Applications of laser electron accelerators in the range 50-500 MeV

G. Grittani, T. Levato, C. Lazzarini, F. Nawaz, M. Nevrkla, M. Precek, R. Versaci and G. Korn

ELI-Beamlines, Dolni Brezany (Czech Republic)

CLIC Workshop 2017, CERN, 09.03.2017

project supported by:

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

OP Research and Development for Innovation

OUTLINE OF THE TALK

- Laser Plasma Accelerators and ELI-Beamlines
- Applications of LPAs
- The Ultra-fast radiotherapy device

Fyzikální ústav
Akademie věd ČR, v. v. i.
project supported by:
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE
2007–13
OP Research and Development for Innovation

OUTLINE OF THE TALK

- Laser Plasma Accelerators and ELI-Beamlines
- Applications of LPAs
- The Ultra-fast radiotherapy device

LASER PLASMA ACCELERATORS

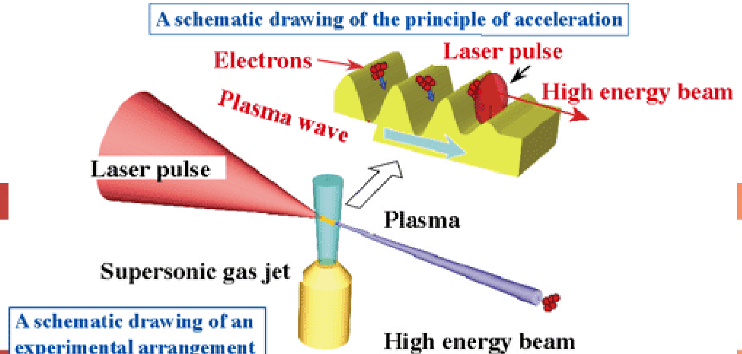
To use plasma as an accelerating medium was firstly proposed to achieve higher accelerating gradients.

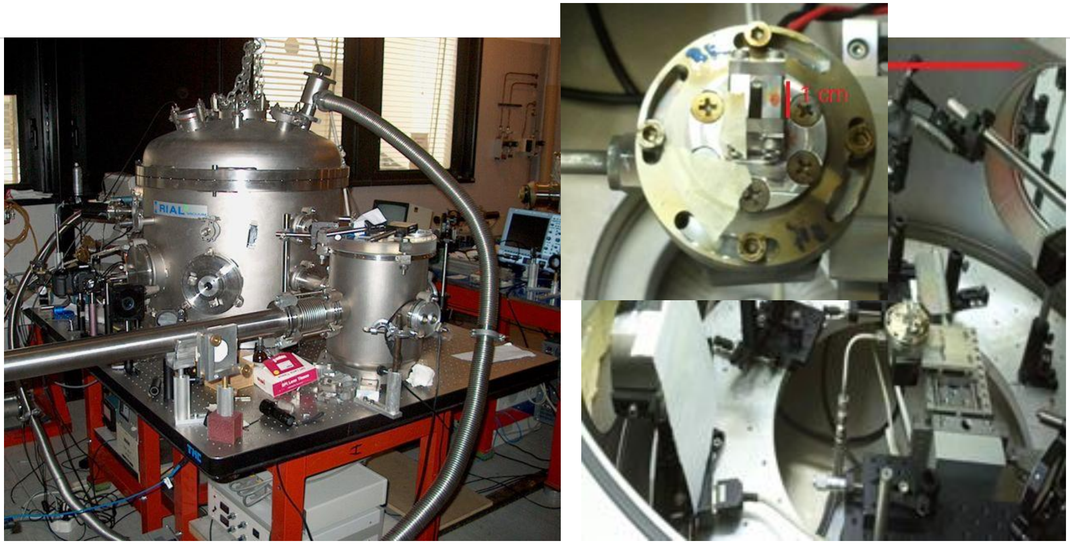
VOLUME 43, NUMBER 4 PHYSICAL REVIEW LETTERS 23 JULY 1979

Laser Electron Accelerator

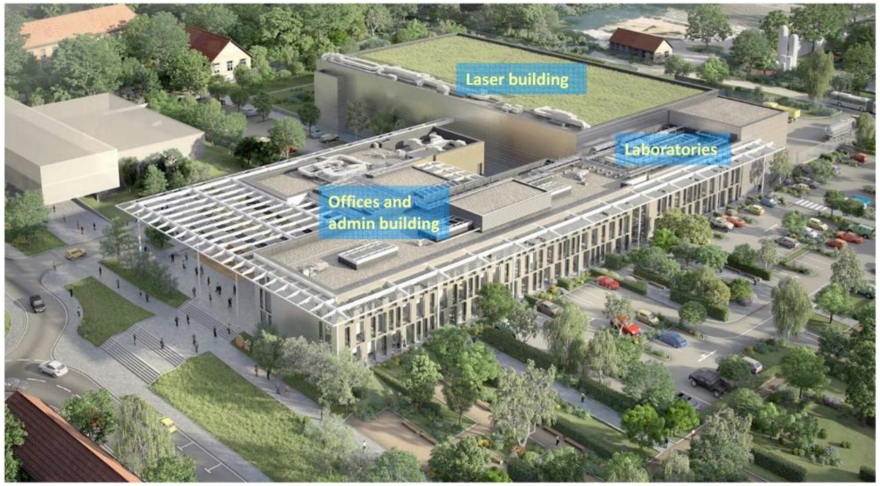
T. Tajima and J. M. Dawson
Department of Physics, University of California, Los Angeles, California 90024
(Received 9 March 1979)

