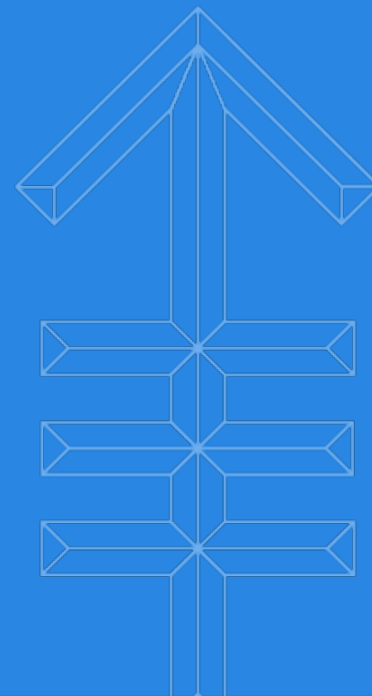
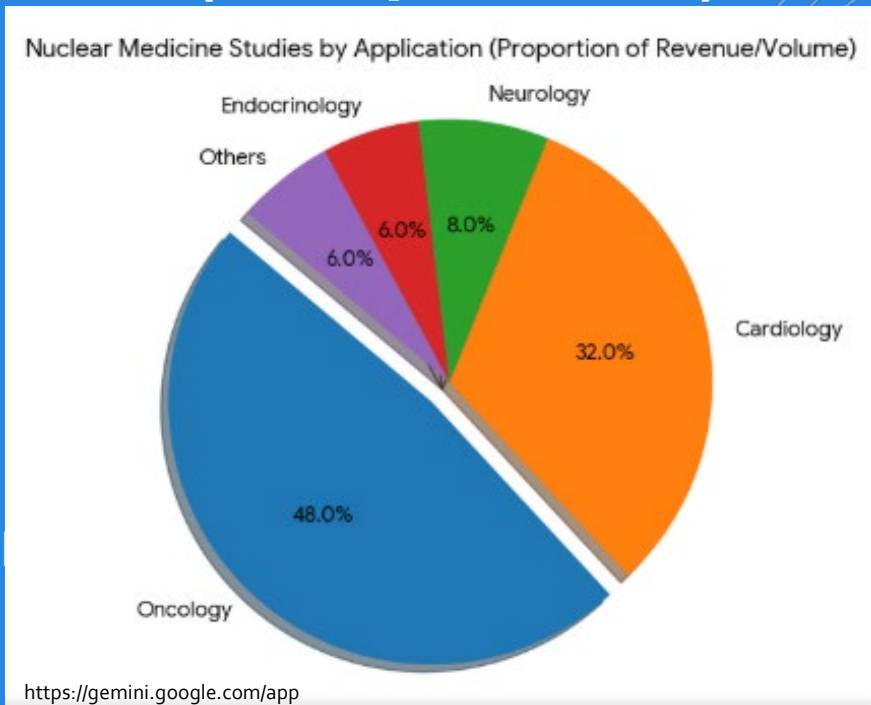


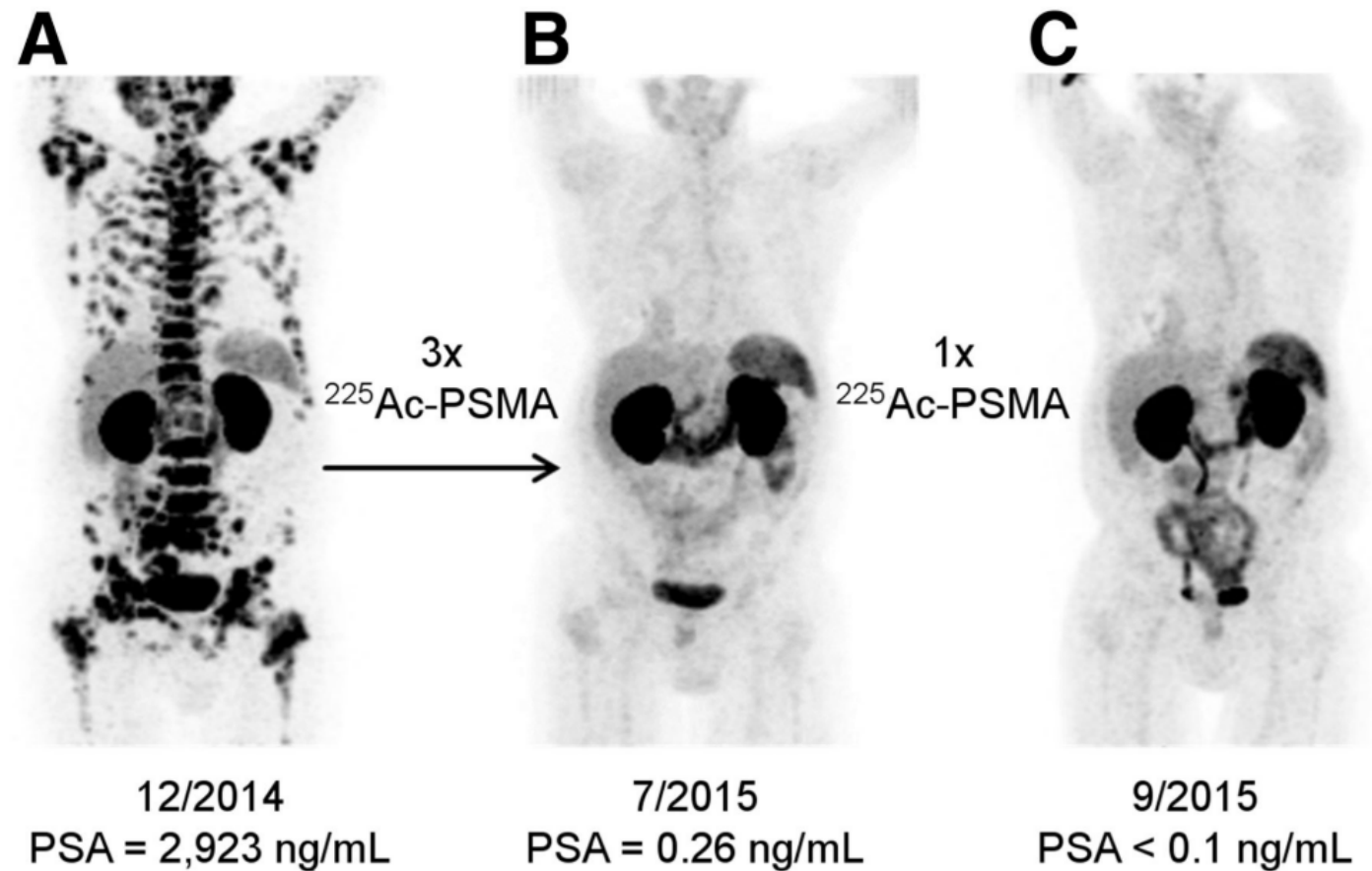


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Физични аспекти в нуклеарната медицина (интервенции)



