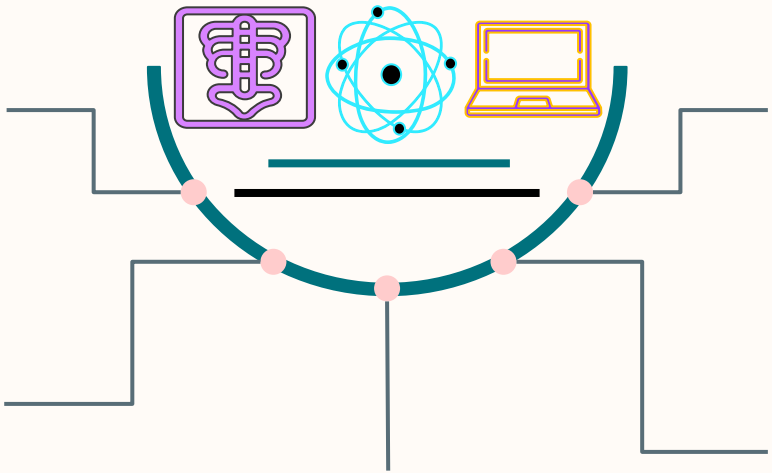
PenMRT: A multi-scale treatment planning system for microbeam radiation therapy

Sarvenaz KESHMIRI[1], Jean François ADAM[1,2]

Assemblée générale 2023 du GdR Mi2B

[1] Univ. Grenoble Alpes, INSERM, UA07 STROBE
[2] Centre Hospitalier Universitaire Grenoble-Alpes

Microbeam Radiation Therapy (MRT)



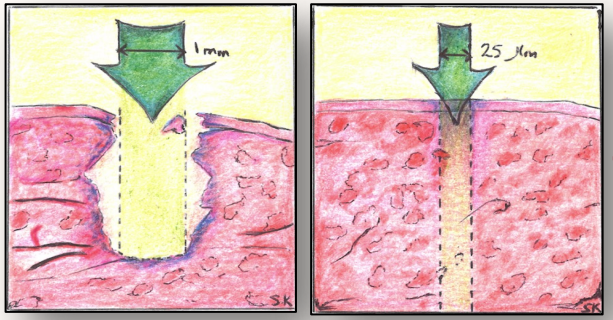
Future of penMRT

Medical physics and biological challenges of MRT

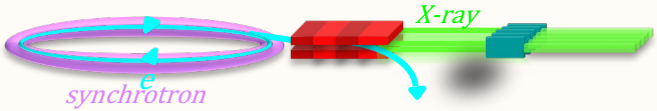
PenMRT in canine and rodent models

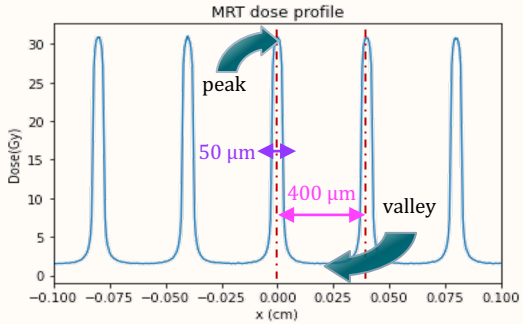
PenMRT dose calculation engine

Microbeam radiation therapy



Inspired by Zeman *et al*, Radiat Res 15, 496,1961 and Curtis, H. J., Radiat. Res., Suppl. 7, 1967



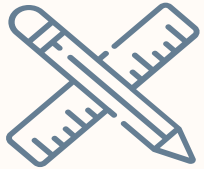


- Microbeam Radiation Therapy (MRT) is based on dose-volume effect.
- Spatial fractionation is a technique to induce dose-volume effect.
- MRT combines spatial fractionation with FLASH photons.

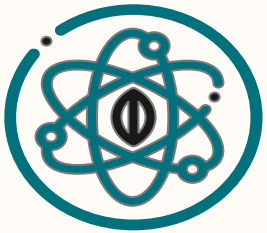
- An array of microbeams are produced using a Multi-Slit Collimator (MSC).
- In MRT, radiotoxic dose is confined to narrow microbeam passage area.

