Proton Minibeam Radiotherapy:

Dose distribution and cell survival

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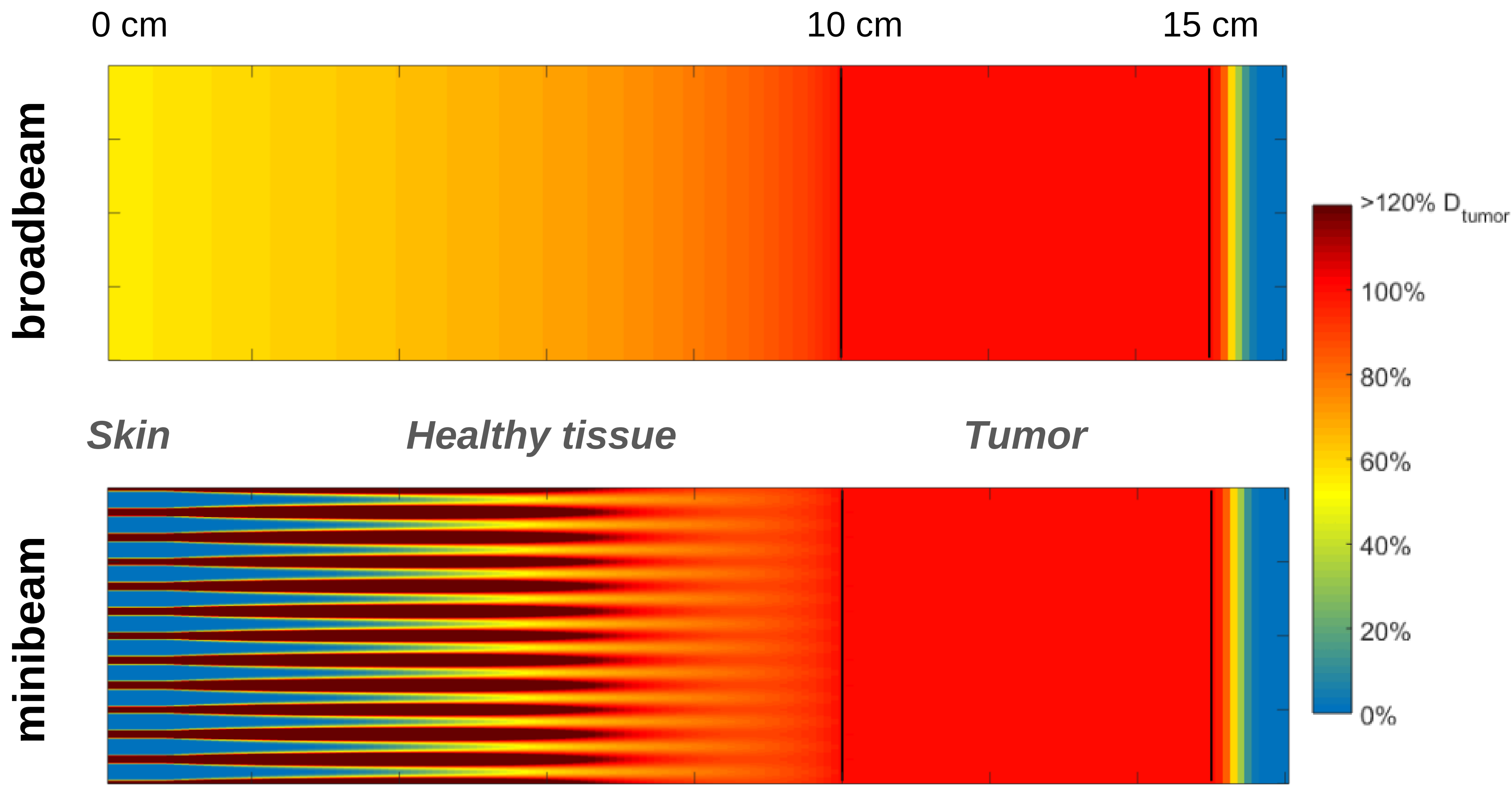
Geneva, 17 February 2016

