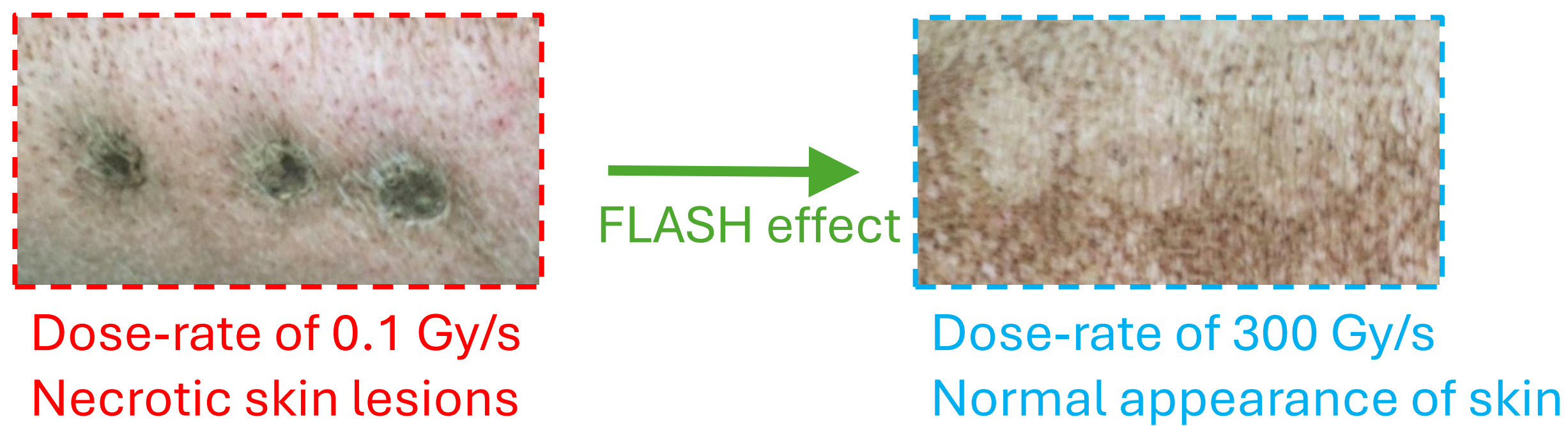


Challenge

What is FLASH radiotherapy?



