Alanine EPR Dosimetry

CIRMS October 2010

Bruker BioSpin

Target Application: Dosimetry

Dosimetry...

... is the method to measure the irradiation dose of ionizing radiation (X-, γ-rays and accelerated electrons)

... is applied in process control (GMP) of irradiation facilities

... can be conducted with various methods, like

- TLD - Thermoluminescence Detection
- Fricke-Dosimeter ($Fe^{2+} \rightarrow Fe^{3+}$)
- Radiochromic Films/Photometry
- Alanine/EPR

Comparison of the Methods

Alanine/EPR

- ↗ Accuracy: 2-3%
- ↗ Fast Dose Determination
- ↗ Calibration over a large dose range
- ↗ One-Step Measurement
- ↗ Transfer Standard (ASTM classification)
- ➔ Dosimeter Costs: ca. 1$/piece
- ↗ Archiving of the Dosimeters

Overall Alanine/EPR Dosimetry is the superior method, if the running costs and the reducing in overdosing are taken into account

Radiochromic Film/Photometry

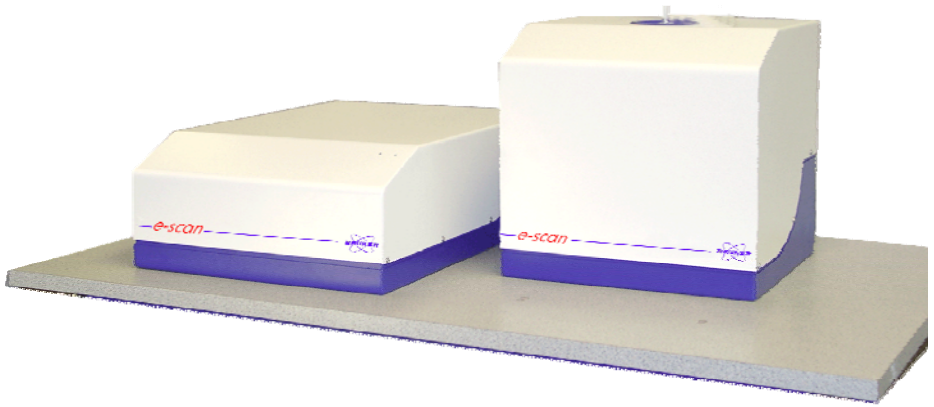
- ↘ Rather Inaccurate, depending on skill of operator. Roughtly 5-10%
  → ‘Overdosing’
- ↗ Very Fast Dose Determination
- ↘ Two-Step Procedure
- ↘ Result dependent on: dose-rate, temperature and light
- ↗ Attractive System Price: 5-10 k$
- ➔ Dosimeter Costs: ca. 1$/piece
- ↘ Archiving of Dosimeter impossible

EPR Spectrometer Series

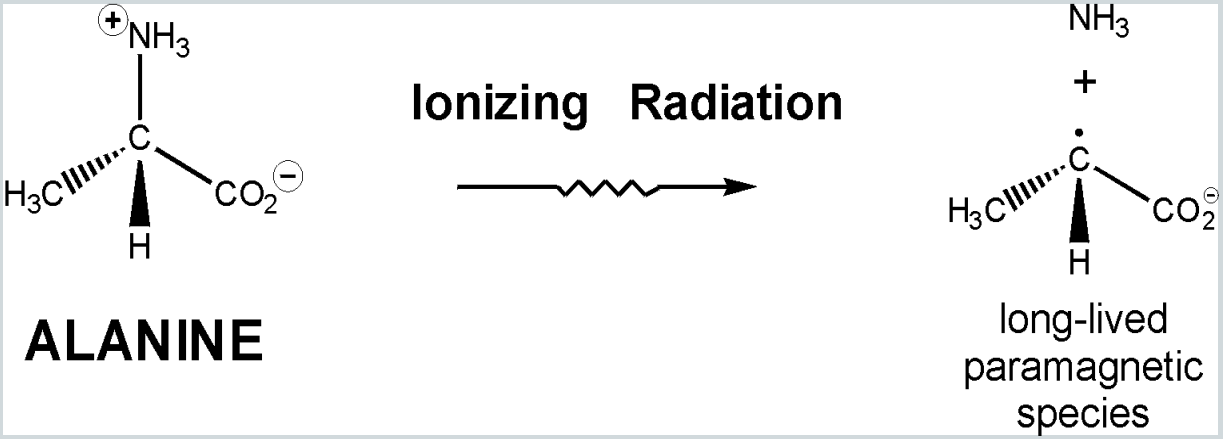
EMX

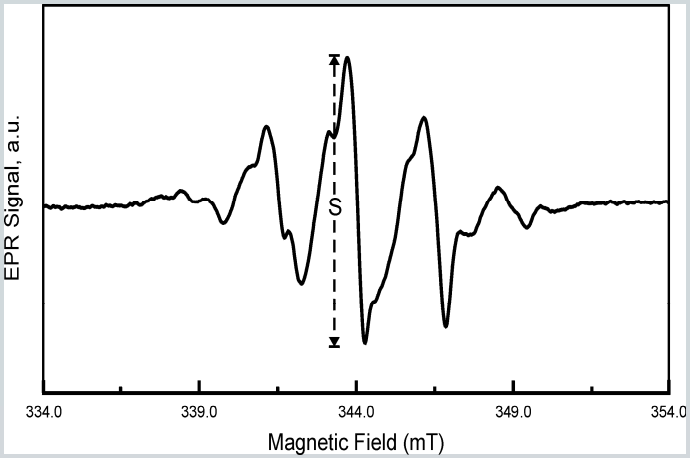
ELEXSYS

e-scan Alanine EPR Analyzer



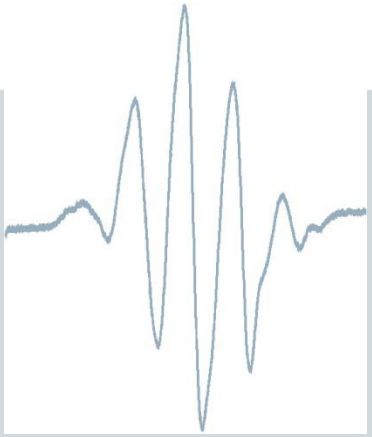
High Energy Ionizing Radiation Produces Free Radicals

