Some Problems in eFLASH radiation therapy and radiation biology

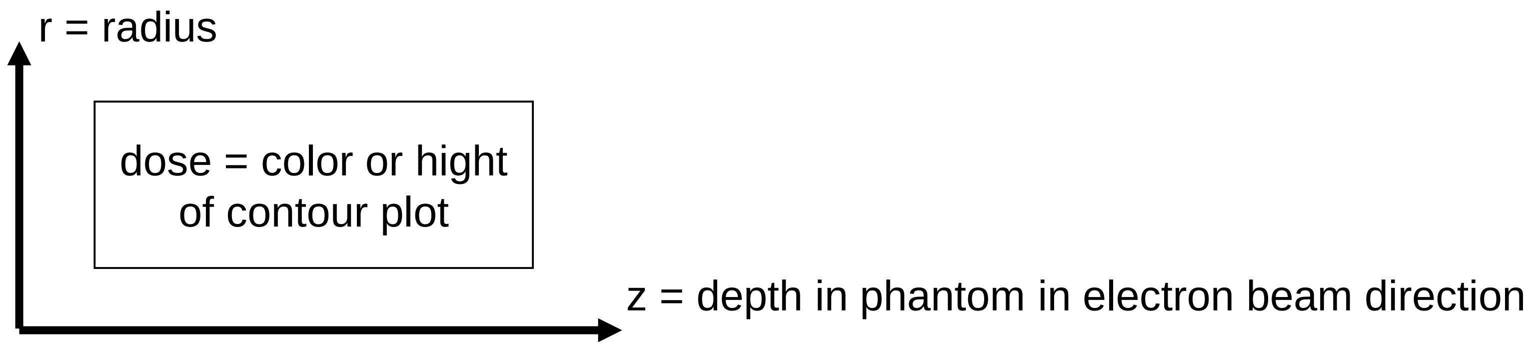
Frank Stephan, DESY, Zeuthen site

How to display the 3D dose distribution

How to present results (simulation, experiment) ?

- Assumption 1: the electron beam is round and cylindrical symmetric AND the phantom is also homogeneous

→ Solution:



- Assumption 2: if phantom is not cylindrical symmetric at entrance point of round beam OR electron beam is NOT cylindrical symmetric (real case for mice and humans)

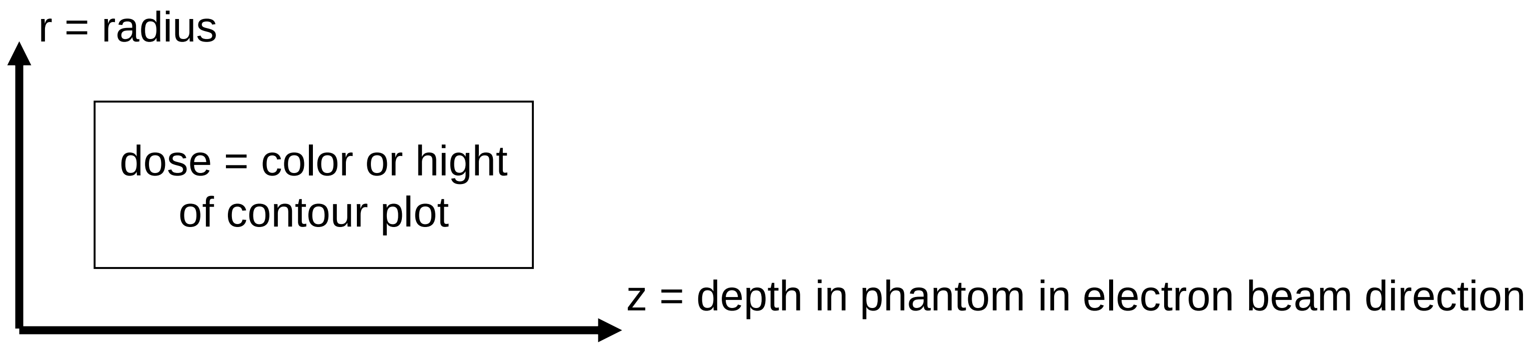
→ Solution: **???**

How to display the 3D dose distribution

How to present results (simulation, experiment) ?

