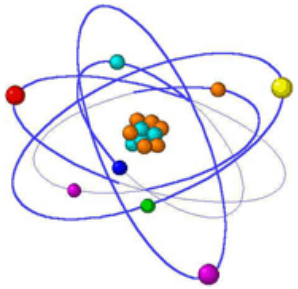
Radioisotope and Radiation Applications (FS2013)



Proton Therapy at PSI (Week 4c, Seminar)

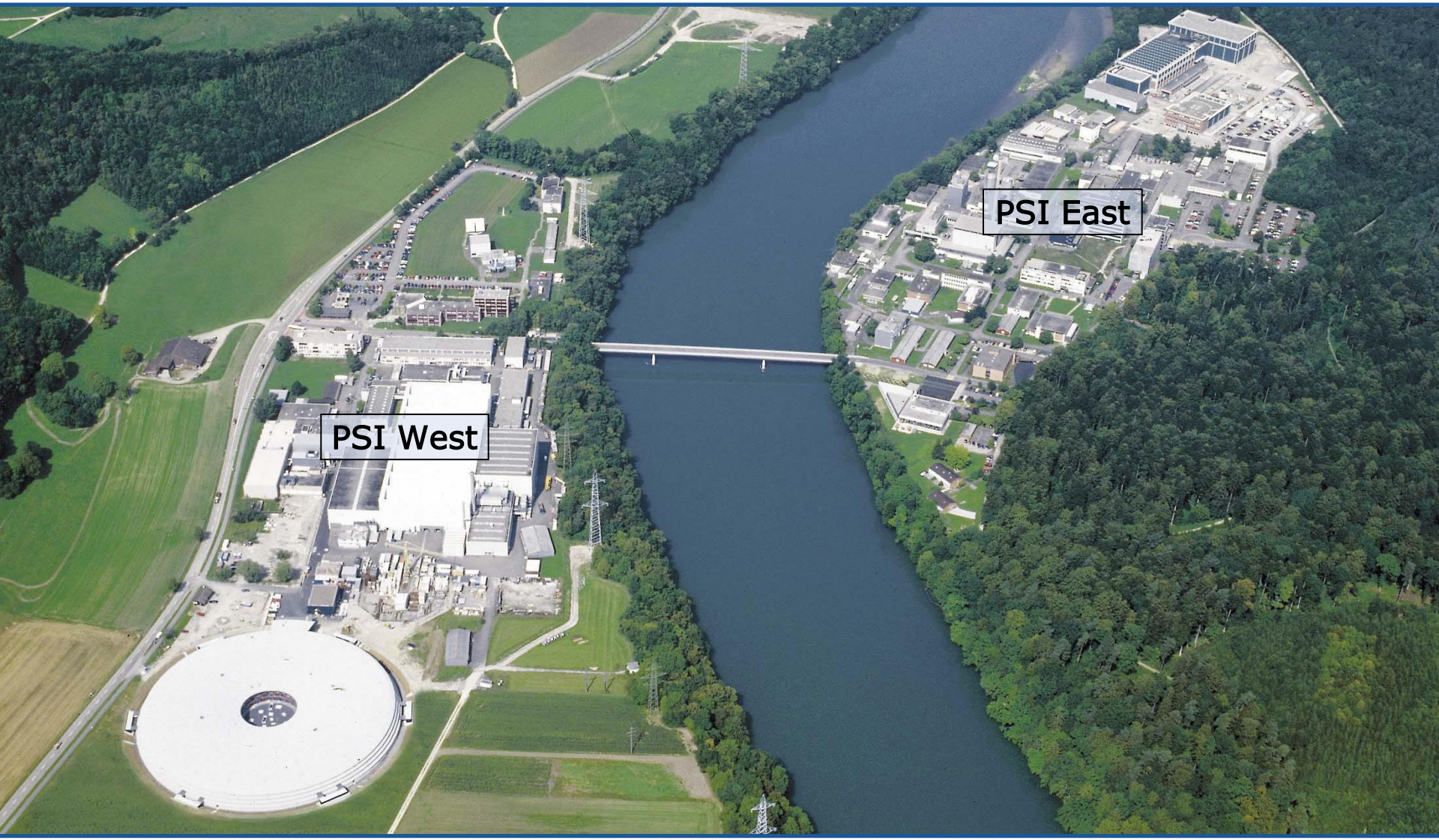
Pavel Frajtag

15.10. 2013

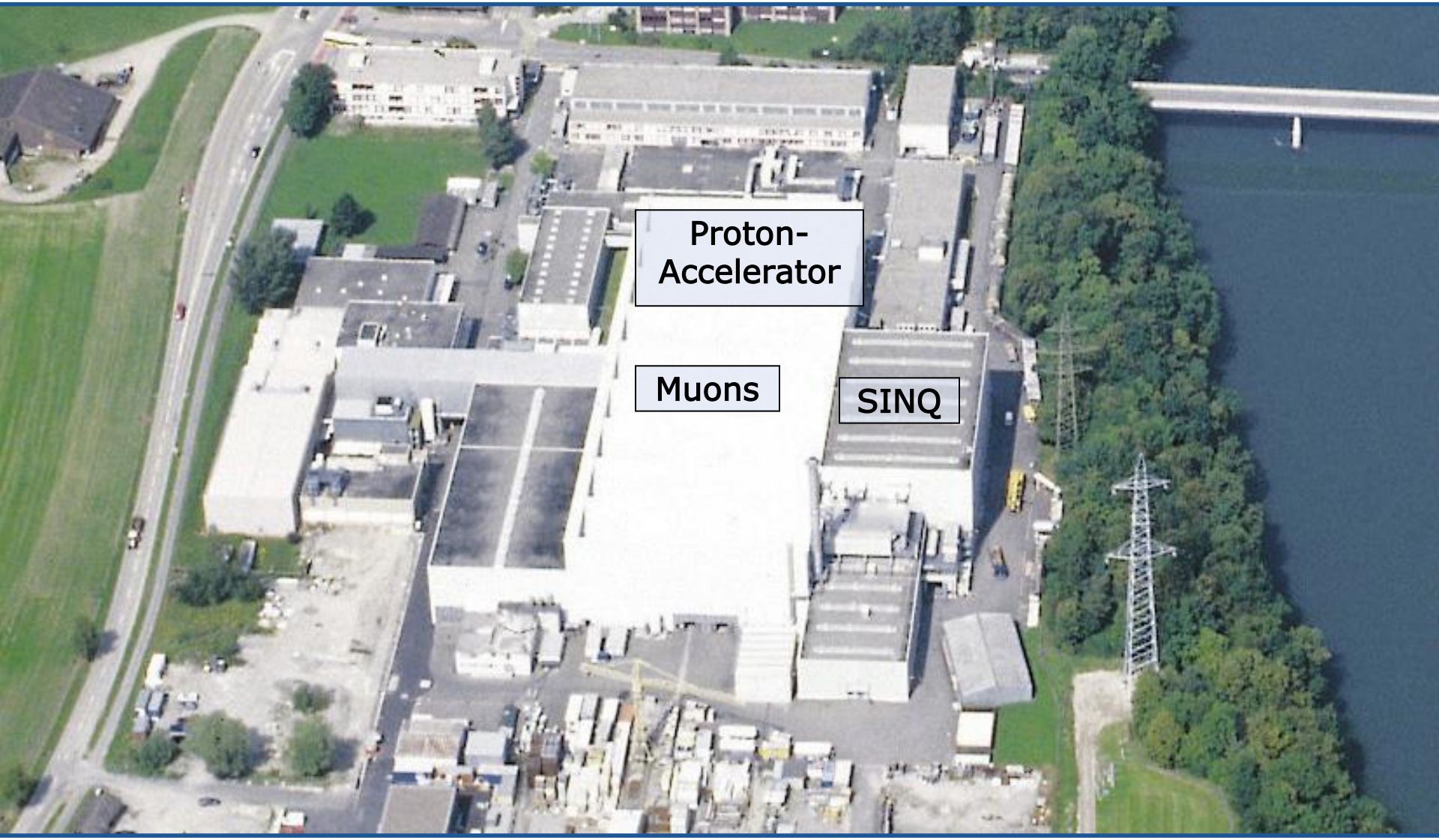
Proton Therapy at PSI: Outline

- Introduction to the Paul Scherrer Institute (PSI)
- History of Proton Therapy at PSI and World-Wide
- The Physics of Proton Therapy
- Comparison Photon Therapy ⇔ Proton Therapy
- The PSI Spot-Scanning Technique
- Facilities/Projects at PSI
  - Optis
  - Gantry I
  - Project PROSCAN (COMET, Gantry II)
  - Gantry II
- Literature / WWW-References

