Eighth Annual Chapman Phytosanitary Irradiation Forum

Dosimetry for phytosanitary applications: dos and don’ts

Florent KUNTZ

June 14th, 2018

Aérial - La bonne dose d’innovation

Question

What does a dosimeter measure ?

A dosimeter measures the dose absorbed in the dosimeter

What about the dose in the product ?

Question

In other words …

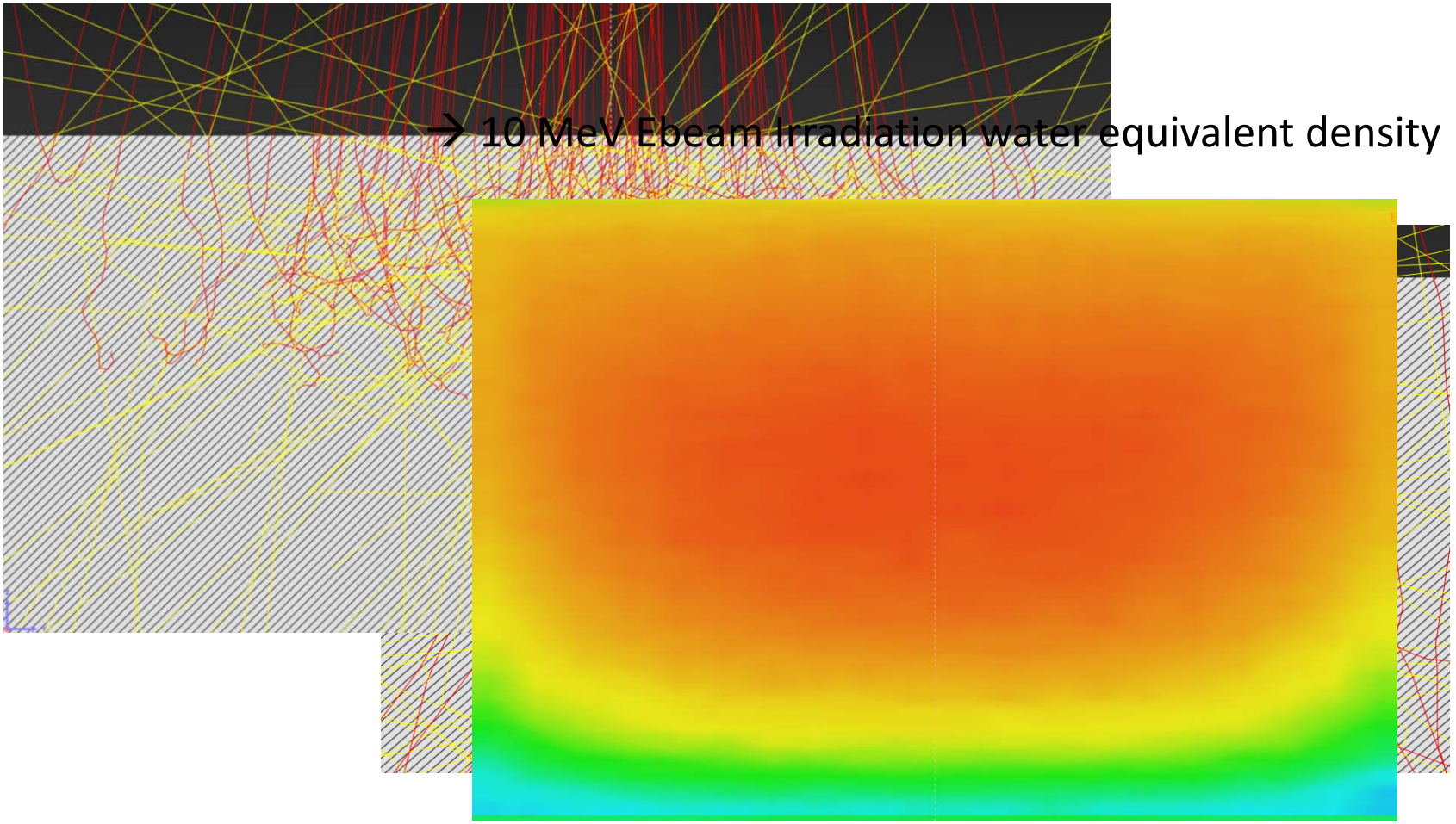
Do these two dosimeters measure the dose absorbed by product ?

Does this dosimeter measure the dose in the product?

RayXpert Simulation (MC)

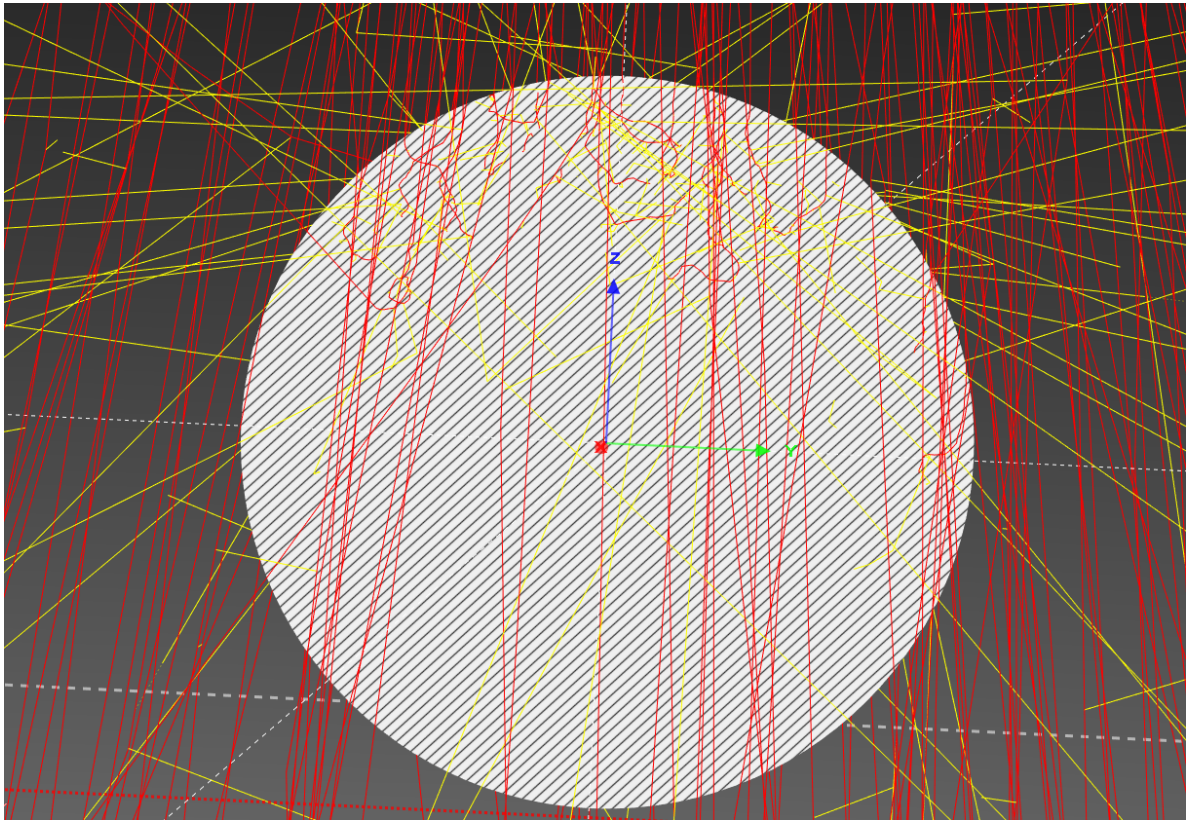
→ 1 MeV Ebeam Irradiation water equivalent density

→ 10 MeV Ebeam Irradiation water equivalent density



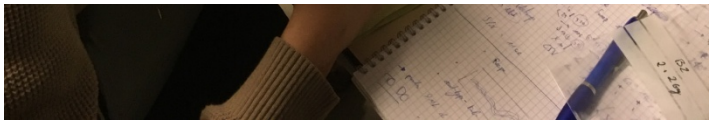
RayXpert Simulation (MC)

→ 1 MeV Ebeam Irradiation water equivalent density (Size of an apple)

