LNS Activity

Pablo Cirrone, Serena Fattori, Giuliana Milluzzo, Luciano Pandola, Giada Petringa

Milestones 2020		Comments
Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread.	100%	La release è stata effettuata. Questo ha comportato sia le operazioni di manutenzione, miglioramento e bug fix, sia il supporto all'inserimento e all'integrazione di nuovi modelli di fisica (scattering inelastico per i gamma JAEA)
Studio e confronto tra codici Monte Carlo della quantificazione del danno biologico indotto dalla frammentazione del target in protonterapia	100%	E' stata completata. Nei prossimi mesi verrà sottomesso un articolo di confronto tra FLUKA e Geant4
Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread.	100%	La release è stata effettuata. Questo ha comportato sia le operazioni di manutenzione, miglioramento e bug fix, sia l'inserimento e all'integrazione di nuovi modelli di fisica (scattering Rayleigh con fattori di forma molecolari) e di un extended example
Inserimento delle sezioni d'urto p-11B e p- 19F all'interno della QGSP_BIC_AllHP	**50%**	Al momento è stata inserita la sezione d'urto della p-11B e non della p-19F. I ritardi sono dovuti al fatto che si sta ancora valutando se inserire la sezione d'urto interamente sperimentale oppure una combinazione tra quest'ultima e le librerie TENDL.
Validazione del nuovo extended example "radiobiology"	**80%**	La procedura di debug e validazione del codice ha finora incluso il calcolo della dose e del Linear Energy Transfer (LET). In particolare, sono state simulate diverse condizioni sperimentali: 60 MeV di protoni; 150 MeV di protoni; 744 MeV di 12C. La distribuzione di dose è stata confrontata con i dati sperimentali acquisiti con una camera Markus standard (mod 3002). Il LET è stato confrontato con due diverse tipologie di rivelatori una TEPC (Tissue Equivalent Proportional Counter) e un rivelatore a Silicio (MicroPlus probe). Attualmente è in corso la validazione dell'algoritmo per la stima del danno biologico espresso in termini di RBE (Relative Biological Equivalent).
Simulazione di una cellula su scala nanometrica con Geant4-DNA per studi sull'uptake	**40%**	E' già stata simulata una geometria semplice che riproduce la struttura cellulare. Al momento si sta valutando quali parametri scegliere per il confronto con i dati sperimentali

Milestones 2021		Deadline
GEANT4 - LNS: Release di Geant4 contenente manutenzione ed eventuali correzioni sui modelli elettromagnetici Penelope e/o sugli esempi (extended, advanced) sotto la responsabilità del gruppo	**50%**	Dicembre 2021
GEANT4 - LNS: Realizzazione di una simulazione Geant4 per l'ottimizzazione della linea di protonterapia per il trattamento dei melanomi oculari realizzata in collaborazione con la ditta BEST-Cyclotron	**100%**	Dicembre 2021

One International Geant4 School in 2021 (Belgrade or Catania)

Milestones 2022 (nuove proposte)

Giugno 2022: Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread.

Dicembre 2022: Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread.

Dicembre 2022: Validazione del calcolo del LET per fasci di ioni carbonio, ossigeno ed elio.

Dicembre 2022: Release del nuovo extended example

Dicembre 2022: Simulazione di una cellula su scala nanometrica con Geant4-DNA per la quantificazione del danno al livello del DNA

