Charge Imaging Performance of a 3×1×1 m^3 Dual Phase TPC

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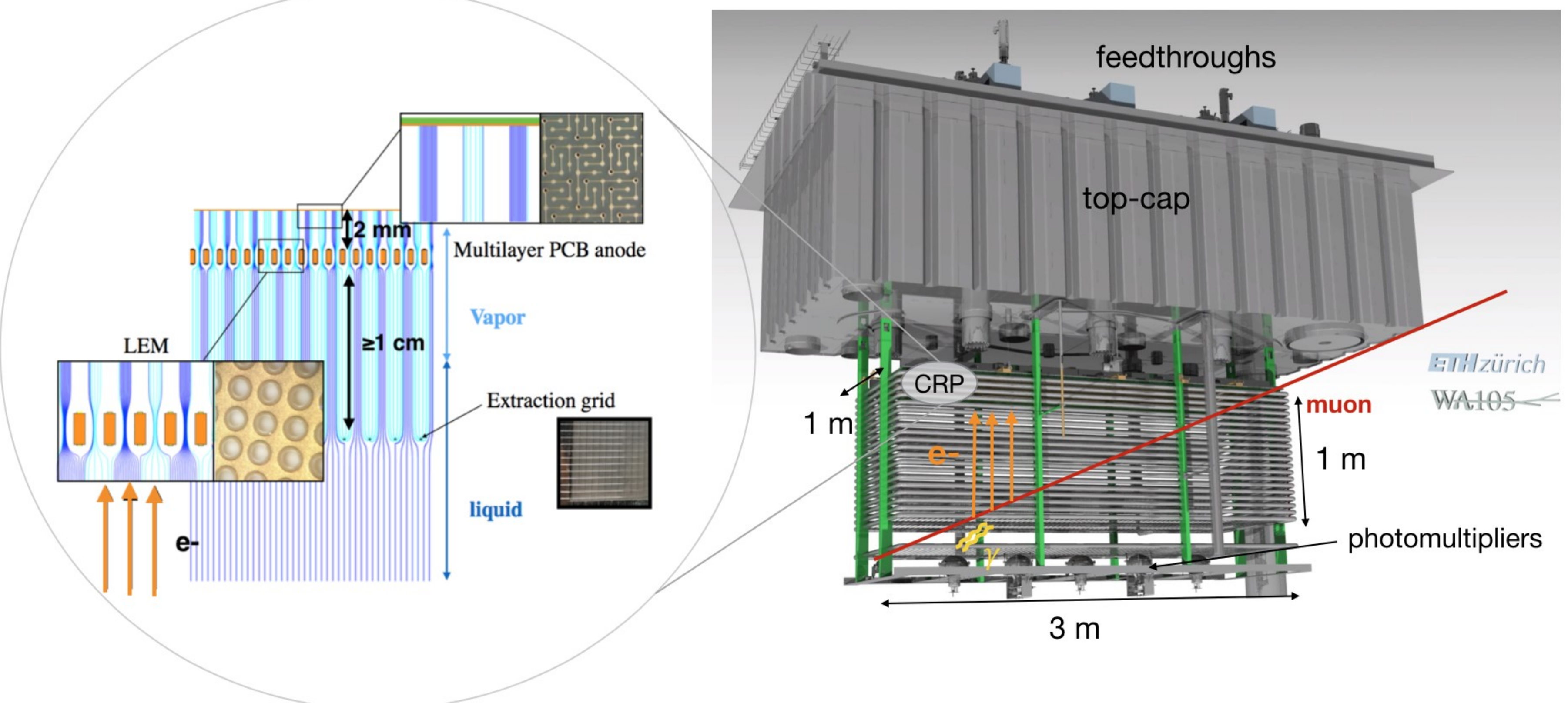
1. Operation Principle of a Dual Phase TPC

The 3×1×1 m^3 Prototype [1] has been operated at CERN over a period of 5 months and collected ~5×10^5 events.



1. A charged particle crossing the detector produces electron-ion pairs and scintillation light.
2. The scintillation light is detected by the PMTs, giving the starting time of the event.
3. The electrons are drifted towards the anode with a drift field of ~0.5 kV/cm, corresponding to a drift speed of 1.6 mm/µs.
4. The electrons are extracted efficiently from the liquid into the vapor phase with an extraction field of ~2 kV/cm.
5. The electrons are amplified in the Large Electron Multipliers (LEMs) where they induce a Townsend avalanche.
6. The electrons are collected on the readout strips of the segmented anode and shared equally between the two readout views.