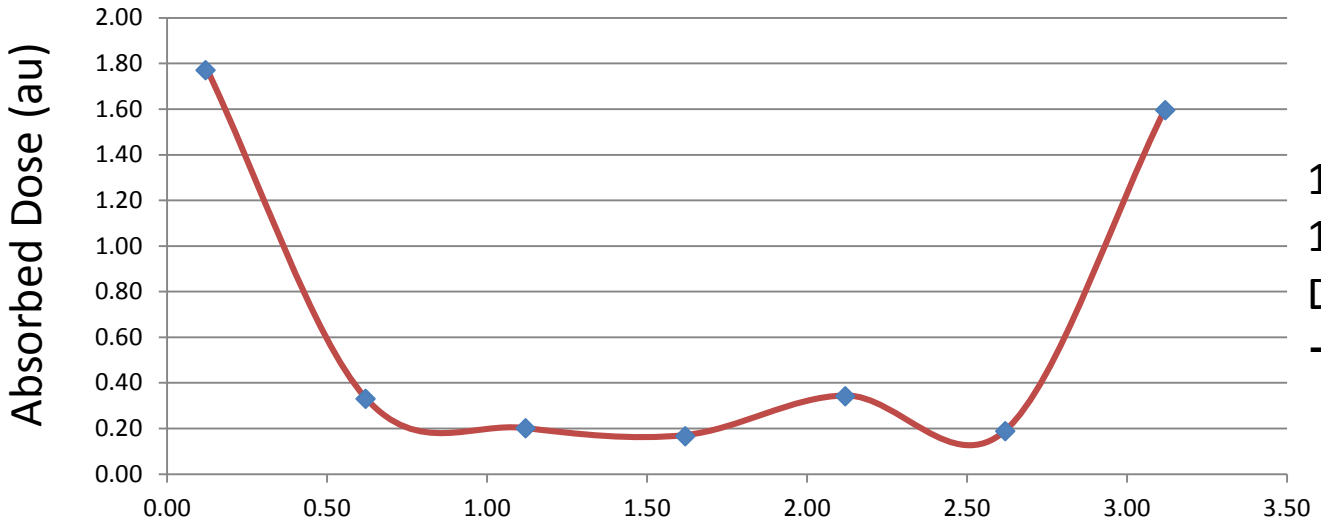


Experimental approach

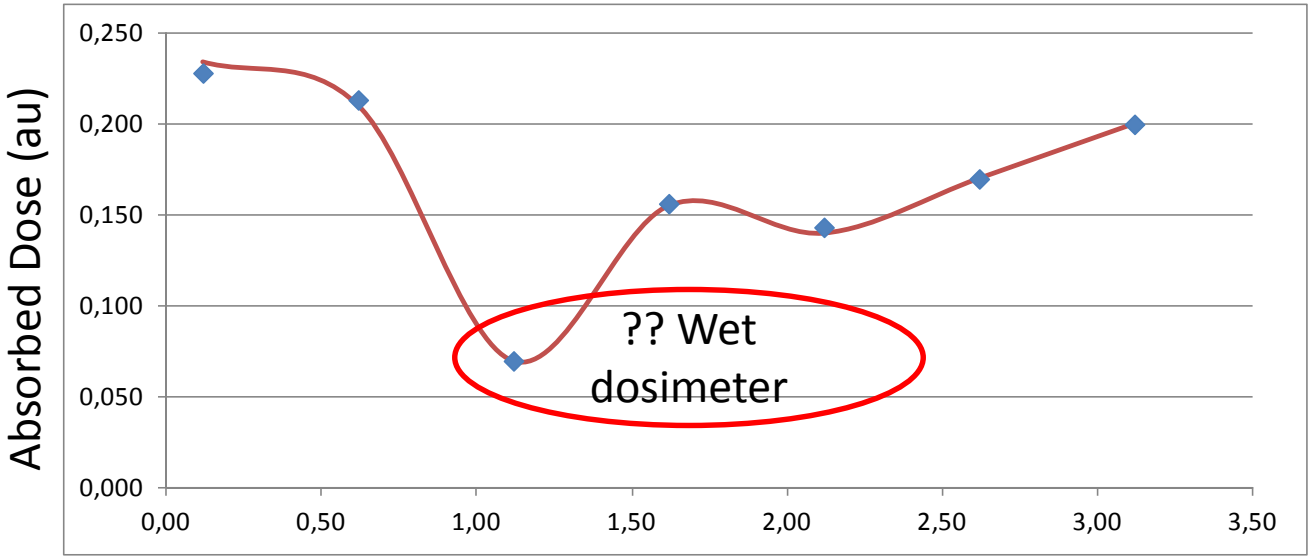
→ Low energy X ray irradiation



Experimental approach

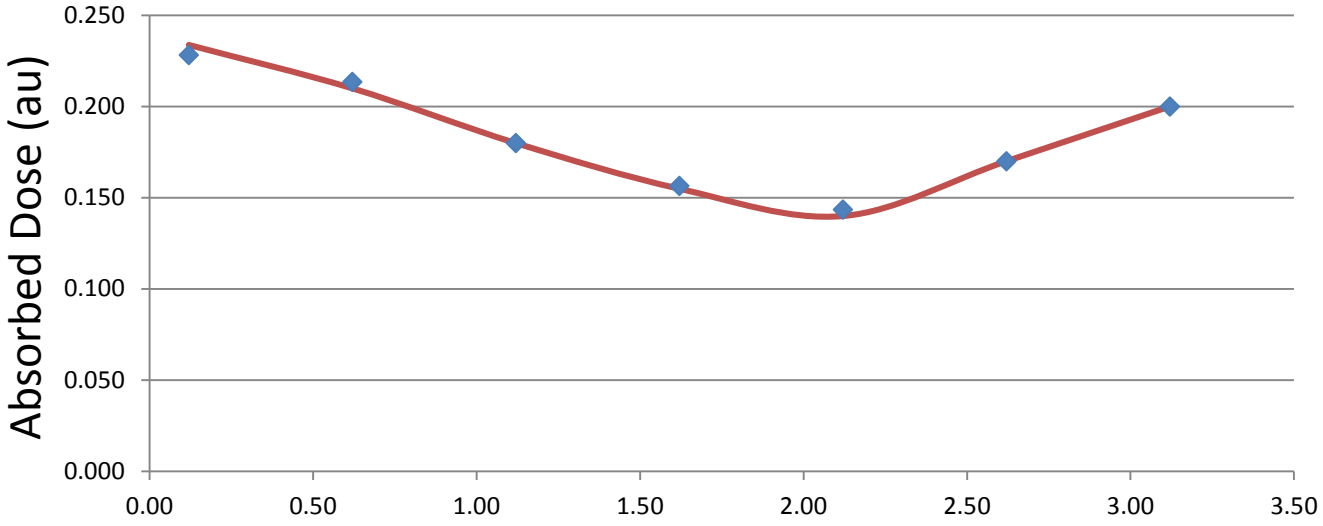


100 kVp
16 keV E_{eff}
Double sided Irradiation
→ DUR = 10



100 kVp with copper filter
32 keV E_{eff}
Double sided Irradiation
→ DUR = ???

Experimental approach



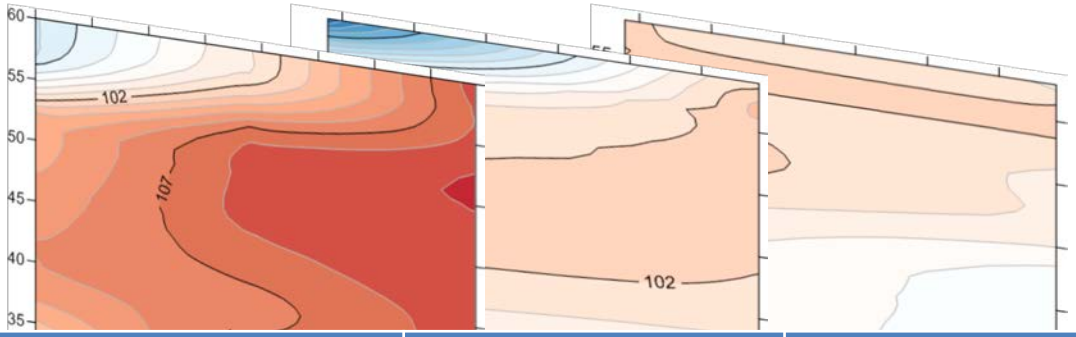
100 kV with copper filter
32 keV E_{eff}
→ DUR = 1.6