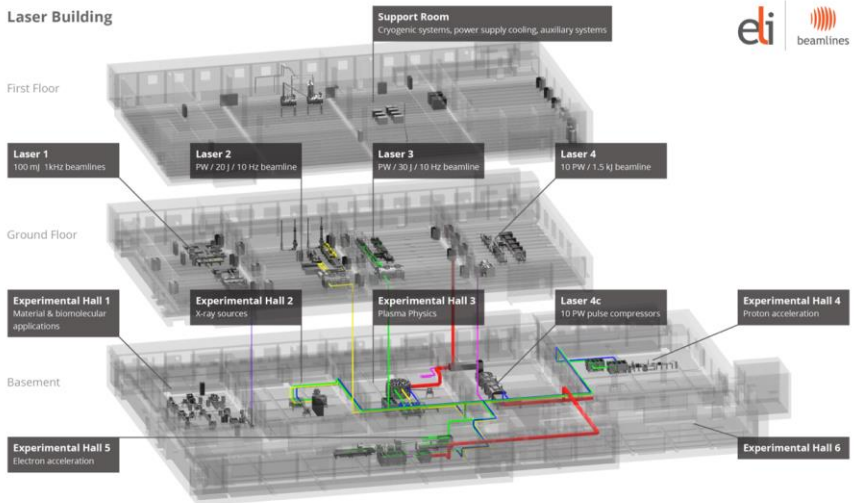
*In **2004**, first quasimonoenergetic bunches have been accelerated with gradients exceeding **100 MV/mm**.*





	RF accelerators	Laser Plasma Accelerators
Energy	Scalable, with accelerating gradients up to 100 MV/m. Energy spread as low as 0.1%.	High gradients higher than 100 MV/mm, but energy gain in single stage limited to few GeV. Energy spread of 1 %.
Current	Peak current limited by the time duration of the bunch, but high average current thanks to the higher frequency.	Peak current of few kA, but average current at the nA level for high energies.
Quality	Very low (µrad) divergence and pointing instability.	Beam divergence and pointing stability at the mrad level. Shot-to-shot fluctuations of beam parameters.
Synchto	Synchronization with other beams limited to the ps level.	Synchronization with a laser or radiation beam up to fs level.





<u>High repetition rate secondary radiation sources by femtosecond lasers:</u>

- XUV and X-ray sources (broadband and monoenergetic)
- Electrons (broadband and quasi-monoenergetic, up to 10 GeV)
- Protons and heavy ions (1-100 MeV/u)
- Gamma ray sources (broadband and quasi-monoenergetic)

STABLE LASER PLASMA ACCELERATOR

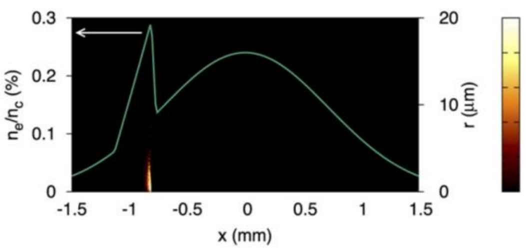
eli beamlines
laboratoire d'optique appliquée

