Radiobiological applications of laser accelerated ion beams and visions for future research infrastructure

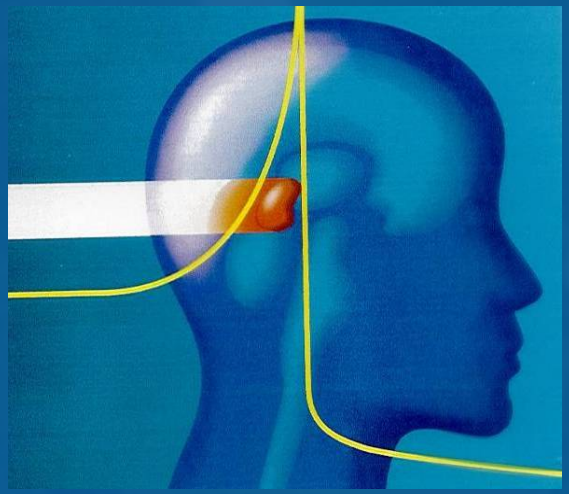
U. Schramm

Laser particle acceleration division
Institut for Radiation Physics

Demonstrate

- stable laser accelerated proton pulses (sufficient energy)
- with a dose rate of some Gy / min in few shots
- dosimetric protocols (and techniques)

for measuring the biological effectiveness, i.e. dose dependent cell damage detected with different methods



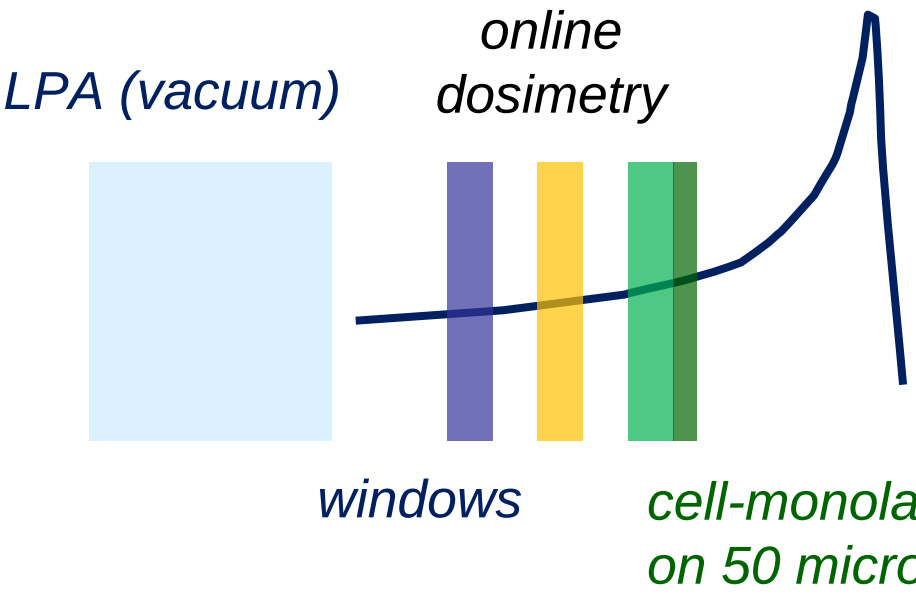
J. Pawelke, L. Karsch,
W. Enghardt, et al.

E. Beyreuther,
Y. Dammene,
L. Laschinsky,
D. Naumburger, et al.

- U. Schramm, S. Kraft, K. Zeil, J. Metzkes, T. Richter, C. Richter, et al.
- A. Irman, A. Jochmann, et al.
- M. Bussmann, A. Debus, T. Kluge, et al.
- M. Siebold, S. Bock, U. Helbig, F. Röser, M. Löser, et al.
- T. Cowan, R. Sauerbrey

requirements for cell irradiation experiments

with laser plasma accelerated proton pulses …



- *Proton energies >5 MeV (no stopping on sub-mm scale)*
- *Dose rates of Gy/min between 0.1 and 10 Gy (pulse dose / stability)*

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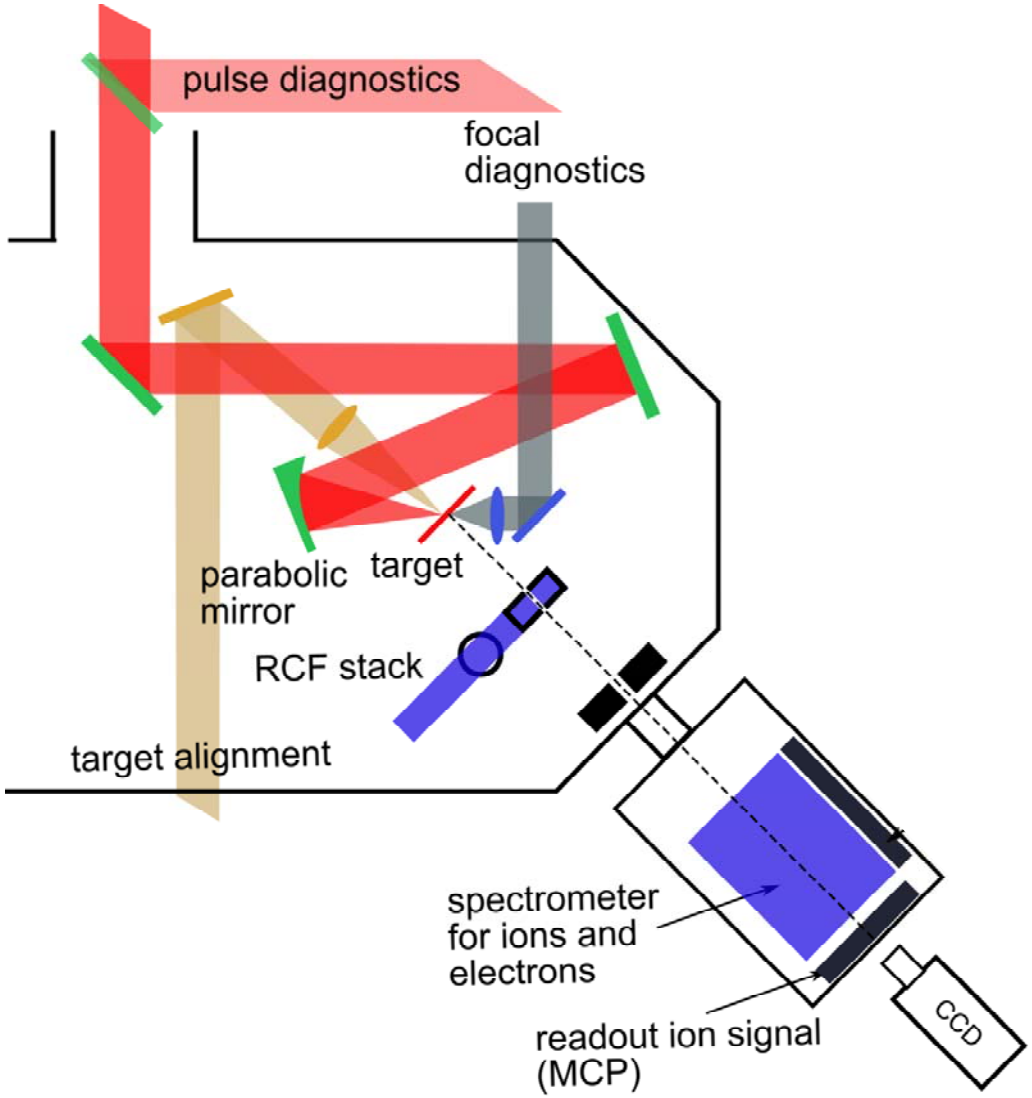

- *Proton energies >5 MeV (no stopping on sub-mm scale)*
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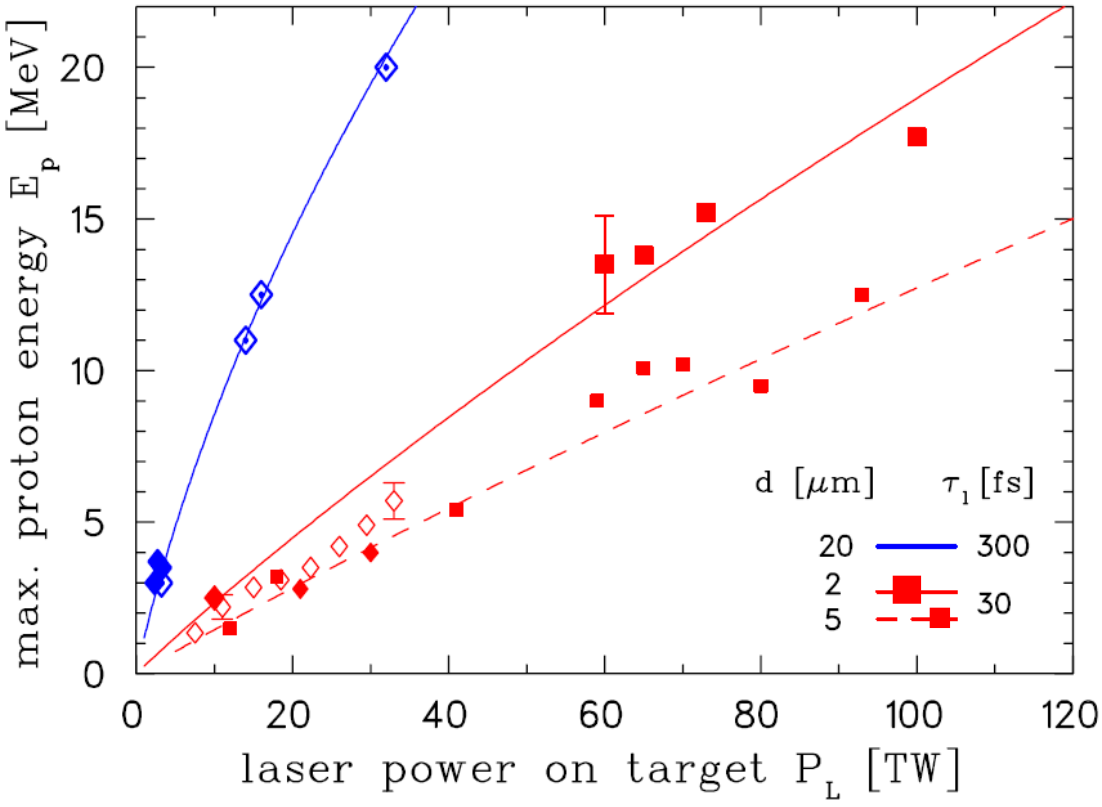
energy requirements for cell irradiation experiments