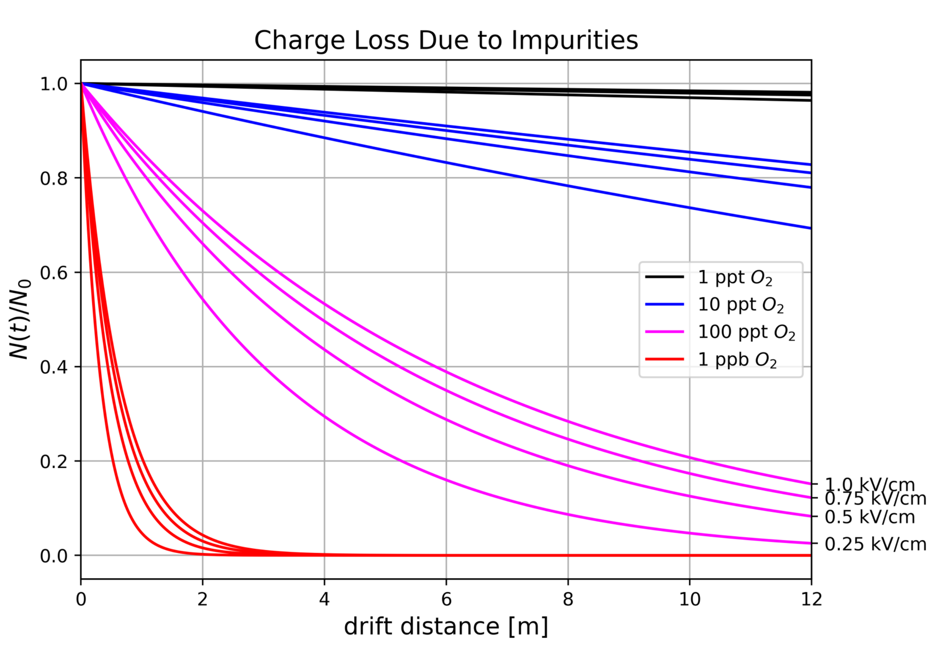
2. Charge Attenuation

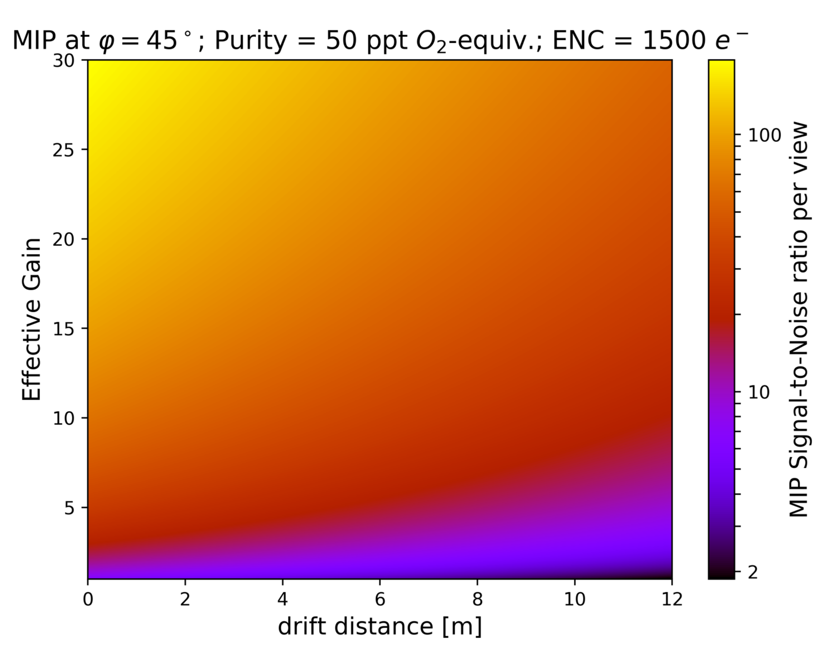
Time dependent number of electrons in presence of impurities:

