Design of a Tabletop Spectrometer following the MAC-E-Filter Principle

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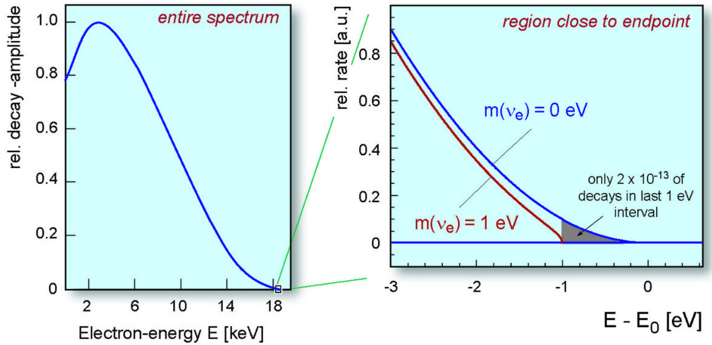
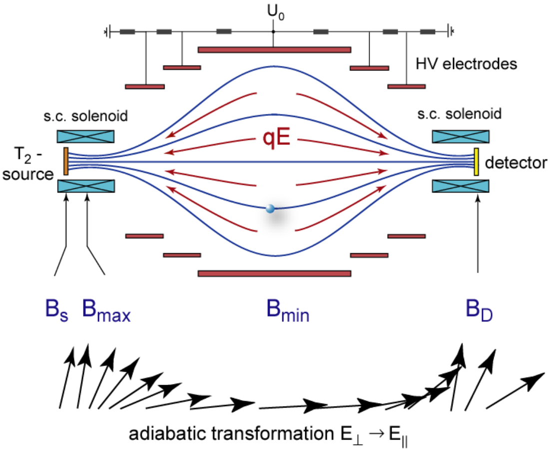
Kinematic Neutrino Mass Search



- kinematic measurement of the neutrino mass
- search for shift in the β-spectrum of tritium
- strongest imprint in the endpoint region

MAC-E-Filter Principle



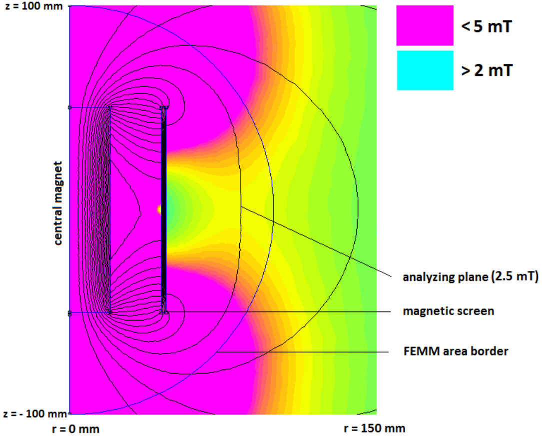
- analyzing voltage qU_0 filters electrodes $\Rightarrow$ highpassfilter
- inhomogenous guiding field generates gradient force $\parallel \nabla \vec{B}$
- adiabatic criteria: $\left|\frac{\nabla B}{B}\right|_{l_{cyc}}$ small

$\Rightarrow$ charactaristic parameter: magnetic moment $\mu = \frac{E_\perp}{B} = const.$

Motivation

- compact setup for the measurement of the tritium β-spectrum in laboratory classes
- usage of permanent staff magnets (NdFeB) up to $\approx 1\ \mathrm{T}$

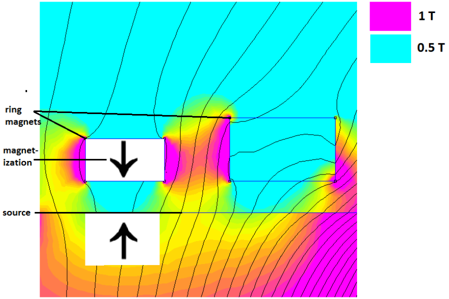
Magnetic Setup



- electrons travel from north- to southpole of central magnet
- iron screen creates magnetic minimum ⇒ analyzing plane

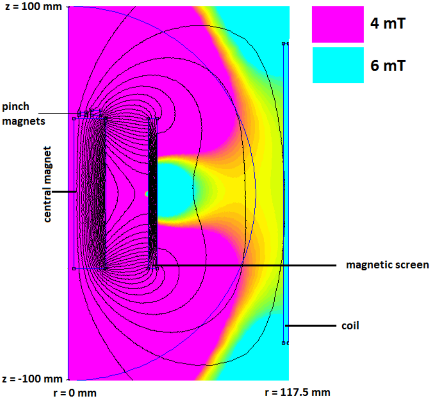
Pinch Setup

- high pitch angle ($\sphericalangle \vec{v}, \vec{B}$) particles are reflected by magnetic maxima
- $\theta_{max} = \arcsin\left(\sqrt{\frac{B_{max}}{B_{min}}}\right)$



