TRIUMF

FLASH Radiotherapy

Treating Cancer in a Second

Cornelia Hoehr

Director | Life Sciences

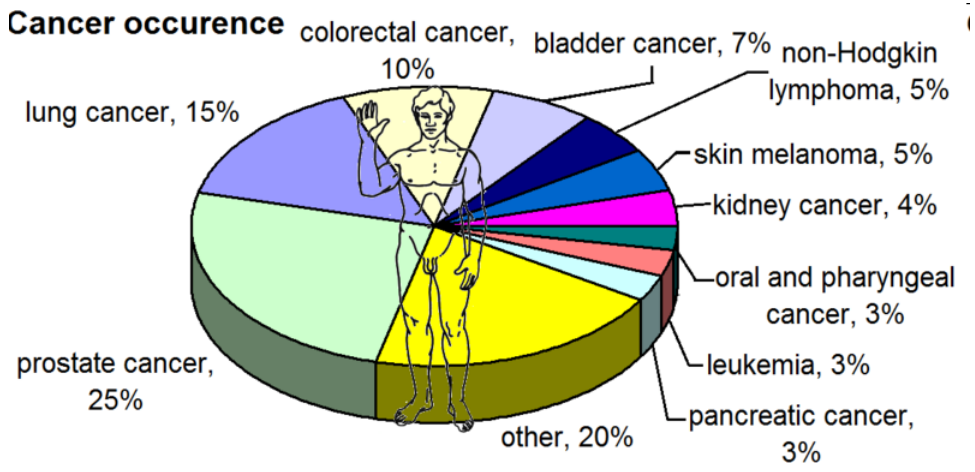
University of Victoria

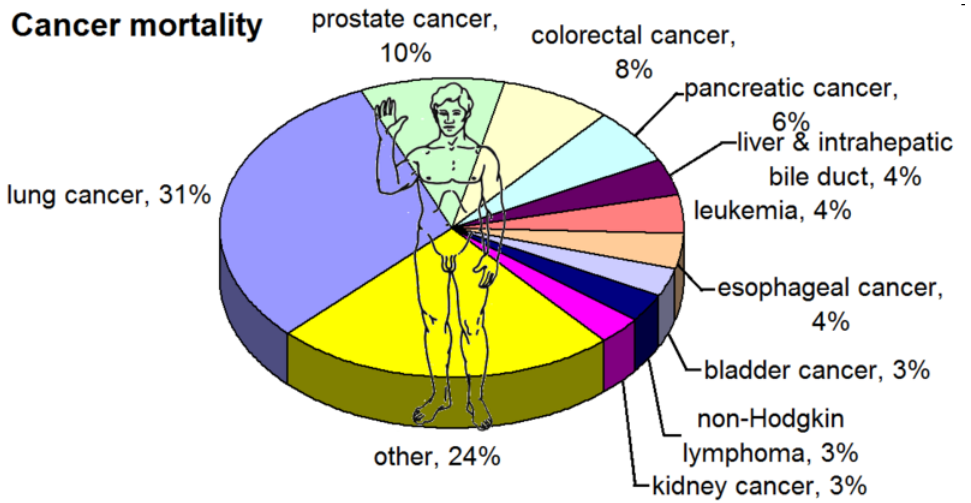
UBC THE UNIVERSITY OF BRITISH COLUMBIA

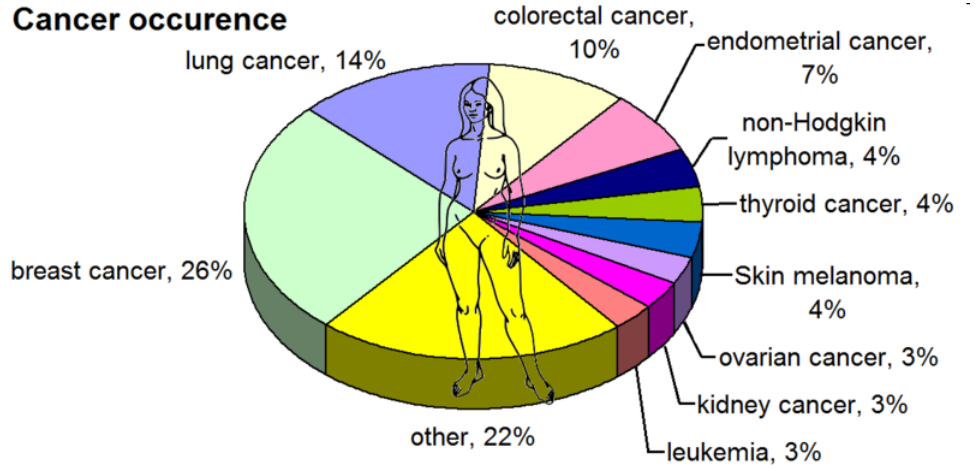
RCNP

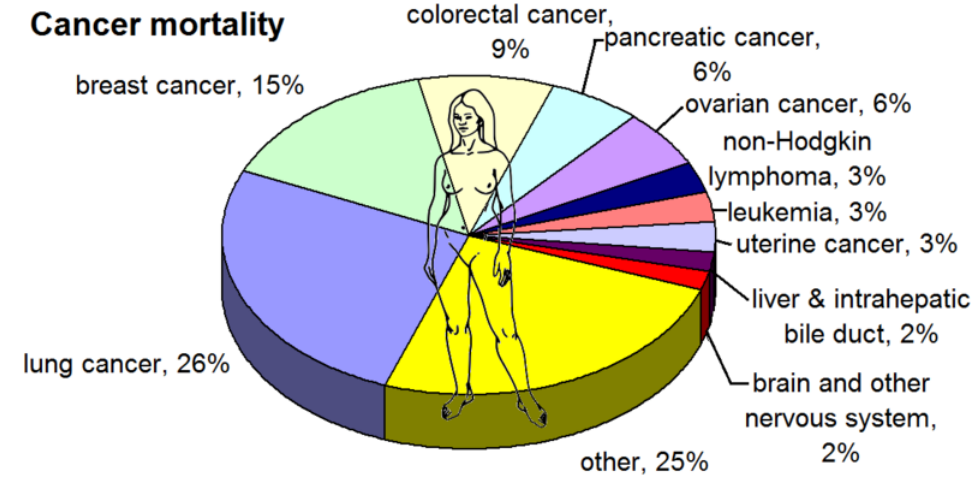
Discovery, accelerated

Cancer


Cancer occurence
colorectal cancer, 10%
bladder cancer, 7%
non-Hodgkin lymphoma, 5%
lung cancer, 15%
skin melanoma, 5%
kidney cancer, 4%
oral and pharyngeal cancer, 3%
prostate cancer, 25%
leukemia, 3%
pancreatic cancer, 3%
other, 20%


Cancer mortality
prostate cancer, 10%
colorectal cancer, 8%
pancreatic cancer, 6%
liver & intrahepatic bile duct, 4%
lung cancer, 31%
leukemia, 4%
esophageal cancer, 4%
bladder cancer, 3%
non-Hodgkin lymphoma, 3%
other, 24%
kidney cancer, 3%

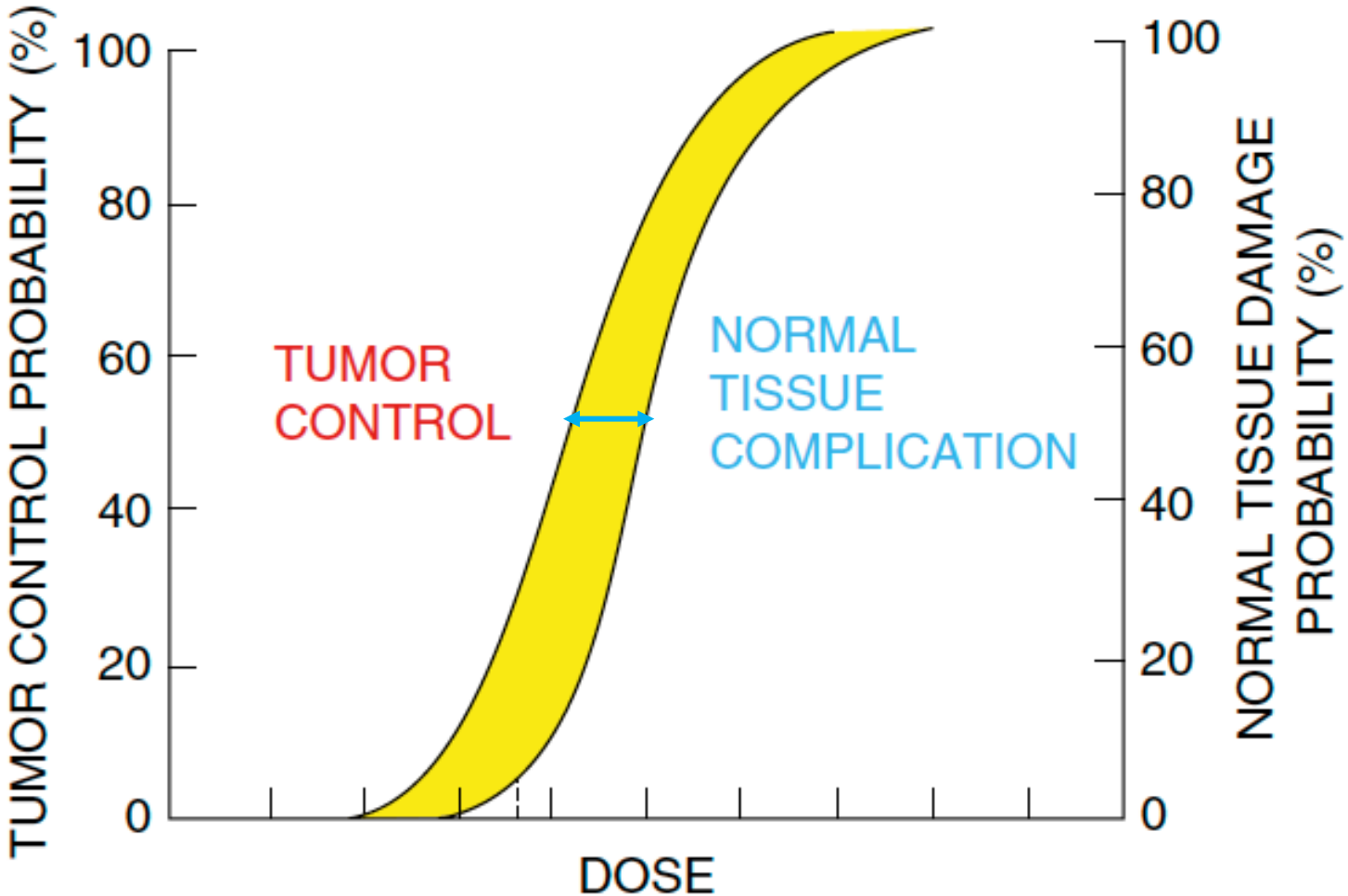

Cancer occurence
colorectal cancer, 10%
endometrial cancer, 7%
lung cancer, 14%
non-Hodgkin lymphoma, 4%
thyroid cancer, 4%
breast cancer, 26%
Skin melanoma, 4%
ovarian cancer, 3%
kidney cancer, 3%
other, 22%
leukemia, 3%


Cancer mortality
colorectal cancer, 9%
pancreatic cancer, 6%
breast cancer, 15%
ovarian cancer, 6%
non-Hodgkin lymphoma, 3%
leukemia, 3%
uterine cancer, 3%
liver & intrahepatic bile duct, 2%
lung cancer, 26%
brain and other nervous system, 2%
other, 25%

Cancer

- Surgery
- Chemotherapy
- Immunotherapy
- Ionizing radiation
- …

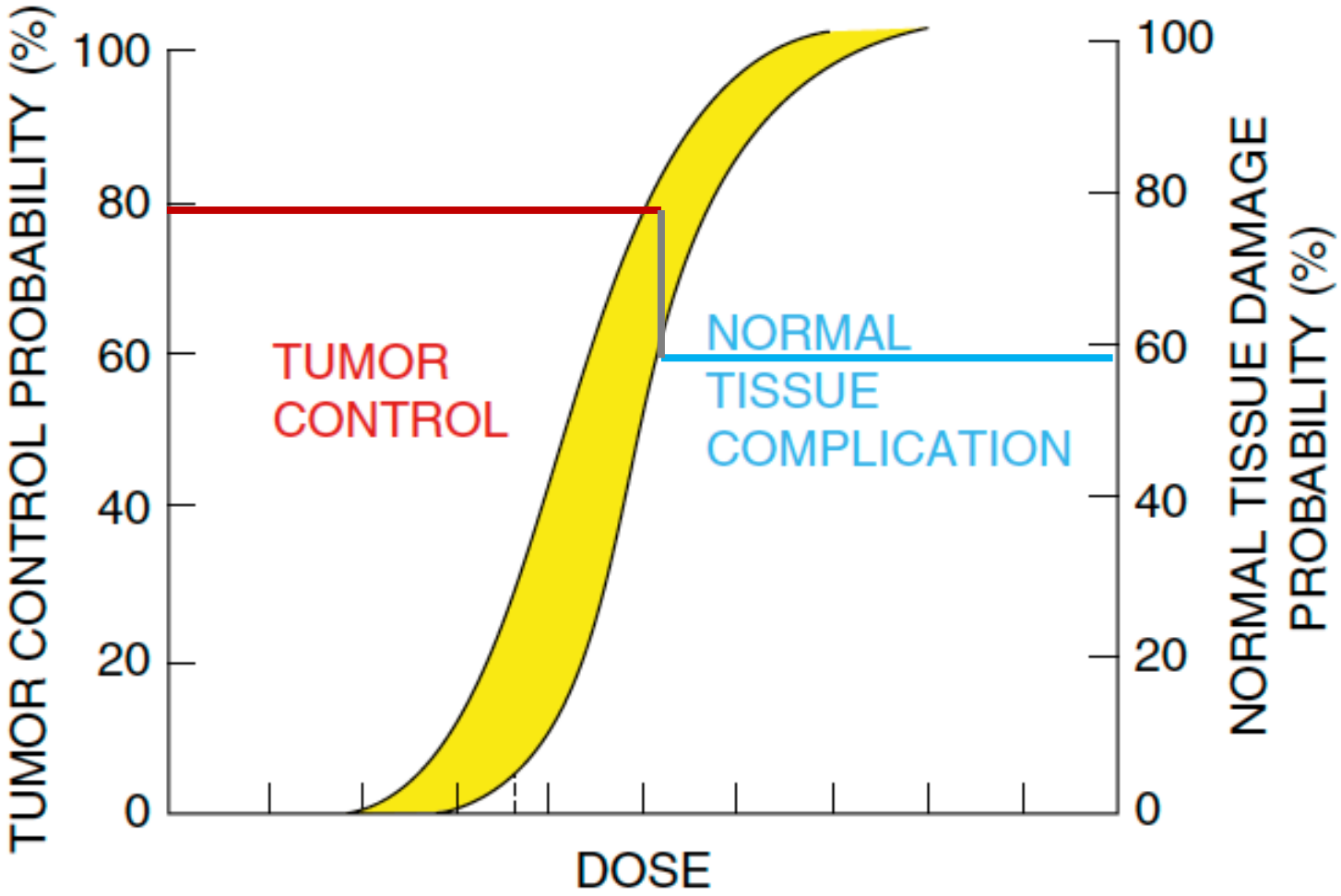
- Holy grail of cancer research: **Increase gap (therapeutic index/ window) as much as possible**



