Quality Control Protocol on SPECT

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Factors affecting image formation

- Distribution of radiopharmaceutical
- Collimator selection and sensitivity
- Spatial resolution, Distance collimator-patient
- Energy resolution
- Uniformity
- Count rate performance
- Spatial positioning at different energies
- Center of rotation
- Scattered radiation
- Attenuation
- Recording system
- Type of examination
- Noise, Background

image quality

Image quality depends on:

- **Radiopharmaceutical**
  - Labeling
  - Administered Dose
- **Technical factors**
  - Equipment used
  - Acquisition protocol
  - Image processing
  - Noise
  - Spatial resolution
  - Scatter
- **Patient factors**
  - Size , Age, Disease , Movement

Quality Control in 3 steps

Measurement:

calculation of values related to system

Assessment:

qualitative evaluation to say is it acceptable or not

Correction/Calibration:

modifying parameters to reduce systematic errors

Acceptance Test vs. QC

Acceptance test:

After installation, and before clinical use
to verify that instrument performs according to its specification

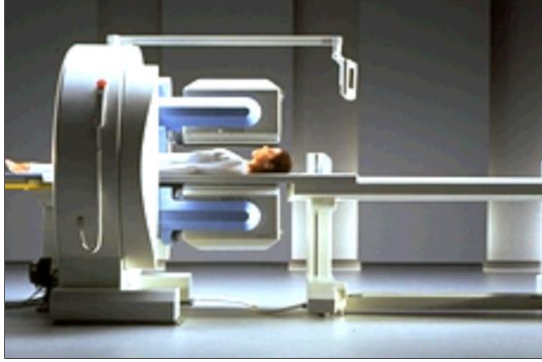
Each instrument is supplied with a set of basic specifications produced by the manufacturer according to standard test procedures (e.g. NEMA)

Quality control:

Once the instrument has been accepted for clinical use
Procedures that are sensitive to changes in performance
Tests must be performed by appropriately qualified and trained staff

- Detailed local operating procedures should be Written for this routine work
- All test results must be **recorded and monitored for variation**
- Appropriate actions taken when changes are observed

Quality Control – Gamma Cameras



	Acceptance	Daily	Weekly	Yearly
Uniformity	P	T	T	P
Uniformity, tomography		P		P
Spectrum display	P	T	T	P
Energy resolution	P			P
Sensitivity	P		T	P
Pixel size	P		T	P
Center of rotation	P		T	P
Linearity	P			P
Resolution	P			P
Count losses	P			P
Multiple window pos	P			P
Total performance phantom	P			P

P: physicist
T:technician

IAEA-TRS-454 Quality Assurance for Radioactivity Measurement in Nuclear Medicine 2006

IAEA-TECDOC-602

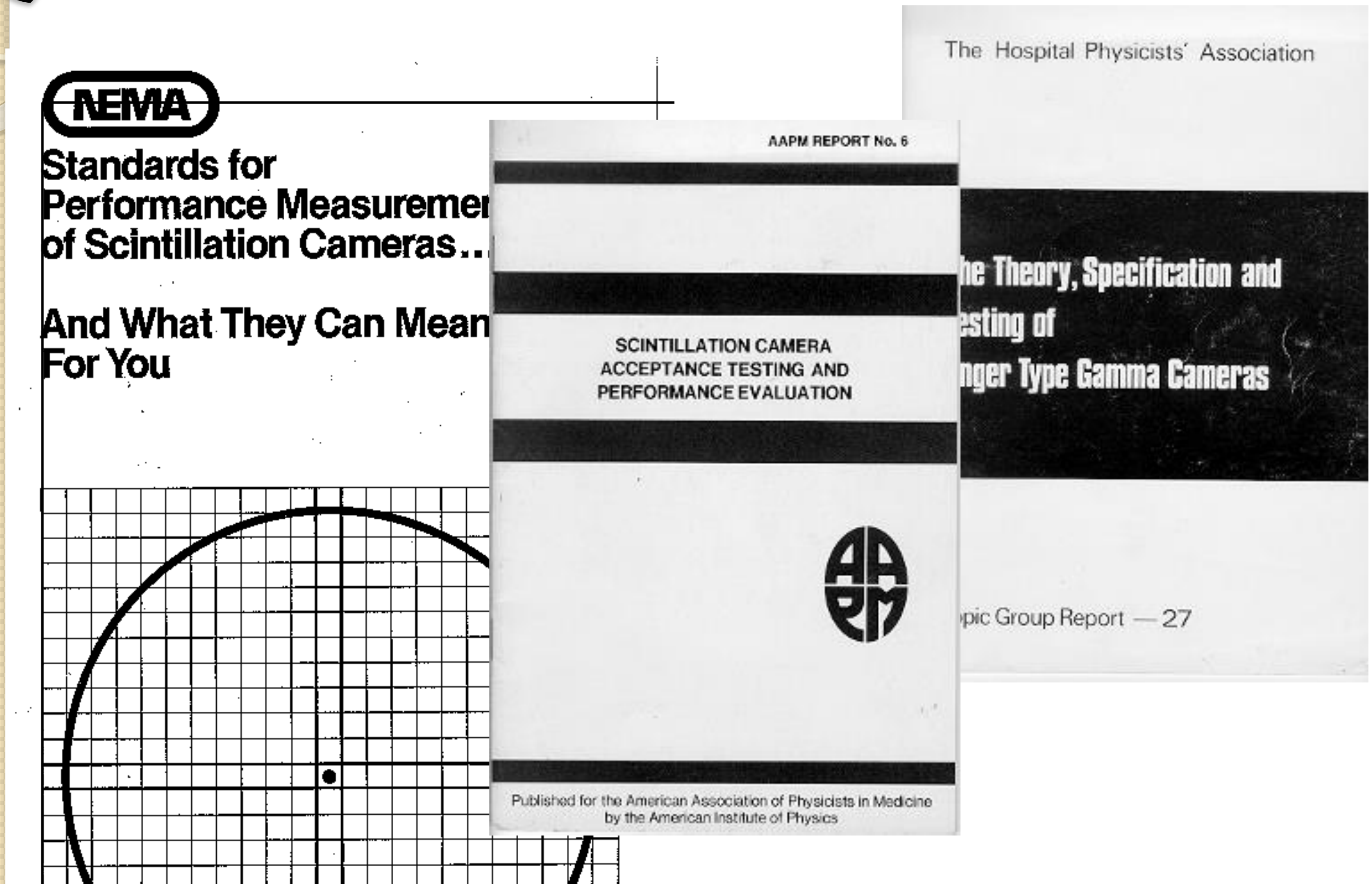
Quality control of Nuclear medicine instruments 1991

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

May 1991

IAEA QA for SPECT systems (in press)

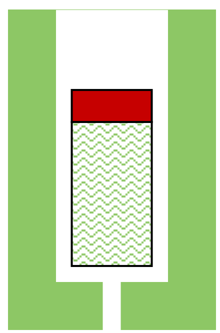
QC Gamma camera



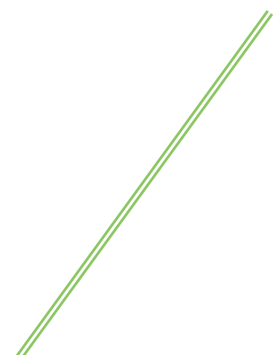
National Electrical Manufactures Association

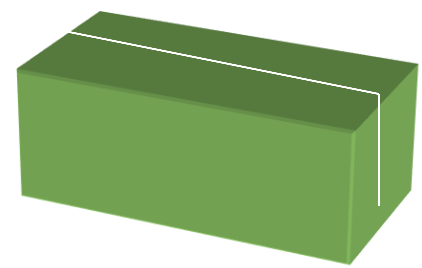
SOURCES FOR QC OF GAMMA CAMERAS

- **Point source**
- **Collimated line source**
- **Line source**
- **Flood source**



<1 mm





Tc99m, Co57, Ga67

QC Activities/ Settings

Intrinsic tests usually 35 – 500 micro Ci.

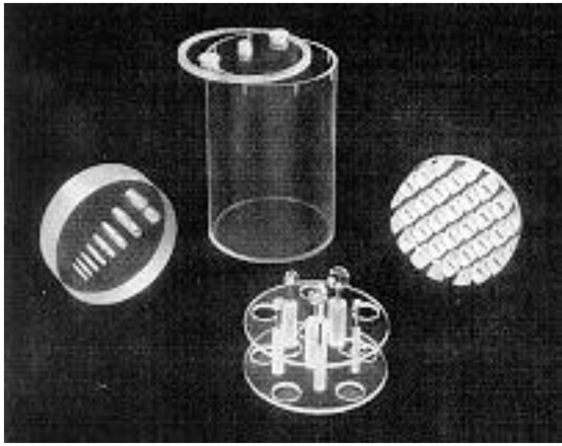
Extrinsic tests usually 2 – 10 mCi.

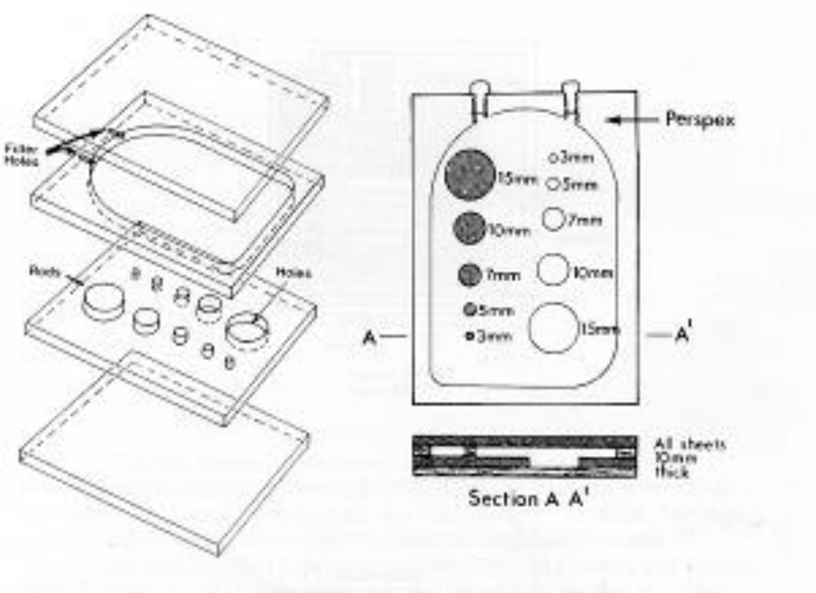
Energy window is usually 15 % of Photopeak, if nothing recommended by vendor.

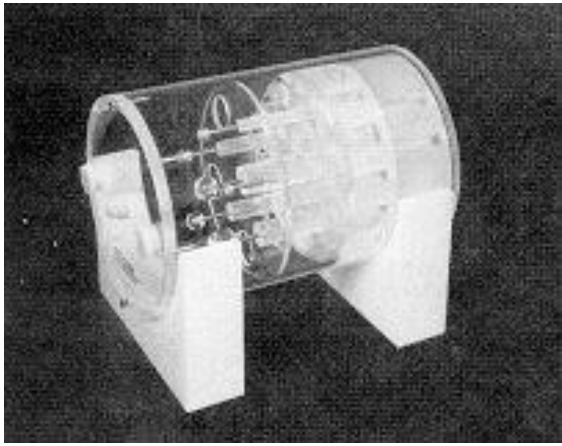
Count rate < **30.000** cps

Phantoms for QC of gamma cameras

- Bar phantom
- Slit phantom
- Orthogonal hole phantom
- Total performance phantom







Phantoms for QC of gamma cameras

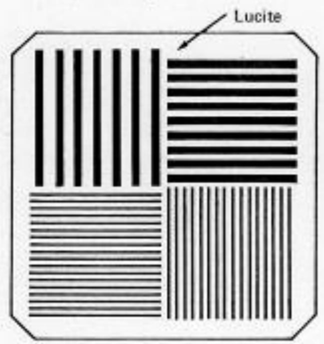
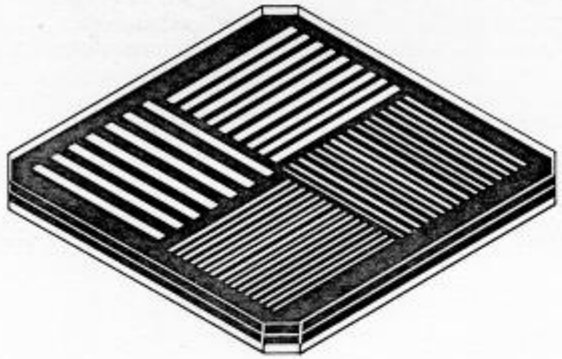
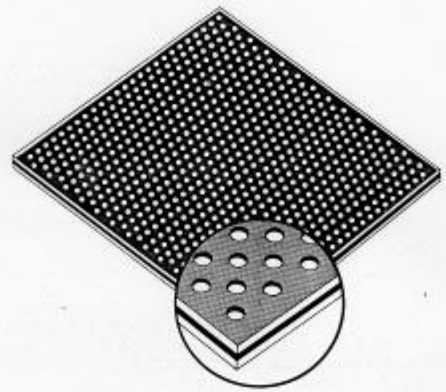
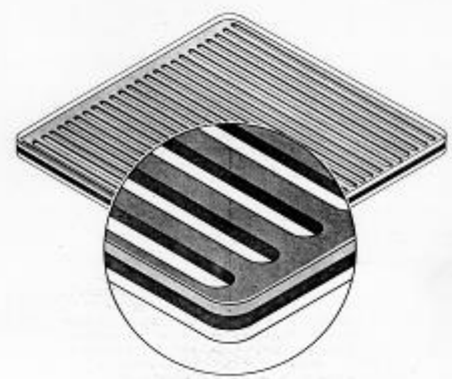


Figure A.5.a. 90° Bar quadrant phantom.







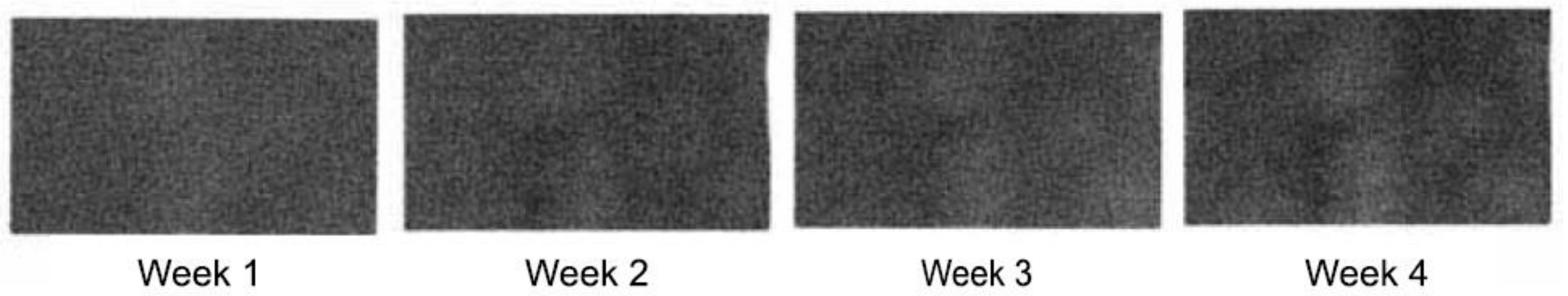
Intrinsic/Extrinsic Uniformity

For a uniform flux we shall expect a uniform image!
Unfortunately not!

The most sensitive parameter, Why?

- Photopeak Window
- Photomultiplier tube (PMT) performance
- Imperfections in the collimators
- Variations in crystal response
- Variations in PMTs’ response
- Minor fluctuations in the electrical circuitry

Intrinsic/Extrinsic Uniformity



Non uniformity due to a drift in circuitry

The single **most important** QC test should be performed **Daily**!

Intrinsic Uniformity

The uniformity of the camera's response can be checked by imaging a **Tc-99m flood source**.

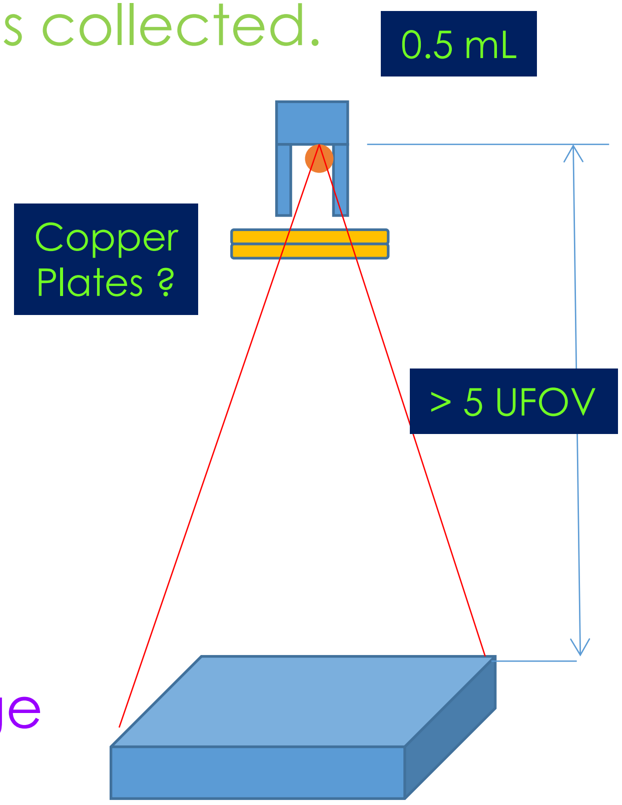
A **5-30 million count** image of the flood is collected.

A **300-500 micro_Ci** point source.

Count rate < **30000 cps**.

64 x 64 Matrix size.

* A minimum of **<u>10,000</u>** counts shall be collected in the center pixel of the image



Extrinsic Uniformity Visual

The uniformity of the camera's response can be checked by imaging a **Tc-99m flood source**.

A **5-30 million count** image of the flood is collected with **LEHR** Collimator.

A **5-10 mCi** point source.

Count rate < **30000 cps**, **512 x 512** Matrix size.

Uniformity

- Field uniformity may be done either as intrinsic or extrinsic
- **Intrinsic**=collimators off. Monitors the condition of sodium iodide crystals and electronics.
- **Extrinsic=collimators** on. Monitors the camera as it is used clinically.

Uniformity

Uniformity images must be inspected daily for nonuniformity and compared to previous flood (uniformity) images.

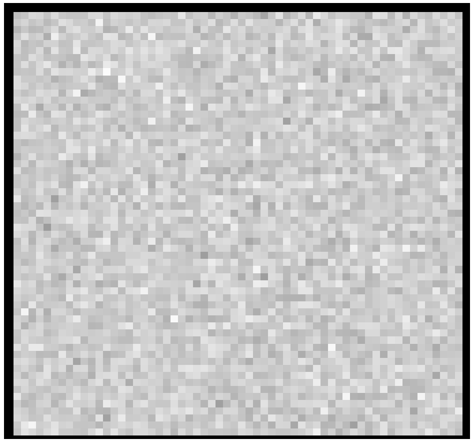
UNIFORMITY

Flood source (Tc-99m, Co-57)
Point source (Tc-99m)

- **Intrinsic uniformity**: Point source at a large distance from the detector. Acquire an image of 10.000.000 counts
- **With collimator:** Flood source on the collimator. Acquire an image of 10.000.000 counts

Uniformity

Uniformity



1. Subjective evaluation of the image
2. Calculate

   Integral uniformity (IU)

   Differential uniformity (DU)

IU=(Max-Min)/Max+Min)*100, where Max is the the maximum and Min is the minimum counts in a pixel

DU=(Hi-Low)/(Hi+Low)*100, where Hi is the highest and Low is the lowest pixel value in a row of 5 pixels moving over the field of view

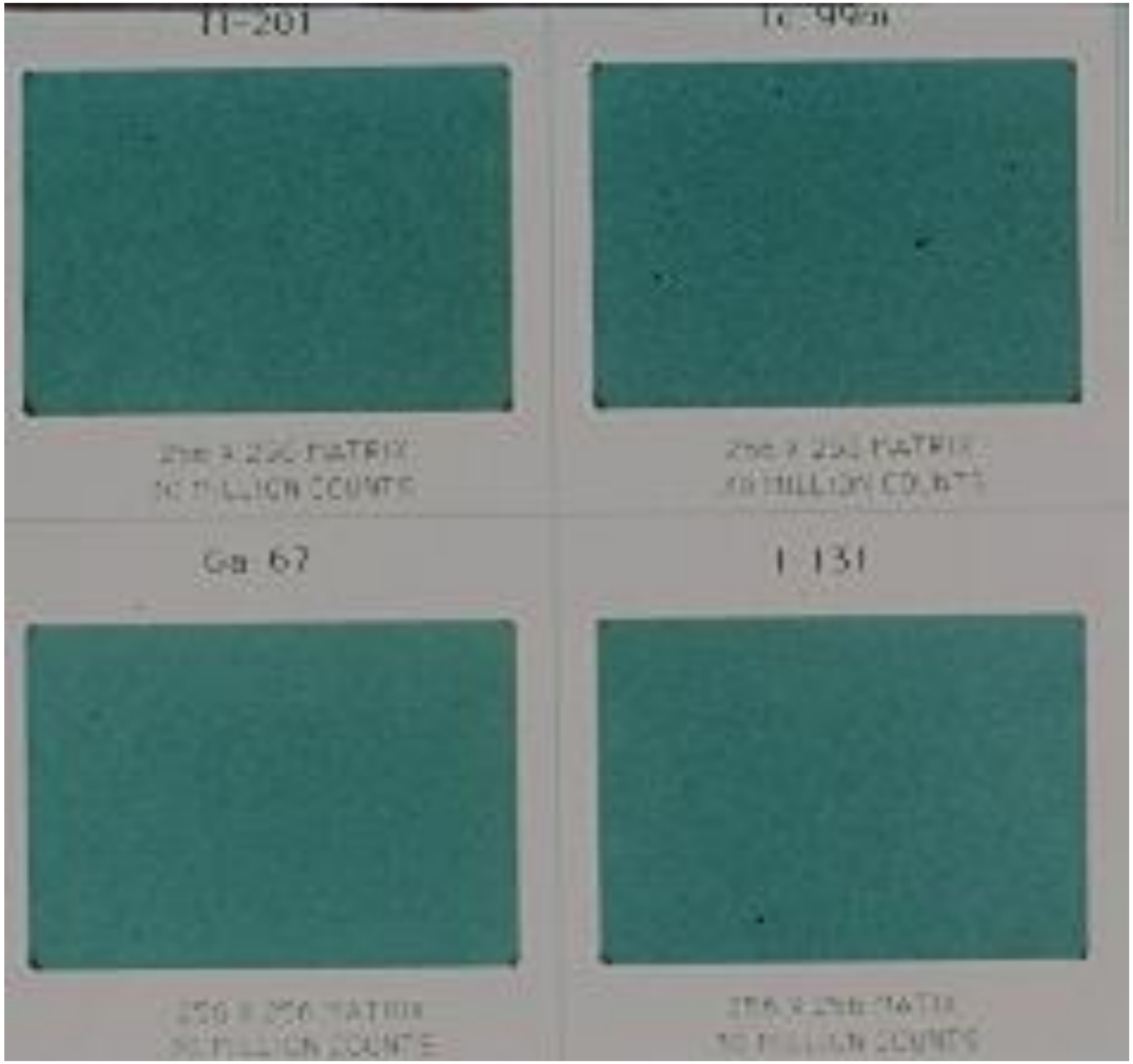
Matrix size 64x64 or 128x128

Uniformity

UNIFORMITY/DIFFERENT RADIONUCLIDES

Tl 201

Tc 99m

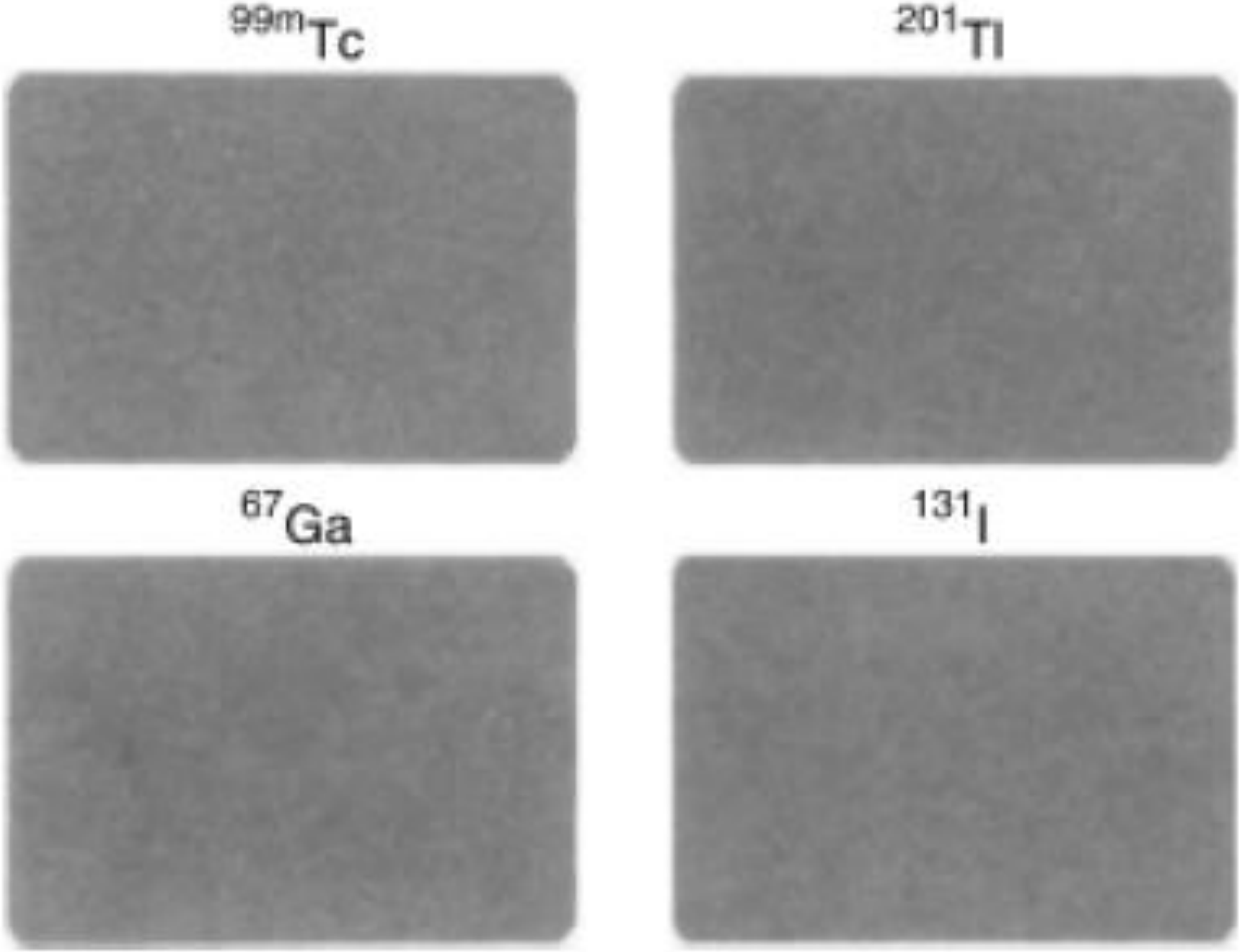


Ga 67

I 131

All 4 images acquired with: Matrix: 256 x 256, counts: 30 Mcounts

Different radionuclides and photon energies



Uniformity

10% energy window

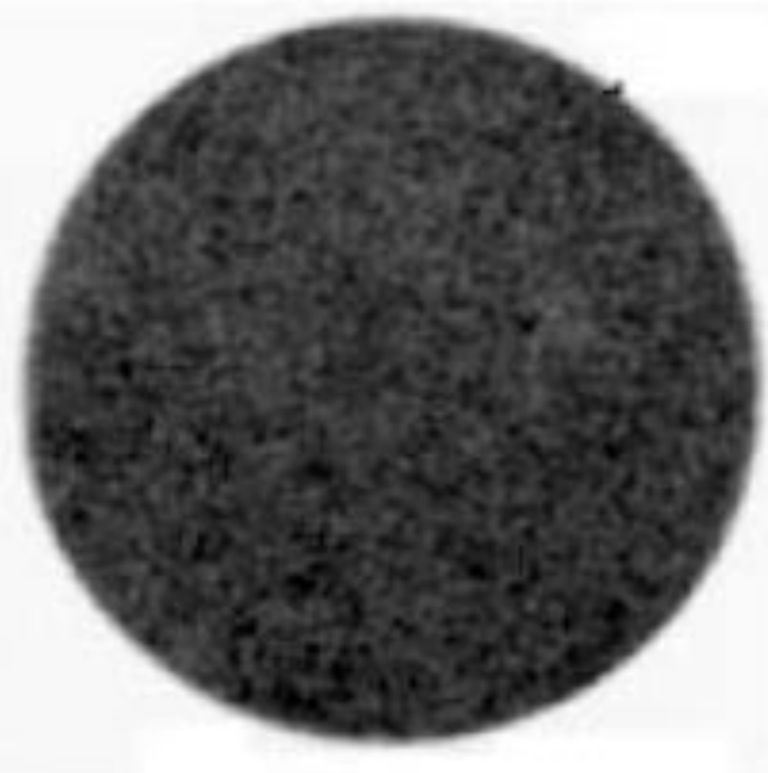
15% energy window

20% energy window

Uniformity with and without a uniformity correction map

Uniformity

without
uniformity correction map



with
uniformity correction map

Uniformity

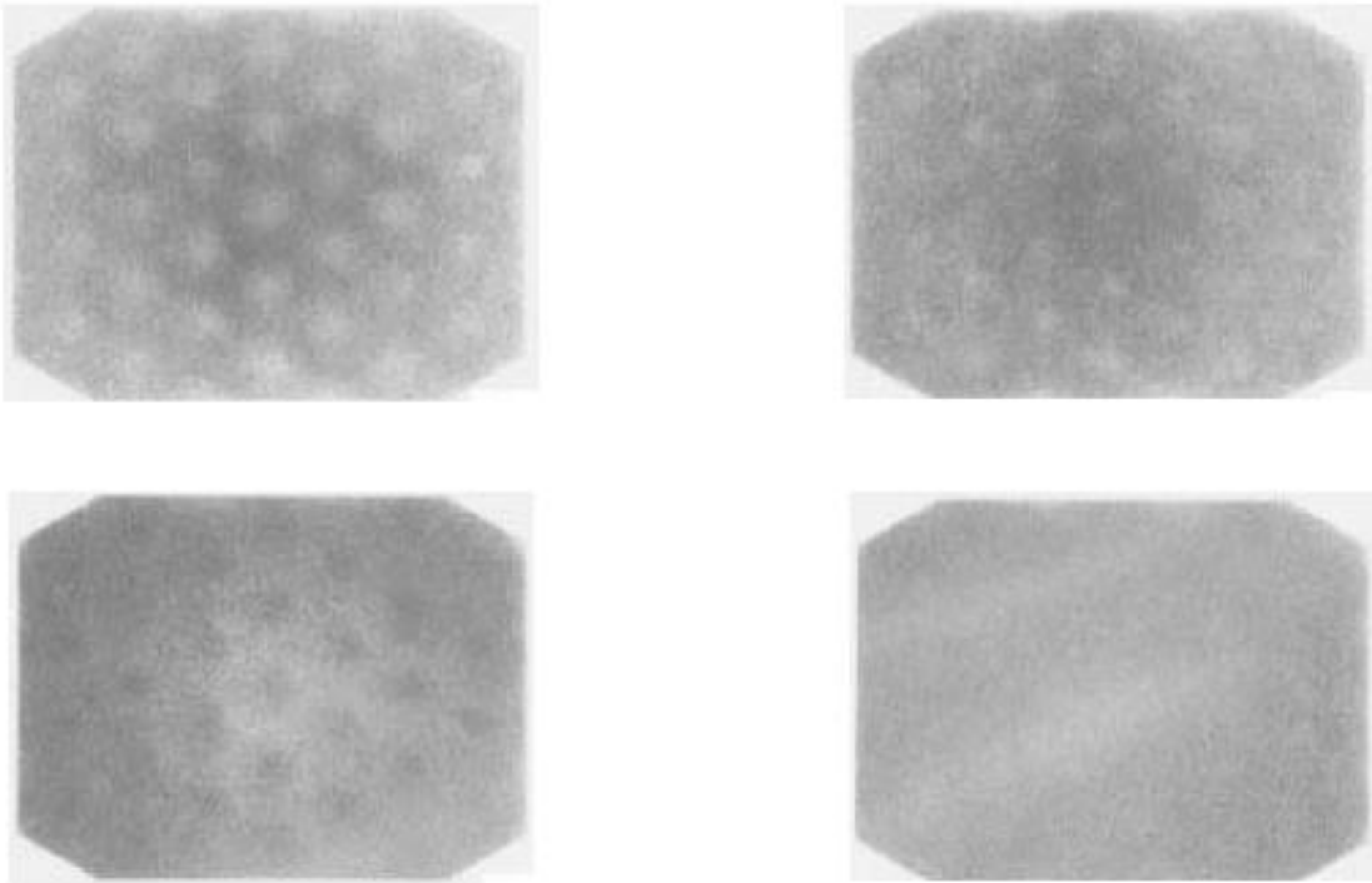
- Symmetric energy window — 99mTc
- Asymmetric energy windows
- Different radionuclides and photon energies
- Uniformity — quantification
- Uniformity — multihead systems
- Corrections (linearity, energy, uniformity)
- Detector crystal
- PM tube and associated electronics
- Collimator
- Artefacts arising from sources/phantoms

Uniformity

Inhomogeneous flood fields can result from:

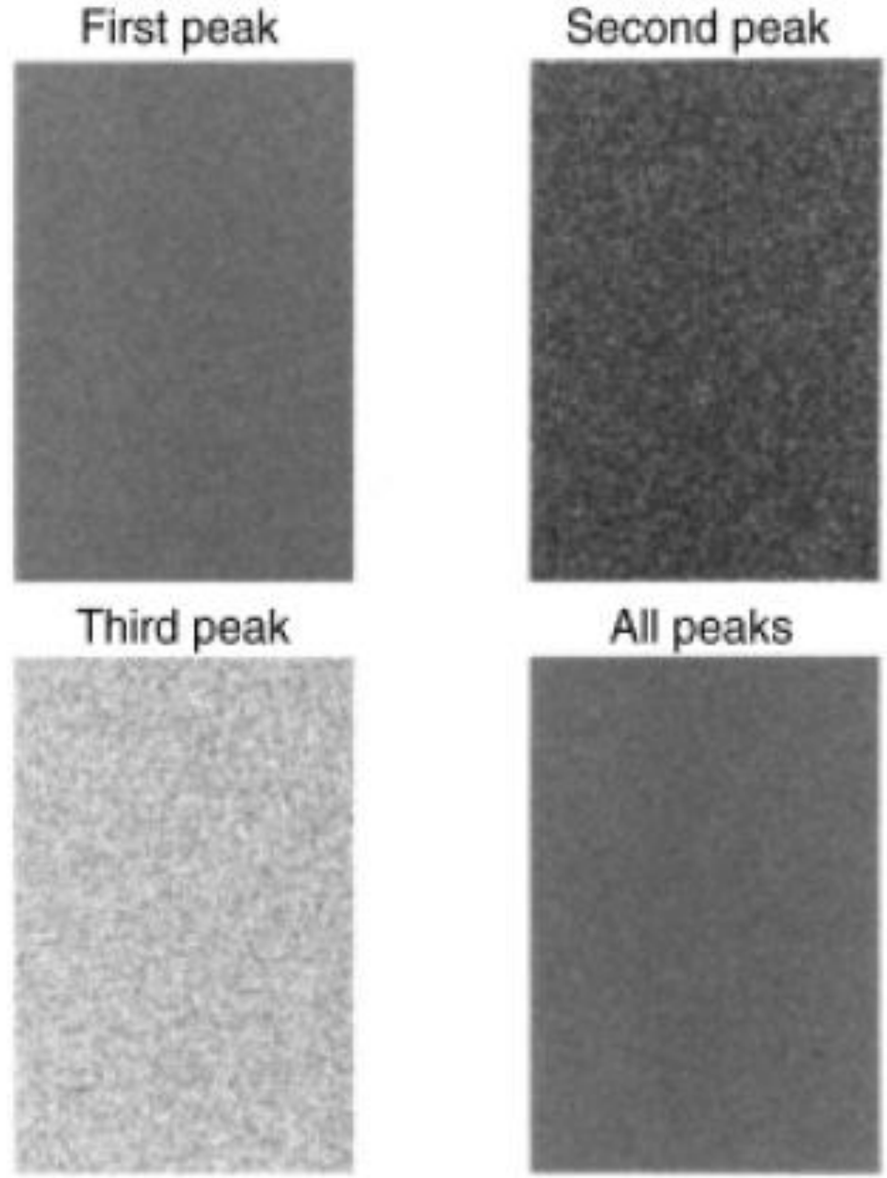
- Inadequate mixing of Technetium flood phantom
- Computer correction turned off
- Loss of coupling between crystal and PMTs
- Bad PMT voltage adjustment
- Camera pulse height analyzer off-peak for the radionuclide

Uniformity — 67Ga — separate and sum of energy windows



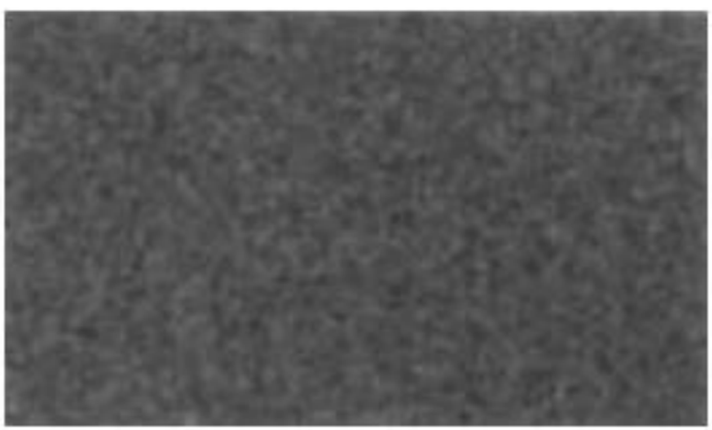
Uniformity

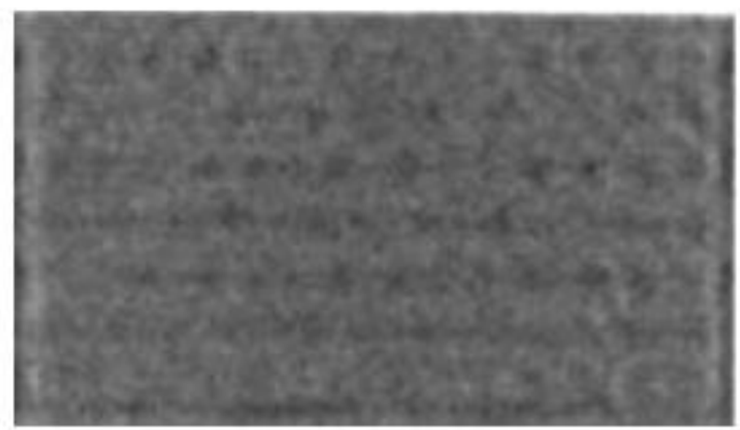
- ✓Peak 1 (93 keV), 25% energy window (3.2 million counts).
- ✓Peak 2 (184 keV), 20% energy window (1.4 million counts).
- ✓Peak 3 (300 keV), 20% energy window (0.4 million counts).
- ✓Sum of these three peaks (5 million counts).



