ФИЗИКАТА В МЕДИЦИНАТА

(ДИАГНОСТИКА И ТЕРАПИЯ)

Bulgarian Teachers Programme

14 July 2024 – 19 July 2024

Genève, Switzerland

CERN

Conseil Européen pour la Recherche Nucléaire

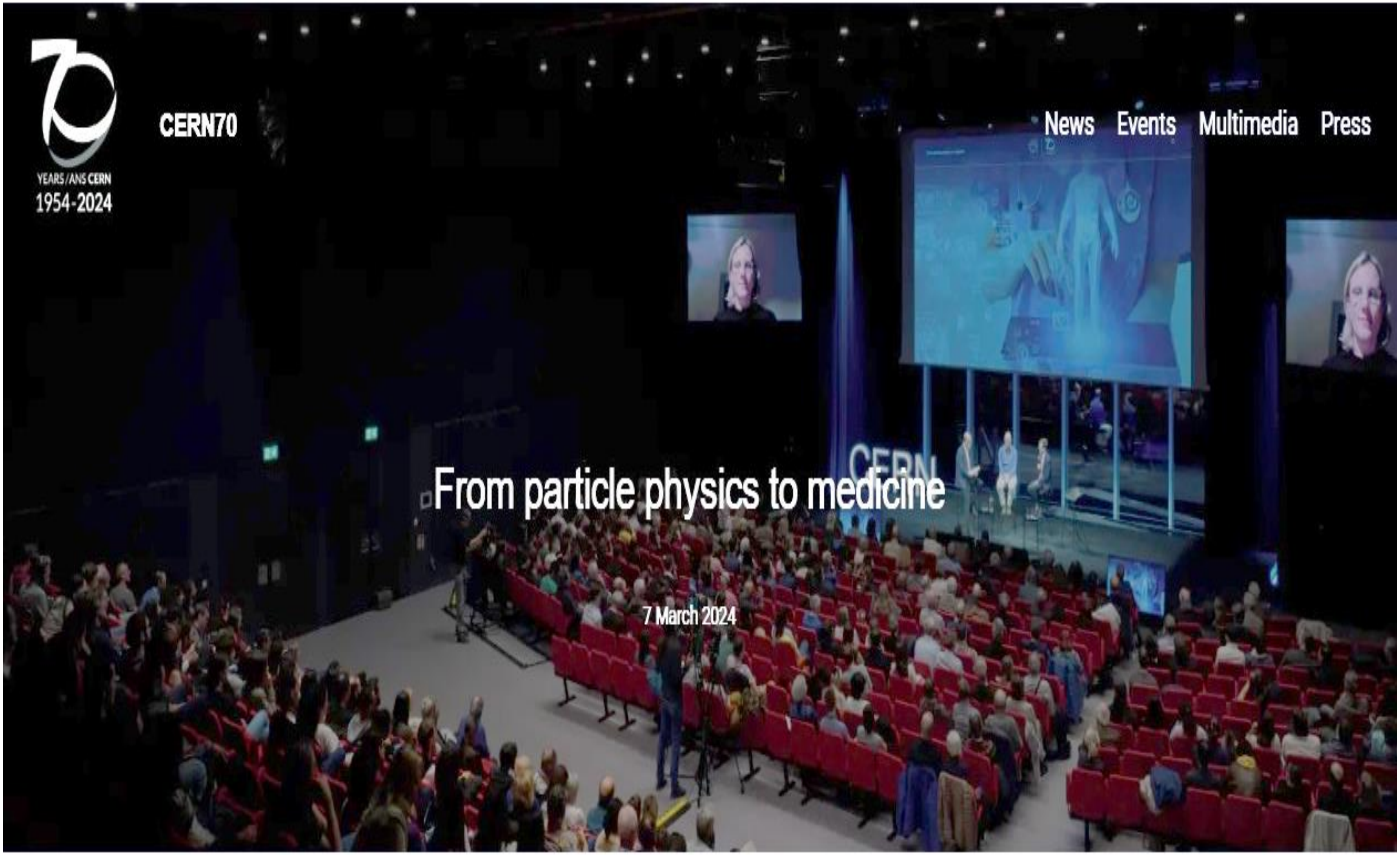
Европейска Организация за Ядрени Изследвания

70 years CERN

Conseil Européen pour la Recherche Nucléaire

1954 – 2024 years

From particle physics to medicine



From particle physics to medicine

As part of the celebrations for **CERN's 70th anniversary**, this event offered a unique opportunity to explore the various applications of particle physics instruments and tools in hospitals and medical research. Medical doctors, biologists and physicists guided the public on a captivating journey, providing insights into the future of therapy and imaging.

The event covered three areas in which particle physics was contributing to the development of new medical technologies:

Accelerators to treat cancer
From radiotherapy for cancer treatment to radiopharmaceuticals: tens of thousands of particle accelerators are used in medicine. New therapies have been made possible by the innovative technologies developed for frontier instruments, like the Large Hadron Collider.

Looking inside the human body
Since the discovery of X-rays, medical imaging and physics have advanced hand in hand. Sophisticated particle detectors, which are at the heart of modern imaging devices, enable doctors to provide early and accurate diagnosis of many diseases.

The digital health revolution
Machine learning and artificial intelligence technologies play a crucial role in particle physics, which is rapidly embracing these tools to advance research. Collaborations with medical doctors, epidemiologists and researchers are leading to game-changing developments that help to preserve or improve our health.

The event brought together renowned specialists and was introduced by Mike Lamont, CERN Director for Accelerators and Technology, and moderated by Professor Antoine Geissbuhler, Dean of the Faculty of Medicine of the University of Geneva, Director of Teaching and Research and Head of the Division of e-Health and Telemedicine, HUG.

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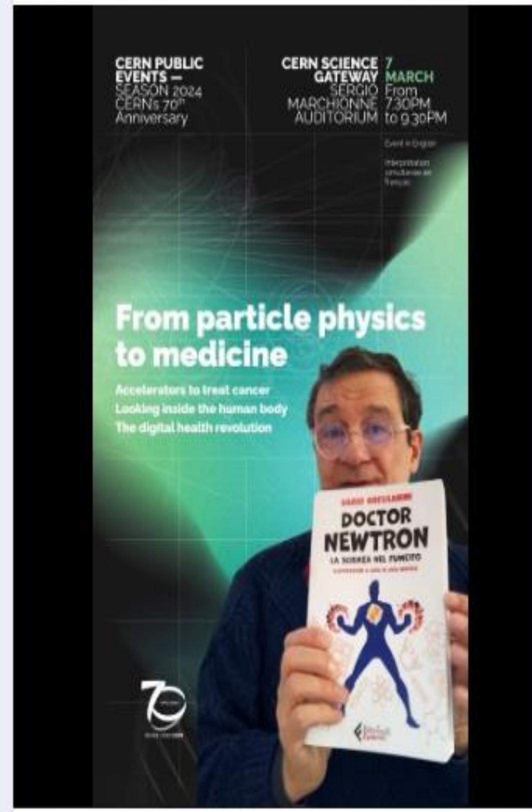
Original audio
View profile

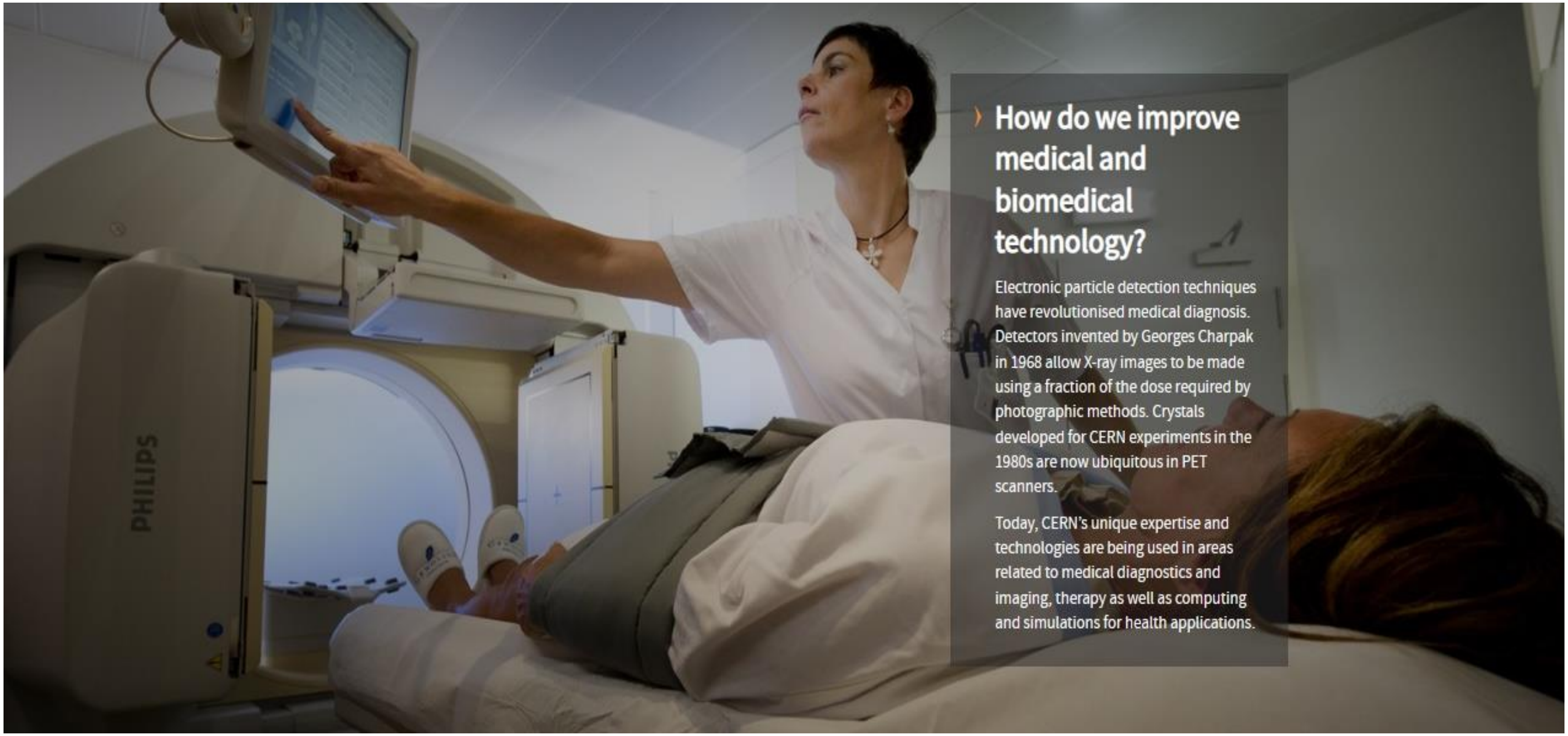


View more on Instagram

Трансфер на нови технологии и експертни познания от CERN в съвременното обществото е неразделна част от цялостната дейност, осигурявайки нови иновативни решения в много области.

Knowledge Transfer Applications Infographic

How do we improve medical and biomedical technology?



Available on: https://www.home.cern/about/what-we-do/our-impac

https://lnkd.in/ejRG8js7

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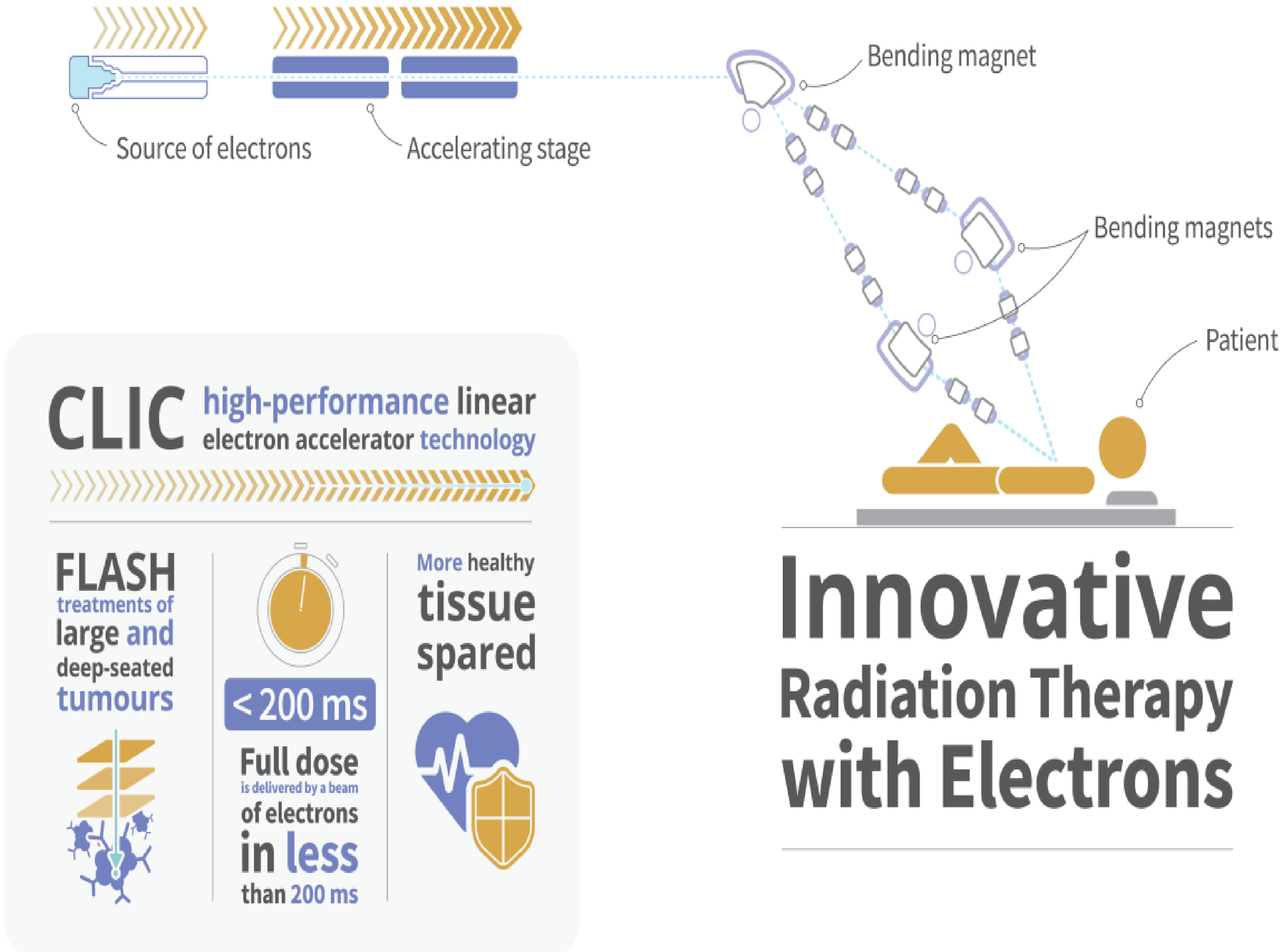

https://www.home.cern/news/news/knowledge-sharing/cern-chuv-and-theryq-join-forces-world-first-cancer-radiotherapy

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https://www.home.cern/news/news/knowledge-sharing/cern-chuv-and-theryq-join-forces-world-first-cancer-radiotherapy

Healthcare related news

MARS Bioimaging partners with the Hospital for Special Surgery (HSS)

[News from our partners] The partnership will assess particular aspects of the MARS 5x120 Extremity scanner.

Healthcare | 15 June, 2023

Terapet SA secures over CHF 2,3 million to bring its first product to market and to accelerate development of new nuclear imaging products

This funding supports the commercialization of Terapet's first product, Qualyscan and the development of new nuclear imaging products.

Healthcare | 17 February, 2023

CERN, CHUV and THERYQ join forces for a world first in cancer radiotherapy

CERN, CHUV and THERYQ have signed an agreement for the development of a revolutionary FLASH radiotherapy device

Healthcare | 25 November, 2022

Available on: https://www.home.cern/about/what-we-do/our-impac

The GEMTEQ detector will be used in microdosimetry to better understand radiation effects in human tissue, and has already been used for measurements at @CNAO

GEMPix at CNAO for the latest measurements in ***October and December 2021***

Available on*: https://kt.cern/annual-report?page=0*

CERN and CNAO, a long-standing collaboration in the fight against cancer **22 NOVEMBER, 2021**

Available on*: https://kt.cern/news/news/knowledge-sharing/cern-and-cnao-long-standing-collaboration-fight-against-cancer*


CNAO
CENTRO NAZIONALE DI ADROTERAPIA ONCOLOGICA

First European hospital receives 3D color X-ray scanner using CERN technology MARS Bioimaging's 3D color X-ray scanner has arrived in Europe to undertake clinical trials that will lead to its medical use.

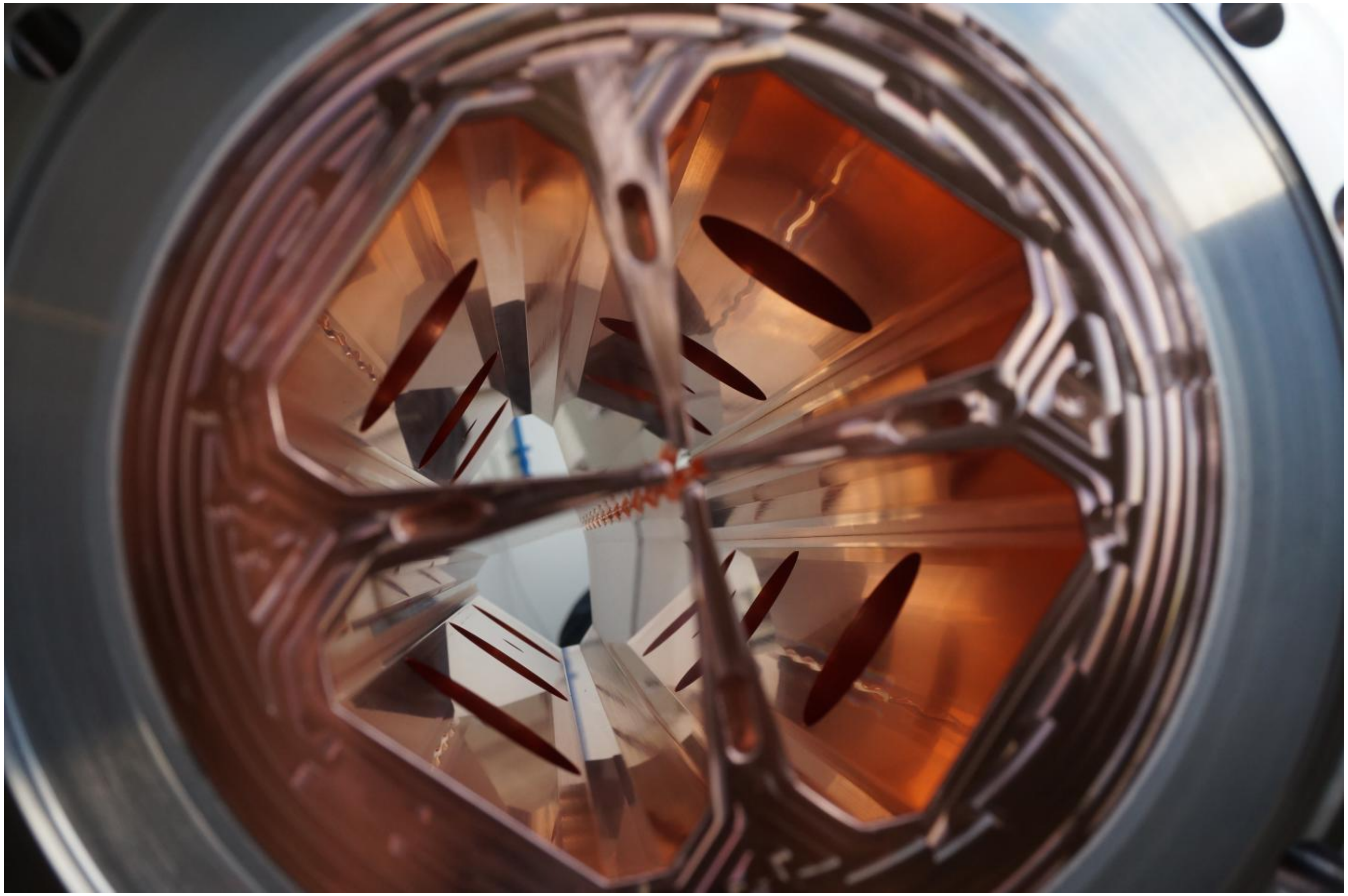
22 JUNE, 2021

***Available on**: https://kt.cern/news/news/knowledge-sharing/first-european-hospital-receives-3d-colour-x-ray-scanner-using-cern*

New 3D colour X-rays made possible with CERN technology

Available on: *https://kt.cern/article/new-3d-colour-x-rays-made-possible-cern-technology*

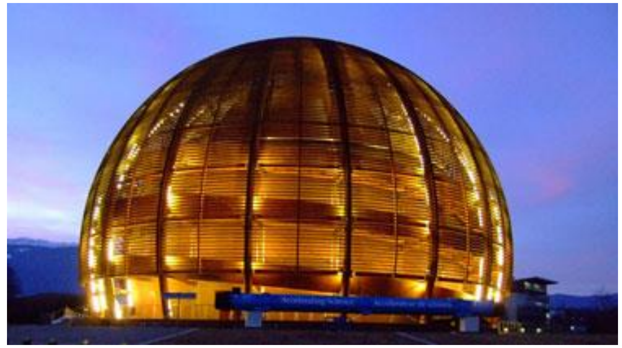
CERN technologies for next-generation ion therapy centres -2019



***Available on**: https://kt.cern/success-stories/cern-technologies-next-generation-ion-therapy-centres*

CERN и Медицинската физика

CERN: catalysing collaboartion for medical advances – March, 2012



CERN established the **Physics for Health (PHE) workshop**.

"I think that the first thing we have to do is to understand each other, to know what is needed, what is available and what is possible," explained **Rolf-Dieter Heuer, Director General of CERN.**

INITIATIVES:

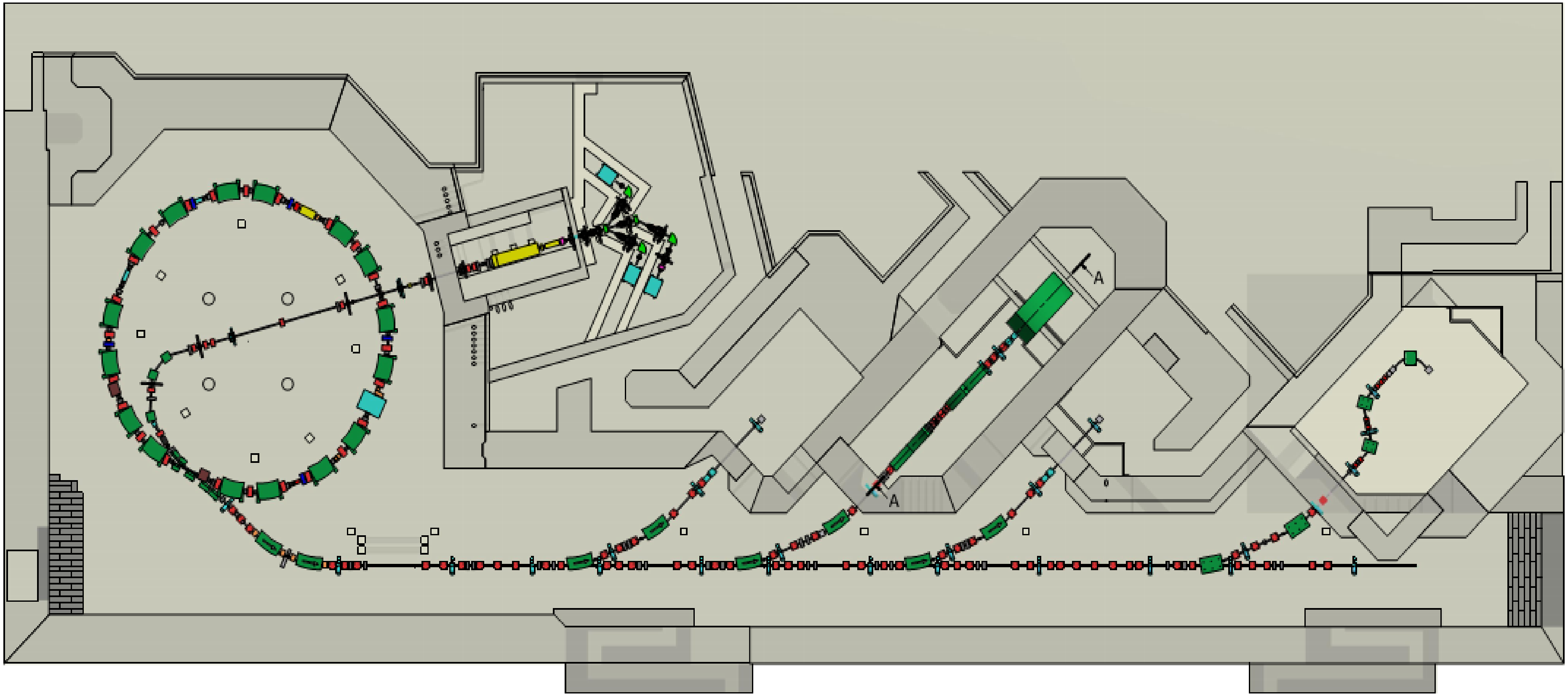
Biomedical research
Accelerator design
Radioisotope development

Available on: http://medicalphysicsweb.org/cws/article/opinion/49110

Proton Center in Vienna, Austria

The MedAustron proton/carbon-ion synchrotron was constructed in collaboration with CERN, the TERA Foundation, INFN and the CNAO Foundation, with help from PSI. Credit: MedAustron

The layout of MedAustron is similar to the one of PIMMS



MedAustron bought from CNAO Foundation the construction drawings for 3.2 million Euro.
IP: CNAO (55%), INFN (30%), CERN (15%)

MedAustron pictures

Protons have been extracted from the synchrotron

First patient in 2016

CERN и Медицинската физика

CERN INTENSIFIES MEDICAL PHYSICS RESEARCH – Feb, 2014

The ultimate aim is for CERN to establish itself as an important facilitator of medical physics in Europe.

"Since the start of this year, we are trying to combine all of our research on medical applications at CERN into one coordinating office," explained **CERN's Director-General Rolf Heuer**, speaking at the recent ICTR-PHE (**International Conference on Translational Research in Radio-Oncology and Physics for Health in Europe**) meeting in Geneva, Switzerland.

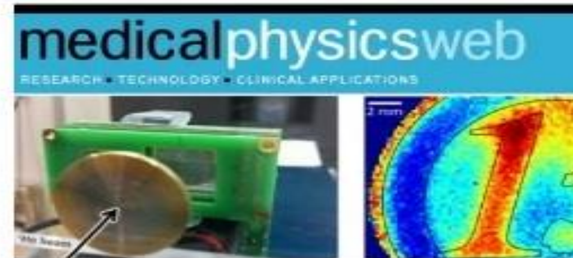
Available on: http://ictr-phe14.web.cern.ch

BBC Click

12 May 2018

Knack

23 Apr 2018



Medical Physics Web

2 Mar 2018

Medical Physics Web

1 Mar 2018

CERN Courier

1 Jan 2018

Pays de Gex

15 Dec 2017

Forbes

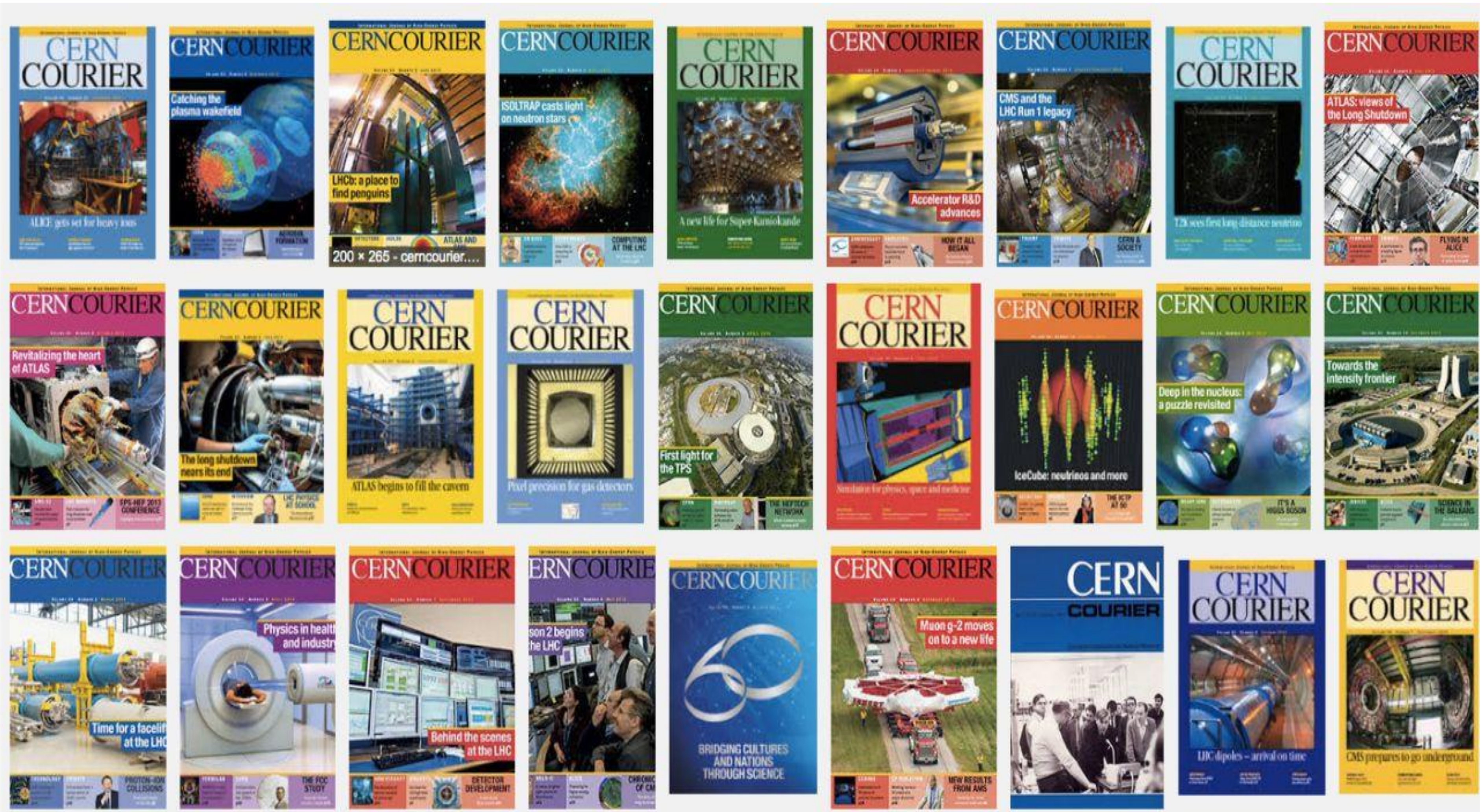
15 Dec 2017

Physics World

13 Dec 2017

Le Pays Gessien

7 Dec 2017



https://cerncourier.com/

WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the May/June 2019 issue of *CERN Courier*.

It is 100 years since Ernest Rutherford published his results proving the existence of the proton. For many decades the proton was considered elementary. But ever since experiments at SLAC and DESY started firing electrons into protons, beginning in the 1960s, deep-inelastic-scattering experiments have revealed a complex internal picture. In this issue we take an expert tour of physicists' evolving understanding of the proton, and find that there is still much to learn about this ubiquitous particle – including the origin of its spin, whether or not it decays and the puzzling value of its radius. Flavour physics is another theme of the issue. LHCb's observation of CP violation in the charm sector represents a milestone result, and the collaboration recently released an update of the ratio R_K concerning the ratio of certain B-meson decays. From a theoretical perspective, new gauge bosons and leptoquarks are promising potential explanations for the current anomalies reported in the b-quark system, although the picture is far from clear and more data are needed. Meanwhile, researchers are also searching for ultra-rare muon decays that violate lepton-number conservation. Also in this issue: LHCb's discovery of a new pentaquark, DESY's astroparticle ambitions, news on the International Linear Collider, the first image of the centre of a galaxy, and more.

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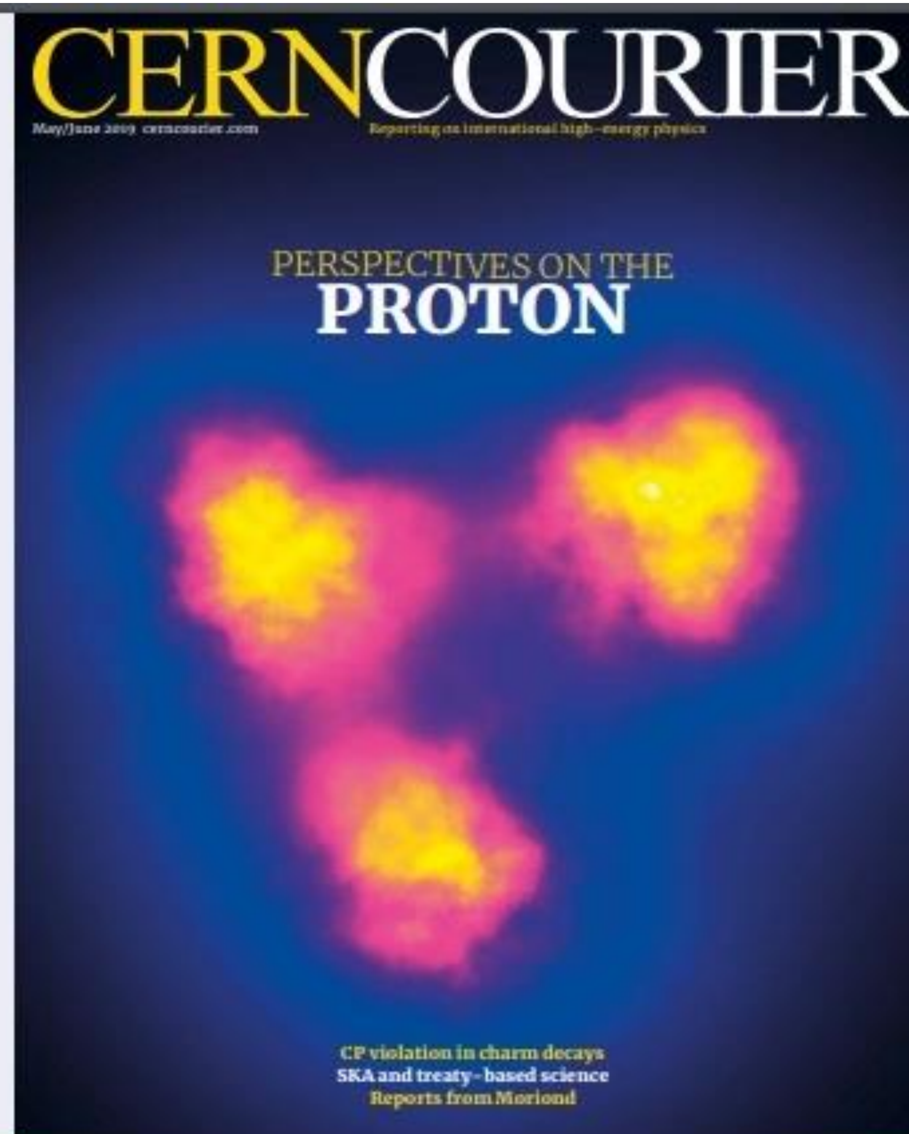

With permission by Dr Matthew Chalmers - Editor, CERN Courier

WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the January/February 2018 issue of *CERN Courier*.

Proton therapy was first administered in a patient at Berkeley National Laboratory in September 1954, the same month CERN was founded. The breakthrough followed the invention of the cyclotron, and the relationship between high-energy physicists and oncologists has grown closer ever since. This issue of the *Courier* takes a look at some of the medical applications of accelerators, in particular for particle therapy. Hadron beams can allow tumours to be targeted more precisely than conventional radiotherapy and the number of centres is growing rapidly across Europe, for example thanks to efforts such as the TERA Foundation. A shift to more compact linac-driven treatment centres, meanwhile, promises to expand access to particle and radiotherapy in the challenging environments of low- and middle-income countries, where cancer rates are predicted to be highest in the coming decades. Accelerator technology is also bringing new opportunities in radioisotope production for theragnostics and advanced treatment modes, as exemplified by the recently completed MEDICIS research facility at CERN, while detector and computing technology from particle physics continue to have a major impact on medical imaging and treatment planning.

Also distributed with the January/February 2018 print issue is the inaugural *Courier* year-planner, copies of which can be obtained by getting in touch at **cern.courier@cern.ch**.

To sign up to the new-issue alert, please visit: **cerncourier.com/cws/sign-up**.

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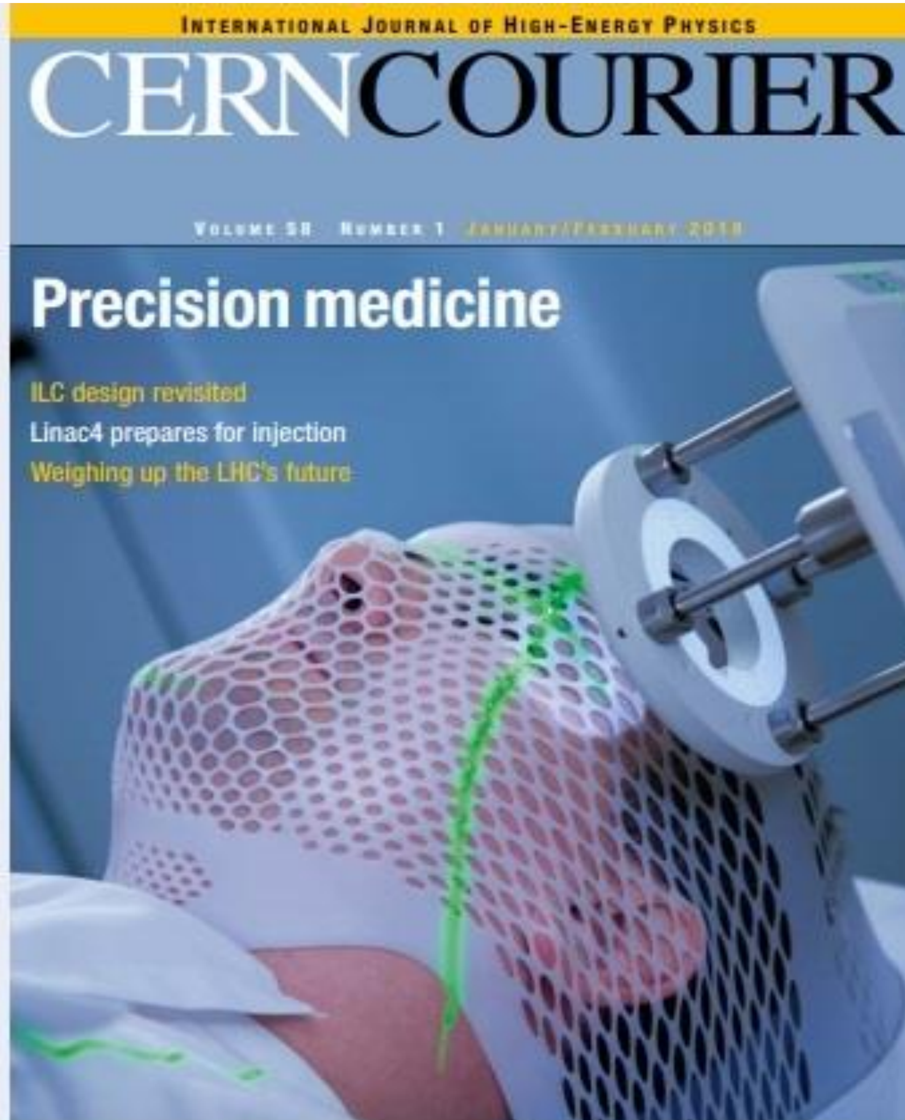

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VOLUME 58 NUMBER 1 JANUARY/FEBRUARY 2018
IOP Publishing

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WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the October 2016 issue of *CERN Courier*.

