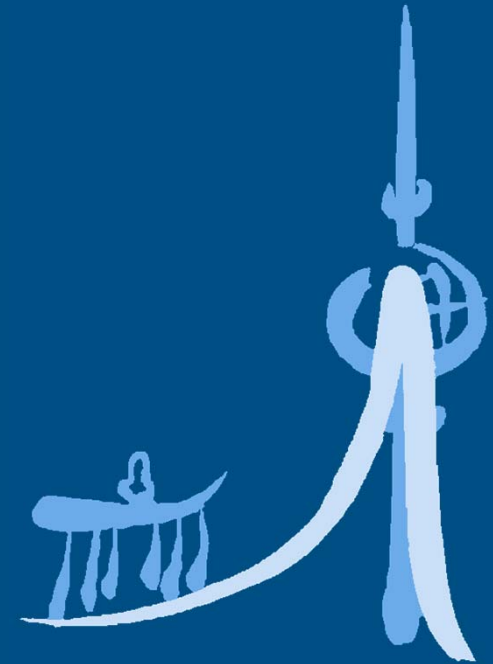


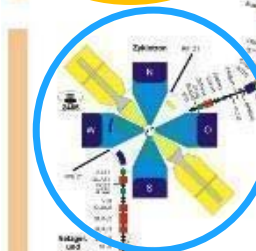
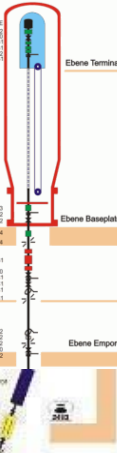
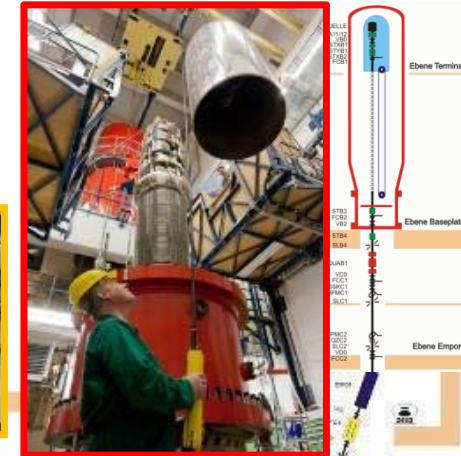
Irradiation Possibilities at HZB

- Protons
- γ -rays: Cobalt Source



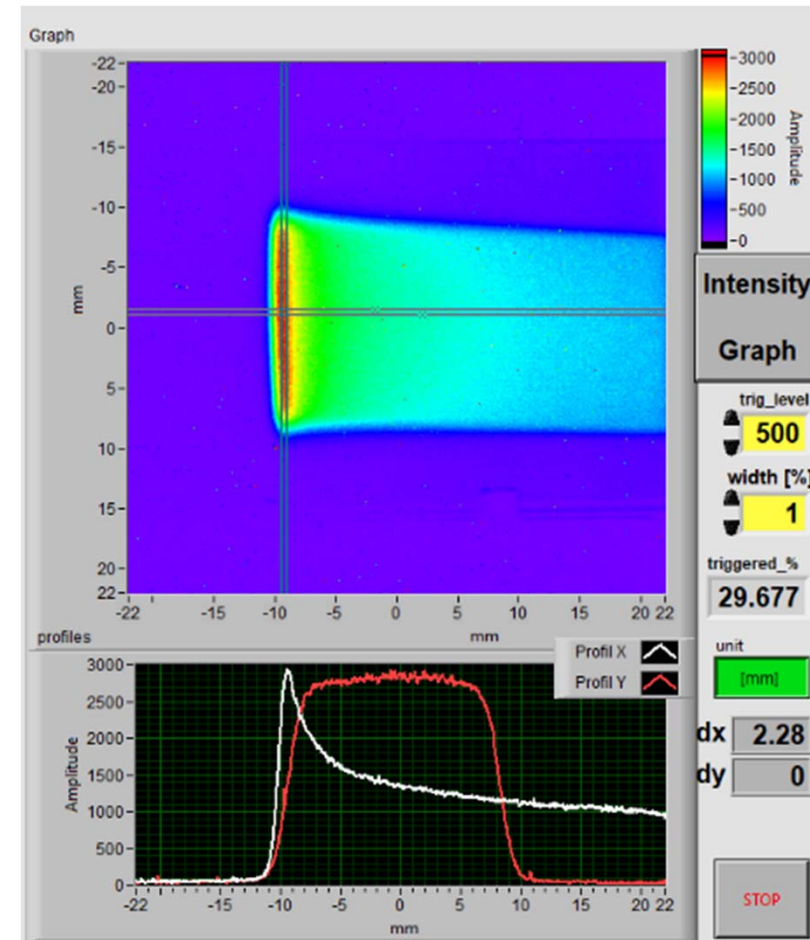
Protons: Layout of the Accelerator Facility

