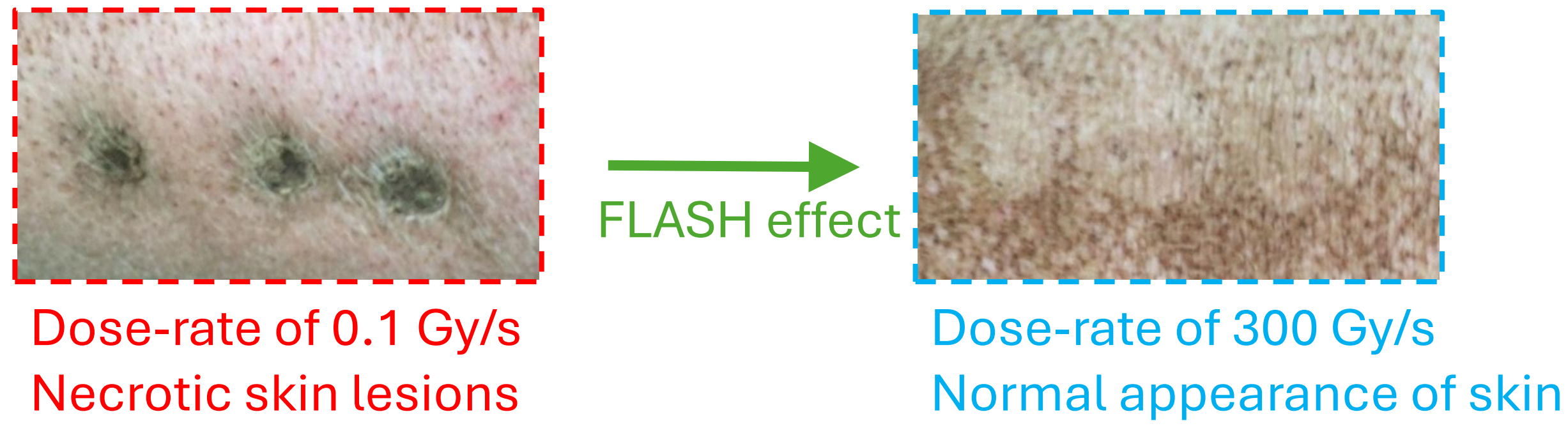


Challenge

What is FLASH radiotherapy?



