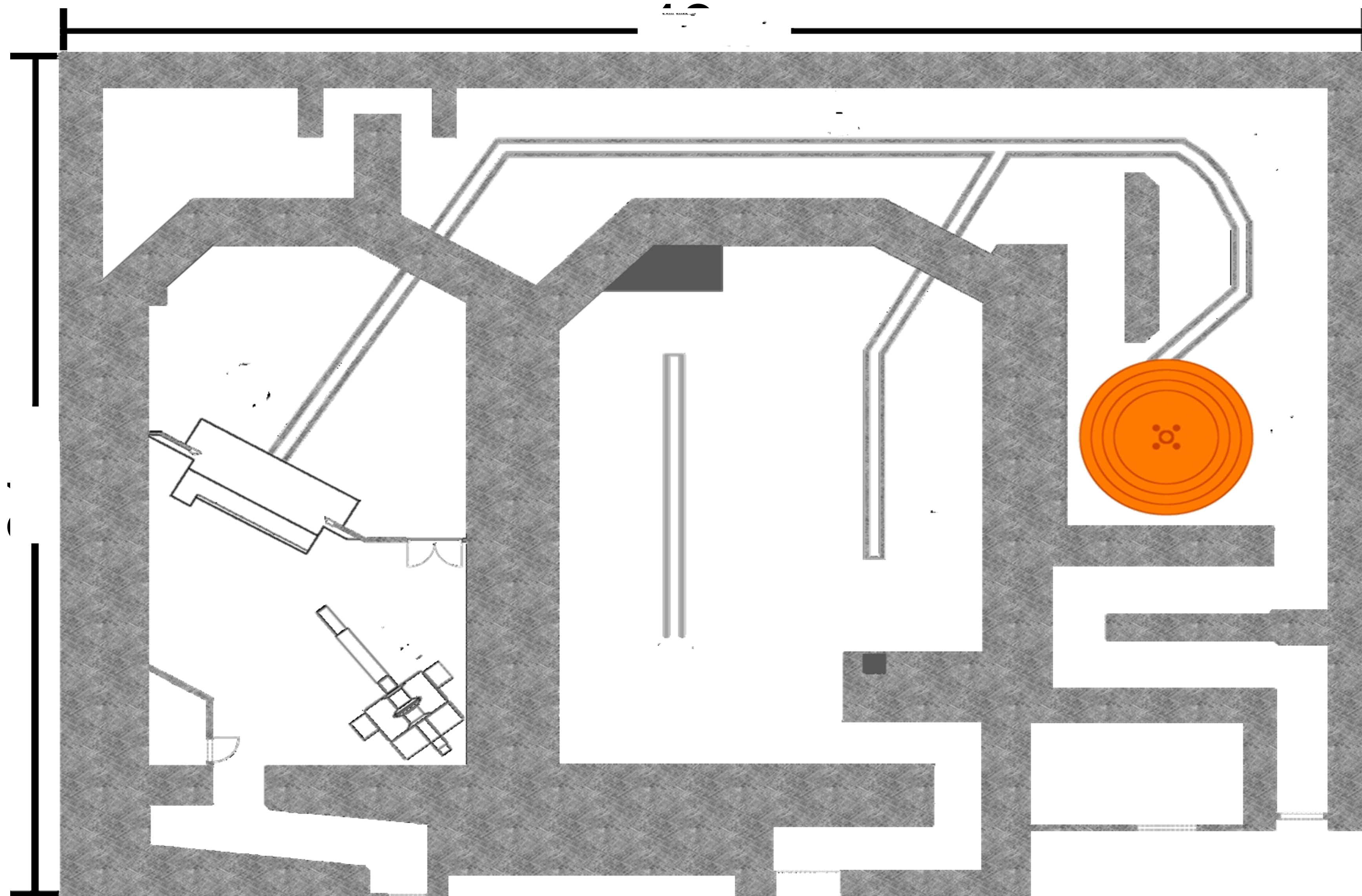


## The OncoRay clinical and experimental facility

### Treatment Room:

- isocentric gantry
- pencil beam scanning & double scattering
- robotic patient positioning system



