Electrode characterisation at JGUM: Sagging measurements and defect searches using Corona discharges

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(with help by L. F. Deibert)

Towards a 60 t to 80 t TPC

The XENONnT and LZ TPCs each have a diameter and height of about 1.5 m, whilst XLZD's electrode diameter will reach ~3 m. R&D is required as the electrodes are crucial for the performance of the detector and such electrodes have never been built.

In the context of Darwin/XLZD and the XENONnT electrode repair, we have developed a set-up to assess the quality of nT size electrodes at room temperature with and without high voltage (HV) under air or other gas atmospheres. The set-up is **capable of**

- **measuring sagging** (due to gravity and due to electrostatic attraction),
- **analyse wire quality with high resolution imaging**
- **study dark current emission** to asses the serverness of defects or "regions of interest" in high resolution images.

The electrode assay set-up

- Gantry robot built upon a granite table as vibrational damping mass
- Measurement devices moveable over an area of 1.4 x 2.0 m^2
- Acrylic glass box to test electrodes in gases:
  - 1.4 x 2.0 x 0.04 m^3 inner volume
  - mirror polished stainless steel floor (ground plane)
  - HV feed-throughs

Laser distance sensor:

- useable range: ~10 mm
- 0.3 μm resolution, 50 kHz sampling

2D laser distance sensor:

- useable range: 92.5 mm to 77.5 mm
- up to 2048 points per profile over 25 mm

High resolution camera and telecentric lens:

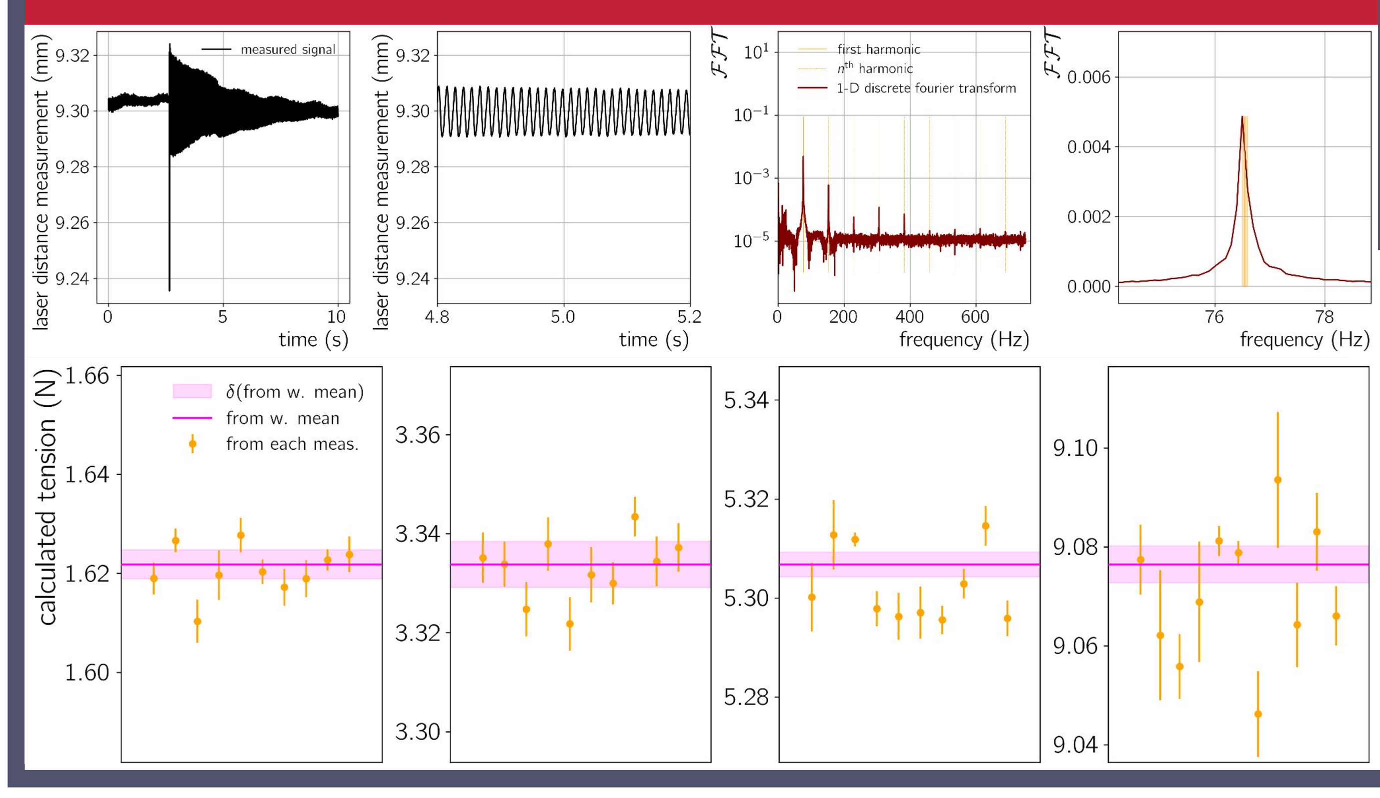
- 4608 x 3288 px
- working distance: 43.1 mm
- depth of field: ~2 mm
- field of view: 12.31 x 8.71 mm^2

