PTCOG 48 – Heidelberg 2009

Laser-accelerated particle beams for radiation therapy

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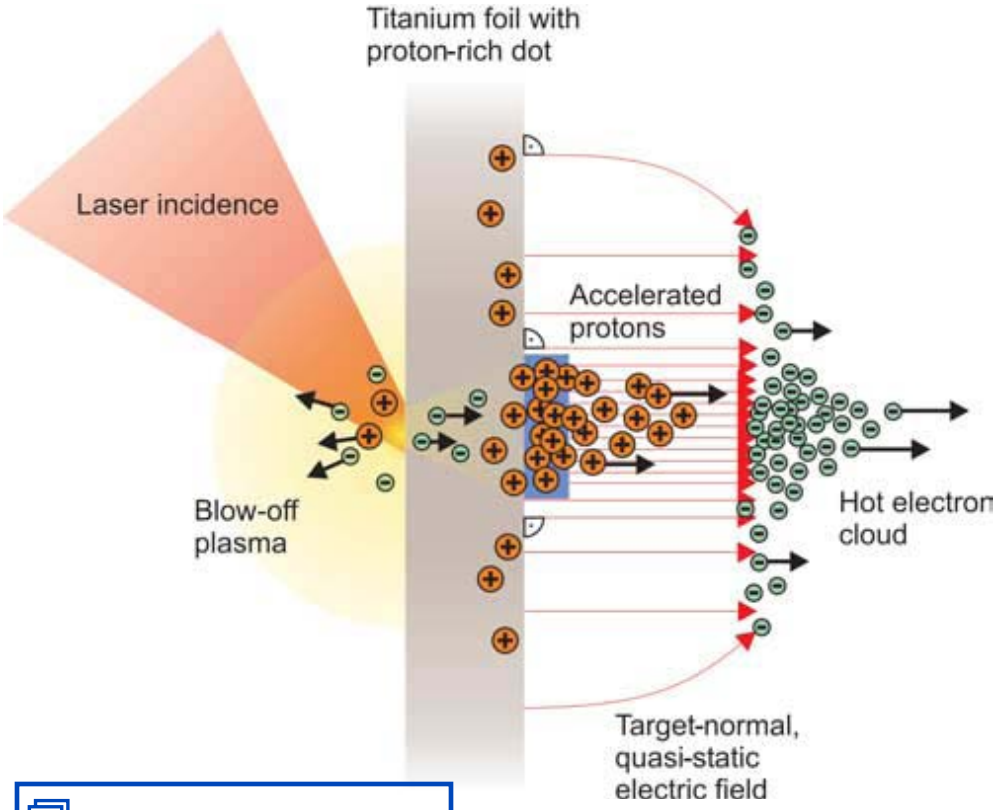
Status of laser-based ion acceleration

Current world records: 67 MeV protons, 40 MeV/u carbon ions

Target Normal Sheath Acceleration (TNSA)



Schwoerer *et al.*
2006 *Nature* **439**

intensity > 10^{19} W/cm^2

pulse length ~ 10-100 fs

foil thickness ~ few µm

new trend:

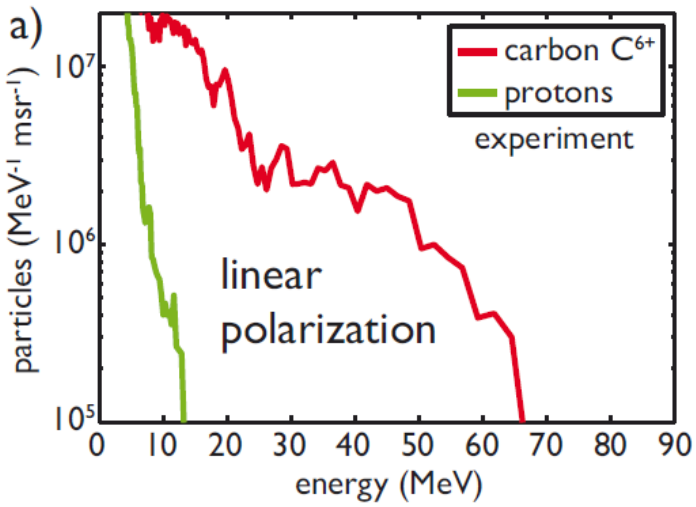
Radiation Pressure Accel. (RPA)

