Simulations of ion beams using Geant4 and Fluka Monte Carlo codes

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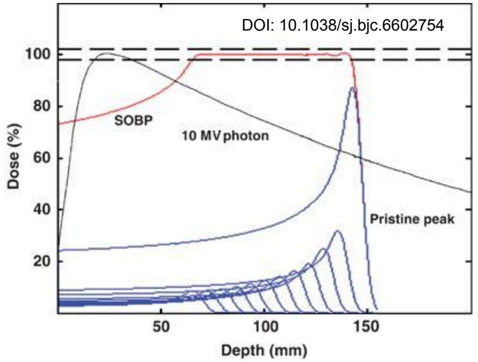
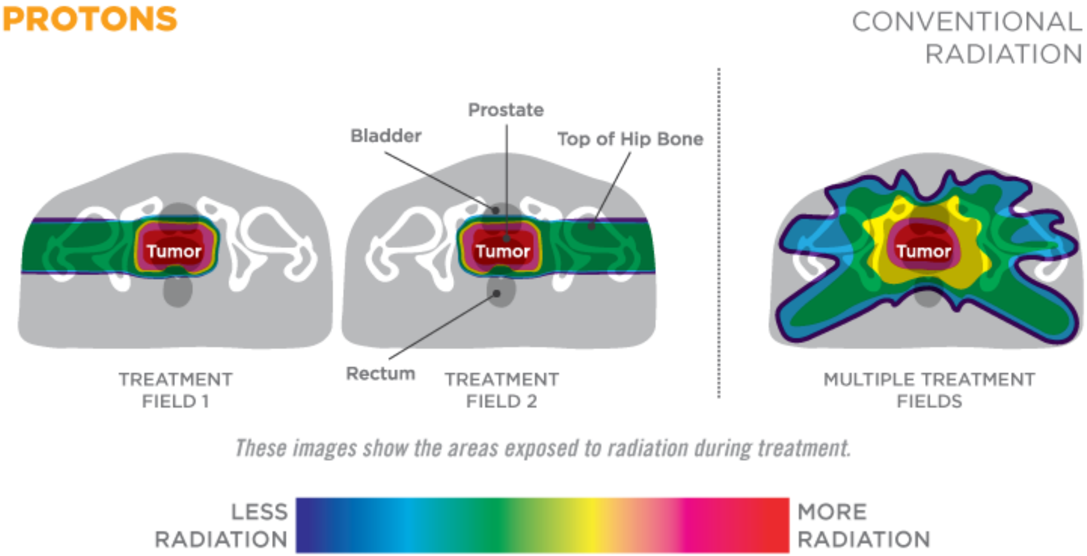
Cancer treatment by hadron therapy

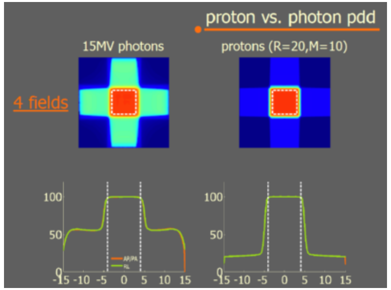


Depth-dose distribution of ions with initial energies <u>20-300 MeV</u> results in **Bragg peak** curve