Challenges in MRT

- Medical physics challenges:
  - ✓ Dose calculation
  - ✓ Experimental dosimetry

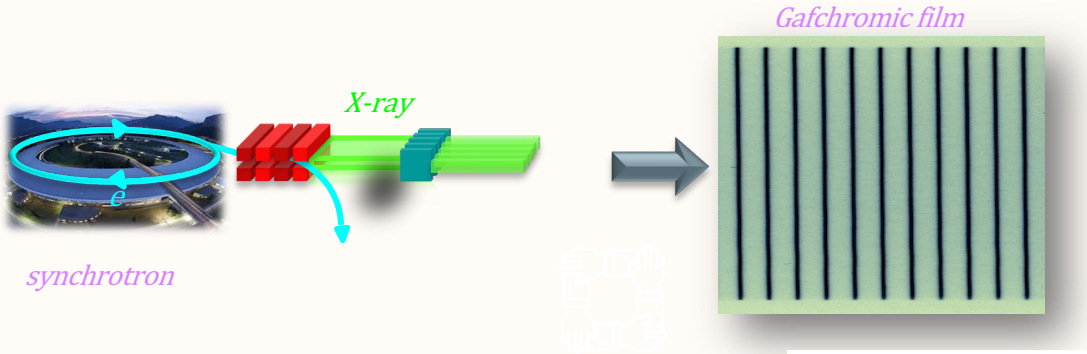


- Biological challenges.

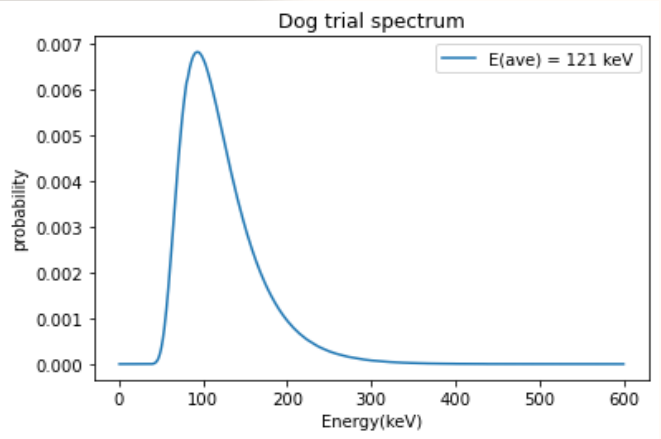


Medical physics challenges in MRT

Dose calculation (1)



- MRT uses orthovoltage polarized photons whilst conventional therapies are based on MV spectrums.

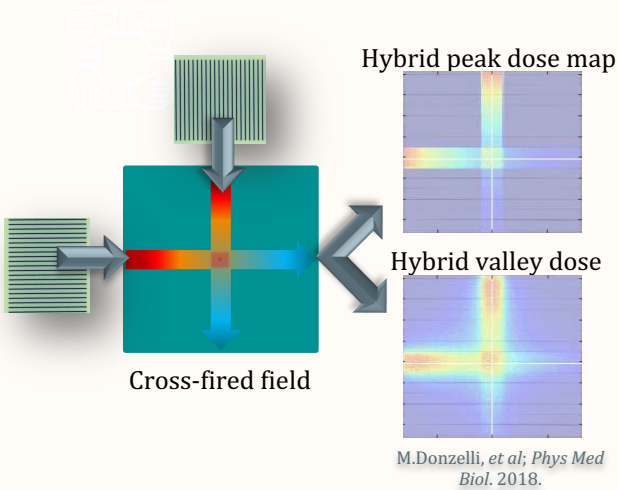


Dose calculation (2)

- Calculation methods in conventional radiotherapy are not adapted to energy spectrum and spatial dose distribution pattern of MRT.

- Dose calculation algorithms in MRT:
  1. Convolution/superposition
  2. Full Monte Carlo
  3. Hybrid

Rodents:
L. Eling *et al., Cancers*, 2021.
Large animals:
N.Coquery *et al., Scientific reports*, 2019.
JF.Adam *et al., RedJournal*, 2022.

