David Meer :: Center for Proton Therapy :: Paul Scherrer Institut

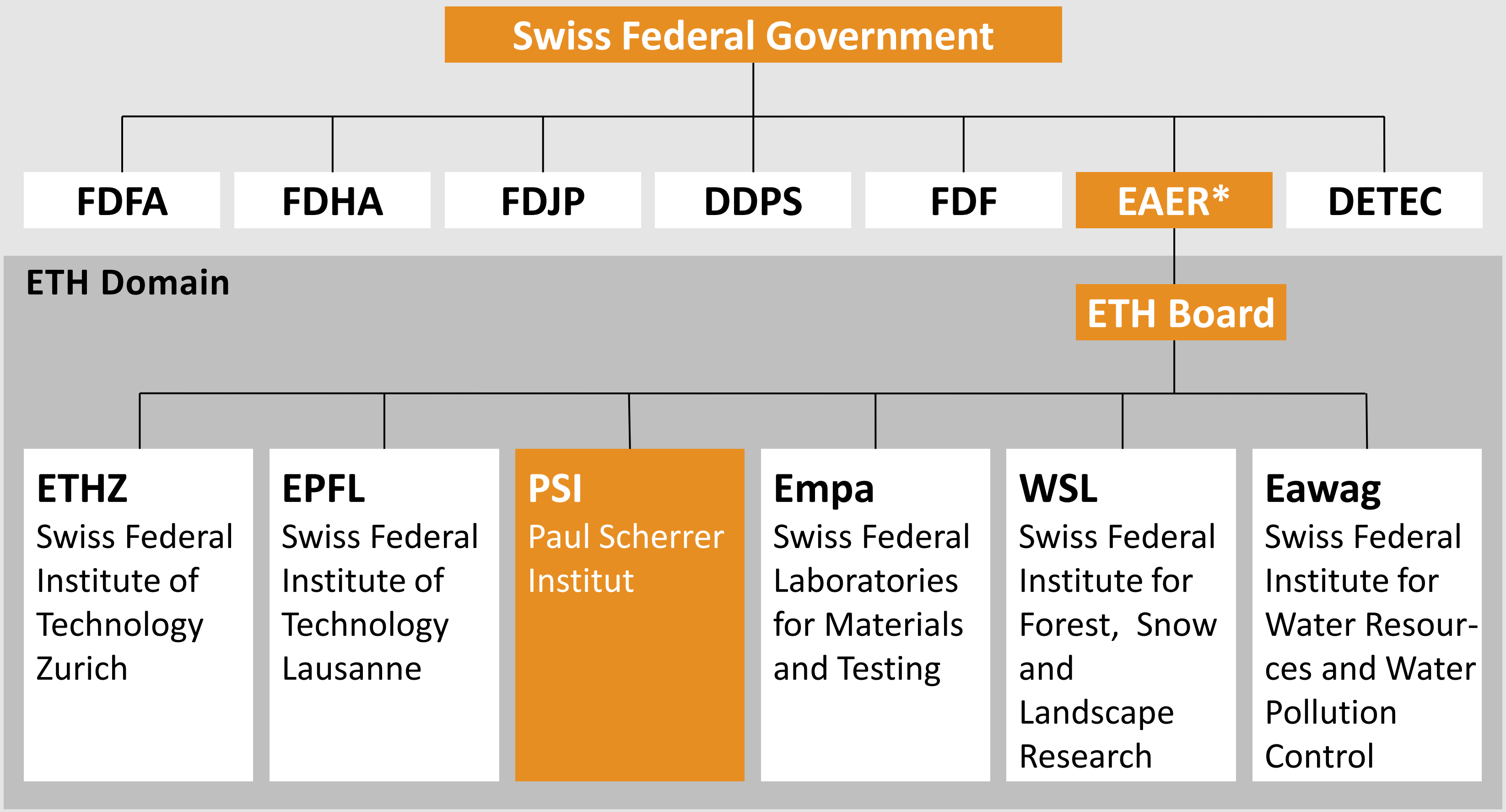
Collaboration between Universities and p- therapy program in PSI

Universities meet Laboratories, 3rd Nov 2016

PSI - the largest research institute for natural and engineering sciences within Switzerland

← Basel | Germany ↑ | Aarau/Bern ↓ | Zürich →

Administrative embedding of PSI



*) Federal Department of Economic Affairs, Education and Research

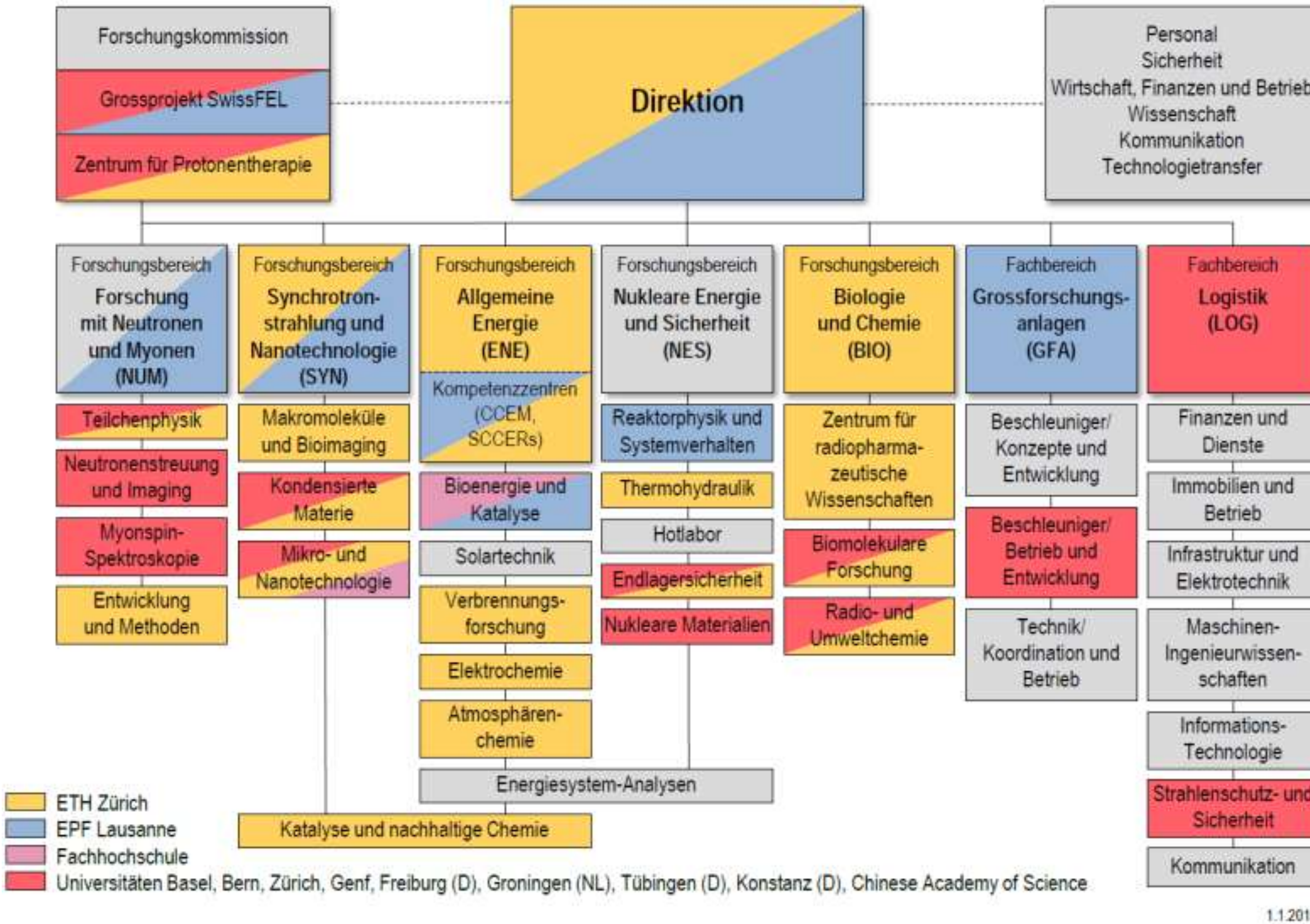
- Universities are governed and financed by the cantons

