

FRCR Lecture II – 22/09/2016

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The Amazing World of PET

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Image Acquisition Techniques

- Planar Imaging
  - Static
  - Dynamic
  - Gated
  - Whole Body / Continuous
- Tomographic Imaging
  - Single Photon Emission Tomography (SPECT)
  - Positron Emission Tomography (PET)

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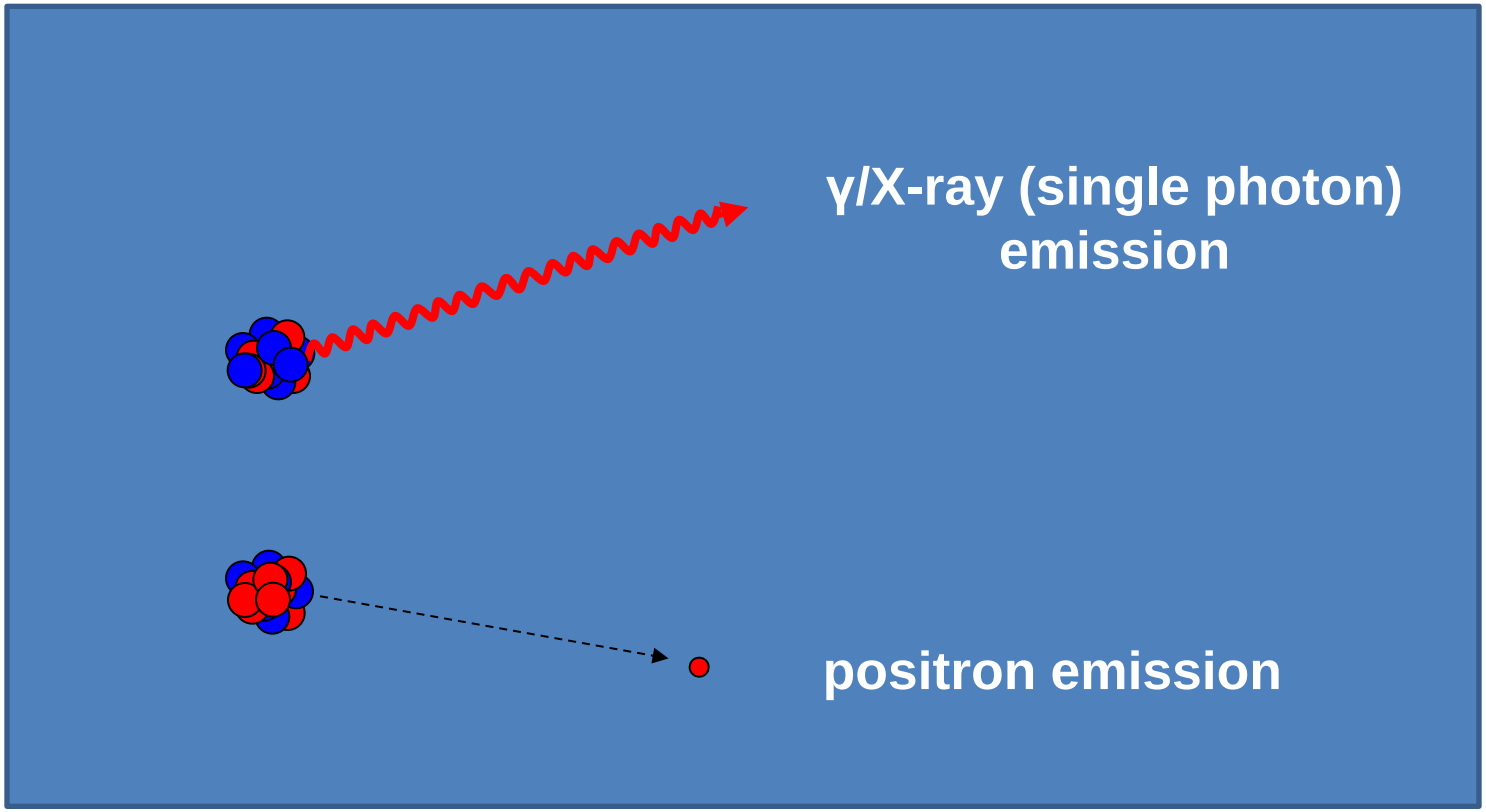
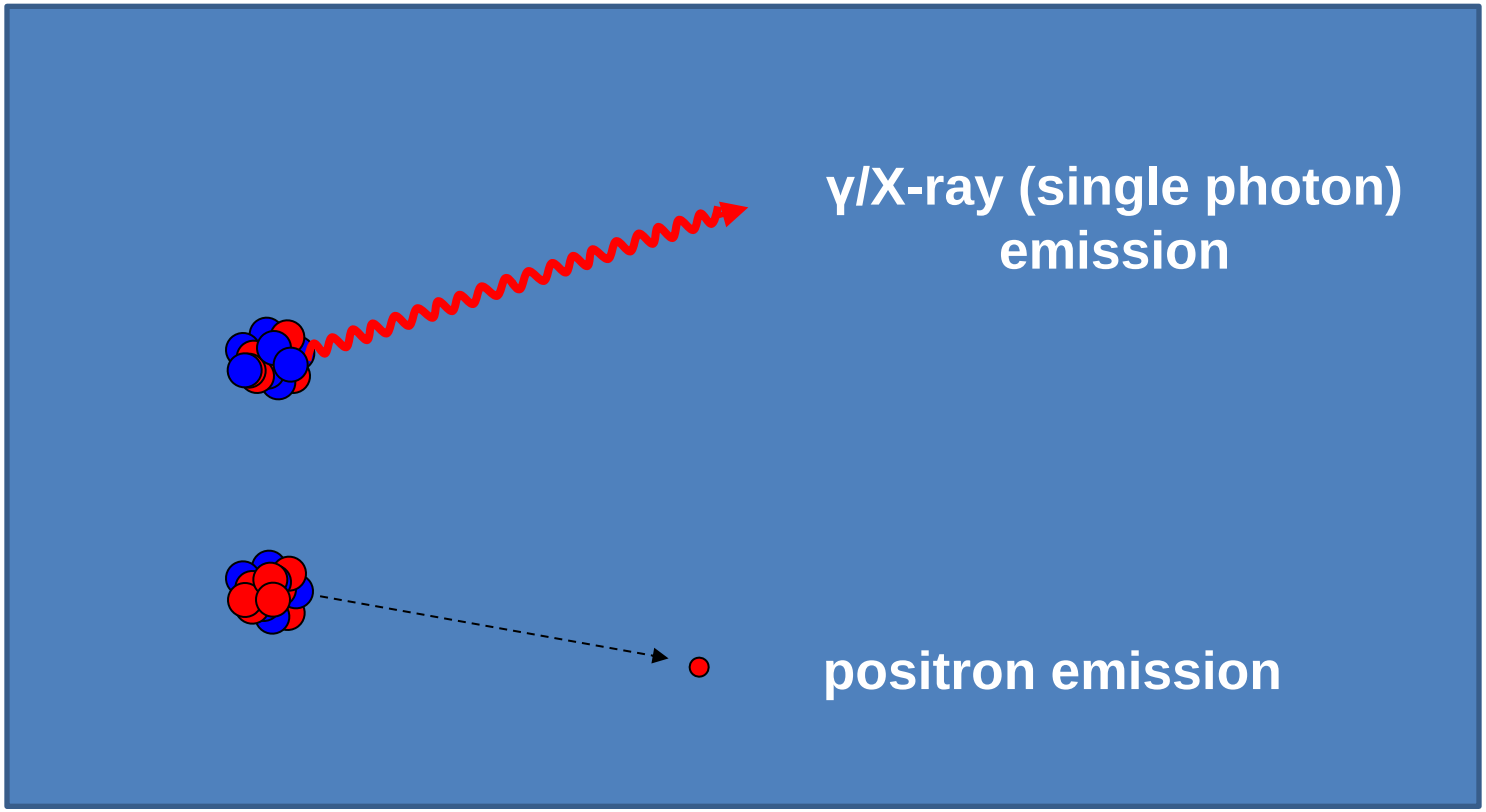
Functional Imaging – PET

Is there another way?

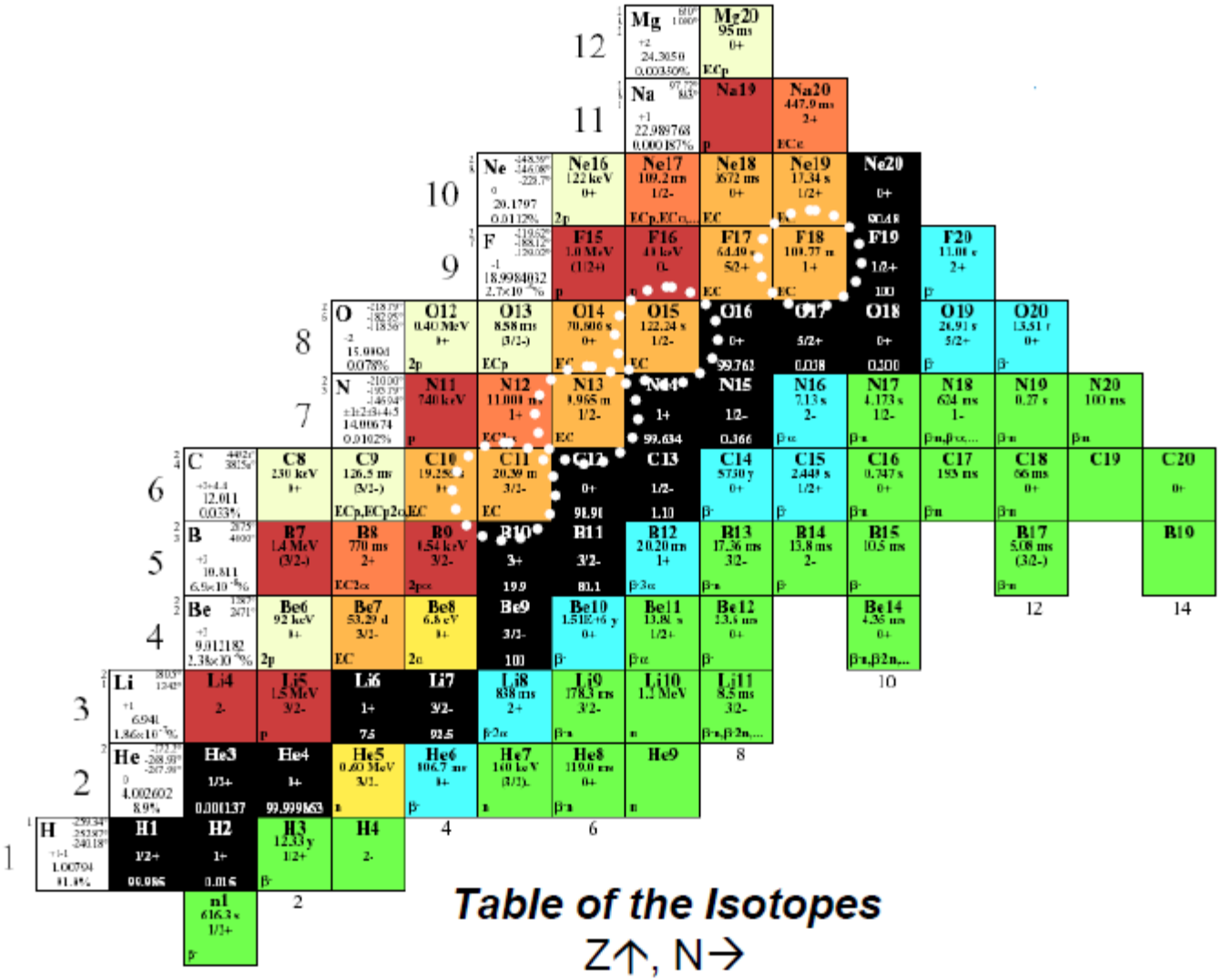


Functional Imaging – PET

Is there a better way?



Radioactive Decay by Positron Emission



Radioisotopes in Functional Imaging

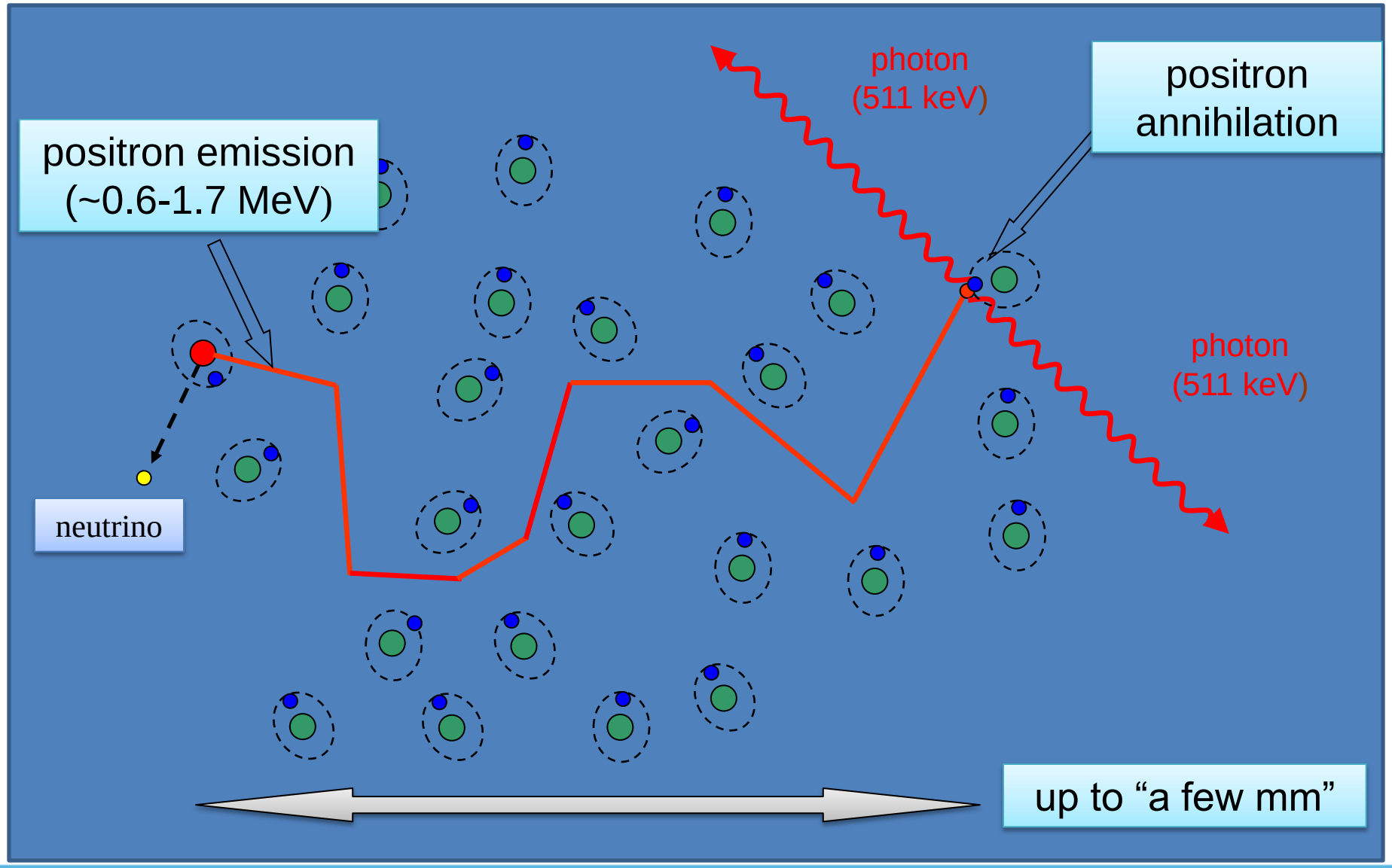
γ/X-rays → SPECT

Isotope	Half-life (hr)	Energy (keV)
$^{99}Tc^{m}$	6.0	140
^{111}In	67.3	171 & 245
^{123}I	13.2	159
^{201}Tl	73.0	69-83

positrons → PET

Isotope	Half-life (min)	Energy (keV)
^{11}C	20.4	511
^{15}O	2.1	511
^{13}N	10.0	511
^{18}F	109.8	511

