

Radiotherapy @ ARIEL

Conny Hoehr

Life Sciences Division

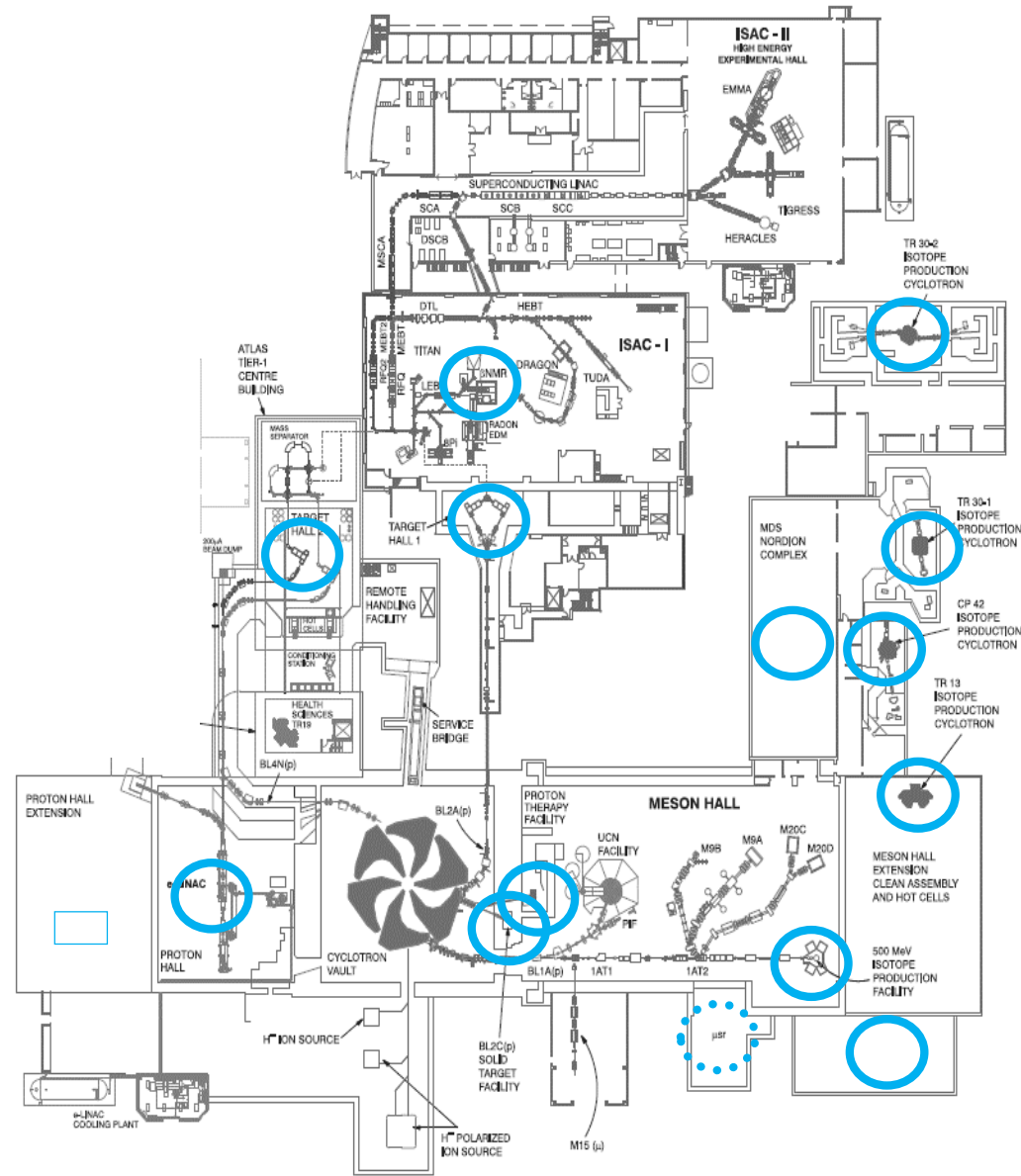
Alex Gottberg

Accelerator Division

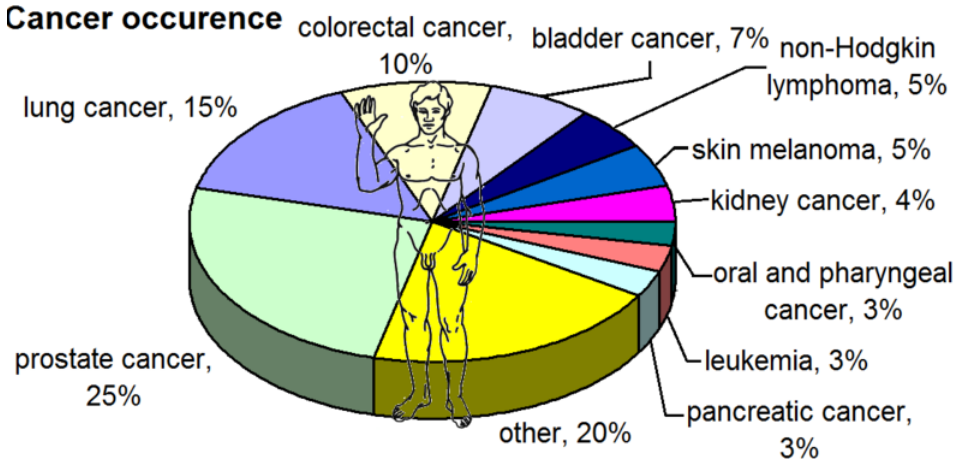
2020-11-20



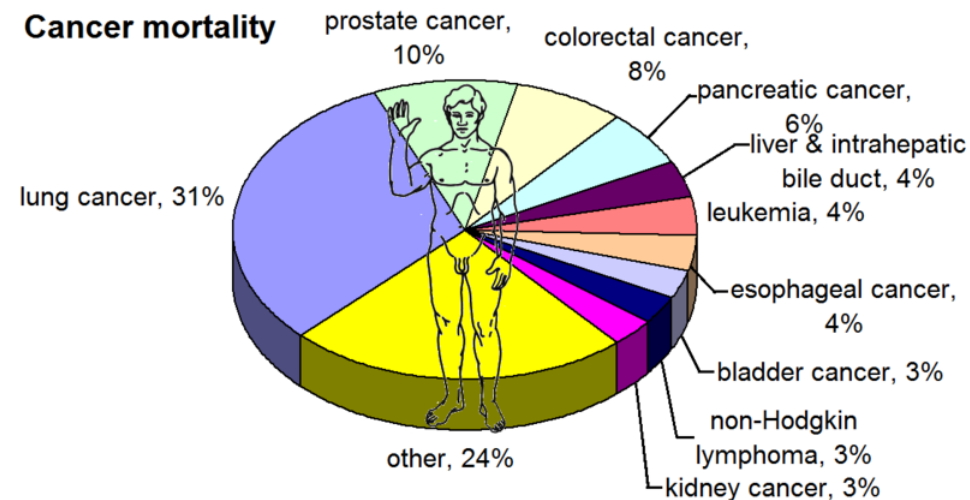
Applicable to
medicine



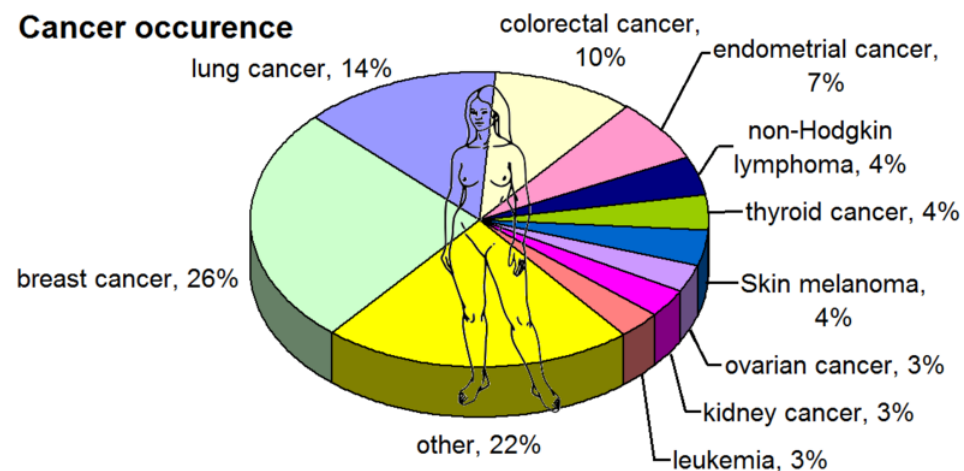
Cancer occurrence



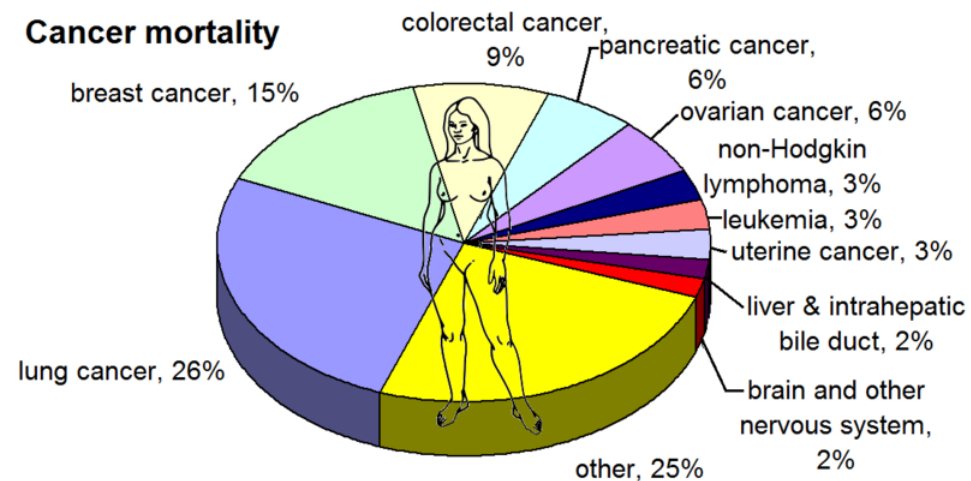
Cancer mortality



Cancer occurrence

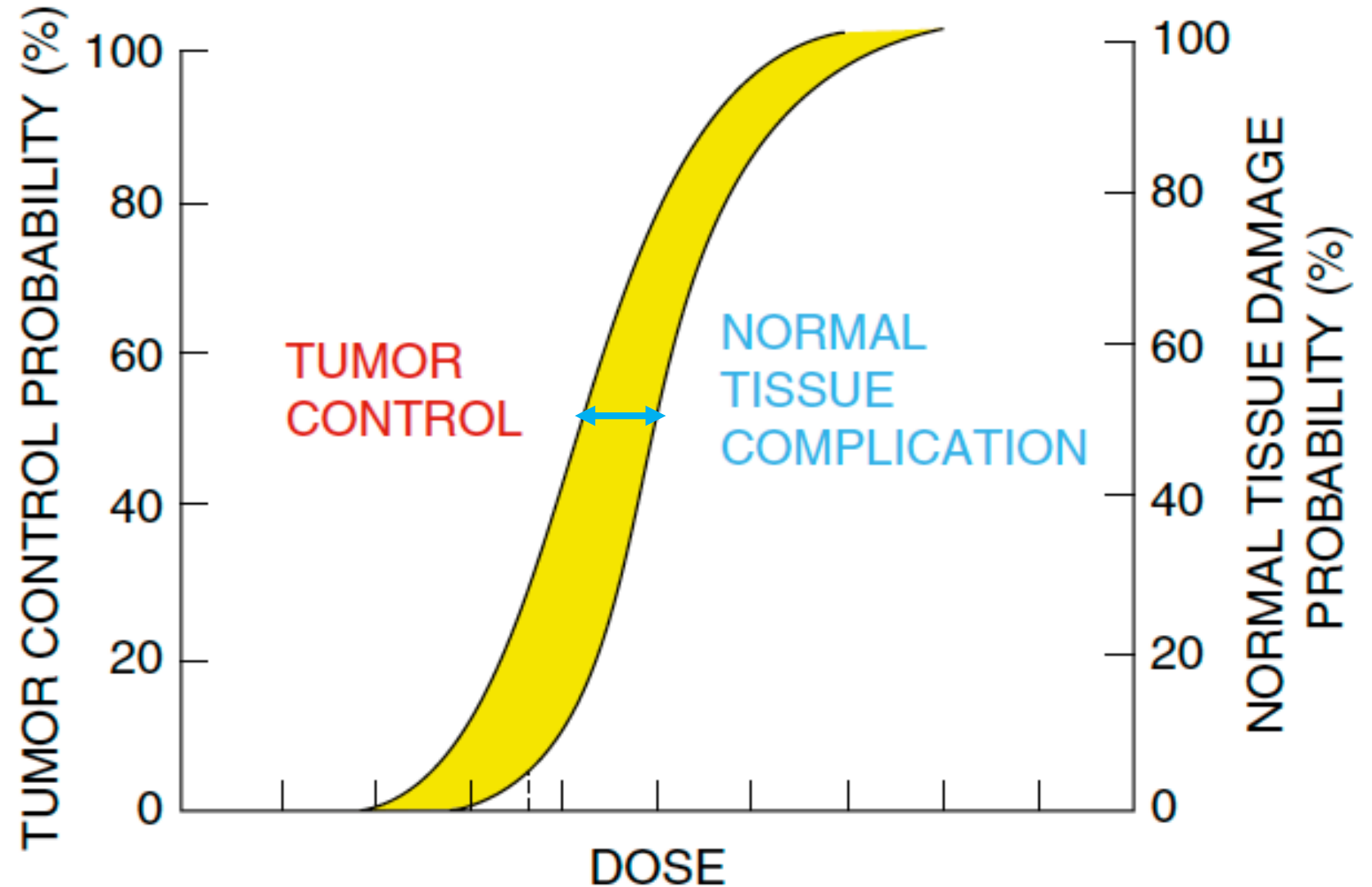


Cancer mortality



