Development of Accurate Dosimetry SiPM-based Detectors for FLASH RT

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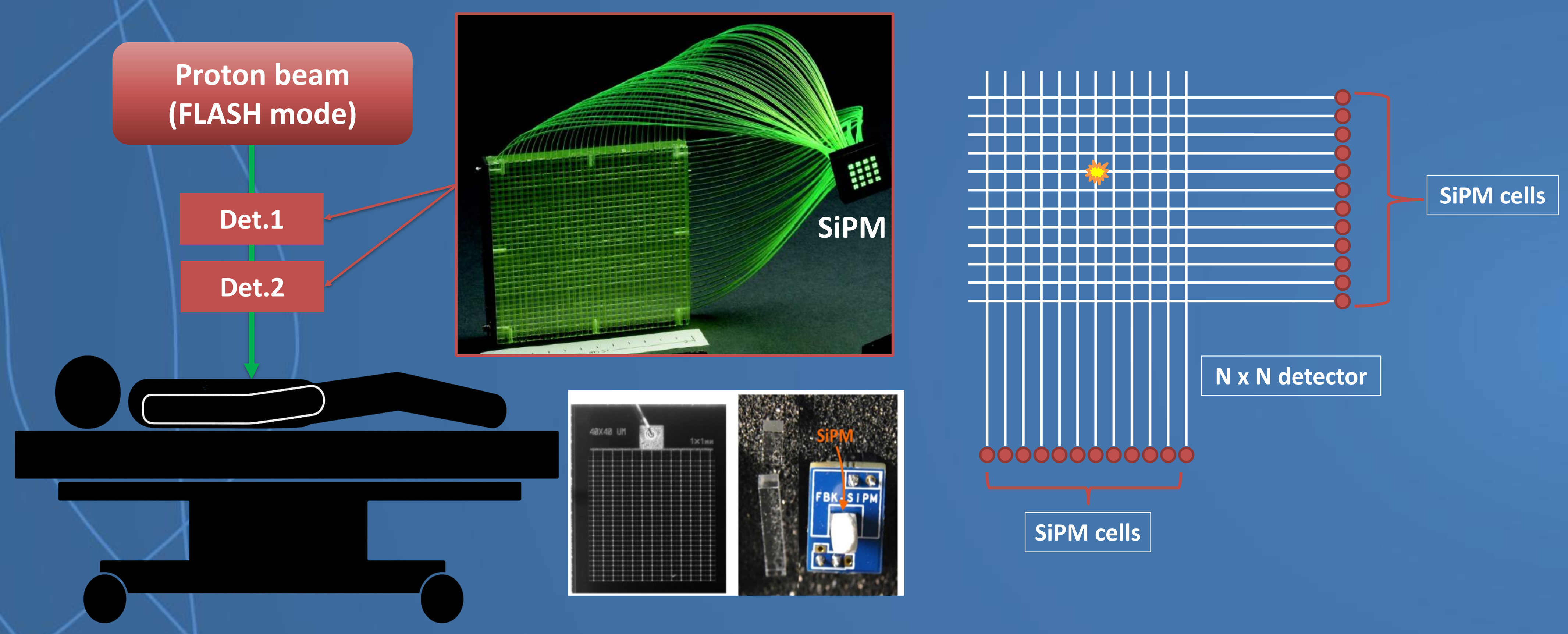
INTRODUCTION

- Today ~50% of all cancer patients are receiving radiotherapy (RT) as the main treatment strategy to treat human tumors. However, the major drawback of radiotherapy treatment is that to deliver a lethal dose to cancerous cells, short- and long-term adverse side-effects are evident due to the irradiation of the surrounding normal healthy tissues [1, p. 1].
- One way to reduce irradiation dose to the surrounding tissue is through Proton Beam Therapy (PBT) where protons are used to deliver the radiation with higher precision [2], thanks to the favorable ratio of Relative dose to Depth [3, p. 20], leading to the safeguarding of the healthy tissue surrounding them.
- In terms of RT and PBT, the recently introduced "FLASH" technique is based on the delivery of Ultra High Dose Rate (UHDR) radiation (> 40 Gy/s) to the patient, i.e. orders of magnitude higher than the conventional RT and induces a phenomenon called FLASH effect where a reduction in normal tissue toxicities is observed [3, p. 47] [4, p. 9] – while still maintaining tumor control [1, p. 1].
- Combining the FLASH effect with the precision of PBT will achieve an even greater reduction of the side effects due to irradiation.
- However, in such a context, accurate dosimetry and real-time beam monitoring are critical for its clinical translation, but current detectors/methodologies suffer from saturation effects.