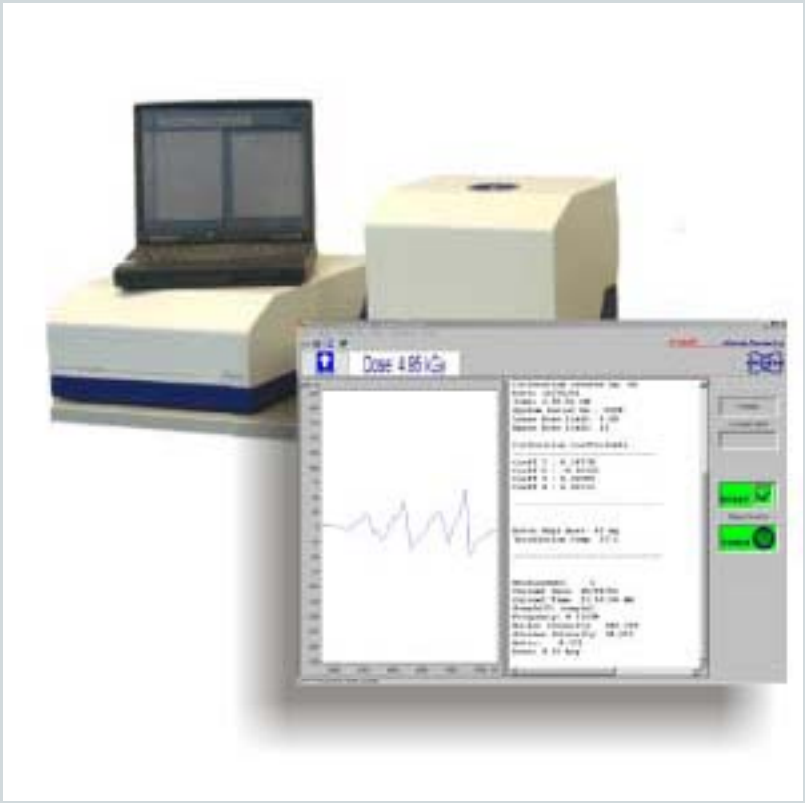


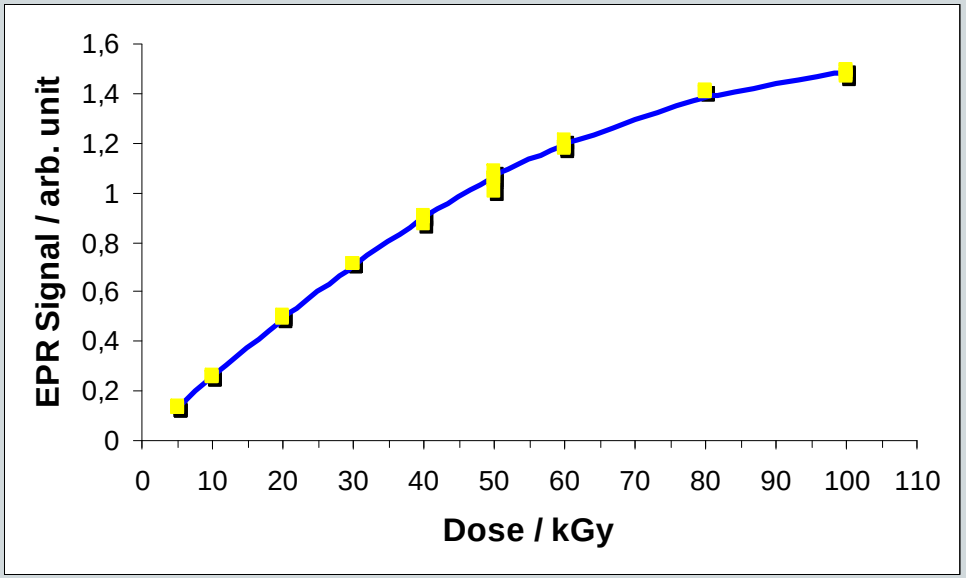


Alanine/EPR Dosimetry

EPR-Signal of irradiated Alanine





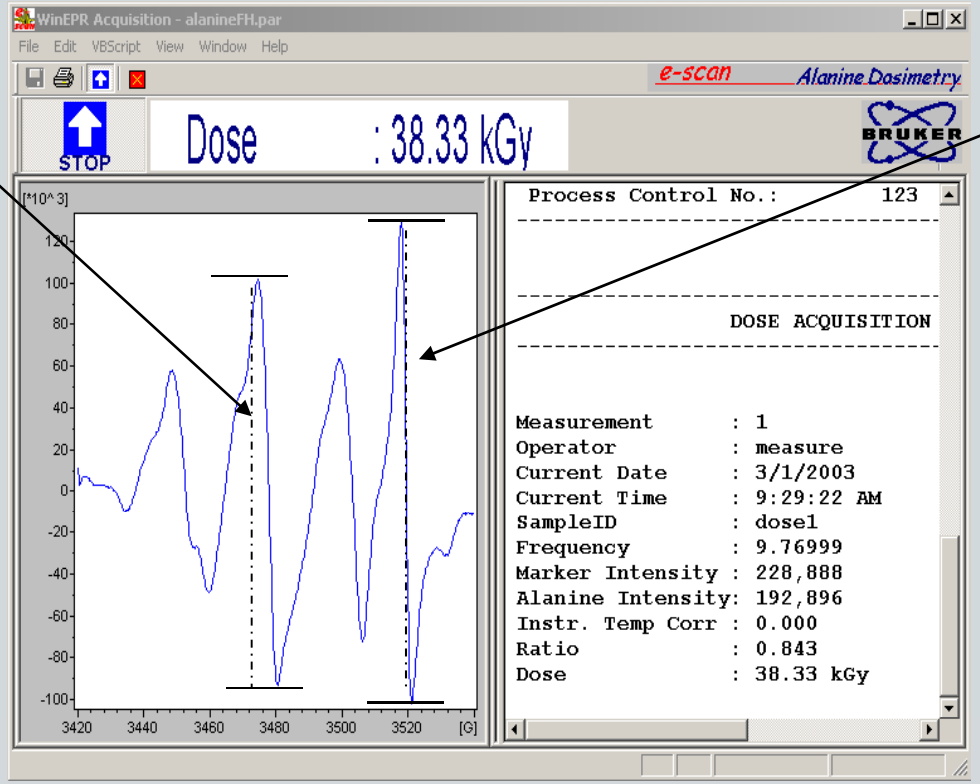


Dose Calibration Curve

EPR Internal Reference Method

The dose calculation is based on the ratio of the alanine EPR signal intensity to the EPR signal intensity from a permanently mounted reference marker.

Alanine signal

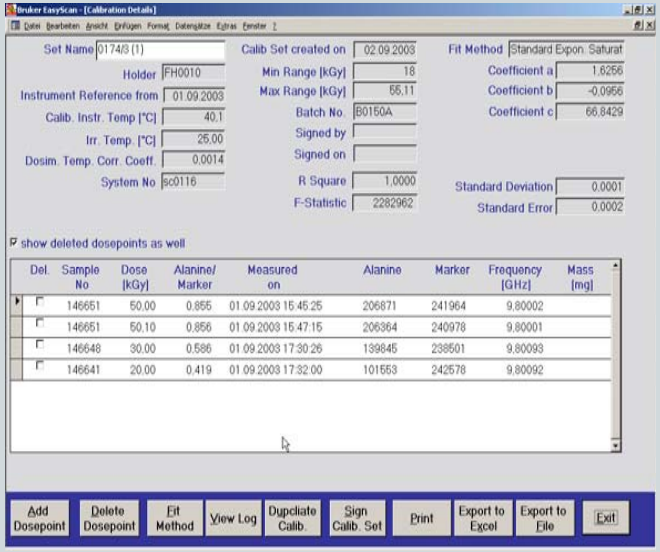


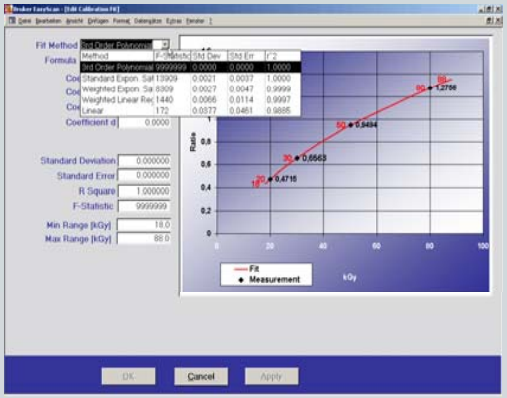
Reference Marker

e-scan Interface

Calibration Features

- ***One Display***
- ***All Information stored in Data Base***
- ***Electronic Signature of Calibration Data Sets***
- ***Export to Excel or File***



