



Unique Aspects of Accelerators for Medical Application: What is so special?

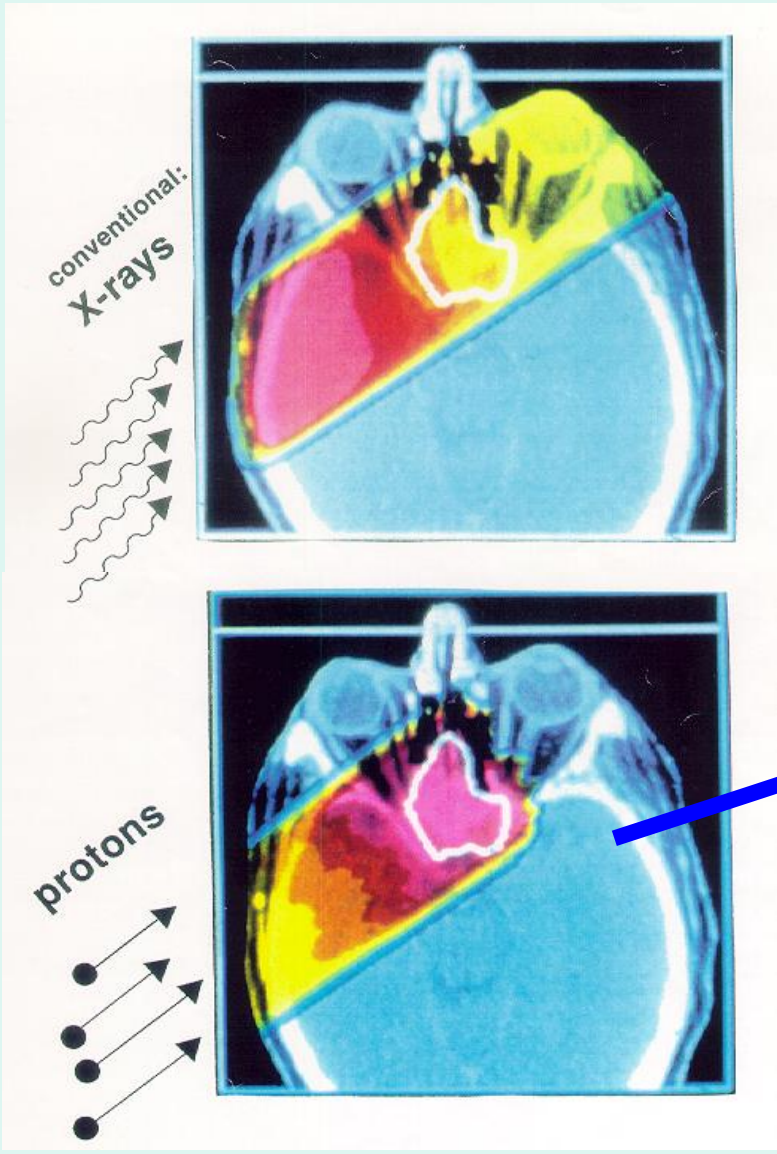
Marco Schippers, Mike Seidel



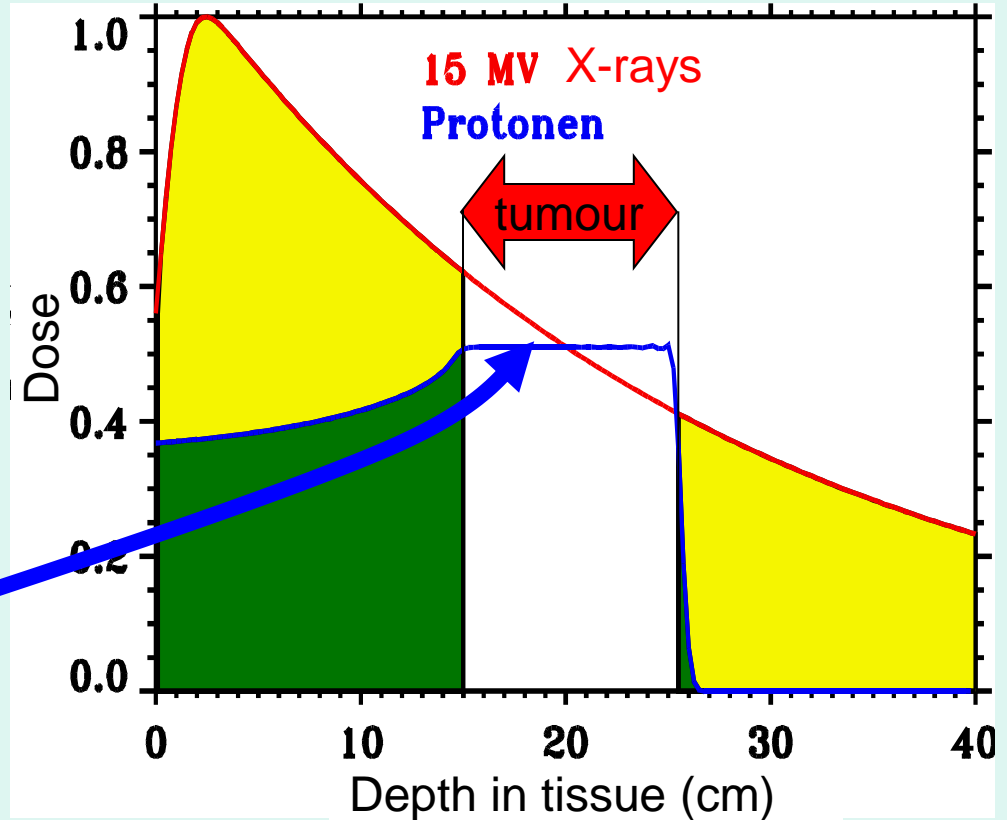
Application: **Particle Therapy**

- Introduction
- How to apply the radiation dose
- Accelerators and beam transport
- Operational aspects
- Safety

X-rays vs. Protons

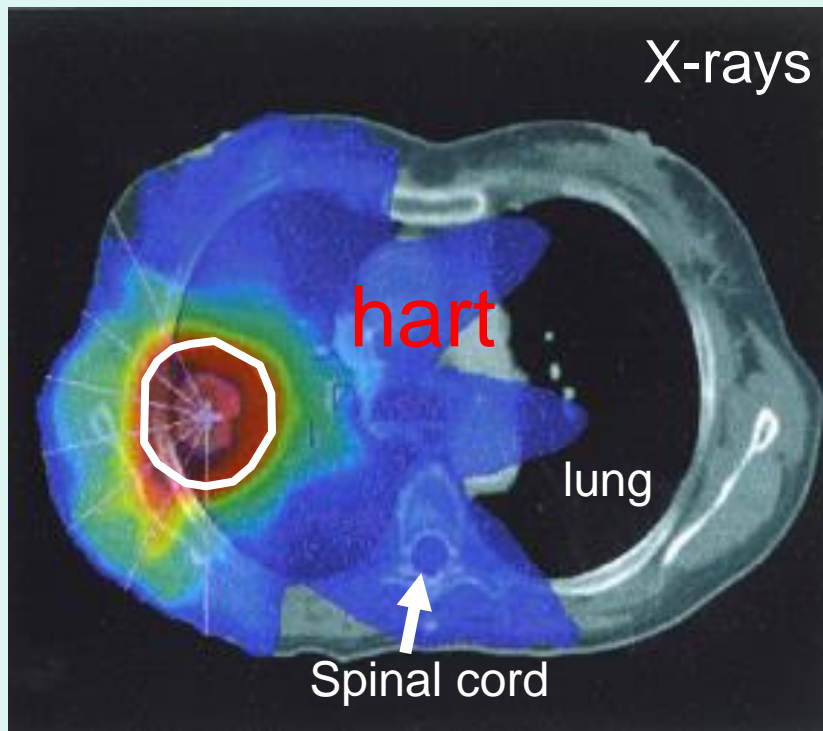


Depth-dose curve:

