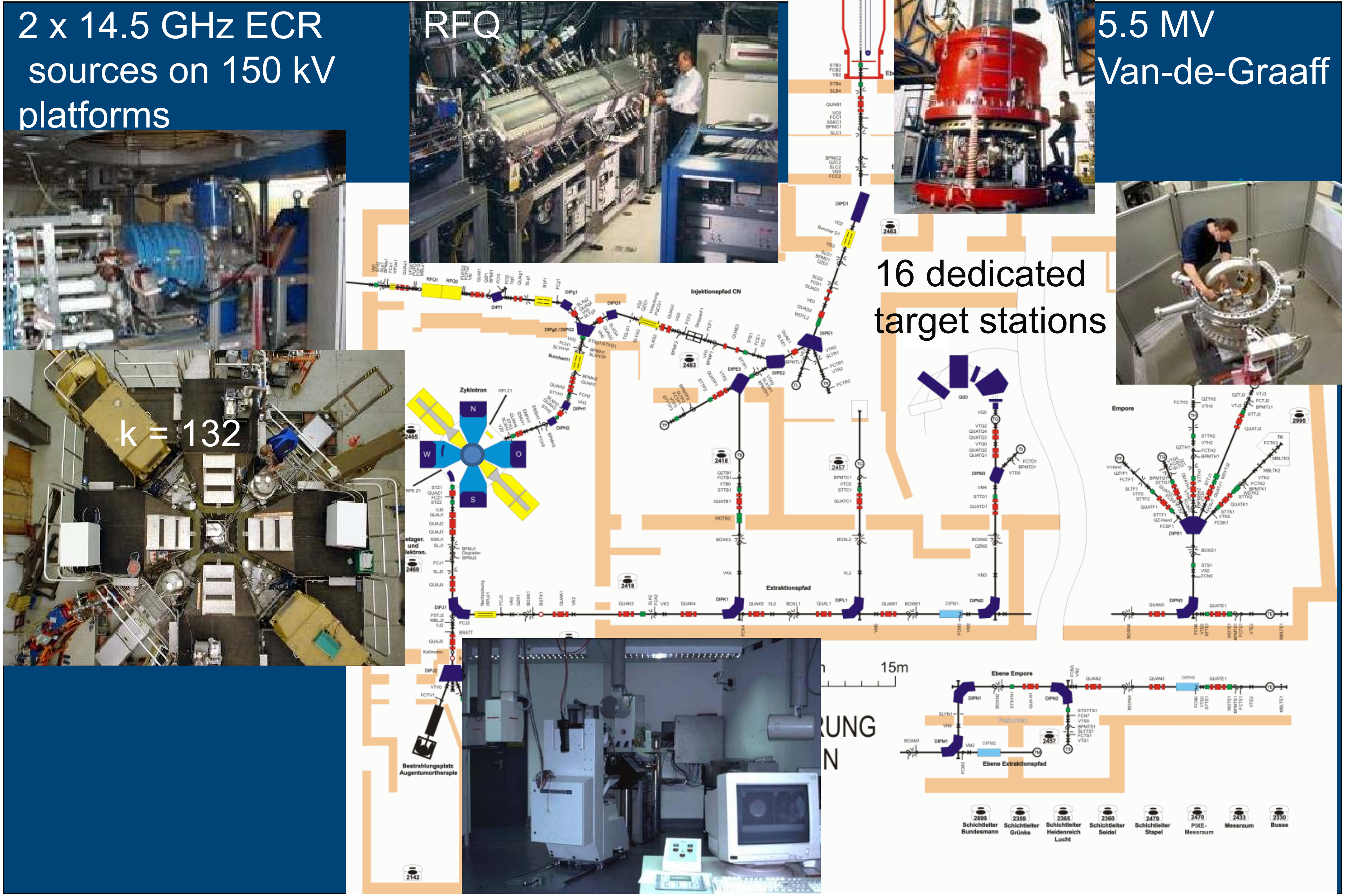
Status of the HZB Cyclotron

A. Denker, J. Bundesmann, T. Damerow, T. Fanselow,
W. Hahn, G. Heidenreich, D. Hildebrand, U. Hiller,
C. Kunert, U. Müller, C. Rethfeldt, J. Röhrich

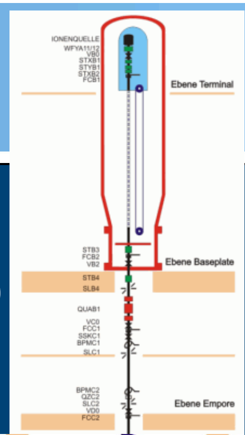
Helmholtz-Zentrum Berlin, Protons for Therapy

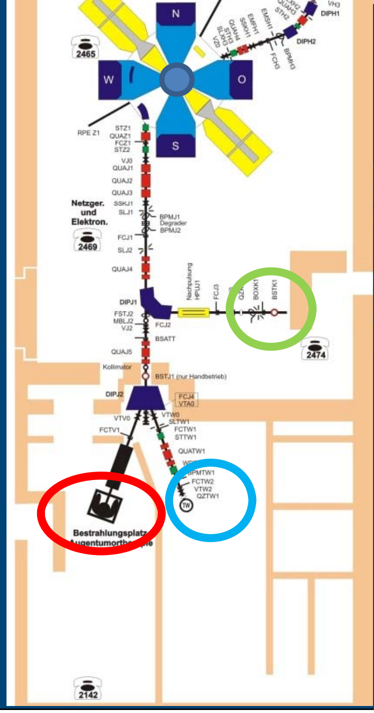
Accelerator Layout 12/2006

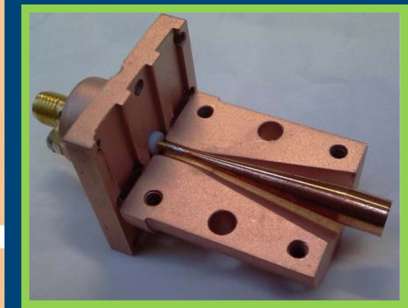


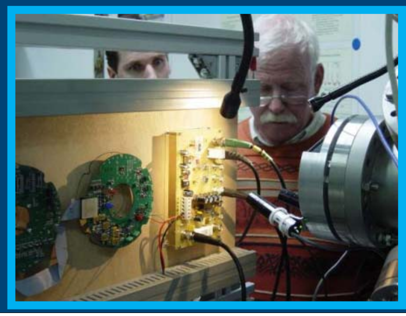
Accelerator Layout Jan/2011

- reduction to two high-energy target stations (68 MeV protons: I_{max} = 10 nA) and one beam end for tests
- replacement of RFQ by tandetron





