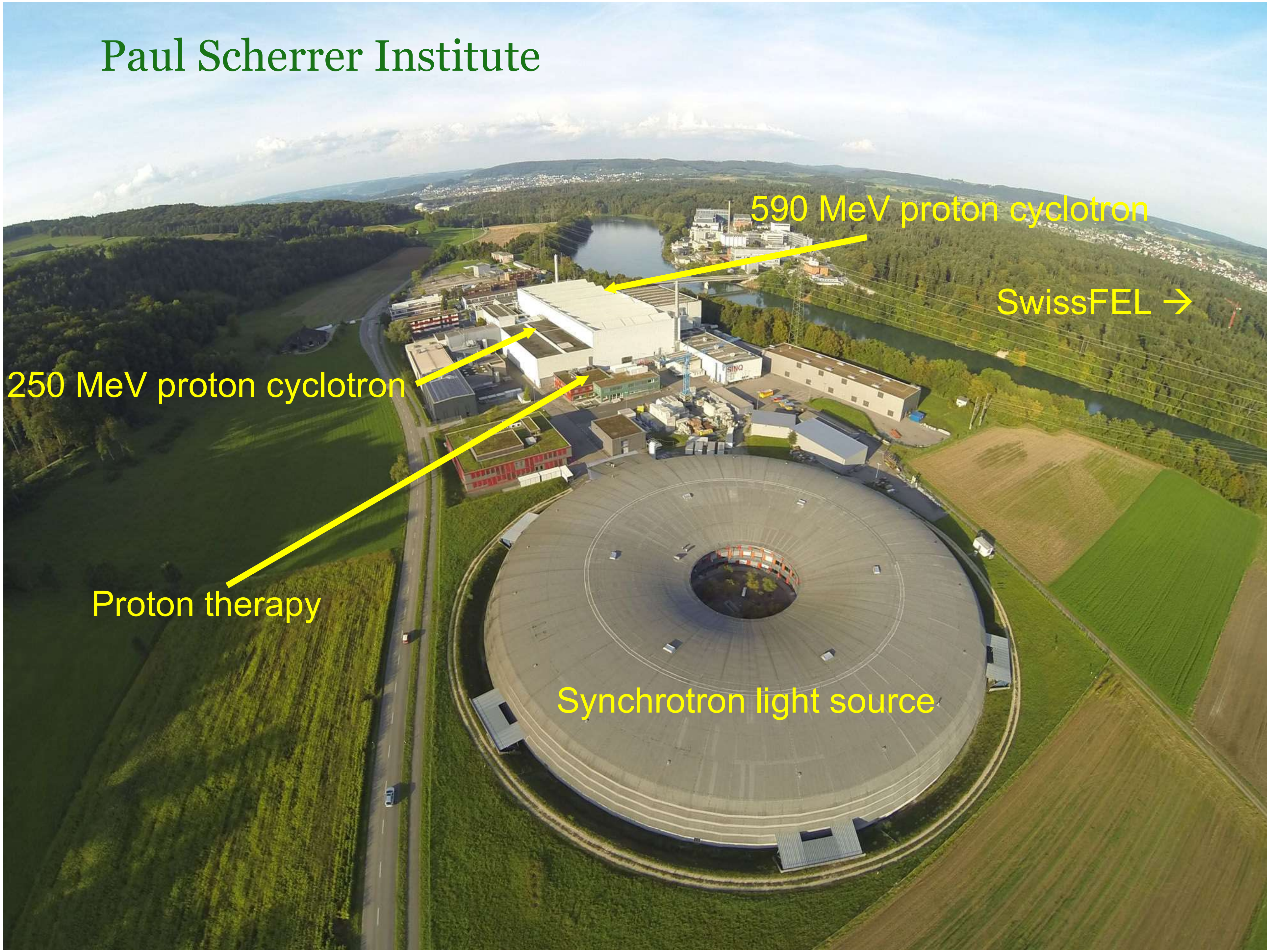
Martin Grossmann :: Center for Proton Therapy :: Paul Scherrer Institute

Protontherapy at PSI


PSI
Island
Schweden
Norwegen
Finnland
Ostsee
Estland
Lettland
Nordsee
Dänemark
Litauen
Moskau
Москва
Irland
Niederlande
Berlin
Polen
Weißrussland
Deutschland
Prag
Tschechien
Wien
Slowakei
Ukraine
Österreich
Moldawien
Ungarn
Frankreich
Rumänien
Kroatien
Serbien
Schwarzes Meer
Italien
Rom
Barcelona
Bulgarien
Georgien
Kaspisches Meer
Portugal
Madrid
Spanien
Tyrrhenisches Meer
Istanbul
Aserbaidschan
Griechenland
Türkei
Turkmenistan
Syrien
Libanon
Tunesien
Mittelmeer
Irak
Iran
Marokko
Jordanien
Google


Paul Scherrer Institute
590 MeV proton cyclotron
SwissFEL →
250 MeV proton cyclotron
Proton therapy
Synchrotron light source

Why Protons?

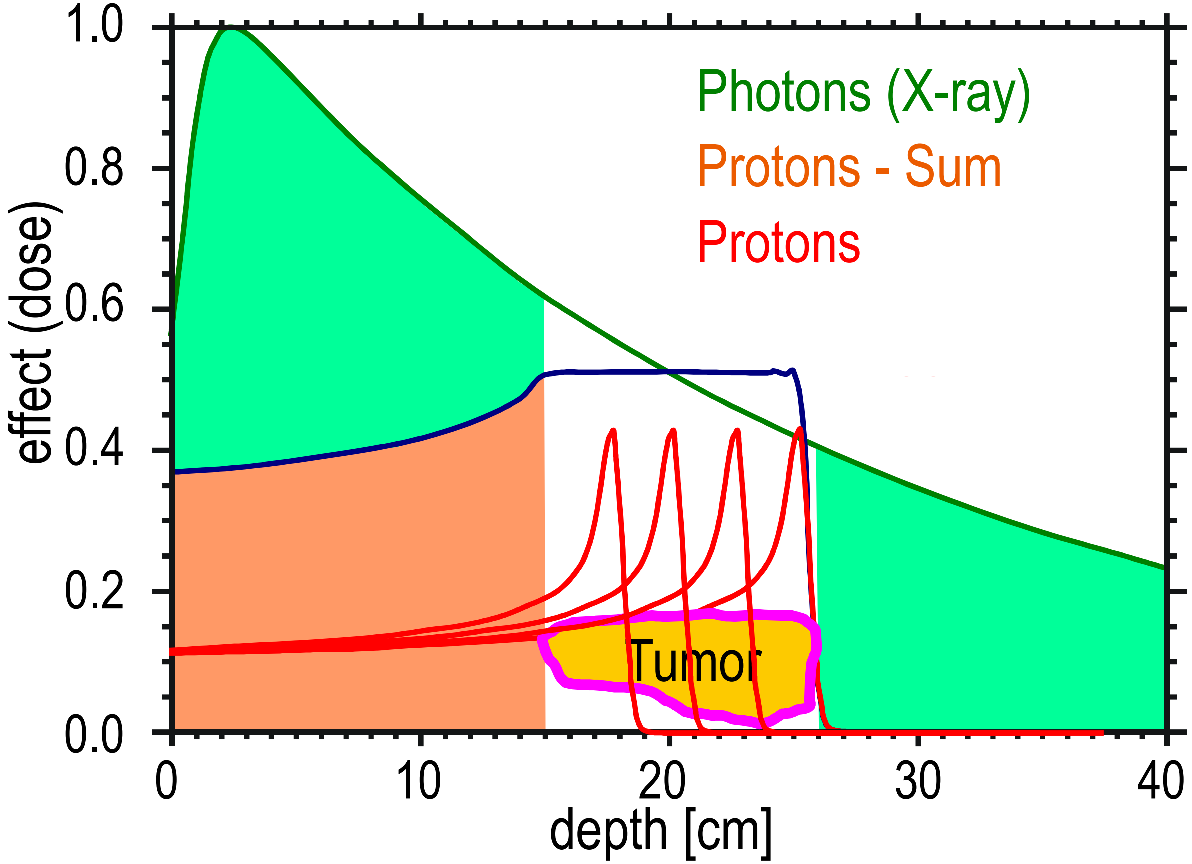
Proton therapy

Mass: ~200 tons

Diameter: ~8 m

Conventional therapy (LINAC)

Why Protons?

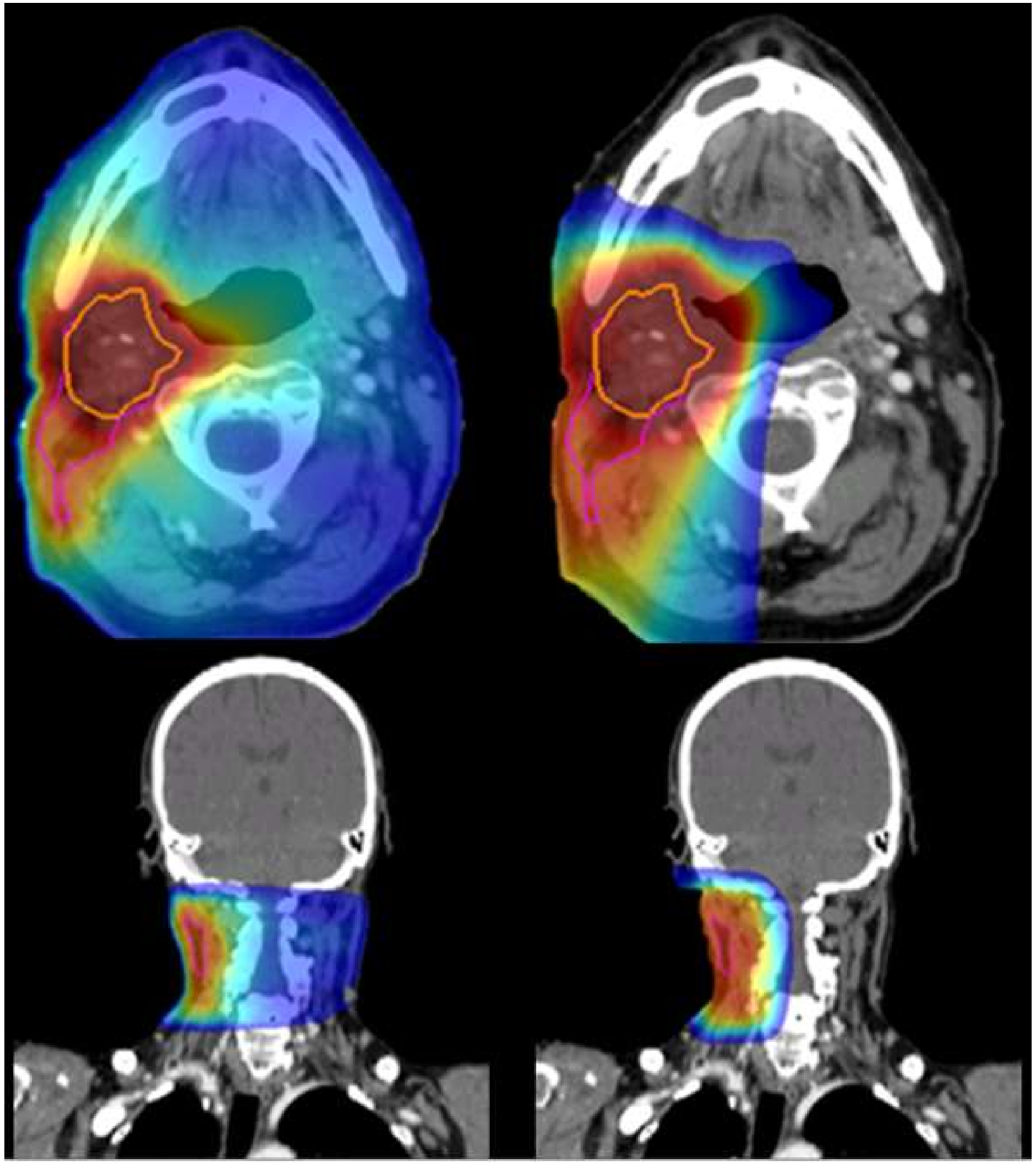


Dose burden - photons

Dose burden - protons

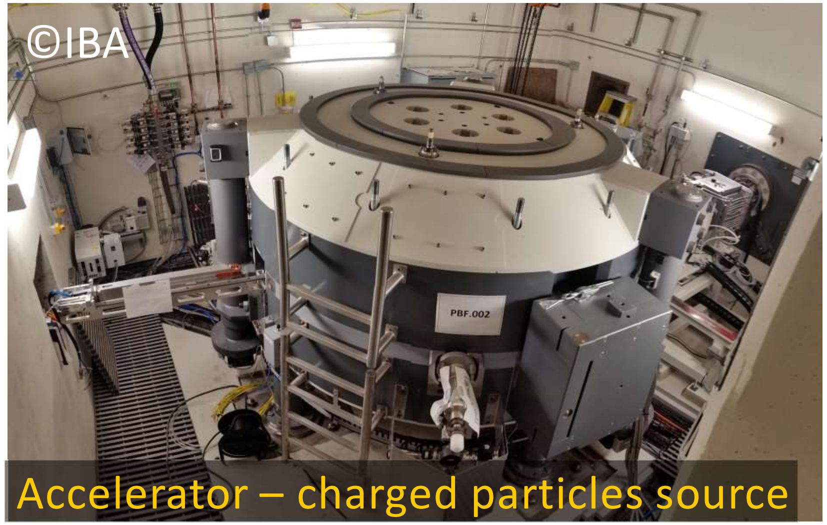
Why Protons?

