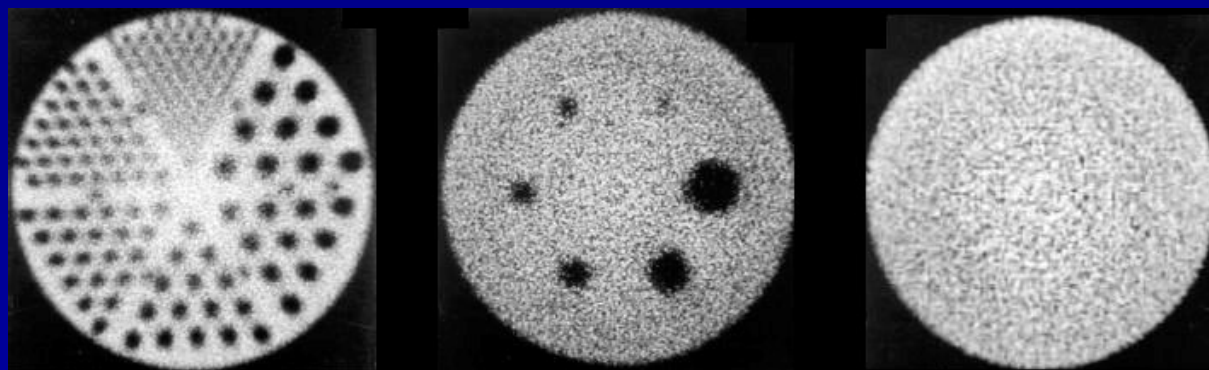




SPECT QA and QC

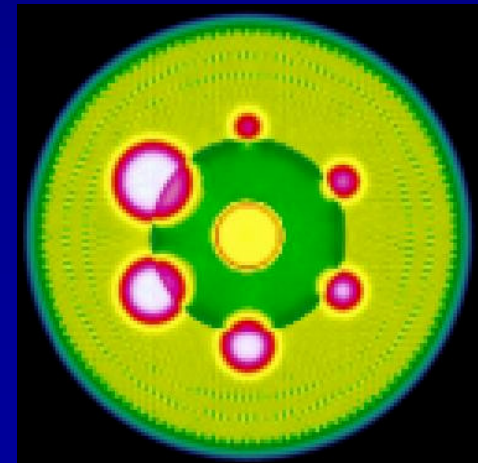
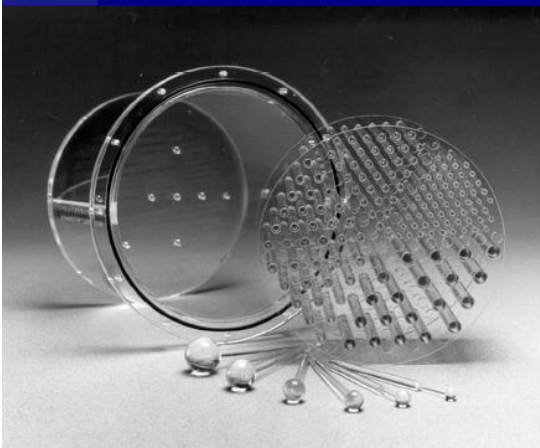
Bruce McBride
St. Vincent's Hospital
Sydney.





SPECT QA and QC

- What is needed?
- Why?
- How often?
- Who says?





QA and QC in Nuclear Medicine

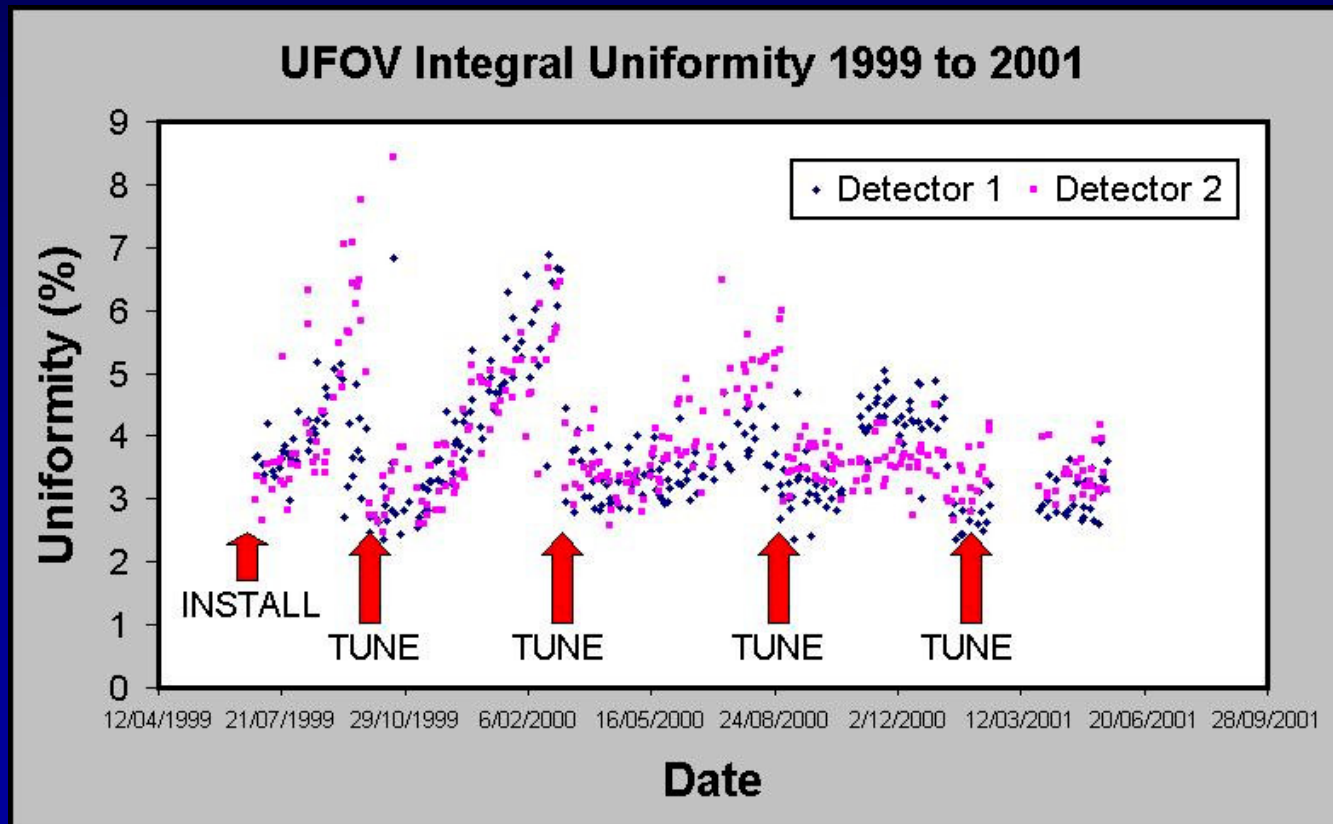
- **QA - collective term for “all the efforts made to produce a quality result”.**
- **QC - a specific test ensuring one particular aspect of a procedure is satisfactory.**

*IAEA-TECDOC-602 Quality Control of
Nuclear Medicine Instruments 1991*



Routine QC tests

- Focus is on detecting changes in performance from a baseline condition - **MUST** keep records!



Performance characteristics



Planar

Energy Resolution
Field Uniformity
Spatial Distortion
Differential ADC uniformity
Integral ADC uniformity
Spatial Resolution
Count rate response

SPECT

Slice thickness
Tomographic Contrast
Tomographic Uniformity
Tomographic Resolution
Linearity of Tomographic response
Quantitative accuracy
Precision of estimation of the centre of rotation
Sensitivity - slice and volume.