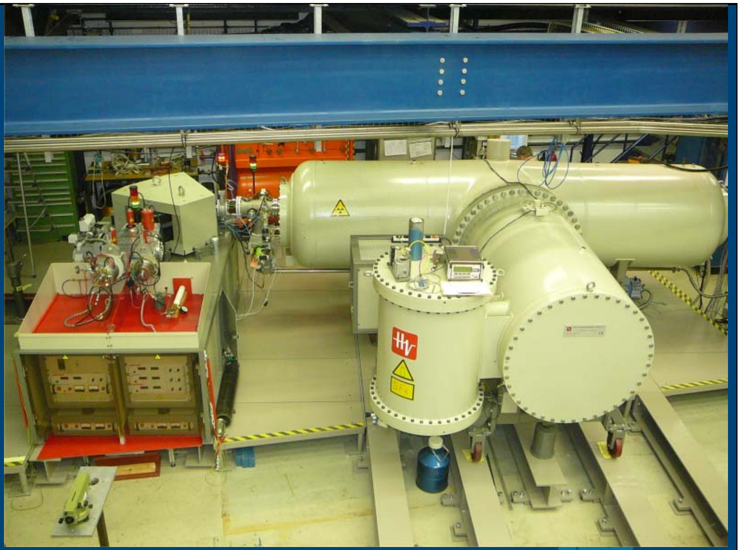




Installation of a Tandetron

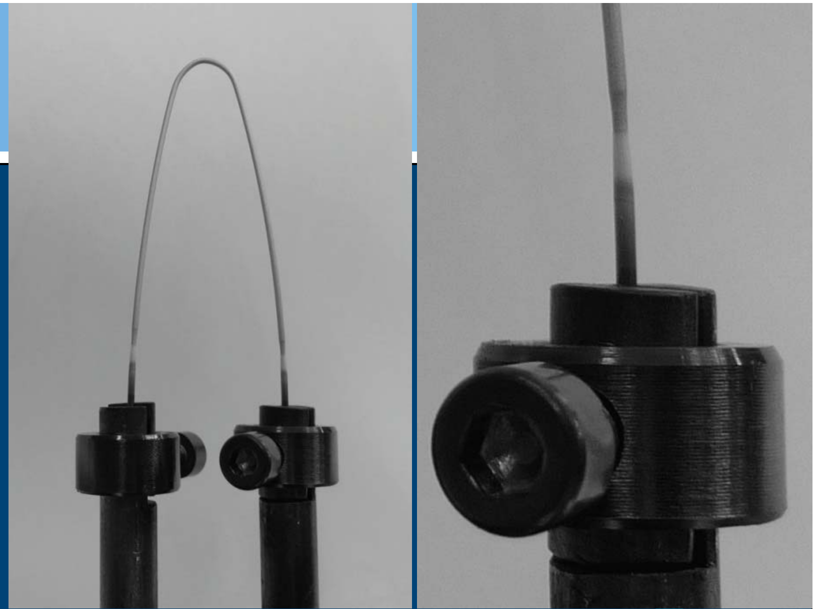
HZB Helmholtz Zentrum Berlin

- further shortening of beam lines
- less rooms required
- reduction of radiation safety
- easy and reliable operation:
  - no moving parts
  - sources on “ground potential”
- installation:



Apr. 07:	purchased from BAM, start of dismantling
Oct. 07:	transfer to HMI, installation starts
Sep. 08:	first beam from source
Oct. 08:	first beam through tandetron
Mar. 09:	first beam through cyclotron
Aug. 10:	acceptance test finished, applied for licence
Dec. 10:	licence granted
Jan. 11:	first therapy with tandetron as injector

