WP 5, Development of a Standardized 2-Dimensional High Energy Dosimetry Method for Proton- and Heavy Ion Beams

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Outline

- Motivation
- 2D Detector Arrays
- Results so far
  - Simulation of Dose Rates for a Pb Beam
  - Simulation of Beam Quality Correction Factors
  - Simulation of Perturbation Factors
- Moving Stage / Mounting Device
- Outlook

Motivation

- Switching the setup between detector and a device under test is often difficult due to activated air and material
- Radiation protection measures have to be taken into consideration before entering the irradiation area
- Dosimetry and irradiation test often not possible at the exact same position

Setup of an experiment conducted at CERN (*V. Wyrwoll et. al, 2021*)

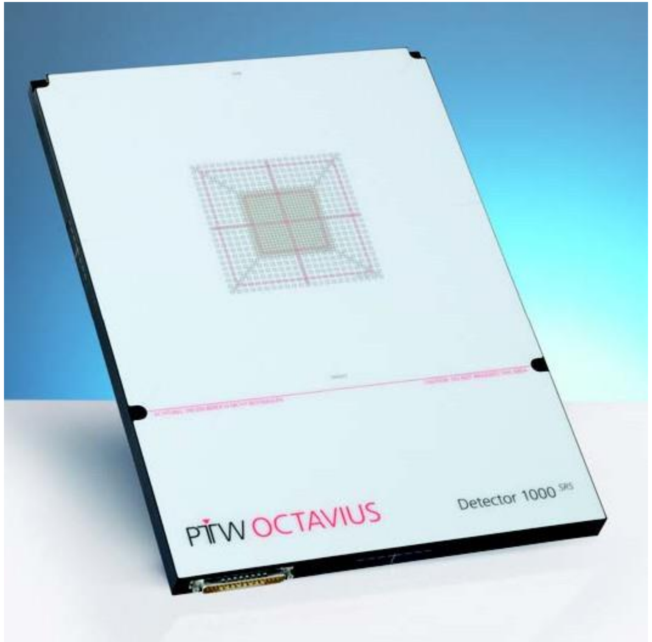
Motivation

- Accurate 2-dimensional beam profile analysis and characterization
- Easy-to-use opportunity to measure the beam at the position of the experiment
- No need to enter the irradiation area to switch between detector and DUT
- New generalized method of proton- and heavy ion dosimetry

Detector Arrays

OD 1000SRS

- 977 single detector chambers
- Liquid filled ionization chambers
- Detector spacing:
  2.5 mm center to center in central 5.5 x 5.5 cm^2 area, 5 mm center to center in outer 11 x 11 cm^2 area
- Range: 0.2 – 36 Gy/min
- Lower dose rates possible by modifications

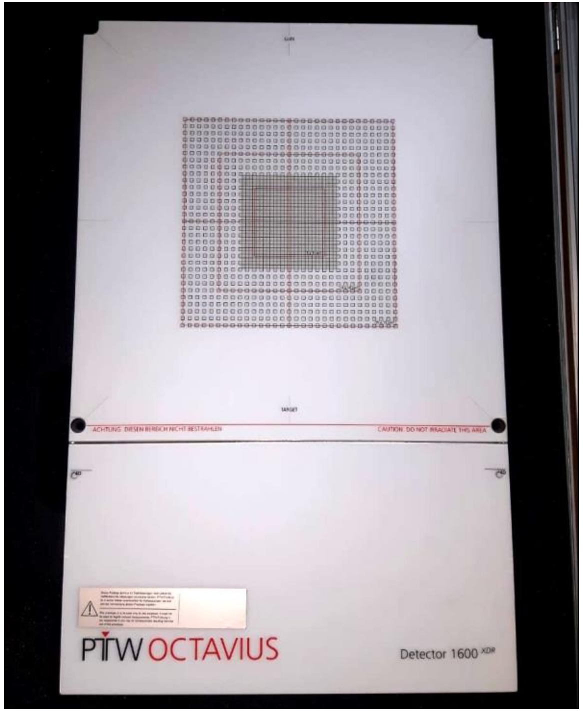


Data and images taken from www.ptwdosimetry.com

Detector Arrays

OD 1600XDR

- 1521 cubic detectors
- Vented ionization chambers
- Detector spacing:
  2.5 mm center to center in central
  6.5 x 6.5 cm^2 area, 5 mm center to center
  in outer 15 x 15 cm^2 area
- Range: 0.4 – 4000 Gy/min
- Absolute dose calibration in ^{60}Co beam

