Negative ionic drift

Being investigated

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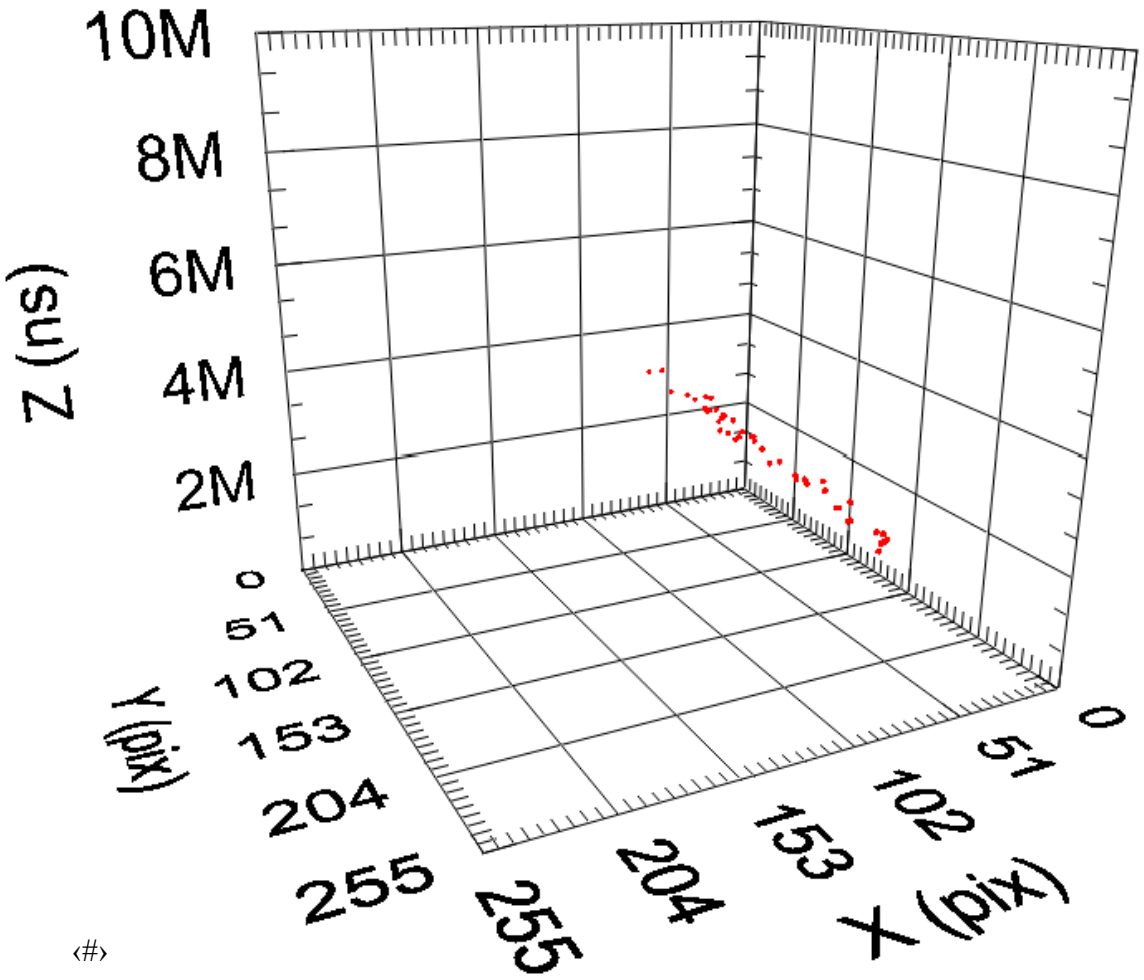
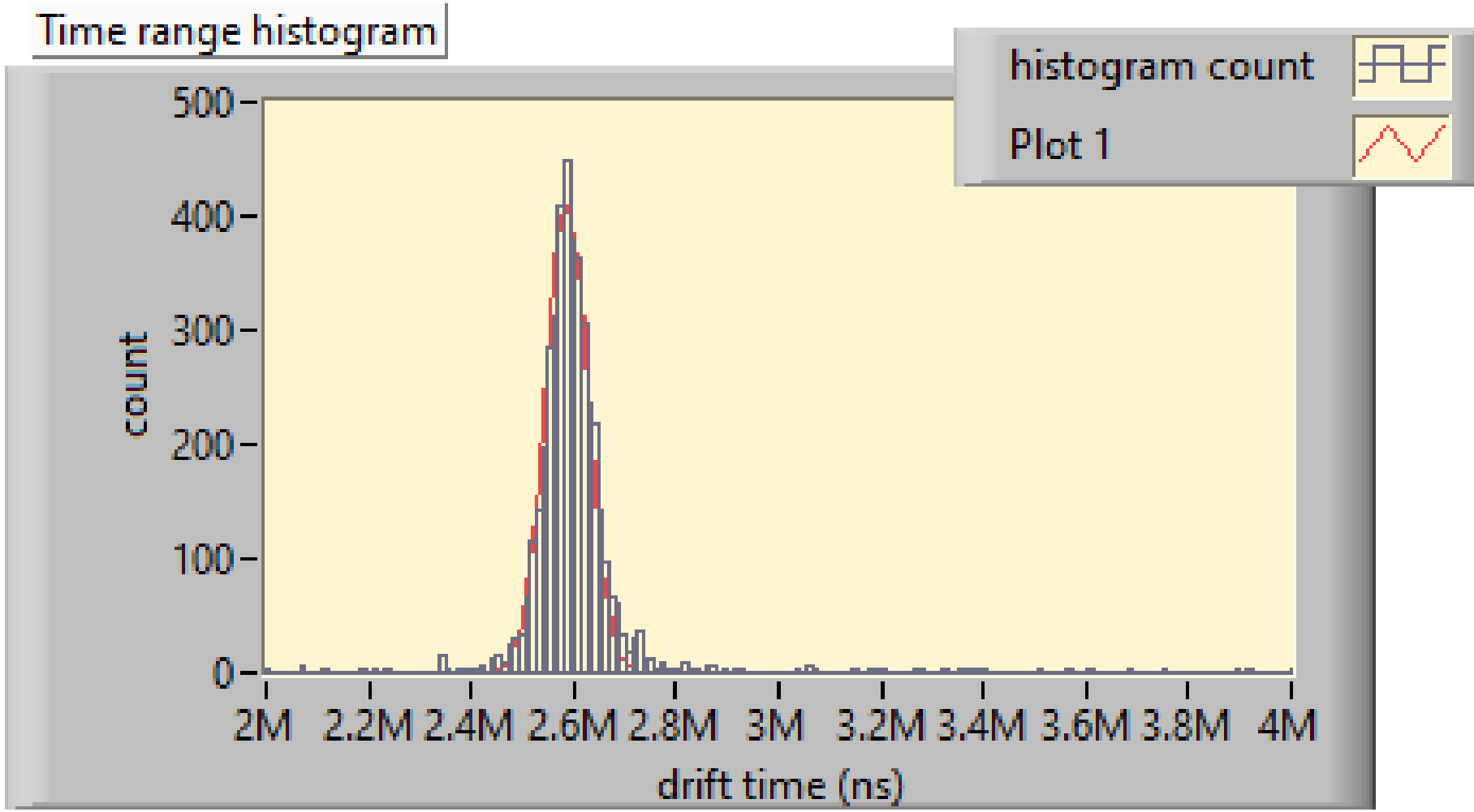


