Simulation of low-level tritium and radon in the KATRIN spectrometers

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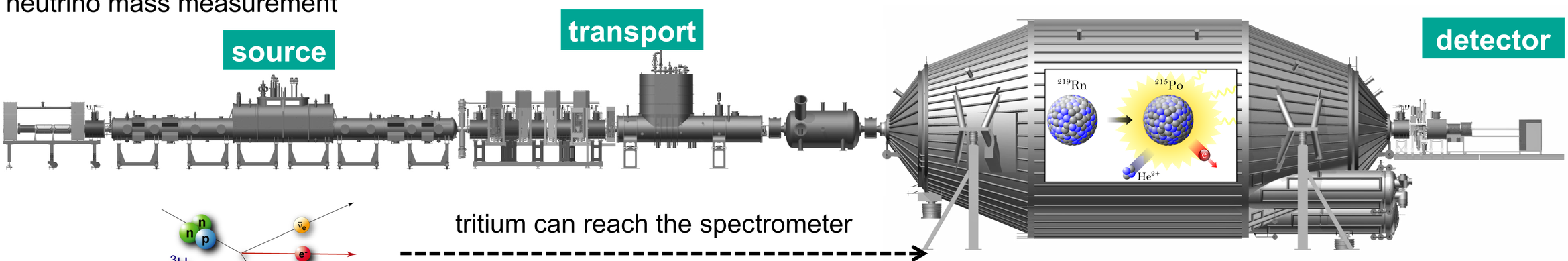
KATRIN experiment overview

neutrino mass measurement



tritium can reach the spectrometer

fraction $<10^{-14}$ → partial pressure $<10^{-20}$ mbar

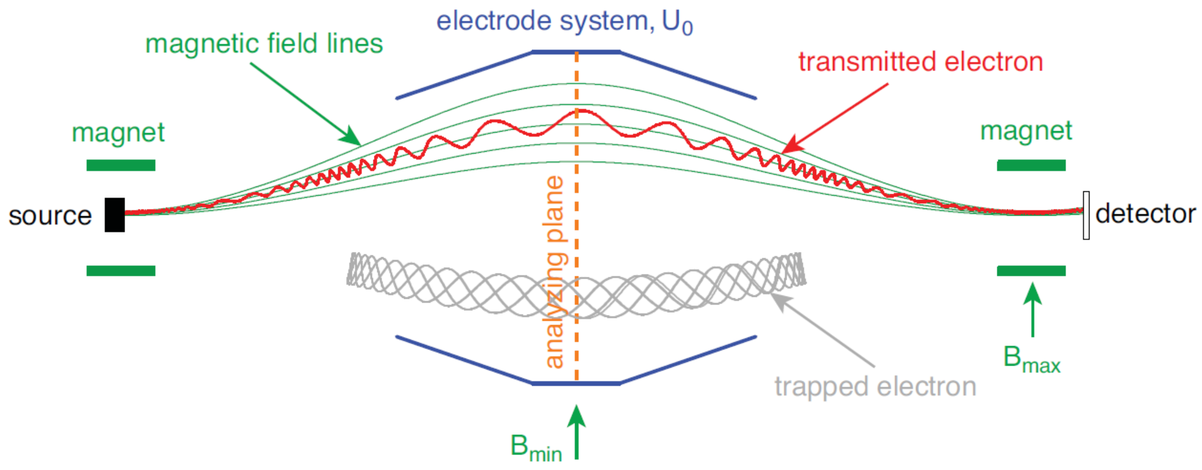
Goal: background below 10^{-2} cps!

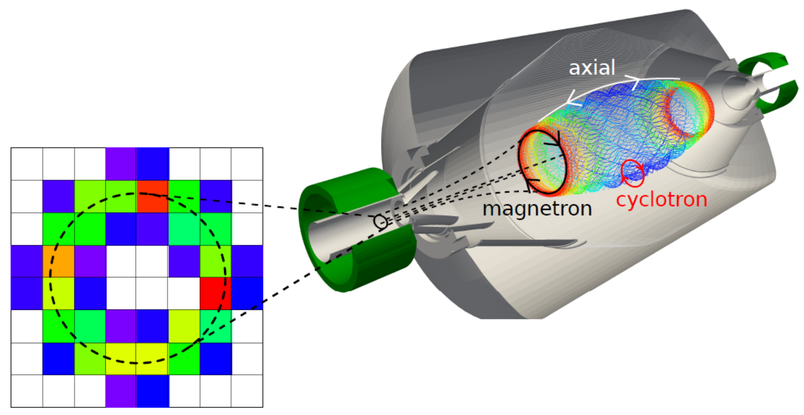
Origin of radon emanation into the spectrometer:
- natural abundance in materials
- getter material (NEG pump)

Background due to stored electrons

arXiv:1103.6238 [physics.ins-det], published in Astropart. Phys. **35**, 128 (2011)
arXiv:1204.6213 [physics.ins-det], published in Astropart. Phys. **41**, 52 (2012)
arXiv:1304.1379 [physics.ins-det], submitted for publication J. Phys. G

- **MAC-E** (*Magnetic Adiabatic Collimation with Electrostatic*) **filter**
- Electrons produced by radioactive decays
  - *Tritium-β-decay* → β-, shake-off electrons
  - *Radon-α-decay* → shake-off, conversion, Auger electrons
- Magnetic mirror → stored electrons → multiple background electrons





KASSIOPEIA: simulation tool for exact particle trajectories
- Ionization of residual gas → secondary electrons
- Primary electron energies: 100 eV < E < 500 keV
- Up to 1200 secondary electrons reaching the detector over a period of hours

