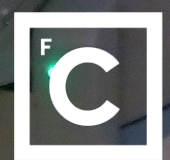




Aceleradores para a Saúde

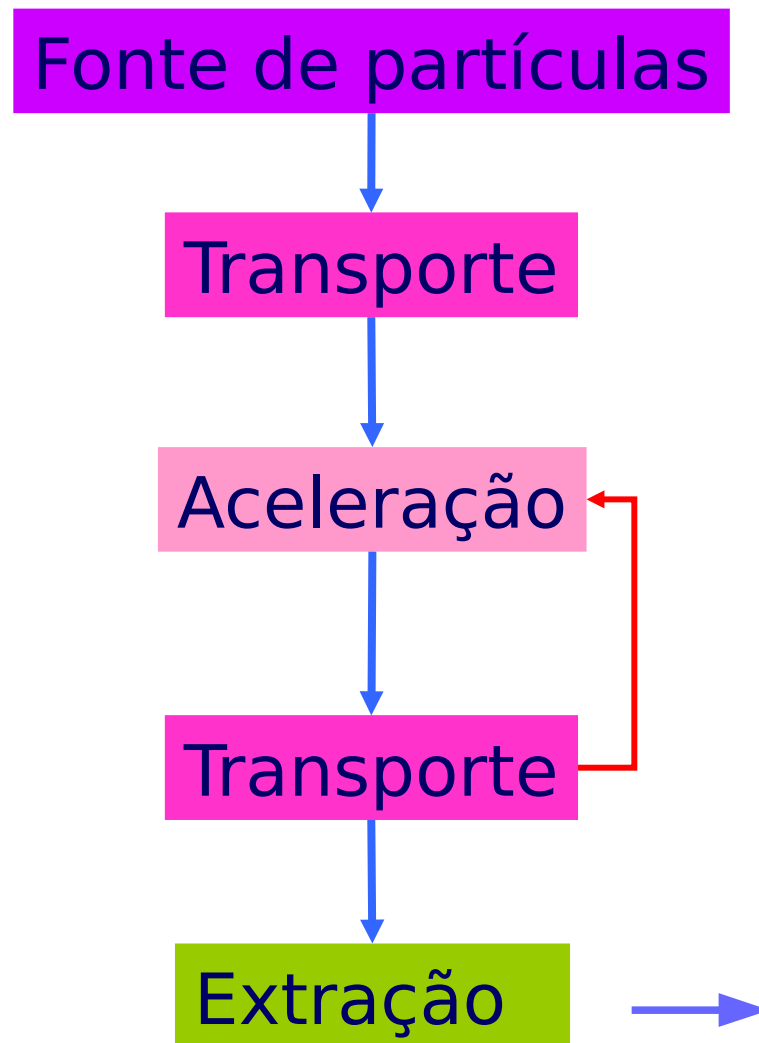
Luis Peralta



Ciências
ULisboa



Esquema básico do acelerador de partículas



Fontes de Partículas



Por efeito termo-iónico podemos obter eletrões livres

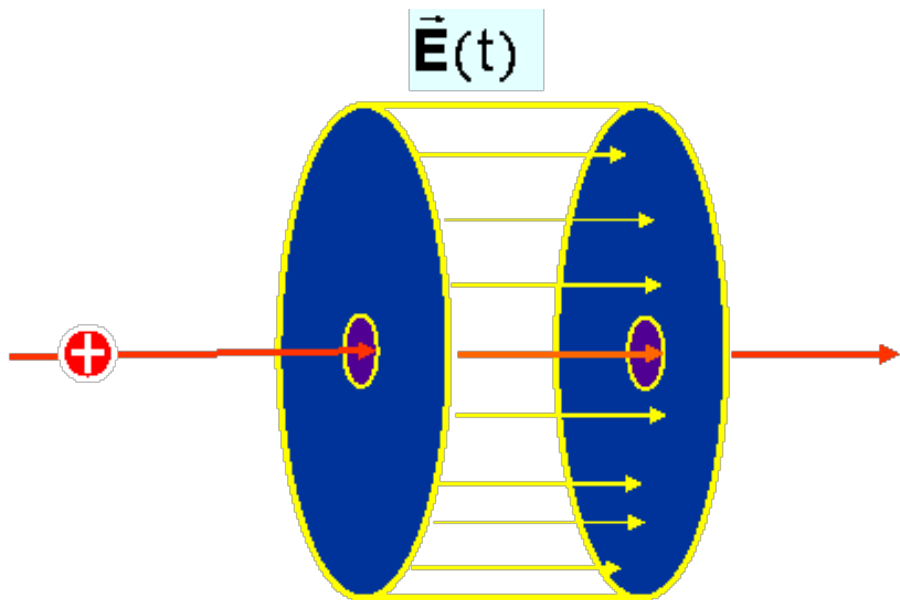


Canhão de eletrões do cinescópio de um televisor (antigo!)

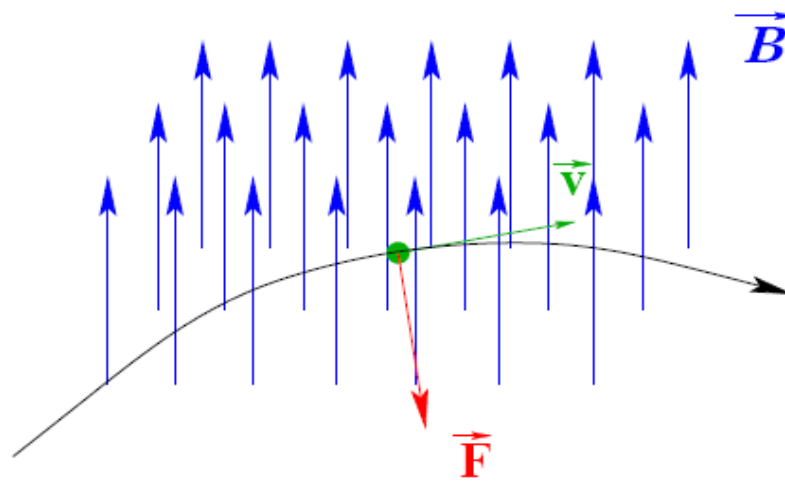
Como acelerar as partículas?

Força de Lorentz

$$\vec{F} = q \vec{E} + \vec{v} \times \vec{B}$$

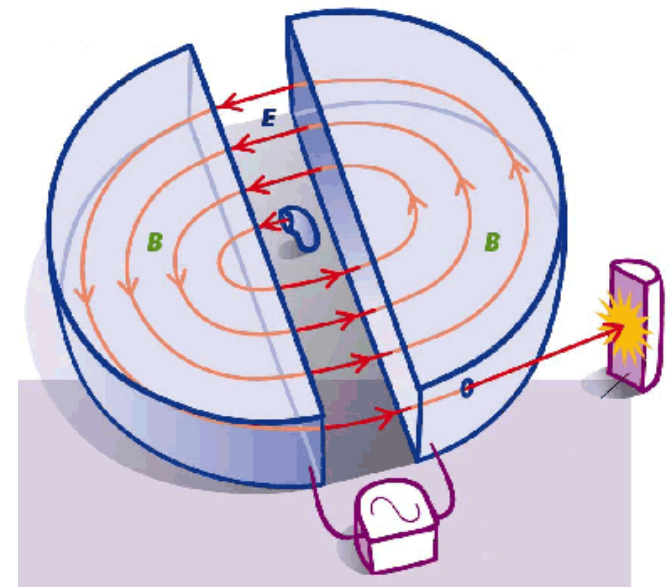
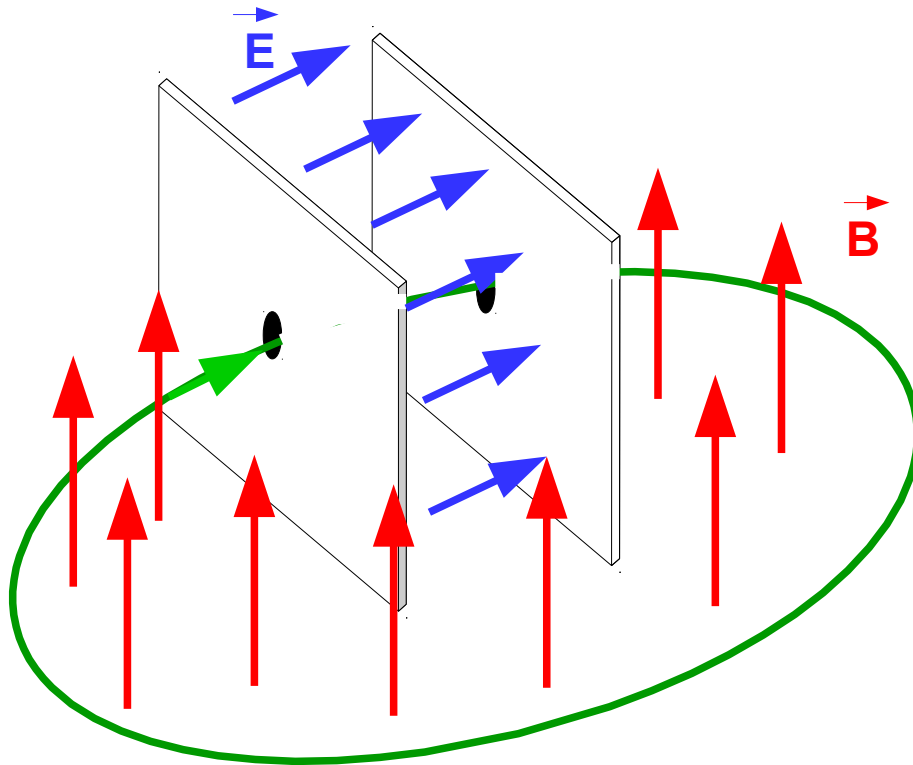


$E(t)$ aumenta a energia



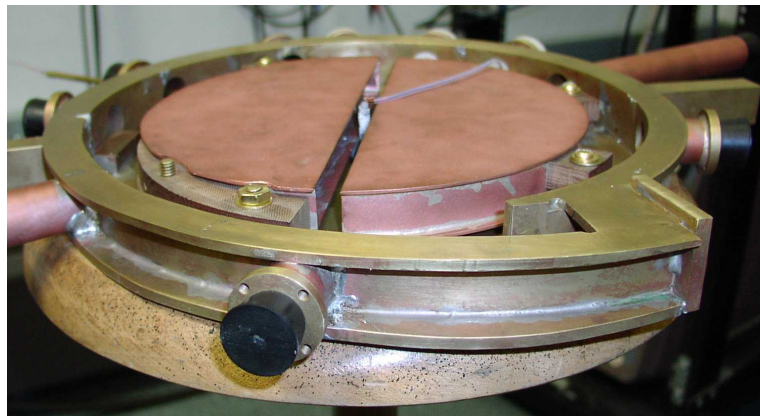
$B(t)$ modifica a trajetória

O ciclotrão



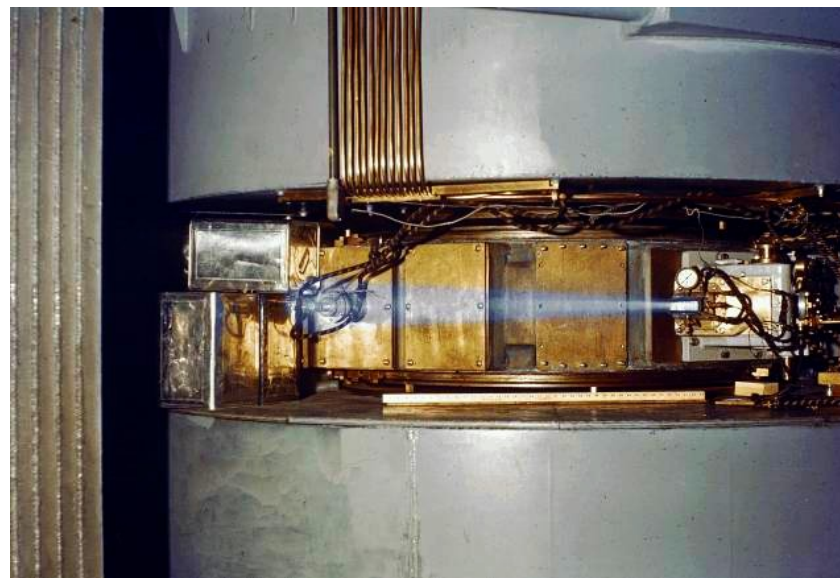
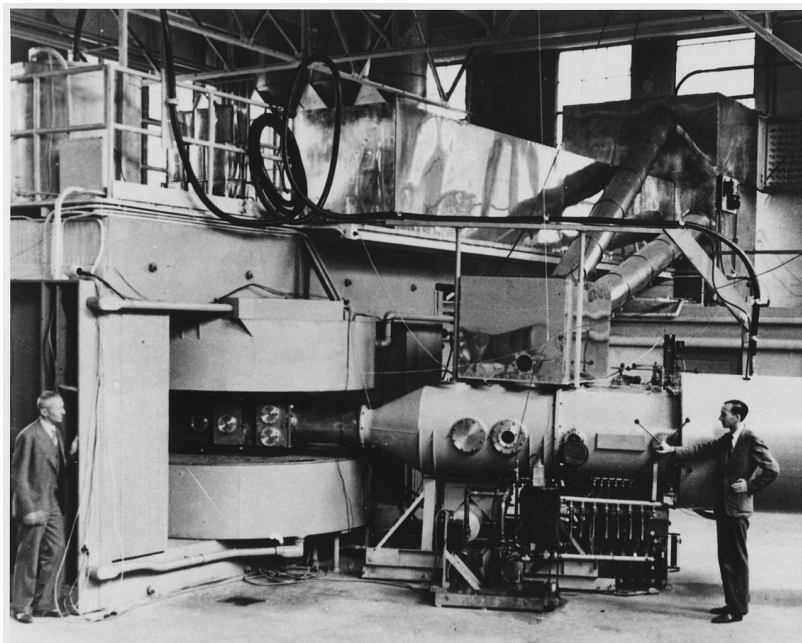
http://www.rad-planning.com/newsletter/2012/2012_images/cyclotron_diagram_400px.gif

O ciclotrão



$$f = \frac{qB}{2\pi\gamma m}$$

frequência do ciclotrão

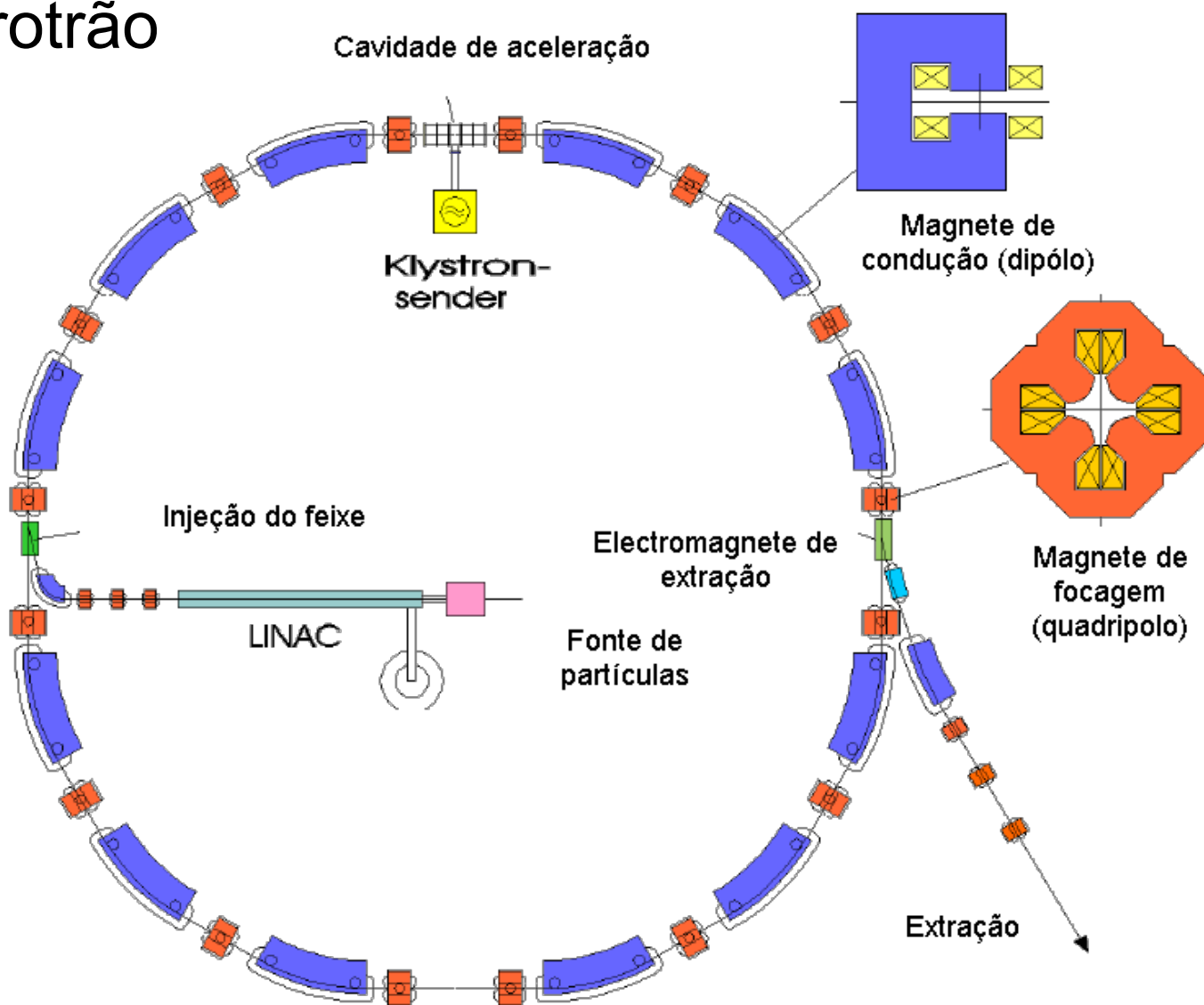


O ciclotrão do ICNAS (Coimbra)