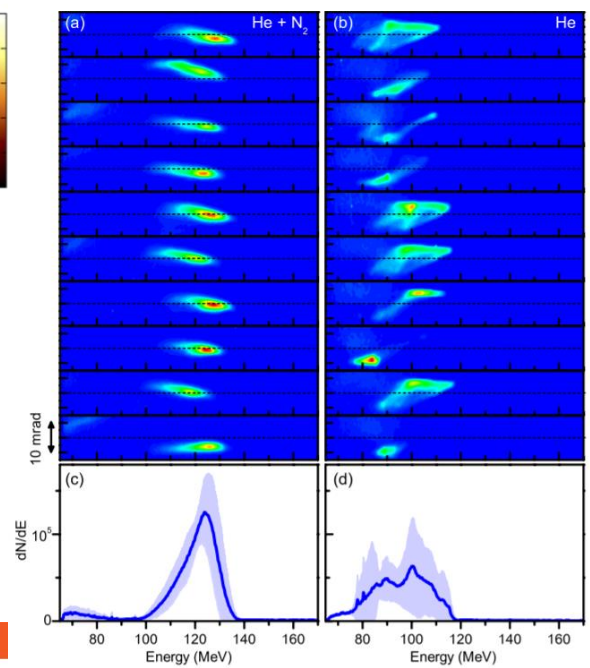
SCIENTIFIC REPORTS

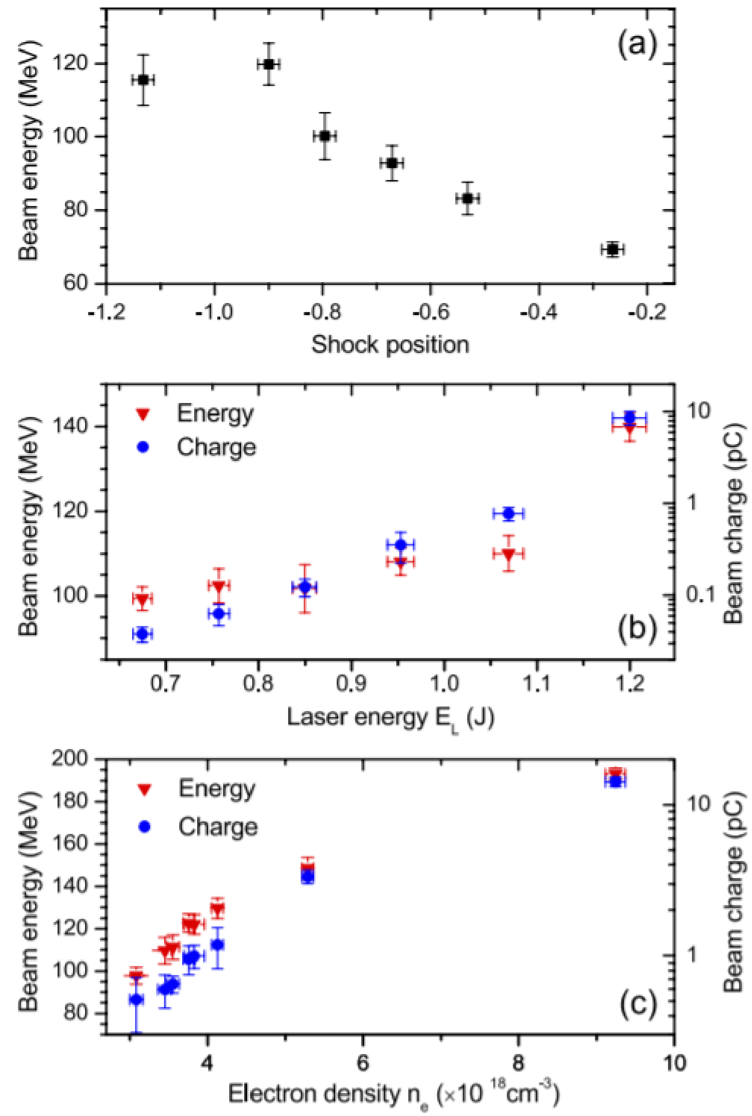
OPEN

Shock assisted ionization injection in laser-plasma accelerators

C. Thaury[1,*], E. Guillaume[1,*], A. Lifschitz[1], K. Ta Phuoc[1], M. Hansson[2], G. Grittani[3,4], J. Gautier[1], J.-P. Goddet[1], A. Tafzi[1], O. Lundh[2] & V. Malka[1]







Fyzikální ústav
Akademie věd ČR, v. v. i.

project supported by:

OUTLINE OF THE TALK

- Laser Plasma Accelerators and ELI-Beamlines
- Applications of LPAs
- The Ultra-fast radiotherapy device

APPLICATION OF LPA

They have to take advantage of compactness and/or high peak current and/or fs synchronization

Physics

QED

Cancer Therapy

VHEE

Radioisotope production

Localized production

Irradiators

Cutting and welding

Imaging

Electron radiography

Radiobiology

Ultrafast femtochemistry

Fyzikální ústav Akademie věd ČR, v. v. i.
project supported by:
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE
2007–13
OP Research and Development for Innovation

RADIOBIOLOGY

Mutation Research 704 (2010) 142–151

Contents lists available at ScienceDirect

Mutation Research/Reviews in Mutation Research

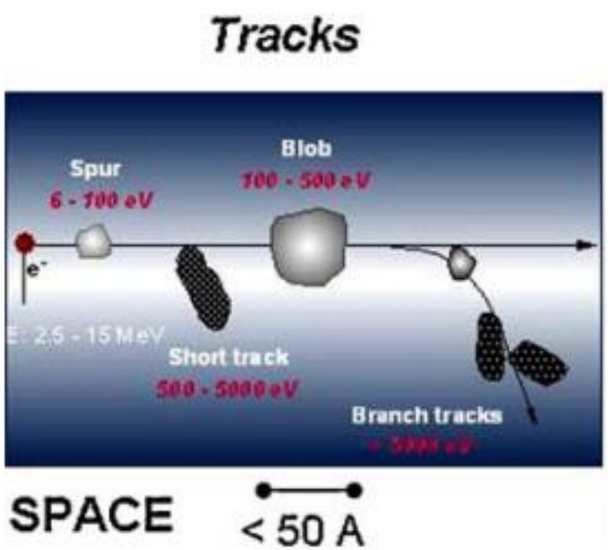
journal homepage: www.elsevier.com/locate/reviewsmr
Community address: www.elsevier.com/locate/mutres