PET Isotopes



Properties of PET Isotopes

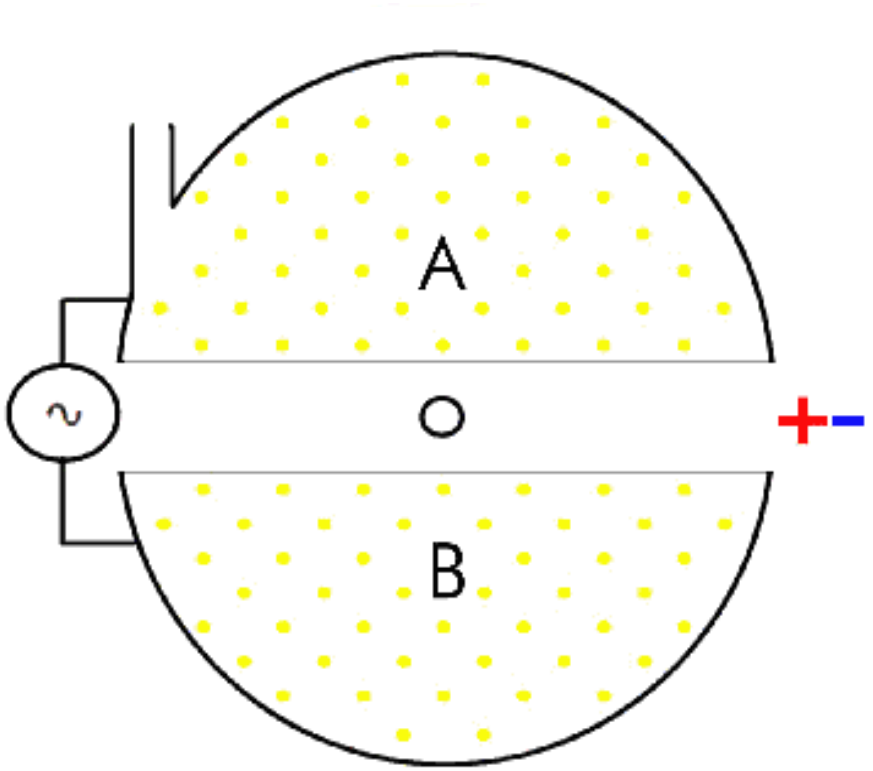
Isotope	Half-life (min)	$E_{max}(\beta^+)$ MeV	Production	Example tracer
^{11}C	20.4	0.96	$^{14}N(p,\alpha)^{11}C$	Methionine
^{13}N	9.96	1.19	$^{16}O(p,\alpha)^{13}N$	Ammonia
^{15}O	2.03	1.72	$^{15}N^*(p,n)^{15}O$ $^{14}N(d,n)^{15}O$	Water
^{18}F	109.7	0.635	$^{18}O^*(p,n)^{18}F$ $^{20}Ne(d,\alpha)^{18}F$	FDG (fluorodeoxyglucose)
^{62}Cu	9.7	2.93	^{62}Zn generator ($t_{1/2}$=9.2 hours)	PTSM (blood flow)
^{82}Rb	1.3	3.35	^{82}Sr generator ($t_{1/2}$=25 days)	Rb^- (blood flow)
^{124}I	4.2 days	2.10	$^{126}Te(p,3n)^{124}I$	Labelled antibodies

Wide range of half-lives, generally shorter than conventional NM

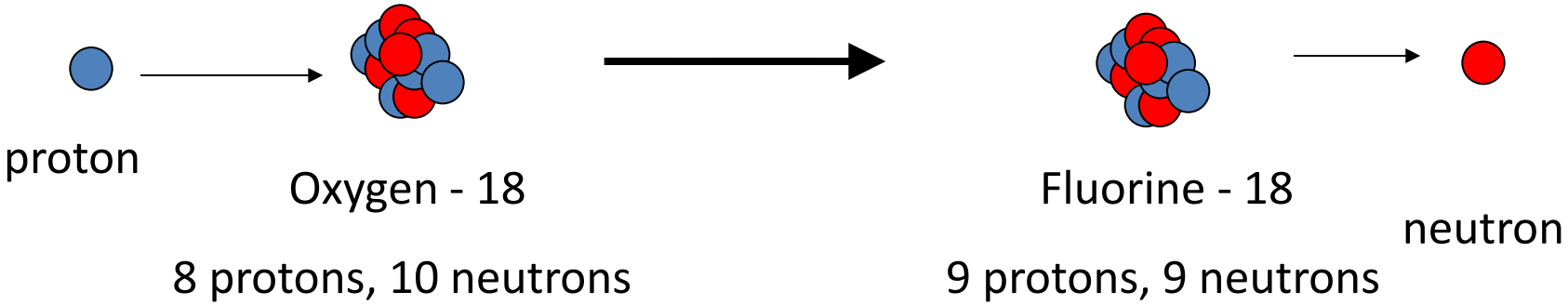
Mainly cyclotron produced but some generators

Physics of the Cyclotron

- A charged particle (p^+)
  - moves in circles in a static magnetic field
- Size of the circle
  - depends on the energy of the particle
- Electric fields are used
  - to accelerate the particle

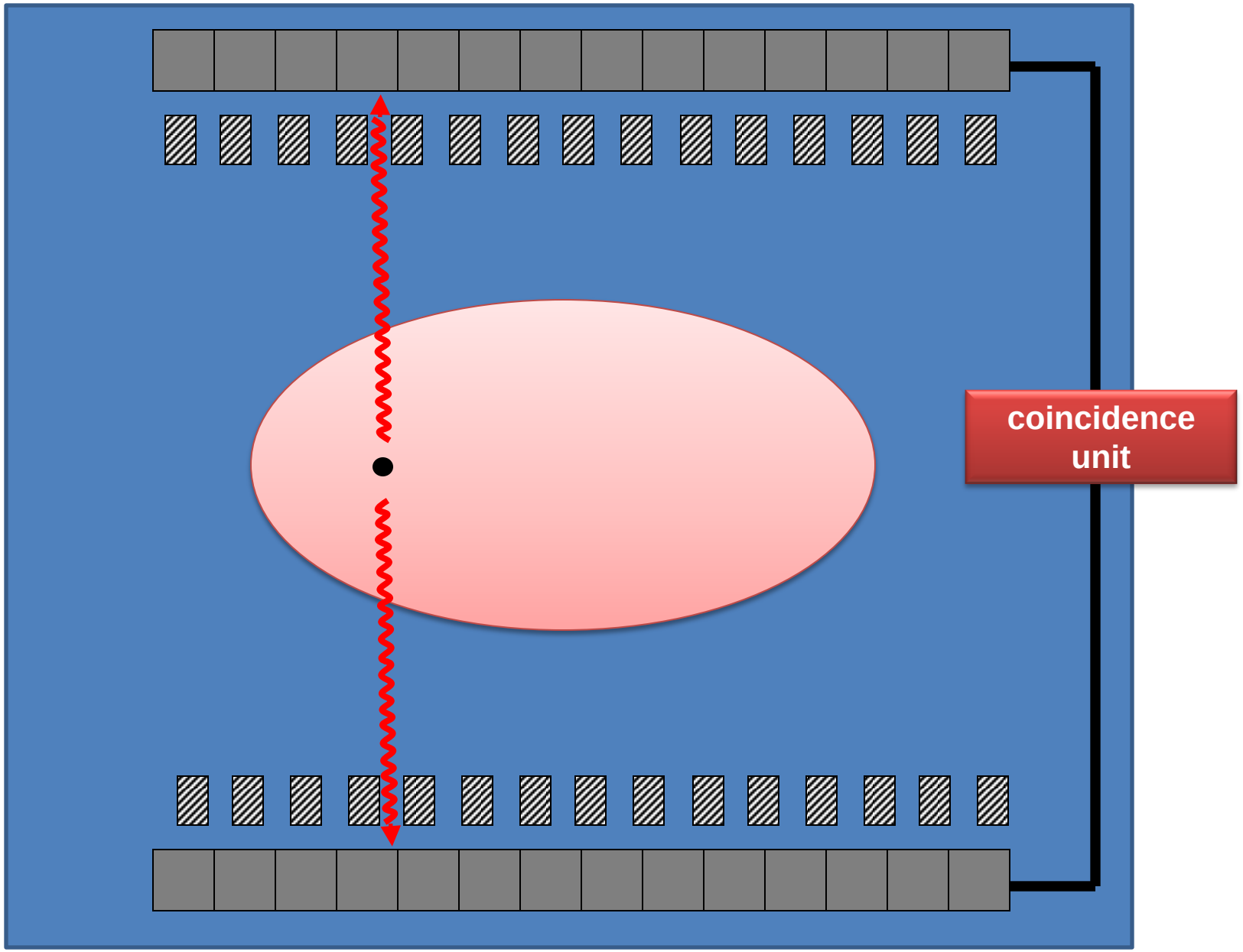


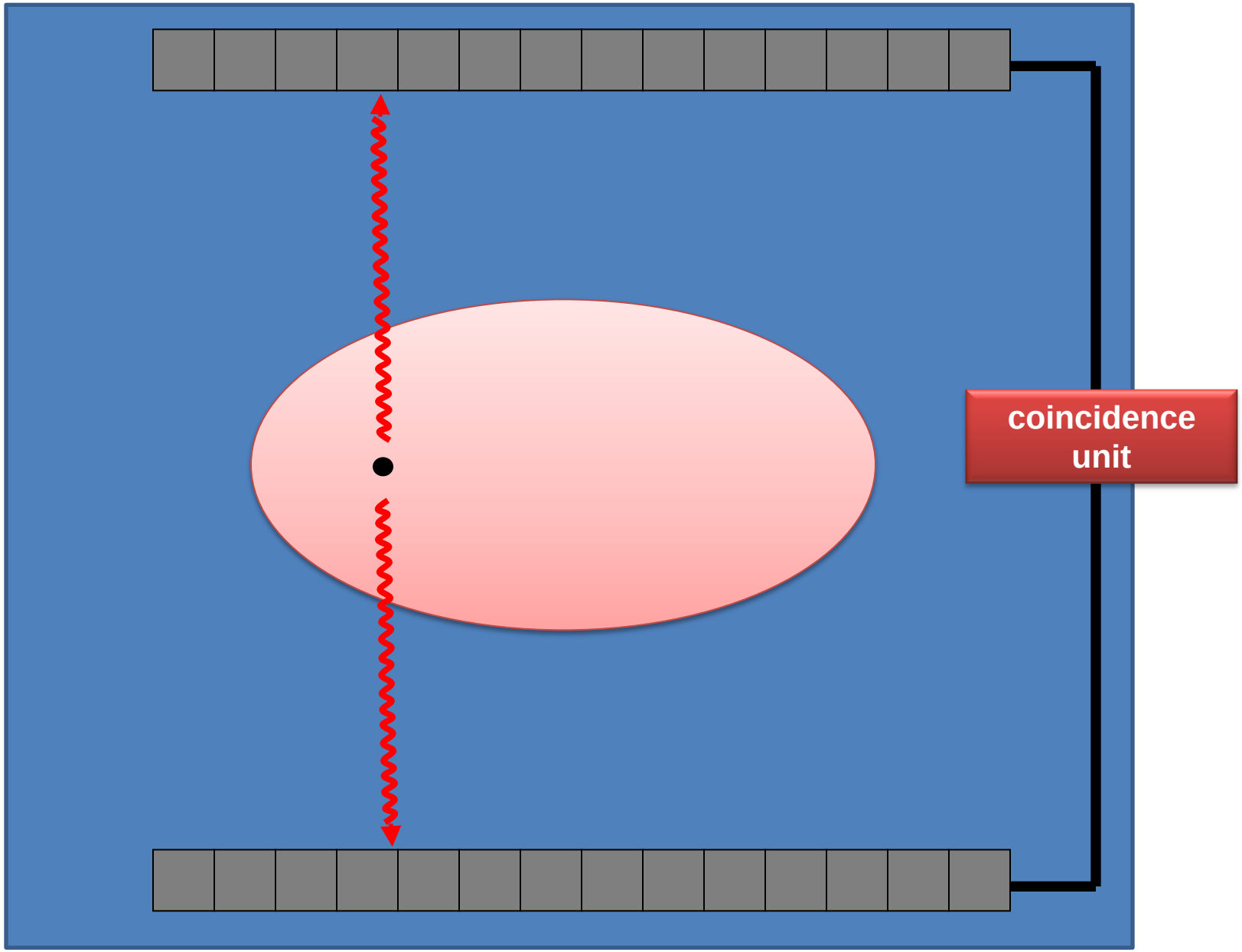
Nuclear Reaction for F-18

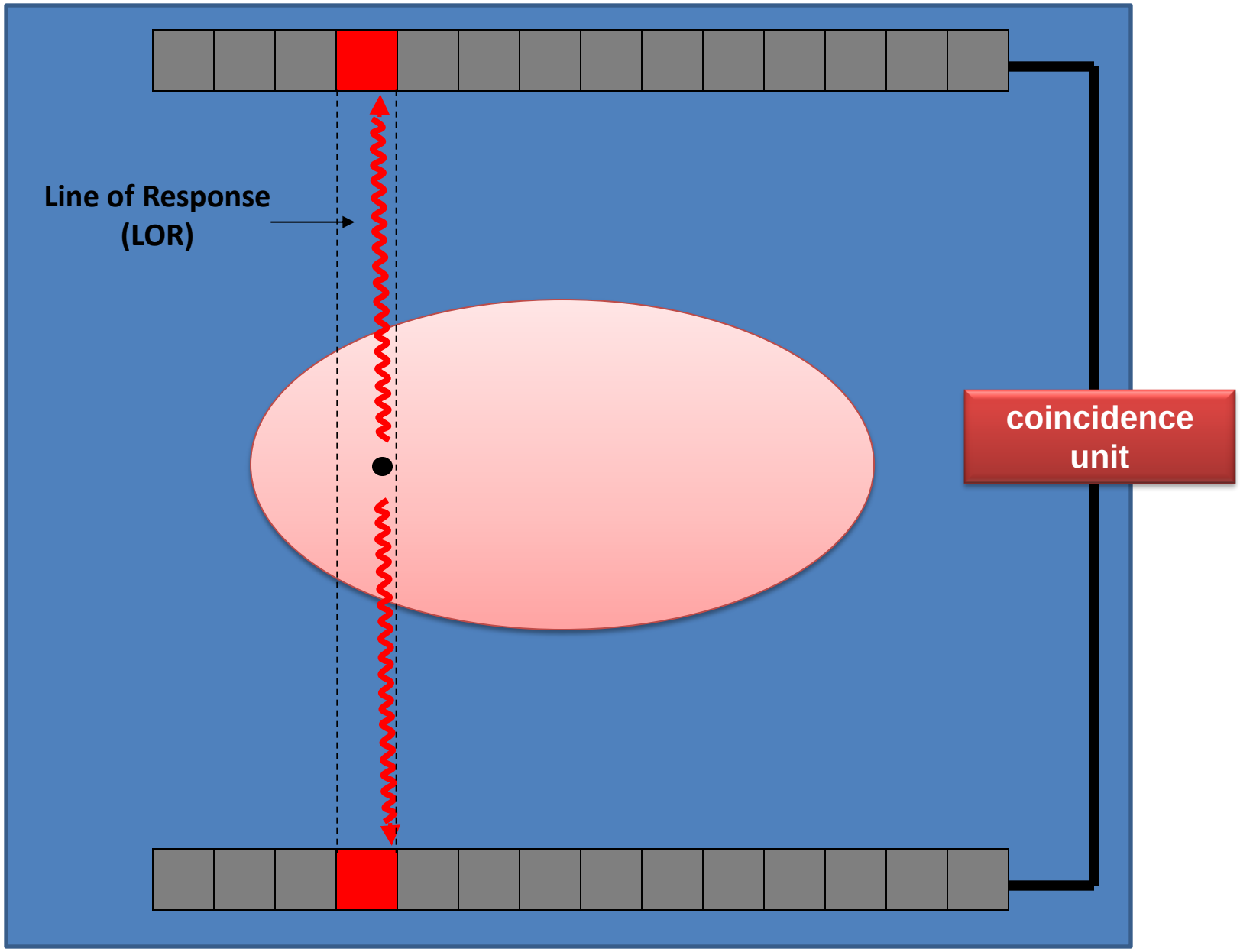


- Proton fired at ^{18}Oxygen
- ^{18}Oxygen absorbs the proton
  - temporary creation of ^{19}Fluorine
  - emission of a neutron
- Creation of ^{18}Fluorine