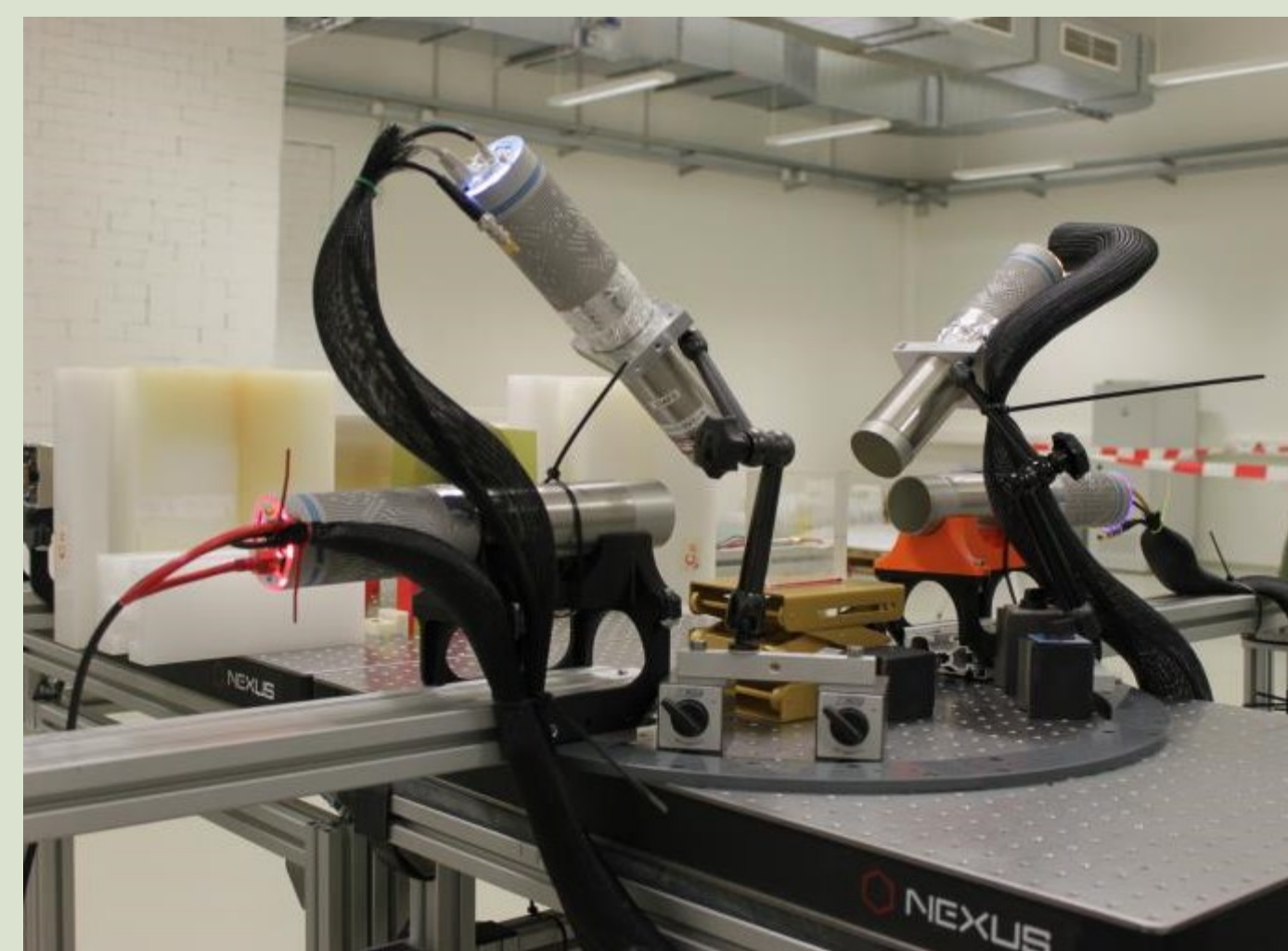
### Cyclotron:

- IBA Cyclone® C230
- proton beam:
  - $E_{\text{beam}} = 230 \text{ MeV}$
  - $I_{\text{max}} = 300 \text{ nA}$
  - $B_{\text{max}} = 2.9 \text{ T}$