PAUL SCHERRER INSTITUT

Key Figures

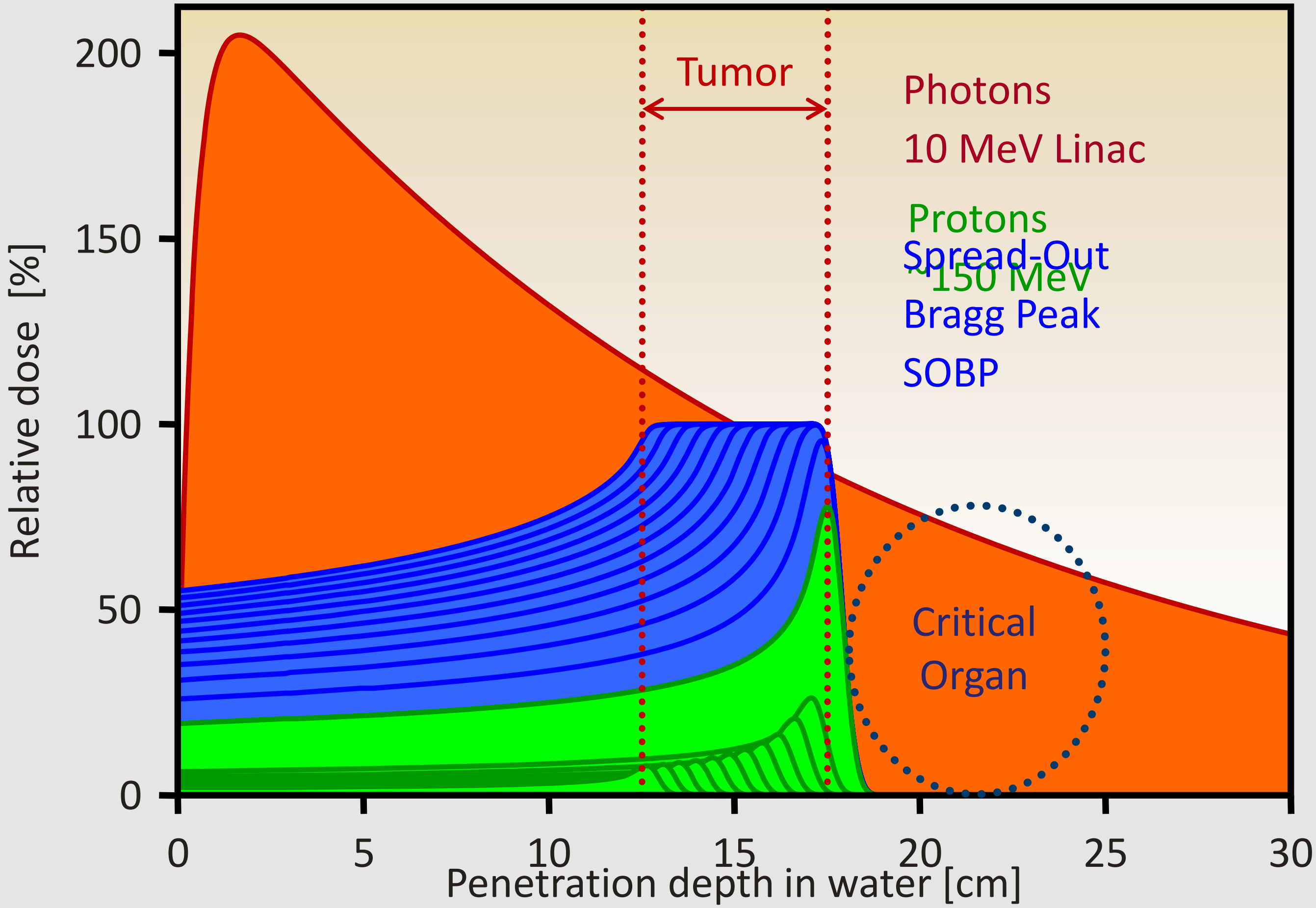
PSI funds (global budget)	270	MCHF
External funding	100	MCHF
Staff	2000	
• Externally financed	650	
• Doctoral students	330	
• Apprentices	100	
External users: people / visits	2300 / 5300	per year
Number of scientific publications	1200 (> 12.2 % high impact)	per year
PSI employees with teaching duties at both ETH and universities	100	