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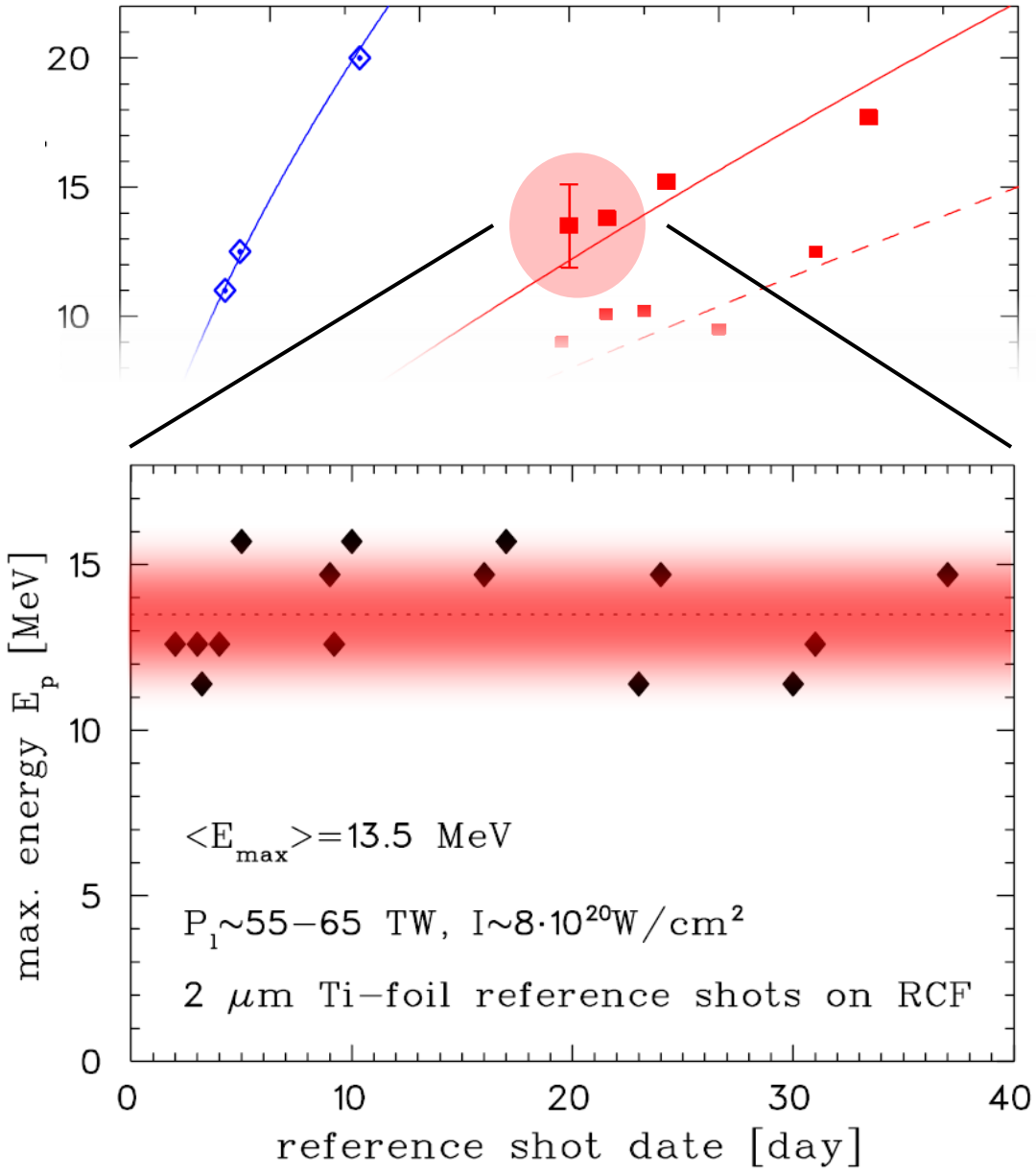
Draco laser parameters : up to 3J on target in 30fs
focused to 3 micron FWHM

stability requirements for cell irradiation experiments



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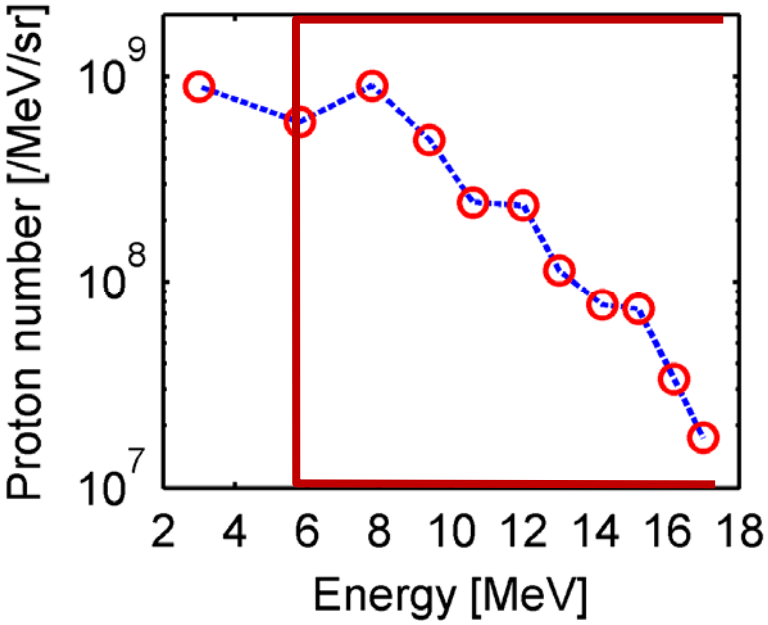
dose requirements for cell irradiation experiments



- *Proton energies >5 MeV*
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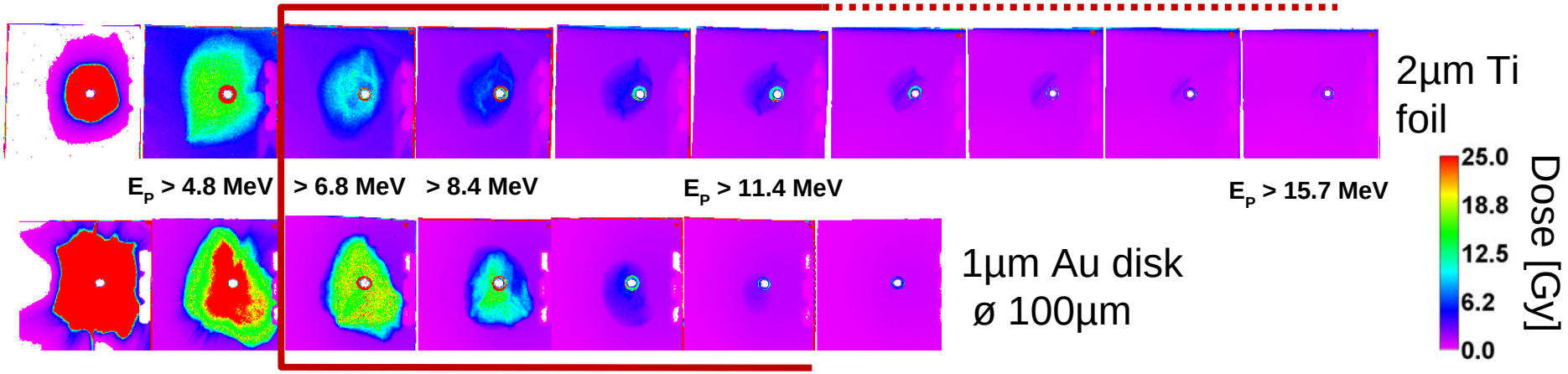
- *Energy filtering (protection from other radiation)*