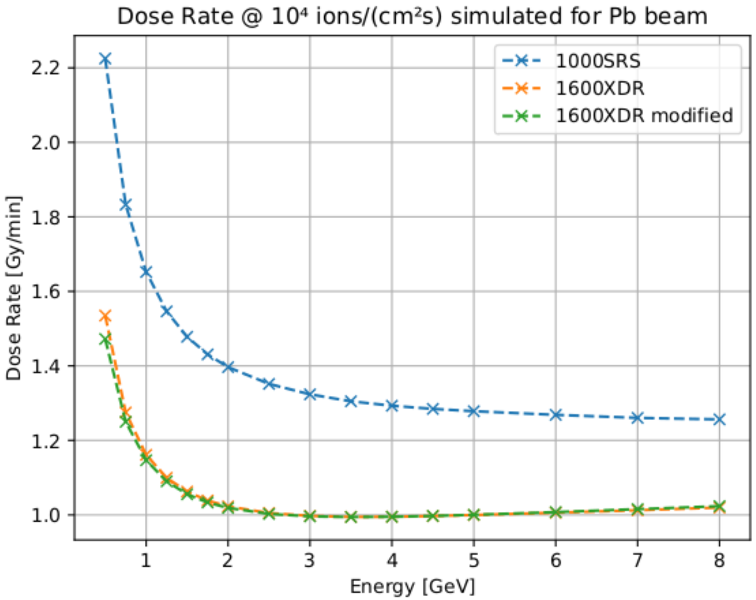


Data and images taken from *www.ptwdosimetry.com*

Results so far

Simulations with FLUKA/FLAIR

- Simulations to determine the dose rate and depth dose curve of specific beams/particles depending on the energy
- Depending on this, decision if the arrays have to be modified for the experiments
- Simulation and calculations to determine beam quality correction factors
- Useful for planning dosimetry experiments at CHARM



Beam Quality Correction Factor k_Q

Why is this needed?

The beam quality correction factor is needed to account for the dose response of the detector arrays to beams that significantly differ in nature from ^{60}Co radiation, for example in the case of heavy ion beams for which a reference is not available.

$$k_Q = \frac{f_Q}{f_{Q_0}} = \frac{\left(\frac{D_w}{D_{\mathrm{chamber}}}\right)_{\mathrm{ion}}}{\left(\frac{D_w}{D_{\mathrm{chamber}}}\right)_{^{60}\mathrm{Co}}}$$

Beam Quality Correction Factor k_Q

Simulations with FLUKA

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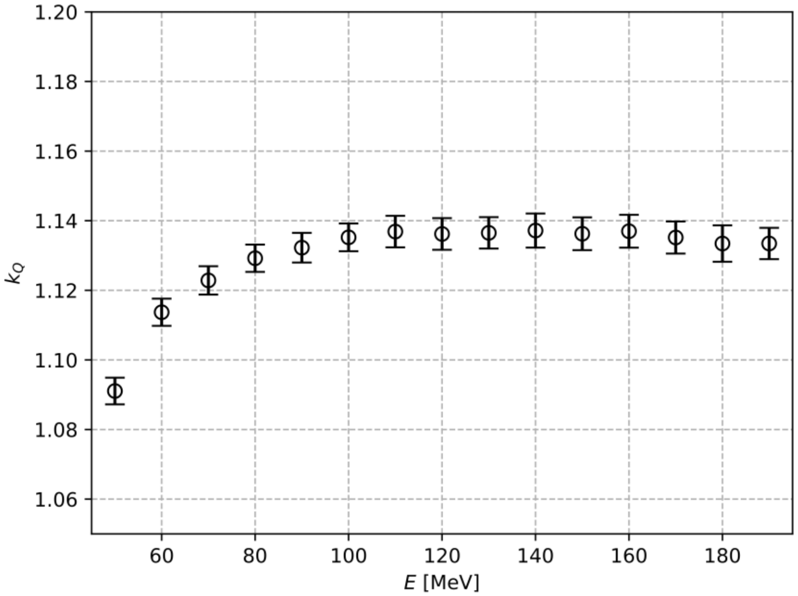
Results so far