Particle physics, and CERN in particular, has made major contributions to medicine. Key to this, in addition to detectors for diagnosis and medical imaging, is accelerator technology. A new high-energy proton therapy centre in Nice, which has its roots in a CERN project, is about to treat its first patients, offering more precise treatment of tumours than is possible with conventional X-rays. Particle beams are also playing an increasingly vital role in the production of medical isotopes, which have traditionally been produced by research reactors. With global demand for isotopes such as technetium-99m growing and many reactors reaching the end of their operational lifetimes, CERN has recently launched a project called MEDICIS to produce isotopes from high-energy proton beams. Meanwhile, Brookhaven National Laboratory in the US has undergone a series of upgrades to boost its long-running isotope programme, and TRIUMF in Canada is pursuing isotopes for the rapidly growing field of targeted alpha therapy. Other particle-physics laboratories are pursuing similar cross-disciplinary programmes, illustrating the benefit of basic science to society.

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WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the April 2014 issue of *CERN Courier*.

It is 60 years since a proton beam was first used to treat cancer at the Berkeley cyclotron. Since then, research has spread to other countries and other beams, notably carbon ions. In February, experts at the ICTR-PHE 2014 conference in Geneva discussed current progress in using these and other techniques derived from nuclear and particle physics in the service of medicine.

It is 80 years since two theoretical physicists first calculated the neutrino cross-section and concluded that "there is no practically possible way of observing neutrinos". Forty years later, measurements of neutrinos by the Gargamelle team at CERN helped to reveal the quark structure of matter. Now, another 40 years later, the MINERvA experiment at Fermilab continues a long tradition at the two labs in studying neutrinos.

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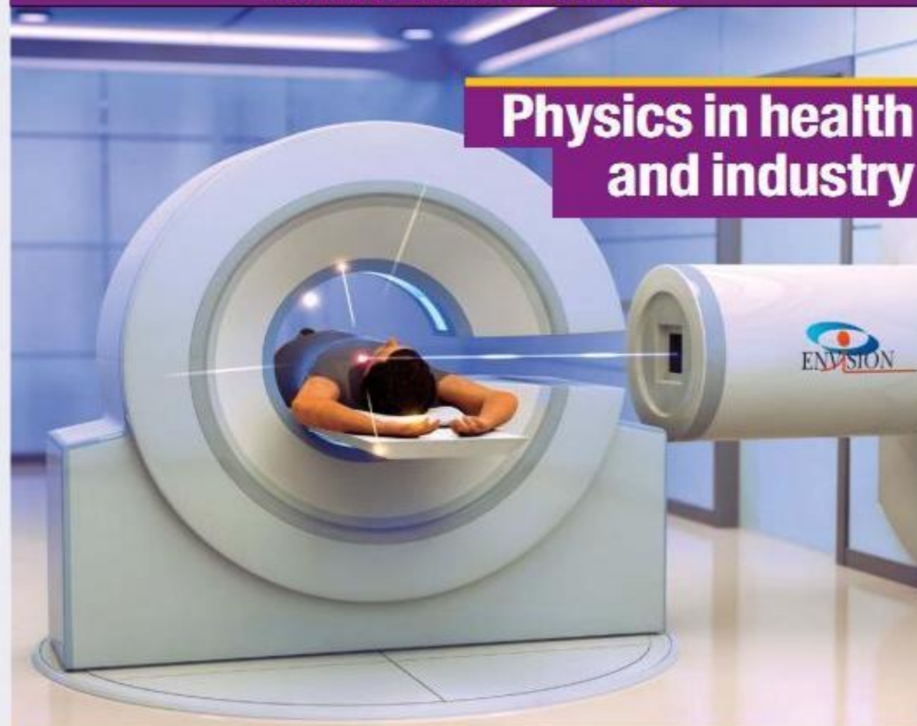
CERN COURIER

VOLUME 54 NUMBER 3 APRIL 2014



Physics in health and industry

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CERN
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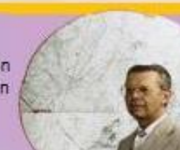

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With permission by Dr Christine Sutton - Editor, CERN Courier

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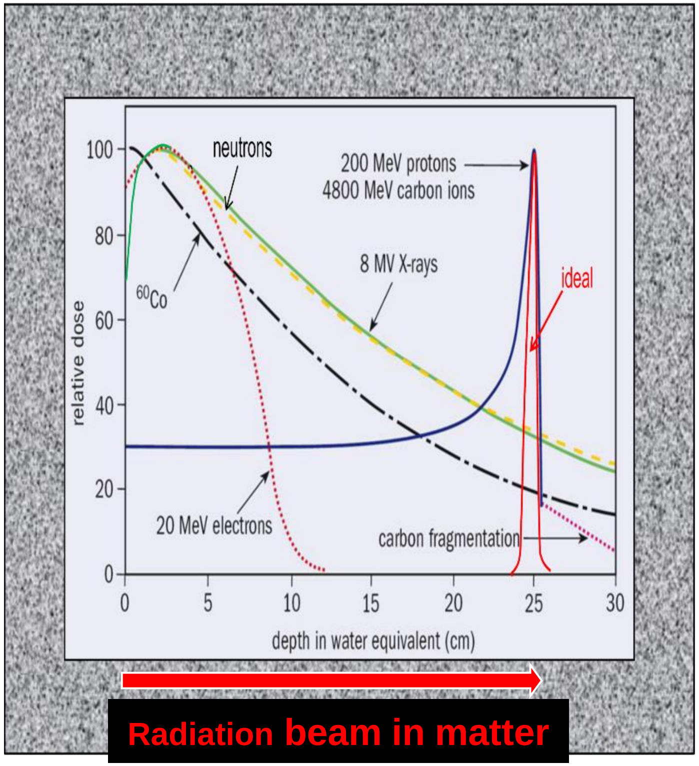
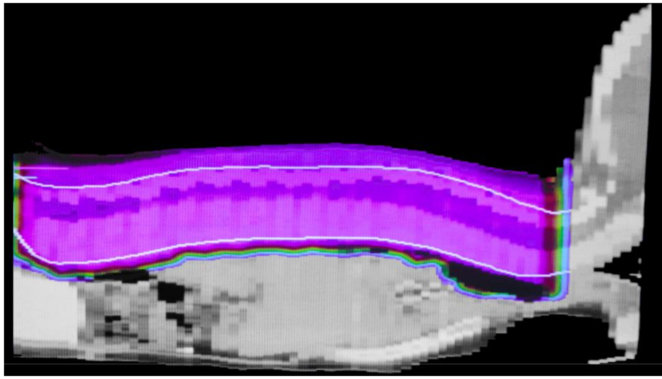
II. Proton Therapy – Протонна терапия.

III. Carbon Therapy - Терапия с карбонови йони.





Bene diagnoscitur, bene curatur.

Правилна диагноза – успешно лечение.

Диагностичните методи са високо ефективни, когато могат да повлияят върху терапевтичното поведение при пациента.

Нуклеарната медицина
– най - бързо развиващата се образна специалност
(Позитронно – емисионната томография (ПЕТ)
Високо технологична дейност)

- **Нов подход в познанието за биологията и функционалната активност на туморите - подобряване на комплексната диагностика и лечение на онкологичните заболявания.**

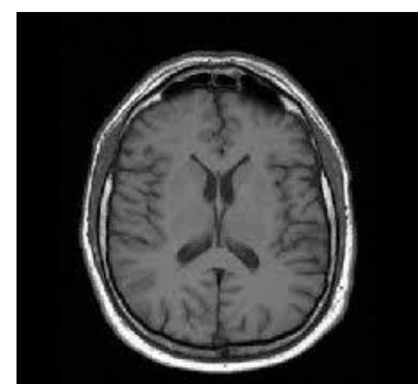
- Нуклеарно - медицинските методи имат по - ниска разделителна способност, но висока специфичност и изобразяват **биологичното поведение** - **функцията на изследвания орган и неговия метаболизъм, преди появата на структурни промени.**

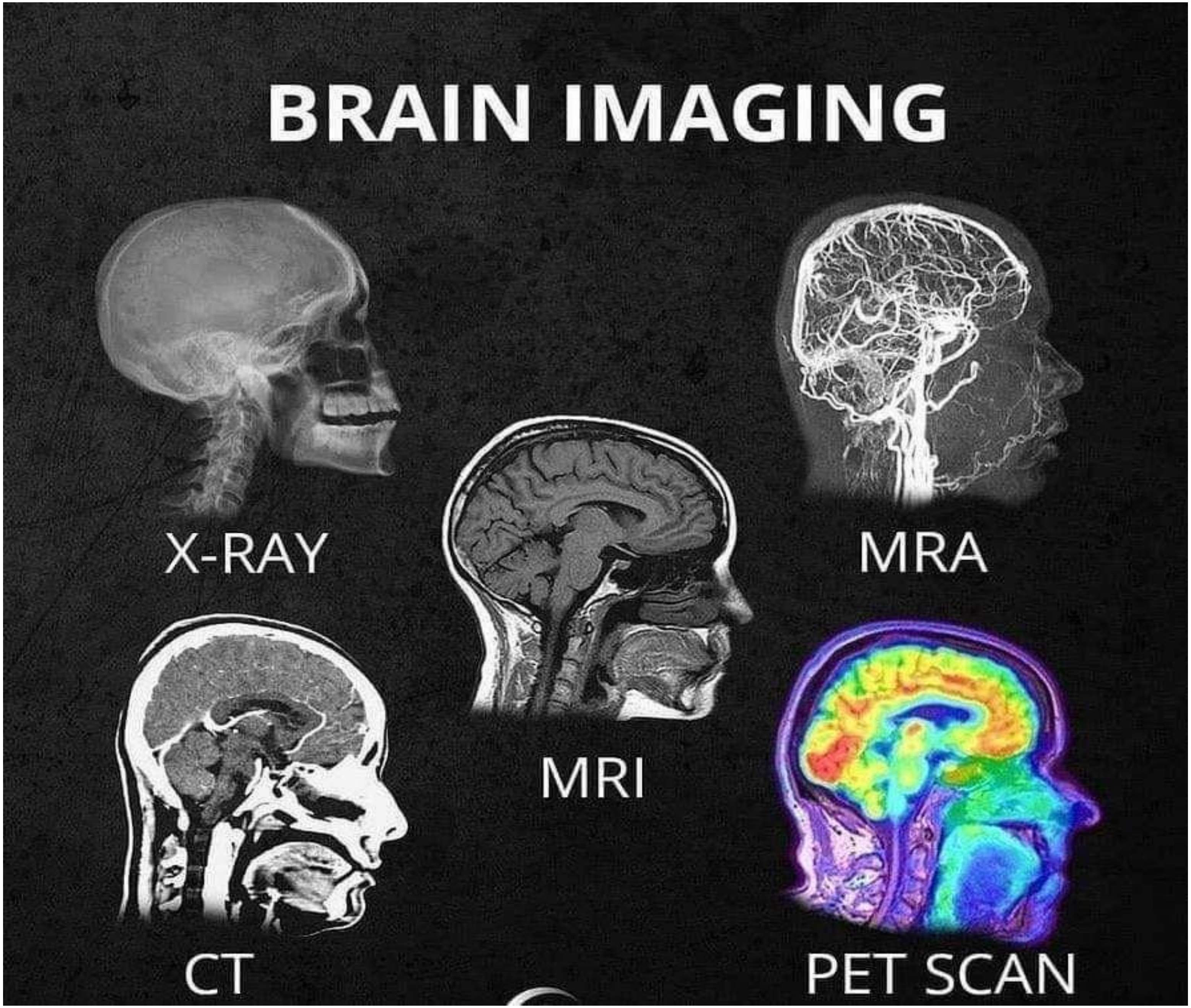
- **Анатомо - структурните промени** на изследваните органи са приоритет на останалите образни методи: конвенционална рентгенология, компютърна рентгенова томография (КТ - СТ), ядрено магнитен резонанс (ЯМР – MRI) - висока разделителна способност и ниска специфичност.

Ro графия

CT

ЯМР



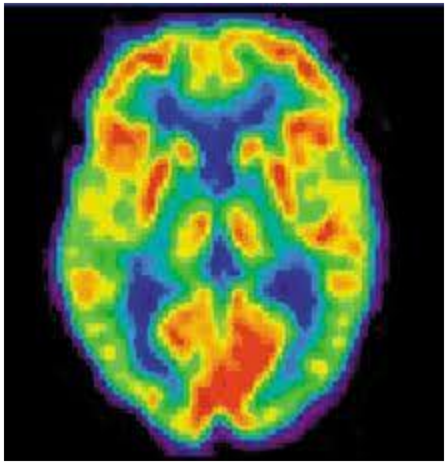

BRAIN IMAGING
X-RAY
MRA
MRI
CT
PET SCAN

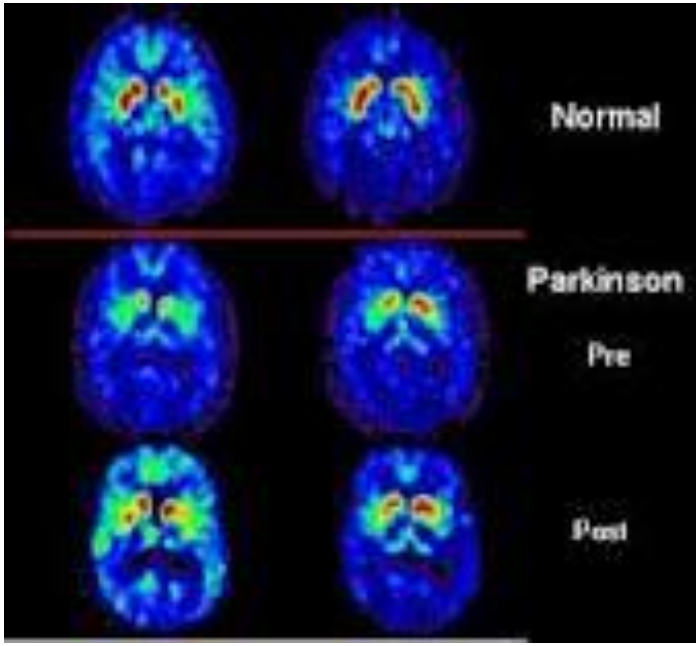
- **Позитронно емисионната томография** (PET) е утвърден метод в нуклеарната медицина с широко приложение в съвременната онкология, позволяващ изследването на **функцията и метаболизма на органите.**

- Това позволява **ранна оценка и диагностика на състоянието на организма, много преди появата на анатомични изменения в даден орган**. Като всяко нуклеарно-медицинско изследване методът е свързан с ***венозно инжектиране*** на **ниски активности радиоактивен материал – радиофармацевтик (185 – 740) MBq - (140μCi/kg).**

- При комбинация на **PET** с компютърна томография ***CT*** (скенер) се получава един изцяло ***нов и съвремен метод за диагностика, наречен позитронно емисионна компютърна томография (PET/CT).***

Конвенционален PET Скенер





Позитронно емисионната томография (ПЕТ)

PET – Positron Emition Tomography

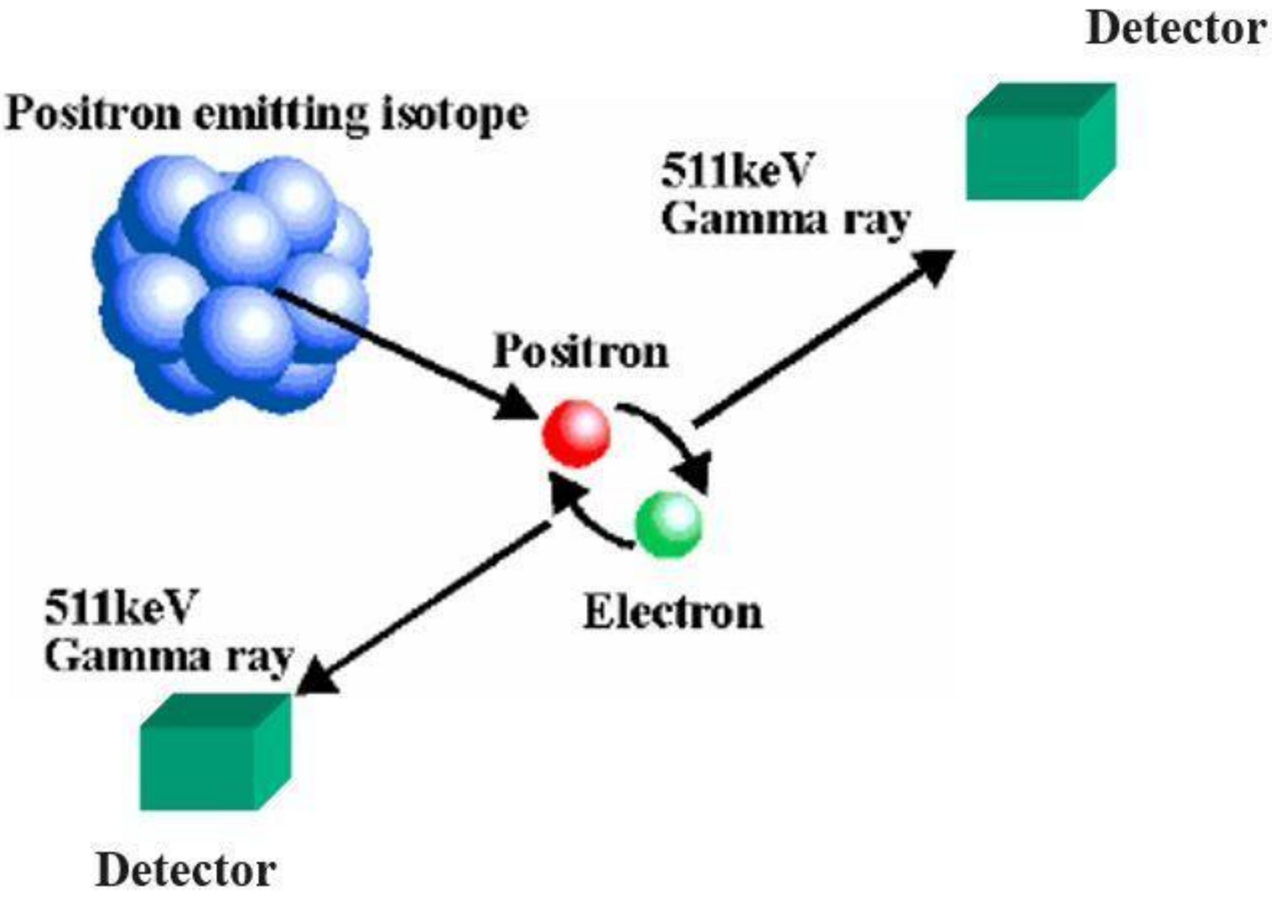
<u>Принцип на действие:</u>

Използва се позитронното лъчение от β^+ превръщането на ^{11}C, ^{13}N, ^{15}O, ^{18}F.

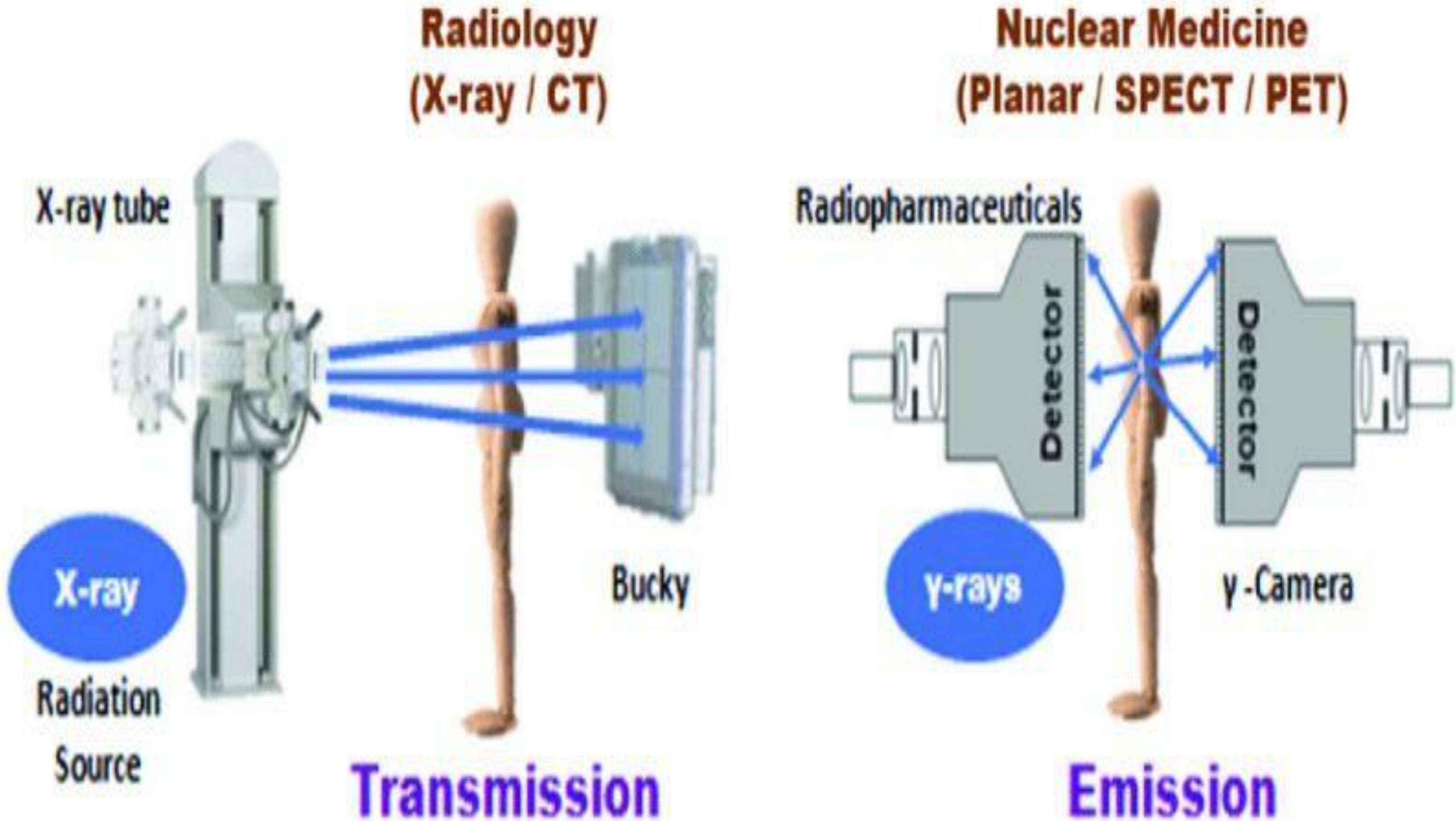
Тези радионуклиди се получават като продукти на ядрени реакции протичащи в ядрени съоръжения – <u>циклотрони</u>.

Анихилационното γ лъчение, получено при взаимодействието на <u>позитроните</u> от радиофармацевтика с <u>електрони</u> от изследваните тъкани се <u>регистрира със сцинтилационни детектори</u>, намиращи се около тялото на пациента.

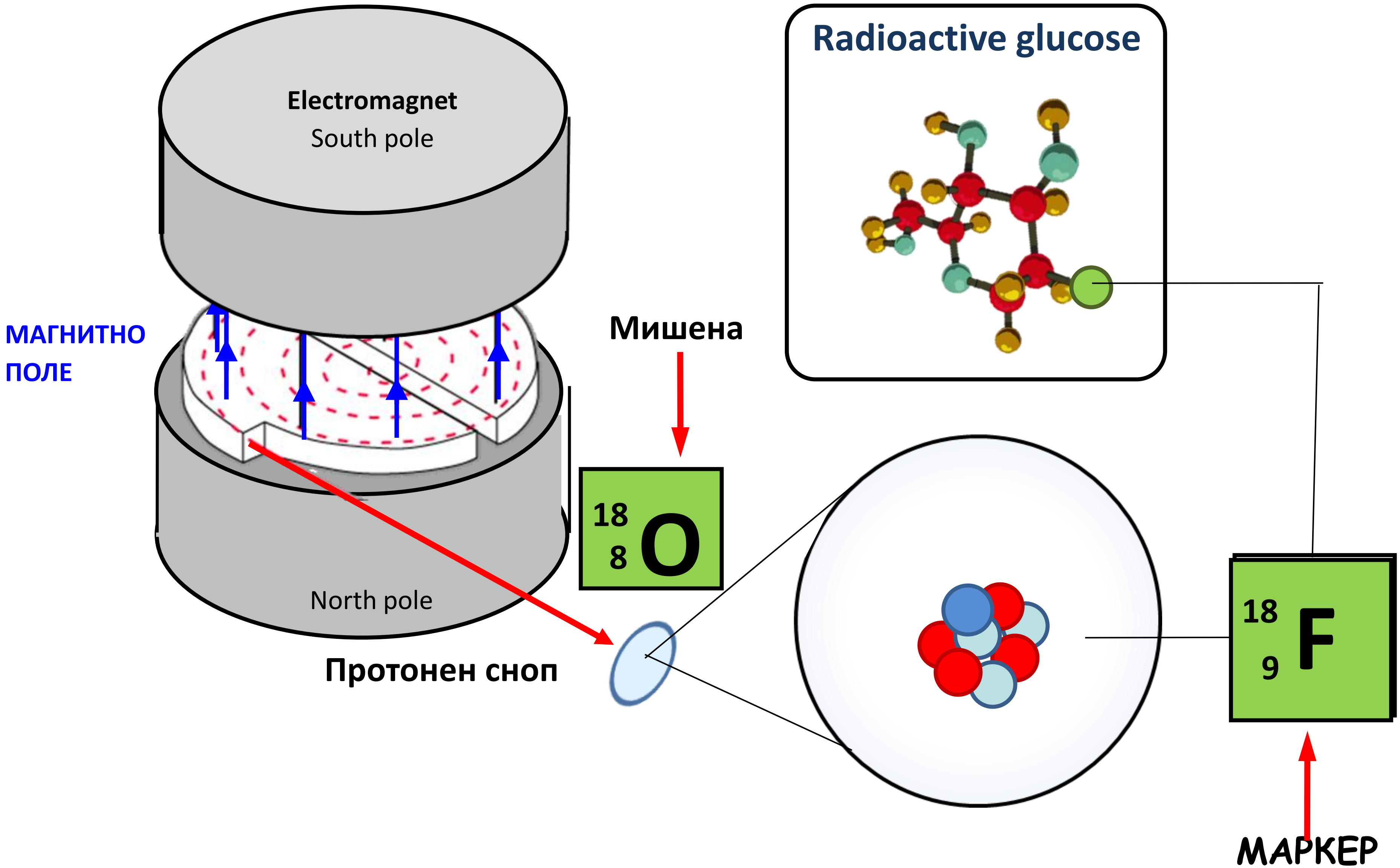
Взаимодействие Positron - Electron



Radiology vs Nuclear Medicine

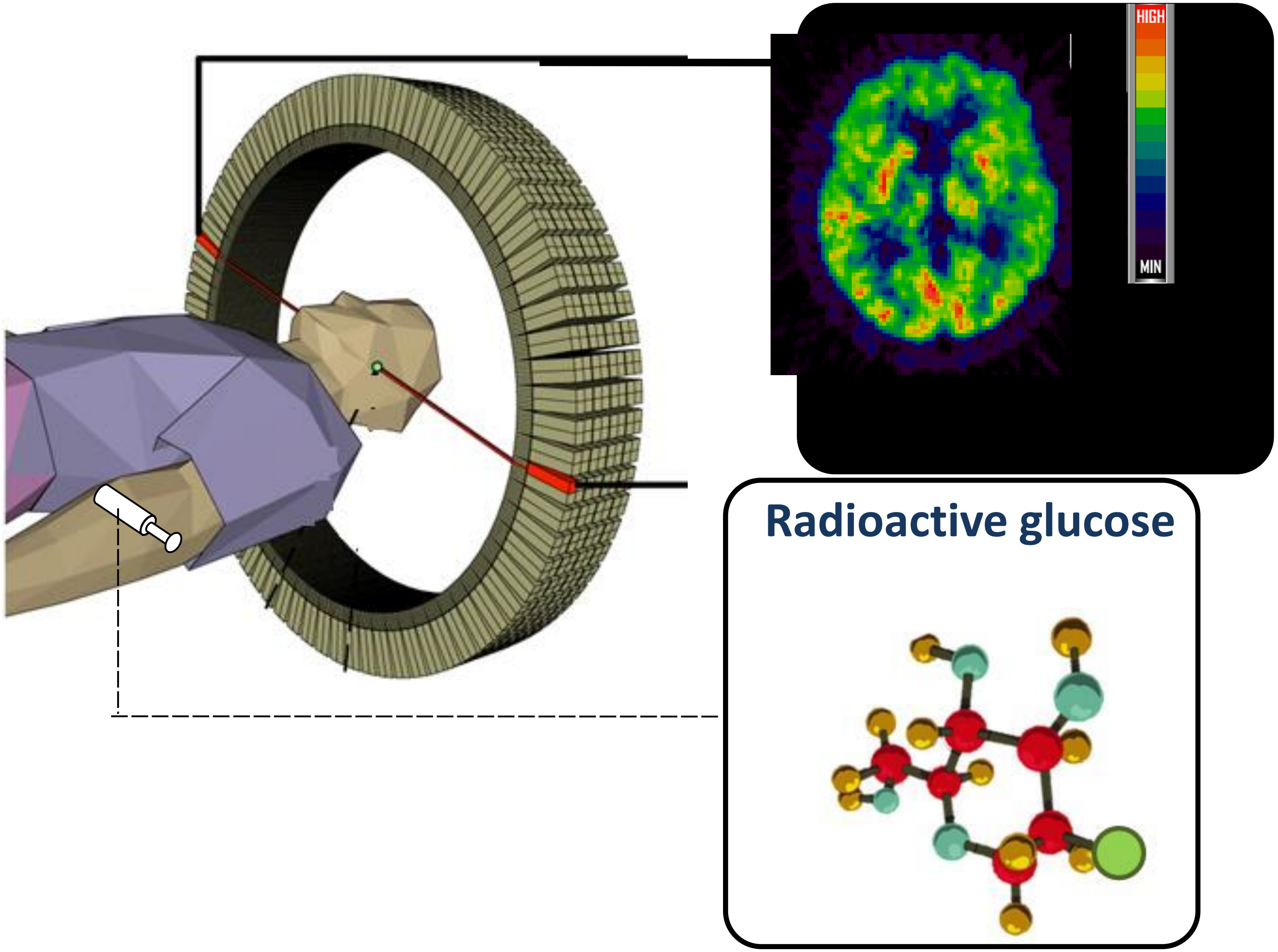


1. Получаване на радиоактивен изотоп (маркер) = радиофармацевтик.



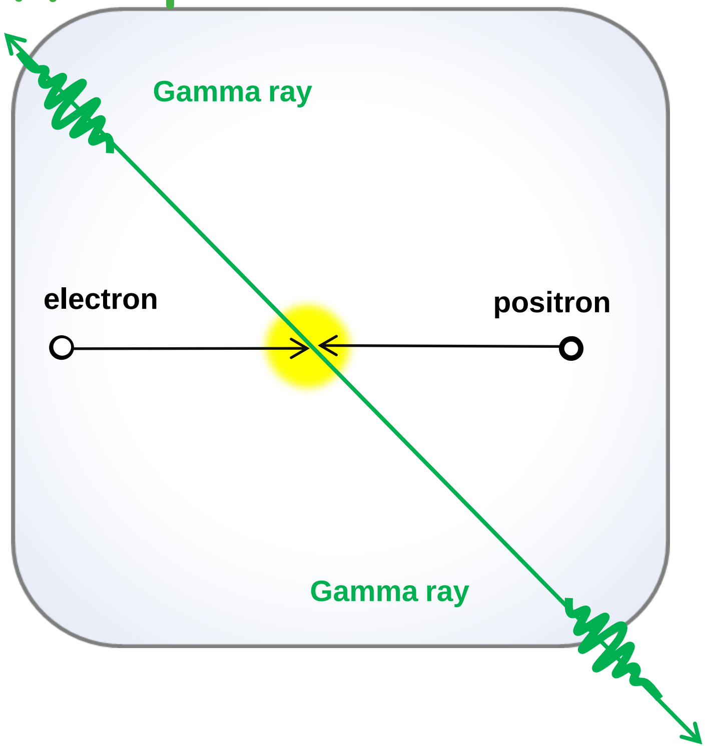
2. Инжектиране на пациента

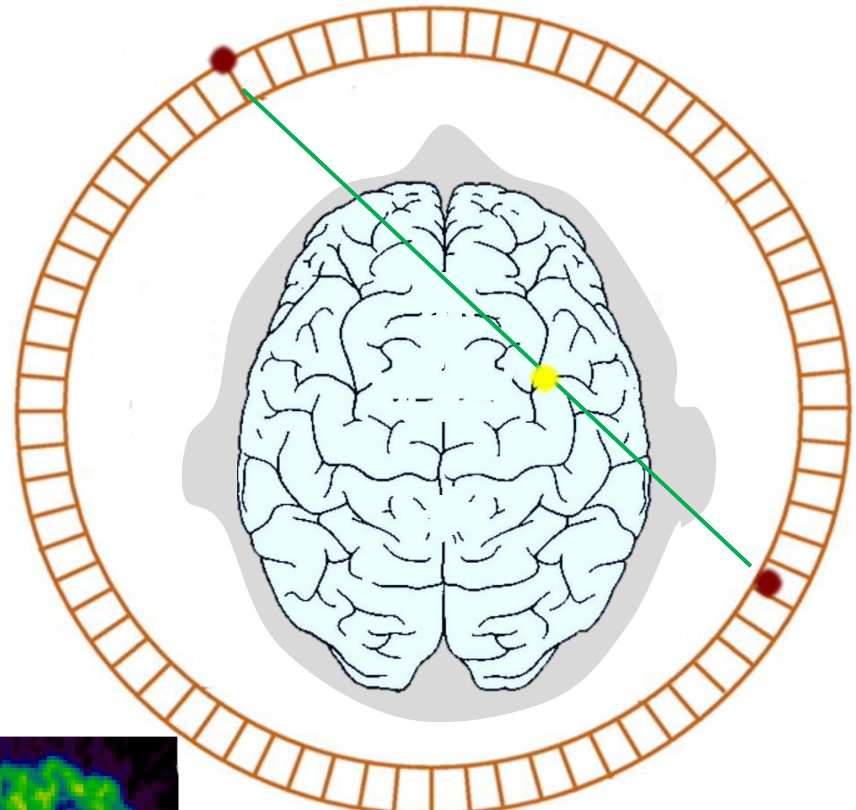
Радиоактивният изотоп се натрупва в тази област на организма, към която маркера има химичен или метаболитен афинитет.

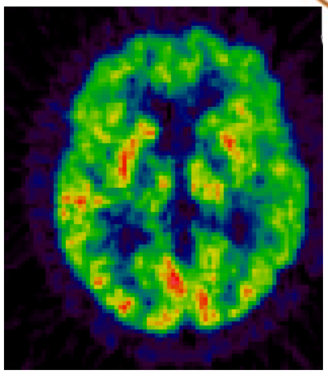


3. Осъществяване на физичното взаимодействие електрон – позитрон.

Два фотона анихилационно гама лъчение

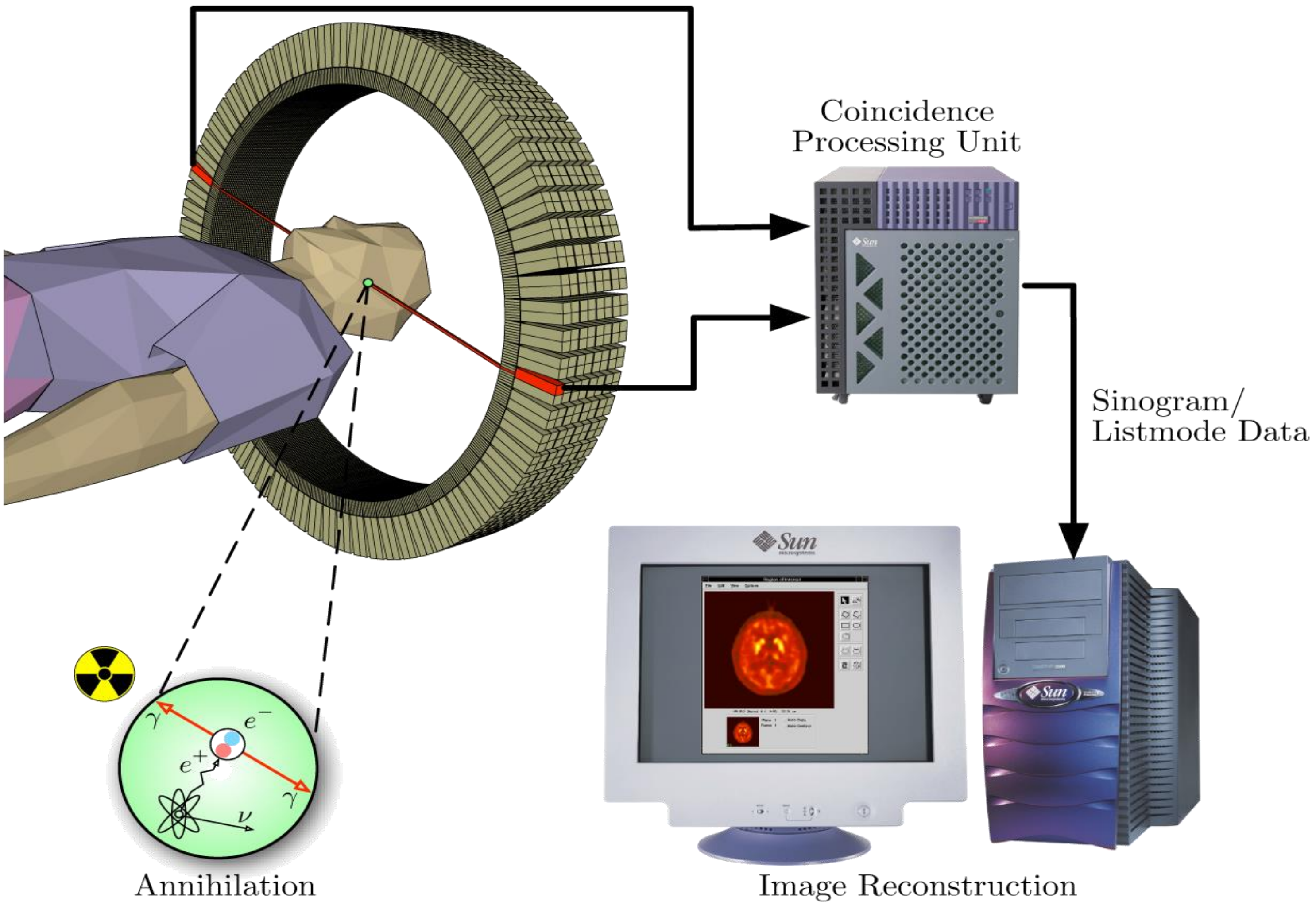






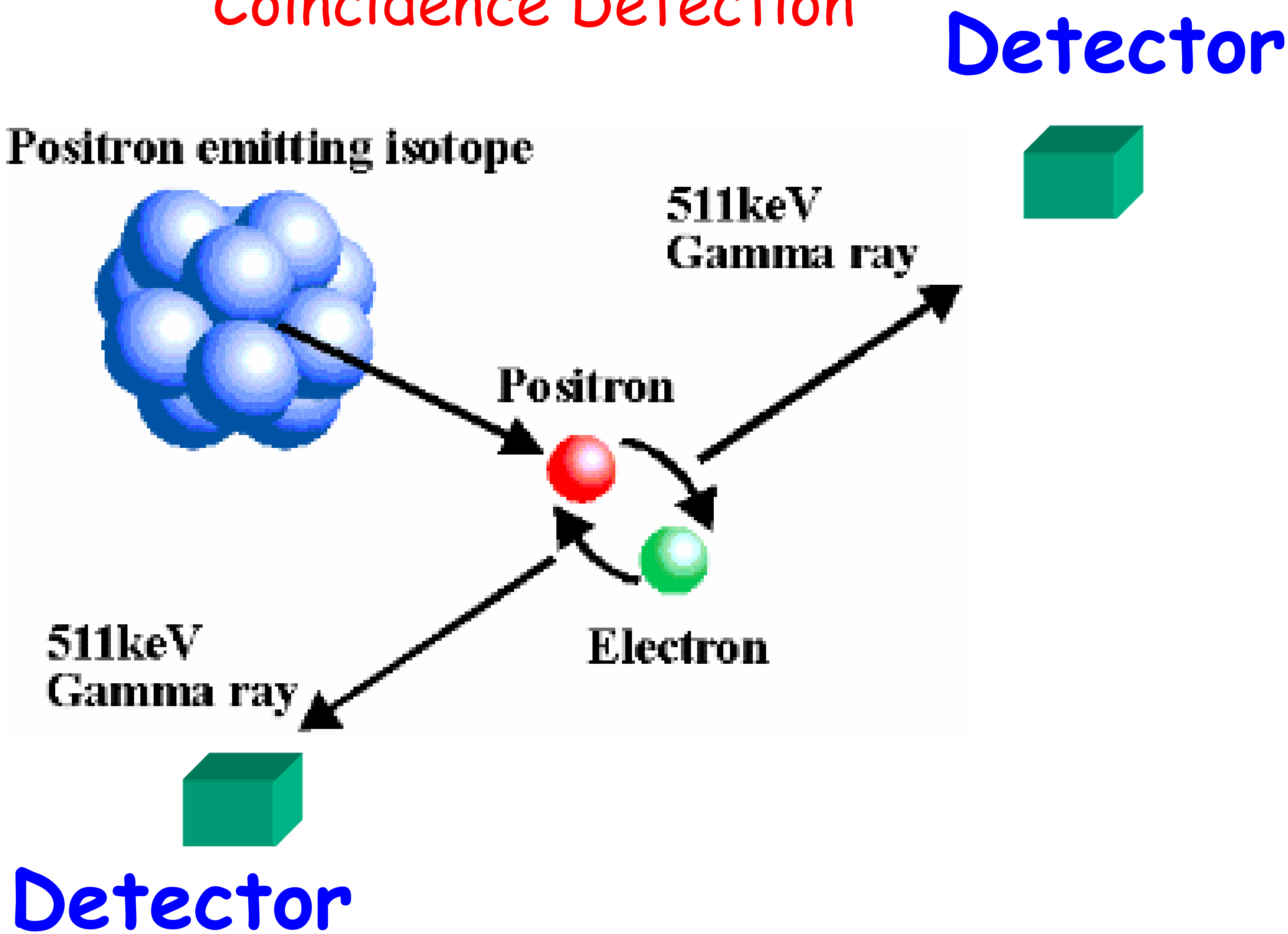
4. Детектиране на анихилационно лъчение.

