HIT
Heidelberger Ionenstrahl-Therapiezentrum

Higher Accelerator Performance in Ion-Beam Therapy at HIT

Overview

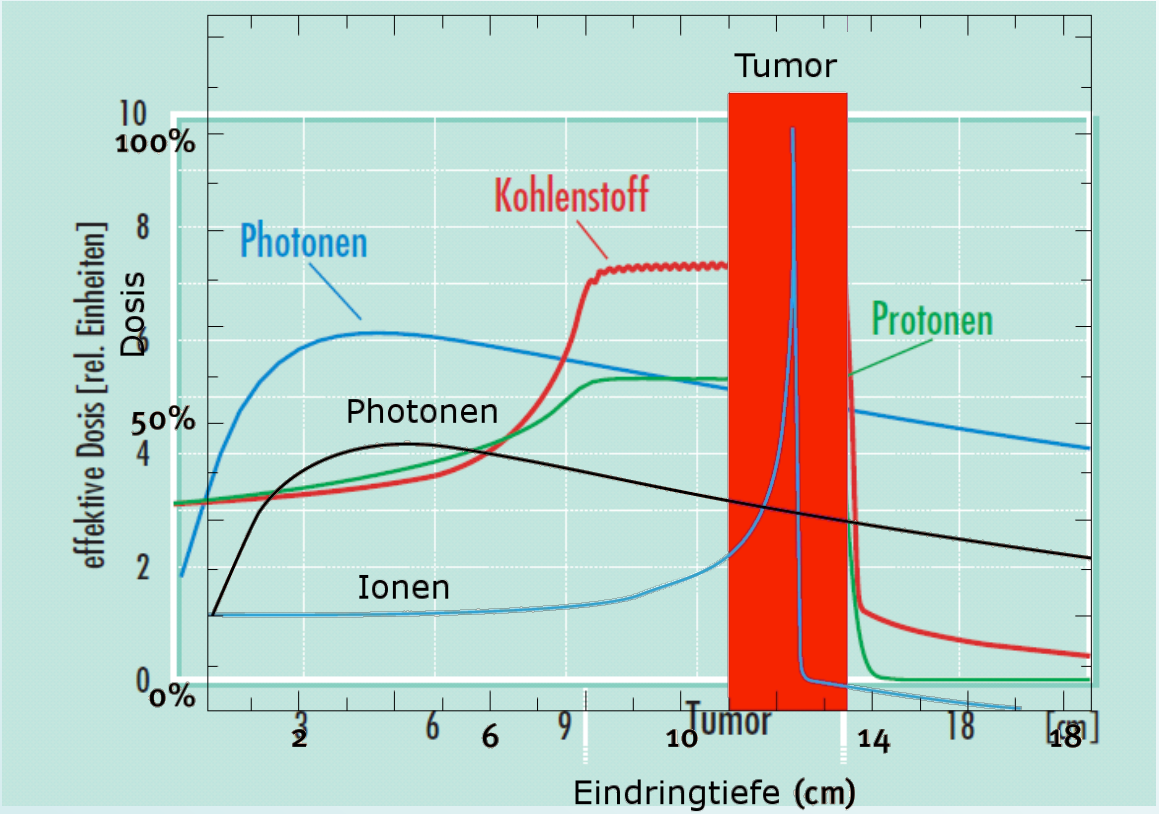
- Ion therapy at HIT
  - Rationales
  - The rasterscanning method
  - The HIT accelerator
  - The HIT heavy ion gantry
  - Ion therapy – challenges and motivation

- Developments to enhance the facility performance
  - Intensity control in the slow extraction process
  - Magnetic field control of synchrotron magnets

Rationales for ion beam therapy

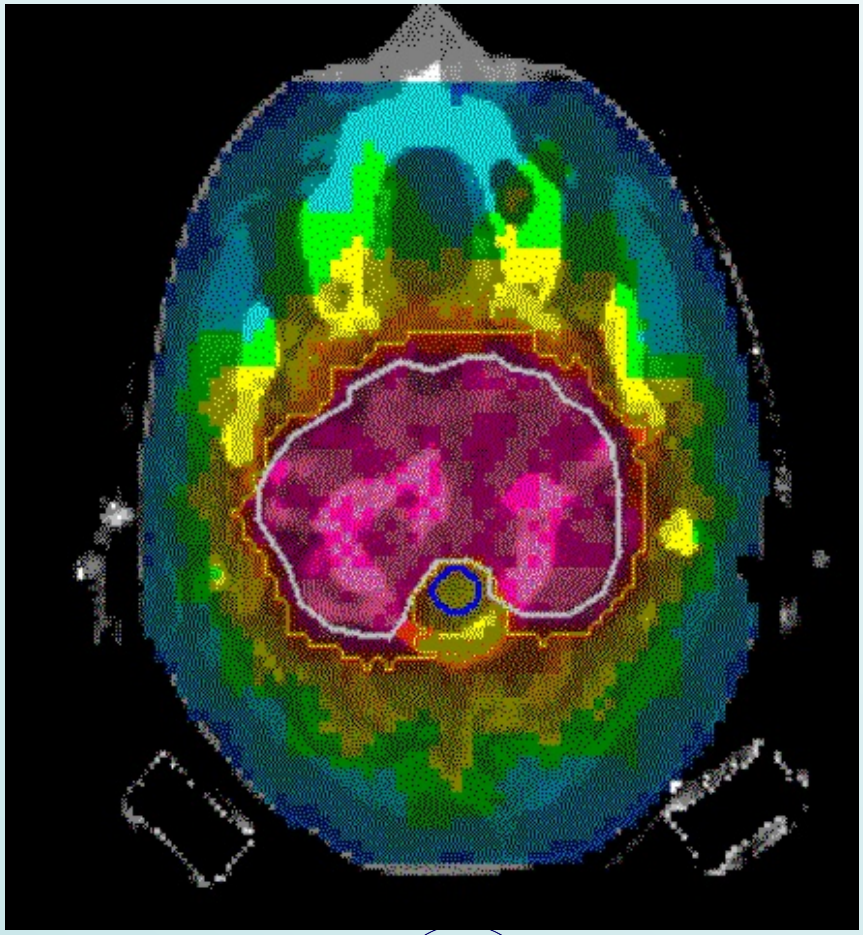
Dose application while the healthy tissue can be spared, due to:

- Dose-depth profile (Bethe-Bloch)
- Less lateral scattering
- Higher biological effectiveness (double-strand breaks)
- Possibility of lateral guidance (scanning)

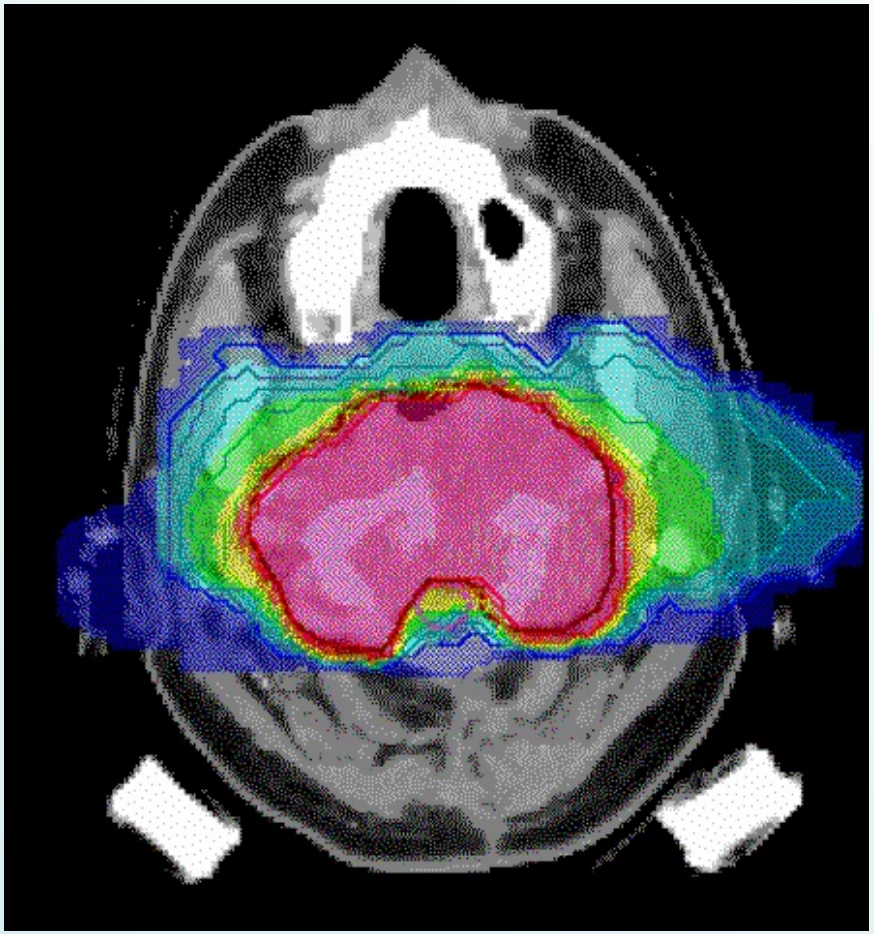


Photons vs. ions I

Conventional (photons, 9 fields)

