Radiotherapy

Marta Anguiano Millán

Departamento de Física Atómica, Molecular y Nuclear

Facultad de Ciencias. Universidad de Granada

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Brachytherapy

Radioisotopes in contact with the tumor

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Radioisotopes in contact with the tumor

External Radiotherapy

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- γ-ray equipment
- LINACS
- Applications

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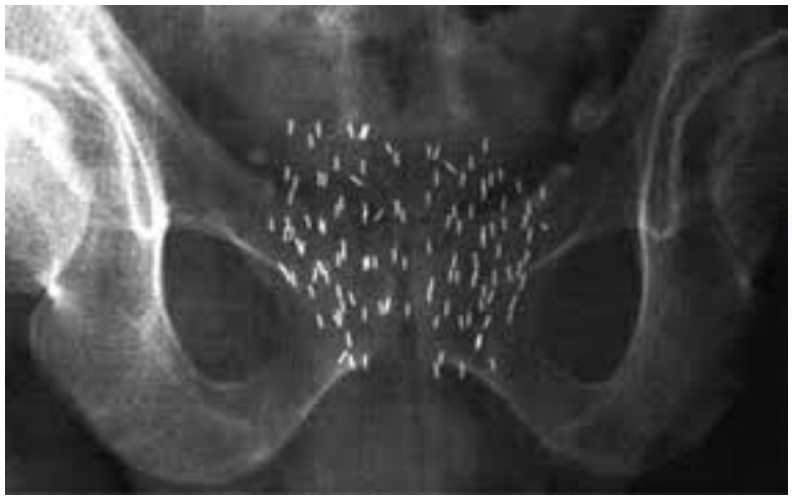
- High doses (40-70 Gy) in delimited areas, with curative purposes.
- Different sources and energies, depending on
  1. Type of tumour.
  2. Location of tumour.
  3. Depth of tumor.

Brachytheraphy

1. Radiactive sources of differences forms and isotopes.
2. Typical forms:
   - Seeds, ribbons, wires, needles, capsules, balloons or tubes.
3. Isotopes:
   - ^{137}Cs, ^{192}Ir, ^{131}I, ^{125}I, ^{60}Co
4. Remote applicators.



Radioisotopes in brachytherapy

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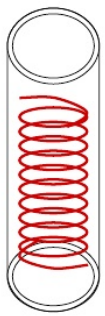
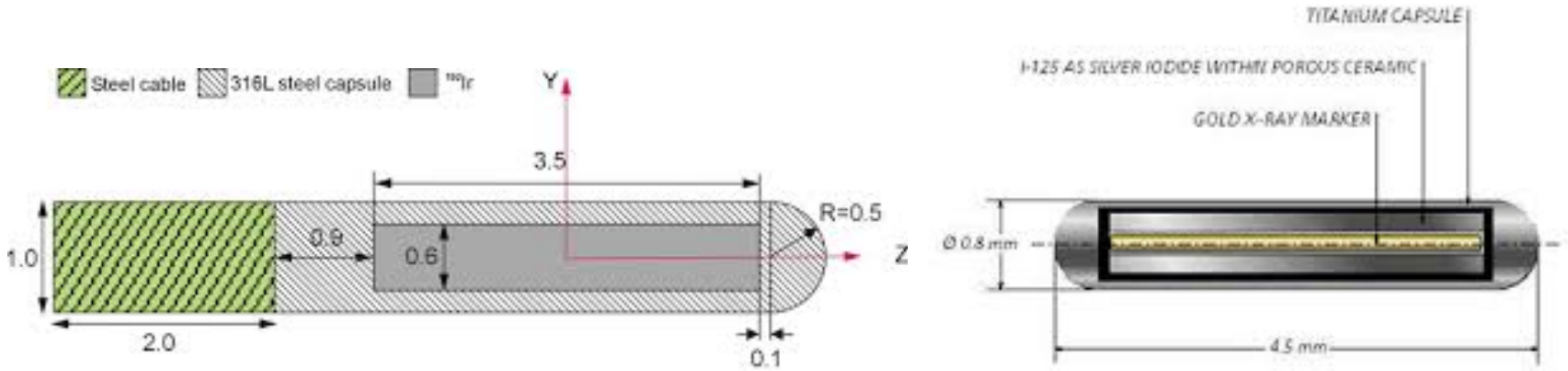
- Intracavitary applications:
  1. Using applicators, ^{137}Cs source in the cavity .
  2. Gynecology, esophagus.