Cancer

- Surgery
- Chemotherapy
- Immunotherapy
- Ionizing radiation
- …

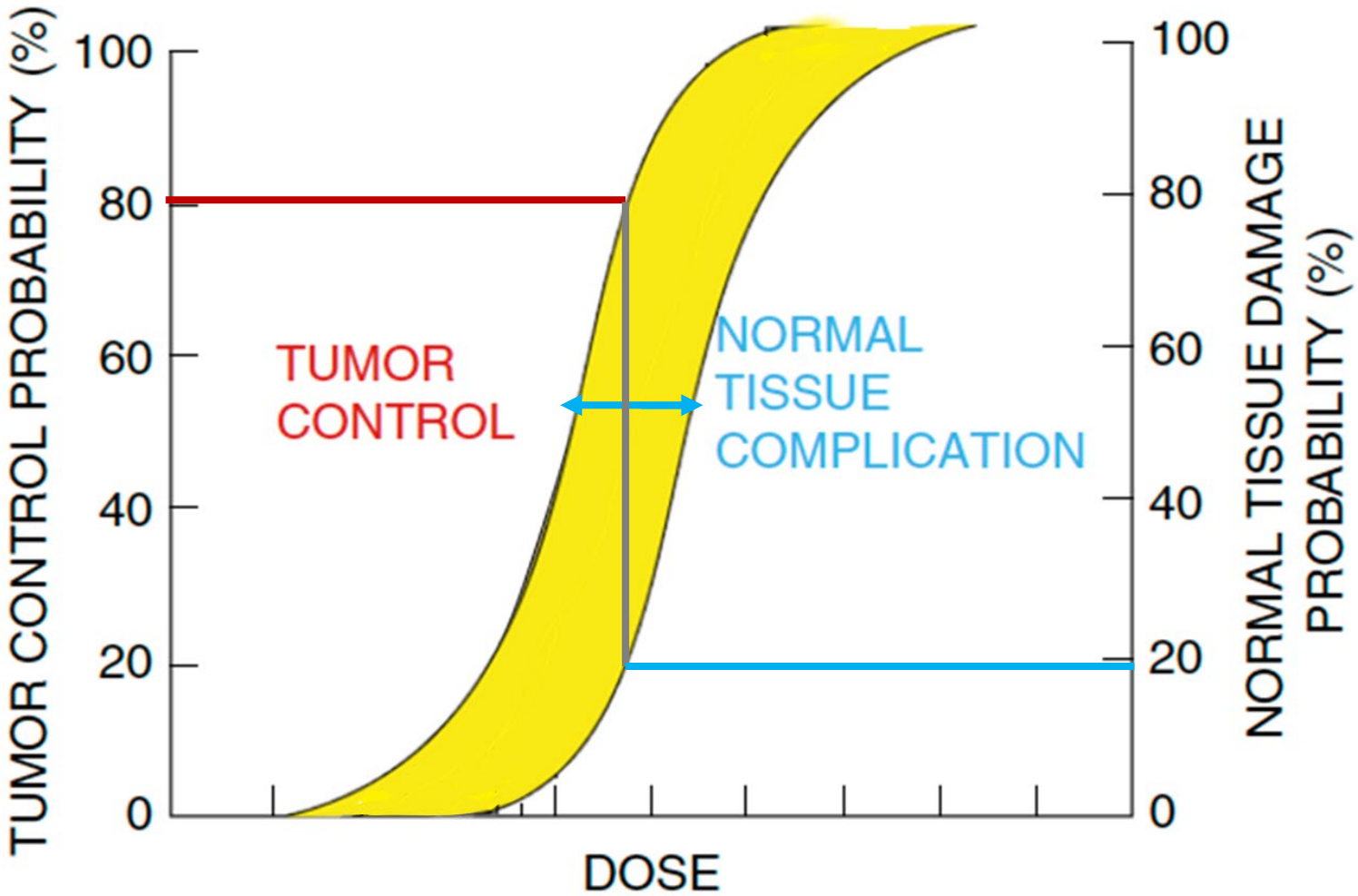
- Holy grail of cancer research: **Increase gap (therapeutic index/ window) as much as possible**



Cancer

- Surgery
- Chemotherapy
- Immunotherapy
- Ionizing radiation
- …

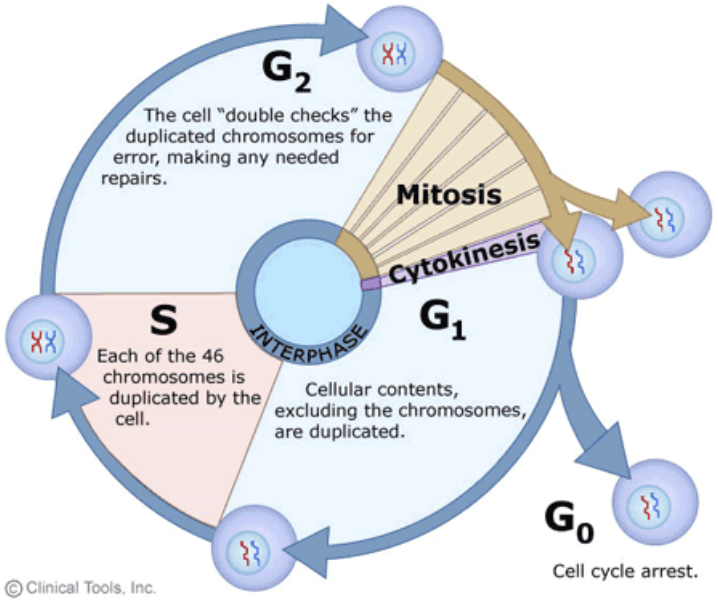
- Holy grail of cancer research: **Increase gap (therapeutic index/ window) as much as possible**

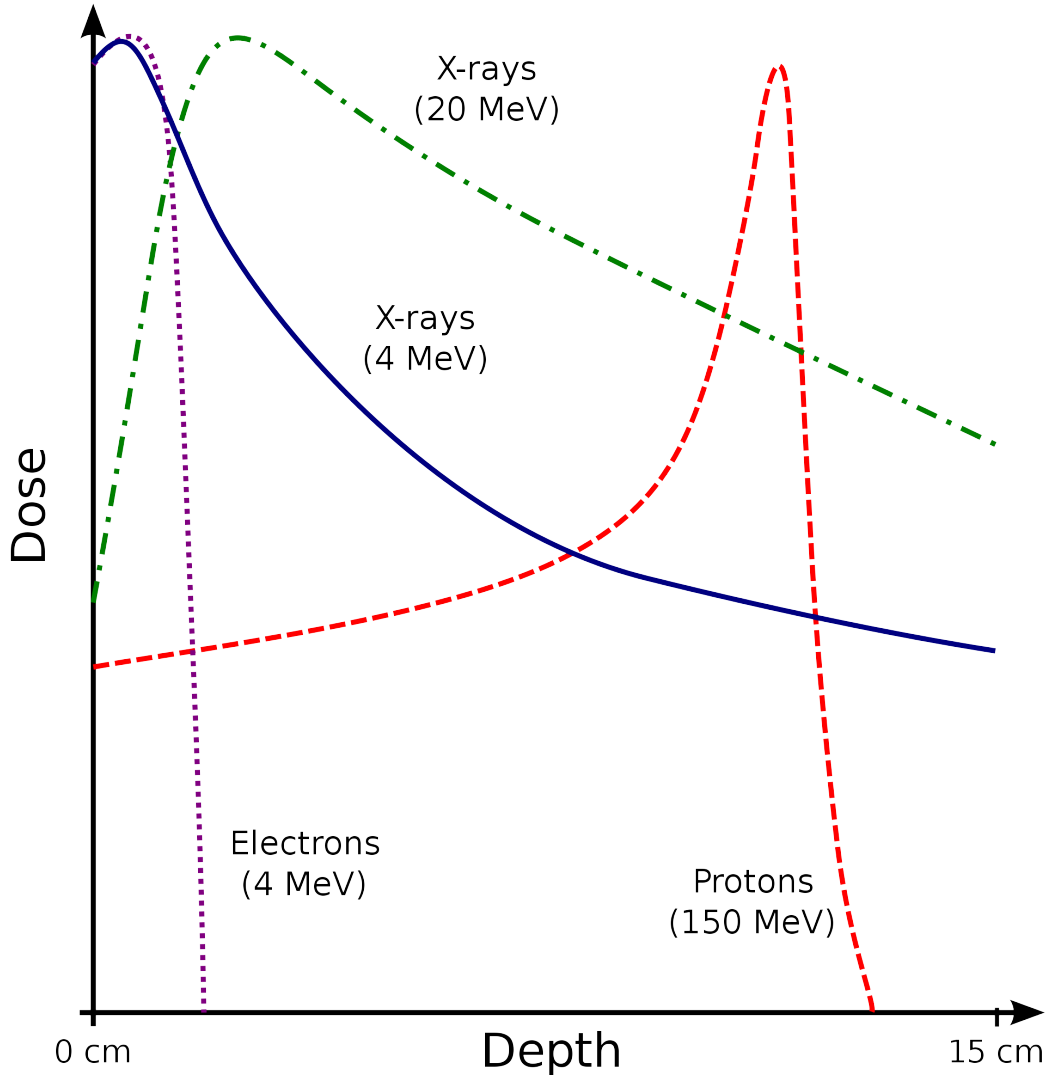


Radiotherapy – External beam therapy

Conventional dose rate ~ 0.03 Gy/s

- In 20 – 30 fractions to affect all cell cycle phases, and to reach the hypoxic centre of a tumour





FLASH effect

Conventional dose rate ~ 0.03 Gy/s

- In 20 – 30 fractions to affect all cell cycle phases, and to reach the hypoxic centre of a tumour

Vozenin *et al.*, 2018

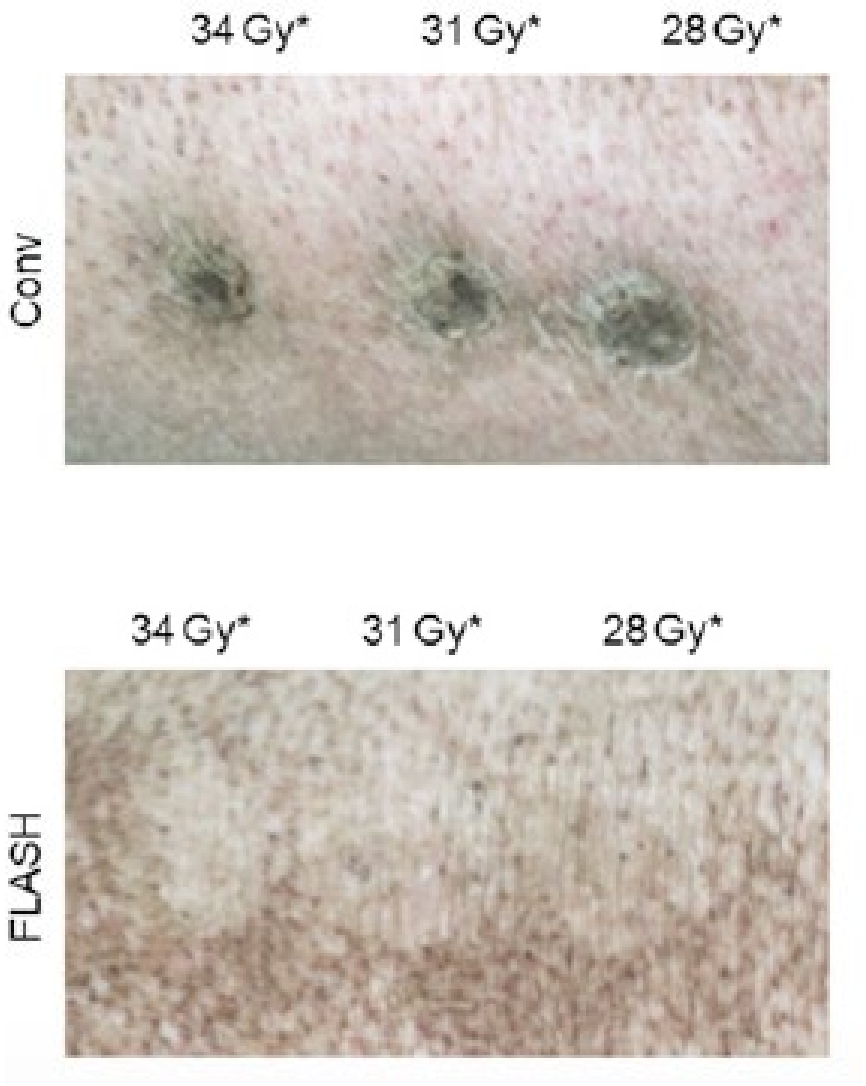
FLASH effect

Conventional dose rate ~ 0.03 Gy/s

- In 20 – 30 fractions to affect all cell cycle phases, and to reach the hypoxic centre of a tumour

FLASH dose rate > 40 Gy/s

- Lower toxicity in healthy tissue but **same** tumour control
- Effect only consistently observed *in-vivo*, not *in-vitro*



