SERVICES IN PERFECTION

Validation and Dose Mapping

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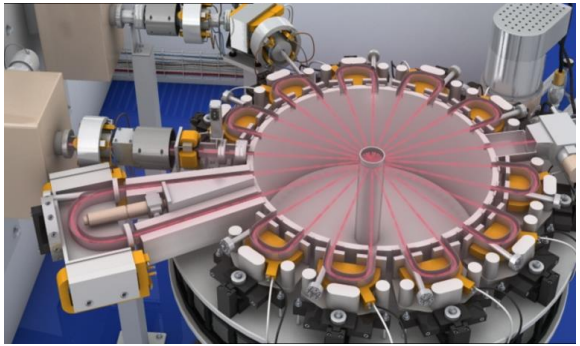
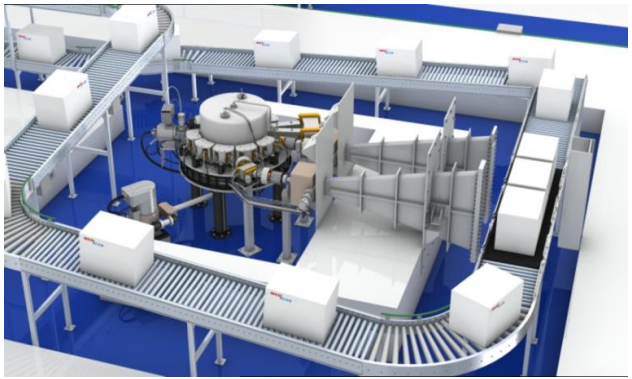
Seminar Copenhagen June 9th 2017

Highly Appreciated Irradiation Service Provider since 1995

Three Technologies: E-Beam – Gamma – X-Ray

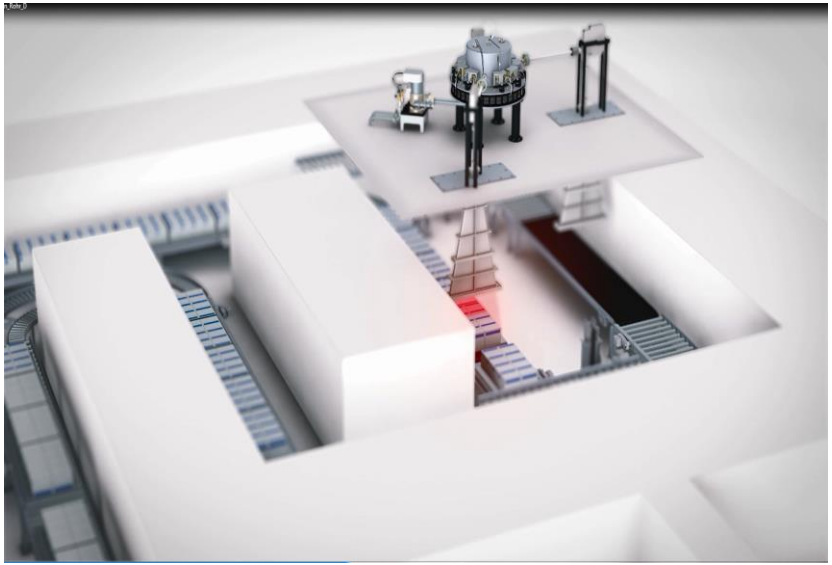
Devoted to Quality of Services and Innovation





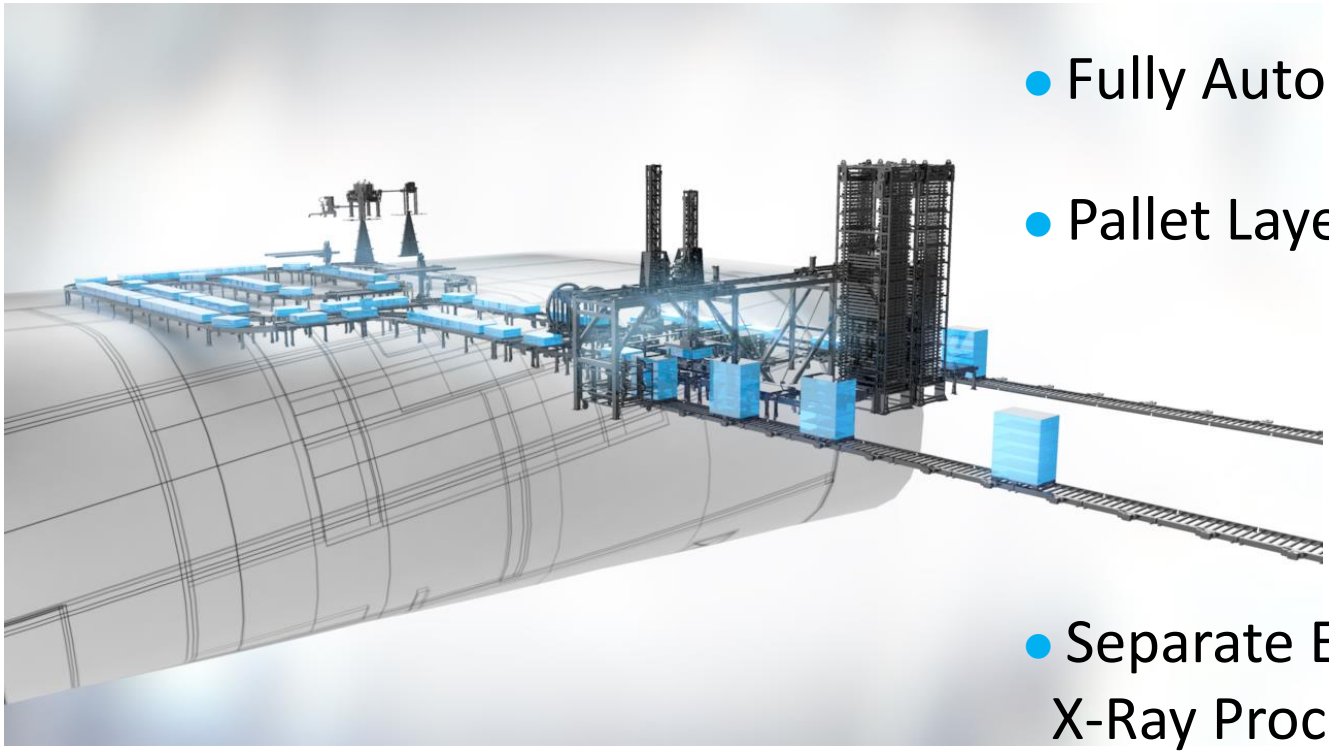
TT-100 Rhodotron 10 MeV and TT-100 10 MeV/6.6 MeV E-Beam/X-Ray

TT-300 “Duo” E-Beam “Workhorse” X-Ray “Special Products”

