Handheld Probes and Mini-Cameras for Intraoperative Guidance during Surgery

Peter Knoll

Dept. of Nuclear Medicine with PET Center

Vienna, AUSTRIA

Conflict of Interest Disclosure Form

NAME : Dr. Peter Knoll

AFFILIATION: Wilhelminenspital

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DISCLOSURE

I have no potential conflict of interest to report

Intraoperative Gamma probes

- **Clinical Applications***
  - **Breast, gastrointestinal, head-neck, gynecoligic, ureologic, thoracic, , NET, …**
- **Isotopes**
  - **Tc99m, Iodine 125, 131**
  - **Indium 111, Fluorine 18**
  - **Gallium 68**
- **Radiation detectors**
  - **Scintillation detectors, Semiconductor Ionization detectors**
- **Performance**
  - **Radial Sensitivity distribution**
  - **Spatial resolution**
  - **Energy resolution**
  - **Shielding and Collimation**
  - **Display**

***Povoski SP et al: A comprehensive overview of radioguided surgery using gamma detection probe technology.**
World J Surg Oncol 2009 Jan 27;7:11. doi: 10.1186/1477-7819-7-11

www.crystal-gmbh.com

http://www.neoprobe.com

www.carewise.com

http://www.gammaprobe.com/products/gamma-probes/

http://www.medecine-nucleaire.lu

www.gammafinder.com

Gamma Probe, RMD Instruments

Radioguided Sentinel Lymph Node (SLN) Surgery

Basic idea:

The tumor drains in a logical way through the lymphatic system.

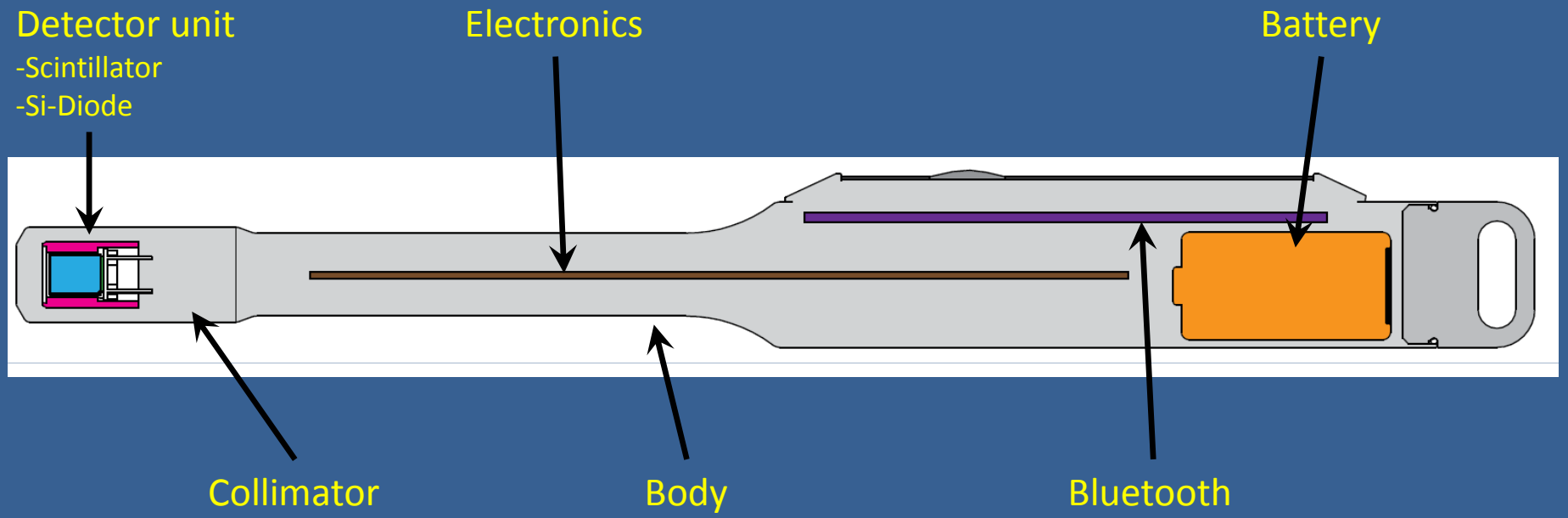
The first node encountered (sentinel node) will most likely be the first affected by metastasis.

Involved departments

Nuclear medicine

Surgery, gynaecology

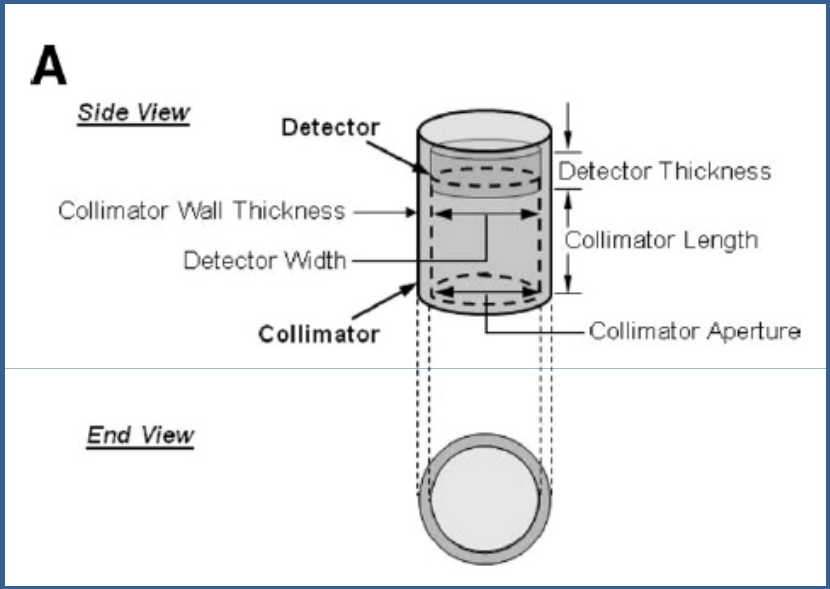
Setup

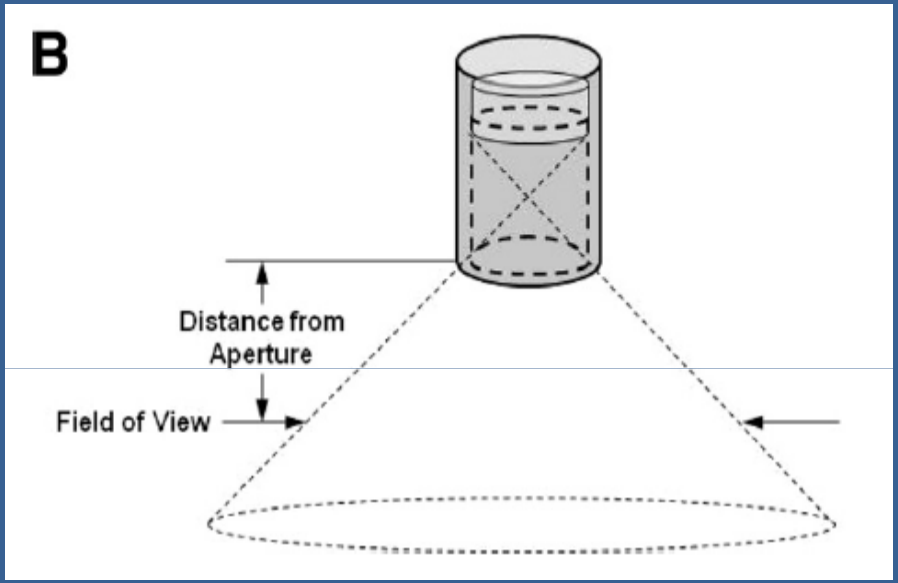


Scintillation detectors:
NaI(Tl), CsI(Tl), CsI(Na), BGO, LSO

Semiconductor Ionization detectors:
CdTe, CZT, HgI_2

Basic design of an intraoperative probe





The collimator is characterized by its aperature, length and wall thickness.