Uniformity

- **Comparison of images acquired with and without a uniformity correction map**





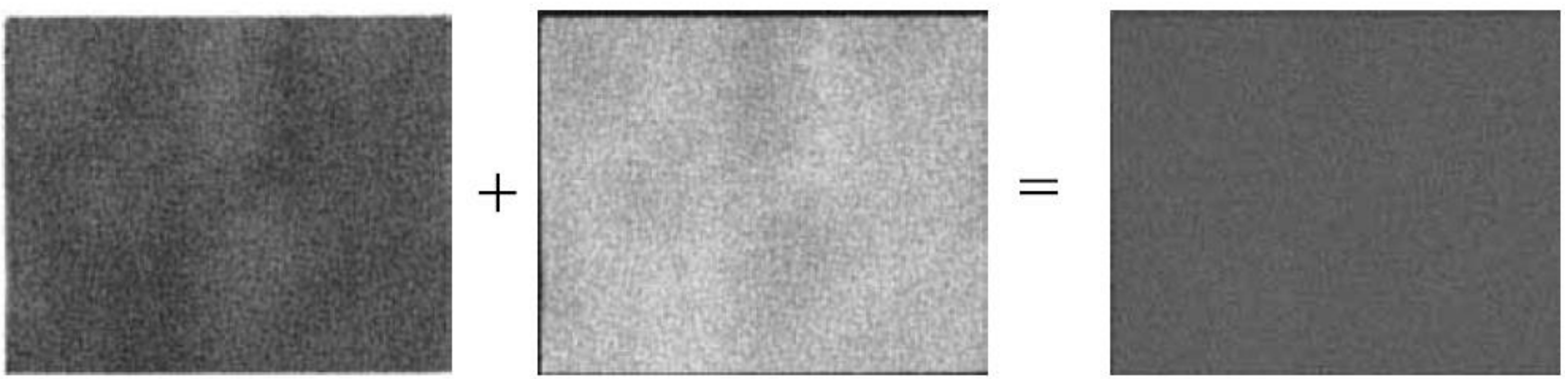
Uniformity

Comparison of intrinsic uniformity for 201Tl and 67Ga on the same scintillation camera — radionuclide specific uniformity correction map

Flood Field

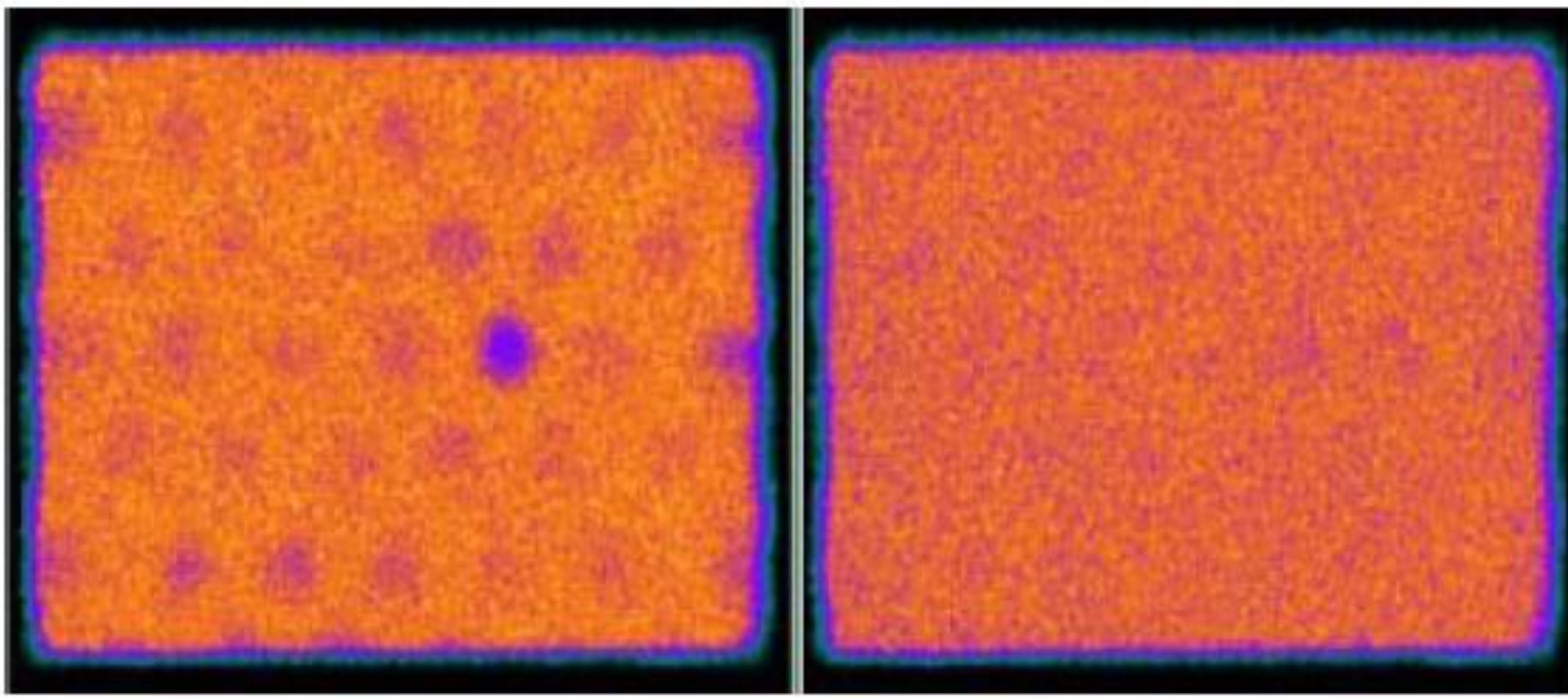
Uniformity Correction Matrix

Corrected Flood Field



Uniformity

Comparison of images acquired without and with a 99mTc intrinsic uniformity map correction — defective PM tube



Symmetric energy window — 99mTc

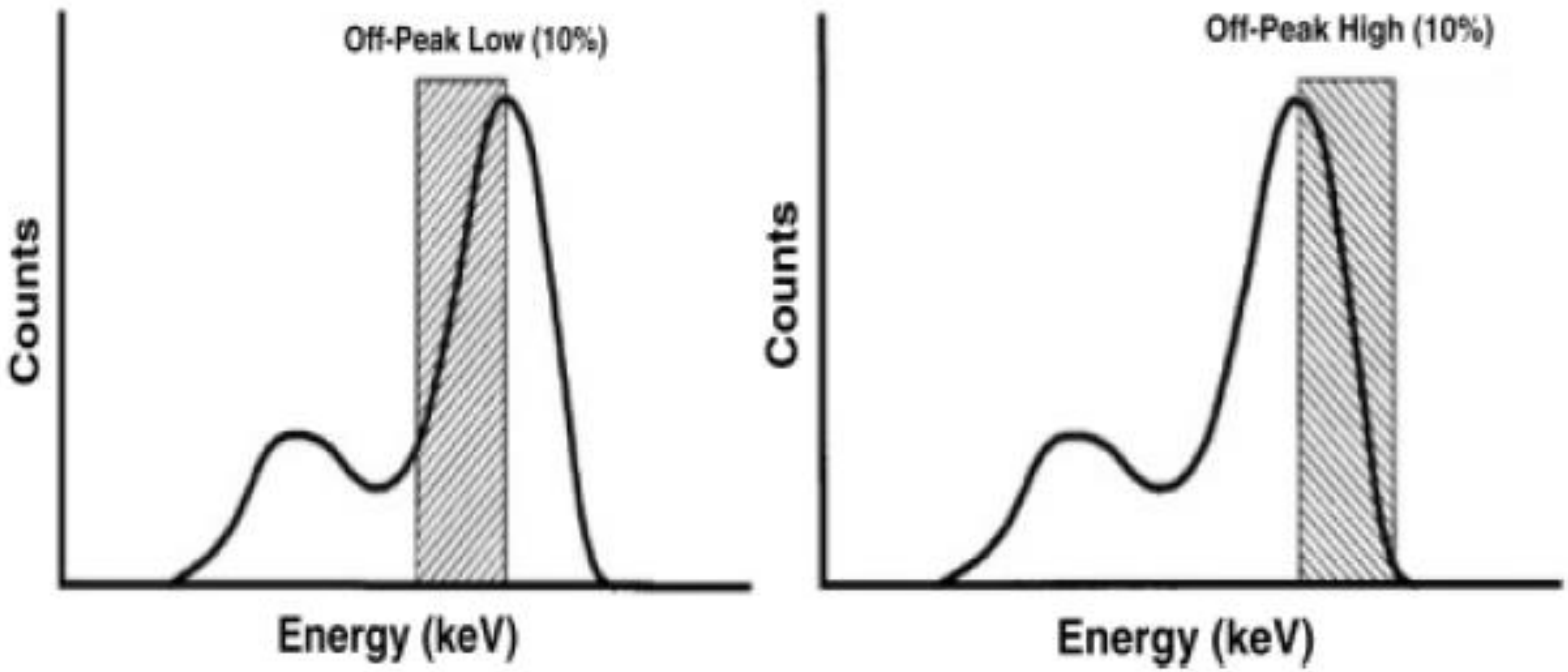
- A symmetric energy window is one where the photopeak energy is at the centre of the window.

For 99mTc:

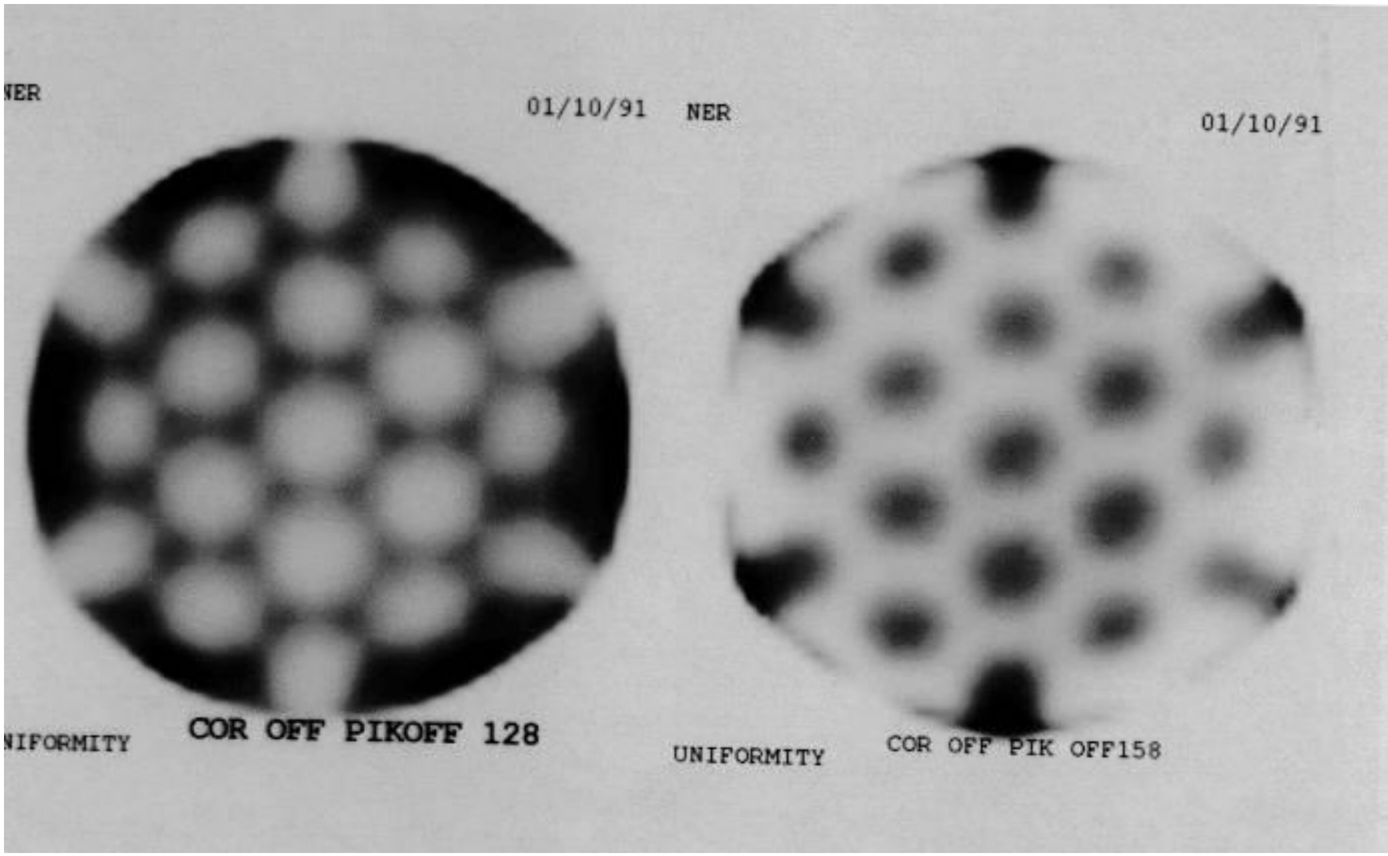
- A 20% energy window set symmetrically over the 99mTc photopeak is equivalent to 140 ± 10% keV or a window spanning 126–154 keV.
- A 15% energy window set symmetrically over the 99mTc photopeak is equivalent to 140 ± 7.5% keV or a window spanning 130–151 keV.
- A 10% energy window set symmetrically over the 99mTc photopeak is equivalent to 140 ± 5% keV or a window spanning 133–147 keV.

Uniformity

Asymmetric window

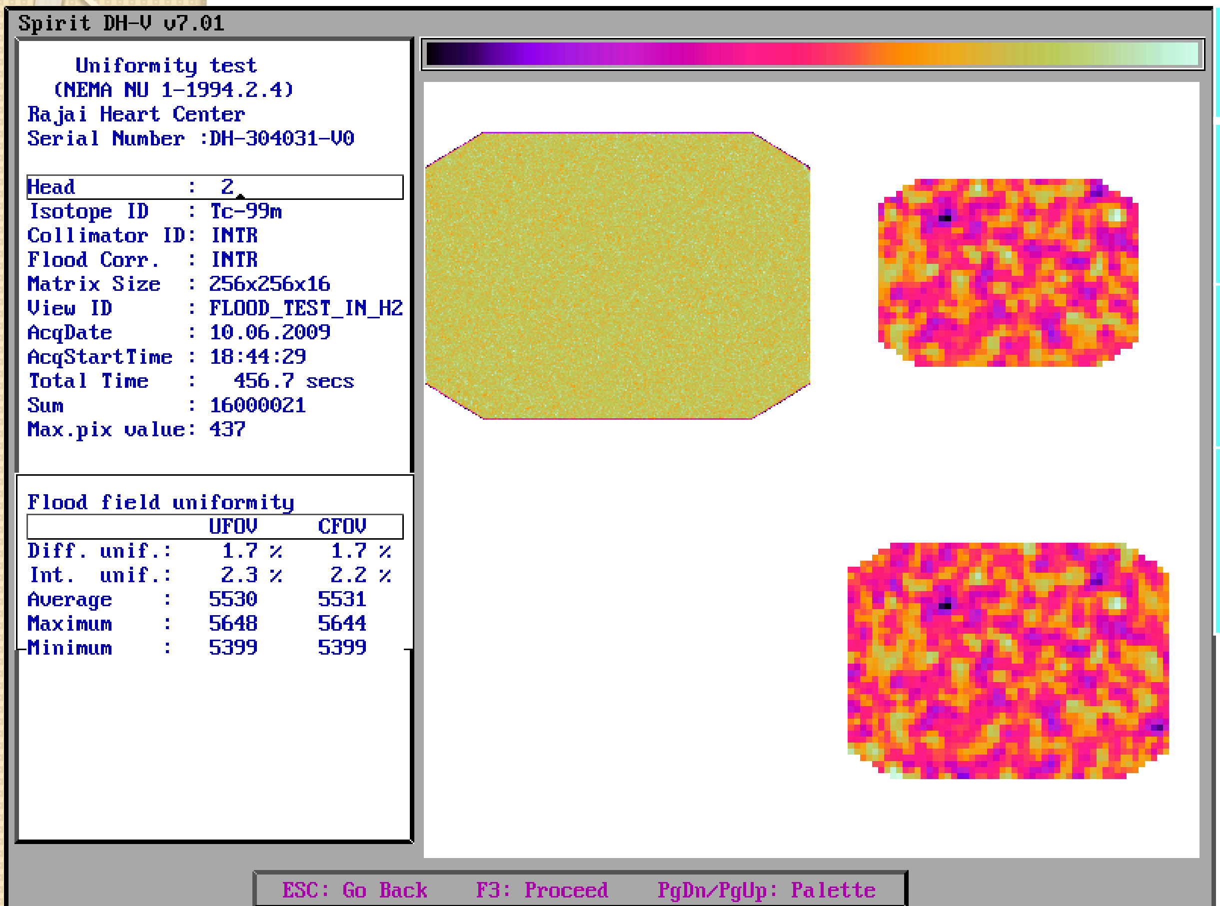


OFF PEAK MEASUREMENTS



Dogan Bor, Ankara

Intrinsic/Extrinsic Uniformity
Quantitative



Intrinsic Uniformity IU in UFOV	Extrinsic Uniformity IU in UFOV
< 3.5 GOOD	< 5 GOOD
3.5 – 5 Marginal	5 – 6 Marginal
Above 5 Unacceptable	Above 6 Unacceptable

UFOV or CFOV DU of 1.5 -2.0% expected

System Report

Full Report of Uniformity Analysis
NAME: 3-04-97 ID: INTR FLD DATE:

UFOV

Integral Uniformity = 2.87%

	Counts	Location
Minimum	7132	(34, 33)
Maximum	7554	(46, 32)

Row Differential Uniformity = 1.69%
Column Differential Uniformity = 1.55%

	Diff.	Location
Max Row	251	(42, 32)
Max Col	230	(46, 28)

CFOV

Integral Uniformity = 2.87%

	Counts	Location
Minimum	7132	(34, 33)
Maximum	7554	(46, 32)

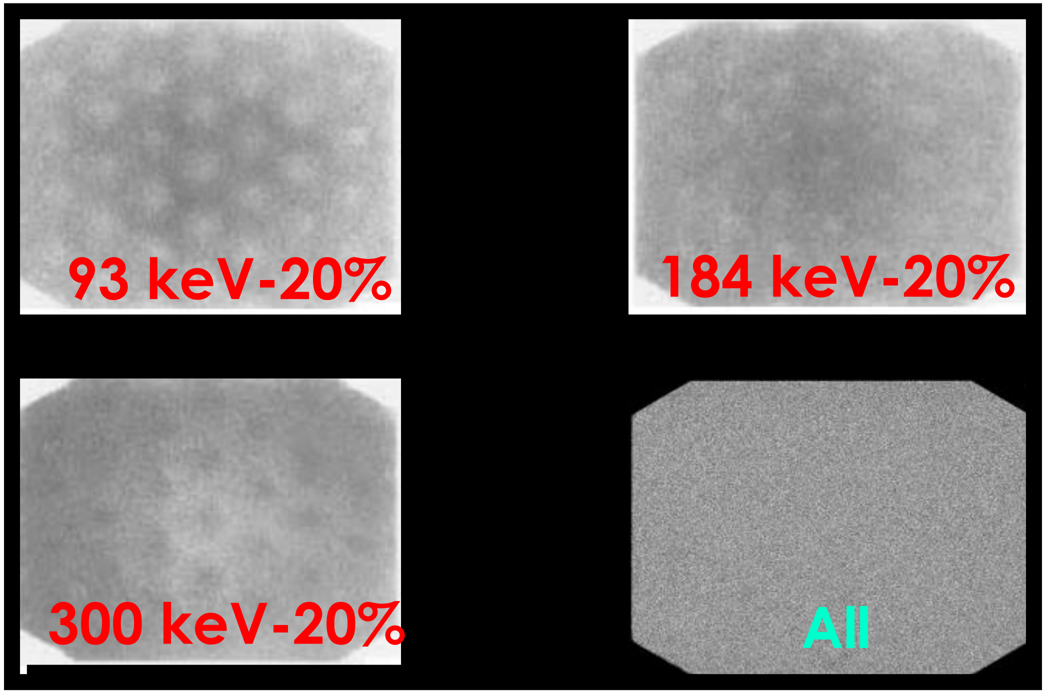
Row Differential Uniformity = 1.69%
Column Differential Uniformity = 1.55%

	Diff.	Location
Max Row	251	(42, 32)
Max Col	230	(46, 28)

UFOV or CFOV DU of 1.5 -2.0% expected

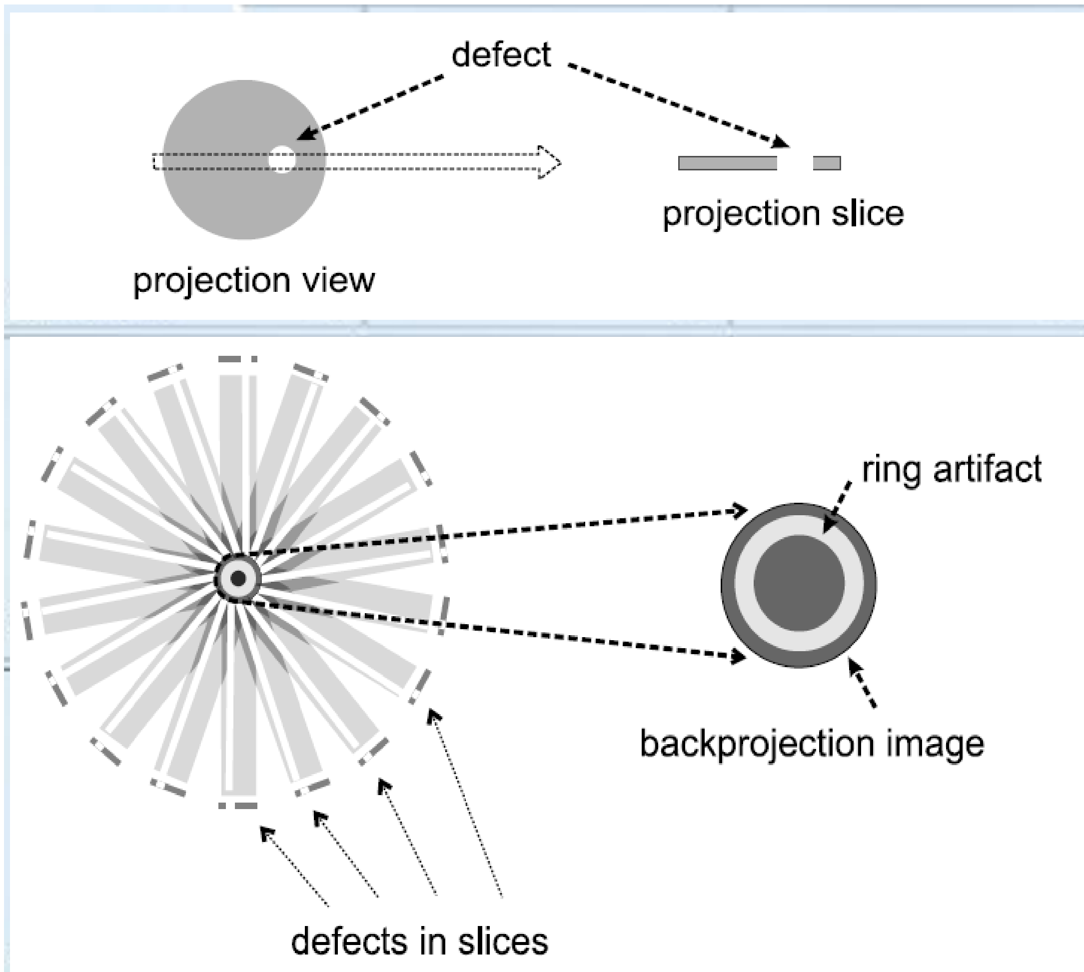
Intrinsic/Extrinsic Uniformity

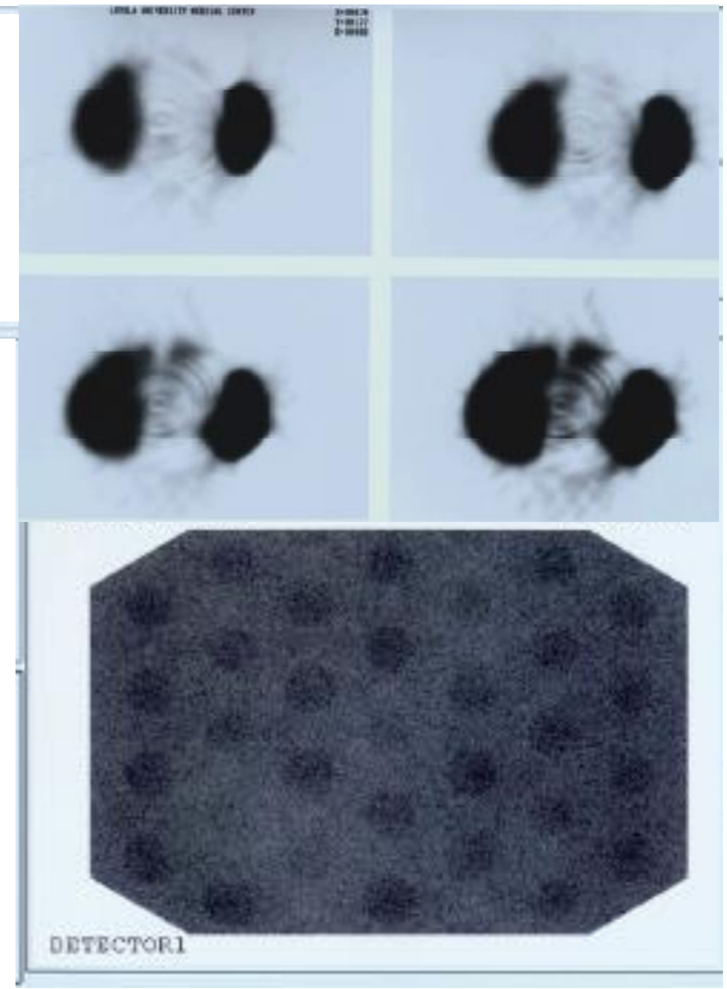
Multi Energy Radionuclides, ^{67}Ga



Each image shows a different non-uniformity. However, the sum image is uniform. Imaging is acceptable only if all three energy windows are used!

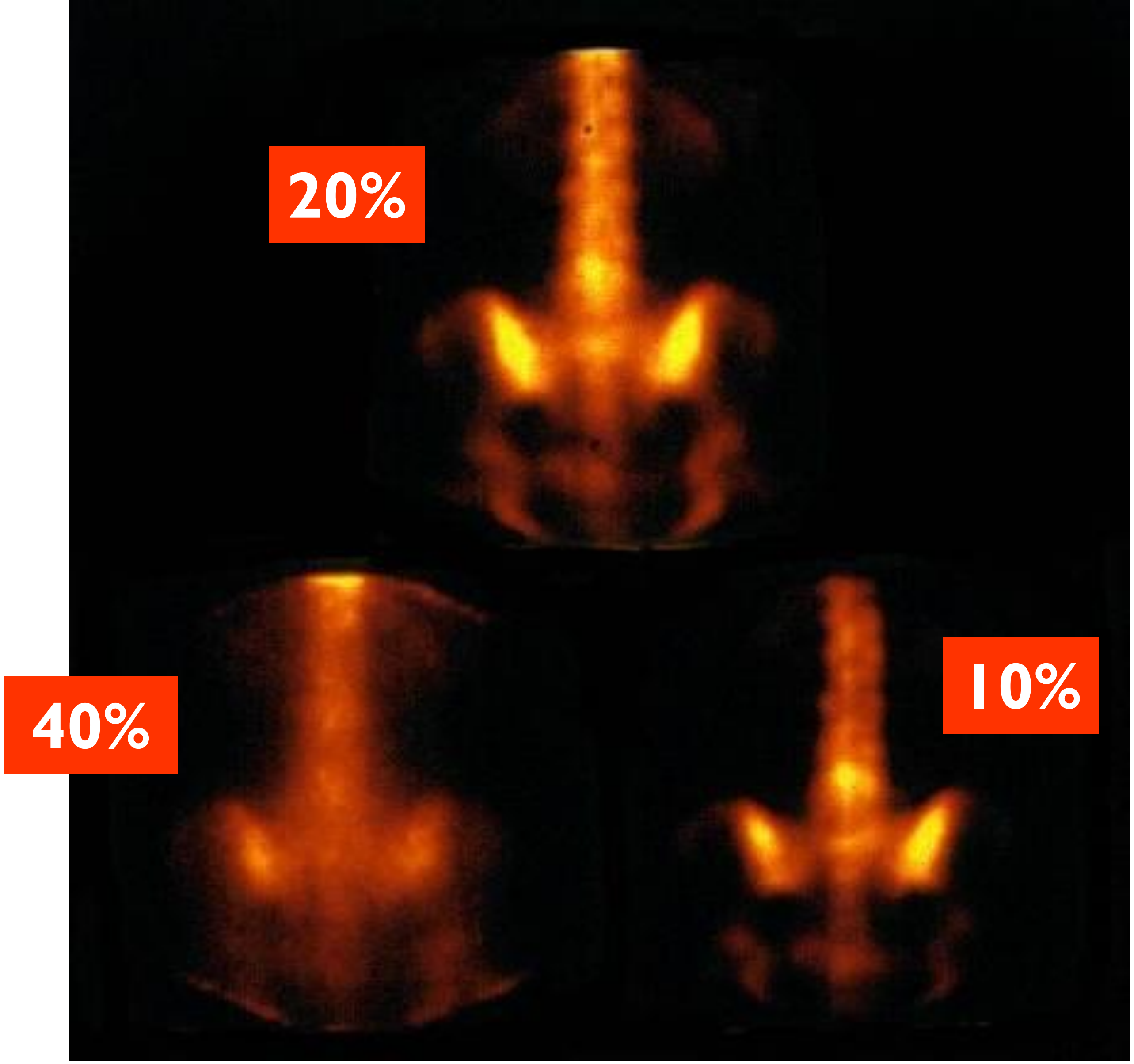
Intrinsic/Extrinsic non Uniformity Artifact





Radius of the ring equals to distance of pixel from center of rotation

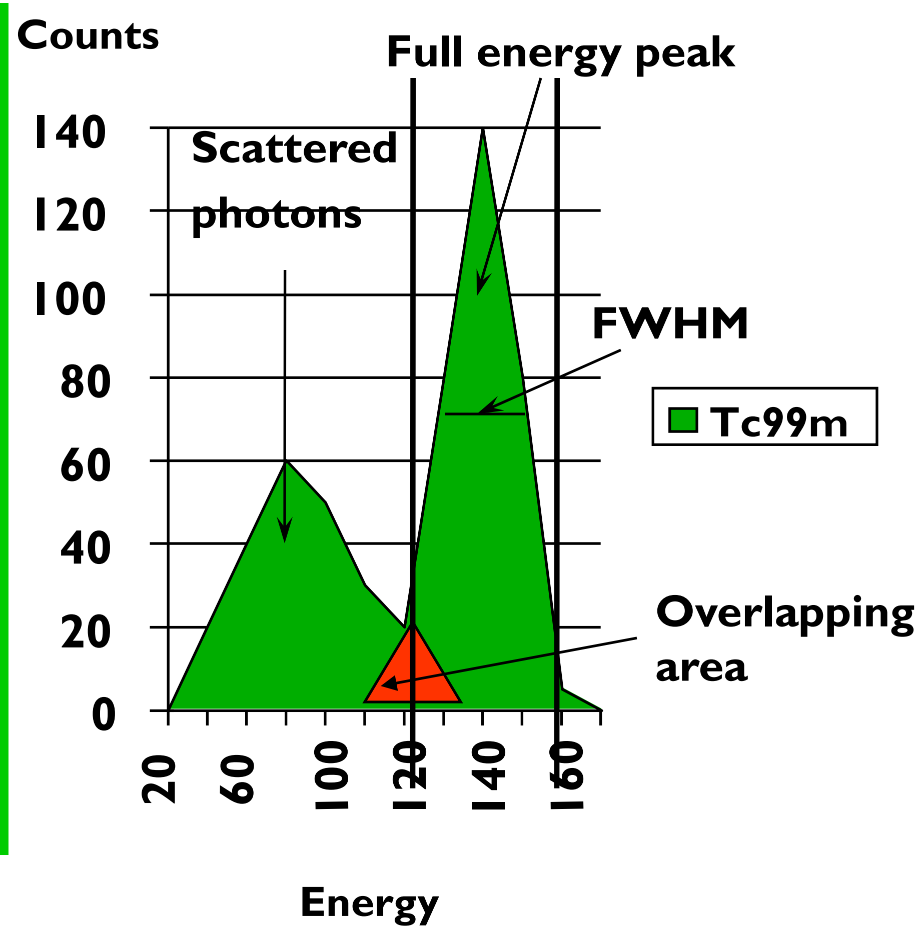
Window width



Increased window width will result in an increased number of registered scattered photons and hence a decrease in contrast

Pulse height distribution

The width of the full energy peak (FWHM) is determined By the energy resolution of the gamma camera. There will be an overlap between the scattered photon distribution and the full energy peak, meaning that some scattered photons will be registered.

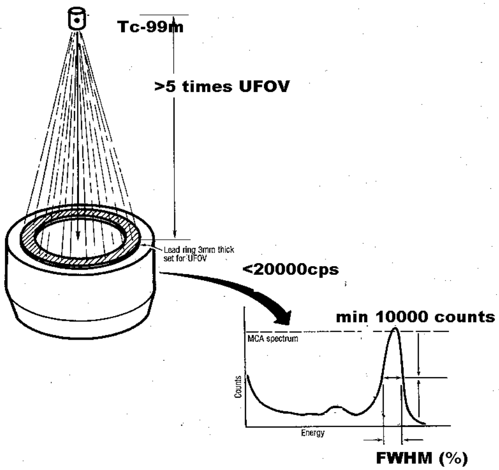


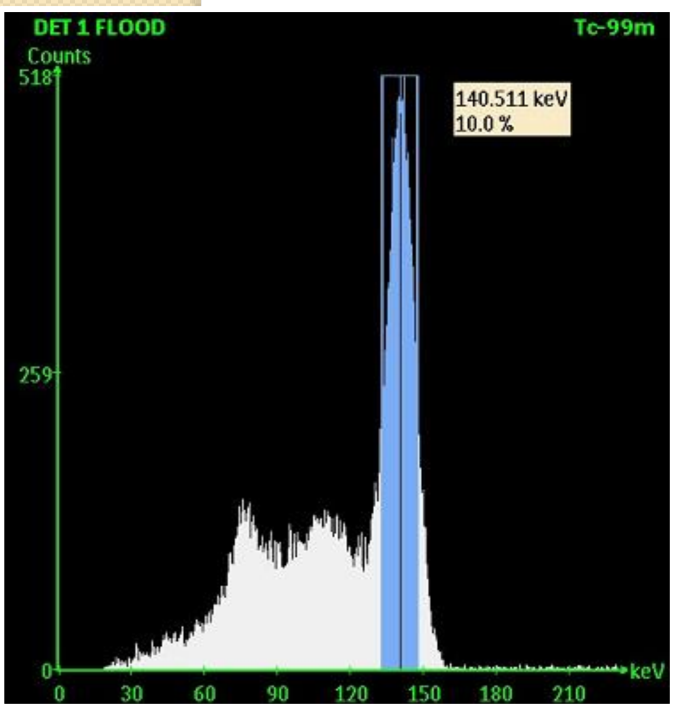
Energy Resolution

A intrinsic test with 500 micro Ci Tc-99m.

Distance of 5 UFOV again.

Little count acquisition is needed (10 k counts).





Energy resolution =

(FWHM / Peak energy) x 100

for NaI(Tl), Normal Value is 6-10%

SPATIAL RESOLUTION

SPATIAL RESOLUTION

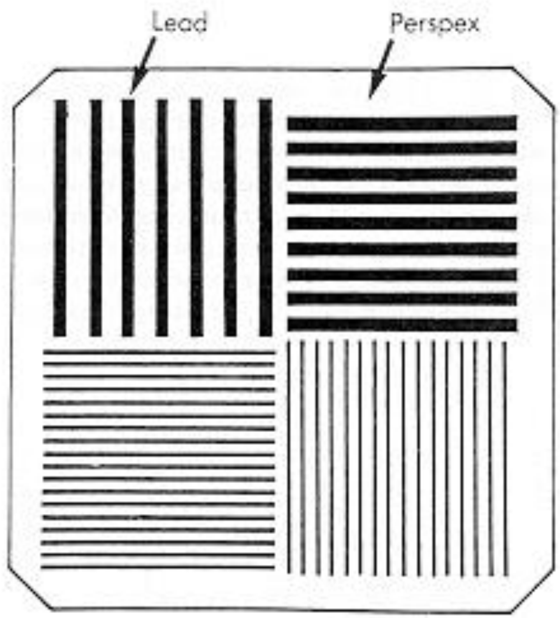
- Can be defined in terms of the amount by which a system smears out the image of a very **small point source or a very thin line of radioactivity.**
- It can be thought of as the distance by which **two small point sources must be separated to be distinguished** as a separate in the reconstructed image.

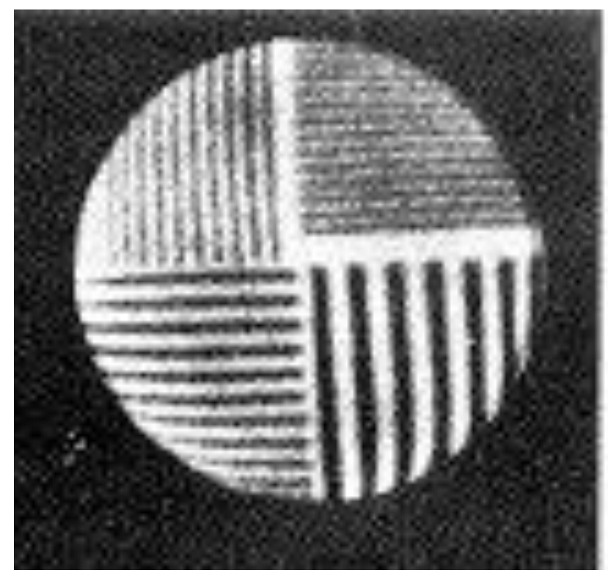
SPATIAL RESOLUTION

- It is usually measured through the use of a transmission phantom (bar phantom)
- It consists of alternating patterns in lead to produce closely spaced areas of differing activity levels, which will allow for the analysis of resolution.
- The better the spatial resolution, the better the ability to detect small abnormalities which will present themselves as different radionuclide concentrations in clinical images.

