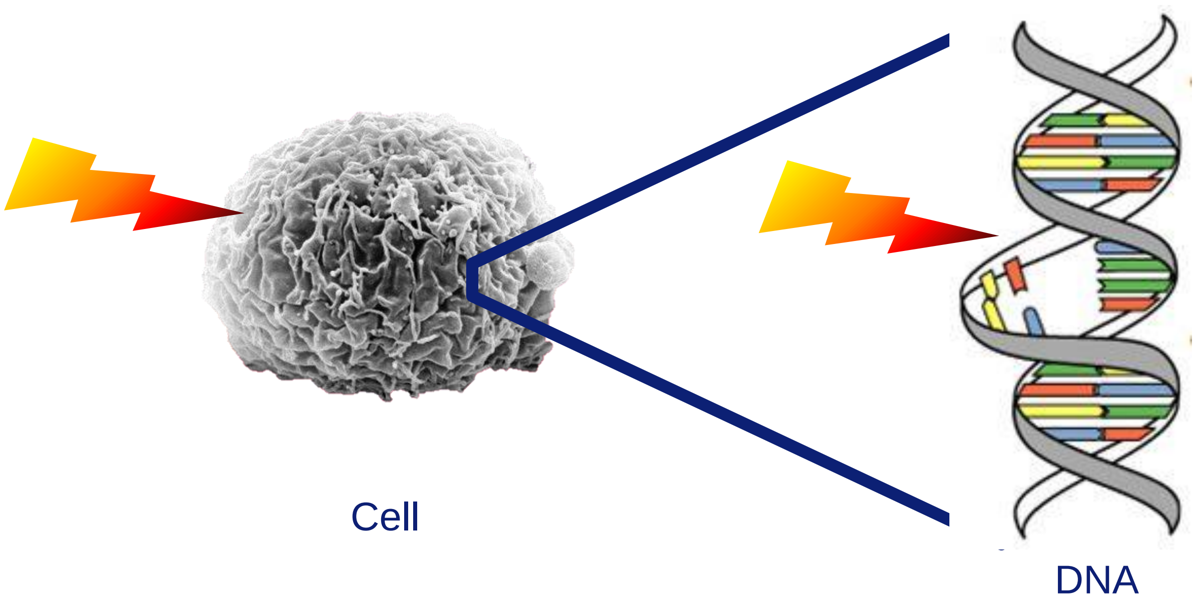
Bringing Probabilistic Planning to Clinic

Eliana Vásquez Osorio, Andrew Green,
Marcel van Herk, **Ian Hinder**

The University of Manchester

Radiotherapy

- Treating cancer using radiation.
- Radiation kills cells by damaging their DNA.



Radiotherapy

- Treating cancer using radiation.
- Radiation kills cells by damaging their DNA.

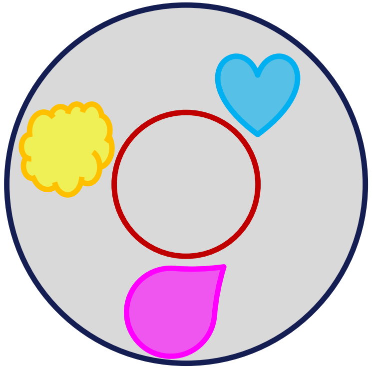
Cancer cells are more sensitive to radiation than healthy cells.

