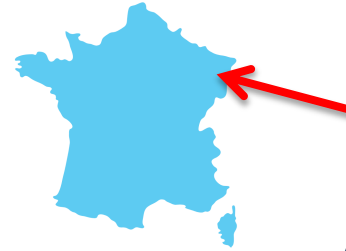


GATE @ DeSIs-IPHC Strasbourg

N. Arbor (nicolas.arbor@iphc.cnrs.fr)

2024 GATE Scientific Meeting
Orsay – 22/05/2024

DeSIs (Dosimetry Simulation Instrumentation)



- Members : 4 (lecturer-)researchers, 3 engineers-technicians, 1 Post-Doc, 3 PhD
- Applied nuclear physics:
 - > MC softwares benchmarking/intercomparison
 - > radiation protection & dosimetry
 - > nuclear measurements

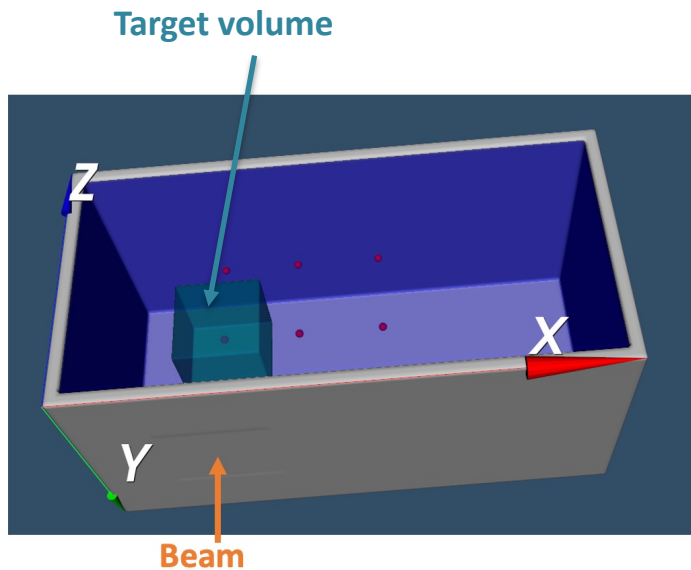
GATE @ DeSIs-IPHC

- **MC softwares benchmarking/intercomparison**
 - Neutron production in hadrontherapy
 - Neutron activation around particle accelerators
- **Radiation protection**
 - Skin dose calculations in breast radiotherapy
 - In/Out-of-field dose calculations in hadrontherapy
 - Patient and staff dosimetry in interventional radiology
- **Nuclear measurements**
 - Neutron field mapping
 - Machine learning algorithm for gamma spectrometry

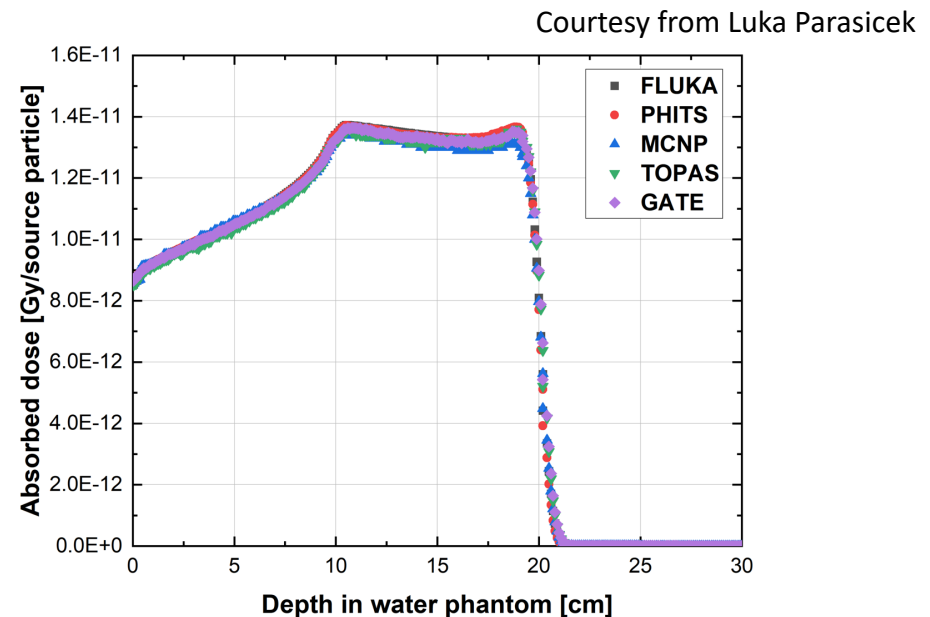
**MC softwares
benchmarking/intercomparison**

Neutron production in hadrontherapy

- EURADOS task group “Monte Carlo comparison in hadrontherapy”
- Protons interacting with beamline and patient creating secondary neutrons:
 - high-energy neutrons created by intra-nuclear cascades (up to proton energy)
 - fast neutrons evaporated by excited nuclei (few MeV)
 - thermal neutrons by slowing down during collisions (0.25 eV)
- MC codes use different physics libraries (TENDL, JEFF, ...), as well as nuclear models

