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BEV
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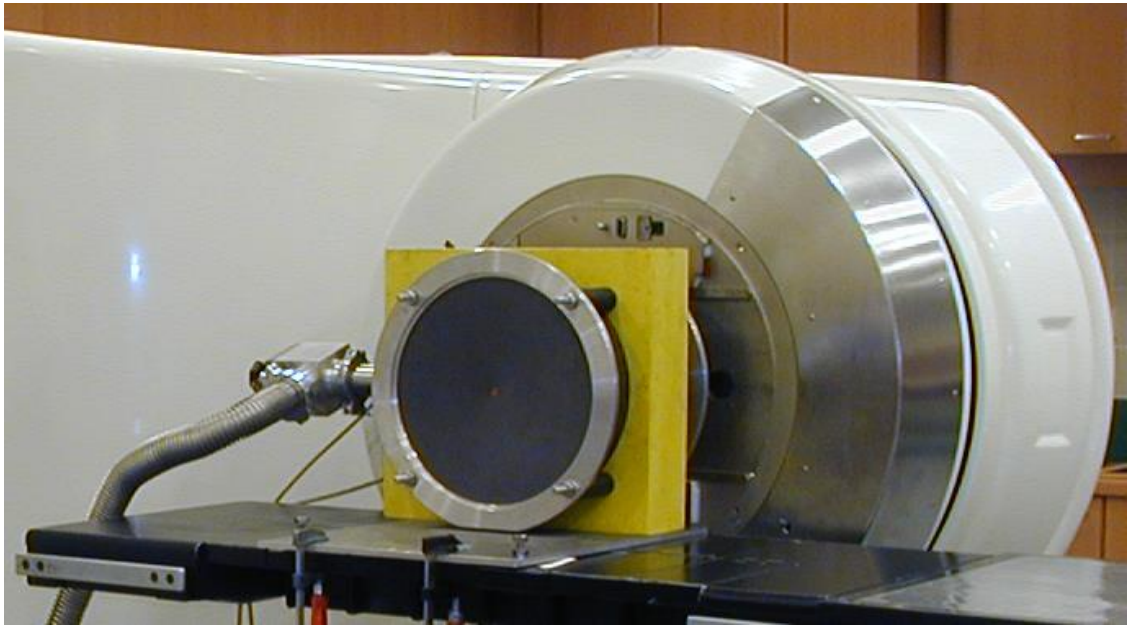


Radiation protection of patients:
status of primary standard dosimetry of high-energy photon and electron beams in Austria

