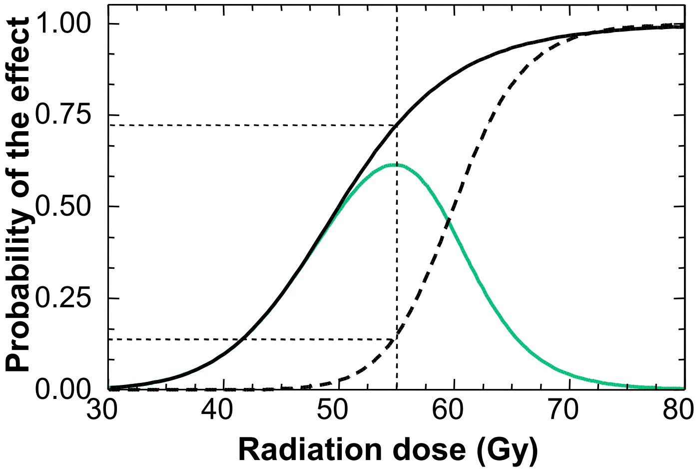
Detectors for radiotherapy

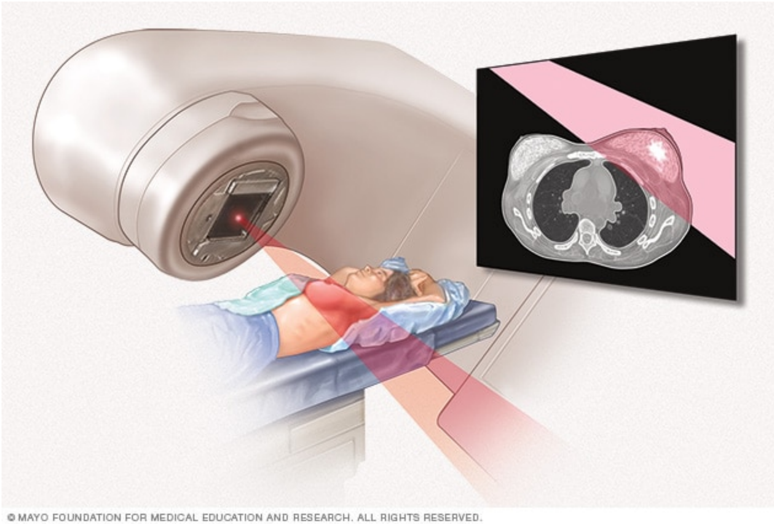
2nd ELICSIR Online Workshop

Radiofísica Hospitalaria y Protección Radiológica
Servicio Andaluz de Salud
HOSPITAL UNIVERSITARIO SAN CECILIO

Damián Guirado
dguirado@ugr.es

Goal of Radiotherapy

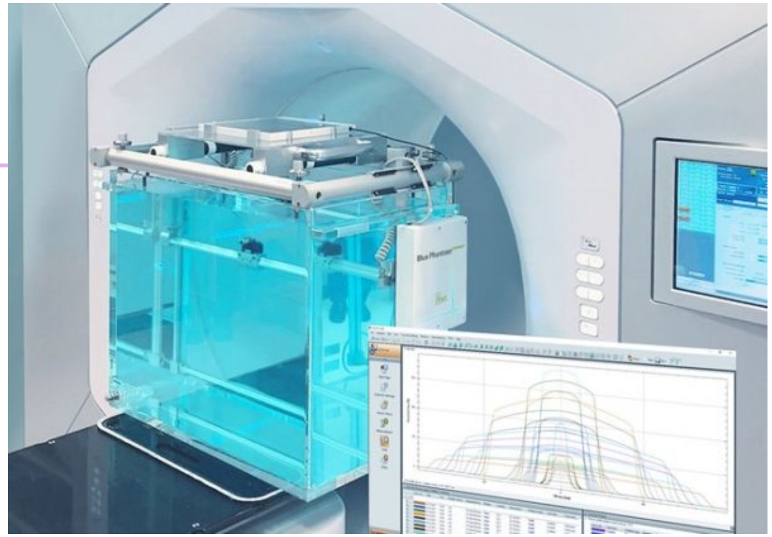




→ How can we open the therapeutic window?

