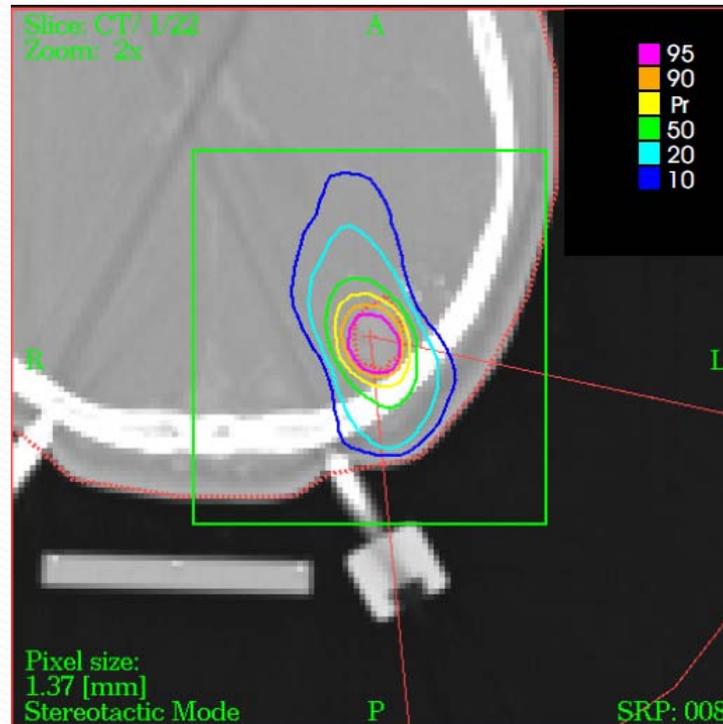


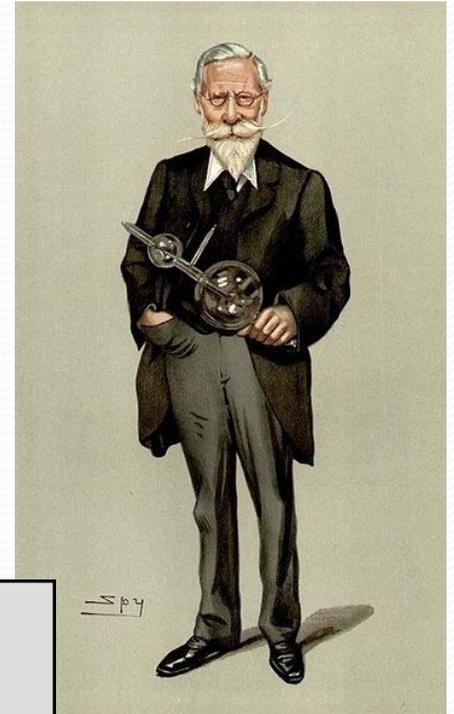
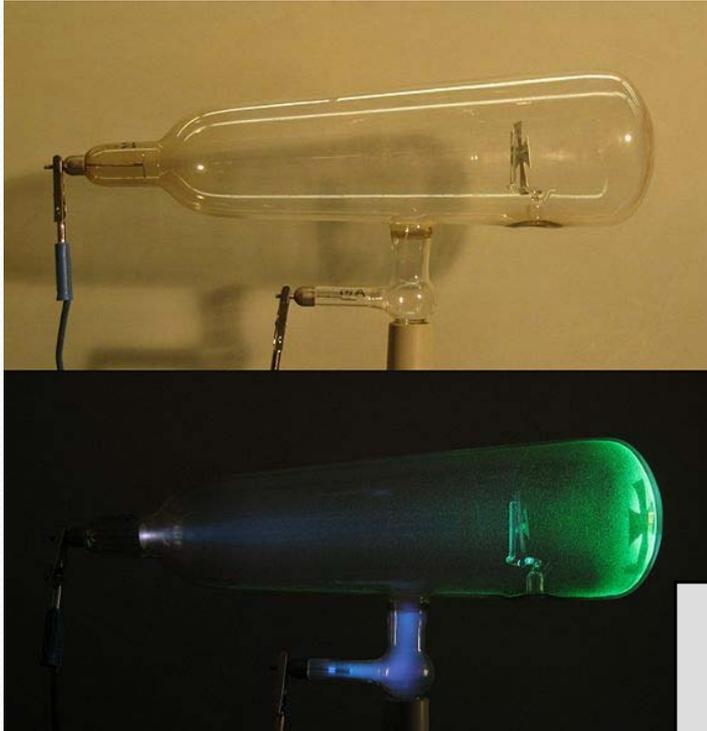
Aplicações da Física de Partículas



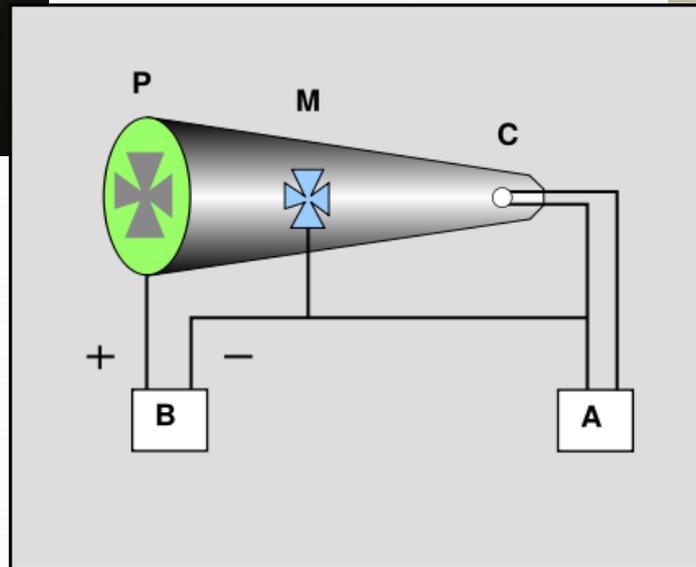
Luis Peralta
(FCUL e LIP)

Aceleradores em aplicações médicas

“A pré-história”



William Crookes



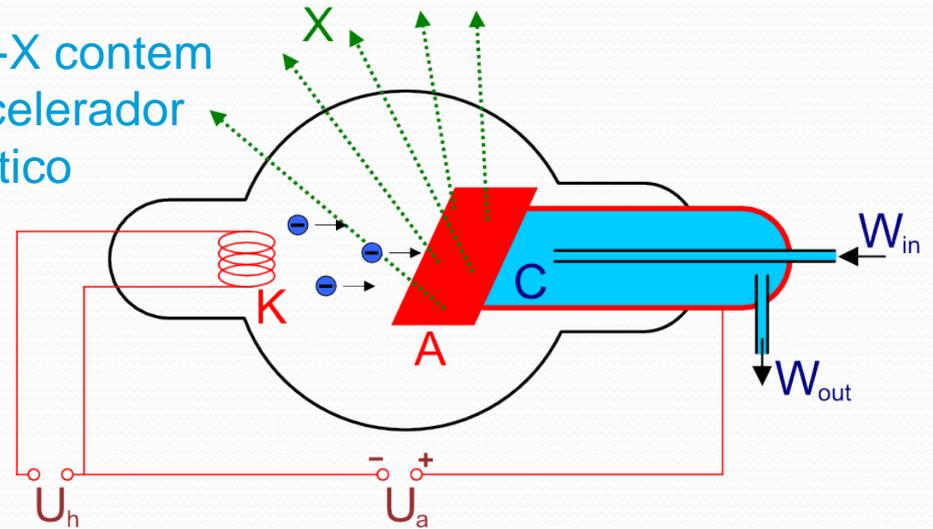
Aceleradores em aplicações médicas

“1895 - Descoberta dos raios-X”

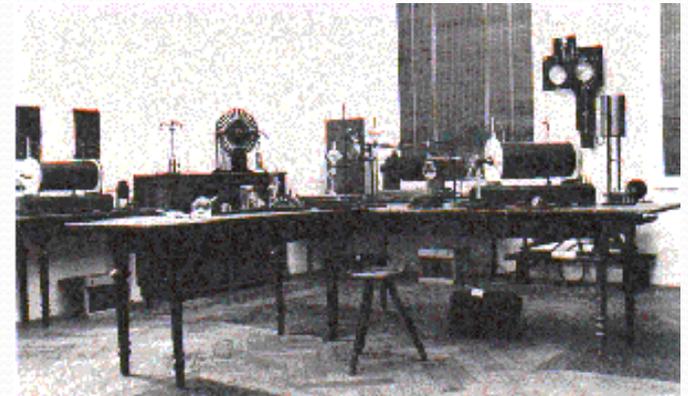


William Roentgen

O tubo de Raios-X contém um pequeno acelerador electrostático



Mão de Anna Berthe Roentgen
22 Dezembro 1895



Instituto de Física da Universidade de Würzburg, Alemanha

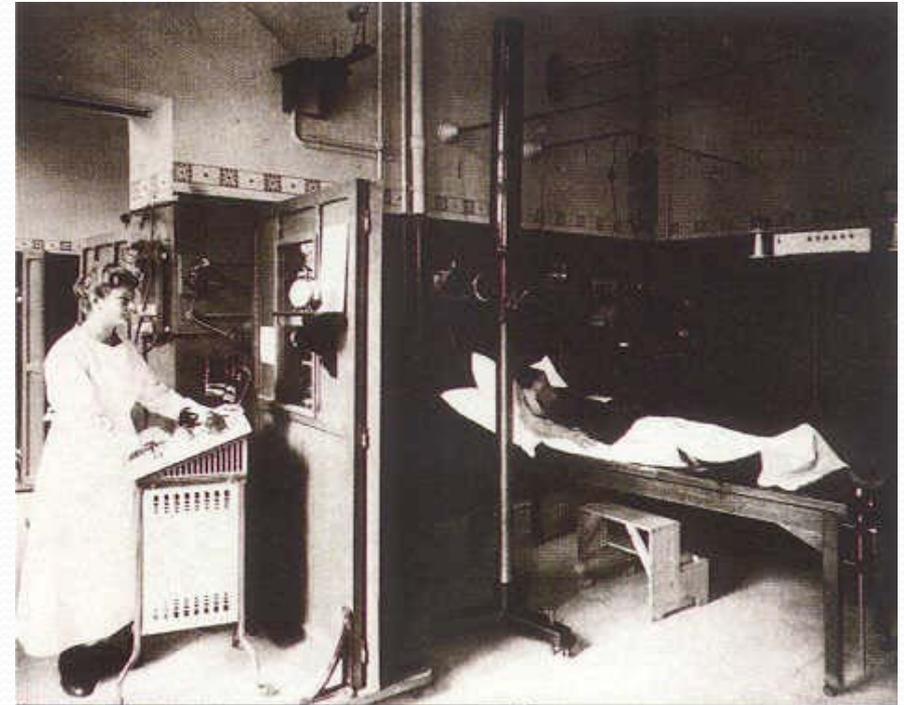
Aceleradores em aplicações médicas

“Primeiras aplicações à Medicina”



Imagiologia
(fluoroscopia)

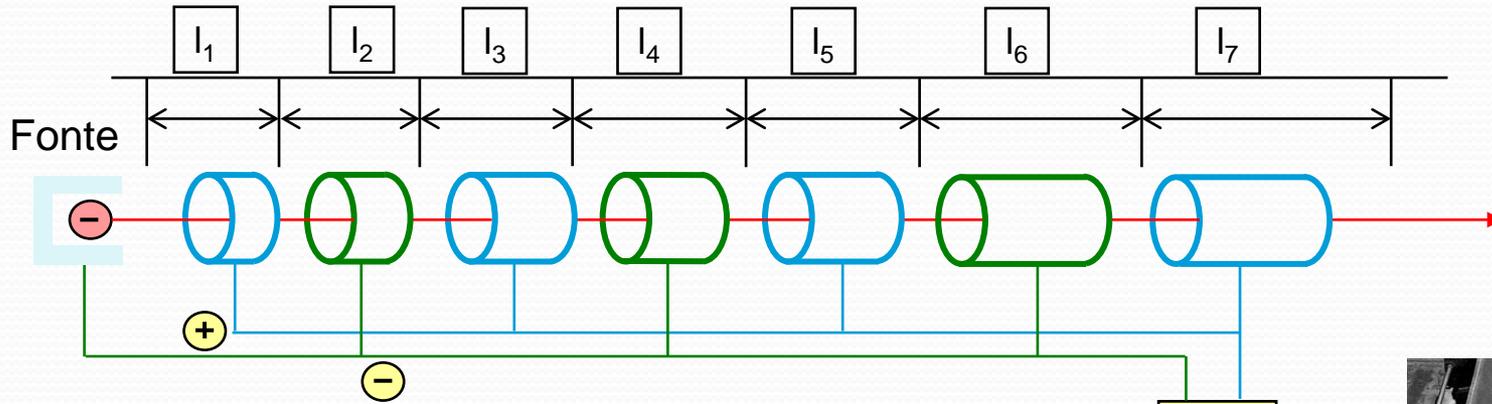
Terapêutica
(radioterapia 1920)



Aceleradores em aplicações médicas

“O acelerador Linear”

Wideroe - 1928

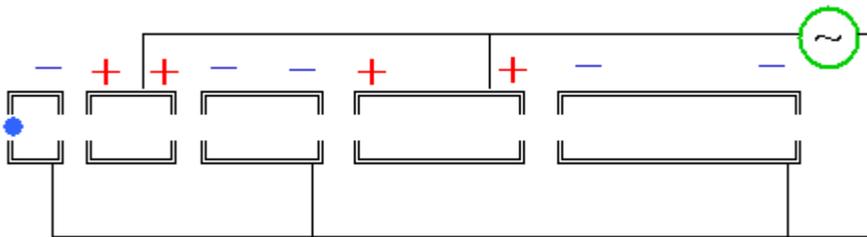
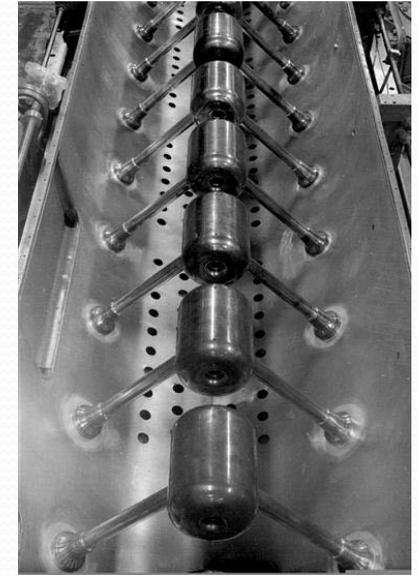


O feixe é descontínuo (pacotes)

$L_1 < L_2 < L_3 \dots$

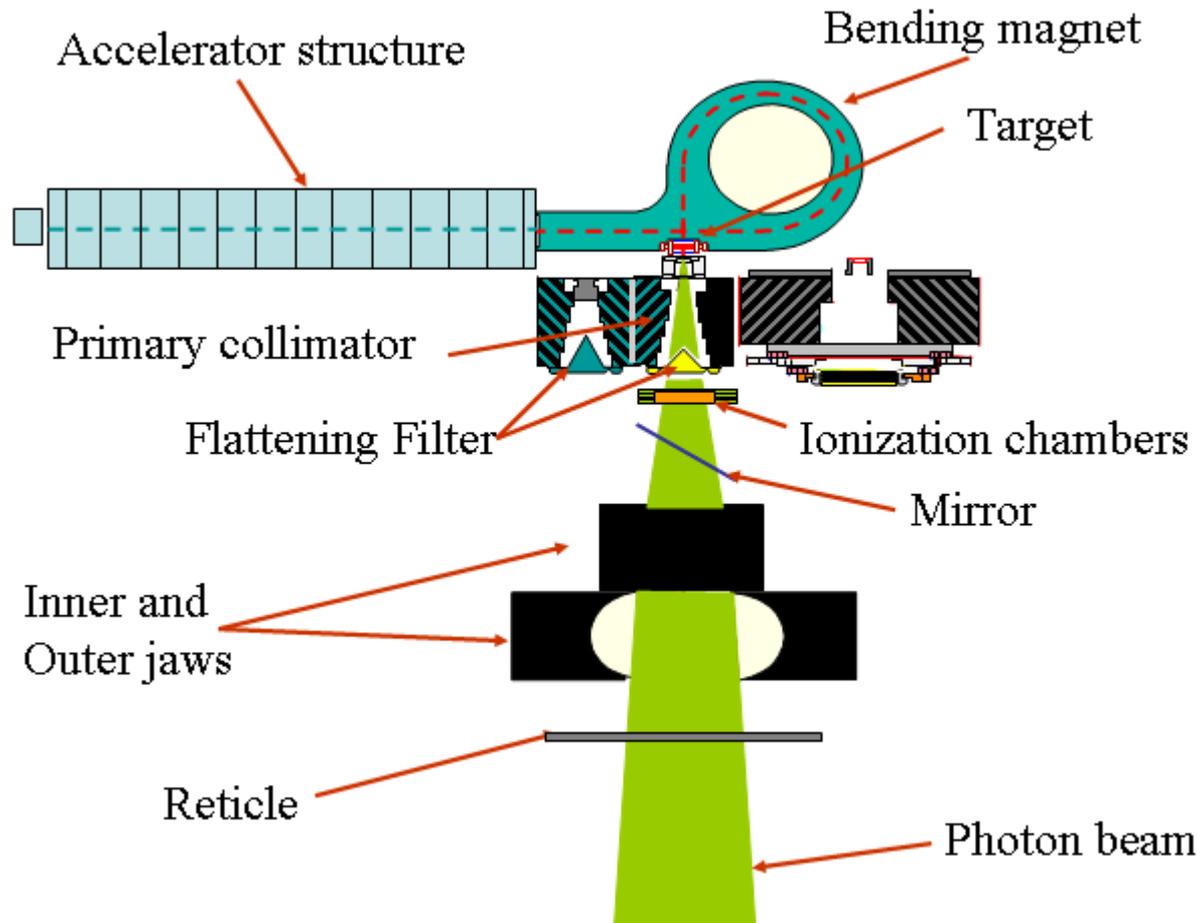
Para se obter uma energia elevada são necessário grandes comprimentos