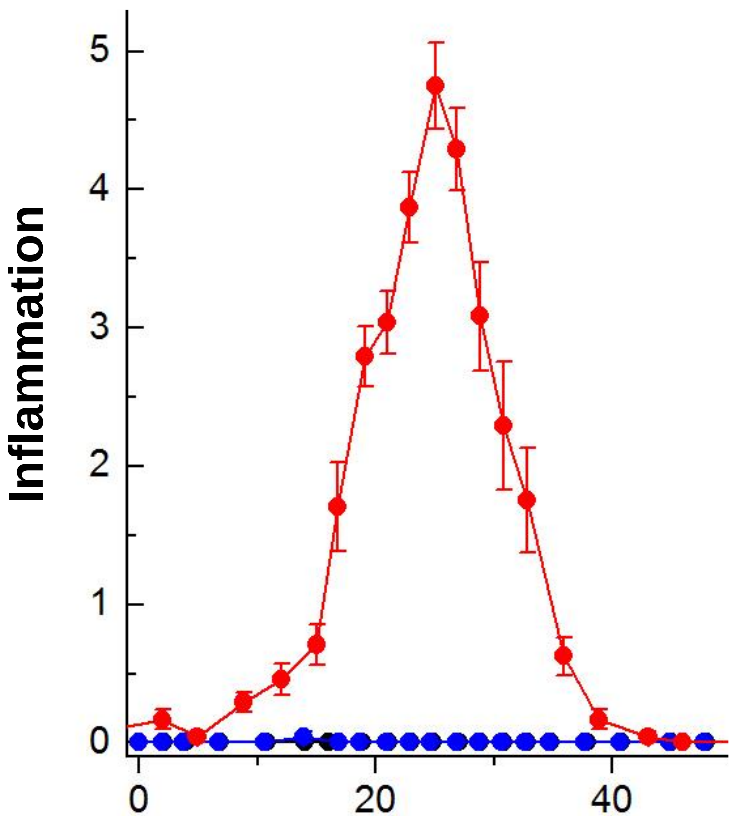
Concept of proton minibeams



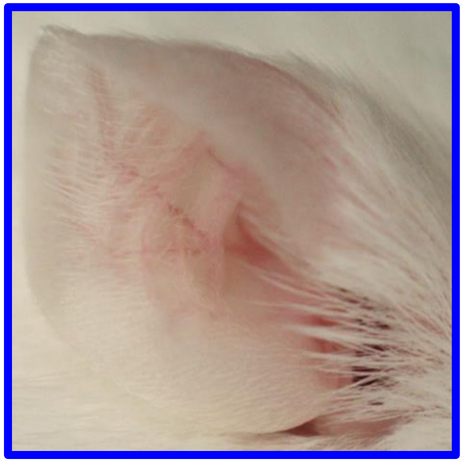
- Tissue sparing, reduced side effects
- normal tumor control

Proton minibeams: tissue sparing

60 Gy average dose



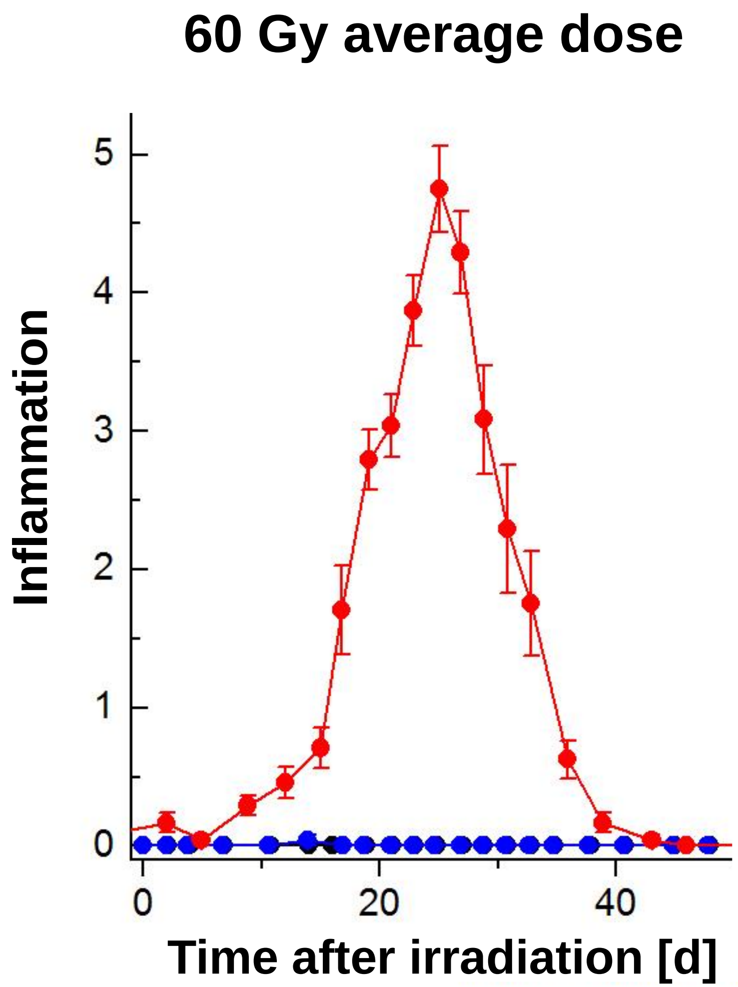
- **broadbeam**
- **minibeam**



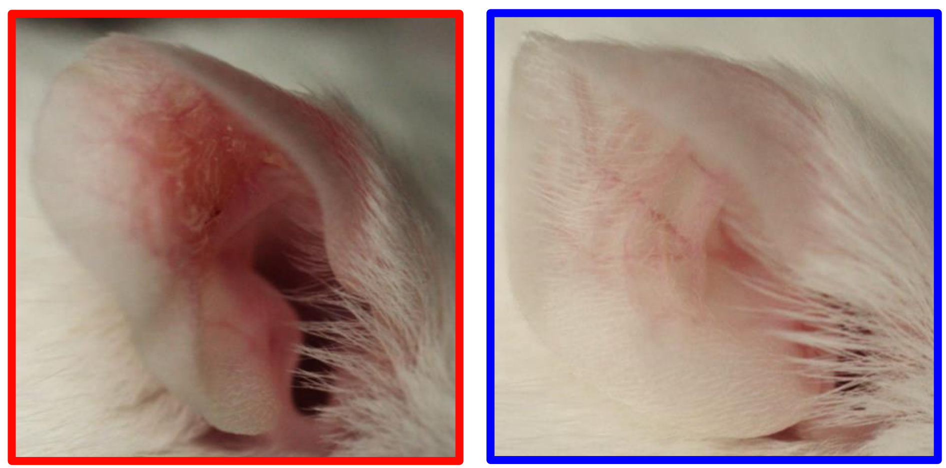
Day 25

Girst et al., Int J Radiat Oncol Biol Phys (2015)