Dedicado principalmente à produção de radioisótopos
(protões, $E=18$ MeV)

O sincrotrão



<https://prezi.com/lgz8qvbqryaz/das-zyklotron/>

LEIR / CERN

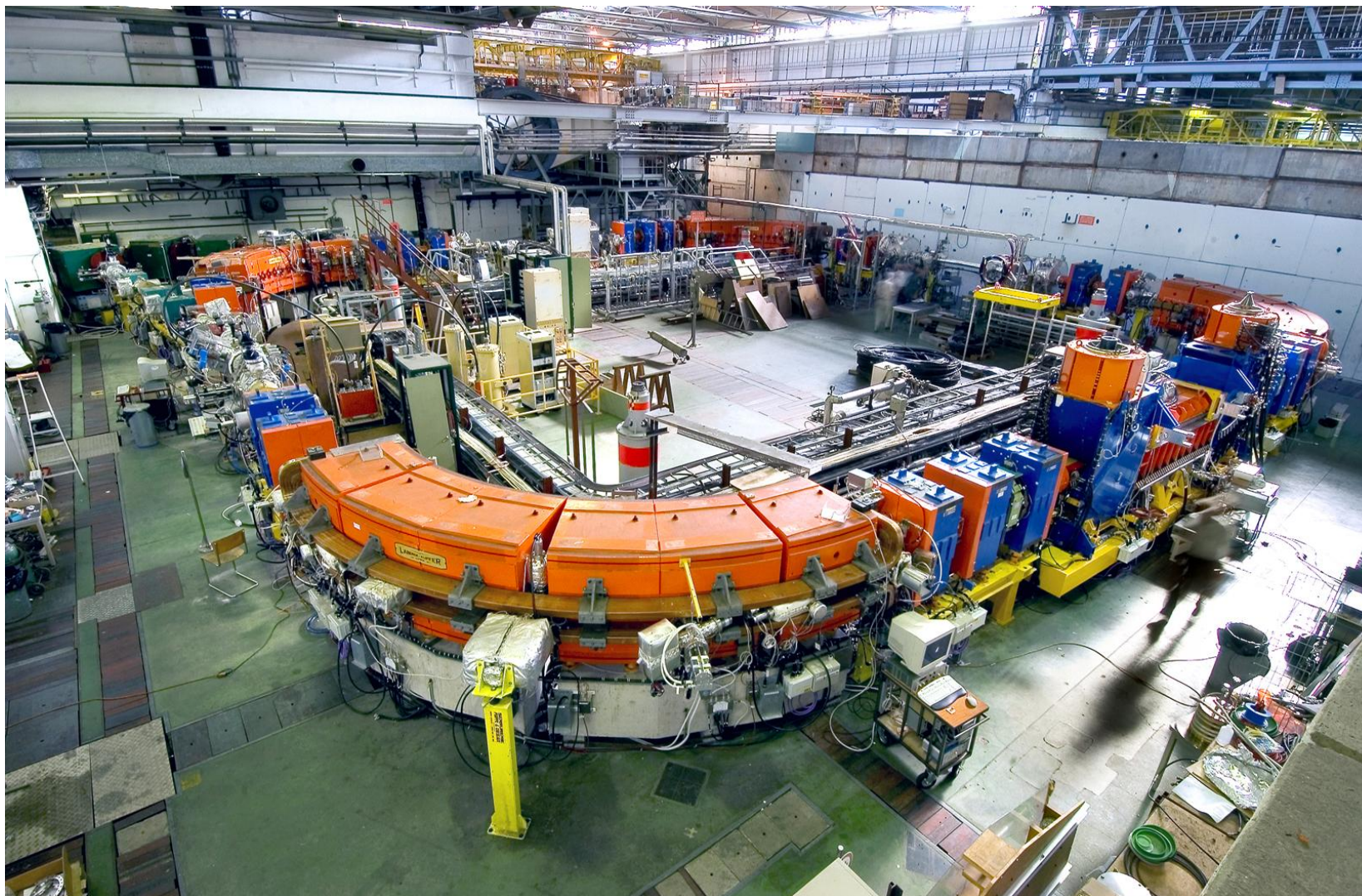
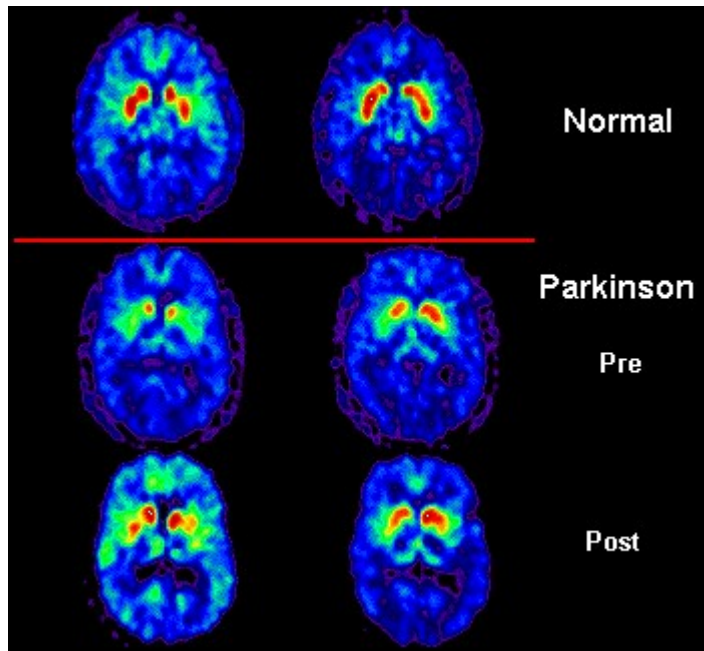


Foto CERN

Principais tarefas dos aceleradores na saúde

Diagnóstico

Terapia

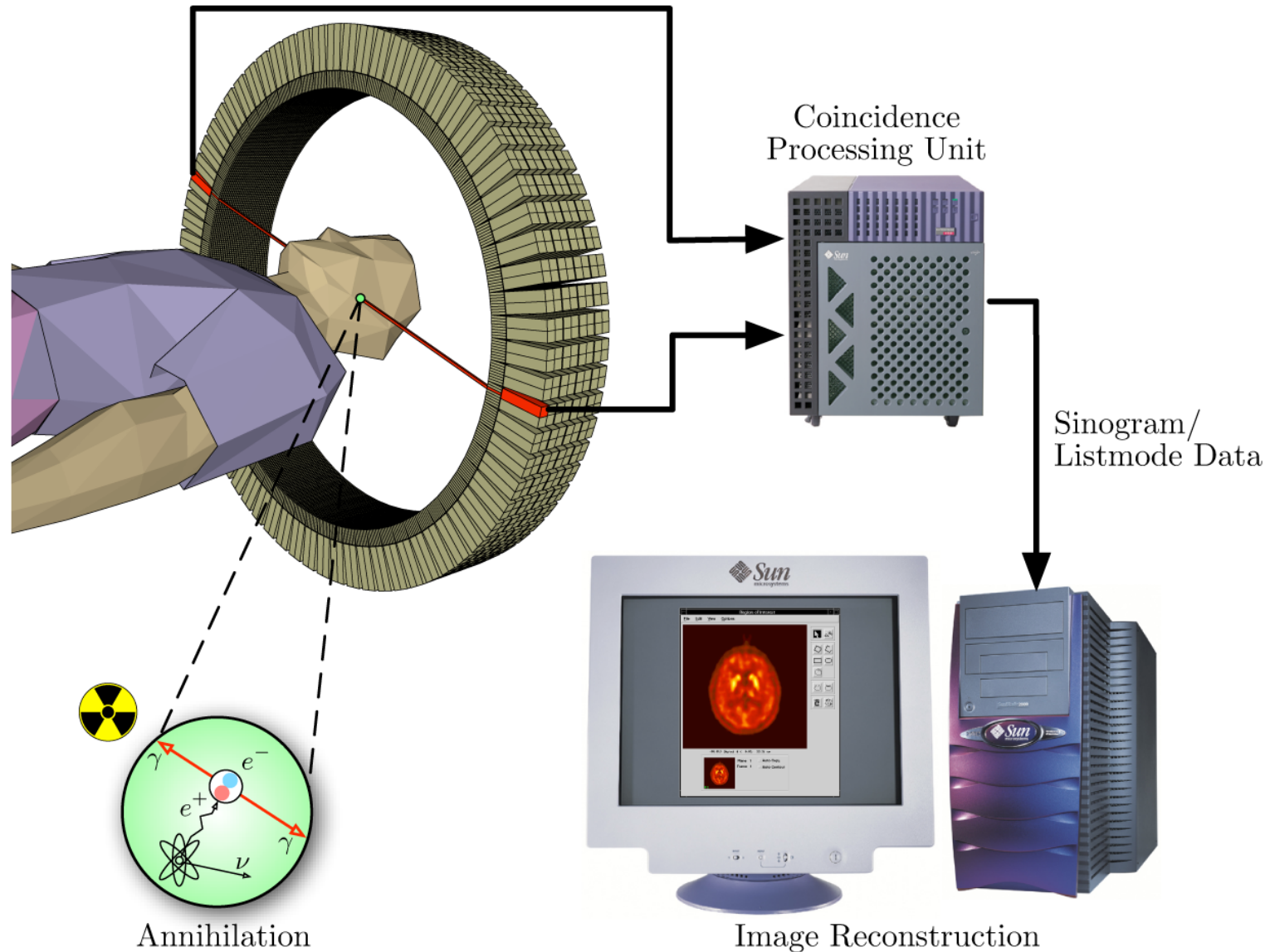


<http://www.hablandodeciencia.com/articulos/2013/03/18/la-antimateria-del-pet/>



<http://www.bancodasaude.com>

PET scan : Positron Emission Tomography



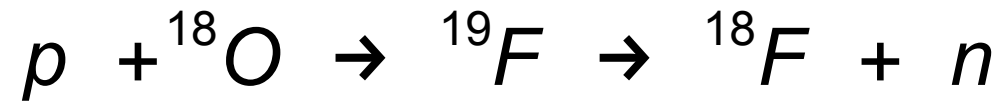
http://jens-maus.de/ftp/langner_mscthesis.pdf

Scan PET/CT

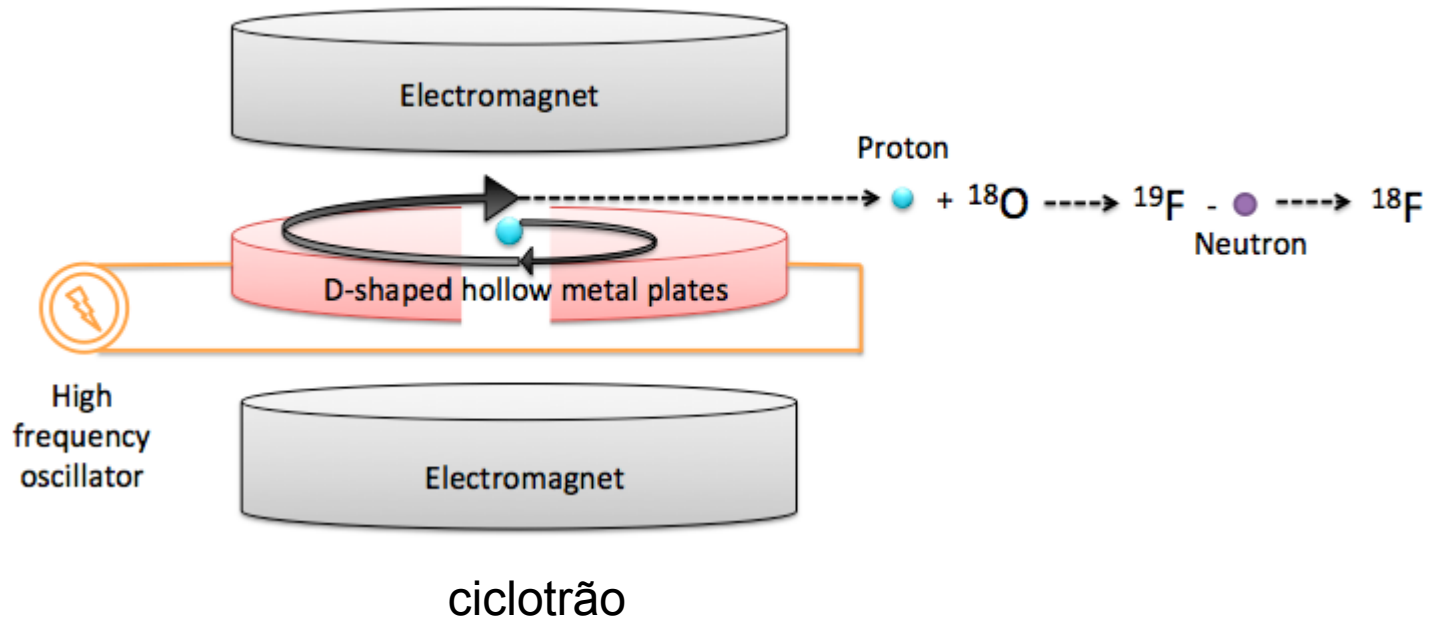


https://en.wikipedia.org/wiki/Positron_emission_tomography

Produção de fluor-18 para diagnóstico PET



Abundância ${}^{18}\text{O} \sim 0,2\%$



PET mamografia (desenvolvido em Portugal com coordenação do LIP)