- → Improving the treatment technique.
- → Improving the dose distribution over time.

What do we need?



- → To determine the dose at a point
  - → Reference conditions
  - → Patients
    - → Pre-treatment verification
    - → In vivo dosimetry

- → To determine dose-distributions
  - → Caracterization of equipments
  - → Patients
    - → Pre-treatment verification
    - → In vivo dosimetry

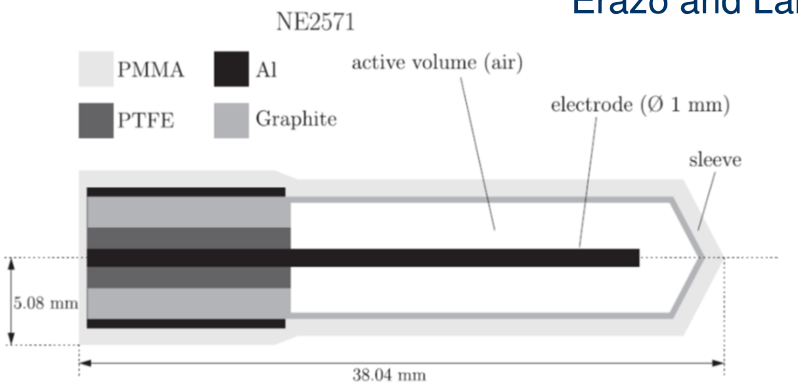
Overview

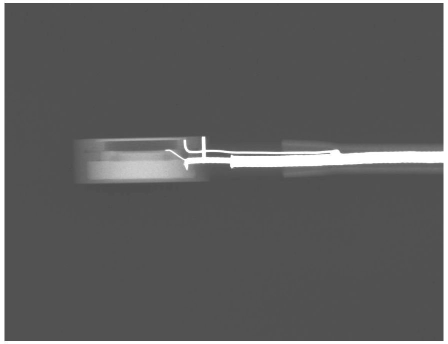
→ Detectors
  → Main detectors
    → Ionization chambers
    → Diodes
    → Radiochromic films
  → Others detectors
    → Diamonds,TLD's, MOSFET
    → EPIDs
  → In development
    → Light-dependent resistor (LDR),…
→ Clinical application of MOSFET
  → In vivo dosimetry in HDR-brachytherapy

Ionization chambers

Farmer type

Erazo and Lallena 2013



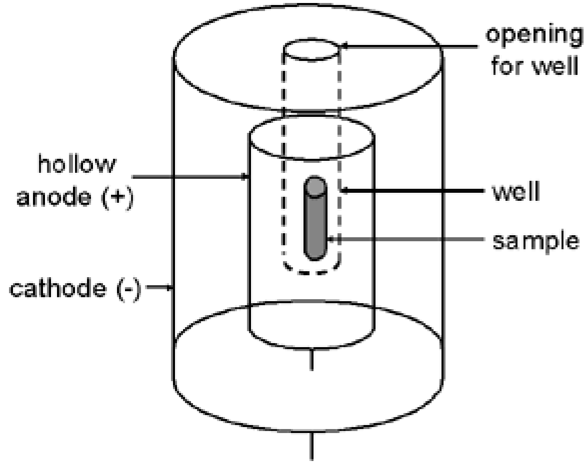


Plain-parallel type

- → Reference detectors in radiotherapy
- → Designs adapted to different applications
  - → External radiotherapy
    - → Photons, electrons, protons, …
  - → Brachytherapy
- → Associated with electrometers: they are stable and robust over time

