Recent developments in the applications of Cyclotrons in cancer therapy

HPPA5

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Ion Beam Applications sa

Belgium

We protect, enhance and save lives.

Organization of presentation

- Why this presentation?
- Systemic cancer therapy based on RI
- Brachytherapy
- Proton therapy
- Carbon therapy

Systemic cancer therapy with RI

- When the caner is not limited to a well defined, primary tumor, systemic therapies must be used
- One well known solution is to graft a therapeutic (toxic) RI on a cancer cell seeking molecule
- Alpha or Auger electron emitting RI are often preferred
- The main problem is the dosimetry and treatment planning: how to assess correctly the radiation dose received by the tumor, and by the healthy organs at risk
- Pairs of diagnostic/ therapy RI are useful in this respect

“Traditional” nuclear medicine

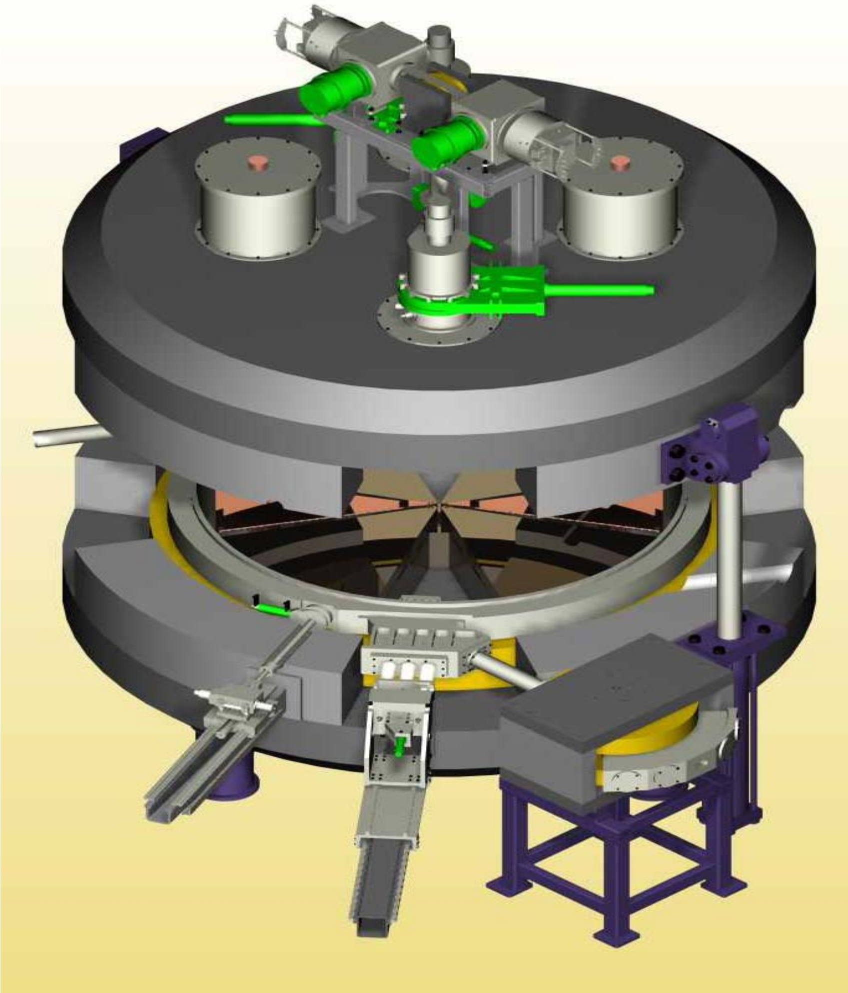
- Technetium 99m, the most commonly used RI in NM is produced in reactors
- But a number of other, very important NM RI are produces with cyclotrons of higher energy energy
  - Tl-201 (Cardiac studies)
  - I-123 (Thyroid, Various examinations)
- For these longer life isotopes, international distribution is possible
- Large, very powerful cyclotrons are owned by by radiopharmaceutical companies

Pairs of radioisotopes

Diagnostic (PET) RI	Therapy RI
^{124}I	^{131}I
^{86}Y	^{90}Y
^{64}Cu	^{67}Cu
Etc!	

New high energy isotope research machine

- **Cyclone 70 for Arronax (Nantes, France)**
  - Proton 35-70 MeV 750 µA
  - Deuterons 17-25 MeV, 50 µA
  - Alpha 70 MeV (fixed) 35 µA
  - HH+ 35 MeV(fixed) 50 µA
- **Main research goals**
  - 211At, alpha emitters
  - 67Cu, 177Lu, beta emitters
  - Pulsed alpha (research)

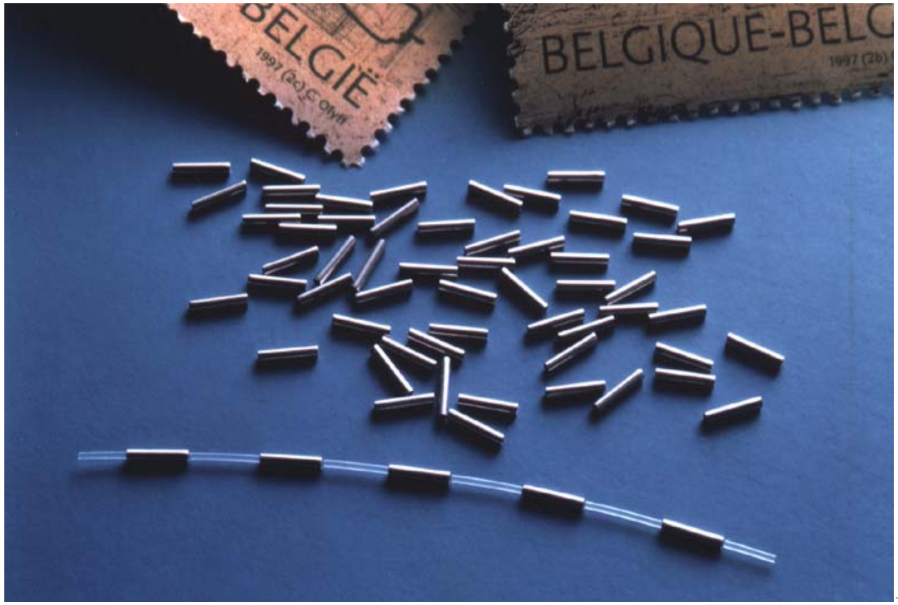


The Nantes cyclotron in April 07

Brachytherapy

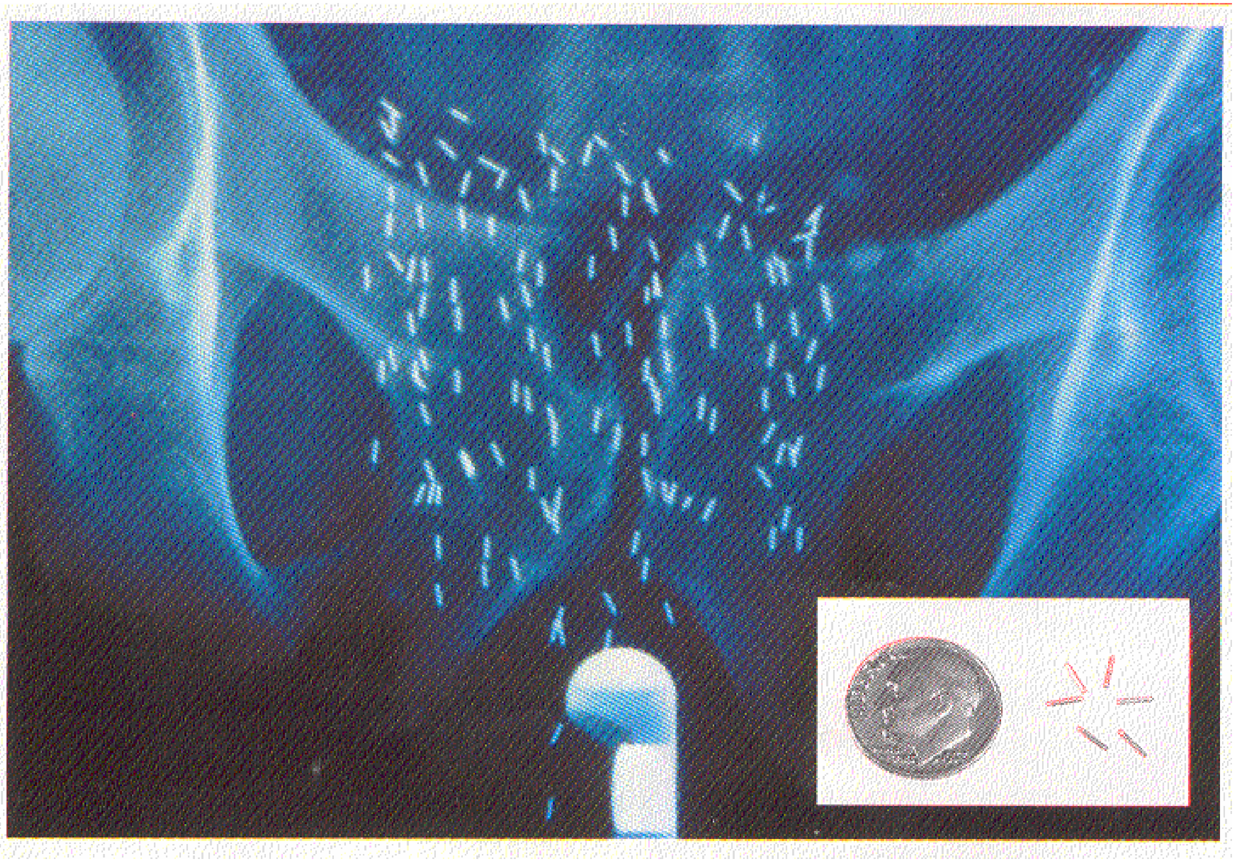
Local Eradication of a Tumor
by Radioactive Implants

