Status update: EDS

Some Straw Detector Calculations

Antonios Athanassiadis

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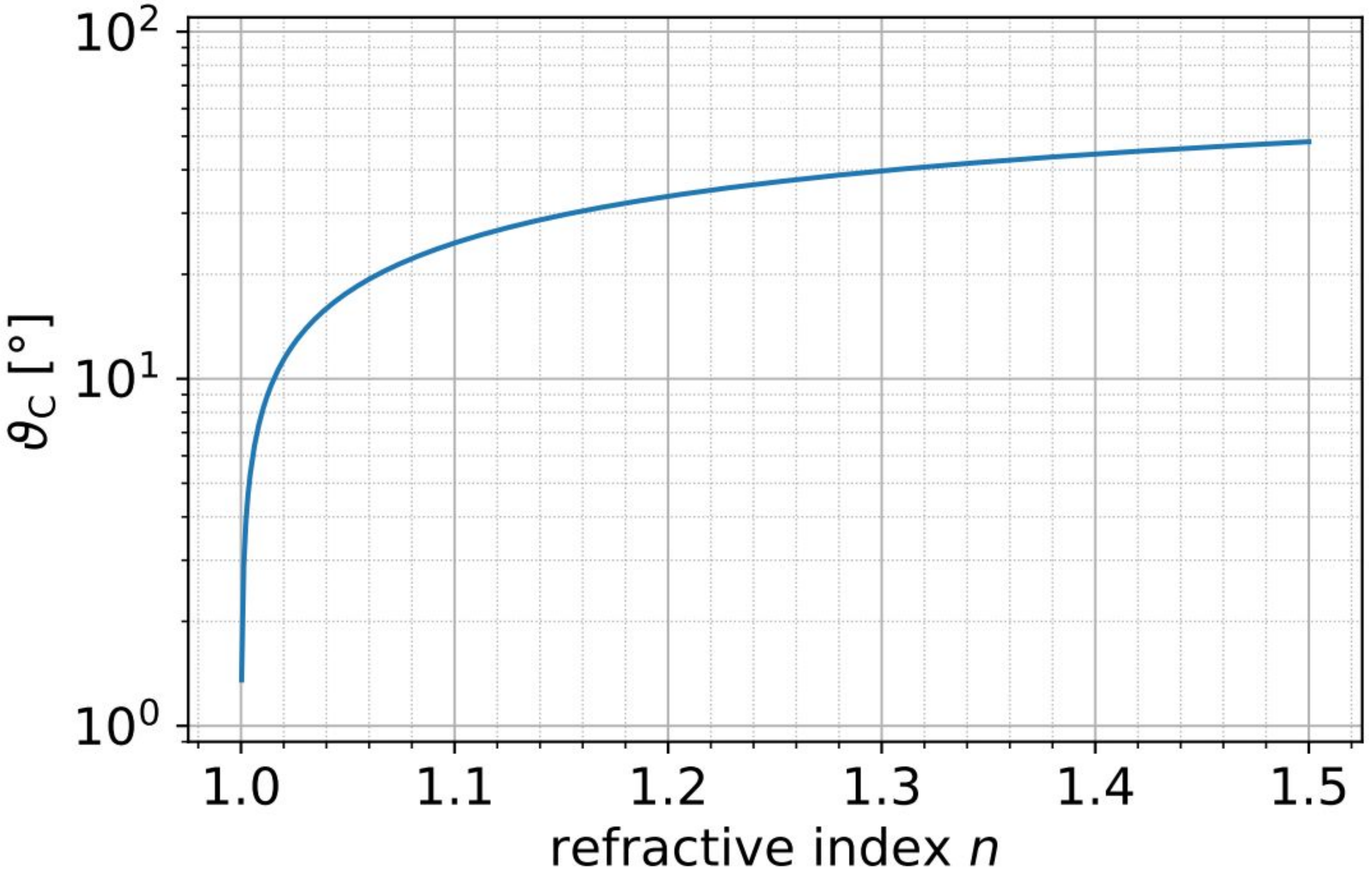
Cherenkov Effect