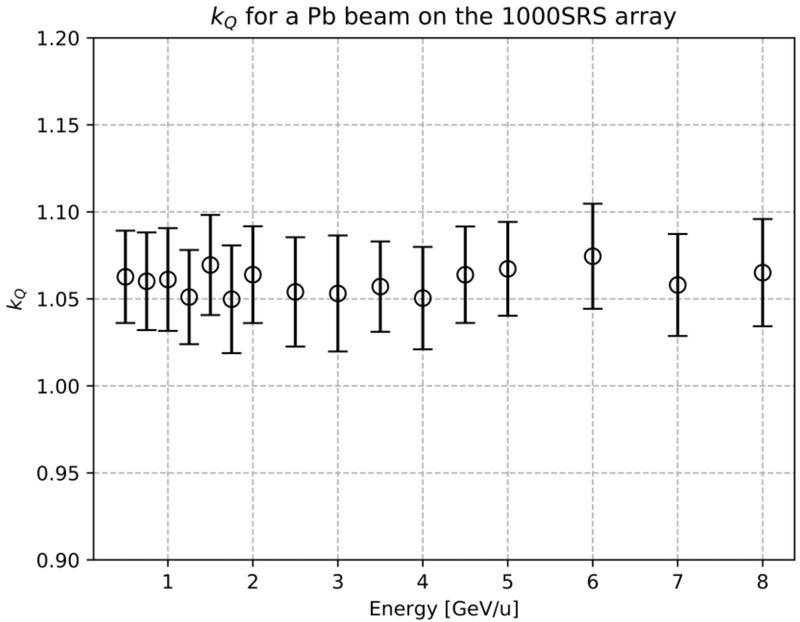
- k_Q for OD 1000SRS constant at 90 to 190 MeV proton beam with $k_Q = 1.134 \pm 0.6\%$
- k_Q for OD 1000SRS in high energy Pb beam (1 to 8 GeV/n) constant
- In an ultra high energy ^{208}Pb beam k_Q decreases for the 1600XDR array with increasing energy in a region from 10 to 150 GeV/n
- But the error margin still has to be reduced significantly for heavy ions

Beam Quality Correction Factor k_Q

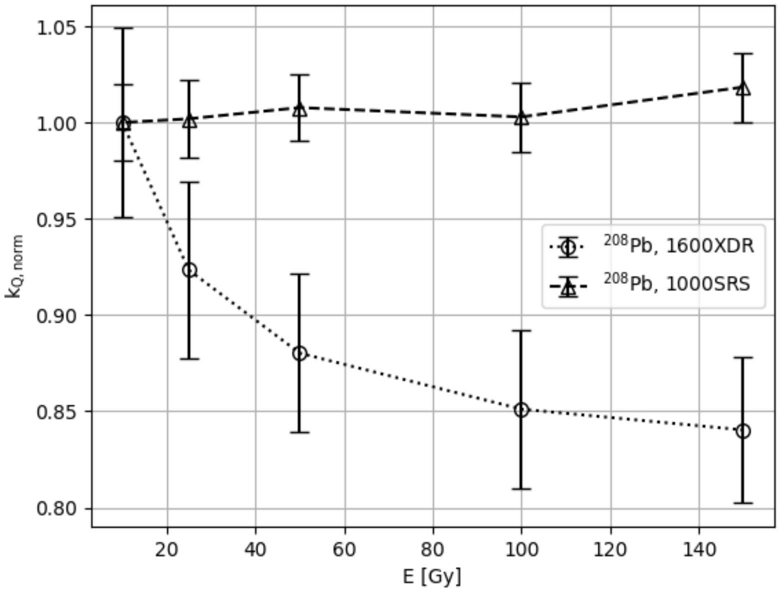


- k_Q for a proton beam at 50 MeV to 190 MeV, OD 1000SRS
- Constant at a range from 90 MeV to 190 MeV with
  $k_Q = 1.134 \pm 0.007$

