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Investigations into the dose to fetus under maternal proton therapy

EURADOS WG6 Webinar

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WG9 activities

- Out-of-field doses in proton therapy (PT)
  - Production of the secondary neutrons
    - Unavoidable due to:
      - Interaction of high energy protons with beam line materials
      - Patients body
- WG9 focuses on:
  - Assessment of neutron dose equivalent for PT facilities
  - Undesired out of field doses during PT
  - Doses to the fetus

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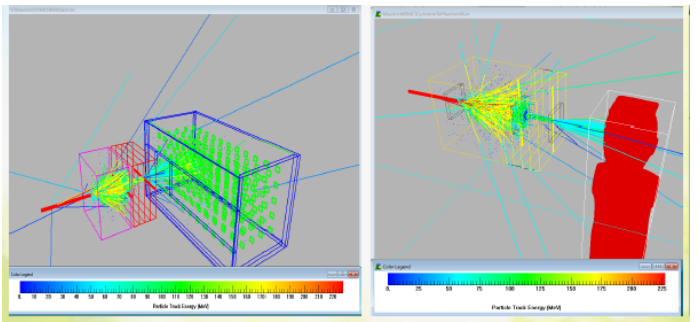
MC simulations in PT

- Compute the neutron doses
  - Not considered by the treatment planning system
- Shielding of the PT facilities
  - Neutron ambient dose equivalent
- Spectral neutron fluence
  - Inside and outside the treatment room



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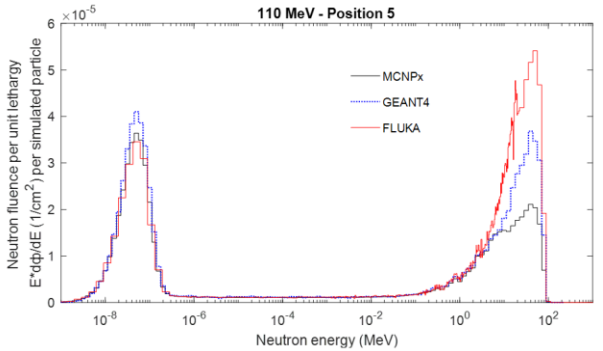
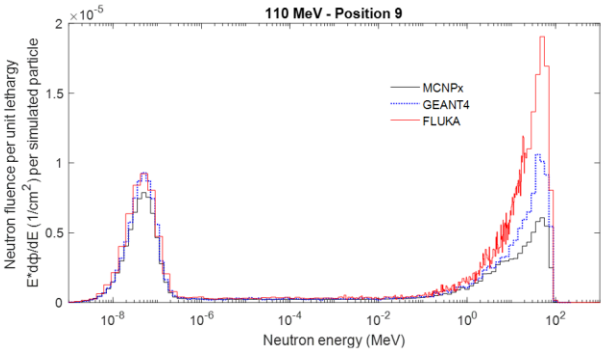
Issues

- Usage of cross sections for higher energies
  - Rely on nuclear models
    - Intranuclear cascade model (INC) (Bertini, ISABEL...)
    - Preequilibrium models
    - Evaporation models (Dresner, Abla)
- Which one is more suitable??



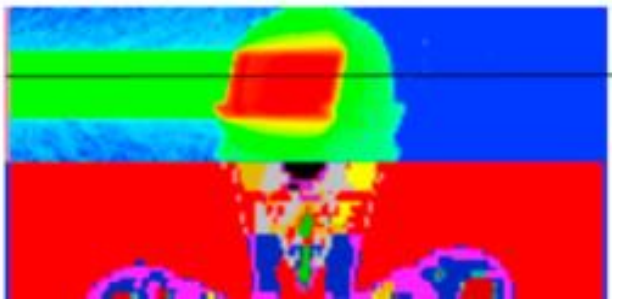


Intercomparisons

- Computational campaigns with no reference solution
  - Different codes (or the versions of the same code)
  - Different approaches
  - Different participants (groups)

Fetus dose estimation

- Initial simulation conditions
  - Circular beam r = 3 cm
  - SOPB range 10 cm, modulation 5 cm
  - 21 energies ranging from 78 to 116 MeV
  - Target center of the brain



