UniversitätsKlinikum Heidelberg

RadioOnkologie

Behandeln
Forschen
Lehren

Quality Assurance for particle beam therapy

PTCOG Educational Workshop, Essen 2013

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Outline

- Introduction: why QA is needed ?
- General Aspects of QA
- QA for particle therapy – some examples
- Conclusions

Fatal Errors in TP

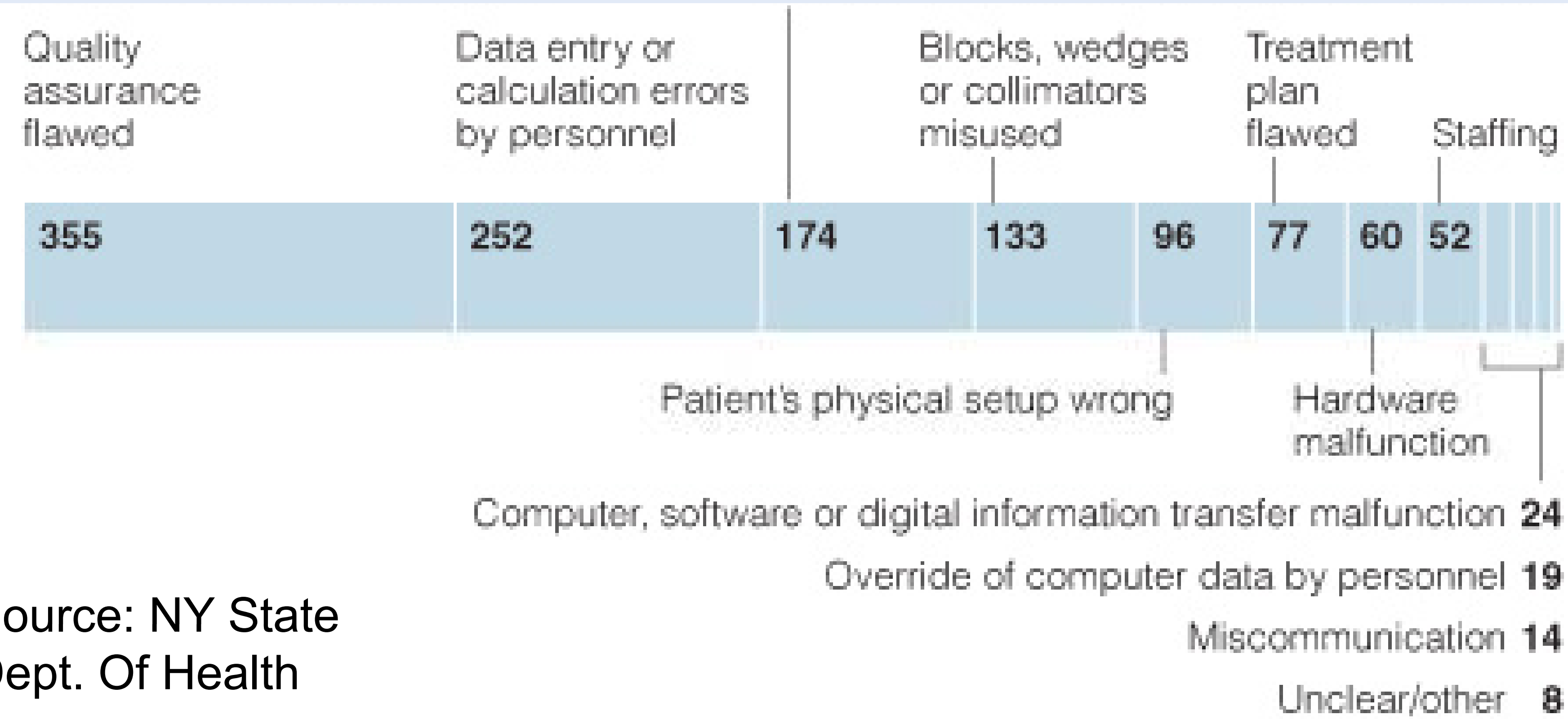
January 24, 2010

The New York Times

THE RADIATION BOOM

Radiation Offers New Cures, and Ways to Do Harm

621 mistakes in NY state 2001-2009: At average 2 mistakes contributing



Source: NY State Dept. Of Health

Common Sources of Error

IAEA: Lessons Learned from Accidental Exposures in Radiotherapy, Safety Reports Series No. 17, IAEA, Vienna (2000):

Most TP errors can be summarized by a lack of:

- Education
- Verification
- Documentation
- Communication

Framework

Acceptance test

Assure that the ***specifications*** of a product and **safety** standards are fulfilled (radiation and electrical hazards)
Tests are performed in the presence of a manufacturer's representative.

Commissioning

Characterization of the equipment's performance over the whole range of possible operation following acceptance incl. the preparation of procedures, protocols, instructions, data for clinical service.

It includes development of SOPs and QC tests and training.

Periodic QA

Procedures which are performed regularly and which allow to assess, if the initial requirements are still fulfilled; may involve different procedures than during commissioning;

Patient specific QA

Procedures performed on patient specific treatment plan or equipment.

Framework: QA and QC

Quality assurance:

All planned and systematic actions necessary to provide confidence that a product will satisfy given requirements for quality and safety.

Quality Control:

The **regulatory process** through which the actual quality performance is measured, compared with existing standards, and the actions necessary to keep or regain conformance with the standards.

The QC process:

(a) the definition of a specification;
(b) the measurement of performance associated with that specification;
(c) the comparison of the measurement with the specification;
(d) the possible action steps required if the measurement falls outside the specification.

