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Geant4 Performance for Medical Physics Applications

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Use of MC in medical physics application

Radiotherapy and radiation protection

- Verification of clinical treatment planning systems (TPS)
- Development of instrumentation for radiotherapy QA
- Radiation protection
- Study of novel radiotherapy treatments
- Radiobiology

Imaging

- Detector development for imaging systems
- Development and assessment of reconstruction algorithms
- Study of new radiopharmaceuticals

Requirements from medical physics

- **Accuracy of results**
  - Less than 5% max discrepancy with experimental/reference data
  - In general it is ok to sacrifice speed for better physical accuracy
- **Regression tests**
  - Benchmark physics processes/cross sections/ final states
  - Execution time

Summary

- Nowadays MC is used
  - as “gold standard” to verify clinical treatment plannings (TPS)
  - To develop dose kernels for clinical commercial TPS
  - To develop and optimise new detector technology
  - To study new radiotherapy treatments

- Still MC is too slow for a clinical use
  - Hospitals usually have limited computing resources and scientific computing skills
  - Hospitals may have local clusters
    - MT option is very useful

Ideally O(min) !!!	1 CPU (~ 3GHz)	Local cluster (200 CPUs)
Brachytherapy Geant4 TPS	~60 days	~ 7 hours
ProtonCT	~90 days	~ 11 hours
Microbeam Radiation Therapy	~ 1.4 years	~2.5 days
Study of novel nanoparticles to enhance radiotherapy clinical outcome (Geant4-DNA)	~1.6 years	~ 3 days
Neutron dosimetry in external X-ray	~3 years	~ 5 days

Keep in mind execution times depend strictly on the application

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How to improve speed

- Use of variance reduction techniques
- Use of Phase Space Files
- Reverse Monte Carlo
- GPU
- Use of extended computing resources (e.g. supercomputers)

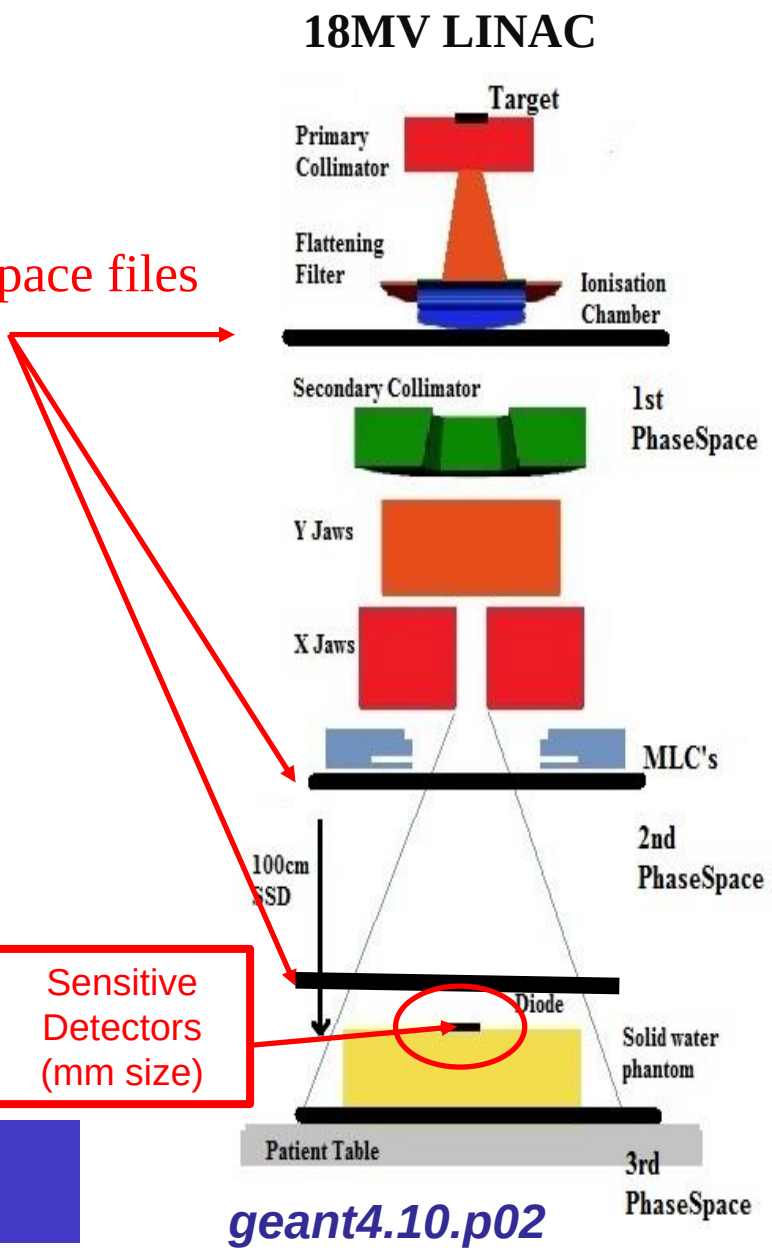
Neutron dosimetry for external X-ray radiotherapy

V. Gracanin, I. Cornelius, S. Guatelli, A. Rosenfeld

Centre of Medical and Radiation Physics, UOW, Australia

- Standard EM Physics
- Hadronic physics with Neutron HP
- Phase Space files are used to reduce computation times.
- Use of Geant4 Cuts Per Region, tracks killing.
- Statistically meaningful results ~10^{12} primary electrons

Execution time ~ 3 years



Use of GPU

- **J. Bert et al, Phys. Med. Biol. 58 (2013) 5593–5611**
  - Speed-up factor ~ 80 for a simplistic simulation for PET.
  - In the case of more clinically realistic simulations for emission/transmission tomography, the acceleration factors is 400–800

- **X. Jia et al, Phys. Med. Biol. 57 (2012) 7783–7797**
  - Development of protontherapy TPS based on TOPAS/Geant4 MC code on GPU (still some approximation in physics are adopted)
  - Execution times: less than 30 s

- **X. Jia et al, Phys. Med. Biol. 56 (2011) 7017–7031**
  - For realistic IMRT and VMAT plans, MC dose calculation can be completed with less than 1% standard deviation in < 1min using MC on GPU.

- **Geant4-DNA on GPU**
  - S. Okada et al, GPU Acceleration of Monte Carlo Simulation at the Cellular and DNA Levels, Innovation in Medicine and Healthcare 2015

Use of supercomputers

- Excellent solution to speed up simulations

- Possible problem: security
  - Confidential patient data
  - Confidential industrial, vendor data
  - May require encrypted processing