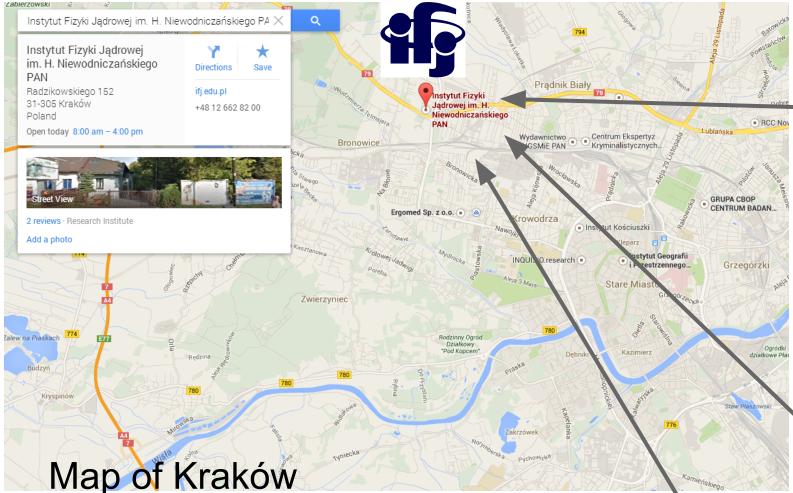


http://provisionha.com/images/uploads/multi_site/ProstateCancer_graphic.png

Golden rule of radiotherapy:
to ***minimize*** *the radiation dose to normal tissues while* ***maximizing*** *the radiation dose to the target volume.*



Cyclotron Centre Bronowice




fot. M. Ptaszkiewicz


http://www.dziennikpolski24.pl/artykul/2944382,protonami-w-nowotwory,id,t.html

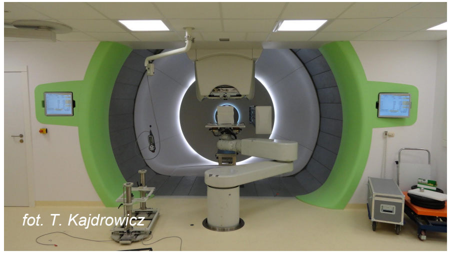
cyclotron AIC-144
60 MeV protons
80 nA intensity
2.9 cm range in water (max)

eye tumours treatment
isotope production


http://www.ifj.edu.pl/ccb/img/cyklotron_Proteus235.

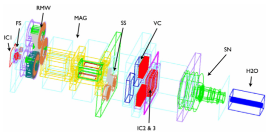
cyclotron Proteus C-235
230 MeV protons
600 nA intensity
33 cm range in water

eye tumours treatment
gantry (x2): any tumor location
experimental cave


fot. T. Kajdrowicz

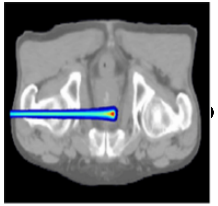
two robotic gantry arms, scanning beam

Why do we need a physical beam model ?