ПЕТ на пациент с рак на простата



PET
 $^{68}\text{Ga-PSMA-11}$

Kratochwill C et al,
JNM, 2016



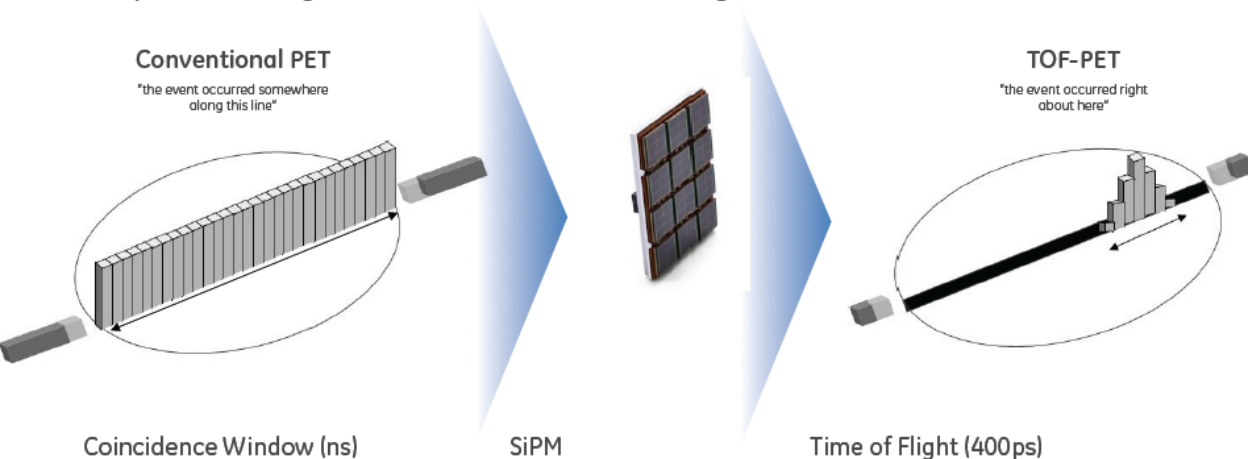
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Cancer Center

Технологични тенденции в ПЕТ: TOF

Principle of TOF

Time of Flight PET

- Digital PET detector module based on Silicon Photomultipliers (SiPM)
- Exceptional timing resolution enables Time-of-Flight reconstruction

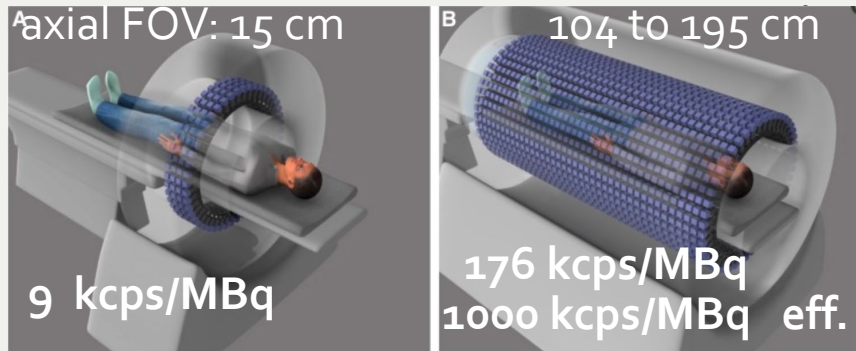


TOF Resolution

Crystal	TOF	Spatial
BGO	2 ns	30 cm
LSO/LYSO	214 ps	3 cm
BGO + Cherenkov	175 ps ?	2.5 cm
Hybrid?	30 ps	4.5 mm
??	10 ps	1.5 mm

Технологични тенденции в ПЕТ

Large Field of View (LAFOV) PET

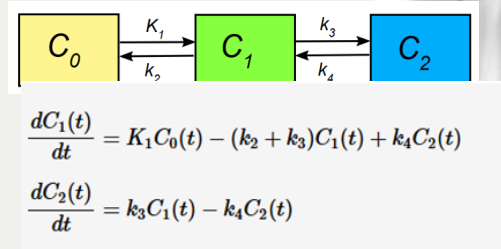
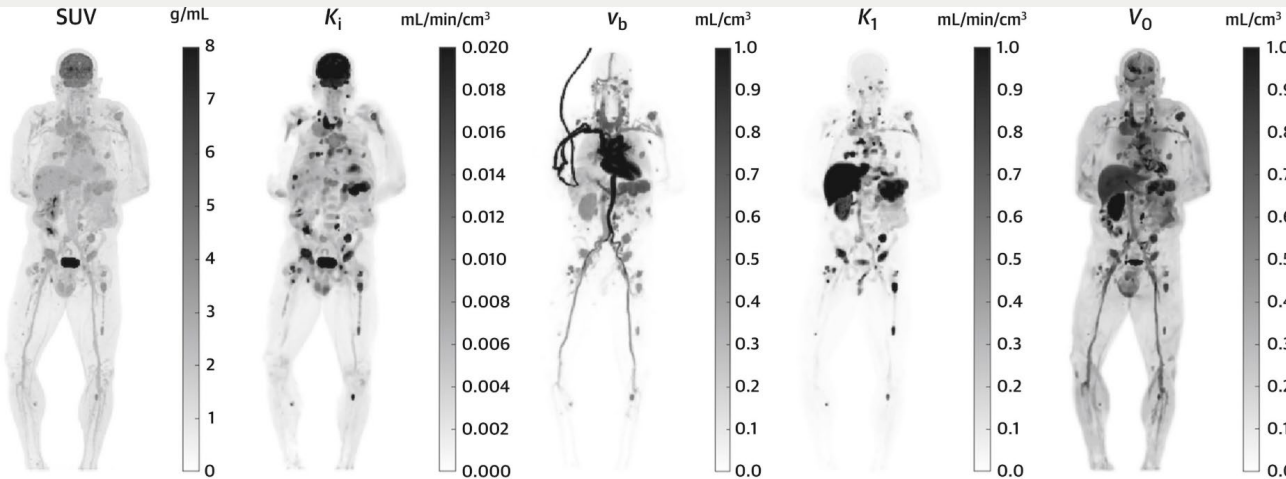


~ 100 times higher sensitivity :

- Reduce A from 10 to 0.25 mCi or
=> dose from 8 to 0.2 mSv

Whole body imaging in ~ 15 s

- Real time monitoring of biol. processes
 - Dynamic imaging
 - Compartmental modelling



Wang et al,
JNM,63 (2022)

Технологични тенденции в ПЕТ: съвпадения с каскадни фотони

ПЕТ с различни радионуклиди

Table 1 | Positron emitting isotopes

Doubles	Half-life	β^+ yield (%)	% use
^{18}F	109.7 min	97	86
^{68}Ga	68 min	89	8
^{89}Zr	3.3 days	23	

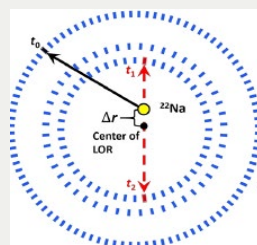
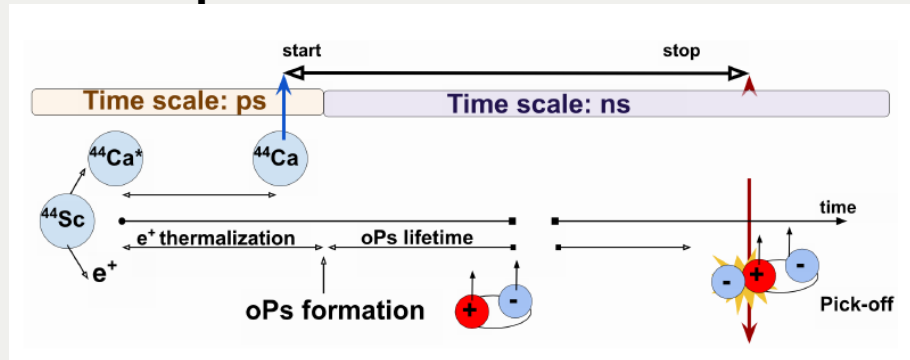
$^{11}\text{C}, ^{13}\text{N}, ^{15}\text{O} \dots$