Дететорите работят в схема на съвпадение



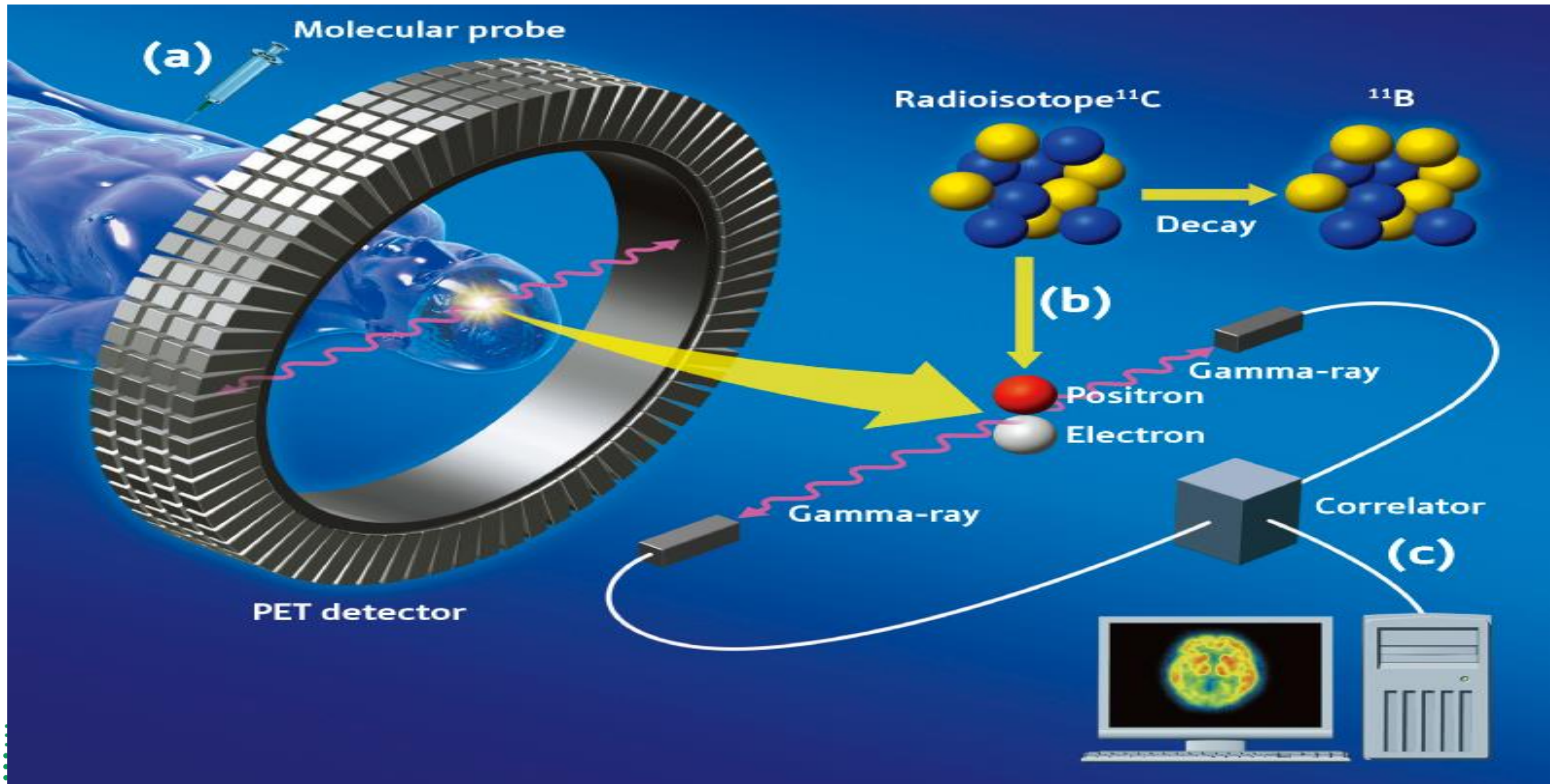
Едновременно Детектиране

Coincidence Detection

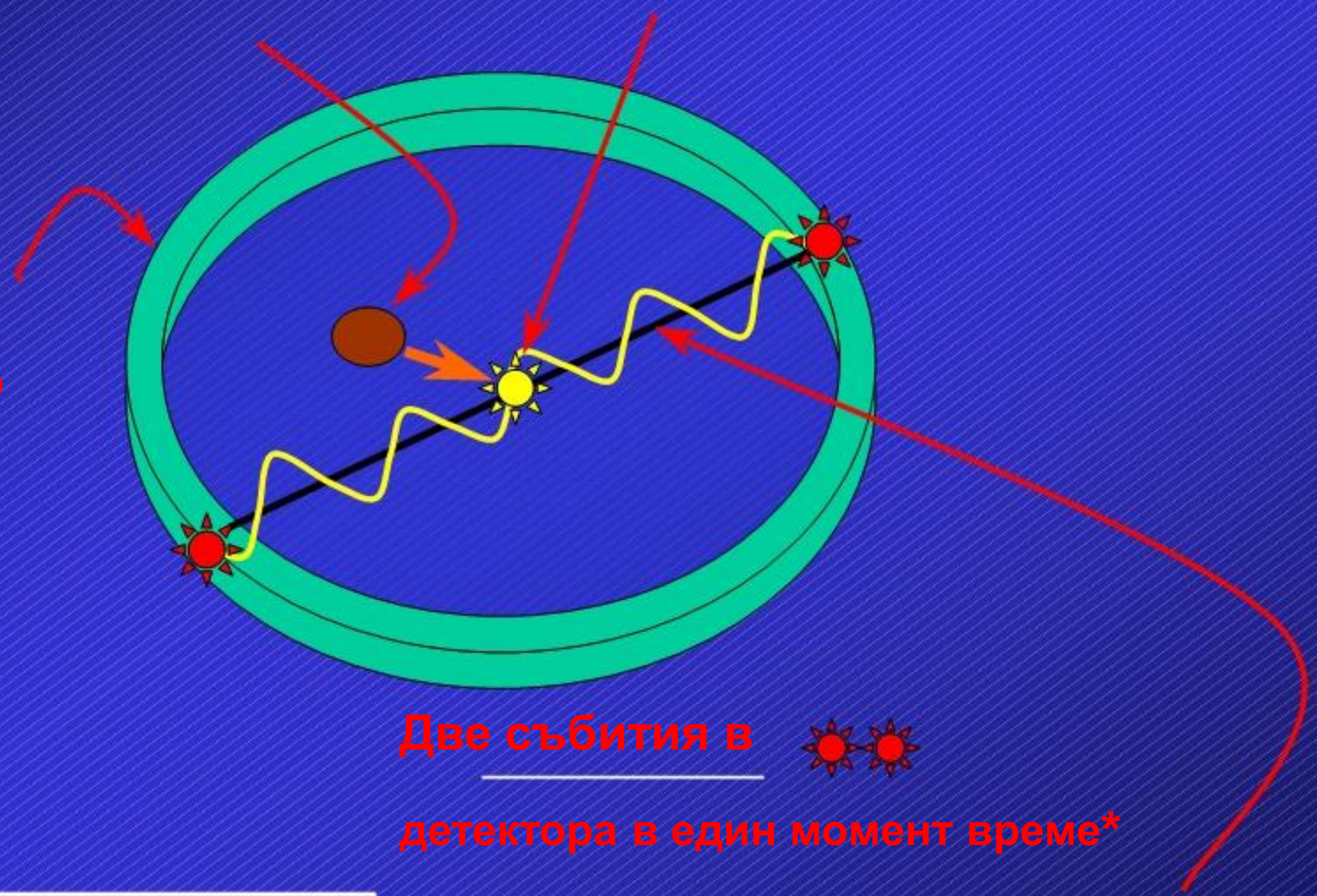


ДЕТЕКТИРАНЕ НА ФОТОНИТЕ ПОЛУЧЕНИ ПРИ АНИХИЛАЦИЯ

Детектира се анихилационно лъчение получавано при взаимодействието на позитроните излъчени от радиофармацефтика, с електрони от изследваните тъкани.



PET - Принцип на детектиране: *Идеален случай*



Две събития в

детектора в един момент време*

Линия на съвпадение

Използва се за реконструкция на образа

***Времеви прозорец 6 – 12 ns**

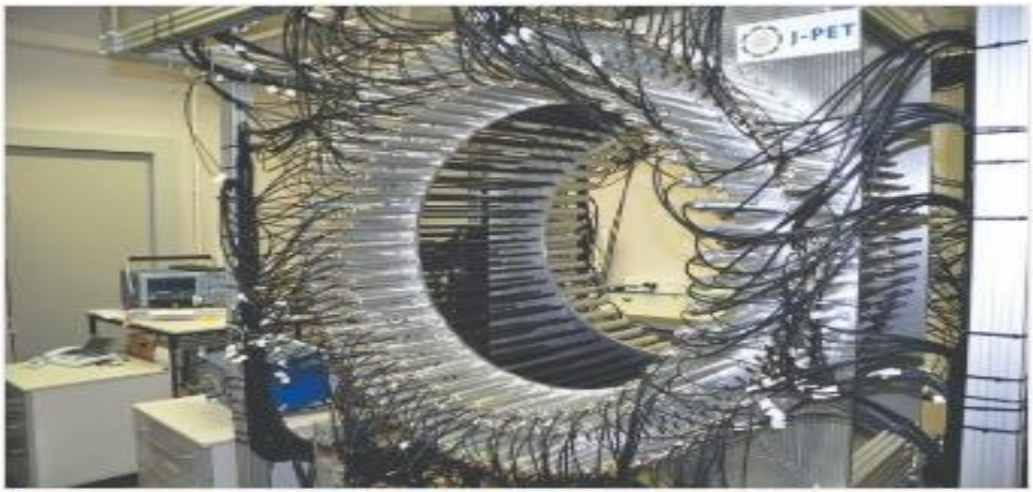
COURIER Reporting on international high energy physics

APPLICATIONS | FEATURE

J-PET's plastic revolution

29 October 2018

A recently developed detector based on inexpensive plastic scintillators paves the way for whole-body PET imaging and precision measurements of fundamental symmetries.



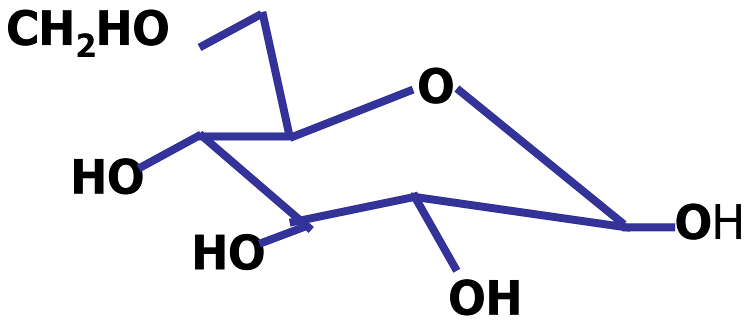
The J-PET detector is made of three cylindrical layers of plastic scintillator strips (black) with photomultiplier tubes at each end. Image credit: M Zieliński

It is some 60 years since the conception of positron emission tomography (PET), which revolutionised the imaging of physiological and biochemical processes. Today, PET scanners are used around the world, in particular providing quantitative and 3D images for early-stage cancer detection and for maximising the effectiveness of radiation therapies. Some of the first PET images were recorded at CERN in the late 1970s, when physicists Alan Jeavons and David Townsend used the technique to image a mouse. While the principle of PET already existed, the detectors and algorithms developed at CERN made a major contribution to its development. Techniques from high-energy physics could now be about to enable another leap in PET technology.

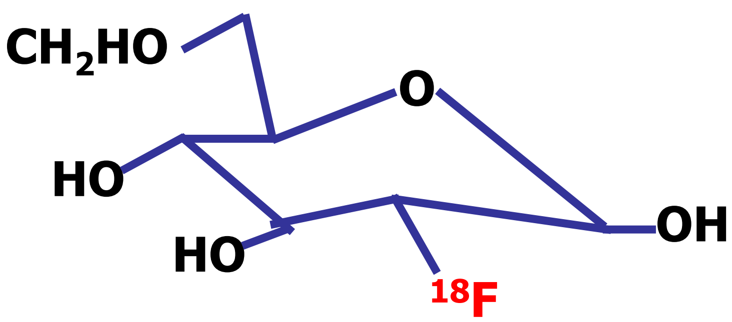
PET Радиофармацевтици

Нуклид	*Период на Полуразпад – T1/2*	*Маркер*	*Приложение*
O-15	**2 min**	**Water**	**Cerebral blood flow**
C-11	**20 min**	**Methionine**	**Tumour protein synthesis**
N-13	**10 min**	**Ammonia**	**Myocardial blood flow**
F-18	**110 min**	**FDG**	**Glucose metabolism**
Ga-68	**68 min**	**DOTANOC**	**Neuroendocrine imaging**
Rb-82	**72 sec**	**Rb-82**	**Myocardial perfusion**

FDG (2-deoxy-2-(F-18) fluro-D-glucose)



glucose



2-deoxy-2-(F-18) fluro-D-glucose

- **Най – широко използвания радиофармацевтик**
- **Аналог на глюкозата**
- **Повечето тумори са със силно повишен глюкозен метаболизъм**

Manufacture of ^{18}F

- **Proton is accelerated**
- **Strikes ^{18}O target**
- **Merges with ^{18}O**
- **Neutron ejected**

$$^{18}_{8}O + ^{1}_{1}p \rightarrow ^{18}_{9}F + ^{1}_{1}n$$

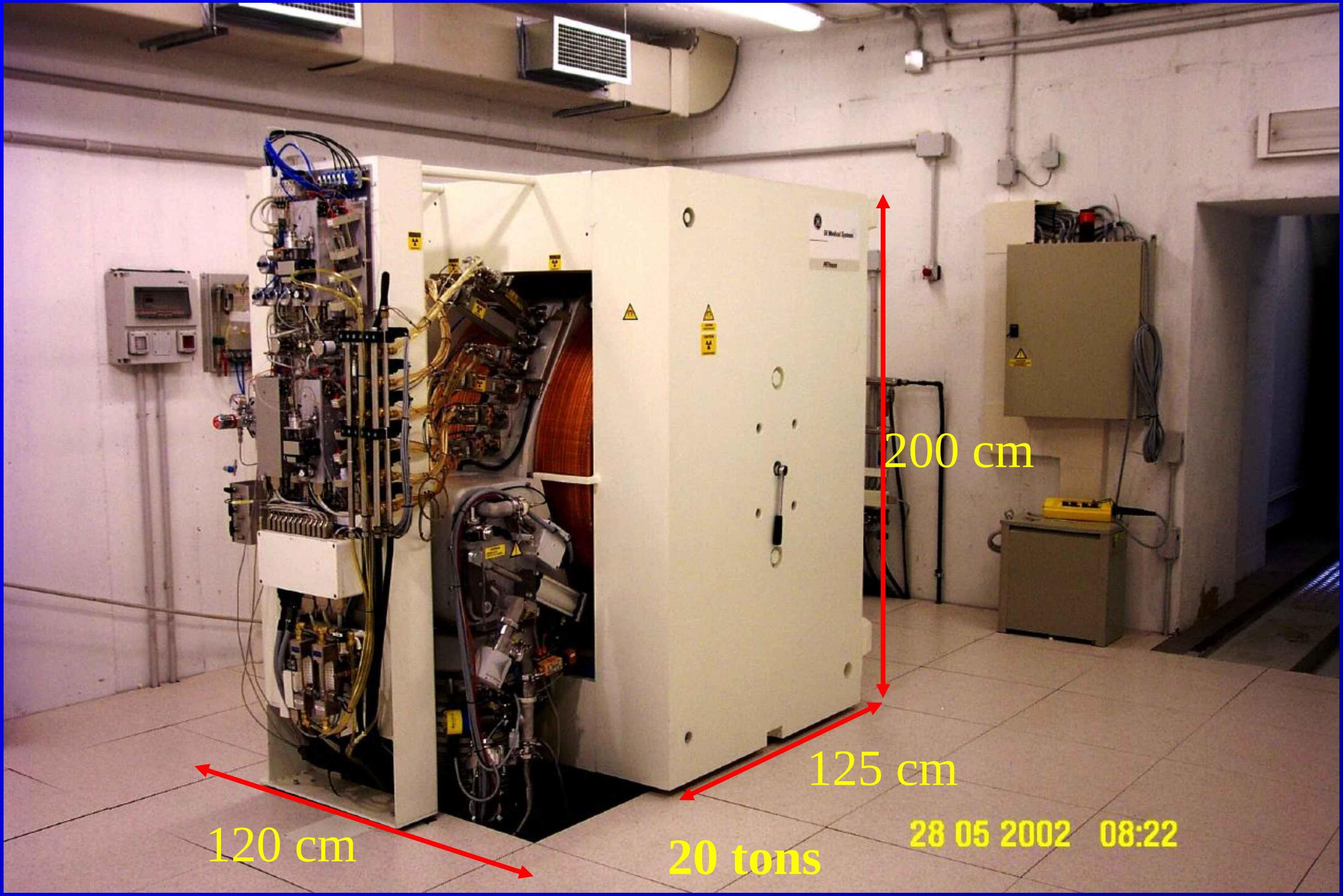
Получаване на FDG

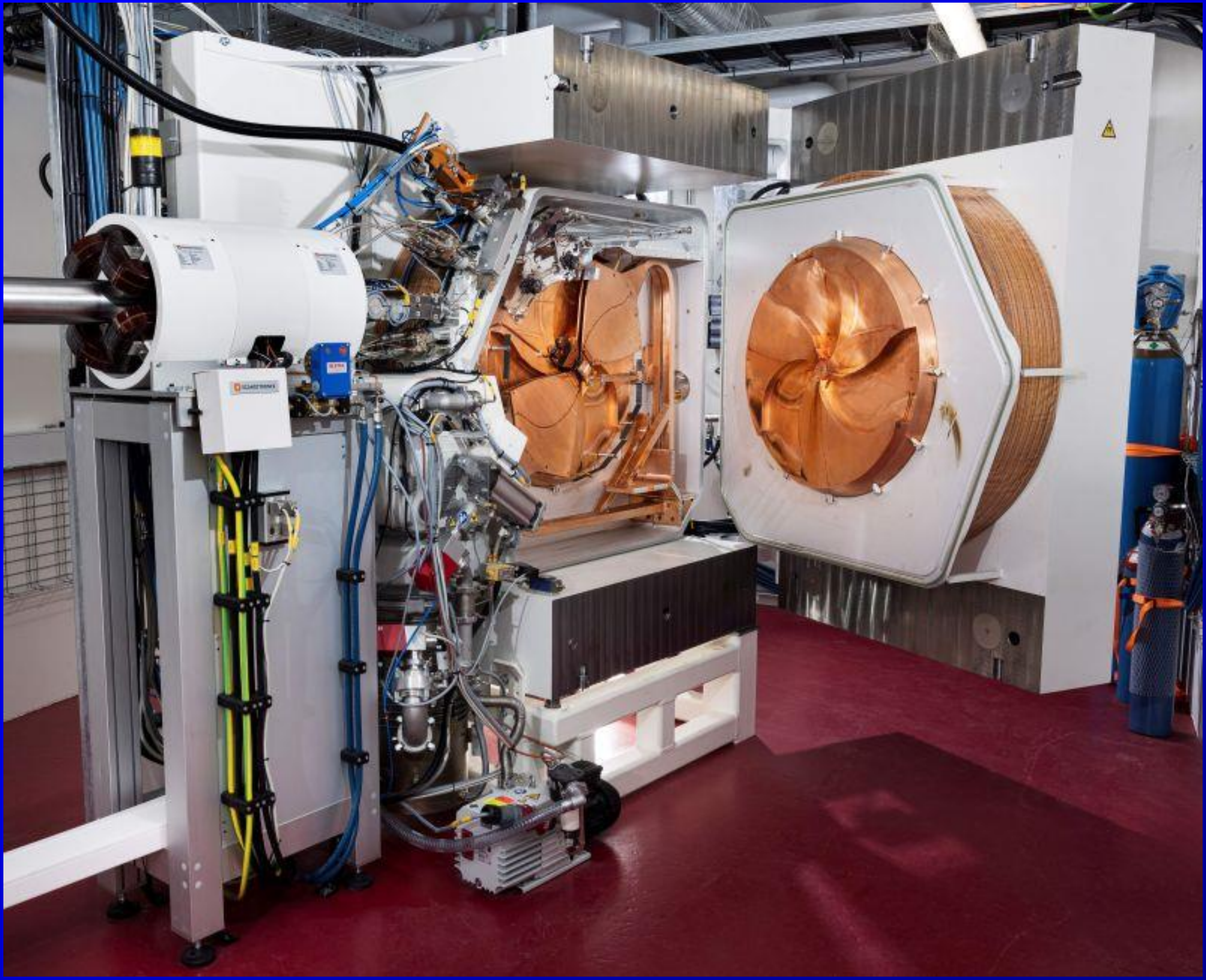
- Бобмардиране на подходяща мишена водеща до получаване на ^{18}F.
- Бомбардирането е около 2 часа (1 T1/2).
- ^{18}F – химичен модул (synthesis module), където се осъществяват реакции с повечето реагенти, така че да се получи fluorinated deoxyglucose – FDG.
- Модул (качествен контрол) на синтезиране обхваща няколко стъпки като нагряване, изстудяване, филтриране, химично пречистване и стерилизиране.

Principal PET radionuclides

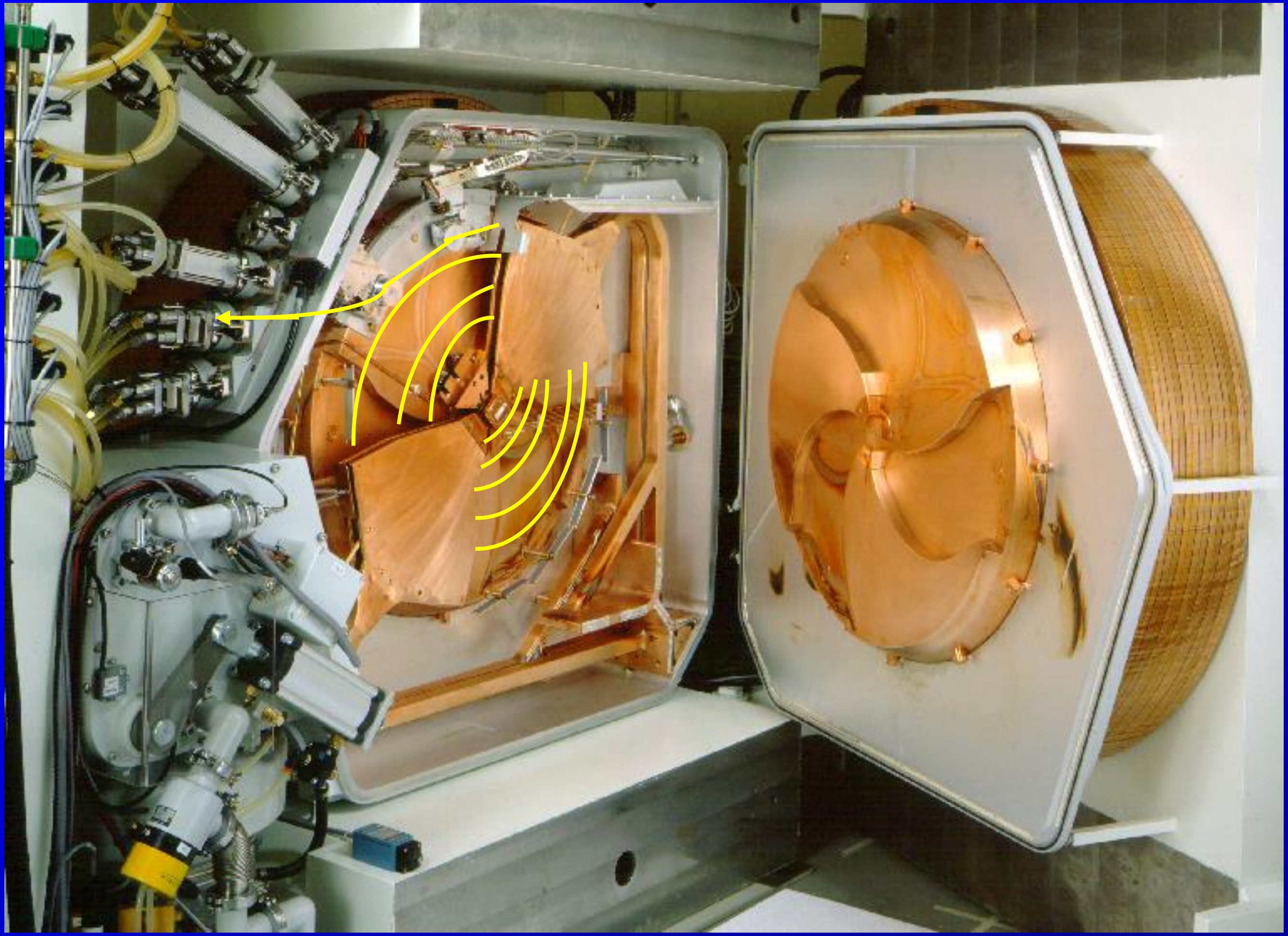
Radionuclide	$T_{1/2}$	Nuclear reaction
Carbon-11	20 min	$^{14}N(p,\alpha)^{11}C$
Nytrogen-13	10 min	$^{16}O(p,\alpha)^{13}N$
Oxygen-15	2 min	$^{14}N(d,n)^{15}O$
Fluorine-18 ($^{18}F^-$)	**110 min**	**$^{18}O(p,n)^{18}F$**
Fluorine-18 ($^{18}F_2$)	110 min	$^{20}Ne(d,\alpha)^{18}F$

The PETtrace cyclotron





Beam acceleration



6. 18 F target

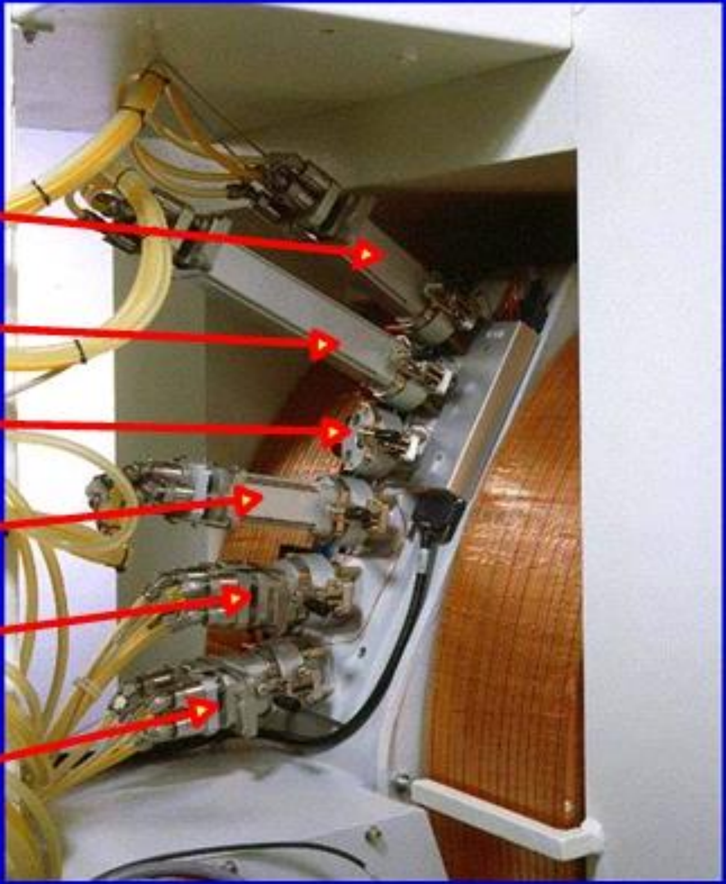
5. 11 C target

4. 18 F target

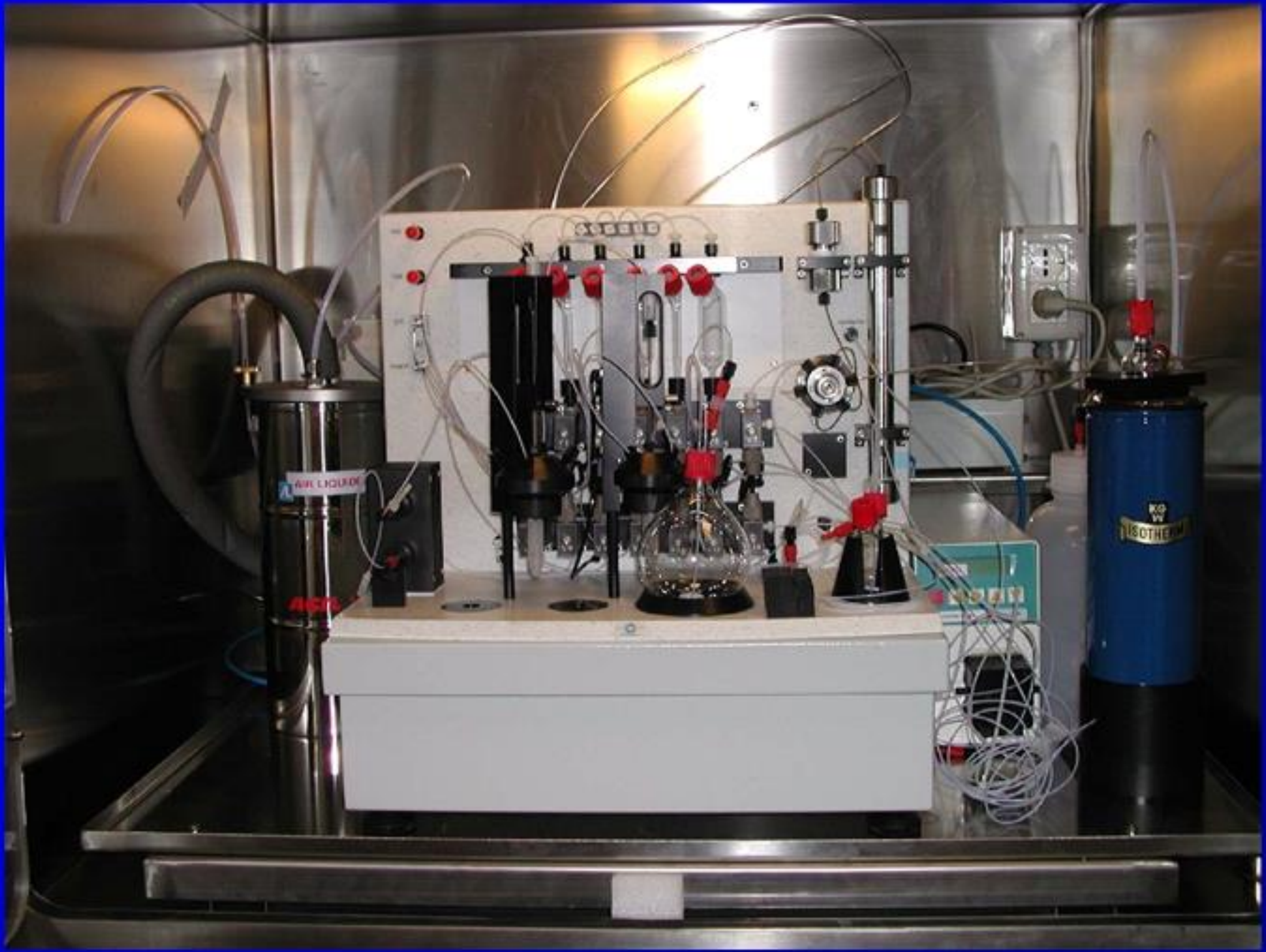
3. 15 O target

2. 13 N target

1. 18 F target



МОДУЛ - СИНТЕЗ

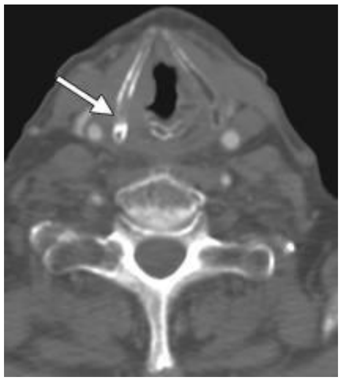


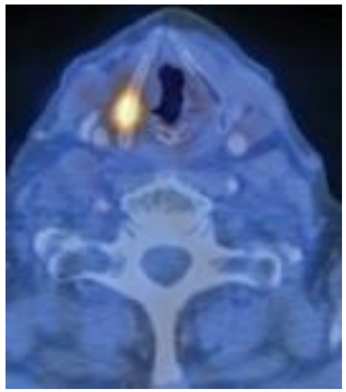
РАДИОХИМИЧНА ЛАБОРАТОРИЯ

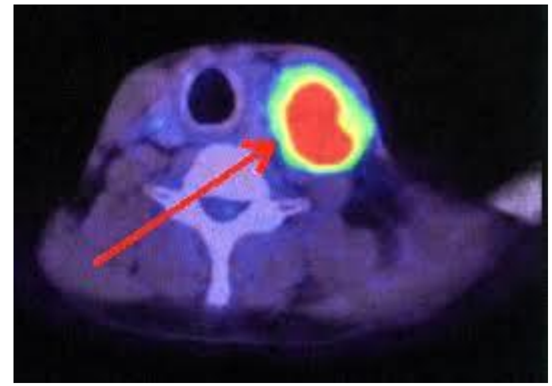
Routine work cycle at the PET centre in Bologna

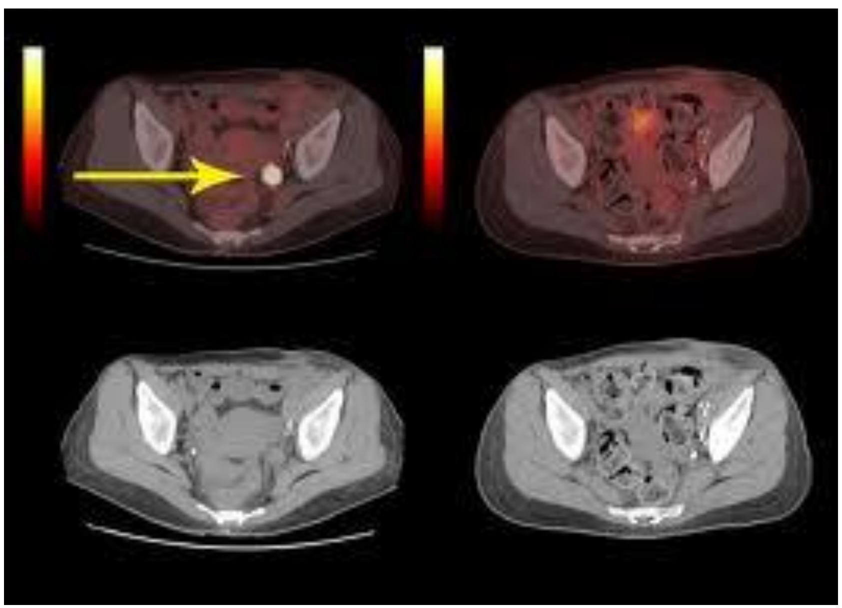
- 5.30: start; environmental and operational tests (temp, gases, voltage …)
- 5.45: pre irradiation of 18F target with H2O16
- 6.00: activity bolus delivered to a research hot cell; test of production; rinse & drying
- 6.00: start testing and loading 18F-FDG module
- 6.10: start of first 18F- production
- 6.15: preparing the vials dispensing unit
- 6.30 – 7.00: checking of cyclotron parameters
- 7.00: preparation of the insulator for unit dose dispensing
- 7.00: start preparation of the QC equipment
- 7.30: first irradiation is almost ready; final check of all systems
- 7.30: start preparation of the 11C module for Choline / Methionine
- 7.45: end of first bombardment and delivery of activity to the 18F-FDG module
- 7.50: rinse the 18F-target; start 18F-FDG synthesis
- 7.50: preparation of the 11C target
- 8.00: start 11C bombardment
- 8.15: end of 18F-FDG synthesis; start of sterilization and vials dispensing
- 8.30: delivery of 11C to synthesis module; start of Choline / Methionine synthesis
- 8.40: first vial of 18F-FDG ready; taken sample for QC
- 8.55: 18F-FDG QC completed; first patient dose dispensed
- 8.55: end of 11C Choline / Methione synthesis; sterilization
- 9.00: 11C Choline / Methione sample for QC
- 9.15: 11C Choline / Methionine QC completed; first patient dose dispensed

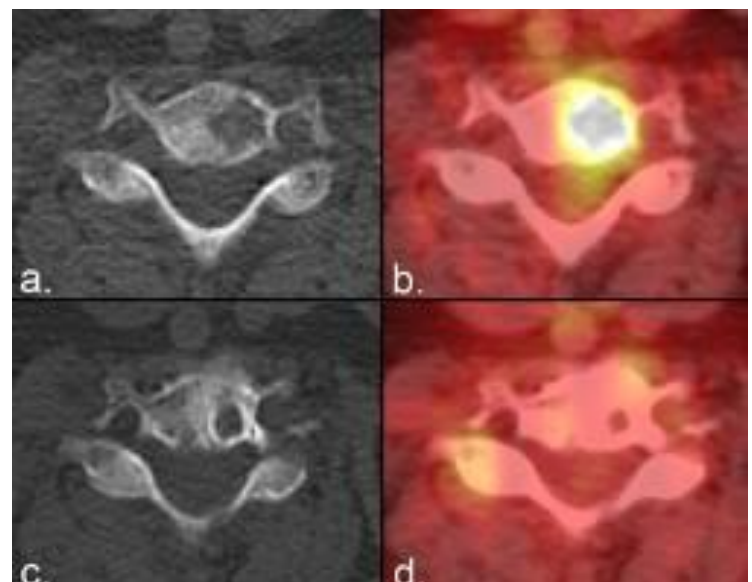
- Получените сигнали се обработват от софтуер ***(алгоритъм “обратна проекция”)***, в резултат се получава **образ изобразяващ локализацията и концентрацията на съответния радиофармацефтик, източник на позитрони в изследвания орган.**



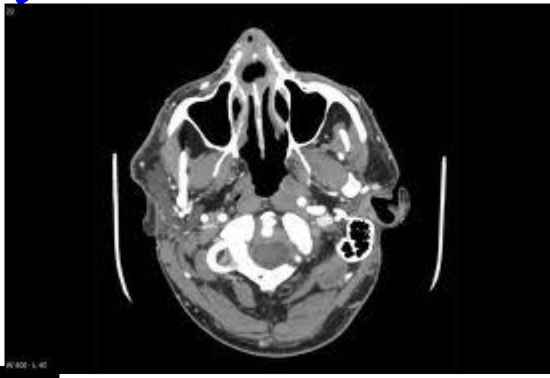


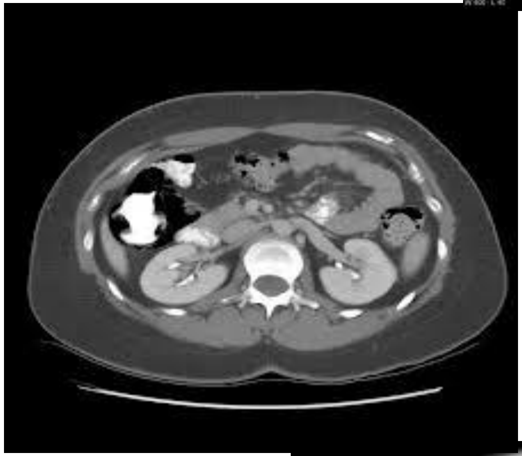




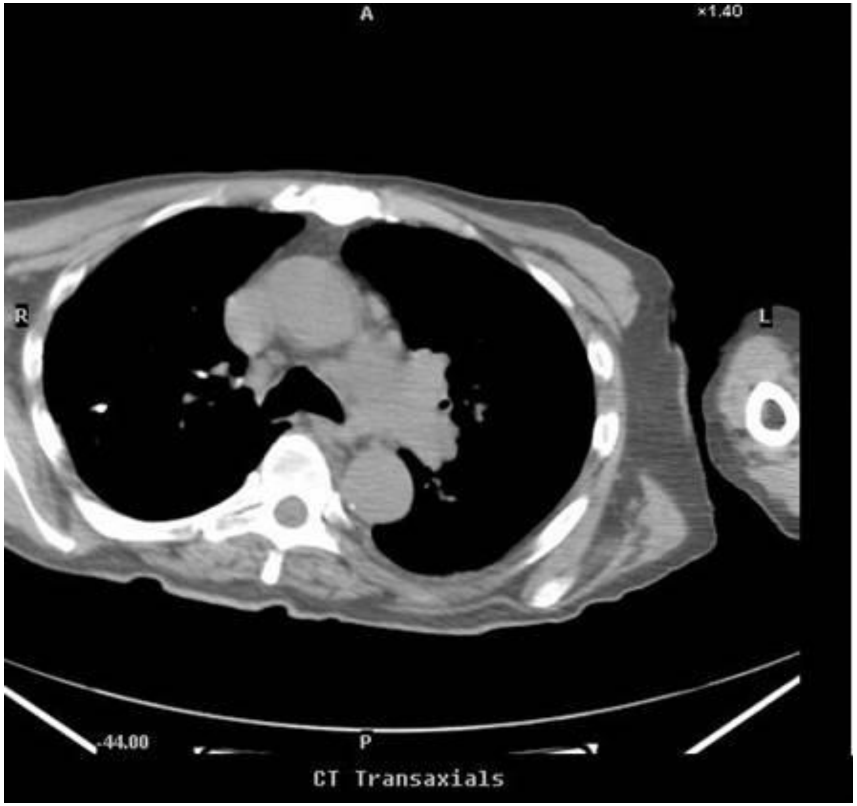


Рентгенова Компютърна Томография
Computer Tomography (CT)



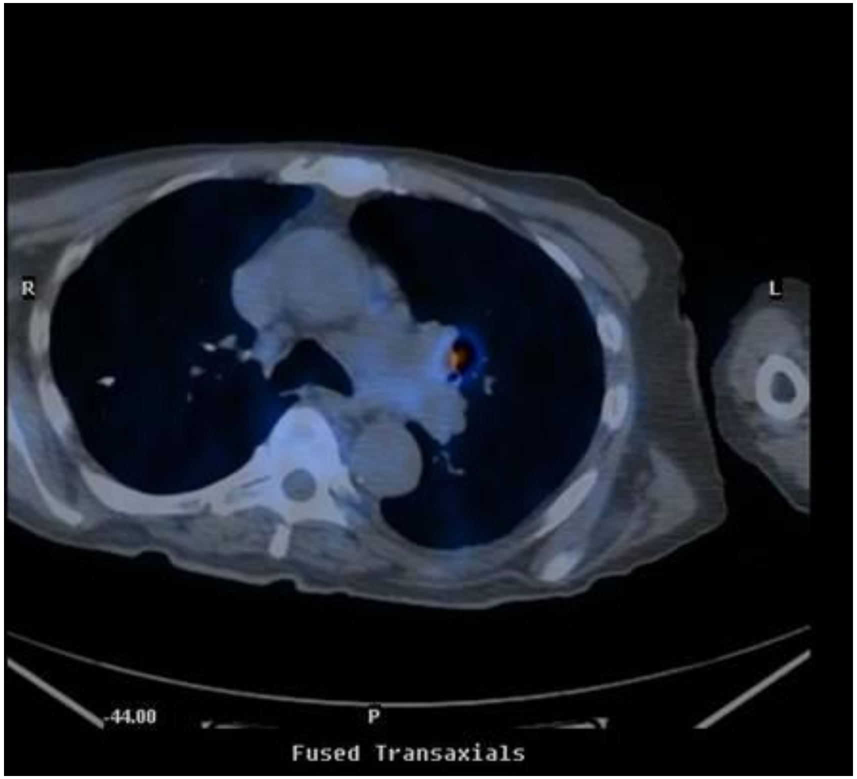


Рентгенова Компютърна Томография/ X-ray Computed Tomography- CT



- Анатомична структура
- По - добра резолюция от PET
- Добра разлика между костна и мека тъкан
- **<u>Не може да диференцира активността на заболяванията</u>**

PET/CT Томография



- Комбиниране на функционалната информация с анатомичните детайли.
- Точна анатомична регистрация.
- Висока диагностична точност спрямо PET или CT използвани по отделно.