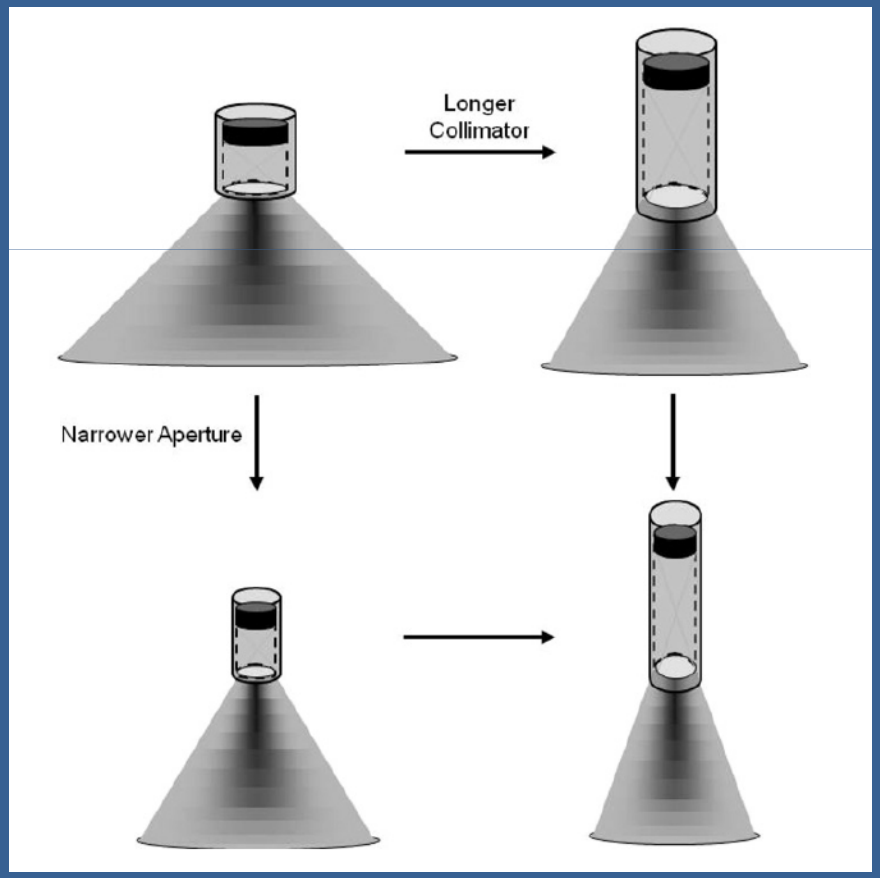
The probes FOV increases with increasing distance from the detector aperature

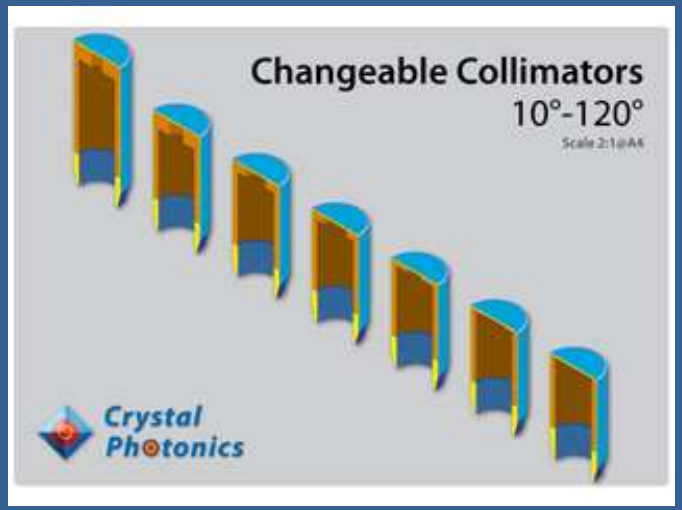
Heller S. and Zanzonico P.: Nuclear probes and intraoperative gamma cameras. Seminars in Nuclear Medicne2011 May;41(3):166-81.

Gamma Probes: Collimator

The collimation influences the sensitiviy and spatial resolution.

Material: to maximize attenuation high-atomic number materials should be used: Lead, tungsten, gold, platinium



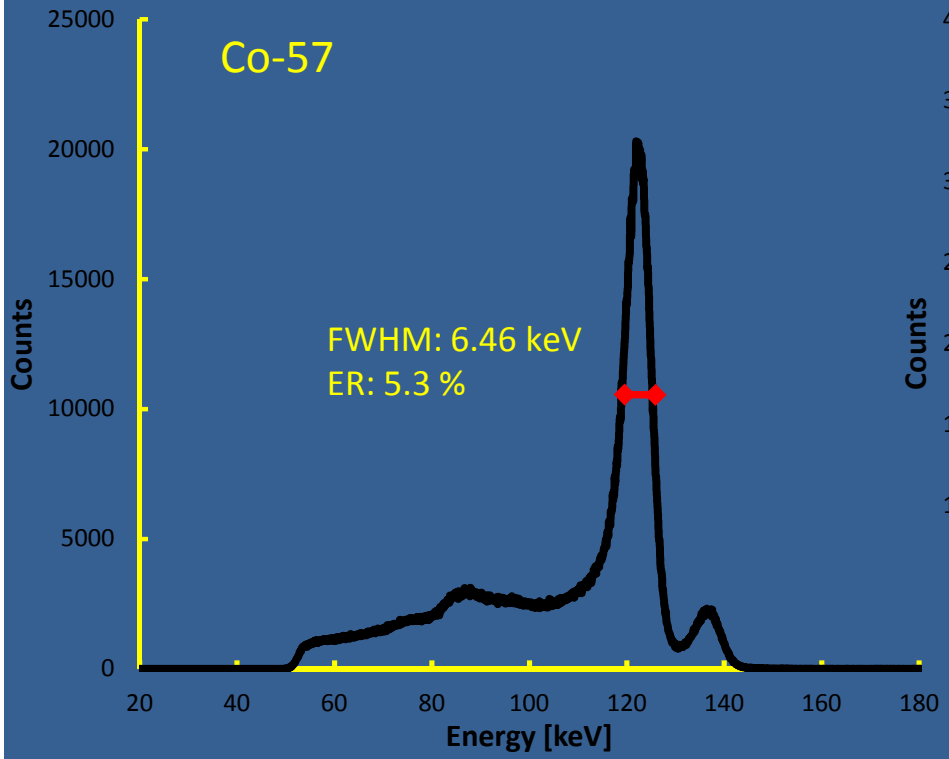


Heller S

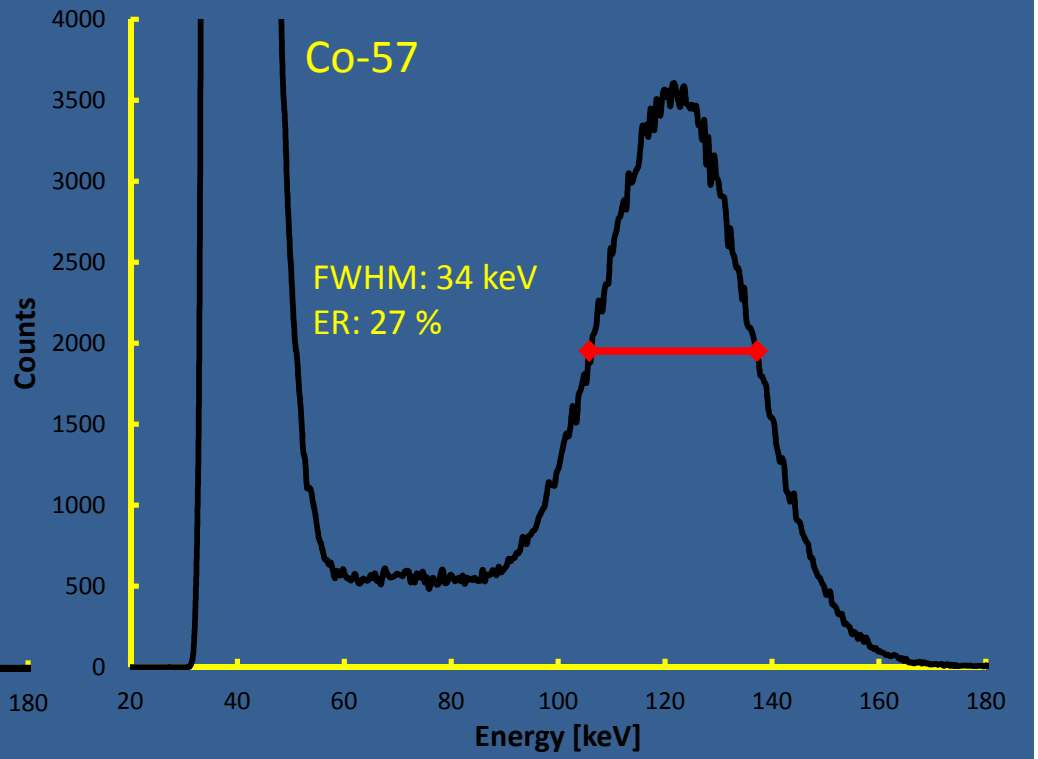
Energy resolution: Comparison

Full-Width at Half-Maximum (FWHM) expressed as the percentage of the photopeak energy