- **k = 130 isochronous sector cyclotron**
10 – 20 MHz
- **two injectors:**
 - 2 MV Tandetron™
 - 6 MV Van-de-Graaff, backup,
time structures: e.g. single pulses with 5 ns, 2 MHz rep. rate
- **three target stations:**
 - treatment room
 - experimental station
($I_{\max}(\text{DC}) = 10 \text{ nA}$)
 - beam line end in cyclotron vault
for high proton intensities



Protons: Energy

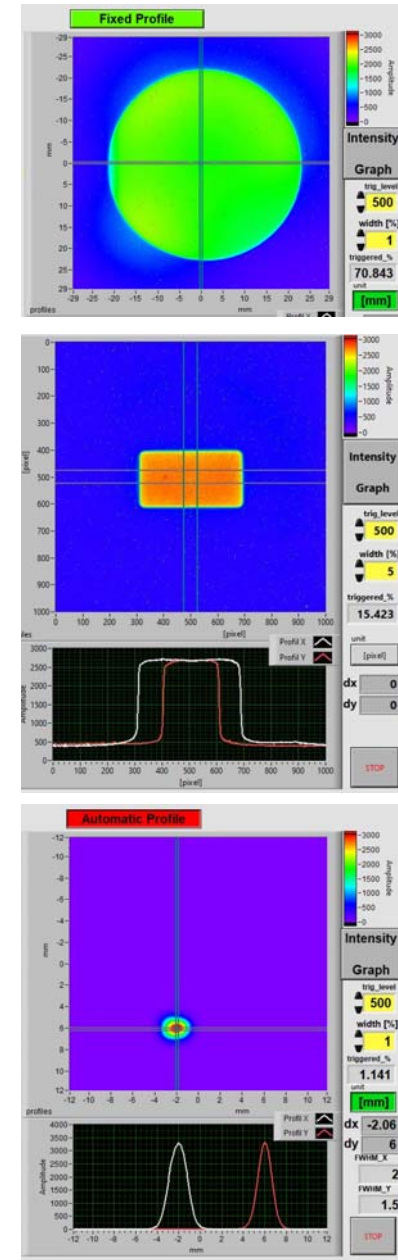
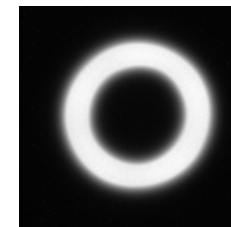
- from accelerator: monoenergetic protons
 - energy range: $15 \text{ MeV} \leq E_{\text{Proton}} \leq 72 \text{ MeV}$
 - change of energy at accelerator: ca. 6 h
- standard energy: 68 MeV (therapy beam)
 - energy spread $< 0,2 \text{ MeV}$
- lower energies by absorber plates
 - typical: 30 MeV und 50 MeV
 - energy spread: $\sim 1 \text{ MeV}$
 - change of energy: 2 min.
 - energy determined by 3D camera



Protons: Irradiation Field

- **broad beam (scattering system I) ~ 45 mm Ø**
 - very homogeneous: $\pm 3\%$
 - max. $1 \cdot 10^8$ p/(cm²s)
- **broad beam (scattering system II)**
 - homogeneous: $\pm 10\%$ for 20 mm Ø
 - max. $5 \cdot 10^9$ p/(cm²s)
- **rotational symmetry, rectangular or quadratic fields achieved by apertures**