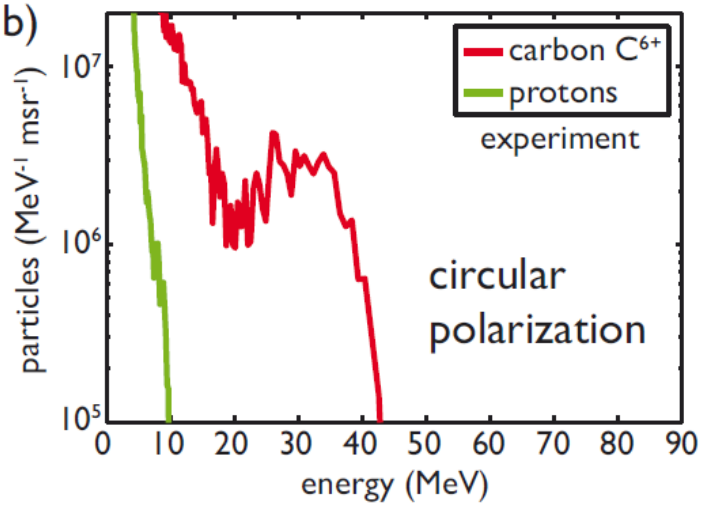
- ultra-thin foils (~ few nm)
- circularly polarized laser
- electrons stay cold

Recent results on ion acceleration

measurement

simulation





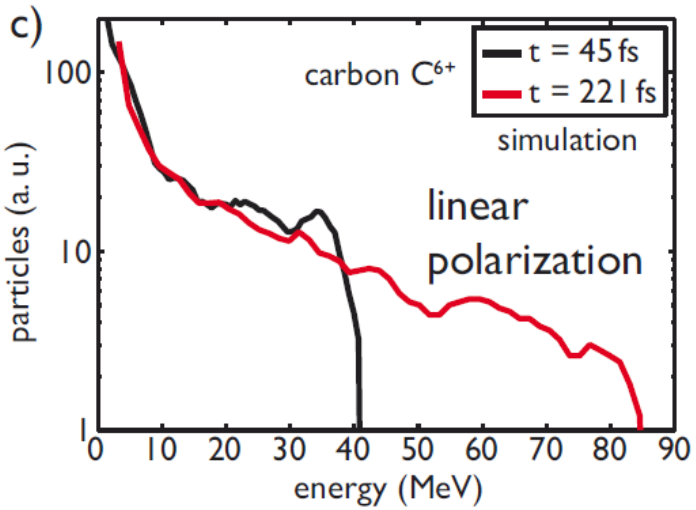
target:

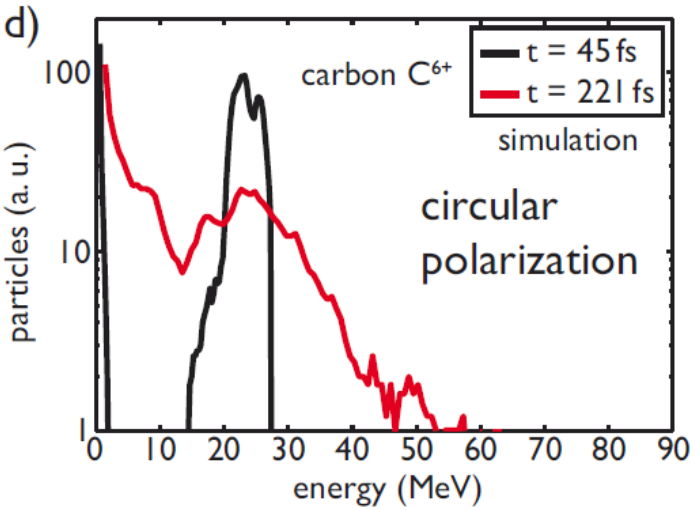
5.3 nm DLC

laser:

$5 \cdot 10^{19}$ W/cm^2

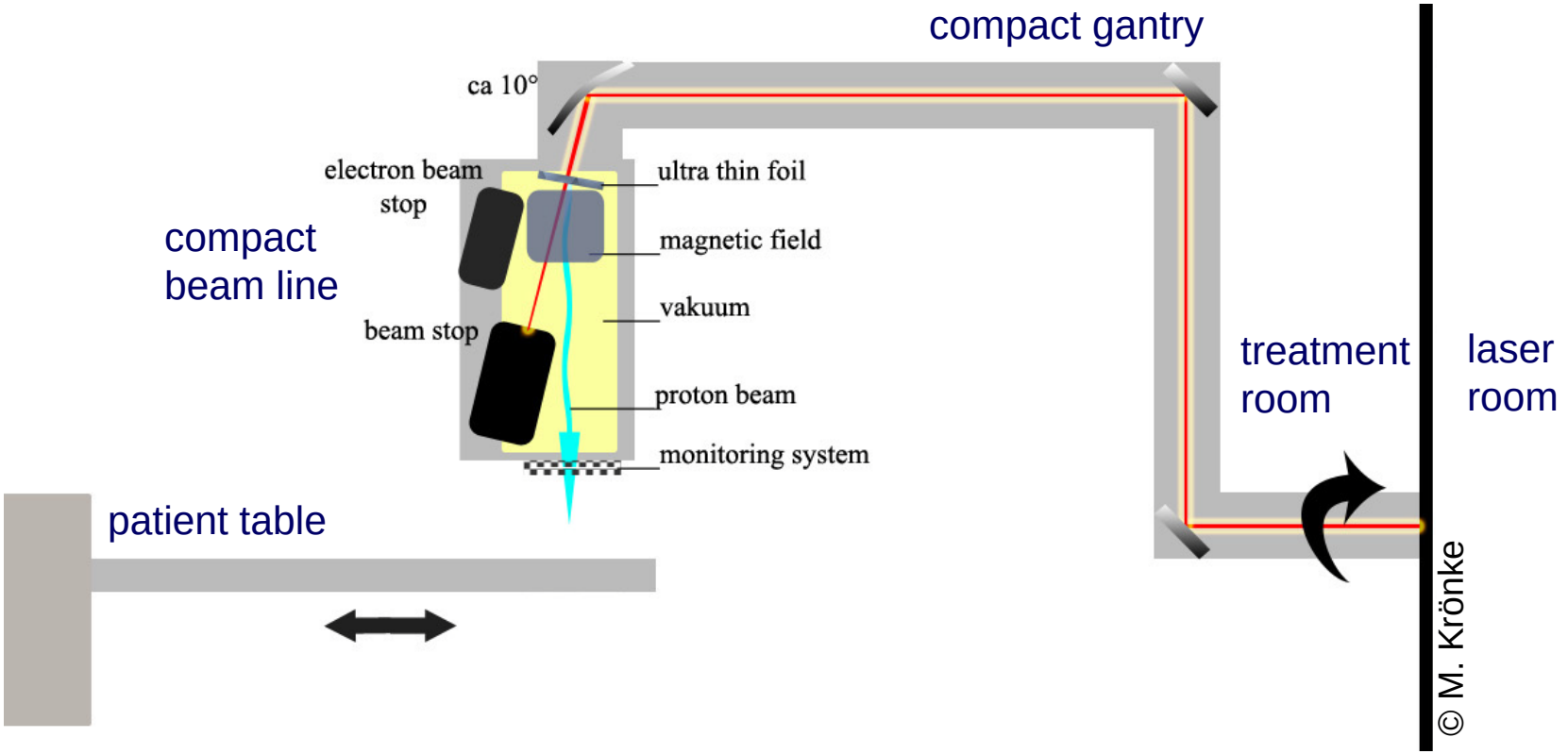
45 fs





Henig *et al.* 2009, arXiv:0908.4057

Design study of laser-based treatment unit

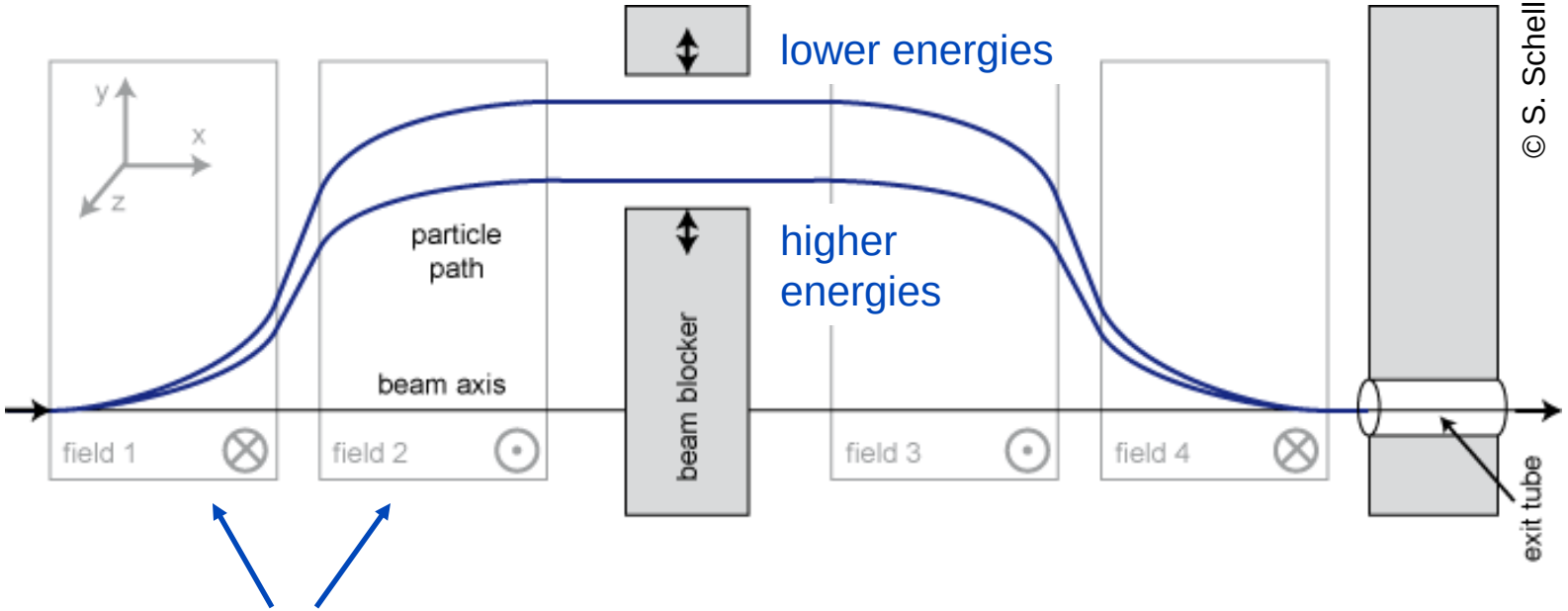


Assumptions:

- (quasi-)monoenergetic spectrum
- energy controllable by laser parameters
- # of particles controllable

Possible addition:
advanced diagnostic imaging
using brilliant, laser-generated x-rays
(e.g. phase contrast imaging)

