Lifetime of Channel Electron Multipliers dedicated to Plasma Instruments for Solar Orbiter and JUICE ESA missions

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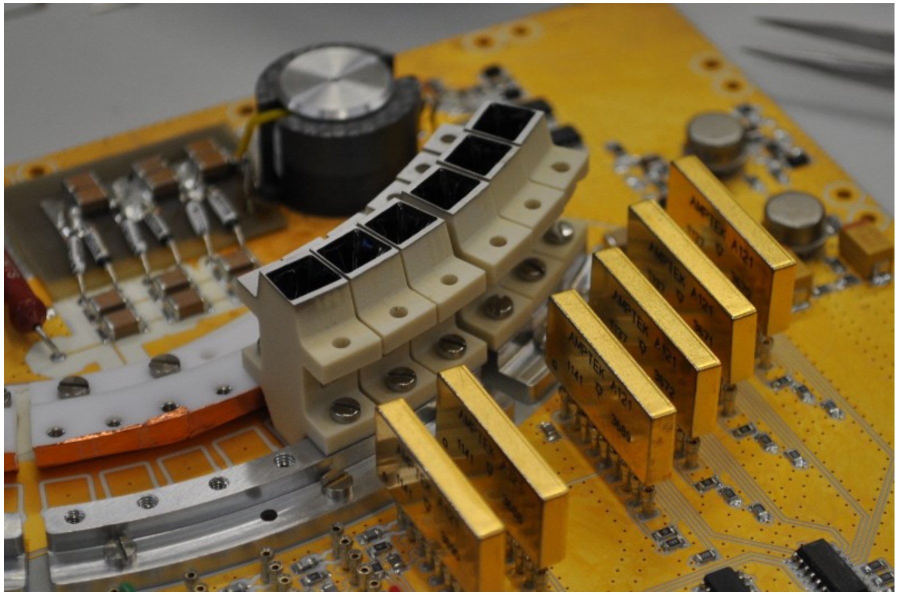


Abstract

Both Solar Orbiter and Jupiter Icy moon Explorer (JUICE) are long-life ESA missions, which should work in extremely hard space environment. A very high thermal load up to 13 Solar constants will affect Solar Orbiter, and JUICE will experience a high penetration radiation influence in the Jupiter magnetosphere. The plasma packages of these missions, dedicated mostly for detection of low energy (between 1eV and 50 keV) ions and electrons shall accept a very high dynamic range of the incident charged particle flow. All these circumstances motivate us to use the Channel Electron Multiplier (CEM) as detectors in both missions.

CEMs are conventional low energy charged particle and X-ray detectors that have been used fore many early space missions. Later, they were forced out by Micro-Channel Plates (MCP), which allow to provide an image of the particle distribution. But for such challenging missions as Solar Orbiter and JUICE we have to come back to CEMs because they 1) are less sensible to the penetrating radiation 2) have much wide dynamical range, 3) have much longer lifetime than MCPs.

The detector lifetime is, actually, the maximum particles number accumulated by detector until its efficiency becomes too low. And this detector feature is critical for Solar Orbiter and JUICE missions.

To check the lifetime of CEMs, for different thermal conditions also, we have made a dedicated experimental setup. We irradiated several CEM samples by a strong electron flux, continuously measuring the CEM gain and keeping 80°C on the sample. The final total number of events, detected by each CEM was equivalent to two Solar Orbiter nominal mission duration.

The detailed analysis of the experimental data shows that the visible degradation of CEMs gain is a function of the vacuum level in the vicinity of the CEM and its outgassing efficiency. If we normalize the CEM gain to the vacuum, expected in the flight, we will see that the pure, completely outgassed CEM can accumulate ten Coulombs of charge without any gain degradation. But in the beginning of the flight, we have to expect very fast gain degradation because of the CEM self-cleaning.