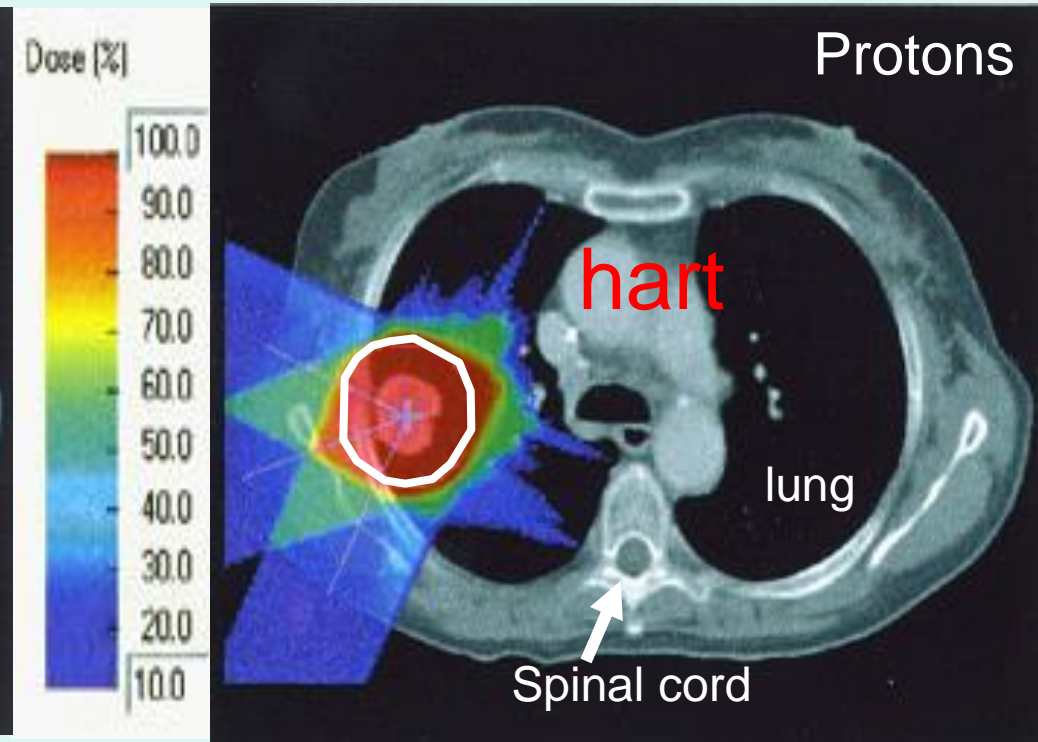


X-rays vs. Protons

X-ray beams (IMRT)
from 7 directions

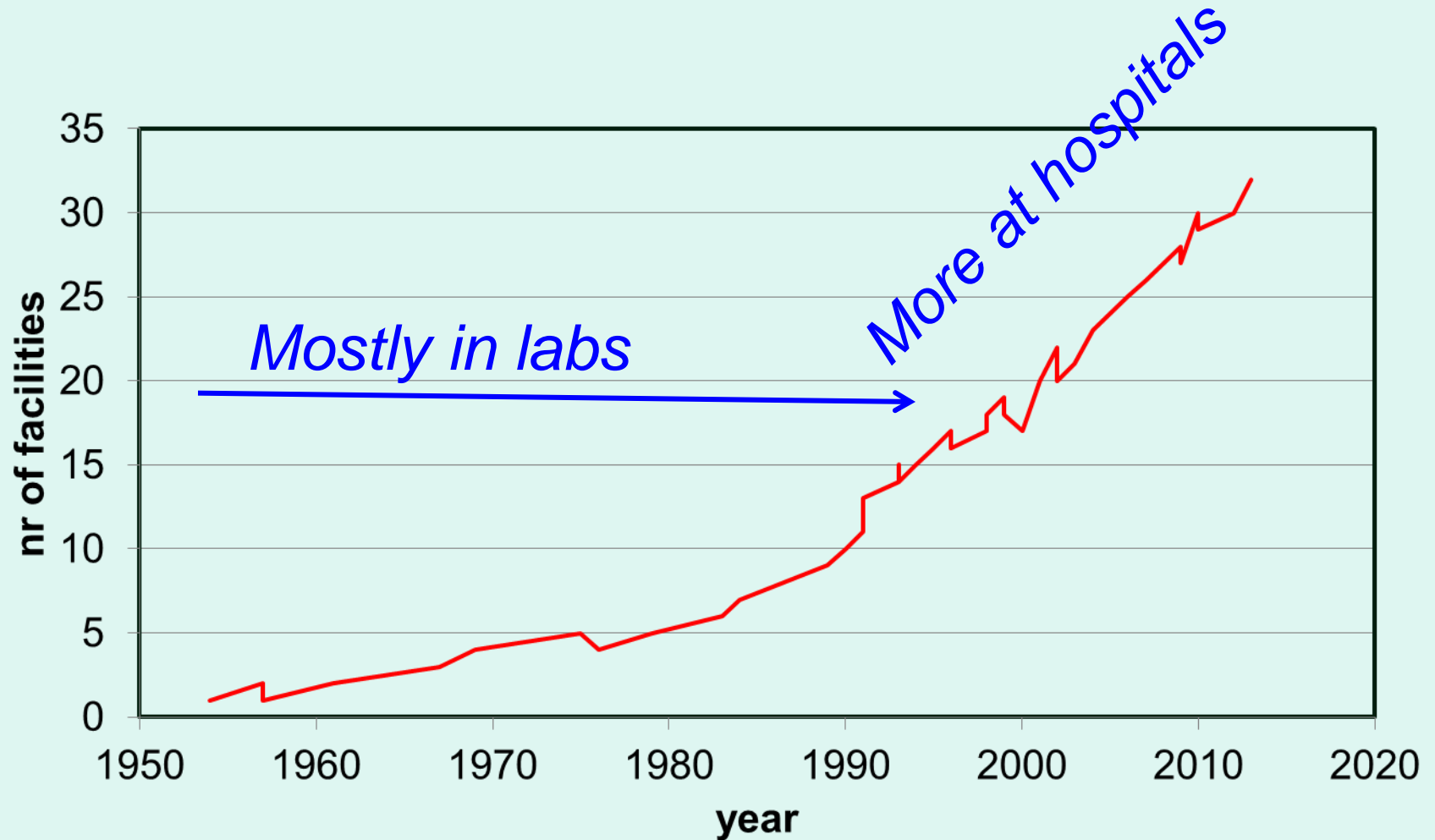


Proton beams
from 3 directions

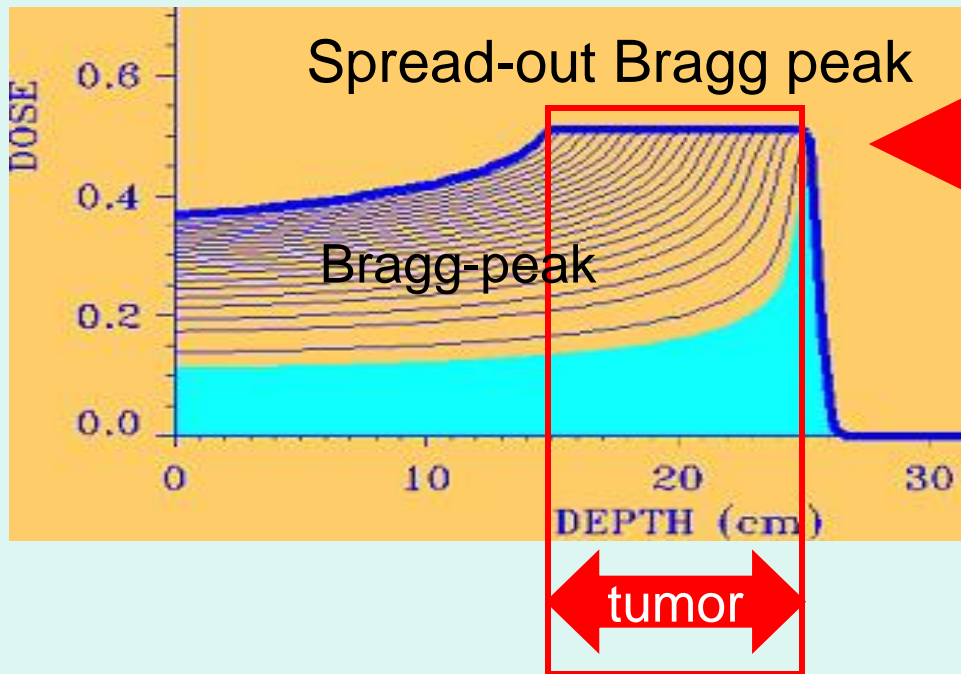


pictures: MedAustron

The boost in particle therapy



Dose delivery techniques: **Depth**



Range

Tumor rear edge

→ Range

→ Maximum Energy
per field → „slow“ (sec)

Tumor thickness

→ spread-out Bragg peak

→ energy modulation

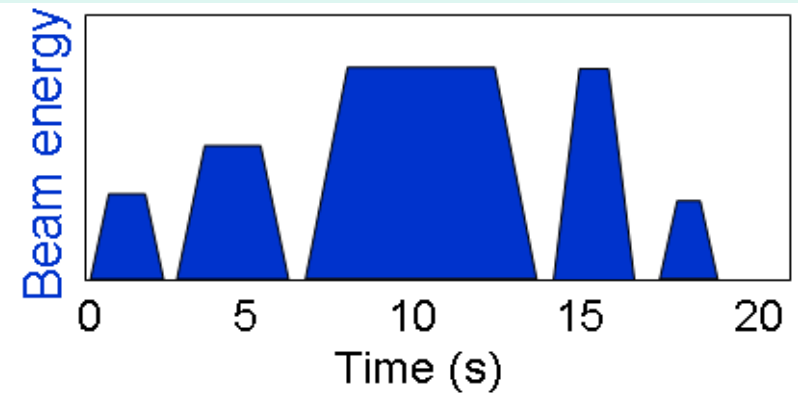
During trmt → „fast“ (<0.1-0.2 sec)

Dose delivery techniques: **Depth**

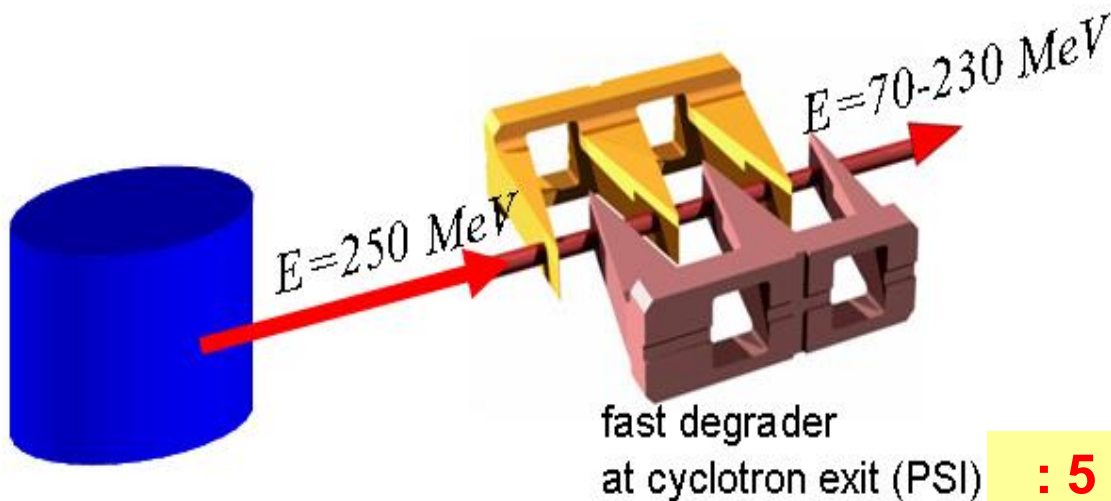
Vary energy at accelerator

Synchrotron: Set energy at each spill:

- Sets range only
- energy modulation in nozzle



Cyclotron has fixed energy => slow down (degrade) to desired energy

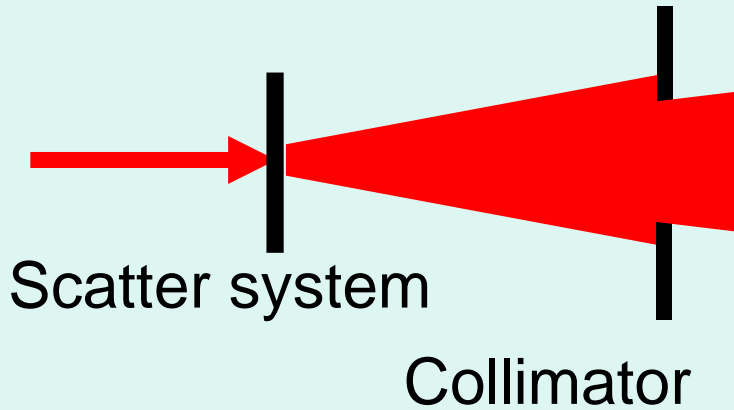


- Sets range
- And**, if fast enough
+ fast magnets:
- also energy modulation

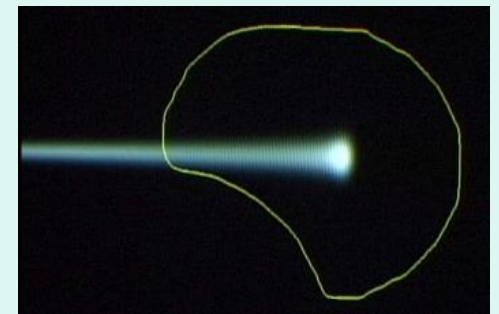
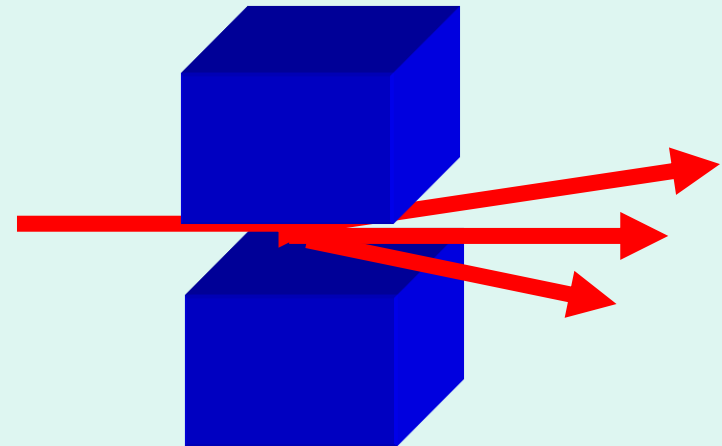
: 5 mm Δ Range in 100-200 ms

Dose delivery techniques: lateral

Scatter technique



Best dose distribution pencil-beam scanning



Pencil beam scanning

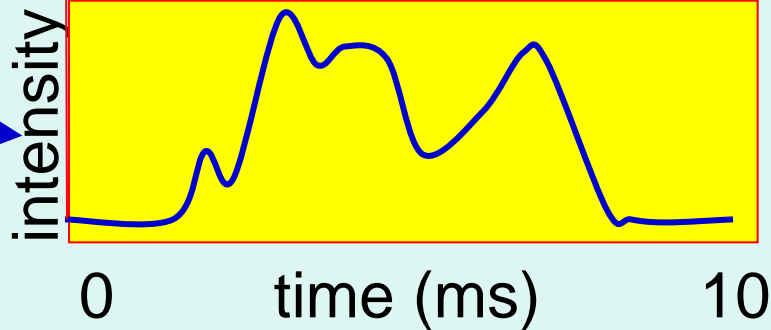
Spot scanning: **step&shoot**



Continuous scanning



kHz-Intensity modulation



Requirements for accelerator:

- stable beam position

allows fast target **repainting**:

15-30 scans / 2 min.

Requirements for accelerator:

- stable beam position
- continuous and stable beam
- fast adjustable beam intensity
- fast adjustable beam energy