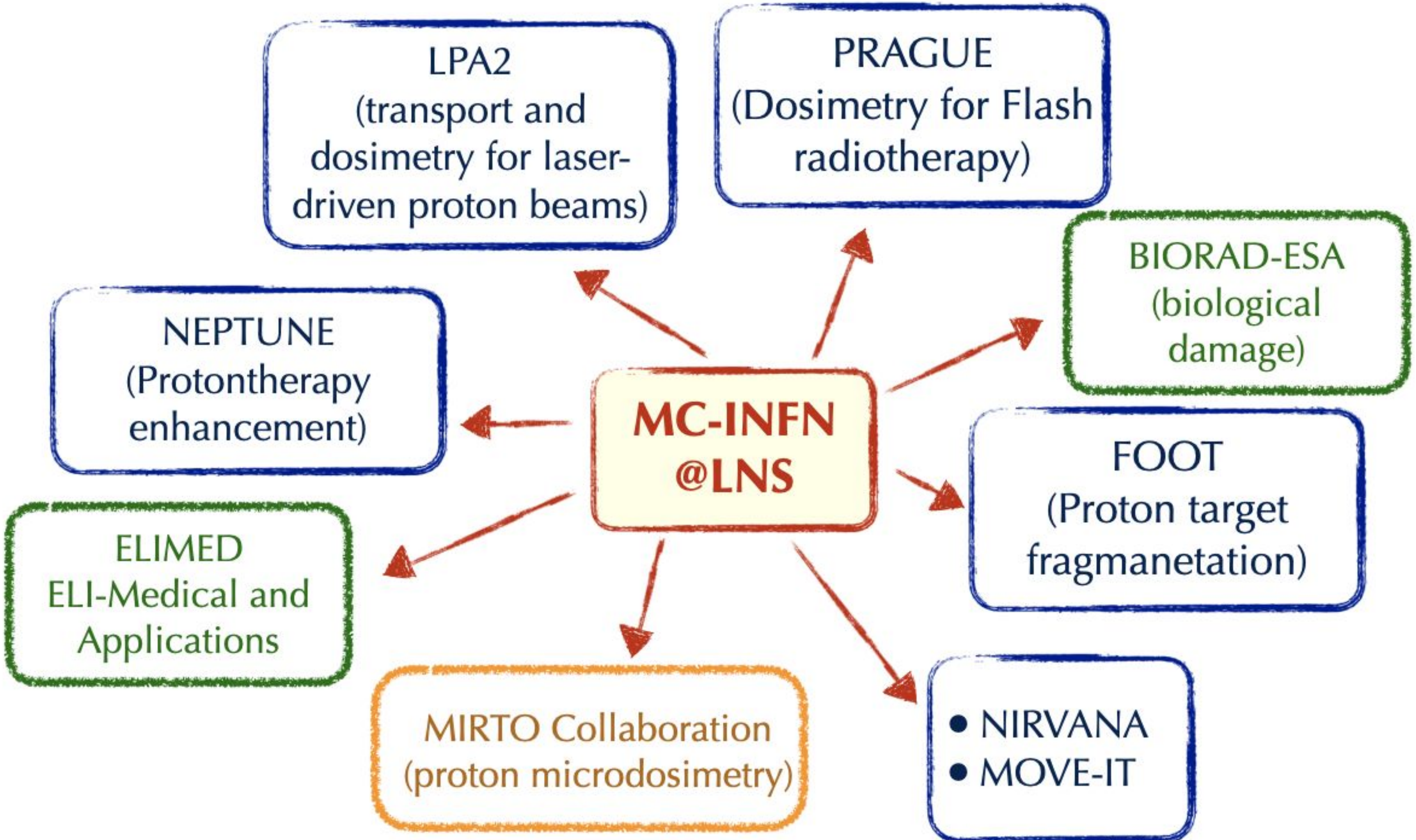
Two International Geant4 Schools in 2022 (Alghero and Catania/Prague)

Papers 2020

- V. Conte et al.,“Microdosimetry of therapeutic proton beam with a mini-TEPC and MicroPlus-Bridge detector for RBE assessment”,PMB (2020)
- A. Ristic-Fira et al. “A radiobiological study of carbon ions of different linear energy transfer in resistant human malignant cell lines”, International Journal of radiation biology (2020)
- P. Arce et al., “Report on G4-Med, a Geant4 benchmarking system for medical physics applications developed by the Geant4 Medical Simulation Benchmarking Group”,Medical Physics, doi:10.1002/mp.14226, (2020)
- G. Petringa et al. “Study and validation of Monte Carlo methods for linear energy transfer calculation in voxelized geometries with clinical proton beams”, PMB, DOI: 10.1088/1361-6560/abaeb9 (2020)
- C. Verona et a. “Microdosimetric measurements of a monoenergetic and modulated Bragg Peak of 62 MeV therapeutic proton beam with a synthetic single crystal diamond microdosimeter”, Medical Physics (2020)
- A. Ristic-Fira et al. “Regulatory mechanism of DNA damage response induced by proton and carbon ion irradiations in human breast and lung carcinoma cells”, Journal of Radiation Research and Applied Sciences (2020)

Other 4 papers on LET calculation are in preparation

Collaboration with other projects



Linear Energy Transfer

Physics in Medicine & Biology

PAPER

Monte Carlo implementation of new algorithms for the evaluation of averaged-dose and -track linear energy transfers in 62 MeV clinical proton beams

G Petringa[1], L Pandola[1], S Agosteo[2,3], R Catalano[1], P Colautti[4], V Conte[4], G Cuttone[1], K Fan[5], Z Mei[5], A Rosenfeld[6] + Show full author list

Published 30 November 2020 • © 2020 Institute of Physics and Engineering in Medicine