SPECT QA Program

- **Comprehensive set of tests collectively sensitive enough to detect changes in performance.**
- **However, criteria for judging individual tests shouldn't be so strict as to identify insignificant changes as important.**



SPECT QA Program

- **Emphasise measures of stability.**
- **Realistically reflect clinical suitability of a system.**

Table of Sensitivity for Failure Detection

	Daily 5M count flood	Peak Spectrum	Cine review of projection data	Sinogram Review	4 Quadrant resolution phantom	Centre Of Rotation	High count Intrinsic uniformity	SPECT Phantom	Background check	Head tilt check	Reconstructed point source	Reconstructed uniformity
Collimator damage	0	-	-	-	-	-	-	0	-	-	-	+
PM Tube drift	+	-	-	-	+	-	+	0	-	-	-	+
Energy peak drift	0	+	-	-	-	-	+	0	-	-	-	+
Electronic Offsets drift	0	0	*	-	0	+	0	+	-	-	+	-
Mechanical COR change	-	-	0	+	-	+	-	+	-	+	+	-
Electronic noise	-	0	-	-	+	-	-	+	0	-	+	0
Crystal or light coupling problem	0	0	-	-	+	-	+	0	-	-	-	+
Contamination	0	0	-	0	-	-	+	-	+	-	-	+
Magnetic fields	0	0	0	0	-	-	0	+	-	-	+	+
Power Fluctuations	0	0	-	-	0	-	0	0	-	-	0	+
Background	-	0	+	0	-	-	+	-	+	-	-	-
Temperature Fluctuations	+	0	-	-	-	-	+	0	-	-	-	+
Variation with angle of rotation	-	-	+	+	-	+	-	+	-	-	0	+

Modified: Hines H, Kayayan R, Colsher J, Hashimoto D, Shubert R, Fernando J, et al.

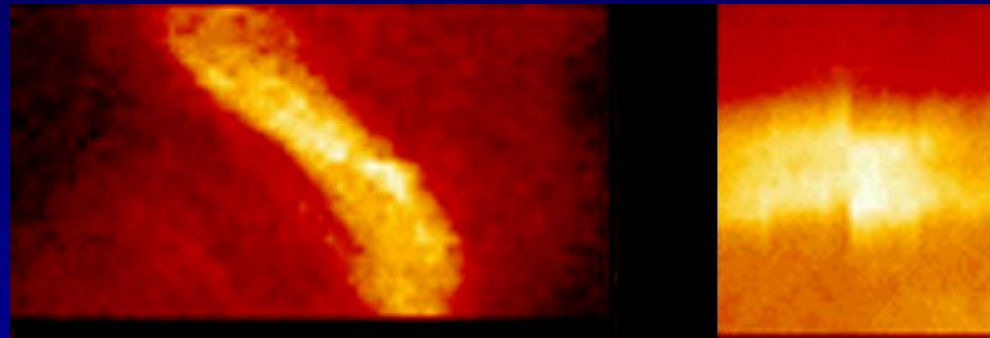
Recommendations for implementing SPECT instrumentation quality control.

JNM 2000; 41(2):383-389



“Good practice” tests.

- Visual check of energy spectrum.
- Cine / Sinogram / Linogram review



Sinogram

Linogram

- Background activity check.

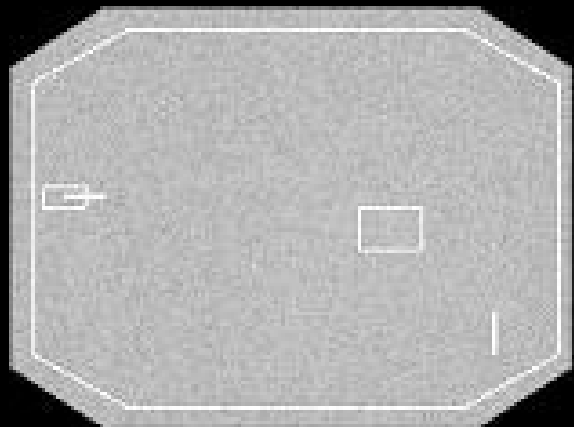


Daily tests

■ Low count flood

- ◆ Tc99m intrinsic or extrinsic / or Co57 extrinsic
- ◆ Integral and differential uniformity
- ◆ 3-5 M counts

ADAC QC



Full Report of Uniformity Analysis

NAME: ADAC QC ID: EXT FLOOD

UFOV

Integral Uniformity =	2.71%
Counts	Location
Minimum 7191	{ 10, 29 }
Maximum 7592	{ 41, 32 }

Row Differential Uniformity =	1.58%
Column Differential Uniformity =	1.52%

	Diff.	Location
Max Row	231	{ 10, 29 }
Max Col	224	{ 51, 40 }

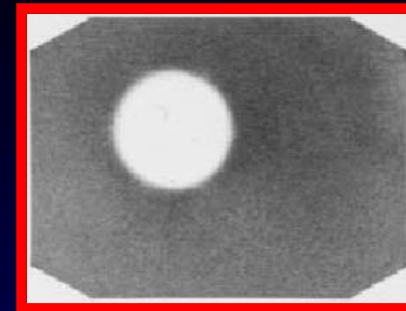
H1

Not only for SPECT!



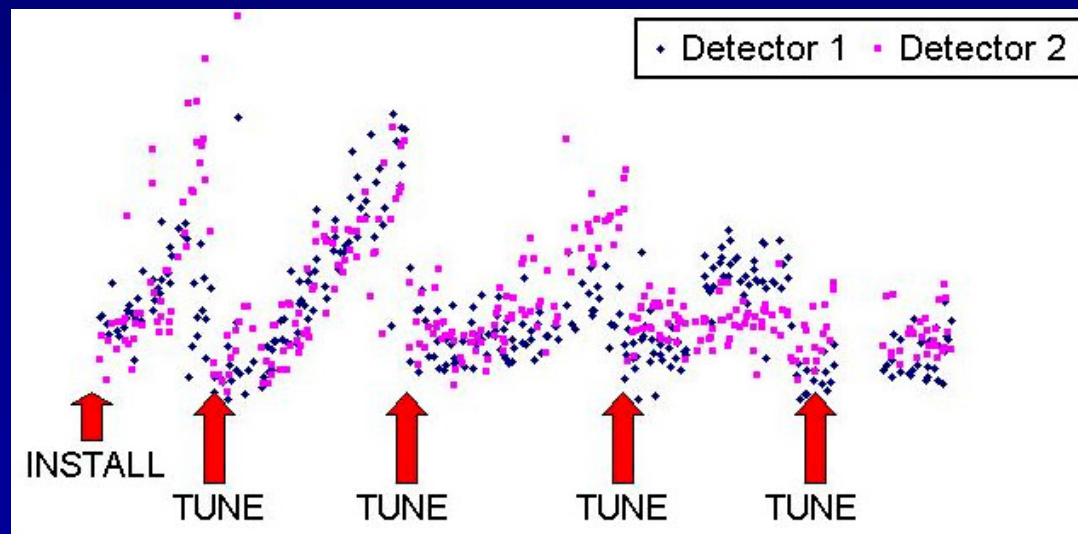
Daily tests

■ Low count flood



Date	Bg	Uniformity												Peak		Tech Initials	Comments
		Det 1 Integral		Det 1 Differential				Det 2 Integral		Det 2 Differential				Det 1 (keV)	Det 2 (keV)		
		UFOV %	CFOV %	UFOV %		CFOV %		UFOV %	CFOV %	UFOV %		CFOV %					
				Row	Col.	Row	Col.			Row	Col.	Row	Col.				
2/10/01	0.02	2.34	1.91	1.69	1.44	1.69	1.44	2.28	1.29	1.6	2.03	1.29	1.17	124	125	FC	
3/10/01	0.02	2.44	2	1.36	1.76	1.36	1.24	2.1	1.83	1.5	1.7	1.5	1.48	124	125	BS	
4/10/01		2.43	2.24	1.45	1.61	1.45	1.61	2.12	1.87	1.42	1.71	1.42	1.29			JK	
8/10/01	0.02	2.48	2.46	1.56	1.59	1.56	1.49	2.34	2.05	1.45	1.48	1.45	1.48	124	124	FC	
9/10/01	0.01	2.71	2.71	1.18	2.09	1.78	2.09	2.15	2	1.54	1.29	1.32	1.29	124	124	BS	The medium energy collimators
10/10/01	0.02	2.49	2.33	1.53	1.73	1.24	1.36	2.38	2.06	1.58	1.73	1.26	1.37	123	124	FC	
11/10/01	0.02	3.01	2.6	2.33	2.04	1.83	1.44	2.65	2.28	2.17	2.41	2.17	1.81	124	124	BS	Only up to 5000kcoun.