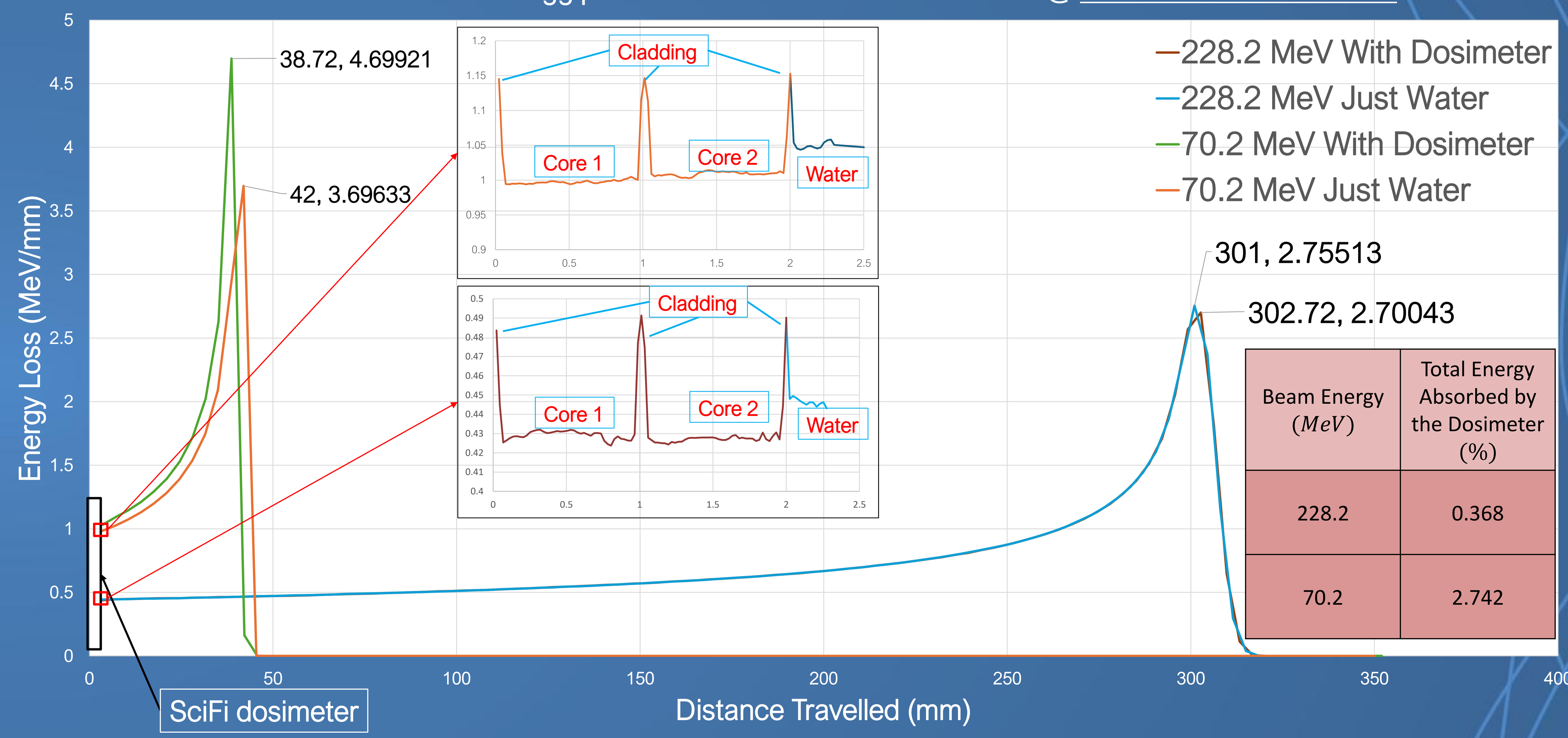
Objective and Methods

- This project aims to develop a novel accurate Dosimeter, suitable not only for FLASH RT/PT conditions, but also for CONV ones, with the goal of aiding in the eventual clinical translation of FLASH RT.
- Recent advances in the Silicon Detector can help in the realization of such kind of detectors. Our implementation will be based on array of Silicon Photomultipliers (SiPM) coupled with array of scintillating fibers (SciFi), aiming towards an improved time and space resolution. A design of this Dosimeter but with Bare Optical Fibers, instead of the SciFi ones, taking advantage of induced luminescence, will also be tested.
- Here we present the dosimeter's impact on the Proton Beam and the results of the first simulations of proton and photon fluxes, necessary to create a prototype detector, considering as target the irradiation conditions of the testing facility (TIFPA Proton Therapy Center). In detail: produced photon flux, during irradiating on Scintillating Fiber (BCF-XL 12) with proton beams at 70.2 MeV (CONV) and 228.2 MeV (CONV and FLASH).

Idea of the system:



Simulations of Bragg peak of 1 Proton on a Water Phantom @ 70.2 MeV and 228.2 MeV



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Summary of the parameters and results of the Simulation:

Regime	Energy	σ_x	σ_y	flux at target	SciFi saturation (Quenching loss)	SiPM	Total photons (Incident to the SiPM)		Time window	Incident Photons (Tw)	SiPM Output (Tw)	SiPM Saturation	SNR
	MeV	mm	mm	$\frac{p}{s}$	%	Model	per sec	per ns	ns		Counts	%	
CONV	228.2	2.74	2.72	4.60E+08	4.2566	NUV-HD-cryo	8.48E+08	0.8482	10	8.48	8.43E+00	1.35	2.71E+00
	70.2	6.93	6.91	7.60E+06	10.3544		1.21E+07	0.01213		0.12	1.21E-01	0.02	3.24E-01
				2.43E+09	10.3544		3.88E+09	3.883		38.84	3.77E+01	6.03	5.72E+00
FLASH	228.2	9.34	10.19	2.30E+12	4.2568		1.25E+12	1249.233321		12492.33	6.25E+02	high	2.33E+01

RESULTS and Conclusions

- Large dynamic range required to fit CONV and FLASH conditions.
- While saturation is still evident under high current and energy conditions – less so in the Scintillating Fiber (~10%), but particularly in the SiPM – it doesn't render them unsuitable for this use case.
- Possible solutions: using multiple SiPM models (each linear over different ranges), or switching to a larger pitch SiPM, which introduces a higher DCR, and so, requires a trade-off between noise and dynamic range → to be tested in future implementations and verifications.

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