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Phantom

- Katja[1]
- 24th week of pregnancy

Phantom	Katja
Weeks of pregnancy	24
Female height [cm]	168
Female mass [kg]	63.6
Fetus mass [g]	730
Voxel size [mm^3]	$1.775 \times 1.775 \times 4.84$
Number of voxels ($*10^6$)	15.7

Becker, Janine, et al. "Katja--The 24th week of virtual pregnancy for dosimetric calculations." *Polish Journal of Medical Physics and Engineering* 14.1 (2008)

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First results

- Results differ
  - Up to 50 % among the participants
- What went wrong?

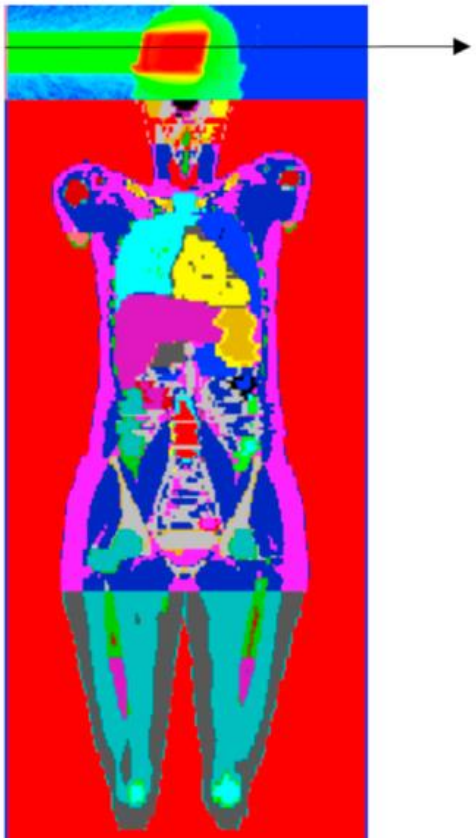
Was it the code?

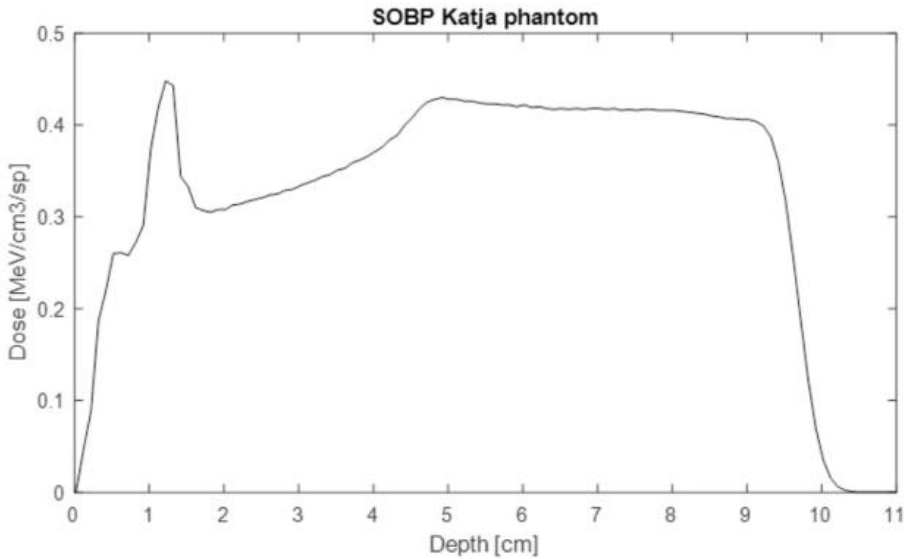
- MCNPX
- MCNP6.2
- All participants repeated simulations with both code versions

Was it the code?

- MCNPX
- MCNP6.2
- All participants repeated simulations with both code versions
- Results still differ significantly

Positioning of the beam?