PET/CT Scanner

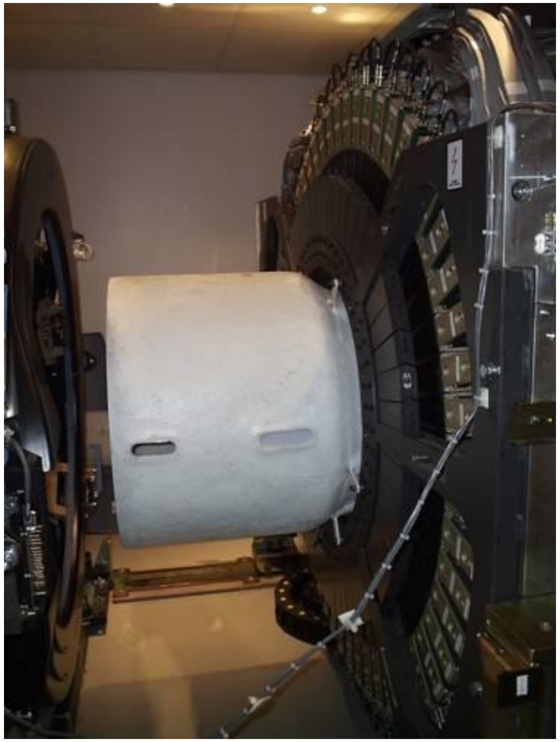
CT unit

PET scanner

PET/CT – Хибриден апарат - физичен принцип на действие

PET & CT в едно гентри

CT

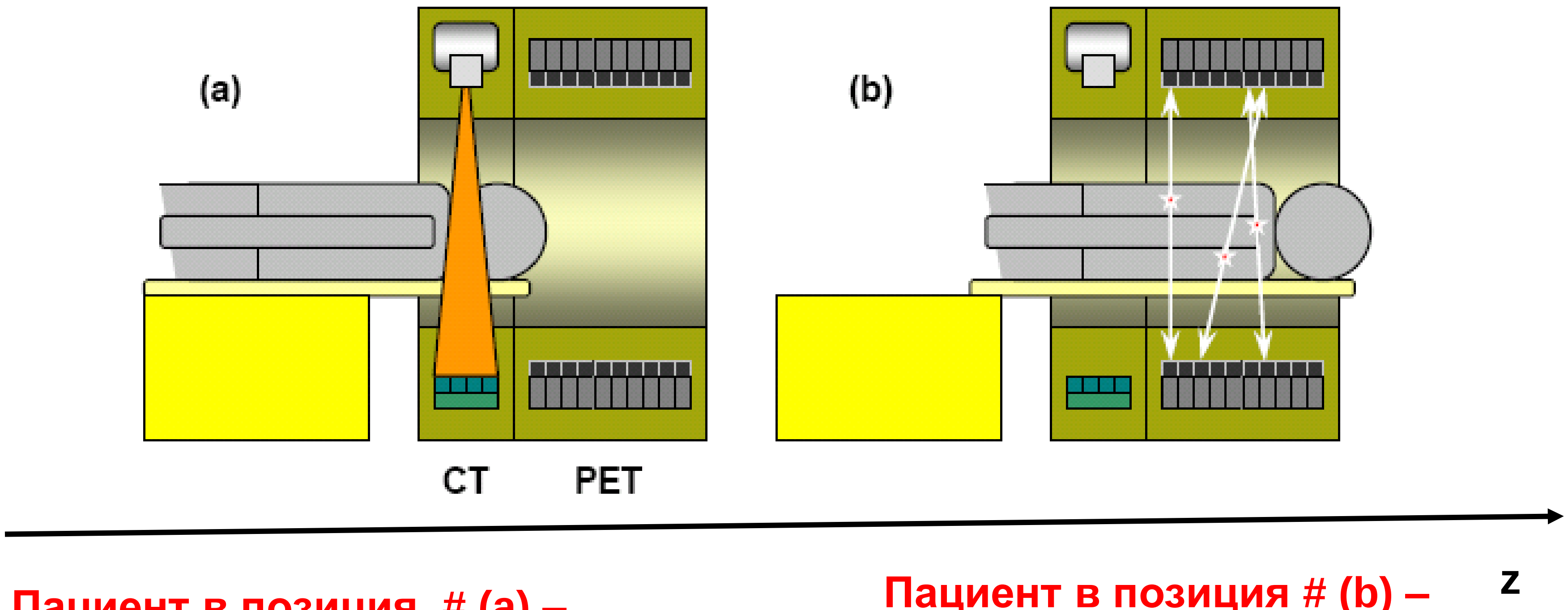


PET

2000г. – д-р David Townsed патентова техническото изобретение

2003г. – BIDMC е първата болница в Massachusetts, USA инсталирала PET/CT

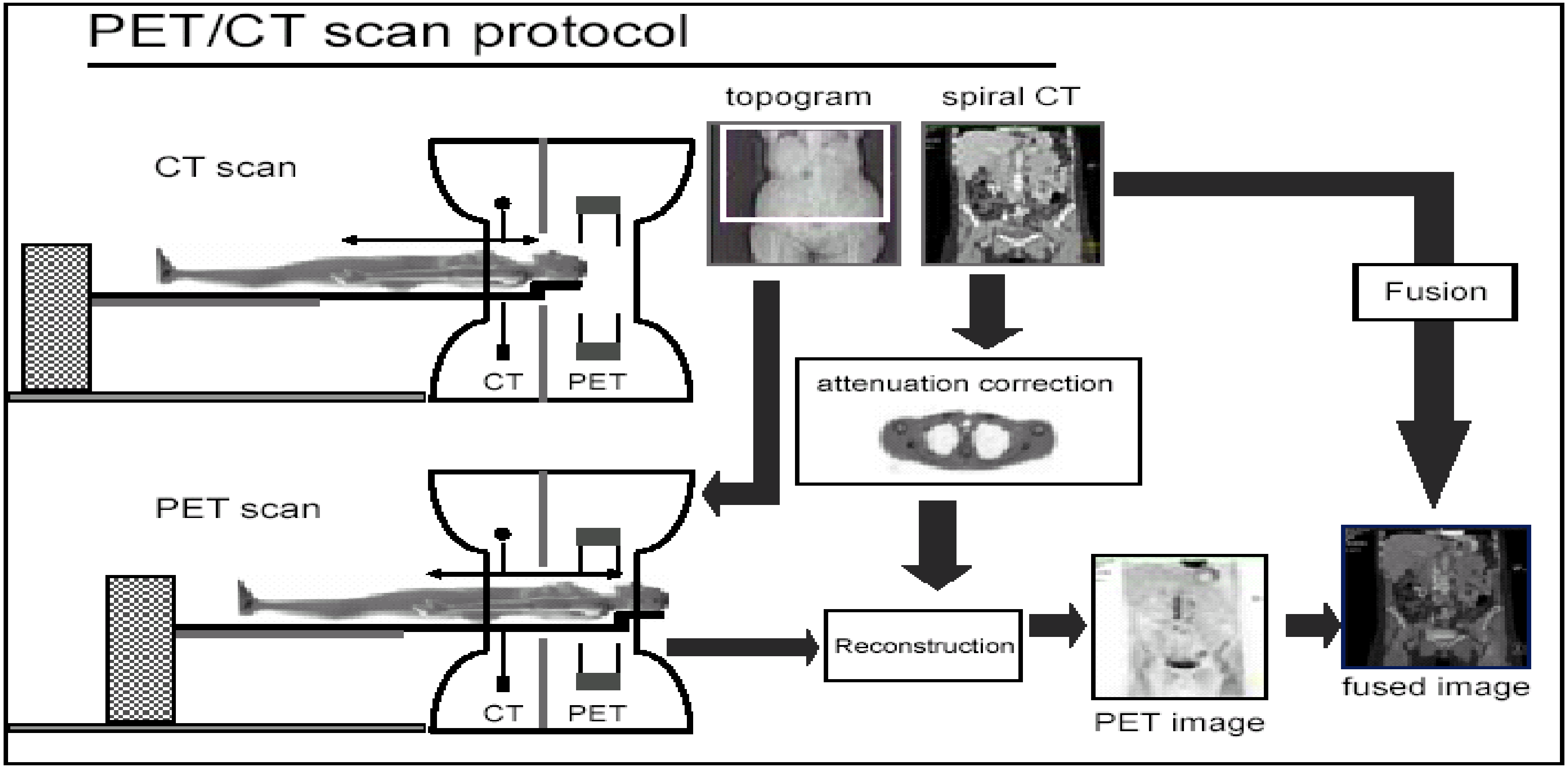
PET/CT Изследване



Пациент в позиция # (a) – CT

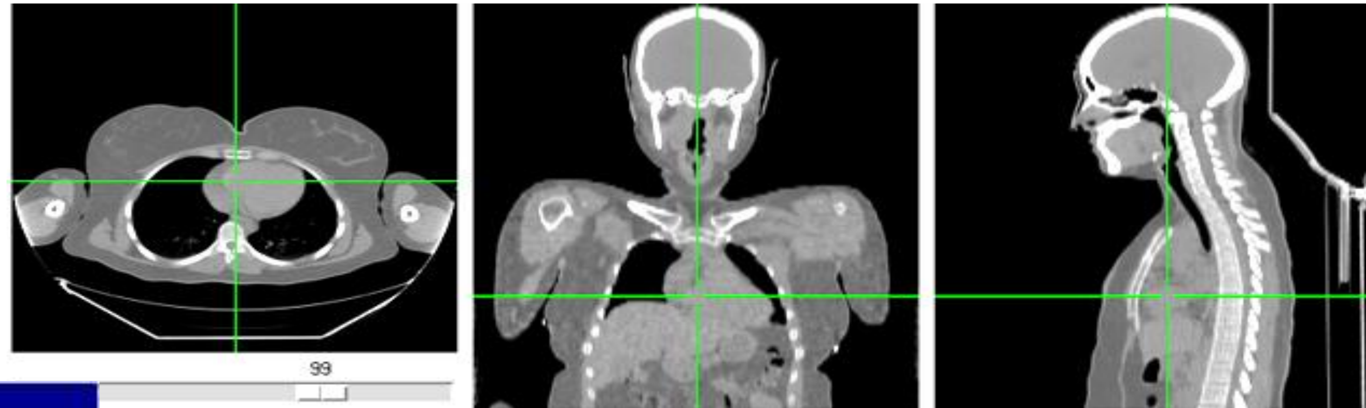
Пациент в позиция # (b) – PET

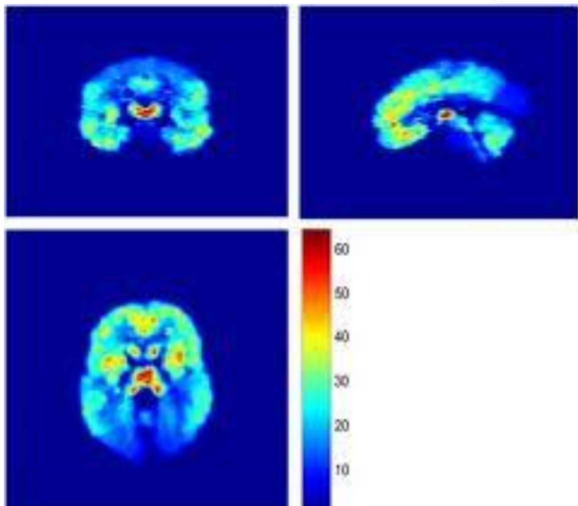
Двете изследвания се извършват последователно във времето.
Пациентът не се движи по време на двете изследвания.
Пациентната маса се придвижва по оста Z, по дефинирана и контролирана посока.
Като резултат образите от CT и PET се наслагват и се получава обединен образ от проведеното изследване.



Компютърният Томограф (СТ) при РЕТ/СТ се прилага за **корекция на отслабването на γ лъчението** и като **анатомична матрица за изобразяване на точната локализация** на ***функционално променените*** *патологични огнища, злокачествени тумори и техните метастази.*

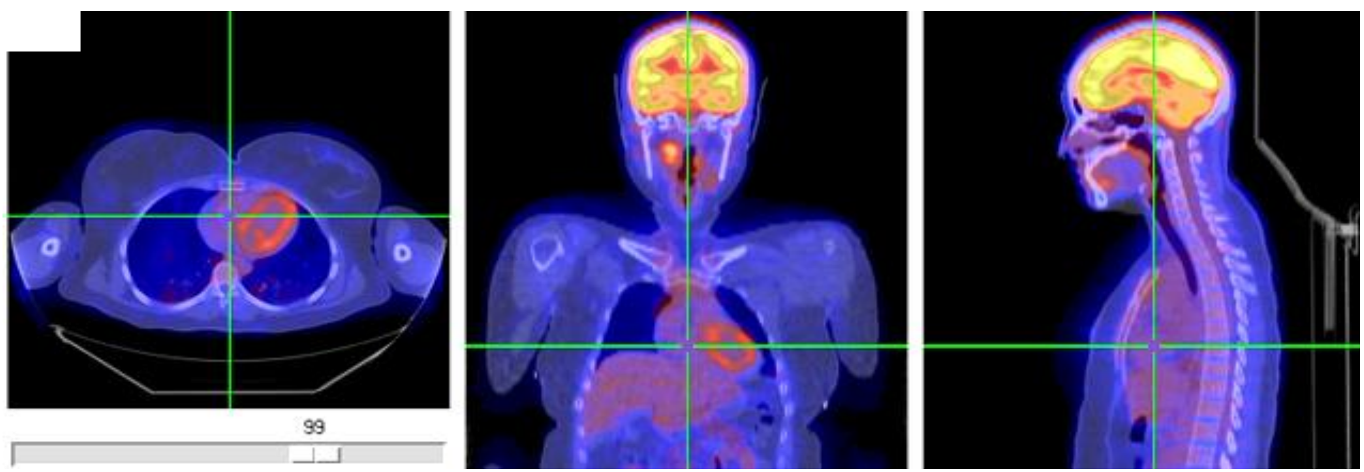
CT образи





PET образи

PET/CT образи

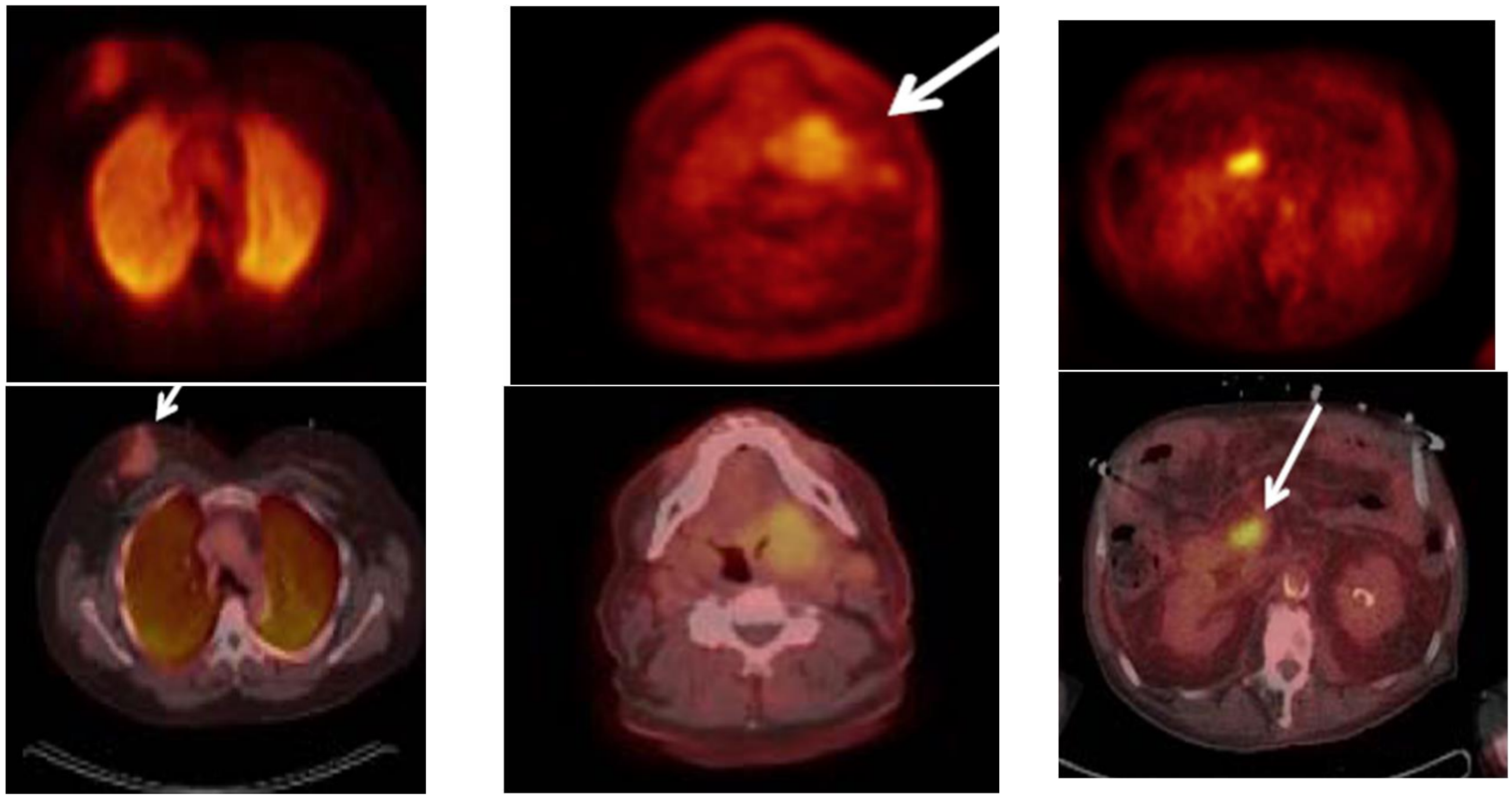


ОБРАЗИ НА РАЗЛИЧНИ ЧАСТИ ОТ ЧОВЕШКОТО ТЯЛО

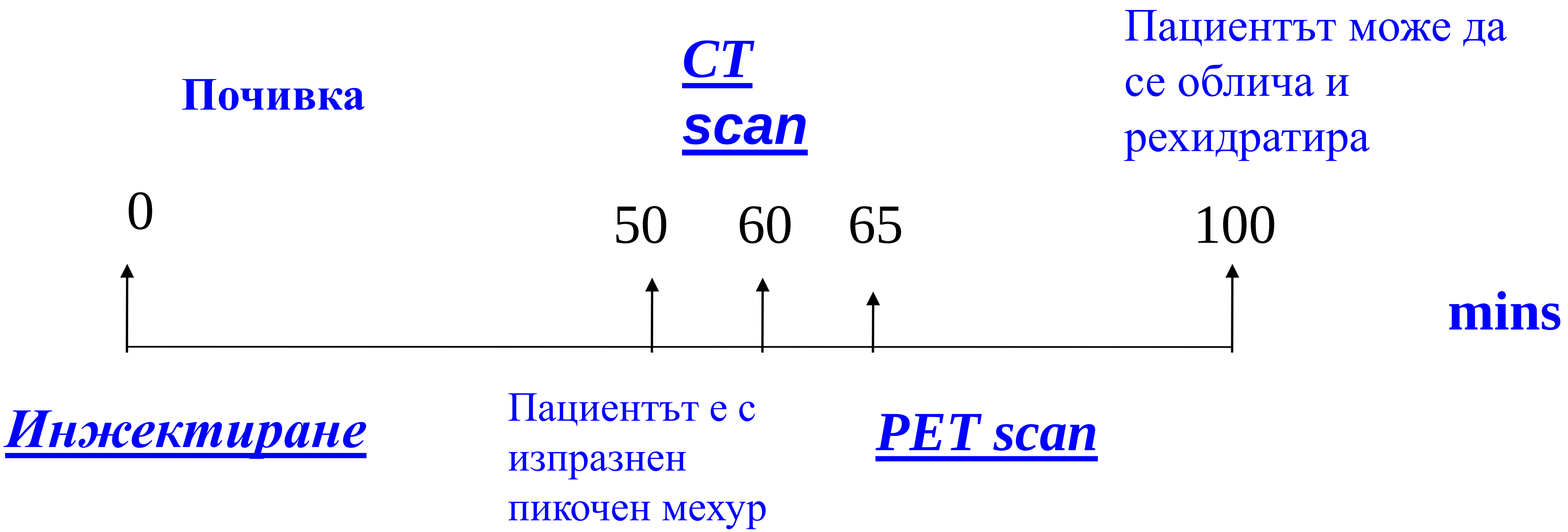
РМЖ | **Глава и Шия** | **Лимфом**

PET

PET/CT



Необходимо време за изследване на Пациент



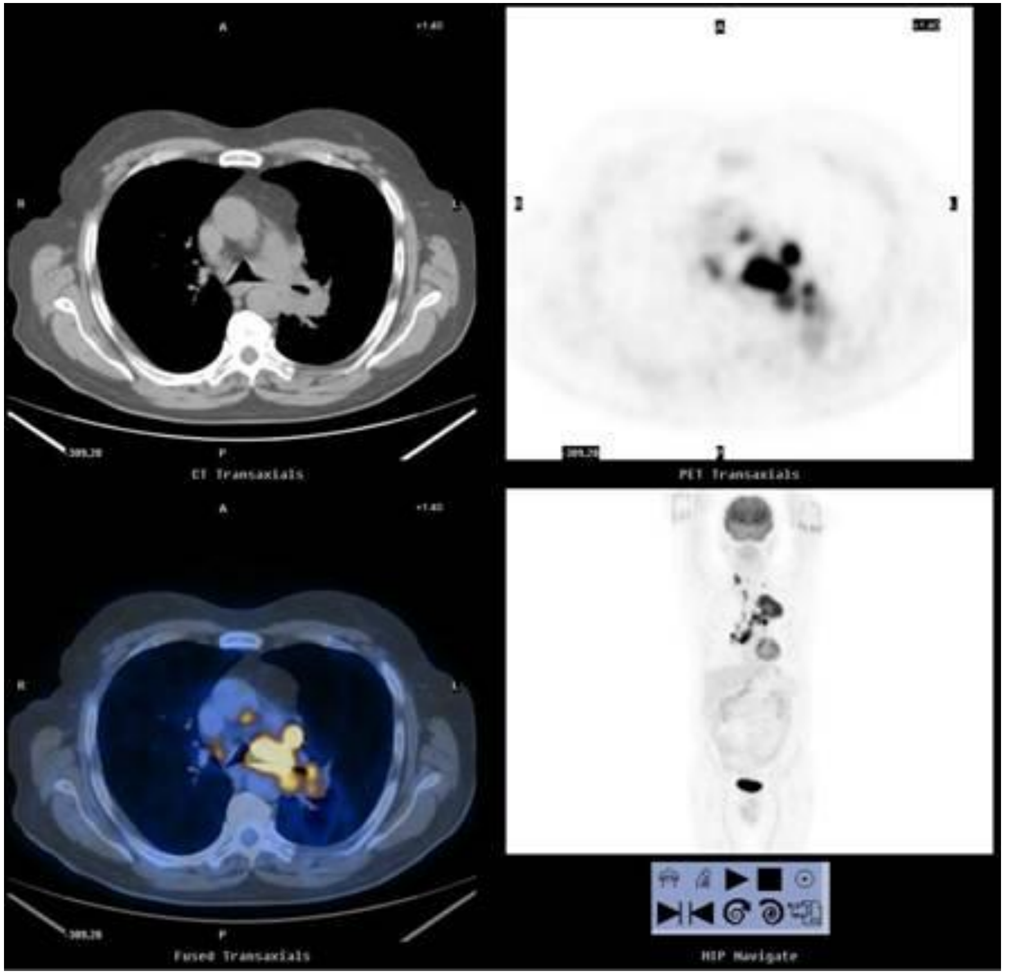
В съвременните PET/CT – времето е по-малко от 20 min.

Клинично Приложение

- Онкология
- Кардиология
- Неврология

Роля в Онкологията

- Диференцира бенигнените от малигнените заболявания
- Стадиране на заболяванията
- Резултатът от лечението
- Повторение на заболяването /рецидив/
- Приложение при Лъчетерапията



Ca Lung

В Онкологията

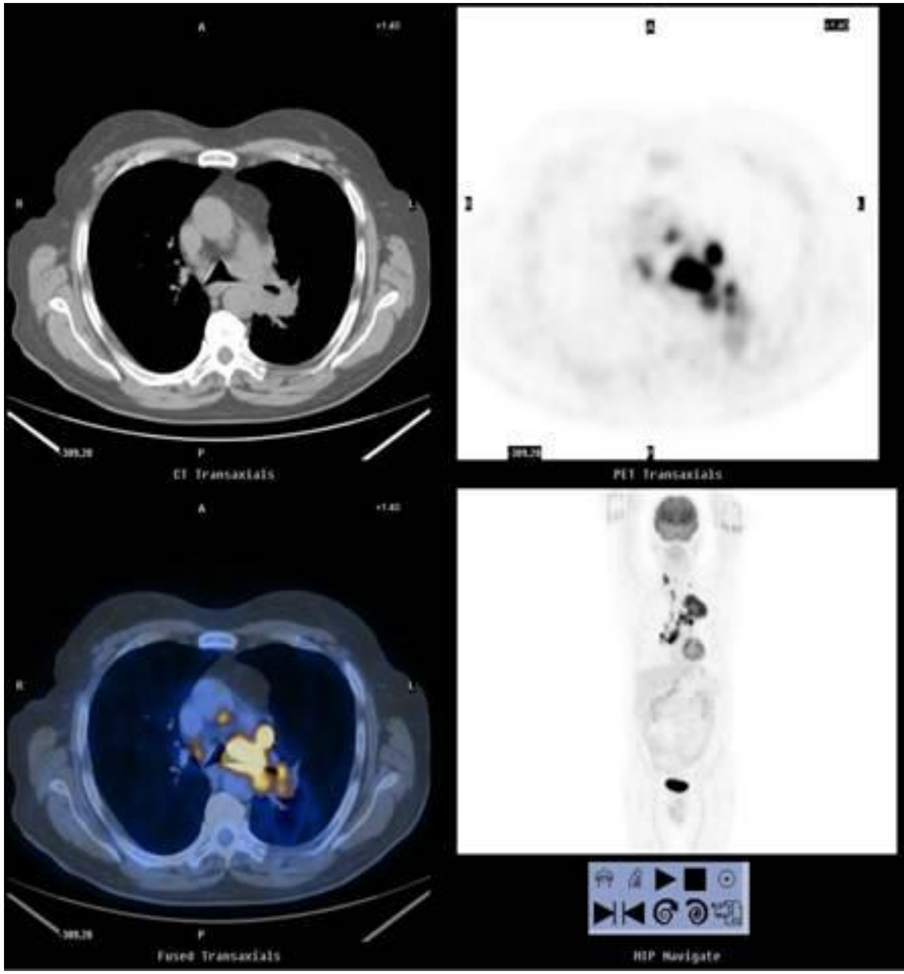
Поставяне на диагноза –
визуализация на жизнеността на тумора, неговите метастази или рецидиви

При тумори ~ 1cm

средна чувствителност 95%*
(91% - 100%)

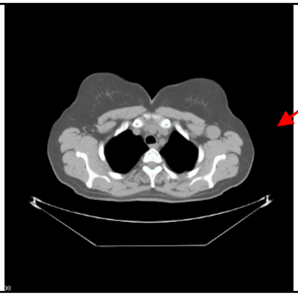
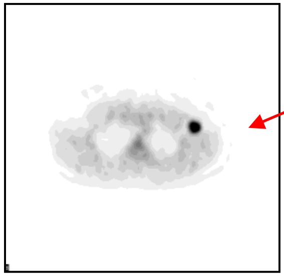
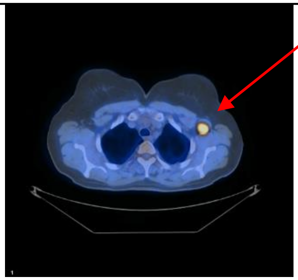
средна специфичност 90%*

(85% - 100%)



Ca Lung

*Taylor A, et all. A clinical guide to Nuclear Medicine. SNM-USA, 2nd printing, 2003

	CT	PET	PET-CT
			
Предимства	**Анатомични образи** Отлична пространствена резолюция, прецизно позициониране.	**Функционални образи** Висока чувствителност и количественост. Стадиране и контрол на заболяванията.	Обединява предимствата на двете техники: чувствителност, специфичност и количественост.
Недостатъци	Ограничена чувствителност при стадиране.	Ограничена пространствена резолюция	Пациентът поглъща доза лъчение ??? ......
Образи	 Анатомия	 Метаболитна активност	 Наслагване на метаболитни и анатомични данни
Продуктивност	~ 4-5 Пациента/час	~ 1 Пациент/час	~ 3 Пациента/час

Instantaneous Dose Rate from Patient

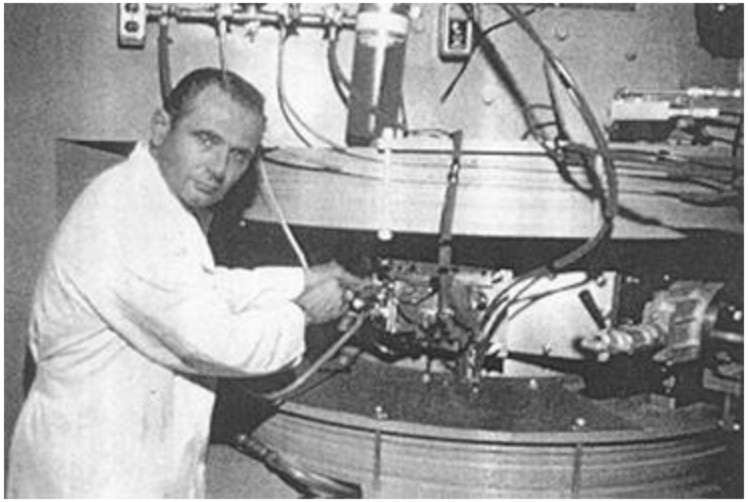
Radiopharma-ceutical	Dose rate at 0.1 m, μSv/hr	Dose rate at 1m, μSv/hr
Tc-99m MDP (600 MBq)	114	5
F-18 FDG (350 MBq)	550	70

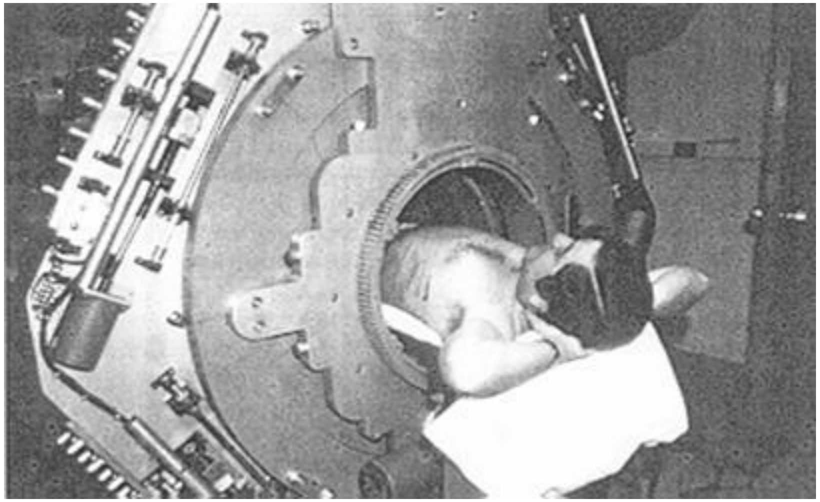
Dose rate measured immediately after injection. Note considerably higher dose rate for ^{18}F versus ^{99m}Tc.

ПРИЧИНИ ЗА ОГРАНИЧЕНО РАЗПРОСТРАНЕНИЕ

- Висока цена на апаратурата.
- Необходимост от циклотрон, който да произвежда краткоживеещи радионуклиди.
- Специално адаптирана апаратура за химичен синтез и контрол на използваните радиофармацевтици.
- Наличие на радиохимична лаборатория.
- Помещения със съответните лъчезащитни изисквания за персонал и население.

Пионери в PET диагностиката

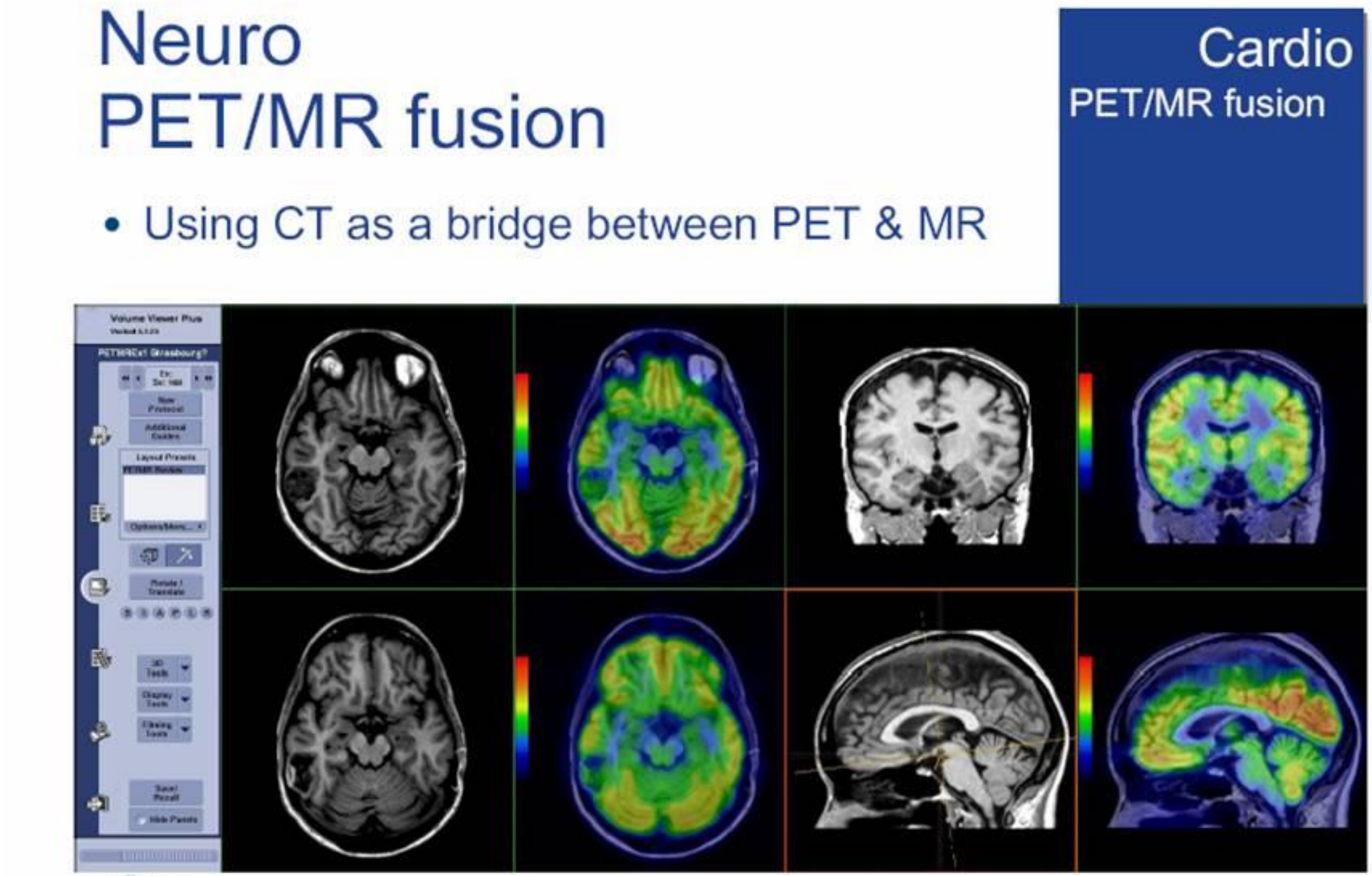




Michel Ter-Pogossian prepares a radiopharmaceutical for an examination of Henry Wagner Jr with one of the first PET- scanners (1975).