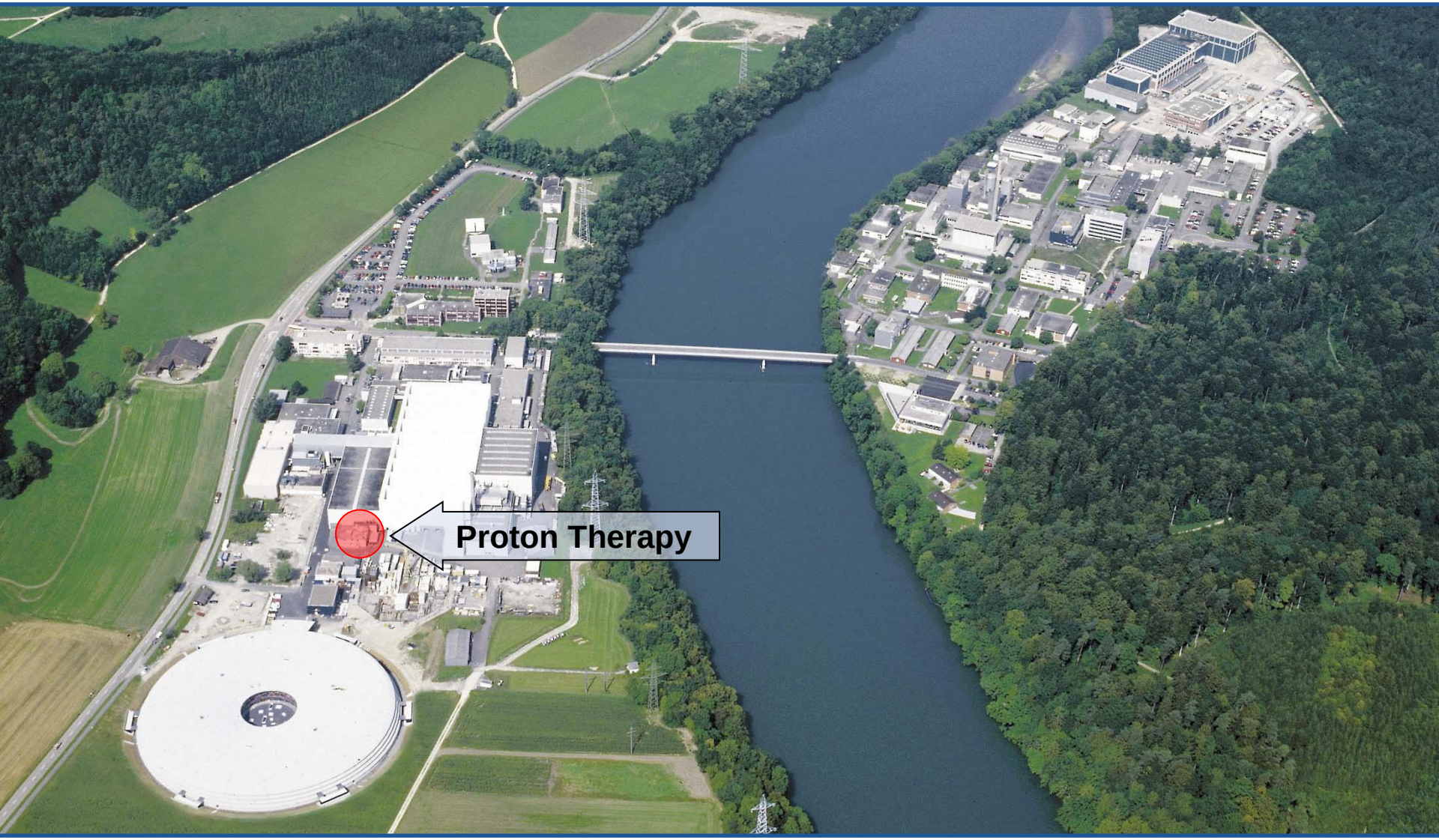
Paul Scherrer Institute 1988: A Merger of EIR and SIN



PSI West



Location of Proton Therapy at PSI West



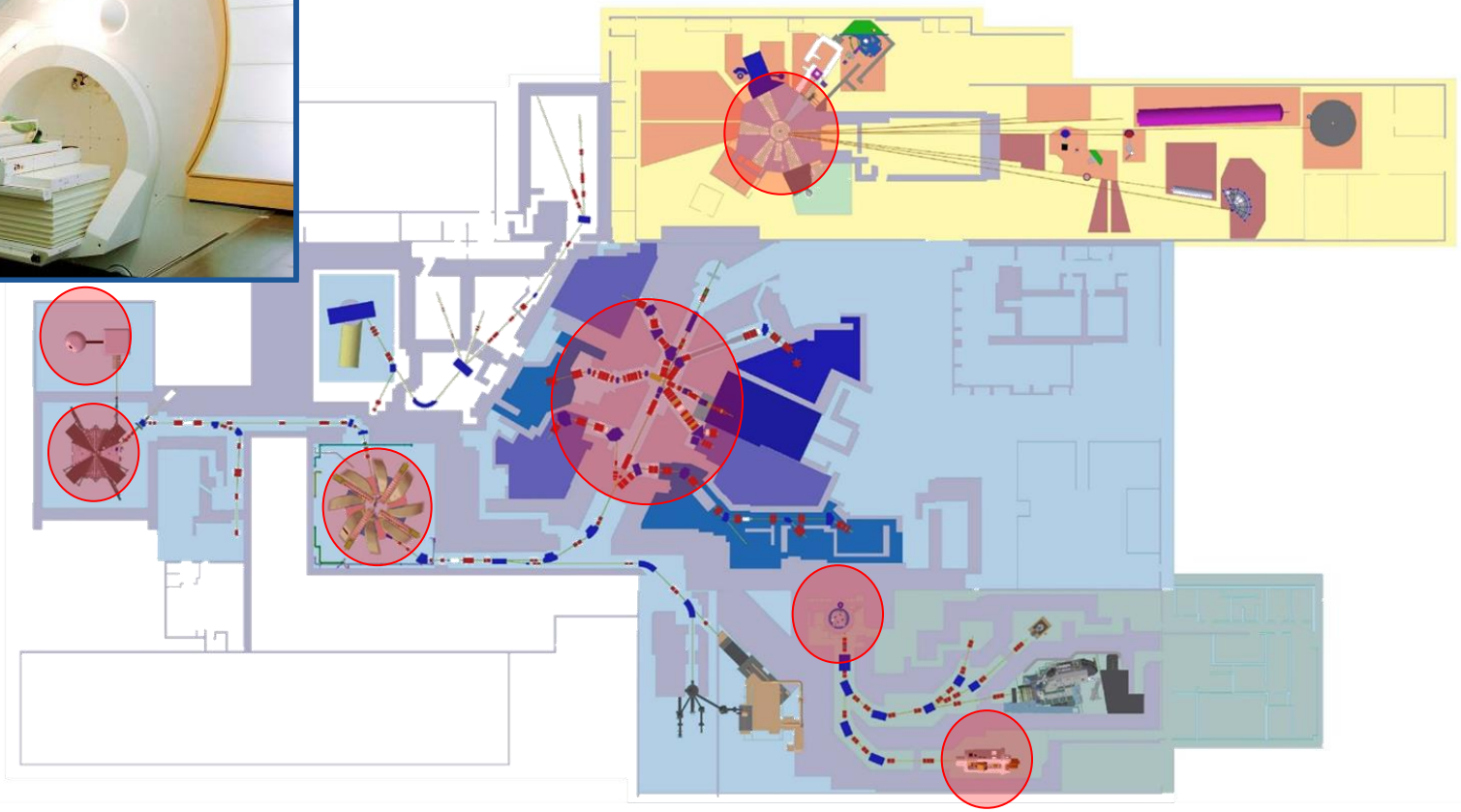
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Proton-Accelerator and Experimental Areas (1)