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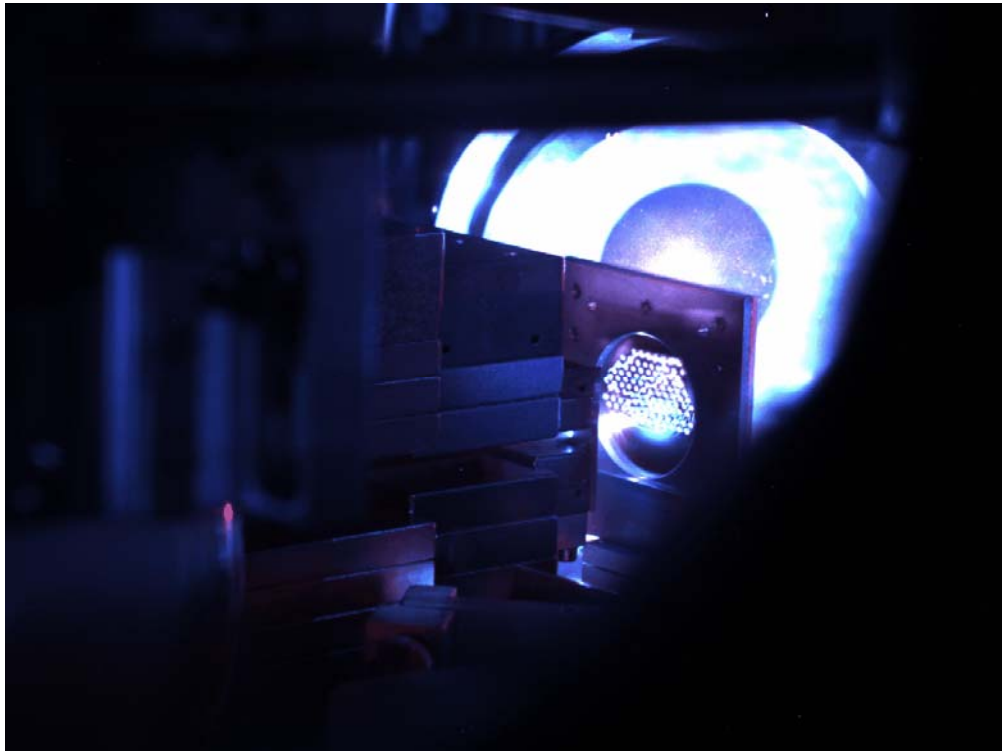

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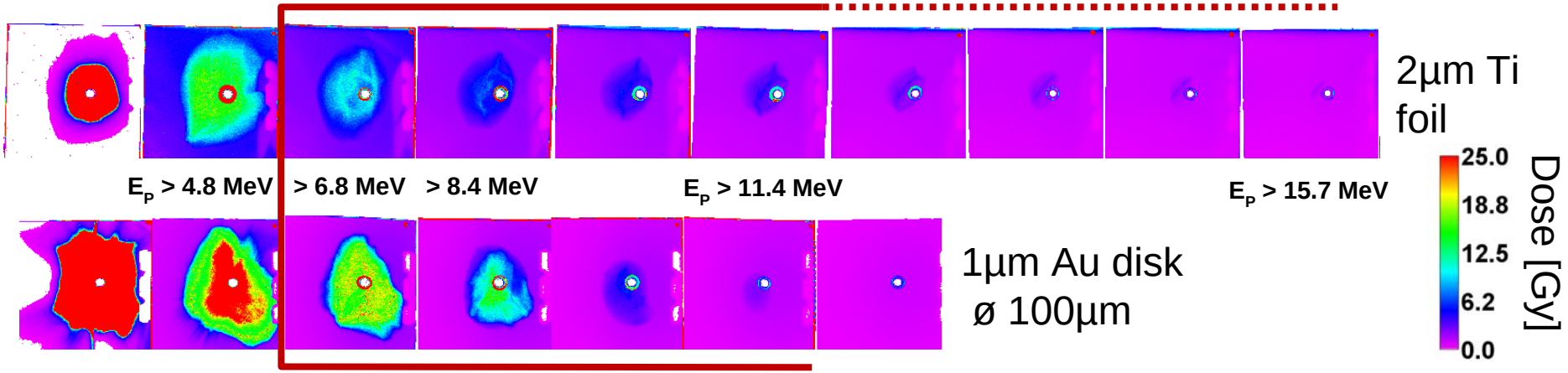
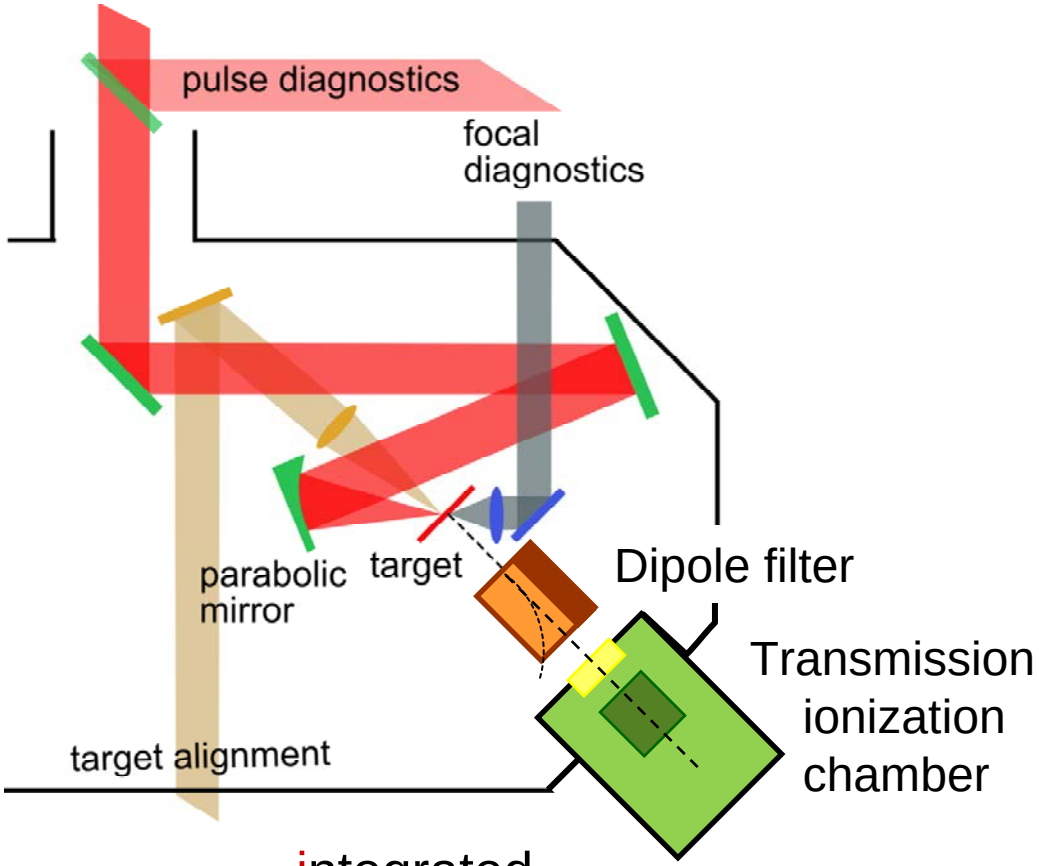


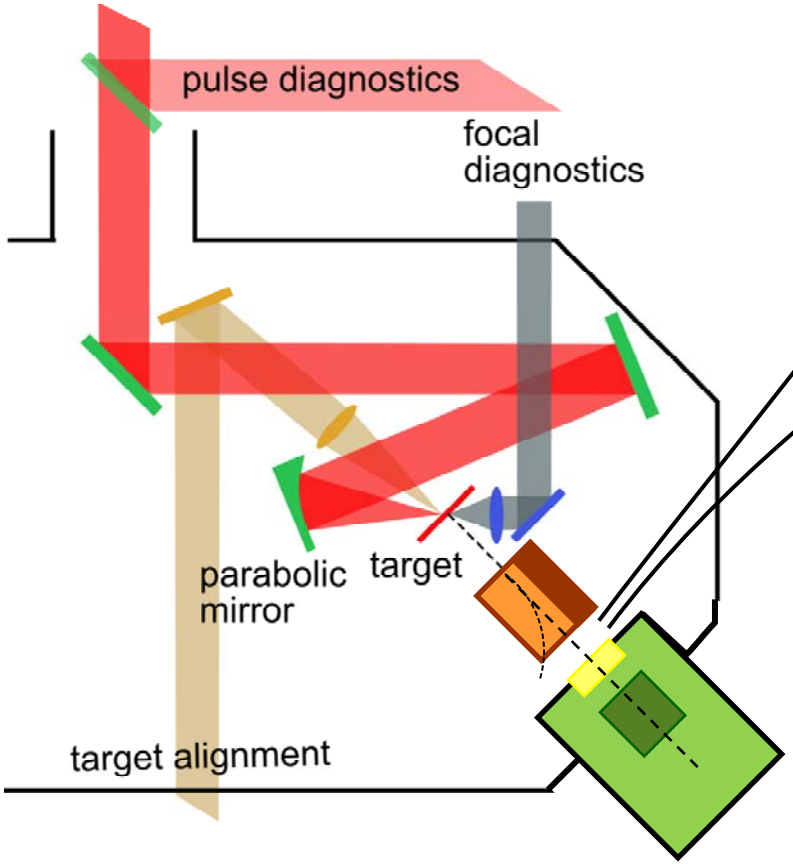
with laser accelerated proton pulses …

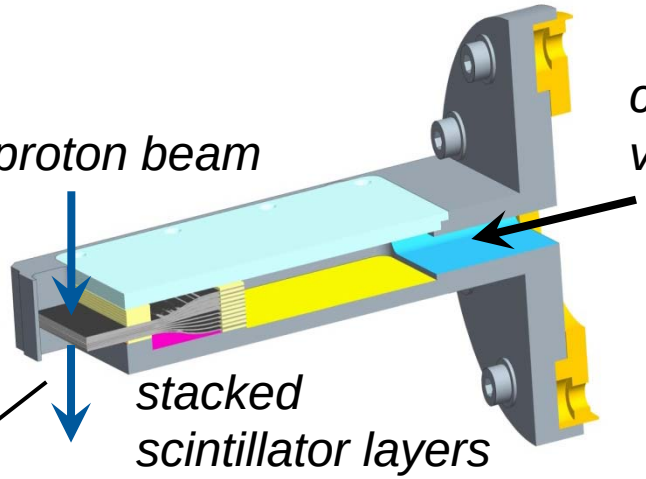


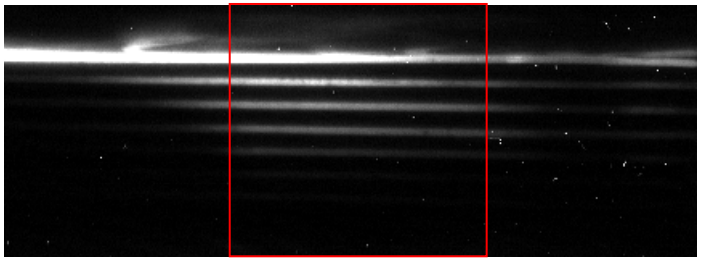
- *Proton energies >5 MeV*
- *Dose rates of Gy/min between 0.1 and 10 Gy (pulse dose / stability)*
- *Energy filtering / transport (radiation protection)*
- *Online and absolute offline dosimetry*
- *Homogeneous irradiation*
- *Sample size ~cm²*
- *Cell irradiation in air*

integrated Dosimetry and cell irradiation system (Faraday-cup, RCFstacks, cell samples)