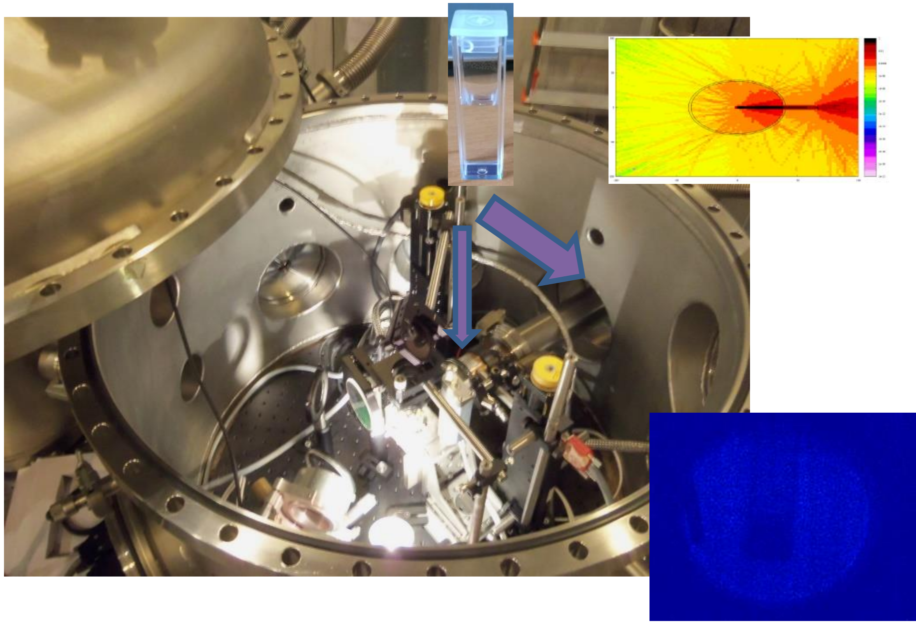
Review

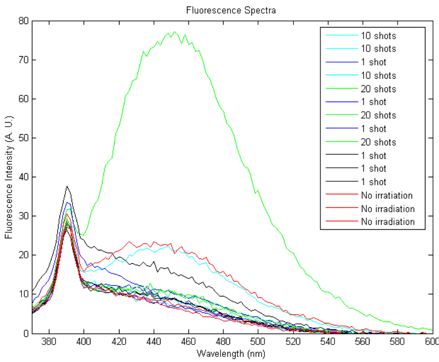
Ultra-short electron beams based spatio-temporal radiation biology and radiotherapy

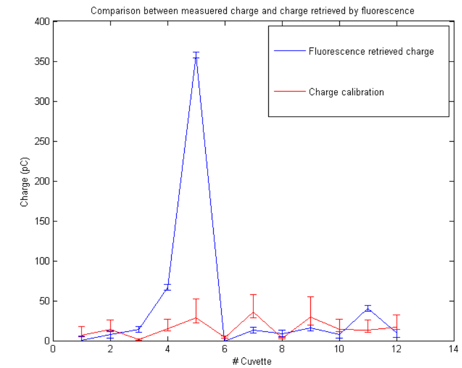
Victor Malka[a,*], Jérôme Faure[a], Yann A. Gauduel[a,b]

[a] Laboratoire d'Optique Appliquée – CNRS UMR 7639, École Nationale Supérieure des Techniques Avancées, École Polytechnique, 91761 Palaiseau, France
[b] Radiation Biology MELUSYN Network – Armir-Collège de Polytechnique, Paris, France









ELECTRON RADIOGRAPHY

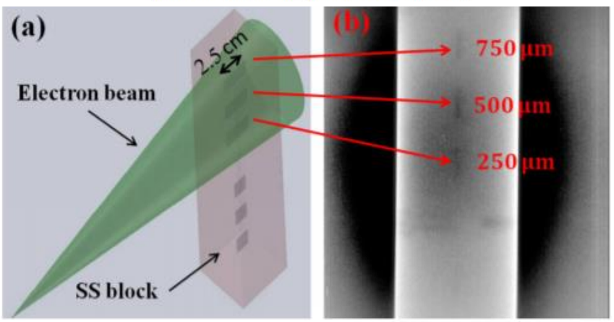
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 104701 (2010)

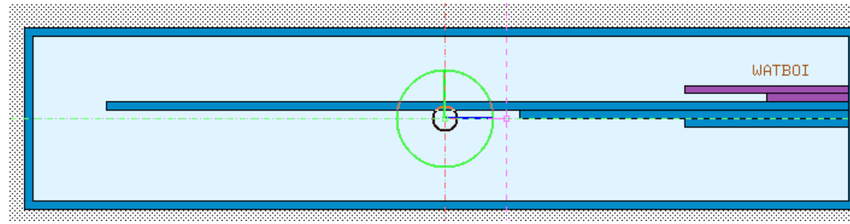
Submillimeter-resolution radiography of shielded structures with laser-accelerated electron beams