Spatial resolution

Measured with: Flood source or point source plus a Bar phantom



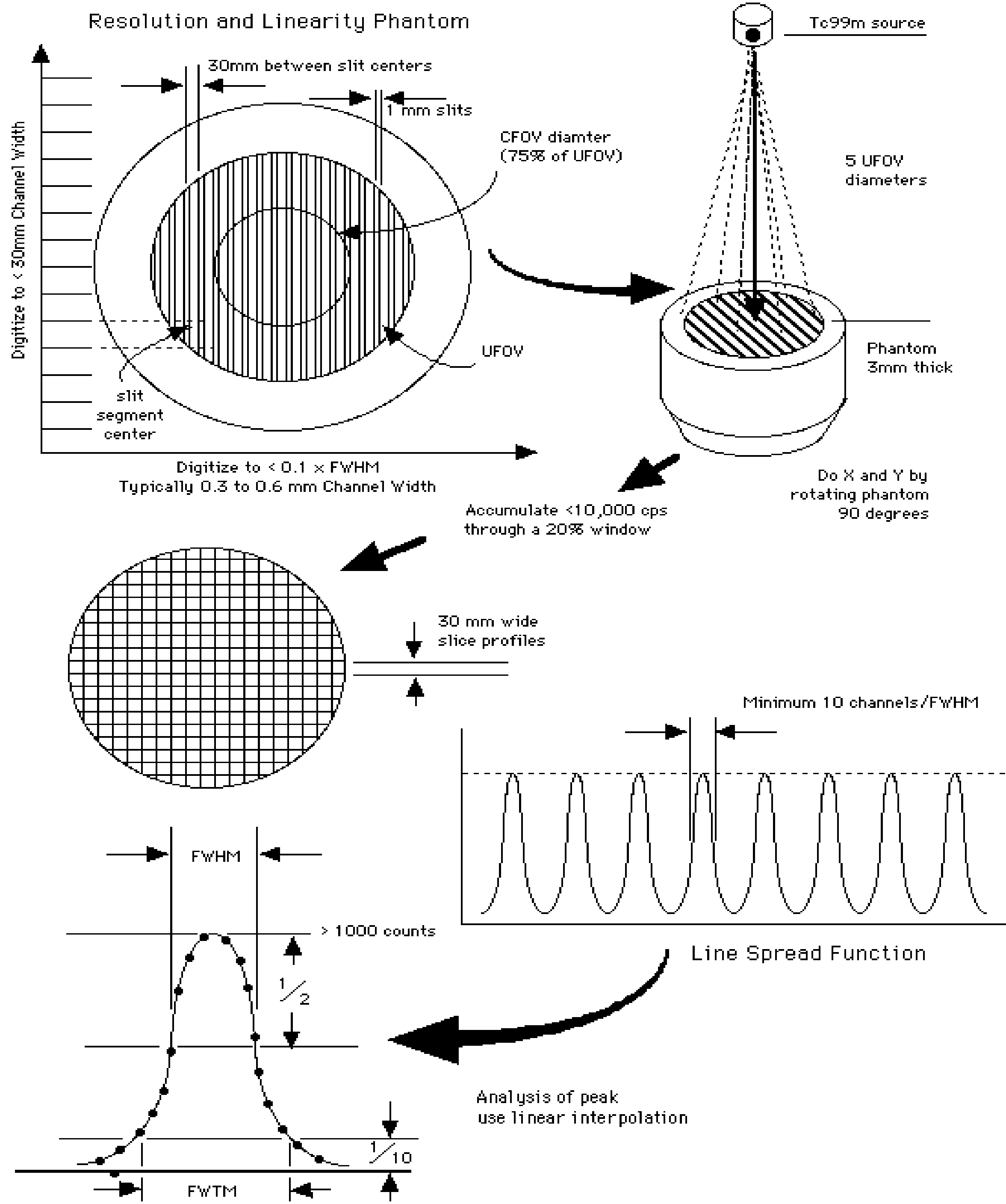


Subjective evaluation of the image

SPATIAL RESOLUTION

- Resolution patterns should be used **without a collimator** to measure intrinsic performance.
- This can be difficult or impossible along with time consuming with some multihead cameras.
- It can also be useful to assess the resolution with a **point or line source**.
- The spread of the point or line is an indication of the degree of blurring, or the loss of the resolution in the camera.
- Resolution should be **checked weekly**.

SPATIAL RESOLUTION



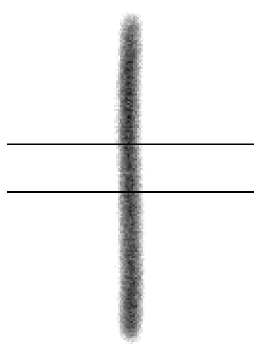
SPATIAL RESOLUTION

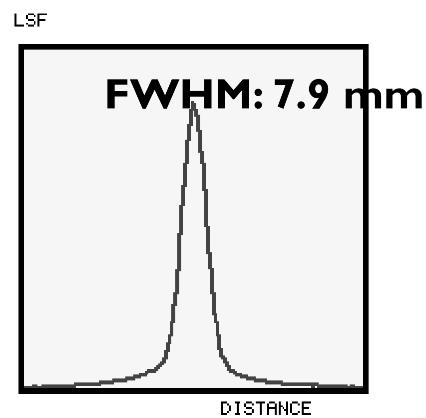
Tc-99m or other radionuclide in use

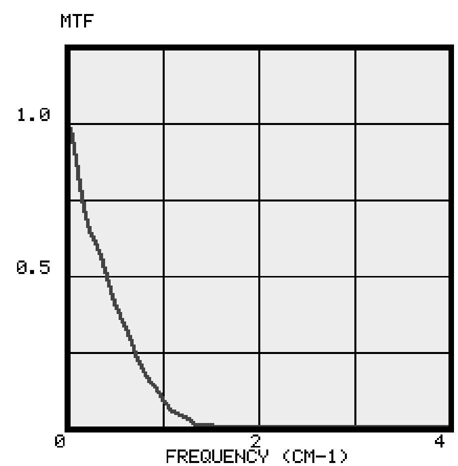
Intrinsic: Collimated line source on the detector

System: Line source at a certain distance

Calculate FWHM of the line spread function







SPATIAL RESOLUTION

Four quadrant resolution studies are usually required weekly.

To perform four quadrant studies you must rotate the barphantom 90 degrees so that all quadrants of the detector are tested.

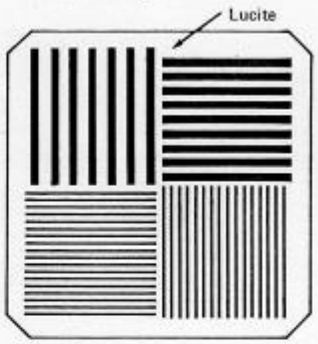
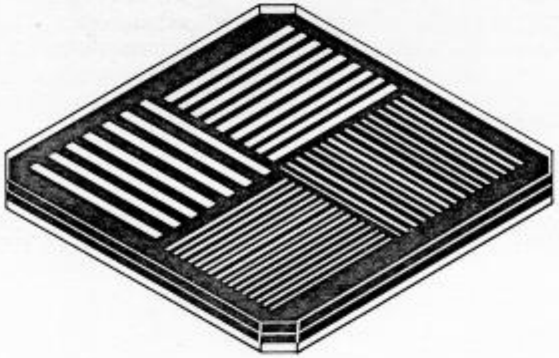


Figure A.5.a. 90° Bar quadrant phantom.



System resolution

Sum of intrinsic resolution and the collimator resolution

Intrinsic resolution depends on:

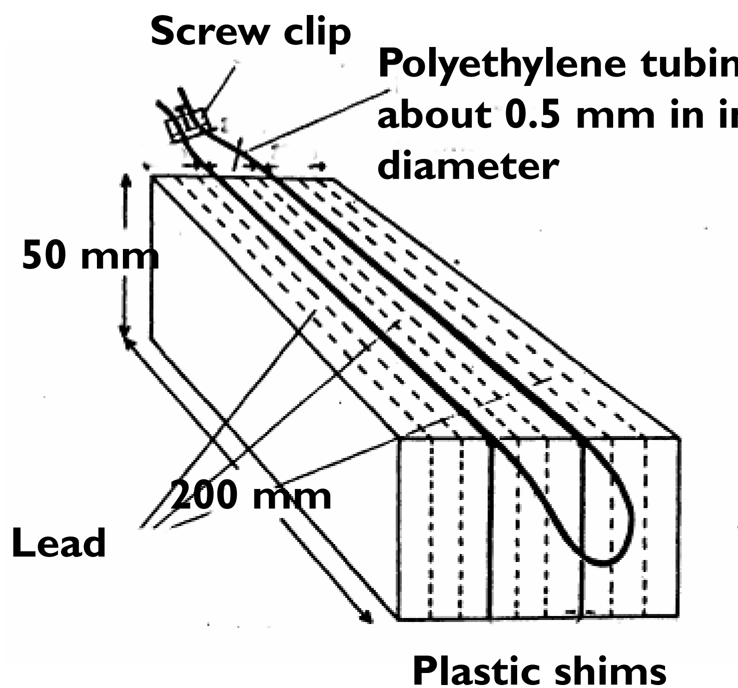
the positioning of the scintillation events (detector thickness, number of PM-tubes, photon energy)

Collimator resolution depends on:

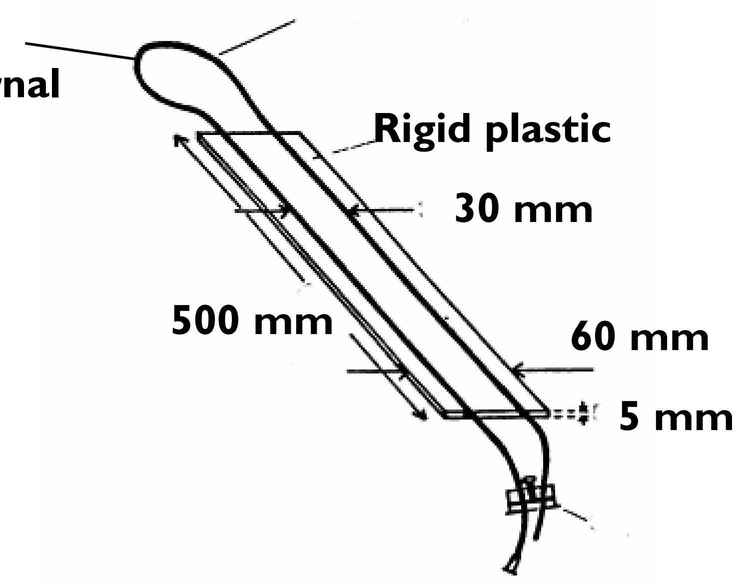
the collimator geometry (size, shape and length of the holes)

SPATIAL RESOLUTION

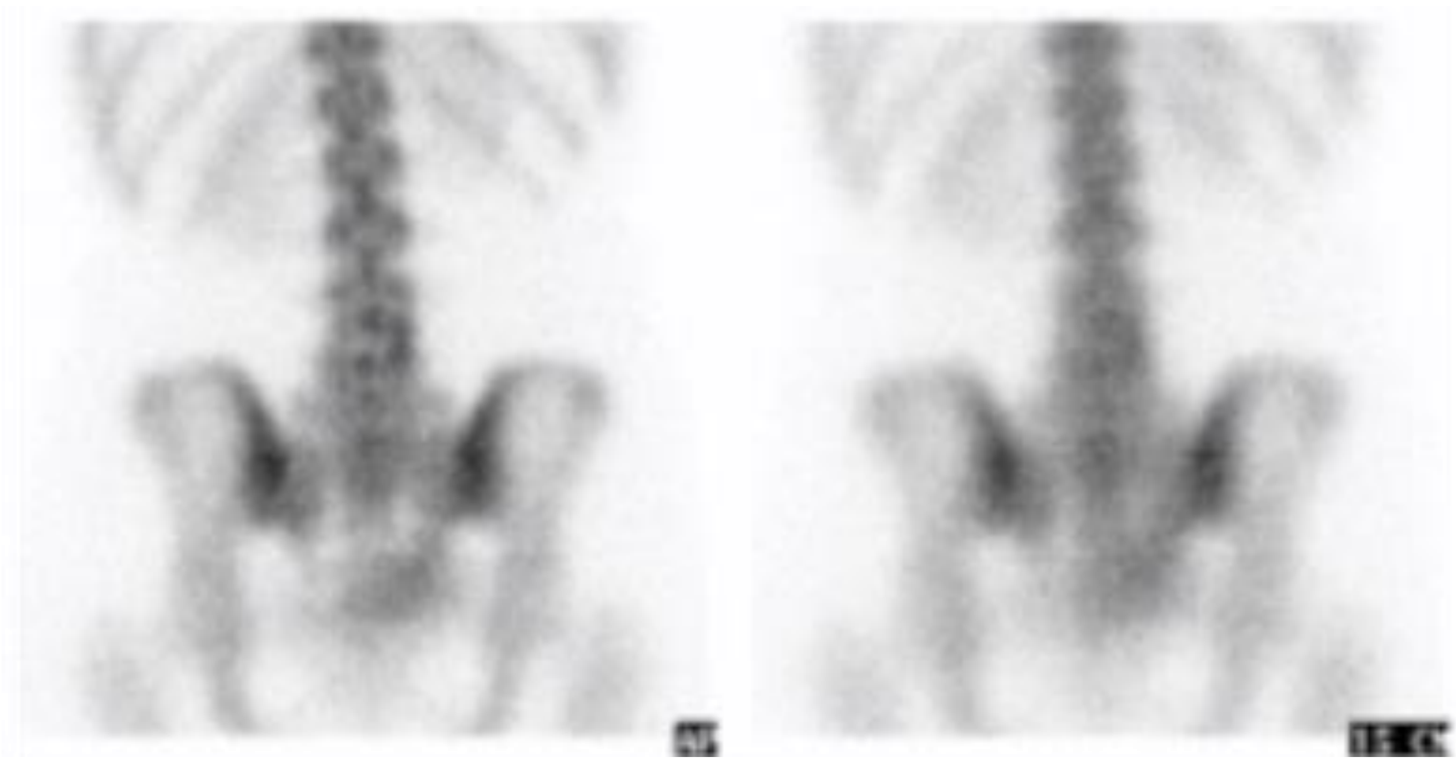
Intrinsic resolution



System resolution



SPATIAL RESOLUTION - DISTANCE

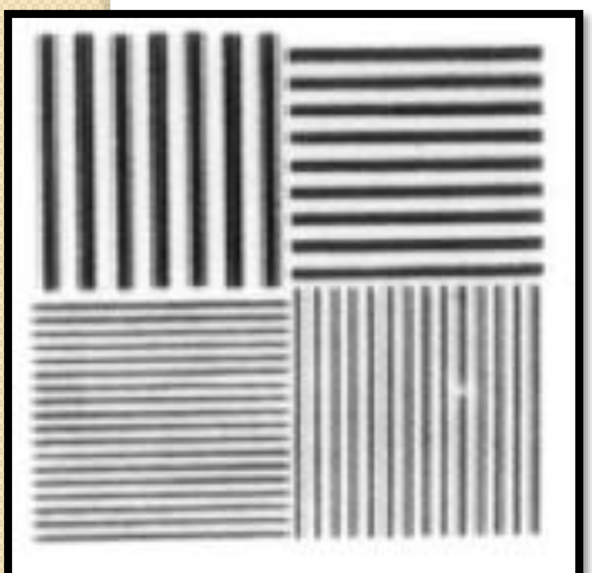


Optimal Large distance

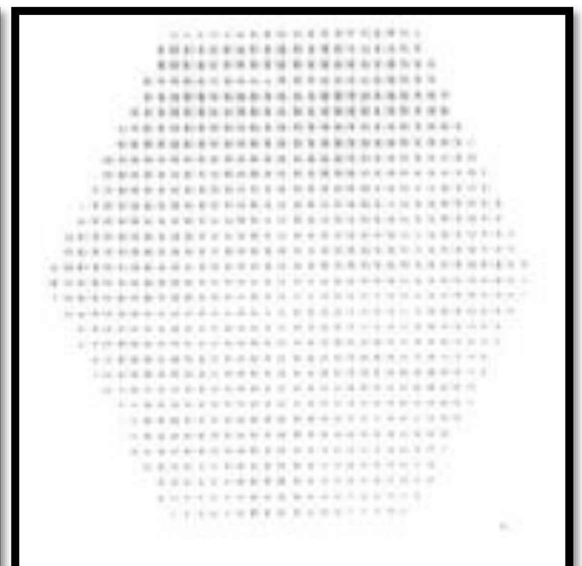
Spatial resolution and linearity

A qualitative index of resolution (performed either intrinsic or extrinsic). Small changes in intrinsic resolution **reduce image contrast**

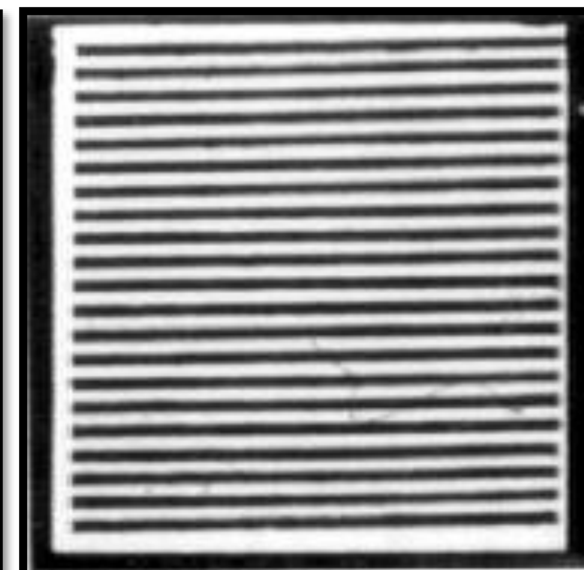
Test patterns phantoms:



Four-Quadrant Bar Phantom

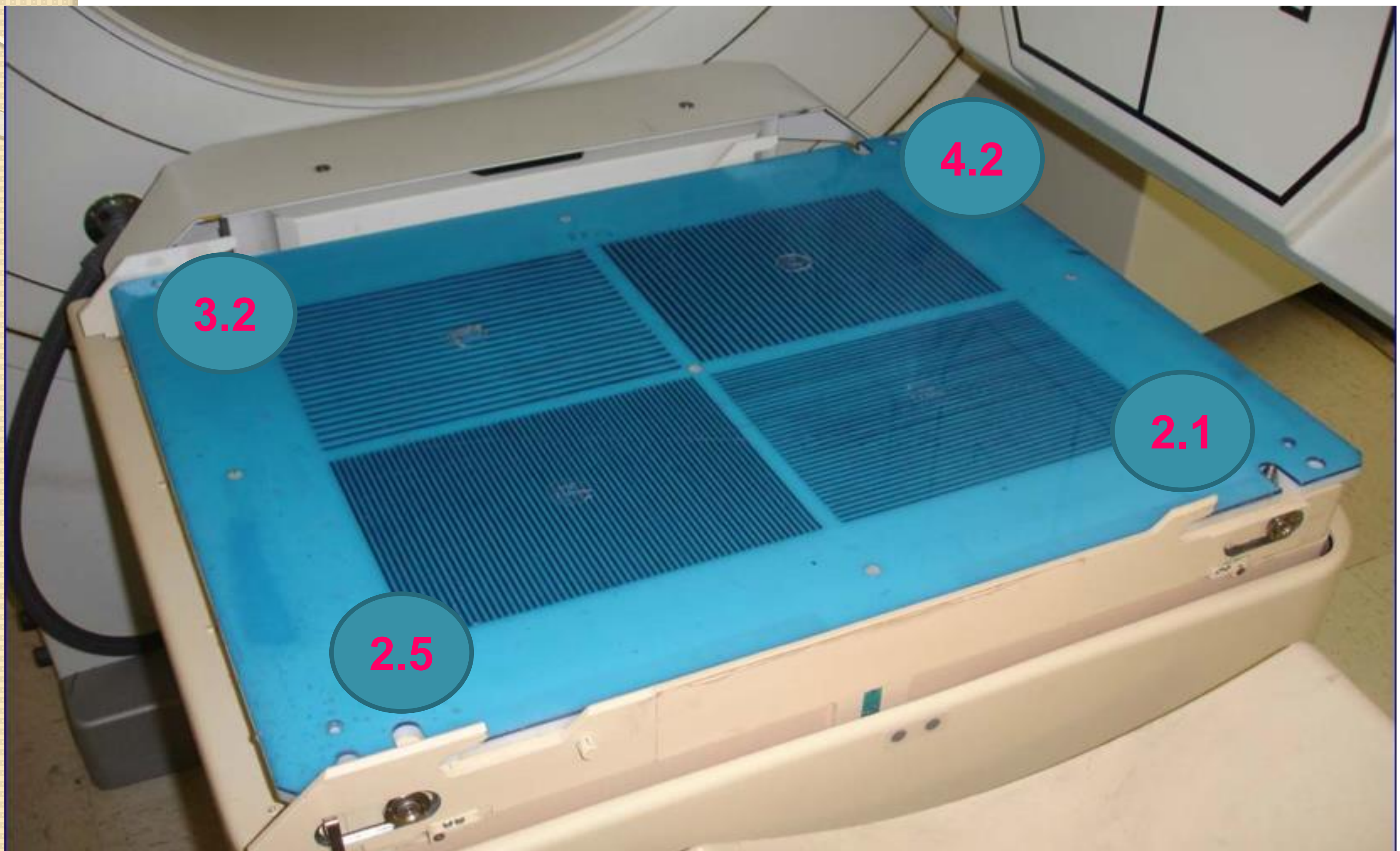


Orthogonal Hole



Parallel Line Equal Spacing (PLES)

Spatial resolution and linearity – visual




150
145
140
135
130
125
120
115
110

Spatial resolution and linearity

System resolution tends to be a **very stable** parameter

Intrinsic:

Attendant risk to the crystal

Extrinsic:

Moiré patterns (interplay of bar pattern & collimator lead septa)

Intrinsic Spatial resolution and linearity

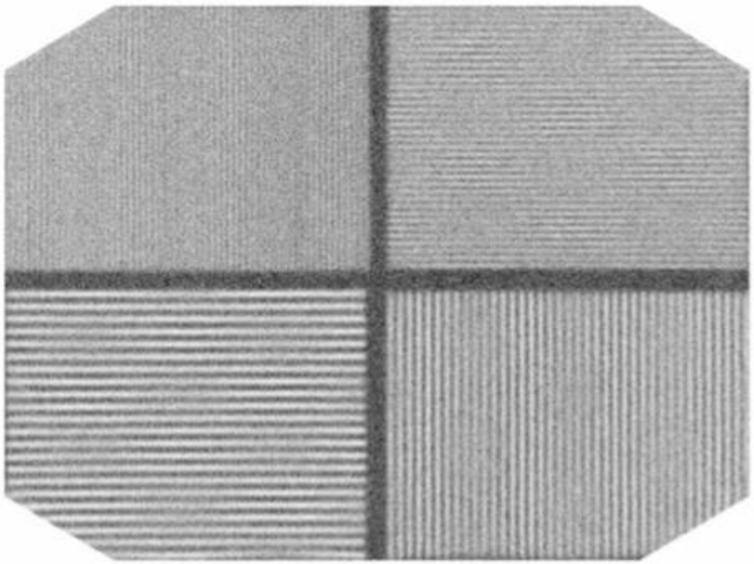
Nearly the Same as Intrinsic Uniformity test.

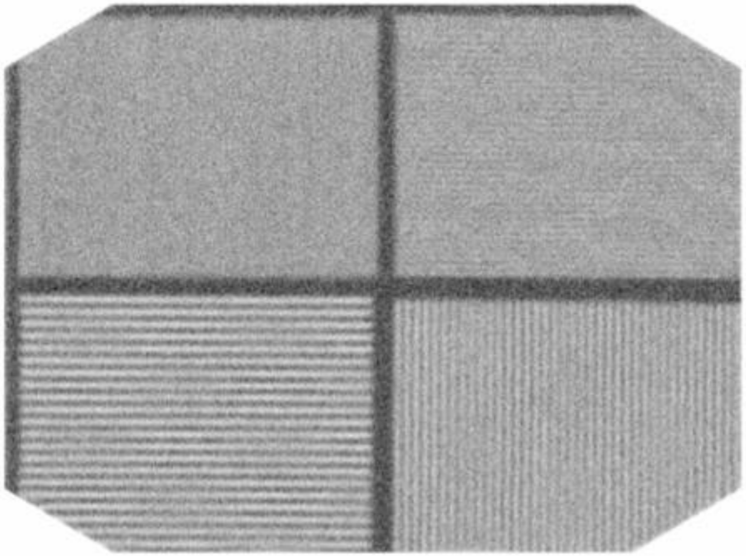
1 mCi Tc-99m in **5 UFOV** distance from detector.

5-10 million counts with **less than 30kcps** count rate acquired in a **512x512** matrix size.

Note:
Intrinsic resolution will be **1.75 times** the distinguishable smallest bars in the final image.

Intrinsic Spatial resolution





Correct use of these phantoms requires that all images be compared with a reference image (e.g. acceptance test)

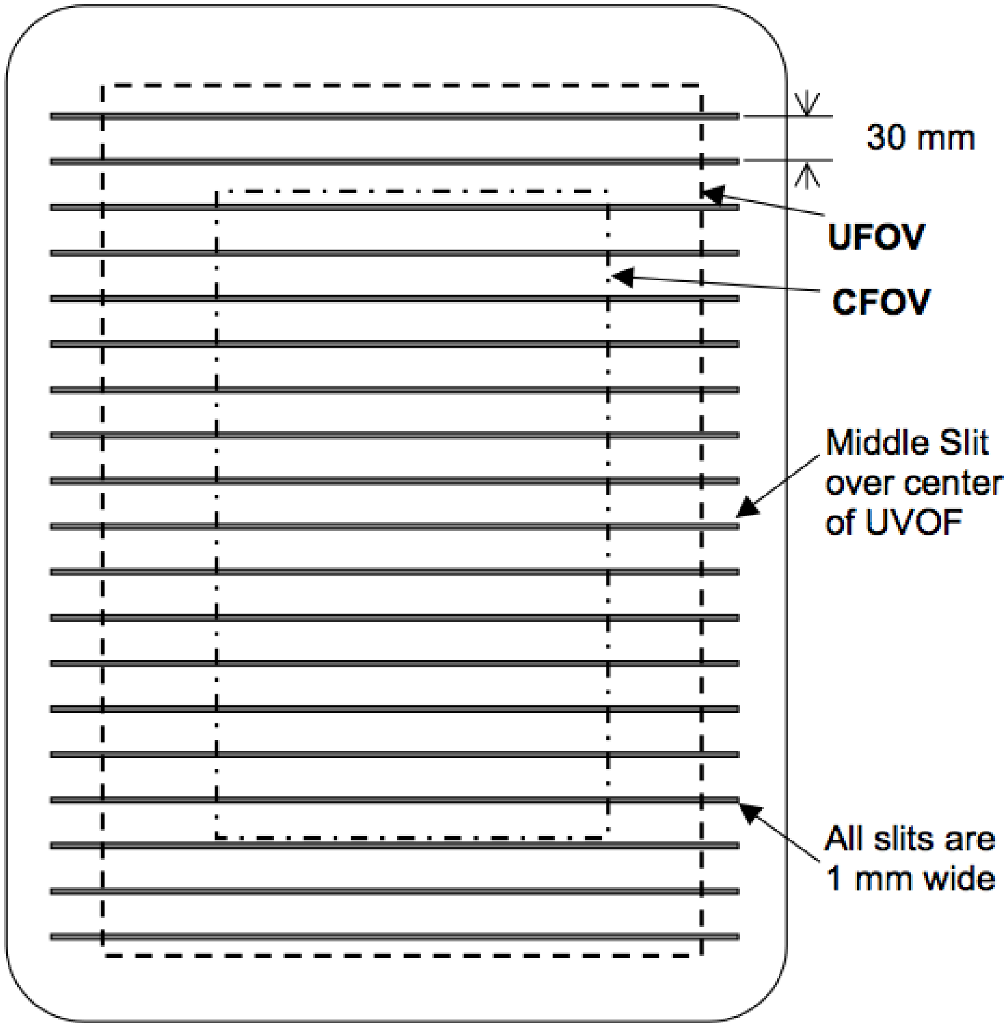
Intrinsic Spatial Resolution & linearity (ISRL)

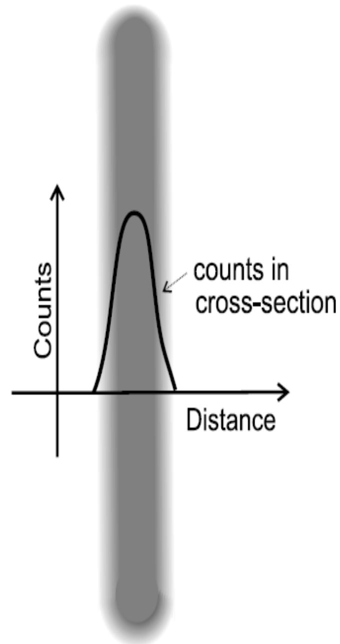
5 mCi Tc-99m

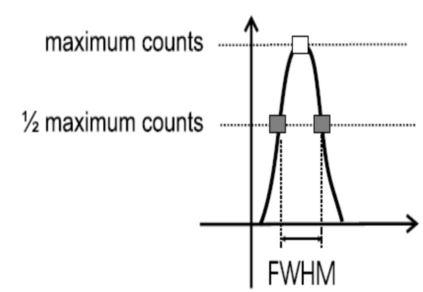
5-10 million counts

30kcps count rate

1024x1024 matrix size



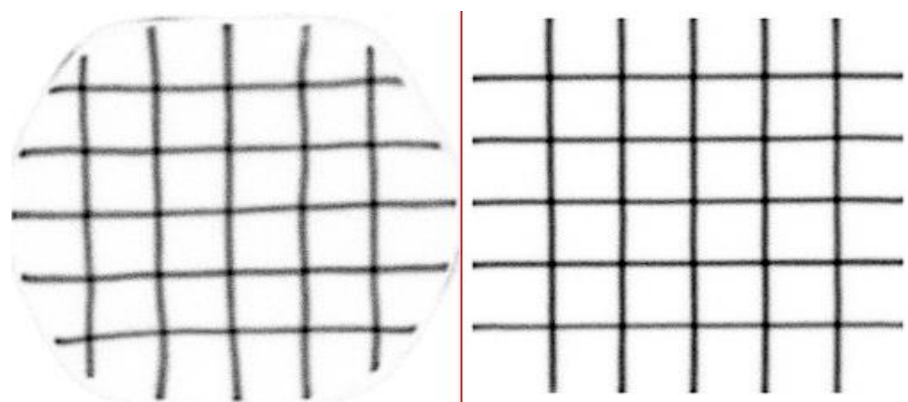




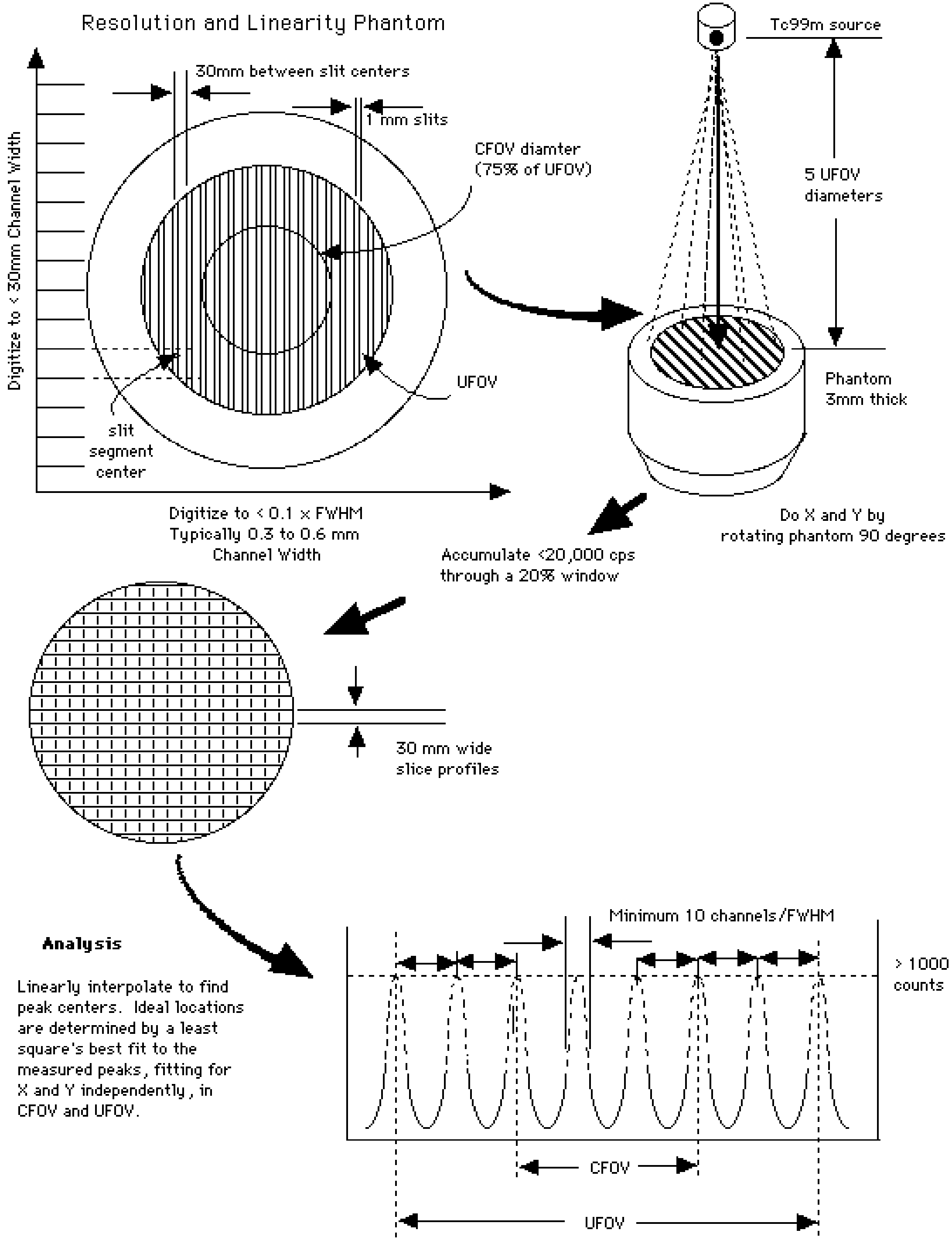
LINEARITY

- The ability to reproduce **a linear activity source as linear** in the image.
- A phantom with either an arrangement of **bars or holes** is usually used.
- The **image produced** should look exactly **like the phantom** that was used.