Beam Quality Correction Factor k_Q



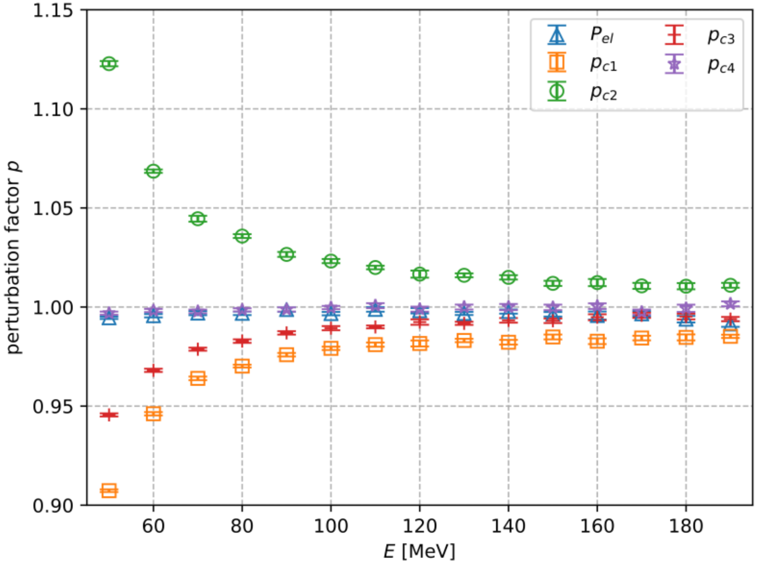
k_Q for a ^{208}Pb beam at 500 MeV/n to 8 GeV/n, OD 1000SRS



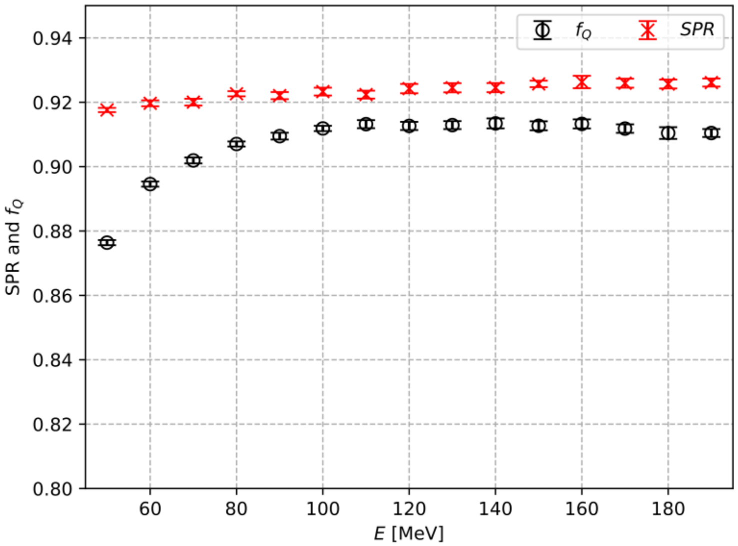
k_Q comparison of OD 1600XDR and OD 1000SRS for a 10 to 150 GeV/n ^{208}Pb beam, normalized at 10 GeV/n

Perturbation Factors OD 1000SRS

$$f_Q = \frac{D_W}{D_{chamber}} = SPR \cdot \prod_i p_i$$



Perturbation factors of the OD 1000SRS components for a 50 MeV to 190 MeV Proton beam.

