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An athermal measurement technique for long time constants traps characterization in GaN HEMT transistors

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Introduction

- The trap characterization techniques generally used on GaN HEMT transistors are limited by self-heating (DLTS, DLOS, ...) [1].
- An athermal method is proposed in order to measure long time constant traps in GaN HEMT transistors.
- Defects with time constants ranging from several ms to 1000s are observable with limitation of self-heating effects.

Principle of the measurement technique

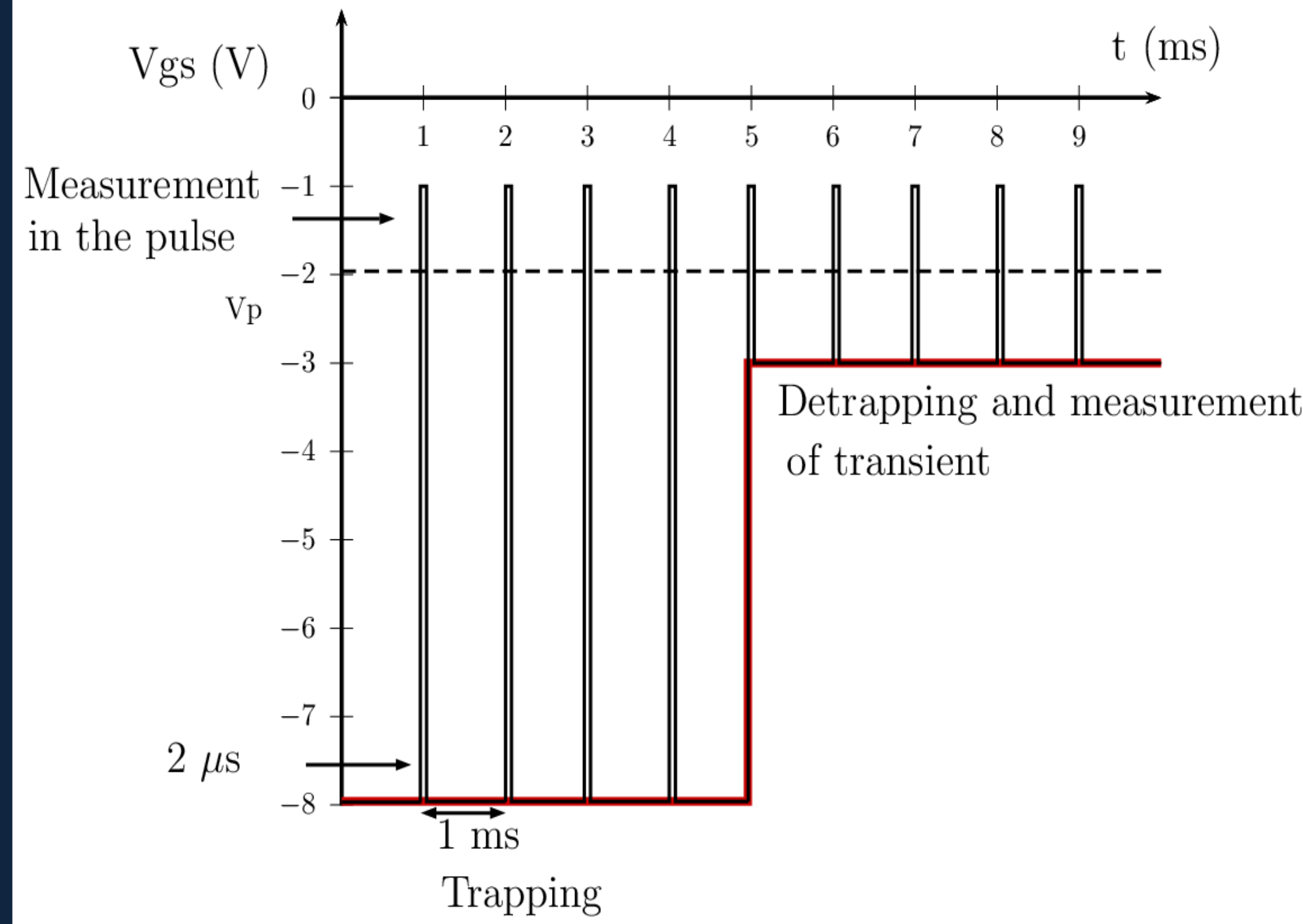


Fig 1 : Principle of the method

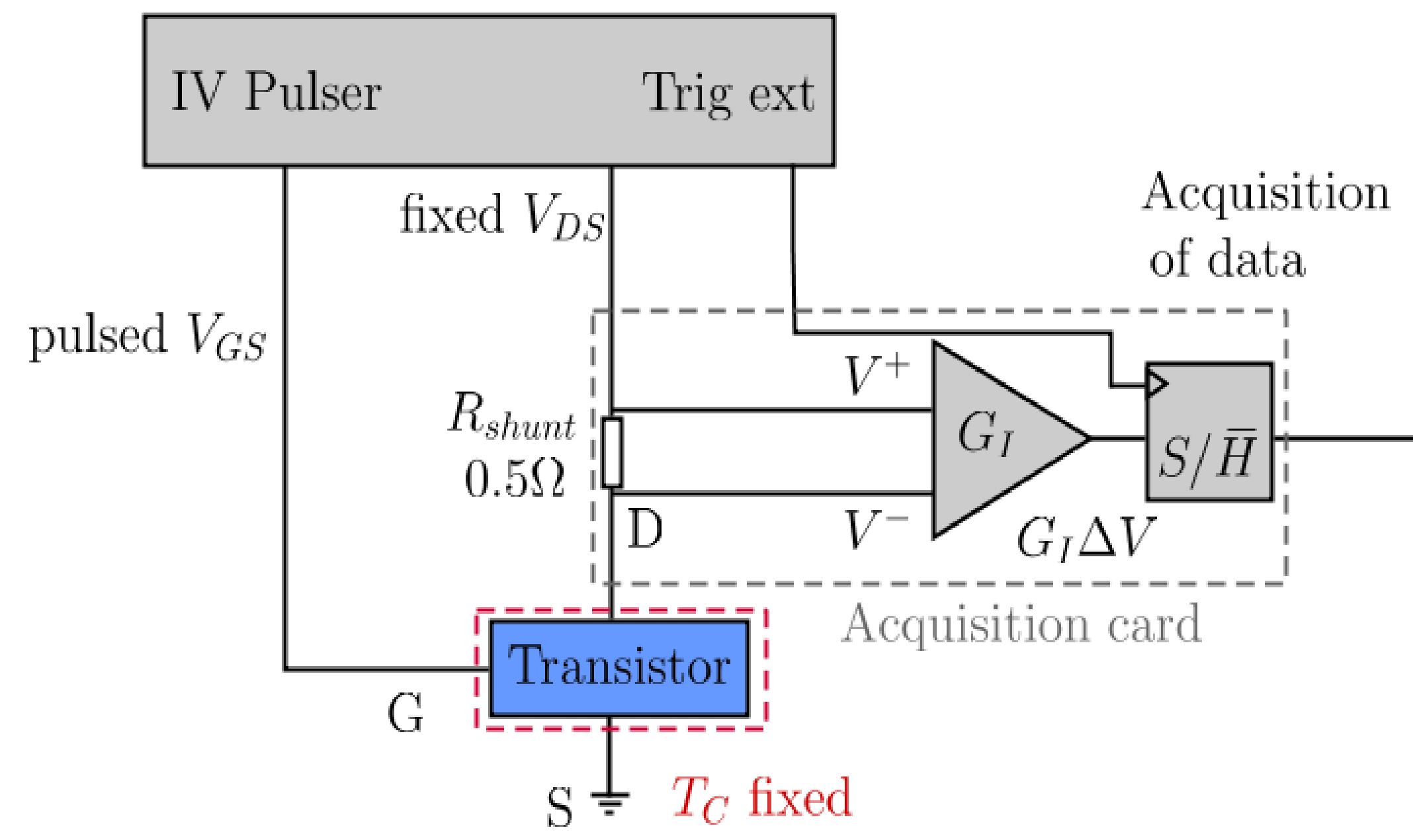


Fig 2 : Measurement bench