Common professorship with universities

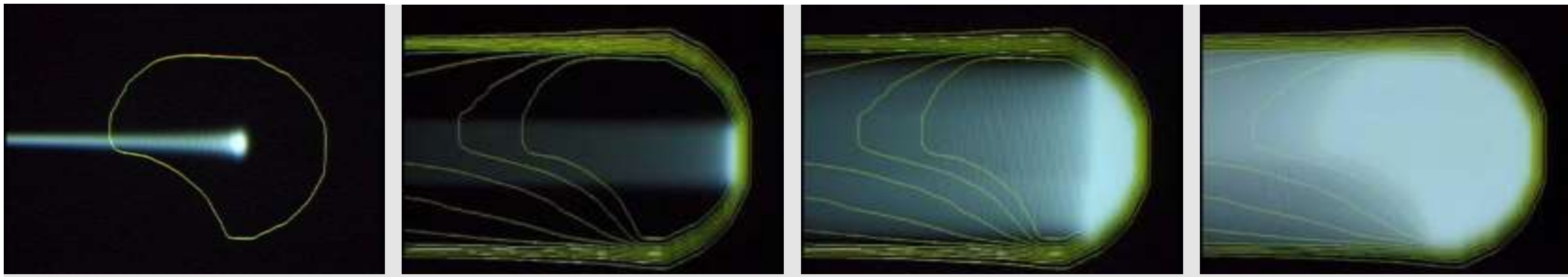


Advantages of proton in cancer treatments

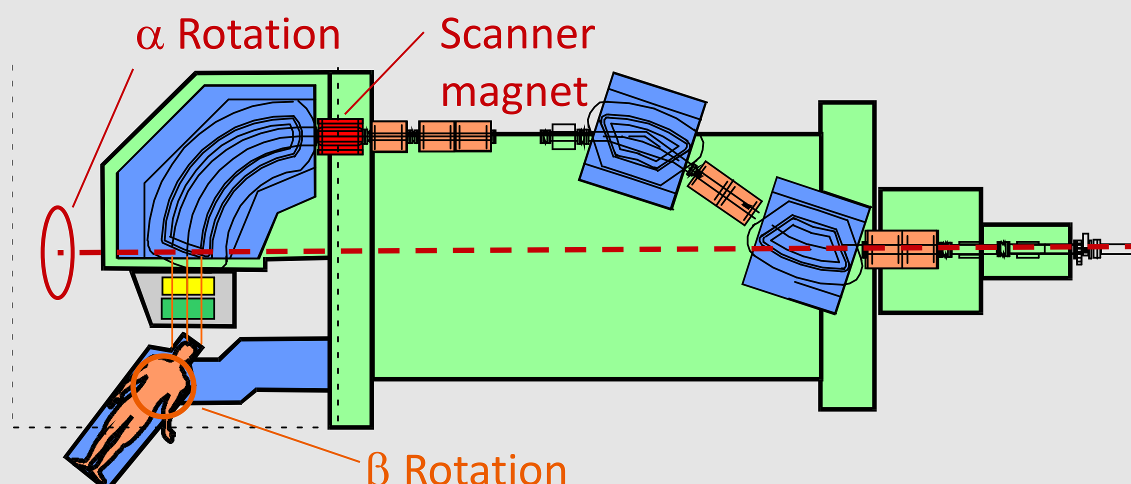
- Proton therapy vs. conventional radio therapy (photons)
- Better dose conformation to target, less dose to healthy tissue



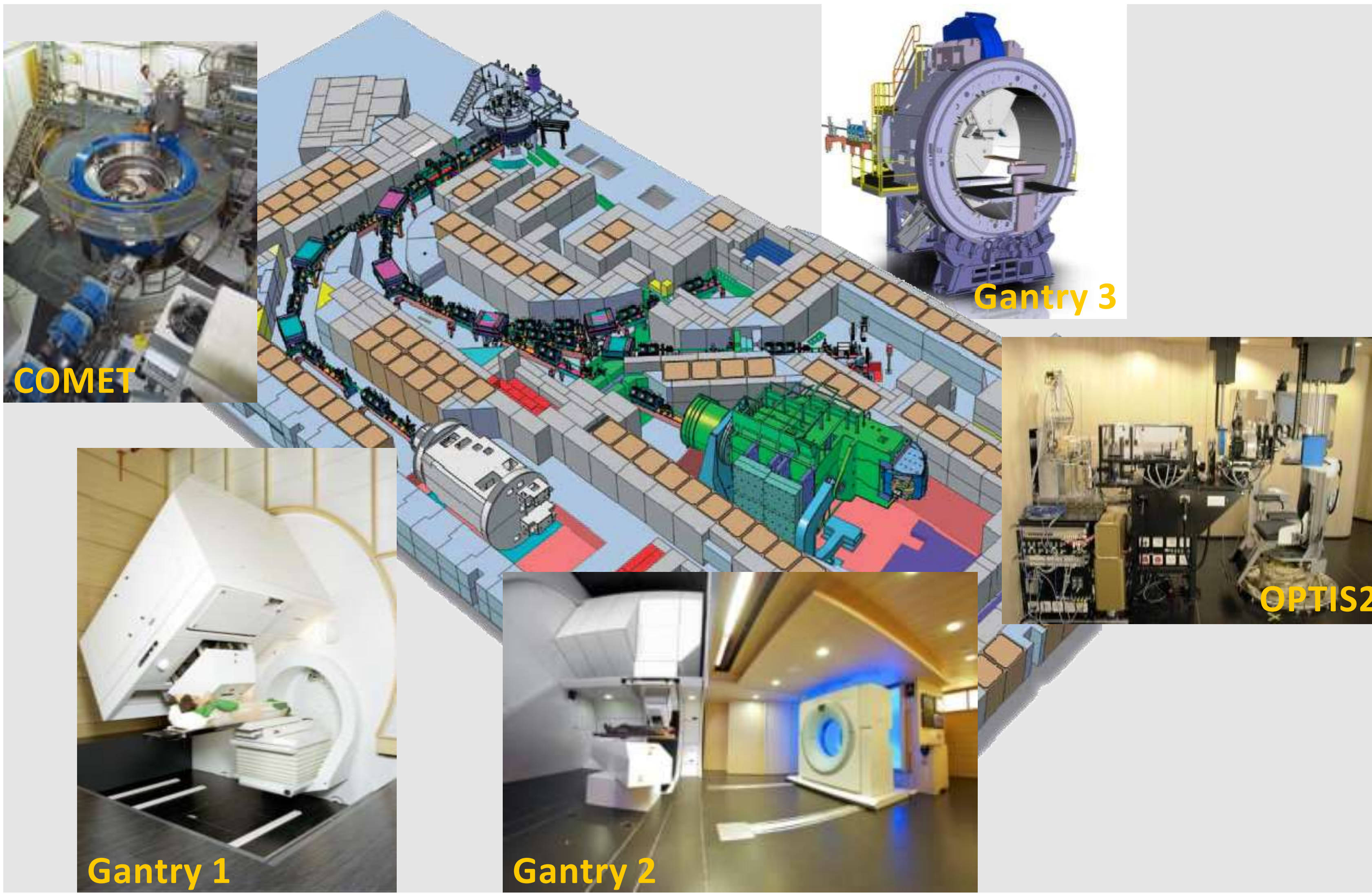
Development and implementation of pencil beam scanning (PBS) technique



- PBS provides more conformal dose distributions to irregular shaped targets
- Implementation of PBS on a Gantry 1, clinical operation since 1996
- During 12 years the only spot scanning gantry worldwide
- Due to eccentric design still the most compact system, r = 2m



Proton therapy at PSI today: Treatment rooms and dedicated accelerator



Proton therapy at PSI: Clinical operation

Milestones:

- 1984 (OPTIS):
  Fixed beam line for ocular treatments
- 1996 (Gantry 1):
  Spot Scanning on a gantry
- 2007 (COMET):
  Dedicated superconducting cyclotron
- 2013 (Gantry 2):
  Second gantry with fast scanning
- 2017 (Gantry 3):
  In collaboration with Uni Zurich

- 350 patients / year
  - 225 eye patients (OPTIS)
  - 125 gantry patients (Gantry 1 & 2)
- Eye treatments
  - 4 fractions per treatment
  - 5-year local tumour control >98%
- Gantry patients:
  - 30 – 40 fractions (conventional)
  - Tumours in the brain, skull base and low pelvis
  - Treatment of young children under anaesthesia
- Treatments on 5 days/week

PAUL SCHERRER INSTITUT PSI

Center for Proton Therapy
A multidisciplinary team

Multidisciplinary department of
3 sections with almost 100 collaborators

- Medicine: physician, care and radiographer
- Medical physics: treatment planning, imaging and quality assurance QA
- Technology: Physicists, engineers and technicians
- Master and PhD students, Postdoc's

