



# MC-INFN

L. Pandola per il gruppo MC-INFN ai LNS

# Milestones 2020



**Giugno 2020:** Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread. **100%**

**Giugno 2020:** Completamento dell'intercomparison tra codici MC per la quantificazione della target fragmentation in protonterapia **80%**

**Dicembre 2020:** Release di Geant4 contenente eventuali correzioni e bug fix sui modelli elettromagnetici Penelope e/o sugli advanced examples, nella modalità multi-thread.

**Dicembre 2020:** Inserimento delle sezioni d'urto p-11B e p-19F all'interno della QGSP\_BIC\_AliHP

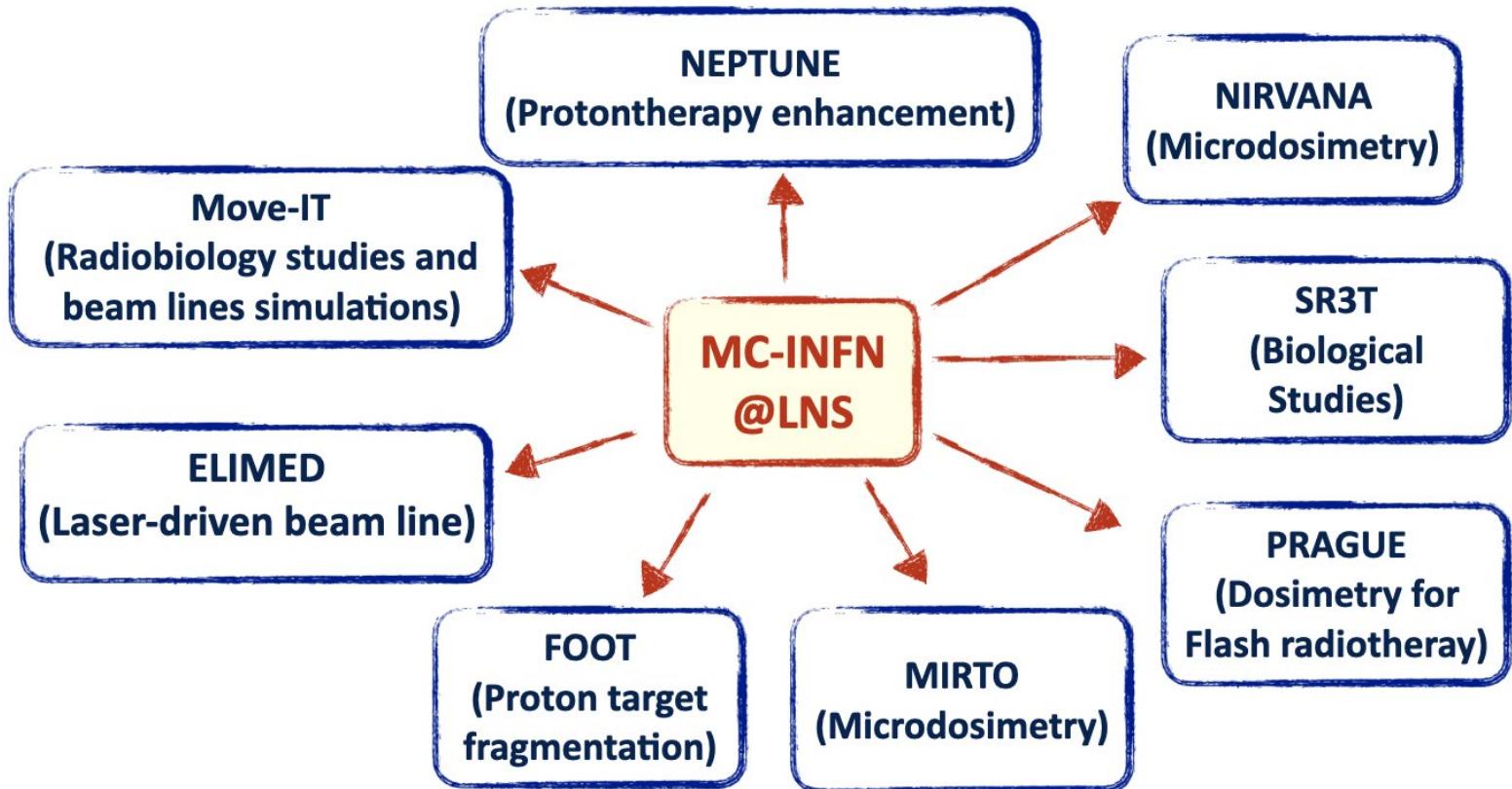
**Dicembre 2020:** Validazione del nuovo extended example