Table 2 | Prompt γ -emitting isotopes

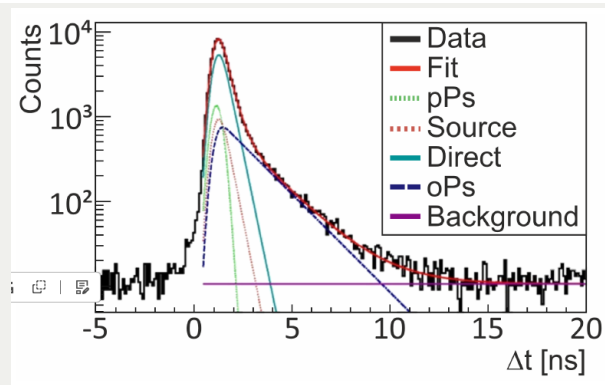
Triples	Half-life	β^+ yield (%)	Main prompt γ (keV) and ($\beta^+ \gamma / \beta^+$ yield)
^{82}Rb	1.27 min	95	777 (13%)
^{86}Y	14.7 h	33	1,080 (83%), 627 (33%)
^{124}I	4.18 days	23	602 (51%)

Pratt et al, Nat Biom Eng, 2023

Използване на свойствата на
позитрониевия атом



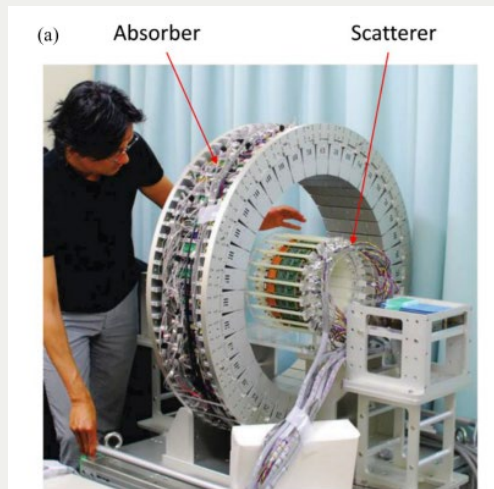
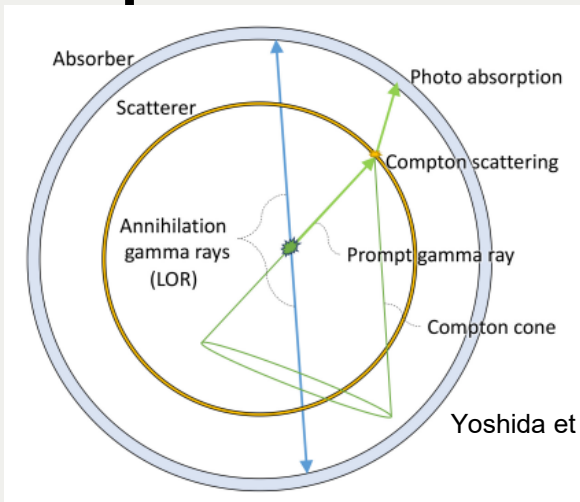
Moskal et al,
2016, ..2025



Compton PET

Dual-detector ring Compton-PET

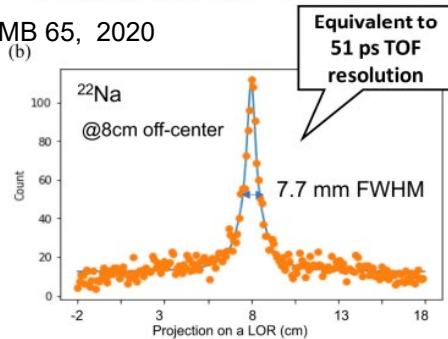
Reconstruction-less image formation ?



Annihilation photon non-collinearity $\sim 0.5^\circ$:

20 cm dia	80 cm dia
7.7 mm	=> 31 mm
	~ 205 s TOF

Small animal imaging
Super Argus PET/CT:
PET: 0.7 mm FWHM
CT: 0.015 mm FWHM
Sedecal .com



Tashima et al, IEEE Rad Plasma Med Sci, 8, 8, 2024

Gamma Cameras and SPECT

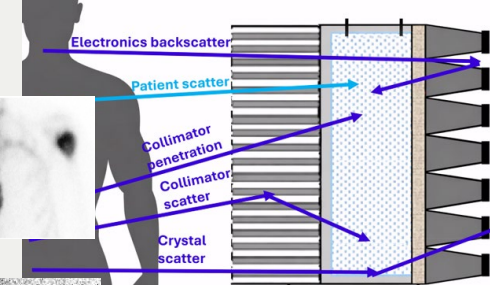
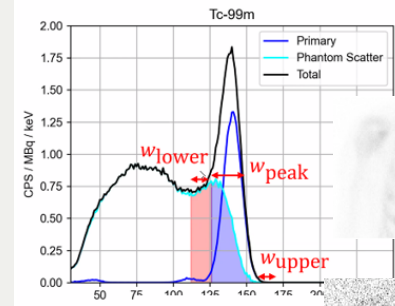
SPECT scanners

Large (~ 50 x 40 x 1.6 cm NaI Crystals)

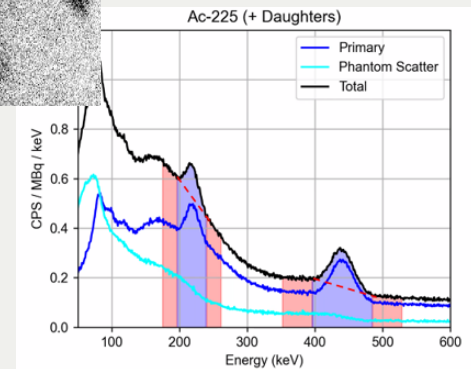
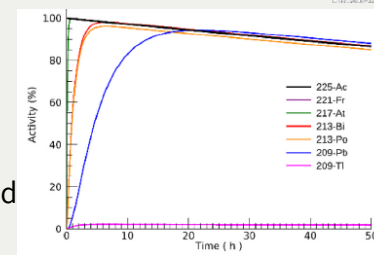


Parallel hole (..etc) collimators
2D: Whole Body scans
3D: SPECT ~ 60 angles

Challenges: Alpha emitting RP Tc-99m Scatter



Ac-225:



Cadmium Zinc Telluride (CZT) on swiveled arms



No collimators
12 independent heads
Detectors extend to patient body
Heads swivel

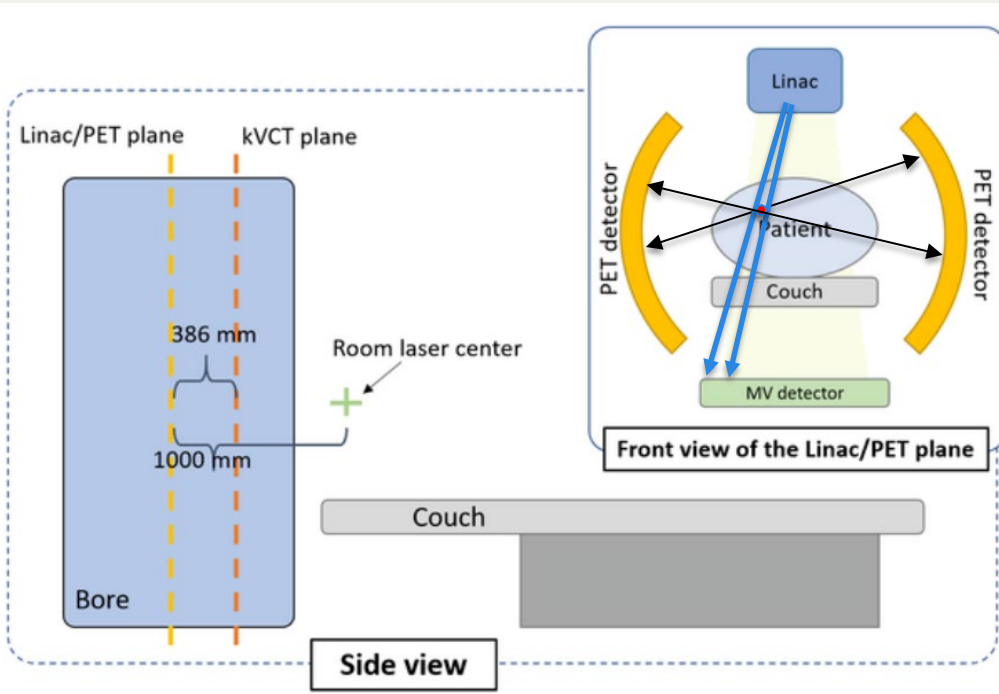
Pablo .. Voximetry and
EANM recommendations 2026