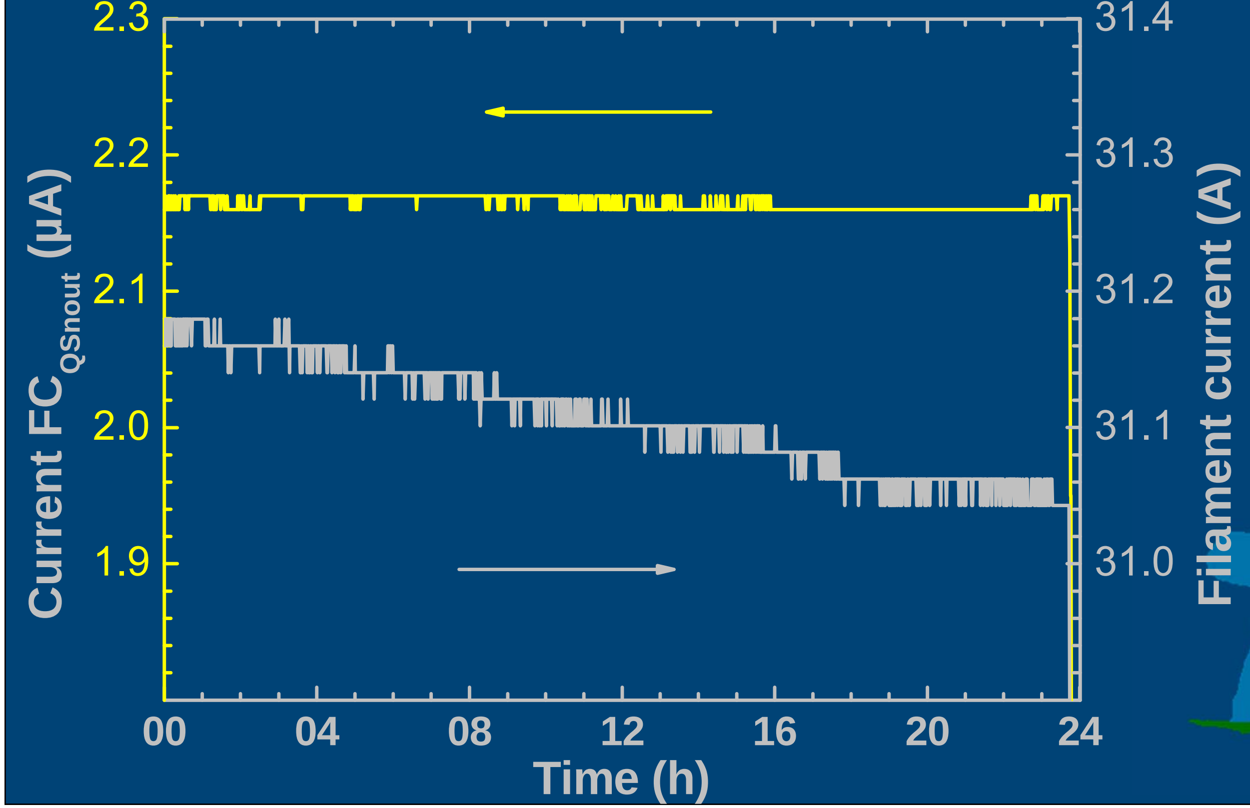
Source development



- standard duoplasmatron with direct off axis extraction of H^-
- hair-needle filaments made from thoriated tungsten wires (good experience at BAM)
- normal thinning with operation time, plus additional constrictions near the clamping points
- reason: purity of the gas
  (plastic tubes for electrical isolation caused filament lifetimes < 100 hours)
- now: mixture of 10 vol.-% H_2 with 90 vol.-% of He
  (available as test gas in 2 l bottles from Linde)
- further advantage:
  reduction of beam intensity (> 20 µA → ~ 2 µA)

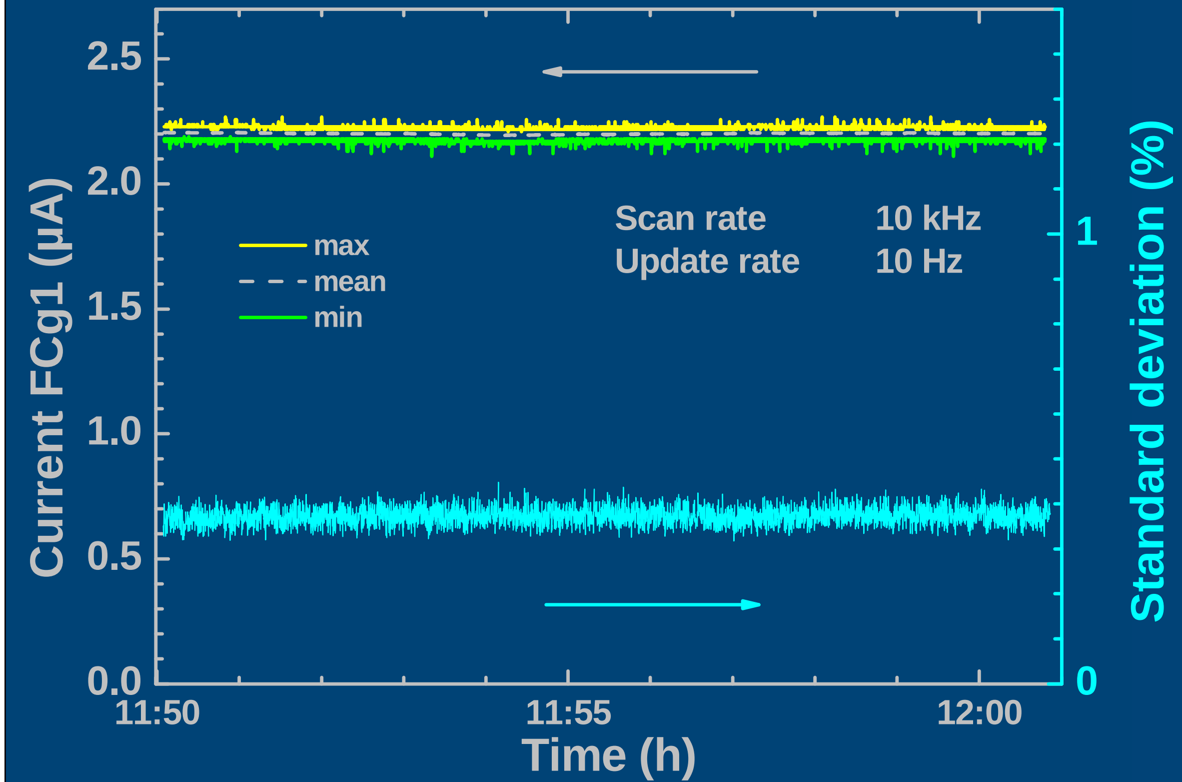
Source development

- change of tandetron operation system from filament current regulation to voltage regulation
- 6 therapy weeks + experimental time (corresponding to > 1000 hours) could be delivered with one filament
- system unexpectedly robust against power failures of the electricity supply



