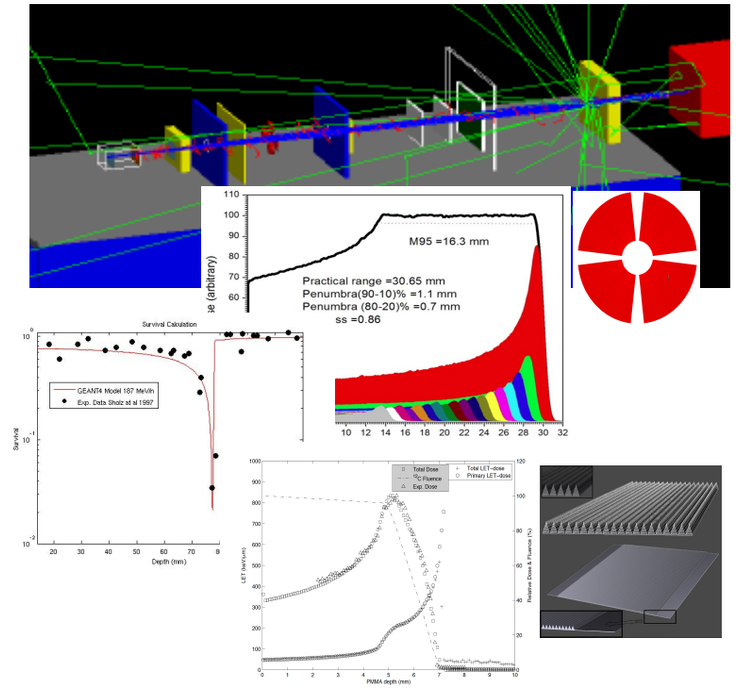
Istituto Nazionale di Fisica Nucleare

Hadrontherapy

GAP Cirrone, F Farrokhi, S Fattori, L Pandola,
G Petringa, A Sciuto

Hadrontherapy



First published in 2002

Full reproduction of a 62 MeV clinical protontherapy beamline;

Improved with two additional beam lines (250 MeV clinical protons and 70 AMeV experimental ions);

Improved with a laser-driven beamline for irradiation studies with new beam modalities;

All the relevant dosimetric and radiobiology quantities:

- Dose, fluence, LET-t, LET-d, RBE, energy spectra;
- For primary and secondaries