**Dicembre 2020:** *Simulazione di una cellula su scala nanometrica con Geant4-DNA per studi sull'uptake*

**Anagrafica:** 8.8 FTE (28 persone)

**Assegnazioni:** 23 k€ missioni (per tutti i gruppi Geant4)  
10 k€ restituiti alla CSN5

# Collaboration with other projects



# Status of GEANT4

**Stable status and regular development**

**Two releases foreseen for 2020:**

- 10.7.beta (June 26th)
- 10.7 (December 4th)

**Major release Geant4 11.0 could come next year**

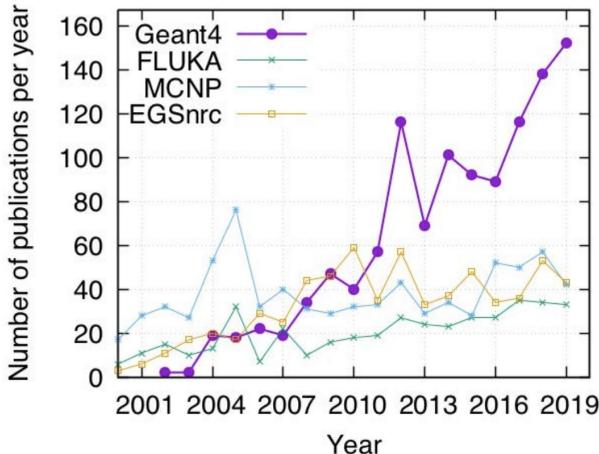
**LNS group involved in regular «System Testing» shifts**

- Entire management system migrated to git in 2018 ([gitlab.cern.ch](https://gitlab.cern.ch))
- Geant4 releases also posted on GitHub (opens up the future possibility to allow for merge request by users)

**Collaboration meeting «in person» (Rennes, Sep 21<sup>st</sup>-25<sup>th</sup>) cancelled due to Covid-19**

- Will be replaced by a remote Collaboration Meeting
- Venue in Rennes confirmed for 2021

Publications related to the most used MC tools on PubMed



# Papers - Conferences - Theses

## Papers

- V. Conte et al., "Microdosimetry at the catana 62 Mev proton beam with a sealed miniaturized tpc.", Physica Medica, Vol.64, (2019)
- C. Mancini Terracciano et al., "Preliminary results coupling Stochastic Mean Field" and Boltzmann-Langevin One Body' with Geant4", Physica Medica 67 (2019)
- **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)**
- A. Ciardiello et al., "Preliminary results in using Deep Learning to emulate BLOB, a nuclear interaction model", Physica Medica 73 (2020) 65

## Conferences

- Giornata monotematica SIRR (Società Italiana per la Ricerca sulle Radiazioni), (Catania, Italia), Maggio 2019
  - Invited talk: "Modelli radiobiologici e simulazioni Monte Carlo in adroterapia"
- 1st International Biophysics Collaboration Meeting, (GSI), Maggio 2019
  - "Relative Biological Effectiveness (RBE) of a clinical eye proton therapy beam experiments and Monte Carlo approach"
- MCMA 2019 conference (Montreal, Canada), Giugno 2019
  - "Improvement of ParticleHP with proton-boron fusion reaction in GEANT4 for medical applications"
  - "MIRTO: A microdosimetric study and RBE measurement with 62 MeV clinical proton beam"
  - Invited talk: "Monte Carlo method in particle therapy"

