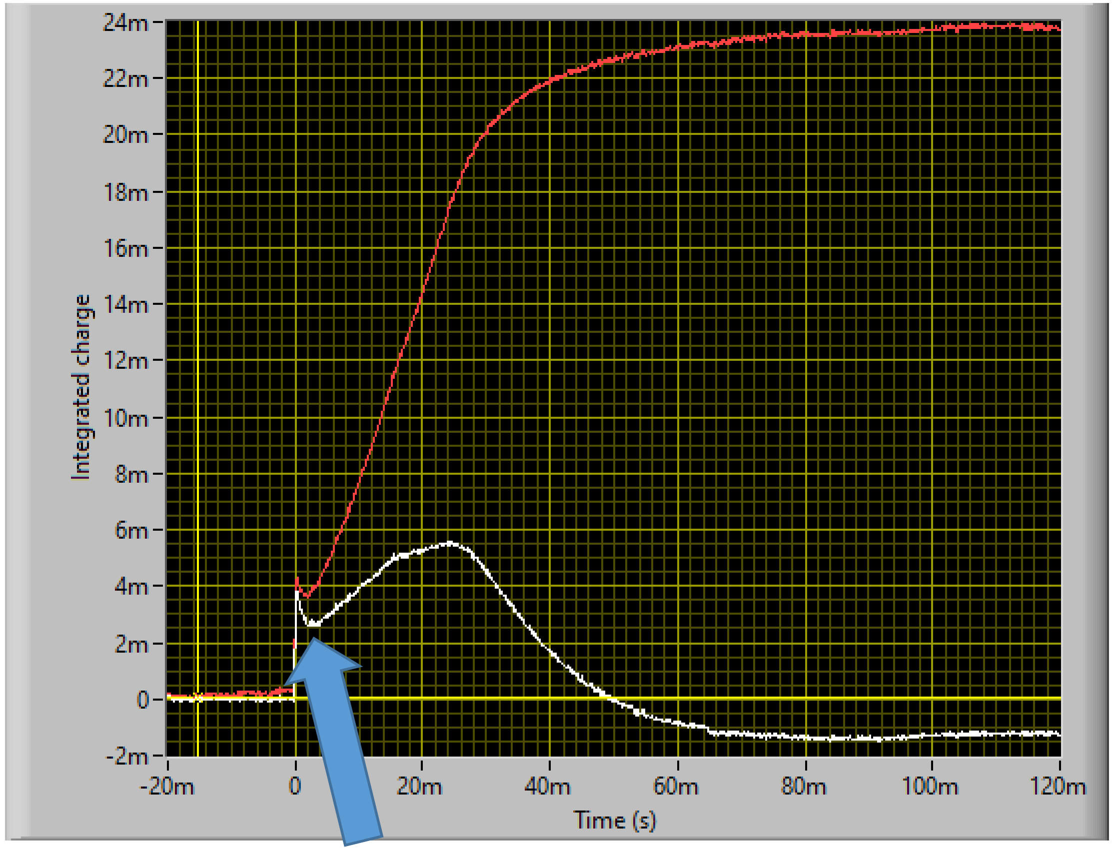
- Main peak probably is identified as Ar+ arriving at 12 ms
- Slow ions all collected at ~ 32 ms
- Mobility 0.45 - 1.1 $cm^2V^{-1}s^{-1}$
- Literature: Ar+ in Ar: ~ 1.5 $cm^2V^{-1}s^{-1}$
- Mobility has some dependence on the applied field, literature measurements normally done at much higher fields
- CF4 and iC4H10 have higher mobilities (2 – 2.5 $cm^2V^{-1}s^{-1}$)
  - Expected to be hidden in the rising edge of the Ar+ curve
- The slow ion peak may be caused by a C8Hn+ ion (Coimbra suggestion)