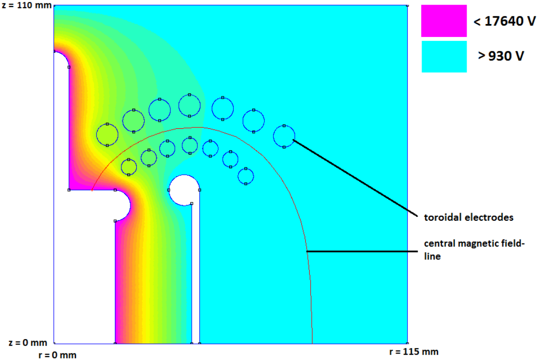
- ring magnets are polarised oppositely to the central magnet
- $\left.\begin{array}{l} B_{max} = 0.92\ \mathrm{T} \\ B_{src} = 0.75\ \mathrm{T} \end{array}\right\} \Rightarrow \theta_{max} = 64.86^\circ.$

Magnetic Setup



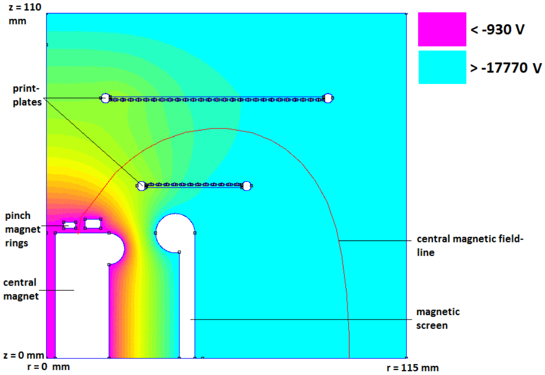
- bigger magnetic screen
- analyzing field supported by an air coil
- pinch setup in front of the source ΔE

Electrostatic Setup



- electrons start at 18.6 kV at the source
- analyzing voltage generated through screen and outer wall voltage of 0 V
- Problem: toroidal electrodes are complex to manufacture

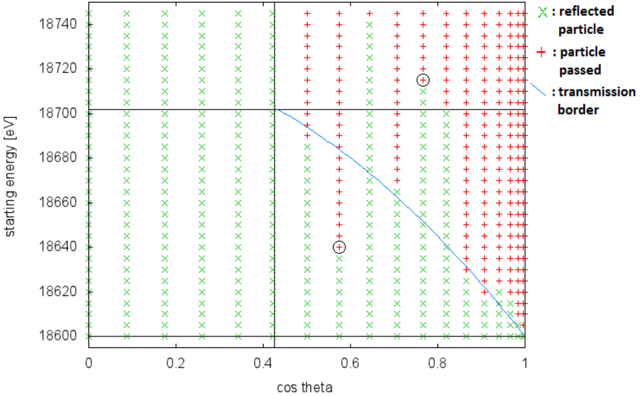
Electrostatic Setup



- electrodes are mounted on circular ring plates
- central magnet and ring magnets on $0\ \mathrm{V}$
- retardation in the pinch still $\approx 1\ \mathrm{kV}$

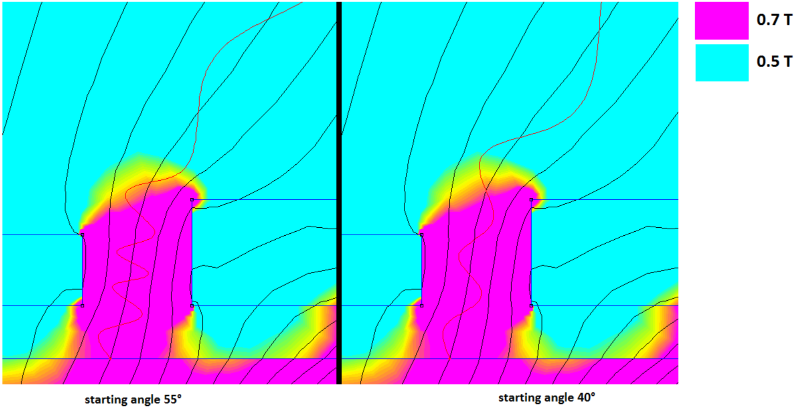
Simulation Results

- track simulation via runge-kutta-method (4th-order)