Кома Кулшан, Каскадни планини



ПЕТ в радиационната терапия

Biologically guided RT Reflexion



Предимства

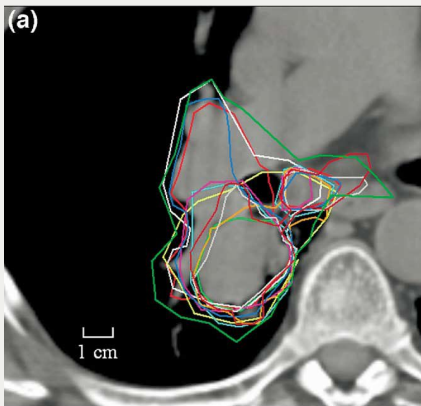
- + Движения на мишената
- + Множество тумори
- + “биологически” по-точно ?

Недостатъци

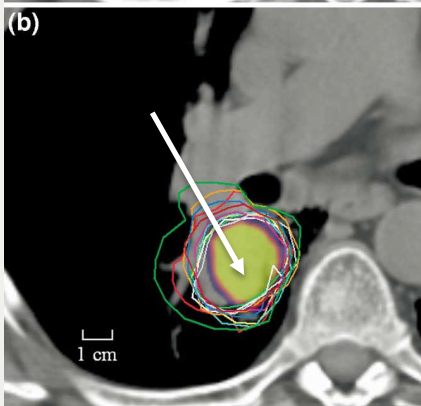
- Необх. висока активност в тум.
- Инж. на висок акт. 15-20 mCi
- проблем ако близо до “горещи” органи
- Трудности в клиниката: инж. на ^{18}F , по-дълги облъчвания

ПЕТ в радиационната терапия

Segmentation of PET lesions



CT only



CT+PET

Accuracy ?

- Ground truth problem
 - Manual contour
 - Consensus
 - MRI
- AAPM Task Groups
 - TG 211
 - TG 363

Steenbakkers, IJROBP,
64, no.2, p. 435 ,2006



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Intra-procedural PET/CT guidance



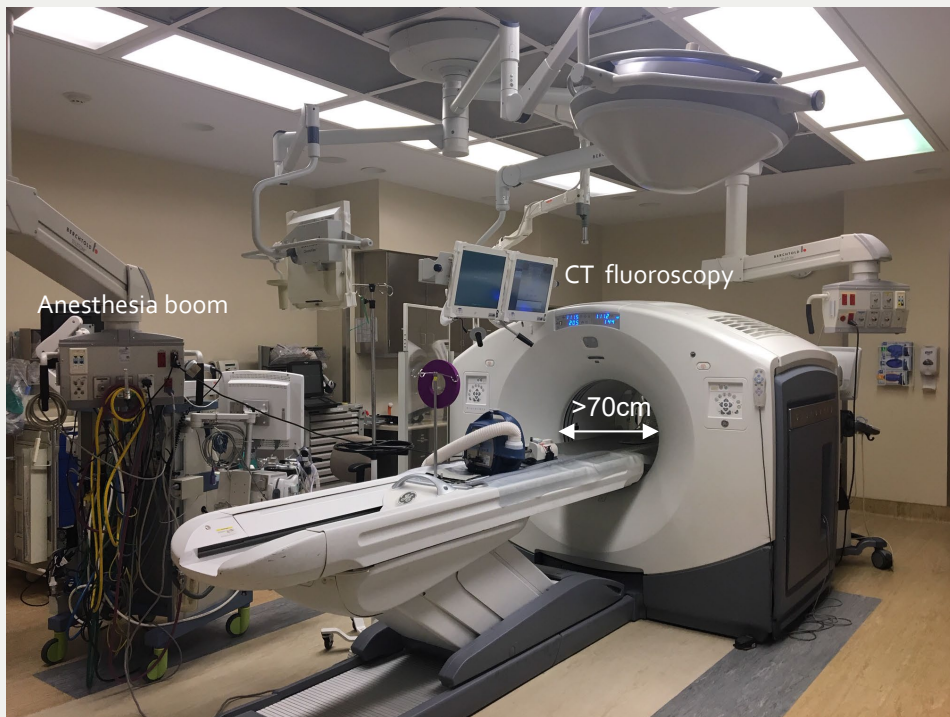
PET/CT in the Interventional Radiology Suite
Center for Image Guided Interventions, MSKCC



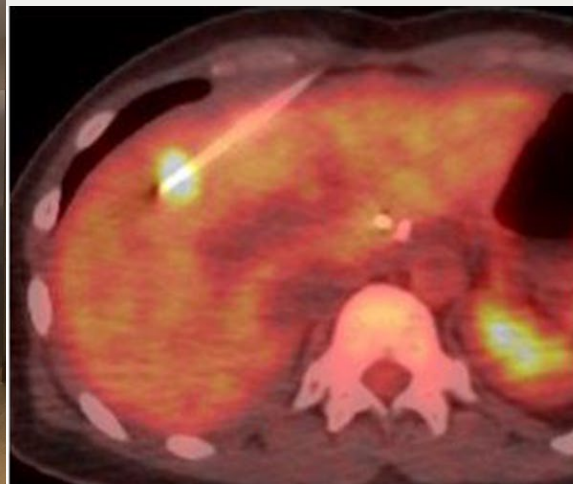
Lesion not seen in
CT image



Intra-procedural PET/CT guidance



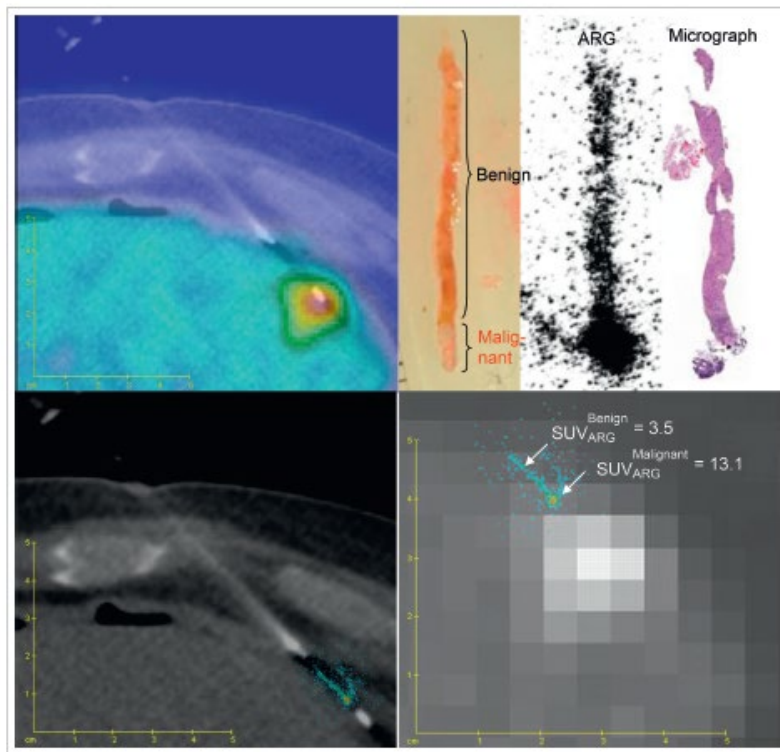
PET/CT in the Interventional Radiology Suite
Center for Image Guided Interventions, MSKCC



Fused PET/CT with
the needle in place



Количественна автораддиография на биопсии



- Quantitative autoradiography of core biopsy specimens obtained under PET/CT guidance correlates ^{18}F -FDG uptake with histopathology findings on a millimeter scale. The method promises to prove useful for many fields in oncology. See page 538.

