FLASHGuard

How to Enable Revolutionary Cancer Treatment With a Particle Physics Device

Gonçalo Roriz

Supervisors: Prof. Pedro Assis, Gonçalo Ribeiro

IST-PhysFront'25, 10 September 2025; Lisbon, Portugal

Cancer: The Biggest Hurdle in Modern Medicine

Up to a quarter of Europeans will develop cancer:

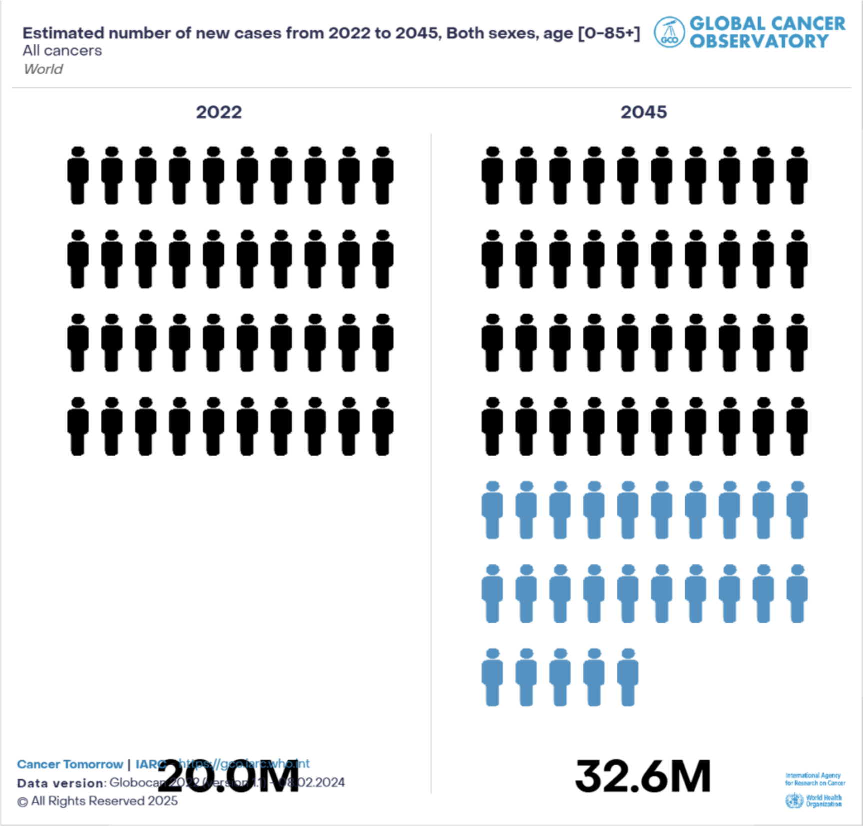
Sep 29, 2022, 12:32 PM

https://www.who.int/europe/news-room/04-02-2020-up-to-a-quarter-of-europeans-will-develop-cancer-from-prevention-early-diagnosis-screening-and-treatment-to-palliative-care-countries-must-do-more

Statistics at a Glance: The Burden of Cancer in the United States

- Approximately 40.5% of men and women will be diagnosed with cancer at some point during their lifetimes (based on 2017–2019 data).
- In 2024, an estimated 14,910 children and adolescents ages 0 to 19 will be diagnosed with cancer and 1,590 will die of the disease.
- The rate of new cases of cancer (cancer incidence) is 440.5 per 100,000 men and women per year (based on 2017–2021 cases).
- The cancer death rate (cancer mortality) is 146.0 per 100,000 men and women per year (based on 2018–2022 deaths).

https://www.cancer.gov/about-cancer/understanding/statistics



Radiotherapy

Review > Int J Med Sci. 2012;9(3):193-9. doi: 10.7150/ijms.3635. Epub 2012 Feb 27.

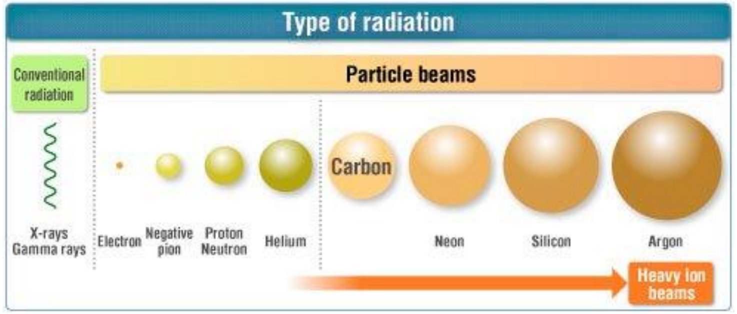
Cancer and radiation therapy: current advances and future directions

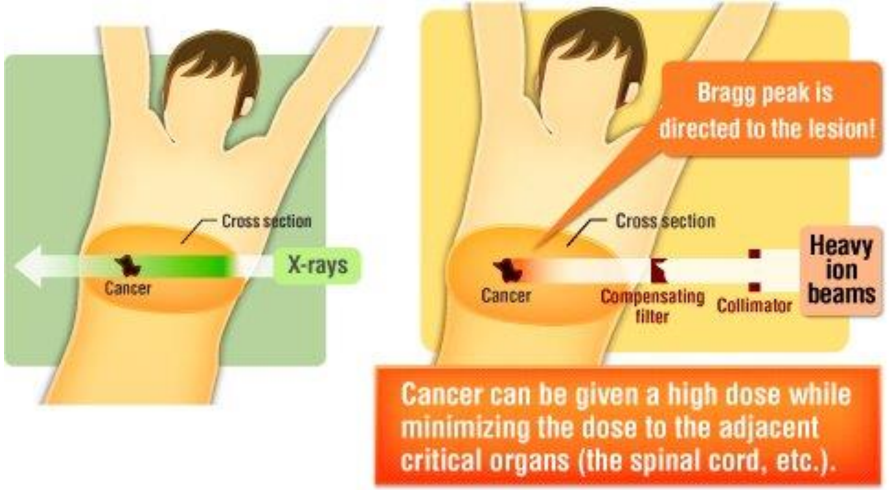
Rajamanickam Baskar [1], Kuo Ann Lee, Richard Yeo, Kheng-Wei Yeoh

Abstract

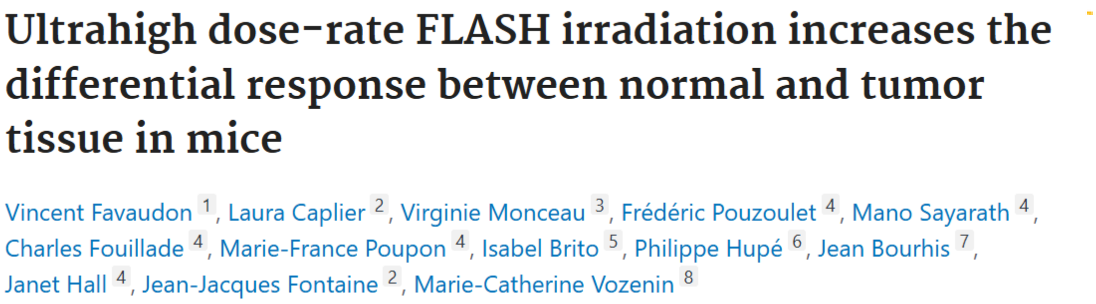
In recent years remarkable progress has been made towards the understanding of proposed hallmarks of cancer development and treatment. However with its increasing incidence, the clinical management of cancer continues to be a challenge for the 21st century. Treatment modalities comprise of radiation therapy, surgery, chemotherapy, immunotherapy and hormonal therapy. Radiation therapy remains an important component of cancer treatment with approximately 50% of all cancer patients receiving radiation therapy during their course of illness; it contributes towards 40% of curative treatment for cancer. The main goal of radiation therapy is to deprive cancer cells of their multiplication (cell division) potential. Celebrating a century of advances since Marie Curie won her second Nobel Prize for her research into radium, 2011 has been designated the Year of Radiation therapy in the UK. Over the last 100 years, ongoing advances in the techniques of radiation treatment and progress made in understanding the biology of cancer cell responses to radiation will endeavor to increase the survival and reduce treatment side effects for cancer patients. In this review, principles, application and advances in radiation therapy with their biological end points are discussed.

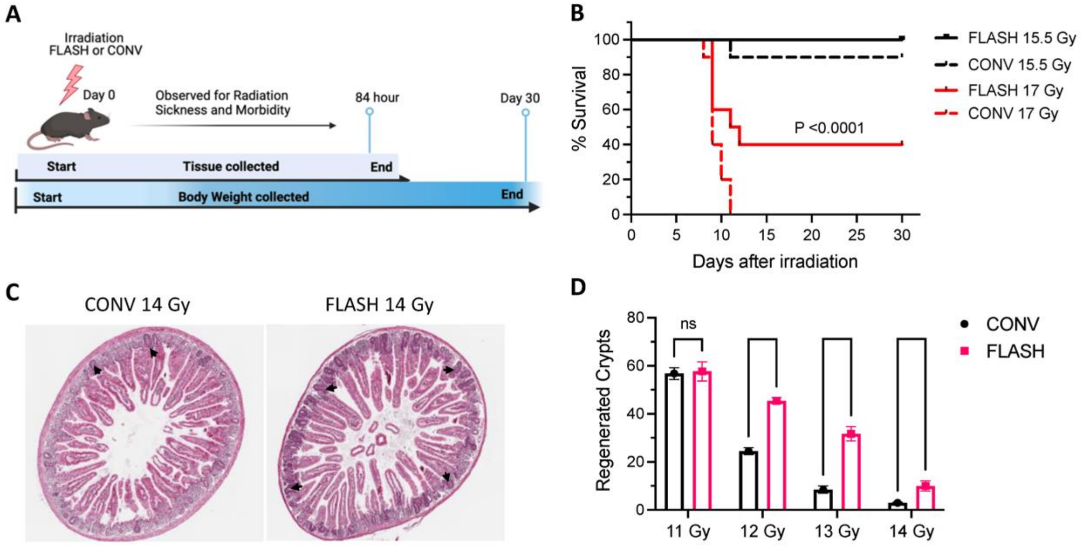
Key words: Cancer, Radiation therapy, Linear energy transfer, Cell death.



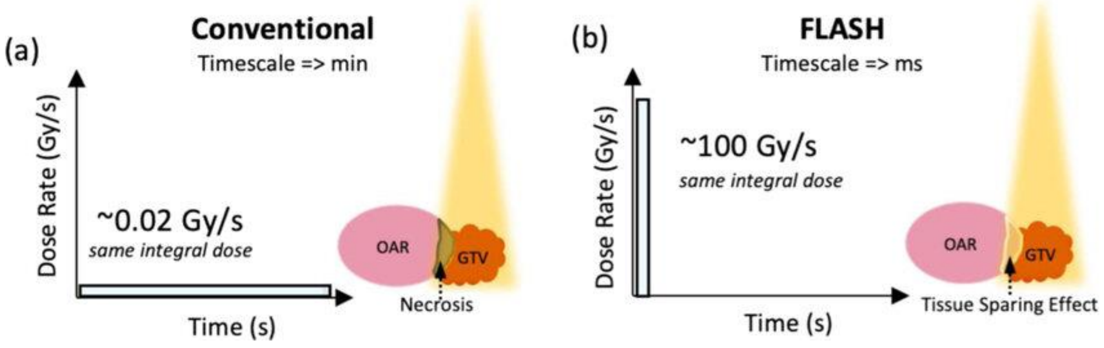


FLASH Radiotherapy





Valdés Zayas, Anet, et al. "Independent reproduction of the FLASH effect on the gastrointestinal tract: a multi-institutional comparative study." *Cancers* 15.7 (2023): 2121.