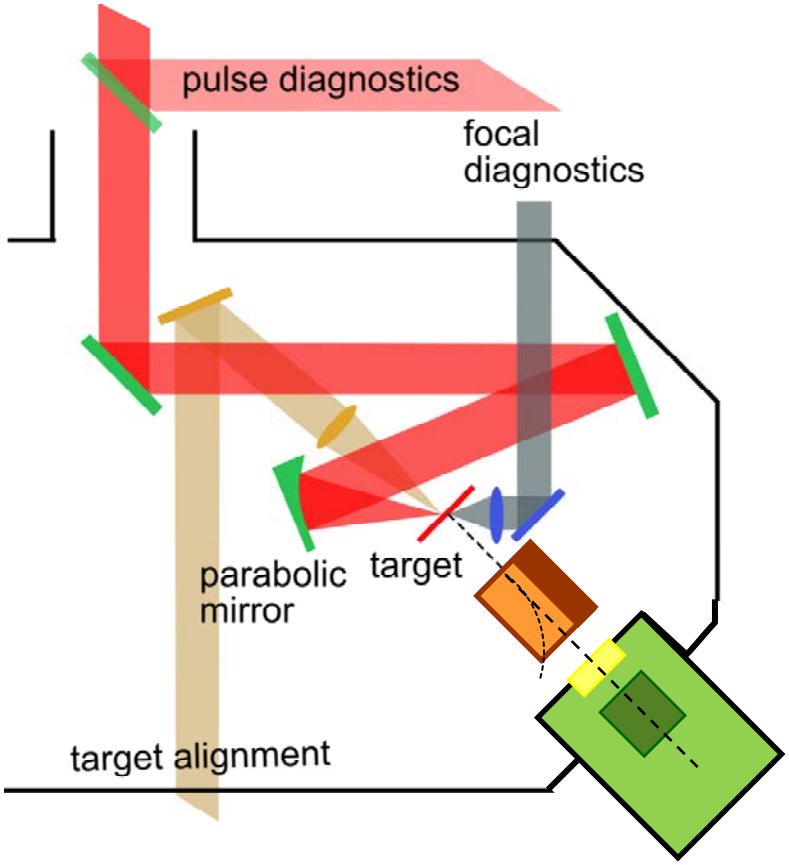
for laser accelerated proton pulses …

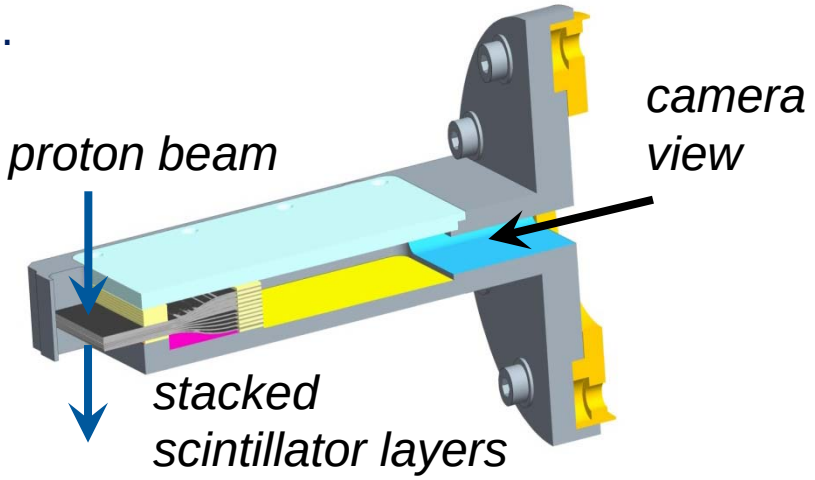


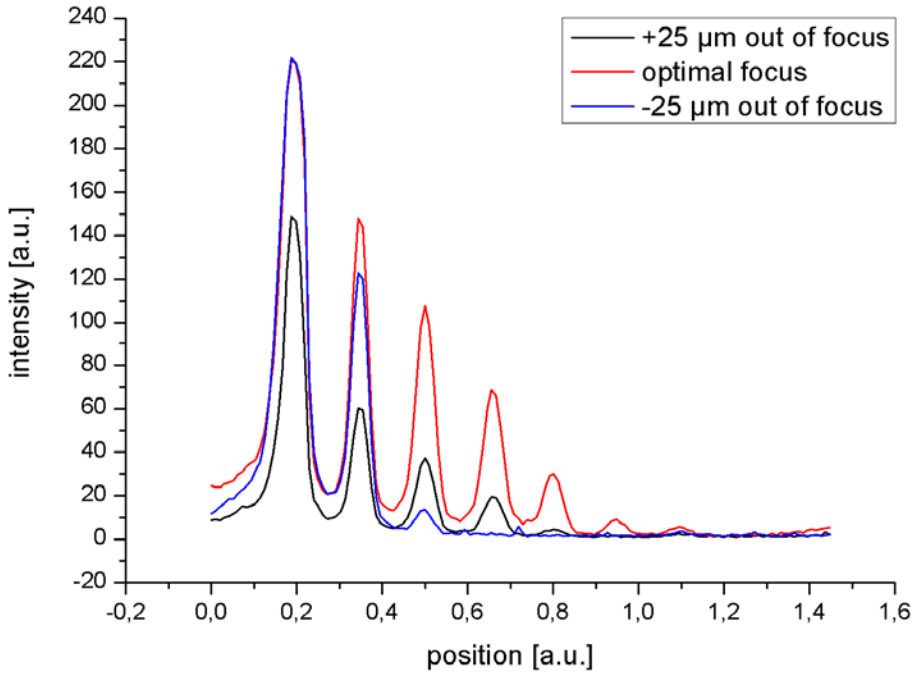




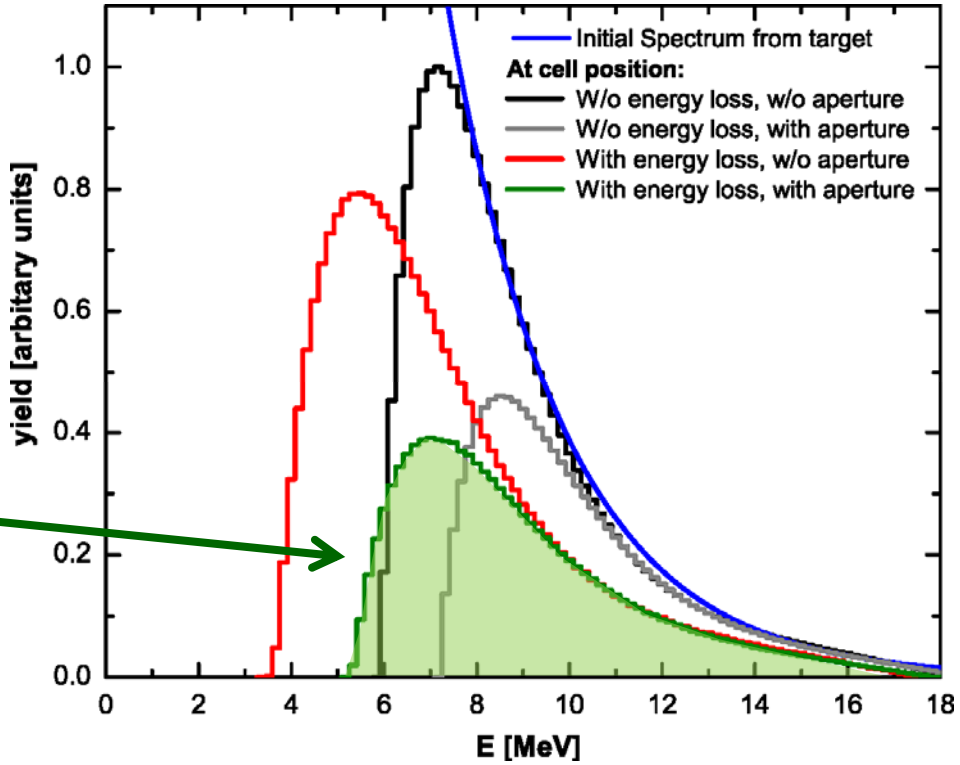
for laser accelerated proton pulses …





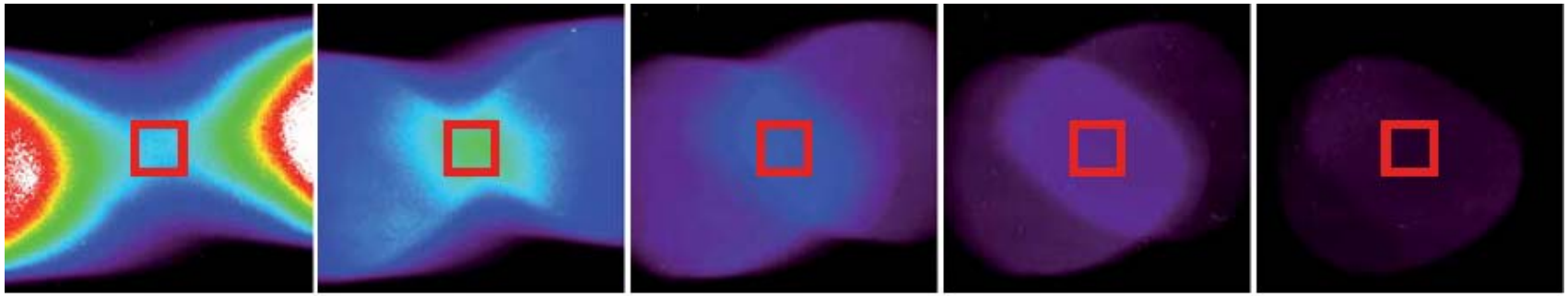


Proton spectrum at cell location