История на Циклотрон, PET & PET/CT

- **1928** Съществуването на позитрона, Paul Dirac
- **1930** Циклотрон, Lawrence et al.
- **1932** Експериментално наблюдаване на позитрона, Carl Anderson
- **1953** Детектиране на анихилация, Brownell & Sweet
- **1975** Трансаксиална томография, Ter-Pogossian, Phelps & Hoffman
- **1977** ^{14}C deoxyglucose, Sokoloff et al.
- **1979** ^{18}FDG PET, Relvich et al.
- **1980 - те** Многосрезови CT & PET циклотрони
- **1990 - те** Клинично приложение на PET
- **2000 - те** PET/CT
- **2010** GE инсталира първият PET/CT + MR образна система в University Hospital Zurich (Nov 2011)



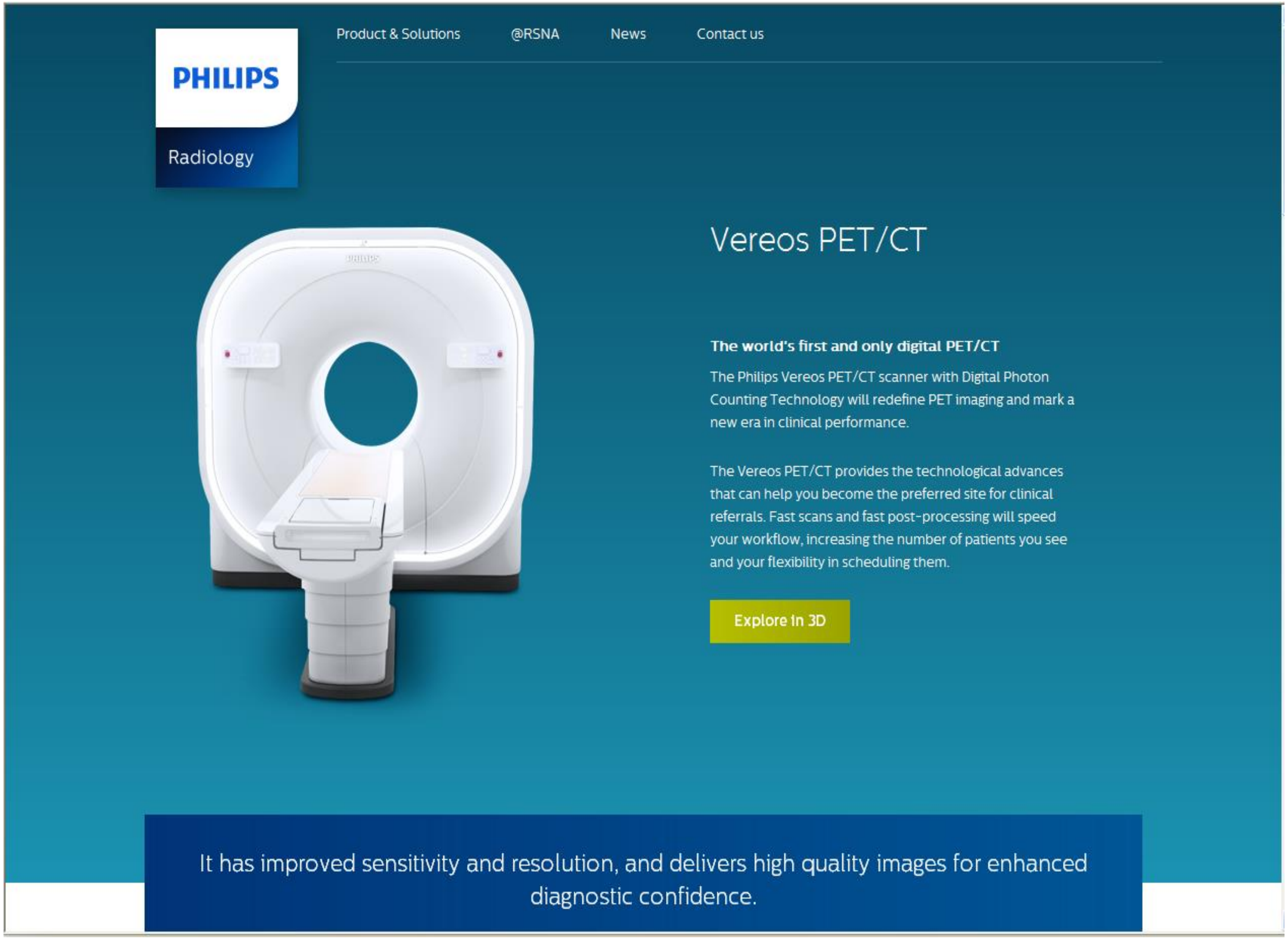
PET machines don't like to work in high magnetic fields. But thanks to more than 30 years of research, since 2010 we have PET/MRI machines installed in clinical settings."

David Townsend

Availabale on: http//:CERN.CH/ENLIGHT/HIGHLIGHTS

June 12, 2014 — Philips Healthcare recently introduced Vereos PET/CT, **the first digital** PET/CT (positron emission tomography/computed tomography) scanner, at the 2014 annual meeting of the Society of Nuclear Medicine and Molecular Imaging (SNMMI) in St. Louis.

Philips Highlights Vereos Digital PET/CT at SNMMI



Avaialable on: http://www.healthcare.philips.com/us_en/clinicalspecialities/radiology/solutions/vereos.html?

CERN 2017

Forty years since the first PET image at CERN

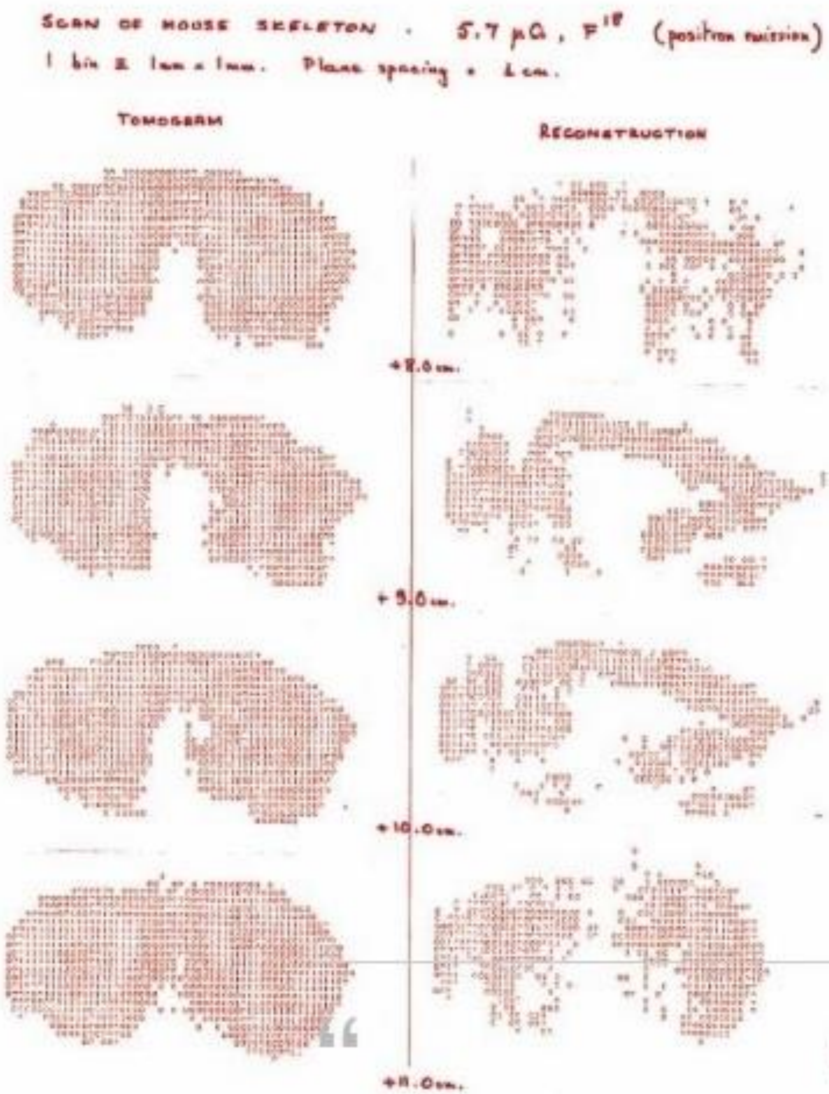
Marilena Streit-Bianchi reminisces about her role in the first PET (positron-emission tomography) image taken at CERN

21 DECEMBER, 2017 | By Iva Raynova

On a peaceful afternoon in early summer 1977, the laboratory of CERN radiobiologist Marilena Bianchi was visited by a physicist with a pretty unusual request. He asked for her help in his quest to create a first image of a mouse using a PET (positron-emission tomography) camera.

The physicist, David Townsend, had been helping Alan Jeavons, also a physicist at CERN. Jeavons had developed a new detector, based on a high-density avalanche chamber, to take PET images. Townsend had developed the software to reconstruct the data from the detector and to turn them into an image.

skeleton of the animal.



The first PET image taken at CERN, in 1977, showing the skeleton of a mouse. Unlike a modern-day image, this one is truly digital – it is composed of numbers. Each number indicates how much of the isotope has been emitted at each point. (Image: CERN)

The isotope she injected emitted positrons, the antimatter twins of electrons. These positrons bumped into nearby electrons and in the collision a pair of photons was created. The photons shot out in exactly opposite directions. By placing two detectors around the mouse, Jeavons and Townsend picked up these pairs of photons, pinpointing where the positron annihilations occurred. "A few days later, David Townsend came back with this beautiful picture. The first mouse scan taken with a PET camera," remembers Streit-Bianchi. "The findings were then presented at a conference in October 1977."

PET was not invented at CERN, but the work carried out by Jeavons and Townsend made a major contribution to its development, thanks to the type of detector and computer programme developed for image-taking analysis. After the initial success, Jeavons and Townsend devoted their careers to improving medical imaging. Later, Townsend and co-workers in the US suggested to combine PET-CT (computed tomography) to see both metabolic and anatomic information. This was a major breakthrough for cancer diagnosis and treatment follow up.

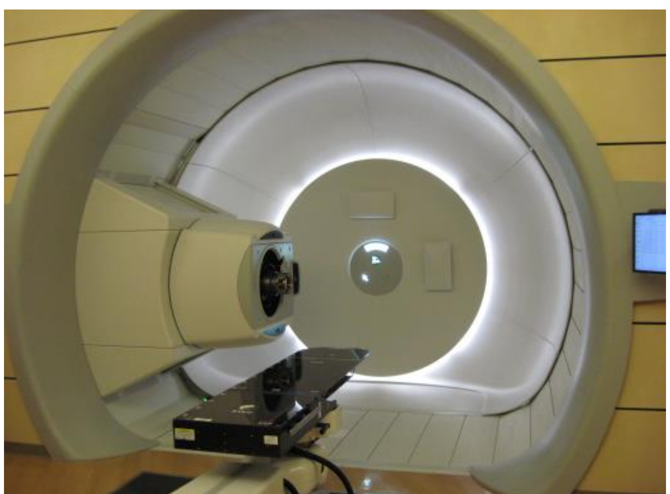
> "I am very proud. The inventiveness of these two physicists and their desire to develop a special PET camera resulted in the further development of a perfectly safe method to inquire what is happening in the body." - **Streit-Bianchi**

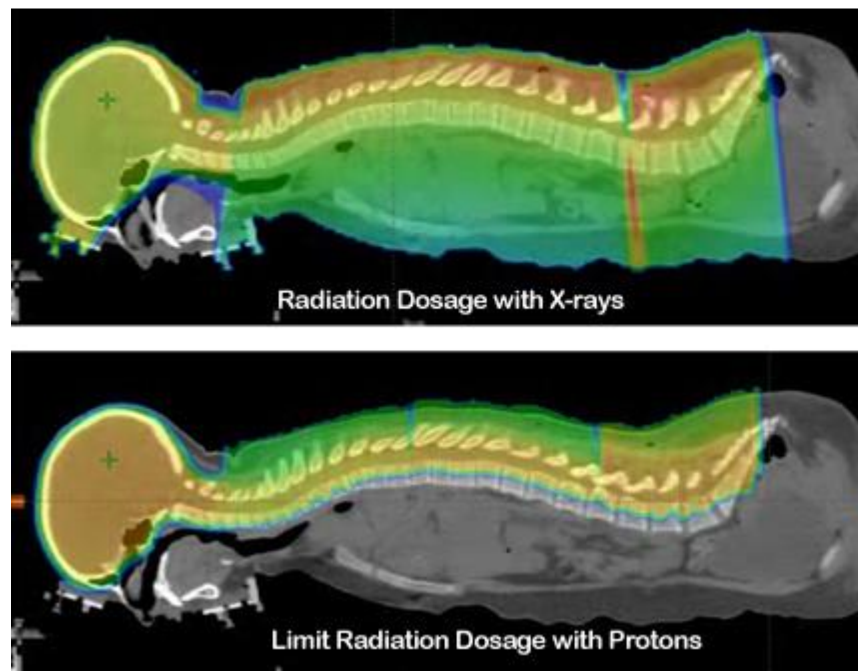
Пионери в диагностиката с РЕТ/СТ в България

УМБАЛ "Света Марина" - Варна

УМБАЛ „Александровска" - София

II. Proton Therapy - Протонна терапия





РАДИОТЕРАПИЯ
(Терапия с йонизиращи лъчения)

Основна цел:

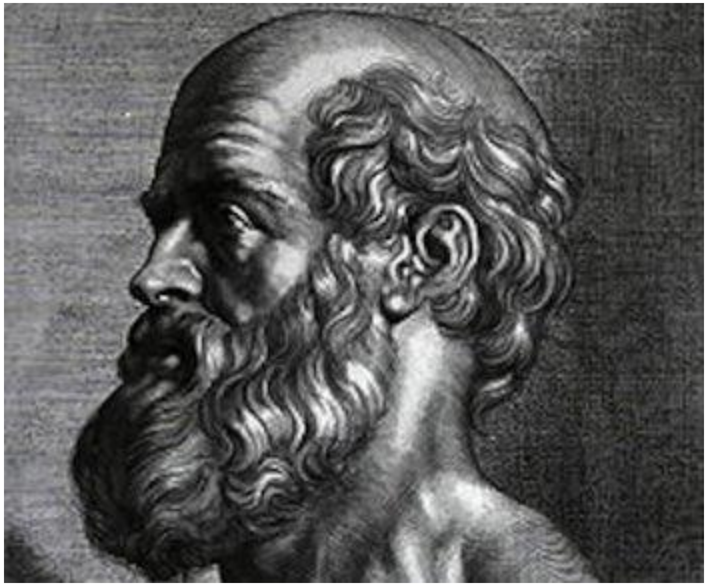
Ликвидиране на жизнеспособността на туморните клетки в даден орган или система на човешкото тяло чрез апплициране на необходимата канцерицидна доза при минимално облъчване на заобикалящите Областта подлежаща на Лъчелечение /ОПЛЛ/ здрави органи и тъкани.

Постигане унищожаването на туморния процес без да се причиняват увреждания на организъм.

РАДИОТЕРАПИЯ

Хирургия

Химиотерапия

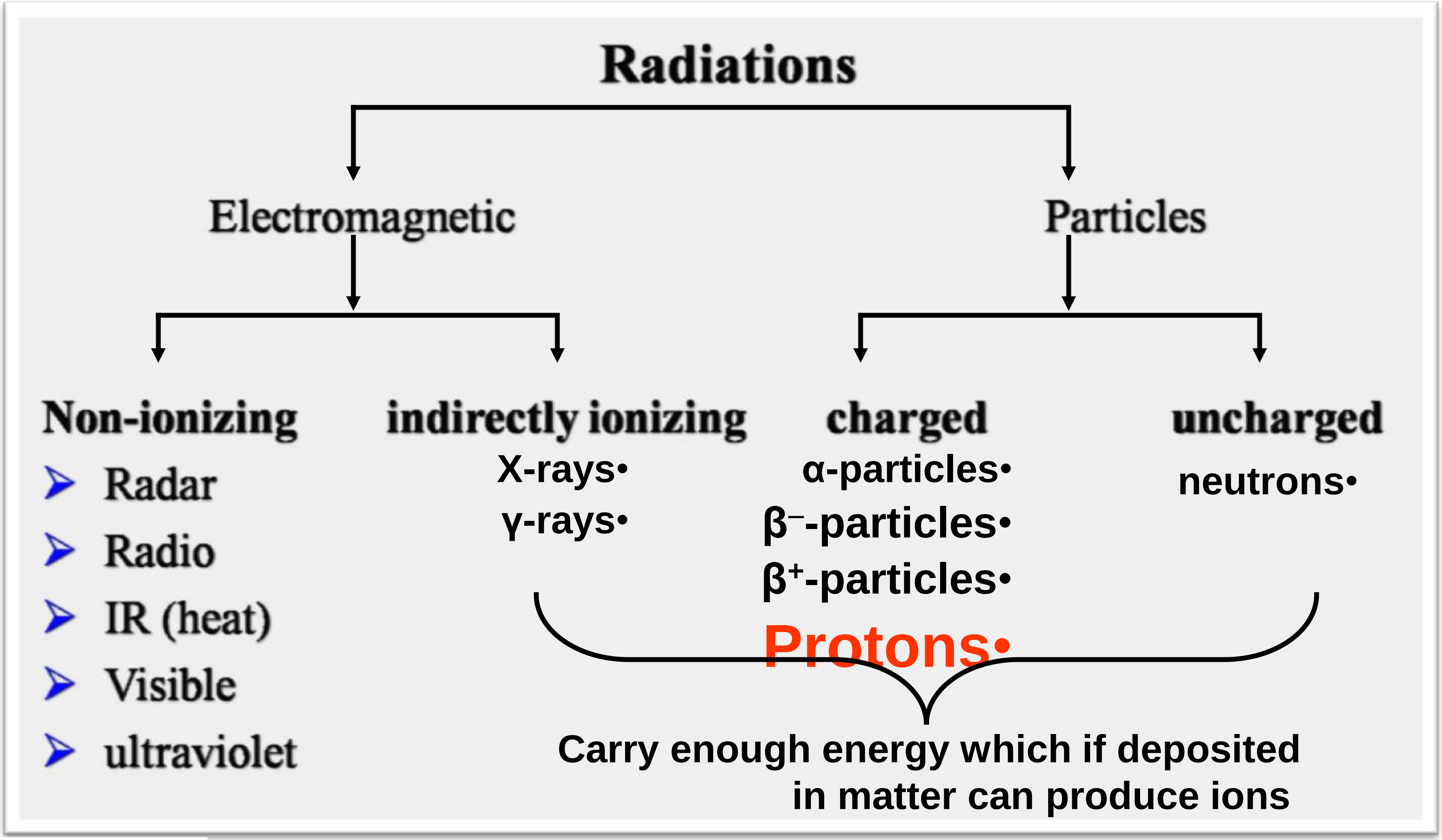


Hippocrates' words

PRIMUM NON NOCERE!

Лекувай, но не увреждай!

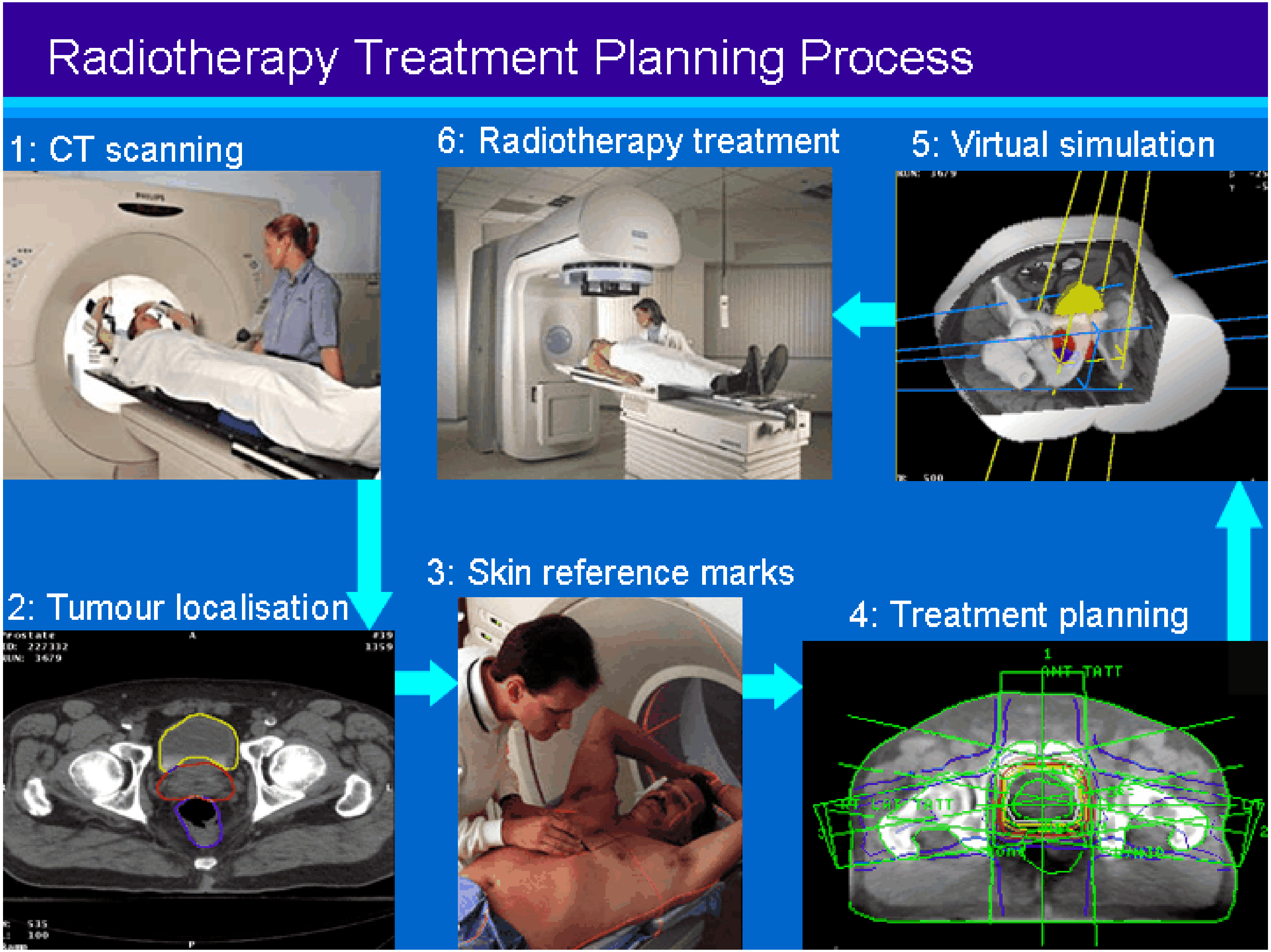
Видове Йонизиращи Лъчения



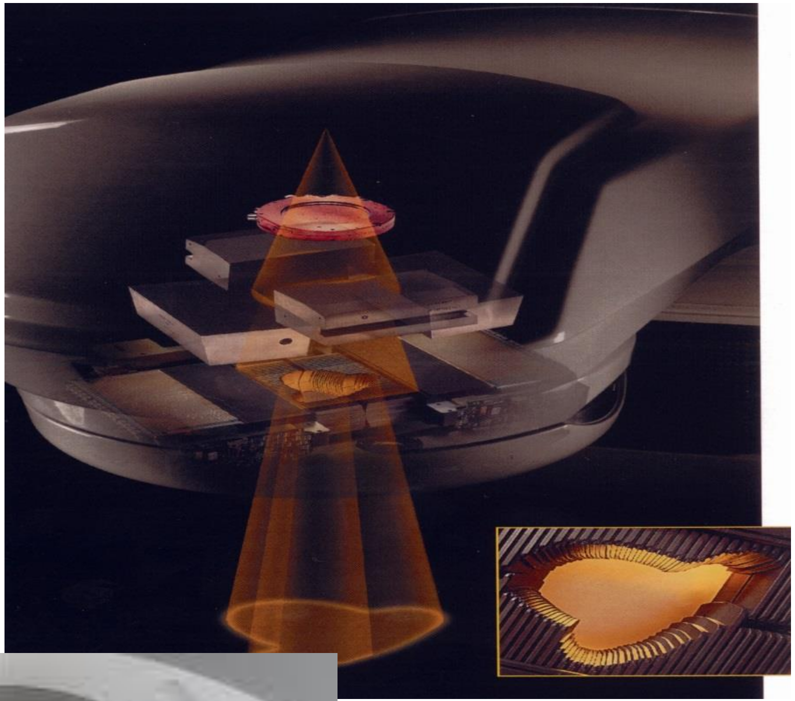
История на Радиотерапията

1895 - Откриване на X лъчи - Vilhem K. Roentgen.
1898 - Откриване на Radium – Maria Curie.
1928 - H&N Cancer клинични резултати.
1950 - Начало на радиотерапията с γ лъчи (Co-60).
1954 - **Начало на протонната терапия** at Berkeley.
1961 - Linear Accelerator (LINAC) at Standford, USA.
1968 - Gamma - knife radio surgery at Uppsala, Sweden.
1971 - Computed Tomography.
1980 - Multi Leaves Collimator (MLC).
1988 - Intensity - Modulated Radiotherapy (IMRT).
2000 - Image Guided Radiotherapy (IGRT).

РАДИОТЕРАПИЯ



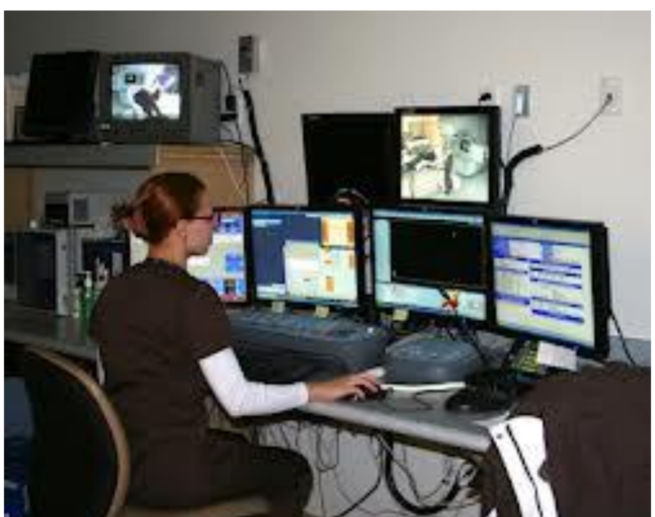
Линеен Ускорител с MLC

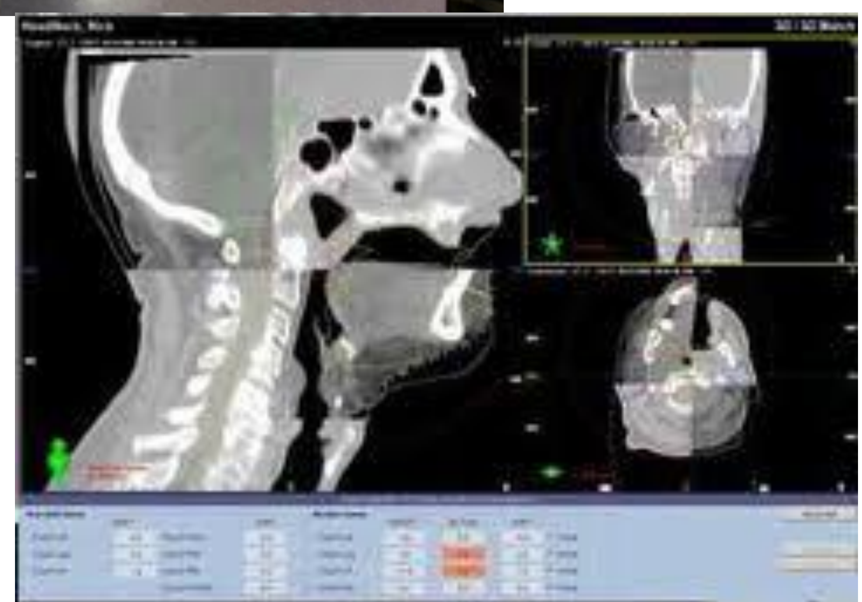


MLC

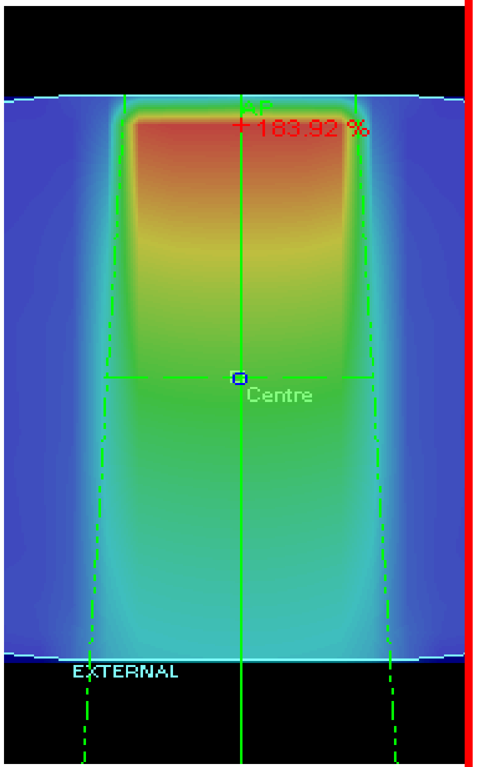
Съвременна радиотерапия с X rays

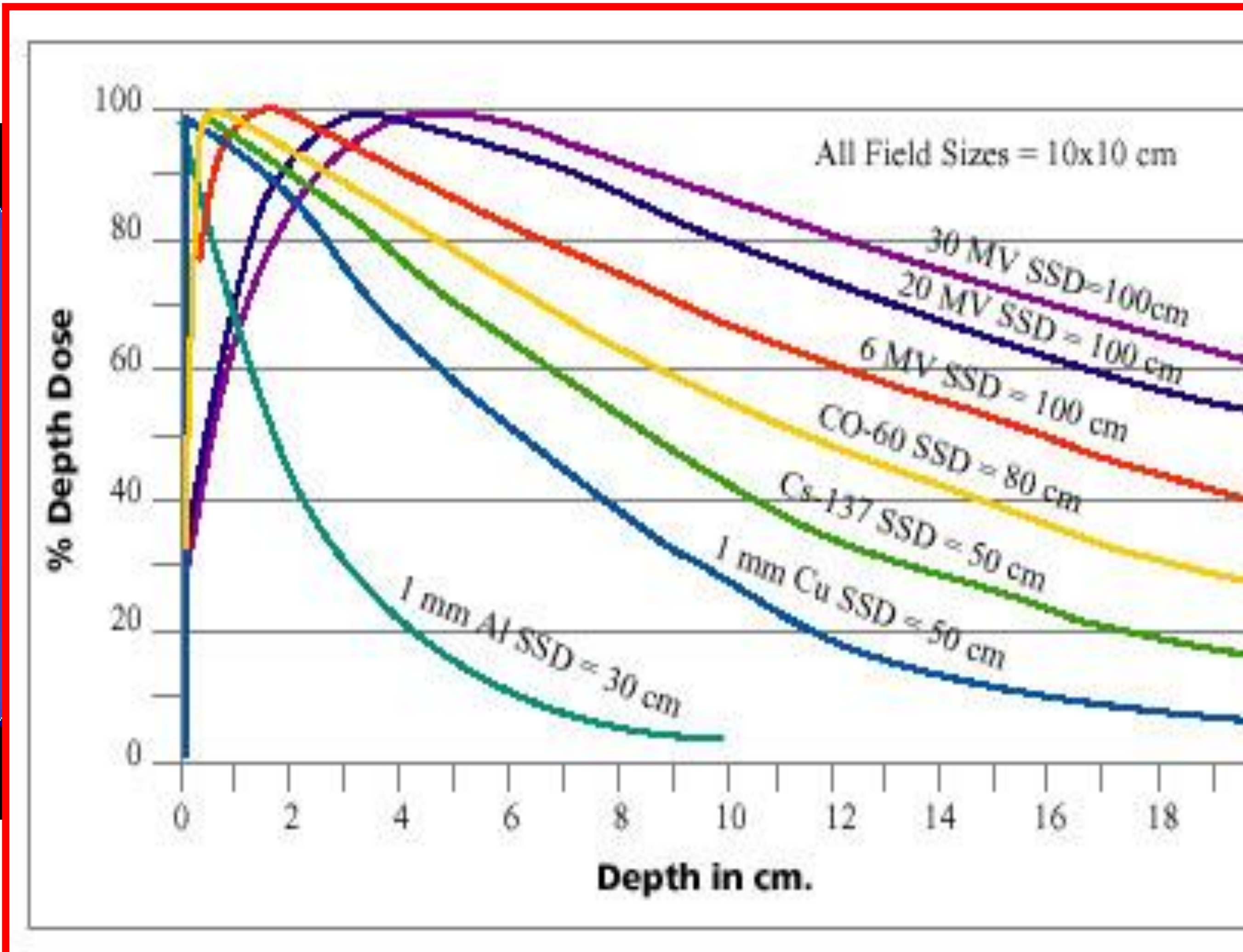
VARIAN Linac
X rays



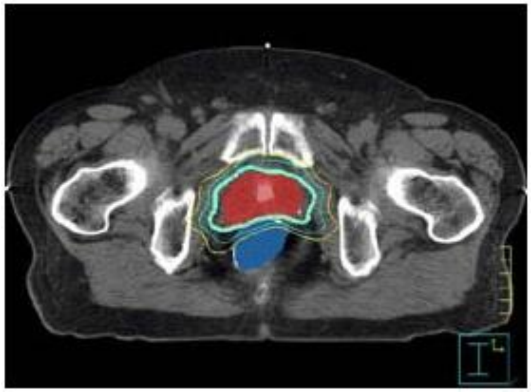


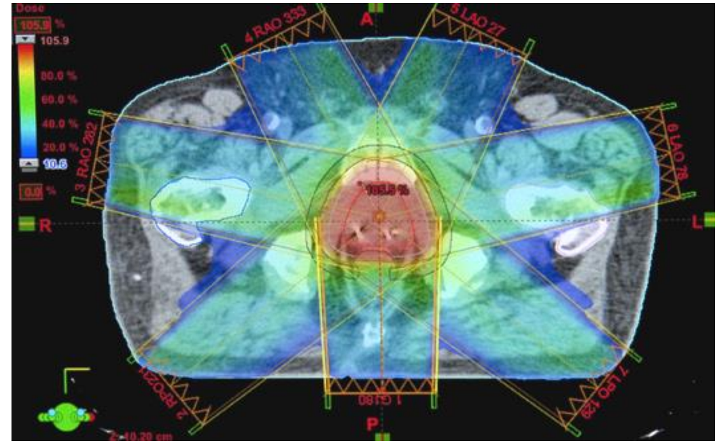
Прониквателна способност на фотонните лъчения в зависимост от енергията