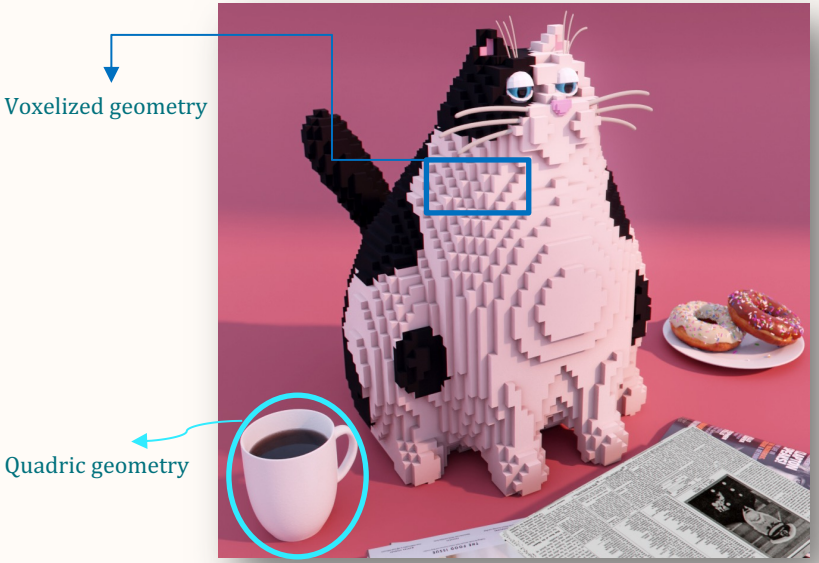


M.Donzelli, *et al*; *Phys Med Biol*. 2018.

PenMRT- Dose calculation engine

To develop penMRT, a general-purpose main program of PENELOPE (2018) was modified to offer:

- A voxelized geometry of the patients (CT-scans),
- A multi-scale dose calculation grid,
- Some hundreds of millions of dose bins necessary for micrometric calculation.

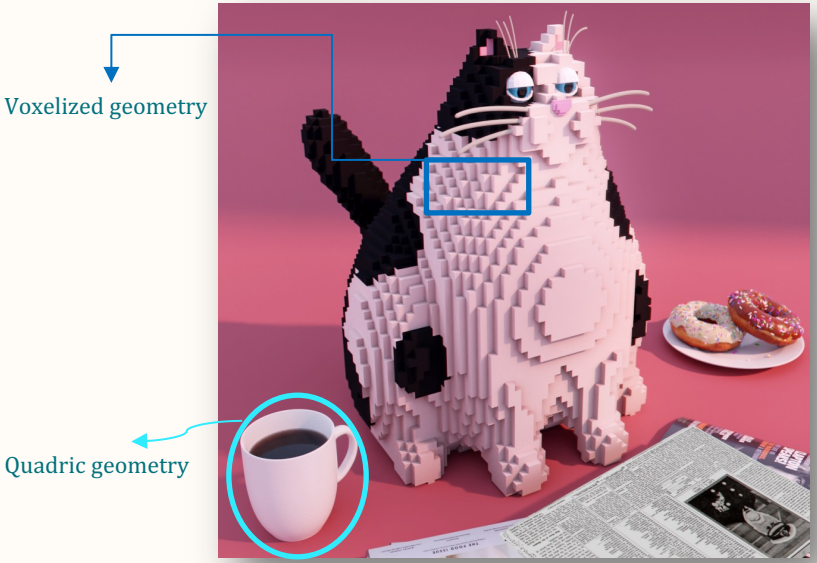


S. Keshmiri, *et al*; *MCMA Conf.* 2022.

PenMRT- Dose calculation engine

To develop penMRT, a general-purpose main program of PENELOPE (2018) was modified to offer:

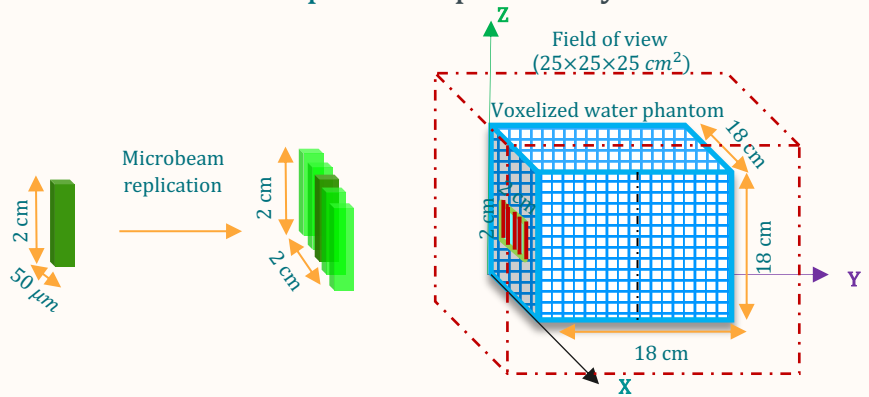
- A voxelized geometry of the patients (CT-scans),
- A multi-scale dose calculation grid,
- Some hundreds of millions of dose bins necessary for micrometric calculation.