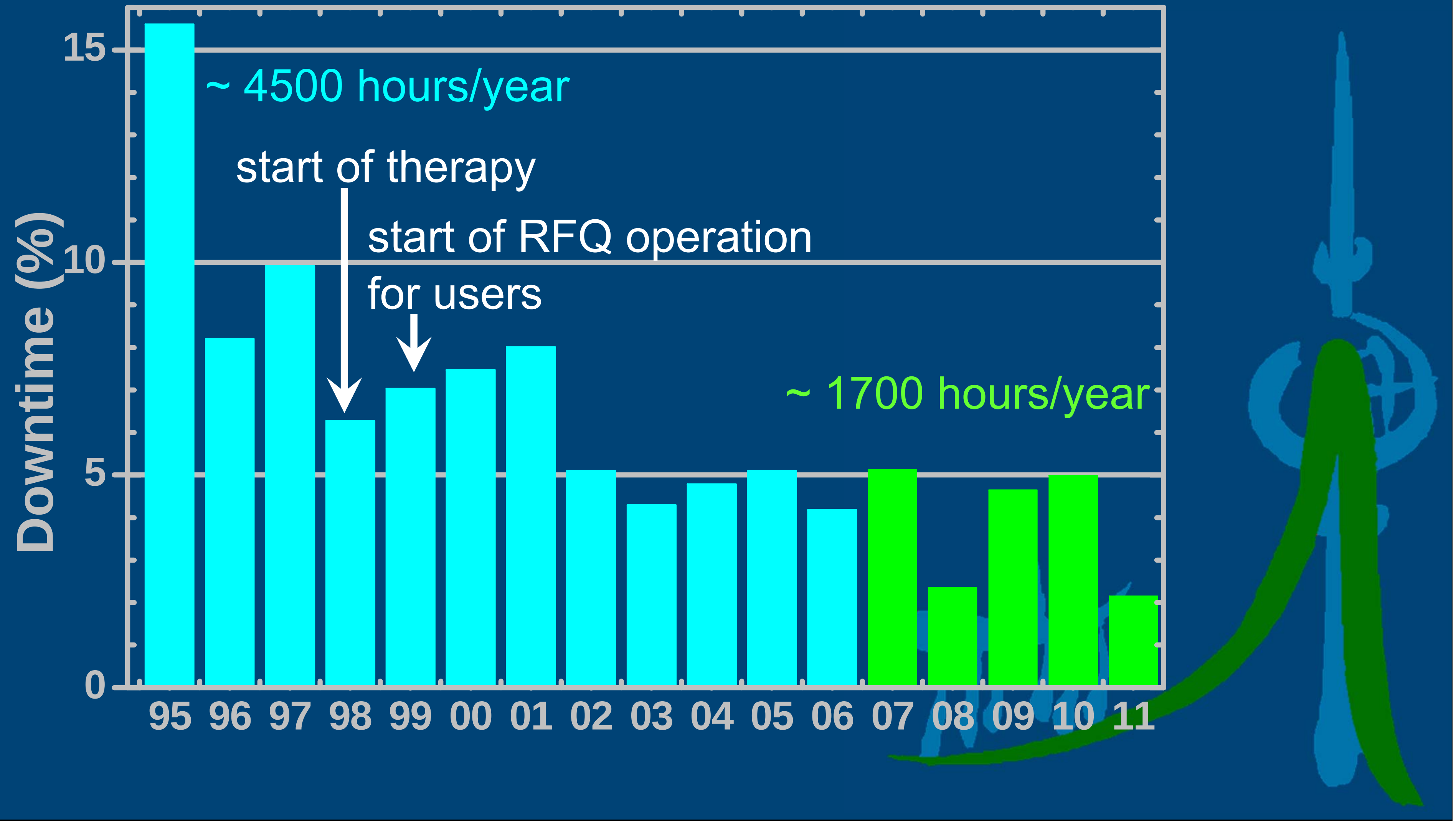
Operation of the Tandetron

- since Jan. 11 only tandetron as injector for therapy
- good long-term and excellent short term stability
- upgrade of tandetron operation system
- tandetron fully fulfilled our expectations:
  - reduction in required maintenance compared to Van-de-Graaff
  - very reliable: only 3% of the overall downtime in 2011



Accelerator Performance

- averaged downtime before 1995: 10 %
- less beam time hours: major events = huge impact on statistics

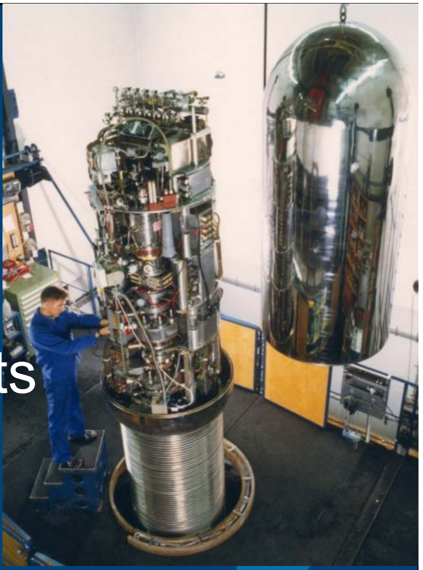


Reduction of Downtime: Step by Step Process

addressing all subsystems:
sources, injectors, beam lines, cyclotron, control system

1) preventive maintenance
2) increased redundancy / reduction of elements
3) modernisation
4) improved diagnosis

Reduction of Downtime



1. Preventive Maintenance

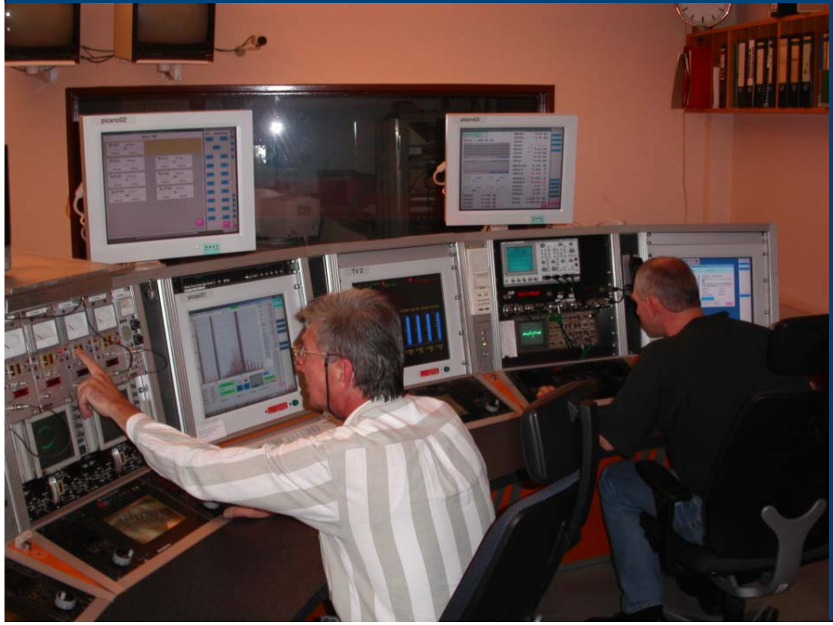
- regular belt change of Van-de-Graaff
- cyclic cleaning of isolators, drying of SF_6 gas
- cyclic replacement of water tubes
- cyclic change of spare power supplies and components
- regular residual gas analysis

2. Redundancy / Reduction of elements

- smaller variety of pumps, vacuum gauges, power supplies….
- whenever possible: spare parts for quick exchange
- low intensity proton beams: no pre-bunching
- no water cooling of deflector plates in beam line dipoles
- turbo pumps on 60 % of rotational speed (standby mode) increases service intervals about factor 5

3. Modernisation

- new computers for control system
- uninterruptable power supplies for computers of control system
- exchange of shunt against transducer regulation in quadrupole power supplies (gain in stability: factor 10)
- discrete rectifiers replaced by complete 3-phase modules
- replacement of main coil power supply of cyclotron
  side effect: less energy consumption