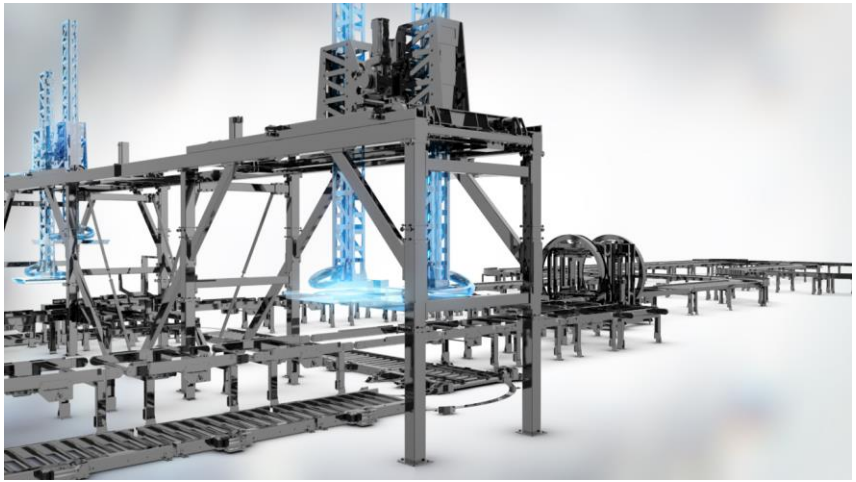


190 kW Power E-Beam: 10 MeV 19 mA

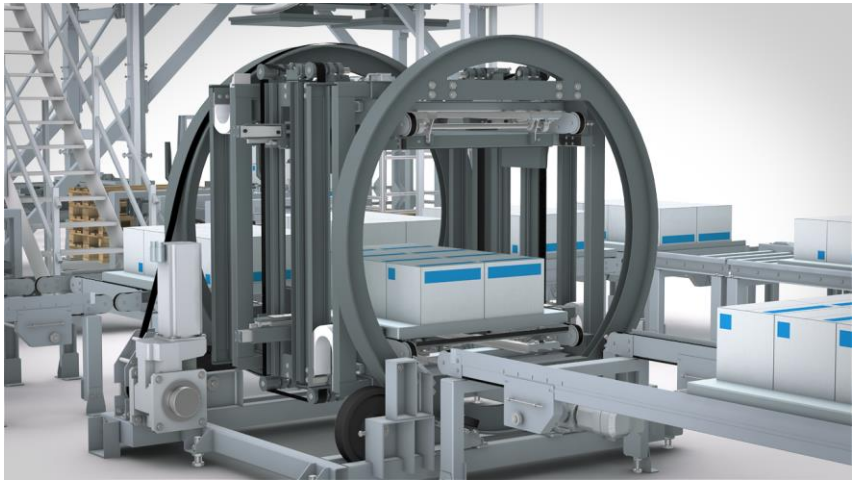
X-Ray: 7 MeV 27 mA



- Fully Automatic
- Pallet Layers on Trays
- Separate E-Beam and X-Ray Process Conveyors



Depalletizer/Palletizer



Product Turning

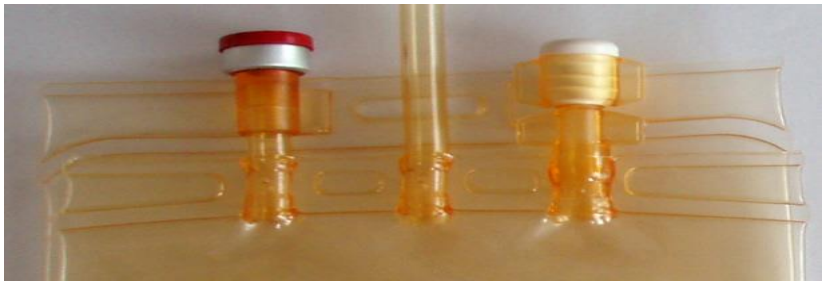
Medical Device Example

- Medical Device
  in its Shipping Container
- Sterilized using
  Ionizing Radiation
- Electron Beam

Process Definition

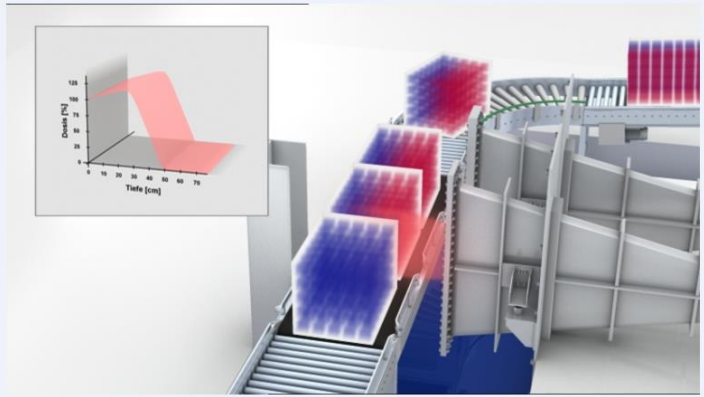
D_{ster} **Minimum dose to ensure sterility (Dose Setting)**

$D_{max,acc}$ **Maximum dose not to harm the product (Material Qualification)**

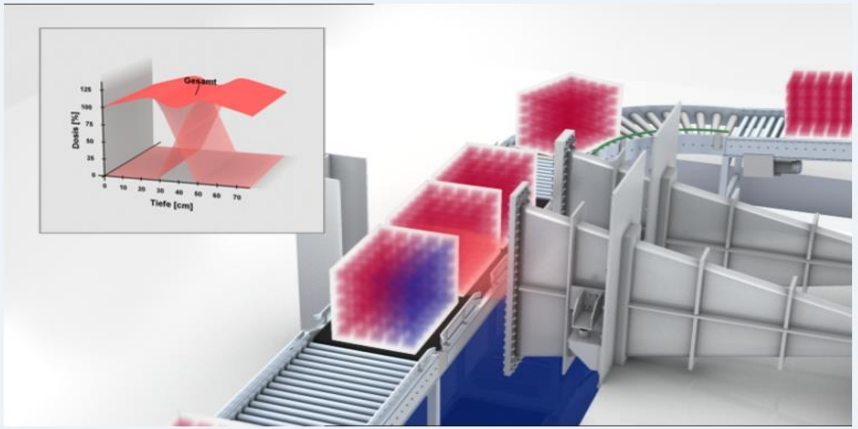


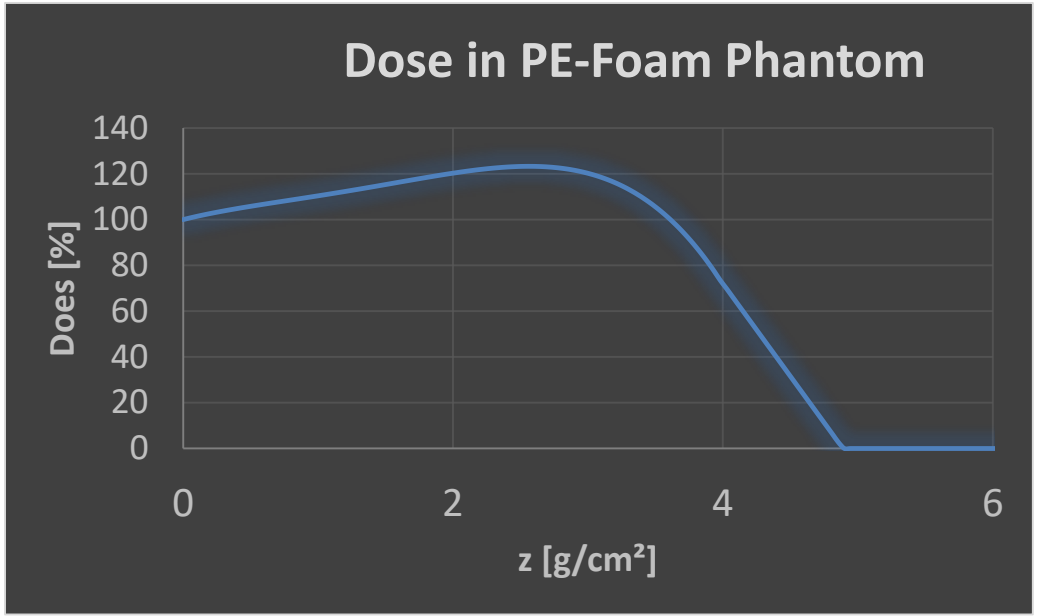
Electron Beam Treatment
Improve Penetration:

1st Pass



2nd Pass





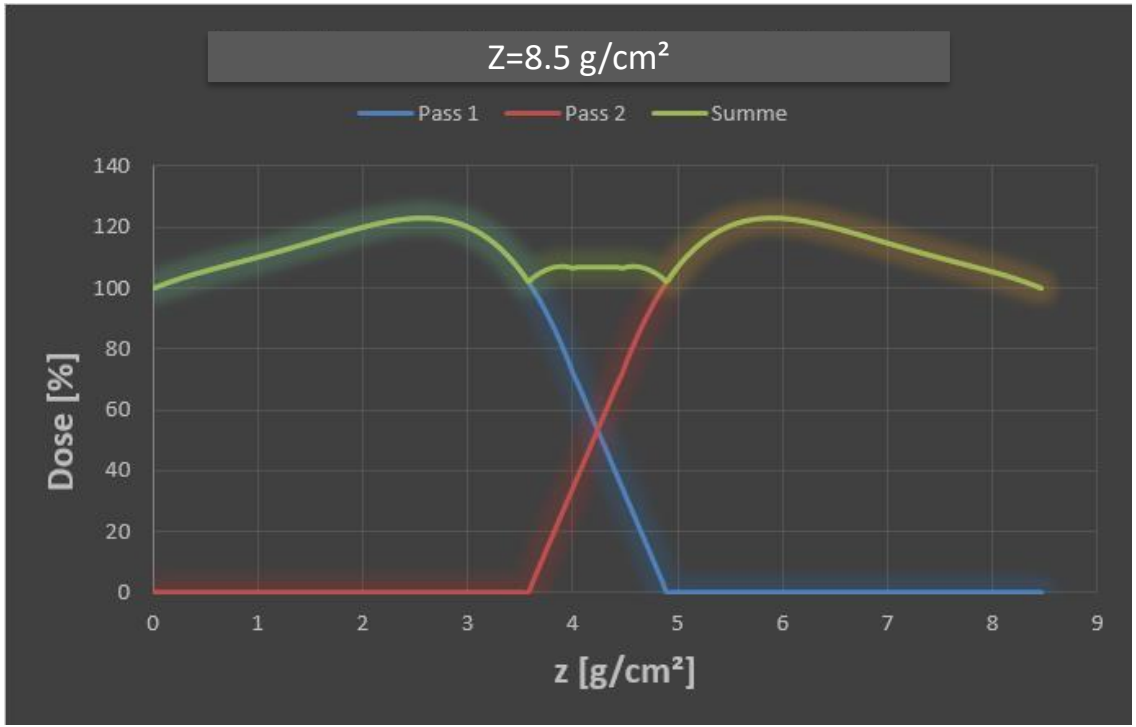
Standardized Depth: z

Build-Up Region

Fast Drop Off

$z=\text{Depth}\ [g/cm^2] = \text{depth}\ [cm] \times \text{Density}\ [g/cm^3]$

Double Sided Treatment to Improve Penetration



ISO 11137-1 PQ Requirements

9.3 Performance qualification

9.3.1 Dose mapping shall be carried out using product loaded in irradiation containers in accordance with a specified loading pattern in order to

a) identify the location and magnitude of the minimum and maximum dose and

b) determine the relationships between the minimum and maximum dose and the dose(s) at the routine monitoring position(s).

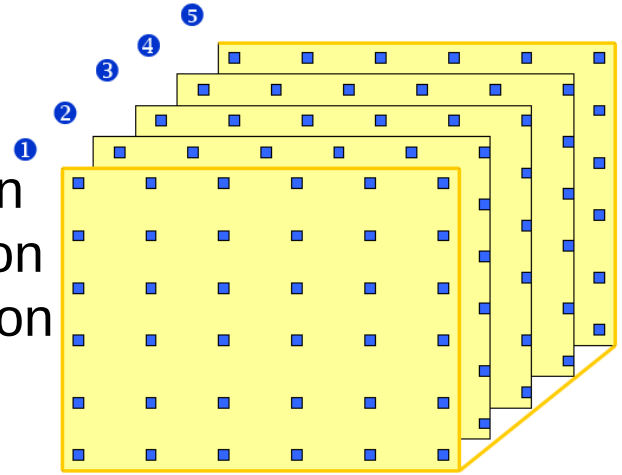
9.3.5 Dose mapping shall be carried out on representative irradiation containers sufficient in number to determine the variability of dose between containers.

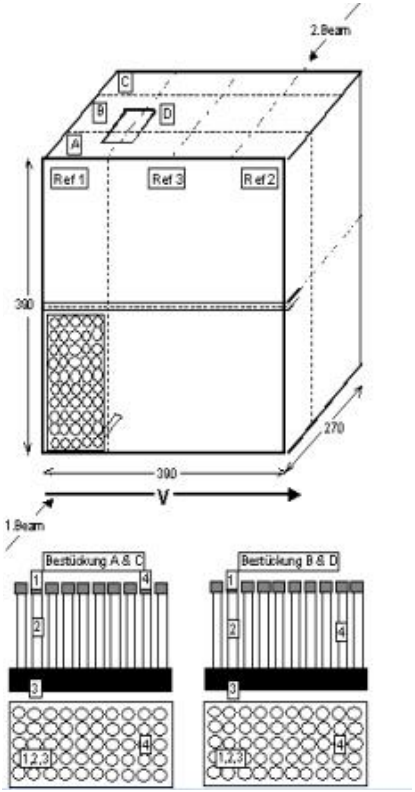
Product Validation- Dose Mapping

Dosimeters are placed **inside** the product to locate the minimum and maximum dose zones

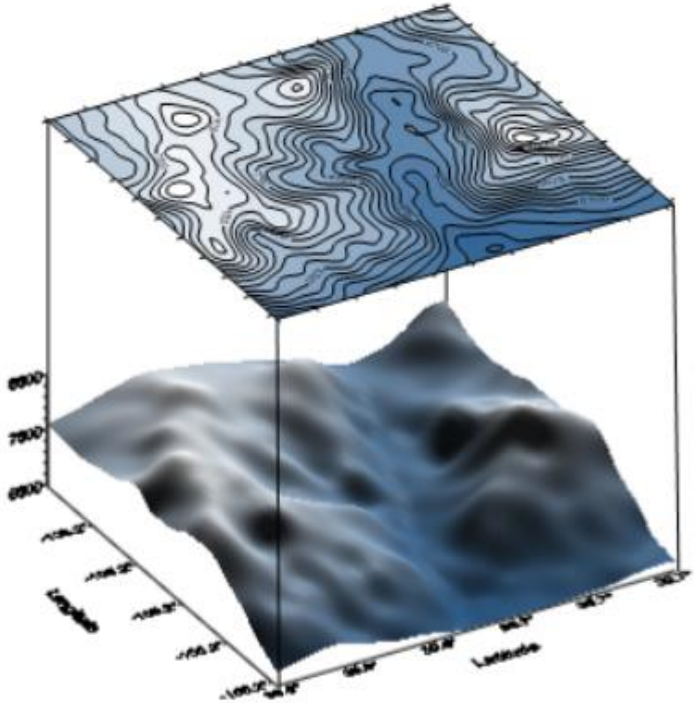
Quantify: D_{min}, D_{max}, D_{mon}

D_{min} Dose at Minimum Position
D_{max} Dose at Maximum Position
D_{mon} Dose at Monitoring Position

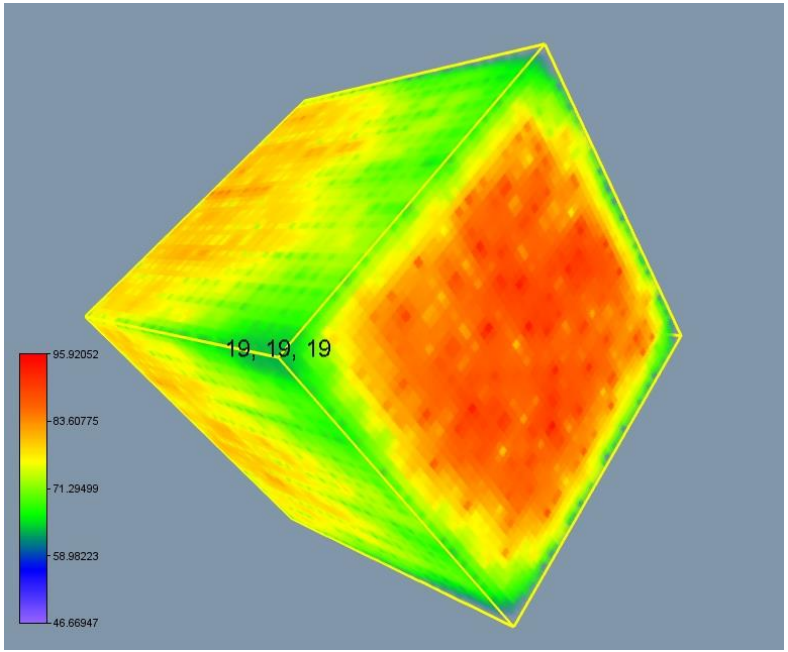




Mapping in General - in 2 Dimensions



Dose Mapping 3-Dimensional



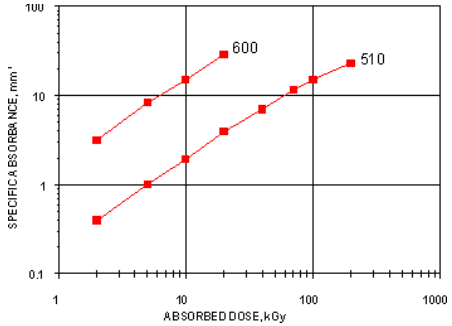
Evalulating dose in x-y-z inside the product:

Where ? → **Locations/Grid**

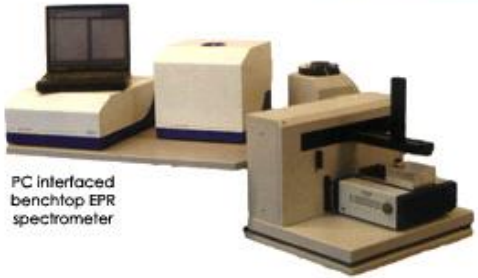
How? → **Dosimeter Modelling**

Dosimeter

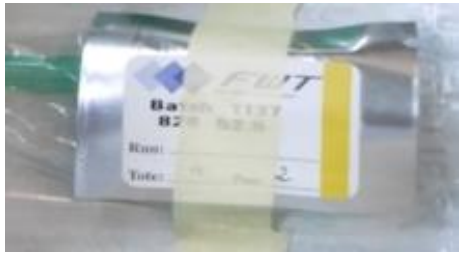
Radiochromic Films



Alanine Pellets



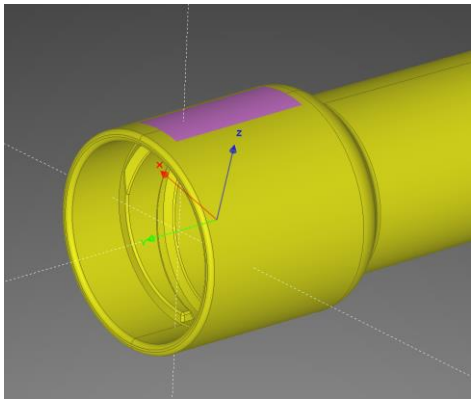
Dosimeter Placement

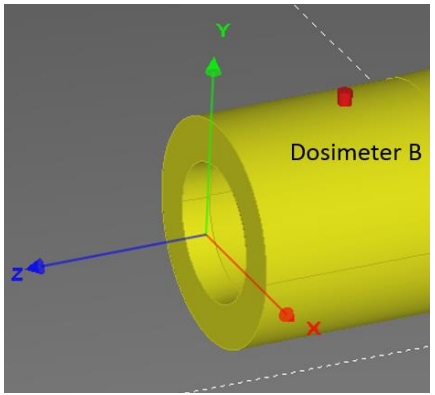


thin film dosimeter with poach
(18- 50 μm) with Al- pouch

Alanine Pellets
Cylinders R=2.4mm
Plastic wrapping
barcoded

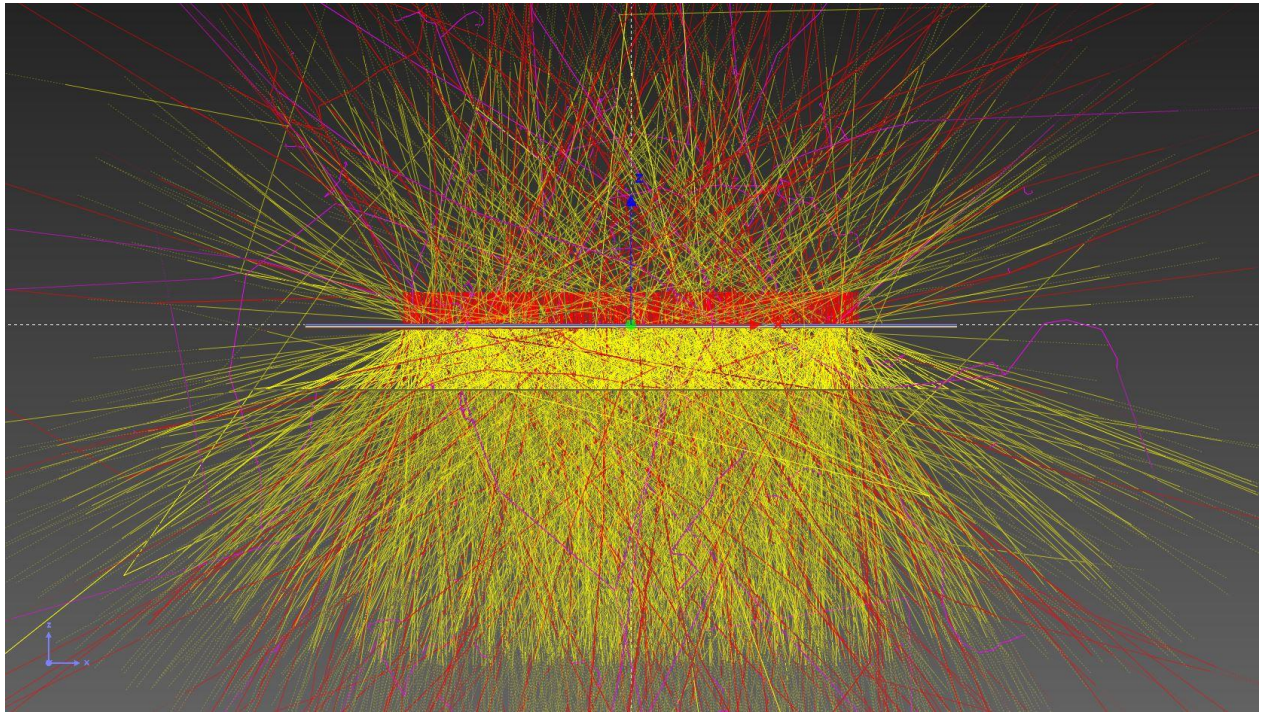
Mathematical Modelling to assist Dose Mapping



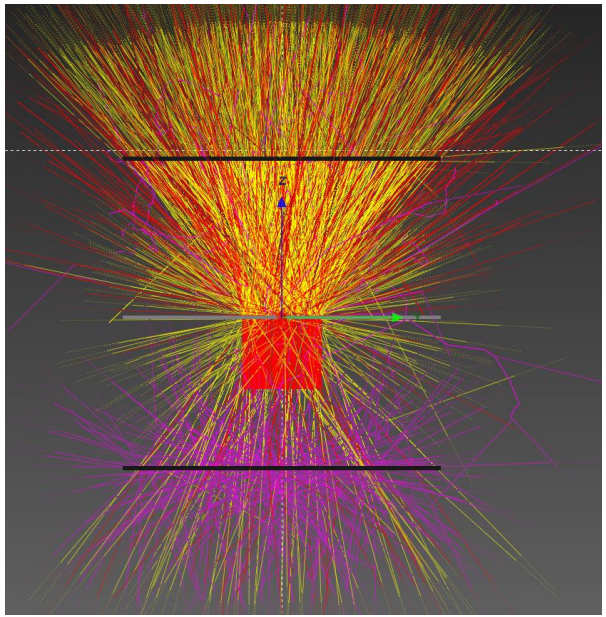


- Established in Medical Physics
- New Possibilities with CAD input
- Place Dosimeters/Object is Dosimeter
- Simulate Changes to Product/Process
- Study Dose Effects