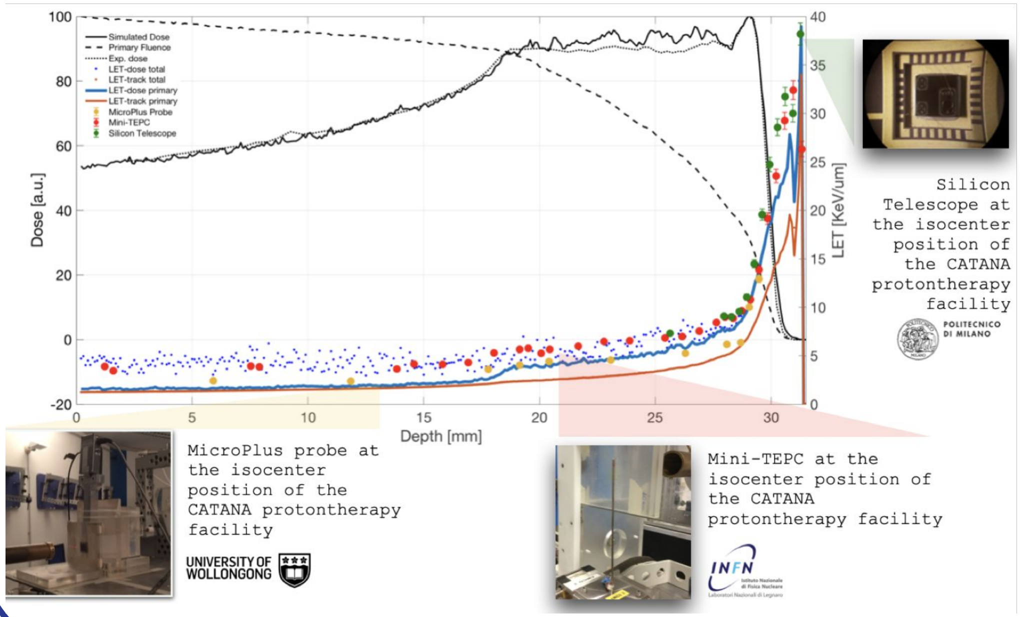
Physics in Medicine & Biology, Volume 65, Number 23

Citation G Petringa *et al* 2020 *Phys. Med. Biol.* **65** 235043

The code was validated against six microdosimetric detectors:

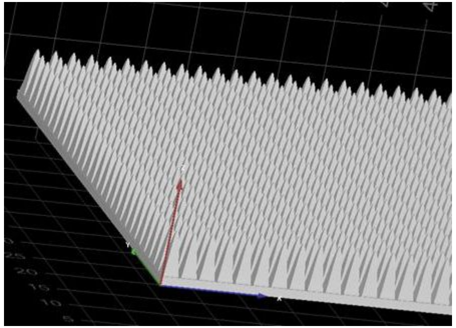
- mini-TEPC (LNL-INFN)
- Silicon Telescope (MI-INFN)
- Diamond (RM-INFN)
- Silicon (LNS-MI)
- TEPC (TIFPA-INFN)
- nano-TEPC (LNL-INFN & MI-INFN)

