

INTRODUCTION TO ION THERAPY @ MEDAUSTRON

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ISOTDAQ, 15th Feb 2018

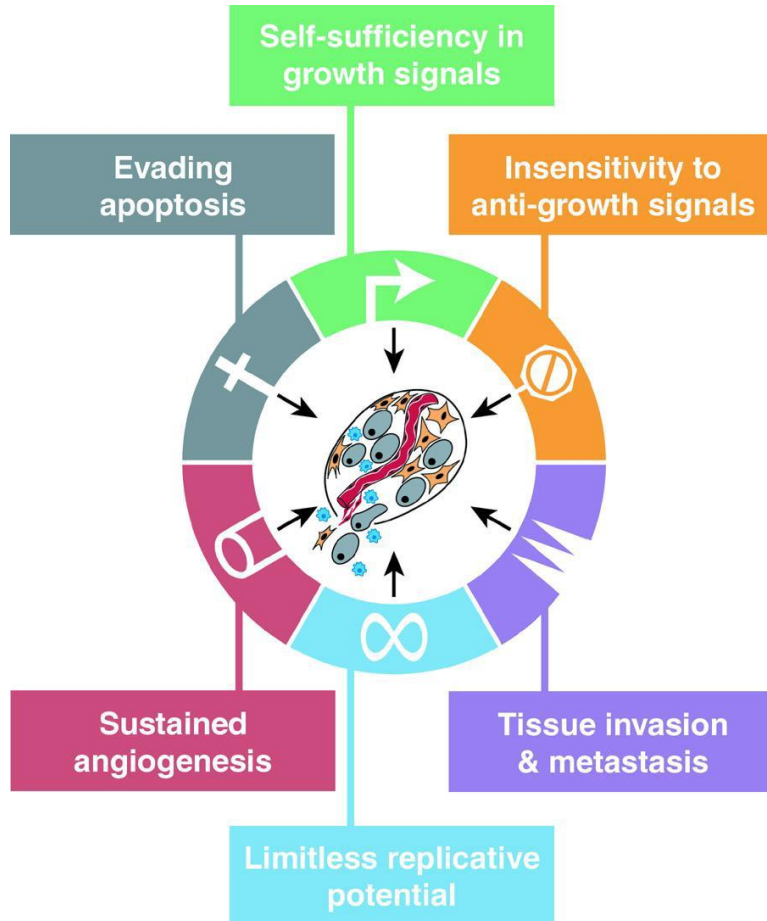
OUTLOOK

**Hadrontherapy:
motivation and challenges**

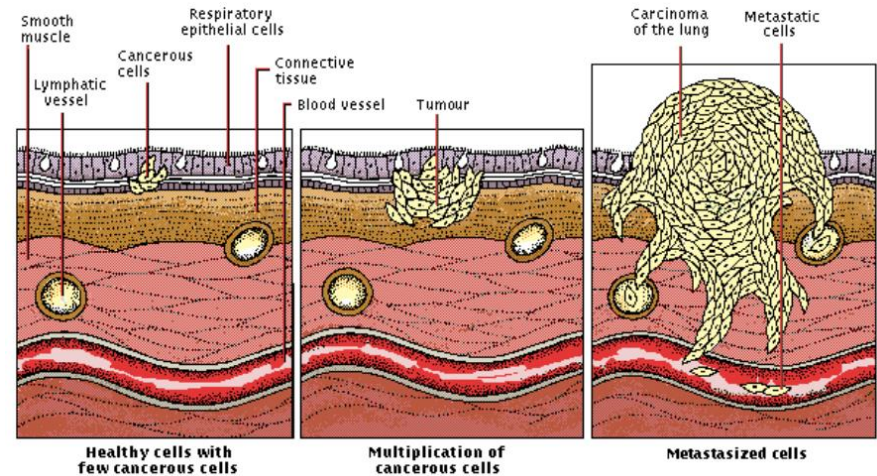
**MedAustron:
state-of-the-art Ion Therapy**

**Example of DAQ @
MedAustron**

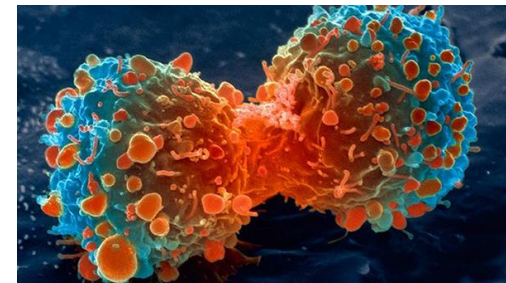
What is a Cancer?



Hanahan, Weinberg, Cell, 2000



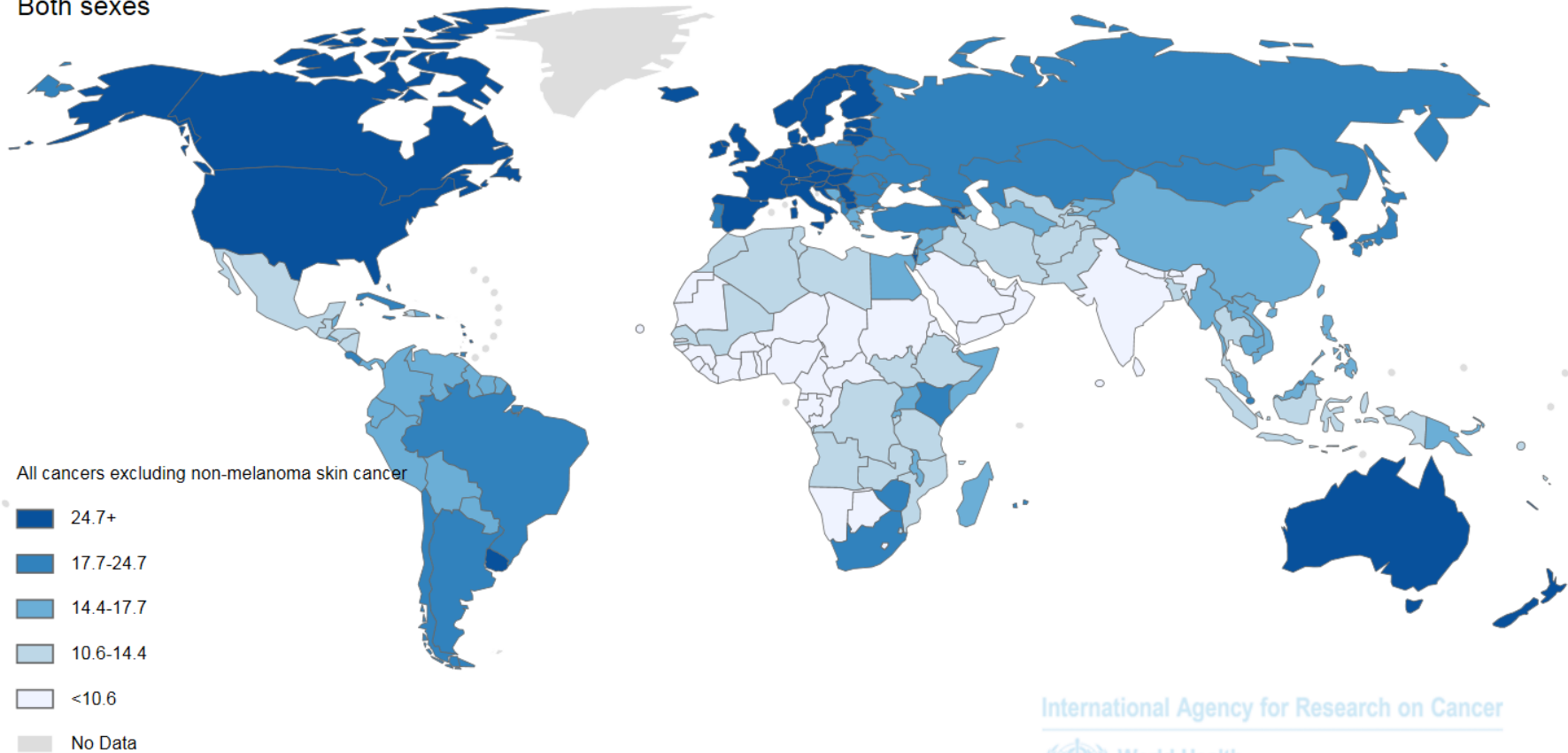
Source: <http://www.macmillan.org.uk>



A dividing lung cancer cell.
Credit: US National Institutes of Health

Incidence Cumulative risk

Both sexes



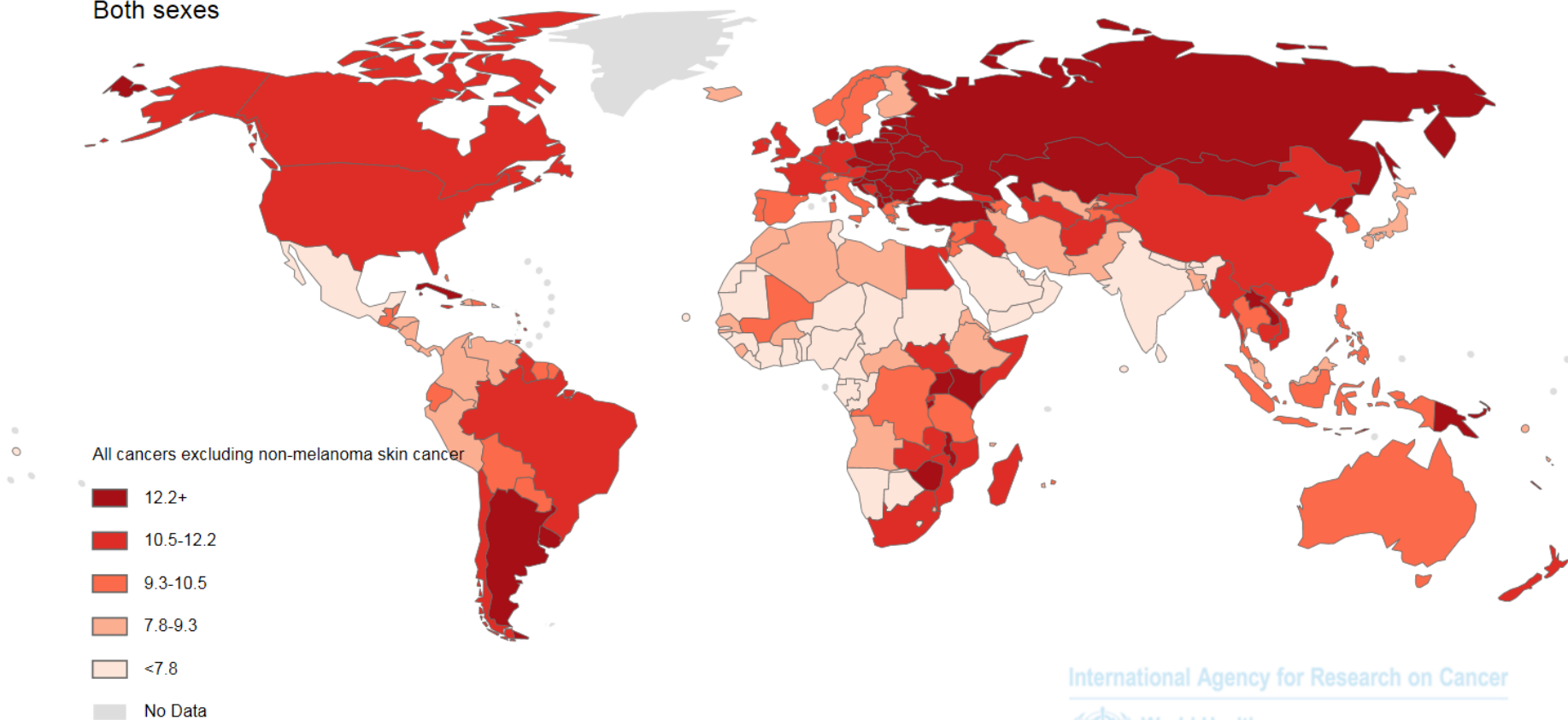
International Agency for Research on Cancer



Source: GLOBOCAN 2012 (IARC)

Mortality Cumulative risk

Both sexes

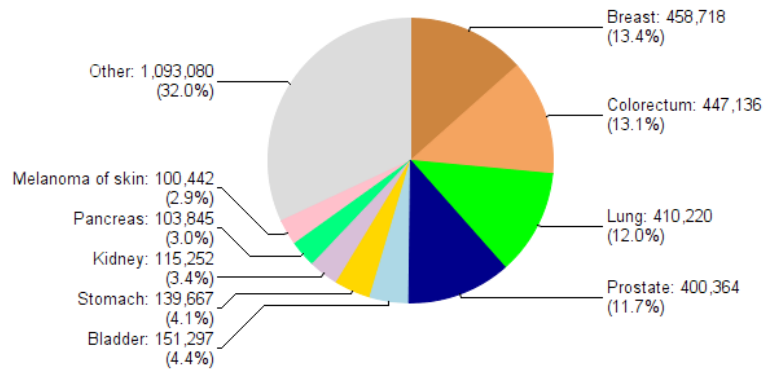


International Agency for Research on Cancer



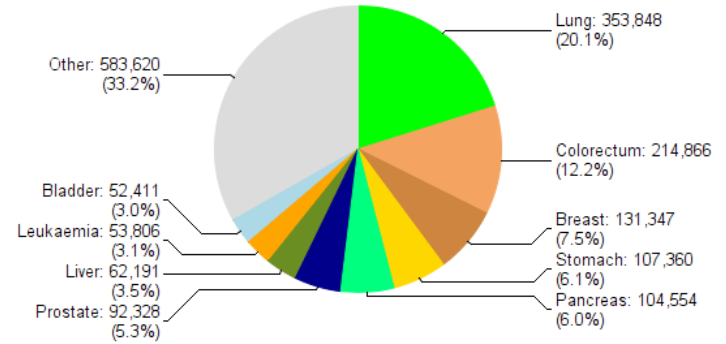
Source: GLOBOCAN 2012 (IARC)

Estimated number of cancer cases, all ages (total: 3420,021)



GLOBOCAN 2012 (IARC) - 13.2.2018

Estimated number of cancer deaths, all ages (total: 1756,331)



GLOBOCAN 2012 (IARC) - 13.2.2018

How do we defeat it?