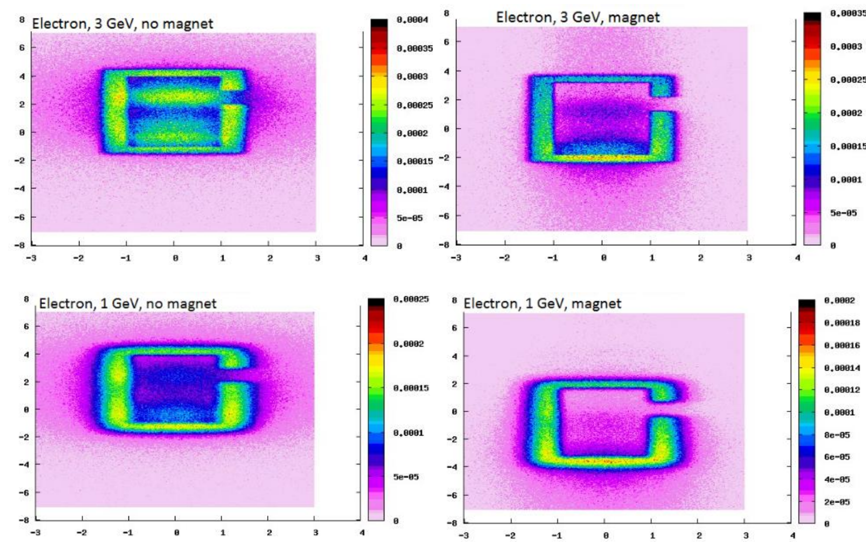
Vidya Ramanathan, Sudeep Banerjee, Nathan Powers, Nathaniel Cunningham, Nathan A. Chandler-Smith, Kun Zhao, Kevin Brown, and Donald Umstadter
Department of Physics and Astronomy, University of Nebraska, Lincoln, Nebraska 68588-0111, USA

Shaun Clarke and Sara Pozzi
Department of Nuclear Engineering & Radiological Sciences, University of Michigan, Ann Arbor, Michigan 48109-2104, USA

James Beene, C R Vane, and David Schultz
Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6372, USA
(Received 24 March 2010; published 14 October 2010)



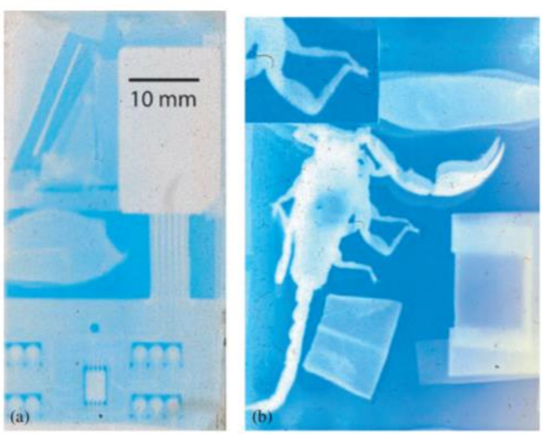


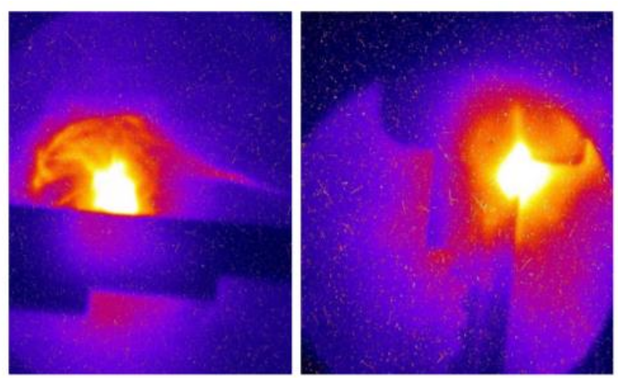


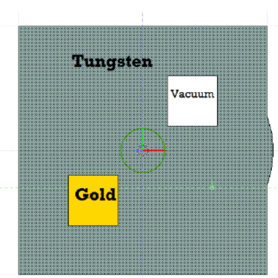
IOP Publishing
Journal of Physics D: Applied Physics
J. Phys. D: Appl. Phys. 46 (2013) 245501 (8pp)
doi:10.1088/0022-3727/46/24/245501

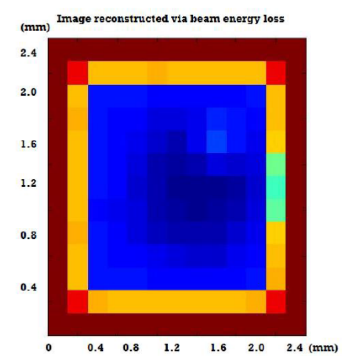
Electron radiography using a table-top laser-cluster plasma accelerator

G C Bussolino[1], A Faenov[2,3], A Giulietti[1], D Giulietti[1,4], P Koester[1], L Labate[1,4], T Levato[1,5,6], T Pikuz[2,3] and L A Gizzi[1,4]