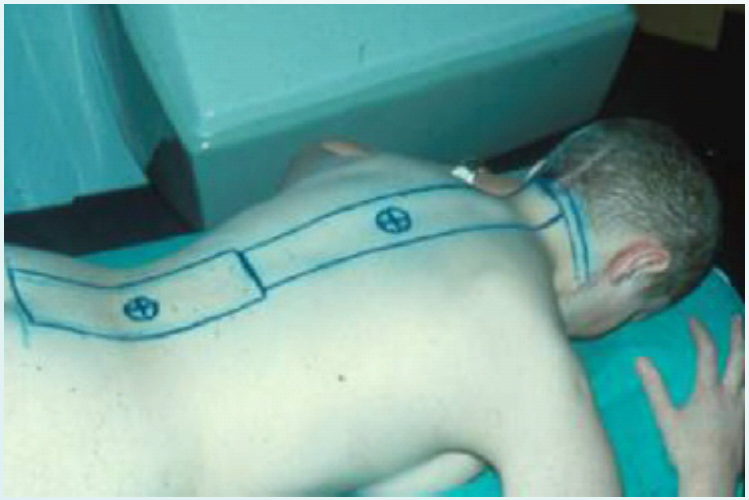


Charged particles (2 fields)

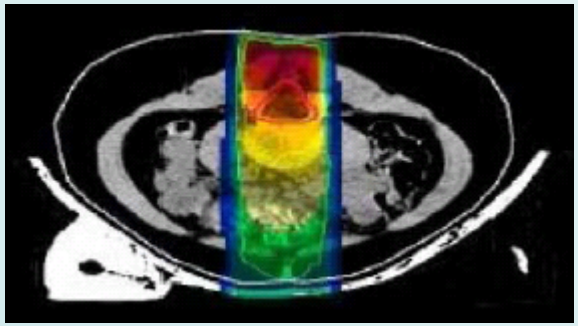


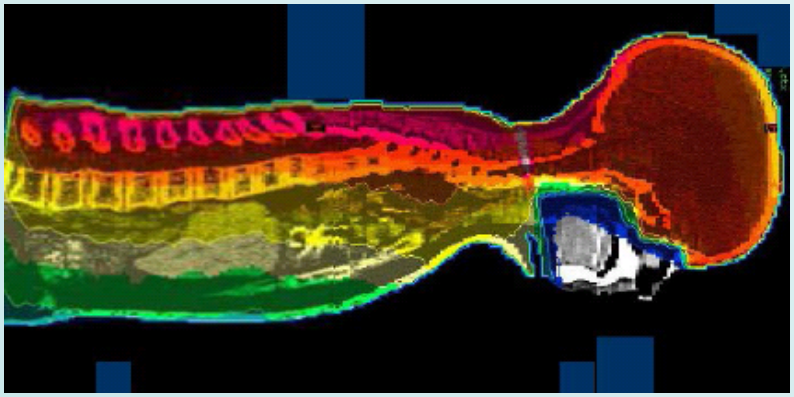
Photons vs. ions II

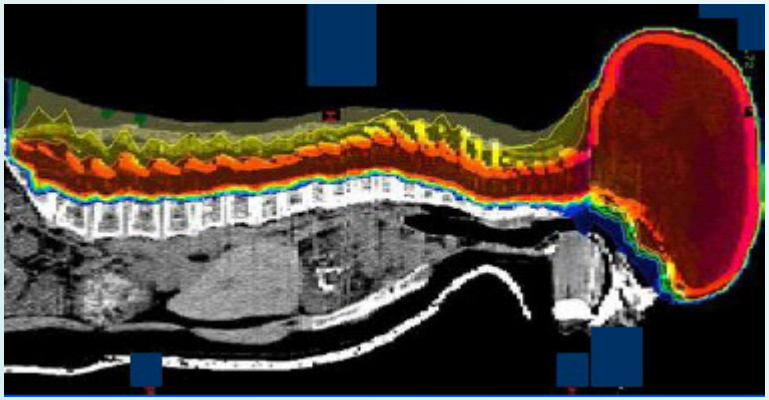
Conventional (photons)