### Experimental Area:

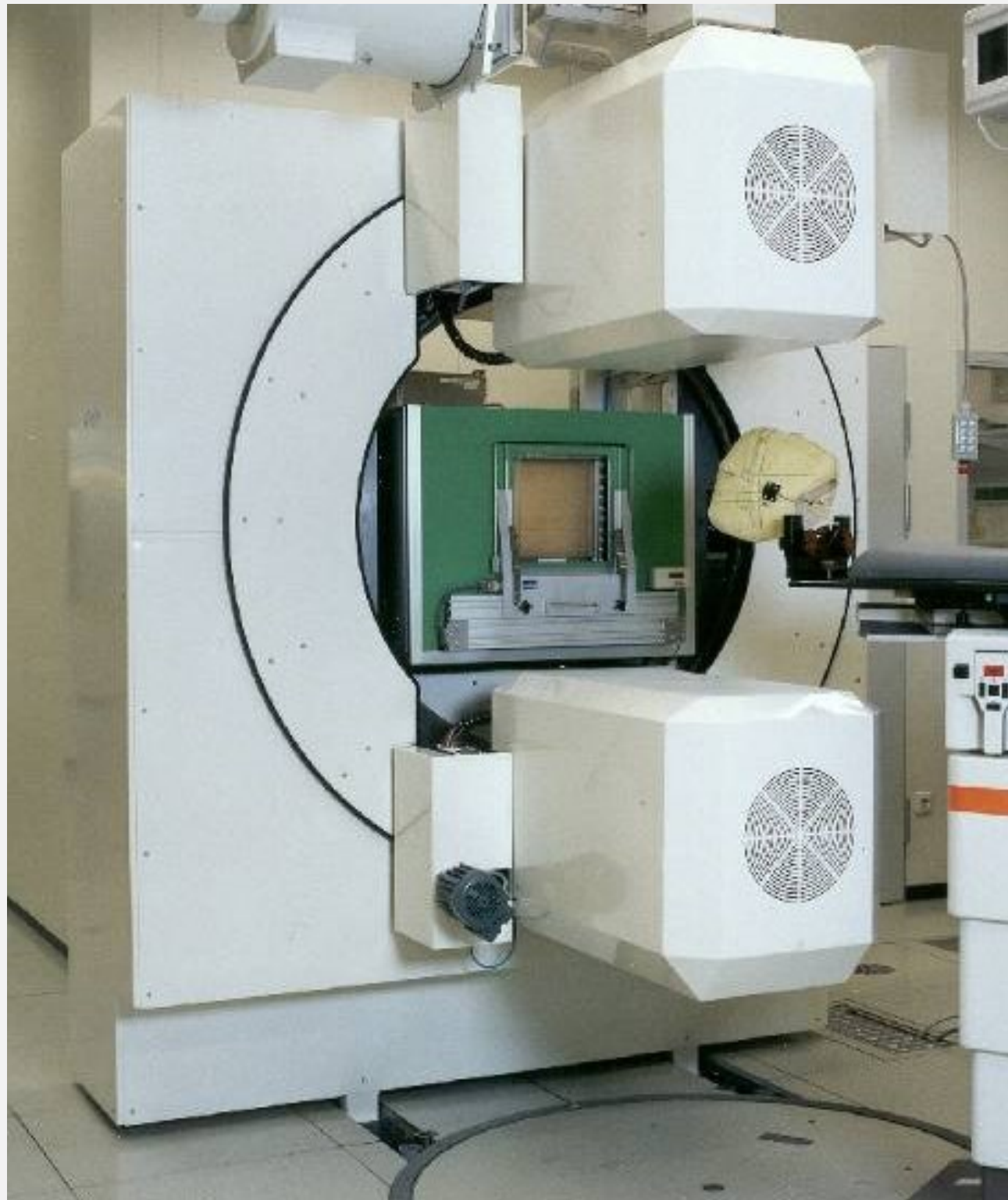
- clinical (pencil) beam for radiation research
- Available proton beam energies: 70–230 MeV
- horizontal beam line