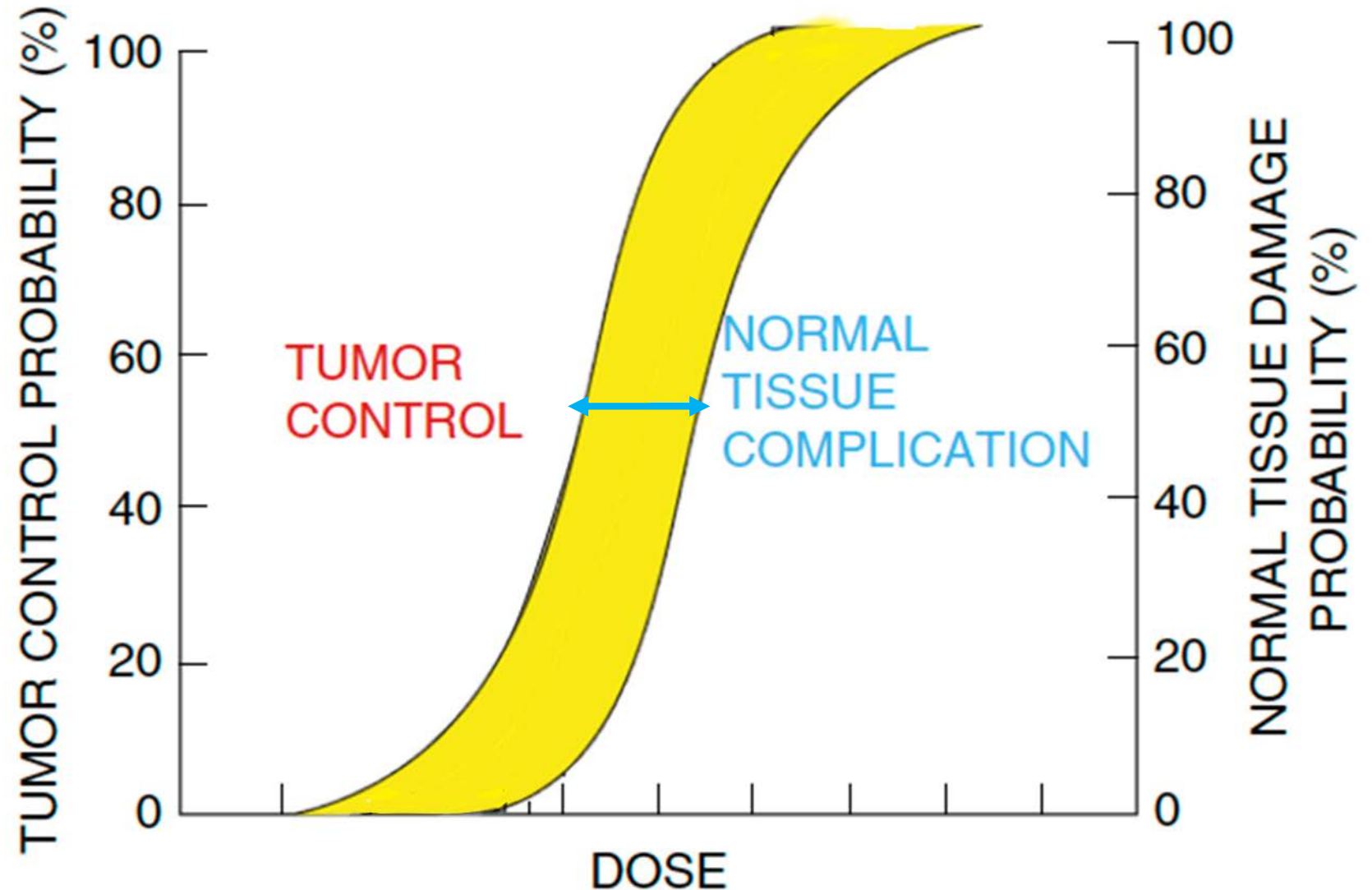
Cancer Research

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



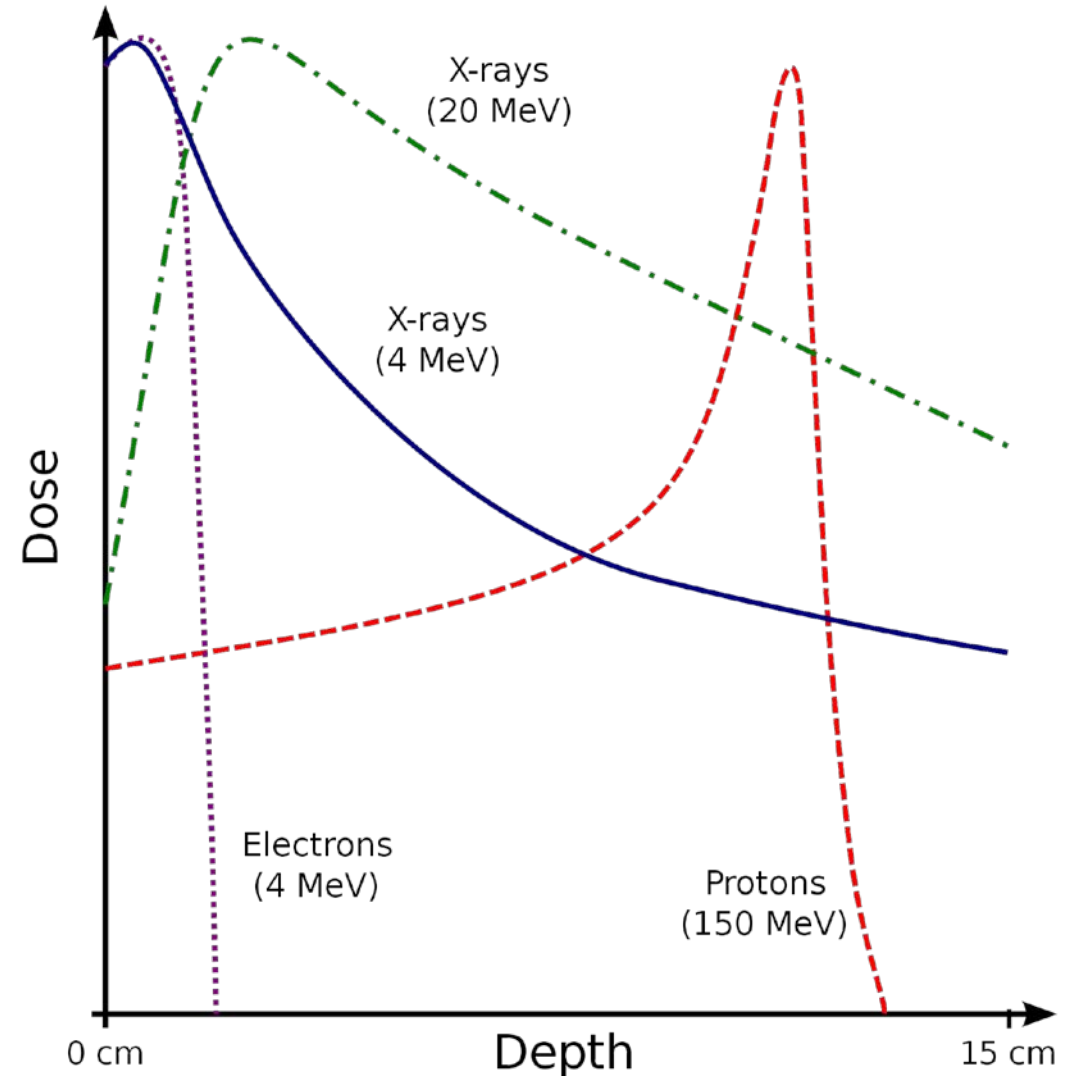
Cancer Research

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

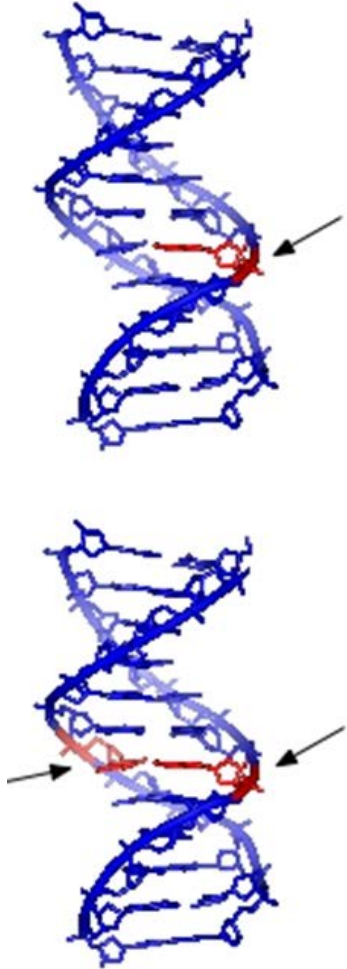


External beam therapy

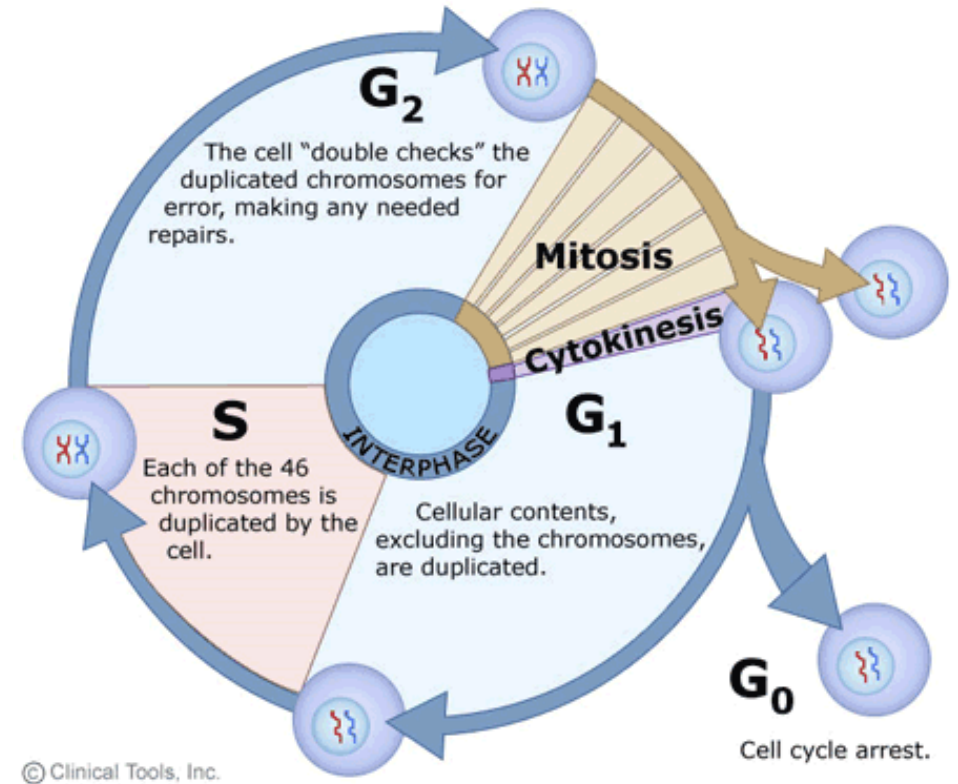
- **Electrons** only used for surface tumours
- **X-rays** (6-18 MV) most commonly used radiotherapy, many techniques to