Ionization chambers

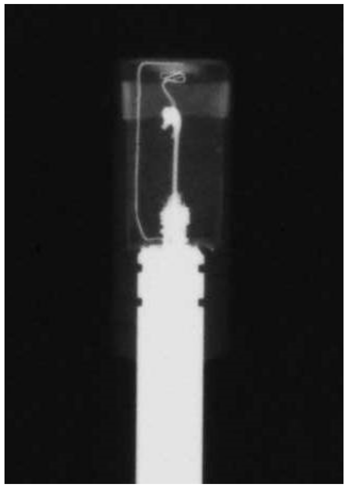
Well chamber

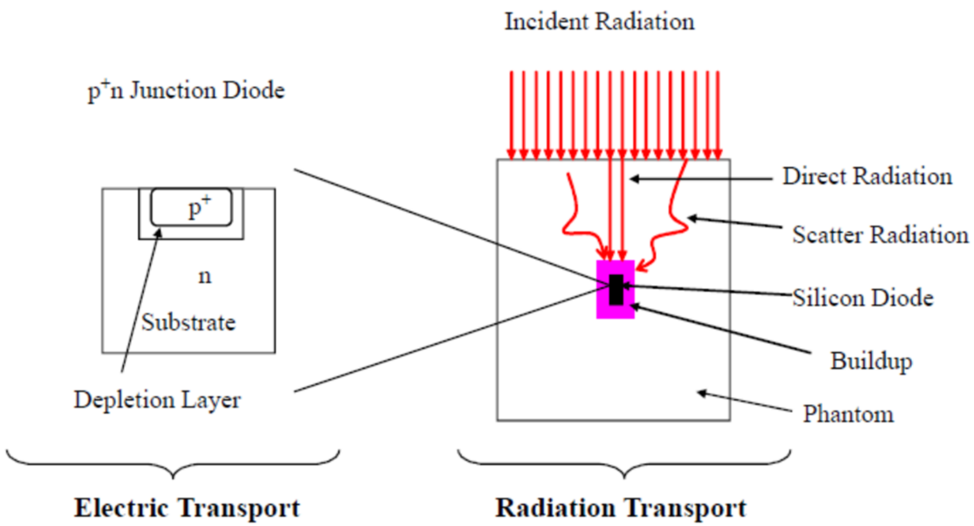


- → Dependences
  - → Recombination
  - → Temperature and presure
  - → Polarity effects

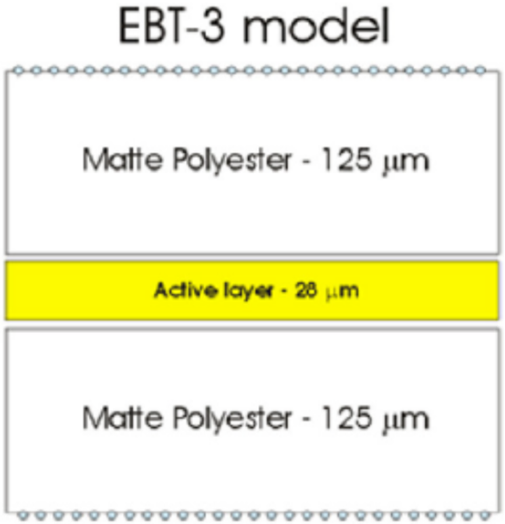
Diodes

- → Very small detection volume
- → Usually used at 0V
- → Dependence with:
  - → Temperature, energy, dose-rate
  - → Radiation incidence angle