Present accelerator choice

e.g:
Boston
Florida
Seoul
Wanjie
PSI
München
Orsay



e.g.:
Loma Linda
Houston
Tsukuba

cyclotron

synchrotron

Protons

in use, \varnothing 3.5-5 m

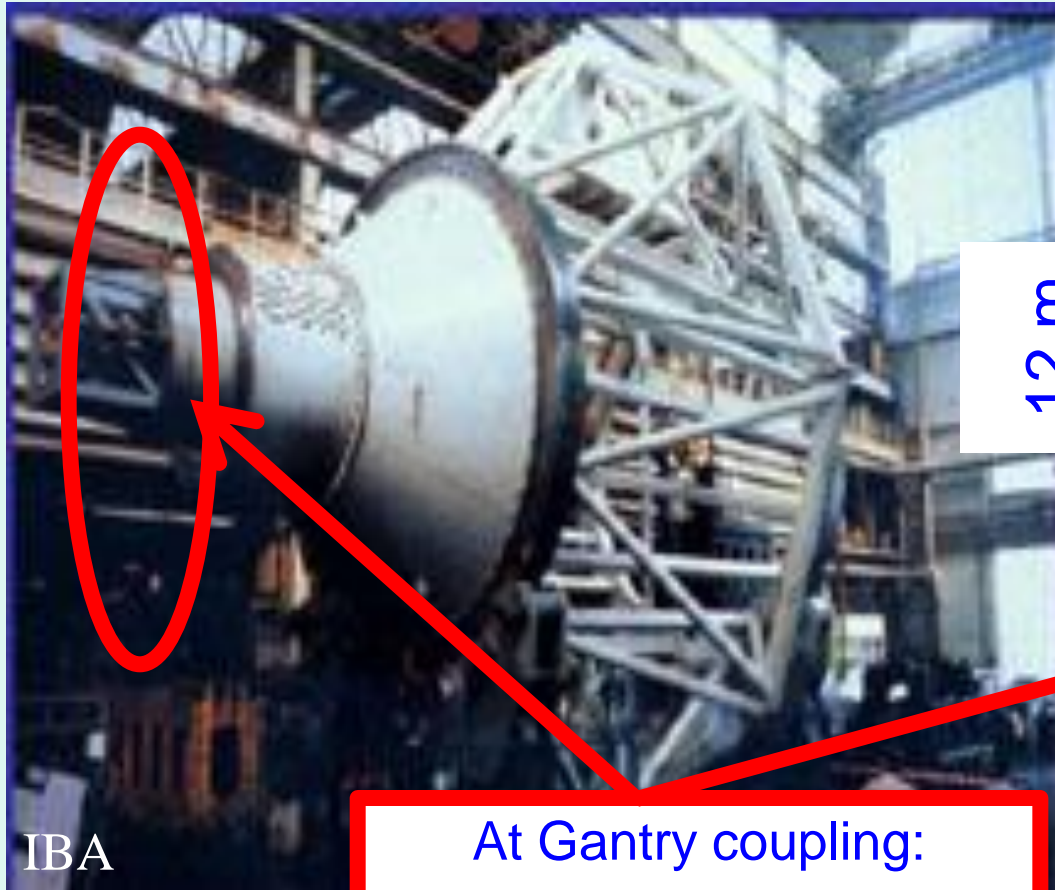
in use, \varnothing 8-10 m

Carbon ions

in design, \varnothing 6 m

in use, \varnothing 25 m

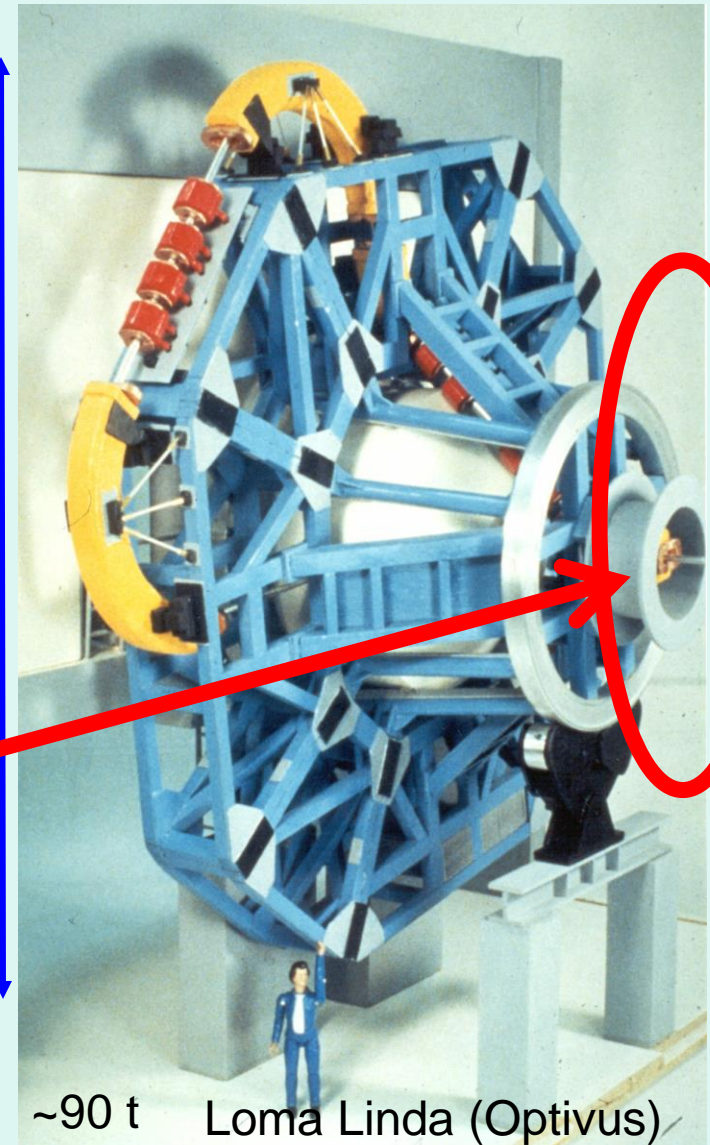
Gantries



12 m

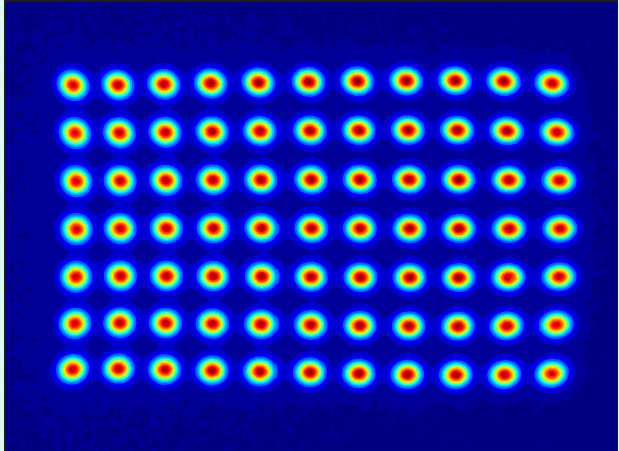
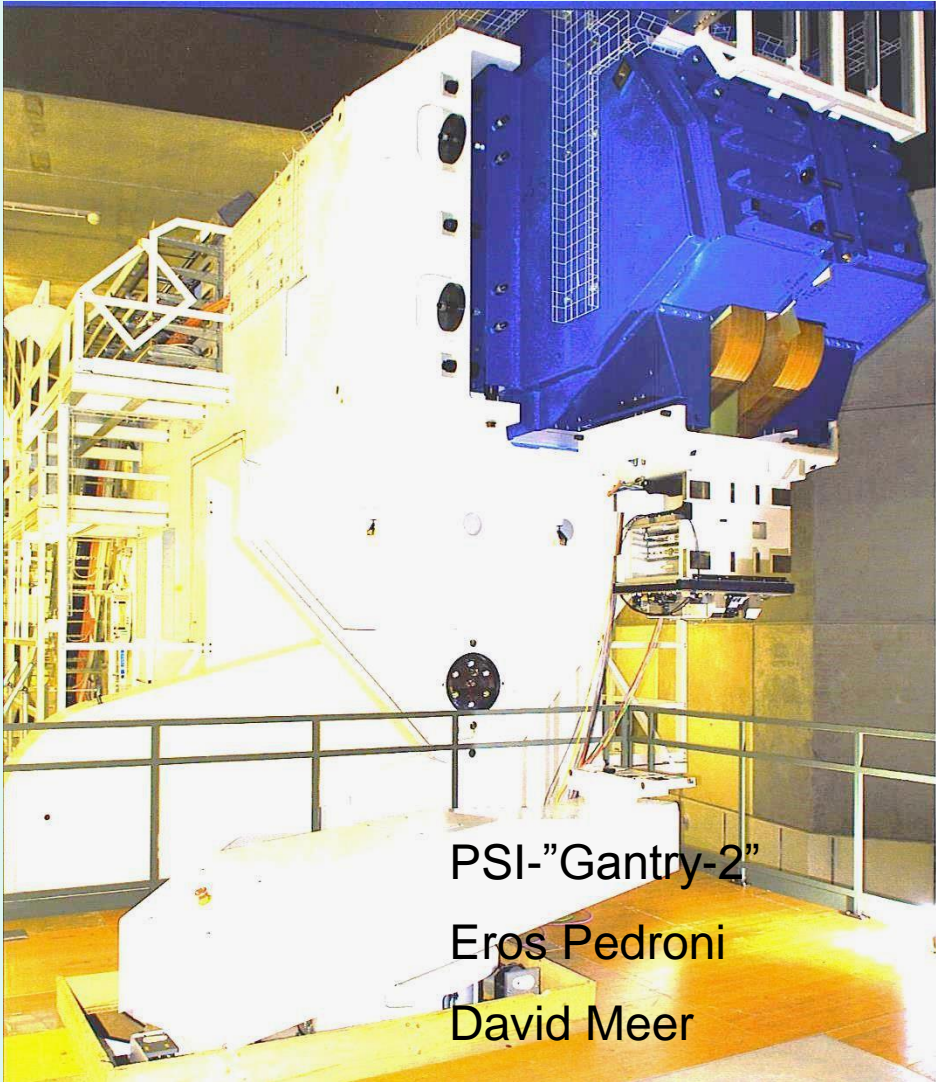
IBA

- At Gantry coupling:
- Phase space symmetric
 - No dispersion

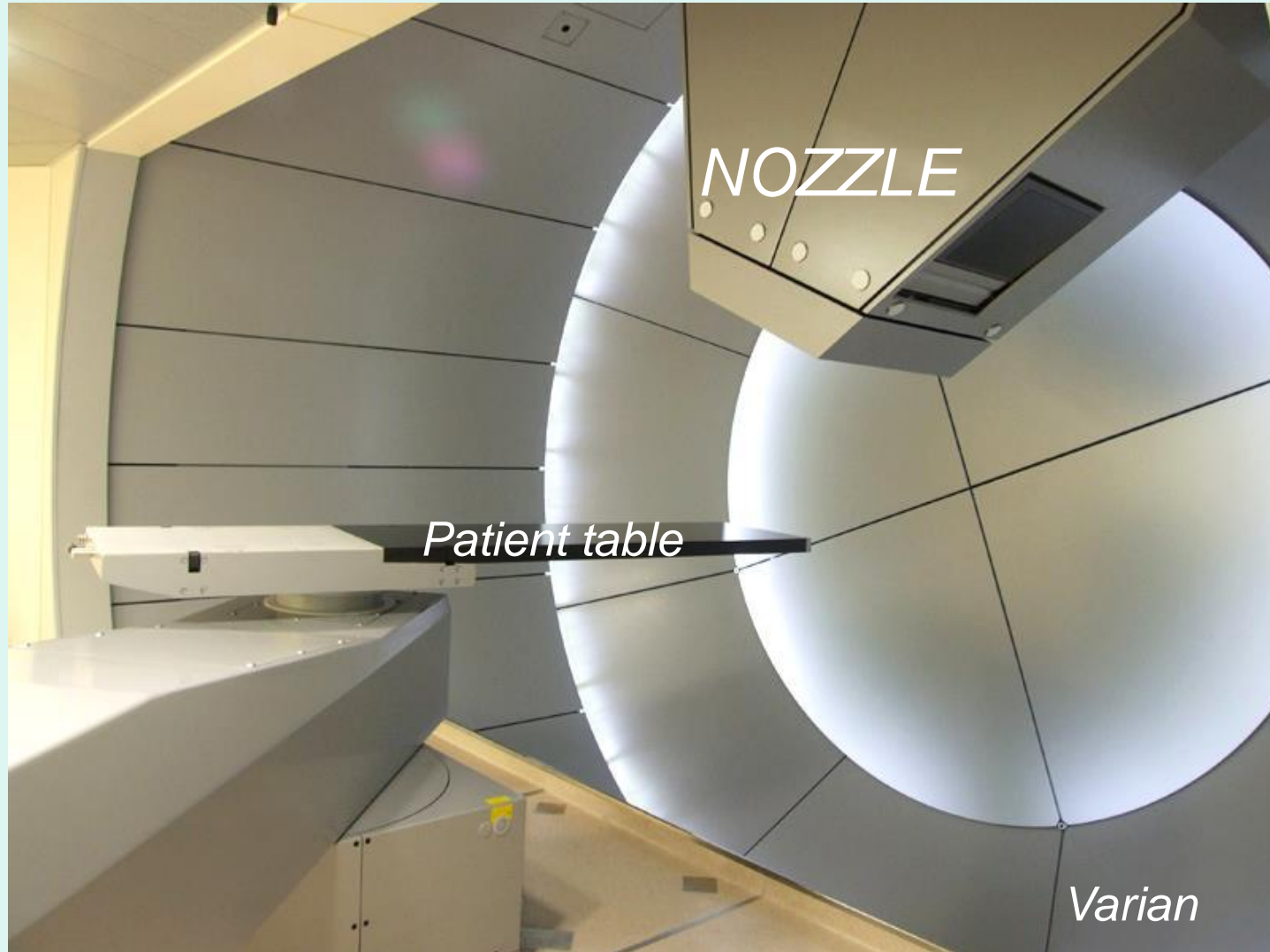


~90 t Loma Linda (Optivus)