Photons

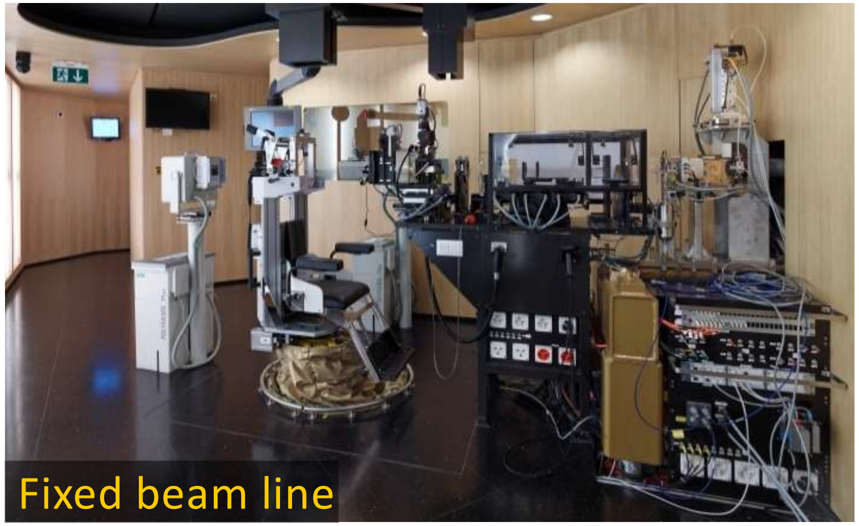


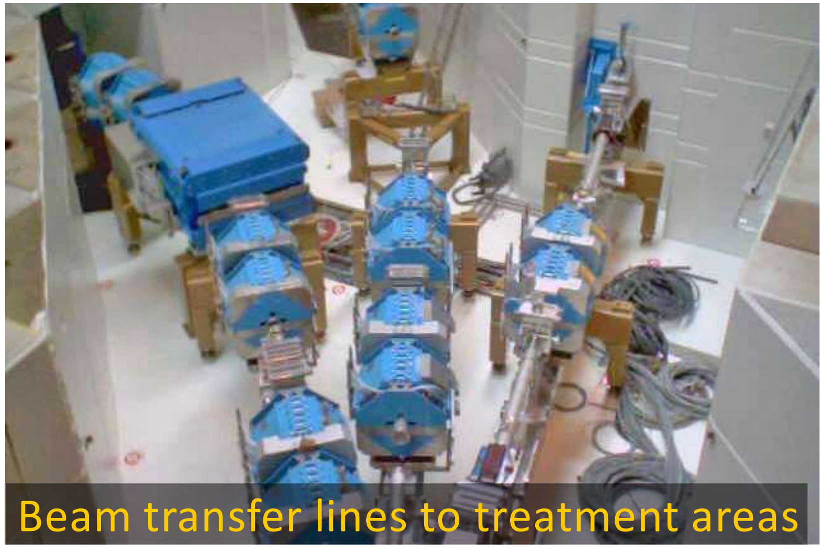
Protons

Main parts of a particle treatment facility



Accelerator – charged particles source

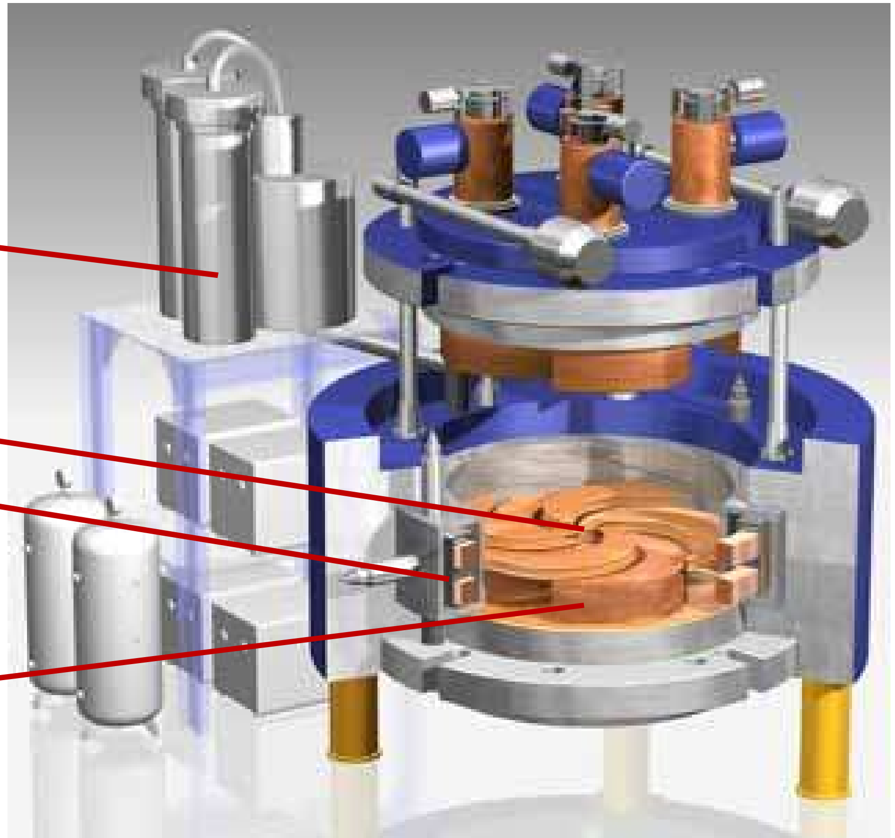

Fixed beam line


Beam transfer lines to treatment areas

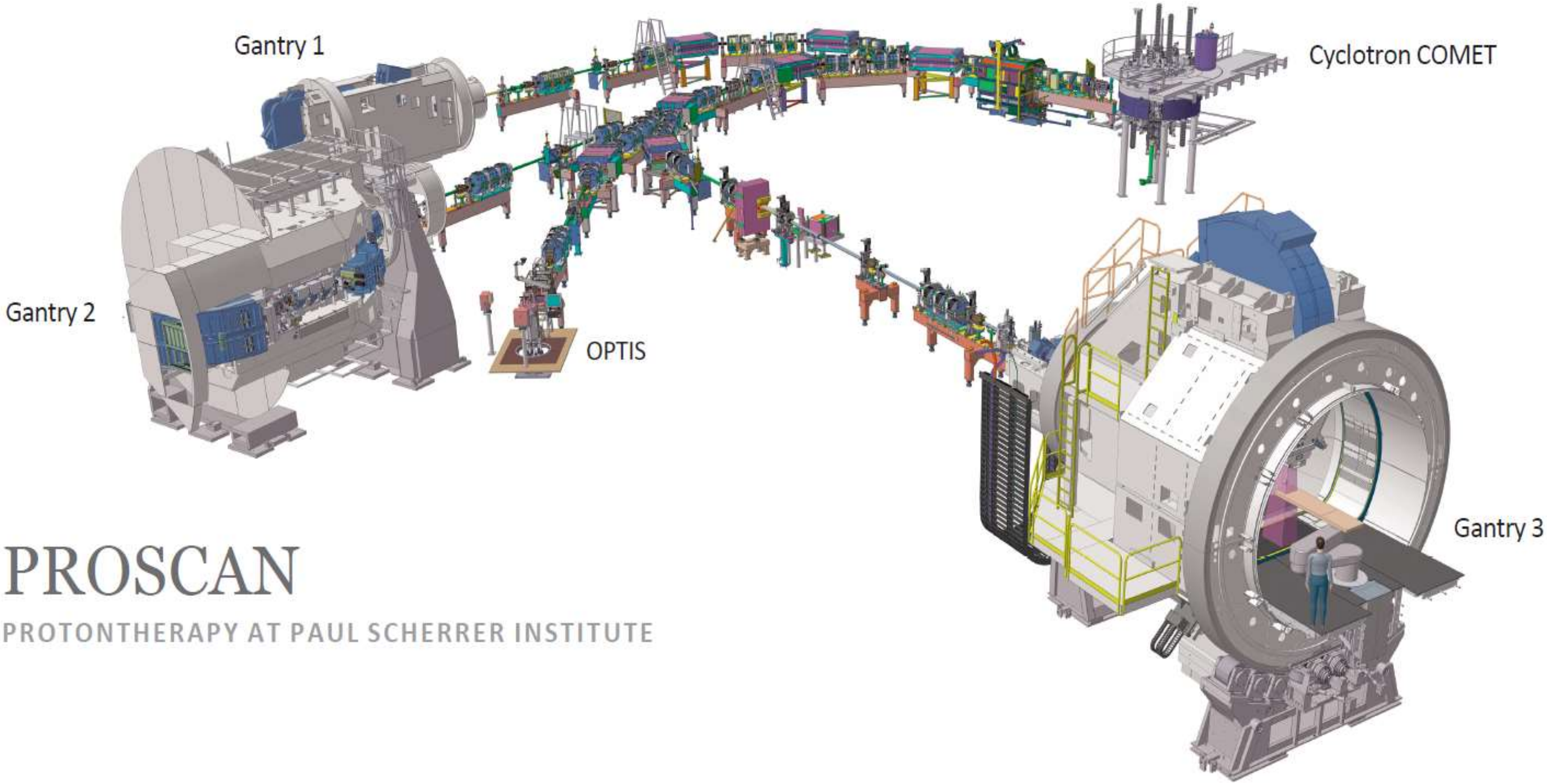

Gantry – rotating beam line

Superconducting Cyclotron COMET (Accel/Varian)

- 90 tons, 300 kW
- Closed He system
  4 cryostats @ 4K
- Protons source
- Superconducting coils 2.4 – 3.8 T
- 4 RF cavities 72 MHz @ 80 kV



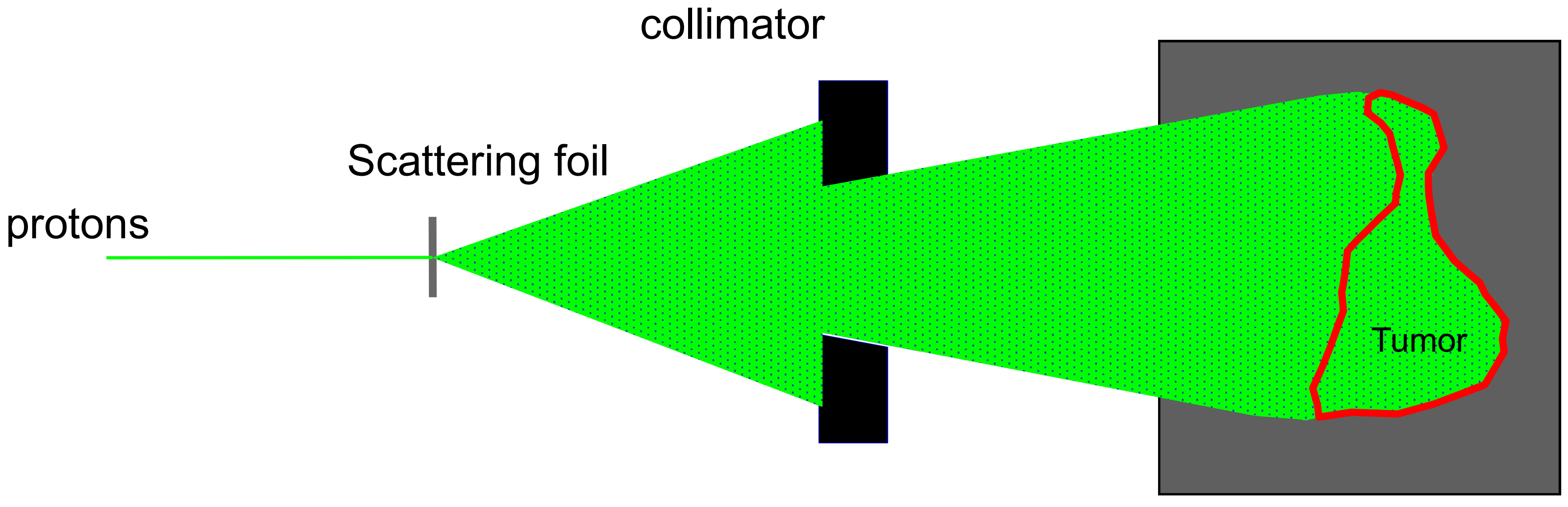
Superconducting Cyclotron COMET (Accel/Varian)