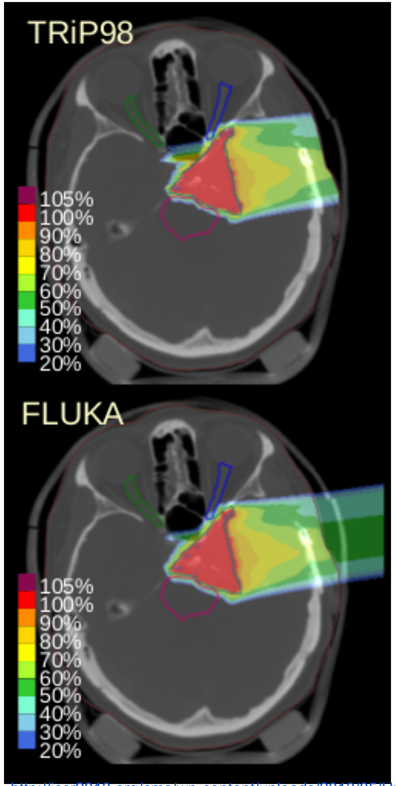
optimization of beam scattering system

patient shielding design and verification

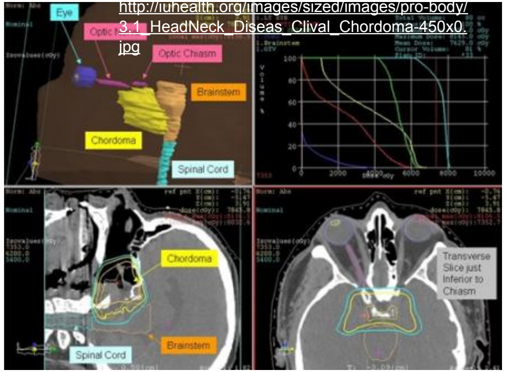


verification of treatment plans

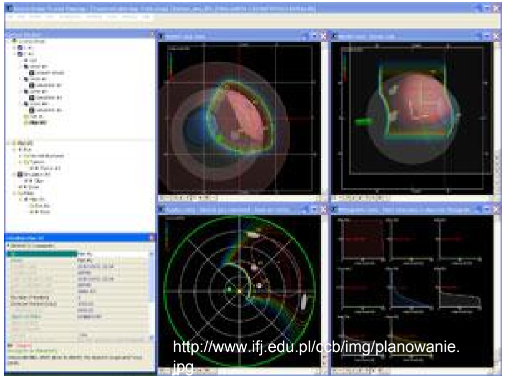
simulation of experiments (TLD, alanine)



http://iccr2013.org/cms/wp-content/uploads/2013/05/Urszula-Jelen.pdf



http://iuhealth.org/images/sized/images/pro-body/3.1_HeadNeck_Diseas_Clival_Chordoma-450x0.jpg



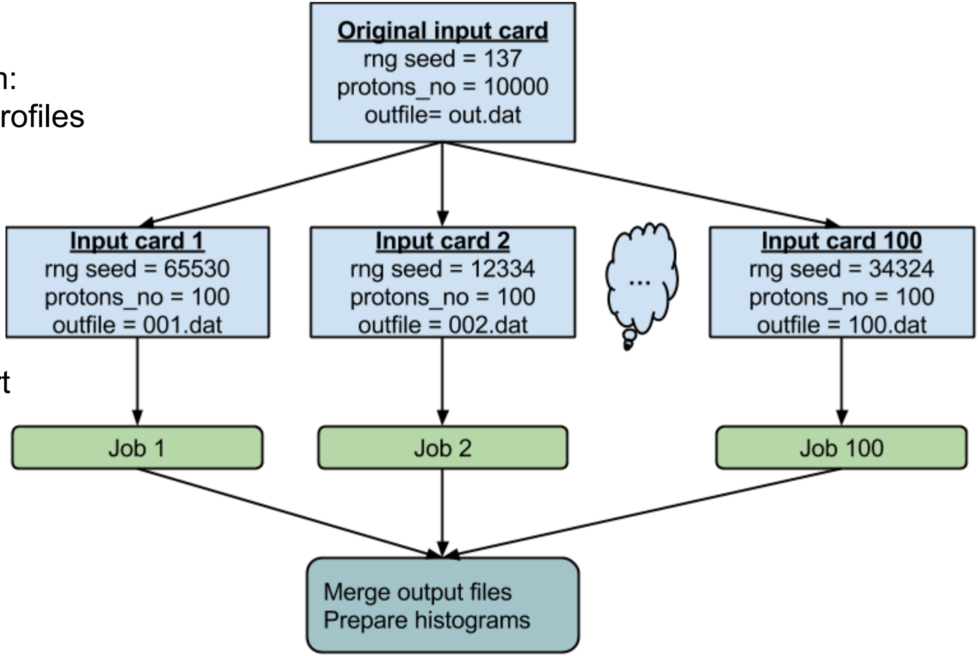
http://www.ifj.edu.pl/ccb/img/planowanie.jpg

Monte Carlo Simulation of a proton beam

Aim:
simulate proton beam:
 - dose and fluence profiles (depth, lateral)
 - complex geometry

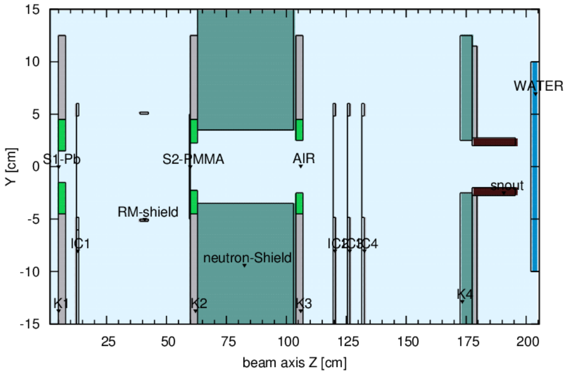
Tools:
Monte Carlo transport codes:
- Fluka 2011.2
- Geant4.96