Proton-Accelerator and Experimental Areas (2)

Gantry I

enquelle SINQ



Main Proton-Accelerator (Ring Cyclotron)

- Boosts protons to an extraction energy of 590 MeV.
- Delivers very high beam intensities: 2.0 mA DC => beam power > 1MW.

History of Proton Therapy at PSI

Tumours of the eye:

- Melanomas of the eye were treated with radiation at PSI for the first time in 1984.
- Optis was the first installation of this type anywhere in Europe.
- Until end of 2007 more than 4800 patients have been treated (205 in 2006).
- In more than 98% of cases tumour growth could be stopped or the tumour eradicated.
- In more than 90% of cases the eye could be saved.

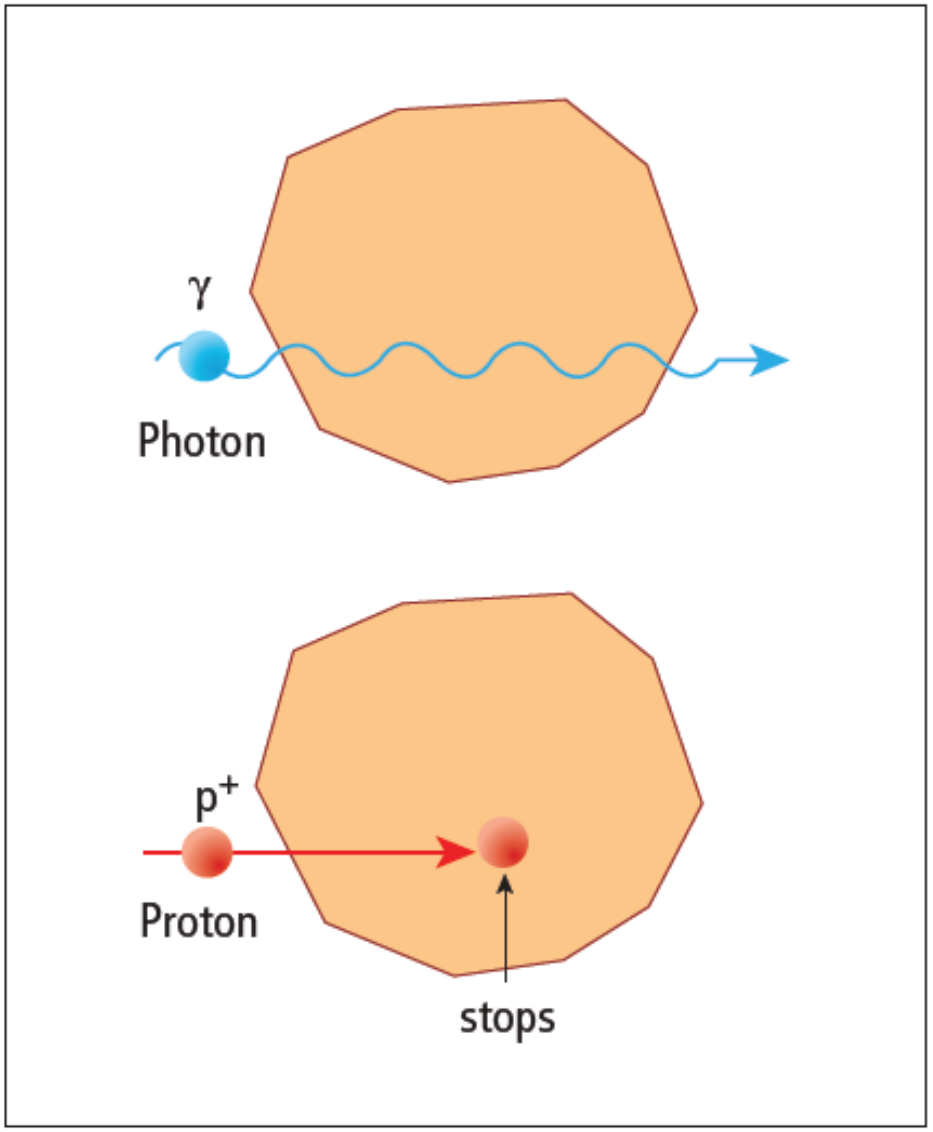
Proton irradiation of body tumours:

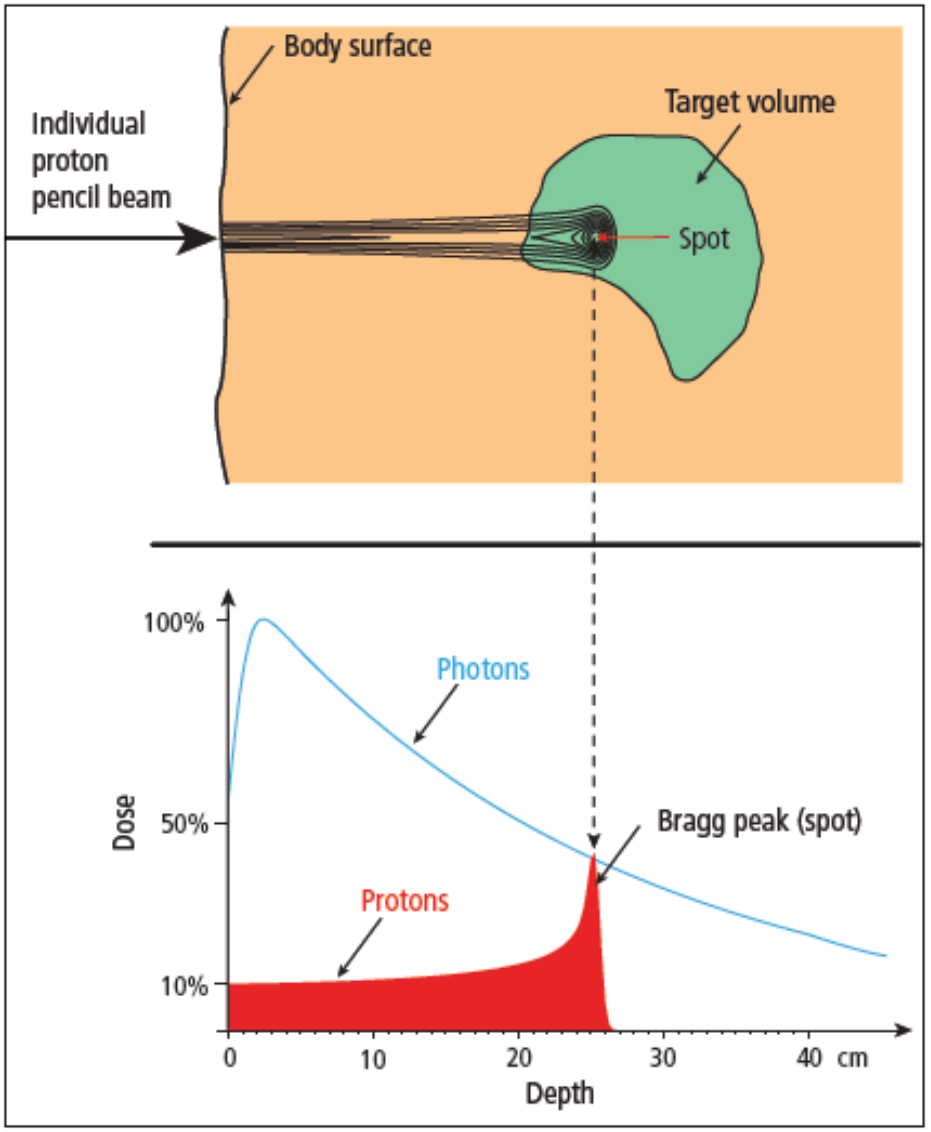
- The first proton gantry for the irradiation of deep seated tumours was taken into service at PSI in 1996.
- It was also the first in Europe.
- Until end of 2005 262 patients have been treated.
- Since 2004 also infants have been irradiated under anaesthetic.
- A further development of this irradiation technique is currently underway at PSI, with the aim of being able to extend the treatment to deal with tumours that move during treatment (e.g. breast and lung cancers) with a high degree of precision.