Fonte RF



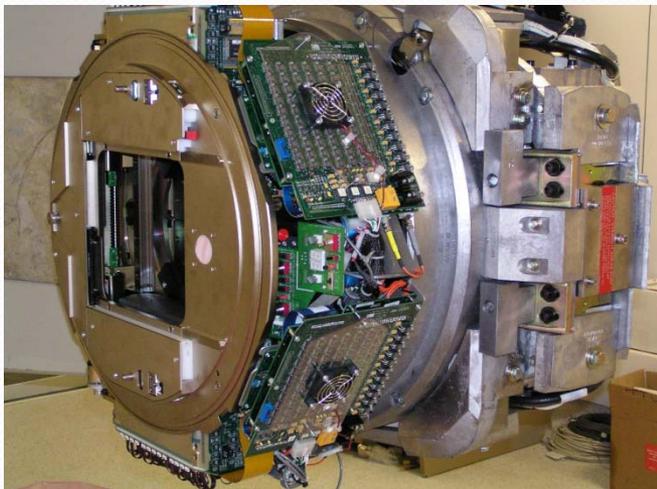
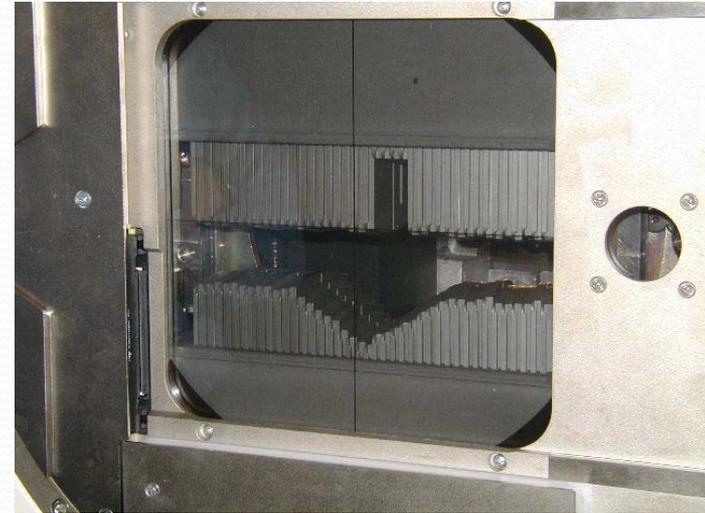
Aceleradores em aplicações médicas

“Acelerador clínico de electrões moderno”



Aceleradores em aplicações médicas

“Instalação de um acelerador linear”

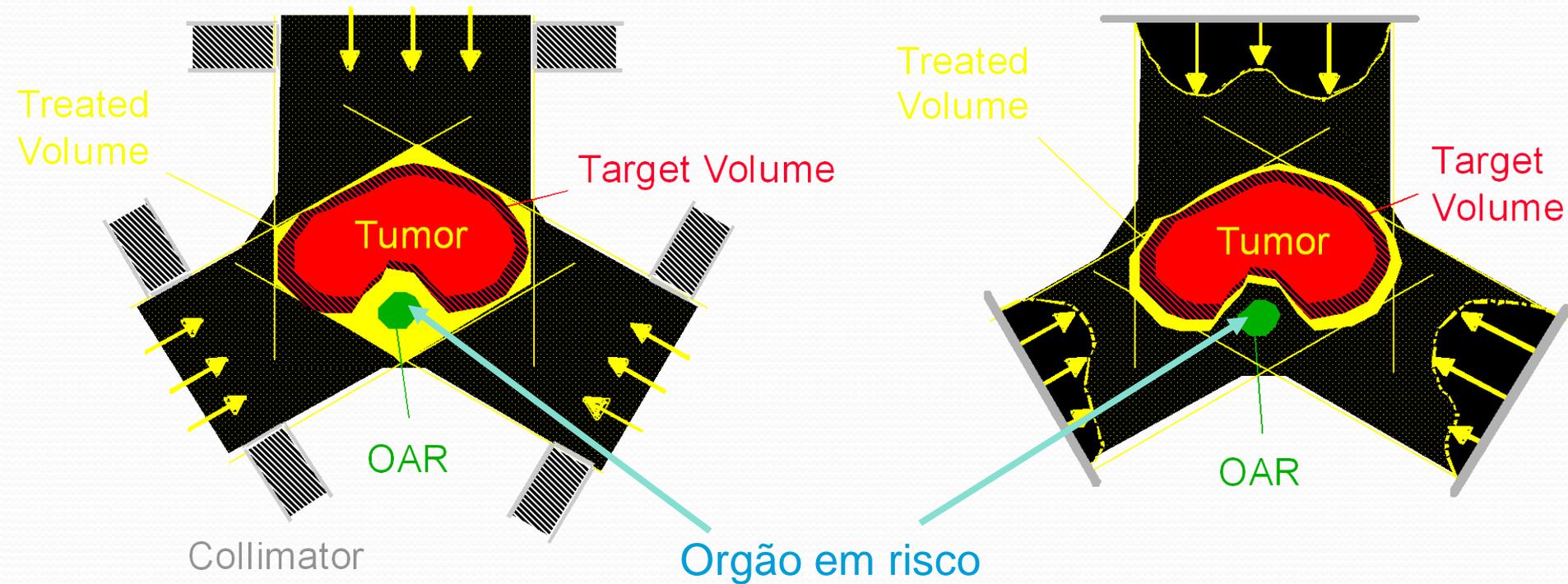


Aceleradores em aplicações médicas

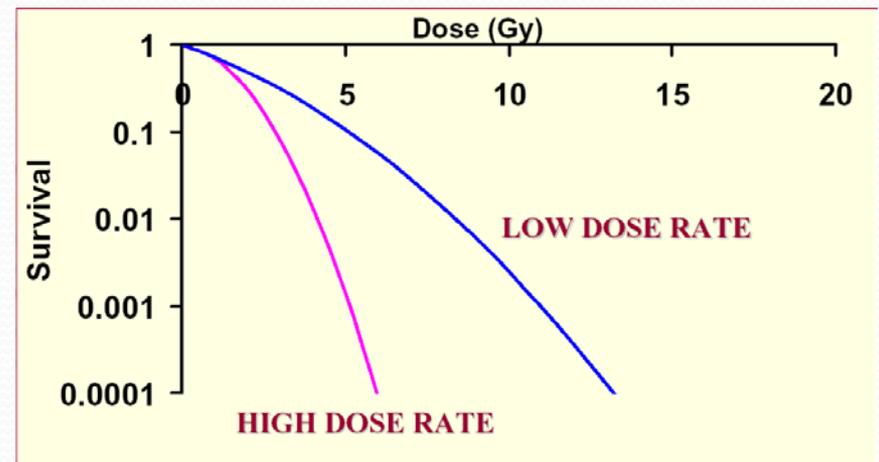
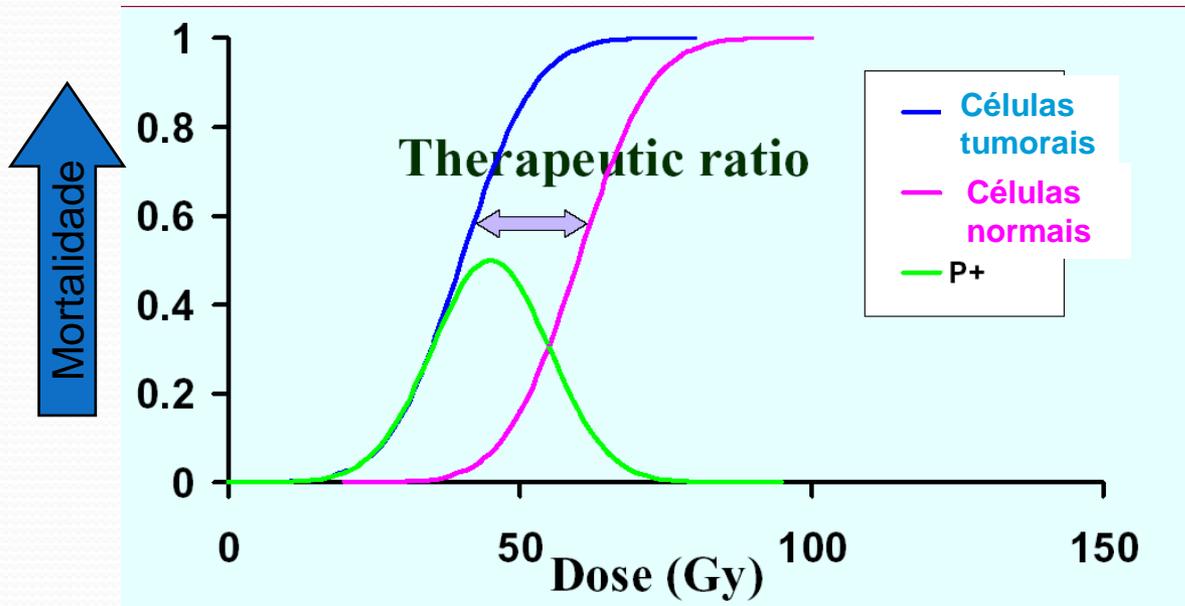
“Conformação do feixe de fótons”

Várias incidências feixe de fótons

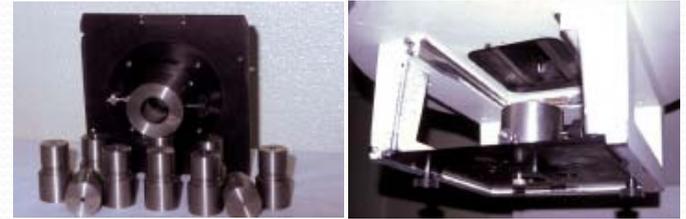
IMRT (RadioTerapia de Intensidade Modulada)



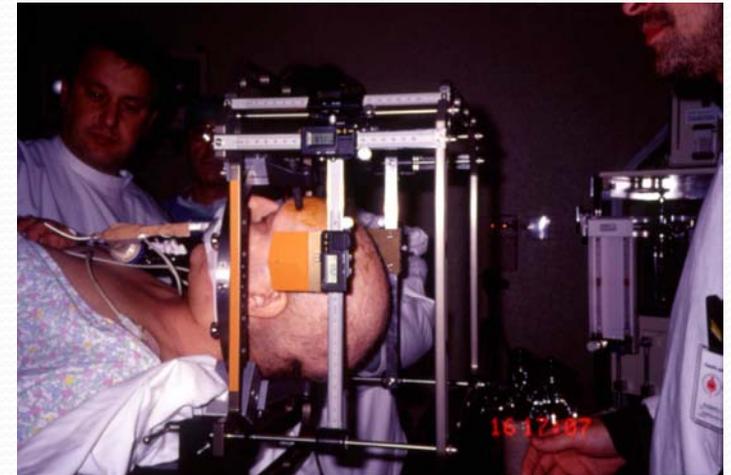
Sobrevivência de células tumorais / normais



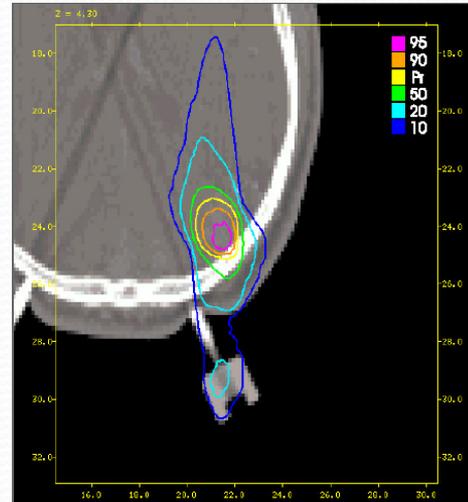
Radiocirurgia - Feixes finos com fótons de alta energia



colimadores adicionais



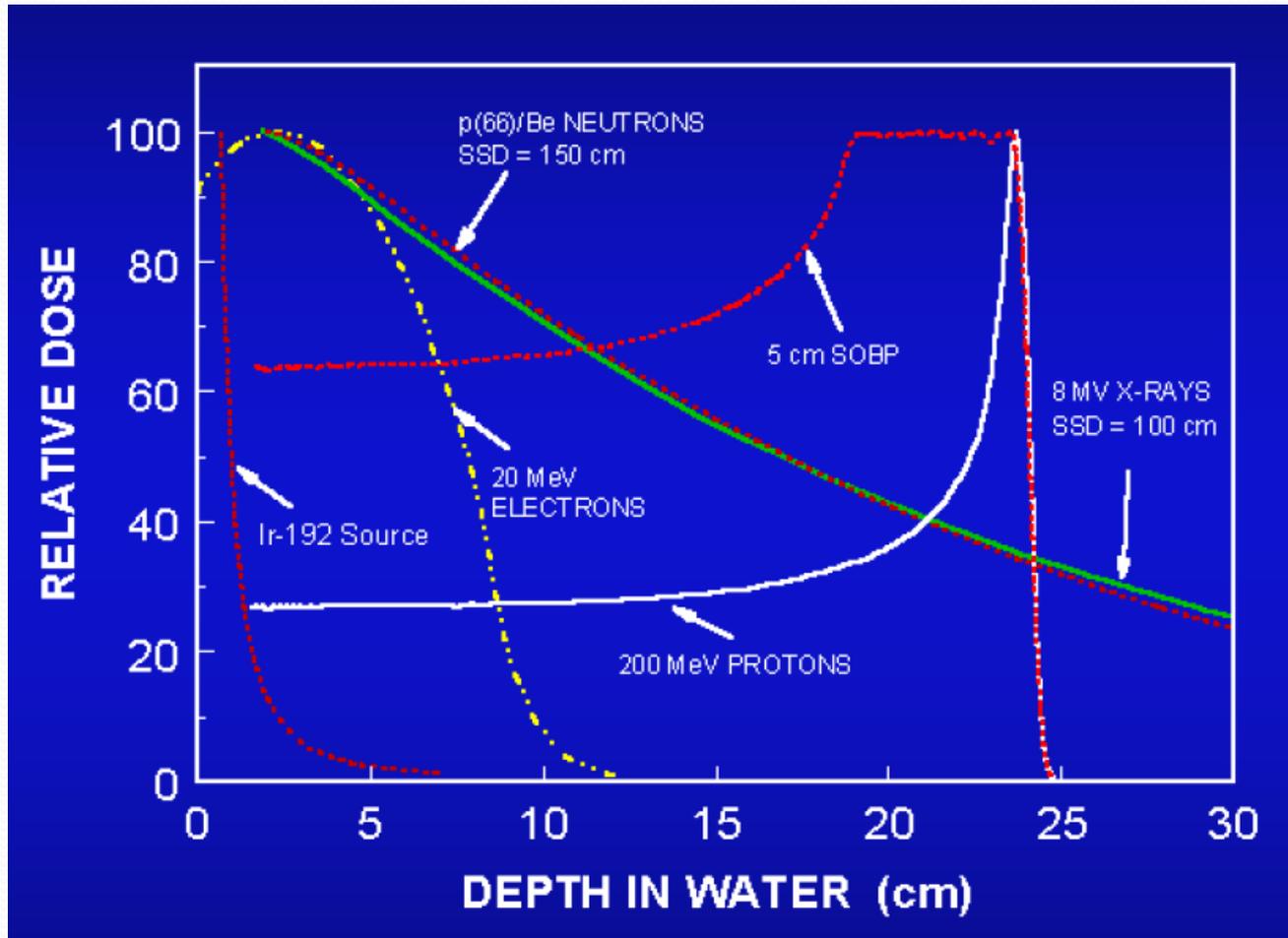
Sistema planeamento comercial



Simulação MC

Aceleradores em aplicações médicas

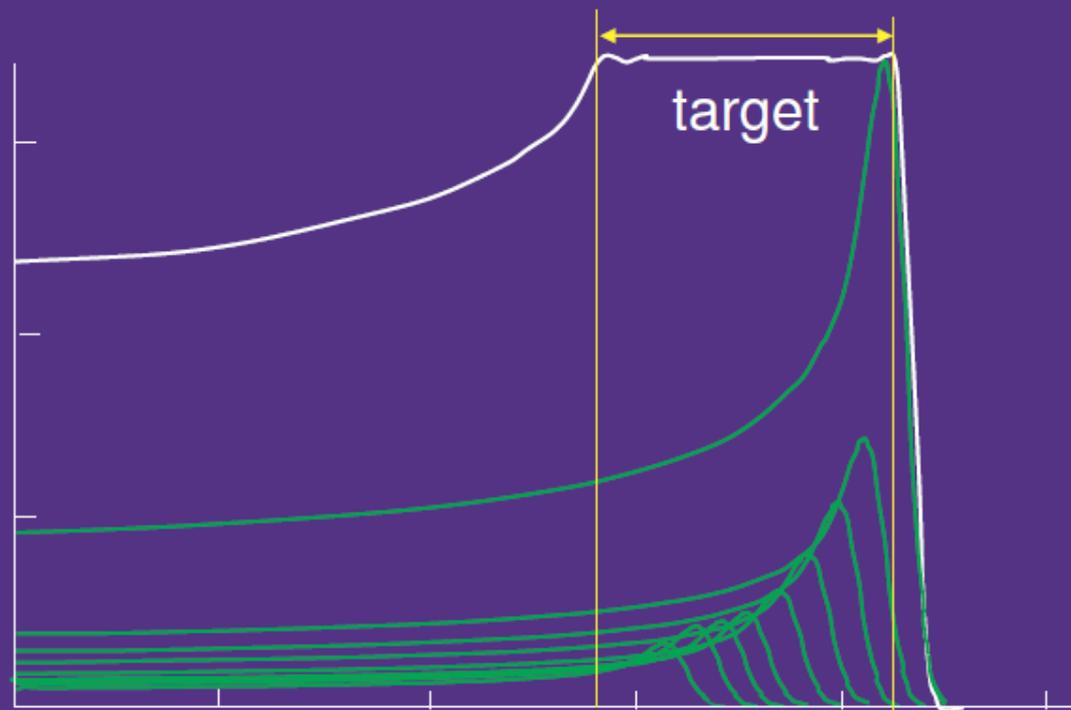
“Deposição de energia”