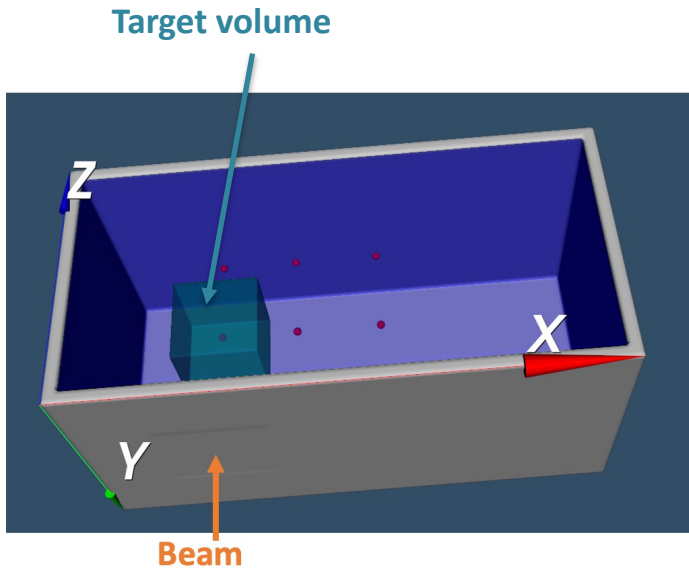


Water phantom (PMMA walls)

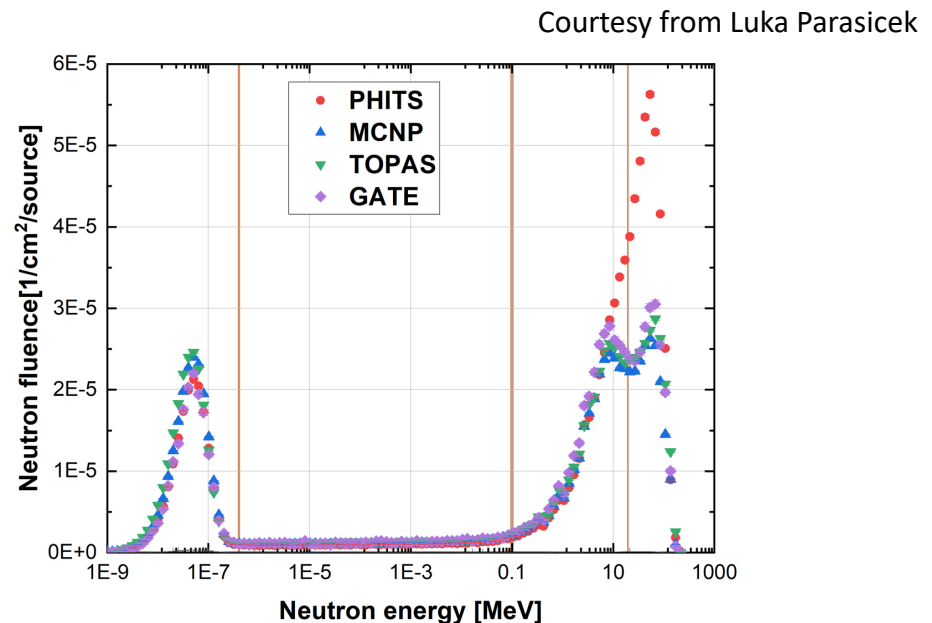


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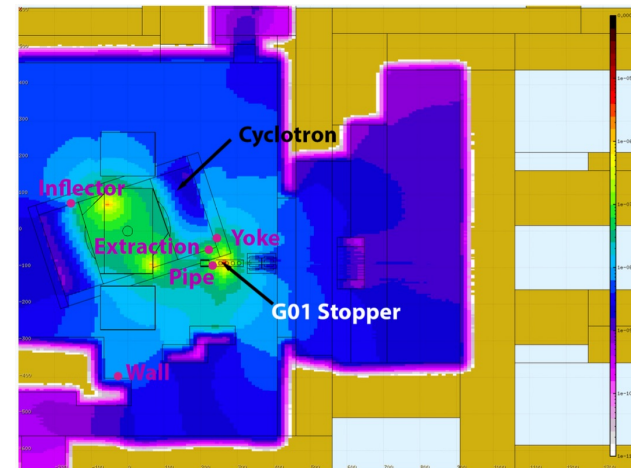
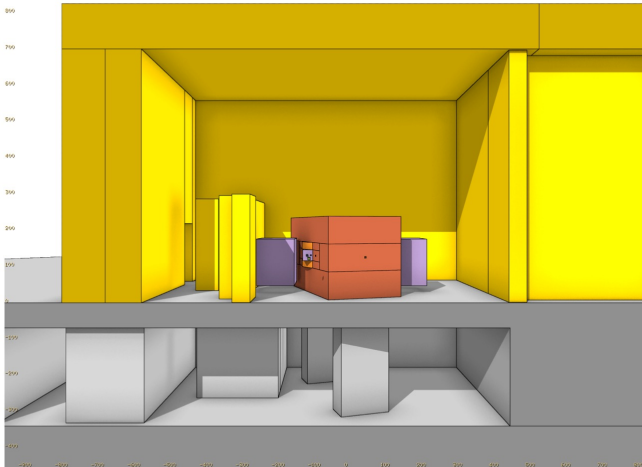
Water phantom (PMMA walls)



Neutron activation

- Sim β -AD project (BPI) about β -emitters produced by cyclotron activation
 - calculation of neutron fields produced during cyclotron activities
 - software development for activated components inventory (γ/β ratio)