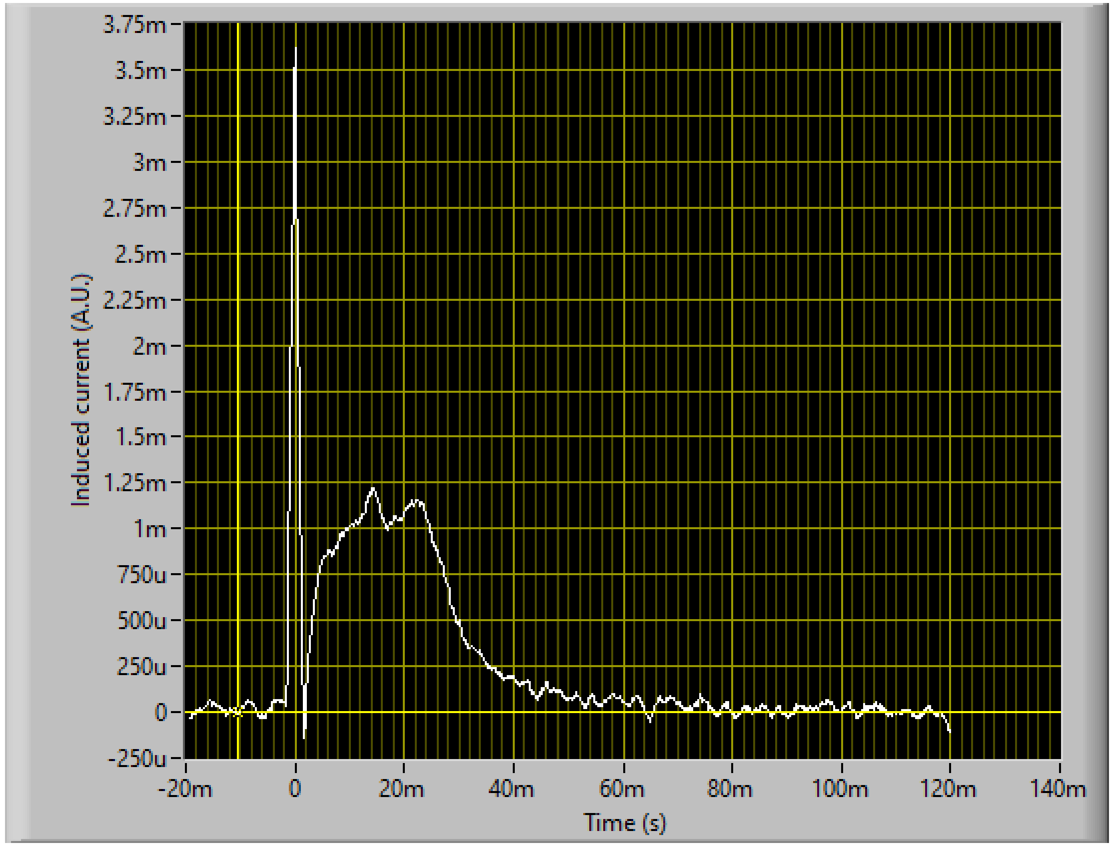
Low drift field: 150 V/cm

- Part of ions passing the grid hole will be still finally collected by the grid
  - => decrease of the originally induced charge