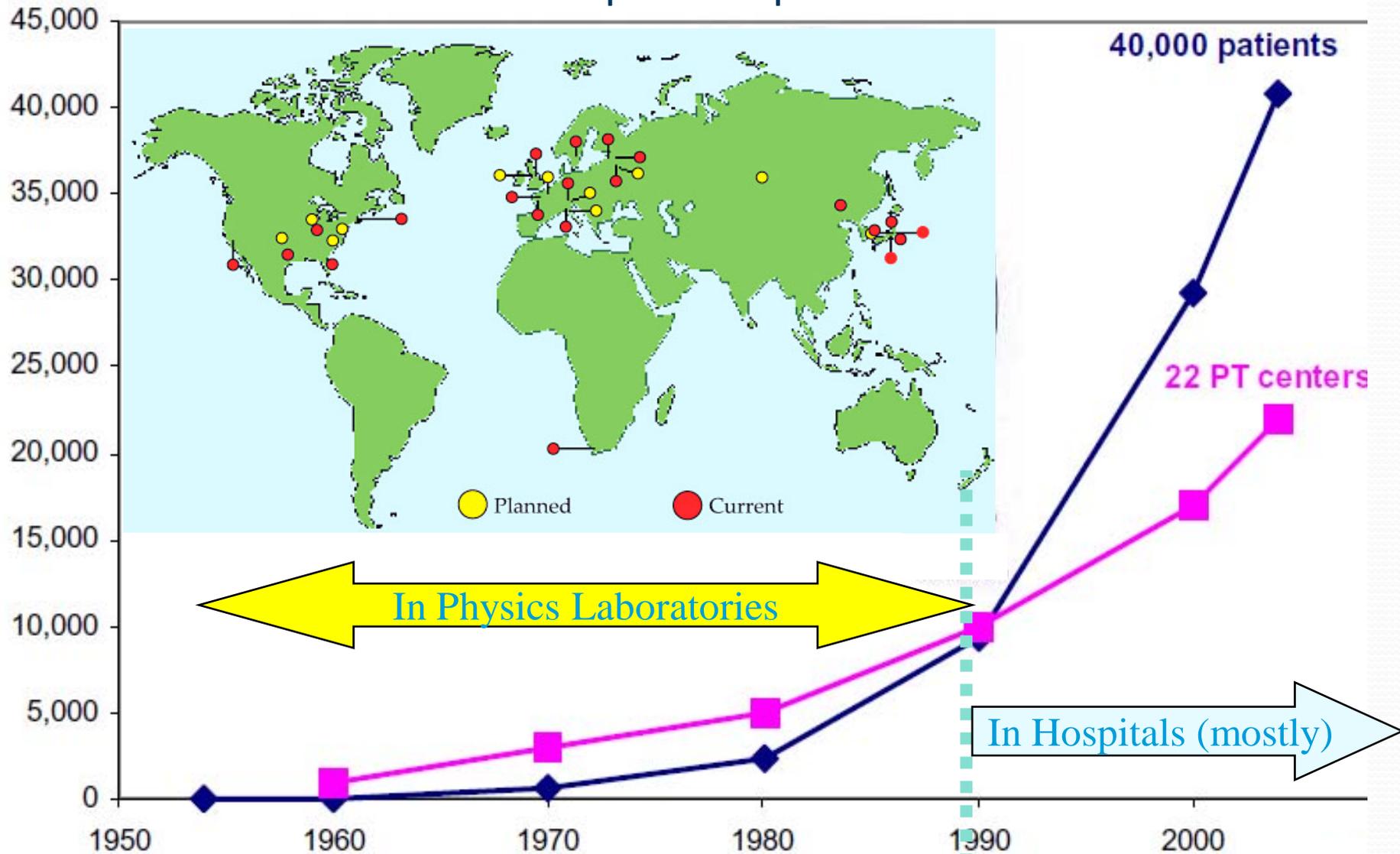
Aceleradores em aplicações médicas

“Deposição de energia dos prótons”

Extending the dose in depth – the ‘Spread-out-Bragg-peak’



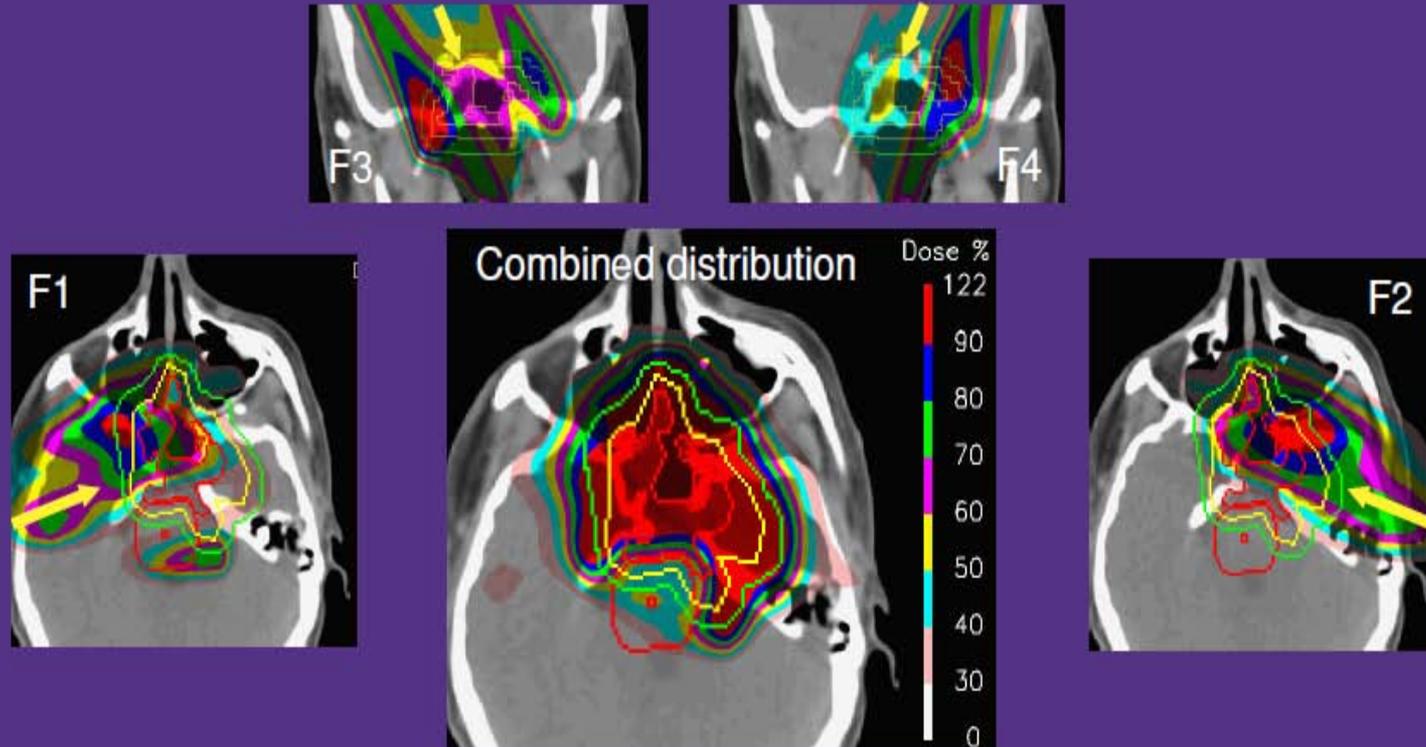
Aceleradores em aplicações médicas “Terapia com prótons”



Courtesy Janet Sisterson, MGH

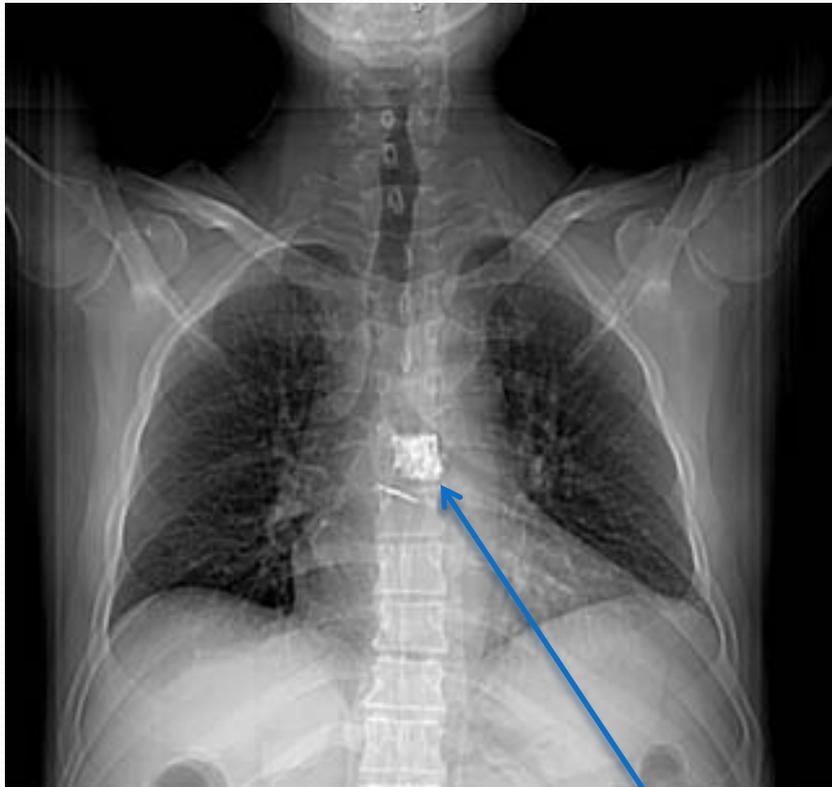
“Terapia com prótons”

Intensity Modulated Proton Therapy: The simultaneous optimisation of all Bragg peaks from all incident beams. E.g..



Lomax, *Phys. Med. Biol.* 44:185-205, 1999

Radiografia com feixe de prótons



Raios-X

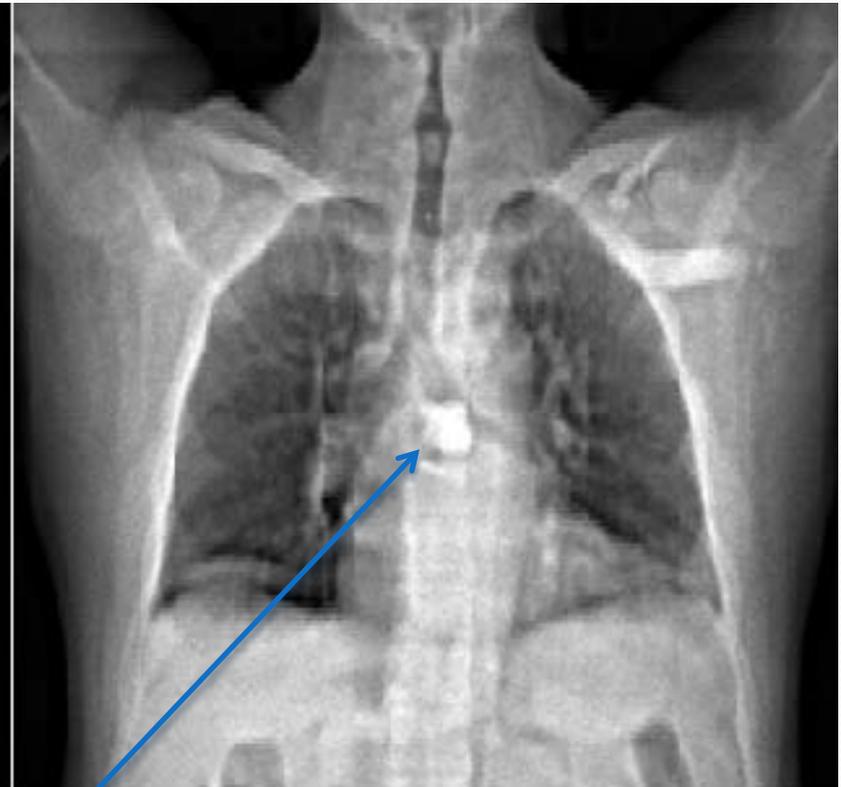


Imagem Protões (MC)

Tumor

Aceleradores em aplicações médicas

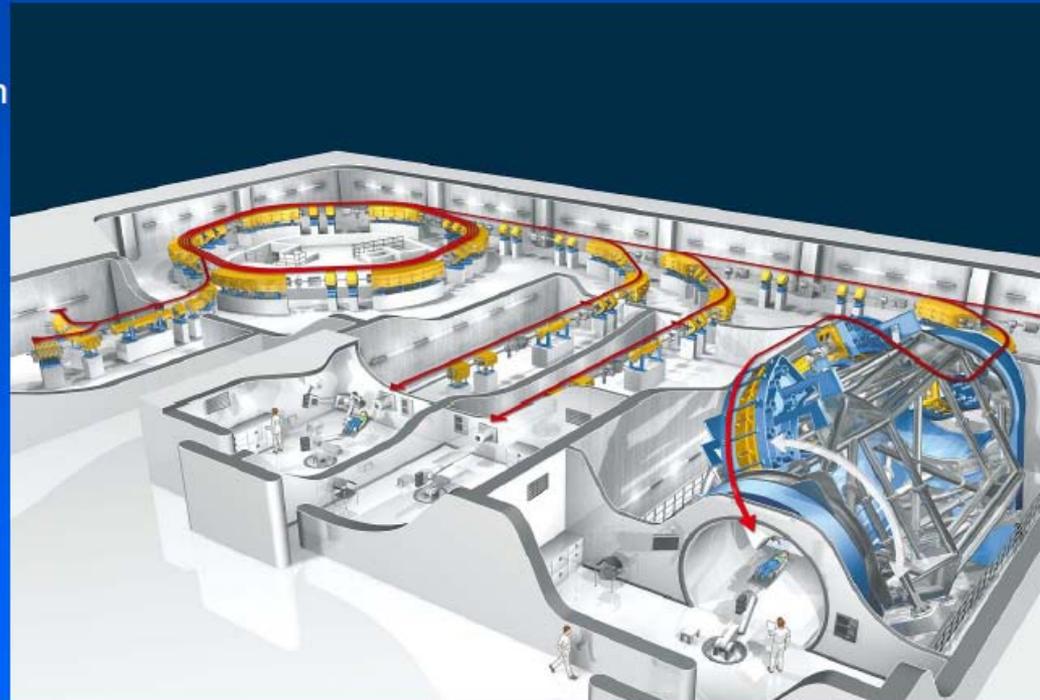
Terapia com íons carbono



The Heidelberg Ion Therapy Center

Heidelberg Ion Therapy Center

- compact design
- full clinical integration
- rasterscanning only
- low-LET modality: Protons (later He)
- high-LET modality: Carbon (Oxygen)
- ion selection within minutes
- world-wide first scanning ion gantry
- > 1000 patients/year
> 15.000 fractions/year