Mirto collaboration



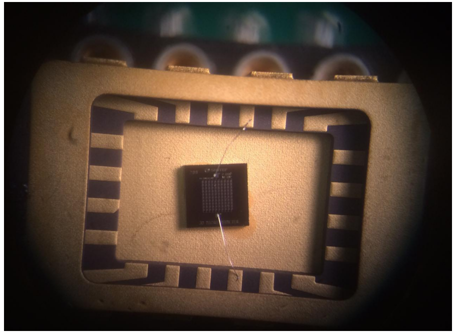
P. Cirrone, S. Fattori, G. Petringa

Linear Energy Transfer

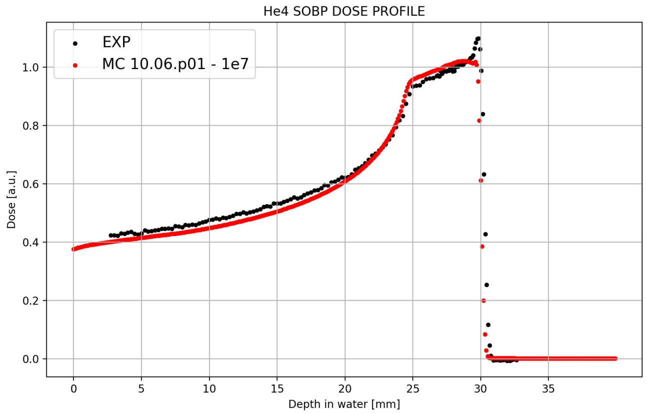


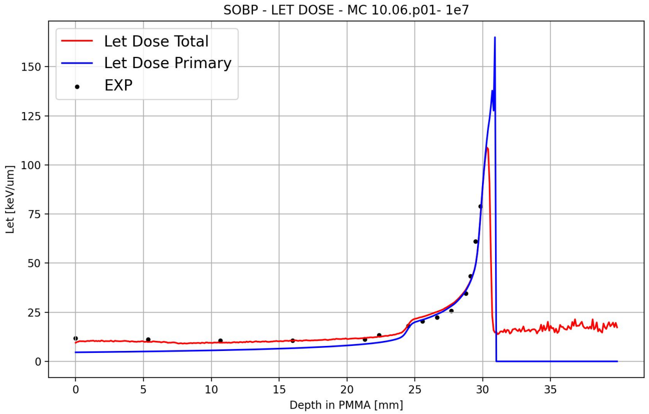
New ridge filter realized for the energy modulation of ion beams

The ridge was simulated and inserted inside the hadrontherapy example



Three experimental campaign with the silicon microdosimeter Microplas probe was performed at the zero degree beam line.

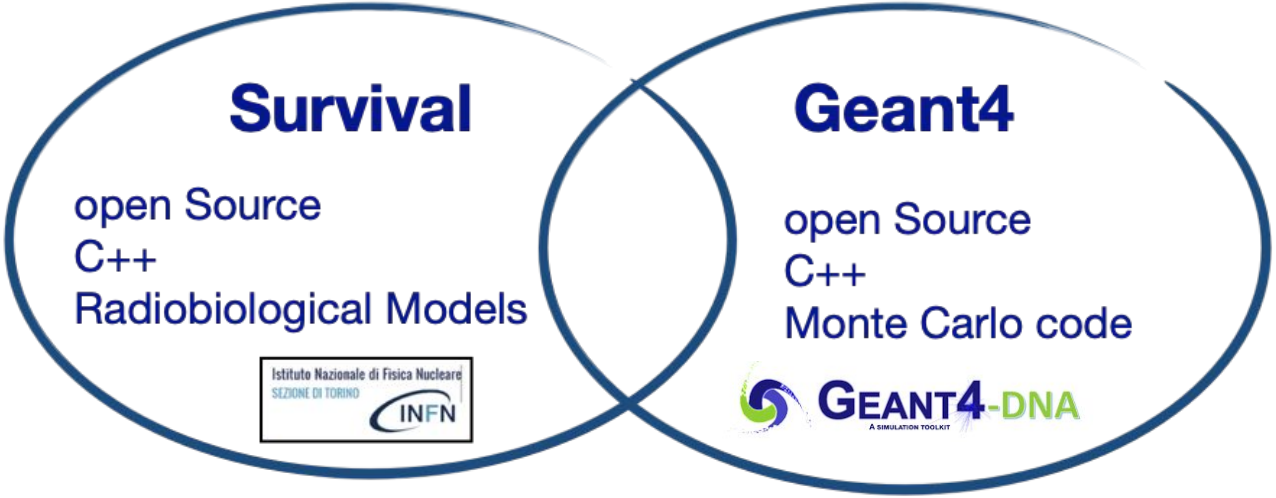




A new G4 Extended Example

The idea

- **create an application dedicated to the radiobiological experiments (able to calculate Dose, LET and RBE distribution)**
- **create a direct link between the radiobiological models (LEM and MKM) abd Geant4 to calculate the RBE in a mixed field condition**