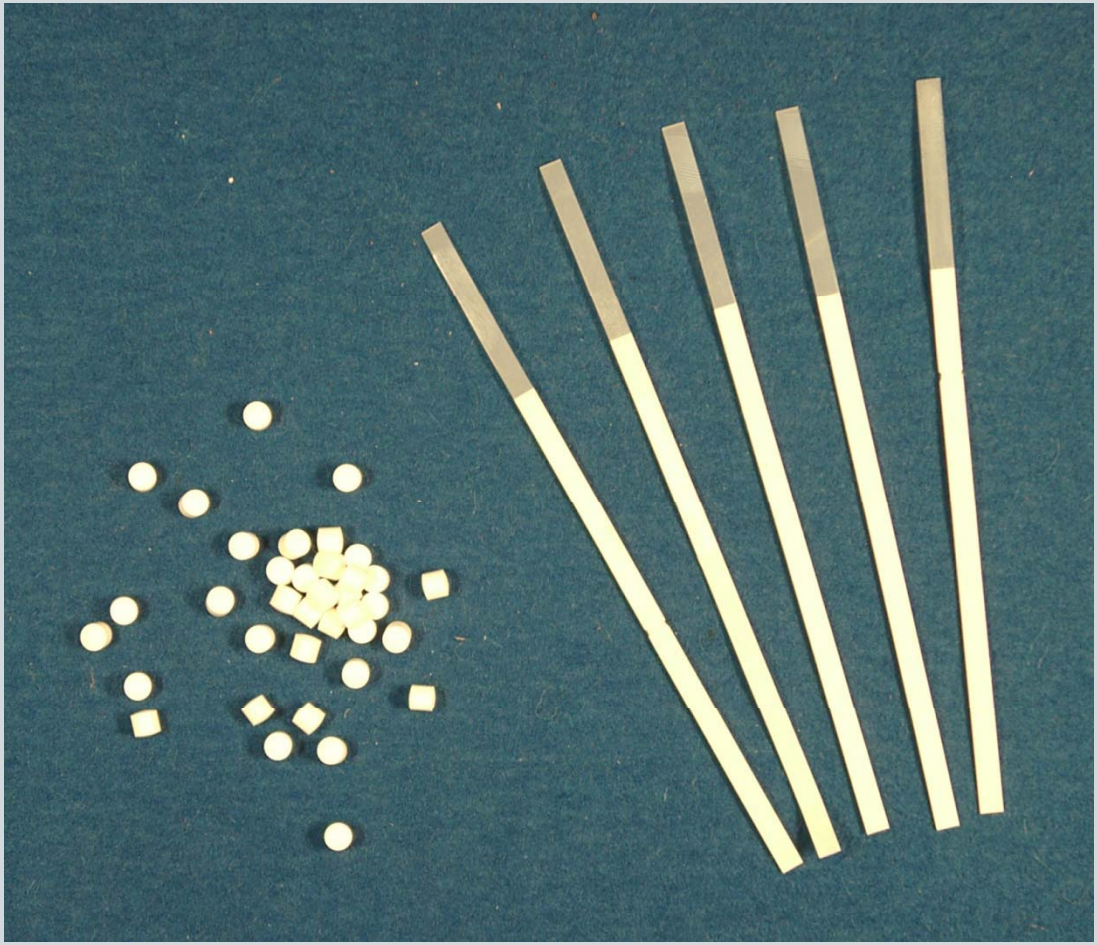


- ***Automatic Fitting of <u>ALL</u> Fitting Functions***
- ***Ranking according to F-Statistics***
- ***Graphical Display***

Alanine as a Dosimeter

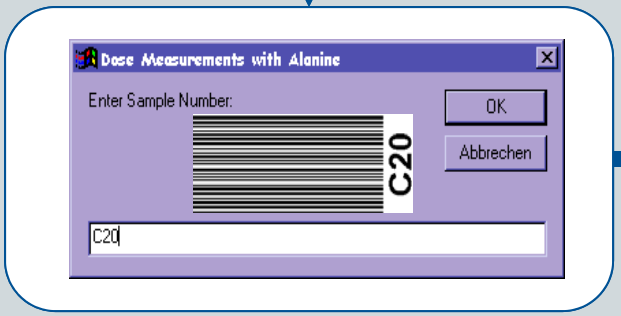
Alanine dosimeters are composed of alanine crystals dispersed in a polymer binder, these dosimeters are considered to be accurate, versatile and robust. Alanine dosimeters have long been used as a traceable transfer standard by National labs such as NIST.

Alanine Dosimeters



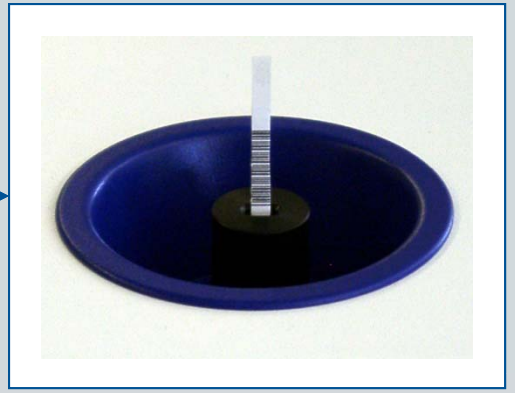
Dosimetry in 60 sec.

Start Measurement
Automatic Self-Test



Enter Dosimeter Code
or use Barcode Scanner

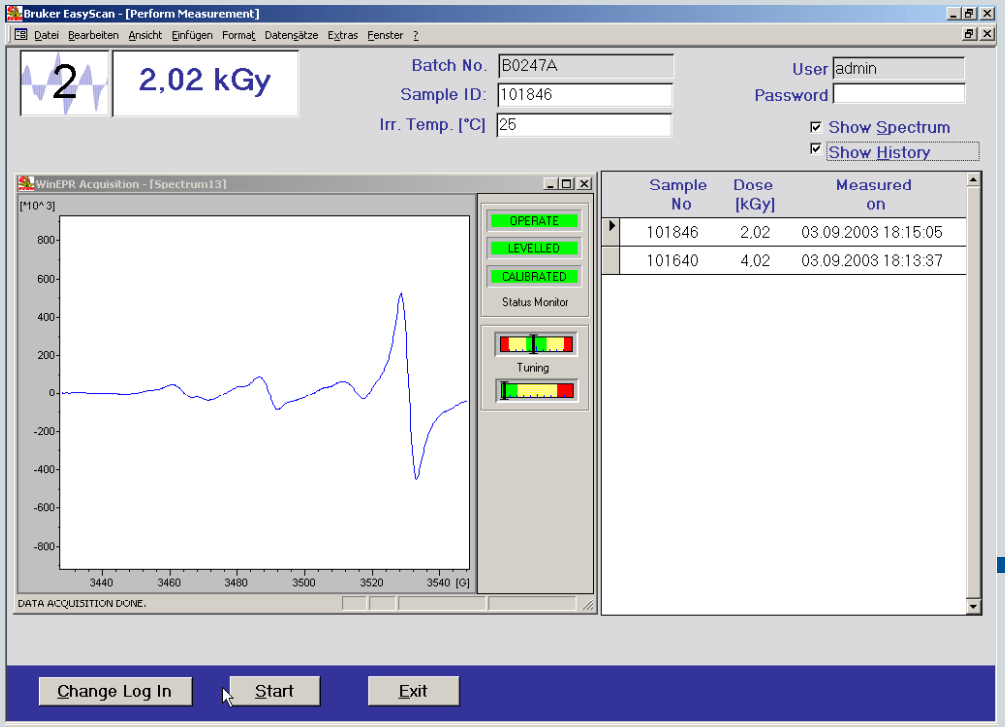
Insert Sample



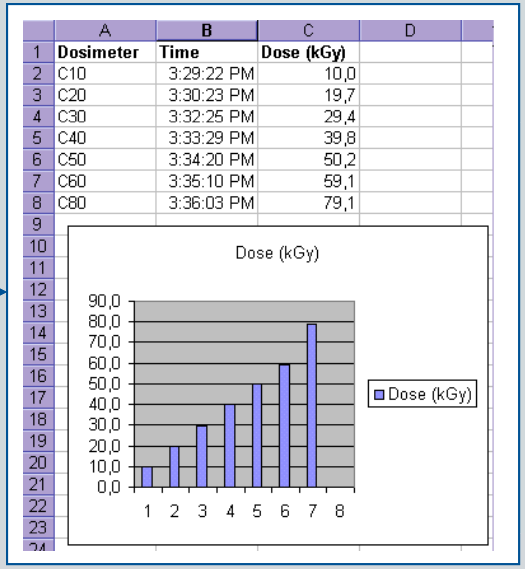
Rear view

Dosimetry in 60 sec. Part II

Result Display



Dosimeter is Measured Automatically



Automatic Transfer to MS Excel etc.