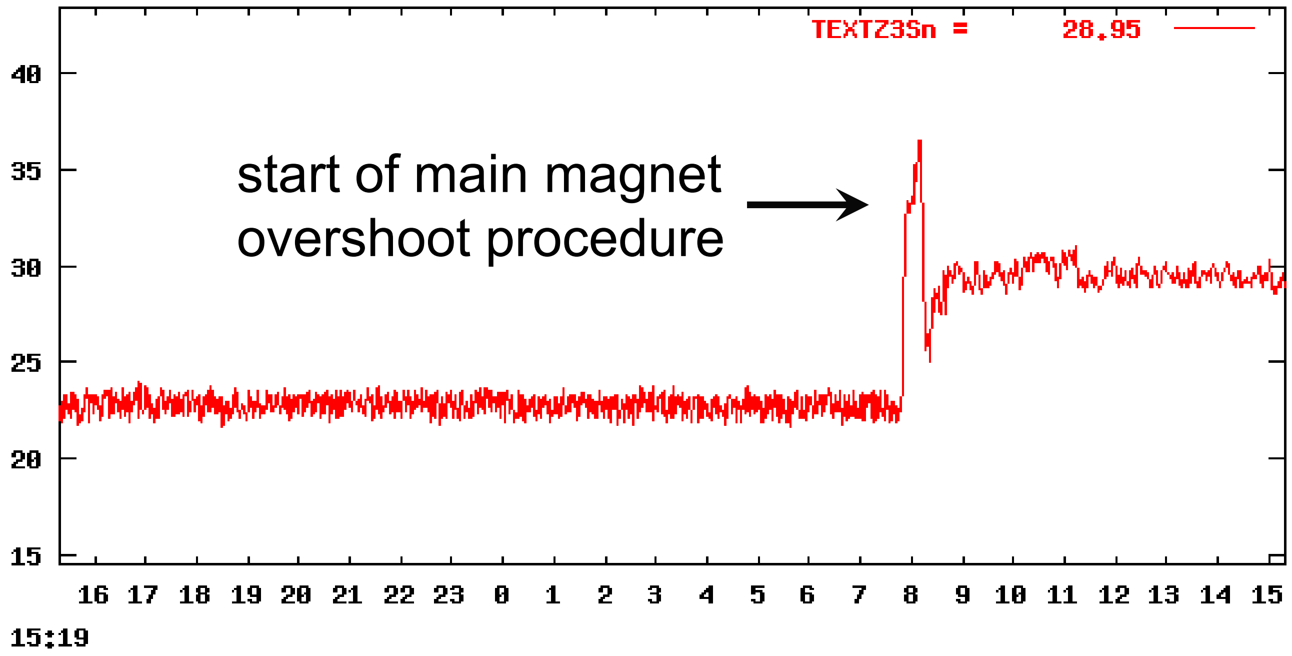
HZB Helmholtz Zentrum Berlin

3. Improved Diagnostics

- 24 h charts (access by WWW possible)