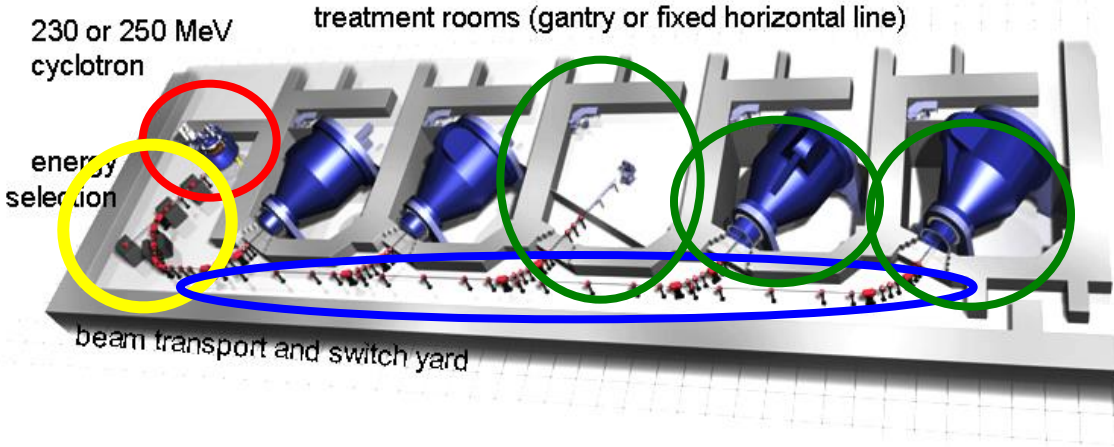
PSI Gantry-2: fast 3D scanning



Gantry as seen from patient side



Particle therapy facility

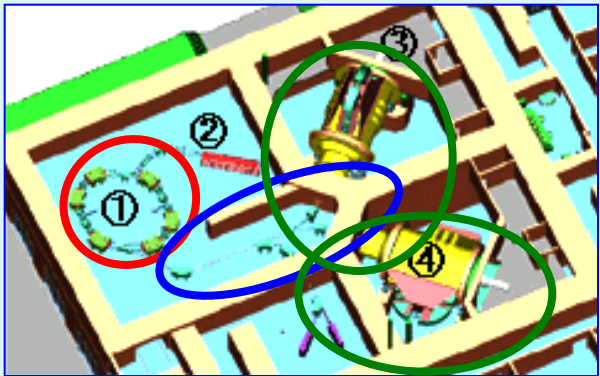
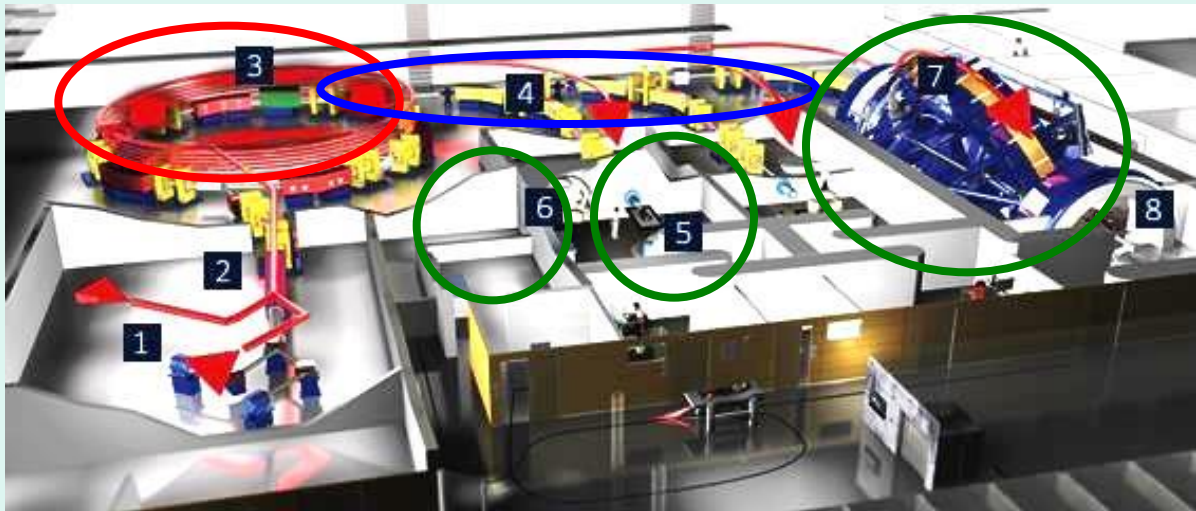