Proton minibeams: tissue sparing



- broadbeam
- minibeam



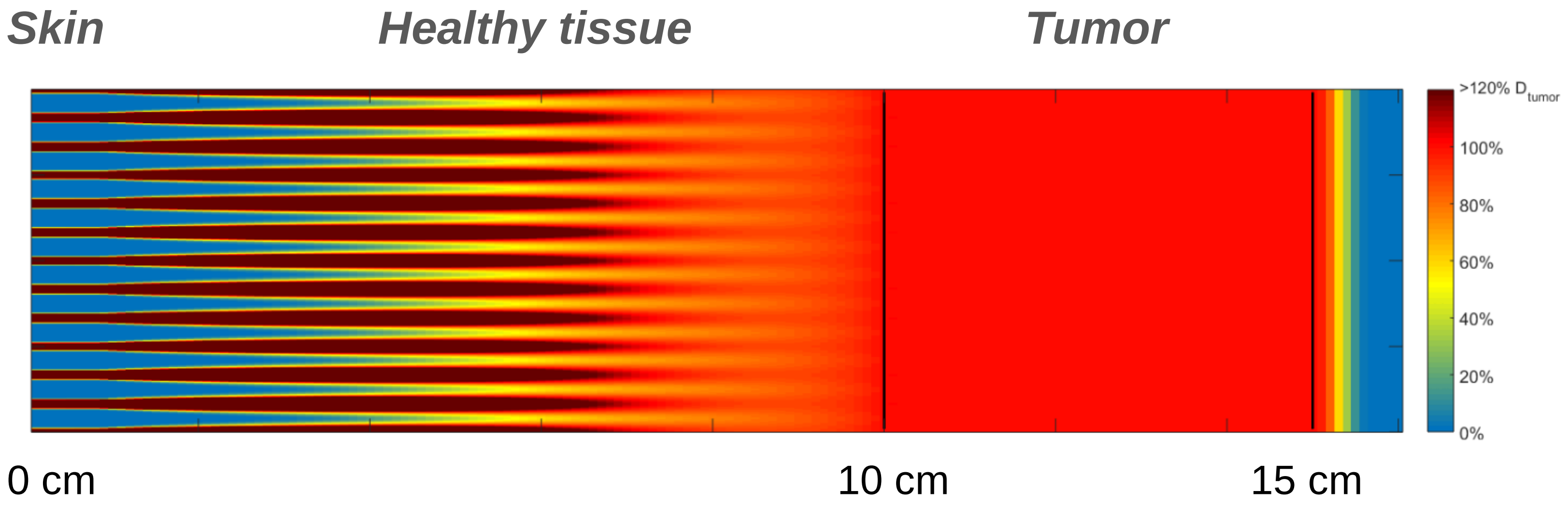
Day 25

For more details see Poster #79!

Girst et al., Int J Radiat Oncol Biol Phys (2015)

