Novel Detection System for Electron and Proton Momentum Spectroscopy

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Abstract

For the measurement of the Fierz interference term ***b*** with the new facility PERC [Dub08,Kon12], we propose a novel detection system for electron and proton momentum spectroscopy based on the **R**×**B** drift effect. In the **R**×**B** spectrometer, the charged decay particles are dispersed in a uniformly curved magnetic field, and then measured with large phase space acceptance and high resolution [Wan12].

Our goal is, inter alia, beta spectroscopy in which the spectra and angular distributions of the emerging particles will be distortion- and background-free on the level of 10^{-4} [Dub08].

Scientific Objectives

In the search for new symmetries, measurements of correlation coefficients, inter alia ***a***, ***A***, ***B***, ***C*** [Abe09], and the Fierz interference term ***b***, are of uttermost importance: unitarity of the CKM matrix, left-right symmetry, fundamental fermion compositeness, new particles, leptoquarks, supersymmetry, supergravity, etc.

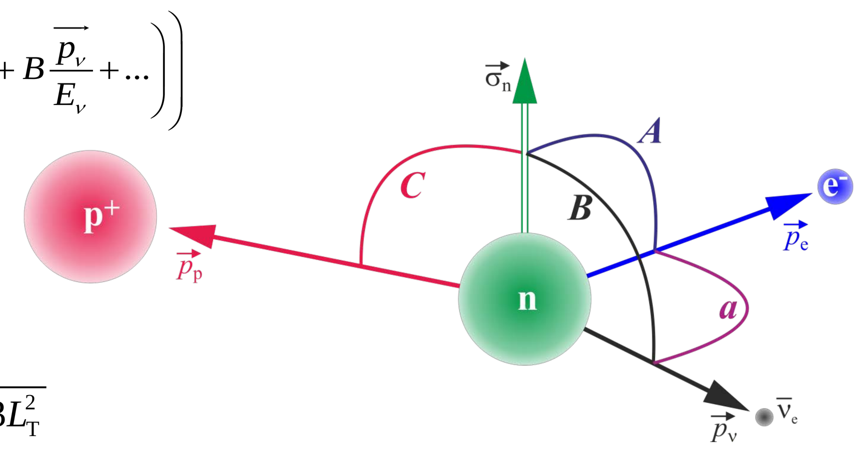
High-precision measurements in neutron beta decay are generally complementary to direct searches in high-energy physics [Abe08]. And with the new instrument PERC, several symmetry tests based on neutron beta decay data become competitive [Kon11].

Observables in neutron beta decay

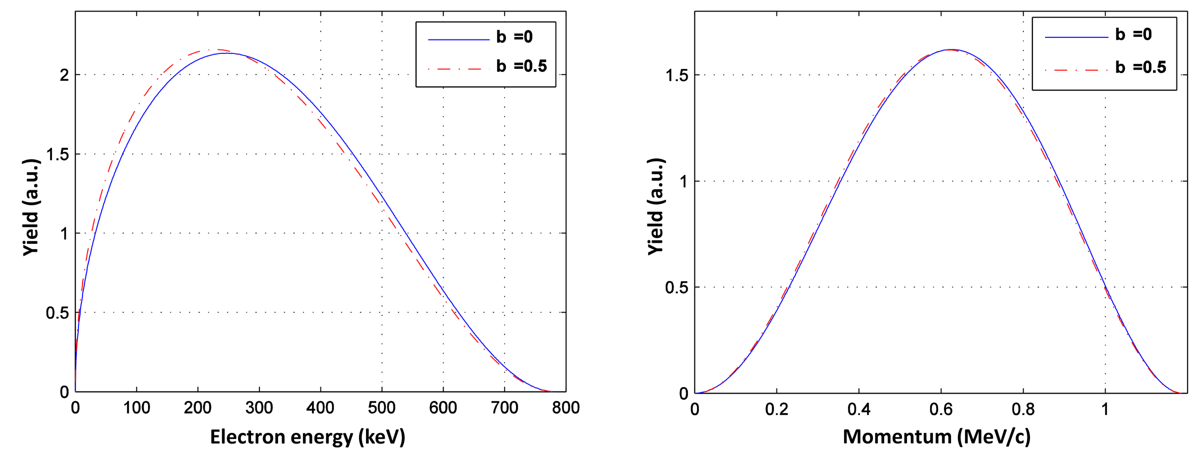
$$\frac{d^3\Gamma}{dE_e d\Omega_e d\Omega_\nu} = \frac{1}{(2\pi)^5}\frac{G_F^2|V_{ud}|^2}{2} p_e E_e (E_0 - E_e)^2 \xi \left(1 + a\frac{\vec{p}_e \vec{p}_\nu}{E_e E_\nu} + b\frac{m_e}{E_e} + \frac{\langle \vec{s}_n \rangle}{s_n}\left(A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + \ldots\right)\right)$$