PROSCAN

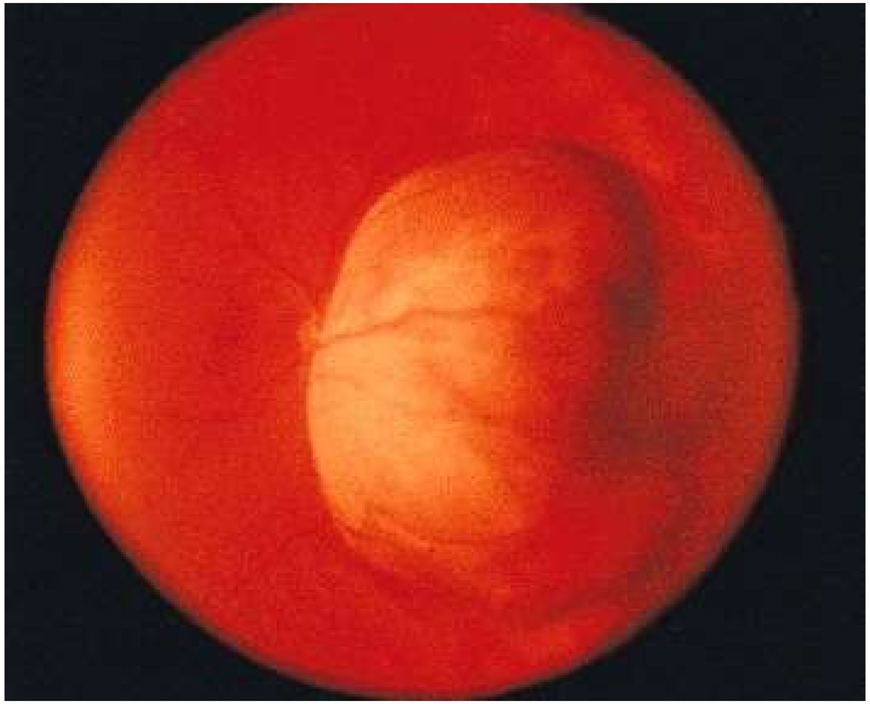
PROTONTHERAPY AT PAUL SCHERRER INSTITUTE

Irradiation technique - classical

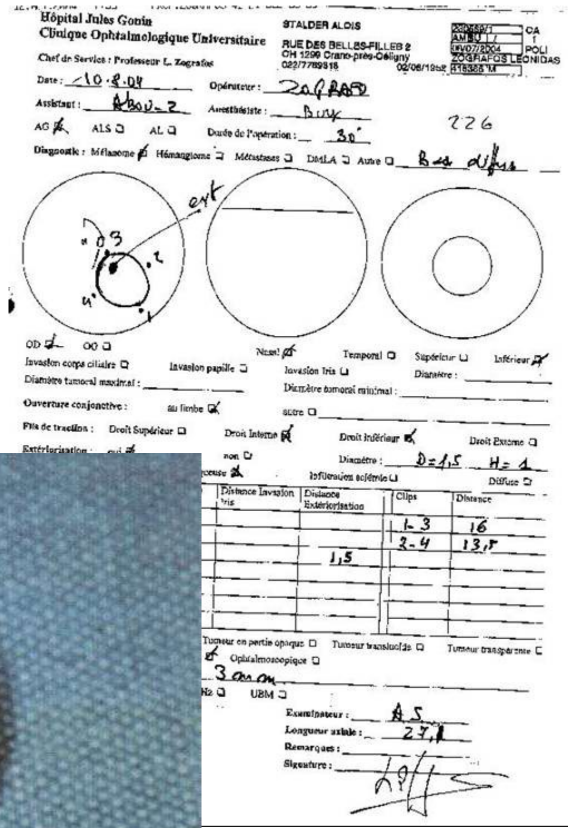


PSI's OPTIS program

- Treating Eye Melanoma
- Collaboration with eye clinic in Lausanne
  (Hôpital Ophtalmique Jules Gonin,
  Prof. L. Zografos)



PSI's OPTIS program


Hôpital Jules Gonin
Clinique Ophtalmologique Universitaire
Chef de Service : Professeur L. Zografos

STALDER ALOIS
RUE DES BELLES-FILLES 2
CH 1299 Crans-près-Céligny
022/7769516
02/06/1952
ZOGRAFOS LEONIDAS

Date : 10.8.04 Opérateur : ZOGRAFOS
Assistant : ABOU-Z Anesthésiste : Buk
AG ☑ ALS ☐ AL ☐ Durée de l'opération : 30'
226
Diagnostic : Mélanome ☑ Hémangiome ☐ Métastases ☐ DMLA ☐ Autre ☐

OD ☑ OG ☐
Nasal ☑ Temporal ☐ Supérieur ☐ Inférieur ☑
Invasion corps ciliaire ☐ Invasion papille ☐ Invasion Iris ☐ Diamètre :
Diamètre tumoral maximal : Diamètre tumoral minimal :
Ouverture conjonctive : au limbe ☑ autre ☐
Fils de traction : Droit Supérieur ☐ Droit Interne ☑ Droit Inférieur ☑ Droit Externe ☐
Extériorisation : oui ☑ non ☐ Diamètre : D = 1,5 H = 1
Infiltration sclérale ☐ Diffuse ☐

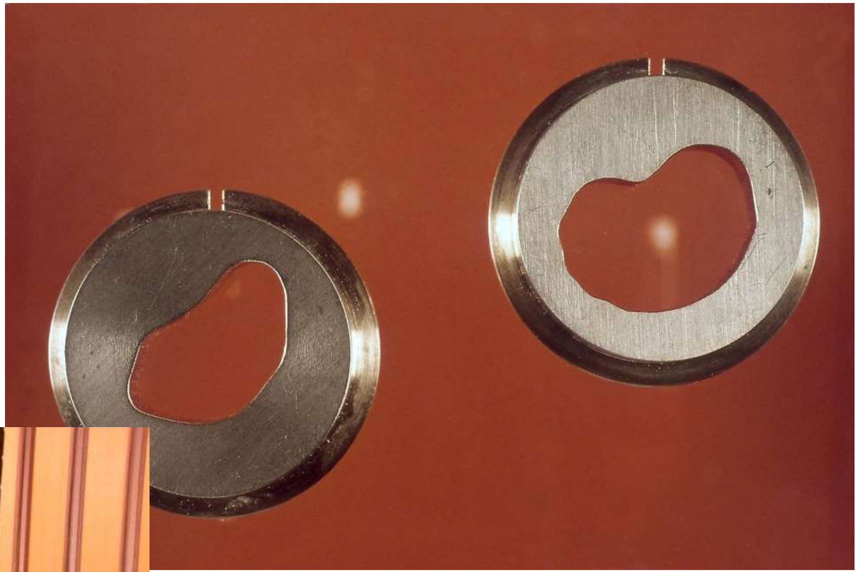
Distance Invasion Iris	Distance Extériorisation	Clips	Distance
		1-3	16
		2-4	13,5
	1,5		

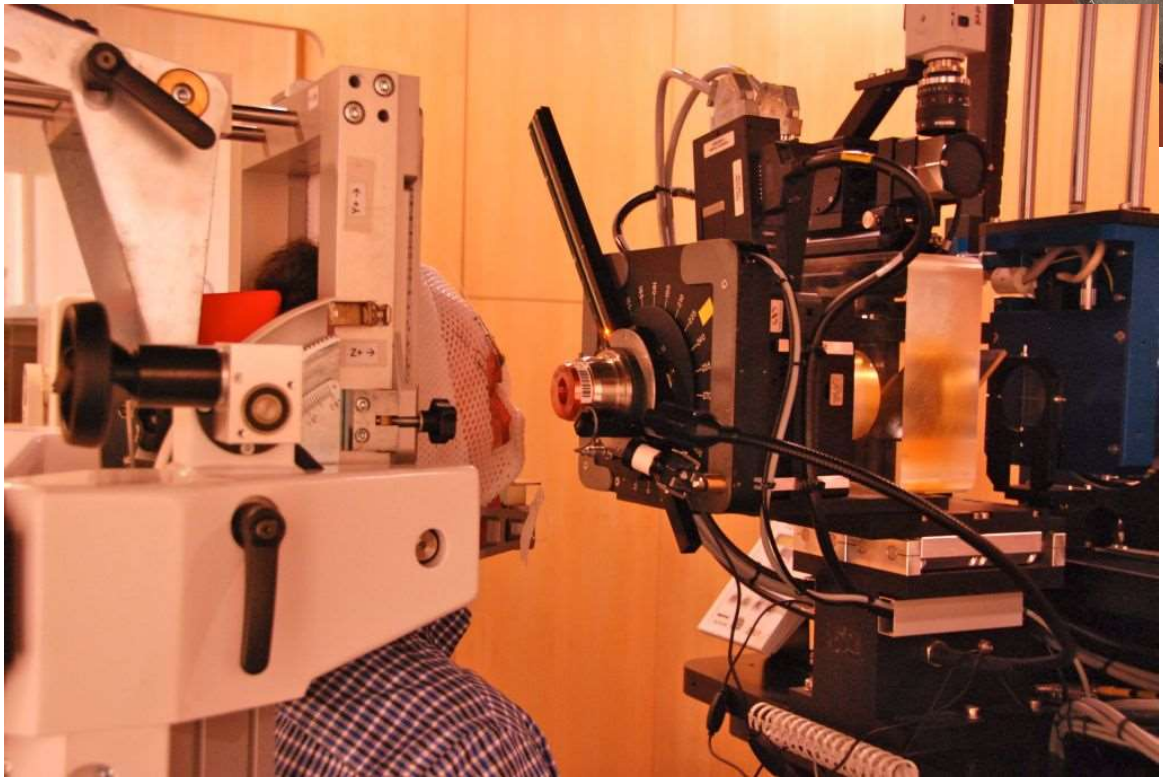
Tumeur en partie opaque ☐ Tumeur translucide ☐ Tumeur transparente ☐
Ophtalmoscopique ☐
3 mm
UBM ☐

Examinateur : A.S.
Longueur axiale : 27,1
Remarques :
Signature :

PSI's OPTIS program

OPTIS



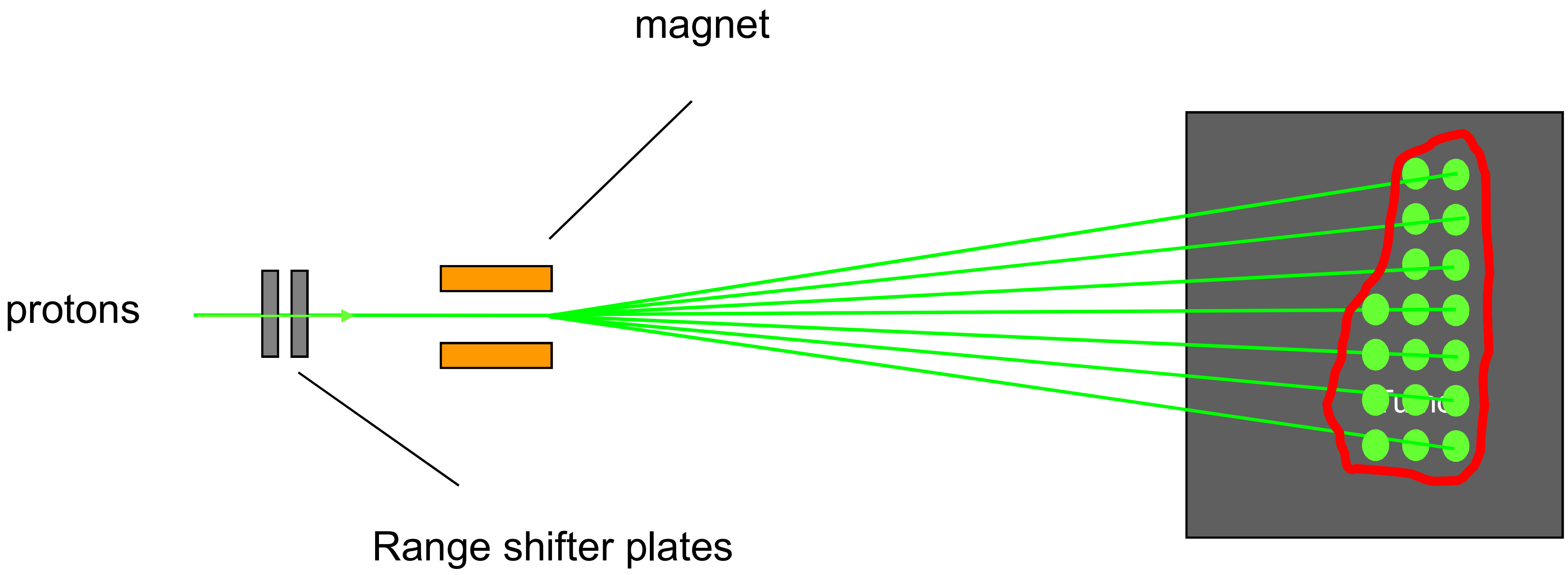


OPTIS – a success story

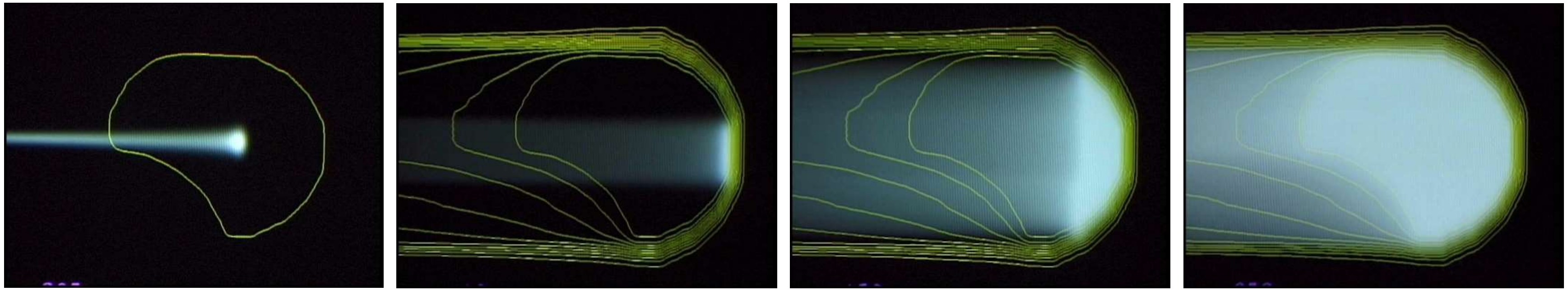
- Since 1984:
  treated more than 6’500 patients
- 98% cure
  (local tumor control)
- Conservation of vision
  100% for small tumors
  90% for big tumors

Protons
are the
standard!