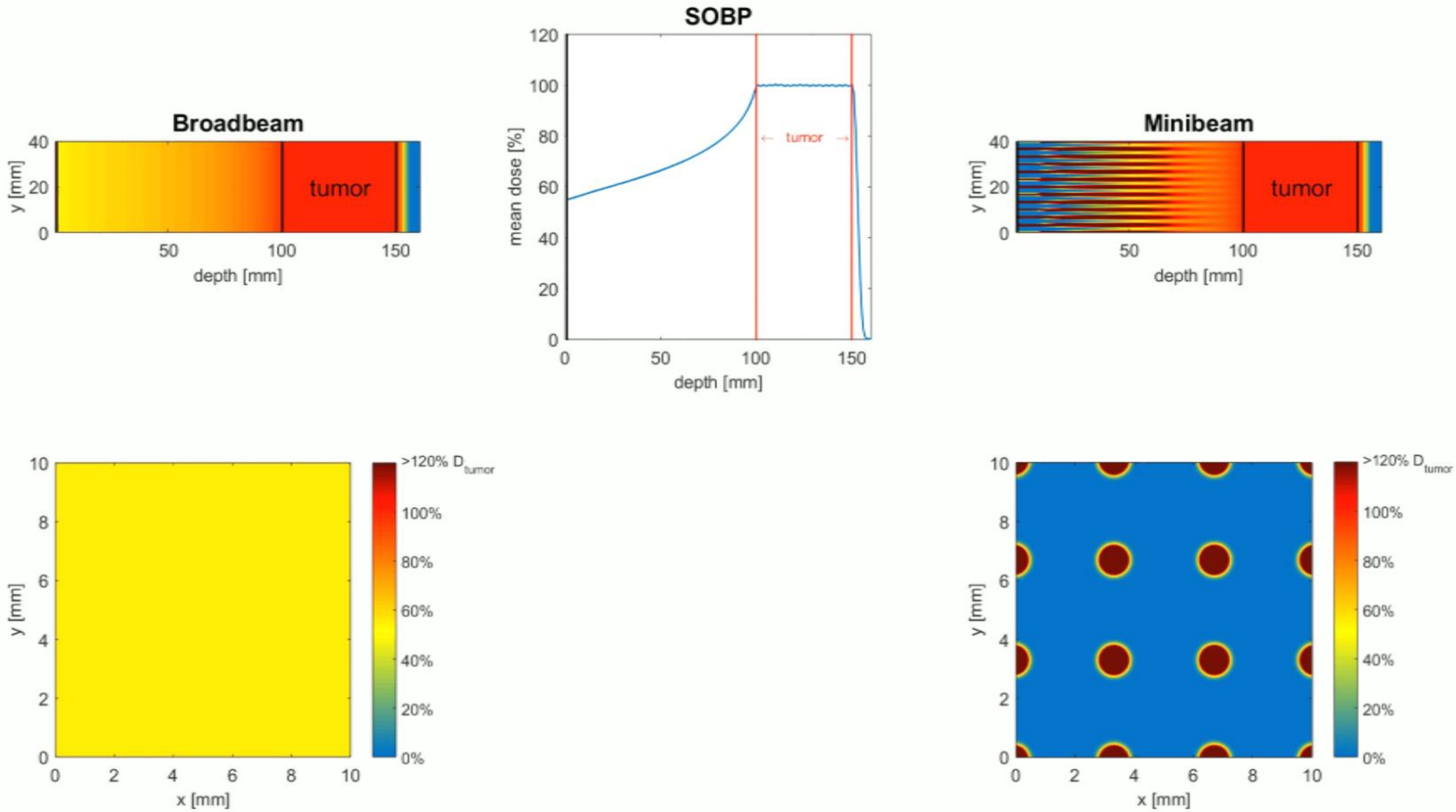
Broadbeam vs. minibeam

- **3D dose distribution**
- **Cell survival**

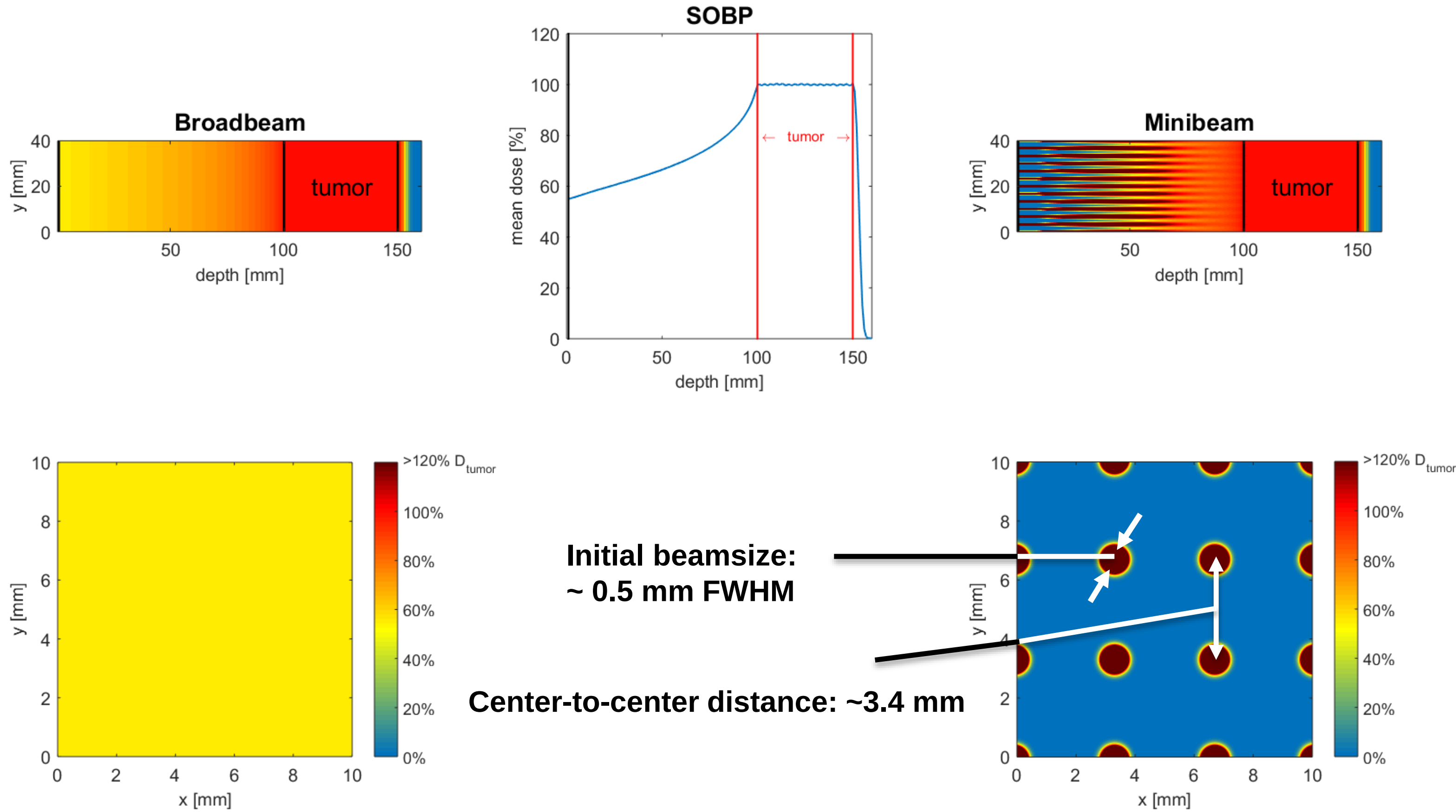


Scatter and Bragg - Peak data: LAP - CERR, diploma thesis, F. Kamp

Dose distribution

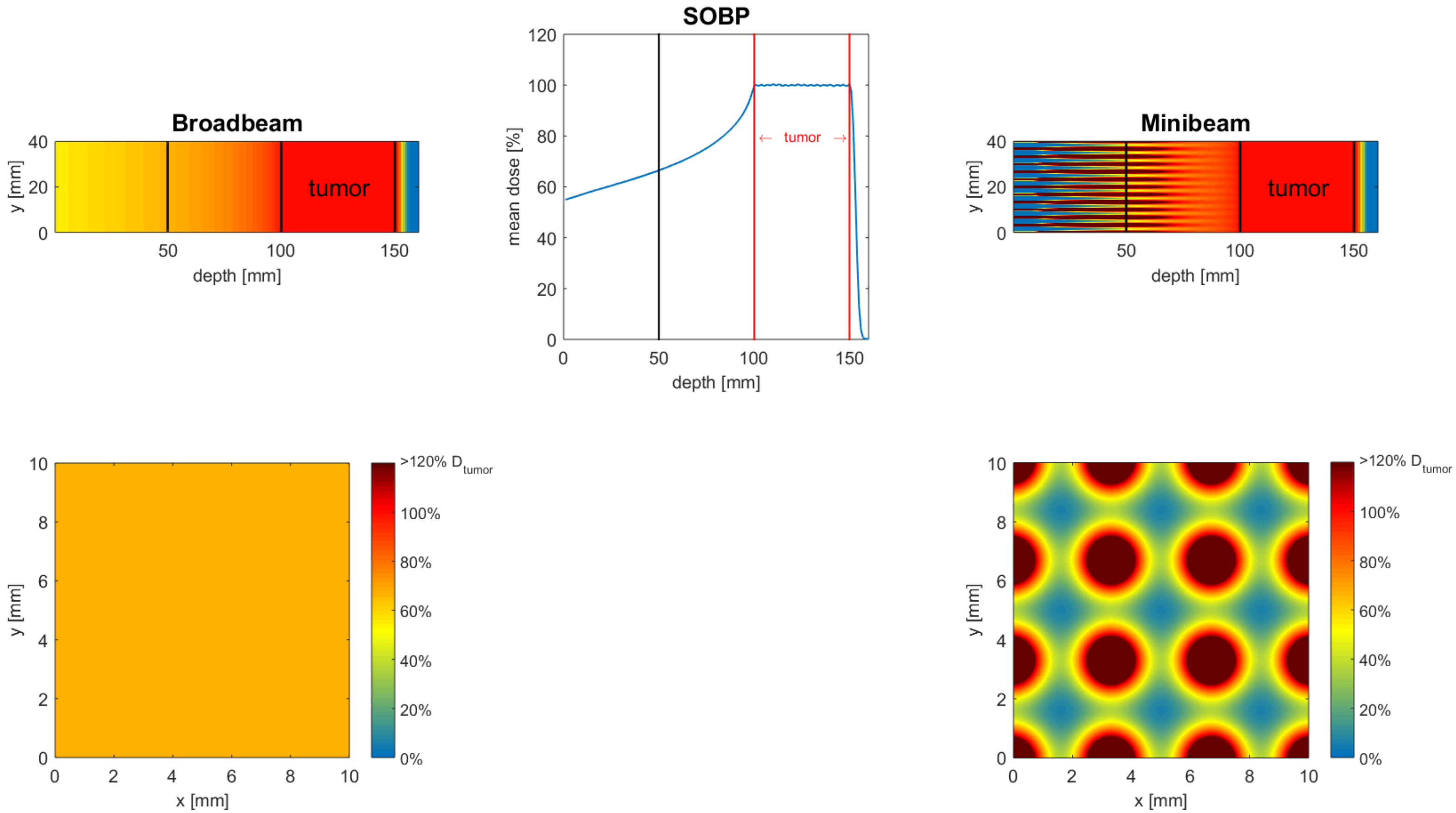