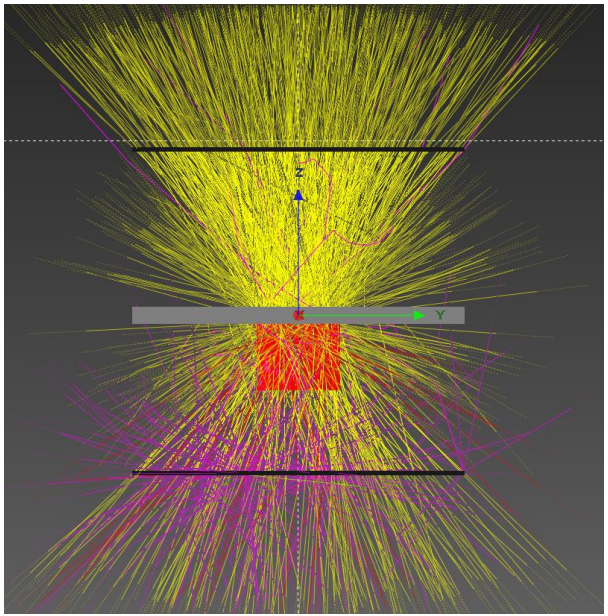
Visualisation - Example X-Ray Treatment



Example Shielding of Medical Devices

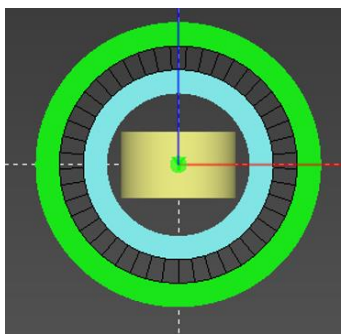
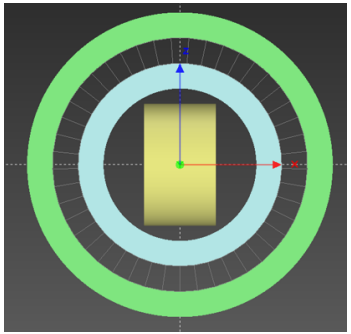
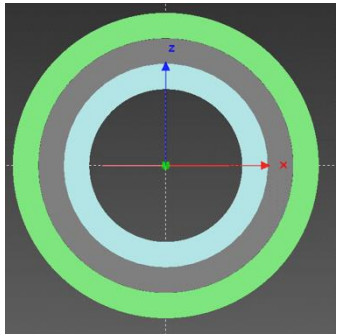
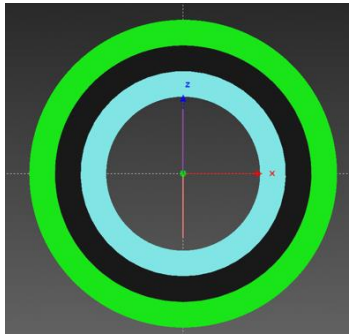


Mo 2 mm



Mo 10 mm

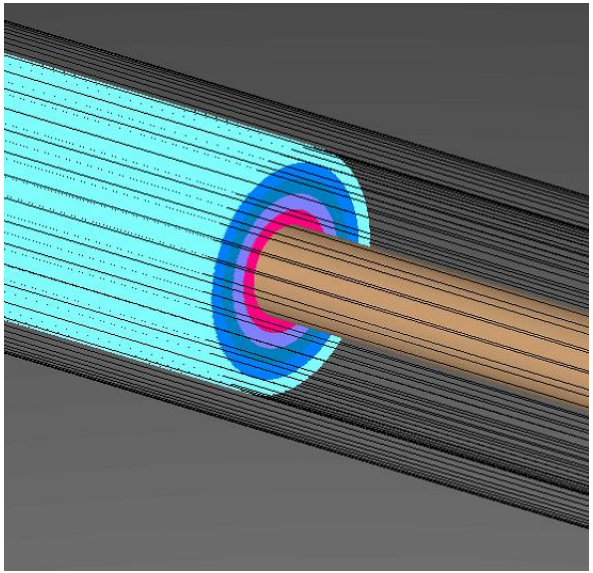
Example: Dosimeter Response and Dose

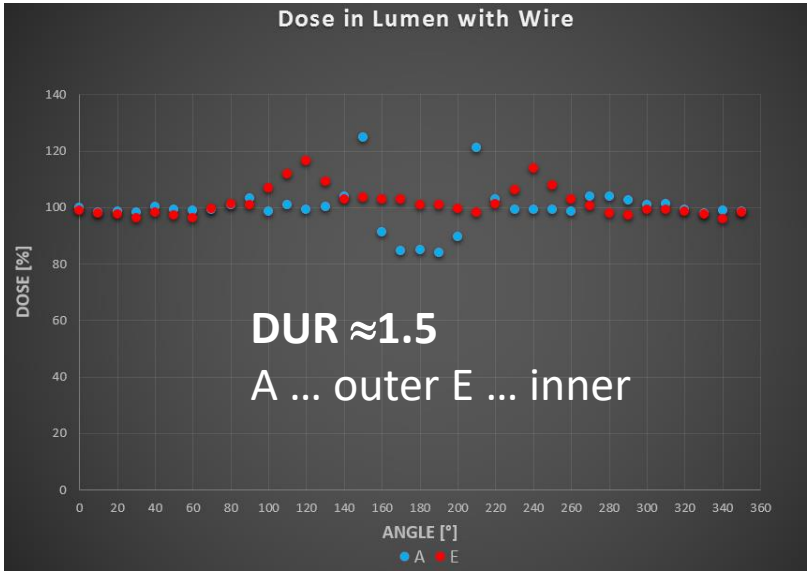





Deviation between Dose in Air and Dosimeter Measurement:

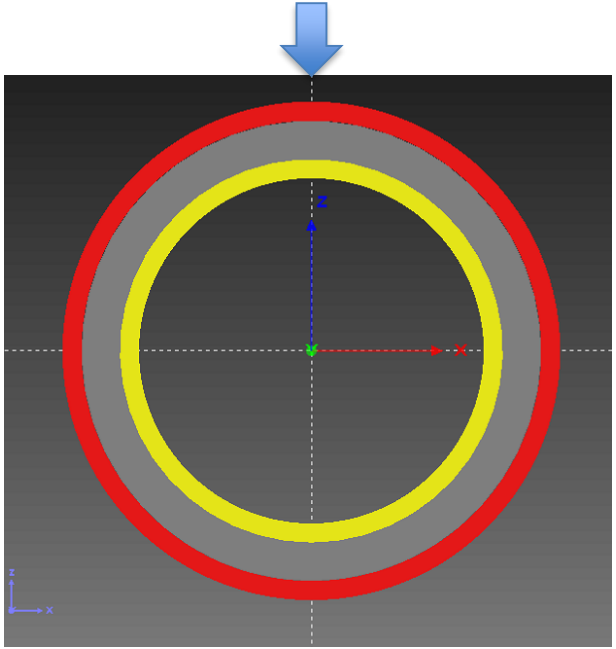
Pellet horizontal	Pellet vertical.	Film horizontal	Film vertical
-0.3%	-2%	-1.8%	- 14.4%

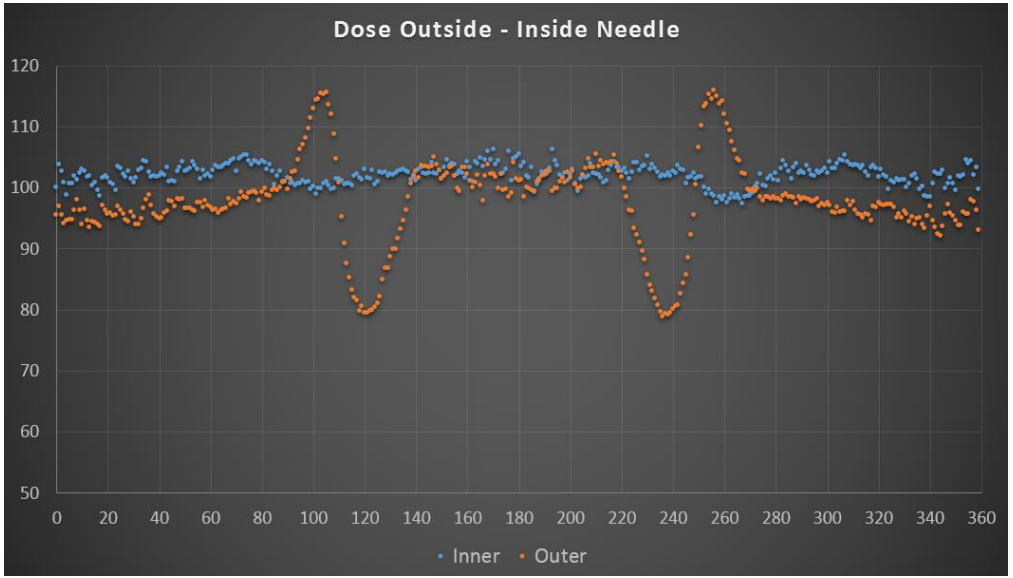
0.5mm Steel Wire in Tube





Steel Needle D=1mm Thickness 100µm





Dose Mapping make synergistic use of:

- Alanine Dosimeter (averaging of microdose effects)
- Mathematical Modelling (validated by experiments) to study and interpret radiation physics phenomena
- No “hunt“ for dose gradients
  Understand - Interpret – Assess Risk

Routine Monitoring Position

- On-Product – Position Laser Guided
- Manual Placement
- Automatic Removal
- Alanine Dosimeter

Validation Report

DSM No.	Position	Dose [kGy]	Dose [kGy]	Dose [kGy]	RSD [%]
Ref	Standard	16,4	17,3	17,4	3,2
1	A1	27,7	30,7	30,7	5,8
2	A2	30,7	30,5	28,3	4,5
3	A3	29,7	32,5	31,8	4,7
4	A4	33,5	32,5	31,8	2,6
5	A5	29	30,2	31,4	4,0
6	B1	27,8	26,9	31,4	8,3
7	B2	28,3	30,9	30,5	4,7
8	B3	30,5	32,9	30,7	4,2
9	B4	32,1	32,8	32,9	1,3
10	B5	30,9	31,1	31	0,3
11	C1	32,6	33,9	33,3	2,0
12	C2	32,1	30,3	32,9	4,2
13	C3	34	36,2	35,4	3,2
14	C4	34,4	33,6	34,9	1,9
15	C5	31,4	34,9	32,8	5,3
16	D1	33,6	35,4	33,7	3,0
17	D2	34,9	35,9	31	7,6
18	D3	34	35,9	35,7	3,0
19	D4	35	35	32,9	3,5
20	D5	34,3	35,3	34,6	1,5

PQ Run Summary

Color Indication:

Hot Spots – Low Dose Region

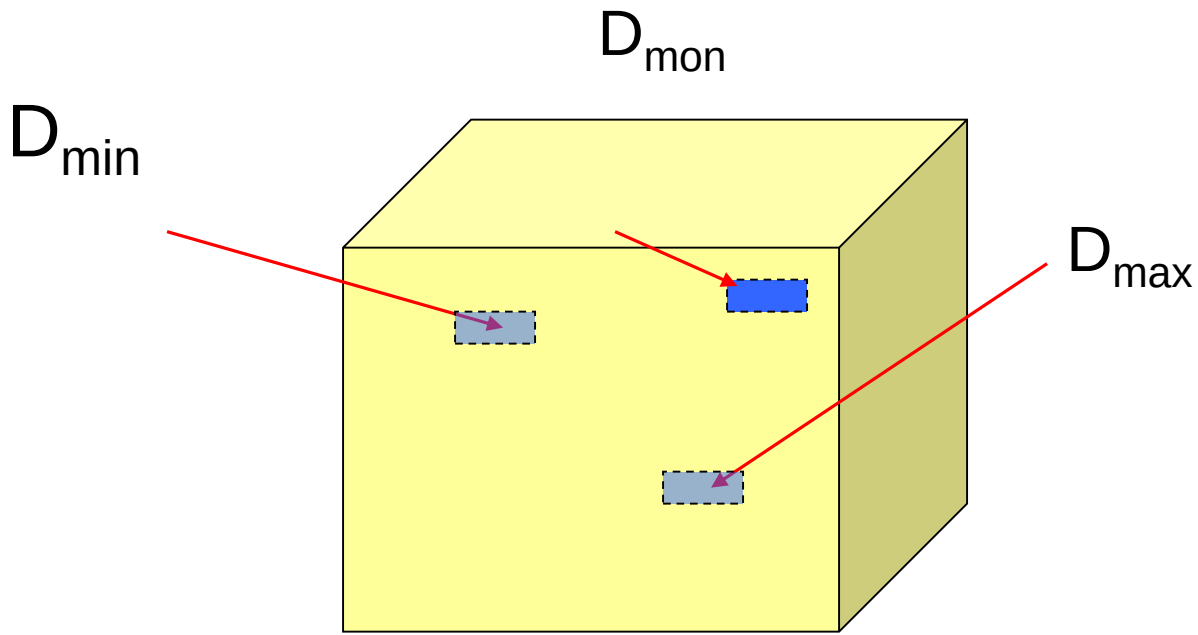
Cold Spots – High Dose Region

Variation between Runs: RSD

RSD <4% 4%<RSD <8%

RSD > 8%

Dose Mapping Summary



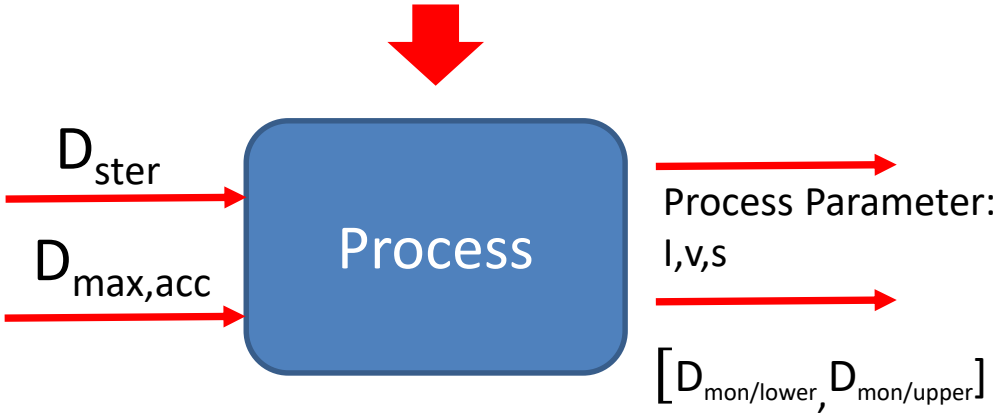
$$R_{min/mon} = D_{min}/D_{mon}$$
$$R_{max/mon} = D_{max}/D_{mon}$$

$$DUR = D_{max}/D_{min}$$

Designing the Process

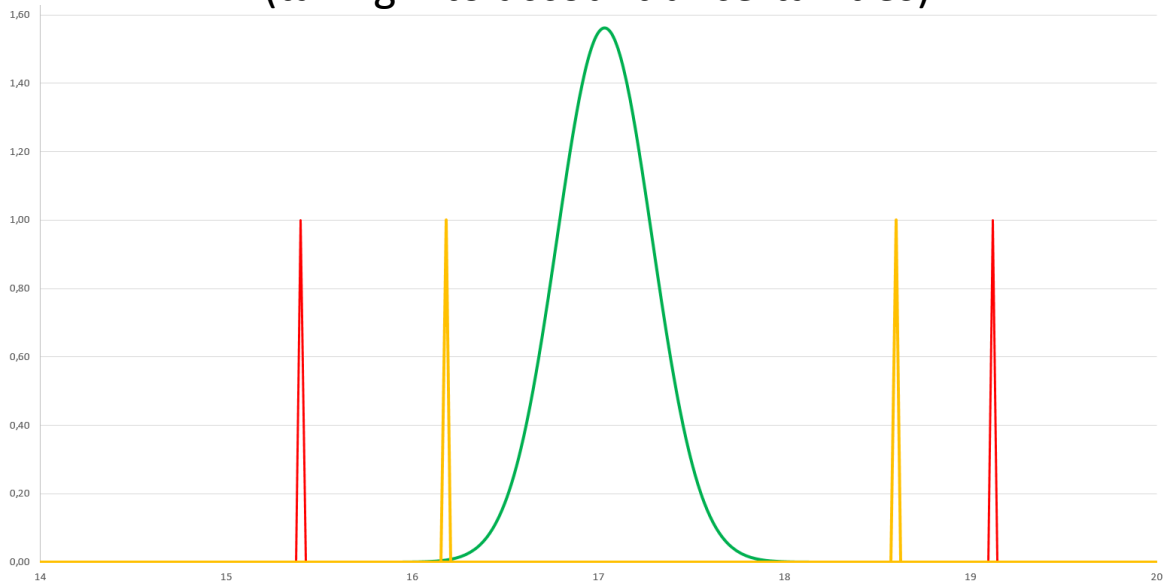
Customer Requirements	D_{ster} [kGy]	**25**
	$D_{max, acc}$ [kGy]	**40**

