

2D Thermoluminescence Dosimetry for scanning ion beam

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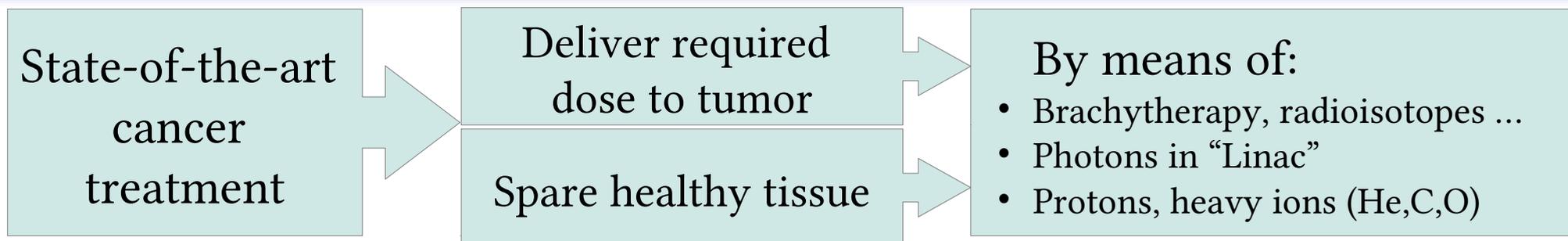


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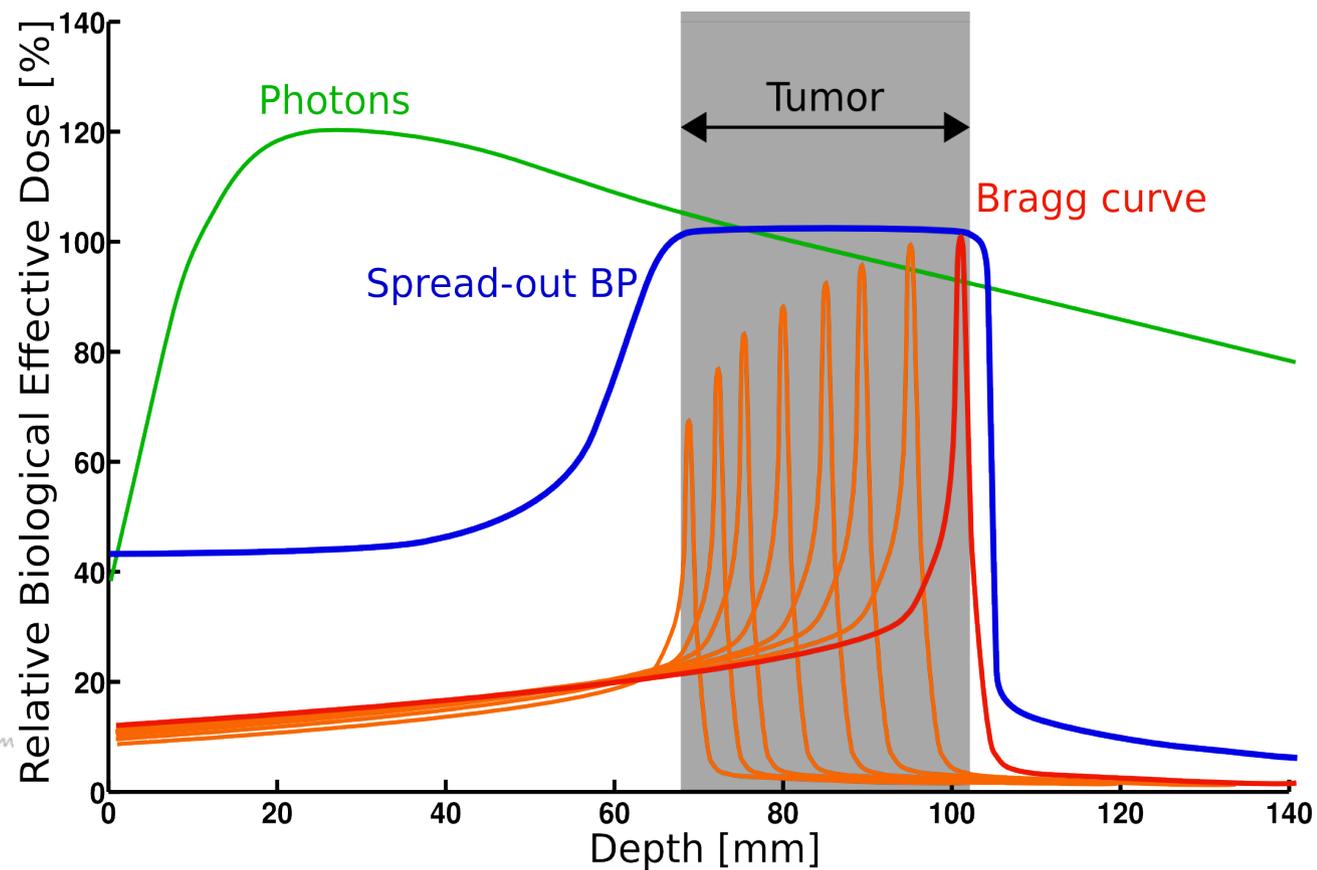
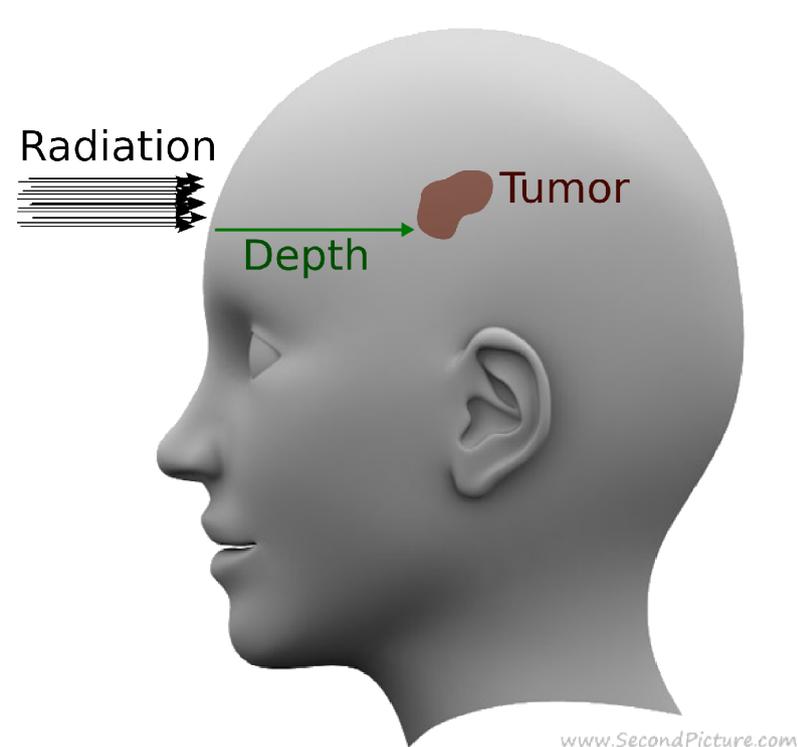
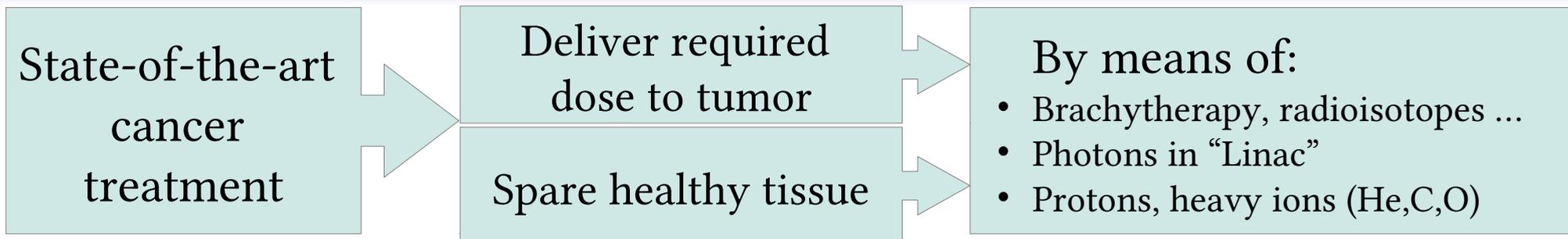
GERMAN
CANCER RESEARCH CENTER
IN THE HELMHOLTZ ASSOCIATION