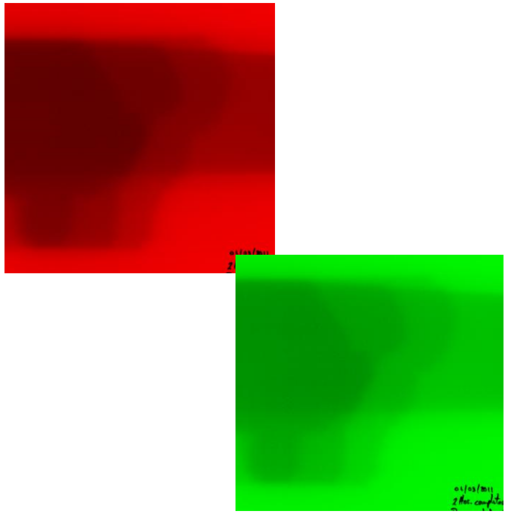




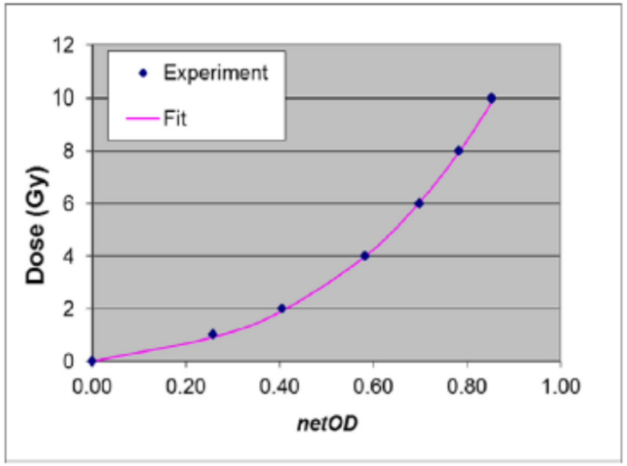
Radiochromic film



Devic et al. 2016



- → High spatial resolution (2D)
- → Energy independent
- → Near tissue equivalence
- → Complex processing
- → Post-irradiation waiting time (24h)



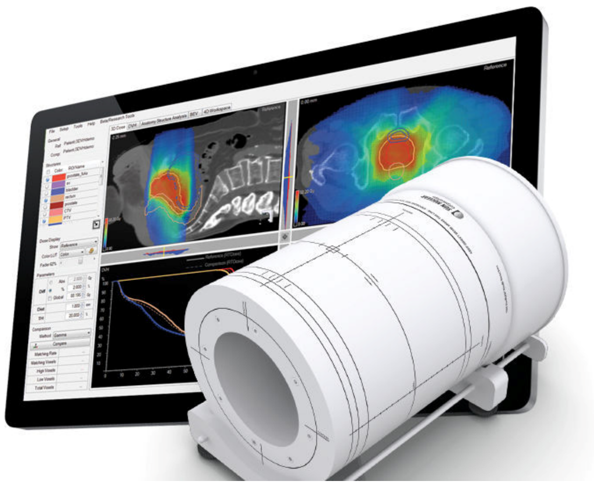
Calibration curve

Other detectors

- → Electronic portal imaging devices (EPIDs)
- → Mosfet detectors
- → Diamond detectors
- → Thermoluminiscent detectors (TLDs)
- → …