spare healthy tissue (3D conformal beams, image guided delivery, real-time motion tracking etc.), compact and cost efficient
- **Protons** need 230 MeV accelerator for clinical use, large facility, expensive



DNA Break



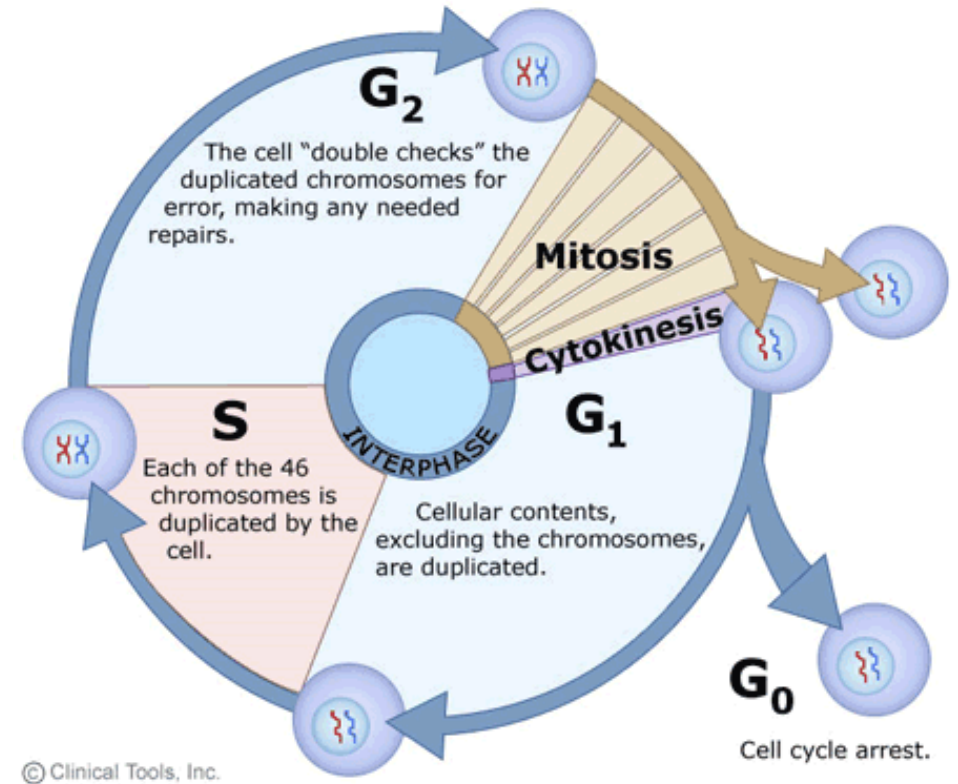
- DNA (Deoxyribonucleic acid): genetic instructions for development and functioning
- Cell needs information from DNA for survival
- Single helix break easy to repair
- Double helix break more difficult to repair
