U O W

Radiation dosimetry for Radiotherapy

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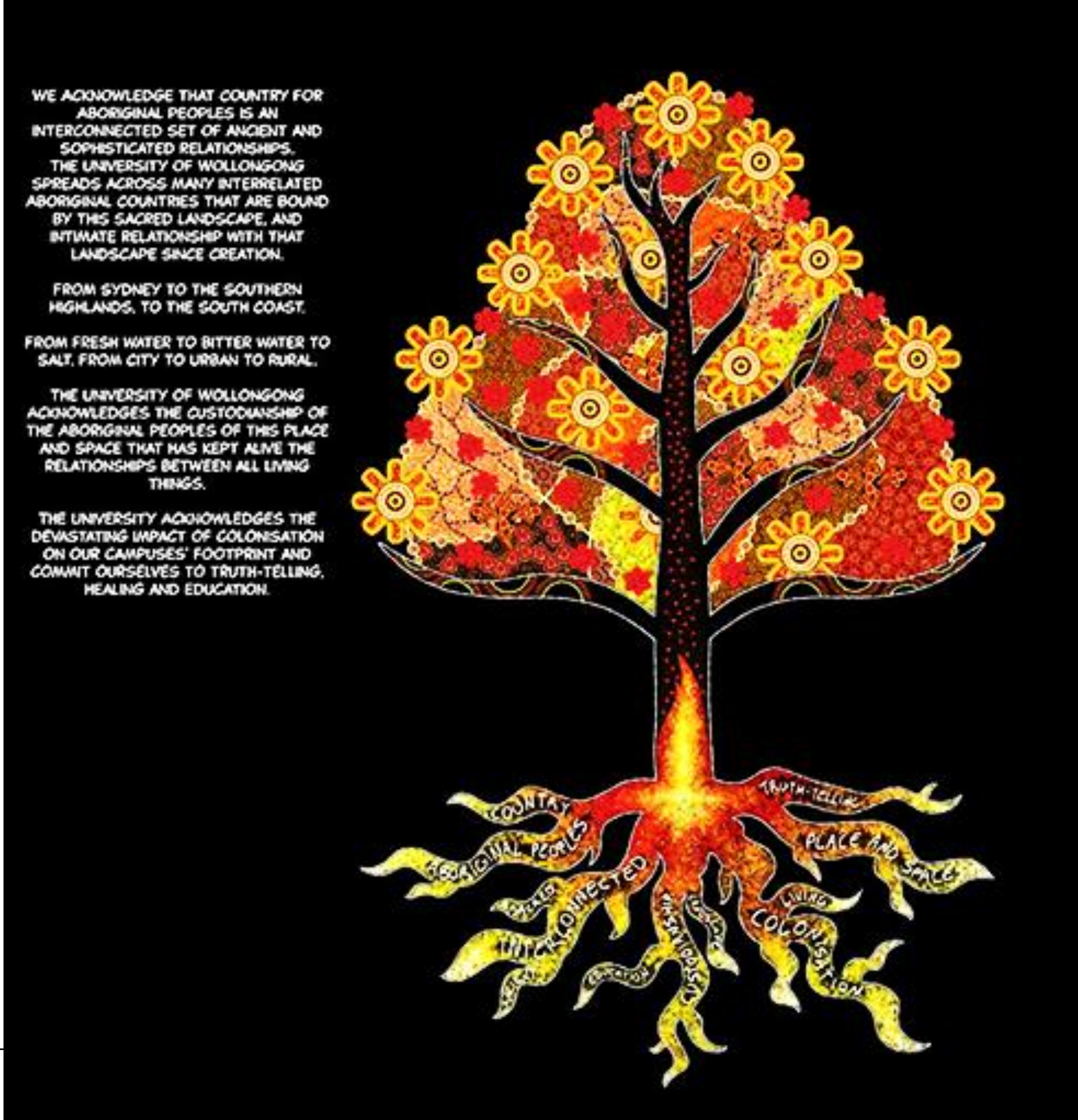
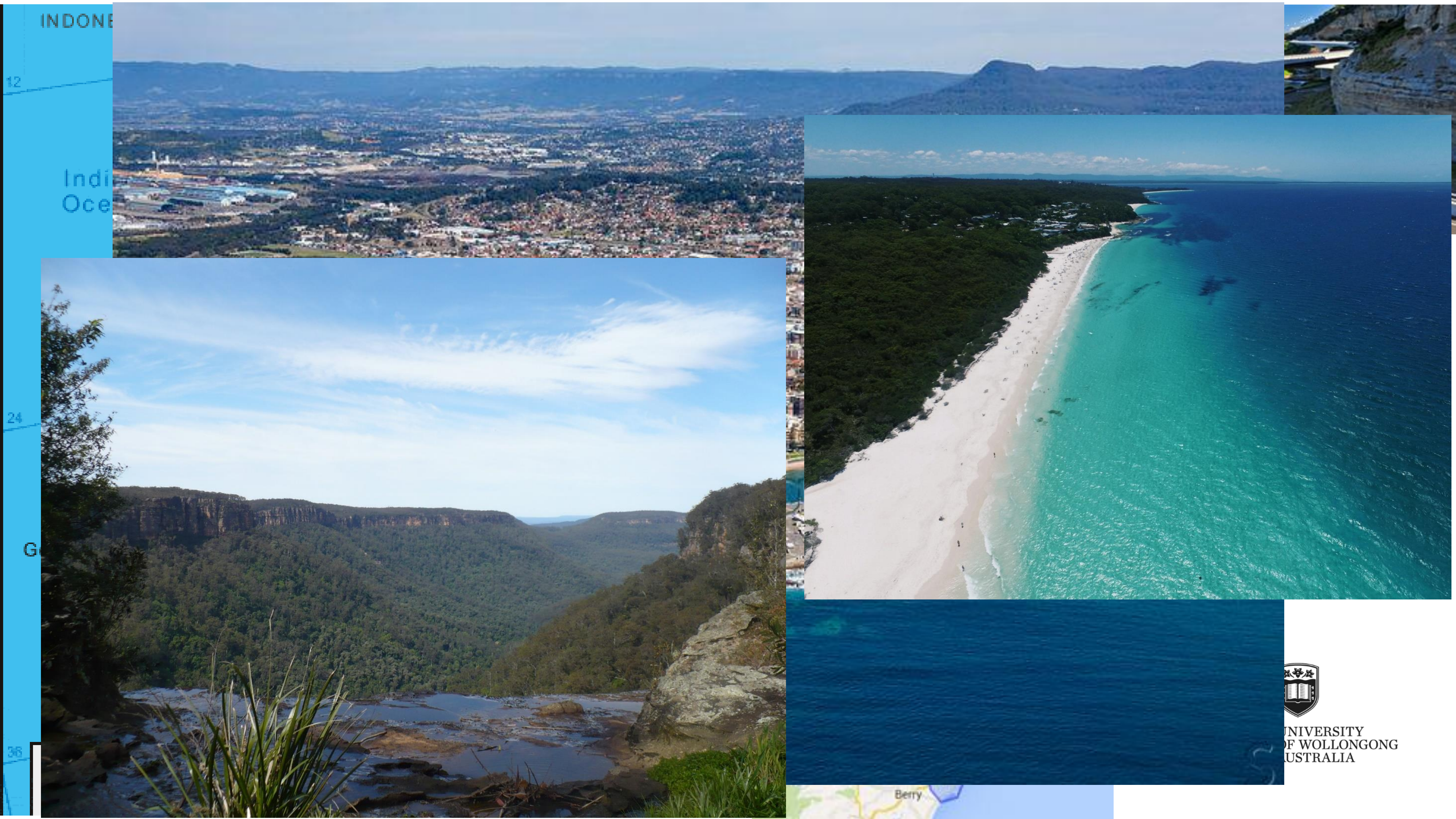
Acknowledgement of country

Before we begin the proceedings, I would like to acknowledge and pay respect to the traditional owners of the land on which I live: the **Dharawal** people; It is upon their ancestral lands that the University of Wollongong is built. As we share our own knowledge, teaching, learning and research practices within this university, may we also pay respect to the knowledge embedded forever within the Aboriginal Custodianship of Country.





NIVERSITY
F WOLLONGONG
USTRALIA

UOW – University of Wollongong

Founded in 1958

5 Faculties,
31,000 students,
Technology Park
2 Hospitals (assoc.)
2000 employees
800 academics
QS ranked top 1% (136th)

Centre for Medical Radiation Physics

Distinguished Prof Anatoly Rozenfeld

Founder and Director

Prof Michael Lerch

Head of School

Sen. Prof Peter Metcalfe

Prof Marco Petasecca

Assoc. Prof Susanna Guatelli

Dr Yujin Qi

Dr Moeava Tehei

Dr Enbang Li

Dr Dean Cutajar

Dr Linh Tran

Dr Brad Oborn

Dr. David Bolst

Dr Jessie Posar

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EDUCATION AND RESEARCH
Knowledge and Training at CMRP

70% of medical physicists in NSW were **trained at CMRP**

Currently studying at CMRP:

30 PhD students

15 Masters (Research) students

Approx. 120 undergraduate/year enrolled

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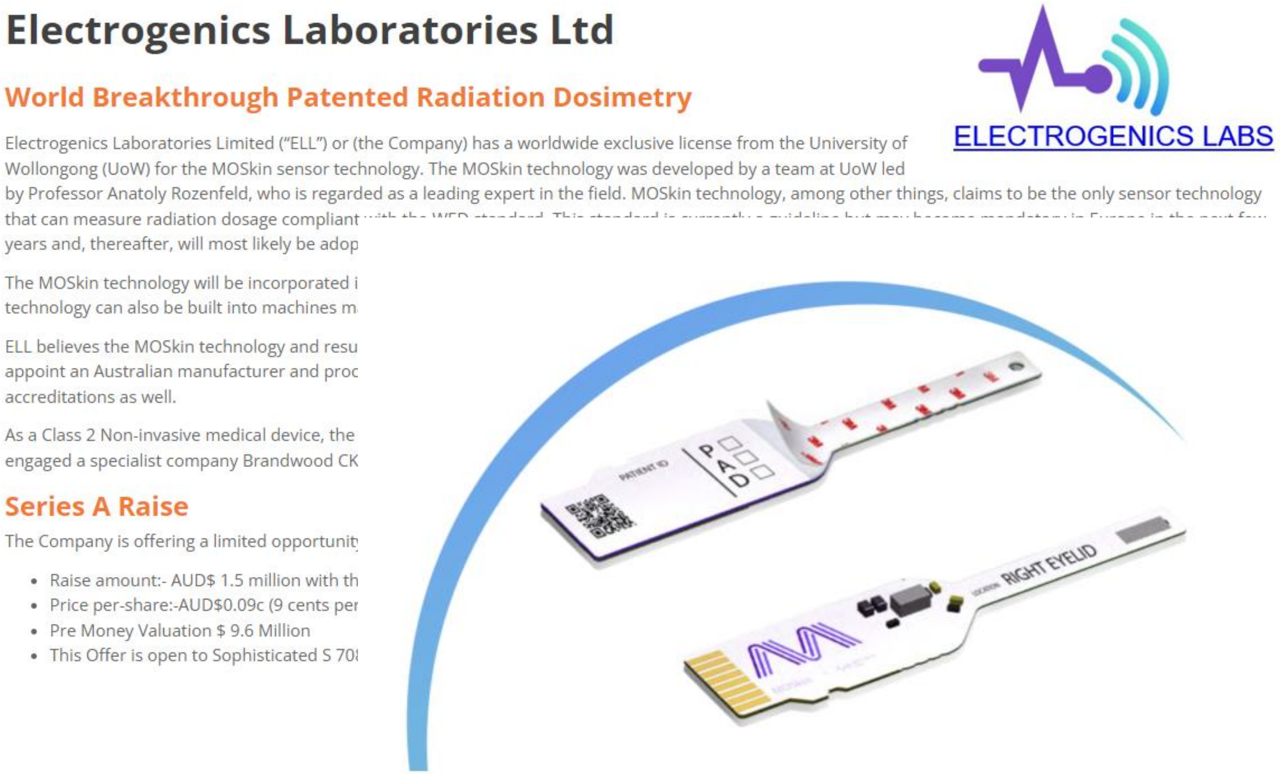
Centre For Medical Radiation Physics

- Research strength of the UOW

- Strong commercial outcome is expected from Research Strengths @ UOW!



Electrogenics Laboratories Ltd

World Breakthrough Patented Radiation Dosimetry

Electrogenics Laboratories Limited ("ELL") or (the Company) has a worldwide exclusive license from the University of Wollongong (UoW) for the MOSkin sensor technology. The MOSkin technology was developed by a team at UoW led by Professor Anatoly Rozenfeld, who is regarded as a leading expert in the field. MOSkin technology, among other things, claims to be the only sensor technology that can measure radiation dosage compliant
years and, thereafter, will most likely be adop

The MOSkin technology will be incorporated i
technology can also be built into machines m

ELL believes the MOSkin technology and resu
appoint an Australian manufacturer and proc
accreditations as well.

As a Class 2 Non-invasive medical device, the
engaged a specialist company Brandwood CK

Series A Raise

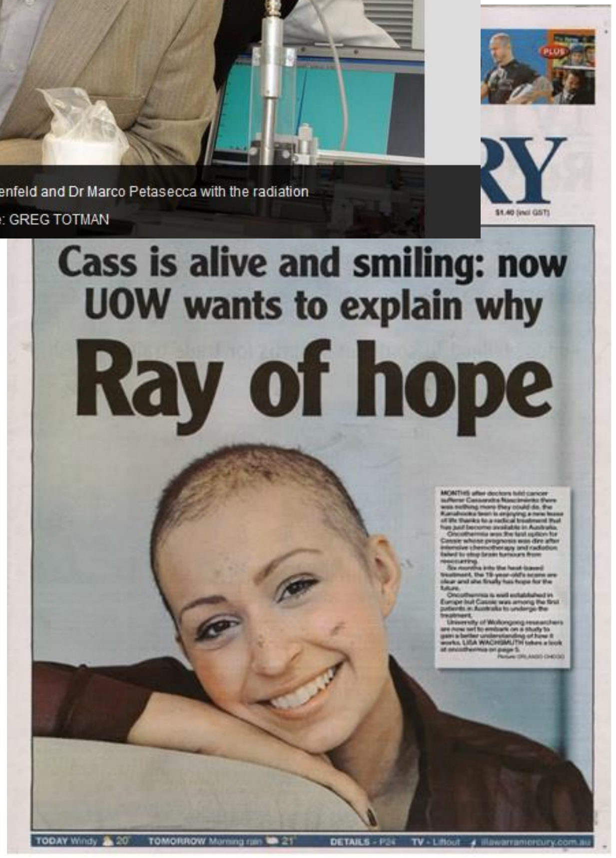
The Company is offering a limited opportunity

- Raise amount:- AUD$ 1.5 million with th
- Price per-share:-AUD$0.09c (9 cents per
- Pre Money Valuation $ 9.6 Million
- This Offer is open to Sophisticated S 70

UOW academics awarded cancer patent

By LISA WACHSMUTH Sept. 29, 2012, 4:03 a.m.

University of Wollongong researchers Dr Michael Lerch, Professor Anatoly Rozenfeld and Dr Marco Petasecca with the radiation detector which is portable and inexpensive compared to other products. Picture: GREG TOTMAN



Cass is alive and smiling: now UOW wants to explain why

Ray of hope

PARTNERSHIPS with Industry

SPA-BIT
Semiconductors

ELECTROGENICS LABS

SINTEF

AMCRYS-H
Scintillators

AMCRYS-H

PARTNERSHIPS in research

MSKCC - Memorial Sloan-Kettering Cancer Center

Memorial Sloan-Kettering Cancer Center

LOMA LINDA UNIVERSITY
MEDICAL CENTER

LLUMC – Loma Linda University Medical Center

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

for Zaky

F.H. Burr Proton Therapy Center – MGH

MASSACHUSETTS GENERAL HOSPITAL

UNITED STATES NAVAL ACADEMY
HONOR... COURAGE... COMMITMENT

United States Naval Academy

NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

NSBRI

ESRF

Wisconsin Institutes for Medical Research - University of Wisconsin

University of Wisconsin
SCHOOL OF MEDICINE AND PUBLIC HEALTH

European Synchrotron Radiation Facility, Grenoble

The Prince of Wales Hospital, Sydney

New South Wales Government
NSW Health Department
South Eastern Sydney & Illawarra Area Health Service

St George Hospital and Community Health Services

Technical Research Centre of Finland

VTT

PTB

Physikalisch-Technishce Bundesanstalt

INFN Istituto Nazionale di Fisica Nucleare

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Dosimetry?