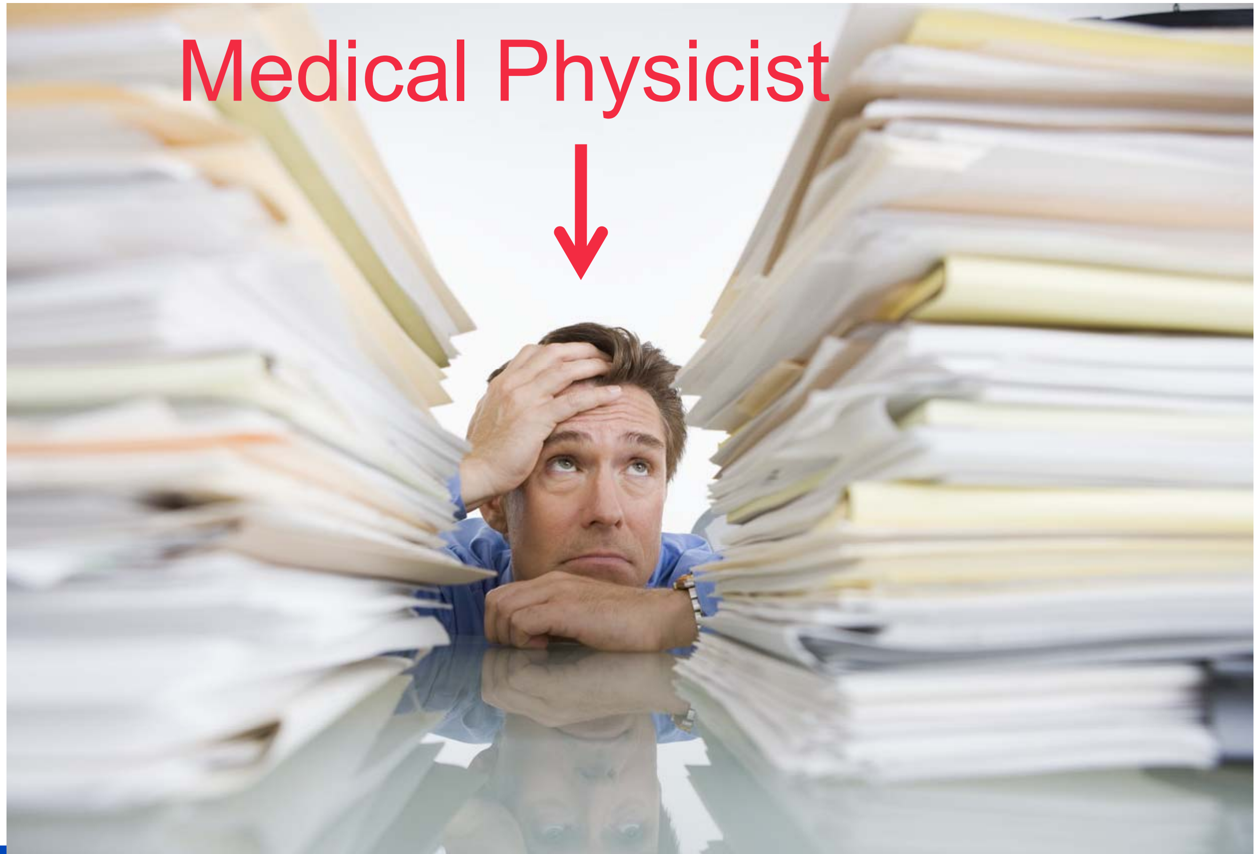
As part of step (d), one needs to define, which deviation from the reference is tolerable (the tolerance).

Vendor responsibility

- **Specifications** of system capabilities and limitations
- **System documentation** (system design and use)
- **User training**: (1) basic training
  (2) commissioning process
  (3) system management
  (4) implementation of a QA program
- **Information** on updates, system alterations
- **Communication** regarding bugs, error reporting

User responsibility

- **Supervision, management** of system
- **Implementation** of the system and upgrades
- **Record keeping** associated with implementation
- **User training:**
  clinical use
  interpret. output
- **Communication:**
  with the vendor
  and the users
  esp. regarding
  errors, limitations
  and updates.



Legal Aspects of QA

- Intl. Recommendations (IAEA TecDoc 1040 QA in RT, ICRU)
- AAPM TG 24 "*Physical aspects of QA in R*T, 1998"
  and TG 40 "Comprehensive QA for RO, 1994", etc…
- In progress: <u>TG 224 - Proton Machine QA (start 2012)</u>
- European directives (e.g. Medical Device Directive)
- <u>National radiation protection regulation</u>
- National Guidelines for medical application of radiation
- National and International standards (ISO, IEC), e.g.:
  - DIN 6870-1: Quality management system in medical radiology – Part 1: Radiotherapy
  - <u>IEC 62C536 (draft): Medical electrical equipment - Basic safety and ess. performance requirements for light ion acc.</u>

There are *few detailed and hard requirements*.
User always has to define a specific QA program.

Framework: Steps in QC

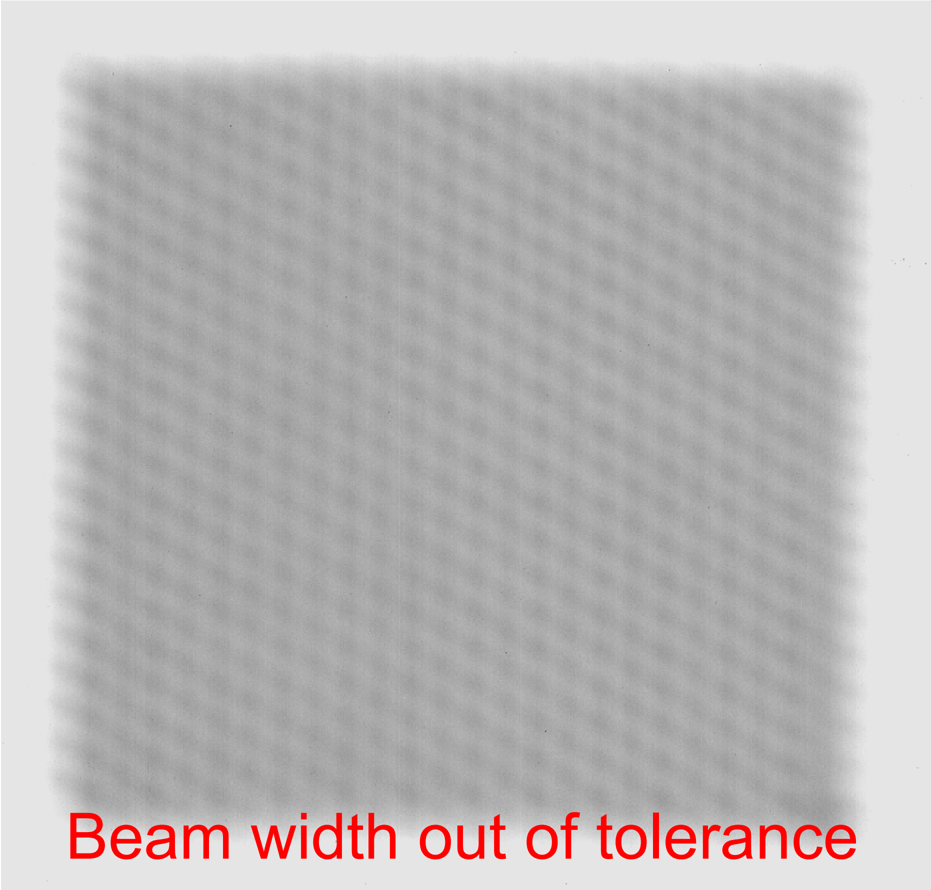
1. Definition of the **specifications**
   (performance and test characteristics)
2. Definition of **tolerances**
3. Definition of detailed tests for all characteristics via **SOP's**
4. Performing tests and **Comparison** w. specs
5. Possible **Action steps** if outside tolerance

Framework: Tolerances

The tolerance is the largest acceptable deviation of a test characteristic from the reference value.