Theragenics



IBt

Prostate Brachytherapy



Pd-103 vs. I-125

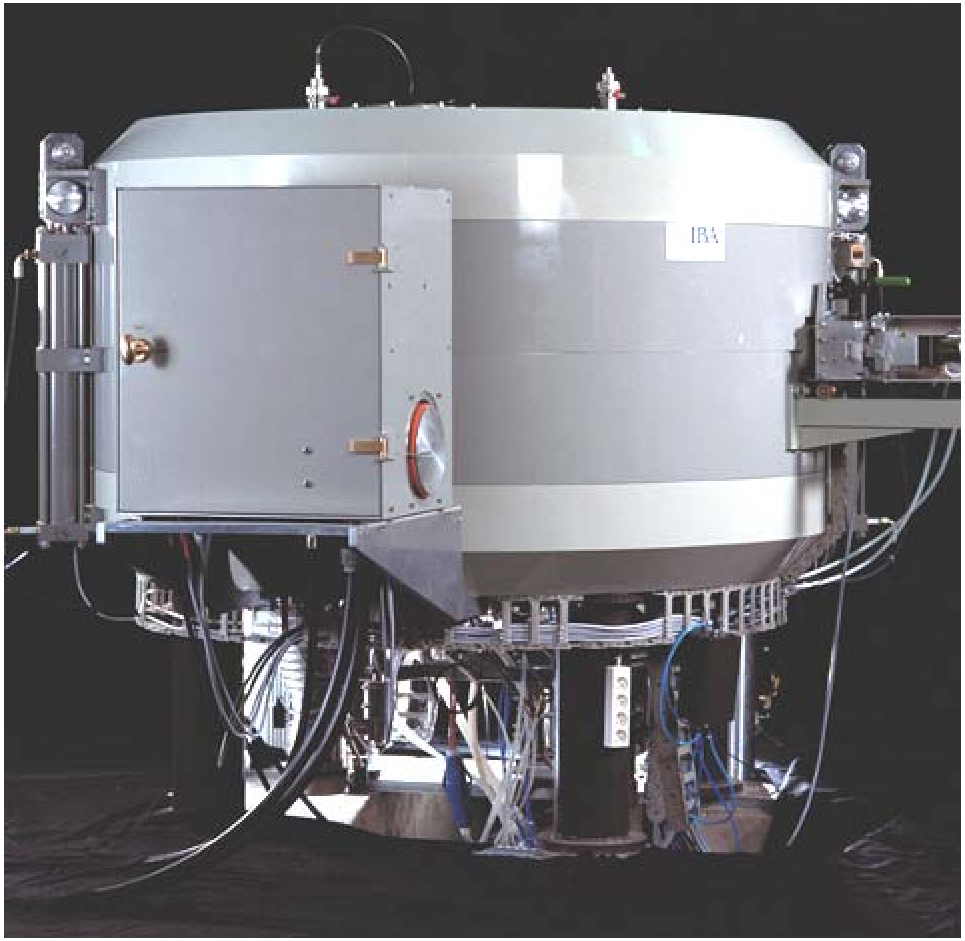
	Pd-103	I-125
Half-life (days)	16.97	60
Energy (keV)	20-23	27-35
Half-value-layer (mm.Pb)	0.008	0.02
Biologic dose equ. (Gy)	115	160
Initial dose rate (cGy/hr)	20-24	6-10

Cyclotrons for brachytherapy

- Large doses, lower cross-section require high current operation

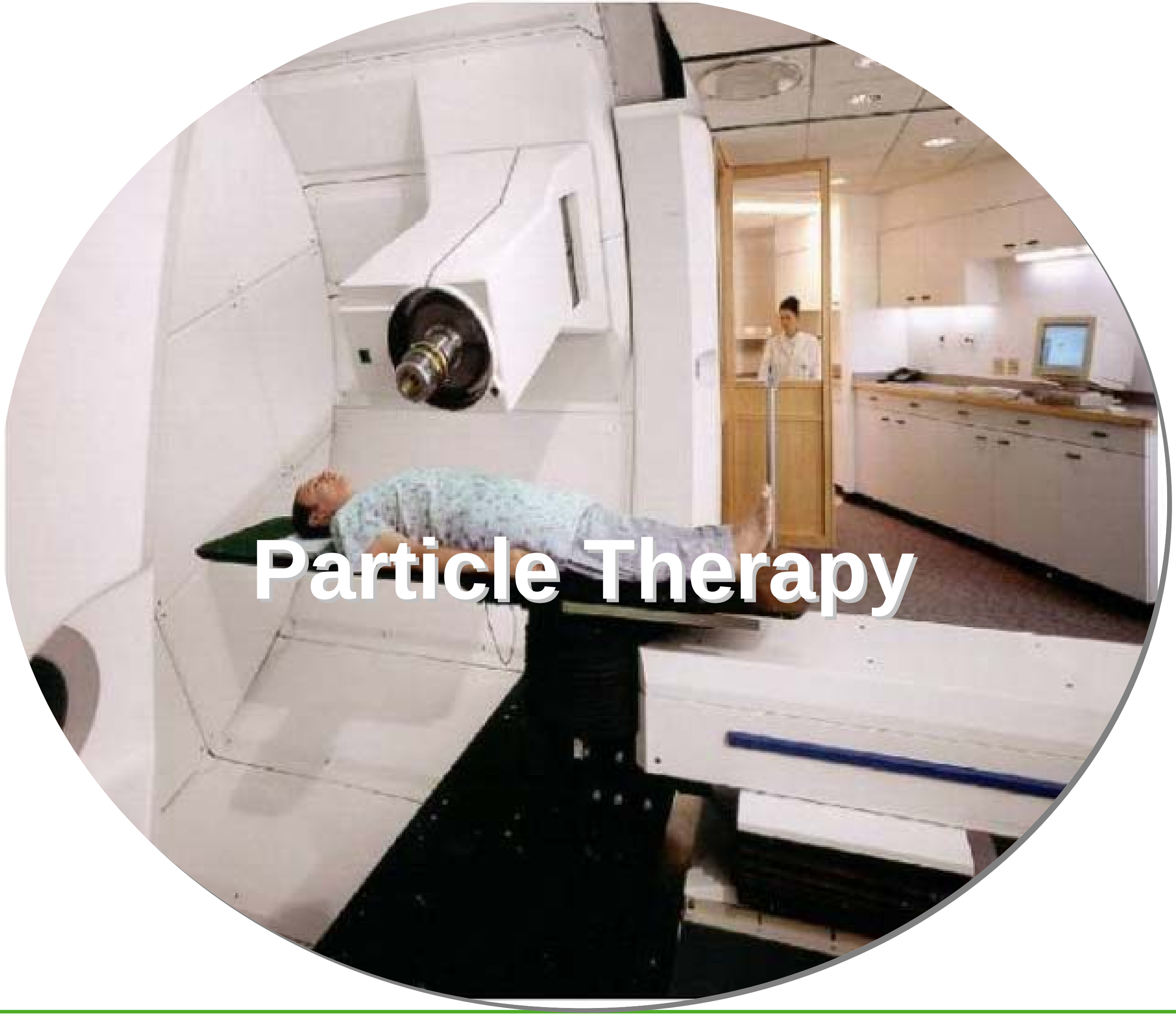
  Examples
  - 18Mev
  - 2mA on target
  - 14 cyclotrons in the same factory: 28 mA total proton beam current
- In such cyclotrons, 80% of the RF power is used for beam acceleration, 20% for building the accelerating field
- Current total accelerator efficiency are over 35%, 50% efficiencies in view !