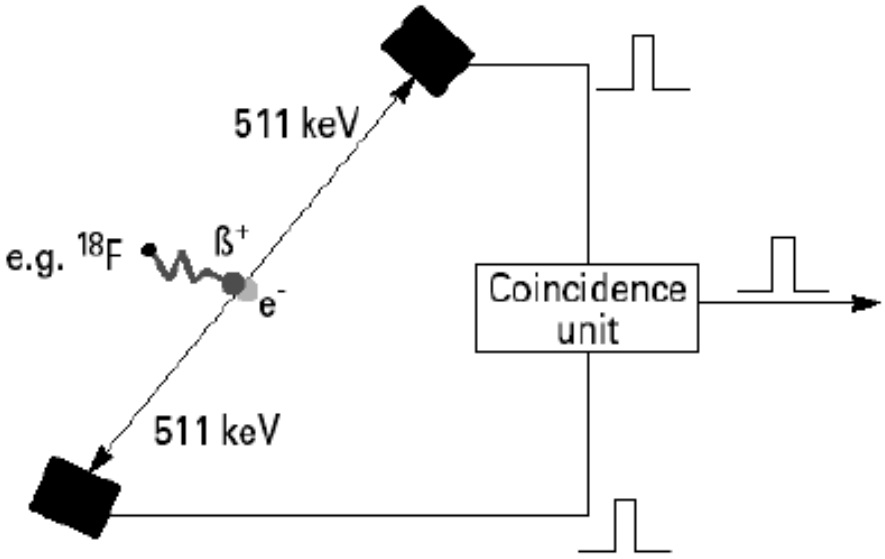

coincidence
unit


coincidence
unit

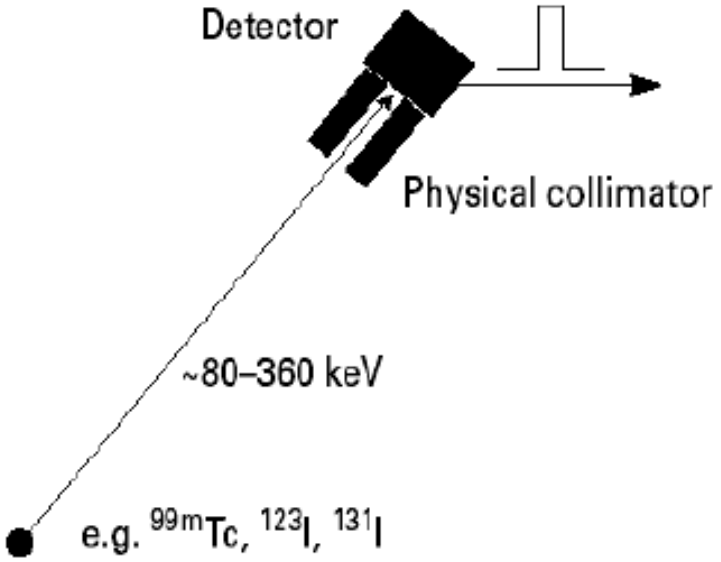

Line of Response
(LOR)
coincidence
unit

Look – no collimator!

PET

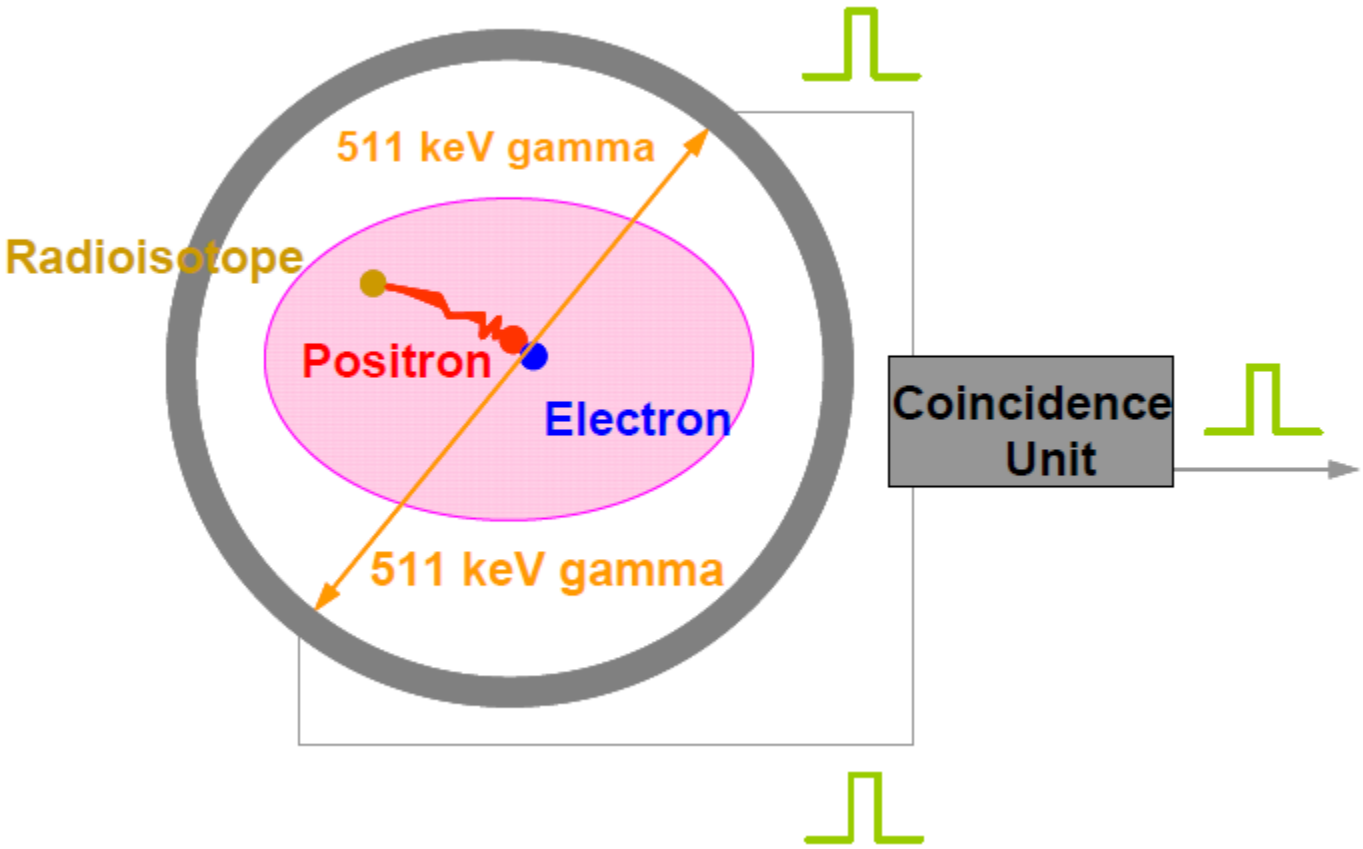


Single-Photon

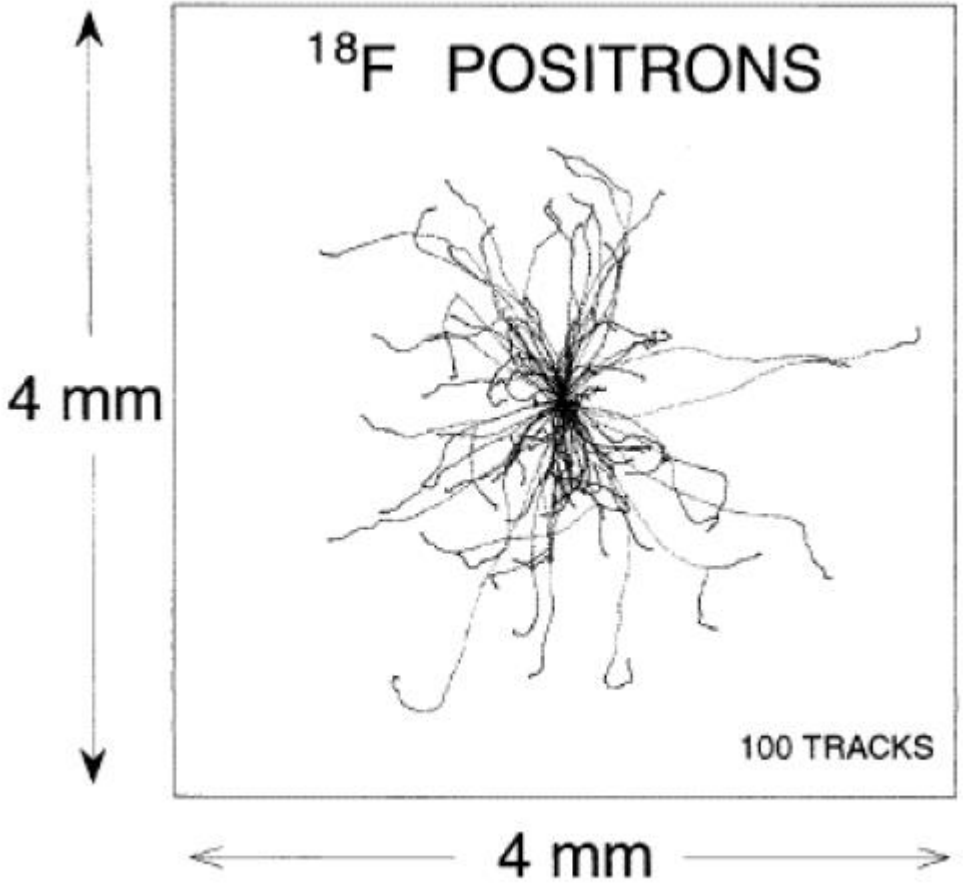


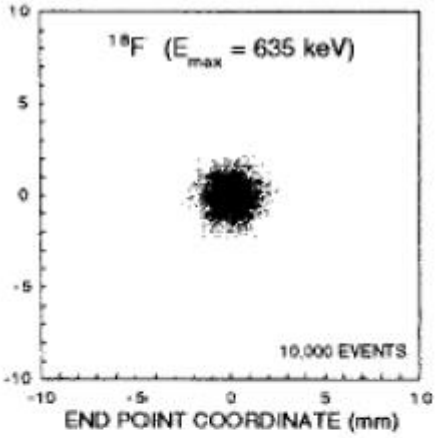
"Electronic collimation"

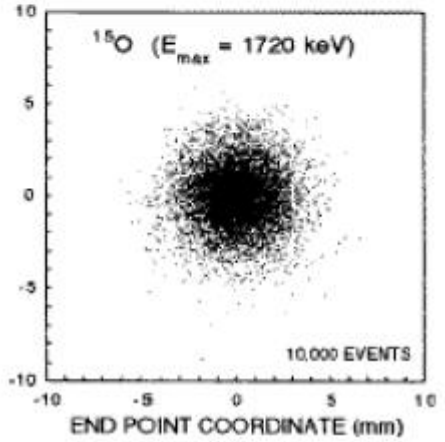
It’s not as simple as that…



Physical Limits on Resolution in PET







Simulated ^{18}F positron tracks from a point source in water.

from Levin & Hoffman PMB 1999; 46:781-799

Variation of Resolution with Positron Energy

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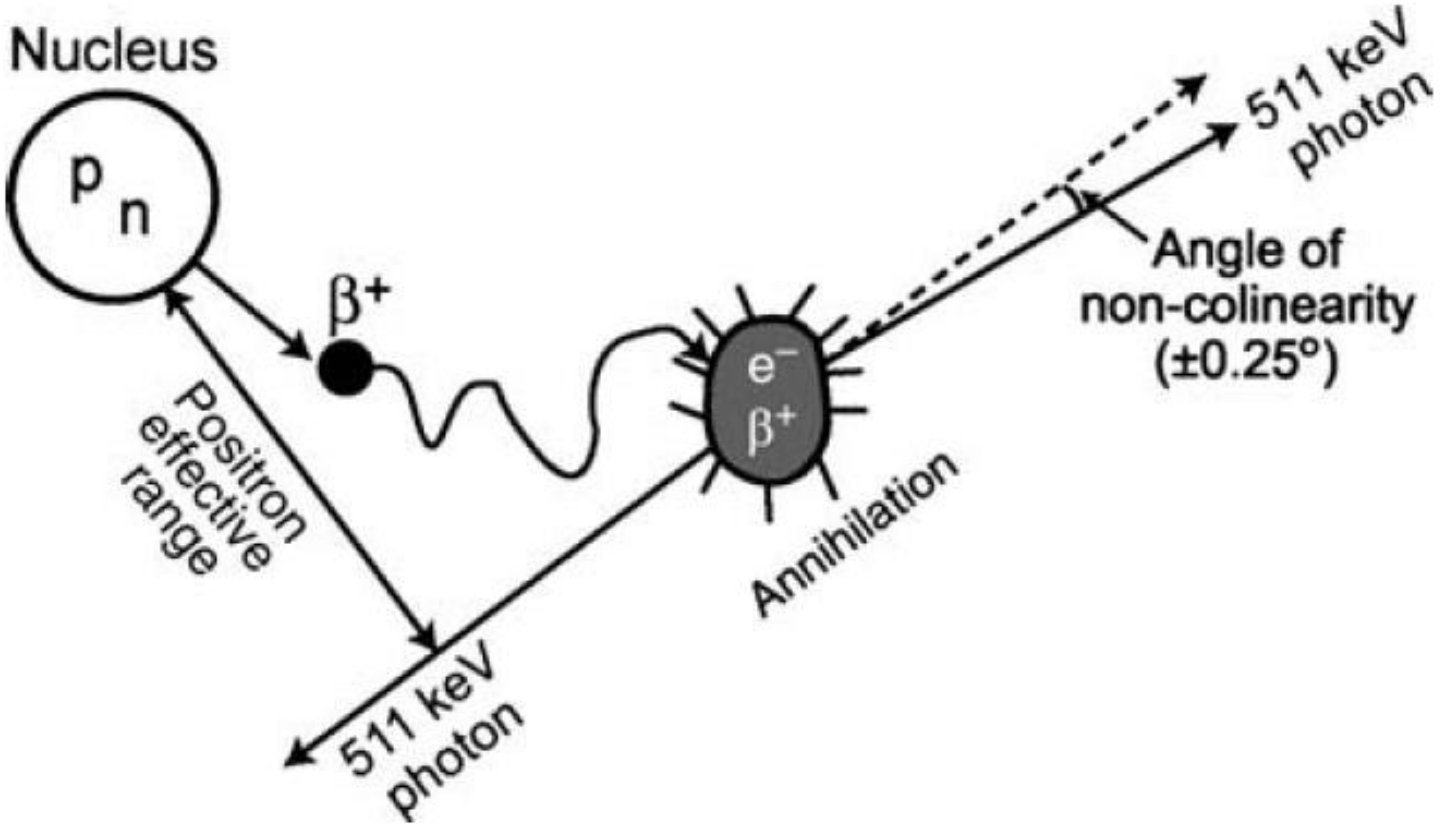
(*=enriched target)