Experimental approach cont'd

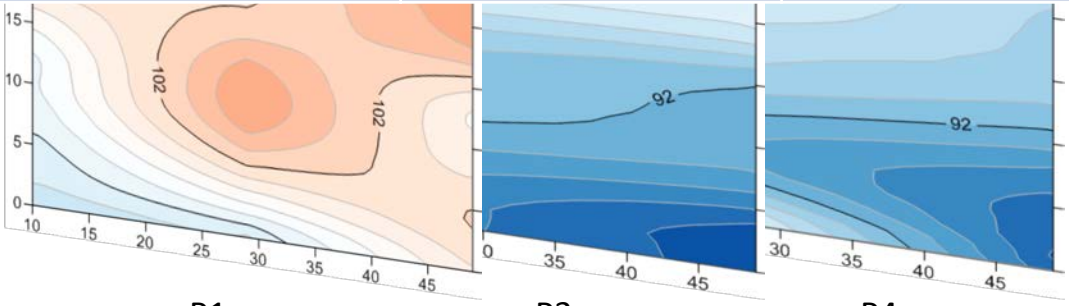
- 7 MV X Ray irradiation of a product pallet

Experimental approach cont'd

- 7 MV X Ray irradiation of a product pallet



Product ID	DUR CTA	DUR Alanine
7 MV X Radiation	1.24	1.19



P1 P3 P4

Performance Qualification

This experimental approach implementing dose measurements is a major part of **Performance qualification**

From ISO 14470 …

The data acquired from a dose mapping exercise in PQ are used to identify locations and magnitudes of minimum and maximum doses within product and to calculate the relationship between these doses and the dose at the routine monitoring position(s).

ISO 14470 Food irradiation -- Requirements for the development, validation and routine control of the process of irradiation using ionizing radiation for the treatment of food

Operational Qualification

How do we know where to place dosimeters during PQ?

From ISO 14470 …

Data from the OQ dose mapping can provide initial information on the placement of dosimeters for PQ dose mapping. Particular attention should be paid to regions of potential minimum and maximum doses that should be more closely mapped than areas of intermediate dose.

Operational Qualification

What is the purpose of OQ?

From ISO 14470 …

The purpose of OQ is to demonstrate that the irradiator, as installed, is capable of operating and delivering appropriate doses within defined acceptance criteria. This is achieved by determining dose distributions and dose magnitude through dose mapping exercises and relating these dose attributes to process parameters.

Operational Qualification

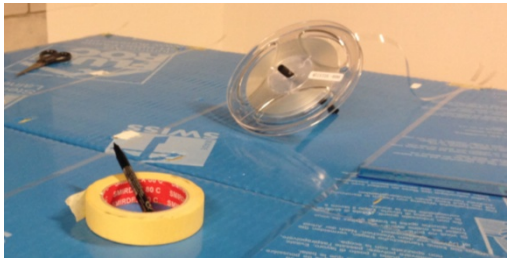
When performing OQ?

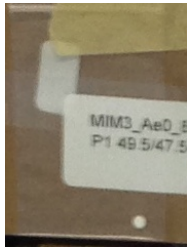
- New plant
- Modification of plant parts having potential impact on dose/dose rate/dose distribution/…
- Need to gather experimental data to get confidence in the process
- …

Operational Qualification - Examples

Gamma and 7 MV X Ray irradiation of medium and high density products

- CTA strips and Alanine
- Pallet irradiators (120 cm x 100 cm)
- Two media
  - Rockwool (0.15 g/cm^3)
  - Clay balls (0.46 g/cm^3)



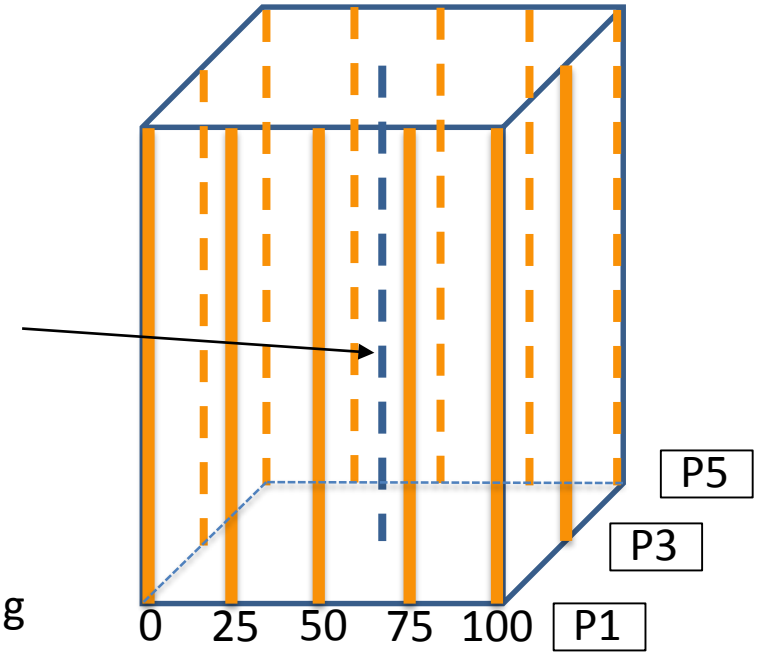


Operational Qualification - Examples

For high density product

- Dosimeter positionning and identification

Inner CTA in tube
(P3, x=50)

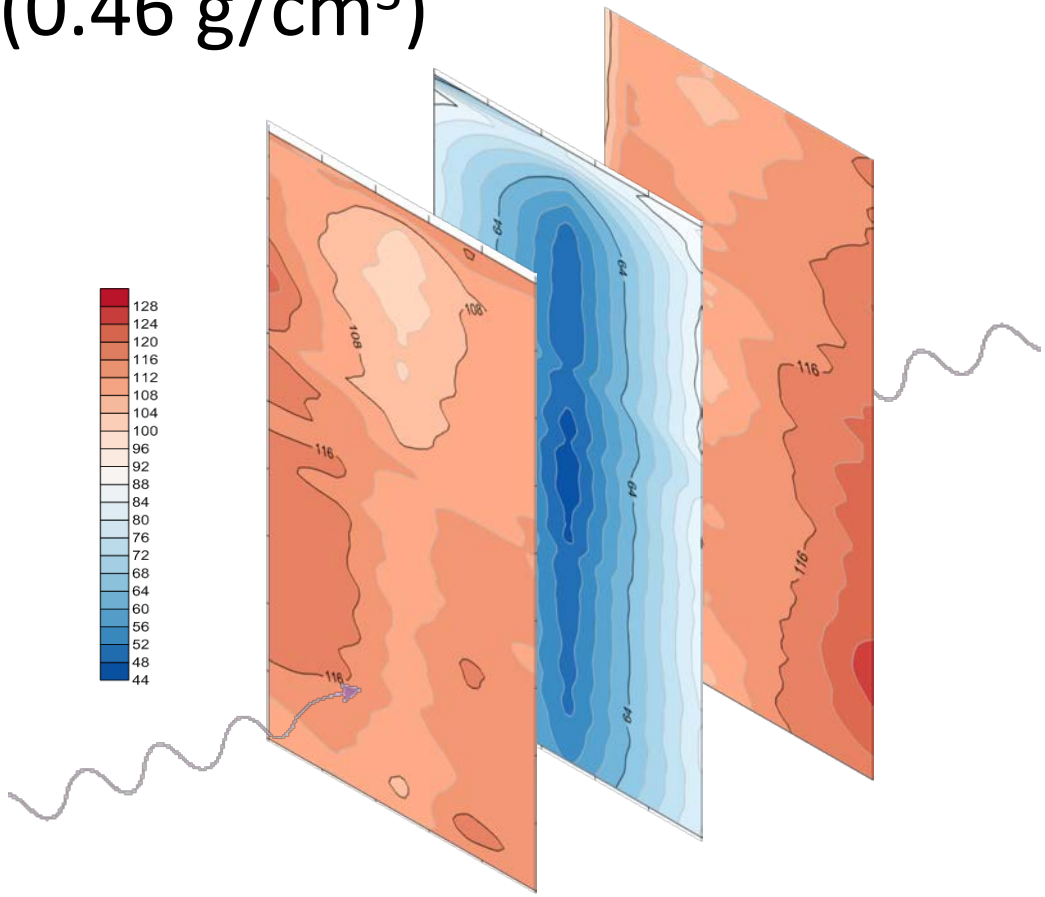


3 vertical planes
Parallele to conveying direction

Operational Qualification - Examples

- High density media (0.46 g/cm^3)