Dose distribution (0 cm)



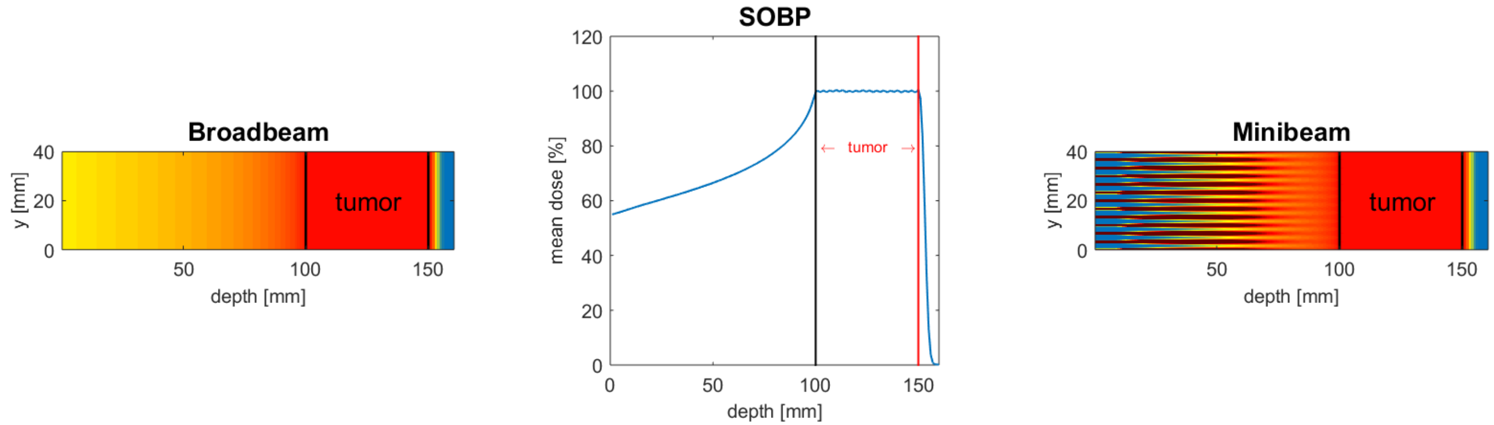
85 % of area receive ≤ 1% of tumor dose

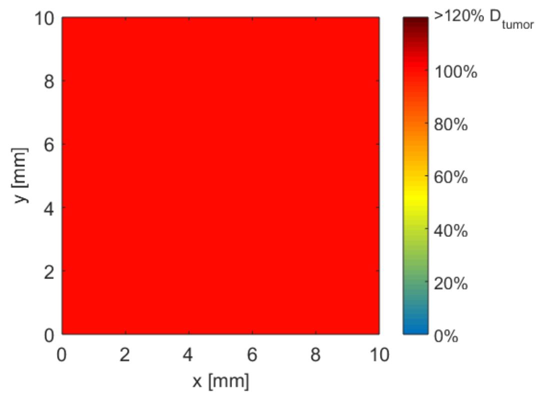
Dose distribution (5 cm)



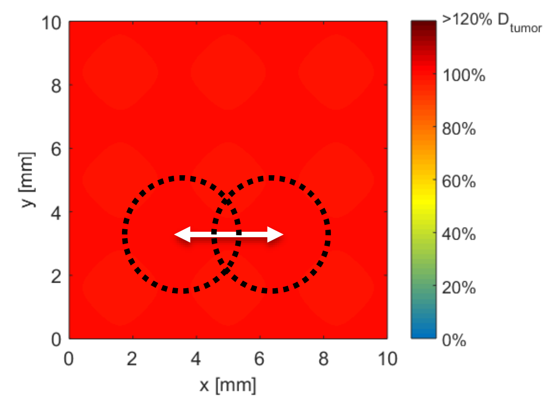
Beamsize increases due to small angle scatter!

Dose distribution (10cm)





Homogeneity!!