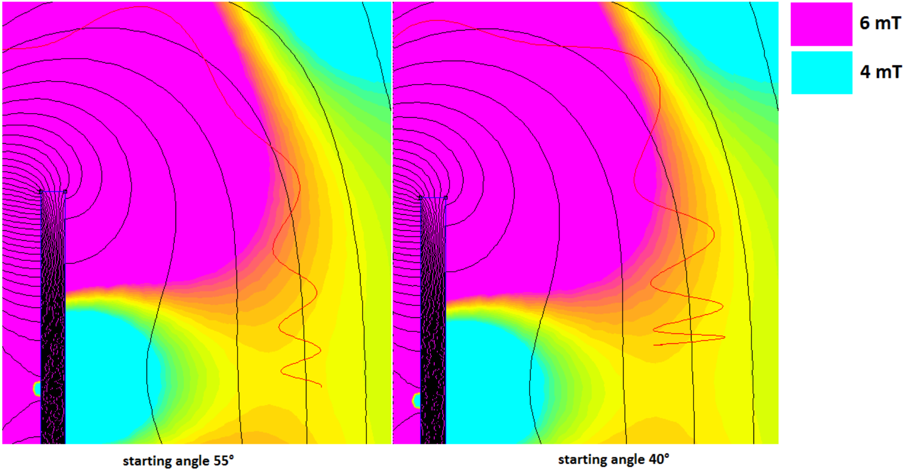
- simulations in 10 $\mathrm{eV}, 5^{\circ}$ steps
- strong deviation from analytical expectation for specific angles

track in the pinch area



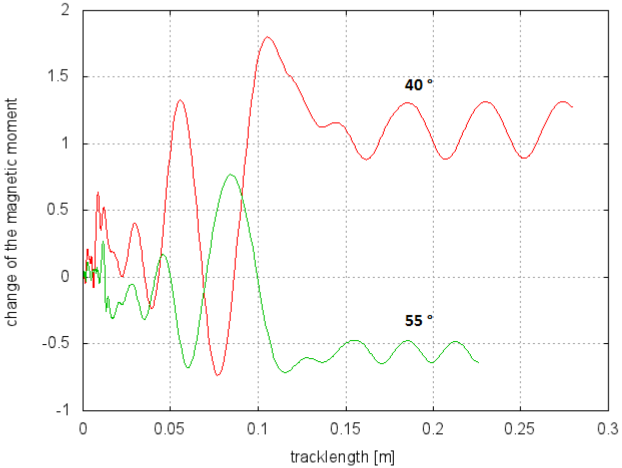
- strong field gradients in one cyclotron motion ($\Delta B = 0.2\ \mathrm{T}$)
- violation of the adiabatic criteria?

track in the analyzing plane



- electrons reach B_{min} before arriving at the analyzing plane!
- $\Rightarrow E_{\perp}$ 'freezes' at this point

progression of the magnetic moment



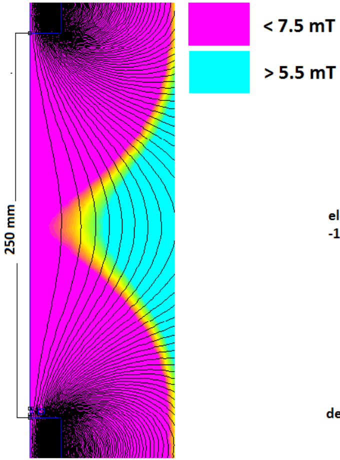
- $\Delta\mu = (\mu - \mu_0)/\mu_0$
- chaotic progress in the pinch area
- oscillation due to cyclotron motion
- effects phase dependent

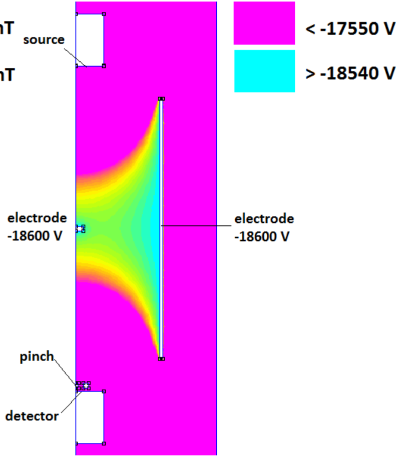
Conclusion+Outlook

- setup not usable as a MAC-E-Filter
- electrons are not able to perform adiabatic motion
- magnetic field strongly inhomogenous near analyzing plane

- locate pinch in front of the detector
- reduce magnetic inhomogeneity

Alternative Setup





- magnetic guiding field spans between two magnets
- electrodes on qU_0 analyzing voltage for retardation