PT-Temperature - Charts

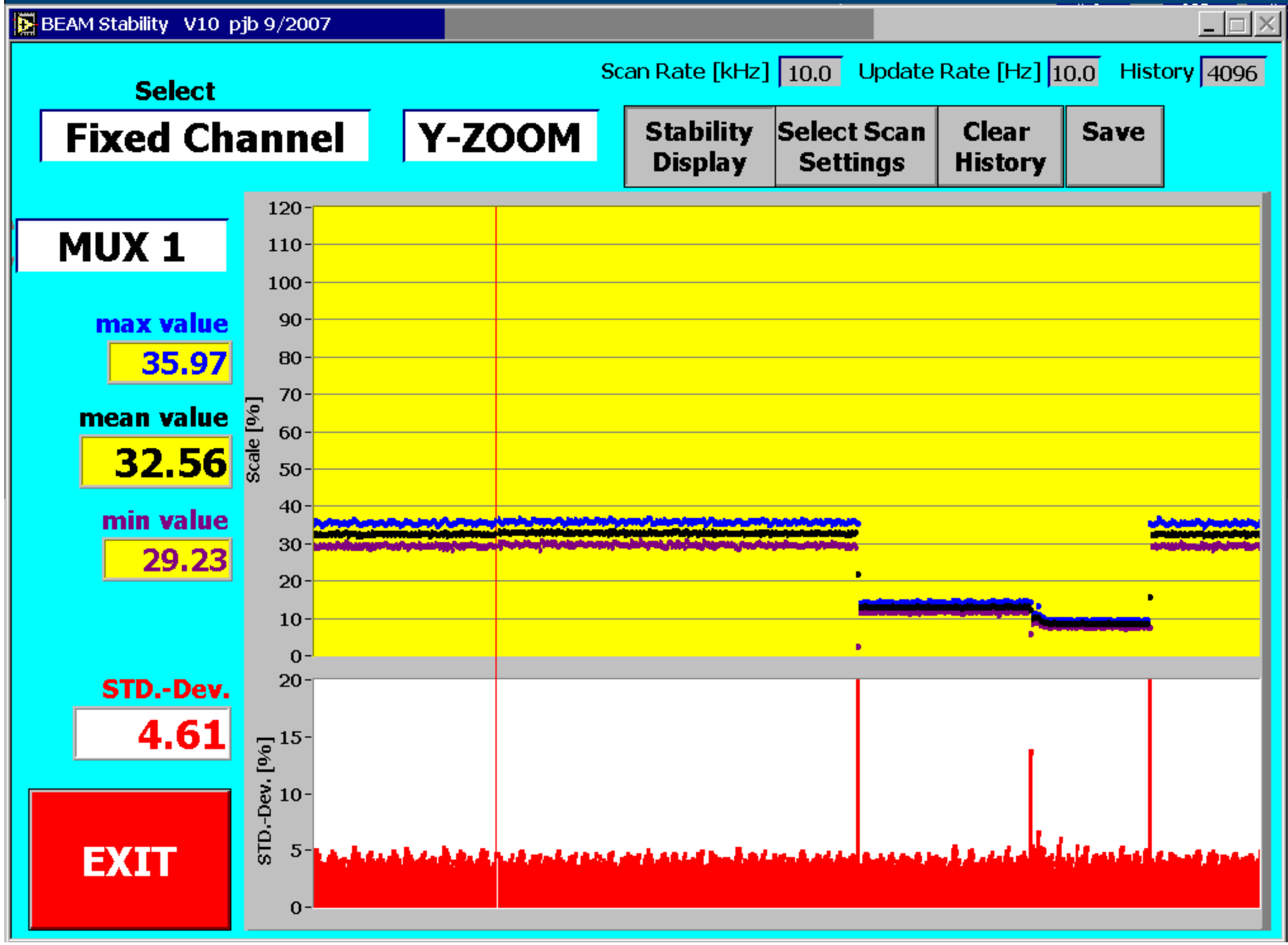
Cyclotron Magnet Temperature



HZB Helmholtz Zentrum Berlin

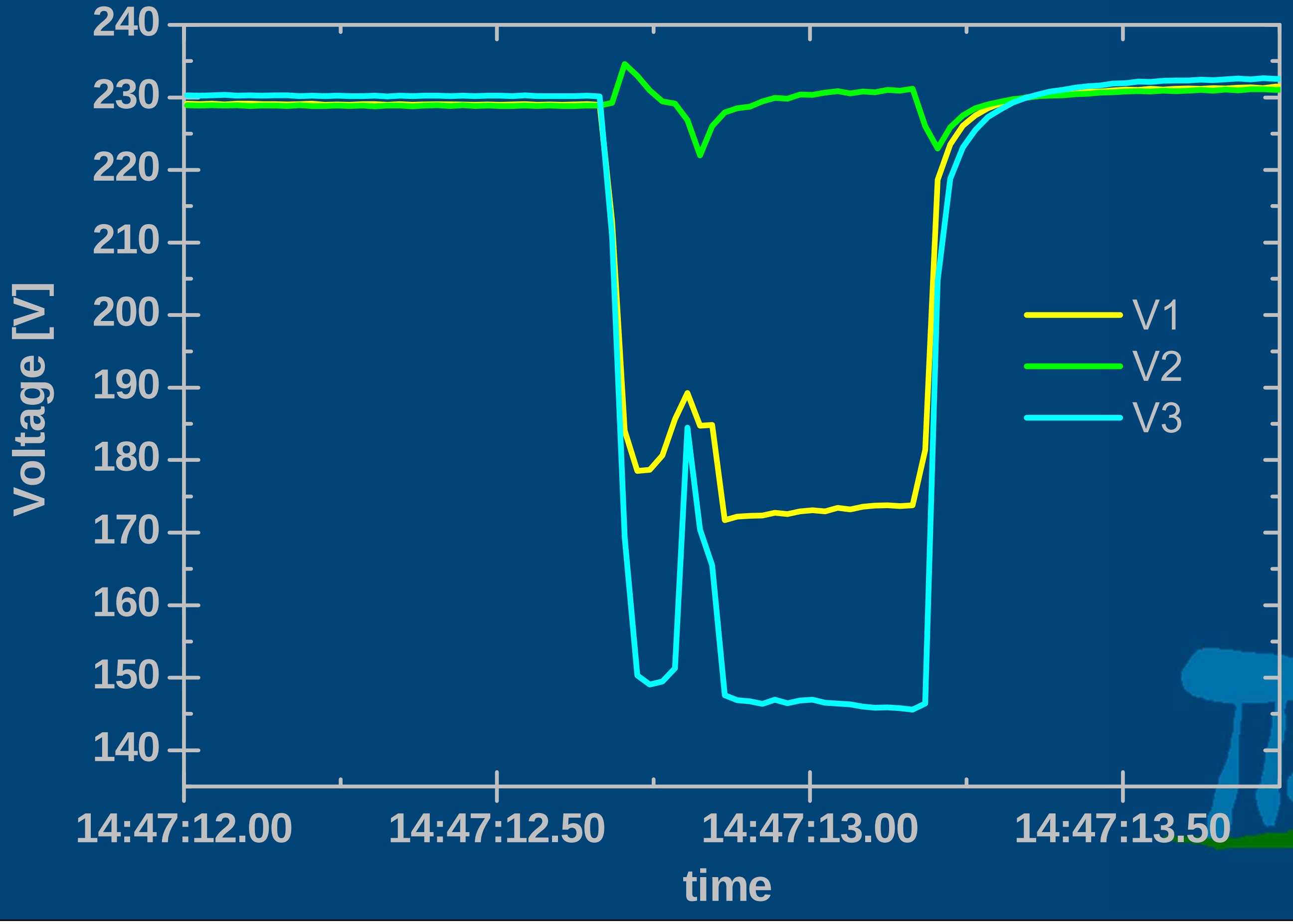
3. Improved Diagnostics

- 24 h charts (access by WWW possible)
- beam stability programme



3. Improved Diagnostics

- 24 h charts (access by WWW possible)
- beam stability programme
- logging of power supply for failure analysis



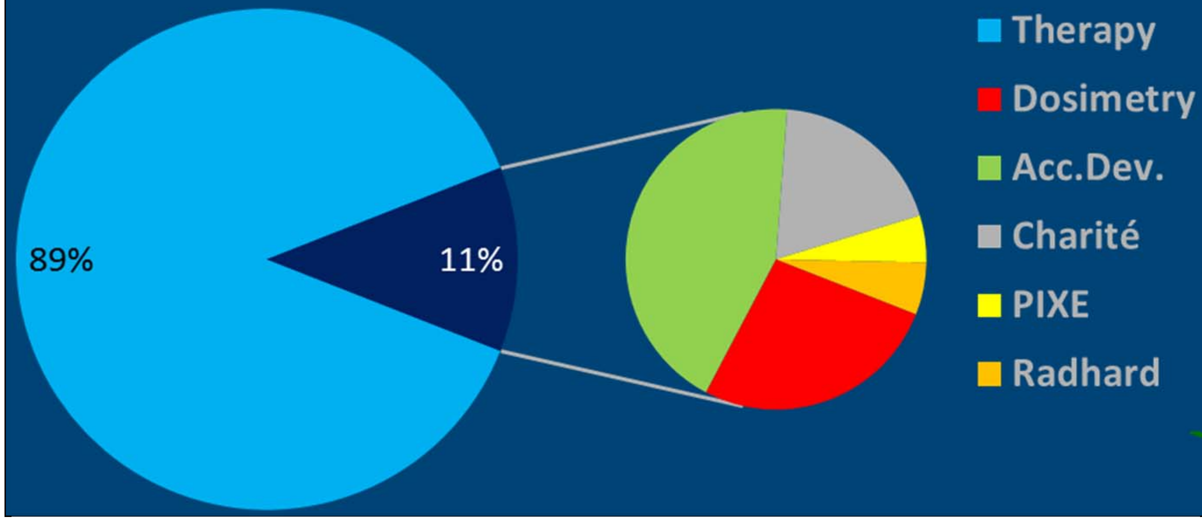
Reduction of Downtime: Luck

- water leak in final amplifier of RF on top of coupling loop
- detected at 6:00 in the morning, RF still running!
- solution (quick and dirty): vacuum cleaner plus time switch, empty cleaner every 3 hours, keeping water level constant = only slight detuning of RF observed

Experiments (2009 – 03/2012)