CEMs Life Time Test idea

1. Our equipment is:

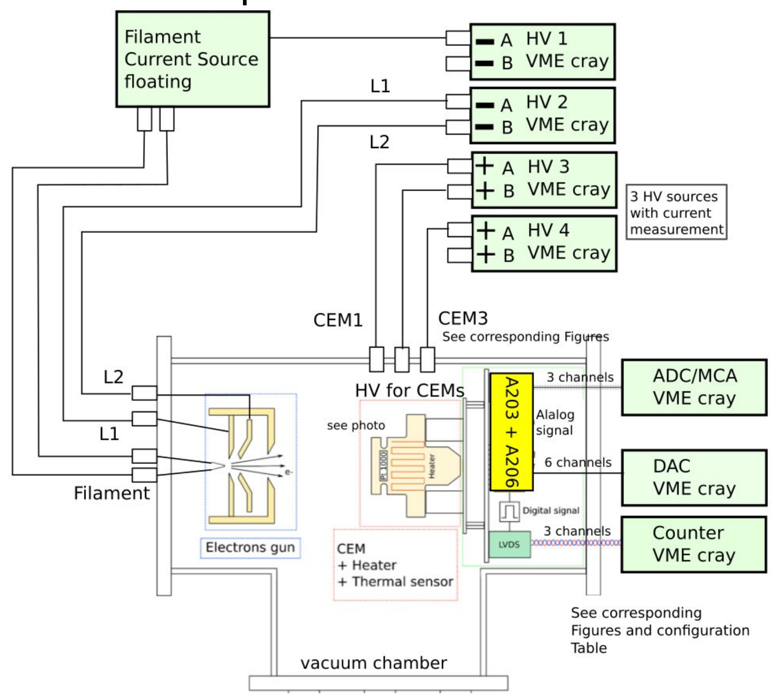
   1. We have a wide beam electron gun. We can vary the beam intensity in a large range keeping the beam spatial distribution constant. Beam energy is 1 keV.
   2. We installed three CEMs from the Solar Orbiter flight batch against the beam. We can vary CEM high voltage (HV) bias individually. We can measure the CEM gain and the bulk anode current (the current of electrons injected by a CEM) at the same time.

2. Our procedure is:
   1. We illuminated the CEMs with a very low intensity electron beam, reading the CEM gain and adjusting the HV bias to get the gain around 6×10^6.
   2. Then we set a high intensity beam to get the CEM anode current around 10% of the CEM strip (resistive) current. We recorded the total accumulated anode charge.
   3. We repeated #1 in 30 minutes.

3. We tested two CEM batches, 3 units in each batch: 80 Mohm and 200 MOhm.

Test Setup:

1. 3 CEMs with individual biases
2. Common heater
3. Two thermocouples
4. A203 amplifier, MCA to get the gain and the count rate
5. Anode current measurement using a HV circuit current high precision reading and a special measurement procedure