Surgery

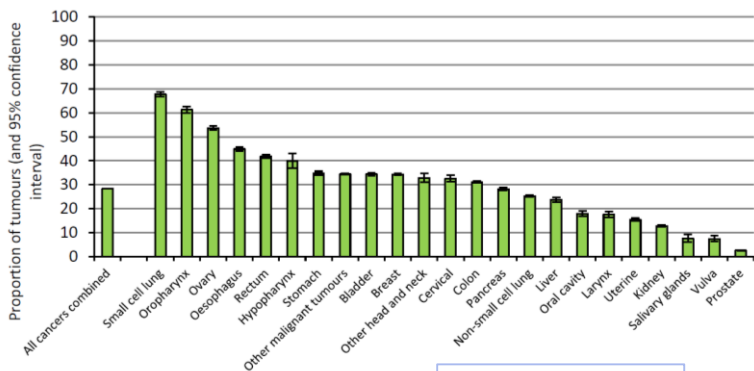


Radiotherapy

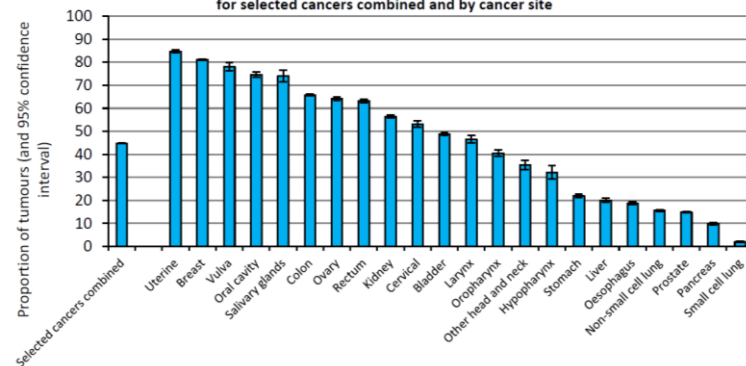


Chemotherapy

Proportion of patients diagnosed in England in 2013-14 receiving chemotherapy, for all cancers combined and by cancer site



Proportion of patients diagnosed in England in 2013-14 receiving tumour resection, for selected cancers combined and by cancer site

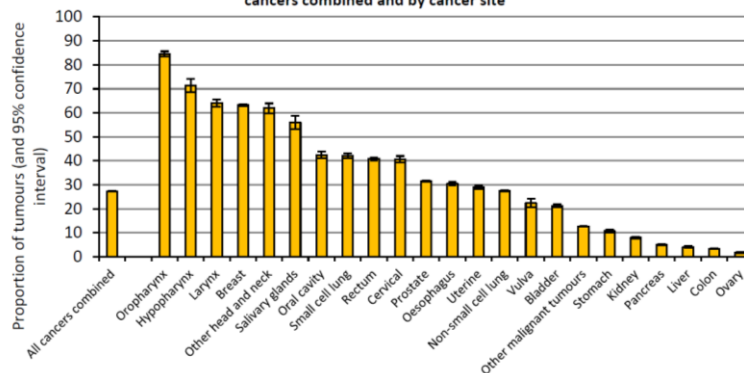


Chemotherapy
27%

Surgery
45%

Radiotherapy
28%

Proportion of patients diagnosed in England in 2013-14 receiving radiotherapy, for all cancers combined and by cancer site



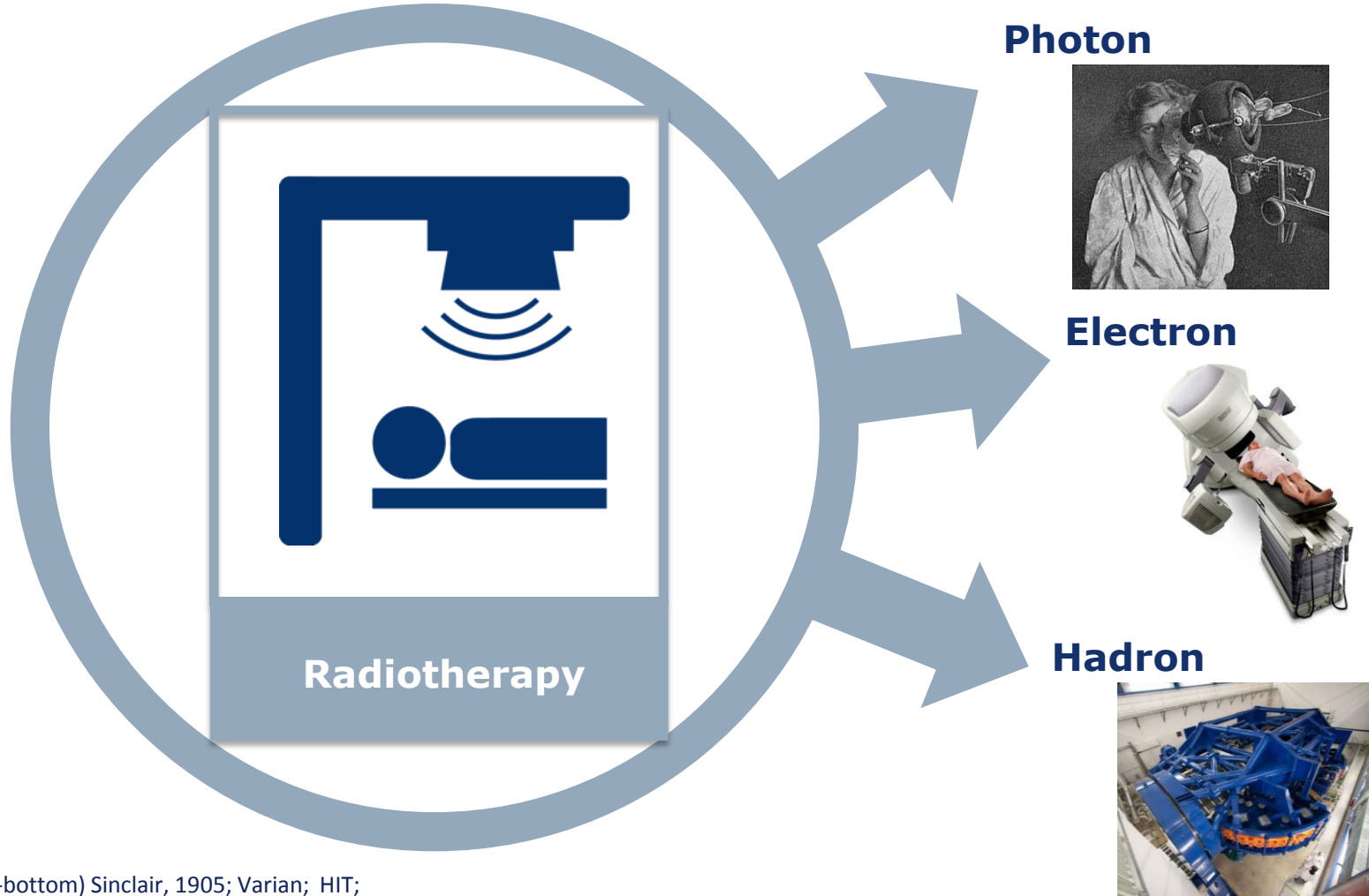
The Story so far

- We know what a cancer is
- 1 in 3 in this room, will develop one in their lifetime
- We have means to fight it
- We can select the best way according to individual situation
- If possible you get surgery

Next:

What are the options for Radiotherapy?
What are the differences?
How can we do it?

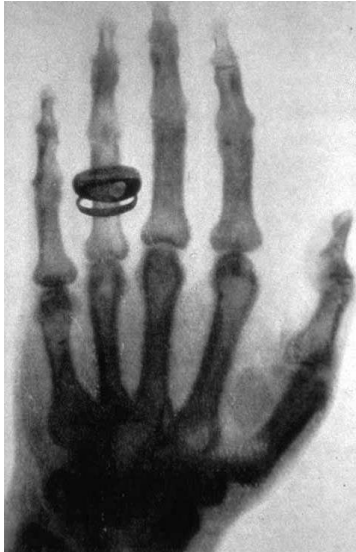
The Options of Radiotherapy



Credit (top-bottom) Sinclair, 1905; Varian; HIT;

Photon

Long history in medicine,
diagnostic and treatment.
Easiest to produce



X-ray of Kölliker's hand,
made by Röntgen (1896)
Source: wikipedia



A child undergoing an x-ray at
University Children's Hospital, Vienna, 1921
Credit: Wellcome Library, London



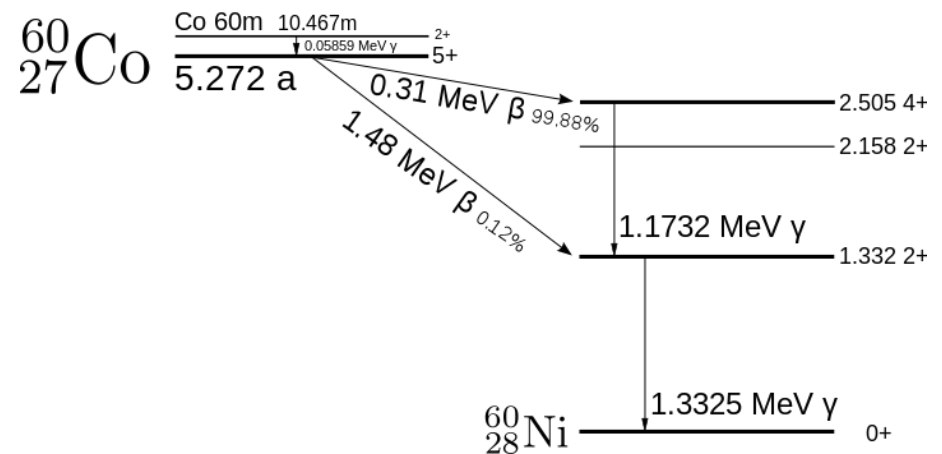
X-ray photo tube
Credit: Oak Ridge Associated Universities, 1999