Collaboration with universities for R&D projects

- Good opportunity for collaboration with universities:
  R&D project with students (master / PhD thesis)

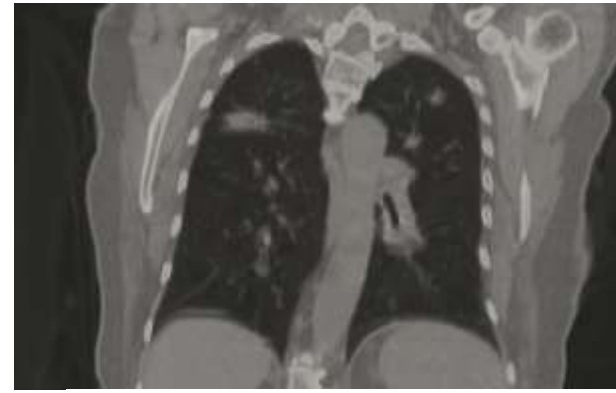
- 7 PhD students / 2 PostDocs

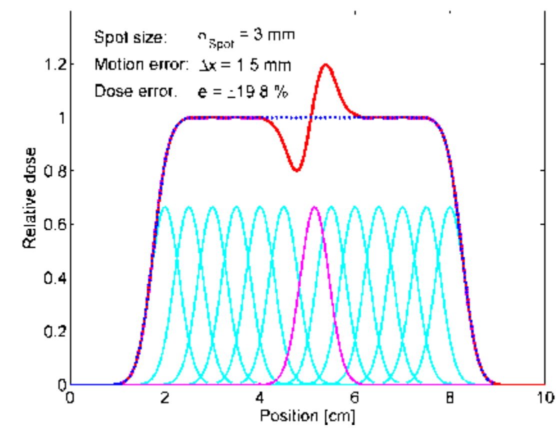
- About 20 Master / Bachelor students or internships per year
  - 50% ETH Zurich
  - 25% Switzerland (EPF Lausanne, Universities of Applied Sciences)
  - 25% from Europe (Italy, Germany, Netherlands, UK)

- Next slides: 3 examples of recent R&D projects with students from universities:
  - Treating mobile tumours with breath-hold (Medical physics)
  - New degrader to improving beam-line transmission (Physics)
  - Imaging with proton radiography (Physics)

Example 1:
Treating mobile tumours with breath-hold

- Pencil beam scanning is sensitive to moving organs (lung tumour)
  ⇨ Interplay with scan sequence
- Gantry 2 offers fast delivery times, irradiation of a small target less than 1 min
- Breath-hold technique is promising approach to tackle motion problem
- Goal: Introduce breath-hold in PBS proton therapy
- PhD project in collaboration with Rigshospitalet, Copenhagen University Hospital





Rigshospitalet

Synergies between two leading institutes

Copenhagen University Hospital

- 260’000 pat./year
- Radiotherapy treatment ~300 pat./day
- 13 medical linear accelerators
- Clinical work close to research
- High profile research projects that are (or soon to be) realized in the clinic
  - Advance treatment technique
  - Moving targets
  - Reduce side effects

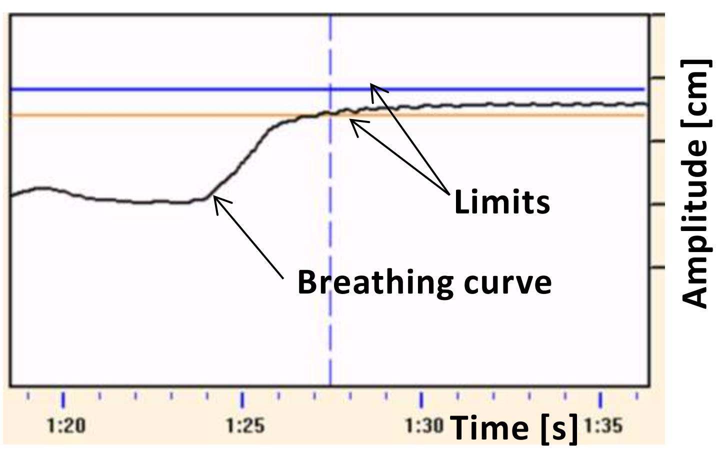
Proton Therapy at PSI

- No treatment of moving targets yet
- Lung cancer may have benefit from proton therapy
- Uniquely designed treatment planning system with great flexibility
- Great knowledge of the proton therapy physics
- However: Lack of clinical experience and data

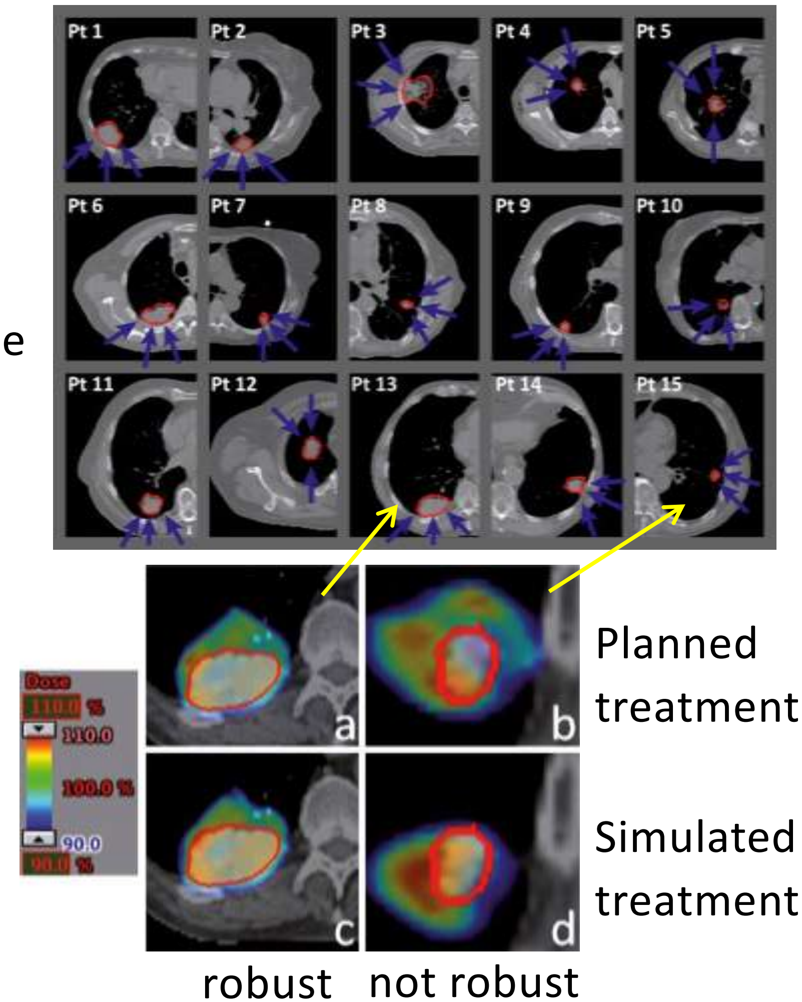
CT image of breathing anthropomorphic phantom