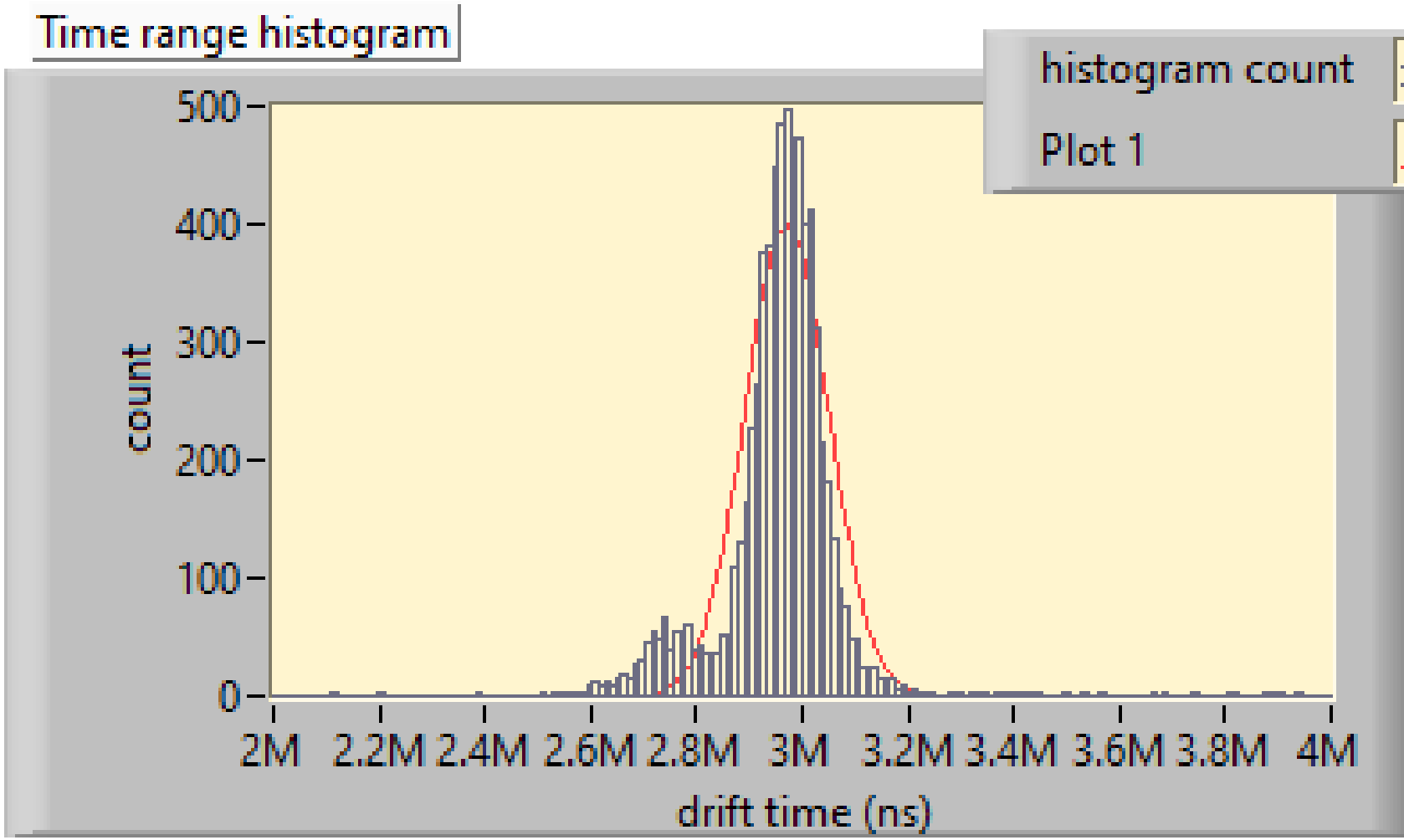
First result: pure Ar + 1.2% CS_2

- Drift time about 2.6 ms across 12 mm
- Rms = 0.0416M ns ≈ 180 μm
- Ar/CS_2 98.8/1.2
  - Run 1017V
- Grid -300 V
- E_d = 280 V/cm
- ToT 750 ns
- **Sparking at higher grid voltages**
- Measurement done in the 8-quad testbox



Now with quencher (isobutane)