- **For example:**
  - straight lines should be reproduced as straight lines and holes should be reproduced as holes



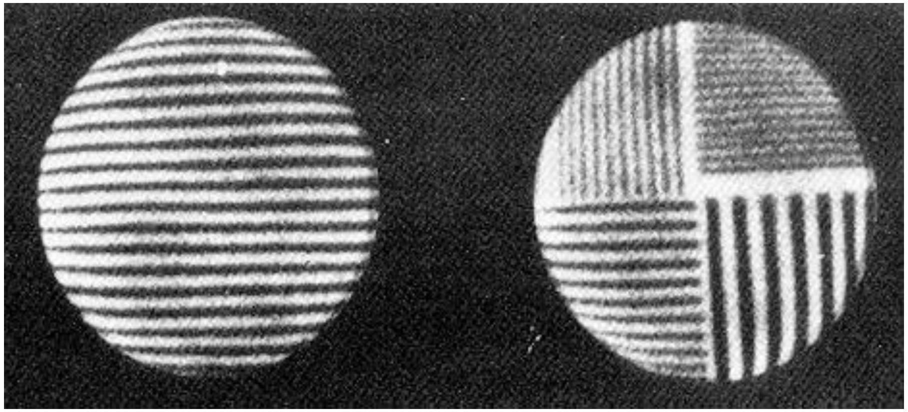
LINEARITY


Resolution and Linearity Phantom
30mm between slit centers
1 mm slits
CFOV diamter
(75% of UFOV)
Digitize to < 30mm Channel Width
UFOV
slit
segment
center
Digitize to < 0.1 × FWHM
Typically 0.3 to 0.6 mm
Channel Width
Tc99m source
5 UFOV
diameters
Phantom
3mm thick
Do X and Y by
rotating phantom 90 degrees
Accumulate <20,000 cps
through a 20% window
30 mm wide
slice profiles
Analysis
Linearly interpolate to find peak centers. Ideal locations are determined by a least square's best fit to the measured peaks, fitting for X and Y independently, in CFOV and UFOV.
Minimum 10 channels/FWHM
> 1000
counts
CFOV
UFOV

LINEARITY

Flood source or point source (Tc-99m)
Bar phantom or orthogonal-hole phantom

1. Subjective evaluation of the image.
2. Calculate absolute (AL) and differential (DL) linearity.



AL: Maximum displacement from ideal grid (mm)
DL: Standard deviation of displacements (mm)

Corrections (linearity, energy, uniformity)

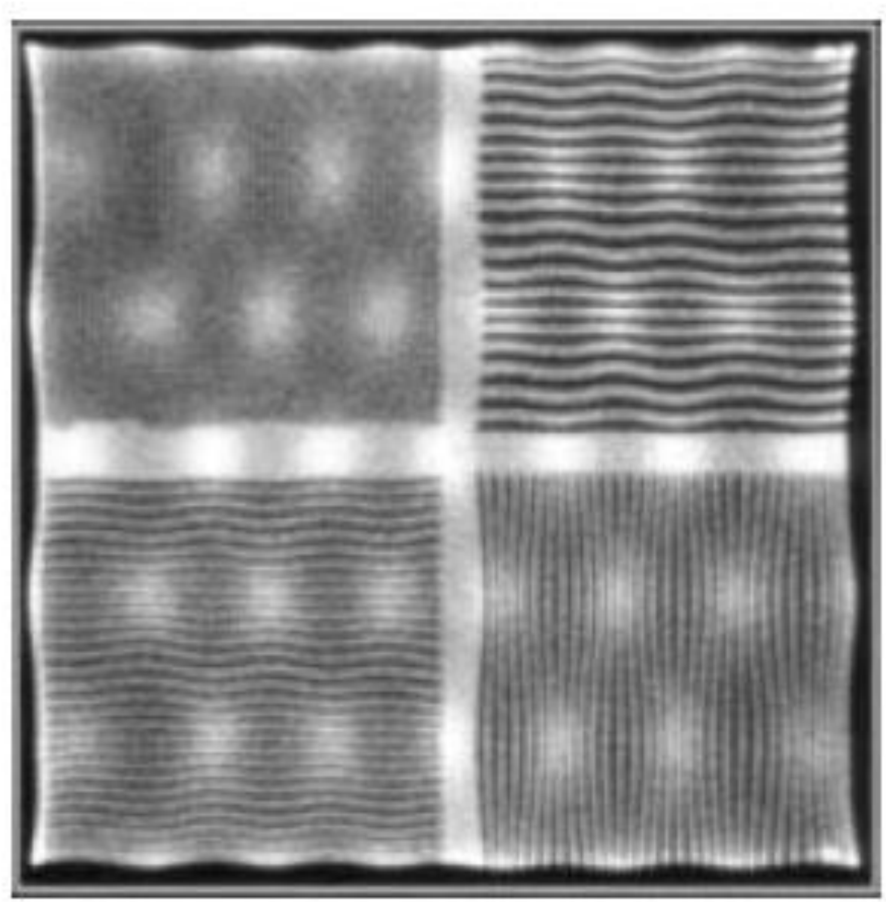


Illustration of the effect of no linearity or energy corrections

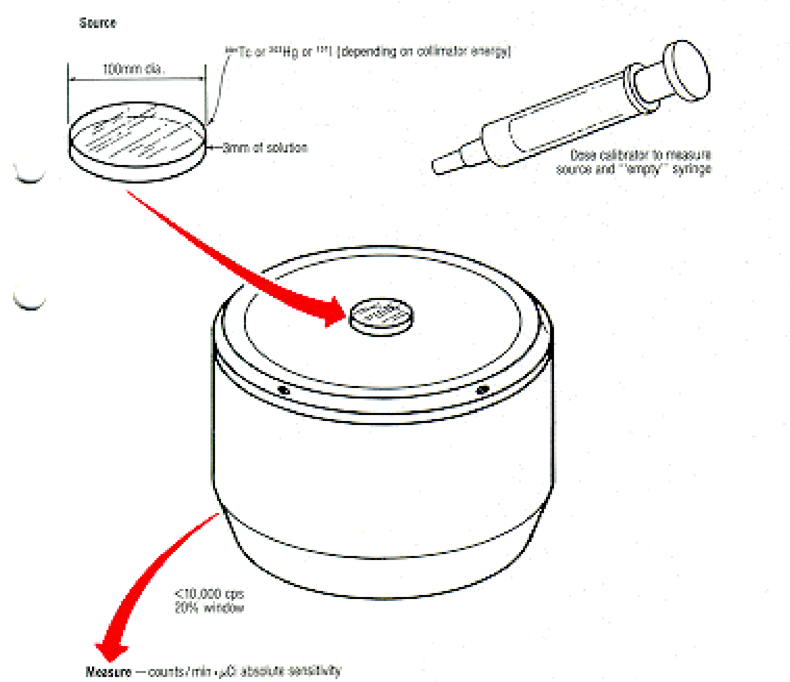
LINEARITY

- Linearity should be checked weekly
- **Linear defects** in a flood field are usually the result of a cracked crystal and less likely the result of a **collimator defect**.
- Linearity is checked along with spatial resolution with the bar phantoms

SENSITIVITY

- Expressed as **counts/min/MBq** and should be measured <u>for each collimator</u>

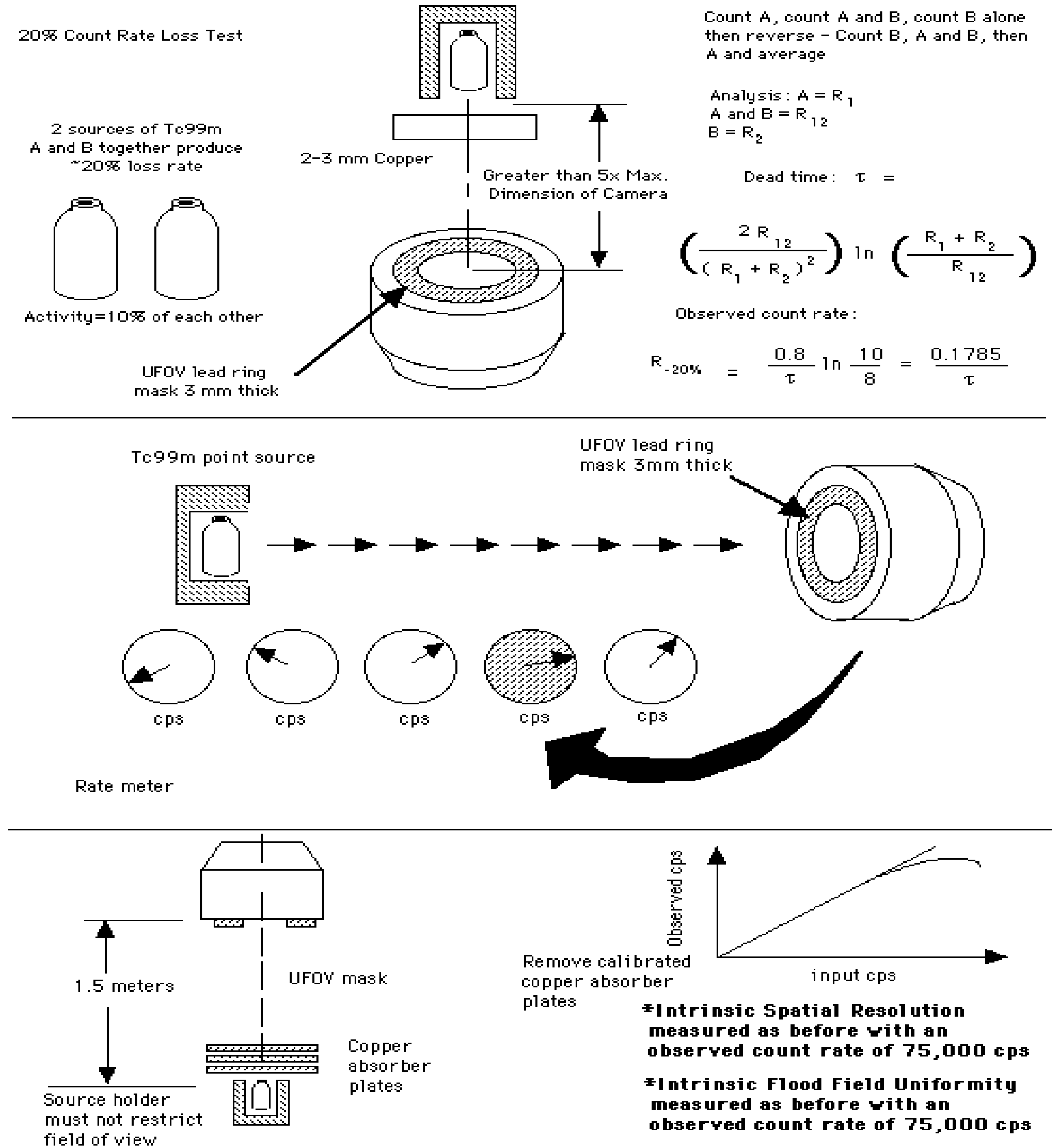
- Important to observe with multi-head systems that variations among <u>heads do not exceed 3%</u>



Count Rate Performance

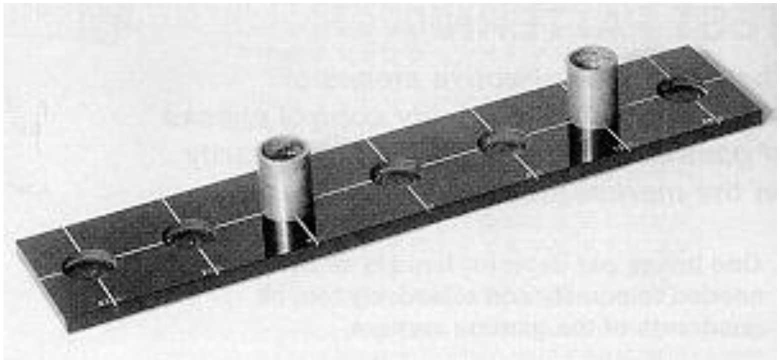
- Performed to **ensure that the time to process** an event is sufficient to maintain **spatial resolution and uniformity in clinical images** acquired at high-count rates

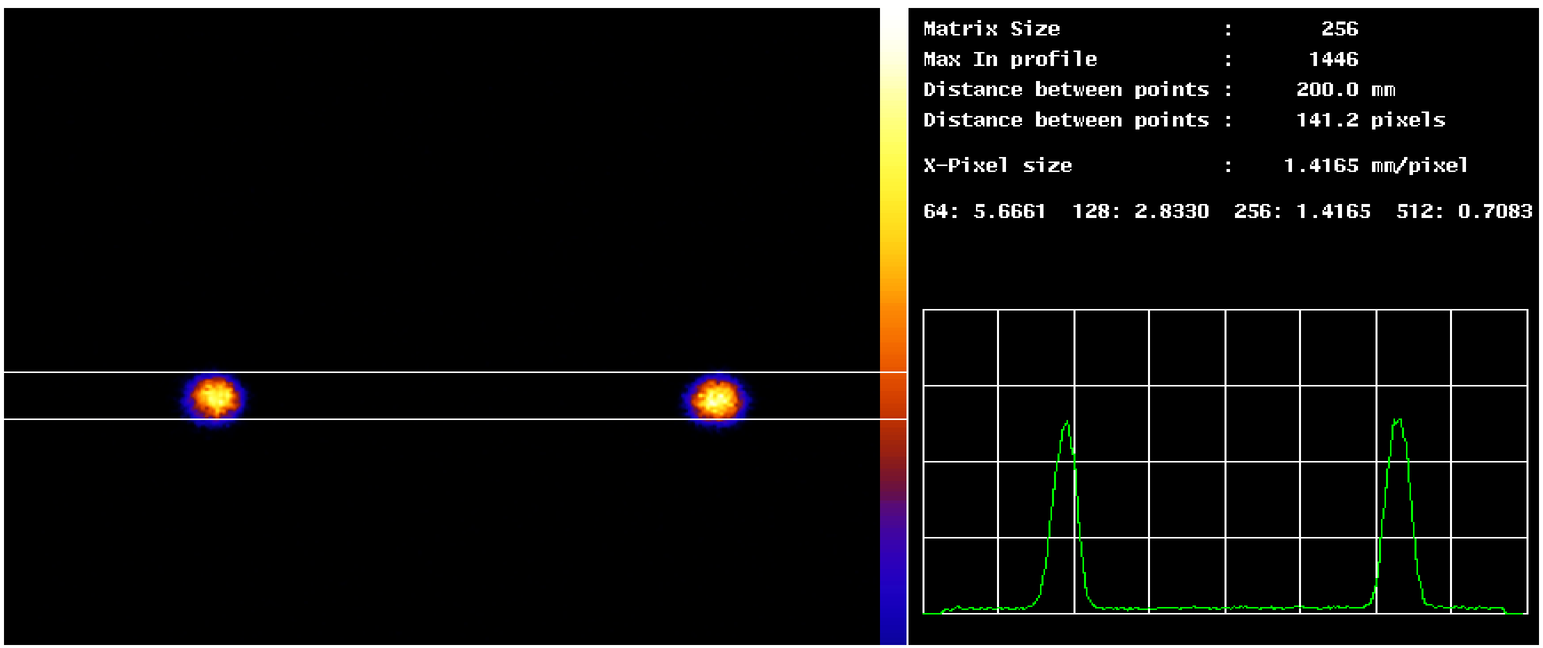
Count Rate Performance



Pixel size

Pixel size





Pixel Size Phantom:

Use a small plate of acrylic, with a 1.2 mm x 1.2 mm hole in the center.

Image the phantom in different perpendicular positions with 10 cm distance from center of the detetor.

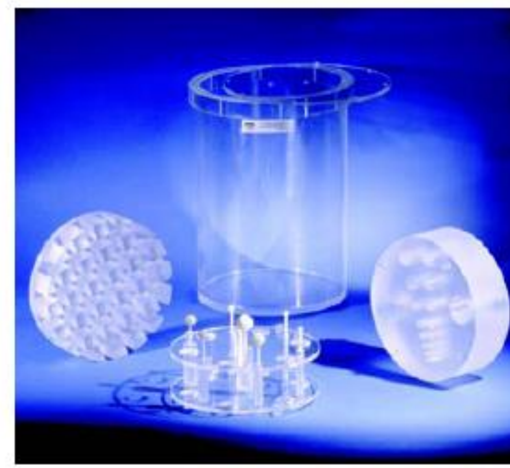
Acquire 50 kcounts within a 1024 x 1024 matrix size, LEGP collimator.

SPECT

- SPECT uniformity
- Uniformity calibration correction
- Spatial resolution
- Centre of rotation (COR)
- Image alignment in *y* for multi-head SPECT systems
- Detector head tilt

SPECT performance

- Spatial resolution
- X- and Y-magnification factors and multienergy spatial registration
- Alignment of projection images to axis-of-rotation



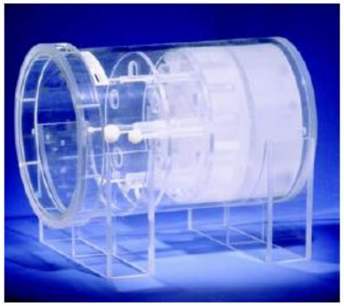
- Uniformity
- Camera head tilt

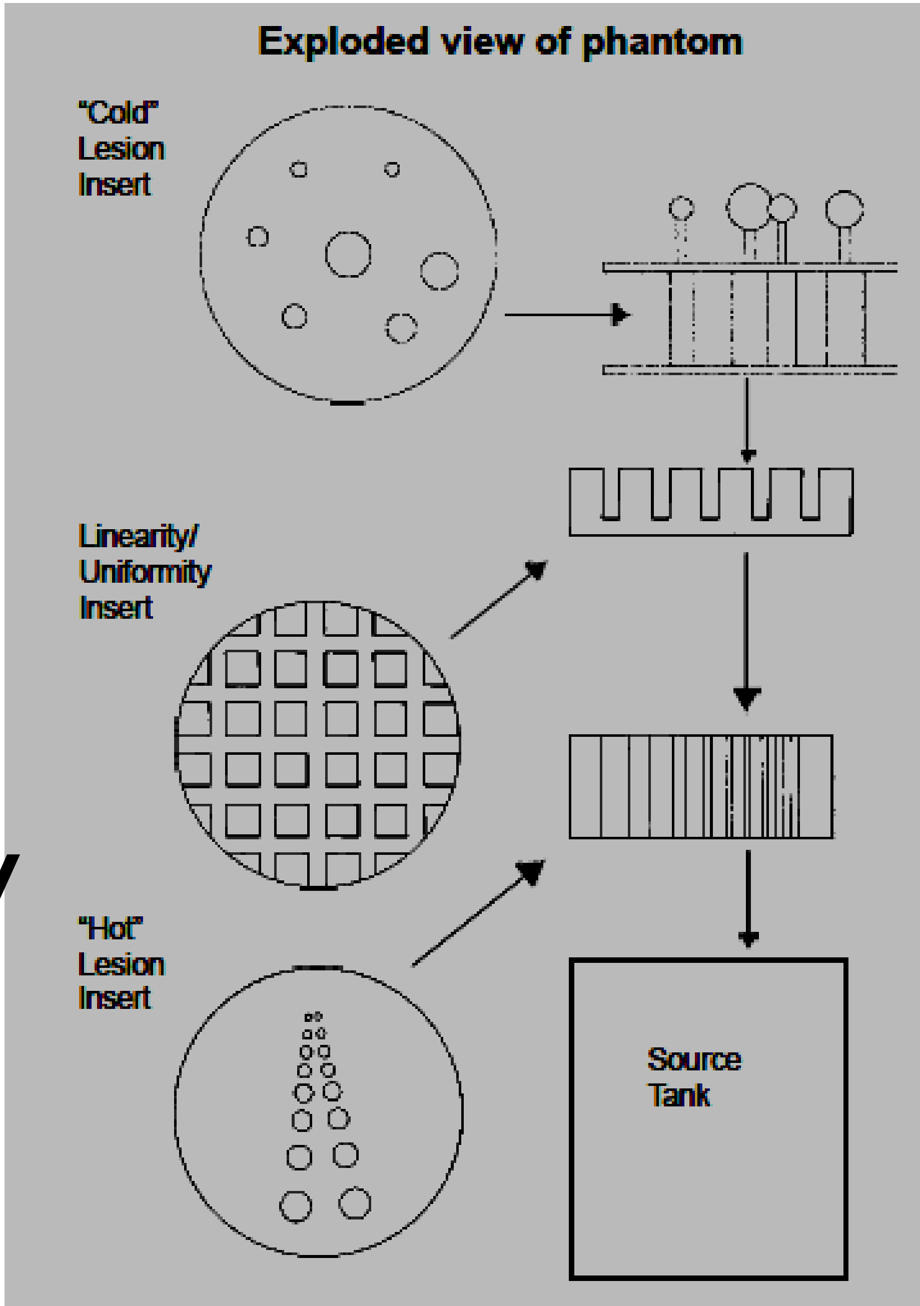
SPECT performance

✓**Reconstruction spatial resolution**

✓**Reconstruction spatial linearity**

✓**Reconstruction flood field uniformity**

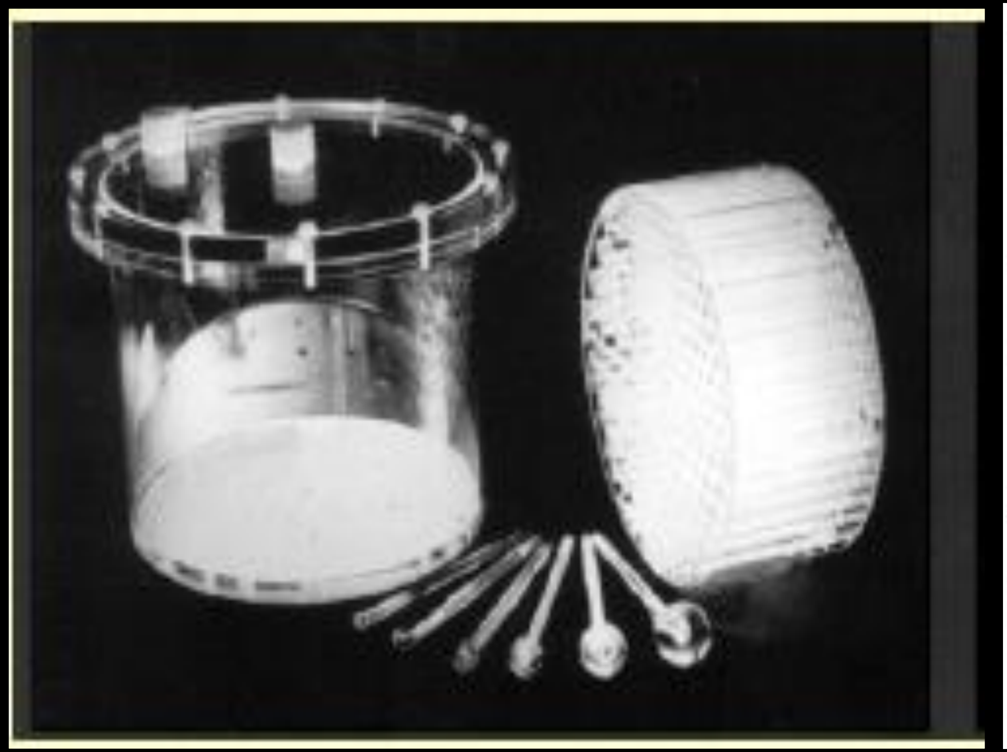


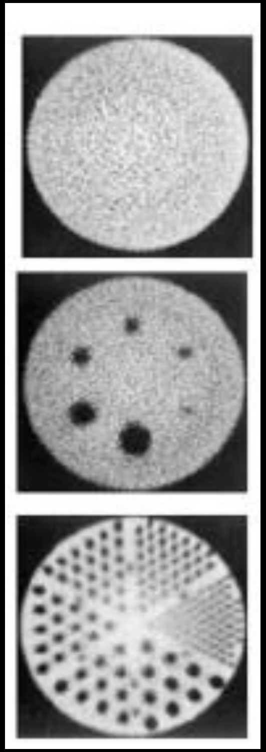


Overall system performance

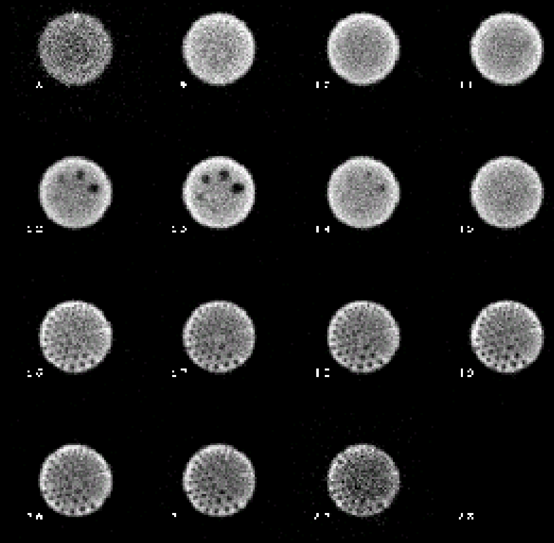
An overall assessment of system performance can be obtained by imaging a suitable tomographic phantom filled with a mixture of water and Tc-99m.

Jaszczak SPECT Phantom



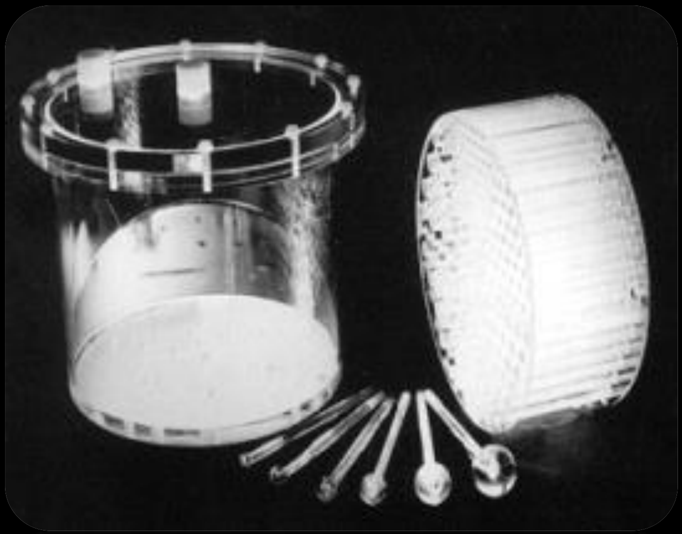


Overall system performance



The phantom is imaged under ideal conditions:

10 mCi Tc-99m
Minimum radius of rotation,
high resolution collimation,
128 x 128 matrix,
120 views
high total counts (**30-50** million)
minimum smoothing recon.



Overall system performance

Thick slices through the **uniform section** of the phantom can be used to evaluate **uniformity** (Ring Artifact).

Thicker slices through the **resolution elements** can be used to determine **tomographic resolution** and **contrast**

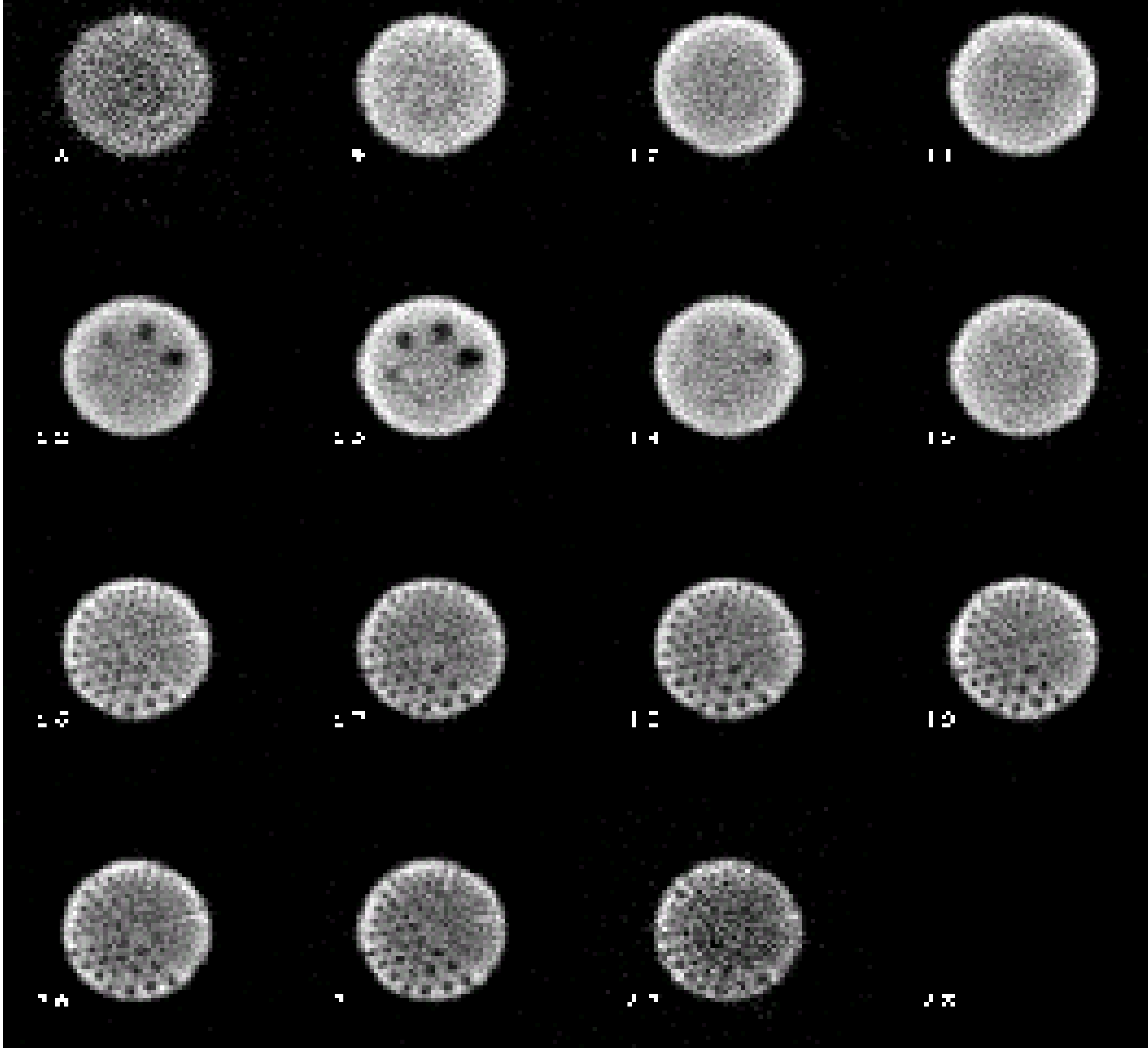
(Look for consist transaxial resolution else acquire new COR).

Uniformity (3-5 slices)

Contrast (3 slices)

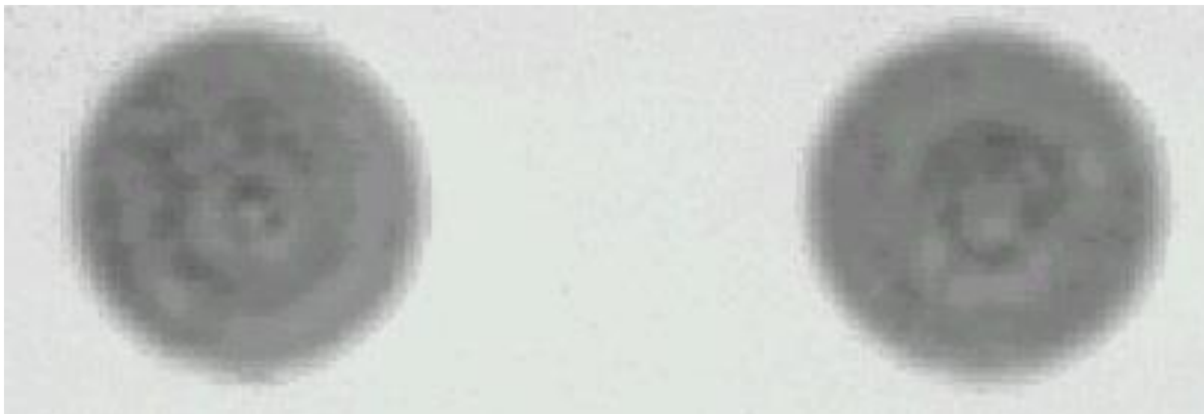
Resolution (8-12 slices)

SPECT PERFORMANCE



TOMOGRAPHIC UNIFORMITY

Tomographic uniformity is the uniformity of the reconstruction of a slice through a uniform distribution of activity



SPECT phantom with 200-400 MBq Tc99m aligned with the axis of rotation. Acquire 250k counts per angle. Reconstruct the data with a ramp filter

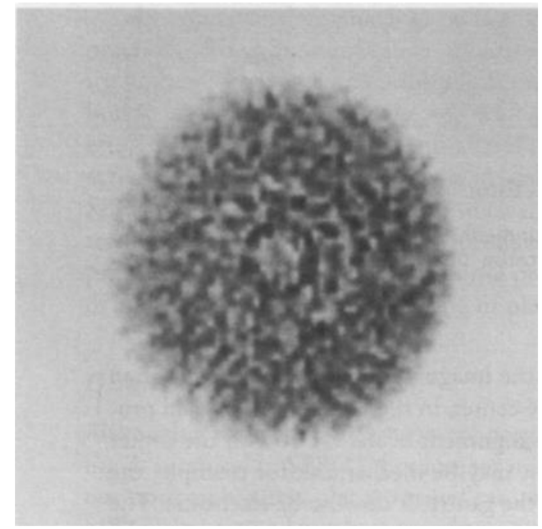
Uniformity

- Nonuniformities that are not apparent in low-count daily uniformity studies can cause significant artifacts in SPECT
- Artifact appears in **transverse images** as **a ring centered** about the AOR
- High-count uniformity images used to **determine pixel correction factors**
  - At least 30 million counts for 64 x 64 images
  - At least 120 million counts for 128 x 128 images

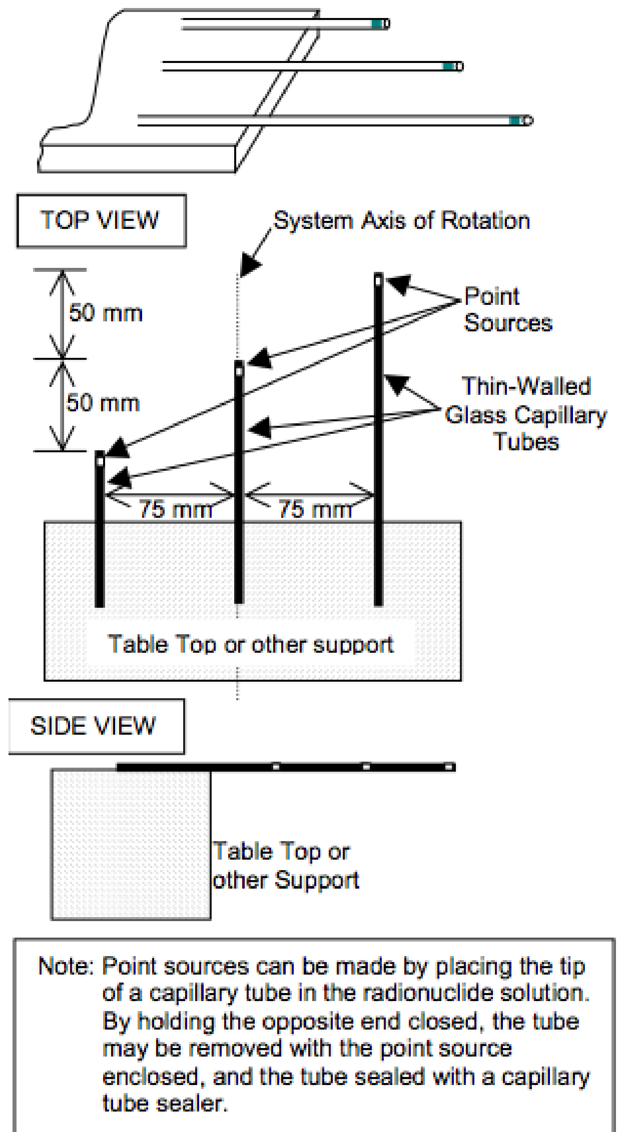
Uniformity

Image of a cylinder filled with a uniform radionuclide solution, showing a **ring artifact due to a nonuniformity**.

Artifact is the dark ring toward the center.



TOMOGRAPHIC RESOLUTION



Method 1: Measurement with the Jaszczak phantom, with and without scatter (phantom filled with water and with no liquid)

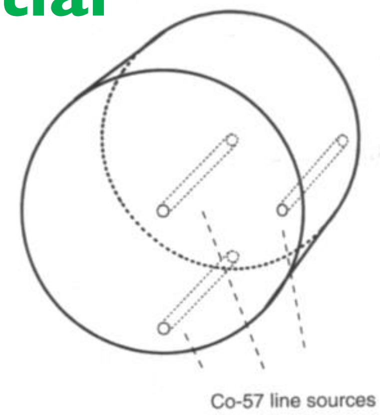
Method 2: Measurement with a Point or line source free in air and Point or line source in a SPECT phantom with water

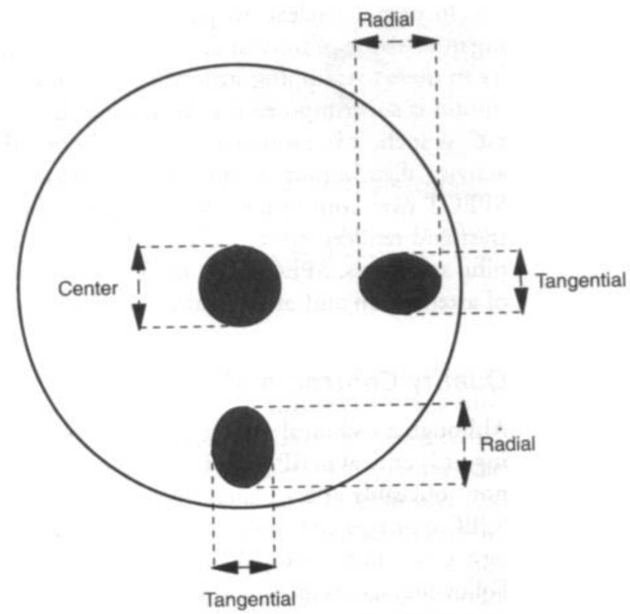
Spatial resolution

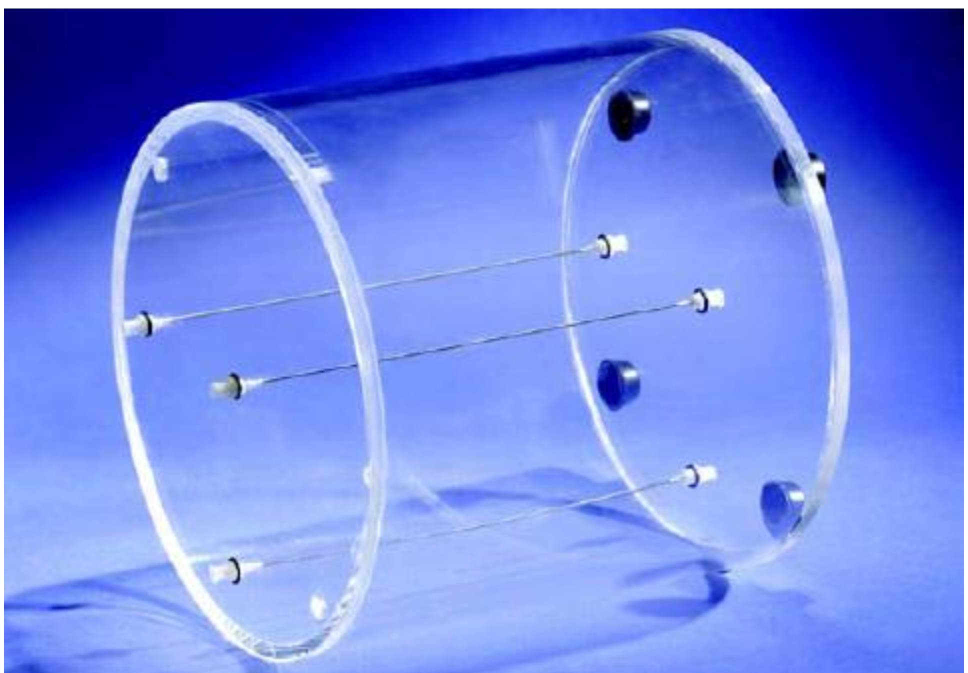
- Can be measured by acquiring a SPECT study of a line source (**capillary tube filled with a solution of Tc-99m**, placed parallel to axis of rotation)
- National Electrical Manufacturers Association (NEMA) specifies a cylindrical plastic water-filled phantom, 22 cm in diameter, containing 3 line sources
- FWHM of the line sources are determined from the reconstructed transverse images (ramp filter)

SPATIAL RESOLUTION

NEMA phantom for evaluating the spatial resolution of a SPECT scanner





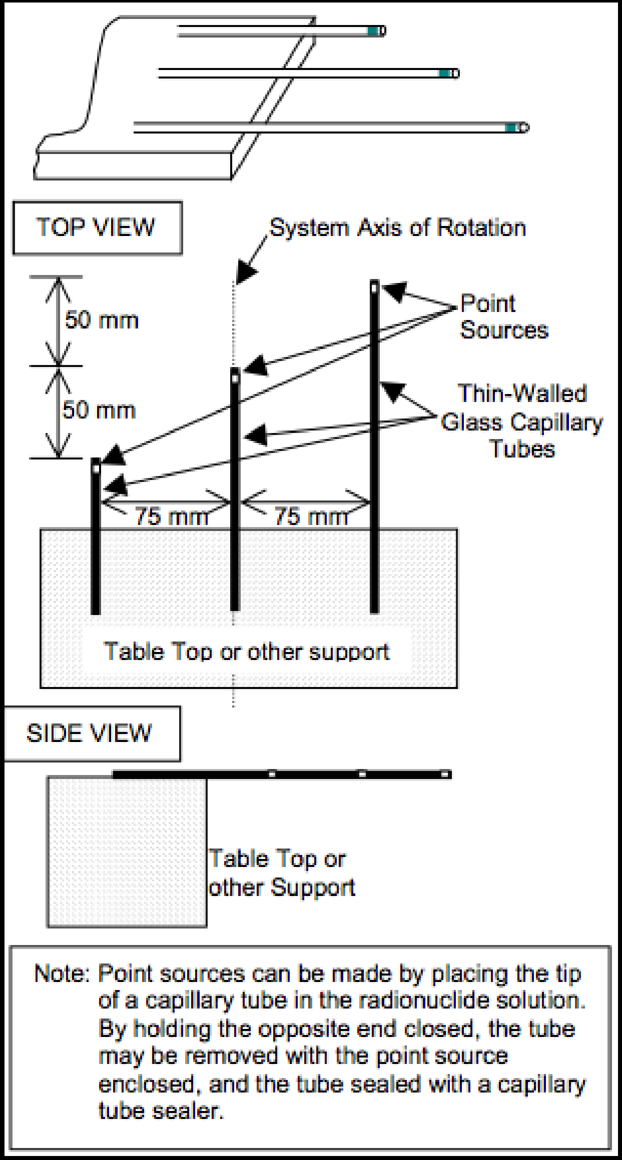


Tomographic spatial resolution in air

Three Point source of ~1 mCi Tc-99m (less than 2 mm)

Three thin-walled glass capillary tubes or equivalent shall be used to form and position the point sources.