The C18+



30 kW of beam with 100 kW of electrical power

80% of the RF power is beam acceleration



Particle Therapy

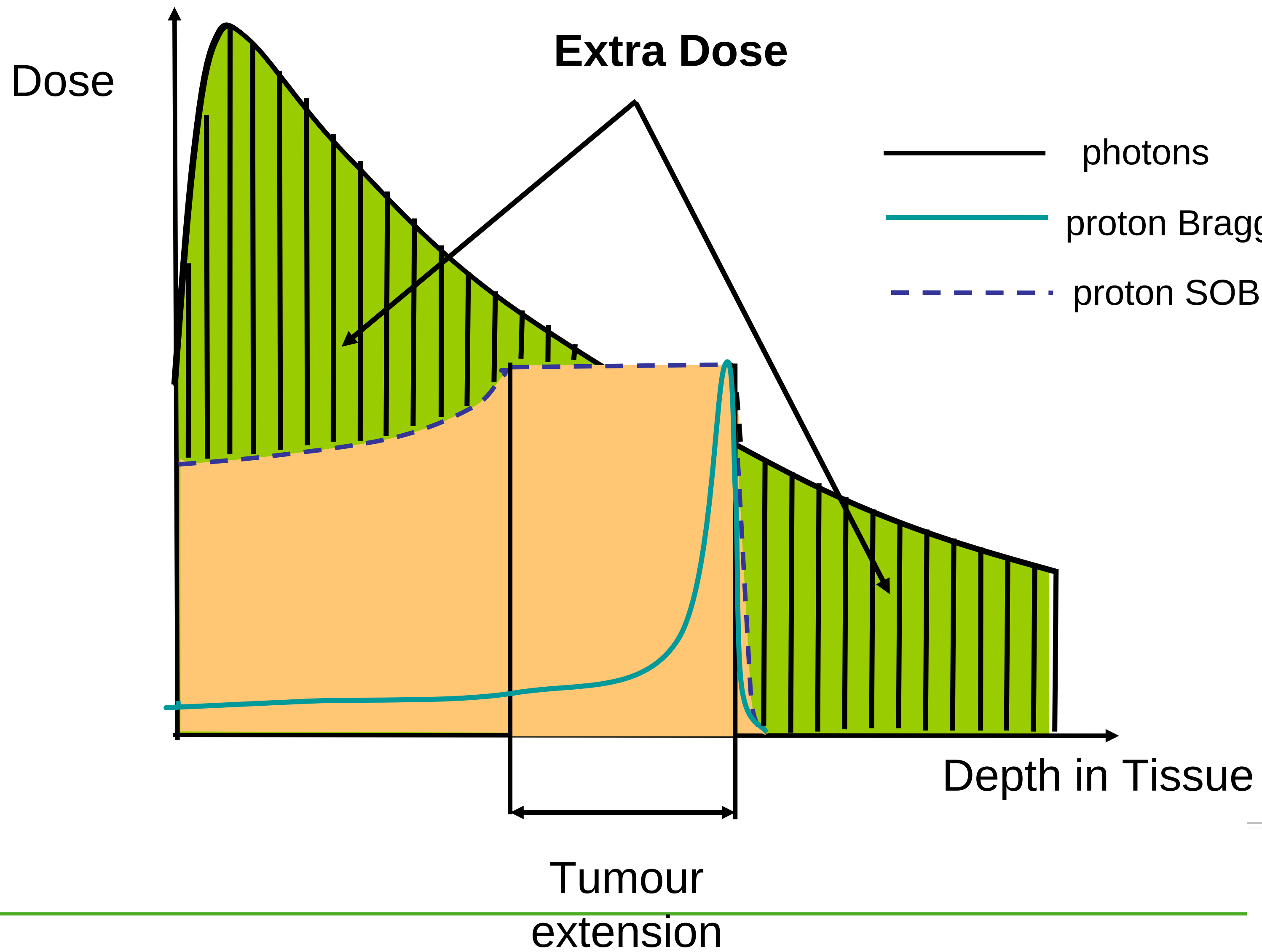
The HOLY GRAIL of Radiation Therapy

Provide a lethal dose
to the tumor

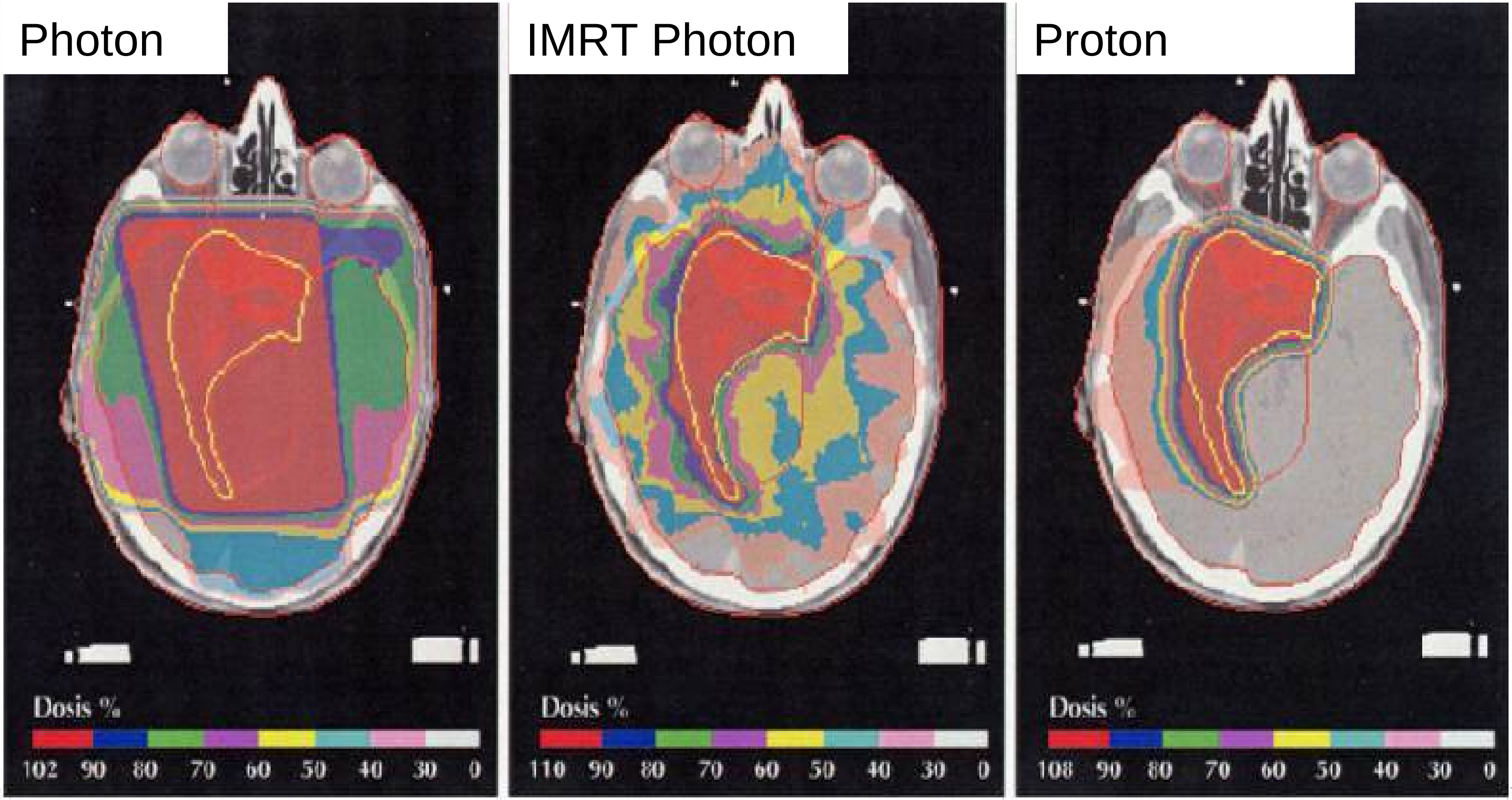
and

Spare perfectly the
surrounding healthy
tissue

Photon-Proton dose distribution comparison



Comparing IMPT, IMRT and conventional RT

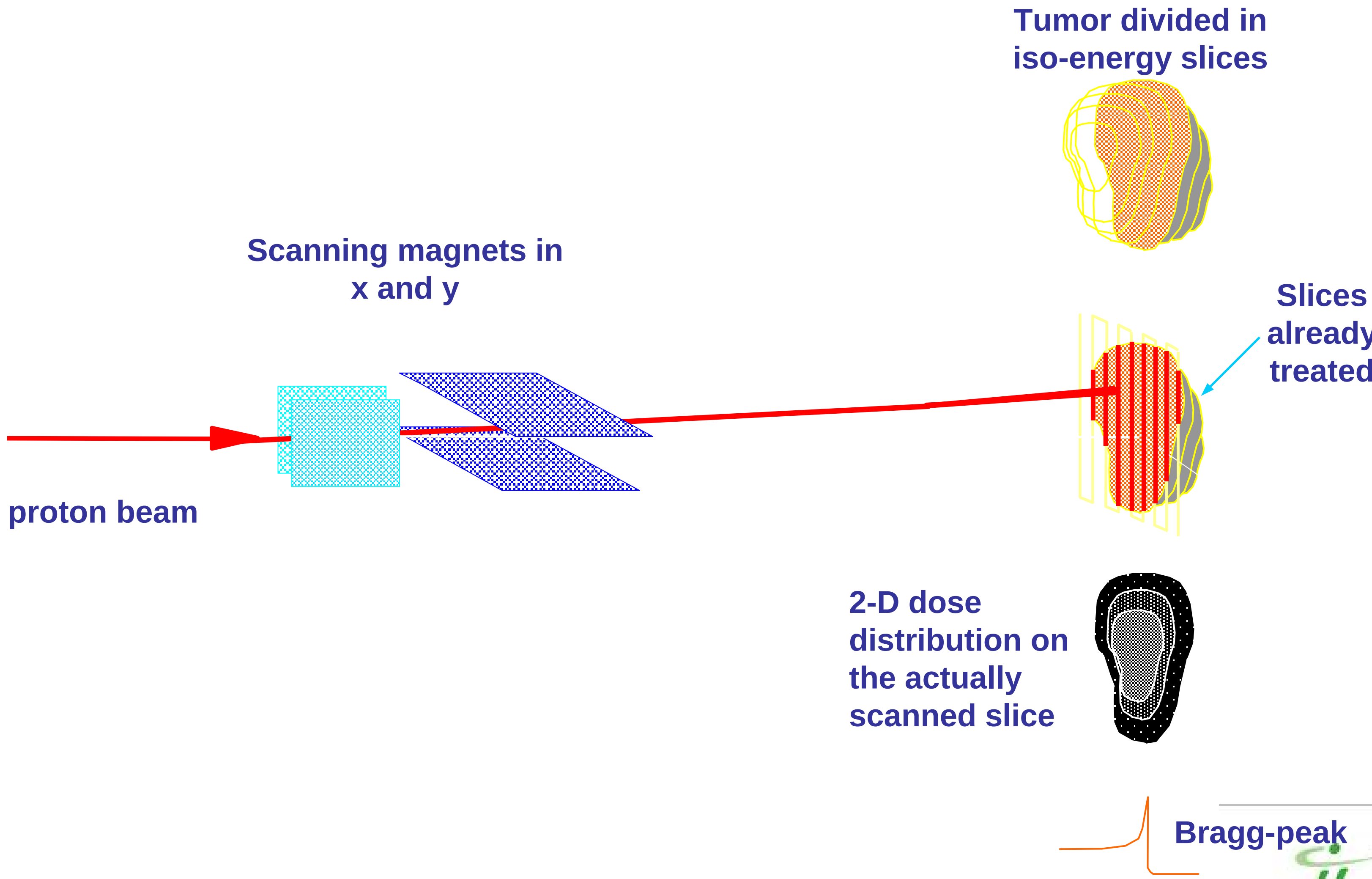


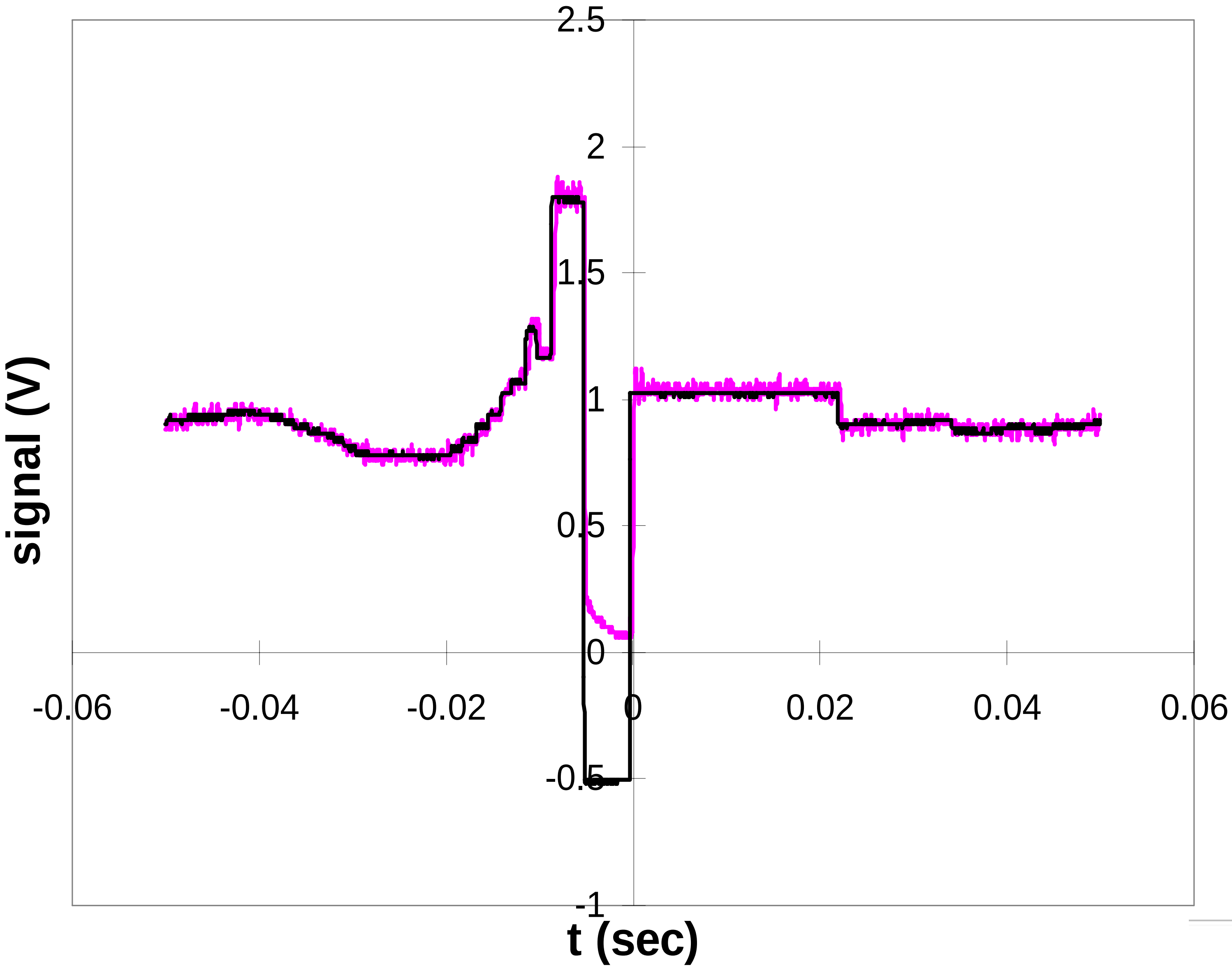
Treatment room in PT

Cyclotrons for proton therapy?

- **In 1991, when we entered in PT, the consensus was that the best accelerator for PT was a synchrotron**
- **IBA introduced a very effective cyclotron design, today the majority of PT centers use the cyclotron technology**
- **Over these 15 years, users came to appreciate the advantages of cyclotrons:**
  - Simplicity
  - Reliability
  - Lower cost and size
  - But, most importantly, the ability to modulate rapidly and accurately the proton beam current