Proton Therapy World-Wide

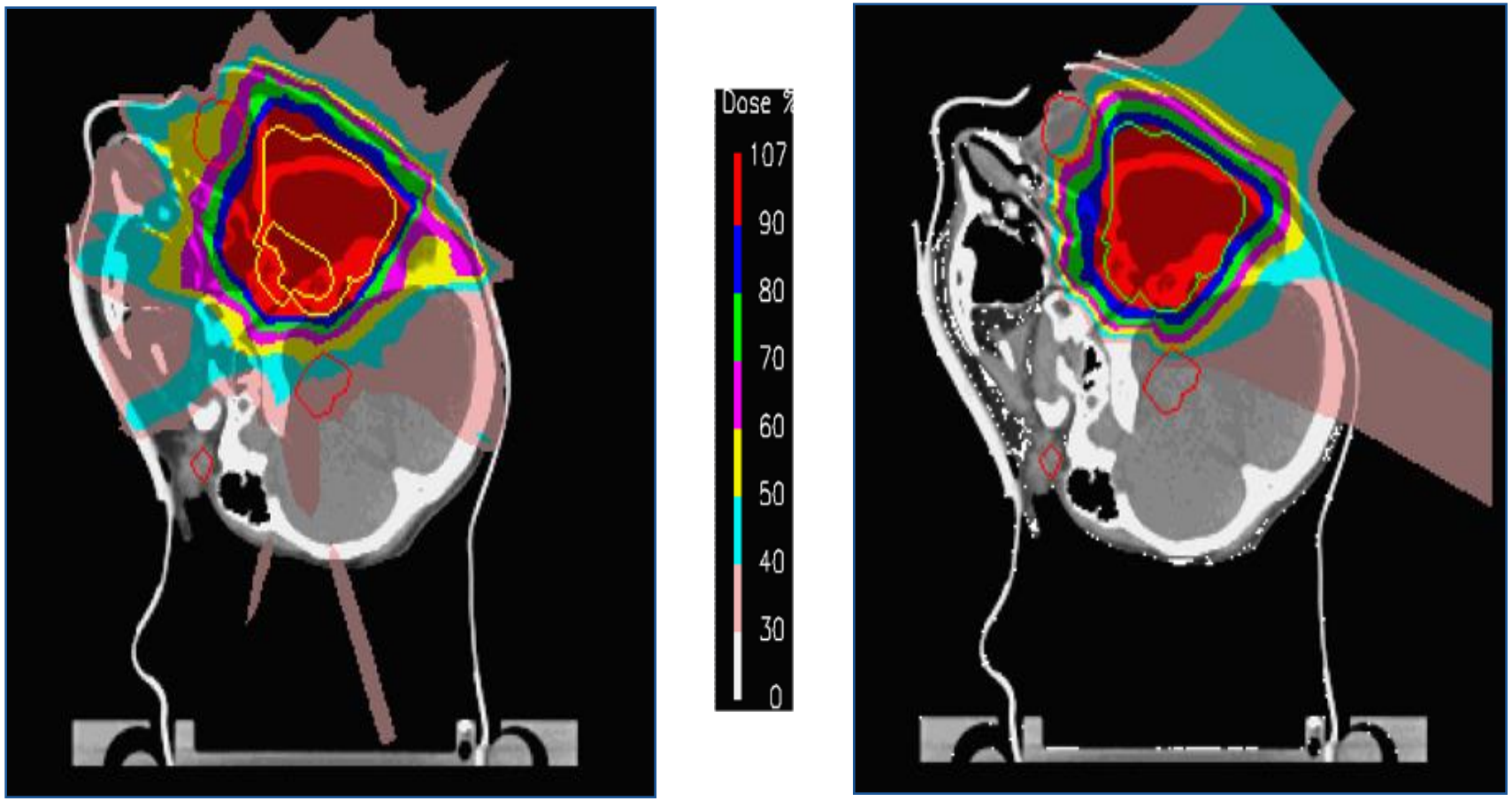
- A patient was treated with protons for the first time at the Lawrence Berkeley Laboratory in California (USA) in 1954.
- The first proton therapy programme in Europe ran in Uppsala (Sweden) between 1957 and 1976.
- In 1961, the Harvard Cyclotron Laboratory and the Massachusetts General Hospital in Boston, USA, started a proton therapy project.
- Melanoma of the eye was treated with protons for the first time in Europe in 1984, at the OPTIS facility developed especially for this purpose at PSI.
- The first proton therapy facility to be used at a hospital went into operation at the Loma Linda University Medical Center, California, in 1990. Following a development and testing phase of almost 10 years, up to 1500 patients have routinely benefited from proton therapy there since 1999.
- Additional clinical centers have gone into operation across the USA in the past few years, at Boston (MA), Houston (TX) and Jacksonville (FL). Proton therapy facilities have also been set up in Russia and Japan.
- By today, more than 50,000 patients have been treated with protons at about 30 centers (predominantly research centers) world-wide. Most of these have suffered from tumours of the eye or brain, or tumours in the neck, pelvis and spinal area. Clinical experience with protons has demonstrated that the spatial precision of the irradiation is often crucial to the successful result of the therapy.