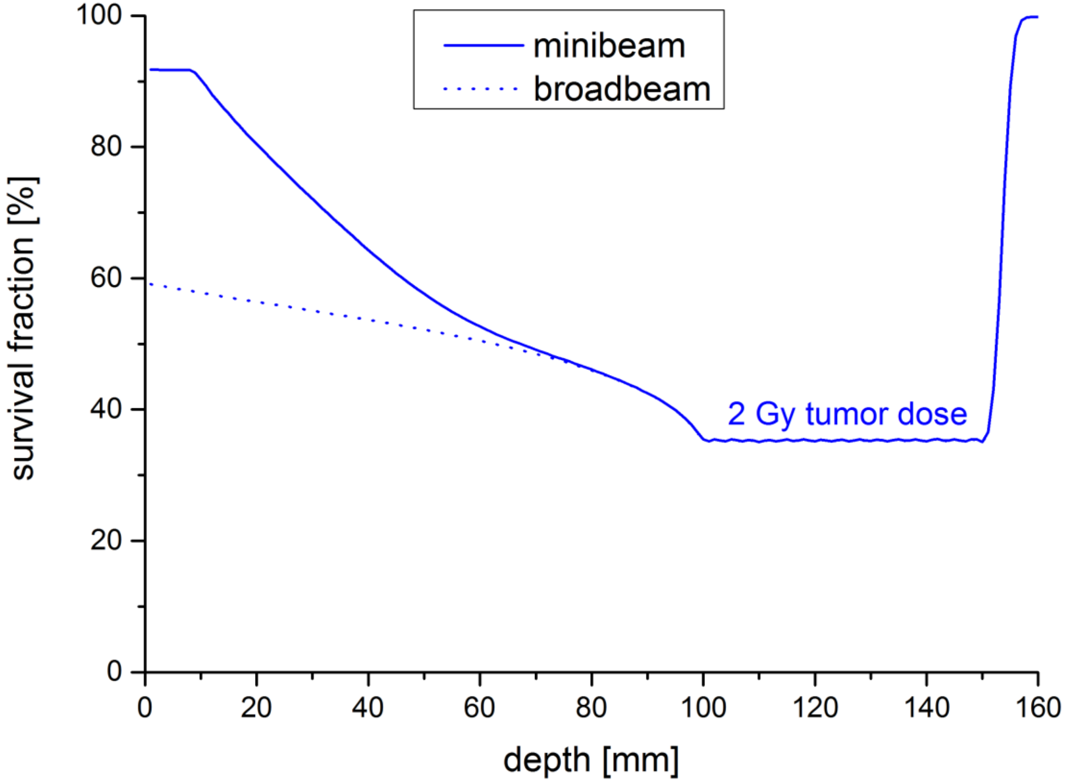


$$\mathbf{0.965 \leq \frac{\textit{D}}{\textit{D}_{tumor}} \leq 1.045^*}$$

$$\mathbf{\frac{beamsize\ (in\ \sigma)}{beamdistance\ d} = 0.5}$$

*including the 1% SOBP uncertainty

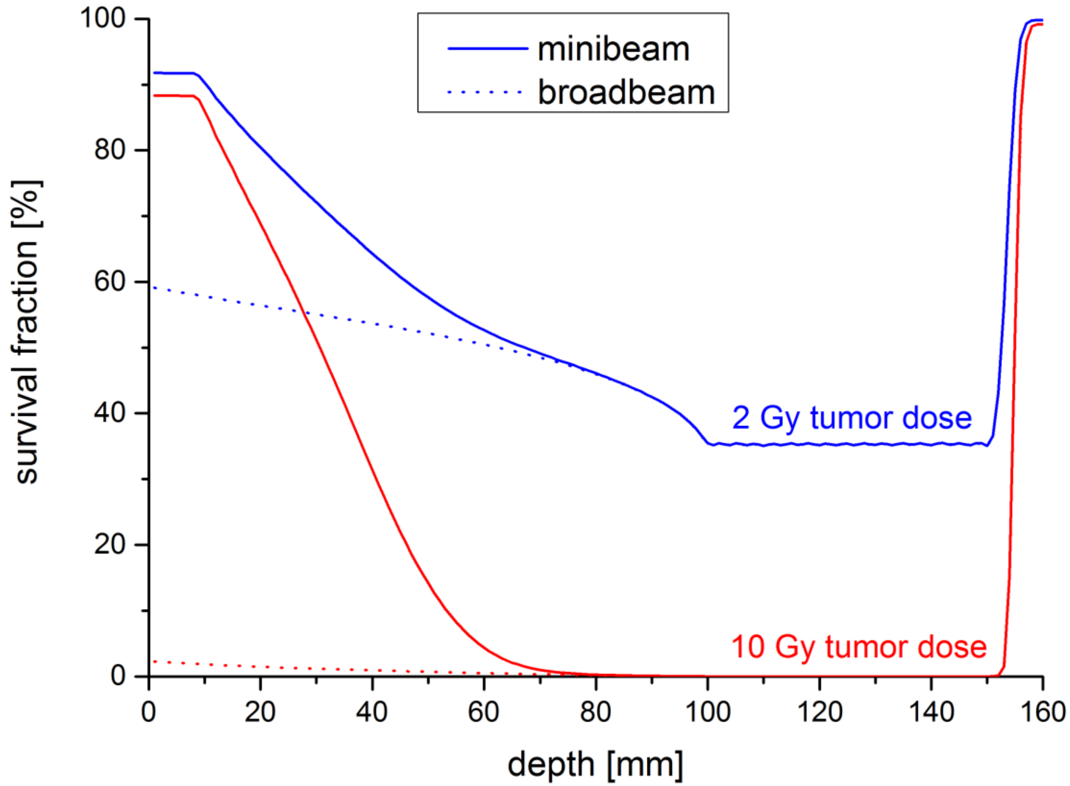
Cell survival*



Minibeams:
Entrance → more cell survival
Tumor → same cell killing

*calculated with the LQ model ($\alpha = 0.425$; $\beta = 0.048$ from PIDE: http://www.gsi.de/bio-pide)