Tolerances are always specific for a certain facility

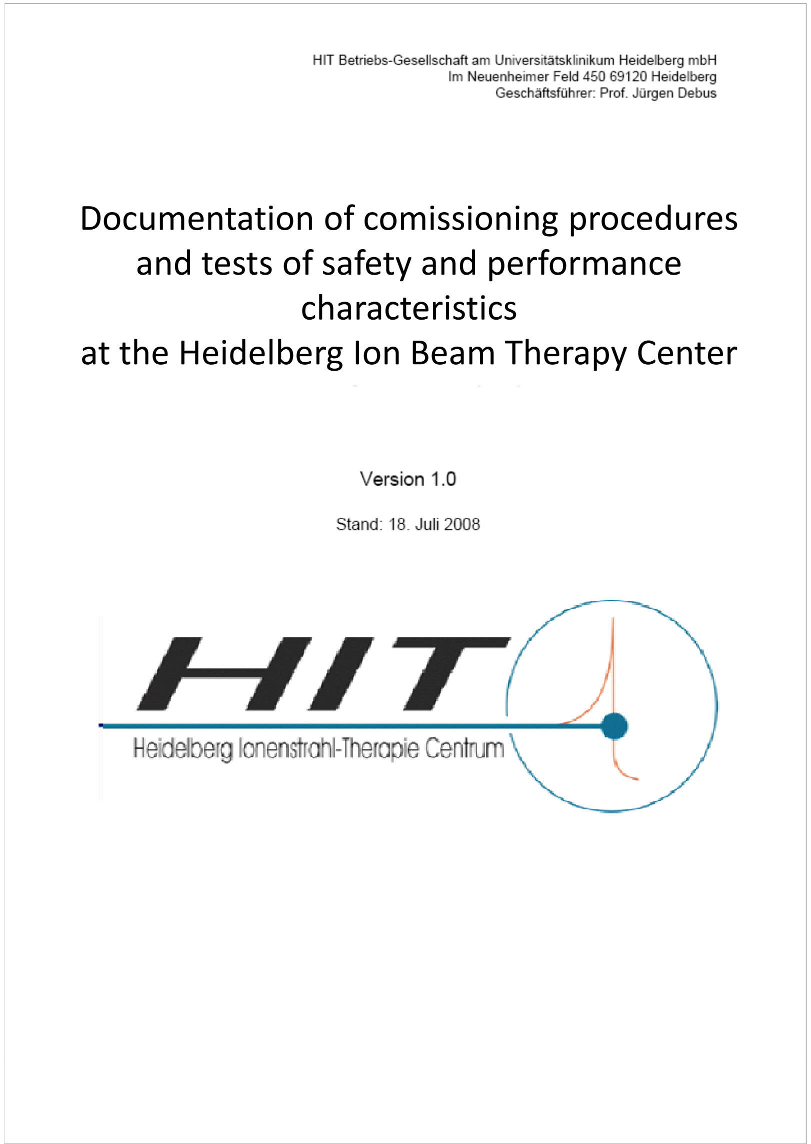
The involved uncertainties of measured values have to be included.



Sources of uncertainty (TPS-QA)

- Dose measurements (Ion chamber, film, etc)
- Setup of phantoms
- Beam delivery (esp. in scanning, dose, field homogeneity, stability)
- Geometric parameters (acc. of readings, instruments)
- Differences between commissioning and constancy checks
- **Dose calculation algorithm**
- **Approximations of the beam model**
- **...**

Examples of Test procedures @ HIT



HIT Betriebs-Gesellschaft am Universitätsklinikum Heidelberg mbH
Im Neuenheimer Feld 450 69120 Heidelberg
Geschäftsführer: Prof. Jürgen Debus

Documentation of comissioning procedures and tests of safety and performance characteristics at the Heidelberg Ion Beam Therapy Center

Version 1.0

Stand: 18. Juli 2008

HIT
Heidelberg Ionenstrahl-Therapie Centrum

A. Introduction

B. Measurement conditions and –tools

C. Commissioning

D. Safety tests

E. Acceptance and constancy tests

- *E.1 Beam quality*
- *E.2 Dosimetry*
- *E.3 Patient positioning*
- *E.4 Treatment planning*

F. Patient related tests

- *F.1 Workflow verification*
- *F.2 Dose verification*

Daily QA

•Daily checks:

• Tests of the control system:

•beam position, feedback loop, interlocks, ...

• Film homogeneity, field alignment

• Monitor calibration f. 6 energies

• Dose in reference field

• Safety checks:

  • Laser/imager alignment
  • Emergency switches
  • treatment table

Required time

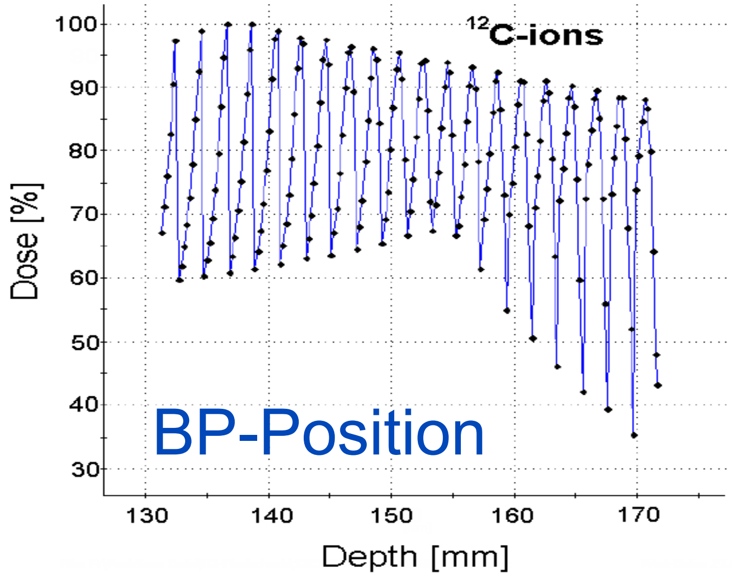
• Safety- & alignment: 20 min

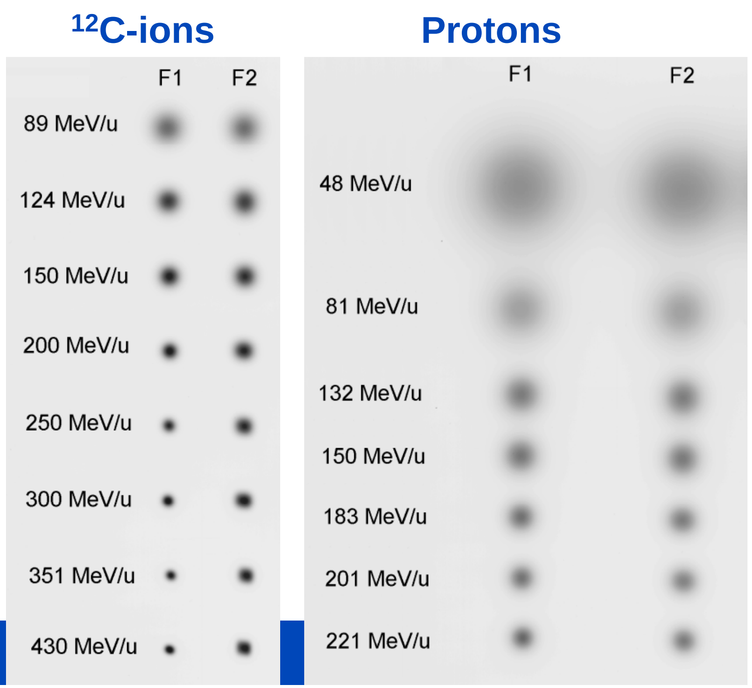
• Monitor calibration: 15 min

• Dosimetry in ref.-field: 10 min

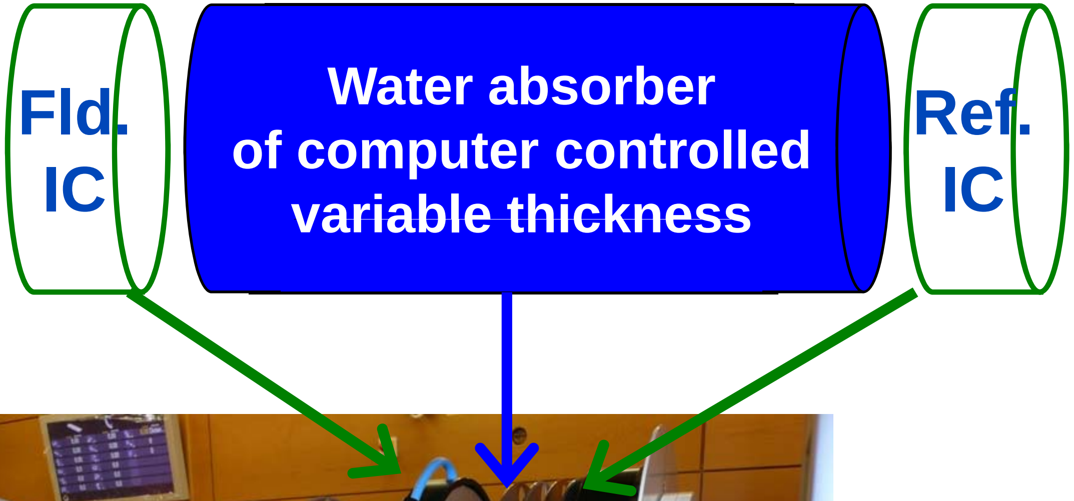
Beam quality

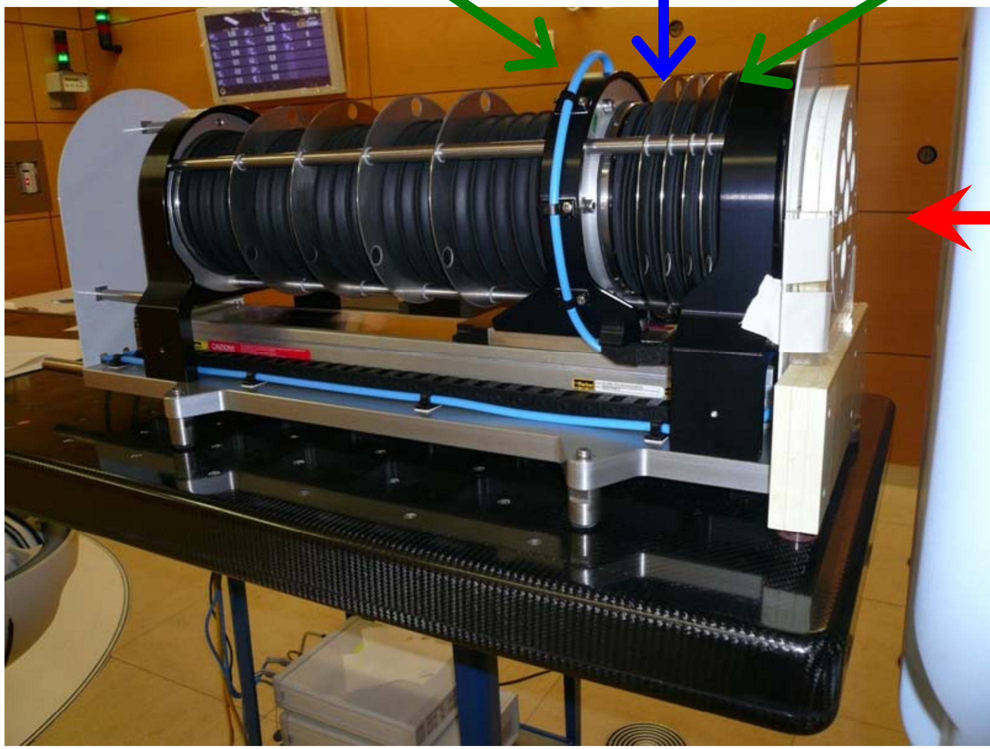
- Ion type (purity<10^{-4})
- Intensity (HIT: 15 steps)
  - *p: $8x10^7$-$2x10^{10}$ ions/s,*
  - *^{12}C: $2x10^6$-$5x10^8$ ion/s*
- Bragg peak position
- Beam position
  - scan position, not only on central axis
  - focus & energy dependent
  - online correction or interlock
- Beam width (HIT: 6 steps)
  - Energy dependent (p: 7-20 mm/^{12}C: 3-20 mm)
  - Protons: depth dependent (scattering)
- Dependence on gantry angle