- Radiation dosimetry is the measure of the effect of radiation on matter
- Radiation dosimetry is used in many fields, including
  - Radiation therapy
    - Treatment verification
    - Critical organ dose
  - Diagnostic imaging
    - Patient doses
    - Operator doses
  - Personnel monitoring
  - Mining, nuclear industries

Dosimetric Quantities

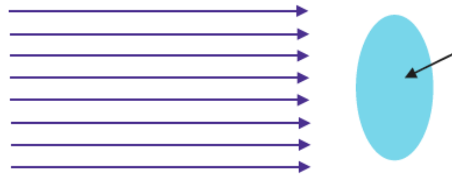
- There are many quantities used to describe the effects of radiation on matter, including
  - Fluence (Φ)
  - Energy fluence (Ψ)
  - KERMA (K)
  - Absorbed dose (D)
  - Exposure (X)
  - Quality factor (Q)
  - Dose equivalent (H)

- Each quantity has a distinct purpose and application in radiation dosimetry

Fluence and Flux density

The fluence of a radiation field, **Φ**, is defined as the number of particles, **N**, passing through an area, **a**, in the limit that the area is infinitesimally small

$$\Phi = dN/da$$



flux density, φ, or fluence rate,

$$\varphi = d\Phi/dt = d/dt(dN/da)$$

Energy fluence

- Energy fluence, ψ, is similar to fluence, however, the energies of the incident particles are considered
- The energy fluence is defined as the total kinetic energy, **R**, incident on an infinitesimally small area, **a**

$$\Psi = dR/da$$

For monoenergetic particles of energy **E**

$$R = E \cdot N$$

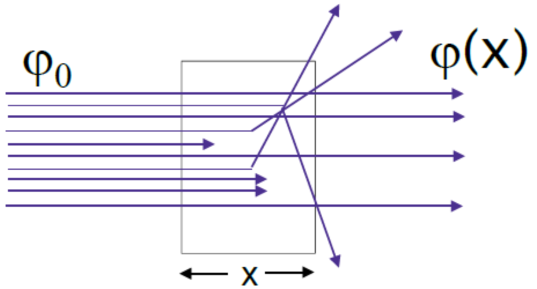
$$\Psi = E \cdot \Phi$$

How radiation interacts with matter?

- Ionisation/Excitation are the main processes of radiation interaction
- Ionisation can be DIRECT or INDIRECT:
  - Photons, neutrons generate ionization by indirect processes:
    - Uncharged particles liberate a charged particle which produces Coulomb interactions
  - Electrons and protons generate ionization by direct processes by producing a Coulomb interaction with the atoms of the material.

Photons interact with matter through

- Photoelectric effect
  - releases100% of original photon energy
- Compton scattering
  - releases a fraction of original photon energy
- Coherent scattering
  - releases zero energy
- Pair production
  - releases 100% of original photon energy
  - Produces electron-positron pair
- Photonuclear interactions
  - releases 100% of original photon energy



$\varphi(x) = \varphi_0 \exp(-\mu x)$

Where μ is the linear attenuation coefficient (m^{-1})

μ/ρ is the mass attenuation coefficient ($m^2 kg^{-1}$)

$$\frac{\mu}{\rho} = \frac{\tau}{\rho} + \frac{\sigma_{coh}}{\rho} + \frac{\sigma_C}{\rho} + \frac{\kappa}{\rho}$$

τ is the photoelectric effect
σ_{coh} is coherent scattering
σ_C is the Compton effect
κ is pair production

Charged particles interact with matter through collisional and radiative interactions

- Collisional interactions
  - Involve inelastic collisions with atomic electrons
  - Result in excitation or ionisation
- Radiative interactions
  - Involve inelastic collisions with an atomic nucleus
  - Energy emitted in the form of photons (Bremsstrahlung)

$$\frac{S}{\rho} = \frac{1}{\rho}\left(\frac{dE}{dl}\right)_{el} + \frac{1}{\rho}\left(\frac{dE}{dl}\right)_{rad}$$

- Energy is lost relative to the mass stopping power

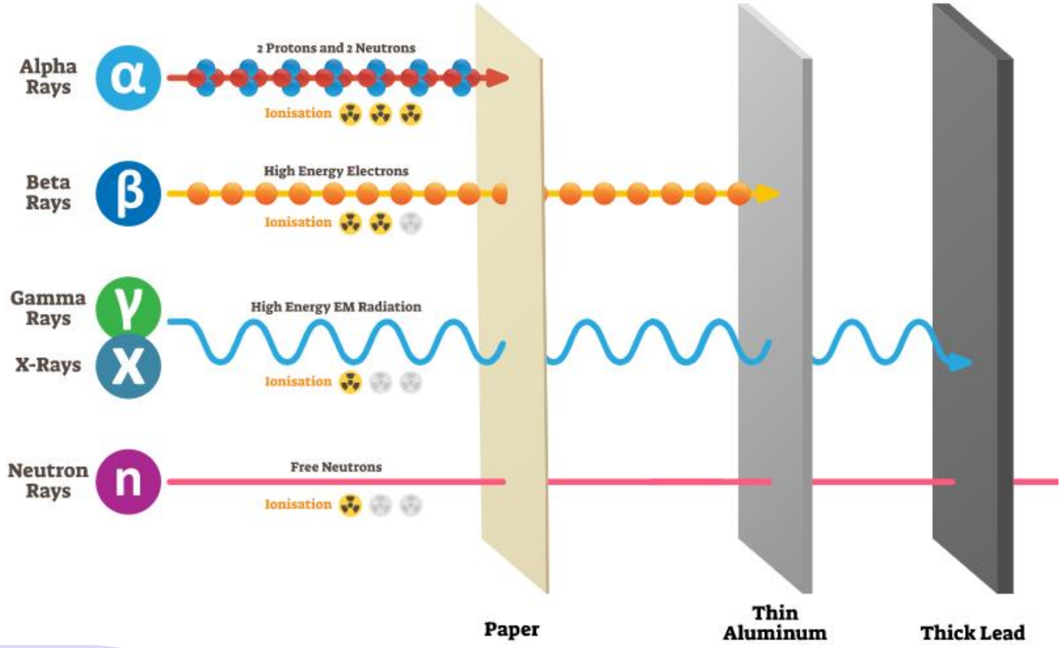
$$\frac{S}{\rho} = \frac{1}{\rho}\frac{dE}{dl} \ (\mathrm{J m^2 kg^{-1}})$$

Where d*E* is the energy lost after traversing a distance d*l*

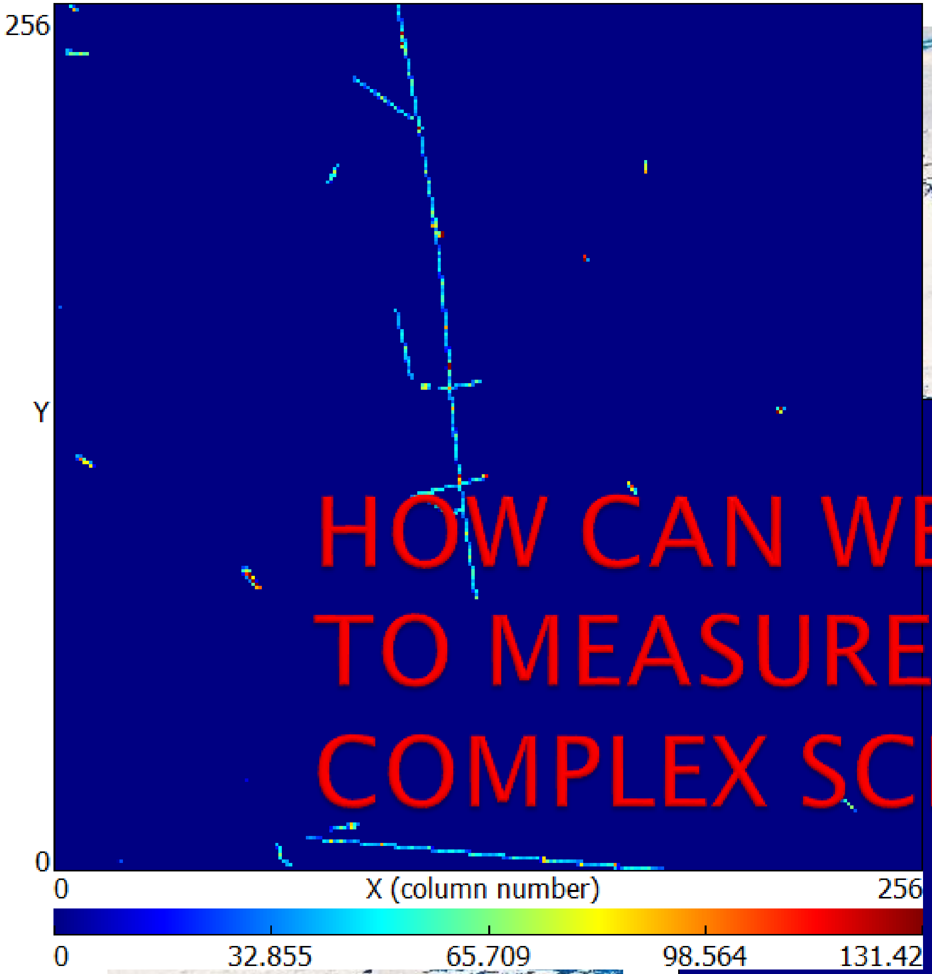
Lineal Energy Transfer (LET)

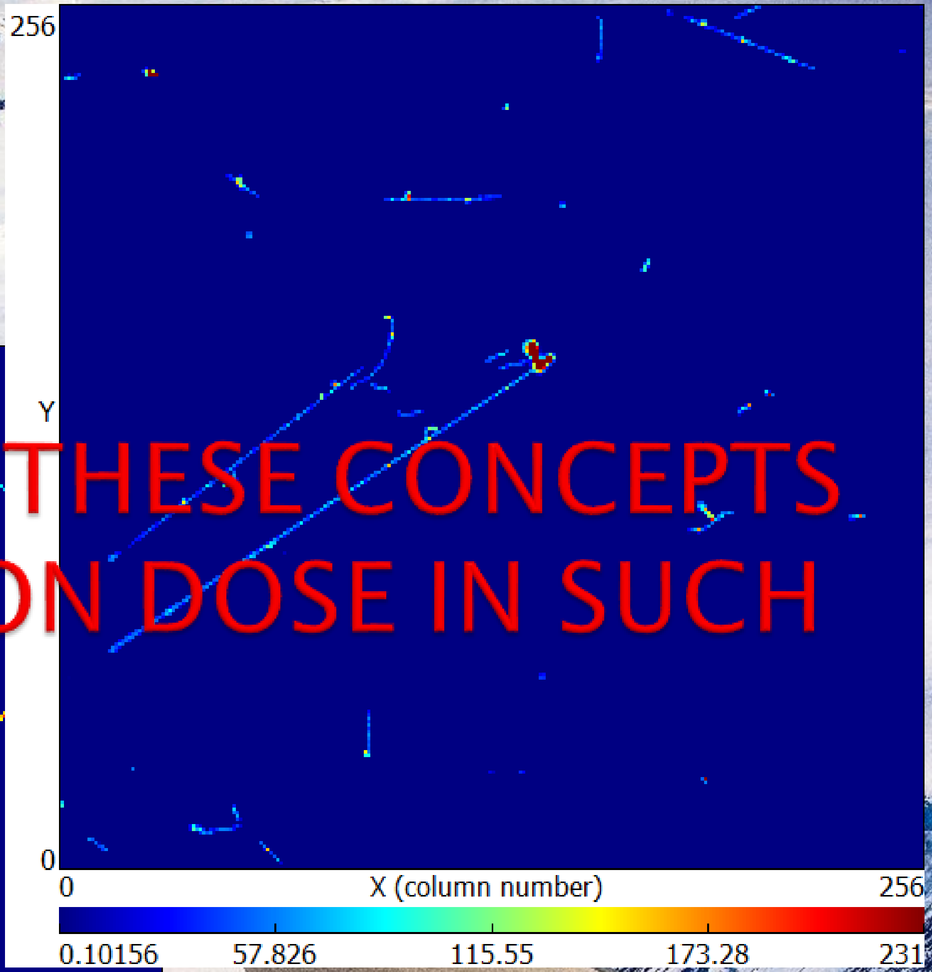
- LET is the measure of the local energy deposition along the track of a charged particle
- Is equivalent to the stopping power, **S**, when radiative energy loss is excluded

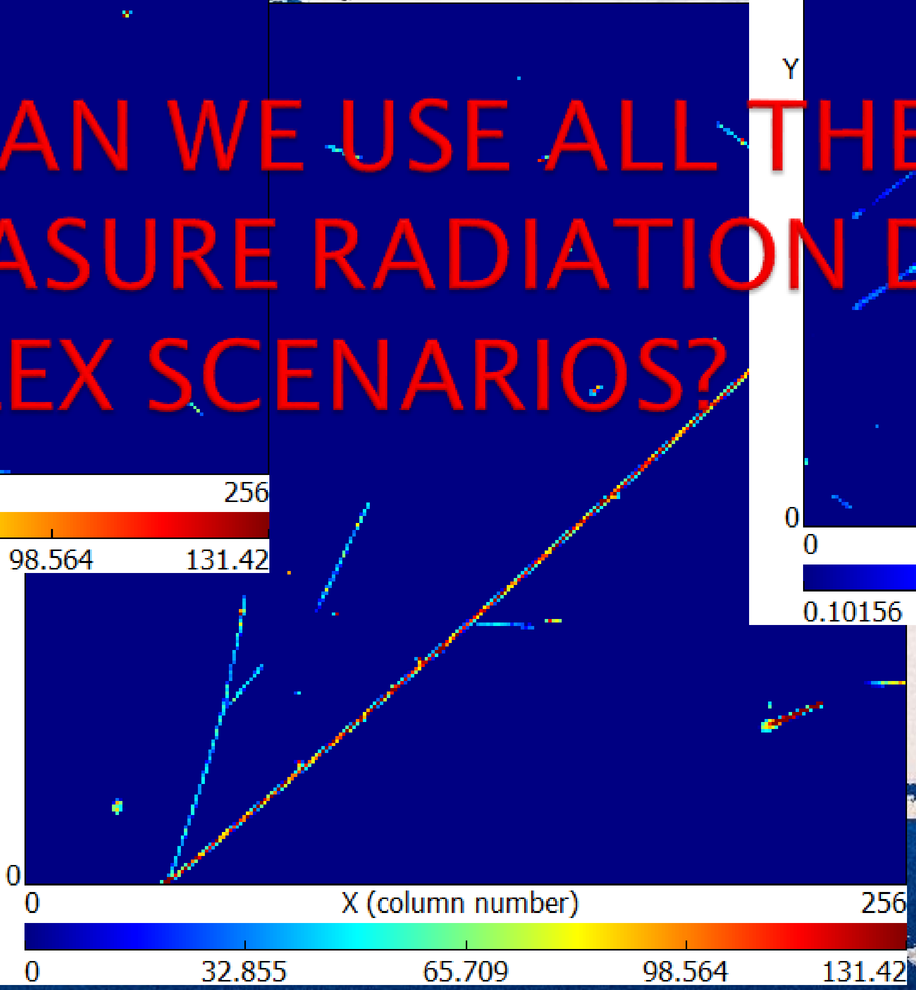
How is the Alpha particle LET in comparison to an electron?



HOW CAN WE USE ALL THESE CONCEPTS TO MEASURE RADIATION DOSE IN SUCH COMPLEX SCENARIOS?







Energy transferred and imparted

Through interactions, energy may be deposited to the medium

The energy deposited in a single interaction is given by

$$\varepsilon_i = \varepsilon_{in} - \varepsilon_{out} + Q \quad \Rightarrow \quad \varepsilon = \sum_i \varepsilon_i$$

Energy Imparted

Mean Energy Imparted or Energy Deposited, include all the contributions of radiative energies:

$$\bar{\varepsilon} = R_{in} - R_{out} + \Sigma Q$$

Where R_{in} is the incoming radiation

R_{out} is the outgoing radiation

Q is the total change in rest mass

Examples: Compton scattering

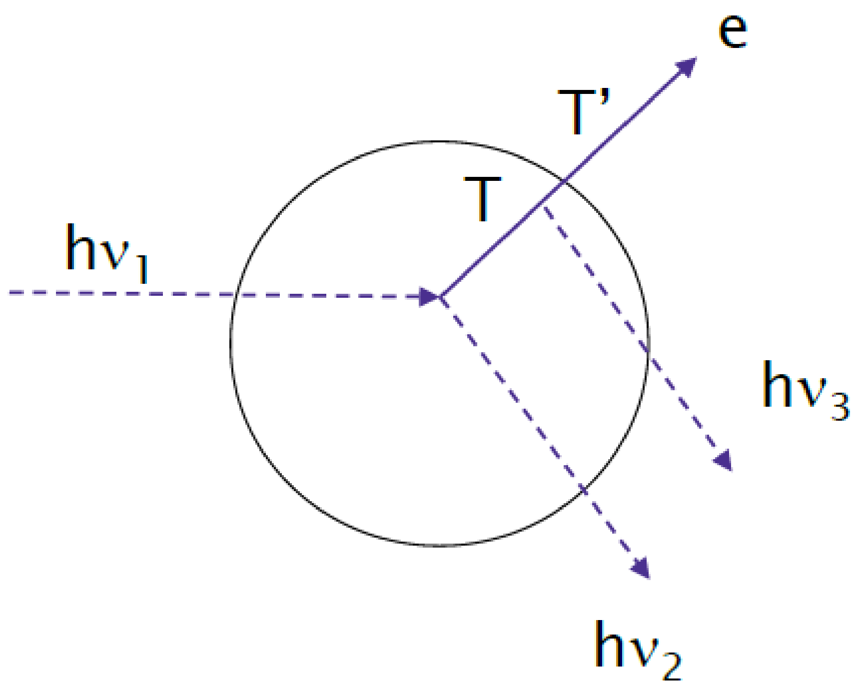
Energy transferred

$E_{tr} = h\nu_1 - h\nu_2 = T$

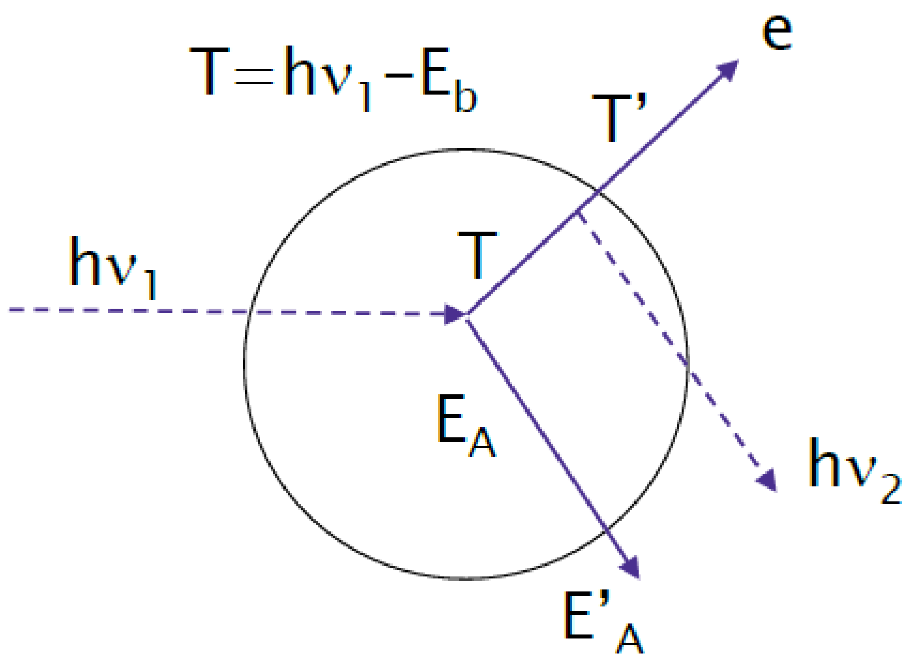
Energy deposited

$\varepsilon_i = \varepsilon_{in} - \varepsilon_{out} + \Sigma Q$

$\varepsilon_i = h\nu_1 - (h\nu_2 + h\nu_3 + T') + 0$



Examples: Photoelectric effect



Energy transferred

Energy deposited

$\varepsilon_i = \varepsilon_{in} - \varepsilon_{out} + \Sigma Q$

Absorbed dose

The energy deposited/imparted in a volume per unit mass

$$D = \frac{d\bar{\varepsilon}}{dm}$$

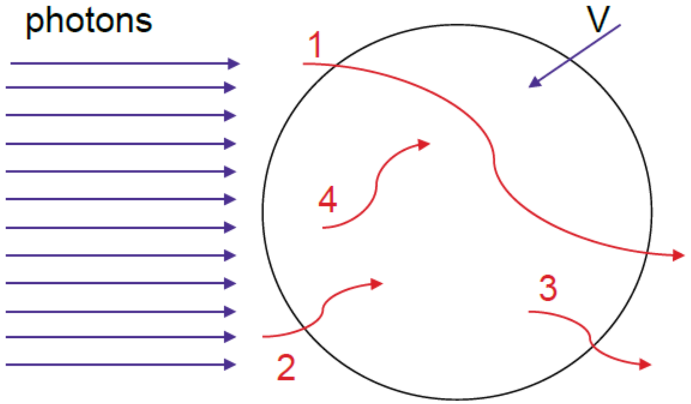
with $\bar{\epsilon}$ the mean imparted energy as defined previously

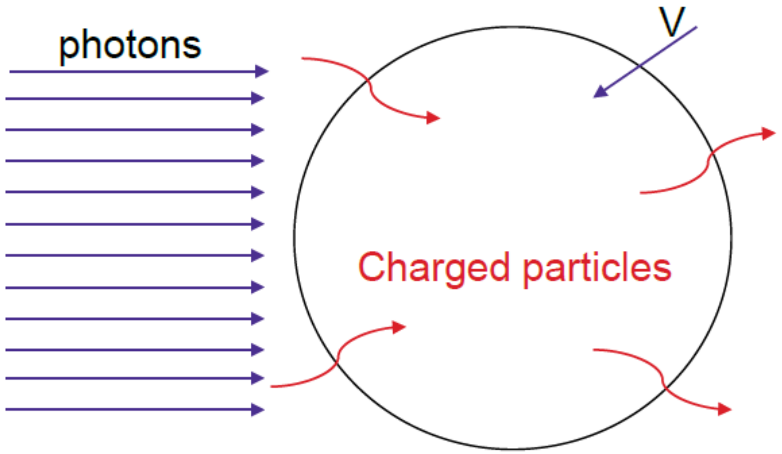
Has units of Gray (Gy) or J/kg

Basic concepts in DOSIMETRY

- Charge particle equilibrium (CPE)

- Charged particles are liberated through interactions of photons with matter
- The total charge liberated in a volume is based on
  1. Crossers
  2. Stoppers
  3. Starters
  4. Insiders





CPE exists if every charged particle leaving the volume is replaced by a charged particle of the same type, energy and direction entering the volume

Dose is defined for all types of radiation

- For mono-energetic photons, assuming charged particle equilibrium

$$D = \Phi E \frac{\mu_{en}}{\rho}$$

Where μ_{en}/ρ is the mass absorption cross section (m^2kg^{-1})

- For charged particles

$$D = \Phi \frac{S_{el}}{\rho}$$

Where S_{el}/ρ is the collision stopping power (Jm^2kg^{-1})

Dose to air is particularly important!

Air ionisation per unit mass

$$X = \frac{dQ}{dm}$$

Where Q is the absolute value of the total charge of the ions of one sign produced in air when all of the electrons or positrons liberated or created by photons in air are completely stopped

Units of Ckg^{-1} or R (Roentgen)

1C/kg=3876R

$$D_{air} = \frac{W_{air}}{e} X$$

Where W_{air} is the mean energy expended in air per electron-ion pair formed

e is the elementary charge

W_{air}/e = 33.97 J/C independent on photon energy

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Cavity Theory

When the cavity is absent, the dose to the same location in the medium x is

$$D_x = \Phi \left(\frac{dT}{\rho dx}\right)_{x,col}$$

Thus, the dose relationship is

$$\frac{D_x}{D_k} = \frac{\Phi \left(\frac{dT}{\rho dx}\right)_{x,col}}{\Phi \left(\frac{dT}{\rho dx}\right)_{k,col}} = {}_k^x\left(\frac{dT}{\rho dx}\right)_{col}$$

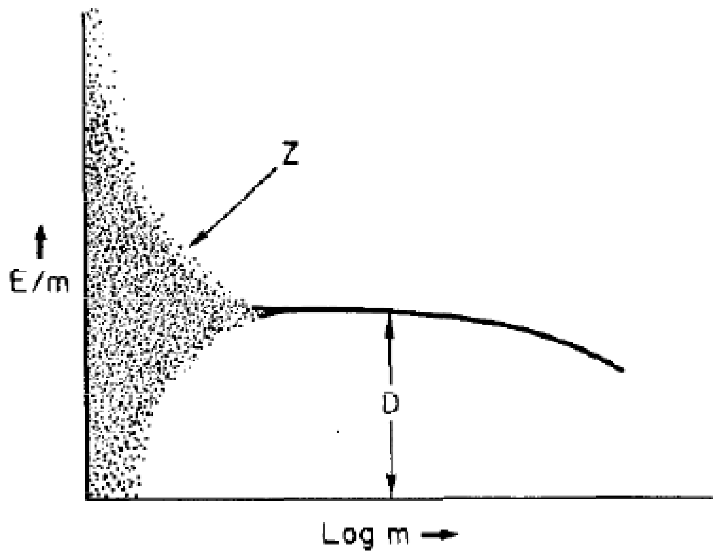
The Bragg-Gray cavity relation

- The relationship between the dose deposited in the medium and the cavity is dependent on the stopping power relationship
- Holds true if
  - The deposited doses are due to charged particles
  - The fluence does not change over the cavity

Dose is a theoretical quantity defined only for MANY interactions

- Absorbed dose, as opposed to the specific energy imparted, $z = {}^{\bar{\varepsilon}}/_{m}$, is a theoretical concept in the limit that the volume and mass approach zero

Imparted Energy	Absorbed Dose
Stochastic	Non-stochastic
No gradient	Gradient dD/dx
No rate	Rate D/dt
Finite mass	Point quantity
Measurable	Theoretical



"Concepts of Radiation Dosimetry", SLAC-153

Conclusions…

- The fundamental quantity in radiation dosimetry is absorbed dose, D
- D only has meaning if the energy deposition is due to many interactions
- Under charged particle equilibrium (CPE), absorbed dose is described by a field quantity and an interaction coefficient
- Under certain conditions, absorbed dose may be approximated by KERMA, which is easier to evaluate

Dose should always be specified in the medium/material, e.g.

- Dose to air
- Dose to water
- Dose to tissue

How much is 1 Gray?

- LD50, the lethal dose to kill 50% of the population, is ~5Gy (total body, photons, short time interval)
- 5Gy to water will raise the temperature by 0.0012°C
- The yearly background radiation dose is ~2mGy

Modern RT Delivery

- Use of immobilization frames presents significant disadvantages (discomfort, cost, inability to fractionate treatment)

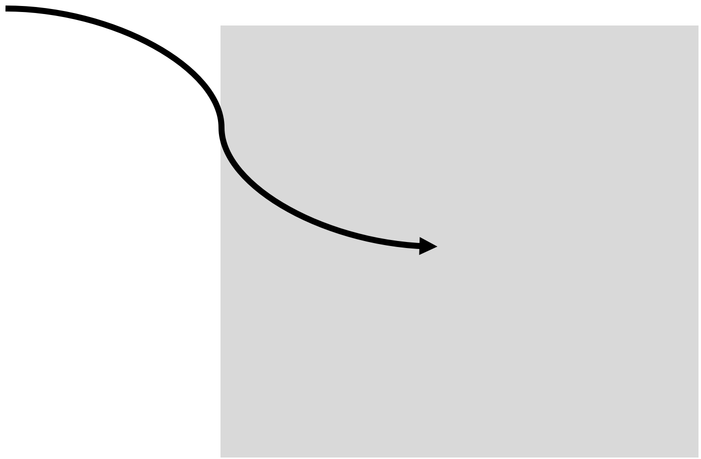
- Leading to advent of **"frameless" high precision image guided radiotherapy** also referred to as **Stereotactic Radiosurgery**

- Beam collimation can be achieved by:
  - **Stereotactic cones,** or
  - **High-definition MLCs**

- Commercially available treatment suites from:
  - **Brainlab** – Novalis, ExacTrac, Vero systems
  - Accuracy – **CyberKnife** Robotic Radiosurgery
  - LINAC based – from Varian (Trilogy, Truebeam, Edge), Elekta (Synergy, Axesse) and Siemens (Artiste)

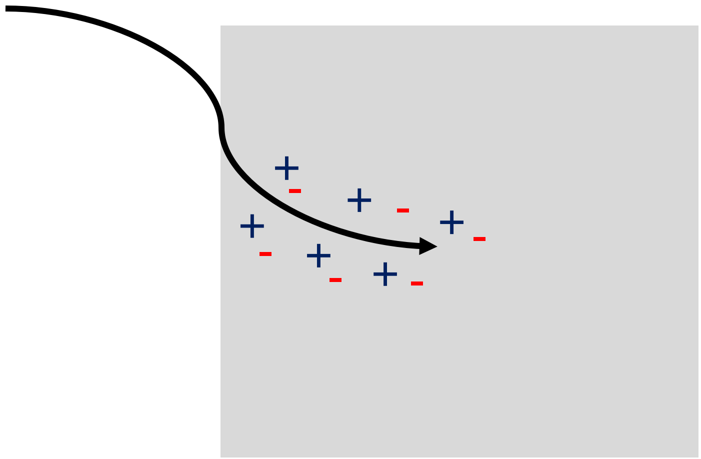
Semiconductor Dosimetry

- When radiation is incident on a detector
  - Energy may be transferred to the detector
  - The energy of the incoming particle may be wholly or partially deposited within the detector
- How can we measure this energy?
- How is this related to dose?



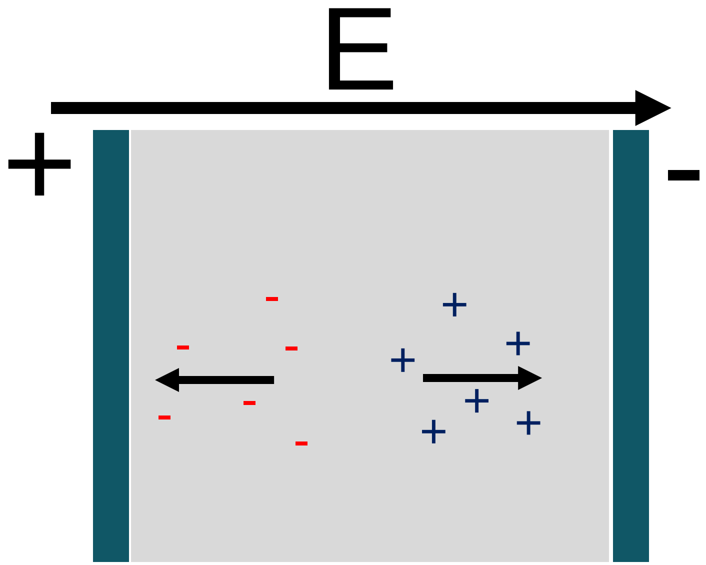
Semiconductor Dosimetry

- Ionising radiation loses energy within a medium by
  - Ionising the atoms within the medium
  - Inducing positive and negative charges
- For a fixed medium, the number of free charges is proportional to the energy deposited
- How can we measure these free charges?



Semiconductor Dosimetry

- By applying an electric field
  - Free charges will migrate in the field
  - A current will be induced → Ramo's effect
  - The amount of collected charge will be proportional to the deposited energy
  - The dose to the medium may be determined using the Bragg-Gray cavity theory



Semiconductors for Dosimetry

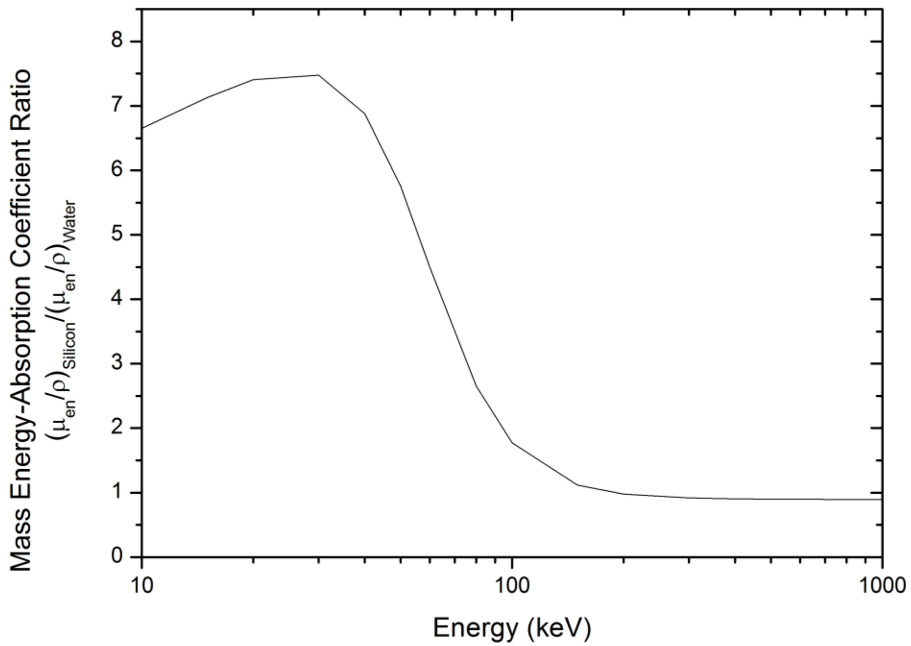
- Semiconductors are ideal as they
  - Can operate with an internal electric field (diode)
  - Have similar charge deposition within detector to ionisation chambers in a much smaller device
    - 18000 times sensitivity per unit volume
    - Smaller ionisation energy than ionisation chamber (~3.6eV for Silicon, ~35eV for ionisation chamber)
  - May be constructed with small volumes to
    - Provide high spatial resolution
    - Satisfy Bragg-Gray cavity theory
    - Use in confined spaces (in-vivo)
    - Use in multiple radiation fields
- The most USED material for semiconductor dosimetry is silicon

Advantages of Silicon

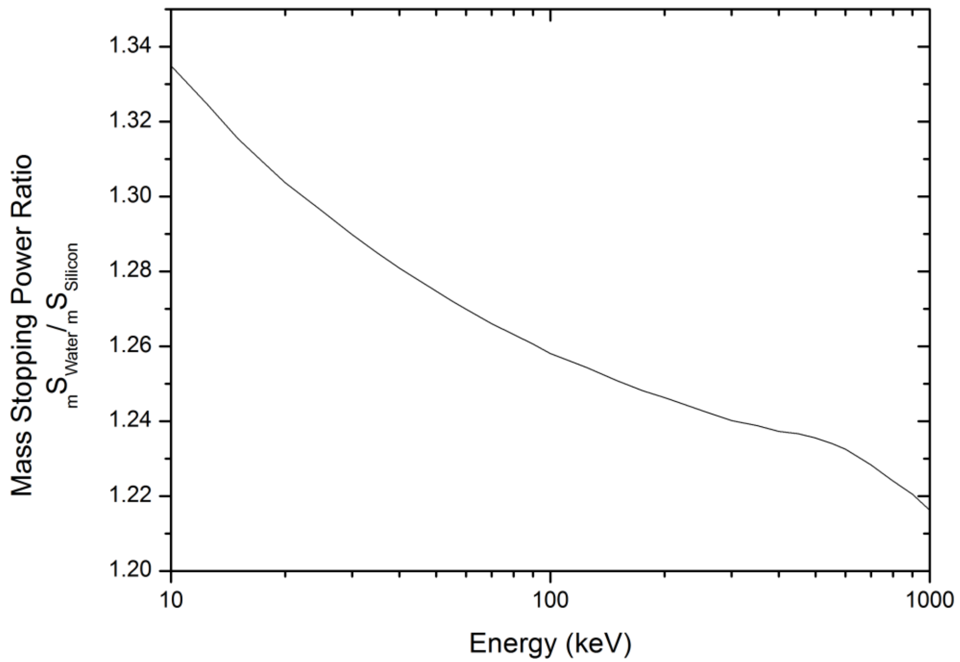
- Silicon has many advantages for dosimetry
  - Relatively low cost to manufacture – till COVID happened, anyway ☺
  - Operation at room temperature
  - Low power of operation
  - Rapidly advancing technology