ION THERAPY – WAY OF CANCER TREATMENT

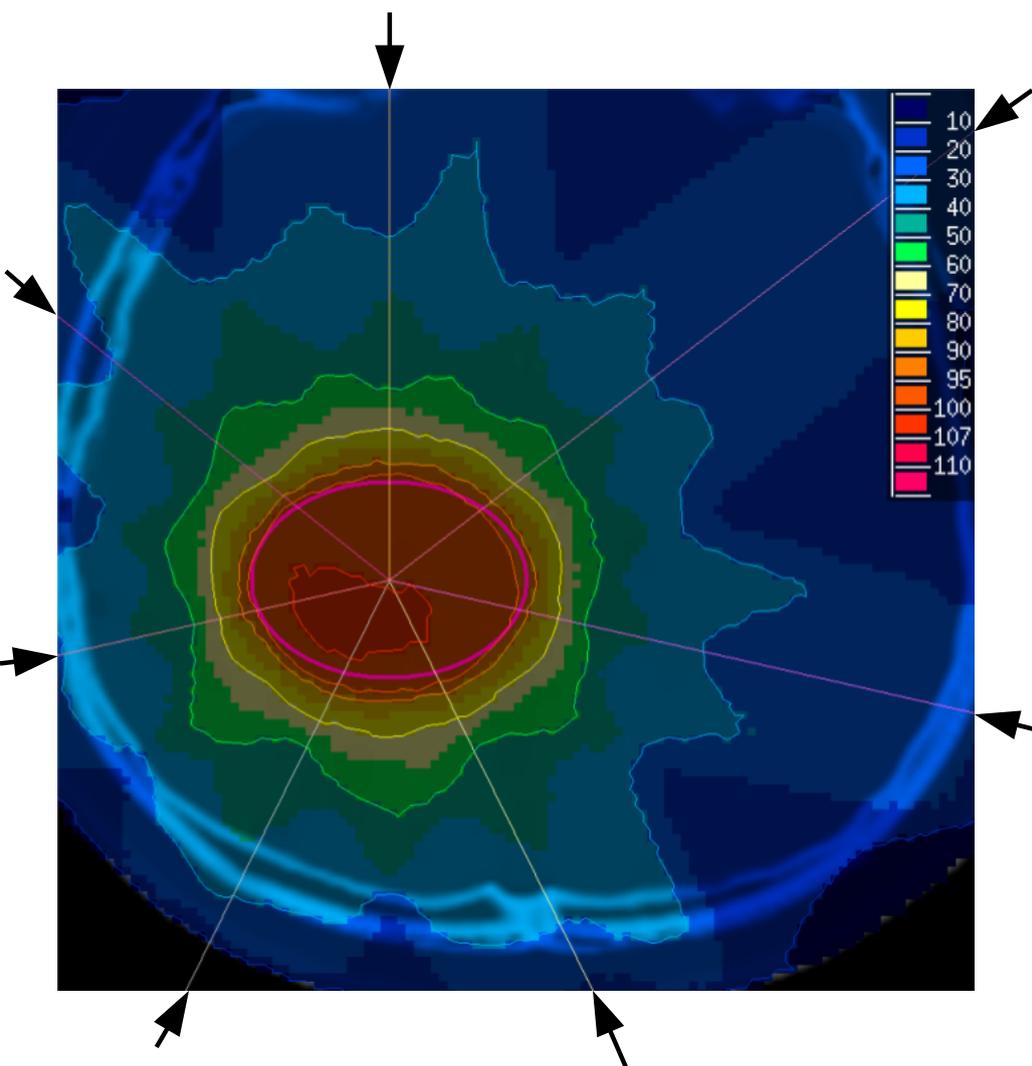


ION THERAPY – WAY OF CANCER TREATMENT

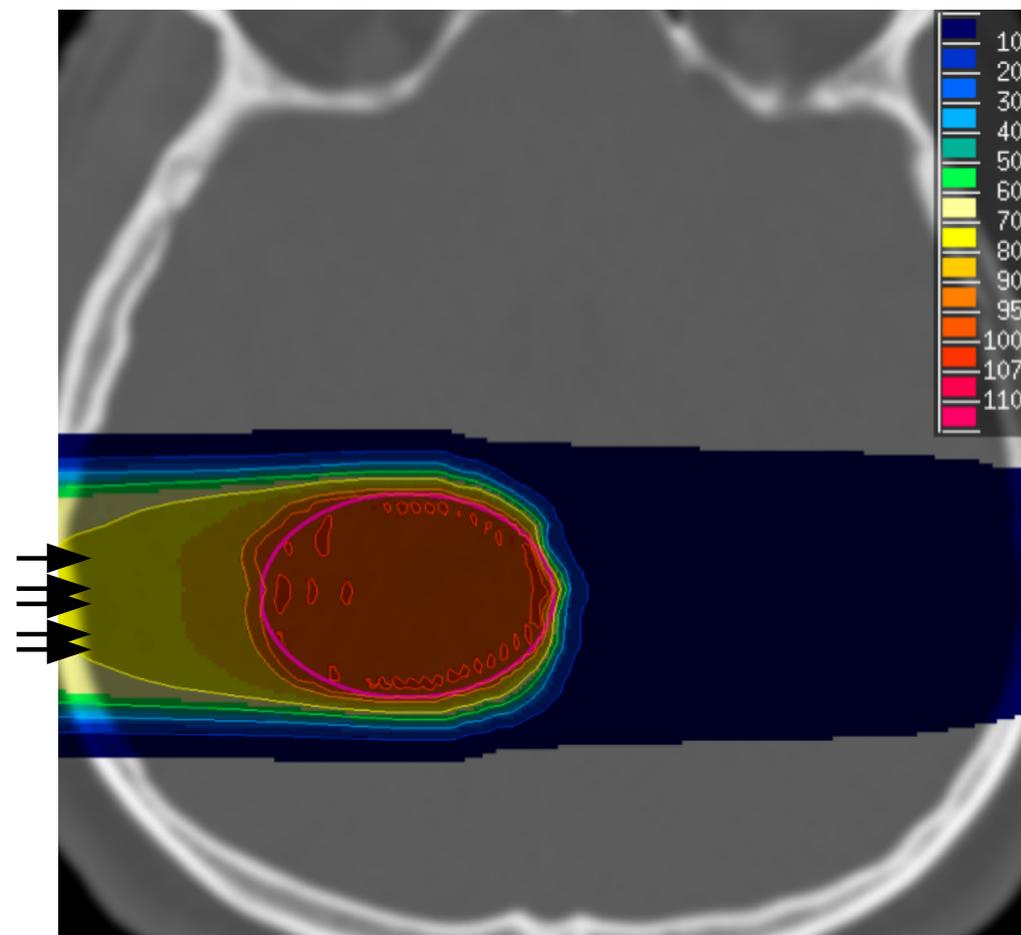


ION THERAPY – METHODS

Gamma treatment

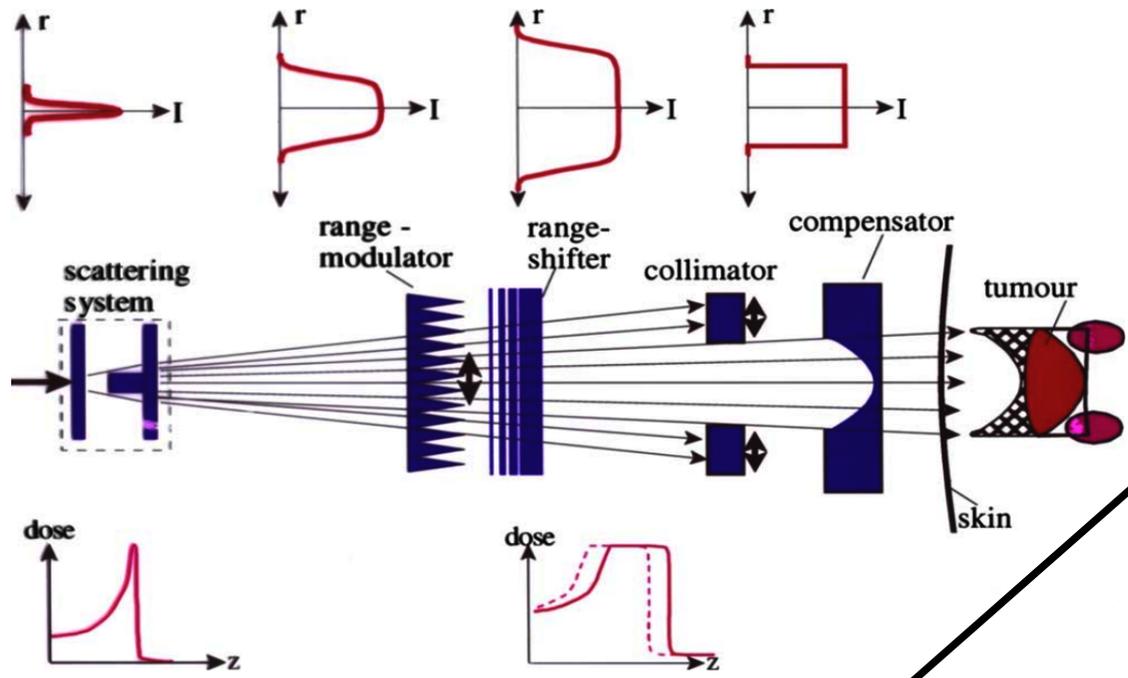


Ion treatment

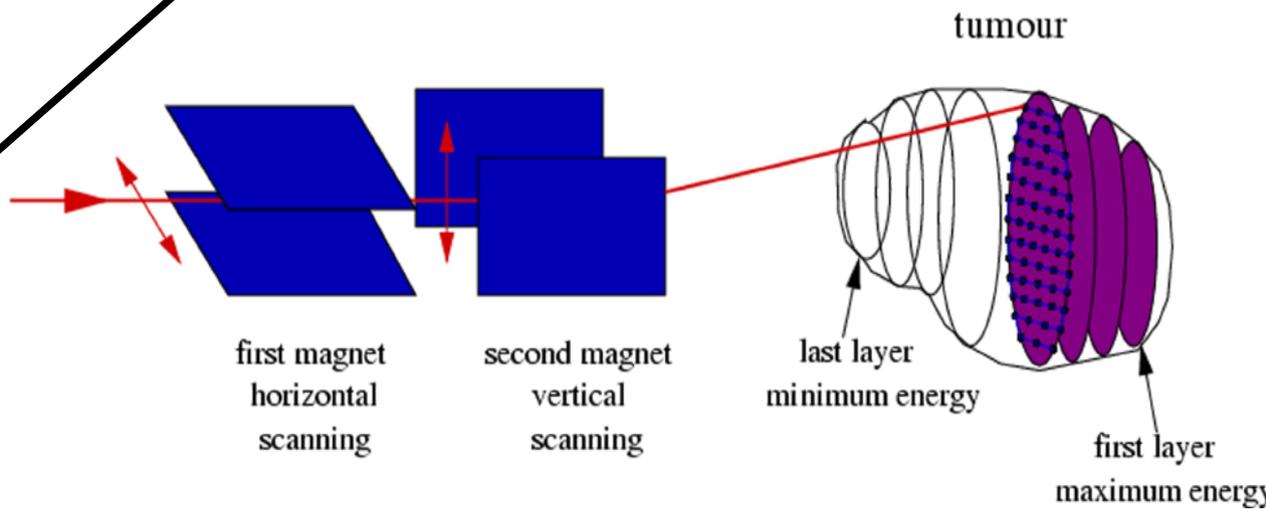


ION DELIVERY SYSTEMS

Passive beam



Scanning Beam



Schardt et. al, *Heavy-ion tumor therapy: Physical and radiobiological benefits*, Rev. Mod. Phys. 82, 383-425 (2010)