CEMs Life Time Initial conditions

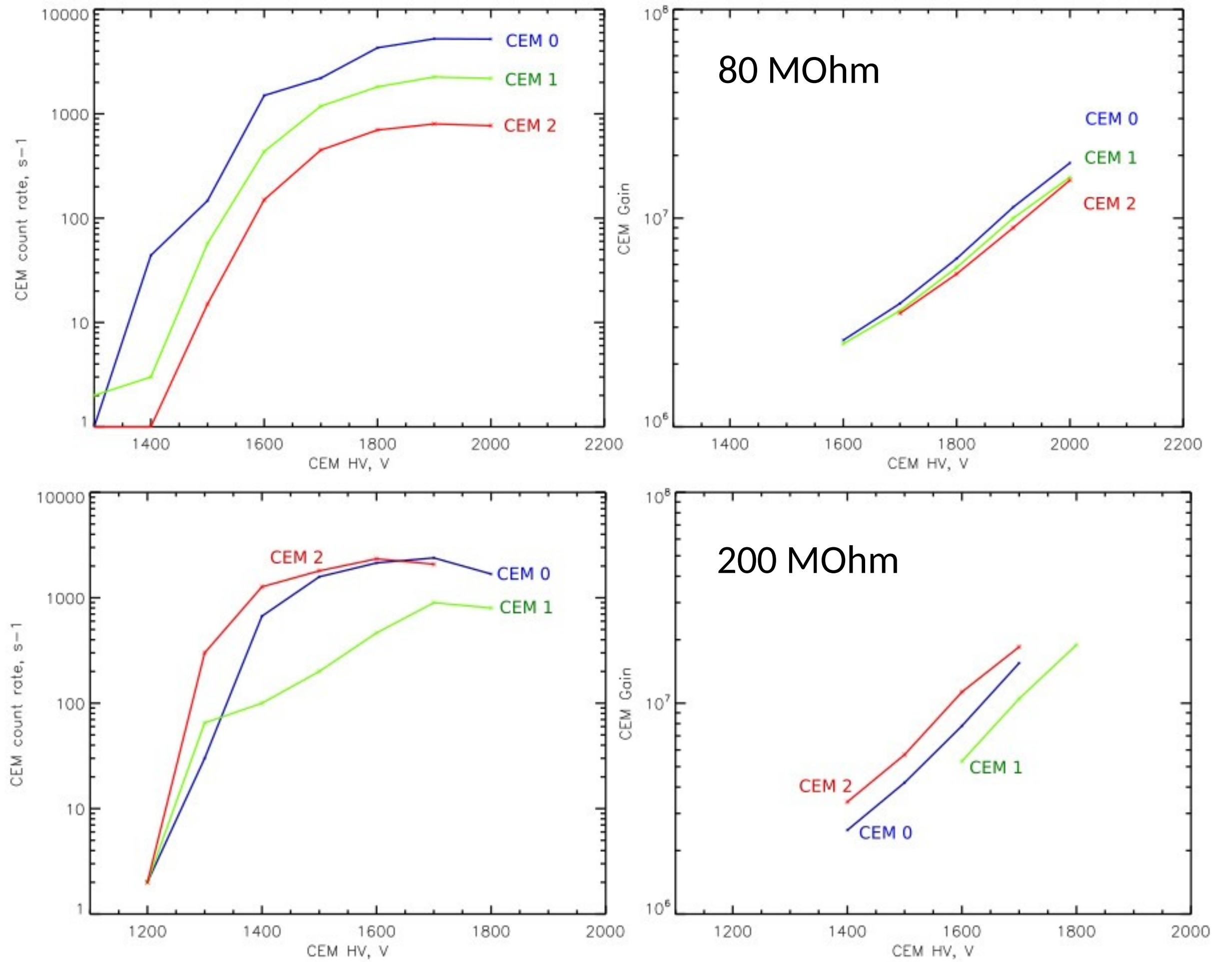