Vozenin *et al.*, 2018

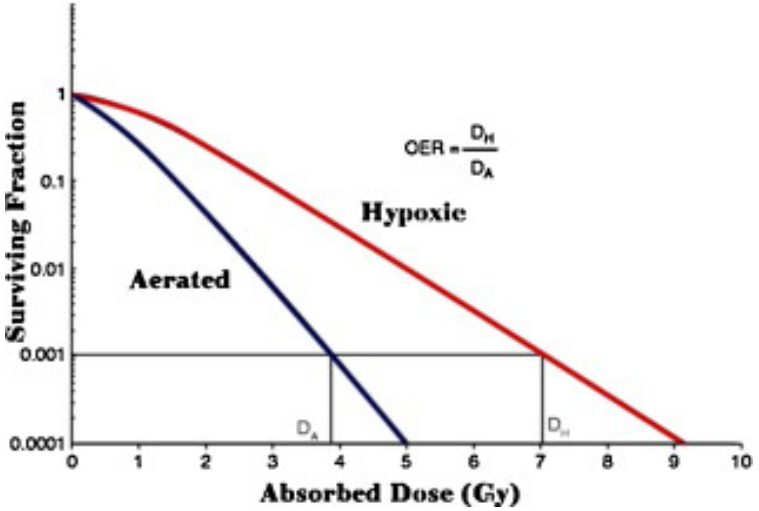
FLASH effect

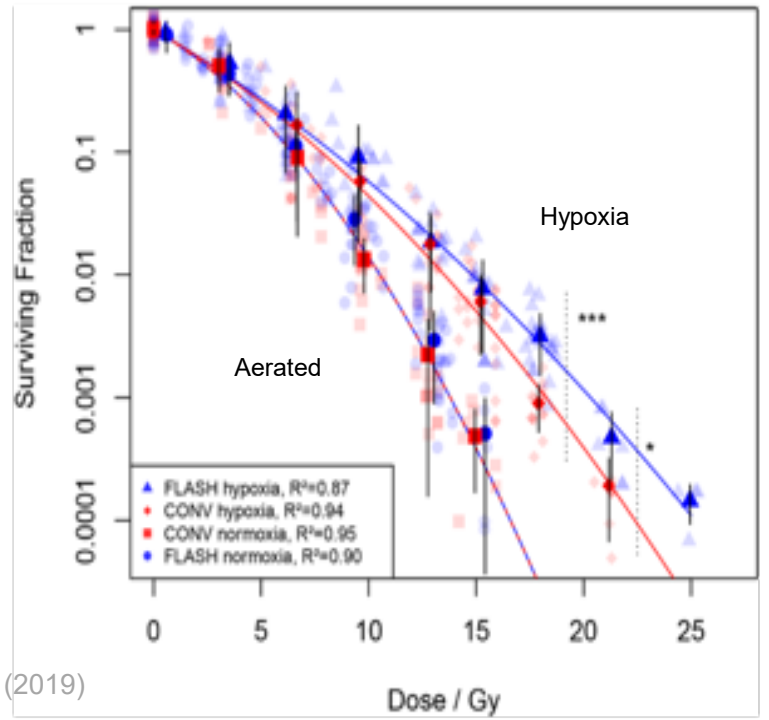
Conventional dose rate ~ 0.03 Gy/s

- In 20 – 30 fractions to affect all cell cycle phases, and to reach the hypoxic centre of a tumour

FLASH dose rate > 40 Gy/s

- Lower toxicity in healthy tissue but same tumour control
- Effect only consistently observed *in-vivo*, not *in-vitro*
- Oxygen – depletion hypothesis, healthy tissue becomes basically hypoxic

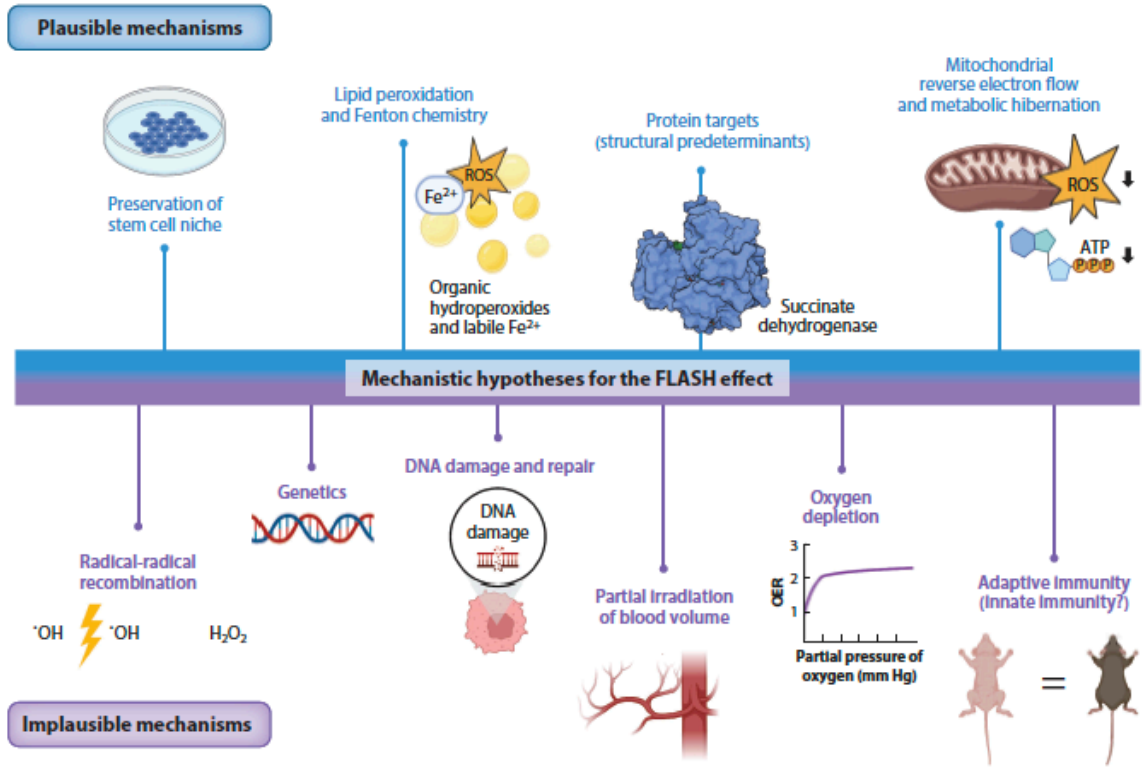




Adrian et al.,Br. J. Radiol. (2019)

FLASH effect

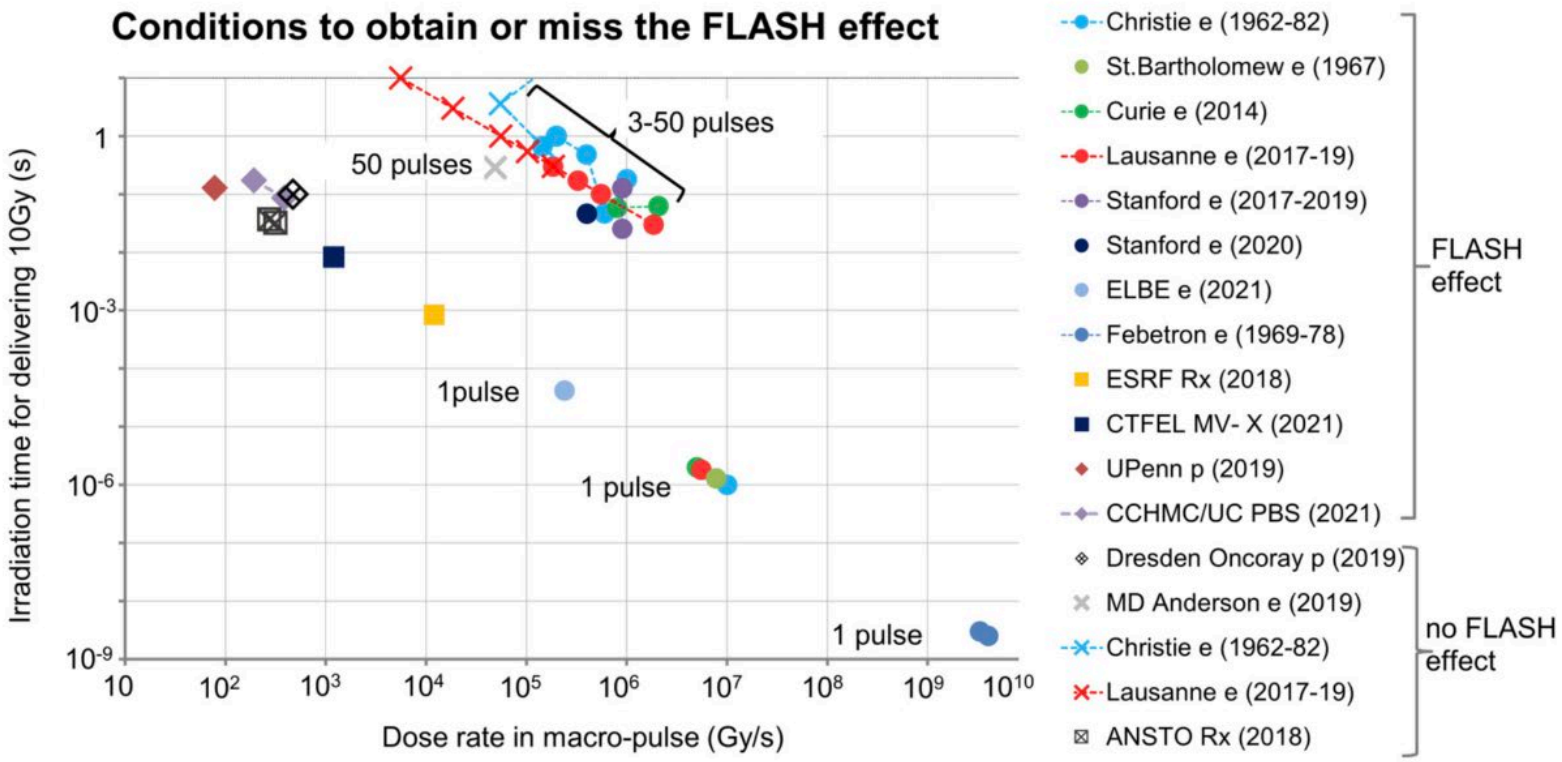
- Many hypotheses, most disproven



C. Limoli, M.C. Vozenin, Annu. Rev. Cancer Biol. 2023. 7:1–21

FLASH effect

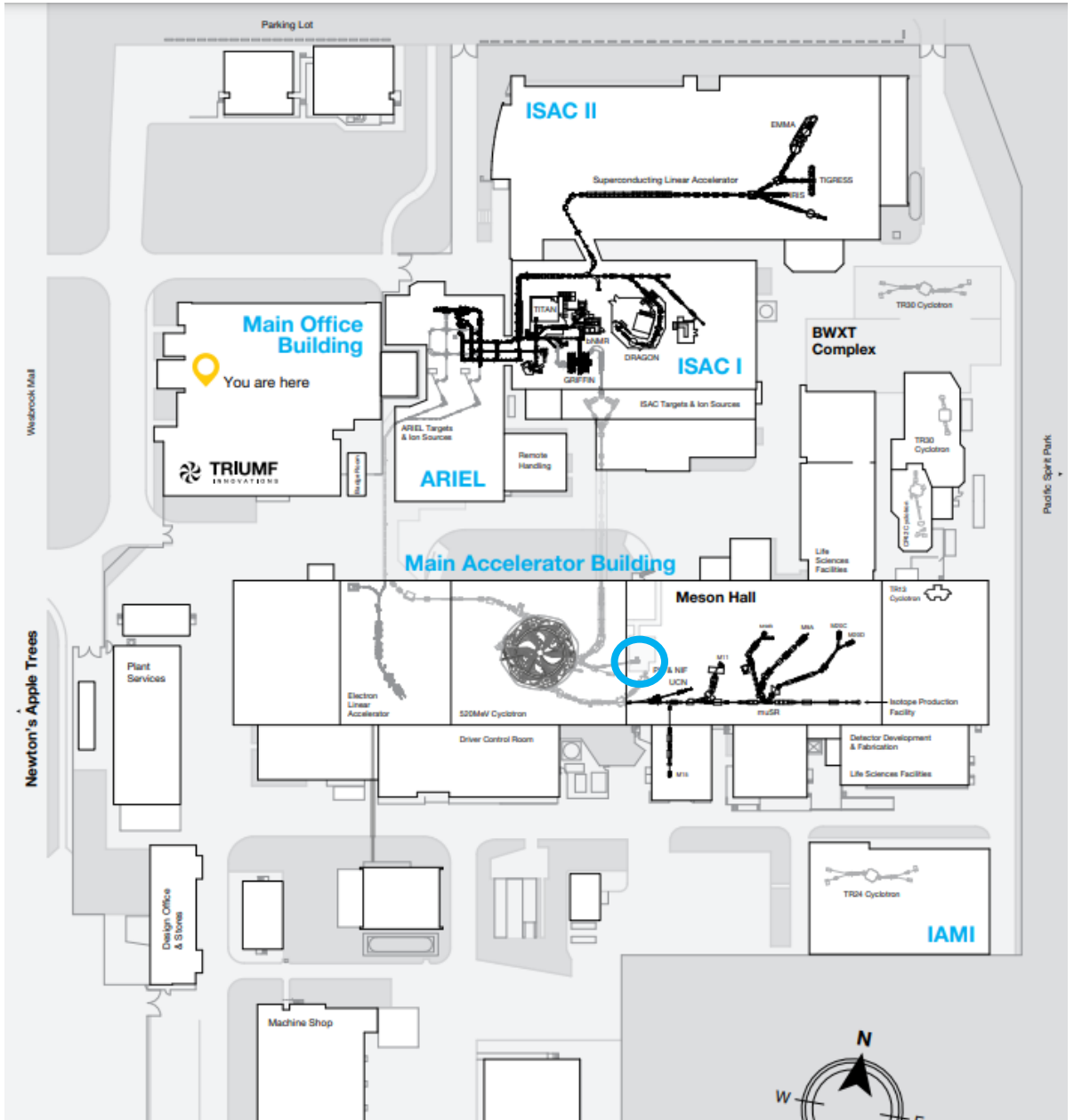
- Consistent irradiation
  - Beam particle
  - Beam delivery
  - Average dose rate vs peak dose rate
  - Dose threshold
  - Fractionation
  - Dosimetry
- Simple model