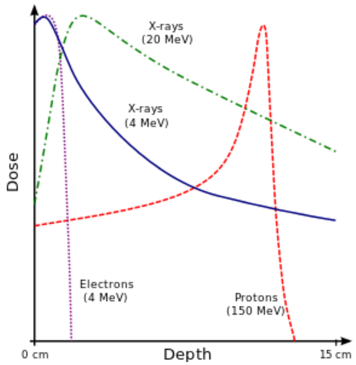
Outline of the talk

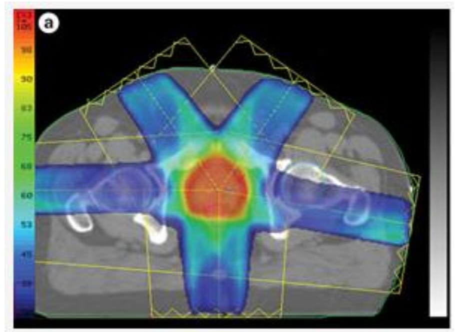
- Laser Plasma Accelerators and ELI-Beamlines
- Applications of LPAs
- The Ultra-fast radiotherapy device

RADIOTHERAPY

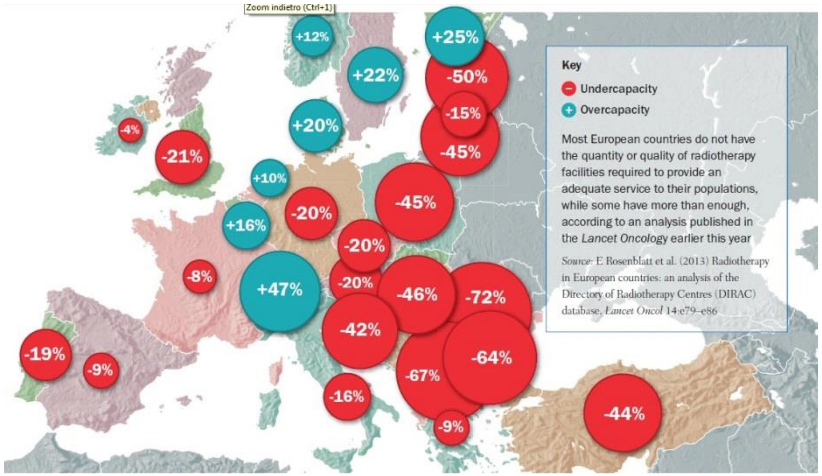
Radiotherapy is a treatment involving the use of high energy radiation

Particle accelerators
vs.
Radioactive sources



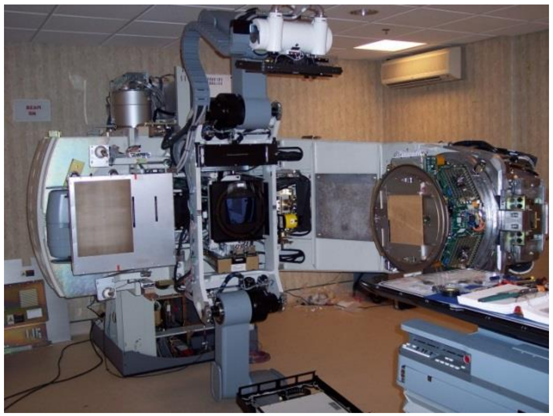


Main cancer diagnosis	New cases/year	Radiotherapy treatments
Lung	6242	38,3%
Breast (females)	5628	82%
Prostate	4289	39%
Rectum	2211	82,8%
Corpus uteri	1734	58,6%
Cervix uteri	1033	78,7%
Other without skin	53522	43,0%



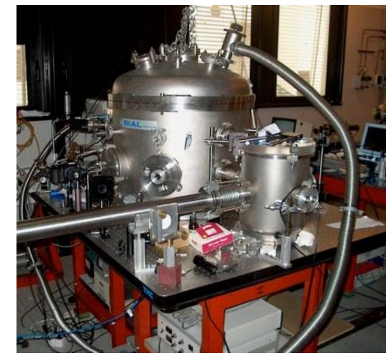
MEDICAL LINAC vs PLASMA ACCELERATOR

Radio-frequency accelerators



- Price: 4 Million USD
- Beam Energy: 6-20 MV
- Energy gain: 10 MV in 1 meter
- Discrete dose range
- 180-360 Hz, <1 mGy/pulse
- Treatment time 5-10 minutes
- Very complex systems
- Old technology, very reliable