$$N_e(t) = N_e(0) \cdot e^{-t/\tau_e}$$

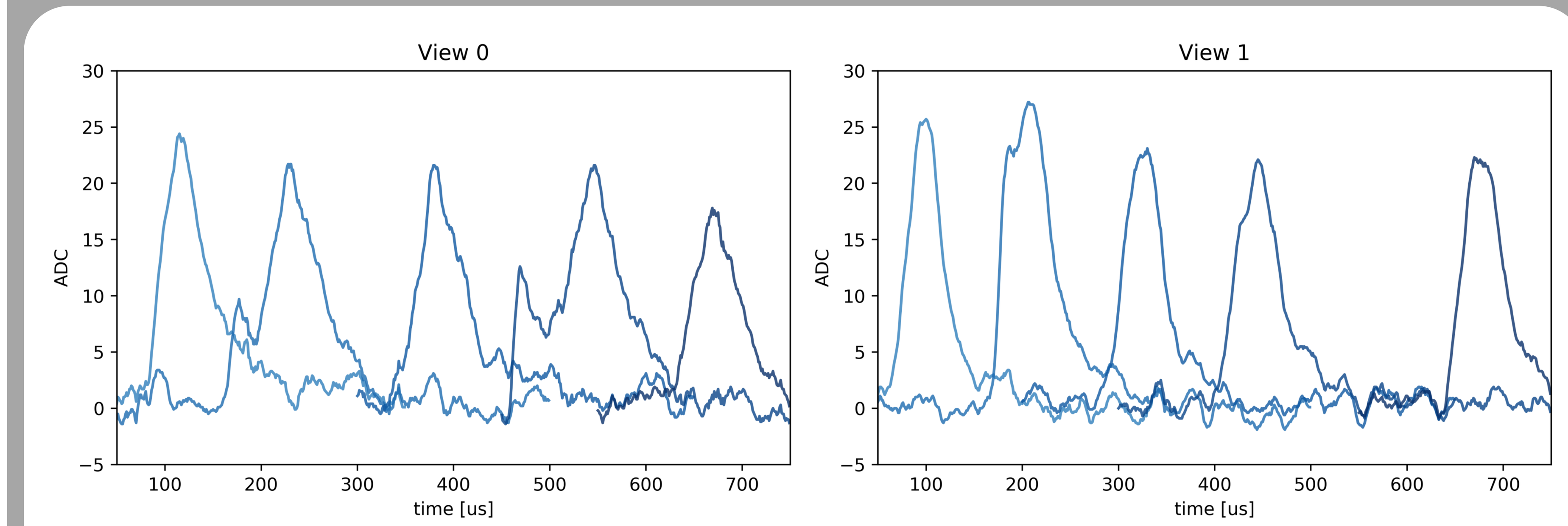
Relation between free electron lifetime τ_e and oxygen/water equivalent contamination:

$$\tau_e[ms] \approx \frac{300}{[O_2][ppt]} \approx \frac{5100}{[H_2O][ppt]}$$





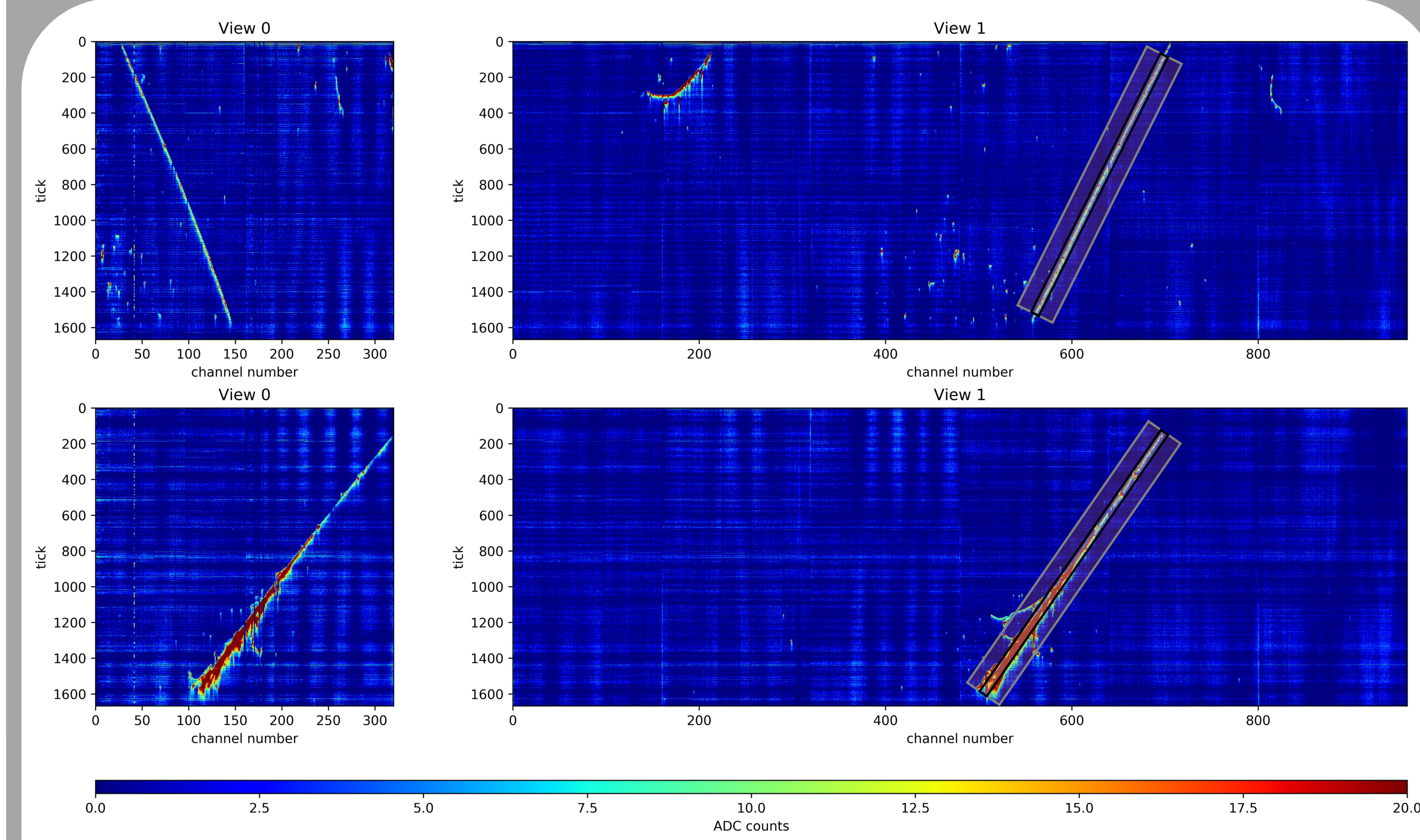
3. Waveforms of a throughgoing Muon



Field Configuration	Drift field	Extraction field	LEM field	Induction field
	0.5 kV/cm	1.7 kV/cm	28 kV/cm	1.5 kV/cm

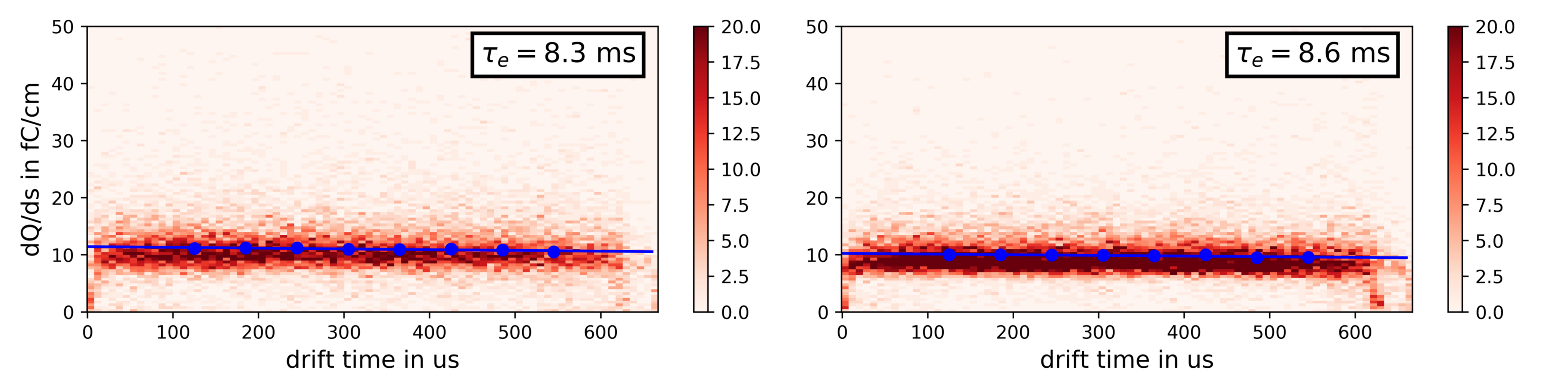
The waveforms of a throughgoing muon, crossing the detector at an azimuthal angle of 45°, have comparable amplitudes. The charge is shared equally between the two collection views of the segmented anode [2], thus simplifying the reconstruction process.

4. Liquid Argon Purity



Procedure for estimating the purity of a TPC:

1. Select top-to-bottom throughgoing (on time) tracks
2. Seperate MIP tracks from EM showers
   - Fit track with straight line
   - Compute deposited charge in a narrow and a wide box around fitted line
   - Select tracks based on charge ratio between the two boxes
3. Obtain local energy deposition per unit length dE/ds by reconstructing the track in 3D
   - Compare for various drift lengths