## Range verification methods based on secondary nuclear signatures

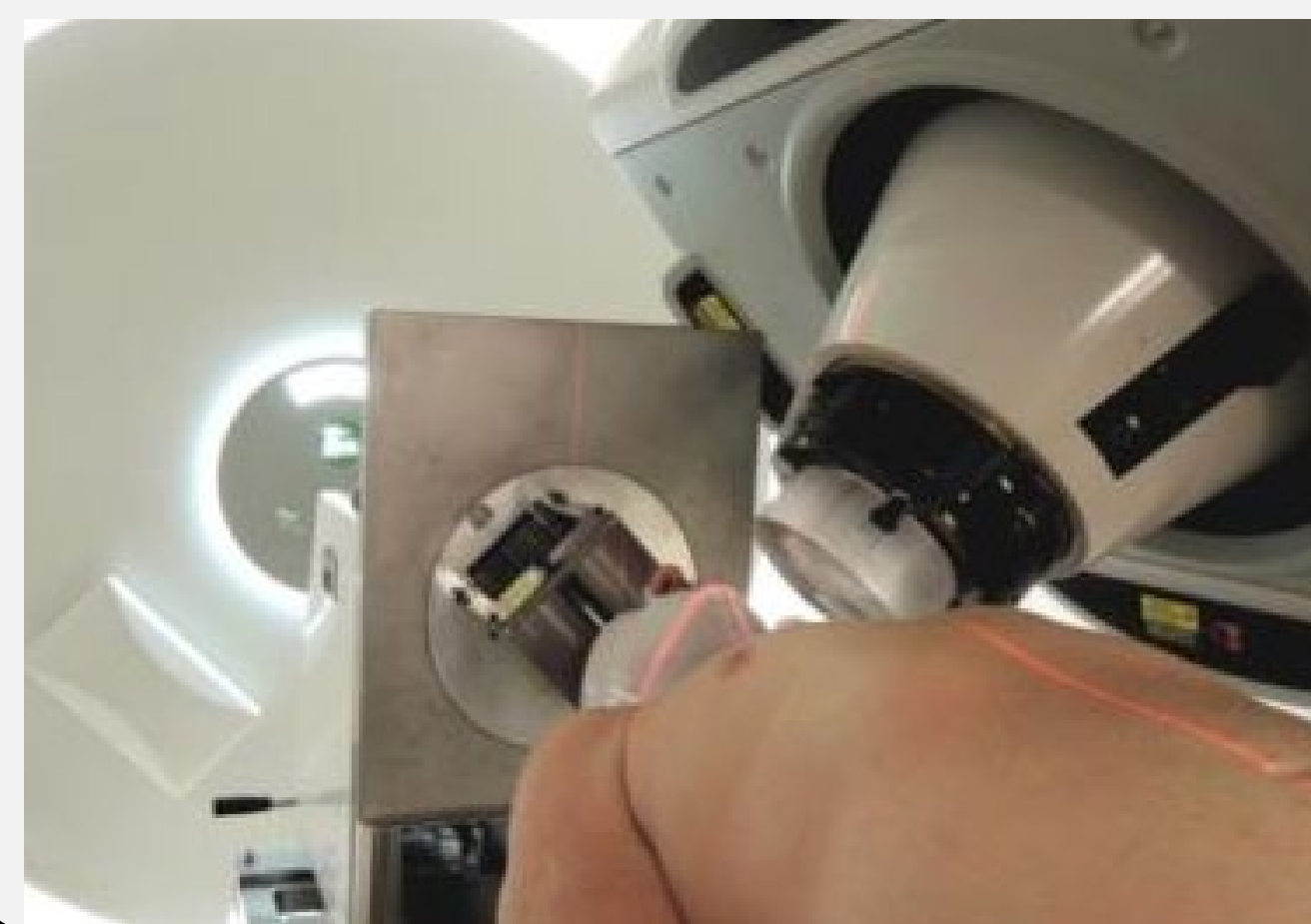
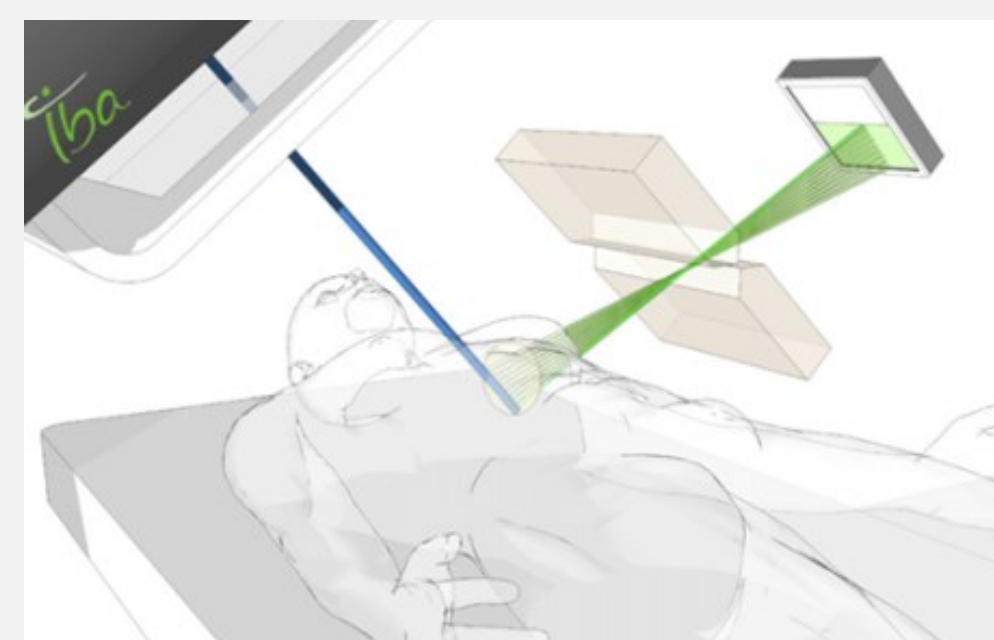
### Particle-Therapy PET (PT-PET) [1]