CZT



Scintillationdetector



Sensitivity

- Max. radionuclide uptake: 0.01-1 %
- Applying 99mTc-Nanocolloid: 0.05% to 0.005% uptake in lymphnode is found intraoperativly
- Activity: 80MBq

- ⇒ Sensitivity measurement for SLN ≥ 5cps/kBq

- Measurement procedure:
  Directly on the tip of the probe or collimator

- Typical values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)
- : 23-0.3 cps/MBq

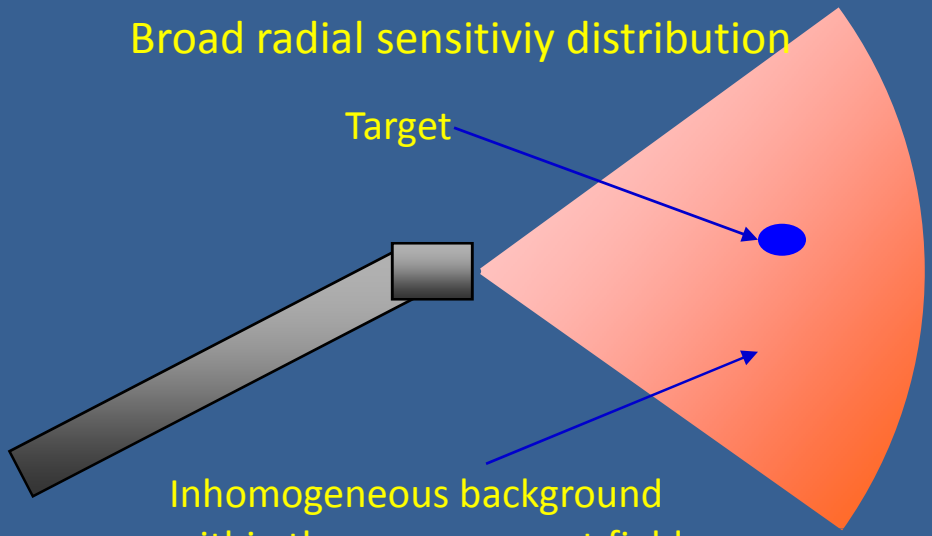
Detector Performance: Radial sensitivity distribution

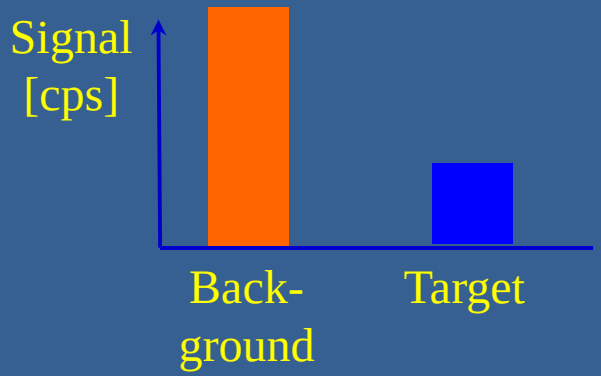
The sensitivity distribution is evaluated equidistant to the frontal radiation entrance window dependant on the polar angle.
The full width at half maximum (FWHM) of the distribution function is a good quality criterion for the detectability of lymph nodes in presence of non target radiation (injection depot, background).
With a broad measurement cone the background signal can exceed the target signal of the lymph node, which then cannot be detected.

A small cone mainly reduces background maintaining a constant target signal.
Therefore with increased background in the target area a smaller FWHM of radial sensitivity distribution is desired.

Radial sensitivity distribution

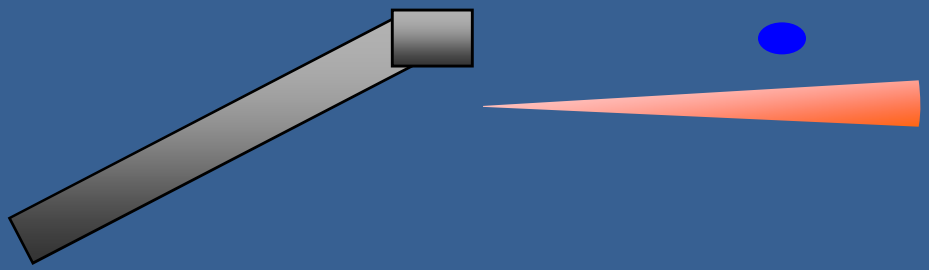
Broad radial sensitiviy distribution

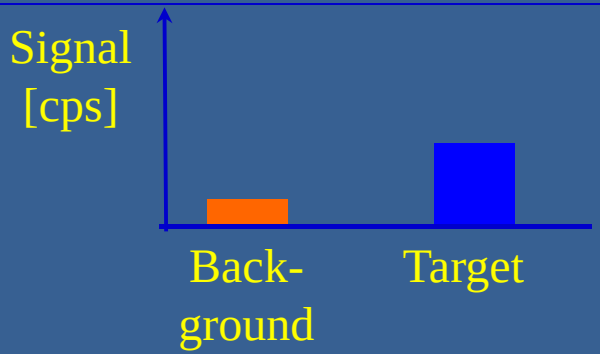




=>Target not detectable

Small radial sensitiviy distribution





=>Target detectable

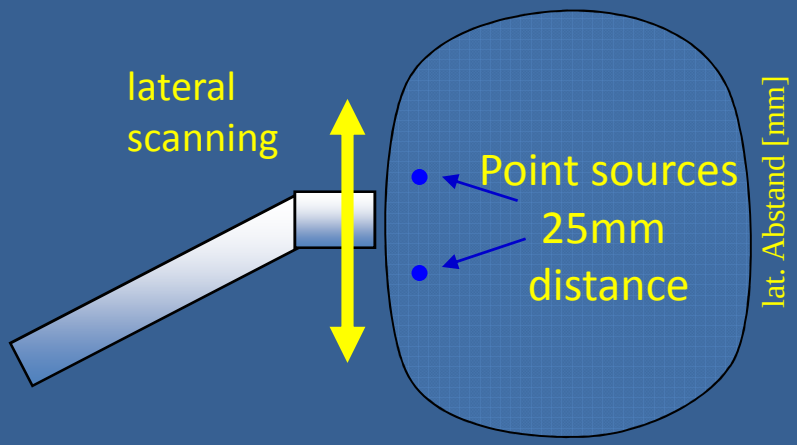
Typ. Values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)
60° collimator: 23°, 30° collimator: 13°, 15° collimator: 10°

Detector performance: Spatial resolution

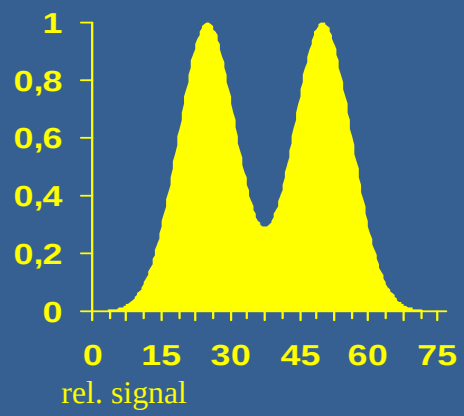
Measurement procedure:

Probe is scanned laterally above a 9mmTc point source.
The FWHM gives the minimal distances at which two pint sources can be detected separately.