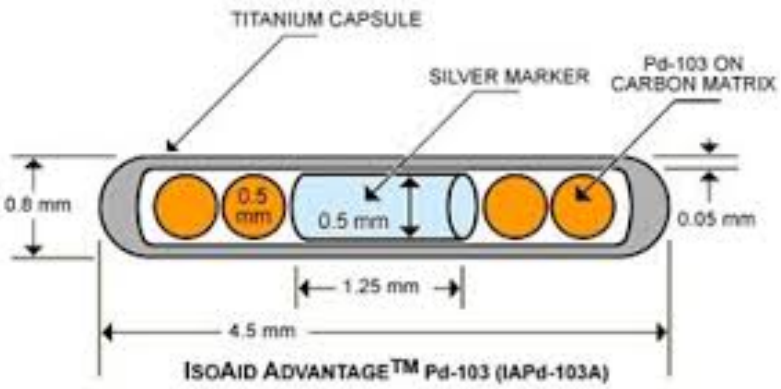


^{192} Ir wire(coil form)

Radioisotopes in brachytherapy



HDR ^{192}Ir model MBDCA-WG source



Radioisotopes in brachytherapy

- Specific applications:
  1. Eyes tumours: plaques of ^{125}I, applied directly on the tumour. 100 Gy, between 5 and 12 days.
  2. Intravascular brachytherapy: Coronary diseases. Lessions around mm. Radionuclide emitting low energy photons: ^{125}I and ^{103}Pd.

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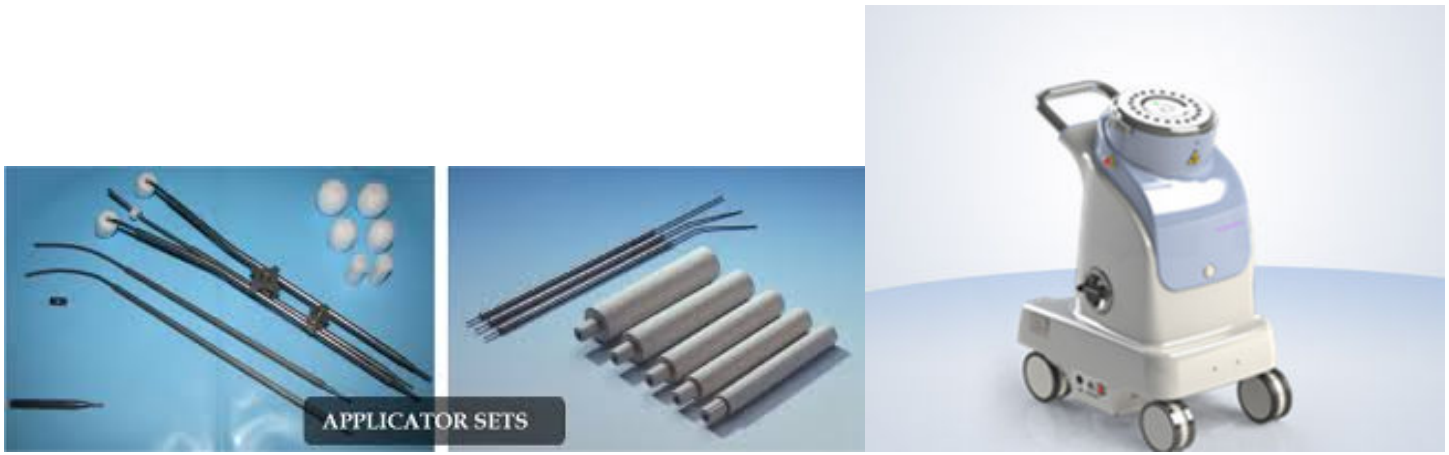

Figure: Applicators (left). Automatic equipment for brachytherapy (right).

External Radiotherapy (ER)

Types of equipment in ER

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  2. Simulation of the treatment.
  3. Anatomical data collection of the patient.
  4. Placement of the target volume to radiate and critical organs.
  5. Calculation of the dose.
  6. Elaboration of individual protections.
  7. Positioning of the beams.
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- **Types of equipment**: X-ray equipment, γ-ray equipment, LINACS,..

External Radiotherapy (ER)

Figure: X-ray equipment (left), Co-60 (right) and LINAC (down)

External Radiotherapy (ER)

X-ray emitting equipment

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- **Filters** (Al or Cu) are used to eliminate photons of lower energies, that are not useful for the treatment.

X-ray equipment

- Usually, for contact therapy (10-50 kV):
  1. Very short distance of treatment (1-4 cm).
  2. Beam sections very small (about cm^2).
  3. Very high dose rates $\approx$ 400-700 cGy/min).
  4. For superficial tumours $\approx$ 3 mm depth.

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- **Problems**:
  1. Energy limitation of the beam.
  2. Important biological effects increasing the dose.
  3. Difficulty to radiate tissues with different densities $\rightarrow$ problems to administrate a homogeneus dose.
  4. LINACS.

X-ray equipment

Figure: A specific X-ray treatment

External Radiotherapy (ER)

γ ray equipment

External Radiotherapy (ER)

γ ray equipment

- Co-60 equipment (before, even of Cs-137).