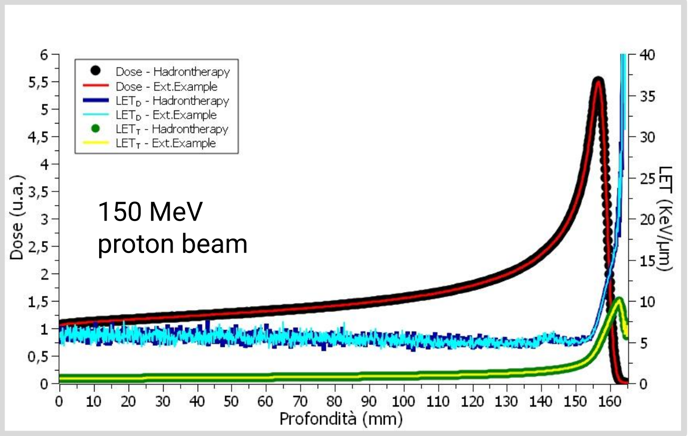


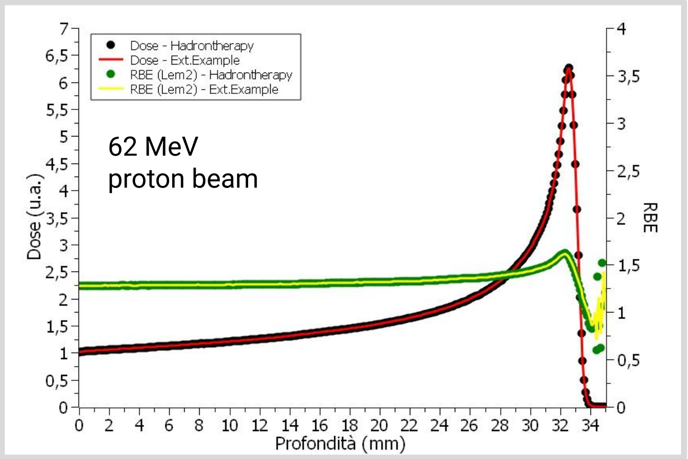
A new G4 Extended Example

D. Chiappara, P. Cirrone, G. Navarra, L. Pandola, G. Petringa

Classes and algorithms for the calculation of dose, LET and RBE was compared with Hadrontherapy advanced example

- 150 MeV proton beam
- 62 MeV proton beam
- 720 MeV carbon ion beam





Next steps:

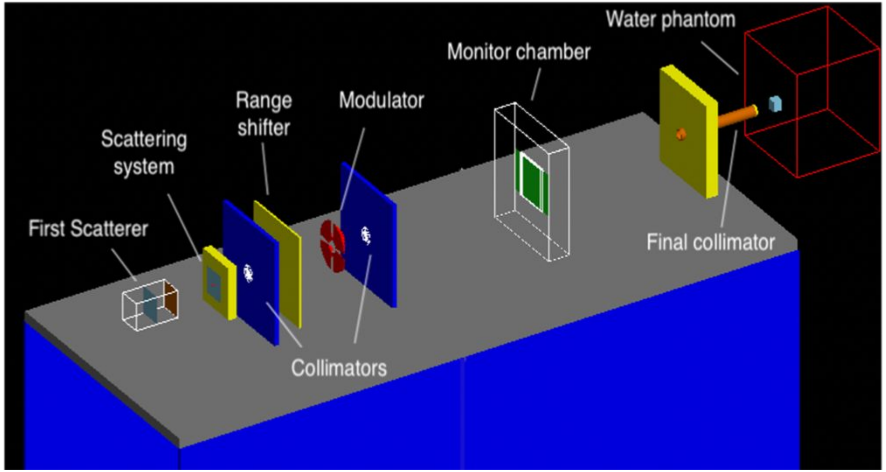
1. inserting a class for the reading an external phase space file
2. validation of the class for the phase space reading
3. release of the new extended example

BEST Cyclotron beamline

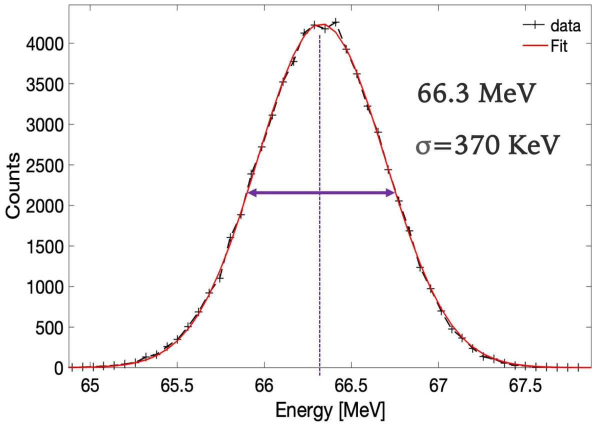
Added class to «hadrontherapy» advanced example implementing the BEST beamline geometry: BESTPassiveProtonBeamline.cc

You can select the BEST beamline by command line or macro:

/geometrySetup/selectGeometry BESTBeamLine



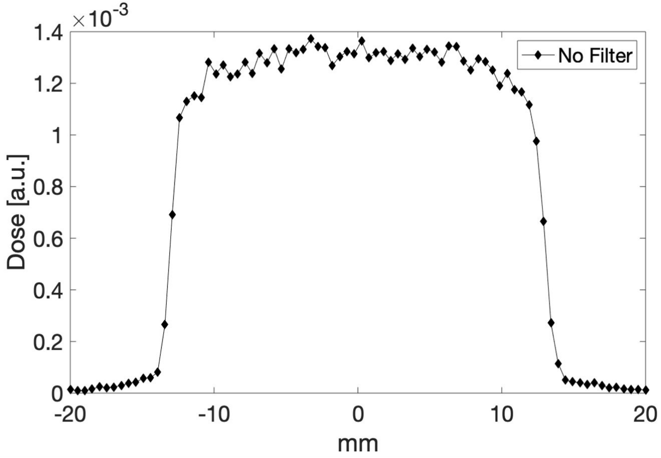
	Best Cyclotron source parameters
Energy	70MeV
Energy spread (sigma)	300keV
Spot dimension (FWHM of a gaussian distribution)	3mm-5mm (sigma)
Spatial distribution type	Circular
Angular distribution type	Gaussian
Angular divergency	~ 0.16 ° (sigma)