Measurement of depth dose with the Peakfinder

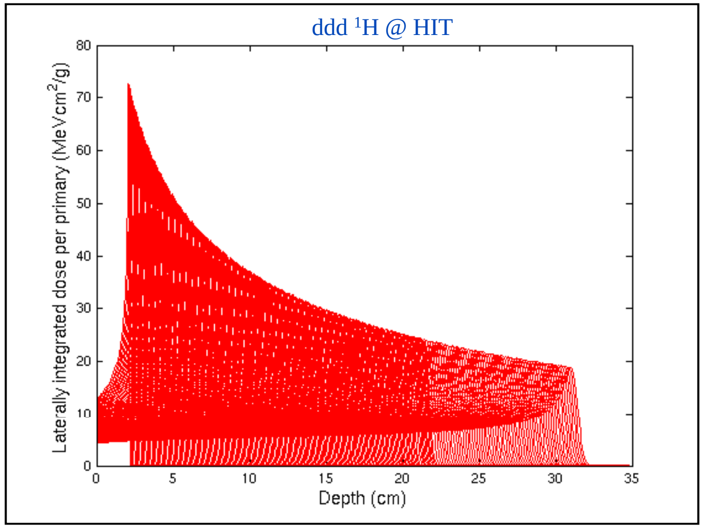


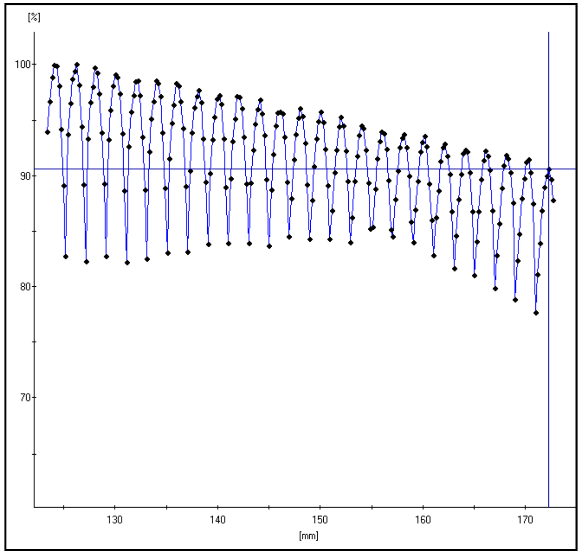


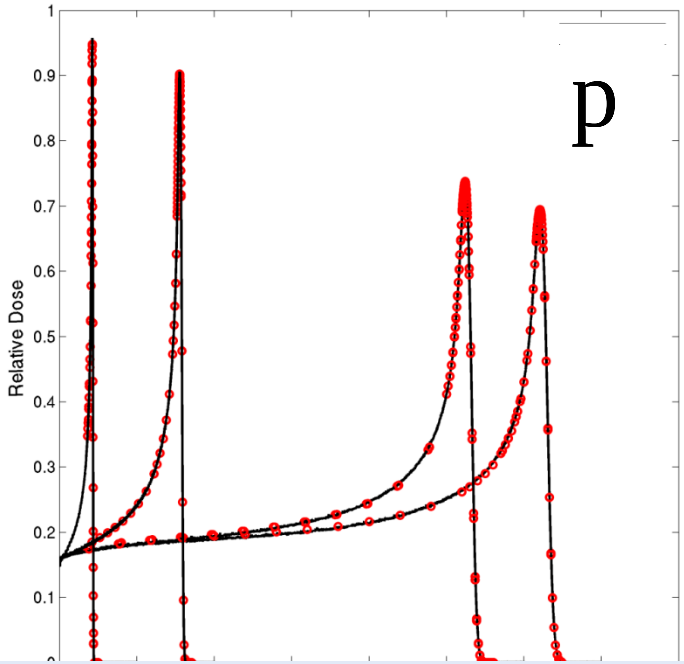
Measure relative depth dose distribution (integrated laterally) with a resolution of 10 µm using the Peakfinder from PTW, Freiburg

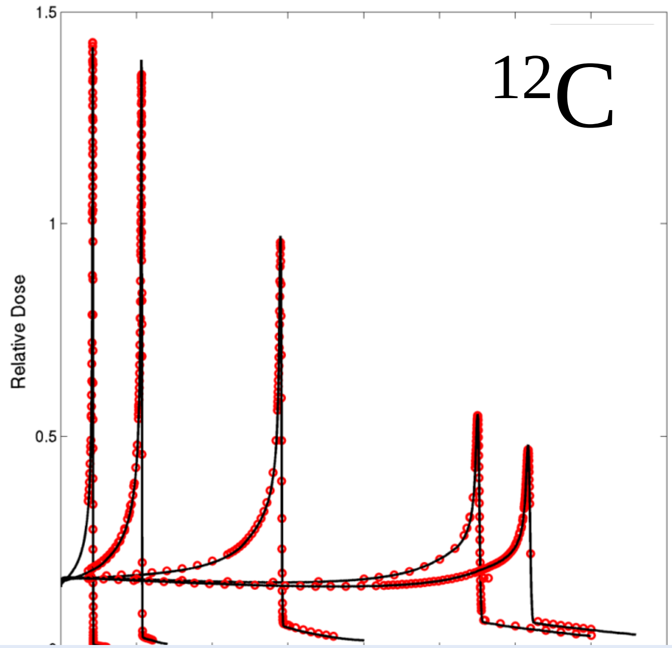
Very efficient tool for fast measurement of Bragg peaks