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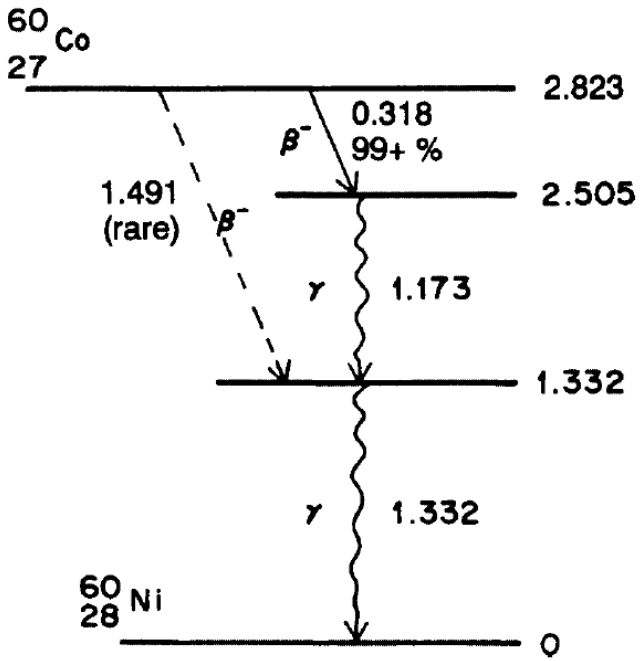

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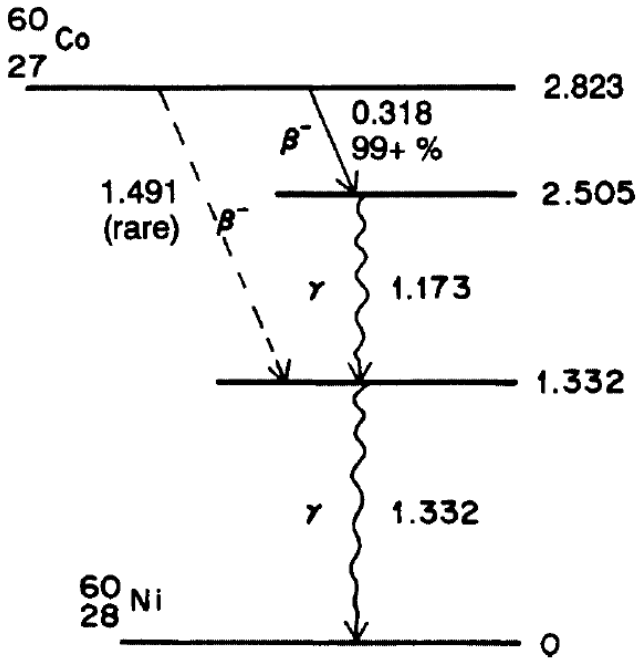

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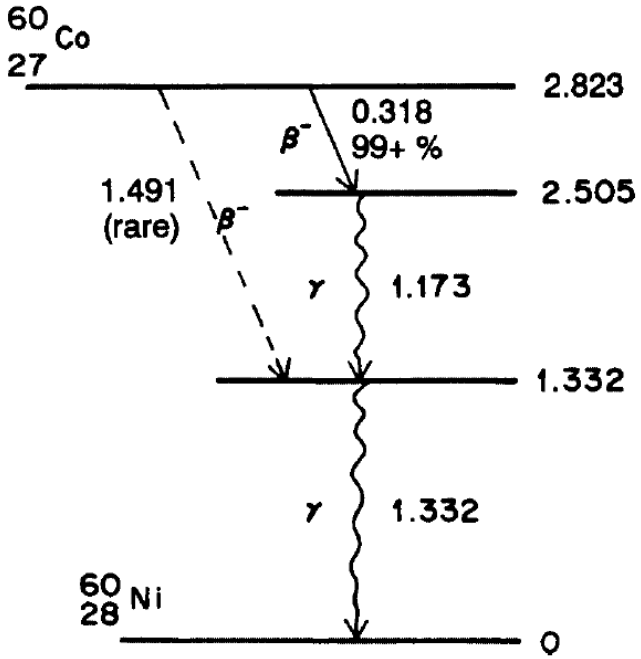

- First design (1951). Security improvements (shielding).
- Decommisioning in favour of LINACS in most of the Radiotherapic Centers.

External Radiotherapy (ER)

γ ray equipment

The different parts are:

1. Arm, which rotates around a horizontal axis. It holds the head, containing the radioactive source, an obturation device and a beam collimator system.
2. Fix part of the equipment and the treatment table.
3. Console to manage the equipment, out of the room.

