Interaction between Fred and Gate?

Nils Krah

Jan Gajewski, Vincenzo Patera, Ilaria Rinaldi, Antoni Rucinski, Angelo Schiavi

In a nutshell

Can we create a FredActor which takes particles from Gate, sends them to Fred, and takes them back afterwards?

Can we write a backend to FredTools to generate Fred **and** Gate simulations from the same input?

But first: What is FRED?

Fast pa**R**ticle th**E**rapy **D**ose evaluator:

- Optimized for proton radiotherapy
- GPU and CPU calculations
- Fast: one proton treatment plan: 3-5 min
- Limited geometry, CT import
- Only voxel-based scorers
- Radiobiology models

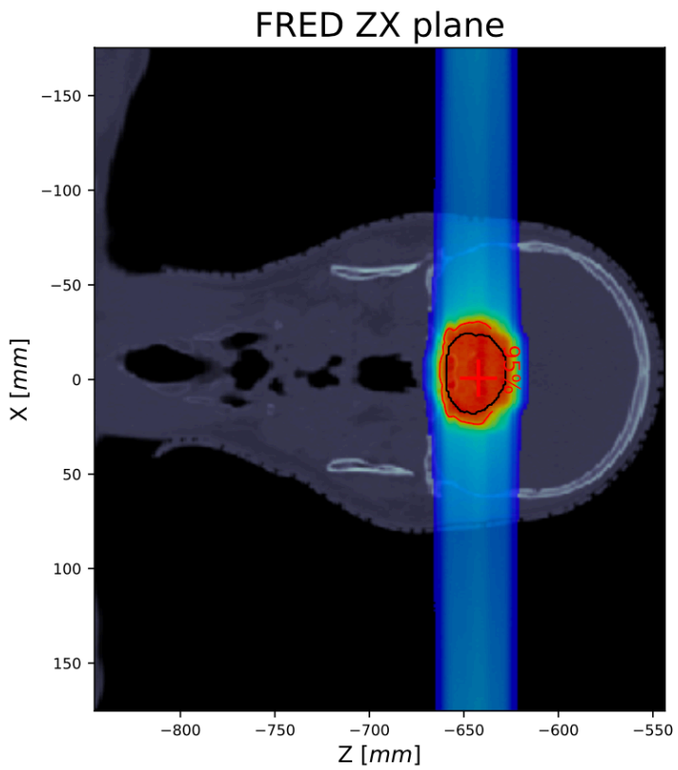
Schiavi, A., Senzacqua, M., Pioli, S., Mairani, A., Magro, G., Molinelli, S., … Patera, V. (2017). Fred: A GPU-accelerated fast-Monte Carlo code for rapid treatment plan recalculation in ion beam therapy. Physics in Medicine and Biology, 62(18), 7482–7504. **https://doi.org/10.1088/1361-6560/aa8134**

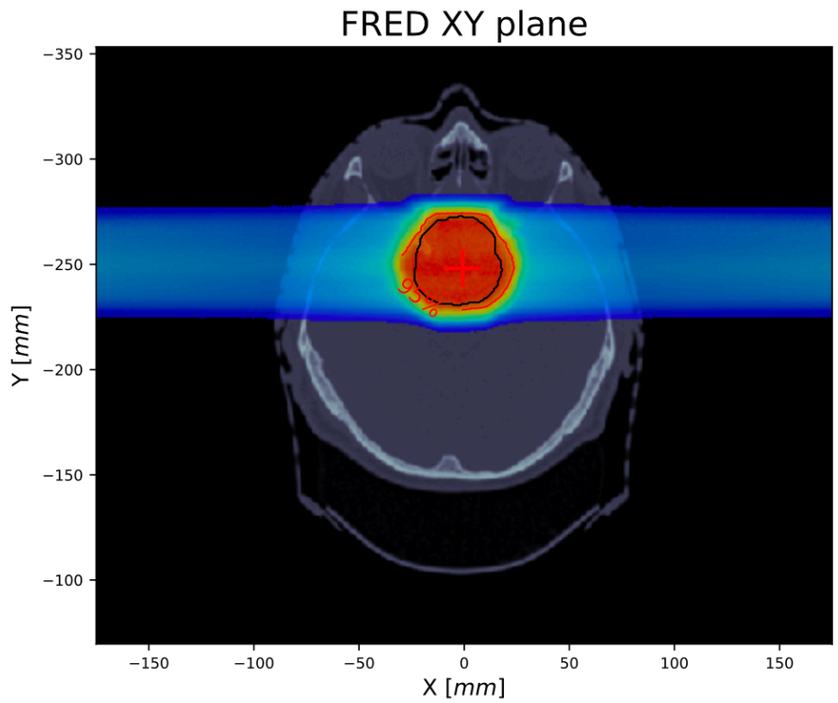
Proton physics

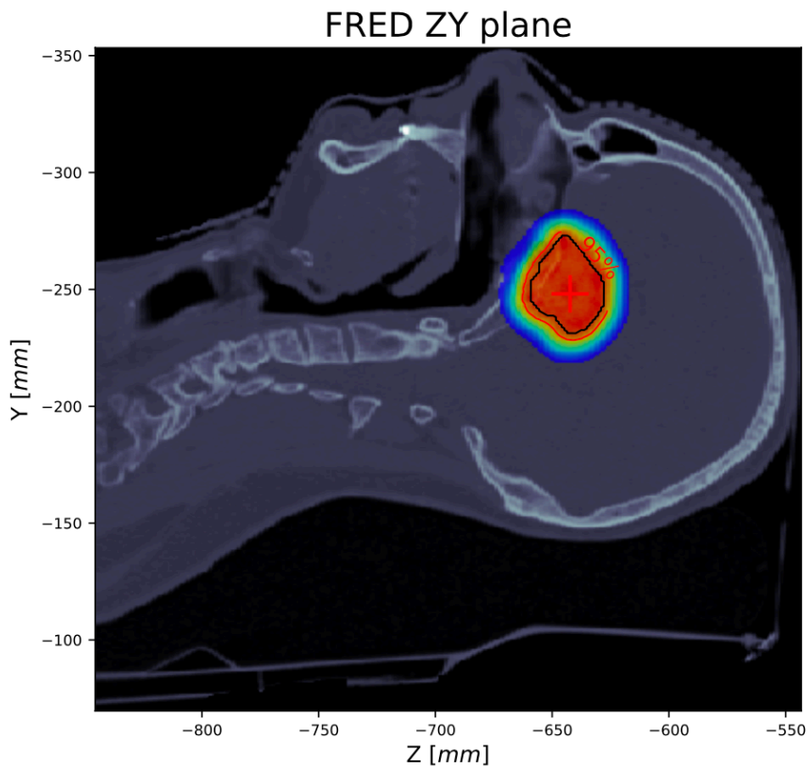
- Processes described by condensed history and point-like interaction models.
- Variable step length (energy, discrete processes, voxel crossing)
- Energy loss (tabulated stopping power)
- Energy straggling (thick and thin regimes)
- Multiple Coulomb scattering: Gauss-Rutherford model tuned to Geant4
- Nuclear elastic and inelastic interactions: p-X
- Secondaries: proton and deuteron; others deposit local dose.

Schiavi, A., Senzacqua, M., Pioli, S., Mairani, A., Magro, G., Molinelli, S., … Patera, V. (2017). Fred: A GPU-accelerated fast-Monte Carlo code for rapid treatment plan recalculation in ion beam therapy. Physics in Medicine and Biology, 62(18), 7482–7504.
https://doi.org/10.1088/1361-6560/aa8134

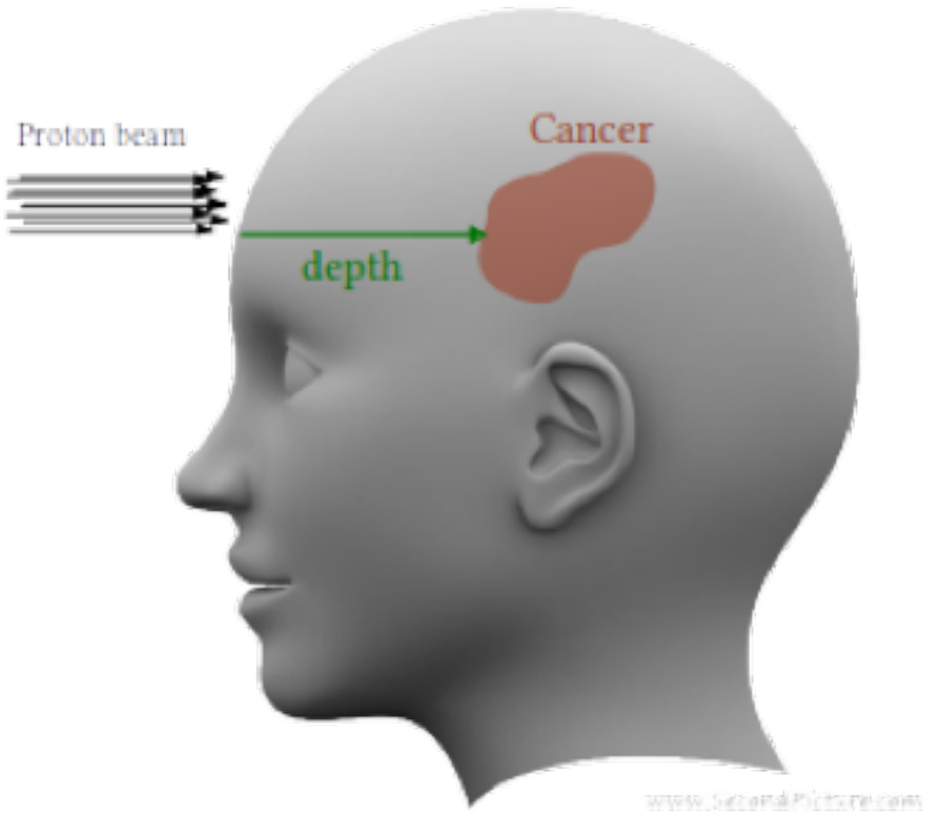
Goal: Calculate dose distribution in proton therapy