Confocal microscope:

- 1200 x 1200 px
- x10, x20, x50 lens
- image on the left: x50:
  - working distance: 1 mm
  - field of view: 320 x 320 μm^2
  - Min z-step: 4 nm

Overview camera (not shown)

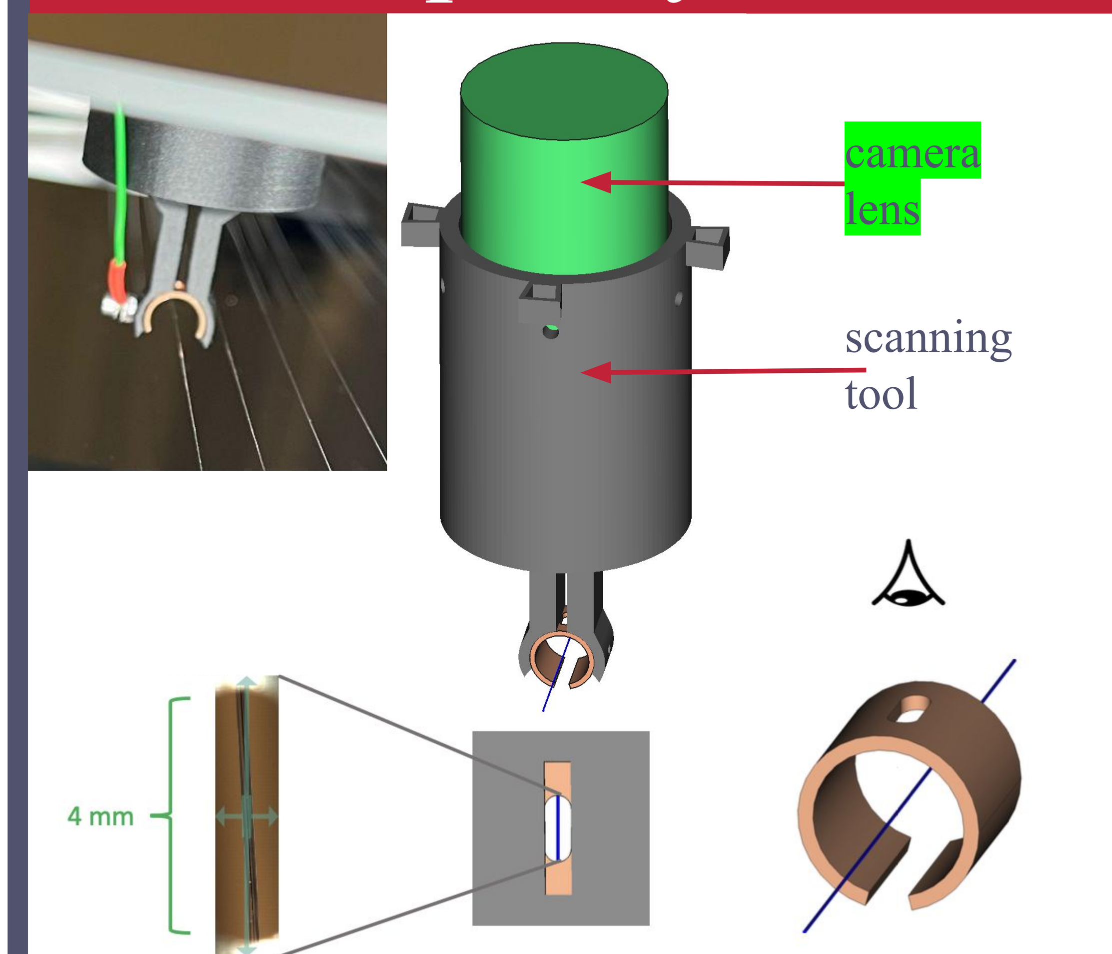
Wire tension measurement



- Move the laser distance sensor to the ~centre of the wire
- Induce vibrations by either a gust of air/N_2 or by applying a tuning fork on the frame
- Find harmonics and calculate the tension

$$T_0 = 4 \cdot \rho \cdot l_{\mathrm{wire}}^2 \cdot A_{\mathrm{wire}} \cdot f_{\mathrm{h}}^2$$