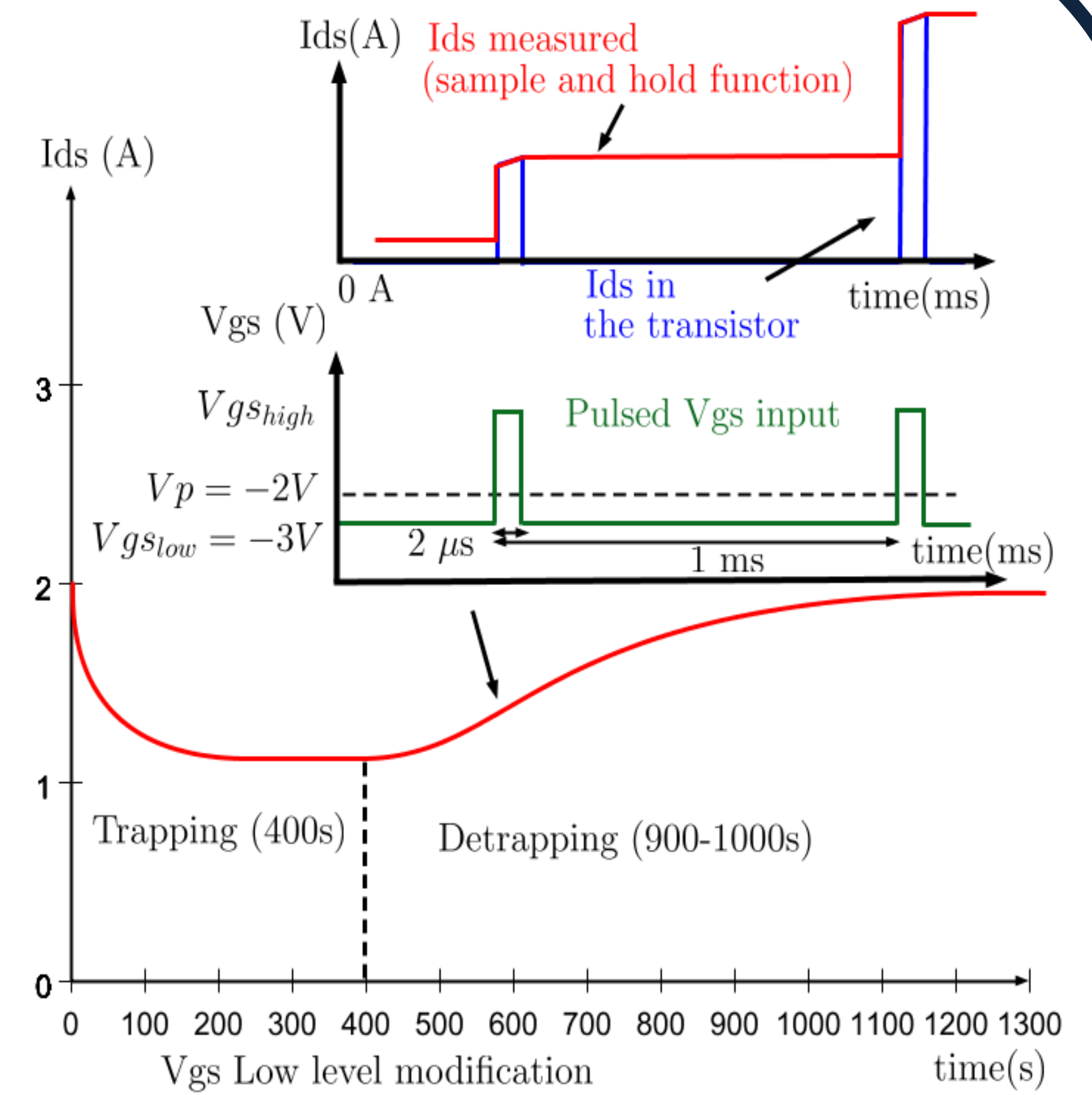


Fig 3 : Extraction of athermal current transients

- The drain bias is fixed (ohmic or saturation region).
- The gate bias is pulsed between two levels (0.2% duty cycle), the lower one being changed after an initial filling (trapping).
- The drain current is measured during the relaxation of traps between these two states.