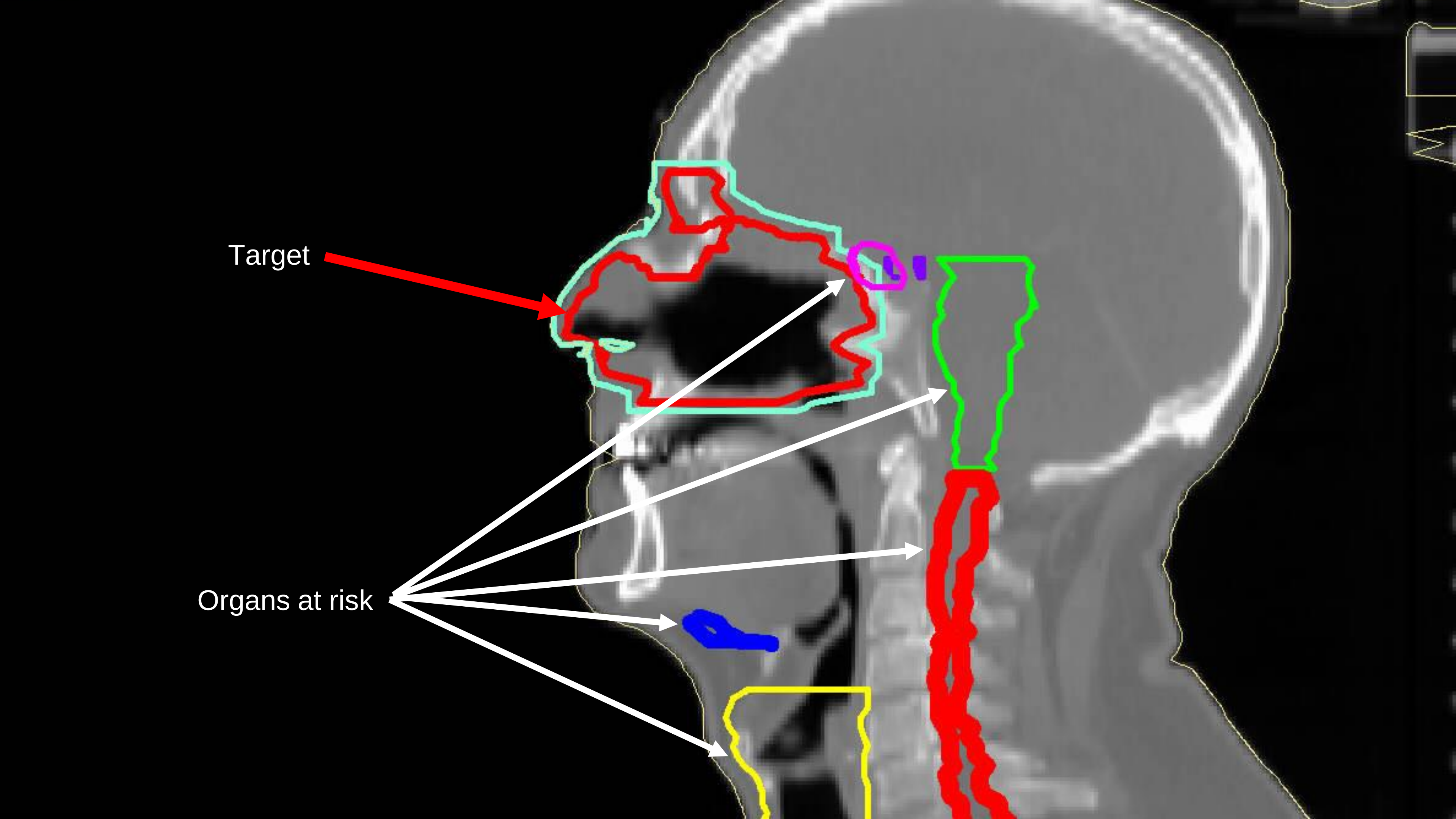
BUT both types are damaged by radiation.

Challenge! limit the radiation to tumor region.

Radiation Therapy Treatment Planning

Aim: deliver a very high dose of radiation to a tumor (or target, O) whilst trying to spare the surrounding healthy tissues ().