3 Vertical Planes
facing source rack

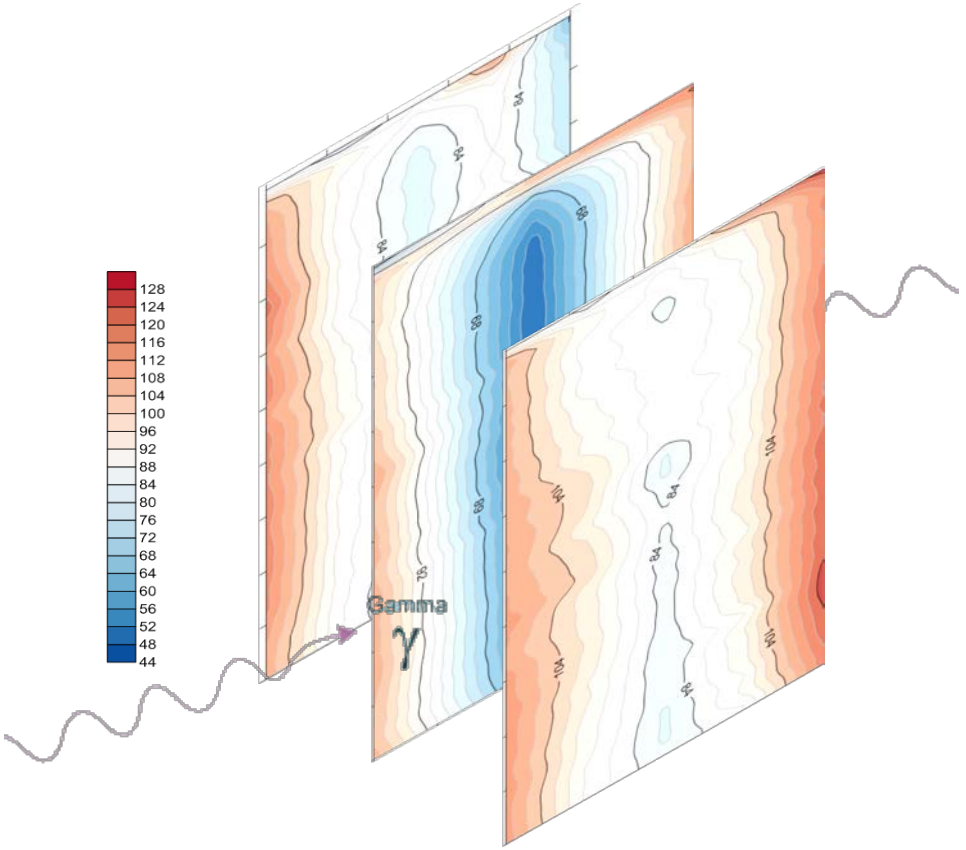


DUR = 2.90

Operational Qualification - Examples

- High density media (0.46 g/cm^3)

3 Vertical Planes in photon direction



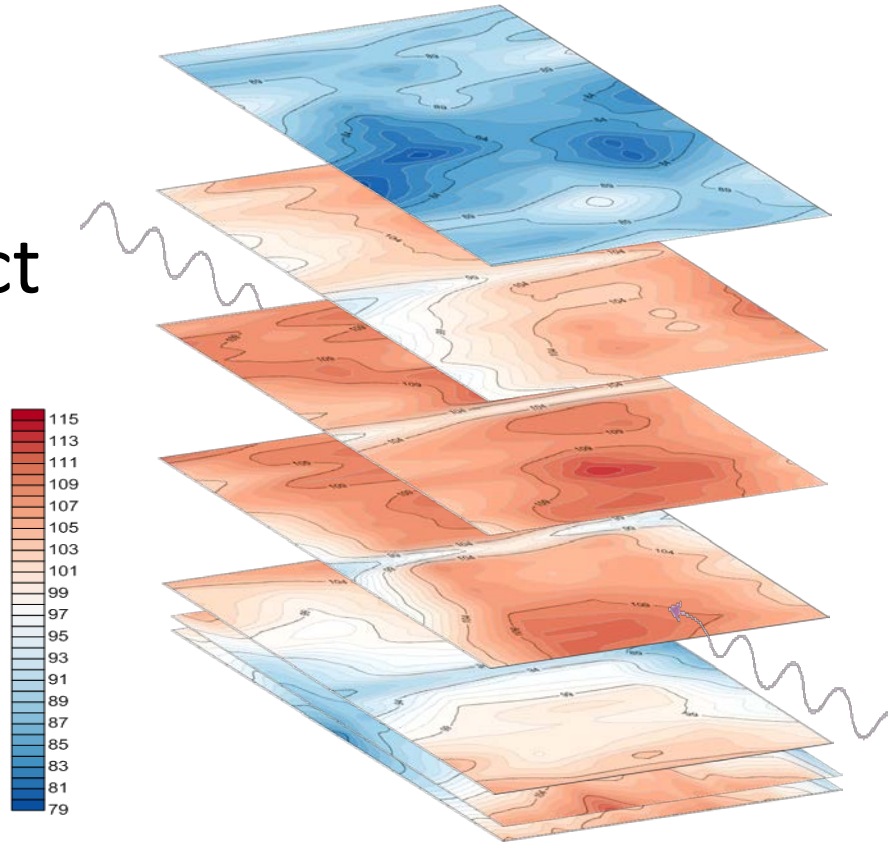
DUR = 2.90

Operational Qualification - Examples

7 MV X Radiation plant

- Medium density product
- 0.15 g/cm^3

Horizontal Planes

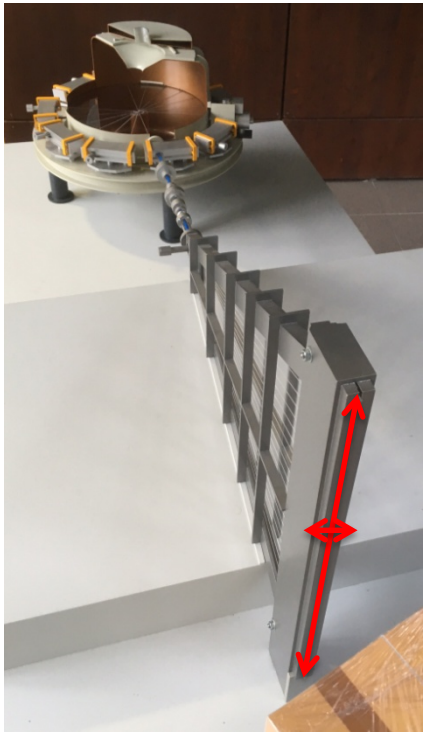


DUR = 1.33

Operational Qualification - Examples

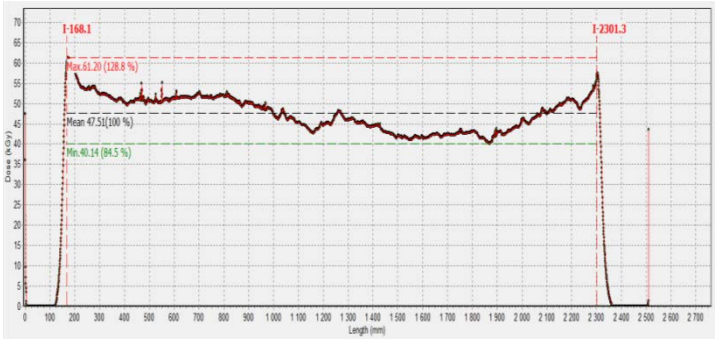
7MV X Radiation beam shape

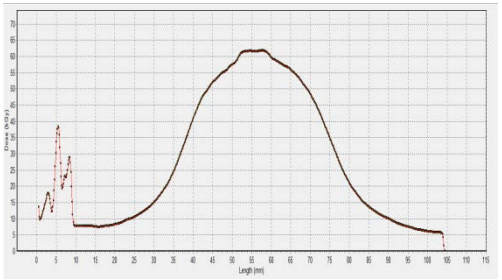
- 7 MeV X radiation plant
  - CTA strips vertical and horizontal