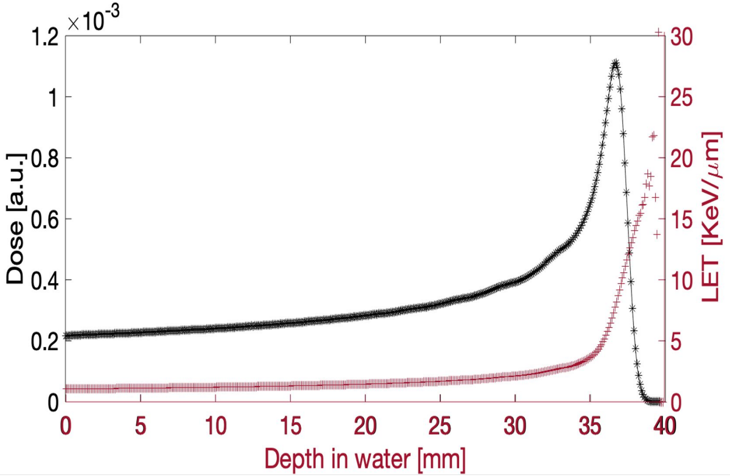


INPUT	OUTPUT
10^7 p	10^5 p
10 nA	0.23 Gy/s
10 nA x 60 s	14 Gy

BEST Cyclotron beamline

P. Cirrone, G. Milluzzo

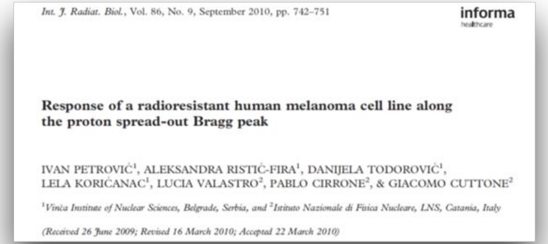




Parameter	Value
Lateral penumbra (80%/20%) (<1 mm)	1.04 mm
H (W90%/50%) (0.9)	0.9
Beam symmetry Sr (<3%)	0.52 %

Parameter	Value
Peak-plateau ratio	5.15
Penumbra 80%-20%	0.73 mm
Practical range	38.13 mm
Distal	37 mm

EXPRO+/BIORADIII


Int. J. Radiat. Biol., Vol. 86, No. 9, September 2010, pp. 742–751

informa healthcare

Response of a radioresistant human melanoma cell line along the proton spread-out Bragg peak

IVAN PETROVIĆ[1], ALEKSANDRA RISTIĆ-FIRA[1], DANIJELA TODOROVIĆ[1], LELA KORIĆANAC[1], LUCIA VALASTRO[2], PABLO CIRRONE[2], & GIACOMO CUTTONE[2]

[1]Vinča Institute of Nuclear Sciences, Belgrade, Serbia, and [2]Istituto Nazionale di Fisica Nucleare, LNS, Catania, Italy

(Received 26 June 2009; Revised 16 March 2010; Accepted 22 March 2010)


Journal of Radiation Research and Applied Sciences ›
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DNA damage assessment of human breast and lung carcinoma cells irradiated with protons and carbon ions

Aleksandra M. Ristic-Fira, Otilija D. Keta, Vladana D. Petković, Francesco P. Cammarata, Giada Petringa, Pablo G.A. Cirrone, Giacomo Cuttone, Sebastien Incerti & Ivan M. Petrović ...show less

Download citation | https://doi.org/10.1080/16878507.2020.1825035

ESA funded project to understand the mechanism of radiation damage

Physics, Chemistry, biological repair, experimental radiobiology

Multiscale platform: from the macro to the nano

Status of Geant4

- After many years of Geant4 10.x, the next release will be a major release: **Geant4 11.0**
  - Beta in June and Major release in December 2021
  - Opportunity to drop a number of deprecated features (e.g. grdm commands, environment variables for the **`HP`** and **`AllHP`**)
  - **May require porting** of the user applications
- Start to pave the way to require the C++ 17 standard (now, C++ 11 required)
  - gcc > 5
- Geant4 Collaboration Meetings
  - Collaboration meeting 2020 (Rennes) → held virtually
  - Trying to have it “in person” in 2021 (Rennes venue confirmed)
    - 26th Geant4 Collaboration Meeting, 20-24 September 2021.
- **Collaboration task force for R&D**, e.g. AdePT and GPU demonstrator (see later)
- Contributions: System Testing Shifts
  - Now open also to non-SB members