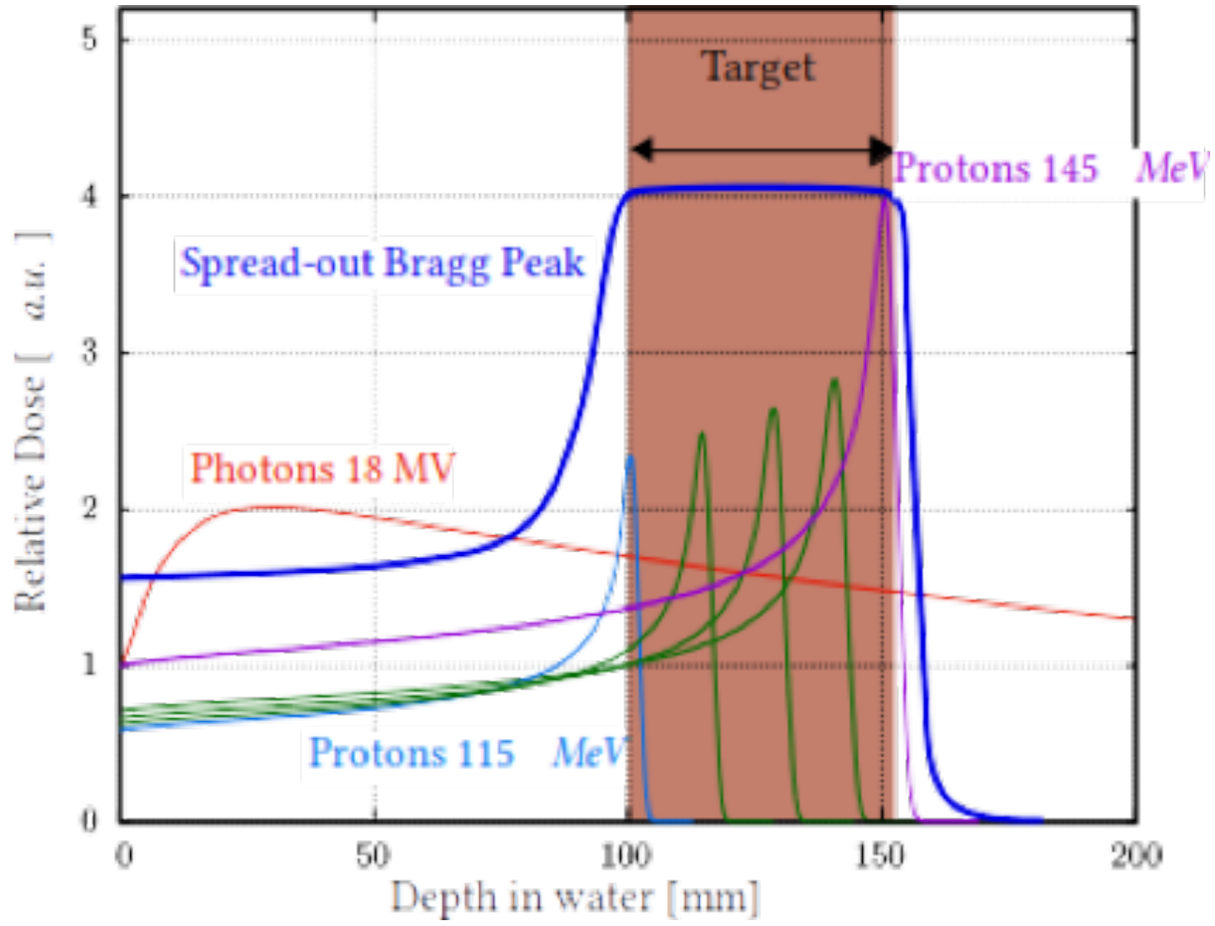




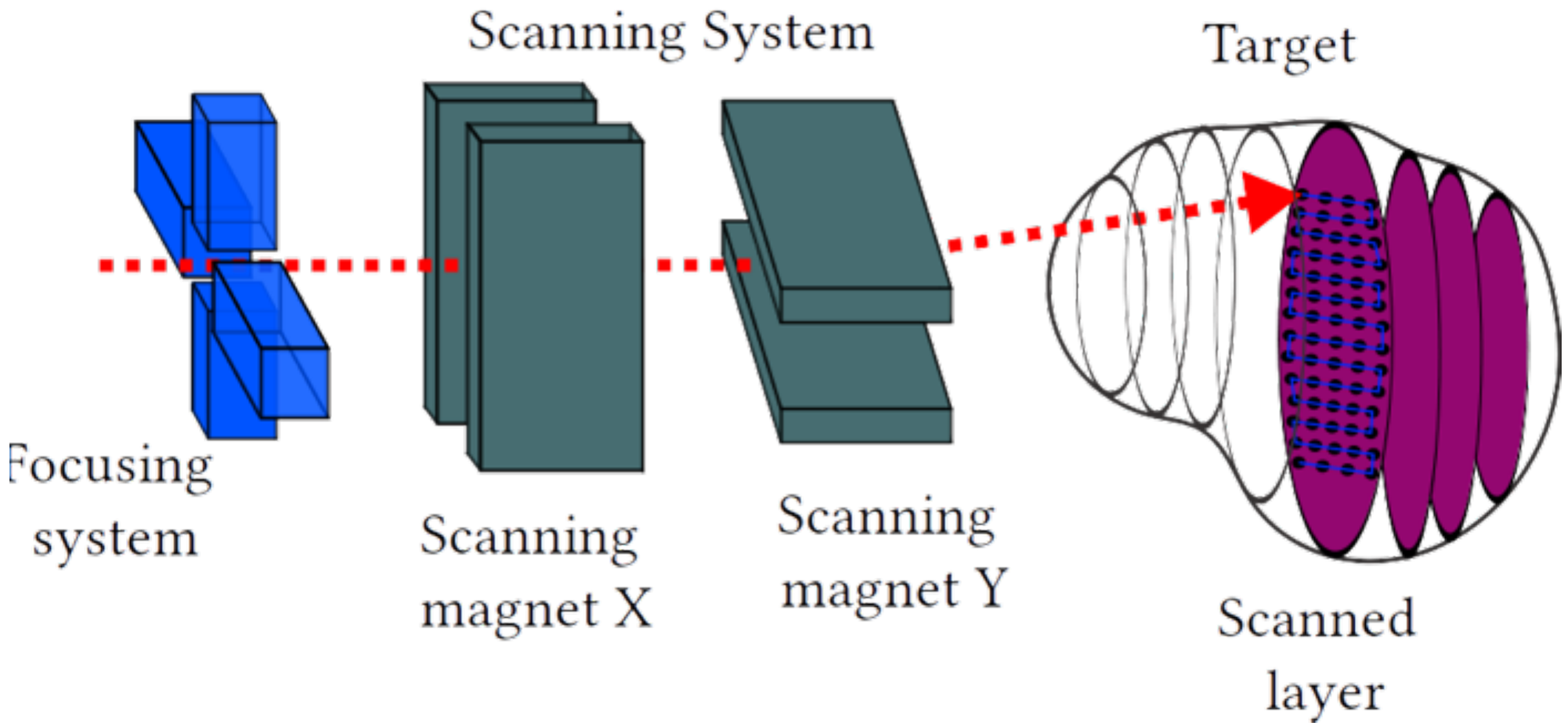


Quick word on proton therapy



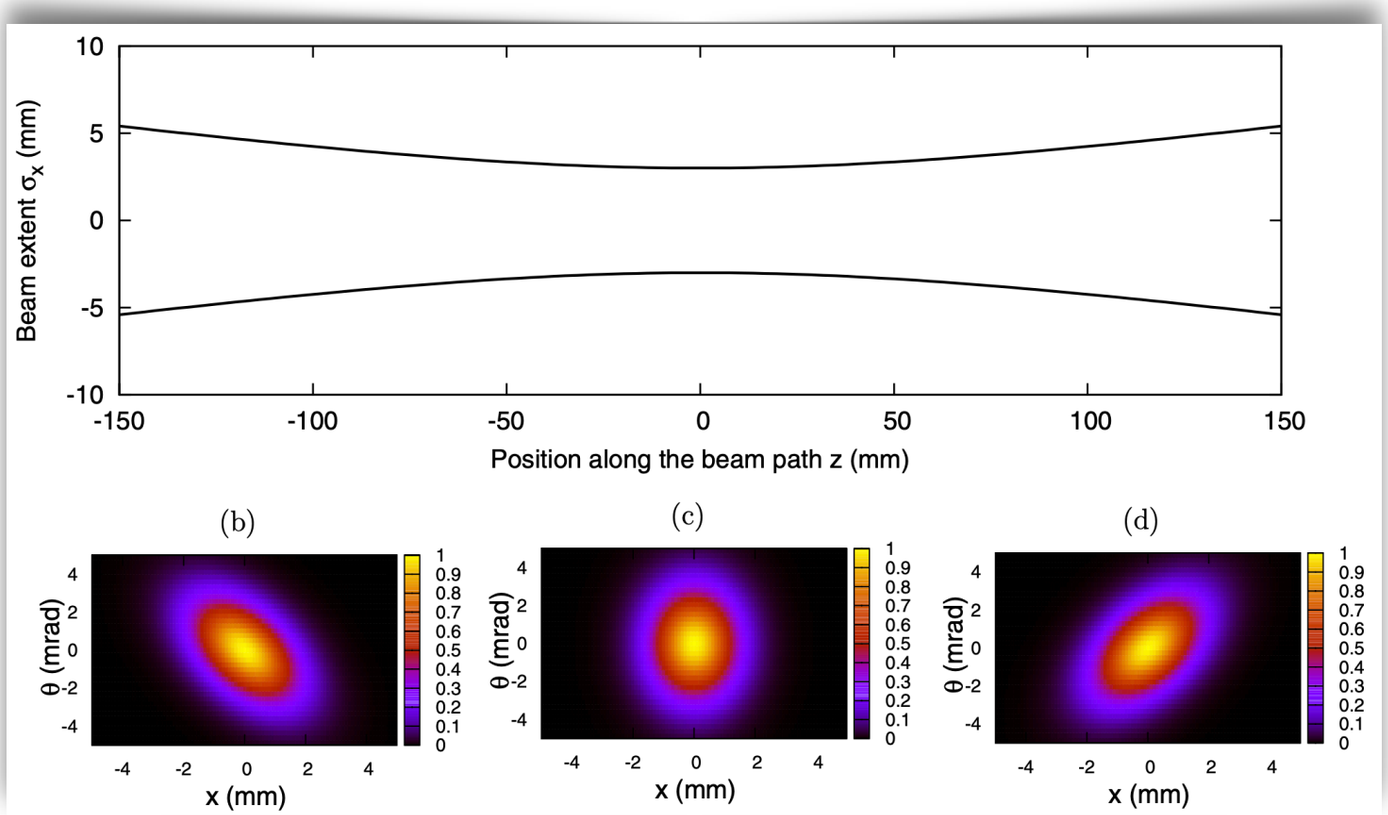


Typical proton beam line



We need a phase space or a beam model.

Beam model



Transversal phase space: beam shape (emittance)

Longitudinal phase space: beam energy distribution

Figures from:

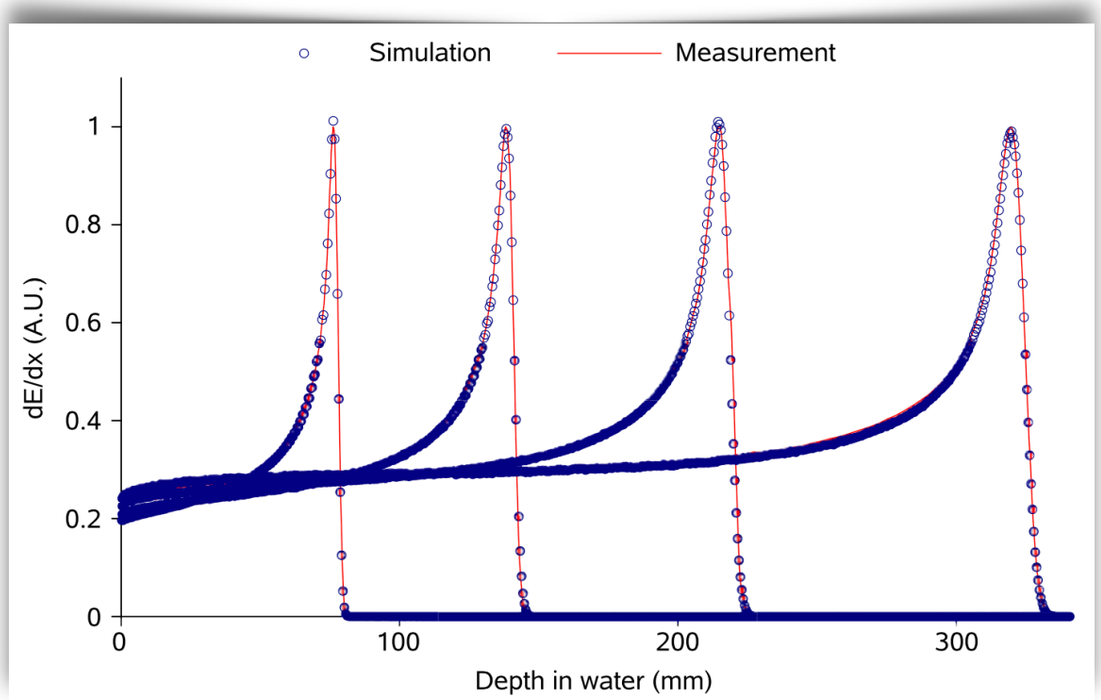
A Monte Carlo pencil beam scanning model for proton treatment plan simulation using GATE/GEANT4

L Grevillot[1,2], D Bertrand[2], F Dessy[2], N Freud[1] and D Sarrut[1]

[1] Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, Lyon, France.