Charged particles

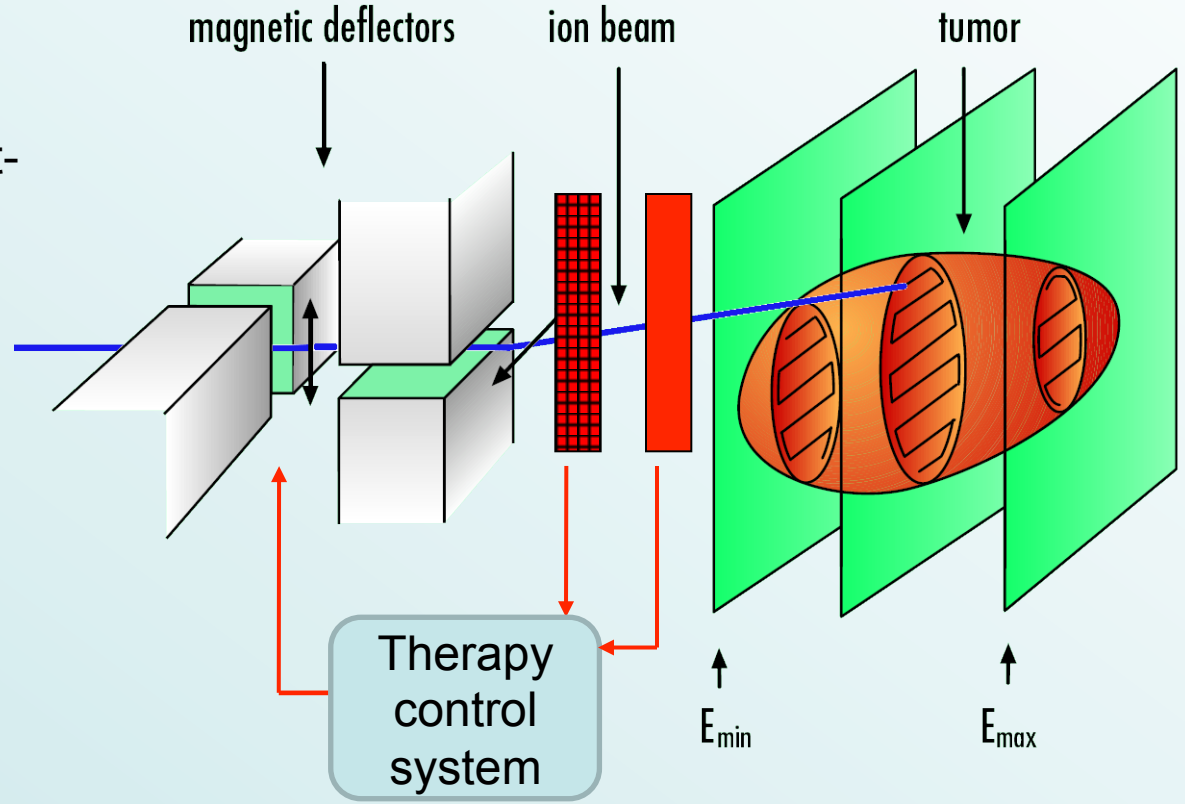




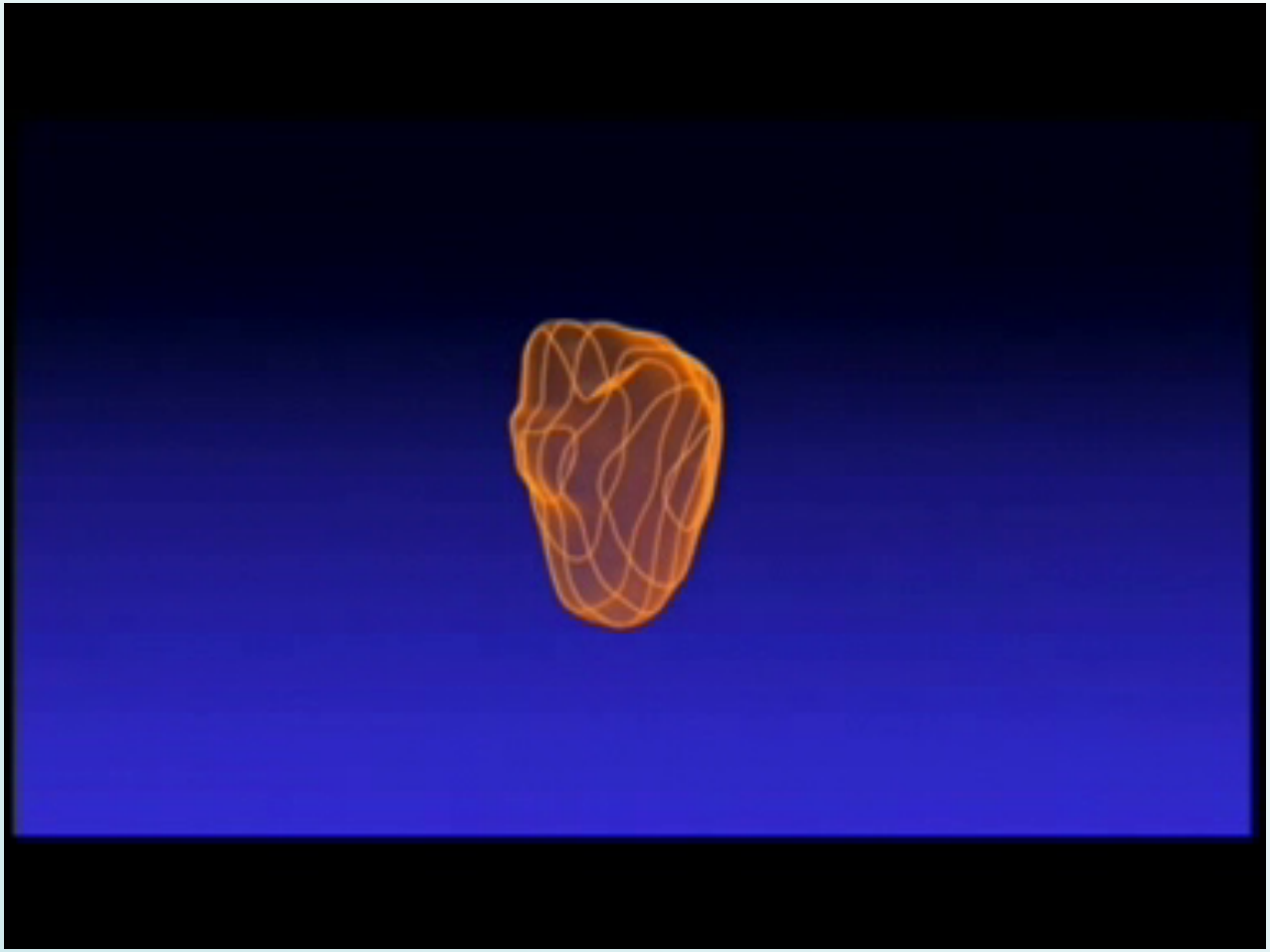


Rasterscanning

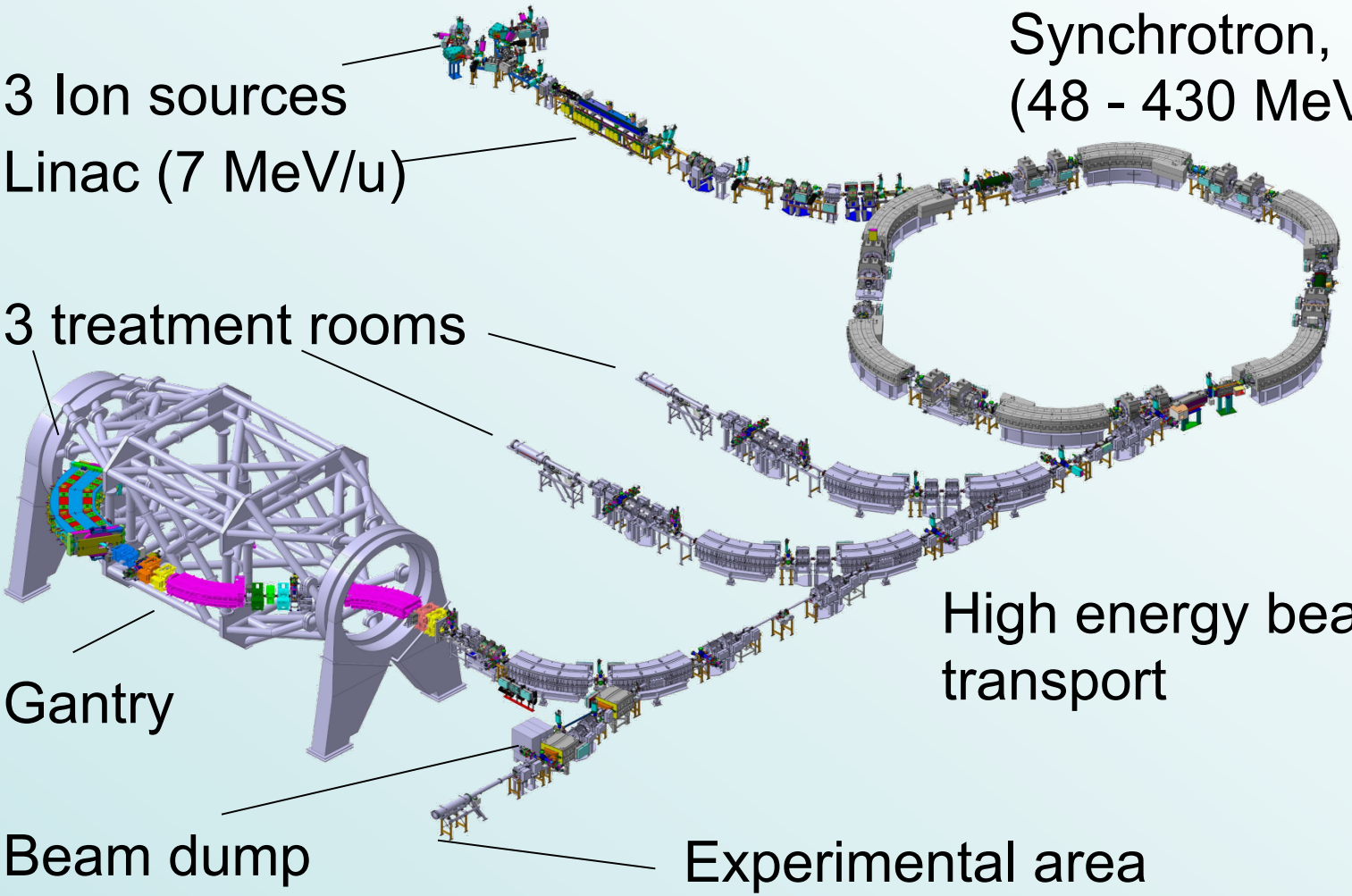
- At HIT the *rasterscanning* method is used
- Tumor is irradiated slice-by-slice and spot-by-spot
- Scanning process needs some time
- Beam spill of several seconds is needed
- Position and intensity are measured, the scanning velocity is adapted