Key Features of the *e-scan*

Hardware

- Bench-Top Dosimeter Reader
- Embedded Barcode Reader
- Automatic Instrument Check
- Dose Determination with:
  - Alanine Films
  - Alanine Pellets (optional)
- Remote NIST-Calibration Service (optional)
- PC as Front-End

Software

- Application-oriented Data Acquisition
- Calibration Curve on Disk
- Automatic Dose Calculation
- Result Display
- Export to Spreadsheet or Data Bases
- Data Logging
- FDA 21CFR11 Compliant

Environmental Influences

- NIST preconditioning – irradiation

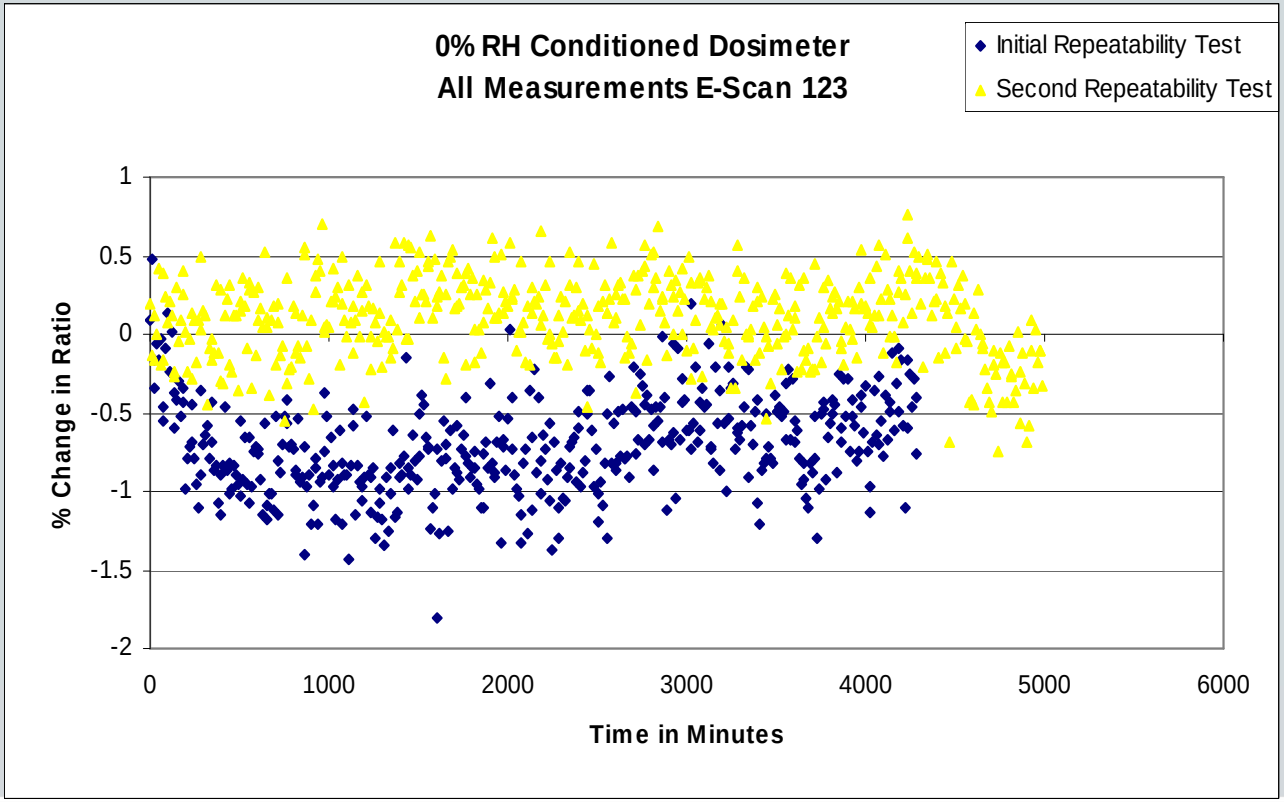
NIST National Institute of Standards and Technology

STERIS 20 kGy

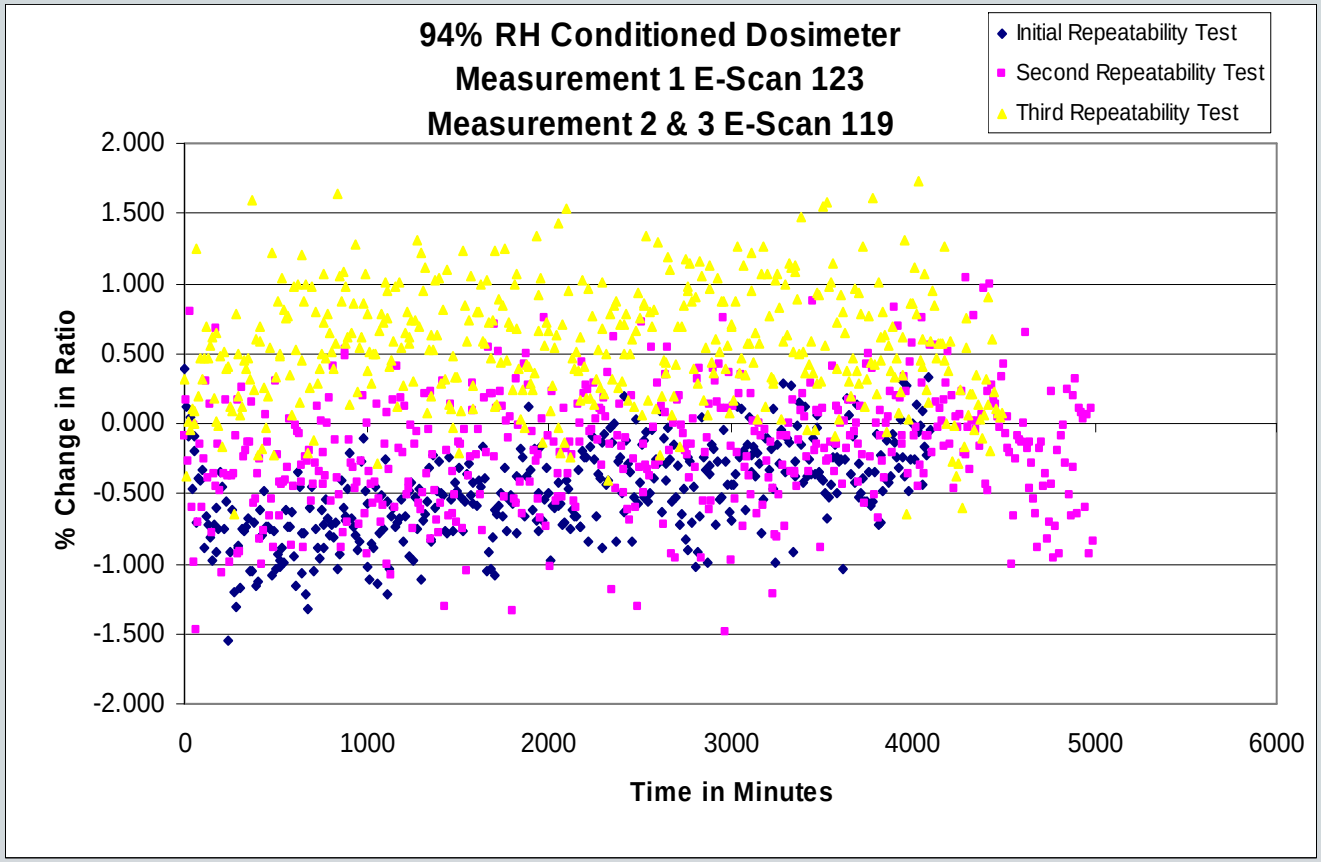
• 0% RH	NIST	Steris
• 33% RH	NIST	Steris
• 44% RH	NIST	
• 57% RH	NIST	
• 75% RH	NIST	Steris
• 94% RH	NIST	Steris

0% RH Alanine Film

All four RH-conditioned dosimeters irradiated at STERIS exhibited a change in alanine-to-marker signal ratio that ranged from –1.5% to +0.5% (See Figs. 1-4) relative to the dosimeter's final response value.