Integral Uniformity (%)



Time



Also check uniformity for:

- “Other” isotopes - recent evidence of uniformity
- Narrow Energy Windows (Tc99m)



20% window

15% Window

10% window

- Asymmetric Energy Windows (Co-57)



Peak - 10%

On Peak

Peak + 10%

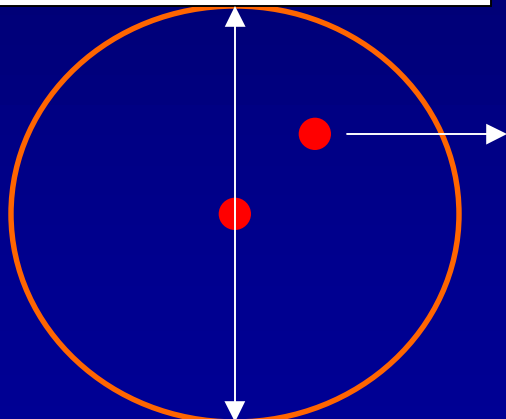


Weekly tests

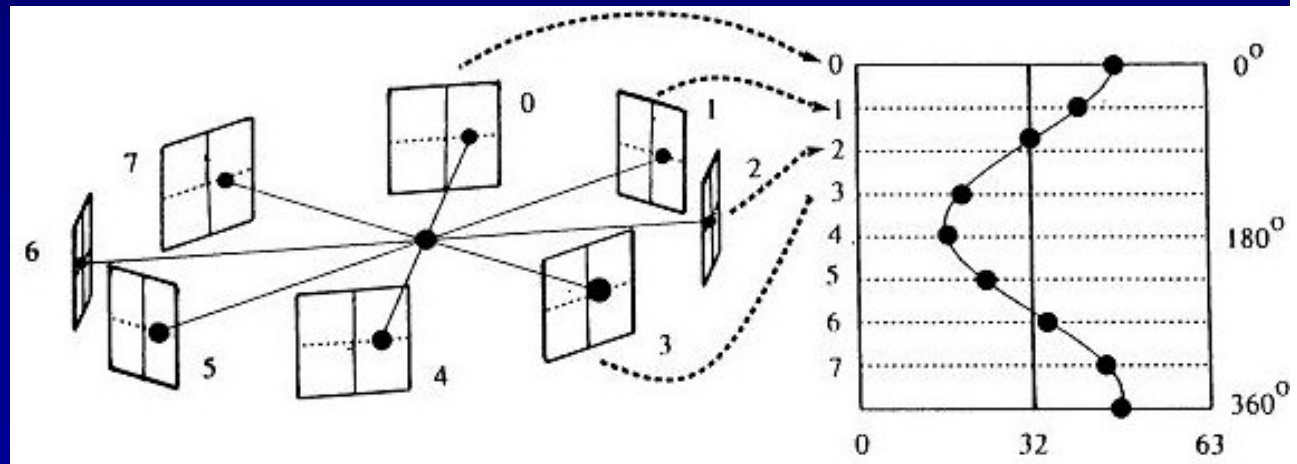
■ Centre of Rotation (COR)

- ◆ is the detector where the software thinks it is?

1 32.5 64



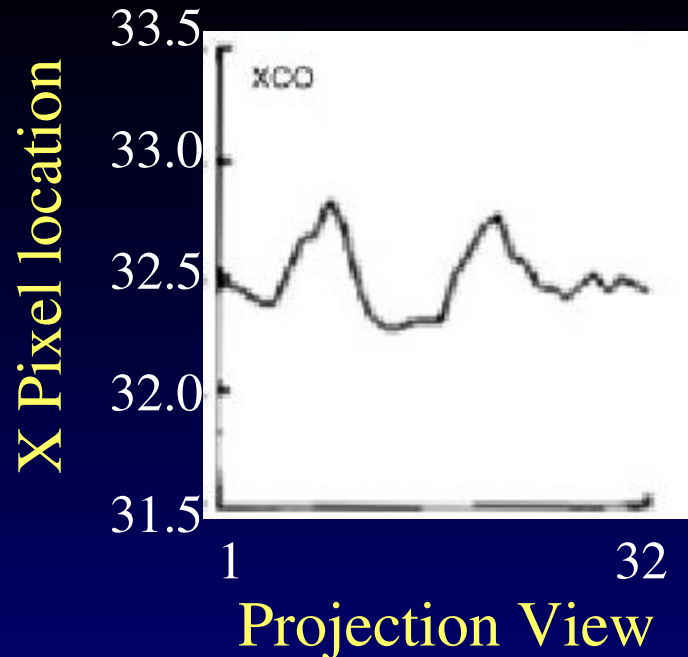
64 32.5 1



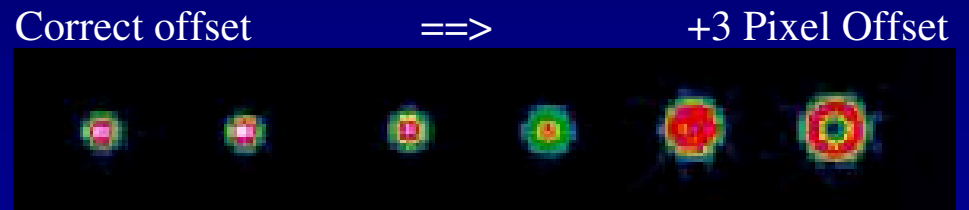
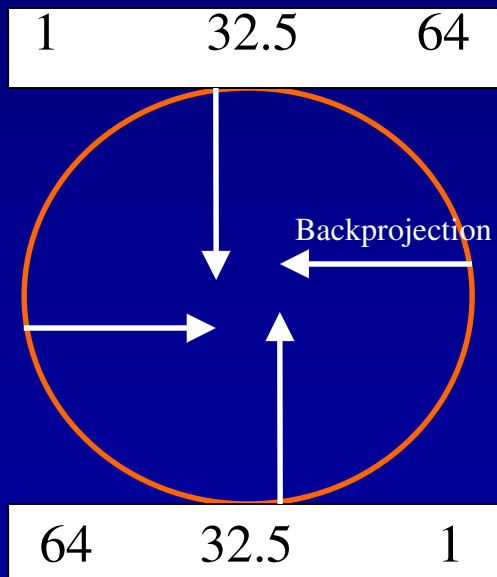


- **COR residual plot**

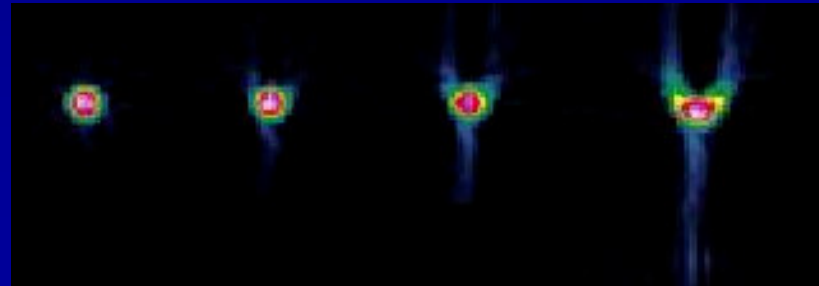
- ◆ average residual
= COR offset



- **Point source backprojection without correction...**



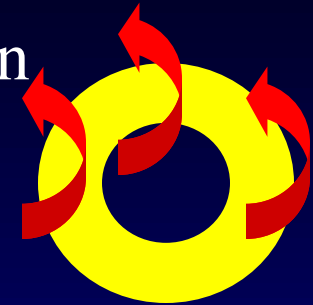
180 degree reconstruction ==> +3 pixel Offset