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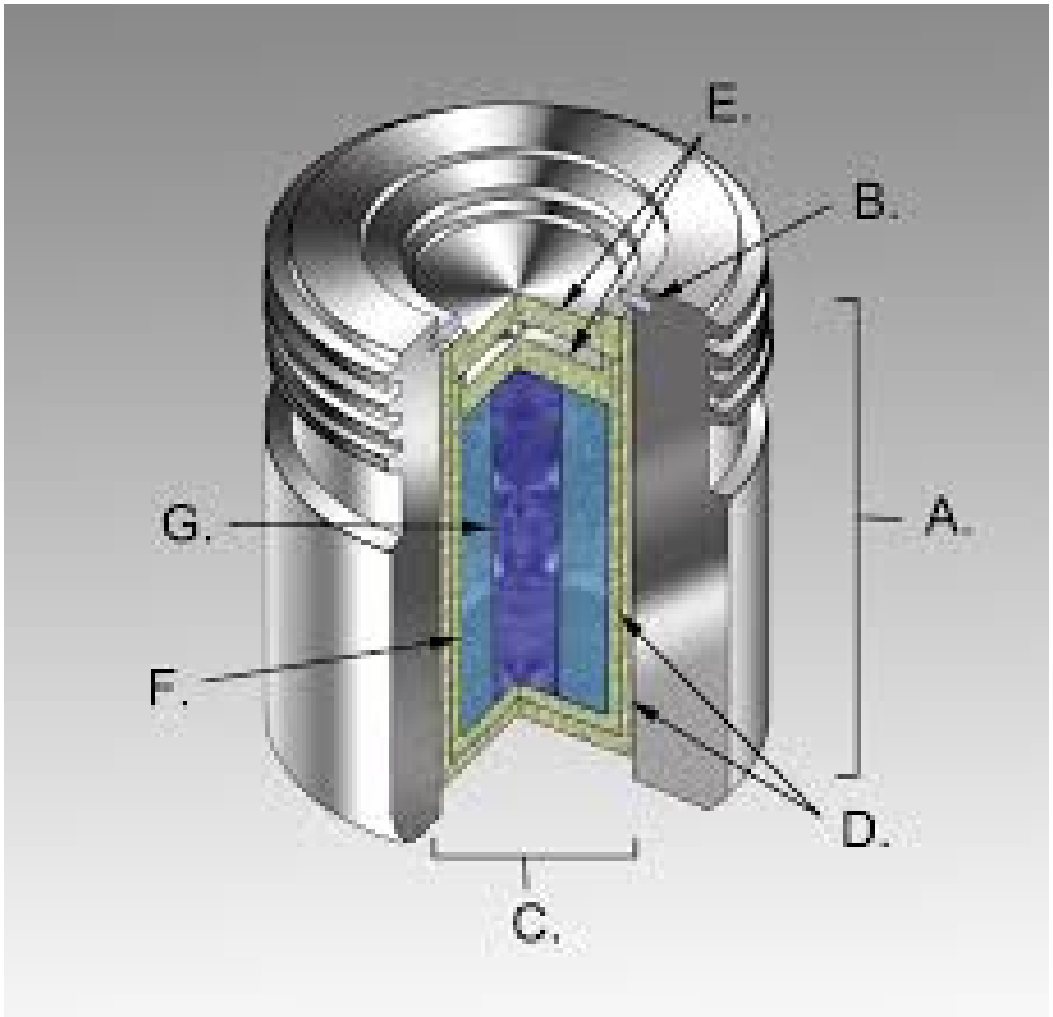
- The goal of the head is to put the source in a secure location to positioning the patient and to radiate with the source during the required time.
- The source, in the form of solid cylinder, discs or pellets, is contained inside a stainless steel capsule and sealed by welding. The capsule is placed into another steel capsule, which is again sealed by welding.

External Radiotherapy (ER)

γ ray equipment



Radioterapia externa (RE)

γ ray equipment

- ^{60}Co decays β^-. Electrons are slow down by the stainless steel capsule. 1.17 and 1.33 MeV photons are used for treatment. $T = 5.27$ y $\rightarrow$ Activity decreases 1% per month.

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- Isocentric setup

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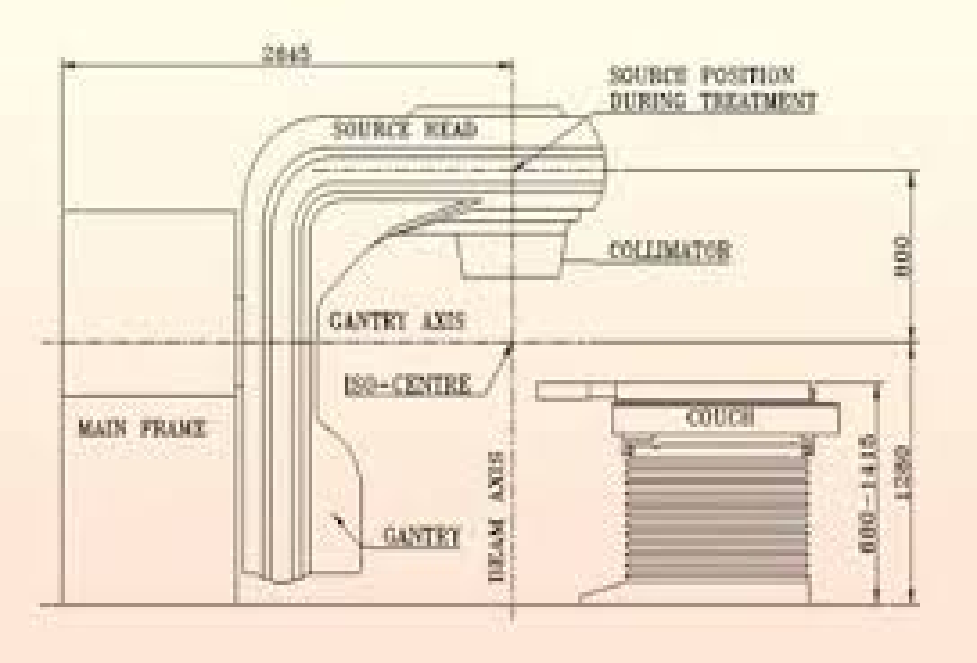
γ ray equipment



Main radiological risks:

1. Wrong management of the source and leak radiation (problems between source and head).
2. Failure of the clock indicating the irradiation time (redundant system), locking of the room door during the treatment and blockage of the source.