[2] IBA, B-1348, Louvain-la Neuve, Belgium.

E-mail: loic.grevillot@creatis.insa-lyon.fr

Received 28 February 2011, in final form 9 June 2011
Published 26 July 2011
Online at stacks.iop.org/PMB/56/5203



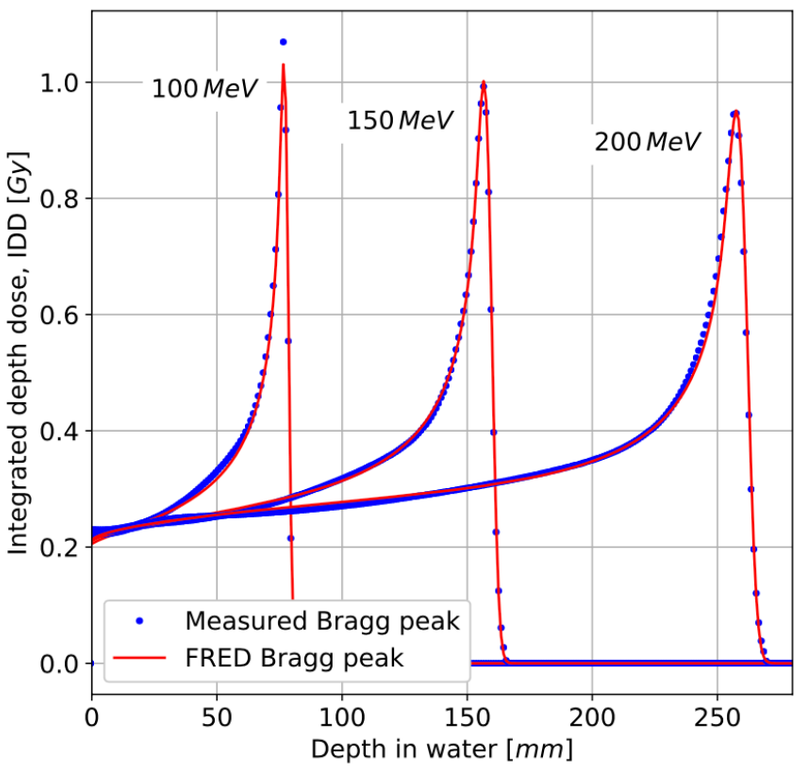
FRED beam model in Krakow proton therapy center (CCB)

- "Conventional" therapeutic cyclotron (IBA)
- Similar approach as in Grevillot et al. 2011
- Measure lateral and longitudinal dose distributions of pencil beams
- … and adjust beam model parameters by fitting measured and simulated data
- Advantage of FRED: simulation is fast so a new beam model can be generated in a few hours.