These three point sources shall be made as spherically symmetric as possible



Tomographic spatial resolution in air

Measurement Procedure:

- The central point source positioned on the axis of rotation (±5 mm)
- Radius of rotation for the circular orbit shall be 100 ± 5 mm
- Reconstructed matrix has an effective pixel size of ≤ 2.5 mm.
- At least 10,000 counts in each of 128 projections angle
- Reconstructed Matrix size is 128 x 128

Calculations and Analysis:

Line profiles across the sources and record the FWHM of the Gaussian fit

Multiply the value with 2.35 to have the FWHM of the tomographic resolution

SPATIAL RESOLUTION

- NEMA spatial resolution measurements are primarily determined by the collimator used
  - resolution:

    for peripheral sources

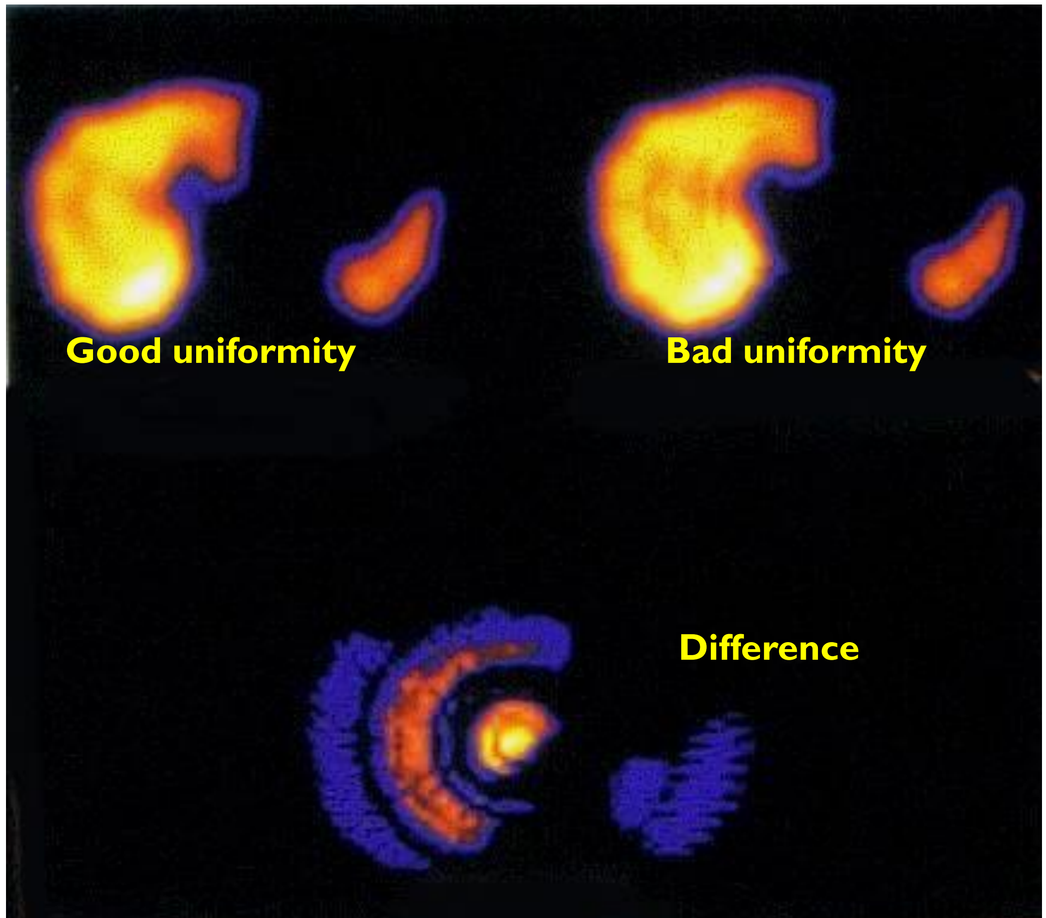
    (7 to 8 mm FWHM collimators)

    to central resolution

    (9.5 to 12 mm) for LEHR or LEUHR

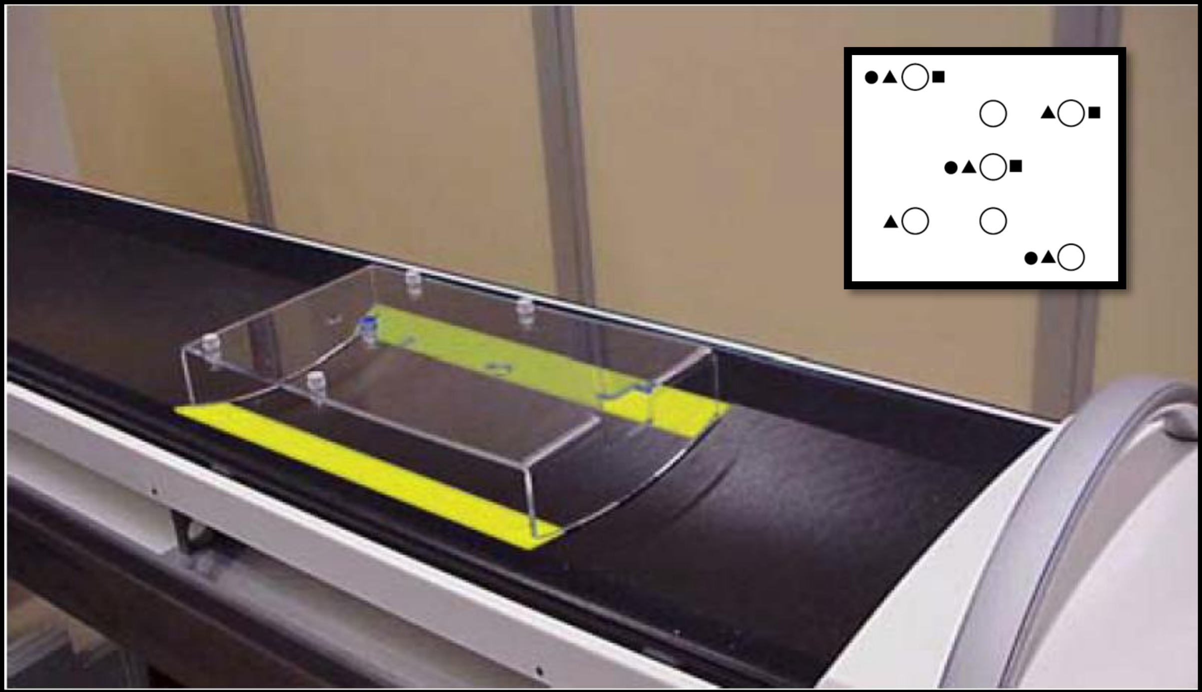
Clinical Sample

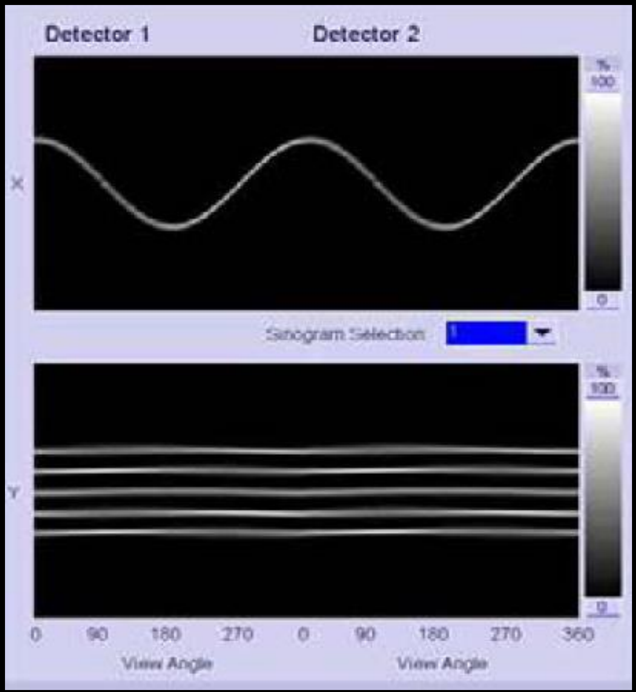
Gamma camera ring artefacts



CENTER OF ROTATION

MHR/COR alignment/calibration





■ Extra High Energy Collimator
▲ UHR, HRES, LEAP & Fanbeam Collimator
● All Others

1-5 mCi Tc-99m for each hole
64 projections of 10 seconds
128 x 128 projections
Count rate < 30000 cps

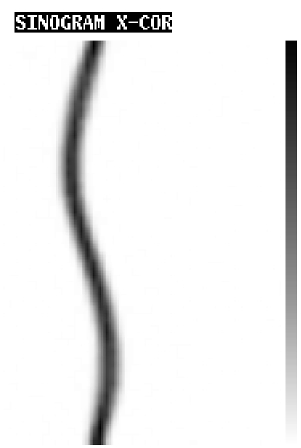
CENTER OF ROTATION

Point source of Tc-99m or Co-57 Make a tomographic acquisition

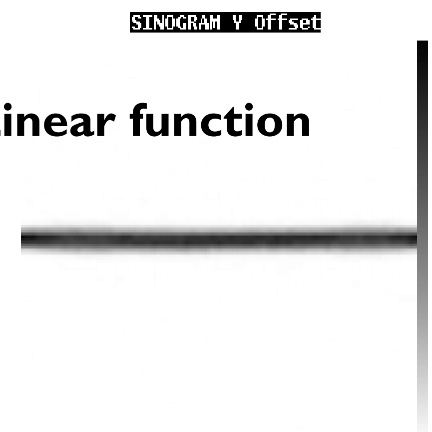
In x-direction the position will describe a sinus- function. In y-direction a straight line.

Calculate the offset from a fitted sinus and linear function at each angle.

sinus function



Linear function



COR

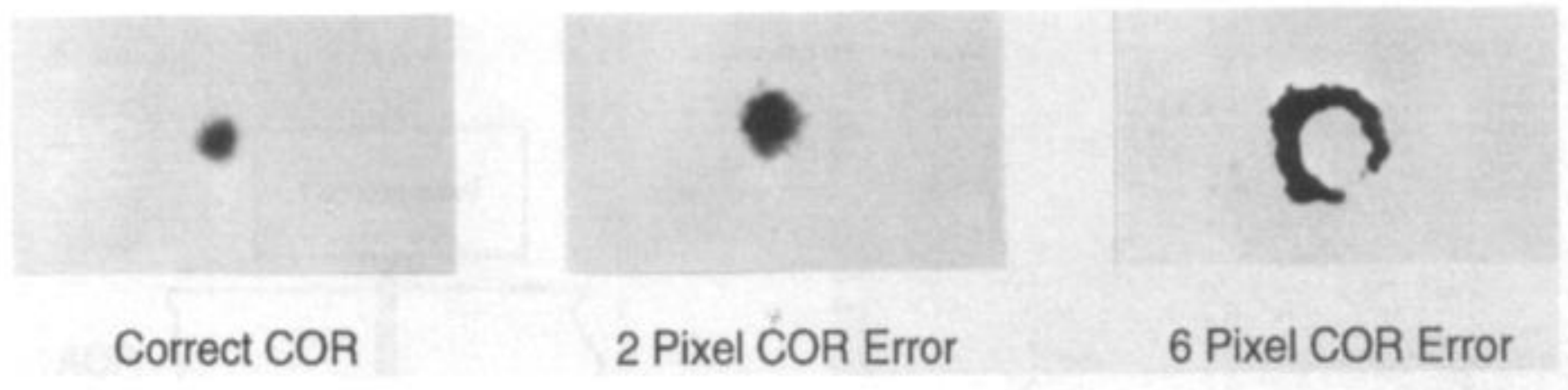
- The *axis of rotation* (AOR) is an imaginary **reference line** about which the head or heads of a SPECT camera rotate
- If a radioactive line source were placed on the AOR, each projection image would depict a vertical straight line near the center of the image
    - This projection of the AOR into the image is called the *center of rotation* (COR)

COR (cont.)

- Ideally, the COR is aligned with the center, in the x-direction, of each projection image
- Misalignment may be **mechanical**
  - Camera head may not be exactly centered in the gantry
- Misalignment may also be **electronic**

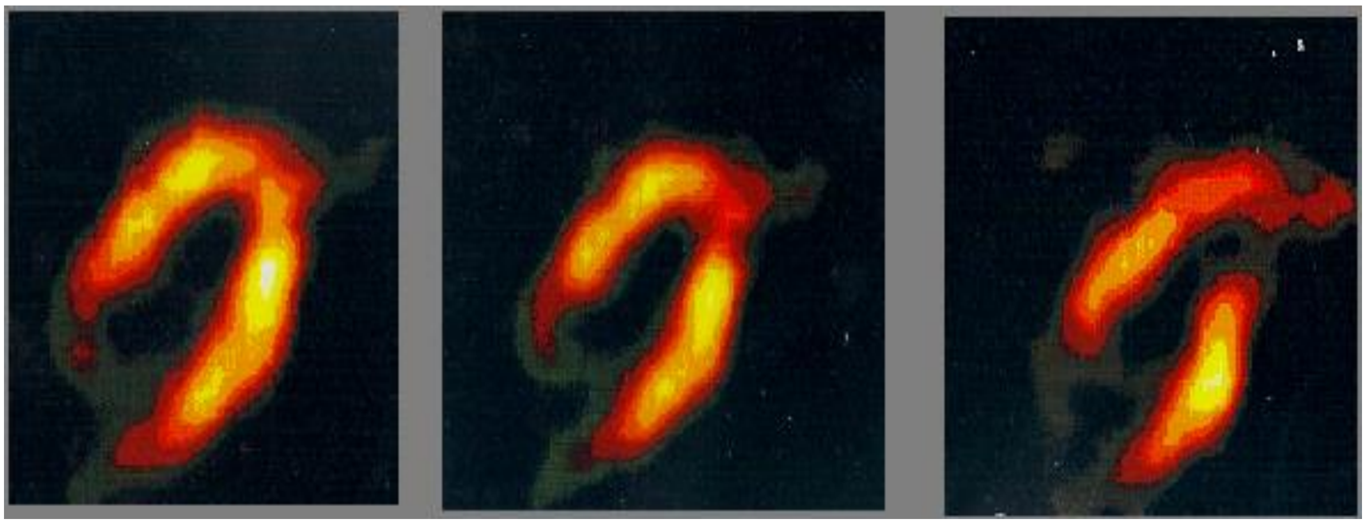
CENTER OF ROTATION

Center-of-rotation (COR) misalignment. Small misalignments cause blurring (*center*), whereas large misalignments cause point sources to appear as "**tiny doughnut**" artifacts (*right*).



Clinical Sample

Quality Control – Gamma camera center of rotation



no offset offset: 1 pixel offset: 3 pixel

COR alignment/calibration

Deviations of greater than **0.5 pixel** in a **128 x 128** matrix from the expected position of the source are considered abnormal.

0 pixel

0.5 pixel

1 pixel

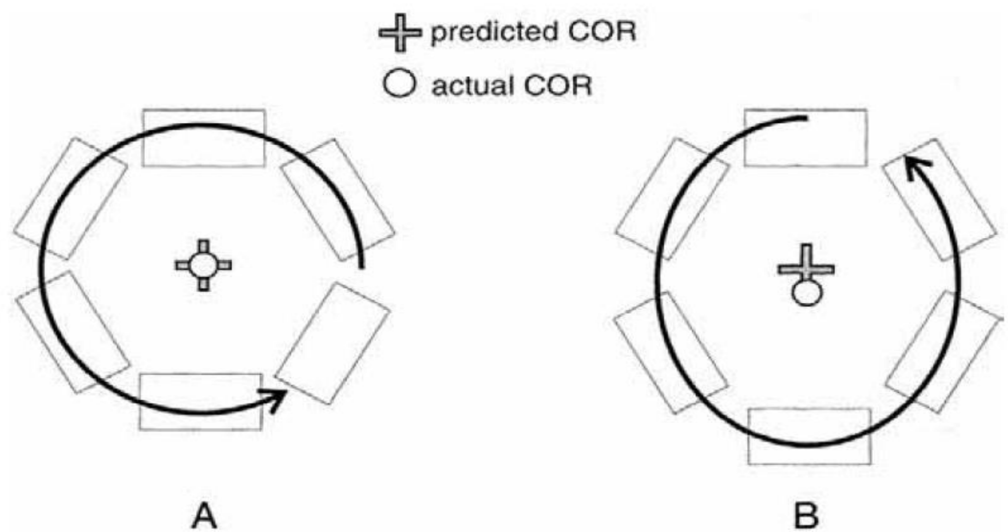
2.5 pixel

COR alignment/calibration

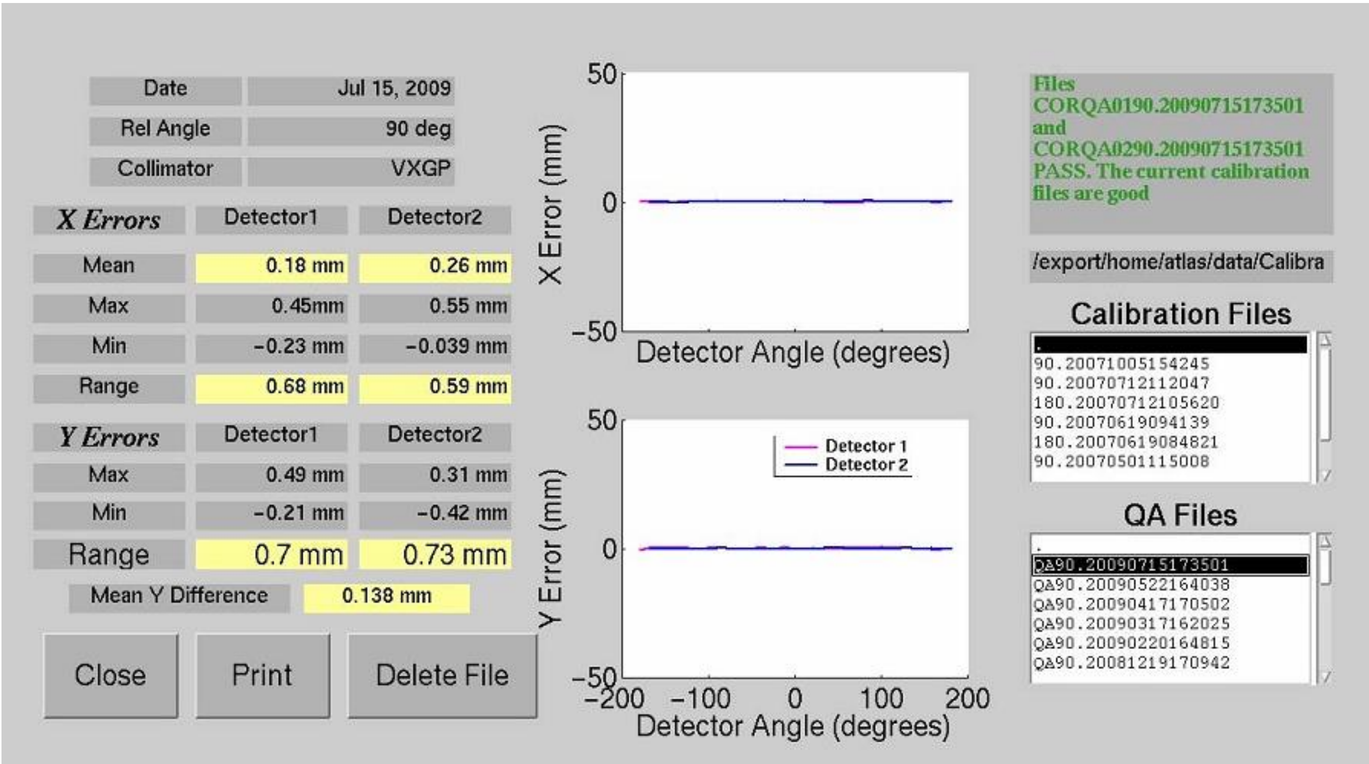
The camera heads will rotate in a near **perfect circle** and will remain almost precisely aligned in their opposing positions…..

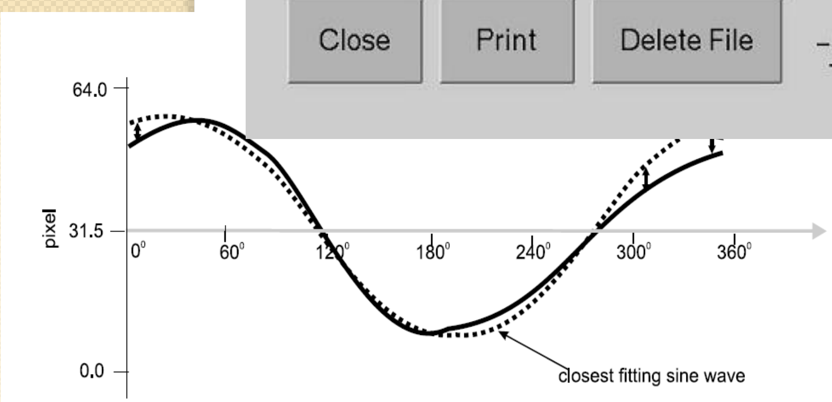
The predicted or **“electronic**” center of the path of **rotation will match** the “mechanical” or actual center of the camera head rotation….

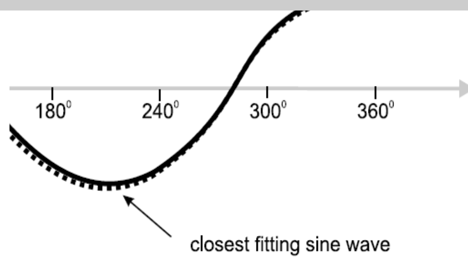
Unfortunately not!

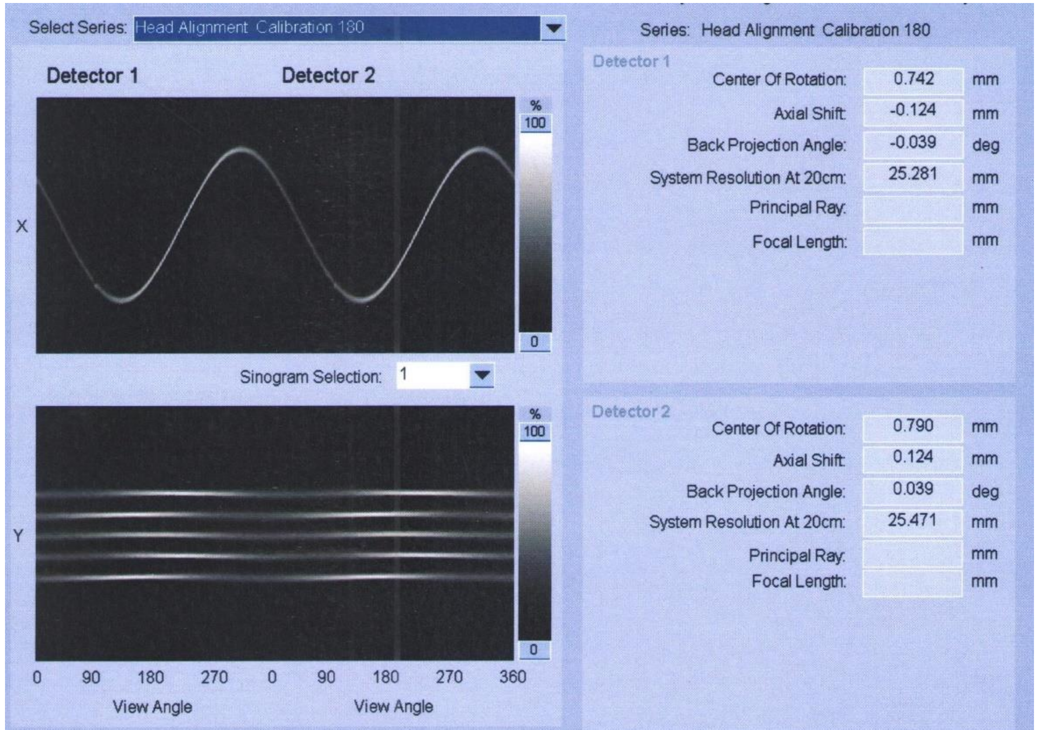


COR alignment/calibration

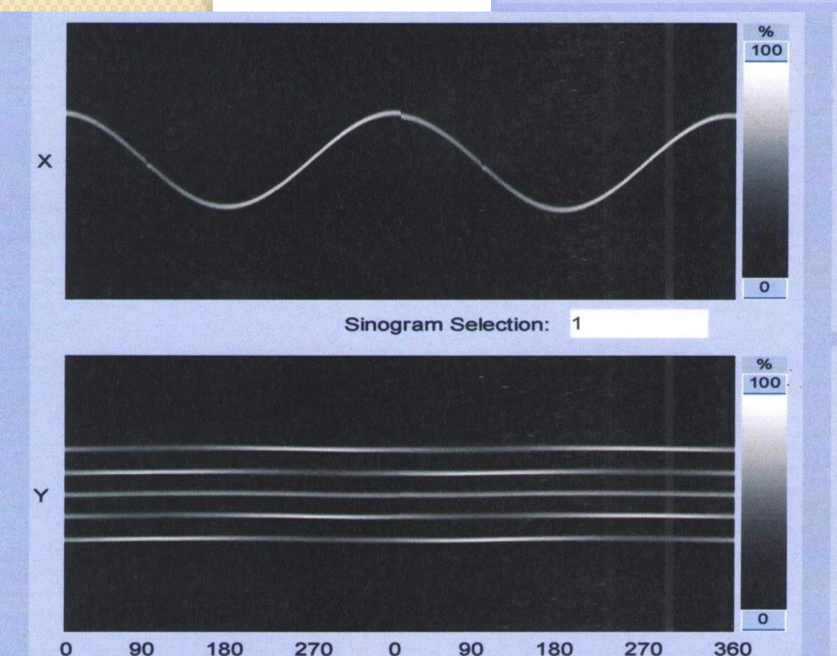




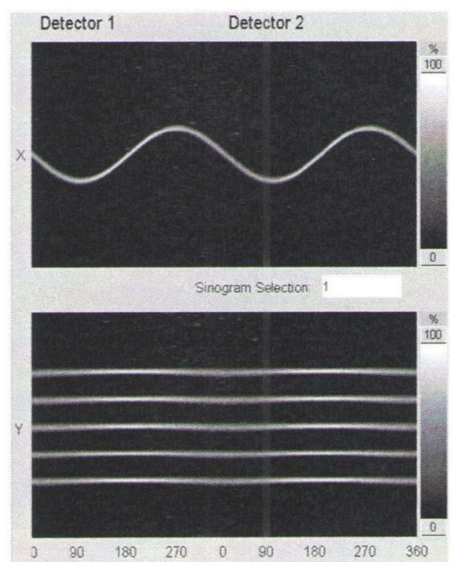




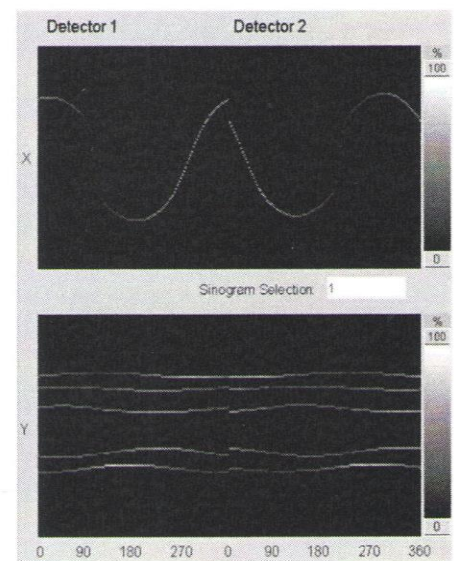
Select Series: Head Alignment Calibration 180
Detector 1
Detector 2
X
Y
Sinogram Selection: 1
0 90 180 270 0 90 180 270 360
View Angle
View Angle
Series: Head Alignment Calibration 180
Detector 1
Center Of Rotation: 0.742 mm
Axial Shift: -0.124 mm
Back Projection Angle: -0.039 deg
System Resolution At 20cm: 25.281 mm
Principal Ray: mm
Focal Length: mm
Detector 2
Center Of Rotation: 0.790 mm
Axial Shift: 0.124 mm
Back Projection Angle: 0.039 deg
System Resolution At 20cm: 25.471 mm
Principal Ray: mm
Focal Length: mm



X
Y
Sinogram Selection: 1
0 90 180 270 0 90 180 270 360

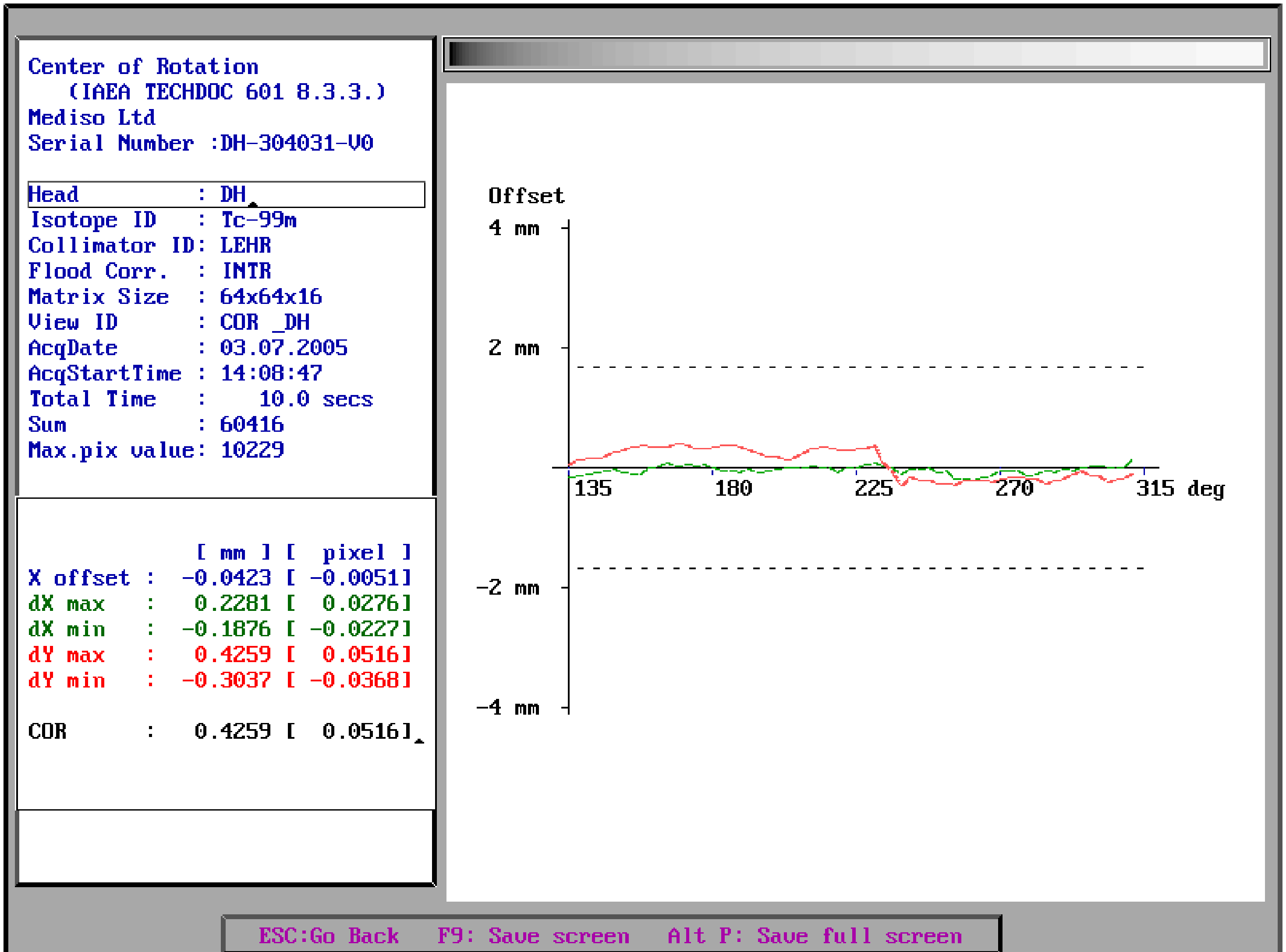


Detector 1
Detector 2
X
Y
Sinogram Selection 1



Detector 1
Detector 2
X
Y
Sinogram Selection 1
0 90 180 270 0 90 180 270 360

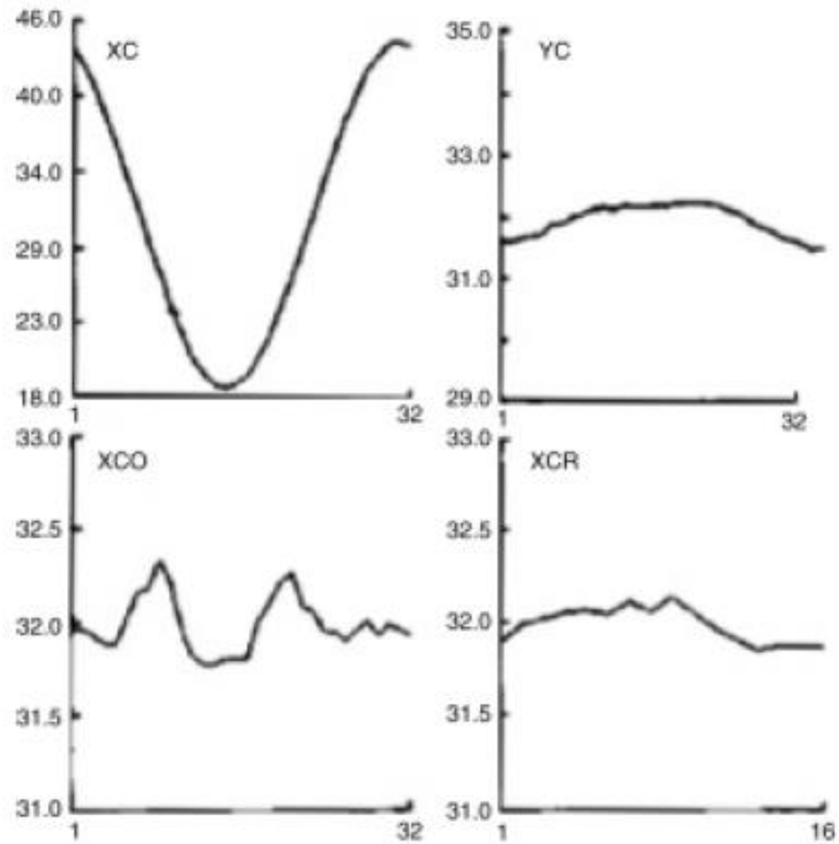
COR calibration analysis



CENTER OF ROTATION

COR calibration analysis

TL: Angular *x* position sinogram of the calibration point source.
BL: Angular position difference between the sinogram and a fitted sine wave.
TR: Angular *y* position of the point.
BR: Angular variation of the COR value.