with ***correlation coefficients***

- in **SM**: $a = \frac{L_V^2 - L_A^2}{L_V^2 + 3L_A^2}$ $\quad b = 0 \quad$ $A = -2\frac{L_A^2 - L_V L_A}{L_V^2 + 3L_A^2}$
- with **LH S,T**: $a = \frac{L_V^2 - L_A^2 - L_S^2 + L_T^2}{L_V^2 + 3L_A^2 + L_S^2 + 3L_T^2}$ $\quad b = 2\frac{L_V L_S + 3L_A L_T}{L_V^2 + 3L_A^2 + L_S^2 + 3L_T^2}$



Electron energy and Momentum spectra

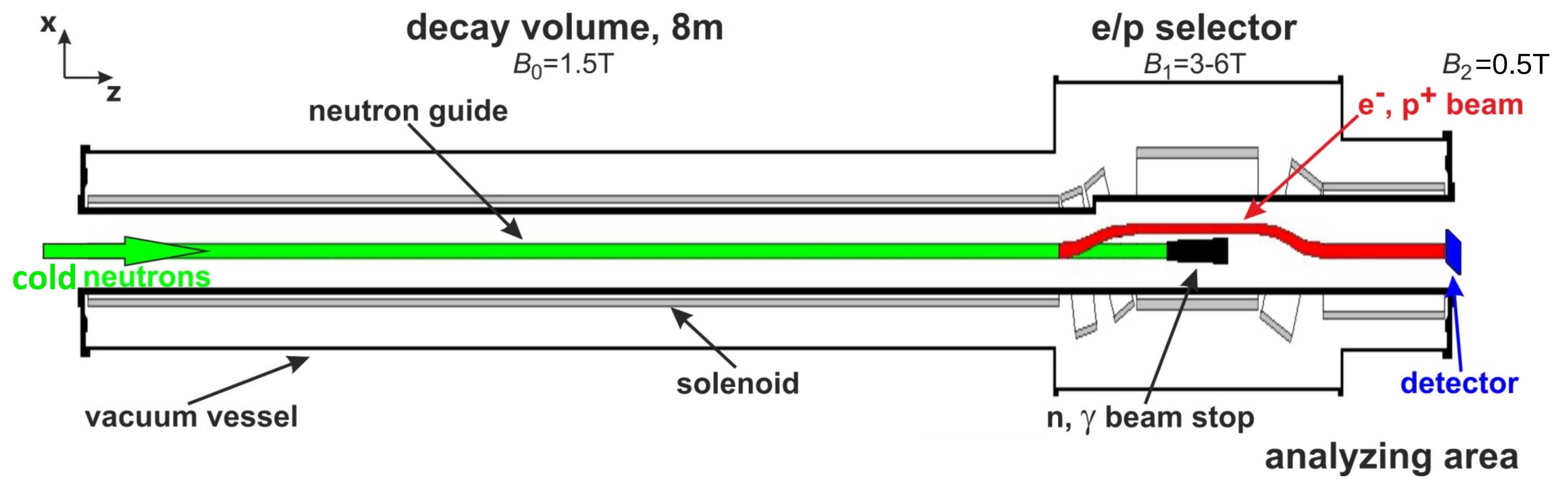


PERC – A clean, bright, and versatile source of neutron decay products

Beam preparation:

- Neutron beam line (neutron polarization and polarization analysis with 10^{-4} accuracy)
  Talk by Ch. Klauser
- Non-depolarizing neutron guide
- Pulsed spatial neutron magnetic spin resonator

Talk by B. Märkisch



For details see [Kon12].