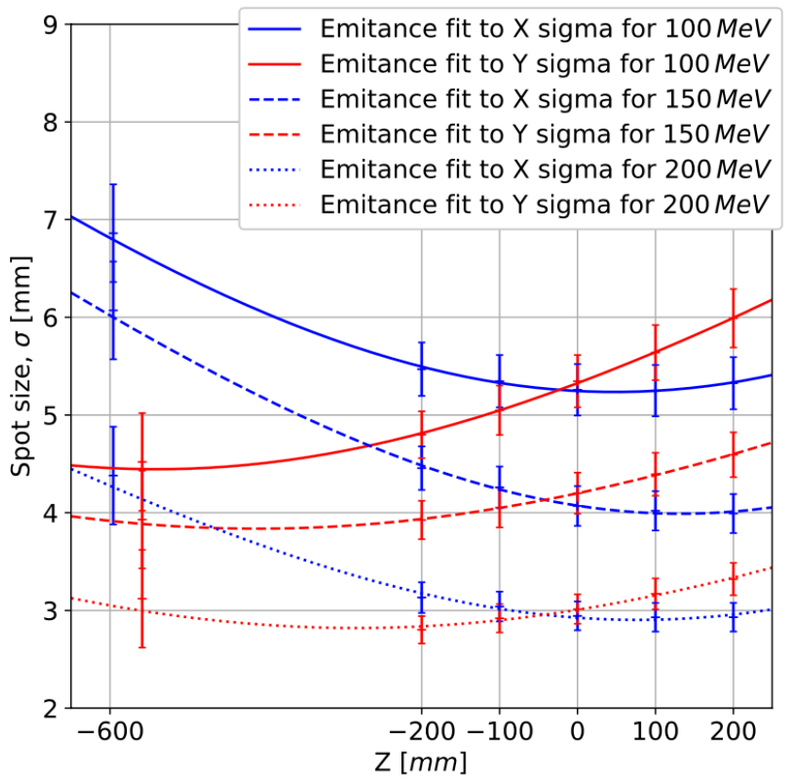
Garbacz, M., Battistoni, G., Durante, M., Gajewski, J., Krah, N., Patera, V., … Rucinski, A. (2019). Proton Therapy Treatment Plan Verification in CCB Krakow Using Fred Monte Carlo TPS Tool. World Congress on Medical Physics and Biomedical Engineering 2018. **doi.org/10.1007/978-981-10-9035-6_144**

FRED beam model in Krakow

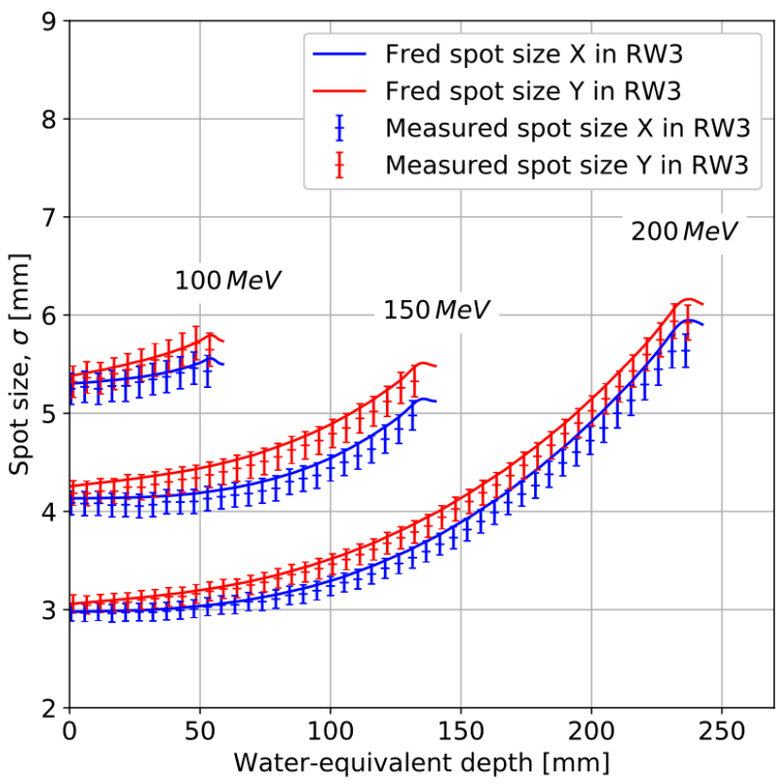
longitudinal beam profiles



lateral beam profiles in air



lateral beam profiles in water

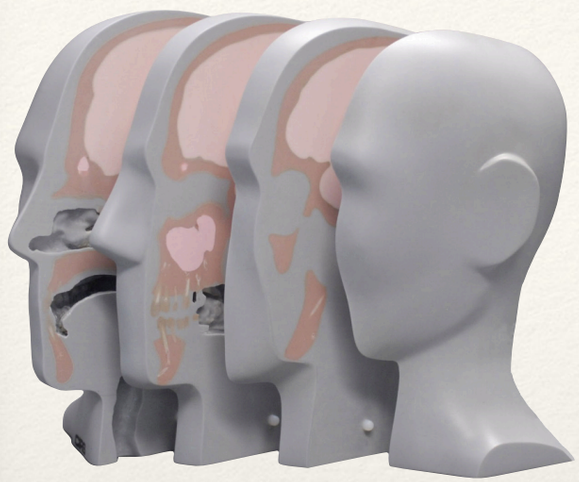


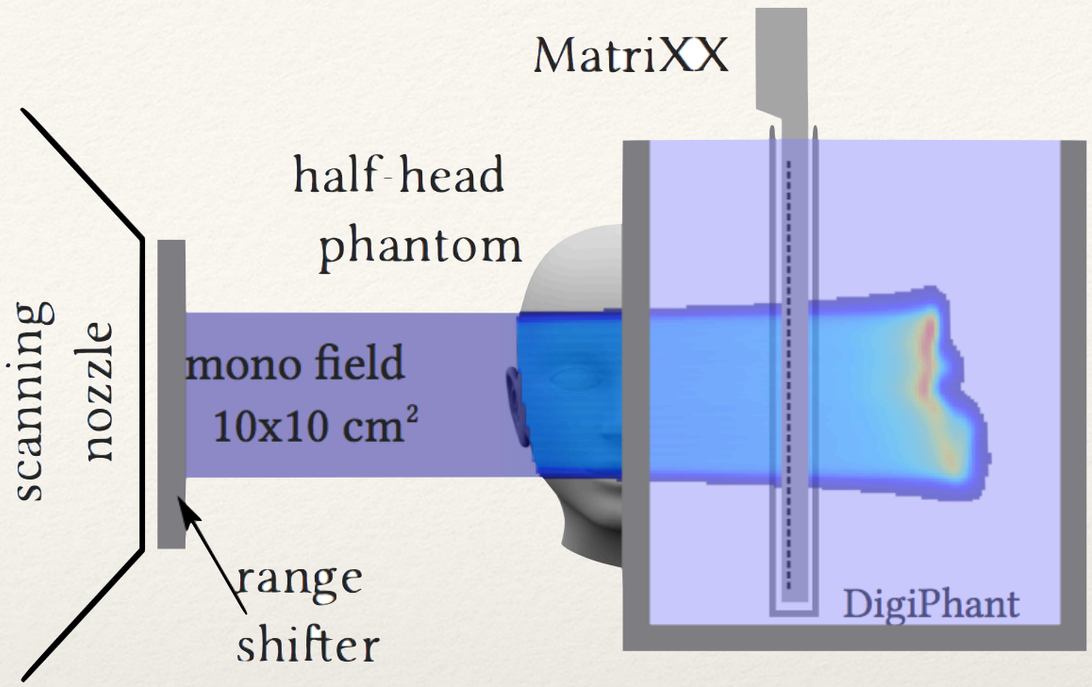
to be submitted to Physics in Medicine and Biology