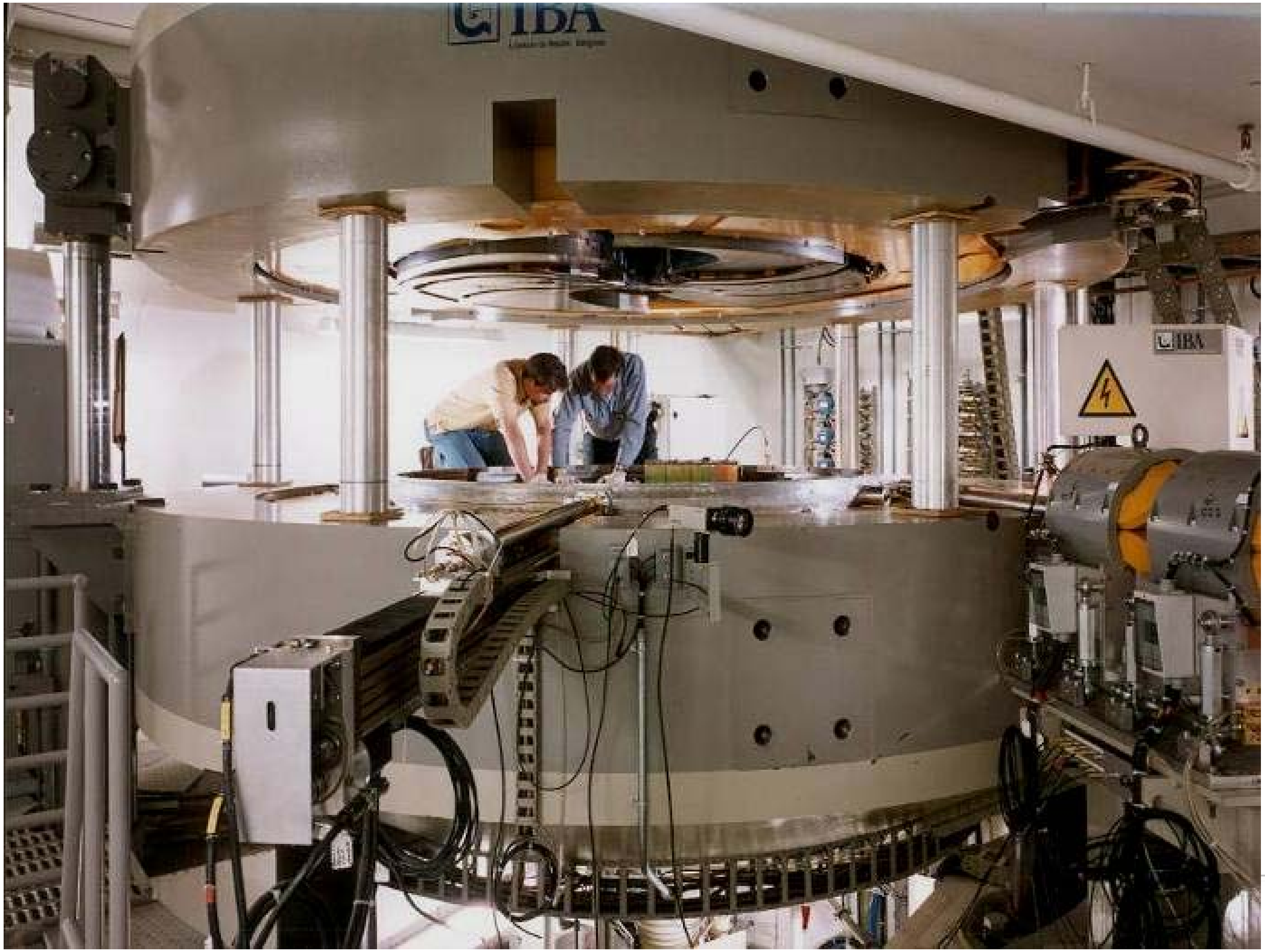
IMPT: Pencil Beam Scanning principle




signal (V)
t (sec)
2.5
2
1.5
1
0.5
0
-0.5
-1
-0.06
-0.04
-0.02
0
0.02
0.04
0.06

The cyclotron at MGH

Cyclotron opens at median plane for easy access



C230 inside view

Zoom on cyclotron center

Patient positioning in PT treatment room

A 3D View of a Proton Therapy Facility

IBA Proton Therapy System

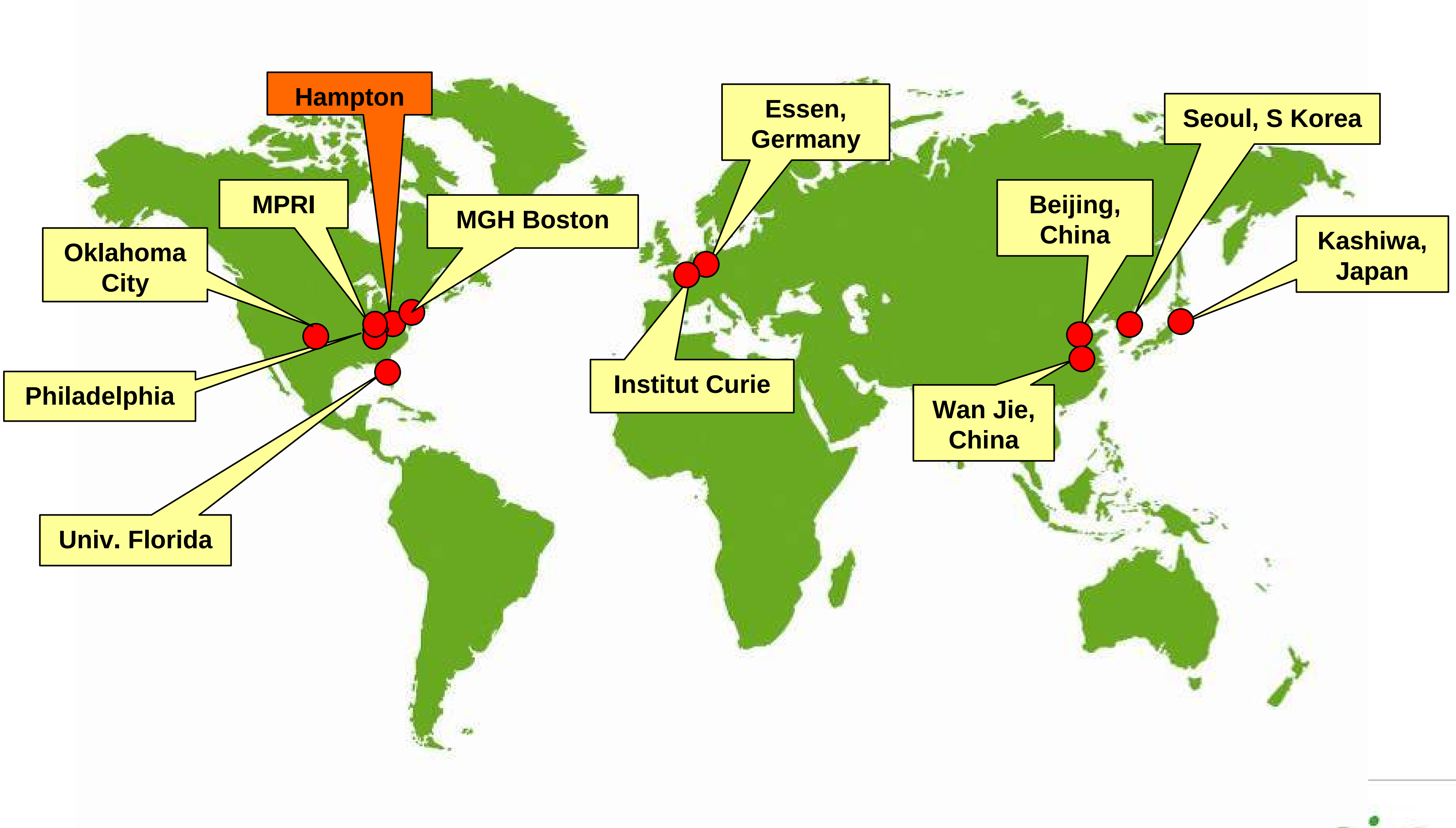
- A Proton therapy system is much more than an accelerator
- It is a complex, multi-room system, filling a Hospital building.
- The total investment is around 100 M€, of which 45 M€ for the equipment