Study: Breath-hold in PBS proton therapy

- Retrospective treatment planning study of 15 patients with peripheral lung tumors
- Investigate robustness of the voluntary breath-hold approach
- 14/15 of the studied cases deemed to be robust to interfractional motion



Breathing signal from patient holding his/her breath

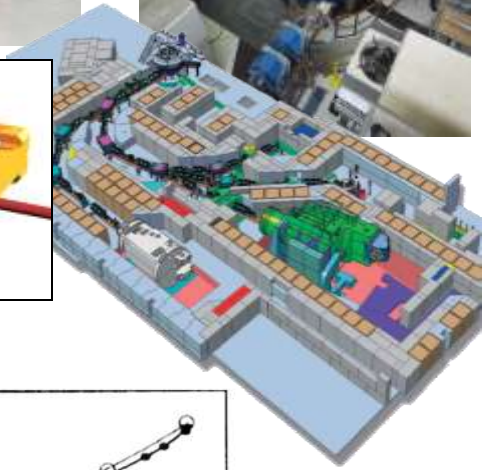


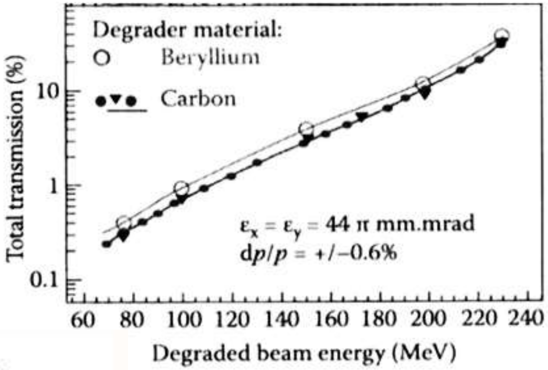
Dueck et al. Int J Radiat Oncol Biol Phys 2016
http://dx.doi.org/10.1016/j.ijrobp.2015.11.015

Example 2:
Beam energy modulation from cyclotron

- Cyclotron is ideal for proton therapy
  – cw beam current
  – High beam current
  – “Small” and mature technology
- But: only one fixed energy
  ⇨ Degrader system (carbon wedges)
- Increase of beam emittance
- Fixed acceptance of beam line (collimators)
  ⇨ Factor 100 intensity loss for lowest energies

- Possibility of new degrader material was studied with a student in engineering physics form Saxion University of Applied Sciences





SAXION University of Applied Sciences

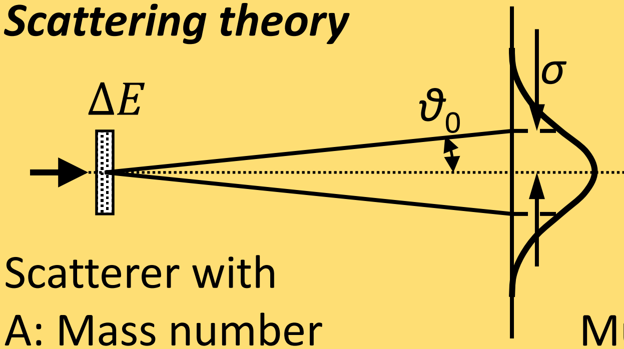
Alternative degrader material: Boron carbide B4C