- The drain current is measured using an acquisition card with instrumentation amplifiers.
- Only the pulse current is retrieved using a sample and hold device.
- The transient is measured during 1000s.
- The time constants are retrieved using Prony and Levenberg-Marquardt algorithms.

Validation of the method using modeling

- Modeling of the electro-thermal source of the device using ADS (Advanced Design System).
- A generic trap activation energy is included in the model.
- Output : We extract the right activation energy down to $\tau = 20ms$.
- **The concept is validated even for high current densities (around 0.42 A/mm).**
- **The simulated temperature rise is $\Delta T_j = 0.4^\circ C$.**

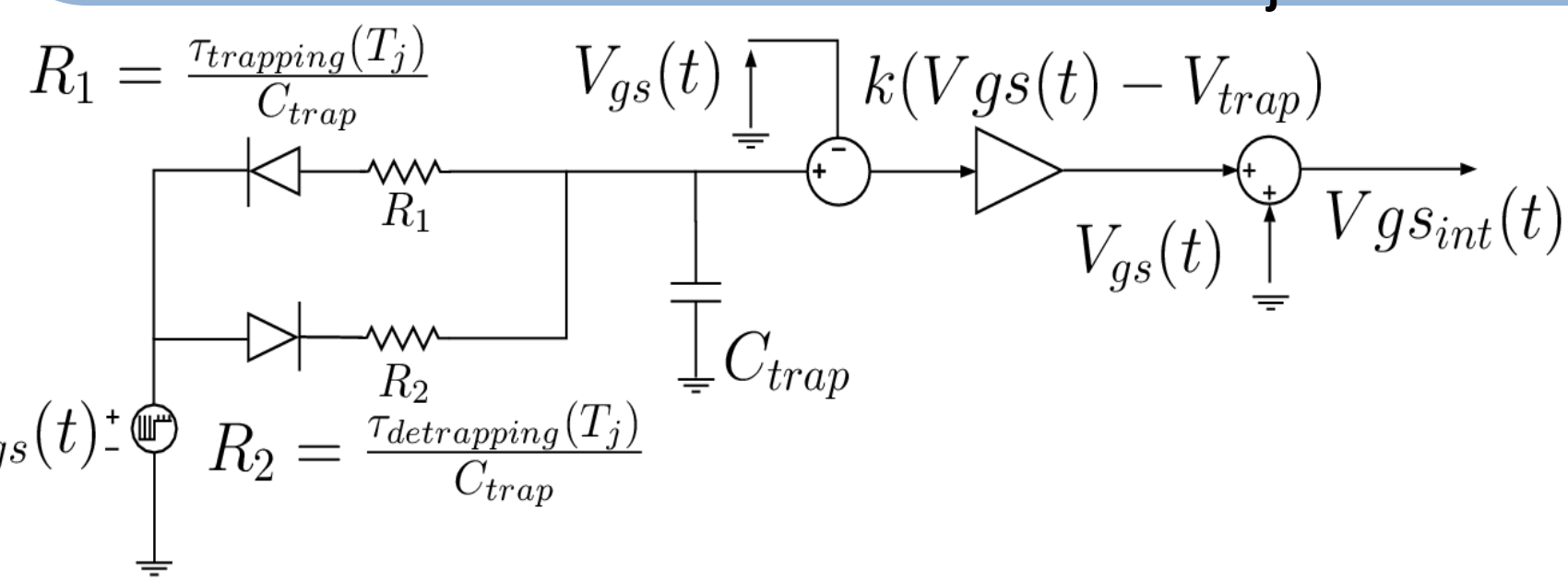


Fig 4 : Simulation of trapping effects

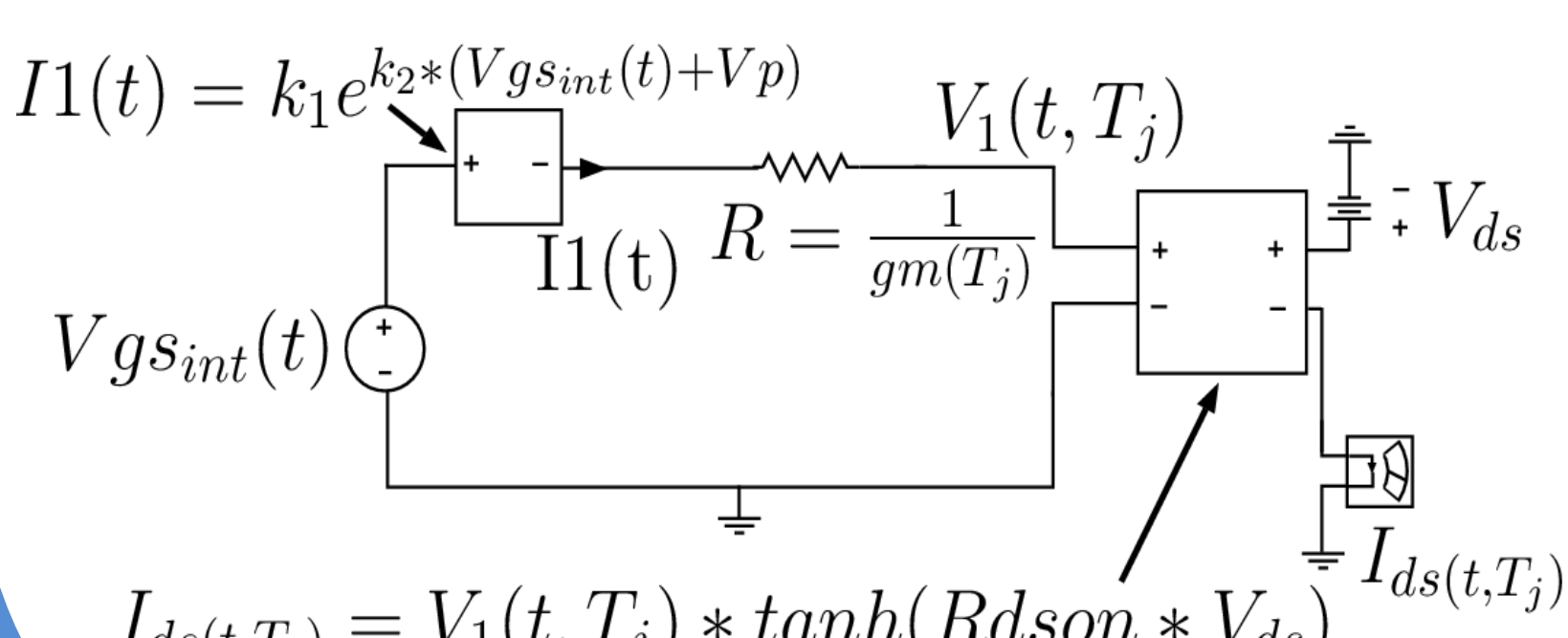


Fig 5 : Simulation of the device's current source (temperature dependent)