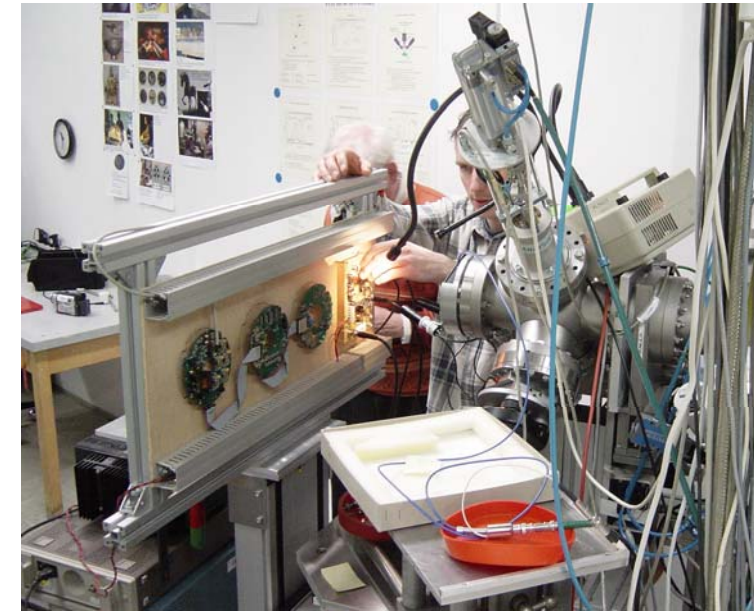
- **focused beam, diameter ~ 1 mm Ø**
 - max. $5 \cdot 10^{10}$ p/s
- **scanned beam**
 - up to 30 mm · 30 mm
 - various shapes possible



Protons: Experimental Station

- **irradiations in air:**
 - on-line measurement of protons by ionization chamber and automatic switch-off of the beam
 - determination of field by apertures or slits
 - verification of field size by 2D camera
 - samples and/or instruments monitored by camera
 - samples may be operated during the irradiation
 - samples on xy-table with 0.1 mm precision of positioning
 - stroke: 50 cm in x and y
 - position of samples verified by laser cross-hair
 - max. weight of samples for the table: 50 kg