S. Keshmiri, *et al*; *MCMA Conf.* 2022.

To accelerate the simulations, we implemented:

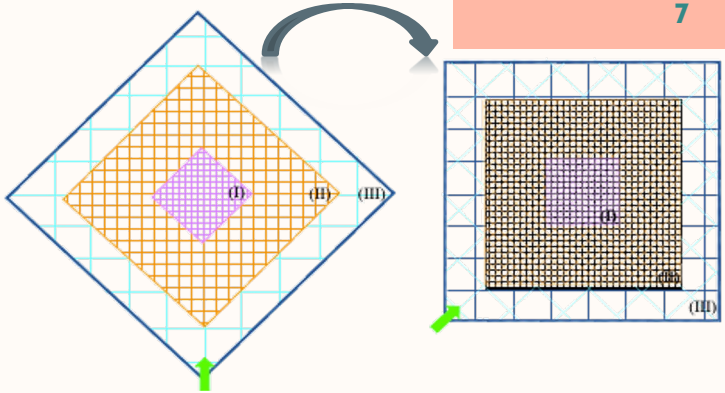
- An optimized parallelization using OpenMPI,
- The source replication possibility.

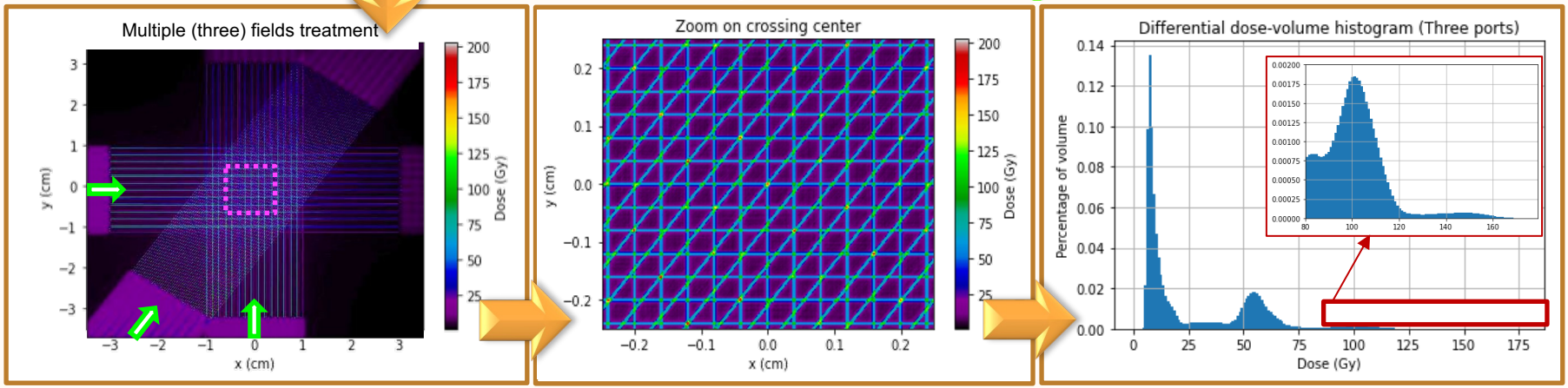


PenMRT- Post processing

In multiple incidences:

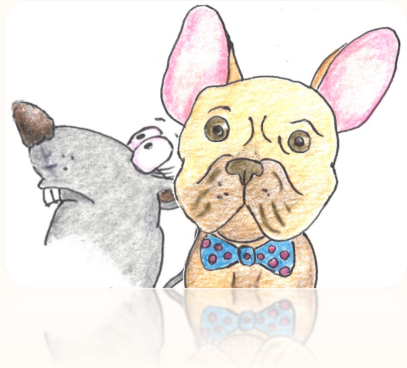
- Dose maps from each angle are rotated,
- Resampled to a grid size of 5µm × 5µm × 1mm,
- Summed together.