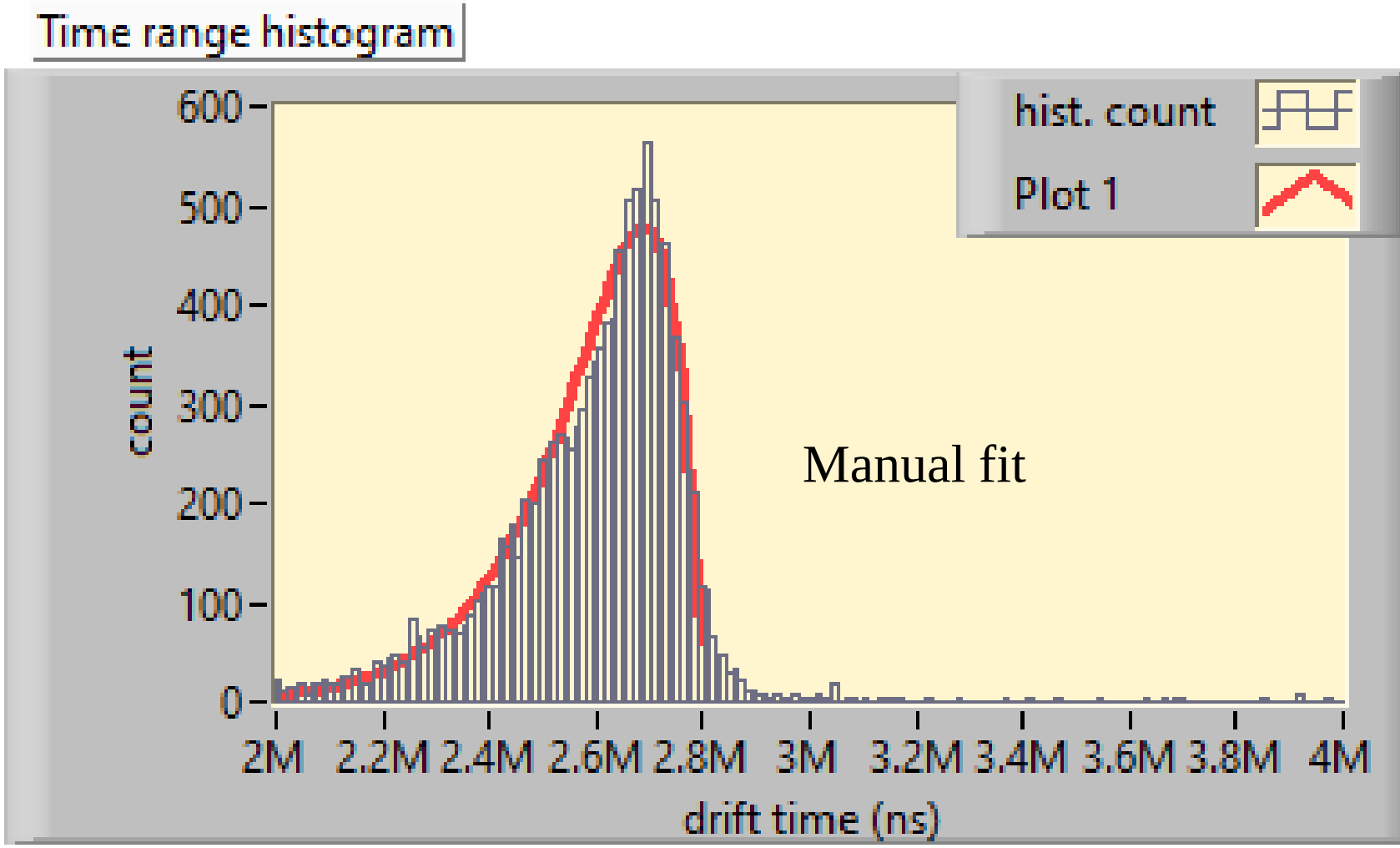
- Ar/iC_4H_{10}/CS_2 90/9/1 run 1025
- Vgrid = -430 V
- ToT 1750 ns
- Z = 12 mm
- Double peak (iC_4H_{10}?)



How low may the CS_2 concentration be?
0.1% CS_2

- $Ar/iC_4H_{10}/CS_2$ 95/4.9/0.1, run 1035
- V_{grid} -380 V
- E = 280 V/cm
- ToT 1100 ns
- Z = 12 mm
- **Curve fitted with:**