- **if needed: irradiations in vacuum possible**

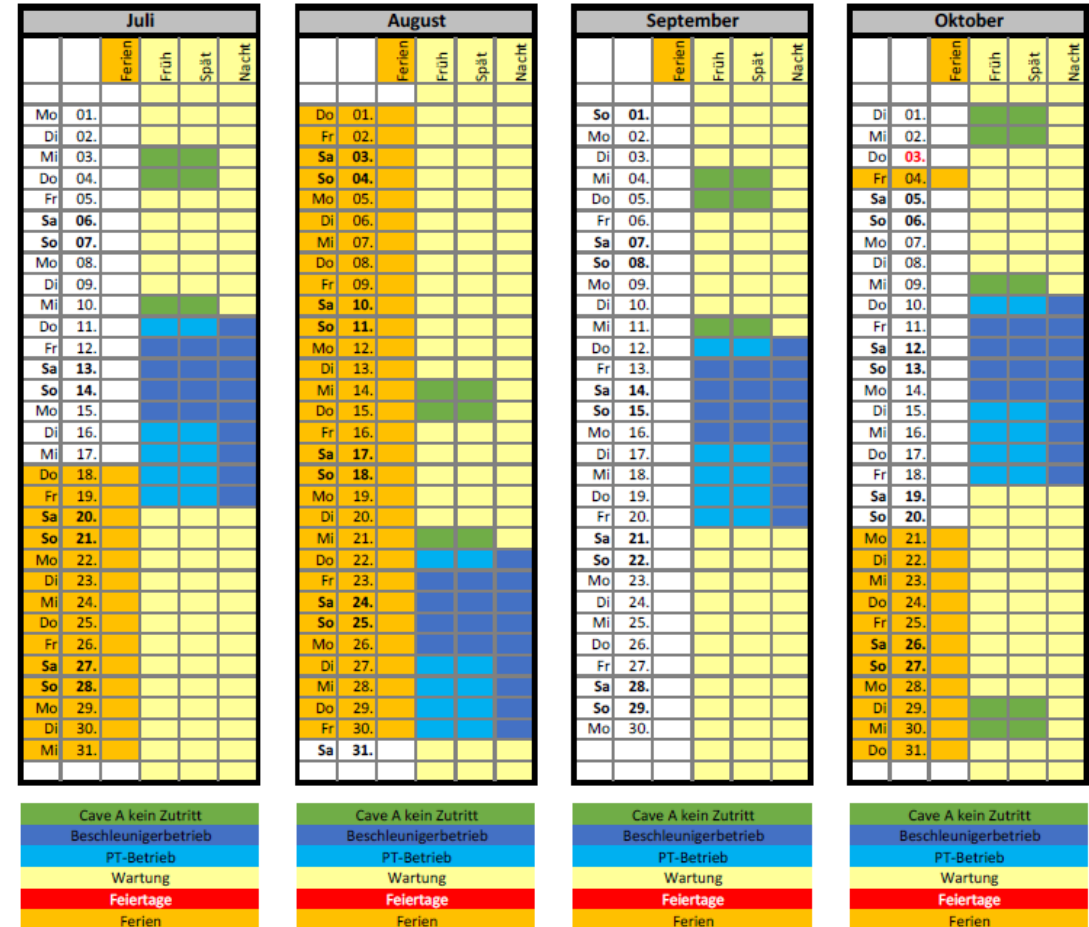


Protons: Time Slots for Irradiations

- beam time is planned in autumn for the coming year
 - at the moment: 12 treatment weeks/year for eye tumour therapy (Mo - Fr)
 - Friday - Sunday before therapy: experimental time
 - generally: from 8:00 to 21:00
- after the irradiation samples have to be checked by the radiation safety department for activation before leaving the laboratory

Betriebsplanung

2024



Protons: New Target Stations

- increased demand of beam time
- broader variety of experiments

→ new target station for **radiation hardness tests:**
InOperando-beam line

→ more time for preparation of experiments

- in collaboration with *Universität München*:
new station for **Minibeams** (Radiobiology)

