Ion monitoring with the KATRIN experiment

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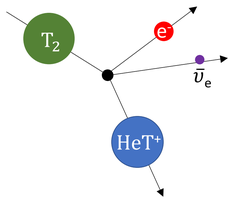
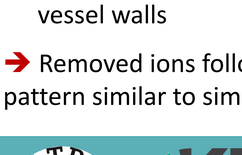
Tritium ions in KATRIN



Created

- 10^{11} ions/s via tritium β decay
- 10^{12} ions/s via impact ionization



Removed

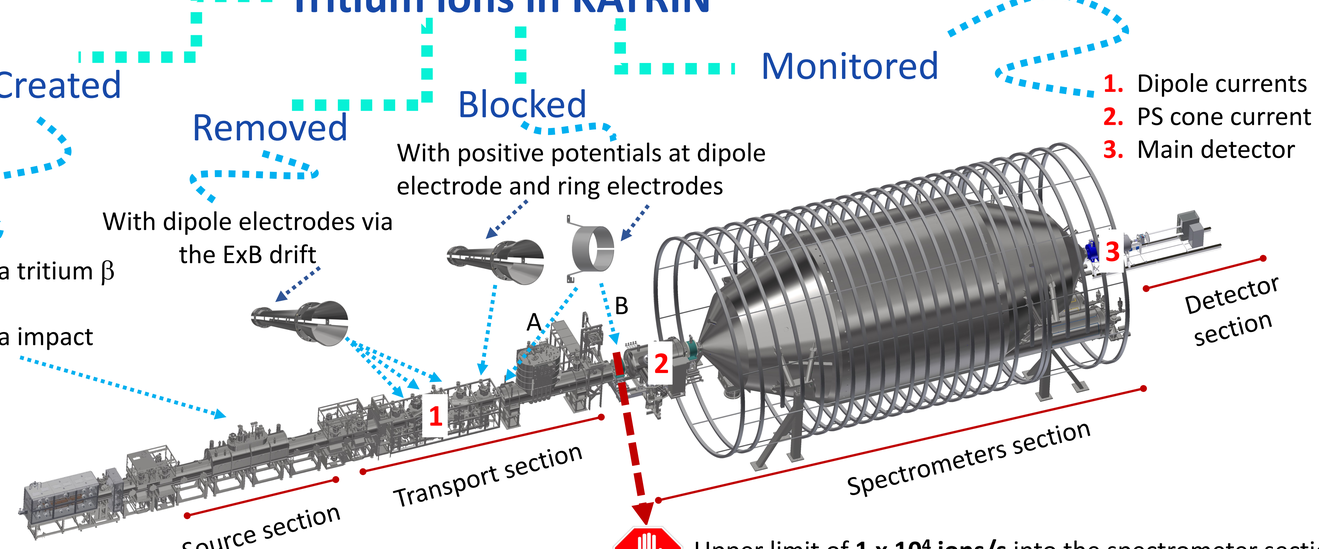
With dipole electrodes via the ExB drift

Blocked

With positive potentials at dipole electrode and ring electrodes

Monitored

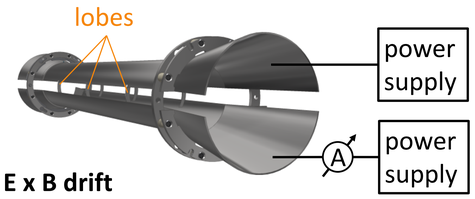
1. Dipole currents
2. PS cone current
3. Main detector

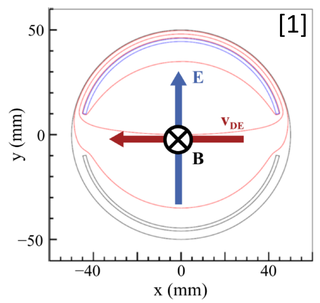


Upper limit of **1 x 10^4 ions/s** into the spectrometer section required to meet KATRIN background requirements [1]

Monitoring ions

Dipole electrode current (1)





