Towards Light Yield Linearity of the BC-440 Plastic-Scintillator under Electron Excitation

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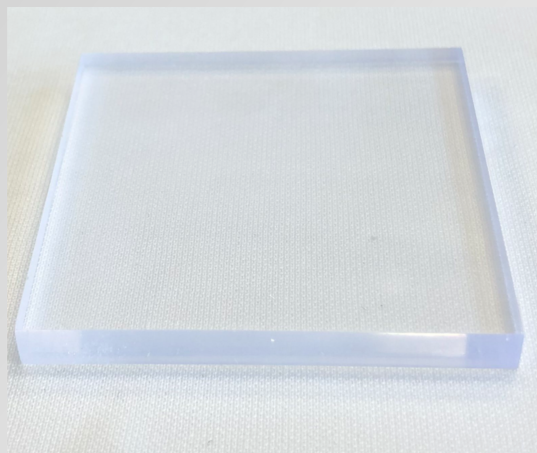
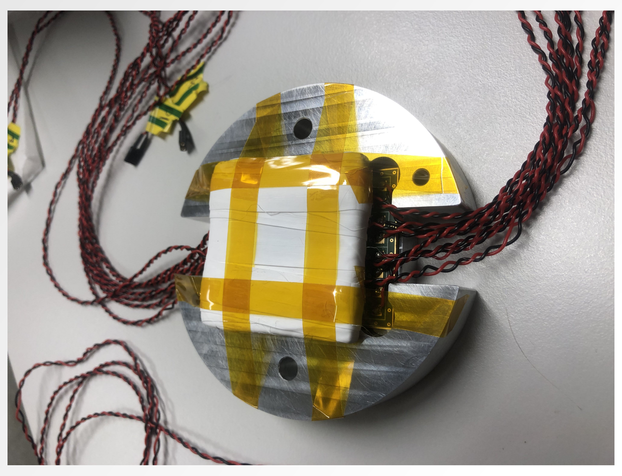
Abstract:

The PERC (Proton and Electron Radiation Channel) facility, located at the neutron source FRM II of the Technical University of Munich (TUM), serves as a clean source of neutron decay products, namely protons and electrons [1,2]. PERC aims to contribute to the determination of the Cabibbo-Kobayashi-Maskawa quark-mixing element (V_{ud}), measure the correlation coefficients of free neutron decay (a, A, b, C) and to search for new physics at the TeV scale. While the main detector is a silicon detector, the backscattering detector system of PERC consists of two scintillation detectors with SiPM read-out. The light output of the plastic scintillator BC-440 is investigated in the low-energy range (0–60 keV) using an electron gun as a beta source and a Silicon Photomultiplier (SiPM). This approach enables continuous testing of the nonproportionality of the light output to the amount of absorbed energy by the scintillator, without relying on the fixed energies of standard radioactive beta sources.

Scintillator:





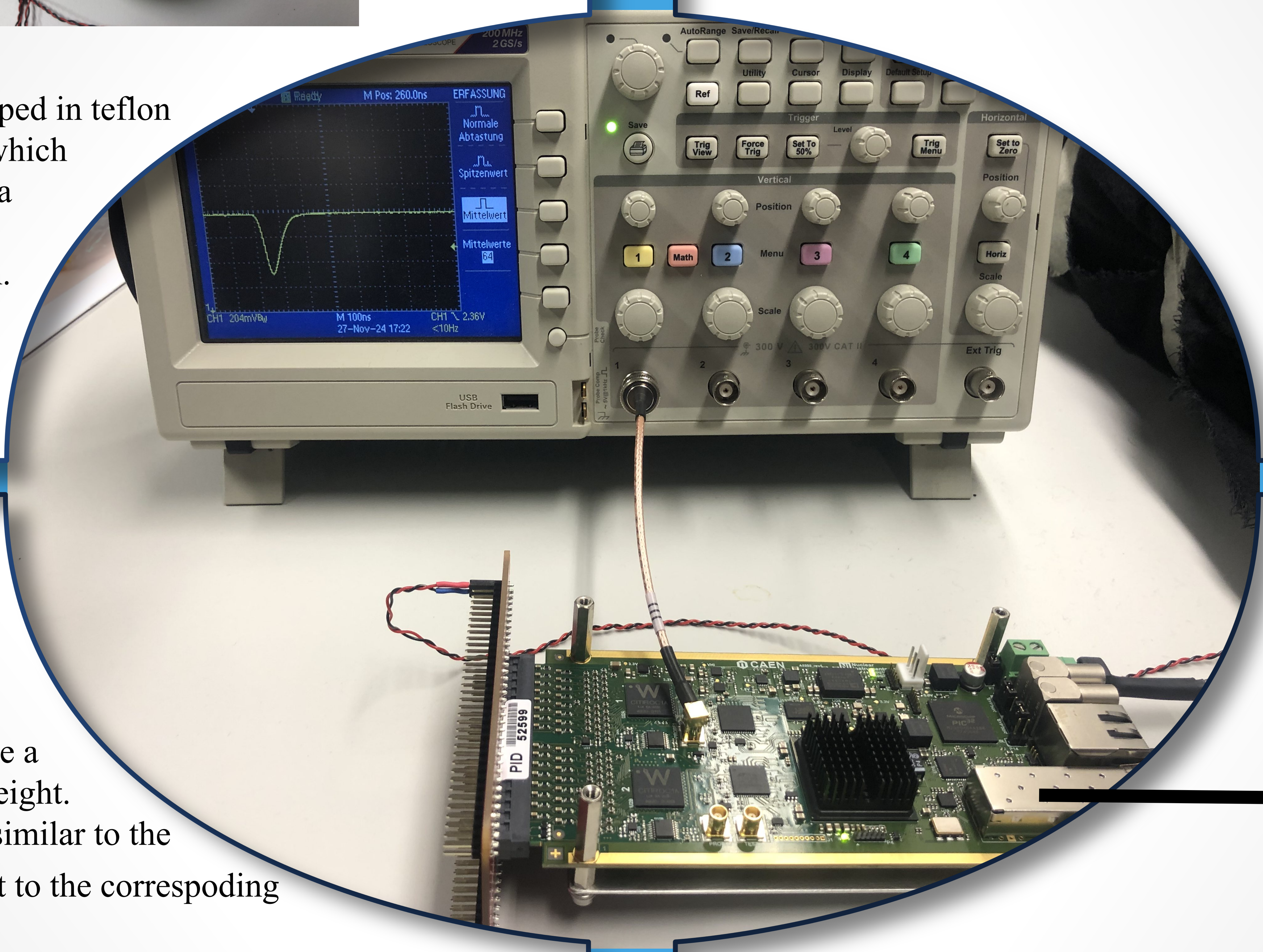
The 50 x 50 x 5 mm^3 plastic scintillator was wrapped in teflon tape to increase the light collection of the SiPM, which has been optically coupled to the scintillator with a silicone wafer. The aluminium holder keeps the center of the SiPM aligned with the electron beam.

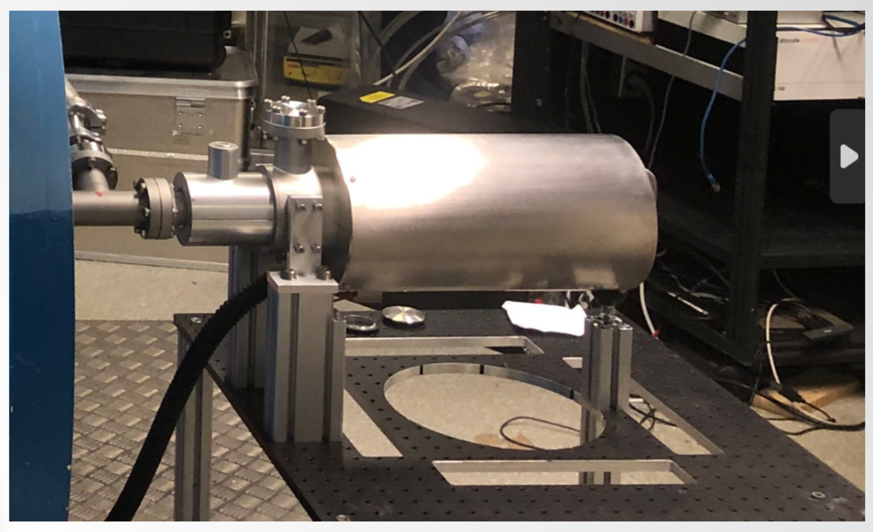
e^- - Source:

An electron-gun providing energies of up to 60 keV will be used to continously increase the energy of the emitted electrons. These electrons will then deposit their energy in the scintillator, which converts it into photons.