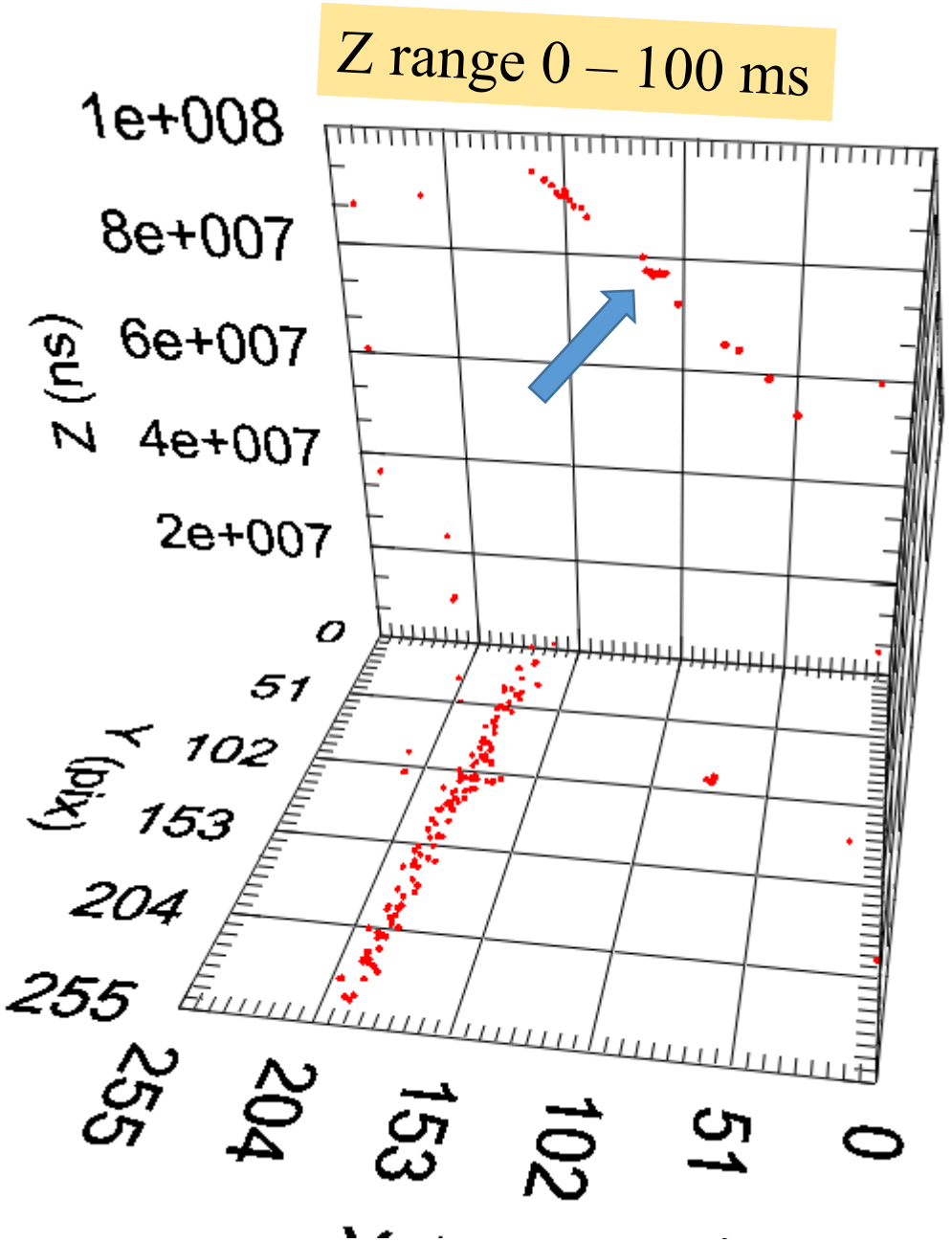
  $\psi = x/\lambda * \exp(x/\lambda)$ †
- λ = 0.11 ms => 470 μm for 0.1 % CS_2
- After deconvolution for diffusion **430 μm** estimated



†*N. Dongari, Y. Zhang and J. Reese, Molecular free path distribution in rarefied gases*
Journal of Applied Physics, 44(12):125502 · March 2011

Are there ions with much longer drift time?

- No other laser tracks visible up to 100 ms
  - **=> no ions with longer drift time involved**
- Accidental cosmic track present



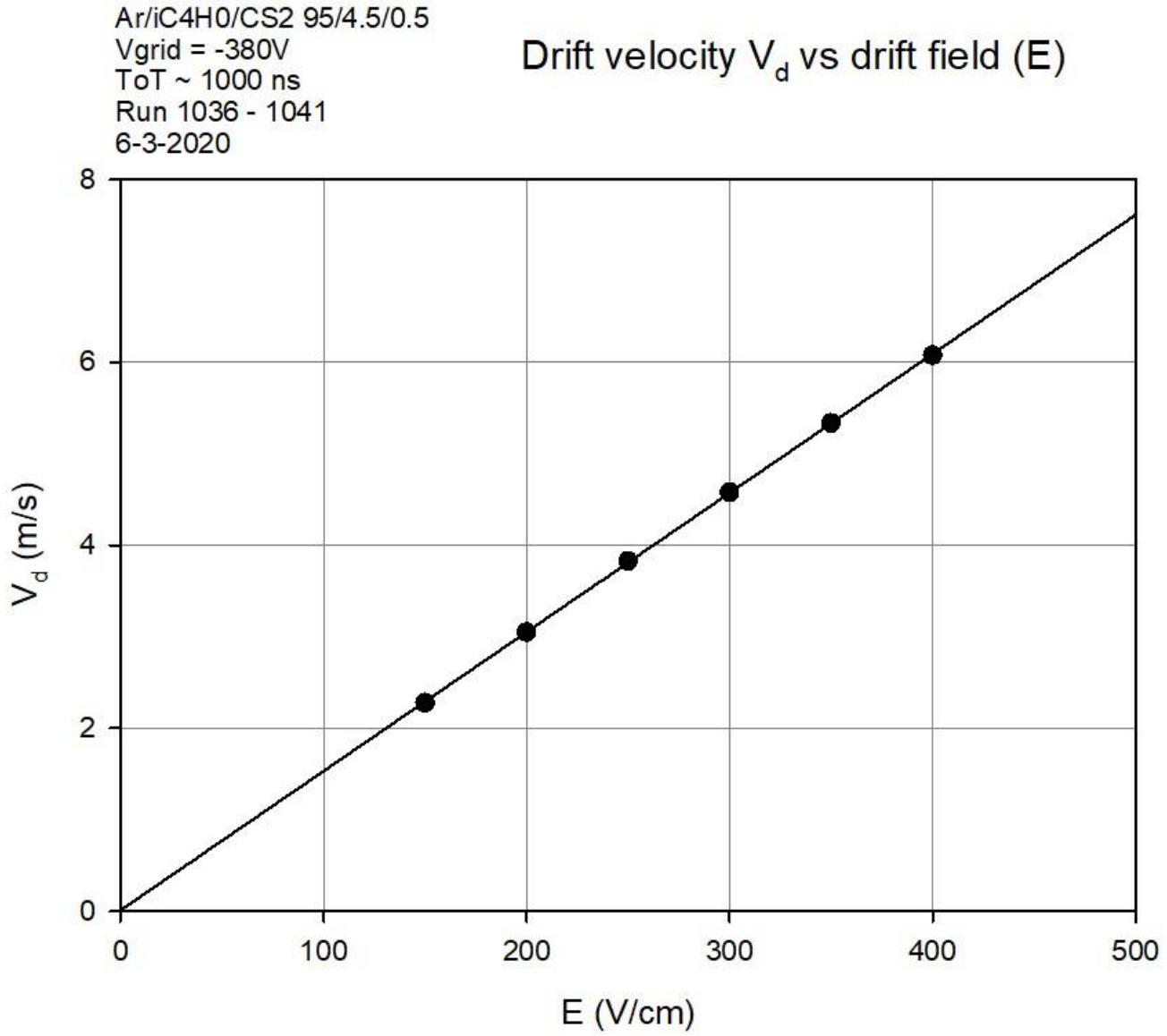
Dependencies on the drift field E measured