Hachadorian, R., E. Cascio, and J. Schuemann. "Increased flexibility and efficiency of a double-scattering FLASH proton beamline configuration for in vivo SOBP radiotherapy treatments." *Physics in Medicine & Biology* 68.15 (2023): 15NT01.

From: https://www.theryq-alcen.com/technologies-in-radiation-therapy/flash-radiation-therapy/

The Beam Monitoring Problem

Prof. Raphaël Moeckli

CHUV

UNIL | Université de Lausanne

"For the clinical transfer of FLASH-RT, a monitoring device capable of real-time output measurement and beam control is necessary."

Gonçalves Jorge P, Geyer R, Kinj R, et al. Machine stability and dosimetry for ultra-high dose rate FLASH radiotherapy human clinical protocol. J Appl Clin Med Phys. 2025;e70102. **April 2025**

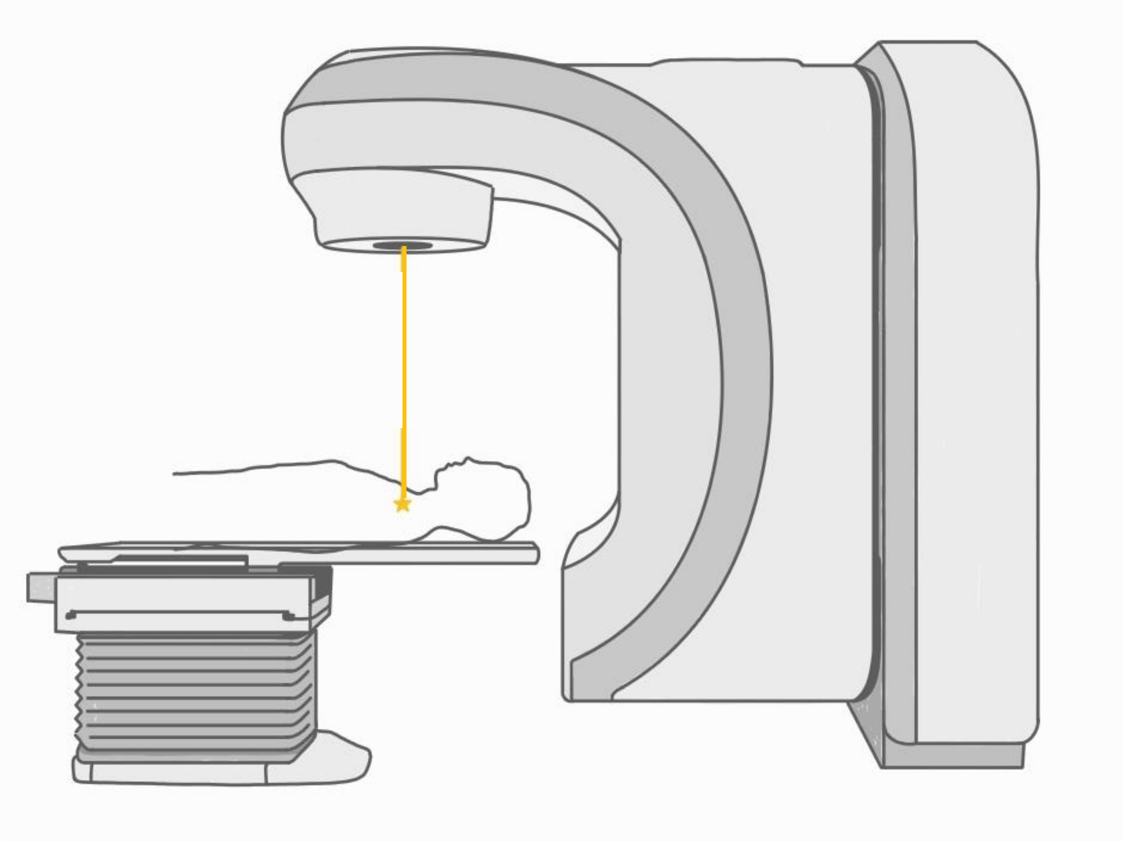
The Solution: FLASHGuard

FLASHGuard is a patent pending *beam monitoring system designed for Ultra-High Dose Rate beams*, enabling the safe implementation and clinical translation of FLASH-RT using the Cherenkov effect.

The device consists of:

- A **radiator** which does not impact the beam significantly;
- A fast photodetector which gives feedback to the machine in sub-microsecond scale.

Radiotherapy treatments



Scheme of current RT machine and beam

Our concept

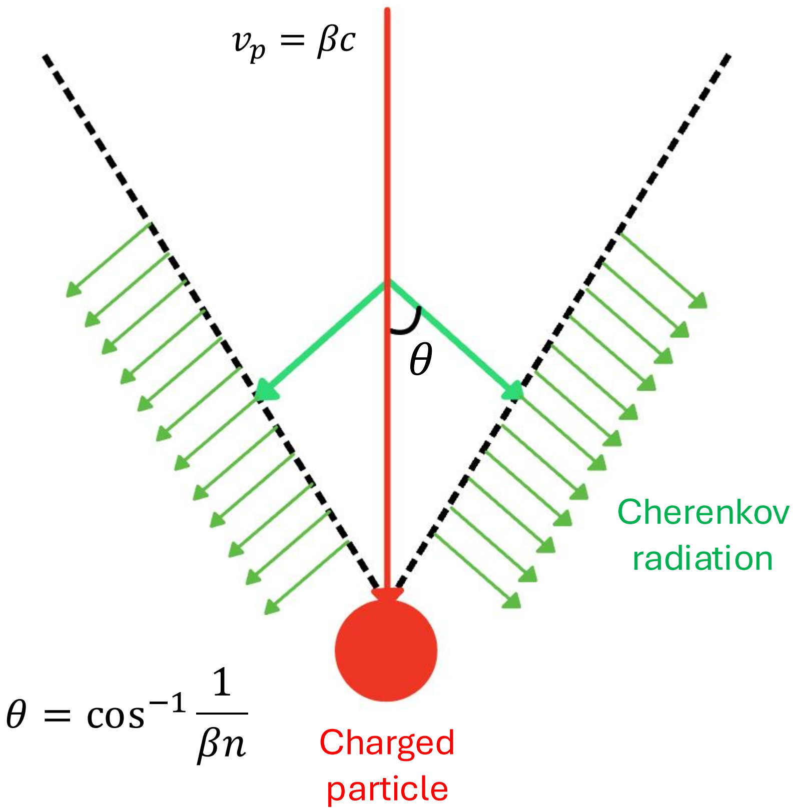
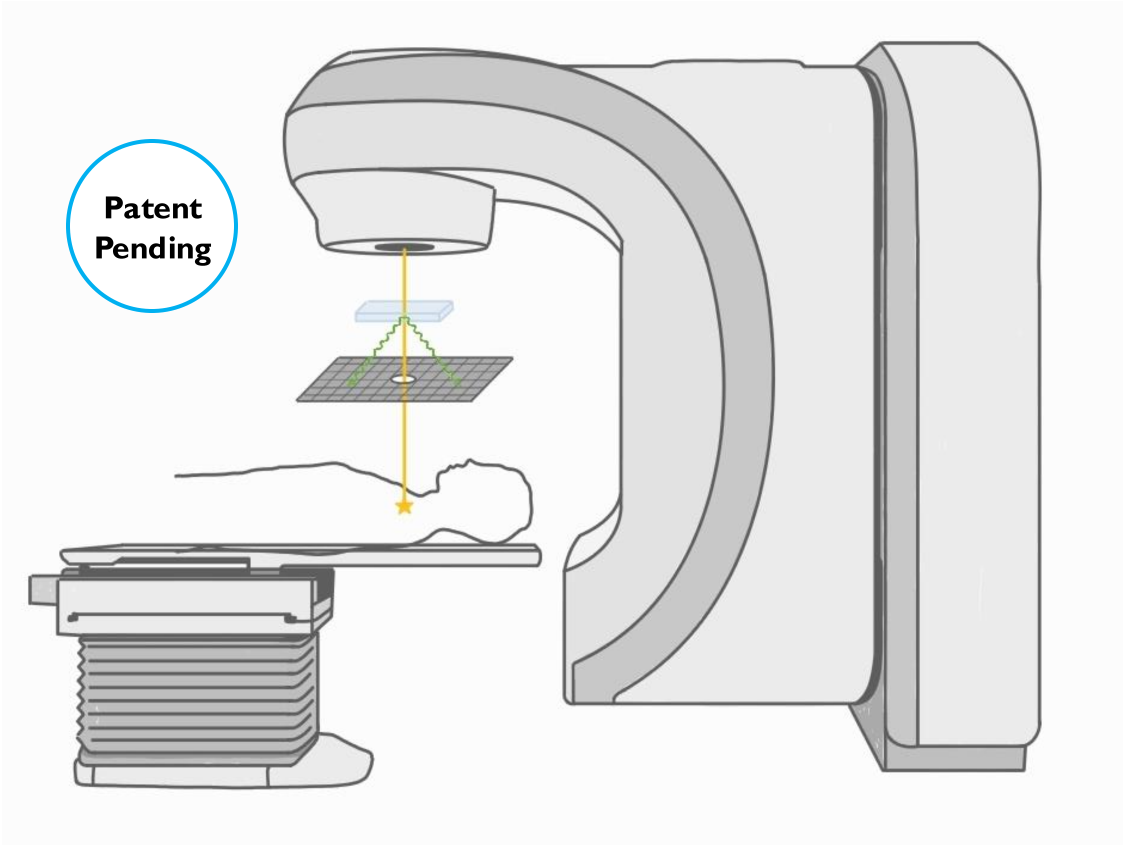


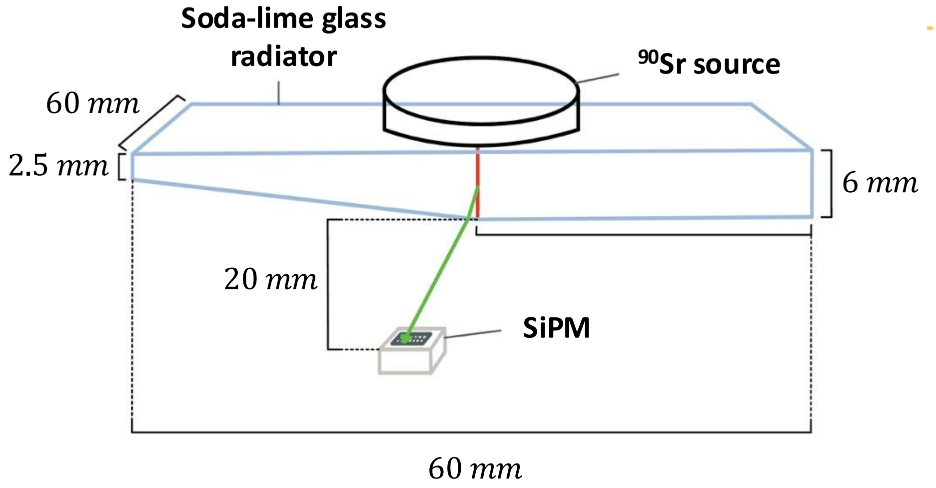
Diagram of Cherenkov photon emission

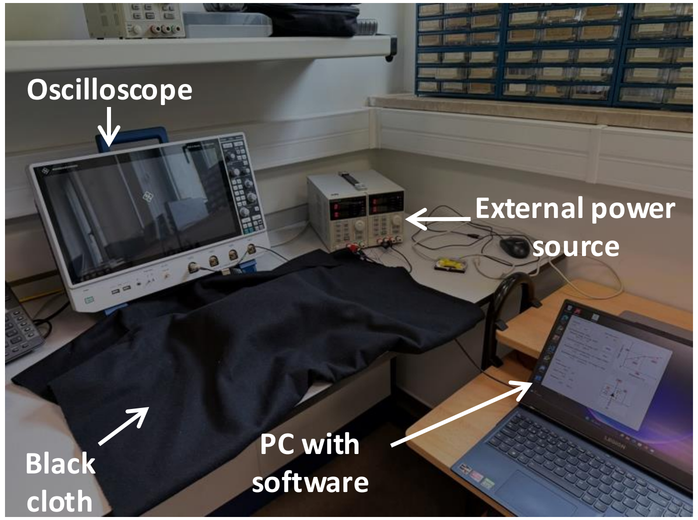


Possible prototype usage in FLASH RT treatments

Unpublished results: please do not disclose.