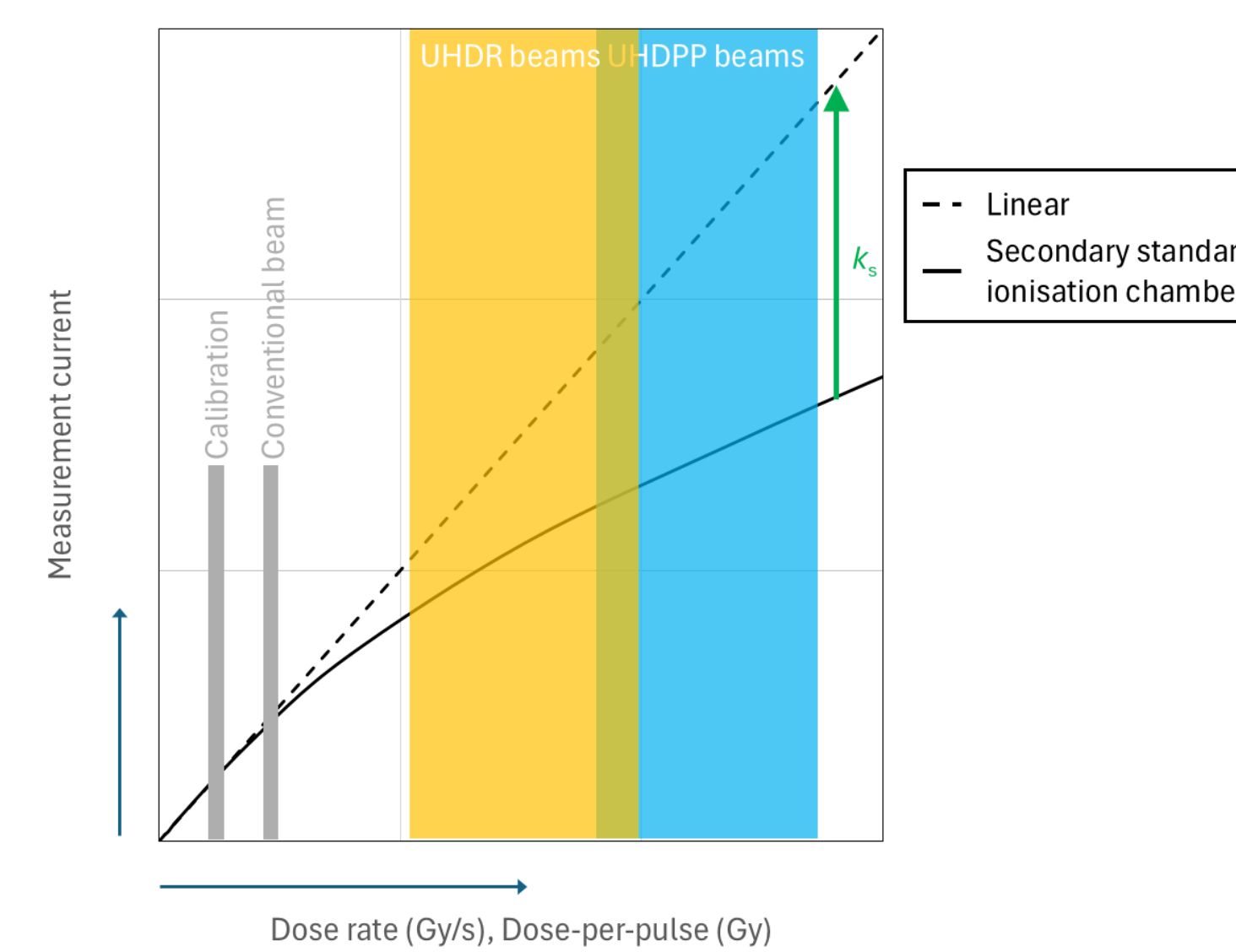
Conventional radiotherapy: delivers radiation dose to patients with dose-rate of 0.1 Gy/s

The FLASH effect: increased sparing of healthy tissue using radiation dose delivery with:

- ultra-high dose rates (UHDR, > 40 Gy/s) or
- ultra high-dose-per-pulse (UHDPP, > 0.6 Gy/ pulse)

FLASH radiotherapy can strongly (~ 50 %) reduce side effects in radiotherapy

The measurement problem



Secondary standards in clinical FLASH beams:

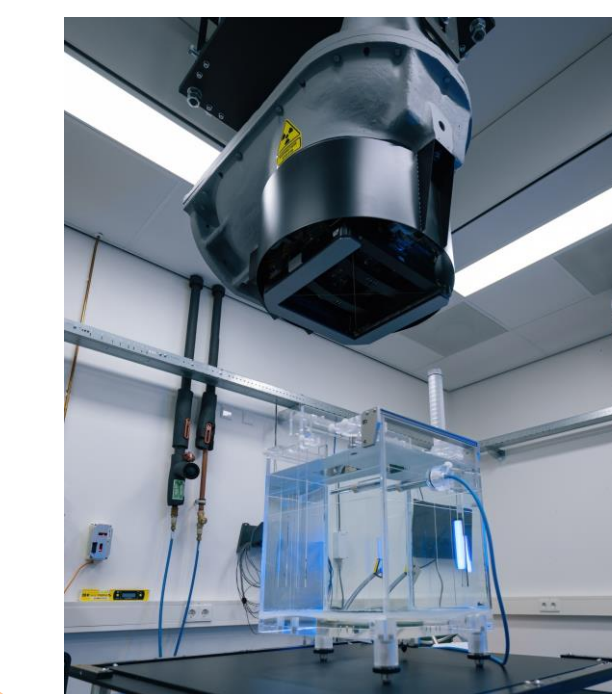
- Pulsed UHDPP electron beams
- UHDR scanning proton beams

show strong **non-linearities** at high dose-rates/ dose-per-pulse due to recombination effects