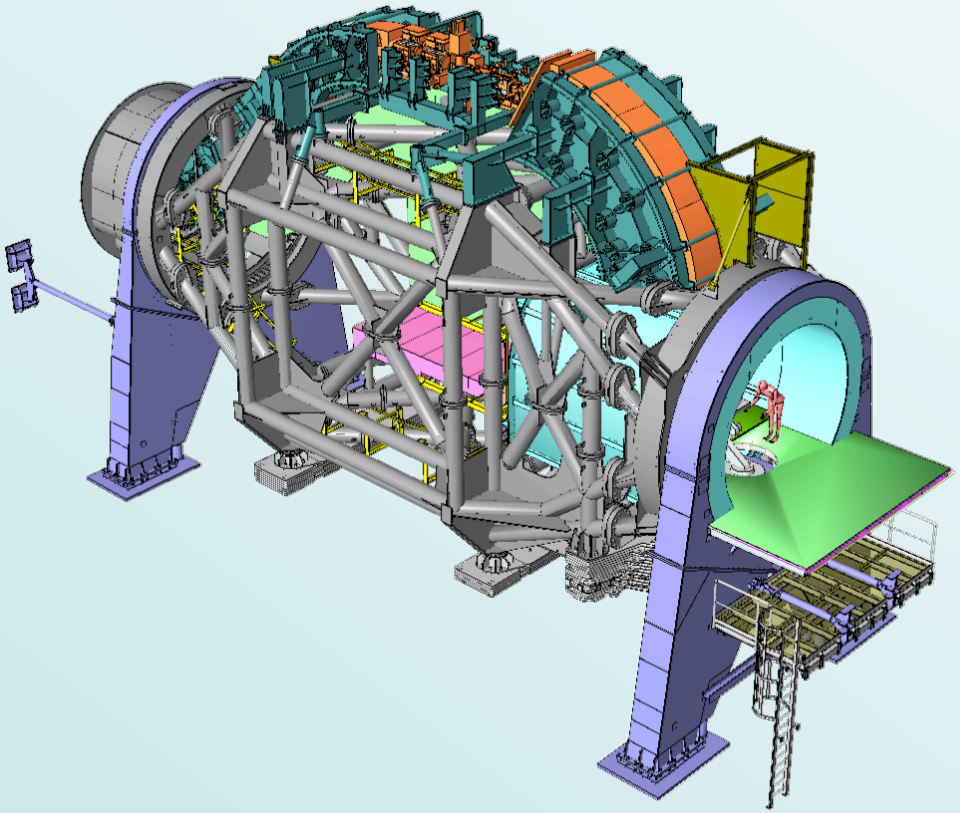
Rasterscanning



HIT – Accelerator



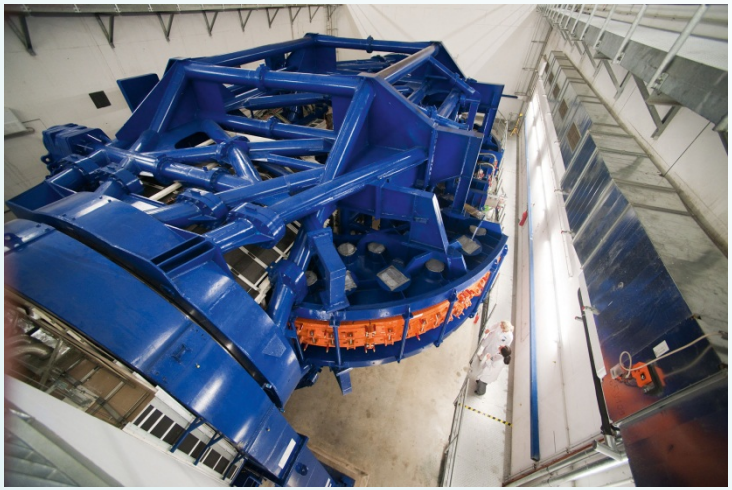
Heavy-ion Gantry – Facts



- First heavy ion gantry worldwide
- Arbitrary entrance angle
- Full 360° rotation
- Weight: 600 t
- Diameter: 13 m
- Length: 25 m
- Accuracy of beam position in isocenter: ± 0.5 mm

[courtesy of M. Galonska]

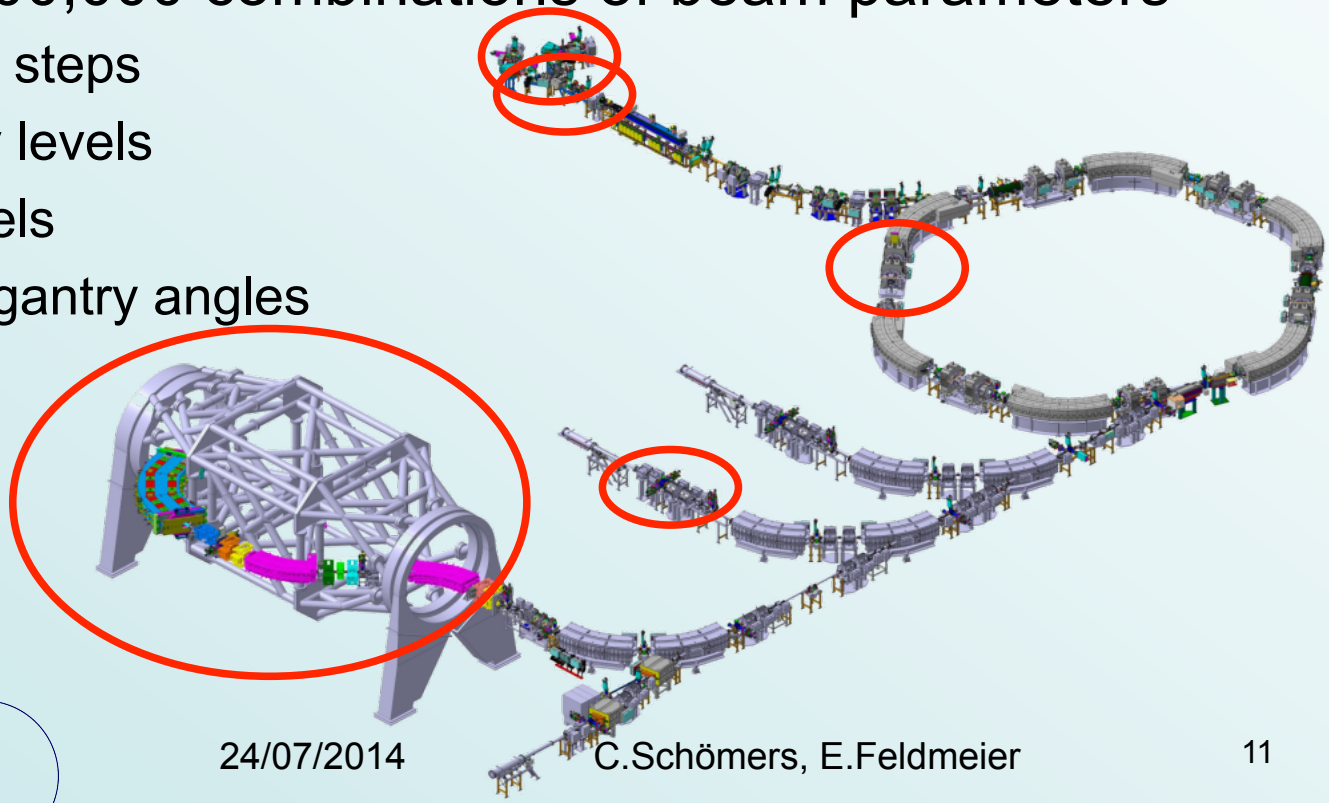
Heavy-ion Gantry – Impressions



[courtesy of M. Galonska]

Some facts about the facility

- > 2000 patients treated since 2009
- Elements used: C, Protons, (He, O)
- More than 100,000 combinations of beam parameters
  - 255 energy steps
  - 10 intensity levels
  - 4 focus levels
  - About 360 gantry angles