- Cell can not survive
- **Radiotherapy: as many double helix breaks in cancer cells as possible with as few double breaks as possible in healthy cells**



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



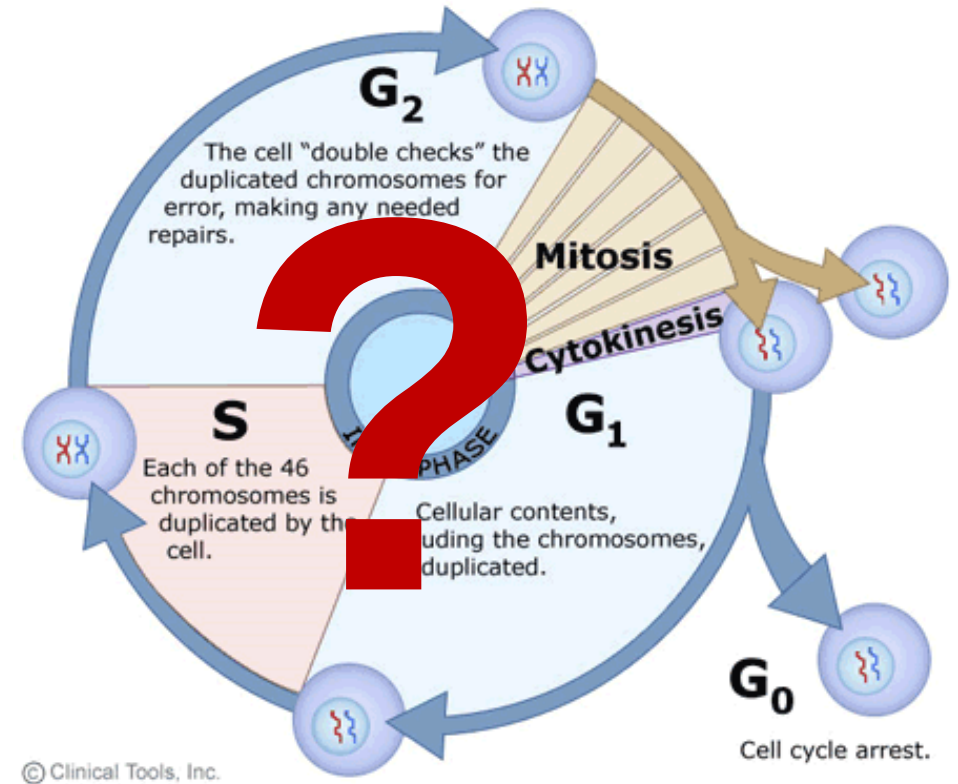
FLASH effect

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



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
- To reach high dose rates – remove target..... **electron beam**