Photon – getting to higher energy

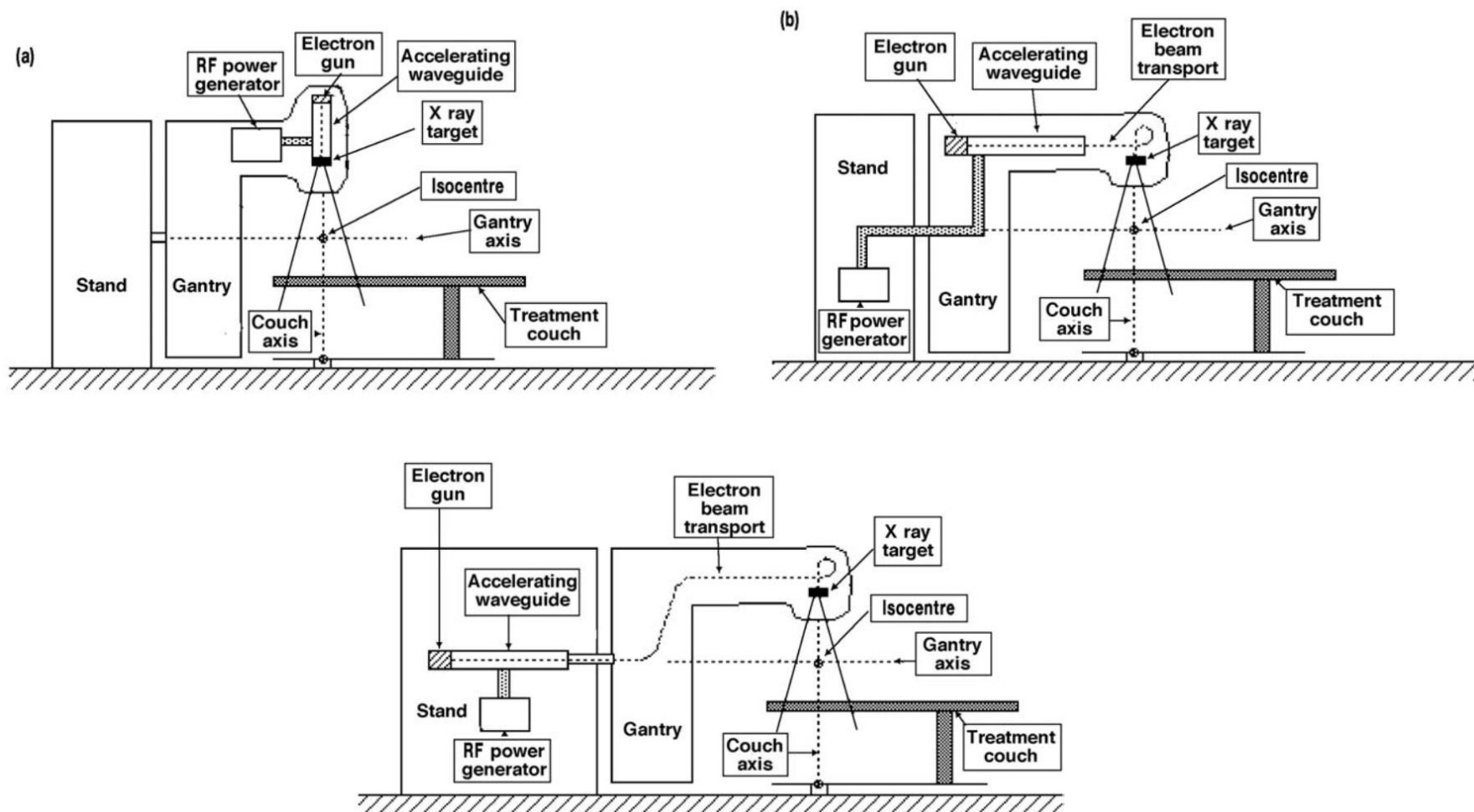


The first cobalt machine in Italy, 1953

Source: wikipedia



Photon – getting it more flexible

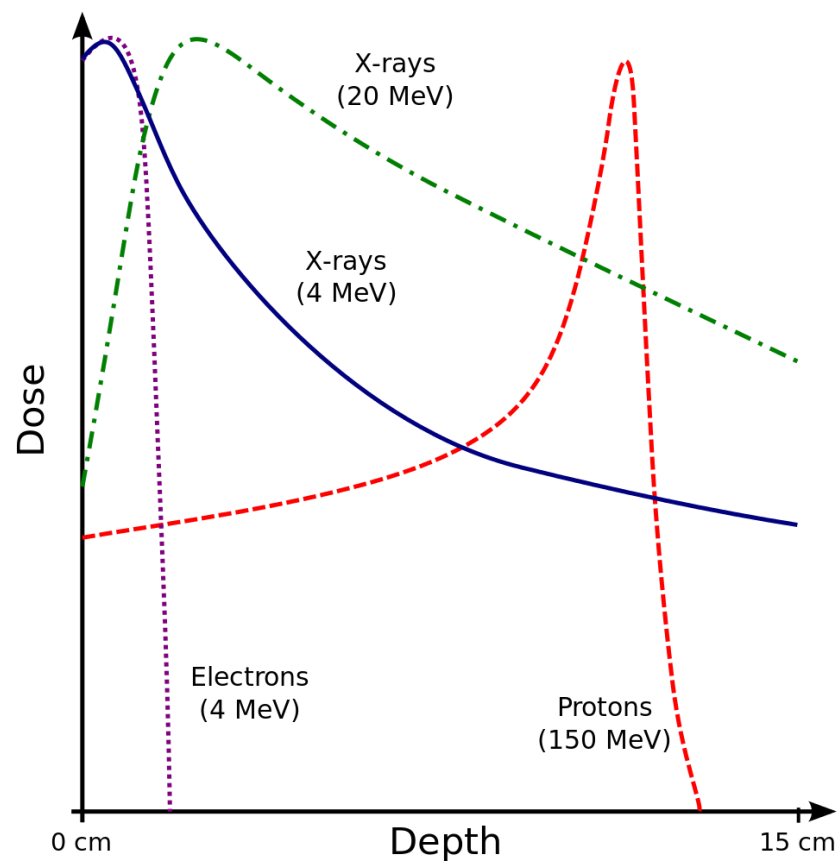


Source: Podgorsak, IAEA

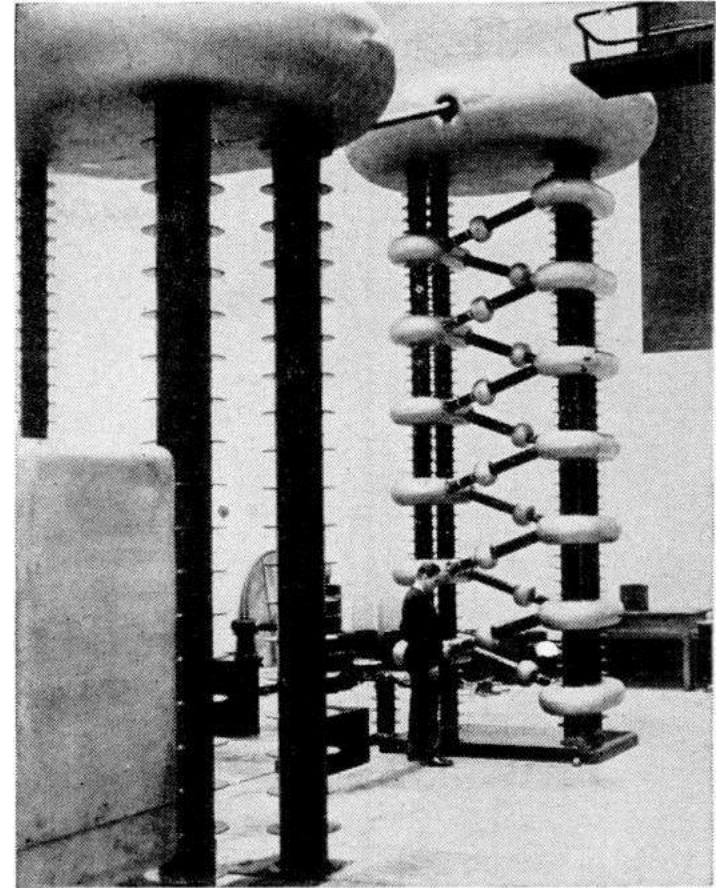
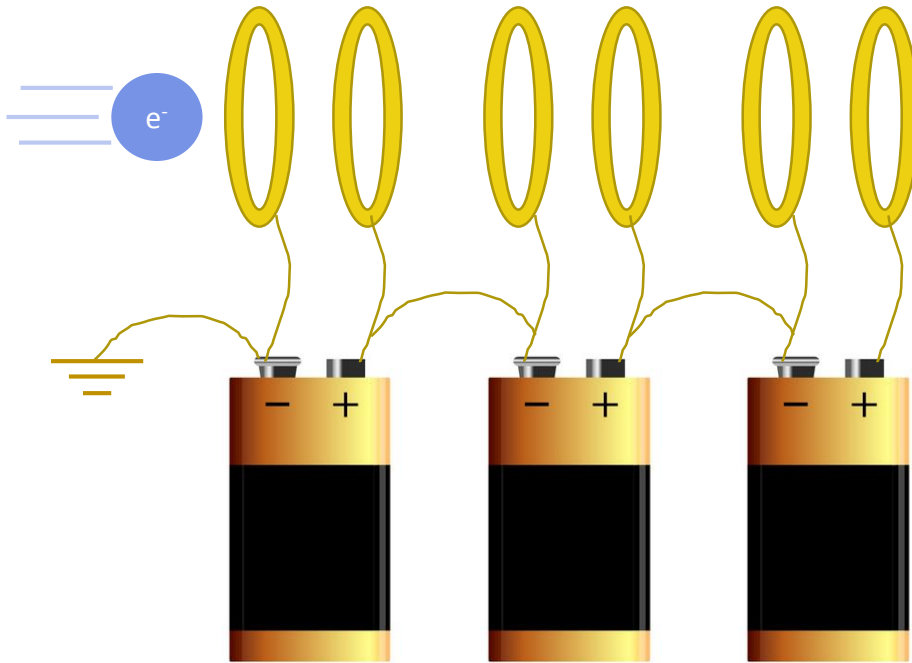
Electron



G. Isaacs, the first retinoblastoma patient treated with an electron beam (1957)

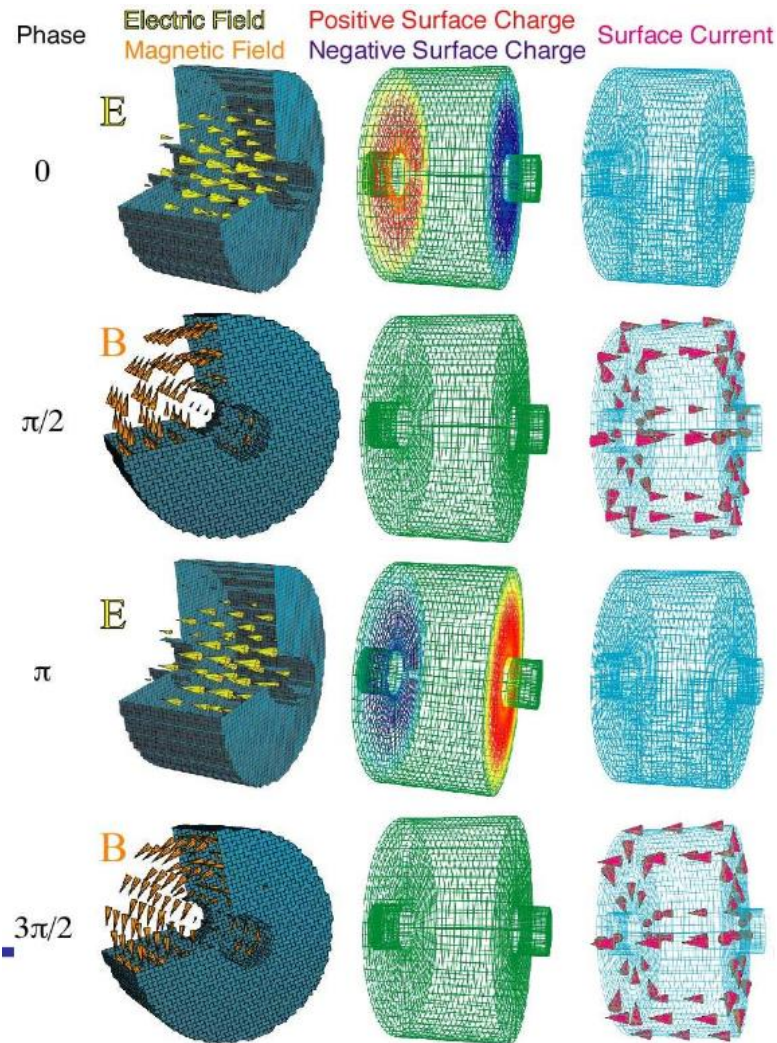


How do we get e to few MeV?

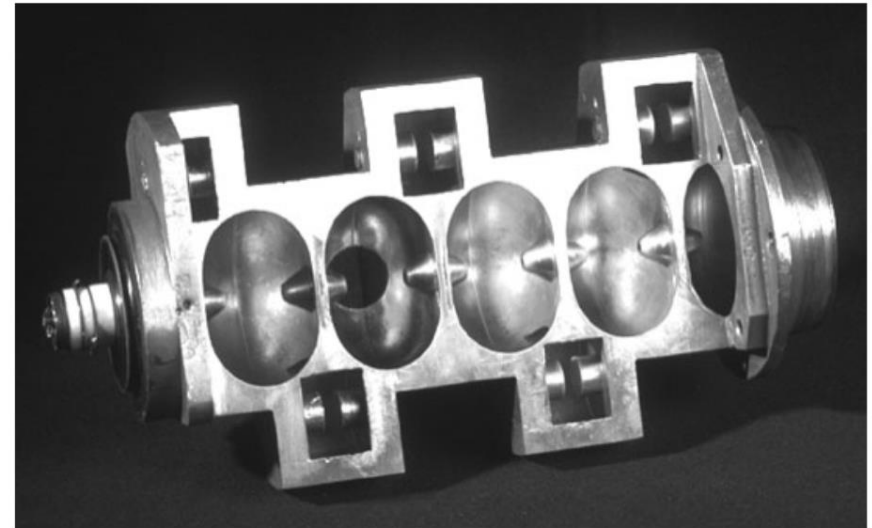


1.2 MV Cockcroft-Walton accelerator at the Clarendon Laboratory, Oxford(1948)

Radio frequency accelerating cavities



Source: M. Liepe, Cornell U. 2008



Cutaway accelerating waveguide of a 6 MV linac.
Source: Podgorsak, IAEA

The Story so far

- We have option to fight cancers.
- Often surgery is the best option
- Radiotherapy can be a powerful tool
- Photon and electron have a long history of success
- We know how to produce and control high quality radiation

Next:

Can we do even better?
What about hadrons?
Can we use the same technology?