Particle detectors:

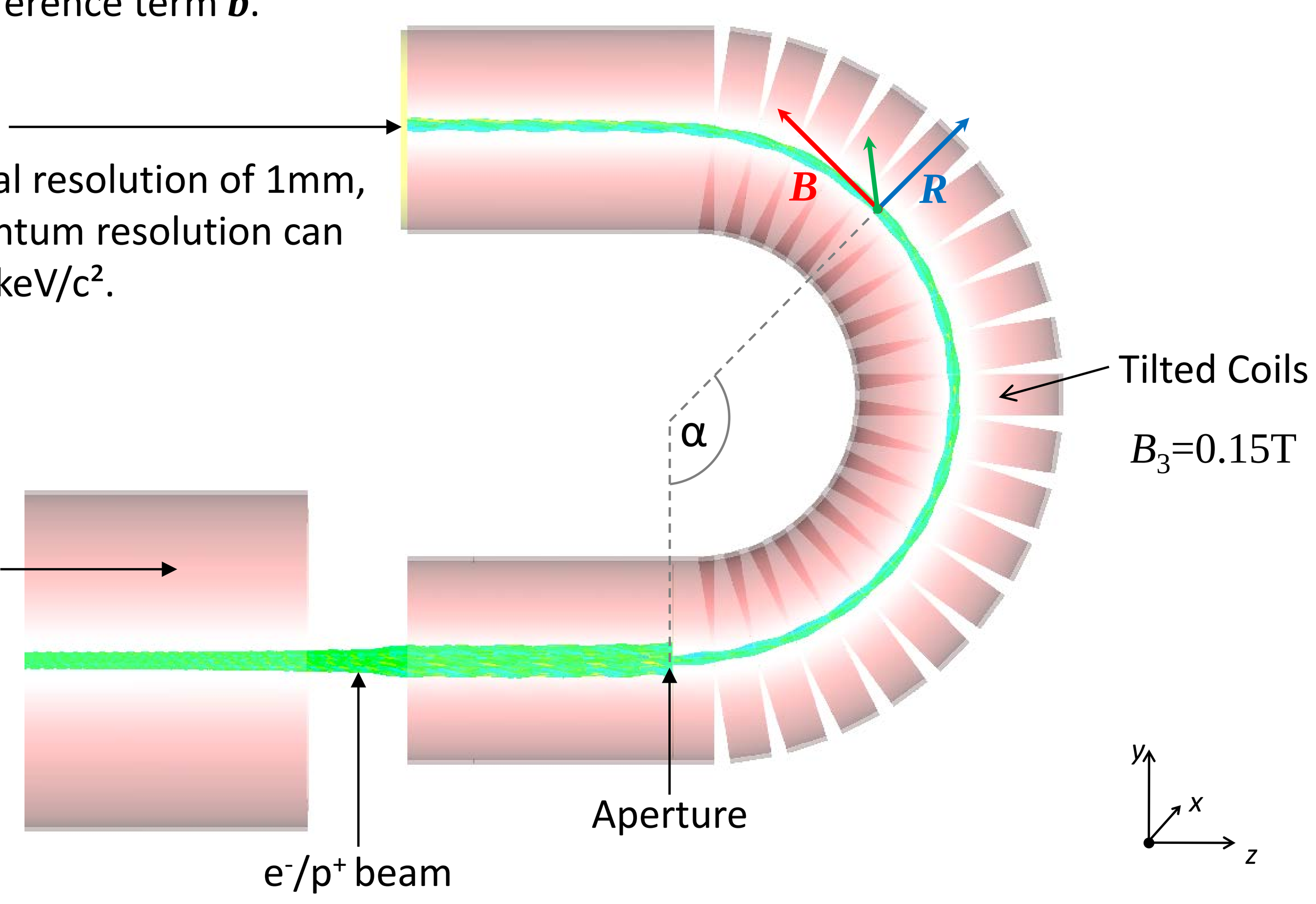
- Electron energy spectroscopy with energy sensitive detectors
- Simultaneous electron and proton momentum spectroscopy with **R**×**B** drift momentum spectrometer
- Proton energy spectroscopy with retardation spectrometer
- Proton TOF spectroscopy where proton pulsed by electric gate voltage

Design of R×B drift momentum spectrometer

Scientific goal:
First measurement of the Fierz interference term ***b***.