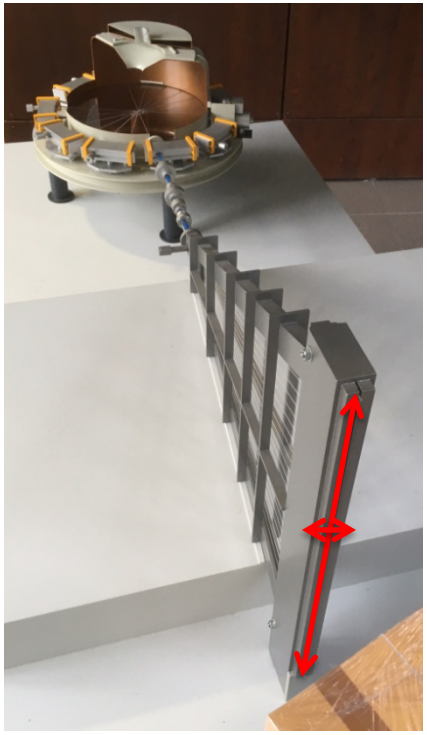


Operational Qualification - Examples

7MV X Radiation beam shape

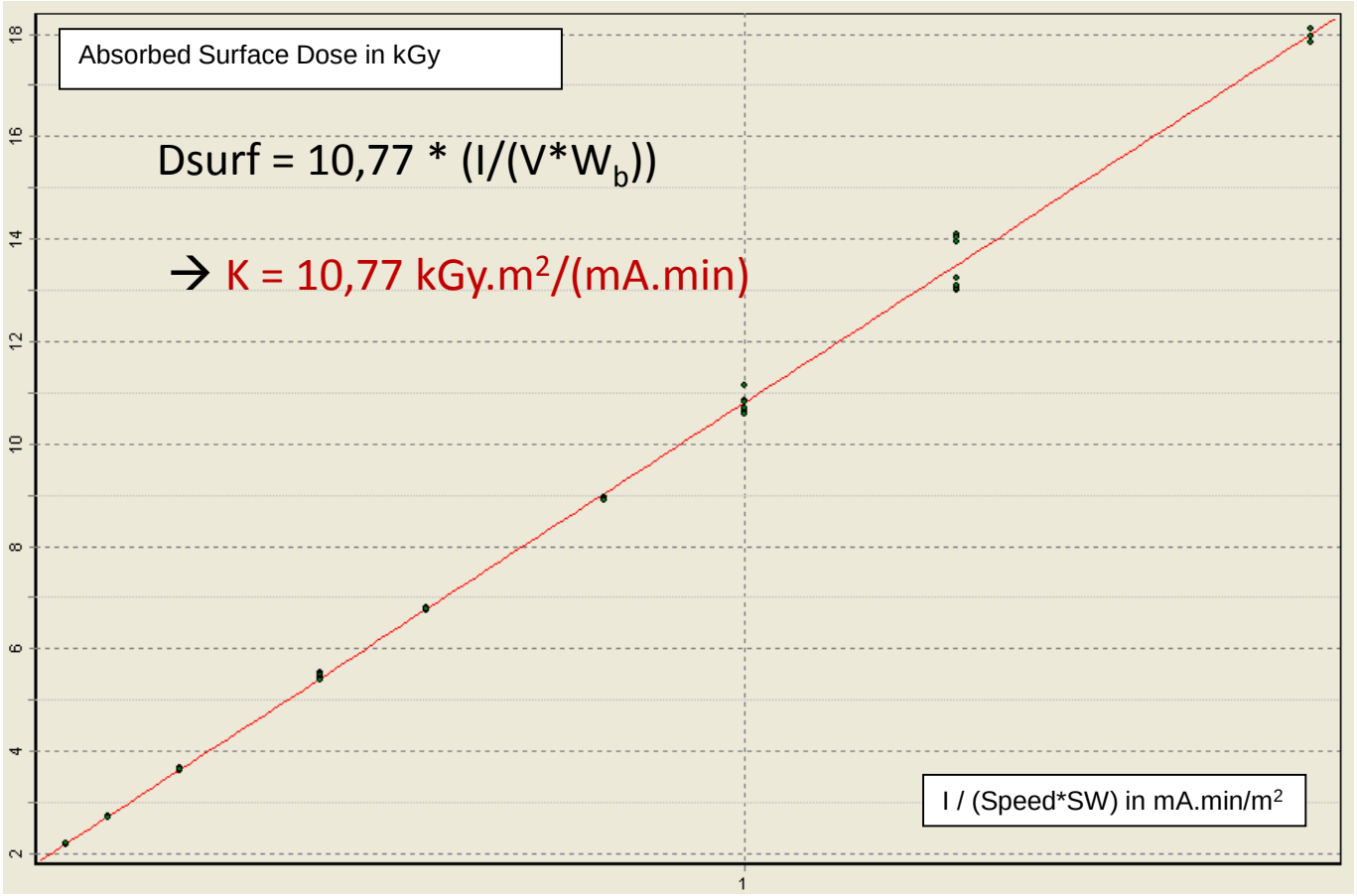






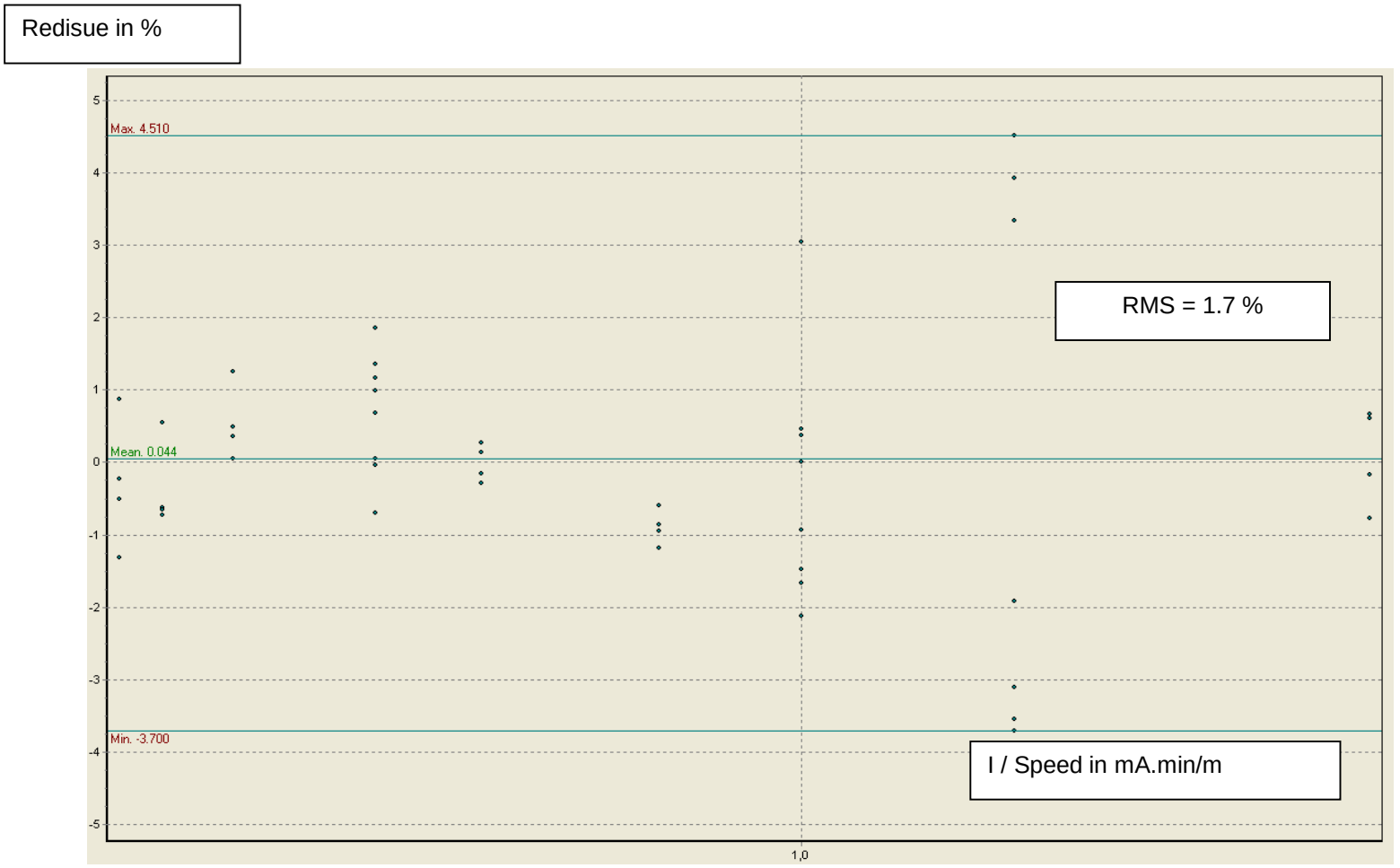
Operational Qualification - Examples

Absorbed dose as function of conveyor speed, beam current, scan width



Operational Qualification - Examples

Assessing process variability …



Installation Qualification

What is the purpose of IQ?