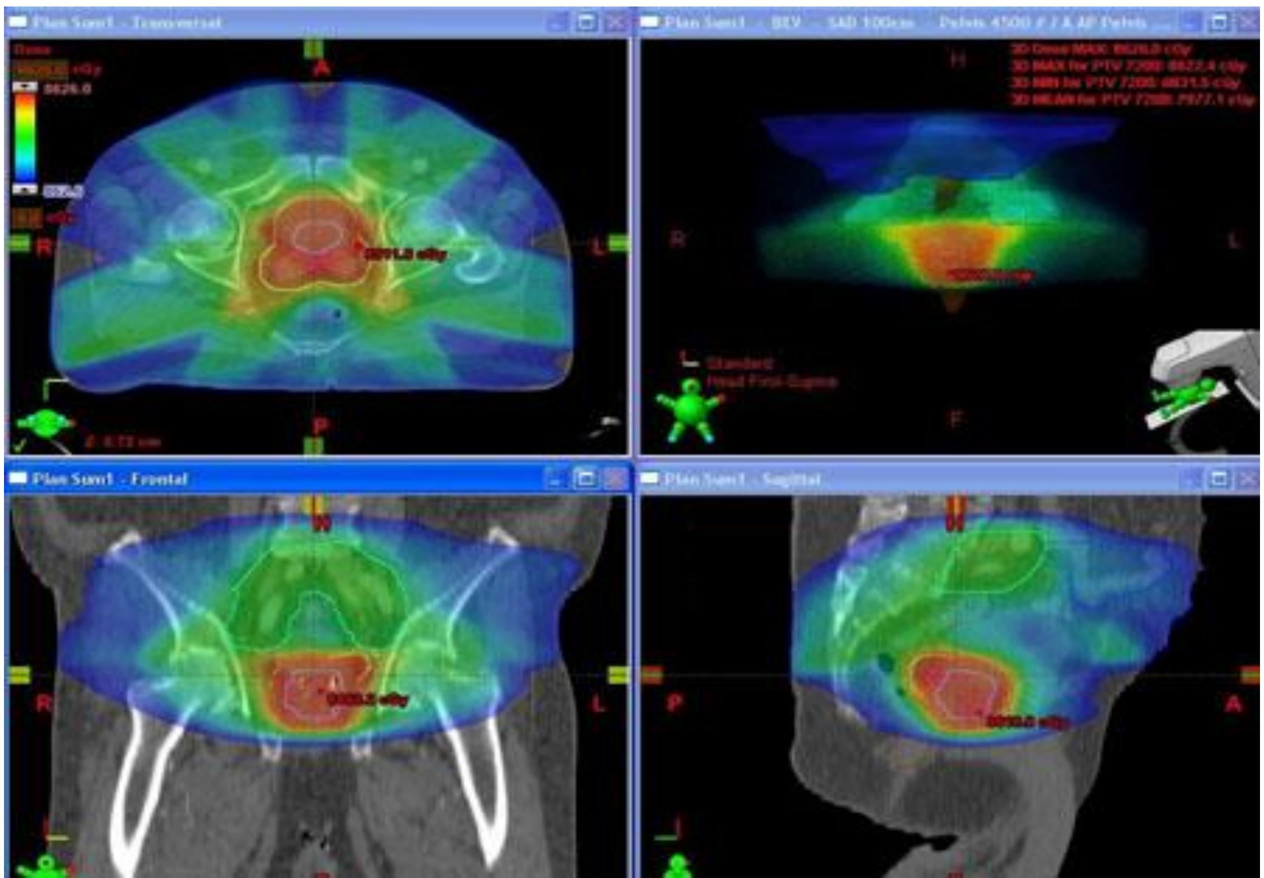




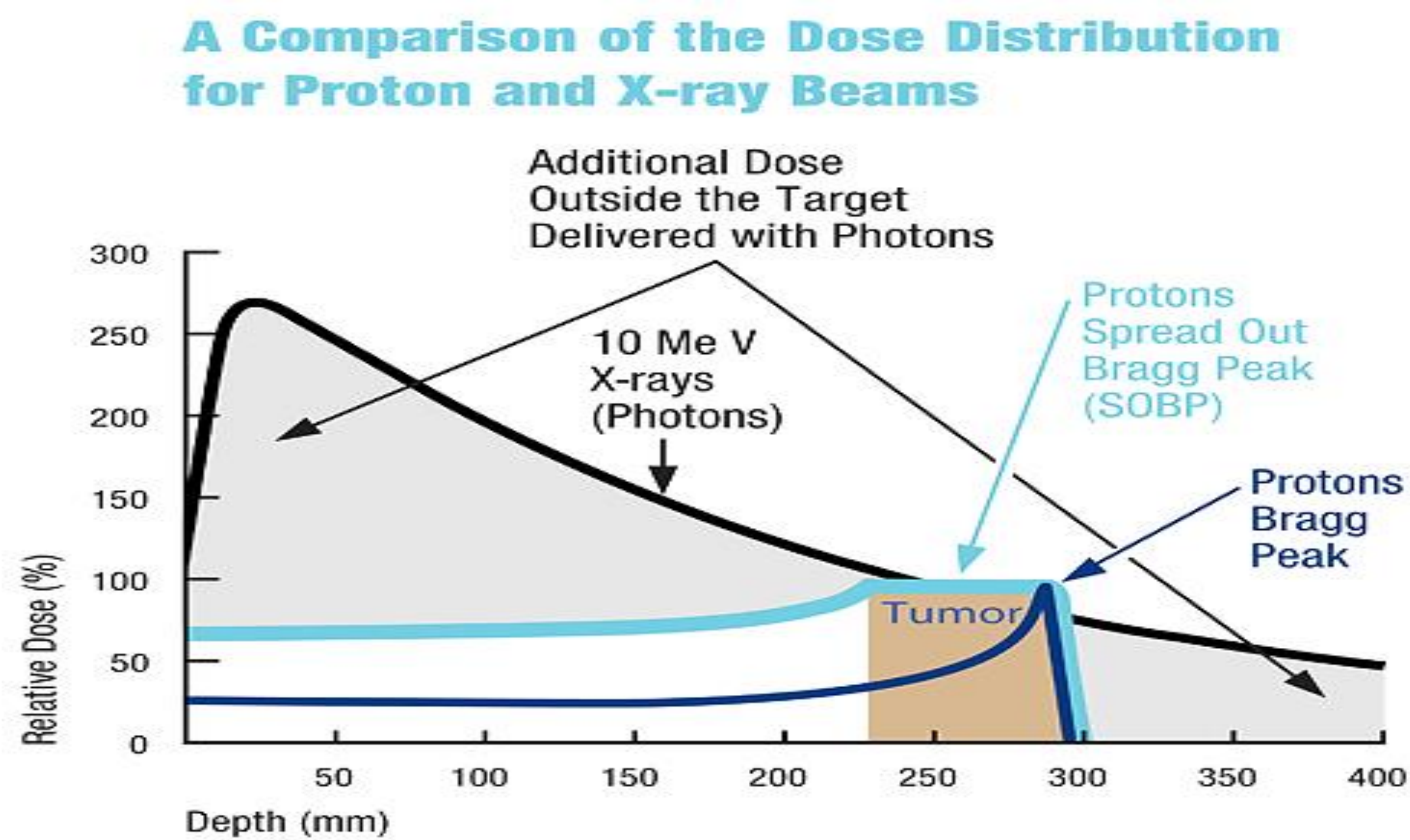
РАДИОТЕРАПИЯ при CA GL. PROSTATAE

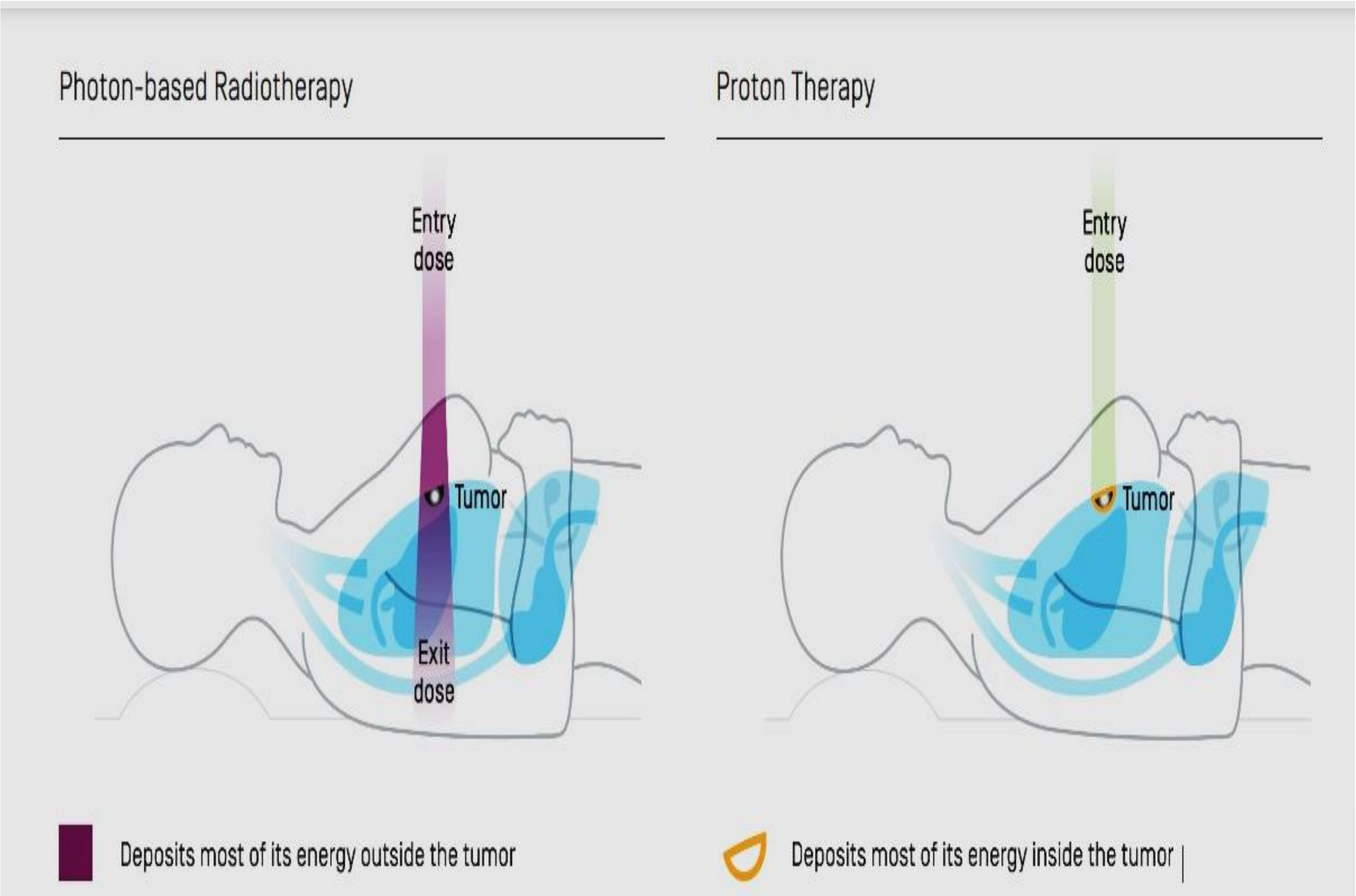






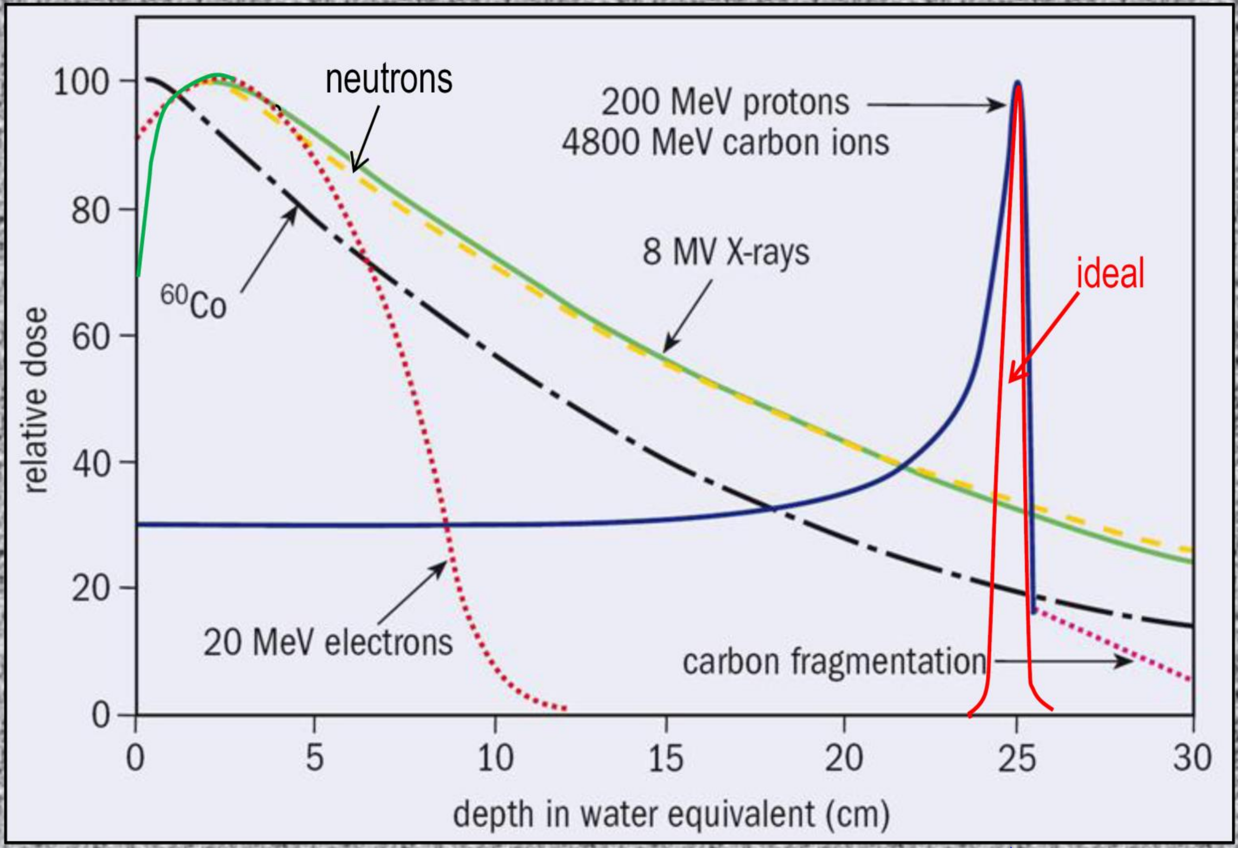
ЗАЩО ПРОТОННА ТЕРАПИЯ ? ? ?



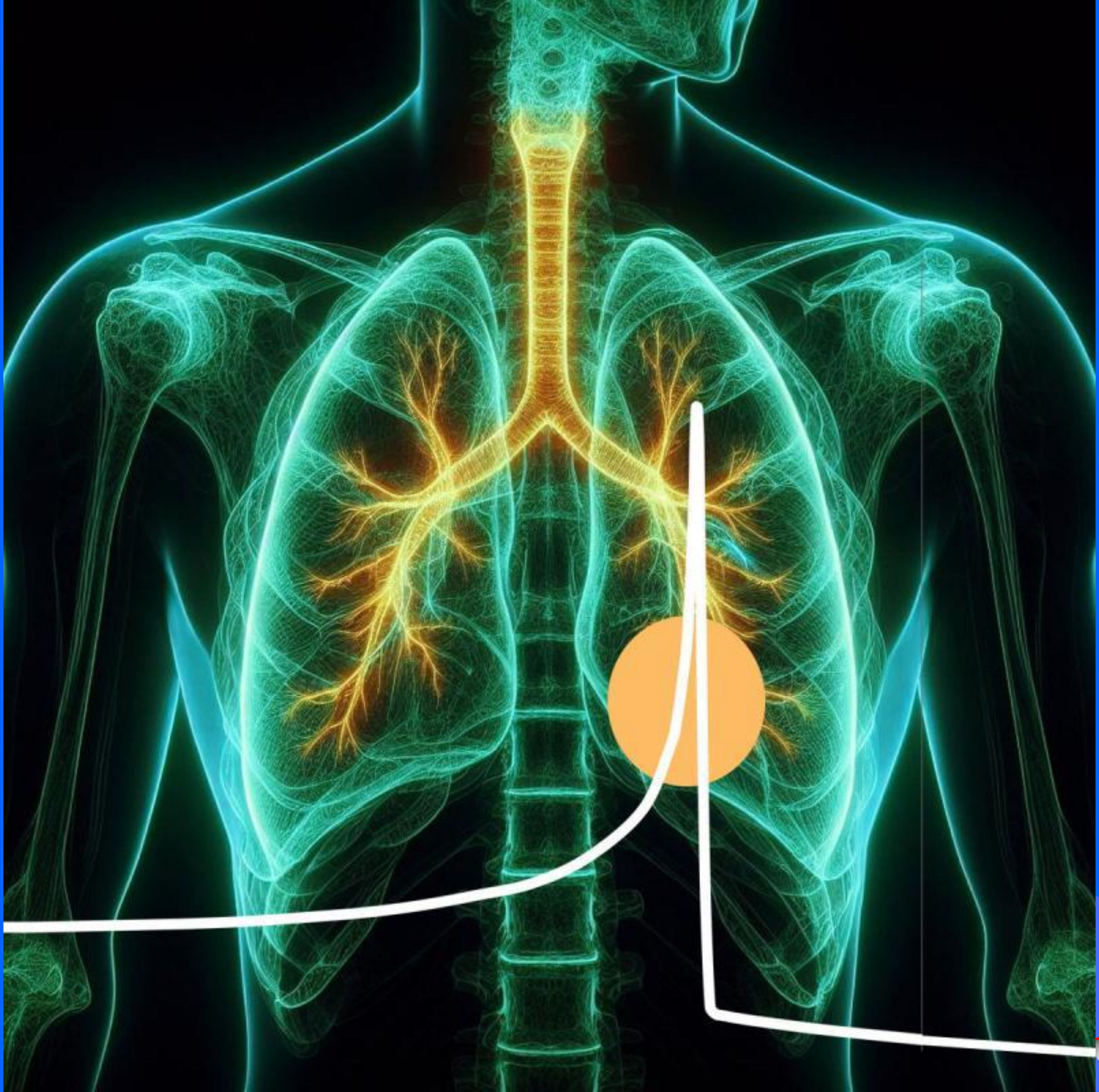


Available on:https://www.iba-protontherapy.com/what-is-proton-therapy

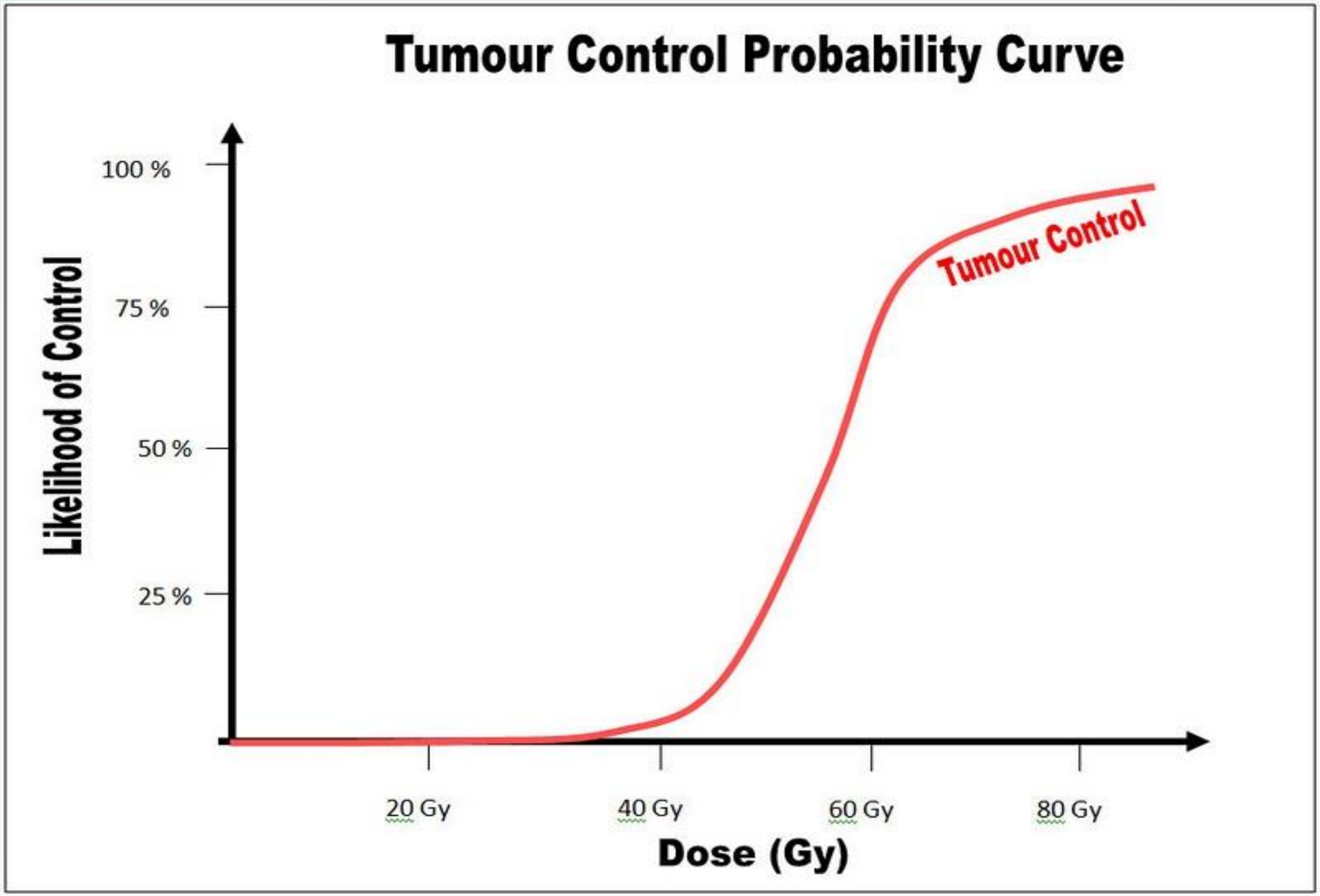
The icon of radiation therapy



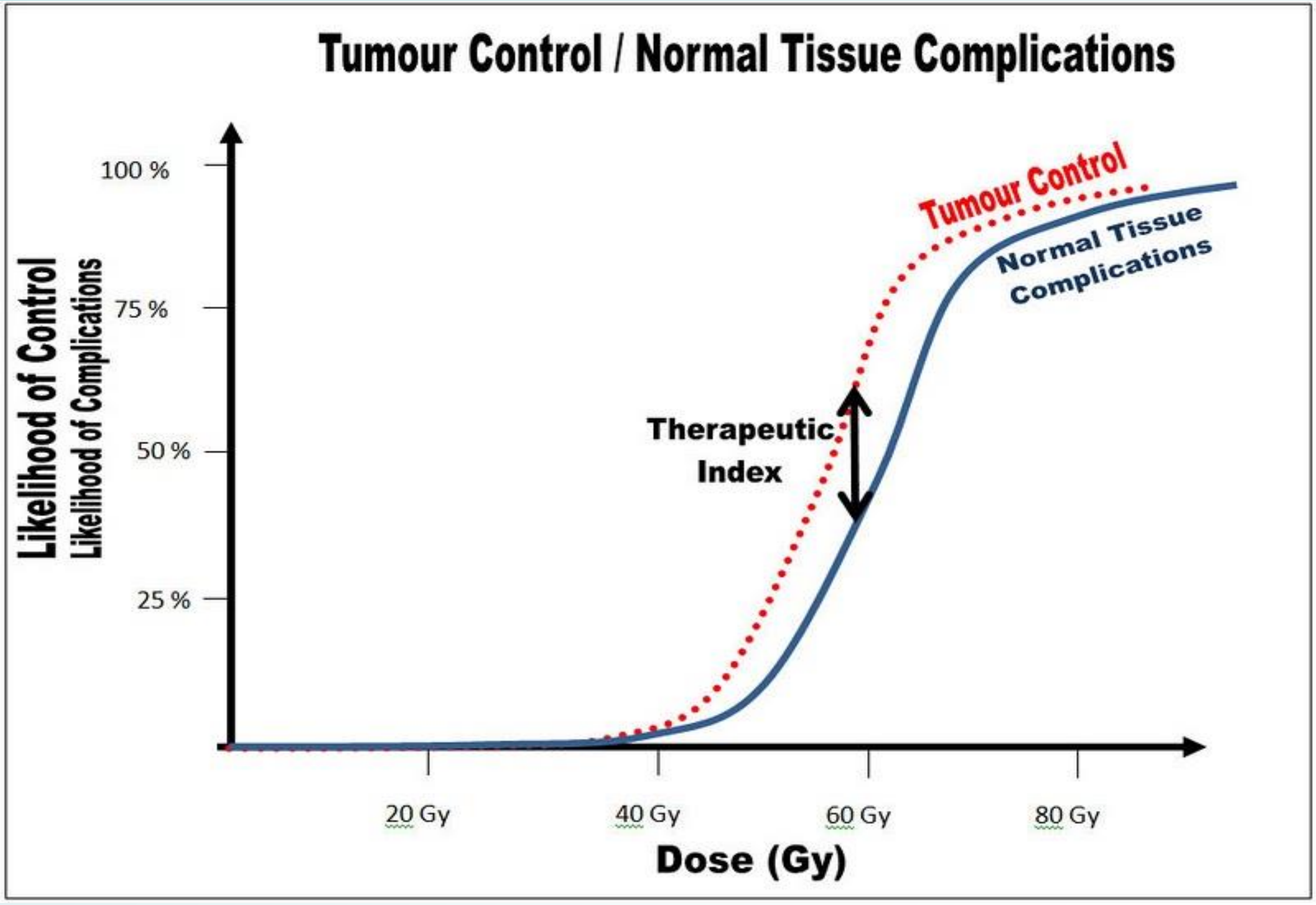
Radiation beam in matter



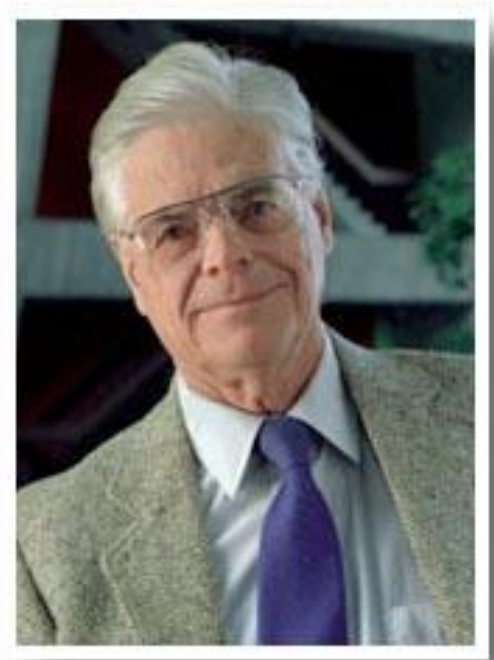
Вероятност за туморен контрол (ТРС)



Вероятност за туморен контрол (TPC) и усложнения на здравите тъкани (NTPC)



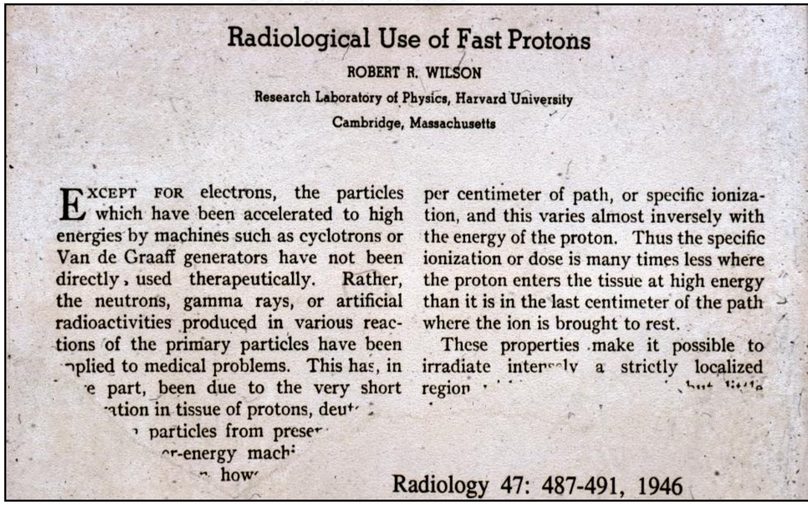
НАЧАЛО на ПРОТОННАТА ТЕРАПИЯ



Robert Wilson

"A man with a vision "

- 1946 - Prof. Robert Wilson - Harvard physicist.
- Протоните могат да имат клинично приложение.
- Максимална доза лъчение може да се реализира в дълбочина.
- Протонната терапия осигурява максимална защита на здравите тъкани.



Radiological Use of Fast Protons

ROBERT R. WILSON

Research Laboratory of Physics, Harvard University

Cambridge, Massachusetts

EXCEPT FOR electrons, the particles which have been accelerated to high energies by machines such as cyclotrons or Van de Graaff generators have not been directly used therapeutically. Rather, the neutrons, gamma rays, or artificial radioactivities produced in various reactions of the primary particles have been applied to medical problems. This has, in ... part, been due to the very short ...ation in tissue of protons, deut... particles from prese... ...r-energy mach... how...

per centimeter of path, or specific ionization, and this varies almost inversely with the energy of the proton. Thus the specific ionization or dose is many times less where the proton enters the tissue at high energy than it is in the last centimeter of the path where the ion is brought to rest.

These properties make it possible to irradiate inter...ly a strictly localized region ...

Radiology 47: 487-491, 1946

История на Протонната терапия (1)

1938 - *Неутронна терапия* at Berkeley Lab
(J. Lawrence and R.S. Stone)

1946 - Предложение за протонна терапия by Robert Wilson in Harvard Cyclotron Laboratory

1954 - Първо клинично приложение in Berkeley.

1957 - Начало на Европейският опит Uppsala, Sweden.

1968 - Протонна установка at JINR, Dubna, Russian Federation.

1969 - Протонна установка at Mosskow, Russian Federation .

1972 - Неутронна терапия at MD Anderson, USA.

1974 - pi meson beam at Los Alamos, USA.

История на Протонната терапия (2)

1975 - Протонен център at St. Petersburg,
Russian Federation.

1975 - Протонен център at Harvard.
(pioneers eye cancer treatment with protons)

1979 - Протонен център Chiba, Japan.

1988 - Proton therapy approved by FDA.

1989- Протонен център at Clatter bridge, UK.

1990 - Particle Therapy Cooperative Group.

1990 - First hospital-based facility at Loma Linda, USA.

1991 - Протонен център at Nice and Orsay, France.

История на Протонната терапия (3)

1993 - Протонна терапия at Cape Town, South Africa.

1996 - PSI proton facility at Villigen, Switzerland.

1998 - Протона терапия at Berlin, Germany.

2001 - Протонен център Massachusetts, USA.

2006 - Протонен център MD Anderson opens, USA.

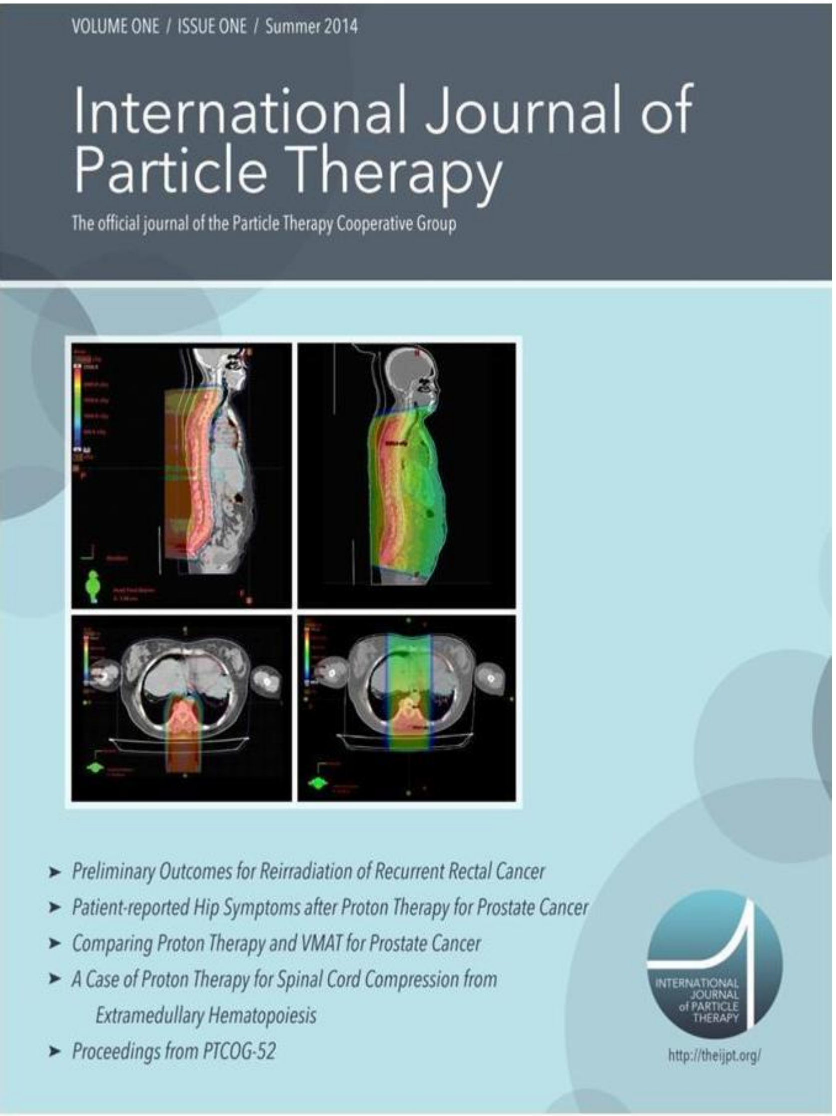
2007 - Протонен център, Jacksonville, Florida, USA.

2008 - Неутронна терапия re-stated at Fermilab, USA.

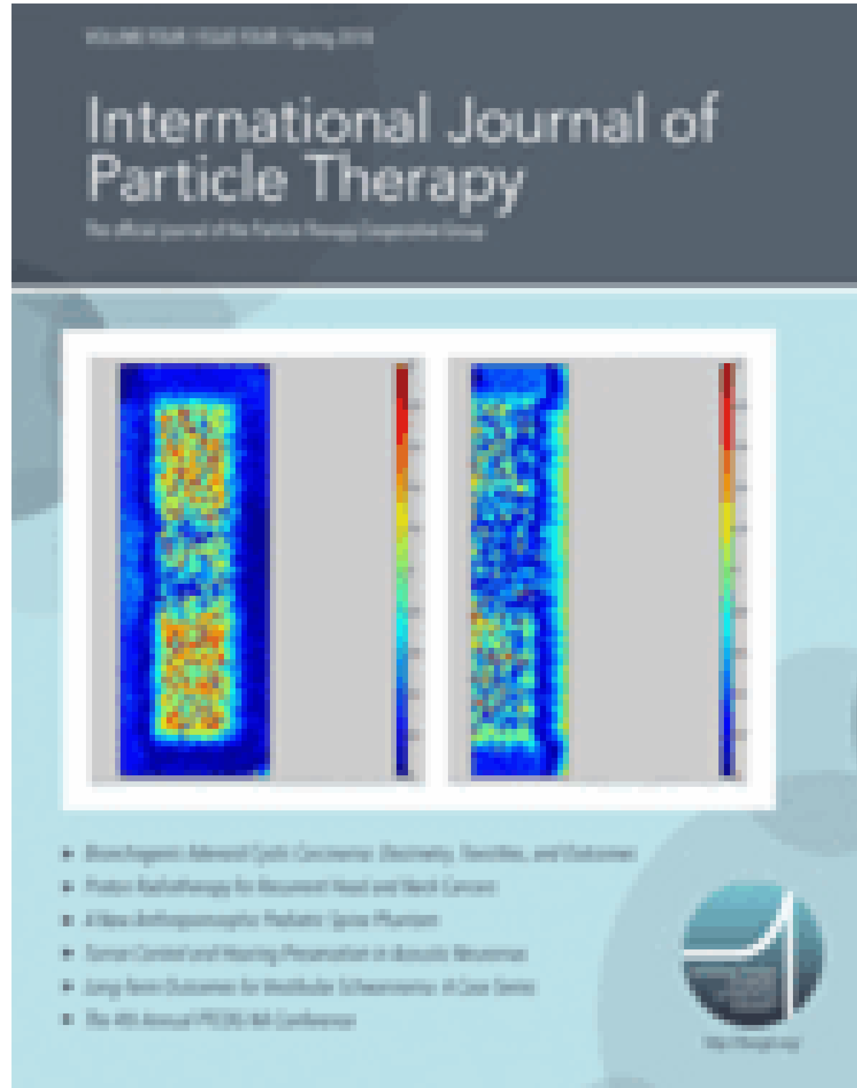
2012 - Протонен център, Prague, Czech Republic.

Официалното издание
на Particle Therapy Cooperative Group

volume 1, issue 1, Summer, 2014



volume 12, issue 3, Spring, 2024



Клинични предимства
на протонната терапия

- висока точност на апликираната доза
- висок туморен контрол
- незначителни увреждания на здравите тъкани
- липса на странични ефекти
- ниска вероятност (риск) от вторичен карцином
- неинвазивна терапия

Център за протонна терапия

- Ускорител на протонни снопове

- Транспортна система на протонните снопове

- Процедурно помещение

- Gantry

- Пациентна маса

Ускорител на протонни снопове

ПРОБЕГ НА ПРОТОНИТЕ ВЪВ ВОДА

energy (MeV)	*range in water (cm)*
70	4.0
100	7.6
150	15.5
200	25.6
250	37.4

C230 key specifications

- Compact isochronous cyclotron

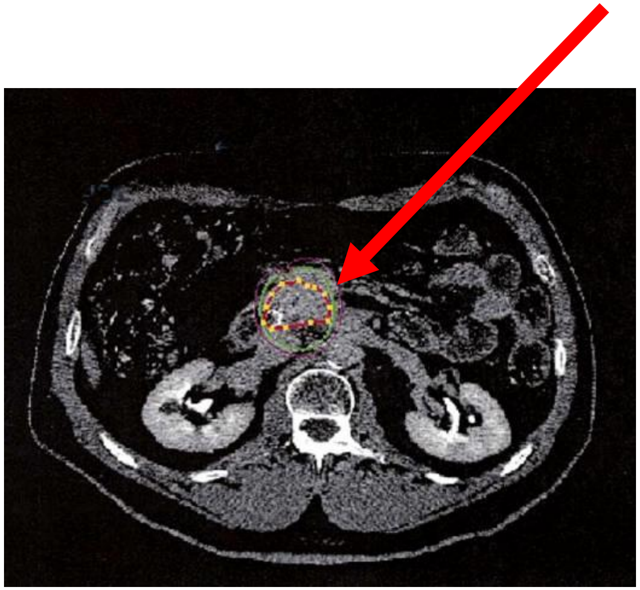
- 235 MeV proton energy
- 300 nA beam current, quasi-continuous
- Typical efficiency : 55 %

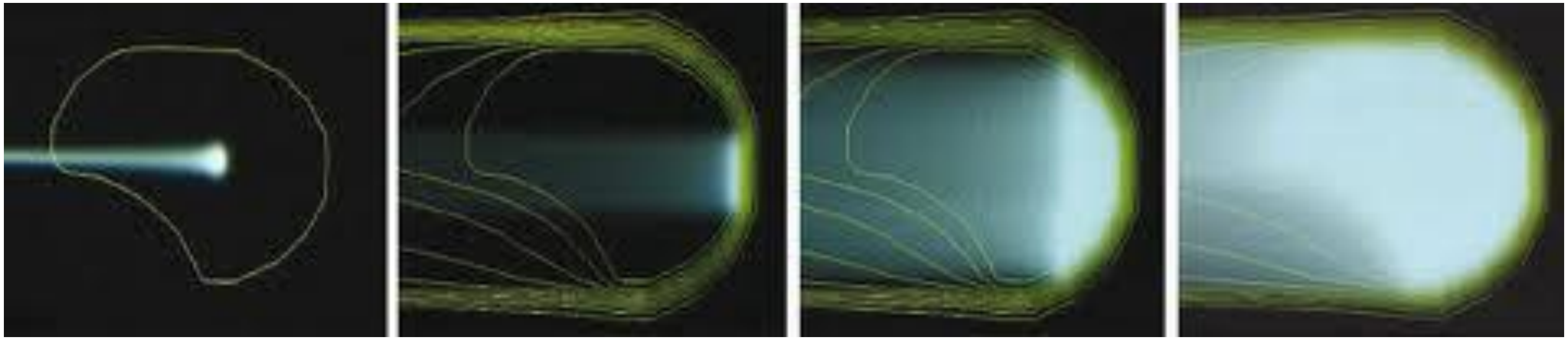
- Approx. weight: 220 T
- Diameter: 4.3 m

- Conventional magnet coil: 1.7 - 2.2 T
- RF Frequency: 106 MHz
- Dee voltage: 55 to 150 kV peak

ПРОТОНЕН СНОП

Клиничен мишенен обем





НАЧИНИ ЗА ФОРМИРАНЕ НА КЛИНИЧНИ ПРОТОННИ СНОПОВЕ

Single Scattering: Delivers a uniform proton dose in small fields with only one scatterer.

Double Scattering: Accepts any energy at nozzle entrance within the 70-235 MeV range. Reduces the distal falloff. Reduces the lateral penumbra and the radiation level.

} **Passive Scaterring**

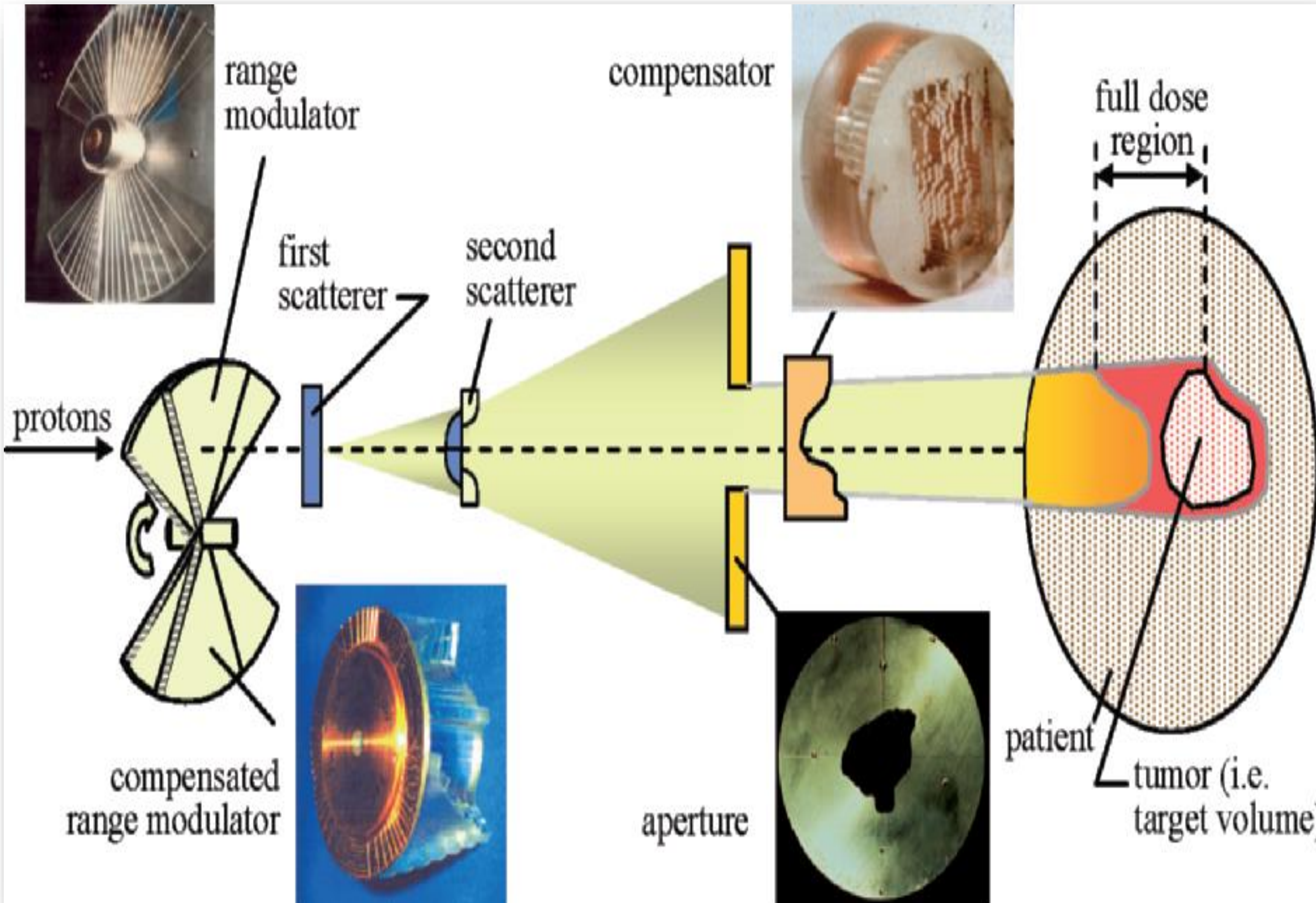
Uniform Scanning: The beam spot is moved by magnetic scanning and allows several mini-irradiations. Full modulation, field uniformity, very safe treatment.