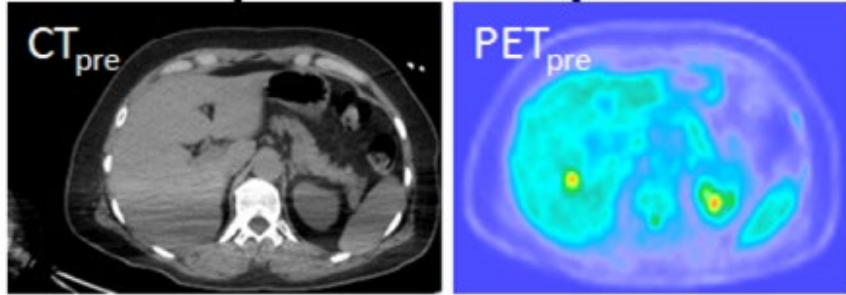
Fanchon L *et al*,
Cover page
Journal of Nuclear
Medicine,
v 56, 4, p538, 2015



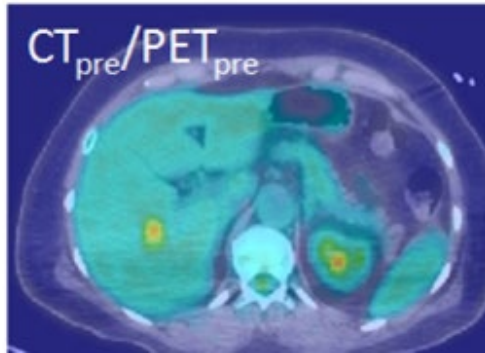
Memorial Sloan Kettering
Cancer Center

Биопсии с PET/CT насочване

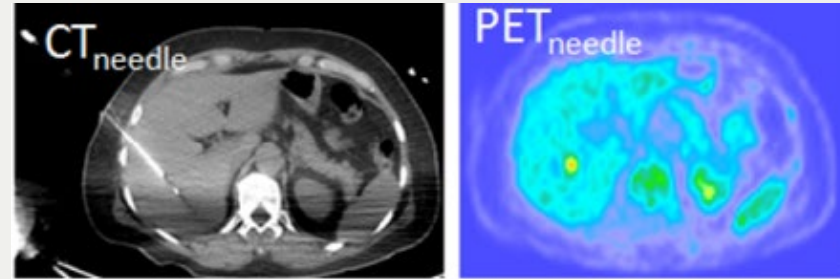
First PET scan before needle insertion



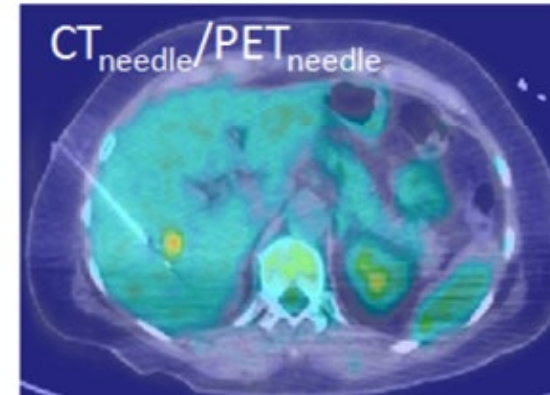
PET_{pre} : 2-5 min
18F-FDG
148 to 222 MBq
(GE D690)



Second PET scan after needle insertion

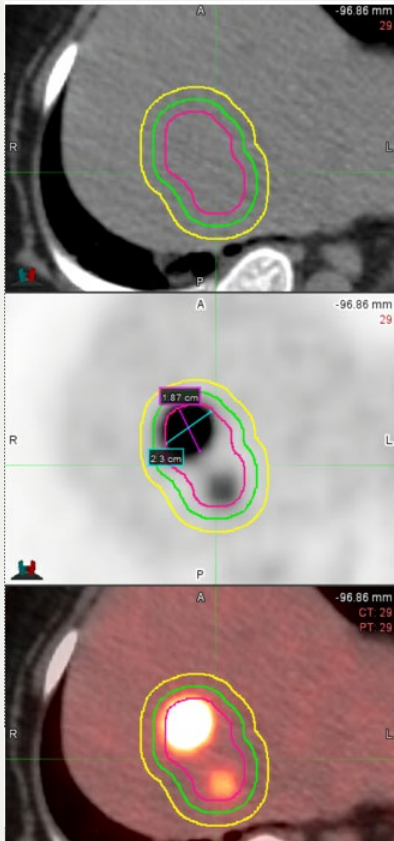


PET_{needle} :
20-90 s
with Breath Hold

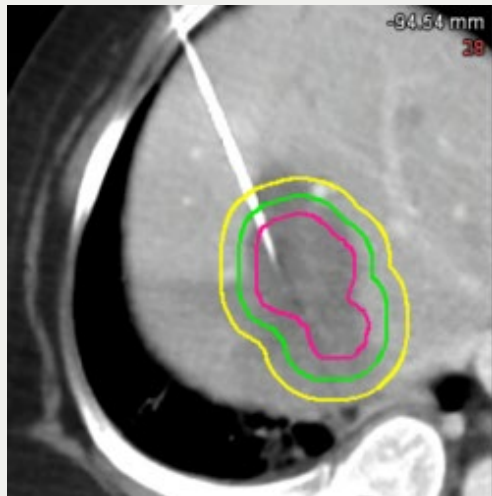


Аблации с РЕТ/СТ насочване

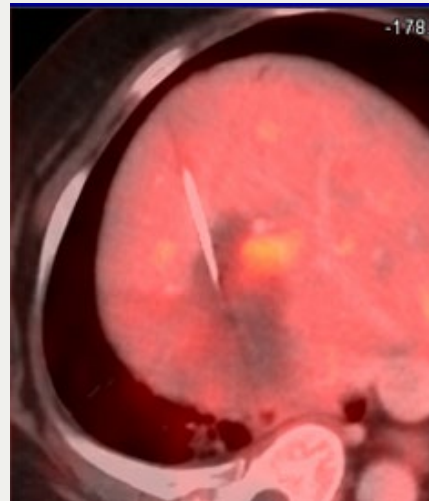
Contouring
on ^{18}F -FDG PET



Post-ablation Portal-
venous phase of CE CT

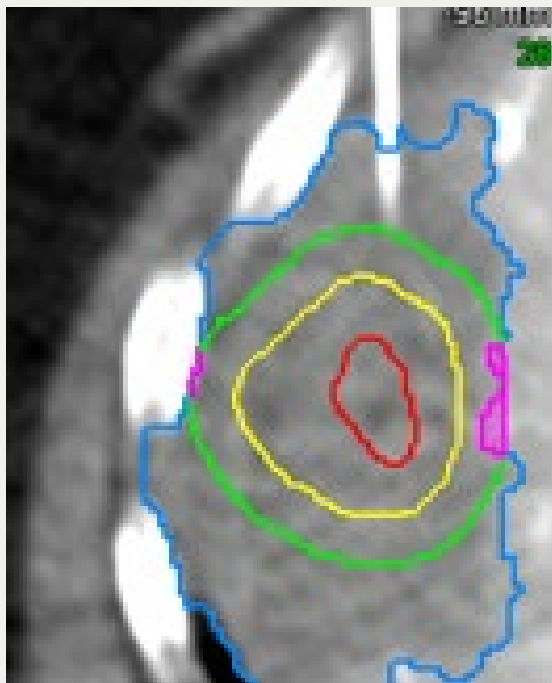


Second post-ablation
PET after a second
post-ablation FDG
injection



Was the Microwave Ablation margin sufficient ?