accelerator

energy selection

beam transport

gantry / fixed hor. line



PAUL SCHERRER INSTITUT



Operators

Technicians

Experienced workshops

More improvised actions

New beam tunes need more procedures

(operator) radiologist operates

Technicians: only small repairs

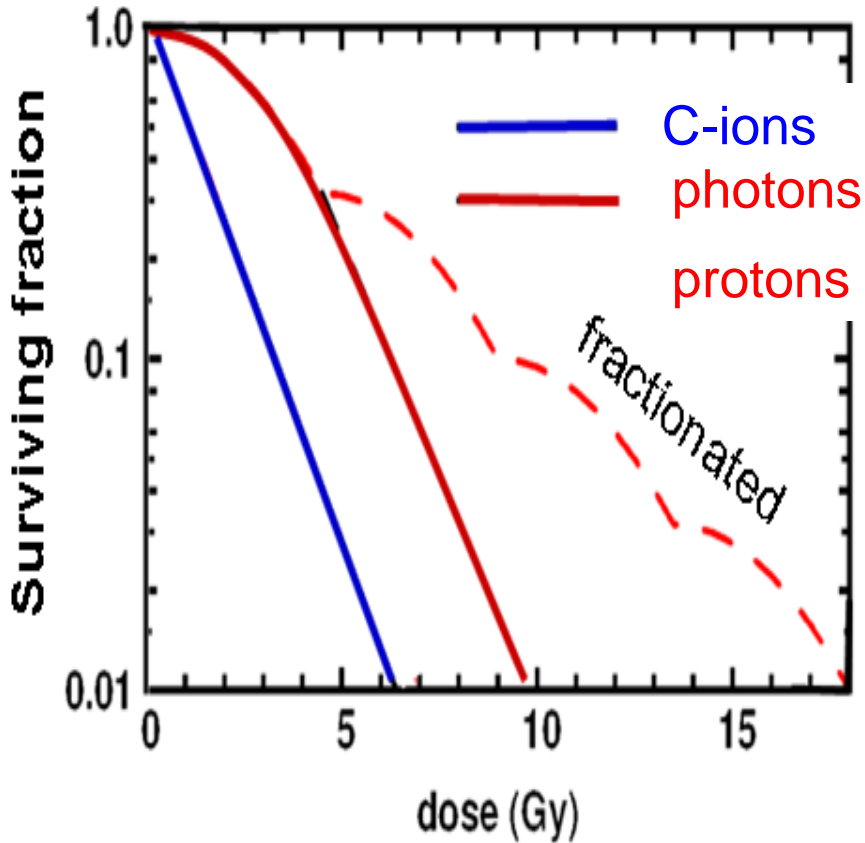
Service by equipment company

CE/FDA-certification: PROCEDURES

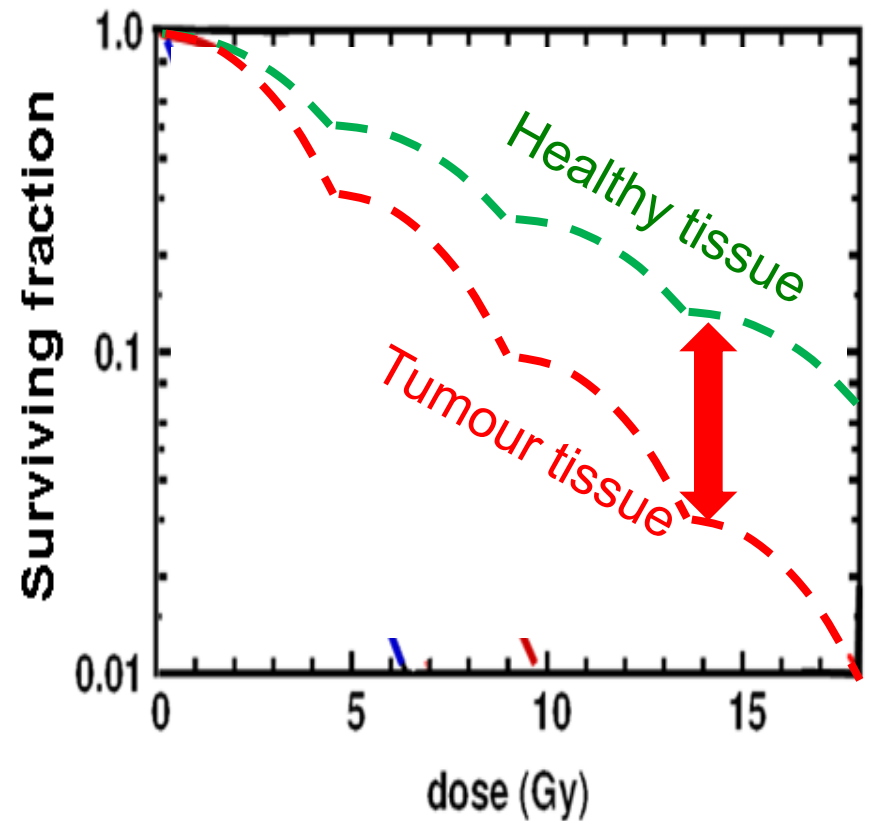
Fractionated treatment

to spare healthy tissue

Cell killing

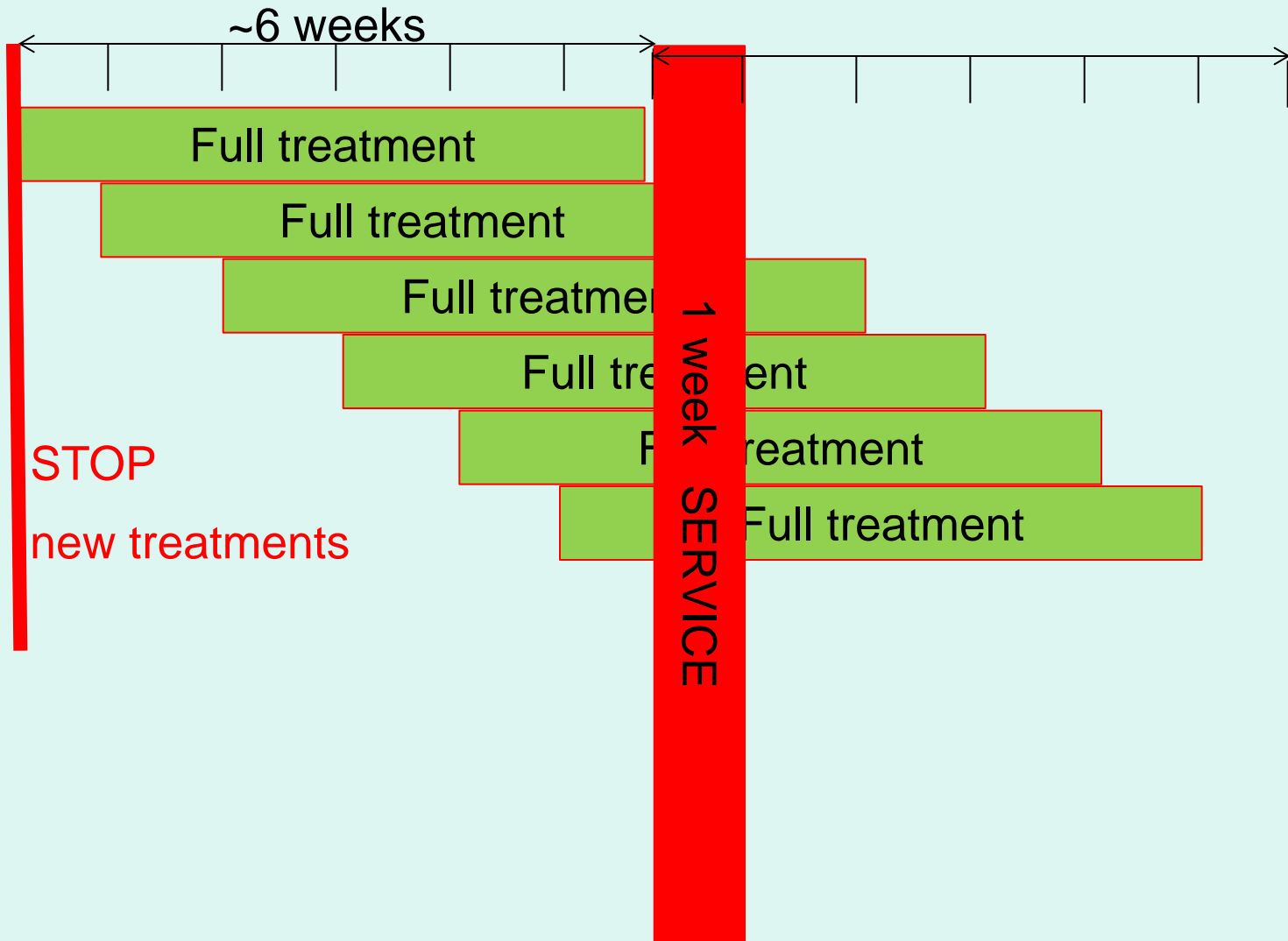


Cell killing

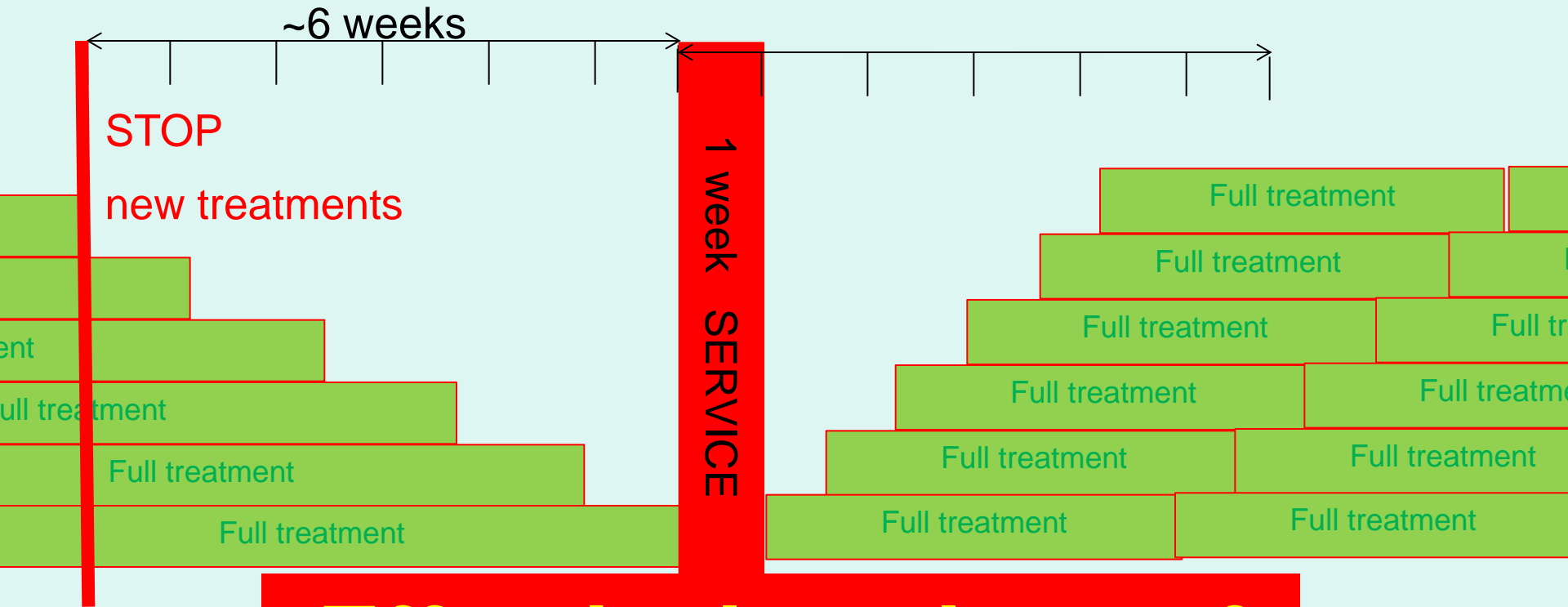


But: DO NOT interrupt treatment for more than 3-5 days

Operational aspects



Operational aspects



**Effectively: a loss of
8-10 weeks**

Operational aspects

So...

no long services =>

- well scheduled short services
- know what to do
- easy access

=> low dose level

many prepared spare parts

- Dose application within 1-2 %: REPRODUCIBILITY
=> beam intensity, on/off, positioning accuracy
- «just retune and do a test»: NOT allowed
- Operational MODES: THERAPY / SERVICE
- Operation by medical staff
- More control rooms => MASTERSHIP concept

with (CE / FDA) certification:

- Procedure for designing / building / repair / testing
- Standardized documentation
- Only certified staff for certain tasks

