Puzzling time properties of electroluminescence in two-phase argon detector with THGEM readout

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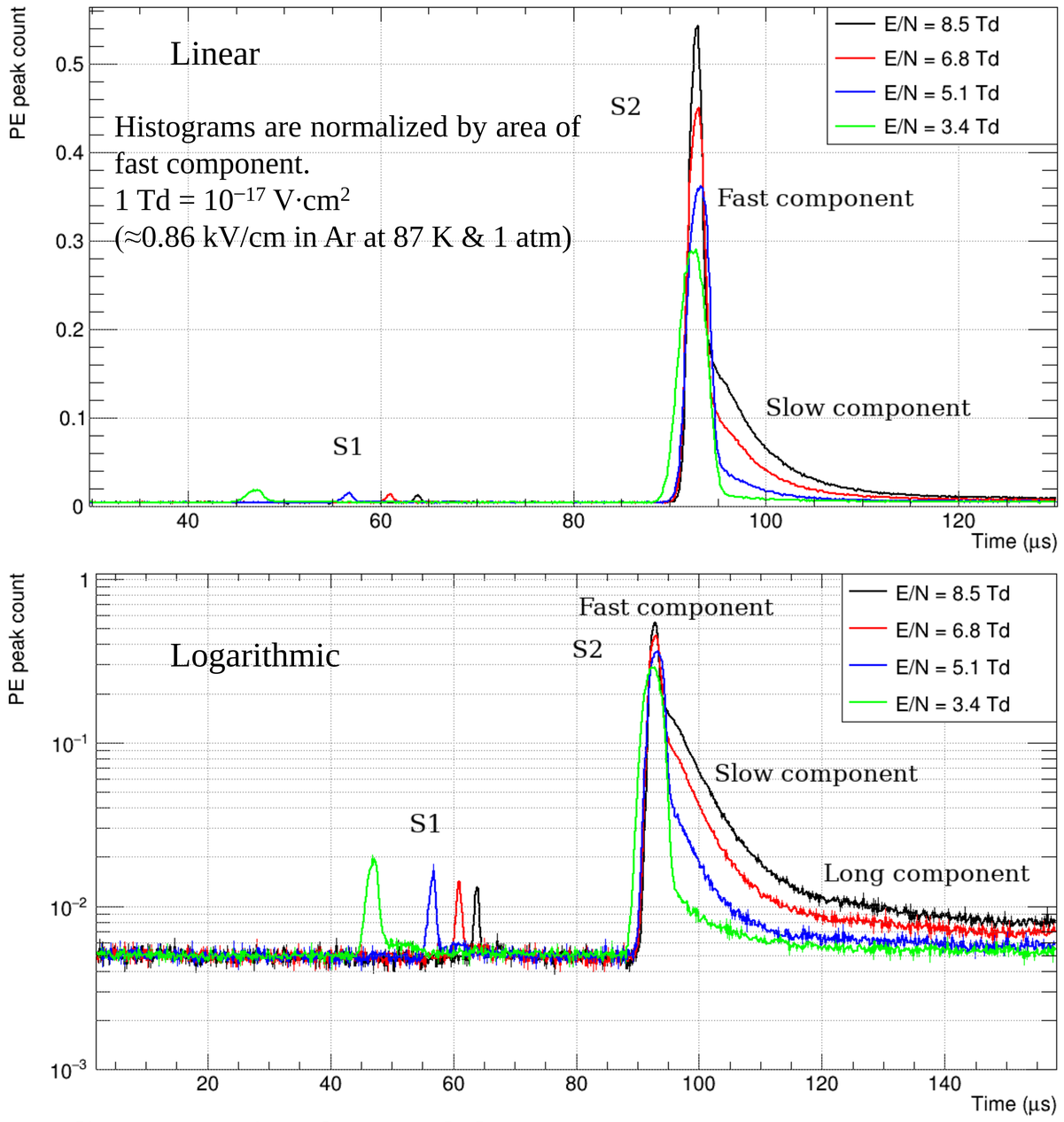
1. Introduction