Cell survival*



Minibeams:
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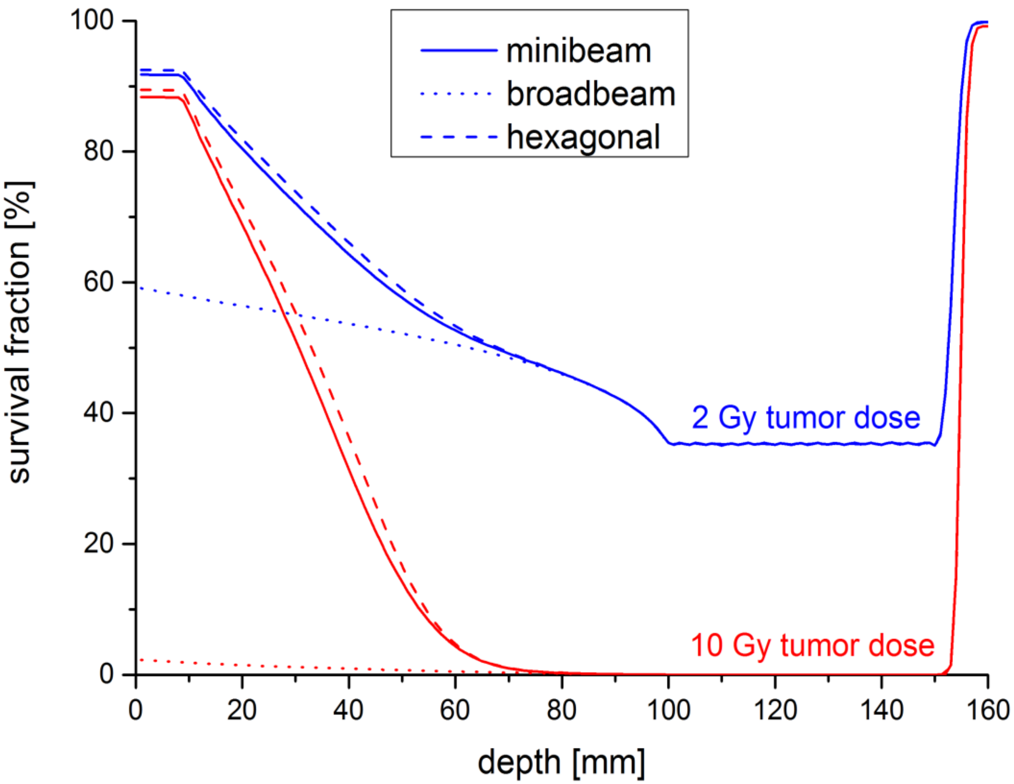
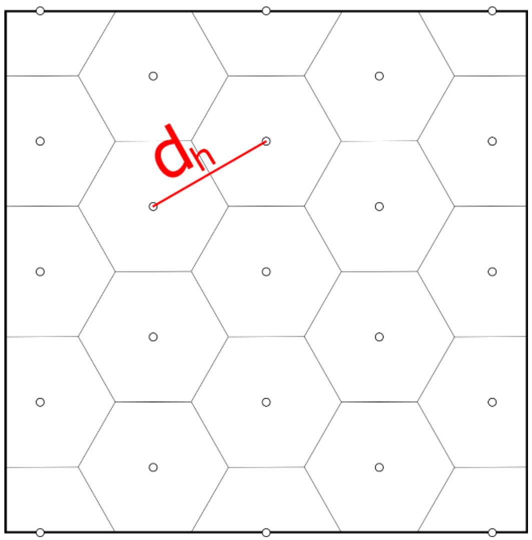
Hexagonal beam alignment





Hexagonal minibeam alignment:
→ Increase beam distance by a factor of 1.144

*calculated with the LQ model ($\alpha = 0.425$; $\beta = 0.048$ from PIDE: http://www.gsi.de/bio-pide)

Summary and Outlook

- **Proton minibeams: spatial fractionation → sparing**
  homogeneous tumor dose → control

- **Fractionation? → Hypofractionation?**
- **Tissue sparing in dependency of depth? → Experiments**
- **Technical feasibility?**