Andreas Baumgartner, Andreas Steurer, Franz Josef Maringer

INTRODUCTION

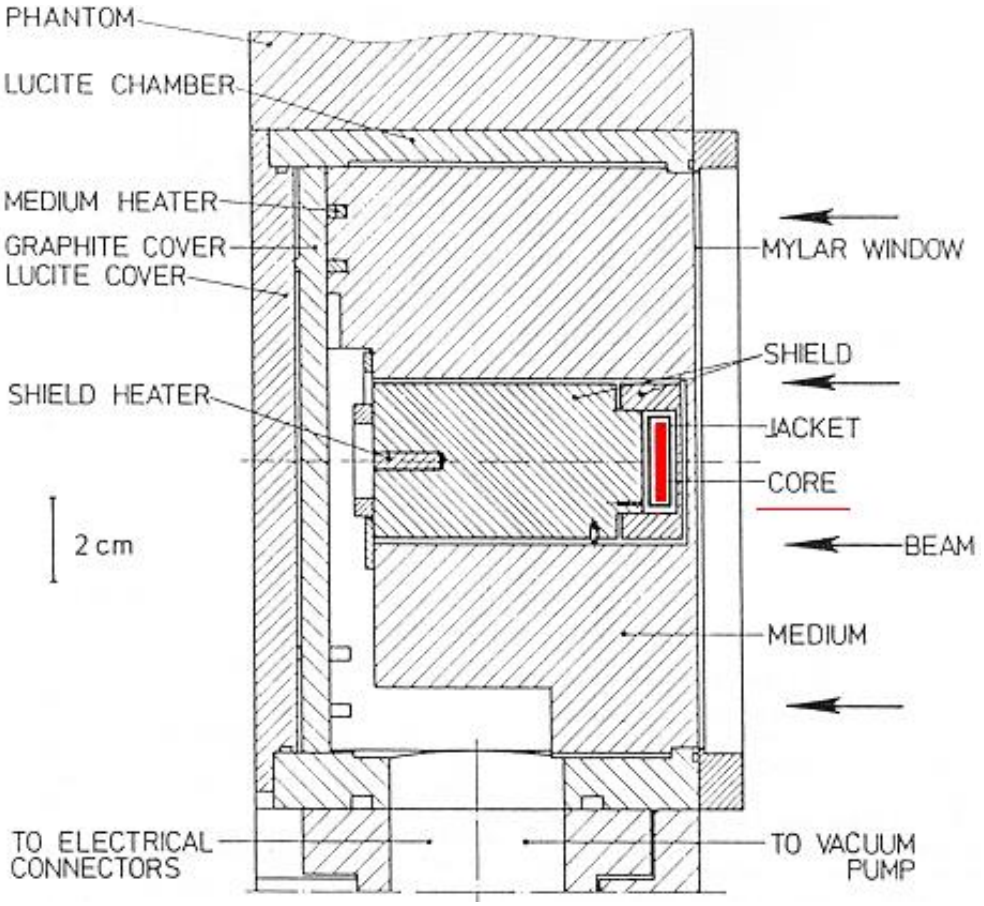
- Improvement of metrology in LINAC radiotherapy
  - → improved radiation protection of patients
- Primary standard for the realisation of the unit of absorbed dose to water: **graphite calorimeter**
- National Metrology Institute (NMI) and national authority on legal metrology in Austria: Federal Office of Metrology and Surveying (BEV - Bundesamt für Eich- und Vermessungswesen)
- Graphite calorimeter was originally designated for ^{60}Co gamma ray beams
  - Ionisation chamber calibrations in terms of absorbed dose to water

DETERMINATION OF ABSORBED DOSE TO WATER – SITUATION IN AUSTRIA

- Calibration and verification of therapy dosemeters is done in the ^{60}Co gamma ray beam
  - Secondary standards are traceable to the BEV primary standard
  - The conversion of the ^{60}Co chamber factor to the chamber factor for higher energies uses the code of practice in the Austrian standard OENORM S 5234-3
- To enable primary standard dosimetry of high-energy photon beams
- → The energy range of the primary standard was extended
- Refurbishment of the BEV calorimeter
  - Revision and replacement of hardware components
  - Development of a new evaluation program with automatic non-linear drift extrapolations, created in LabView®
  - Verification of calorimeter response for the complete temperature working range
- Calorimeter adaptation to measurement requirements for high-energy radiation fields
  - Set of beam quality specific correction and conversion factors is needed