- Silicon is used in multiple types of radiation detectors, including
  - Diodes
  - MOSFETs
  - PHOTODIODES for indirect detection

Dosimetric Ratios of Silicon-to-Water



Mass-Energy Absorption Coefficient Ratio for Silicon to Water



Mass Stopping Power Ratio for Silicon to Water

- The energy response of Si detector which is satisfying B-G cavity theory and placed in water will be relatively flat in a wide energy range

- Silicon is not water equivalent in free air geometry or in case of a range of secondary electrons in Si is smaller than Si cavity

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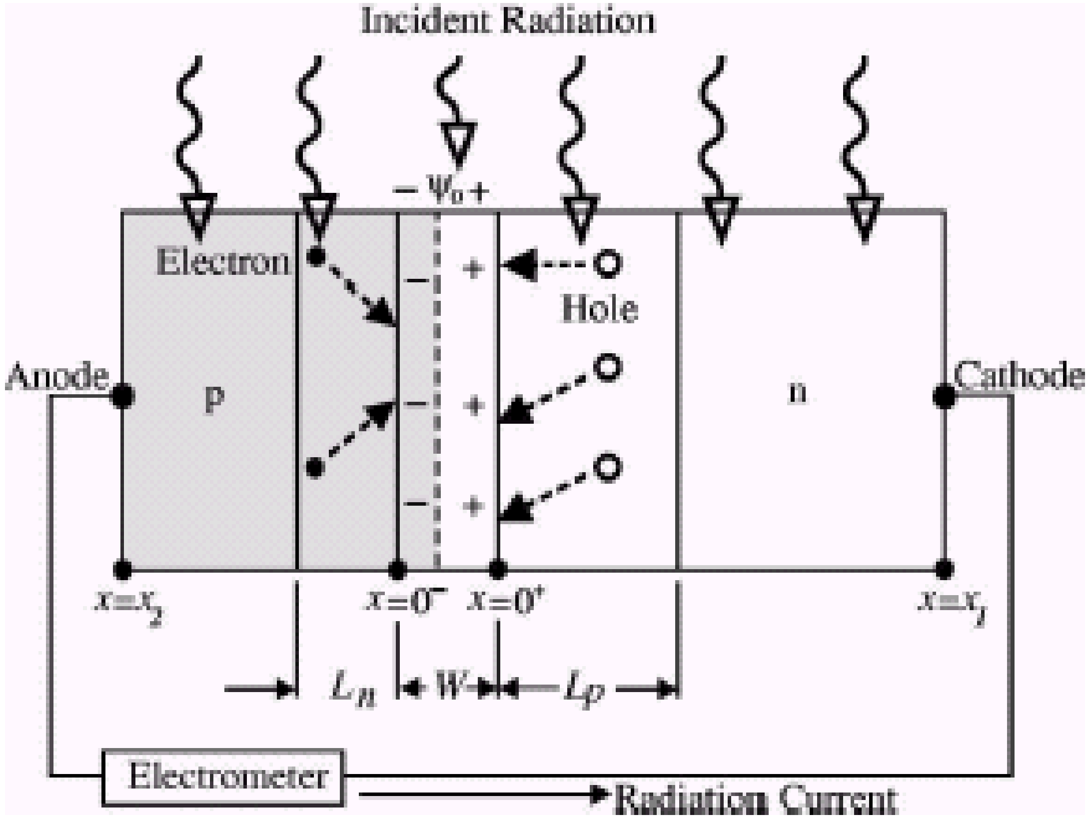
Diode – Principle of Operation



J Shi et al. Med. Phys. 30 (9), 2003, 2509–2519

The sensitivity of the diode, S, represents the amount of charge collected without recombination

$$S = \alpha(D\tau)^{0.5}$$

Where:

τ = minor charge carrier lifetime

$\alpha = 4.2 \times 10^{13} \times 1.6 \times 10^{-19}$

$= 6.72 \times 10^{-7}$ C/cGy/cm.

Diode Operation

- Important operational parameters are
  - Sensitivity, S
  - Dose rate dependence
  - Response Temperature Instability (RTI), (dS/dT)
- Radiation damage stability (often Pre irradiation improves sensitivity stability by stabilising life time)

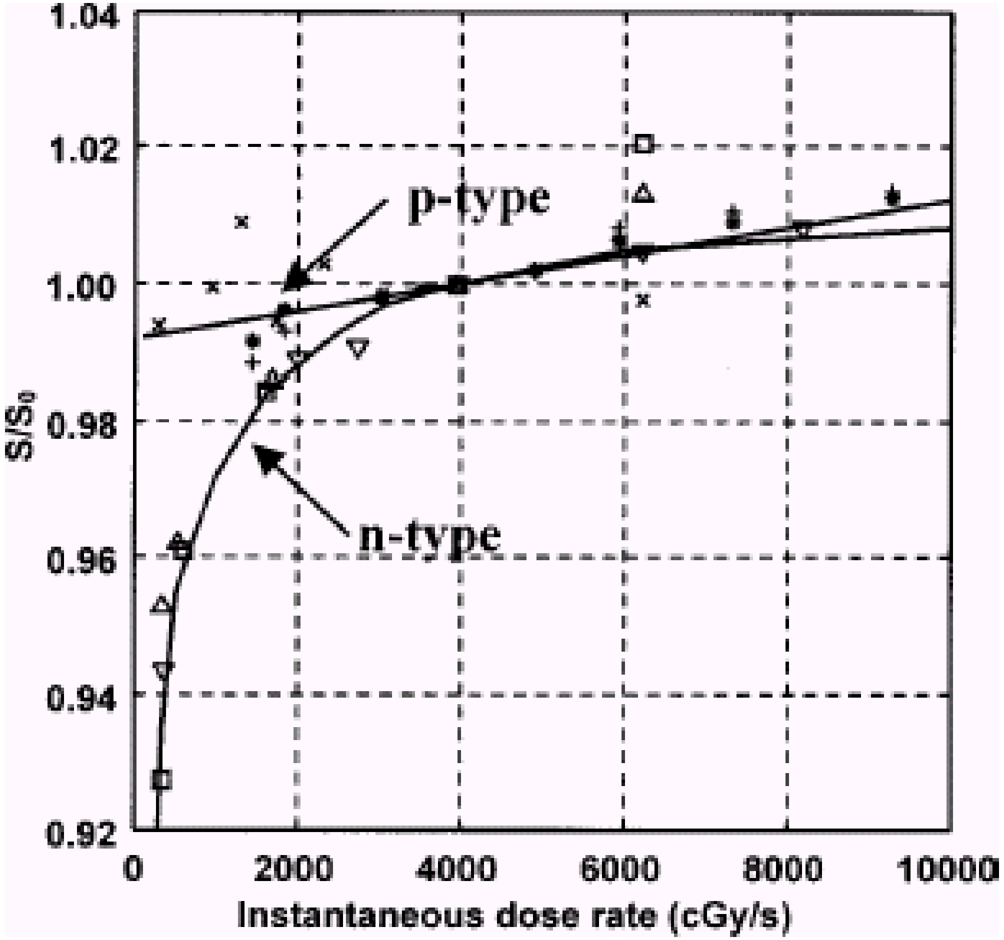
$$\tau = \tau_0 \left(1 + \frac{\delta p}{n_0} \right)$$

by introduction of radiation defects N_t, τ decreases and injection dependence is simplified

RTI~N_t

RTI increases, dose rate effect is temperature independent and sensitivity degradation is reduced through application

Diode Dose Rate Dependence



AS Saini et al. Med. Phys. 29 (4), 2002, 622-630

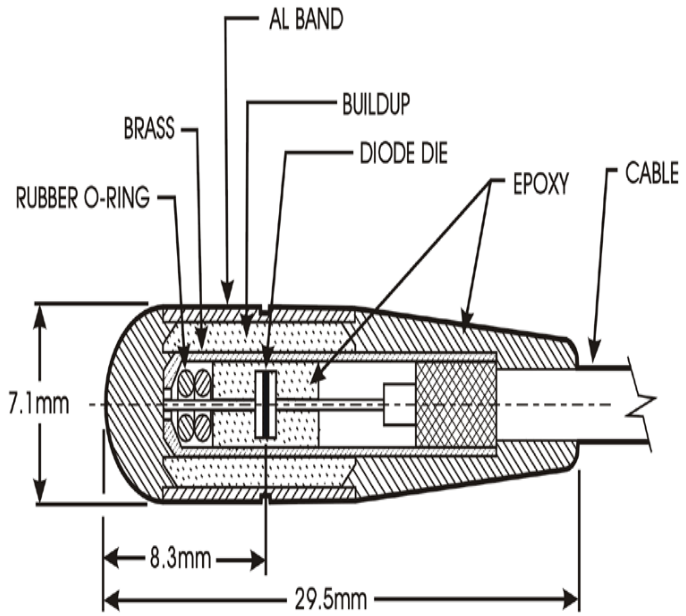
Typical dose rates in LINAC radiotherapy applications are 10^3–10^4 cGy/s

p-type diodes generally have less dose rate dependence due to different defect energy levels

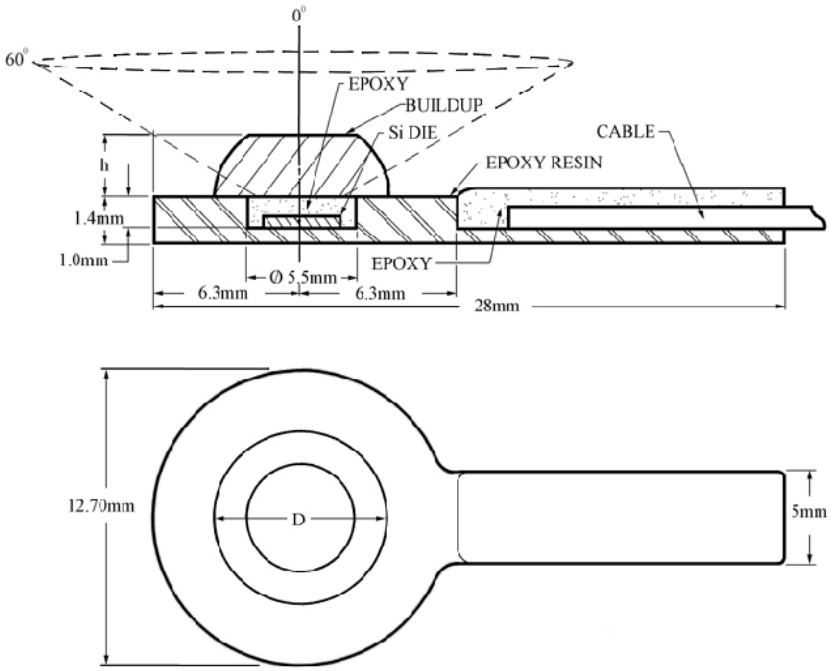
In n-type diodes it is possible to reduce the dose rate dependence through Au or Pt doping

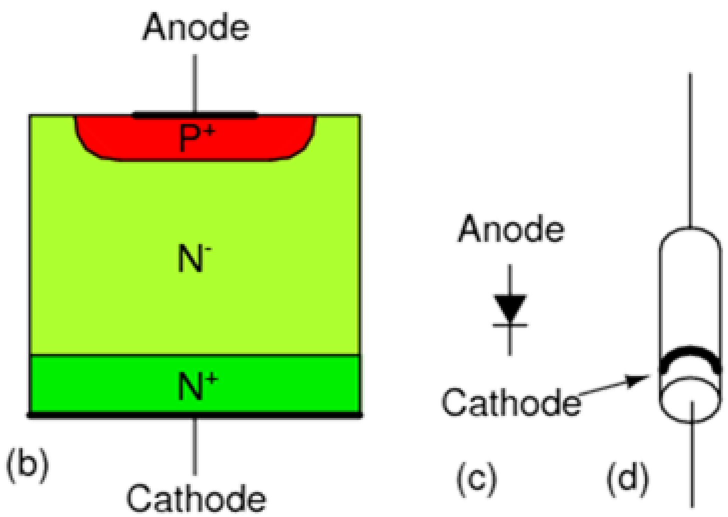
Decreasing the silicon resistivity will reduce the dose rate dependence

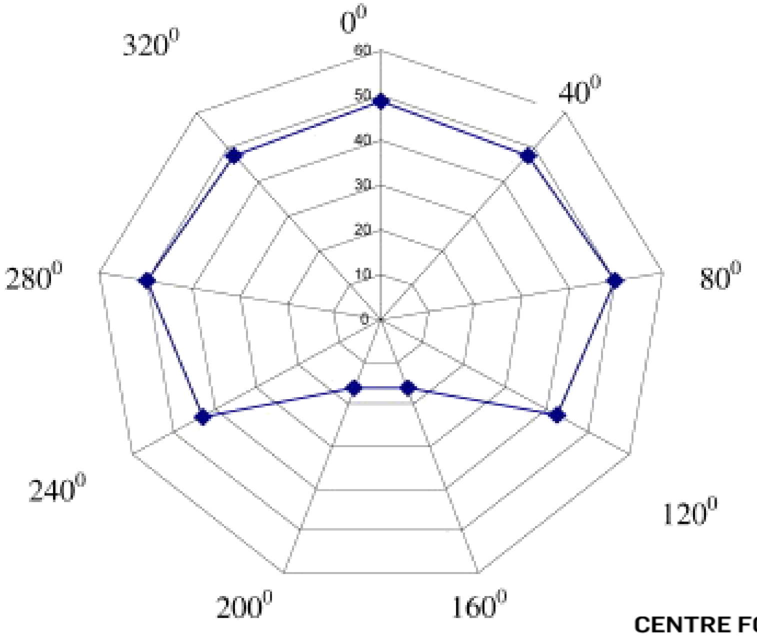
Typical commercial diode for RT



http://www.sunnuclear.com







PACKAGING and ANGULAR DEPENDENCE are very important in DOSIMETRY

Phys Med Biol. 2010 Feb 21;55(4):N97-109. doi: 10.1088/0031-9155/55/4/N01. Epub 2010 Jan 20.

An in-house developed resettable MOSFET dosimeter for radiotherapy.

Verellen D[1], Van Vaerenbergh S, Tournel K, Heuninckx K, Joris L, Duchateau M, Linthout N, Gevaert T, Reynders T, Van de Vondel I, Coppens L, Depuydt T, De Ridder M, Storme G.

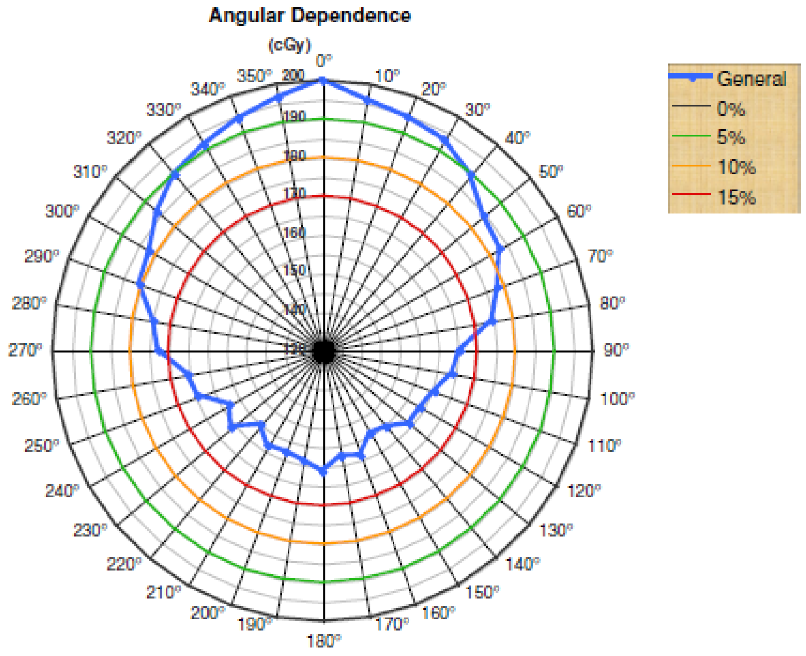


Figure 6. Angular dependence assessed in a 6 MV photon beam by irradiating the MOSFET detector at isocentre inside a cylindrical phantom for different gantry incidences.