- A PT facility can treat 2500 patients/year, generating revenues in excess of 40 M€/year!

Most recent example

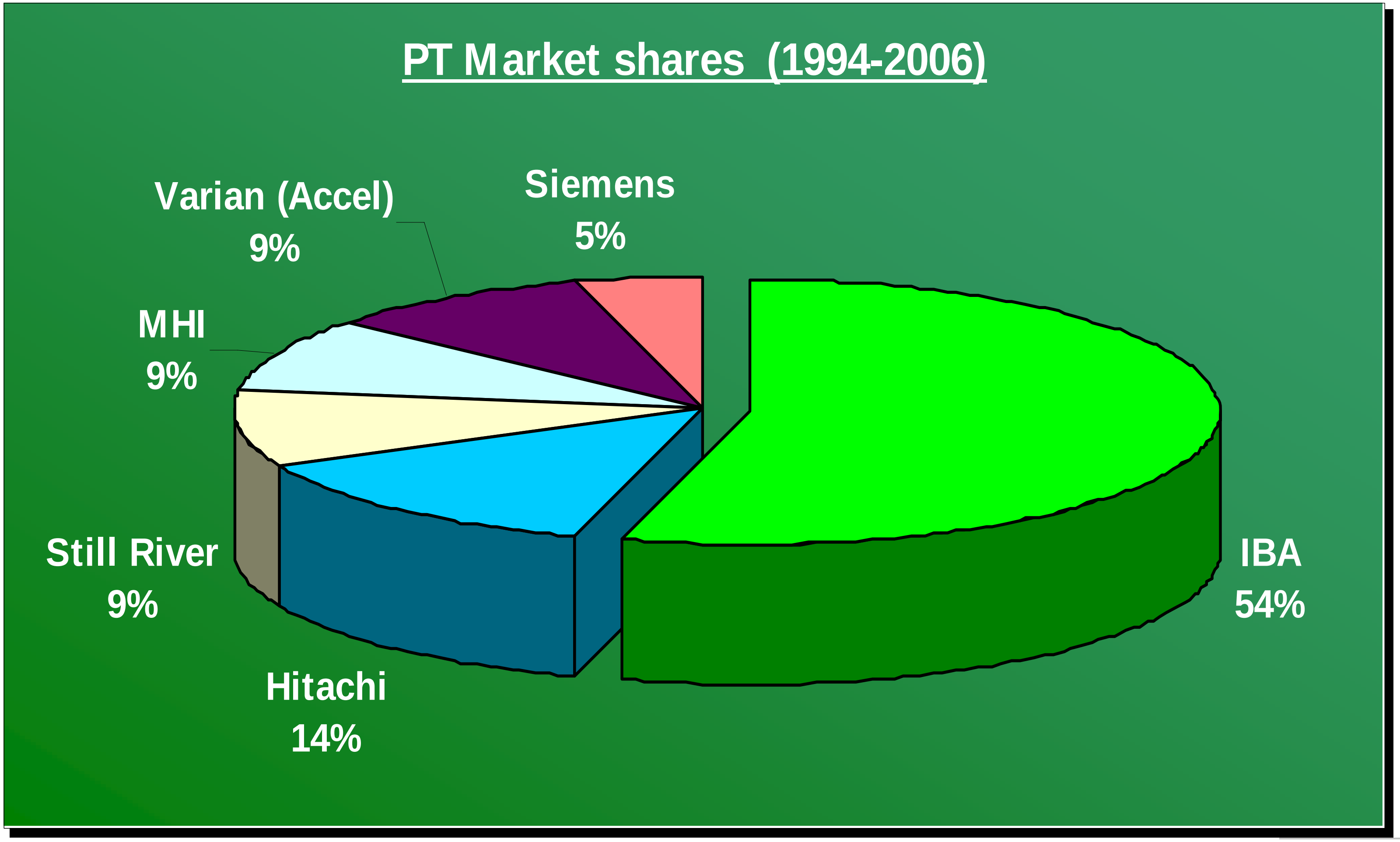
The University of Florida Proton Therapy Institute, Jacksonville, USA

- **Construction start date: Mar 2004**
- **PT equipment installation start: Mar 2005**
- **1st Patient : Aug 2006 !**
- **60 patients/day treated today in 3 Gantry rooms**
- **Reliability > 99% (in fractions) since start of treatments**
- **3 Gantry Rooms + 1 Eye Treatment Room**

11 IBA Particle Therapy Partners world wide



IBA as market leader in PT



If proton therapy is so great,

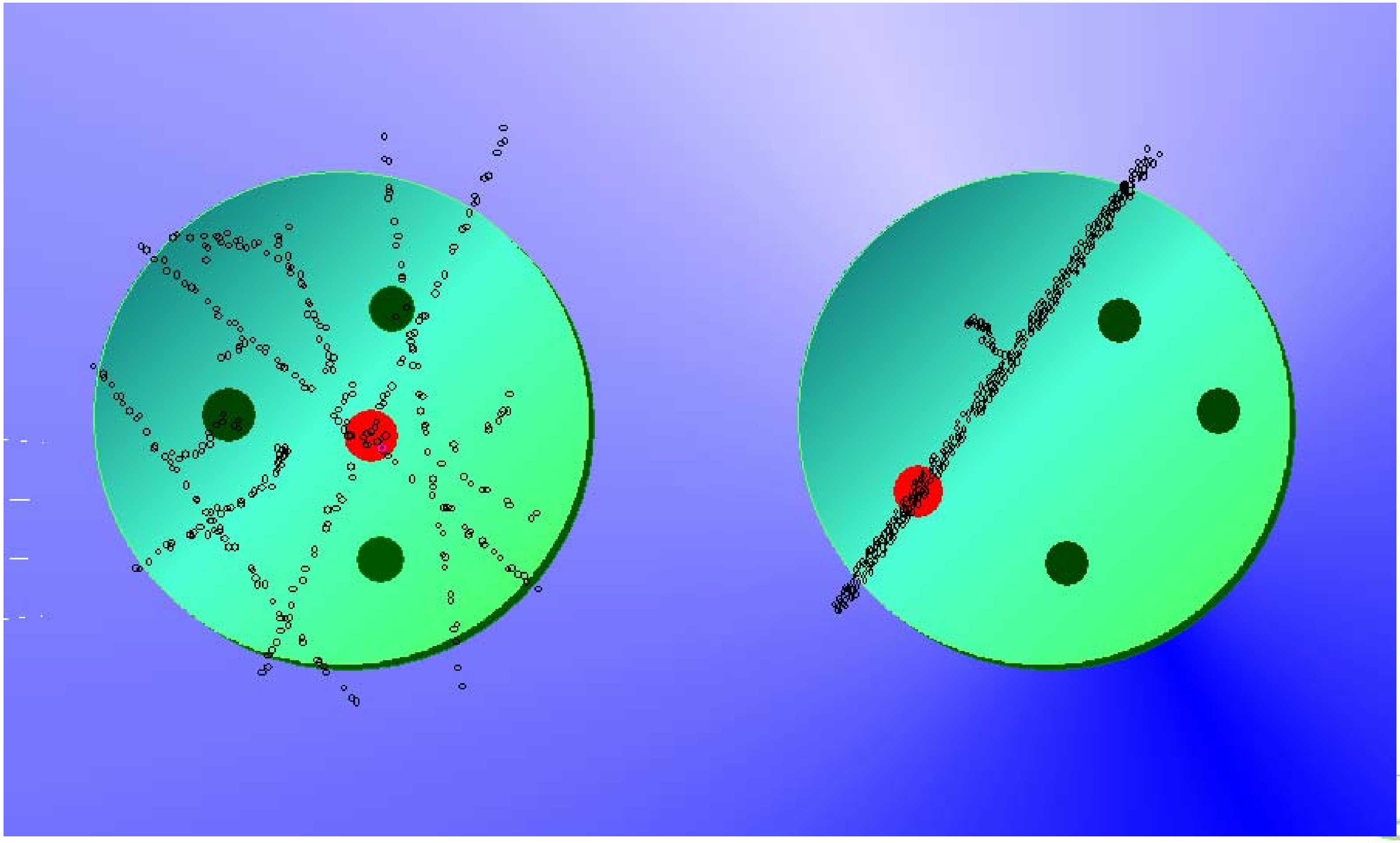
Why use Carbon beams?