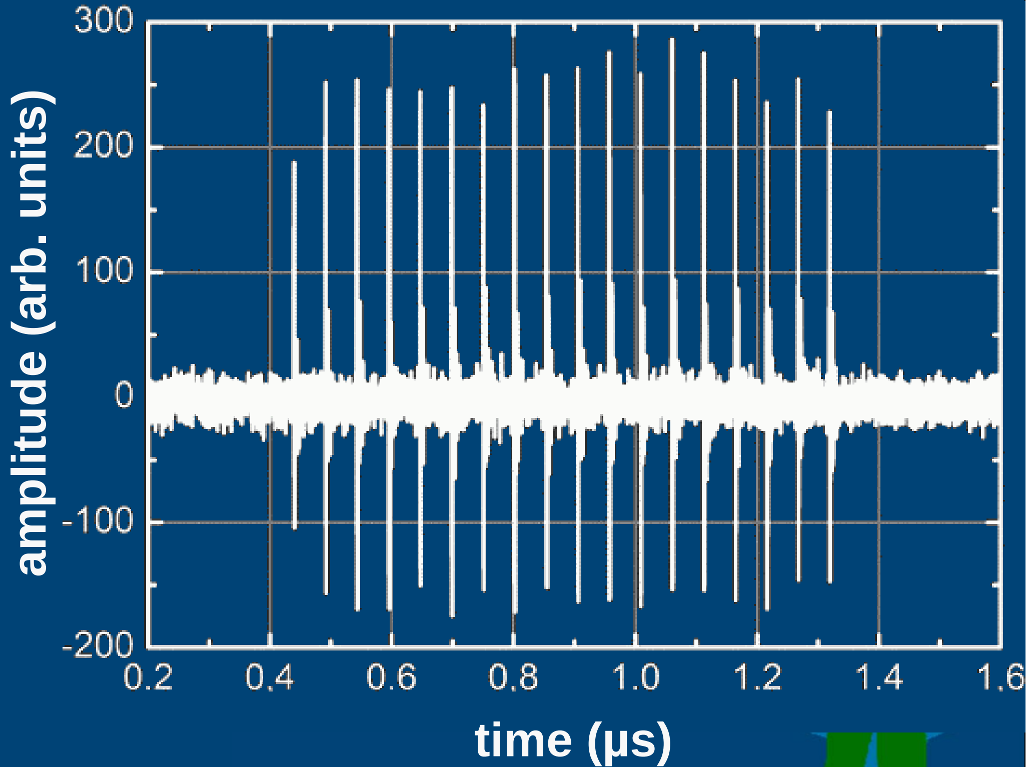
- since 2009: accelerator physics = important research topic of HZB
  - accelerator development outside pure medical use possible
  - experiments possible for metrology and radiation physics
- "standard" : 68 MeV protons, quasi-DC,
  broad or focused beam on target,
  changes in intensity: 0.1 pA ≤ I_{target} ≤ 10 nA

  deliverable by either Van-de-Graaff or tandetron as injector
  - therapy and experiments for Charité
  - PIXE
  - radiation hardness tests



New Beam Requests

- quasi-DC: DC injection, time structure defined by cyclotron RF
- pulsed beam possible?
  - pulse length: 1 to 10 µs
  - repetition rate 100 Hz
  - intensity in the pulse: 5 nA to 1 µA on target ($500\ fA \le I_{average} \le 1\ nA$)



- ➲ for better transmission through cyclotron: revive bunchers
- ➲ for time structures: revive pulse suppressor
- ➲ Van-de-Graff as injector
- but: bunchers and pulse suppressor designed for heavy ions
- ➲ development of beam diagnostics, triggering electronics….

New Beam Requests

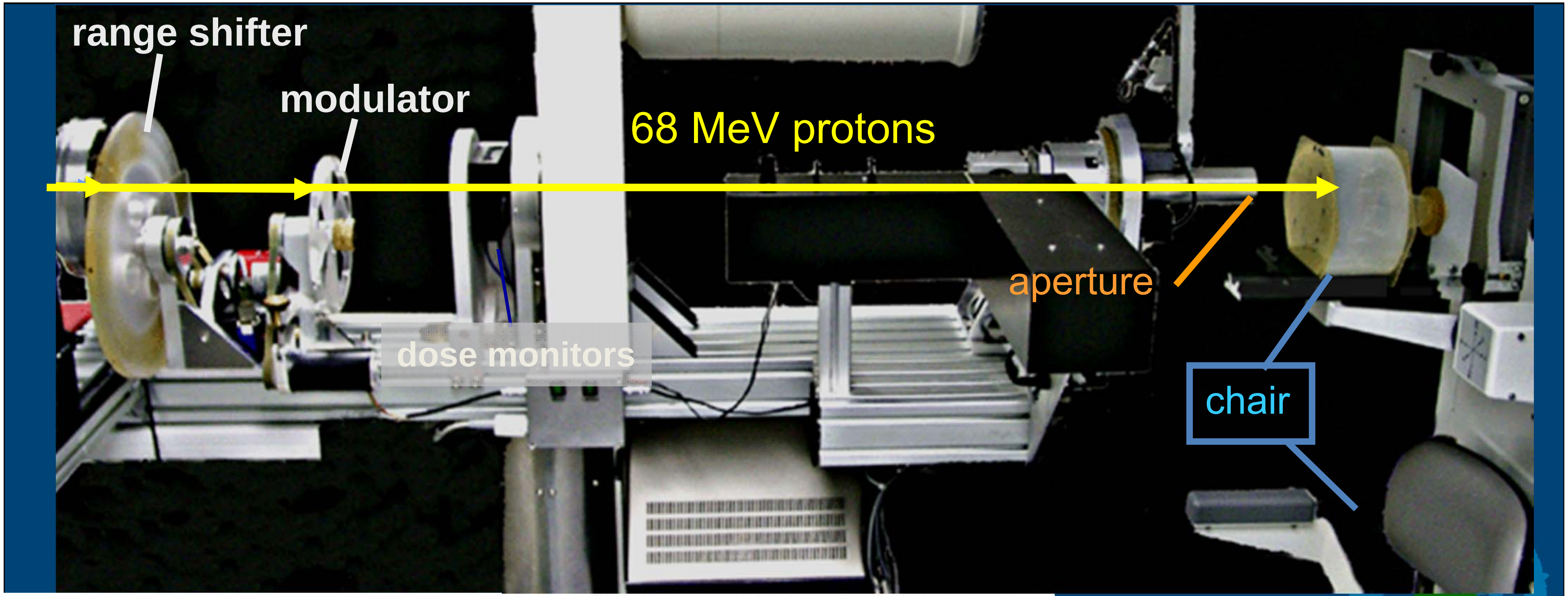
- goal: linearity tests of dosimeters in pulsed neutron fields by EURADOS
  (European Radiation Dosimetry Group)
- neutrons produced by 68 MeV protons on tungsten target
  - intensity in the pulse: 5 nA to 1 µA on target (roughly 0.1 nSv to 150 nSv per pulse)
- measurement campaigns in Feb and March 2012, more than 10 different dosimeters tested
- data under evaluation