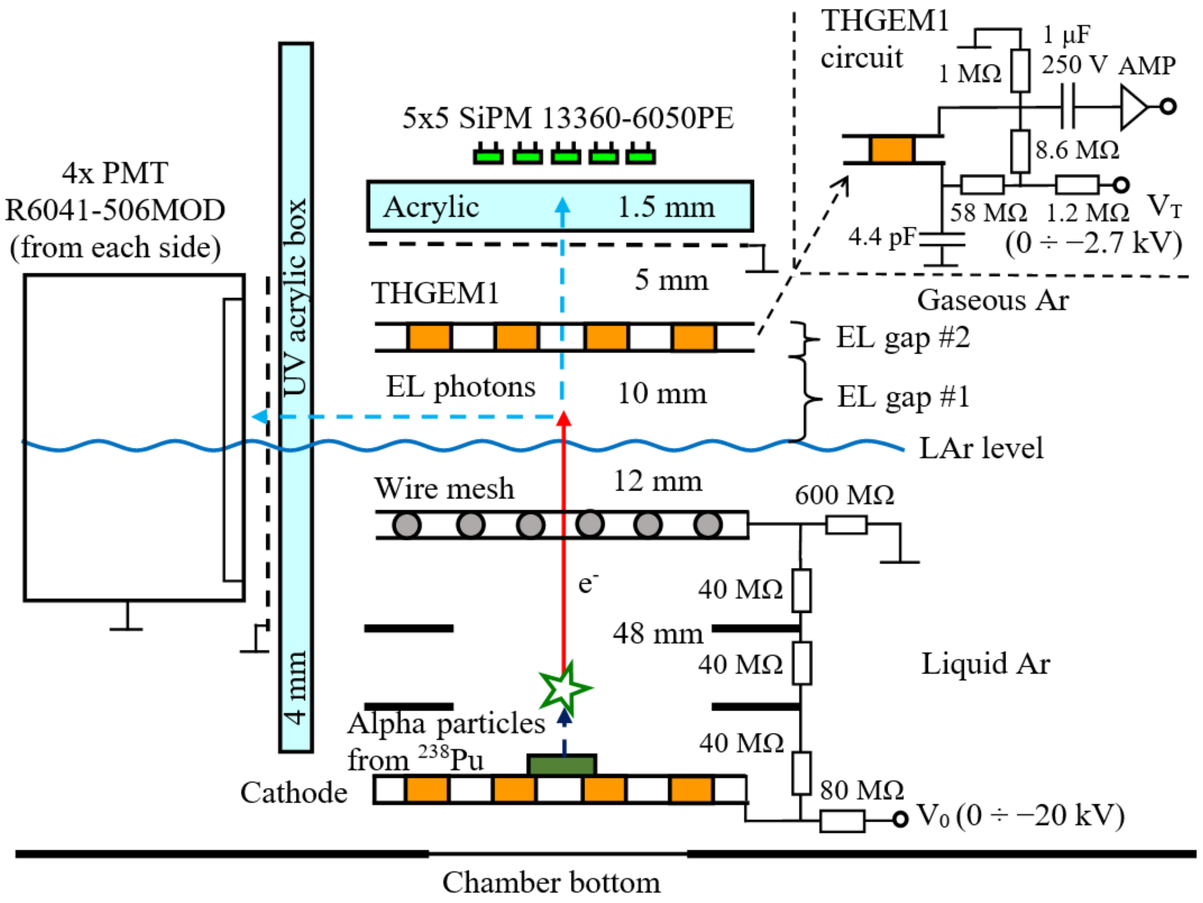
Two-phase argon detectors are one of the most successful detectors for direct dark matter (WIMP) search. Recently [1, 2, 3], unusual slow components have been observed during systematic studies of electroluminescence (EL) signal time properties.