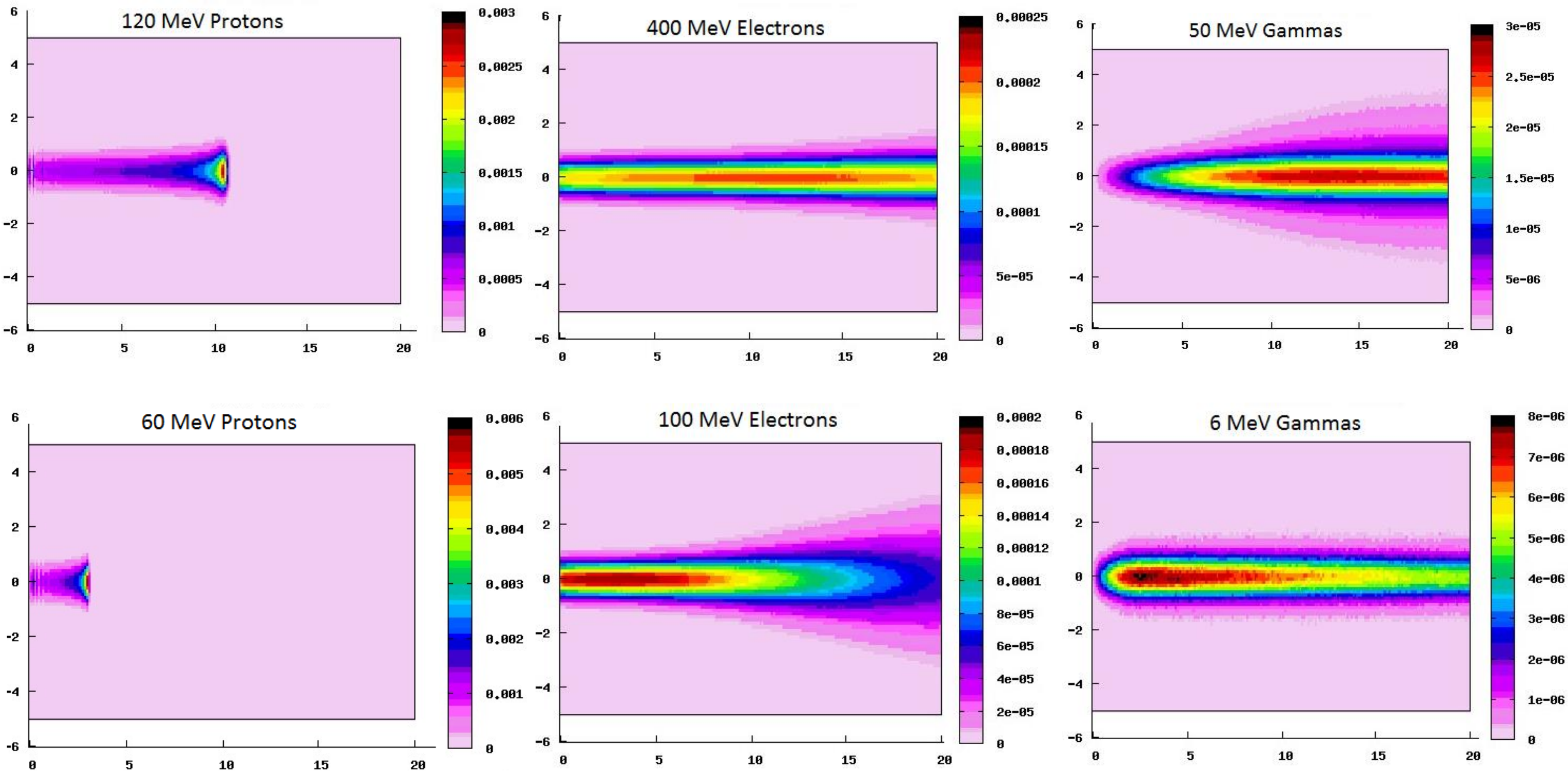
Laser-Plasma accelerators



- Price: <2 Million USD **CHEAPER**
- Beam Energy: up to 300 MV **BETTER**
- Energy gain: 100 MV in 1 mm
- Continuous dose range
- 50 Hz frequency, 100 mGy/pulse
- Treatment time <1 minute **FASTER**
- More simple systems
- New technology

V. Malka et al. / Mutation Research 704 (2010) 142–151

2D DOSE PROFILES IN WATER



Fyzikální ústav
Akademie věd ČR, v. v. i.

project supported by:

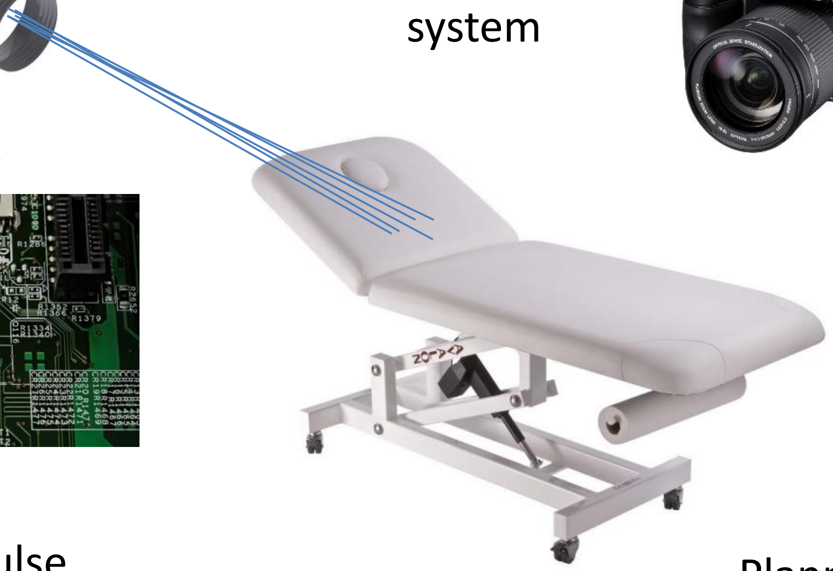
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