Verification devices for IMRT and VMAT

ArcCheck – Sun Nuclear - DIODES



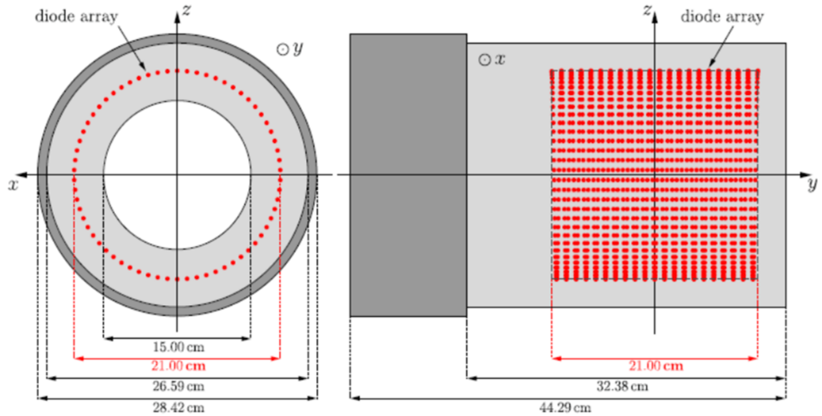
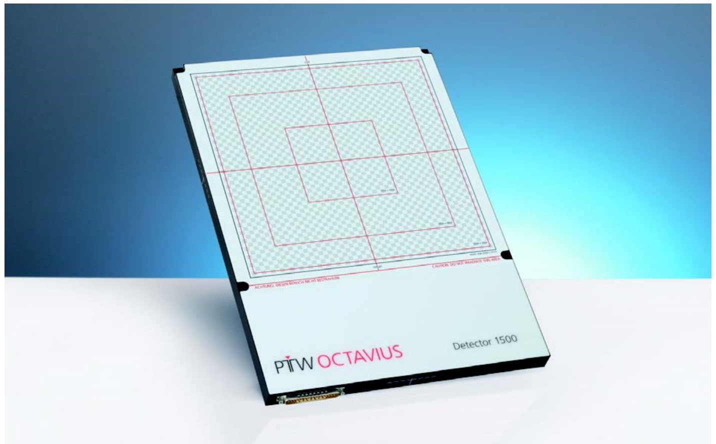
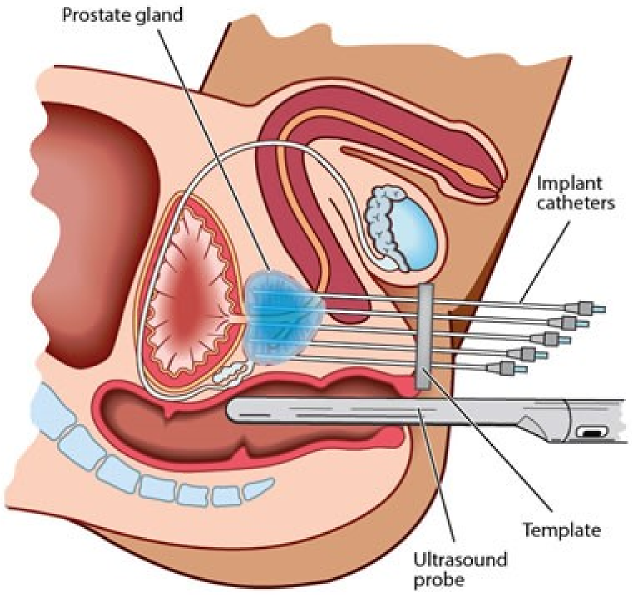


Fig. 1. Sketch of the geometry of the ArcCHECK® device.