Th. Haberer, Heidelberg Ion Therapy Center

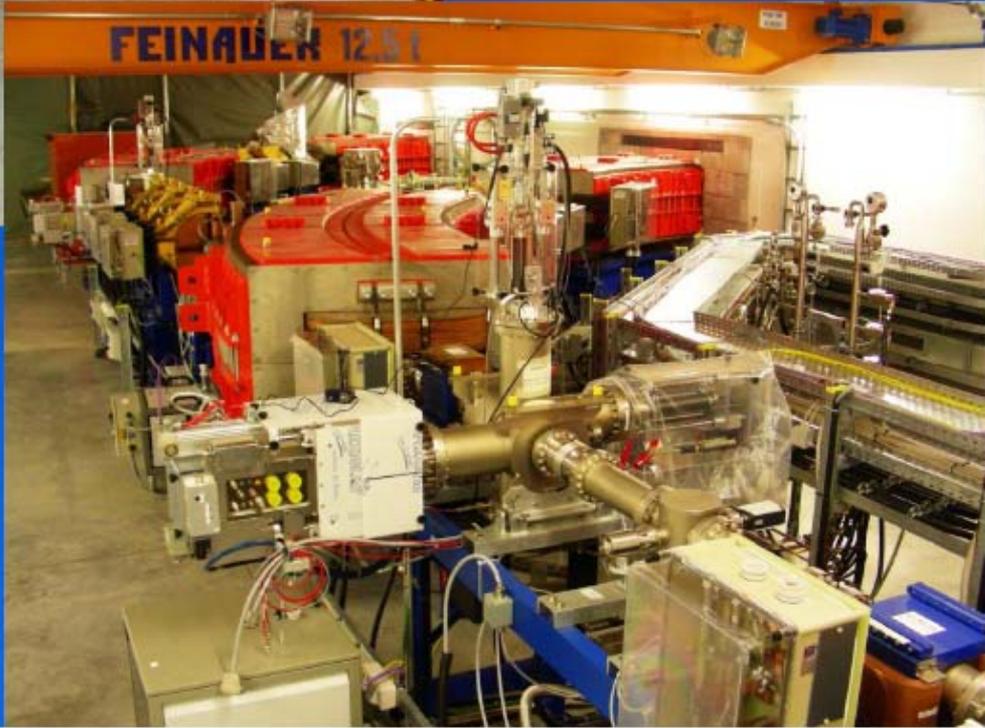




high energy
beam transport

synchrotron

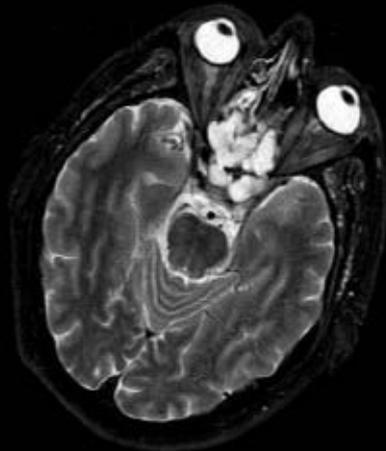
Th. Haberer, Heidelberg Ion Therapy Center



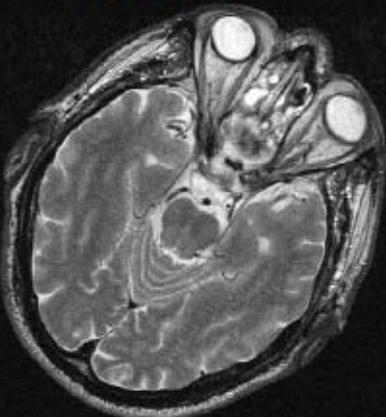
Patient Positioning



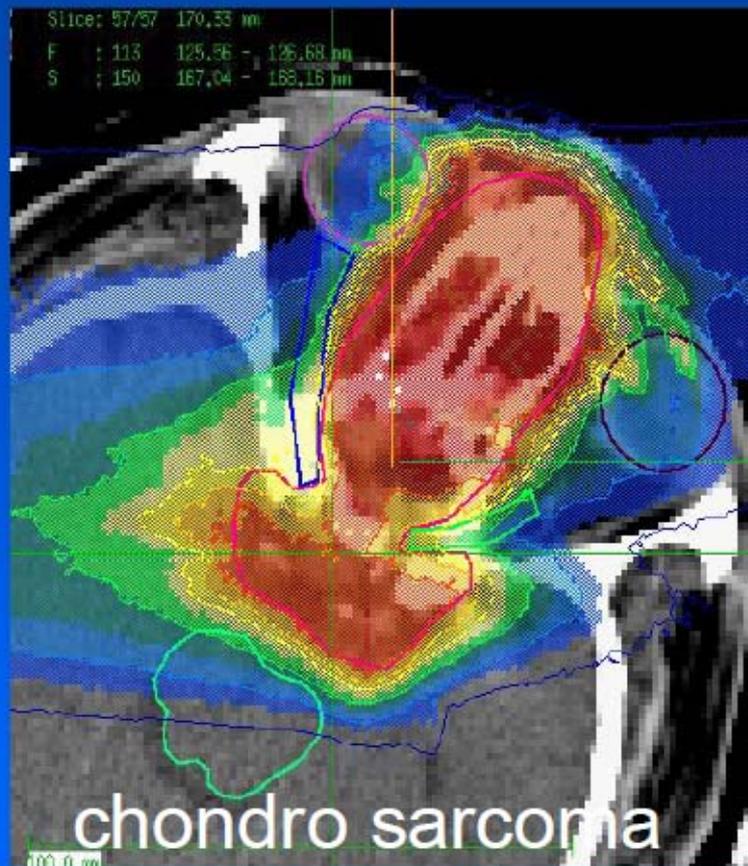
Pre OP



Post OP



Results



dose [%]

20 - 40
40 - 60
60 - 80
80 - 100
100 - 120

raster-scanned carbon ions



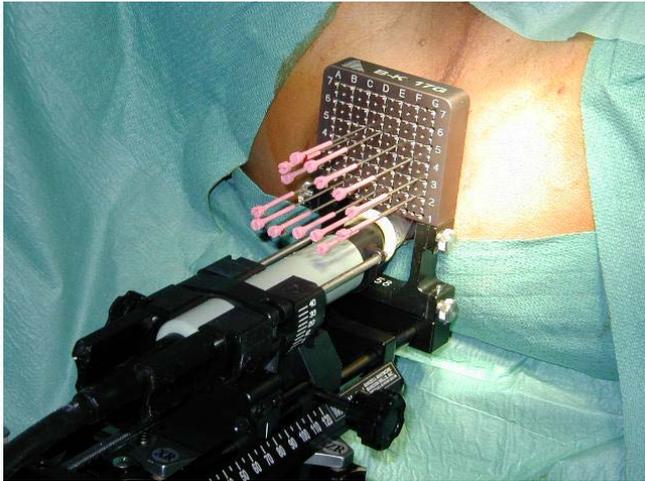
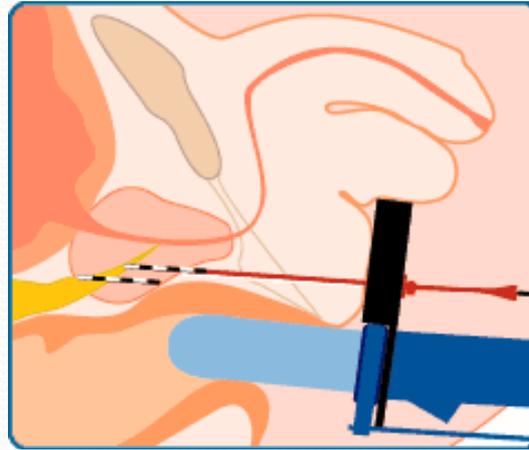
Terapia com fontes radioactivas

Braquiterapia Mamária



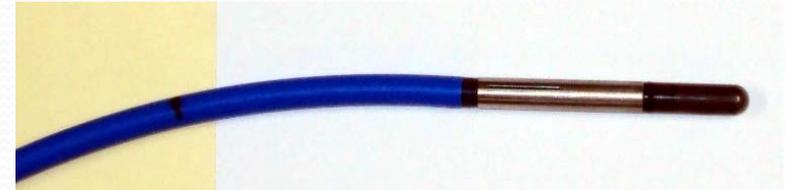
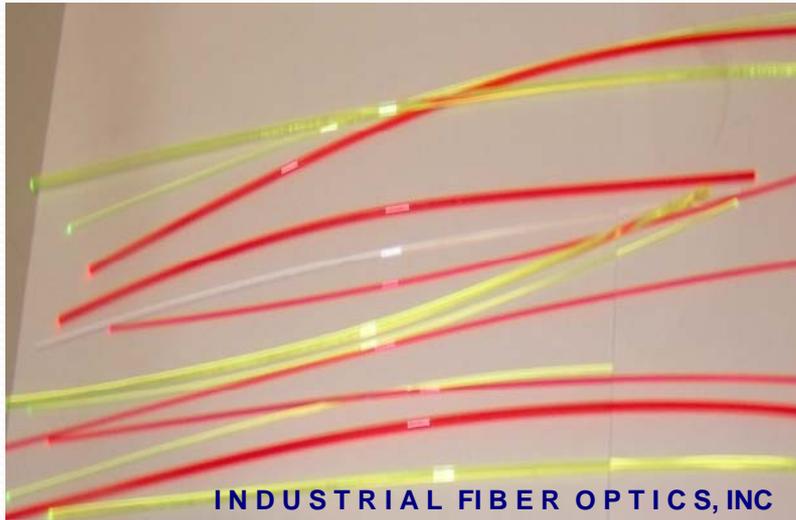
Terapia com fontes radioactivas

Braquiterapia da Próstata

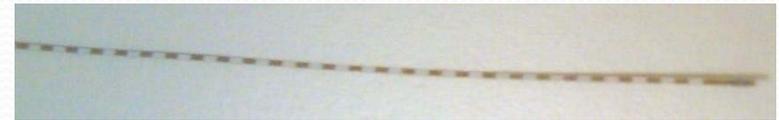


Fibras ópticas como dosímetros

FIBRAS DE POLIESTIRENO



Câmara de ionização

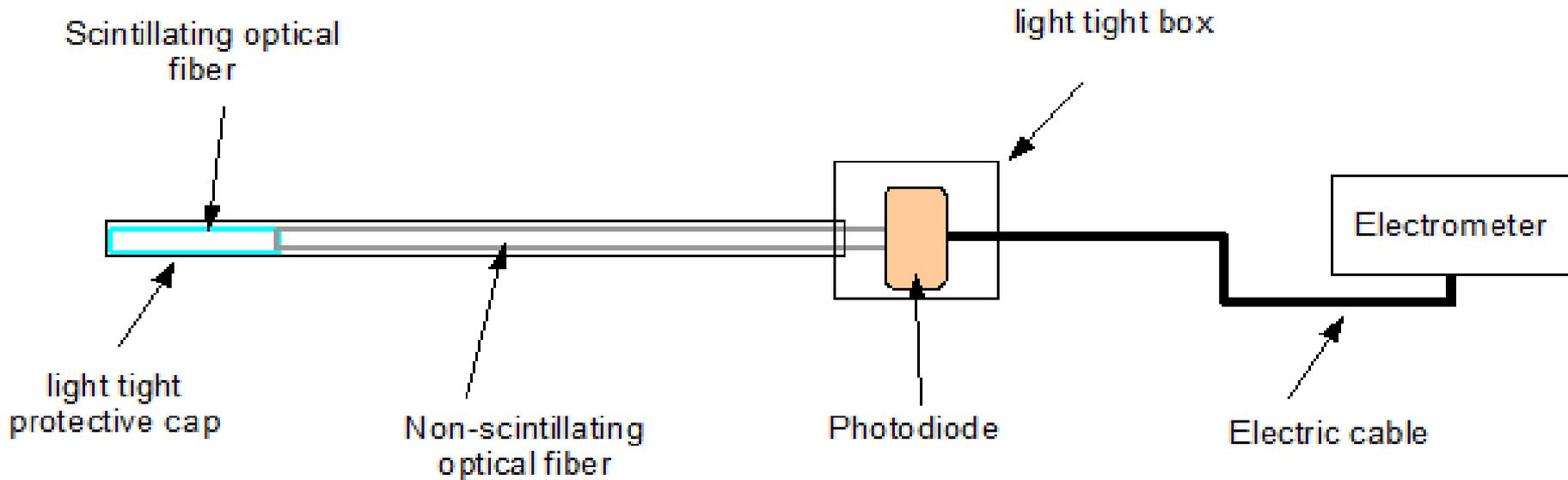


Dosimetro MOSFET



Dosimetro de Fibra

O DosFib



Fibra plástico emitindo no azul, 5 mm comprido (2 mm diâmetro)