1a : Day 0



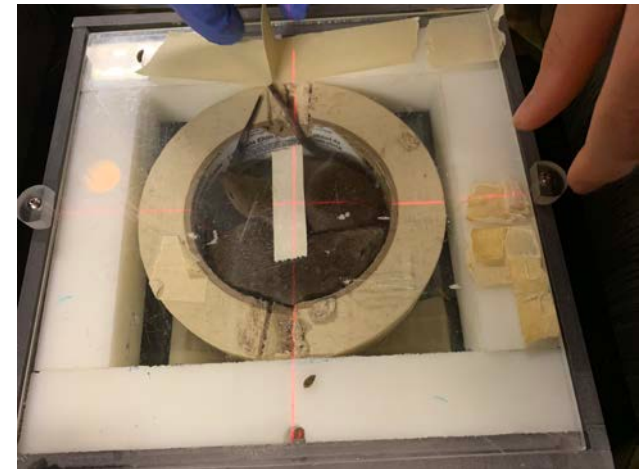
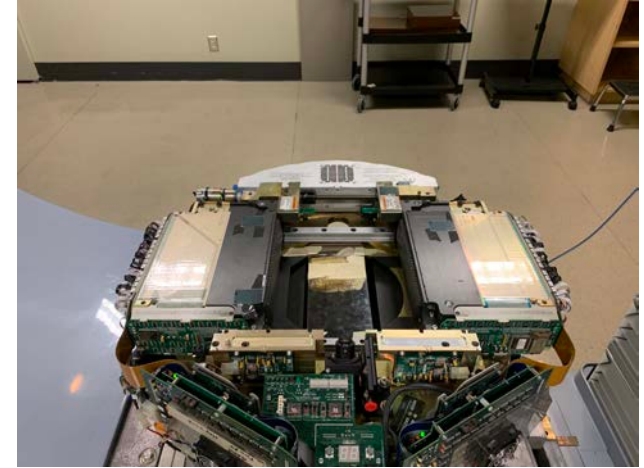
1b : 3 weeks



1c : 5 months

How does it work and how can it be used clinically?

Electron FLASH in Vancouver

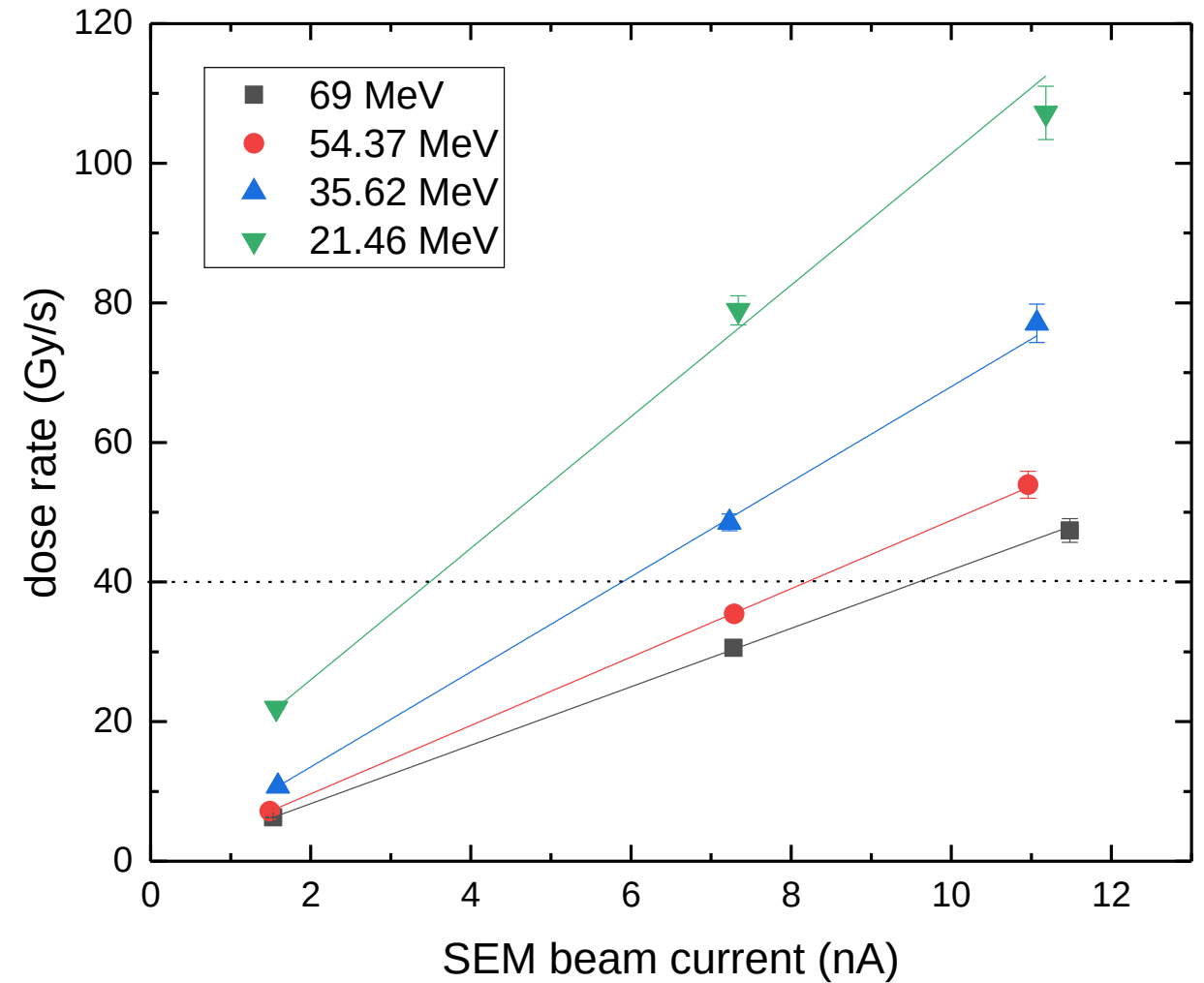


- Around 260 Gy/s
- FLASH effect observed!!!
- **But: Not penetrating enough for deeper tumors.....**