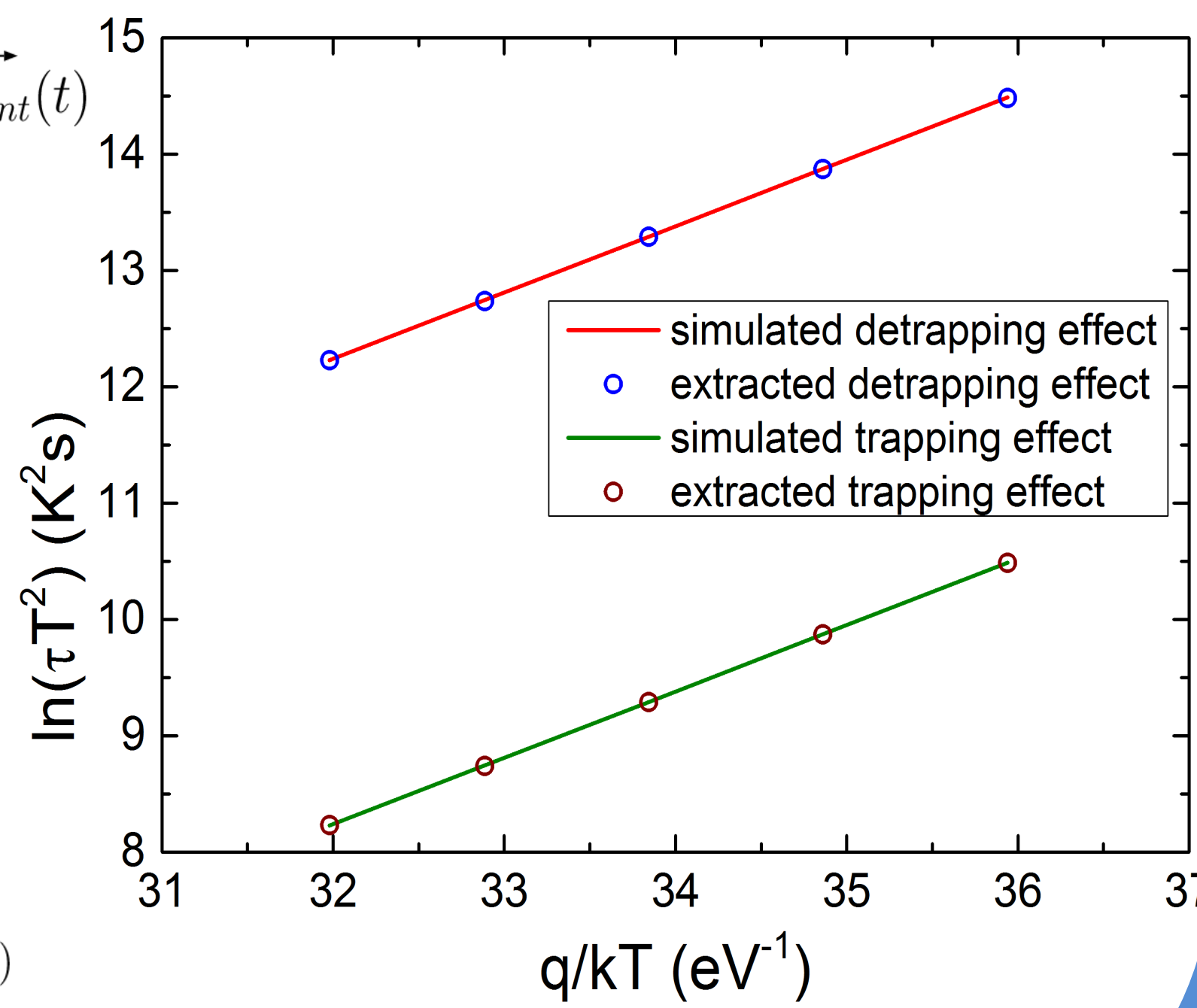


Fig 6 : Output of the simulation Validation of the concept

Measurements on AlGaIn/GaN HEMTs on SiC substrate

- Different polarization protocols were used in order to characterize the trapping state in GaN HEMT transistors : in saturation and ohmic region.
- Time constants are found to be slower in the ohmic region.
- **A trap at $E_a = 0.65$ eV is found at every protocol (not dependent on voltage) and is linked to gallium vacancies [2].**
- **Other defects are retrieved at 0.45, 0.86, 0.69 and 0.76 eV which are dependent on voltage and temperature.**