Verification of MC-generated database



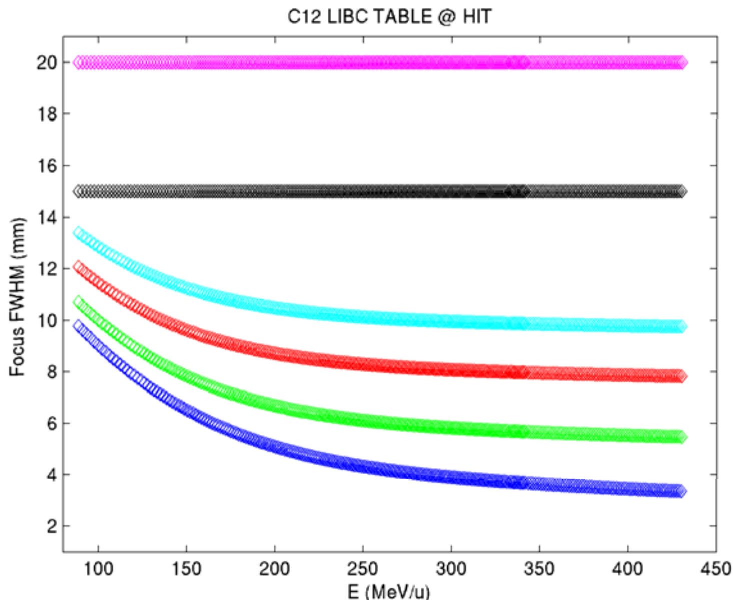


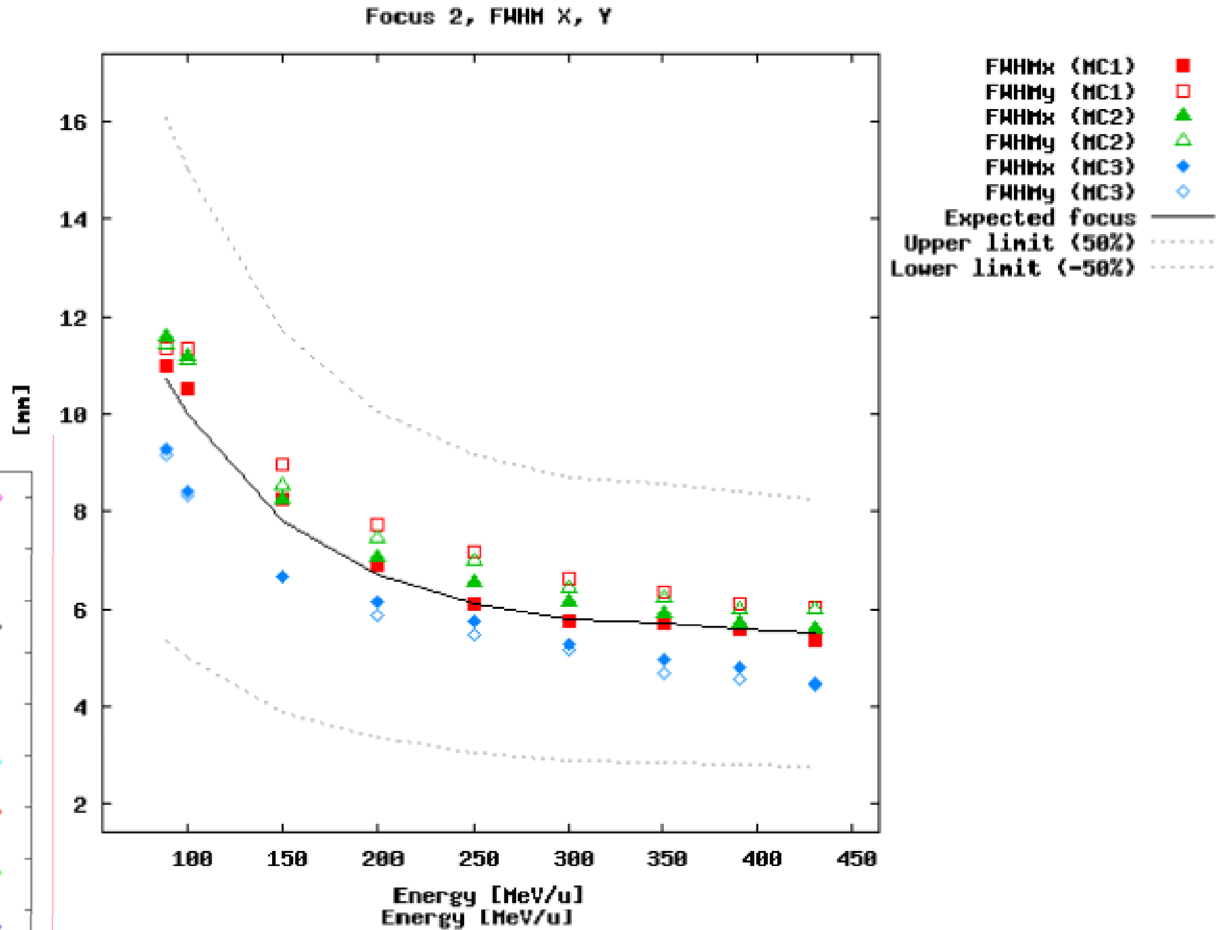




Measurement of min. 10 energies for C-12 and protons

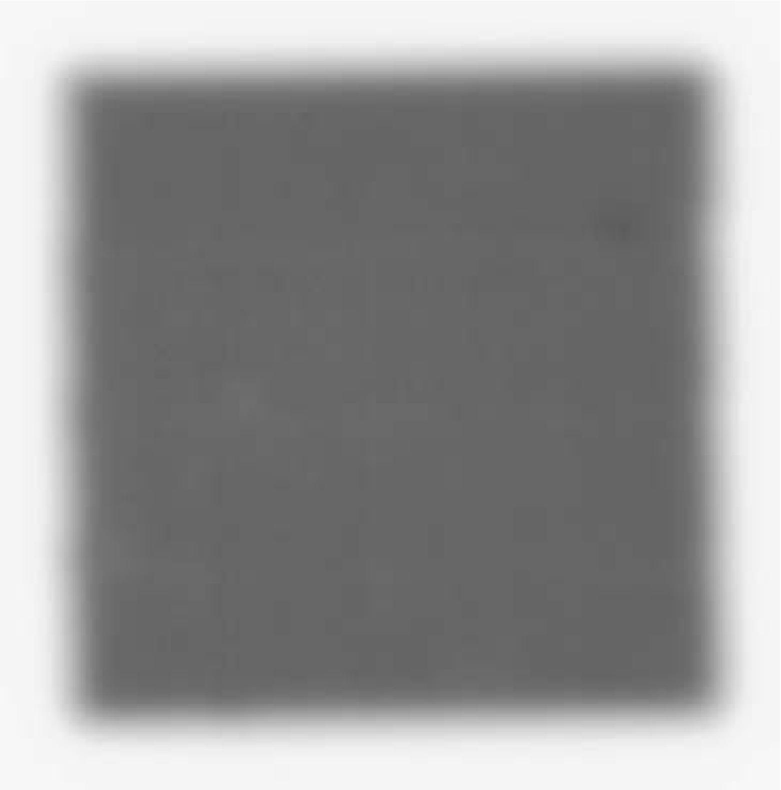
Measurement of beam position & width





QA Example: homogeneity of 2D scans