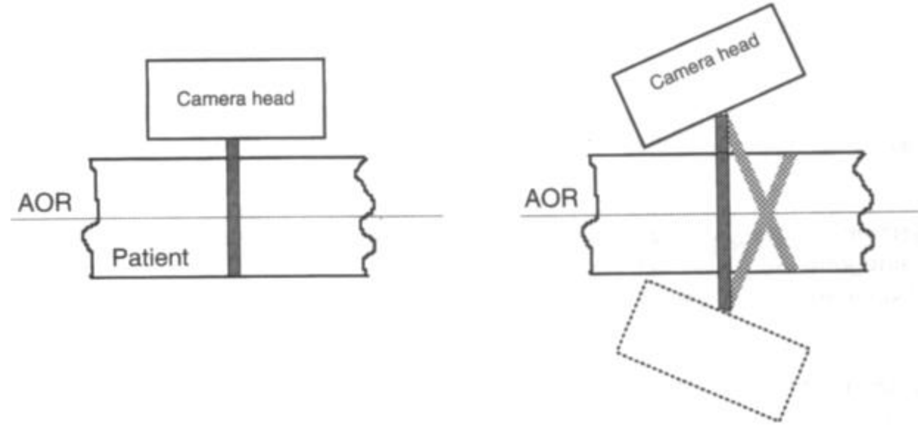
Camera head tilt

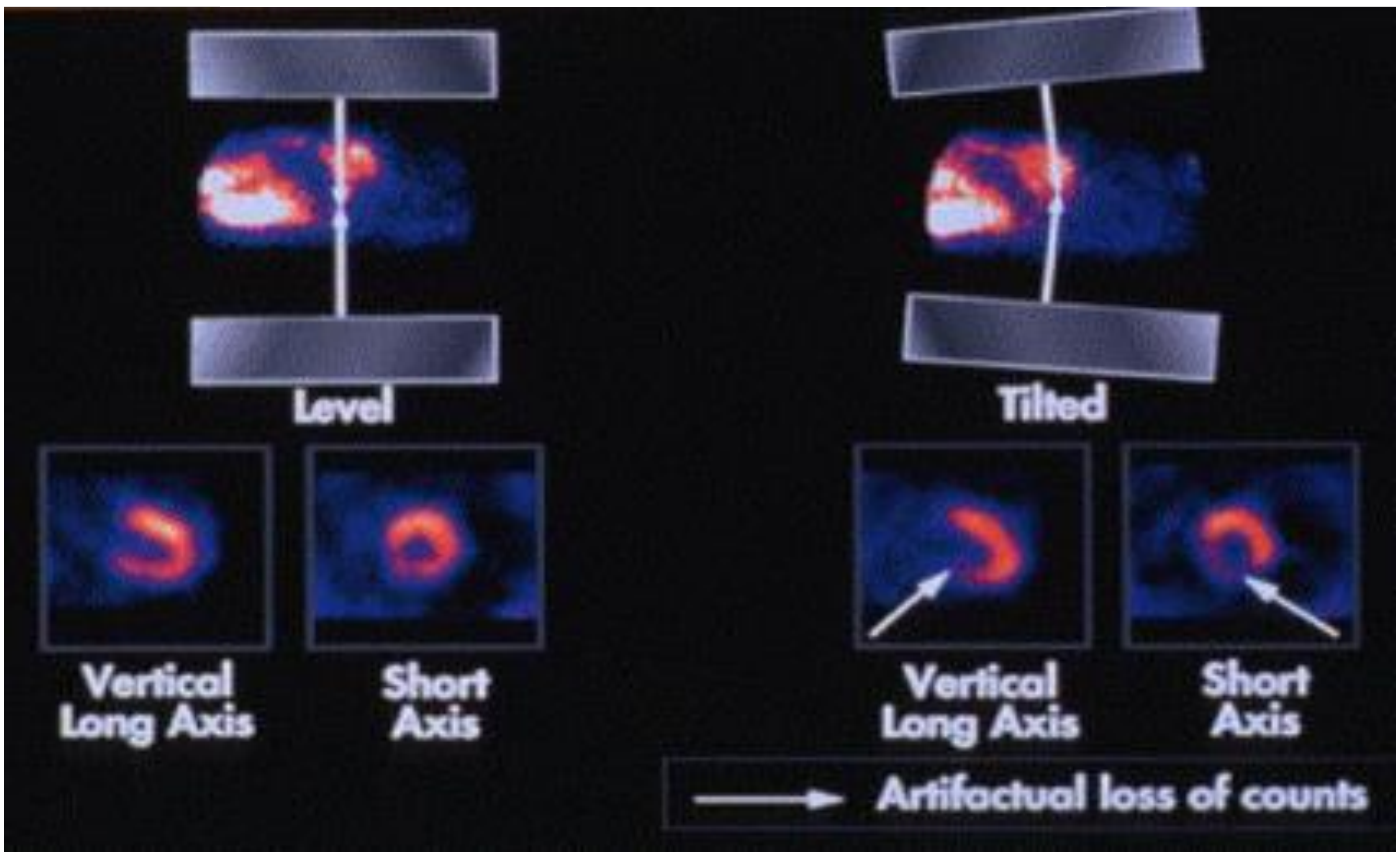
Camera head tilt

- Camera head or heads must **be exactly parallel to the AOR**
  - If not, loss of spatial resolution and contrast
  - Loss will be less toward the center of the image and greatest toward the edge of the image

- Can assess **using a point source** in camera's FOV, centered in the axial (y) direction, but near the edge in the transverse (x) direction
  - If there is head tilt, position of point source will vary in y-direction from image to image

Tilted detector





COR calibration

- **Misalignment** may be corrected **by shifting each image in the x-direction** by the proper number of pixels prior to filtered backprojection
- If **COR misalignment** varies with camera head angle, it can only be corrected if computer permits **angle-by-angle corrections**
- Separate assessments of **COR correction must be made for different collimators**

Conclusion

Test	Purpose	Frequency
Physical inspection	Collimator mounting and damage	Daily
Collimator touch pad and gantry emergency stops	Unexpected collision with the patient or an obstacle during motion	Daily, and after collimator change
Energy window setting	To check and center the energy window on the photopeak	Daily, for any radionuclide
Background count rate	Detect radioactive contamination	Daily
Intrinsic/extrinsic uniformity and sensitivity- visual	Test response to uniform flux of photons, record cps/MBq and monitor sensitivity	Daily (low count)
Intrinsic/extrinsic uniformity and sensitivity- quantitative	To monitor the trend in uniformity with quantitative indices, check the sensitivity	Weekly/monthly (high count)
Spatial resolution and linearity – visual	To detect distortion of spatial resolution and linearity	Six-monthly
Multiple window spatial registration (MWSR)	To test that all images superimpose in an additive or subtractive mode	Six-monthly yearly

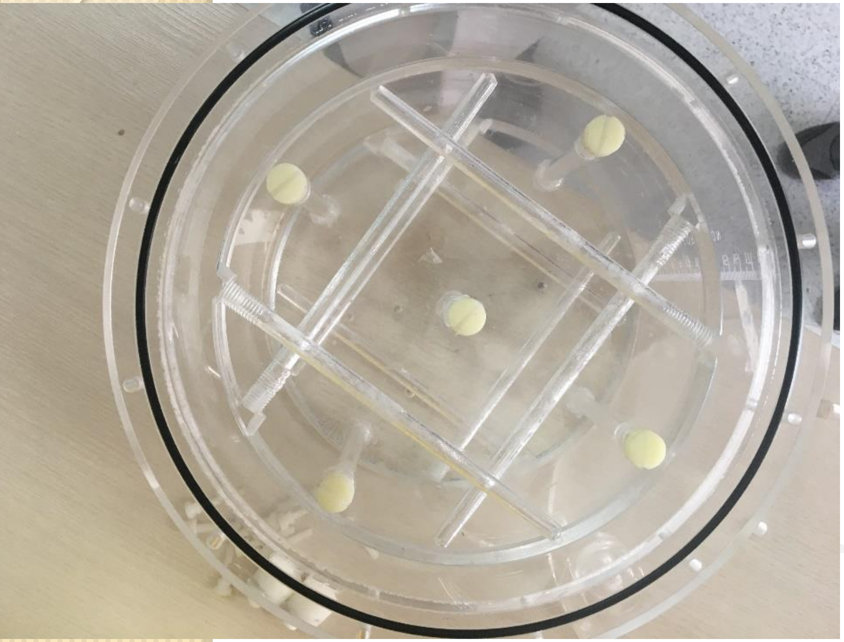
Conclusion

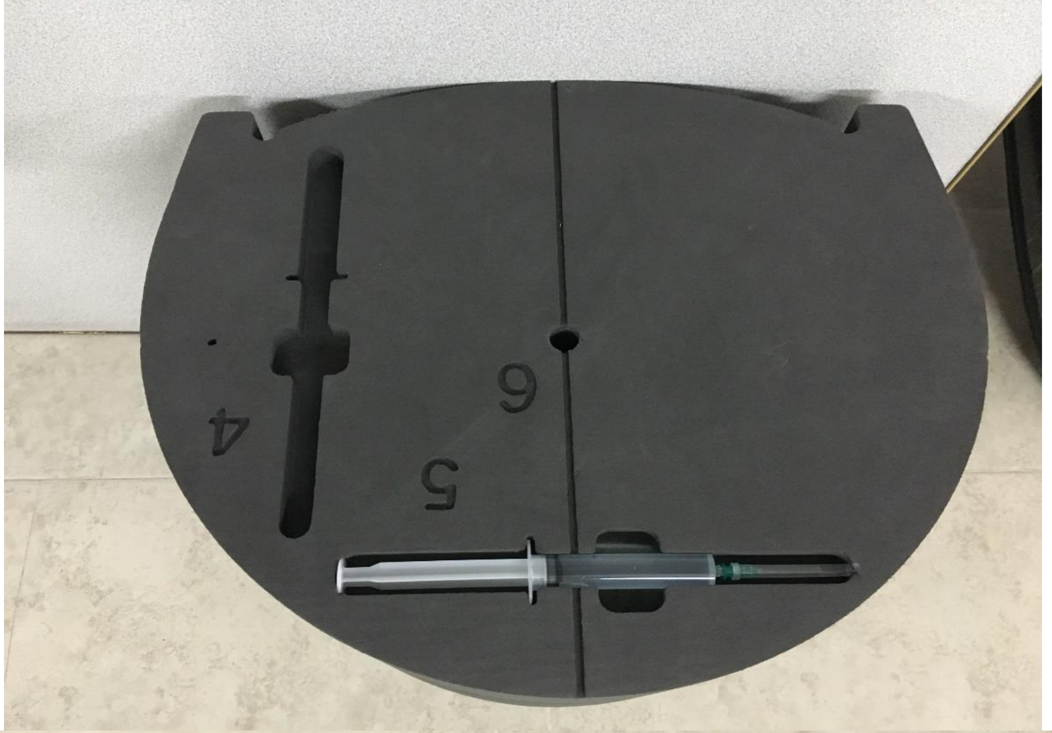
Test	Purpose	Frequenc y
Detector head tilt	To adjust the alignment of detector head tilt in the Y-axis	Before use
COR alignment/calibration	To check that the mechanical and electronic CORs are aligned	Weekly/As required
Overall system performance	Tomographic uniformity and contrast resolution	Six-monthly
Tomographic spatial resolution in air	To check tomographic spatial resolution of the system in air, with no scatter	Six-monthly
Pixel size	To determine absolute pixel size for quantitation, fusion and AC	Six-monthly

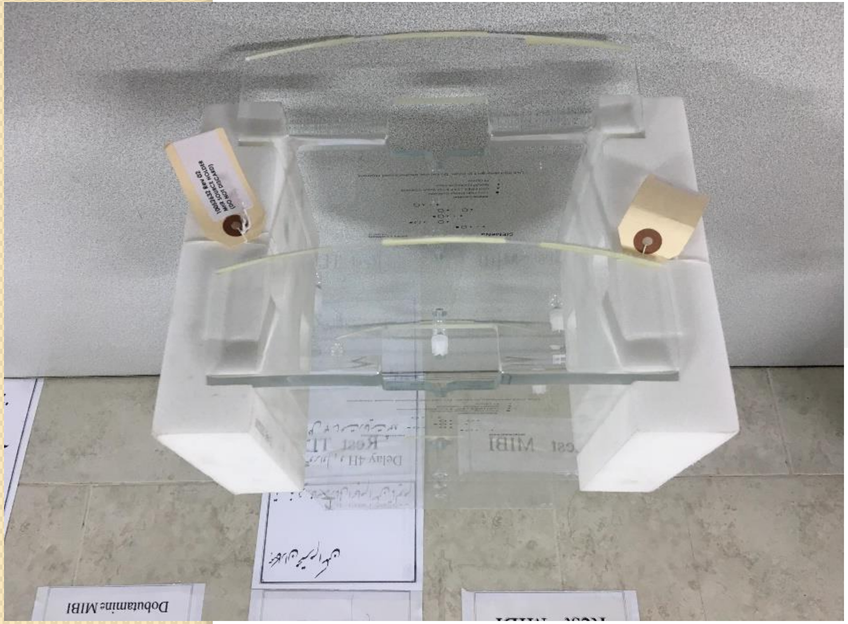

Thank you for
your Attention!

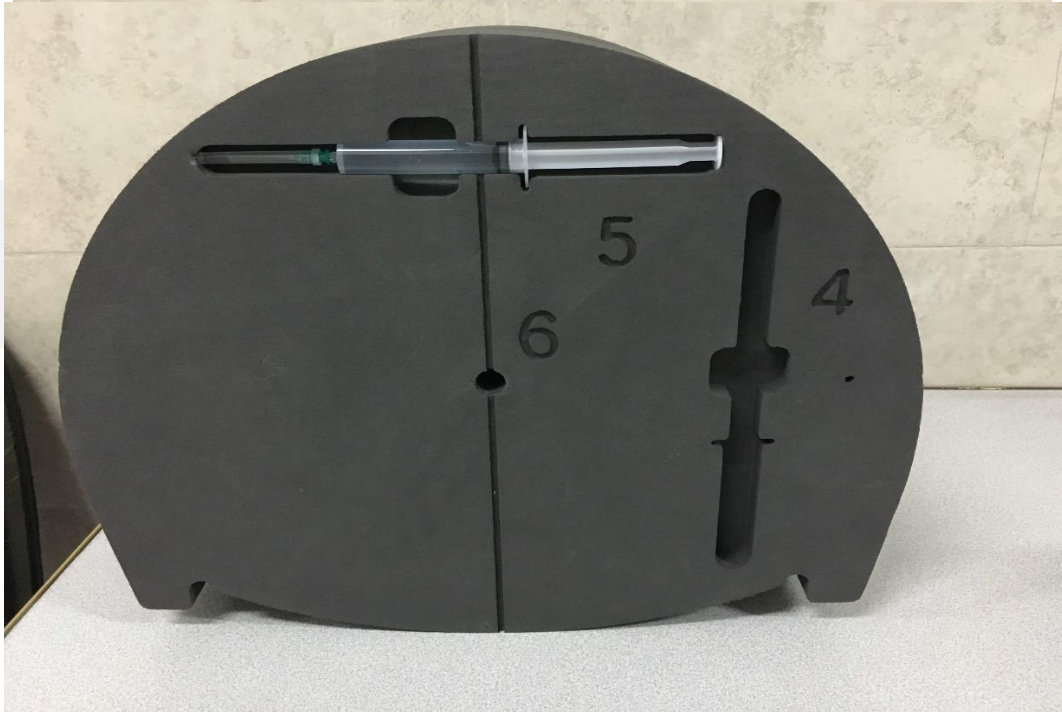
SPECT/CT Artifacts & Solutions

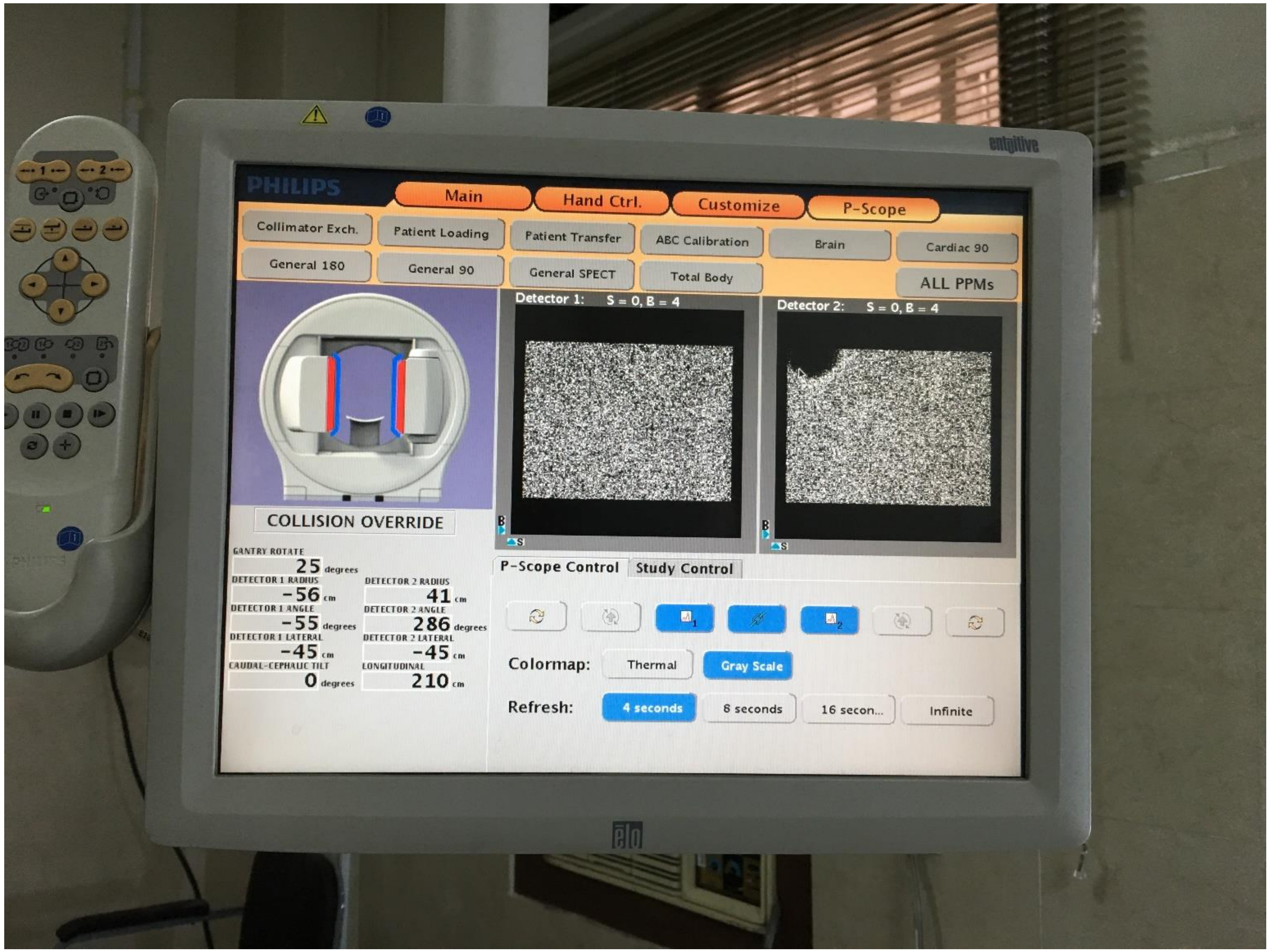
Artifact Type	Cause	Appearance	Solution
COR Offset	Gantry-detector misalignment	Blurring, double images	Recalibrate COR weekly (<0.5 mm error)
Bubble Artifact	Air trapped in PMT-crystal gap	Circular cold spots in flood images	Reseal or replace detector module
Detector Hydration	Moisture in NaI(Tl) crystal	Yellowed crystal, patchy uniformity	Replace crystal; control humidity
Ramp Filter Artifact	Over-filtering in FBP	Star-like noise streaks	Use Butterworth filter or switch to OSEM
Reconstruction Error	Wrong OSEM iterations/μ-map	Checkerboard pattern, false defects	Optimize iterations/subsets; verify CT-SPECT alignment
Gantry Misalignment	Mechanical tilt or loose parts	Asymmetric blurring	Relevel detector; mechanical service
Donut Artifact	Severe non-uniformity/COR error	Concentric rings in SPECT	Recalibrate uniformity and COR
Attenuation Artifact	Misaligned CT μ-map	False cold spots near bones/metal	Verify CT-SPECT registration; use MAR algorithms
Scatter Artifact	Wide energy window	Halo around high-uptake organs	Narrow window (±10% for Tc-99m); apply scatter correction
Edge Packing	Aggressive edge enhancement	Artificial bright edges	Reduce high-pass filtering
Photopeak Offset	Energy calibration drift	Global non-uniformity	Daily energy peak recalibration
Fusion Misregistration	Patient motion/gantry error	Misaligned anatomy (e.g., heart vs. ribs)	Immobilize patient; manual re-fusion
HU-to-μ Map Error	Uncalibrated CT attenuation	Artificial cold/hot spots	Calibrate CT-SPECT μ-conversion monthly
Non-Uniformity (SUV Errors)	Detector calibration skipped	Inaccurate quantification	Daily uniformity flood correction



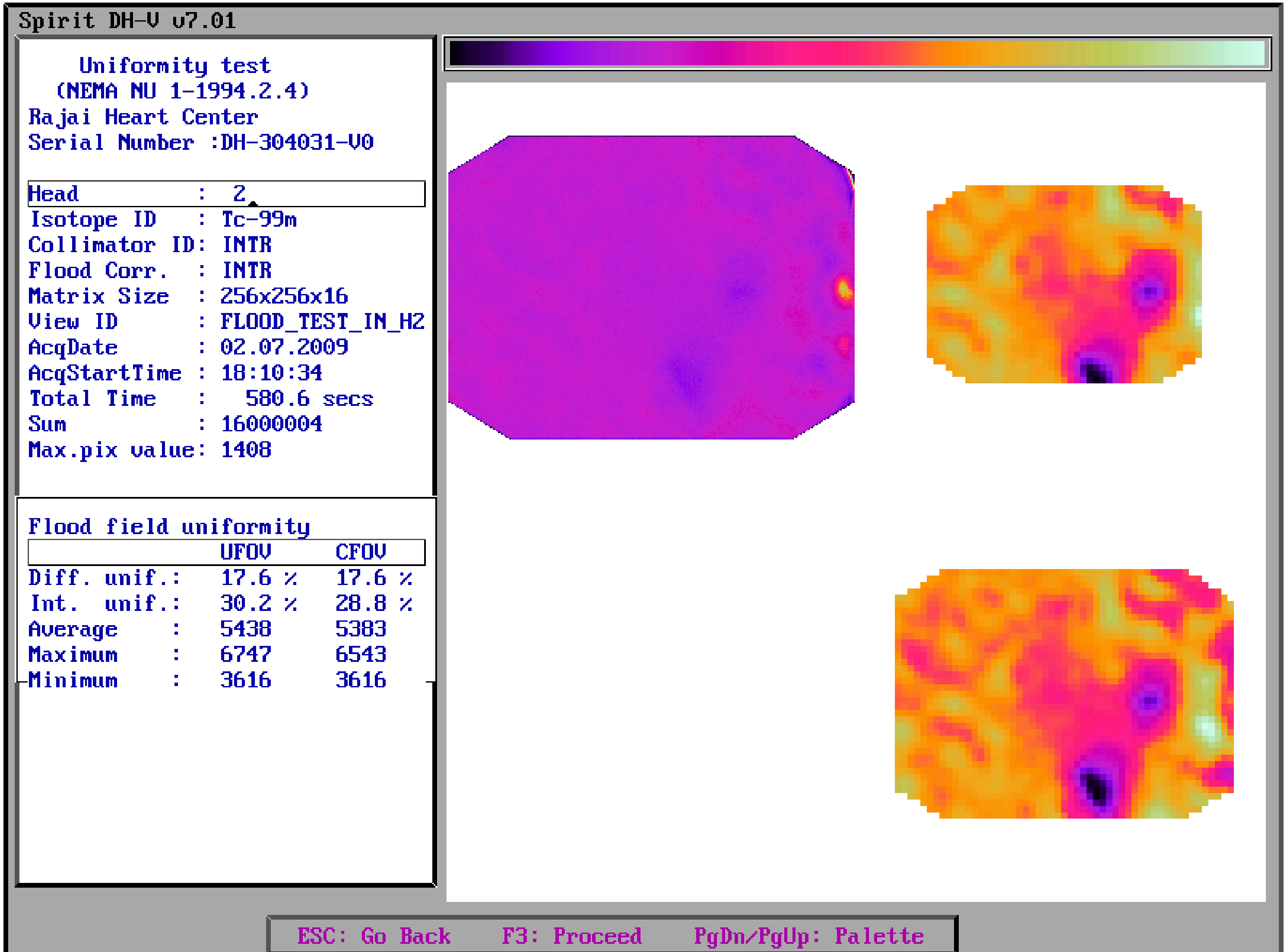


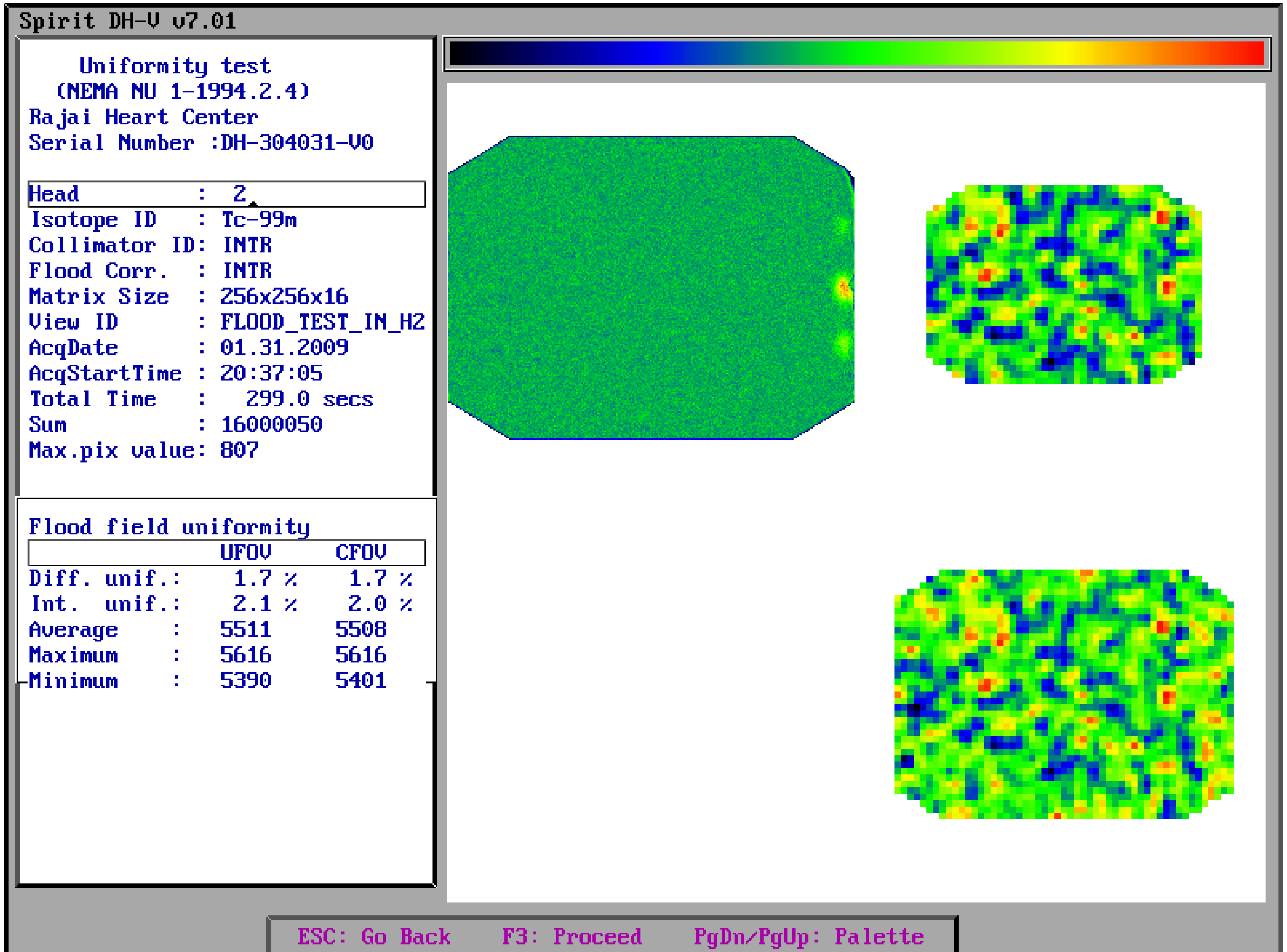



5
4
6

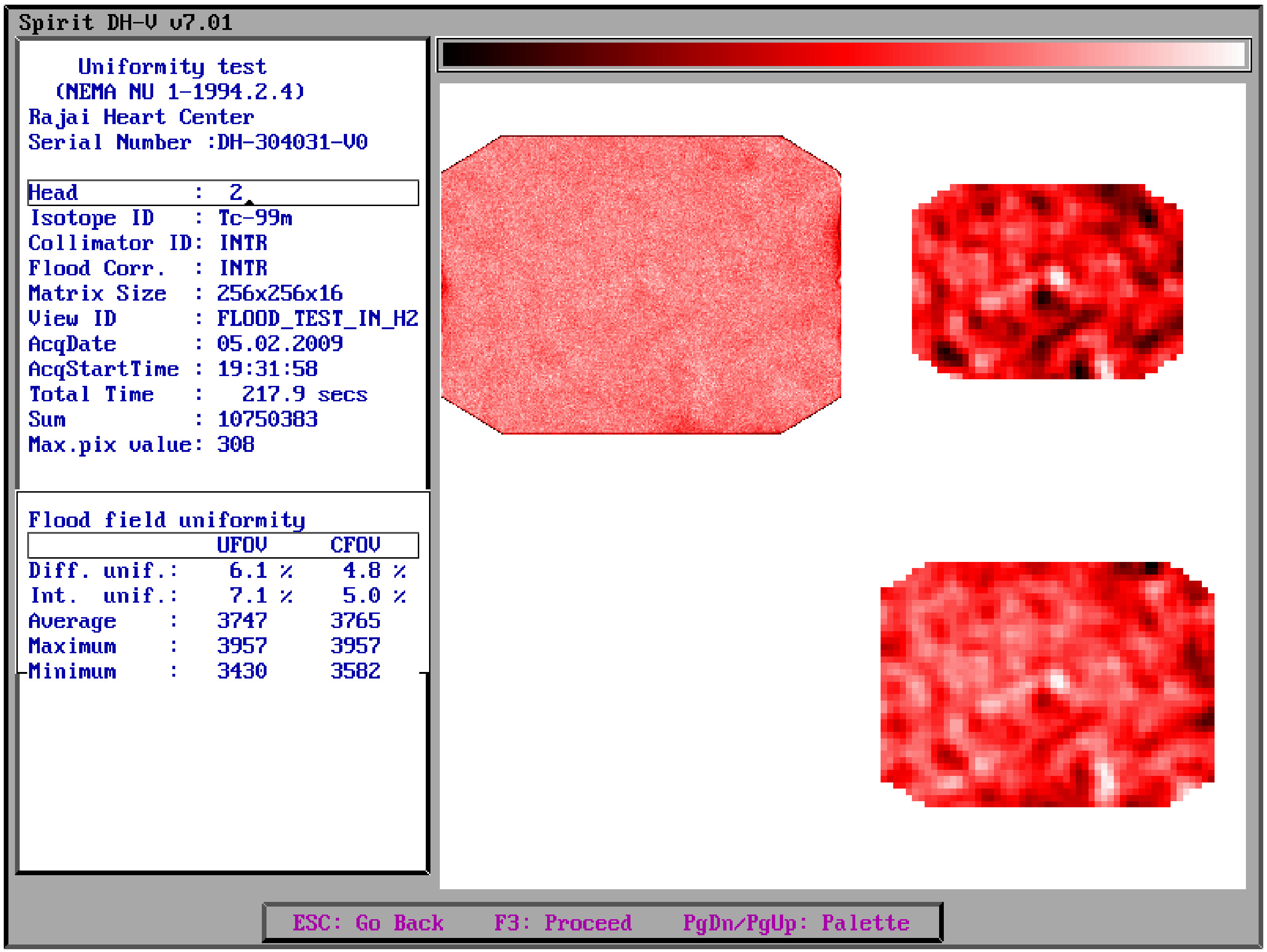

PHILIPS
Main
Hand Ctrl.
Customize
P-Scope
Collimator Exch.
Patient Loading
Patient Transfer
ABC Calibration
Brain
Cardiac 90
General 180
General 90
General SPECT
Total Body
ALL PPMs
Detector 1: S = 0, B = 4
Detector 2: S = 0, B = 4
COLLISION OVERRIDE
GANTRY ROTATE 25 degrees
DETECTOR 1 RADIUS -56 cm
DETECTOR 2 RADIUS 41 cm
DETECTOR 1 ANGLE -55 degrees
DETECTOR 2 ANGLE 286 degrees
DETECTOR 1 LATERAL -45 cm
DETECTOR 2 LATERAL -45 cm
CAUDAL-CEPHALIC TILT 0 degrees
LONGITUDINAL 210 cm
P-Scope Control
Study Control
Colormap:
Thermal
Gray Scale
Refresh:
4 seconds
8 seconds
16 secon...
Infinite

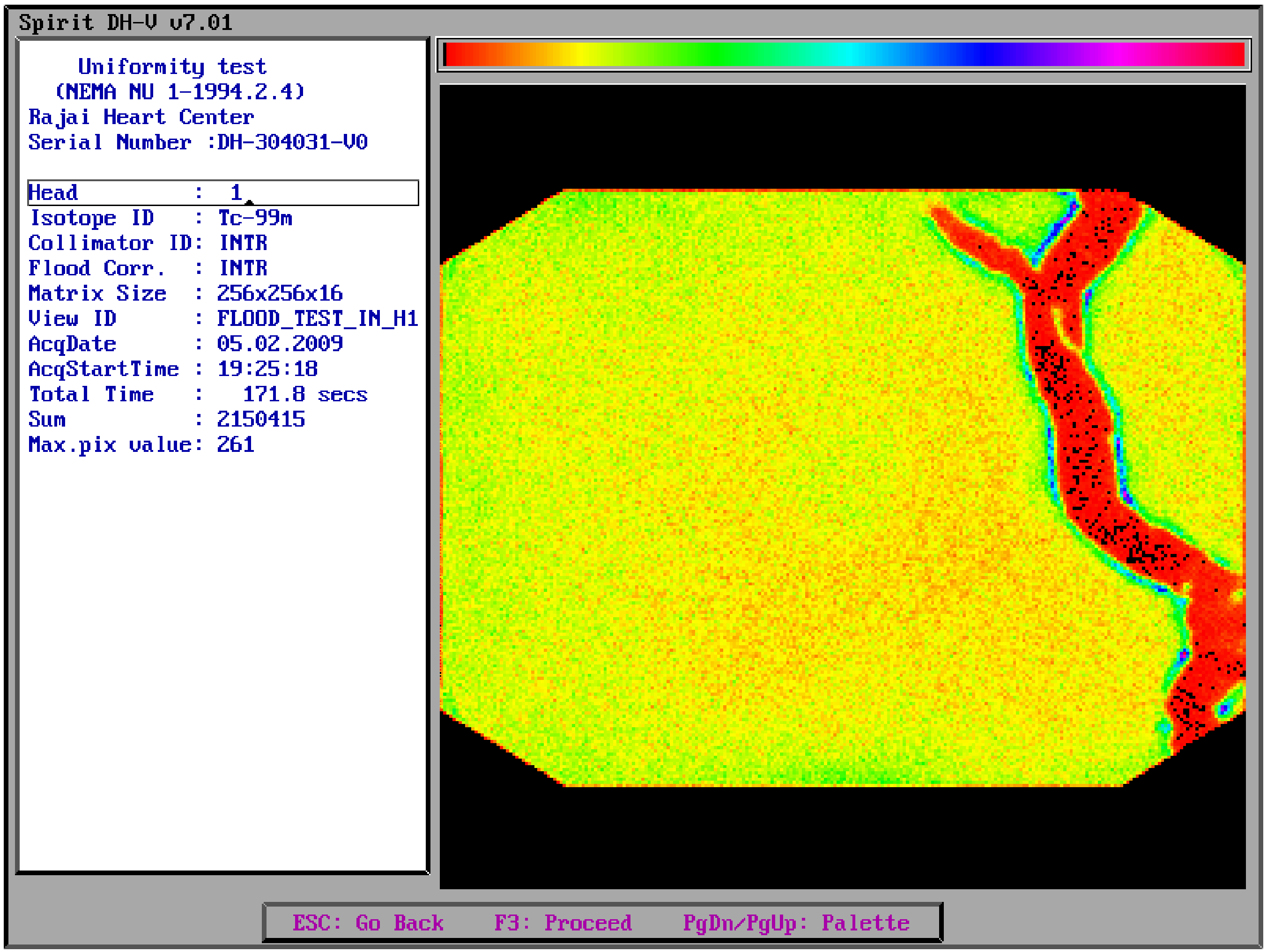

PHILIPS
PHILIPS
PHILIPS
PHILIPS

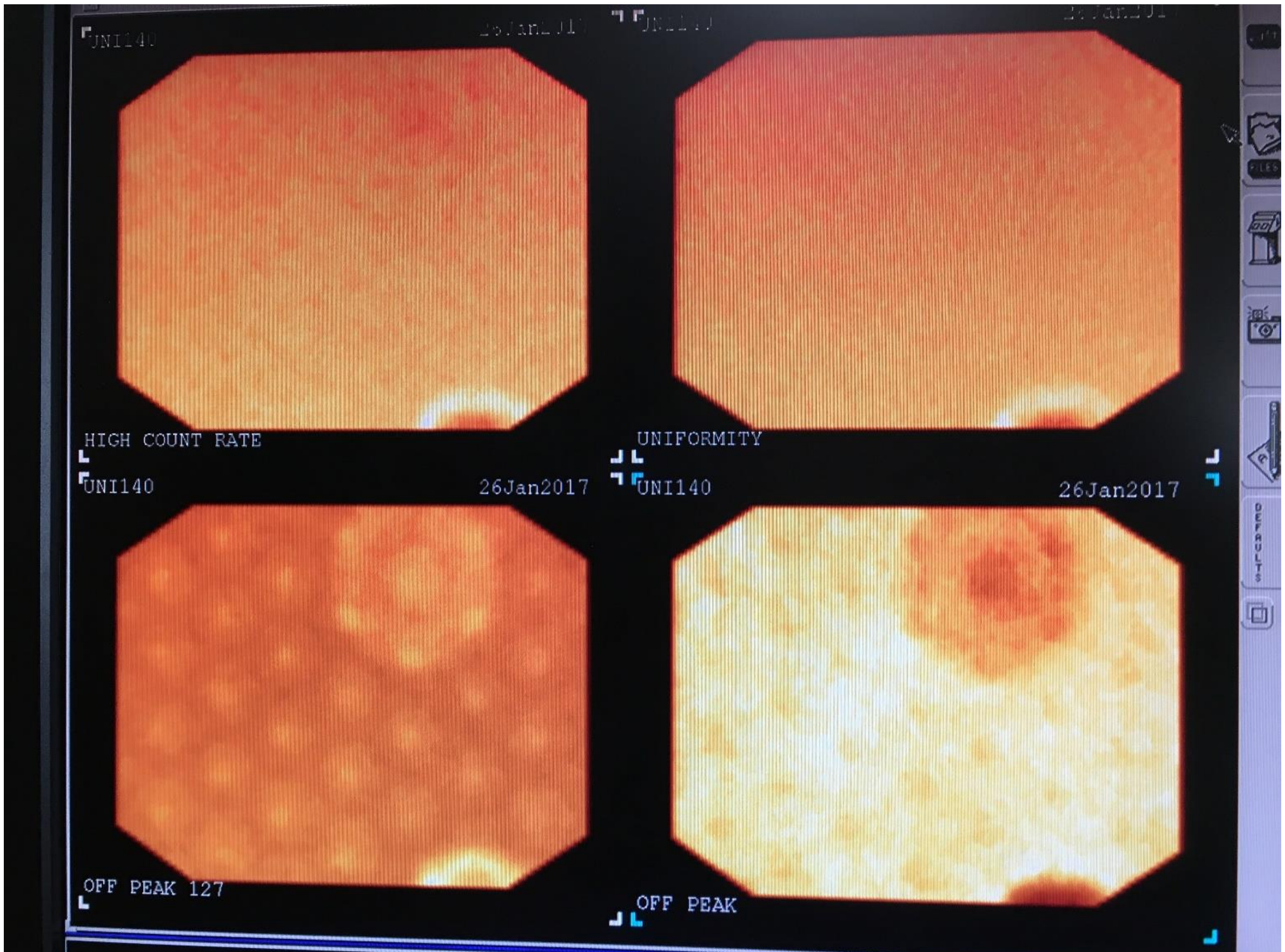

Spirit DH-V v7.01
Uniformity test
(NEMA NU 1-1994.2.4)
Rajai Heart Center
Serial Number :DH-304031-V0
Head : 2
Isotope ID : Tc-99m
Collimator ID: INTR
Flood Corr. : INTR
Matrix Size : 256x256x16
View ID : FLOOD_TEST_IN_H2
AcqDate : 02.07.2009
AcqStartTime : 18:10:34
Total Time : 580.6 secs
Sum : 16000004
Max.pix value: 1408
Flood field uniformity
UFOV CFOV
Diff. unif.: 17.6 % 17.6 %
Int. unif.: 30.2 % 28.8 %
Average : 5438 5383
Maximum : 6747 6543
Minimum : 3616 3616
ESC: Go Back F3: Proceed PgDn/PgUp: Palette