Proof of Concept: Setup

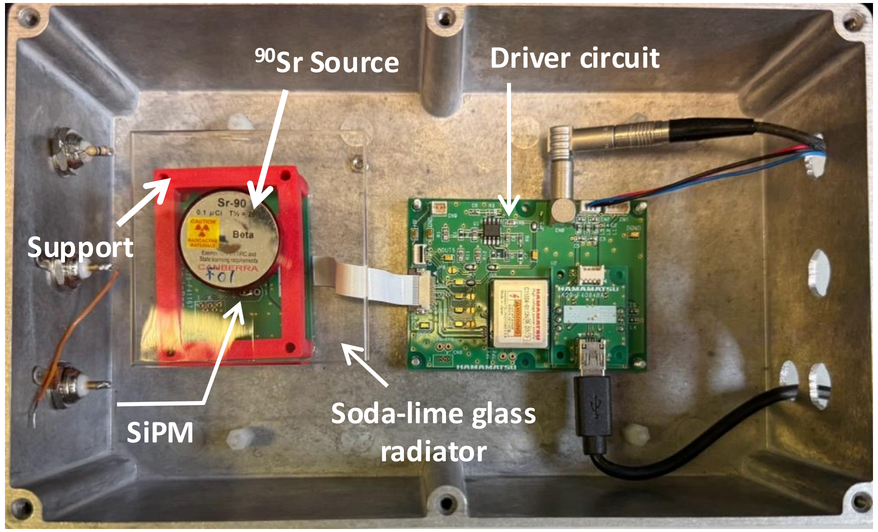




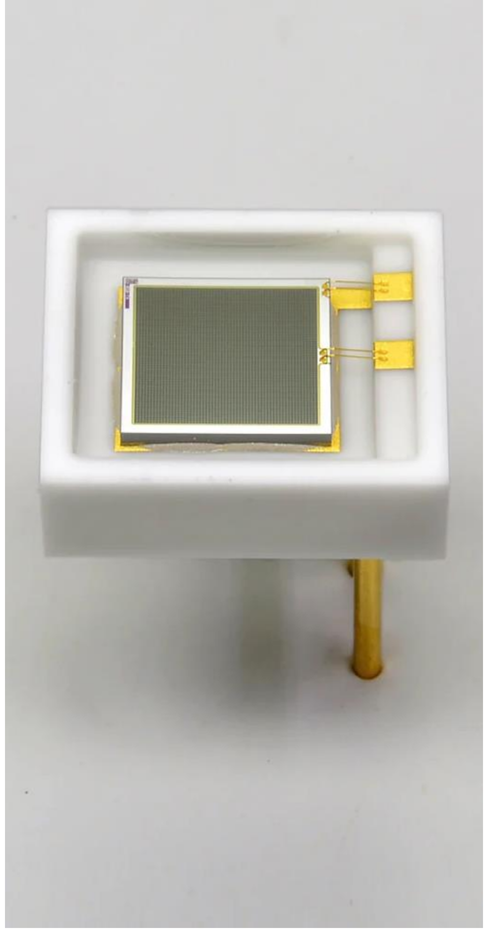
^{90}Sr source to emit e^- with enough energy to produce Cherenkov photons

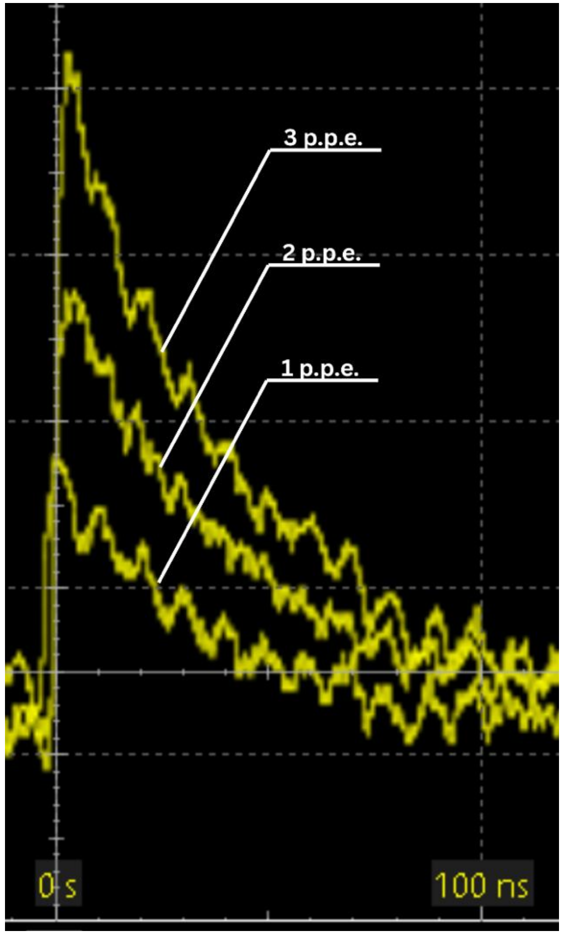
Soda-lime glass radiator with chamfer to reduce total internal reflection of light, while protecting the photodetector from the emitted electrons

SiPM for fast detection of the emitted photons



Silicon Photomultiplier





SiPM consist of avalanche photo diodes connected in parallel. They present:

- **high** gain;
- **sub-microsecond** rise-fall time;
- **thermal** noise;
- a cost-effective option :)

Conclusions and Future Work

Advisory Committee:

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HITRIplus
Heavy Ion Therapy Research Integration

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PhD

DARTMOUTH

DOSEOPTICS

Lab2Market – programa de inovação do Técnico premeia tecnologia de apoio à radioterapia

5 Junho

Projeto FLASHGuard monitoriza feixes utilizados em tratamentos oncológicos, reforçando a segurança dos pacientes ao longo de todo o procedimento.

FLASHGuard vence 9.ª edição do programa Lab2Market com tecnologia inovadora para tratamentos oncológicos

9 de Junho, 2025

Next Step: hospital testing of a functional device in FLASH Radiotherapy conditions

FLASHGuard: How to Revolutionise Cancer Treatment With a Prototype

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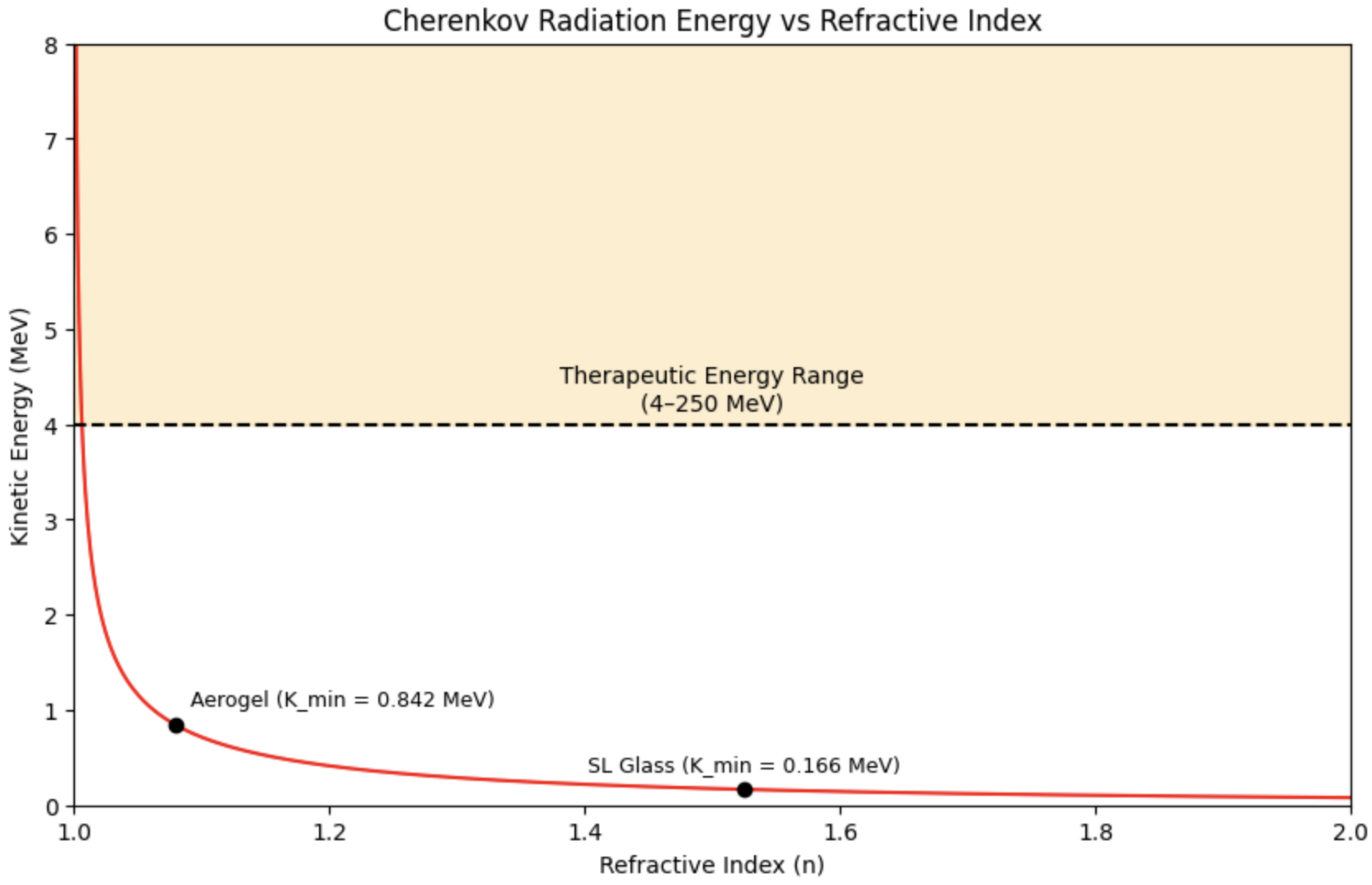
Current Solutions vs FLASHGuard