Pencil Beam Scanning: Slice-by-slice irradiation of the target with millimetre precision. Primary advantages include: multiple fast repainting, no use of aperture, no compensator devices, dose uniformity, intensity modulation (IMPT).

} **Active Scanning**

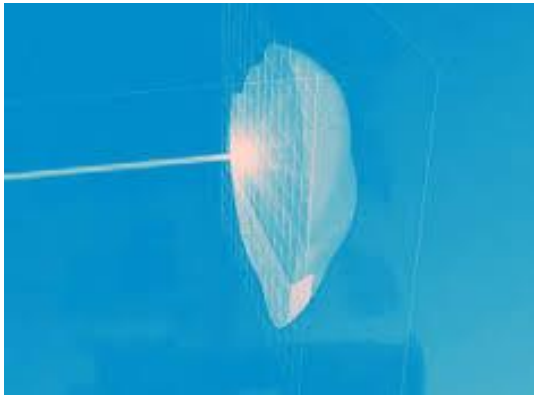
ФОРМИРАНЕ НА ПРОТОННИЯ СНОП ЗА КЛИНИЧИНО ПРИЛОЖЕНИЕ

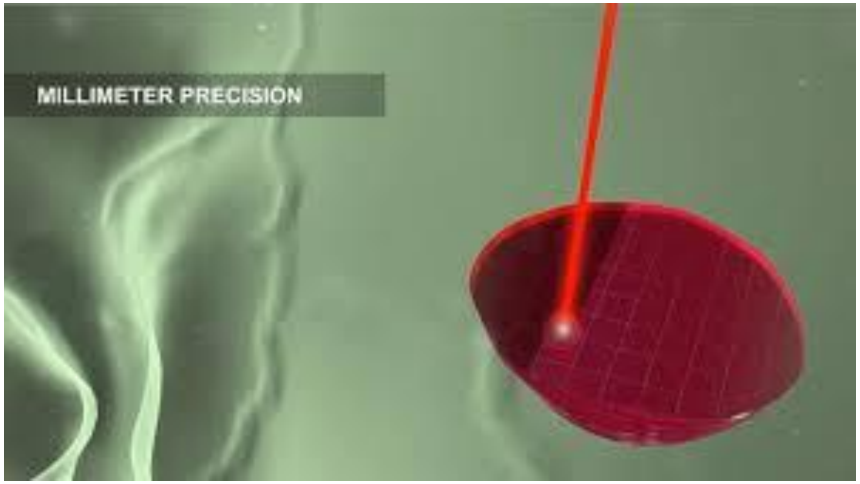
I. Пасивен

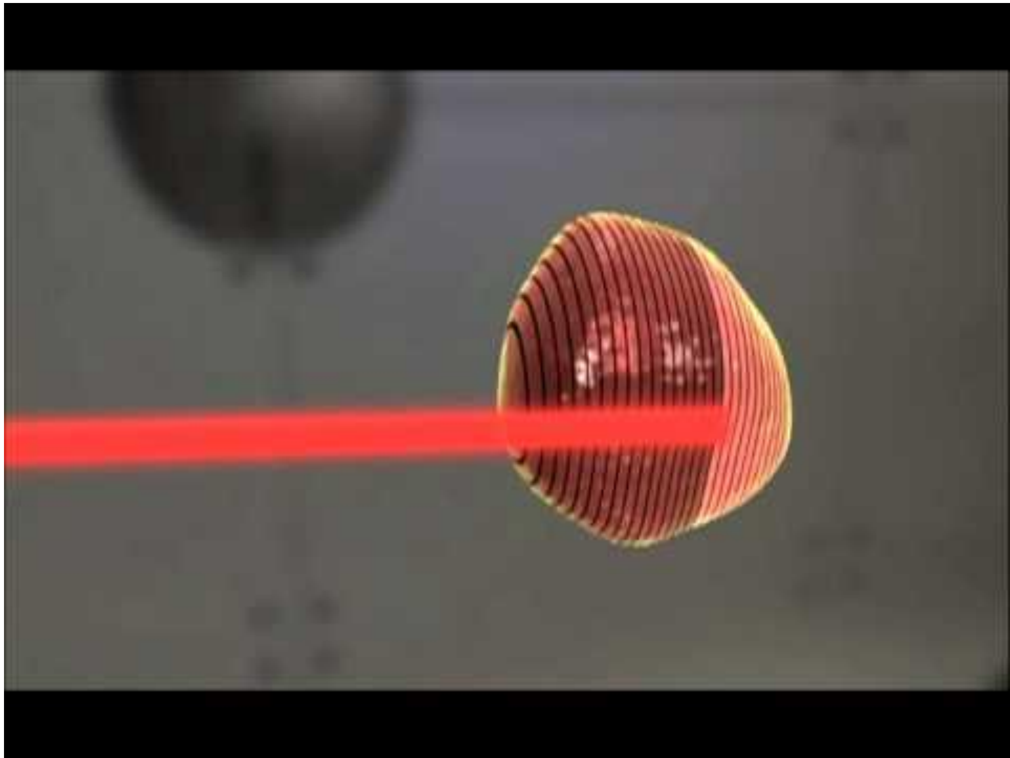


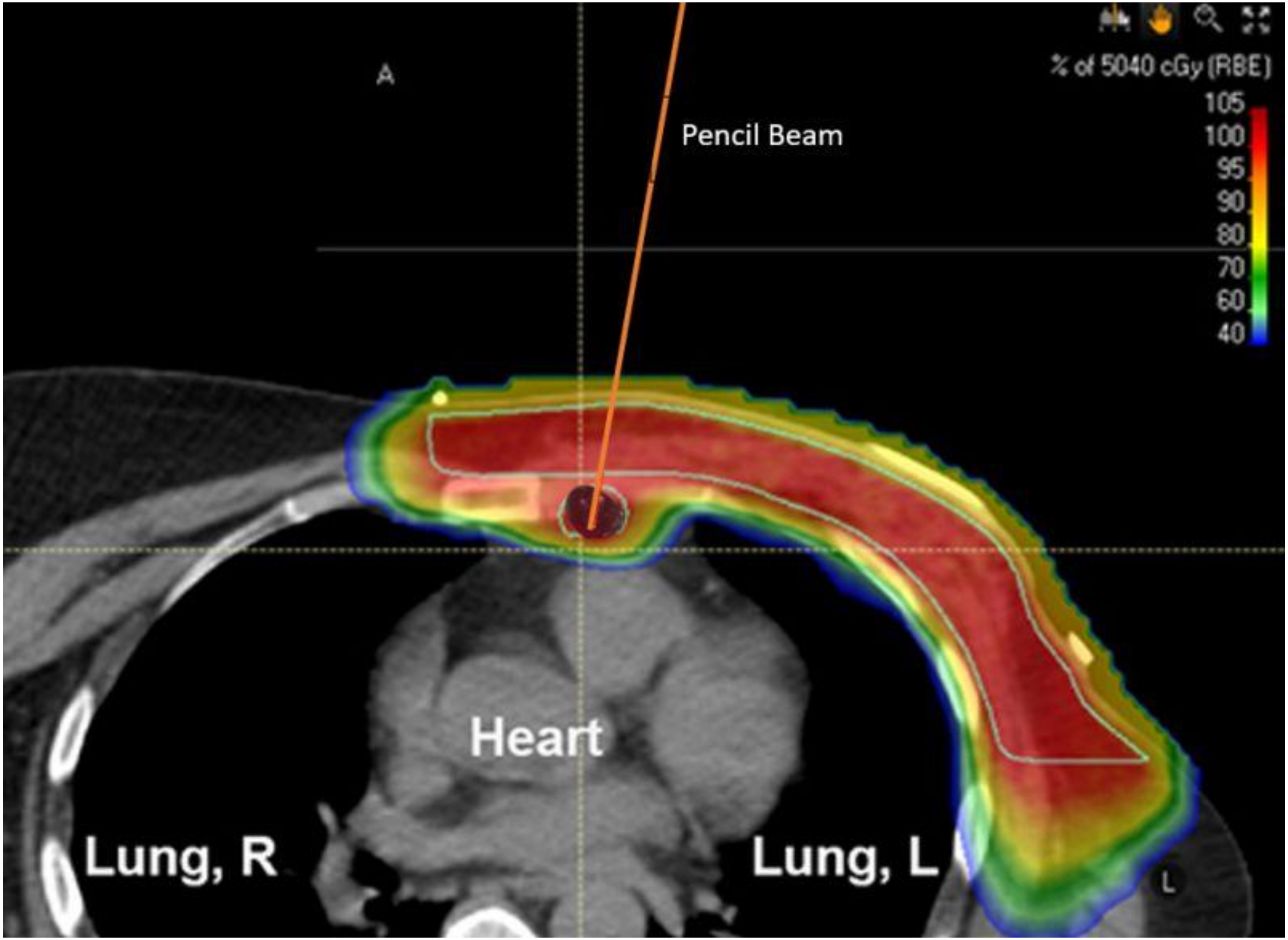
ФОРМИРАНЕ НА ПРОТОННИЯ СНОП ЗА КЛИНИЧИНО ПРИЛОЖЕНИЕ

II. Активно сканиране (Pensil Beam Scannig)

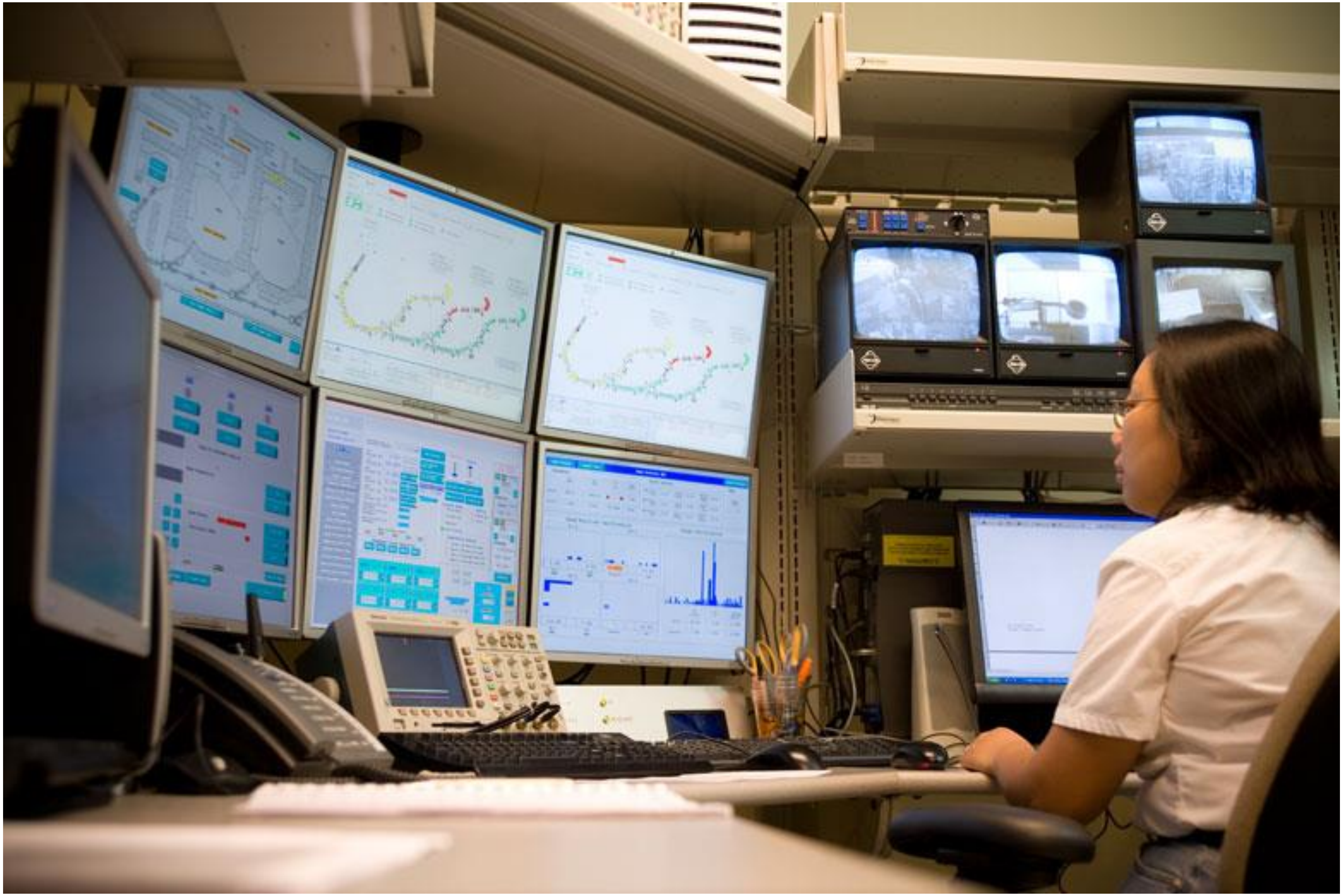







A
Pencil Beam
% of 5040 cGy (RBE)
105
100
95
90
80
70
60
40
Heart
Lung, R
Lung, L
L

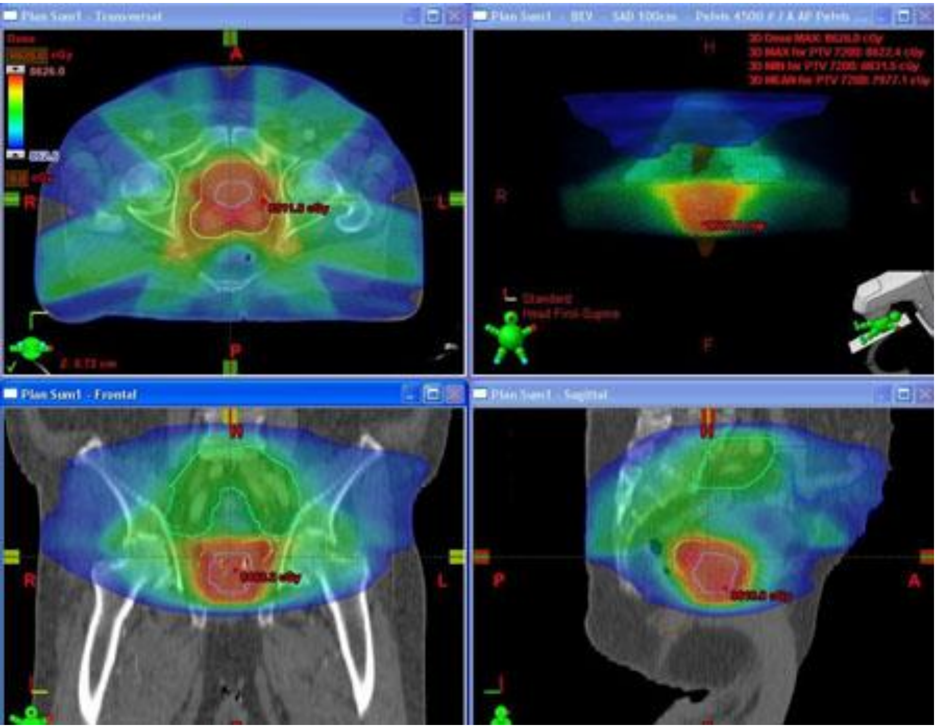
Control room of Proton Therapy Center

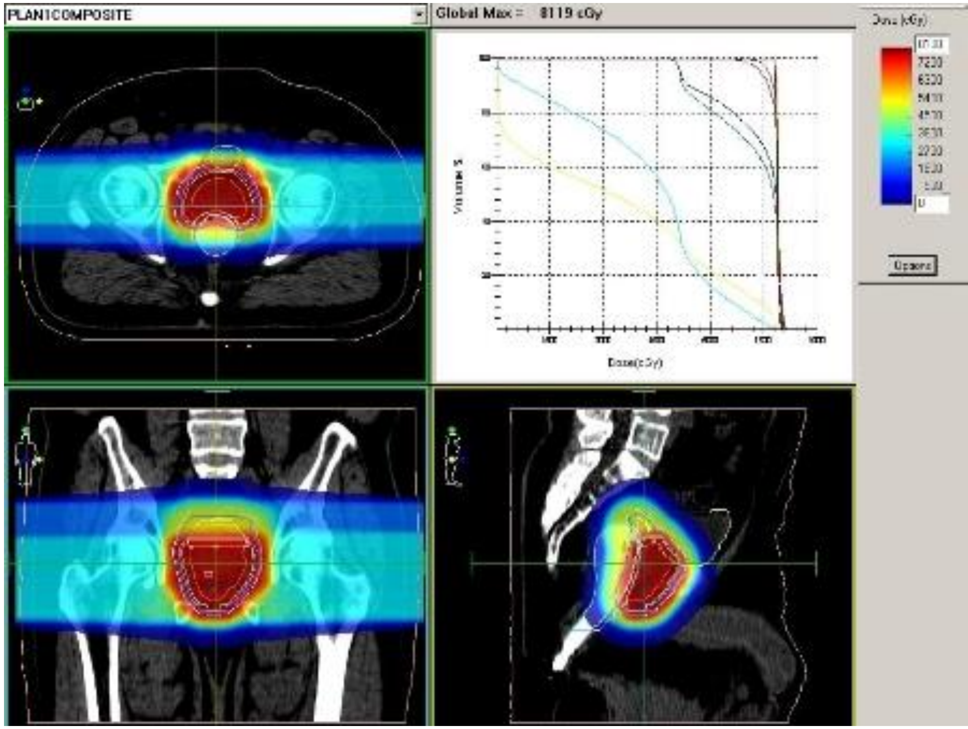


РАДИОТЕРАПИЯ при CA GL. PROSTATAE

IMRT X rays

Proton Therapy

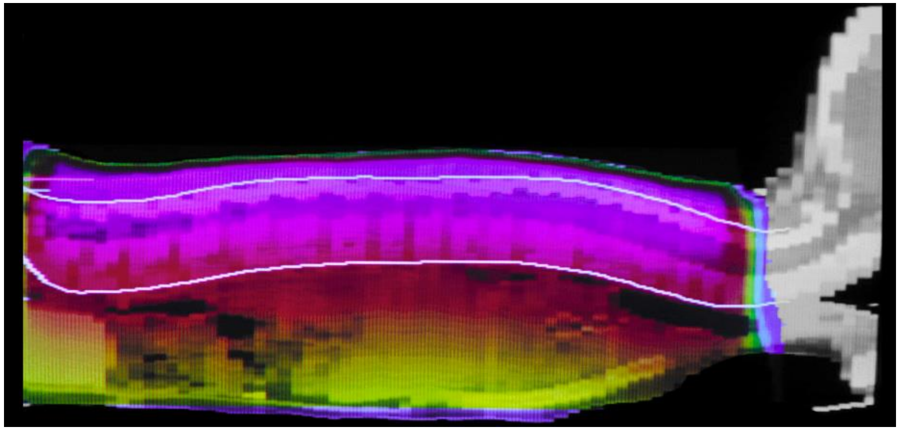




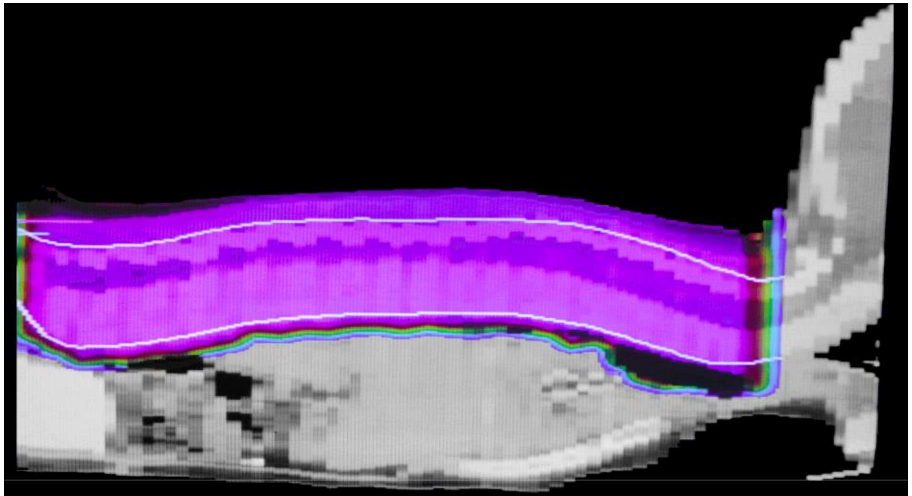
Протонна терапия

Радиотерапия при Cancer Pediatric Decease (Medulloblastoma)

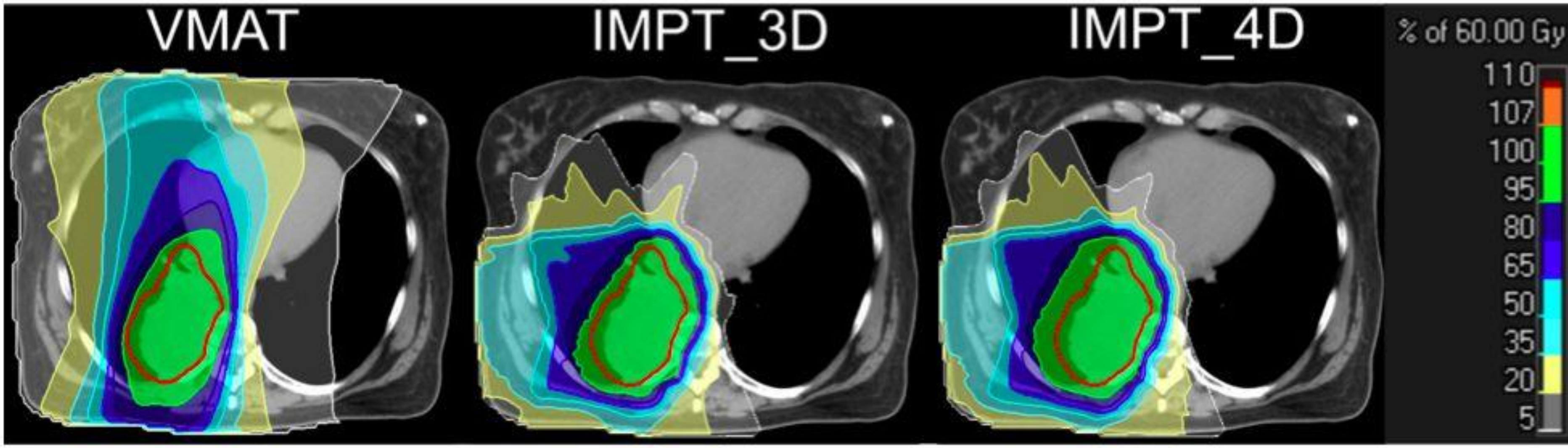
IMRT с X лъчи



Протонна терапия



PROTON THERAPY for Lung CA



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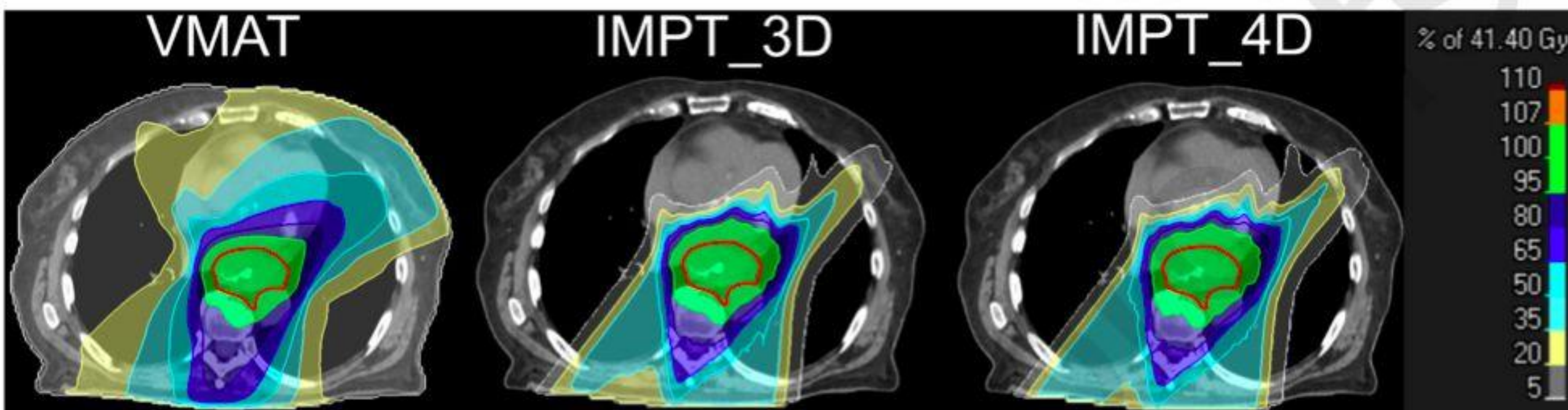
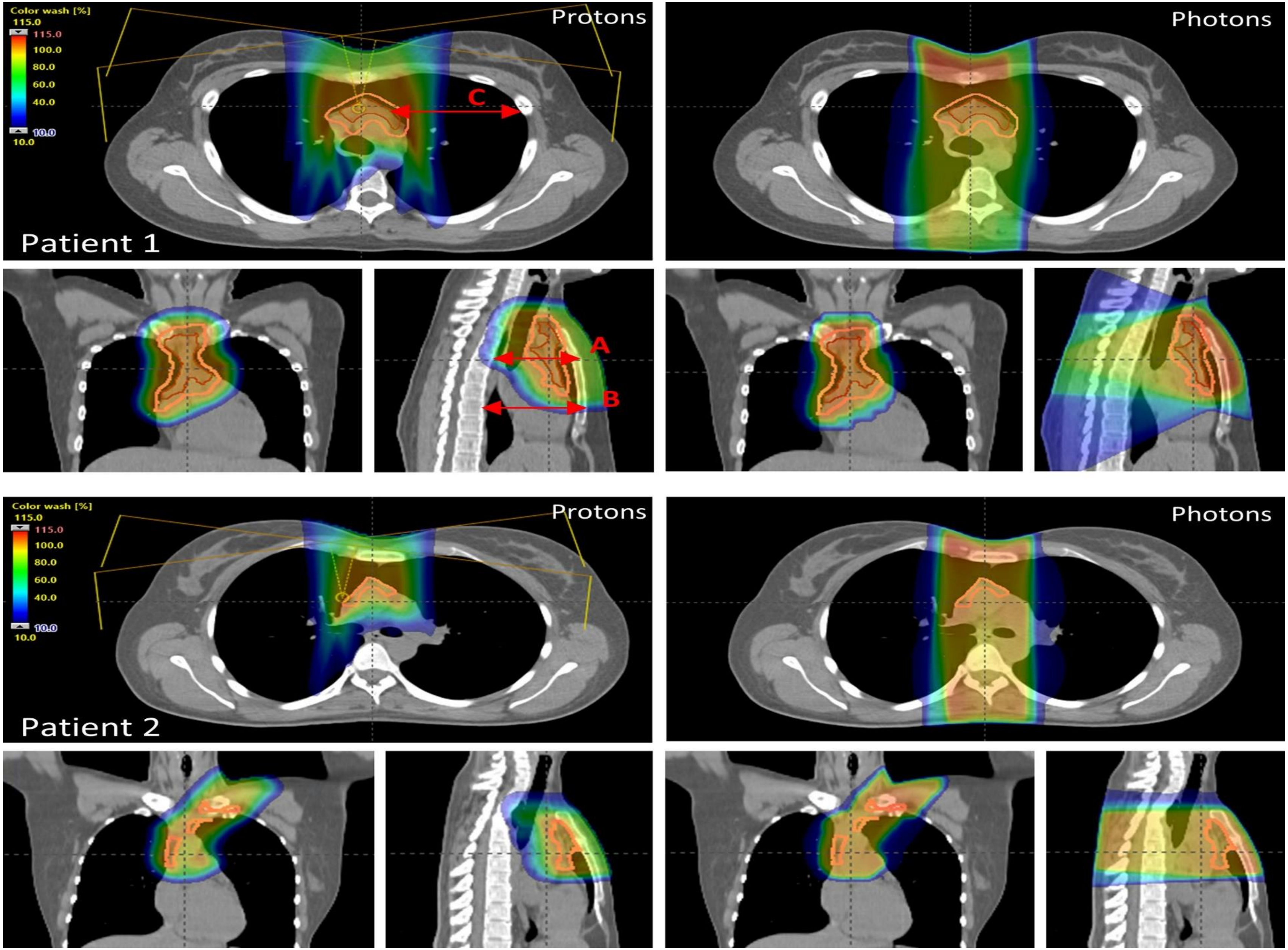


Proton Therapy/Photon therapy



- Протонната терапия е следващата логична стъпка в развитието на радиотерапията, подобрявайки дозното разпределение.

- Протонната терапия е сериозно предизвикателство за професионалистите, работещи съвременни форми на радиотерапията.

- Днес протонната терапия е атрактивна, прецизна и модерна форма на радиотерапията.

Scripps Proton Therapy Center, San Diego, USA

- XV- ия - Протонен център – 20 Февруари 2014
- 250 MeV
- 5 Gantries, 5 процедурни помещения, 2400 пациенти/годишно
- Инвестиция – $220 млн.

Dr. Carl Rossi – “Using pencil beam to treat tumors is like using a very fine paint brush to apply the radiation, whereas earlier proton technology is more like using a can of spray paint”.

Available on: http://itnonline.com/article/scripps

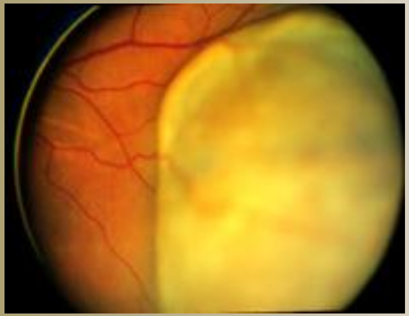
Paul Scherrer Institute, Villigen, Switzewrland

Proton-Radiotherapy:

Eye tumors

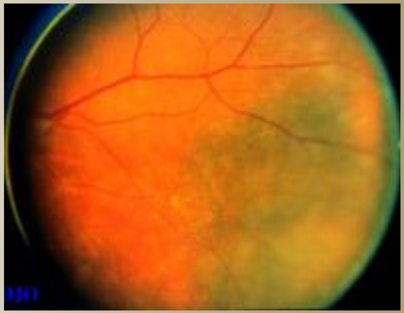
Fundus of the eye

PRIOR to therapy



Fundus of the eye

AFTER therapy



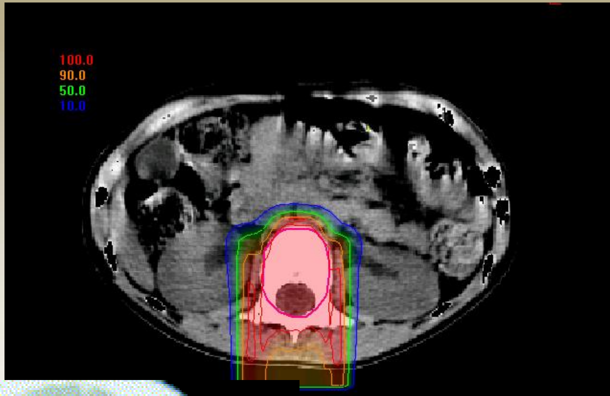
Local Tumor Control (at actuarial 10 years and depending in size and site)

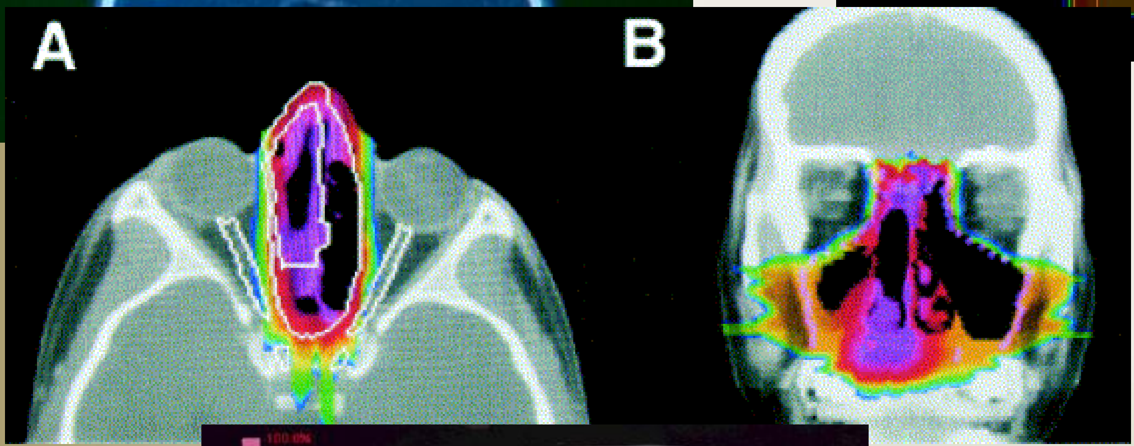
- **98 % (PSI, > 4700 patients)**
- **95.7% (MGH/MEEI)**

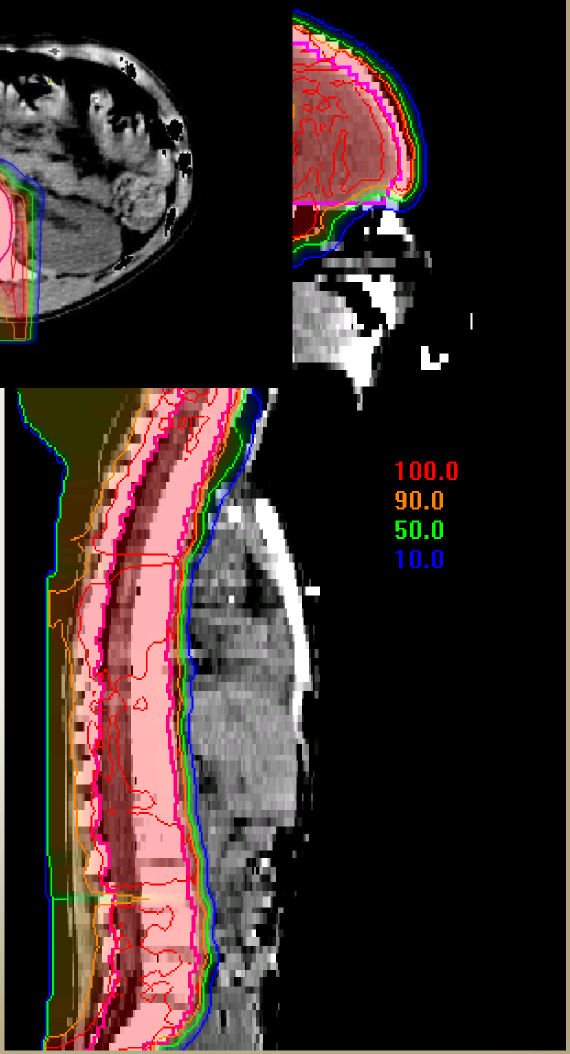
Retention of the eye: depending on tumor size and location, about 70-97% (PSI)

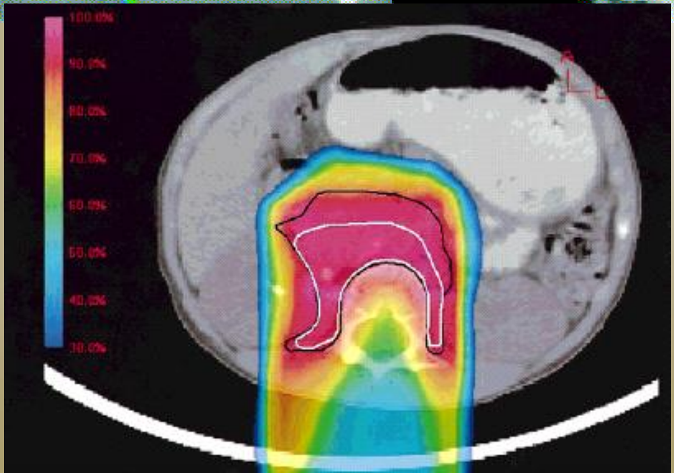
E. Hug

Pädiatrische Protonen- Radiatiotherapie









E. Hug

ПЕРСПЕКТИВИ ЗА РАЗВИТИЕ

- Последни постижения в ядрените и информационните технологии.
- Последни постижения в CERN.

The recent technical innovations in proton therapy – modulation of pencil proton beams, intensity modulated proton therapy (IMPT) and grid proton therapy **(reducing a radiation beam diameter from 1 mm to 25 μm)** – will allow us to really accurately "paint" the dose to the tumor and spare critical structures, much as we do with intensity-modulated photon therapy (IMRT), but also to further reduce the dose compared to IMRT [1,2].

[1] COMBS, S.E., JAKEL, O., HABERER, T., DEBUS, J., Particle therapy at the Heidelberg Ion Therapy Center (HIT) / Integrated research/driven university-hospital-based radiation oncology service in Heidelberg, Germany, Radiother. Oncol. 95 1 (2010 Apr.) 41-44.

[2] LOMAX, T., Grid therapy: the IMPT approach, 2012
Available from: http://medicalphysicsweb.org/cws/article/research/49072

Future prospects for proton therapy
Mar 5, 2012

"Don't treat tomorrow's patients with yesterday's proton therapy technology." This was the opening observation from Marco Schippers, speaking at last week's **ICTR-PHE meeting in Geneva**, Switzerland. Schippers, from the Paul Scherrer Institute (PSI) in Switzerland, emphasized the necessity of developing novel proton therapy techniques, citing a **wish list** of **"five highs":**

higher quality, **h**igher accuracy, **h**igher flexibility, **h**igher intensity and **h**igher energy.

He also listed one **low**: lower equipment costs – generally achieved via a reduction in the size of the accelerator system.

Available on: http://medicalphysicsweb.org/cws/article/opinion/48842

Towards a novel, low-cost PT accelerator

- Lower cost & standardized Proton Therapy System
- Compact treatment room and small footprint
- Shorter installation time on site
- Operator less
- Reduced maintenance

Proteus One : low cost, smaller footprint

Compact Proton Therapy in record time at Aizawa Hospital

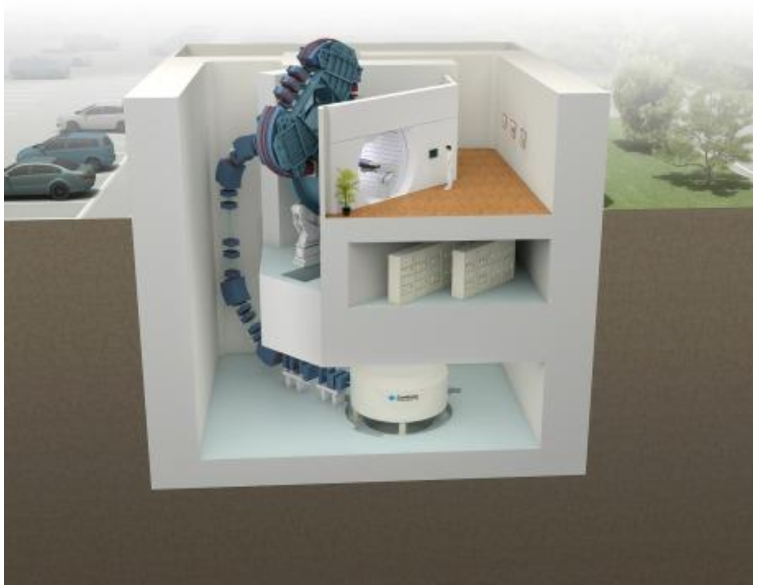
The next generation Proton Therapy System is already installed.