Courtesy of JM. Horodyski

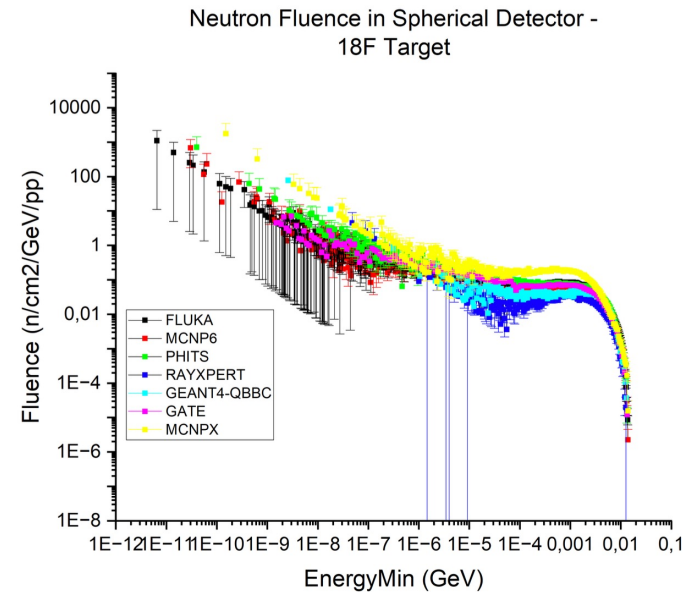
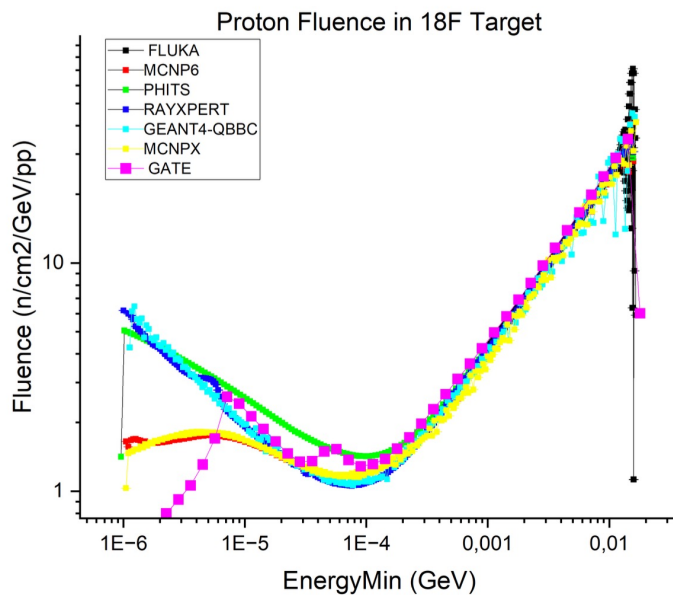


Neutron activation

- Sim β -AD project (BPI) about β -emitters produced by cyclotron activation
 - calculation of neutron fields produced during cyclotron activities
 - software development for activated components inventory (γ/β ratio)
 - Monte Carlo codes intercomparison