Technique	Journal	Year
MOSFET	Phys Med Biology	2010

International Journal of Medical Physics, Clinical Engineering and Radiation Oncology, 2016, 5, 26-32
Published Online February 2016 in SciRes. http://www.scirp.org/journal/ijmpcero
http://dx.doi.org/10.4236/ijmpcero.2016.51003

Small Volume Ionization Chambers Angular Dependence and Its Influence on Point-Dose Measurements

Jon Feldman[1,2], Itzhak Orion[1]

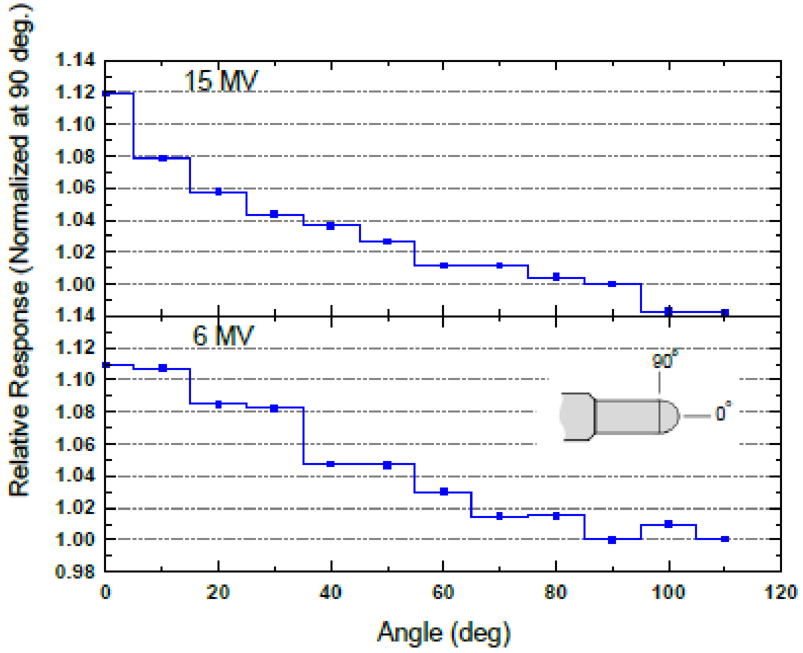
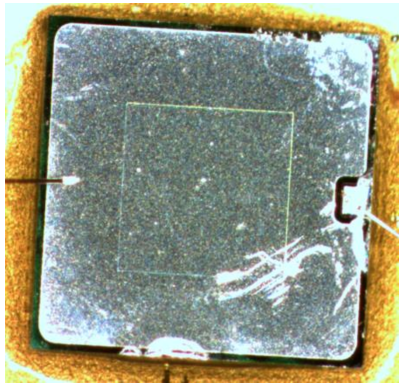


Figure 5. The PinPoint ion chamber calculated response vs. angular position using EGS5 simulations at 6 MV and 15 MV. All results are normalized to the response at 90°.

Technique	Journal	Year
Ionising chambers	IJMP	2016

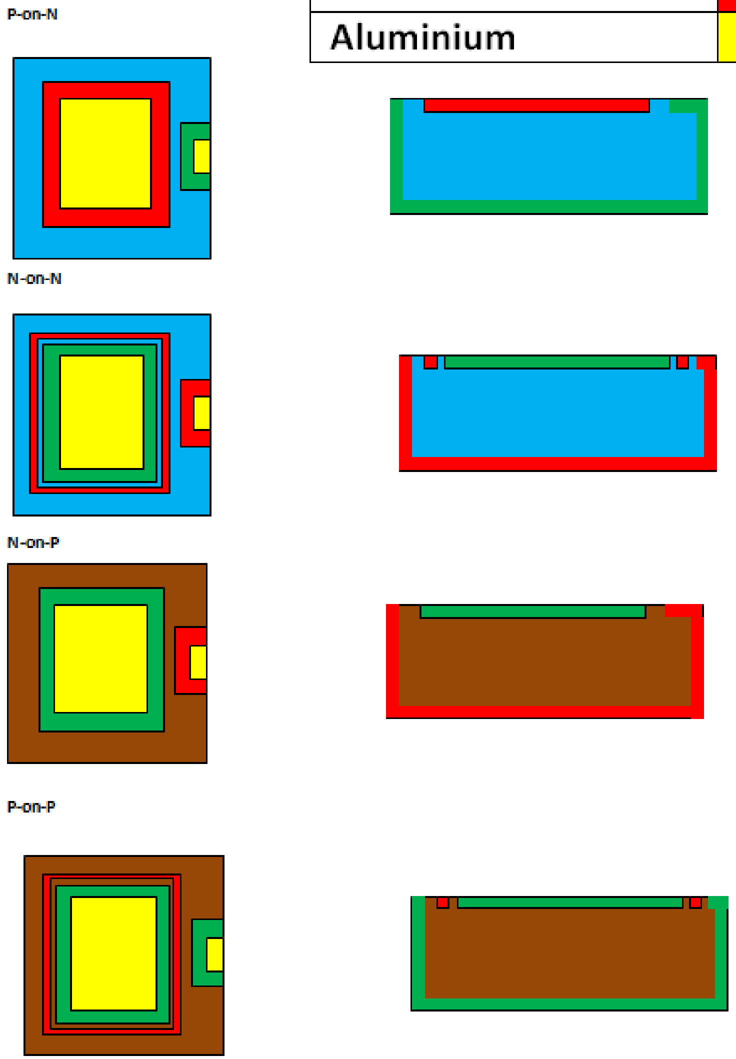
UOW "Edgeless diodes": solution for angular independent dosimetry

- Four different geometries
- 2 different substrates
- 2 different dimensions (0.5x0.5 mm^2 and 1x1 mm^2)
- 2 different thicknesses (500 um and 100 um)



Junctions and substrates code:

N substrate	(blue)
P substrate	(brown)
N+	(green)
P+	(red)
Aluminium	(yellow)

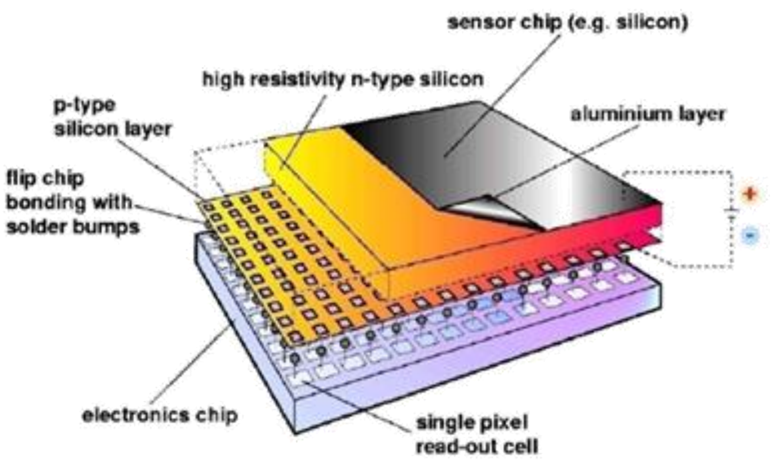


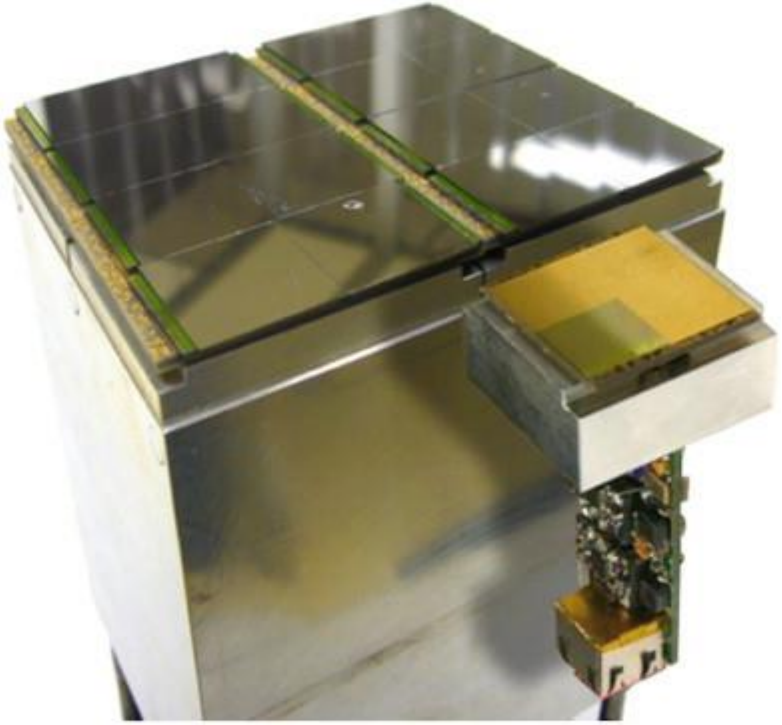
Type	Substrate	Top Juncti on	Edge Juncti on	Resistivity (koHm-cm)	Dimen (mm^2)
PN	N	P+	N+	10	0.5x0.5 / 1x1
NN	N	N+	P+	10	0.5x0.5 / 1x1
NP	P	N+	P+	7	0.5x0.5 / 1x1
PP	P	P+	N+	7	0.5x0.5 / 1x1

Proposed method

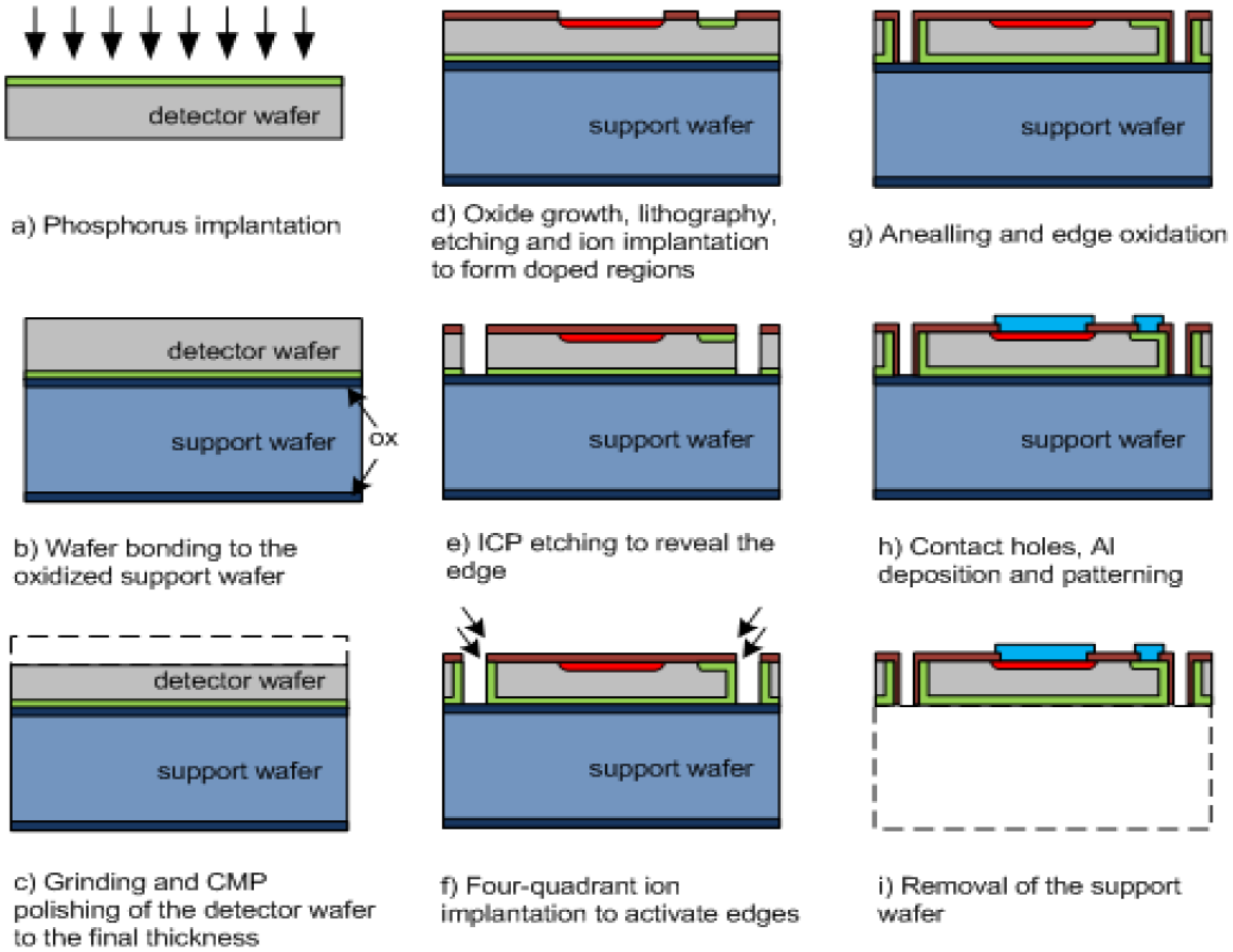
Use of a new technology named “Edgeless” developed by VTT (Finland) for the Medipix CERN Collaboration (spin-off of HEP detector development):

- Designed for “100% fill factor” imaging detector fabrication for particle tracking
- Large area detector “tiled” with element of $14x14cm^2$ and 256x256 pixels/element (55um/pixel)
- Active pixels with electronic readout (full MCA chain in 0.19um CMOS standard technology) bump-bonded underneath the sensitive silicon substrate manufactured by high resisitivity FZ silicon





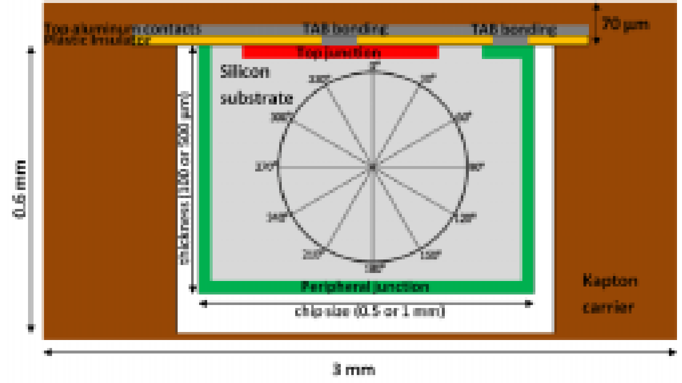
Active edge VTT technology



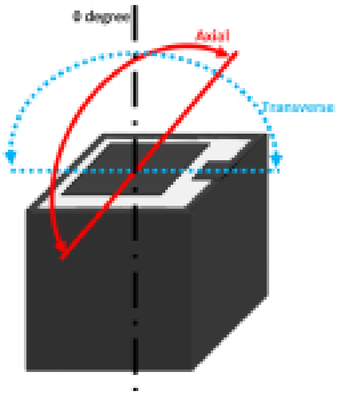
UO

CENTRE FOR
MEDICAL
RADIATION PHYSICS

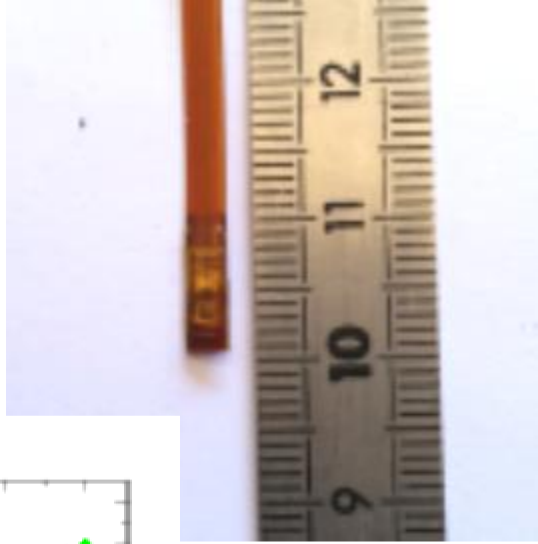
Edgeless diodes: packaging and basic dosimetry for EBRT



a)



b)



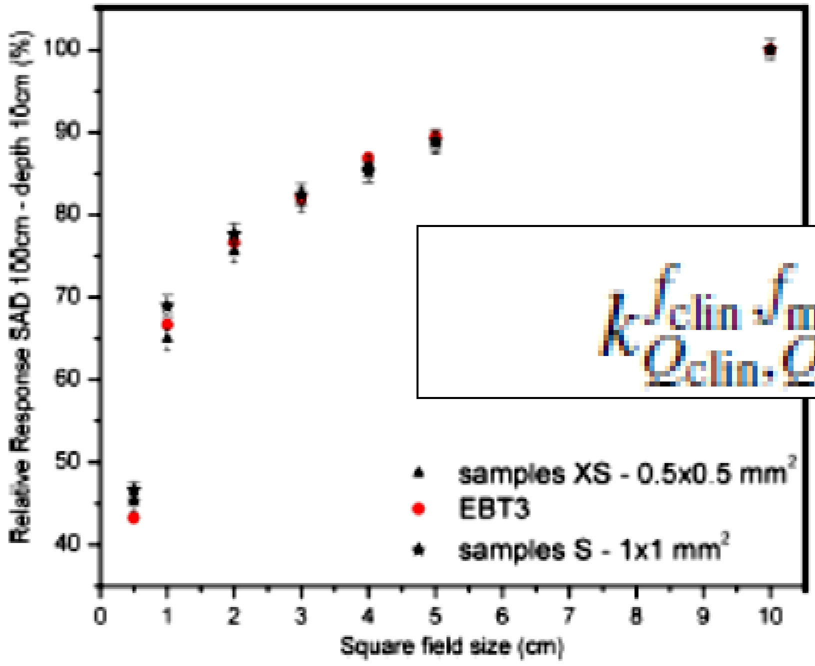


Fig. 6. Field size dependence response of edgeless detectors compared to EBT3 film normalized to response at $10 \times 10\ cm^2$ field size.

$$k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}} = 0.985$$

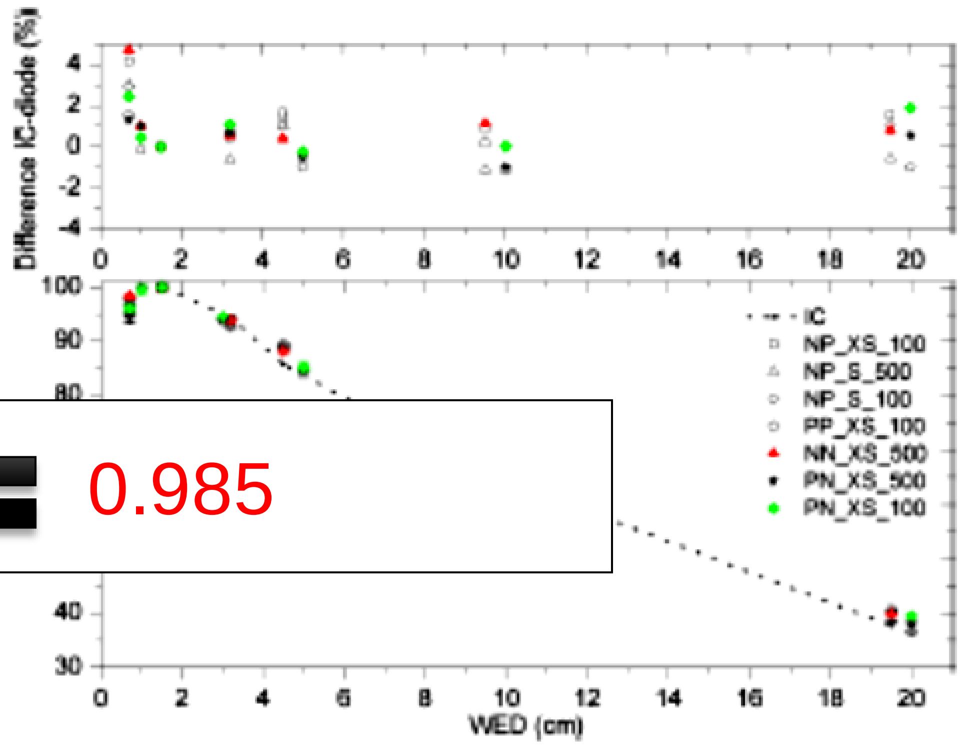


Fig. 5. PDD measured for the whole set of edgeless detectors at 6 MV photons, $10 \times 10\ cm^2$ field, and SSD 100 cm, in comparison with ion chamber.