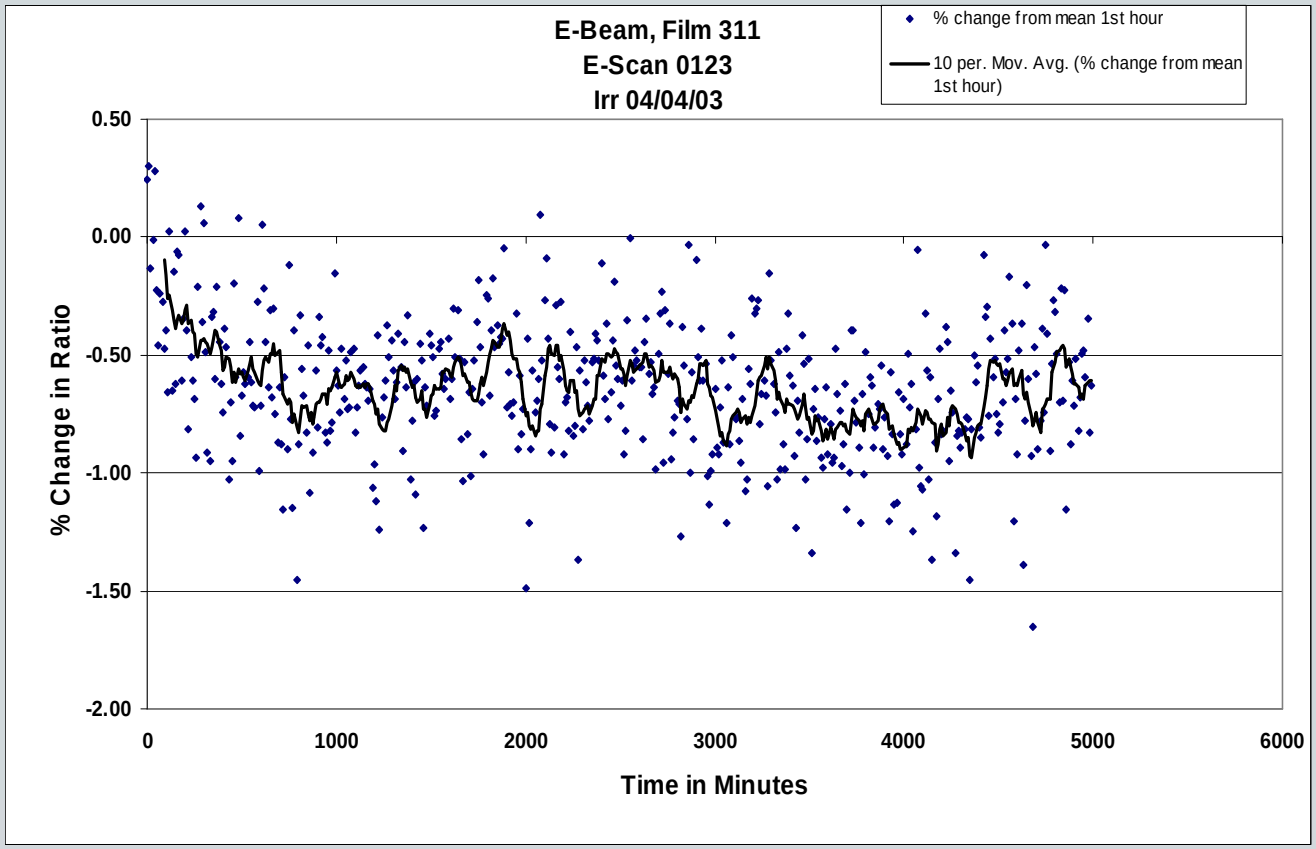


94% RH Alanine Film



Time Dependence

The electron-beam irradiated dosimeter experienced an overall change in response of 1.5% that ranged from -1.5 to 0.0% of the initial value.



Alanine Dose Measurement Uncertainty

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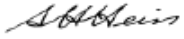
e-scan Uncertainties Worksheet

Uncertainties Worksheet - This table demonstrates the combined uncertainty of the e-scan alanine dosimeter reader system.
Each irradiation facility should use this worksheet in addition to other individual plant determined uncertainties to determine an overall combined dose uncertainty following the guidance of the ISO/ASTM 51707:2002 and NIST Technical Note 1297 (1994) .