LAST IMPROVEMENTS

Laser-driven beamline

Phase Space **—> Not released**

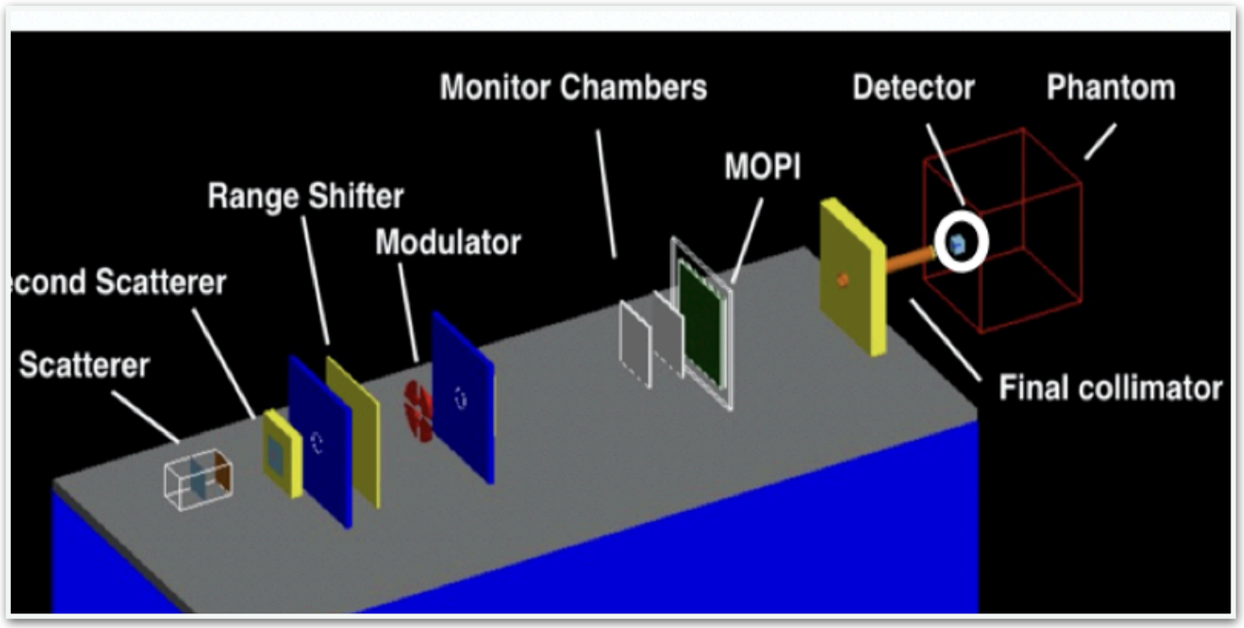
Dose averaged and track averaged LET

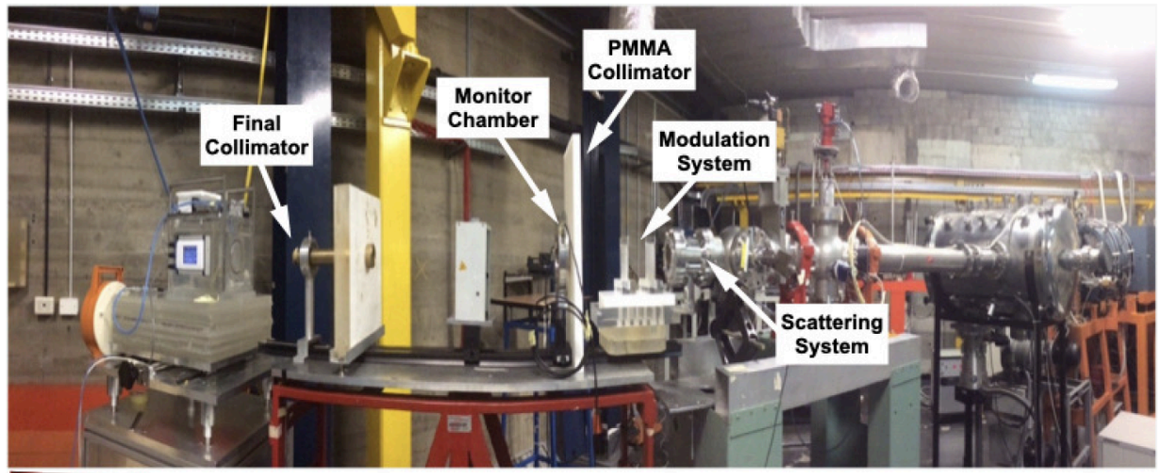
RBE calculations

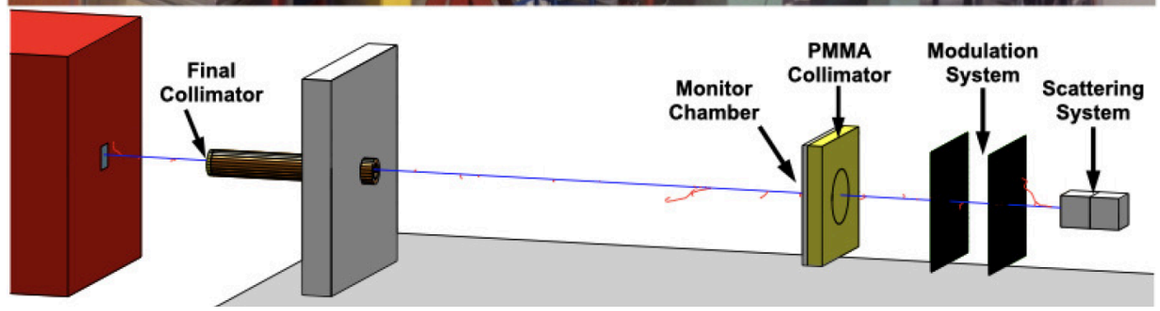
Bragg peak/radiobiology validation

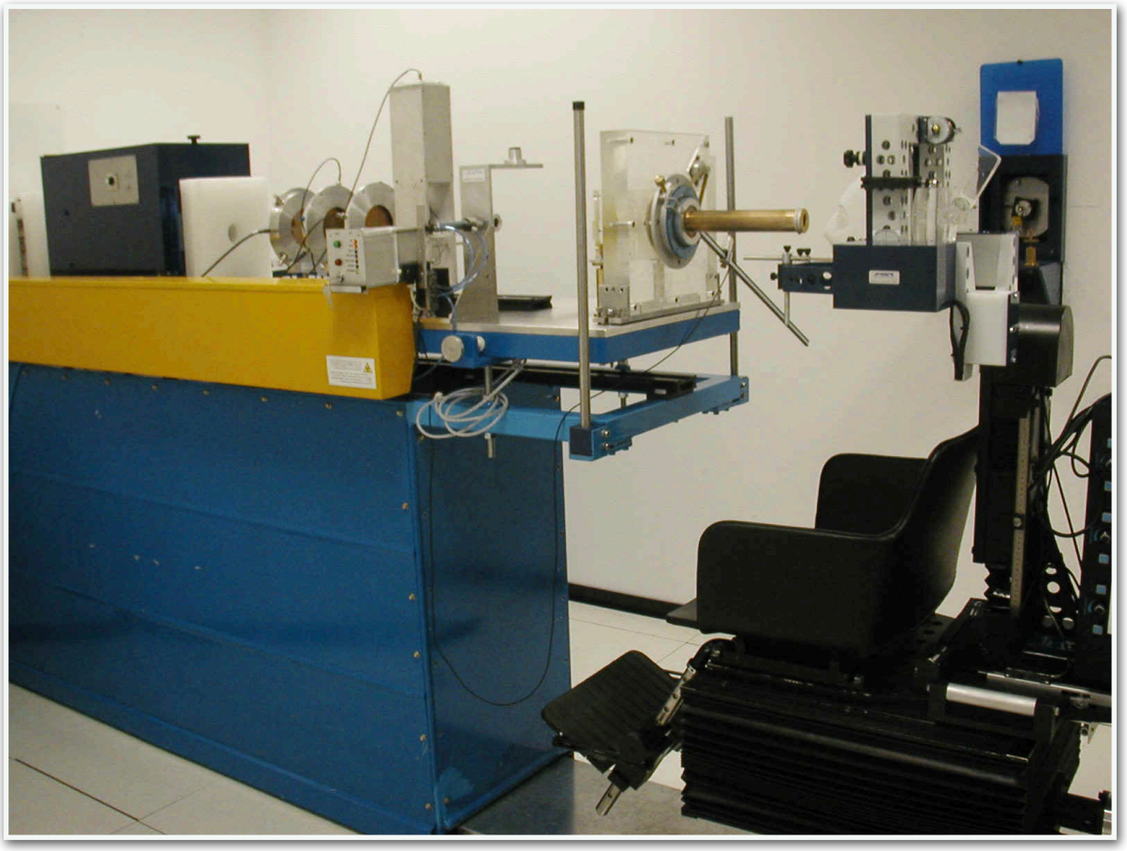
DICOM interface **—> Not released**

Hadrontherapy





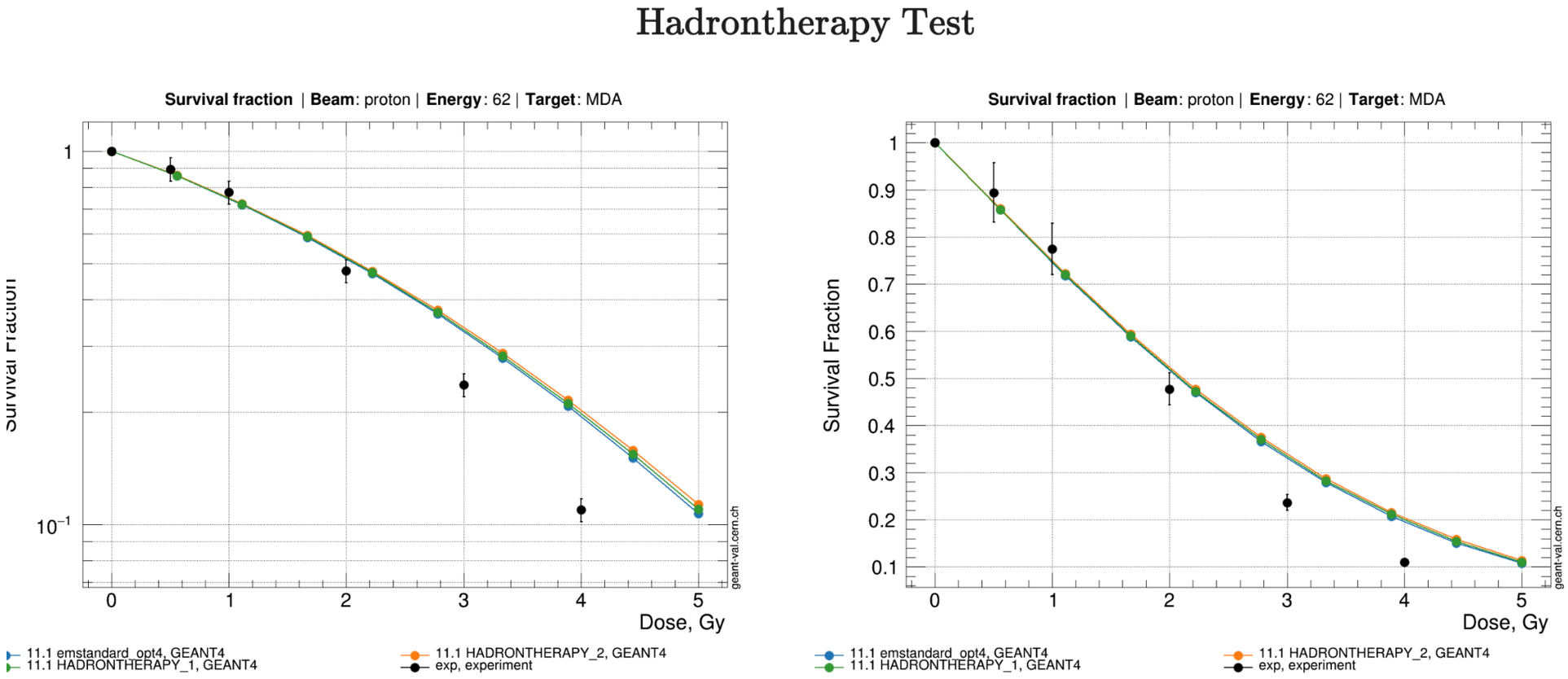




Voxelised water phantom where **relevant quantities** are derived in 1D - 2D and 3D geometries