Hadron - Proton

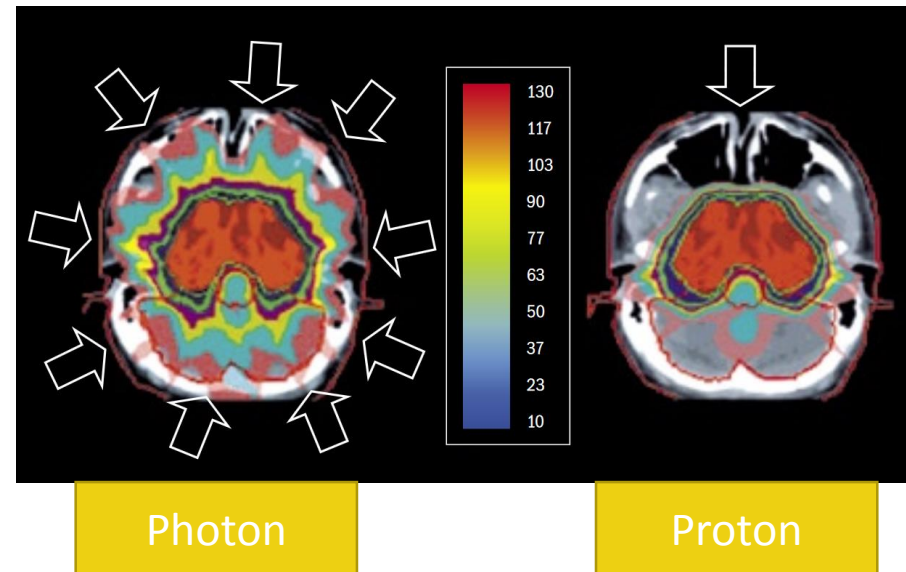
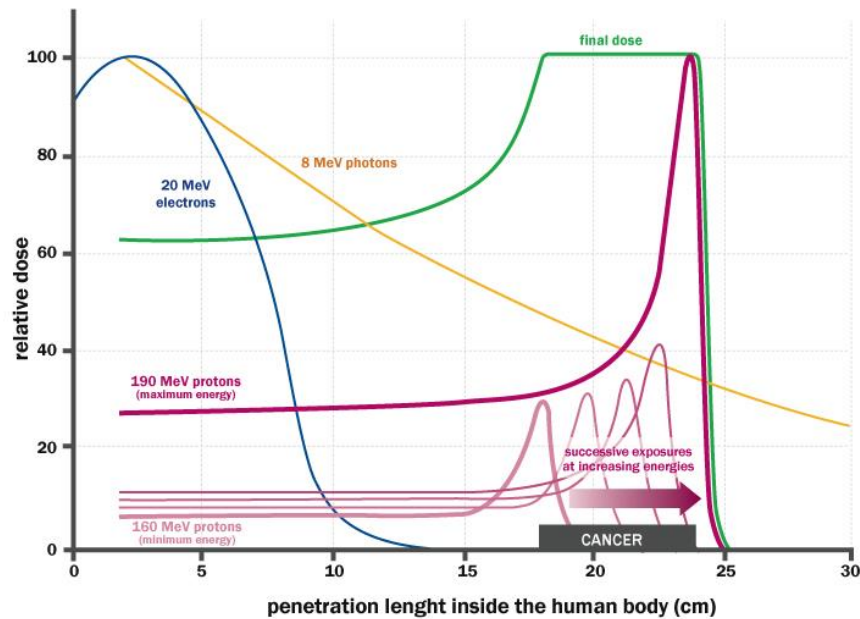
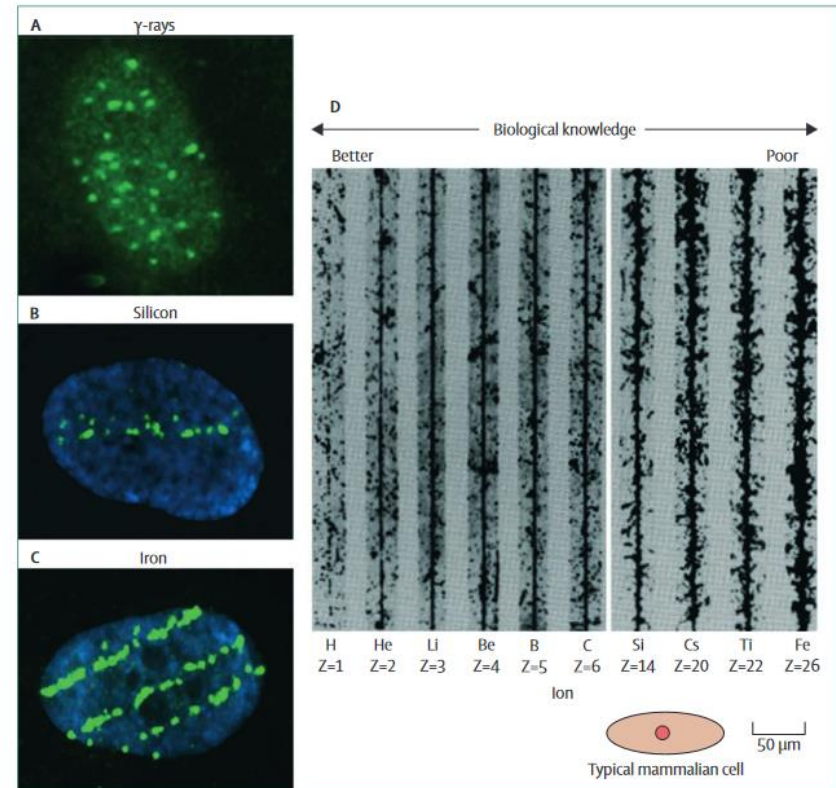
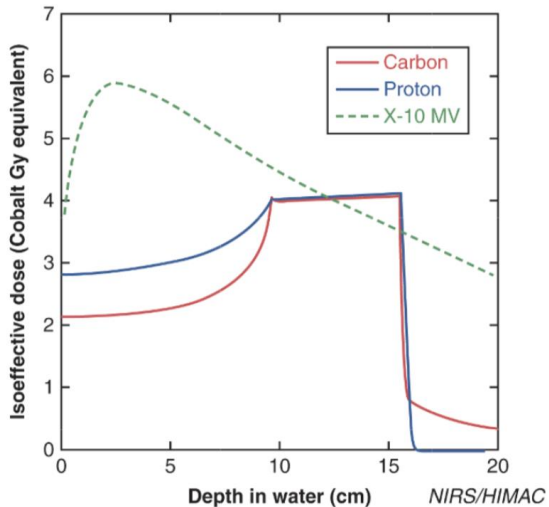
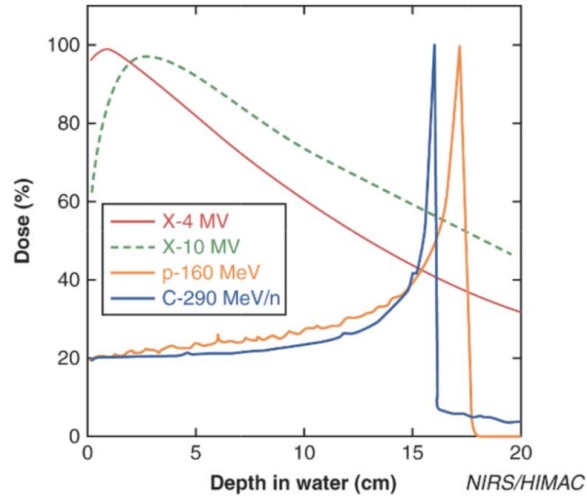


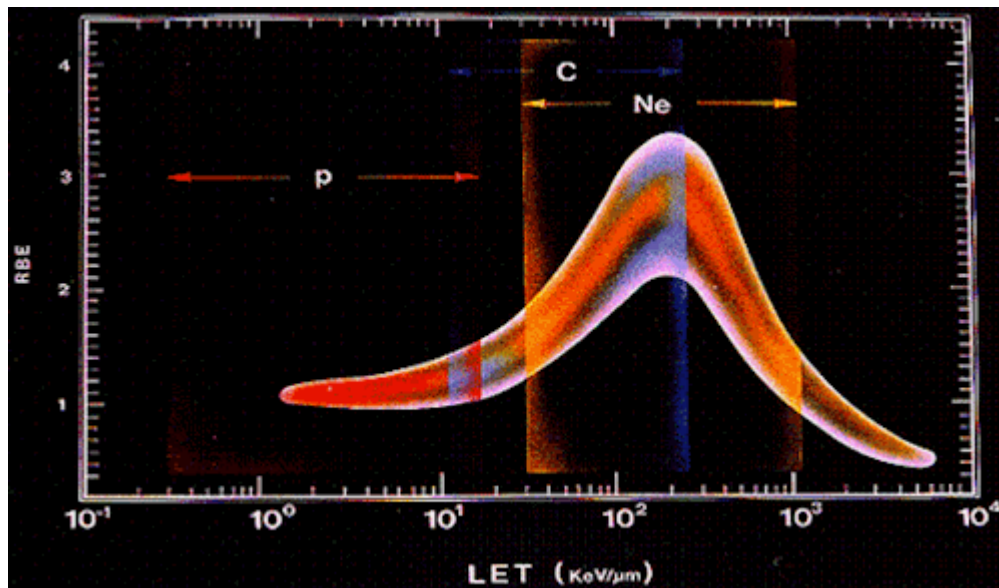
Image credit: INFN/Assimetrie

Hadron – Heavy Ions



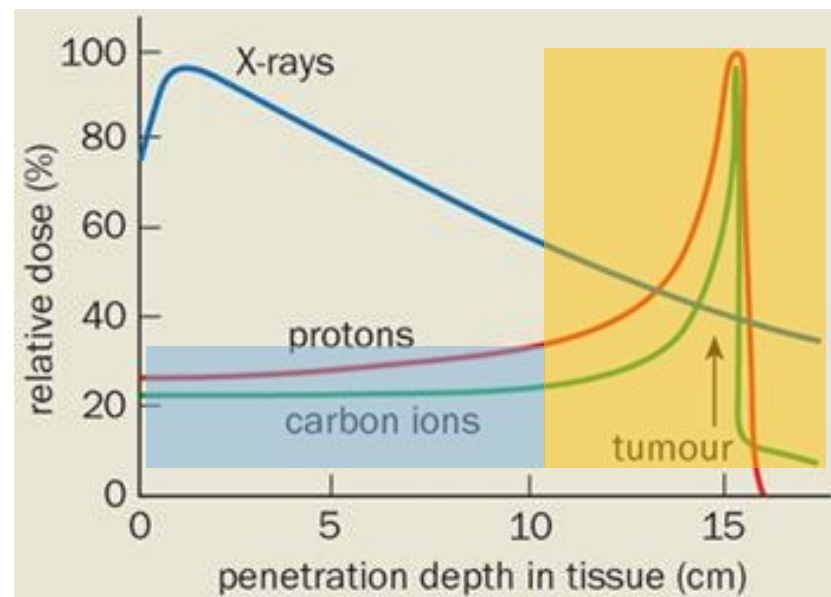
Cucinotta, Durante, 2006

Perez, Brady, Practice of Radiation Oncology, 6th ed.



Source: eli project

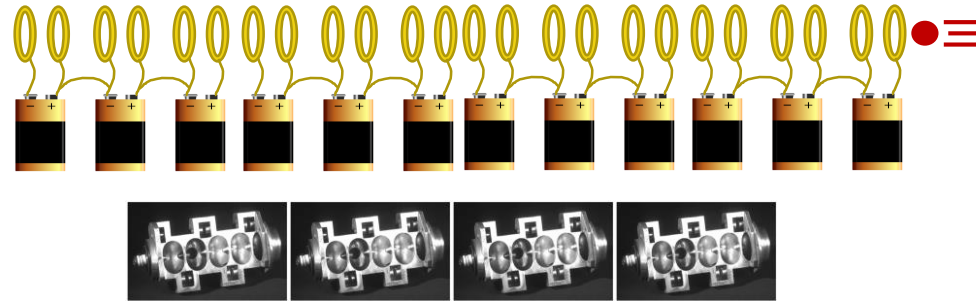
- C: Low radiobiological effect
- C: High radiobiological effect



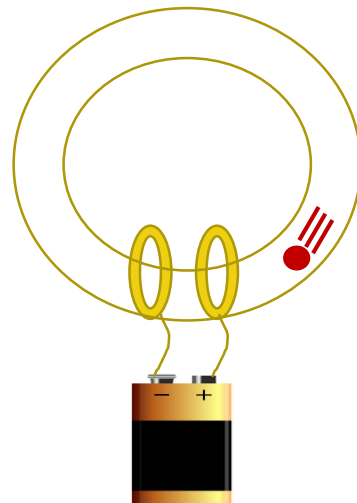
Not discussed hadron: Pion, neutron, He, (antiproton), ...

Accelerate even further?

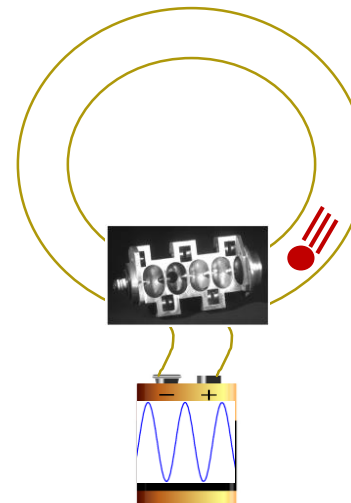
Option A



Option B



Option C

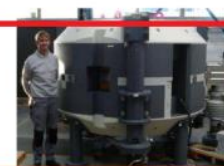
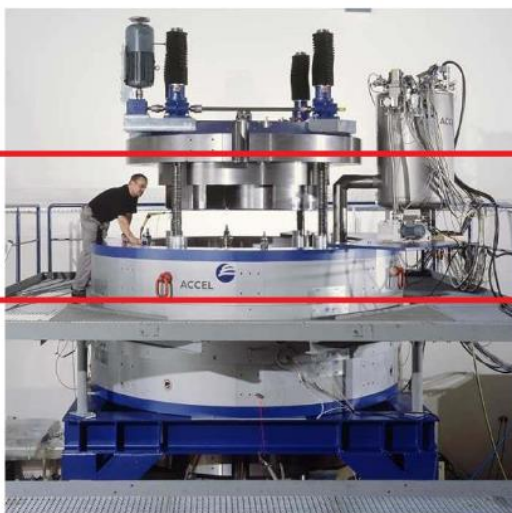
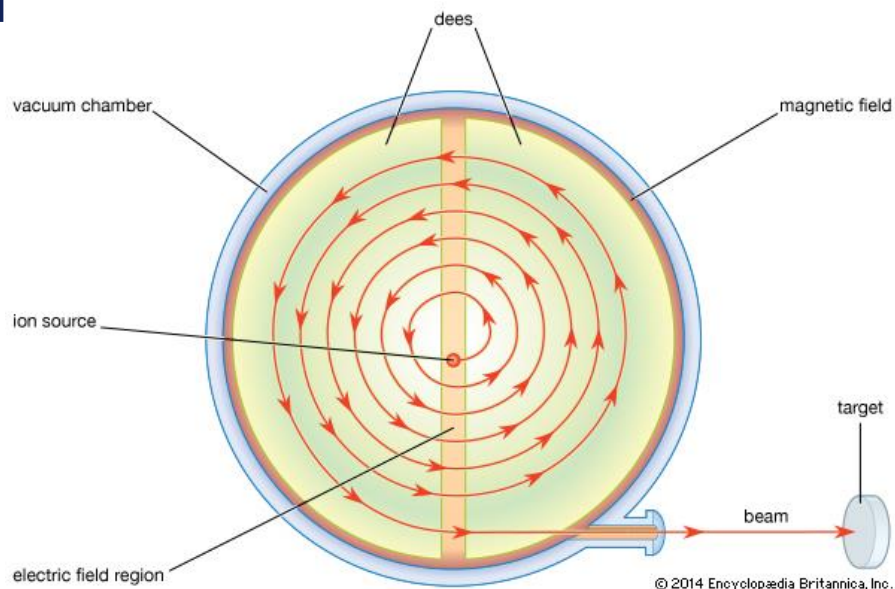