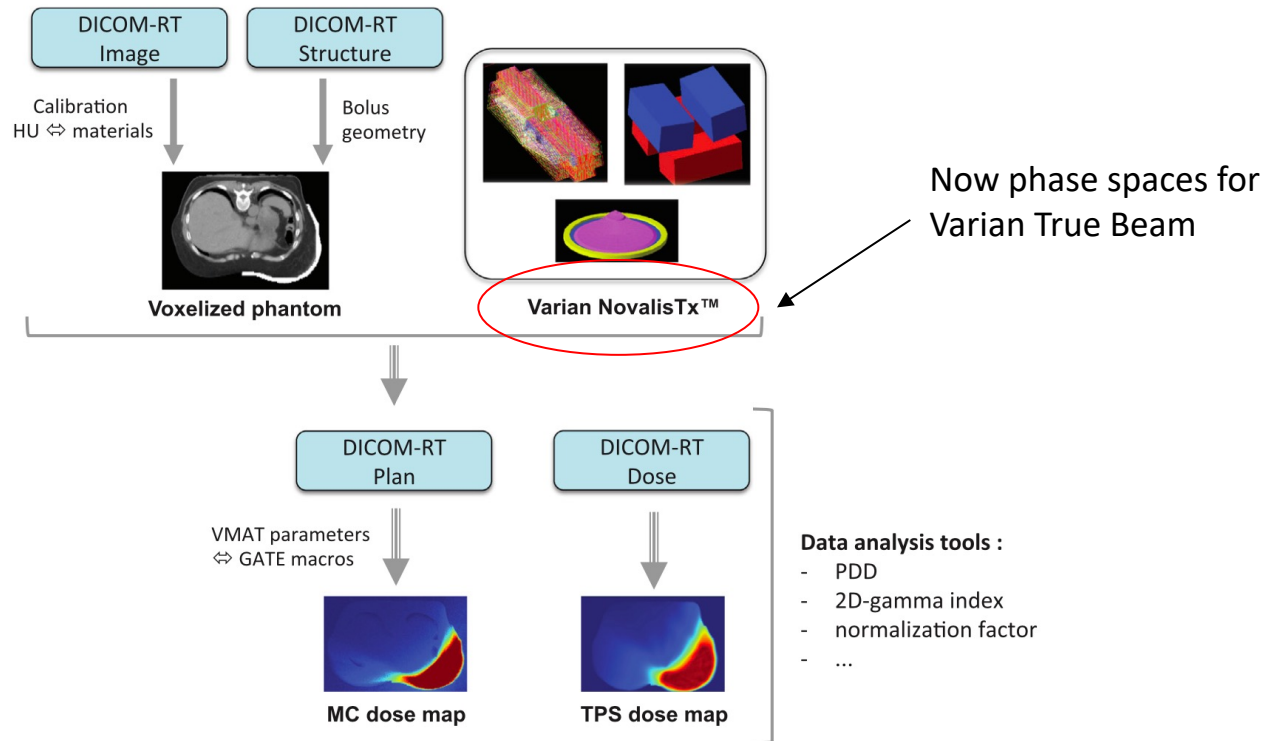
Courtesy of JM. Horodyski



Radiation Protection

Skin dose in breast RT

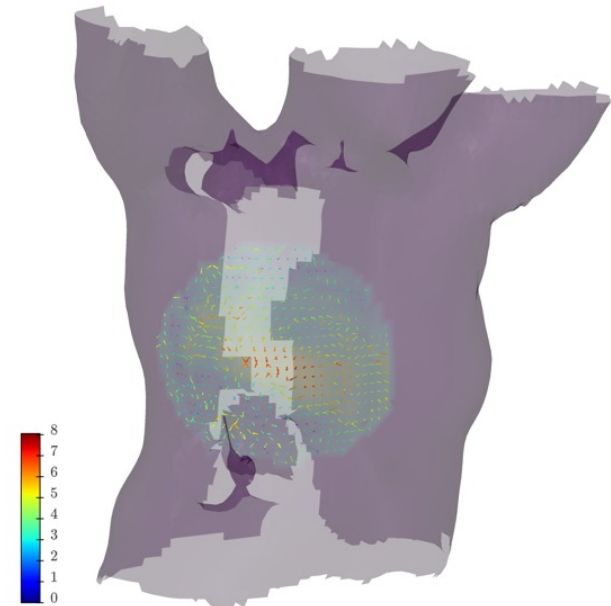
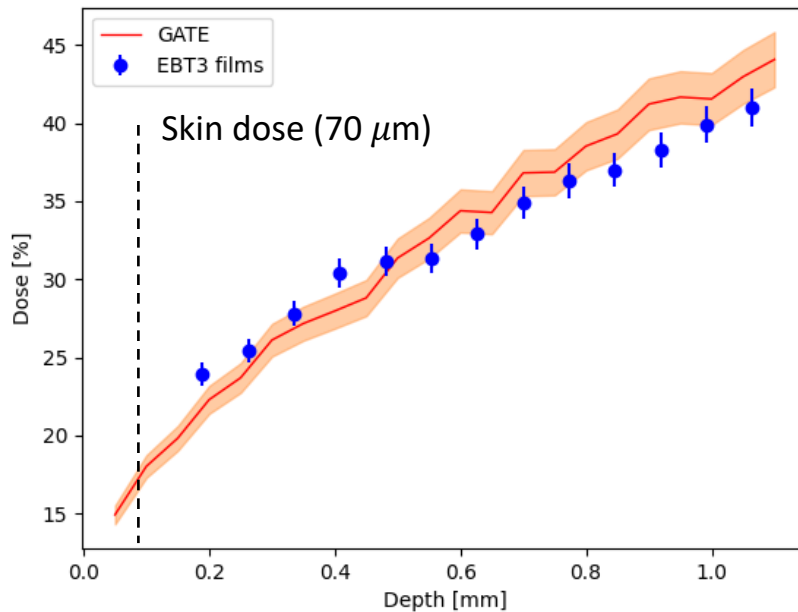
- Skin dose is a key issue to reduce side effects in breast RT...but still hard to compute (TPS)
- Python/GATE framework for VMAT skin dose calculations (2019)



<https://doi.org/10.1016/j.ejmp.2019.04.012>

Skin dose in breast RT

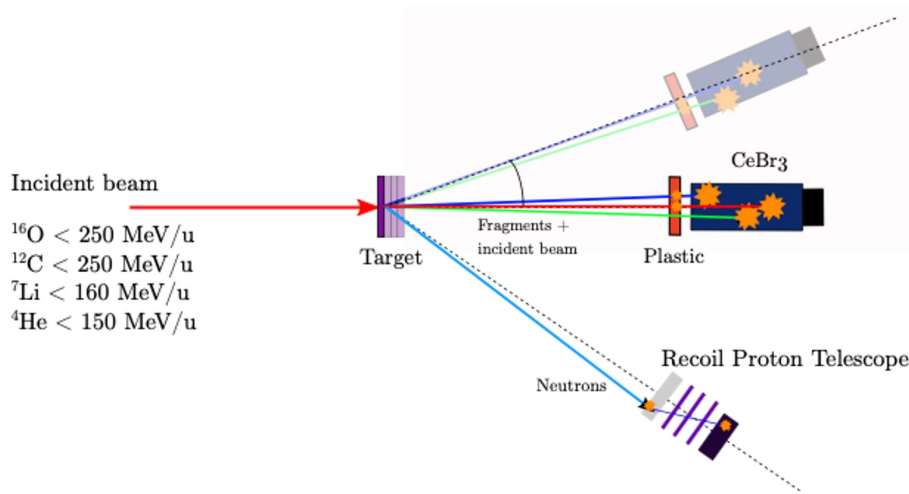
- Skin dose is a key issue to reduce side effects in breast RT...but still hard to compute (TPS)
- Python/GATE framework for VMAT skin dose calculations (Varian True Beam)
- Monte Carlo calculations from deformed vector fields (DVF)-driven CT images
→ *impacts of breast deformations on skin dose distribution (clinical study)?*