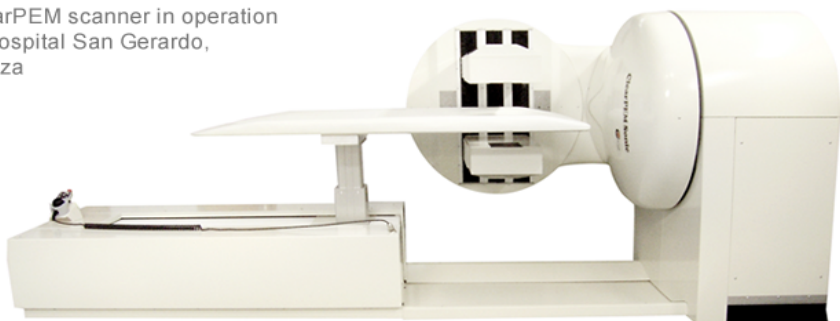
ICNAS - Coimbra



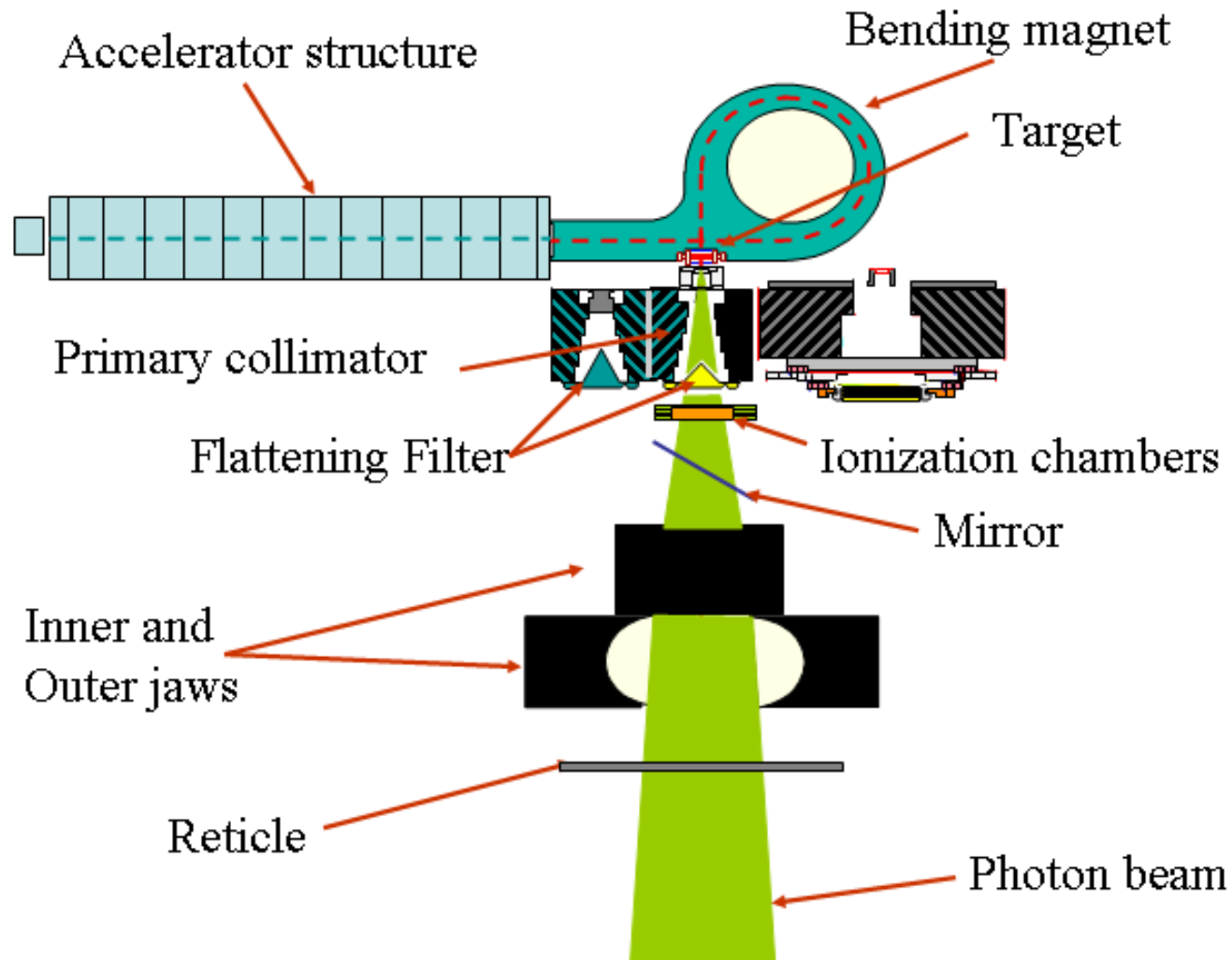
Hôpital Nord, Marselha

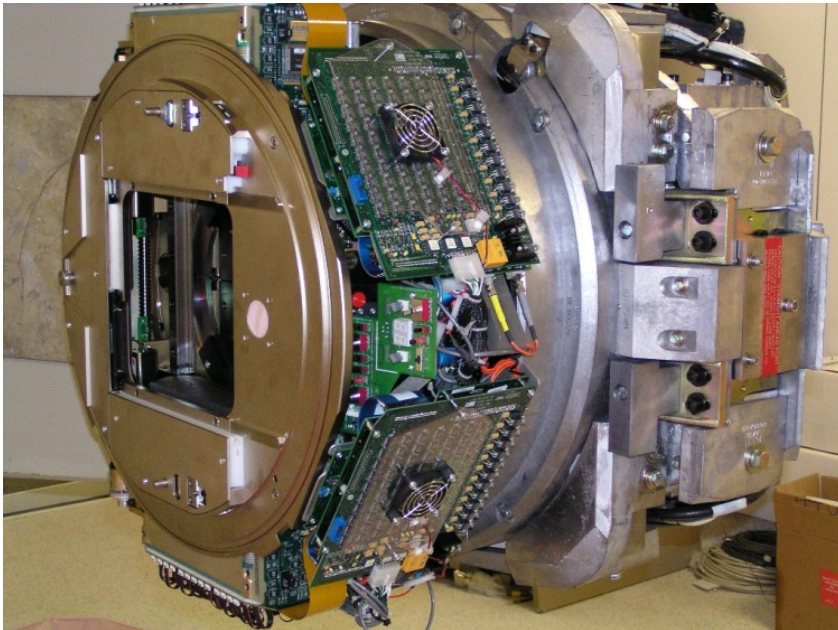
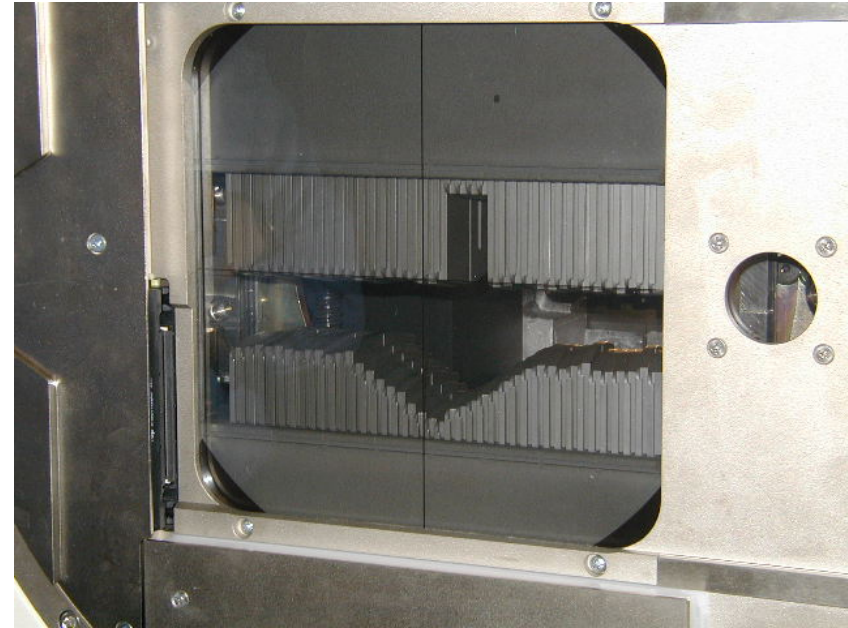
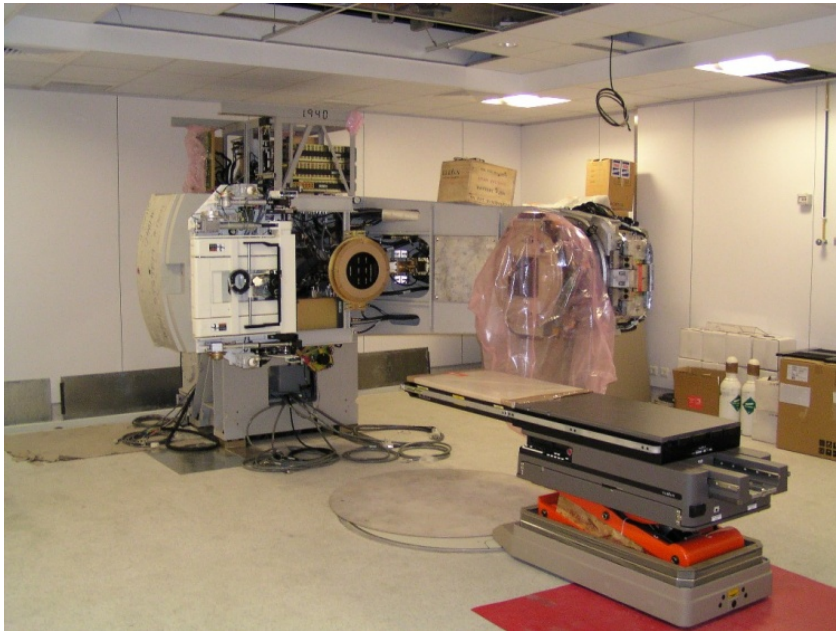


ClearPEM scanner in operation
at Hospital San Gerardo,
Monza



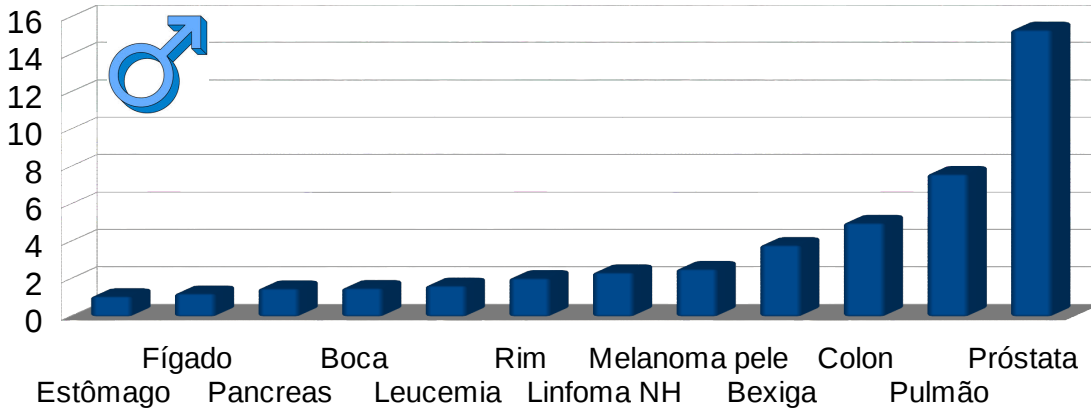
Acelerador Linear eletrões (clínico)