## Theses

- D.Chiappara, "Preliminary modeling for the Proton Boron Capture Therapy", Università degli Studi di Padova, A. A. 2018/19
- G.Colelli, "Use of the Monte Carlo approach for the calculation of radiobiological parameters. The case of study of Proton Boron Capture Therapy approach", Università degli Studi della Calabria, A.A. 2018/19
- O.Chidera, "Monte Carlo approaches for the estimation of radiobiological quantities: a new irradiation study to enhance the radiobiological effectiveness of proton beam", Università degli Studi di Catania, A.A. 2018/19

# Status of Low Energy EM

**After more than 10 years, LowEM and StdEM group merged:**

- Coordinator: V. Ivanchenko. Deputies: L. Pandola (lowEM), S. Incerti (DNA), D. Sawkey (optical)

**LNS activity in the maintenance and development of Low-Energy EM models**

- Code is stable and tested, so no major bugs found recently
- Monitor performance and stability at each monthly reference tag

**Technical support to integrate and test external contributions:**

Dedicated model for  $\gamma$  elastic scattering

- includes coherent combination of Rayleigh, Delbrück and Thomson contributions
- Ready for the 10.7.beta release



Including Delbrück scattering in GEANT4

Mohamed Omer <sup>a,\*</sup>,<sup>1</sup>, Ryoichi Hajima <sup>a,b</sup>

<sup>a</sup> Integrated Support Center for Nuclear Nonproliferation and Nuclear Security, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

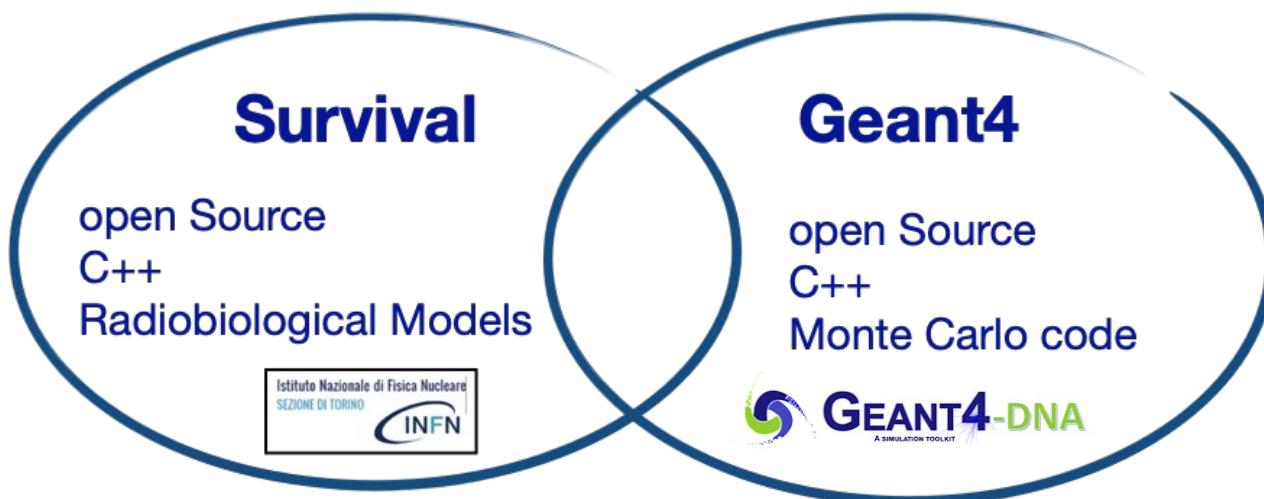
<sup>b</sup> National Institutes for Quantum and Radiological Science and Technology, Tokai, Ibaraki 319-1106, Japan