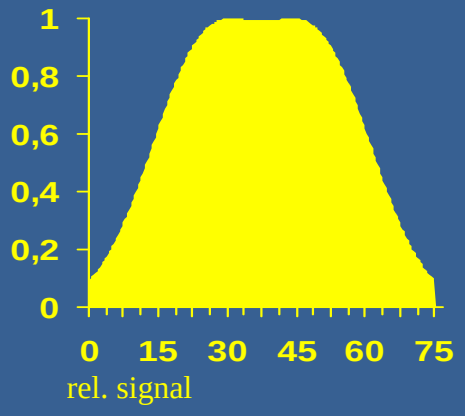
Typical values:
24 mm - 8 mm



FWHM=15mm



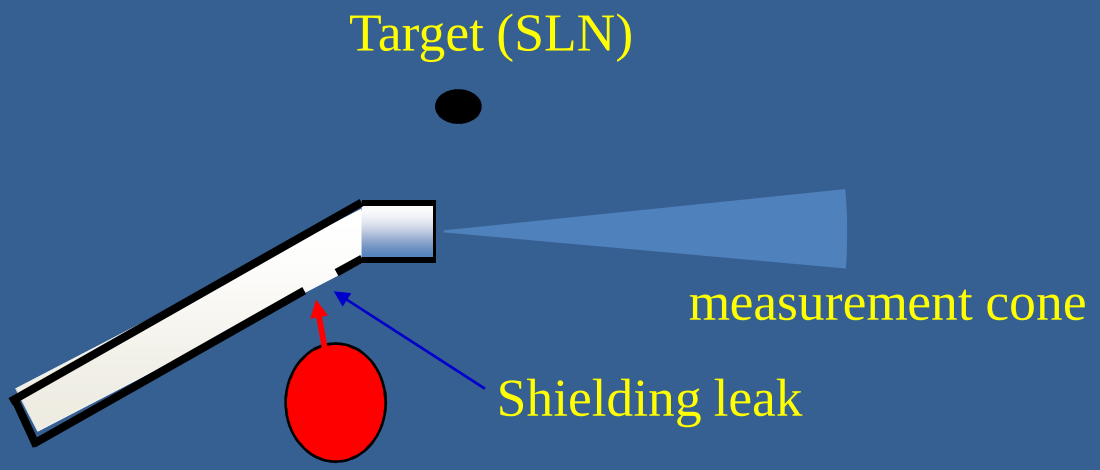
FWHM=28mm



Typ. FWHM values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)
60° collimator: 12 mm, 30° collimator: 8 mm, 15° collimator: 5mm

Shielding

Apparent SLN in the measurement cone by background activity nearby a shielding leak.

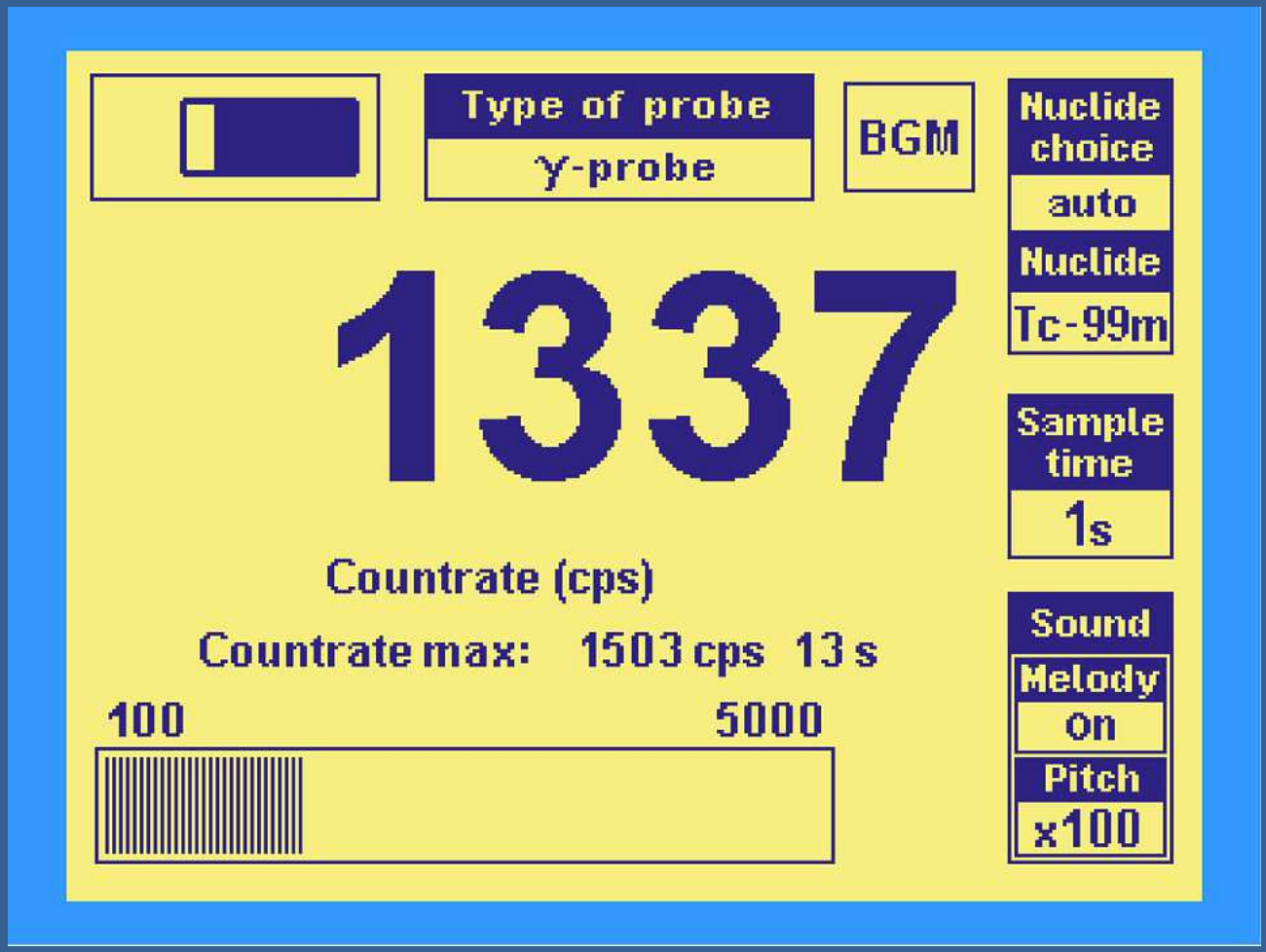


Typ. values: 0.1-8.2%

Wengenmair, H. et al. Qualitätskriterien und Vergleich von Gammasonden zur Sentinel-Lymphonodektomie. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280

Display

Correlation between accoustic tone and measurement signal



Different measurement conditions

Melanoma:
Mostly large distance between SLN and injection spot, good uptake in the SLNs

Mamma carcinoma:
short distance between SLN and injection spot, poor uptake in the SLNs

	Melanoma	Mamma carcinoma	Prostate carcinoma	Parathyroid
Sensitivity	(+)	+	+	+
Spatial selectivity		+	+	+
Spatial resolution	+ (head, neck,etc.)			+
Shielding		+	+	+
Energy discrimination		+	+	+

Wengenmair, H. et al. Qualitätskriterien und Vergleich von Gammasonden zur Sentinel-Lymphonodektomie. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280

Minimal requirements for an intraoperative probe system

Criterion	Minimal requirements
Spatial selectivity	FWHM ≤ 40°
Spatial resolution	FWHM ≤ 15 mm
Sensitivity	>> 5cps/kBq
Shielding	≤ 0.1 % of maximum system sensitivity
Energy selection	energy selection possible
Display	Acoustic, digital/analoue

Wengenmair, H.. Et al. Qualitätskriterien und Vergleich von Gammasonden zur Sentinel-Lymphonodektomie. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280

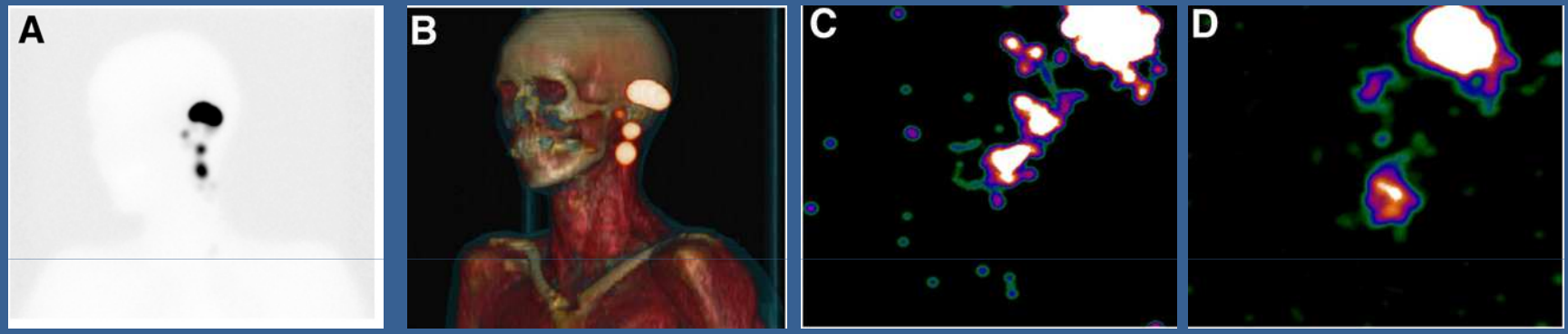
- **Intraopeartive gamma probes and additionaly „blue-dye“ technique results in an overall sensitiviyt of more that 90% and a false negative rate of 8.4%[*].**