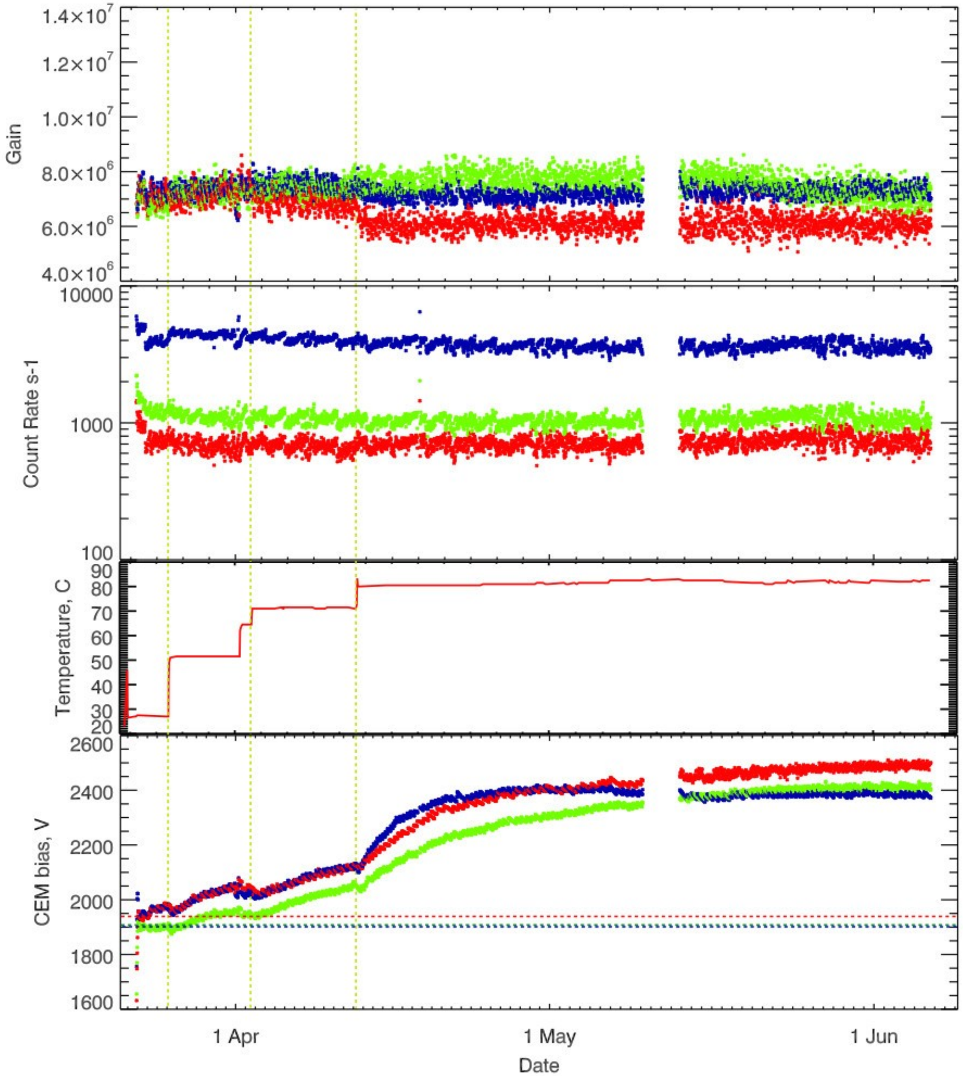
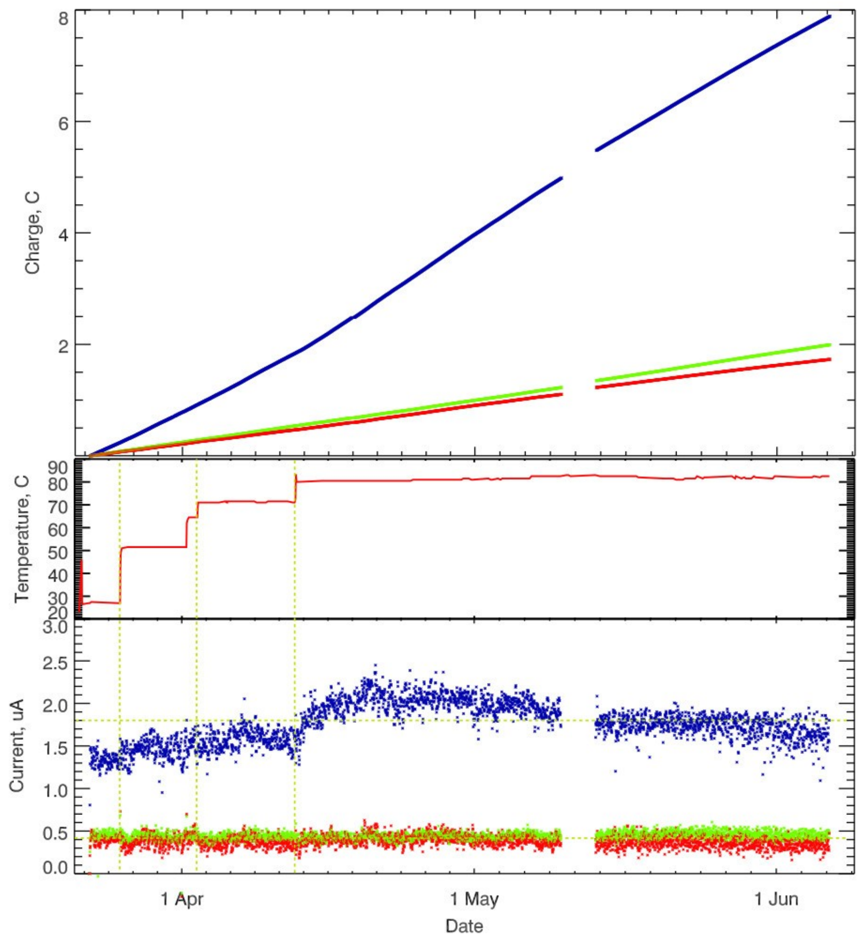