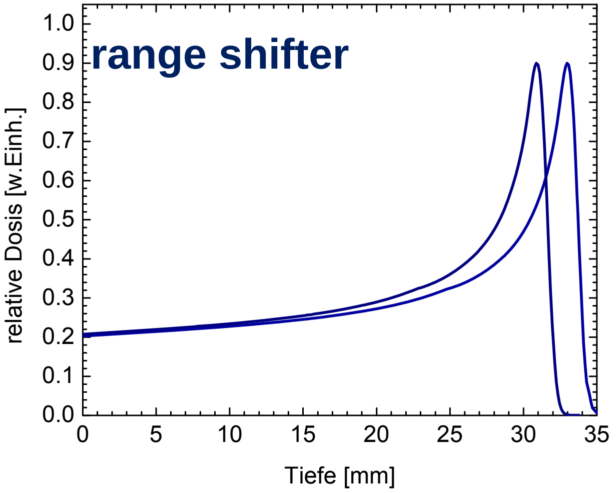
Conclusion

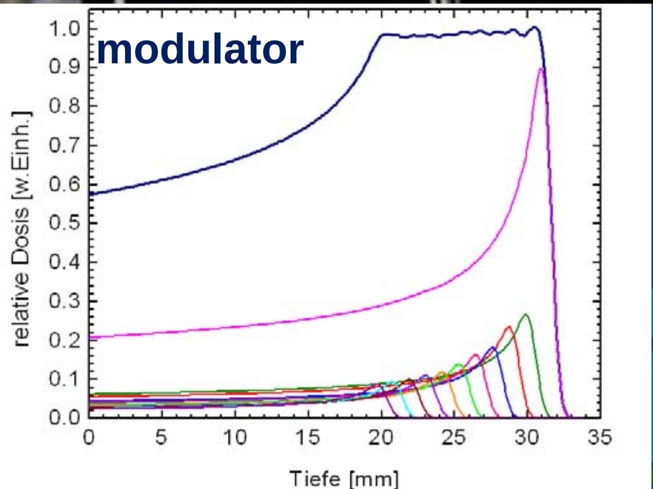
- reliable accelerator operation, past years: uptime at least 95 %
- 11-12 therapy weeks per year, ~ 200 patients/year
- interesting new beam requests

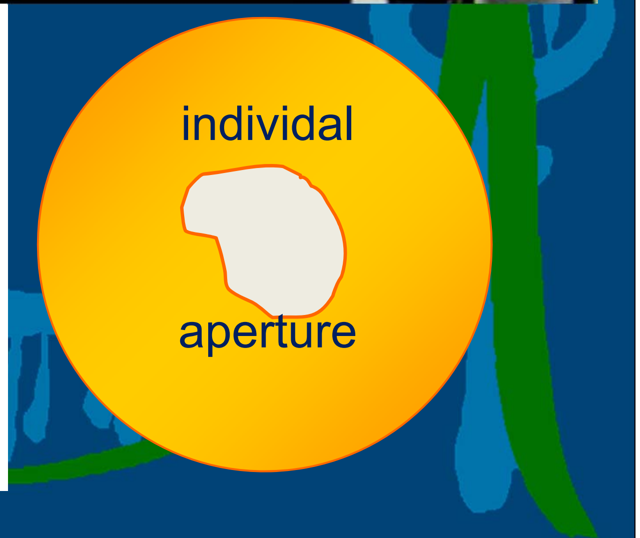
Thank you for your attention!

Tumour Therapy: Set-up





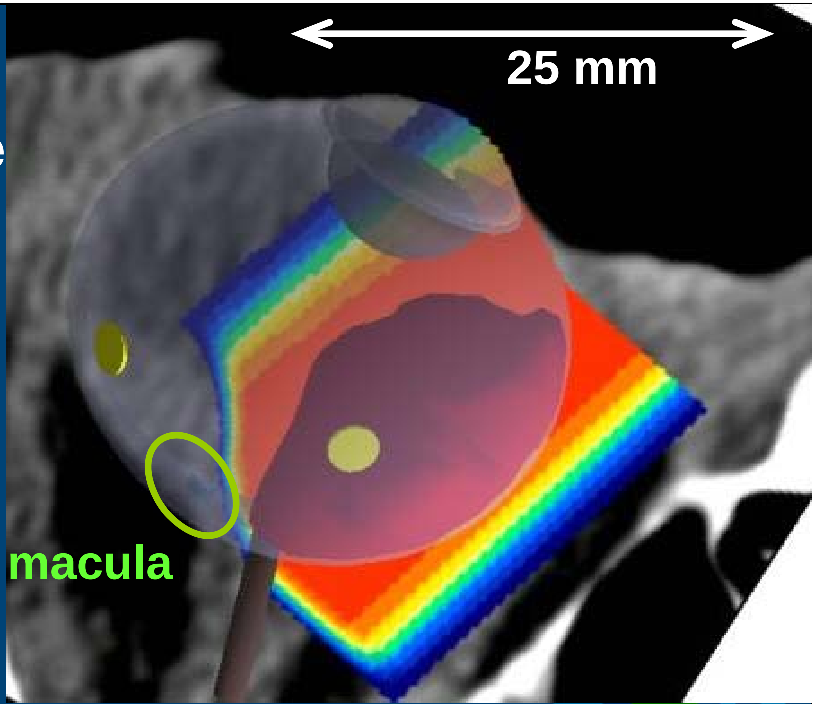




Consequences of Degraded Beam

- 1. goal = tumour control
- 2. goal = spare healthy tissue from dose
  → quality of life, e.g. capacity to read

- ocular tumour therapy has to accept compromises regarding side effects or requires a sophisticated beam shaping technique as at OPTIS2 / PSI



➲ suggestion for a dedicated facility, optimized for the needs of ocular melanomas