Traceability of dosimetry in radiotherapy

- Secondary standards ionization chambers are calibrated against primary dosimetry standards in (Co-60) reference fields
- Dosimetry Codes of practice provide methods to correct secondary standard calibration coefficients for differences with clinical fields:
 - Beam quality (k_Q)
 - Dose-rate dependent recombination effects (k_s)
 => Non-linearity

Calibration beam



Clinical beam

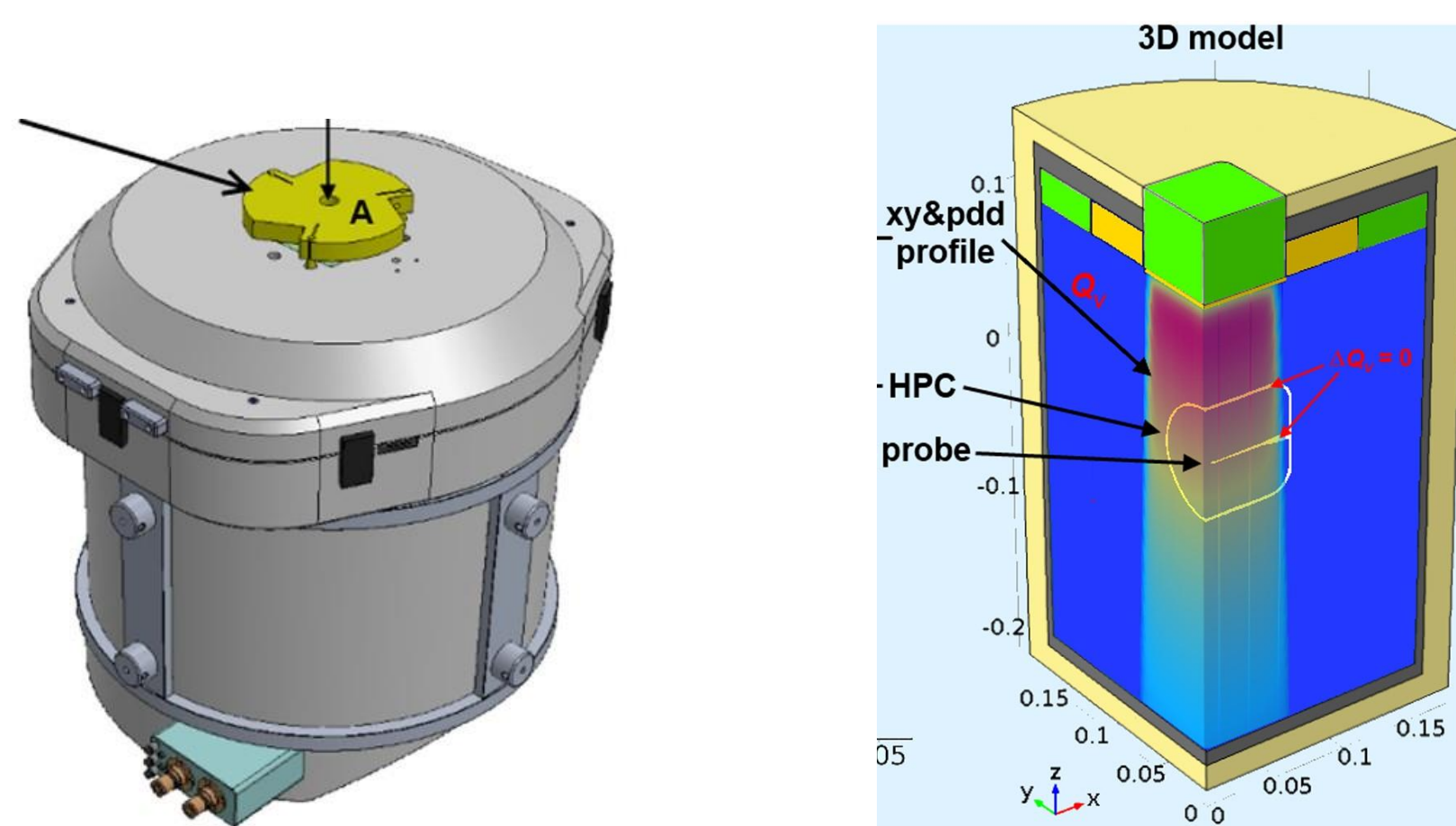


k_Q, k_s

Solution

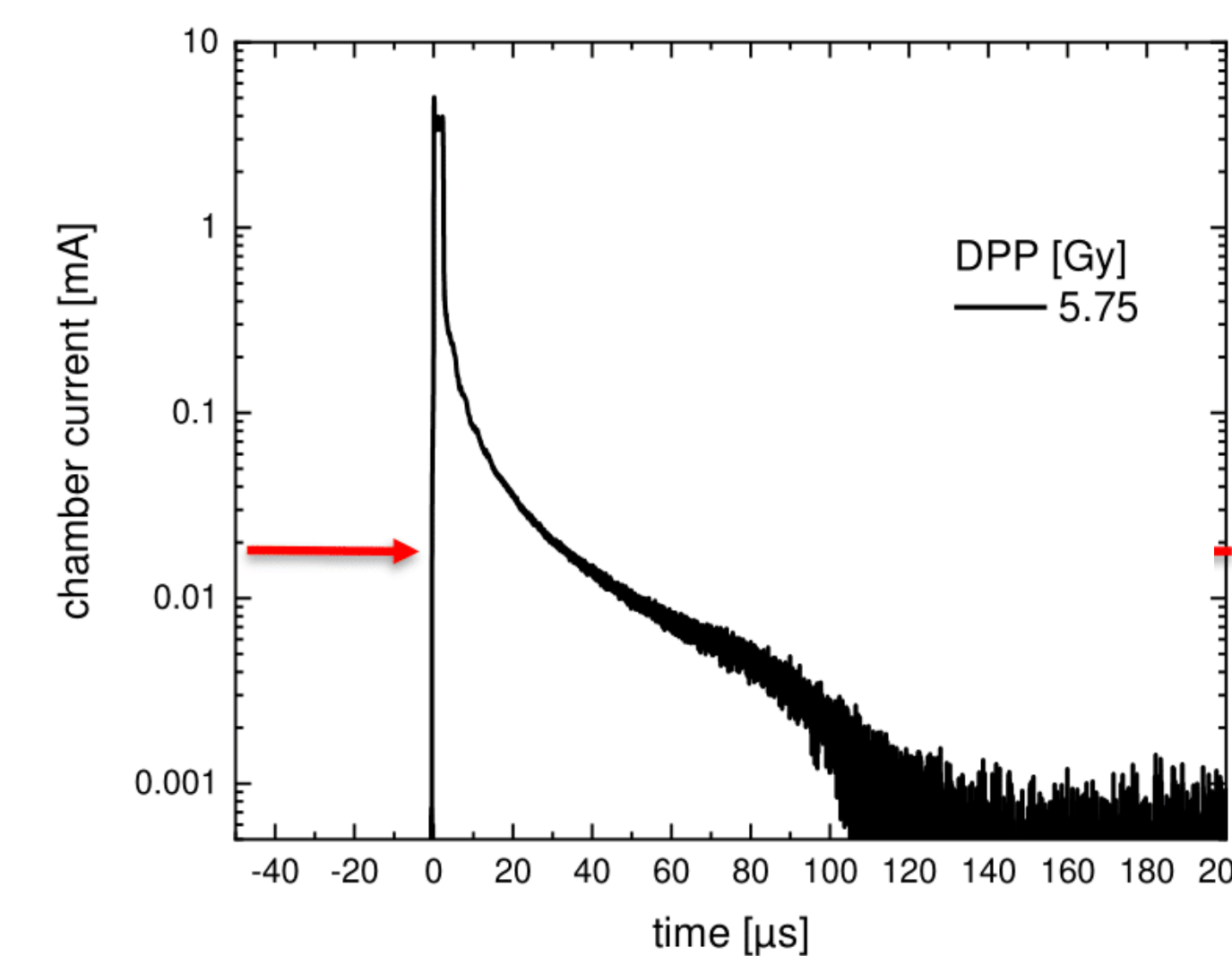
Primary standards for UHDR and UHDPP beams