■ COR Error - clinical effect

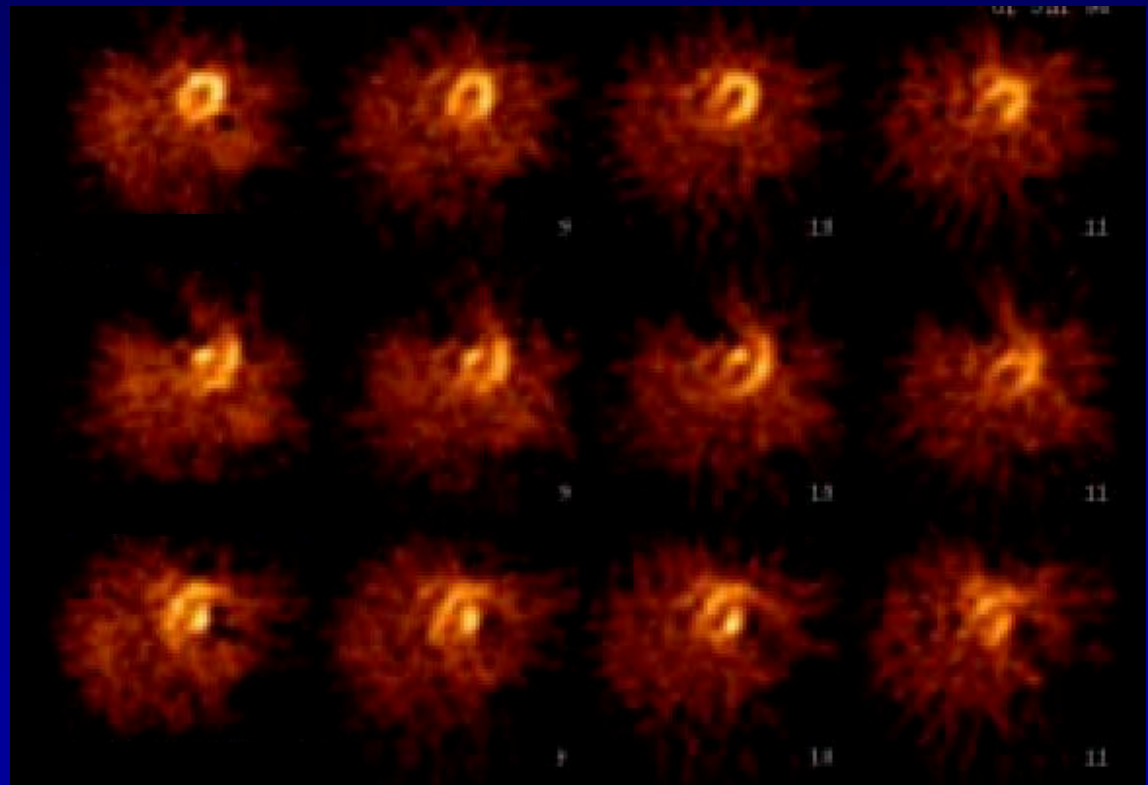
- ◆ Data are smoothed in a “circular” direction
- ◆ Artefacts may have a “comet tail” or ring like appearance



Corrected Data

+ 3 pixels COR error

- 3 pixels COR error





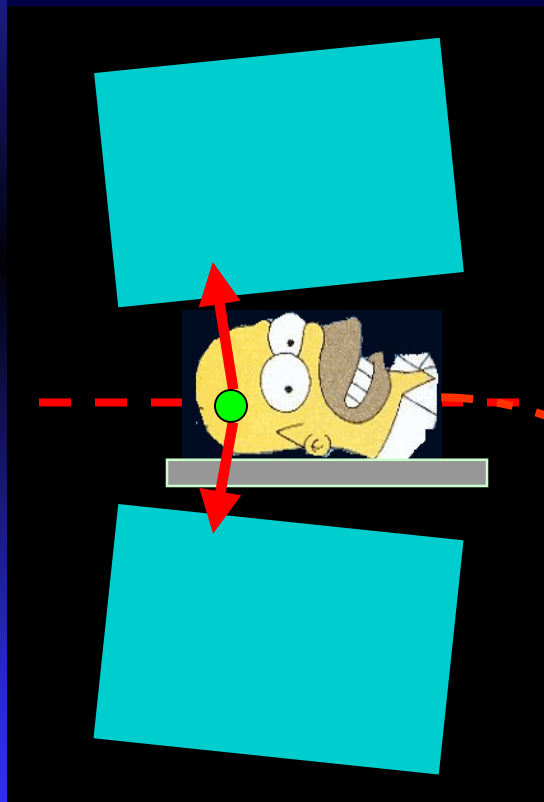
■ COR

- ◆ Follow manufacturers protocol.
- ◆ Ideally, correct for all collimators used for SPECT.
- ◆ Variable angle heads checked in all configurations
- ◆ Specific corrections for some isotope / collimator combinations

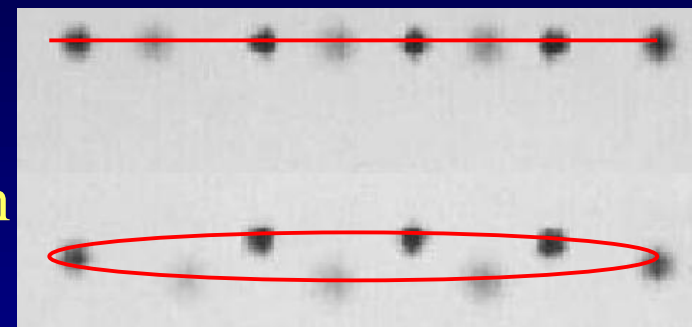


■ COR

- ◆ For evaluation of head tilt.



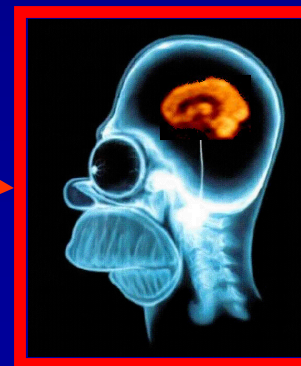
Y Pixel
location



Level

Not Level

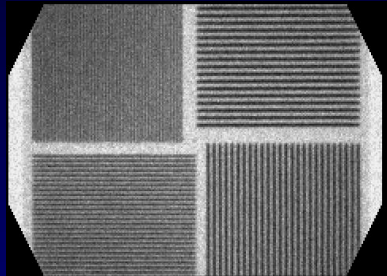
Projection View



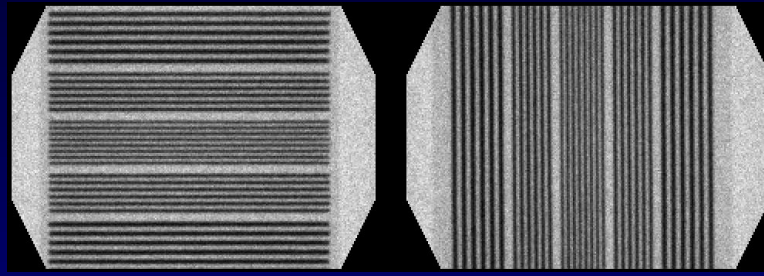


1-2 Weekly tests

■ Intrinsic / Extrinsic Resolution and Linearity check

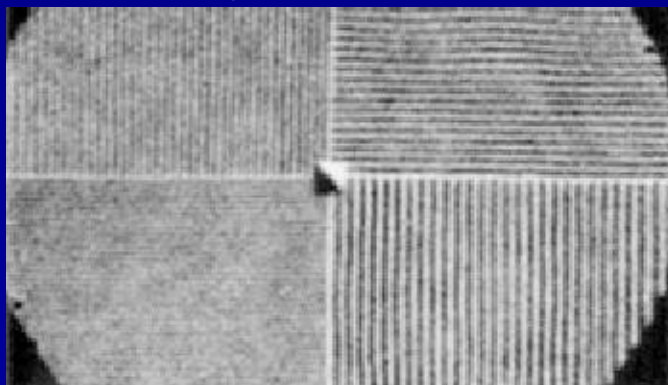


Extrinsic Spatial Resolution



Extrinsic Linearity

- ◆ Resolution loss - electronic noise or crystal / crystal interface degradation.
- ◆ Linearity loss - drift of individual PMT's