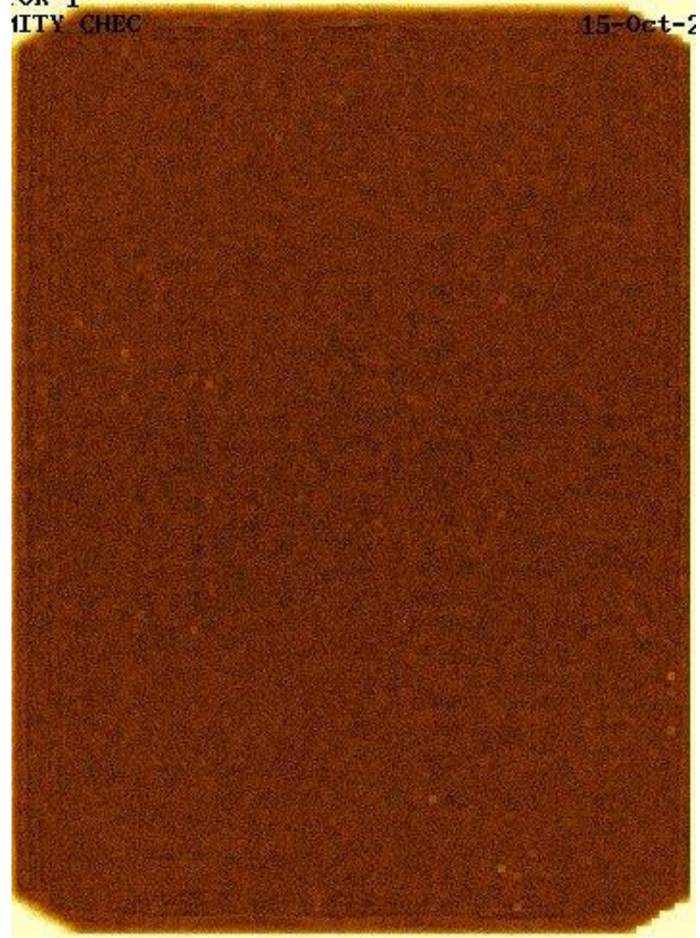


Spirit DH-V v7.01
Uniformity test
(NEMA NU 1-1994.2.4)
Rajai Heart Center
Serial Number :DH-304031-V0
Head : 2
Isotope ID : Tc-99m
Collimator ID: INTR
Flood Corr. : INTR
Matrix Size : 256x256x16
View ID : FLOOD_TEST_IN_H2
AcqDate : 01.31.2009
AcqStartTime : 20:37:05
Total Time : 299.0 secs
Sum : 16000050
Max.pix value: 807
Flood field uniformity
UFOV CFOV
Diff. unif.: 1.7 % 1.7 %
Int. unif.: 2.1 % 2.0 %
Average : 5511 5508
Maximum : 5616 5616
Minimum : 5390 5401
ESC: Go Back F3: Proceed PgDn/PgUp: Palette


Spirit DH-V v7.01
Uniformity test
(NEMA NU 1-1994.2.4)
Rajai Heart Center
Serial Number :DH-304031-V0
Head : 2
Isotope ID : Tc-99m
Collimator ID: INTR
Flood Corr. : INTR
Matrix Size : 256x256x16
View ID : FLOOD_TEST_IN_H2
AcqDate : 05.02.2009
AcqStartTime : 19:31:58
Total Time : 217.9 secs
Sum : 10750383
Max.pix value: 308
Flood field uniformity
UFOV CFOV
Diff. unif.: 6.1 % 4.8 %
Int. unif.: 7.1 % 5.0 %
Average : 3747 3765
Maximum : 3957 3957
Minimum : 3430 3582
ESC: Go Back F3: Proceed PgDn/PgUp: Palette

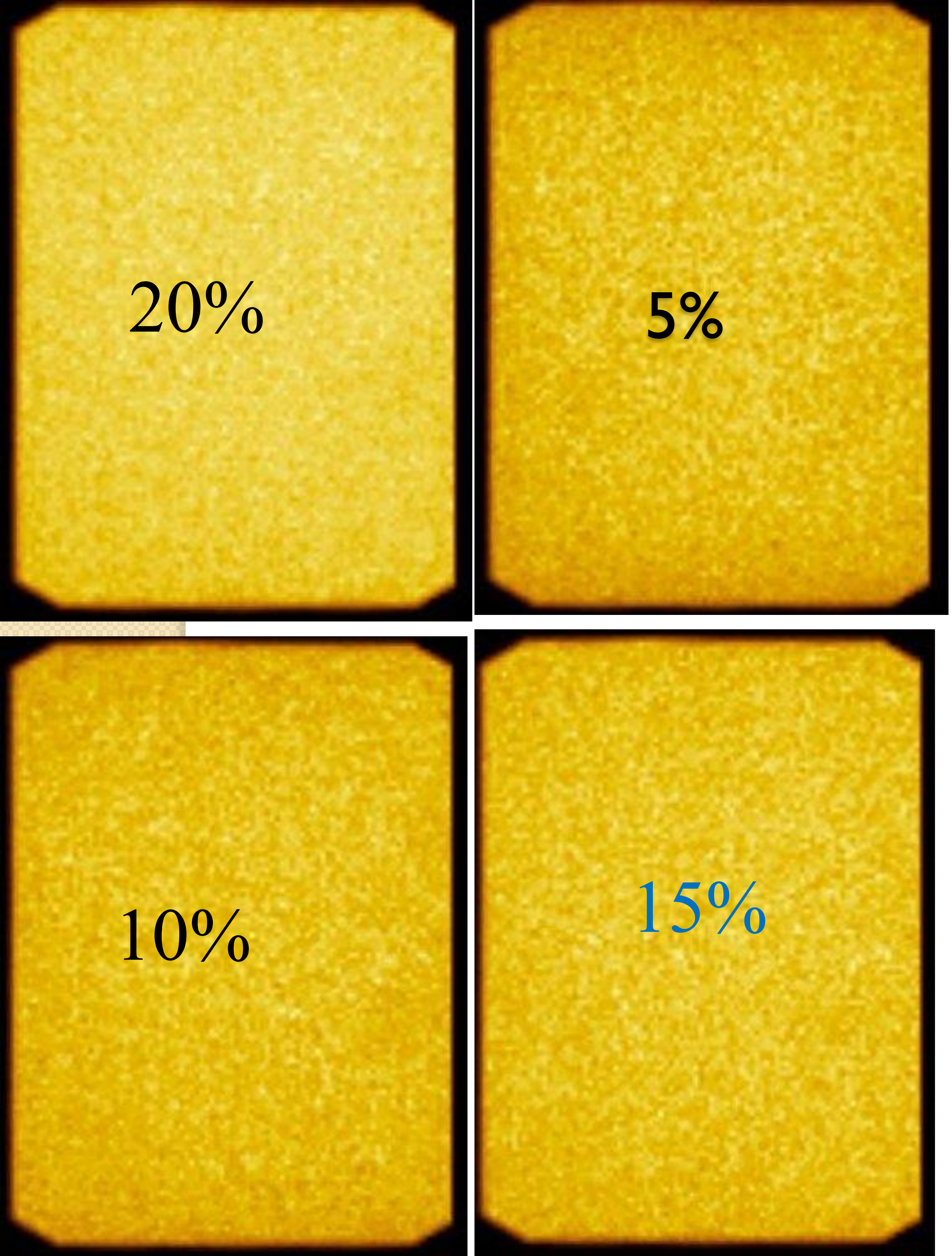

Spirit DH-V v7.01
Uniformity test
(NEMA NU 1-1994.2.4)
Rajai Heart Center
Serial Number :DH-304031-V0
Head : 1
Isotope ID : Tc-99m
Collimator ID: INTR
Flood Corr. : INTR
Matrix Size : 256x256x16
View ID : FLOOD_TEST_IN_H1
AcqDate : 05.02.2009
AcqStartTime : 19:25:18
Total Time : 171.8 secs
Sum : 2150415
Max.pix value: 261
ESC: Go Back F3: Proceed PgDn/PgUp: Palette

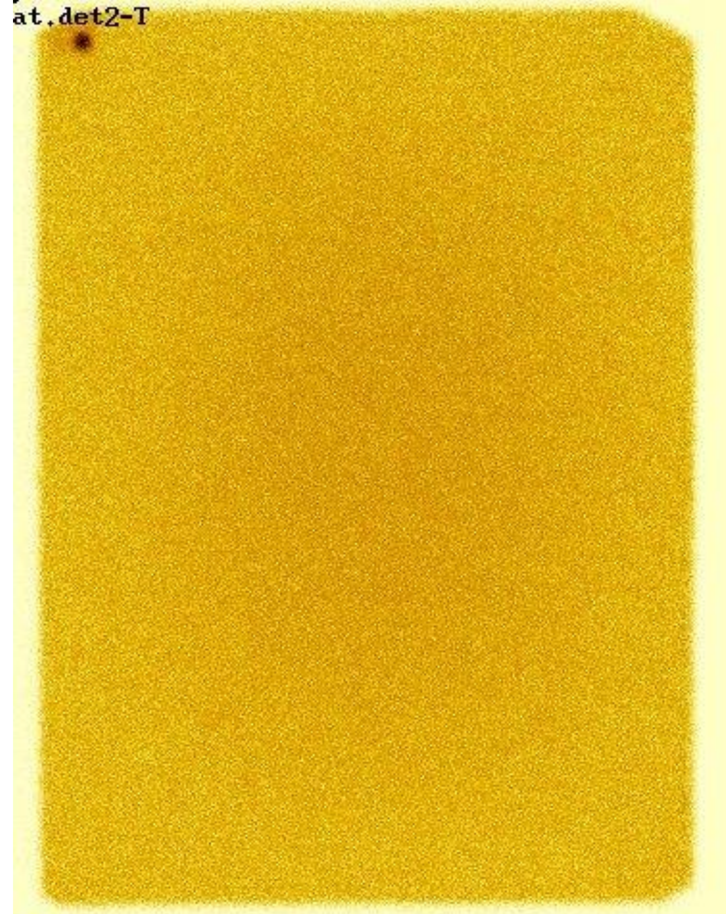

HIGH COUNT RATE
UNIFORMITY
UNI140
26Jan2017
UNI140
26Jan2017
OFF PEAK 127
OFF PEAK



Non Uniform

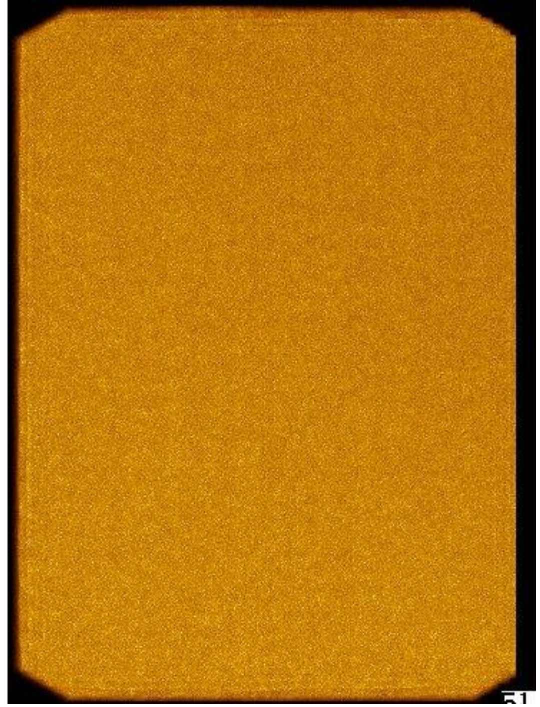
Uniform





Extrinsic Uniformity

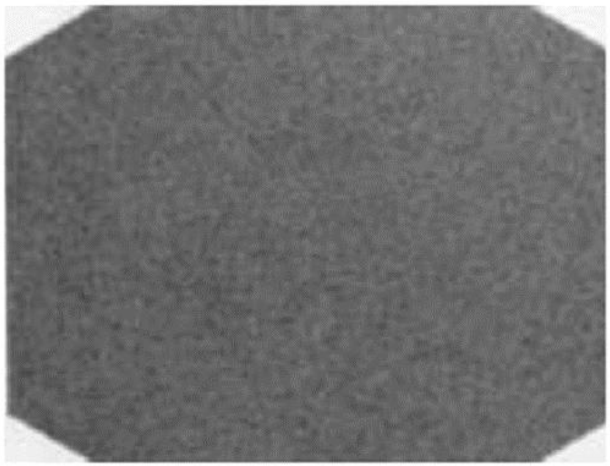
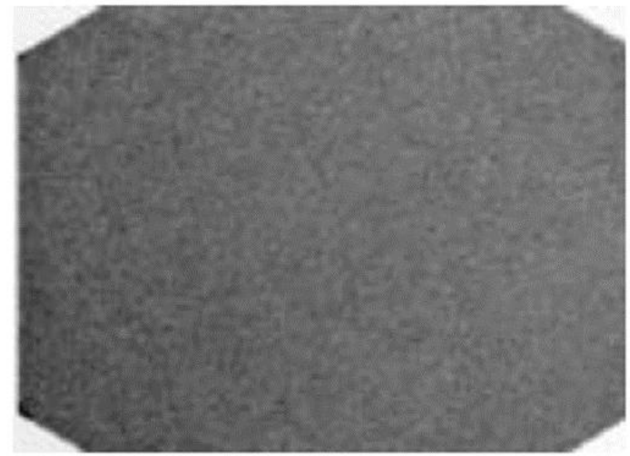
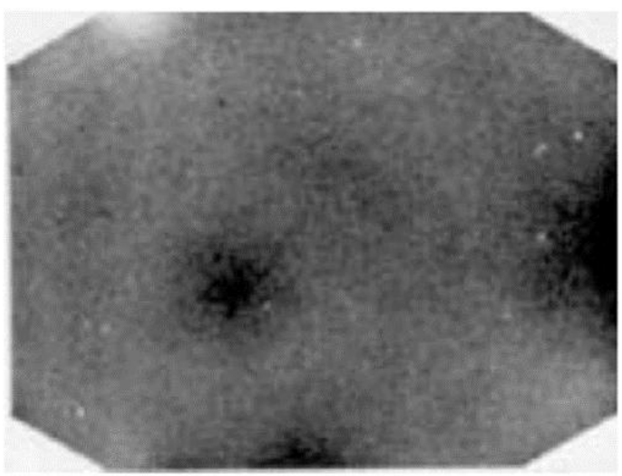
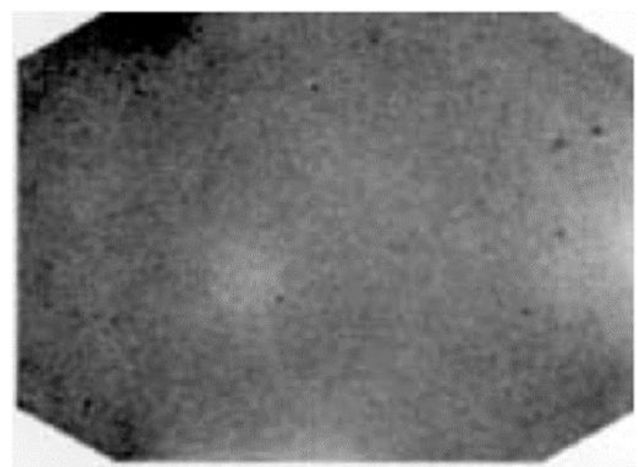
128 × 128



512 × 512

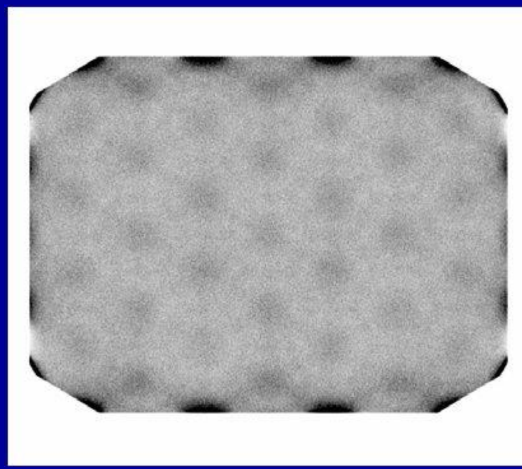
64 × 64

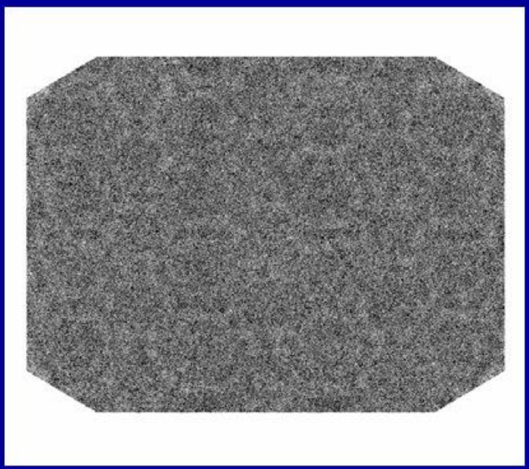
Unusual Artifacts

Correction Tables

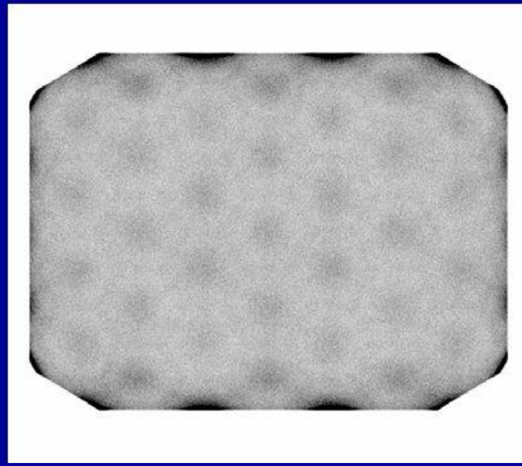
No corrections

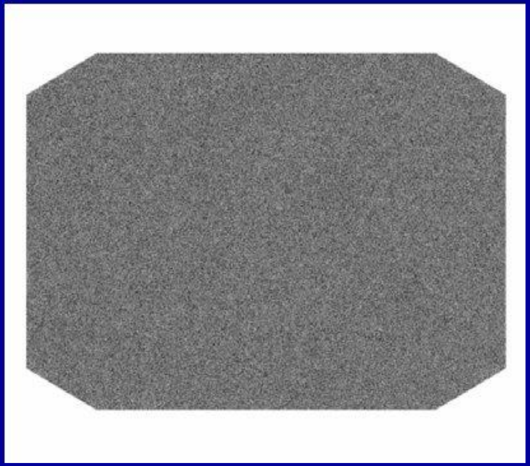




Energy And Linearity

Energy only



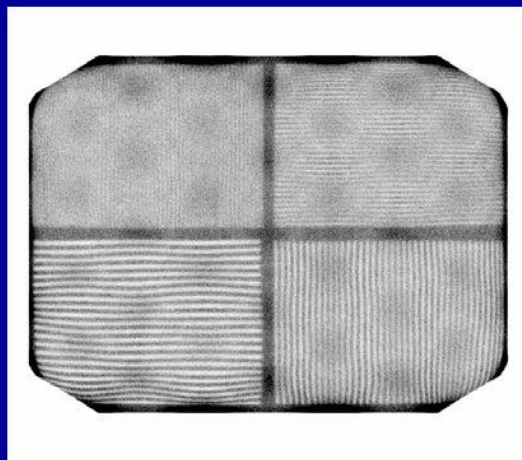


Energy, Linearity, Uniformity (all corrections)

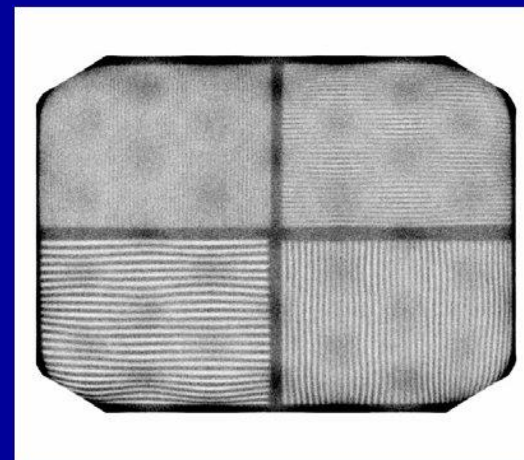
^{99m}Tc Intrinsic Flood Images

Correction Tables

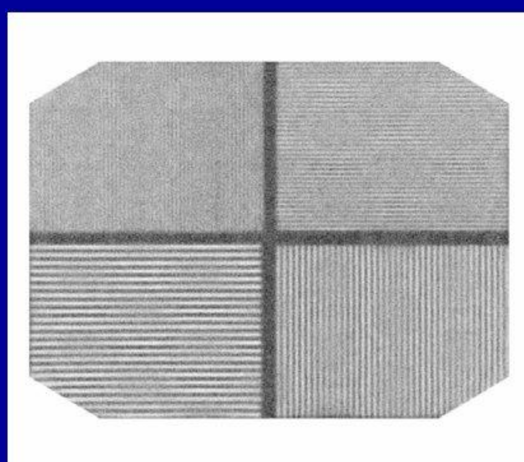
Energy only



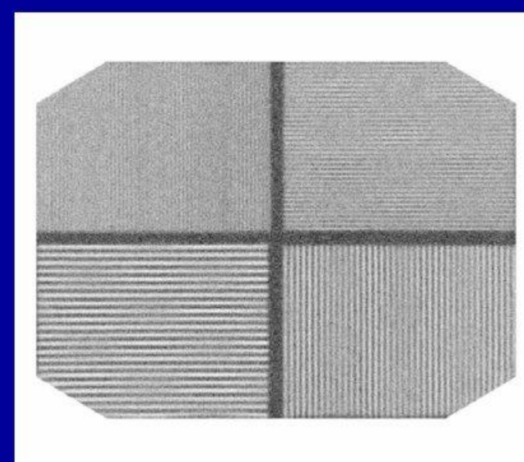
Energy and Uniformity, No Linearity Correction



Energy And Linearity Only

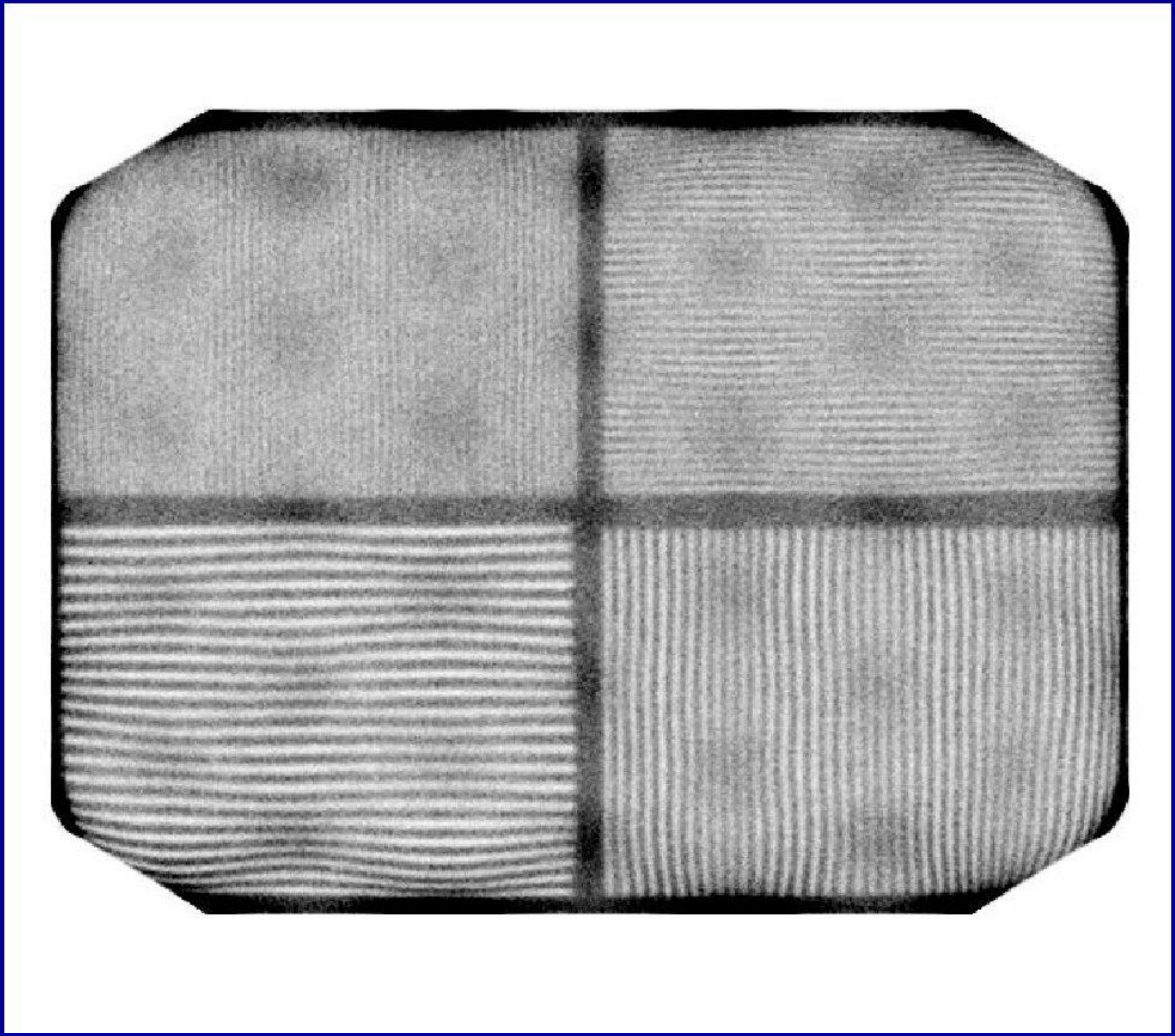


All Corrections On

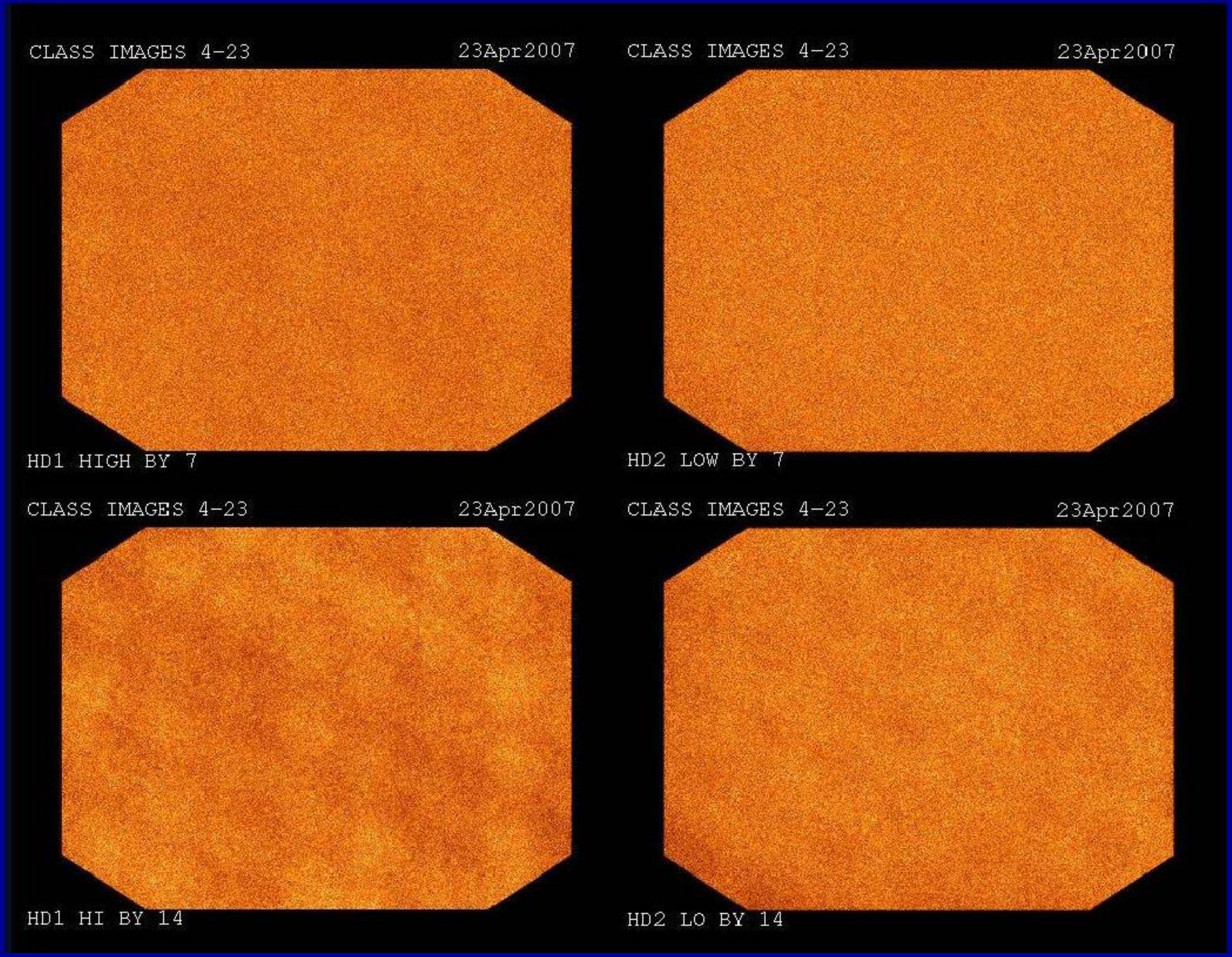


^{99m}Tc Intrinsic

Intrinsic Bars – Linearity Correction Off



Flood Images – Off Peak

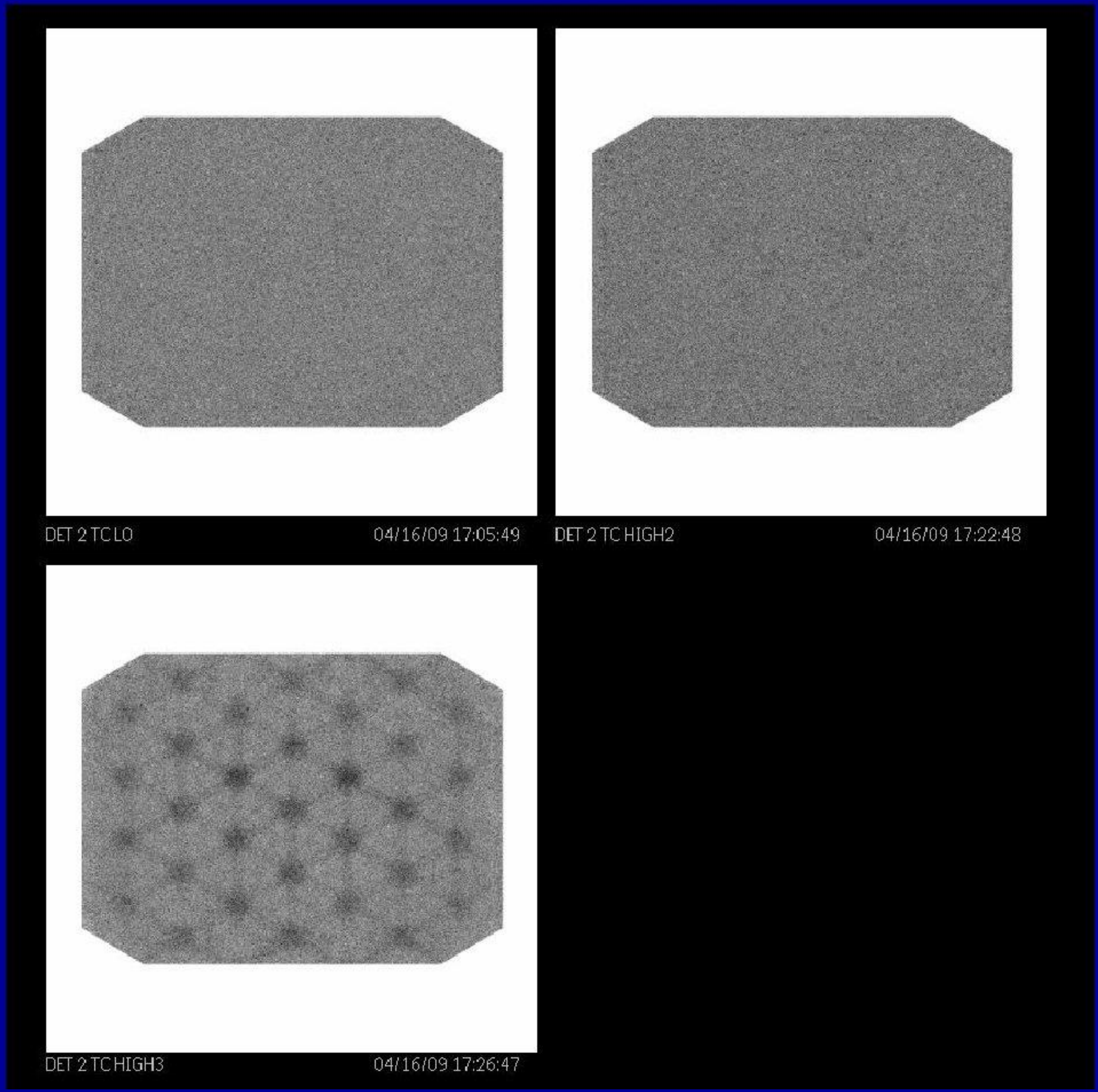


Low to High Count Rate Intrinsic Floods

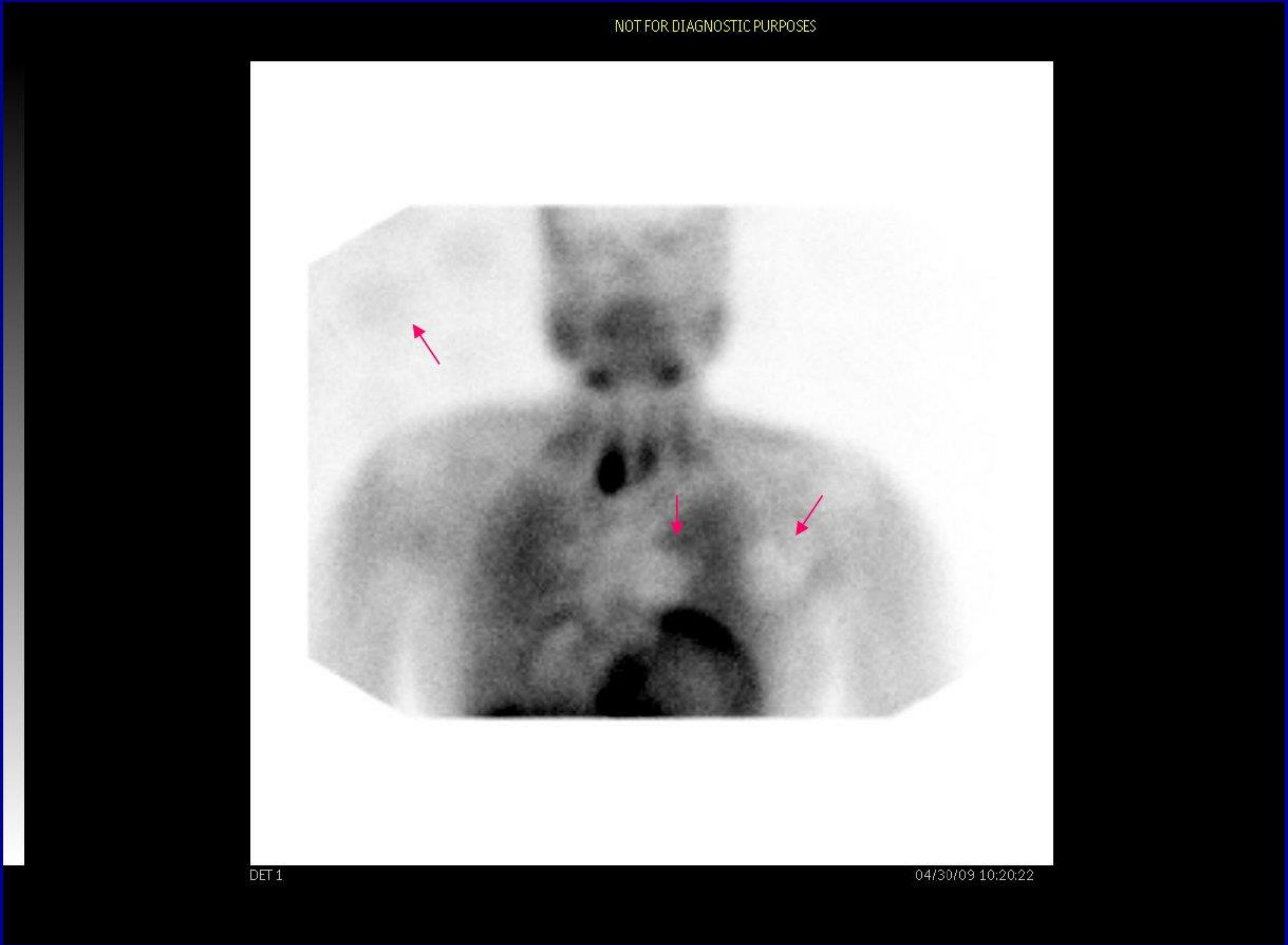
19 kcps

79 kcps

109 kcps
(too high)



Tube-like Artifacts visible in Parathyroid study



Cause: ^{99m}Tc Aerosol from previous patient pulled into camera head by fans

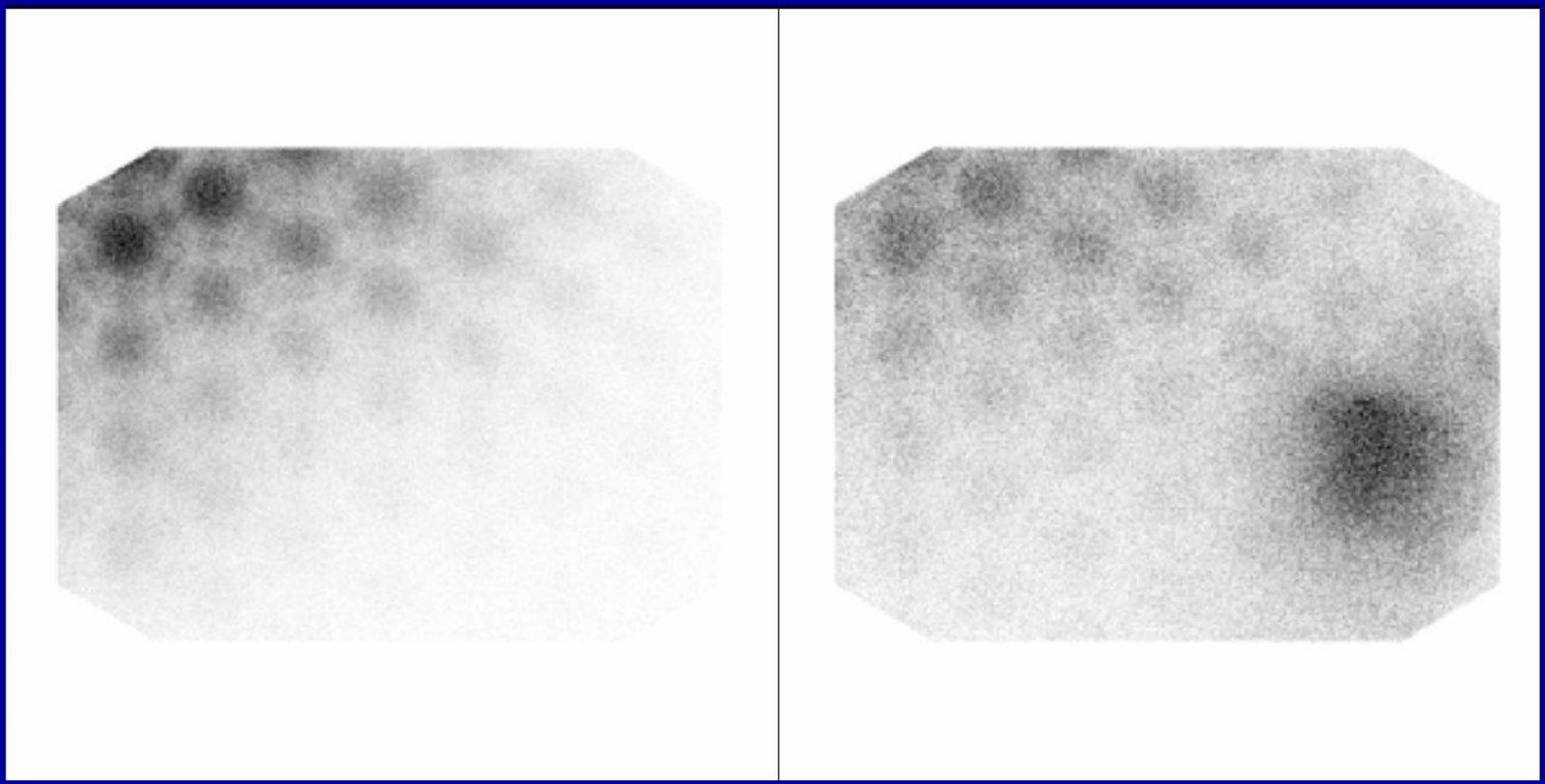
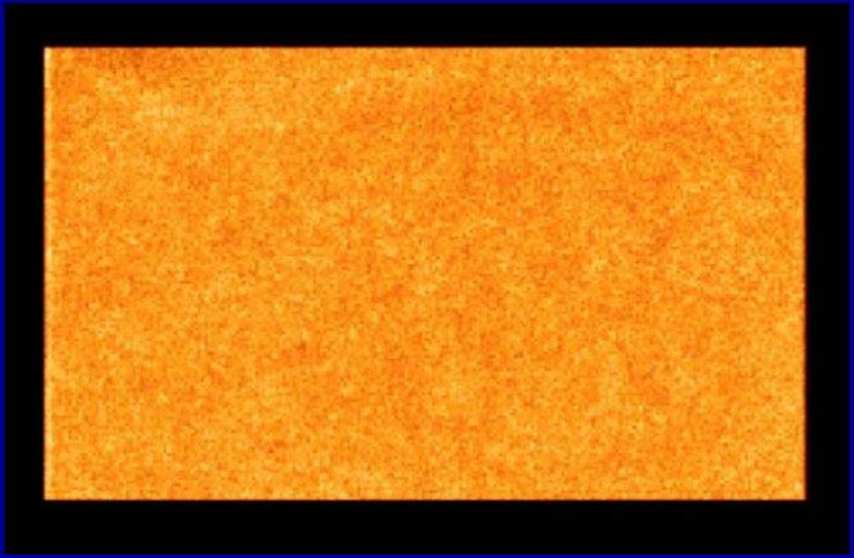


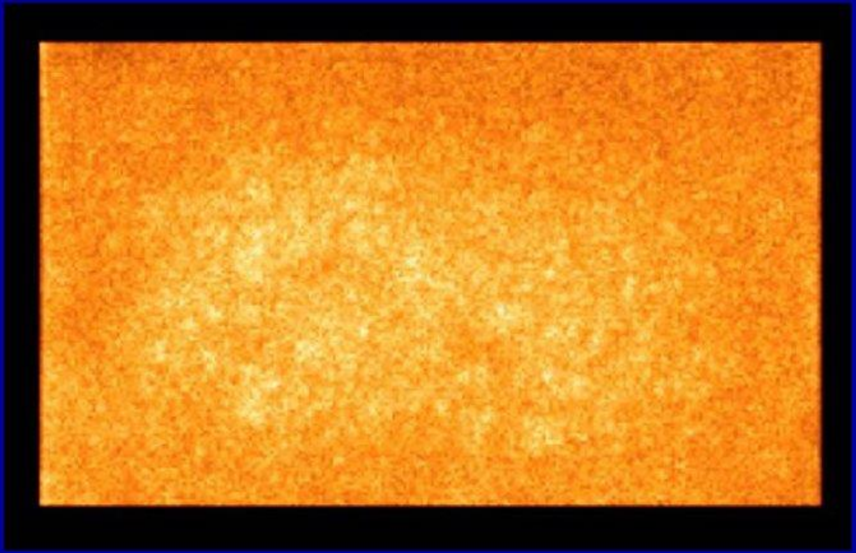
Image made with no other source other than aerosol pulled into camera heads. Tc present behind the crystal. Patient breathed aerosol close to camera heads and leakage occurred around breathing apparatus.