- Minimize effect of multiple coulomb scattering
- Maximize energy loss

⇨Material with low atomic number Z

⇨Boron carbide (B4C)
- Good chemical resistance but extreme hardness

Scattering theory



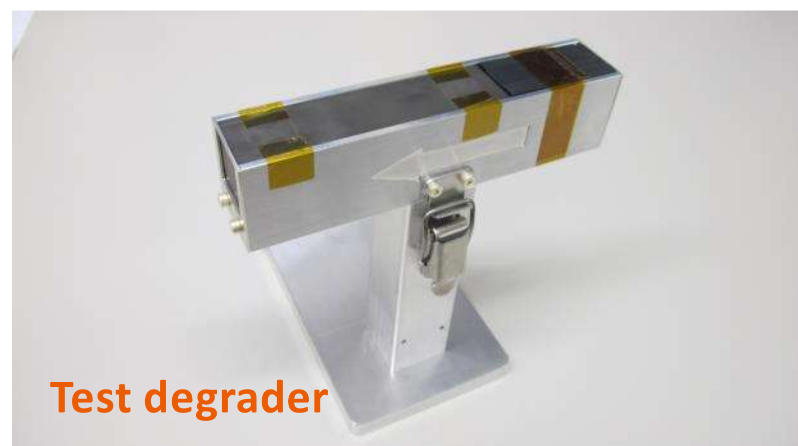
$$\vartheta_0 \propto Z/\sqrt{A}$$

$$\Delta E \propto Z/A$$

Scatterer with
A: Mass number
Z: Atomic number

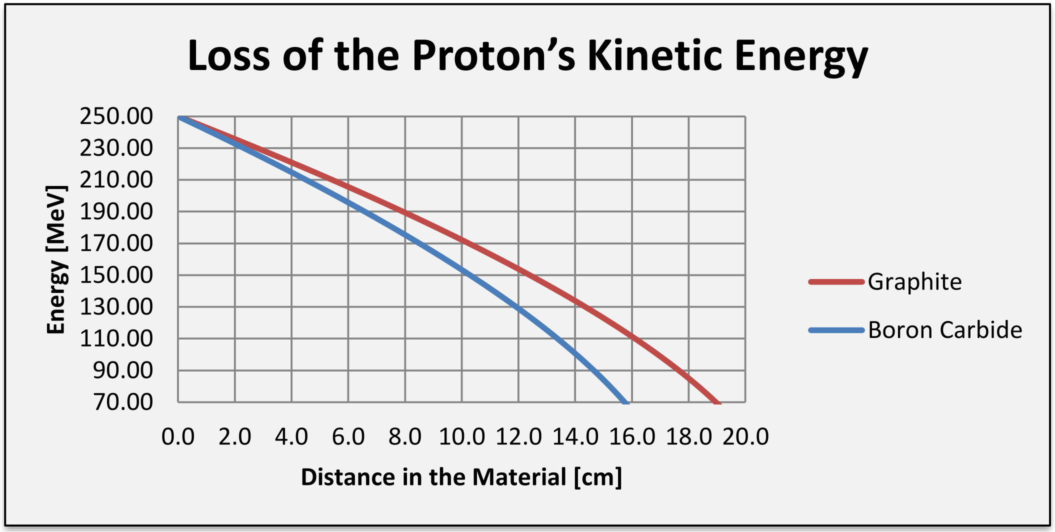
Multiple Coulomb Scattering MCS

Degrader unit

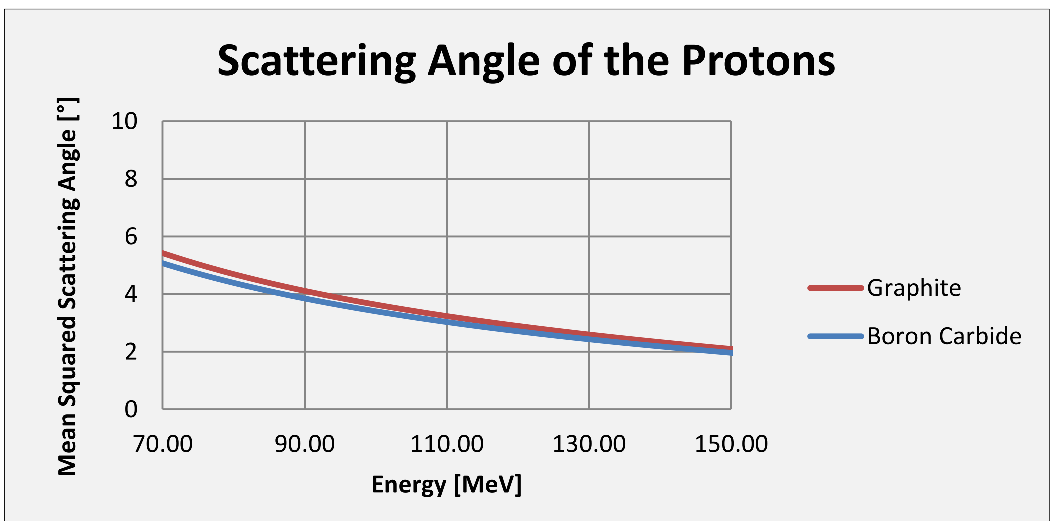


Test degrader

Theoretical comparison
Boron carbide vs. Graphite



	Boron Carbide	Graphite
Degraded energy [MeV]	84.0	
Material thickness [cm]	15.0	18.1



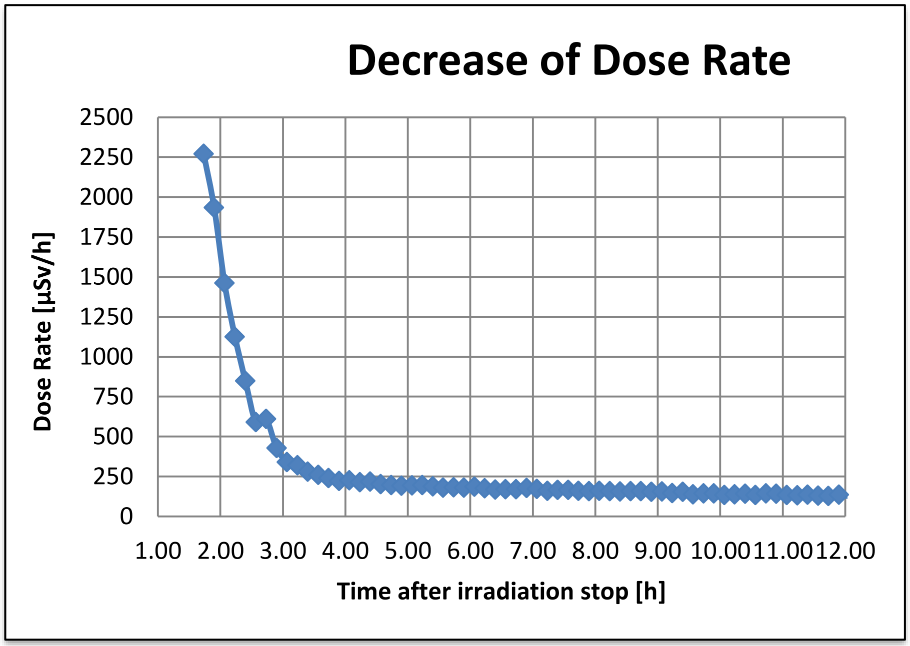
	Boron Carbide	Graphite
Degraded energy [MeV]	84.0	
MC Scattering angle[°]	4.2	4.5

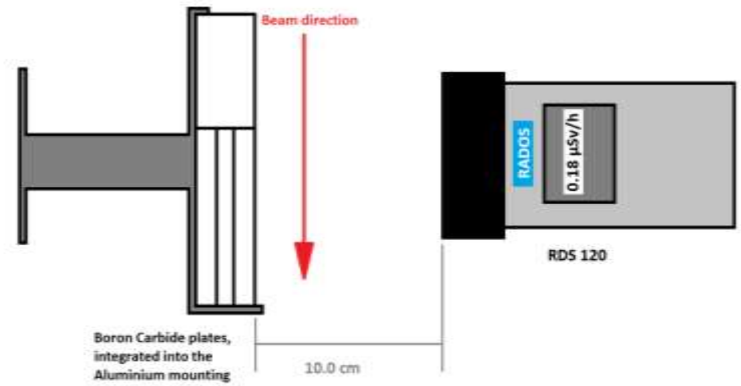
Experimental measurement at the physical beam line

Transmission for 84 MeV @ MMAP25x [%]	
Boron Carbide	0.59
Graphite	0.43

→ Boron carbide has increased the transmission by about 37% @ 84 MeV!

Measurement of the activation





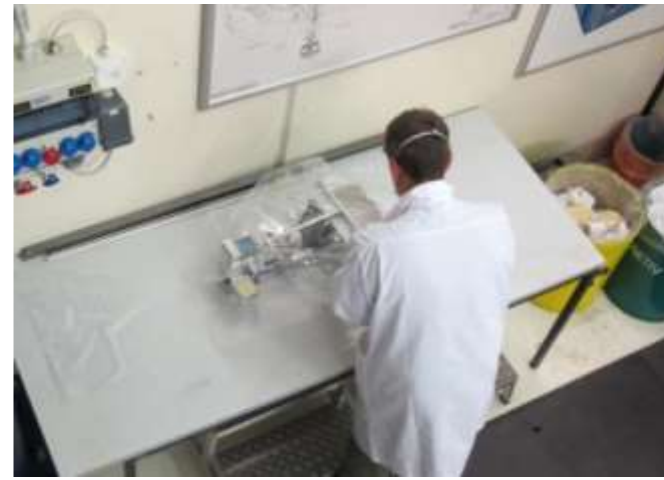
→ Fast decrease of activity, same level of activity as graphite degrader after 1 hour

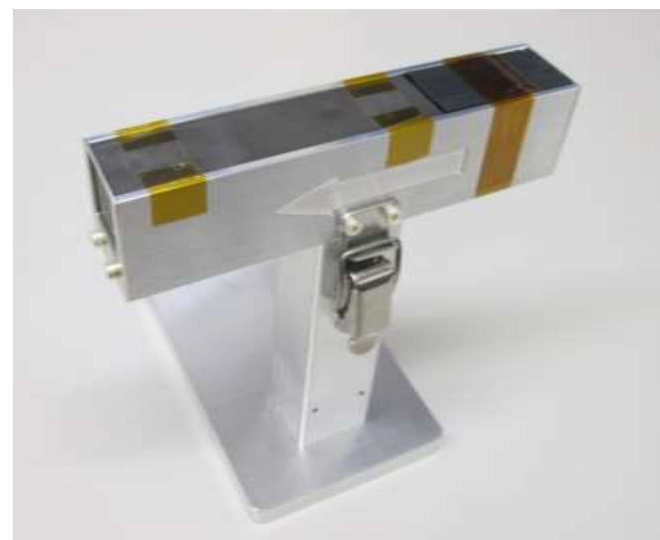
The decrease of activity is sufficient enough to limit the risks for the service staff!