Challenges for therapy

Key aspects of ion therapy:

- Patient-safety
- Accurate irradiation
- Reliability of the facility
- High patient numbers

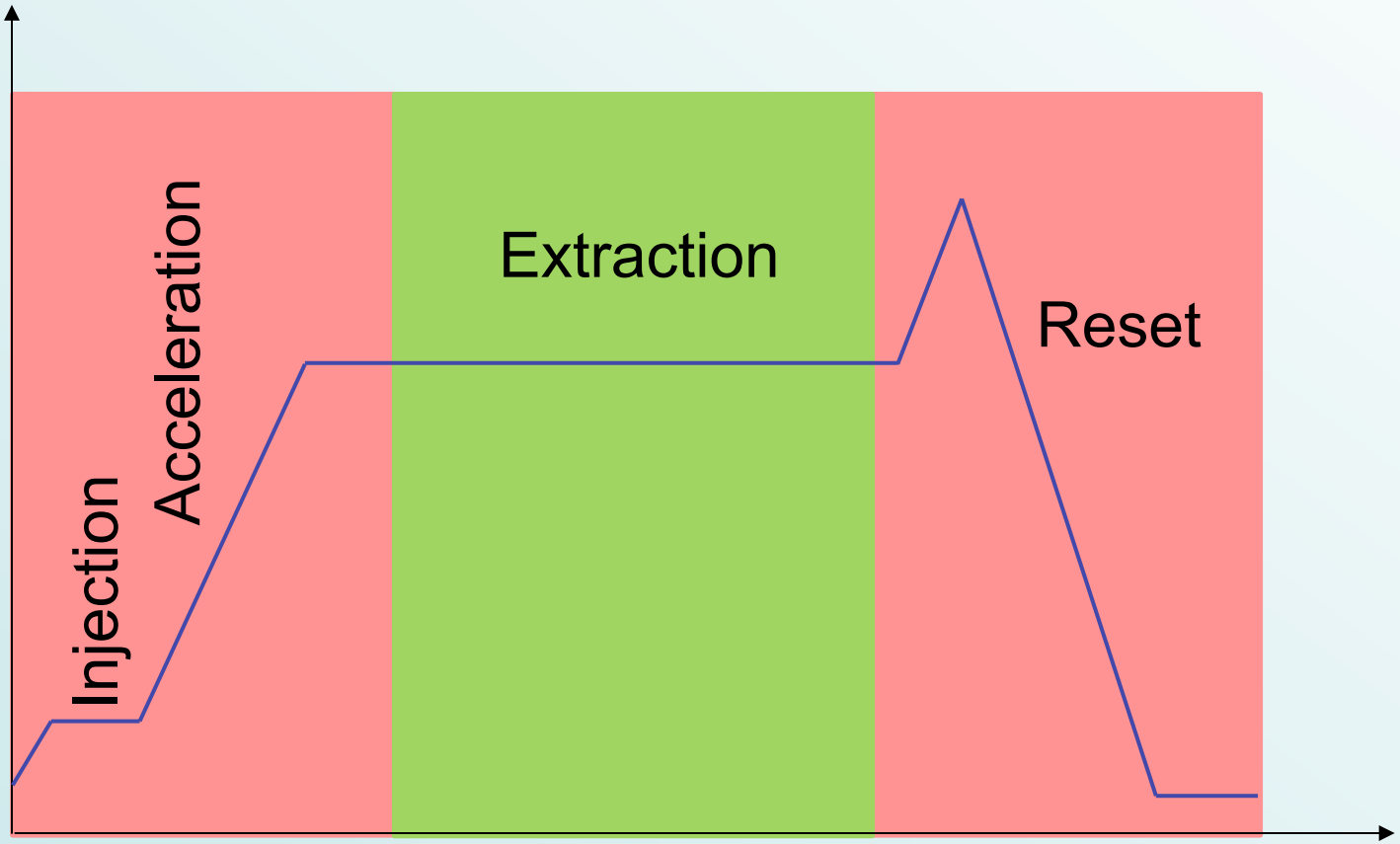
Motivation for higher efficiency

Therapy works fine – why do we need higher performance?

Reasons for the reduction of individual treatment time are:

- More comfort for the patient (locally immobilized!)
- More patients
- Economic facility operation
- Higher dose conformity

Synchrotron-cycle



Presented topics

1. Intensity control in the slow extraction process

2. Magnetic field control of synchrotron magnets

Recent developments

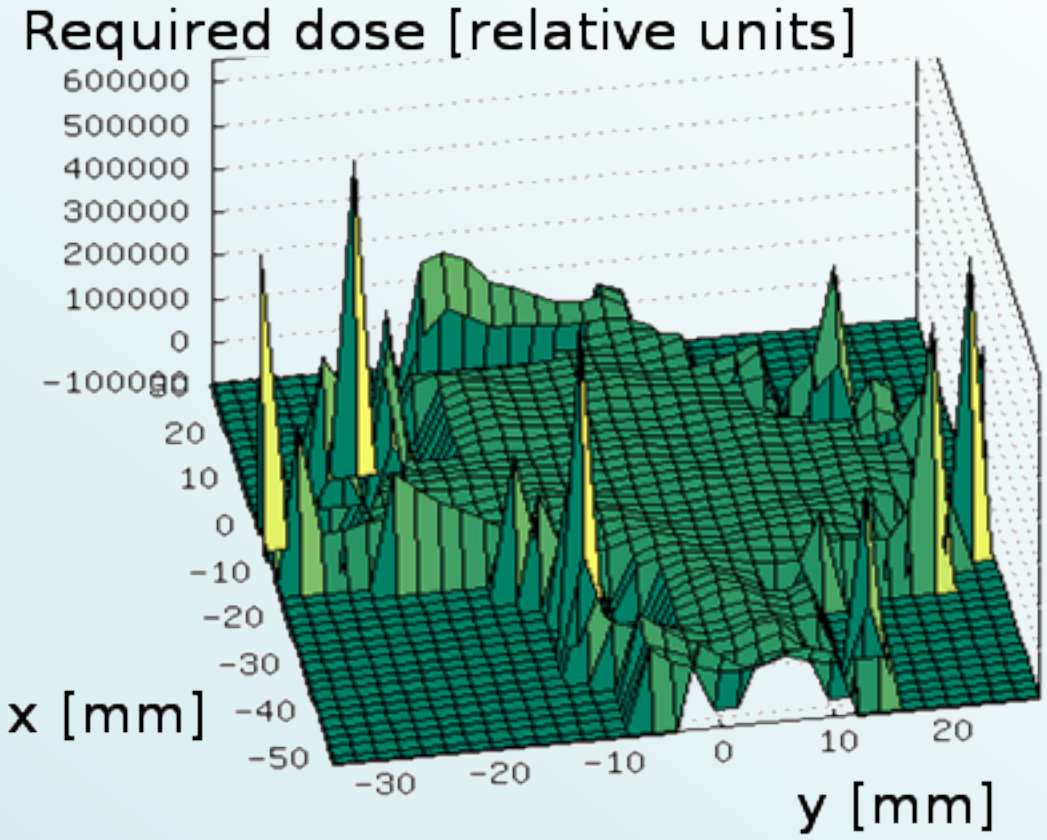
Topic 1:

Intensity control

(of a slowly extracted ion beam)