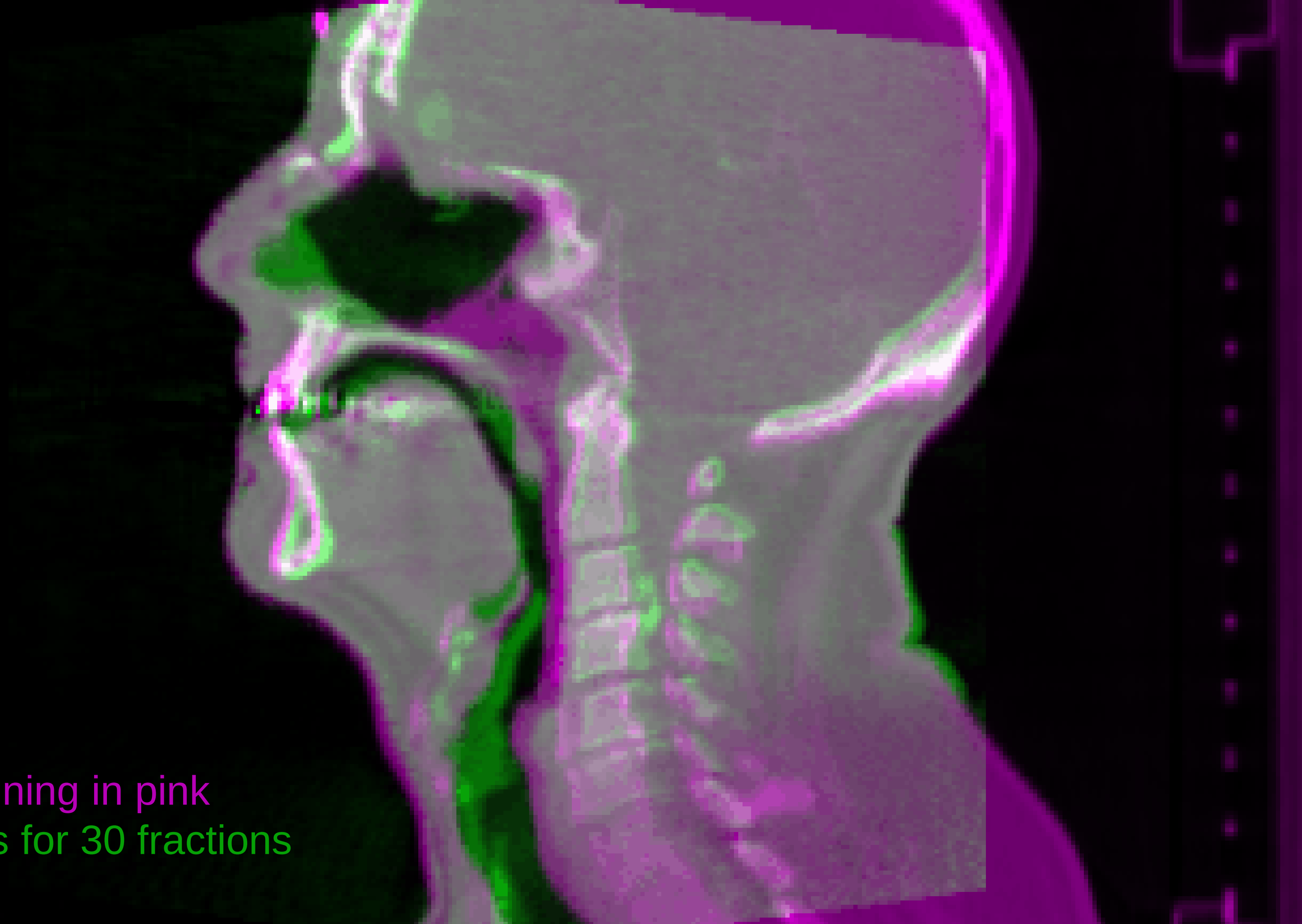



Target
Organs at risk

Radiation Therapy Treatment Planning

Aim: deliver a very high dose of radiation to a tumor (or target, O) whilst trying to spare the surrounding healthy tissues ().

But… there are uncertainties in the location/shape of the target and healthy tissues.

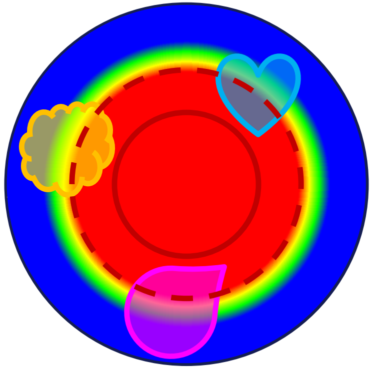


Scan at planning in pink
Daily images for 30 fractions

Radiation Therapy Treatment Planning

Aim: deliver a very high dose of radiation to a tumor (or target, O) whilst trying to spare the surrounding healthy tissues ().

But… there are uncertainties in the location/shape of the target and healthy tissues.
Classic approach: extend target volume with **margins** (planning target volume, PTV).



Why margins are not good enough?