Magnetic energy selection systems

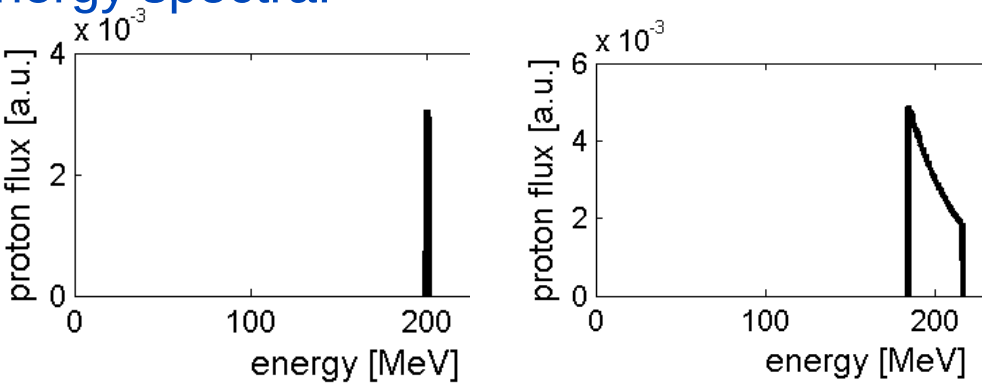


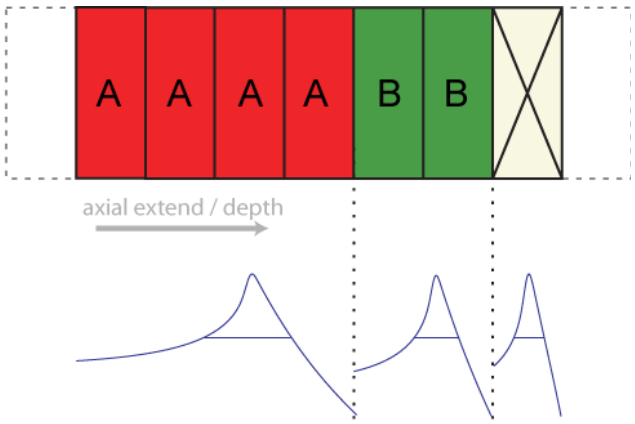
- to pick the required energy
- low particle efficiency
- proper shielding required

Fourkal *et al.* 2003
Med Phys **30** 1660-70

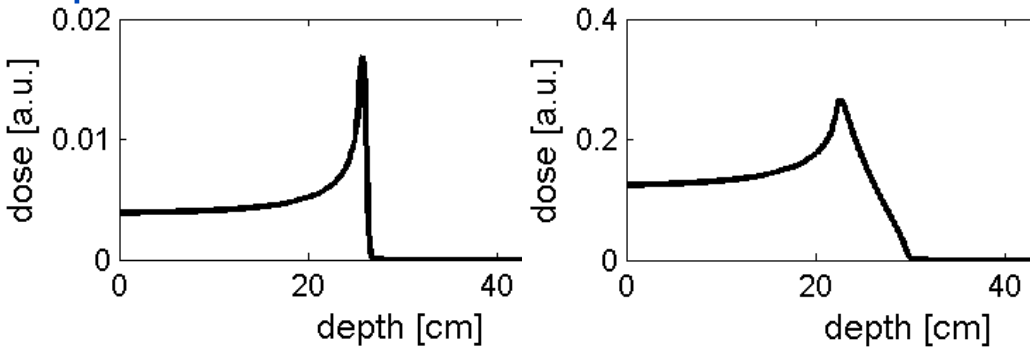
Efficient treatment planning strategies

energy spectra:





depth dose curves:

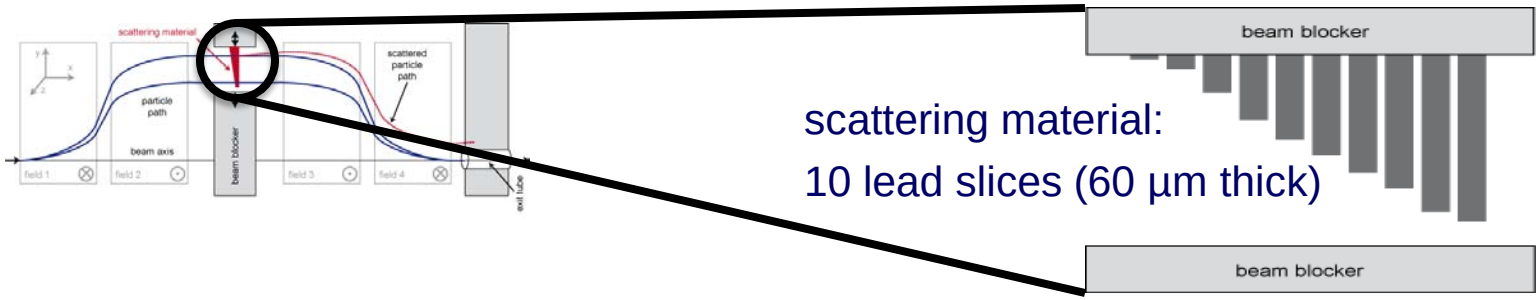


use broader energy spectra in the center of the target

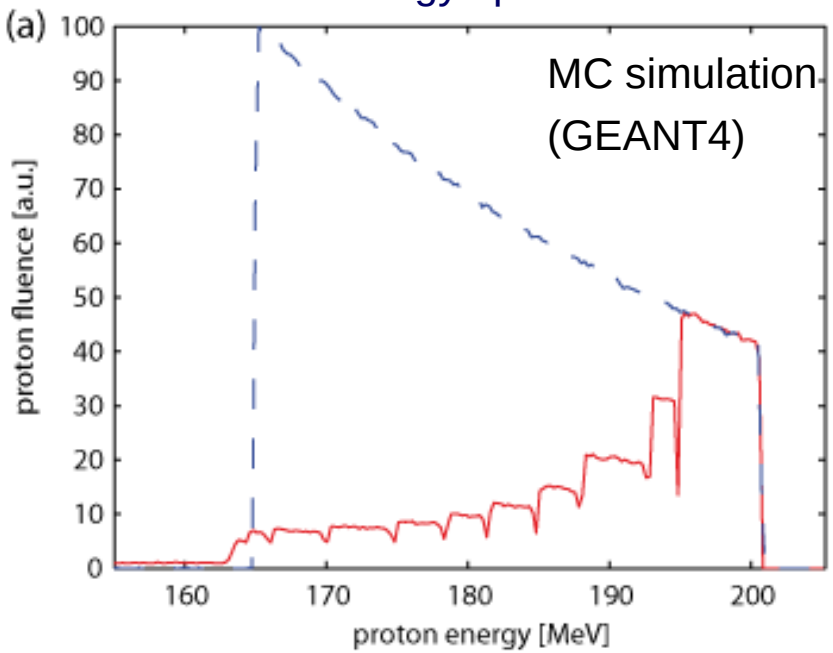
➔ higher particle efficiency

Schell *et al.* 2009 *World Congr Med Phys* Springer, IFMBE Proc. Vol. 25/XIII, 28-31

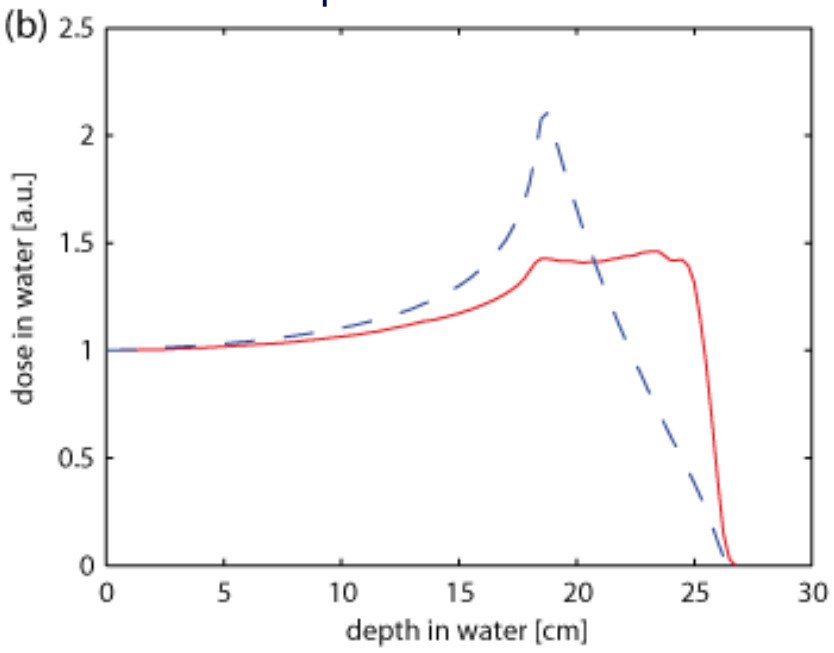
SOBPs in one laser shot (spectral shaping)



energy spectra



depth dose curves



Schell *et al.* 2009 *Phys Med Biol* **54** N459-66

➔ **see Poster P124**

RBE of laser-accelerated beams

Conventional delivery: ~ **100 ms** per cell / voxel

Laser-based delivery: ~ **1 ns** per cell / voxel

10^{-8}

Is this time factor of biological relevance?