Fibra não-cintilante c/ 1 m comprimento

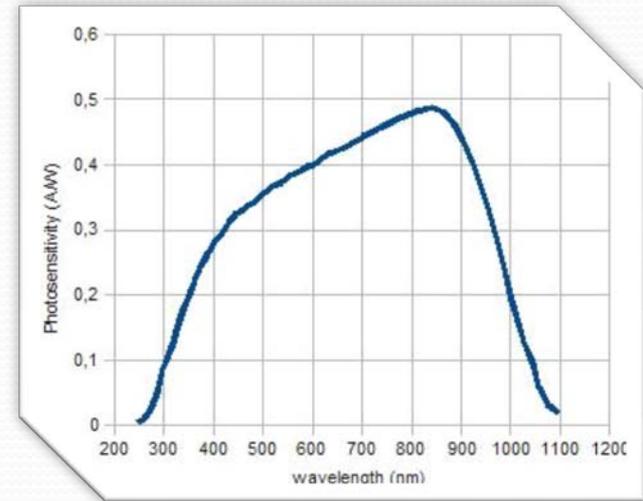
Fotodetector de silício

Leitura do sinal com electrómetro

Elementos do DosFib



Hamamatsu Photodiode S9195



Resposta espectral



Fibras azuis e verdes

Testes em laboratório do DosFib

O DosFib foi testado com feixes de raios-X de 20 a 100 kVp



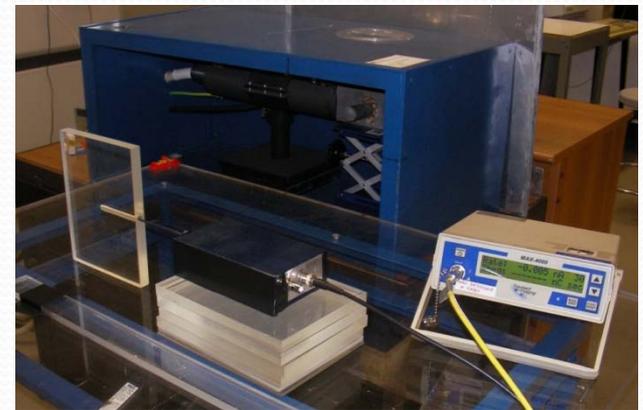
Philips PW 2184/00 X-ray tube



Dosimetro num fantoma de acrílico



Câmara de ionização
para testes



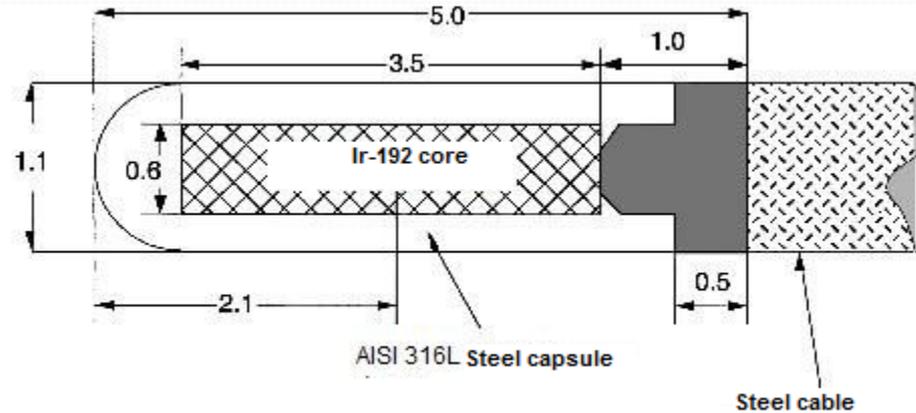
Dispositivo experimental

Testes do DosFib no Hospital de Santa Maria

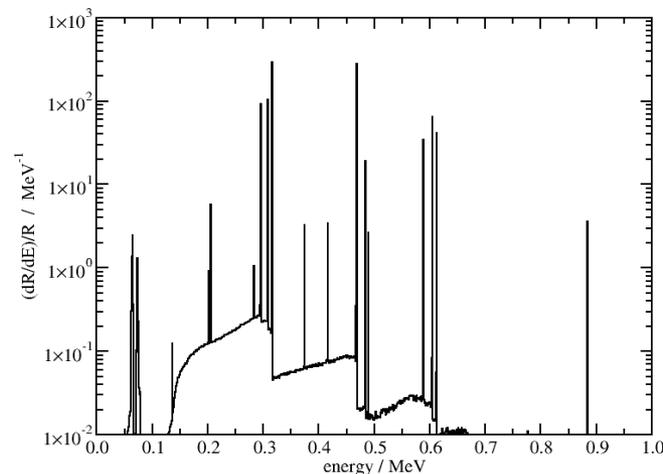


Afterloading

Ir-192 Source



Energia Ir-192

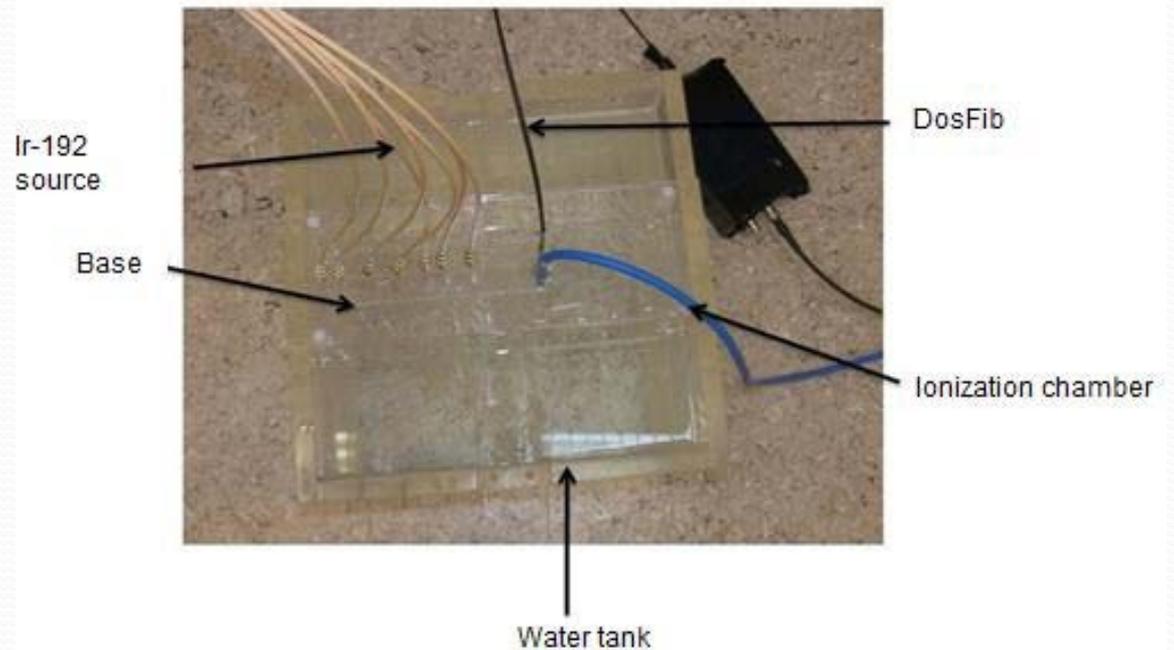
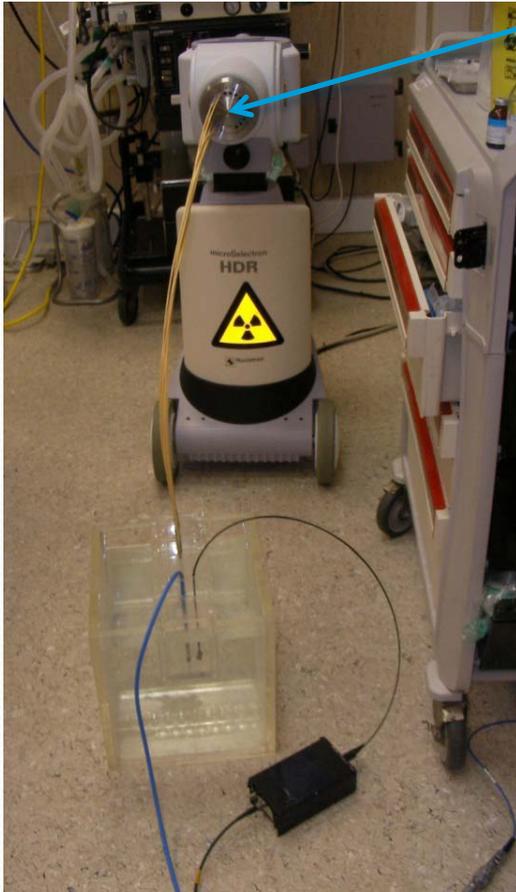


Energia Raios- γ (keV)	I_{γ} (%)
295	29
308	30
316	83
486	48
604	8
612	5

http://www.physics.carleton.ca/clrp/seed_database/Ir192_PDR/microSelectron_v2/

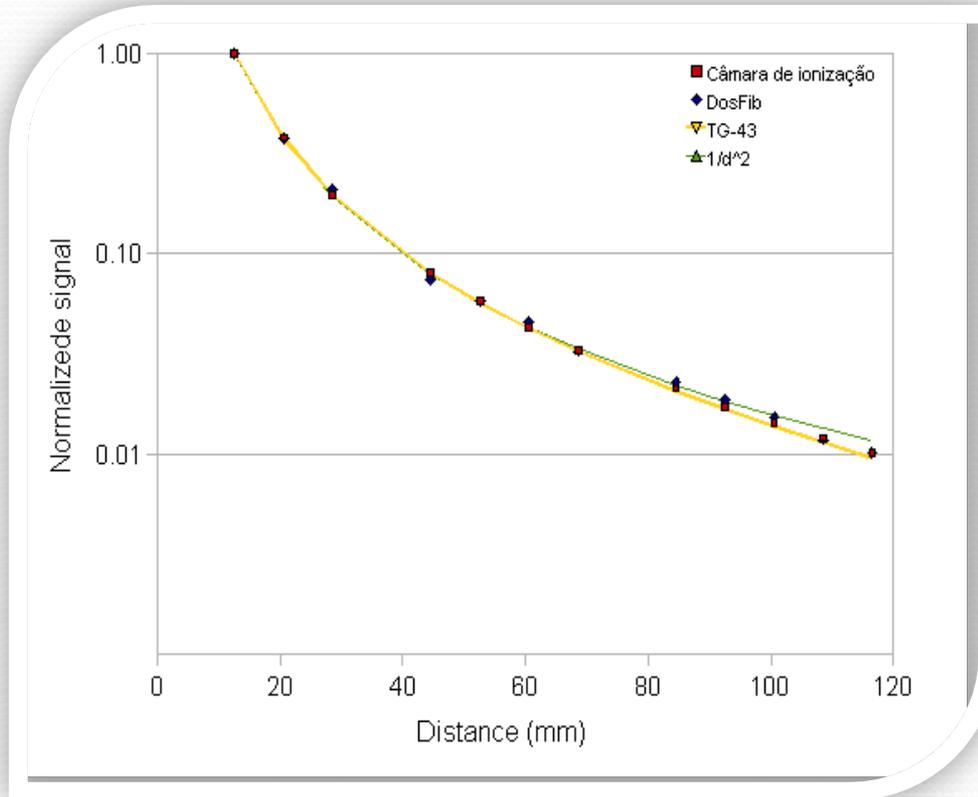
Testes do DosFib no HSM

Fonte Ir-192

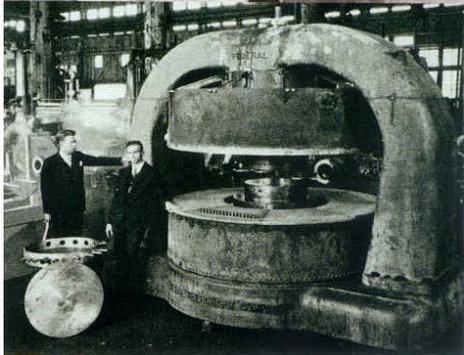


Dispositivo experimental

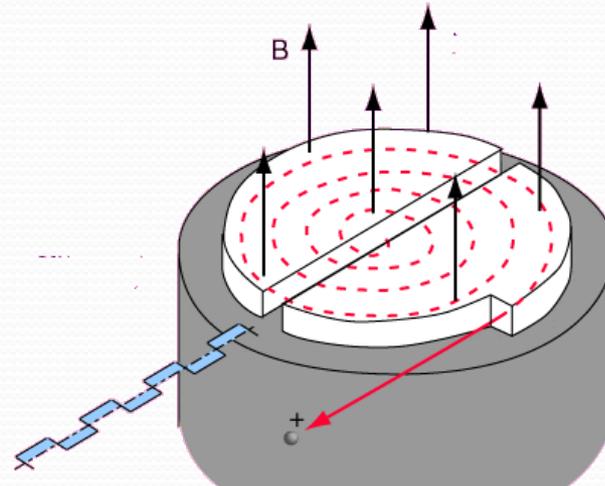
Resposta do DosFib



O ciclotrão



E. Lawrence 1929



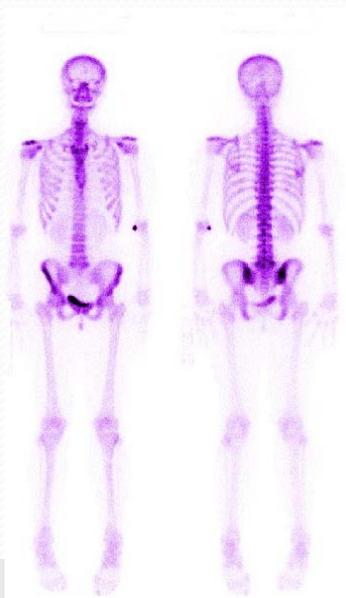
Cintigrafia - Preparação do radiofármaco



Cintigrafia – O exame clínico

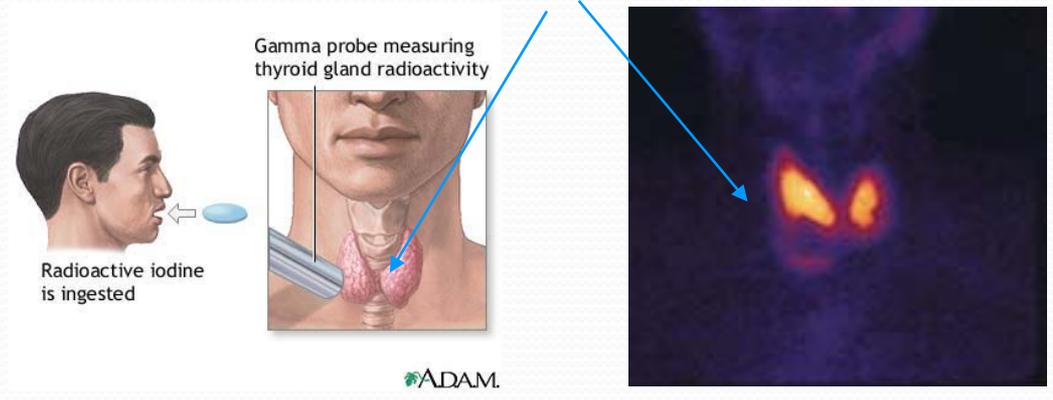


A radiação emitida pelo radiofármaco é detectada na câmara gama



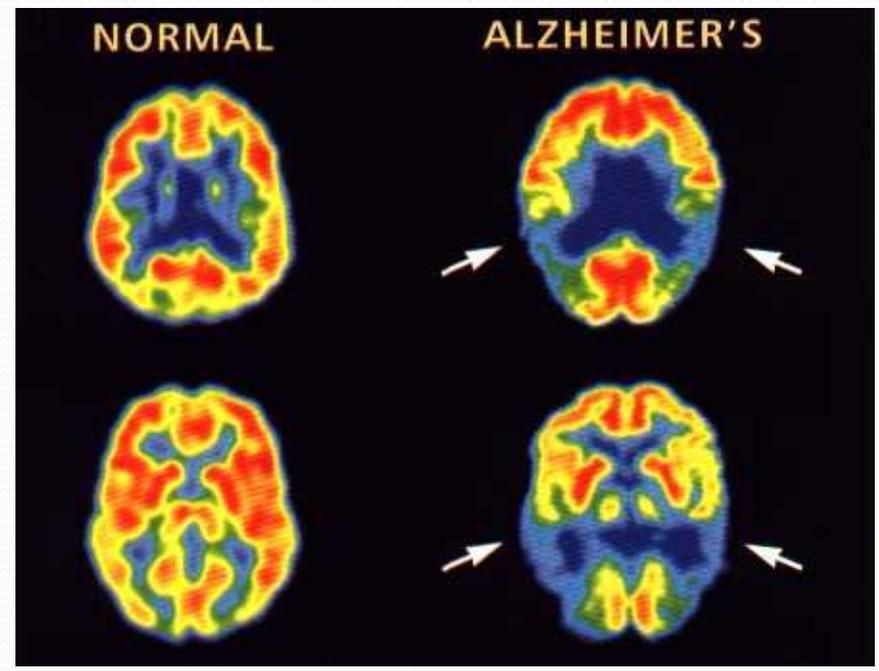
Exemplos de cintigrafias

Tiróide



Detecção de anomalias na tiróide

Doenças no cérebro

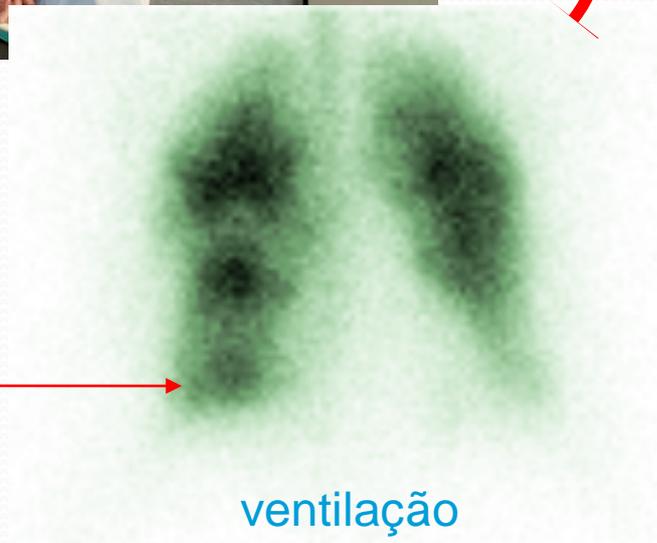


Exame aos pulmões usando gás kripton radioactivo



a perfusão (feita com um radiofármaco injectado) mostra que um coágulo de sangue impede a circulação!

o ar circula
mas ...