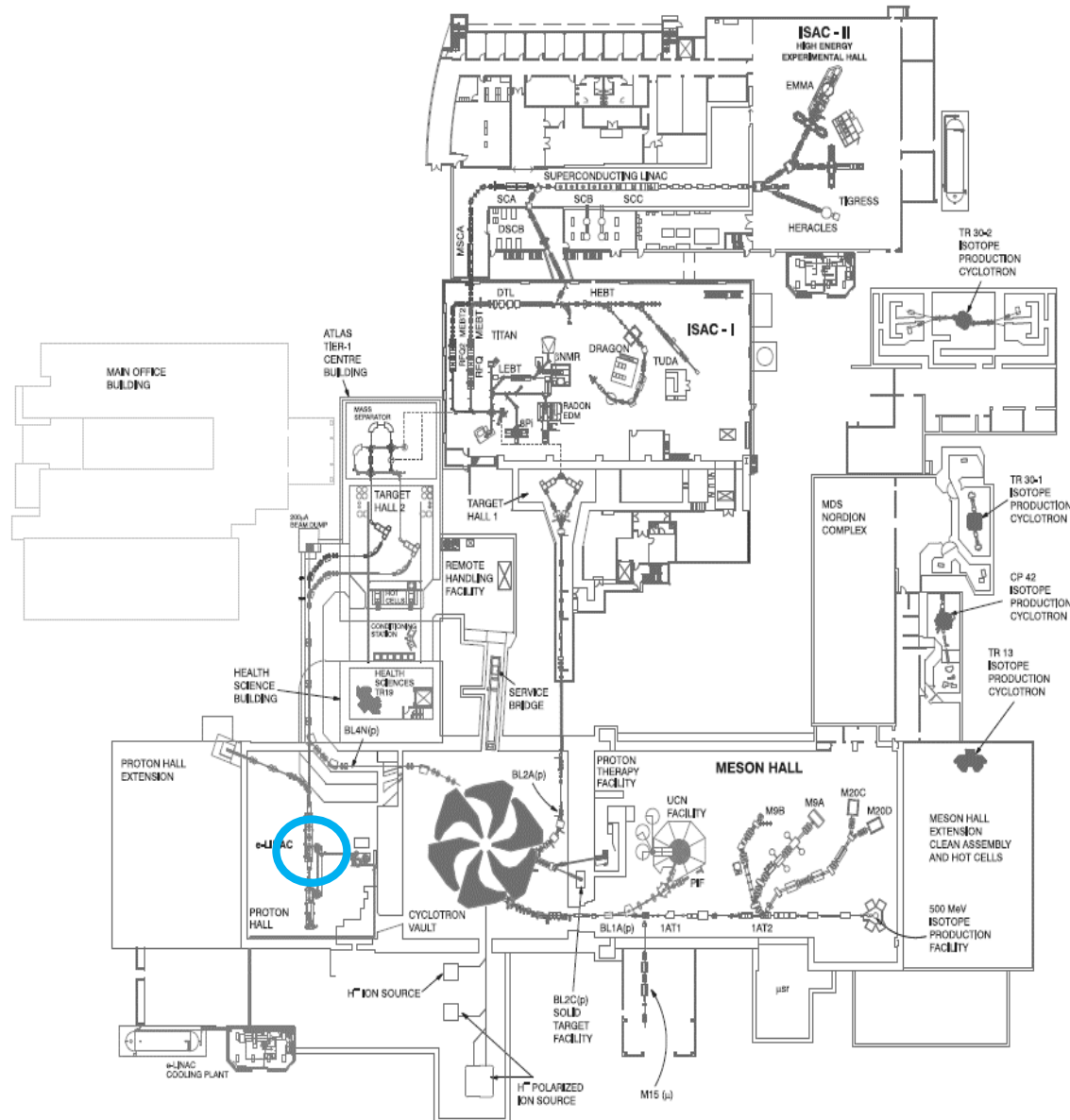
Proton FLASH @ TRIUMF



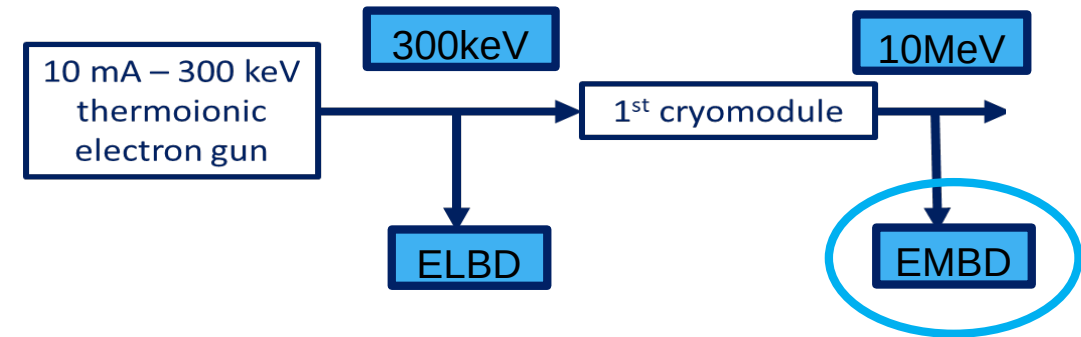
- Started to explore FLASH beam delivery at TRIUMF Aug 2020
- Dosimetry with fibers
- **But: Proton Therapy requires expensive accelerator**



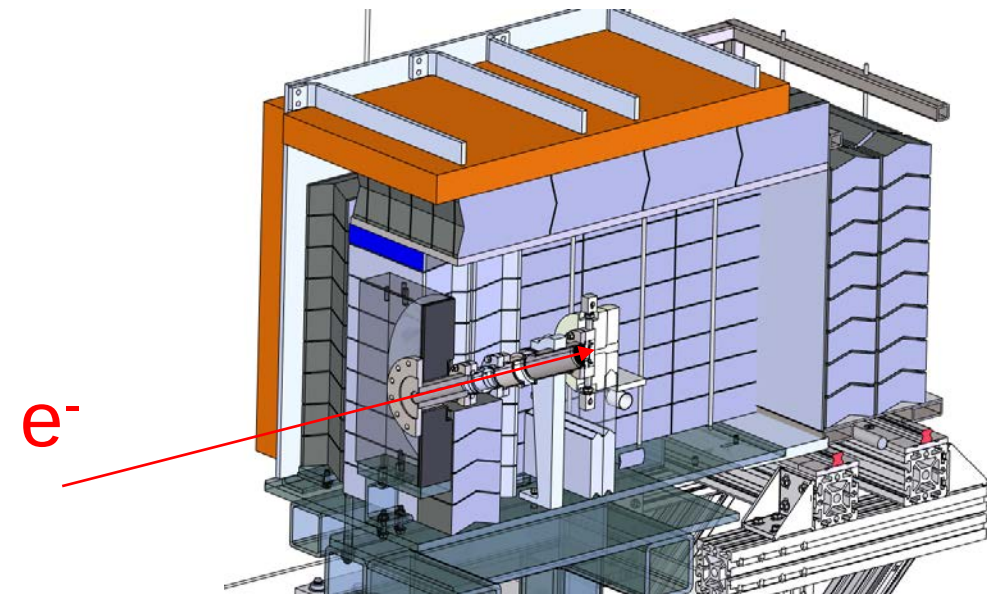
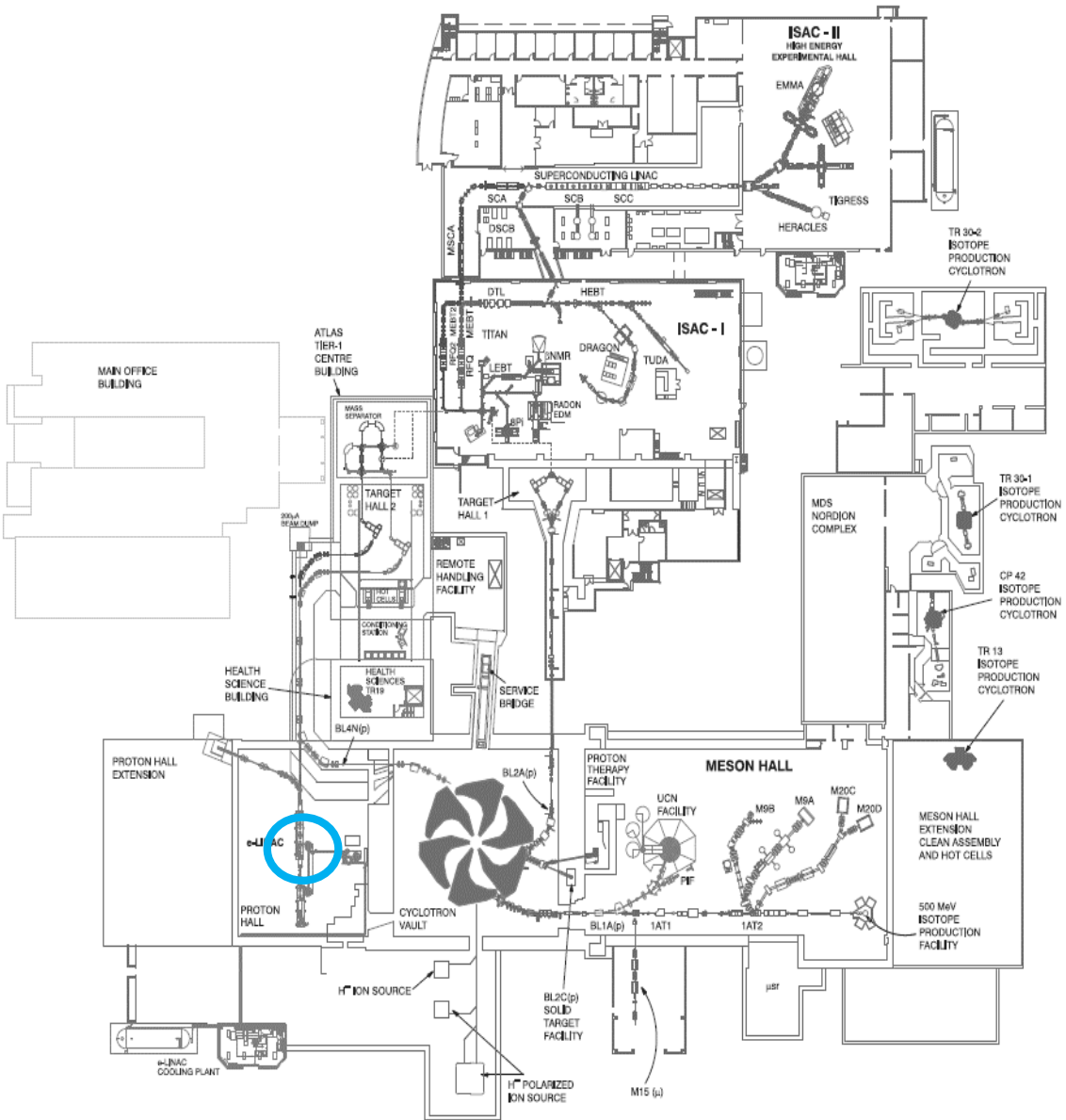
Photon FLASH @ ARIEL e-linac