Conclusion of B4C degrader test

- Boron carbide improves the transmission for lower energies by more than 30%.
- Very beneficial for low energy irradiations (eye treatment), reduction of treatment time
- Problematic and expensive manufacturing ↔ Cost-Benefit Factor
- We decided to produce a new set of B4C degrader wedges and will upgrade the facility with the new degrader

➢ Student project helped to promote and accelerate the idea of a new degrader





Example 3:
Improving imaging with proton radiography

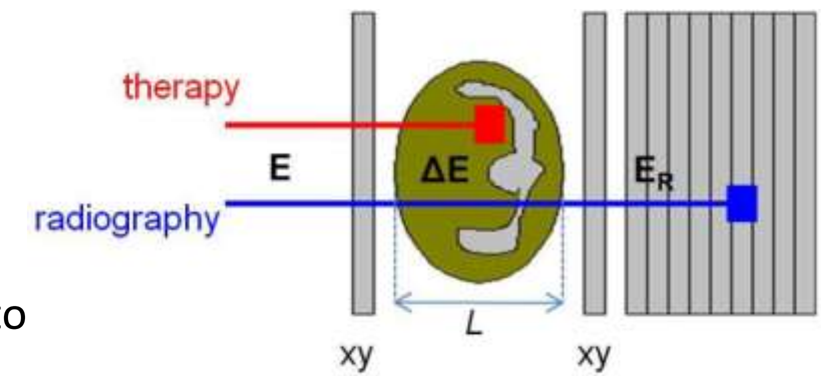
The problem:

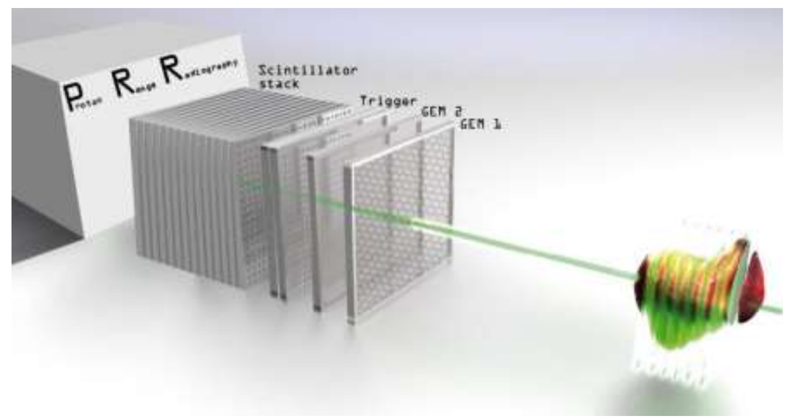
- Proton therapy is very sensitive to range uncertainties (finite range of protons, over-/undershoot)

- Use the high energetic proton beam to measure the integral stopping power

- Beam tracker based on gas electron multiplier (GEM)
- Energy measurement based on residual range in stack of scintillator

- Dissertation from University Bern, collaboration with TERA foundation, measurements performed at PSI.





UNIVERSITÄT BERN

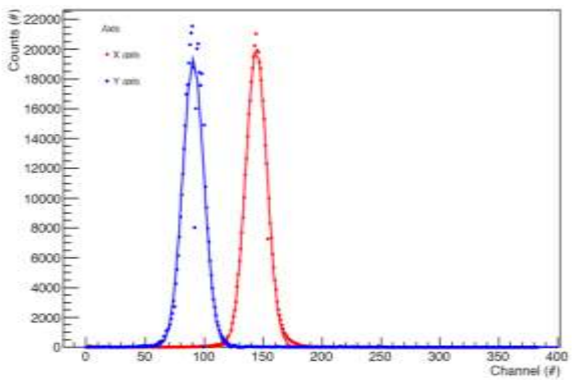
Measurement setup at PSI Gantry 2

- Main goal: Characterisation of the tracker and calorimeter
- Well-defined beam condition on Gantry 2 (Very low beam intensities)
- Tracker (GEM): 30 x 30 cm^2, 0.8 mm pitch
- Calorimeter: 48 scintillating plates, 30 MeV – 175 MeV residual range
- Issues in synchronisation of tracker and calorimeter(read-out electronics)

Results and conclusion

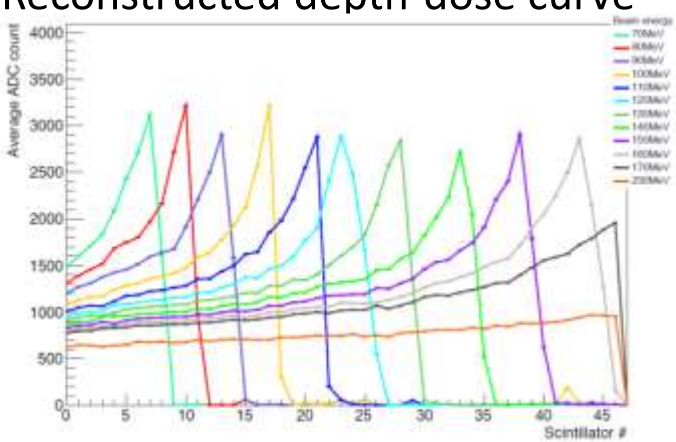
Tracker (GEM)

- High event rate > 1MHz
- Recorded beam profile



Calorimeter (energy measurement)

- Reconstructed depth-dose curve



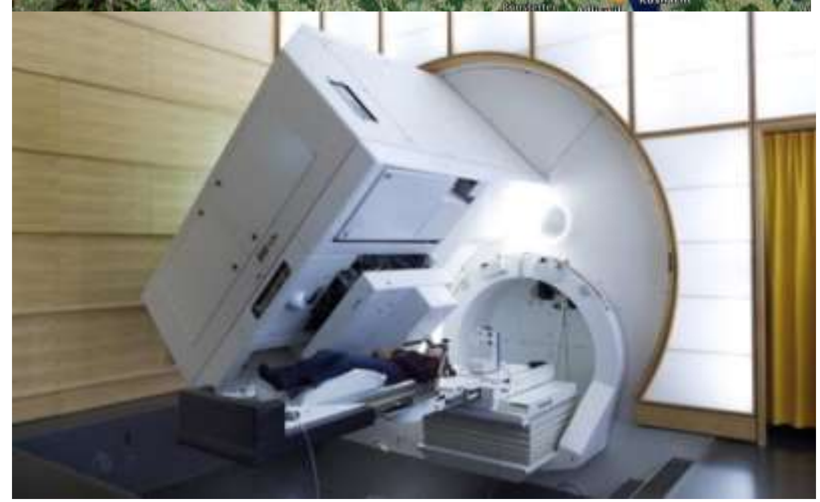
- Test of equipment in real conditions to assess performance
- Challenging beam requirements, helped to further understand our system
- Synergies of two groups:
  - Know-how in detector and read-out development (F. Sauli)
  - Technical expertise in beam delivery and control (PSI)