Irradiation technique – «spot scanning»



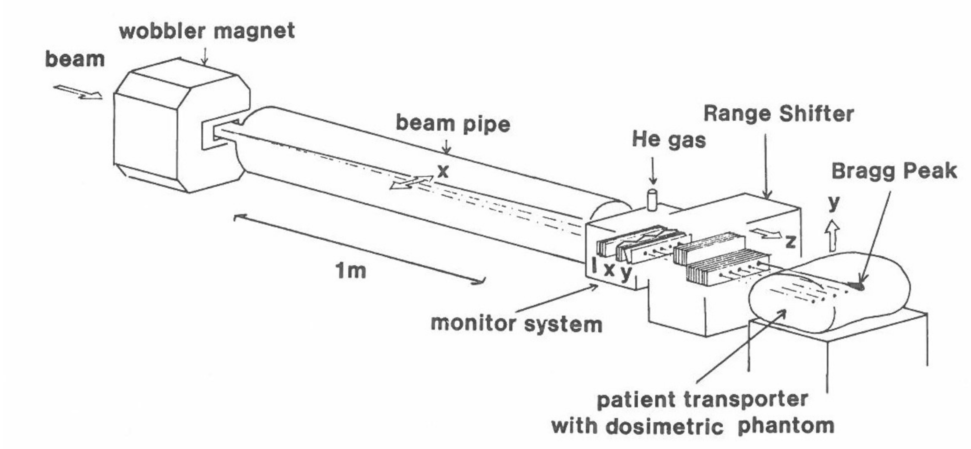
Feasibility demonstrated in 1989



Experimental setup for spot scanning with protons

Horizontal beam line

- Scanning in 1 dimension only
- Range shifter to modifiy proton energy



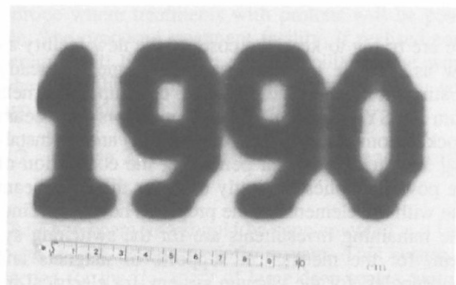


Fig. 4: X ray film irradiated with the 200 MeV proton beam using the spot scanning method.

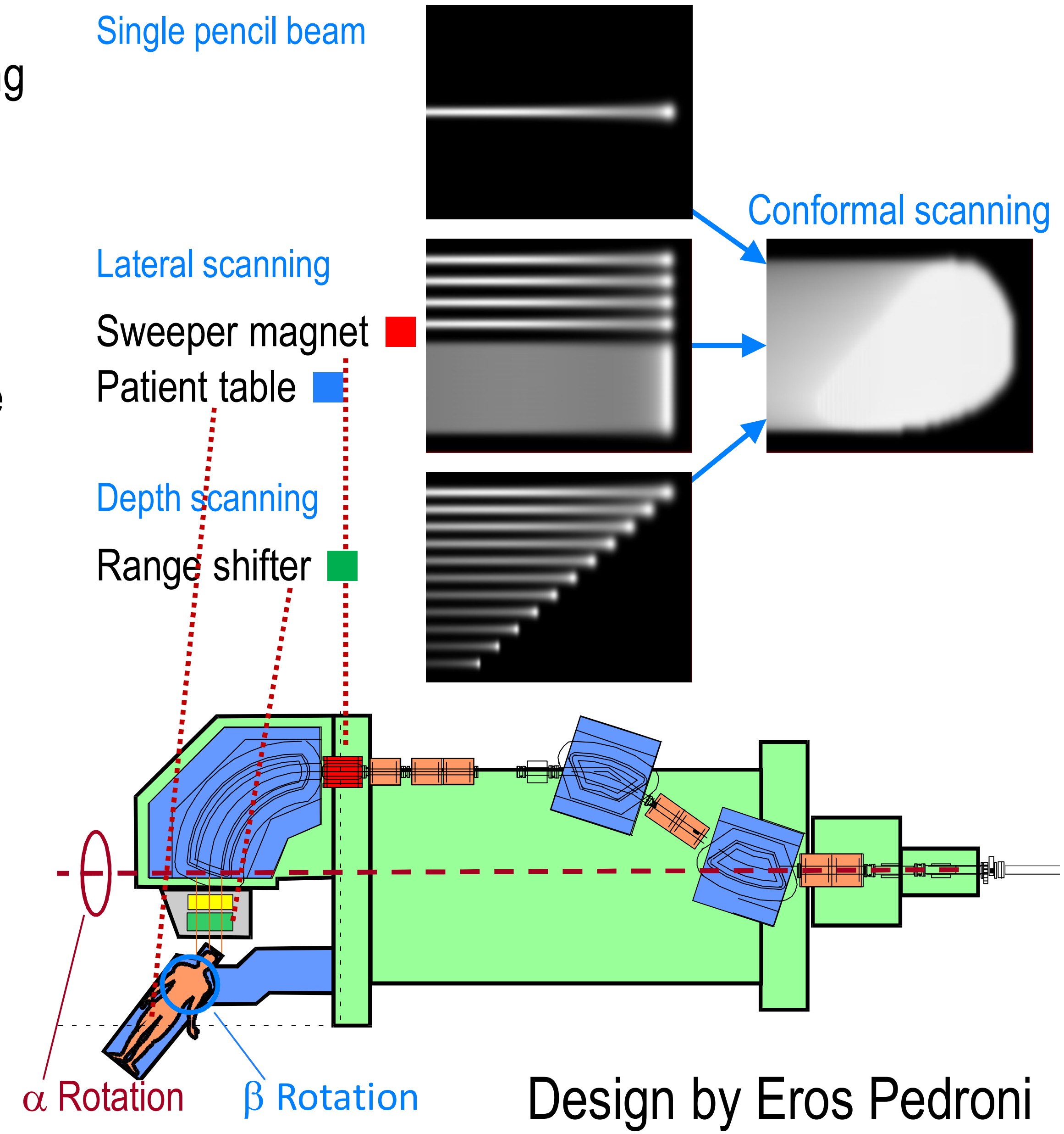
Gantry 1: A compact system for spot scanning

Implementation of spot scanning technique

Start patient operation 1996

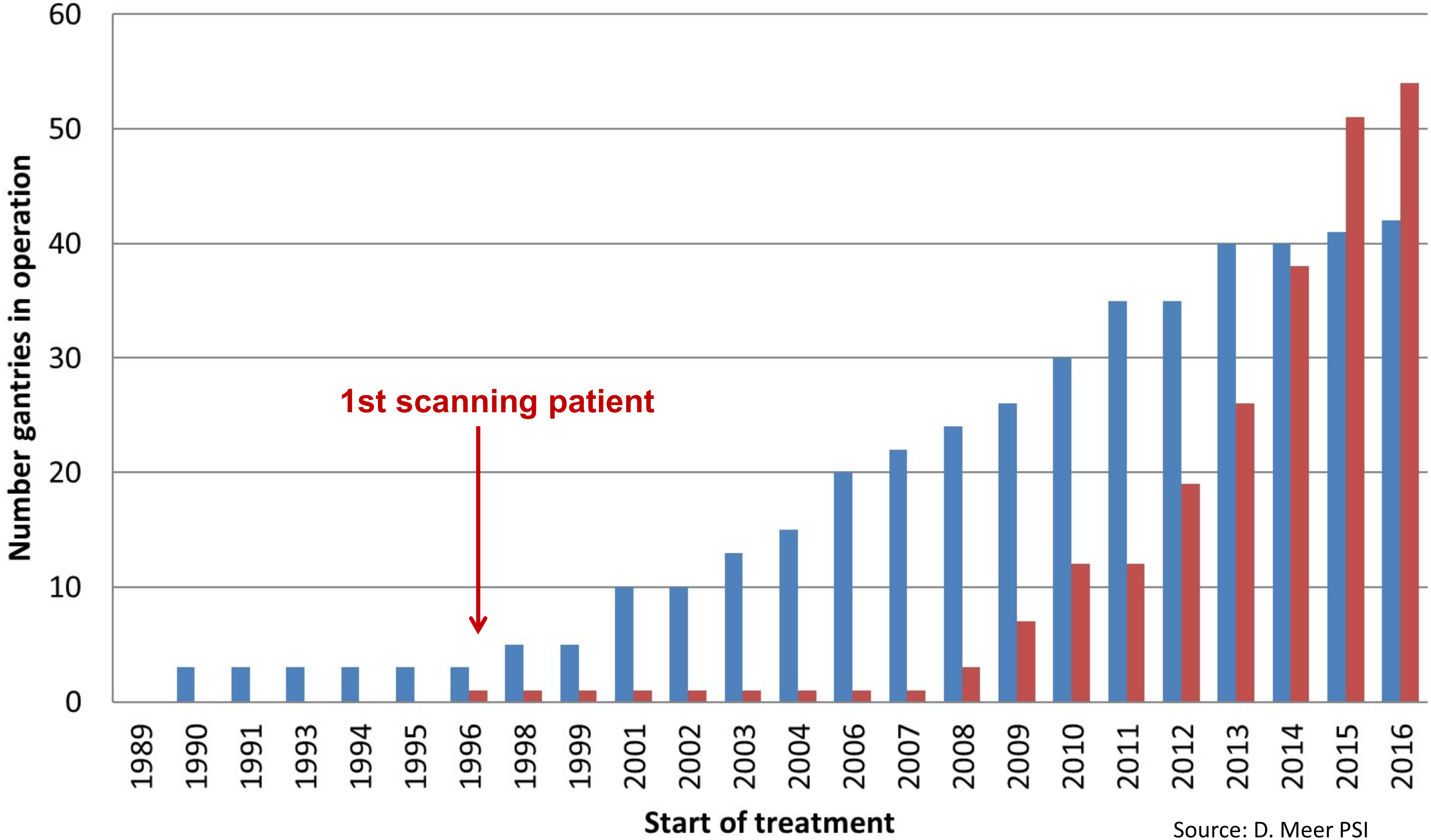
During 12 years the only spot scanning gantry worldwide

Due to eccentric design still the most compact system, r = 2m



Design by Eros Pedroni

Scanning-Technology is today's standard



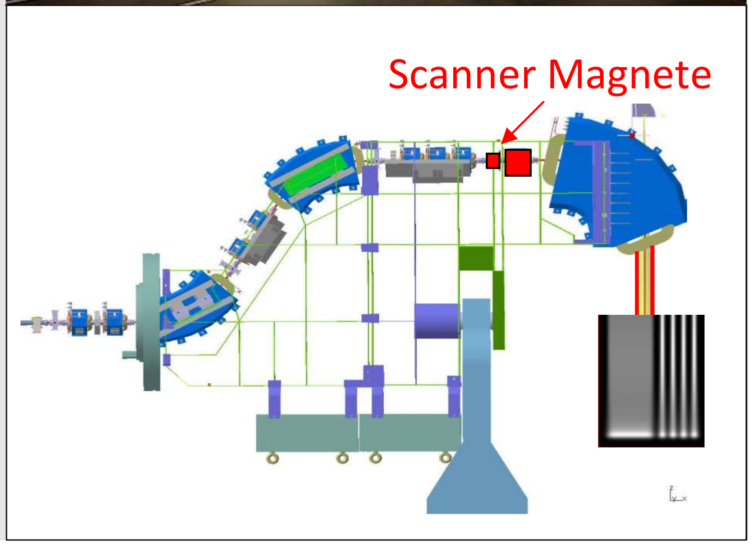
Source: D. Meer PSI

Gantry 2: next generation spot scanning

Easy access to patient at all times
- Rotation limited to 210°
- Patient table rotatable 180°
  (→ still full flexibility)
- No pit

Fast scanning in 2 dimensions
- Re-scanning possible
- Parallel Scanning
- Field size 12 x 20 cm

Fast energy change → 3rd dimension
- Energy step < 100 ms
- Re-scanning possible in 3 dimensions