- Imaging the distribution of  $\beta^+$  emitters during or shortly after dose delivery
- **Uncollimated detectors**
- Clinically proven



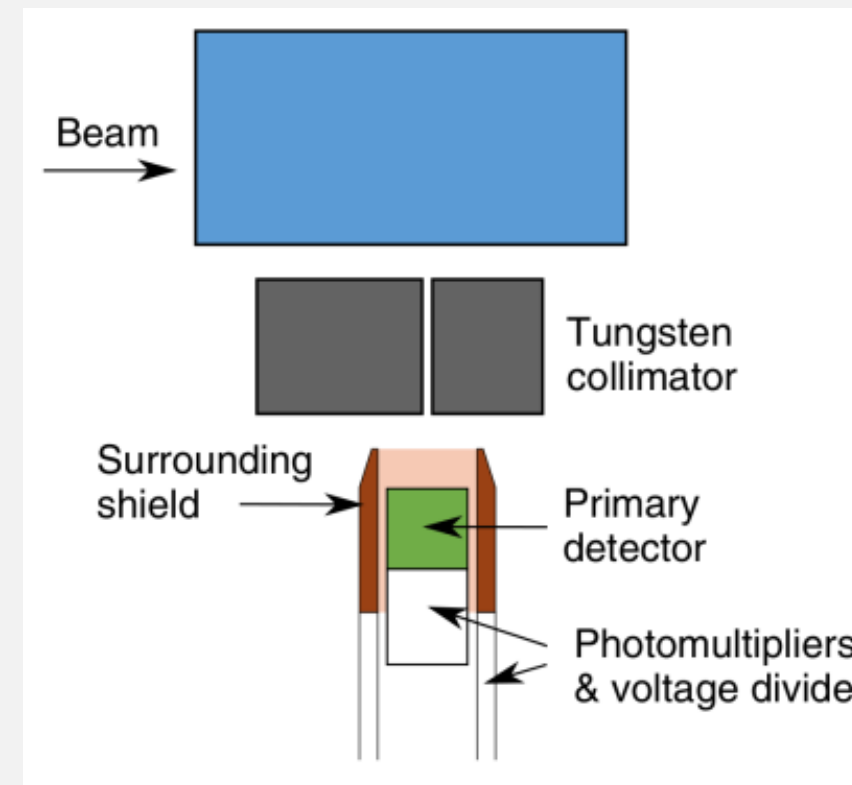
### Prompt Gamma-Ray Imaging (PGI) [2-3]