Octavius – PTW – IONIZATION CHAMBERS

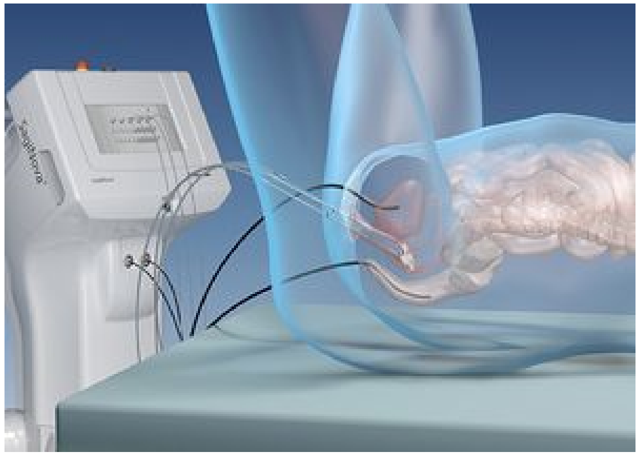


High dose-rate brachytherapy of prostate cancer



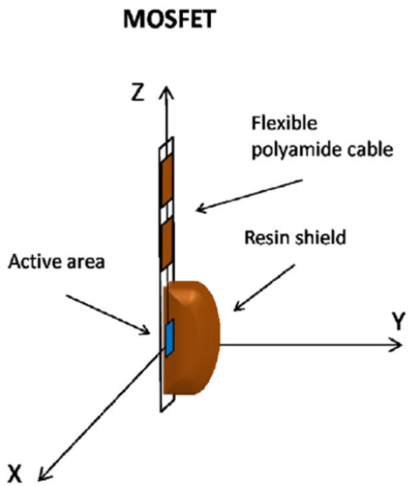
→ Need for *in vivo* dosimetry

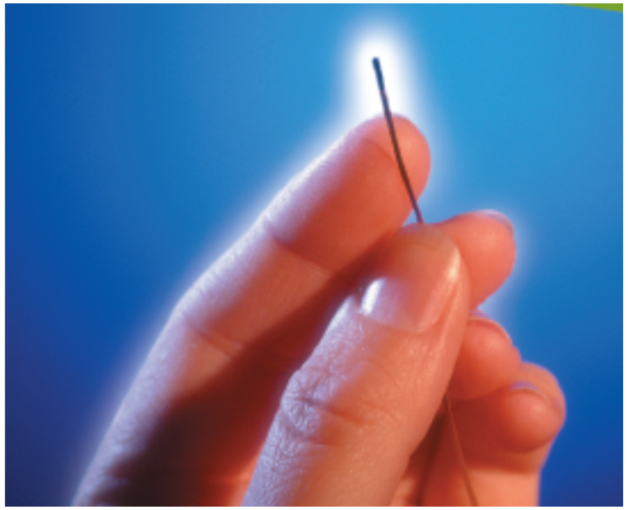
→ Selection and characterization of detectors