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Linear accelerators (LINACS)

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  1. Drive stand: klystron or magnetron, RF waveguide , circulator and cooling water system.
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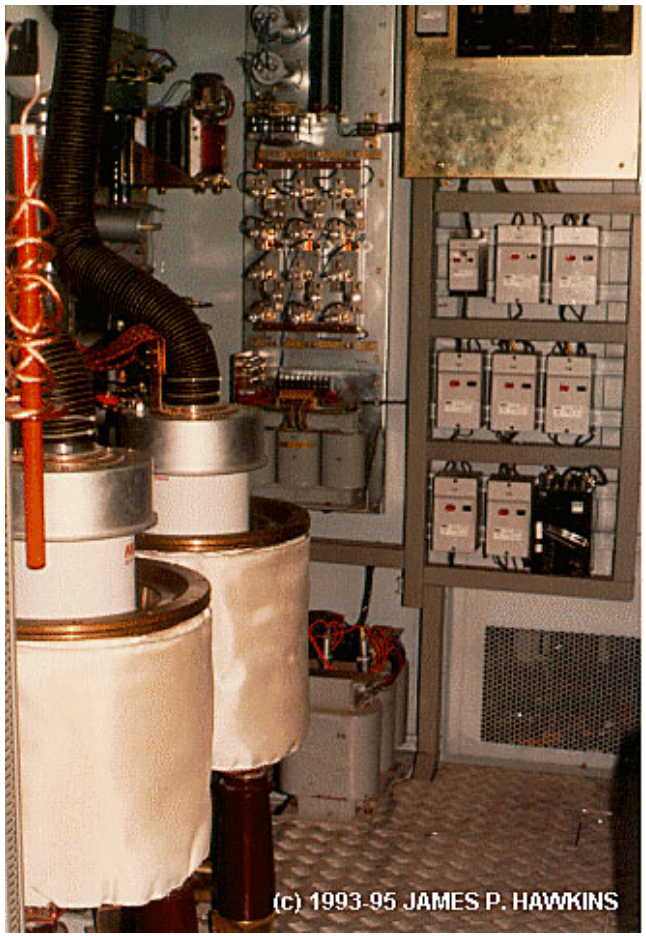
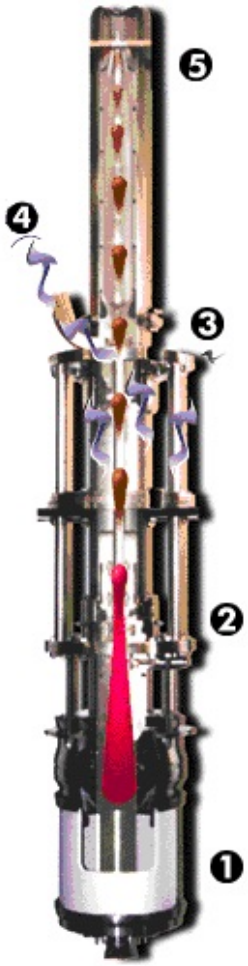
(LINACS: The modulator cabinet)

- It is the noisiest part of the Linac. Contains:
  1. Fan Control, cooling the power distribution system.
  2. Auxiliary power distribution system, containing the emergency off button.
  3. Primary power distribution system.



Linear accelerators (LINACS: The klystron)