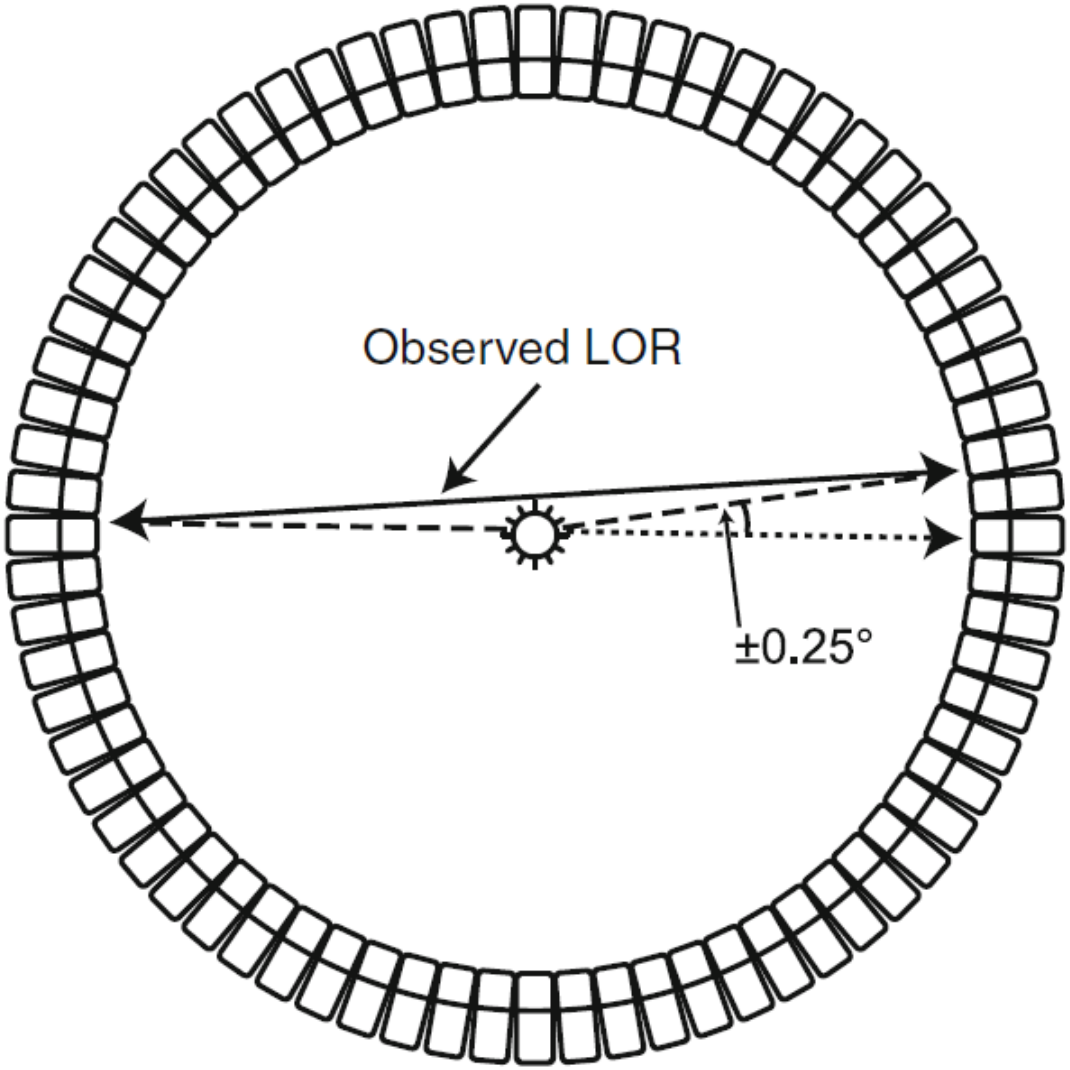
Wide range of positron energies

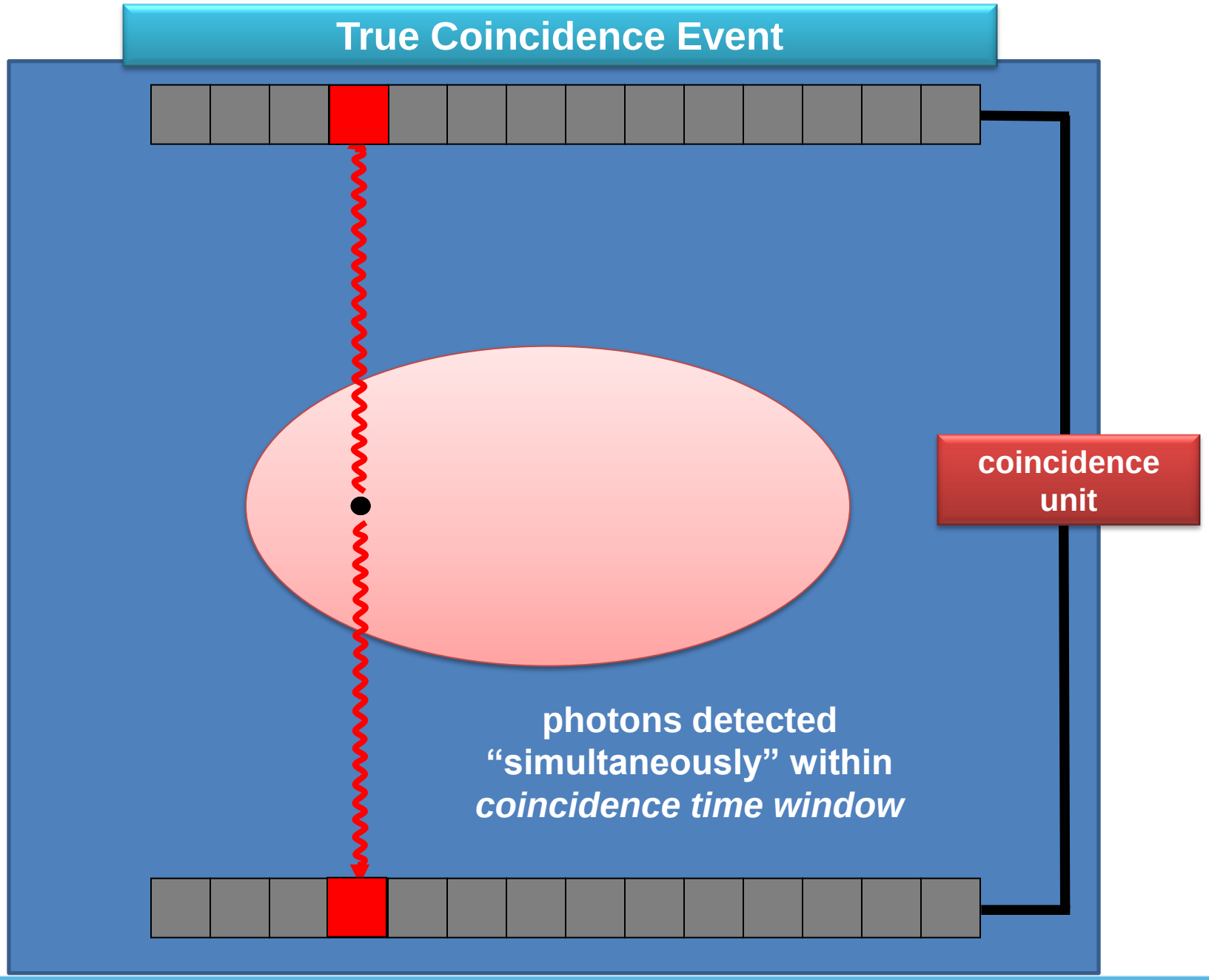
higher energy ⟶ worse spatial resolution

Variation of Resolution with Positron Energy

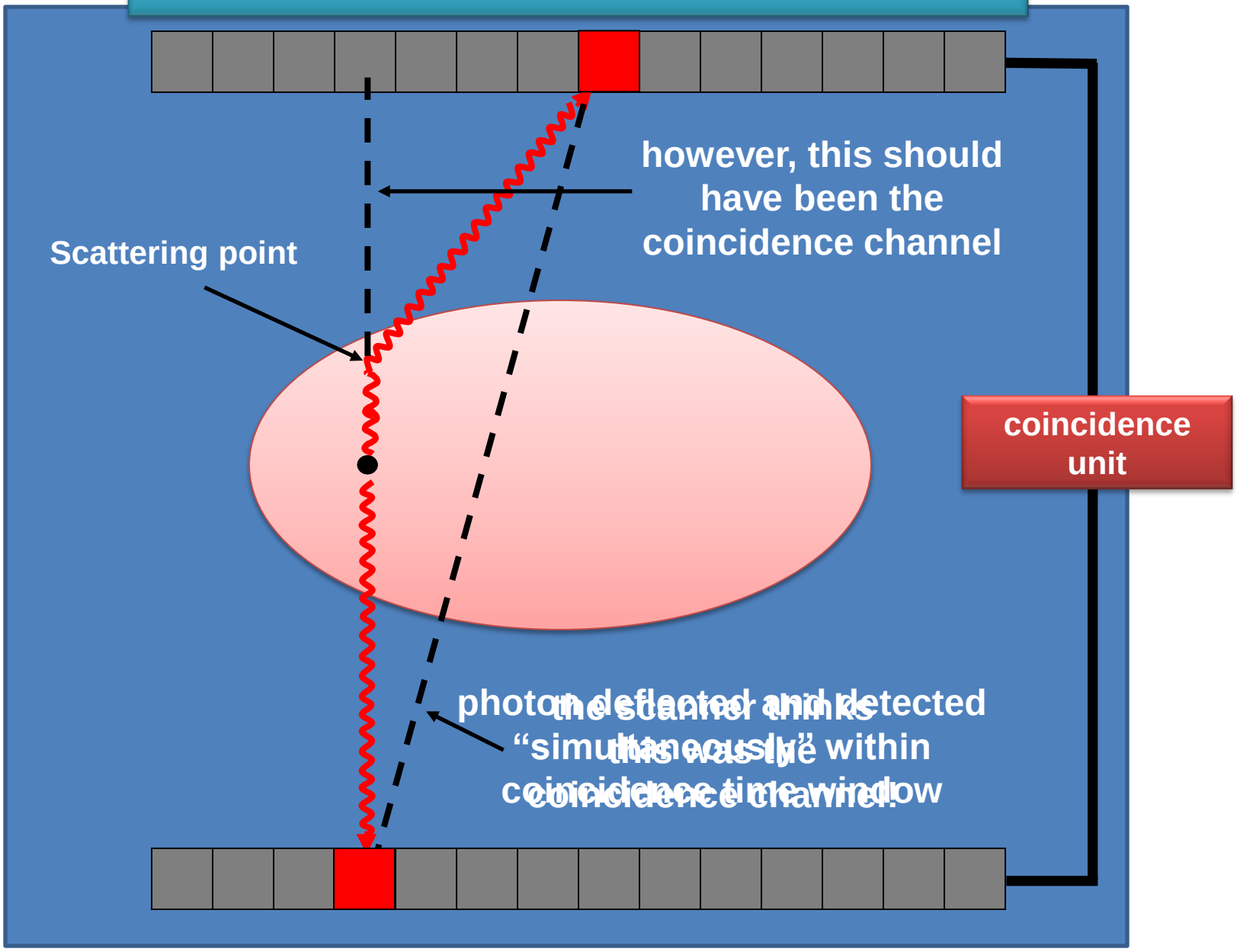


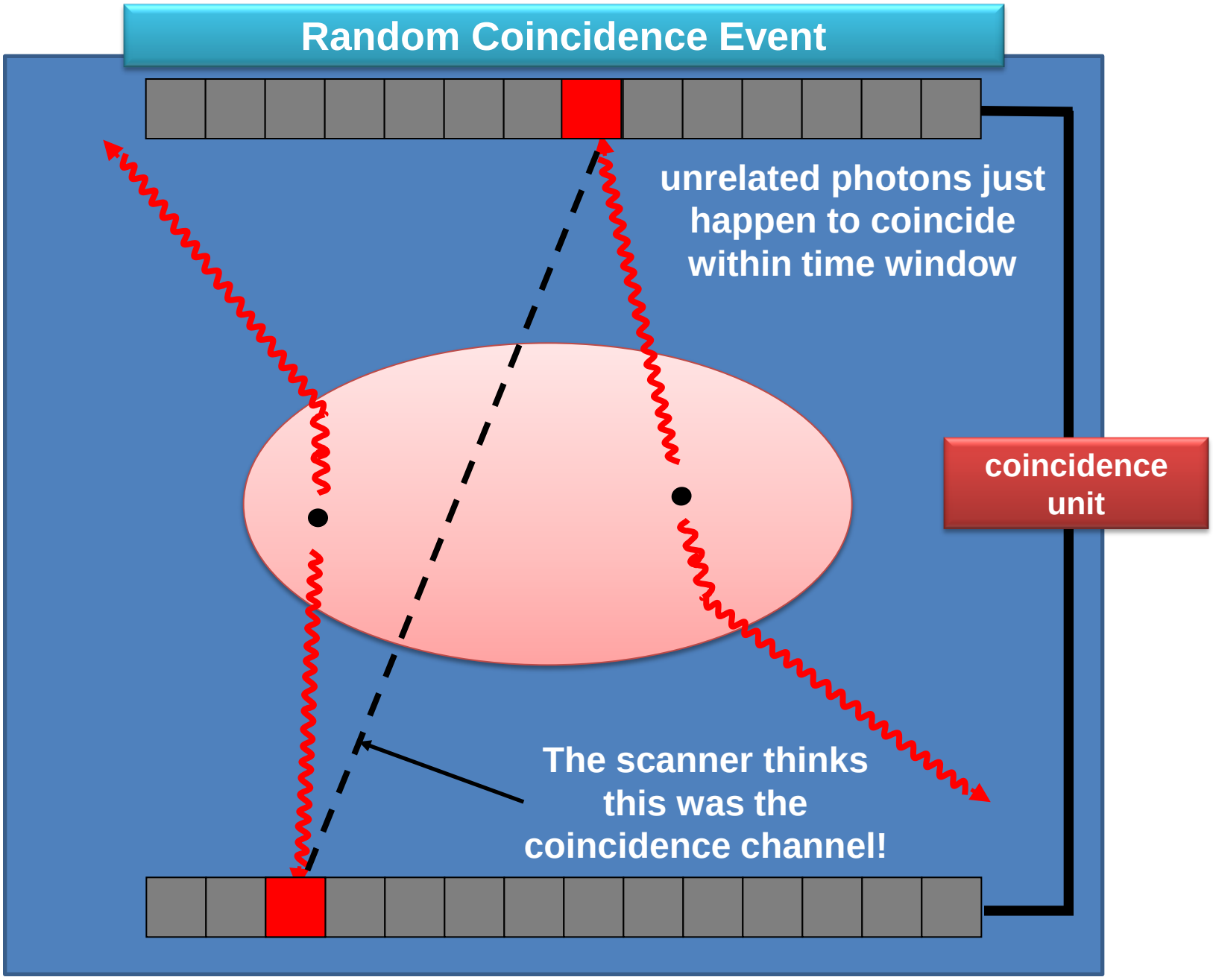
Variation of Resolution with Positron Energy