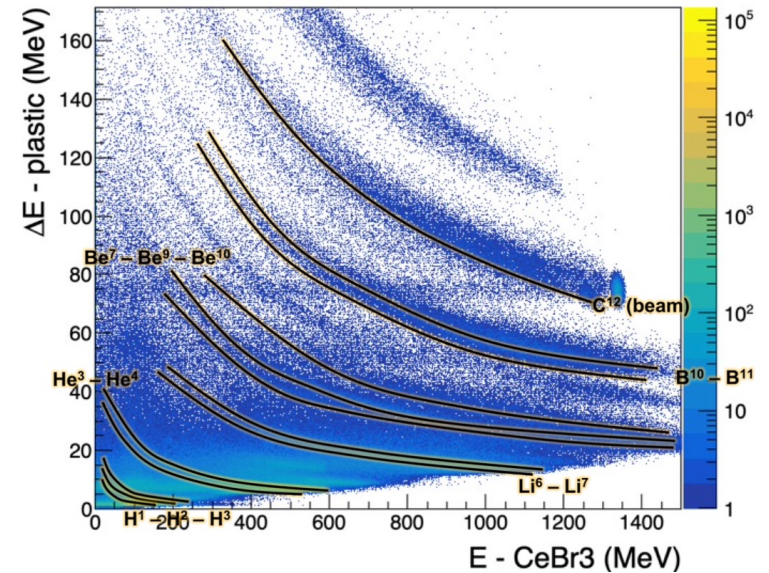
Courtesy of P. Galmiche

In/Out-of-field dose in hadrontherapy

- Measurements/calculations of secondary particles from ion fragmentation
- Parallel measurements of radiolysis effects (radiochemistry team (IPHC), S. Chefson PhD)
- Coupling of GATE (nuclear physics) and Geant4-DNA (radiolysis)

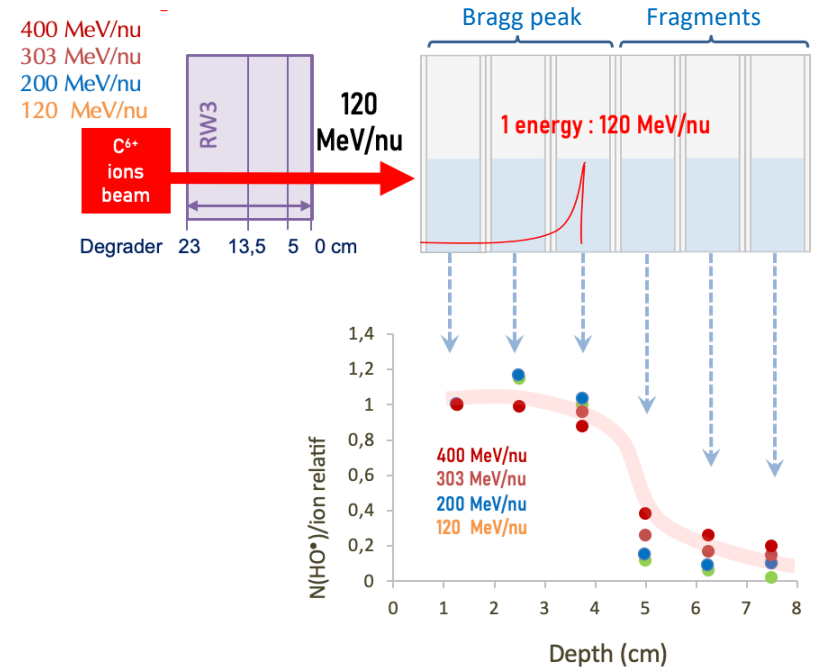
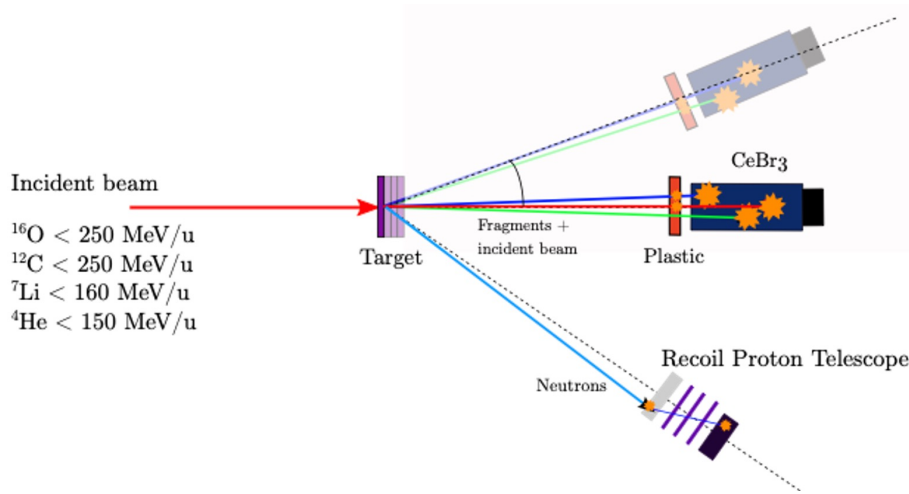