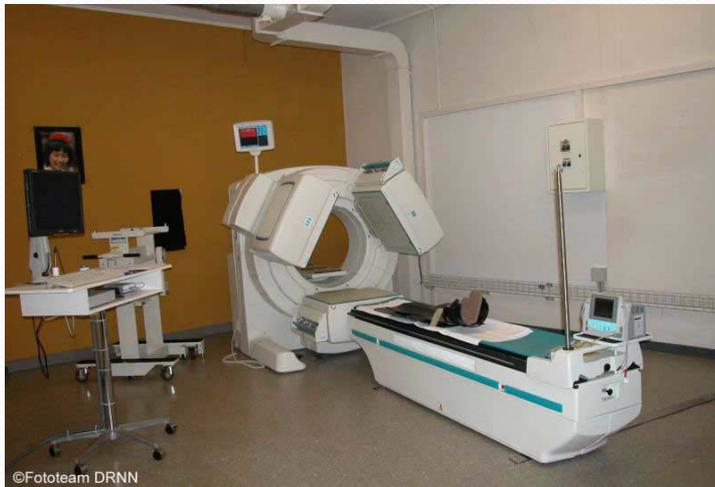
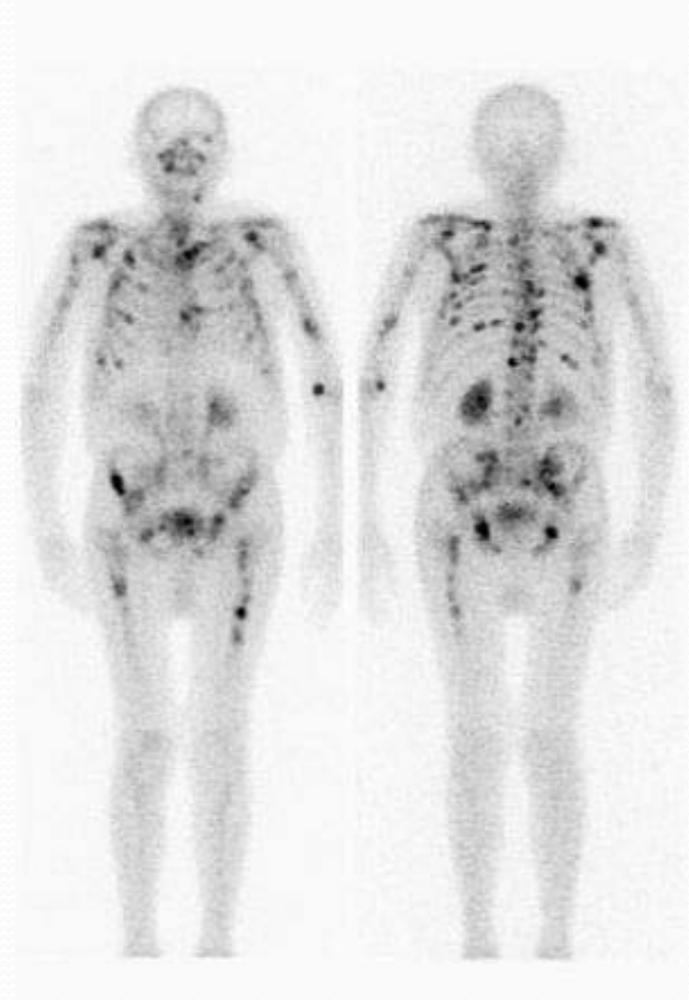


ventilação



perfusão

Detecção de metastases



©Fototeam DRNN

Tomografia de Emissão de Positrões



O radiofármaco (FDG) é preparado num ciclotrão

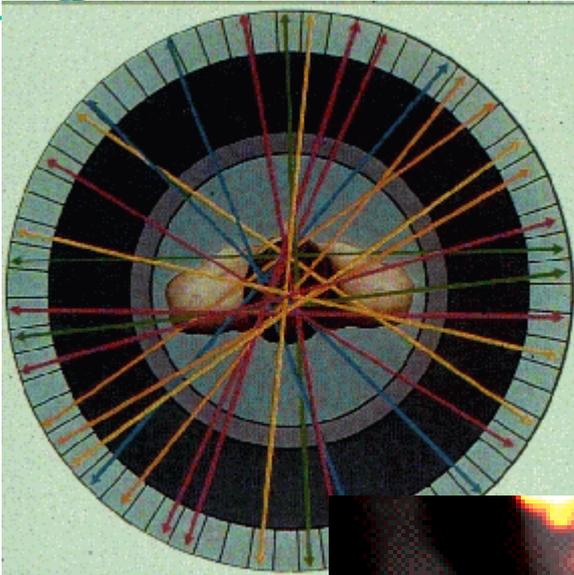
O Fluor-18 é um emissor de positrões
Positrão + Electrão \rightarrow 2 Fotões



Preparação do doente



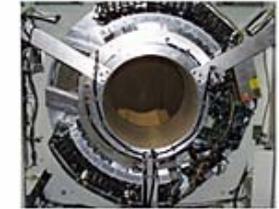
Câmaras PET-CT



Combined PET/CT Scanner
University of Pittsburgh Medical Center



CT component (above); PET component (below)



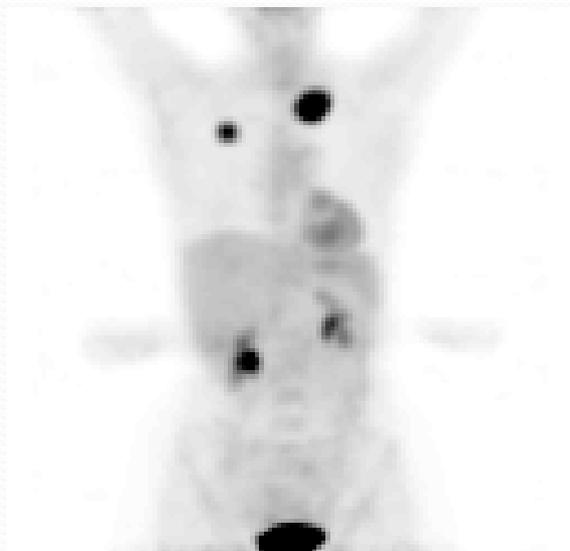
CT



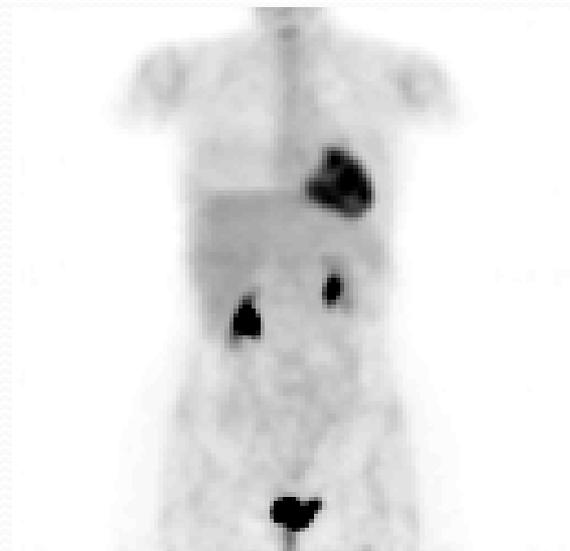
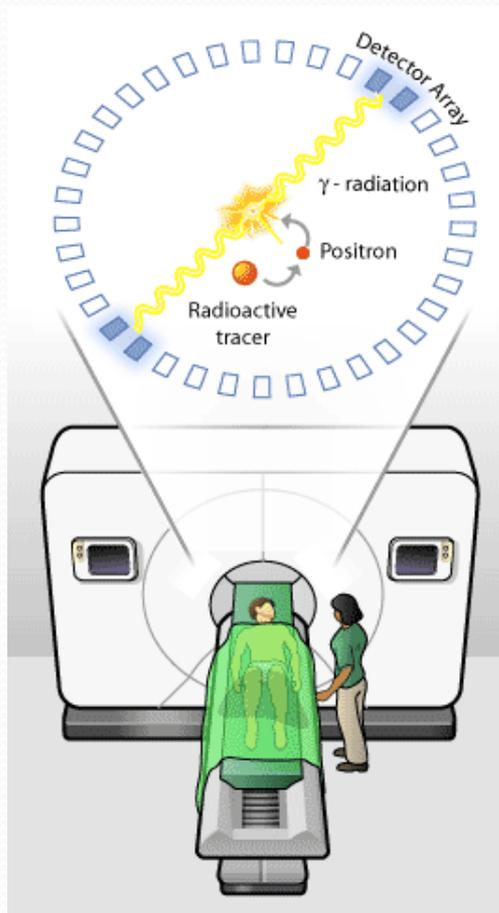
PET



Um caso clínico de utilização: mulher 47 anos



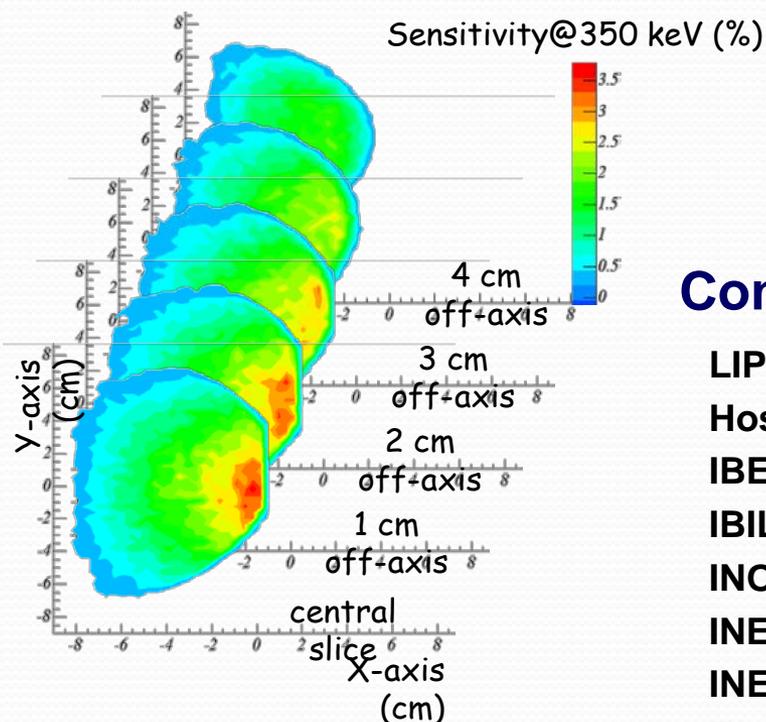
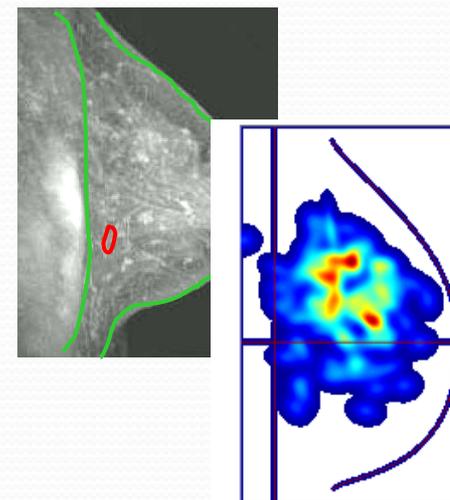
Antes do tratamento



8 meses após tratamento

O projecto ClearPEM

Scanner ClearPEM desenvolvido no quadro da colaboração Crystal Clear Collaboration do CERN



Consórcio PET-Mammography.

LIP - Laboratório de Instrumentação e Partículas

Hospital Garcia Orta - Serviço Medicina Nuclear

IBEB - Instituto Biofísica e Engenharia Biomédica

IBILI - Instituto Biomédico de Investigação da Luz e Imagem

INOV- INESC Inovação

INESC-ID - Instituto de Engenharia de Sistemas e Computadores

INEGI - Instituto de Engenharia Mecânica e Gestão Industrial

TAGUSPARK – Parque de Ciência e Tecnologia

Mamografia de emissão de positrões

→ PET dedicado a mamografia

→ Requisitos **ClearPEM** :

→ Alta sensibilidade

→ Boa resolução espacial (1-2 mm FWHM)

→ Boa resolução temporal p/rejeição fundo (1-2 ns)

→ Exames mais curtos menos radiação dada ao paciente
(370 MBq)

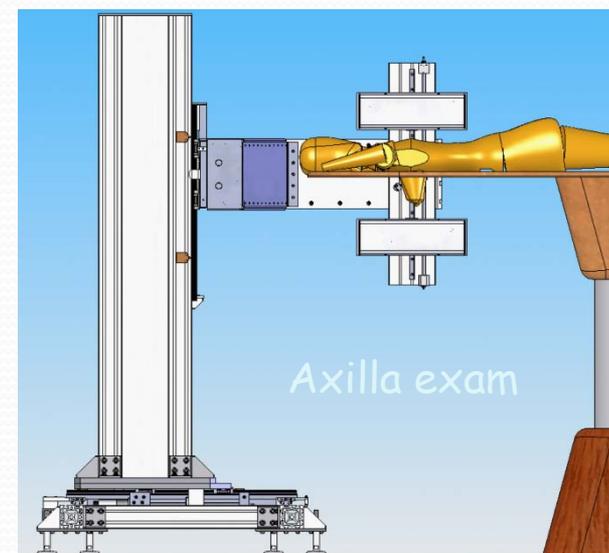
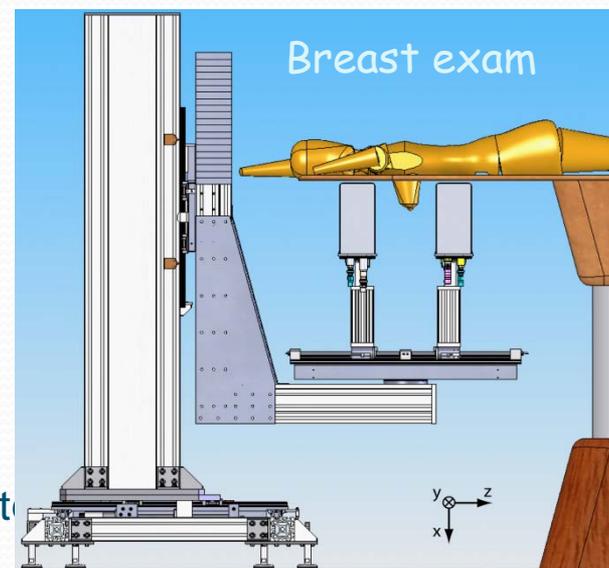
→ **Conceito do detector:**

→ Duas cabeças planas

→ Exame mama e axila

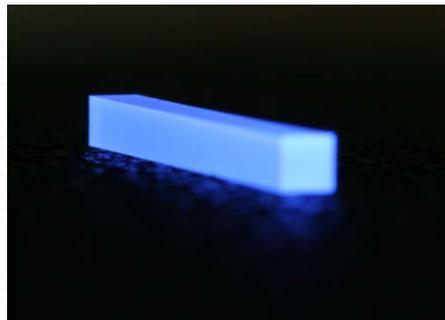
→ Exame c/paciente deitado

→ Distância ajustável das cabeças e rotação



Tecnologia usada no Detector

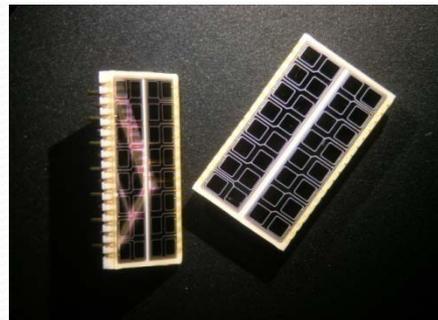
- Cristais 20 mm de LYSO:Ce
- Matriz de cristais de BaSO₄ reflector
- Fotodiodos de avalanche (APD)
- Duplo readout mode
- “Depth-of-interaction (DOI) measurement”



6144 cristais



Arrays com 32 cristais



384 APD arrays
(2 APD por cristal)



192 detector modules
(2 APD cada módulo)

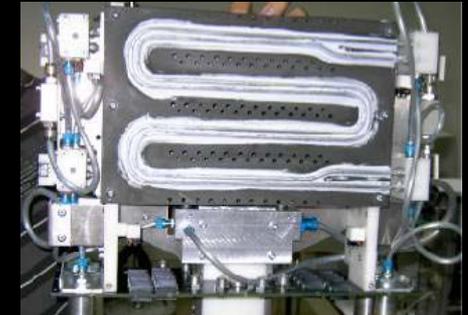
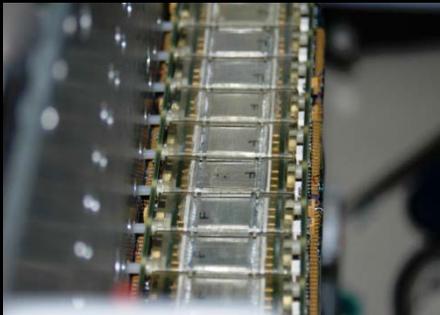
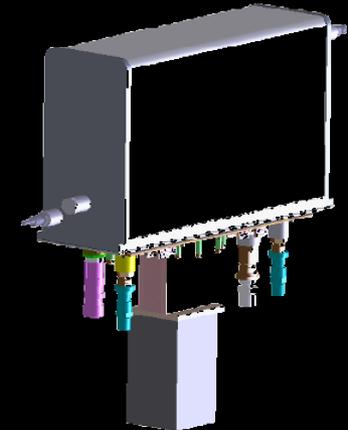
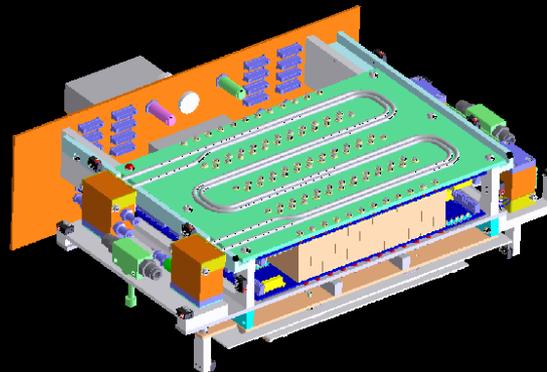
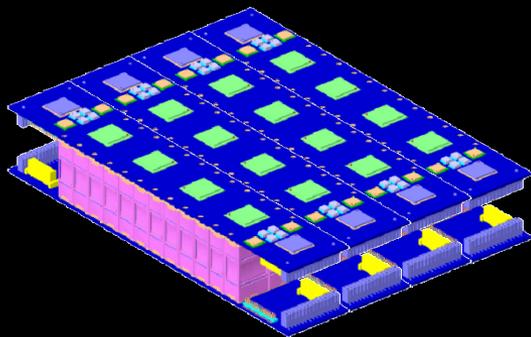
Cabeça do detector