Current Challenges:

- shield sensitive SiPM-Array from light produced by the filament
- reduce electron flux (10^{12} e^- per s)

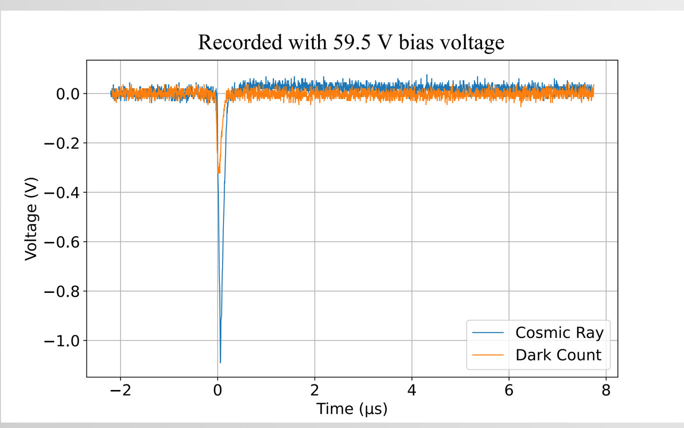


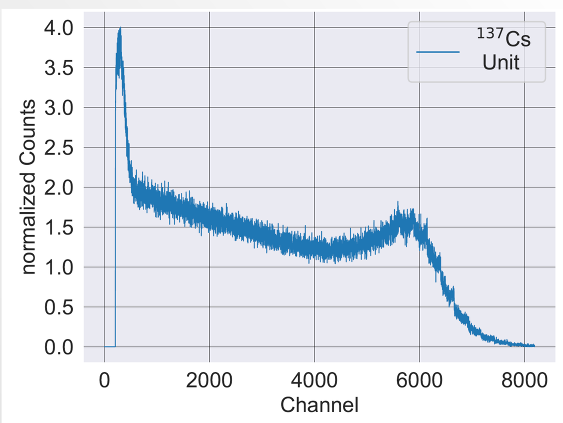


First Measurements:

One pulse coming from a cosmic ray and one pulse coming from a typical dark count. They share a similar timescale, but clearly differ in their peak height. Once the proper threshold is selected, a spectrum similar to the ^{137}Cs spectrum will be used to map the pulseheight to the correspoding electron energy.

CAEN A5202 64-Channel Citiroc-1 A Unit for FERS-5200 used to power and read out the Hamamatsu 16 channel SiPM array. The board is also used to process the voltage pulses and to create a spectrum.





Thesis:

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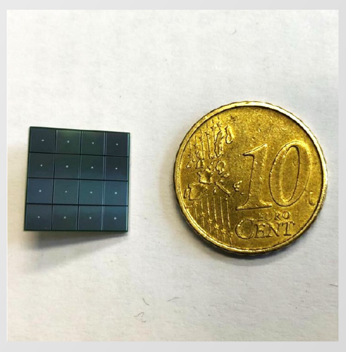
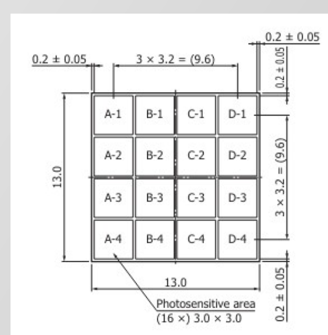
Hamamatsu MPPC SiPM array:

Parameter	Symbol	Value	Unit
Breakdown Voltage	V_{Br}	53±5	V
Operating Voltage	V_{Op}	V_{Br}+3	V
Gain	M	1.7×10^6	-
Spectral response range	λ	320-900	nm
Temperature coefficient of recommended operating voltage	$\Delta T\ V_{Op}$	54	mV/°C
PDE at peak	-	40	%