Poor Spatial Resolution / Linearity



1-2 Weekly tests

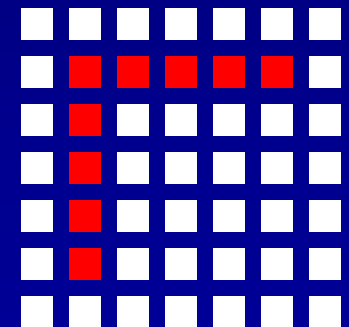
■ High count flood (intrinsic or extrinsic) ± uniformity correction

◆ Integral Unif. =
$$\frac{(\text{Global Max} - \text{Global Min})}{(\text{Global Max} + \text{Global Min})} \times 100 \%$$

◆ *indicates variation across the whole image*

◆ Differential Unif. =
$$\frac{(\text{Regional Max} - \text{Regional Min})}{(\text{Regional Max} + \text{Regional Min})} \times 100 \%$$

◆ *“regional” idea of worst case uniformity.*



◆ typical figures with correction applied:

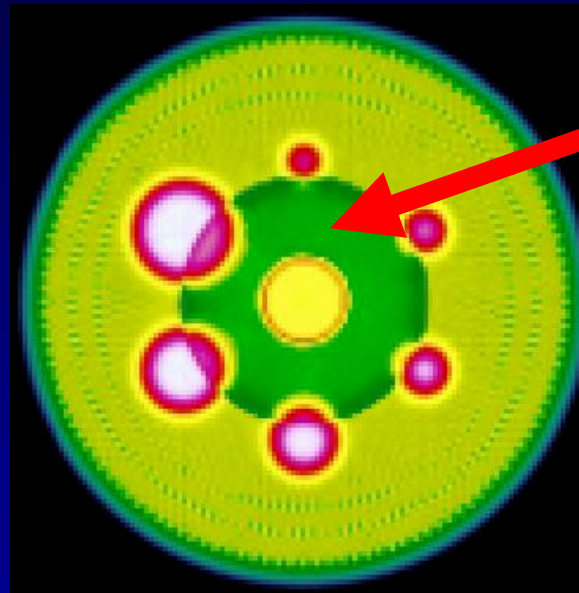
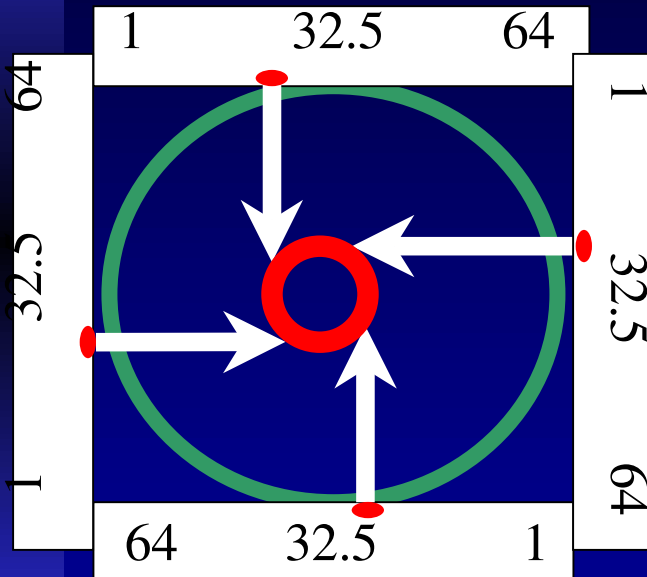
◆ Integral 1.5 - 4%

◆ Differential 1.0 - 2.5%



■ Non-Uniformity - Ring artefact

- ◆ Ring artefacts from back projected non-uniformities



Ring artefact:

Non- uniformity is:

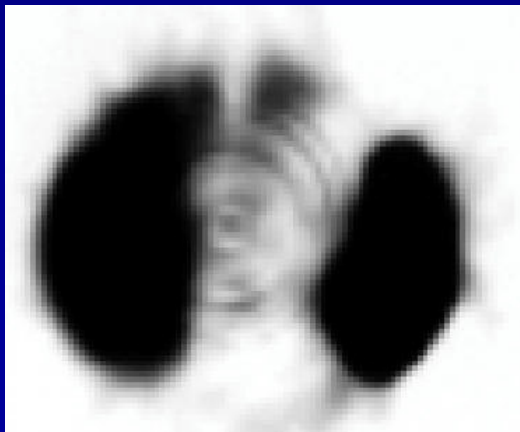
- 10 pixels wide
- 5 pixels from COR

- ◆ radius of ring = distance of non-uniformity from COR

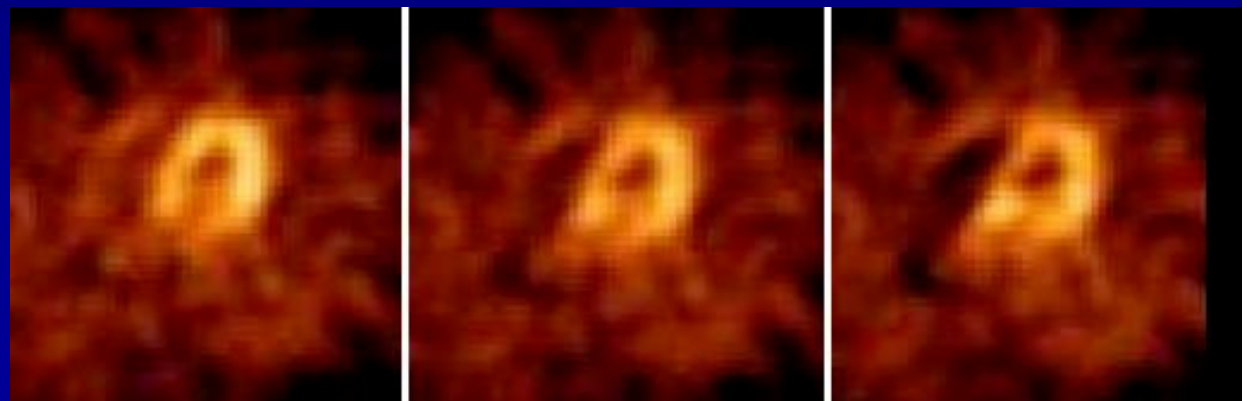
■ Non-Uniformity - Ring artefact

- ◆ Differential uniformity is sensitive to detection of ring artefacts.
- ◆ Does artefact magnitude exceed image noise?
 - ◆ Value for differential uniformity required depends on study noise.
 - ◆ More problems in high count studies.