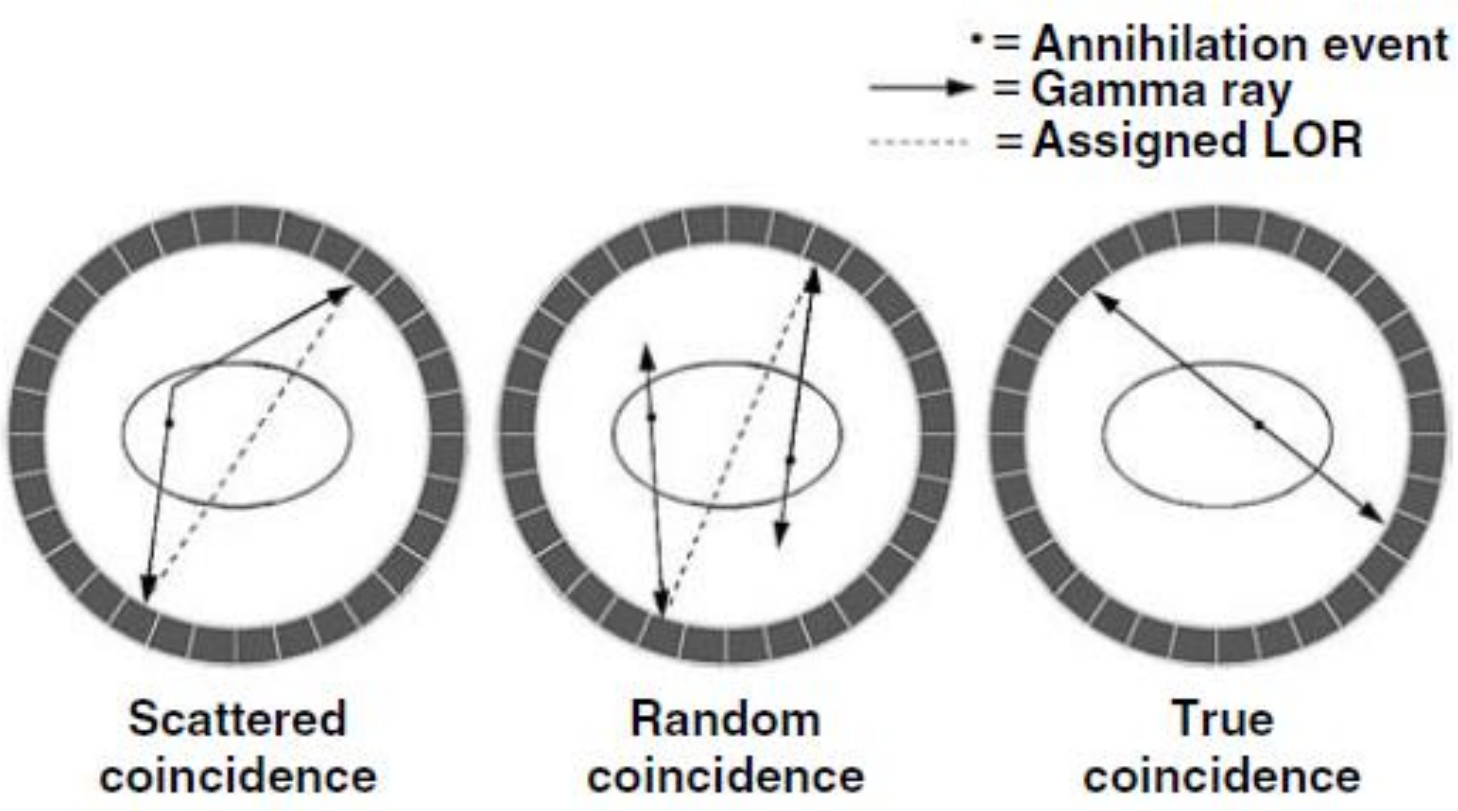

True Coincidence Event
coincidence unit
photons detected "simultaneously" within coincidence time window

Scatter Coincidence Event



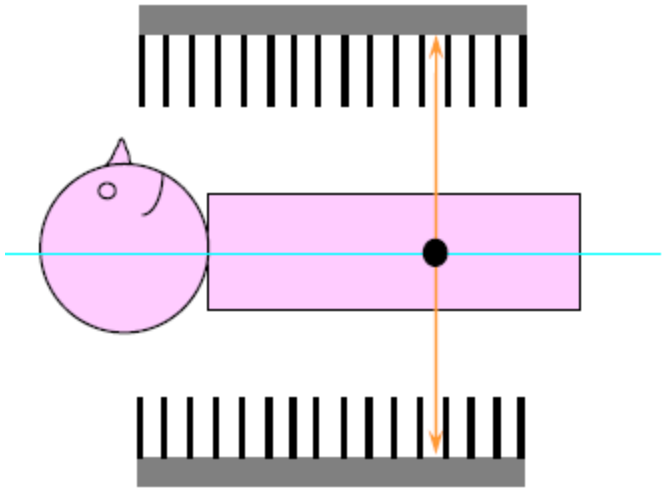

Random Coincidence Event
unrelated photons just happen to coincide within time window
coincidence unit
The scanner thinks this was the coincidence channel!

Type of Events in PET



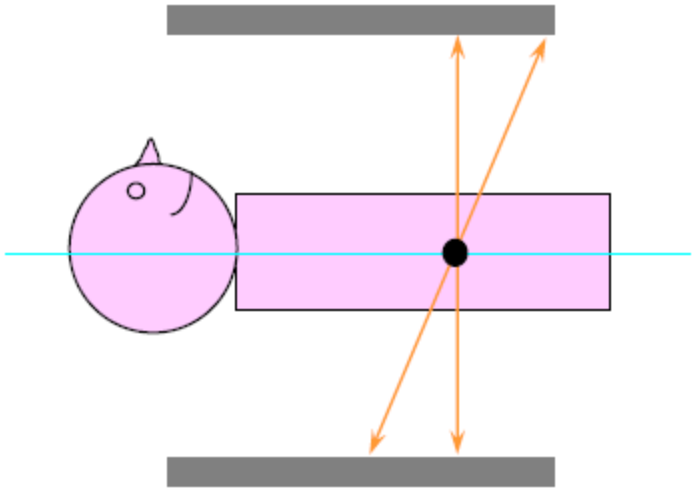
Acquisition Modes

- **2D**



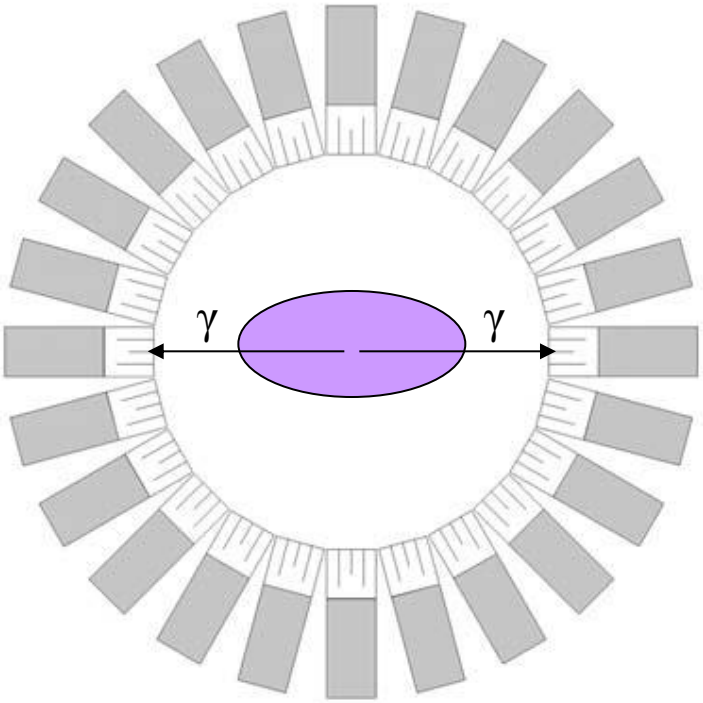
- Less randoms and scatter, but reduced sensitivity

- **3D**

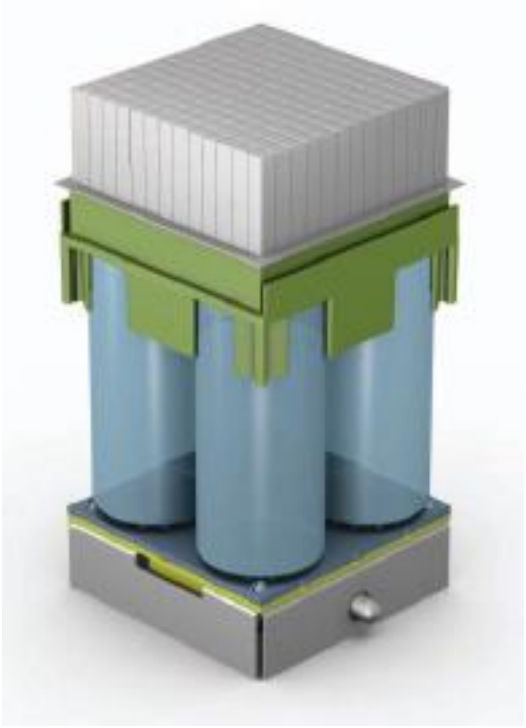


- Highest sensitivity but high randoms and scatter

PET Crystal Array

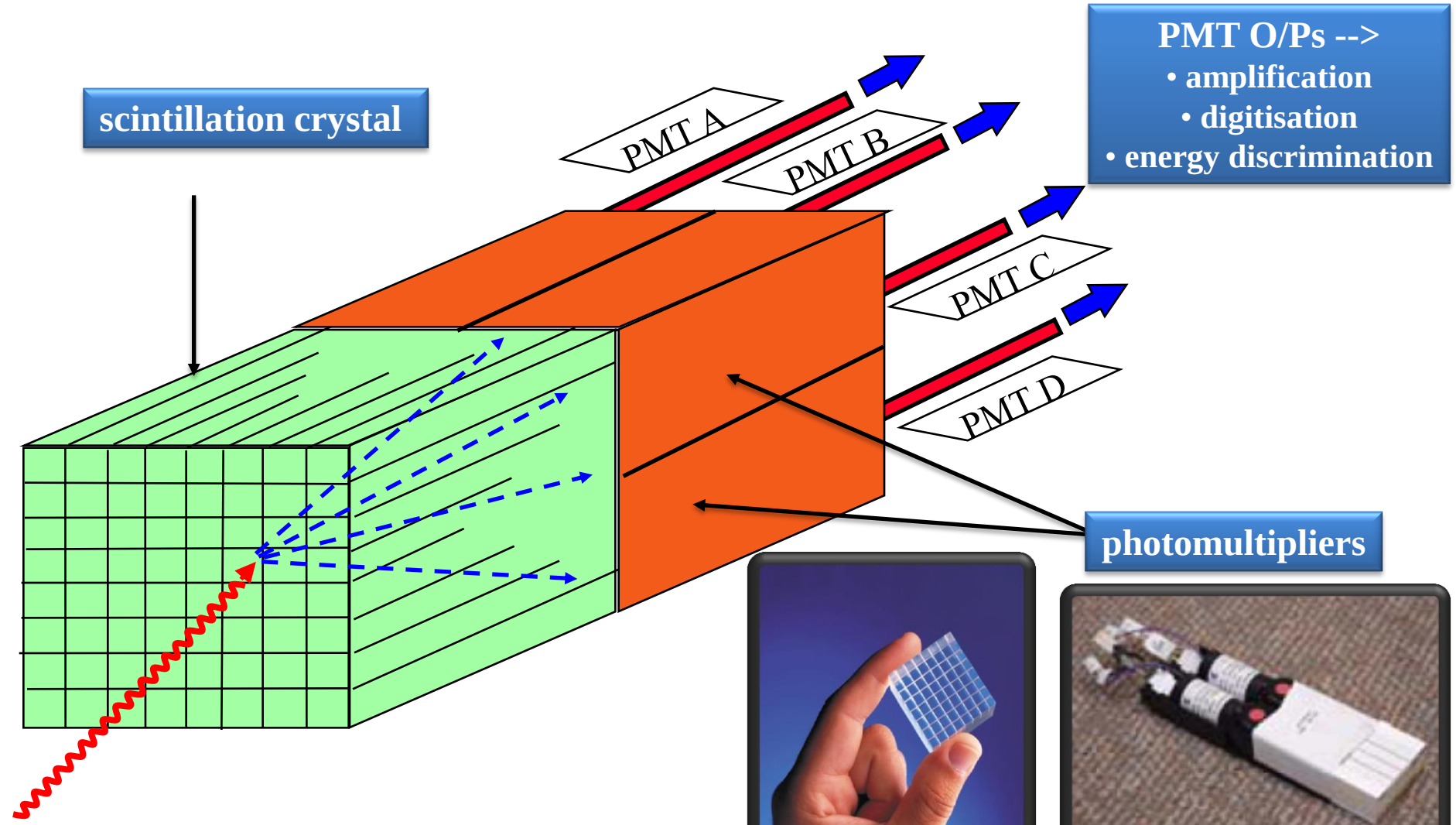


Annular Detector Array



Detector Block

PET Detector Block



Scintillator Crystals

Crystal	Relative Light Output (%)	Decay Time (ns)	Density (g/cm^3)	Effective Atomic Number (Z)	Energy Resolution at 511 keV (%)
NaI(Tl)	100	230	3.7	51	7.8
BGO	15	300	7.1	75	10.1
LSO	75	40	7.4	65	10.0
GSO	35	60	6.7	59	9.5

All crystals emit light with wavelengths ranging from 410 to 480 nm

Detectors based on BGO are still common, but crystals such as LSO and GSO (and those with similar properties) are increasingly being used. Both potentially offer improved count rate performance due to shorter decay times and improved energy resolution