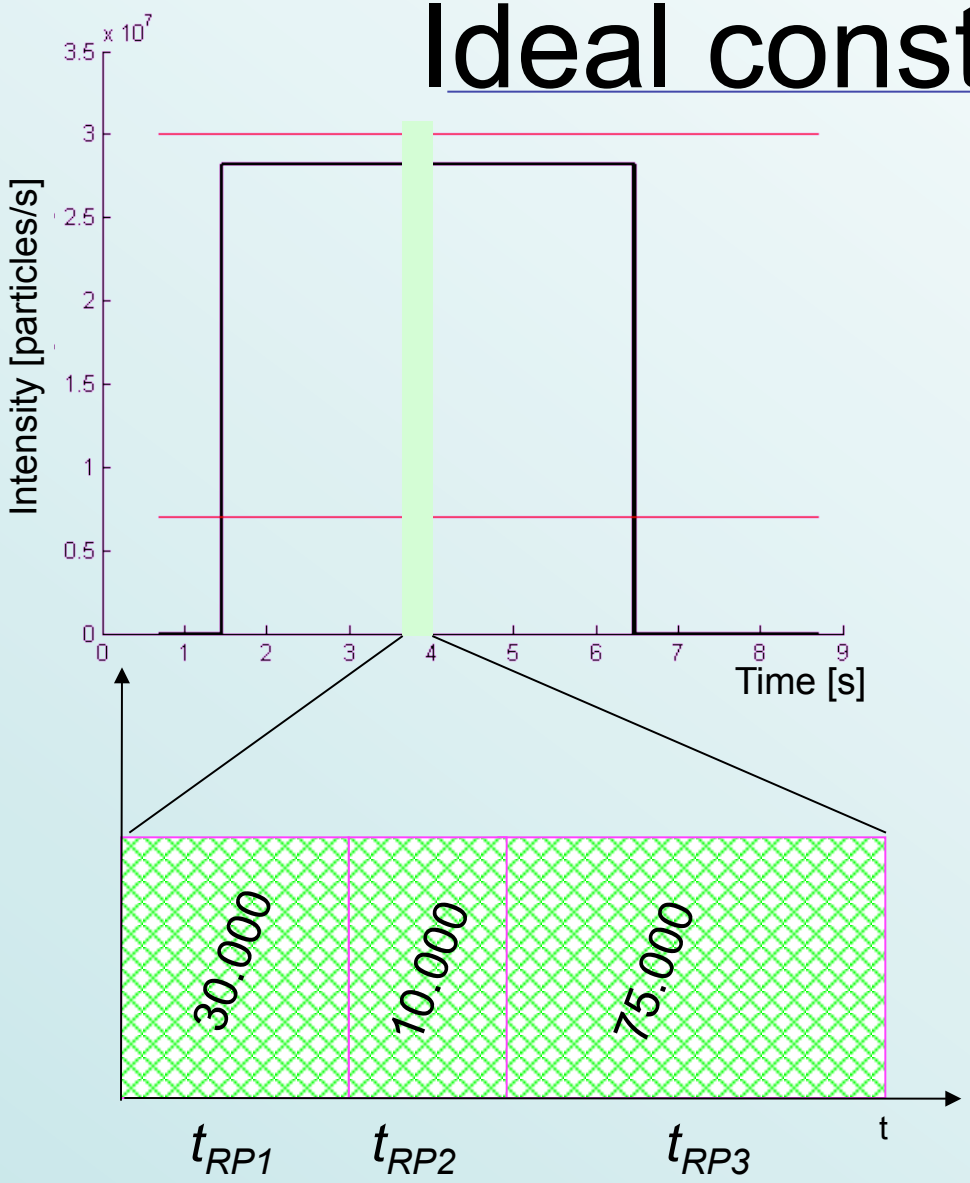
Dose distribution of one slice

- Example of dose distribution of one slice
- Dose and thus irradiation time per raster point can vary by a factor of 100!



[courtesy of J. Naumann]

Ideal constant spill



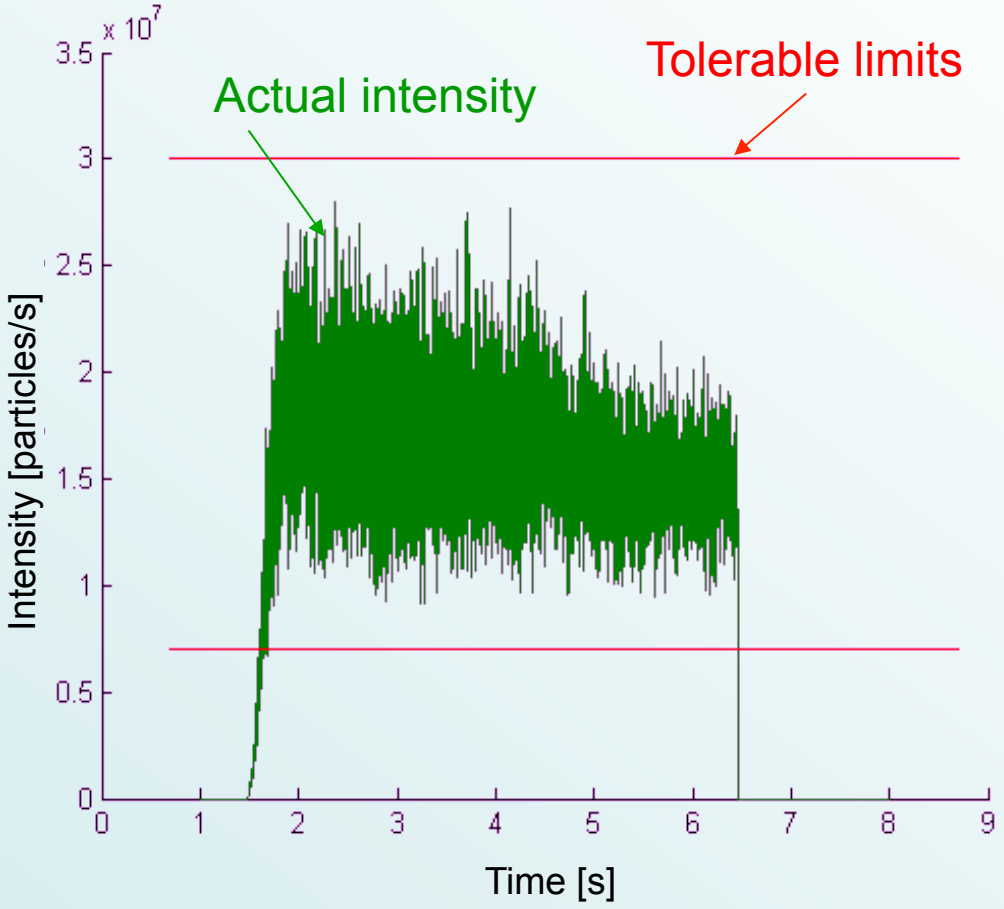
Spill = time structure of extracted particle rate

- Assume intensity is constant over time
- Choose intensity as high as possible
- Rasterpoints that require high dose are irradiated longer
- Irradiation time would be well known if intensity was constant

However, reality looks different...

Motivation

- Particles are extracted slowly by transverse RF-knockout
- Typical spill shape at HIT ⟹
- Spill quality is essential for the achieved treatment time!
- Fluctuations due to inhomogeneous phase space distribution unavoidable