Photons, Protons

Low LET

Neutrons, Carbon ions

High LET



The famous experience of Dr. Harold Gray

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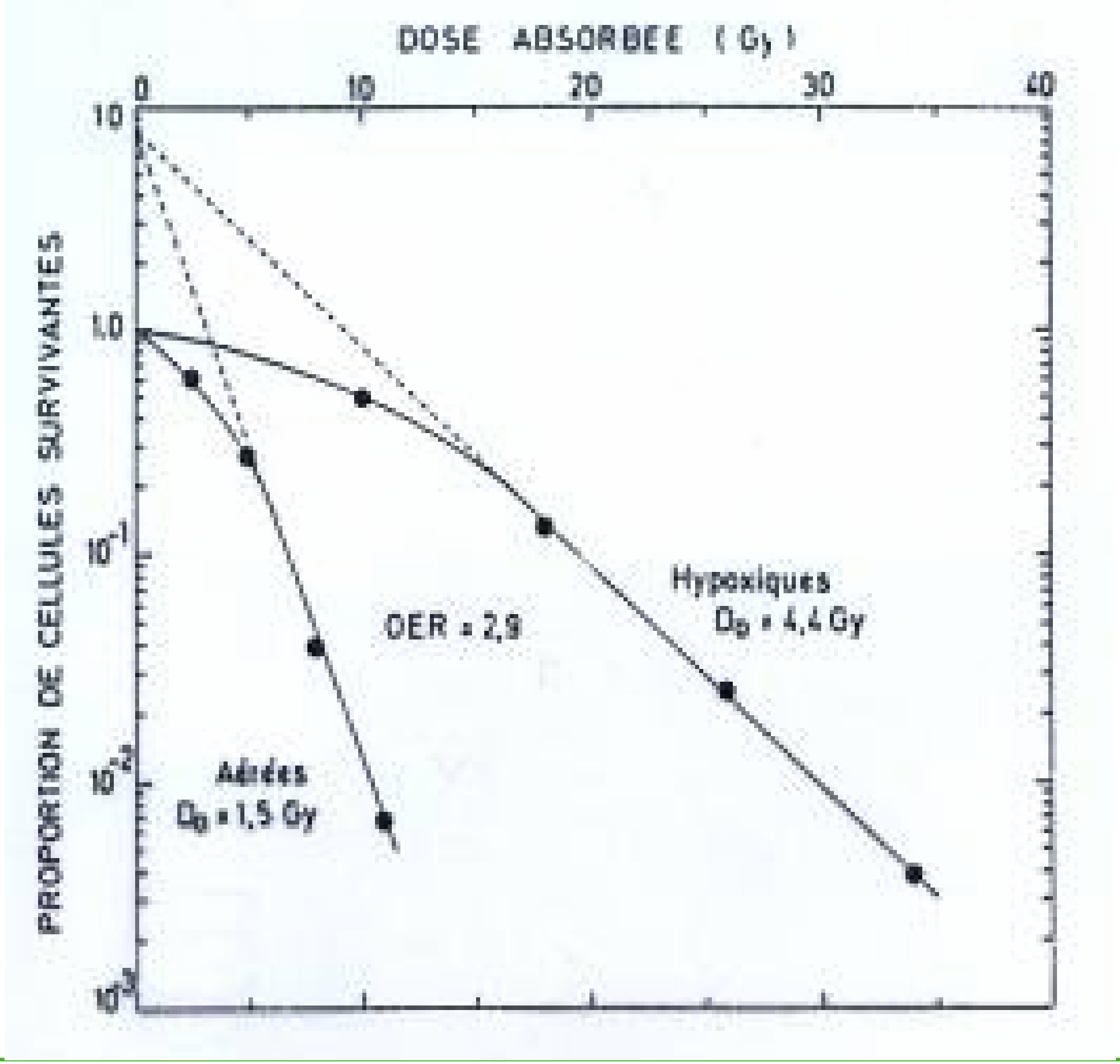
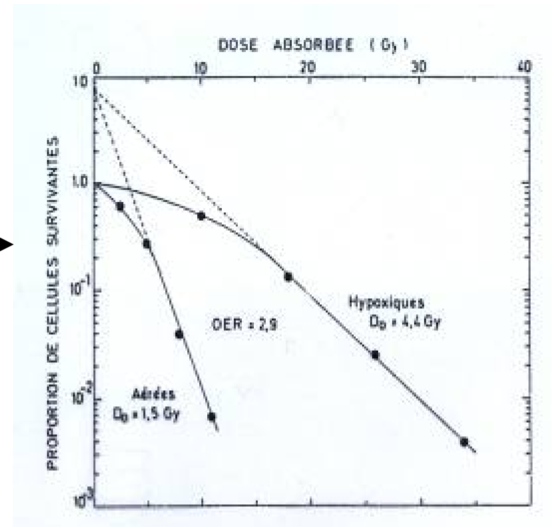