Figure above shows the initial CEM properties. Left: CEM HV bias – count profile, Right: CEM gain as a function of HV bias.

CEMs Life Time 200 MOhm test execution

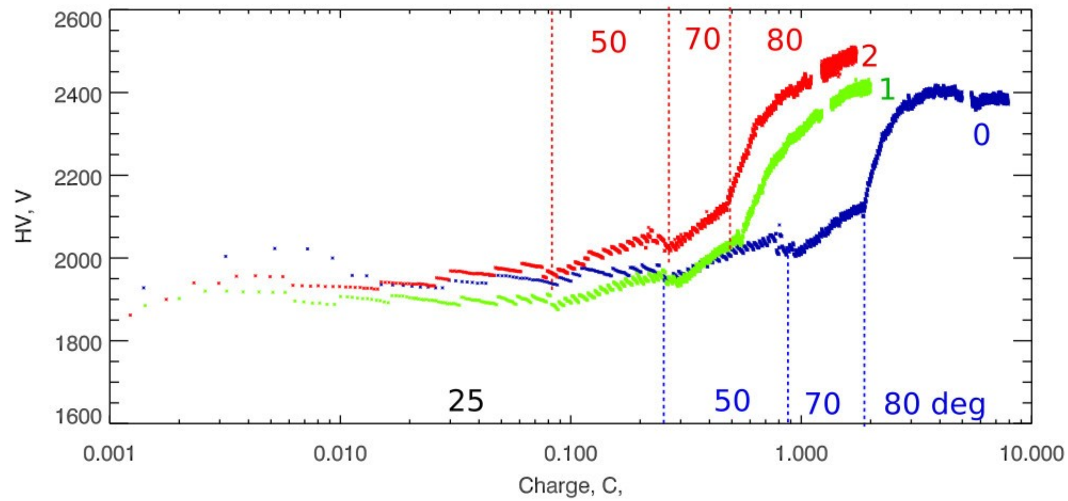


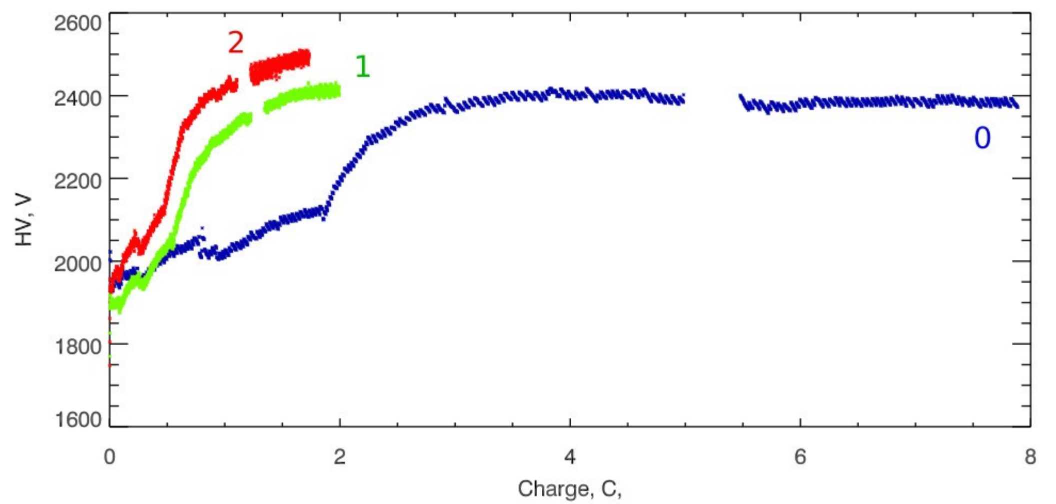
200 MOhm CEMs, 2.6 month data



This page shows a summary of the 200 Mohm CEM test execution. Top left: the CEMs gain profiles. Left middle: the CEMs temperature profile. Left bottom: CEMs bias evolution (with a quasi-constant CEMs gain). Top right: anodes charge accumulation, Bottom right: CEMs anode currents.