- 6 different fields from 150 to 400 V/cm
- Ar/iC_4H_{10}/CS_2 95/4.5.0.5
- Vgrid = -380 V => ToT ≈ 1000 ns
- Kinetic energy of the ions probably mainly thermal, not depending on E_d
  - 3/2 kT
- => we expect several **first order dependencies**
- $V_d \propto E_d$ **Proven hereafter**
- Diffusion $\sigma^2 \propto^{-1} E_d$ **≈ proven hereafter for σ_L**
- Mean free path of electrons $\lambda \propto E_d$
  - The number of collisions per second does not depend on E_d
- $\lambda \propto^{-1}$ CS_2 concentration

Drift velocity $V_d \propto E_d$

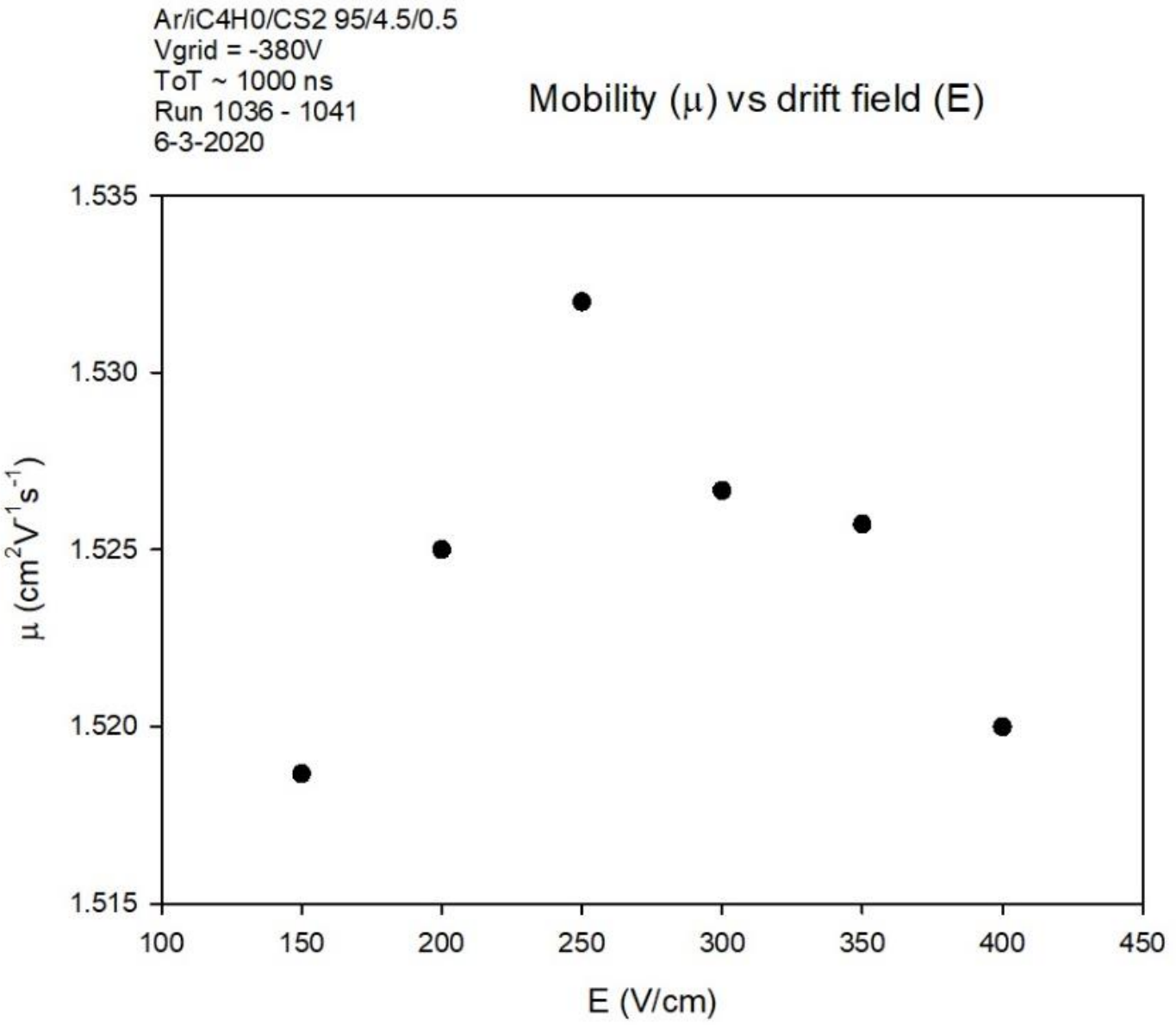
- $Ar/iC_4H_{10}/CS_2$ 95/4.5.0.5

- **Precise proportionality**



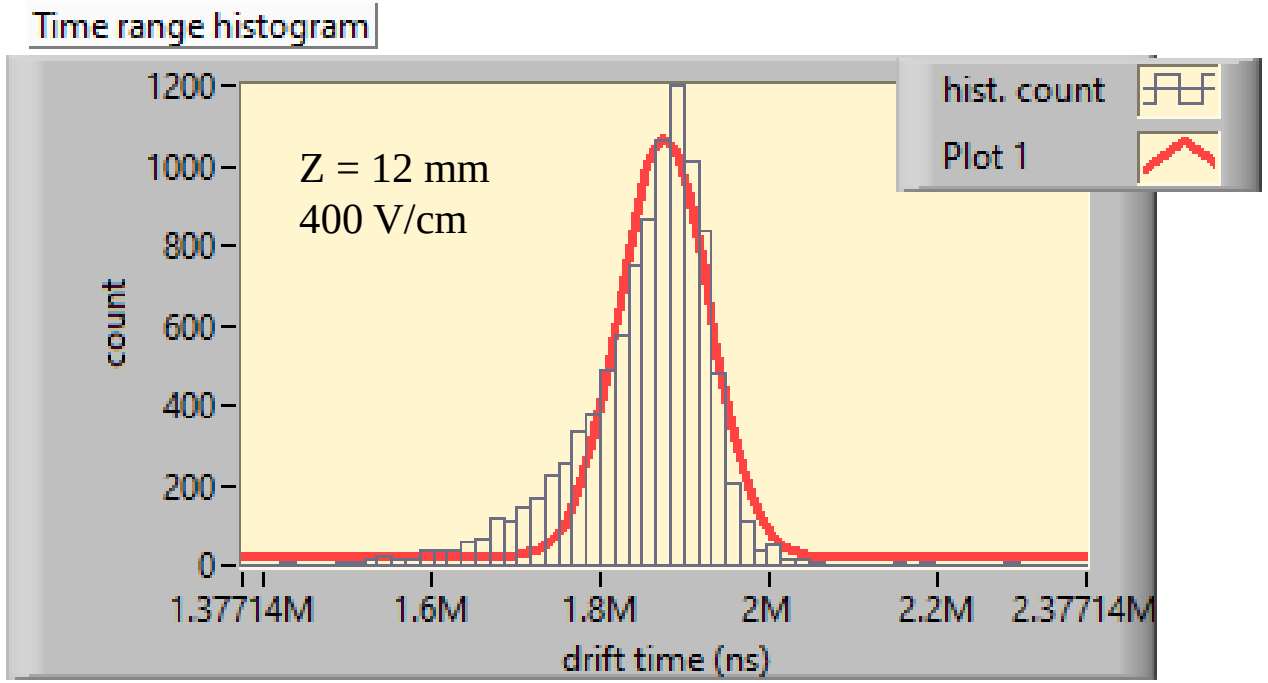
Mobility

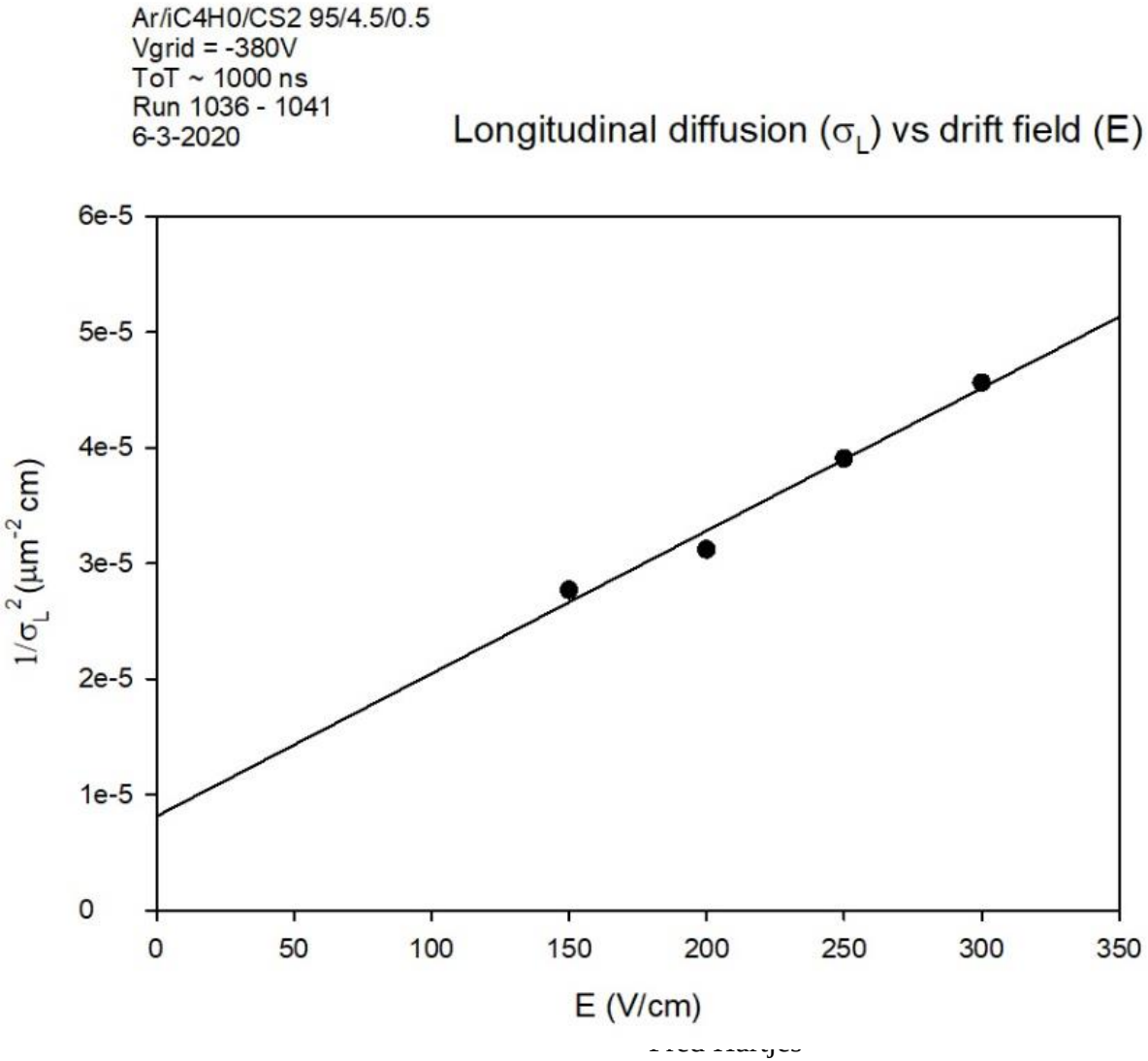
- $Ar/iC_4H_{10}/CS_2$ 95/4.5.0.5
- Mobility is constant at 1.525 $cm^2V^{-1}s^{-1}$ (+/- 0.5%)
- No visible dependence on E_d