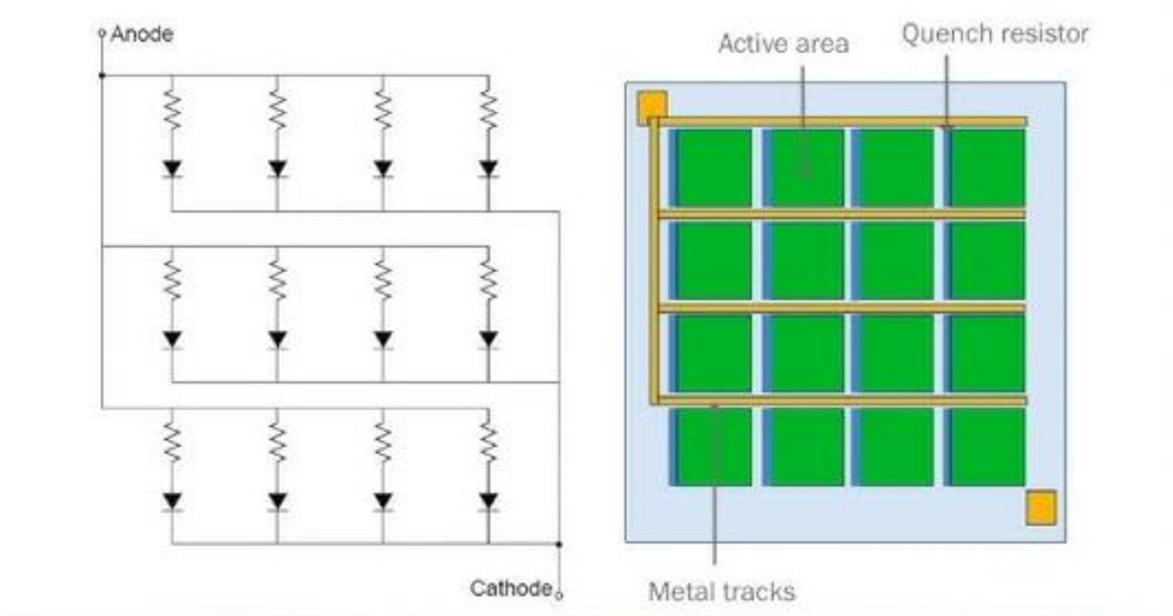
	Standard: Ionization Chambers	Integrated Current Transformers (ICTs)	FLASHGuard
Absence of saturation effects	No	Yes	**Yes**
Temporal resolution	10-200 μs	Sub-μs	**Sub-μs**
Spatial resolution	Several mm	N/A	**TBD**
Radiation hardness	Yes	Yes	**Radiator is radiation hard**
Independent from beam position	Yes	No	**Yes**

Romano F; Bailat C; Jorge PG; Lerch MLF; Darafsheh A. Ultra-high dose rate dosimetry: Challenges and opportunities for flash radiation therapy. Med Phys, 49:4912–4932, 2022.

Cherenkov Emission Threshold for Electrons



The Detector: how SiPM's work and their architecture



From: https://www.youtube.com/watch?v=Oc-JEjaTHGs

SiPM's operate using the avalanche principle:

- Initially the SiPM is externally biased, with each APD operating in Geiger mode;
- If a photon is absorbed, a charge carrier is created, triggering an avalanche in the gain region (the avalanche can produce 10^5 - 10^6 carriers);
- The quenching resistor then restores the APD back to Geiger mode

Using the SiPM's, we can count the **number of photons** emitted by the Cherenkov effect

SiPM Properties

- **Dark Count Rate** (DCR) is a form of thermal noise presenting a Poisson distribution

$$P_X(k) = \frac{\mu^k \cdot e^{-\mu}}{k!}$$

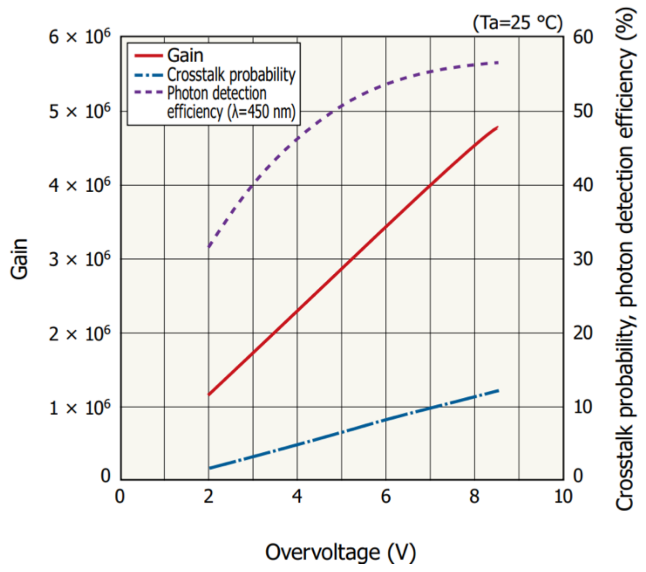
- **Gain (M)** is defined as the ratio of the charge of the pulse generated by a single-pixel detection event (Q) and the elementary charge (q)

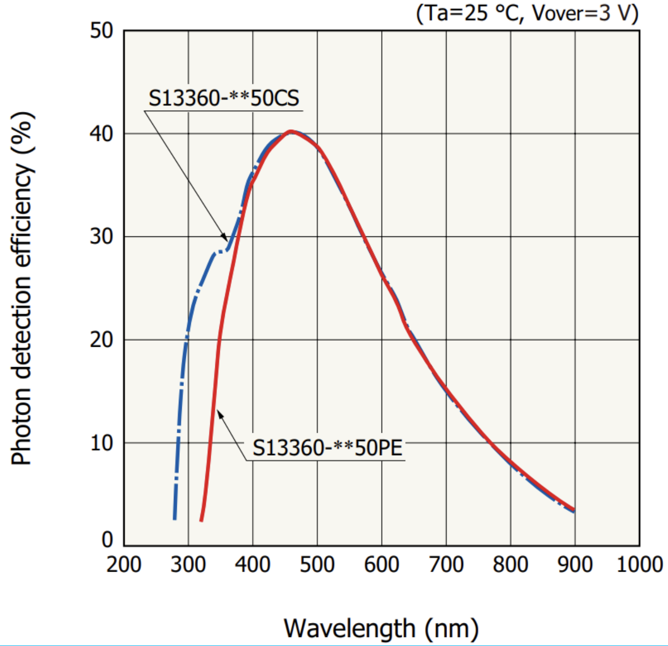
$$M = \frac{Q}{q} = \frac{C \times (V_R - V_{BR})}{q}$$

- **Photon Detection Efficiency (PDE)** is directly proportional to the fill factor (Fg), quantum efficiency (QE) and avalanche probability (Pa)

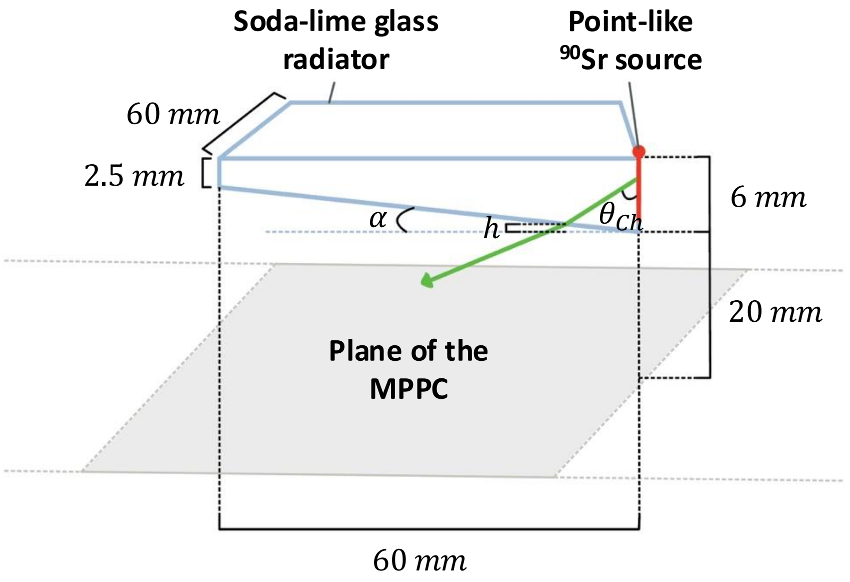
$$PDE(\lambda, T) = Fg \times QE(\lambda, T) \times Pa(T, V_{OV})$$

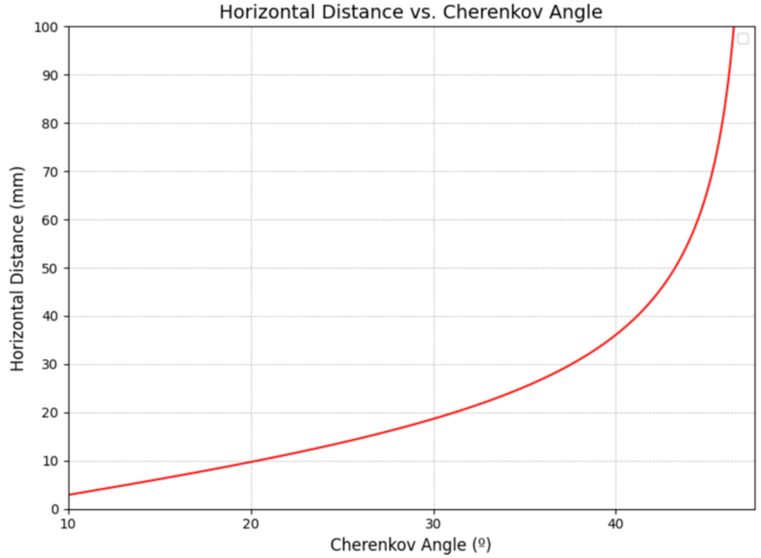
$V_{ov} = V_{op} - V_{BR}$





Horizontal Distance Travelled by Photons





Horizontal distance travelled inside the radiator:

$$d_i = \frac{h}{tg(\alpha)}, \quad h = \frac{5.84 \cdot tg(\alpha) \cdot tg(\theta_{CH})}{tg(\alpha) \cdot tg(\theta_{CH}) + 1}$$

Horizontal distance travelled outside the radiator:

$$d_o = (19.92 + h) \cdot tg(R),$$

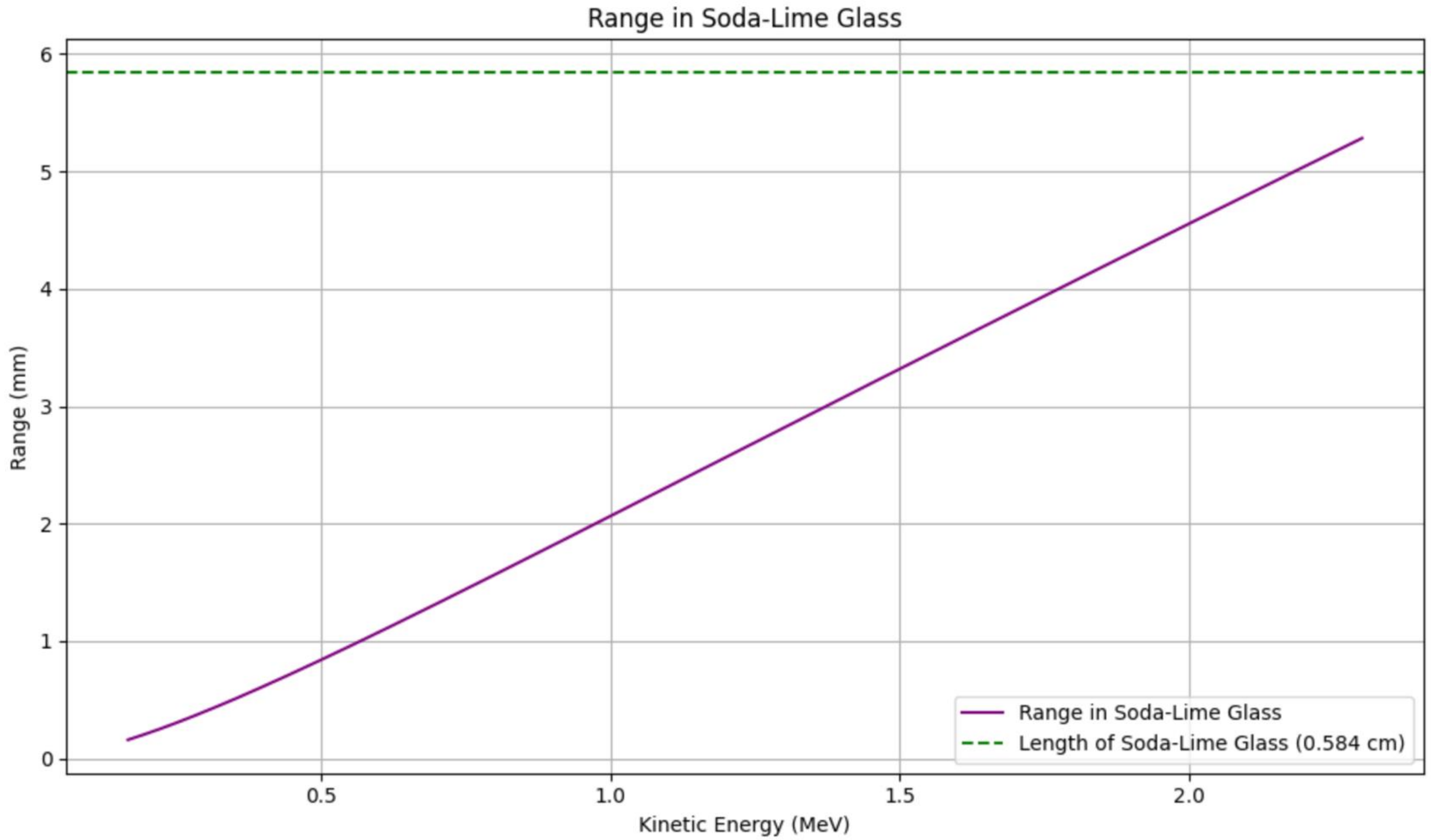
$$R = arcsin(1.55 \cdot sin(\theta_{CH} - \alpha))$$

Total horizontal distance travelled:

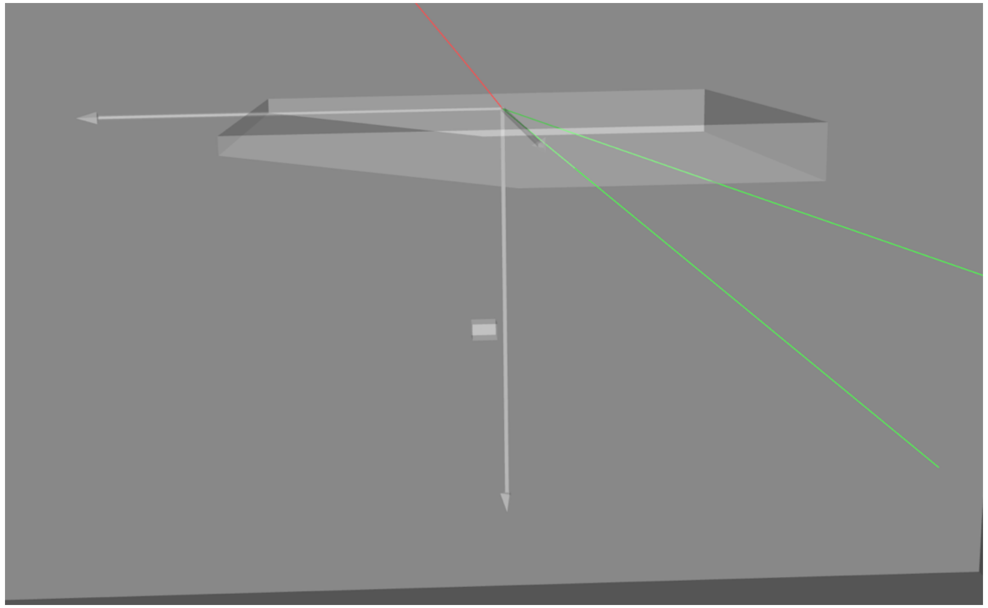
$$D = d_i + d_o = \frac{5.84 \cdot tg(\theta_{CH})}{tg(\alpha) \cdot tg(\theta_{CH}) + 1} + (19.92 + h) \cdot$$

$$\cdot tg(arcsin(1.55 \cdot sin(\theta_{CH} - \alpha)))$$

Range of Electrons in Soda-Lime Glass



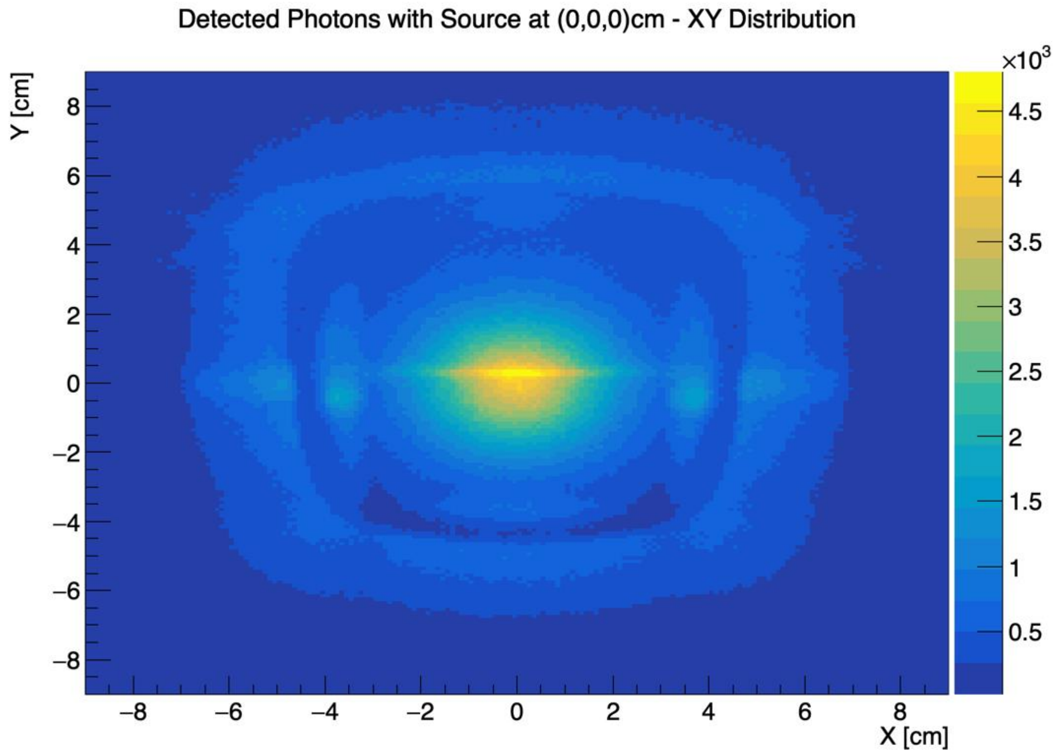
Geant4 Simulation - Overview

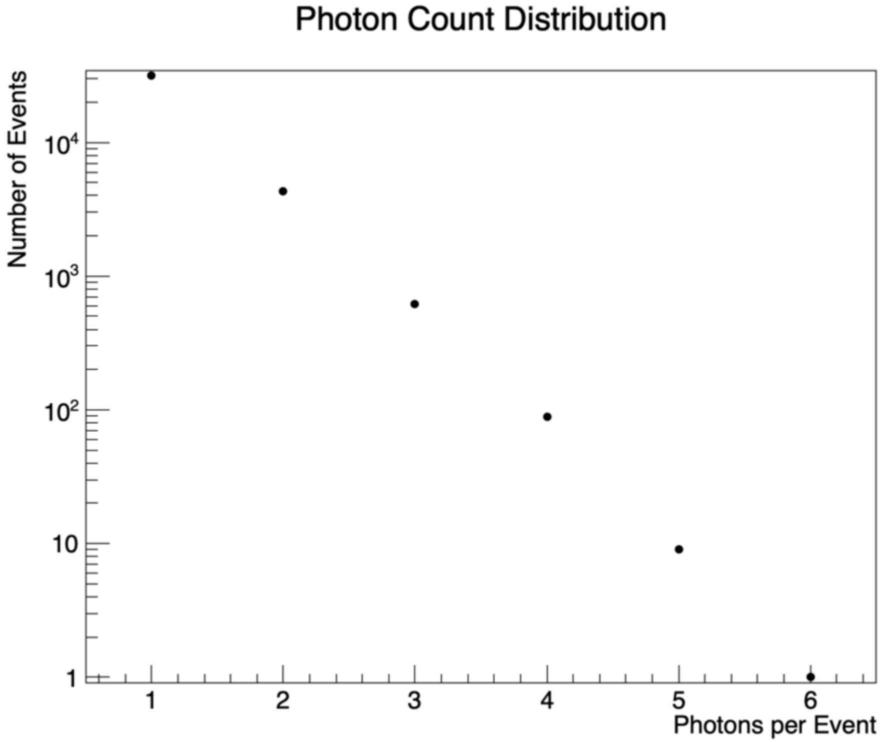


Experimental setup modelled and tested with:
- ^{90}Sr source as a point-like emitter;
- Photodetector assumed to collect all photons.

- Runs with source at varying positions on top of the radiator in order to determine best source placement and $3.0 \times 3.0\, mm^2$ detector area with highest photon detection;
- Run with source and detector at preferred position.