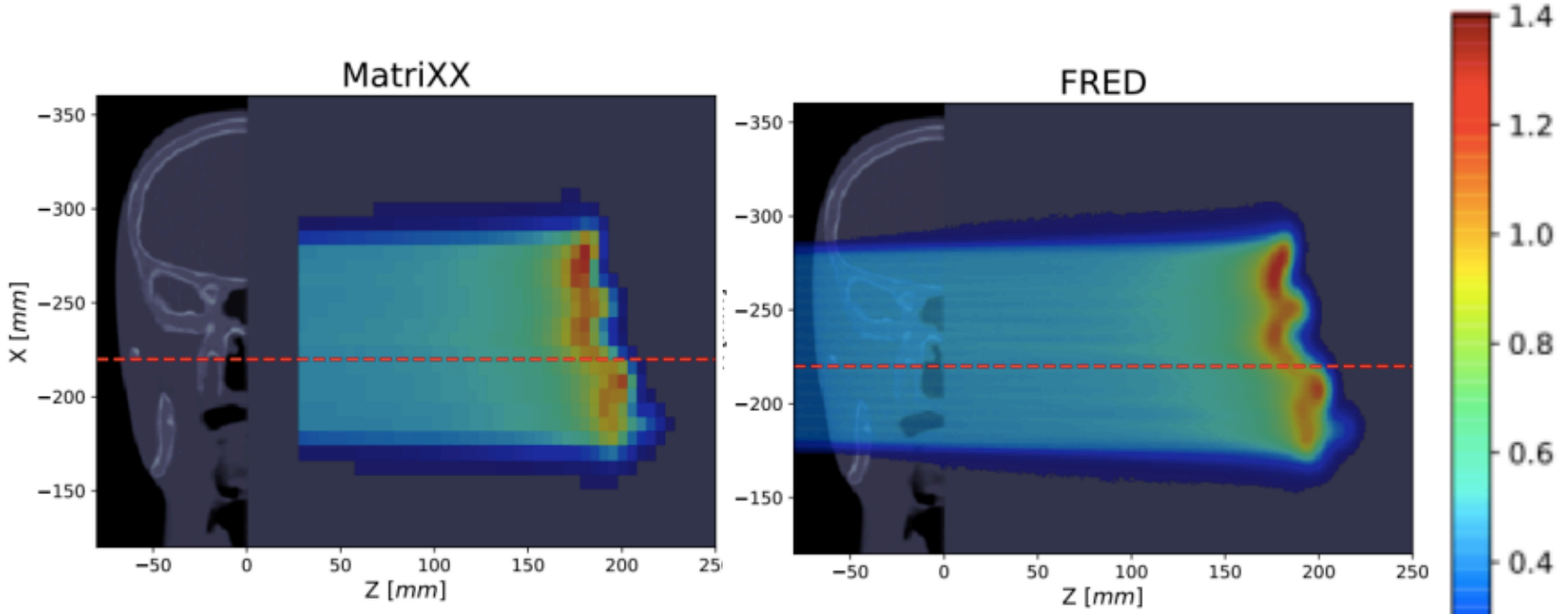
THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

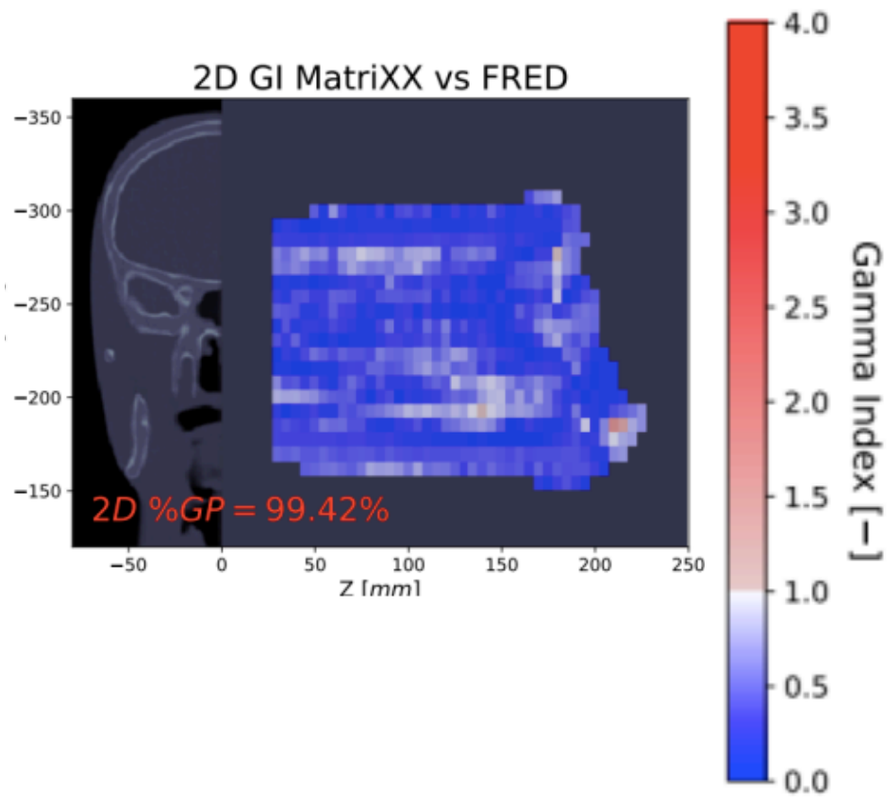
Validation in heterogeneous media

- Heterogeneous head phantom
- MatriXX measurement in water
- Single energy: 100, 150 and 200 MeV
- Range shifter









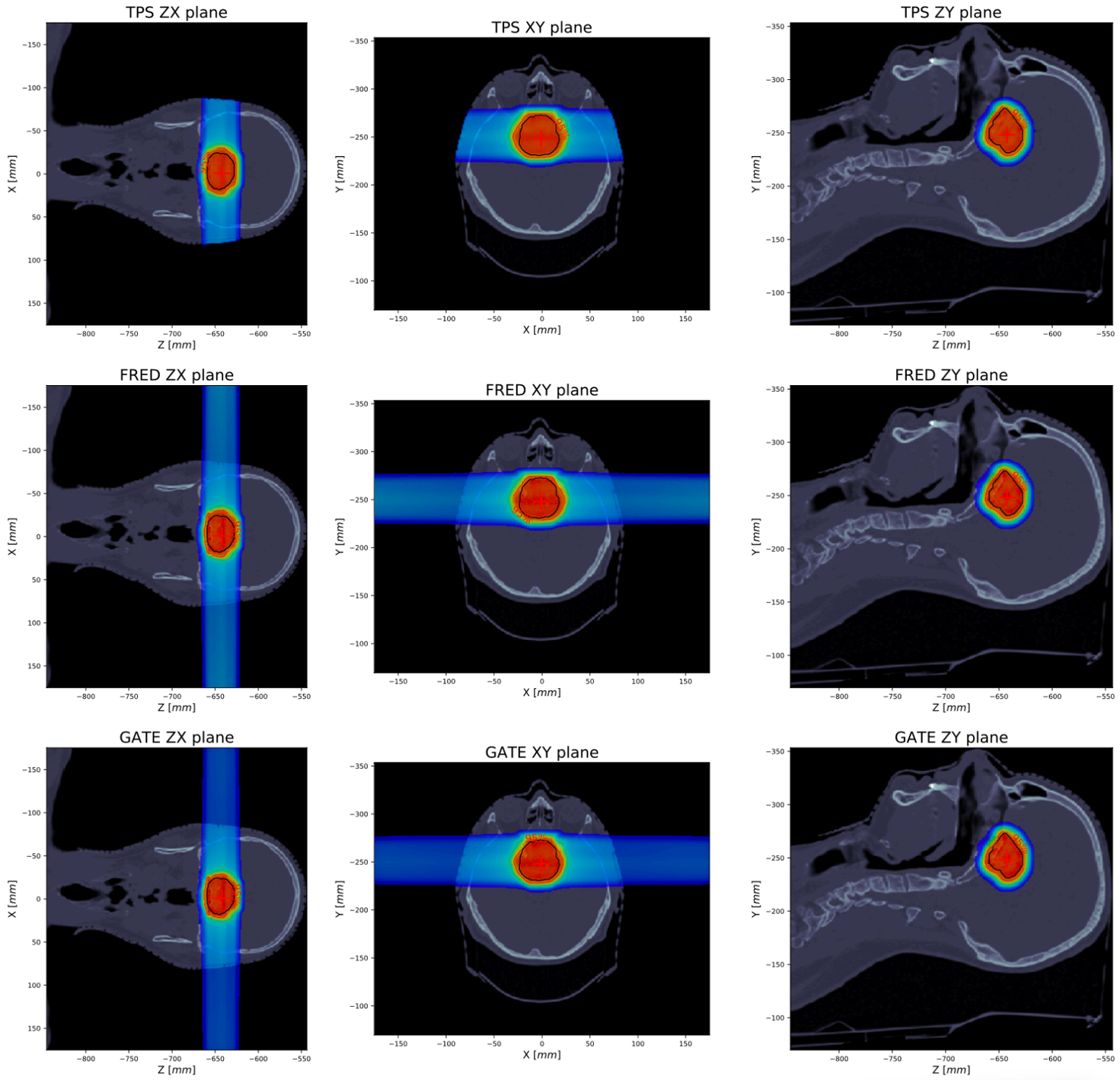
3D Gamma index (2mm/2%) passing rate for all measurements **>99%**