Hadrontherapy testing in G4-MED

Hadrontherapy is one of the examples present in the **Geant-Val platform**



Current version monitories the cell **Survival Fraction and RBE calculation** for a 62 MeV Proton Beam with the three em options of the example: emstandard_opt4, HADRONTHERAPY_1 and HADRONTHERAPY_2;

LET calculation and comparison with data for proton, Carbon, Helium and Oxygen beams of clinical interest, are being inserted

LET simulations vs microdosimetry data: protons

$$\bar{L}_d = \frac{\sum_{i=1}^{N} L_i \varepsilon_i}{\sum_{i=1}^{N} \varepsilon_i}$$

$$\bar{L}_d^{Total} = \frac{\sum_{j=1}^{n} [\sum_{i=1}^{N} L_i \varepsilon_i]_j}{\sum_{j=1}^{n} [\sum_{i=1}^{N} \varepsilon_i]_j}$$

$$\bar{L}_T = \frac{\sum_{i=1}^{N} L_i l_i}{\sum_{i=1}^{N} l_i}$$

$$\bar{L}_T^{Total} = \frac{\sum_{j=1}^{n} [\sum_{i=1}^{N} L_i l_i]_j}{\sum_{j=1}^{n} [\sum_{i=1}^{N} l_i]_j}.$$

L: total electronic stopping power

ε: energy loss

t: track length

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

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], A Selva[4] and GAP Cirrone[1,*]

(2020) doi.org/10.1088/1361-6560/abaeb9

New formulation for

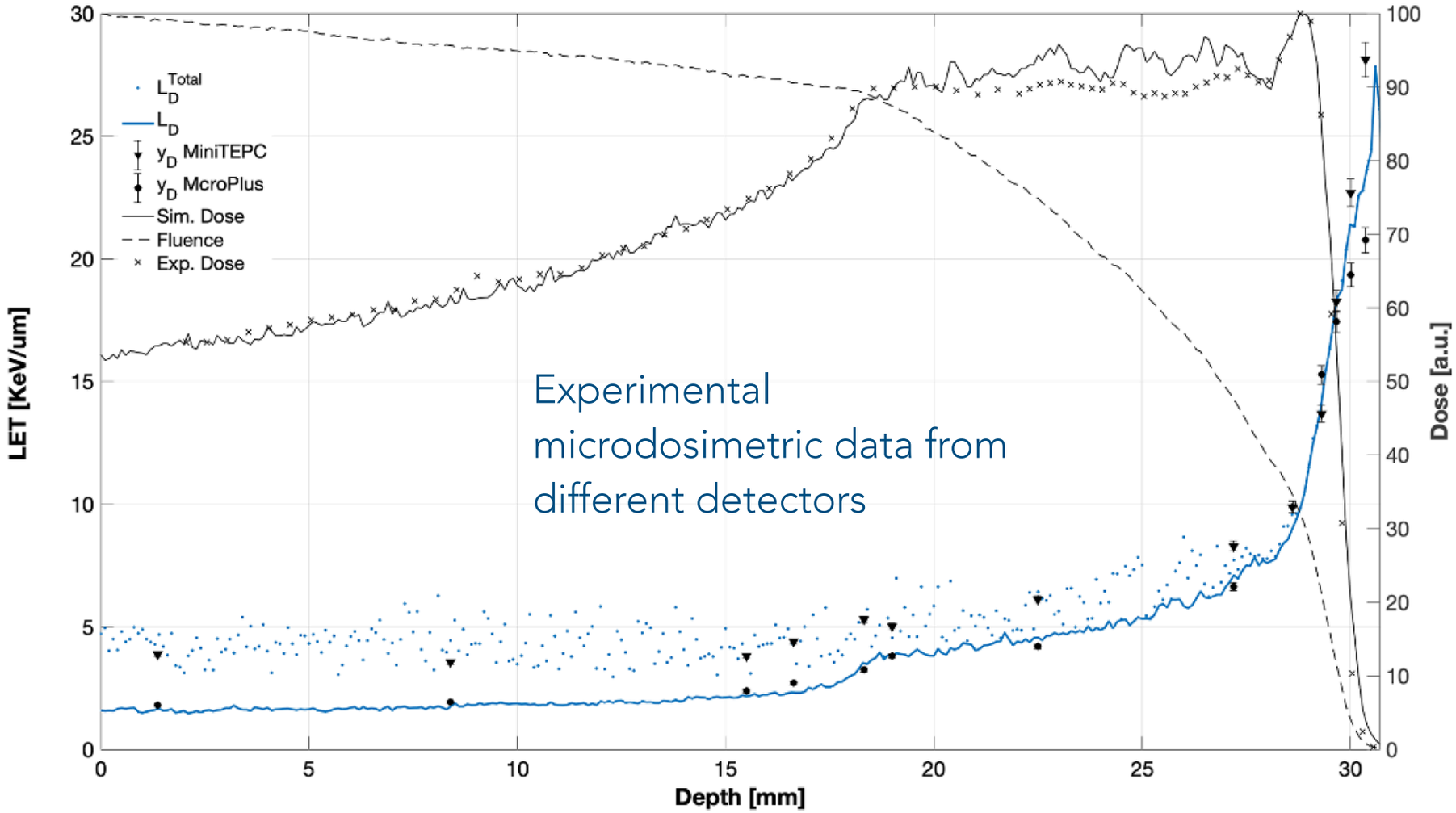
LET-dose and LET-track

Independence from the **production cut**

Extensible to **higer-Z ions**

Taking into account the **primary** beam and the **secondaries produced** in hadronic interactions

LET simulations vs microdosimetry data: protons



Contribution of **secondaries**;

Agreement with detectors able to also evaluate the **fragments**;