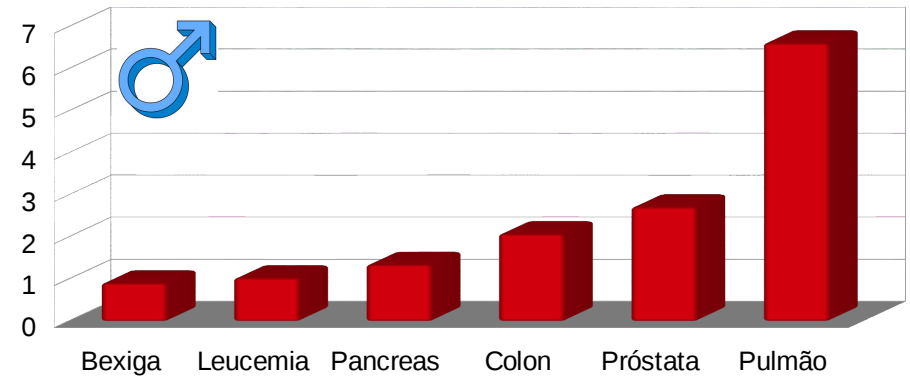
Risco desenvolver cancro

44% todos tipos



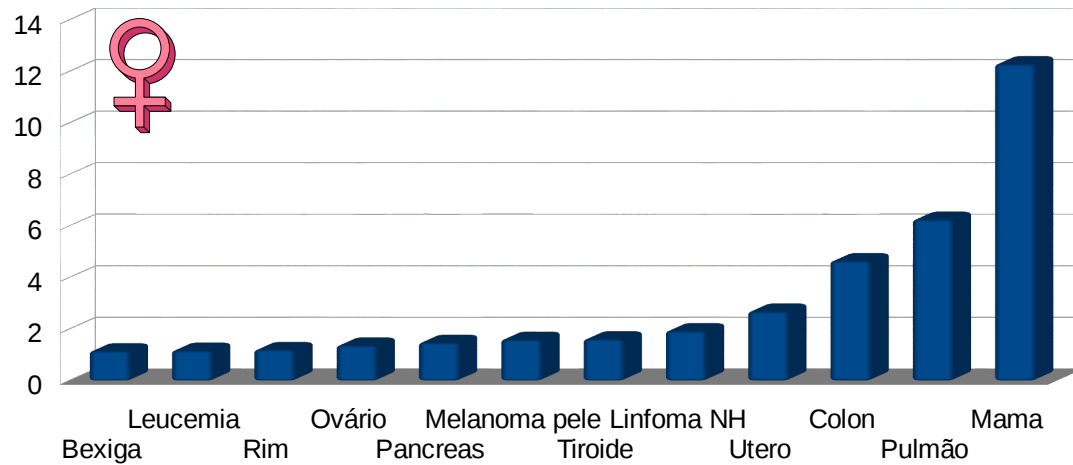
Risco morrer cancro

23% todos tipos



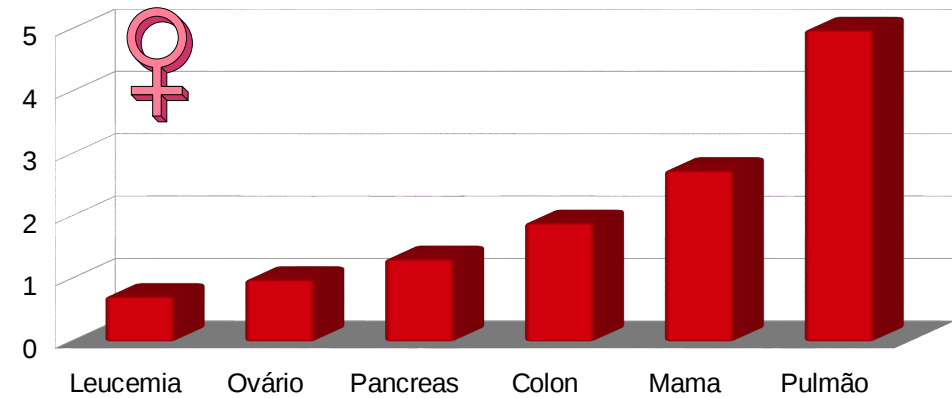
Risco desenvolver cancro

38% todos tipos



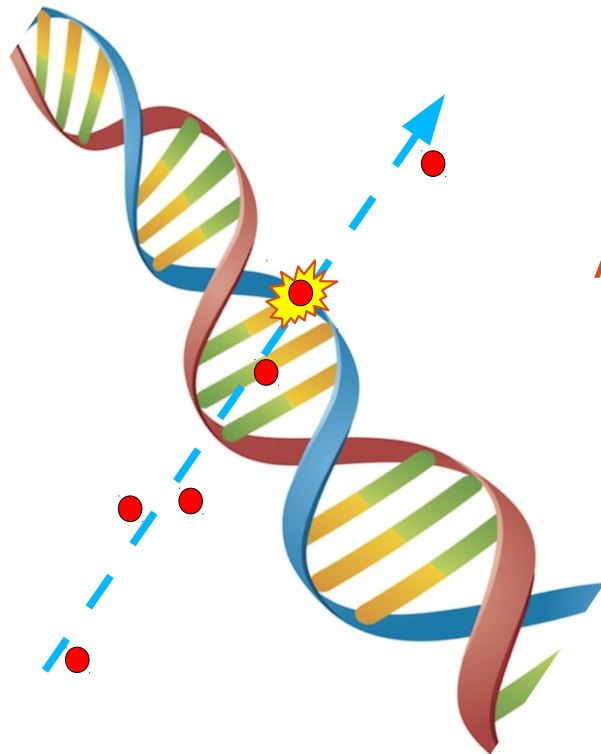
Risco morrer cancro

19% todos tipos

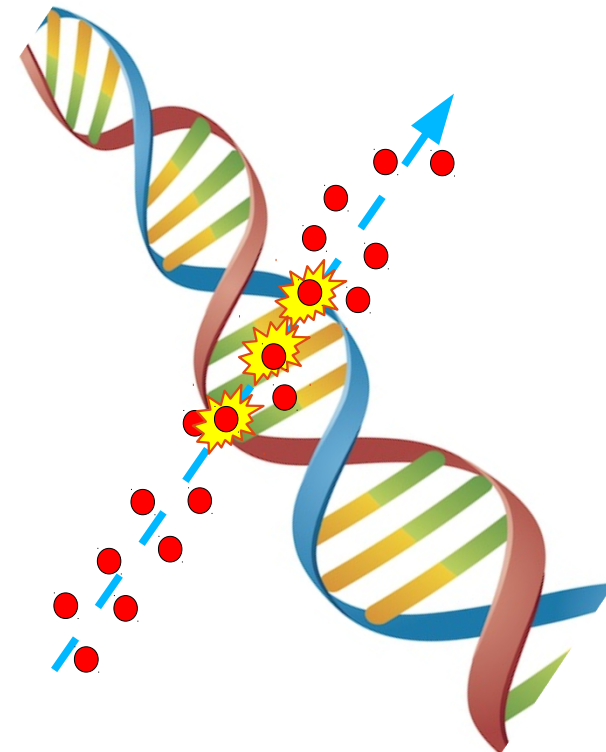


Efeito direto da radiação

Radiação pouco ionizante



Radiação altamente ionizante

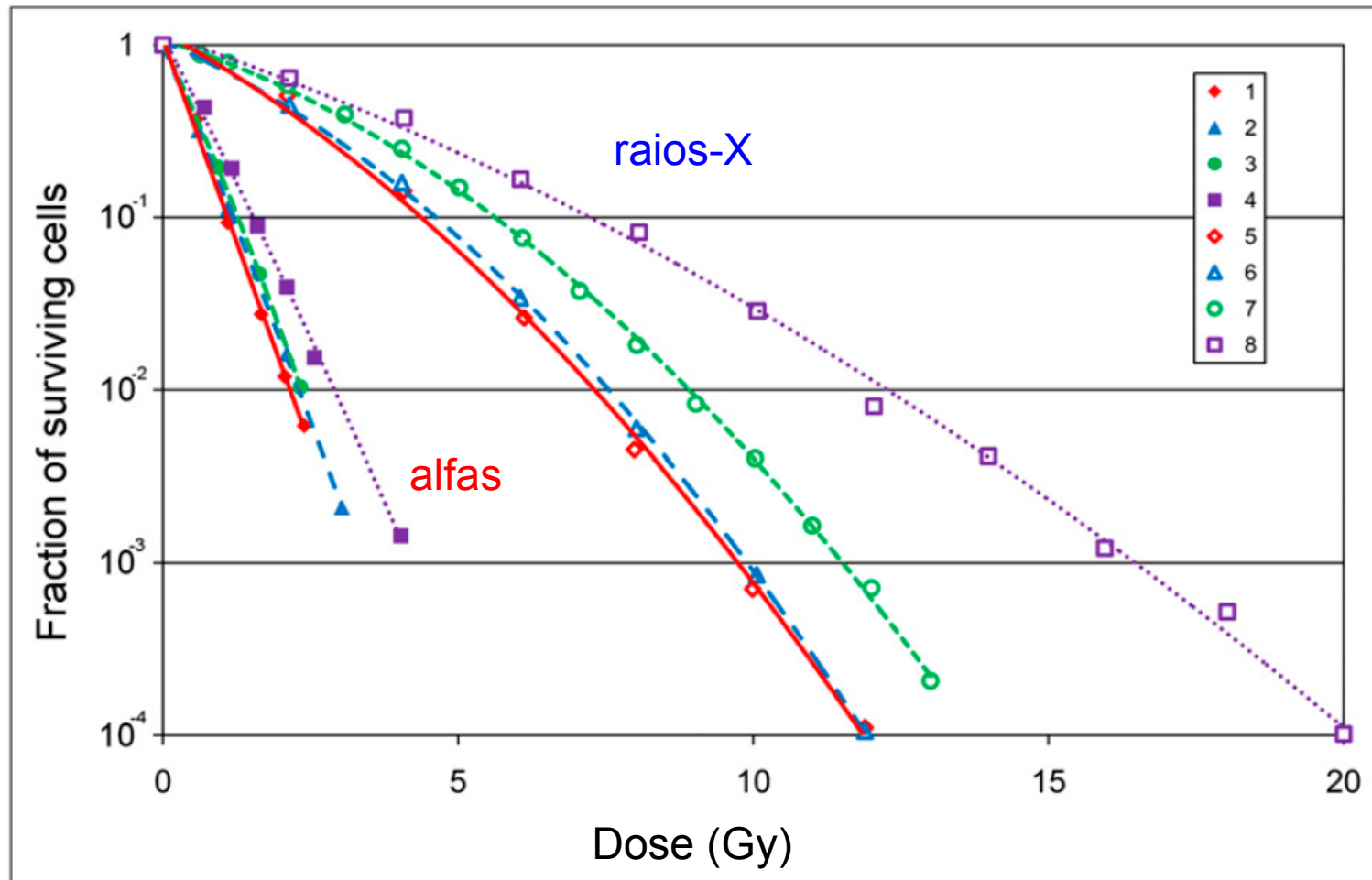


Alvo preferencial:
DNA da célula

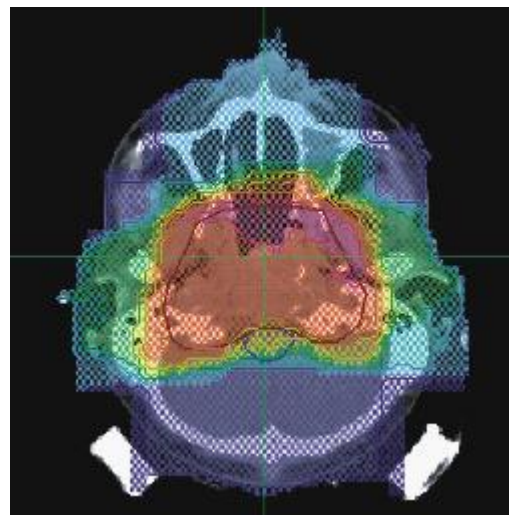
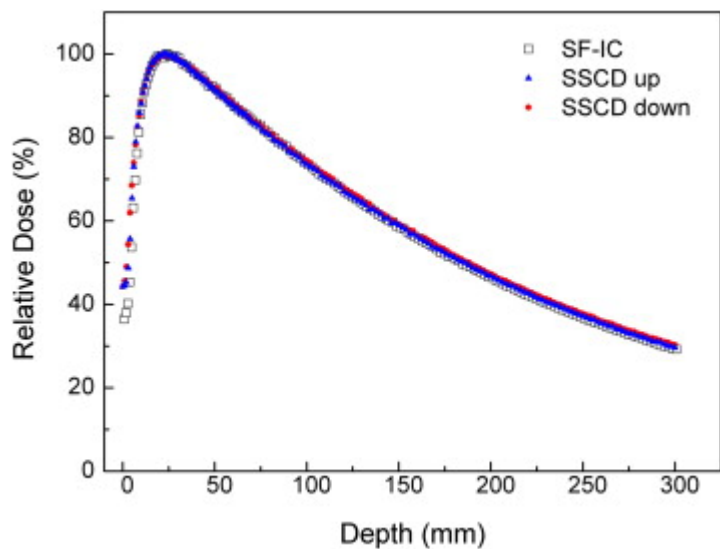
Lesões isoladas: reparação fácil

Lesões agrupadas: reparação difícil

Eficácia biológica relativa - RBE



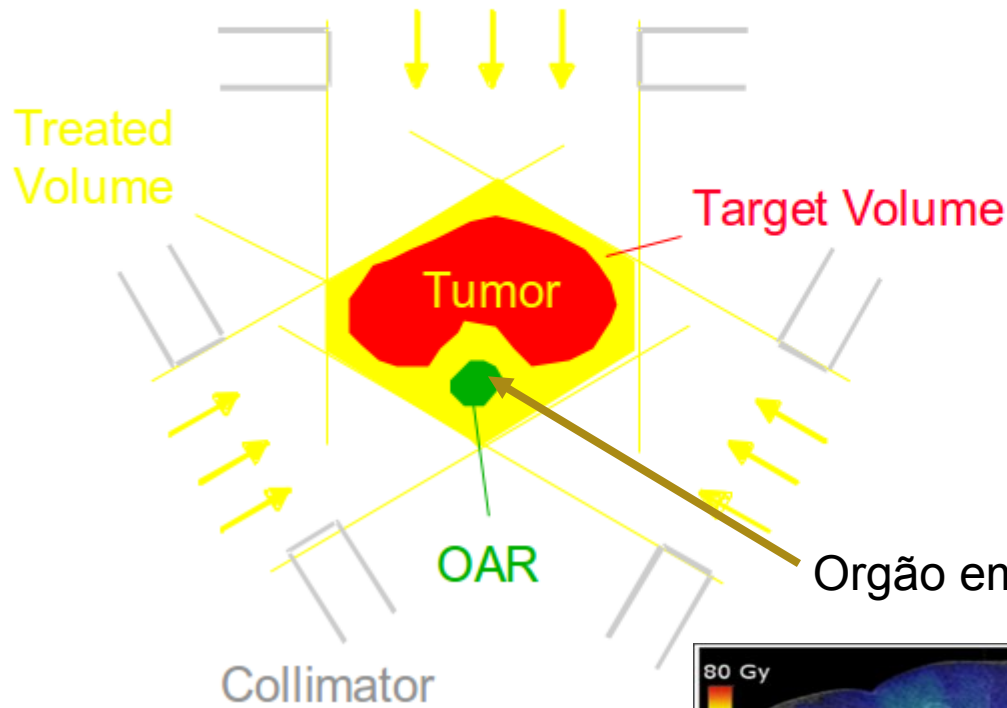
Tratamento com um feixe de fótons



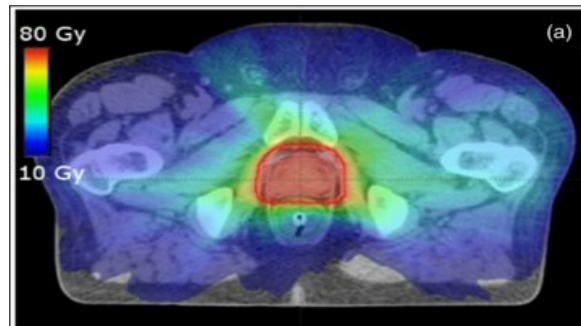
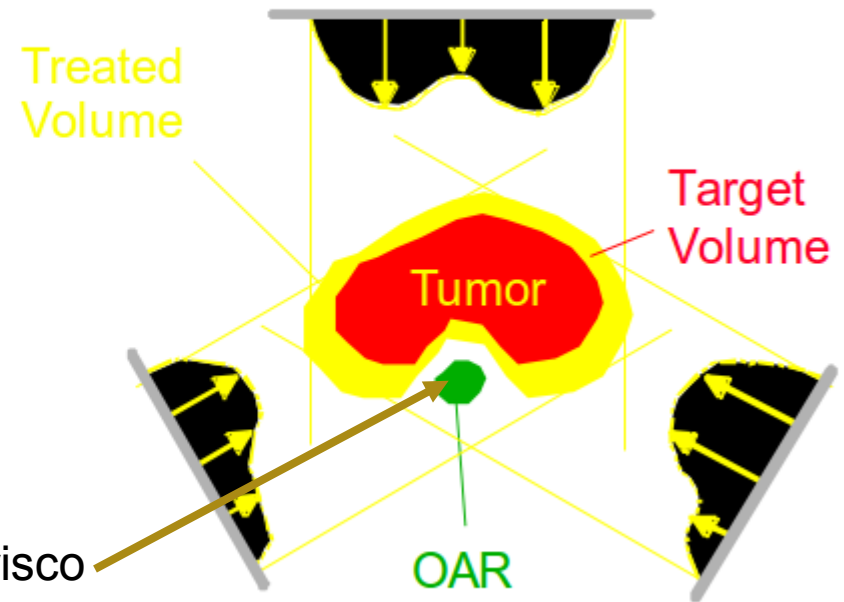
Dose varia com a profundidade

Conformação do feixe de fótons

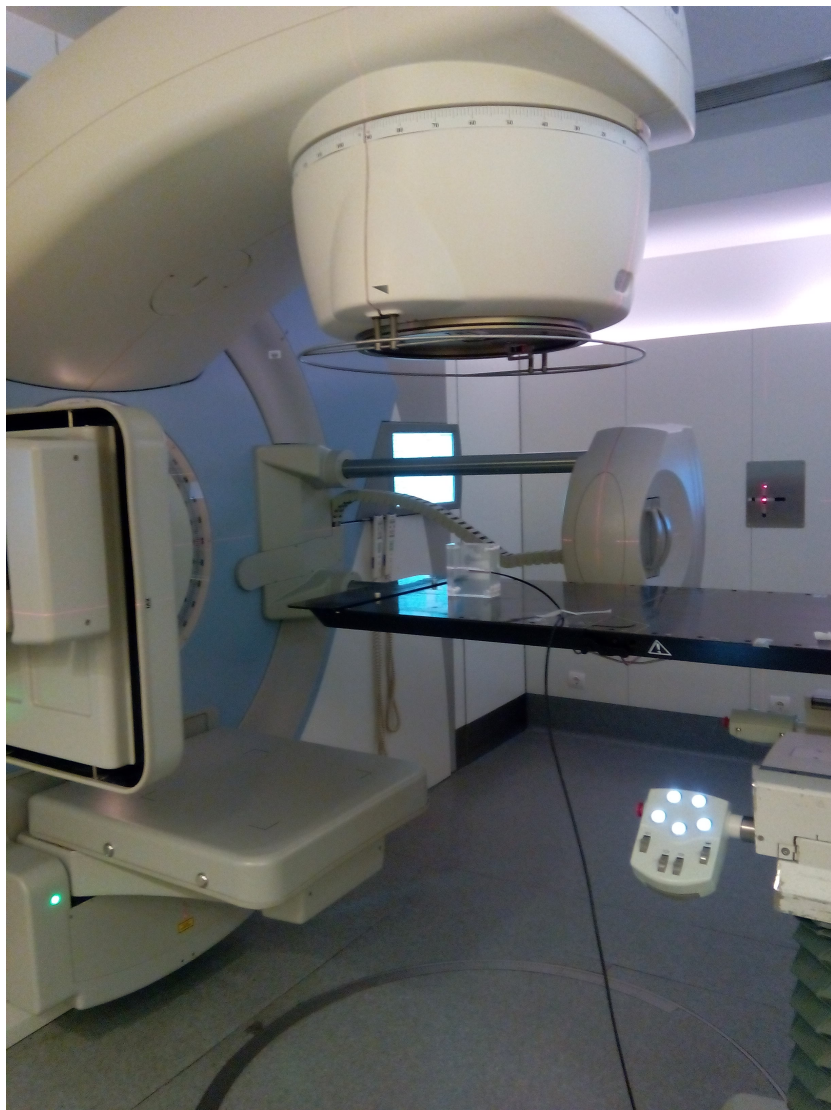
Várias incidências feixe de fótons



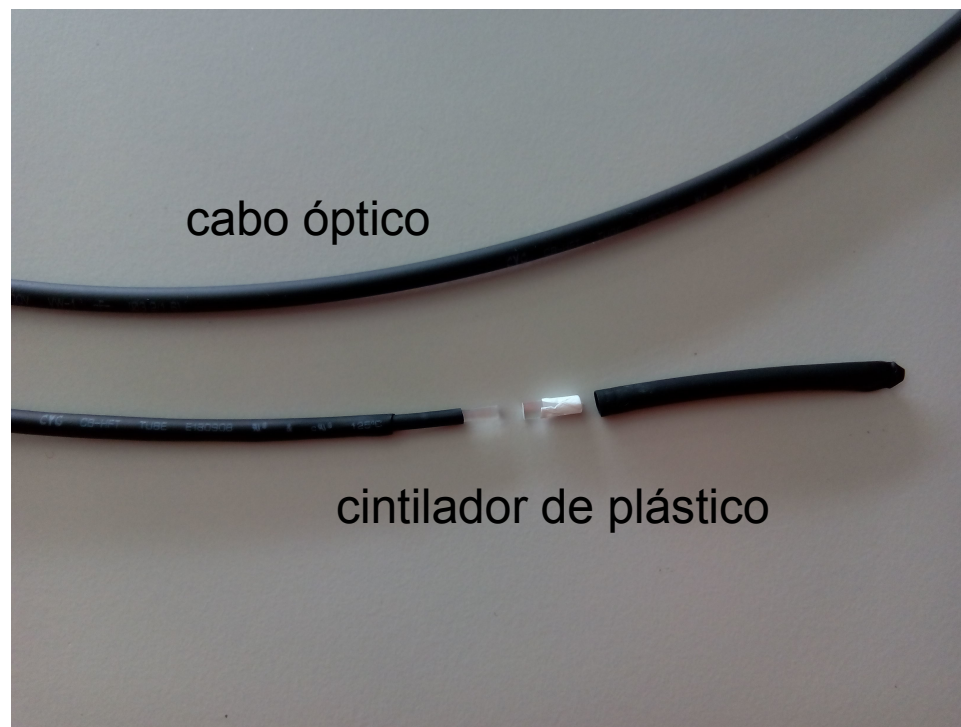
IMRT (RadioTerapia de Intensidade Modulada)