The Physics of Proton Therapy



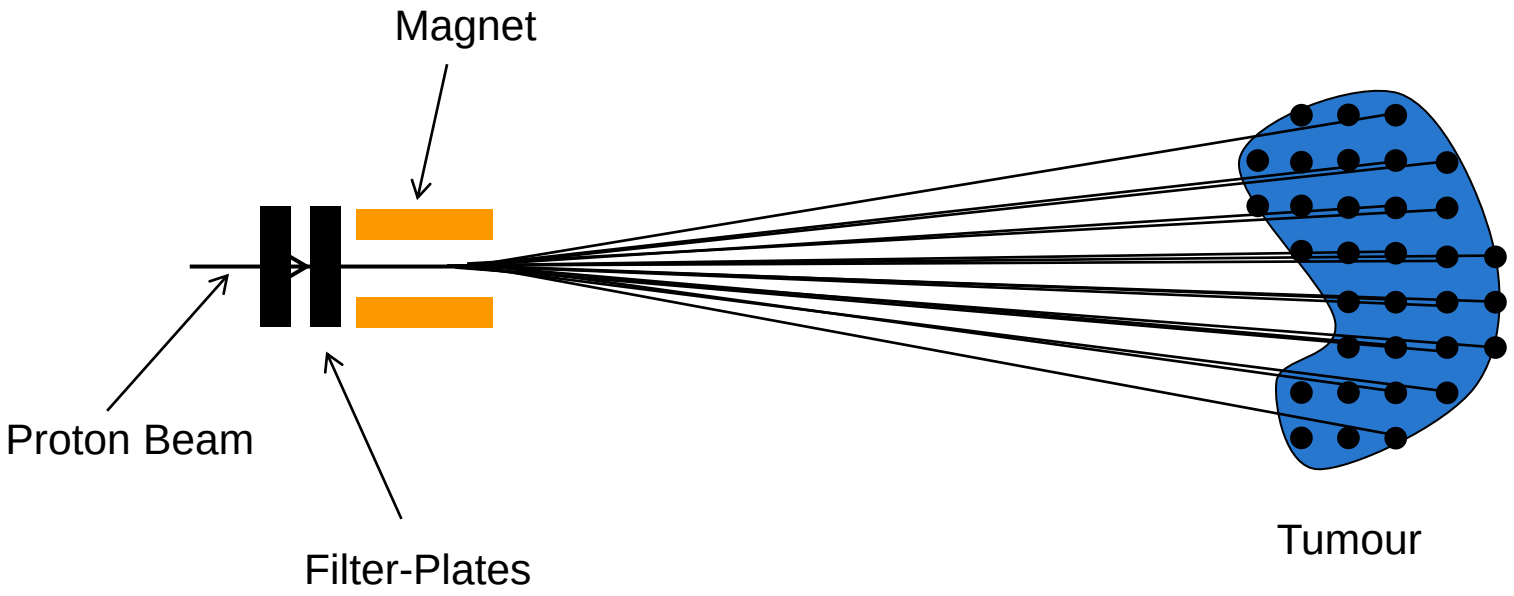


Comparison: Photons ⇔ Protons

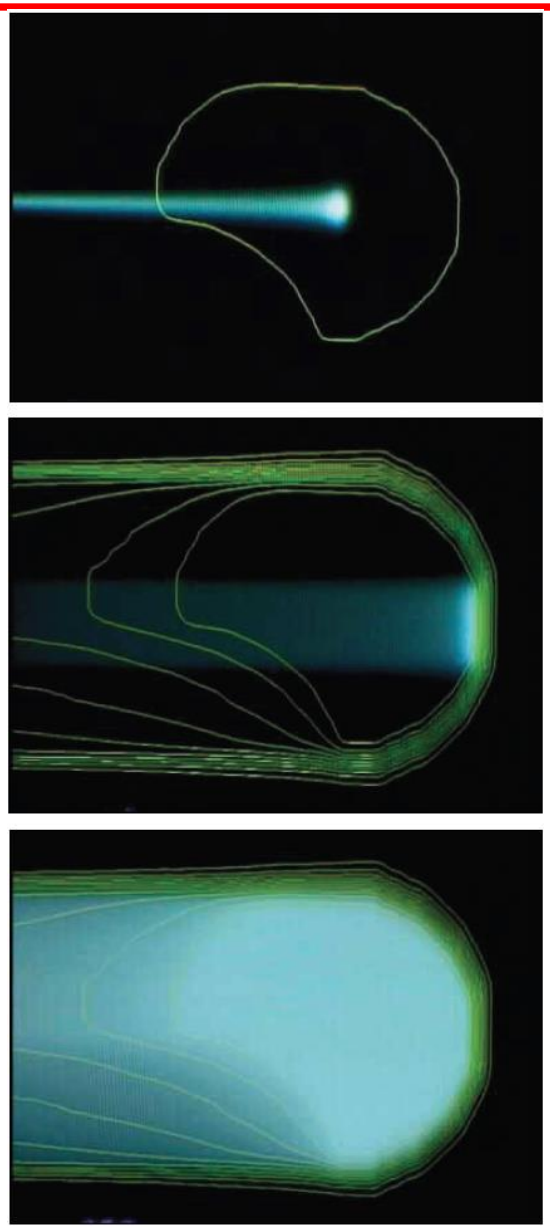


A tumour in the head region of a 7-year-old child irradiated at PSI. Irradiation plan for radiation treatment using modern conventional photon therapy (left) and using proton therapy at PSI (right). Irradiation by photons generates a «dose bath» in a large part of the brain, and also affects the brain stem and optical nerves. This can be avoided by using proton therapy.

The PSI Spot-Scanning Technique (1)



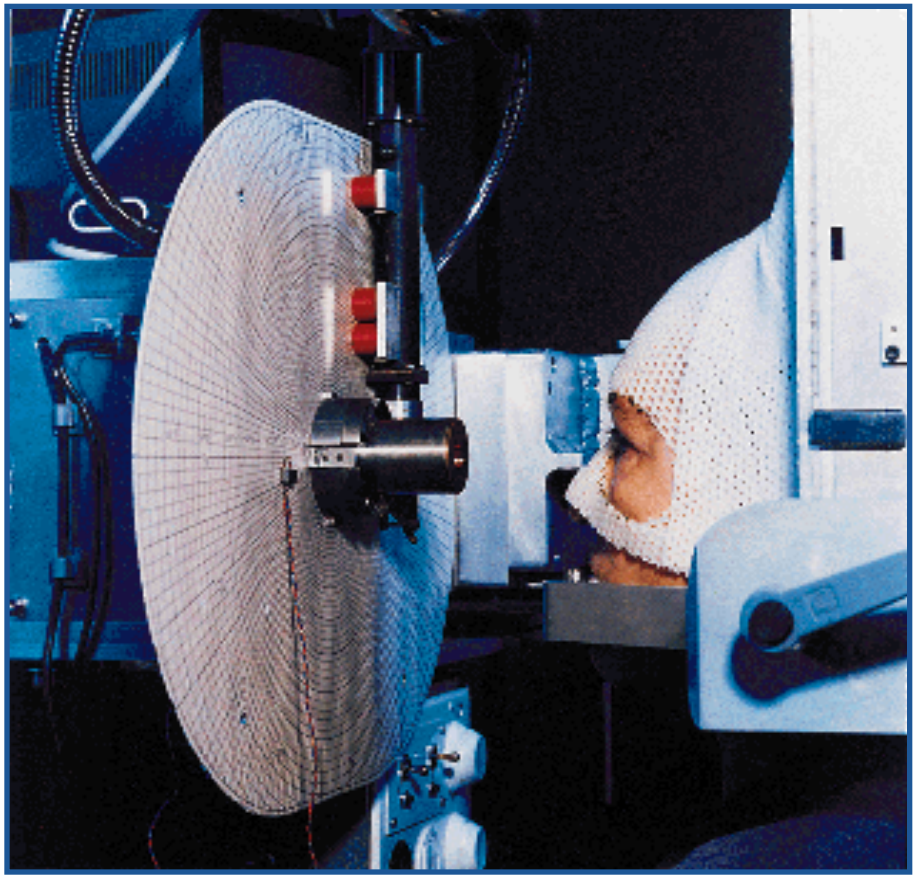
The PSI Spot-Scanning Technique (2)



The principle of the spot-scanning technique developed at PSI. Dose distributions of any shape can be produced by shifting and superimposing the dose spot of a proton pencil beam, and the dose can be matched extremely accurately in three dimensions to the shape of the tumour.