Insufficient uniformity
for high count study



180 degree acquisition (transaxial slices)



Correction
applied

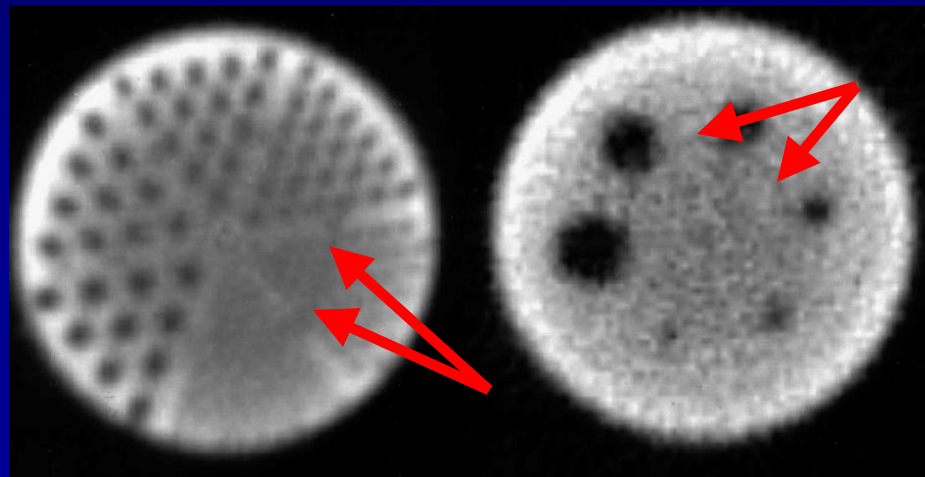
10% uniformity
defect

20% uniformity
defect



■ Uniformity Correction

- ◆ must acquire appropriate counts to reduce ring artefacts in highest count studies.
- ◆ 10,000 counts per pixel
 - ◆ 30 million - 64 x 64 matrix
 - ◆ 120 million - 128 x 128 matrix



High count phantom study showing slight ring artefact- OK for clinical use.

- ◆ Frequency depends on system stability

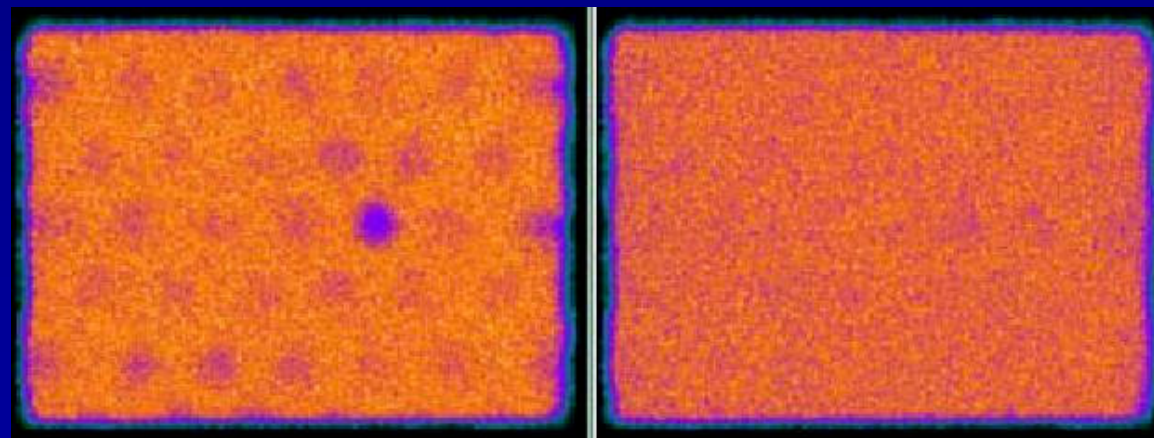


■ Uniformity Correction

- ◆ Collimator must be taken into account
- ◆ Extrinsic uniformity correction or “collimator map”.
- ◆ meant to correct minor variations across FOV.
(not replace proper energy and spatial tuning, including “Second order” corrections required for some isotopes).

Uncorrected

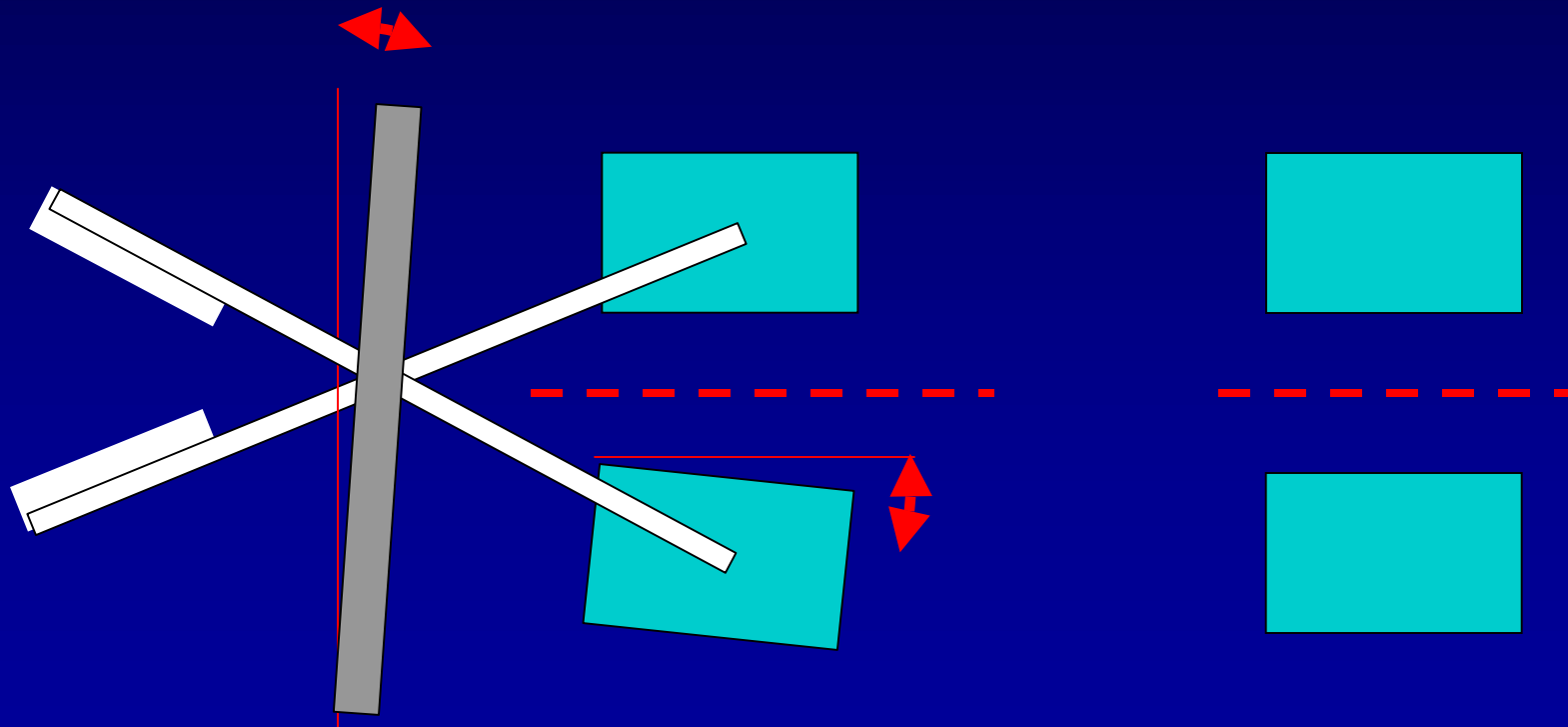
Corrected





Quarterly tests

- Gantry alignment.