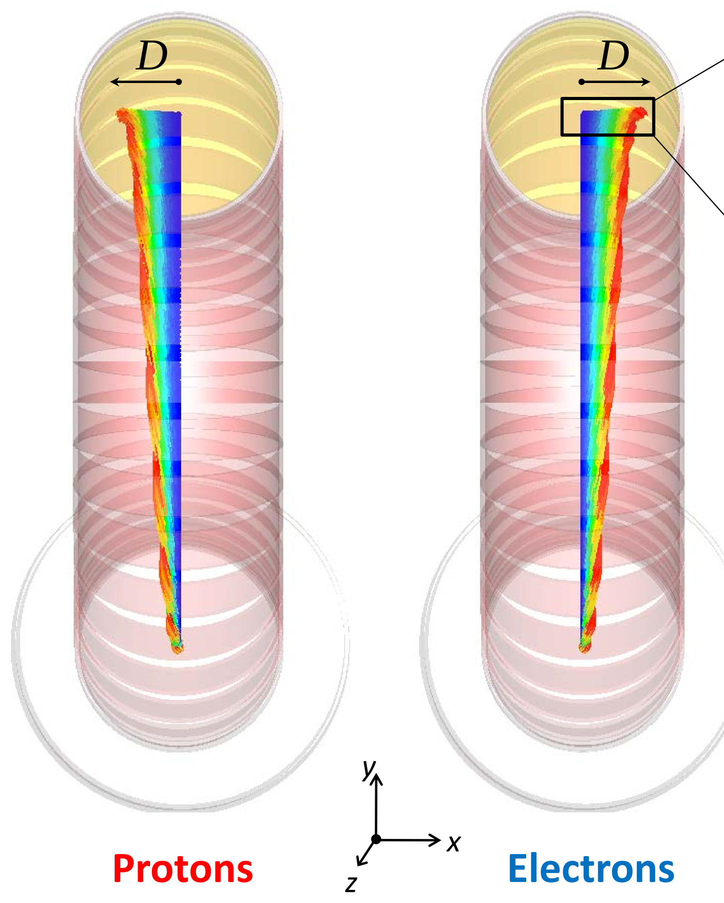
$$\vec{v}_d = \frac{mv^2}{qBR}\left(\cos\theta + \frac{1}{\cos\theta}\right)\cdot\frac{\vec{R}\times\vec{B}}{RB}$$

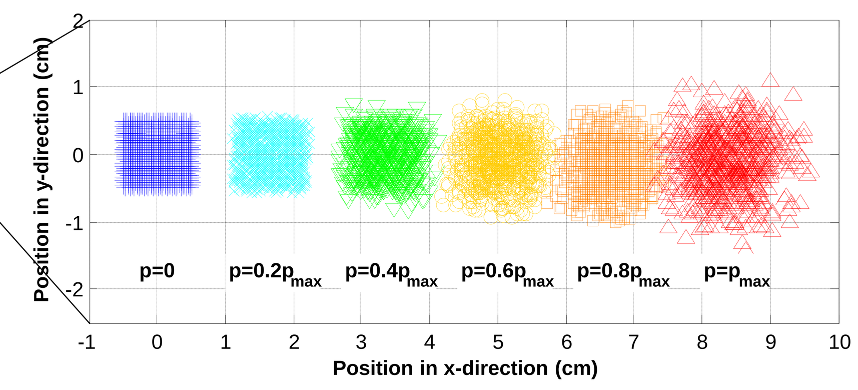
Detector:
For a spatial resolution of 1mm, the momentum resolution can reach 14.4keV/c².