Geant4 Simulation - Results



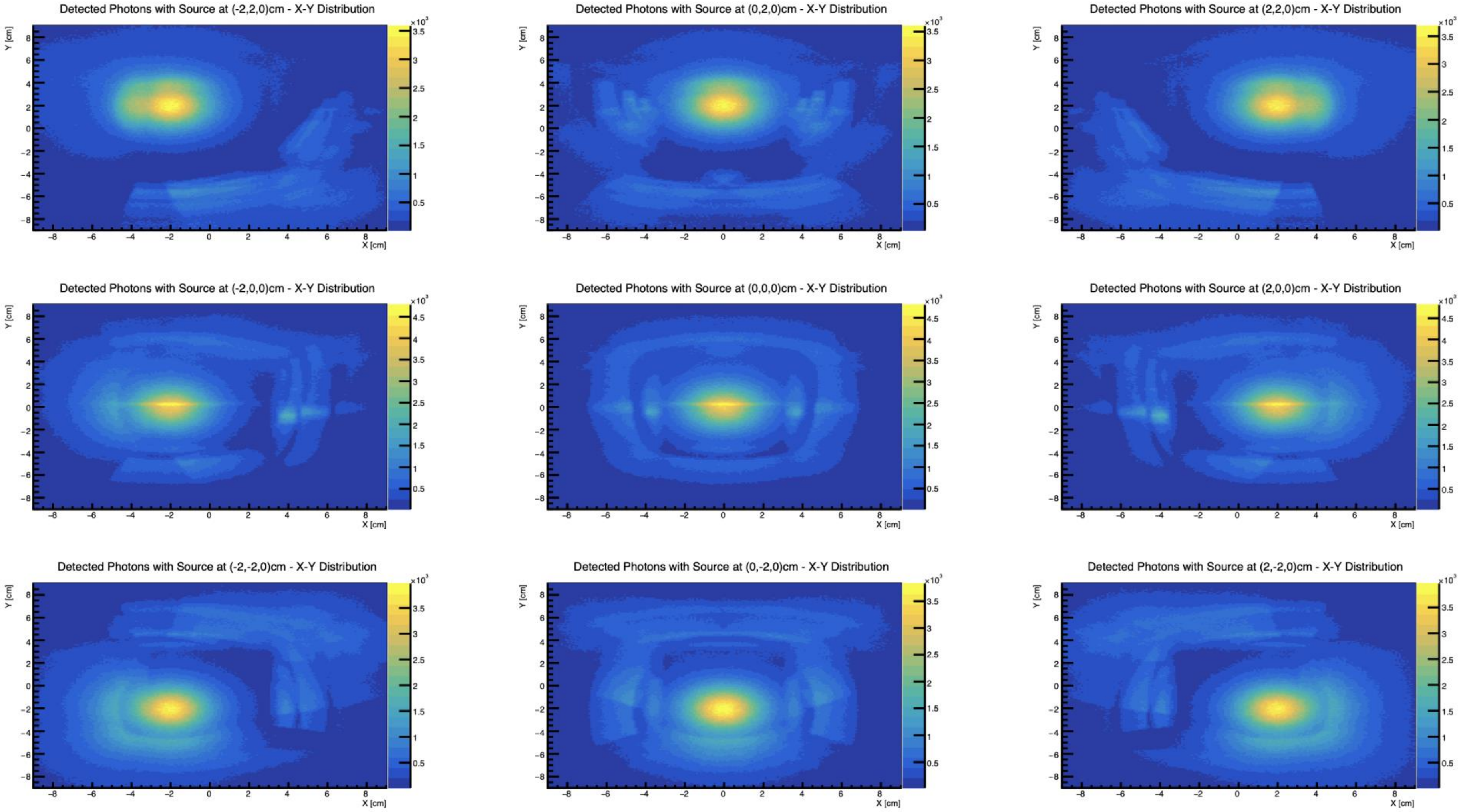


Best positions for maximum photon incidence on SiPM:

Source: *(0,0,0) mm*

SiPM: *[-2, 1] x [1, 4] mm*

Geant4 Simulation

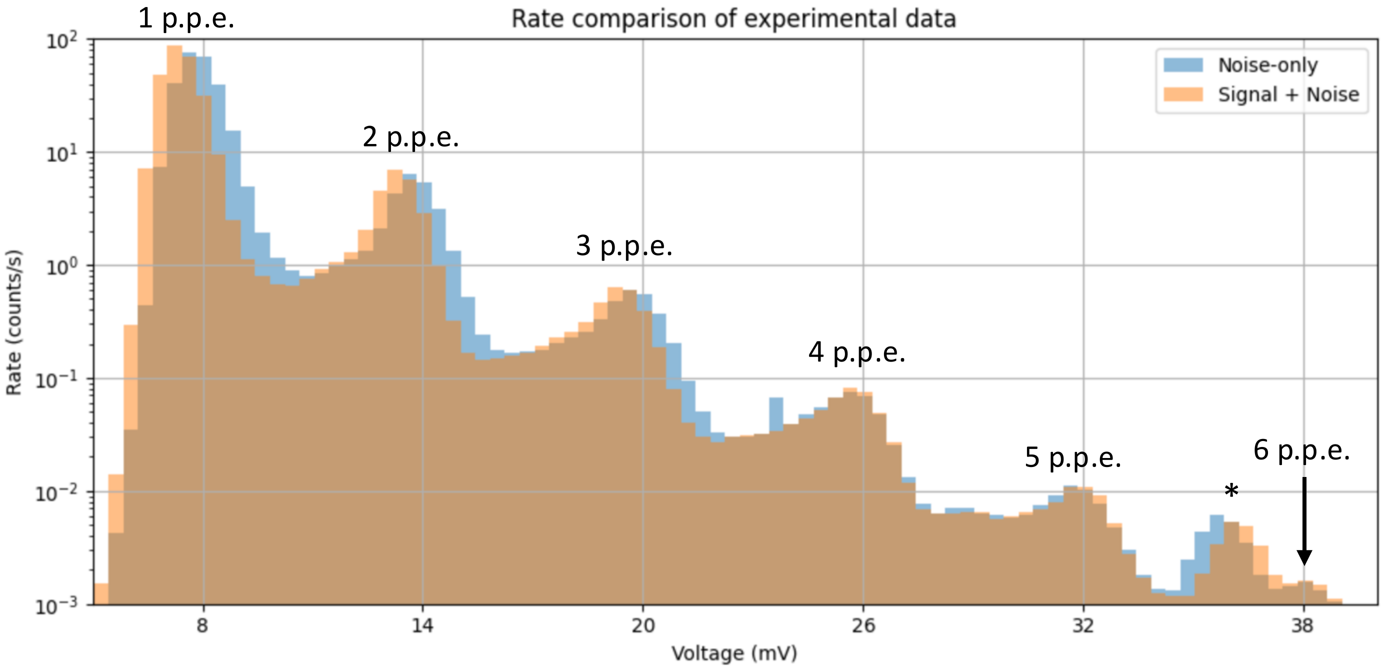


Positions for maximum photon incidence on photodetector:

Source: *(0,0,0) mm*

SiPM: *[-2, 1] x [1, 4] mm*

Experimental Work and Results

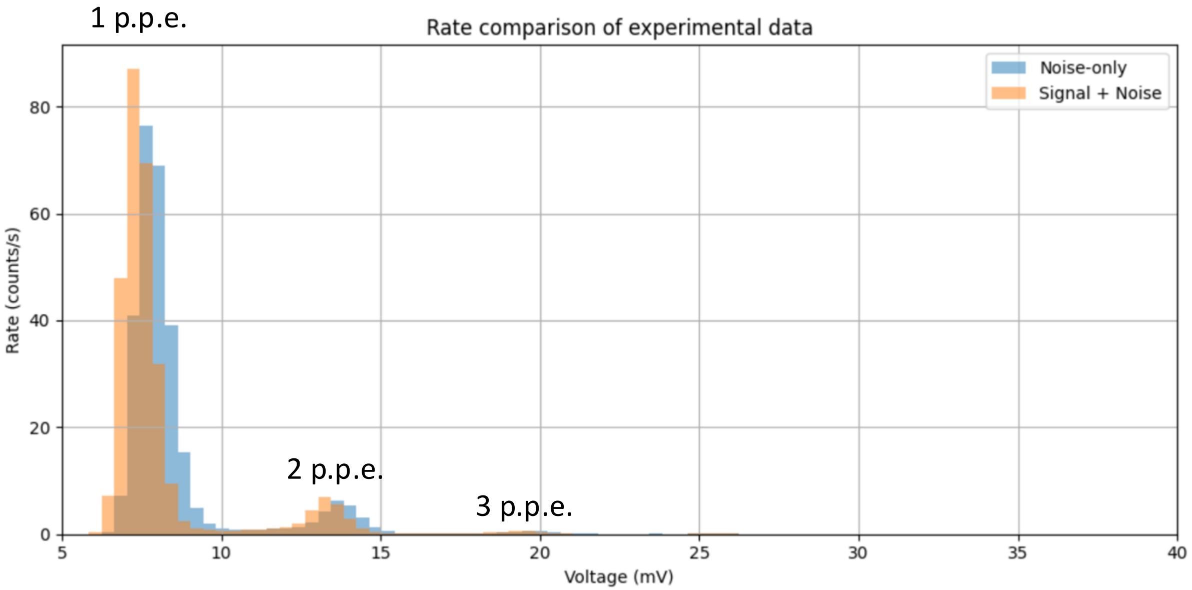


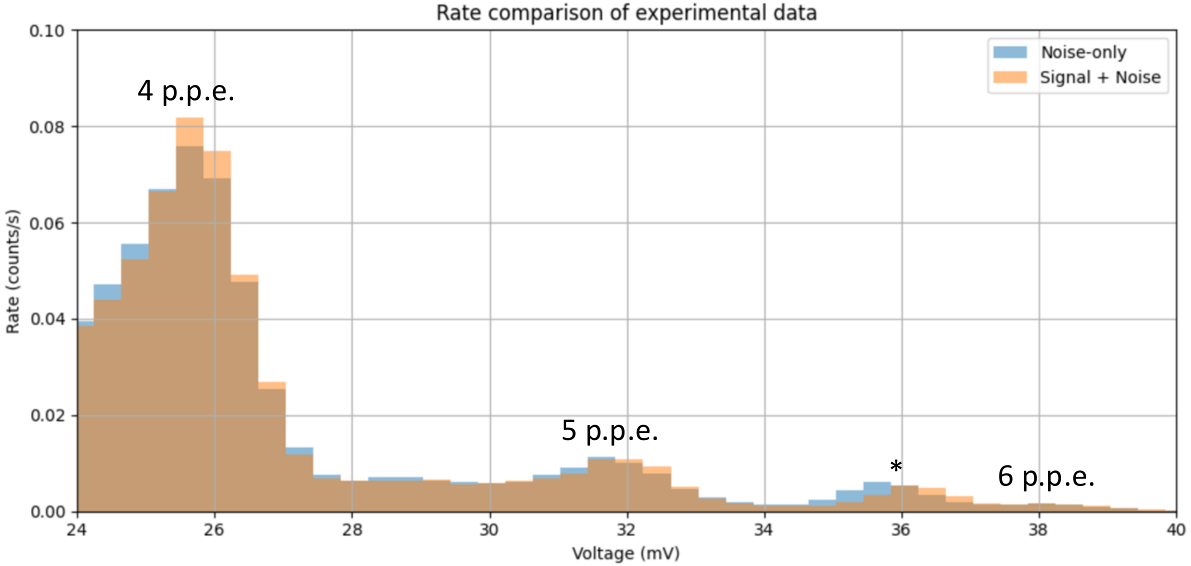
Gaussian fit parameters	Noise	Signal + Noise
Peak 1 (1 p.p.e.)	$A = (78.5149 \pm 3.3006)\ cps$ $\mu = (7.8155 \pm 0.0250)\ mV$ $\sigma = (0.5089 \pm 0.0323)\ mV$ $\chi^2/\text{dof} = 19452.11$	$A = (87.2823 \pm 0.6685)\ cps$ $\mu = (7.3842 \pm 0.0162)\ mV$ $\sigma = (0.5451 \pm 0.0126)\ mV$ $\chi^2/\text{dof} = 3397.01$
Peak 2 (2 p.p.e.)	$A = (6.2725 \pm 0.1503)\ cps$ $\mu = (13.6528 \pm 0.0250)\ mV$ $\sigma = (0.5818 \pm 0.0298)\ mV$ $\chi^2/\text{dof} = 725.26$	$A = (6.7856 \pm 0.1502)\ cps$ $\mu = (13.3883 \pm 0.0140)\ mV$ $\sigma = (0.5444 \pm 0.0159)\ mV$ $\chi^2/\text{dof} = 837.38$
Peak 3 (3 p.p.e.)	$A = (0.6068 \pm 0.0016)\ cps$ $\mu = (19.5779 \pm 0.0028)\ mV$ $\sigma = (0.7135 \pm 0.0047)\ mV$ $\chi^2/\text{dof} = 0.58$	$A = (0.6430 \pm 0.0034)\ cps$ $\mu = (19.4004 \pm 0.0050)\ mV$ $\sigma = (0.6655 \pm 0.0062)\ mV$ $\chi^2/\text{dof} = 6.72$
Peak 4 (4 p.p.e.)	$A = (0.0743 \pm 0.0018)\ cps$ $\mu = (25.8321 \pm 0.0647)\ mV$ $\sigma = (1.0417 \pm 0.1267)\ mV$ $\chi^2/\text{dof} = 6.22$	$A = (0.0825 \pm 0.0005)\ cps$ $\mu = (25.6860 \pm 0.0059)\ mV$ $\sigma = (0.7102 \pm 0.0098)\ mV$ $\chi^2/\text{dof} = 0.40$
Peak 5 (5 p.p.e.)	$A = (0.0111 \pm 0.0003)\ cps$ $\mu = (31.8365 \pm 0.0290)\ mV$ $\sigma = (0.7996 \pm 0.0567)\ mV$ $\chi^2/\text{dof} = 0.82$	$A = (0.0110 \pm 0.0003)\ cps$ $\mu = (31.8396 \pm 0.0343)\ mV$ $\sigma = (0.8402 \pm 0.0721)\ mV$ $\chi^2/\text{dof} = 1.17$
Peak 6 (6 p.p.e.)	$A = (0.0015 \pm 0.0001)\ cps$ $\mu = (37.8719 \pm 0.0521)\ mV$ $\sigma = (1.0240 \pm 0.0582)\ mV$ $\chi^2/\text{dof} = 0.52$	$A = (0.0016 \pm 0.0001)\ cps$ $\mu = (37.8606 \pm 0.0502)\ mV$ $\sigma = (0.9760 \pm 0.0456)\ mV$ $\chi^2/\text{dof} = 0.64$