Wire quality with respect to field emission



Images of carefully cleaned & passivated wires still feature "spots" or other "regions of interest". We studied dark currents of Corona discharges and correlated these with high resolution images. Field emission current

$$J = \frac{c_1}{\phi} \cdot 10^{\frac{c_2}{\sqrt{\phi}}} (\beta E)^2 \cdot \exp\left(\frac{-c_3 \sqrt[3]{\phi}}{\beta E}\right)$$

depends on the field enhancing factor β. For example, an asperity on a wire surface may enhance the electric field of the wire E.

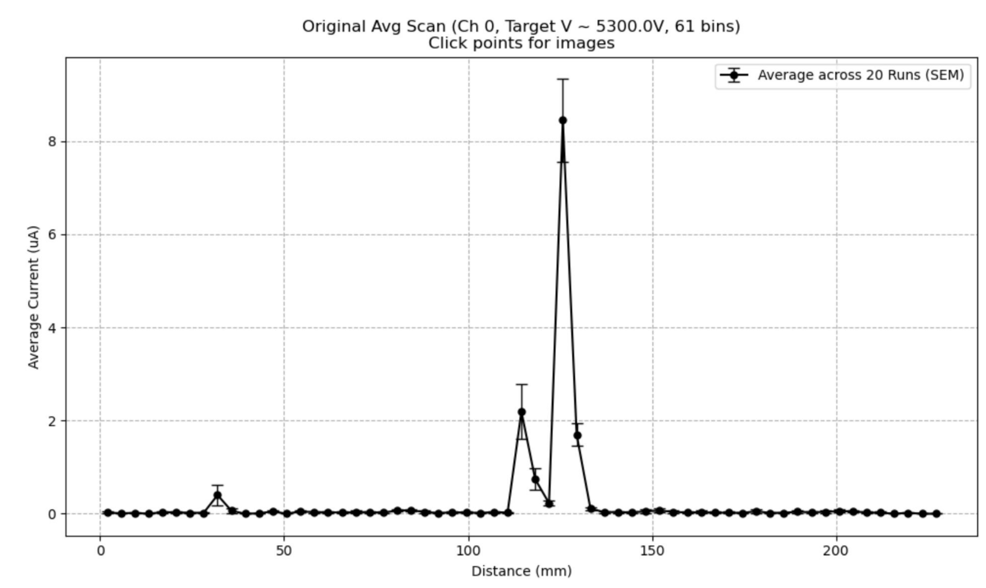
$$E_c = 31 \cdot \delta \cdot \left(1 + \frac{0.308}{\sqrt{\delta r\,[\mathrm{cm}]}}\right) [\mathrm{kV\,cm^{-1}}]$$

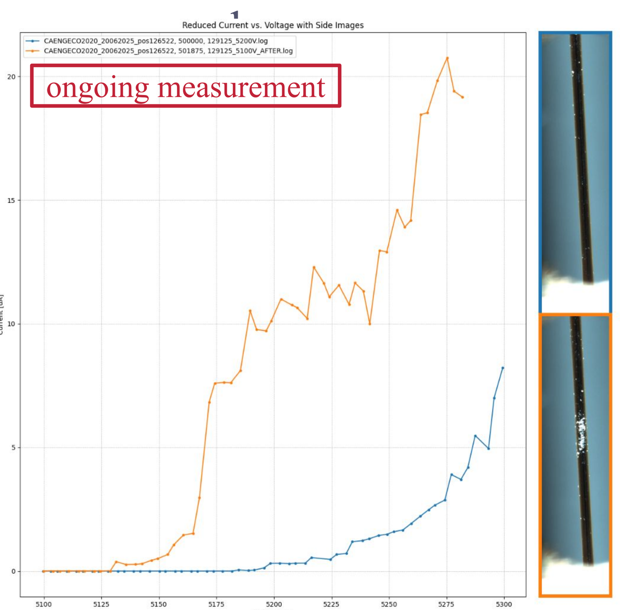
$$V_c \sim \frac{E_c}{2} r \cdot \ln\left(\frac{2d}{r}\right)$$

Such an asperity would lead to an earlier onset of corona discharge than expected from the simple wire-anode geometry.