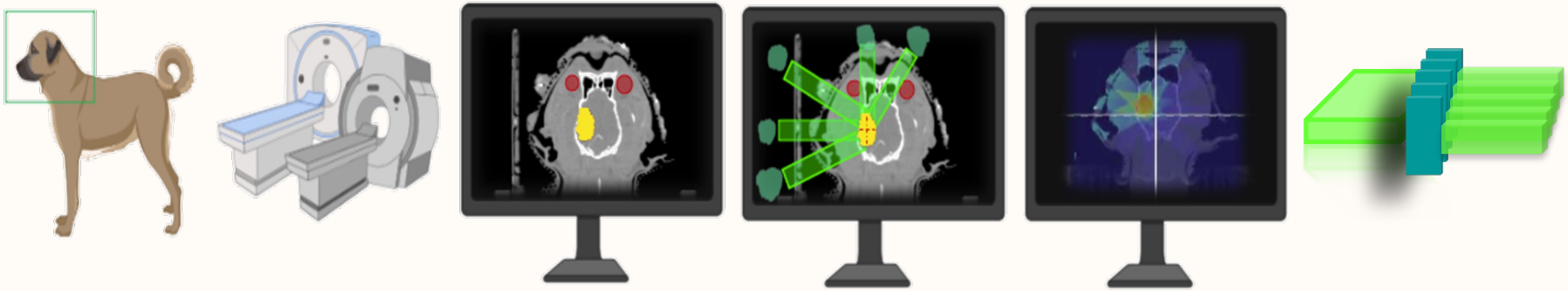




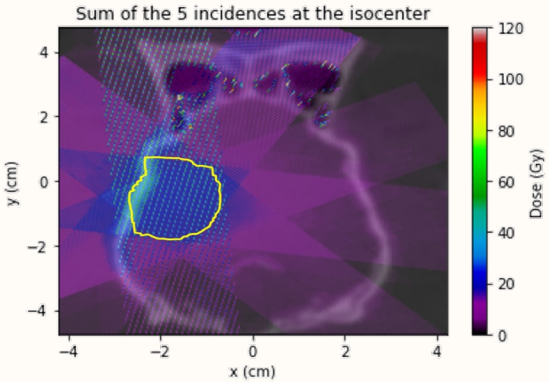
S. Keshmiri, *et al*; *Med Phys.* 2022.