Courtesy of M. Vanstalle



In/Out-of-field dose in hadrontherapy

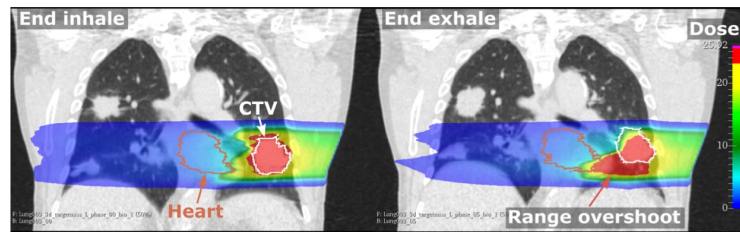
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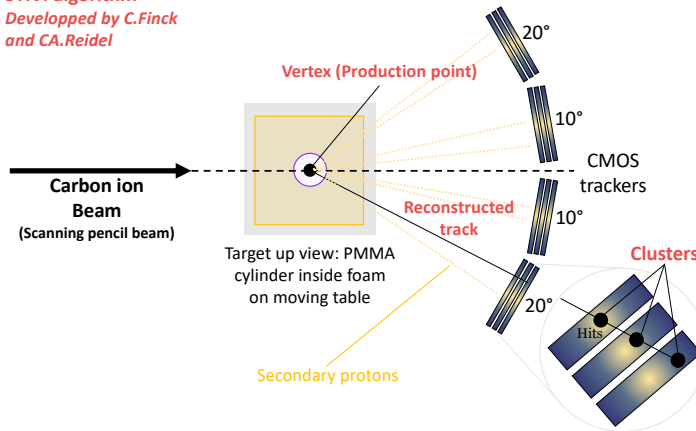
In/Out-of-field dose in hadrontherapy

- CMOS tracking device for secondary protons detection (Lévana Gesson PhD):
 - real-time beam position reconstruction
 - improve 4D treatments plans and reduce margins (respiratory movements)
- GATE simulation on a clinical case to study the clinical feasibility

Courtesy of L. Gesson



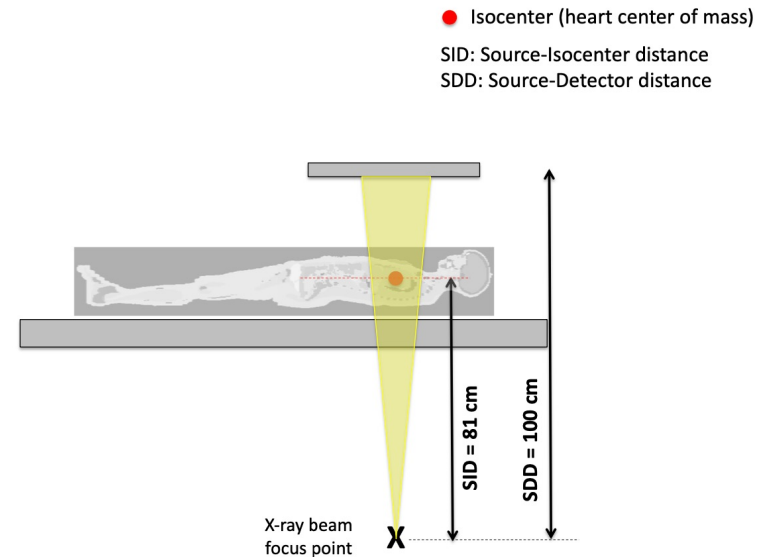
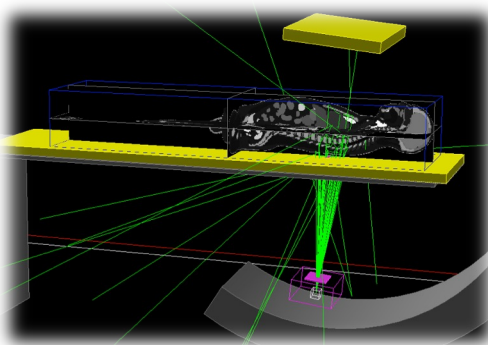
STIVI algorithm
Developed by C.Finck
and CA.Reidel