My top 5:

- Ambiguous when extended volume overlaps healthy tissues.
- “One margin fits them all”
- All errors are treated equally important → all elements within extended volume are treated as tumor.
- Not suitable for protontherapy*

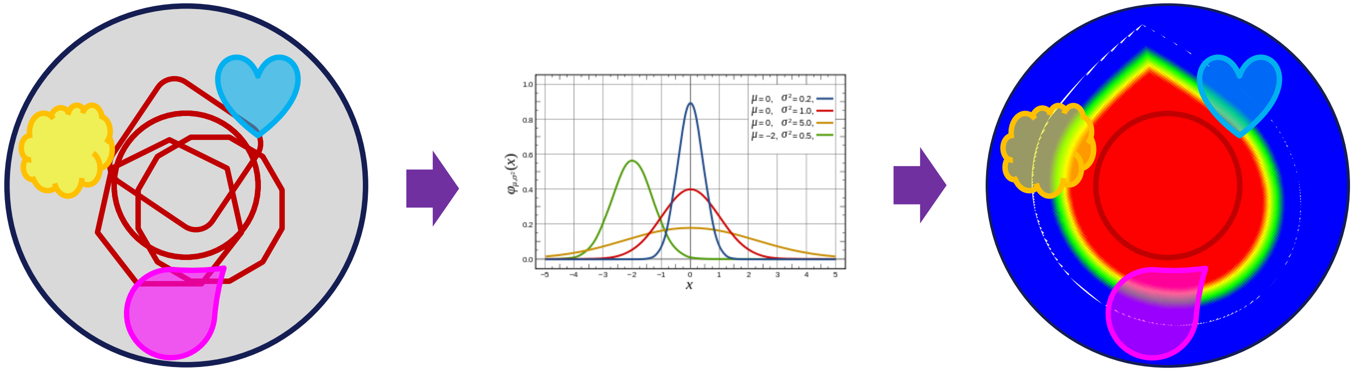
What can we do?

- Let the optimizer choose the best expansion depending on the uncertainties and the anatomy → Probabilistic Treatment Planning

* shift-invariance cannot be assumed, i.e., dose distribution changes when anatomy changes → range uncertainties.

Probabilistic treatment planning (PTP)

- Optimization takes into account uncertainties (starting with set-up uncertainties).



- You ask the optimizer certain value with a given confidence level e.g. minimum dose = 10Gy, with a 90% confidence!

Probabilistic treatment planning (PTP)

In general terms:

- Error distributions should be given directly to the optimiser

- The optimisation cycle includes several runs to calculate statistics (e.g. 90% confidence!)
  → one run used to take a couple of hours, but in RayStation it is in the order of seconds/minutes

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. **58** (2013) 3563–3580 doi:10.1088/0031-9155/58/11/3563

Probabilistic objective functions for margin-less IMRT planning

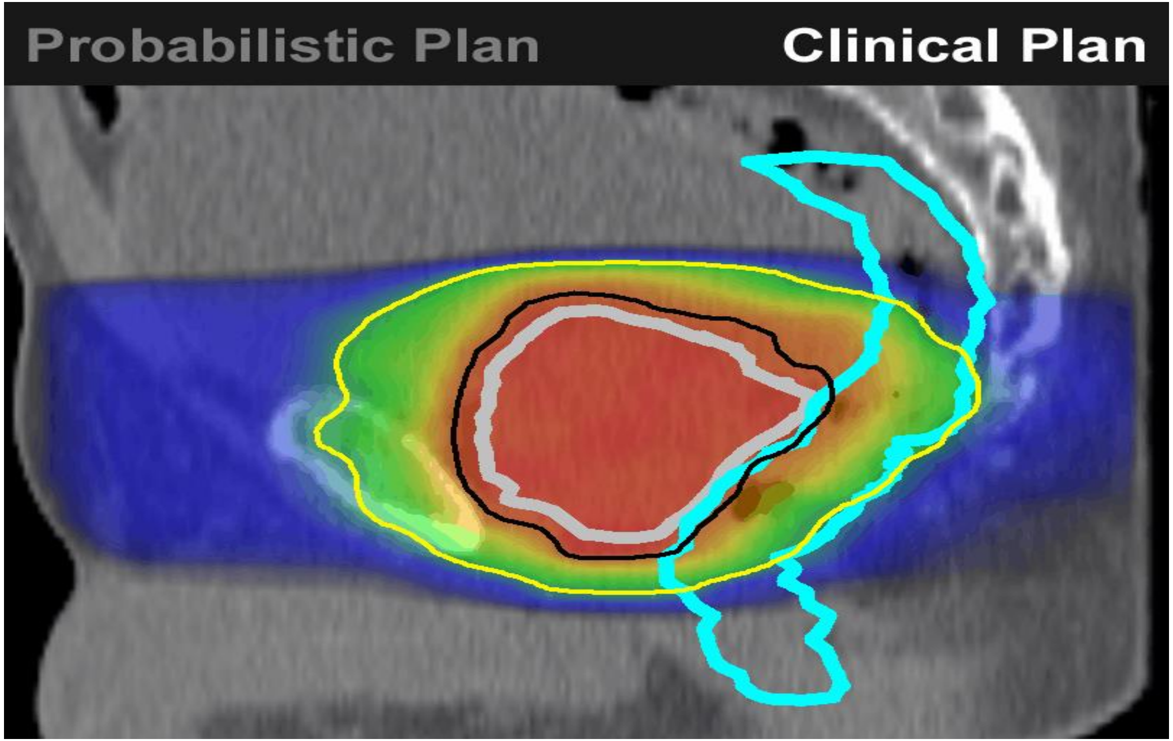
Román Bohoslavsky, Marnix G Witte, Tomas M Janssen and Marcel van Herk