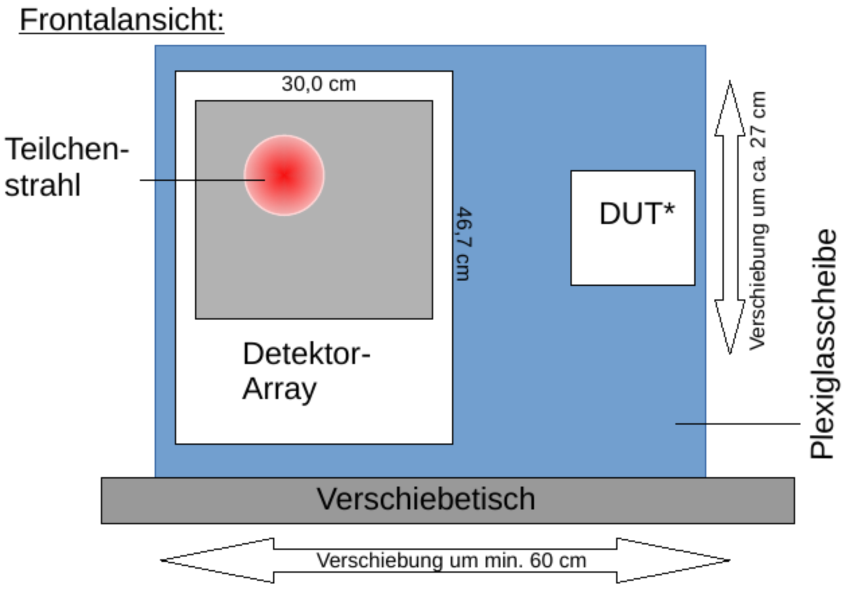


fQ as the product of all perturbation factors and the stopping power ratio for the OD 1000SRS.

Moving Table

Work in Progress

- Table with options to mount a detector array and a DUT
- Movements in vertical and horizontal direction
- Enables localisation of the beam center and to position the DUT accordingly



*DUT: Device under test (zu bestrahlendes Objekt)

Goal

The main goal is the characterization of heavy ion and proton beamlines directly at the position of the experiment, for which the proposed device will provide benefits in terms of time efficient and easy usage. The expected results will be similar to those of a former experiment at CERN by Vanessa Wyrwoll *et. al* (published 2021) where it has been shown that not only dose and LET but also the particle fluence can be derived from the measurements and simulations.

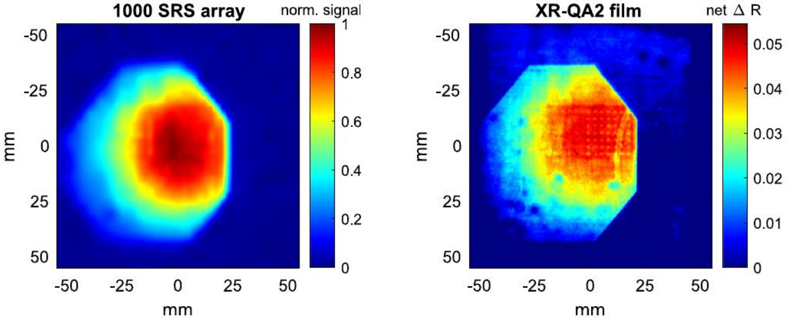


Fig. 10. 2D illustration of the measurement with the film attached behind the array (right) and recorded by the array (left).

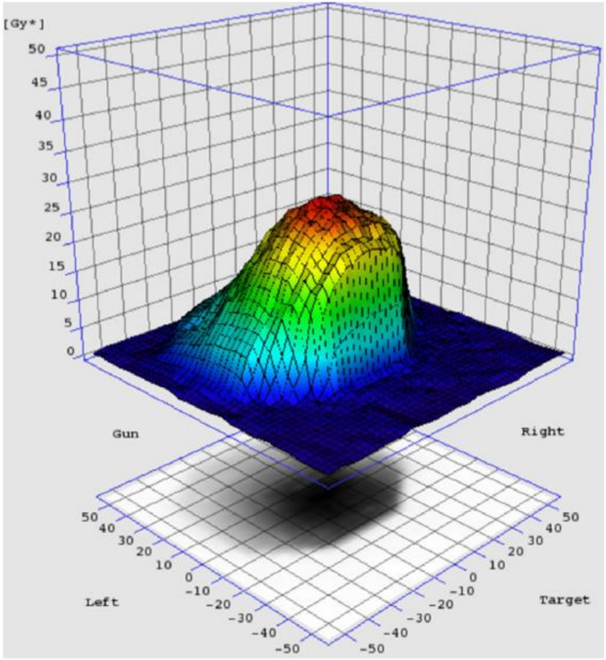


Fig. 5. Illustration of on-line beam monitoring during exposure to the 150 GeV/n ^{208}Pb beam in H8 of the SPS-NA using the OCTAVIUS 1000SRS liquid ionization chamber array.

Outlook

- Continuation of the development of the standardized method for beam characterization and dosimetry
- Beamtime at KVI Groningen, NL granted through RADNEXT TA, planned for late summer/autumn 2023
- Measurements and tests at CERN, CH
- Further simulations to back the results of the measurements
- Perturbation factors and k_Q simulations also for OD 1600XDR

Thanks for your attention!

Image Source: CERN