Opening Angle for 10 GeV Electrons

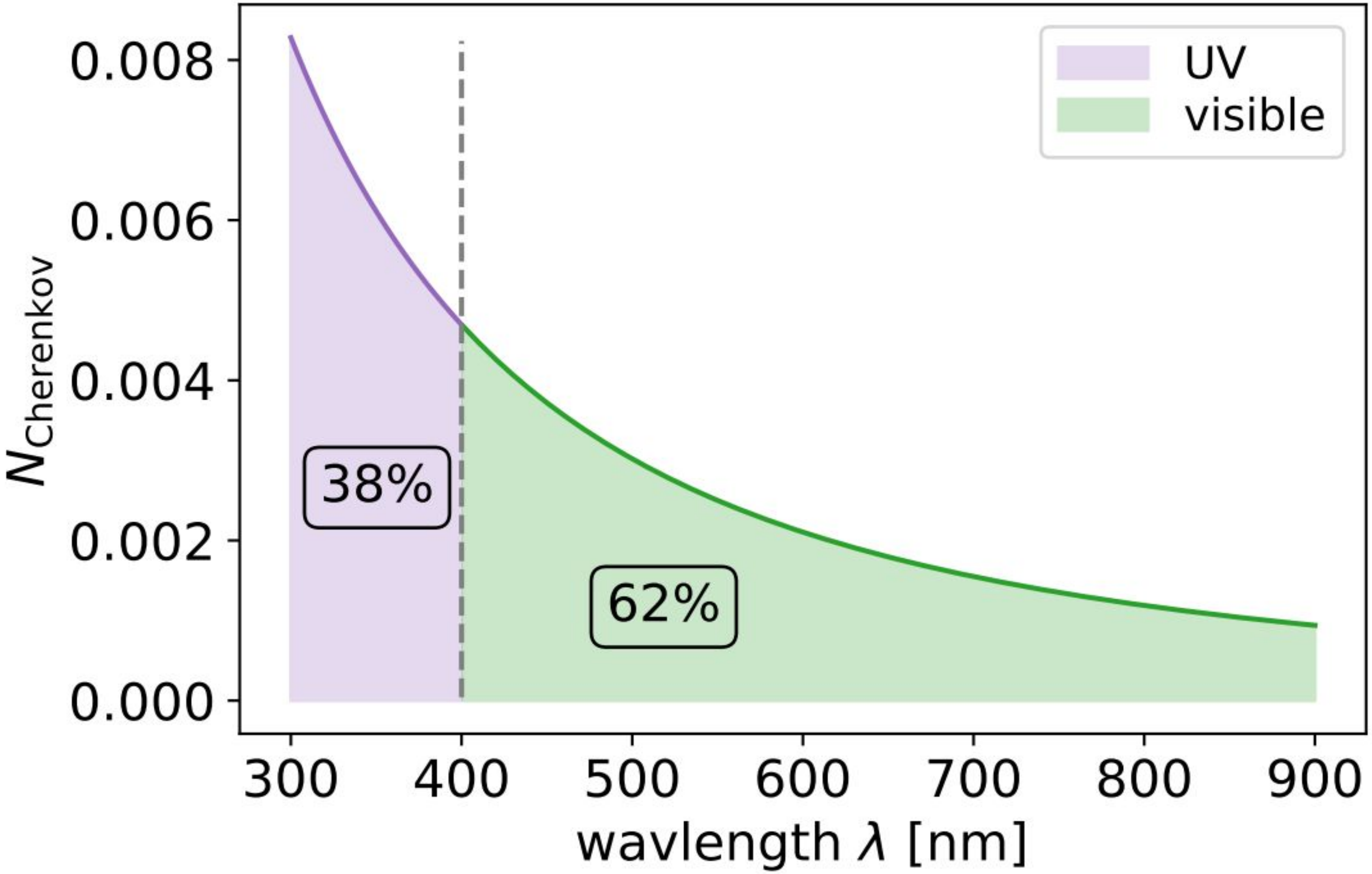
$$\cos(\vartheta_C) = \frac{c_m t}{vt} = \frac{1}{\beta n}$$



Cherenkov Effect

Spectrum in Detectable Range of 10 GeV Electrons in 3 mm Air

$$N_{\text{Cherenkov}} = 2\pi\alpha z^2\ L\ \sin^2(\vartheta_C)\left[-\frac{1}{\lambda}\right]_{\lambda_1}^{\lambda_2}$$