CMOS trackers setup

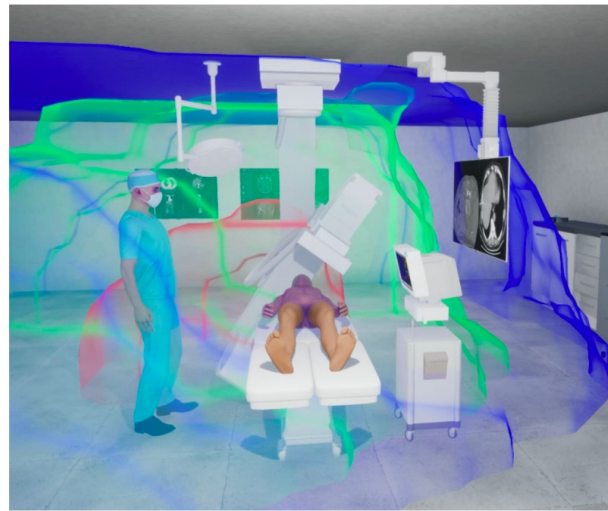
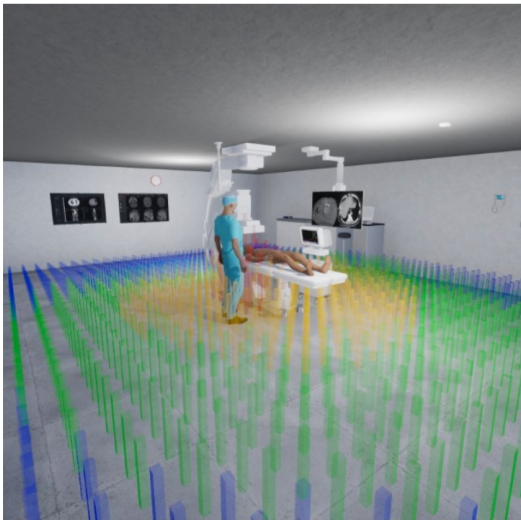
Patient & staff dosimetry in interventional radiology

- EURADOS task group “Organ dose in interventional radiology”
- Global experimental and MC comparison to better understand (and limit) variability of organ dose measurements/calculations in IR :
 - *methodology for organ dose intercomparison*
 - *benchmark of Monte Carlo softwares for organ dose calculations*



Patient & staff dosimetry in interventional radiology

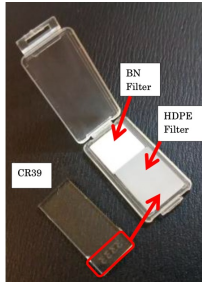
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- Development of a VR-software for radiation protection training in IR (staff)



Nuclear Measurements

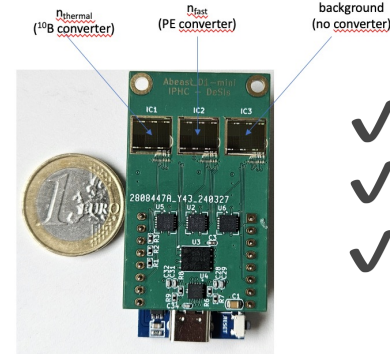
Neutron fields

- Development of a 4D (3D + real-time) neutron mapping system



CR-39

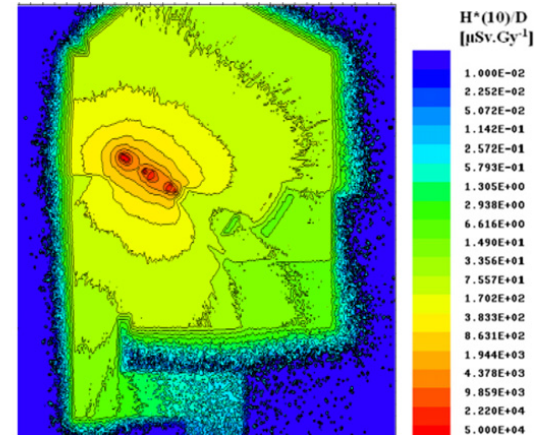
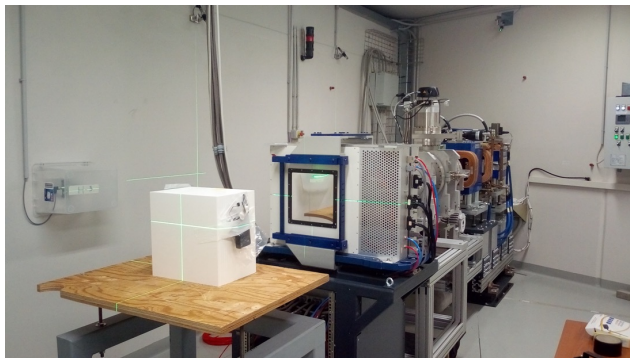
- ~~Single use~~
- ~~No real-time~~
- ~~Time consuming~~



AlphaBeast (CMOS)

- ✓ Electronic
- ✓ Real-time
- ✓ Autonomous

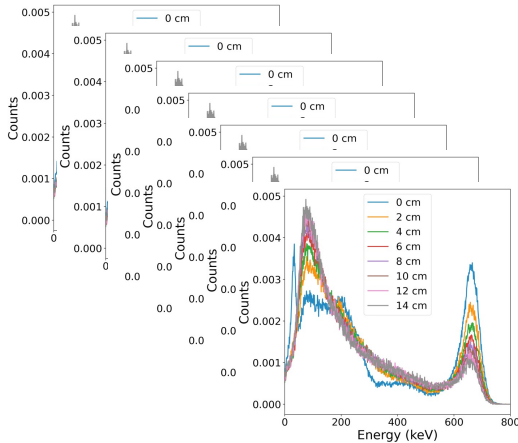
- Measurements coupled with GATE 3D neutron fluence maps (data/MC cross-check)