dT = 1.6 ms

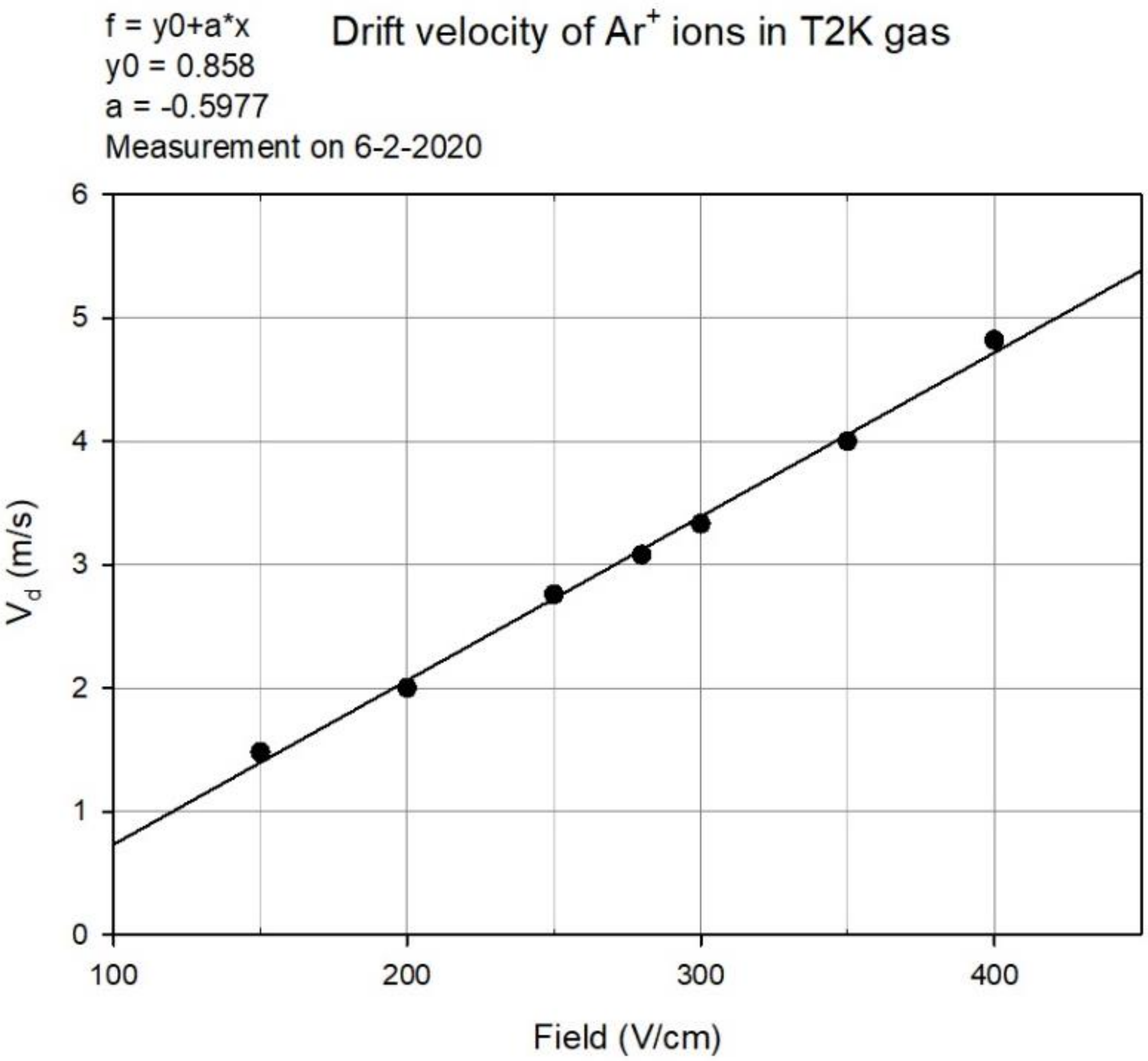


differential measurement



Ar+ drift velocity vs drift field

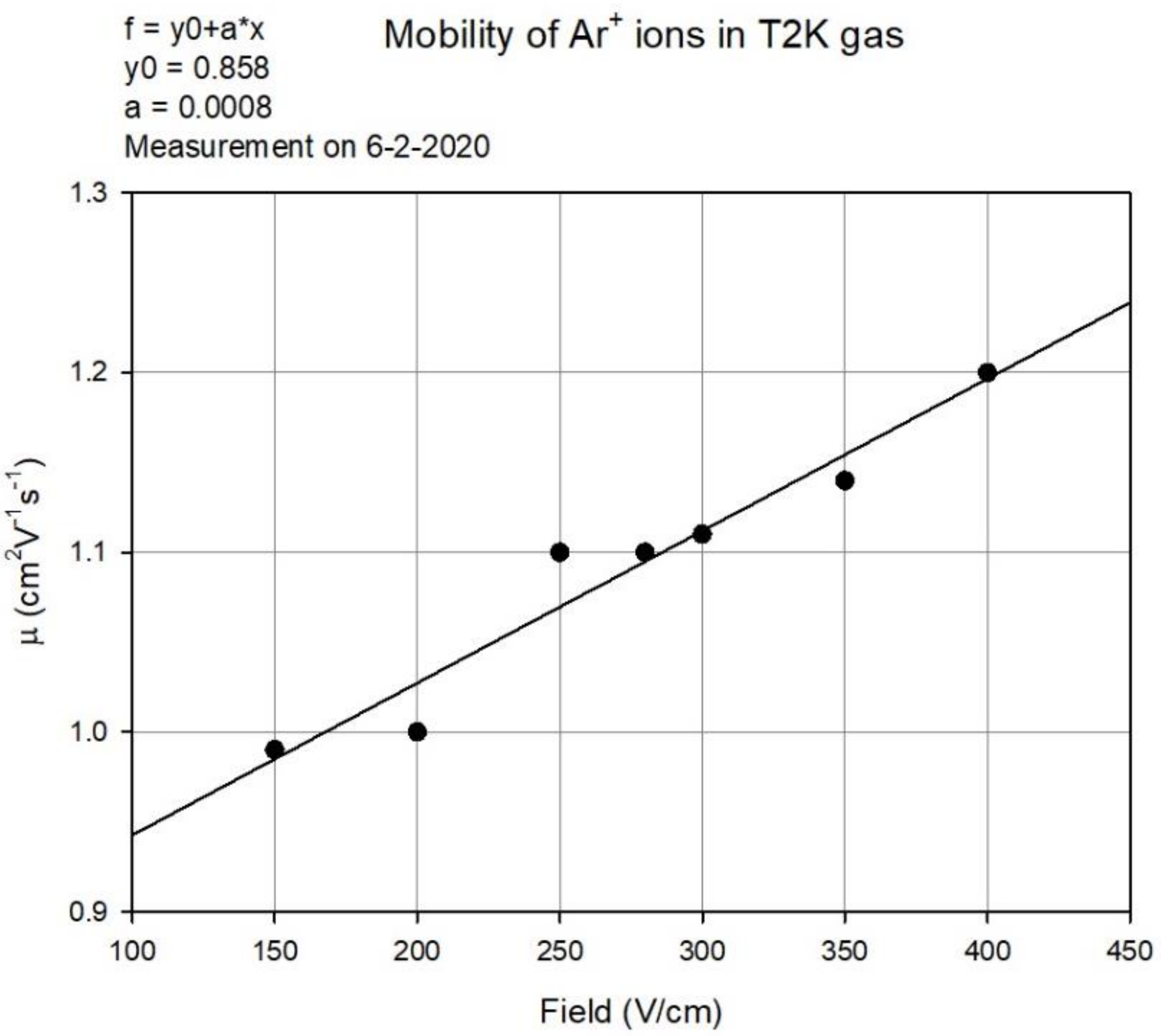
- Still to be reanalyzed
  - Curve does not pass X, Y = 0, 0