This treatment plan demonstrates the particular precision of the spot-scanning technique, using the example of a brain tumour. The dose is matched individually in each plane of the relevant boundary (yellow). The tissue outside the tumour remains largely unaffected.

Optis (1): Treatment of Melanomas of the Eye

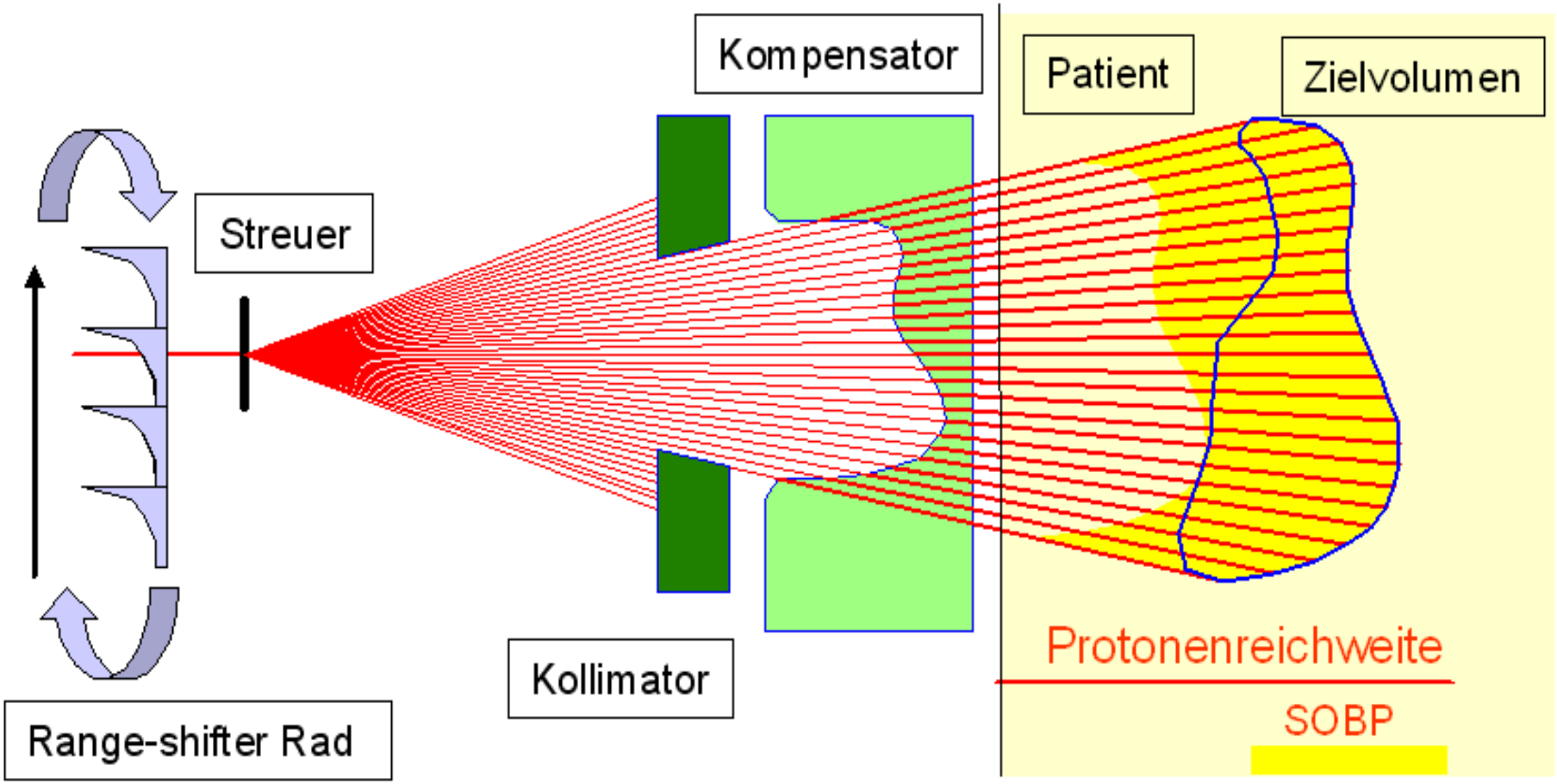


OPTIS is a pioneering therapy facility which has inspired six further installations in Europe. OPTIS can currently treat the following eye tumours (about 200 to 250 patients a year):

- Uveal melanomas, including those which have only partly responded to other therapies
- Choroidal hemangiomas, growths in the blood vessels of the eye
- Intraocular metastases in the eye
- Melanomas of the conjunctiva
- age related macular degeneration

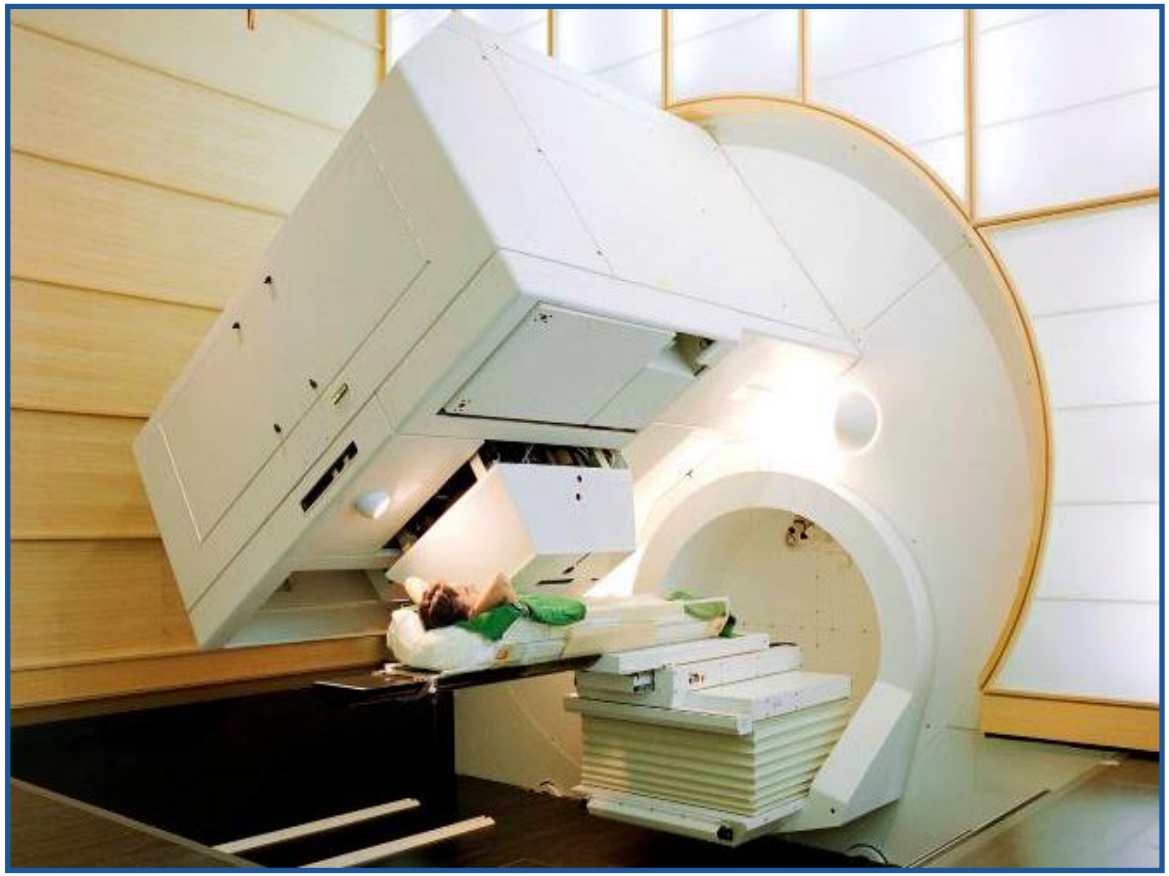
The patient is fixed using an individual mask and a bite-block.
The therapy consists of one treatment a day, for four consecutive days.
The radiation itself lasts 10 to 30 seconds.
In order to position the eye correctly the patient fixes a light point on a coordination grid.
Before each radiation the position of the eye is checked with an x-ray picture.
Only when the position deviates less than 0.2mm from the correct position is the radiation carried out.