$$\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$$

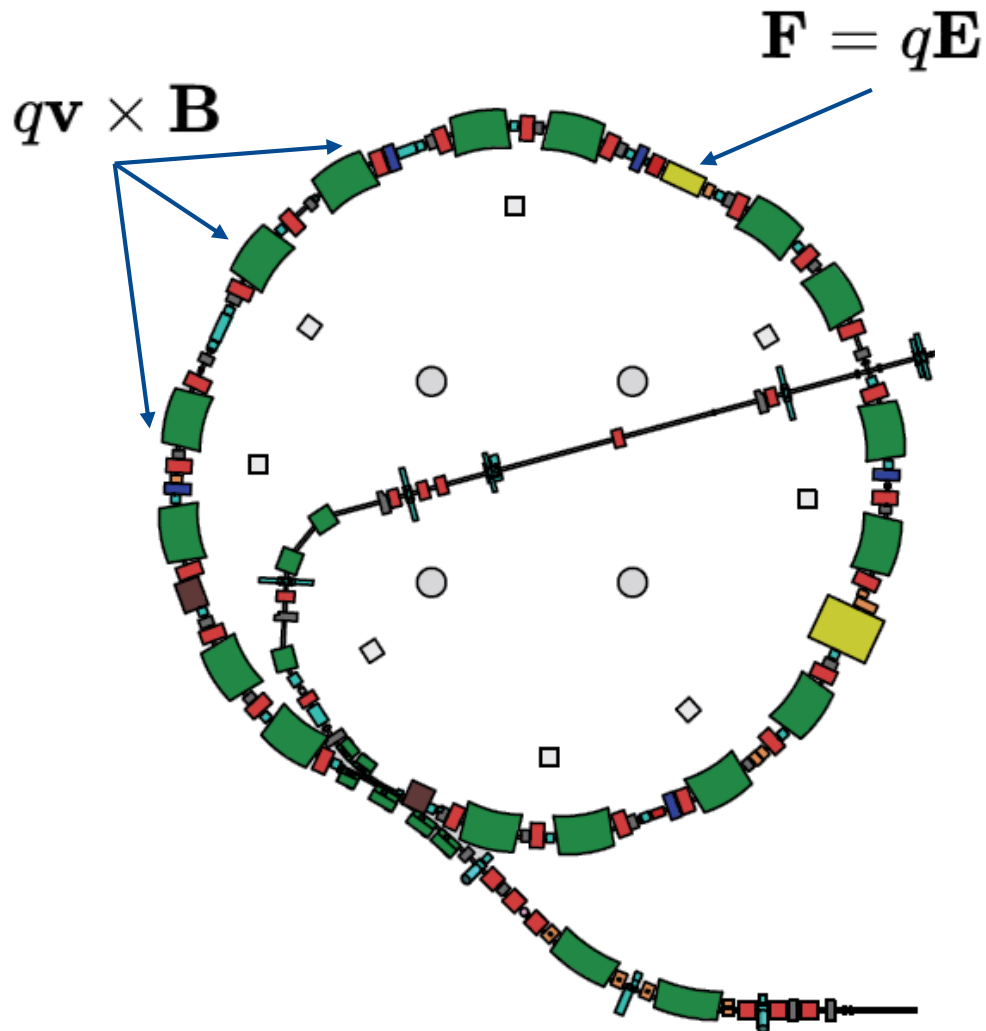
Cyclotron



The first cyclotron,
Lawrence Berkeley National
Laboratory Photo Archives



Synchrotron

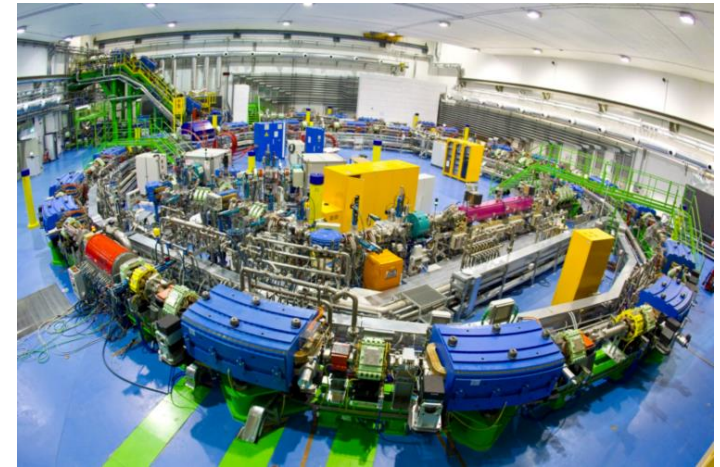


$B \uparrow$ to keep constant path

Same path, with more energy

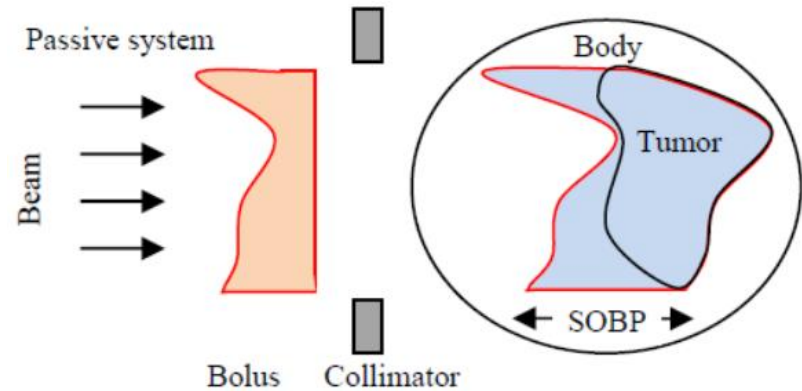
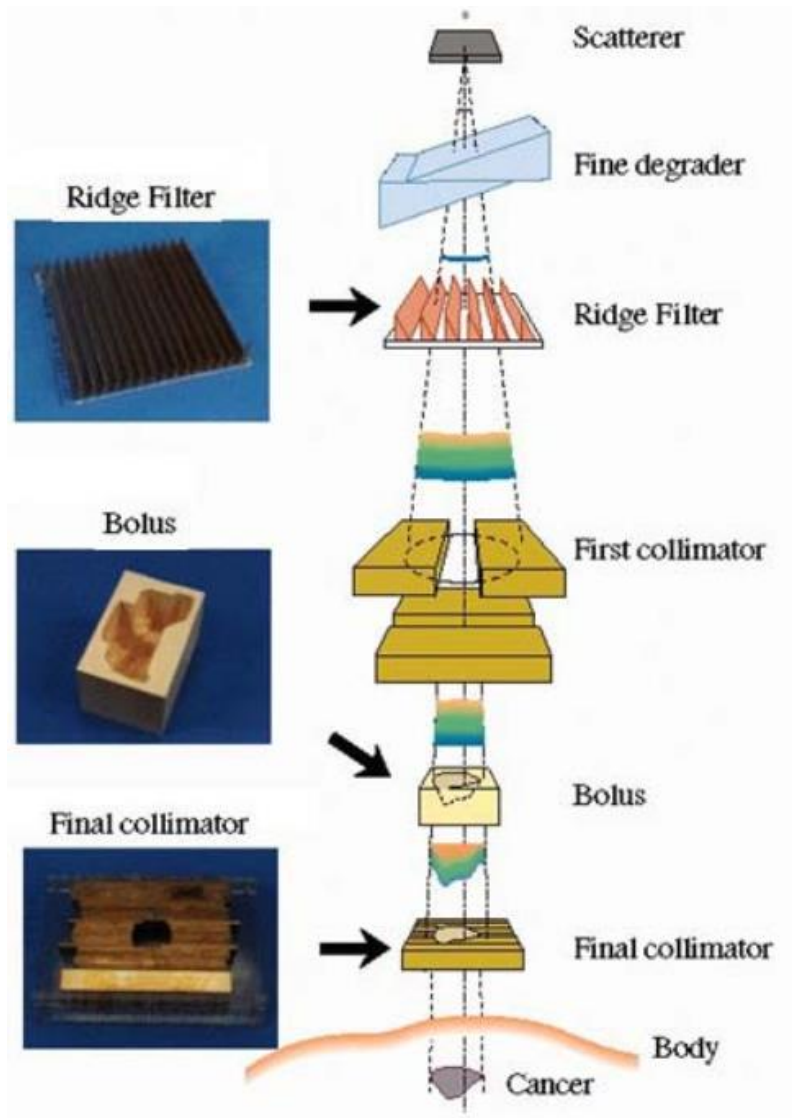
Shorter revolution time

RF freq \uparrow to keep accelerating

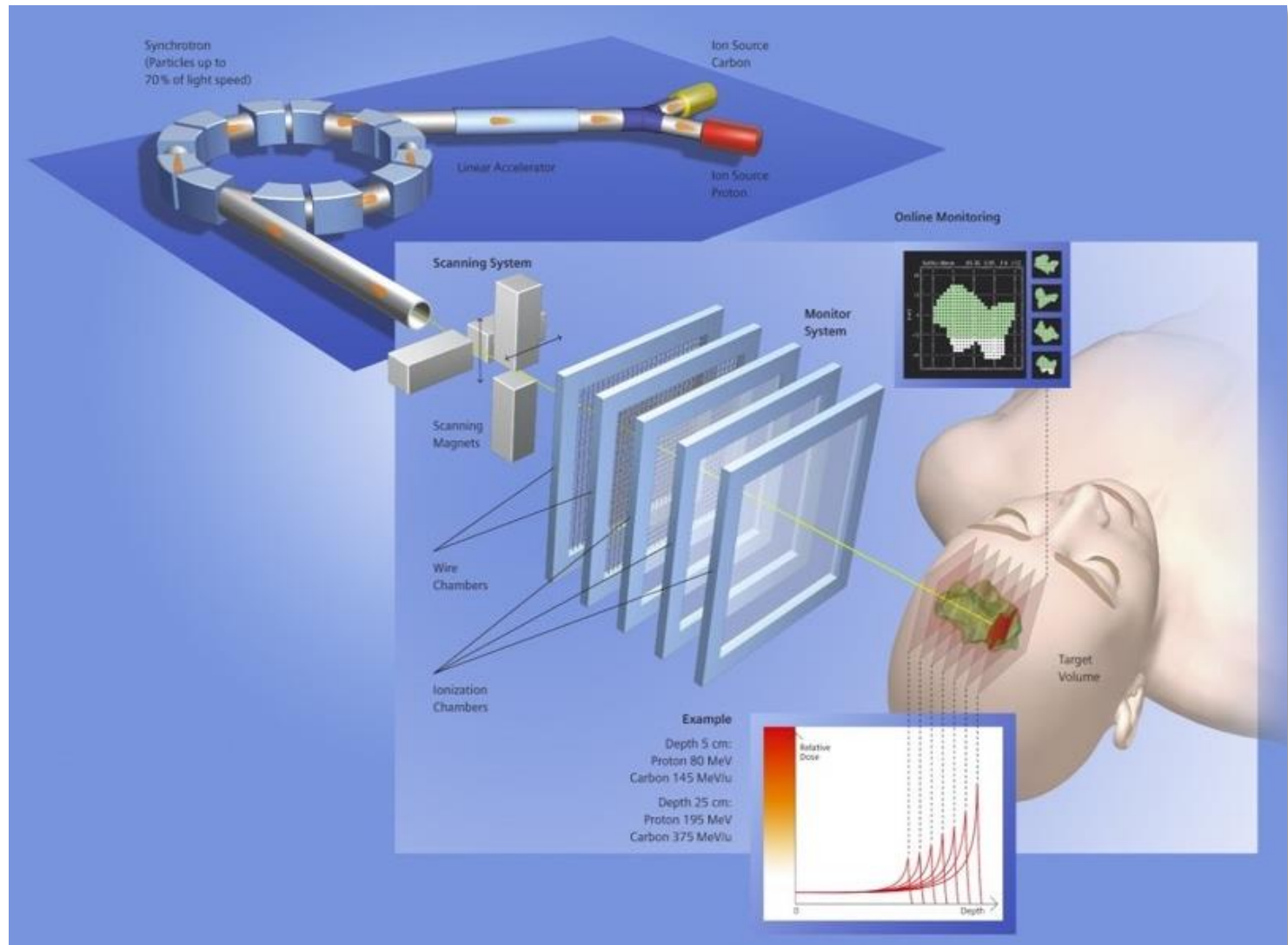


Fondazione CNAO, Pavia Italy

Passive beam delivery



Active beam delivery



The Story so far

- We have option to fight cancers, surgery often best
- Radiotherapy long history, but constantly improving
- We can create photon, electron and hadron based therapy
- We know how to accelerate and precisely deliver charged particles
- We have options tailored for energy and particle type

Next:

From now on focus on hadron therapy.
How available is this technology?
Is it everywhere?
When do we start talking about MedAustron??