Safety <-> Availability

At Psi: **Separate interlock systems:**

Machine interlocks:
all components technically OK

Area access & area dose:
Doors closed, dose rate < $\mu\text{Sv/h}$

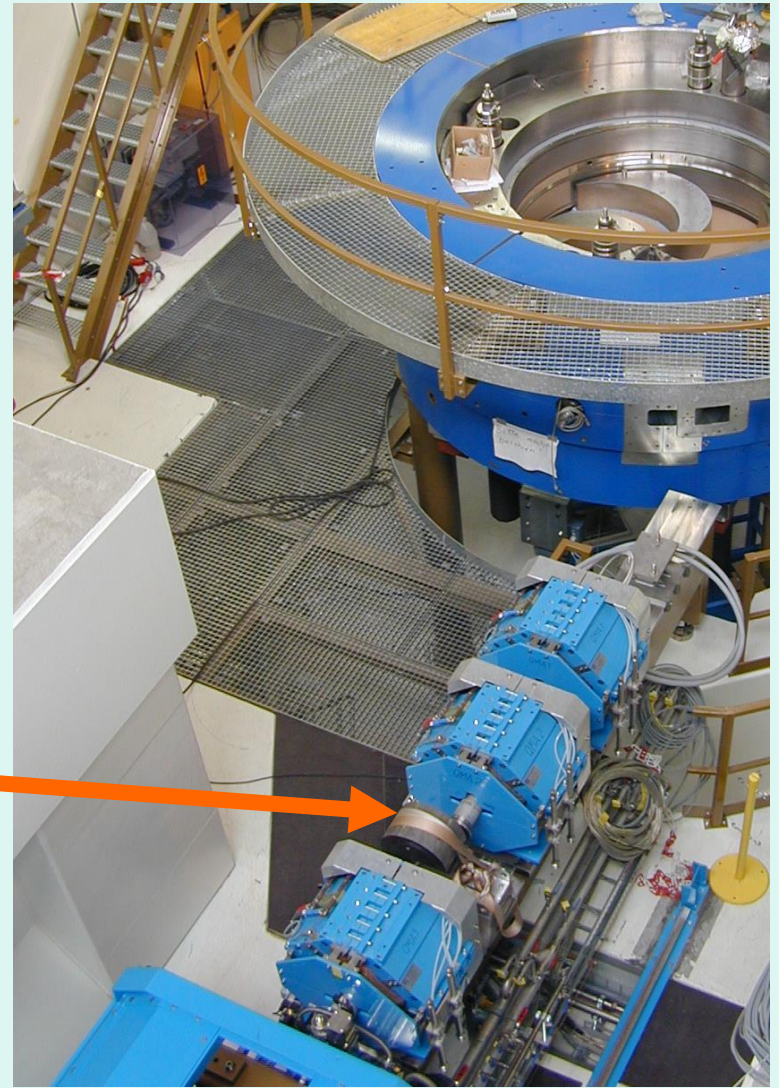
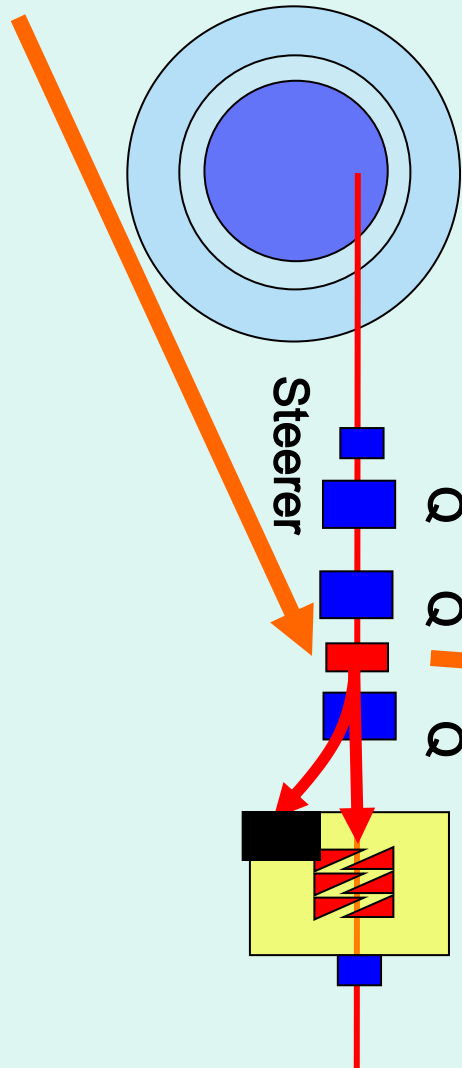
Patient safety:
Dose delivery as planned

A large, vertical arrow pointing downwards, with a color gradient from green at the top to red at the bottom. The text 'More special for treatments' is written vertically inside the arrow.

More special for treatments

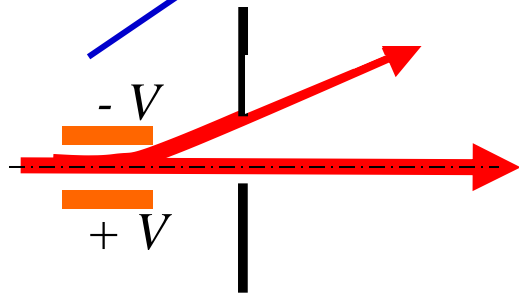
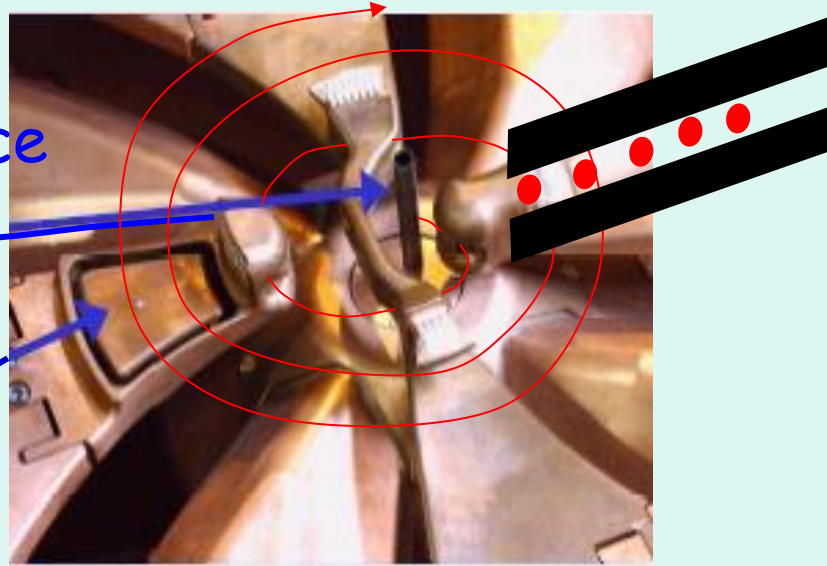
Beam on/off at PSI

Fast kicker magnet: **beam on/off**



On/off in Cyclotron (at PSI):

proton source



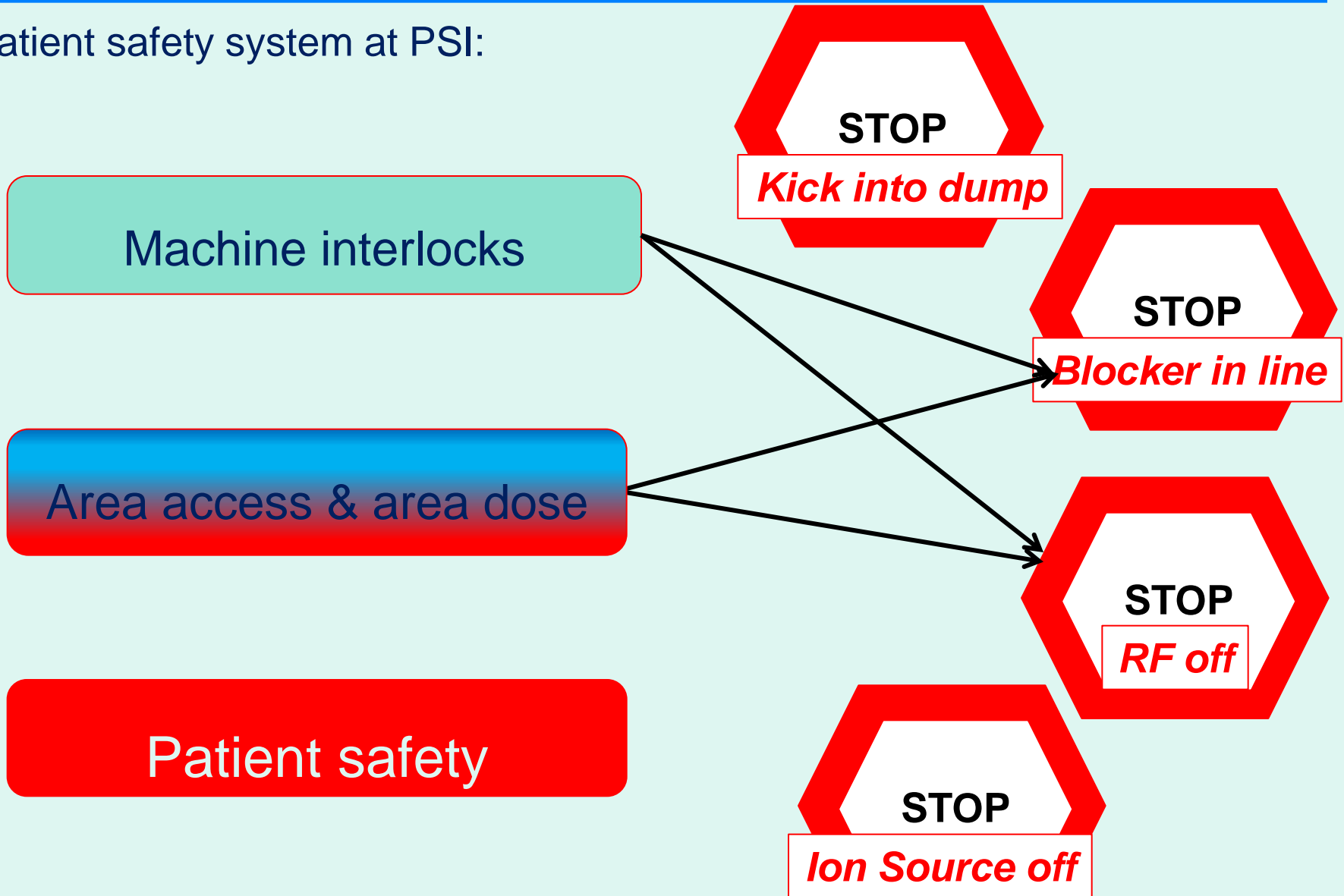
Deflector plate:
sets intensity
- within 50 μ s
- 3% accuracy

Possible ON / OFF:

- RF Voltage low or off
- Ion Source off
- Deflector plate 2 kV

Hierarchy of Interlock signals

Patient safety system at PSI:



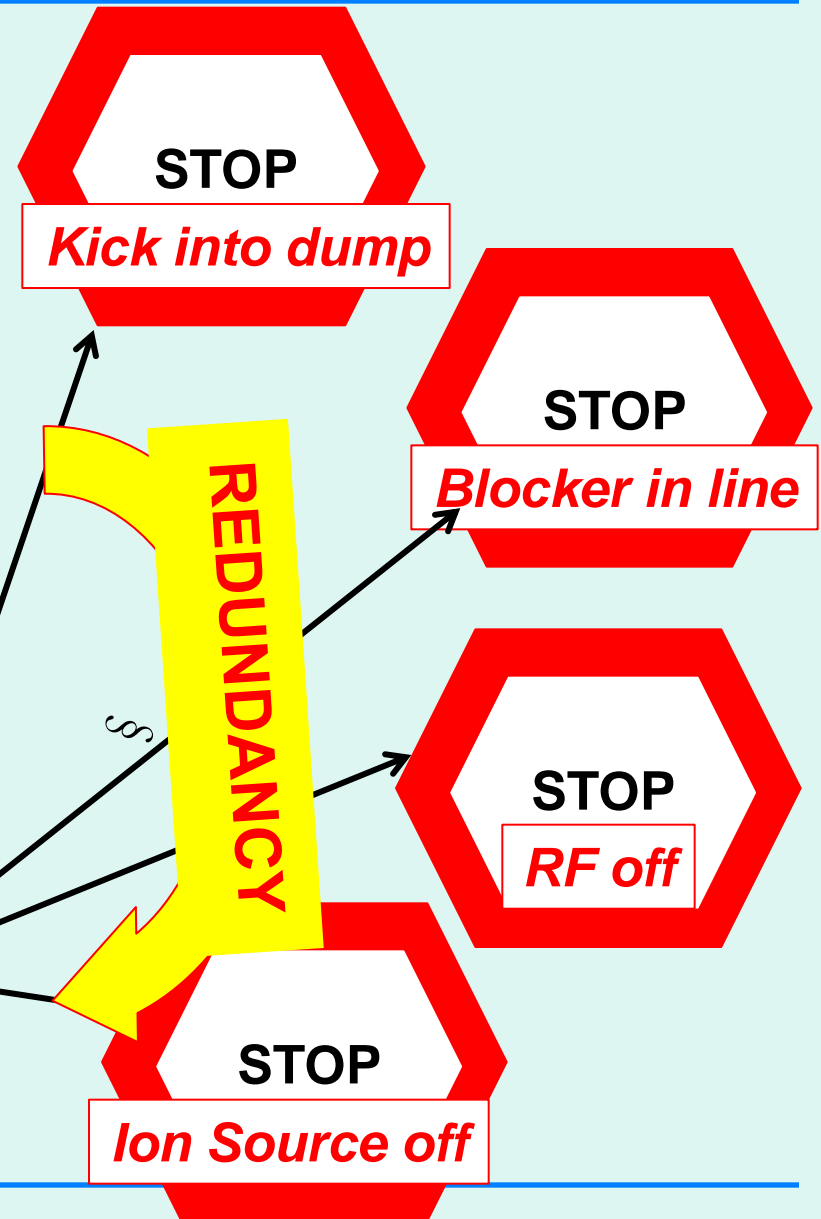
Hierarchy of Interlock signals

Patient safety system at PSI:

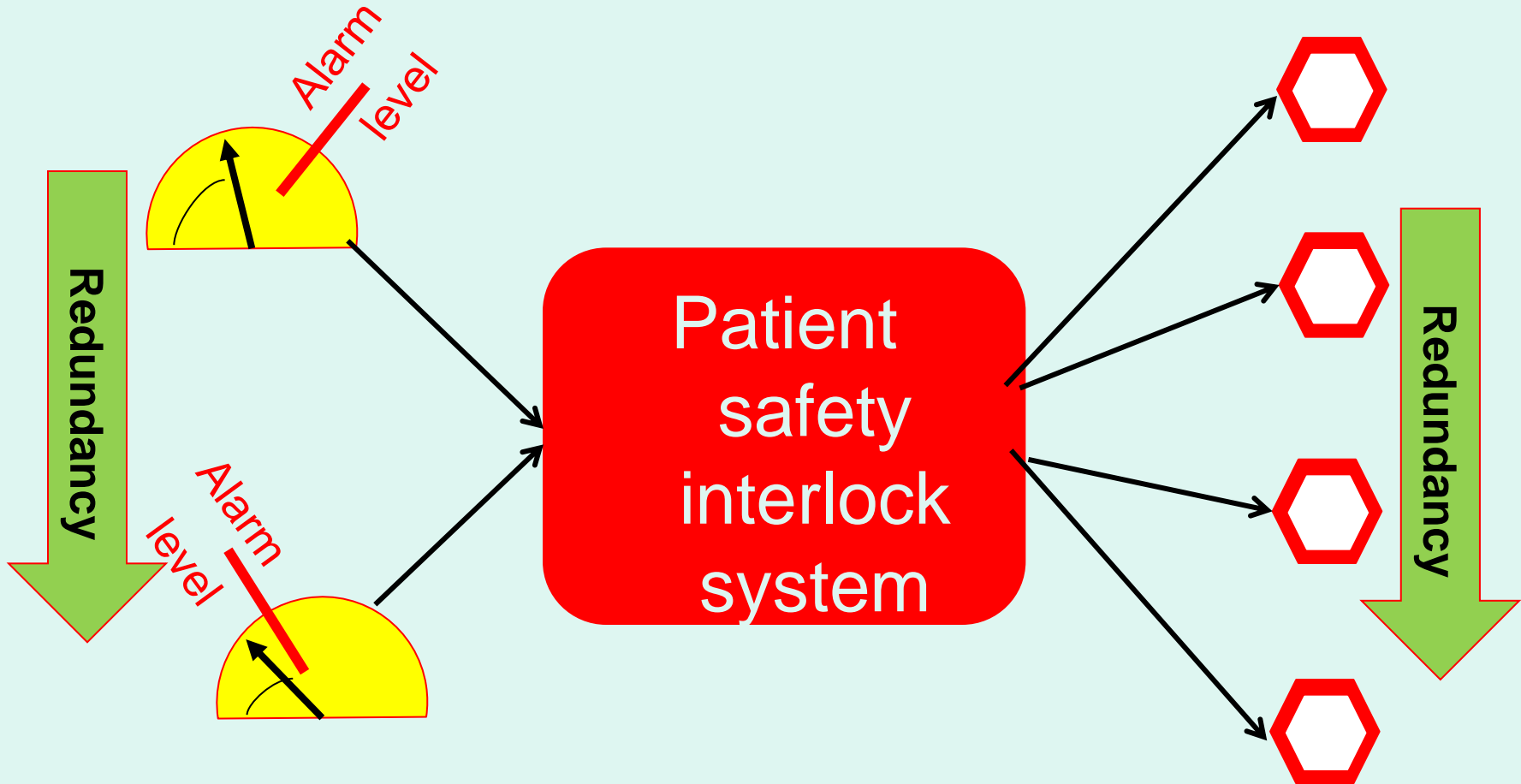
Machine interlocks

Area access & area dose

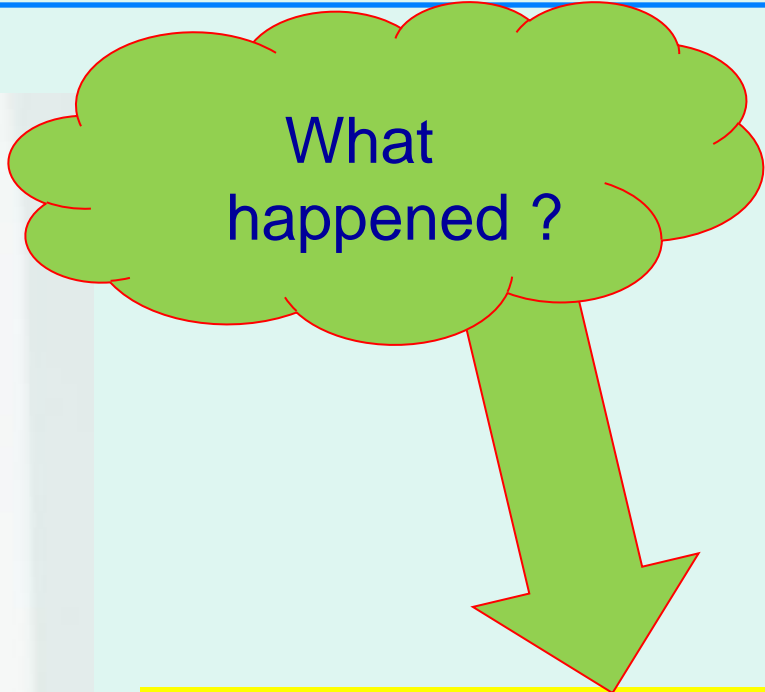
Patient safety



measurement → BEAM off



Operation: non-accelerator experts



NO BEAM

Strong need for
ERGONOMIC
display of: **Status**
Instructions

SUMMARY

Unique Aspects of Accelerators for Medical Application:

What is so special?

- **Technics:** dedicated, but not on the limitbut...
Reliable, Reproducible, Reliable, Reproducible
- **Operation:** by non accelerator experts
strictly according procedures
NO long services or shut downs

Control and **safety:**

VERY DEDICATED and SPECIAL :

Reliable, redundant, but not too sensitive

.... Motivation

first scanning gantry : PSI, 1990



Gantry: Eros Pedroni

Tumours in kids: Beate Timmermann, Gudrun Goitein