KRAKÓW – HEIDELBERG



by car: 1050 km

Dresden

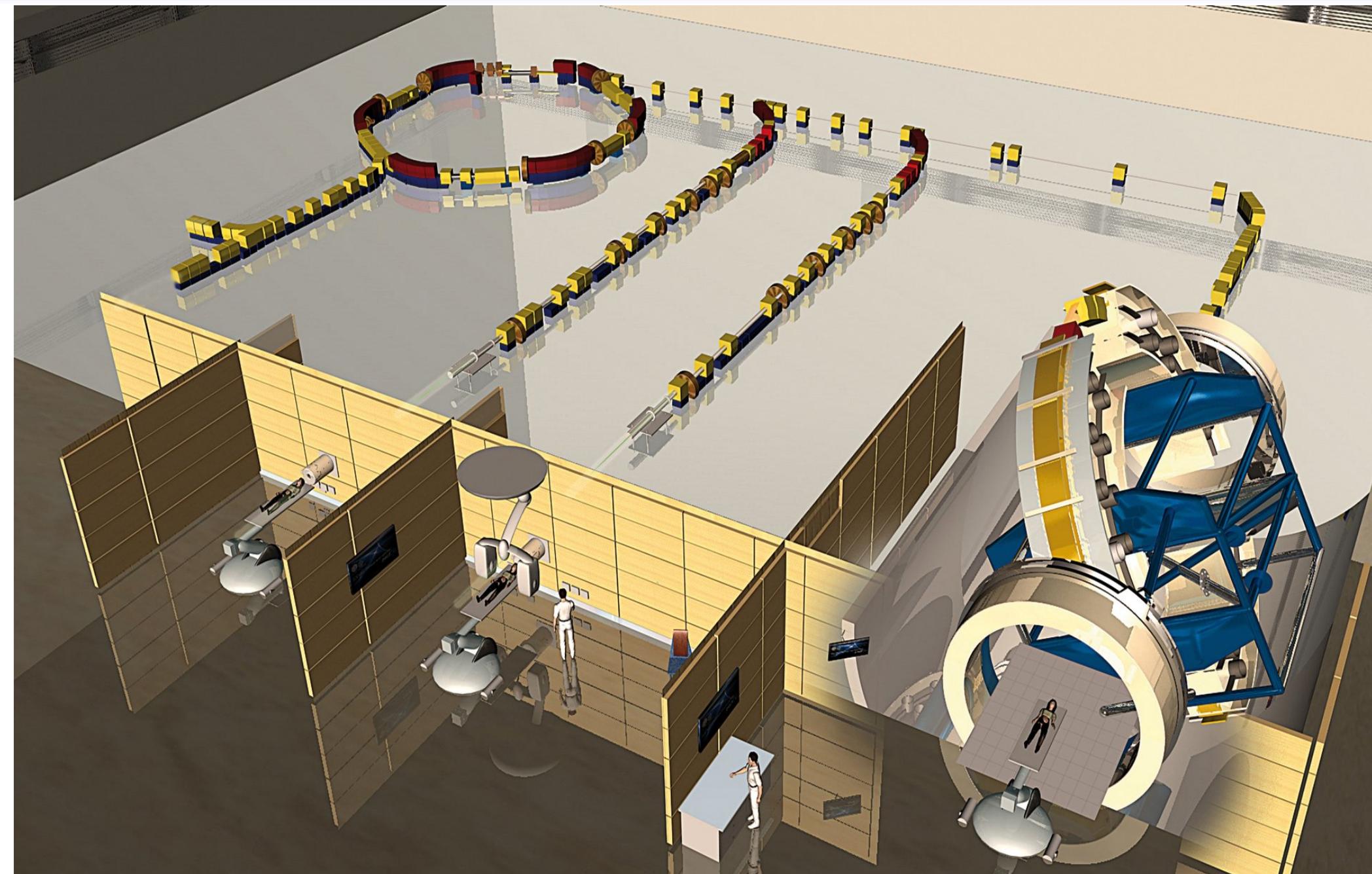
Kraków

walking: 930 km

Prague

Heidelberg

HEIDELBERG ION BEAM THERAPY CENTER (HIT)



HIT SCANNING BEAM ONLY BUT A HUGE GANTRY



www.klinikum.uni-heidelberg.de

HIT facility properties:

- Carbon energies: 88 – 430 MeV/u
 - Proton energies: 48 – 221 MeV
 - Range in H₂O: 2 – 30 cm (1.5 mm step)
 - Spot sizes: 4 mm for ¹²C – 30 mm for ⁺p
 - Field for Scanning: 20x20 cm²
- } 255 steps

QUALITY ASSURANCE OF ION BEAM

Different tools for beam QA

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graph TD; Root[Different tools for beam QA] --> Radiographic[Radiographic films]; Root --> Gafchromic[Gafchromic® films]; Root --> Ionization[2-D arrays of ionization chambers]; Root --> FlatPanel[Flat-panel detectors]; Root --> TLD[2D TLD]; Root --> Scintillator[Scintillator + camera]; Root --> MWPC[multi-wire proportional chamber]; Root --> Photodiodes[Single/multi photodiodes];
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Radiographic films

Gafchromic[®] films

2-D arrays of
ionization chambers

Flat-panel detectors

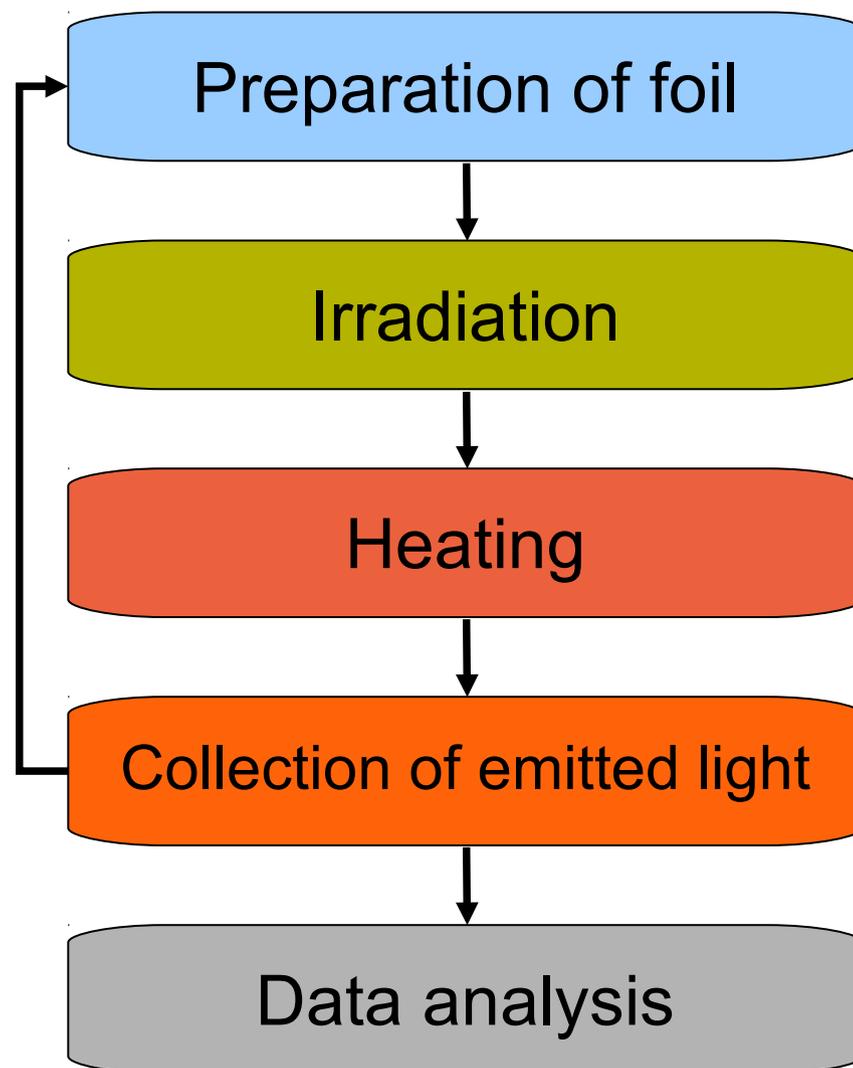
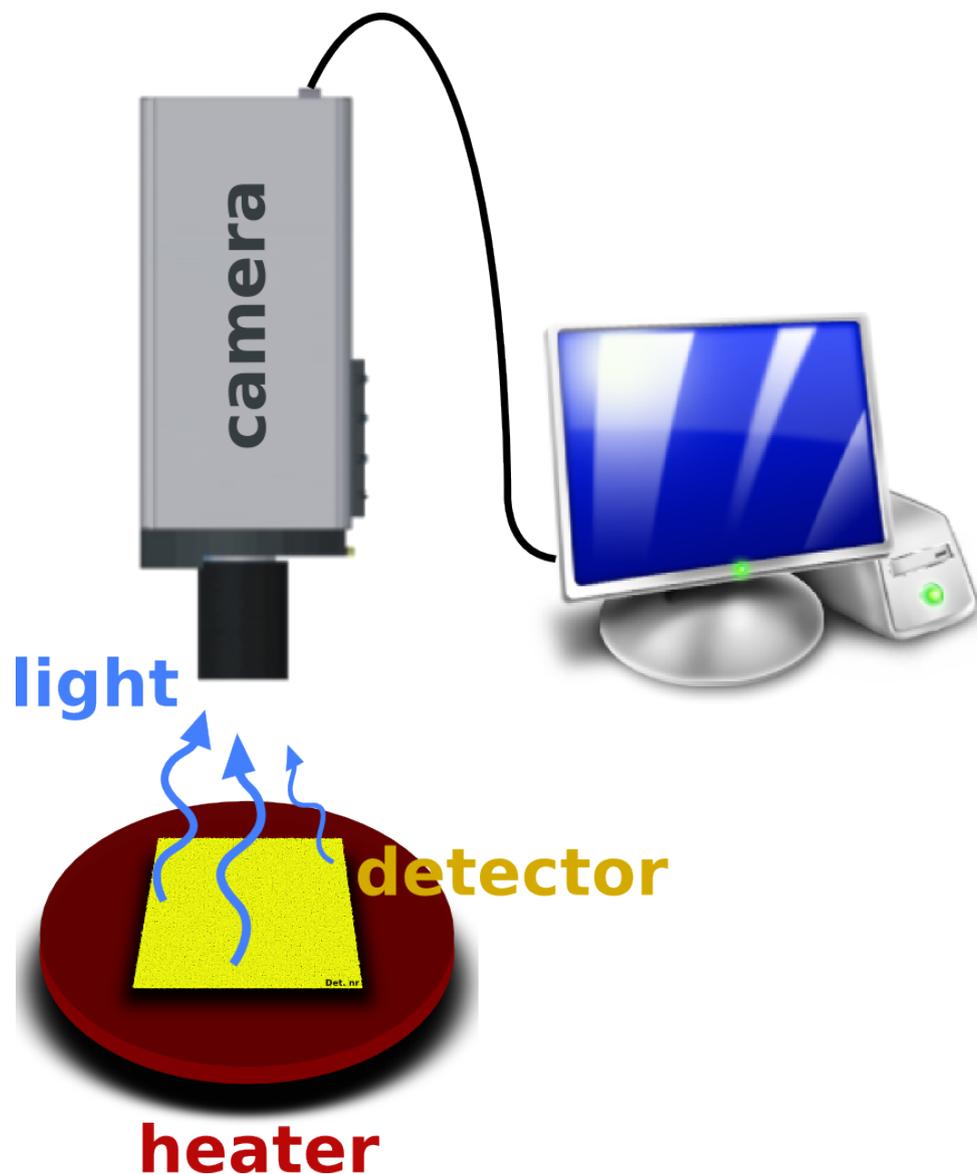
2D TLD