Achieved Purity in the 3×1×1 m^3: ~35 ppt O_2-equivalent

5. LEM Gain

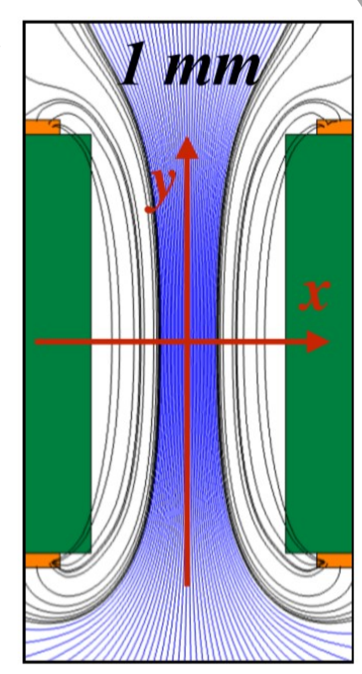
The LEMs consist of copper cladded epoxy plates with a thickness of 1 mm and ~200 holes/cm^2 with a diameter of 500 µm. A potential difference of ~3 kV is applied to the copper plates, resulting in a very high electric field inside the holes of ~30 kV/cm, which causes the arriving electrons to accelerate. If their kinetic energy exceeds the ionization energy of the argon atoms, secondary ionization occurs. For sufficiently high electric fields, these secondary electrons cause further argon atoms to ionize, and a cascade, known as a Townsend avalance, occurs. The gain achieved in the LEMs is given by [3]:

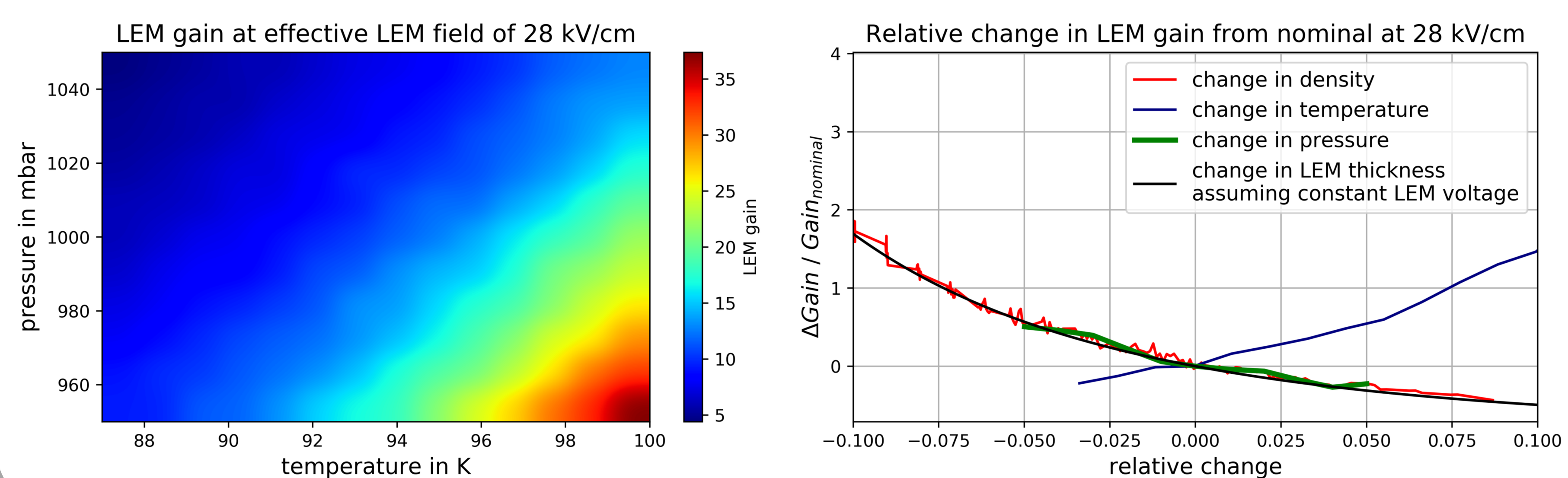
$$G_{LEM} = e^{\alpha x}$$

where x is the amplification length and α is the first Townsend coefficient, parametrized by:

$$\alpha = A\rho e^{-\frac{B\rho}{E}}$$

α has been simulated for various pressures and temperatures with MAGBOLTZ:





References

[1] S. Murphy, The WA105-3x1x1 m3 dual phase Lar-TPC demonstrator, arXiv: 1611.05846, 2016.

[2] C. Cantini, et al., Long-term operation of a double phase LAr LEM Time Projection Chamber with a simplified anode and extraction-grid design, JINST 9 (2014) P03017. arXiv: 1312.6487.

[3] C. Cantini, et al., Performance study of the effective gain of the double phase liquid Argon LEM Time Projection Chamber, JINST 10 (03) (2015) P03017. arXiv: 1412.4402.