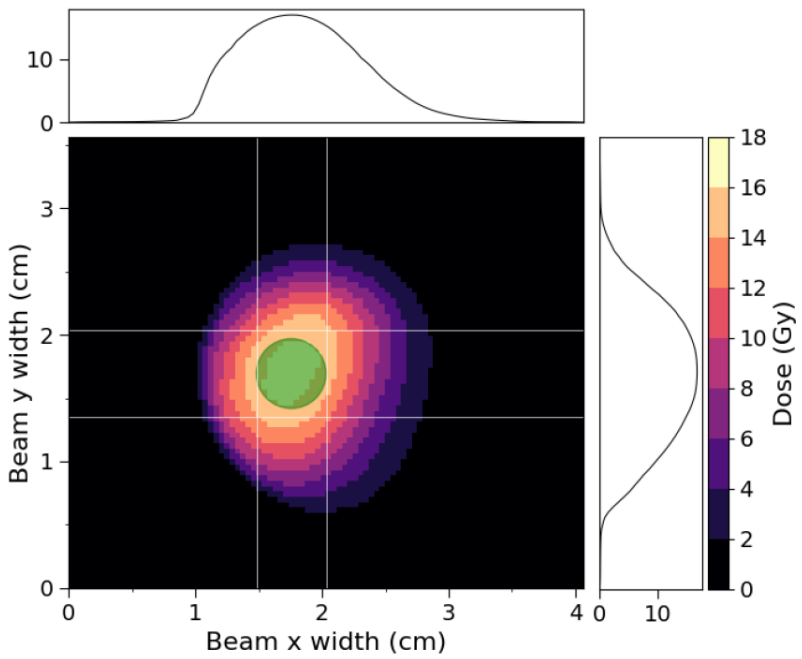
Marie-Cathrine Vozenin et al. , Rev. Mod. Phys. **96**,2024

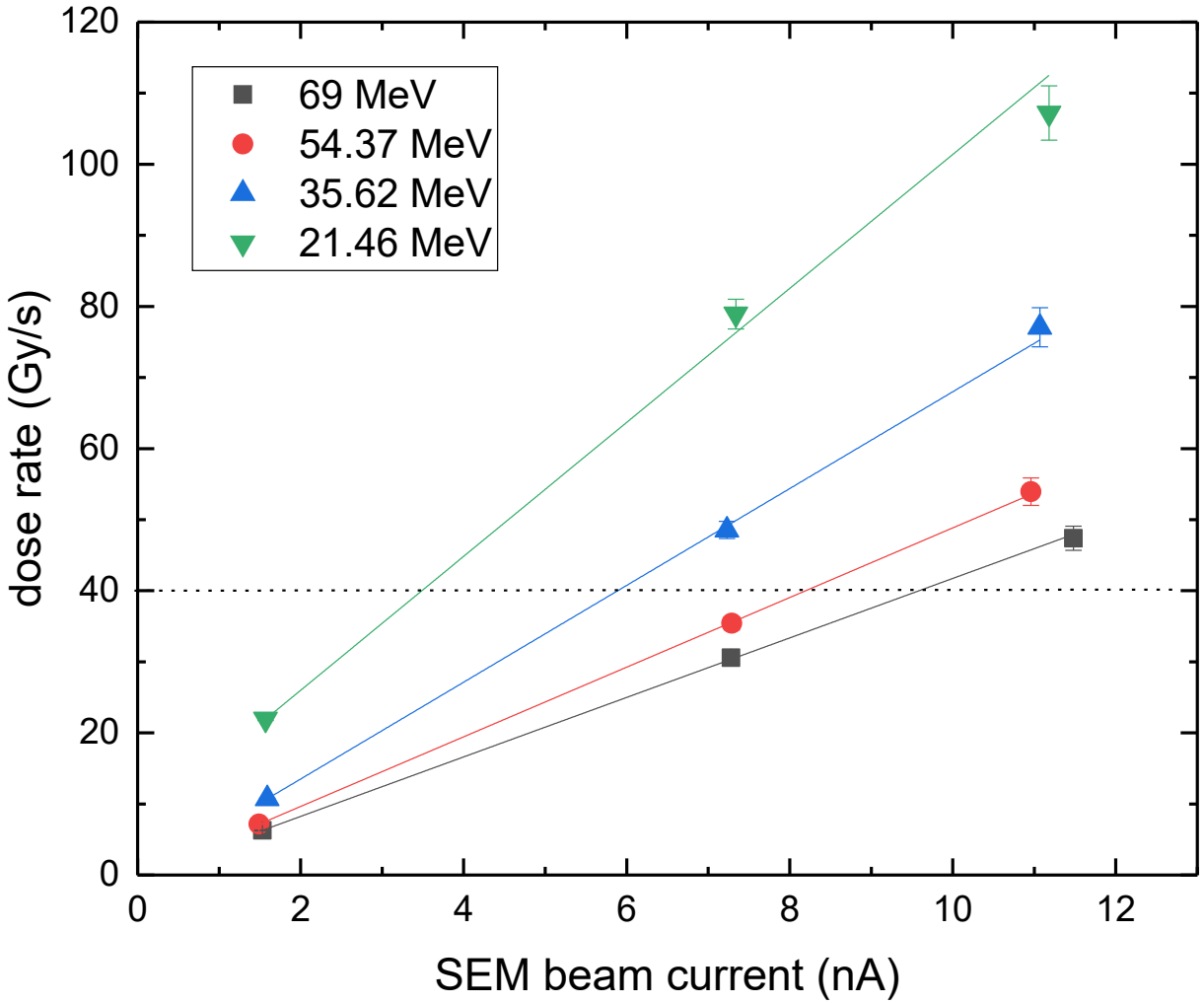
Proton Therapy at TRIUMF

- Clinical operation since 1995
- Canada's only proton therapy facility
- Ocular melanomas
- Clinical treatments ended Feb 2019



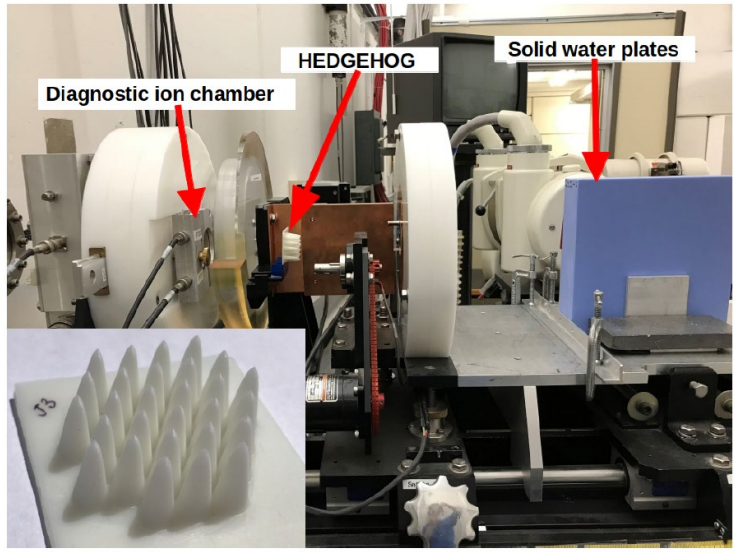
Proton FLASH @ TRIUMF





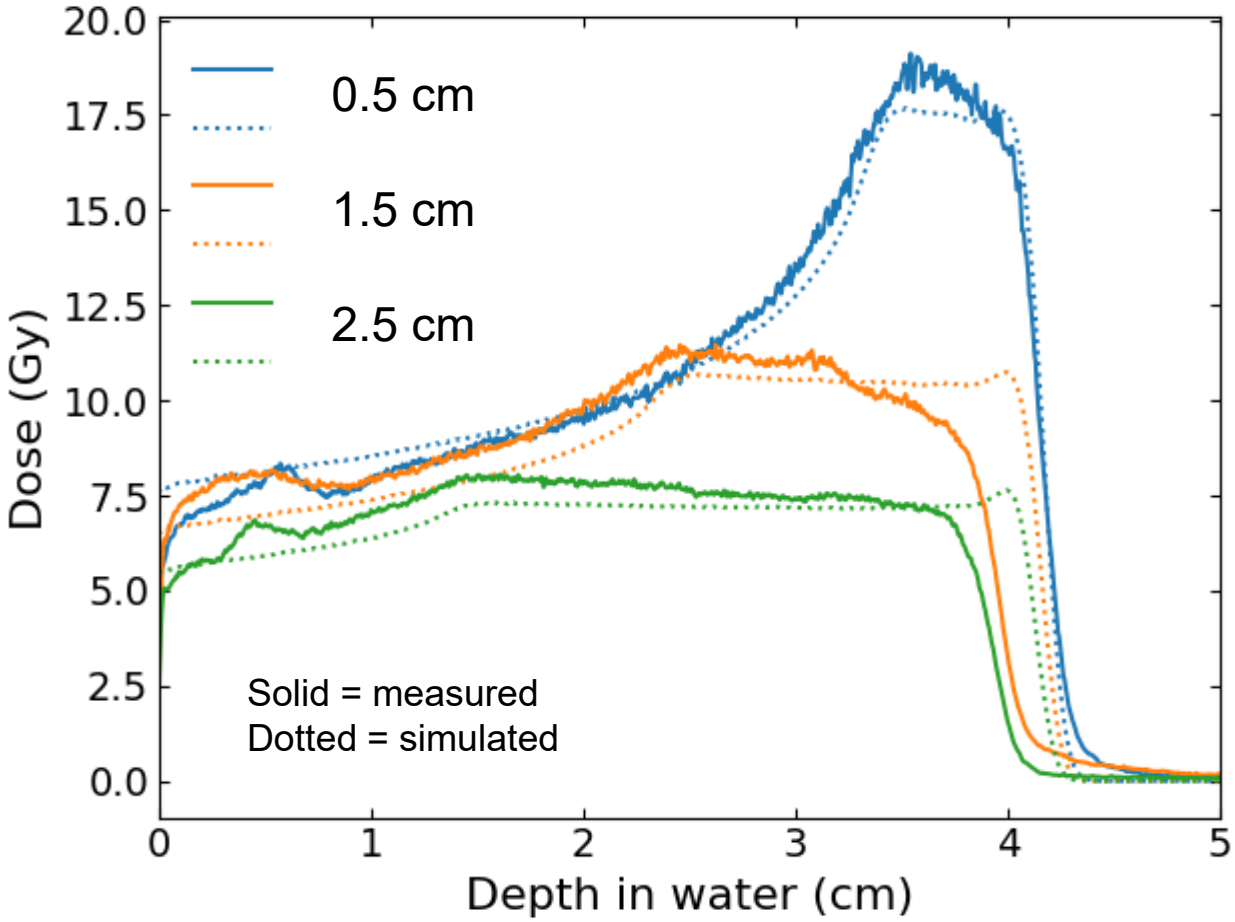
- Started to explore FLASH beam delivery at TRIUMF Aug 2020
- Dosimetry with fibers

Proton FLASH @ TRIUMF



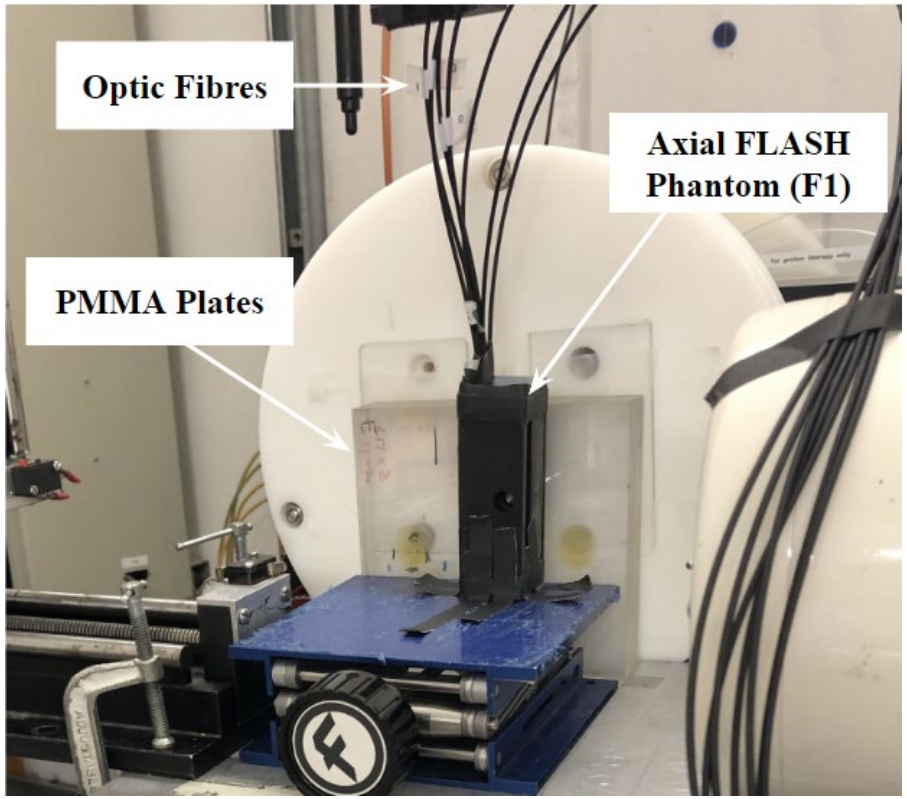
HEDGEHOG
(Homogeneous Energy Distribution GEnerator for tHerapeutic prOton beam shapinG).