Scintillator + camera

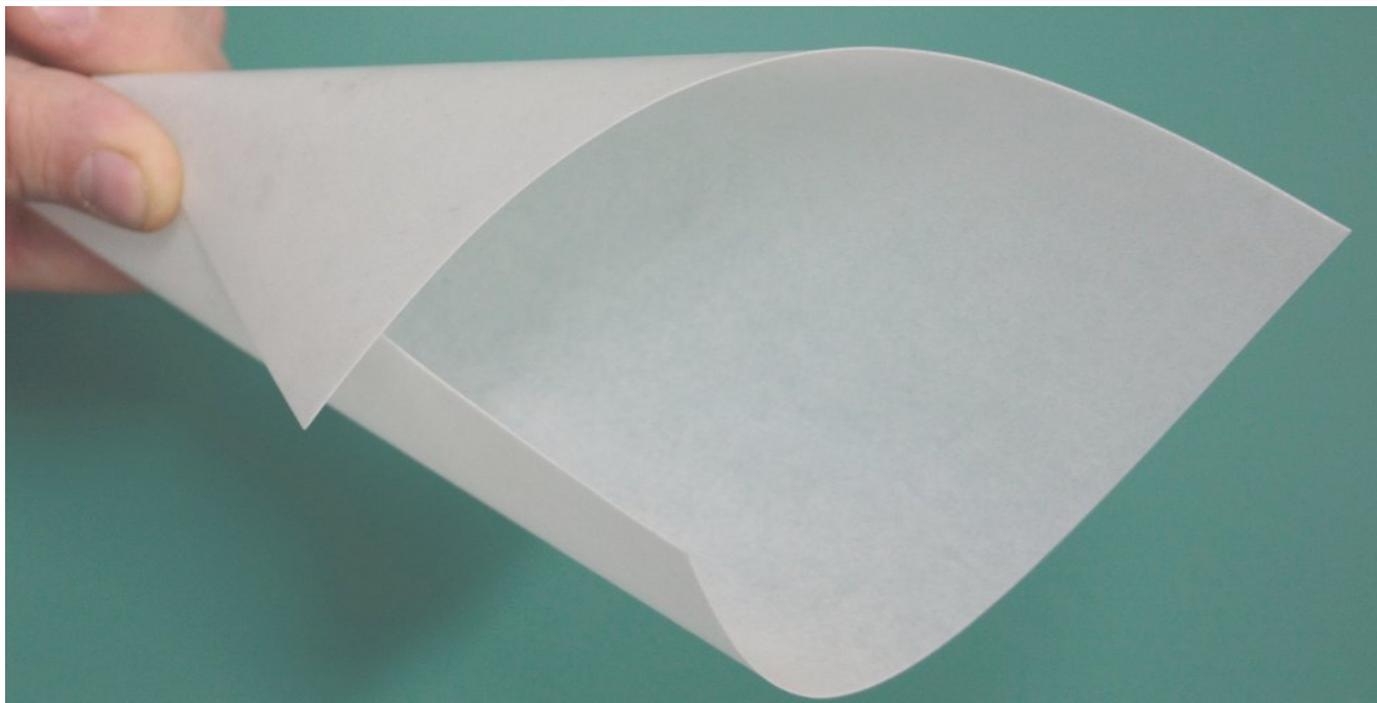
multi-wire
proportional chamber

Single/multi photodiodes

THE PRINCIPLE OF 2D TL DOSIMETRY



DOSIMETRIC SYSTEM



- Water resistance and flexibility
- Up to 20 x 20 cm²
- Reusability
- Resolution ~0.2 mm
- Linearity of dose response: 0.5-20 Gy
- $1\text{mm}_{\text{TLD}} = 1.64\text{mm}_{\text{H}_2\text{O}}$ (<0.01‰ ag. with MC sim.)

	MPC-2D	CaSO ₄
Z _{eff}	8.1	13.4

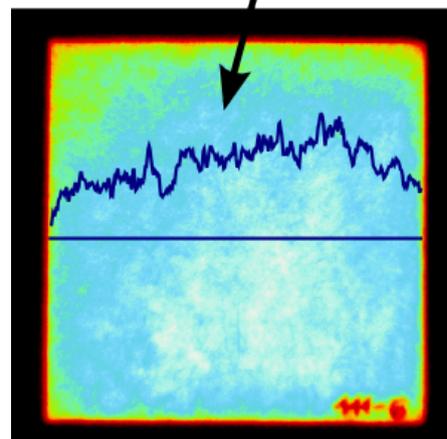


Clinical reader

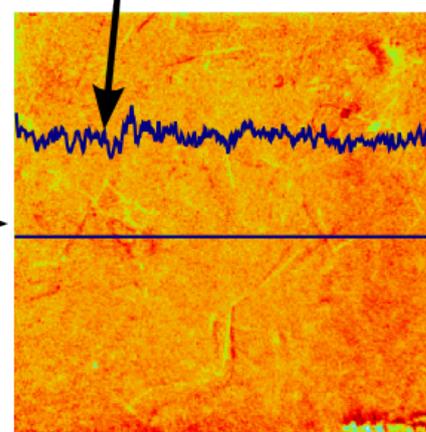
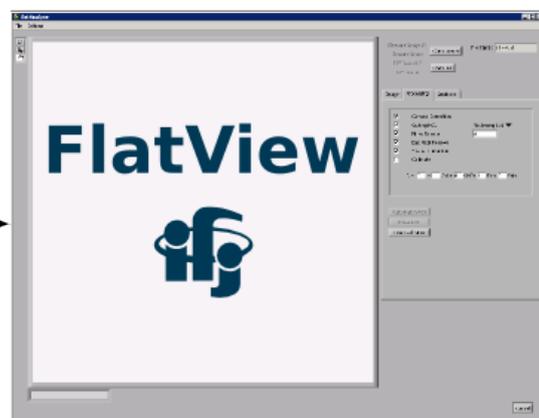
DOSIMETRIC PROPERTIES – UNIFORMITY