Projectile fragmentation already predicted in 2014 by our group

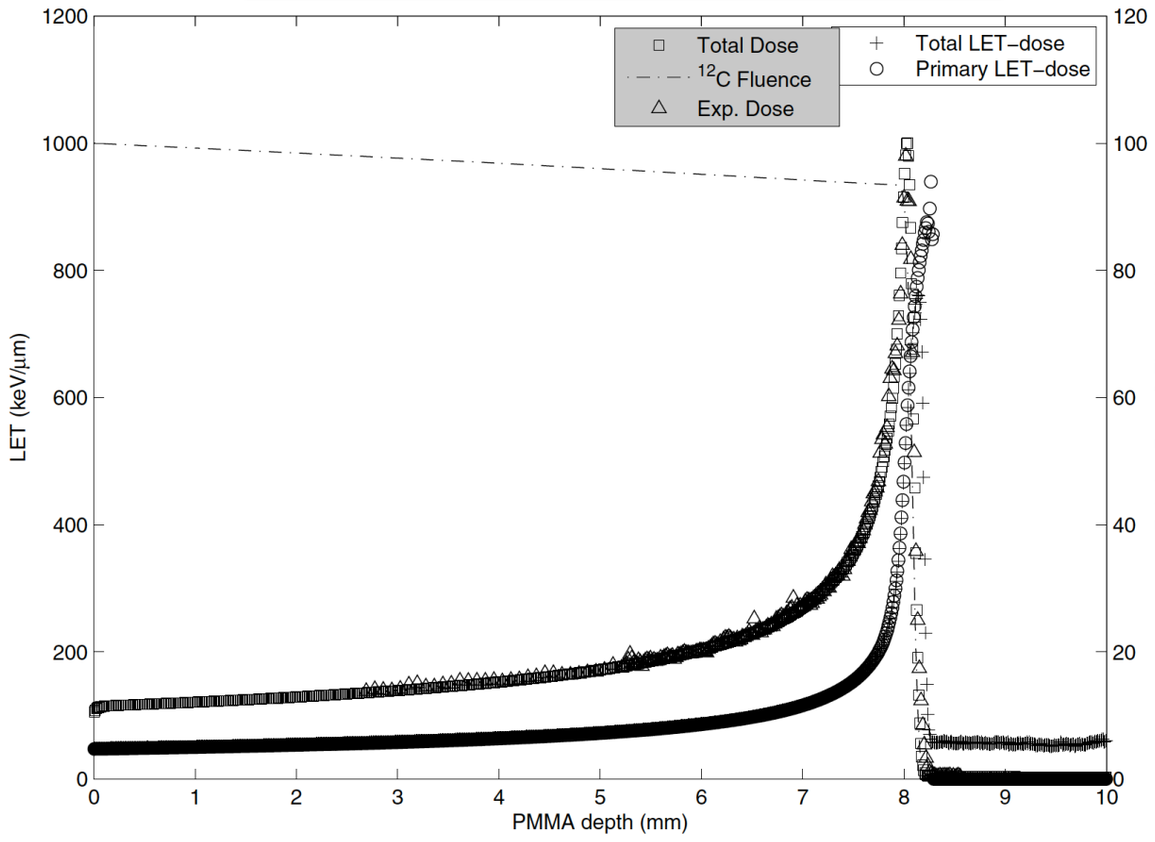
LET simulations vs microdosimetry data: Carbon

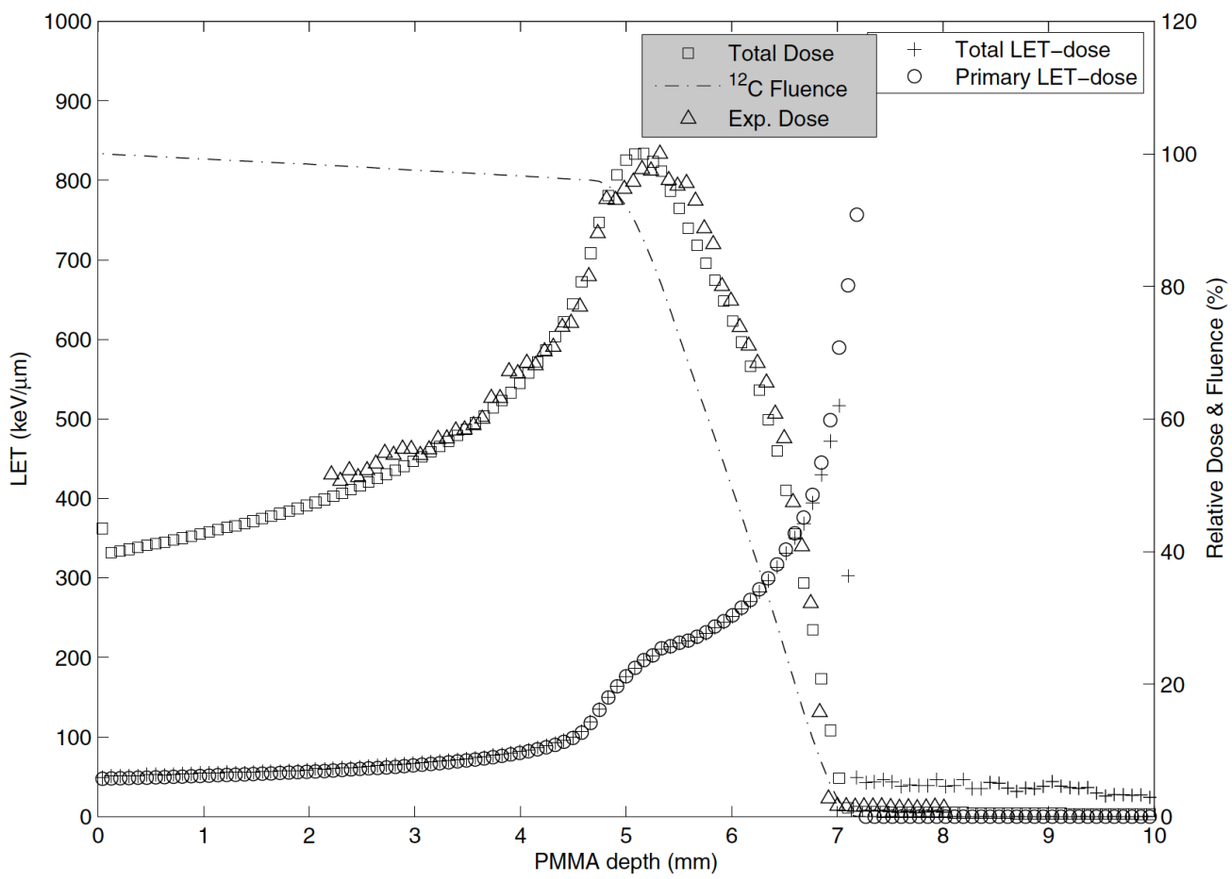
IOP Publishing | Institute of Physics and Engineering in Medicine
Physics in Medicine and Biology
Phys. Med. Biol. **59** (2014) 2863–2882
doi:10.1088/0031-9155/59/12/2863

A Monte Carlo study for the calculation of the average linear energy transfer (LET) distributions for a clinical proton beam line and a radiobiological carbon ion beam line

F Romano[1], G A P Cirrone[1], G Cuttone[1], F Di Rosa[2], S E Mazzaglia[1], I Petrovic[3], A Ristic Fira[3] and A Varisano[1]

(2014) doi.org/10.1088/0031-9155/59/12/2863





Mono- and poly-chromatic 62 AMeV Carbon beam

Also validated against microdosimetric data

LET simulations vs microdosimetry data: Helium, 62 AMeV

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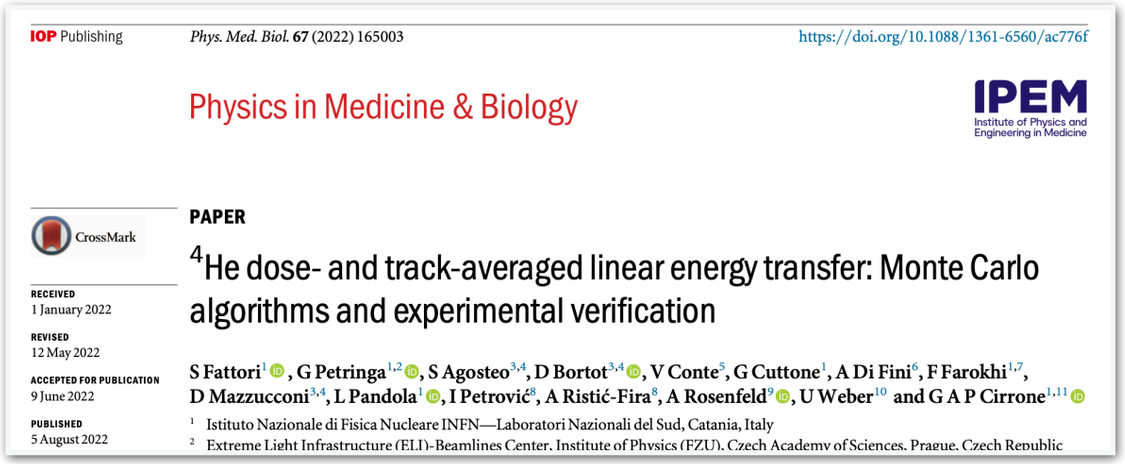