Daily QC – Water filled sheet source with ^{99m}Tc MAA added

Morning QC looked bad

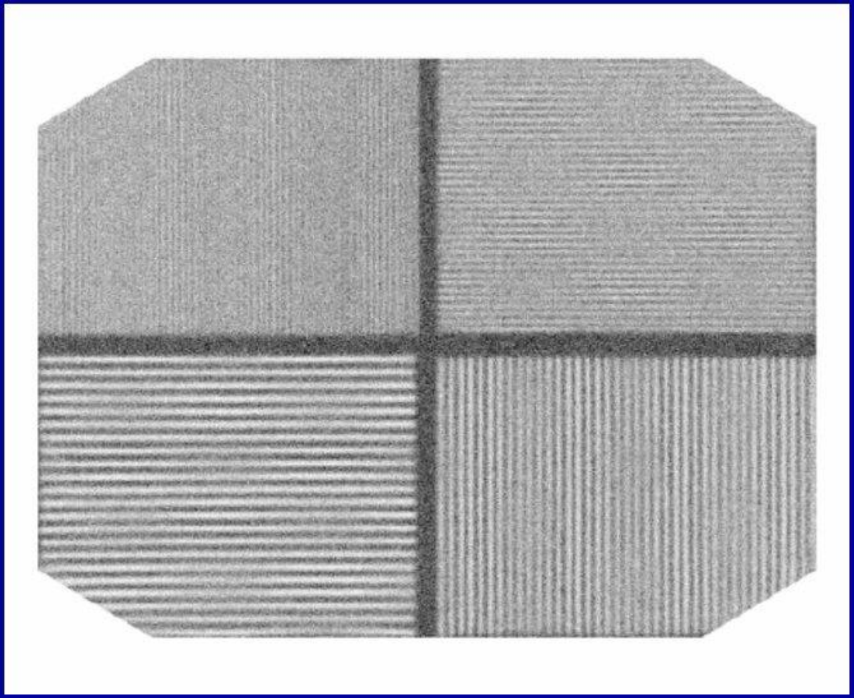


QC repeated with same source later in afternoon

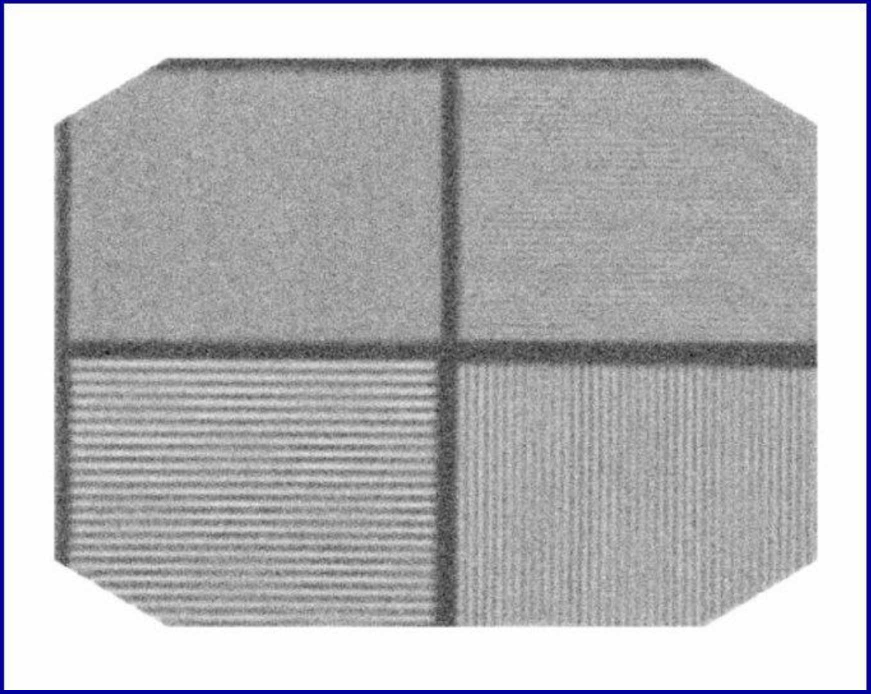


Note "clumping" effect caused by using MAA.
^{99m}Tc MAA (normally used for lung perfusion imaging) was used by mistake. Should use ^{99m}Tc pertechnetate.
Sheet source had to be emptied and rinsed

Bar pattern – intrinsic vs. extrinsic

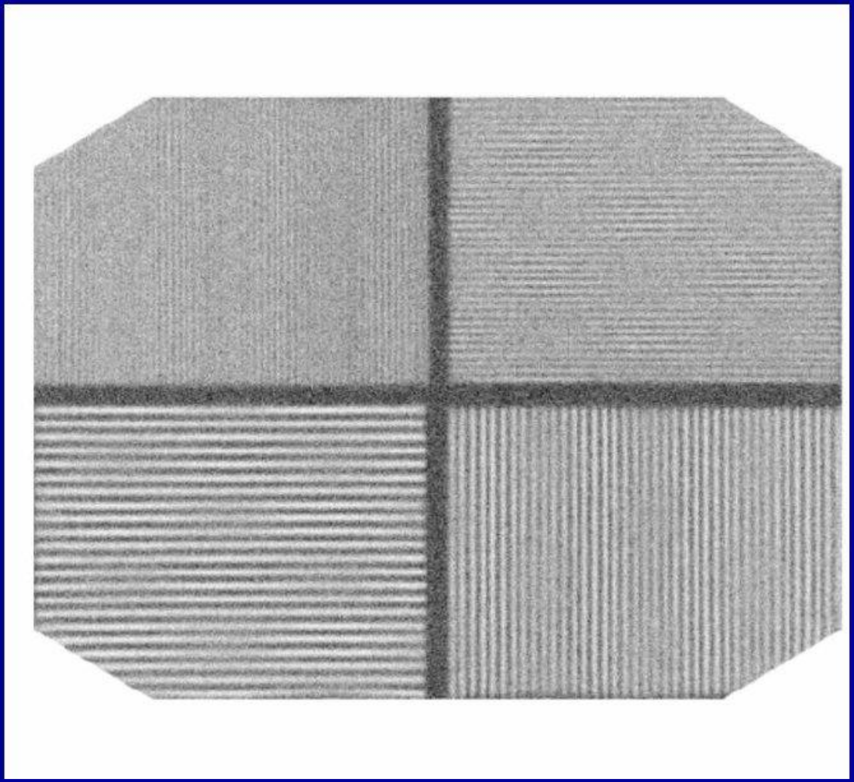


Intrinsic – better resolution than extrinsic

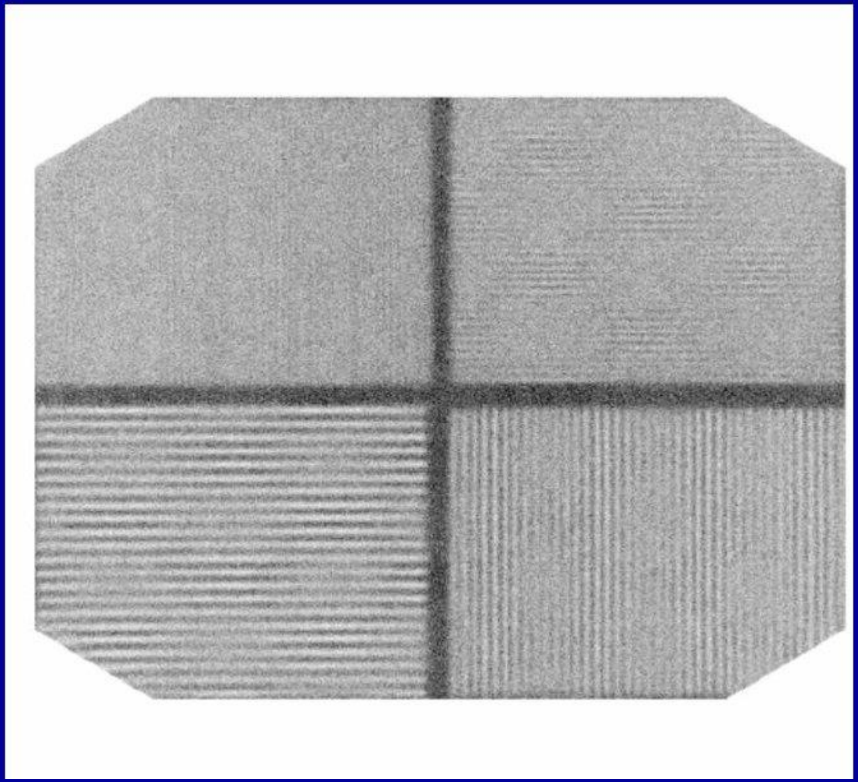


Extrinsic

Intrinsic Bar Pattern Tc and Thallium

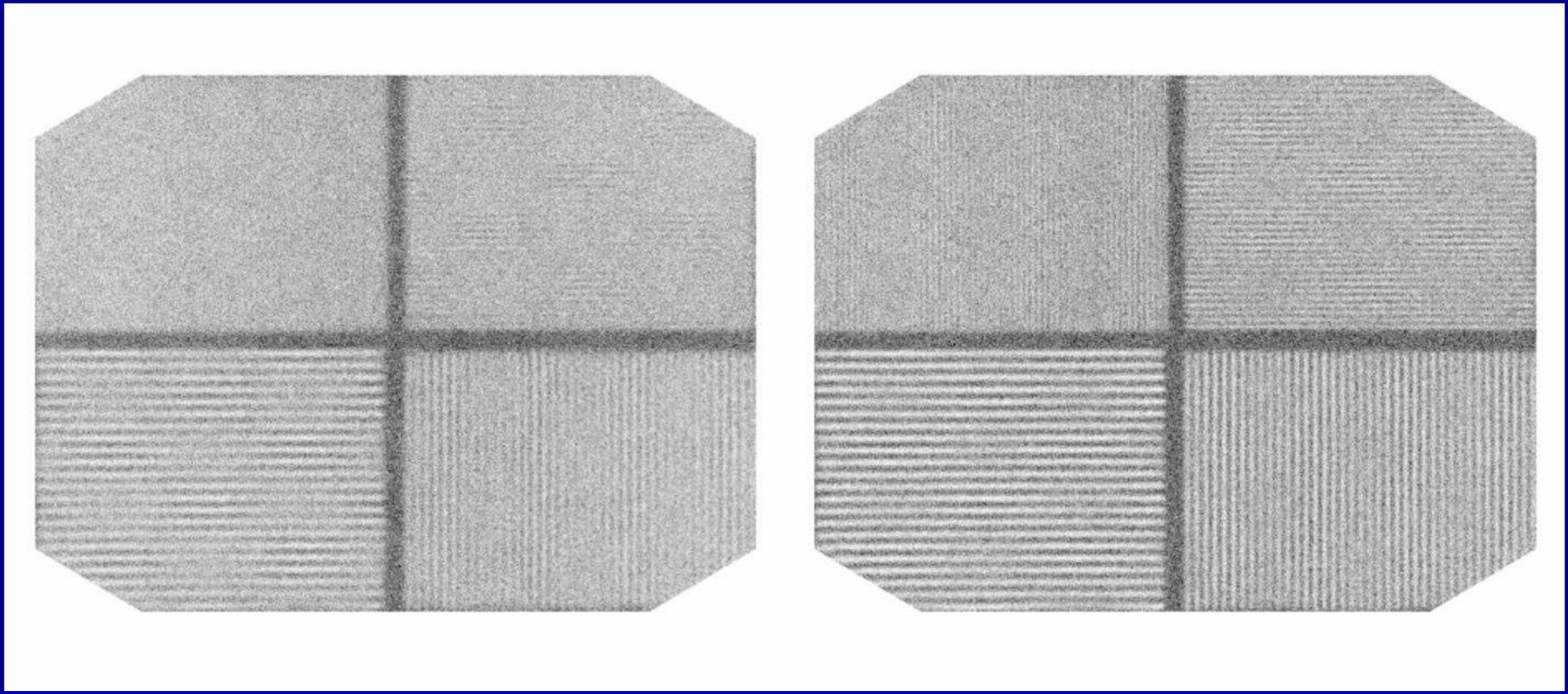


^{99m}Tc



^{201}Tl

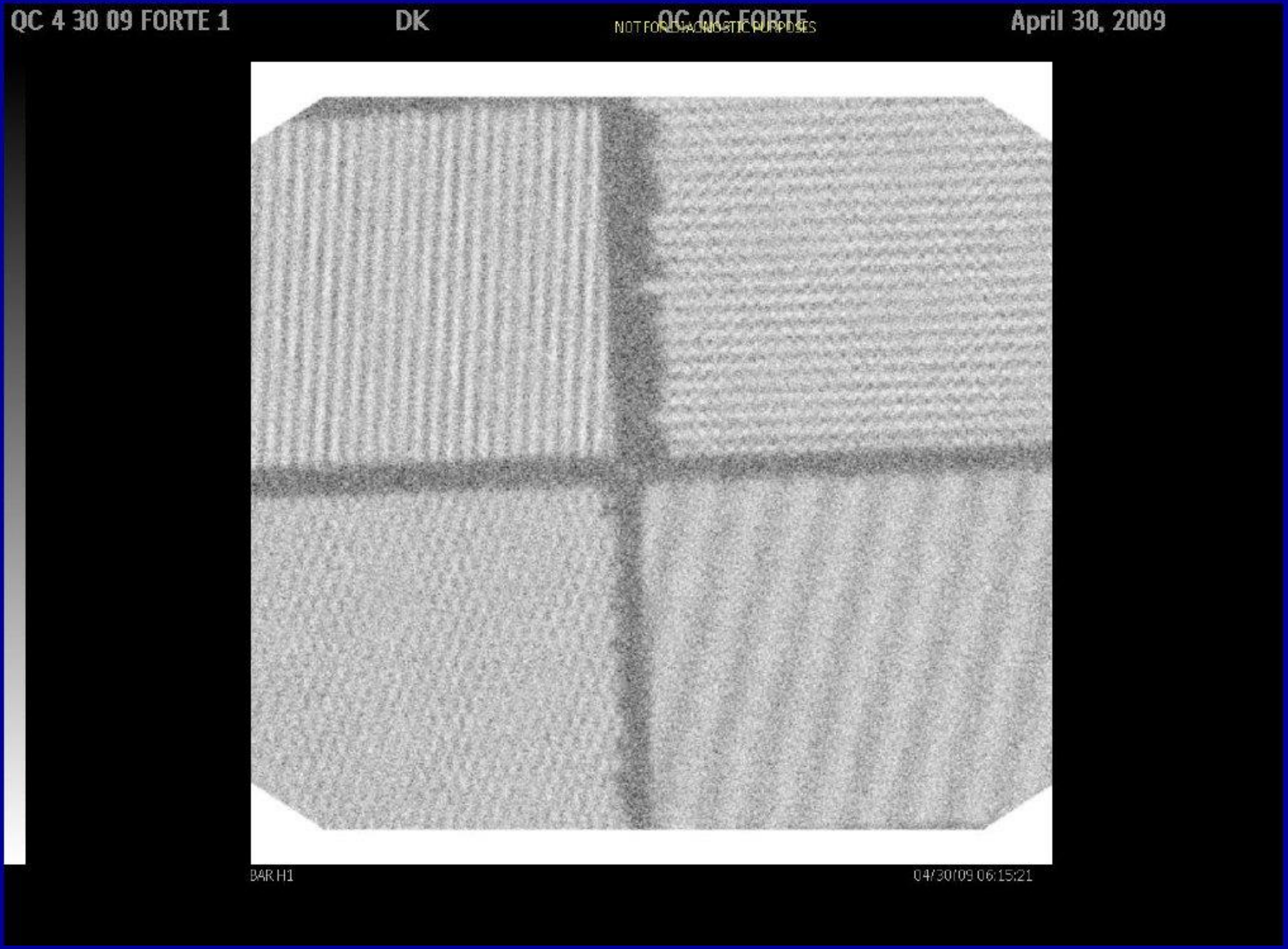
Intrinsic Thallium bar pattern, One Peak at a time



Lower energy peak only, 69 keV

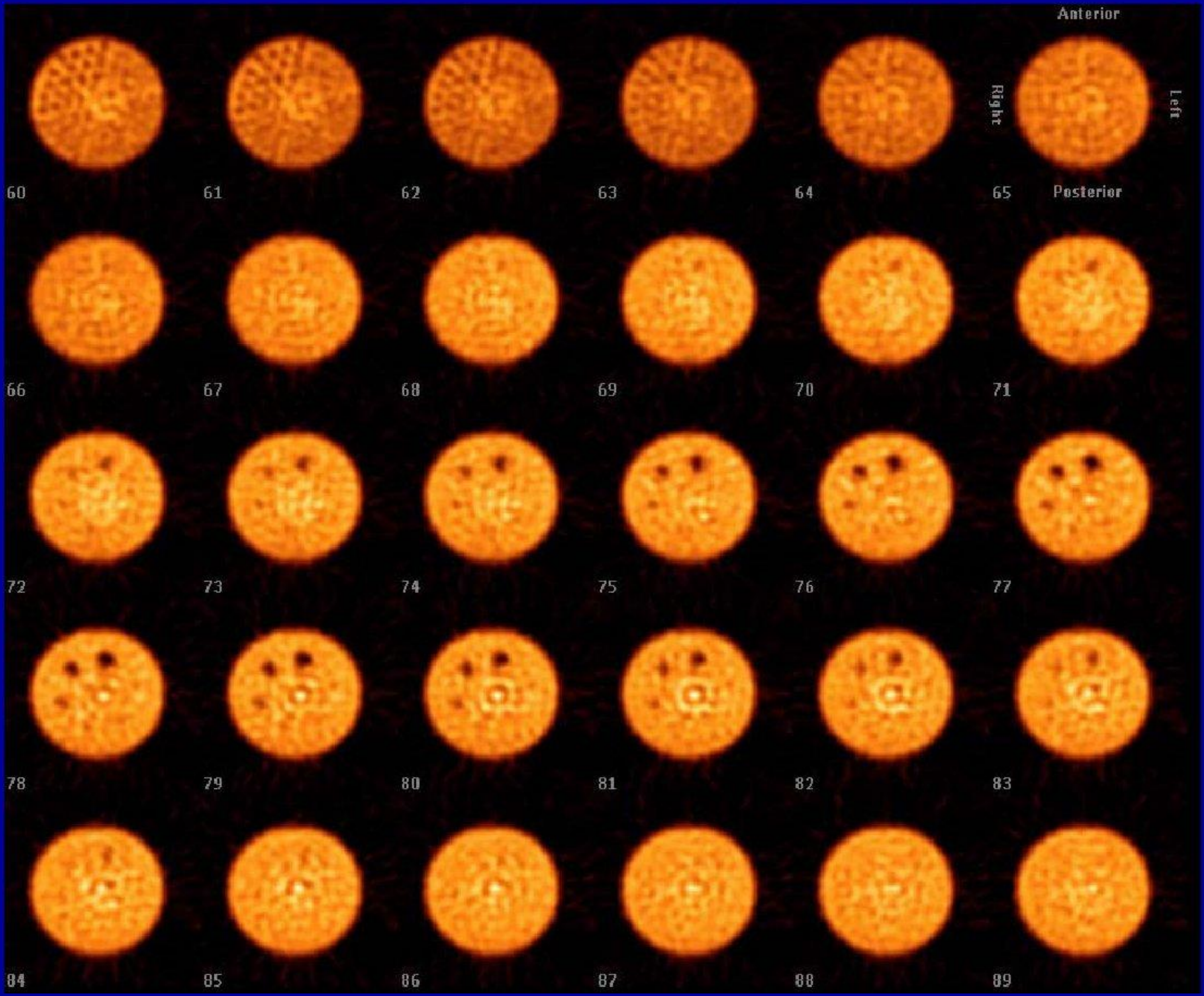
Upper energy peak only, 167 keV – Better resolution at higher energy

Bar Pattern with wrong collimator
Medium Energy Collimator



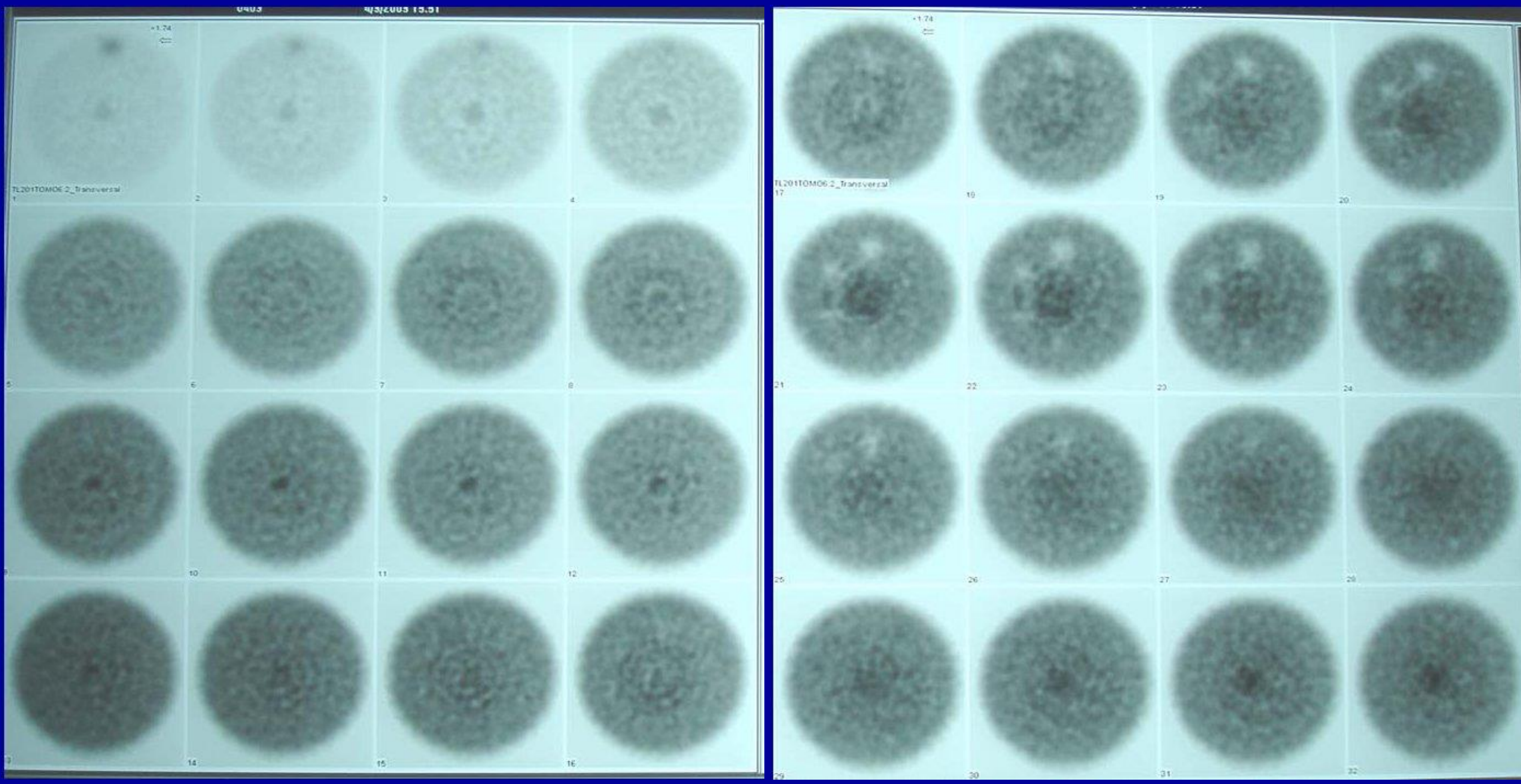
Bar pattern – slight nonlinearity in corner

Ring Artifacts

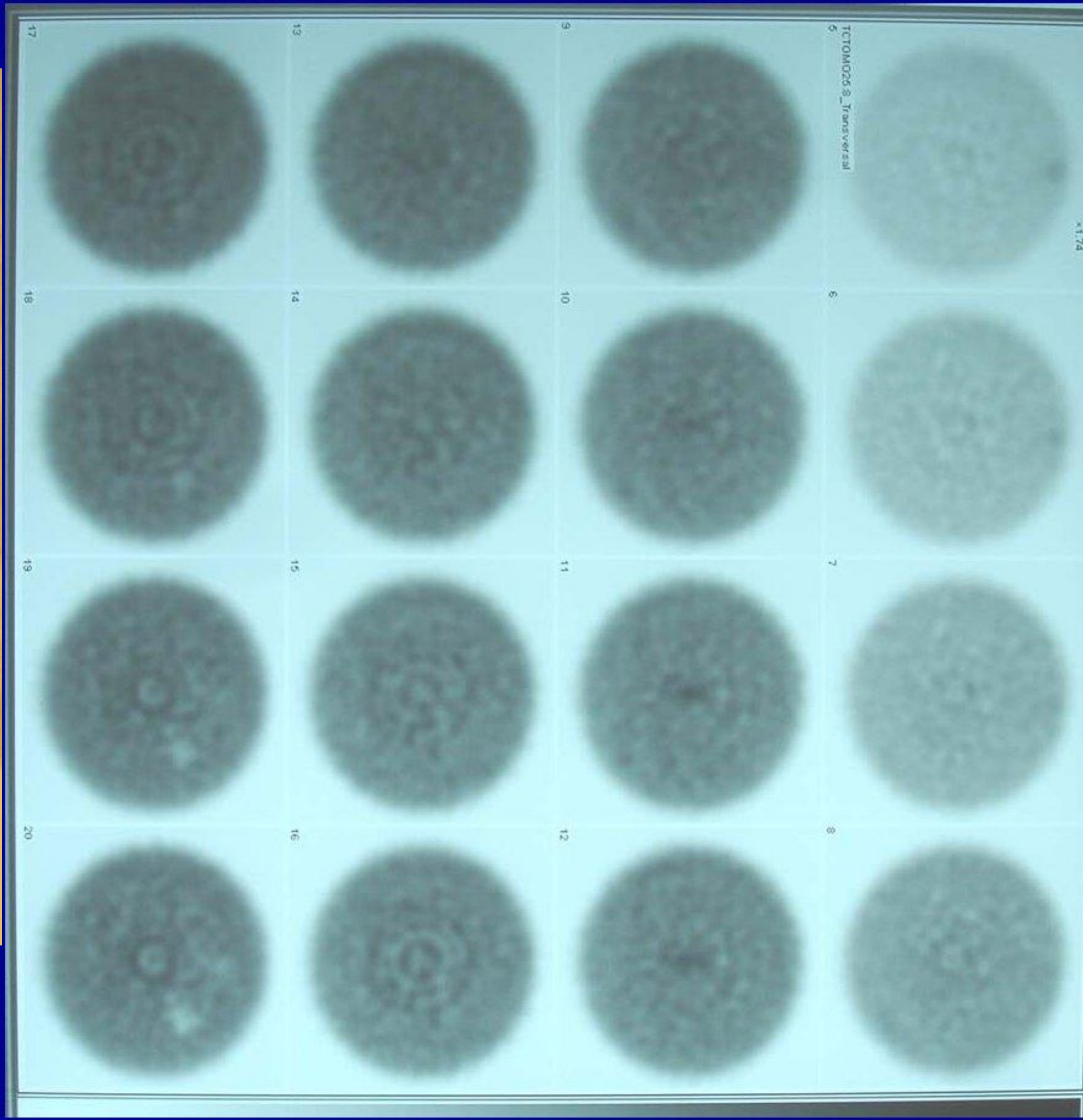


Ring artifacts visible

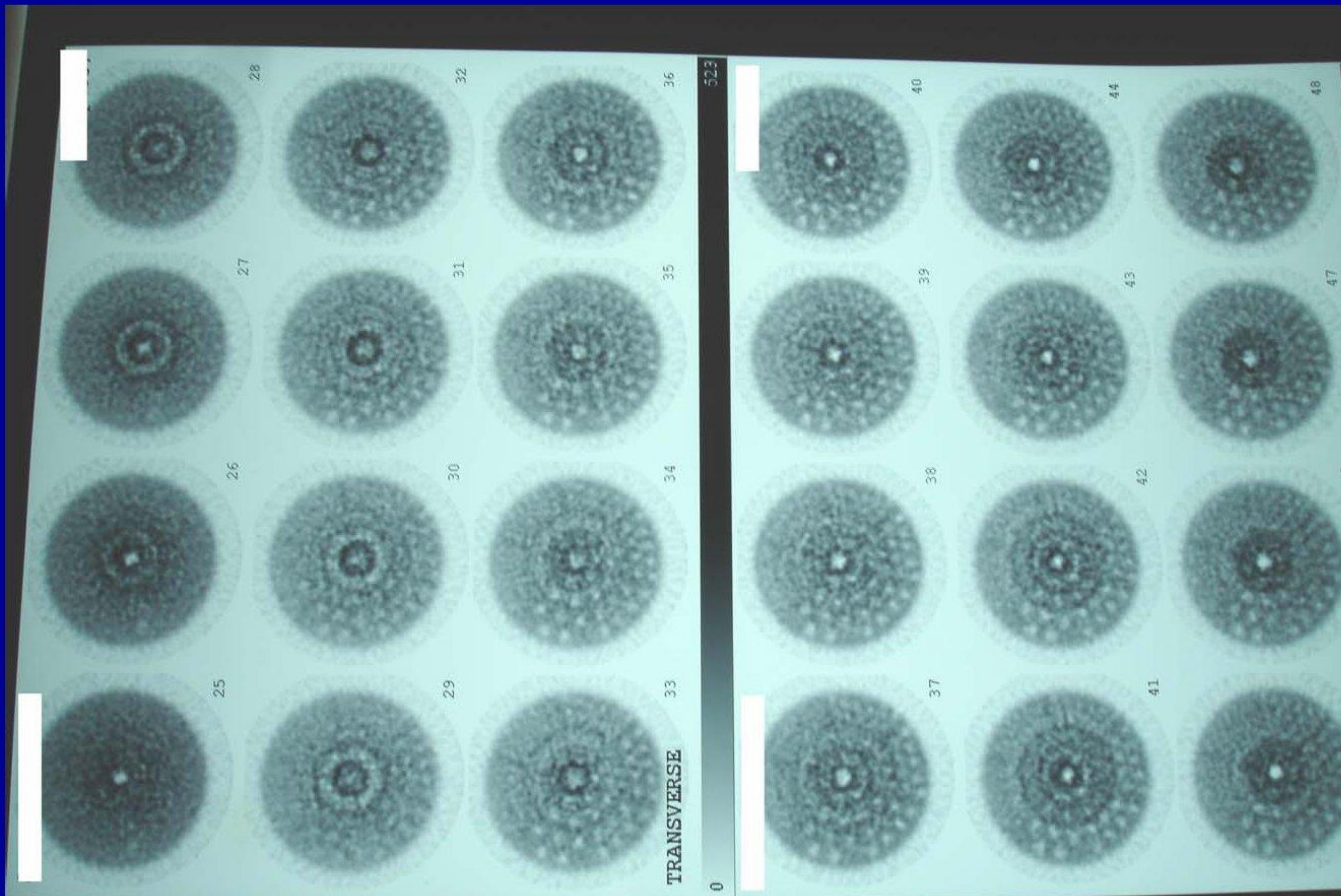
Ring Artifacts



Ring Artifacts



Severe Ring Artifacts



SPECT Ring Artifacts

- Caused by non-uniformities such as:
  - Visible non-uniformities in flood image due to camera being off peak, PMT gain imbalance, or need for new correction tables
  - Shift in photopeak as camera head rotates
  - Collimator defect or damage (not visible in intrinsic flood image)

- Even small non-uniformities can cause ring artifacts


Thank you for
your Attention!

NOISE

Count density

WHOLE BODY

- Scan speed
- Image size
- Multiple scan paths
- Detector uniformity
- Energy window Radioactive contamination

Multiple Window Spatial Registration

Multi-peak imaging with isotopes such as **Ga-67** or **In-111** assumes images acquired at **different energies** are directly **superimposable**.

Unfortunately not!

Magnitude of the positioning signals generated by the pulse arithmetic circuitry changes with gamma ray energy!

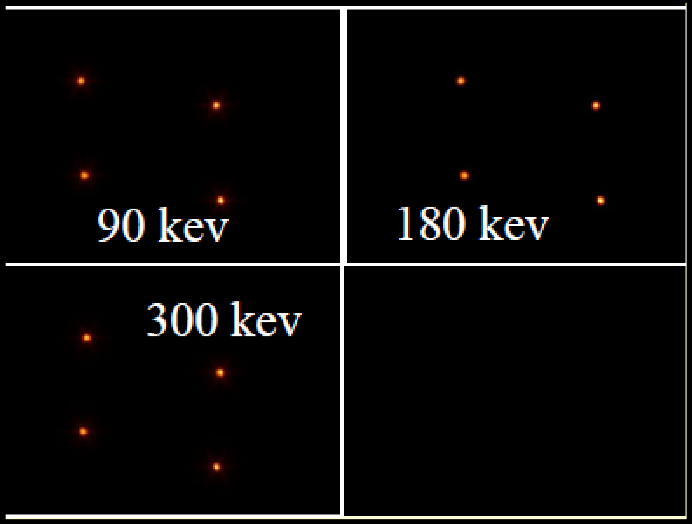
SO:
These signals are normalized to some reference energy to insure that the position of an event is independent of gamma ray energy.

This correction is achieved in term of **MWSR**!

Multiple Window Spatial Registration

Image a set of 5 collimated point sources of Ga-67 (or Ba-133) at their different photopeaks acquired at 1024 x 1024 matrix size.

Subtract the 93 keV from the 296 keV image, is a **simple visual** indication of the co-registration of the two images.



The worst difference between location of 2 different energies is MWSR! In modern gamma cameras, the use of energy and linearity correction maps has significantly improved the MWSR.