The KATRIN experiment: Kinematic determination of $m(\nu_e)$

**KATRIN spectrometers** constitute a unique setup to perform the MAC-E filter concept and high resolution measurements on the electron neutrino mass. The MAC-E filter is used to select the adiabatic component of the electron energy spectrum and to reduce background contributions. The main spectrometer and the pre-spectrometer are assembled in a single vacuum vessel to maximize the source-limited electron flux.

This setup allows for an improved sensitivity on the neutrino mass to be achieved, especially with respect to the systematics. The main spectrometer is equipped with a MAC-E filter to separate the adiabatic electron component from the non-adiabatic component. The pre-spectrometer is used to reduce the background rate and to increase the effective mass resolution.

**Interspectrometer Penning trap**

The configuration between the two KATRIN spectrometers constitutes a Penning trap where background electrons can accumulate.

The trap is formed by:
- Magnetic field of the solenoid between the spectrometers;
- Retarding potentials of both spectrometers.

Danger of Penning discharges: possibility of damaging the KATRIN detector and nearby isolators.

**Solution: Penning wipers**

Metal rod (Titanium Grade 5) to empty the Penning trap:
- Collects electrons when moved into the flux tube, since stored electrons will hit the wiper within sub-ms time scale due to their magnetron motion;
- Mechanical movement by a pneumatic muscle;
- Mechanical movement by a pneumatic muscle;
- Pneumatic muscles for wiper movement.

**Measurements**

**Background dependence on pre-spectrometer voltage**
- Effect of the Penning trap on background rate becomes pronounced at high pressures.
- As expected from effect of the Penning trap, background rate increases with applied voltage to the pre-spectrometer (with main spectrometer set up to nominal 18.6 kV retarding potential).

**Effectiveness of Penning wiper in discharge counteraction and pressure dependence**
- Pressure was shown to be a crucial parameter affecting Penning trap background activity and strength and probability of discharges.
- The extractor ion gauge at the pre-spectrometer was identified as an extra source of background which very likely feeds the Penning trap additionally.
- The gauge was deactivated for the final Penning trap tests.
- The Penning wipers effectively clean out trapped particles and stop discharges. The gauge was deactivated for the final Penning trap tests.

**Background measurement at nominal KATRIN settings**
- During a concluding two-week measurement with nominal spectrometer settings and pressure (~2-11 mbar) no discharges were observed.
- Lower background because extractor ion gauge was switched off and due to higher magnetic field and therefore smaller flux tube.

**Summary/Outlook**
- Pressure was shown to be a crucial parameter affecting Penning trap background activity and strength and probability of discharges.
- The extractor ion gauge at the pre-spectrometer was identified as an extra source of background which very likely feeds the Penning trap additionally.
- The gauge was deactivated for the final Penning trap tests.
- The Penning wipers effectively clean out trapped particles and stop discharges.
- With longer intervals the wipers can be used precautionary to ensure free-of-discharges measurements with tritium.

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