IOP Publishing Phys. Med. Biol. 67 (2022) 165003 https://doi.org/10.1088/1361-6560/ac776f

Physics in Medicine & Biology

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CrossMark

PAPER

RECEIVED 1 January 2022

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ACCEPTED FOR PUBLICATION 9 June 2022

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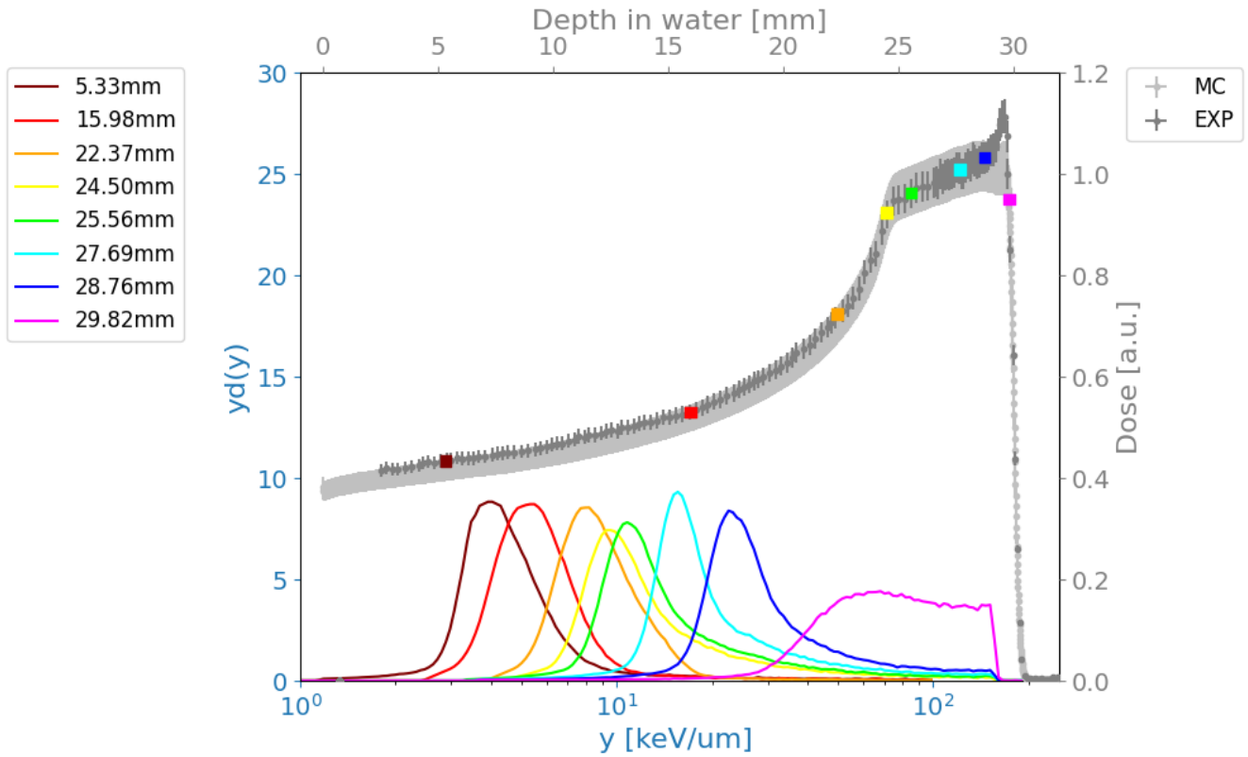
^{4}He dose- and track-averaged linear energy transfer: Monte Carlo algorithms and experimental verification

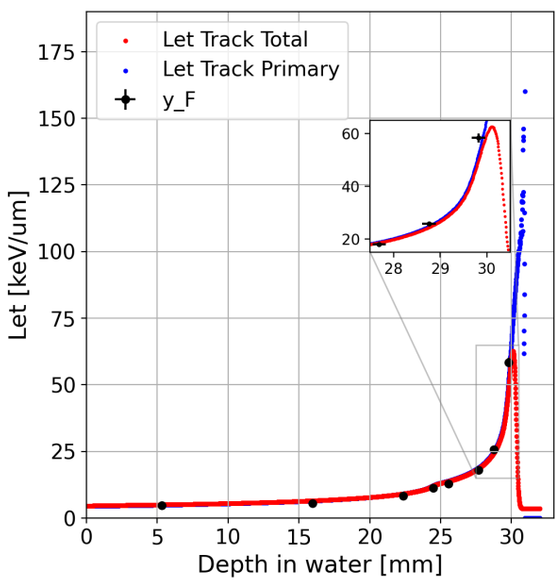
S Fattori[1], G Petringa[1,2], S Agosteo[3,4], D Bortot[3,4], V Conte[5], G Cuttone[1], A Di Fini[6], F Farokhi[1,7], D Mazzucconi[3,4], L Pandola[1], I Petrović[8], A Ristić-Fira[8], A Rosenfeld[9], U Weber[10] and G A P Cirrone[1,11]

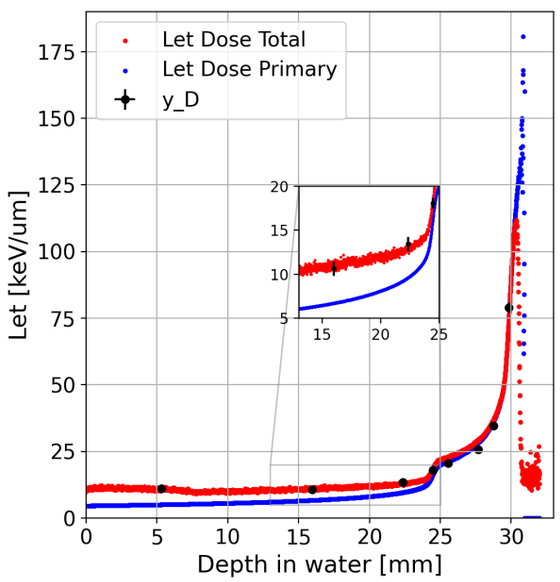
[1] Istituto Nazionale di Fisica Nucleare INFN—Laboratori Nazionali del Sud, Catania, Italy