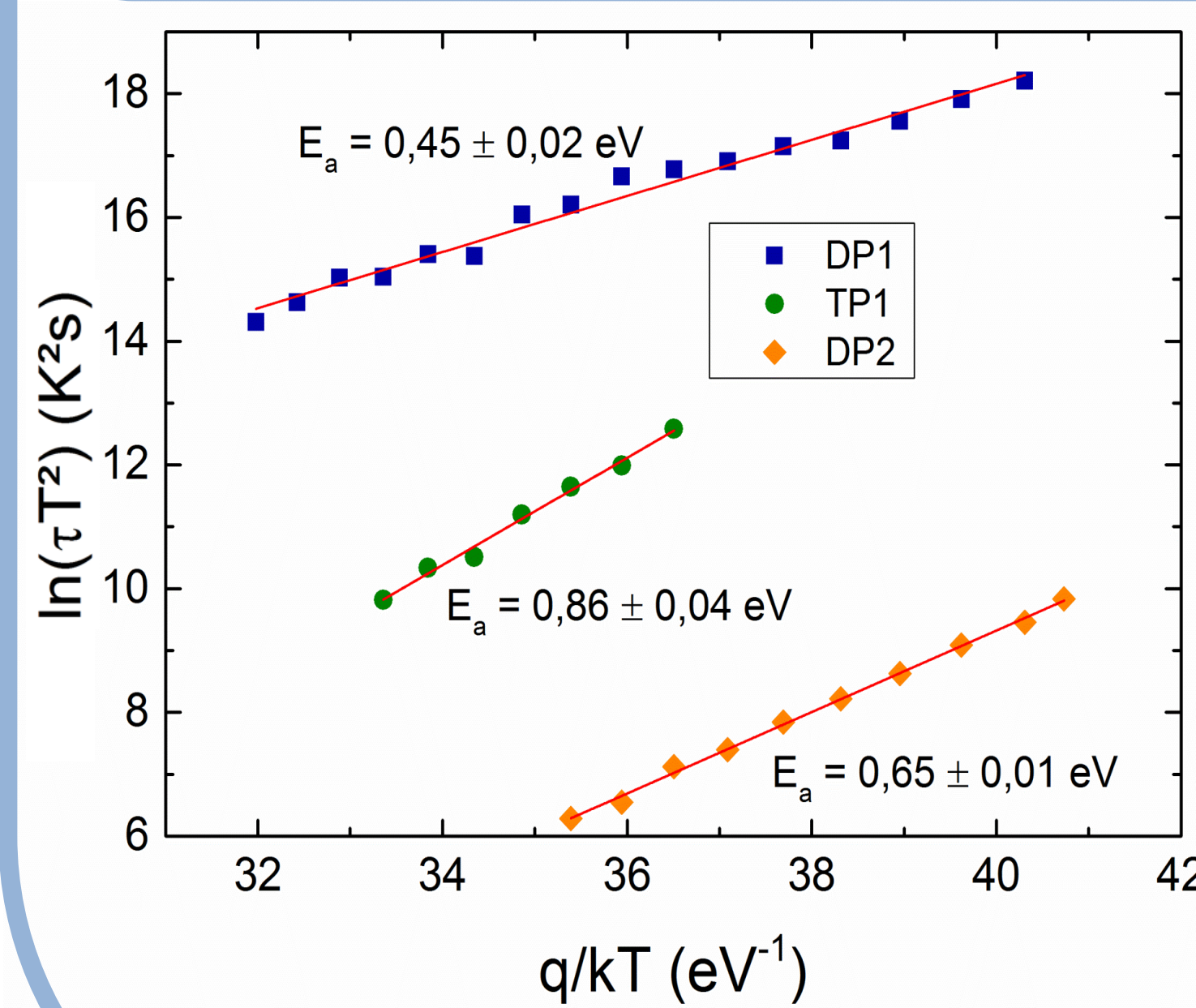


Fig 7 : Athermal measurement of traps $V_{Gsh} = -1.9V, V_{DS} = 10V$

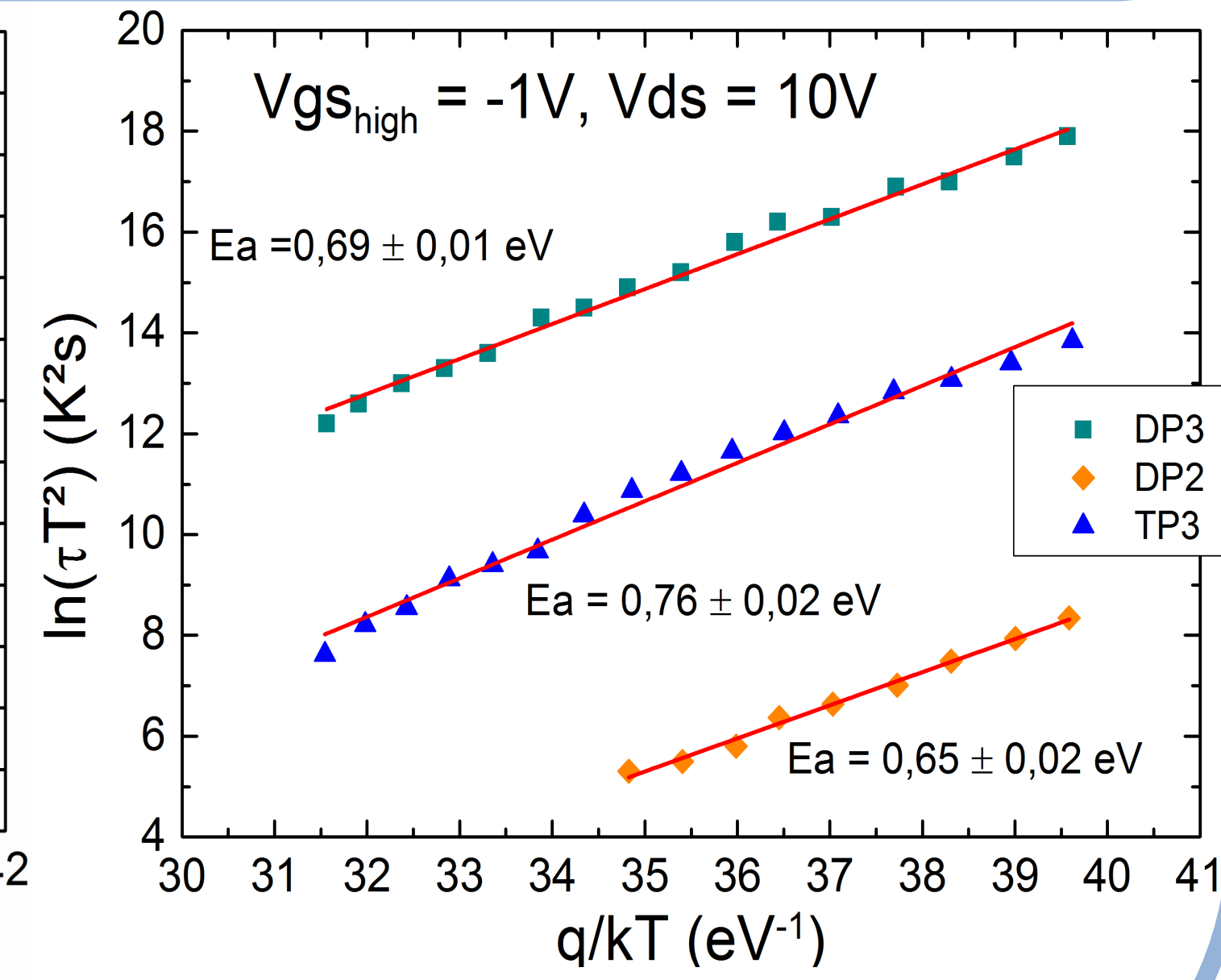


Fig 8 : Athermal measurement of traps $V_{Gsh} = -1V, V_{DS} = 10V$

Conclusion

- The measurement concept is validated by the simulation, the temperature rise during the measurement is estimated around $0.4^\circ C$.
- The various polarization protocols allow the measurement of traps in different localization and have shown several activation energies.
- A good precision on the extracted activation energies is obtained : $\pm 0.02-0.04$ eV.

References

- [1] J. Joh, J.A. del Alamo, J. Jimenez, IEEE Electron Trans. On Electron Devices 48 (3) (Mar. 2001) pp. 560-566
- [2] L. Stuchlíková, J. Šebok, J. Rybár, et. Al., Advanced Semiconductor Devices & Microsystems (ASDAM), 2010 8th International Conference on (Oct. 25-27 2010), pp. 135-138