Results:
(following page))



Parallelization procedure

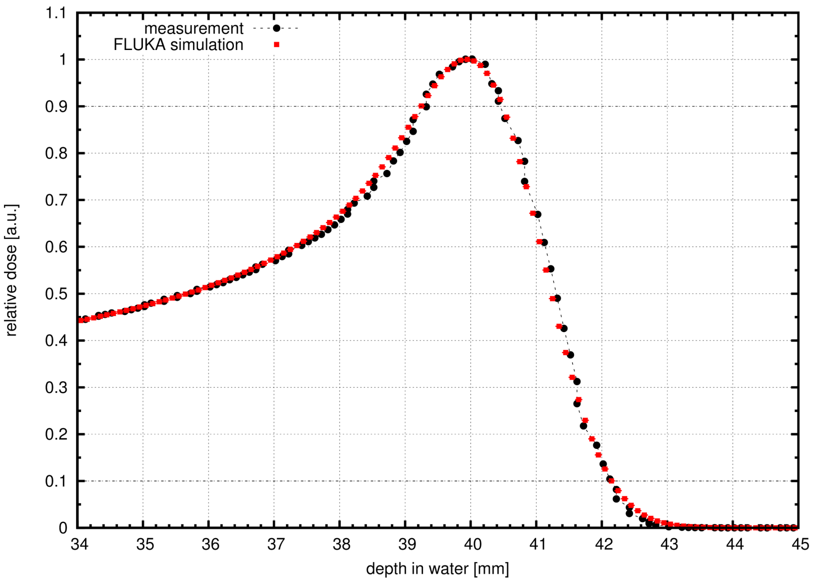
Eye-line scattering system in the treatment room (top) and defined in simulation geometry (bottom)



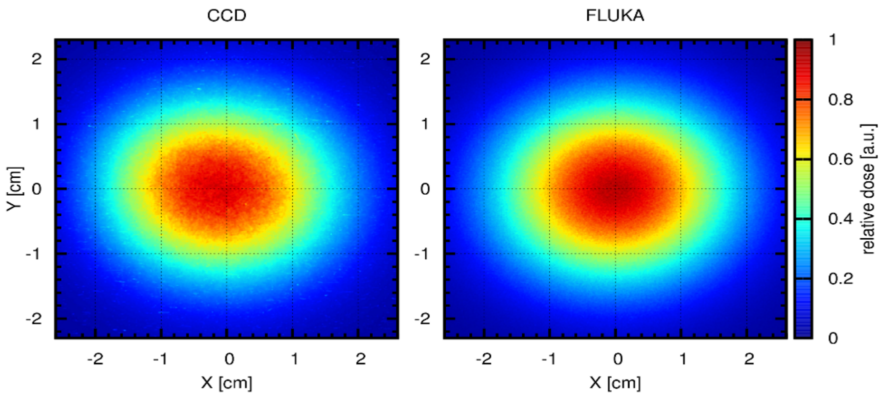
Monte Carlo simulation of a 70 MeV proton beam

Parallelization of an exemplary simulation scenario:

No of protons x No of jobs	Mean calc. time	Result error
$2.0*10^5$ x 5	10 min/job	15%
$5.5*10^6$ x 25	120 min/job	1%



Measured depth-dose distribution (black) compared with FLUKA results (red)



CCD beam image (left) compared with FLUKA results (right)

Monte Carlo simulation of a carbon beam

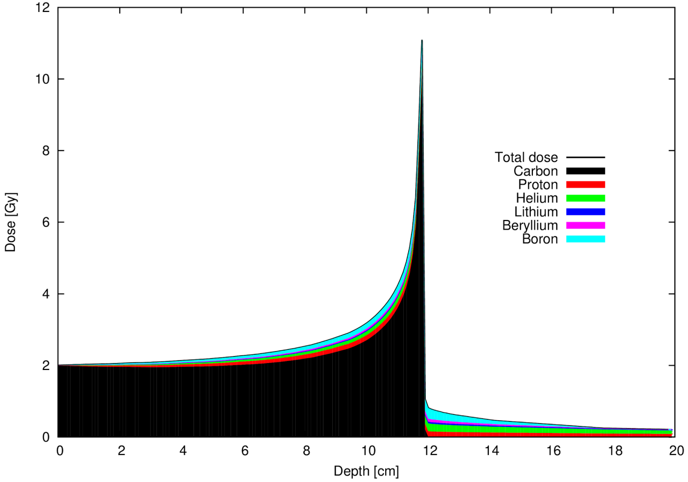
Aim:
scoring beam characteristic in liquid water