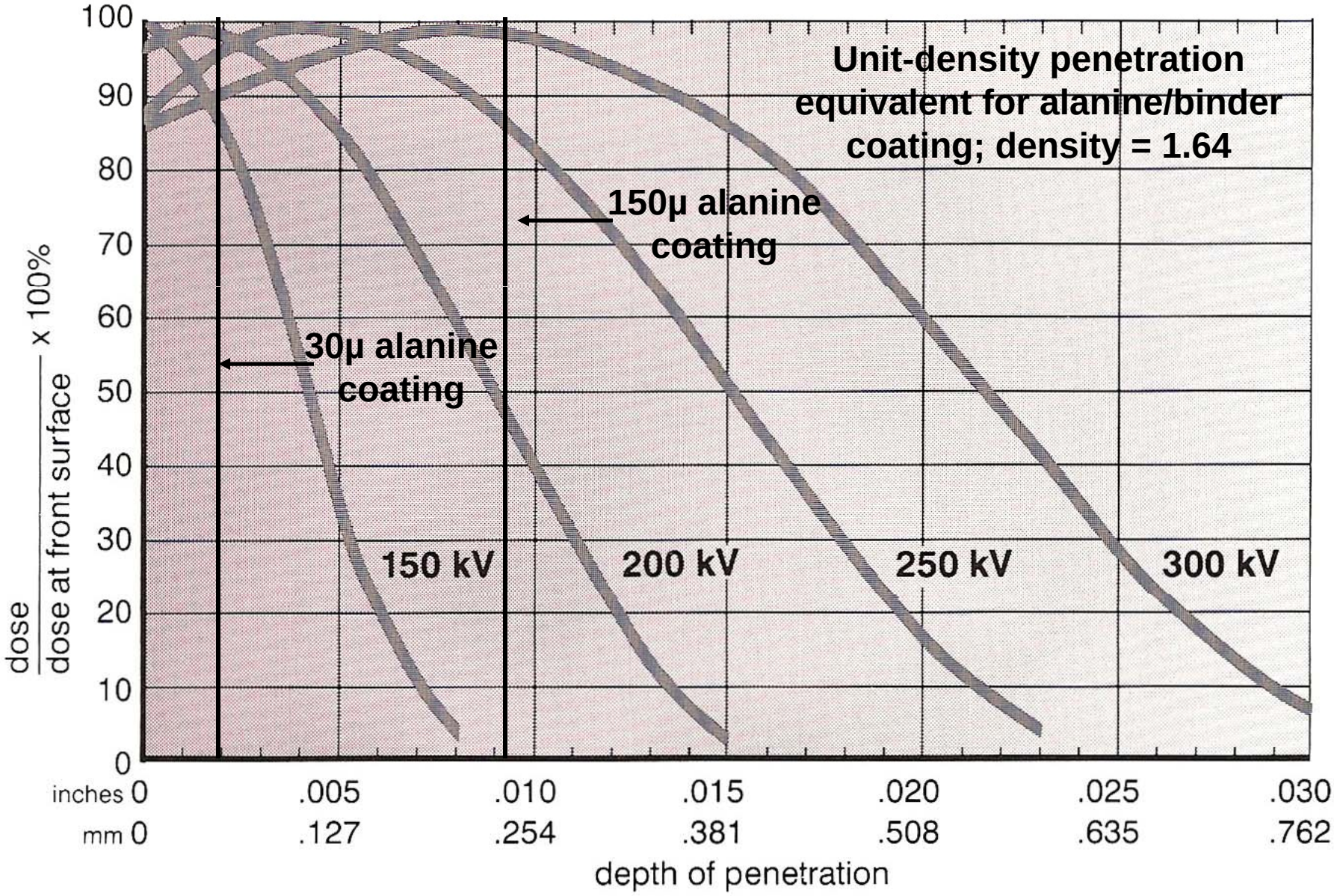
Dosimeter Holder Type FH

		LOW		MID		HIGH	
		Type A (%)	Type B (%)	Type A (%)	Type B (%)	Type A (%)	Type B (%)
NIST calibration		0.38%	0.86%	0.38%	0.86%	0.38%	0.86%
Response variation	low	1.54%					
	mid			1.08%			
	high					1.18%	
Mass Variation (film, Mfg. tolerance)		0.000%		0.000%		0.000%	
Repeatability	low	1.31%					
	mid			0.23%			
	high					0.29%	
Calibration Curve error		0.28%		0.28%		0.28%	
Contamination (flaking, chipping, dust, etc.)			0.001%		0.001%		0.001%
Marker Correction			0.05%		0.05%		0.05%
System drift			0.10%		0.10%		0.10%
Temperature Coefficient			0.10%		0.10%		0.10%
Dose rate			0.10%		0.10%		0.10%
Energy dependence			0.10%		0.10%		0.10%
Combined Type A or B		2.08%	0.88%	1.20%	0.88%	1.30%	0.88%
Combined type A and B (in quadrature)			**2.26%**		**1.49%**		**1.58%**
T-Factor [Degrees of Freedom = (n-1) = 40]			2.06		2.06		2.06
Expanded Combined Uncertainty			**4.65%**		**3.07%**		**3.25%**

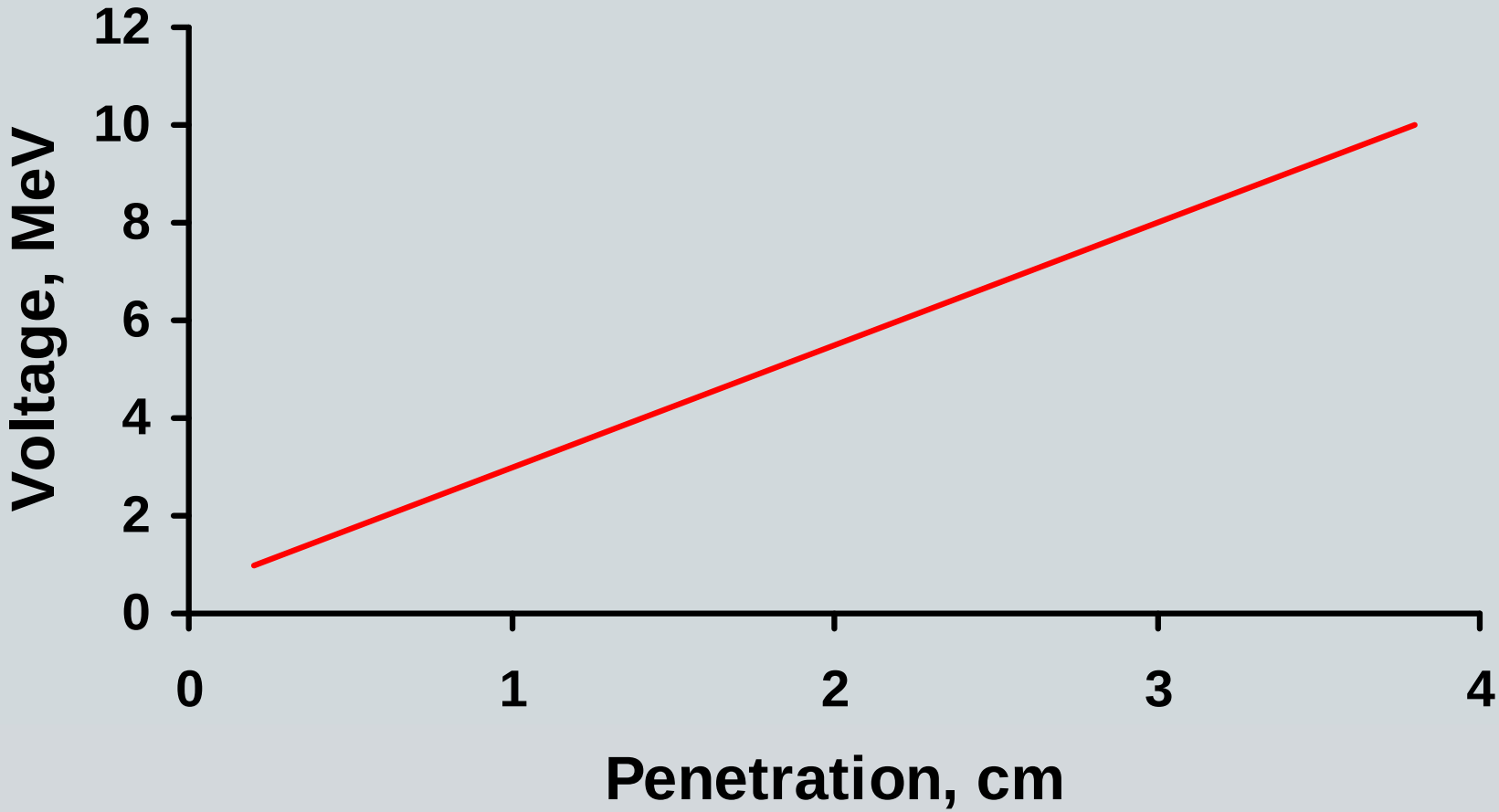
Sheet 3-5-7: Response Variation	Measure 41 dosimeters from the middle range of the dosimeter holder. Enter the RSD in the green field above.
Sheet 4-6-8: Repeatability	Measure the same dosimeter 41 times. Enter the RSD of these measurements in the blue field above.
Sheet 2: Calibration	Enter the % Calibration error from the calibration curve used to measure dosimeters in the yellow field above
	Type B uncertainties of the e-scan alanine dosimetry reader system as designated by NIST

Approved by:  Date: 2/14/2005

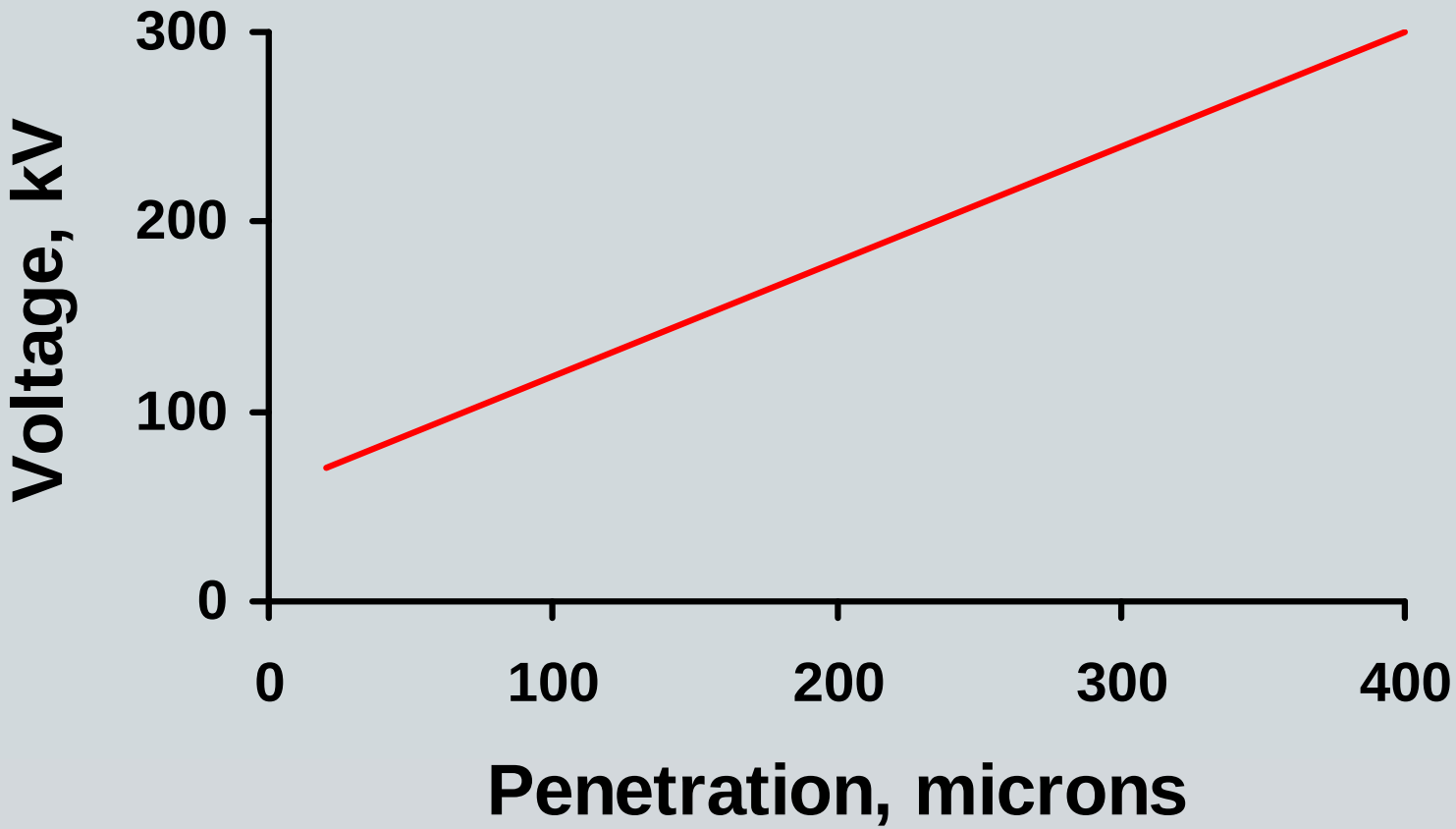
Low-voltage EB Penetration into Alanine Coatings