Uncertainties: Dose Mapping (R-factors), Machine, Dosimeter



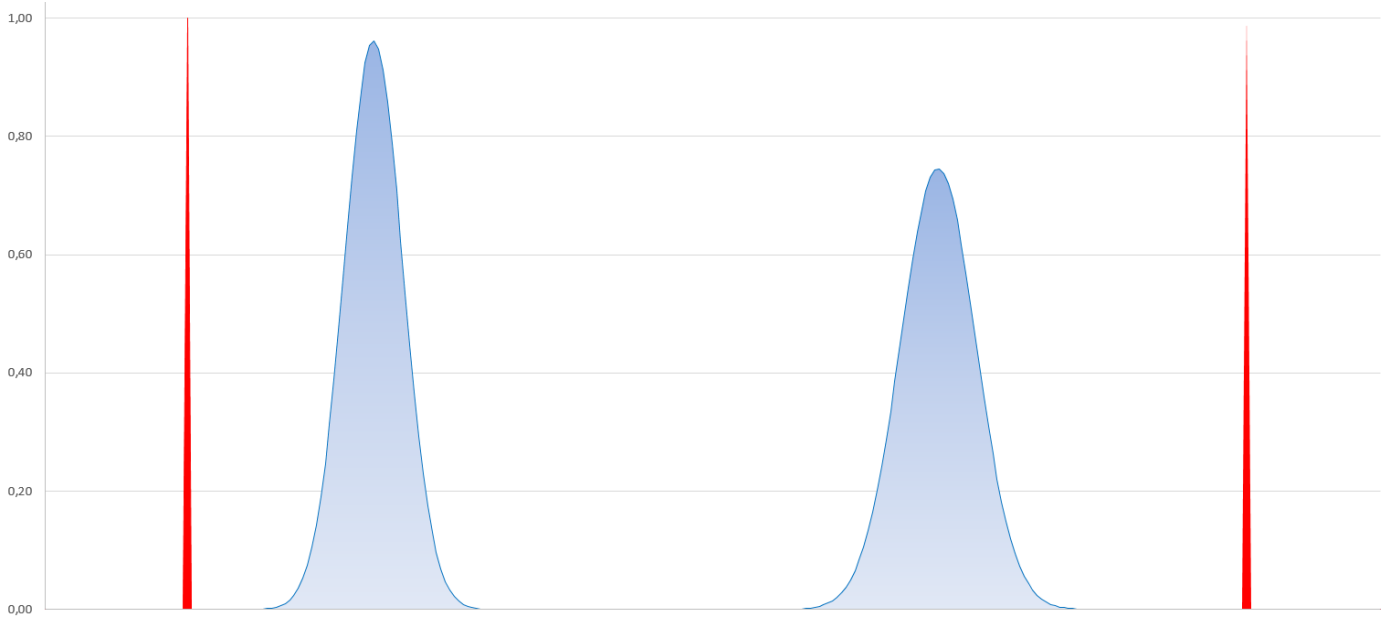
Setting Target Dose

(taking into account uncertainties)



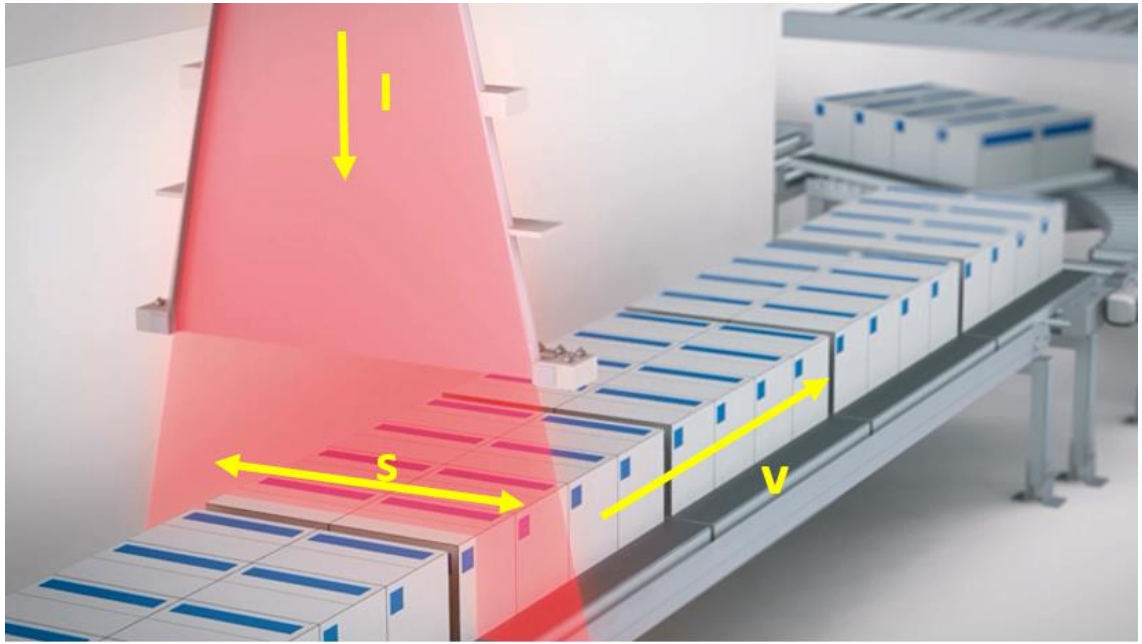
D_{mon}^{ster} 15.4 kGy D_{target}^{lower}=16.2kGy D_{target}^{upper}=18.6kGy $D_{mon}^{max,acc}$ 19.1 kGy