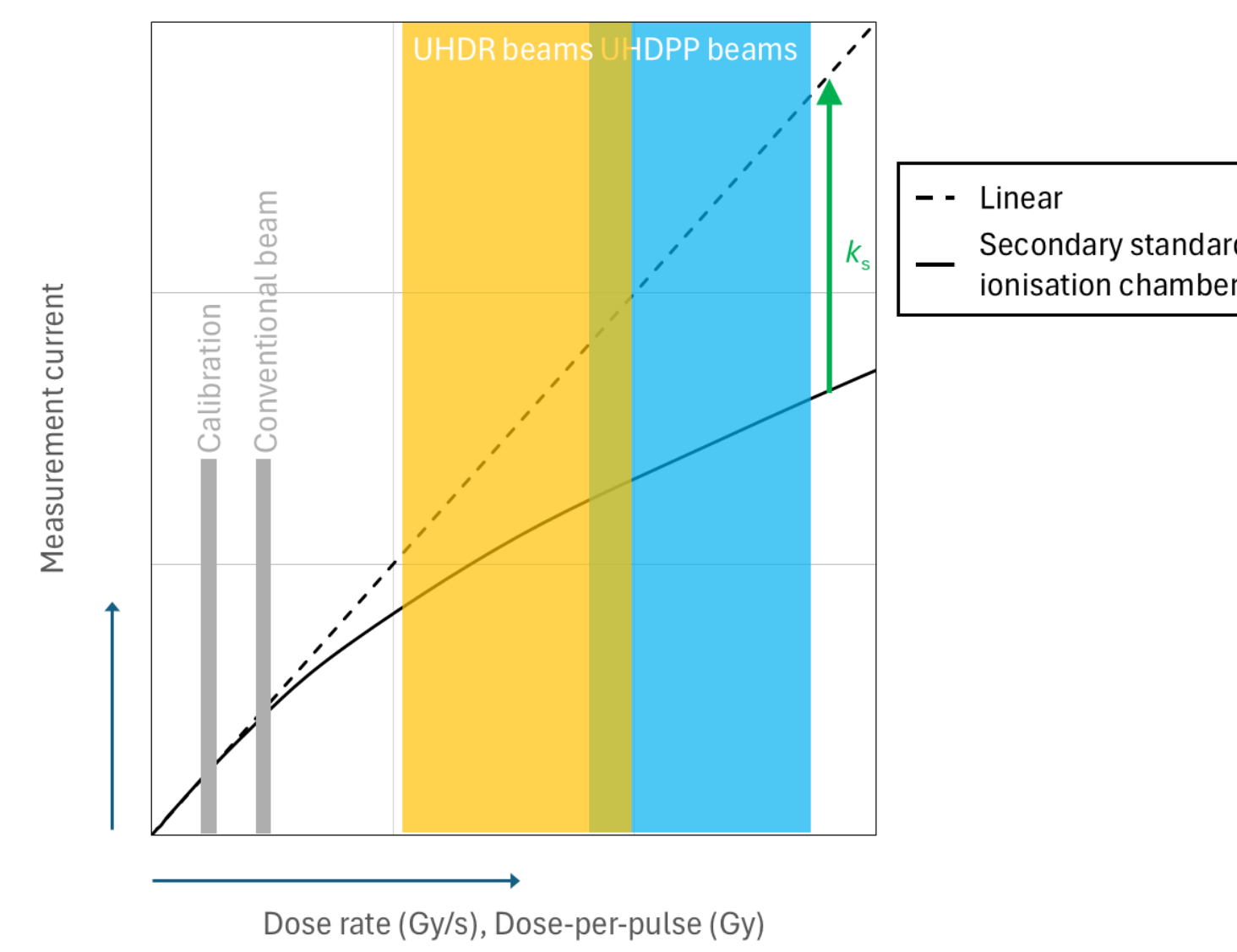
Conventional radiotherapy: delivers radiation dose to patients with dose-rate of 0.1 Gy/s

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

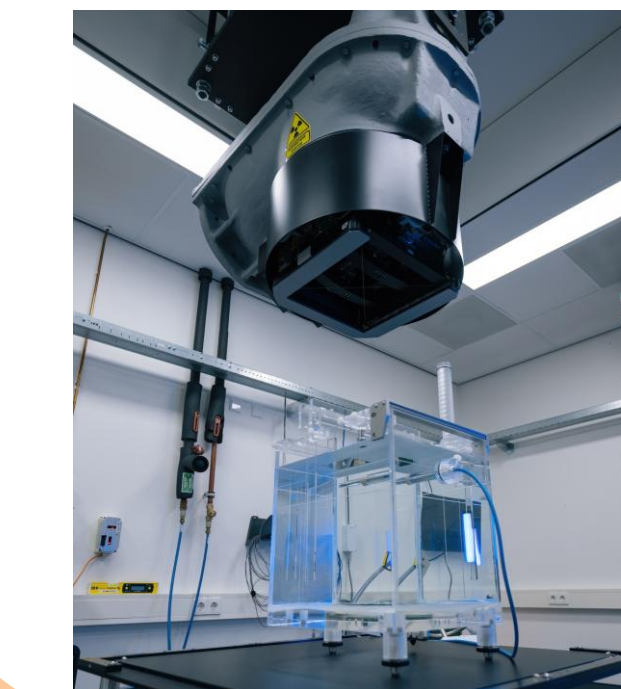
show strong **non-linearities** at high dose-rates/ dose-per-pulse due to recombination effects