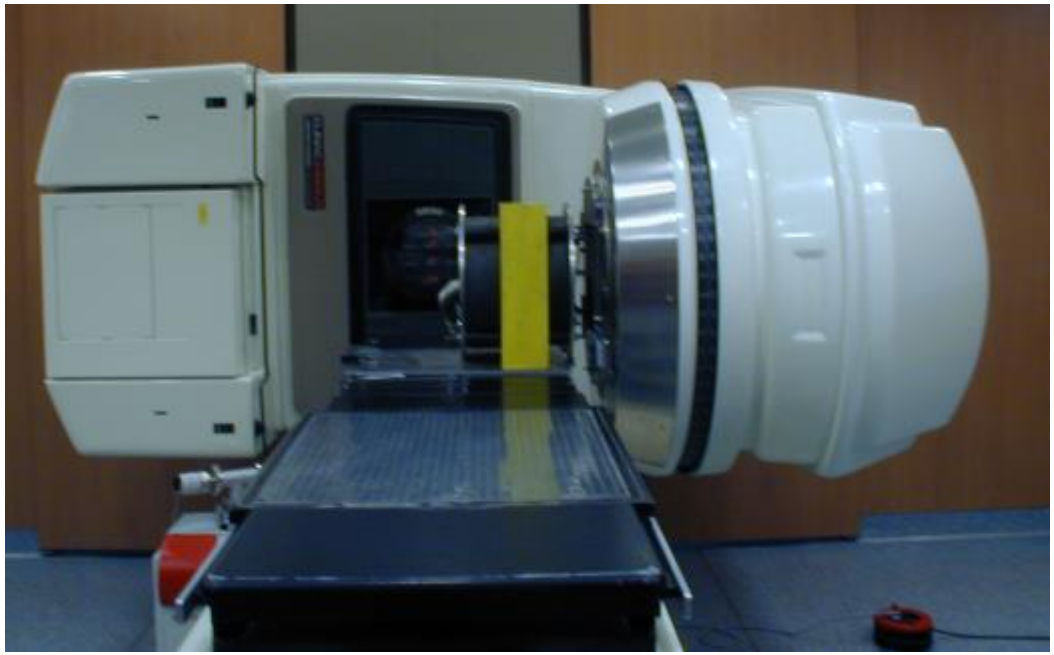
REALISATION OF THE UNIT OF ABSORBED DOSE TO WATER

- **1st step: calorimetric determination of absorbed dose to graphite**
  - Dose ~ temperature change
  - 1 Gy → 1.4 mK in graphite (0.24 mK in water)
  - Quasi-adiabatic operation mode
  - Quasi-isothermal operation mode
- **2nd step: conversion in absorbed dose to water**
  - Conversion methods are based on photon-fluence scaling theorem
  - Method 1: computing (scaling theorem)
  - Method 2: experimental / measurements

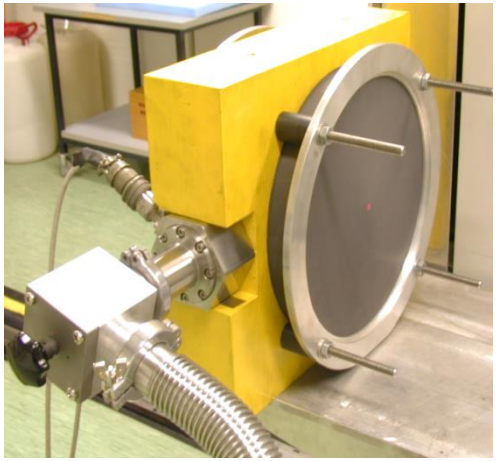


MEASUREMENTS

1) measurements in the BEV dosimetry laboratory: ^{60}Co therapy facility
2) measurements at accelerator: cooperation with an Austrian hospital
3) measurements at accelerators of PTB, Germany and METAS, Switzerland

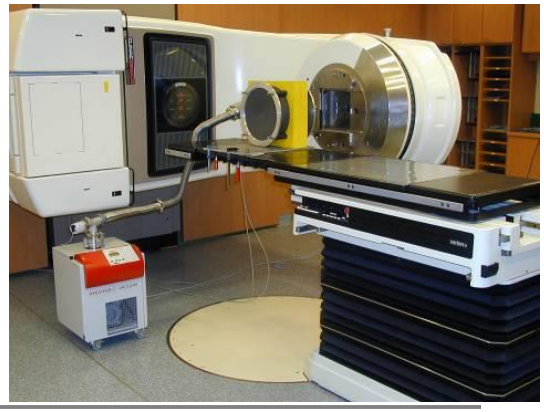


Graphite calorimeter measuring position



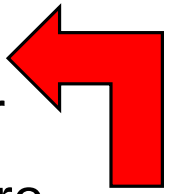
calorimeter mounted in the phantom

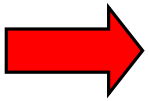
Overview measurement setup

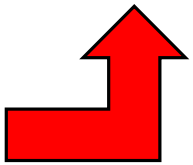


SIMULATION STUDIES

- Calculation of beam quality specific (application specific) correction factors for the graphite calorimeter
  - Correction for the effect of the vacuum gaps around the core
  - Correction for the deviation of the graphite phantom dimensions from the scaling requirements
  - Correction for the difference in air attenuation
- Monte Carlo code: PENELOPE-2006 (*pencyl, penmain*)
  - Preparative simulations with monoenergetic photons (1,25 MeV), under variation of the field size
- Beam quality specific corrections require the MC-modelling of the irradiation facilities
- → Realistic input radiation fields