- Imaging the prompt gamma-ray emission pattern during dose delivery
- **Collimated detectors**
- Clinically tested



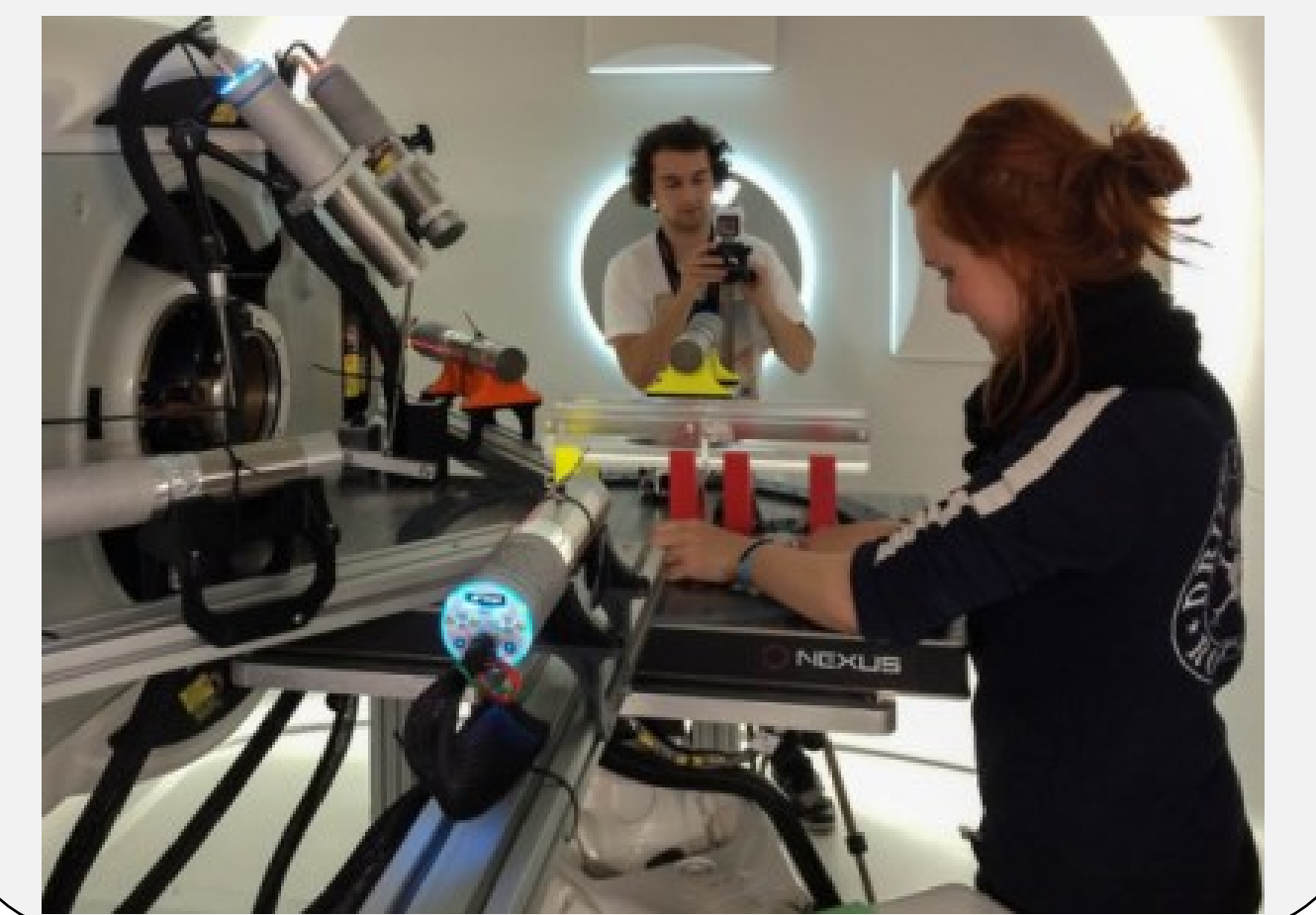
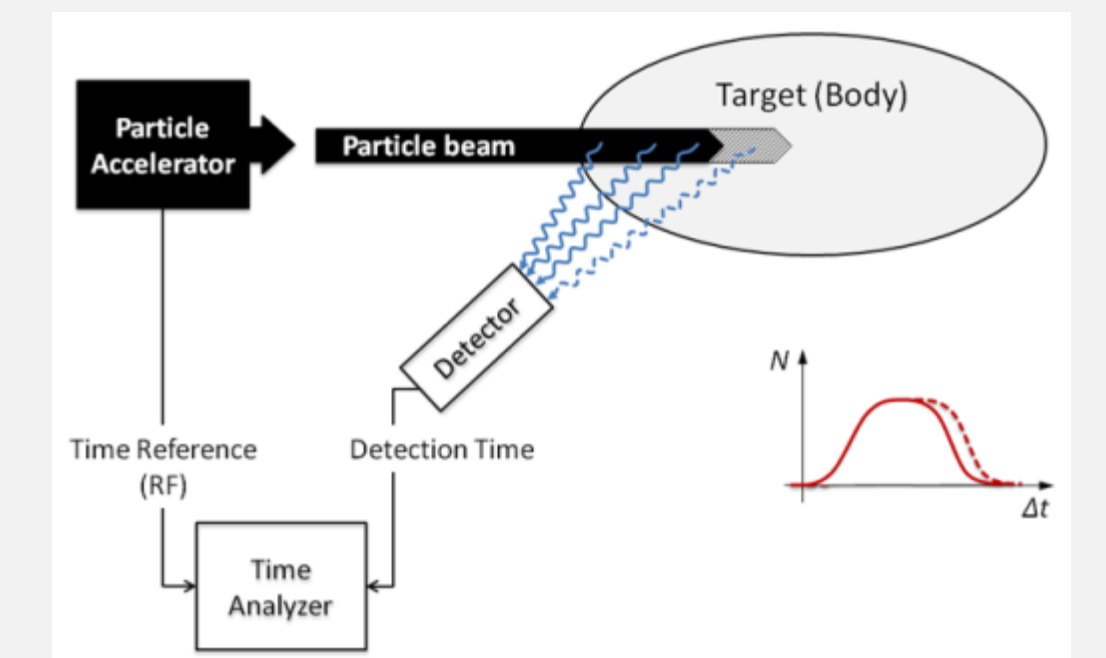
### Prompt Gamma-Ray Spectroscopy (PGS) [4]