Tumor and 5 and 10 mm margin contours from PET_{pre}
on Venous phase CT



on PET post



IRB 19-233 protocol and Ro1 , PI: Dr. C. Sofocleous

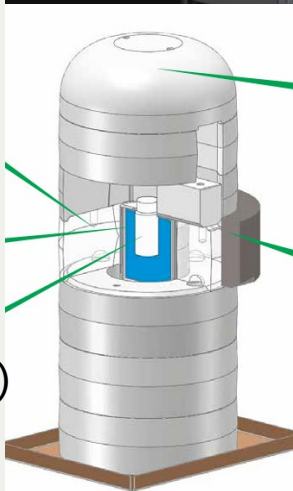


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Измерване на активността в образците

Кладенчов брояч



3"
NaI(Tl)

Hidex AMG

~ 1 nCi to ~ 1 micro Ci

Авторадиография: 2D

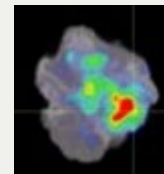
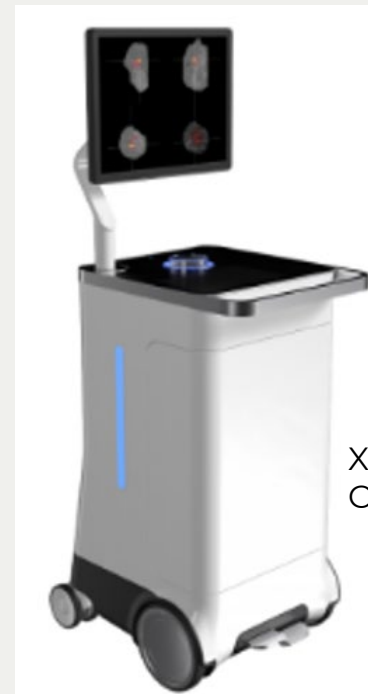


Spatial res.: Alpha 20 μm
Beta 20 μm
High en. e-,e+ 50 μm

Linearity over 5 orders of magnitude

Sensitivity: 0.0005 cpm/ mm²

спец. PET/CT : 3D



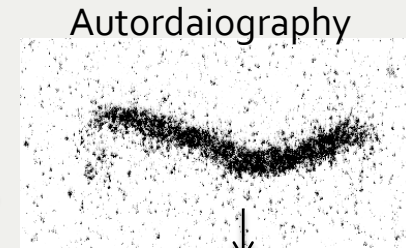
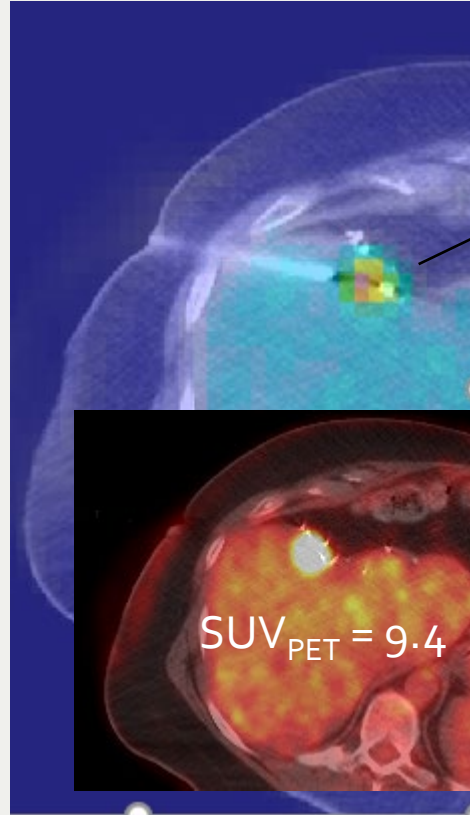
XEOS AURA 10
CareWise



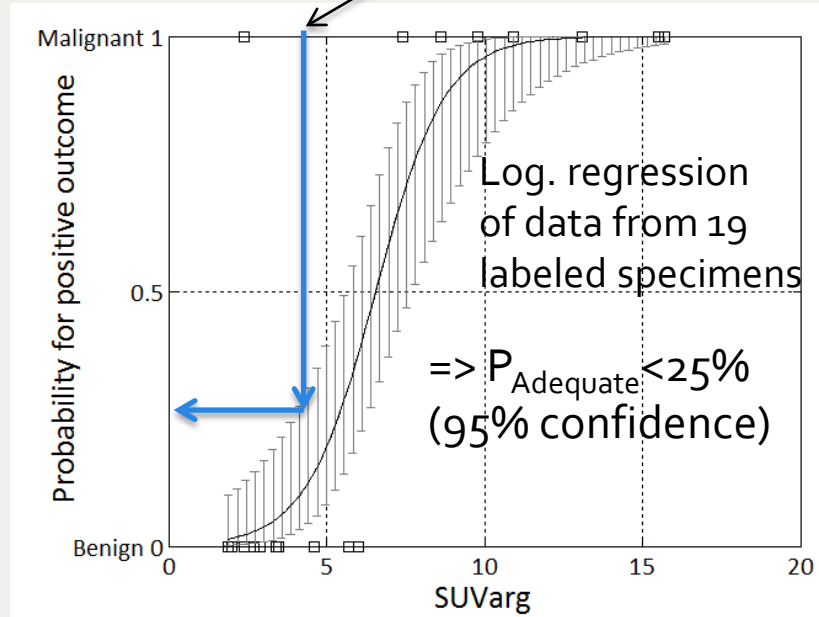
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Оценка на адекватността на биопсиите: чернодробни метастази на рак на дебелото черво