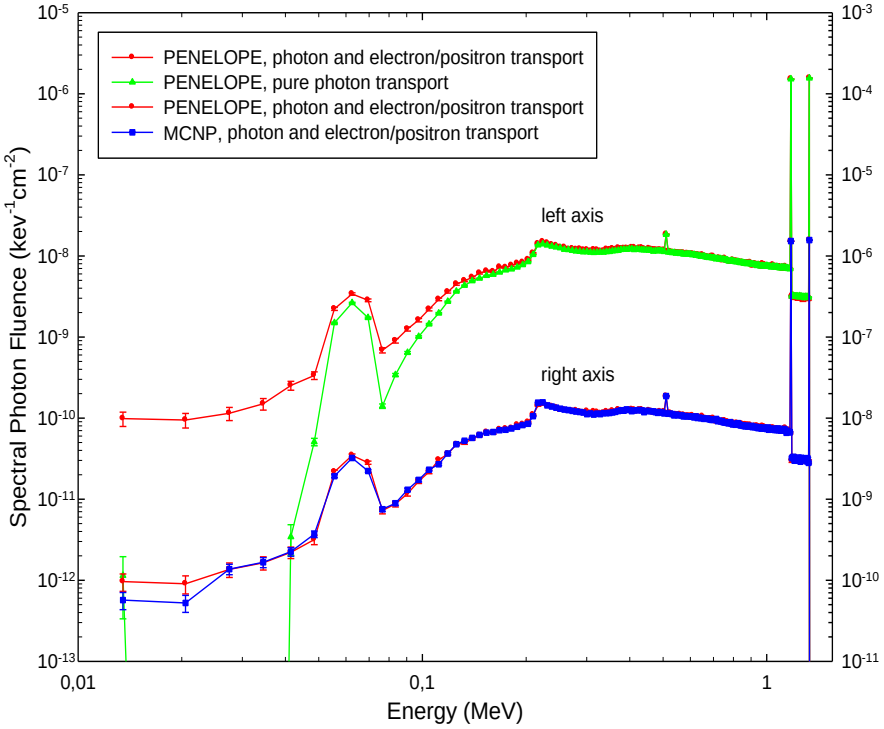


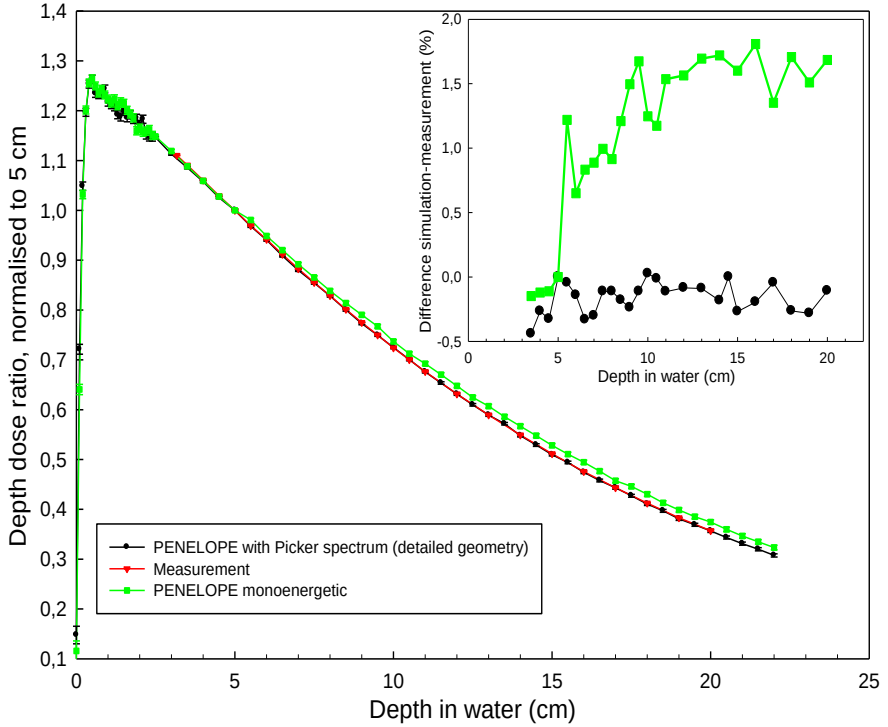




RESULTS

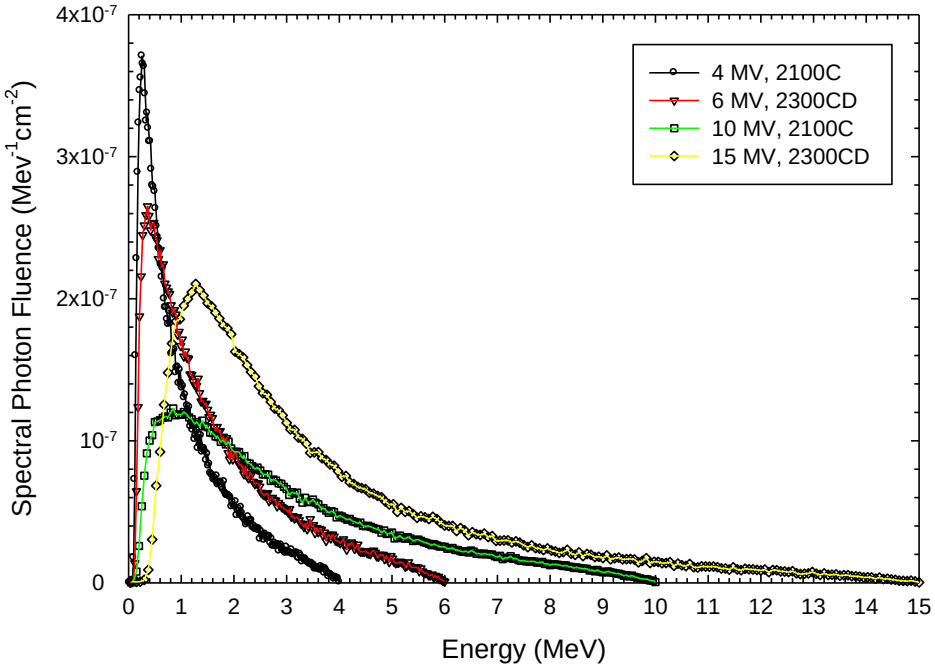
- Simulation of photon fluence spectra
  - verification based upon depth-dose distribution measurements