Department of Radiation Oncology, The Netherlands Cancer Institute–Antoni van Leeuwenhoek Hospital, Plesmanlaan 121, 1066 CX Amsterdam, The Netherlands

E-mail: r.bohoslavsky@nki.nl

Received 10 December 2012, in final form 19 March 2013
Published 2 May 2013
Online at stacks.iop.org/PMB/58/3563

Effect of probabilistic planning



GTV

Rectum

95% isodose (74.1 Gy)

50% isodose (39.0 Gy)

Prescribed dose to the target: 78 Gy

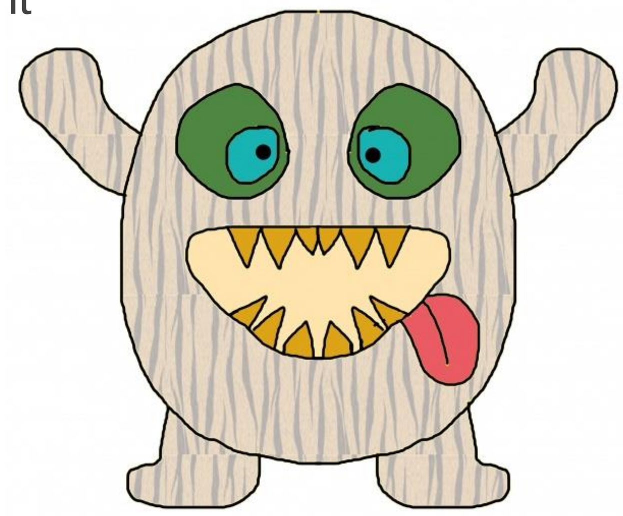
Role of Research IT

Dr. Ian Hinder

Research IT role in this part of the project

- Research code used for a different system
  → Migration,
  → General clean up of external data structures,
  → Integration using RayStation research environment
  →Testing

- PhD student takes over and further develops PTP



Some details of the implementation

- Visual Studio C++ project
- Adapt existing PTP code to work with RayStation
- Add **ResearchInterface** for obtaining information from RayStation
- **Convert** ROIs, dose, etc. from RayStation to PTP code format

Some details of the implementation

- From **same source code**, build:
  - TestPTP.exe: **Command line** version of the code for testing outside RayStation using **simulated data** from **files**
  - PTPPlugin.dll: **RayStation plugin**

- Set systematic, random errors, etc through a **textual “ini” file**
- Output logging and intermediate calculations to files for debugging
- Results from each run can be stored separately:

Command Prompt

```
C:\Work> TestPTP.exe mytest.ini experiment004
TestPTP: Test tool for PTPPlugin
Setting systematic error to 0.1,0.1,0.1 from
mytest.ini
Writing output and logs to C:\Work\experiment004
Result of MinDose is: 0.00224
C:\Work>
```

Some details of the implementation

- We use Git (git-scm.com) to keep track of different **versions** and **collaborate**
- **Regression tests**: script to check results against known good results after changing the code
- **Audit trail**: version number of code (from Git) reported in log along with results
- Correctness testing:
    - Compare with RayStation example
    - Compare with analytic solution for ideal dose distribution

Conclude

- Did we ‘get what we wanted’ from our collaboration with Research IT?
  - Absolutely YES!
  - We even got some push to get our projects in version control (Git)

- Would you ask help from Research IT again?
  - Yes!