Luciano Pandola

Status of Low Energy EM

- Contribution to maintenance, improvement and bug fixes in the LowEnergy EM package
  - **Major clean-up** of the emlowen classes in January-February 2021
    - Coordinated with the other parts of the EM libraries (standard, utils, etc.)
  - No change in physics, but made code more clear and readable
  - Some performance improvements, fix of defects identified by Coverity
  - Use C+11 features (`auto`, `override`, `explicit`, etc.)

- Contribution to implementation, integration and testing of new physics models
  - JAEA model: gamma elastic scattering, including (Rayleigh, Thomson and Delbrück terms) [1]
  - Penelope Rayleigh model with molecular interference (work by **INFN-Ferrara**). Coming with the extended example `saxs`

emlowen-V10-07-09, emdna-V10-07-03: improvement of G4PenelopeGammaConversionModel, clean-up of tests directory — MERGED
!1673 · opened 1 month ago by Luciano Pandola

emlowen-V10-07-08: Cleanup and performance improvement of Penelope models — MERGED
!1654 · opened 1 month ago by Luciano Pandola

emlowen-V10-07-07: fix of Coverity defects — MERGED
!1644 · opened 1 month ago by Luciano Pandola

emlowen-V10-07-06: Complete cleanup of lowenergy directory — MERGED
!1626 · opened 1 month ago by Luciano Pandola

emlowen-V10-07-04 Lowenergy clean-up — MERGED
!1595 · opened 2 months ago by Luciano Pandola

emlowen-V10-07-05: Lowenergy clean-up (cont'd) — MERGED
!1611 · opened 1 month ago by Luciano Pandola

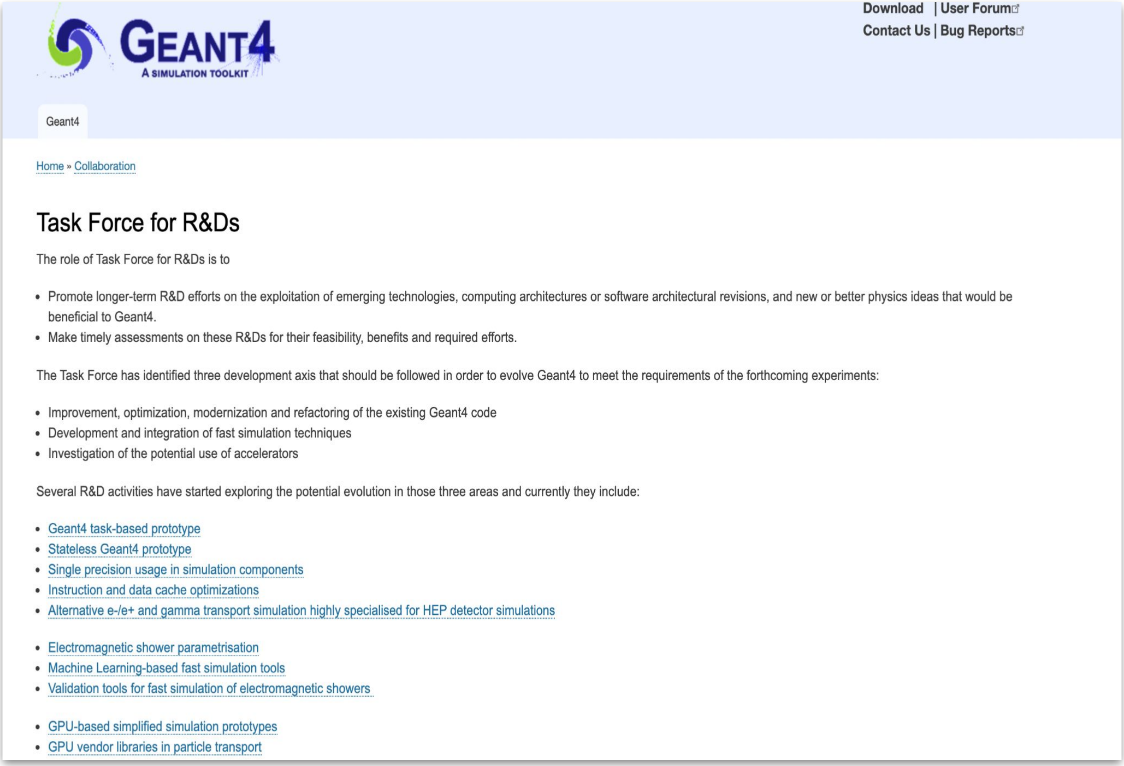
hadrontherapy-V10-06-06: Update README and macro — MERGED
!1381 · opened 5 months ago by Luciano Pandola