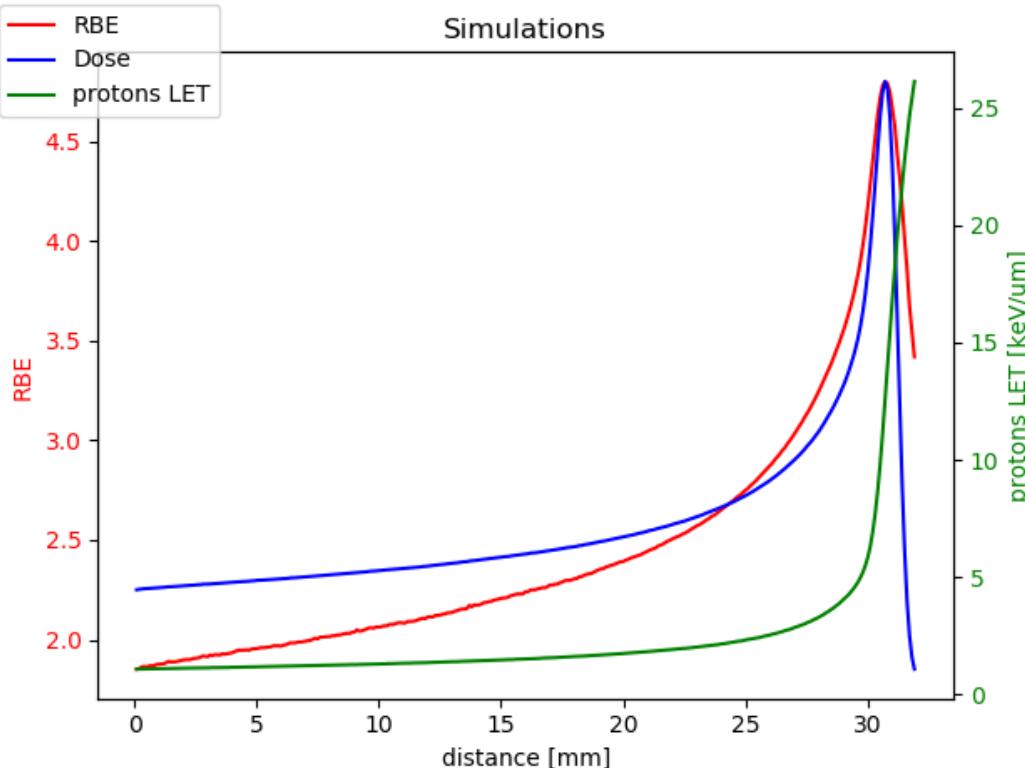
# A new G4 Extended Example

## 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



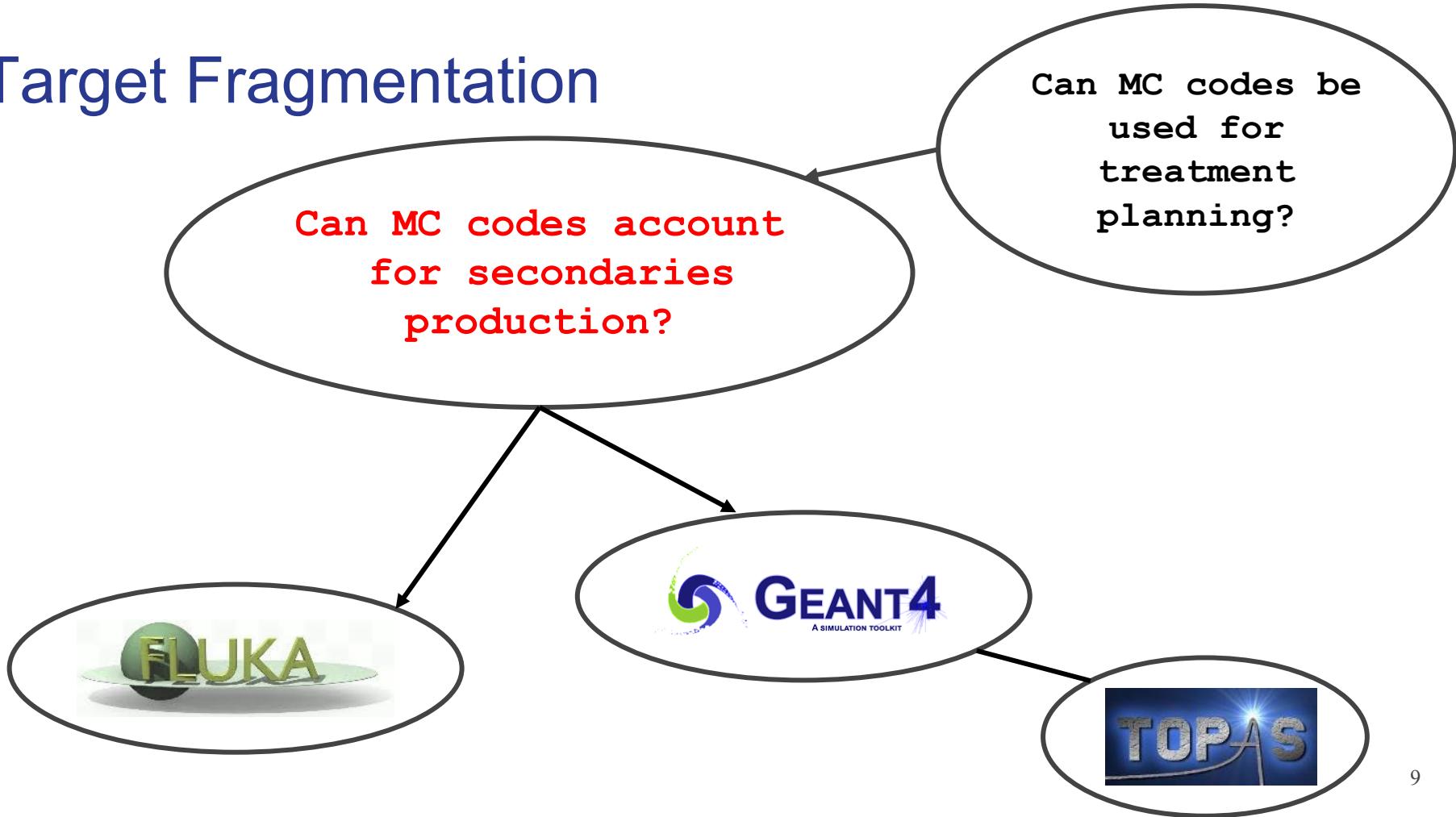
# A new G4 Extended Example



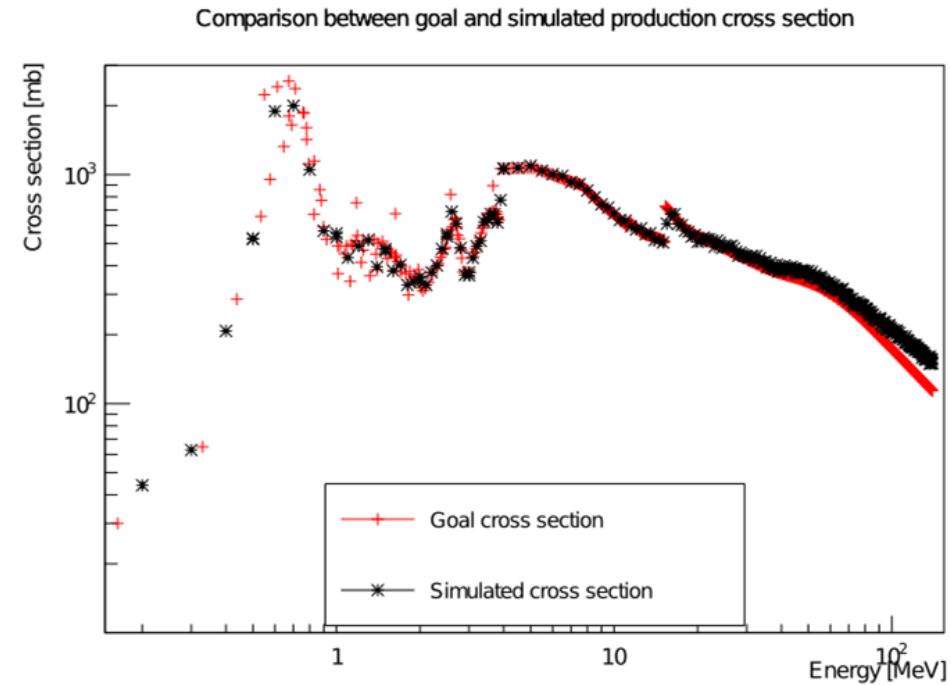
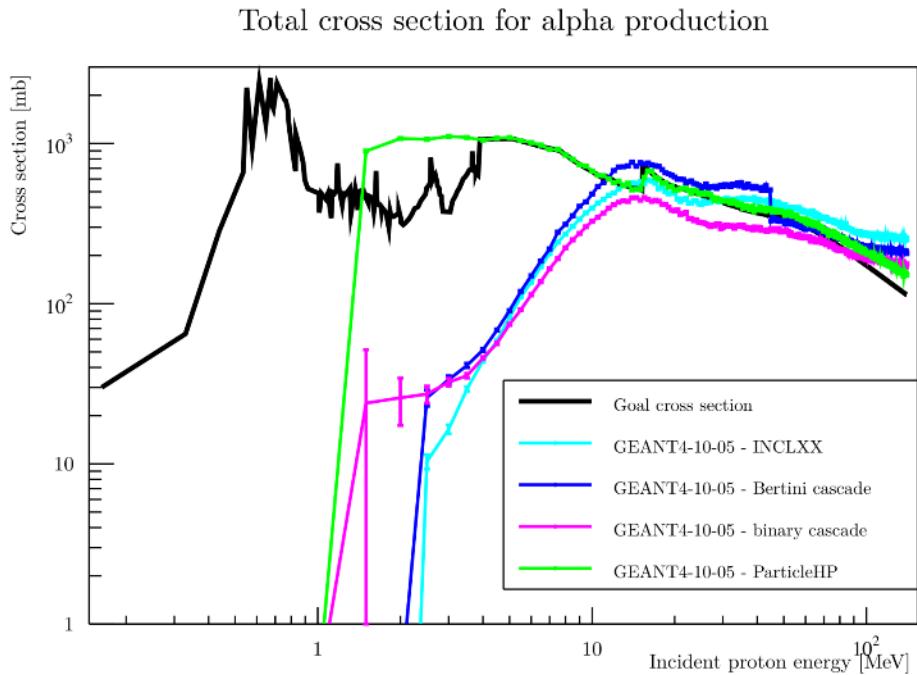
## User-friendly implementation:

- Default algorithms for Dose, LET, RBE using LUTs from SURVIVAL;
- Default important quantities computed every step (energy release, step length, ...);
- Virtual classes linked to Geant4 kernel for easy implementation of user-defined new algorithms;