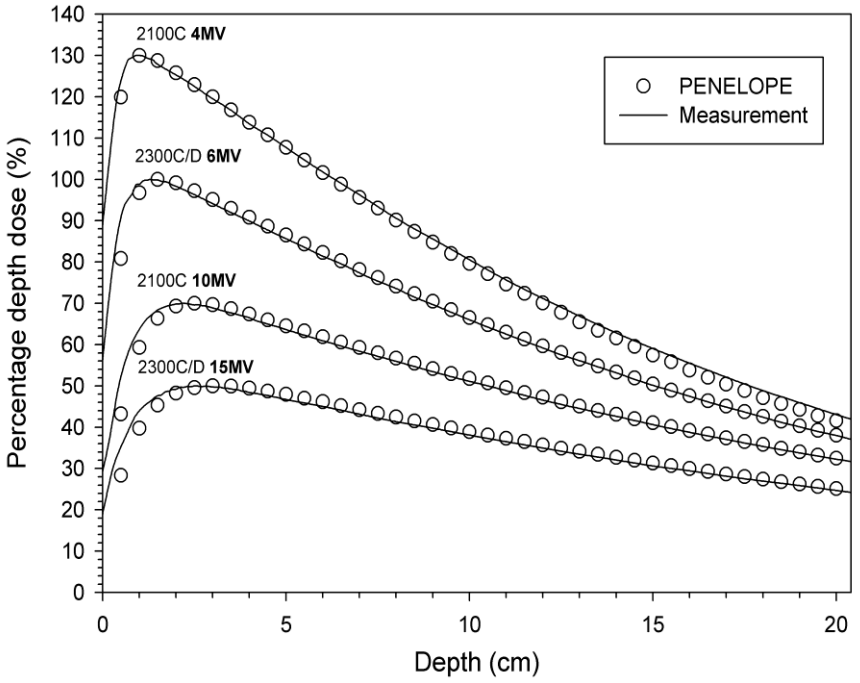




RESULTS

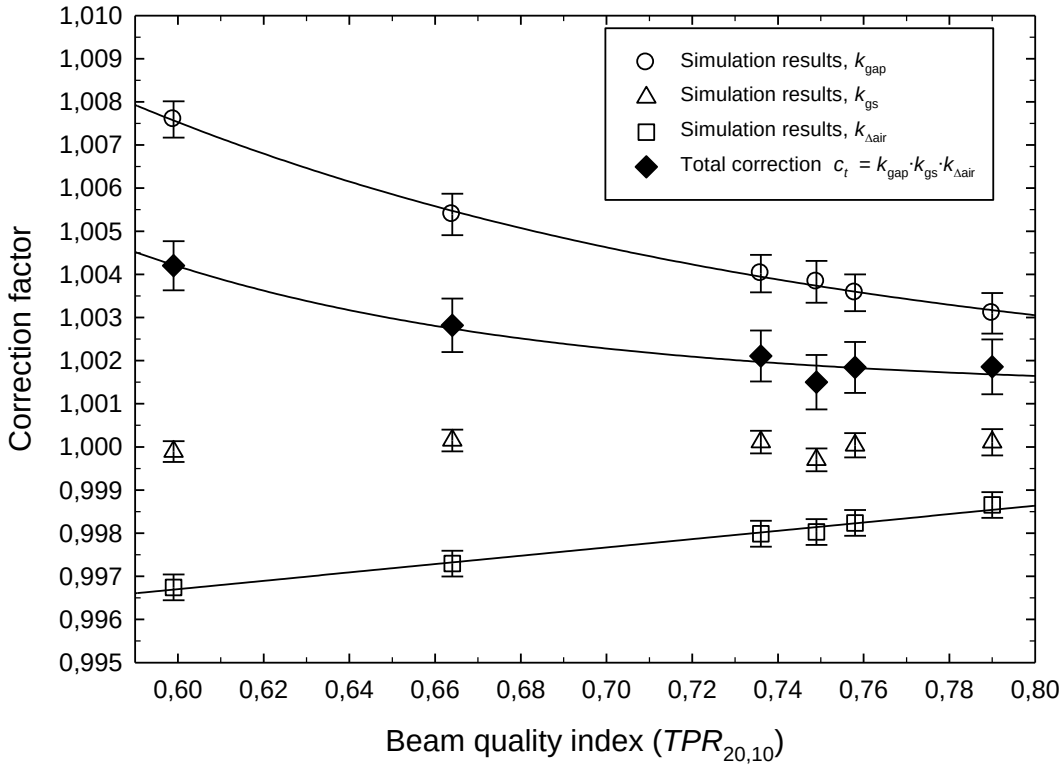
- **Determination of photon fluence spectra of linear accelerators**
  - Varian Clinac 2100C u. 2300C/D : 4 MV, 6 MV, 10 MV, 15MV
  - Verification with depth-dose measurements / calculated and measured $TPR_{20,10}$ indices
    - Difference between measurement and simulation: $\Delta TPR_{20,10} < 1\%$ (4MV < 2%)