Extend the operational range of portable water and graphite calorimeters to calibrate secondary standards under UHDR and UHDPP conditions



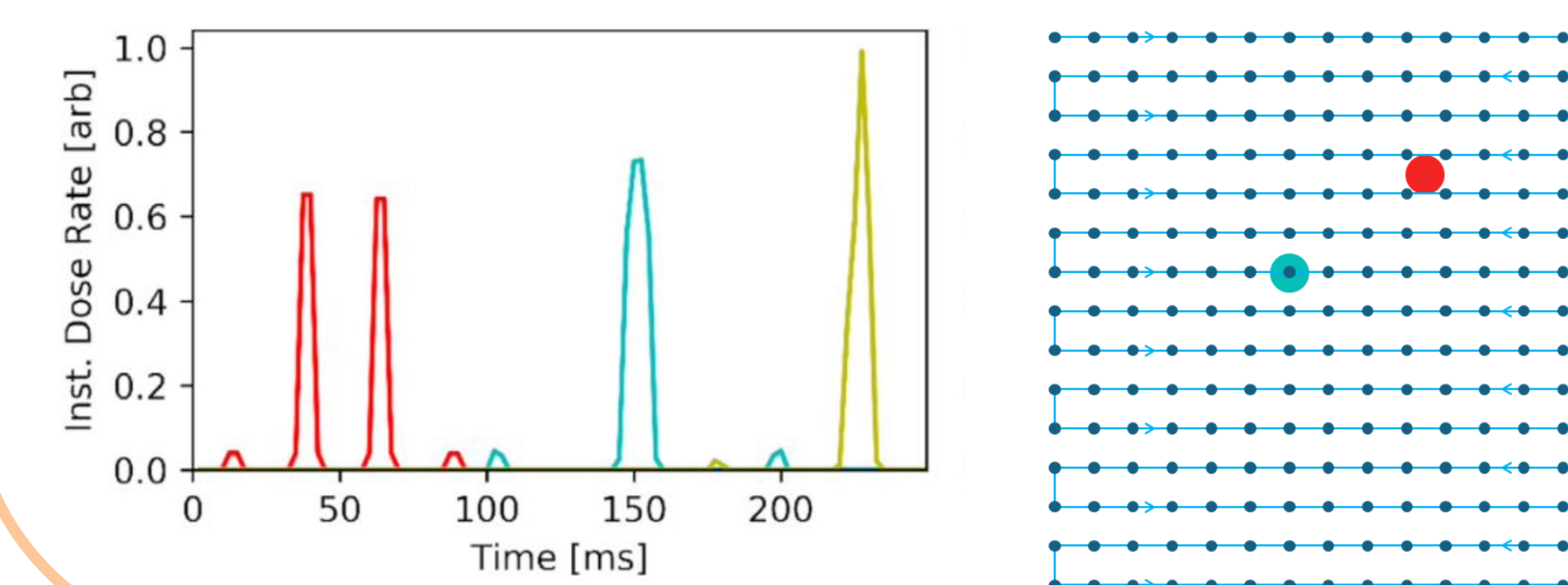
Clinical-like UHDPP reference fields

- Mimic the reference conditions of clinical UHDPP electron beams for direct calibration of secondary standards