Vertical scale	$10\ mV/Div$
Horizontal scale	$500\ ns/Div$
Sampling rate	$10\ GSa/s$
Trigger level	$4.68\ mV$
Time gate	$[-30,\ +80]\ ns$
Reverse bias (SiPM)	$56.67\ V$
AC Temperature	$20.5°C$

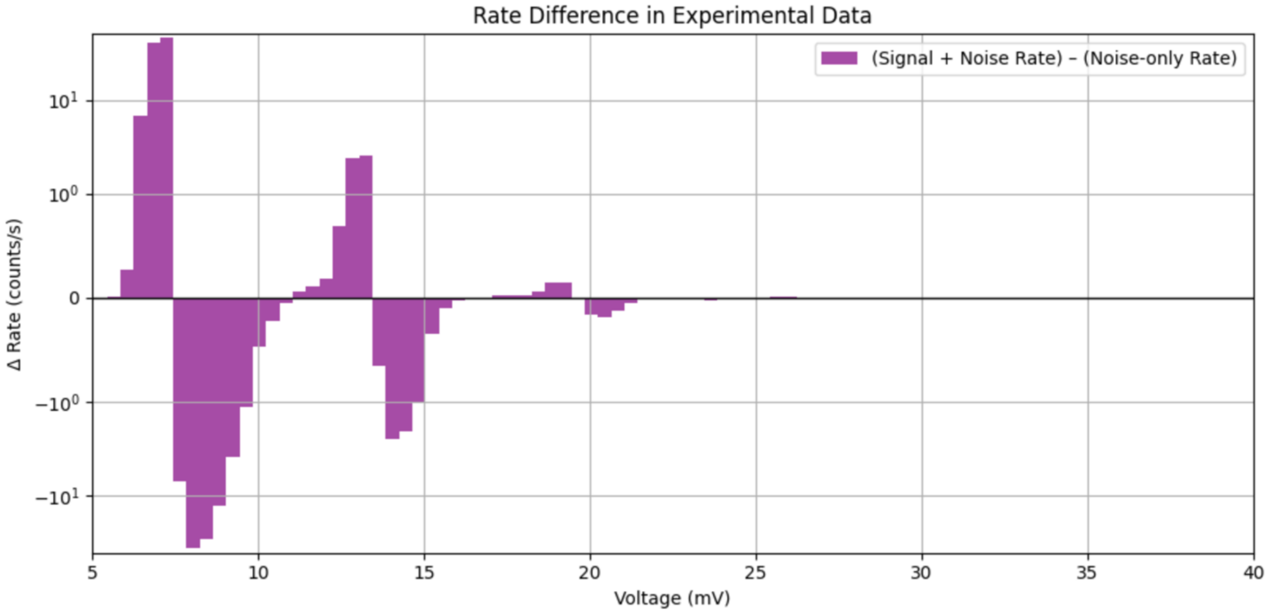
- Horizontal lag due to temperature-driven gain drift;
- Peak * due to superposition of previous peaks;
- Total difference in rate = *0.11 cps* -> expected due to oscilloscope saturation;
- Total rate for each peak determined by fitting Gaussians to each peak and determining their area.

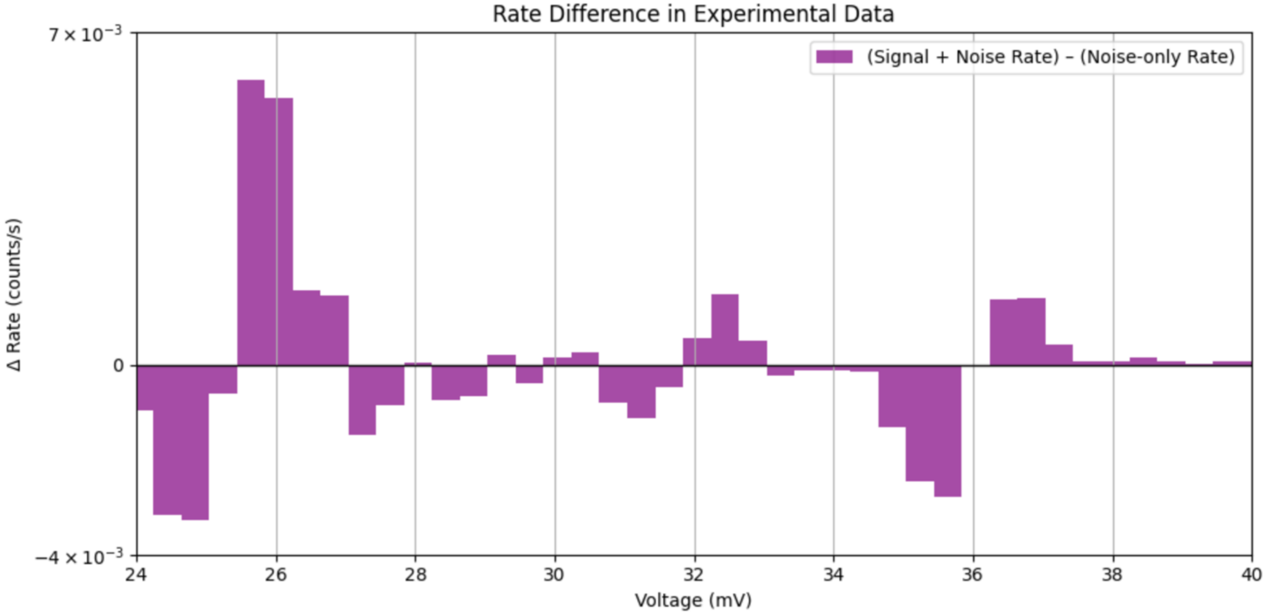
Experimental Work and Results



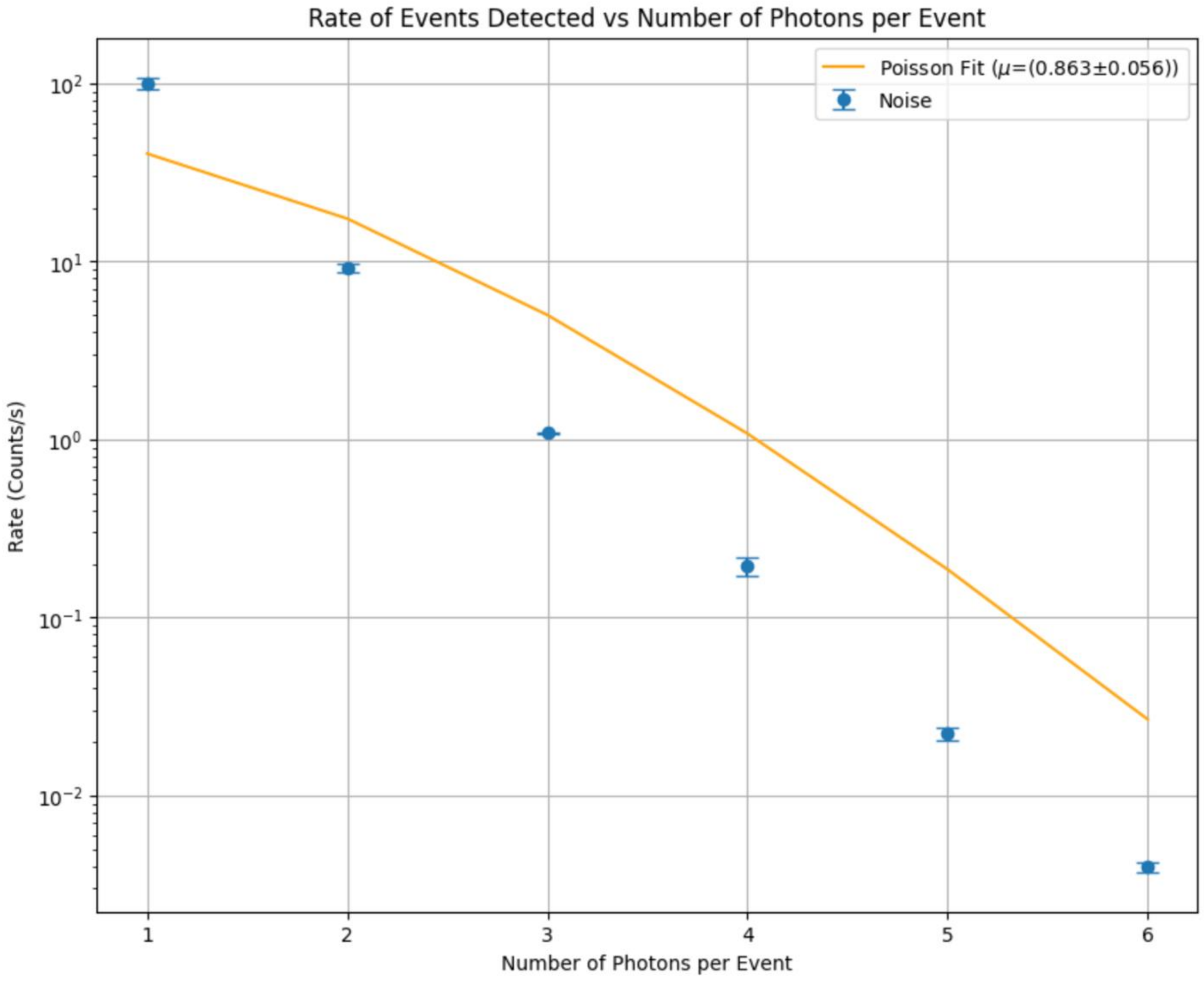


Experimental Work and Results





Experimental Work and Results



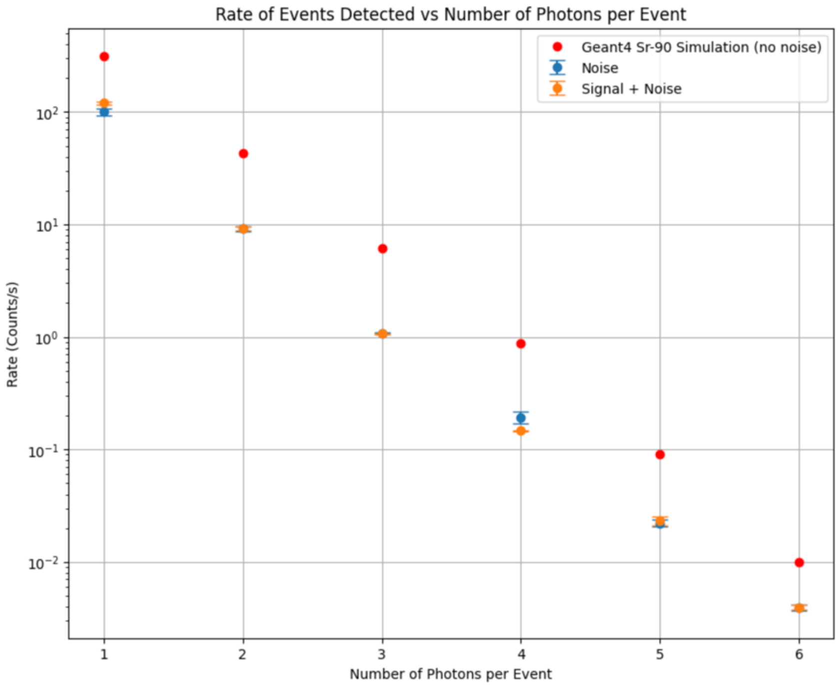
Poisson fit :