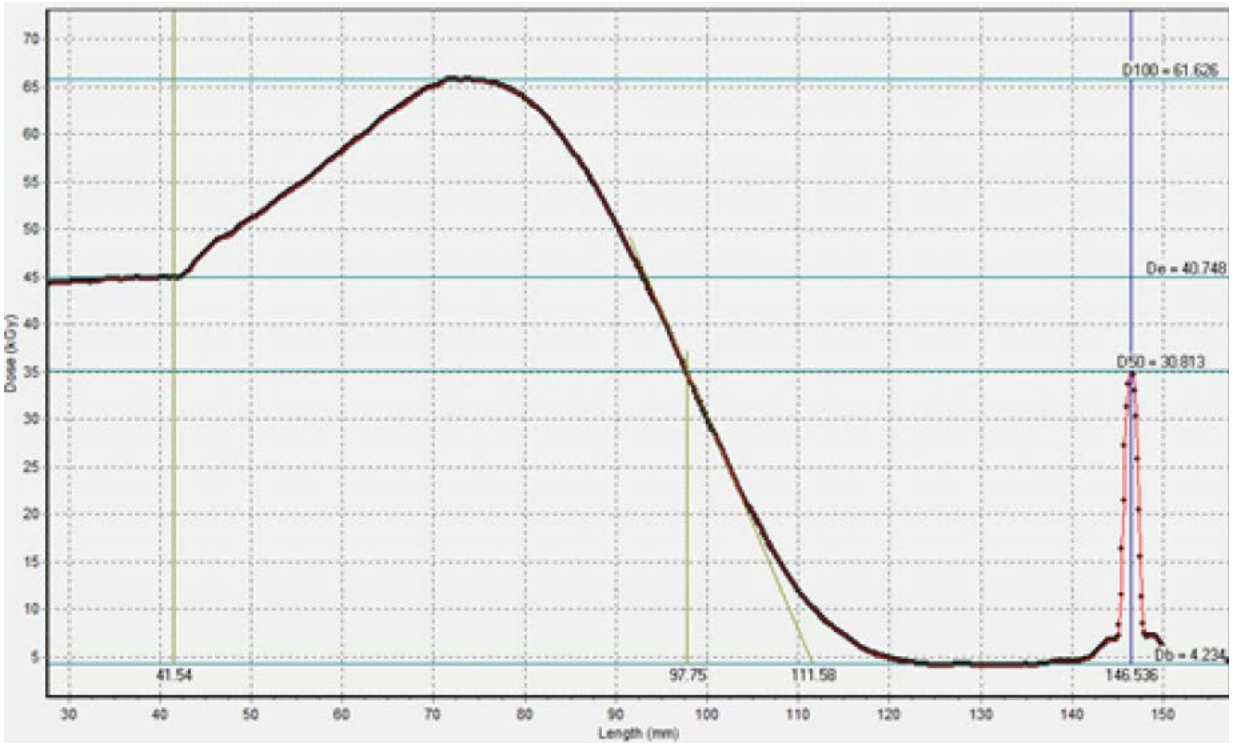
From ISO 14470 …

The purpose of Installation Qualification (IQ) is to demonstrate that the irradiator has been supplied and installed in accordance with its specifications

→ The specifications the customer has requested from plant manufacturer

Installation Qualification - Examples

E Beam energy assessment

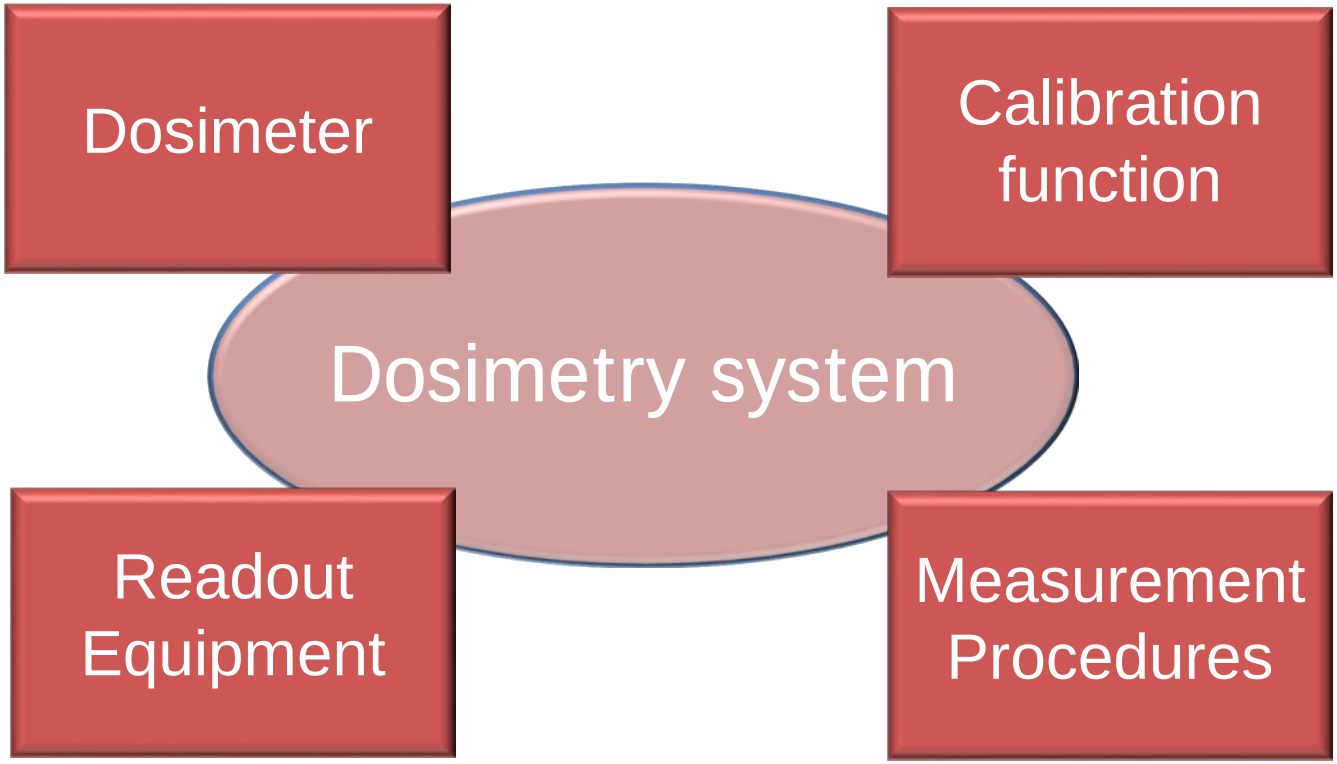


Wedge	Aluminium	
Density (g/cm^3)	2.711	
CSDA r0 (g/cm²)	5.859	
Angle (degree)	16	
Distance between mark and entrance	-105	
Formula :		
E_p	0.2+5.09*Rp	
E_a	6.2*R50	
E	0.423+4.69*Rp+0.0532*pow(Rp,2)	
Mark position (mm)	153.13	153.13
Start X (mm)	48.130	48.130
	7.582	7.582
Ep (MeV)	10.207	10.207
Ea (MeV)	9.734	9.734
E (MeV)	9.849	9.849