Oxygen Enhancement Ratio

Low -LET

OER for low LET

= 3

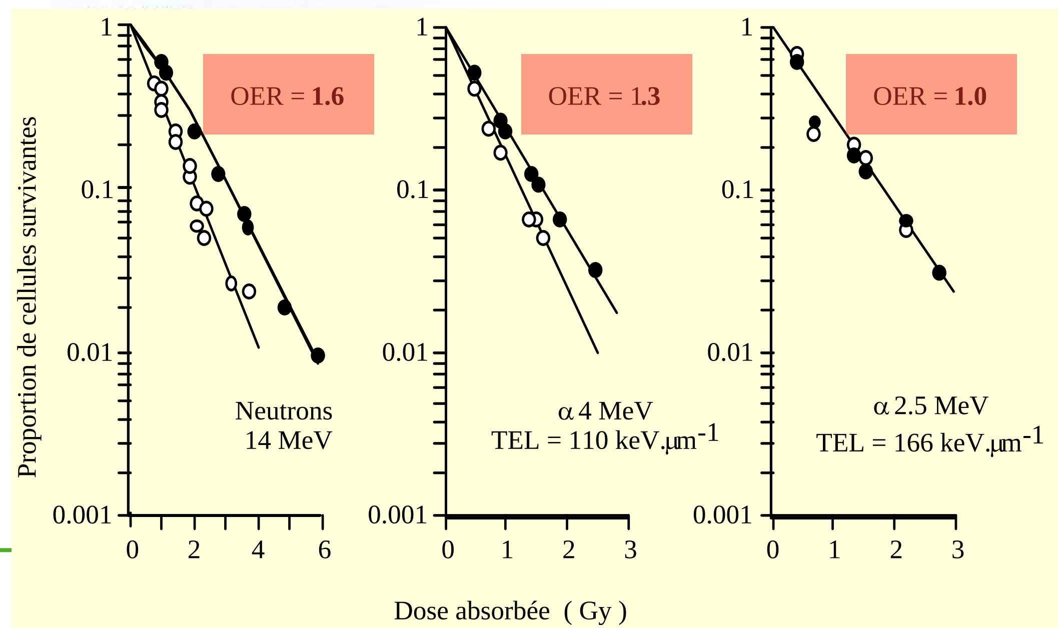


OER decreases as the LET increases

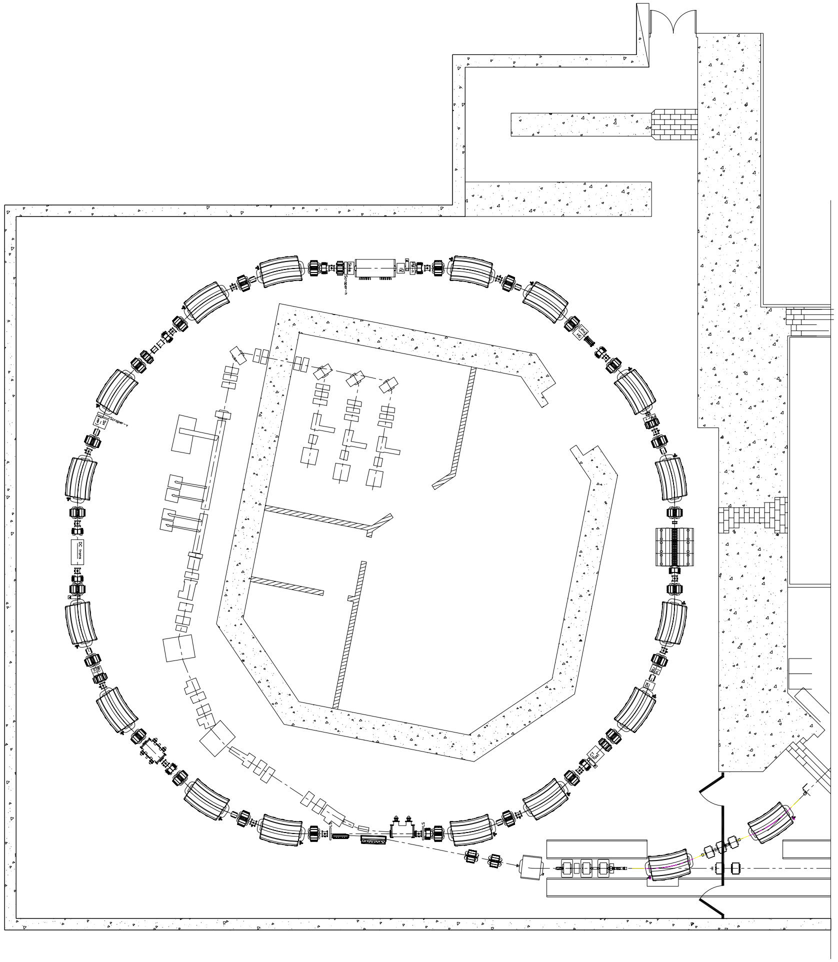
High -LET

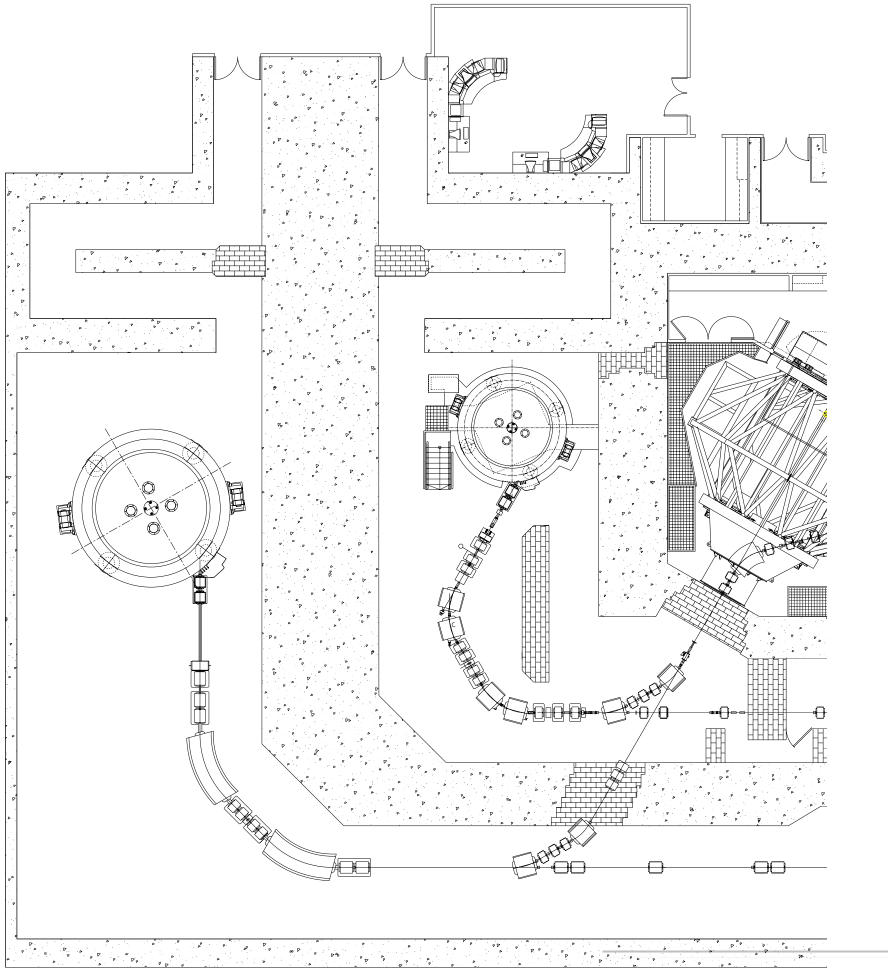
OER for high LET

= 1 - 1.7

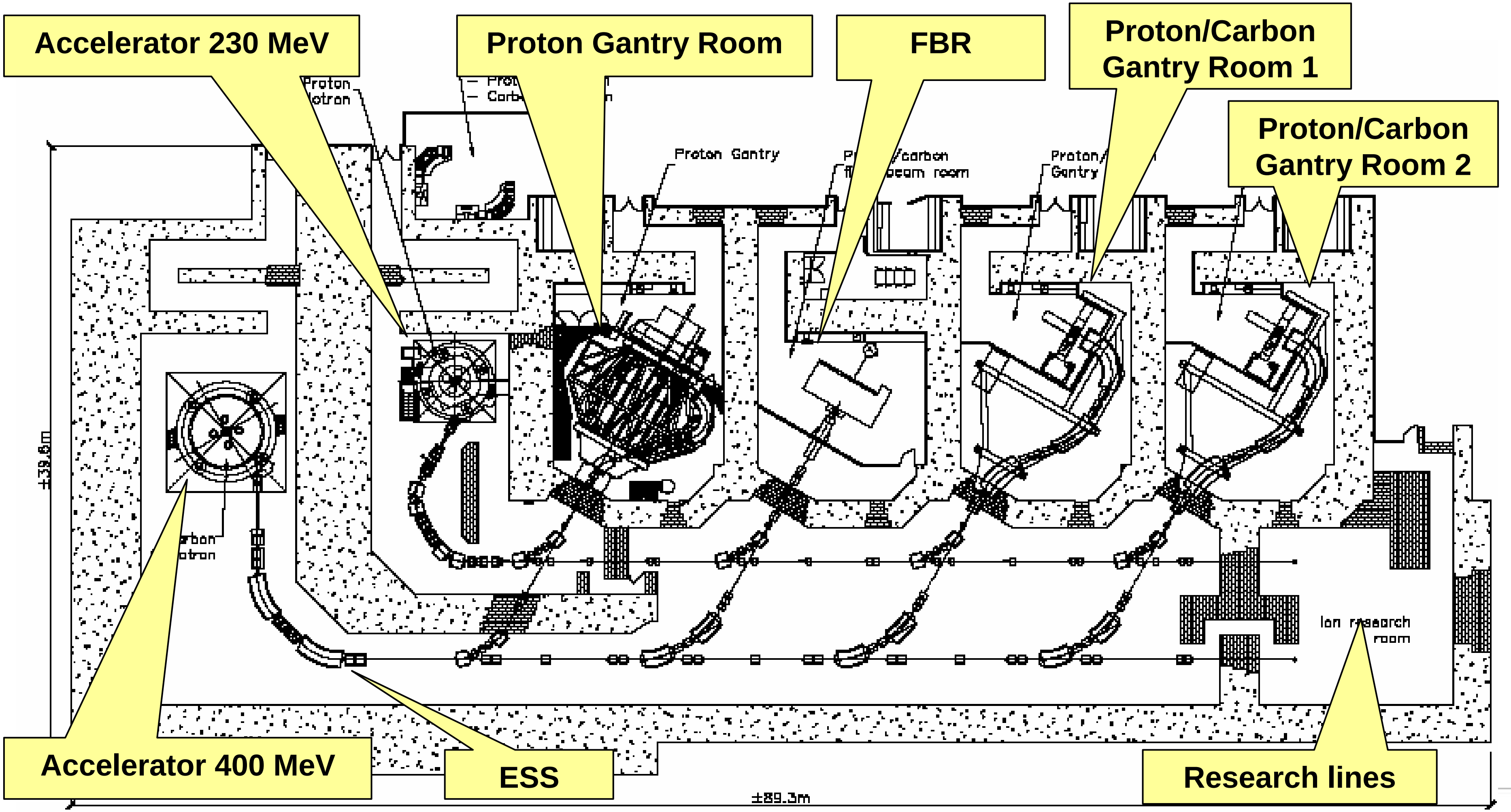


In less space and cost than a synchrotron: a two cyclotrons phased approach





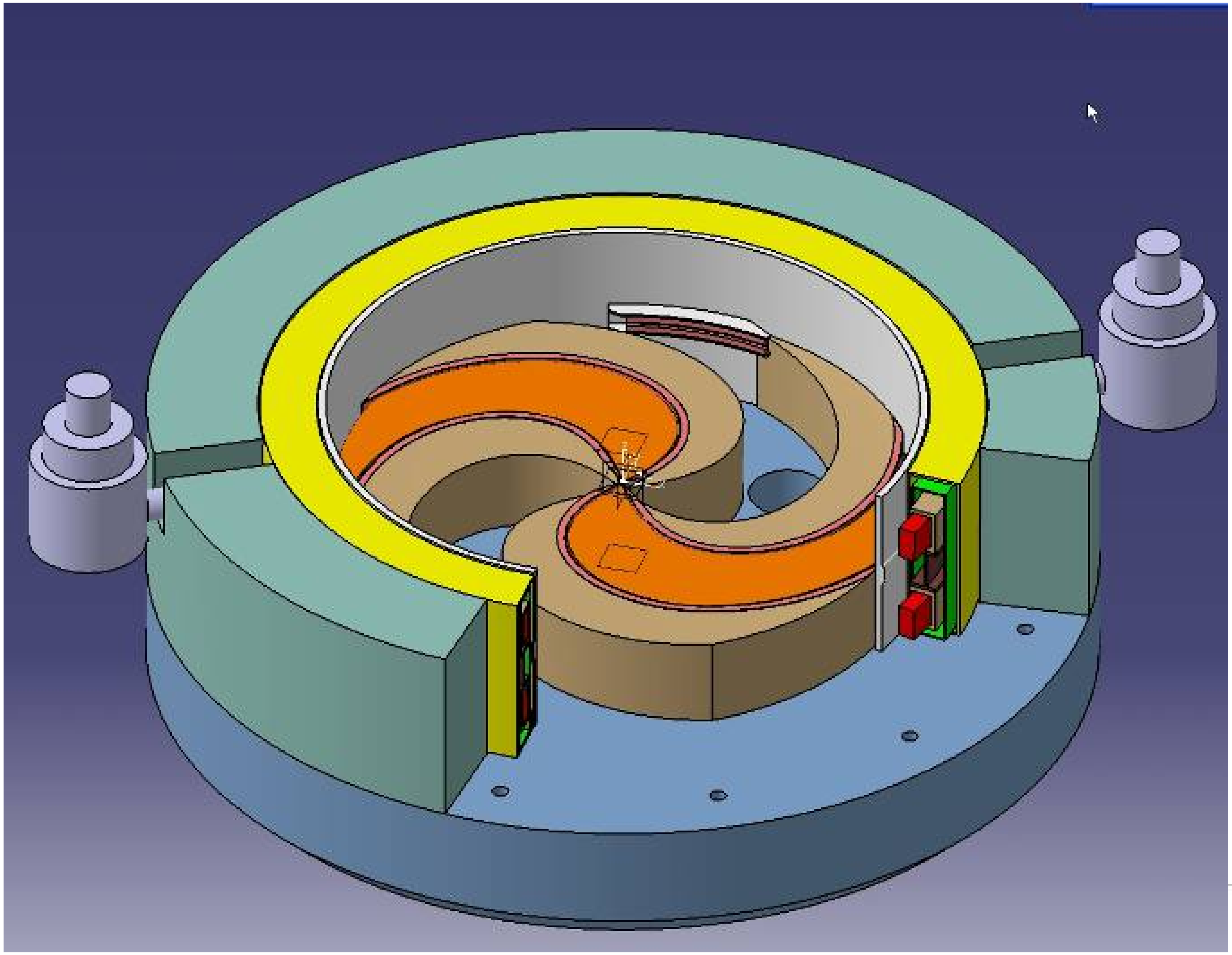
The IBA proton-carbon facility



The IBA Carbon cyclotron design

- Superconducting isochronous cyclotron, accelerating Q/M = 1/2 ions to 400 MeV/U (H2 +, Alphas, Li6 3+, B10 5+, C12 6+, N14 7+, 016 8+, Ne20 10+)
- Design very similar to IBA PT cyclotron, but with higher magnetic field thanks to superconducting coils, and increased diameter (6.3 m vs. 4.7 m)

Engineering view of the 400 MeV/u cyclotron



Status of the cyclotron design

- During the last two years, a team of accelerator physicists at the JINR in Dubna has completed the physical design of the cyclotron
- This study has been summarized into a comprehensive design report.
- On January 8th 2007, an international design review was organized by IBA, with worlds key key superconducting cyclotron experts.
- The outcome of the review was completely positive.