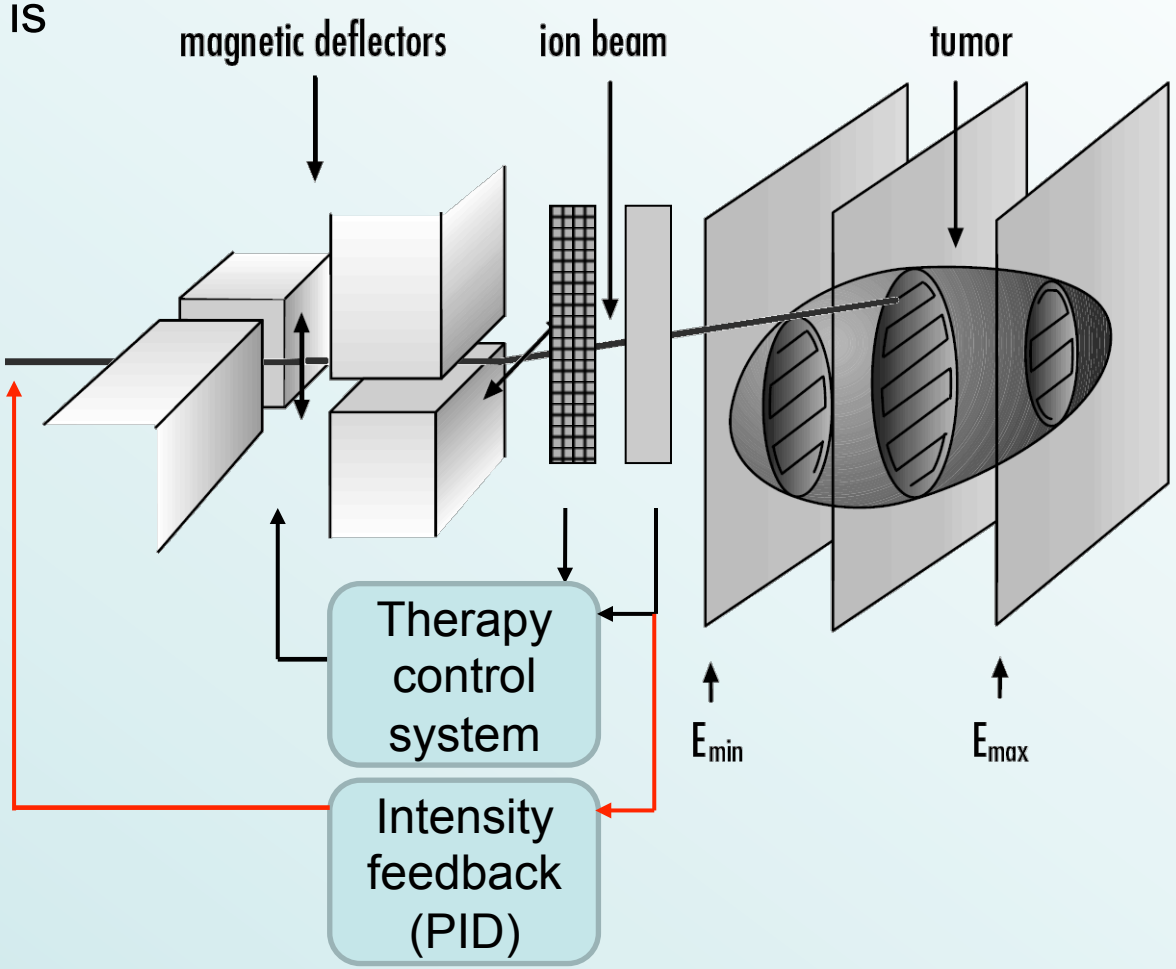


Setup

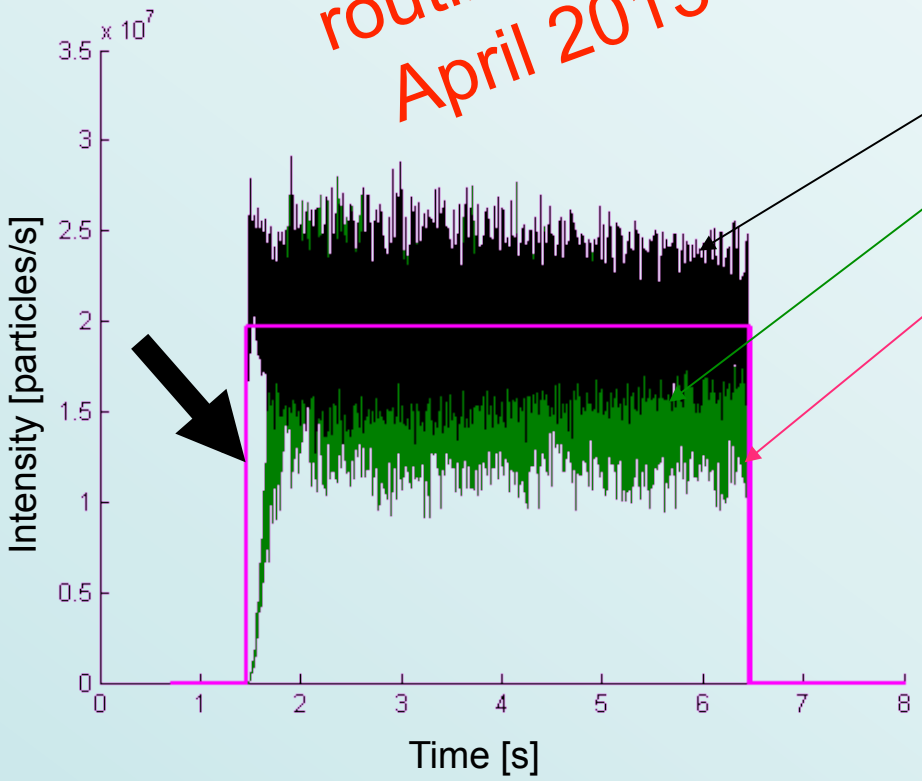
- Intensity is monitored → scanning velocity is adapted

- Use intensity signal
- Add feedback loop

- Influence on RF-Knockout exciter and thus the delivered intensity



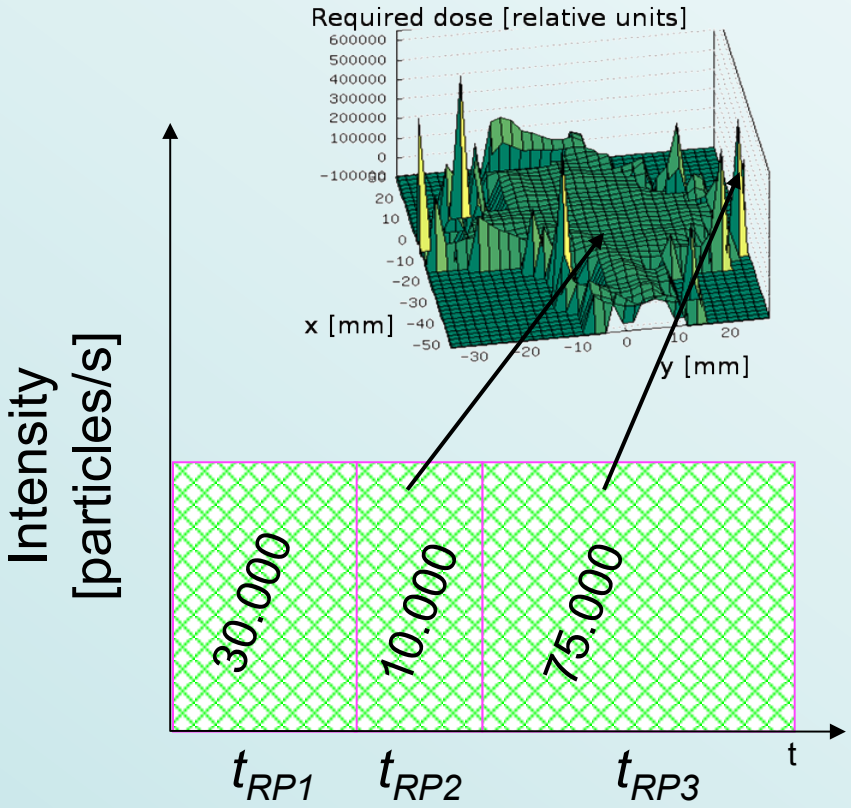
Result: better spill quality step I



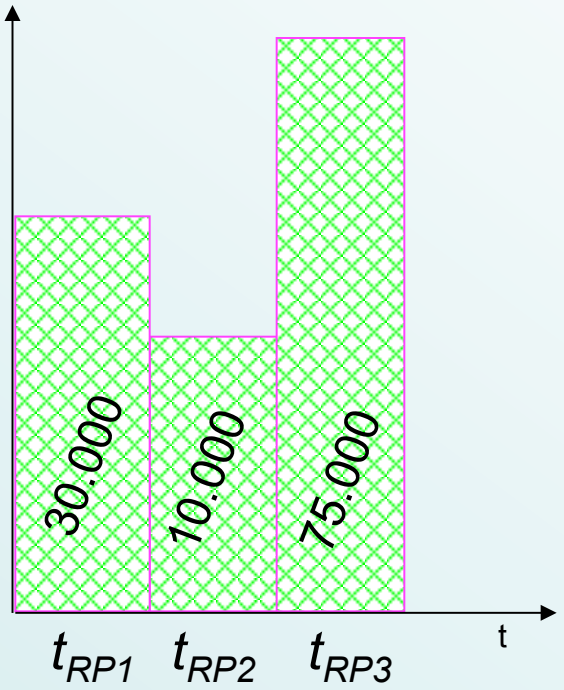
- Spill shape
  - With feedback
  - Without feedback
  - Reference value
- Higher average intensity (+15 %!)
- Plus 4-5 patients per day!