A3.14 from ISO/ASTM 51649 standard

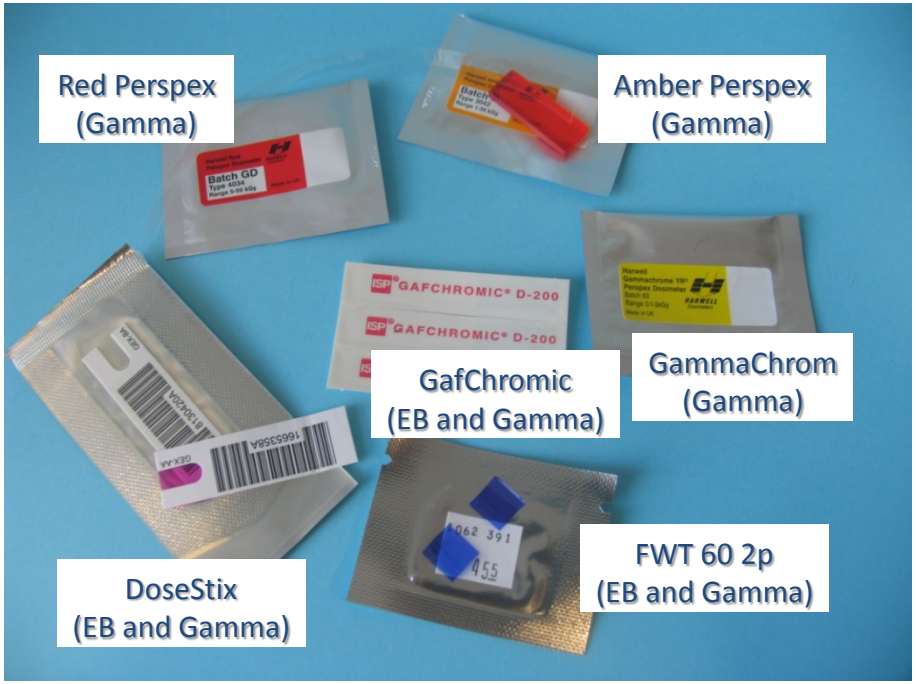
How to measure a dose

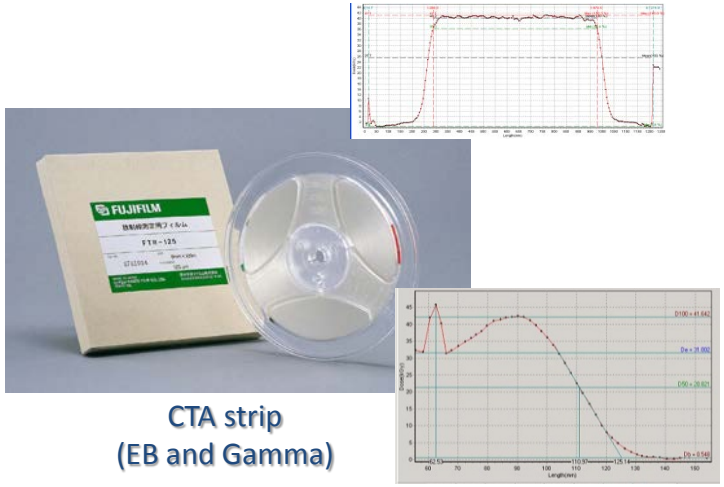
One need a dosimetry system



How to measure a dose

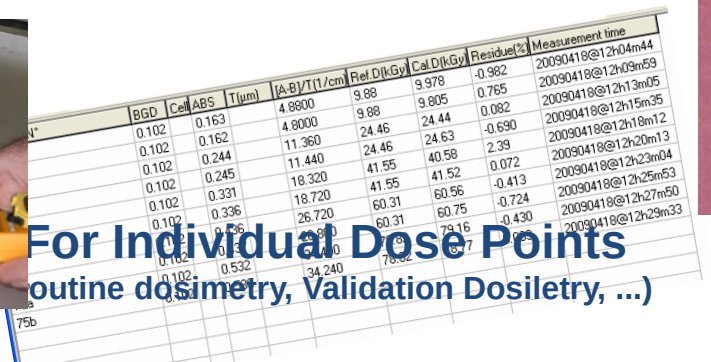
Dosimeter types
(routine/reference)





CTA strip
(EB and Gamma)

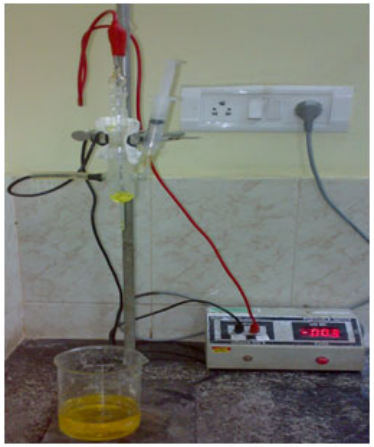
For Dose profiles
(energy, Scanning length, ...)



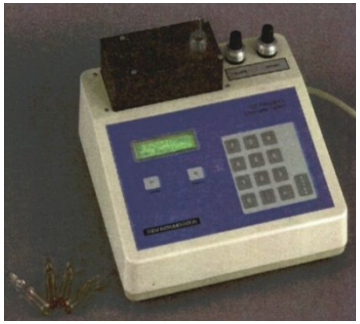
For Individual Dose Points
(routine dosimetry, Validation Dosiletry, ...)

For Reference Dosimetry
(Calibration, Verification)

How to measure a dose



ELECTRO CHEMICAL CELL (ECC)



Readout equipments (examples)

Making use of existing standards

ISO/ASTM standards and guides

Which dosimeters should I use for my application?
How to use the dosimetry system?
How do dosimeters behave under specific irradiation conditions? (influence quantities like Temperature, Dose rate, humidity, dose fractionation, …)
Appropriate storage conditions for dosimeters
And others …

Caution when homemade dosimeters are used !

Making use of existing standards

Dosimeter	Description	Reference ISO/ASTM Reference
Alanine / EPR	Pellet or film containing alanine. Measured by EPR spectroscopy of radiation-induced radicals.	51607
Ceric-Cerous Sulphate	Liquid solution of ceric and cerous ions in sulphuric acid. Measured by spectrophotometry or potentiometry.	51205

Implement existing standards

Dosimeter	Description	Reference ISO/ASTM
Calorimeter	Calorimetric body (absorber), thermal insulation, and temperature sensor with wiring.	51631
Cellulose Triacetate	Cellulose triacetate (CTA) film. Measured by spectrophotometry.	51650
Ethanol Chlorobenzene	Liquid solution containing chlorobenzene in ethanol. Measured by spectrophotometry or oscillometry.	51538

Implement existing standards

Dosimeter	Description	Reference ISO/ASTM
LiF photo-fluorescent	Lithium fluoride in film. Measured by photo-stimulated luminescence.	E2304
PMMA	Specially developed dyed or clear polymethylmethacrylate. Measured by spectrophotometry.	51276
TLD	A phosphor, either alone, or incorporated in a material. Measured by thermoluminescence.	51956