FRED in Krakow: Comparison with Gate

TPS

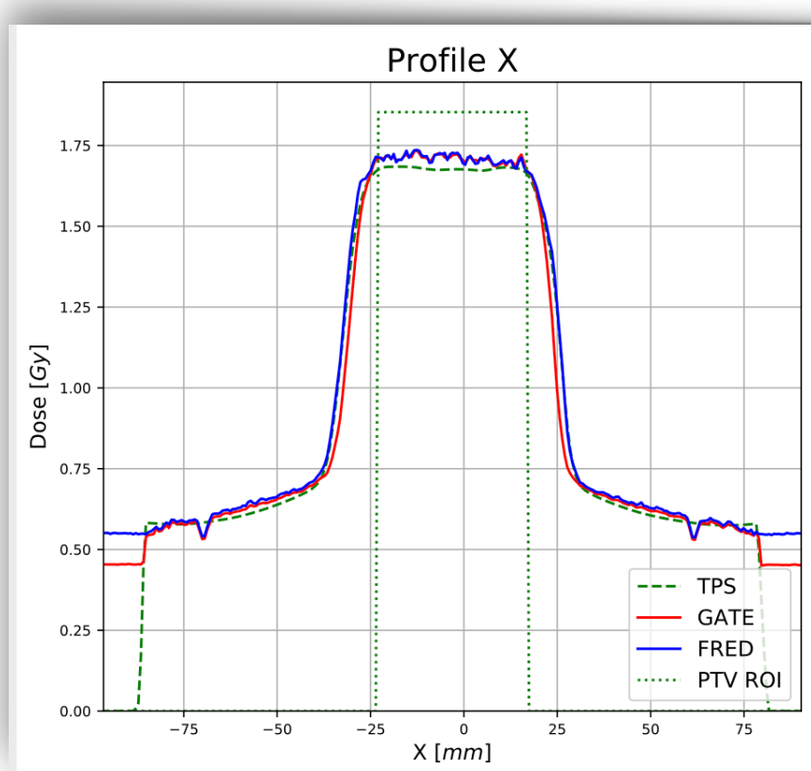
FRED

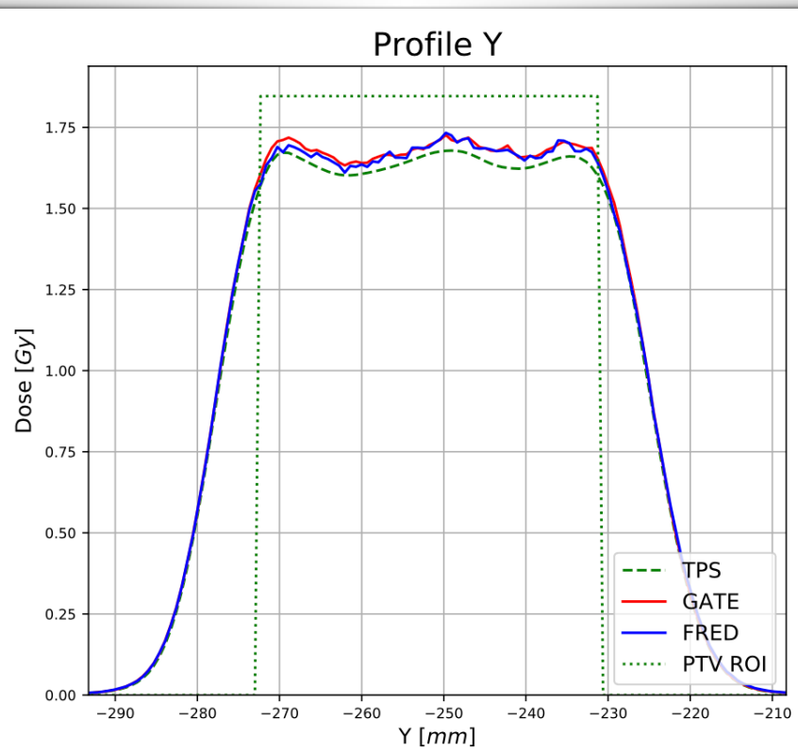
GATE

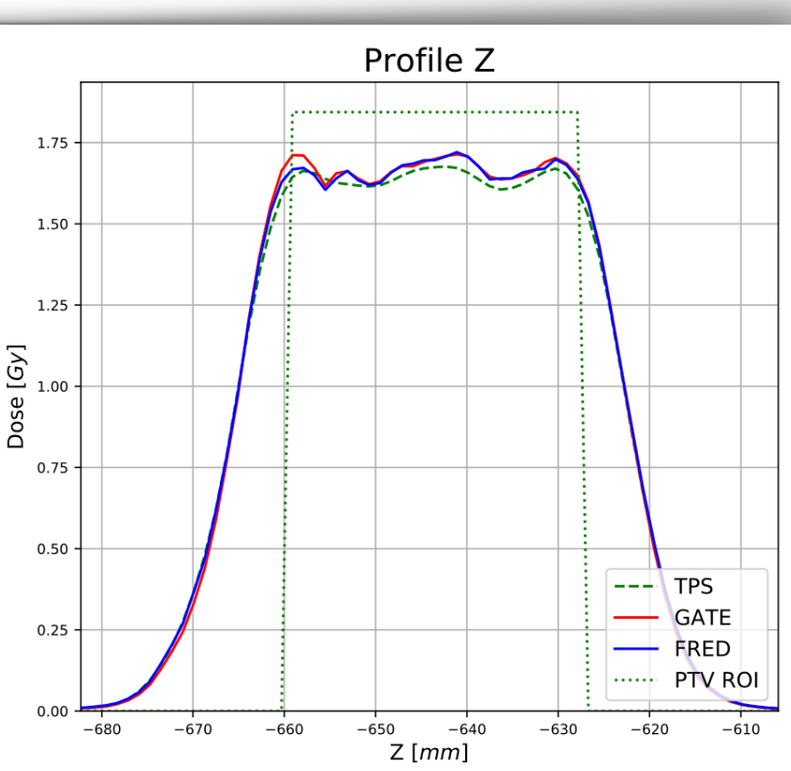


Study performed in the context of the JPET project - see preceding talk by Wojciech

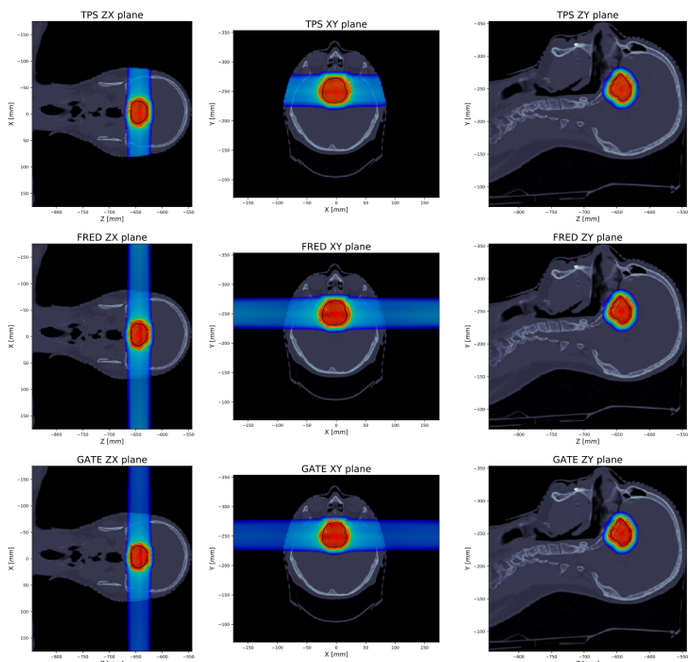
FRED in Krakow: Comparison with Gate







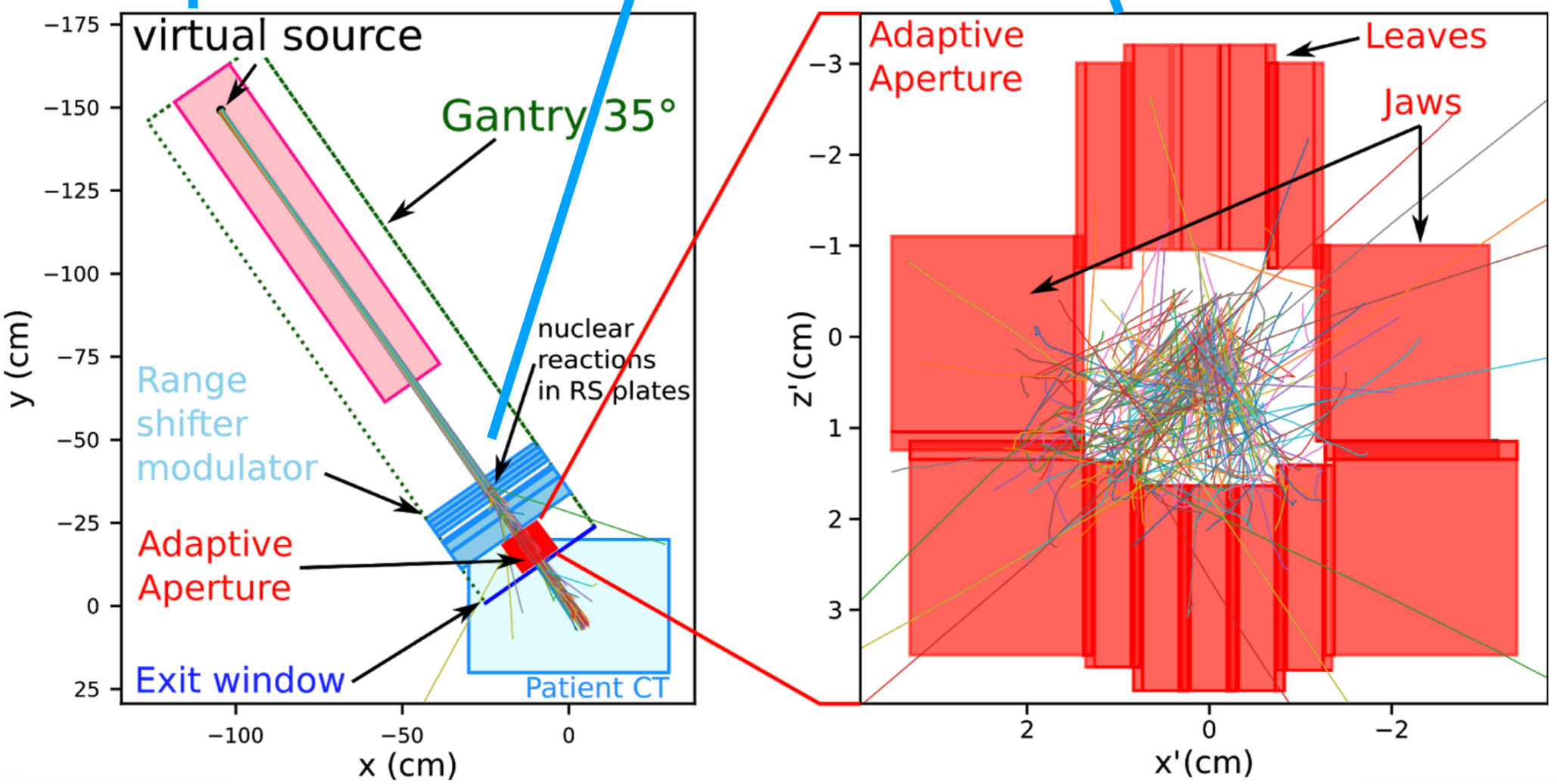
Conclusion: Dose accuracy well beyond clinical requirements. Fred can be used as secondary dose engine or for radio biological studies.