What else can be done?

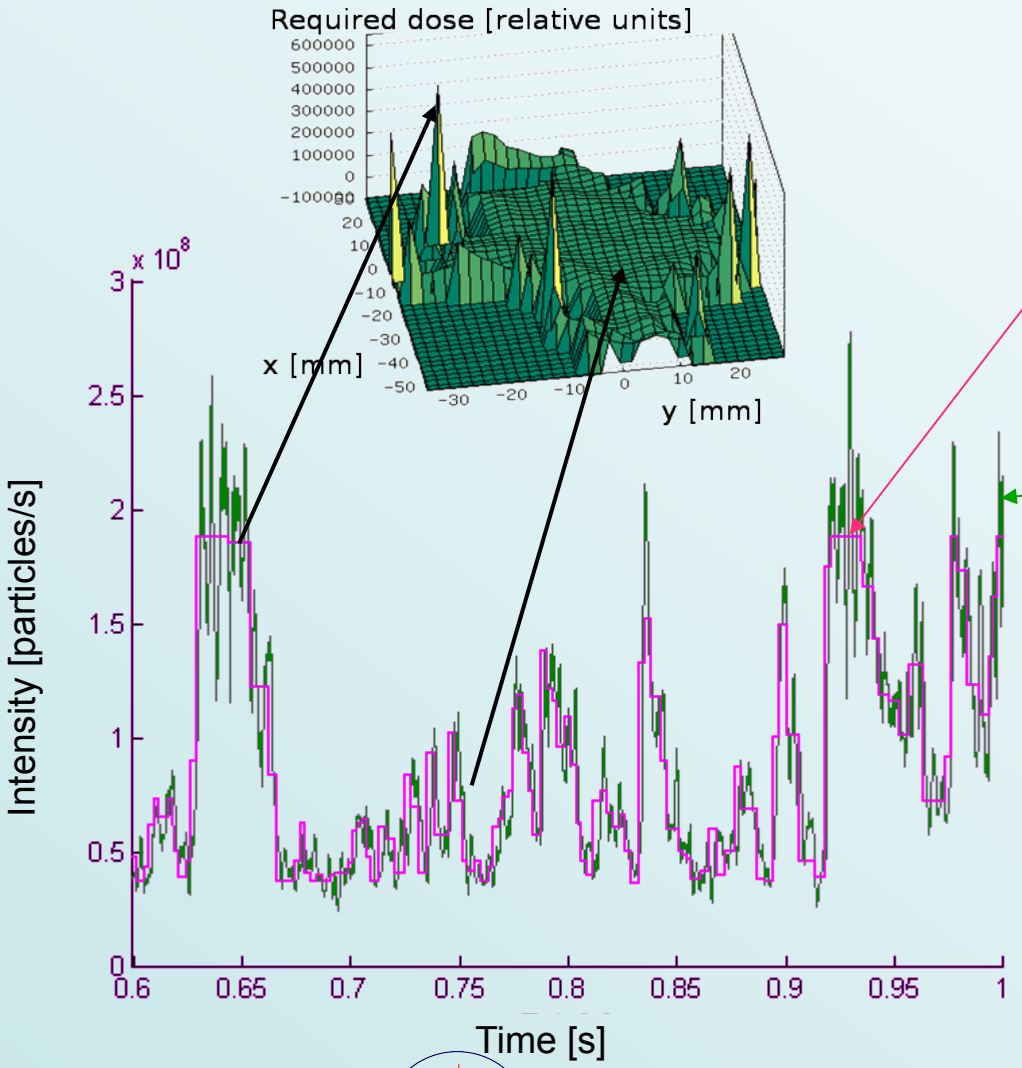
Irradiation time of rasterpoints
with constant intensity with ratserpoint-individual intenisty



Beam plan-/ patient specific



Result: better spill quality step II



- Rasterpoint individual reference value
- Feedback loop adapts the actual intensity
- Total treatment time was again be reduced by ≈11%!
- In operation since April 2014!

Thank you for your attention!

...and to the entire HIT-crew, especially:

- M. Galonska, Th. Haberer, J. Naumann, R. Panse, A. Peters

Summary

- Radiotherapy with ions gives many advantages compared to conventional therapy
- Accuracy, safety, patient comfort and economic aspects are the major criteria
- Efforts to reduce the individual treatment time have been presented:
  - Intensity control in the slow extraction process
  - Magnetic field control of synchrotron magnets
- Performance of the facility has been and will be enhanced considerably!

Schema der Intensitätsregelung

Strahl Parameter

Therapie Kontrollsystem

Beschleuniger Kontrollsystem

IC

Weitere Strahlziele

Soll- und Istwerte

Intensitäts-regler (PID)

Umlaufender Strahl

Extrahierter Strahl

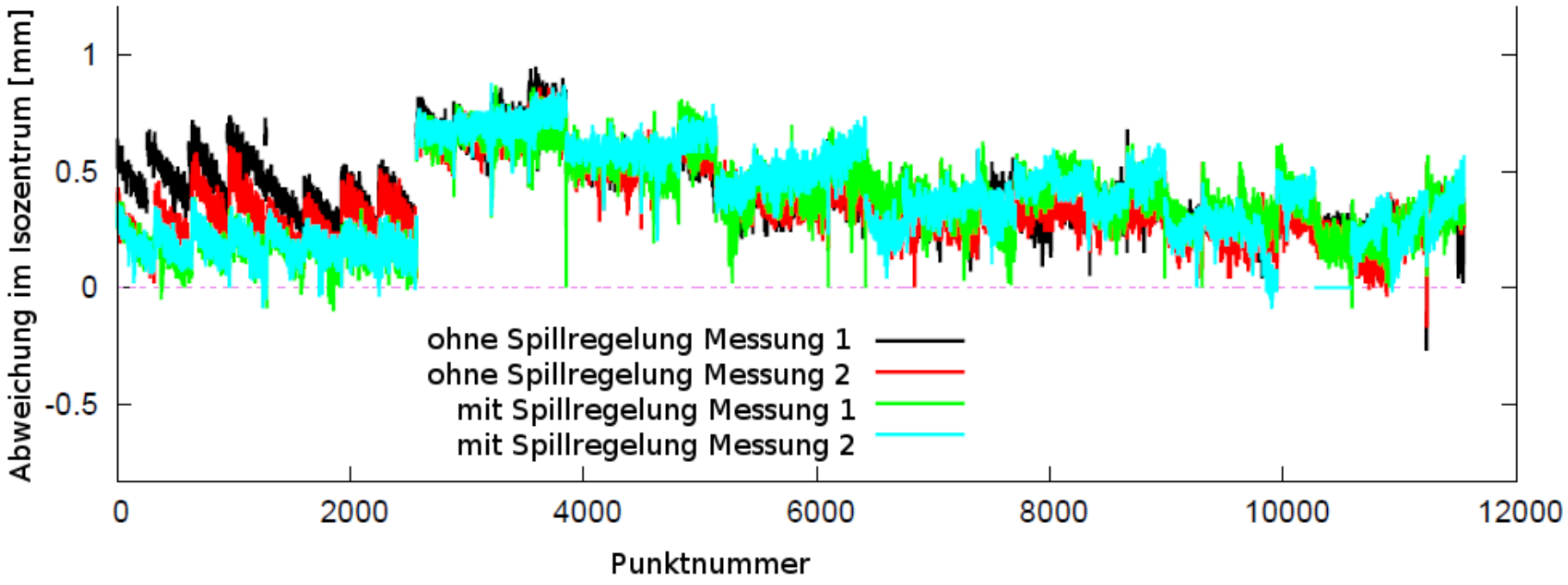
Korrektursignal

RF-KO Exciter in der Strahlführung

Verstärker

RF-KO Exciter Steuereinheit

Herausforderungen



- Genaue Einstellung des Reglers in Abhängigkeit der 255 Energie- und 10 Intensitätsstufen für 2 Ionensorten (> 5000 Kombinationen)!