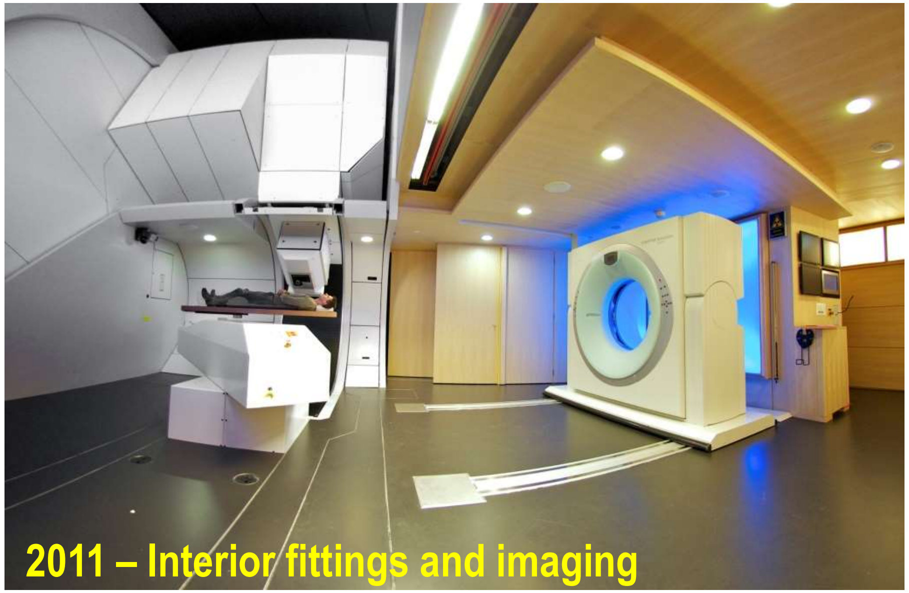


PAUL SCHERRER INSTITUT

Gantry 2: next generation spot scanning

2006 - Delivery of mechanical structure

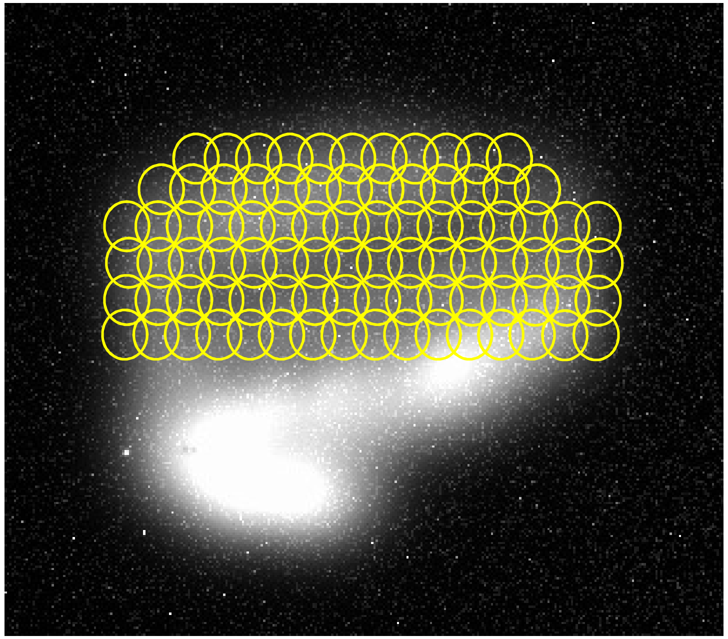
2008 - Beam line with innovative 90° dipole



2011 – Interior fittings and imaging

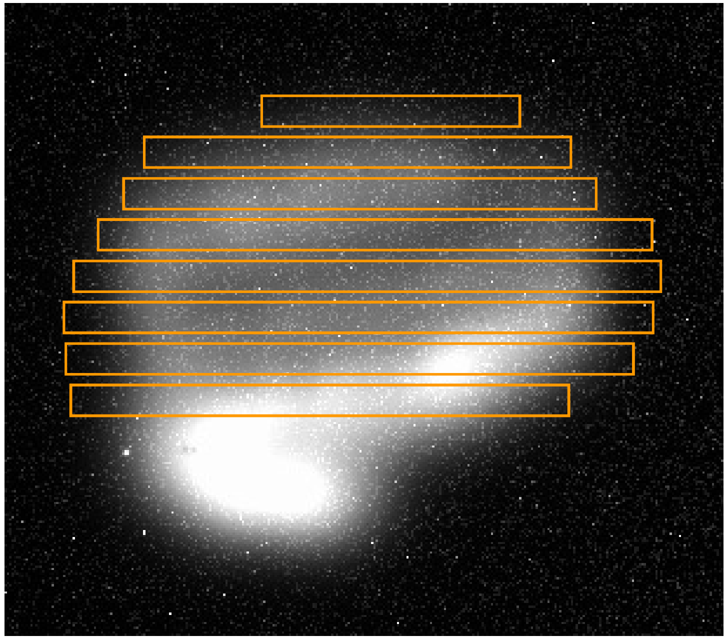
2013 - 1st patient treated

Improvements in scanning technology



Discrete spot scanning

- Switching off the beam after each spot
- Dead time per spot ~3 ms.
  Typically field: 10’000 spots
  → 30 s dead time, scales with number of re-scans!
- Accurate dose delivery
- Spot scanning is actual operation mode of Gantry 2

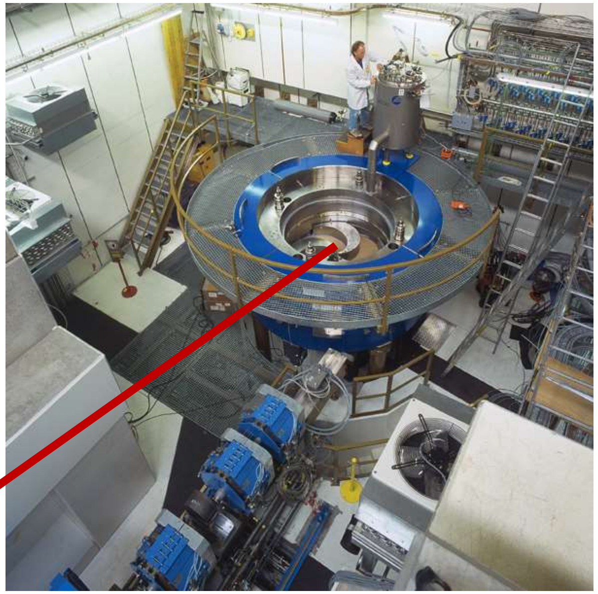


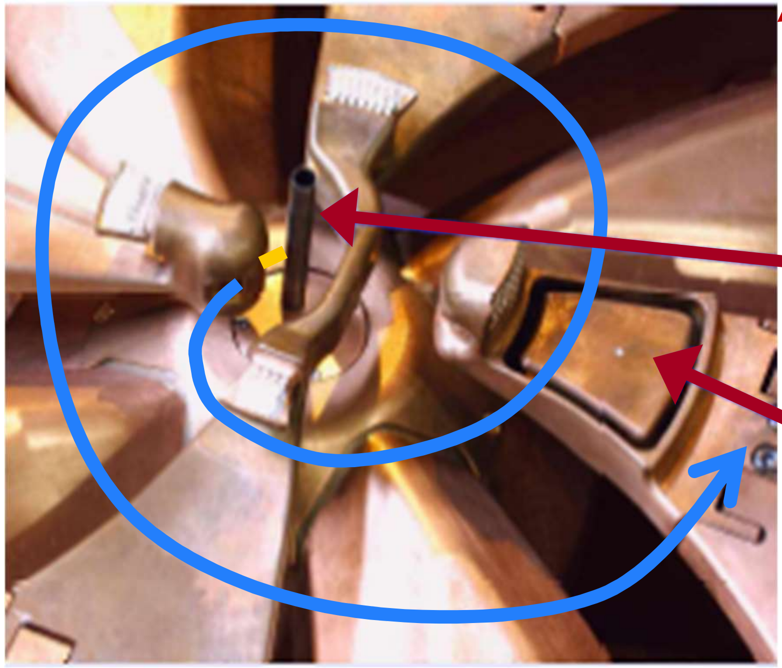
Continuous line scanning

- Paint lines of dose with continuous beam on using
  - Beam intensity modulation
  - Beam motion speed modulation
- For efficient and effective repainting
- Operational in experimental mode, in development

Proton beam intensity modulation

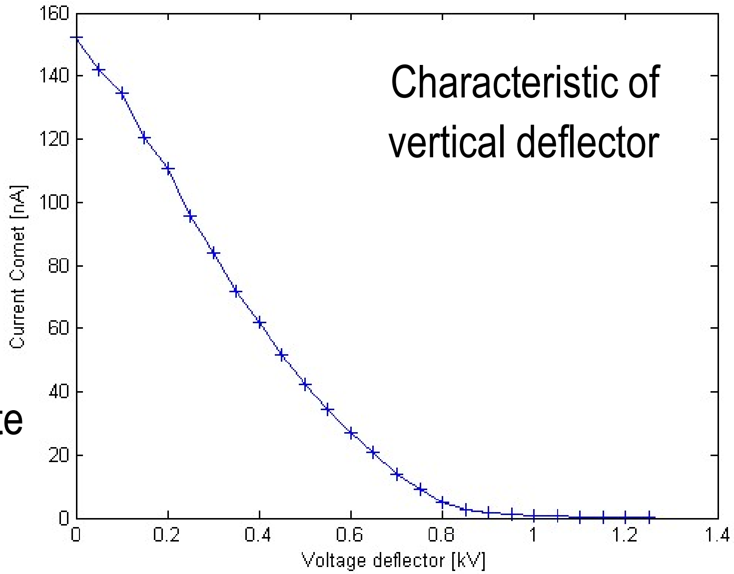
- Fast electrostatic beam deflection inside cyclotron (< 50 μs)
- Switch beam on/off
- Intensity modulation
- Little activation of the cyclotron