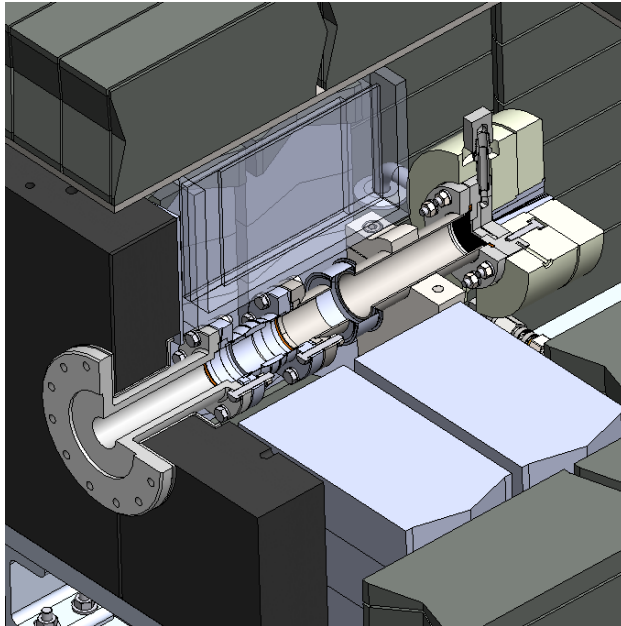
- Electron gun 300 keV 10 mA (CW)
- Three accelerating superconductive cryomodules
- Irradiation stations:
 - Low energy (CTS – 300 keV)
 - High energy (EABD – up to 30 MeV)
 - Medium energy (EMBD - up to 10 MeV)