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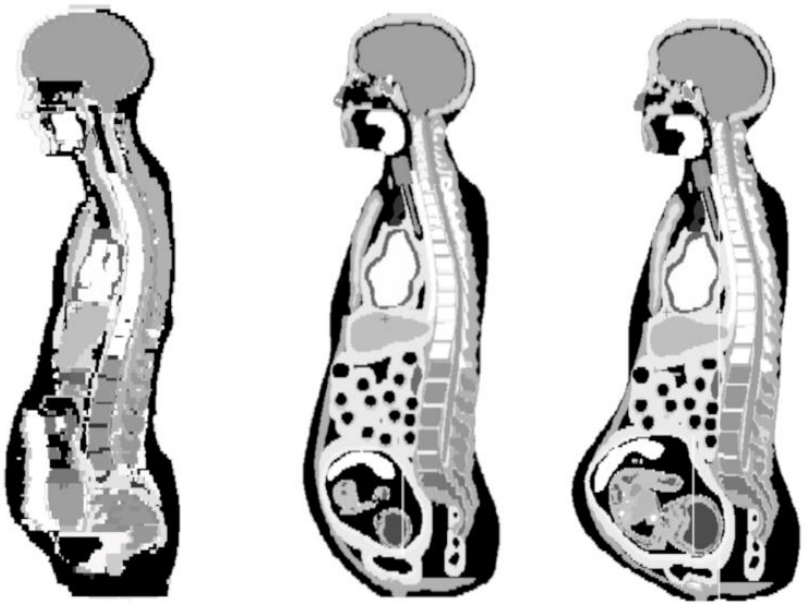
Is it the phantom?

- UF phantoms were engaged

- Gestational age and post conceptual

Phantom

- Katja
- University of Florida (UF) family of phantoms[2]



Physical and geometrical characteristics of the different phantoms used.

Phantom	Katja	UF20	UF25
Weeks of pregnancy	24	22	27
Female height [cm]	168	164	164
Female mass [kg]	63.6	63.6	65.8
Fetus mass [g]	730	468	986
Voxel size [mm^3]	$1.775 \times 1.775 \times 4.84$	$1.26 \times 1.26 \times 2.7$ Mother $0.301 \times 0.301 \times 0.301$ Fetus	$1.26 \times 1.26 \times 2.7$ Mother $0.381 \times 0.381 \times 0.381$ Fetus
Number of voxels ($*10^6$)	15.7	53.65 fetus 57.24 Mother	51.96 fetus 66.78 Mother

Paulbeck, Colin, et al. "Dosimetric impact of a new computational voxel phantom series for the Japanese atomic bomb survivors: pregnant females." *Radiation Research* 192.5 (2019): 538-561.

Is it the phantom?

- UF phantoms were engaged
- Gestational age and post conceptual
- Tissue composition definition (only 0.3 % difference)

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Nuclear models

- Different code version uses different cross section data libraries
- MCNPX
- MCNP6.2
- Definition of atomic number of the element, mass number of the nuclide and cross-section identifier

Models used for	
MCNPX	MCNP6.2
6000.c	6000.h
12000.c	11023.h
16000.c	12000.h
17000.c	16000.h
19000.c	17000.h
20000.c	19000.h
26000.c	19000.h
53000.c	20000.h
6000.h	26000.h
11023.h	53127.h
12000.h	
16000.h	
17000.h	
19000.h	
20000.h	
26000.h	
53000.h	