The next steps for the C400 (K1600) cyclotron

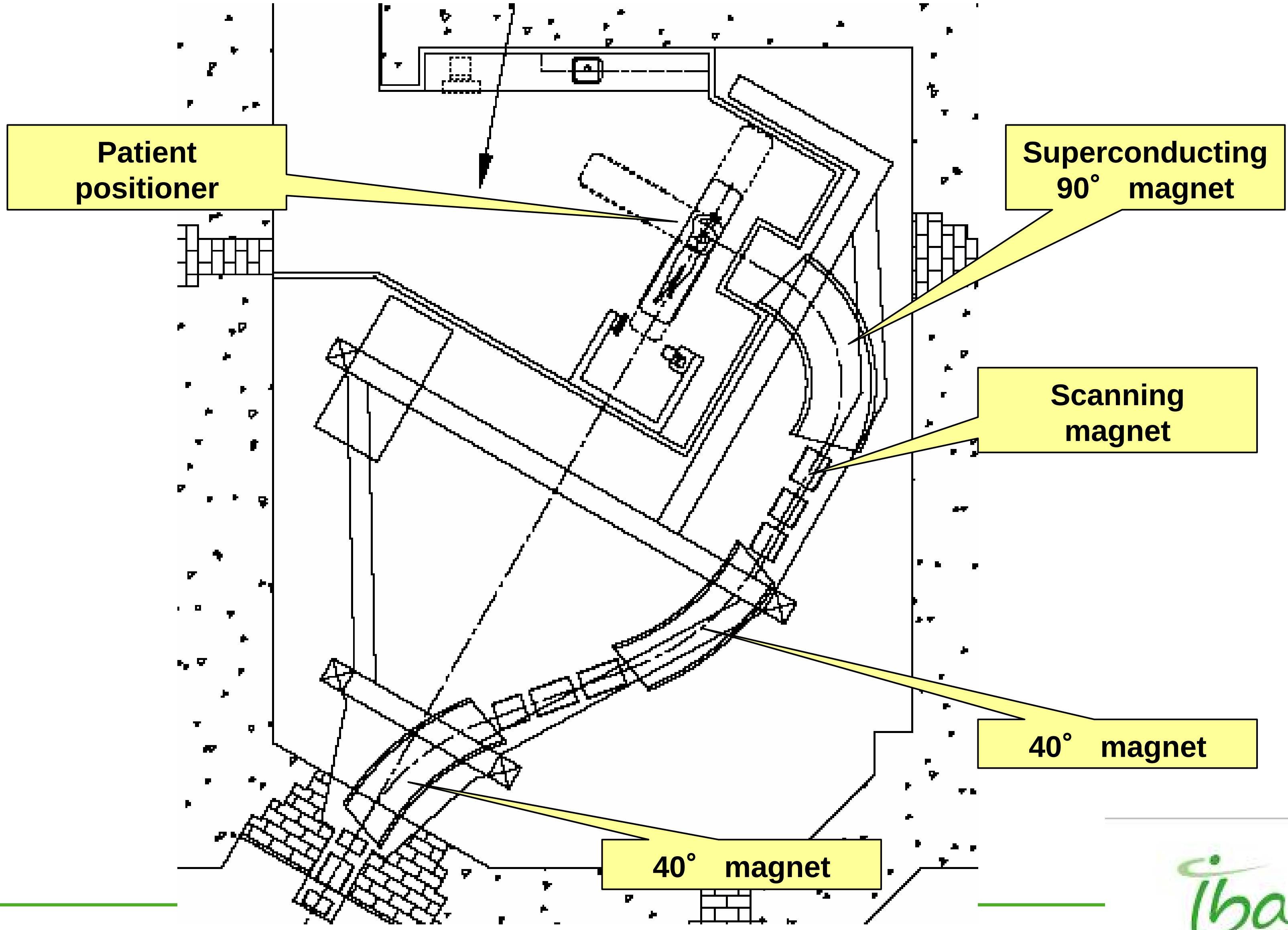
- In 2007, the design study will continue, and focus progressively more on industrial construction issues
- The detailed design of critical subsystems, such as the superconducting coils will be subcontracted
- When the contract for a system will be signed, the final design and construction process will be launched, to reach a working prototype in 3 years
- However, some alternatives are considered to start the construction of a prototype before a sales contract is signed

iba

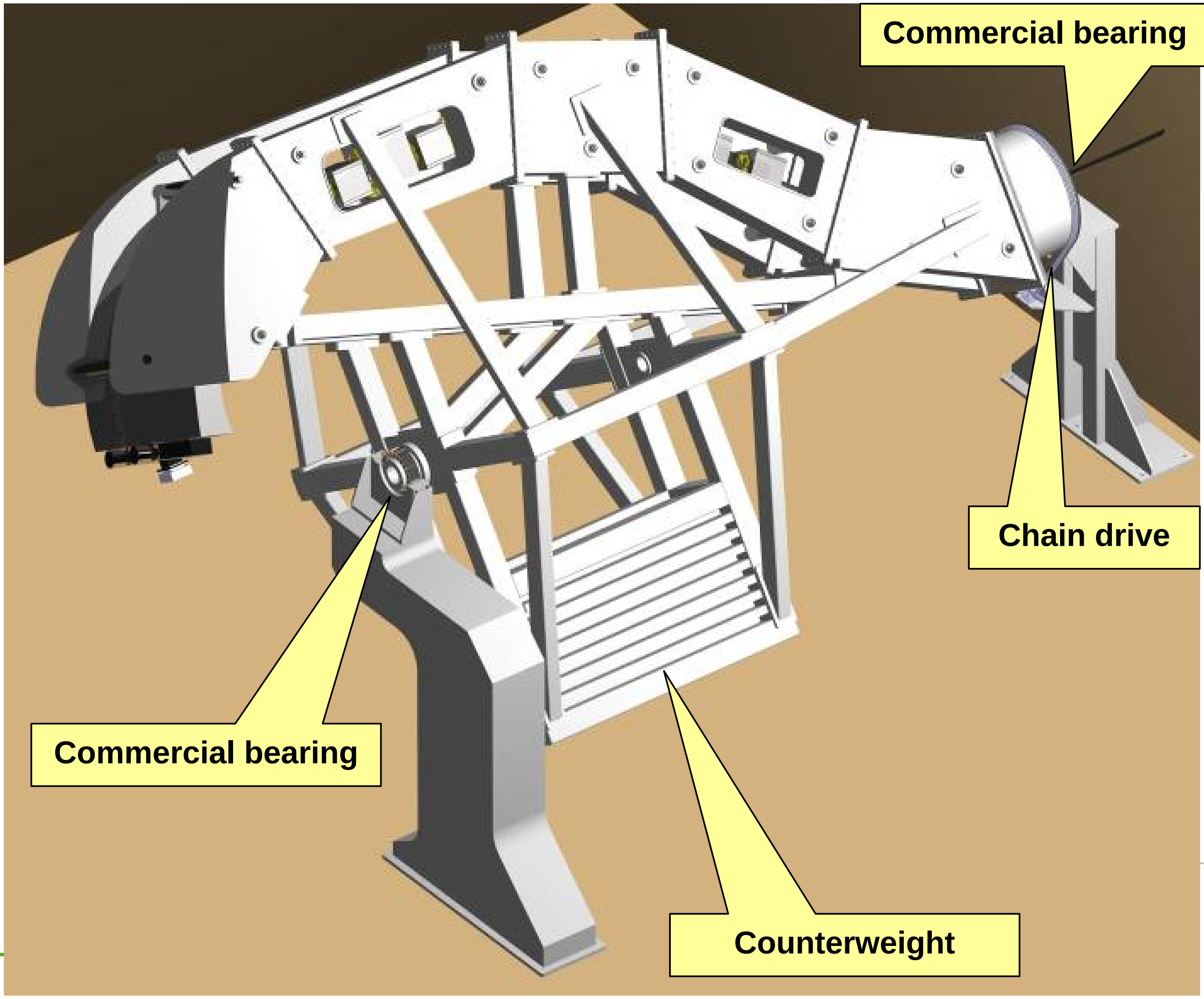
Compact isocentric gantry for Carbon beams

- Most physicians prefer a true isocentric gantry
- The gantry of Heidelberg (20 m long, 12 m diameter, 600 Tons) is often seen as too large, heavy and expensive to be selected as a solution
- Is it possible to build a Carbon gantry of the size and cost of a proton gantry?
- Yes, if the last magnet is superconductive!

The compact carbon gantry



Mechanical structure of gantry



Thank you

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