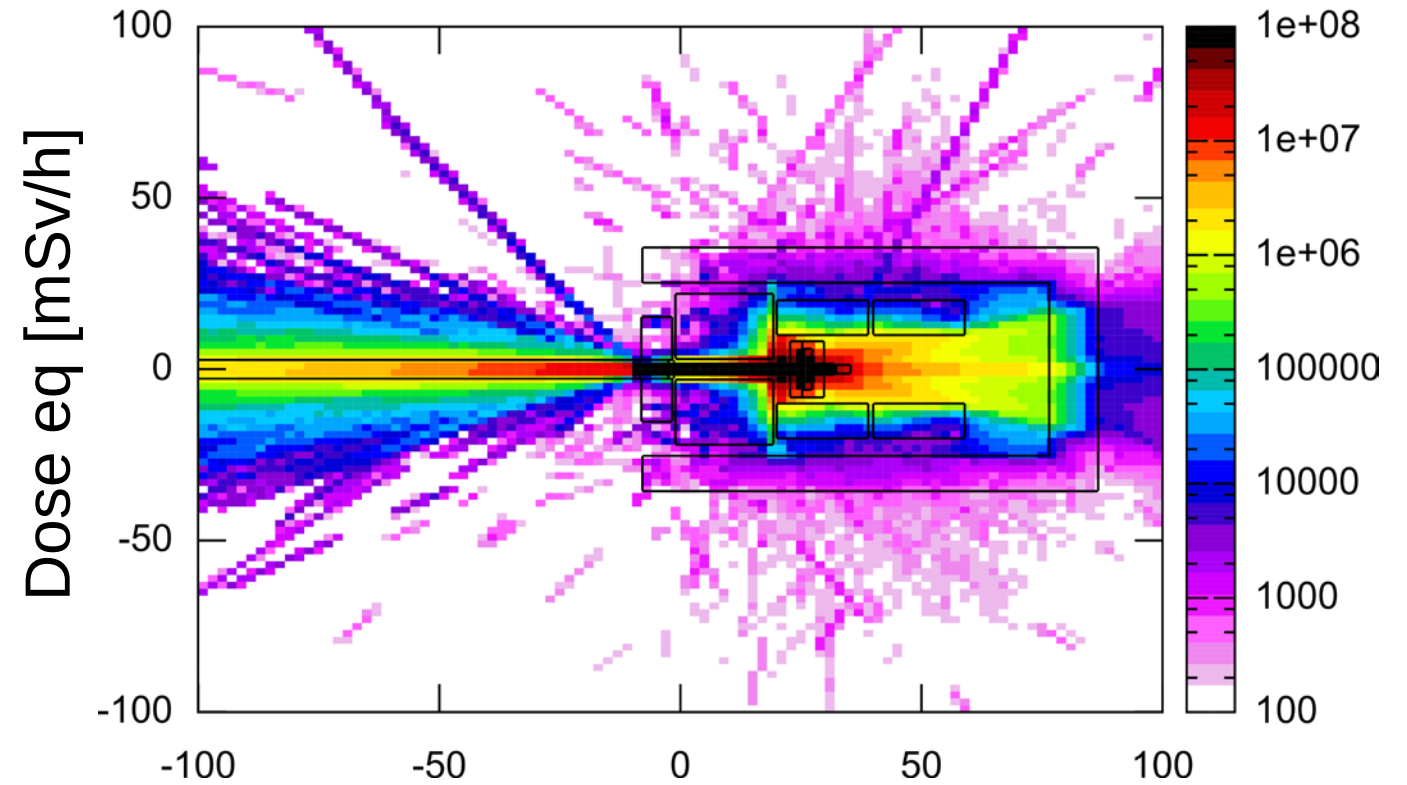
Photon FLASH @ ARIEL e-linac



FLASH – DoseEq @ 10 MeV

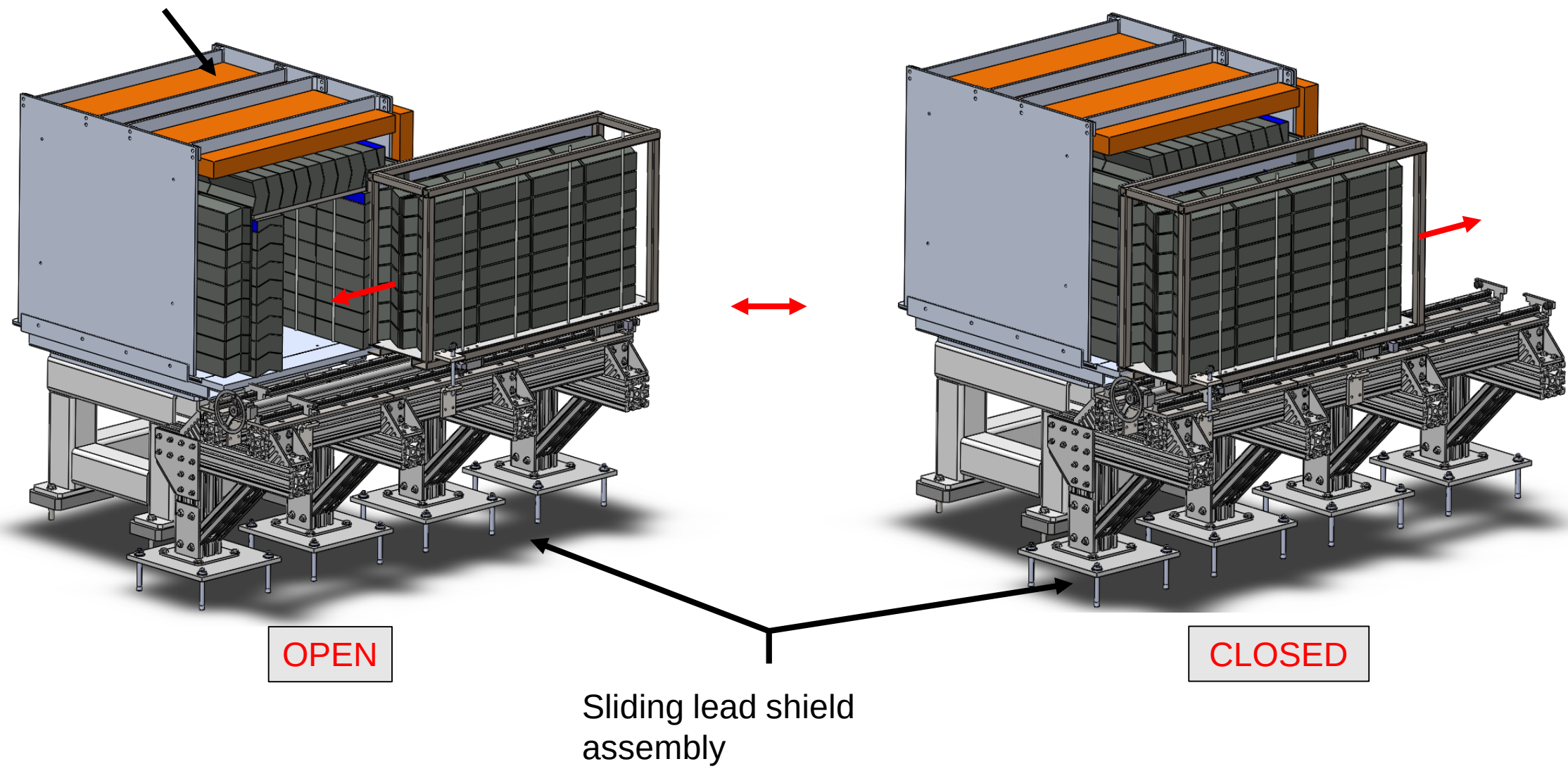


Average dose rate up to ~ 200 Gy/s



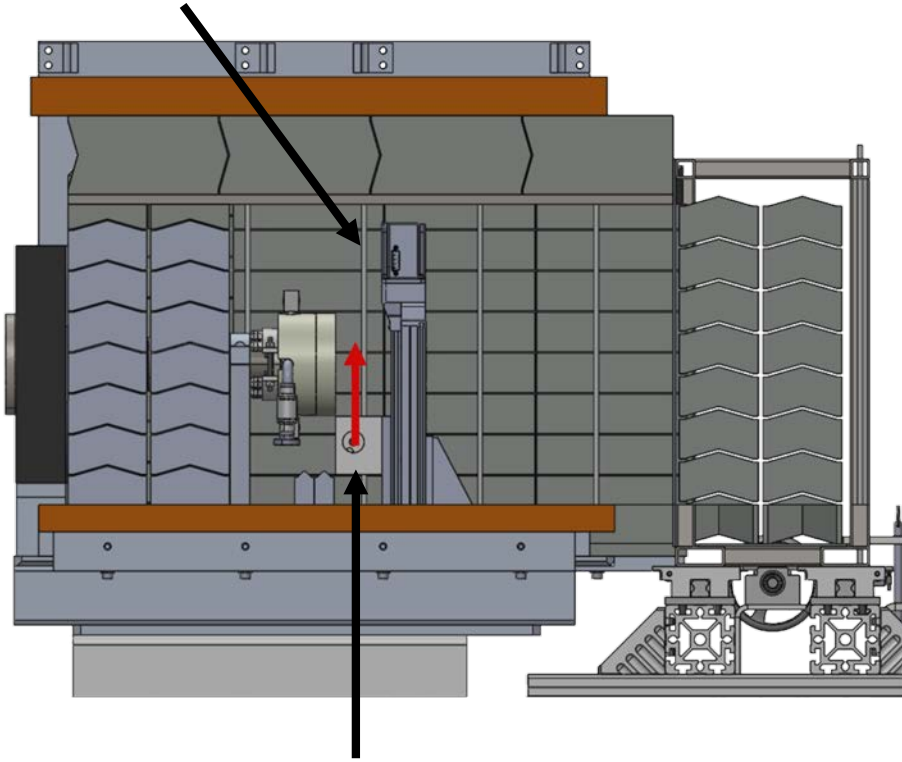
EMBD Retrofit for FLASH

Retrofit EMBD structure

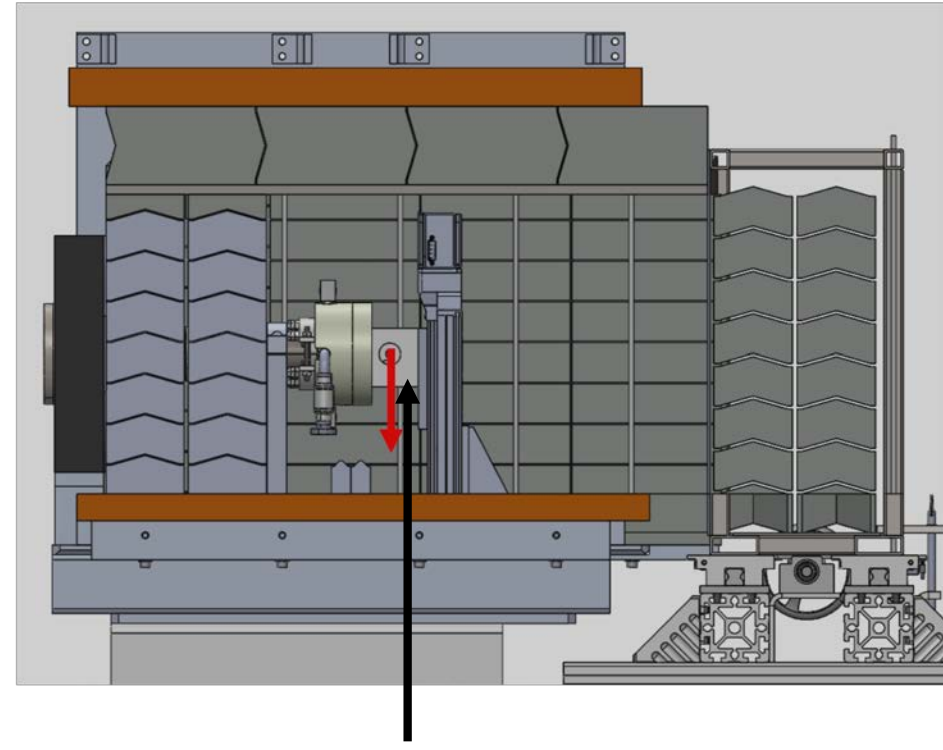


FLASH Irradiation Setup

Vertical motion stage



Holder
(retracted*+shielded†)



Holder
(aligned, ready for delivery)

What's next?

- Manufacture, installation and testing winter/spring 2020/2021
- Experiments with biological samples **fall 2021**

Thank you
Merci

www.triumf.ca

Follow us @TRIUMFLab