Clinical collaborations with hospitals for patient treatments

- First proton irradiation facilities were installed in or close to research / accelerator labs (like PSI)
- PSI is treating only a few niche indications (mainly head and skull-base)
- Good national oncology network is essential to get access to the right patients

➢ Common professorship at the medical faculty of university Bern and Zürich

➢ Virtual tumour board: Video conferencing system with major hospitals



Collaboration with University Hospital Zurich for paediatric patients

- Paediatric program to treat (very) young patients under anaesthesia started in 2004
- Collaboration with University Children's Hospital in Zurich
- Daily treatment of 3-4 patients under anesthesia
- Standardized evaluation of treatment to asses quality of life (doses to organs at risk, toxicity)

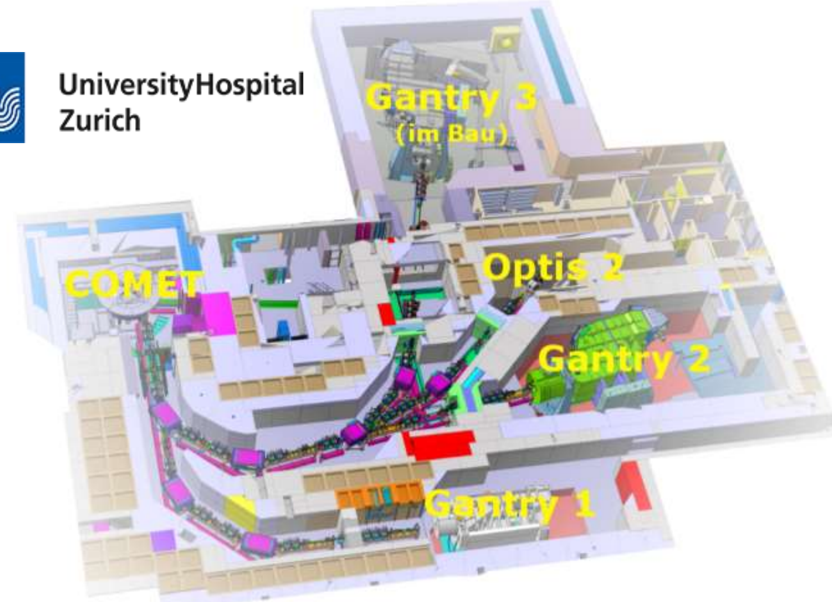
UNIVERSITY CHILDREN'S HOSPITAL ZURICH

Collaboration with University Hospital Zurich to expand treatment capacity (Gantry 3)

- Canton Zurich invests 20 MCHF to increase treatment capacity at PSI and to have direct access to p-therapy
- Installation of a new Gantry 3 based on a commercial system
- Close clinical collaboration with University Hospital Zurich
- Start clinical operation mid-2017

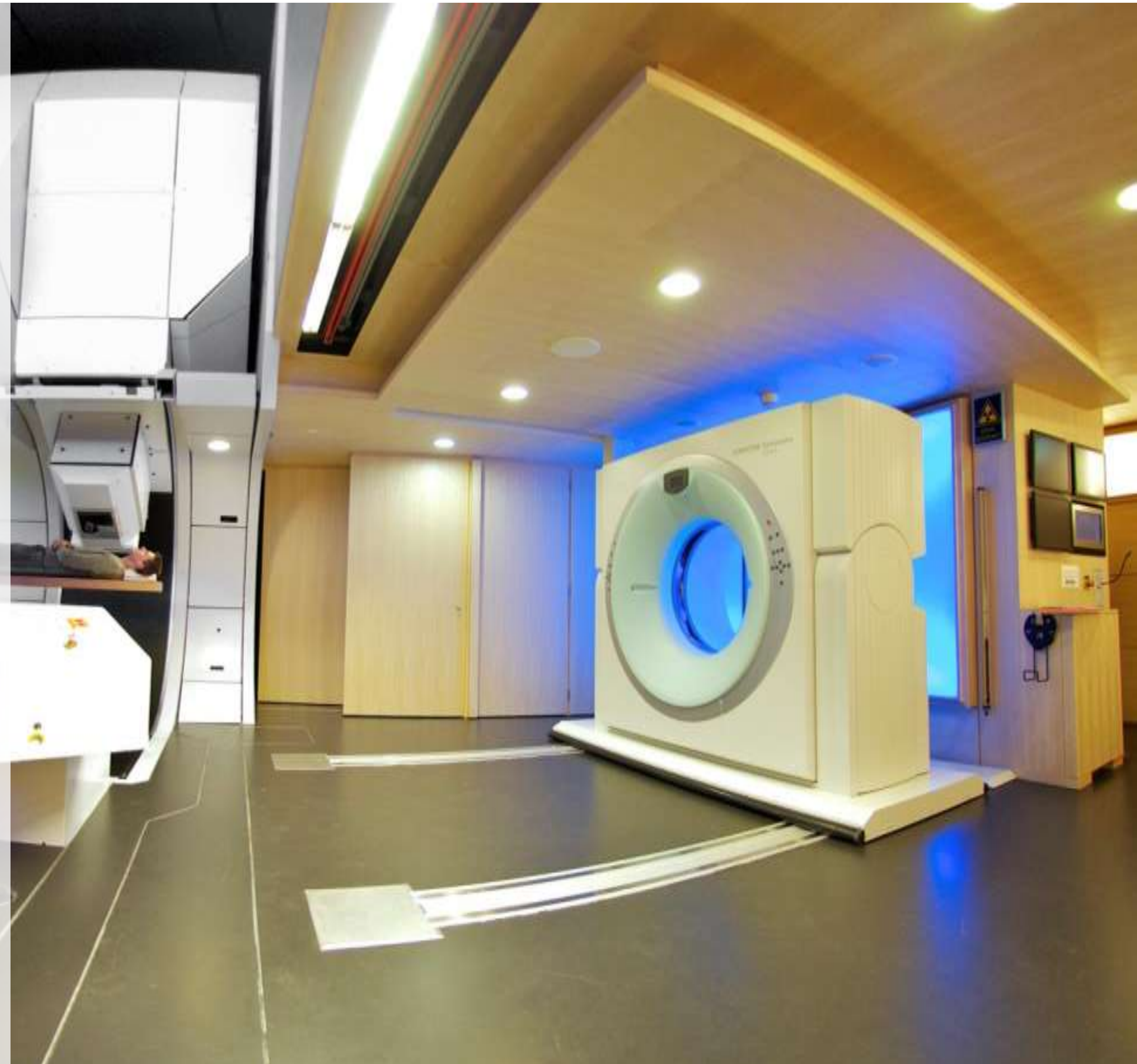
- Challenges during realization:
  - Integration of commercial system into existing proton facility
  - Integration with full clinical operation
  - Tight time schedule

UniversityHospital Zurich



Collaboration with universities is essential:

- Technical projects mainly with (PhD) student
- Collaboration with university hospitals to provide adequate treatment to all patients
- Paediatric program with Children's Hospital Zurich
- Realisation of a new Gantry 3 together with University Zurich



My thanks go to

- Jenny Dueck
- Yannik Reiser
- Martina Bucciantonio
- Marco Schippers
- and full CPT team