E x B drift

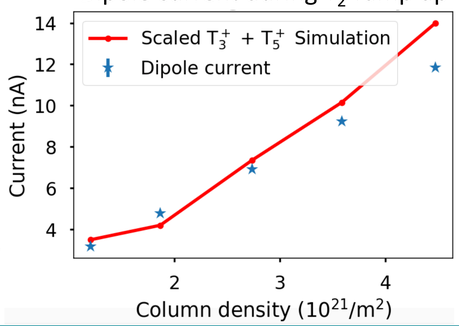
- Negative dipole field
- Transversal drift of positive ions

Current measurement

- Ions neutralized on lobes attached to one dipole half-shell
- Neutralization current measured by rbd 9103 picoammeter

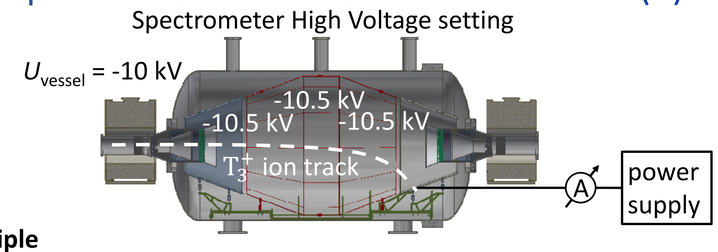
Performance during T_2 operation

- Linear current increase with T_2 column density
- Discrepancies from simulation due to beam line blocking potentials and ion neutralization at vessel walls



➔ Removed ions follow a linear pattern similar to simulations

Pre-Spectrometer cone electrode current (2)

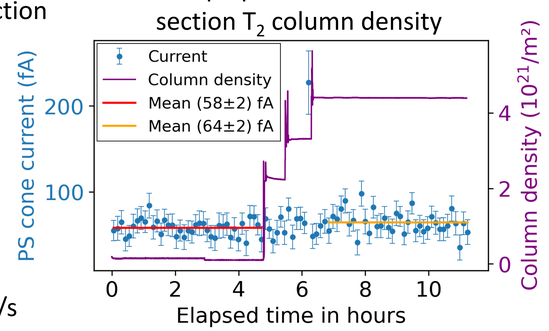


Principle

- Positive ions are neutralized on cone electrode
- Current monitoring in real time

Performance during T_2 operation

- Ramping the source section to ~90% of the design column density does not lead to a strong ion signal in the spectrometer section



➔ Positive tritium ions are successfully blocked, residual ion flux < 10^5 ions/s

Ion conversion to electrons (ICE) (3)

Principle

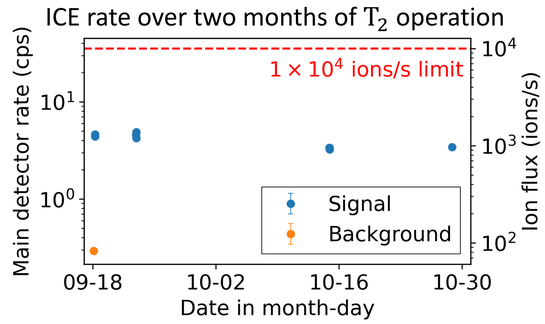
- Spectrometer section operated in special HV setting
- Positive tritium ions potentially entering the spectrometer section are converted to electrons via
  (a) impact ionization of residual gas
  (b) surface-driven mechanism

Sensitivity: Every count corresponds to 280±10 ions [2]

Performance during T_2 operation

- Requirement for maximum ion flux into spectrometer section met

➔ Positive tritium ions are successfully blocked, residual ion flux < 2 x 10^3 ions/s



Blocking ions

Neutralization

Principle: Electrons captured inside positive blocking potentials eventually lead to their neutralization

Device	Setting (V)	Neutralized voltage (%)	Days
Ring A	+40	< 0.9	8
Ring B	+200	< 0.7	14

➔ Ring electrode potentials do not show fast neutralization times

Conclusion

- Tritium ions in the spectrometer section would be a background source for the neutrino mass measurement
- Various monitoring devices with sufficient sensitivity for measuring ion flux below 1 x 10^4 ions/s are in place
- Results from long-term KATRIN T_2 operation demonstrate the effectiveness of ion blocking

Acknowledgments and References

[1] M. Klein, *Tritium ions in KATRIN: blocking, removal and detection*, PhD thesis, KIT, 2019

[2] E. Weiss, *Determination of the Ion Conversion to Electron efficiency of the KATRIN Pre-Spectrometer*, thesis, KIT, 2019

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