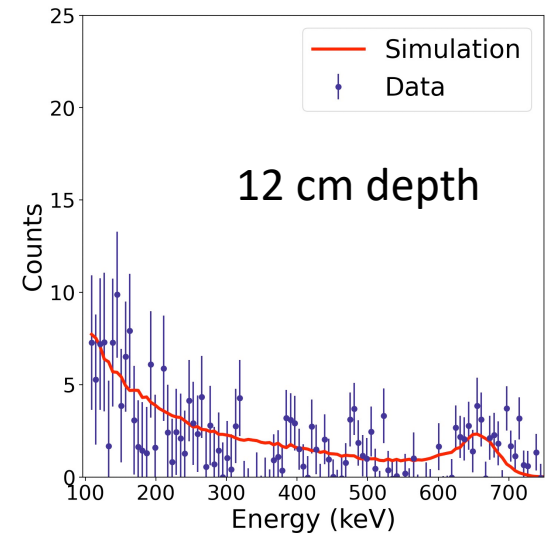
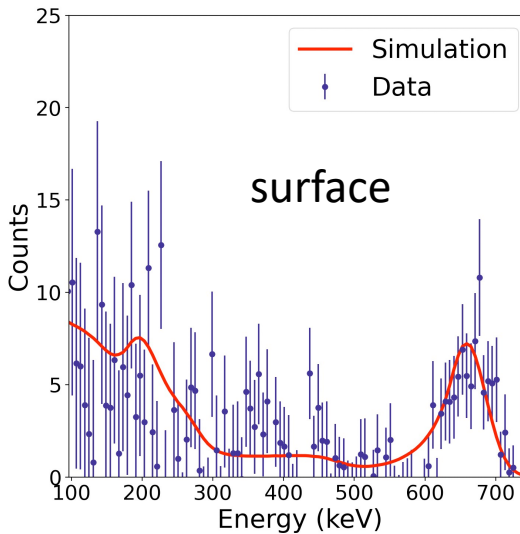
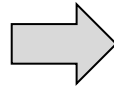
J. Farah, Phys. Med. Biol. 59 (2014)

ML for gamma spectrometry

- Machine learning algorithms for automatic data correction (background, screening, ...) in gamma spectrometry
- Use of GATE to produce training database for various application (drone-borne systems, beacons, ...)



Training: altitude
materials
source distribution
radionuclides



ML for gamma spectrometry

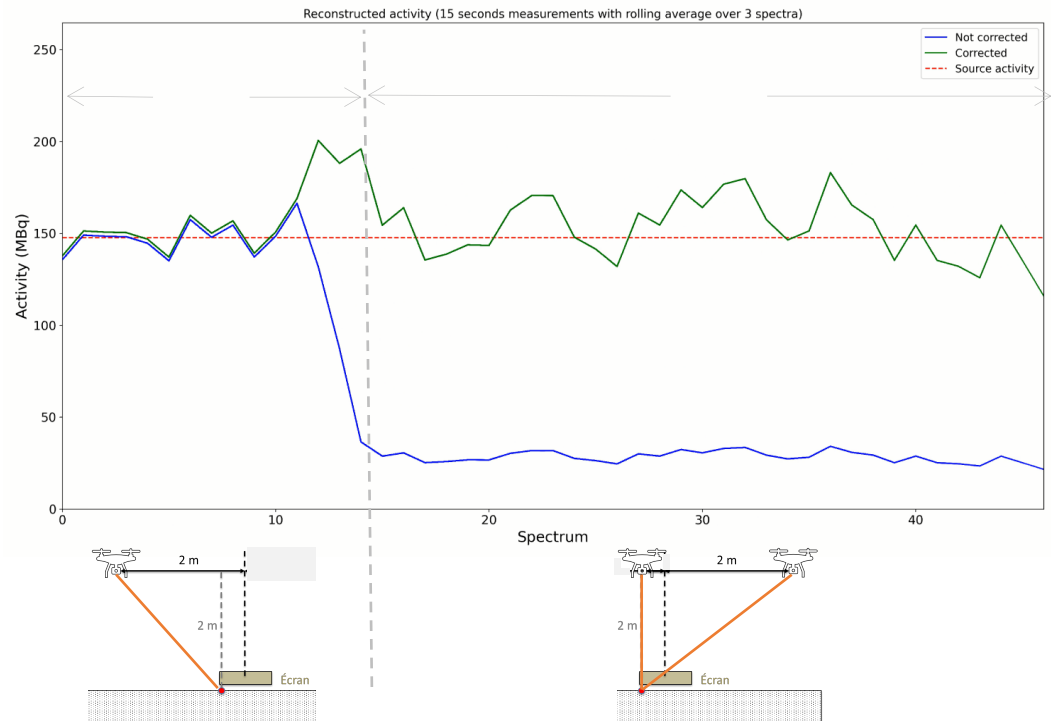
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Nal (3''x3'')



CZT (1cm³)



Conclusion & Outlook

- Thanks to all GATE technical developers for maintaining/improving this nice tool !
- GATE 'way of life' enables easy calculations for various applications in radiation protection and nuclear measurements
- Our on-going GATE to do list:
 - update documentation for Isotope definition (+ GATE10)
 - Radioactive Ion Beam (RIB) benchmark
 - graphical user interface (*à la* Flair - <https://flair.web.cern.ch/flair/>)