Product Doses



D_{ster}=25kGy D_{min}=27.7kGy D_{max}=35.6kGy $D_{max,acc}$=40kGy

Dose vs. Process Parameter

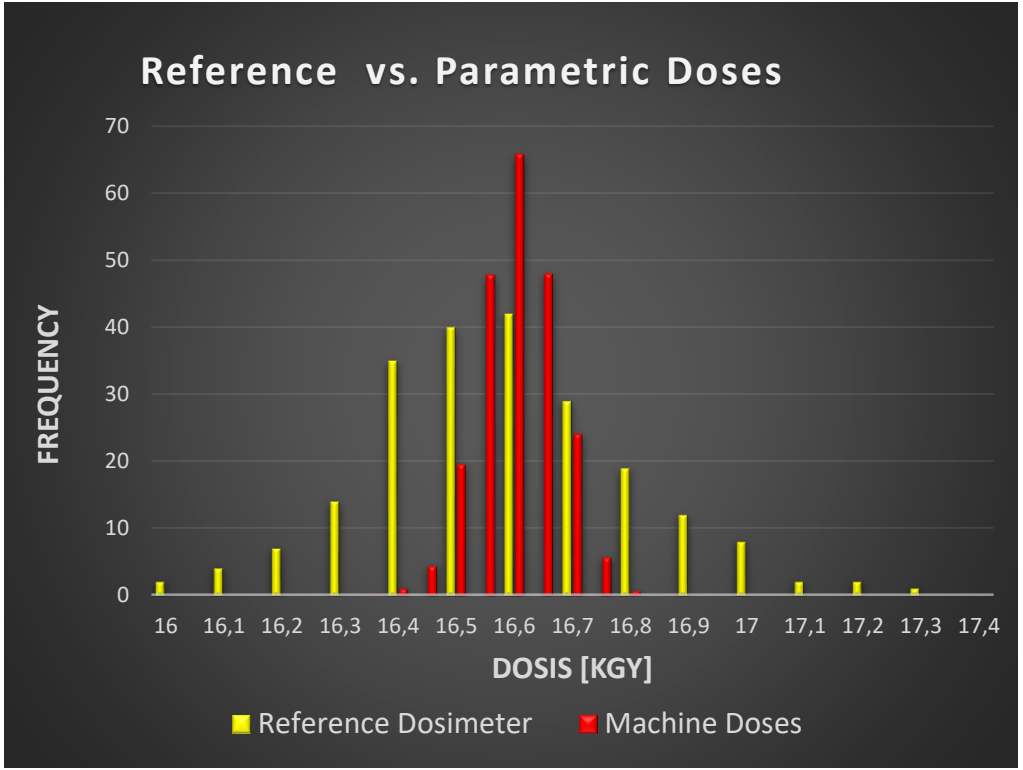


$$D = k.\frac{I}{v.s}$$

D Dose in kGy
I Beam Current
v Process Speed
s Scan Width

k= $D_e(0)*F$

Surface Dose – Beam Parameter Relationship



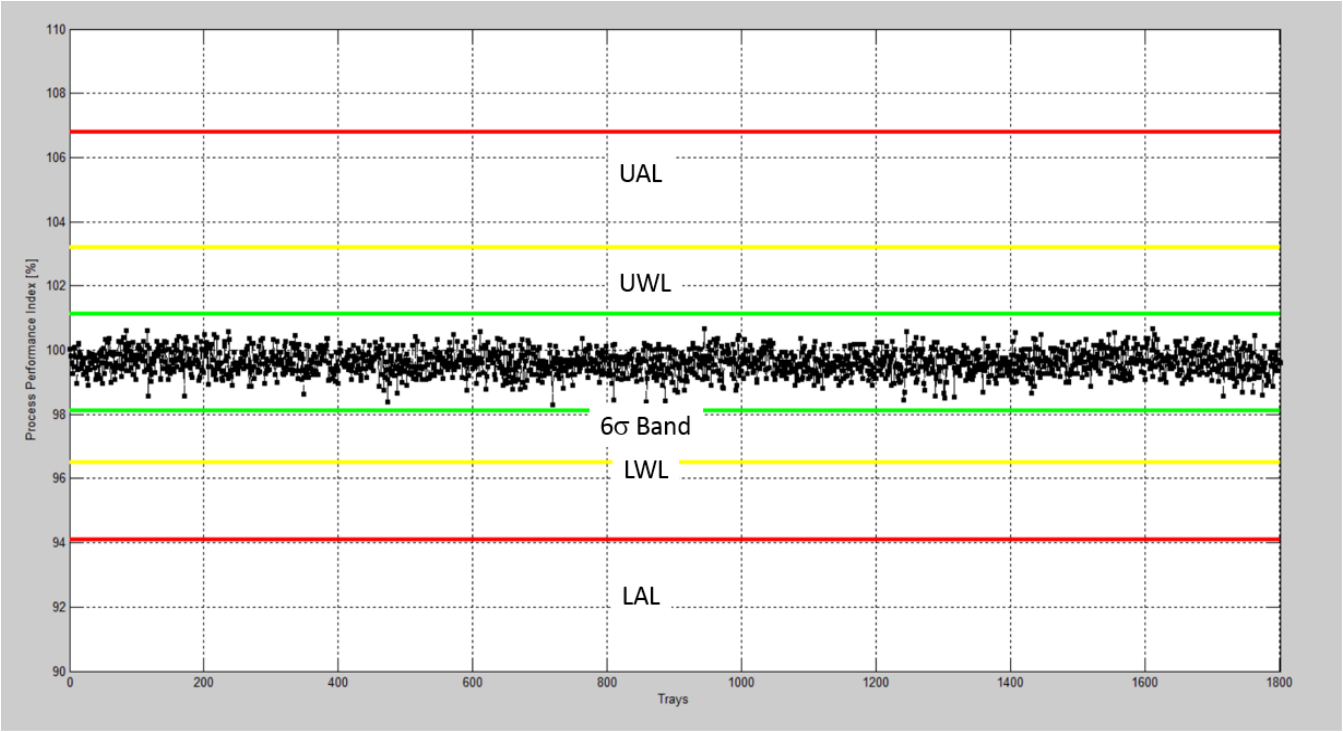
Reference Dose:

RSD ≈ 1.4 % (k=1)

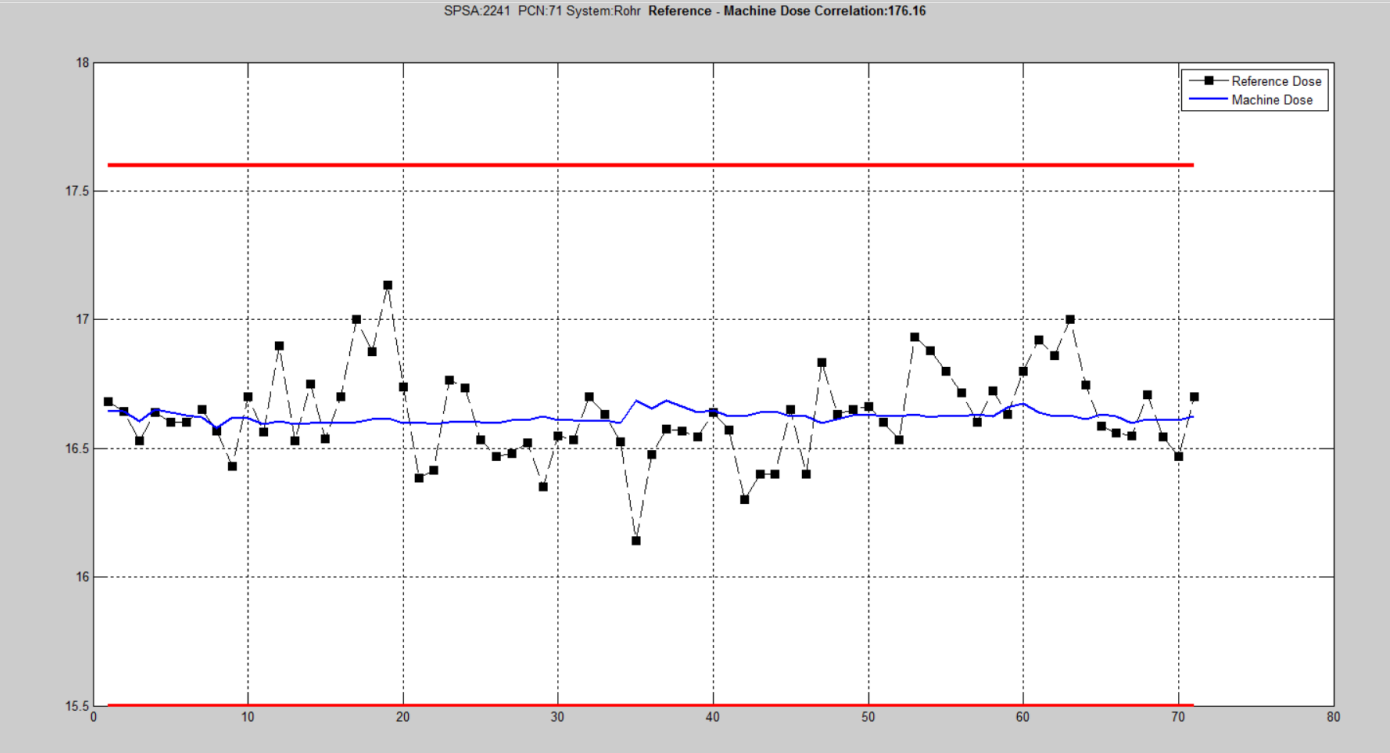
Parametric Dose:

RSD ≈ 0.5 % (k=1)

Product Batch Control Chart



Long Term Reference Dose Analysis



CONCLUSION

Dose Mapping is a core instrument to render a sterile product while sparing product from harm by preventing overdosing

A fine-tuned, robust method, state-of-the-art dosimeters and advanced modelling are vital in achieving this goal