Tissue-Phantom Ratio (TPR) on Cyberknife

- Both experiments (in G4 and M6 machines) were performed using large size (60 cm^3) MP3 motorized water tank (PTW).
- Measurement depth: : 0, 3, 5, 8, 10, 13, 15, 20, 30, 50, 100, 150 and 200 mm.
- diodes attached to bird cage in order to align them in radiation center.
- 3 different IRIS and cone field sizes: 10, 30, 60 mm.
- The edgeless diodes measurements were compared with PTW 60016 and PTW 60018 diodes.

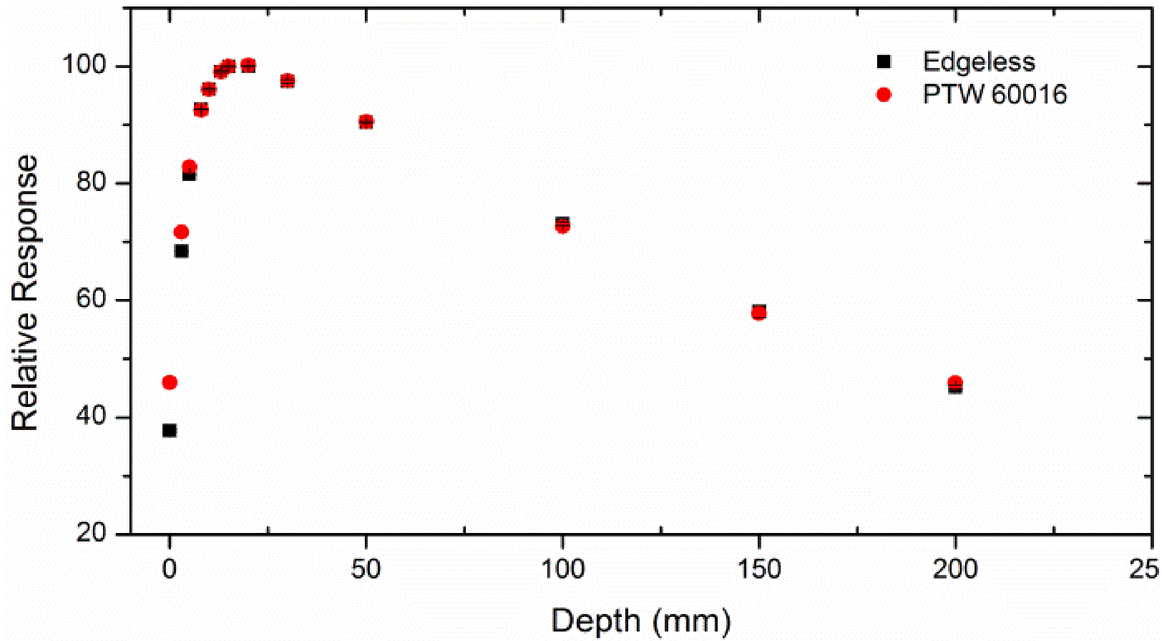
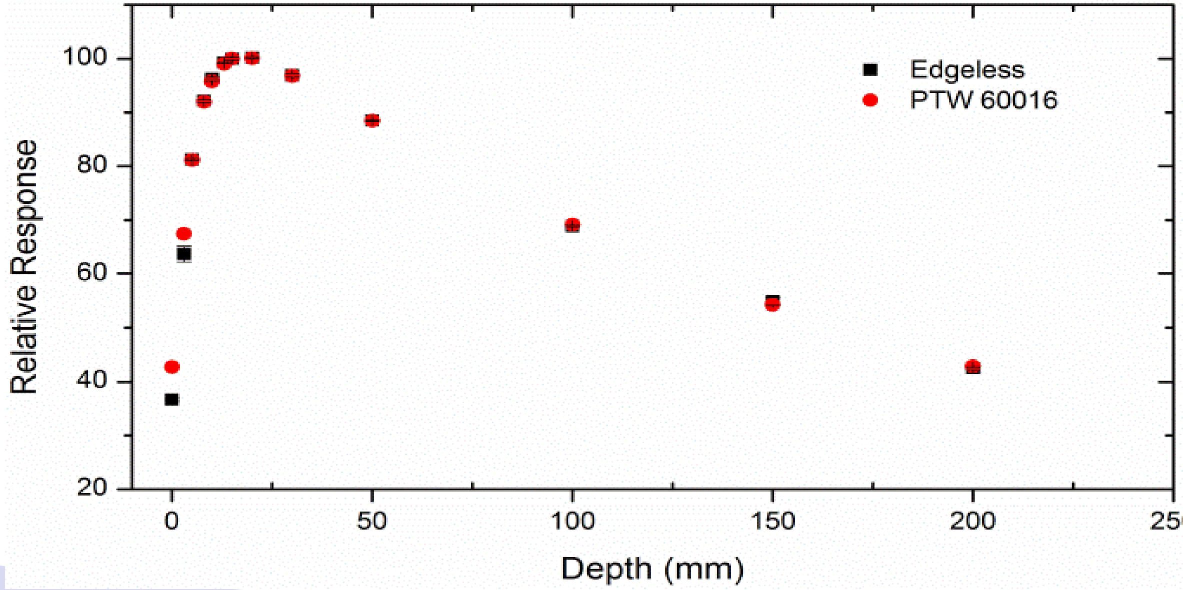
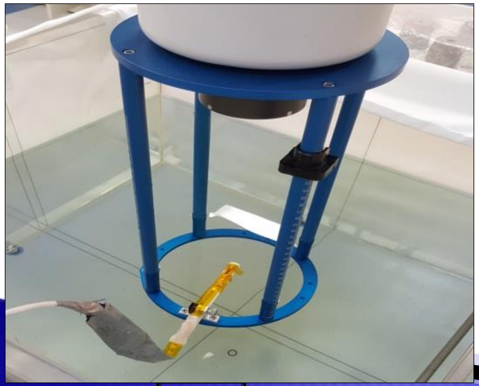
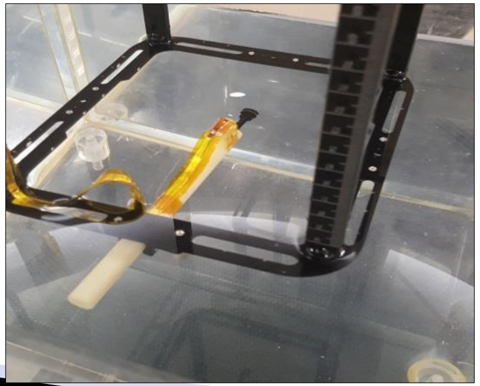


Fig.10: *M6 Cyberknife (Perth),15 mm depth, 800 SAD mm, cone 60 mm.*




TPR setup in 4G cyberknife (Riyadh)


TPR setup in M6 cyberknife (Perth)

Angular dependence: Exp on VARIAN ClinacXi.

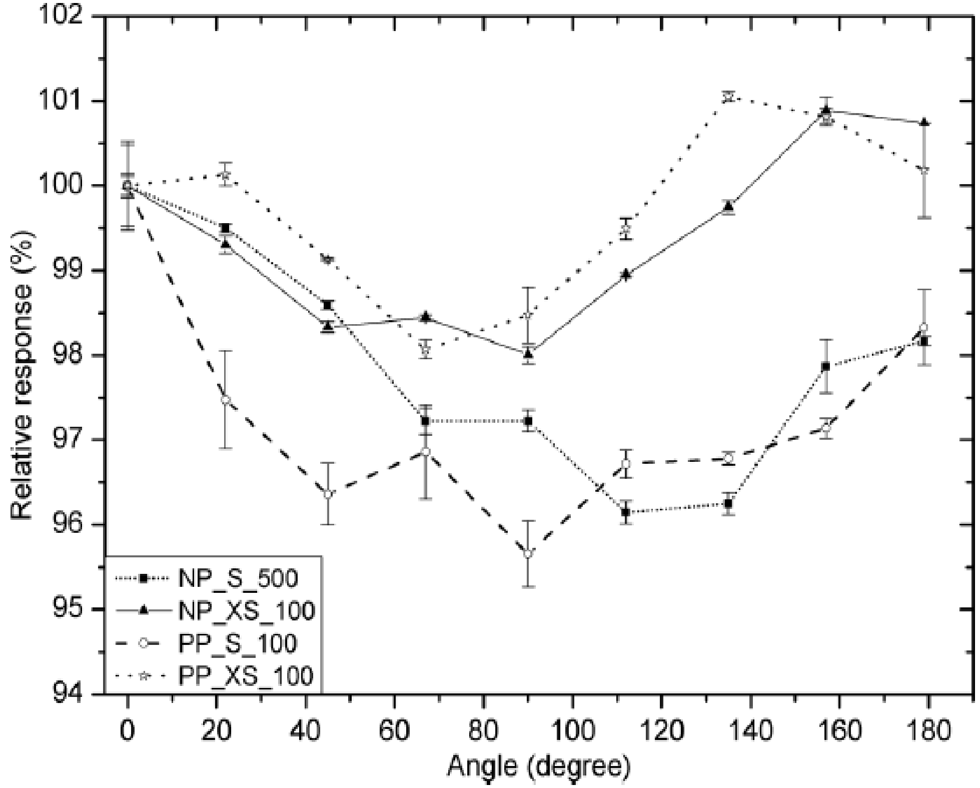
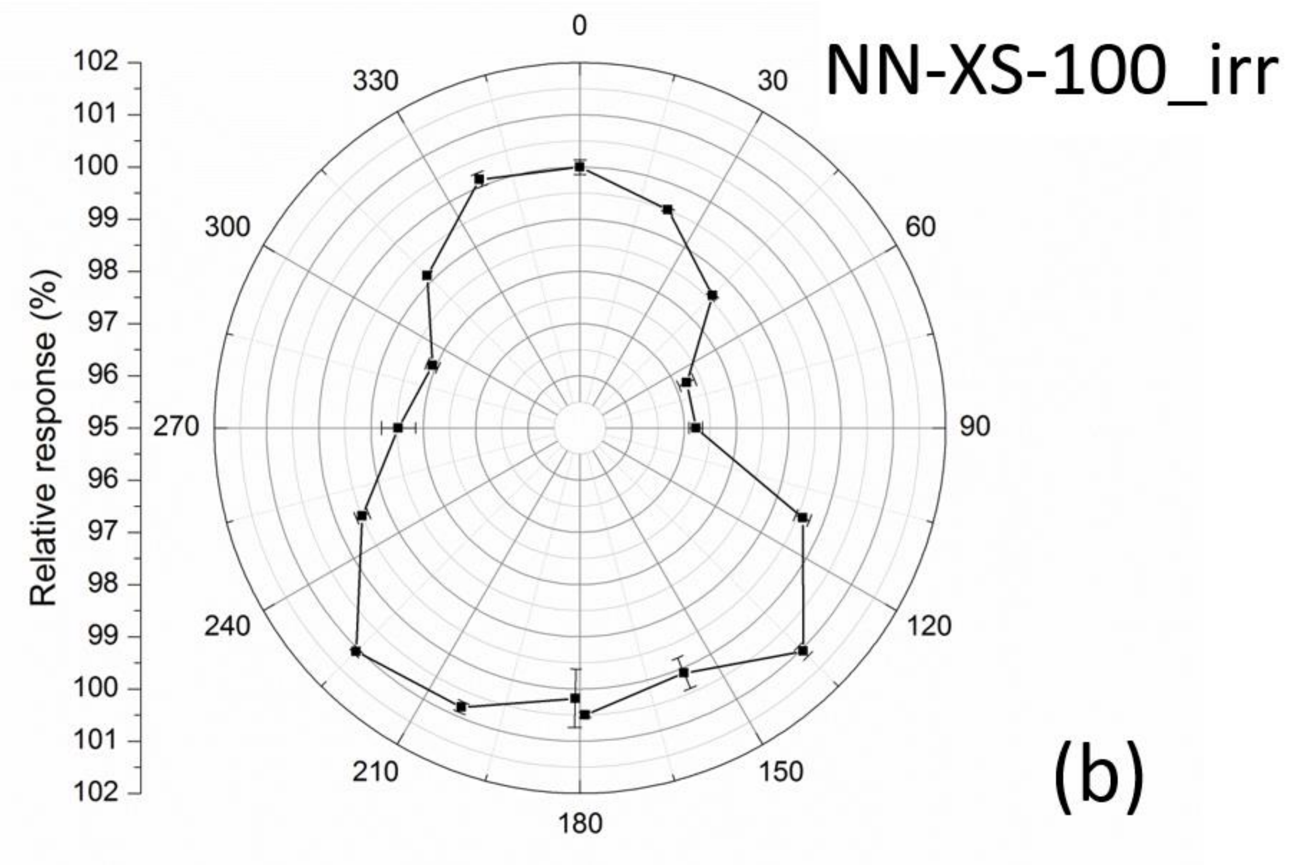


FIG. 9. Angular dependence of P-type substrate devices.