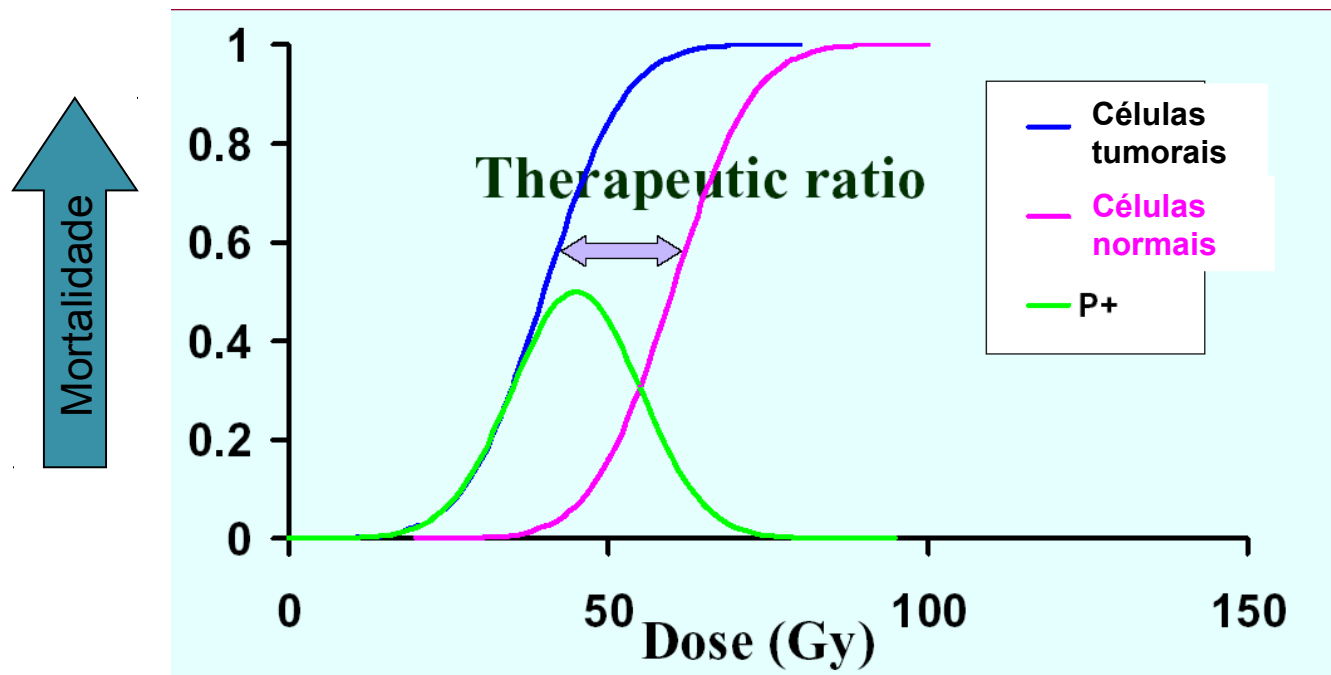
Controlo da dose ao paciente



Hospital de Santa Maria, Lisboa

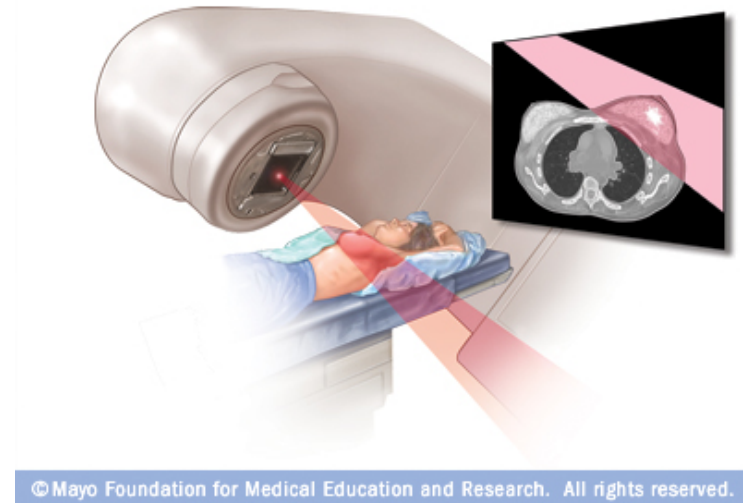
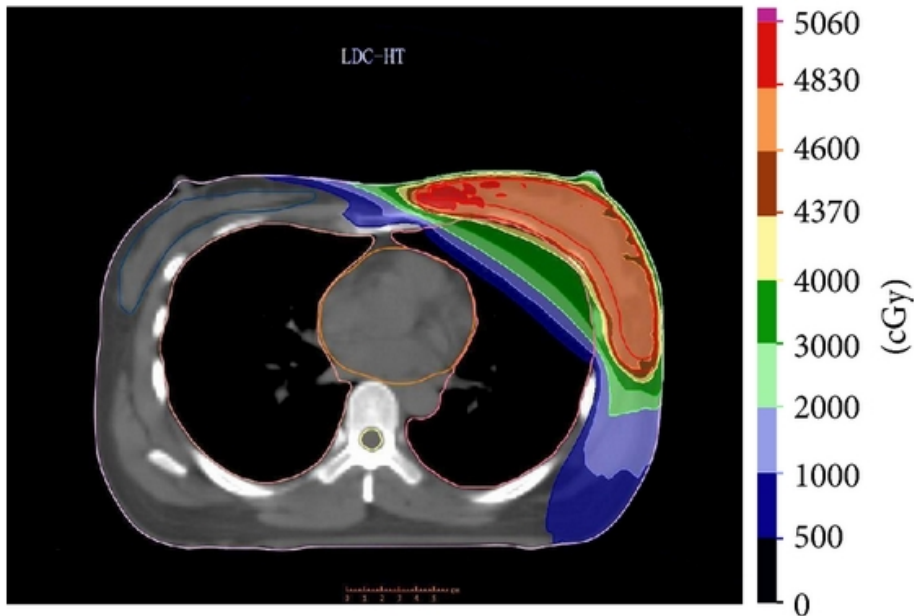


Sobrevivência de células tumorais / normais

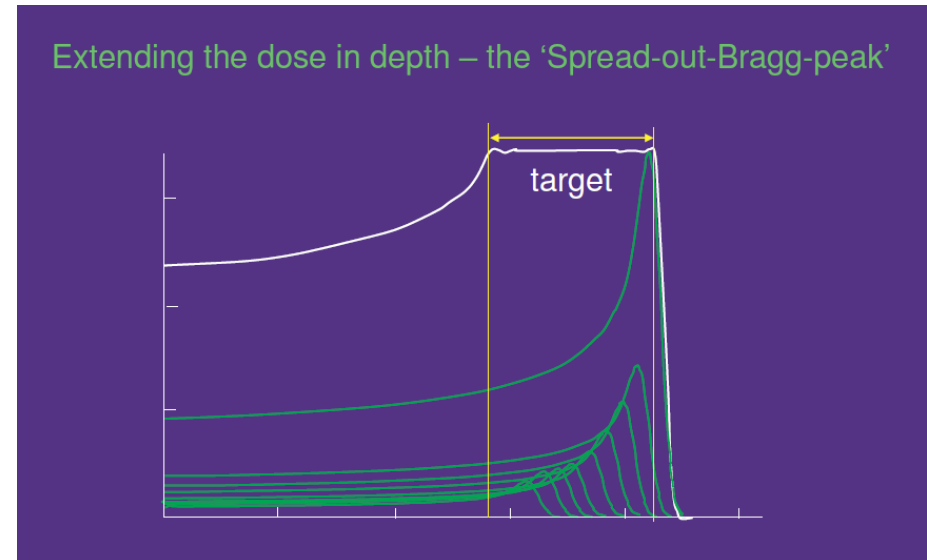
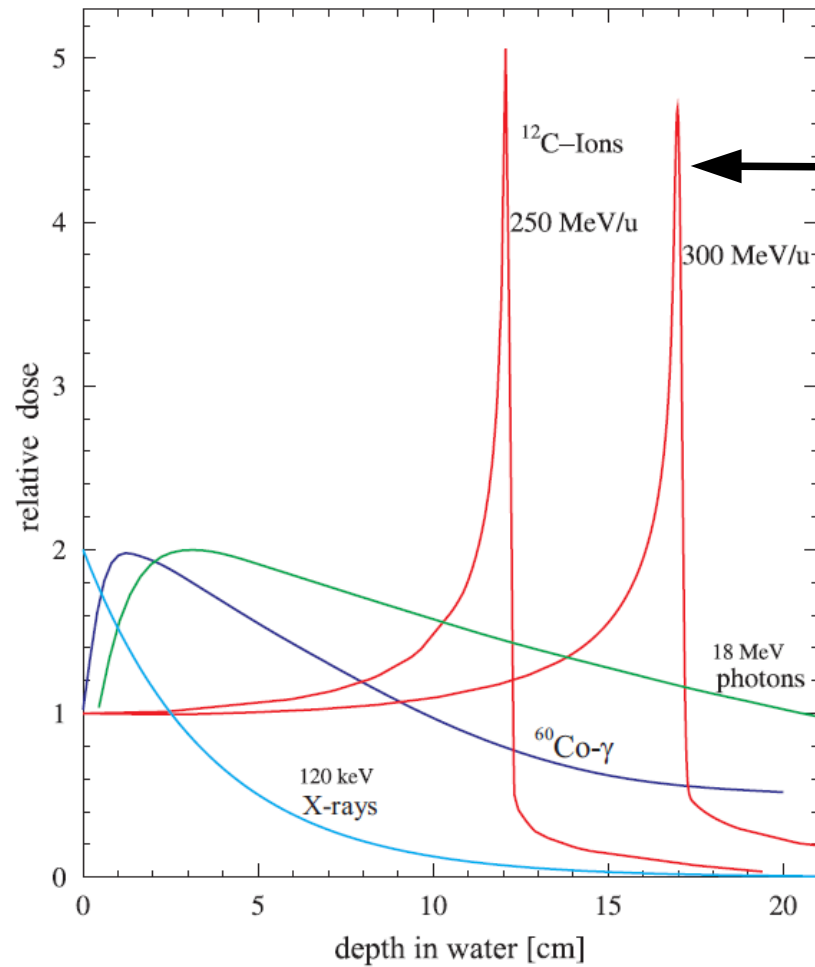


Hipofracionamento

50 Gy -> 25 sessões (padrão)
12 sessões (hipo)

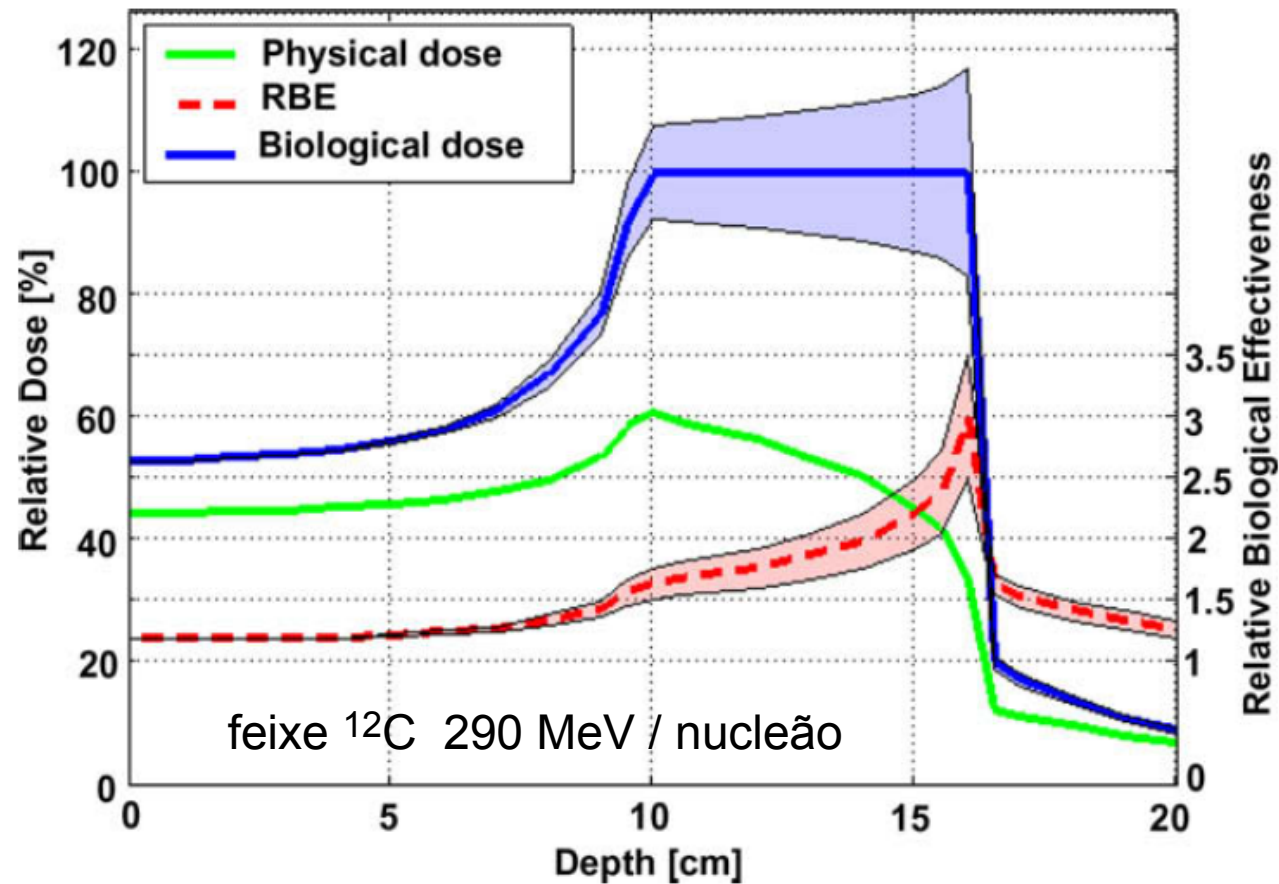


Princípio físico da terapia com prótons / iões

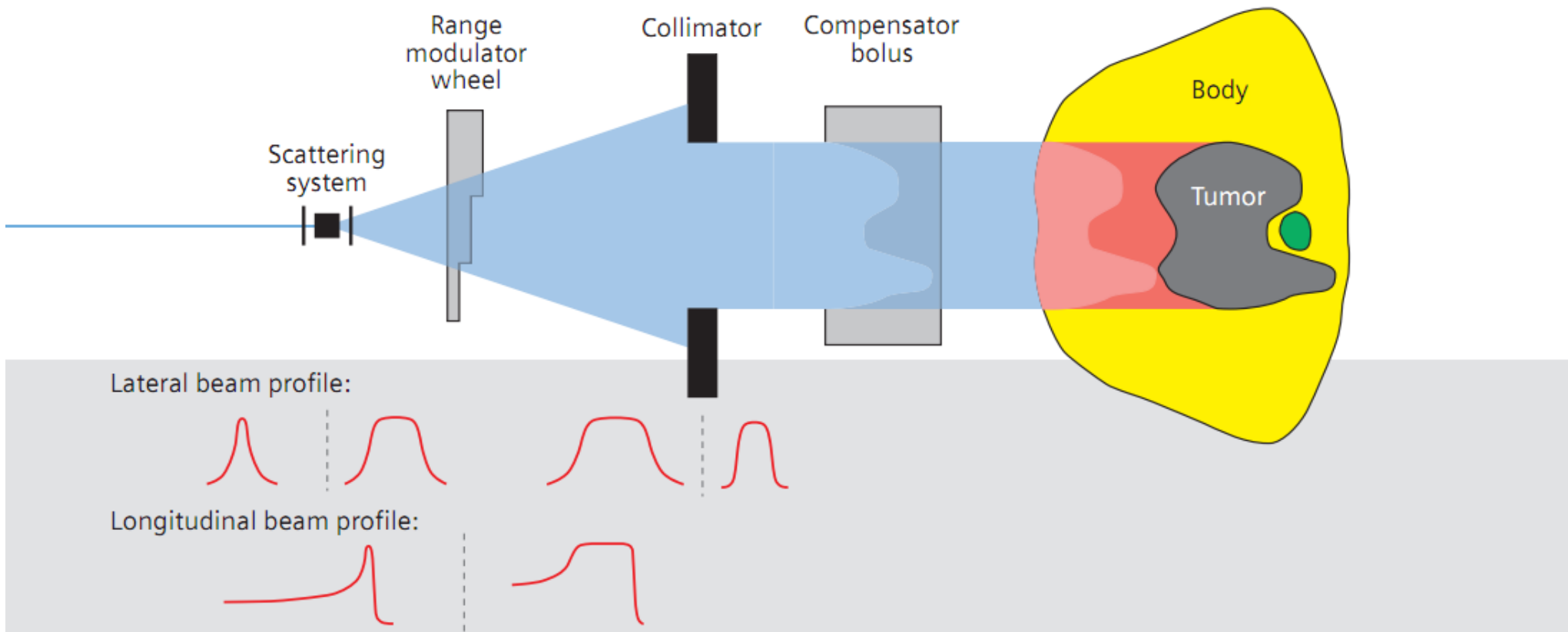


Eficácia biológica relativa

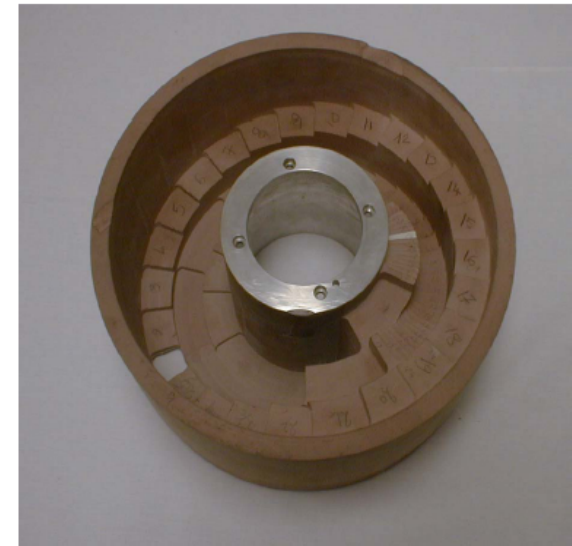
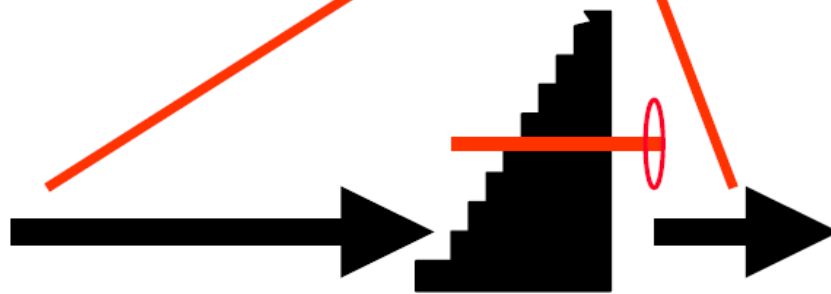
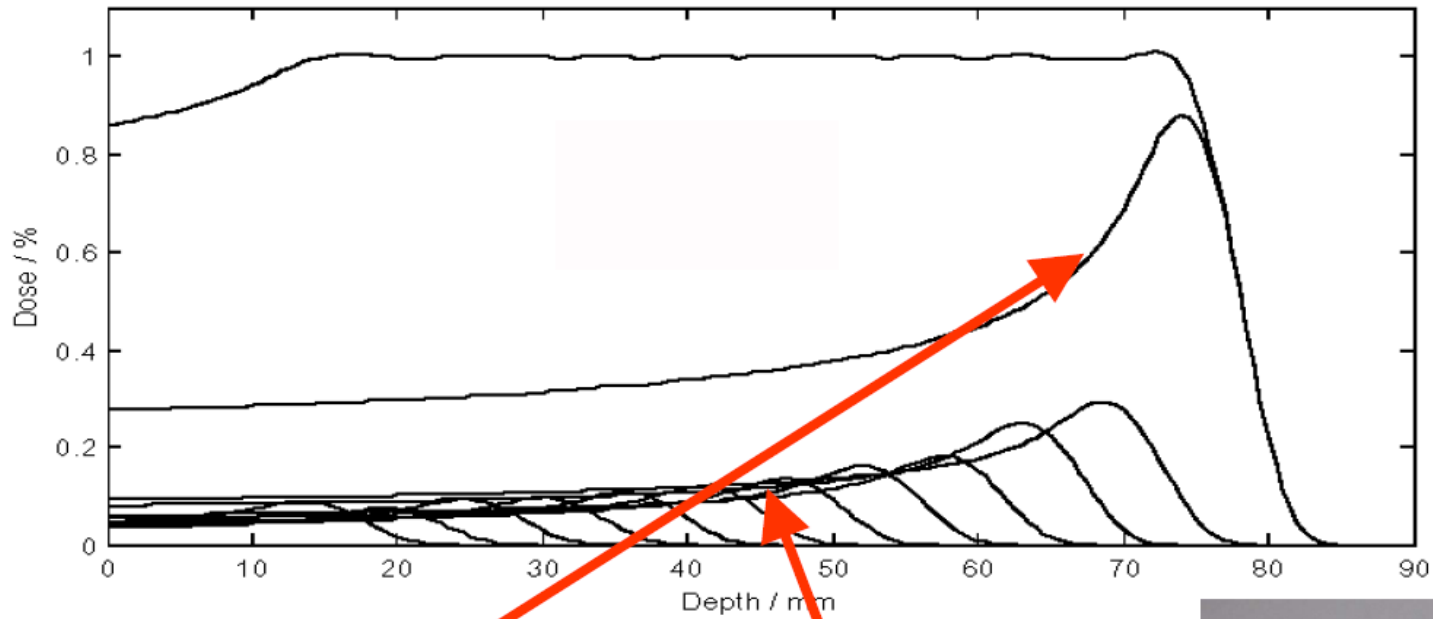
$$RBE = \frac{Dose_{RX}}{Dose_{C12}}$$