Particle tracing with CST EM STUDIO

$$D = \int_T v_d \,dt = \frac{p}{qB}\cdot\alpha\cdot\frac{1}{2}\left(\cos\theta + \frac{1}{\cos\theta}\right) \quad \text{with} \quad \alpha = \frac{v_\parallel \cdot T}{R}$$





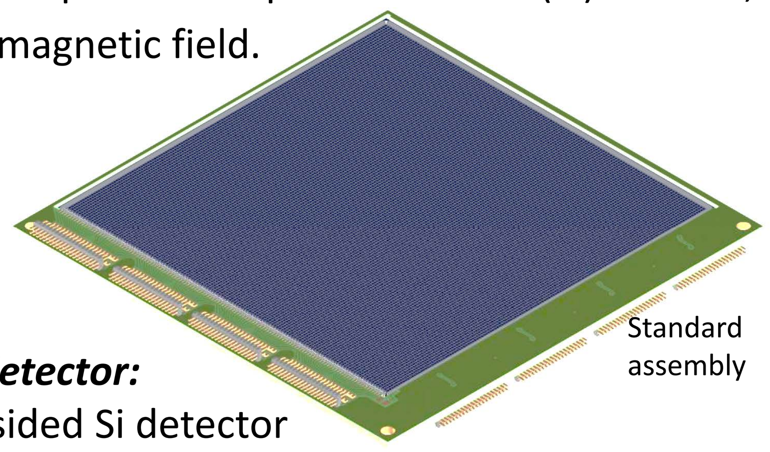
Spectrometer parameters:

- Field line curvature: R=40cm
- Aperture size: w×h=1x1cm²
- Bending angle: α=180°
- Max. incident angle: θ_{max}=9.1°
- Max. gyration radius: r_{max}=0.42cm
- Max. **R**×**B** drift: D_{max}=8.3cm

Large area position sensitive detector

Requirements:

- Active area ~ 100 x 30 mm²,
- Spatial resolution < 1mm,
- Full energy deposition requires thickness(Si)>2.5mm,
- Tolerating magnetic field.

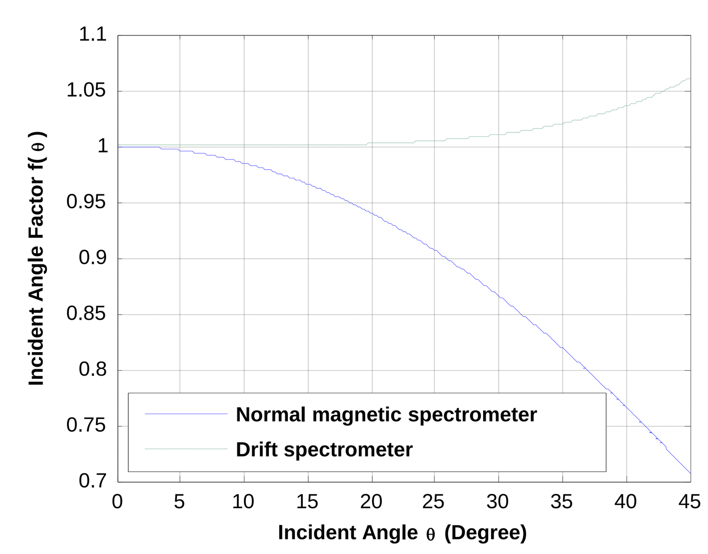


Design TTT detector:

- 2 x Single sided Si detector
- Active area: 100x100mm²
- No. of strips: 128 each
- Strip width: 700 µm
- Thickness: 1mm

Pros and Cons

- \+ ***Adiabatic transport of particles*** ensures that the angular distribution of the decay products can be kept and measured
- \+ ***Low momentum measurements***, also for *D<w*, in contrast to normal magnetic spectrometer
- \+ ***Large acceptance of incident angle*** with
- \+ ***Small corrections for incident angle***: aberration <10^{-4}
- – Small drift distances in the order of cm



For details see [Wan12].

References

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