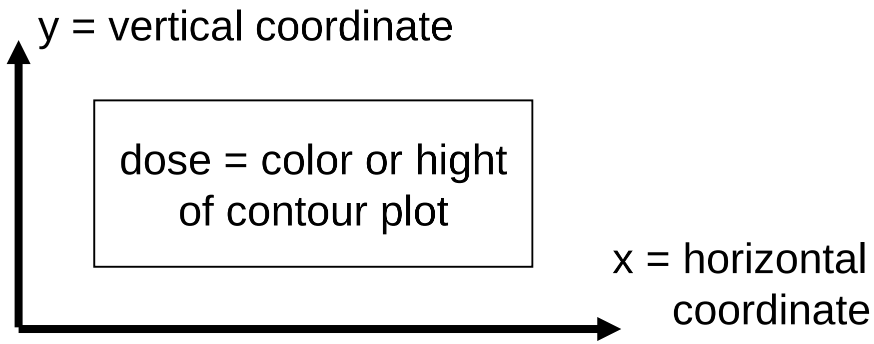
- Assumption 1: the electron beam is round and cylindrical symmetric AND the phantom is also homogeneous

→ Solution:



- Assumption 2: if phantom is not cylindrical symmetric at entrance point of round beam OR electron beam is NOT cylindrical symmetric (real case for mice and humans)

→ **non-optimal** solution: thin slices at different z locations showing
→ features at specific z can be missed if number of samples if not high enough → **hard to keep the overview**



e.g. **z=1mm, Δz=1mm**

How to obtain homogeneous irradiation of a large tumor ?

In transverse extension but also in the depth of the tumor

Principal idea: use the pulses of 1 bunch train to "paint" the tumor within 1 ms

- Tumor close to surface: - scan small \`Gaussian´ beam profiles to obtain homogeneous dose in the tumor

  - maybe cross check with overlaying central part of wide beam distribution with subsequent bunches (to protect surrounding healthy tissue this option requires good collimator at sample, or at an earlier point and imaging optics) ← more complicated approach

- Tumor in depth: - transvers offset of the different small \`Gaussian´ beam profiles has to be chosen such that a homogeneous dose distribution is obtained at the depth of the tumor (multiple scattering in the tissue)
  - for non-homogeneous phantom this might require iterative procedure
  - the radiation planning program "VMAT" might be a suitable tool. → **Can someone try how it works ? Can one make it work with beams at different off-axis positions from one direction ?**

How to obtain homogeneous irradiation of a large tumor ?

In transverse extension but also in the depth of the tumor

- Andreas Schuller told me that a group in the Netherlands is discussing the case for protons fully travelling through the phantom (NOT using the Bragg peak). They are asking how large the FLASH effect has to be and how many irradiation directions are needed in order still to be beneficial compared to the case WITH using the Bragg peak. He told that maybe Marta Rovituso (Holland PTC) could have some information about this study. Maybe there is also an abstract at FRPT2021. **Could someone study this case (find corresponding papers, talk to the group in Holland) and report about this case in a PPS ?**

- homogeneous depth dose profile: → higher beam energy helps
  but for the beginning we have to live with 22 MeV

Checking the dose distribution during treatment

This is KEY in order to ensure that nothing goes wrong. Would then allow also safety interruption.

- If the 3D dose distribution can't be measured online (granularity and time resolution of detectors might be limited)
  then the **electrons have to be measured online** and **parasitically** for

  - beam energy: → this could be measured with a dipole and the position in a dispersive arm or the offset after a dogleg
    → this requires 1 or 2 dipoles and a precise BPM in deflection direction

  - transverse beam distribution: → **how this could be done online and parasitically ???**

Checking the dose distribution during treatment

This is KEY in order to ensure that nothing goes wrong. Would then allow also safety interruption.

- If the 3D dose distribution can't be measured online (granularity and time resolution of detectors might be limited)
  then the **electrons have to be measured online** and **parasitically** for

  - beam energy: → this could be measured with a dipole and the position in a dispersive arm
    or the offset after a dogleg
    → this requires 1 or 2 dipoles and a precise BPM in deflection direc

  - transverse beam distribution: → **how this could be done online and parasitically ???**

  *** Are there RF beam profile monitors that do not only measure the average beam position but the transverse beam distribution parasitically and online ?**

Checking the dose distribution during treatment

This is KEY in order to ensure that nothing goes wrong. Would then allow also safety interruption.

- If the 3D dose distribution can't be measured online (granularity and time resolution of detectors might be limited)
  then the **electrons have to be measured online** and **parasitically** for

  - beam energy: → this could be measured with a dipole and the position in a dispersive arm
    or the offset after a dogleg
    → this requires 1 or 2 dipoles and a precise BPM in deflection direc

  - transverse beam distribution: → **how this could be done online and parasitically ???**

  *** Are there RF beam profile monitors that do not only measure the average beam position but the transverse beam distribution parasitically and online** (TUD, TUB) **?**

  *** could a thin Cherenkov radiator with an optical readout of the light do the job ?**