Measured Dose Profile

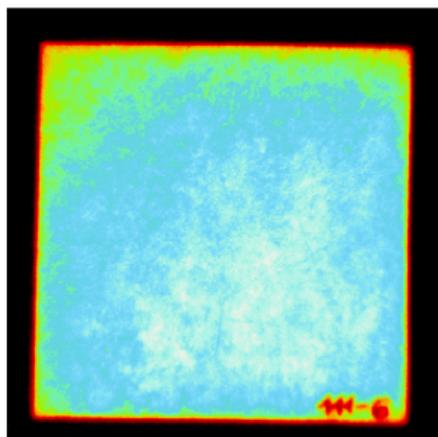
Corrected Dose Profile



Original Image

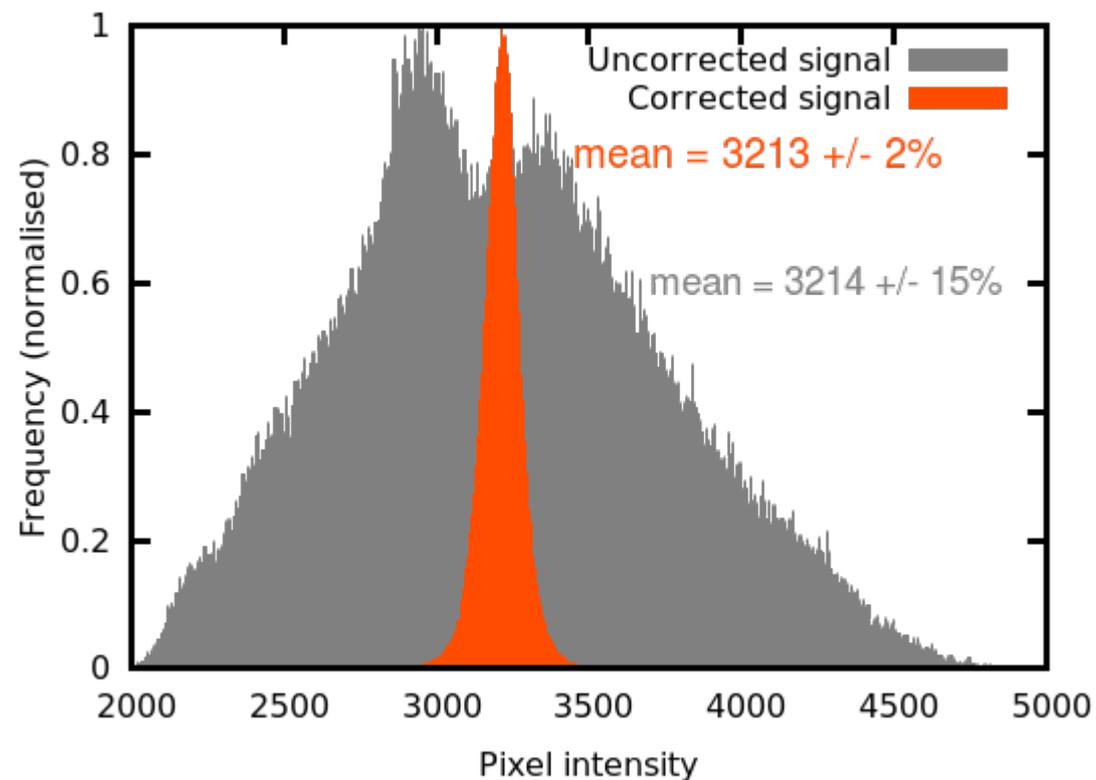


Corrected Image



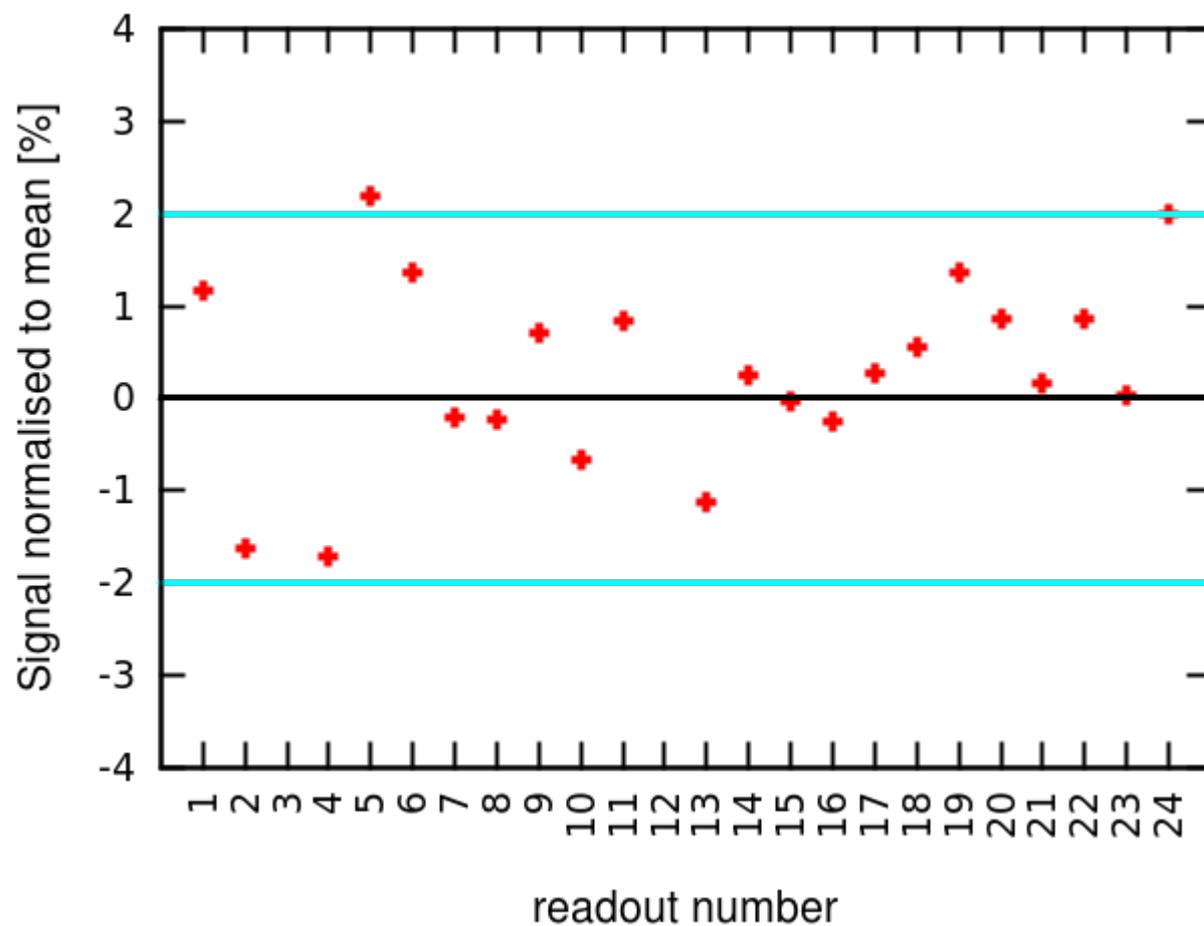
IRF Image

After
corrections the
uniformity of
readouts is
around 3%



DOSIMETRIC PROPERTIES – REPRODUCIBILITY

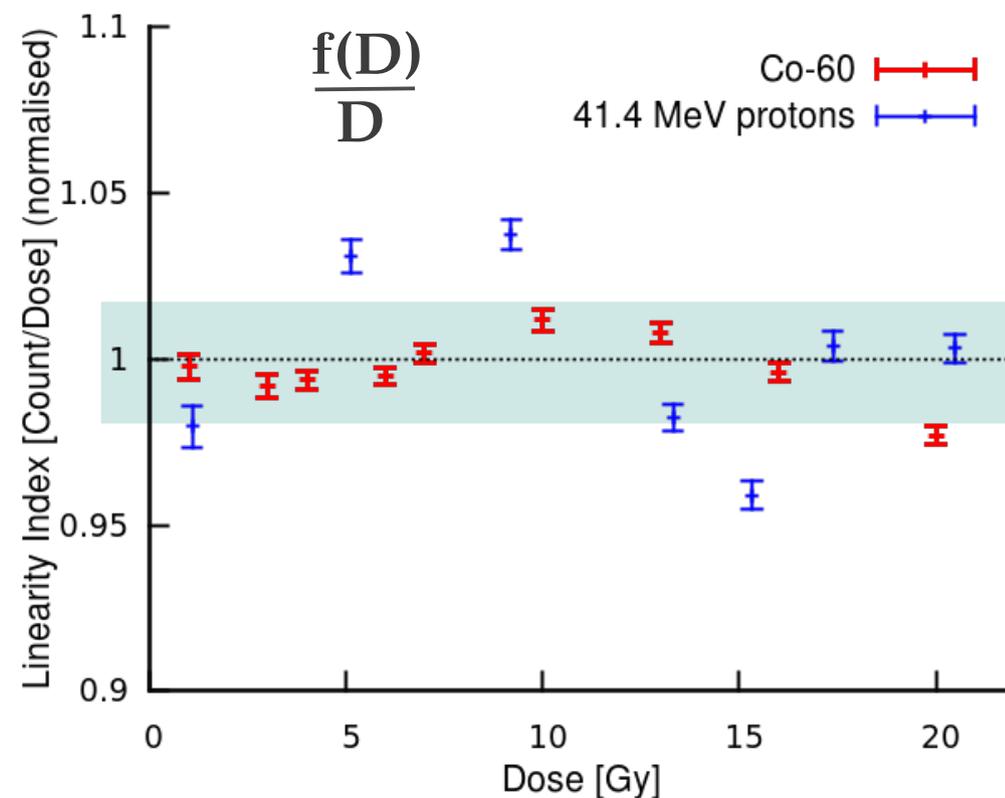
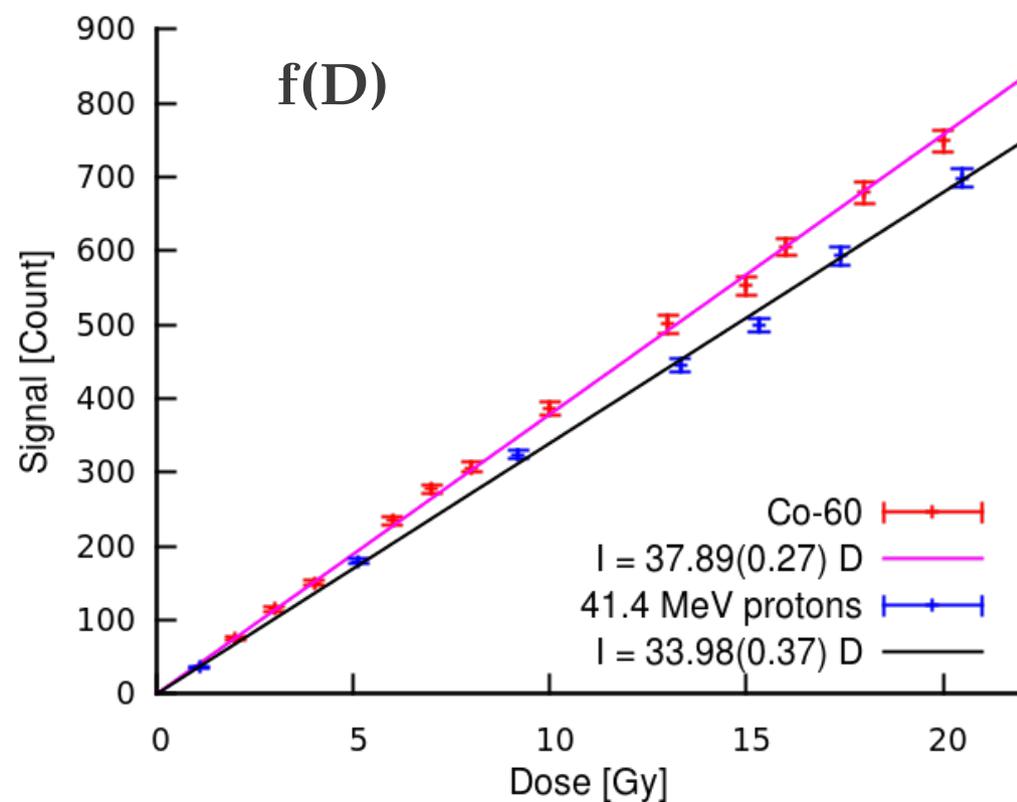
More than 20 equivalent irradiations and readouts



Repeatability was found below 3%

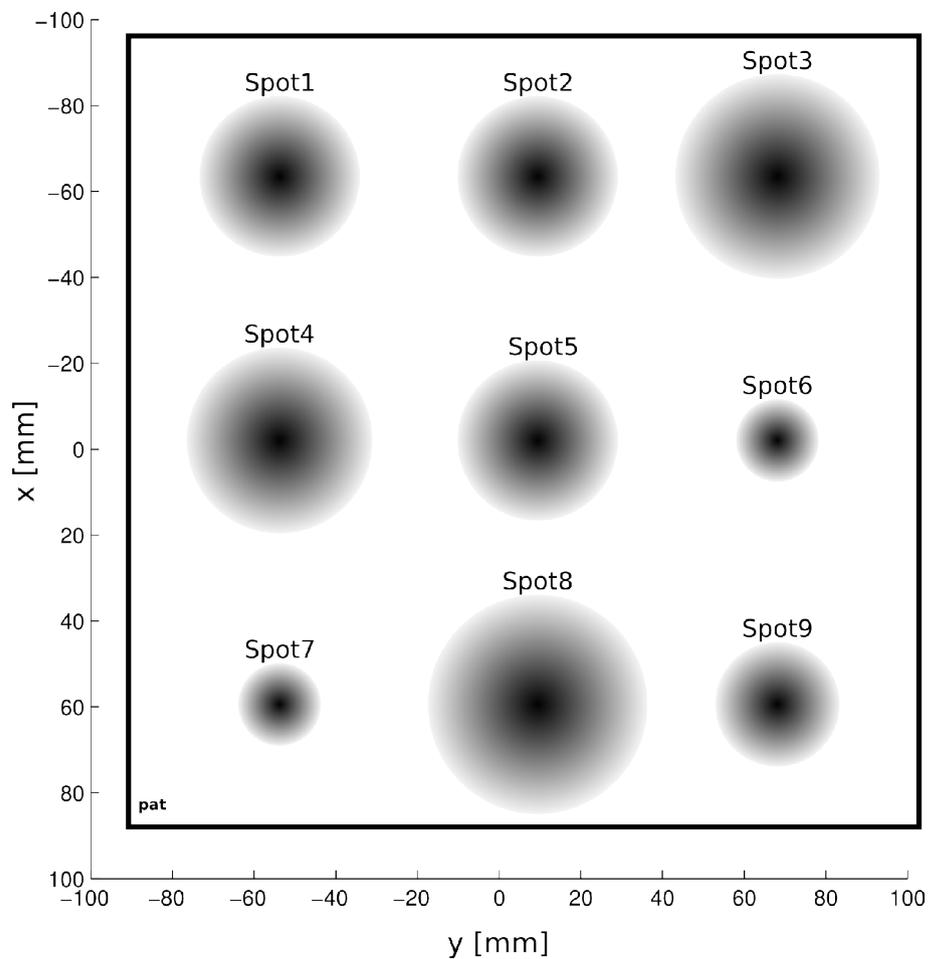
DOSIMETRIC PROPERTIES – DOSE RESPONSE

Linearity Index $\frac{f(D)}{D}$ is constant within $\pm 5\%$ for protons (older reader) and $\pm 3\%$ for Co-60 (newer reader)