Optis (2): Irradiation Technique



Gantry I (1): Tumours are irradiated with high precision

- Today in Europe 1/3 person contracts a malign tumour at some point in their life, and 1/5 dies of cancer.
- In Switzerland alone, about 28,000 people discover that they have cancer every year. 70% of these will require radiotherapy during their illness.
- The survival rate for cancer patients is currently some 45%, with:
  about 22% cured by surgery, 12% by radiotherapy, and 6% by a combination of both.
  A further 5% of patients are cured by chemotherapy.

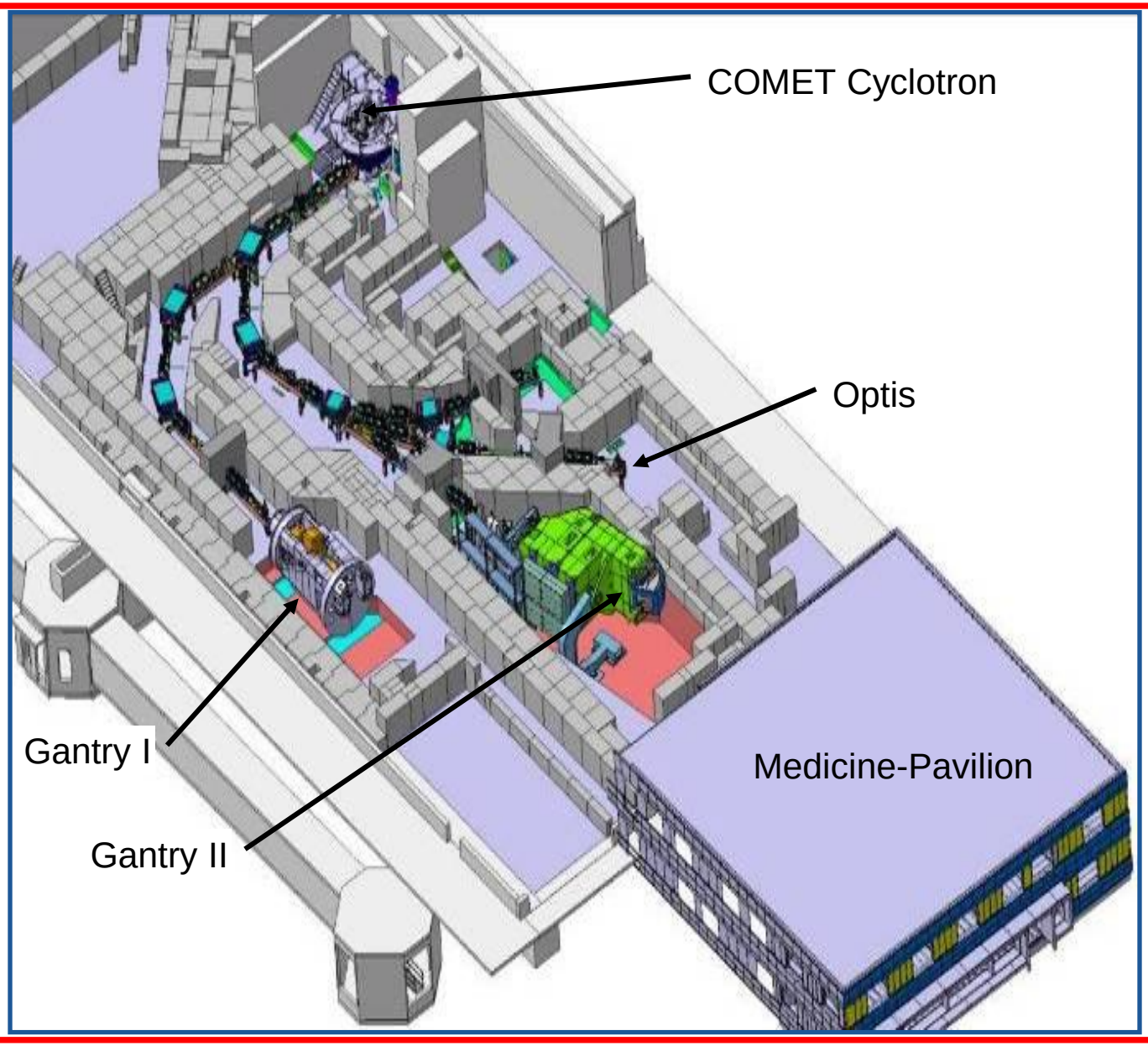


- Patients are selected by the medical team at PSI on the basis of the added medical value that might be anticipated from the proton therapy.
- For each patient a dedicated moulage is prepared for fixation.
- To precisely determine the position of the tumour CT images are taken.
- The dose is administered in individual daily fractions, a course of treatment usually lasts 6 to 8 weeks (approx. 30 to 40 sessions).
- The costs amount to 30,000 to 40,000 CHF, which is comparable to those of surgery.

Gantry I (2): Since 2004 also infants have been treated

Infants are anaesthetised when they undergo radiation treatment. Proton therapy offers particular advantages in their case, since an infant's organism reacts extremely sensitively to radiation.

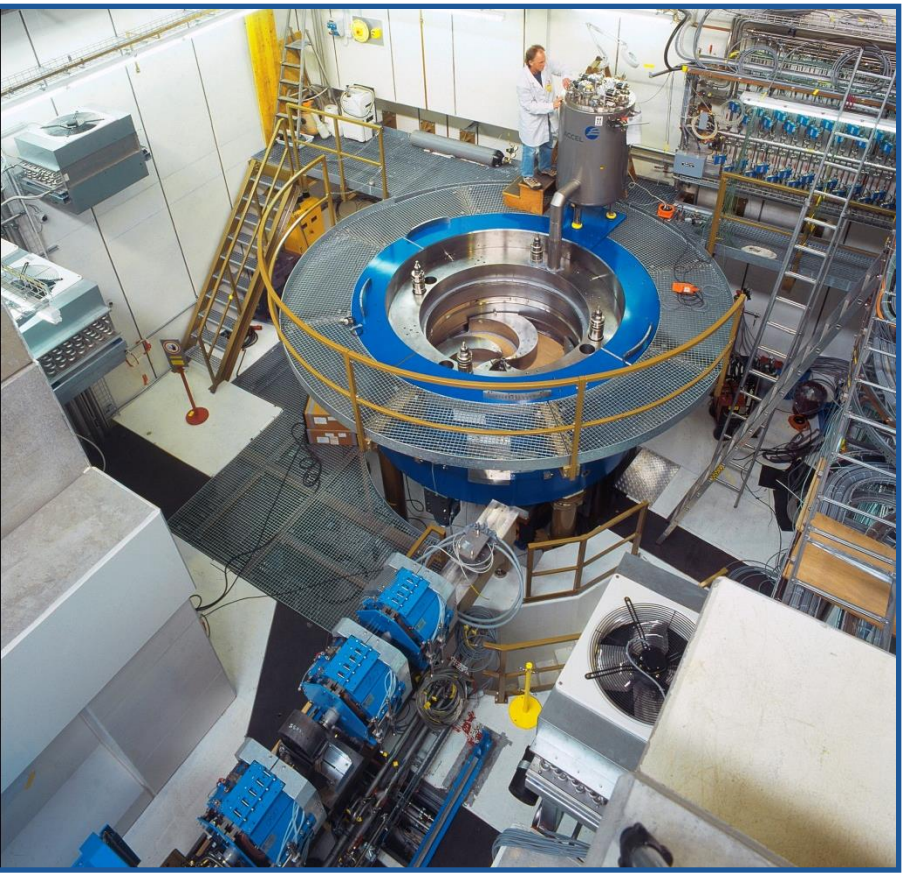
Project PROSCAN (1)