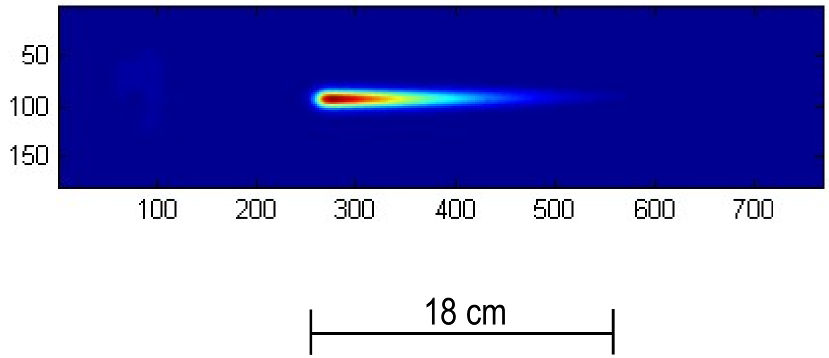
Ion source

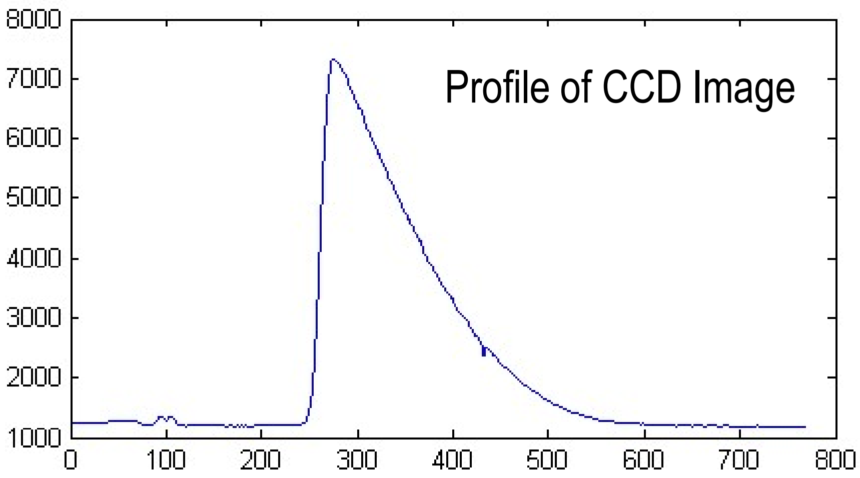
Vertical deflector plate

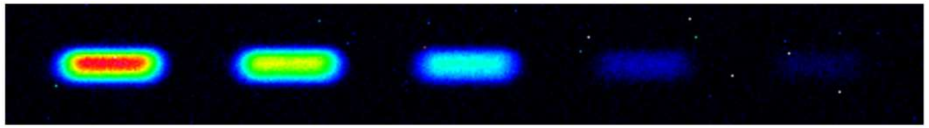


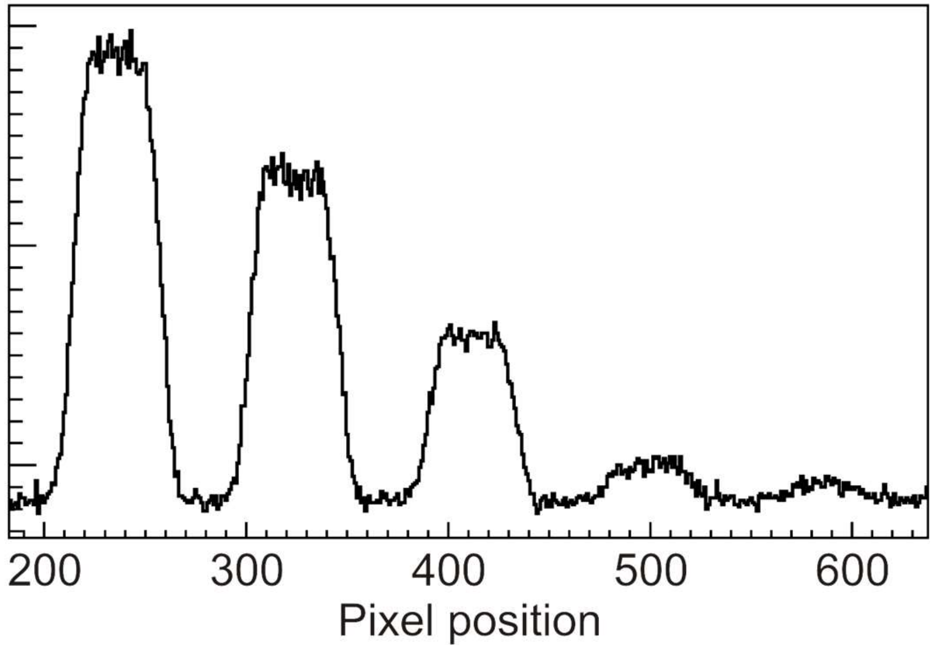
Painting intensity modulated lines

Continuous line (18 cm) with linear increasing vertical deflector voltage





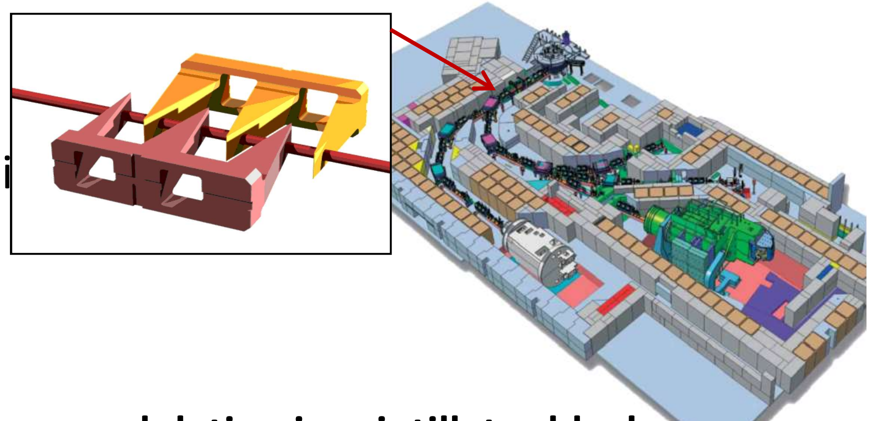




Intensity modulated line segment (15 cm) painted in 30 ms.

Fast changes of the beam energy

- The Gantry 2 and PROSCAN are optimized for fast energy changes:
  - Cyclotron provides fixed energy
  - Fast degrader mechanical
  - Laminated magnets / dedicated power suppli
  - Need to consider magnetization and hysteresis effects
  - On-line correction of “drift” effects



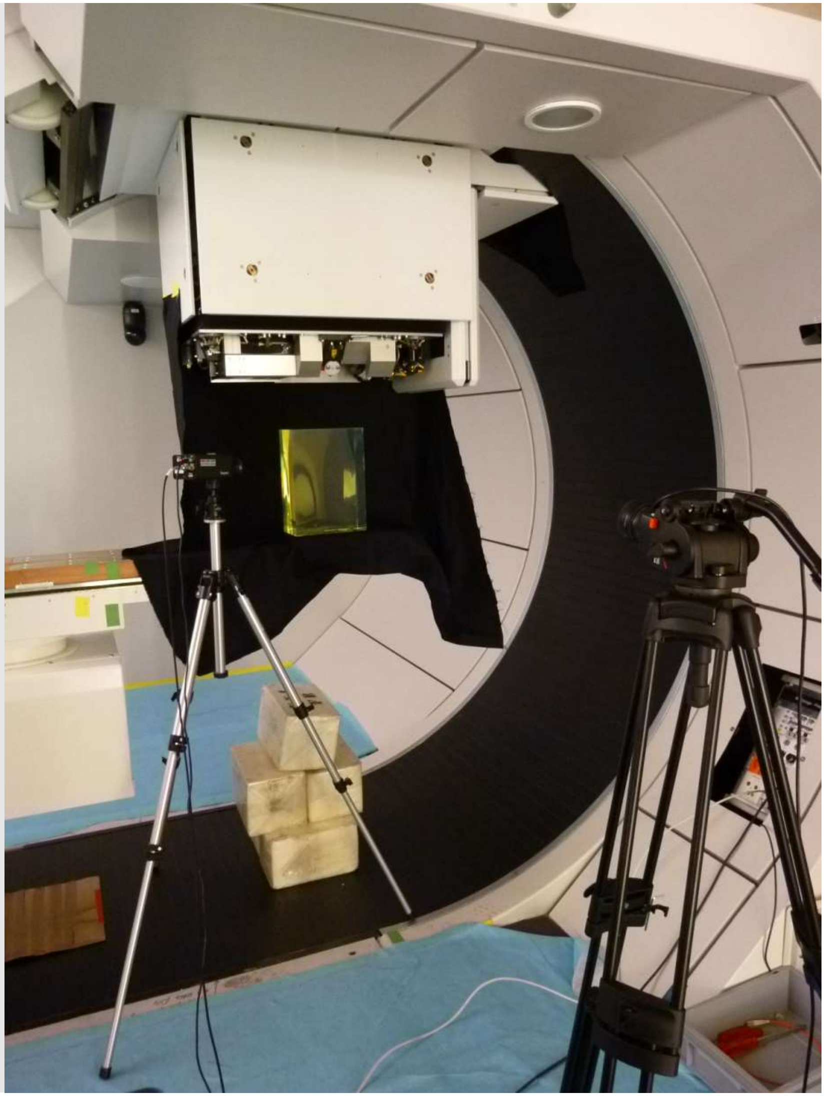
Energy modulation in scintillator block

- Realized:
  - **~100 ms** dead time for range steps of 5 mm

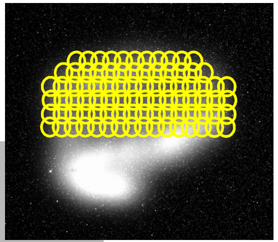
Benefit

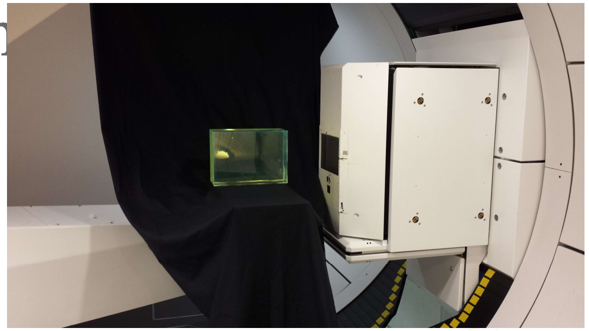
- Faster treatments
- Potential for volumetric repainting

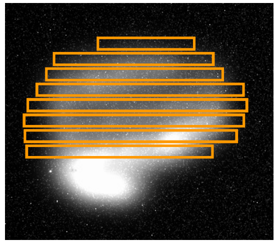

ciclobby
Cal



Demonstration to show potential of fast line-scannin







Discrete spot scanning

20412 spots, 28 energy layers

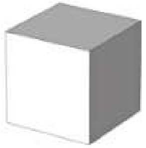
Beam-on time: 17s

Dead time: 80s

Total time: 97s

→ 5 re-scans: ~7min

Cubical target, V = 1l



Spot grid 4 mm

Dose: 0.6 Gy (typical 3 field fraction dose)

Standard dose rate (<6 Gy/s)

Continuous line scanning

27 lines / energy, 28 energy layers

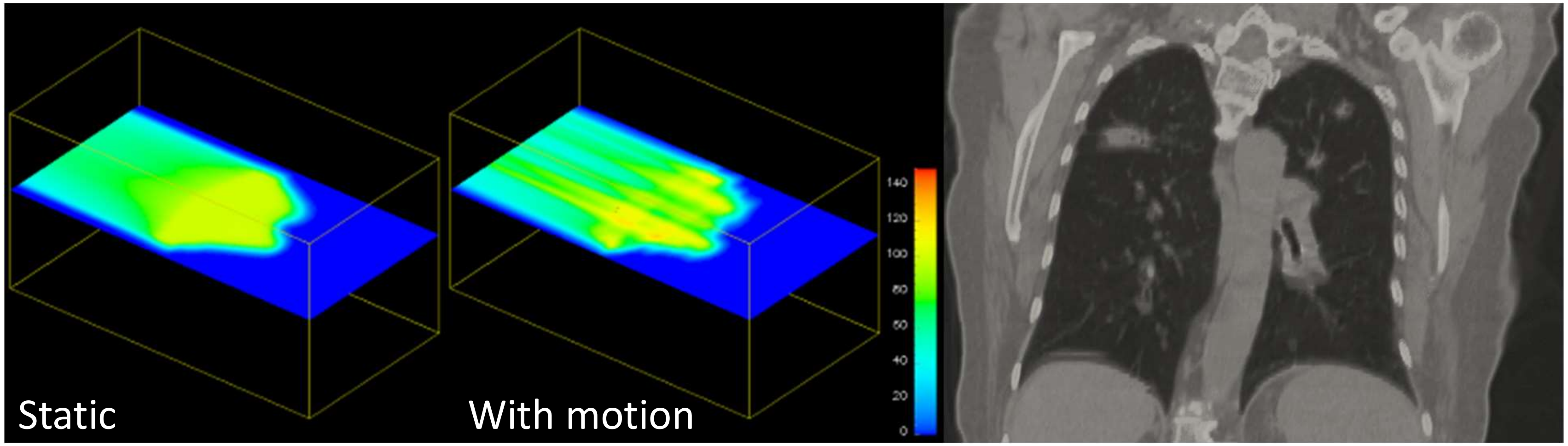
Beam-on time: 17s

Dead time: 3s

Total time: 20s

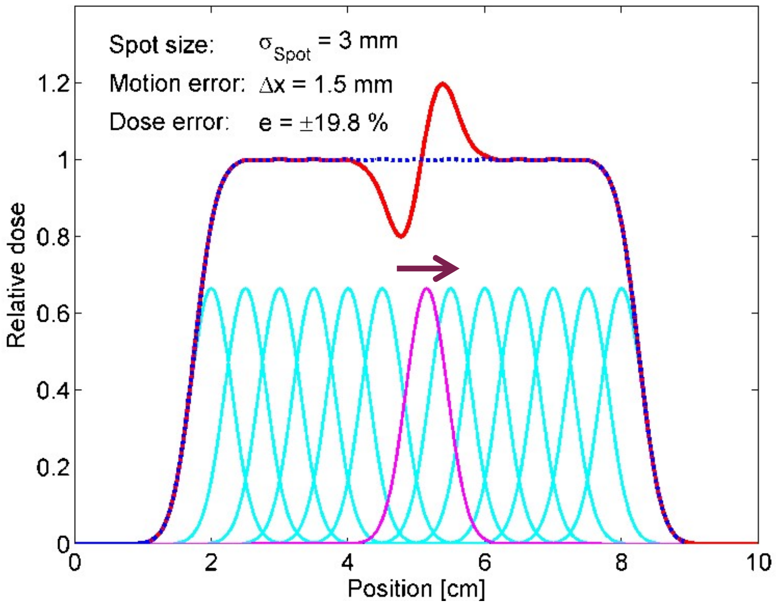
→ 5 re-scans: ~30s

A mayor challenge in PBS: Moving targets / organ motion



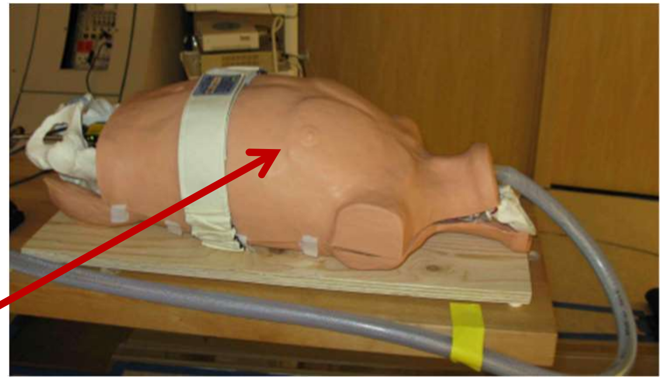
- Interplay effect between beam delivery sequence and organ motions destroys dose homogeneity
- Mitigation techniques:
  – Deliver dose multiple times (Rescanning)
  – Patient hold his/her breath (Breath-hold)
  – Irradiation only in exhaled phase (Gating)

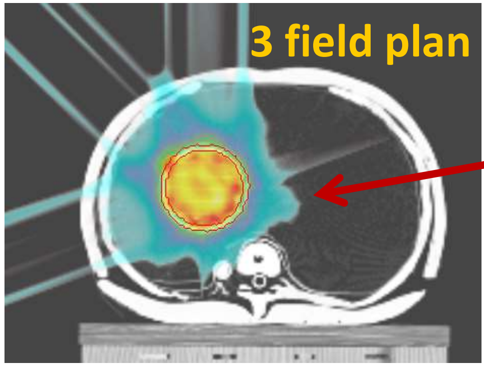
⇨ All approaches require fast beam delivery