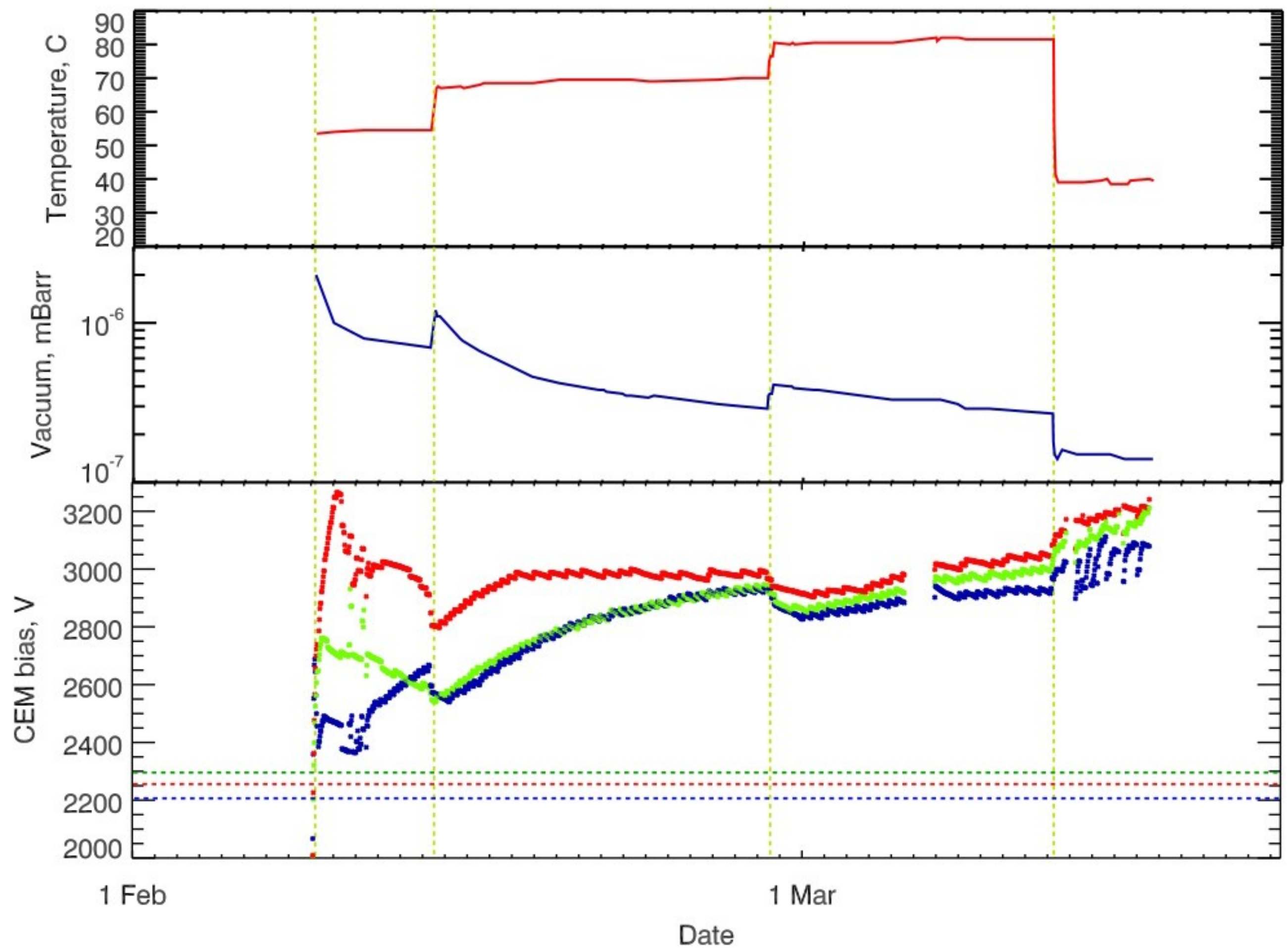
CEMs Life Time 200 Mohm Test Raw Data





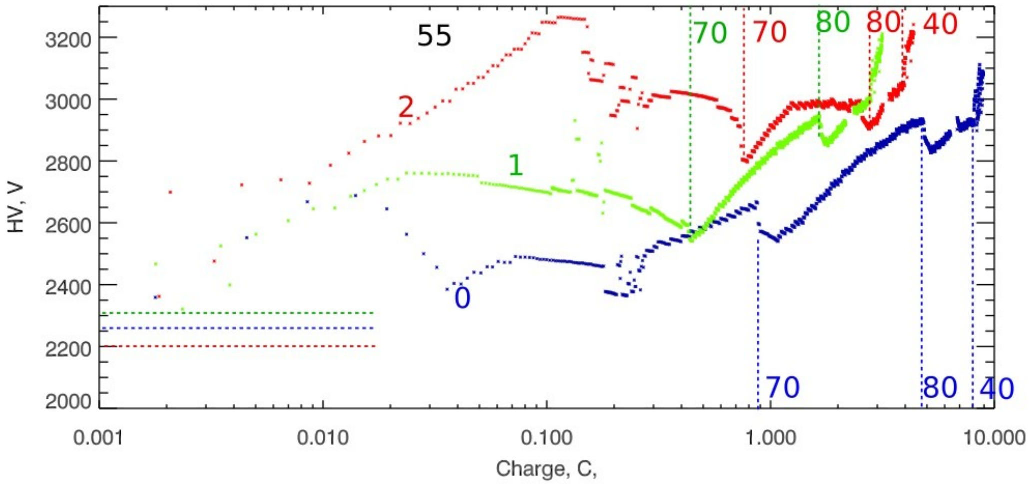
Here we plot the CEM biases as the total anode charge in the linear (bottom) and logarithmic (top) scales. You see that the CEMs HV stabilized after 0.01C total charge. It is a result of CEM “scrubbing”. But later, when the temperature >= 70°C, it seems the HV bias profiles do not depend on the total accumulated charge. The profiles vary synchronously with the temperature.

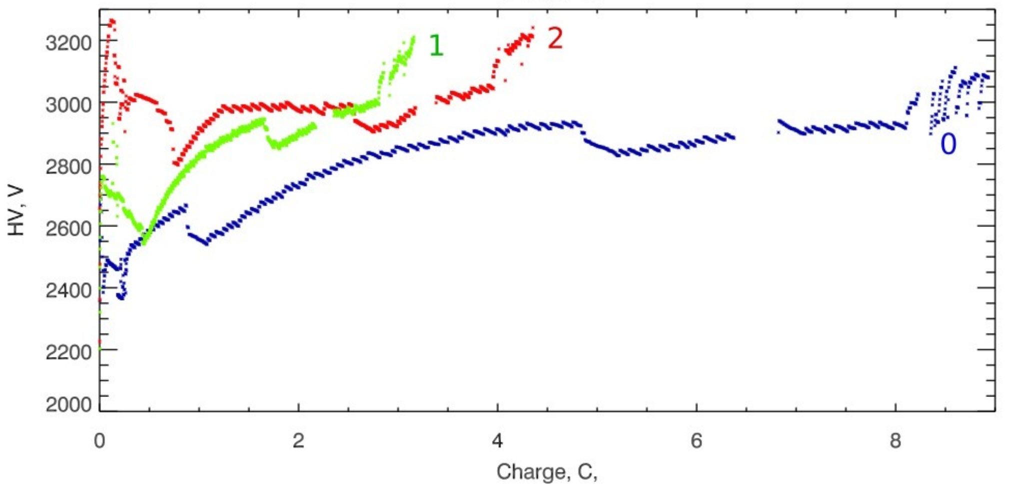
CEMs Life Time 80 MOhm Test Raw Data



80 MOhm CEMs test. The CEM #2 (blue) accumulates the charge factor 3 faster than #0 and #1. Top panel shows the temperature. Middle panel shows the vacuum in the chamber and bottom panel shows the CEM bias needed to keep the CEM gain constant. It seems that the HV bias profile follows the pressure rather than accumulated charge.