Ionic mobility vs drift field

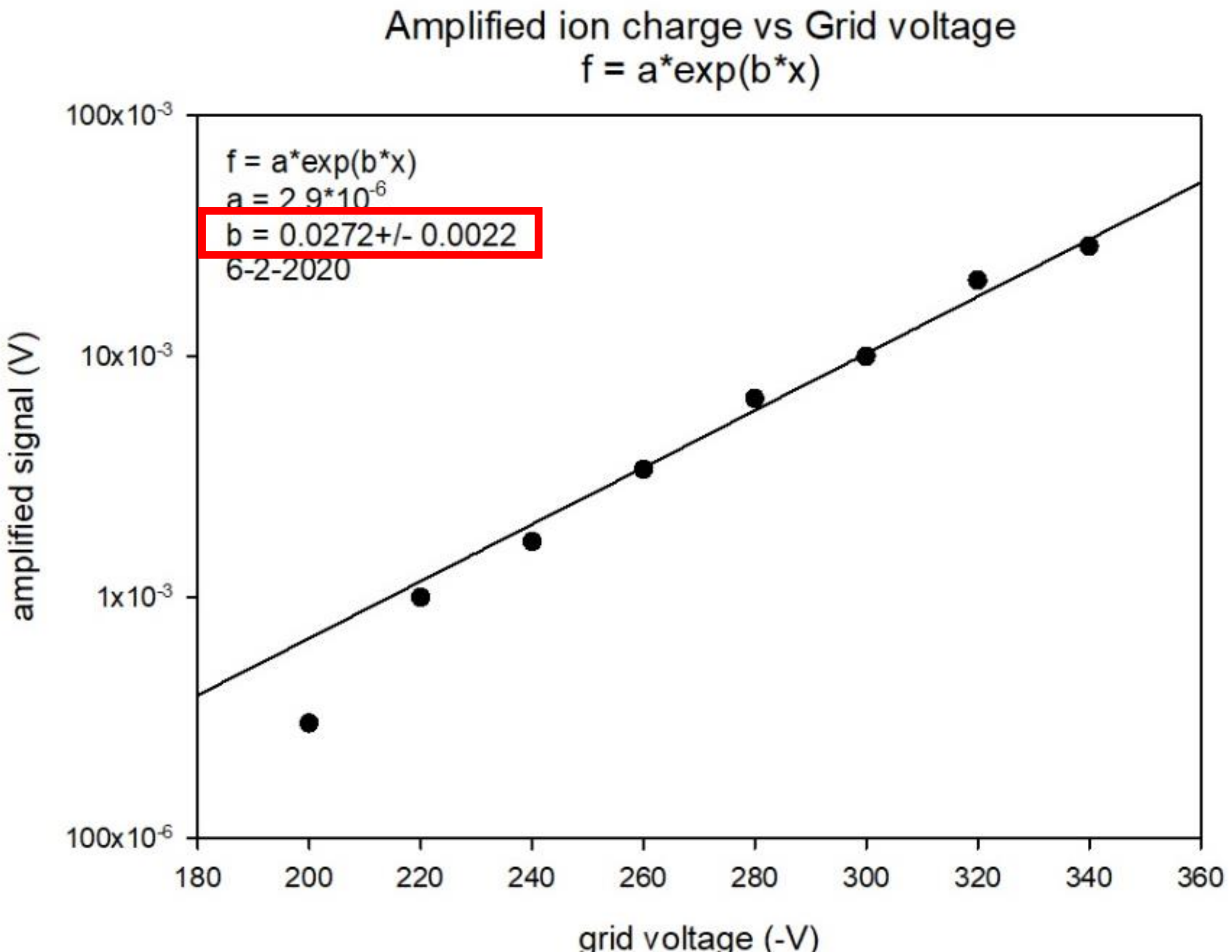
- Assuming the meain peak originates from Ar+ ions