Cada cabeça

- 4 supermodulos, 92 módulos
- 1 Bordo de serviço
- 2 pratos de arrefecimento

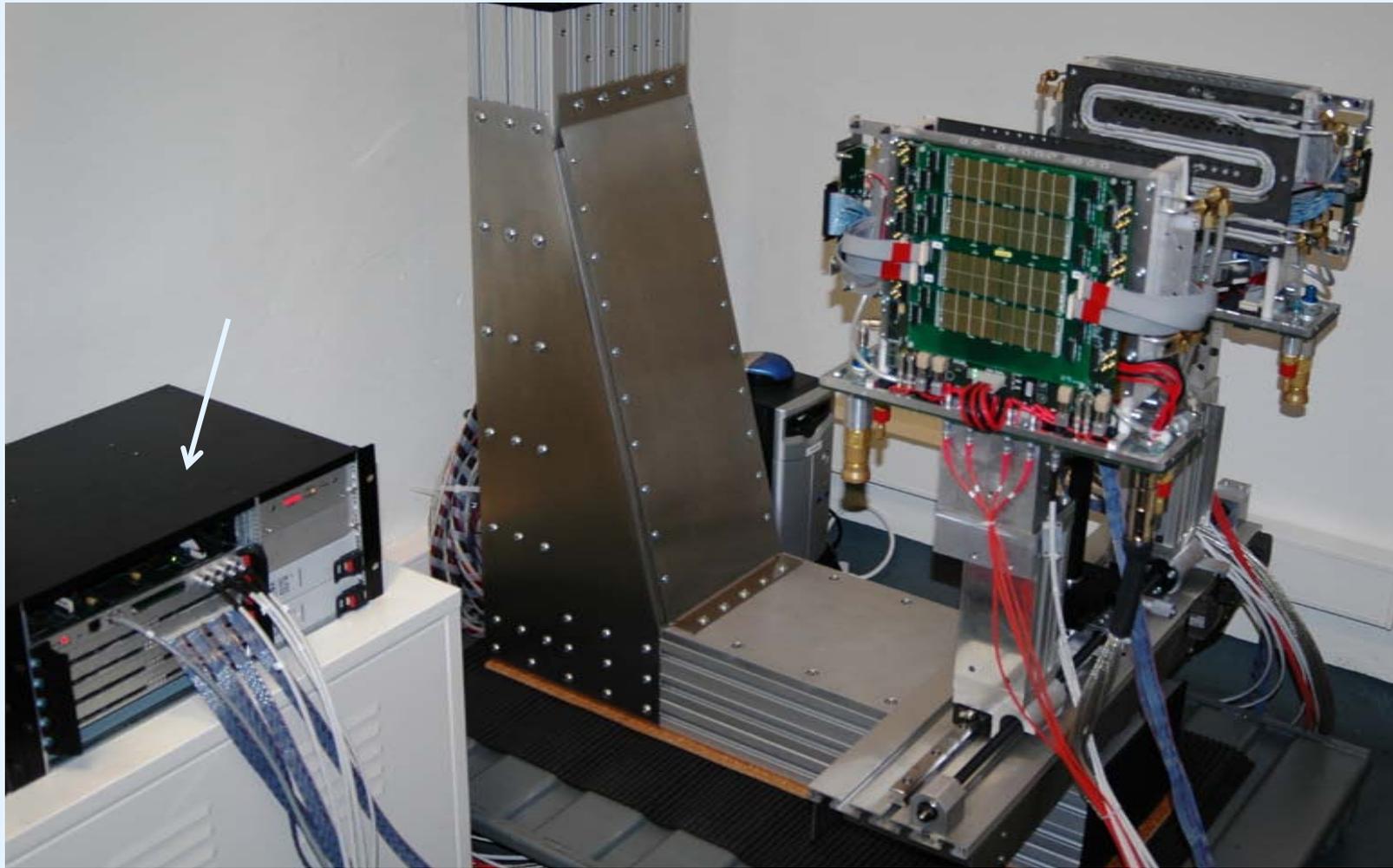
Cada Supermodulo:

- 24 grupos de módulos



12 288 electronic channels

Detector montado no robot



PET-Ultra-Sons

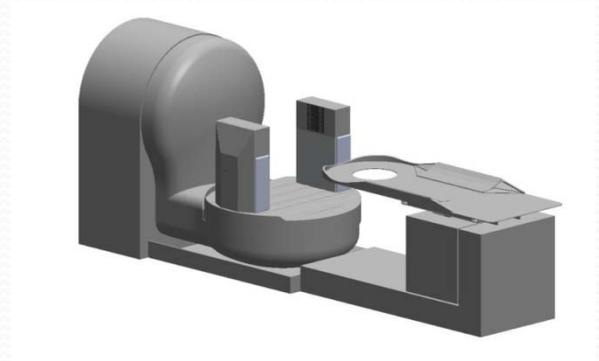
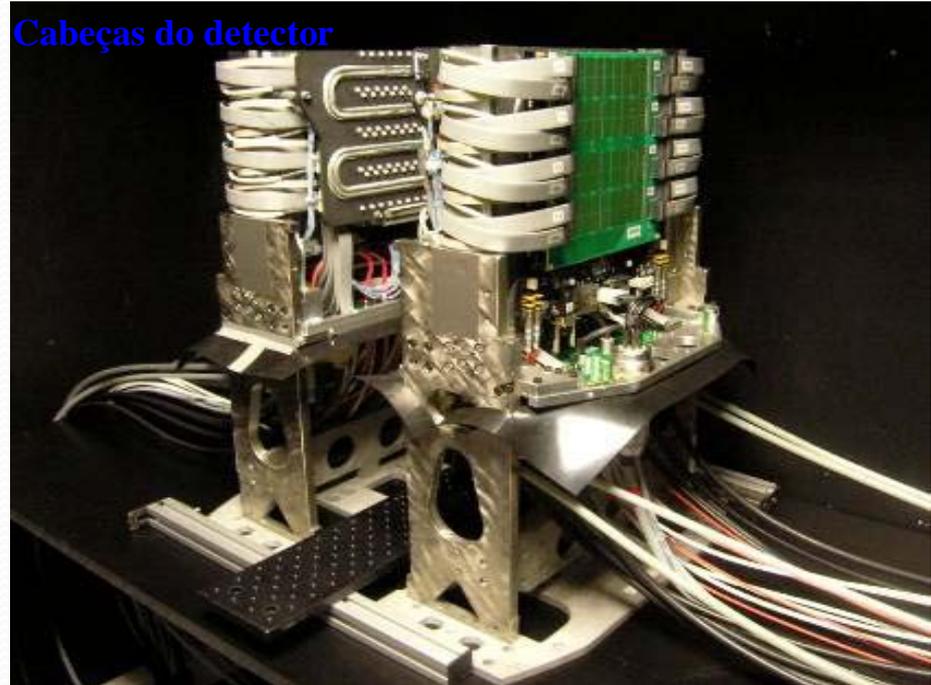
Baseado no ClearPEM

Permitirá melhor qualidade de imagem

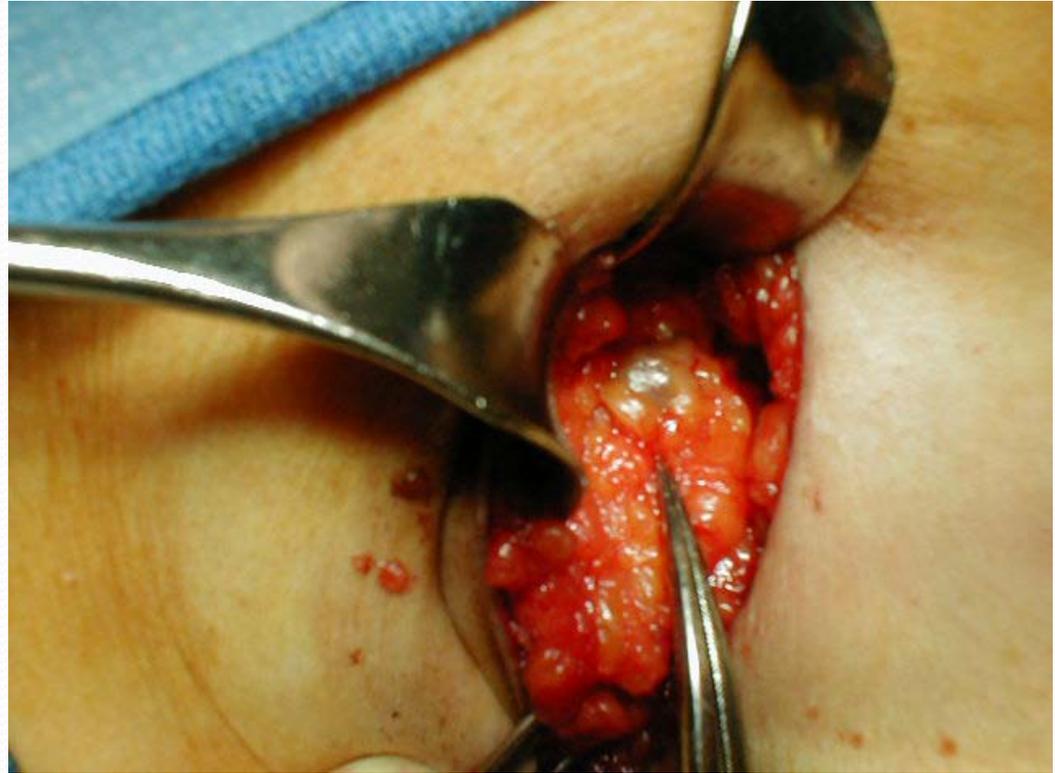
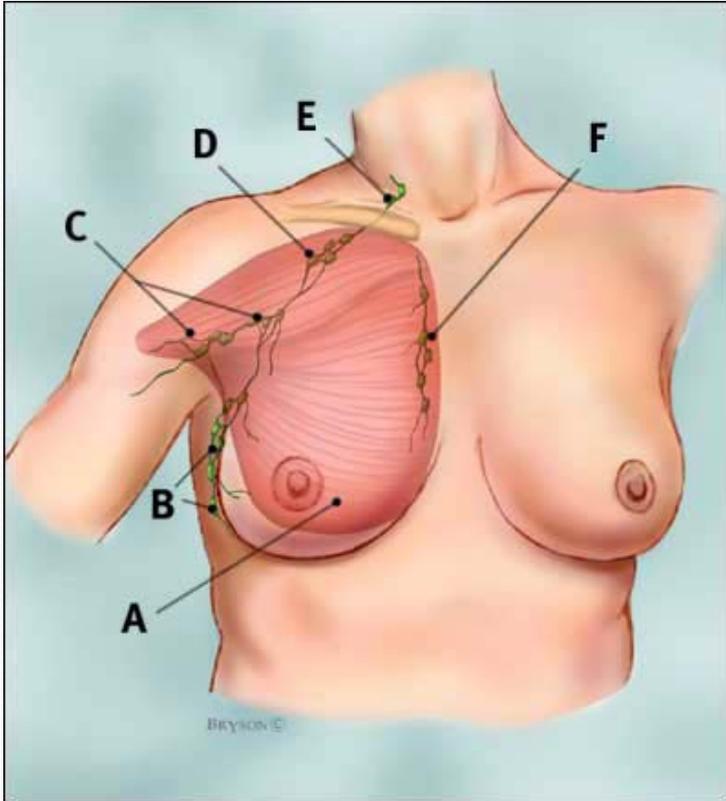
Visualização de tecidos moles

Não adiciona dose de radiação ao paciente

Cabeças do detector

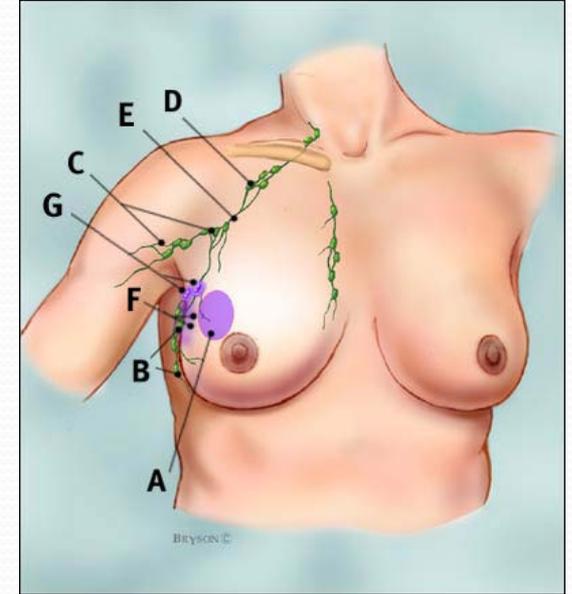
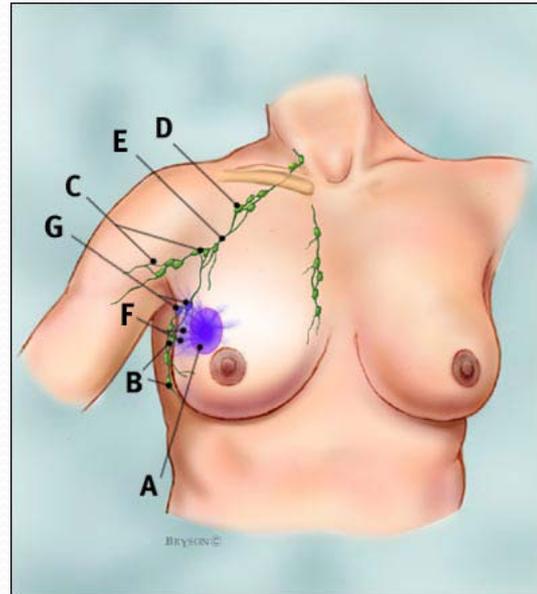
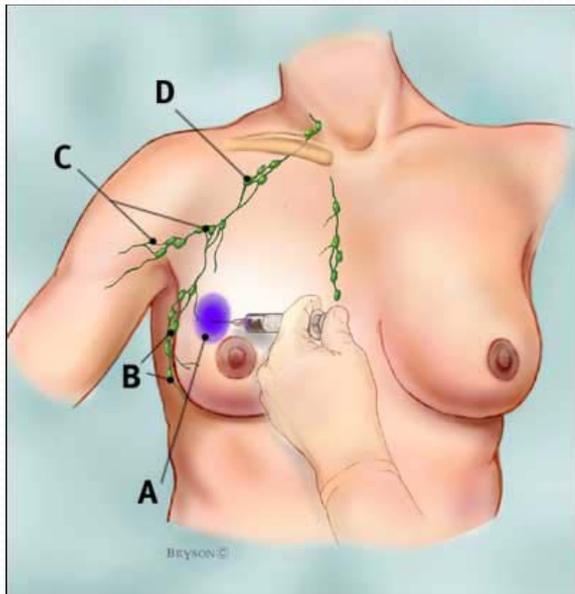


Tumor na mama



Remoção do nódulo sentinela

Identificação do nóculo sentinela

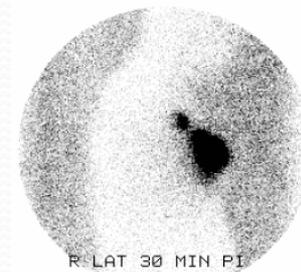
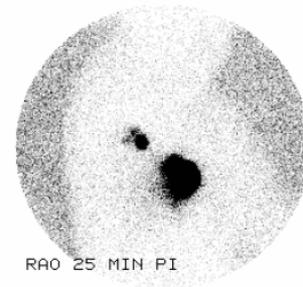
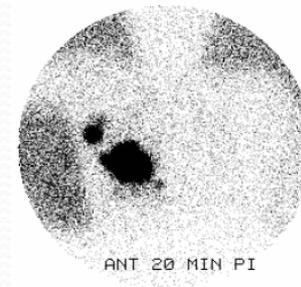