Summary and Outlook

- **Proton minibeams: spatial fractionation → sparing**
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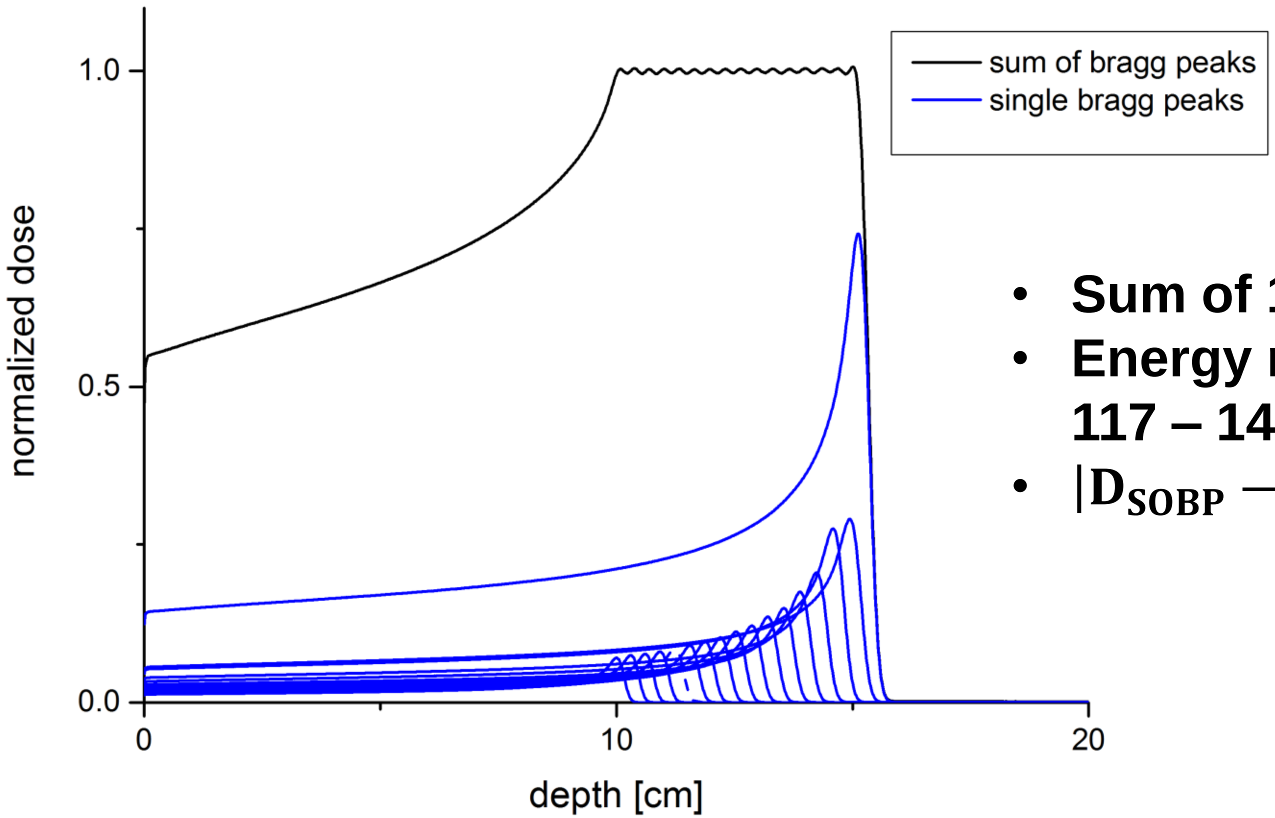
Thank you for your attention!

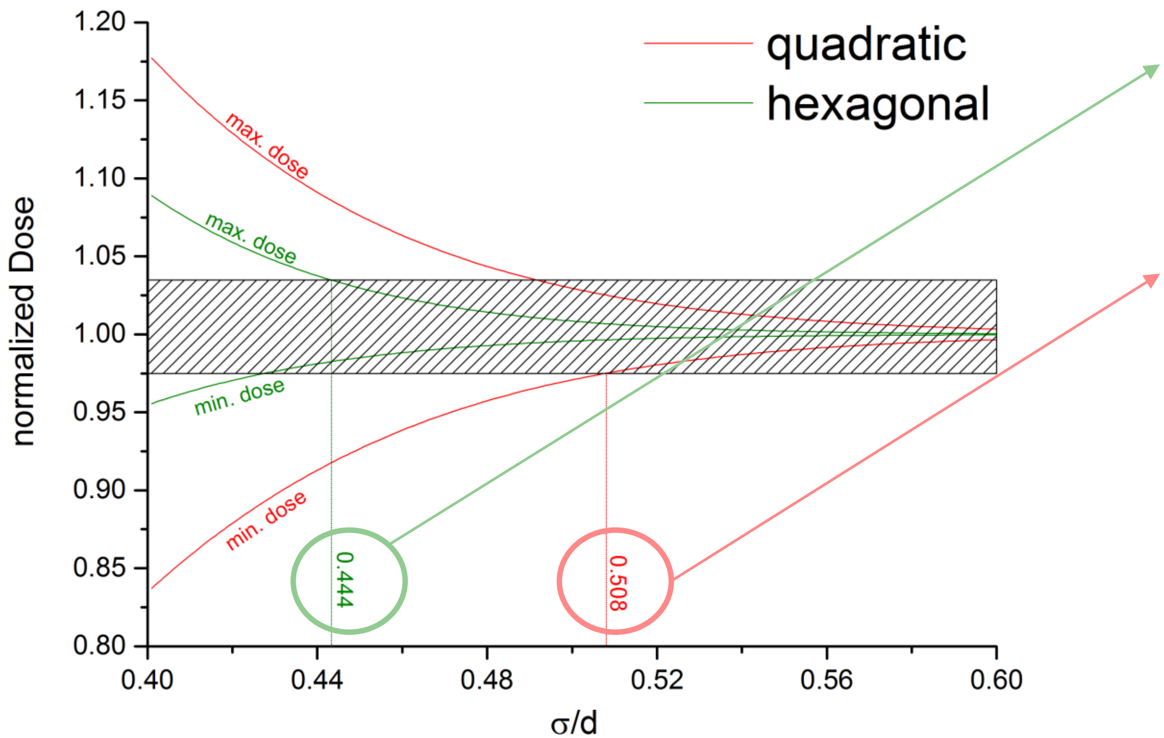
Spread Out Bragg Peak



- **Sum of 17 Bragg peaks**
- **Energy range: 117 – 148 MeV**
- $|\mathbf{D_{SOBP}} - \mathbf{D_{tumor}}| < 1\%$

Constraint on homogeneity

$$0{,}975 \leq \frac{D}{D_{\text{tumor}}} \leq 1{,}035$$



$\sigma_h/d = 0{,}444$

$\sigma_q/d = 0{,}508$

Determination of the distance d

- **Beam alignment needs to fulfill the $\sigma/_{d}$ constraint of homogeneity at 10 cm depth**
- **Protons with maximum energy (148 MeV) scatter the least → key σ**

So: $\sigma = \sqrt{\sigma_0^2 + \sigma_{auf_{148}}^2}$ **and** $\sigma/_{d_q} = 0,508$ **bzw.**

$$\sigma/_{d_h} = 0,444$$

→ $d_q = 3,415\ \mathrm{mm}$

→ $d_h = 3,905\ \mathrm{mm} = 1,144\ d_q$