Particle Therapy Centers Worldwide: 68

(in operation by August 2017)



© MedAustron • Data: PTCOG, August 2017

Particle Therapy Centers in Europe: 20

(in operation by August 2017)

- Protons
- Protons & Carbon Ions



© MedAustron • Data: PTCOG, August 2017

Carbon Ion Centers Worldwide: 11

(in operation by August 2017)

4

HIT Heidelberg
MIT Marburg
CNAO Pavia
MedAustron

Europe

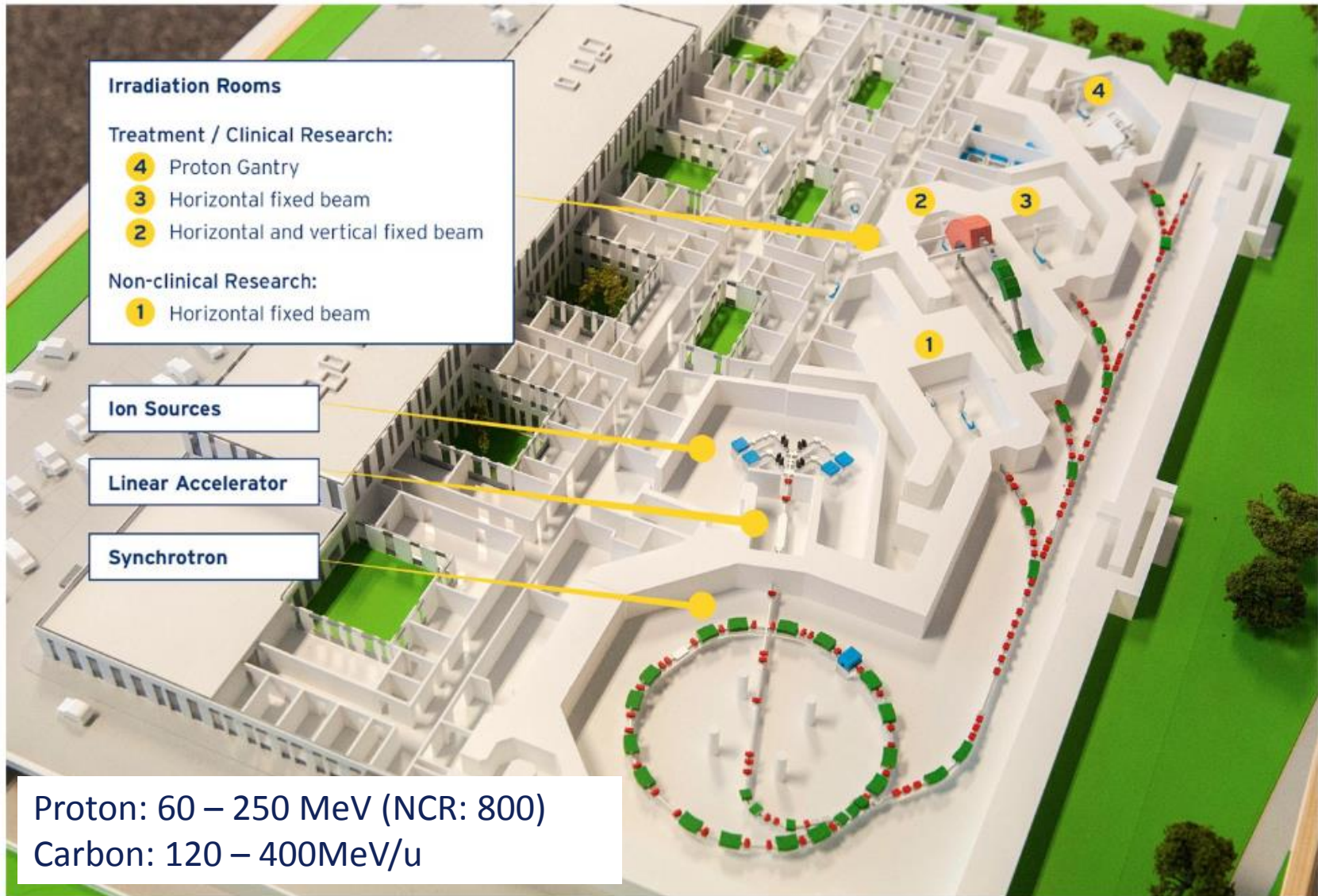
7

Asia

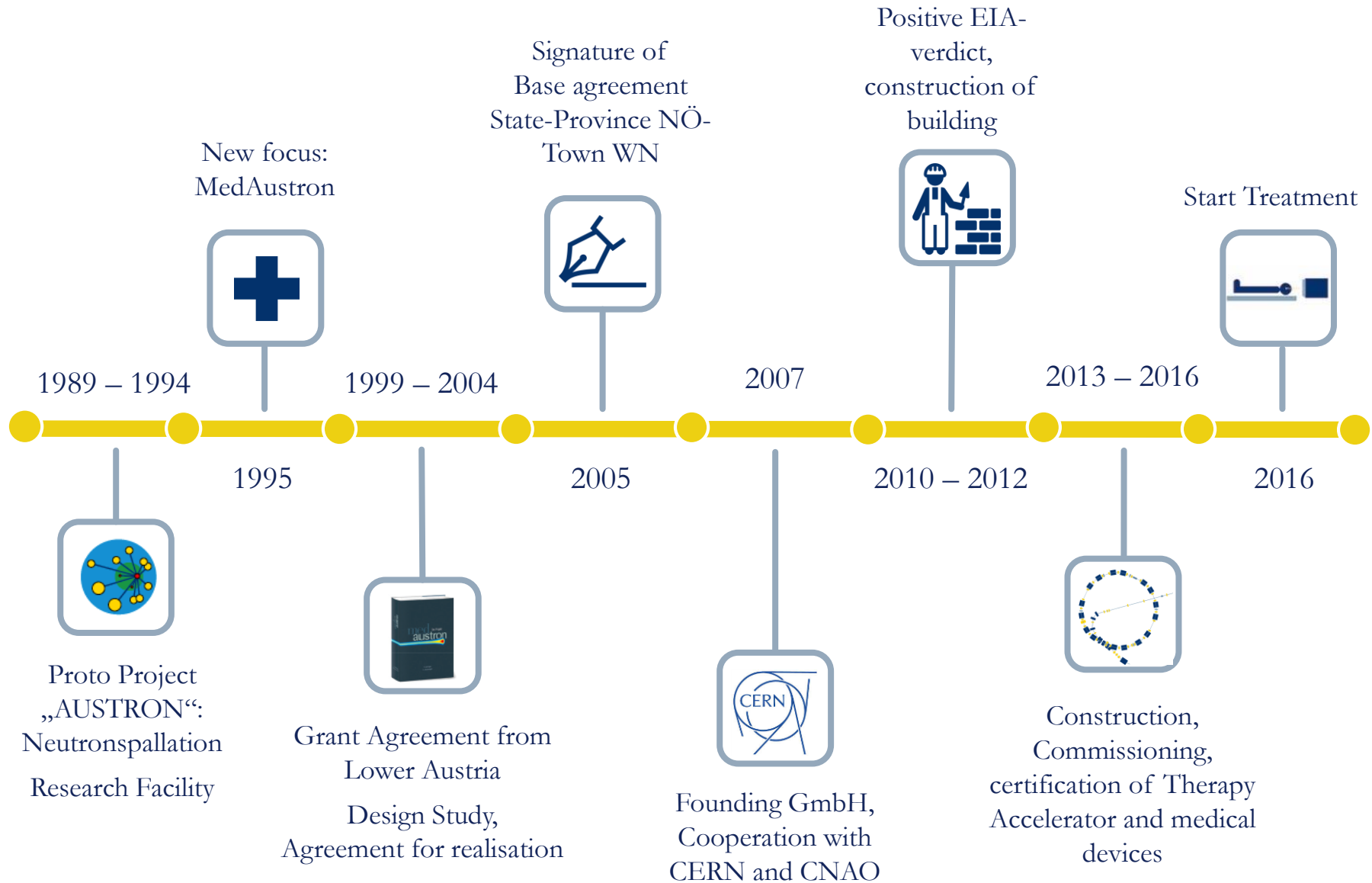


© MedAustron • Data: PTCOG, August 2017

MedAustron: The Facility

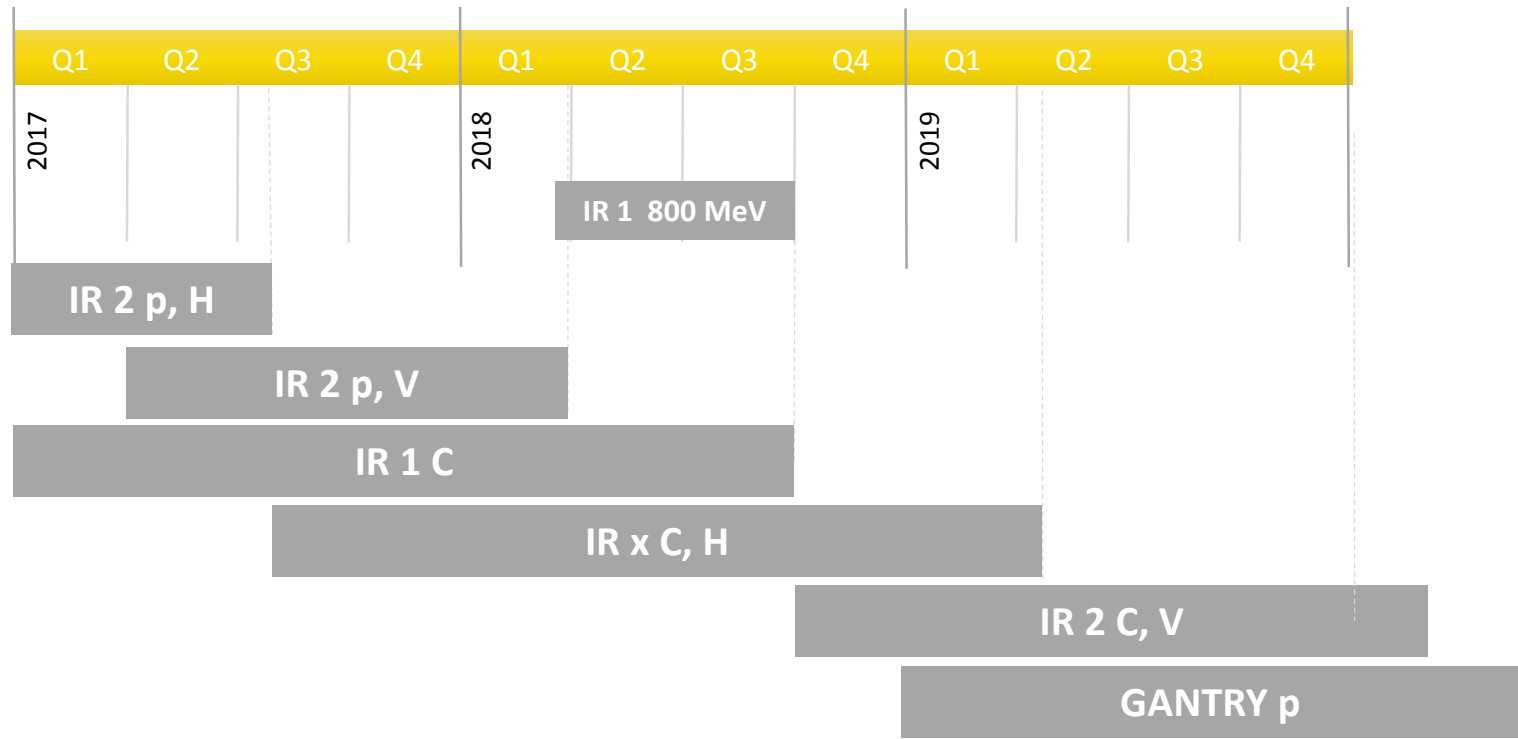


The History



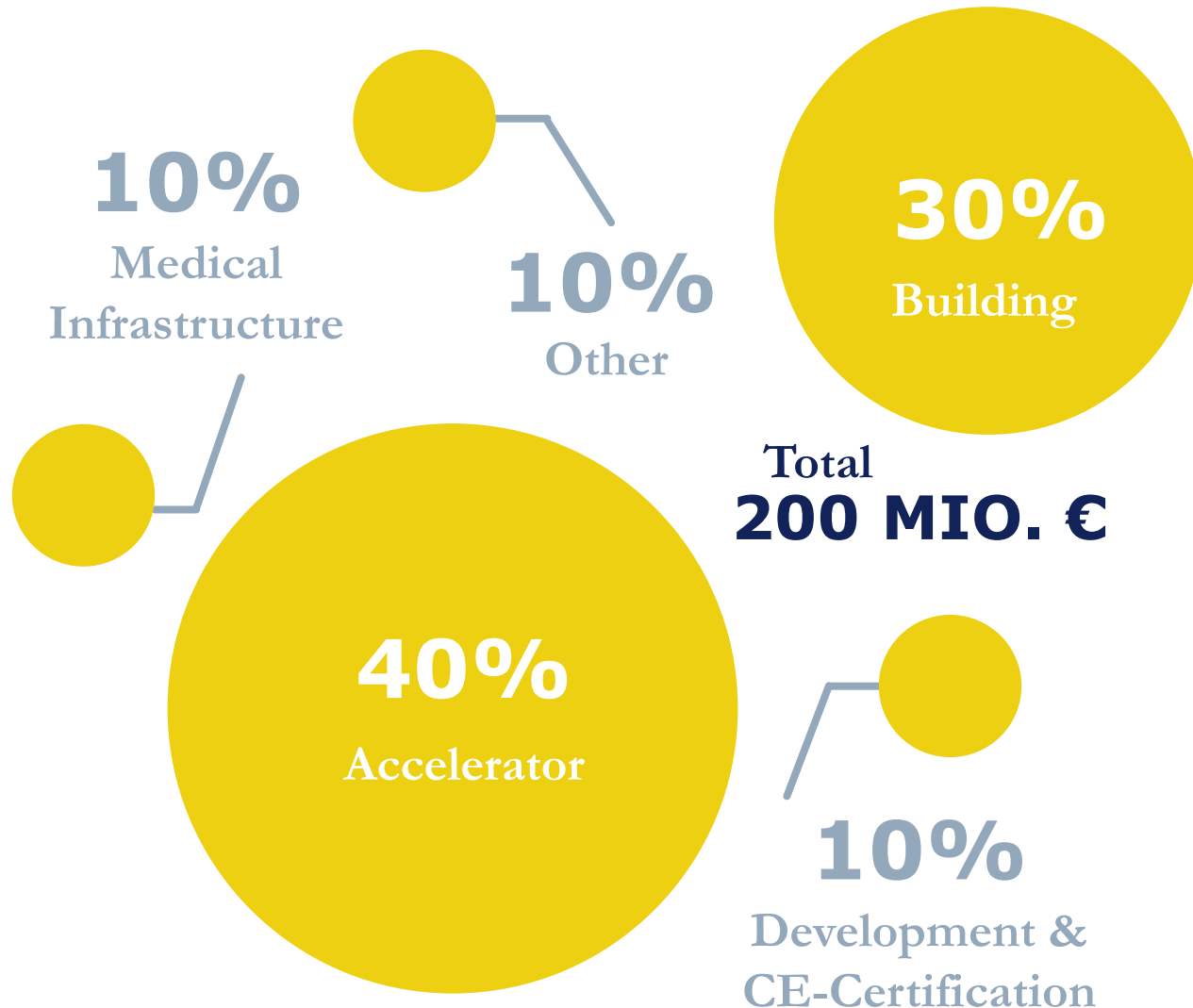
The Future

MedAustron roadmap 2017 - 2019



And many development in between...