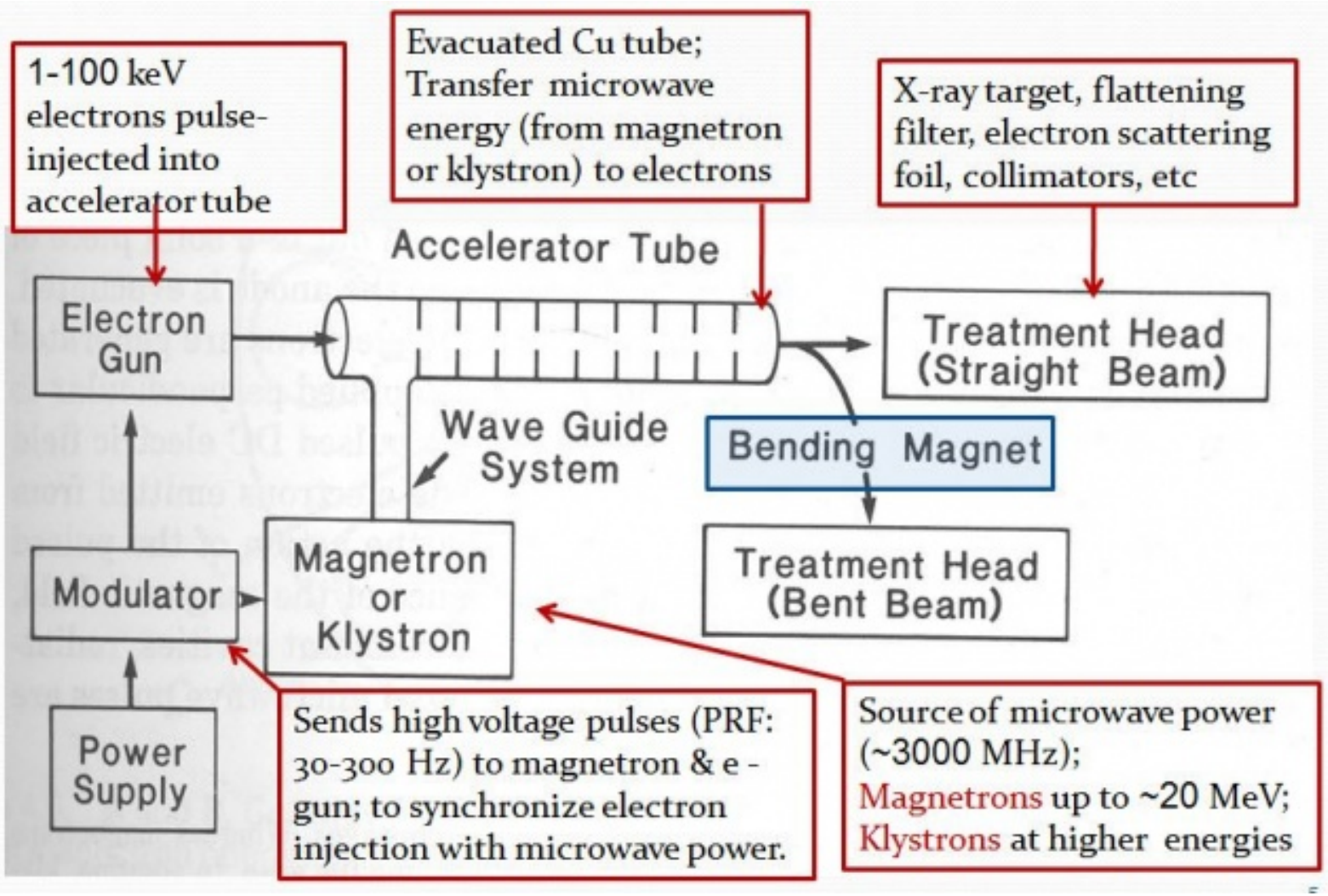
1. Flow of electrons produced by a thermionic cathode.
2. Bunching cavities regulate the speed of the electrons $\rightarrow$ they arrive in bunches at the output cavity.
3. Bunches of electrons excite microwaves in the output cavity of the klystron. Kinetic energy of the electrons, converted to potential energy, amplifying the field.
4. The microwaves flow into the waveguide, transporting them to the accelerator.
5. Spent electron beam is stopped.

LINACS

- **Working mode**:
  1. Electrons gun (cathode) generates electrons that pass to the aceleration tube in *bunches* produced by pulses coming from the modulator.
  2. The modulator controls the microwaves emission by the klystron.
  3. The microwaves, that produces the acceleration of electrons, are guided by the waveguide to the acceleration tube. Even the electrons coming from the gun electrons, synchronized with them.
  4. After the acceleration, electrons arrive to the Bending Magnet.
  5. The beam for treatment is ready. Two possibilities:
     - Electron mode: Using directly the electrons (after doing more extense and homogeneus the beam).
     - Photon mode: The beam strikes a wolframium target, obtaining X-rays of high energy.

External Radiotheraphy(ER)

LINACS



LINACS

- **Radiological risks**:
  1. Fail in the interceptation of the beam.
  2. Fail in the monitorization of the dose.
  3. Beam not uniform.
  4. Fail in choosing the modality (electrons or photons).
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  6. Radiation leak from the head.
  7. Production of neutrons (LINACS 10 MeV).