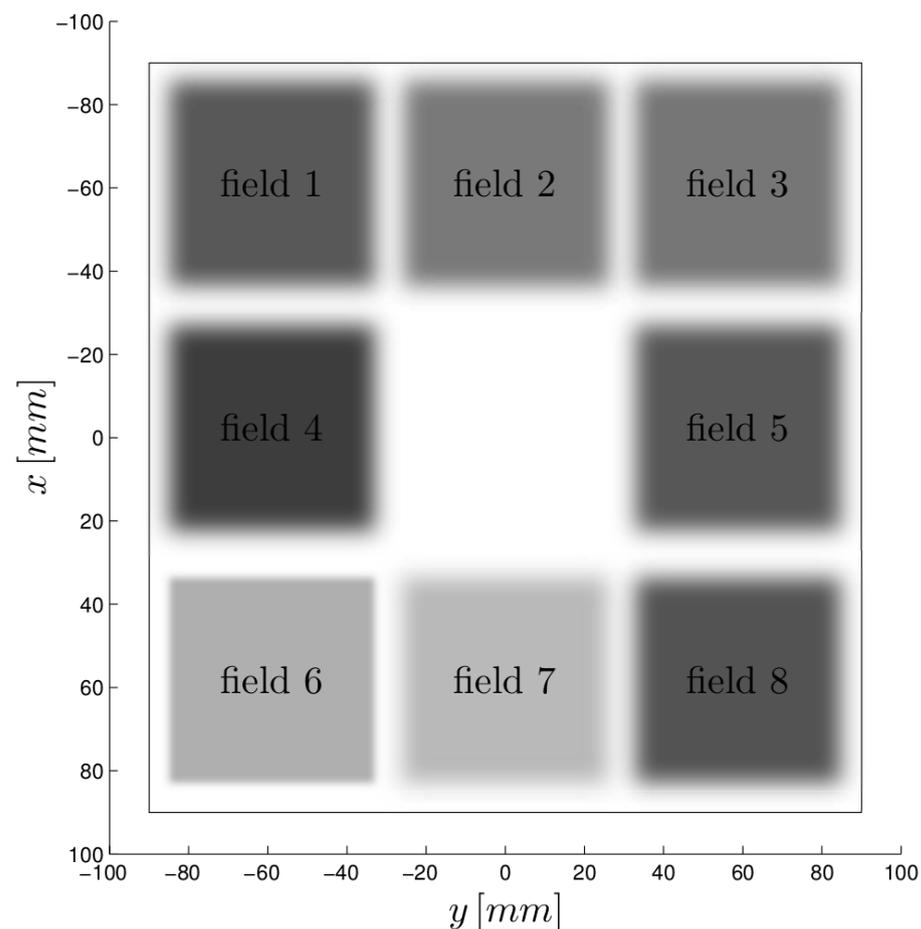


SCANNING BEAM QUALITY ASSURANCE

Main parameters in QA



Uniformity of large fields

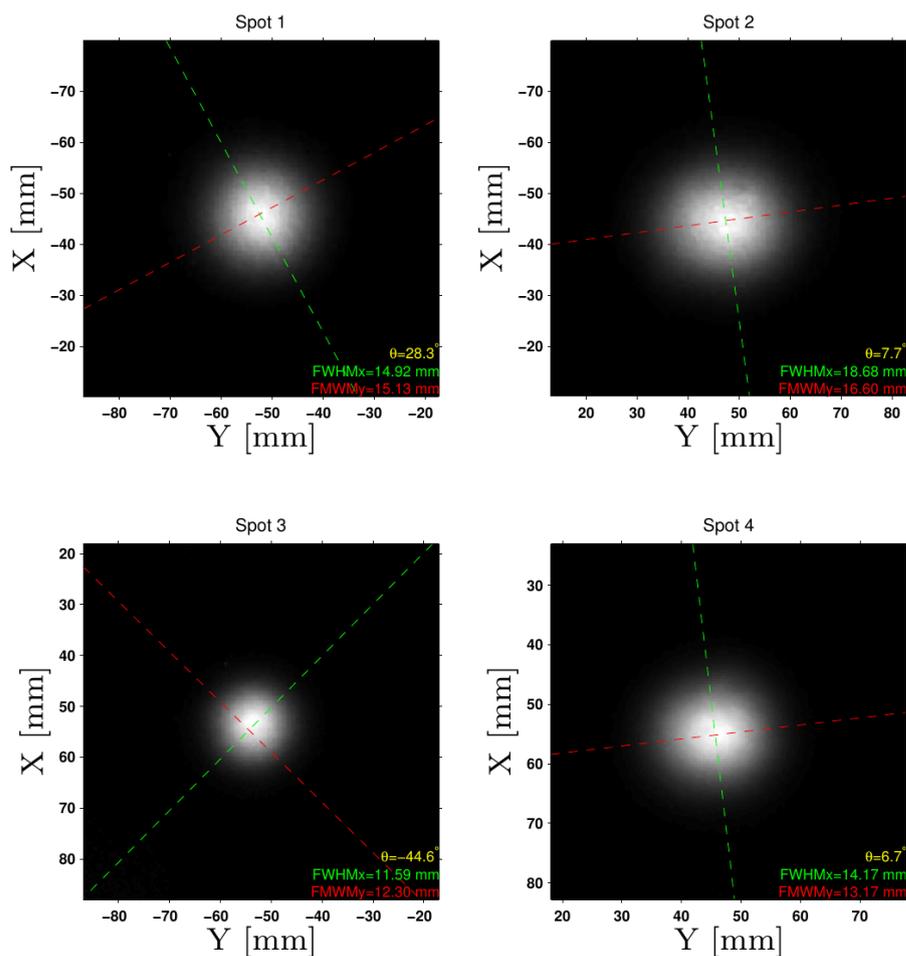


Positions and shapes of spots

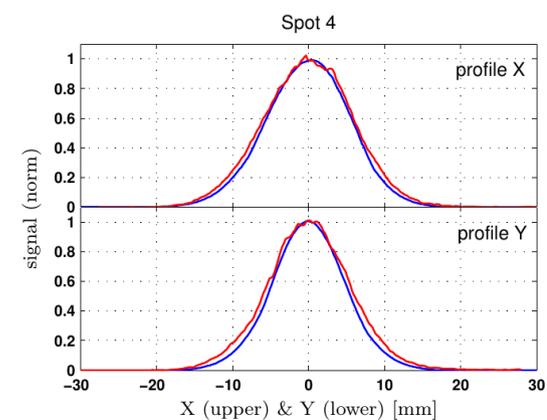
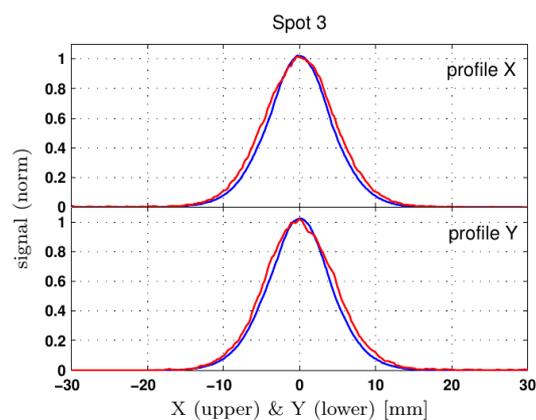
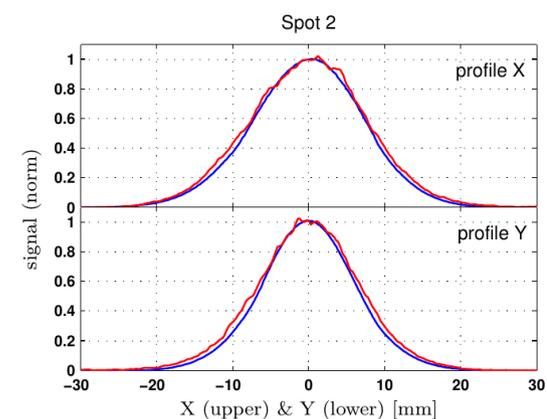
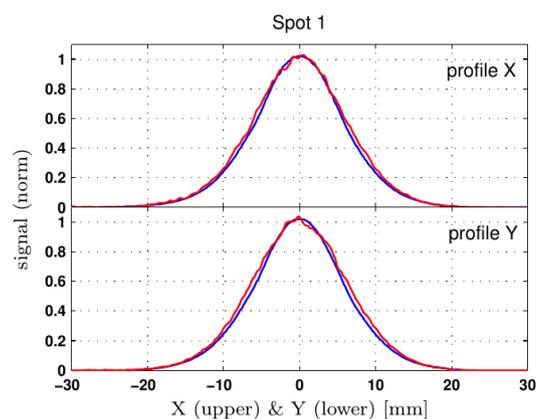
Scanning Beam QA – single spots

Reference methods:

- Fluka simulations
- Kodak® EDR2 films
- Multiwire Proportional Chamber



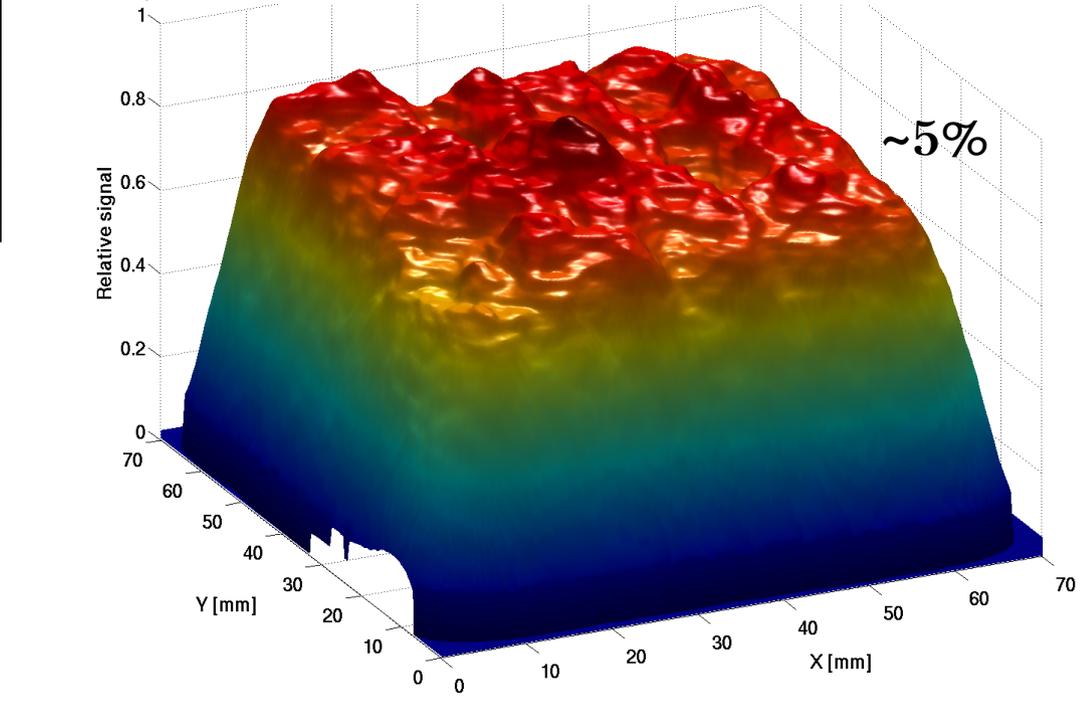
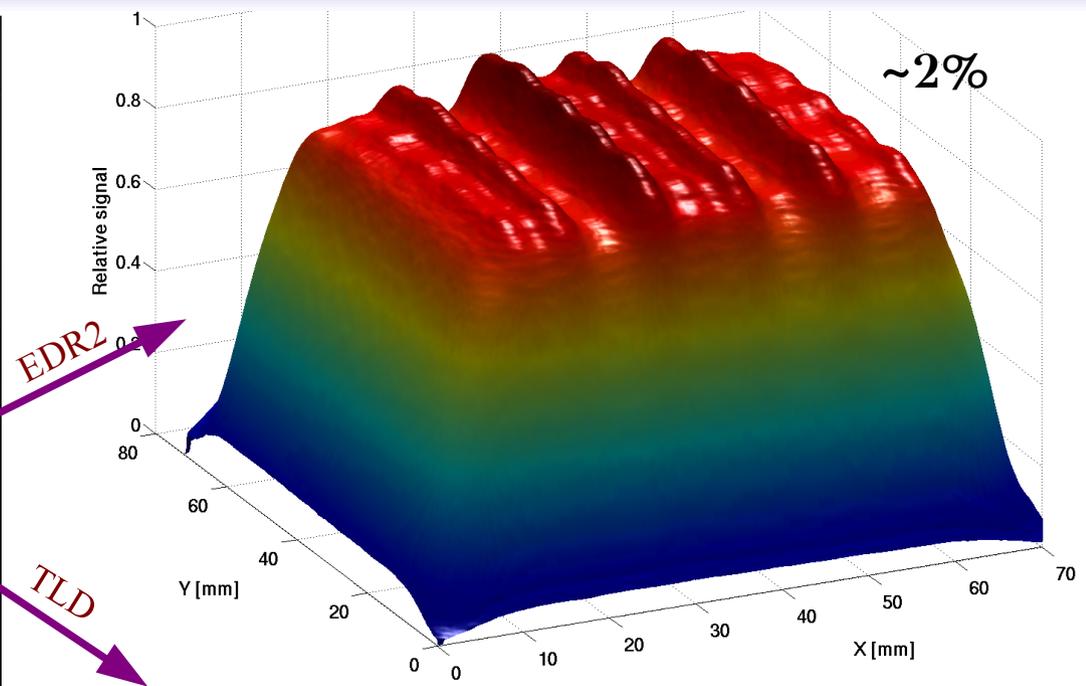
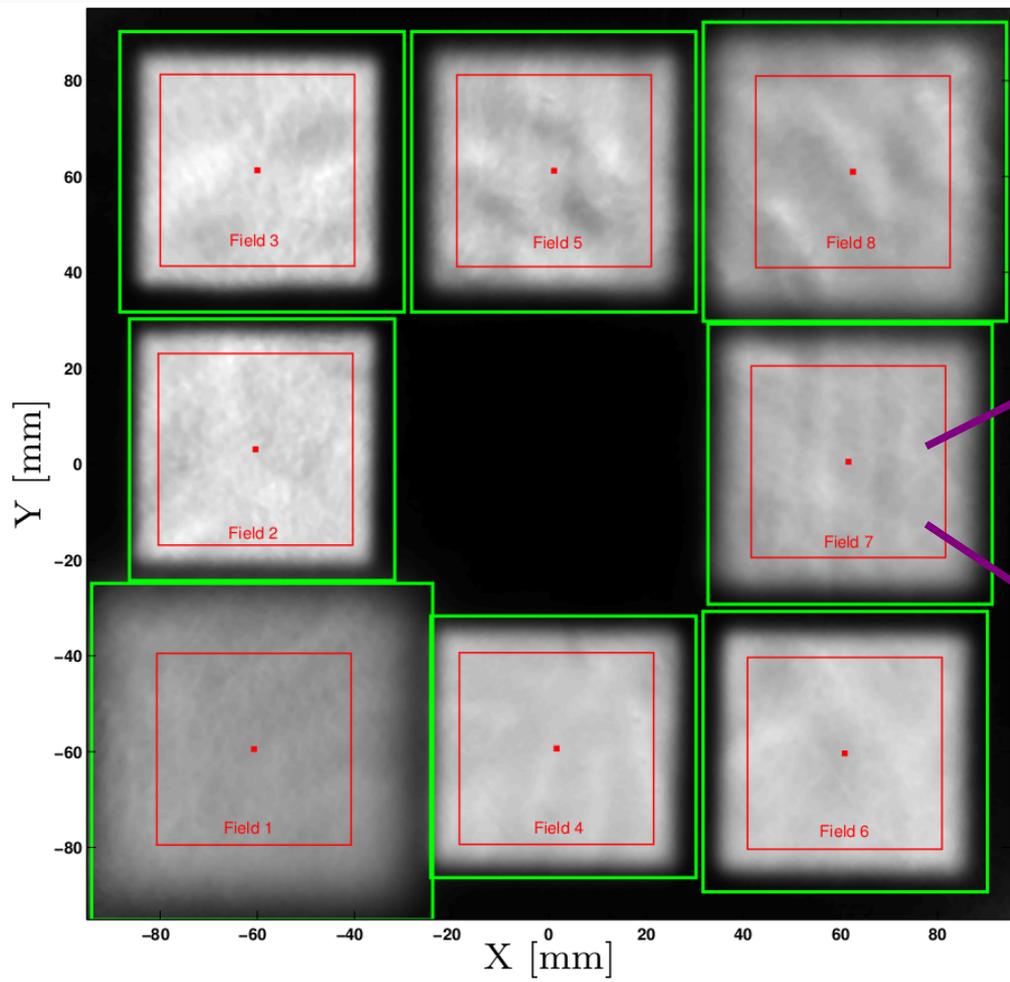
- Positions agree in $<1\%$ ($\sim 0.3\text{mm}$)
- Shapes the same in $\sim 10\%$