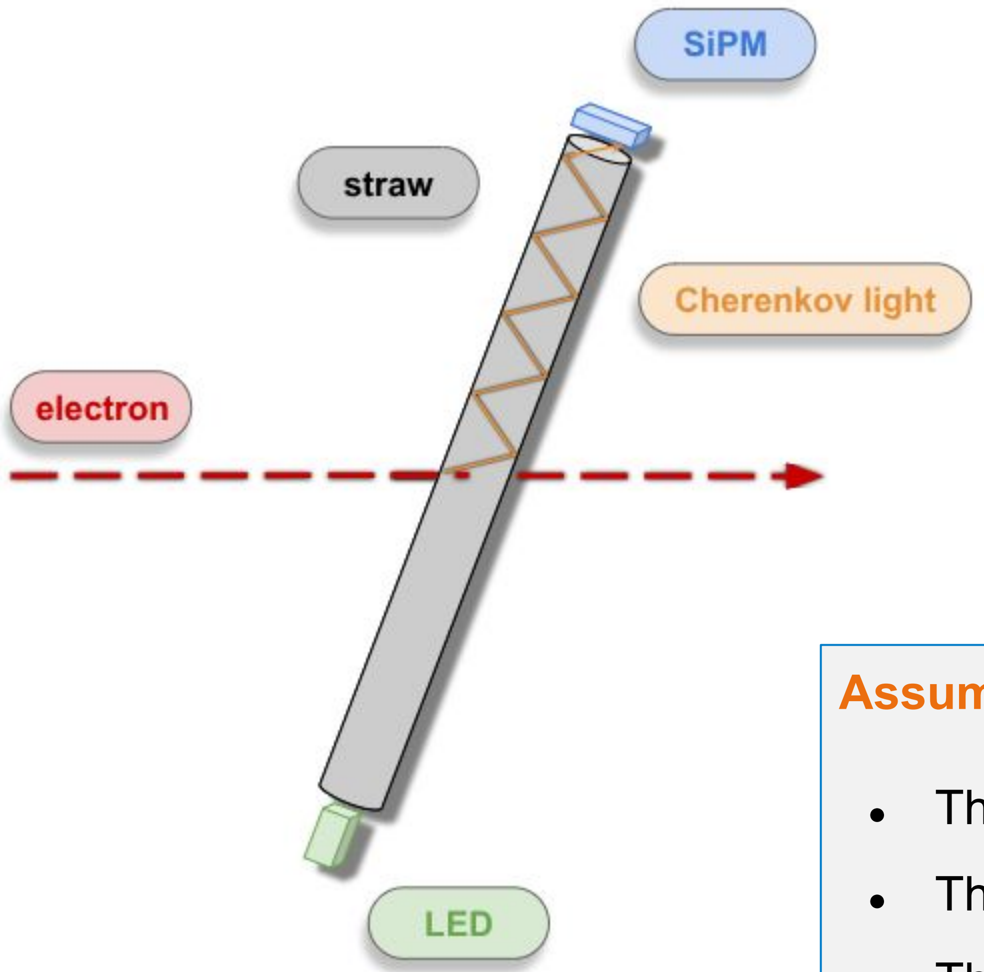
Cherenkov Effect

Comparison of Air and Glass

Property	Material	
	air	glass
Composition	N_2, O_2,	SiO_2
Density [kg/m^3]	1.2	2200
Refractive index n	1.00028	1.53
ϑ_C [°]	1.4	49.2
$N_{\text{Cherenkov}}$ [$N_\gamma/(e^- \times 3\ \text{mm})$]	0.17	175

Straw Reflectivity

Setup



Parameters

- Length L = 200 mm
- Diameter d = 3 mm
- Angle α = 25°
- Reflectivity R = 90%

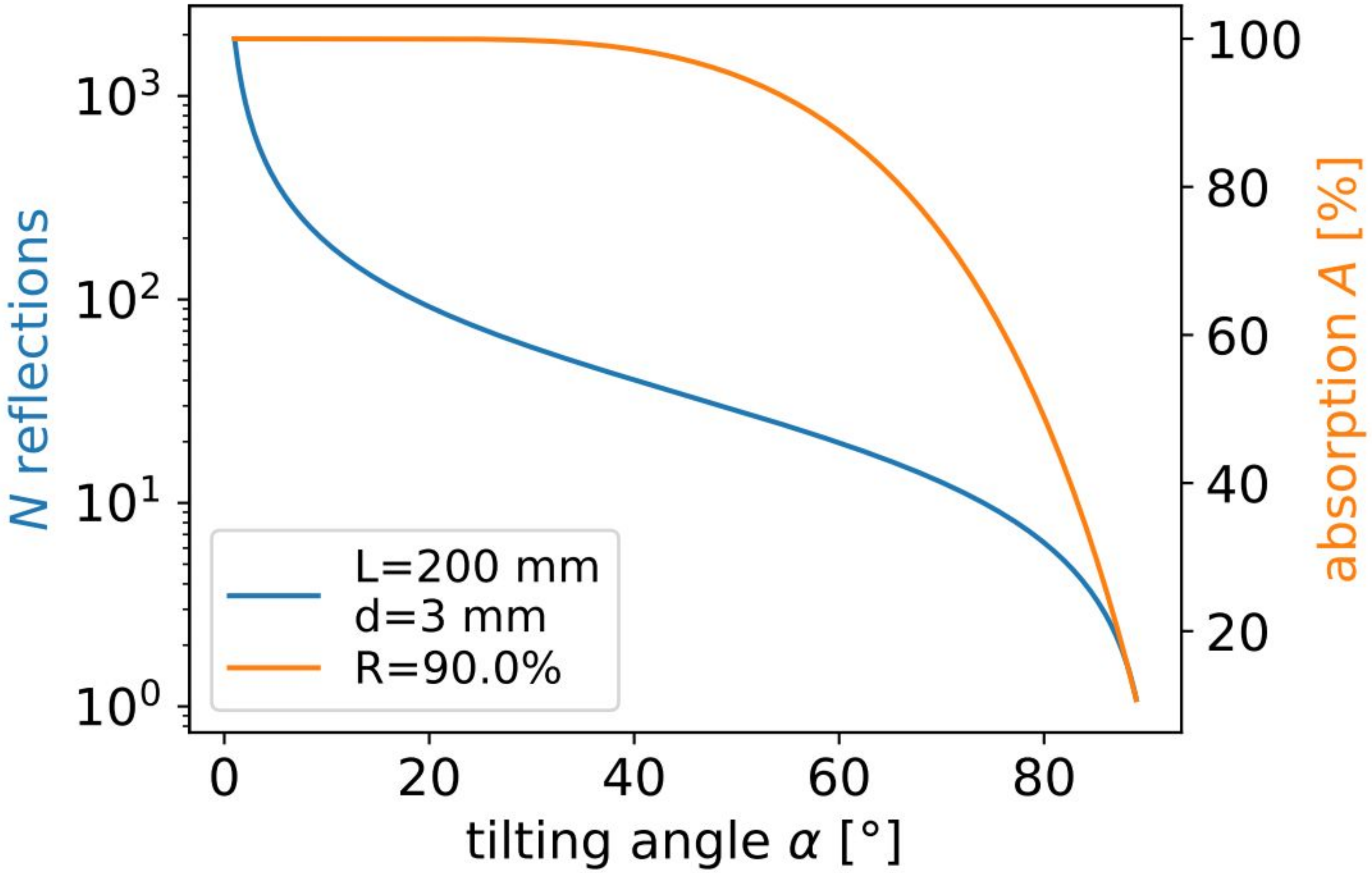
Assumptions

- The electron beam is point-like and hits perfectly centered
- The Cherenkov angle is 0°
- The absorption is maximal at 0° is and zero at 90°