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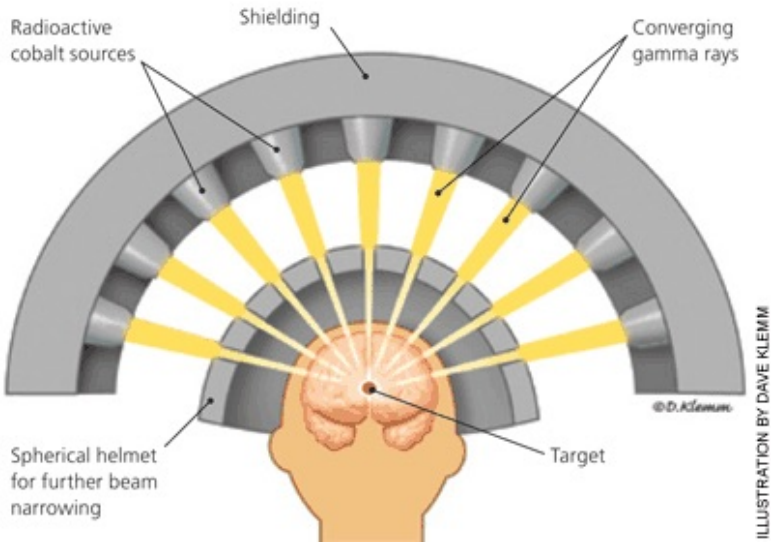
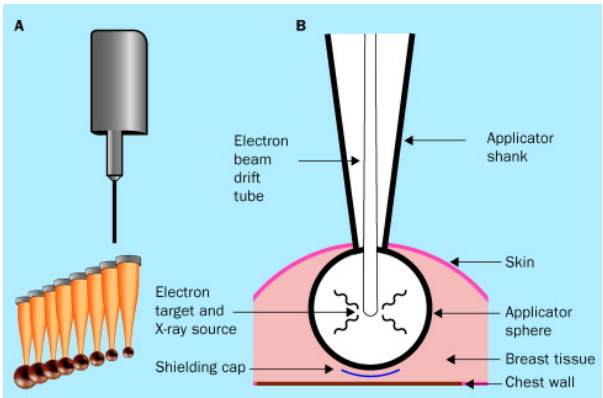
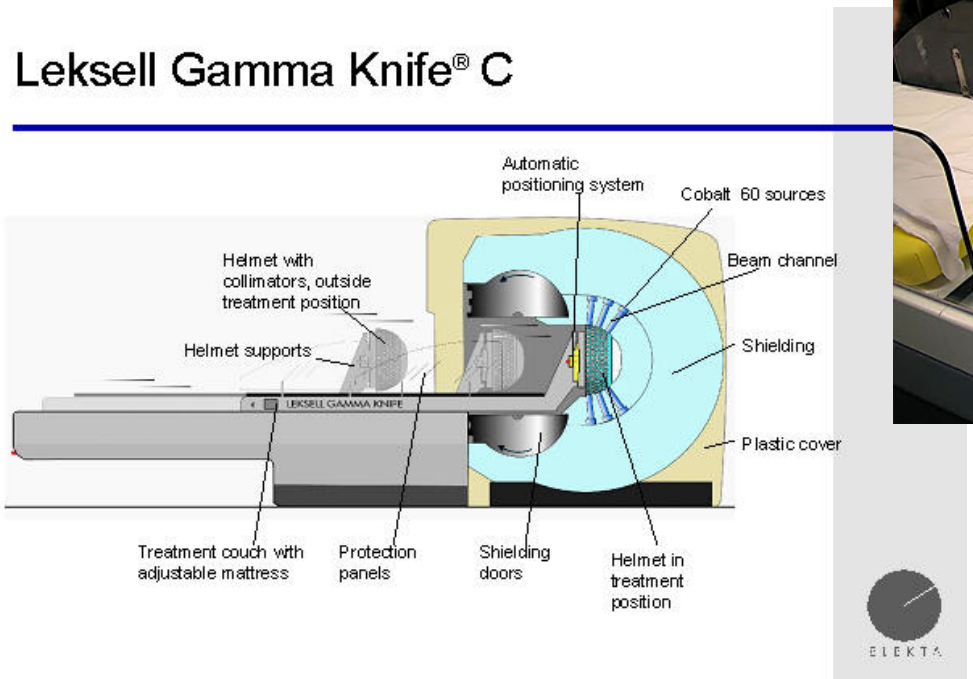
- **Applications**:
  1. IMRT: Photons beams with modulated intensity $\rightarrow$ Variable flow $\rightarrow$ protection of the healthy tissue.
  2. Stereotactic radiosurgery: very narrow beams to irradiate intracraneal structures. 20 Gy.
  3. Intraoperative radiotheraphy: Electrons applicators.

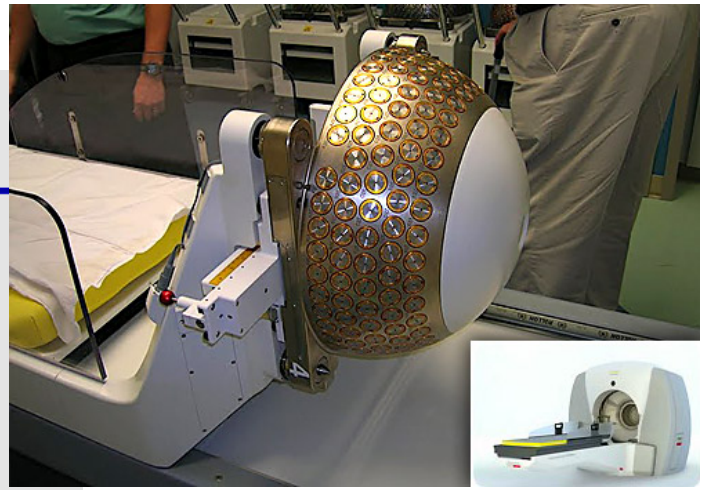
LINACS


Radioactive cobalt sources
Shielding
Converging gamma rays
Spherical helmet for further beam narrowing
Target
ILLUSTRATION BY DAVE KLEMM


A
B
Electron beam drift tube
Applicator shank
Skin
Electron target and X-ray source
Applicator sphere
Shielding cap
Breast tissue
Chest wall