— EDR2 film

— TLD foils

Scanning Beam QA – uniform fields



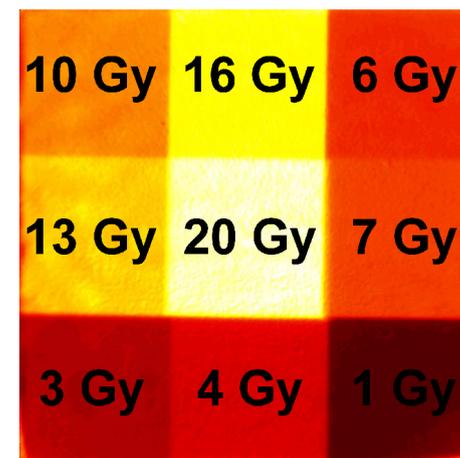
Uniformly irradiated fields

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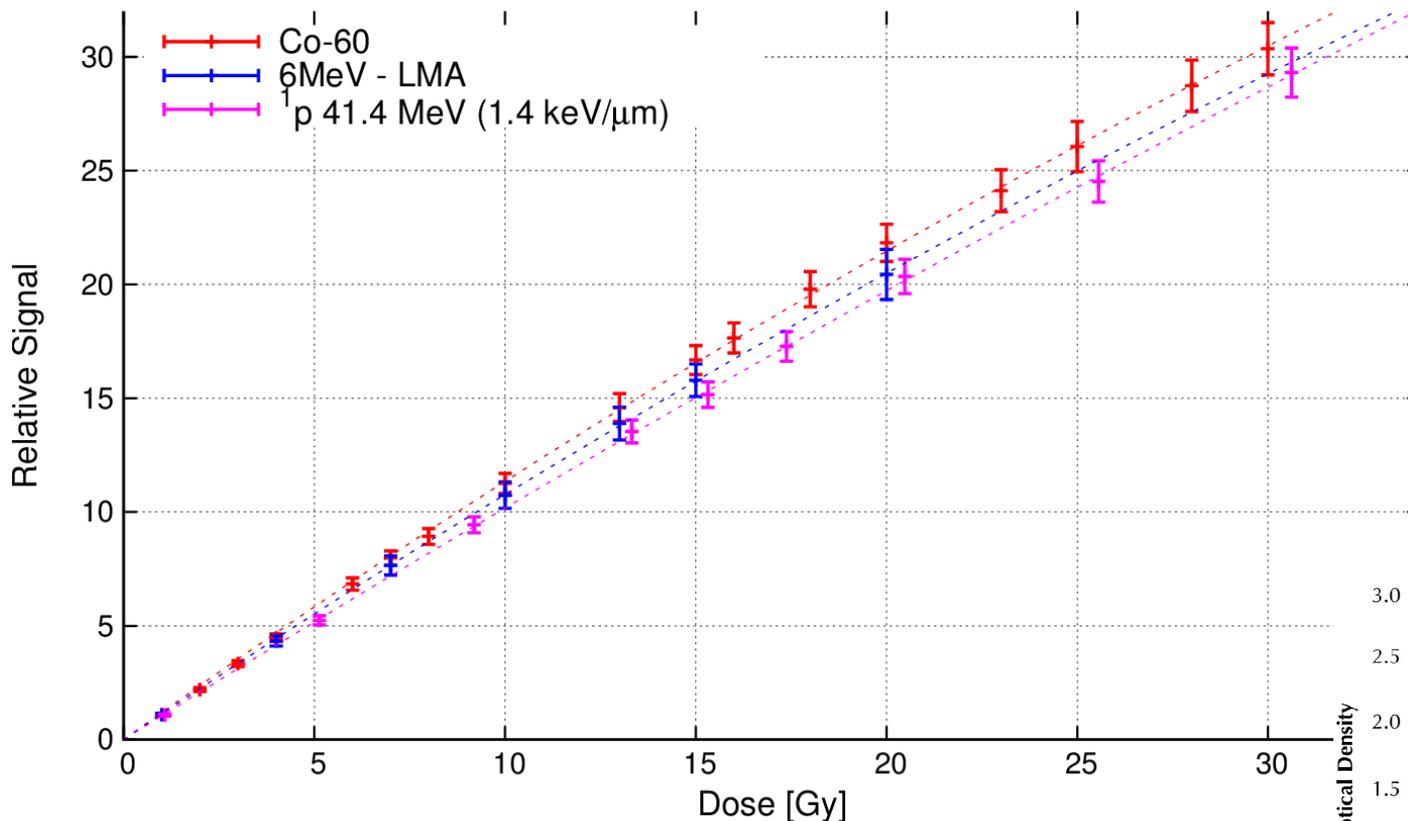
hundreds of spots

DOSE RESPONSE

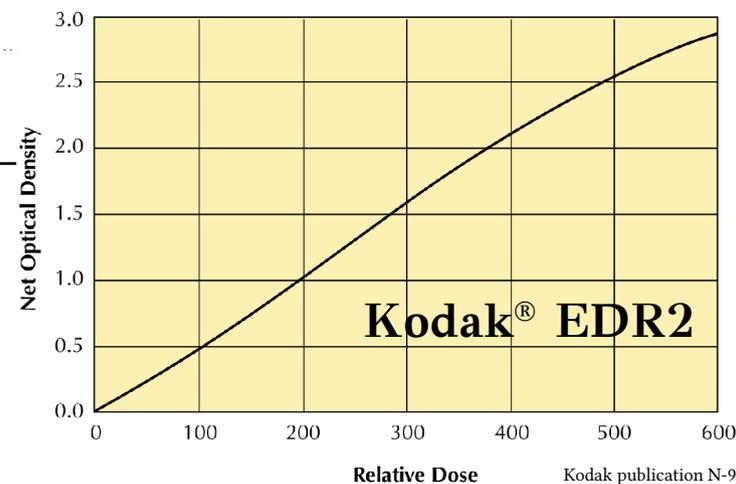
Amount of light \propto *absorbed dose*



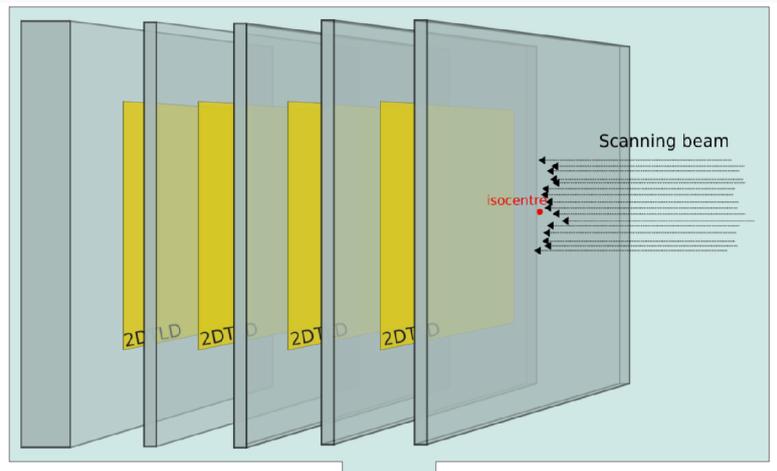
Different calibration for different radiation