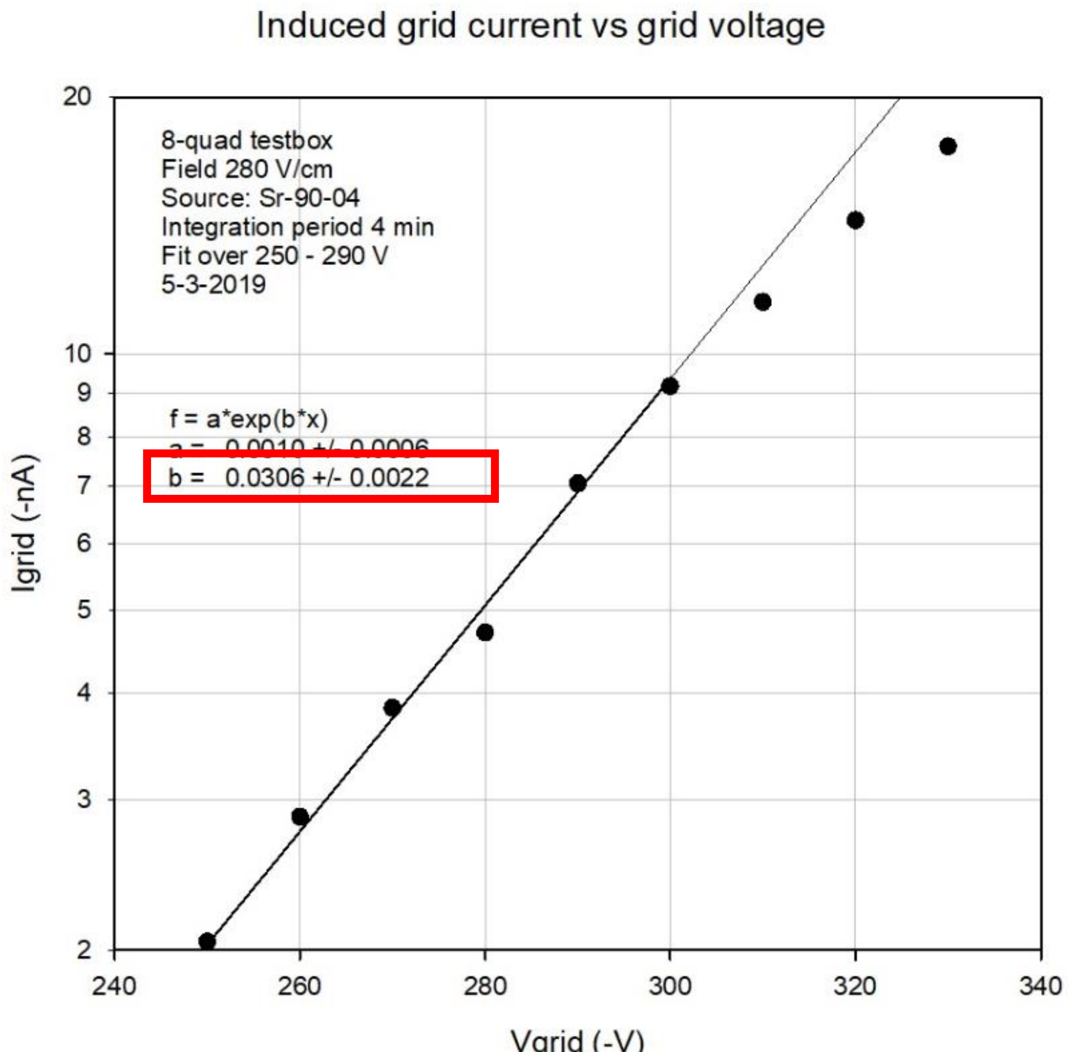
- Literature (Ar+ ions in Ar) (Madson, Hornstein 1967, 1951)
- ~ 1.3 – 1.5 $cm^2V^{-1}s^{-1}$ measured in 20 – 25 kV/cm range