- **Possible improvement by Small-field-of-view gamma camera**

Newman LA: Current issues in the surgical management of breast cancer. Abstract. 2002 Breast Cancer Symposium **from Heller S. and Zanzonico P.:** Nuclear Probes and Intraoperative Gamma Cameras. Sem. Nucl. Med. 2011

Comparison of preoperative images with intraoperative images

Lenka Vermeeren1 et al.: A Portable g-Camera for Intraoperative Detection of Sentinel Nodes in the Head and Neck Region. J Nucl Med 2010; 51:700–703

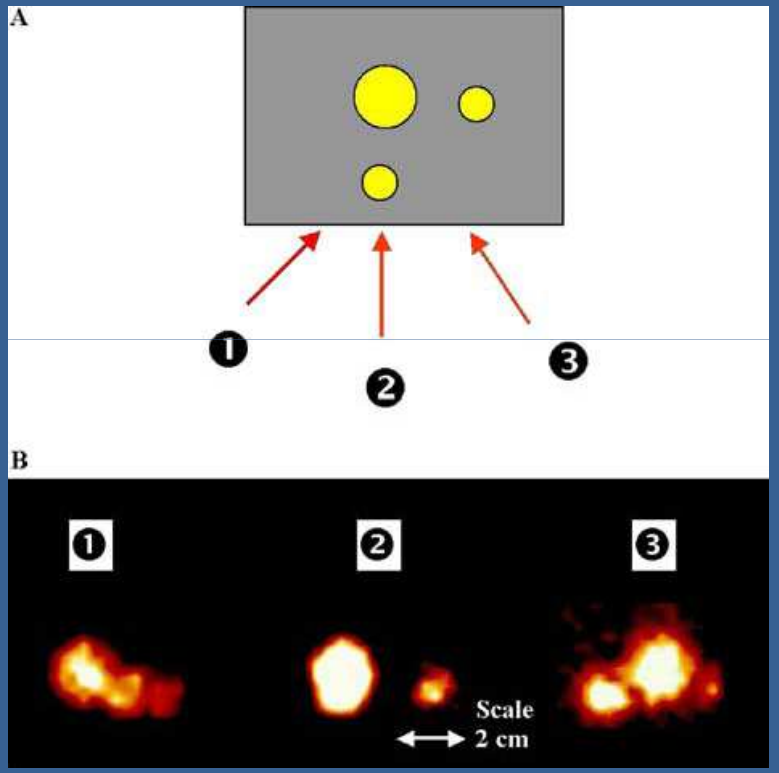


In patient with melanoma cranial to left ear, lateral planar lymphoscintigraphy after 2 h (A) showed 2 hot spots caudal to injection area and weak preauricular hot spot. All 3 hot spots had already been visualized on dynamic scans and on static planar images after 15 min.

On 2-dimensional and 3-dimensional (B) SPECT/CT fusion, 2 sentinel nodes were localized just ventral to sternocleidomastoid muscle and 1 preauricular sentinel node was localized within upper part of parotid gland. In concordance with SPECT/CT, intraoperative images before incision showed injection area and 3 sentinel nodes in same relation to each other (C).

After excision of first sentinel node, portable g-camera showed remaining sentinel nodes (D), which were then localized and removed.

Why a portable gamma camera might be useful?



D. Koppelmann et al.: A newly developed intra-operative gamma camera: performance characteristics in a laboratory phantom study Eur J Nucl Med Mol Imaging (2005) 32:1217–1224

Small Field of View Gamma Camera

www.gem-imaging.com

Intramedical imaging

http://crystal-photonics.com/

Kerrou K. etal: The usefulness of a preoperative compact imager, a hand-held gamma-camera for breast cancer sentinel node biopsy: final results of a prospective double-blind, clinical study. J Nucl Med. 2011 Sep;52(9):1346-53

M. Tsuchimochi, K. Hayama: Intraoperative gamma cameras for radioguided surgery: technical characteristics, performance parameters, and clinical applications. Phys. Medica (2013) 29, 126-138

Characteristics of the IHGC and other intraoperative gamma cameras.

Small gamma camera	Detector	Matrix size	FOV (detector)	Size (detector head)	Weight	Energy range	Collimator
IHGC	NaI (Tl) PS-PMT	29 × 29	50 mm × 50 mm	64 mm × 64 mm × 76 mm	1.1 kg	30–300 keV	Parallel-hole
POCI	YAP (Ce)		⌀ 24 mm		2 kg	Tc-99m, I-125, In-111	Parallel-hole
Minicam®	CdTe	16 × 16	49 mm × 49 mm	⌀ 95 mm height 150 mm		20–200 keV	Parallel-hole
MinicamII®	CdTe	16 × 16	40 mm × 40 mm	70 mm × 170 mm × 250 mm	700 g	30–200 keV	Parallel-hole
LumaGEM	CsI (Na) PS-PMT	16 × 16	20 mm × 20 mm			30–300 keV	Parallel-hole, pinhole
eZ-SCOPE®	CdZnTe	16 × 16	32 mm × 32 mm	60 mm × 60 mm × 220 mm	800 g	71–364 keV	Parallel-hole, pinhole, coded ap.
Second POCI	CsI (Na) IPSD	50 × 50	⌀ 40 mm	⌀ 95 mm height 90 mm	1.2 kg	105–175 keV	Parallel-hole
Sentinella 102®	CsI (Na) PS-PMT	300 × 300	40 mm × 40 mm	8 cm × 9 cm × 15 cm	1 kg	50–200 keV	Pinhole
GE camera	CdZnTe	16 × 16	40 mm × 40 mm	Height 150 mm	1.2 kg	40–200 keV	Parallel-hole
CarollReS	Gd2SiO5 (Ce) PS-PMT		50 mm × 50 mm	78 mm × 78 mm × 275 mm	2.49 kg		Parallel-hole
HRC	CsI (Tl) PS-PMT	20 × 20	49 mm × 49 mm		2 kg		Parallel-hole
MediPROBE	CdTe	256 × 256	14 mm × 14 mm	200 mm × 70 mm × 30 mm	1.5 kg		Pinhole
SSGC (prototype)	CdTe	32 × 32	44.8 mm × 44.8 mm	152 mm × 166 mm × 65 mm	2.7 kg	550 keV maximum	Parallel-hole
SSGC (clinical)	CdTe	32 × 32	45 mm × 45 mm	82 mm × 86 mm × 205 mm	1.4 kg	550 keV maximum	Parallel-hole

Detector: NaI, CZT, YAP, CdTe, CsI, etc.