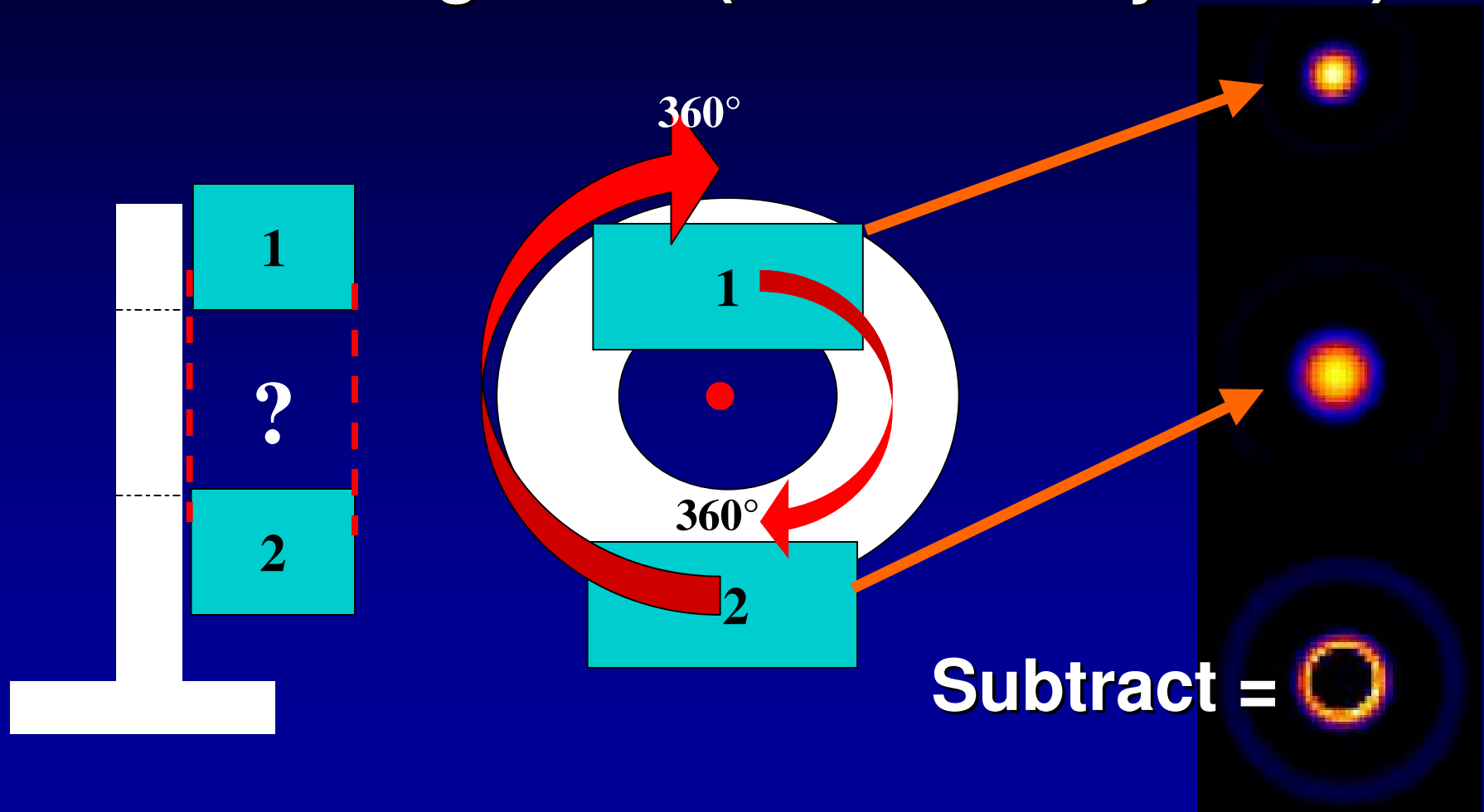
Quarterly tests

- **Rotational Uniformity**
 - ◆ **Uniformity change as a function of angle.**
 - ◆ magnetic fields
 - ◆ thermal gradients
 - ◆ optical coupling
 - ◆ **Test - high count tomo with Co-57 source secured to detector and view cine.**

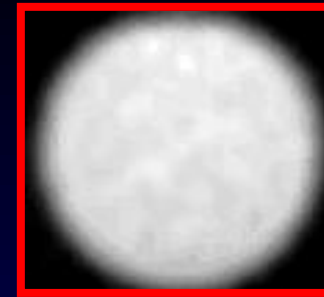


Quarterly tests

- Head alignment (mutlihead systems).



Quarterly tests



■ Reconstructed uniformity

- ◆ Sensitive to planar uniformity, but could uncover some angular variation not picked up by other tests.
- ◆ Slices should be obtained over large part of FOV

■ Pixel size

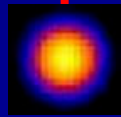
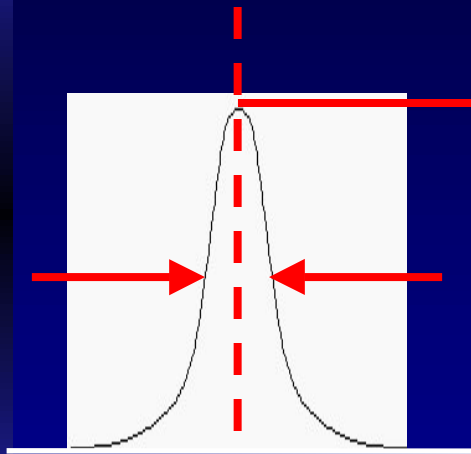
- ◆ needed for size, volume, AC operations and SPECT reconstruction
- ◆ more variation for older systems
- ◆ image point sources known distance apart (now usually combined with linearity correction).



Quarterly tests

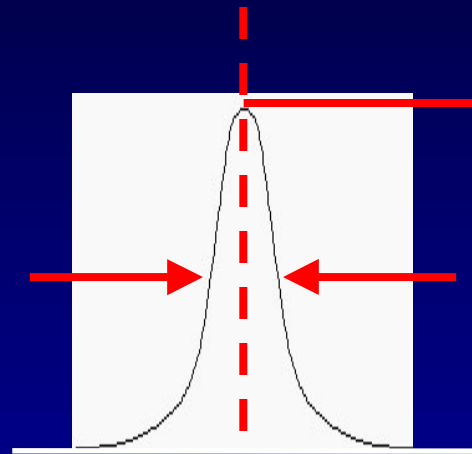
■ Reconstructed Spatial Resolution

SPECT



Transaxial

Planar



Line Source

(at average ROR of SPECT)

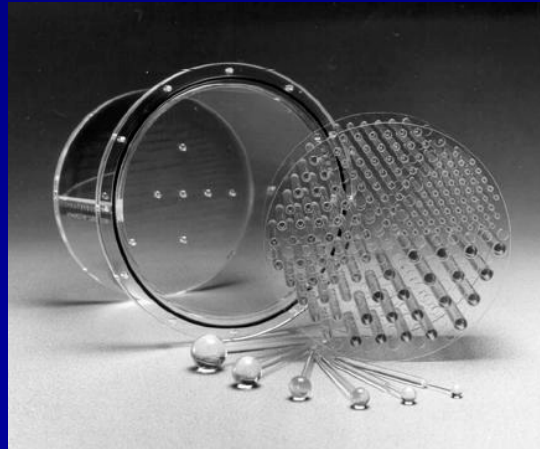
“SPECT : Planar ratio”
a sensitive indicator
of resolution loss
caused by SPECT
only parameters.

FWHM \cong FWHM (within 10%)



Quarterly tests

- **“Total Performance”**
 - ◆ high quality projection data and reconstructions needed to guarantee optimum operation of a SPECT system.
 - ◆ Jaszczak performance phantom (and others) commercially available.