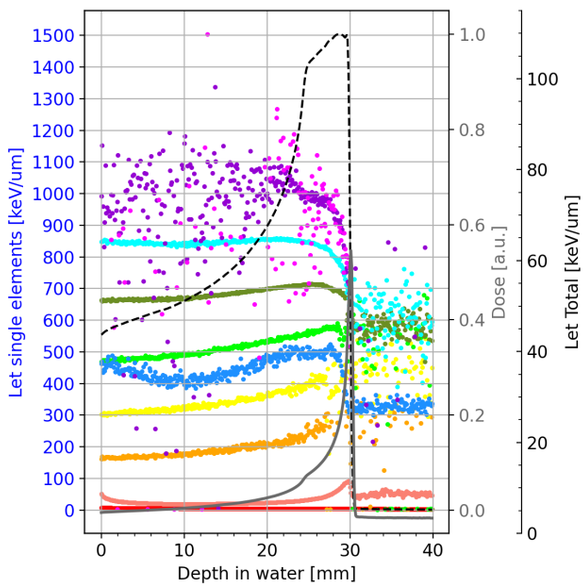
[2] Extreme Light Infrastructure (ELI)-Beamlines Center, Institute of Physics (FZU), Czech Academy of Sciences, Prague, Czech Republic

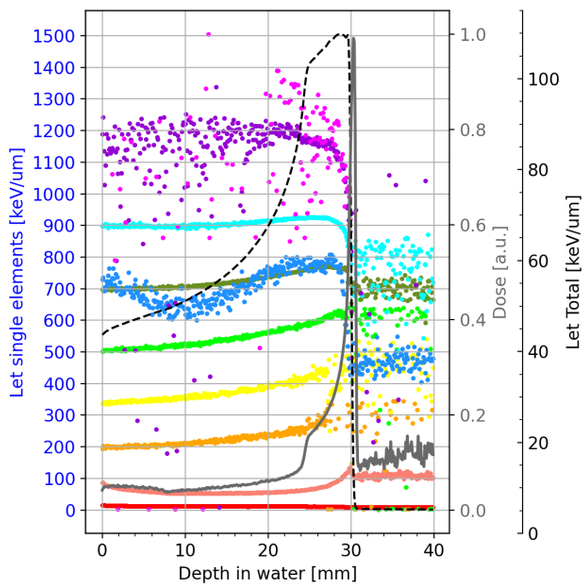
(2022) doi.org/10.1088/1361-6560/ac776f











Oxygen study is ongoing

Relative Biological Effectiveness (RBE)

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Computation Method coupling Geant4 to LEM

Generation of Look Up Table based on LEM (Survival code)

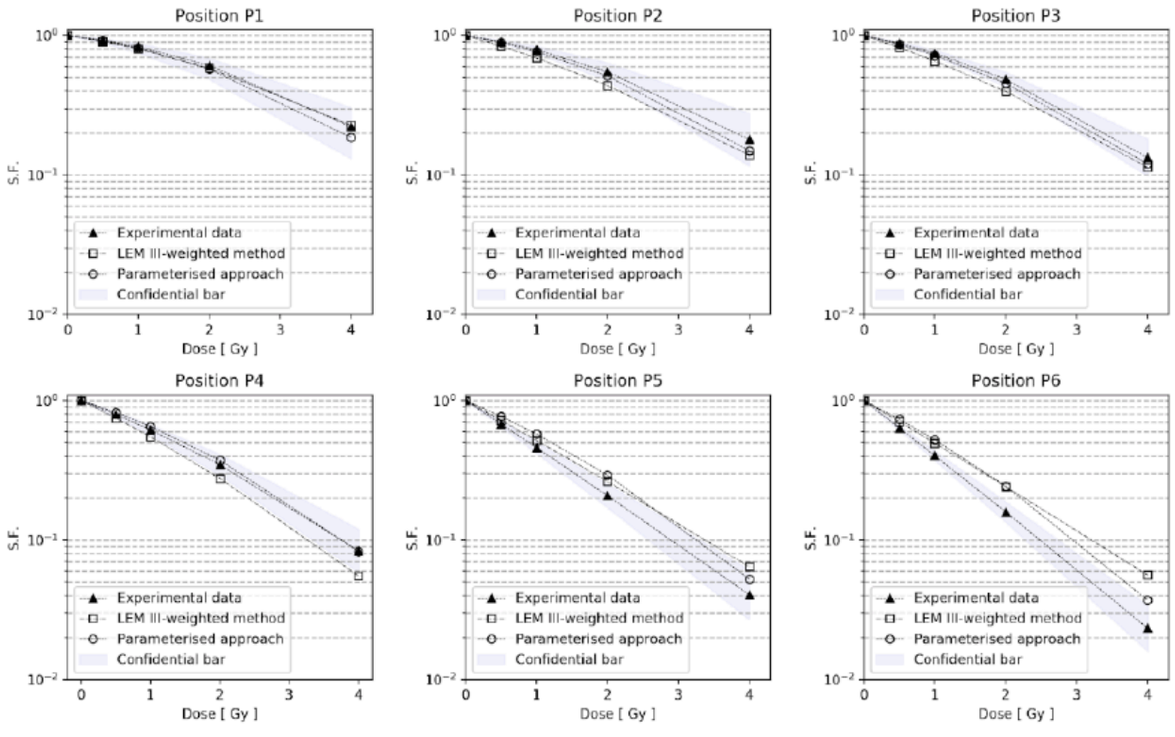
$$\langle \alpha_D \rangle = \frac{\sum_i \alpha_{D_i} \cdot D_i}{\sum_i D_i}$$

$$\langle \beta_D \rangle = \left(\frac{\sum_i \sqrt{\beta_{D_i}} \cdot D_i}{\sum_i D_i}\right)^2$$

Mixed Field calculation

$$SF = e^{-(\langle \alpha_D \rangle D + \langle \beta_D \rangle D^2)}$$

Survival Fraction



Physica Medica 58 (2019) 72–80

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

Original paper

Radiobiological quantities in proton-therapy: Estimation and validation using Geant4-based Monte Carlo simulations

G. Petringa[a,b], F. Romano[a,h], L. Manti[c,d], L. Pandola[a], A. Attili[e], F. Cammarata[a,f], G. Cuttone[a], G. Forte[a,f], L. Manganaro[e], J. Pipek[g], P. Pisciotta[a,b], G. Russo[a,f], G.A.P. Cirrone[a,g,*]

applied sciences

MDPI

Article

Radiobiological Outcomes, Microdosimetric Evaluations and Monte Carlo Predictions in Eye Proton Therapy

Giada Petringa [1,2,†], Marco Calvaruso [1,3,*], Valeria Conte [4], Pavel Bláha [5], Valentina Bravatà [1,3], Francesco Paolo Cammarata [1,3], Giacomo Cuttone [1,6], Giusi Irma Forte [1,3], Otilija Keta [7], Lorenzo Manti [5,8], Luigi Minafra [1,3], Vladana Petković [7], Ivan Petrović [7], Selene Richiusa [1,3], Aleksandra Ristić Fira [7], Giorgio Russo [1,3] and Giuseppe Antonio Pablo Cirrone [1,6,9,†]

- The code was already successfully validated with clinical proton beams.
- A study with 12C is currently ongoing
- The next step is to extend the validation with multiple light ions: 4He and 16O