saxs-V10-06-01: Update of documentation — MERGED
!1357 · opened 5 months ago by Luciano Pandola

[1] M. Omer and R. Hajima, Nucl Instr. Meth B **405** (2017) 43

Accelerators and Geant4

- Geant4 Task Force for R&D
  - Promote longer-term R&D efforts on the exploitation of emerging technologies, computing architectures or software architectural revisions, and new or better physics ideas that would be beneficial to Geant4.
- Three development axis
  - Improvement, optimization, modernization and refactoring of the existing Geant4 code
  - Development and integration of fast simulation techniques
  - Investigation of the potential use of accelerators



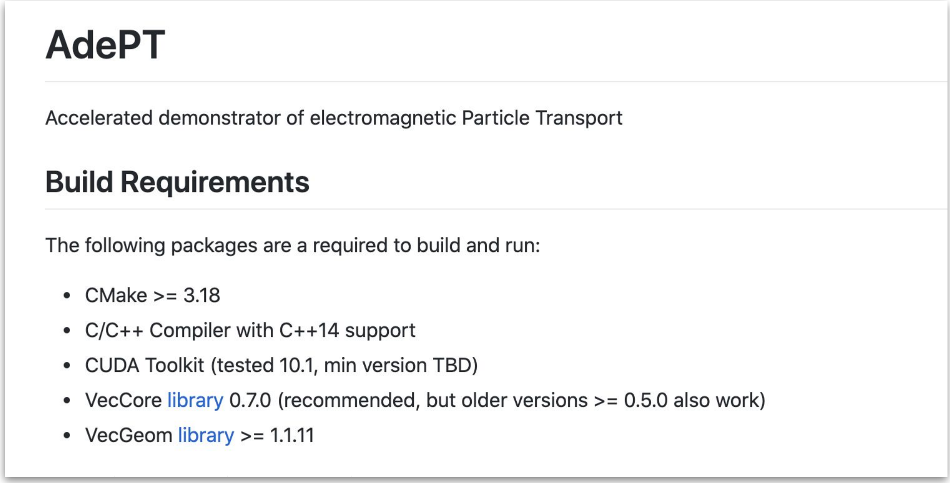
https://geant4.web.cern.ch/collaboration/task_force_rd

Accelerators and Geant4

- Main goal:
  - Understand the technical possibilities and limitations of GPU usage for full simulation and develop adapted solutions, using a prototype demonstrating a complete simulation workflow rather than testing only individual components.
  - assessment in a time scale of 6 month - 1 yr on the feasibility (EM shower simulation confined to GPU
- Prototype:
  - e+/e-/gamma transport featuring track-level parallelism, calorimeter setup (eg ATLAS EM calo), magnetic field
  - VecGeom-based transport manager
  - a set of (simplified) physics processes allowing to simulate
  - EM showers simple data structure for scoring, transferred to host at the end of events
- Technical objectives:
  - develop a first implementation of a GPU-friendly transport engine
  - understand the constraints and hard limits for performance, data handling, memory management, ...
- How:
  - Dedicated design and technical discussions to start with: what the prototype should do and how, implement a simple data model and workflow suitable for GPU
  - Create a dedicated prototype repository, project linked to main dependencies: VecCore, VecGeom

Accelerators and Geant4

- "AdePT" project, aiming for a demonstrator
  - GPU-accelerated Monte Carlo transport in a EM calorimeter
- CUDA addressed at first stage
  - Future perspective is to get platform-independent by using middleware and interfaces as ALPaKA
- We are searching for INFN manpower for a concrete contribution in the next years



AdePT

Accelerated demonstrator of electromagnetic Particle Transport

Build Requirements

The following packages are a required to build and run:

- CMake >= 3.18
- C/C++ Compiler with C++14 support
- CUDA Toolkit (tested 10.1, min version TBD)
- VecCore library 0.7.0 (recommended, but older versions >= 0.5.0 also work)
- VecGeom library >= 1.1.11

`https://github.com/apt-sim/AdePT`

Grazie per l’attenzione!