Straw Reflectivity

Absorption and # Reflections

$$A_{\text{straw}} = 1 - \prod_{i=1}^{N_{\text{reflections}}} R_{\text{i,straw}} = 1 - R_{\text{straw}}^{N}$$



$$N_{\text{reflections}} = \frac{L}{2d} \cot(\alpha_{\text{straw}}) + \frac{1}{2}$$

Straw Reflectivity
Surviving Photons

For a single Cherenkov photon we find

$$N_{\text{reflections}} \approx 72 \quad \text{and} \quad A_{\text{straw}} \approx 99.95\%$$

With 200 pC and N photons from Cherenkov, the number of surviving photons is

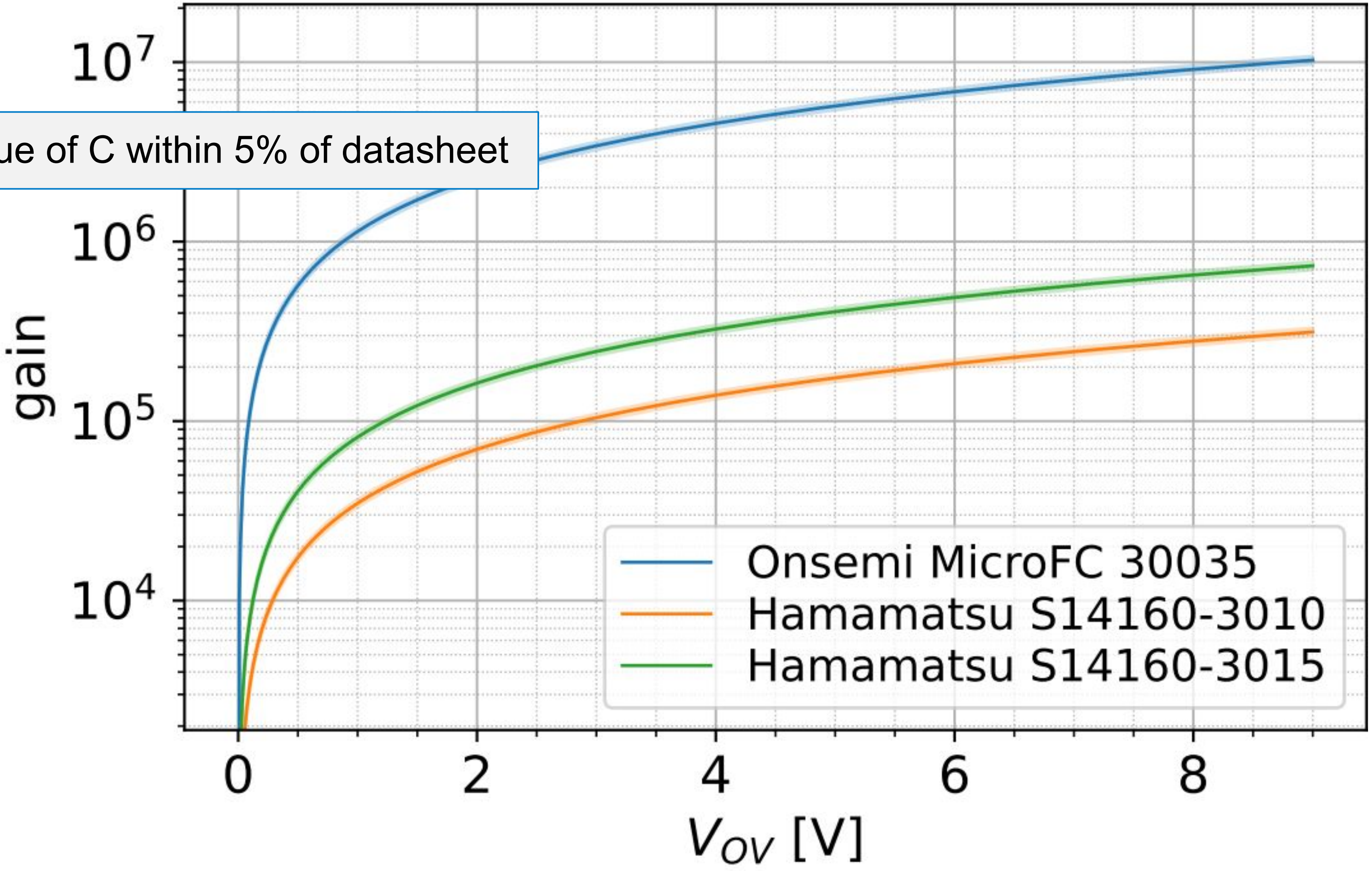
$$\begin{aligned} N_{\text{photon}} &= N_{\text{beam}} \times (1 - A_{\text{straw}}) \times N_{\text{Cherenkov}} \\ &= 1.2 \times 10^9 \text{ electrons} \times 5 \times 10^{-4} \times 0.17 \text{ photons/electron} \\ &\approx 10^5 \text{ photons.} \end{aligned}$$