FRED beam model in Maastricht

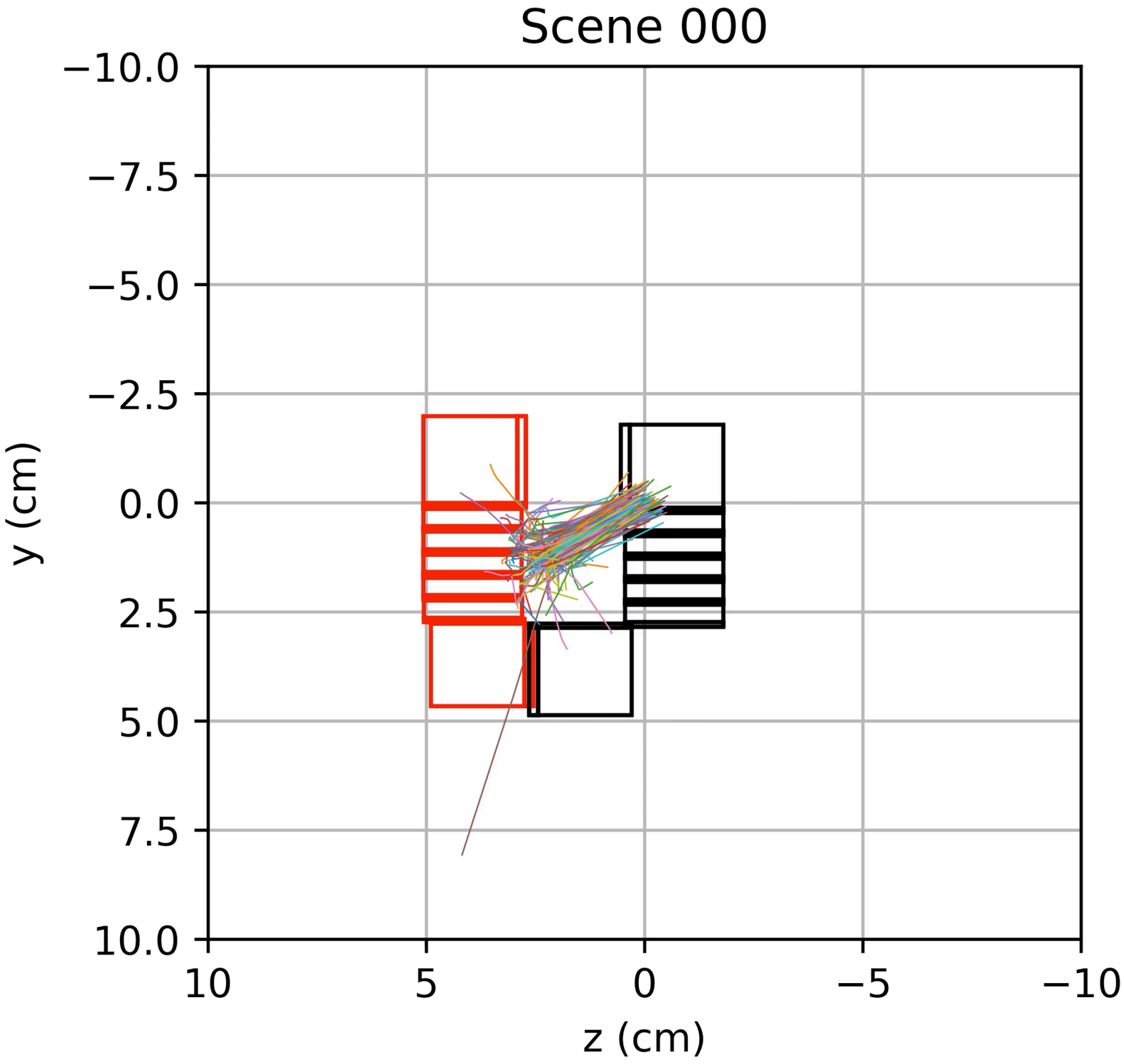
Pristine beam modeled as in Krakow

Degrader plates and aperture explicitly modeled in Monte Carlo



Possible overlap of gantry and phantom: primaries have a place of birth

Challenging: Adaptive Aperture



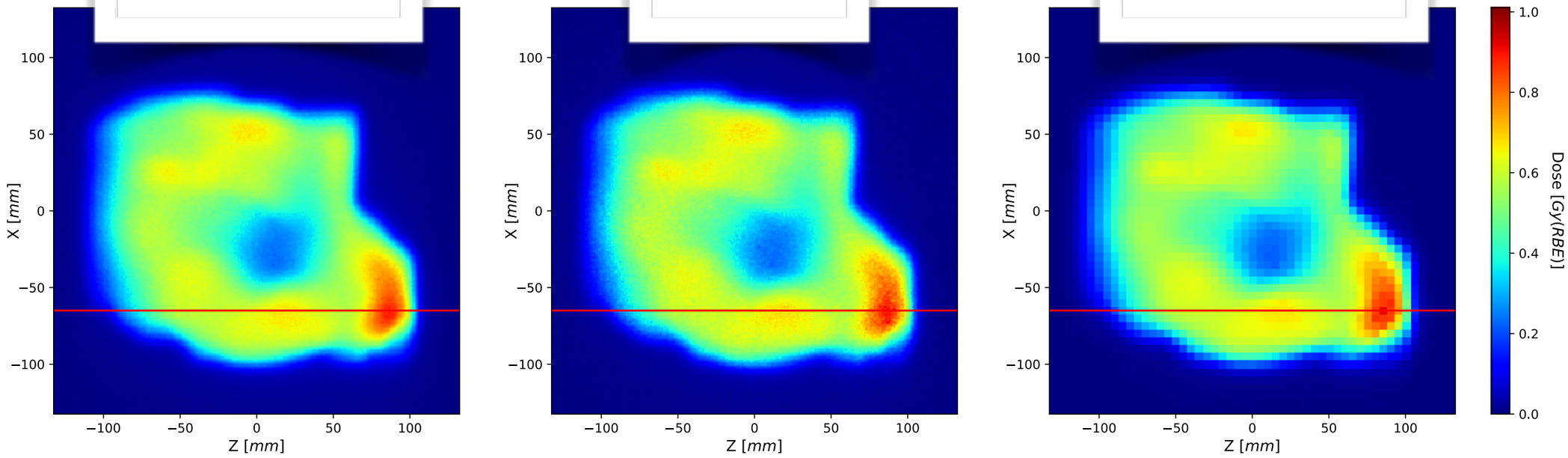
Patient QA @ Maastro

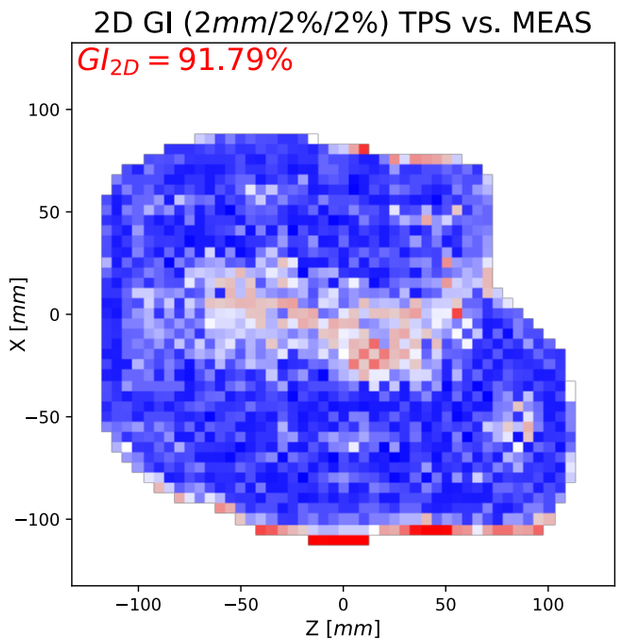
Octavius

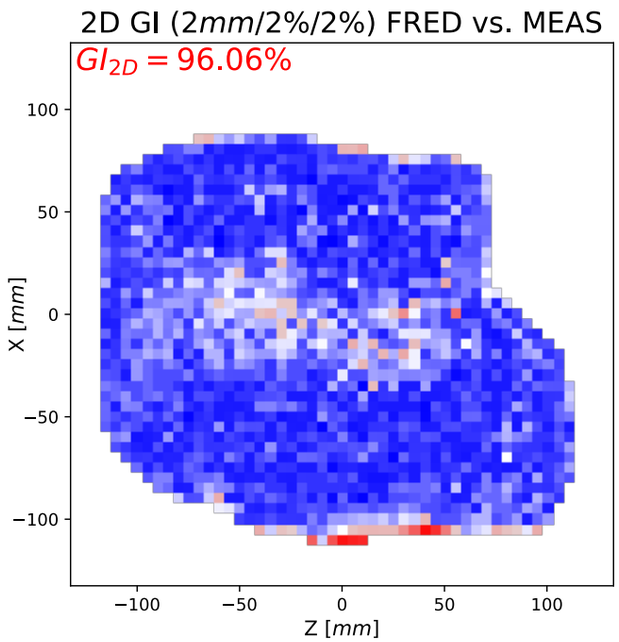
MC-TPS

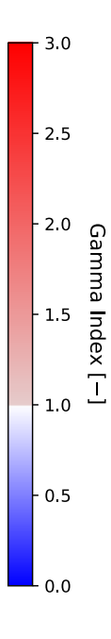
Fred

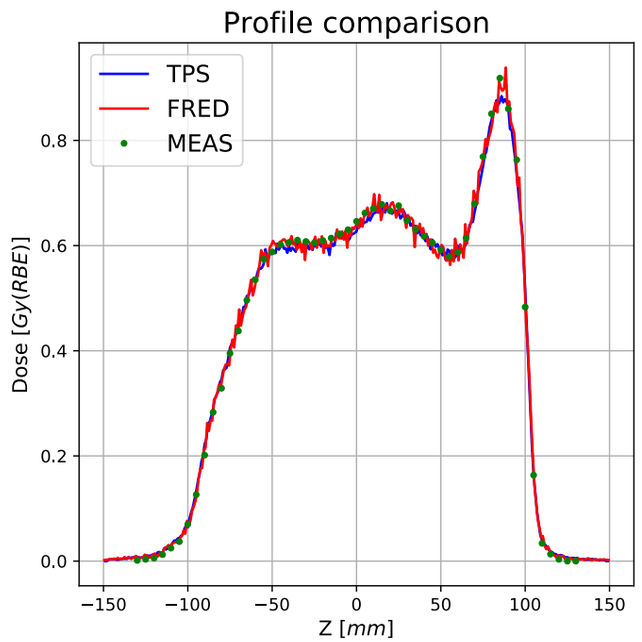
Measure











FRED in Maastricht: Perspectives

- Maastro proton center will build a log-file based dose recalculation pipeline using Fred as Monte Carlo engine.
- Integration with clinical (commercial) QA tools
- 4D dose recalculation studies
- Robustness studies
- In the future: Photons?

FRED as a library

FRED core:
transports particles and scores desired properties

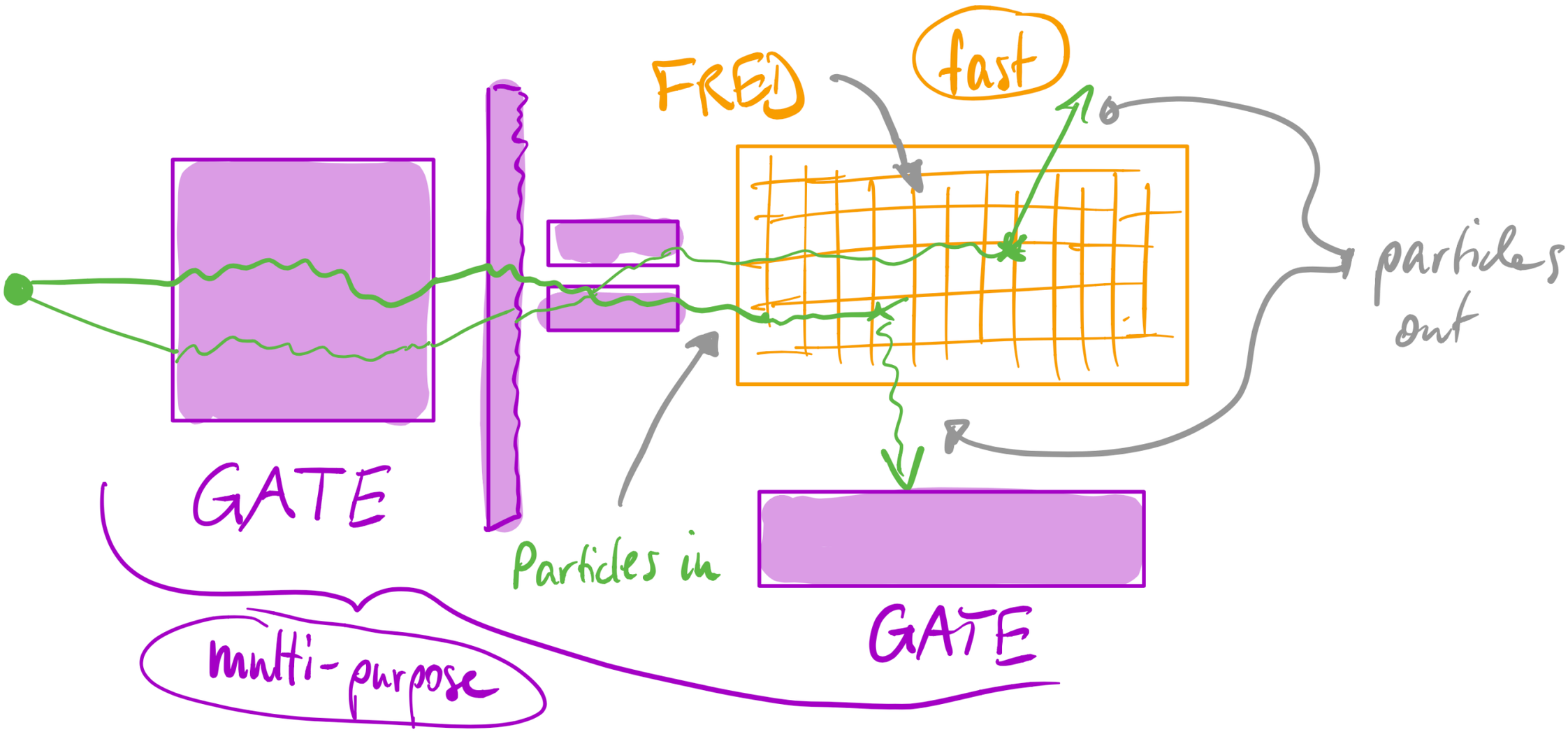
dynamic C library (API):
communicates with FRED core through exposed functions

FredTools:
pure python toolkit to create simulations

python wrapper:
exposes library functions as python functions

Back to the nutshell

Can we create a FredActor which takes particles from Gate, sends them to Fred, and takes them back afterwards?



FRED as a library

FRED core:
transports particles and scores desired properties

dynamic C library (API):
communicates with FRED core through exposed functions

FredTools:
pure python toolkit to create simulations

python wrapper:
exposes library functions as python functions

FredTools (python)

User interface

Components of a simulation:

- **Frame of Reference**
- **Region**
- **Scorer**
- **Beam source**

… are python objects. Can be manipulated dynamically through their methods.

Configuration:
"snapshot" of the current properties of the components stored as dictionary.

List of configuration
e.g. different gantry angles, energies, breathing cycle (4D CT)

back-end:

- Dump as json, XML
- send to FRED (API) and run simulation directly
- Generate GATE macro file and run GATE

Back again to the nutshell

Can we write a backend to FredTools to generate Fred **and** Gate simulations from the same input?

Can we create a FredActor which takes particles from Gate, sends them to Fred, and takes them back afterwards?

Can we write a backend to FredTools to generate Fred **and** Gate simulations from the same input?