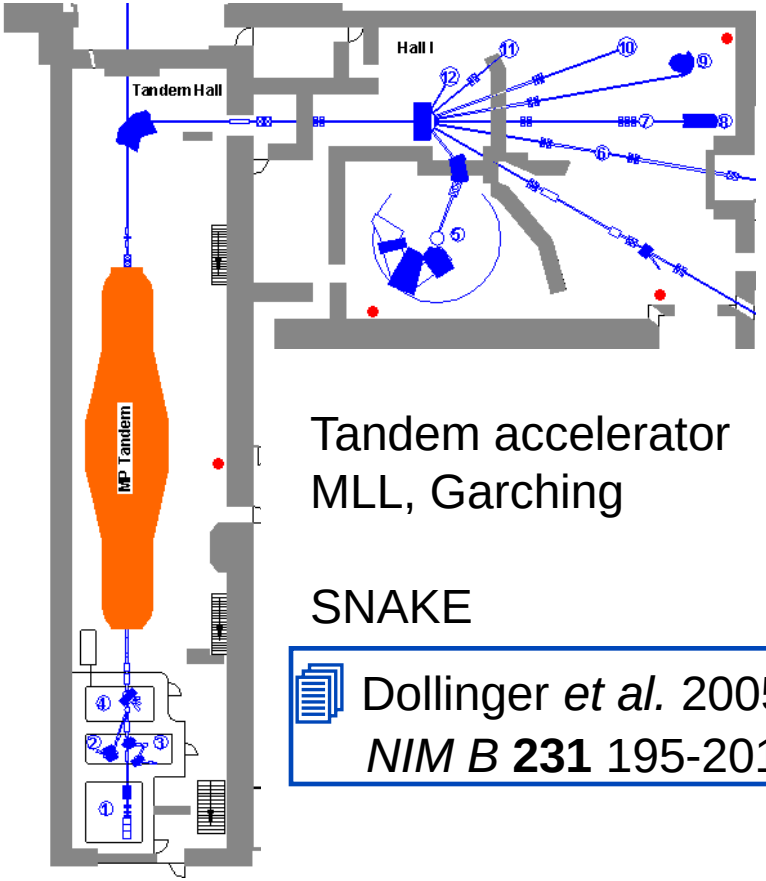
Theory/simulation: maybe, maybe not…

Kreipl *et al.* 2009 *RadEnvBio* **48**(1) 11-20

Kreipl *et al.* 2009 *RadEnvBio* in press

Experiment: no RBE studies in laser-acc. ion beams yet

RBE experiments in Munich



Tandem accelerator
MLL, Garching

SNAKE

Dollinger *et al.* 2005
NIM B **231** 195-201

Micronucleus assay in HeLa cells

20 MeV protons, 3 Gy

Results for RBE:

	continuous (100 ms)	**pulsed** (~1 ns)
Exp. 1	1.06 ± 0.10	1.07 ± 0.08
Exp. 2	1.05 ± 0.11	1.09 ± 0.08
		n.s.