Current PET ≈ PETCT

GE MEDICAL SYSTEMS



Discovery
ST
STE
VCT
STE RX
VCT RX
600
690

PHILIPS



Gemini GXL
Gemini TF

SIEMENS

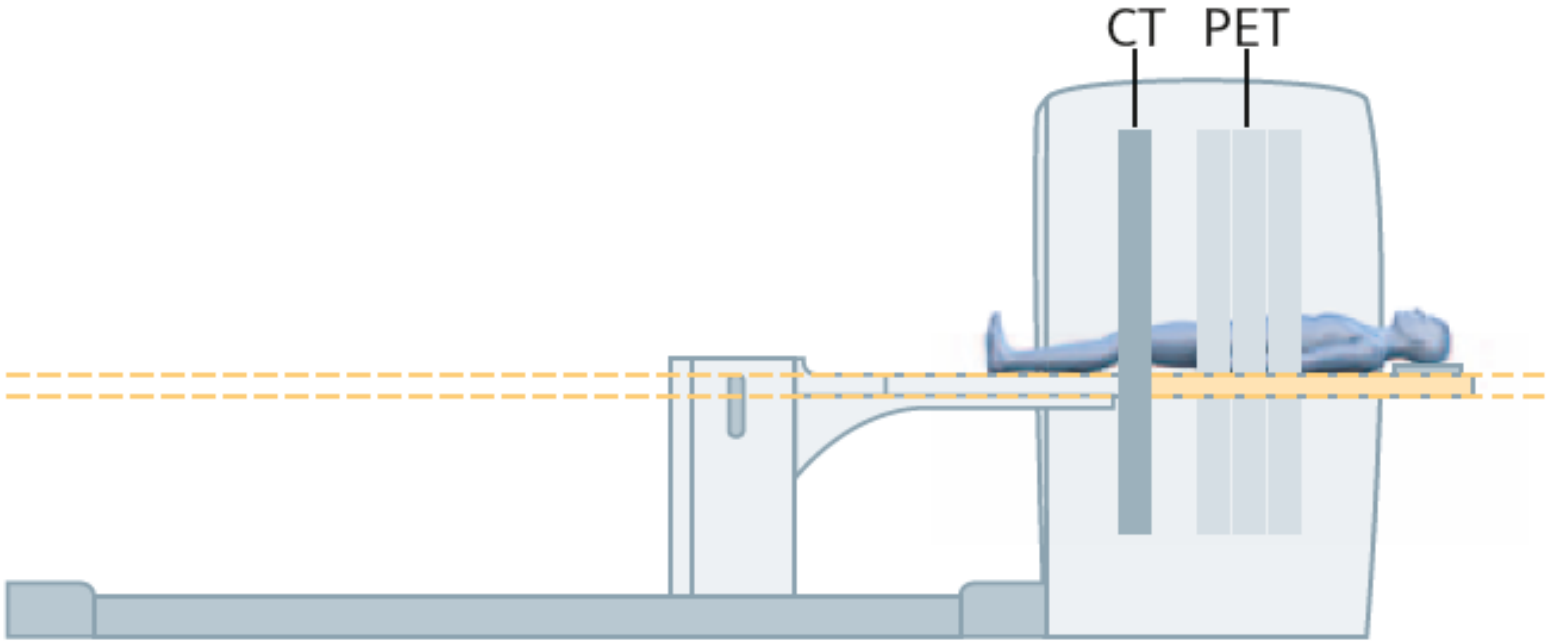


Biograph

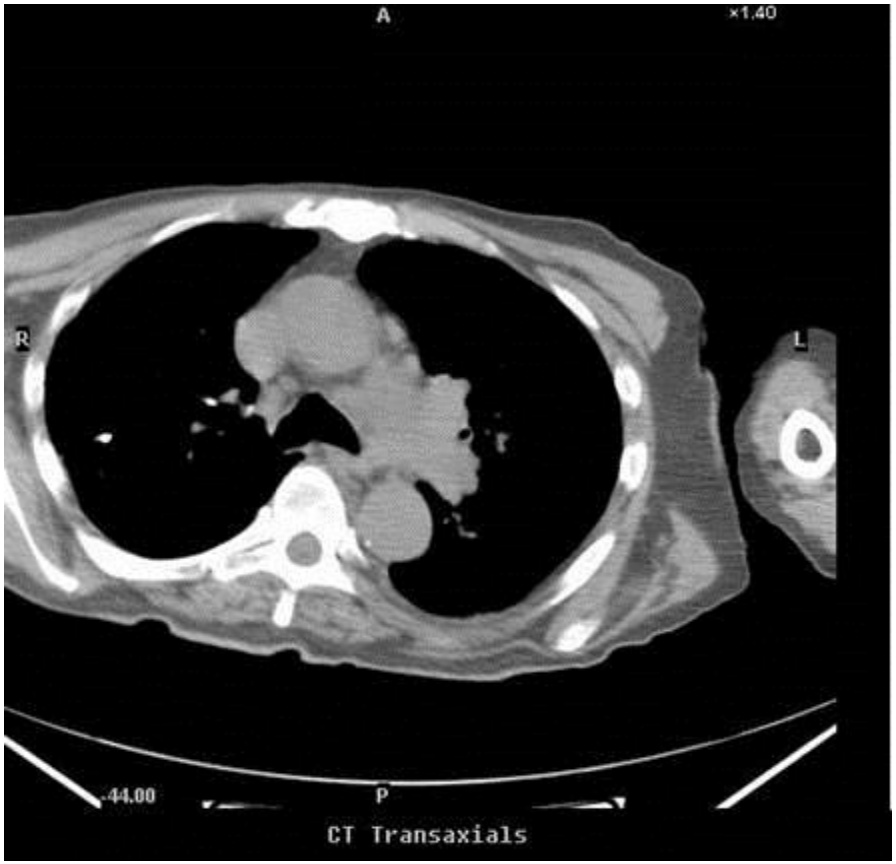


mCT

Current PET ≈ PETCT

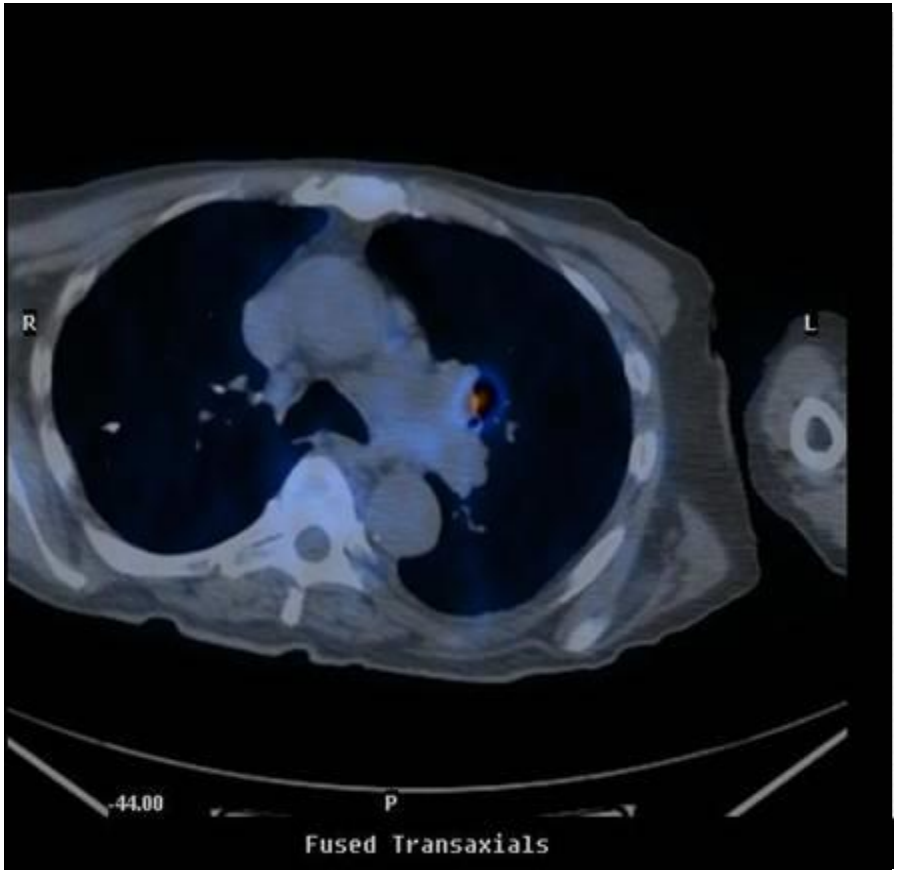


Computed Tomography (CT)



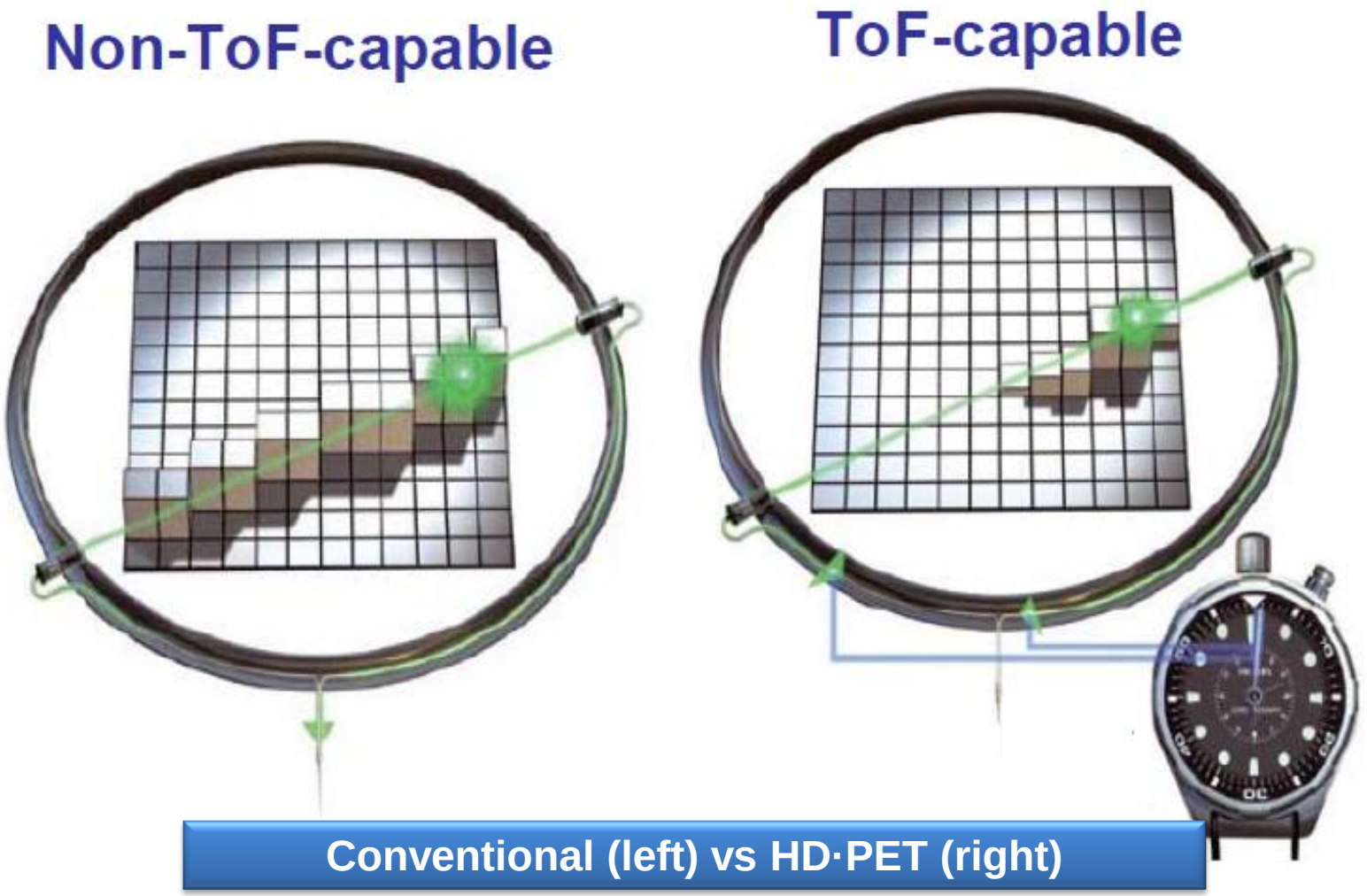
- Anatomical detail
- Cannot differentiate between active and benign disease
- Better resolution than PET

PET/CT



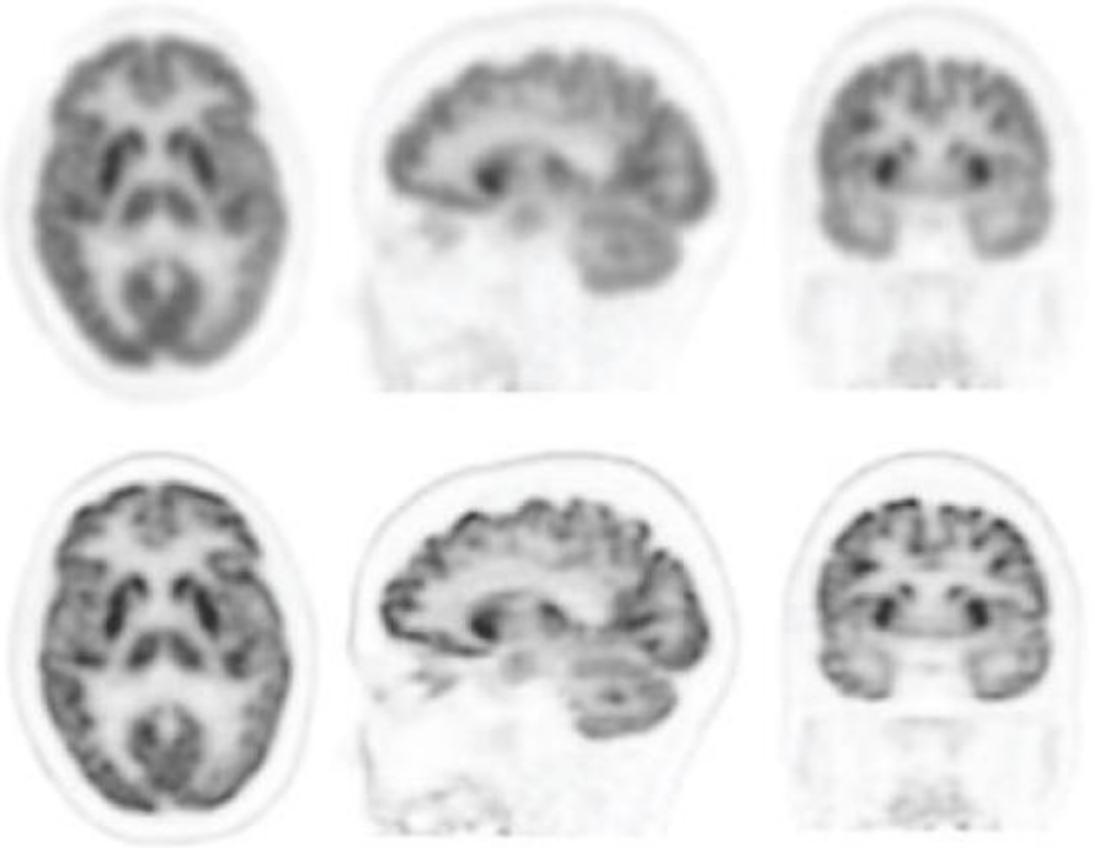
- Combines function with anatomy
- Accurate anatomical registration
- Higher diagnostic accuracy than PET or CT alone

“Time-of-Flight” (TOF)



Conventional (left) vs HD·PET (right)

Improved Contrast with (TOF)



Conventional (top row) vs HD·PET (bottom row)

Standardised Uptake Value (SUV)

- Semi quantitative analysis based on
  - region of interest values
  - applying activity (kBq/ml) in the region of interest to patient weight and dose:

$$\text{SUV} = \frac{Uptake\ (\frac{kBq}{ml})}{activity\ (MBq)/weight(kg)}$$



before chemotherapy
SUV = 17.2



chemotherapy day 7
SUV = 3.9



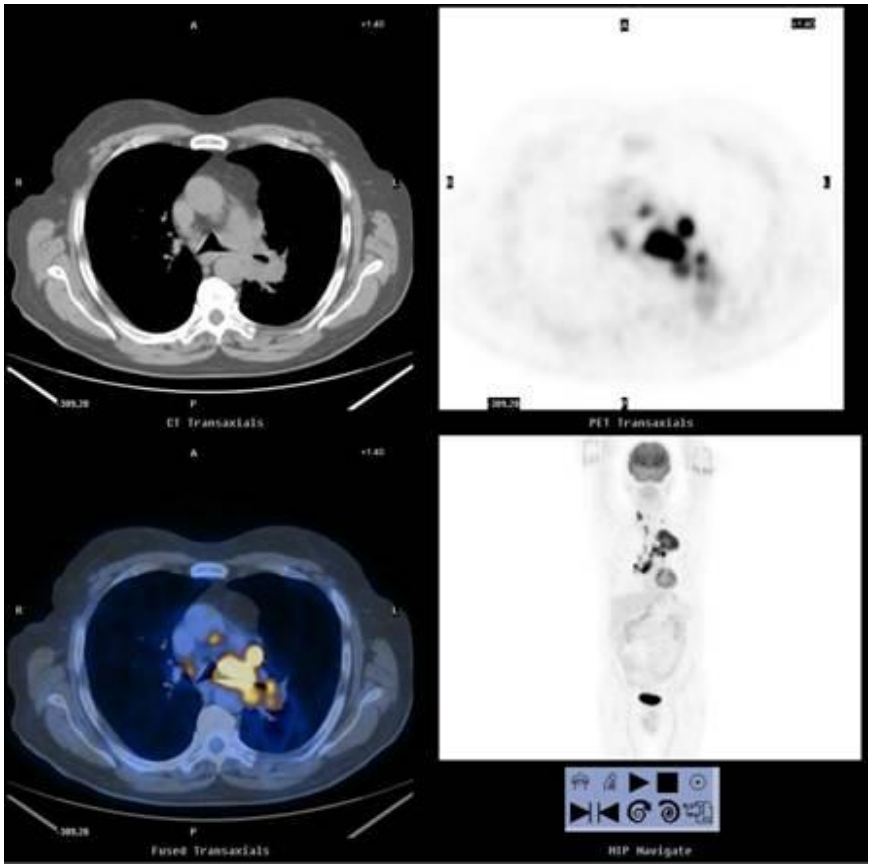
chemotherapy day 42
SUV = 1.8

PET Applications

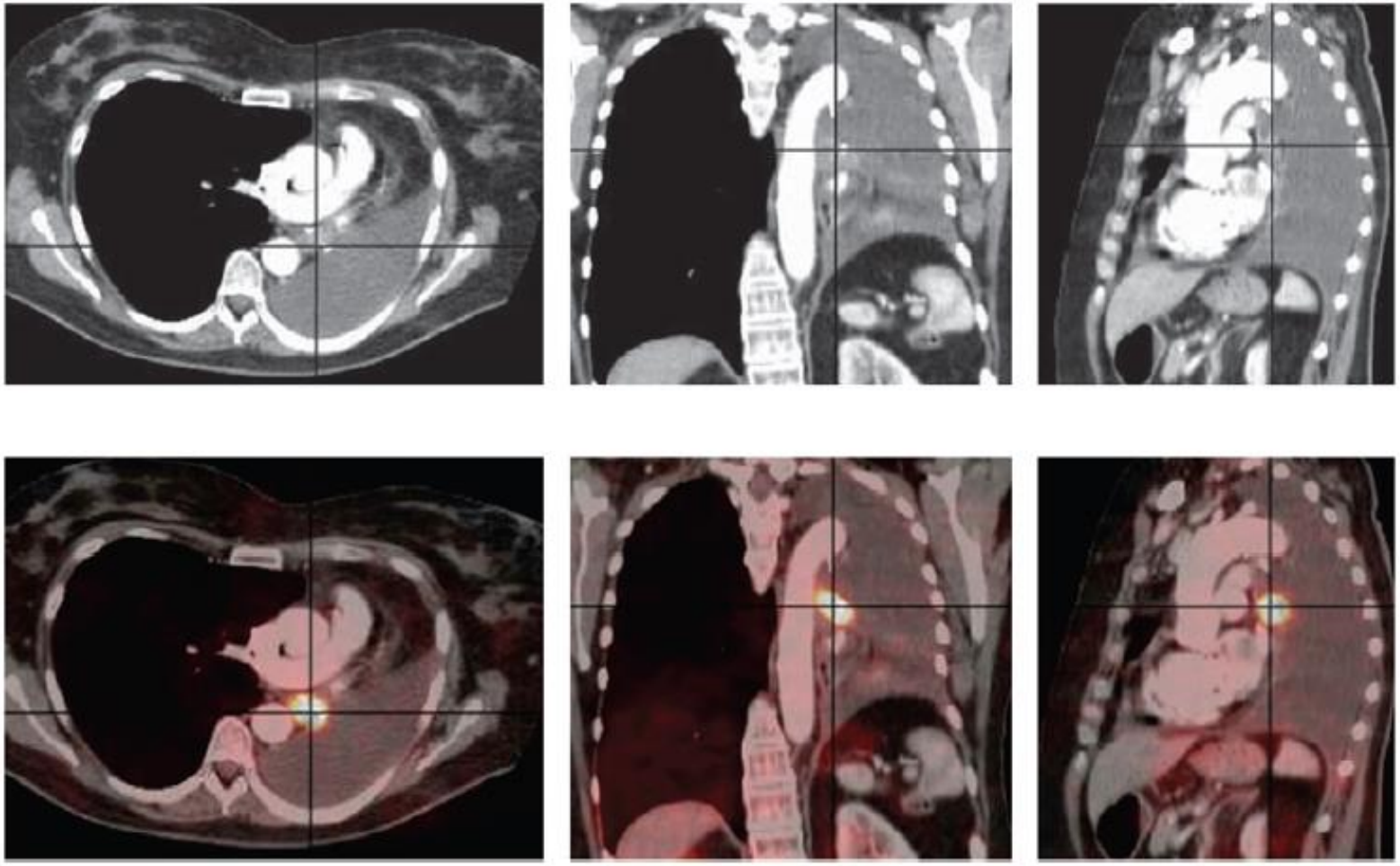
PET Applications
Oncology

Role in Oncology

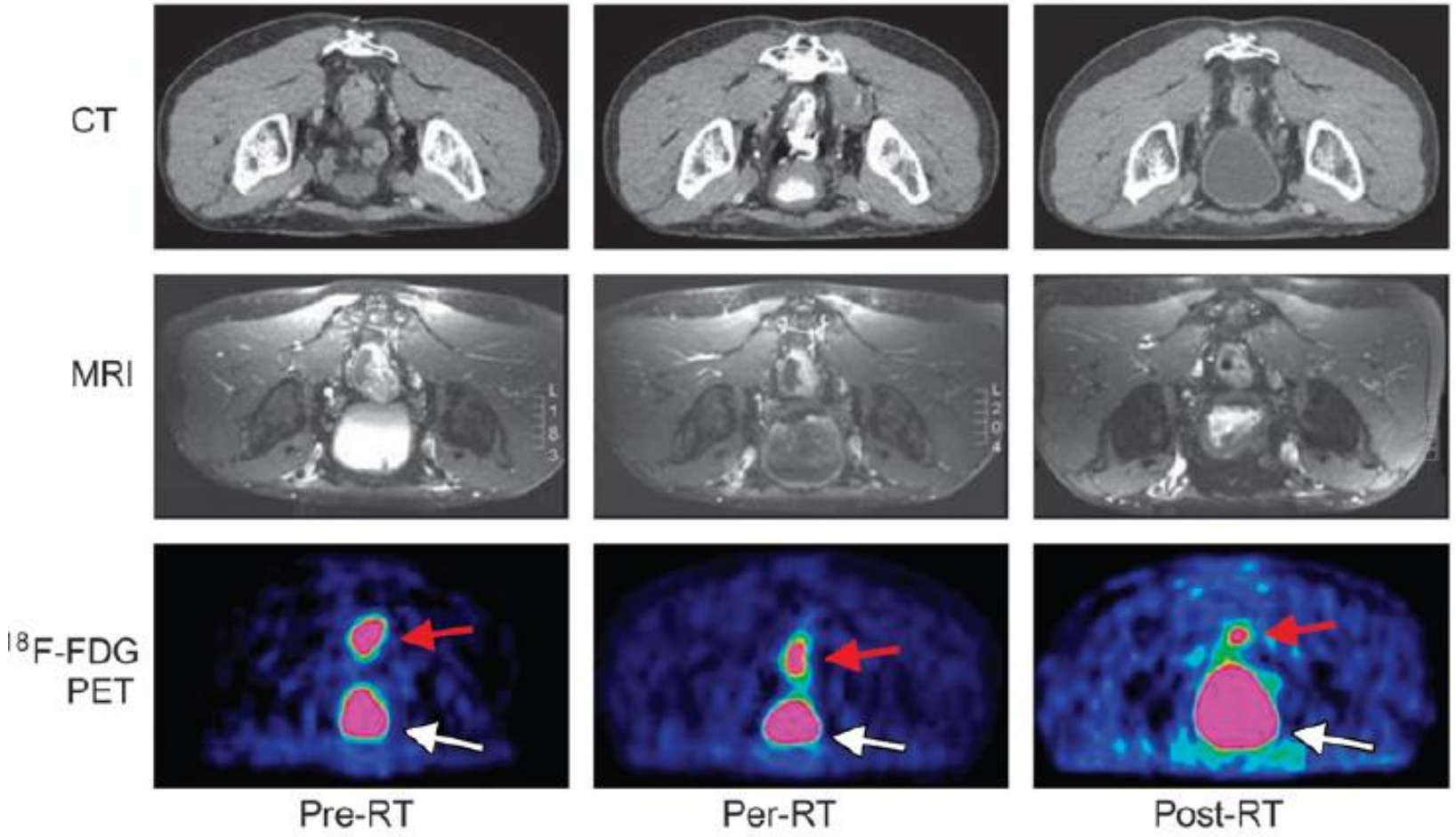
- Differentiate benign from malignant disease
- Staging of disease
- Treatment response
- Radiotherapy treatment planning



Volume Delineation

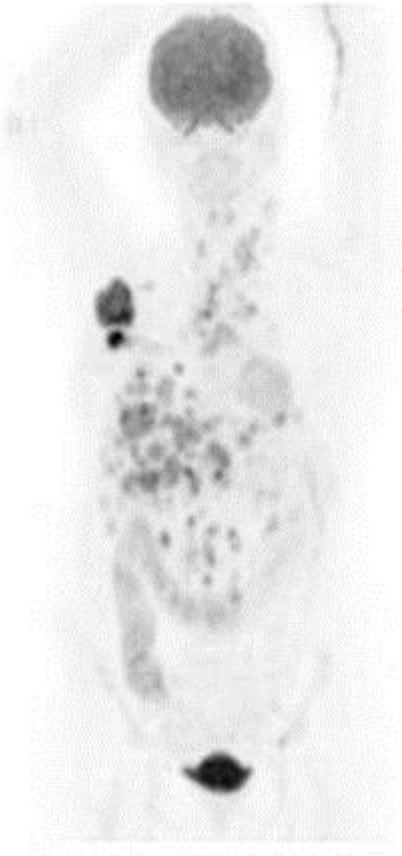


Volume Delineation



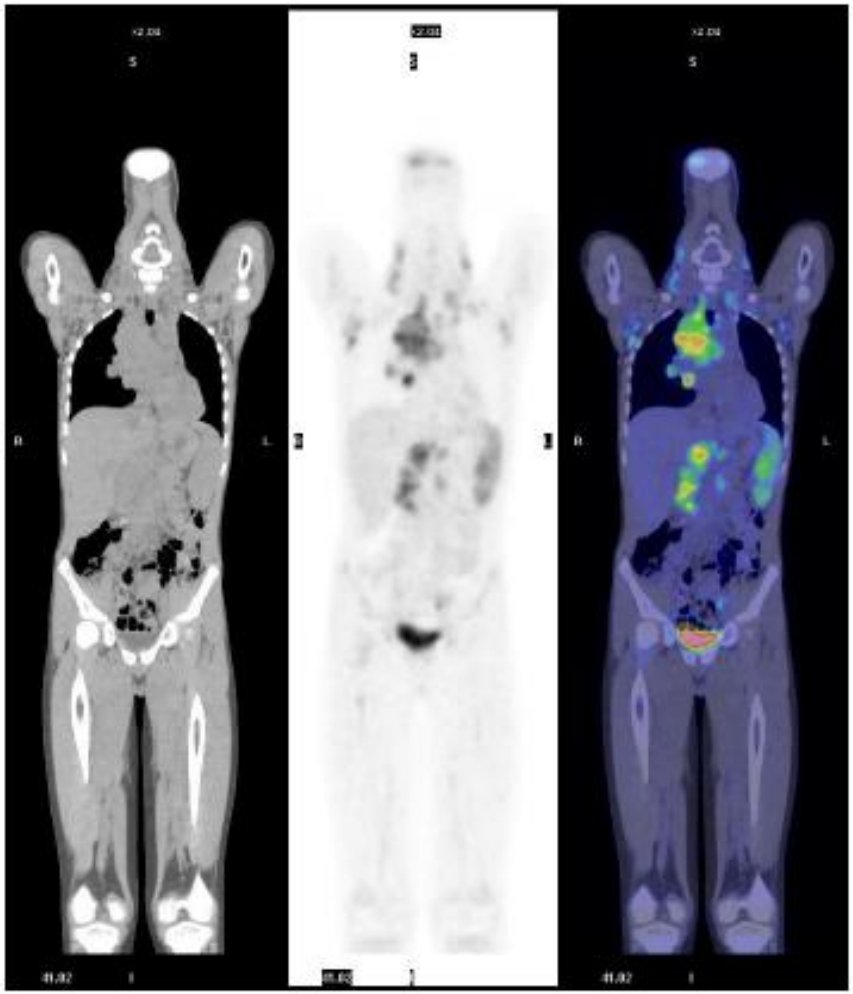
Disease Progression





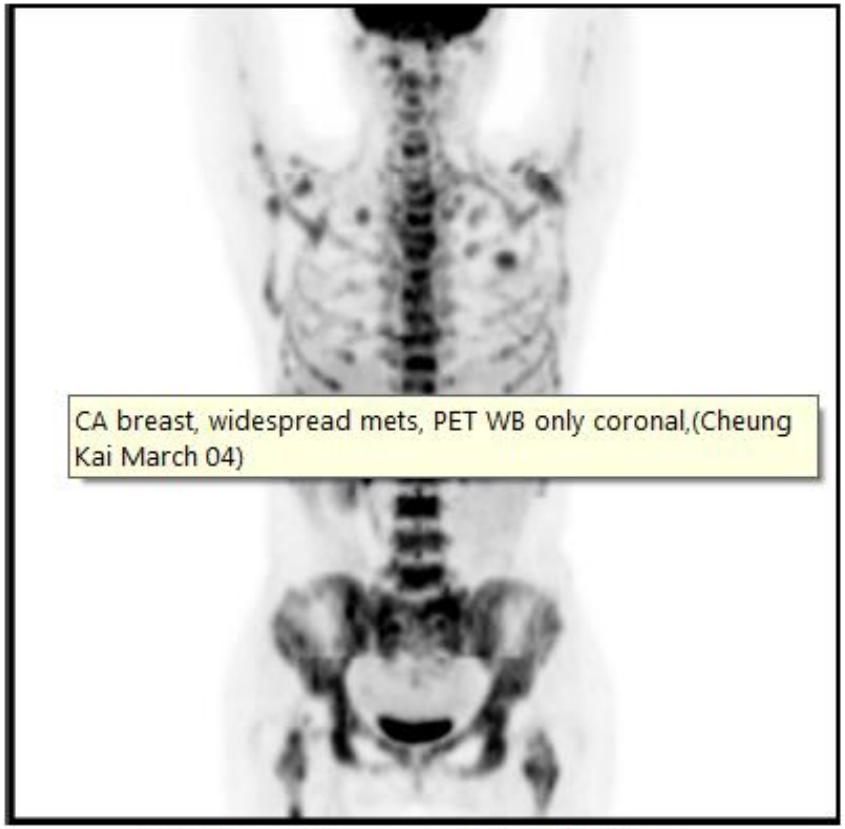
2004 **2005**

Oncology – Glucose Metabolism (^{18}FDG)