Traceability of dosimetry in radiotherapy

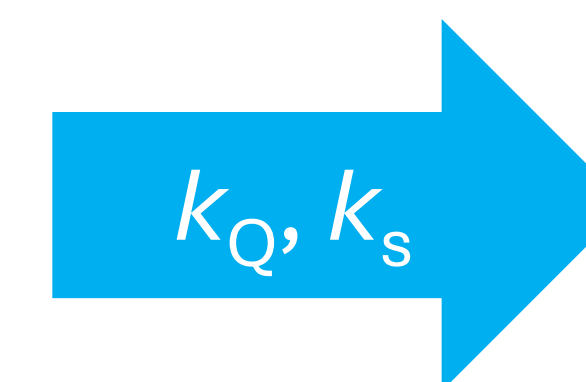
- Secondary standards ionization chambers are calibrated against primary dosimetry standards in (Co-60) reference fields
- Dosimetry Codes of practice (e.g. IAEA TRS-398) provide methods to correct secondary standard calibration coefficients for differences with clinical fields:

- Beam quality (k_Q)
 - Dose-rate dependent recombination effects (k_s)
- => Non-linearity

Calibration beam



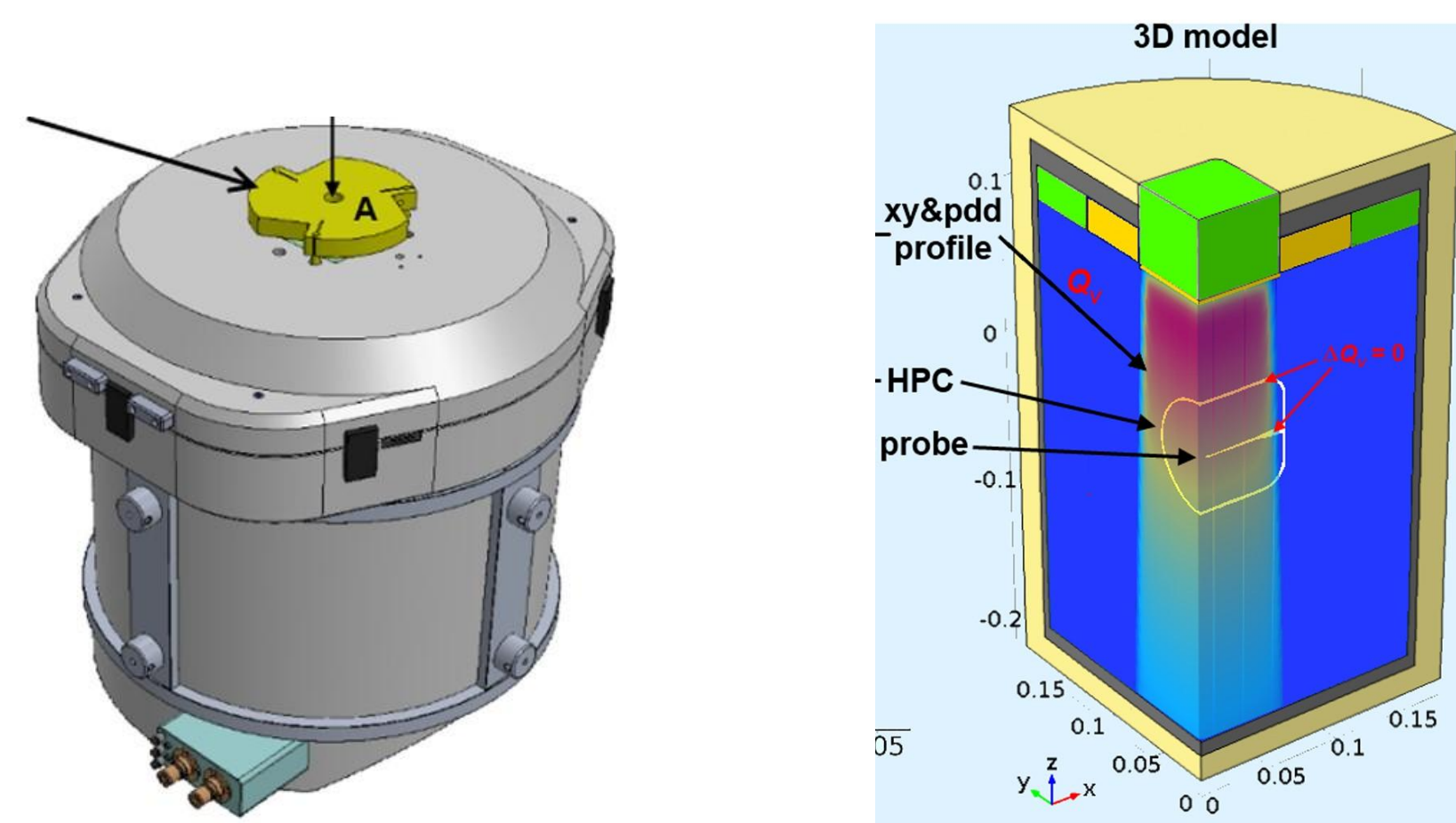
Clinical beam



Solution

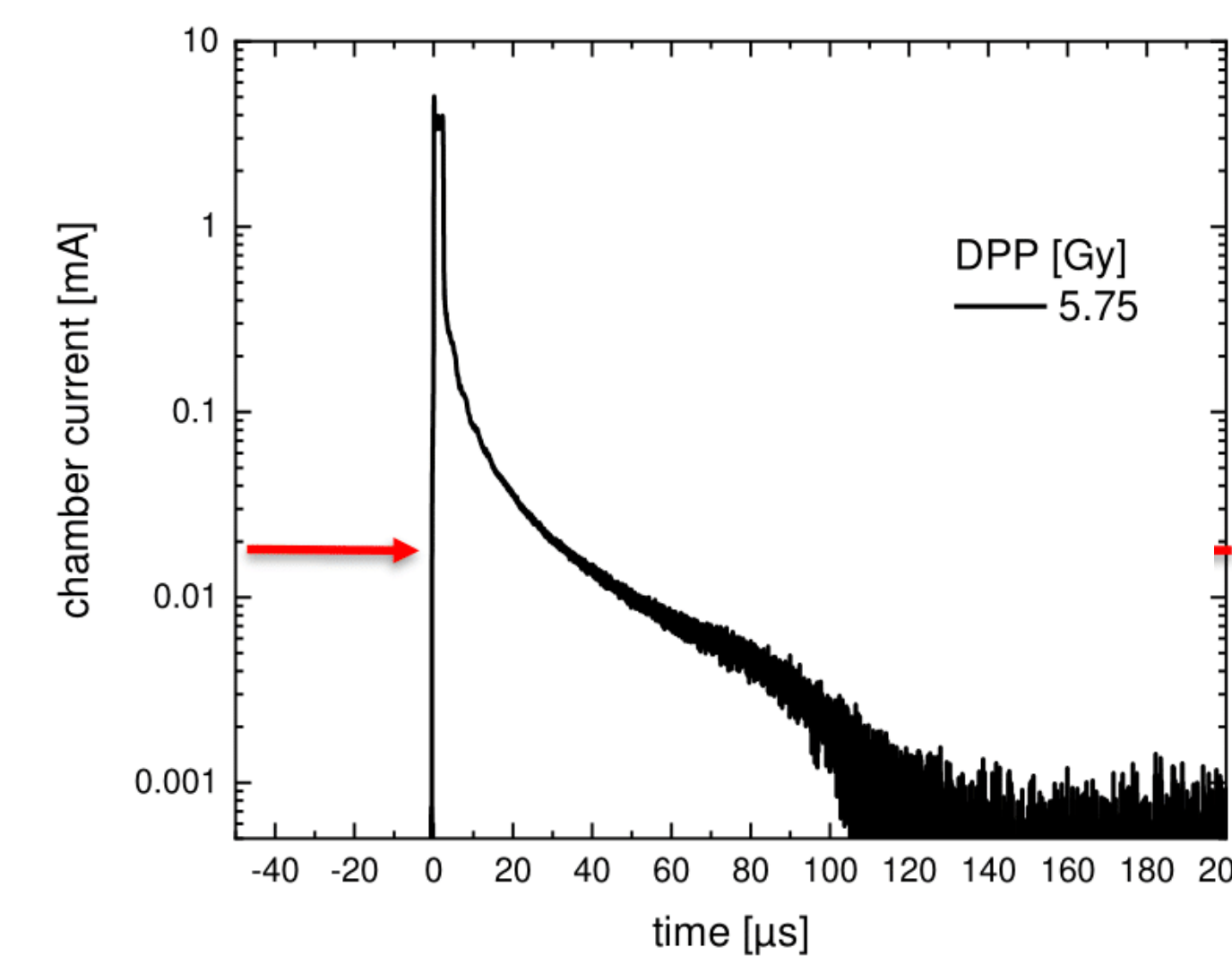
Primary standards for UHDR and UHDPP beams