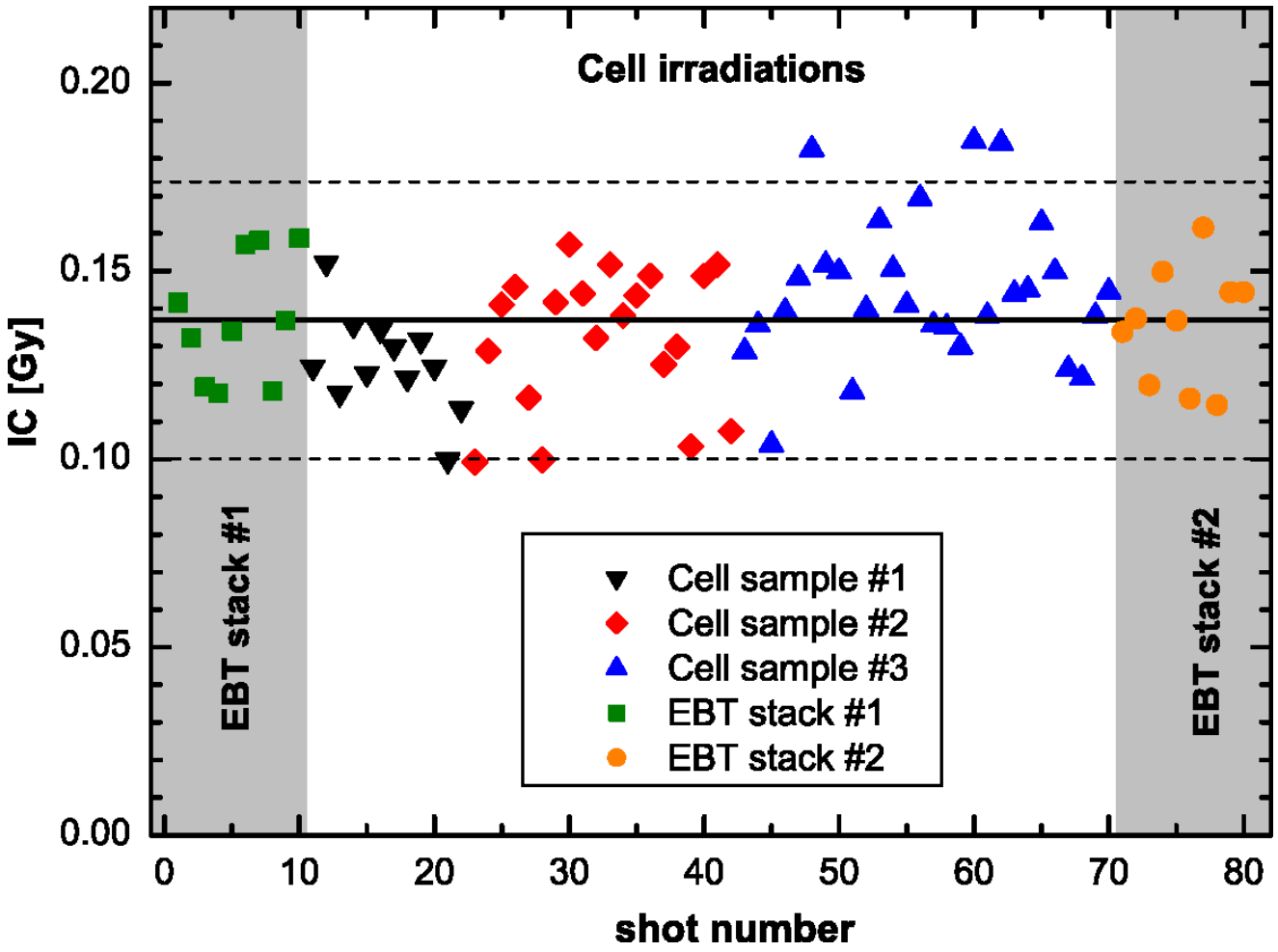


accumlated pulses

rotated sample



> 4 MeV > 6.3 MeV > 8.0 MeV > 9.5 MeV > 10.8 MeV

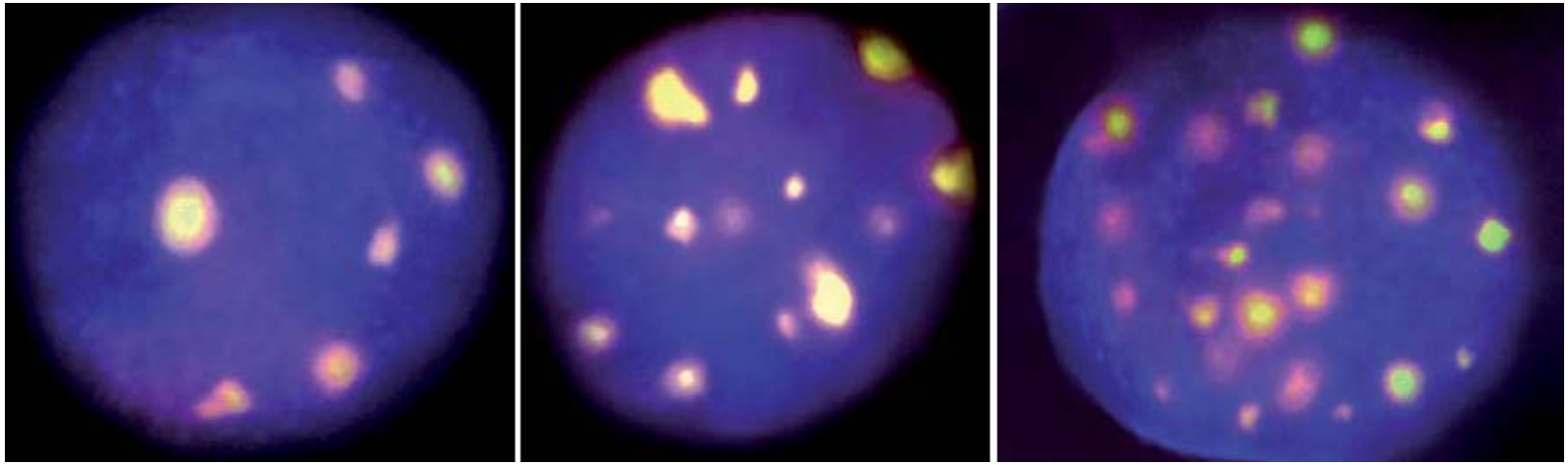


140 mGy per shot

Stable and online monitored pulse-to-pulse operation for controlled irradiation of three samples and reference irradiations