microMOSFET detectors for in vivo dosimetry

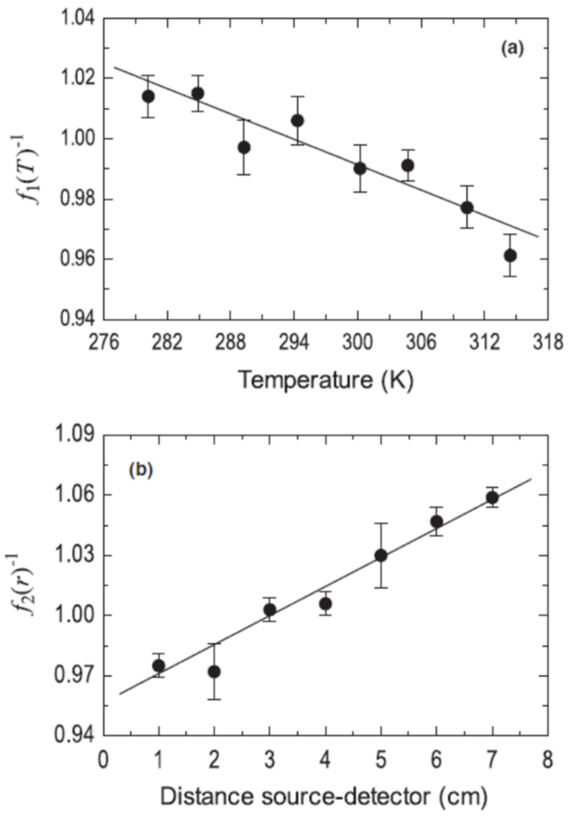
Best Medical Canada microMOSFET



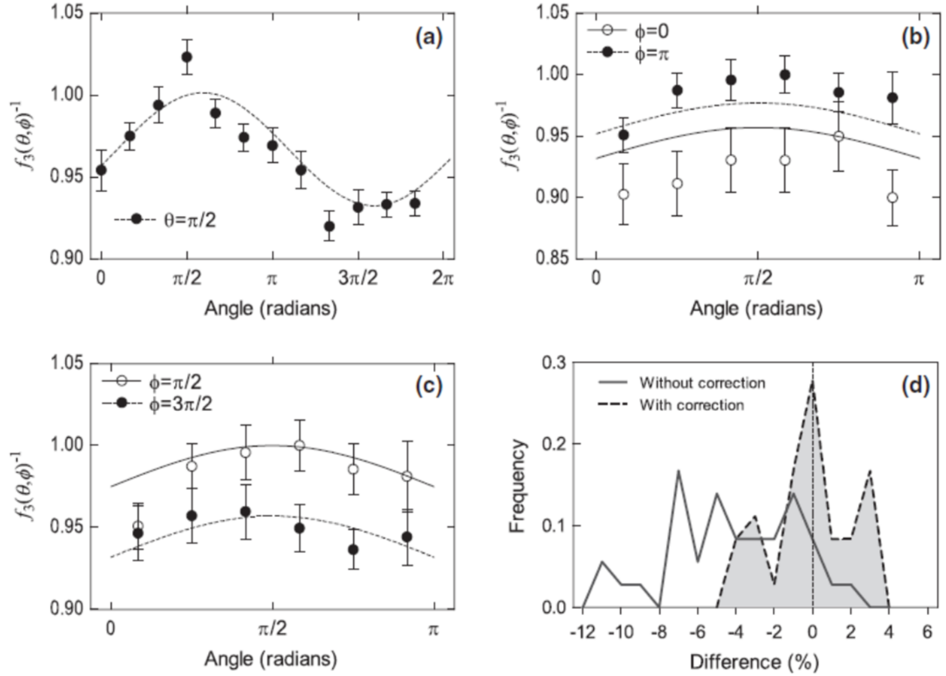


- → MicroMosfet dependences:
  - → Temperature
  - → Detector-source distance
  - → Relative orientation detector-source