Longitudinal diffusion $\sigma^2 \propto^{-1} E_d$

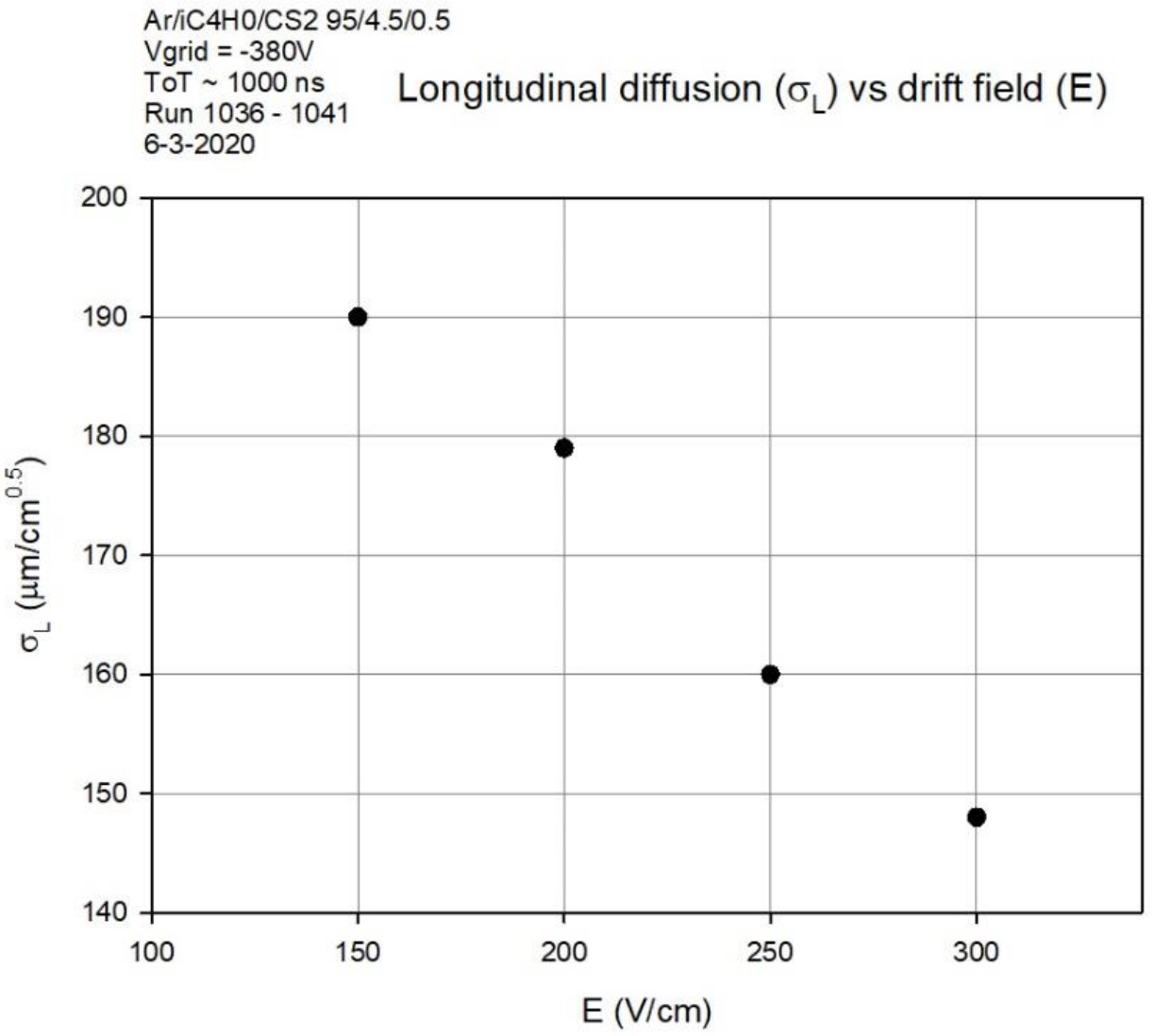
- $Ar/iC_4H_{10}/CS_2$ 95/4.5.0.5
- Not measured for E = 350 and 400 V/cm
  - Tail from finite mean free path
- Limited accuracy of the measured points
  - Fit does not pass the origin (0,0)
  - Effect from λ tail?





Longitudinal diffusion in µm/√cm

- $Ar/iC_4H_{10}/CS_2$ 95/4.5.0.5
- Not measured for E = 350 and 400 V/cm
  - Tail from finite mean free path
- At 250 V/cm σ_L = 150 µm/√cm
- To go down to 75 µm/√cm we need E = 1 kV/cm



Conclusions on negative ions so far

- Detecting negative ions instead of electron we are entering a completely unknown domain