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



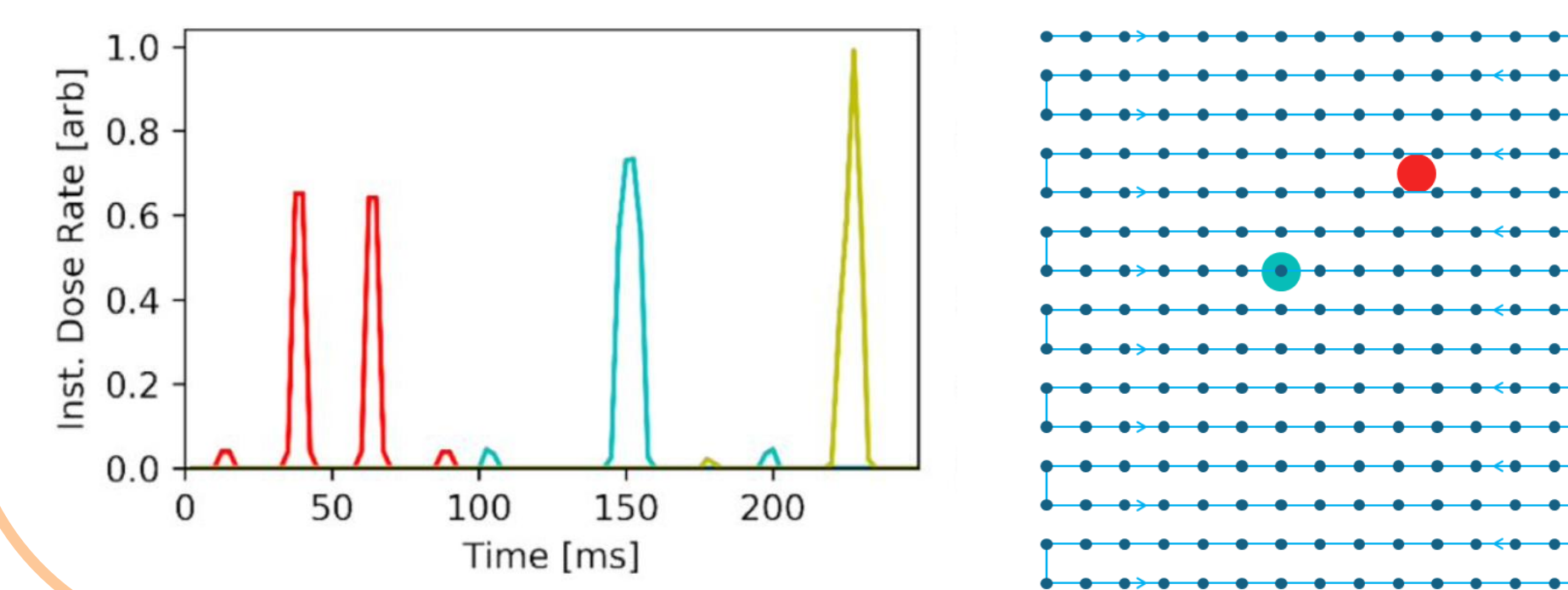
Clinical-like UHDPP reference fields

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



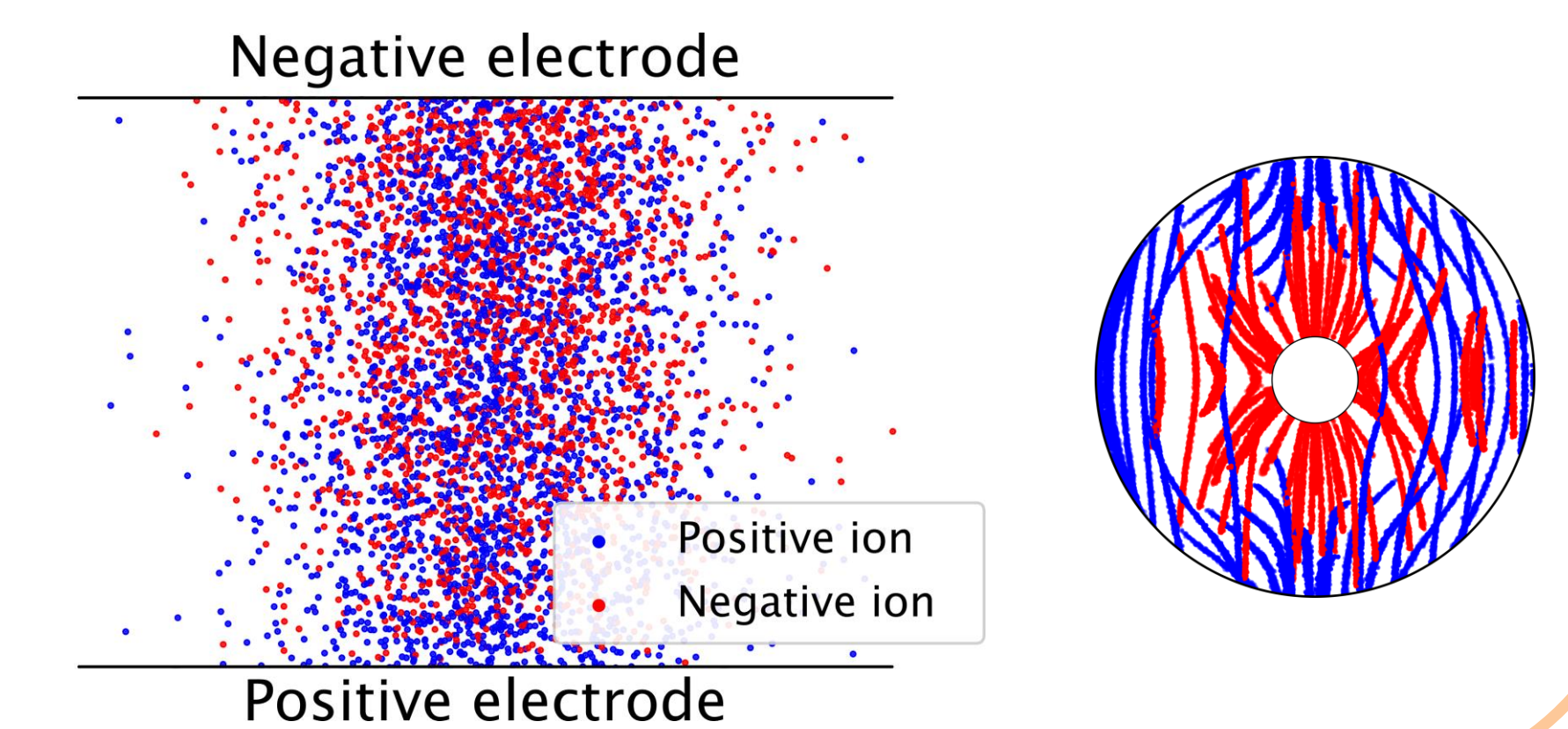
Time resolved dose-rate measurements

- 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 (e.g. IAEA TRS-398)
- Contribute to IEC standards on the performance of secondary standard dosimeters