Medical Physics
The International Journal of Medical Physics Research and Practice

Angular independent silicon detector for dosimetry in external beam radiotherapy

M. Petasecca, S. Alhujaili, A. H. Aldosari, I. Fuduli, M. Newall, C. S. Porumb, M. Carolan, K. Nitschke, M. L. F. Lerch, J. Kalliopuska, V. Perevertaylo, and A. B. Rosenfeld

Citation: Medical Physics **42**, 4708 (2015); doi: 10.1118/1.4926778

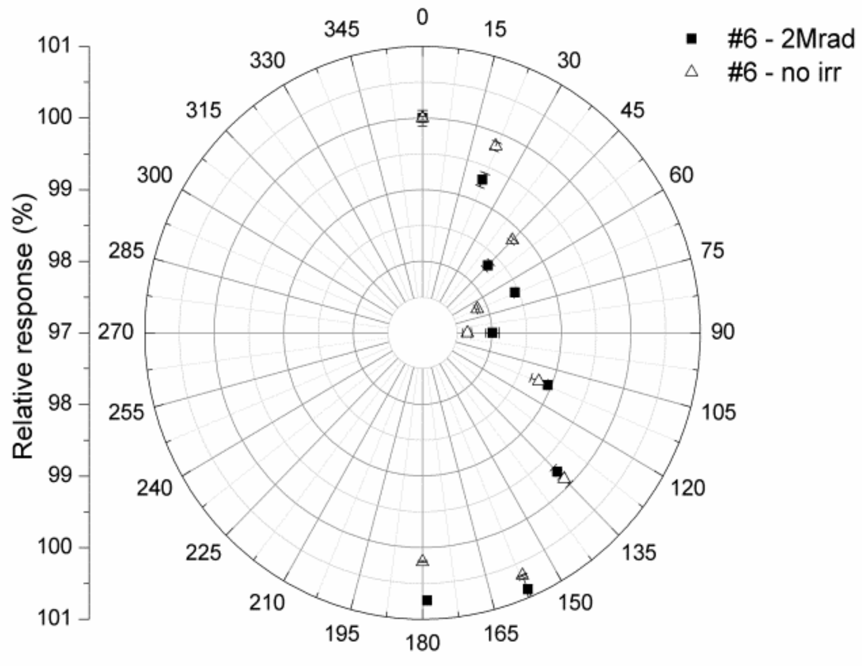
Angular dependence vs radiation damage

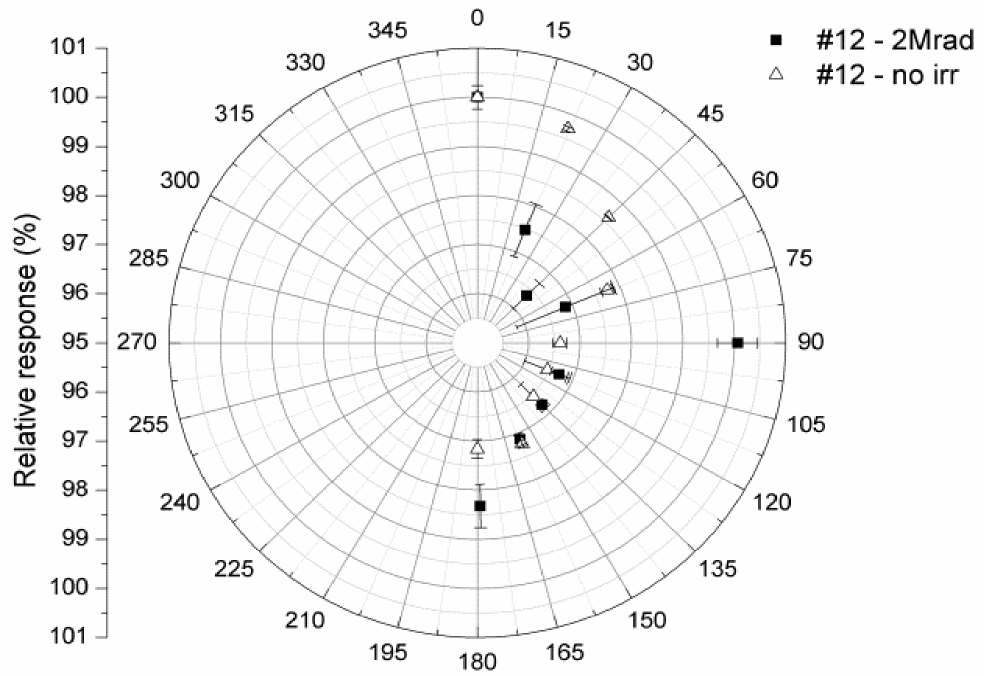
- PP, NP, devices
- Unbiased
- 6MV LINAC 10x10cm^2
- from 0 to 180 degree
- 2 Mrad Co-60 irradiation

- Negligible effect of radiation damage on angular dependence

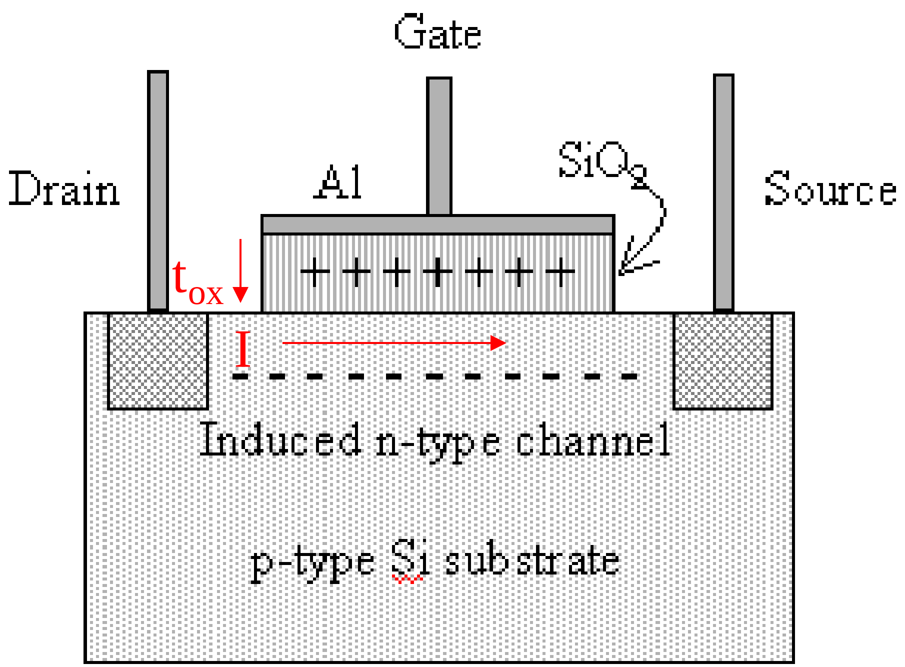
- very low angular dependence +/-1.5% - 2.2% over 180 degree

- Very high stability and reproducibility of the data.





MOSFET: Principles of Operation



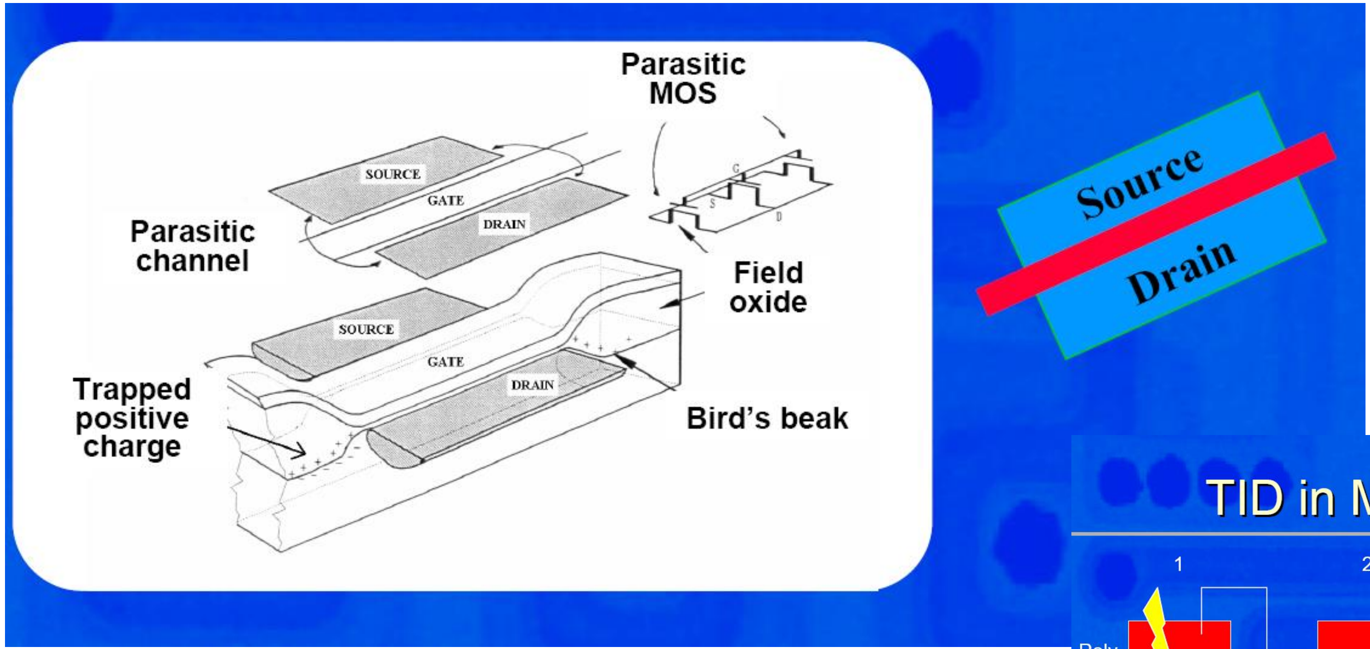
- Generation of electron-hole pairs in silicon oxide by ionising radiation
- Trapping of holes on the SiO_2–Si interface
- Shift in the IV characteristics leads to a change in the threshold voltage under constant channel current

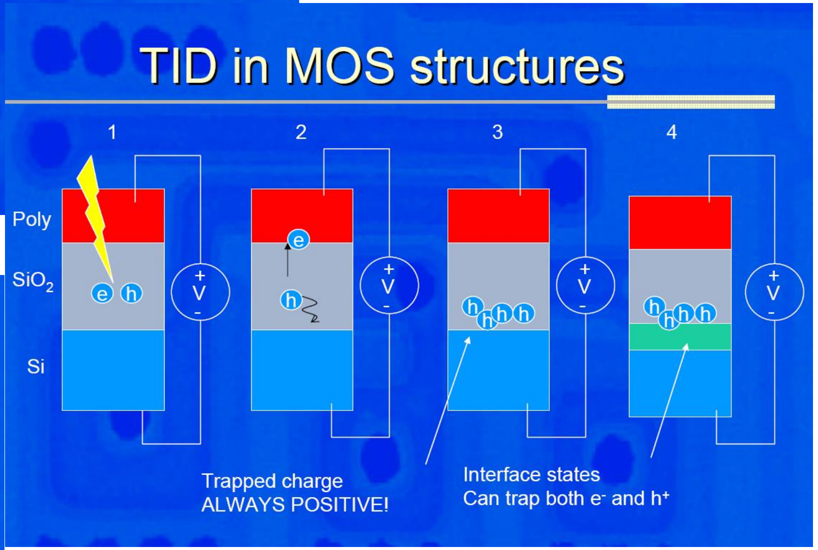
Passive mode - $\Delta V_{th} \sim 0.0022\, D^{0.4}\, t_{ox}^2\, f$

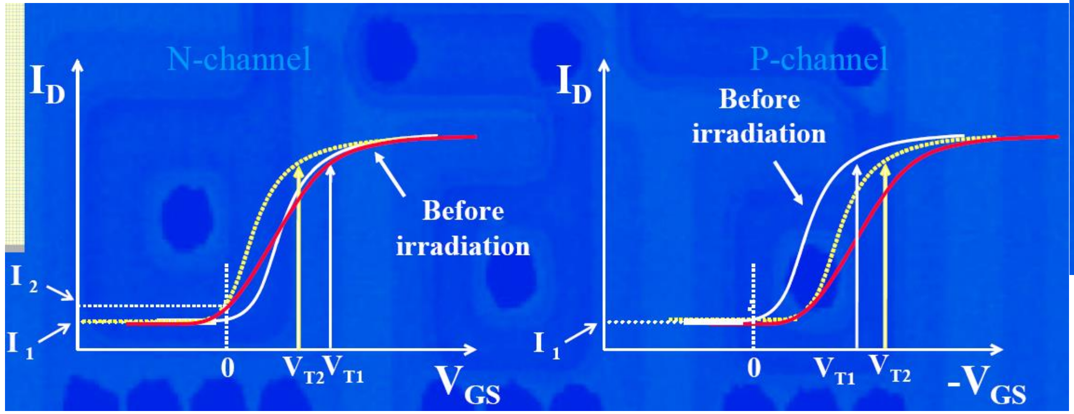
Active mode - $\Delta V_{th} \sim 0.04\, D\, t_{ox}^2\, f$

Active mode has a positive bias on the gate during operation

TOTAL DOSE EFFECTS (TID) on MOSFETs: Voltage threshold shifting







MOSFET: Principles of Operation

- Generation of electron-hole pairs in silicon oxide by ionising radiation
- Trapping of holes on the SiO_2-Si interface
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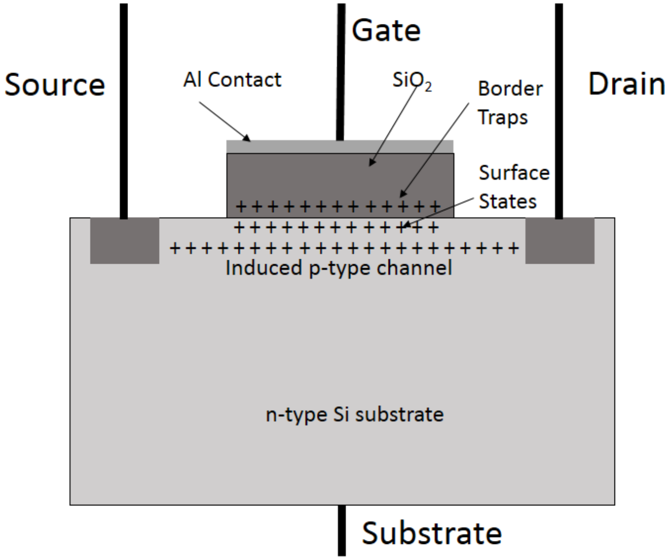
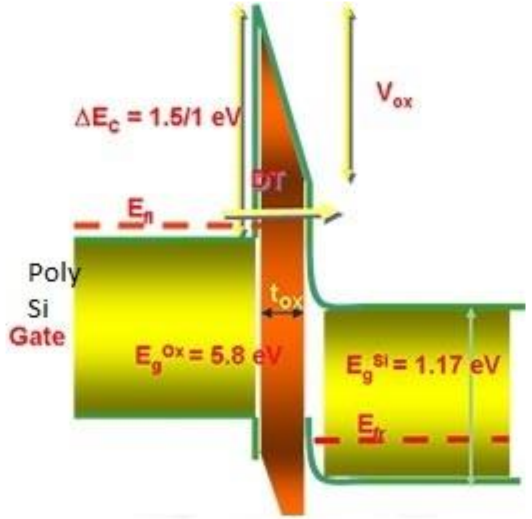


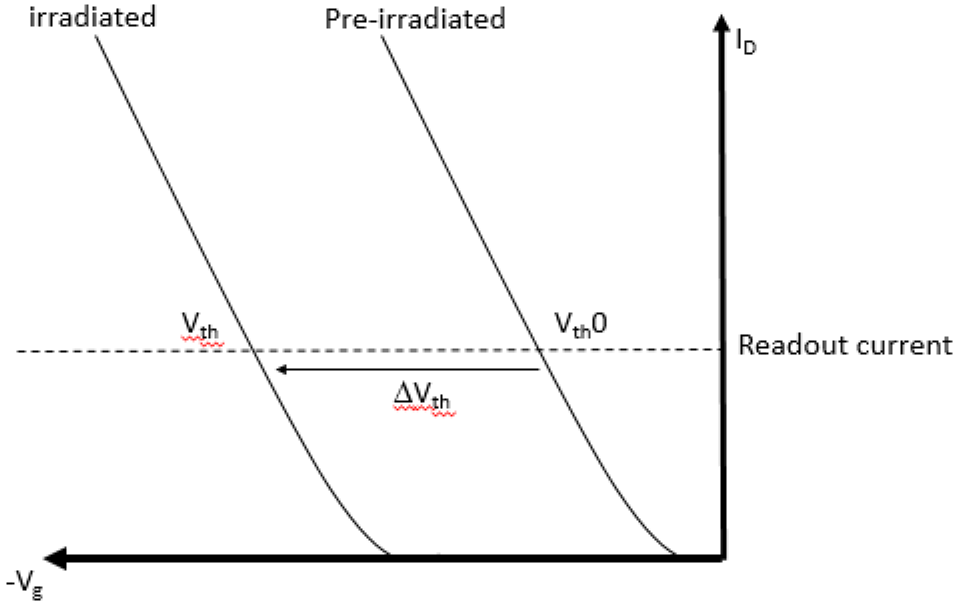


p-channel MOSFET band structure

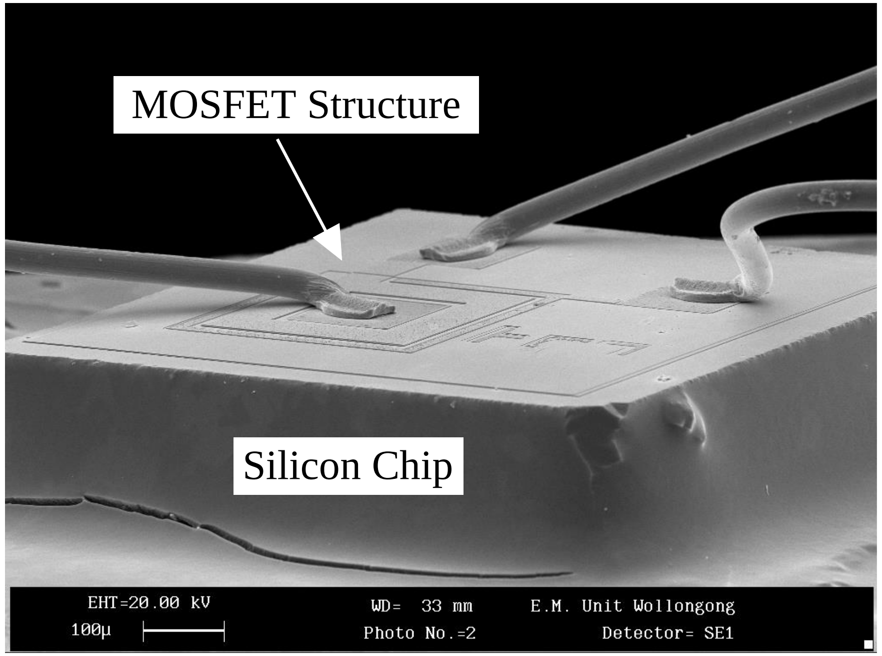
MOSFET: Principles of Operation

- The threshold voltage is the voltage required to pass a set current through the channel
- After irradiation, this threshold voltage shifts proportional to the dose absorbed by the SiO_2 gate

$$\Delta V_{th} \approx \Delta D \text{ in } SiO_2$$



MOSFET Chips



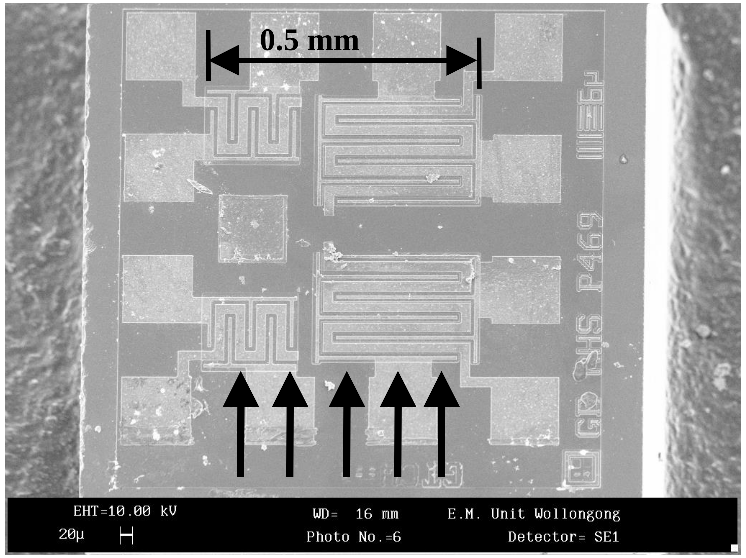
Single MOSFET detector

CMRP MOSFET

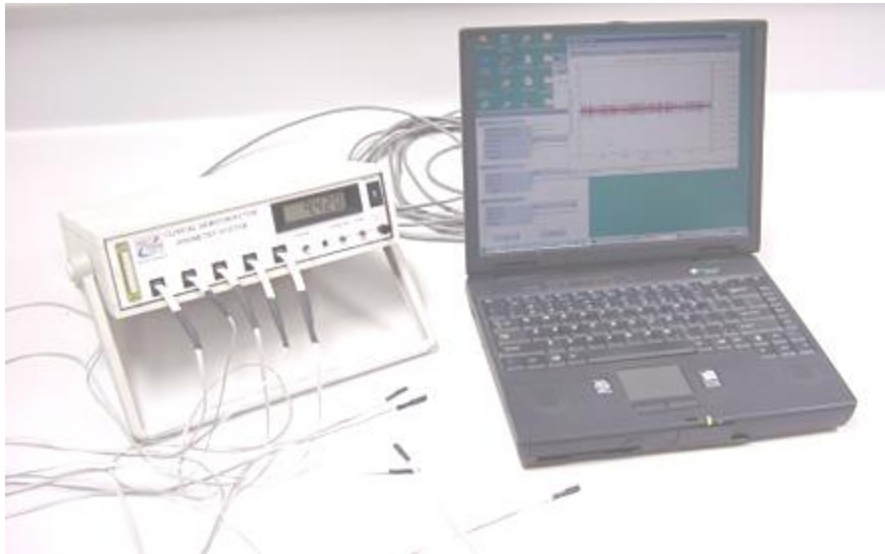
Advantage of MOSFET detectors-Extremely thin sensitive volume (<1µm)