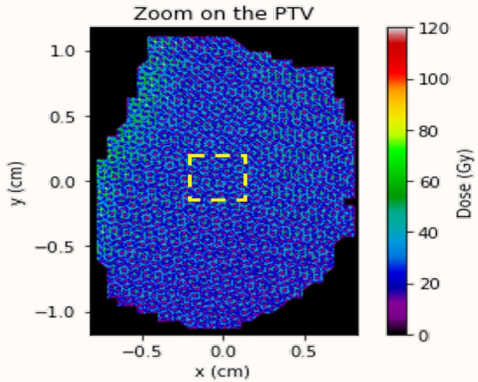
PenMRT in preclinical studies

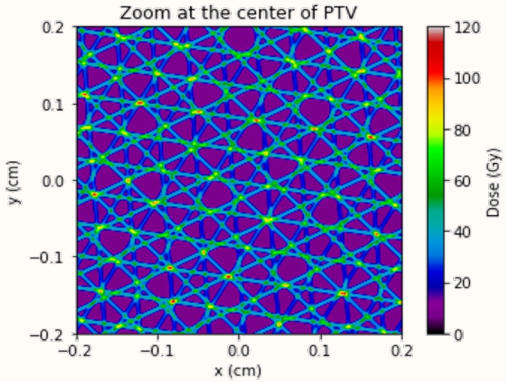


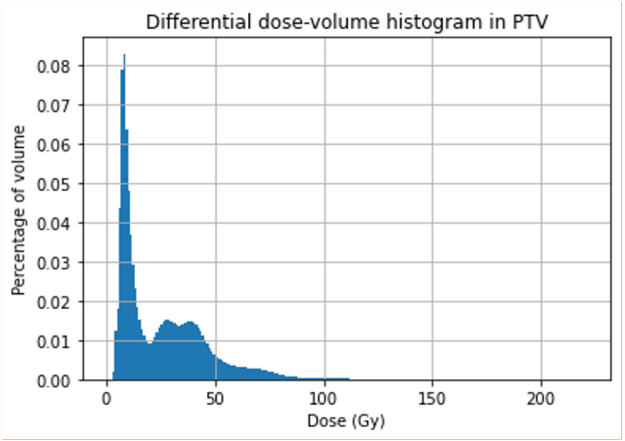


Canine patient





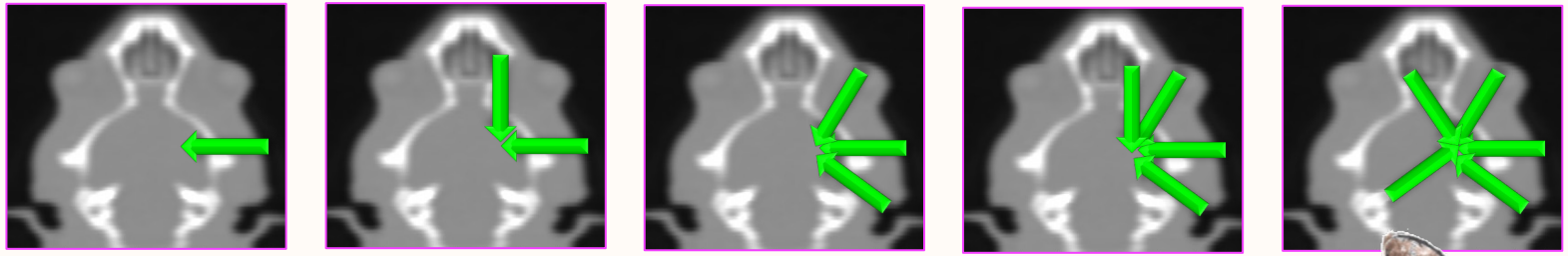




JF.Adam *et al.*, *RedJournal*, 2022.

Rodent patients

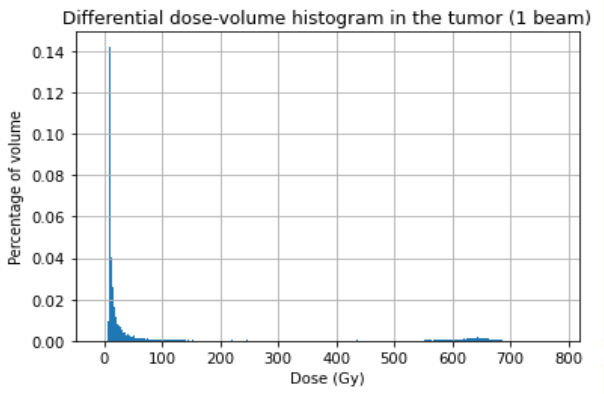
Based on a publication from Eling et al., (2021), MRT treatments of rats with 1 to 5 irradiation ports have been simulated:

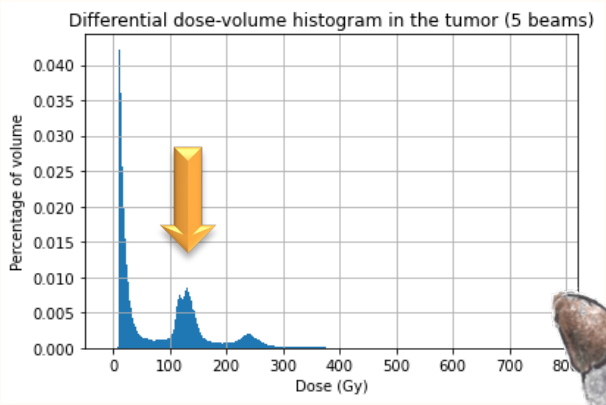


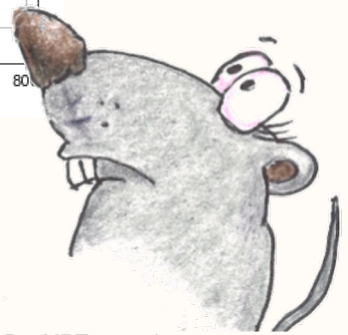
Maximum valley dose: 10 Gy

Rodent patients

Based on a publication from Eling et al., (2021), MRT treatments of rats with 1 to 5 irradiation ports have been simulated:

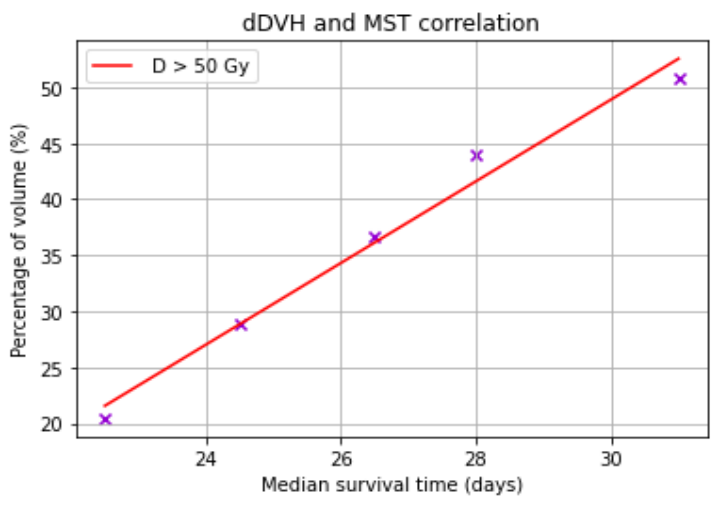




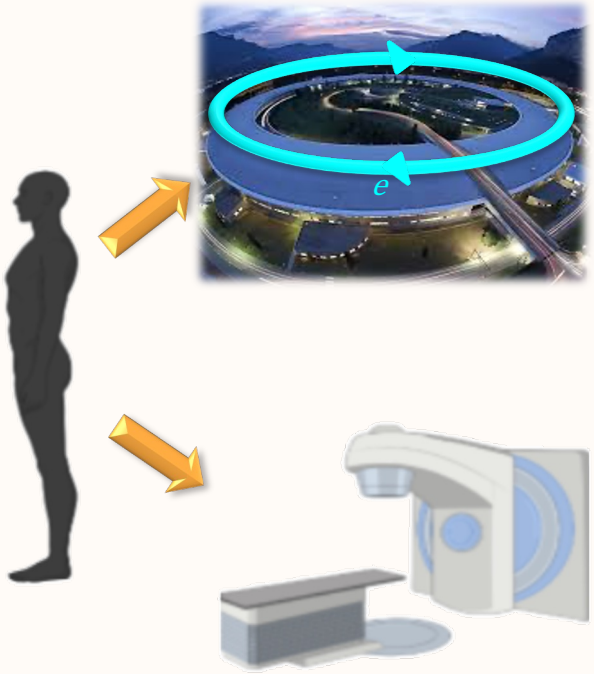


Rodent patients

Based on a publication from Eling et al., (2021), MRT treatments of rats with 1 to 5 irradiation ports have been simulated:



Translational studies



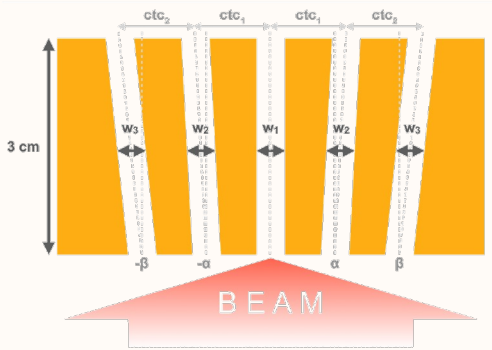
Small Animal Radiation Research Platform (SARRP) as an alternative:

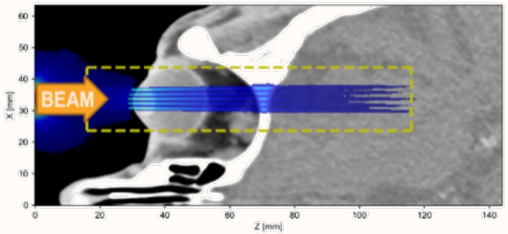
Translational studies

Small Animal Radiation Research Platform (SARRP) as an alternative:

PenMRT will be used for:

- ✓ Collimator design
- ✓ Treatment planning





T. Schneider et al., cancers, 2023.

Thank you for your attention

For SARRP reservation:
sarvenaz.keshmiri@univ-grenoble-alpes.fr