Puzzling properties of unusual slow components:

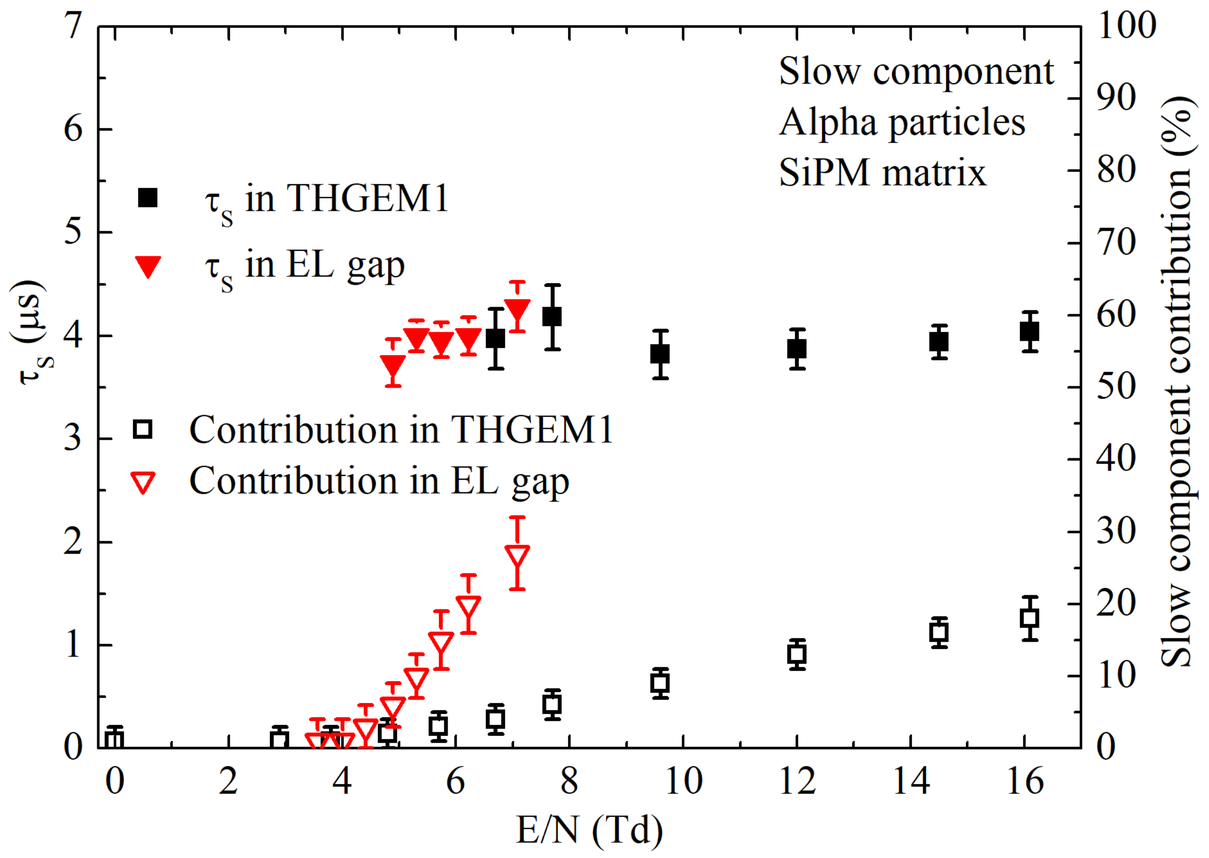
- Are present in visible electroluminescence: are not due to Ar_2* eximers.
- Both time constants and contributions of the unusual slow components increase with electric field. Can not happen neither in the eximer mechanism nor in the thermionic electron emission from liquid.
- The E/N threshold of their appearance is 4.8 ± 0.2 Td. It does not depend on gas density (pressure) or EL gap thickness.

2. Experimental setup



- THGEM1 functioned as independent EL gap decoupled from the liquid-gas interface.
- Using THGEM1 in avalanche mode (charge gain of 20) allowed to directly measure charge signal from 5.5 MeV alpha-particles (6000 $\bar{e}$).