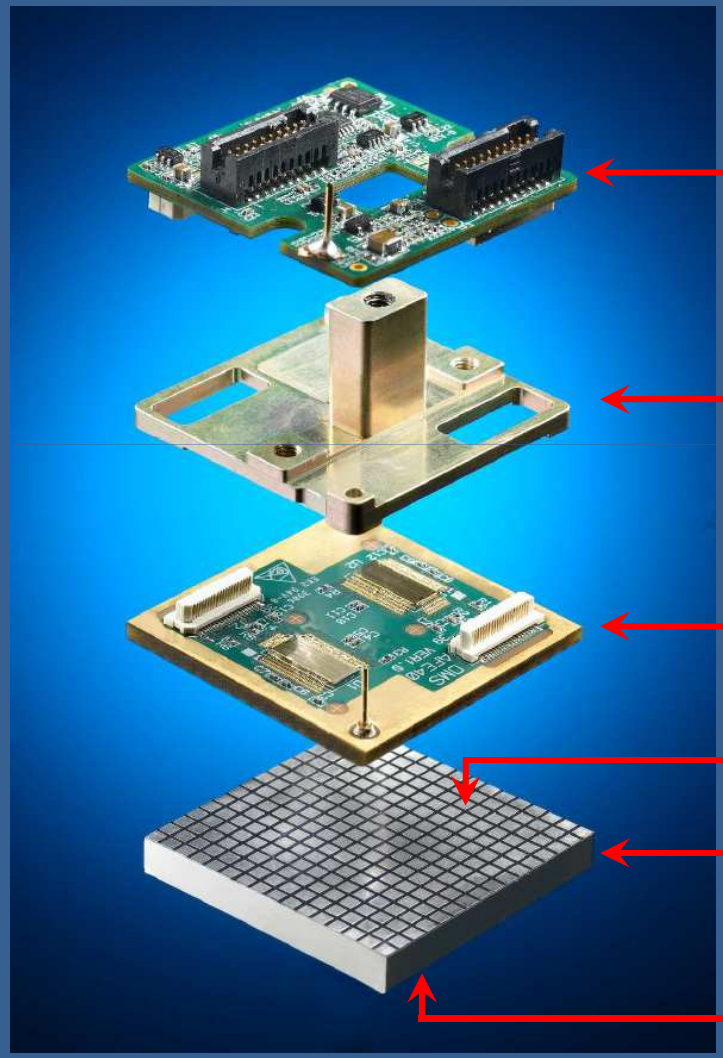
Matrix size: 16x16 – 256 x 256

FOV: 14x14 – 50 x 50 mm

Weight: 700 g – 2200 kg

Handheld-gamma camera

CrystalCam von CrystalPhotonics, Berlin



„Read-out“-elektronics

Cooling system

Front-End Electronics

Pixellierte Anode

CZT-crystal

Cathode

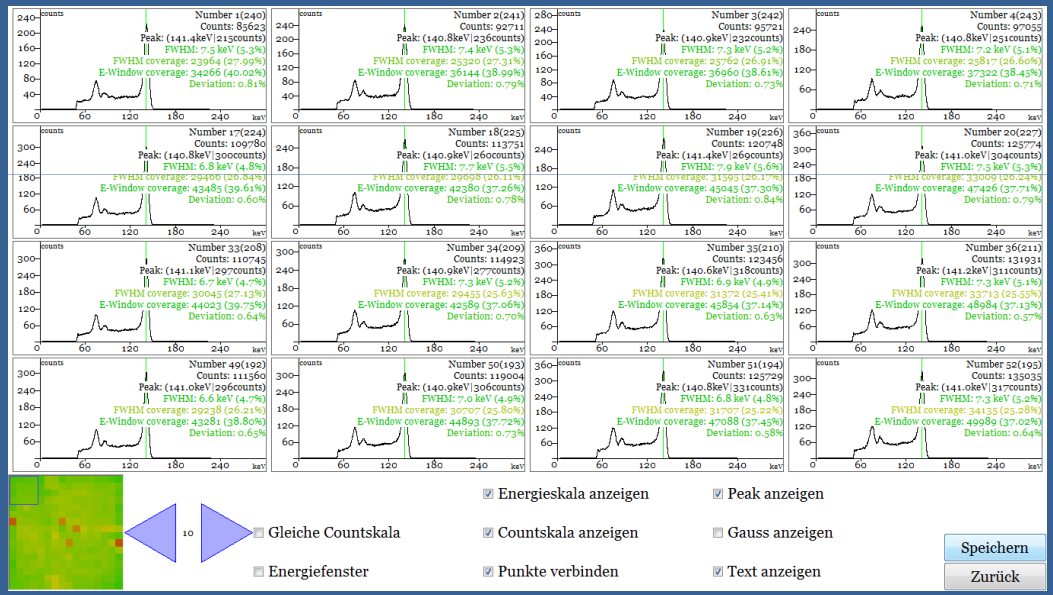
Standard energy range of the gamma camera is 40 – 250 keV.

Acceptance test handheld gamma camera: Intrinisic measurements

Intrinisic uniformity

Integral uniformity	3.2%
Differential uniformity	1.8%

Intrinisic energy resolution

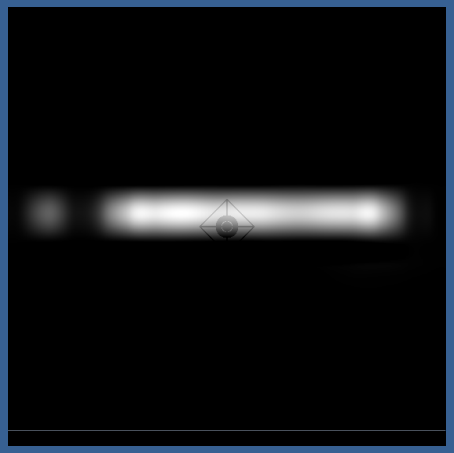


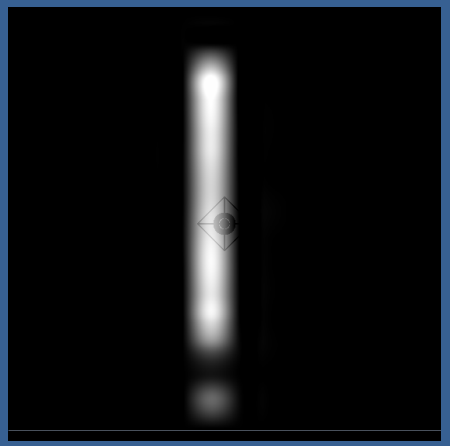
Average: 5.2%

System uniformity

	int [%]	diff[%]
LEHR	5.8	3.8
MEGP	5.3	3.5
LEHS	5.3	3.0

Acceptance test handheld gamma camera: System resolution without scatter

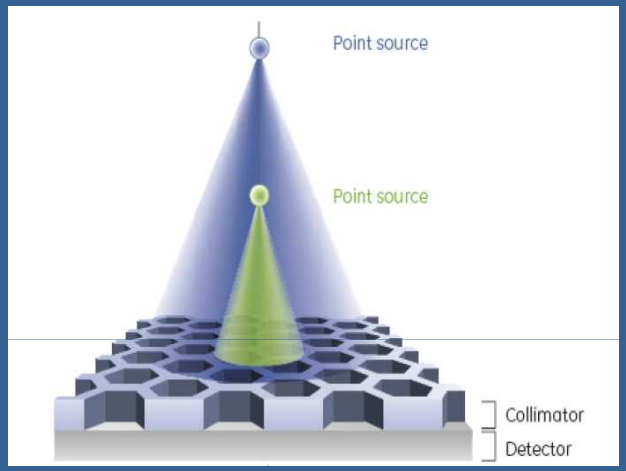




Collimator type	Distance 0 cm			
	FWHM [mm]		FWTM [mm]	
	x-direction	y-direction	x-direction	y-direction
LEHR	1.93	2.03	3.49	3.66
MEGP	1.91	1.89	3.46	3.42
LEHS	2.27	2.98	5.17	7.74

System resolution without scatter: 0 mm distance, various collimators

Acceptance test handheld gamma camera:
System resolution without scatter for various distances



Distance from the detector	FWHM [mm]		FWTM [mm]	
	x-direction	y-direction	x-direction	y-direction
0.0 cm	1.93	2.03	3.50	3.66
2.5 cm	3.74	3.89	6.88	8.07
5.0 cm	5.02	4.78	9.00	10.60

System resolution without scatter: various distances, LEHR collimator

Data from Literature: 1.5-18mm*

* M. Tsuchimochi, K. Hayama: Intraoperative gamma cameras for radioguided surgery: technical characteristics, performance parameters, and clinical applications. Phys. Medica (2013) 29, 126-138

Acceptance test handheld gamma camera: System planar sensitivity

The sensitivity measurements were done with 75 MBq 99mTc that were filled in a bottle. The analysis of the acquired data was done with a software tool provided by the acquisition software