# Target Fragmentation



# $p-^{11}B$ cross section



A modified version of ParticleHP library can reconstruct alpha particle creation from  $p-^{11}B$  reaction

# Dissemination

P. Cirrone Editor of a Review Book about MC in ion therapy  
(to be published by Taylor&Francis, 2022)

## Monte Carlo for new challenges in ion therapy

Editor:

GAP Cirrone

*Istituto Nazionale di Fisica Nuclear - Laboratori Nazionali del Sud*

(+) leading author

(\*) corresponding author

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- 1.1. Current physics issues of heavily charged particle therapy  
[K PARODI, G DEDES, P CIRRONI]
- 1.2. Current radiobiological issues of heavily charged particle therapy  
[DURANTE]
- 1.3. Physics models in Monte Carlo simulations for heavily charged particle therapy  
[PANDOLA, IVANTCHENKO]

### 2. Dosimetry enhancement

- 2.1. Solving range uncertainties with Gamma prompt/charged particle prompt  
[PINTO, PATERA]
- 2.2. Macroscopic and microscopic calculation approaches for LET  
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- 2.3. Nuclear Fragmentation in Monte Carlo and validation  
[LA TESSA]
- 2.4. Low energy inelastic process in hadrontherapy  
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- 2.5. Quality assurance with PET  
[BISOGNI]