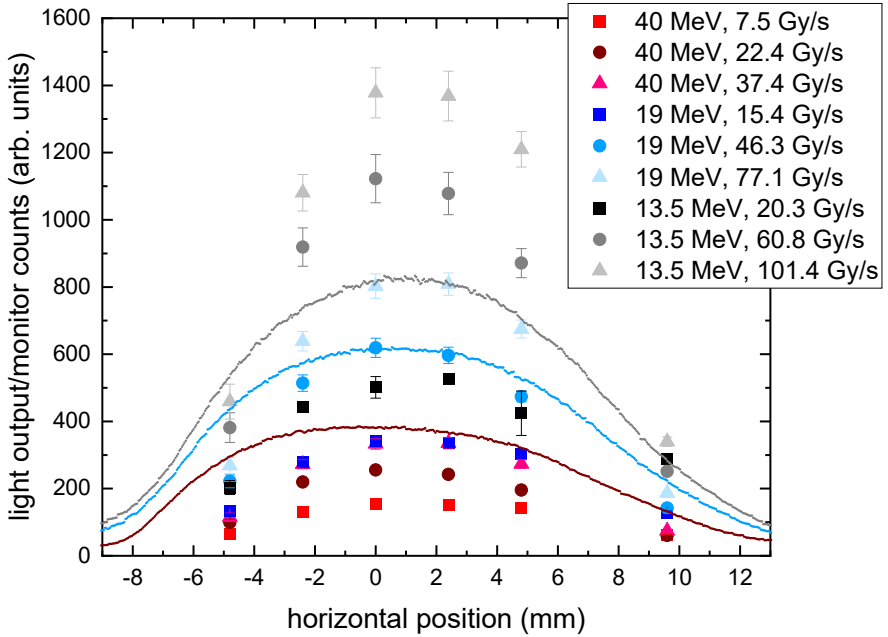
- SOBP of different widths
- Optimized printing material and pin diameters

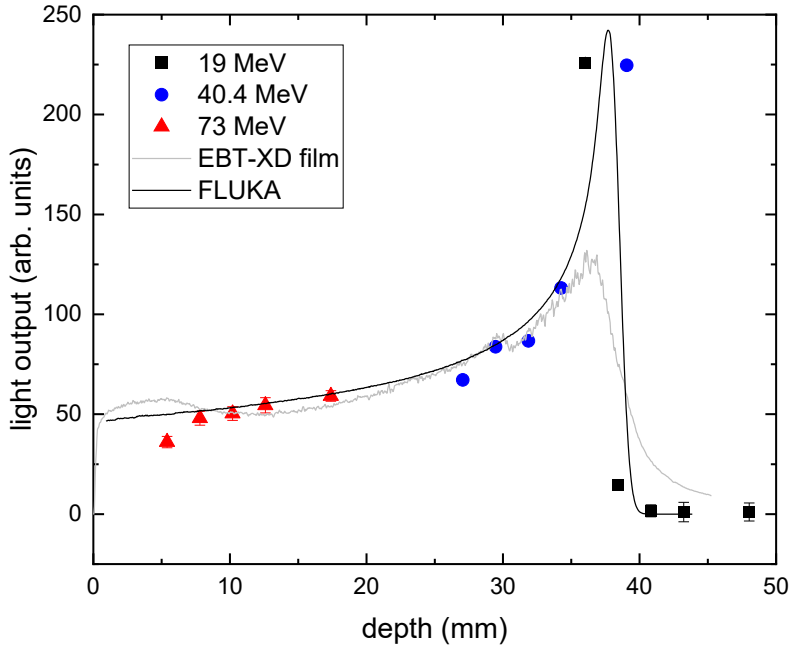


MSc thesis,
David Roddy

Fibres for Proton FLASH at TRIUMF



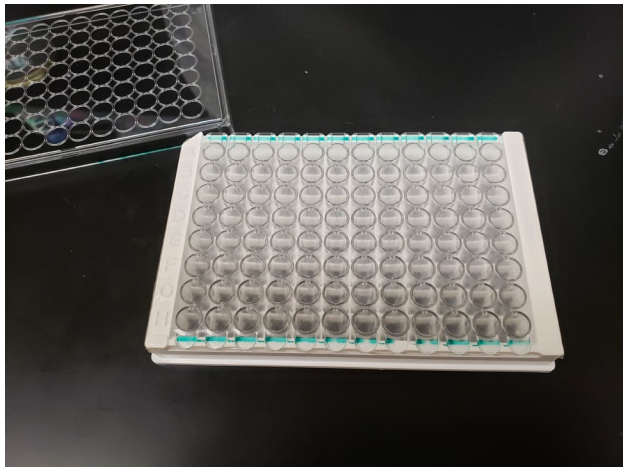


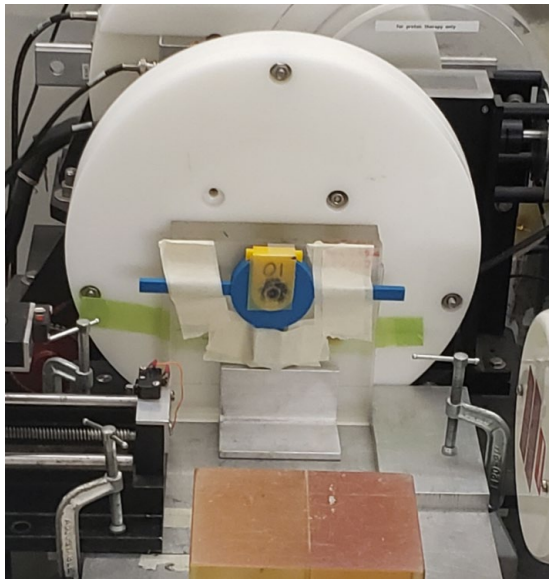


- Pure PMMA fibres embedded in a 3D-printed phantom of similar density

PhD thesis, Crystal Penner

Cell irradiation – Proton FLASH





Desiccated yeast model:

- *Usage:* In space radiation research

(BioSentinel, Deep Space Radiation Genomics)

- No specific transport or storage requirements (Can be prepared off-site)

Research aim:

Validate desiccated yeast model to be an appropriate model for radiobiology experiments, to be used in extreme conditions

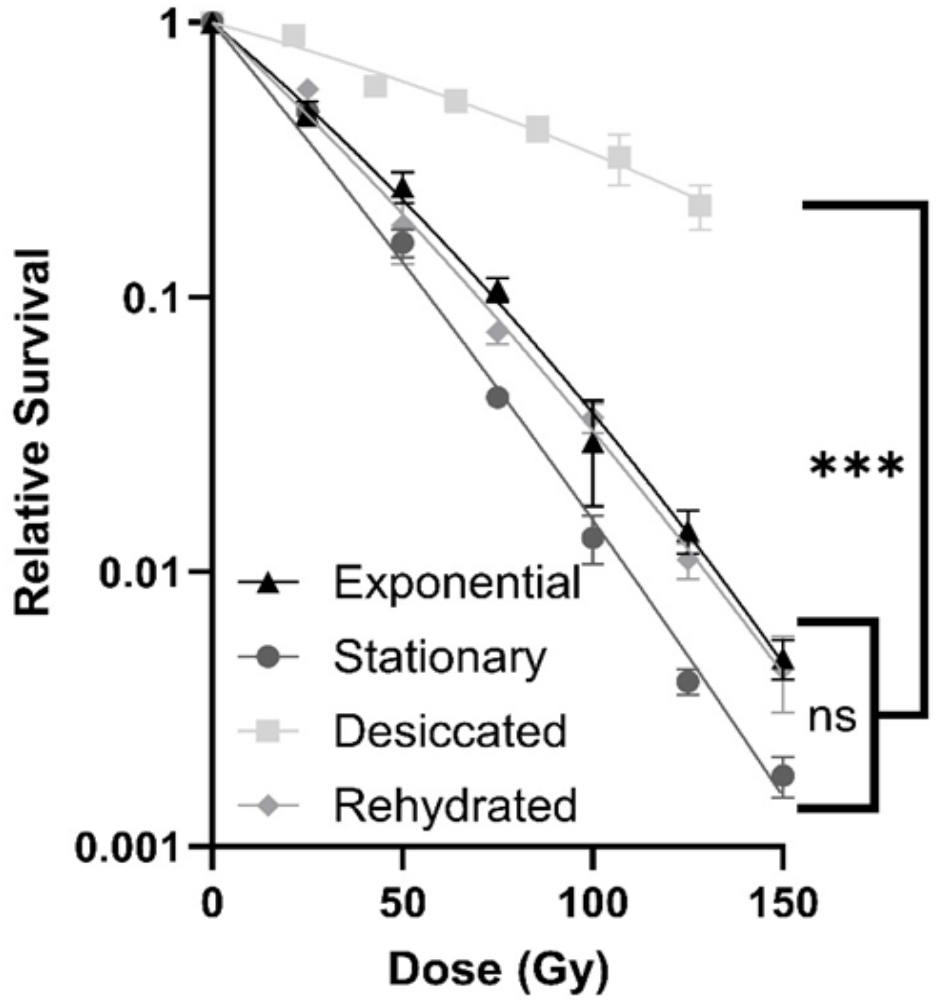
PINT collaboration: C. Thome, S. Tattenberg, NOSM

Validating the model

Desiccation

Oxygen enhancement (OER)

Relative biological effectiveness (RBE)



Validating the model

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Oxygen enhancement (OER)

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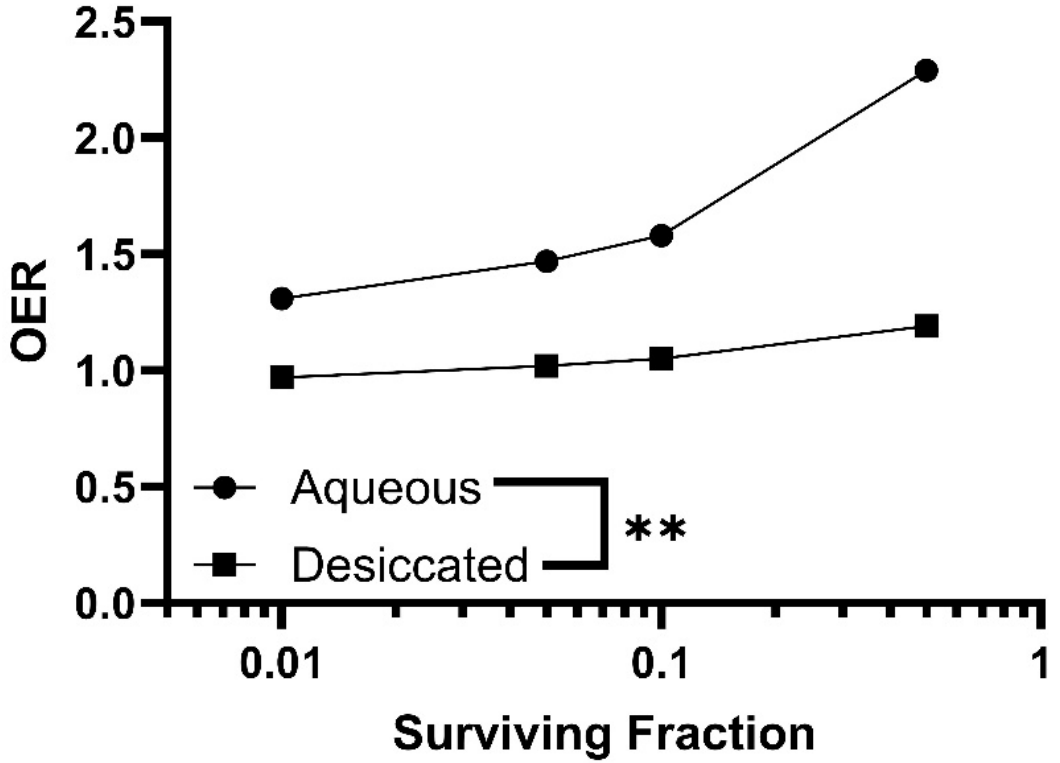

Validating the model

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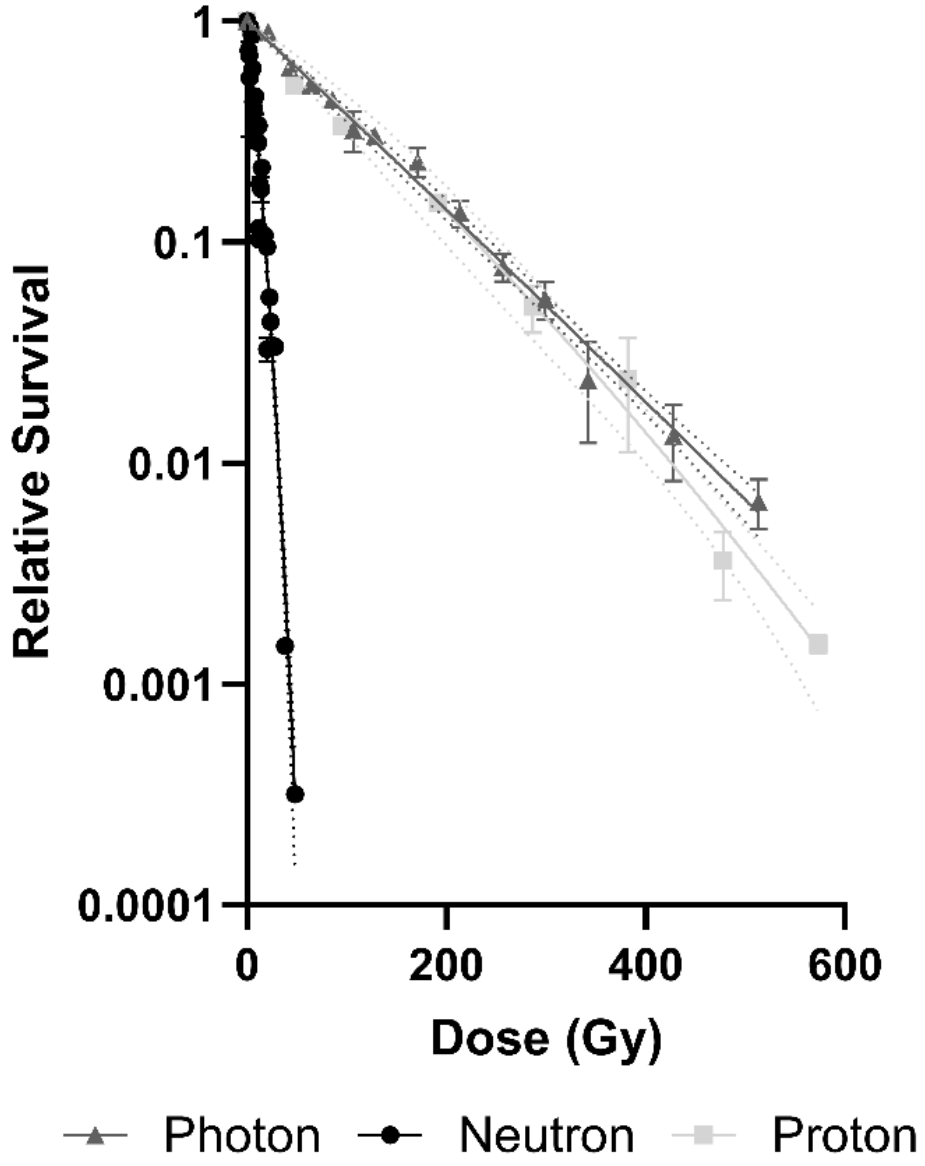