SiPM Characteristics

Gain

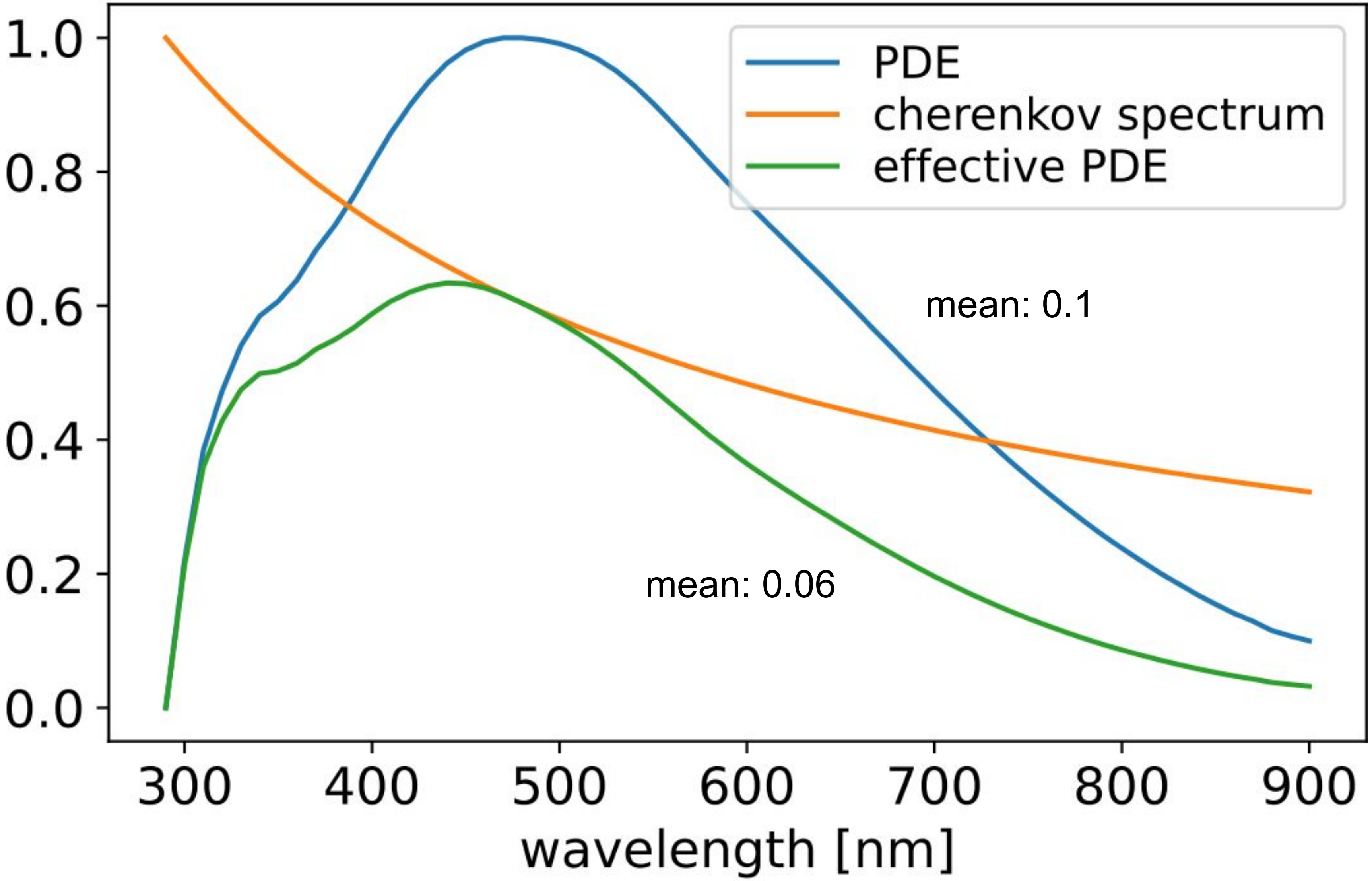
$$G(U_{\mathrm{OV}}) = \frac{Q_{\mathrm{pixel}}}{e} = \frac{C_{\mathrm{SiPM}}}{eN_{\mathrm{pixel}}} \times U_{\mathrm{OV}}$$