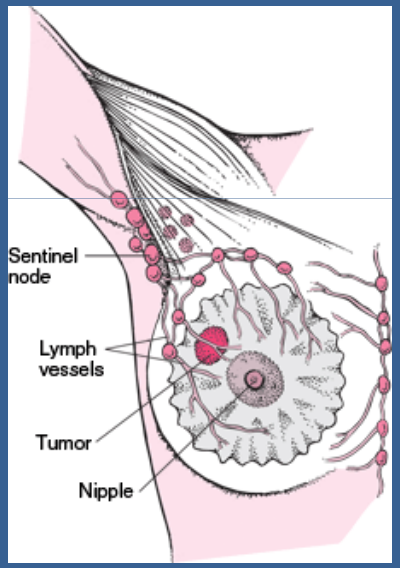
Collimator type	cps/MBq
LEHR	237
MEGP	177
LEHS	554

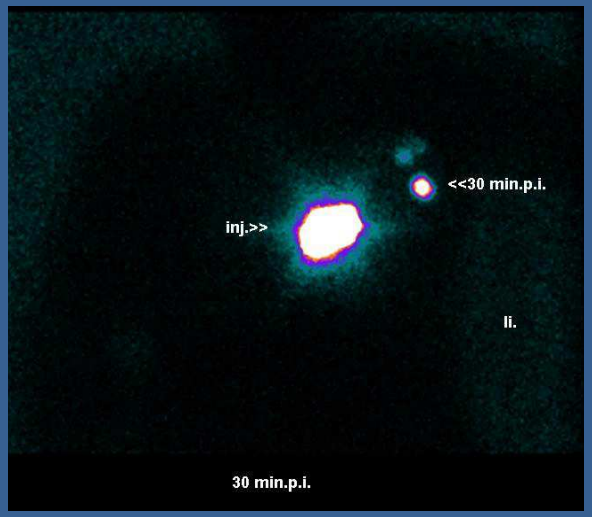
System planar sensitivity measured for various collimators

Data from Literature: 6.6 – 1600 cps/MBq*

*** M. Tsuchimochi, K. Hayama: Intraoperative gamma cameras for radioguided surgery: technical characteristics, performance parameters, and clinical applications. Phys. Medica (2013) 29, 126-138**

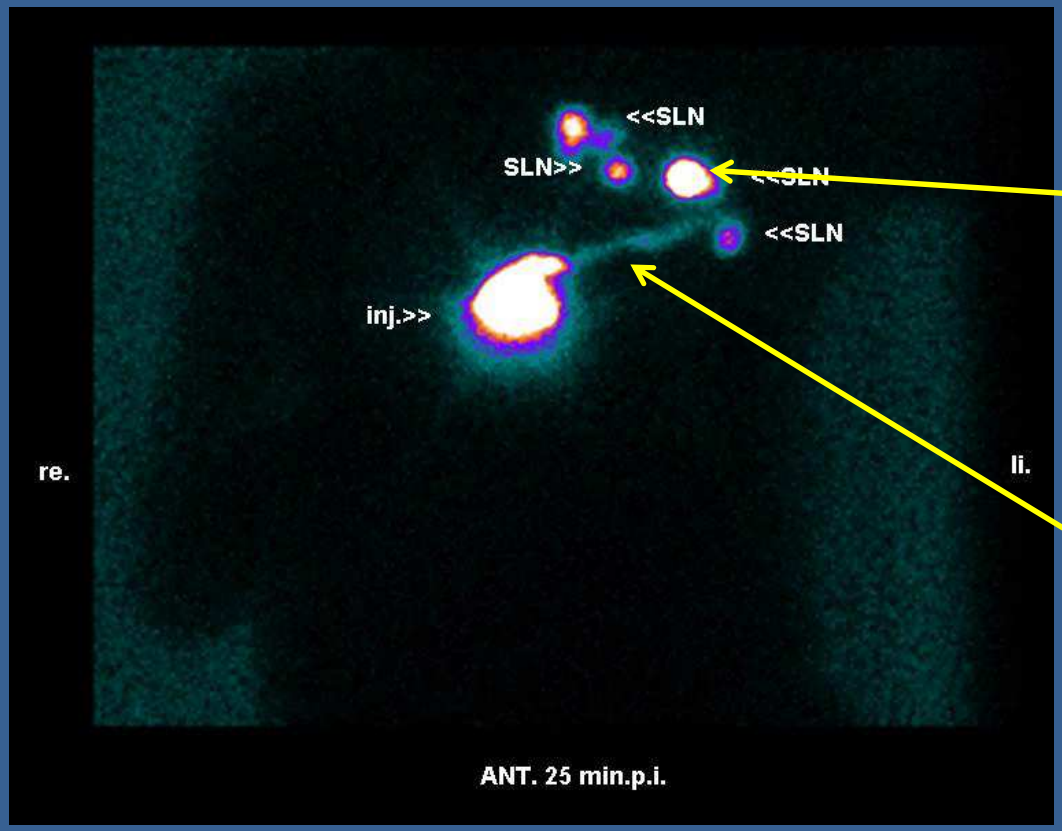
Patient studies



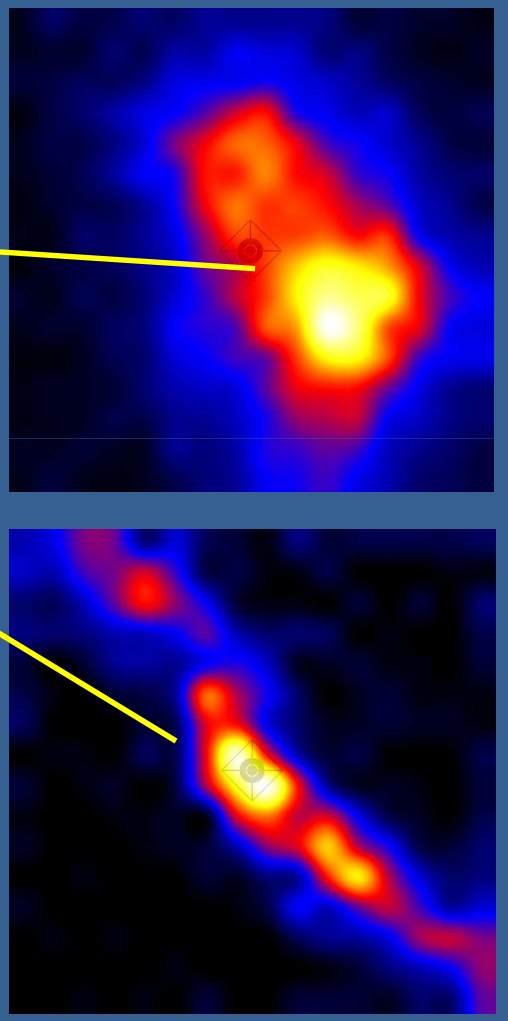


The sentinel lymph node (SLN) is defined as the first lymph node that drains the primary tumor basin.
The SLN can be mapped by using a sulphur-colloid radiotracer labeled with 99mTc that is injected near the primary tumour. Approximately 18- 37 MBq of tracer is injected near the primary tumor, with up 74 kBq of activity accumulating in the sentinel lymph nodes after it drains through the lymphatic channel.
Till now 27 patients were imaged using the novel handheld gamma camera system.