### 3. Microdosimetry and radiobiology

- 3.1. Monte Carlo and Microdosimetry  
[CONTE, PETRINGA, MAGRIN, AGOSTEO, GUATELLI, ROSENFIELD]
- 3.2. Monte Carlo to link RBE with radiation quality quantities  
[A ATTILI, G PETRINGA, G MAGRO, G RUSSO]
- 3.3. Solving for the contribution of target and projectile fragmentation (mixed fields)  
[TOMMASINO, ELETTRA, ATTILI, SCIFONI]

### 4. Biological enhancement

- 4.1. Nanoparticle Sensitization with Monte Carlo Methods  
[MARTINA FUSS, SUSANNA GUATELLI]
- 4.2. Increasing particle therapy biological effectiveness by nuclear reaction-driven binary strategies [CUTTONE, ATTILI, MANTI, (to be confirmed:  
CHIAPPARA, PETRINGA)]
- 4.3. Solving alpha target issues with Monte Carlo  
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[DARIA BOSCOLO (GSI), Martina Fuss, Walter Tinganelli, Pankaj Chaudary]

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[NIELSS BASSLER]
- 5.2. Towards Multiple Ion therapy in Particle therapy  
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- 5.3. Radioactive beams: overview and Monte Carlo studies  
[A ROSENFIELD, OTHERS]

### 6. Approaches at nano and chemistry level

- 6.1. Monte Carlo for chemistry  
[Janik Planet]
- 6.2. Recent developments in the TRAX particle track structure code  
[MICHAEL KRAEMER, SCIFONI]

### 7. Speed-up MC in charged particle applications

- 7.1. Machine-learning and Monte Carlo: the case of low energy hadronic simulation  
[BOCCALDI\*, C MANCINI]
- 7.2. Speed-up of Monte Carlo for the introduction in the clinic (FRED, FoCa)  
[A Schiavi, angelo.schiavi@uniroma1.it]
- 7.3. Monte Carlo and Analytical codes for Dose planning and recalculation: limits and differential advantages  
[A MAIRANI]

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BOOK SERIES

Series in Medical Physics and Biomedical Engineering

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# Dissemination

G. Petringa vincitrice del premio "Formazione e passione" 2018/2019 indetto dall'INFN per l'attività di docenza svolta nell'ambito della formazione INFN per la divulgazione del codice Geant4

L. Pandola e G. Petringa, "Il casinò della Fisica", Asimmetrie n. 27, Rivista ufficiale dell'INFN

Corso di formazione INFN Locale (Sezione di Firenze)

**IX International Geant4 School**

Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud,  
Catania, Italy

**ORGANIZERS**

G.A. Pablo Cirrone  
Giacomo Cuttone  
Luciano Pandola  
Giada Petrigna  
Gaetano Agnello

**TOPICS**

Basic overview on the main aspects of the Geant4 Monte Carlo toolkit

Lectures on the Geant4 code complemented by hands-on practical sessions

Basic course on C++

A maximum of 50 participants will be admitted

Up to 15 Master Students will be admitted for free

The INFN-LNS guest-house will be available for a limited number of participant

This school is recognised by the PhD and Master Courses of the Department of Physics and Astronomy "Ettore Majorana" of Catania University as:

- 3 CFU for PhD students
- 2 CFU for Master Degree Students

<https://www.facebook.com/SharingSoftwareKnowledge>  
<http://agenda.infn.it/event/IXInternationalGeant4School>

# Milestones 2021

**Giugno 2021:** Release di Geant4 contenente manutenzione ed eventuali correzioni sui modelli elettromagnetici Penelope e/o sugli esempi (extended, advanced) sotto la responsabilità del gruppo.

**Giugno 2021:** Simulazione di una cellula su scala nanometrica con Geant4-DNA per studi sull'uptake

**Giugno 2021:** Consegna di una simulazione Geant4 per l'ottimizzazione della sorgente ELIMED

**Dicembre 2021:** Release di Geant4 contenente manutenzione ed eventuali correzioni sui modelli elettromagnetici Penelope e/o sugli esempi (extended, advanced) sotto la responsabilità del gruppo.

**Dicembre 2021:** Realizzazione di una simulazione Geant4 per l'ottimizzazione del trasporto in aria dei protoni nella linea ELIMED

**Dicembre 2021:** 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