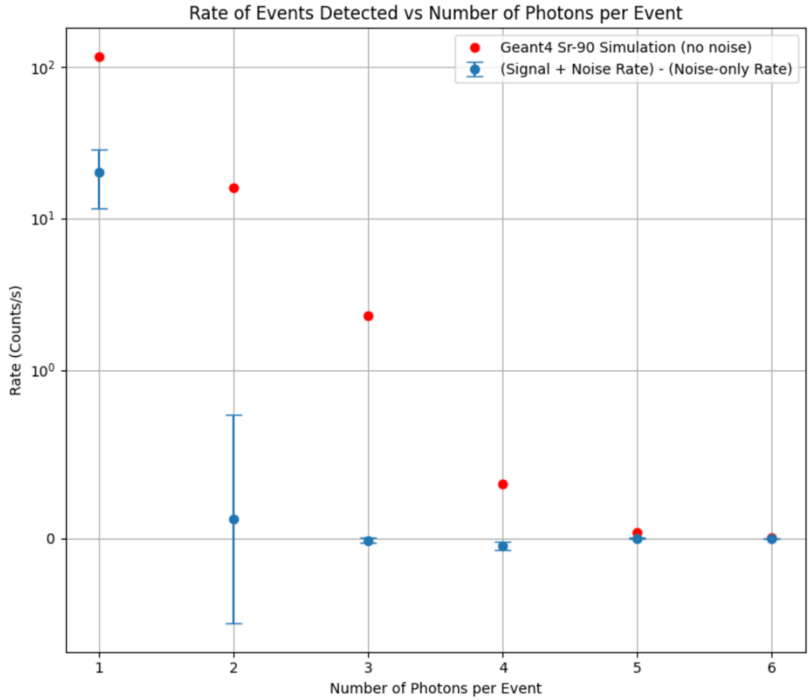
- $\mu = (0.863 \pm 0.056)\ p.p.e.$
- $\chi^2/dof = 19.4$

Characterization of SiPM's noise:

- Mean appears under 1;
- Elevated value for χ^2/dof.

Experimental Work and Results

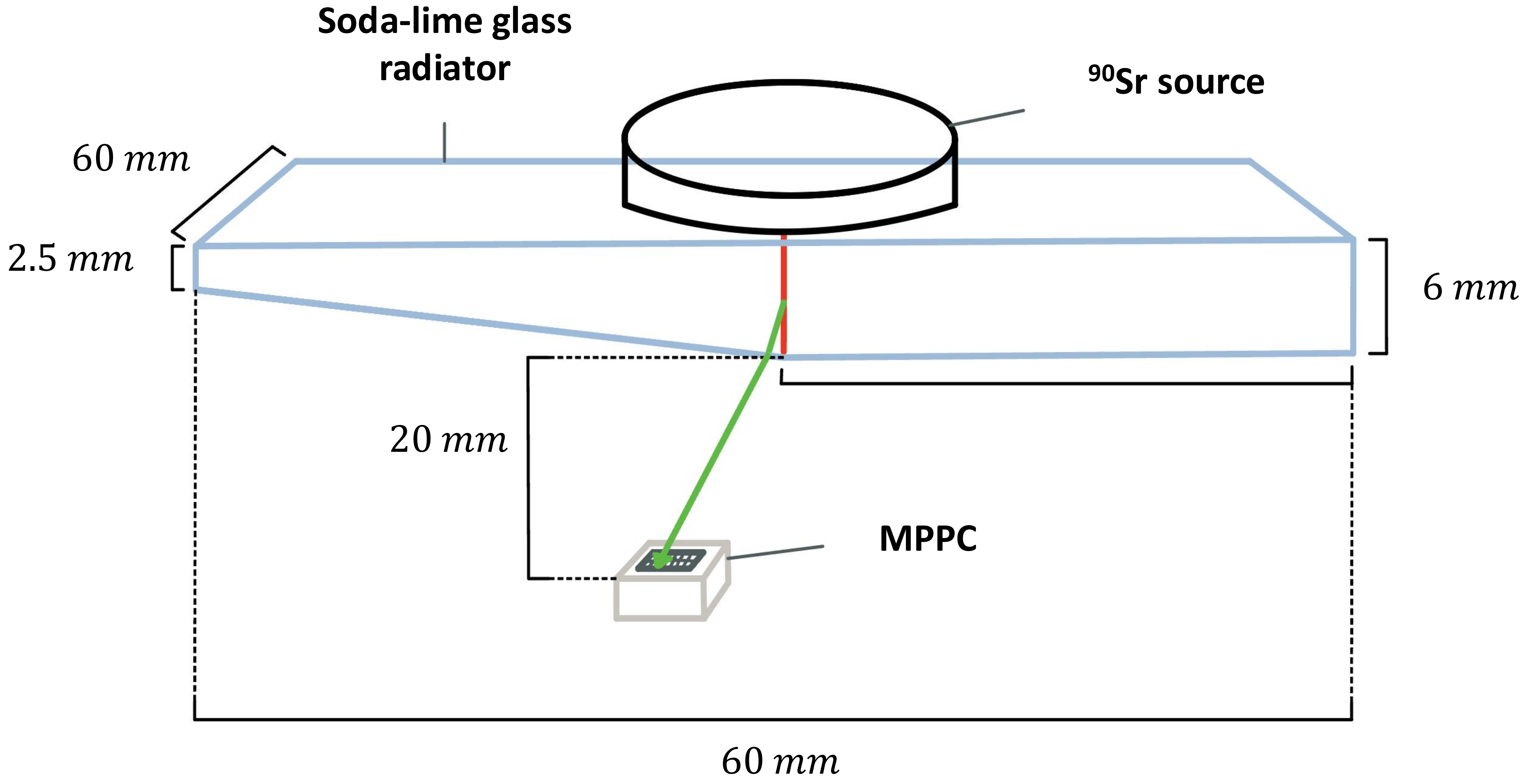


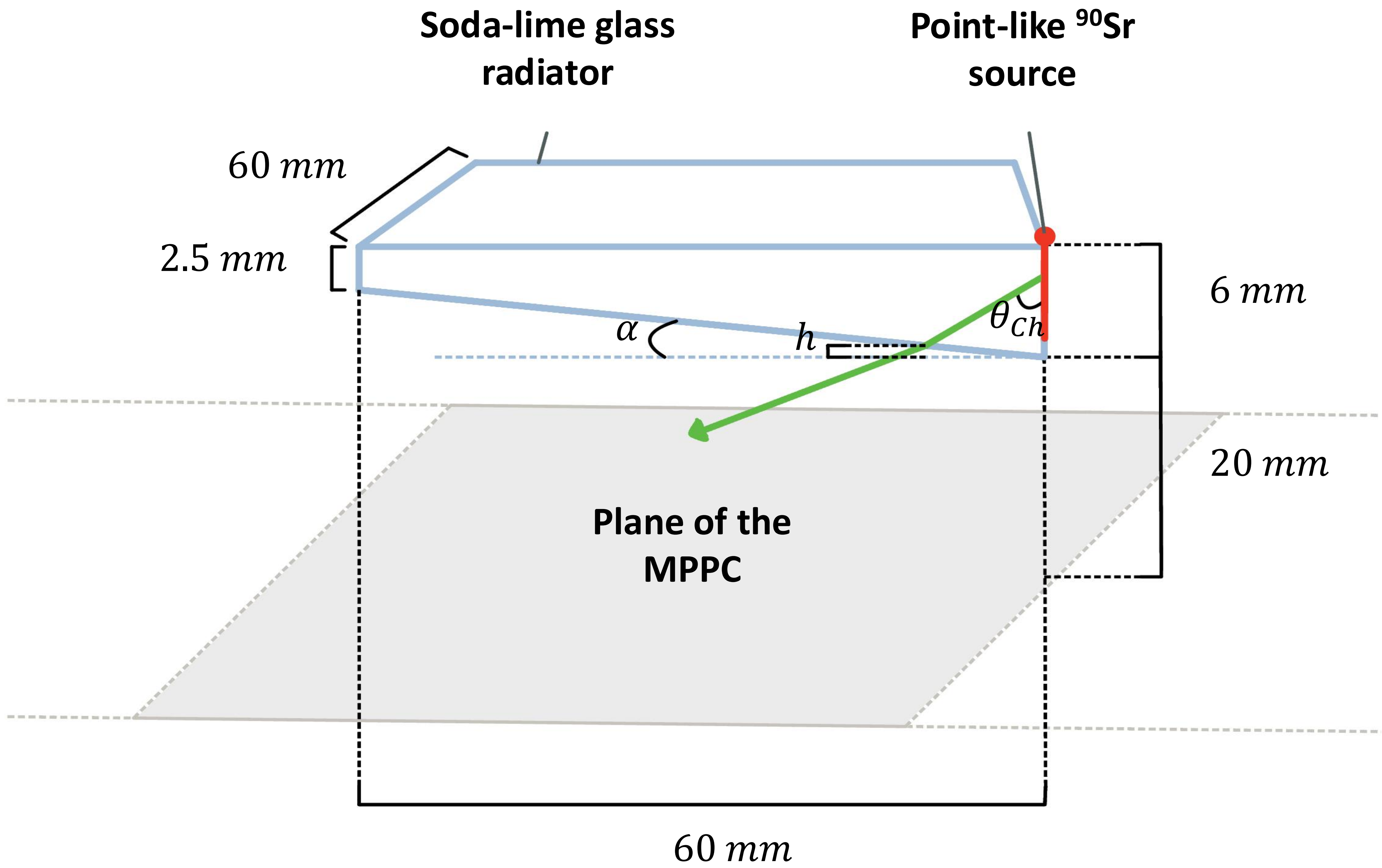


Total rate difference:

- Experimental results: $(20.14 \pm 8.46)\ cps$
- Simulation results: $135.48\ cps$

- Discrepancy in total excess rate:
  - **overestimation** of total number of detected events in simulation;
  - **low precision** in source placement relatively to the SiPM.
- **Positive rate difference** in experimental data supports the **detection of Cherenkov photons**.


Soda-lime glass radiator
90Sr source
60 mm
2.5 mm
6 mm
20 mm
MPPC
60 mm


Soda-lime glass radiator
Point-like ^{90}Sr source
60 mm
2.5 mm
6 mm
α
h
θ_{Ch}
20 mm
Plane of the MPPC
60 mm