Experimental validation of rescanning

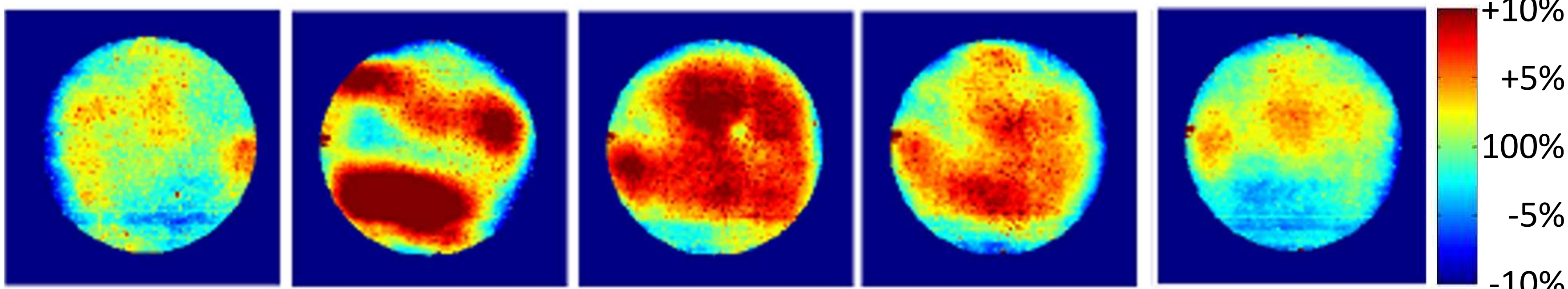
- Anthropomorphic phantom with lung tumour and tissue equivalent materials (bone, skin, lung)
- Simulation of different breathing parameters
- Rescanning to minimize motion interferences
  → Dose homogeneity can be recovered





Tumour with insert for dose measurements with film

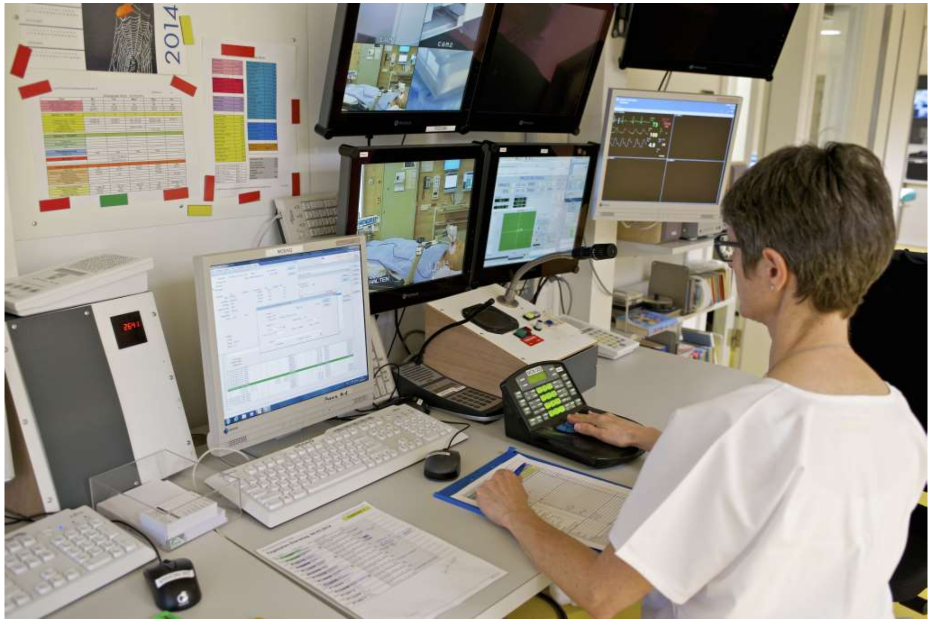
R. Perrin, PSI



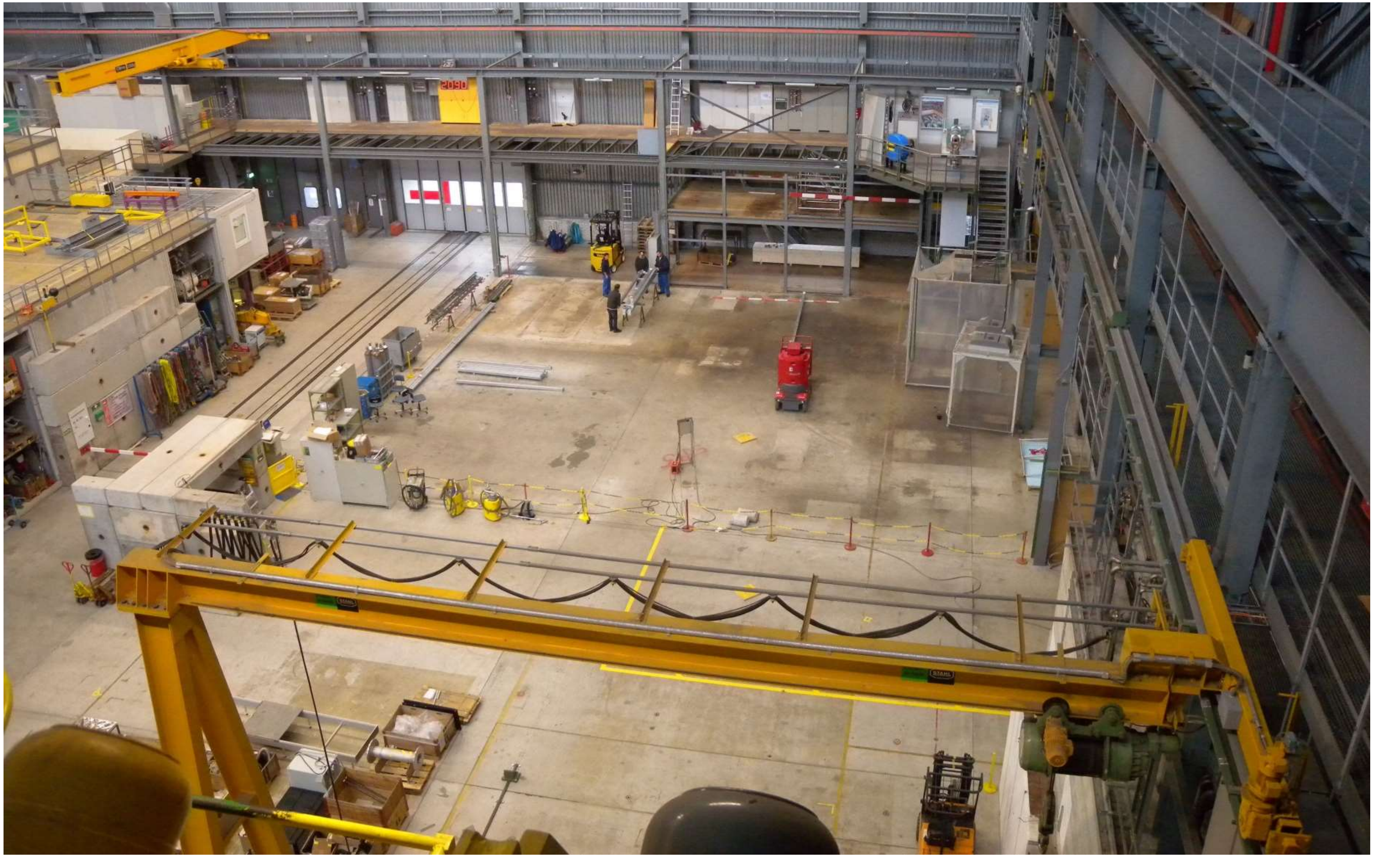
Static Motion, 1 cm 2x rescanning 5x rescanning 8x rescanning

Treating small children

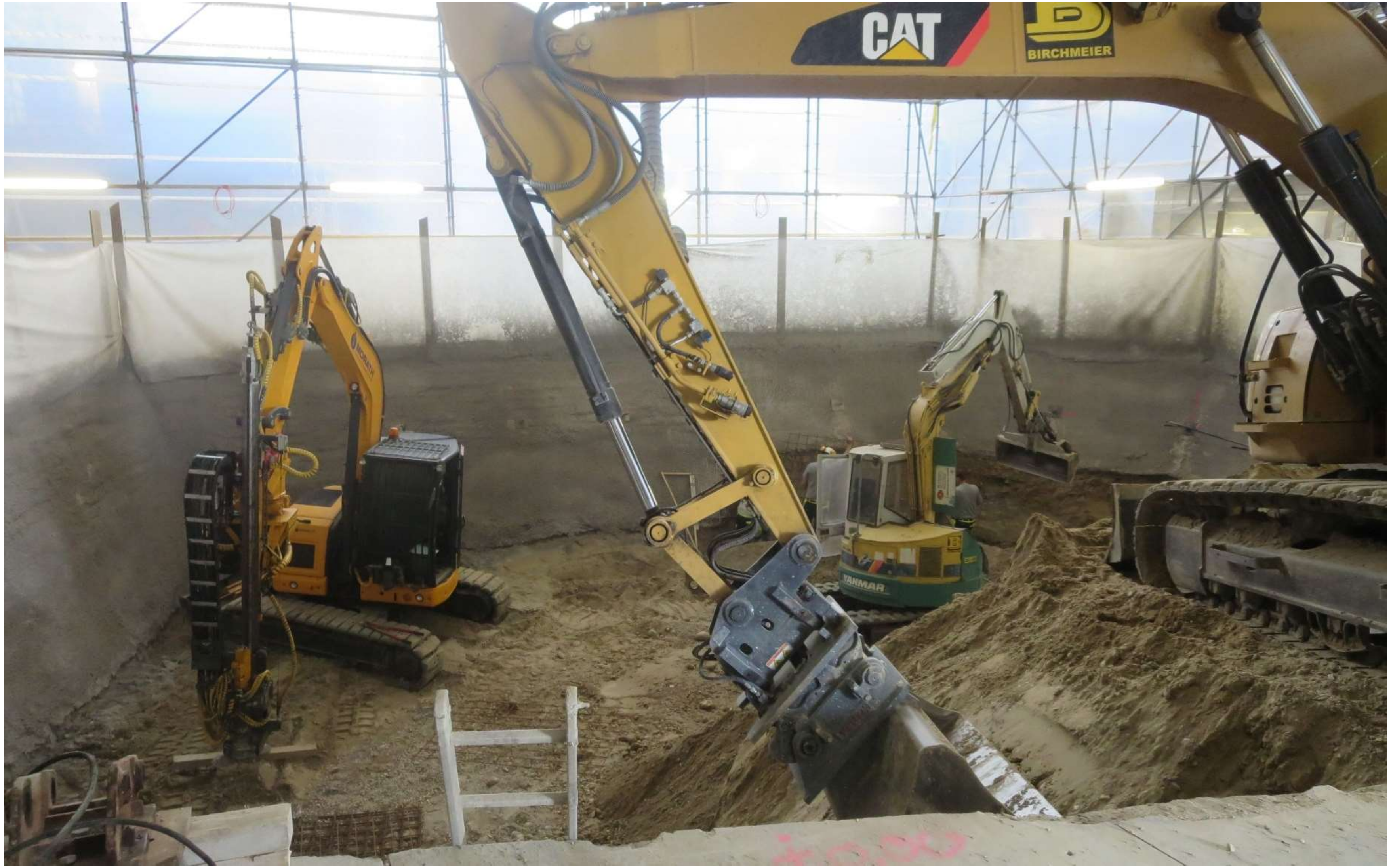
- Since 2004 treatments of small children
  → **anesthesia team from children's hospital in Zurich**
- Ca. 500 patients