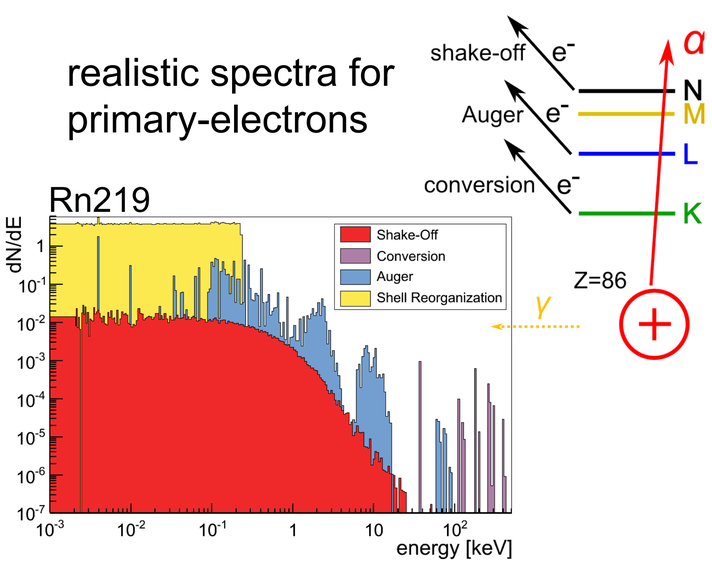
Detailed MC simulations are used to investigate the background due to stored electrons!

Simulating stored electrons

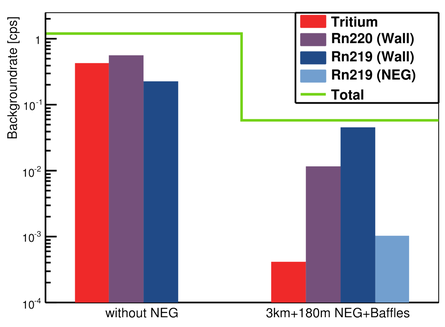
arXiv:1205.3729 [physics.ins-det], pubslished in JINST **7**, 8025 (2012)
arXiv:1304.1375 [physics.ins-det], submitted for publication in NJP

Activity Calculations

realistic spectra for primary-electrons



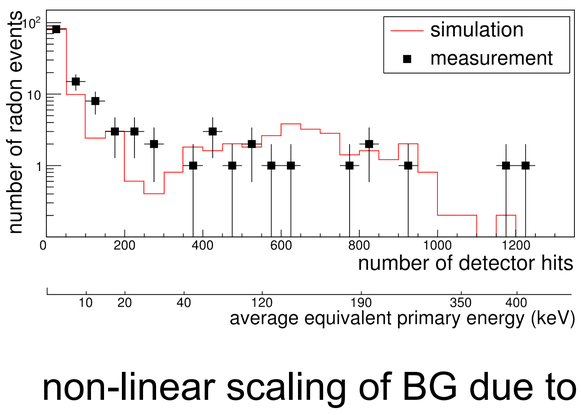
optimization of vacuum-setup



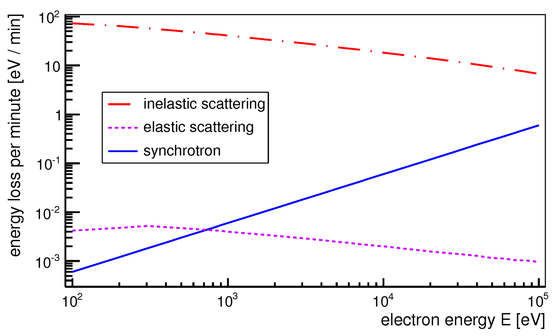
NEG+cold baffles reduce background by a factor of 10!

Simulation of stored electrons

measurement closely reproduced by simulations



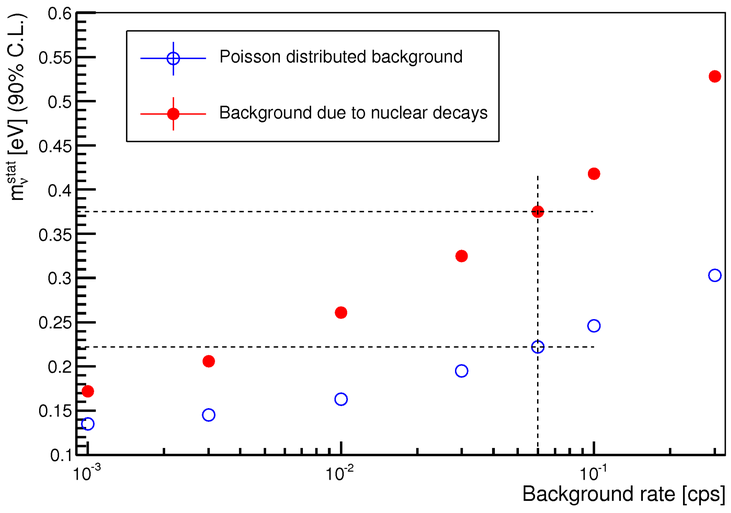
non-linear scaling of BG due to synchrotron radiation



very precise simulation of stored electrons

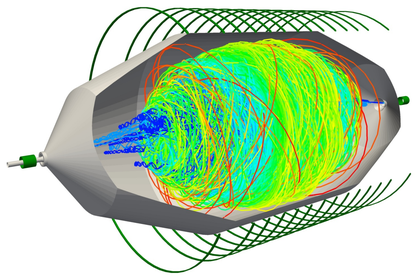
Impact on the experiment

non-poisson-distributed BG would worsen KATRIN's neutrino-mass-sensitivity



methods for active BG-removal are needed:

→ electric dipole
→ magnetic pulse
→ stochastic heating through ECR



methods for background-removal are developed based on simulations

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