- dose (vs depth)
- fluence (vs depth)
- energy-fluence spectra of all ions (vs depth)

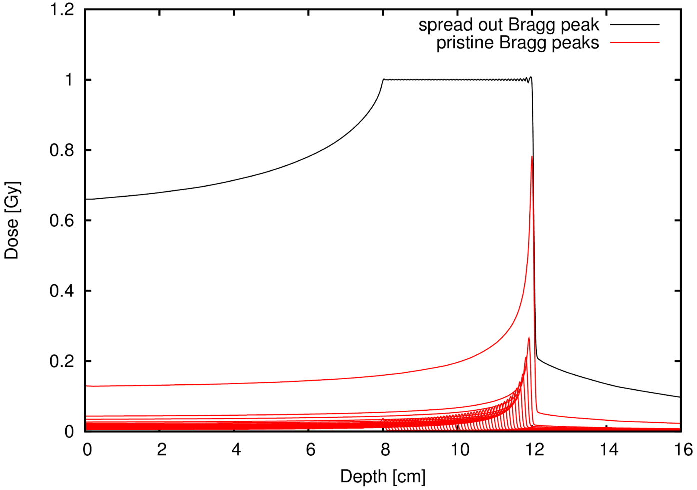
Tools:
Monte Carlo transport codes

- SHIELD-HIT10
- Geant4.96

Results:
database of 45 beam profiles for initial energies between 50 and 400 MeV/amu



Dose vs depth of a carbon beam of 270 MeV/amu initial energy and of beam fragments.

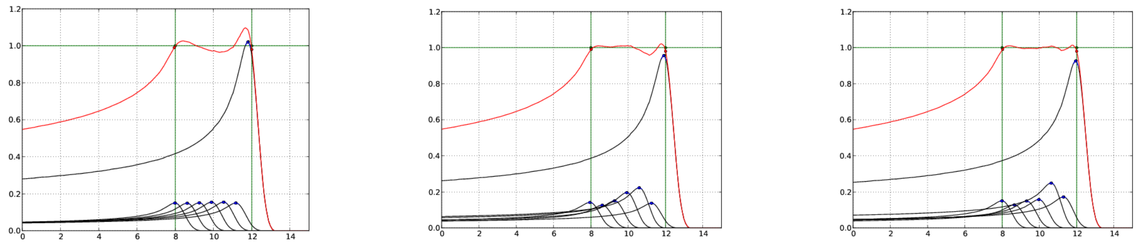


Flat depth-dose distribution over 8-12cm depth range obtained by summation of 49 pristine carbon beams with different initial energies and fluences.

No of particles	Total calc. time	Number of nodes
10^4	10 min	1
10^8	70 days	1
10^8	17 hours	100

Optimization of the depth dose distribution:

Aim:
find the initial energies and intensities of the beamlets which, superimposed, produce a given depth-dose (depth-survival) profile



First three steps of the dose profile optimization algorithm.