3. Results

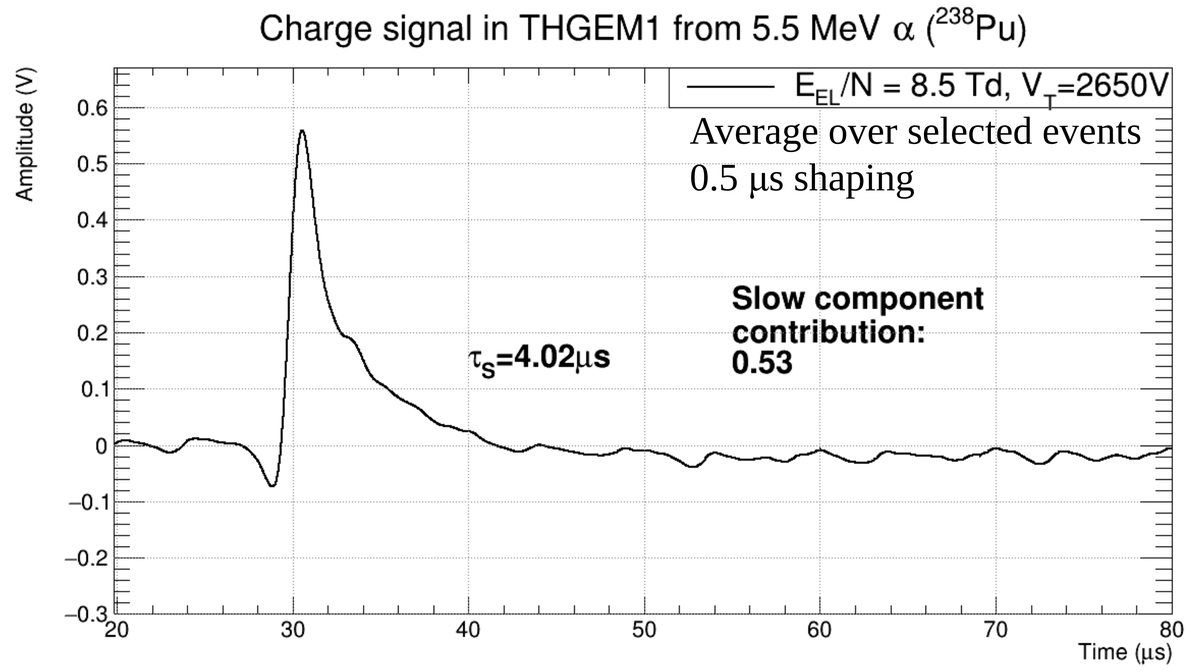


Changing V_0, V_T=0: the unusual slow component forms in EL gap. E/N is taken in the EL gap.

VS

Changing V_T, V_0 is minimal (3.7 Td): the unusual slow component forms in THGEM1. E/N is taken at the hole center.

- The unusual slow components indeed form in the gas phase. They are not related to liquid or liquid-gas interface.
- The difference of slow component contribution in THGEM1 and EL gap can be explained by different effective EL gap thickness.



- This is direct evidence that unusual slow components are due to electron trapping (delay) during their drift in gas.

4. Conclusions

All observed properties can be explained in the hypothesis that drifting electrons are trapped due to formation of long-lived (~4 and ~50 μs) metastable negative Ar ions of yet unknown nature:

$$e^- + 2\mathrm{Ar} \rightarrow \mathrm{Ar}^- + \mathrm{Ar},$$
$$e^- + \mathrm{Ar}_2(\mathrm{X}\,^1\Sigma_g^+) \rightarrow \mathrm{Ar}^- + \mathrm{Ar},$$
$$\mathrm{Ar}^- \rightarrow e^- + \mathrm{Ar}.$$

Significance/practical application:

- Delayed electrons effectively increase single electron noise in the two-phase argon detectors. This effect may become crucial near low-mass detector threshold where only S2 signal corresponding to few electrons is detected.

[1] A. Bondar, et al., JINST 15 C06064 (2020)
[2] A. Bondar, et al., Phys. Atom. Nuclei 83, 949–953 (2020)
[3] A. Buzulutskov, et al., Eur. Phys. J. C 82, 839 (2022).

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