Ageing tests for the MEG II drift chamber

The MEG II Drift Chamber

The MEG II experiment will search for the $\mu^-\rightarrow\text{e}^-\gamma$ decay at the Paul Scherrer Institut (PSI) with an expected sensitivity of $\sim 5 \times 10^{-15}$. Positrons from $\mu^-$ decays will be tracked by a magnetic spectrometer composed of a cylindrical drift chamber and two matrices of plastic scintillator tiles for timing. The single volume drift chamber (see [1]) is composed of 10 layers with alternating stereo angles $7^\circ\pm8^\circ$. Drift cells have an approximately squared shape $7 \times 7 \text{mm}^2$. As a trade-off between transparency and ionisation statistics an ultra-low mass gas mixture with helium and isobutane 85:15 has been chosen. With an expected single-hit resolution of $\sim 110 \mu\text{m}$ (see [2]), the chamber will track positrons with a resolution of $\sim 130 \text{keV}$ on momentum and $\sim 5 \times 10^{-14}$ on the emission angles.

Single-cell prototypes

For ageing test purpose we built $20 \text{cm}$-long single cell prototypes. Field and guard wires are set to negative high voltage, while the sense wire is at ground. The working point of the prototype is chosen according to Garfield++ simulations [5]. Two $20 \text{cm}$-long single cell prototypes were used for calculating $\beta$. As an indicator of the ageing of the chamber, we measured the behaviour of current as a function of temperature and pressure dependence on temperature and pressure, which allows for calculating the power index by fitting the curve.

Test procedure

As an indicator of the ageing of the chamber, we measured the relative gain loss as a function of the collected charge. Gain loss evaluation is obtained by measuring the anode current variations under constant irradiation. For reducing the operation time from about 600 days to about a month a factor 20 of accelerated irradiation should be set in order to study the high voltage of the wires.

Environmental changes

Since the gas system keeps the absolute pressure of the chamber fixed, the gas status was monitored by measuring temperature through a Pt100 sensor. Current oscillations induced by temperature variations were removed offline. Since gas gain has a power dependence on temperature and pressure with opposite power indices

$$\left(\frac{G}{G_0}\right) = \left(\frac{T}{T_0}\right)^p \left(\frac{P}{P_0}\right)^{-r},$$

we measured the behaviour of current as a function of the gas pressure, and obtained the power index by fitting the curve.

Saturation

Saturation represents an intrinsic limit on gain loss evaluation in accelerated test. The dependence of drift chamber current from the rate of incoming radiation shows clear deviation from linearity. For describing the curve we adopted a phenomenological expression

$$I = I_0 \exp \left(\frac{-y}{y_0}\right),$$

where $y = \frac{Q}{Q_0}$ is the non-saturated current, proportional by definition to the X-ray tube current. For small deviations from linearity, we can calculate the non-saturated current as

$$I^{\text{n.s.}} = I \exp \left(kI\right)$$

with the parameter $k$ obtained from the fit in the figure below. Since the non-saturated current is proportional to the gain, it can be used for calculating $\gamma$.

Results and Conclusions

The ageing rate of the chamber was measured in two distinct tests at several working points (reported in detail in the table on the left). No significant slope change corresponds to modification of the chamber working conditions. However a slope change is visible in the normalized gain as a function of the collected charge with Prototype I. The ageing rates measured in the two tests are compatible within 20%.

$R_1 = 108 \pm 1 \ %/\text{(C/cm)}$

$R_2 = 90.9 \pm 0.3 \ %/\text{(C/cm)}$

In the central region of the hottest wire the gain loss is about 16 %/year, while in modest wires the gain loss is below 10%/year. This can be easily recovered with a small increase in the high voltage of the wires.

Bibliography


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