Laser-driven acceleration

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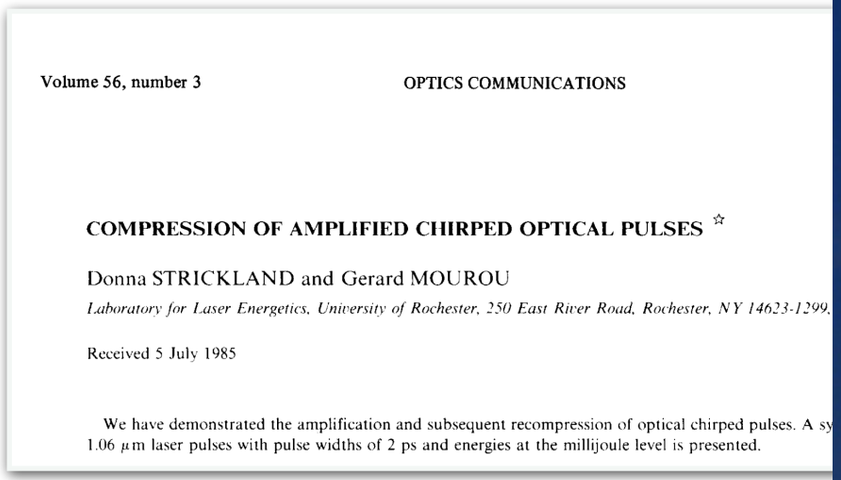


Volume 56, number 3 OPTICS COMMUNICATIONS

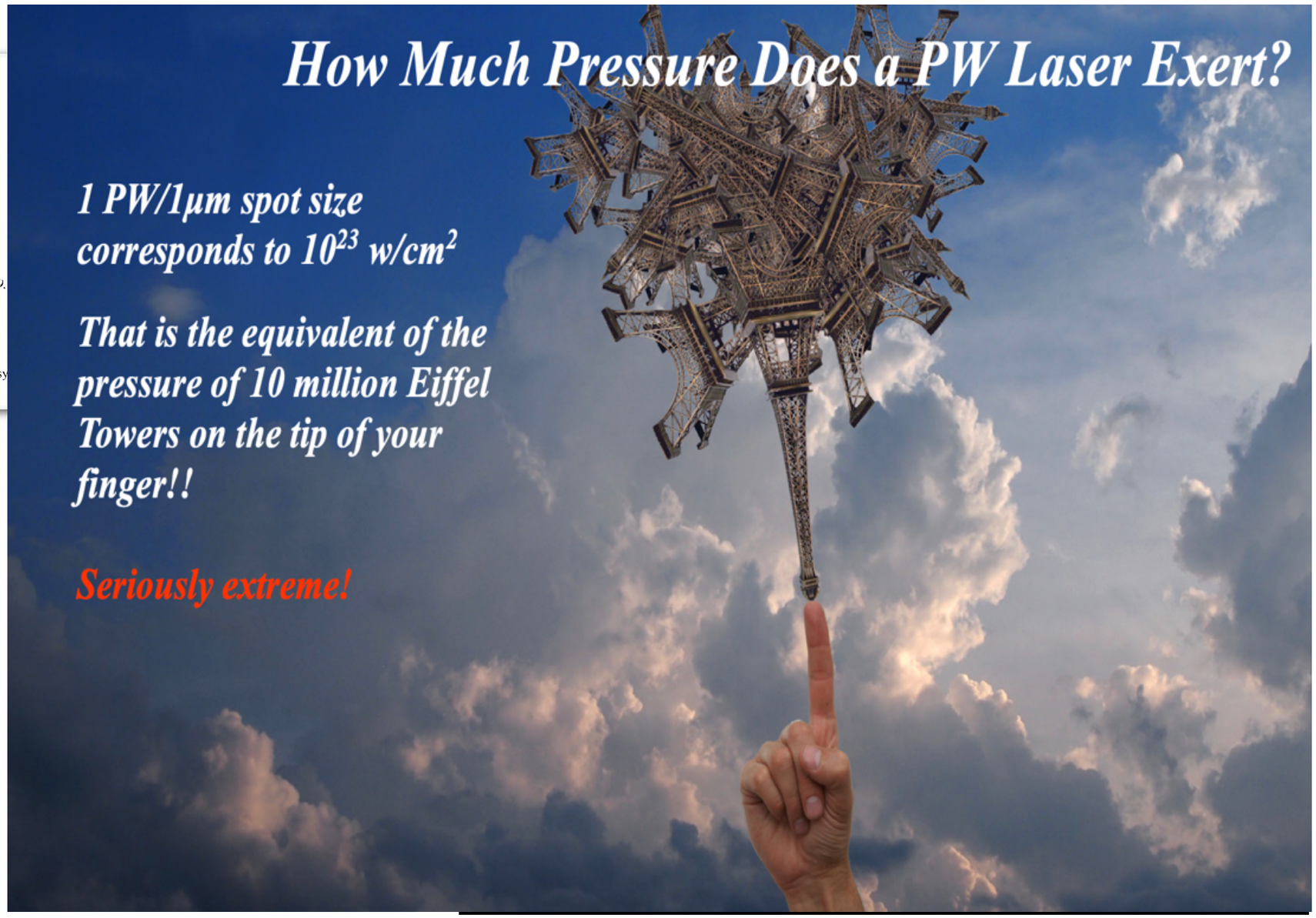
COMPRESSION OF AMPLIFIED CHIRPED OPTICAL PULSES ☆

Donna STRICKLAND and Gerard MOUROU

Laboratory for Laser Energetics, University of Rochester, 250 East River Road, Rochester, NY 14623-1299.

Received 5 July 1985

We have demonstrated the amplification and subsequent recompression of optical chirped pulses. A sy
1.06 μm laser pulses with pulse widths of 2 ps and energies at the millijoule level is presented.



Beam with peculiar characteristics:

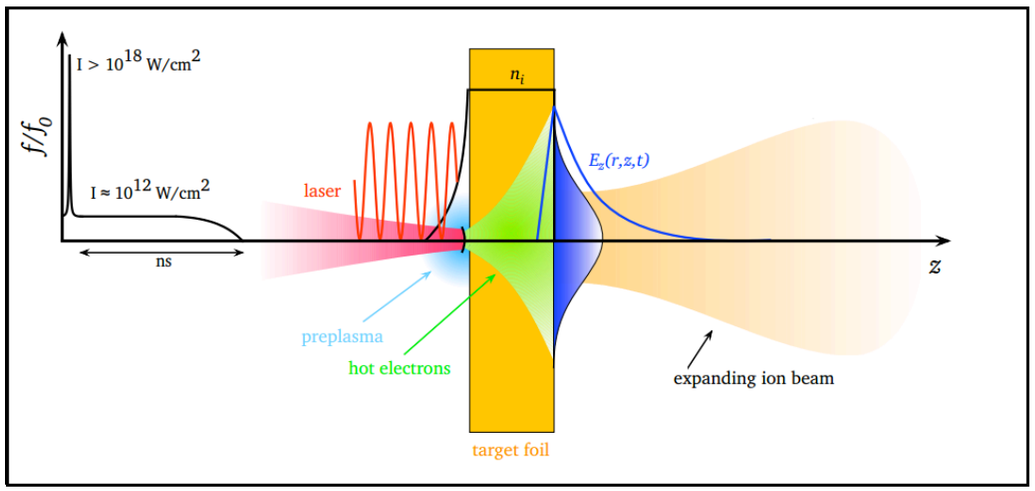
- intense 10E13
- very short in time (ns or less)