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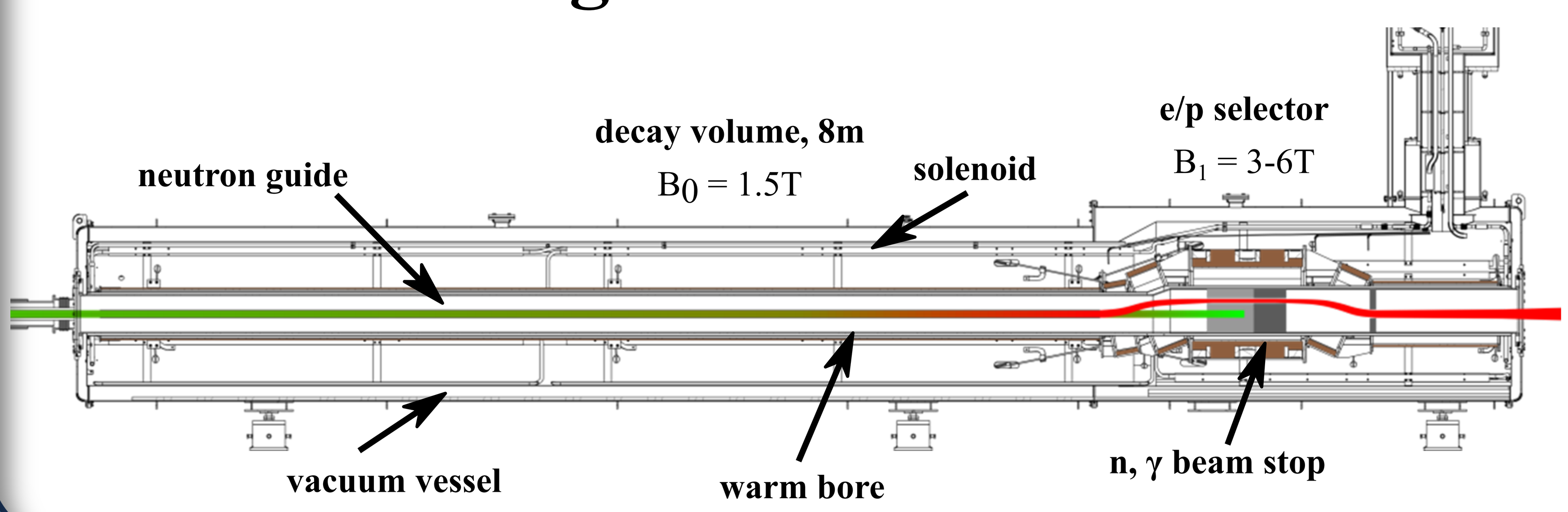
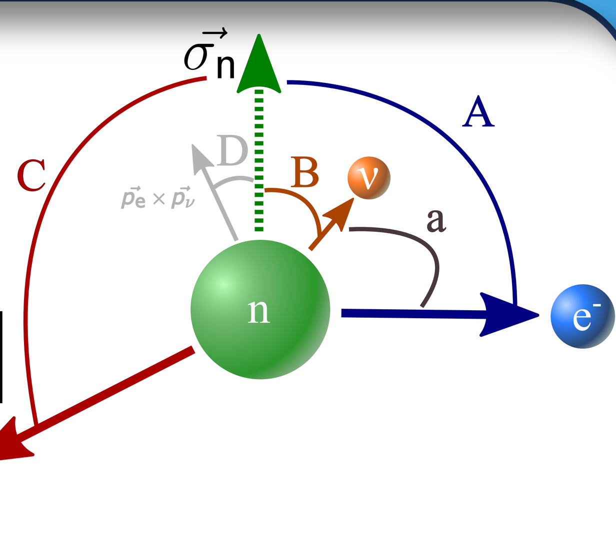
The PERC Magnet:



Free Neutron Decay:

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



in the standard model:

$$a = \frac{1-|\lambda|^2}{1+3|\lambda|^2} \quad A = -2\frac{|\lambda|^2+\lambda}{1+3|\lambda|^2} \quad B = 2\frac{|\lambda|^2-\lambda}{1+3|\lambda|^2} \quad C = x_C\frac{4\lambda}{1+3|\lambda|^2} \quad \lambda = \frac{g_A}{g_V}$$

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References:

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