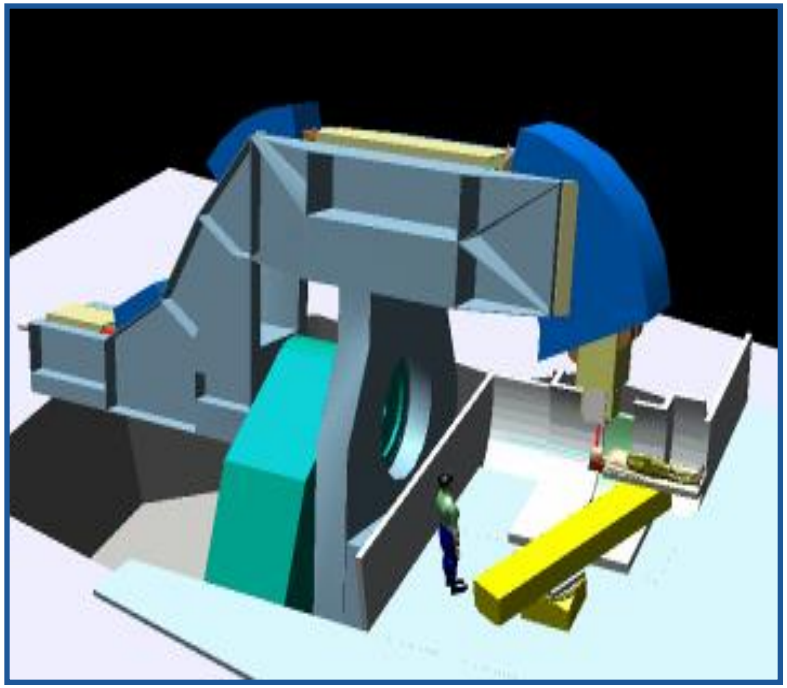


- The success of OPTIS and the international interest generated in its technology, led PSI in 1998 to examine strategies for extending the scope of proton therapy. The medium term goal was to transform the institute's breakthrough in cancer therapy into a marketable product, by developing techniques and equipment in collaboration with industrial partners.
- Parts of the project are to: (1) install the new COMET cyclotron, designed specifically for medical applications (start 2005), (2) and in parallel to develop and build the new Gantry II.
- The investment costs of the project stand at about 50 million CHF.

Project PROSCAN (2)

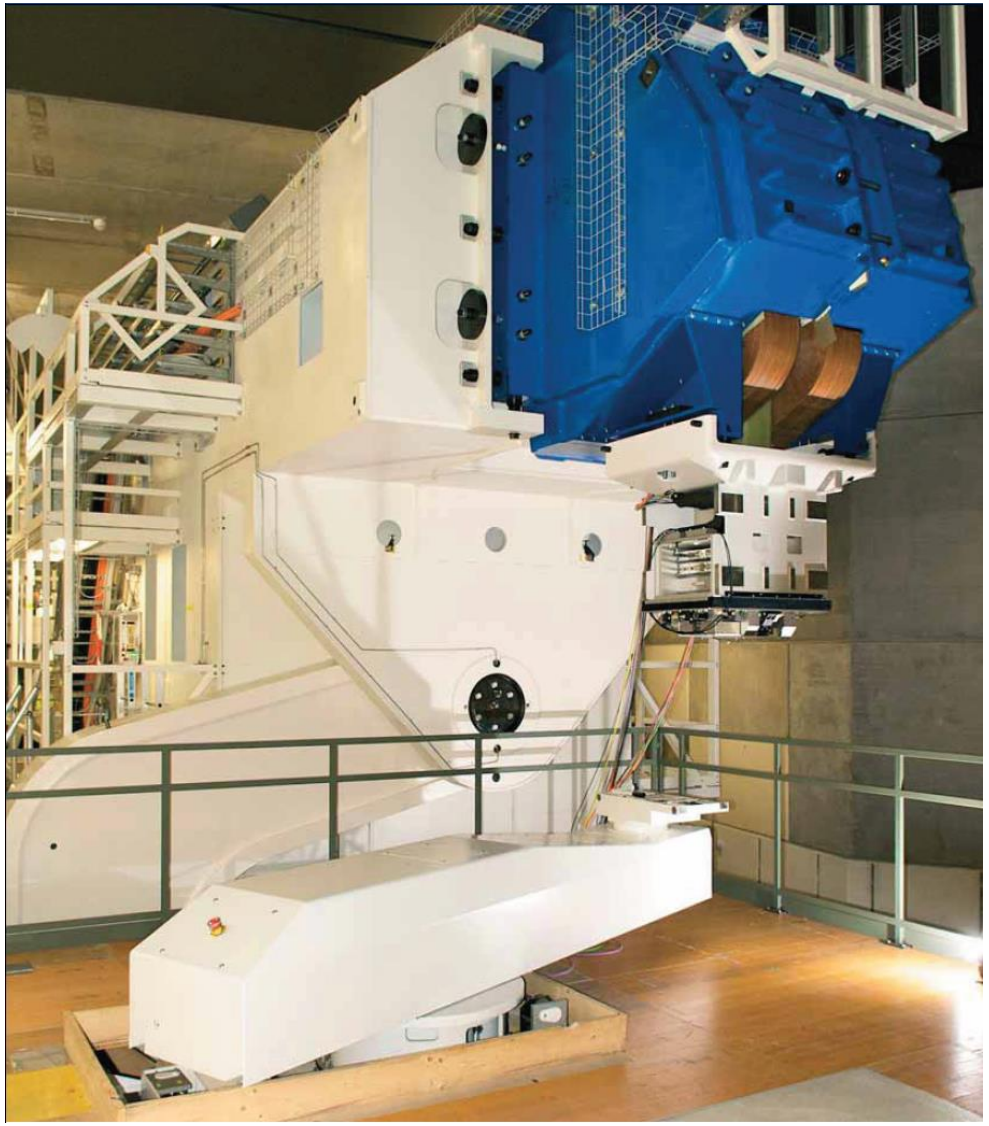
- **COMET: a compact proton accelerator**





- **Gantry II:**
  - **Irradiate tumours extremely accurately, even if they move while they are being irradiated (e.g. lung or breast tumours).**
  - **The proton beam is guided by deflecting magnets in two dimensions at a pre-set energy level into the tumour, and a slice of the tumour is irradiated.**
  - **The energy can be changed in a fraction of a second to irradiate the next layer of the tumour, which is therefore «scanned» in three dimensions.**

Gantry II: During construction/with 90º deflecting magnet and radiation head



Literature / WWW-References

- PSI-Brochures:
  - **Proton therapy** at the Paul Scherrer Institute, (Villigen PSI, December 2008)
  - **Die Protonentherapie** am Paul Scherrer Institut, (Villigen PSI, Oktober 2008)
  - **La protonthérapie** à l´Institut Paul Scherrer, (Villigen PSI, octobre 2008)

- Protonentherapie (proton therapy) @ PSI:
  http://p-therapie.web.psi.ch