Fit gives a value of C within 5% of datasheet



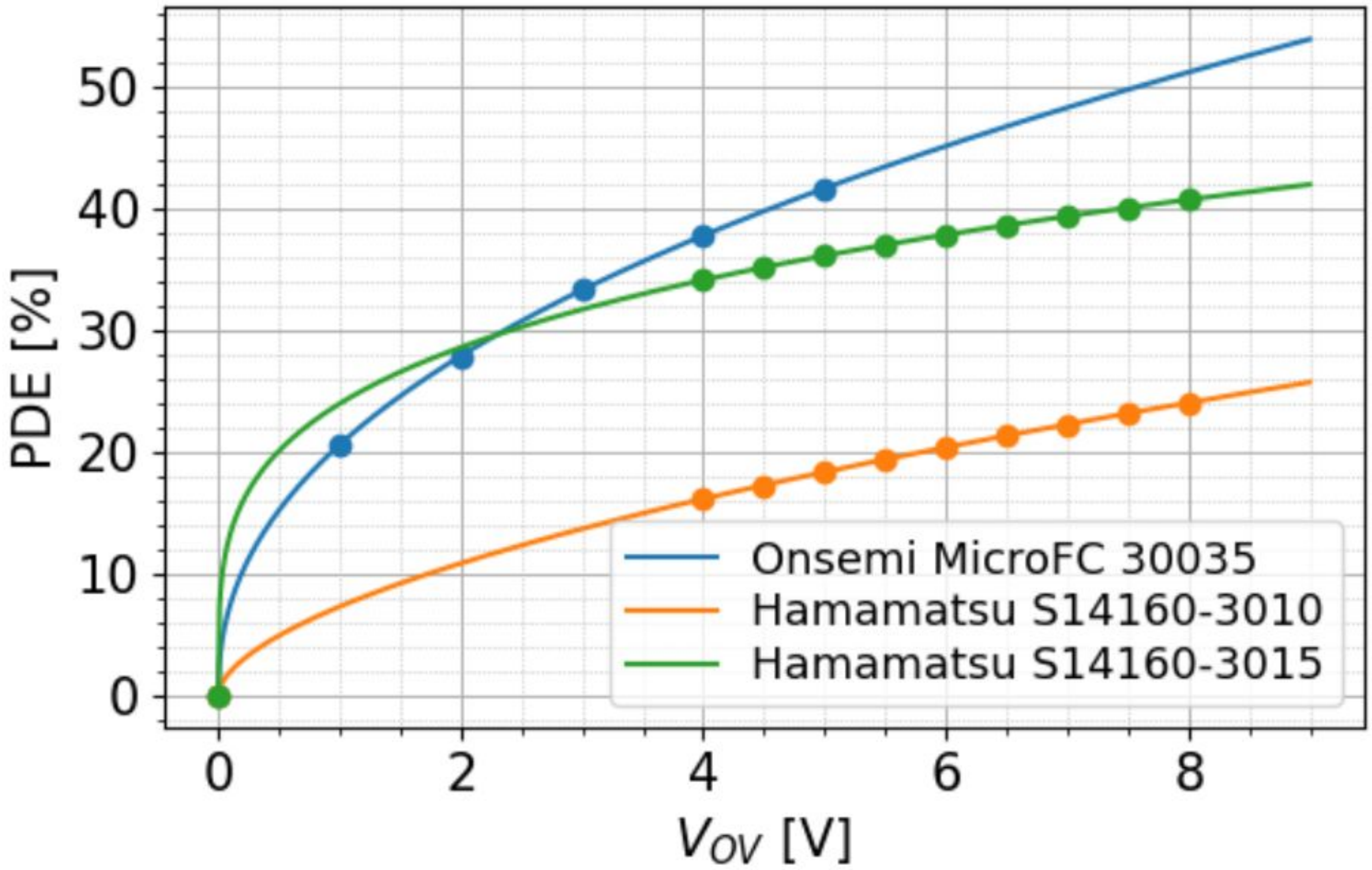
SiPM Characteristics

Photon Detection Efficiency (PDE) per Wavelength



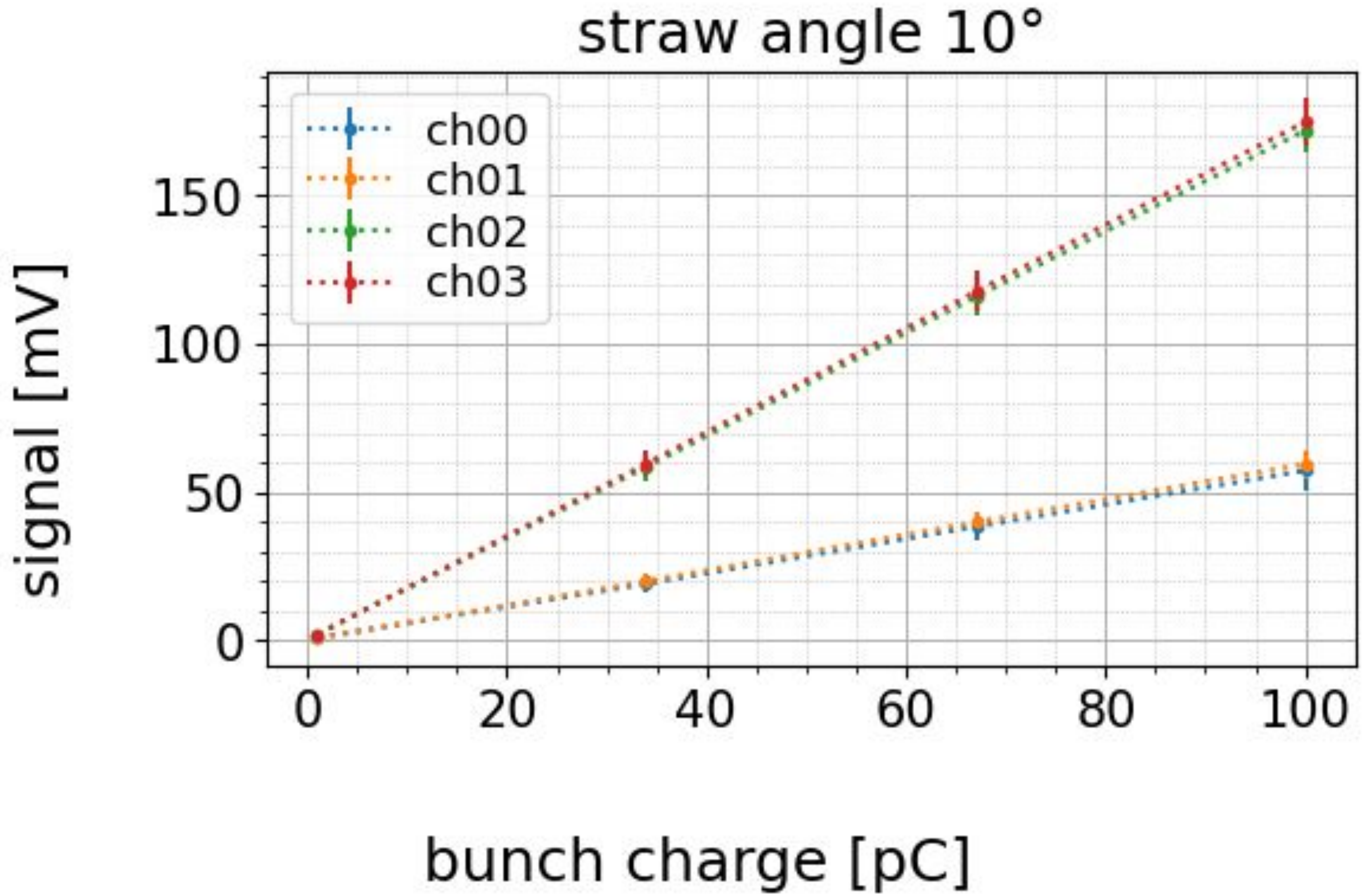
SiPM Characteristics

Photon Detection Efficiency (PDE) per Overvoltage



SiPM Characteristics

ARES SiPM Comparison



LED Characteristics

Working Principle

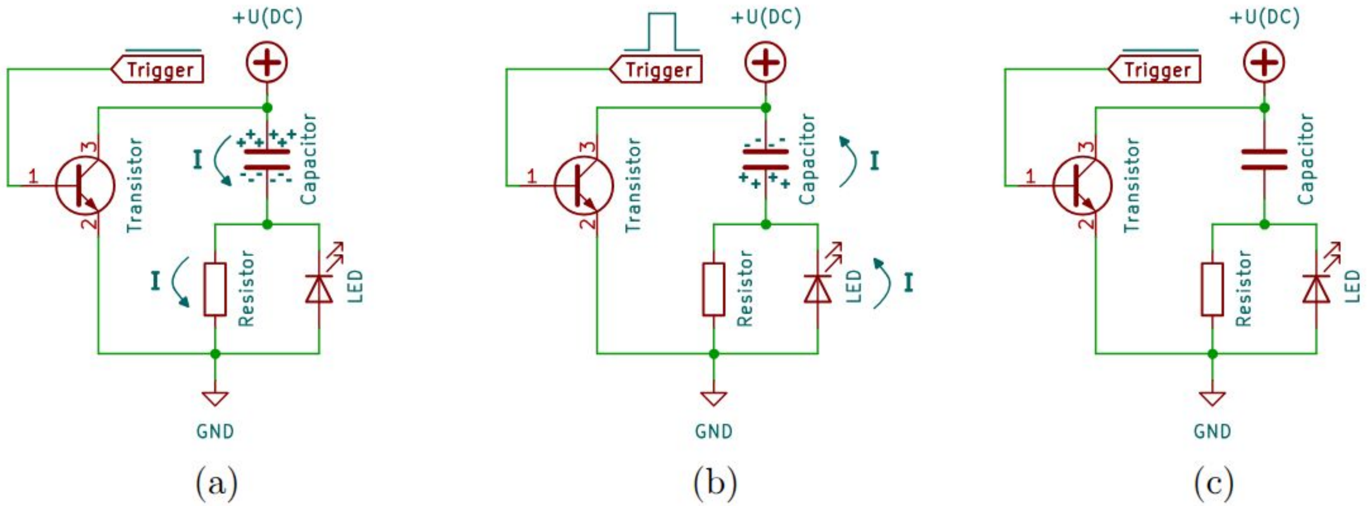


Figure 4.7: An LED in reverse is placed parallel to a resistor and in series to a capacitor and a positive voltage supply $+U_{\mathrm{DC}}$. In parallel to that, a transistor is used to pull $+U$ to ground (GND) when a trigger occurs. (a) At first, when the power supply is turned on and the transistor is off, a current flows from $+U_{\mathrm{DC}}$ via the resistor to GND and charging the capacitor. (b) When a trigger causes the transistor to switch through which pulls $+U_{\mathrm{DC}}$ to GND, a discharge of the capacitor takes place. The potential on the cathode side of the LED changes to $-U_{\mathrm{DC}}$ as a consequence of the change of potential on the opposite end of the charged capacitor. This creates a current flow in the opposite direction, causing the LED to emit light. (c) When the capacitor is discharged or the transistor is closed, no reverse current is flowing, and the LED stops lighting up. Afterwards, the cycle repeats with charging the capacitor.