2014


Bair Hugger




CAT


CAT
BIRCHMEIER
YANMAR


BIRCHMEIER
MANITOU


RACETECH
Schwerlast
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5000kg LOAD
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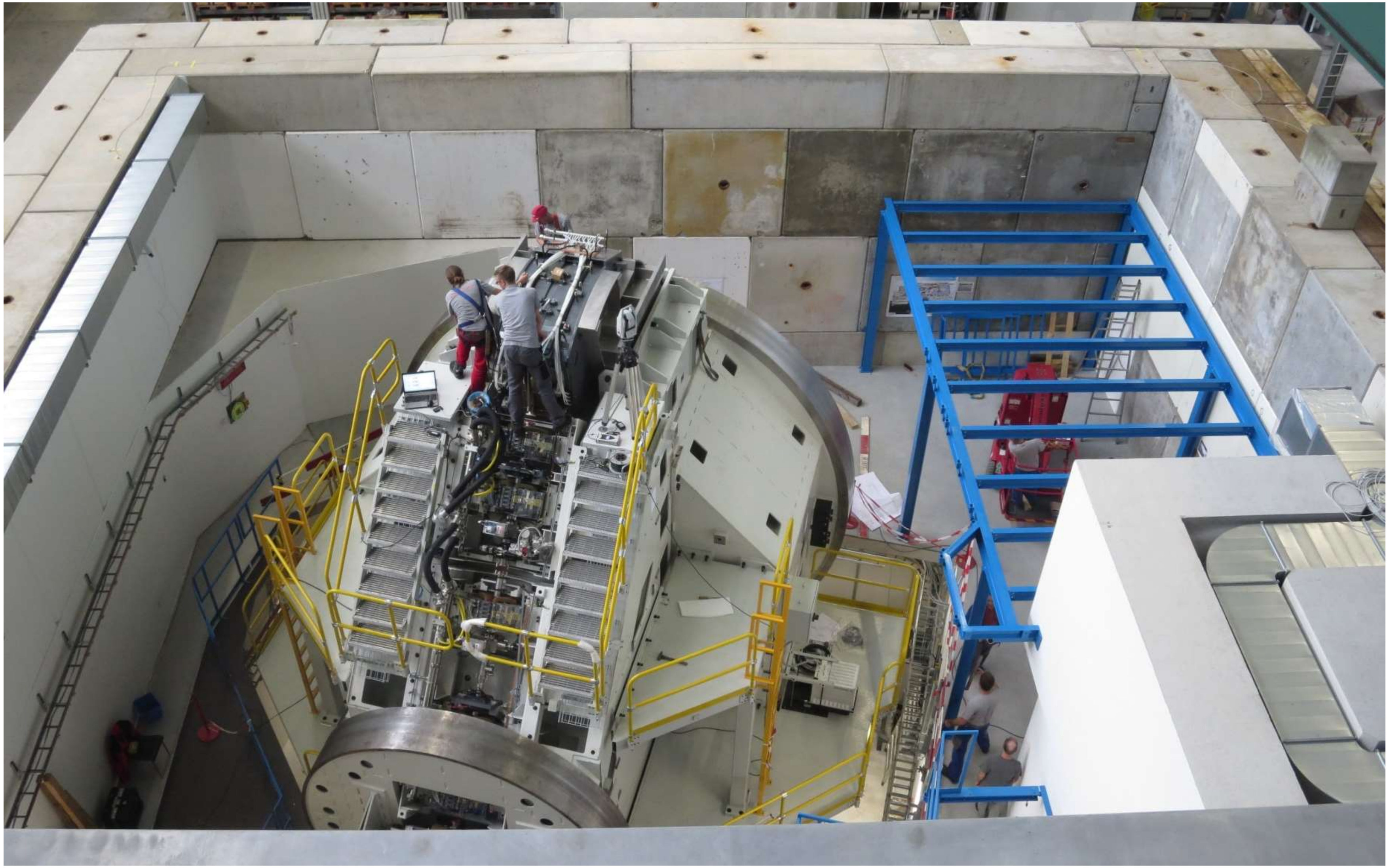
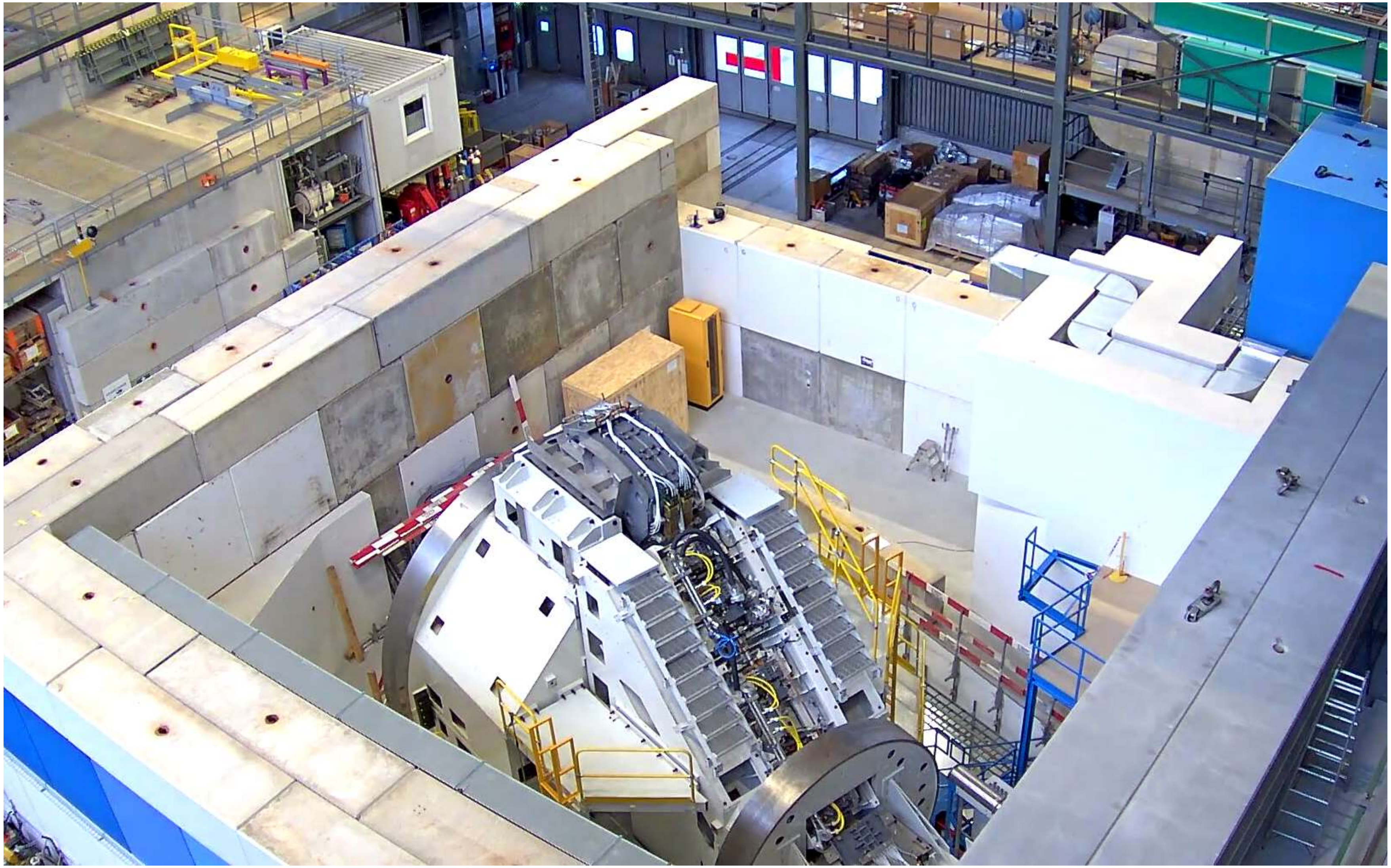
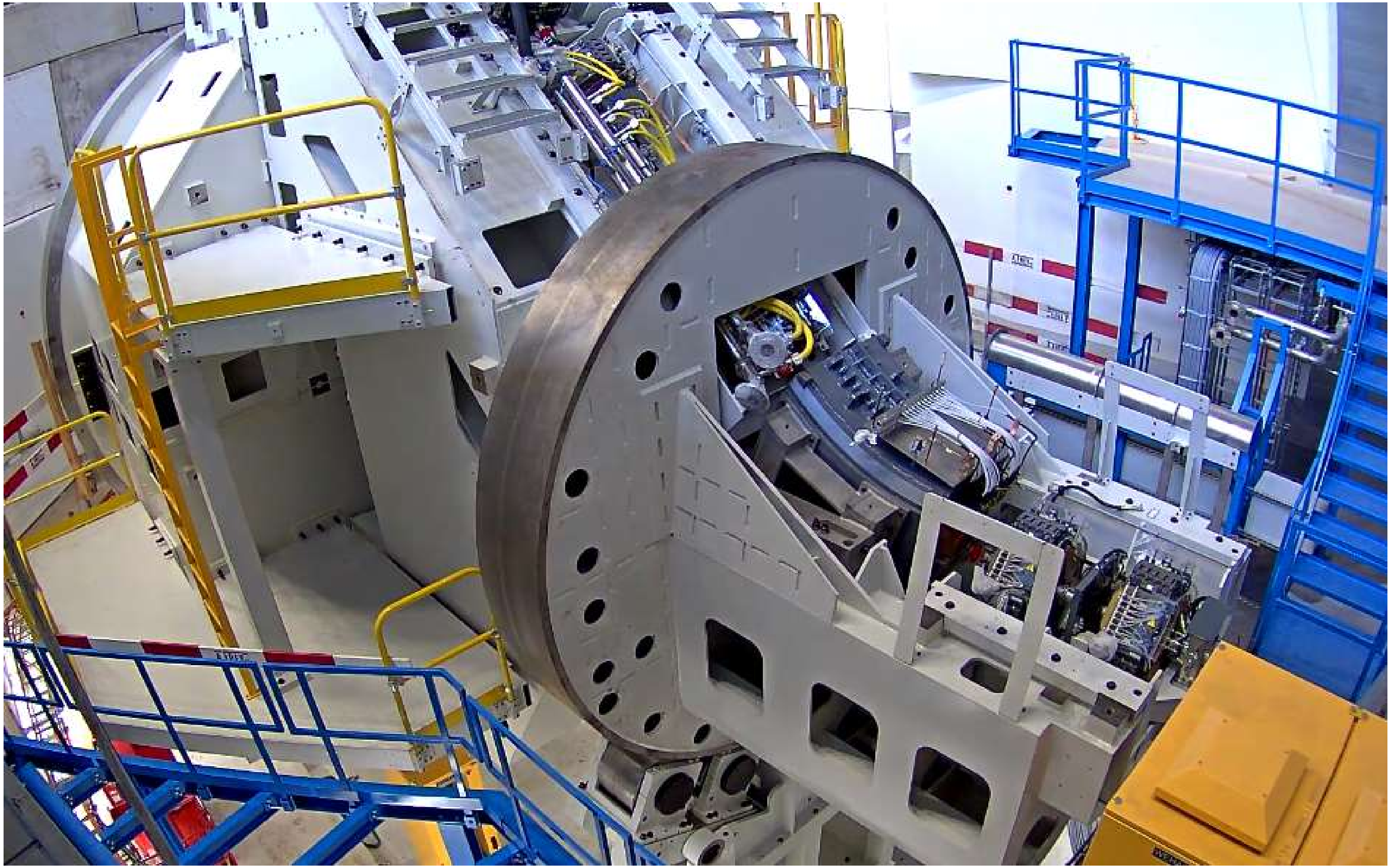


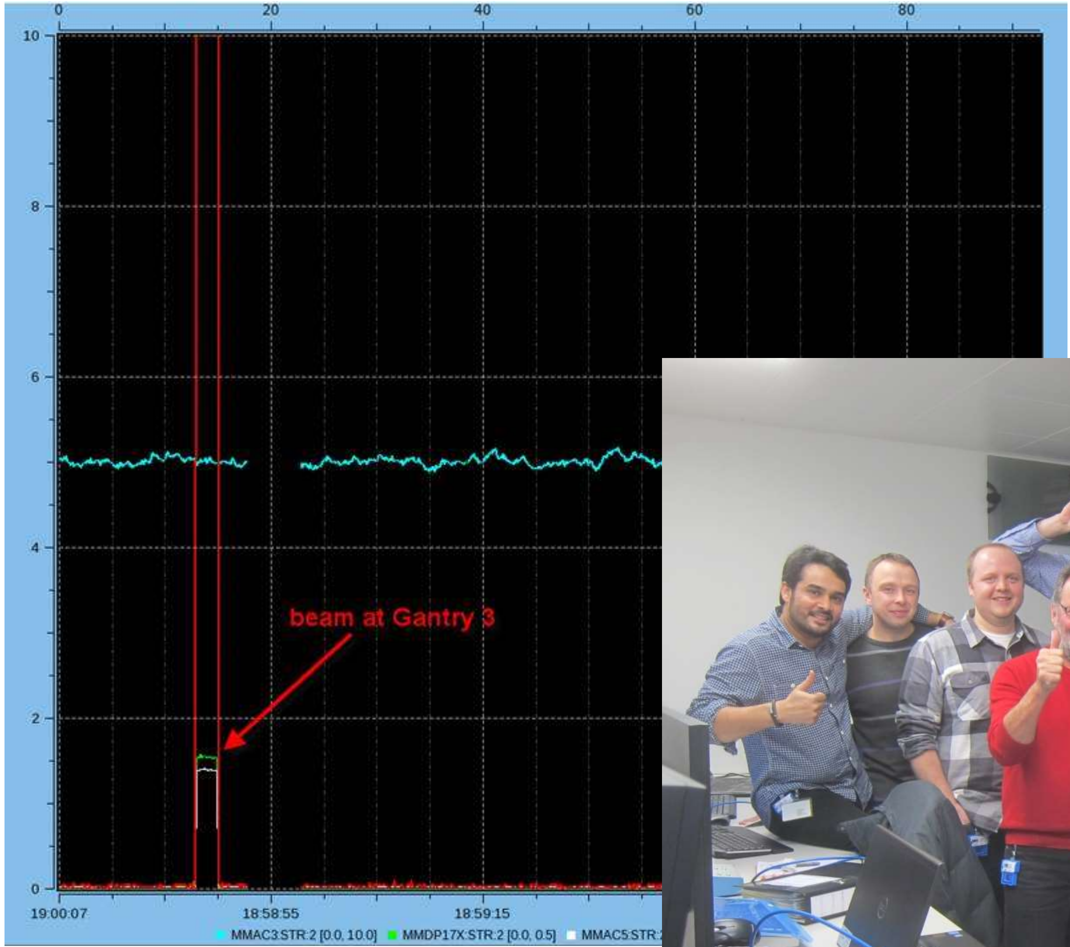


09.2015




A. FREY AG

First beam 01.12.2015 19:00:20




O.D. 102X32X75
FRAGILE


VARIAN
ProBEAM