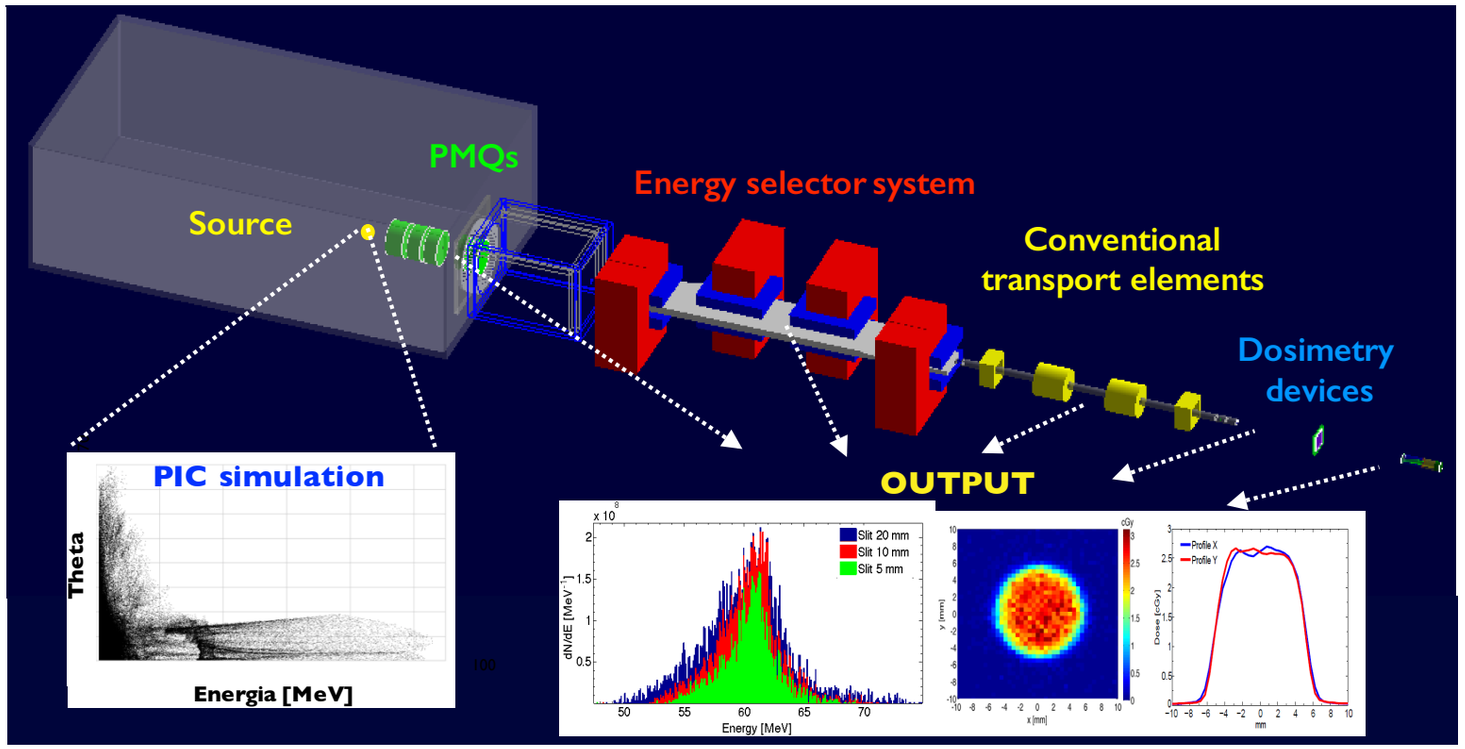
Need to transport in e.m. fields

Need to use (also) G4DNA physics to evaluate effects

Can we use nano-tube, oriented crystals?

Laser-driven





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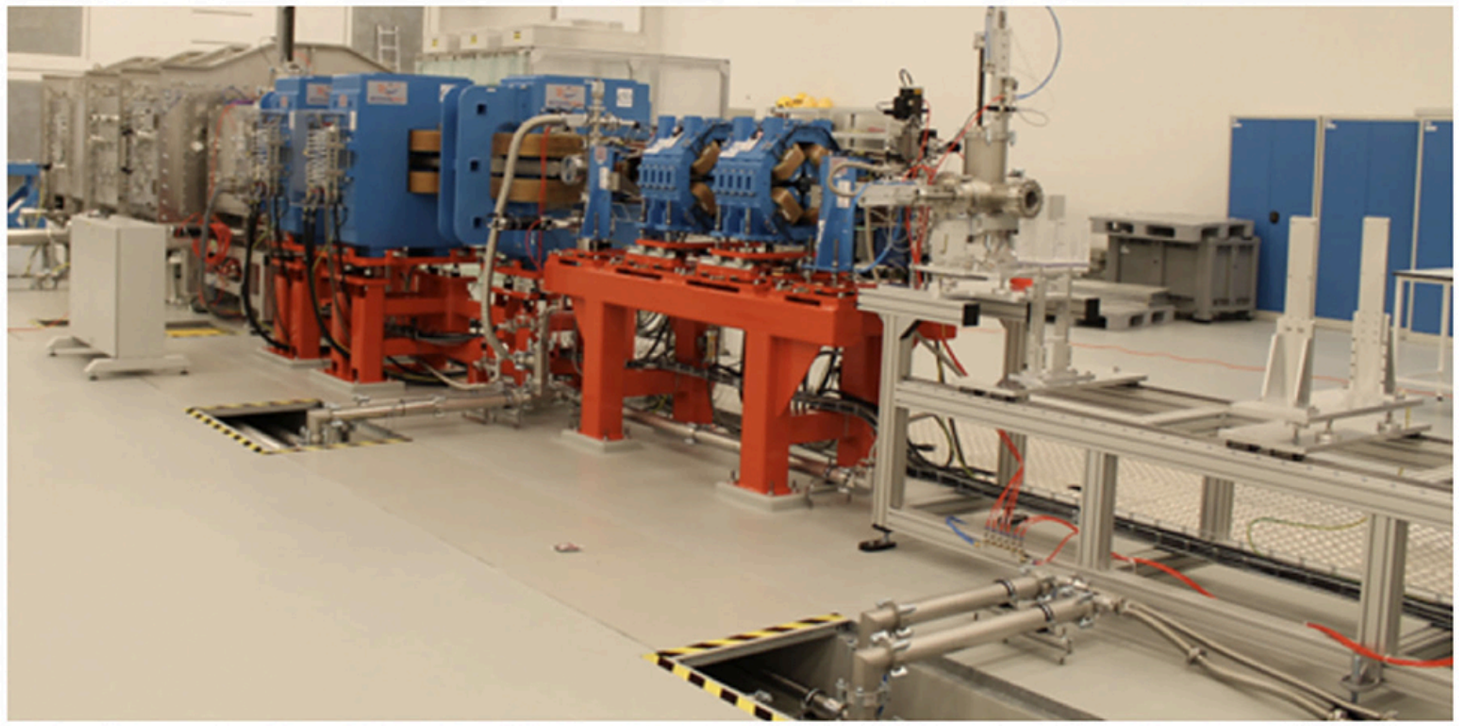

ELI-Beamline facility, Prague (CZ)

Thanks for Listening

Left to right:
Roberto Catalano, Davide Passarello, Pablo Cirrone, Emilio Zappalà, Nino Amato, Luciano Pandola, Giuliana Milluzzo, Michele Costa, Mariacristina Guarrera, Serena Fattori, Antonio Russo, Beatrice Cagni, Alma Kurmanova, Carmen Altana,Andrea Matamoros, Giuliana Navarra, Salvo Tudisco, Giacomo Cuttone, Giada Petringa, Gustavo Messina
INFN-LNS Medical Physics Group - Catania, April 30, 2021