Complications:
pneumothorax



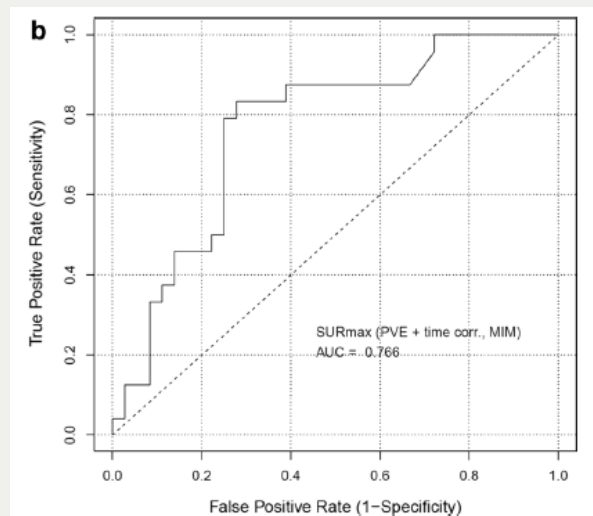
$SUV_{ARG} = 3.9$



Предсказване на $KRAS+$ мутации

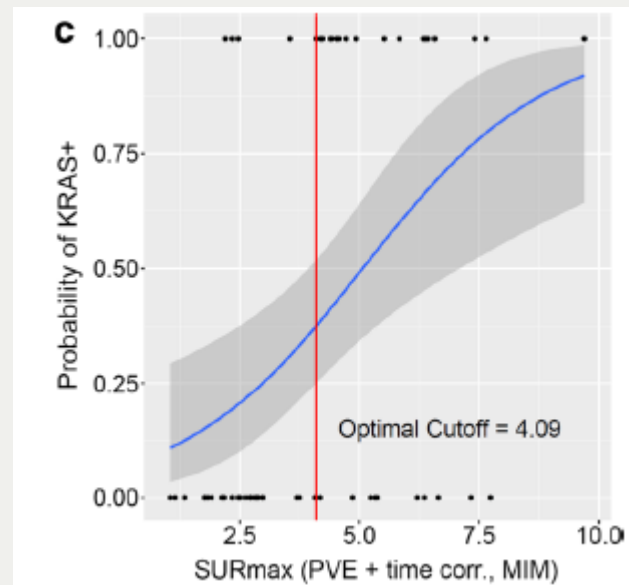
- Correlation of uptake with genomic profile of same lesion
- 60 lesions of which 31 with “on the spot” gen. profile
- Colorectal adenocarcinoma liver metastases
- PVE and uptake time corrected tumor-to-blood ratio, SUR_{max}

$KRAS+$: $SUV_{max} = 17.5$



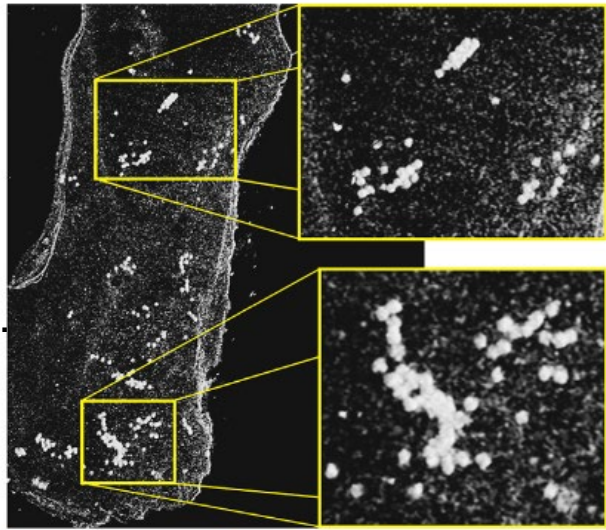
Student's T-test $p < 0.001$

SUR_{MAX} AUC=0.77

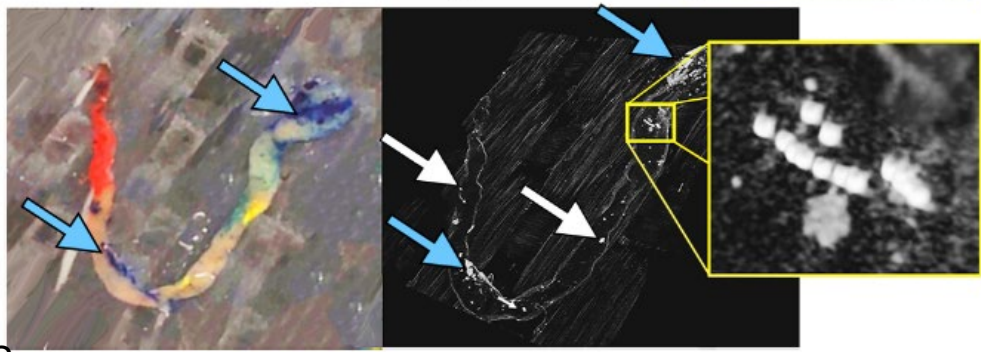


Микро-СТ на образци след транс-артериална радиоемболизация с ^{90}Y

Custom-built micro-CT scanner
(Nikon Metrology NV, Leuven, Belgium):
4 to 9 micron voxels
120 kV peak voltage, 7.0W,
2401 projections over 360°, 1 frame per proj.
exposure time 500 ms per frame.



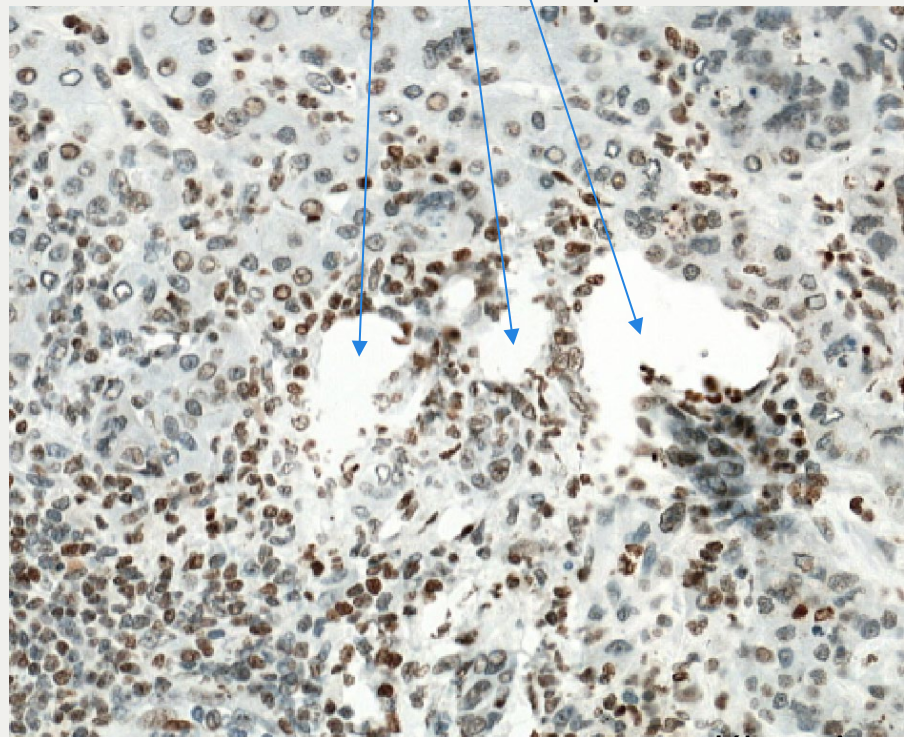
Resin spheres
20-60 microns
Aver. 32.5 microns



Glass spheres
20-30 microns
Aver. 25 microns

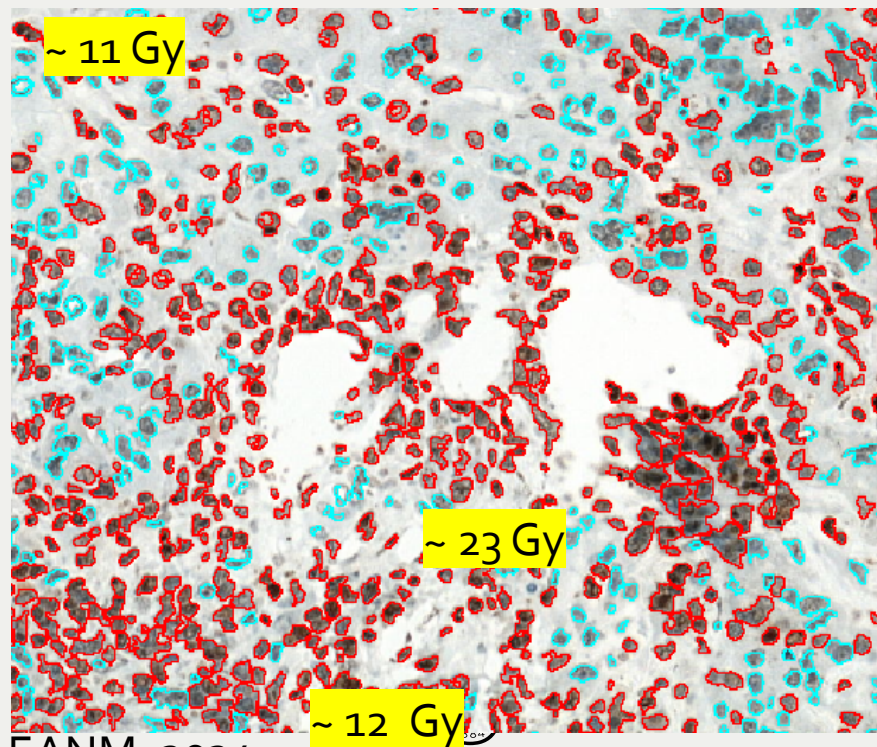
Двуверижни прекъсвания на ДНК и рад. дози