Tools:
optimization package included in the libamtrack library (python,C)

Results:
several projects of beam shaping elements
depth-dose and depth-survival profiles (radiobiological experiment)

Pristine beams superposition:

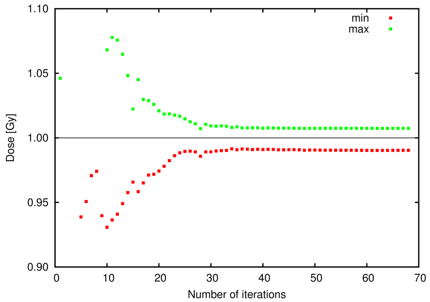
$$f(x;p_1,\ldots,p_m,h_1,\ldots,h_m)=\sum_{i=1}^{m}h_i f(x;p_i)$$

Objective function:

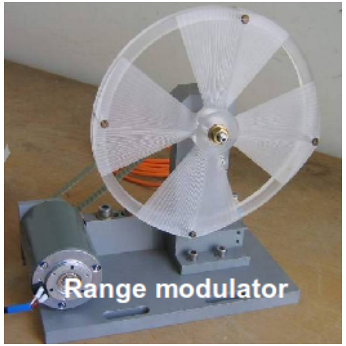
$$M=\sum_{j=1}^{n}\left(f(x_j;p_1,\ldots,p_m,h_1,\ldots,h_m)-g(x_j)\right)^2$$

Gradient of objective function:

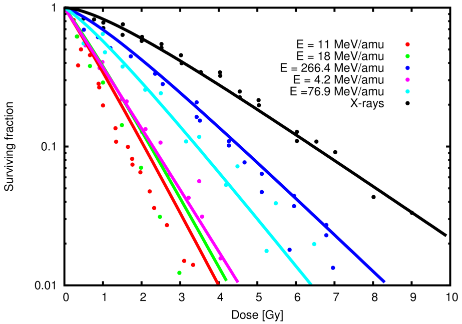
$$\frac{\partial M}{\partial h_i}=\sum_{j=1}^{m}2\left(\sum_{i=1}^{m}h_i f(x_j;p_i)-g(x_j)\right)f(x_j;p_i)$$



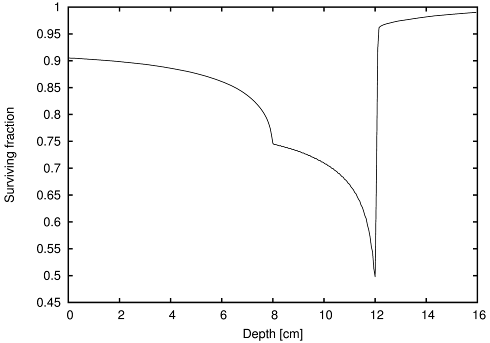
Convergence of the dose profile optimization algorithm.



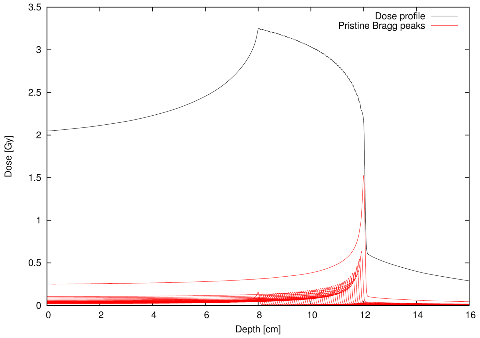
Modelling of biological effect: carbon beams



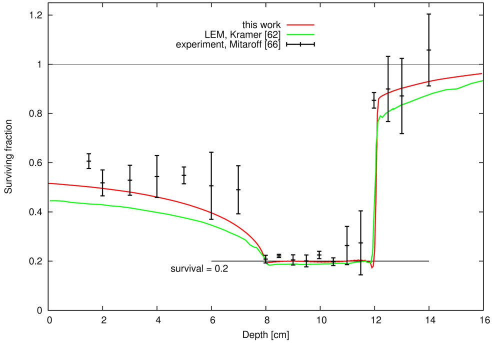
1. Cell survival at given dose depends on the particles energy



2. Constant dose level of carbon ions leads to non-uniform cell survival



3. Specific depth-dose distribution is needed to obtain constant biological effect of carbon ions



4. Predicted cell survival profile stays in agreement with experimental results

Questions, comments ?

http://naukawpolsce.pap.pl/fotogalerie/gallery,57,montaz-cyklotron-proteus-c-235.html

http://www.ifj.edu.pl/ccb/

https://libamtrack.dkfz.de/


Thank you and we ask for more !!!