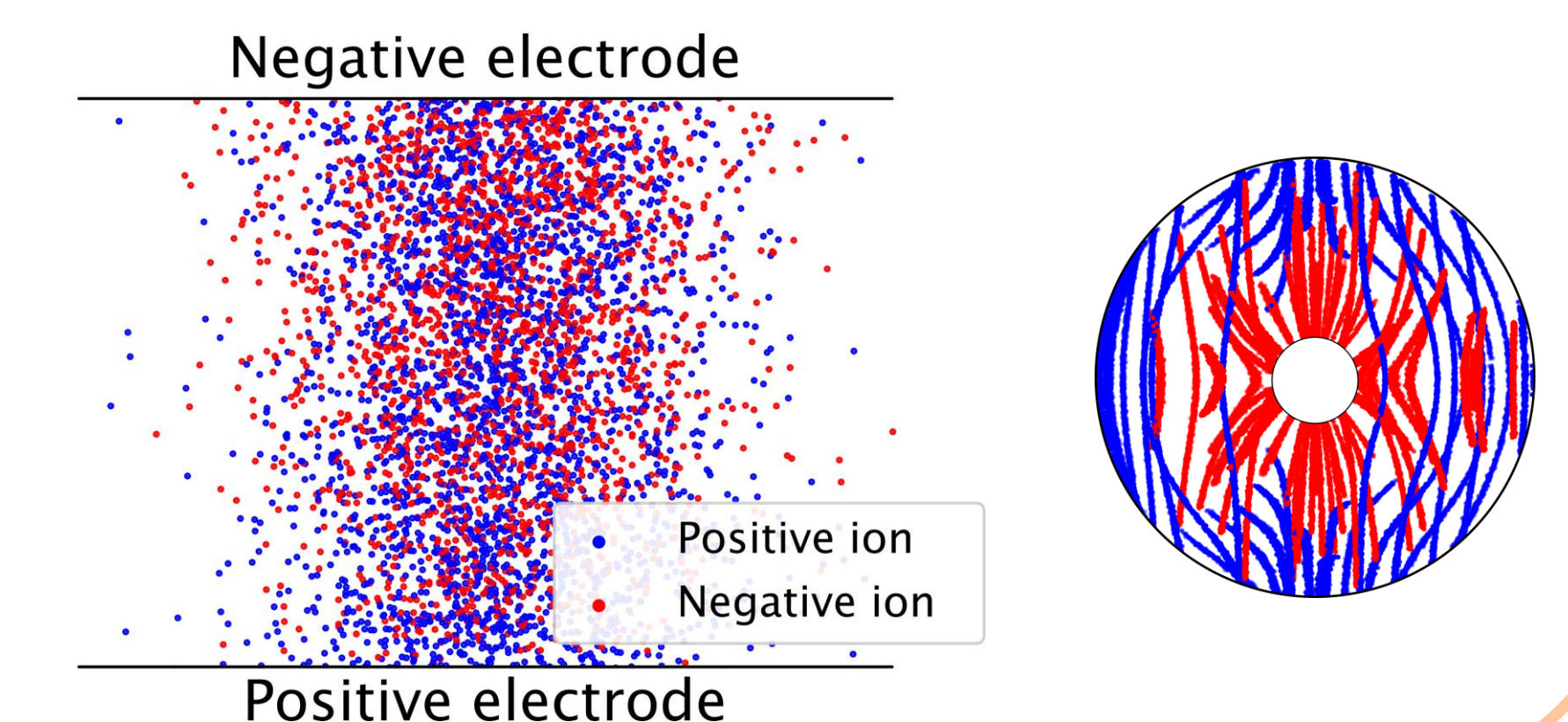
Time resolved dose-rate measurements

- Time resolved dose-rate in scanning UHDR beams depends on position and scanning pattern
- k_s depends on dose-rate
- Measurement of time-resolved dose-rate needs to be developed



Enhanced understanding of recombination by simulations

- Develop new correction techniques for recombination effects (k_s)
- Uncertainty estimation of k_s
- Improve design of secondary standards to reduce k_s



Impact

Societal and Economic

- 10 M cancer patients benefit from reduced side effects and will have improved quality of life
- Enhanced cost effectiveness of radiotherapy
- Enhanced reliability in FLASH facilities (market > 1 B€)
- Enhanced reliability in new detectors and new measurement systems dedicated for FLASH beams

Metrological

- NMI Calibration services of secondary standards in clinical-like reference fields for UHDPP beams
- Demands for dosimetry Key comparisons at high-dose rates and dose-per-pulse
- Contribute to Codes of Practice for reference dosimetry and IEC standards for dosimeters
- Enabling widespread clinical implementation of FLASH facilities