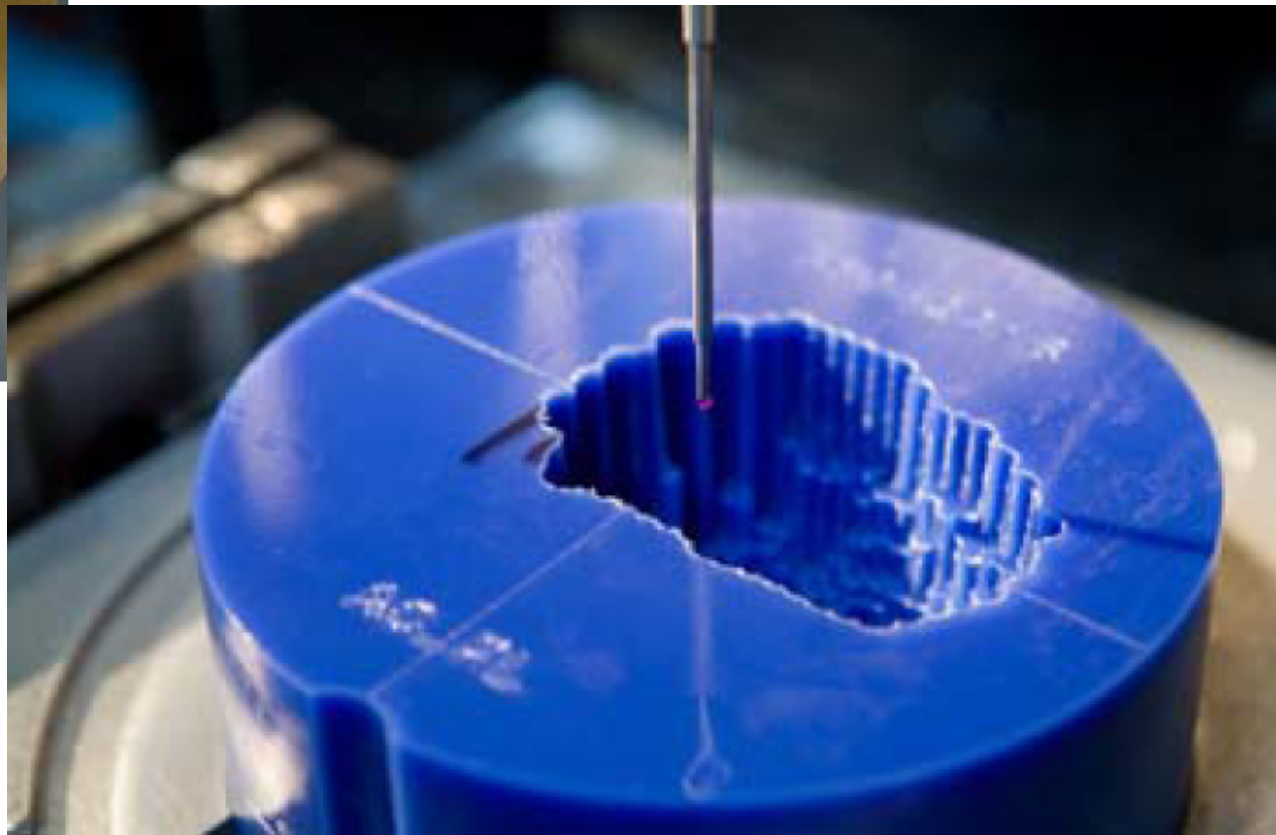
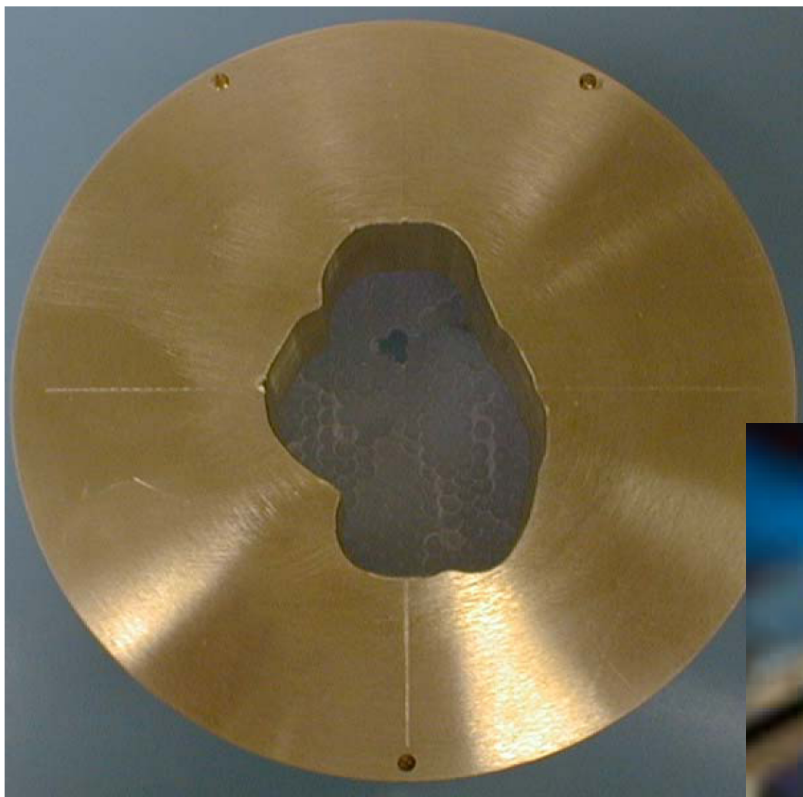
Sistemas passivos de formatação do feixe de prótons



Modulação do alcance do feixe

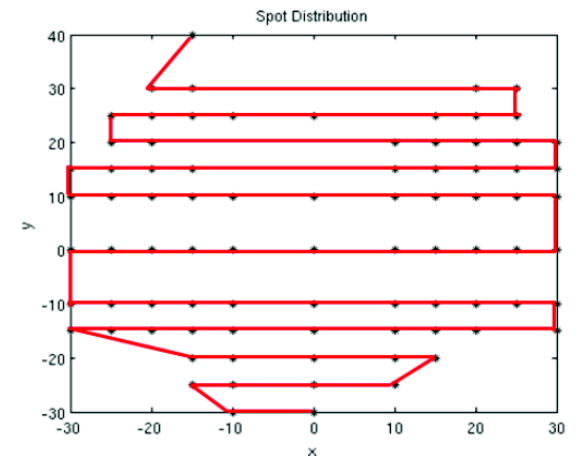
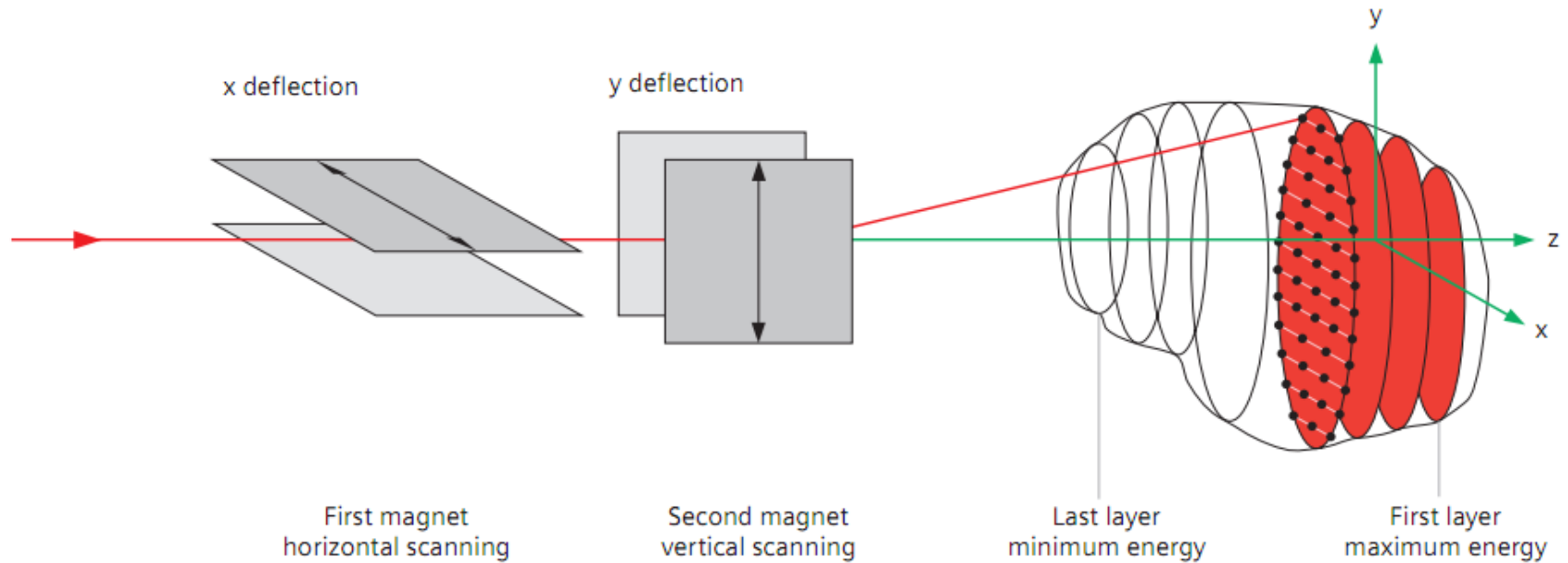


Colimador em bronze



Compensador alcance

Sistemas ativos de formatação do feixe



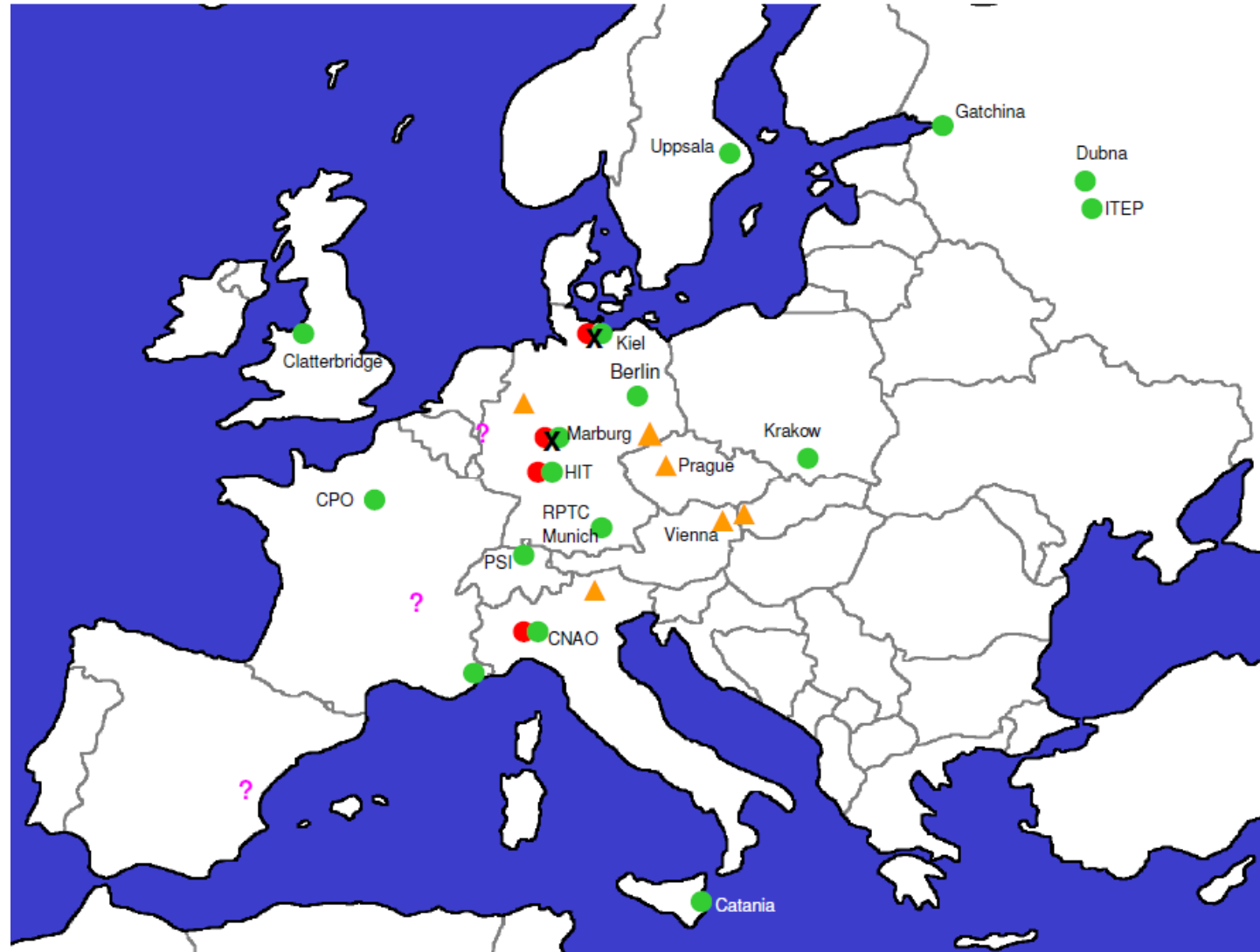
Centers in Operation

- Protons
- Light Ions
- X** Marburg / Kiel (stopped)

Under construction



Under discussion

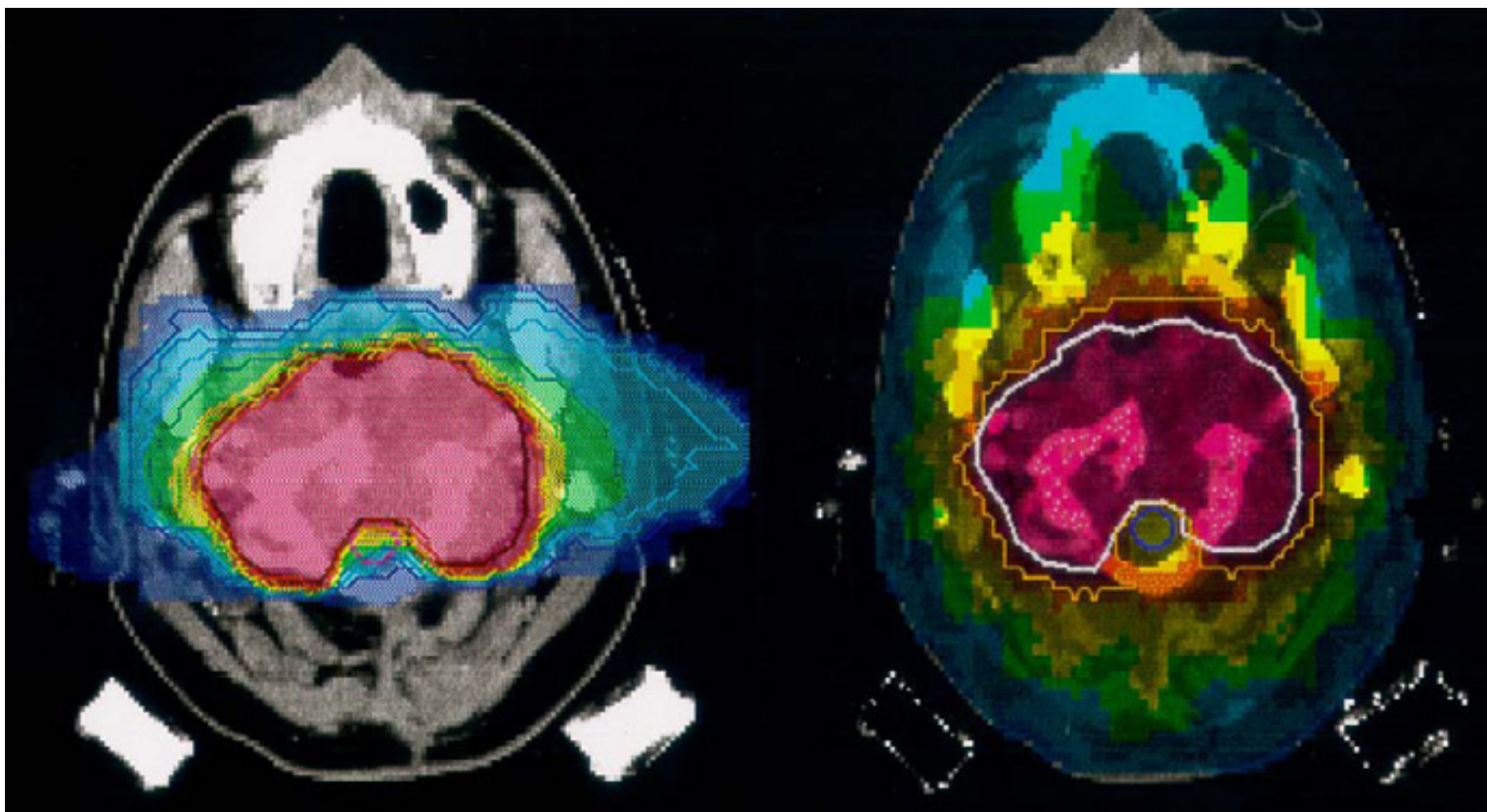


Como funciona a terapia com protões?
(filme)