Increase ion charge with Vgrid

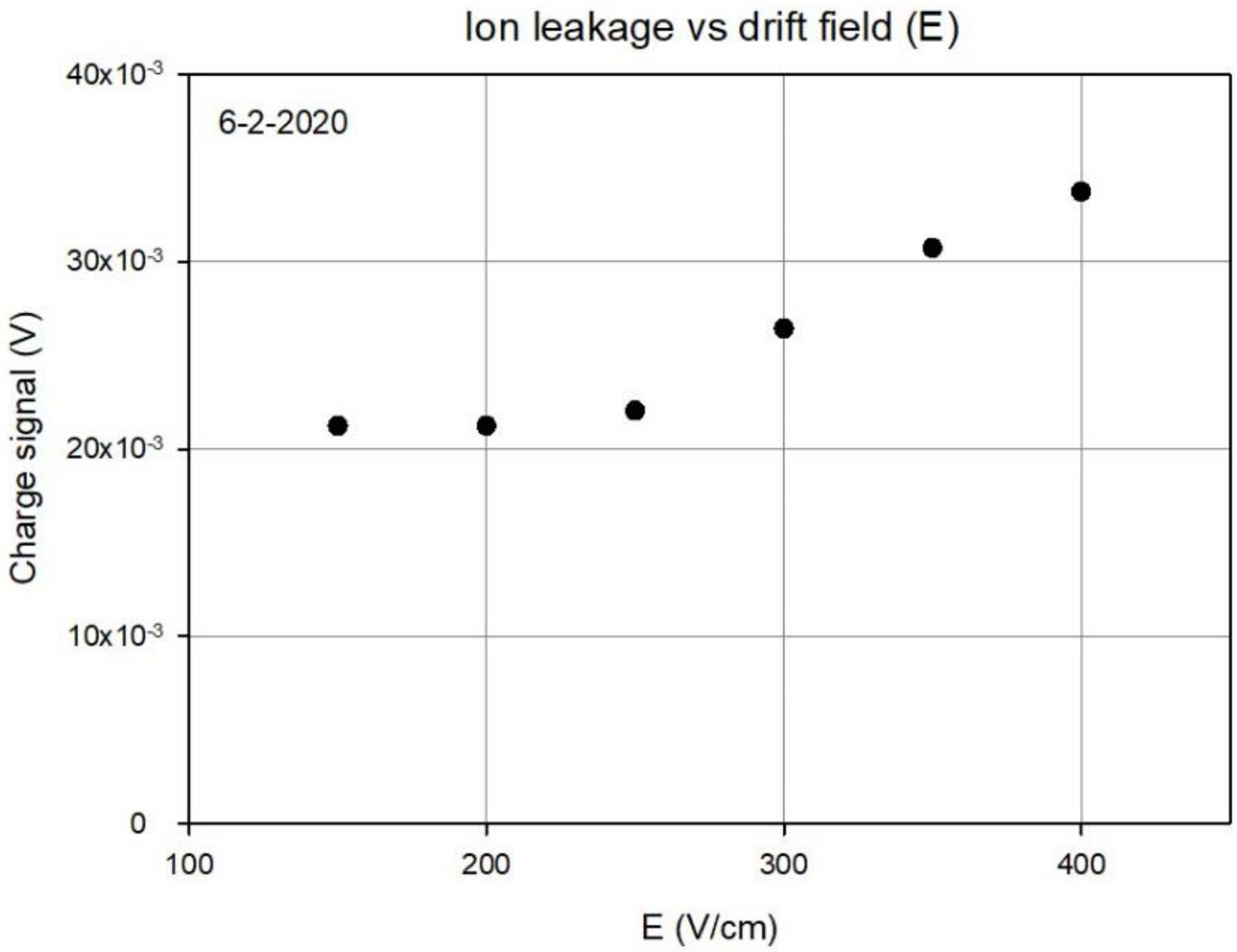
- Slope at used extremely high ionization density (~ 60 e-/hole) vs regular (< 0.1 e-/hole) is within error margin
  - 0.0272 vs 0.0306
  - So not too much **saturation effects**