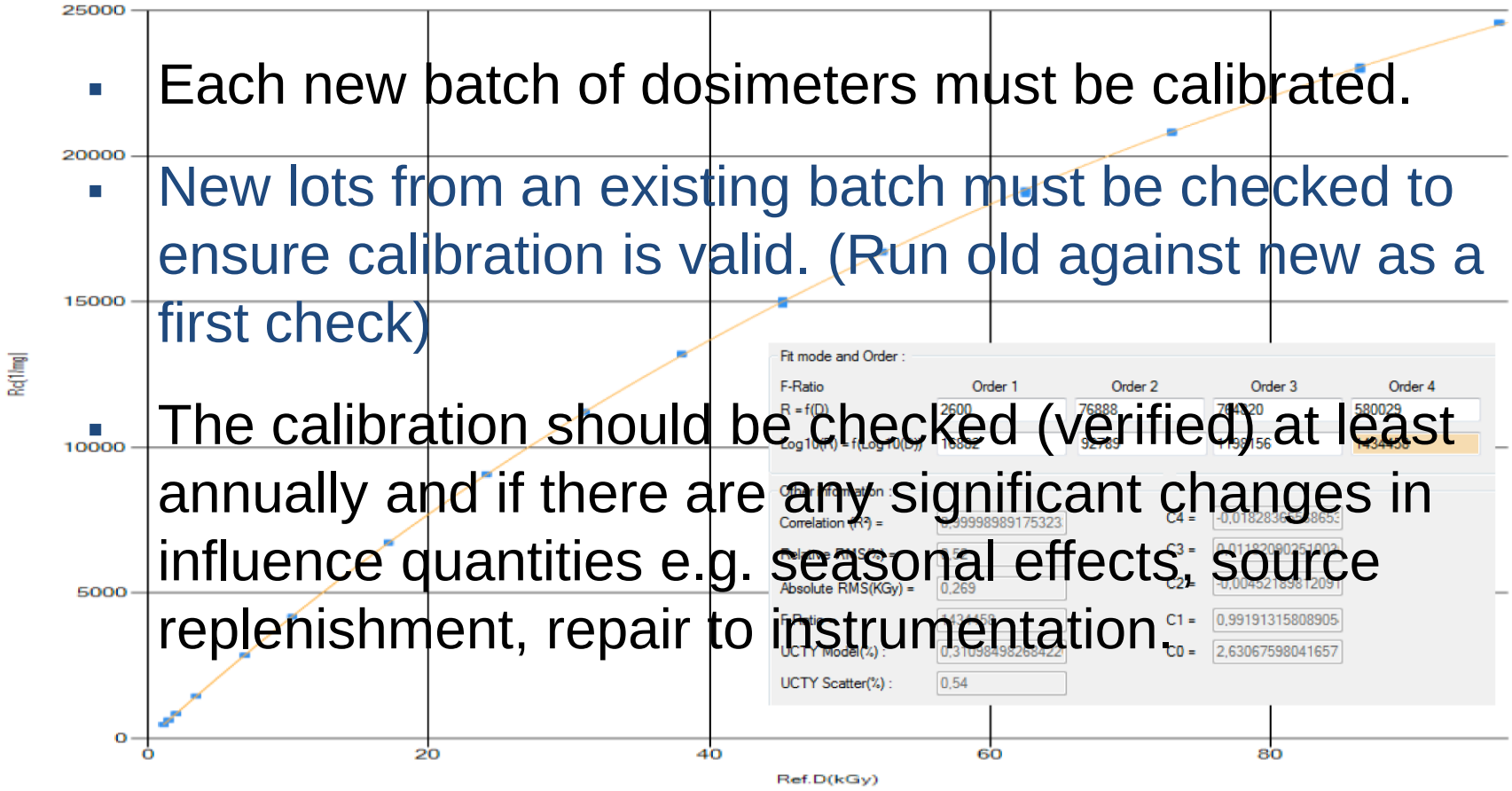
Implement existing standards

Dosimeter	Description	Reference ISO/ASTM
Radiochromic Film	Specially prepared film containing dye precursors. Measured by spectrophotometry.	51275
Radiochromic Liquid	Specially prepared solution containing dye precursors. Measured by spectrophotometry.	51540
Radiochromic Optical Waveguide	Specially prepared optical waveguide containing dye precursors. Measured by spectrophotometry.	51310

Calibrating a dosimetry system

Refer to ISO/ASTM 51261

Calibration relies on constructing a calibration curve based on the measurement of dosimeters irradiated to known doses.



- Each new batch of dosimeters must be calibrated.
- New lots from an existing batch must be checked to ensure calibration is valid. (Run old against new as a first check)
- The calibration should be checked (verified) at least annually and if there are any significant changes in influence quantities e.g. seasonal effects, source replenishment, repair to instrumentation.

Calibrating a dosimetry system

Refer to ISO/ASTM 51261

- The dosimetry system must be calibrated over a range of doses greater than that of intended use.
- Calibration curves must not be extrapolated to increase the dose range.
- Uncertainties will increase at the extremes of a calibration curve.
- At least five dose points should be used for each factor of 10 in dose.

$$N_{\text{dose points}} >= 5 * \log_{10}(Dmax/Dmin)$$

- At least four replicate dosimeters at each dose point.

Calibrating a dosimetry system

Refer to ISO/ASTM 51261

There are two principle methods of calibration of a routine dosimetry system:

- Irradiation in-plant using transfer standard dosimeters.
- Irradiation at a calibration laboratory, followed by a calibration verification exercise.

In Situ calibration is preferred

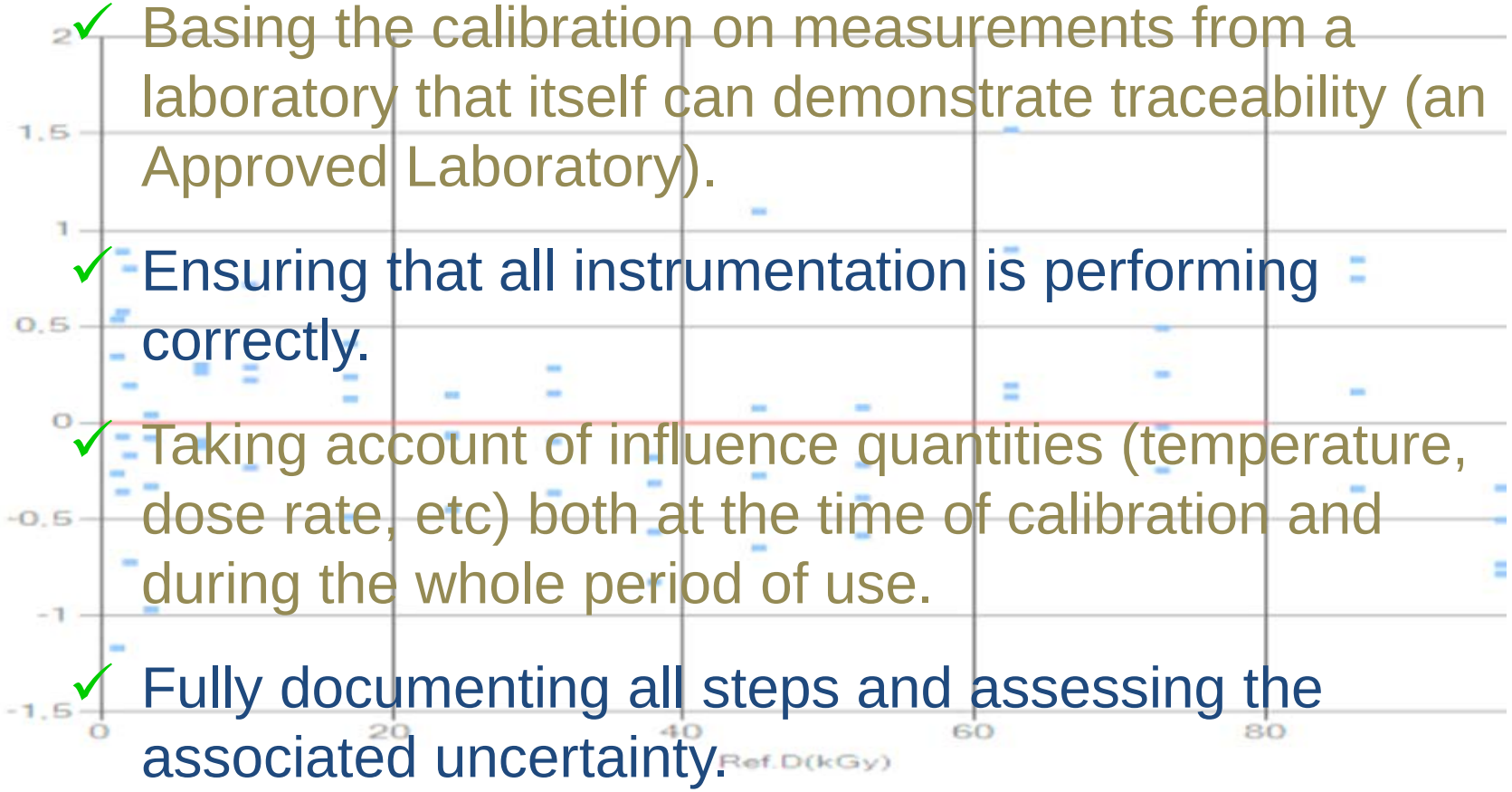
→ it helps mitigating influence quantities

Calibration of a dosimetry system

Refer to ISO/ASTM 51261

is achieved by:

- ✓ Basing the calibration on measurements from a laboratory that itself can demonstrate traceability (an Approved Laboratory).
- ✓ Ensuring that all instrumentation is performing correctly.
- ✓ Taking account of influence quantities (temperature, dose rate, etc) both at the time of calibration and during the whole period of use.
- ✓ Fully documenting all steps and assessing the associated uncertainty.



Conclusion

Dos

- Implement existing/relevant standards
- Calibrate dosimetry system with traceability to certified lab
  - -Assess uncertainty of dose measureme
- Perform IQ/OQ/PQ
  - -Assess variability of process
  - -Assess product variability

ดีแล้ว

Très bien
Very good
jayid jiddaan
Wszystko w porządku
muito bem
…

Don’ts

Ignore or skip any of the above if you want to have proper control of the process

Eighth Annual Chapman Phytosanitary Irradiation Forum

Dosimetry for phytosanitary applications: dos and don'ts

Thank you very much !

Florent KUNTZ

June 14th, 2018