Injecção de um corante ou radioisótopo

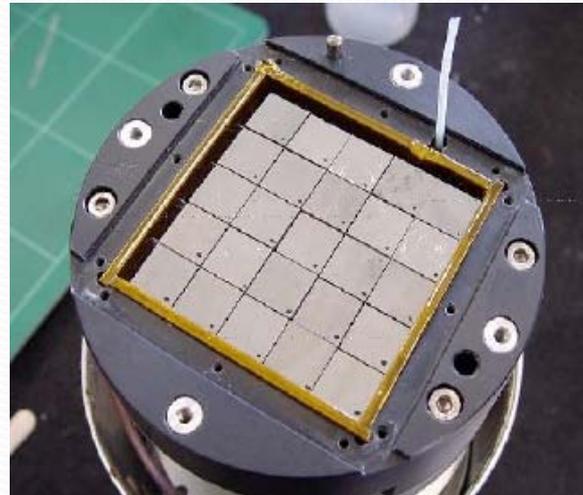
Cirurgia



Imagens pre-operativas da localização
do nódulo sentinela



Câmaras portáteis



MiniCam II

Images obtained with MINICAM II

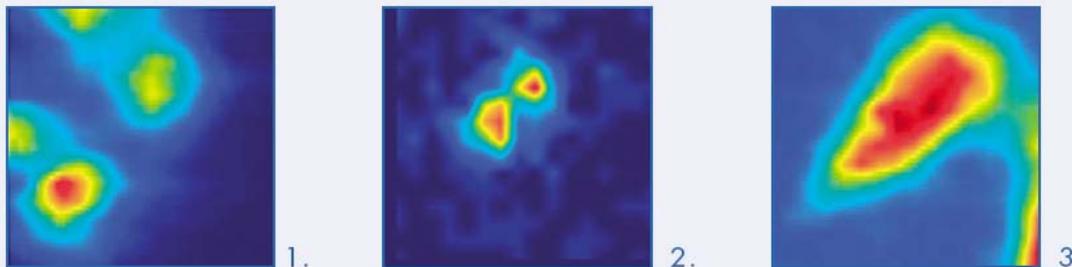
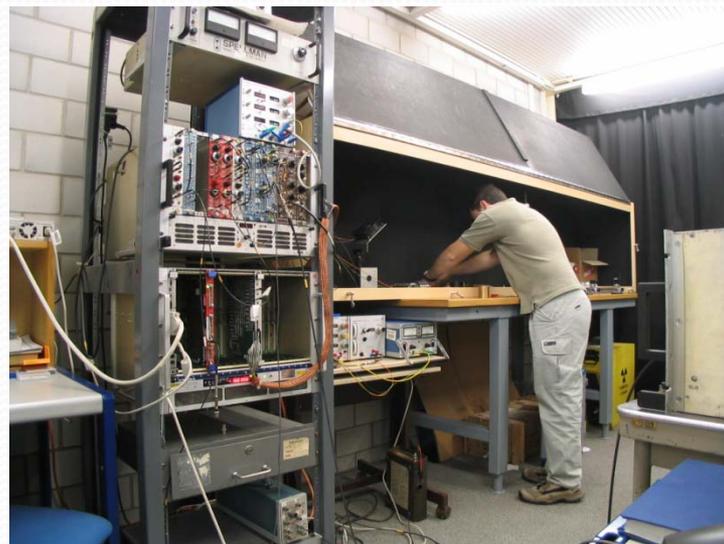
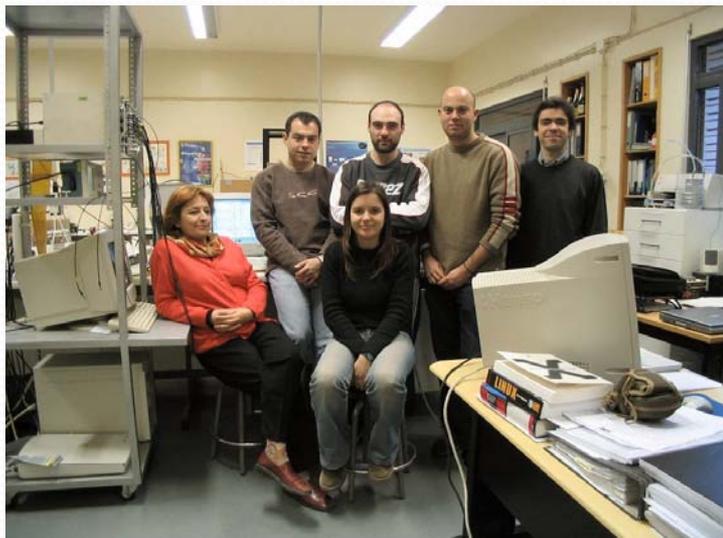


Image 1 : Injection spot acquisition 30 seconds

Image 2 : sentinel nodes ex-vivo 148kBq acquisition 60 seconds

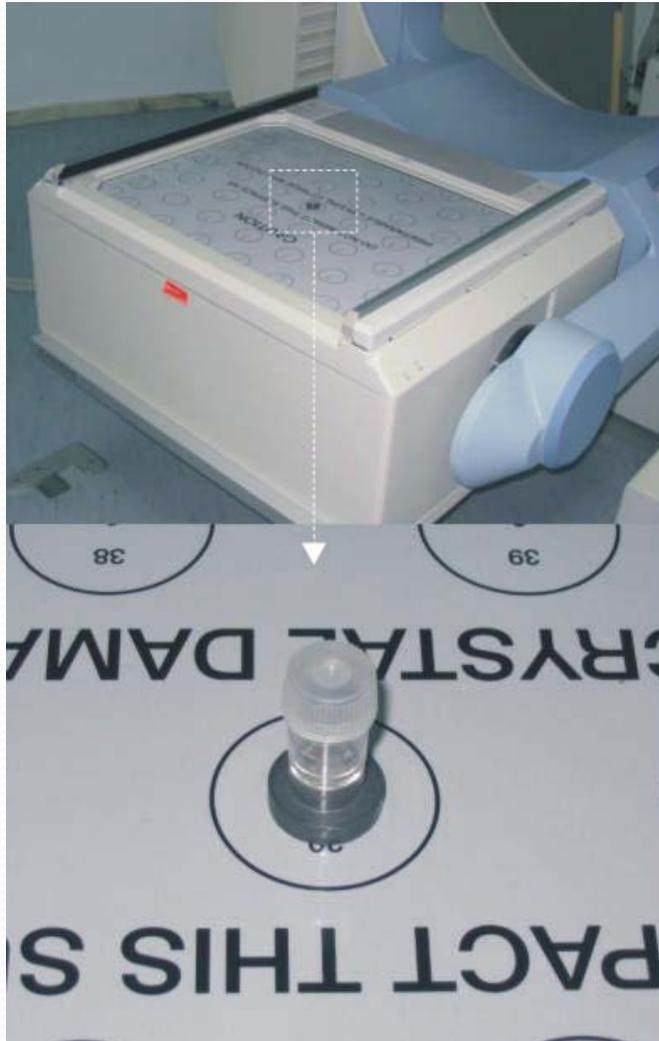
Image 3 : Thyroid left lobe acquisition 115 seconds

O Detector ISPA

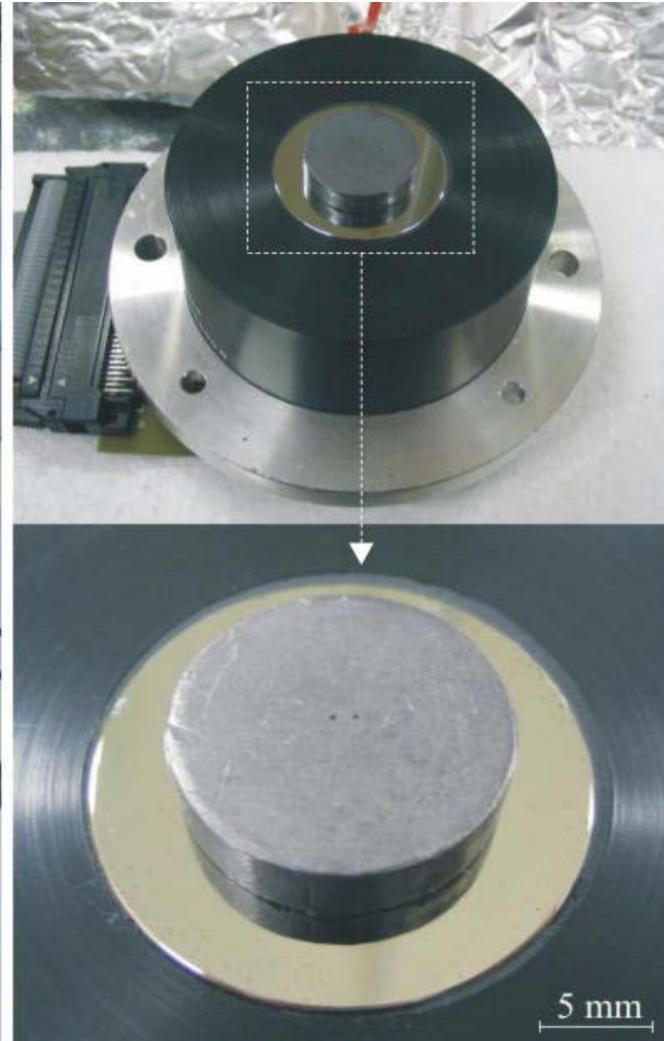


Avaliação

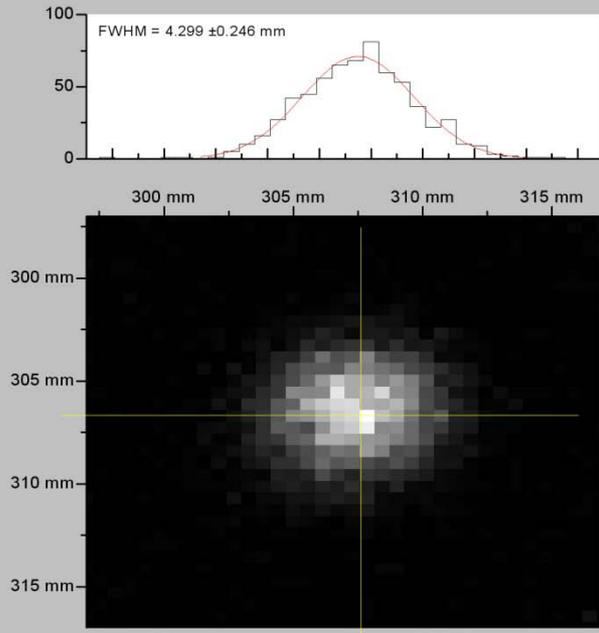
SPECT camera
140 keV point source



ISPA-tube
122 keV point source

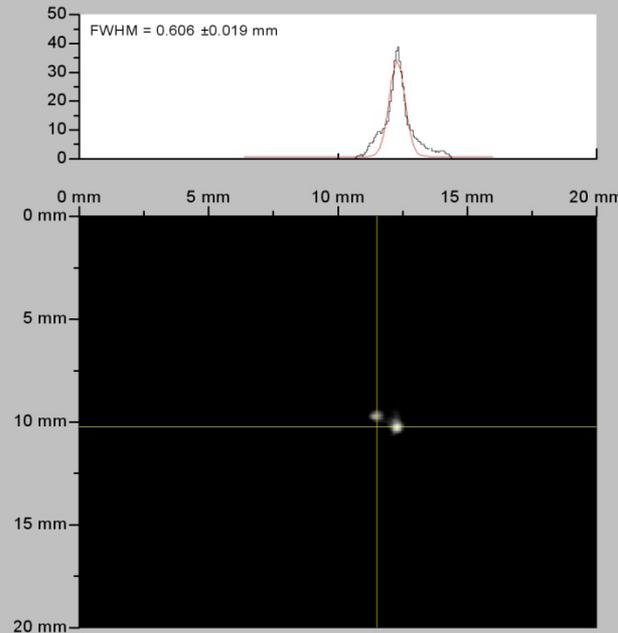
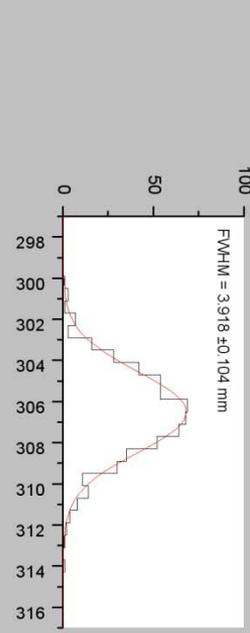


Avaliação da qualidade da imagem



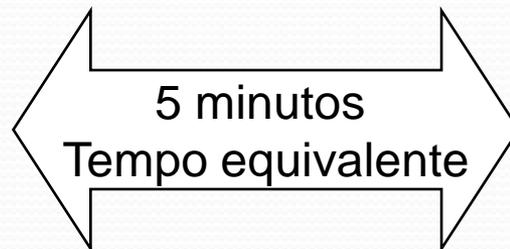
SPECT camera

14000 contagens
FWHM ~4.3 mm

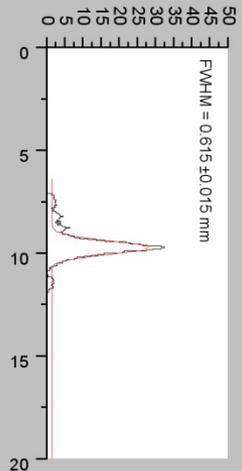


ISPA-tube

2800 contagens
FWHM ~0.6 mm



5 minutos
Tempo equivalente



Efeitos de uma irradiação aguda corpo inteiro

Dose (Gy)	Sintomas	Observações
0 - 0,25	Nenhum	Não existem efeitos clínicos relevantes
0,25 - 1	Nada ou algumas náuseas	Medula óssea danificada. diminuição de glóbulos vermelhos e brancos bem como de plaquetas. Nódulos linfáticos e baço danificados. Diminuição do número de linfócitos.
1 - 3	Náusea e anorexia intensa, mal estar geral, surgimento de infecções.	Os danos hematológicos são mais severos. A recuperação é possível mas não é segura.
3 - 6	Hemorragias, infecções, diarreia, epilação, esterilidade temporária.	As mortes começam a verificar-se para doses superiores a 3,5 Gy
mais que 6	Dano do sistema nervoso central. Incapacidades várias.	Morte provável 

Irradiação excessiva durante uma angioplastia coronária

1990

Indivíduo de 40 anos

120 min exposição RX



6 - 8 semanas



16 - 20 semanas



18 - 21 meses

Adult Effective Doses for Various Diagnostic Radiology Procedures

Examination	Average Effective Dose (mSv)	Values Reported in Literature (mSv)
Skull	0.1	0.03–0.22
Cervical spine	0.2	0.07–0.3
Thoracic spine	1.0	0.6–1.4
Lumbar spine	1.5	0.5–1.8
Posteroanterior and lateral study of chest	0.1	0.05–0.24
Posteroanterior study of chest	0.02	0.007–0.050
Mammography	0.4	0.10–0.60
Abdomen	0.7	0.04–1.1
Pelvis	0.6	0.2–1.2
Hip	0.7	0.18–2.71
Shoulder	0.01	...
Knee	0.005	...
Other extremities	0.001	0.0002–0.1
Dual x-ray absorptiometry (without CT)	0.001	0.001–0.035
Dual x-ray absorptiometry (with CT)	0.04	0.003–0.06
Intravenous urography	3	0.7–3.7
Upper gastrointestinal series	6*	1.5–12
Small-bowel series	5	3.0–7.8
Barium enema	8*	2.0–18.0
Endoscopic retrograde cholangiopancreatography	4.0	...

* Includes fluoroscopy.

Radiology: Volume 248: Number 1—July 2008

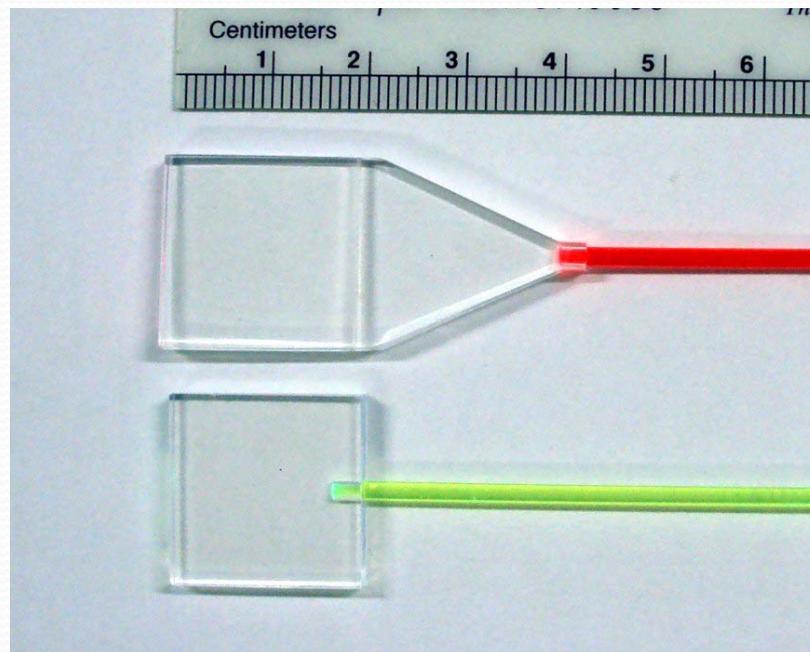
Adult Effective Doses for Various CT Procedures

Examination	Average Effective Dose (mSv)	Values Reported in Literature (mSv)
Head	2	0.9–4.0
Neck	3	...
Chest	7	4.0–18.0
Chest for pulmonary embolism	15	13–40
Abdomen	8	3.5–25
Pelvis	6	3.3–10
Three-phase liver study	15	...
Spine	6	1.5–10
Coronary angiography	16	5.0–32
Calcium scoring	3	1.0–12
Virtual colonoscopy	10	4.0–13.2

Radiology: Volume 248: Number 1—July 2008

Dose média anual devida a radiação de fundo ~ 2.5 – 3 mSv

Desenvolvimento de dispositivos de monitorização pessoal



Agradecimentos

João Varela (CERN)

Adérito Chaves (IPO)

João Seco (Harvard)

Marta Dias (FCUL)

Patrick Sousa e Conceição Abreu (LIP)

Florbela Rego (LIP)

FIM