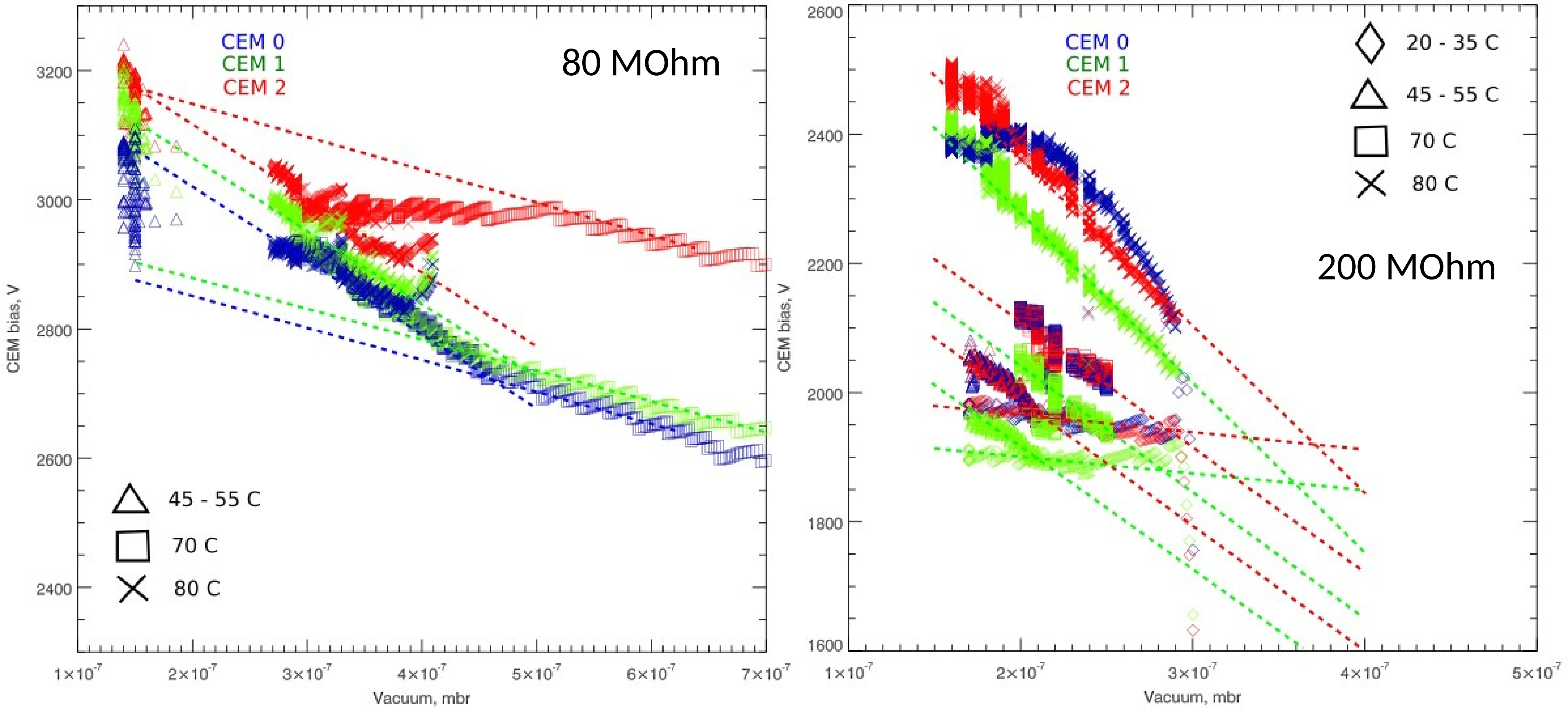
CEMs Life Time 80 MOhm Test Raw Data





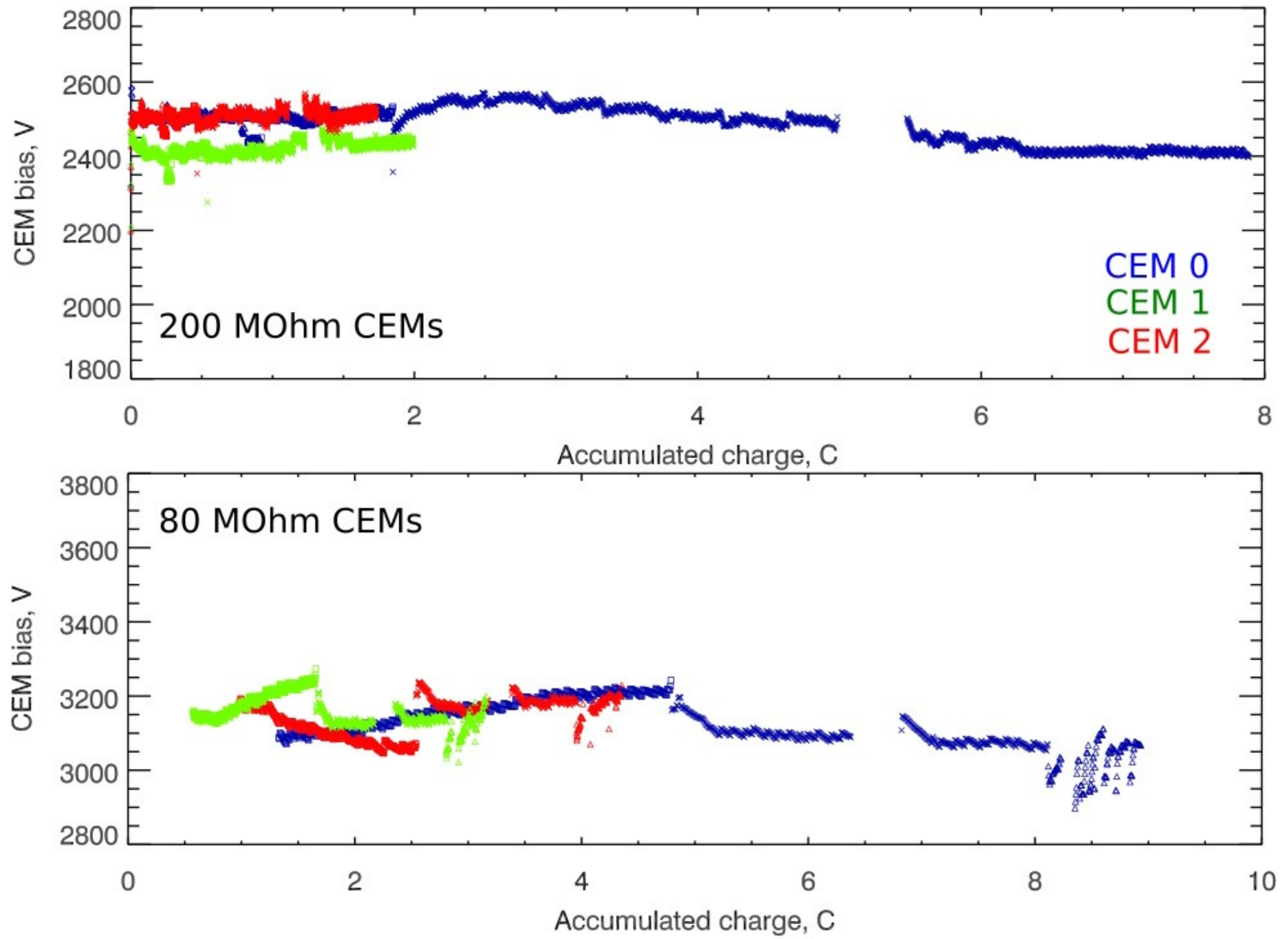
Here we plot the CEM biases as the total anode charge in the linear (bottom) and logarithmic (top) scales. You see that the CEMs HV stabilized after 0.01C total charge. It is a result of CEM "scrubbing". But later, when the temperature >= 70°C, it seems the HV bias profiles do not depend the total accumulated charge. The profiles vary synchronously with the temperature and/or vacuum level.

CEMs Life Time Bias Pressure Profiles



If we make a scatter plot of the HV bias versus the vacuum chamber pressure, we see several linear regressions corresponding to different temperatures. It is important to note that the final points for 50°C lie on the same line as the 80°C points (left panel). It means that CEM reaches the maximal HV bias (needed to keep a constant gain) at the maximal outgassing conditions. It seems that this result does not depend on the total anode charge.

CEMs HV Bias v. Charge Profiles normalized to the outgassing conditions



We normalized each experimental point along the corresponding HV bias – vacuum line down to the 1.5×10^{-7} mbar pressure and then moved this point up to the distance between the current linear regression line and the final (upper) regression line. The resulting profile shows the absence of the charge depending degradation.

CEMs Life Time Bias Conclusions

1. After a long bakeout at 80°C and under the heavy load no one CEM lost the gain completely, but arrived to a stable state.
2. The CEM bias at the stable state and about 1.5×10^{-7} mbar pressure is 600 V - 800 V higher than the values declared by CEMs suppler (Dr. Sjuts Optotechnik GmbH)
3. If the external pressure continues going down, we can expect new bias increasing up to 200 V.
4. The accumulated charge of 8 - 9 C did not modify the CEM stable bias, thus we have not seen any signature of CEMs degradation.
5. Increasing of the CEMs bias with the temperature and the time is due to the outgassing and cleaning of the CEM channel.
6. We need to continue this study with cryogenic vacuum equipment to get a full understanding of CEM properties.