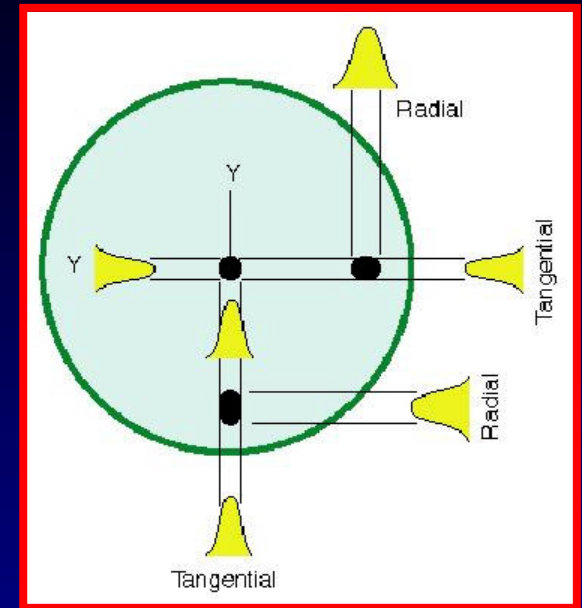




Quarterly tests

■ “Total Performance”

- ◆ uniformity
- ◆ radial and tangential resolution limits with scatter
- ◆ artefacts
- ◆ accuracy of uniform AC
- ◆ lesion detectability and contrast
- ◆ effect of collimators, filters, acquisition parameters.
- ◆ No patient motion, count limitation

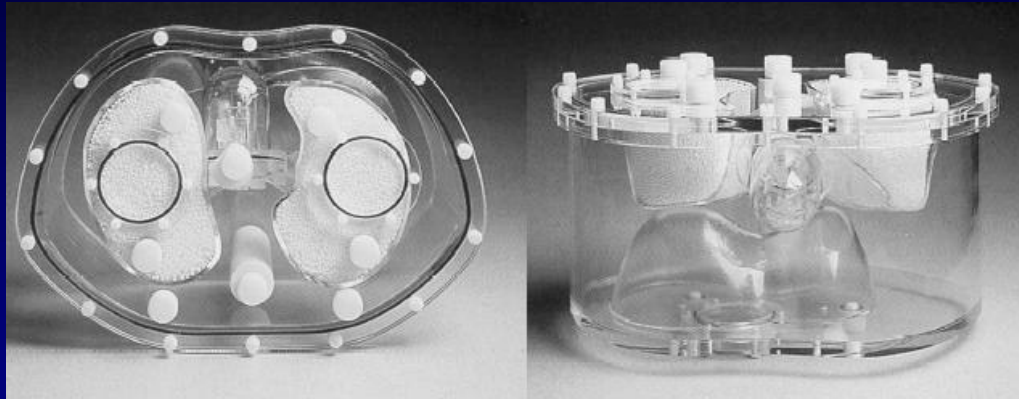


◆ reference study - **REPRODUCIBLE**

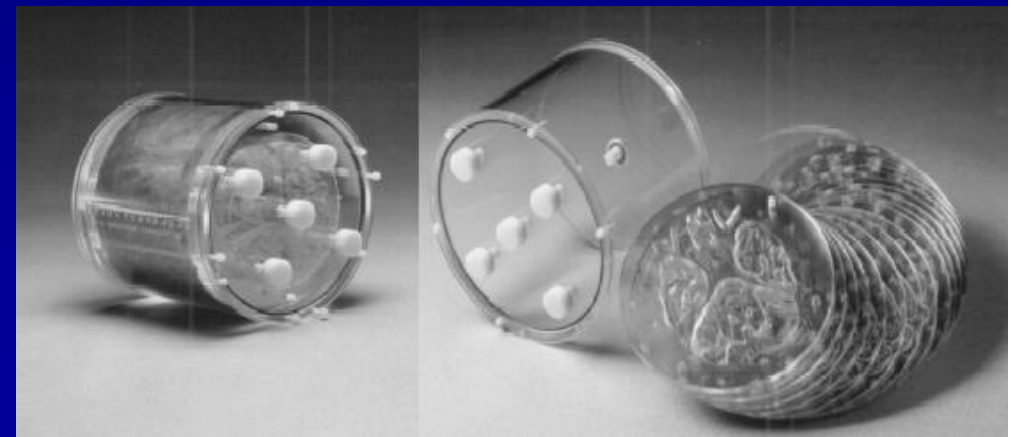


■ Application specific SPECT performance phantoms

Anthropomorphic Torso Phantom™



Hoffman 3-D Brain Phantom™



DATA SPECTRUM CORPORATION
*A Worldwide Leader in
Medical Imaging Phantom Design™*



SPECT QC - Who says...?

- IAEA Techdoc 602 (1991) “*Quality control of nuclear medicine instruments*”.
- AAPM (1995) “*Quantification of SPECT performance: Report of Task Group 4, Nuclear Medicine Committee*”
Med Phys, 22:401-409
 - ◆ no special analysis software required.
 - ◆ completed in a reasonable time.
 - ◆ Suggests acceptable results.



SPECT QC - Who says...?

- ANZSNM Technical Standards Subcommittee
“Minimum QC Requirements for Nuclear Medicine Equipment”. www.anzsnm.com.au/standards/minimum_qc_requirements_for_nuclear_medicine_equipment.pdf
- NEMA (2000) *“Recommendations for implementing SPECT instrumentation quality control”* JNM, 41(2):383-389.



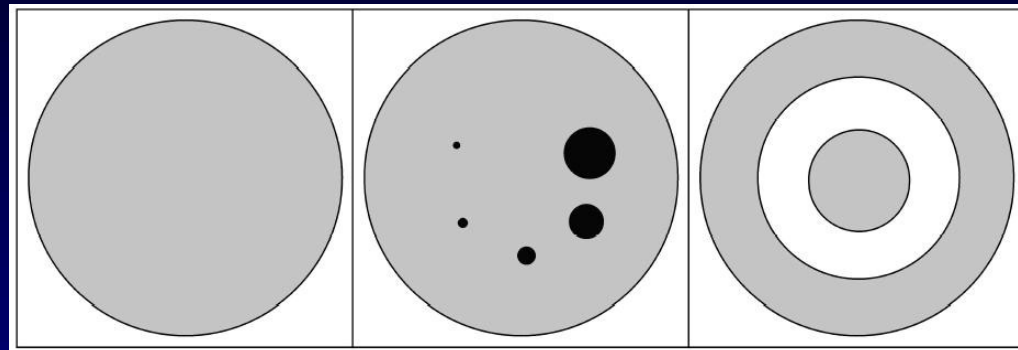
SPECT QC - Who says...?

- IPEM (UK) Report 86 (2003) “*Quality Control of Gamma Camera Systems*” Order from <http://www.ipem.org.uk>
Chapter 5: Single Photon Emission Tomography Quality Control
 - ◆ Role of warranty period in defining required frequency for QC tests
 - ◆ QC tests for non-uniform AC.
 - ◆ **SPECT software QC...**
 - ◆ SPECT Software Audit - IPEM + BNMS **
 - ◆ Simulated data used for software audit across UK.
 - ◆ Highlighted significant differences between practices.

** Jarritt P, Whalley D, Skrypniuk, J, Houston A, Fleming J and Cosgriff P. (2002)
“*Quality Control of Gamma Camera Systems*” IPEM Report 86, 23, 483–491.



- SPECT software audit (IPEM and BNMS)
 - ◆ projection data of simulated objects distributed.



- ◆ Centres asked to :
 - reconstruct (ramp only).
 - Provide simple count and FWHM statistics, which were compared to known values.
 - Discrepancies between suppliers as well as different revisions of software.



- SPECT Software audit (IPEM and BNMS)
 - ◆ Issues of concern:
 - ◆ Data scaling.
 - ◆ Implementation of coding and reconstruction algorithms.
 - ◆ Users unaware of changes between software revisions.
 - ◆ SPECT software QA program is indicated, especially where any quantitation is undertaken.

SPECT QA and QC

■ Conclusions:

- ◆ Equipment and procedures evolving rapidly (?).
- ◆ QC tests, documentation needs review.
- ◆ Specialised analysis tools required to manage changes.
- ◆ SPECT software QC identified as an area for attention.