der Bundeswehr



München



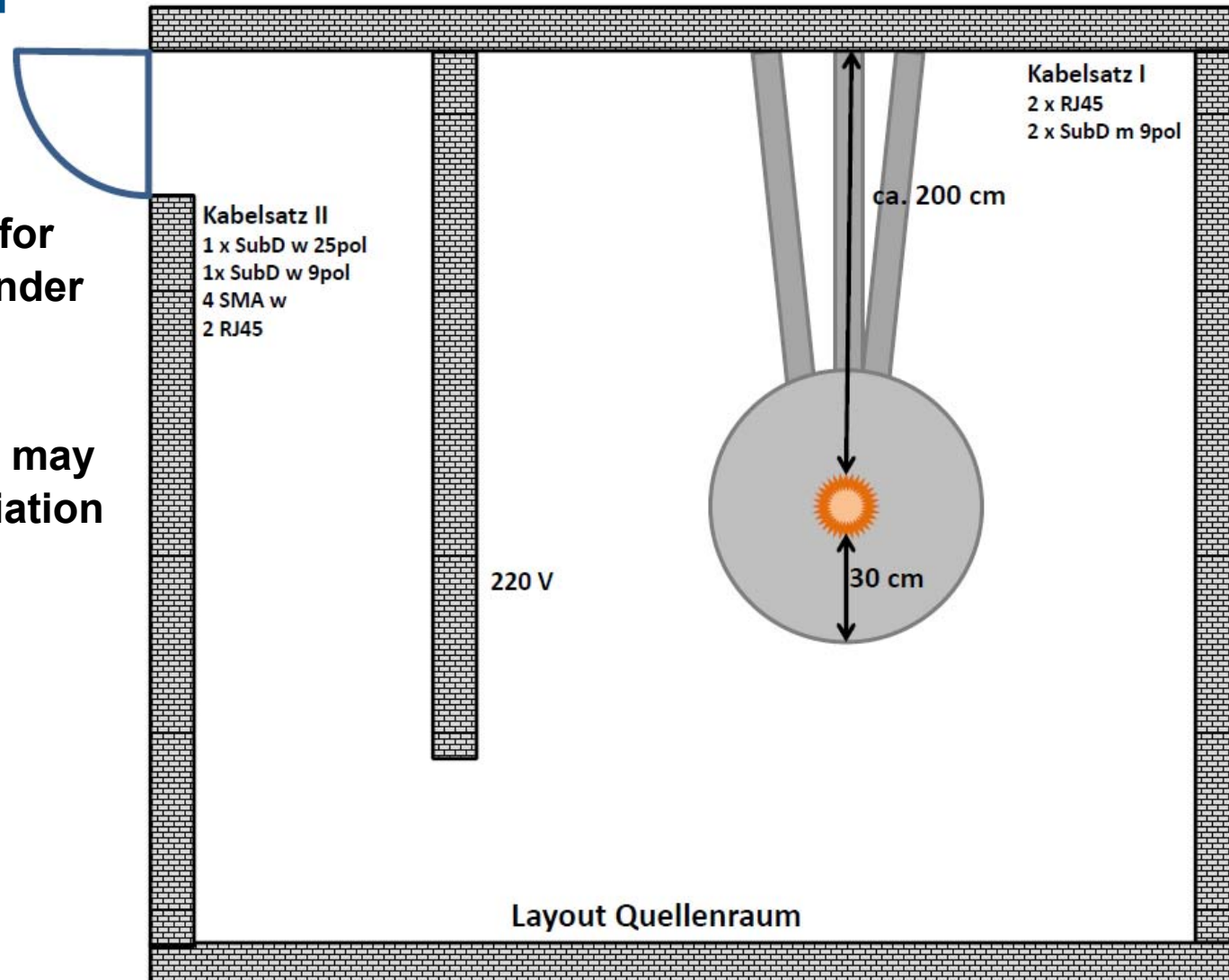
γ -rays: Cobalt Source

- ^{60}Co rods, ~ 20 cm high
- energy: 1,17 MeV und 1,33 MeV
→ samples can leave the laboratory directly after the irradiation
- pure γ -rays
(β -rays shielded by stainless steel tube)