Quadruple MOSFET detector

RADFET REM Oxford

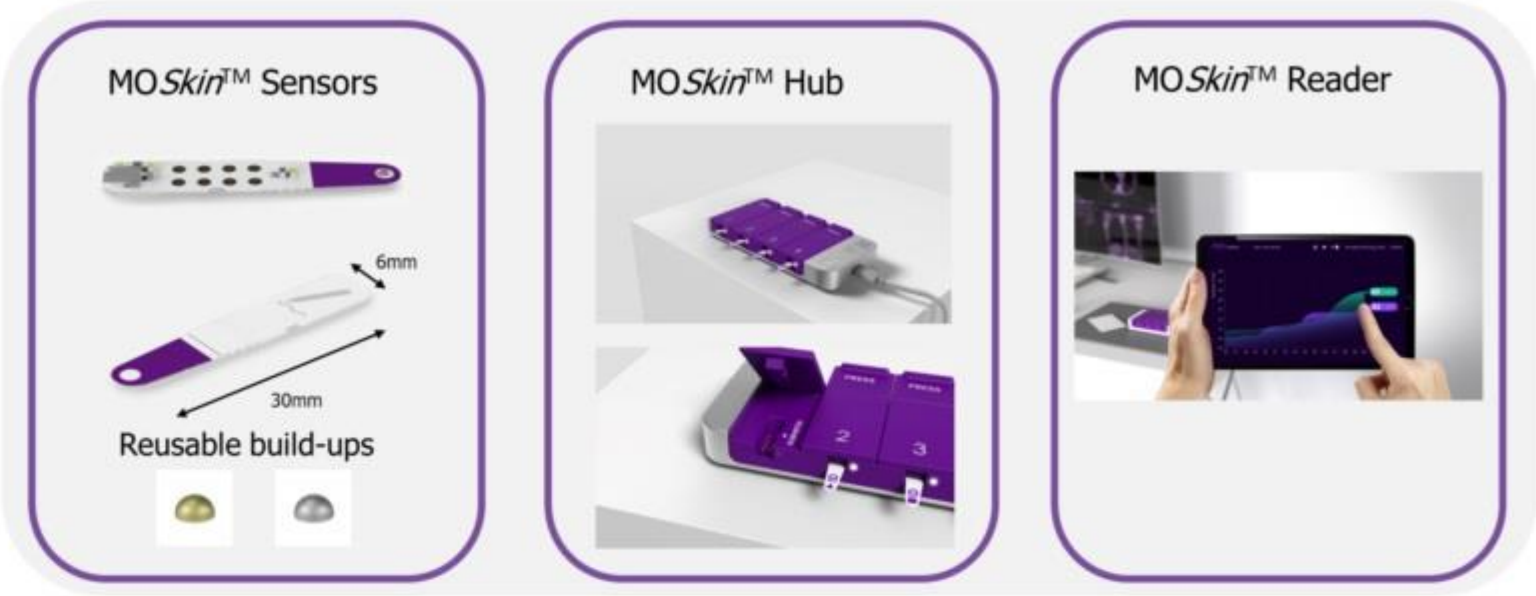


MOSFET Dosimetry System



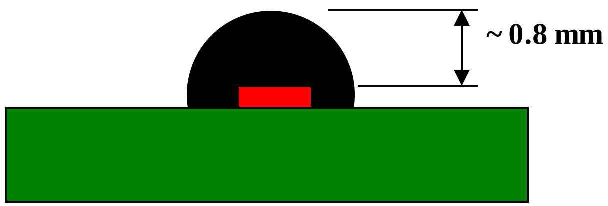
MOSFET Research Prototype Dosimetry System

20 years later….

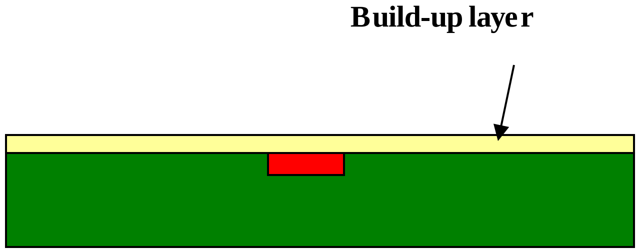


New MO*Skin* Design

- The **Centre of Medical Radiation Physics (CMRP)** has designed a new MOSFET-based dosimeter called the **MO*Skin***™.
- **The new MOSkin detector**
  1) Incorporates a single MOSFET sensor.
  2) Is temperature independent.
  3) Used in either passive or active mode.
  4) Has a highly reproducible build-up layer, capable of measuring skin dose according to the ICRP 1992 recommendations (0.07 mm basal layer depth)



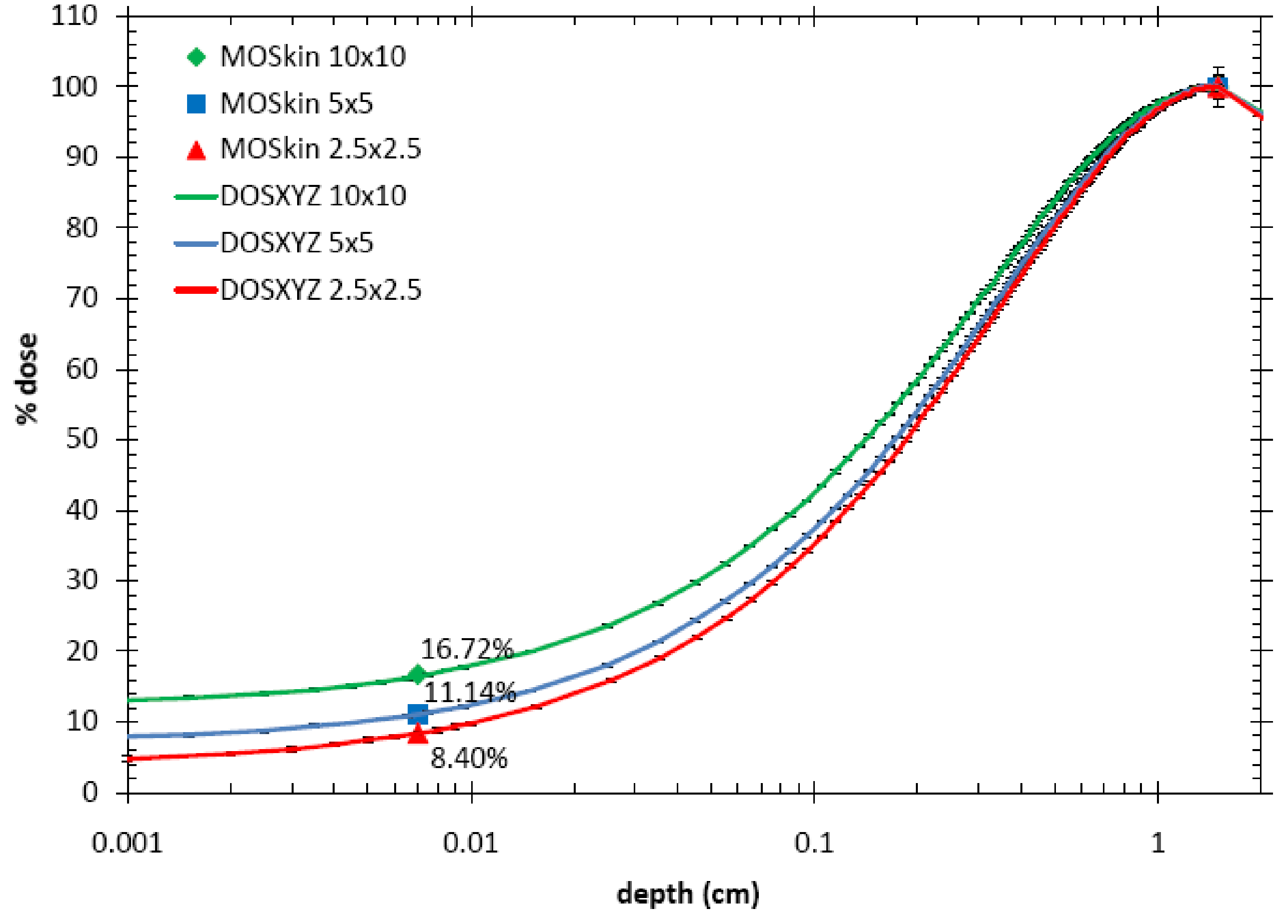
Epoxy bubble MOSFET

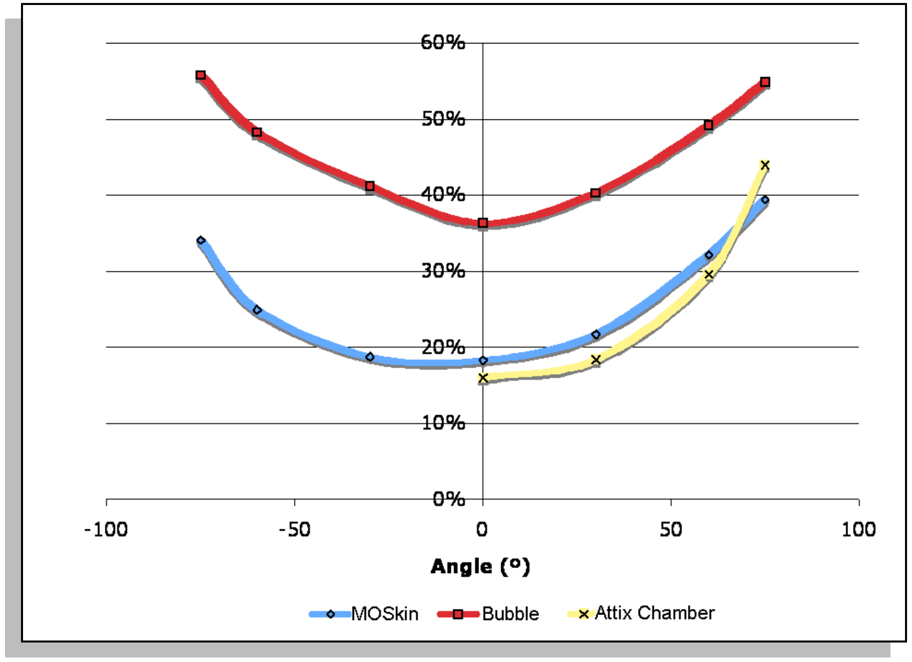


MO*Skin*

MO*Skin* detector: Water Equivalent Depth and Surface angular dose distribution

Monte Carlo vs Experiment





MOSkin vs MOSFET and ATTIX

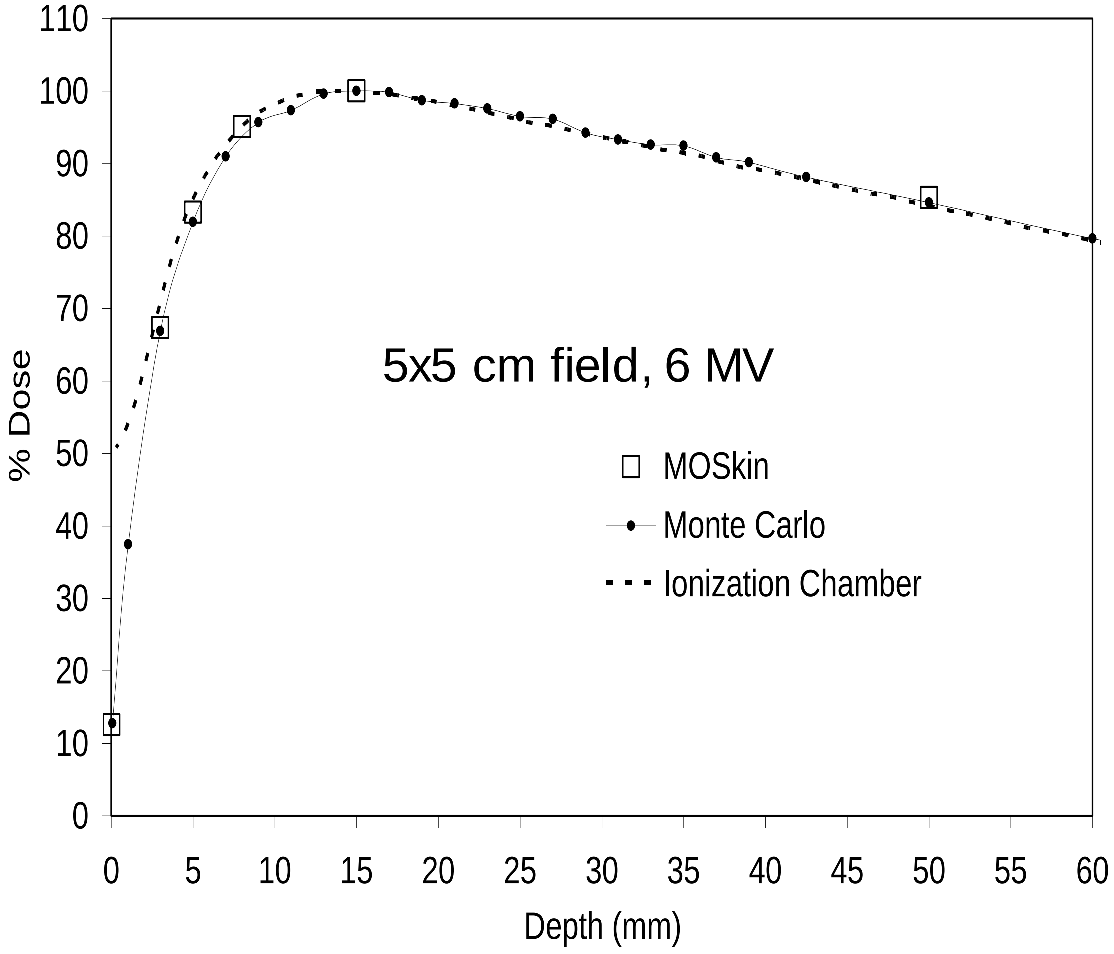
MO*Skin* detector: comparison with ATTIX IC

Percentage depth doses (PDD) measured with the MO*Skin*™ detector and the Attix chamber, respectively, at the phantom surface for both normal and oblique incident beams.

Incident angle (°)	0	30	60	75
MO*Skin* (%)	19.49±1.7%	21.42±1.6%	28.51±1.7%	37.98±1.7%
Attix chamber (%)	18.95±0.03 %	20.82±0.03 %	26.88±0.03 %	35.92±0.02 %
Normalized ratio	1.000	1.000	1.031	1.028

The Attix chamber measured a PDD of 16%

The MOSkin reported a mean PDD of 18.3 ± 0.7%, while the epoxy bubble MOSFET detector measured 36.3 ± 1.5%.



Conclusions

- Ionisation chambers are the gold standard for basic dosimetry in radiotherapy
- Advanced radiotherapy modalities requires advanced radiation sensors able to answer to challenging conditions:
  - Low angular dependence,
  - Extremely thin sensitive volumes
  - Realtime and correction free response
- Semiconductor dosimeters can answer to those challenges by design and development of specialized sensors.
- Although, road to clinical/commercial success is LONG and quite difficult, but certainly doable.

THANKS FOR YOUR ATTENTION!