Gamma Knife


Leksell Gamma Knife® C
Automatic positioning system
Cobalt 60 sources
Beam channel
Helmet with collimators, outside treatment position
Helmet supports
Shielding
Plastic cover
Treatment couch with adjustable mattress
Protection panels
Shielding doors
Helmet in treatment position
ELEKTA



External Radiotheraphy (ER)

Hadrontherapy

Today: **Particle therapy is applied in purly clinical centers, e.g.**

- Francis H. Burr PTC, Boston; MD Anderson, Houston, University of Florida
- HIT, Heidelberg; Rhön Klinikum AG, Marburg; CNAO, Milano; RPTC, Munich
- HIBMC, Hyogo; NCC, Kashiwa; Shizuoka; PMRC, Tsukuba

1996/97 **First tumor conform radiation with scanned beam – protons at PSI (Villigen, Switzerland), ^{12}C-Ions at GSI (Darmstadt, Germany)**

1993 **First center for ^{12}C-ions therapy in Chiba (Japan)**

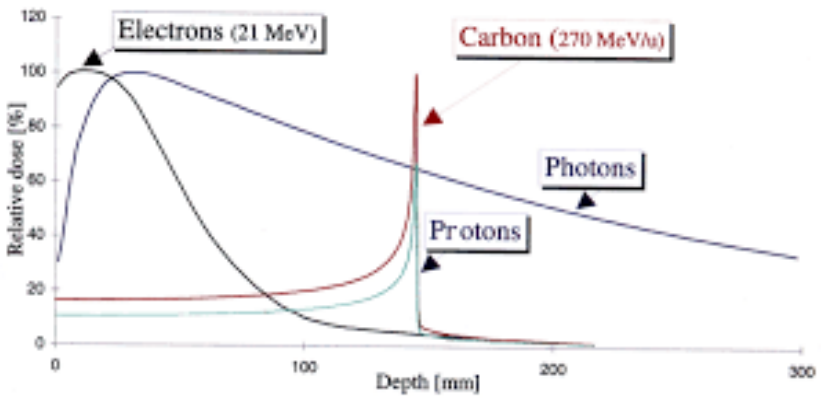
1990 **First center for proton therapy in Loma Linda (USA)**

1975 **LBL irradiated for the first time with ions (helium, carbon, neon)**

1954 **LBL (Lawrence Berkeley Laboratory, USA) started radiotherapy for deep located tumors with protons**

1946 **R.R. Wilson proposed charged particles (p, ions) for applications in radiotherapy**

Hadrontherapy



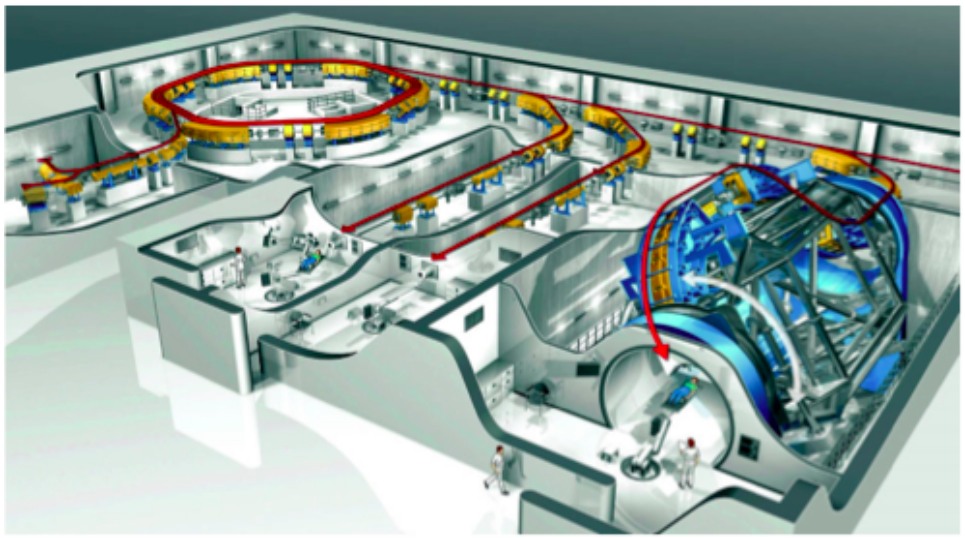
- The Bragg peak is an advantage, but it is a problem too.
- It is needed to modulate the ions velocity $\rightarrow$ positioning of the peak at a variable depth to irradiate the full volume.

- Very complex and a high cost installations, based on cyclotrons or synchrotrons.
- There is the possibility to produce neutron beams by p-Be reactions

External Radiotheraphy (ER)

Hadrontherapy

- Heidelberg Ion-beam Therapy center (HIT). From 2009.
- GSI synchrotron: Energy modulation, beam scanning and PET on-line.
- Light ions can activate the β^+ decay in some elements $\rightarrow$ Dose estimation at real time.
- More than 600 patients. Very good results in some brain tumors.



Hadrontherapy: Installations in the world

	Proton therapy	Particle therapy
Project development	1	6
Under construction	4	3
Running	3	1
Total	8	10