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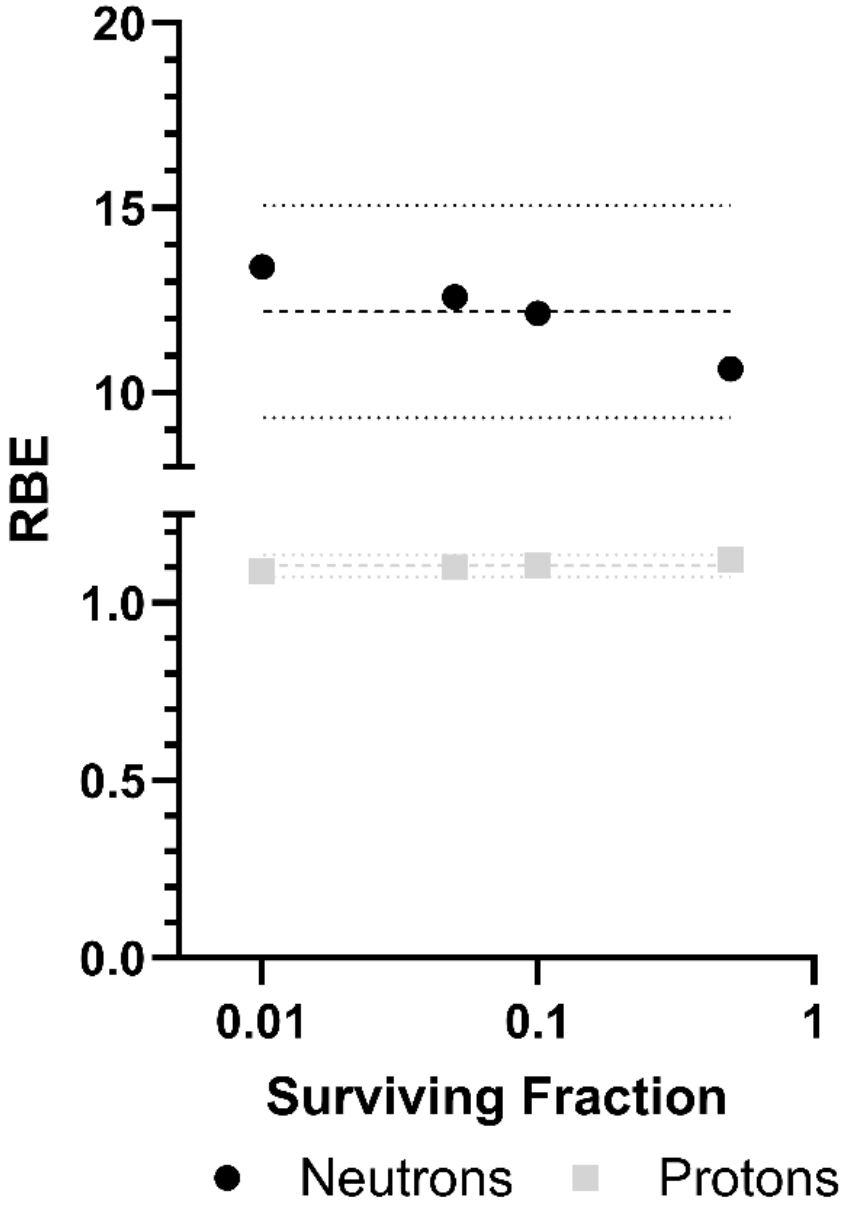
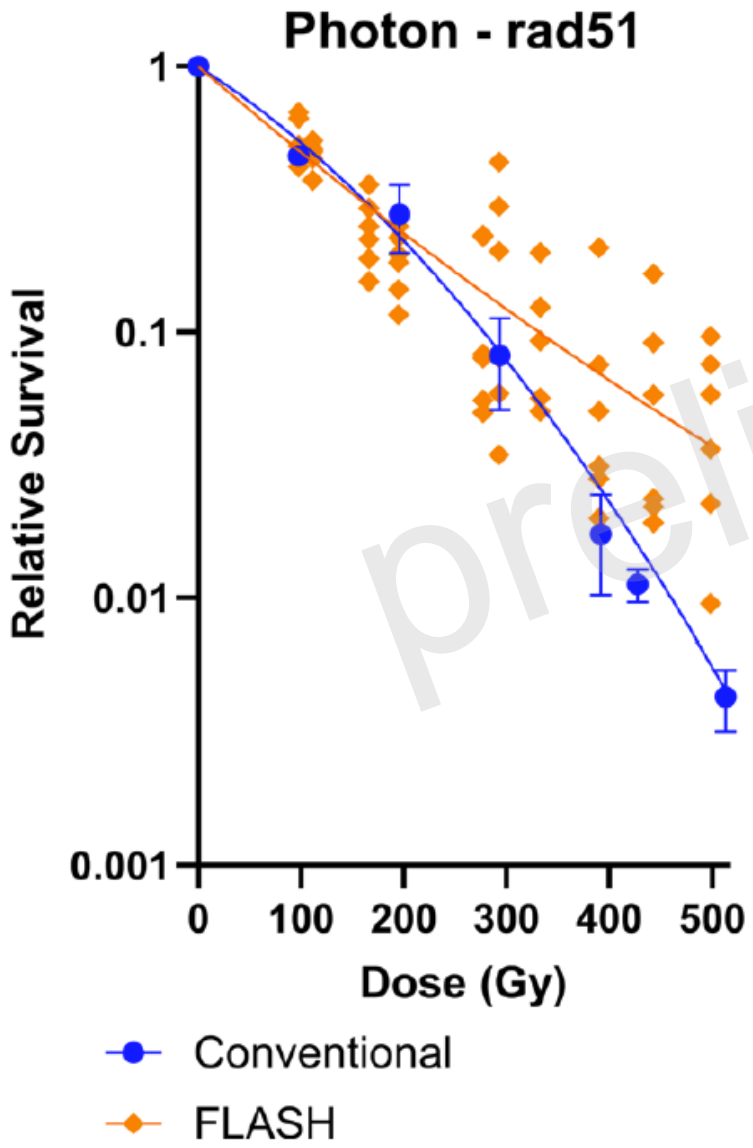
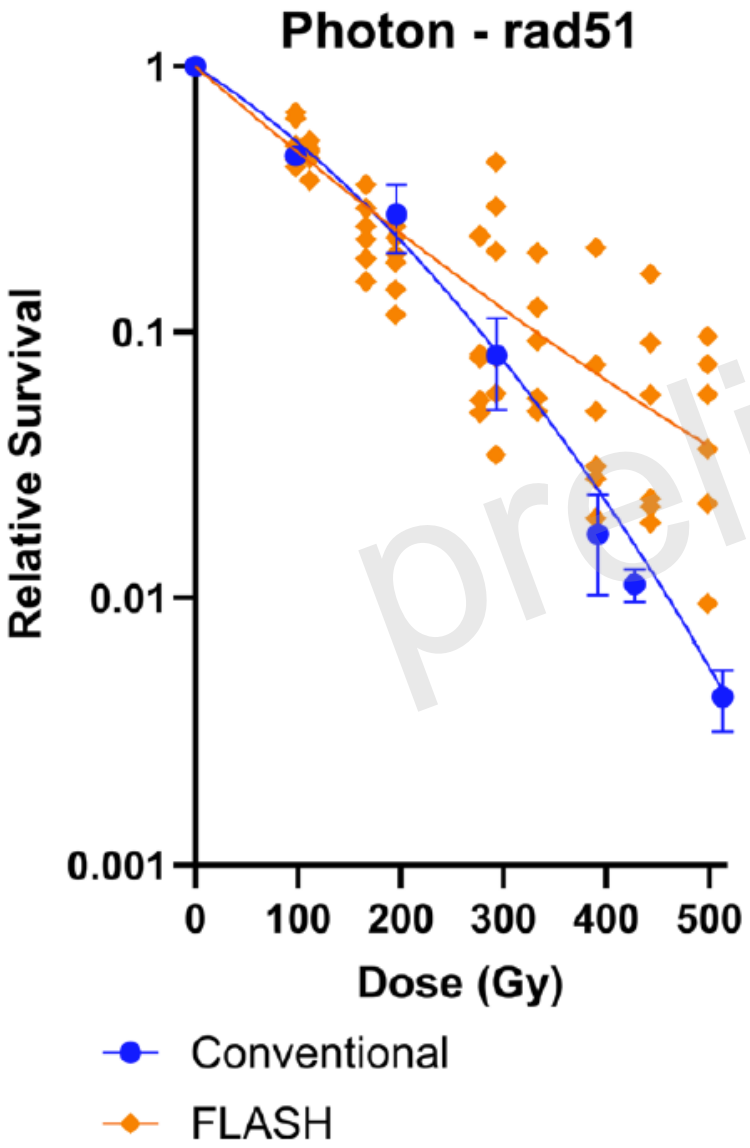
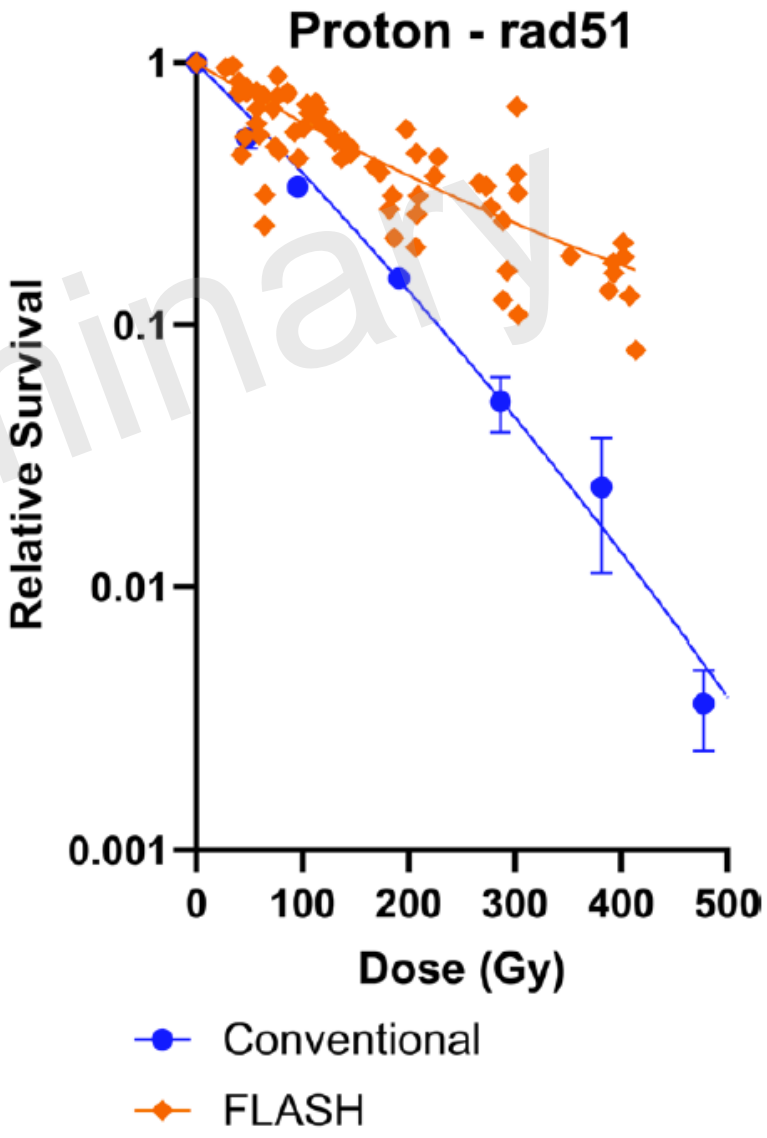