RESULTS

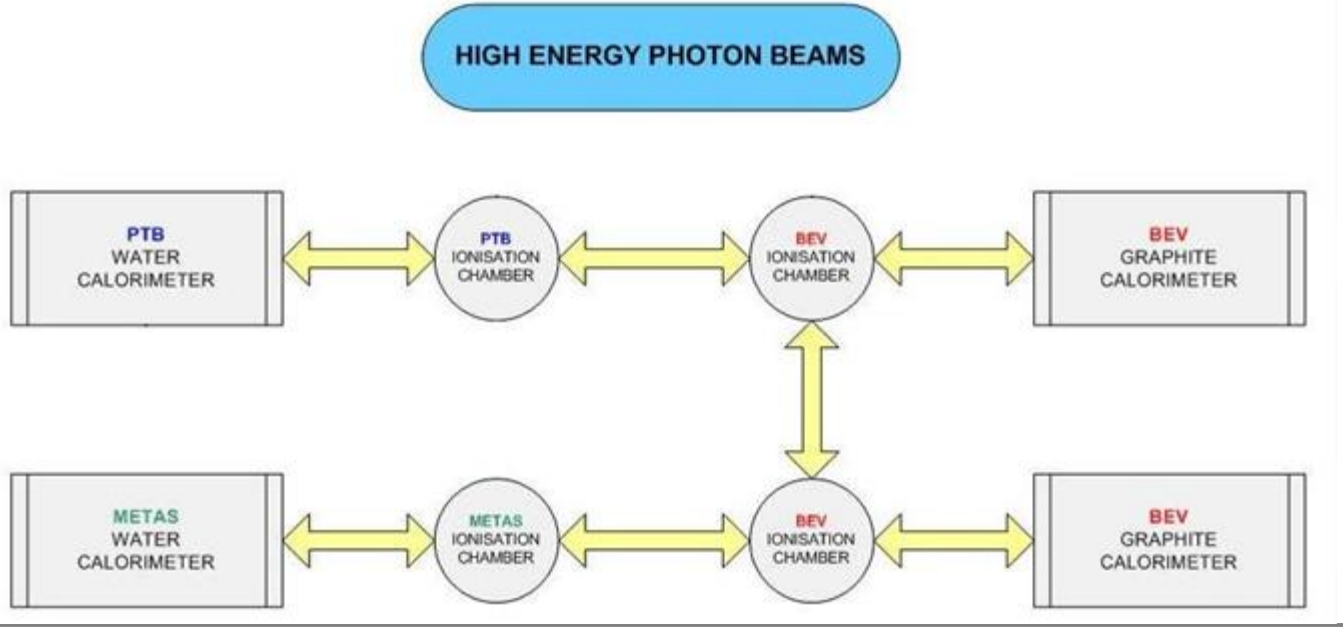
- **Correction factors for high-energy photon beams**
  - Evaluation in dependence on $TPR_{20,10}$



- **Verification**
  - **BIPM, Paris, key comparison**: indirect comparison of the standards for absorbed dose to water of the BEV and the BIPM
  - Comparison exercise of the **European Association of National Metrology Institutes (EURAMET)**
    - Project partners:
      - BEV (pilot laboratory)
      - METAS (NMI of Switzerland)
      - PTB (NMI of Germany)

EURAMET COMPARISON

- Direct comparison of primary standards of absorbed dose to water in ^{60}Co and high-energy photon beams
  - photon beam qualities: generated by electrons with energies of 4, 6, 10 and 15 MeV
- The BEV transported the graphite calorimeter primary standard to the project partners in Germany and Switzerland
- The results obtained by the different NMI's are widely in agreement and mostly within the standard measurements uncertainties



SUMMARY & CONCLUSIONS

- The application of the calorimeter in high-energy photon and electron beams requires:
  - Beam quality specific correction factors and conversion factors
  - Determination is mainly based upon MC-simulations
- Confirmation of the implemented correction factors in the framework of:
  - BIPM key comparison
  - EURAMET project 1021
- → Work carried out provided the methodological basis for the primary standard dosimetry of high-energy photon and electron beams with the BEV calorimeter
  - → Metrological directly traceable dosimetry
- Essential improvement in radiation protection of radiotherapy patients
  - Improvement of dosimetry and quality assurance in LINAC radiotherapy
  - Accurate knowledge of the applied dose is a main factor influencing the success of a radiotherapy and therefore of great importance for the treatment planning

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Thank you for your attention