Measurements with good agreement with model predictions

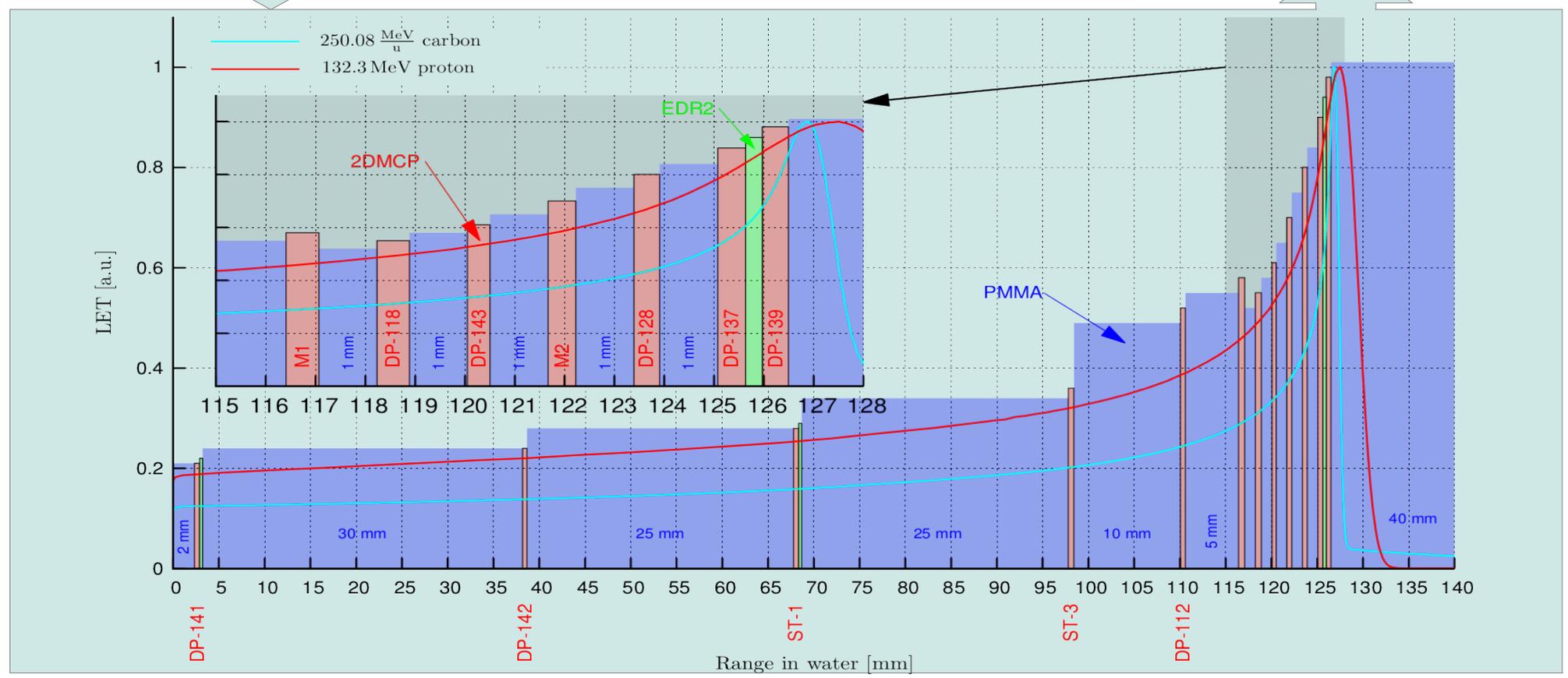
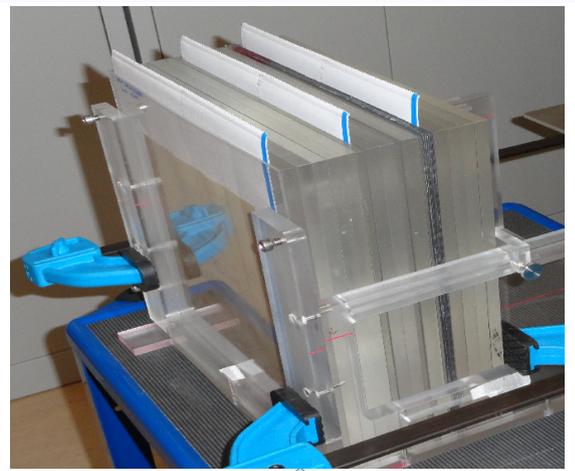


ENERGY/LET DEPENDENCE

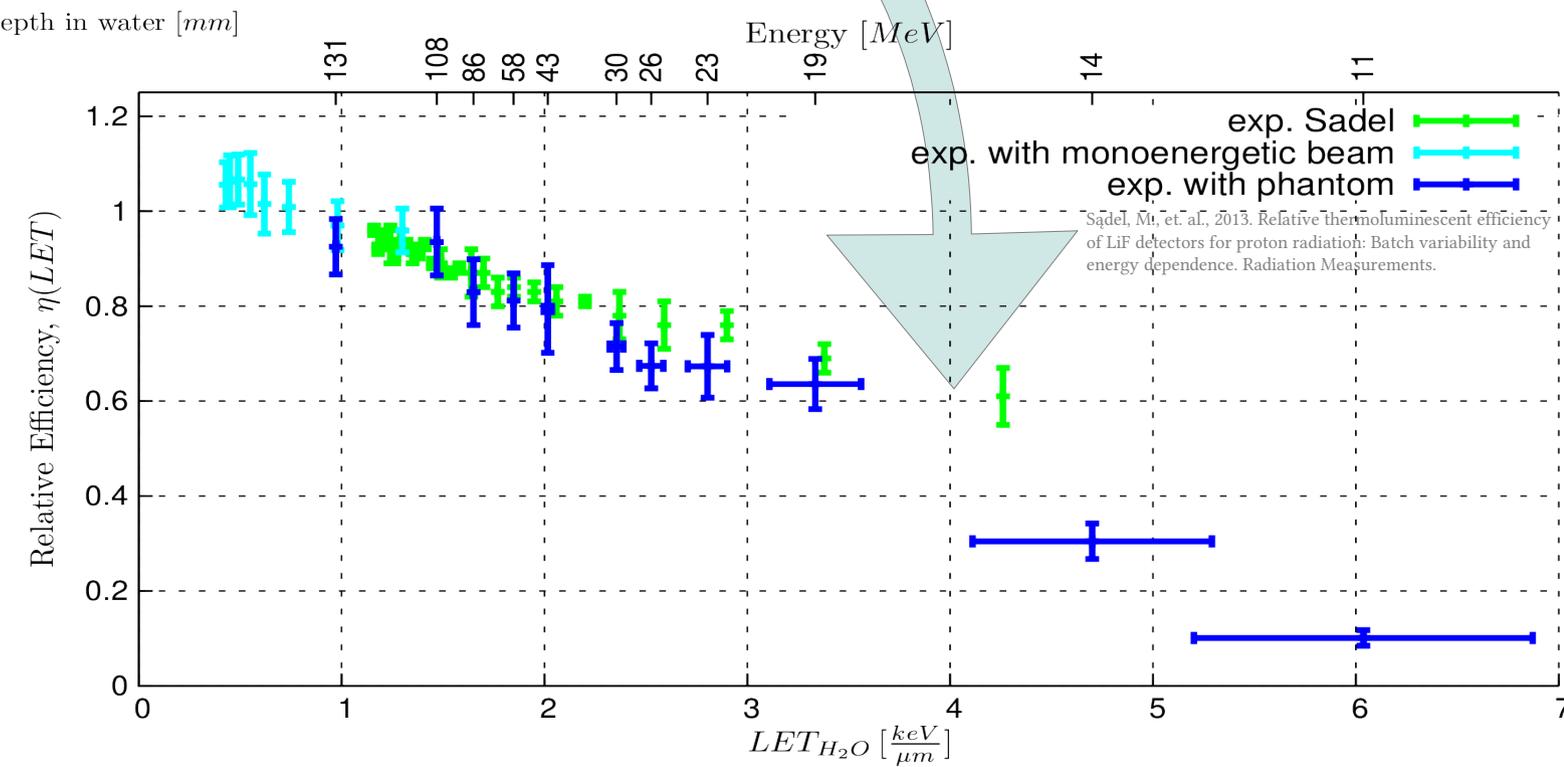
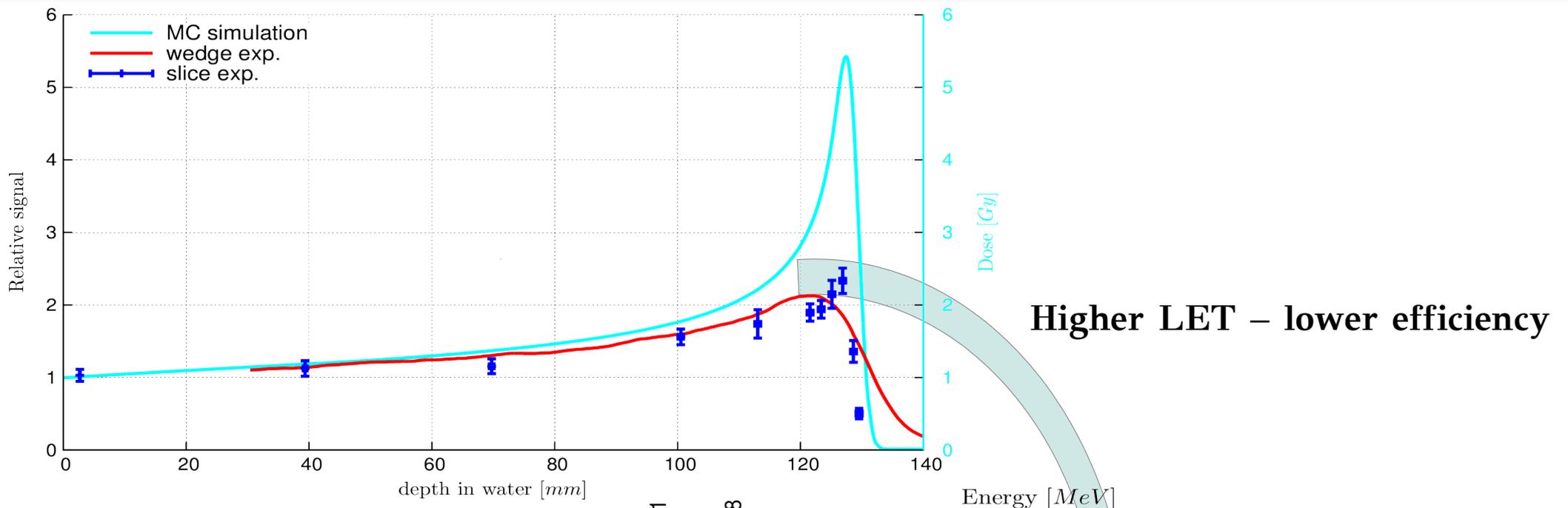


Different energy/LET = Different signal

Correction needed



ENERGY/LET DEPENDENCE



Good agreement
with other
experiments

Sadel, M., et. al., 2013. Relative thermoluminescent efficiency of LiF detectors for proton radiation: Batch variability and energy dependence. Radiation Measurements.

SUMMARY

Made at HIT:

- The main dosimetric properties measured
- Suitability for scanning beams QA checked



TO DO:

- Prepare procedures of usage
- Prepare standards for scanning beam QA
- Use the system at CCB



Thank You for Your attention



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**INNOWACYJNA
GOSPODARKA**
NARODOWA STRATEGIA SPÓJNOŚCI



UNIWERSYTET
JAGIELLOŃSKI
W KRAKOWIE



Fundacja na rzecz
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