- Measuring the energy spectra of prompt gamma rays during dose delivery
- **Collimated detectors**
- Clinically applicable



### Prompt Gamma-Ray Timing (PGT) [5-7]

- Measuring the time distribution of prompt gamma rays during dose delivery
- **Uncollimated detectors**
- Clinically applicable



## References

- [1] W Enghardt et al, *Charged hadron tumour therapy monitoring by means of PET*, Nucl Instr Meth A 525 (2004) 284
- [2] J Smeets et al, *Prompt gamma imaging with a slit camera for real-time range control in proton therapy*, Phys Med Biol 57 (2012) 3371
- [3] C Richter et al, *First clinical application of a prompt gamma based in vivo proton range verification system*, Radiotherapy and Oncology 118 (2016) 232
- [4] JM Verburg and J Seco, *Proton range verification through prompt gamma-ray spectroscopy*, Phys Med Biol 59 (2014) 7089
- [5] C Golnik et al, *Range assessment in particle therapy based on prompt  $\gamma$ -ray timing measurements*, Phys Med Biol 59 (2014) 5399
- [6] G Pausch et al, *Scintillator-Based High-Throughput Fast Timing Spectroscopy for Real-Time Range Verification in Particle Therapy*, IEEE Trans Nucl Sci 63 (2016) 664
- [7] G Pausch et al, *Method and apparatus for monitoring the range of a particle beam*, US Patent No. 9364688 (2014)