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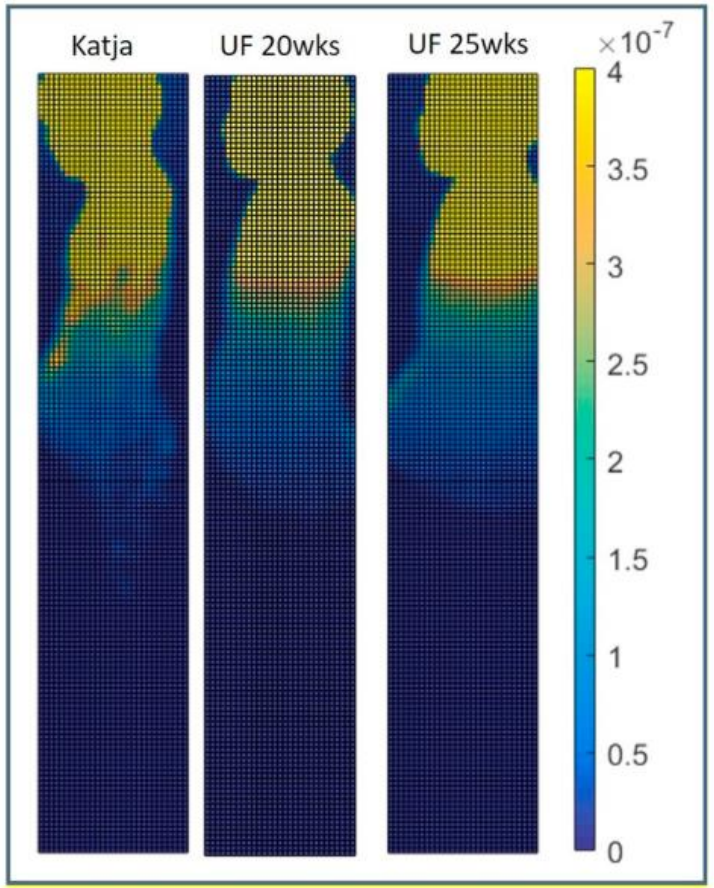
Results



	Katja	UF20	UF25
Dose equivalent per target dose [nSv/Gy]	750	355	396

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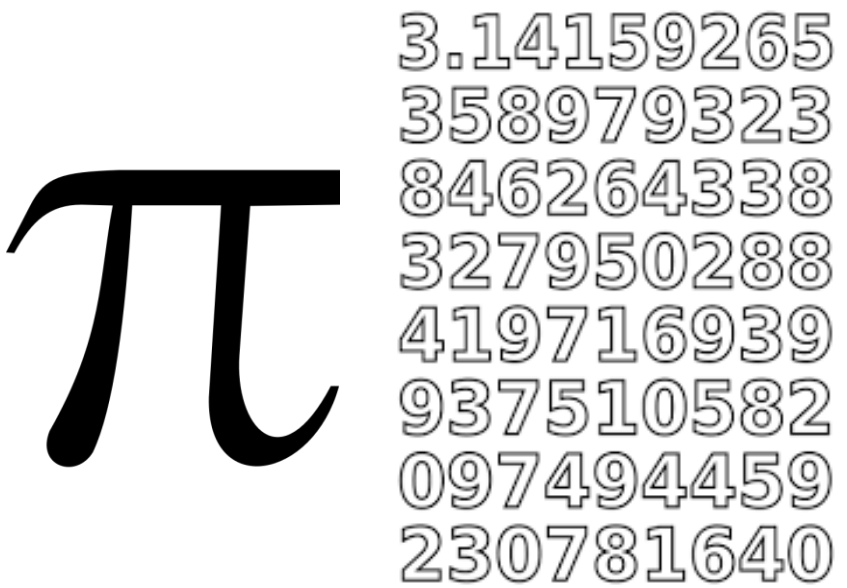
Hints to pick up

- Keep Your files and file names organized
- Regular periodic meetings of the group
- Avoid biasing (i.e. sharing the input)
- Compare Your results with already published data
- Cross section data libraries should be added to papers when published to allow for comparison

Hints to pick up

- Skipping the geometry check might speed up the calculations
- When PT is considered for the simulations consider engaging the code that can read input and geometries from the DICOM files
- Start with simple problem and try to benchmark the results

Thank You for Your attention!



Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Fetus dose calculation during proton therapy of pregnant phantoms using MCNPX and MCNP6.2 codes

Marijke De Saint-Hubert [a], Katarzyna Tymińska [b], Liliana Stolarczyk [c,d], Hrvoje Brkić [e,f,*]

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Radiation Measurements

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The influence of nuclear models and Monte Carlo radiation transport codes on stray neutron dose estimations in proton therapy

M. De Saint-Hubert [a,*], J. Farah [b], M. Klodowska [c], M.T. Romero-Expósito [d,e], K. Tyminska [f], V. Mares [g], P. Olko [h], L. Stolarczyk [h,i], S. Trinkl [j]

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