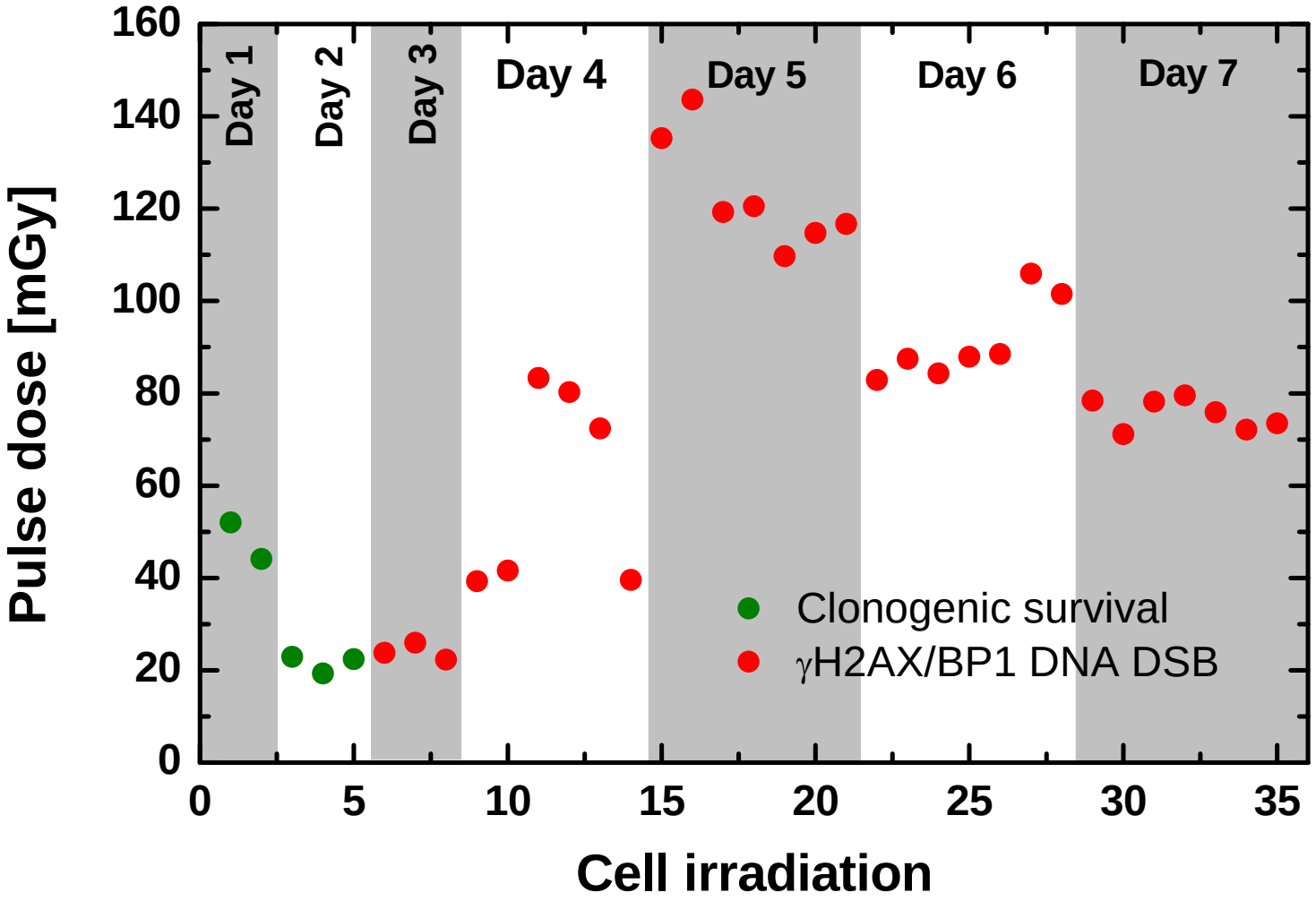
Dose dependent cell irradiation

1.5 Gy *2.7 Gy* *4.1 Gy*



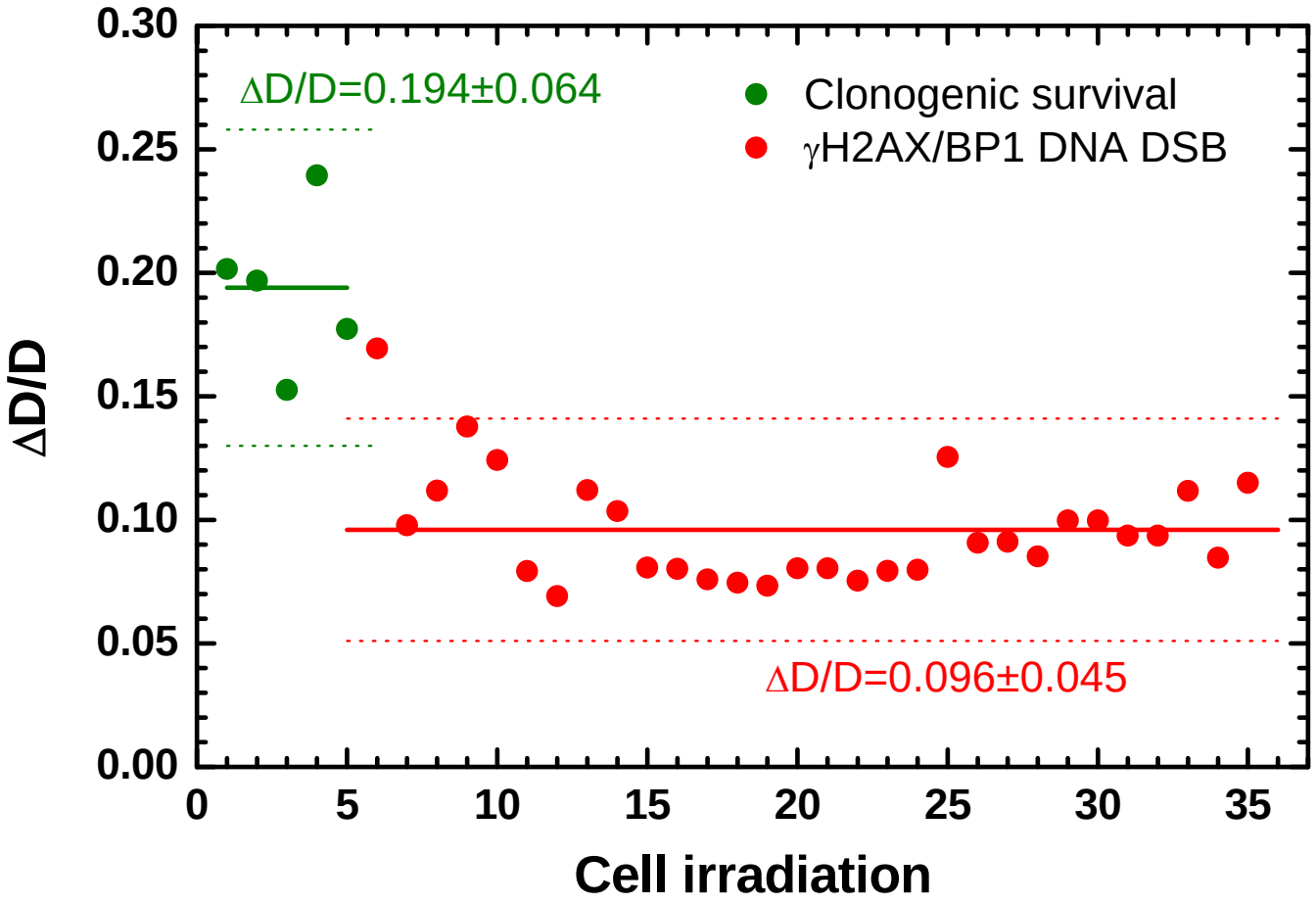
DNA double strand breaks in a cell nucleus, stained

Intra- and inter-day reproducibility of dose



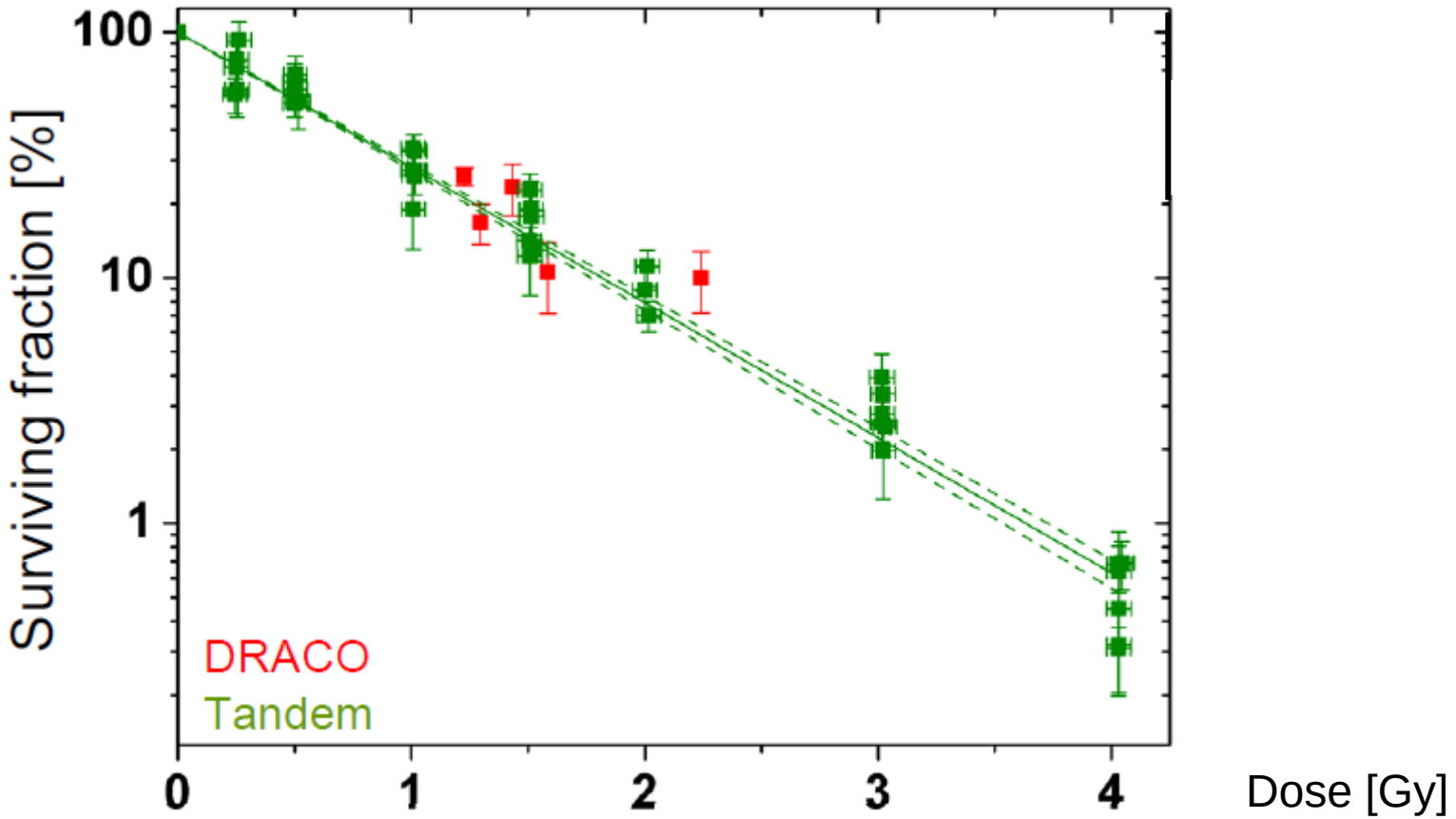
Curve represents ~ 4180 laser shots (50% for cell irradiations)

Relative dose accuracy



- first experiment with reliable dose & dose uncertainties
- radiobiological data analyzable

Preliminary message …



As expected, no difference between pulsed laser accelerated beam and continuous tandem beam (same result with improved dynamics for DNA double strand break endpoint)