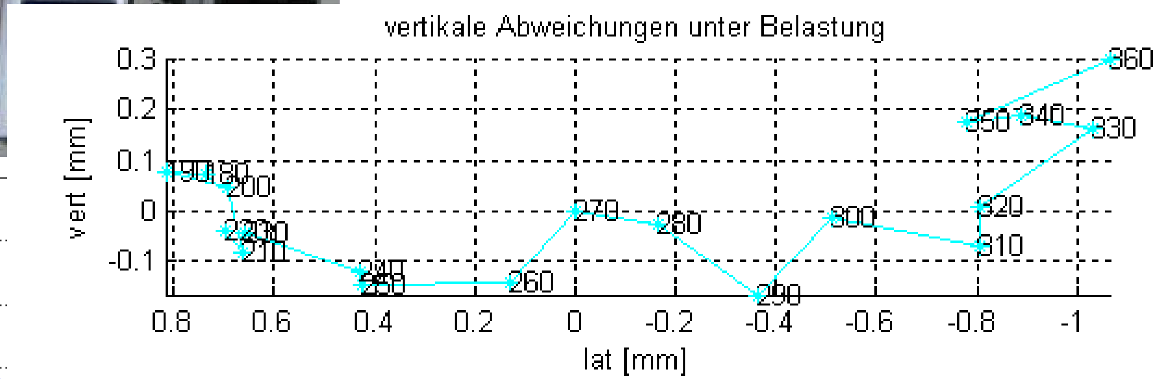
270MeV/u C12 , 6mm fwhm, dx=2mm
w/o feedback loop for position correction:

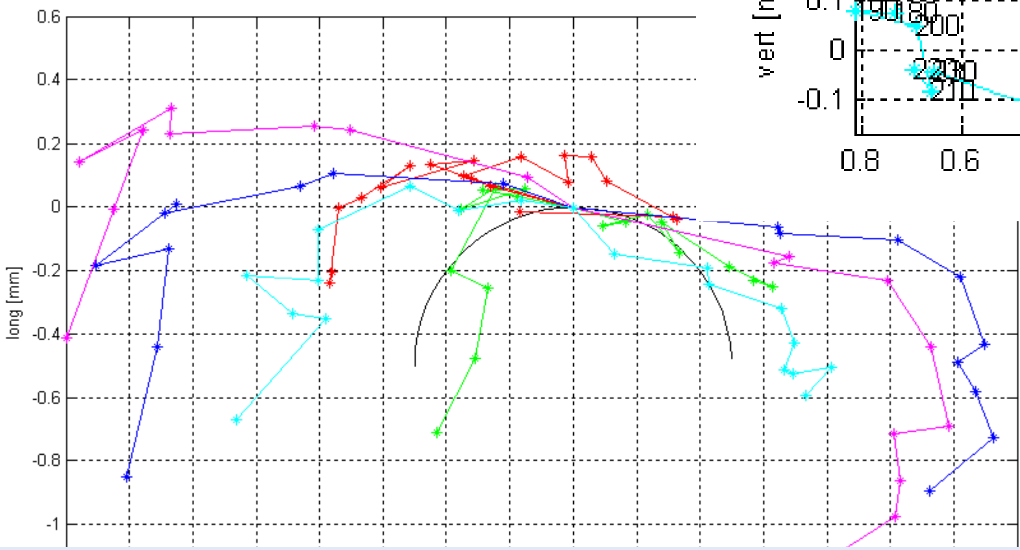


Excellent stability of the beam (position, width) and good performance of the monitoring and scanning system, but …