microMOSFET detectors for in vivo dosimetry

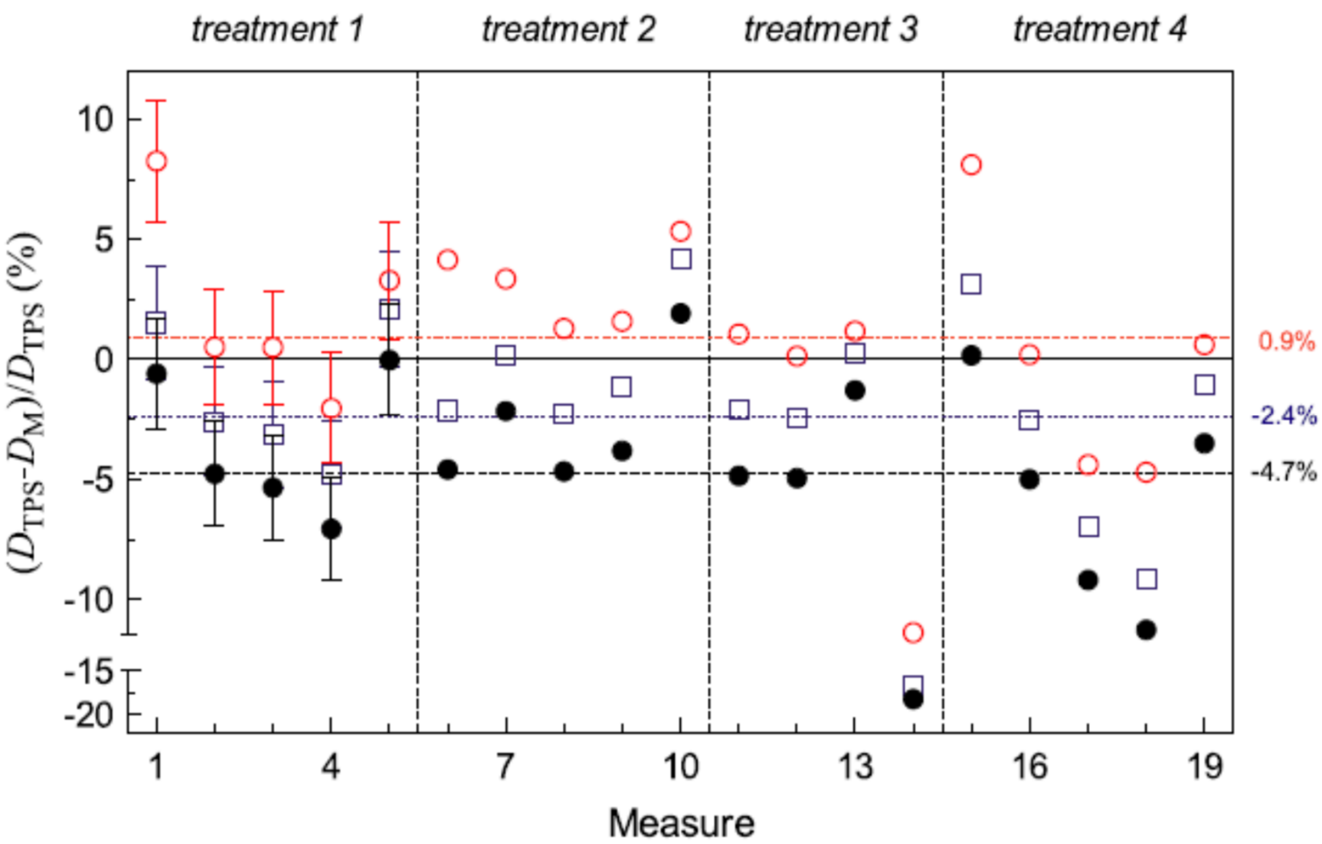


Ruiz-Arrebola et al. 2020



$$D(\vec{r}) = CF \cdot f(T, r, \theta, \phi) \cdot M(\vec{r})$$

microMOSFET detectors for in vivo dosimetry



Summary

Device -Accuracy	**Common Uses**	**Advantages**	**Limitations**
Ion Chambers ±1%	-Reference Dosimetry -Percent Depth Dose Distributions	-Best understood -Below 1% accuracy possible -Low energy dependence	-Size limitations -ADCL calibration required
Diode Detectors ±2-3%	-Small field dosimetry -Array devices -Electron PDD	-Small volume -Rapid readout -No external bias	-Temperature dependence (0.5%/C) -Dose rate dependence -Energy dependence
Film ± 5%	-Planar dose distributions -Electron PDD	-Best spatial resolution (μm) -Large area measurement -Persistent dose record -Tissue equivalent (radiochromic only)	-Delayed readout -Batch-to-batch variation -Chemical development (radiographic only)
Luminescent Dosimeters ±3%	-In Vivo Dosimetry -Personnel dosimeters -End-to-end testing (IROC)	-Small size -Low MV energy dependence	-Delayed readout -Signal loss over time -Supralinear response with accumulated dose
MOSFET Detectors ± 5-12%	-In vivo dosimetry -Small Field Dosimetry -Surface dose	-Extremely small effective volume -Permanent dose record -Instant readout	-Finite life (~100Gy) -Energy Dependence -Temperature Dependence -Sensitivity changes with accumulated dose

References

→ Erazo F, Lallena AM. Calculation of beam quality correction factors for various thimble ionization chambers using the Monte Carlo code PENELOPE. Phys Med 2013;29:163-70.

→ Devic S, Tomic N, Lewis D. Reference radiochromic film dosimetry: Review of technical aspects. Phys Med 2016;32:541-56.

→ Ruiz-Arrebola S, Fabregat-Borrás R, Rodríguez E, et al. Characterization of microMOSFET detectors for in vivo dosimetry in high-dose-rate brachytherapy with 192Ir. Med Phys 2020;47:2242-2253.