Pat, 70y, f, N. Mammae, left, Injection of 22 MBq 99m Tc Sentiscint



Millenium VG, GE Healthcare

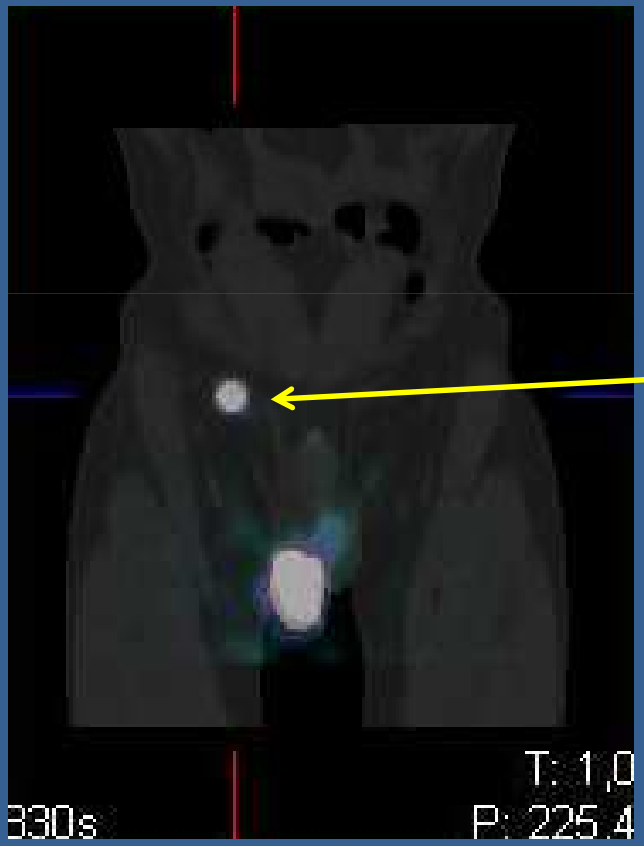


Handheld, CrystalCam

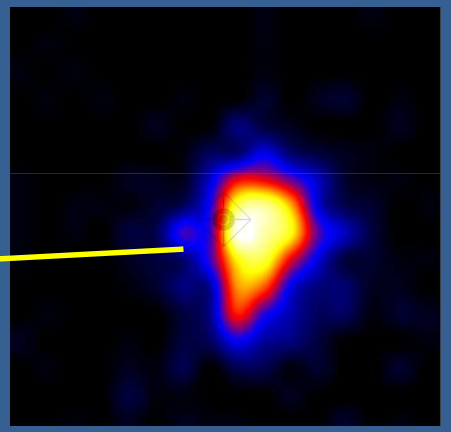
Patient, 45Y, penis carcinoma

SPECT

Image fusion

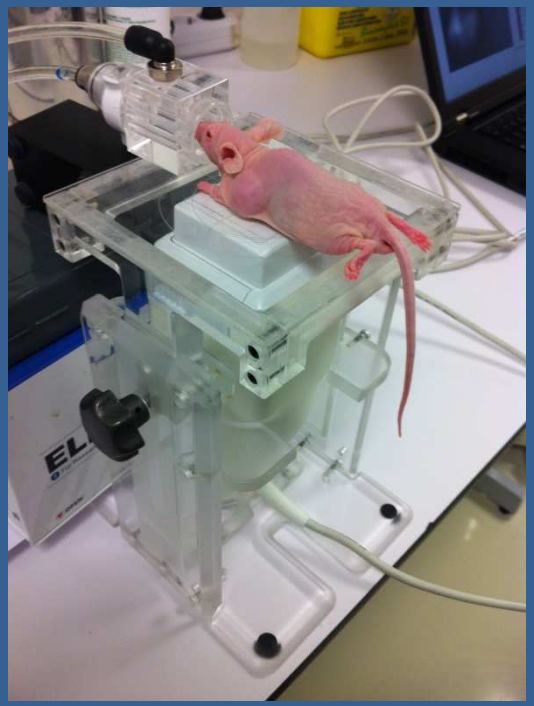


Handheld



Infinia, GE Healthcare

SaveMe

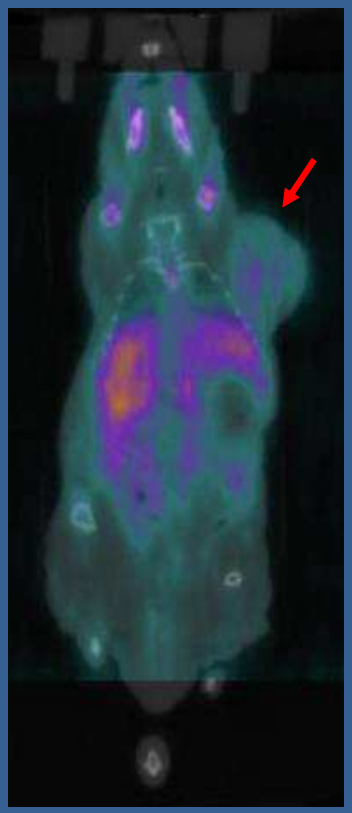


Handheld gamma camera setup

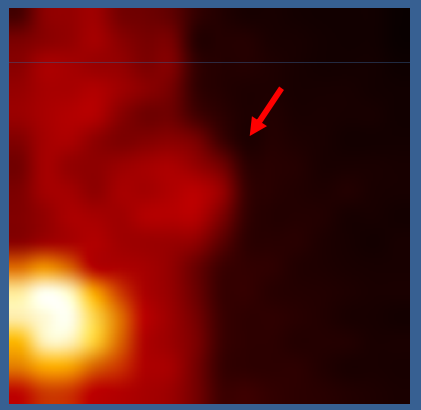
Ga67-DOTA+ Nanoparticle + PTR

3 h

24 h



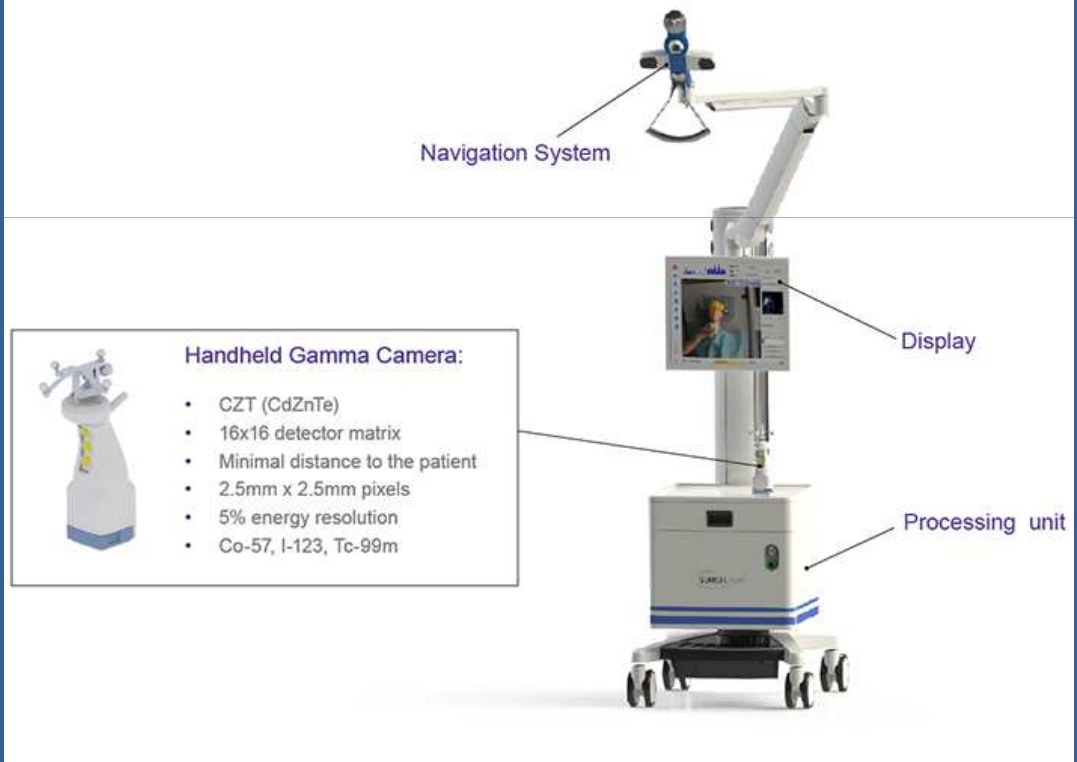
48 h

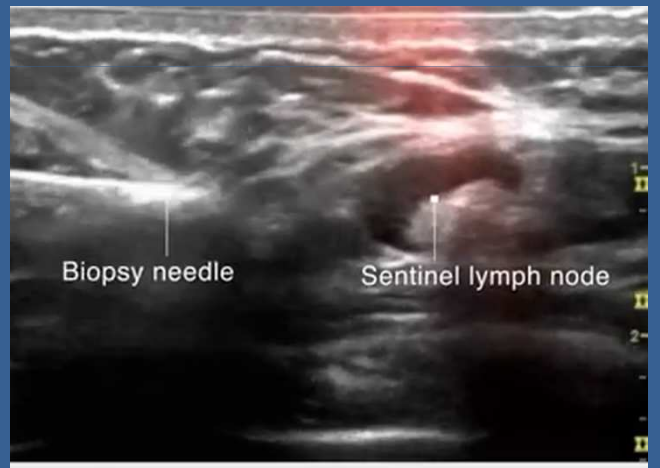


48h

SurgicEye

The declipse®SPECT Ultrasound Fusion consists of
a high precise optical navigaton system,
a gamma detector
a high resolution ultrasound system.





Identification of SLN: SPECT data in red

SurgicEye GmbH, Munich, Germany

Thank you very much for your audience