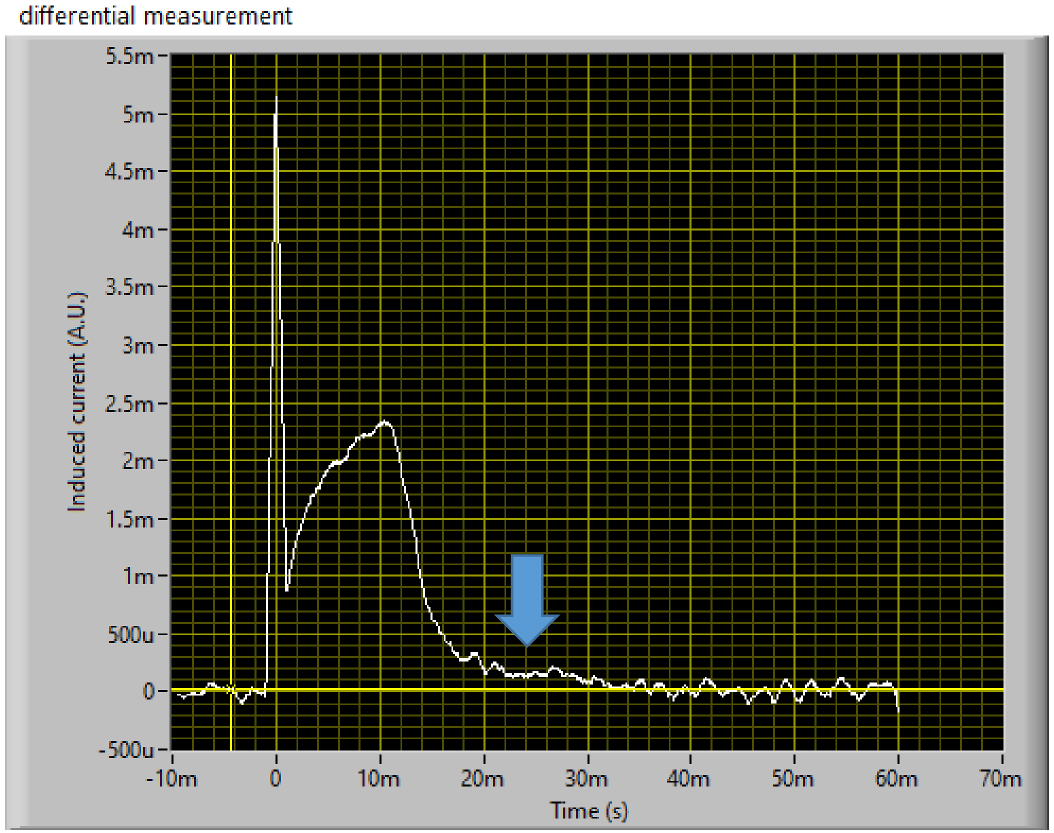
Ion leakage vs drift field

- Data still have to be corrected for the dependence of the gain on the drift field



Conclusions

- Leakage of ions through holes of the grid not very high
  - Assuming gain = 2000 at Vgrid = - 340 V => **0.75% is leaking**
- Main peak probably originates from **Ar+**
  - Faster peaks of CF4+ and C4Hn are probably hidden in the rising edge
  - But 8% of the ions have an about 3x **lower mobility**
- Ions of the same type all arrive at the same time at the cathode
  - See the sharp peak of the primary laser ionization
  - But the curve of the avalanche ions has a **soft edge** => several types of ions are involved



Conclusions cntd

- Part of the ions appearing at the hole of the grid are finally captured by the grid
  - This is especially seen at low drift fields
- There is no clear sign of **saturation** of the gas gain at the very high input rate (40 – 60 e-/hole)
  - Note that for the laser measurements the voltage drop across the protection layer is not too high (very low duty cycle)
  - Grid current ~ 0. 5 nA
- Calibration of the gas gain from the measured grid current and the amount of primary ions still to be done