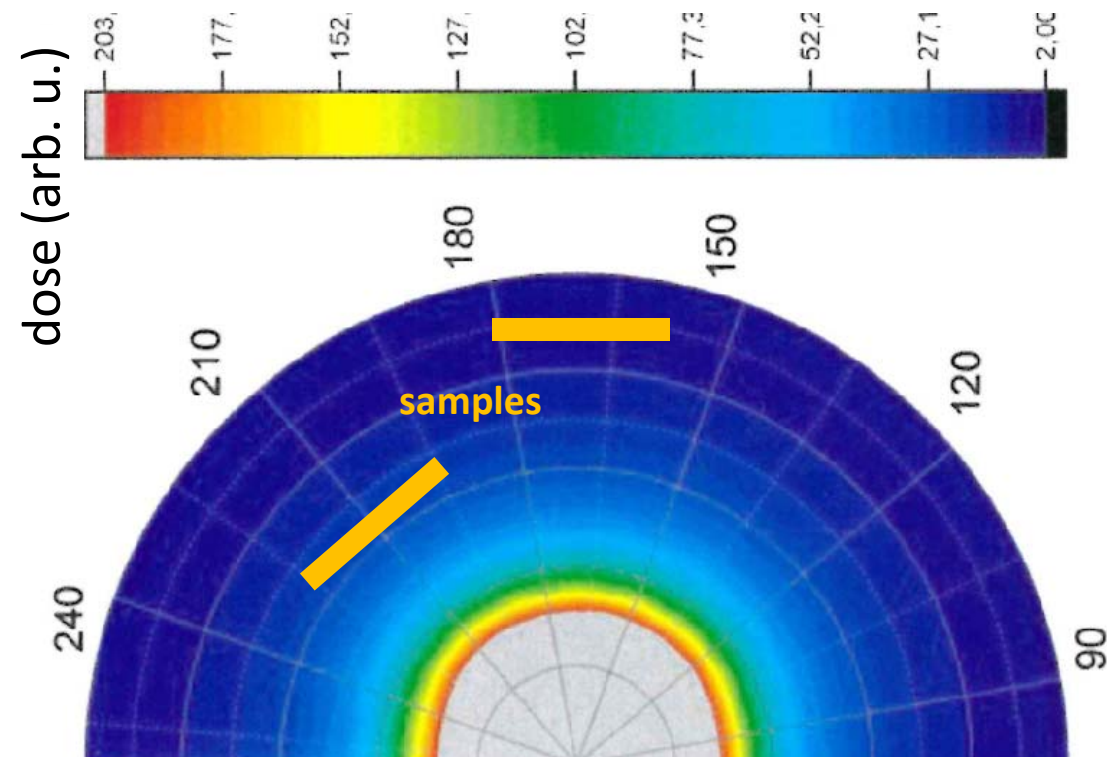
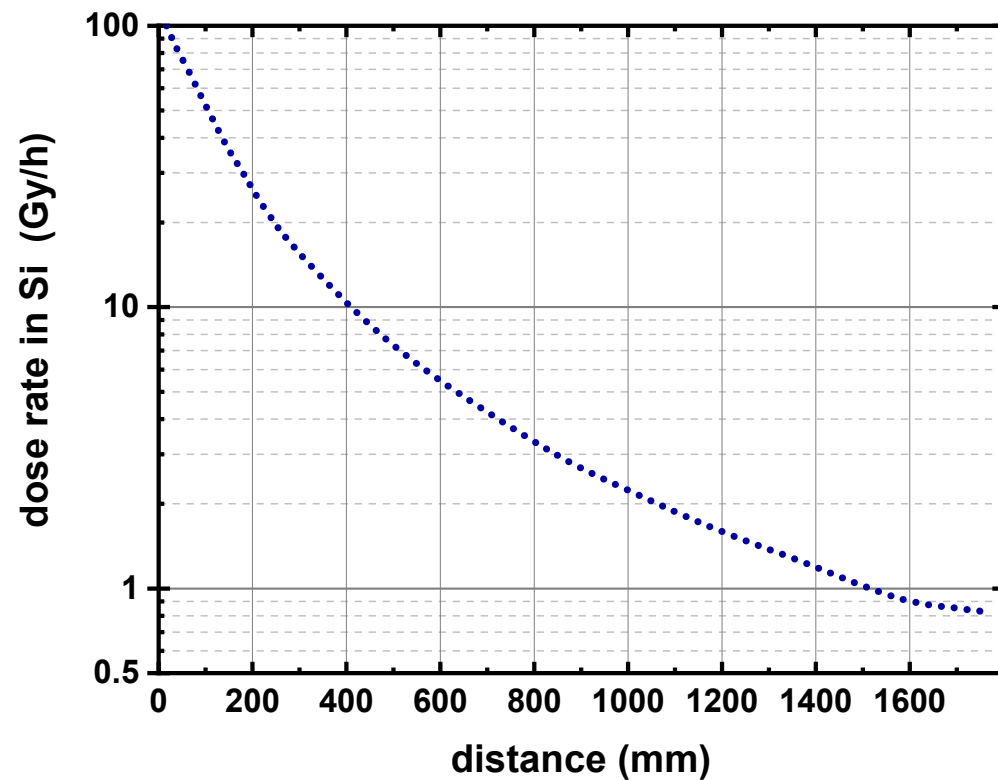
Cobalt Source: Irradiation Room

- large room:
ca. 3 m · 4 m
- various cables and connectors for
operating/read out of devices under
test
- sensitive measurement devices may
be installed outside of the irradiation
room



Cobalt Source: Dose Rate

- determination of dose with calibrated dose monitor
- dose rate 2024: between 0.4 Gy/h und 100 Gy/h in Si (0.04 krad/h to 10 krad/h)
- $T_{1/2} = 5.2$ years
- decrease of dose rate with increasing distance to source



Cobalt Source: Time Slots for Irradiations

- cobalt source available the whole year (24/7)
- generally access to the source for set-up or changes:
Monday to Friday between 8:00 and 17:00
- 6 RJ45 connections to measurement room
- measurement room with day light, internet and telephone



Conclusion

- **first proton therapy facility in Germany, more than 4600 Patients since 1998**
- **→ huge experience in reliable accelerator operation**
- **flexible irradiation facilities for protons and γ -rays**
- **new target station under construction: InOperando beam line**

Thank you for your attention

patient statistics with patient apertures