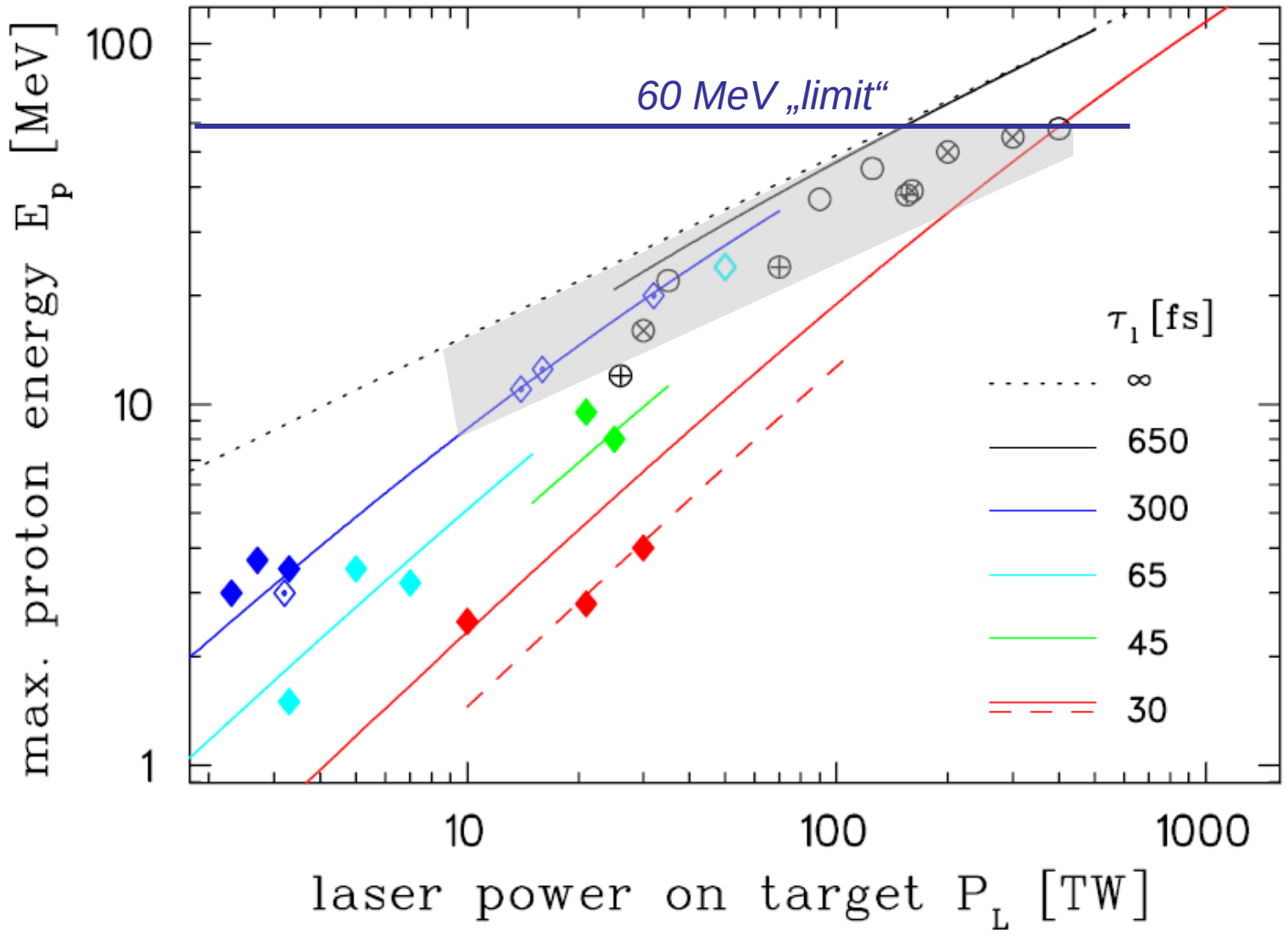
Dose dependent cell irradiation

- two successfull campaigns so far (about 5000 fully controlled and monitored shots)
- first step in translational research, animal studies as soon as ~ 30MeV available

- increase proton energy and stability

  - Increase the laser power
    up to PW level, diode pumped
    scaling to be determined (absorption, etc.)
  - Use clever target design (RMTs, cones, etc.)
    that enhances acceleration fields
  - Exploit radiation pressure regime …

TNSA – proton energy power scaling



scaling following J. Schreiber, et al., PRL 97, 045005, 2006

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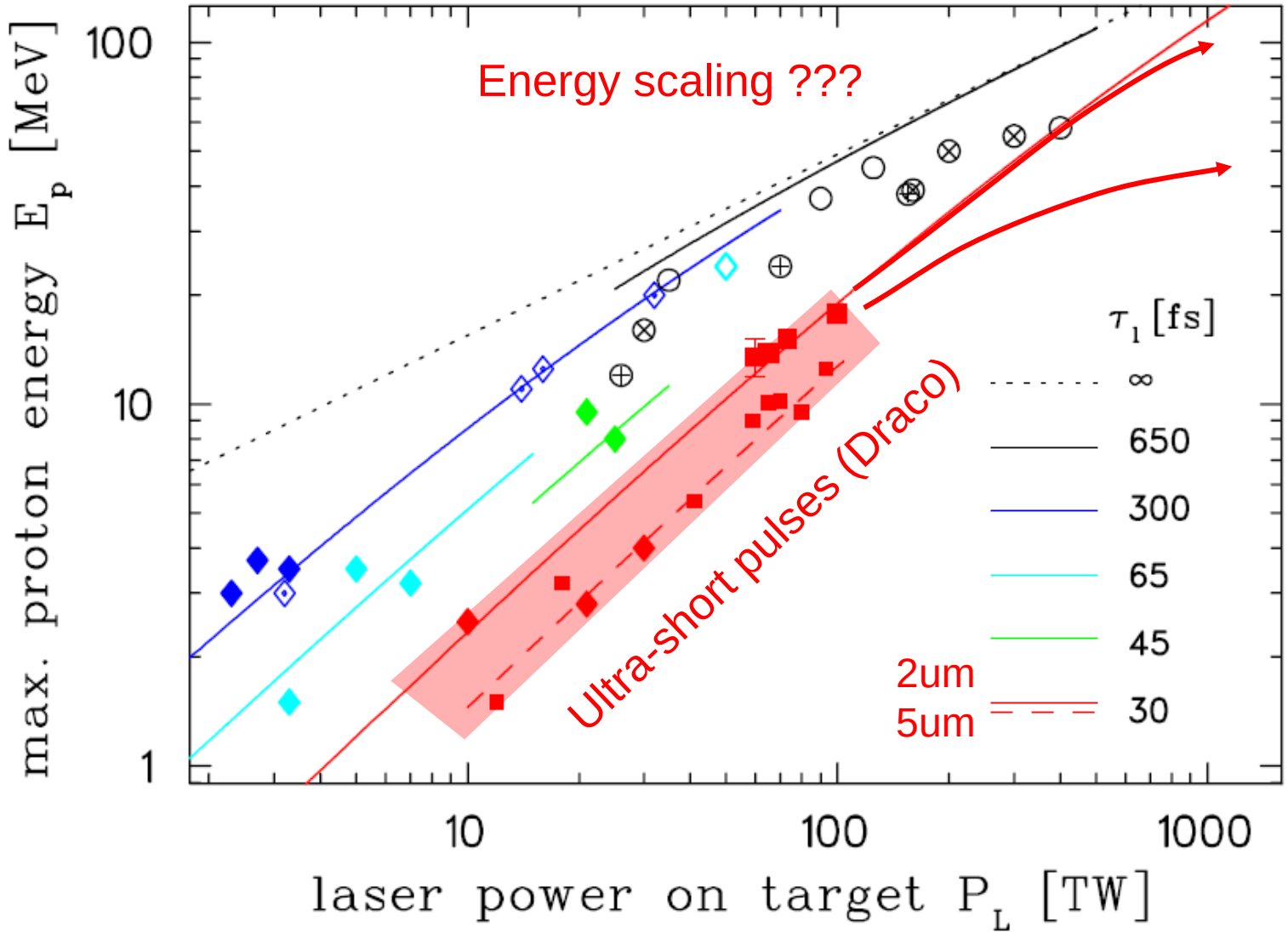
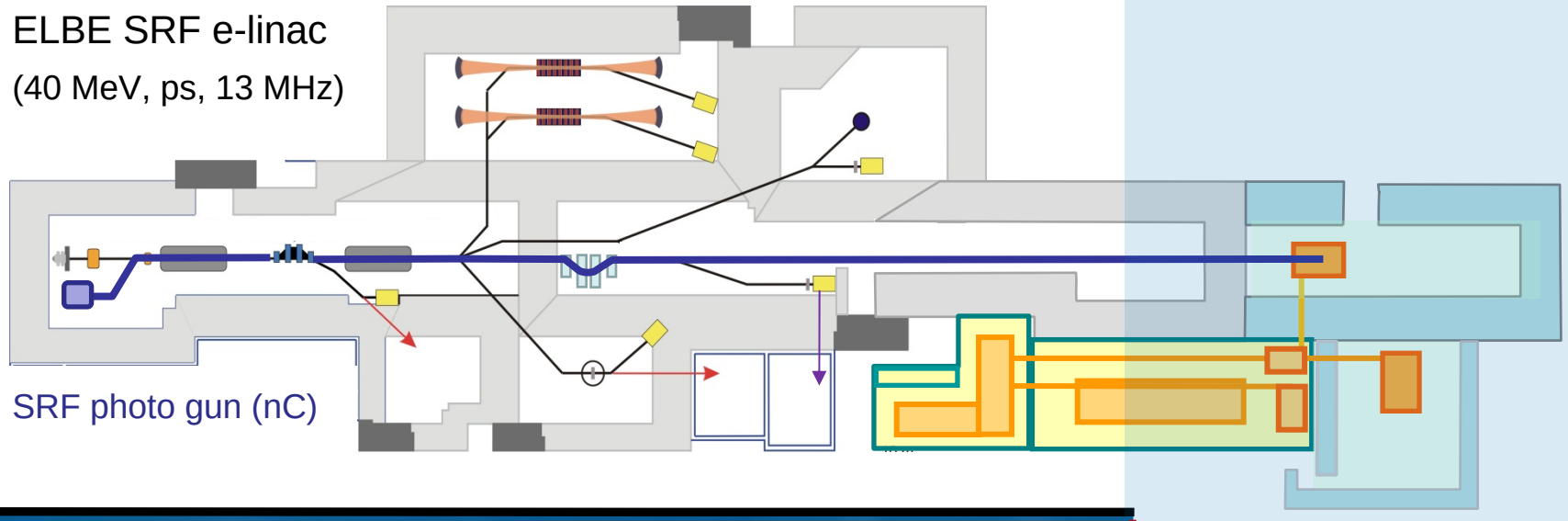