Diferenças partículas / fótons

Carbono: 2 campos opostos

Fótons IMRT: 9 campos

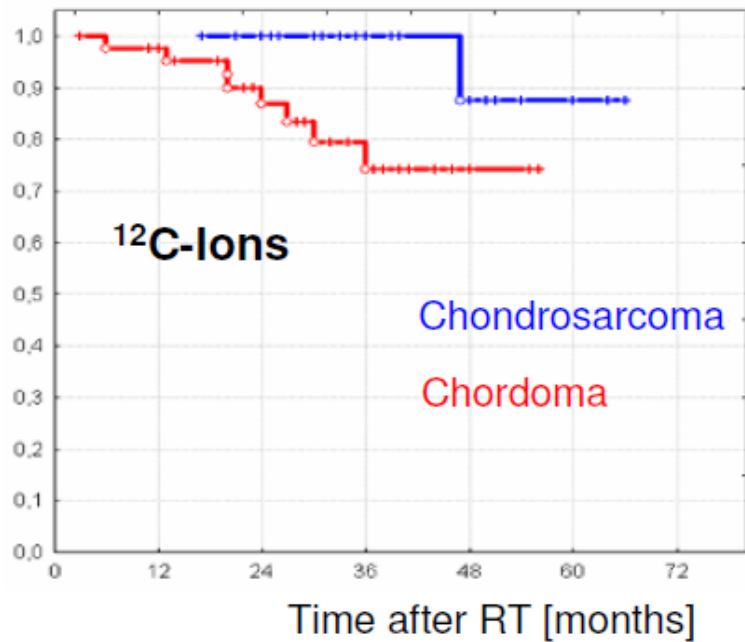


U. Amaldi & G. Kraft, Rep. Prog. Phys. 68 (2005) 1861–1882

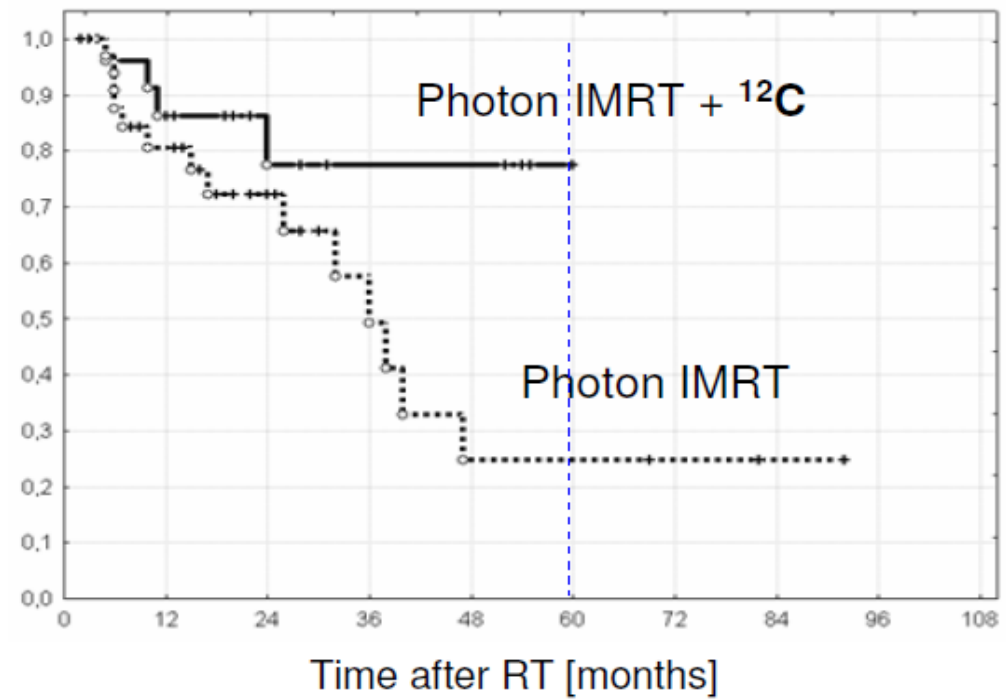
A terapia com feixes de carbono permite poupar os tecidos normais

Melhor controlo local do tumor

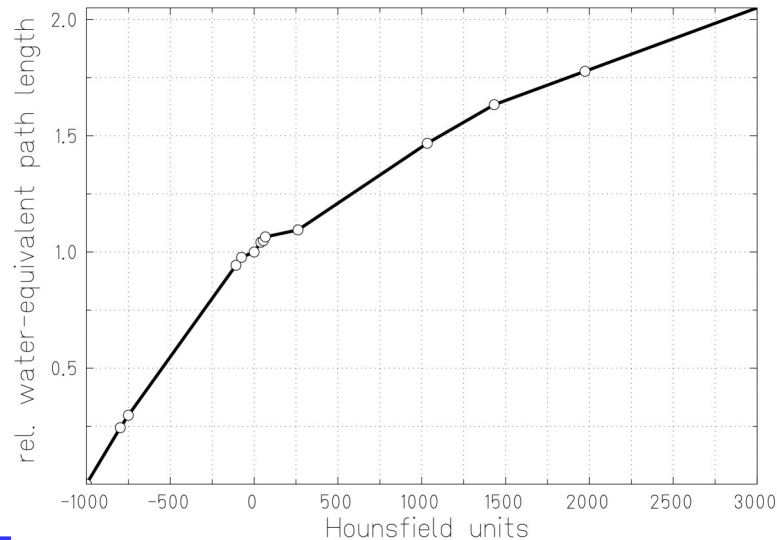
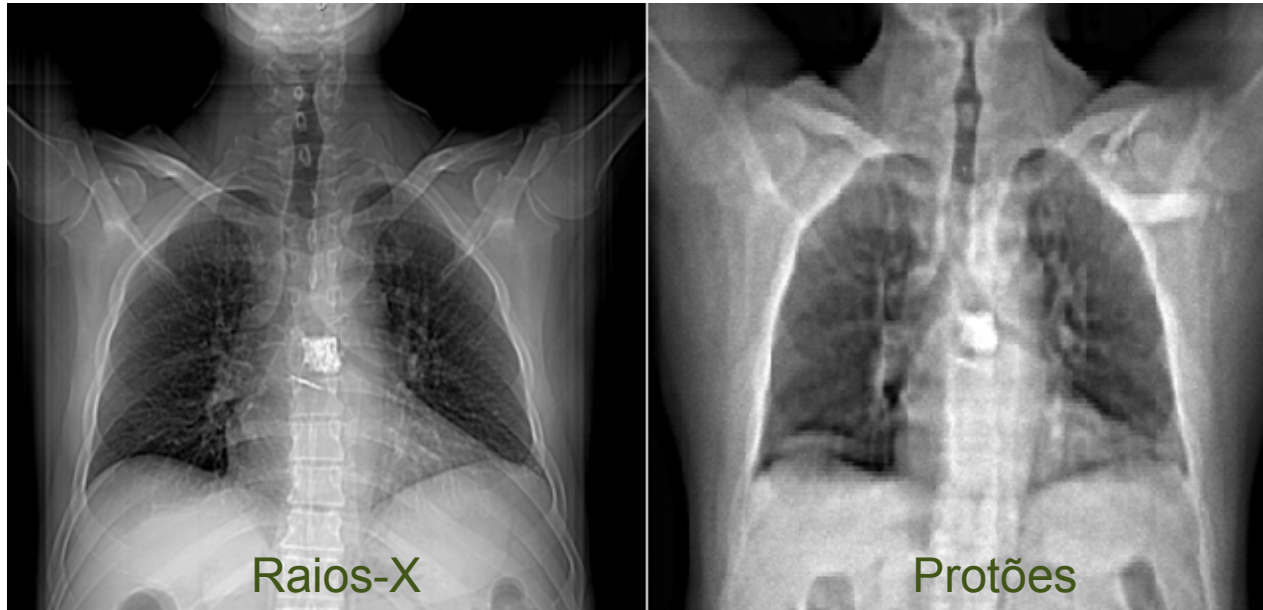
Chordoma and Chondrosarcoma



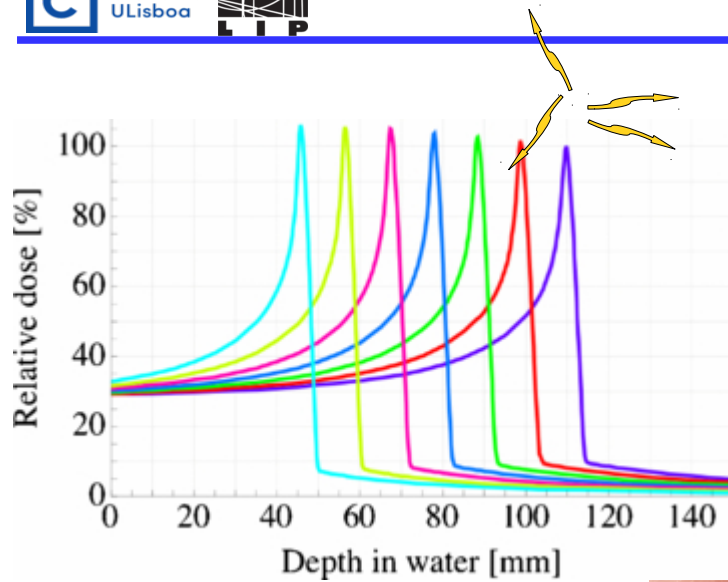
Adenoid-cystic carcinoma



Relação Housenfield Units / Water Equivalent path length

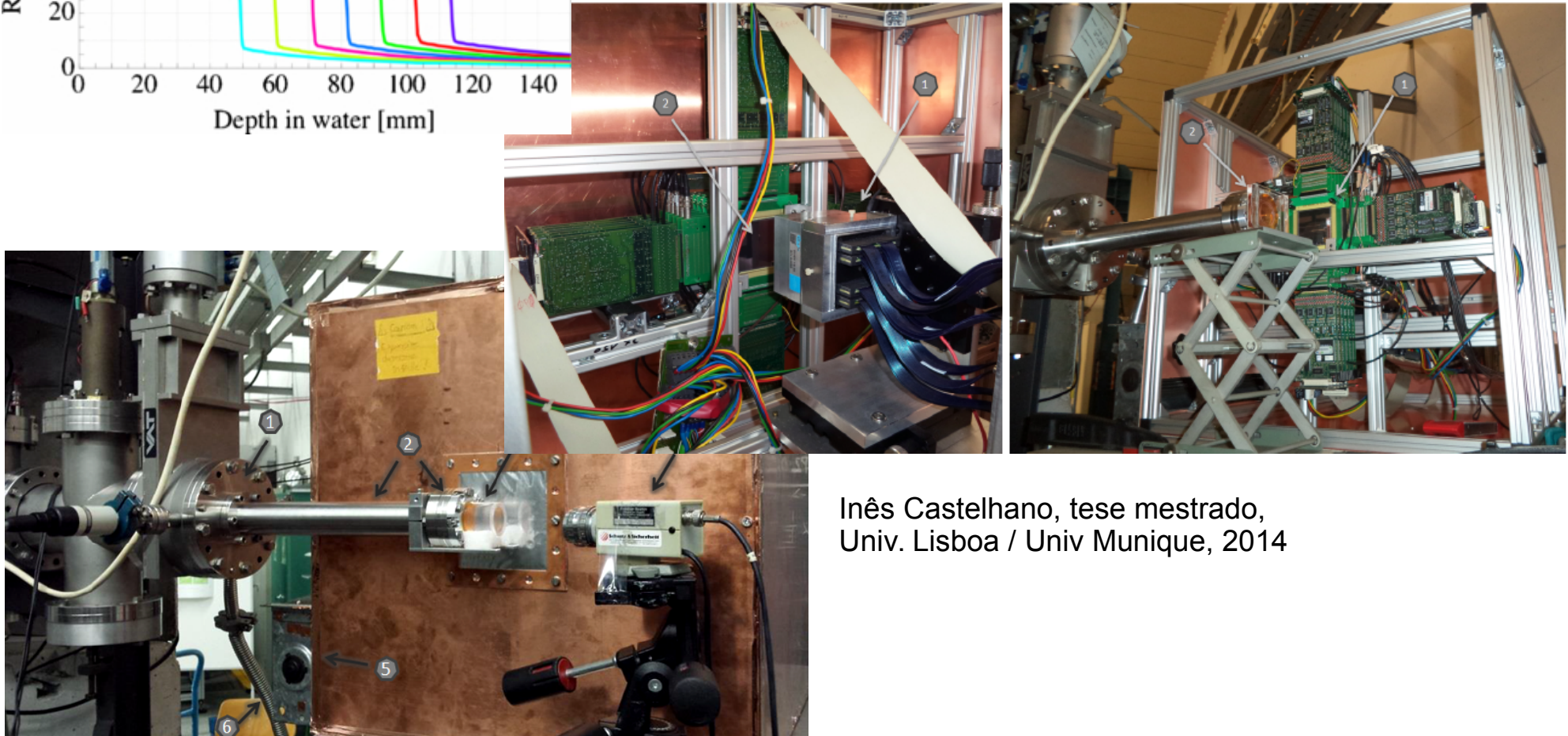


Uma incerteza de 1-3% no alcance corresponde a 1-3 mm de incerteza na deposição da energia



Melhor determinação do pico de Bragg em tempo real

Reações nucleares induzidas no alvo produzem fótons que permitem a sua localização



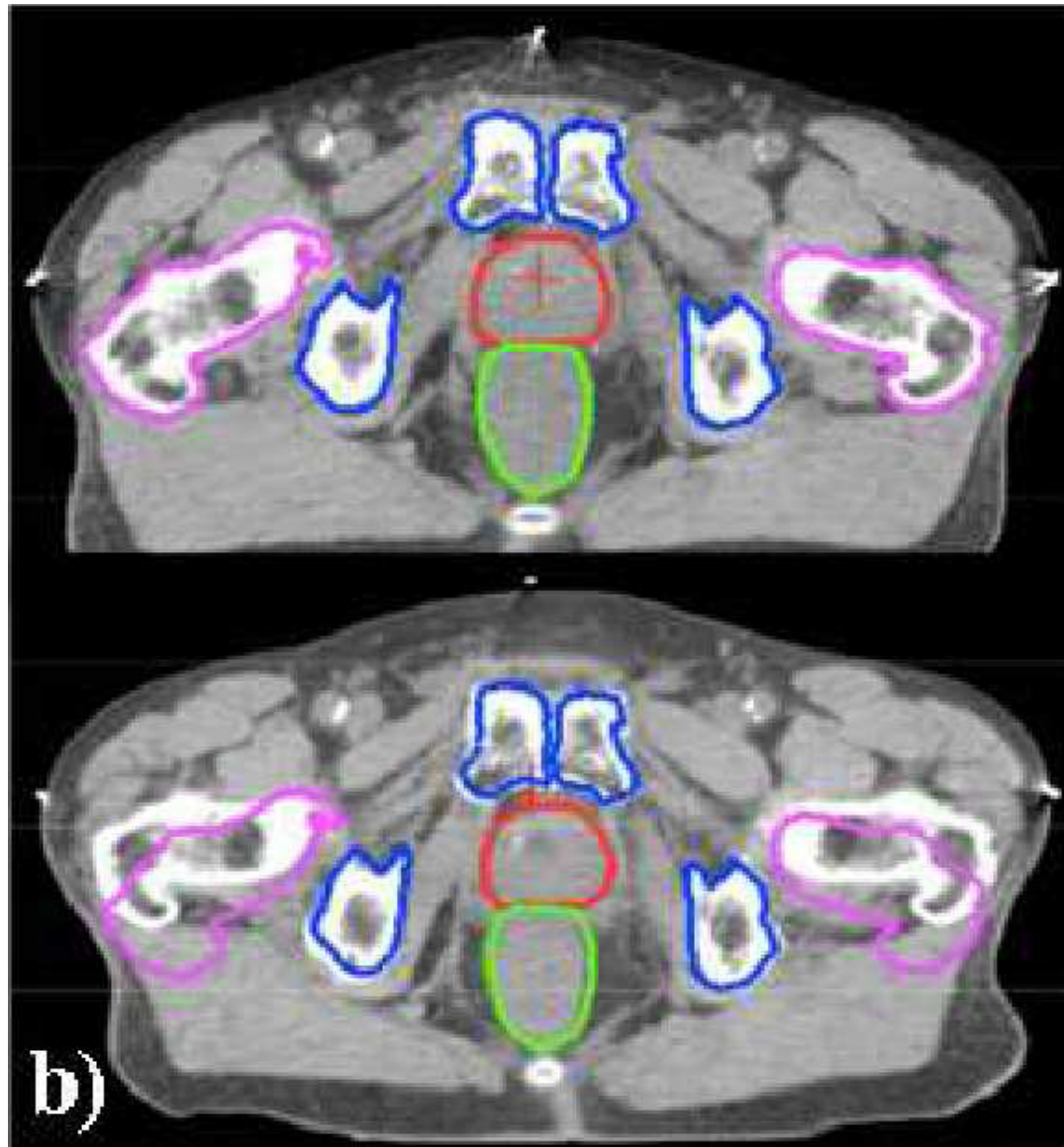
Inês Castelhana, tese mestrado, Univ. Lisboa / Univ Munique, 2014