Proton FLASH at TRIUMF

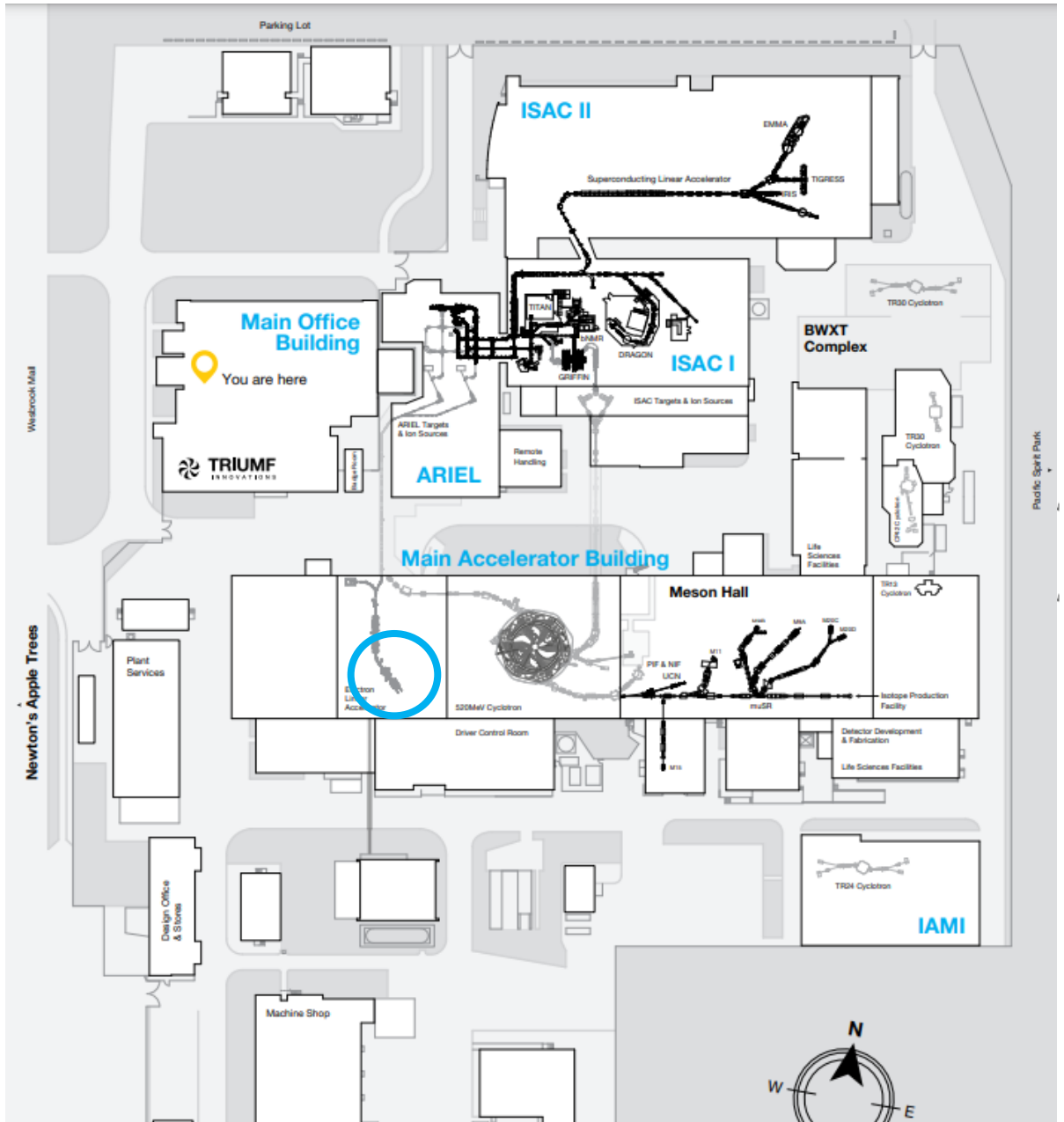


Proton FLASH at TRIUMF

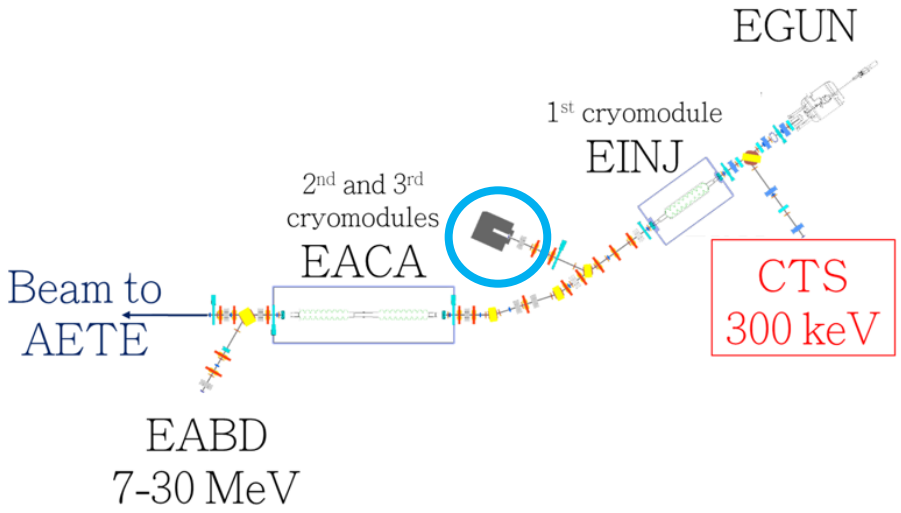




Photon FLASH @ TRIUMF

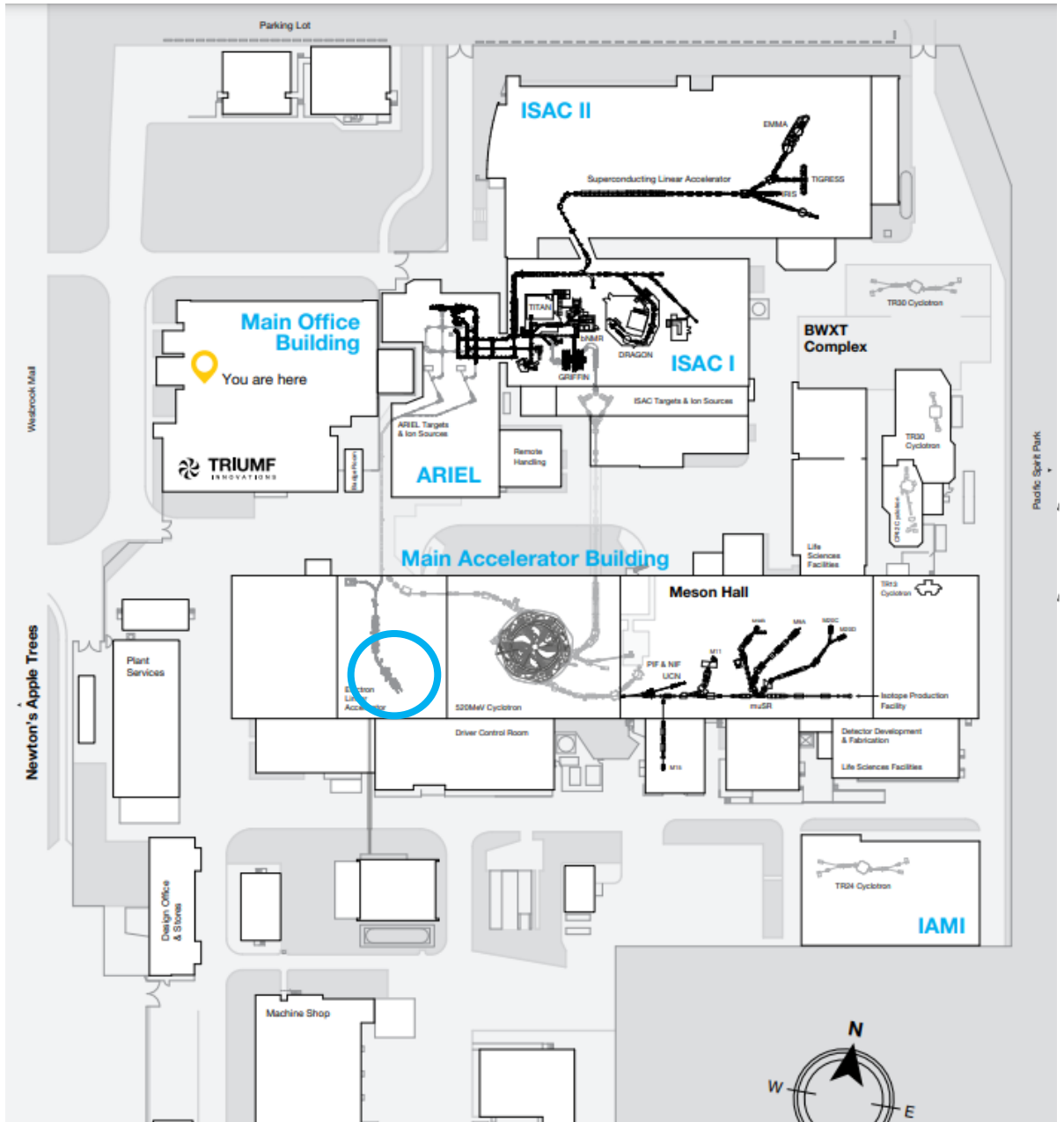


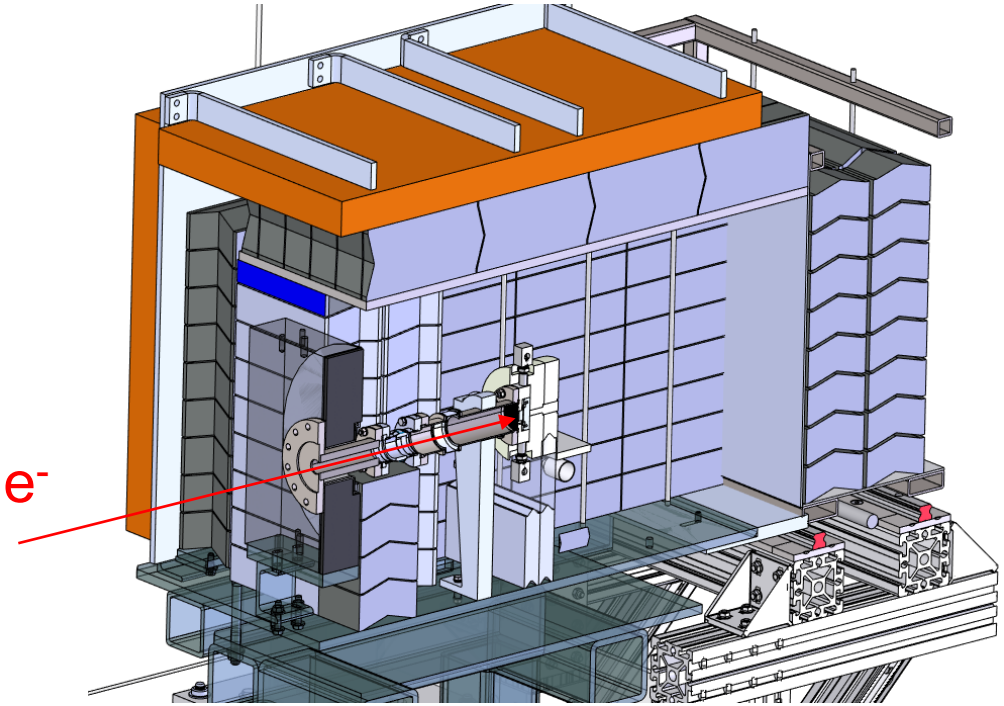
- Electron gun 300 keV 10 mA (CW)
- Three accelerating superconductive cryomodules
- Irradiation stations:
  - Low energy (CTS – 300 keV)
  - High energy (EABD – up to 30 MeV)
  - Medium energy (EMBD - up to 10 MeV)



Magdalena Bazalova-Carter, UVic
Alexander Gottberg, TRIUMF

Photon FLASH @ TRIUMF

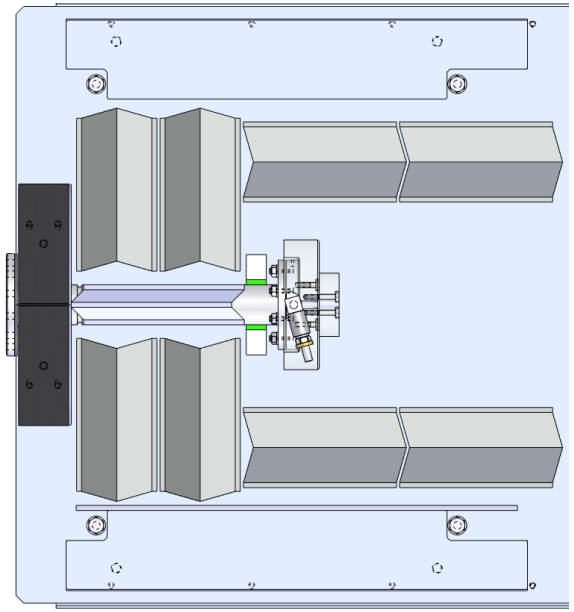




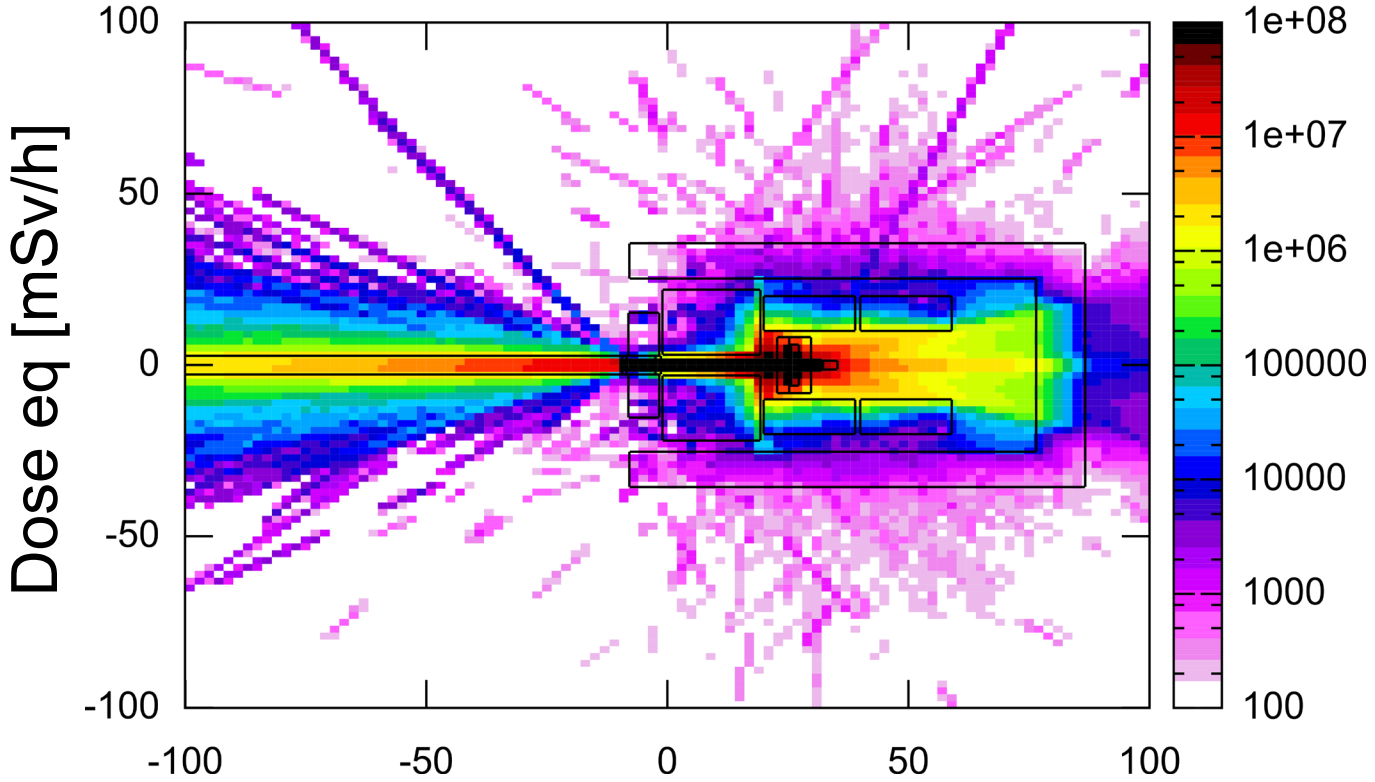
Magdalena Bazalova-Carter, UVic
Alexander Gottberg, TRIUMF