K. Zeil, et al., New Journal of Physics 12, 045015 (2010)

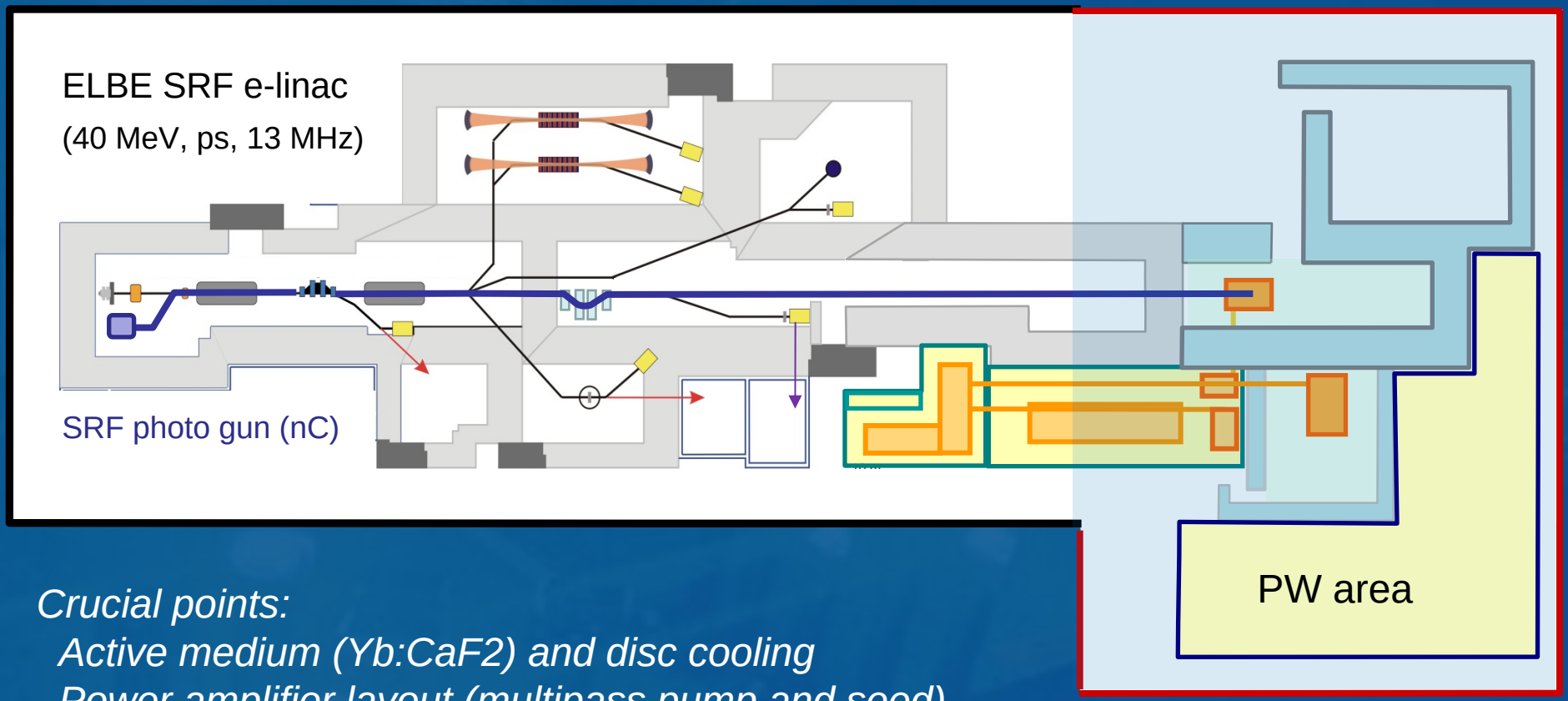
Upgrade of the Ti:Sapphire laser Draco



- Dual beam option (50TW / 500TW)
  installation scheduled for mid 2012
- Synchronized to ELBE

PEnELOPE

Petawatt, Energy-Efficient Laser for Optical Plasma Experiments



Crucial points:

- *Active medium (Yb:CaF2) and disc cooling*
- *Power amplifier layout (multipass pump and seed)*
- *Brightness of diode laser pumps (almost solved)*

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EXPOSÉ

Helmholtz-Roadmap für
Forschungsinfrastrukturen
Stand 2011

HELMHOLTZ GEMEINSCHAFT

Plans / Ideas for the next HGF Research Infrastructure

(very preliminary)

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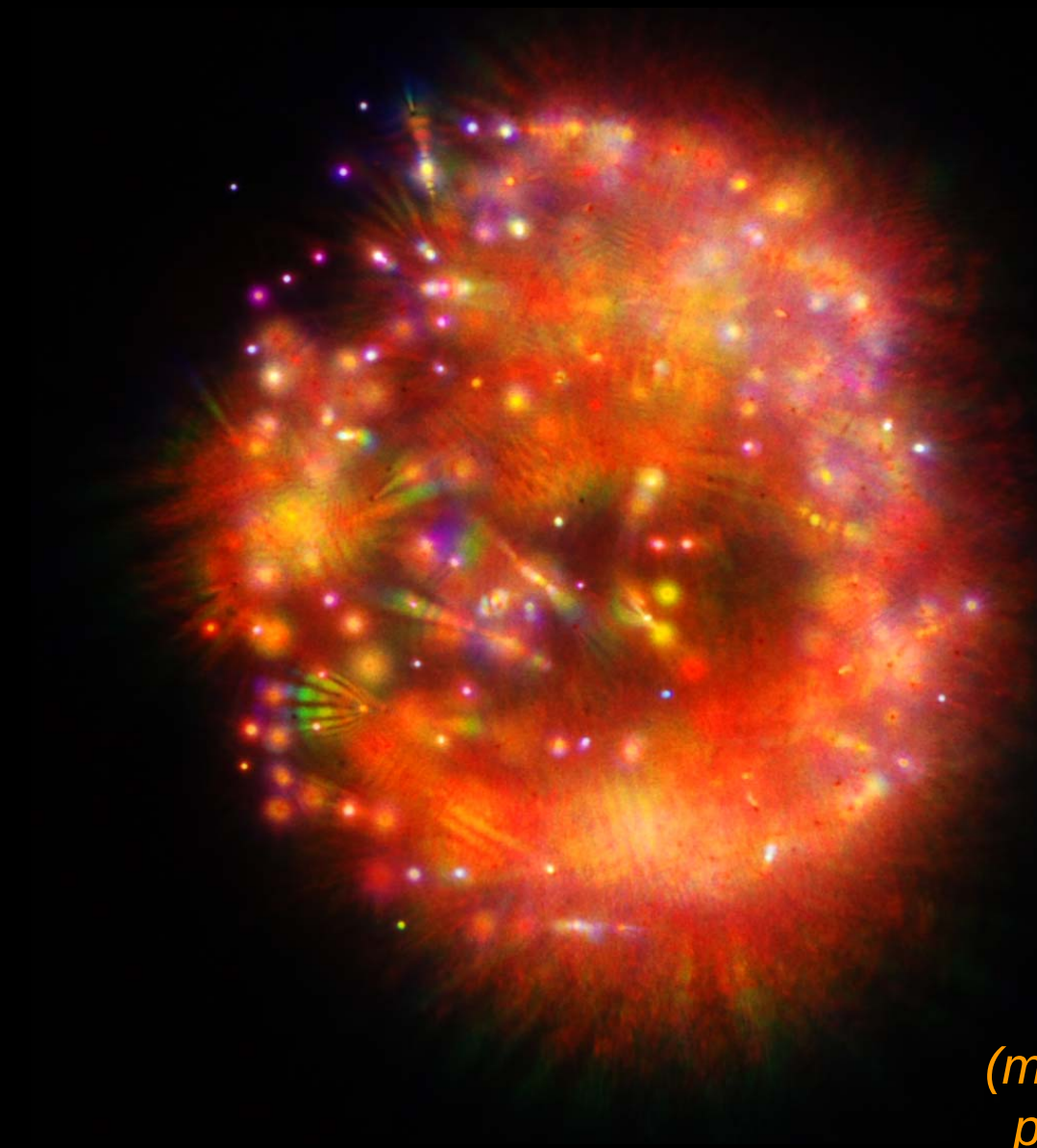
ARD Test facility - distributed facility for investigating acceleration schemes with high gradients (plasma wakefield, laser plasma of any kind)

Helmholtz beamline @ European XFEL - high power (rep-rated) laser systems and high energy laser synced to (new or planned) XFEL end station

Helmholtz beamline @ FAIR - high power (rep-rated) laser systems synced to FAIR beam line(s)



(multiple filamentation of freely propagating 100 TW beam in air)