The Investment



VIRTUAL TOUR

MedAustron 

MedAustron



Gas

Proton from H_2 . C from CO_2 (+ He_2)



Ion Sources

Where it begins



Low Energy Beam Transfer

Source / Particle type selection



LINEAR ACCELERATOR

A kick to 7MeV/nucleon

SYNCHROTRON

2012



SYNCHROTRON

2013

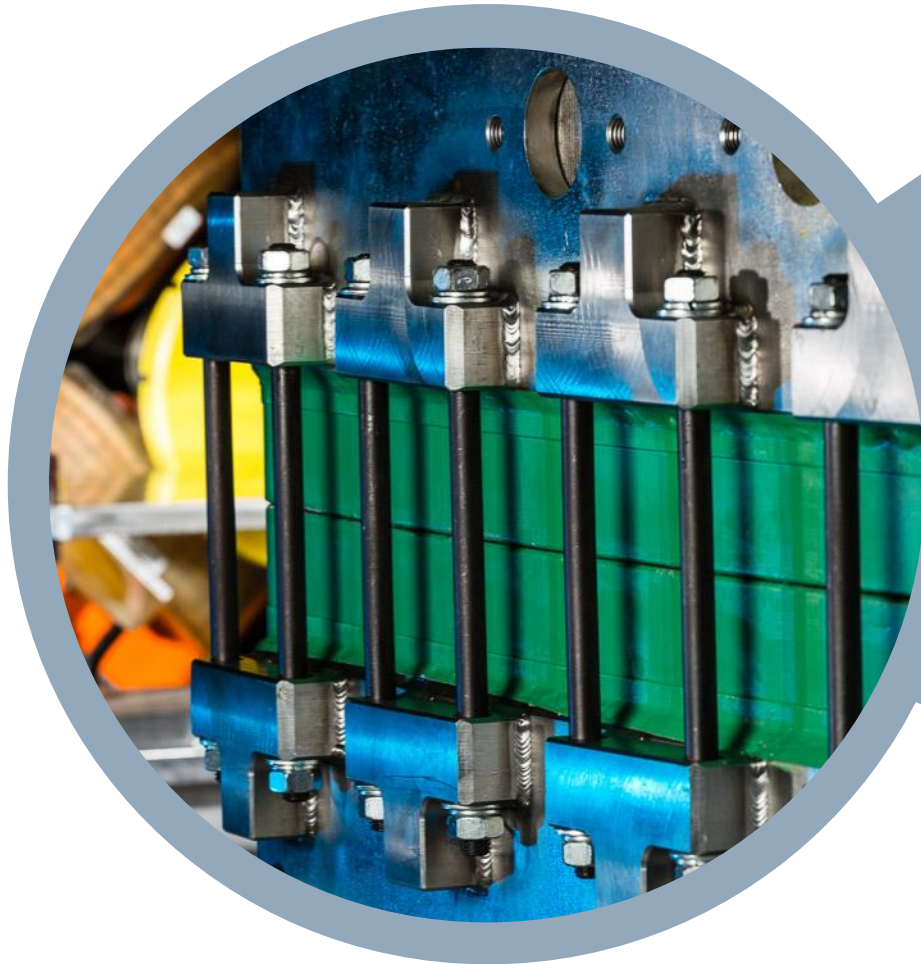


SYNCHROTRON

Where the magic happens



MAGNETS



285 Magnets

30 different types

700 Tons of steel

90° Dipole

The beast...September 2015



90° Dipole

120 Tons



PROTON GANTRY



- Weight: 220 t
- Curvature diameter: 7.5 m
- Precision: $< 0.1^\circ$
- Isocenter: $< 0.3 \text{ mm}$



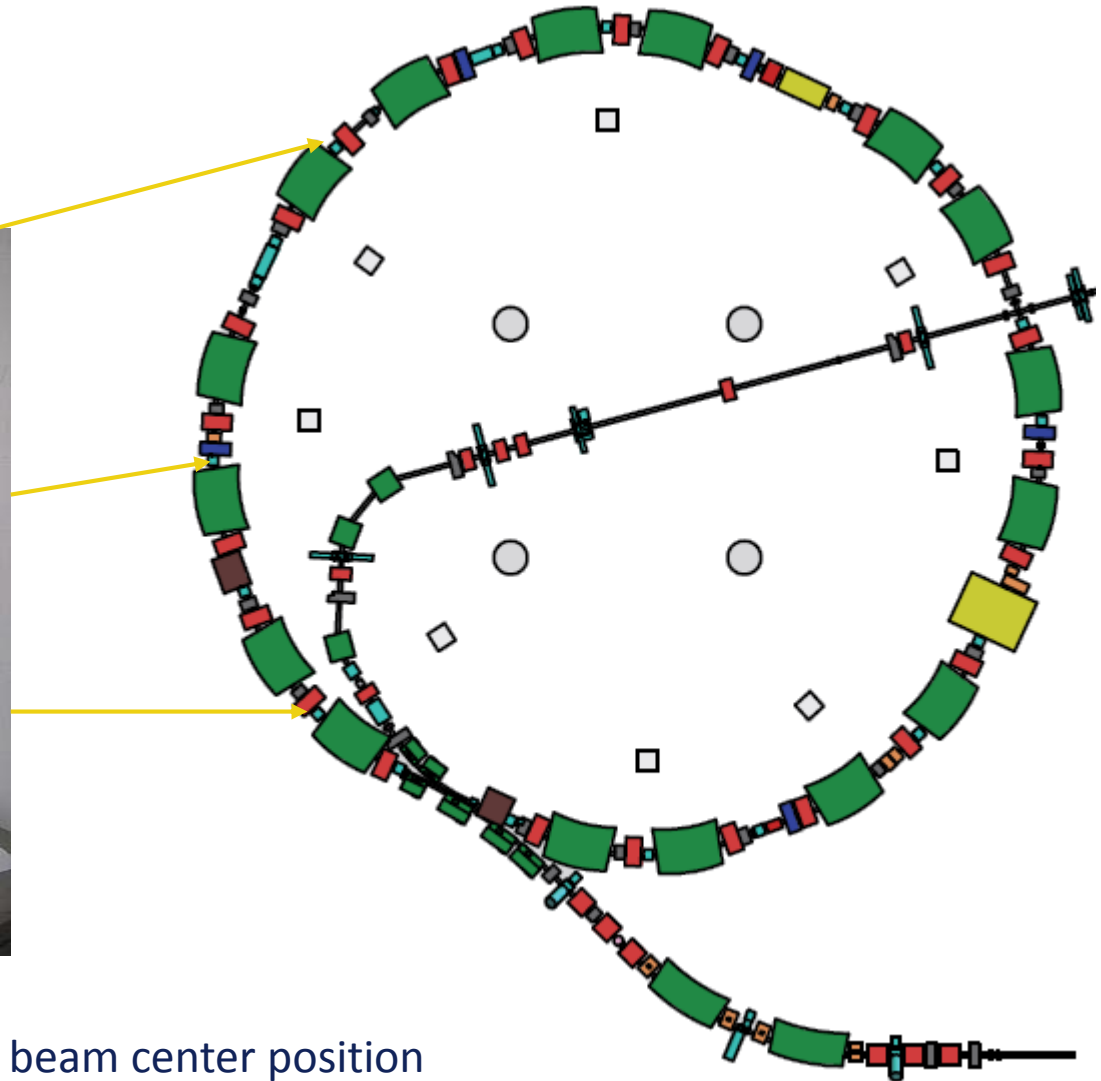
PROTON GANTRY

With Irradiation Room

THE TOYS

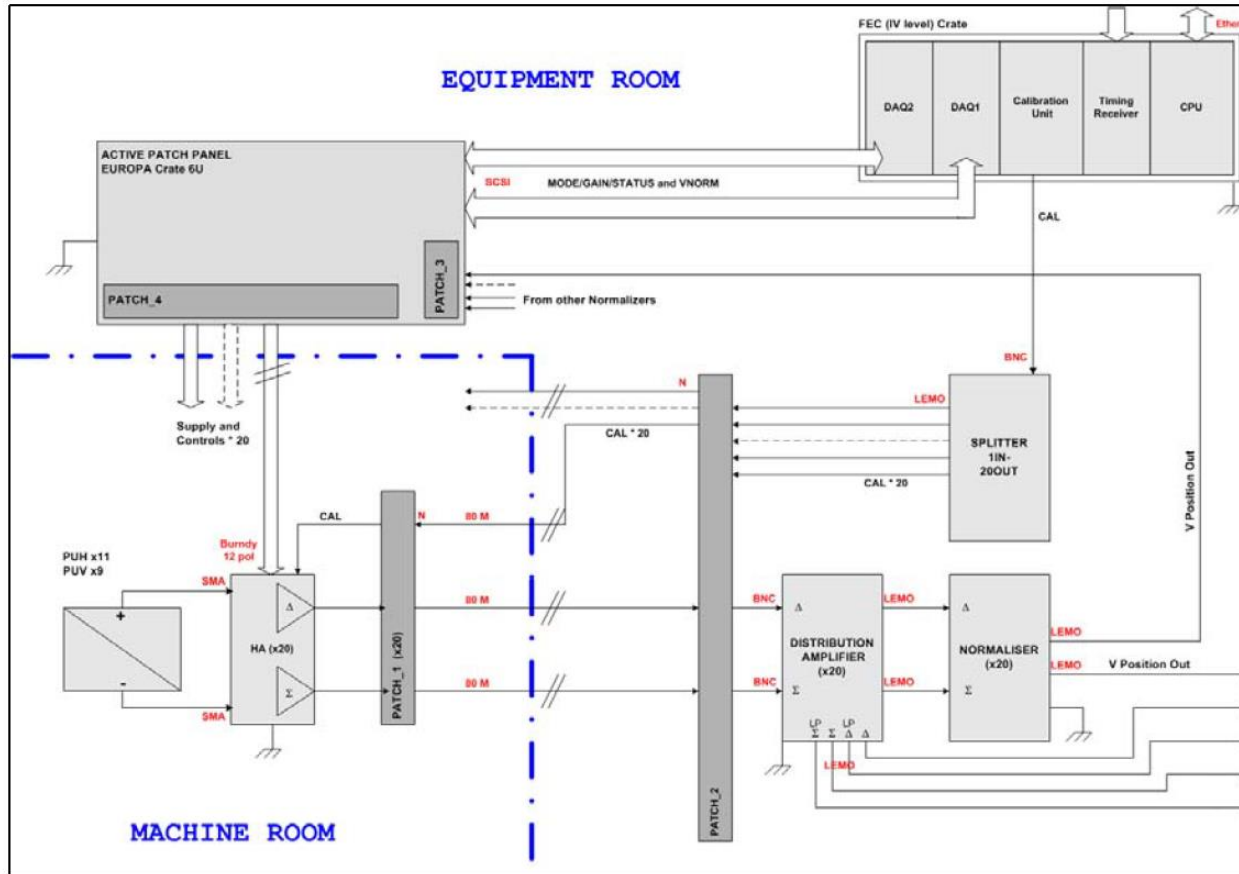
Example: Position measurement in the ring