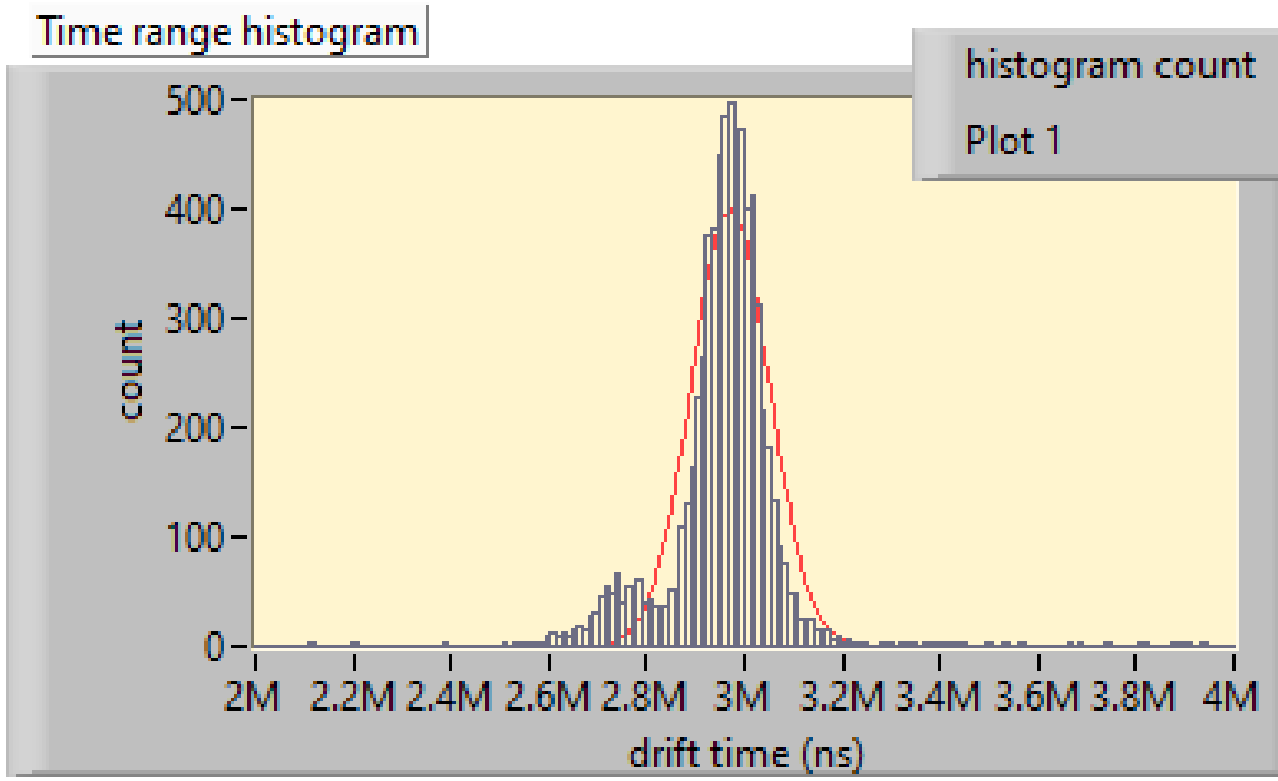
- Using a GridPix detector (integrated grid on a pixel chip, 50 um gap), negative ions from CS_2 are easily detected
  - Probably the attached electron is stripped in the high avalanche field and can thus create an avalanche in the regular way
  - At 1% CS_2 the required grid voltage is only elevated by ≈ 10%

- The negative ion mobility is about **4 orders of magnitude smaller** than for electrons

- To create negative ions, CS_2 is a quite acceptable additive with efficient electron capture
  - No serious environmental hazard (unlike SF_6)
  - Personal risk is reduced by the strong smell
    - As long as you hardly smell it or not at all, it is safe
  - Mean free path of electrons 43 μm * $\%C_{CS2}$ vapour @ E = 280 V/cm

Conclusions on negative ions so far cntd

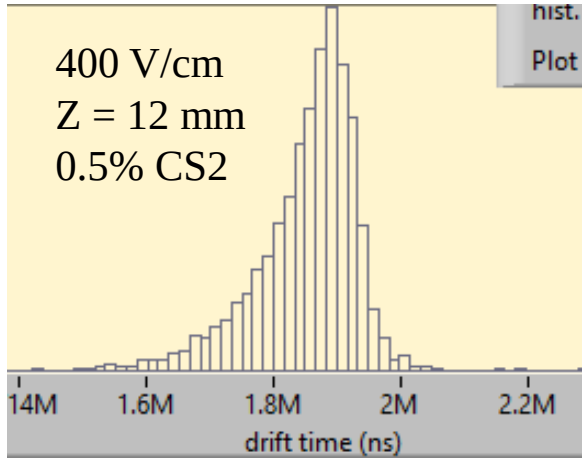
- Under certain conditions (9% iC_4H_{10}) a double peak is **sometimes** seen
- The ratio between the two peaks corresponds about to the ratio of the components of the gas mixture (Ar/iC_4H_{10} 90/9)
  - But for a repeated measurement the second peak is hardly visible
- There is **no easy way to identify** the measured ion peaks
  - Both mass and cross section of the molecules in the gas mixture are unknown
  - Maybe we do not see CS_2 ions at all, but only Ar and/or iC_4H_{10} ions??



Conclusions on negative ions so far cntd

- Track detecting with negative ions has certain limited advantages
- Diffusion is modest for higher drift fields (< 100 μm @ 1 kV/cm)
- The absence of electronic time walk is a clear advantage
  - => Accidental cosmic tracks often look very narrow

- For large TPCs (drift gap in the meter range) with quite low drift fields and thus elevated diffusion, the asymmetric λ tail is not visible
  - => lower CS_2 concentrations are possible



- But for smaller TPCs (drift gap in the decimeter range) where we will profit from the reduced diffusion at higher drift fields, the λ tail in σ_L may become dominant => use high CS_2 concentrations (> 1%)

- At 1% CS_2 we have $\lambda \approx 43$ μm at $E_d = 280$ V/cm
  - We may easily increase the CS_2 concentration until 3% easily or 30% (more effort)
  - But **we do not know the long term effects of CS_2** vapour affecting the detector materials
    - Until now the 8 quad testbox has been exposed a few times for < 2 hours at 0.5 - 1% CS_2