Schmid *et al.* 2009
RadRes in press

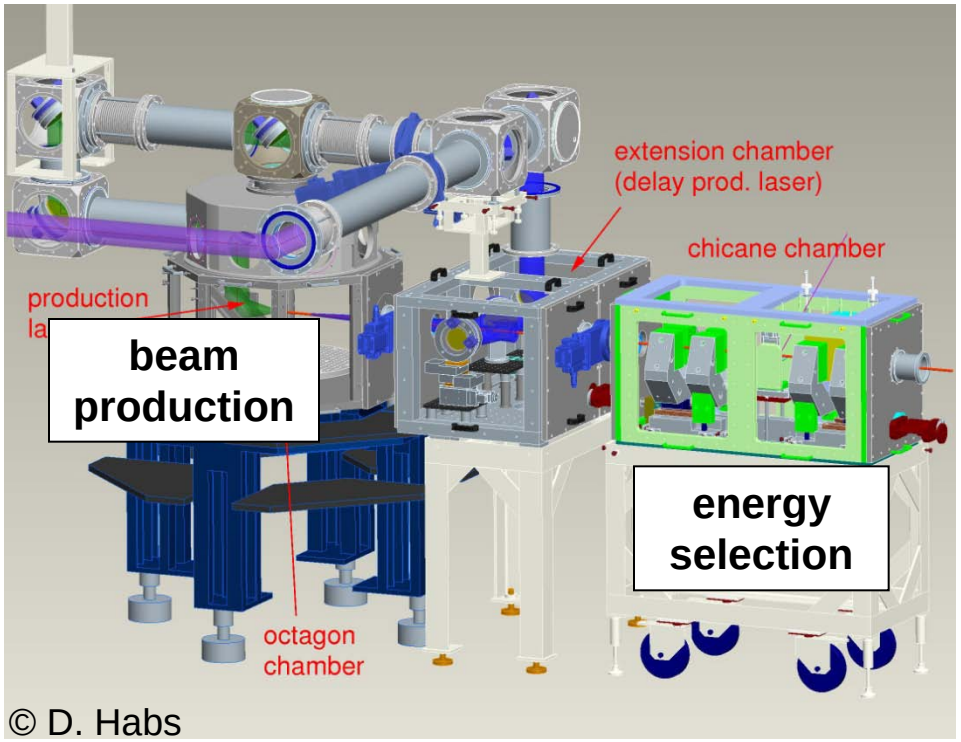
other endpoints: apoptosis, γH2AX kinetics, …

in HeLa, VH7 fibroblasts, and 3D tissue (Epiderm FT): **n.s.**

planned: tumor xenografts in mice in vivo (2010)

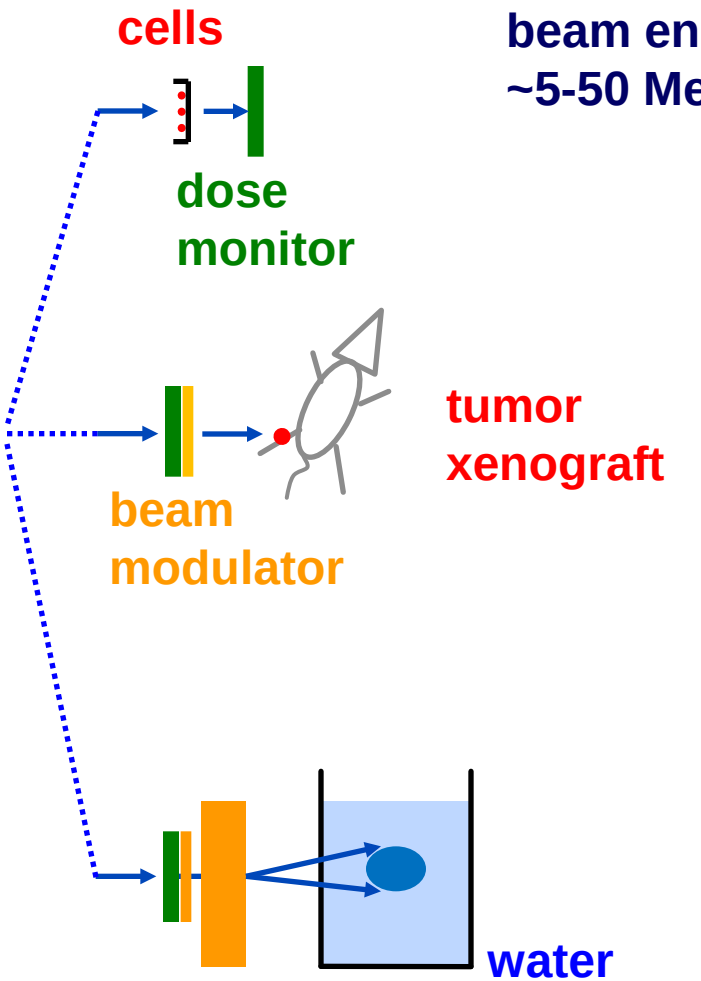
The Munich Medical Beam Line

ATLAS – Laser (MPQ)



© D. Habs

(1-2 J, 25 fs, 10 Hz)



beam energy:
~5-50 MeV

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