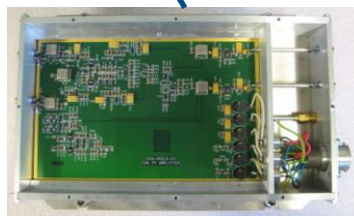
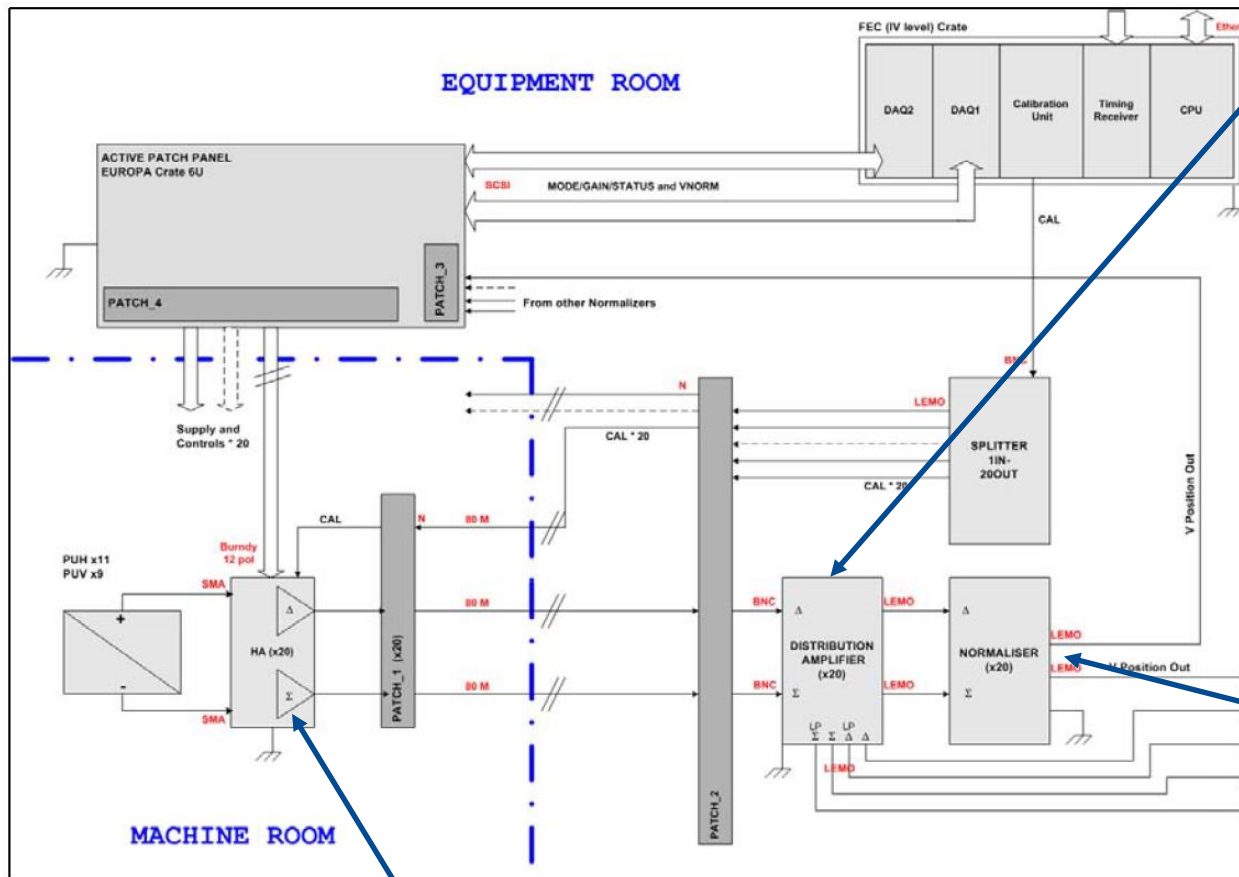
Pick up in the ring

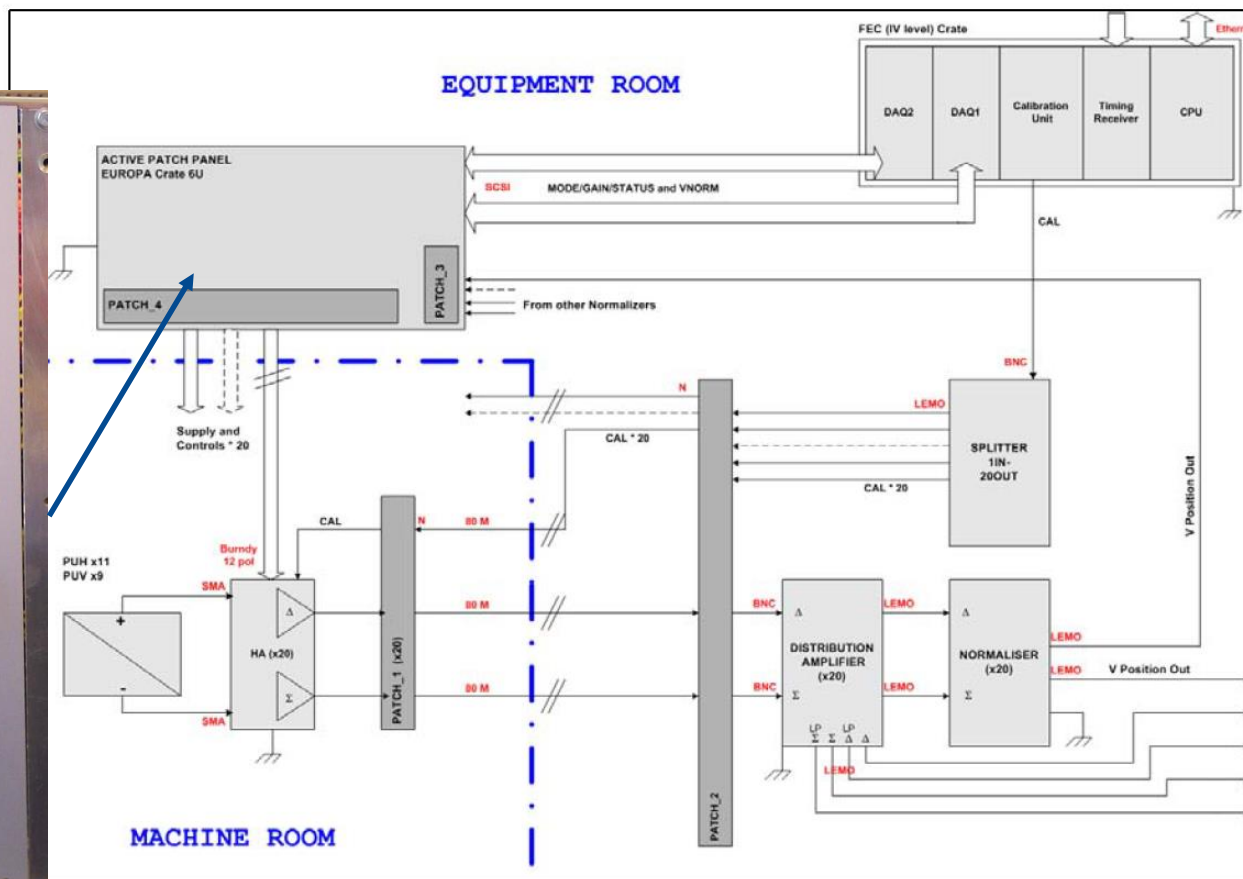


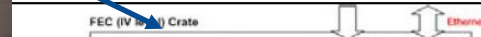
A device sensitive to the beam center position

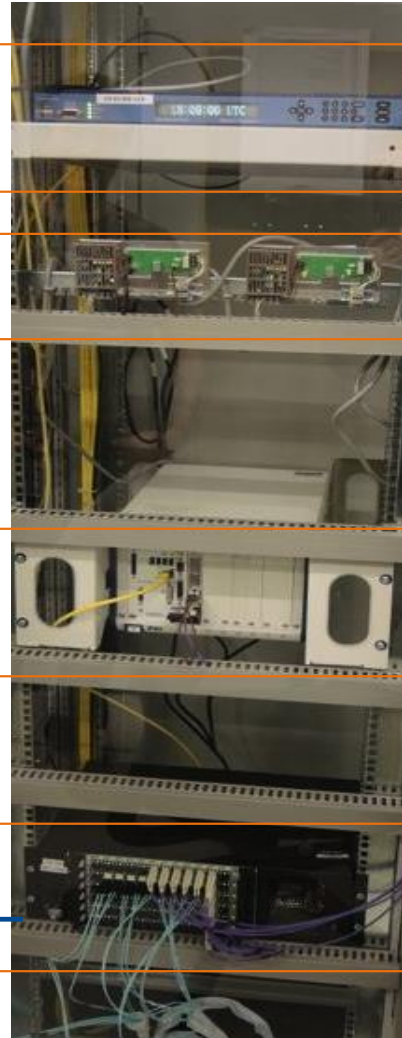
Pick up in the ring - DAQ











GPS/NTP

Provides pulse per second,
10 MHz reference
GPS date and timestamp

OCXO

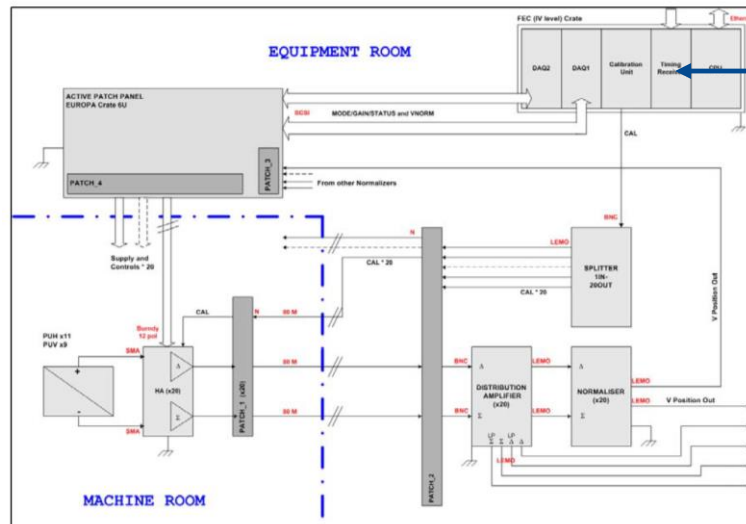
Multiplies 10 MHz to 100 MHz
for PXIe reference frequency

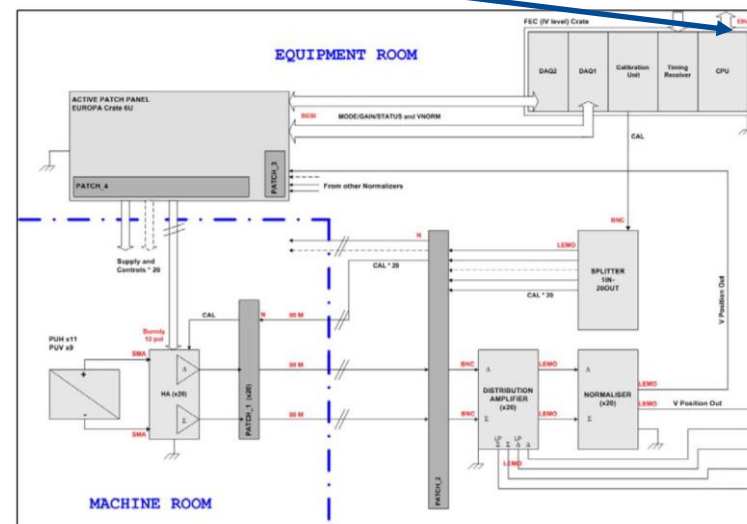
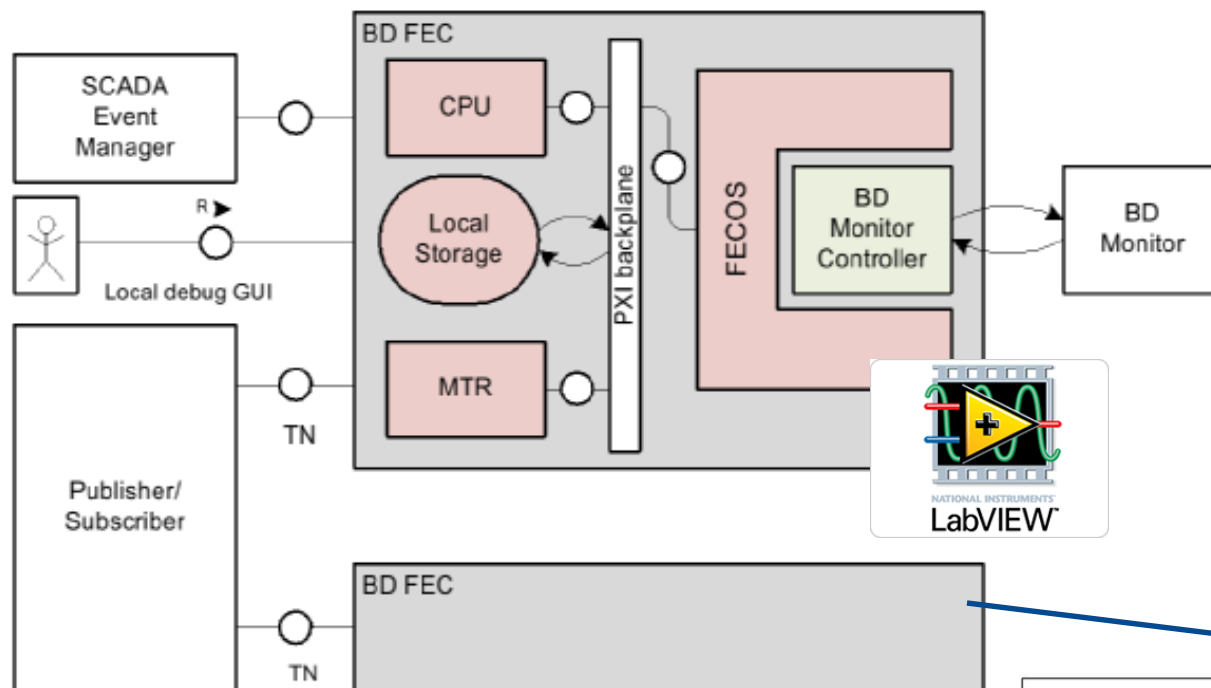
Main Timing Generator

PXIe crate & CPU, MRF EVG,
application software

Optical Fanout

Broadcast of timing event and
Command stream to FECs





THANK YOU