Available: http://www.lightions.com/news/compact-proton-therapy-in-record-time-at-aizawa-hospital/9

Sumitomo Heavy Industries, Ltd. (President and CEO: Shunsuke Betsukawa; hereinafter referred to as "SHI") today announces that clinical treatment started at Aizawa Hospital (Chairman and Director: Takao Aizawa; hereinafter referred to as "Aizawa") in Matsumoto, Nagano Pref. on September 30, 2014 as the first proton therapy facility in Koshinetsu region. (10 patients were treated per a day on October 6.)

This proton therapy system has a single gantry treatment room in the world's first vertical arrangement with a short length compact gantry and a 230Mev cyclotron which enables significant space saving. This system incorporates Multi-purpose nozzle which enables either conventional broad beam or pencil beam scanning, depending on treatment planning for a targeted disease.

Furthermore, accurate patient positioning by 2D & 3D image guidance is possible.



Available on: http://www.shi.co.jp/english/info/2014/6kgpsq0000001ln0.html

III. Carbon Therapy - *Терапия с карбонови йони*

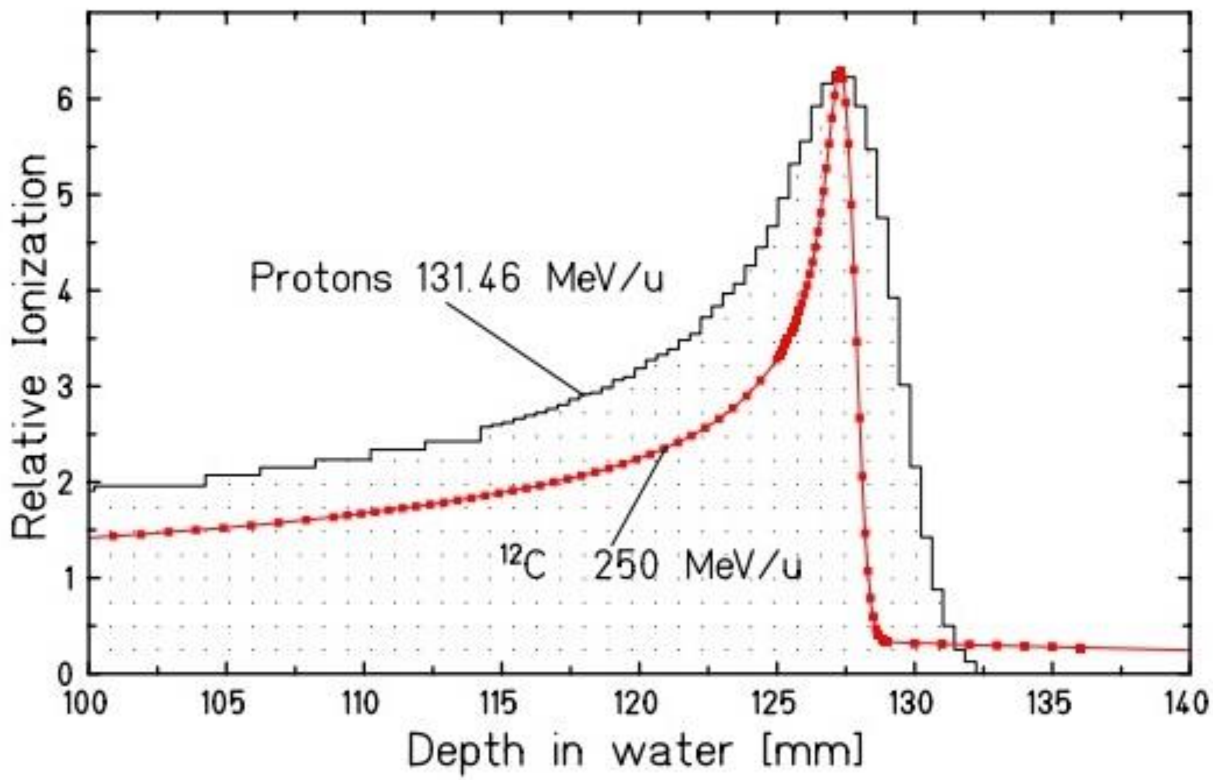


FIG. 4. (Color online) Measured Bragg peaks of protons and ^{12}C ions having the same mean range in water (Schardt *et al.*, 2008).

Carbon Therapy - *Терапия с карбонови йони*

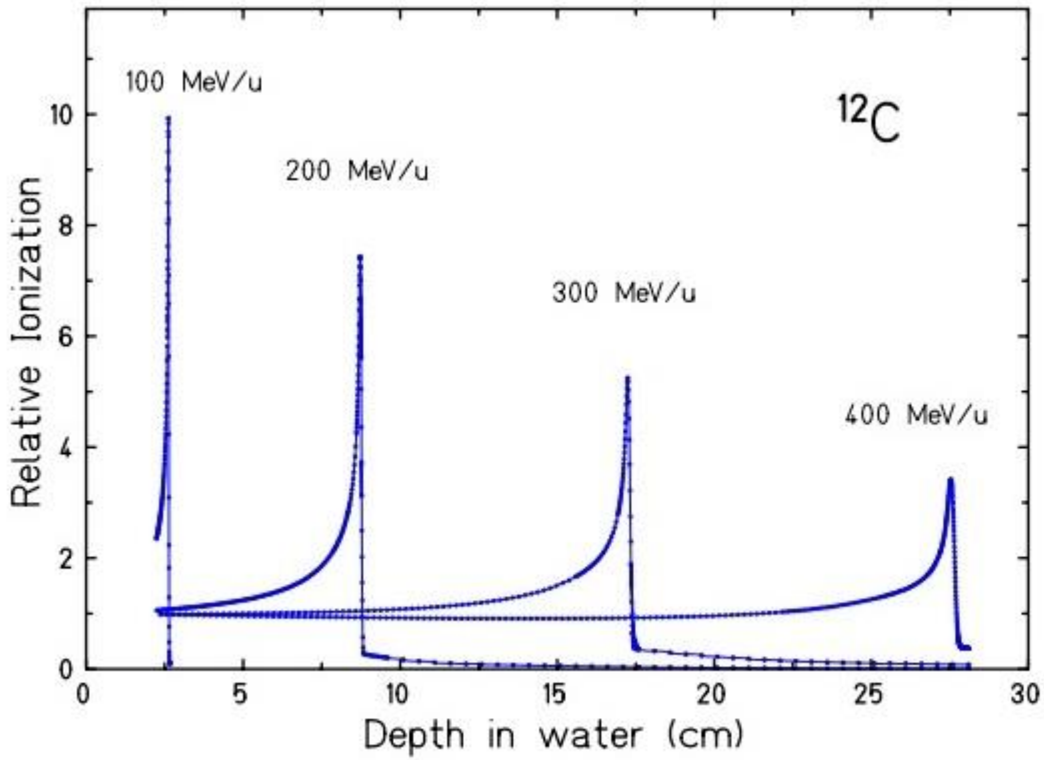
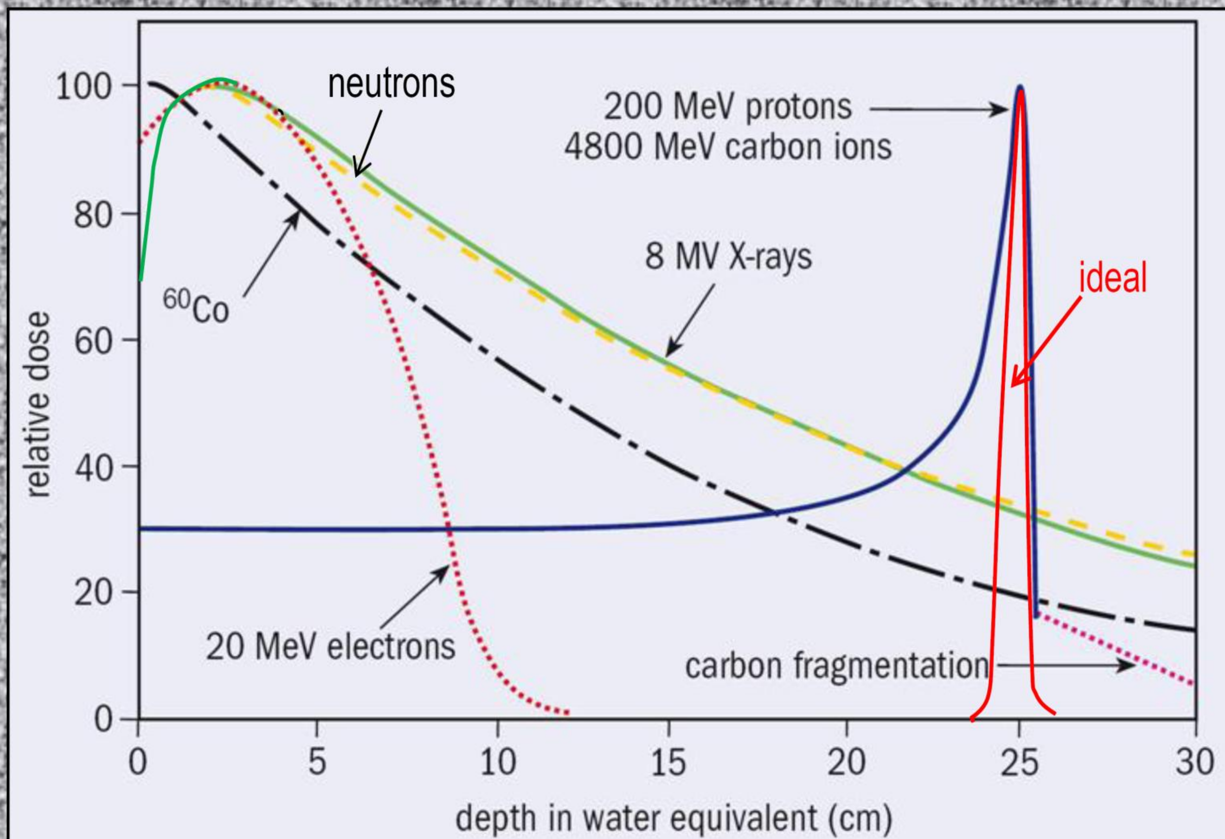


FIG. 8. (Color online) Measured Bragg curves of ^{12}C ions stopping in water. From Schardt *et al.*, 2008.

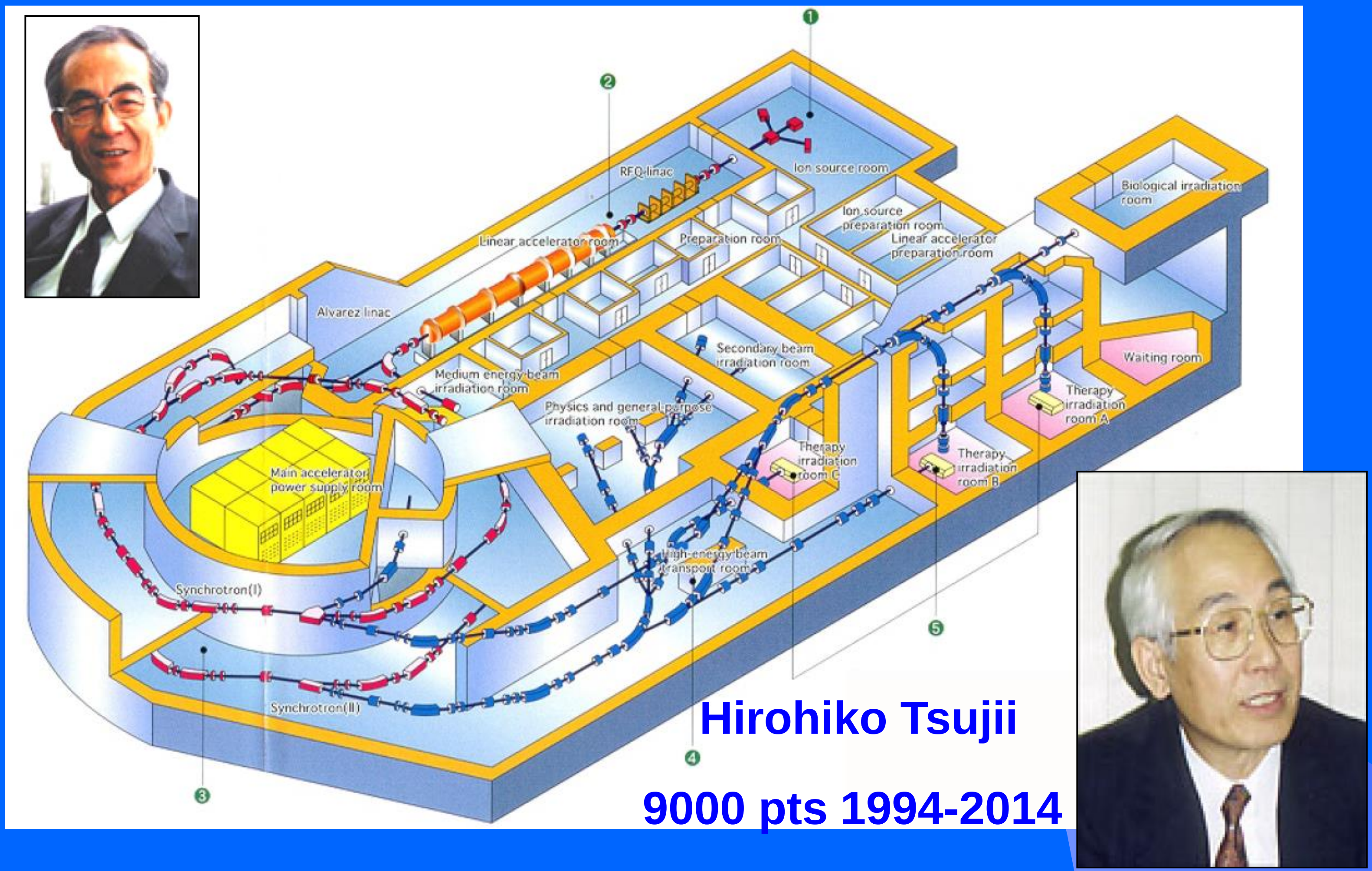


Radiation beam in matter

HIMAC in Chiba is the pioner of carbon therapy (Prof H. Tsujii)

Yasuo Hirao

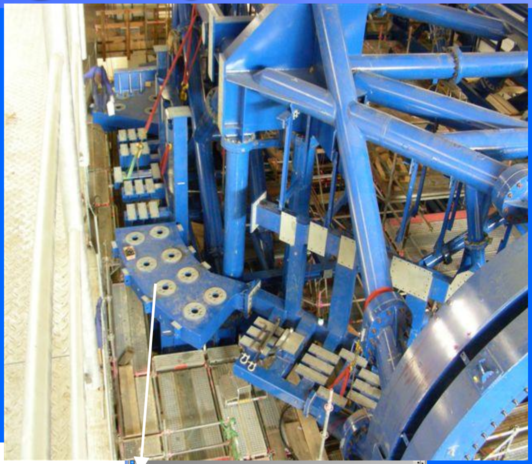
[15] Hirao, Y. et al, "Heavy Ion Synchrotron for Medical Use: HIMAC Project at NIRS Japan" Nucl. Phys. A538, 541c (1992)

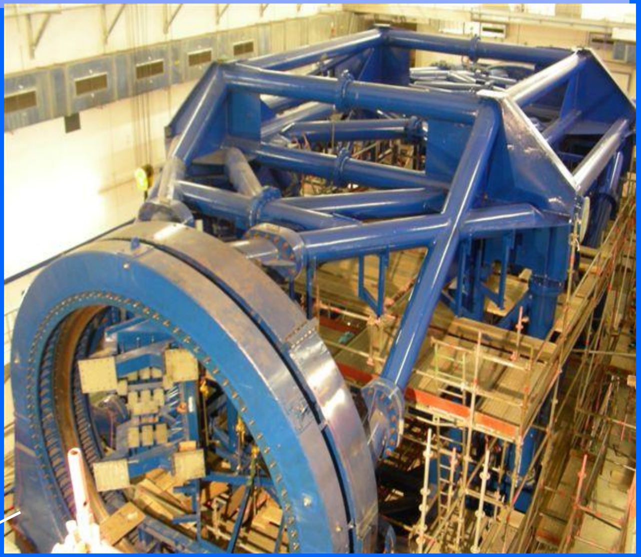


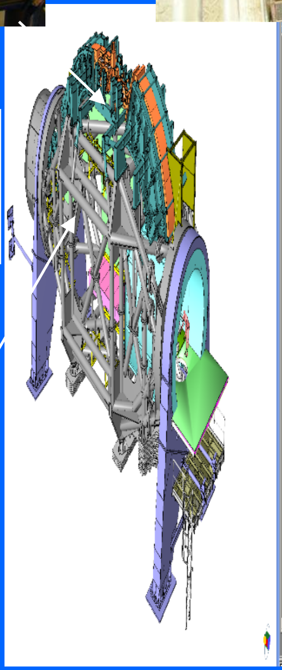
Hirohiko Tsujii

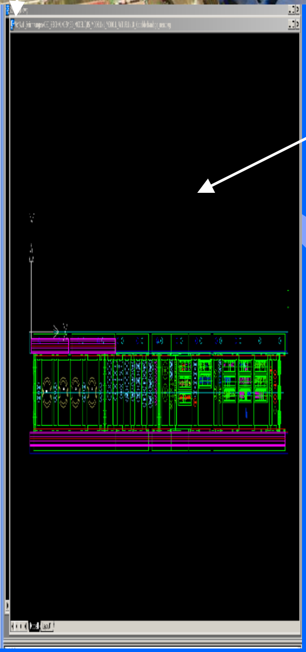
9000 pts 1994-2014

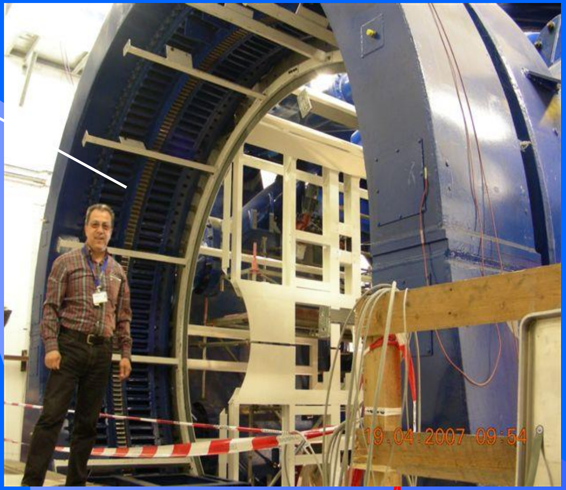
First carbon gantry in the world: 700 tons – 400 kW





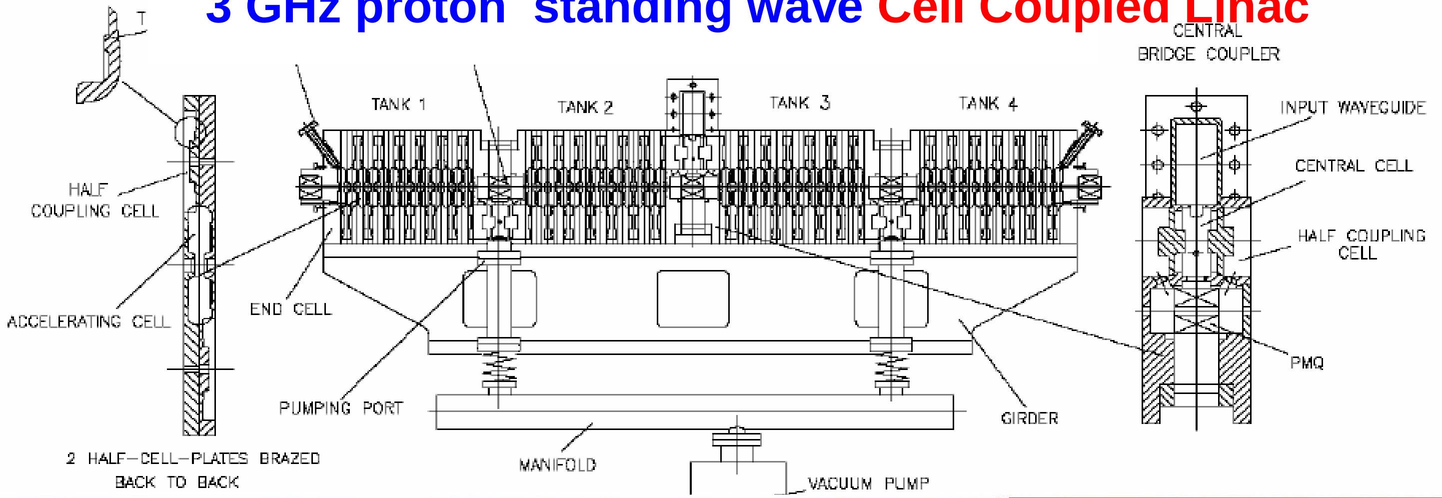


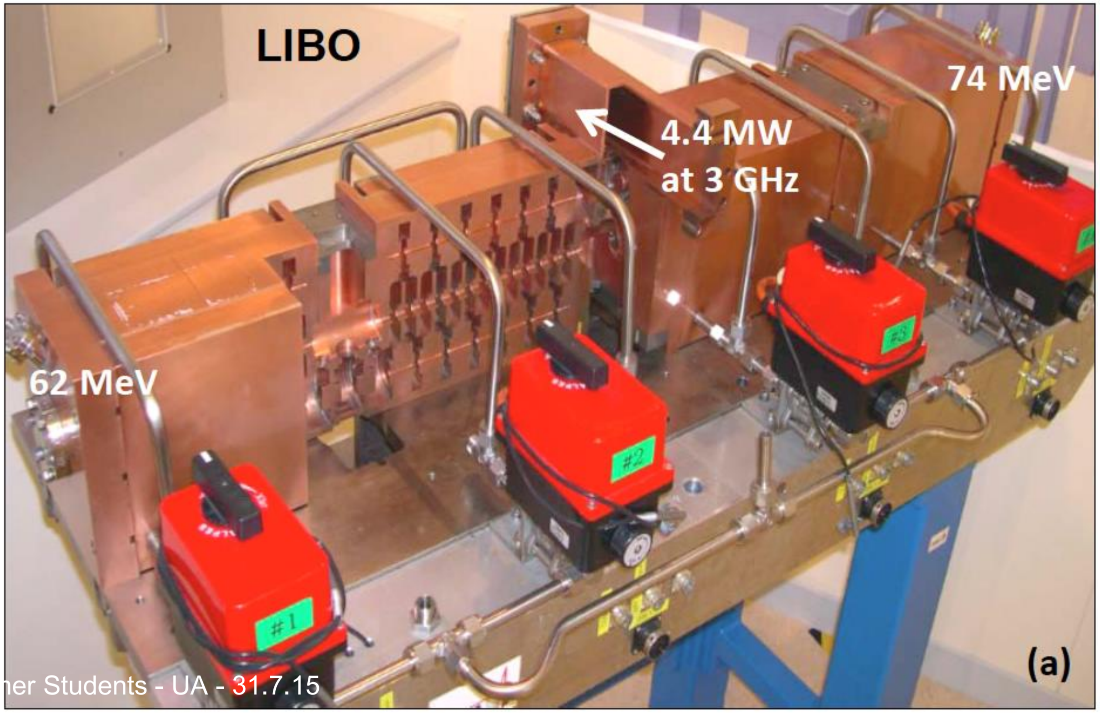


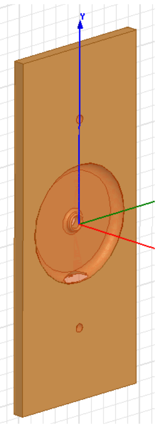


Scientific prototype built and beam tested by TERA-CERN-INFN

3 GHz proton standing wave Cell Coupled Linac





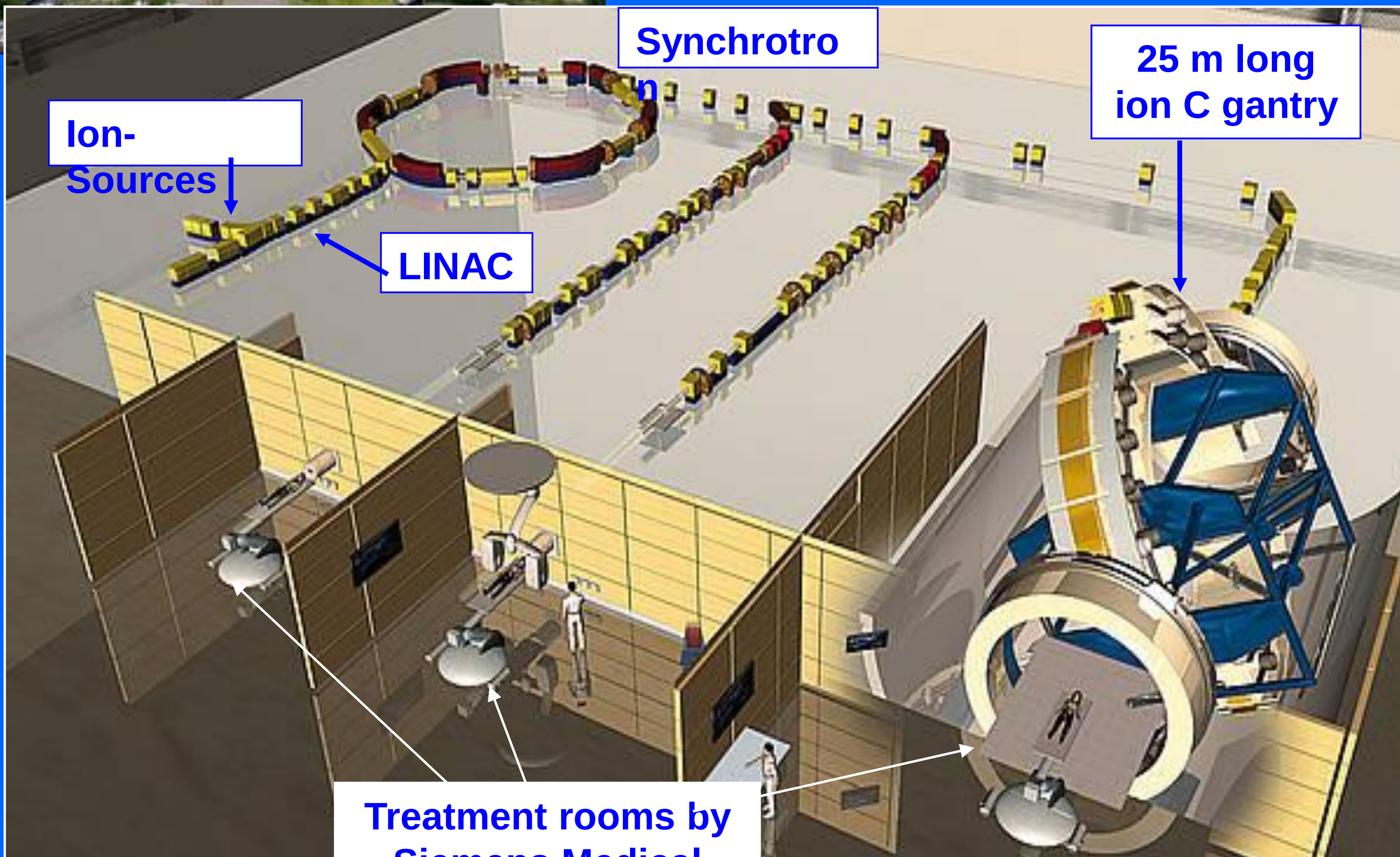


Basic unit: half-cell

HIT at Heidelberg

First patient: September 2009

December 2014: 1700 patients



Heidelberg carbon ion gantry: patient room

Patient Gantry Roo 7

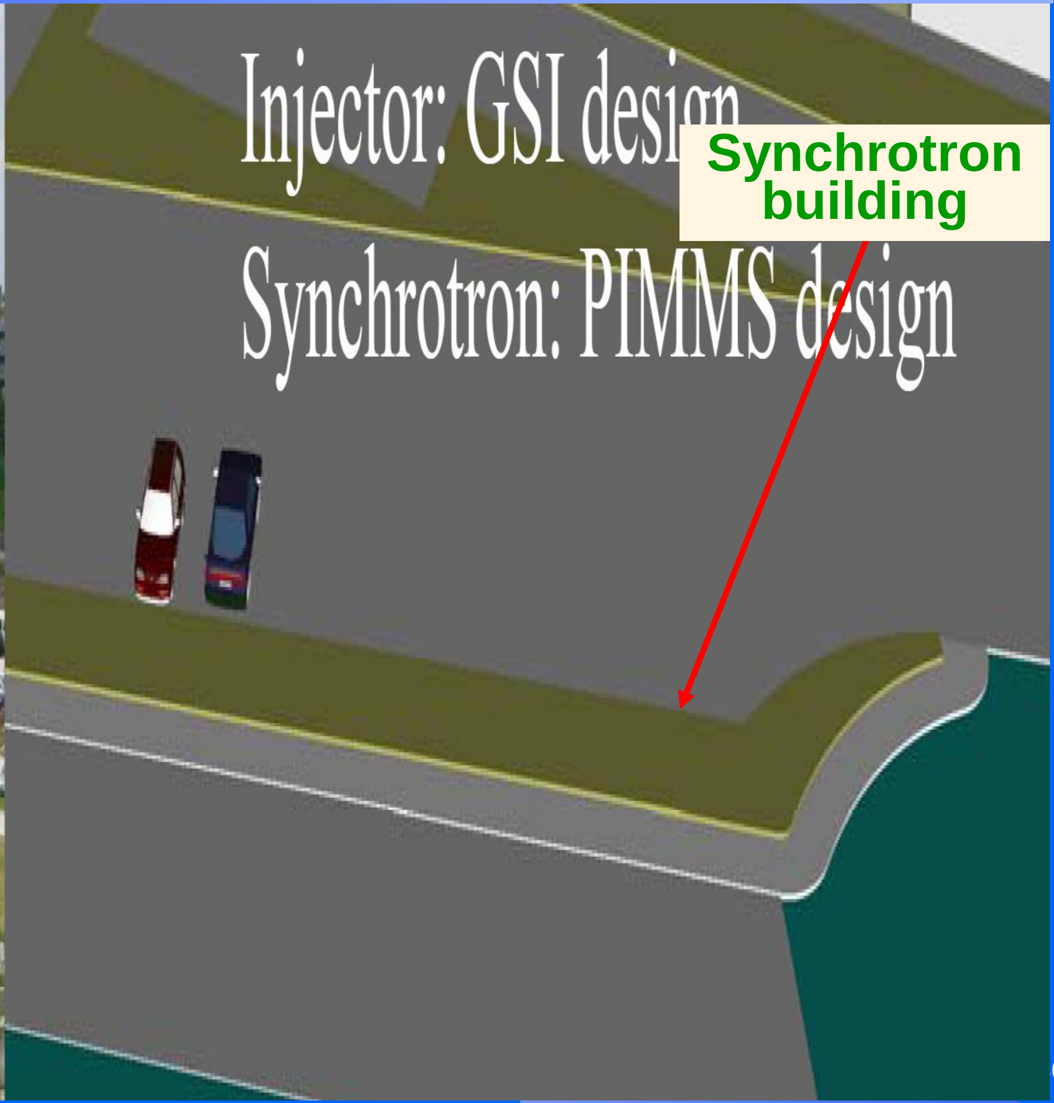
Tilt floor, pending on Gantry position

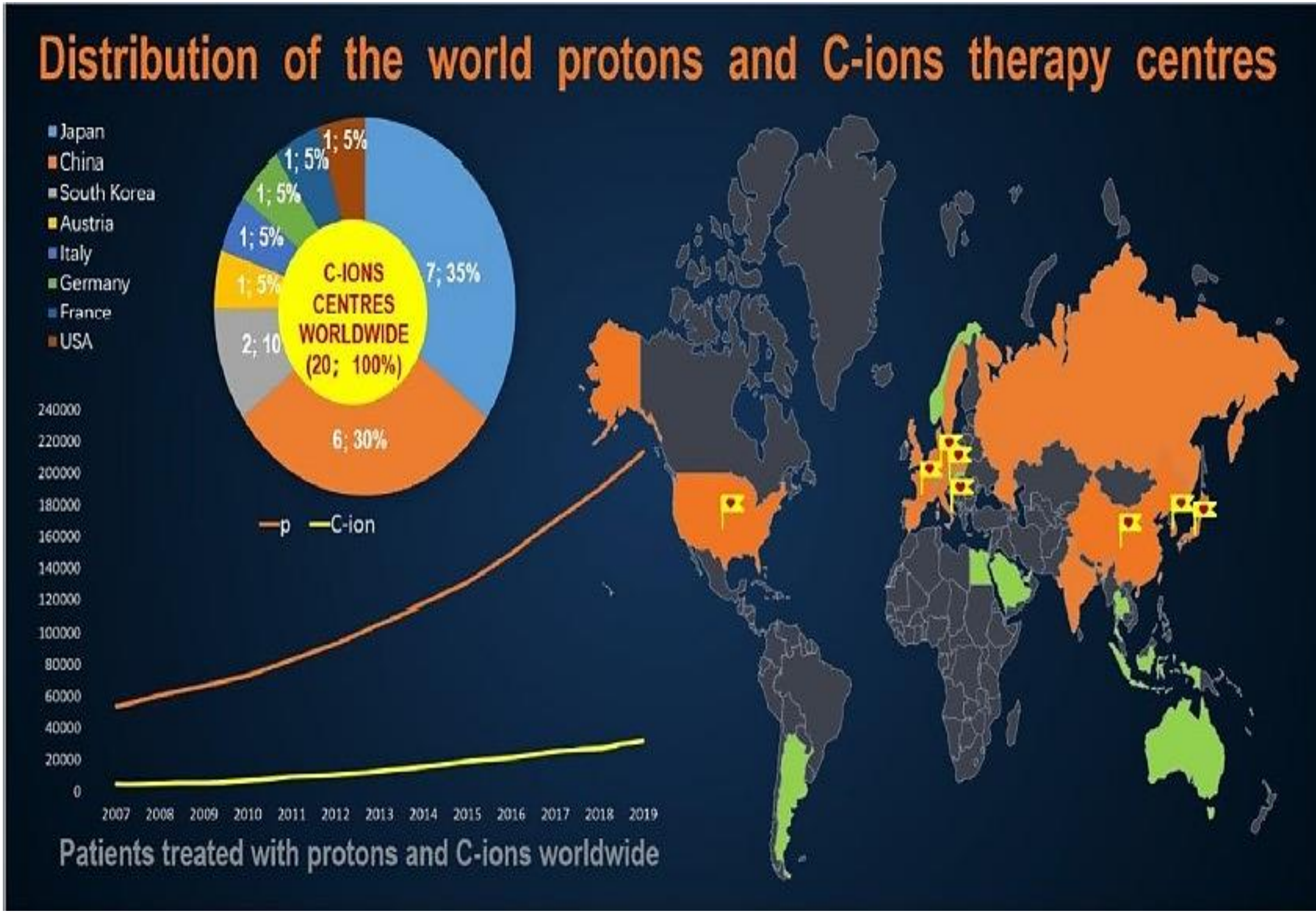
Nozzle

Bumber mats

Patienttable, Roboter

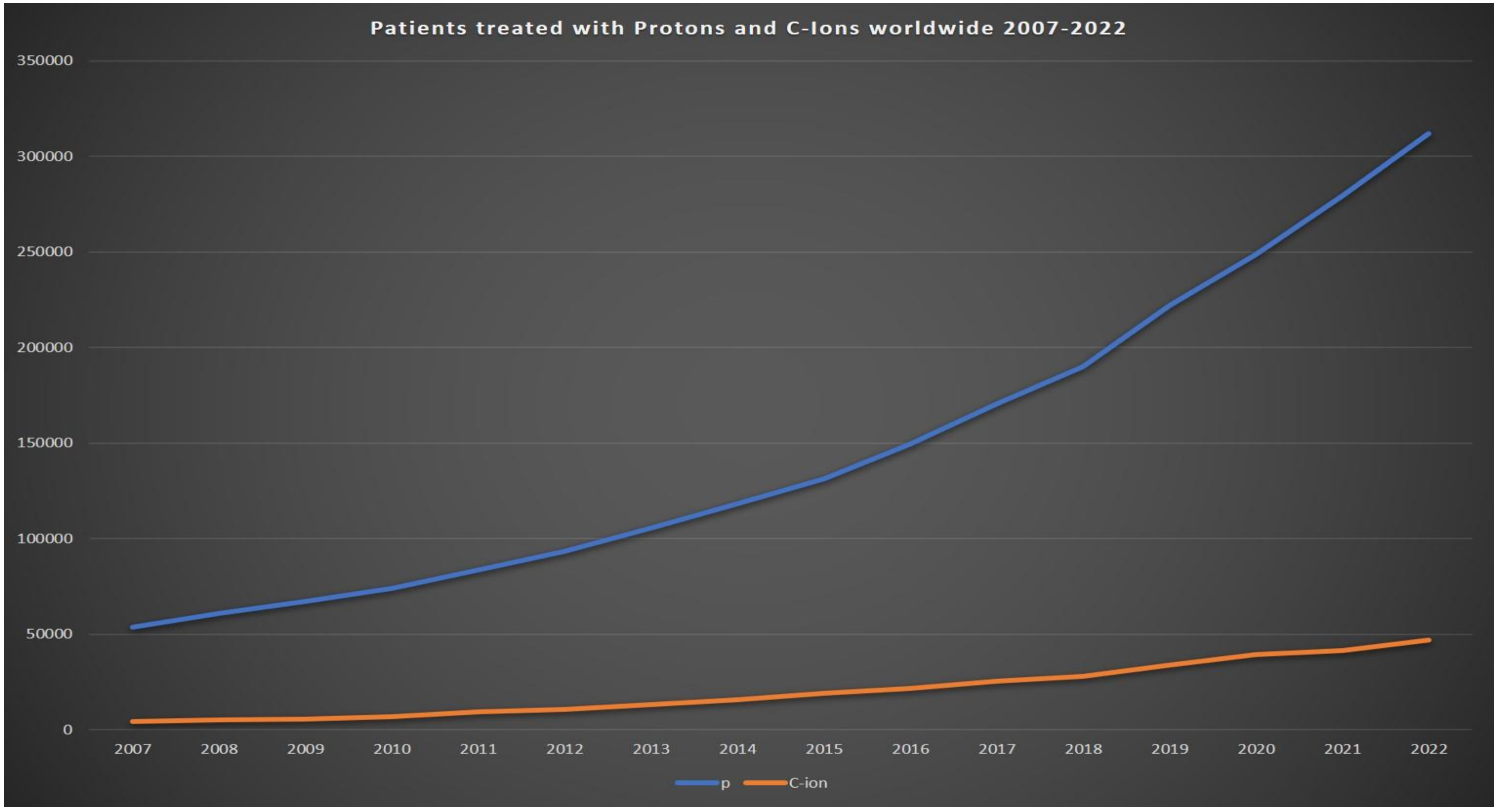
CNAO = Centro Nazionale di Adroterapia Oncologica





Available on: *Frontiers in Oncology | www.frontiersin.org 1 July 2021 | Volume 11 | Article 708724 doi: 10.3389/fonc.2021.708724*

Patient statistics 2007 - 2022



PTCOG Particle Therapy Patient Statistics per End of 2023

Update: Per end of 2023 close to 410'000 patients have been treated worldwide with particle radiotherapy, close to 350'000 with protons, about 56'000 with C-ions and about 3'500 with He, pions and other particles.

Available on: https://www.ptcog.ch/index.php/ptcog-patient-statistics

PTCOG55
PRAGUE
2016

55th Annual Conference of the

Particle Therapy Co-operative Group

Particle therapy: what evidence is necessary for a clinical standard

22 – 28 May 2016, Prague Congress Centre, Czech Republic

THANK YOU
FOR YOUR ATTENTION
AND
HAVE A NICE STAY IN CERN!

ACKNOWLEDGEMENTS

Mr. Jeff Wiener, CERN

Ms. Zornica Zaharieva, CERN

Ms. Svejina Dimitova, Astronomical observatory "Nicolaus Copernicus" Varna, Bulgaria

Ms. Roumyana Hajiiska, BAS, Bulgaria

Dr.Mario Marengo, PhD

(University Hospital "S.Orsola – Malpighi", Bologna, Italy)

Dr.Damien Bertrand, IBA Group

Prof. Ugo Amaldi (slide 23,24, 134 – 140)

http//: www.iba-protontherapy.com

http//:ptcog.ch

http//: iaea.org

http//: Slideshare.net (slide 108 and 109)

http//: Google

http//: Wikipedia