2007-13
OP Research and
Development for Innovation

THE ULTRA-FAST RADIOTHERAPY DEVICE

Pulsed Radiation Source

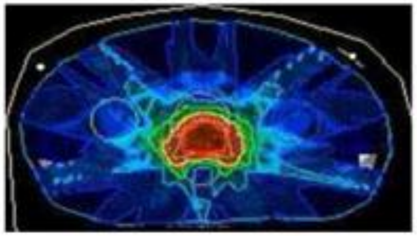
Radiation Pulse Parameters



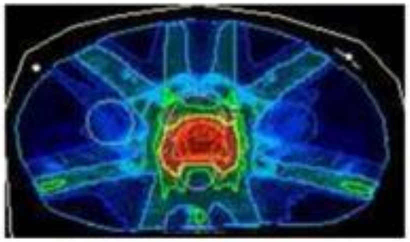
Fast-imaging system

On-line target region imaging

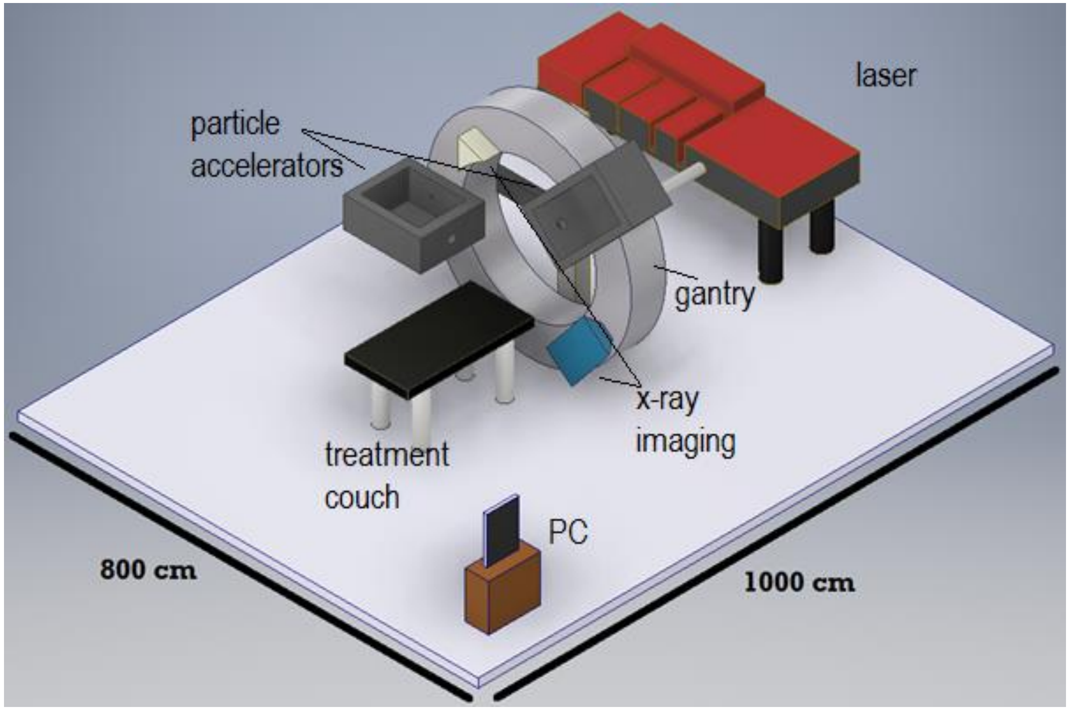
Planned treatment



Real treatment



THE ULTRA-FAST RADIOTHERAPY DEVICE



HIGHEST DOSE RATE ON THE MARKET
(>20 mGy in less than 1 ps)

REAL-TIME IMAGING
(time resolution <100 ms)

TUNABLE ELECTRON ENERGY
(100 different beams in the range 10-300 MeV)

HIGH CUSTOMIZATION
(# radiation sources, complex geometry)

LOWER COMPLEXITY
(no high vacuum, no complex electronics)

LONGER LIFETIME
(lifetime >10 years with minor replacements)

EXTREMELY VERSATILE
(dosimetry tests, biomedical research, radioisotope production)

LOW FREQUENCY
(<10 Hz)

INCREASED SHIELDING
(higher electron energy)

BEAM STABILITY
(shot-to-shot fluctuations)

TECHNOLOGY DEVELOPMENT RISKS
(device automation, increased costs)

Fyzikální ústav
Akademie věd ČR, v. v. i.
project supported by:
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE
OP Research and Development for Innovation

eli beamlines

PROJECT STATUS AND ROADMAP

7 years

IP Protection
- Patent filed in June 2016
- Technical design
- Doctor’s opinion

6 M Euro
- Beta-Prototype at 50 MeV, 20 mGy/pulse
- Software development
- Certification

10 M Euro
- Final Prototype at 300 MeV, 100 mGy/pulse
- Medical tests
- Certification

beamlines

Compact Linear Collider

THANK YOU FOR YOUR ATTENTION

Gabrielemaria.Grittani@eli-beams.eu

Fyzikální ústav
Akademie věd ČR, v. v. i.

project supported by:

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

2007–13
OP Research and
Development for Innovation