Accuracy of Robotic Positioning

Vertical & lateral movement
at different positions



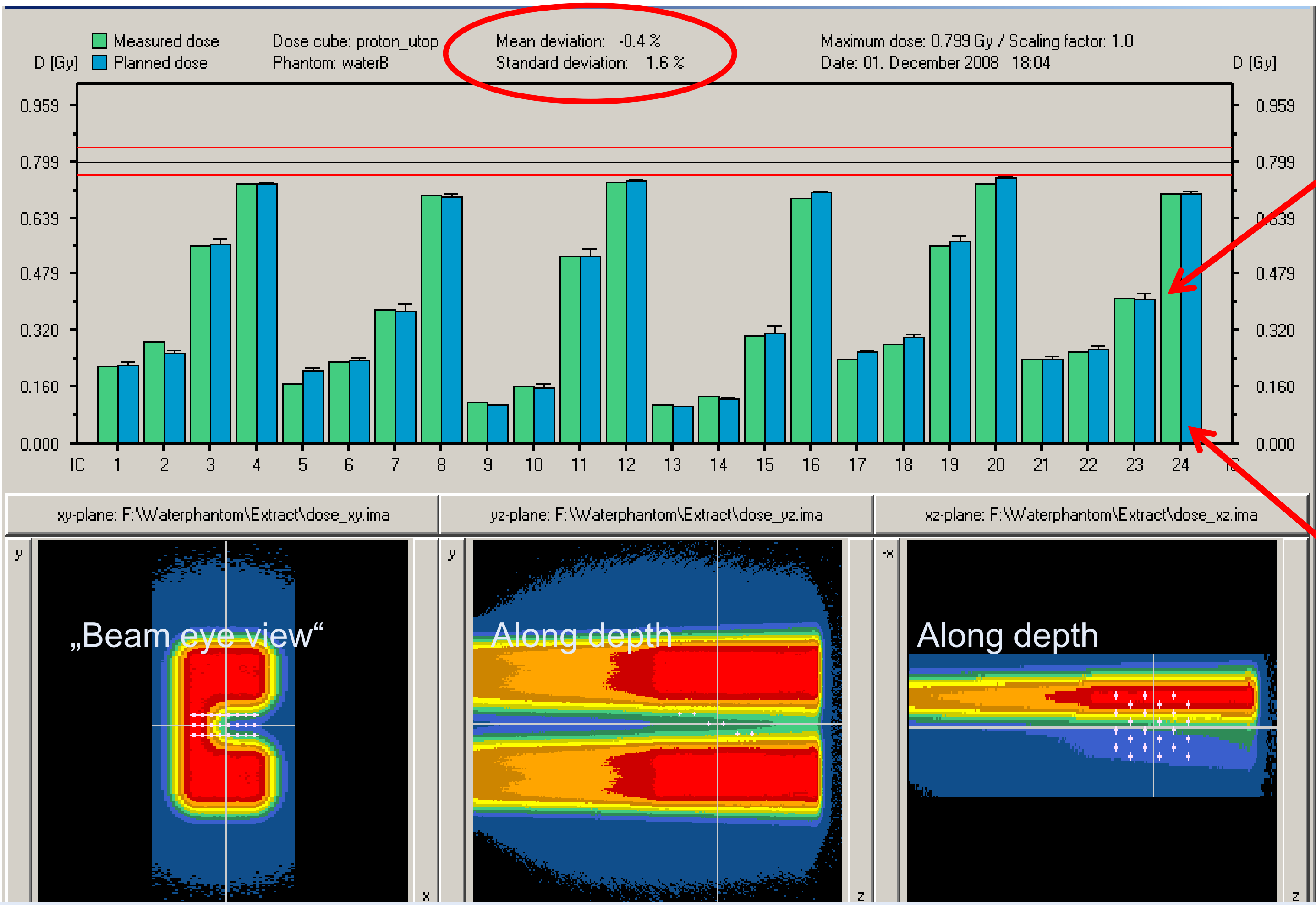


Lateral & longitudinal
movement of sphere during
isocentric rotation

Now a laser tracker is used to monitor movement during operation

MC application to active beam delivery @ HIT

FLUKA dose calculations of scanned fields for comparison with measurements and TPS calculation to ***support TPS-commissioning***



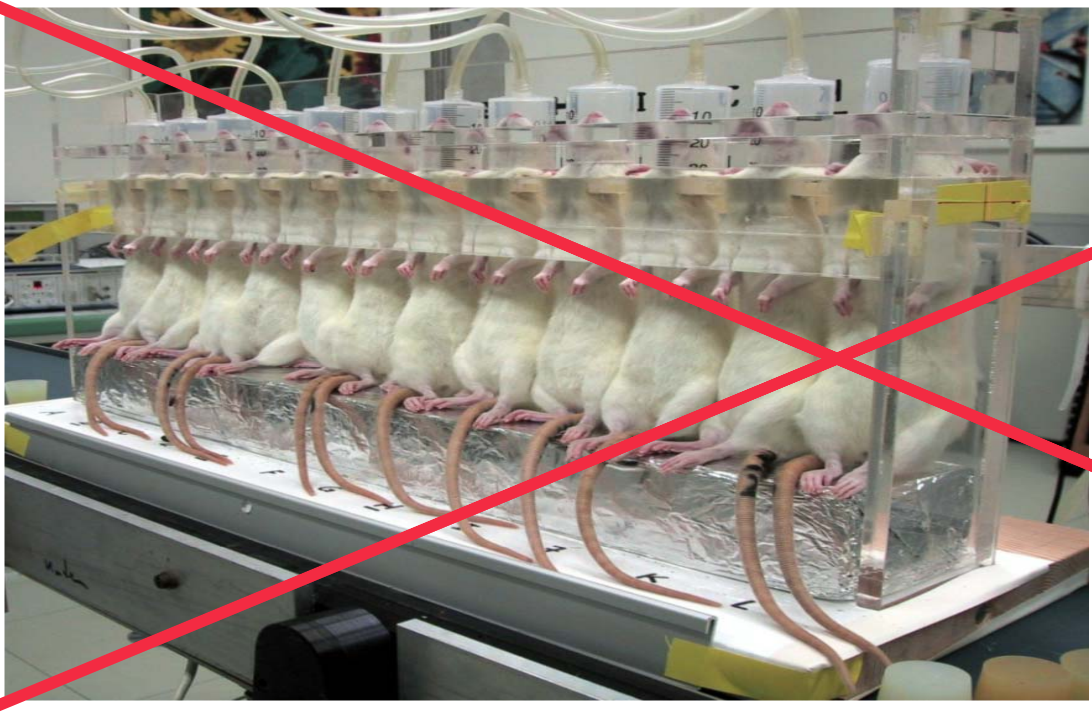
Protons

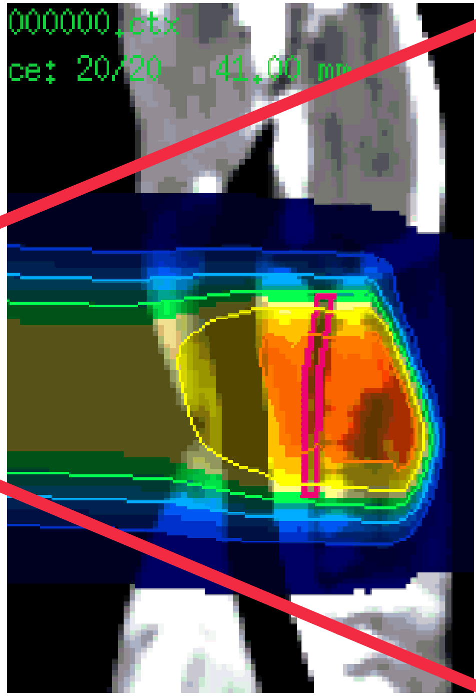
***Meas.**: ICs in water phantom + data acquisition system from C. Karger (DKFZ)*

***FLUKA**: ~ 10^8 p out of 4.4 10^{10} irradiated*

A MC is very valuable to decide if the TP or the delivery is right
However, it has to be verified and is not automatically correct

Radiobiological QA @ HIT





- **No real biological QA**
- Test only constancy of algorithms
- Benchmark of new algorithm vs. old algorithm
- Check input in data base

Conclusion

- Carefully analyze the clinical needs and document the specifications
- Define test characteristics, tolerances, actions and SOPs
- Analyze uncertainties
- Don’t forget about verification, documentation, education, communication!

Thanks for your attention !