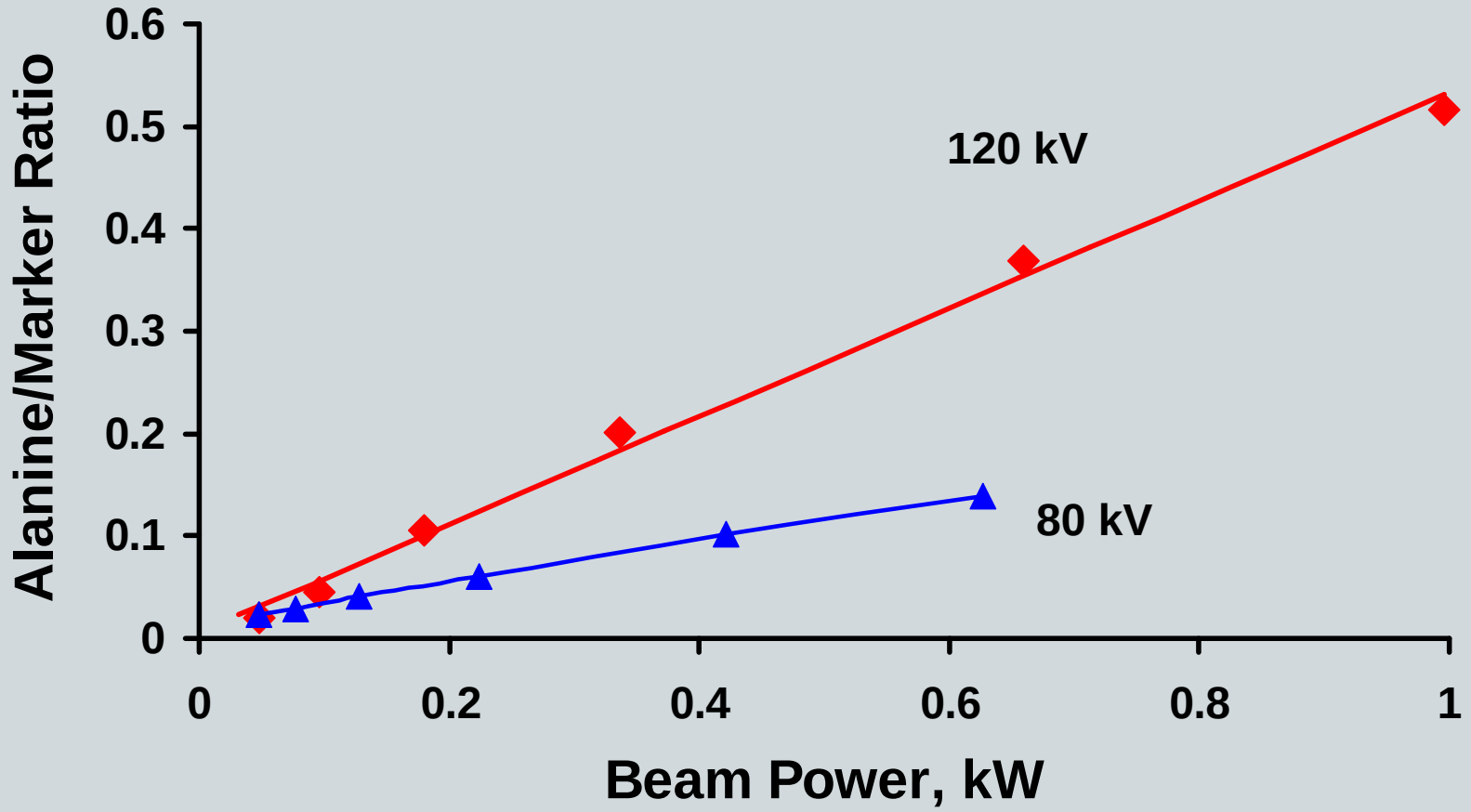
Electron Beam Penetration



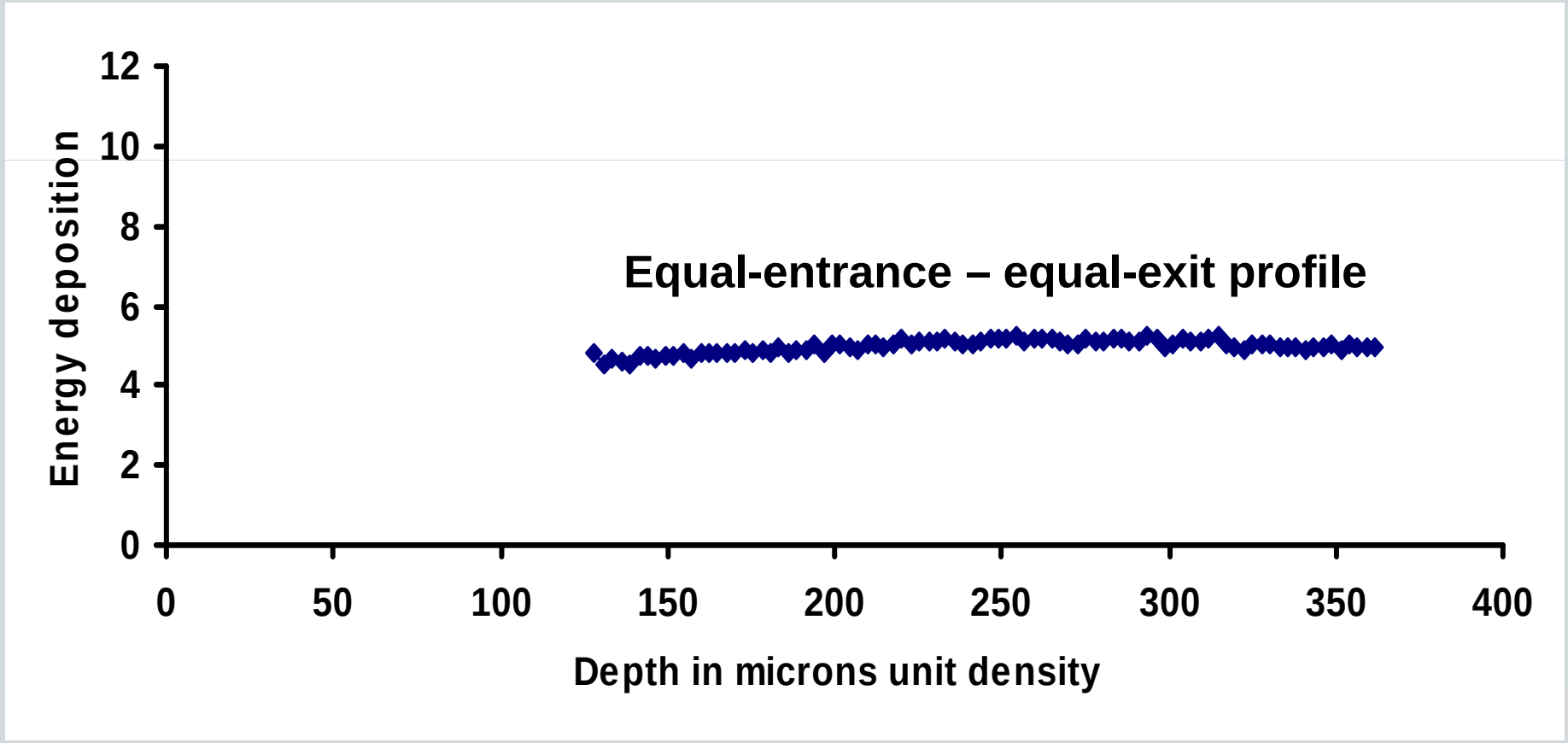
Low-voltage EB Penetration



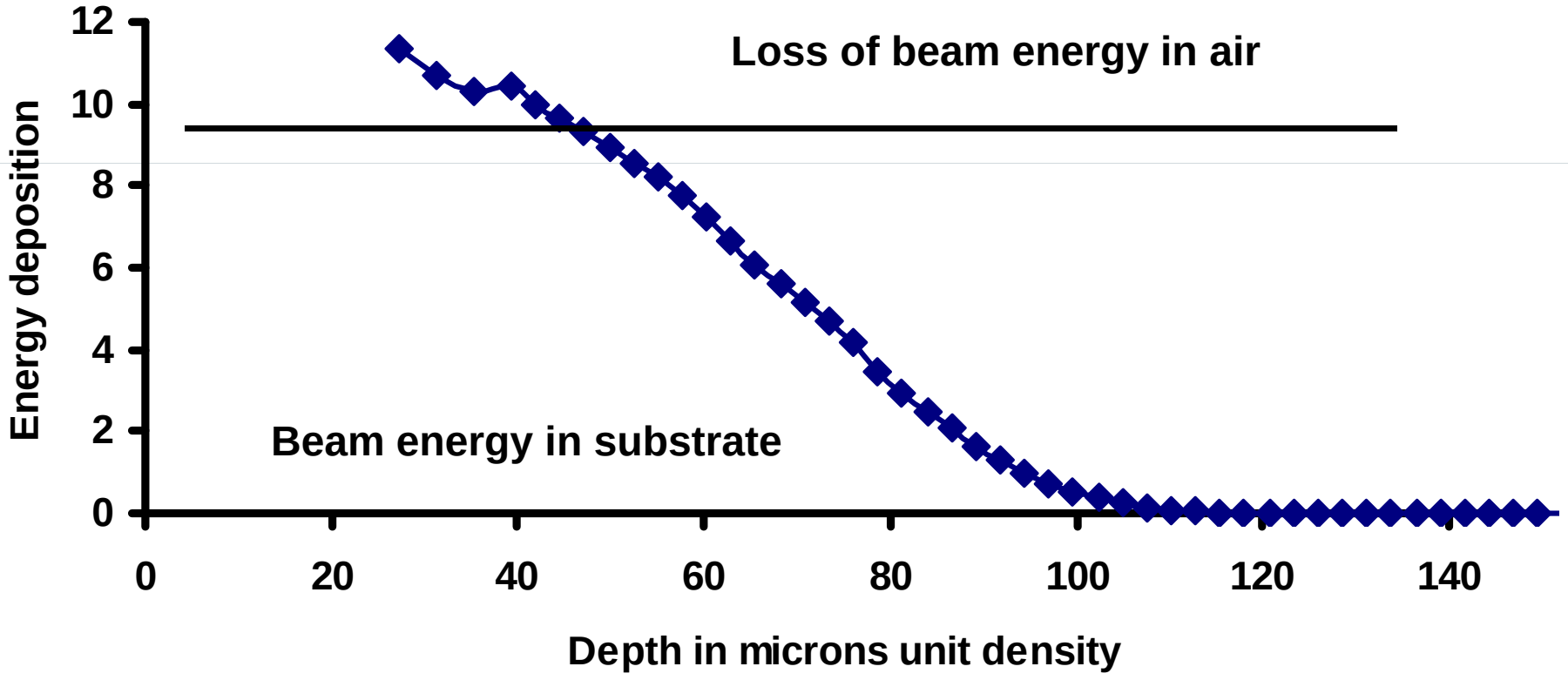
150µ Alanine Coated Dosimeter
Low-voltage Laboratory EB Response



300kV 15µ Ti window
5cm air gap; 144µ alanine coating



80kV 6µ Ti window
1cm air gap



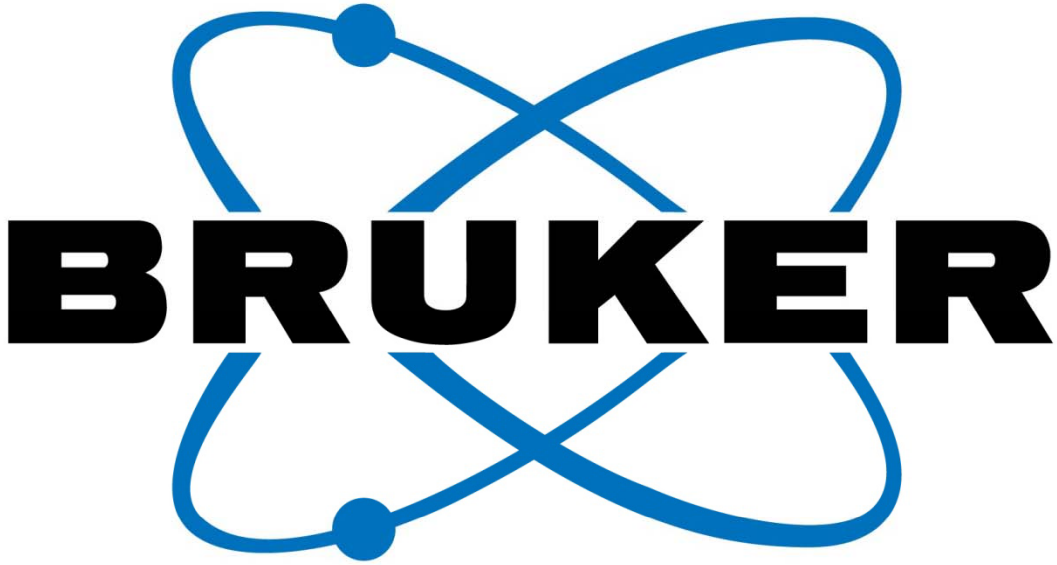
Summary – Bruker Dosimety Solutions

- Bruker EMX and ELEXSYS Systems provide <1Gy measurements
- Bruker e-scan Alanine Dosimetry provides reference dosimeter accuracy with routine dosimeter convenience, 21CFR11 compliance and LIMS interconnectivity
- Increased accuracy can offset higher instrumentation cost
- Bar-coded film dosimeters available from Bruker
- Two sources of pellet dosimeters (Harwell – GammaService/Far West)
- Ideal for gamma and medium to high energy electron beam irradiators
- Can be used for low-energy electron beam with Monte Carlo assist … *but* …
- Bruker Polyethylene FT-IR Dosimetry offers the low-energy solution

Acknowledgements

- Marc Desrosiers – NIST
- Marsh Cleland – IBA-RDI
- Tony Berejka – Ionicorp+
- Deepak Patil - Steris

- Andreas Kamlowski
- Diether Maier
- David Barr



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