Movimentos de órgãos: desvio do tumor (respiração)



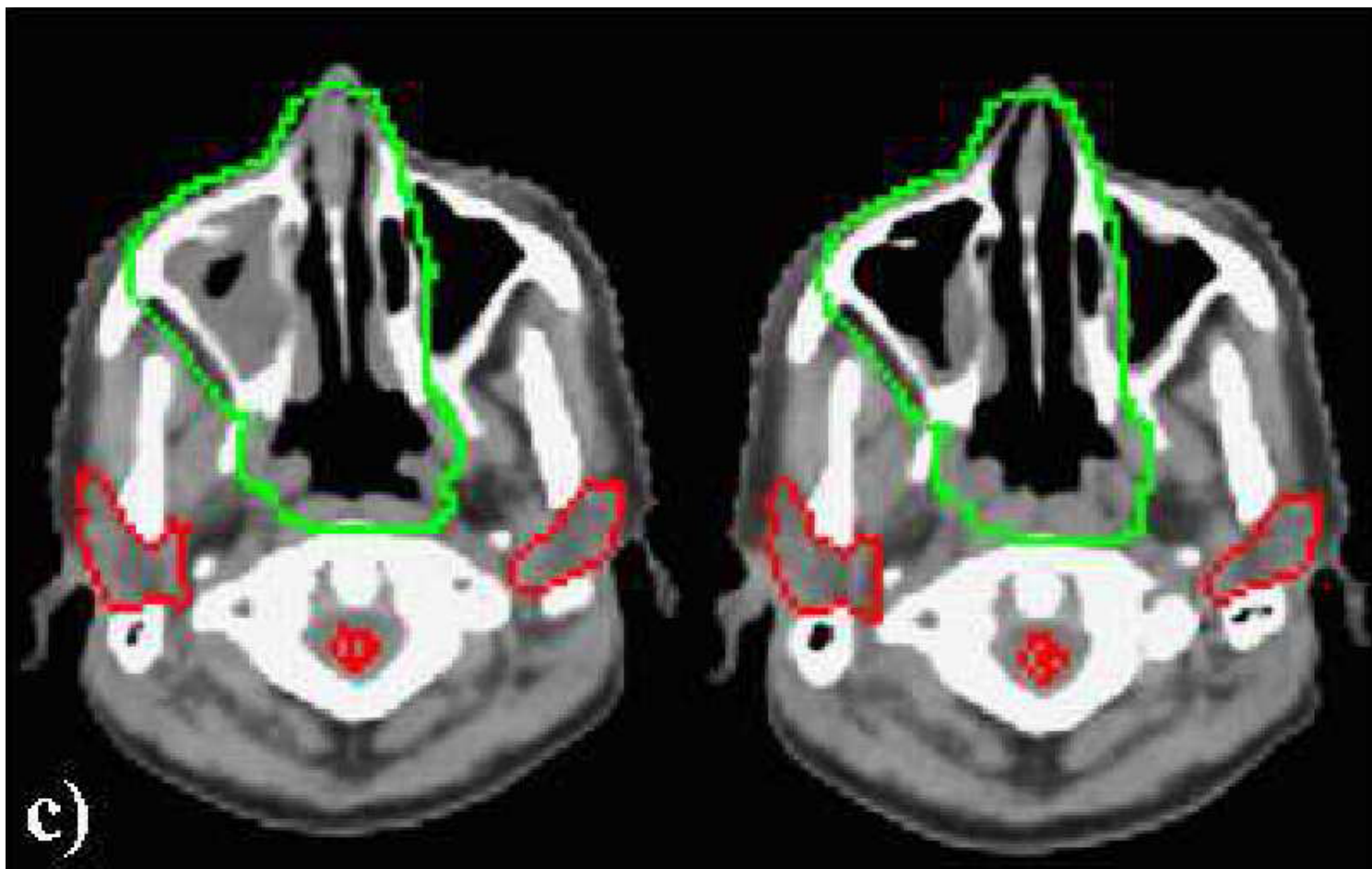
Engelsman and Bert 2011
L'uchtenborg PhD 2012

Movimentos do alvo: deformação do paciente (mau posicionamento)



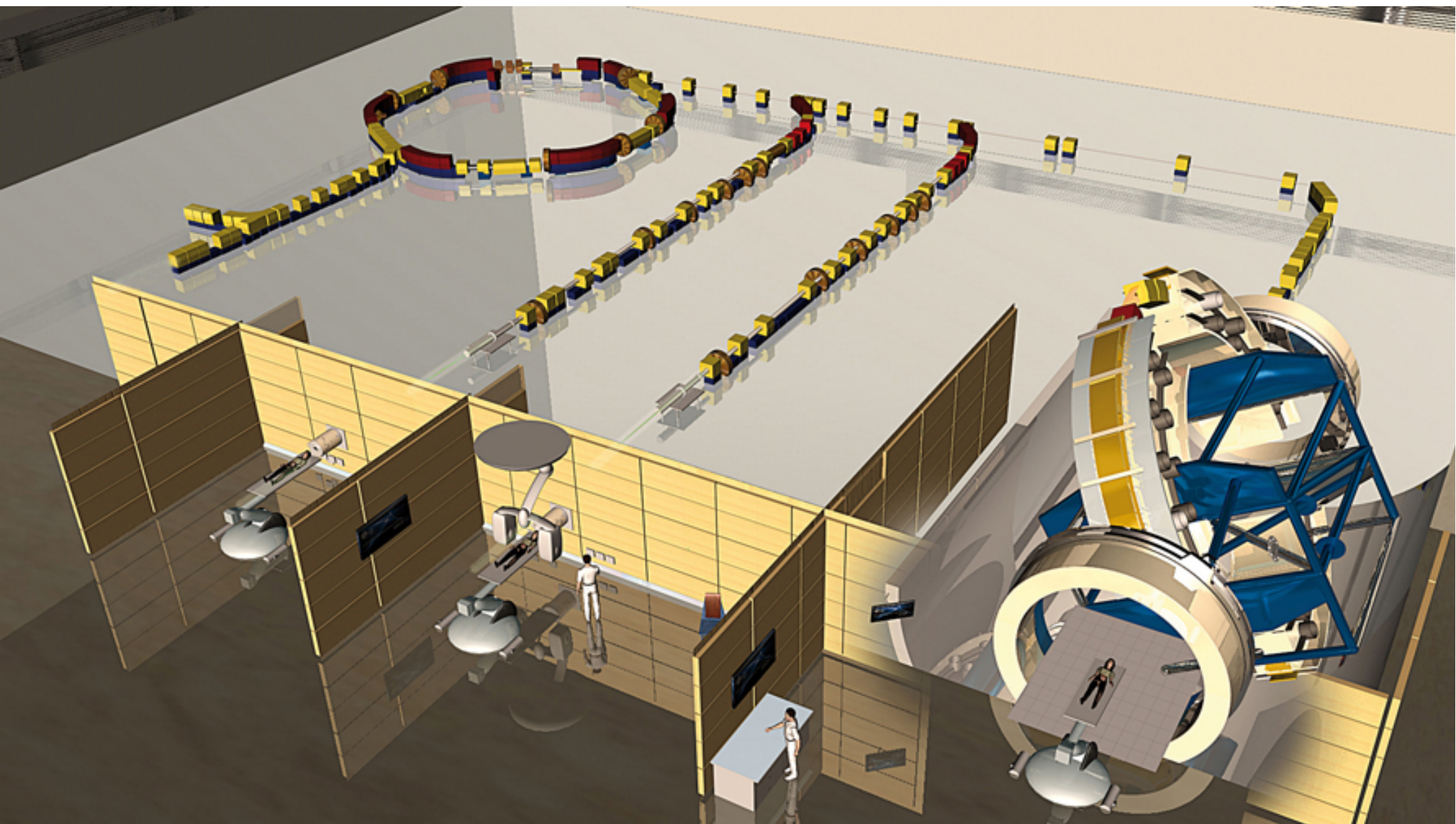
Engelsman and Bert 2011
Lüchtenborg PhD 2012

Modificação de órgãos: preenchimento de cavidades (variação da densidade)



Heidelberg Ion Beam Therapy Centre (HIT)

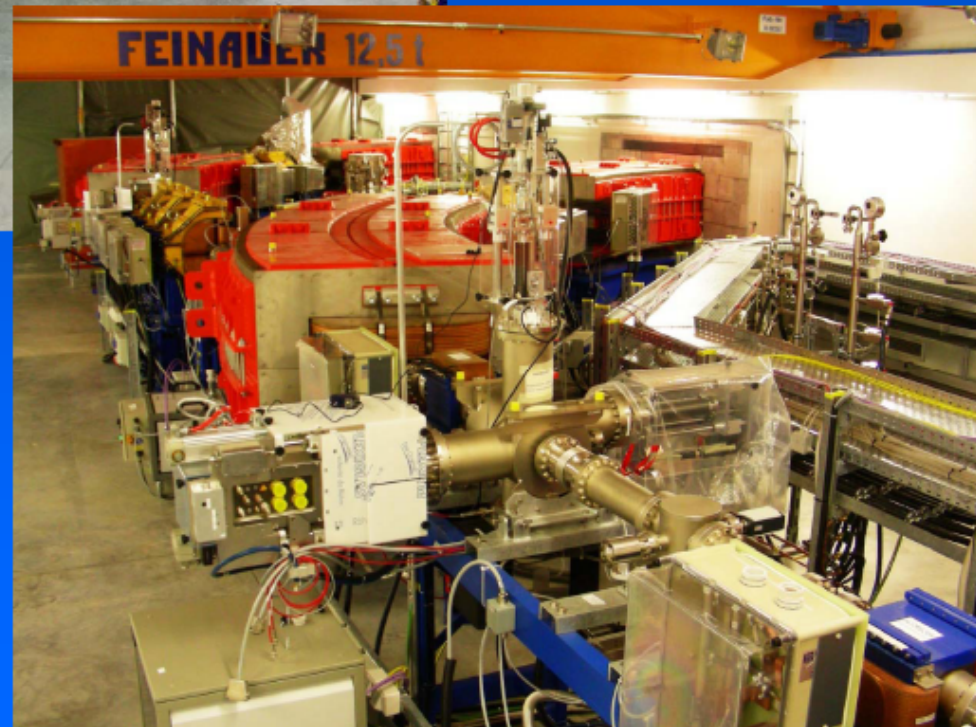






high energy
beam transport

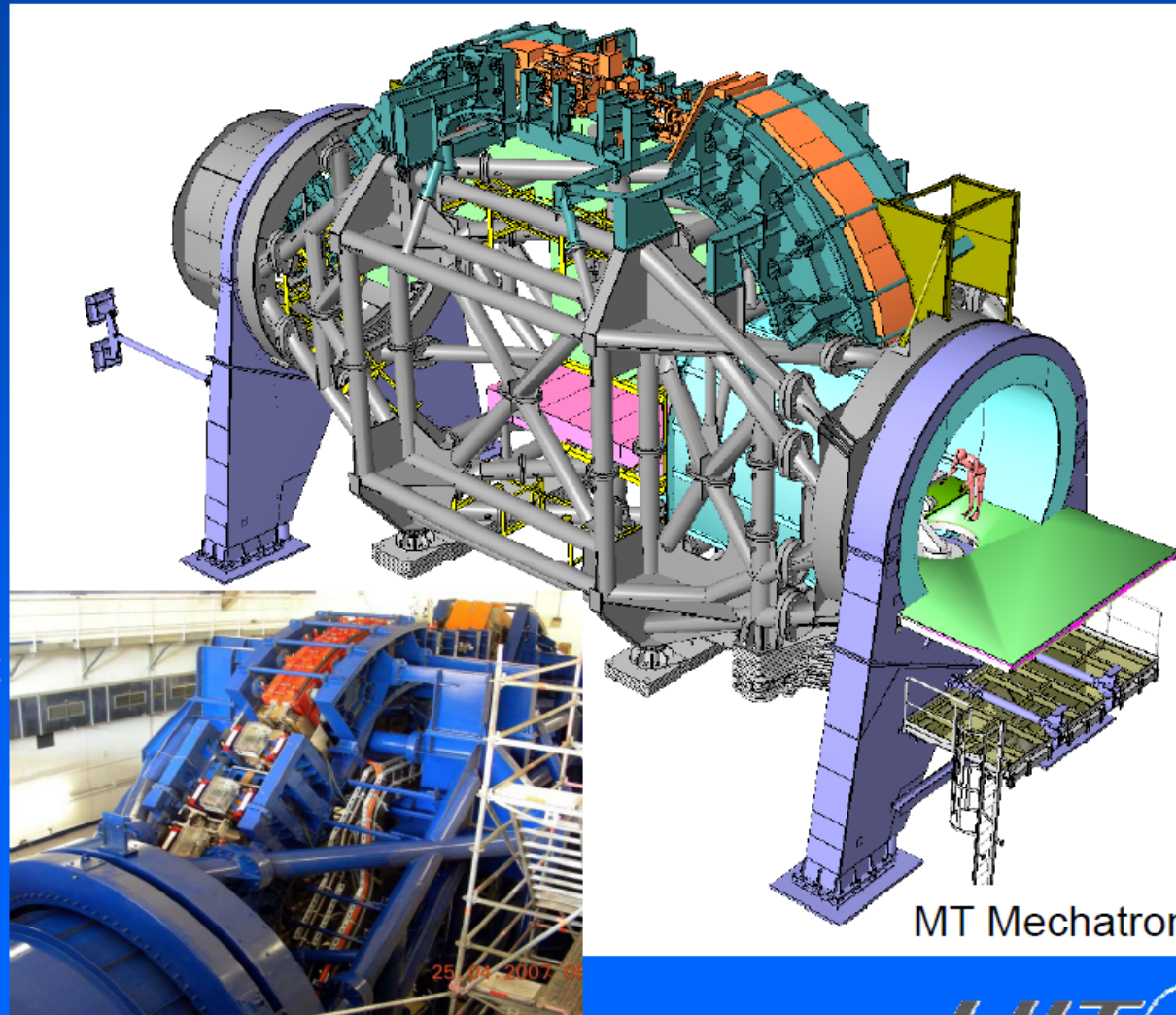
synchrotron



Th. Haberer, Heidelberg Ion Therapy Center

Scanning Ion Gantry

- optimum dose application
- world-wide first ion gantry
- world-wide first integration of beam scanning
- 13m diameter
25m length
600t overall weight
0,5mm max. deformation
- prototype segment tested at GSI



MT Mechatronics

Th. Haberer, Heidelberg Ion Therapy Center



Ion Gantry



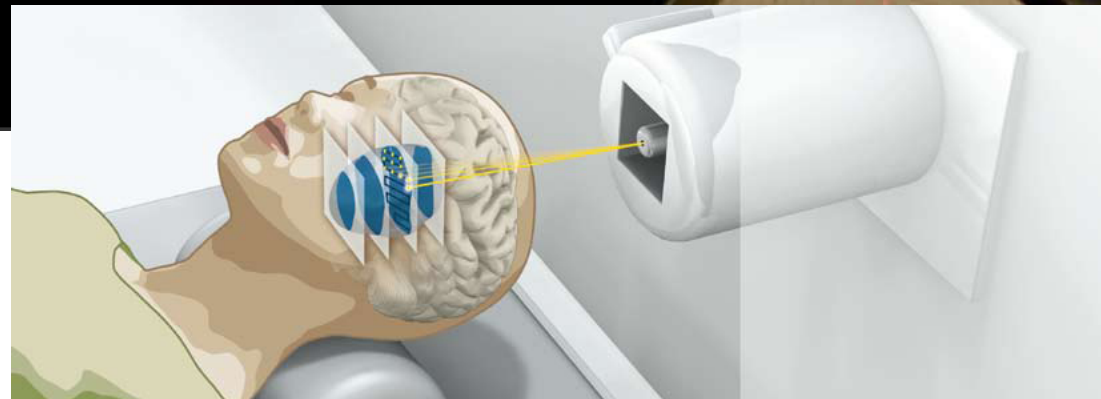
Mesa de tratamento



Sala de tratamento







Agradecimentos

Prof. Paulo Crespo (Univ. Coimbra)

Eng^a Marta Dias (ULisboa)

Eng^o Tiago Marcelos (ULisboa)

Eng^a Inês Castelhana (ULisboa)

FIM