LED Characteristics

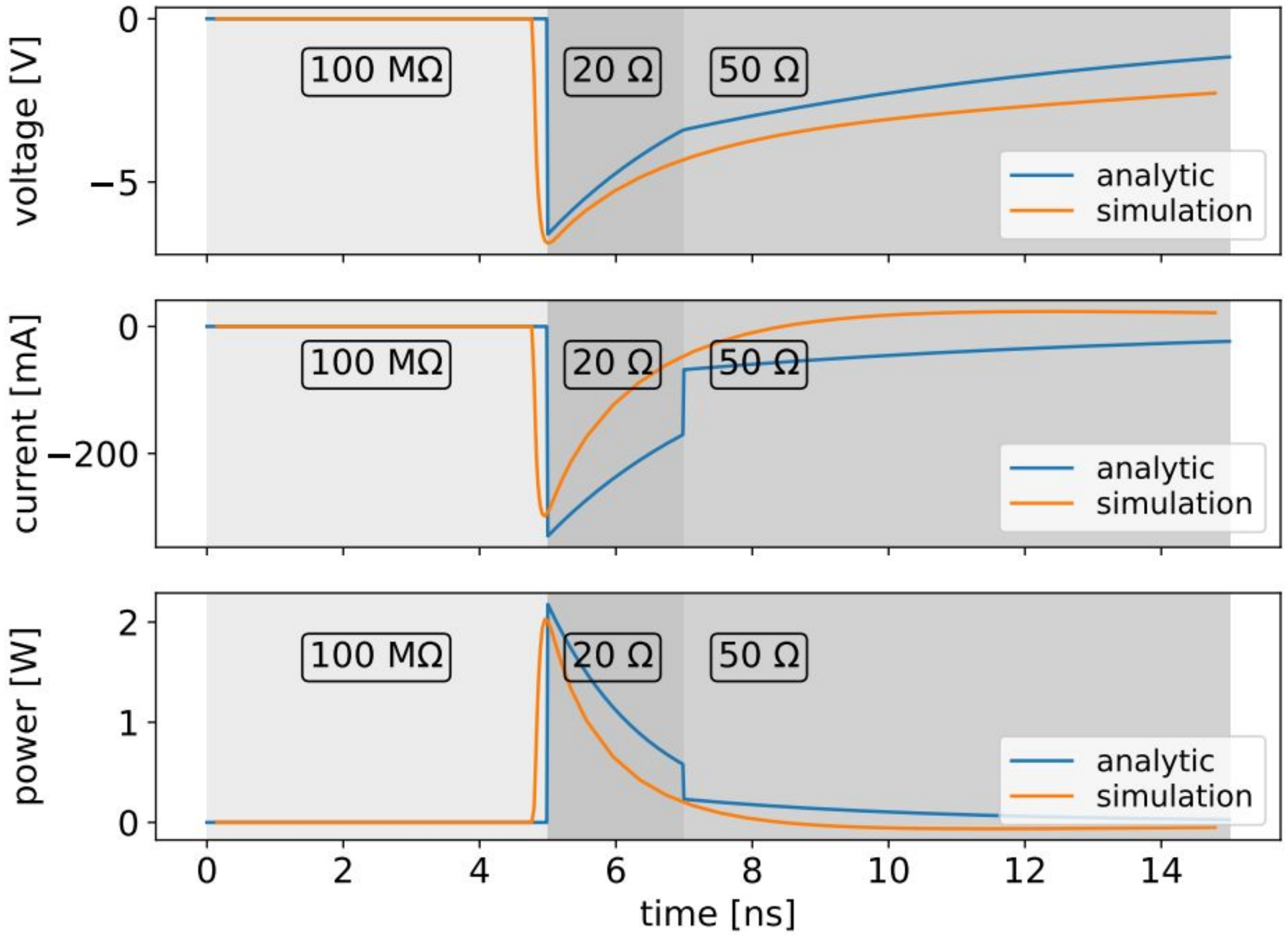
Some Formulars

$$P(t) = U(t) \times I(t) \approx \frac{1}{R} \times U(t)^2 \quad | \quad I(t) \approx \frac{U(t)}{R}$$

$$U(t) = \begin{cases} U_0 \exp[-t/(CR_{\text{transistor}})] & \in \quad [U_\text{D}, U_0) \\ U_\text{D} \exp[-t/(CR_{\text{resistor}})] & \in \quad [0, U_\text{D}) \end{cases}$$

LED Characteristics

Analytical Predictions and Simulation



$$U(t) = \begin{cases} U_0 \exp[-t/(CR_{\text{transistor}})] & \in \quad [U_D, U_0) \\ U_D \exp[-t/(CR_{\text{resistor}})] & \in \quad [0, U_D) \end{cases}$$

$$I(t) \approx \frac{U(t)}{R}$$

$$P(t) = U(t) \times I(t) \approx \frac{1}{R} \times U(t)^2$$