Measurements:

- 5x wires of nT-suitable quality, 26 cm long, mounted on a dedicated frame; first cleaned and passivated; then cleaned between every measurement series in an ultrasonic bath
- Move the scanning tool with the gantry along a wire, and record high resolution images and current data for different HV applied to the wires
- Re-alignment precision of the wire-frame after cleaning or flipping better than 0.2 mm
- Train an auto-decoder on images without current





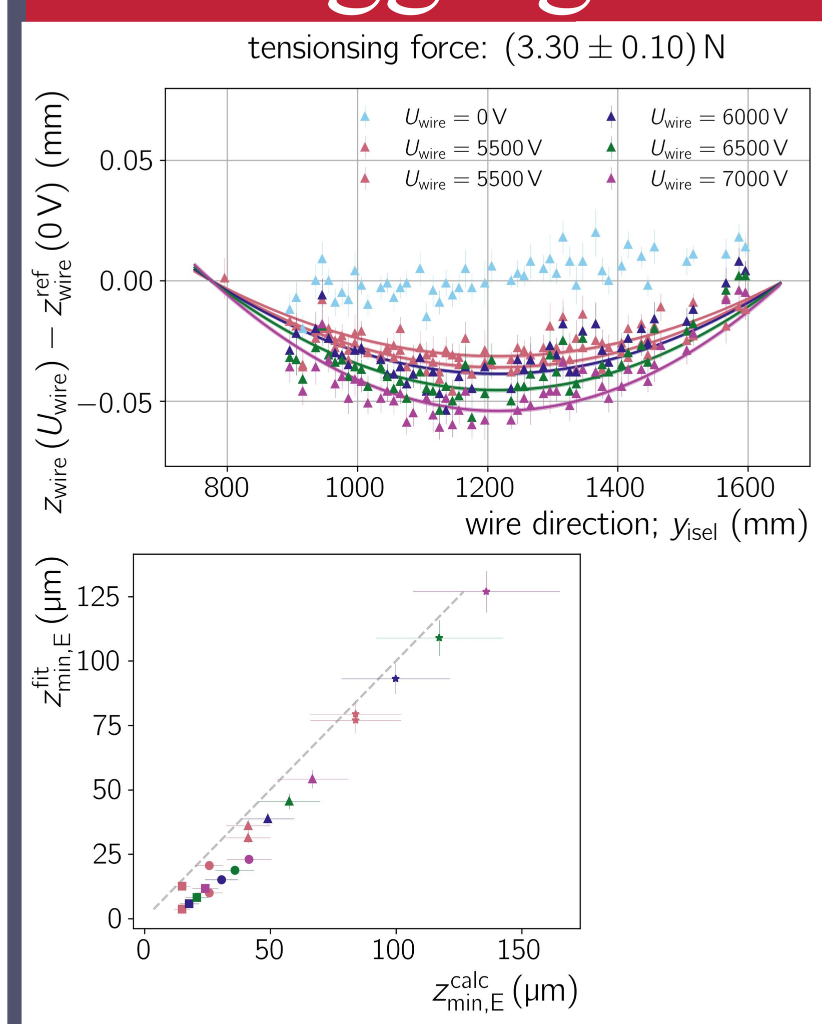
Results:

- The majority of locations of large current disappear after re-cleaning in the ultrasonic bath → dust
- Only one persistent location between cleaning identified
- Current scanning significantly faster than imaging → possibility of quick check in a cleanroom in air

Ongoing:

- Cause controlled damage to wires and measure the damage with the confocal microscope
- Establish the minimal size of defects detectable with this method

Sagging measurements w. and w.o. HV



- We stretched wires with varying tension to sample the range of expected electrostatic sagging depths ($z_{min,E}$) as well as gravitational ones for future dark matter detectors
- Extract the wire height and location from 2D laser scanner data for the wires in different locations and for different HV settings
- **Gravitational sagging:** Absolute measurement, larger systematic uncertainties due to gantry effects
- **Electrostatic sagging:** Relative measurement between U_{wire} = 0 V and other HV settings.

Preliminary results:

- O(10 μm) precision for relative measurements
- O(50 μm) precision for absolute measurements
- Measured sagging matches the calculated sagging well → gives confidence for sagging measurements of more complicated (to calculate) geometries as e.g. meshes

A set-up for XLZD

Work has begun on a "Cobot" based set-up to assay XLZD sized electrodes