Photon FLASH @ TRIUMF

FLASH – DoseEq @ 10 MeV



Average dose rate up to ~ 200 Gy/s



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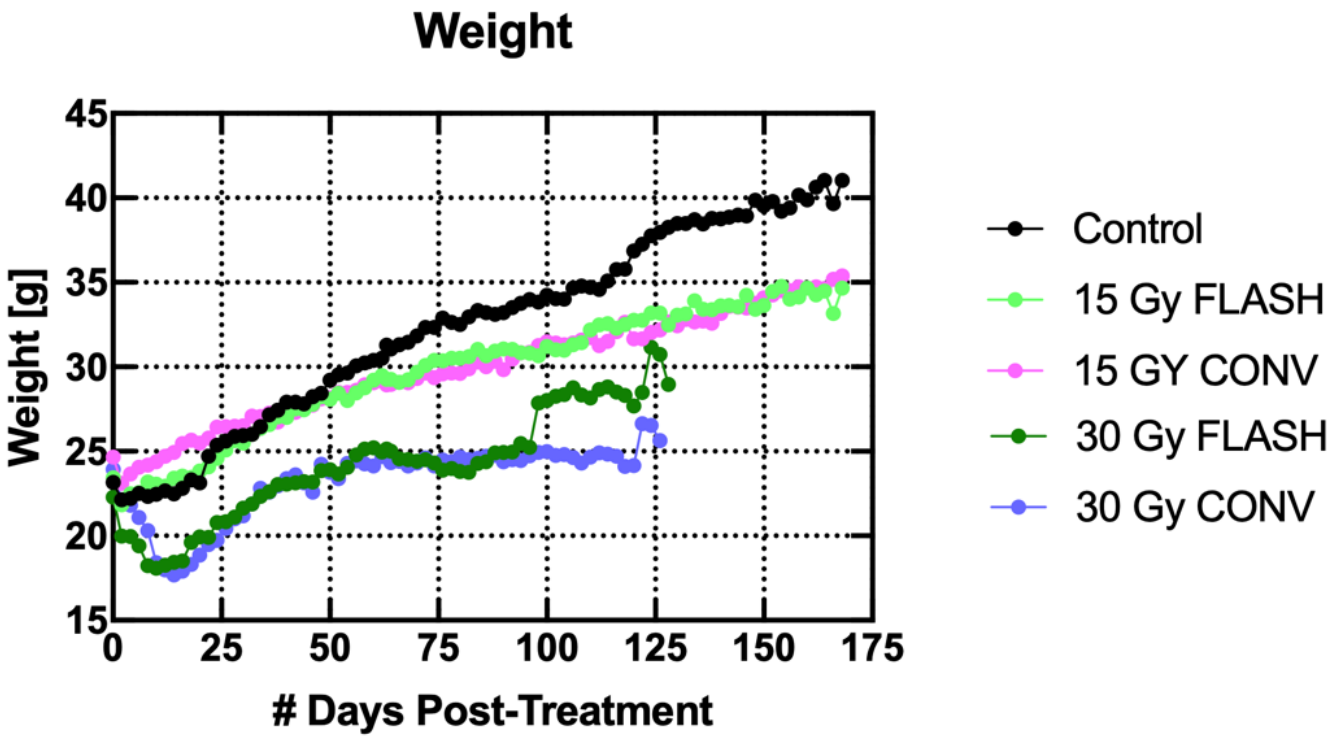
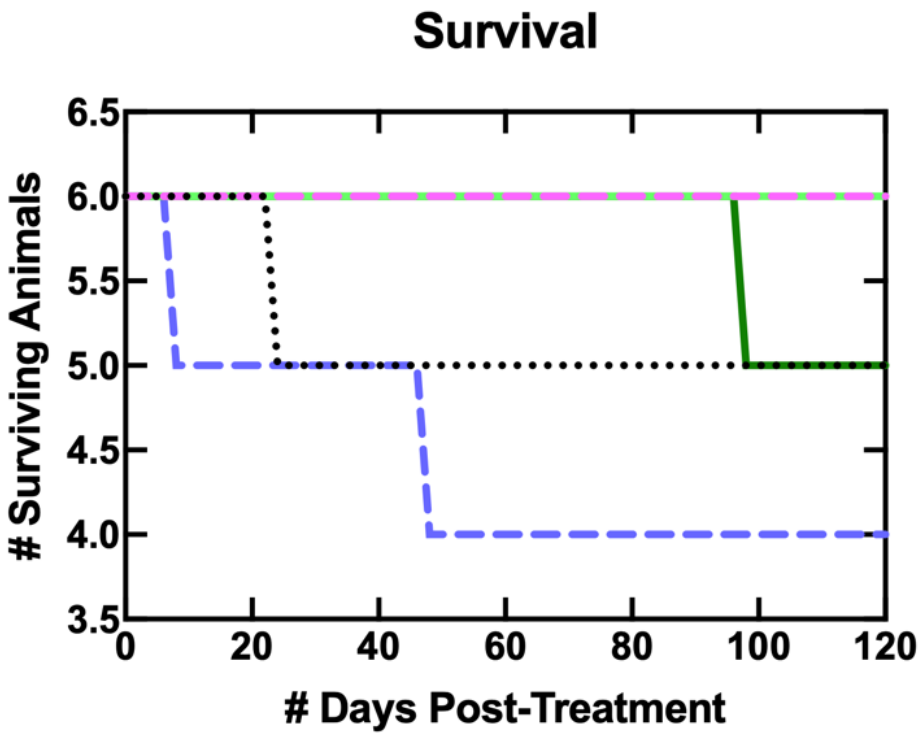
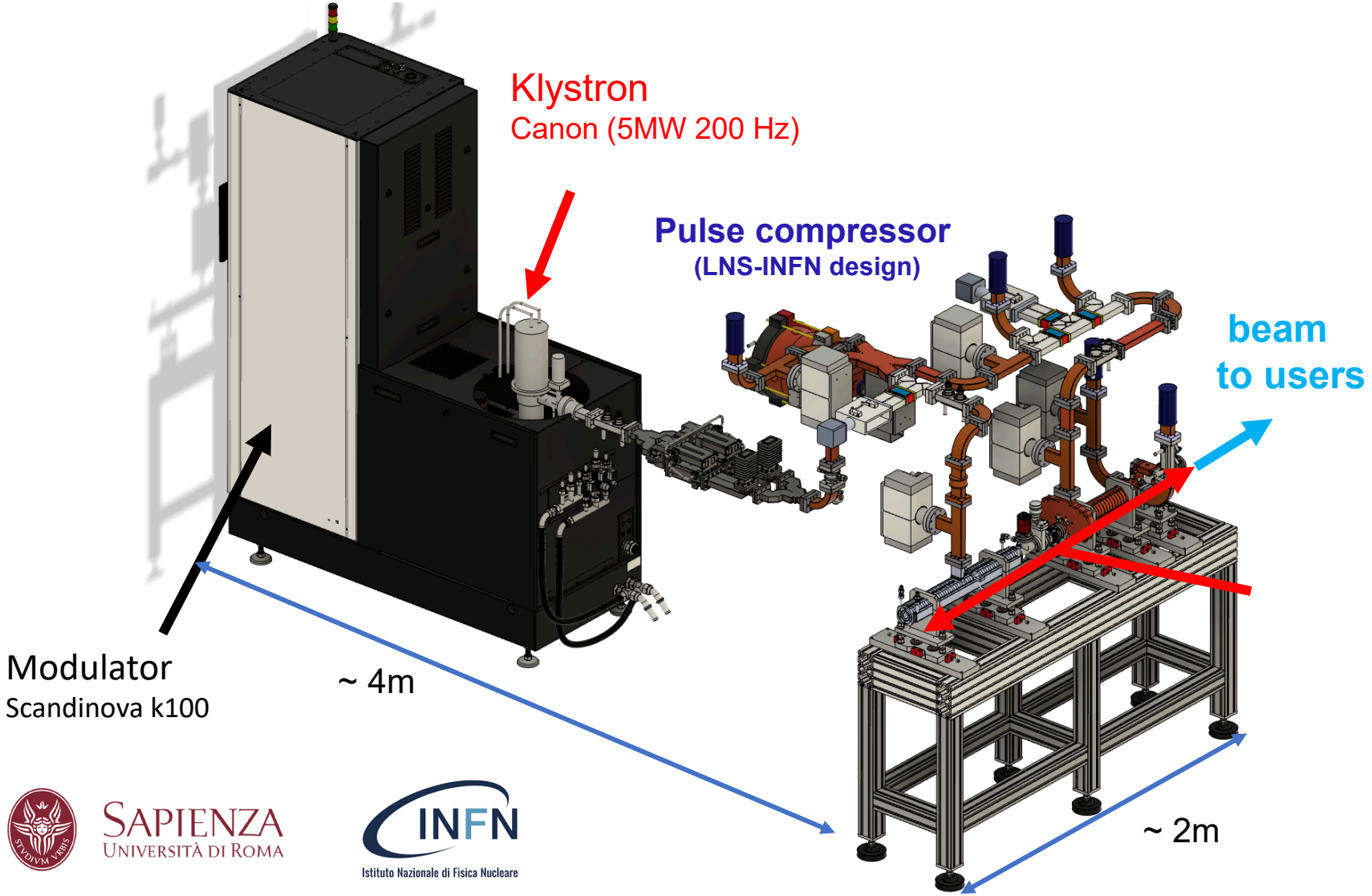




Nancy Ford et al.

Photon FLASH with Sapienza University

SApienza Flash Electron Source for radio-Therapy (SAFEST)



In final construction phase at University of Rome “Sapienza”

Testing VHEE SW & TW technology

C-Band (5.712GHz) LINAC, compact and modular layout
Optimal compromise for
a) High-charge electron bunches
b) Compact accelerating structures
c) Low disperse flux

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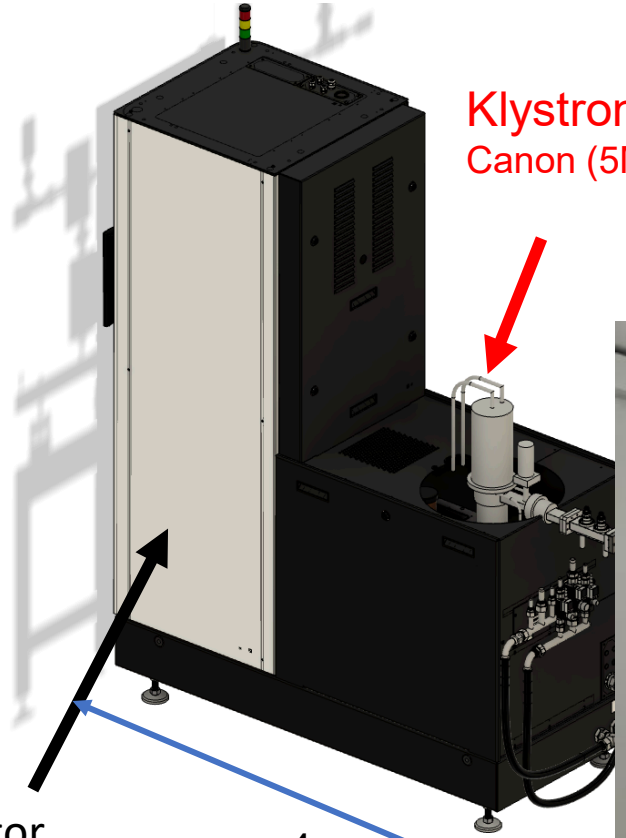
Slide Prof. V. Patera

Photon FLASH with Sapienza University

SApienza Flash Electron Source for radio-Therapy (SAFEST)



Klystron
Canon (5MW 200 Hz)

Pulse compressor

Modulator
Scandinova k100

~ 4m

C-Band (5.712GHz) LINAC, compact and modular layout
Optimal compromise for
a) High-charge electron bunches
b) Compact accelerating structures
c) Low disperse flux

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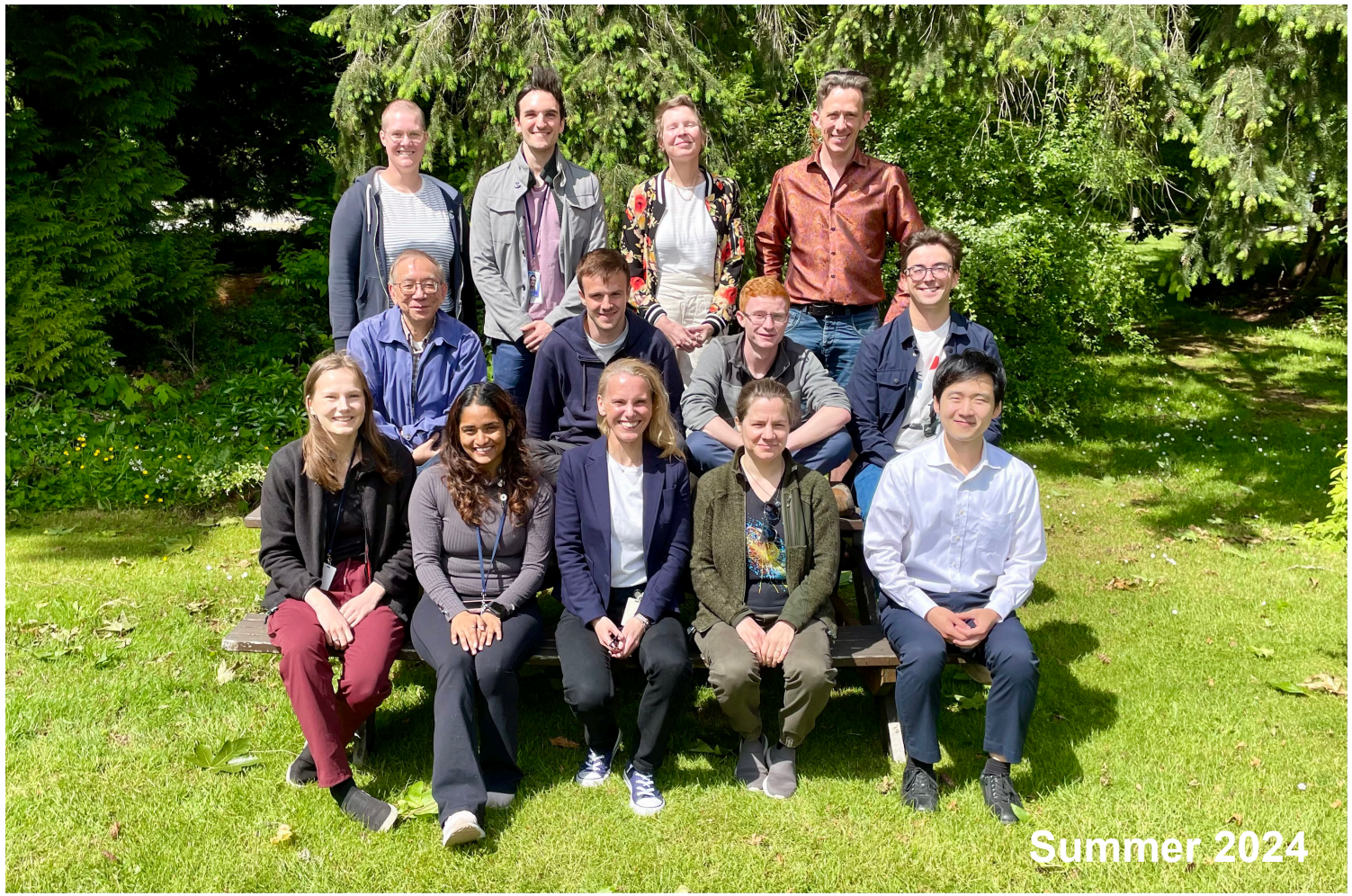
Slide Prof. V. Patera

Acknowledgment

- Prof. Girard and collaborators, Uni St. Etienne, France
- Prof. Bazalova-Carter and collaborators, University of Victoria, Canada
- Prof. Thome, NOSM, Canada
- Prof. Patera, Sapienza University, Italy

Thank you
Merci



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