Section with pH2AX staining
Location of microspheres



pH2AX stained cells (red)
not stained (cyan)

Doses at time of biopsy (4.3 h post infusion)

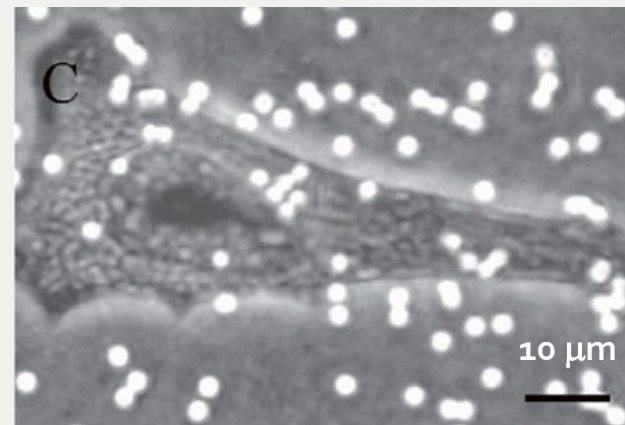
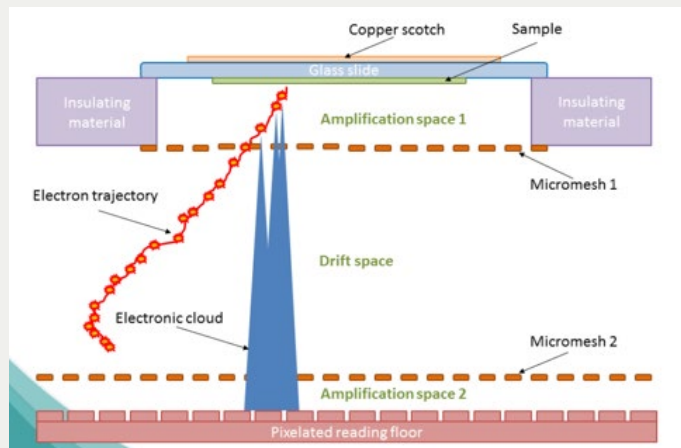
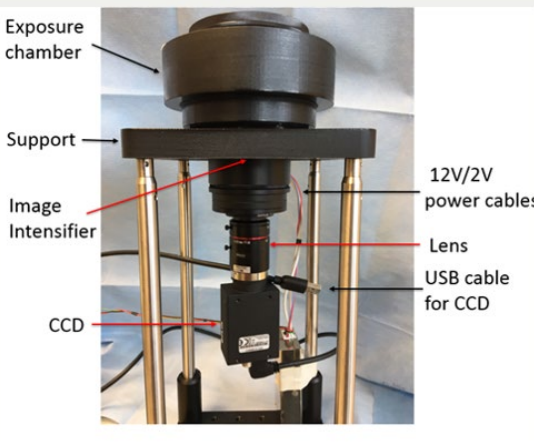


Методи за броячна автордиография

Сцинтилационни

Газови проп. камери

Следи на α в CR-39



iQID, QScint

Spatial res. $\sim 20 \mu\text{m}$

Sens. $\sim 0.00006 \text{ dpm}$
for $\alpha \sim 100\%$

BeaQuant, Ai4r

Spatial res.: Alpha $20 \mu\text{m}$
Beta $20 \mu\text{m}$
High en. e^-, e^+ $50 \mu\text{m}$

Linearity over 5 orders of magnitude
Sensitivity: 0.0005 cpm /mm^2

CR-39 plastic

Spatial res.: $\sim 2 \mu\text{m}$

Limited dose range



Memorial Sloan Kettering
Cancer Center

Research Contributors

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Pathologists

Yukako Yagi
Snjezana Dogan

Biologists

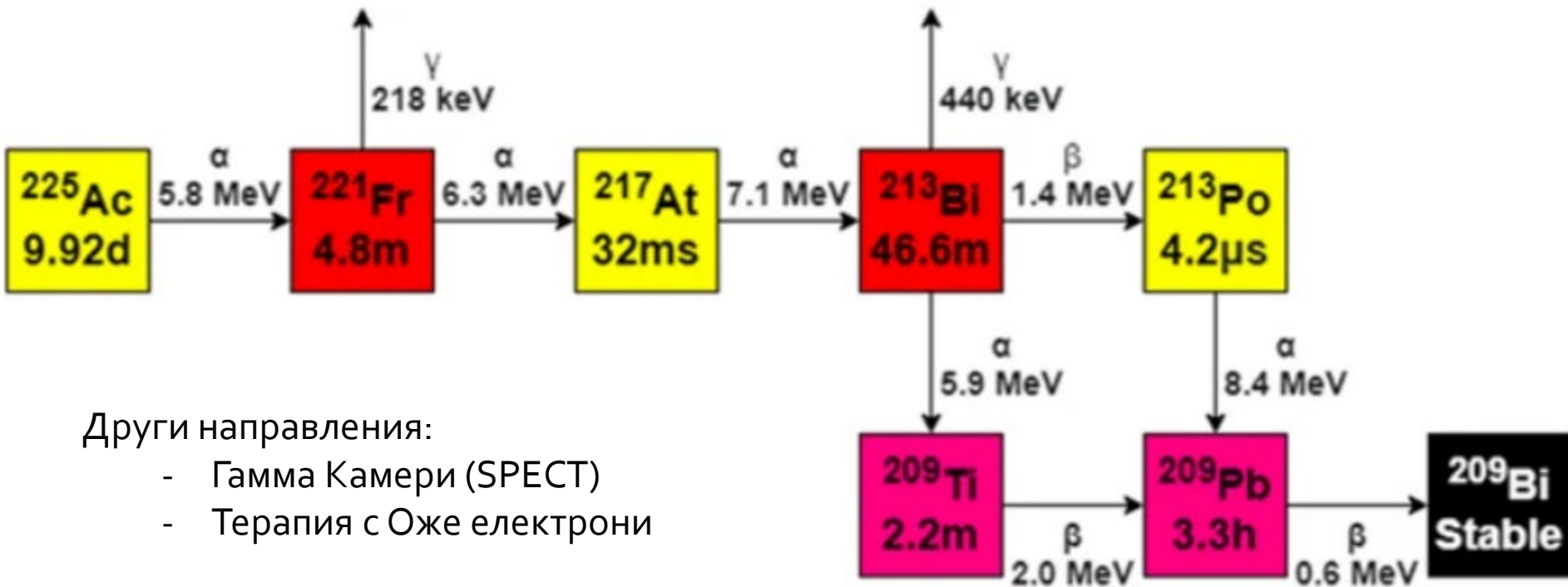
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Alexei Teplov
Olga Talarico



Прогнози





Вулкан Кома Кулшан, Каскадни планини