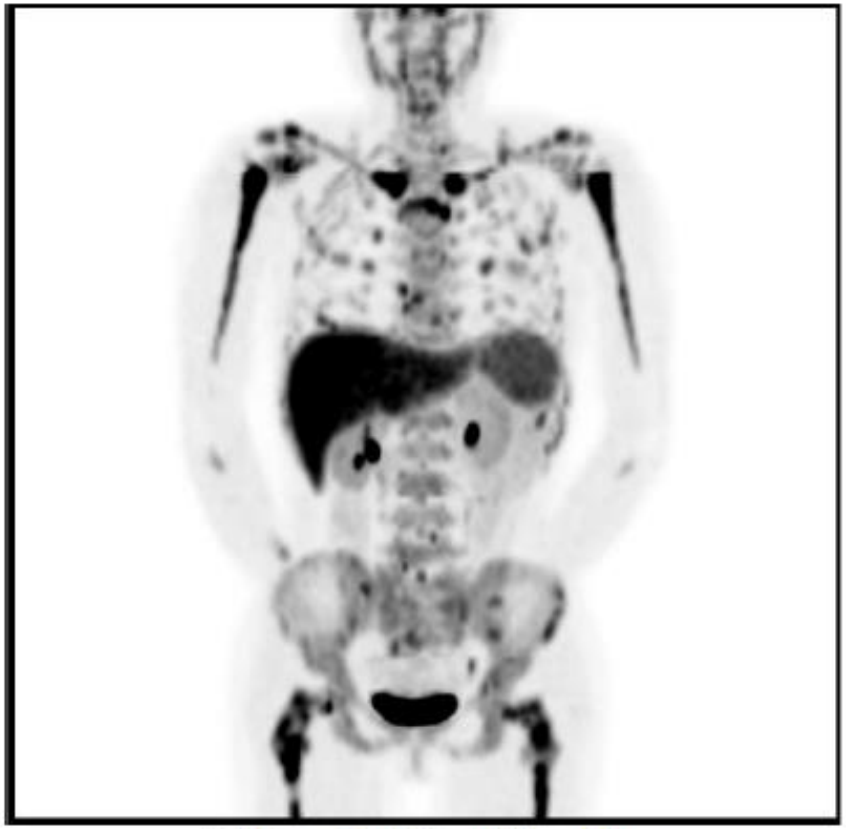




Different Tracers

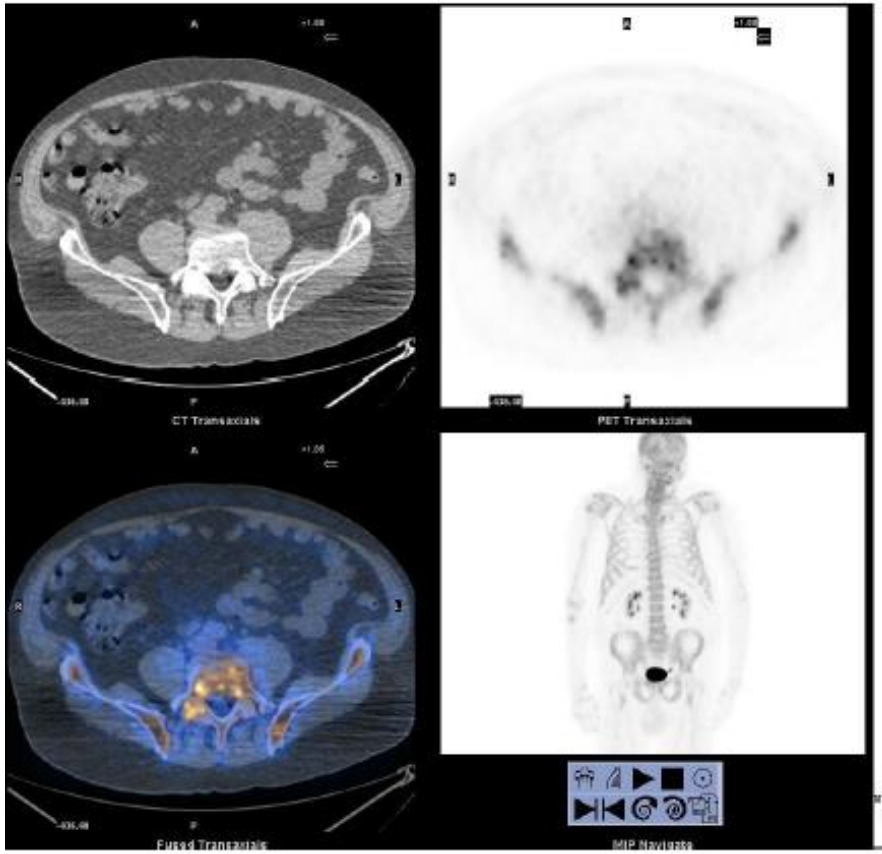


FDG – Glucose Metabolism



FLT – Cell Proliferation

Different Tracers

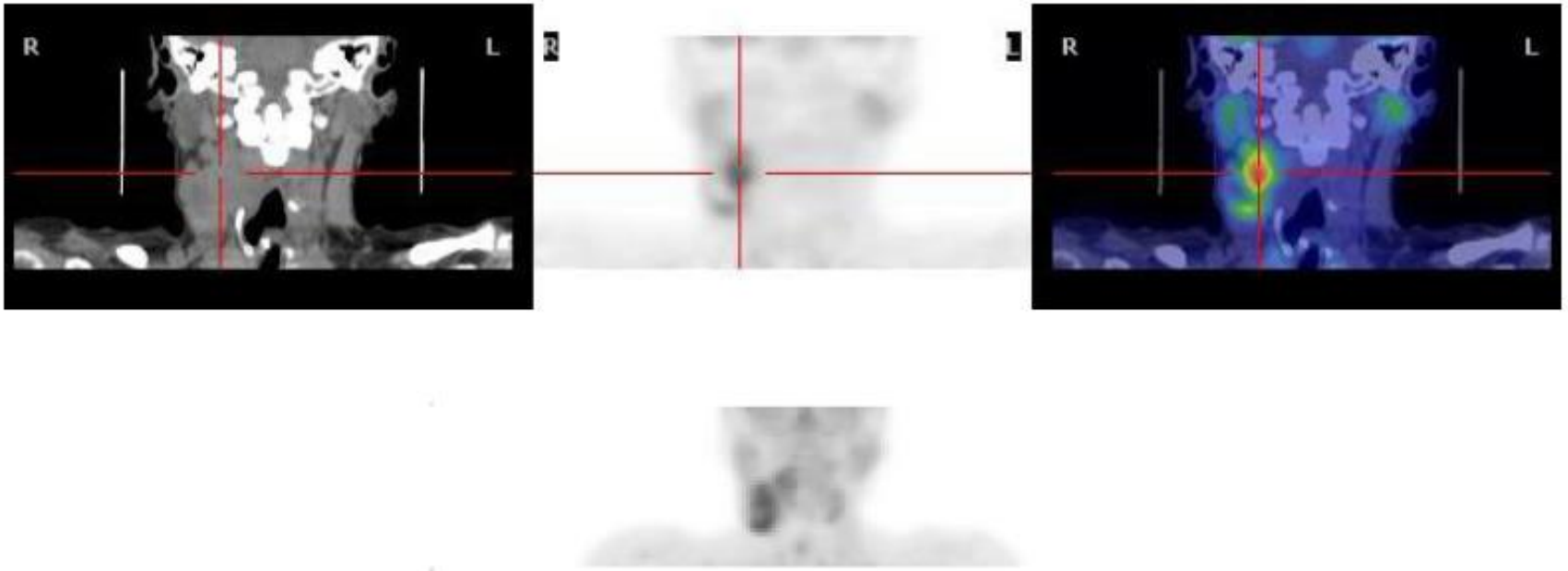


Fluoride Bone Scan



Tc-99m HDP

Different Tracers

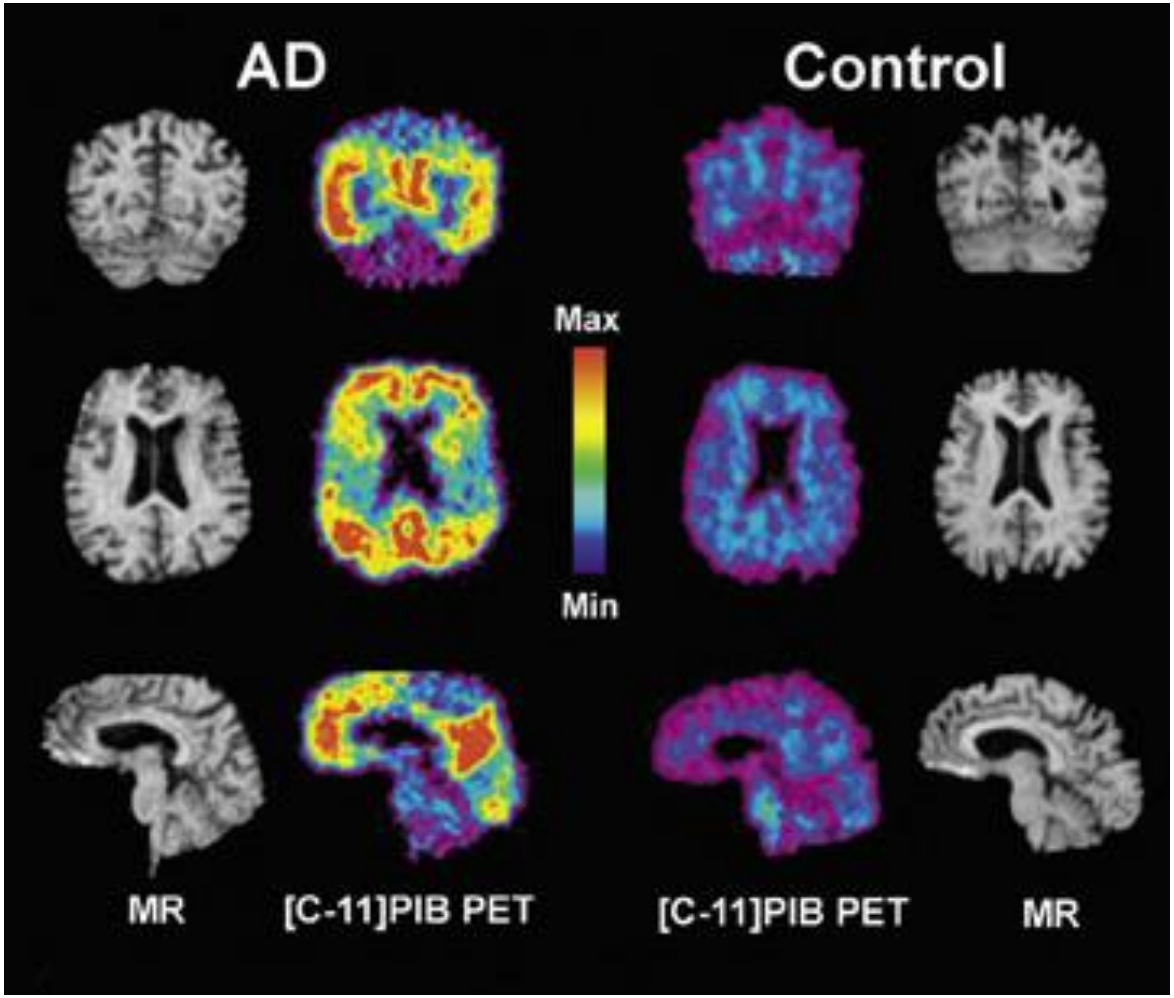


Cu64 ATSM - Hypoxia

PET Applications

PET Applications
Neurology

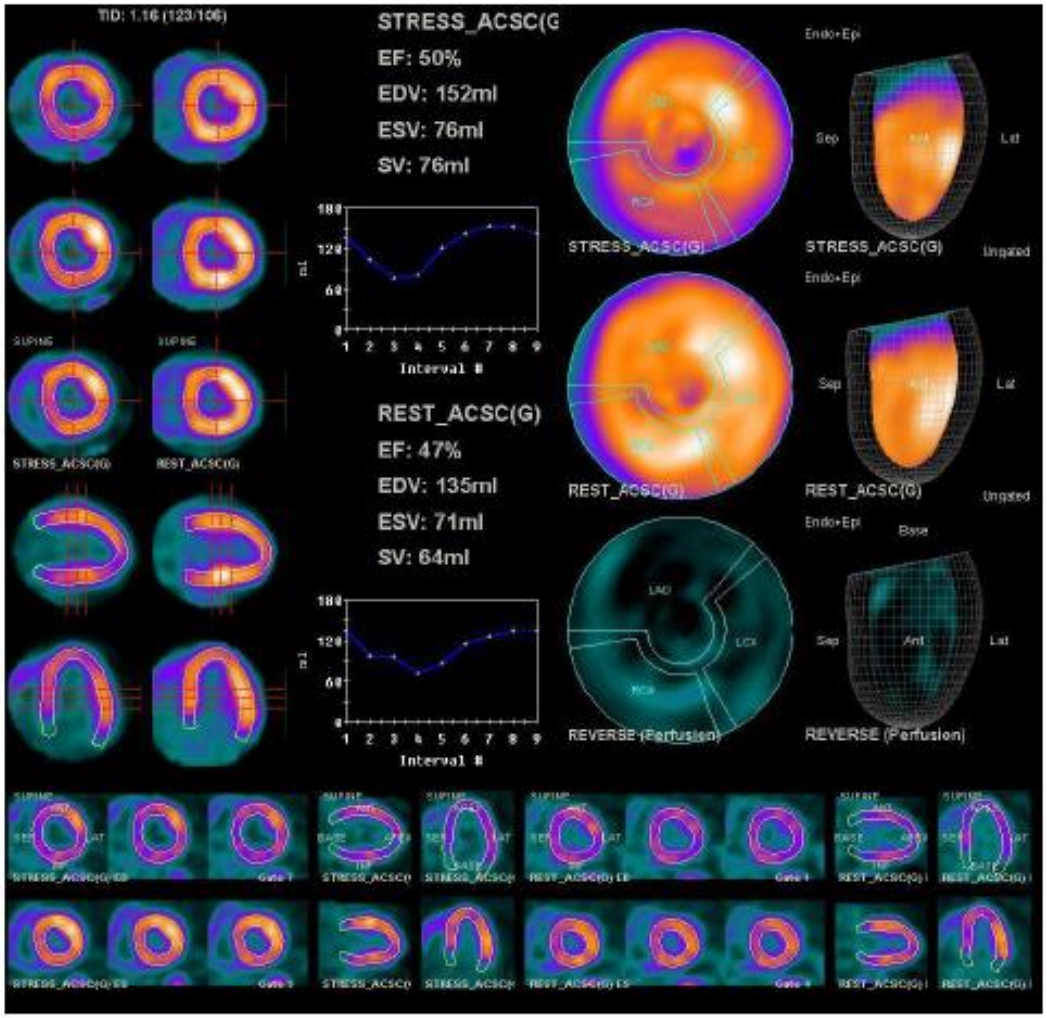
Neurology – Alzheimer's



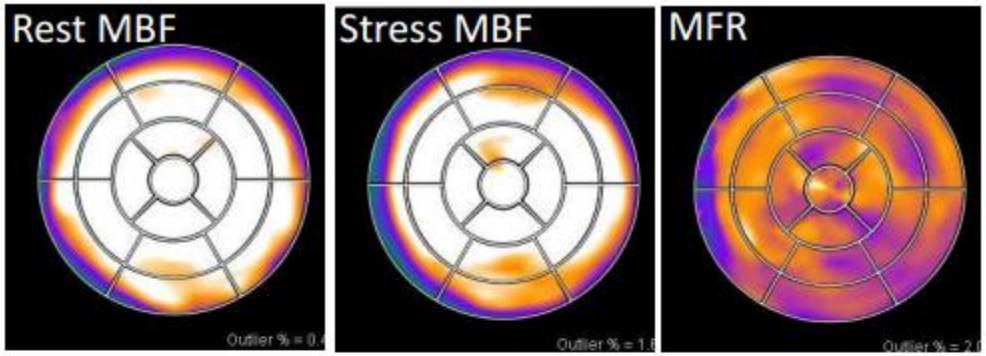
PET Applications

PET Applications
Cardiology

PET Myocardial Perfusion



True Myocardial Blood Flow

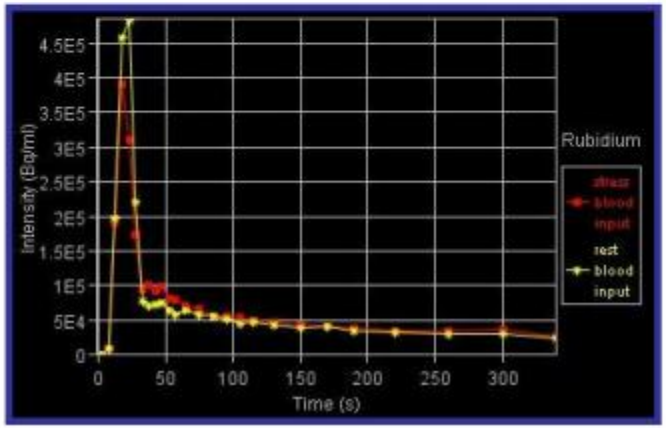


Myocardial Flow Reserve
=
Stress MBF / Rest MBF

Normal Ranges
Rest MBF: 0.6 – 1.3 ml/gm/min
Stress MBF: 1.2 – 3.3 ml/gm/min

"Normal" MFR: > 2.0
"Equivocal" MFR: 1.5 – 2.0
"Abnormal" MFR: < 1.5

	QMP (ml/g/min)				Reserve	
	Stress		Rest			
	mean	std dev	mean	std dev	mean	std dev
LAD	2.47	0.61	0.93	0.17	2.67	0.63
LCX	2.42	0.58	0.90	0.23	2.72	0.33
RCA	2.81	0.70	0.93	0.26	3.10	0.54
Global	2.53	0.64	0.92	0.21	2.79	0.57



Quality Assurance in Nuclear Medicine

Quality Assurance

- Quality Assurance:
  - *“all those planned and systematic actions necessary to provide adequate confidence that a product or service under consideration will satisfy given requirements for quality”*

Quality Assurance

- Regulation 32(3)-(4) of the IRR99 states:
  - *"every employer shall make arrangements for a suitable quality assurance programme to be provided in respect of the equipment or apparatus for the purpose of ensuring that it remains capable of restricting so far as is reasonably practicable exposure to the extent that this is compatible with the intended clinical purpose or research objective"*

Quality Assurance vs Quality Control

- Quality Assurance – all aspects of a procedure
  - staff training
  - testing of radiopharmaceuticals
  - assessment of equipment performance
  - reporting of clinical studies
- Quality Control (QC) – assessment, optimisation and maintenance of a particular aspect
  - performance of imaging equipment (e.g. gamma camera)

Radiopharmacy Quality Control

- Radionuclide Purity
  - ^{99}Mo 'breakthrough'
- Chemical Purity
  - Aluminium 'breakthrough'

} first eluate from each generator

- Radiochemical Purity
  - Free $^{99}Tc^{m}$ ($Na^{99}Tc^{m}O_4$)
    - Different bio-distribution
    - Unnecessary radiation of organs
    - Misdiagnosis

} First vial of new batch for commercial kits

- Sterility
  - Aseptic techniques
  - Routine monitoring for microbiological, particulate and radioactive contamination

Radiopharmacy Quality Control

- Radionuclide Purity
  - Radionuclide calibrator
- Chemical Purity
  - Aluminium ‘breakthrough’

} first eluate from each generator

- Radiochemical Purity
  - Free $^{99}Tc^{m}$ ($Na^{99}Tc^{m}O_4$)
    - Different bio-distribution
    - Unnecessary radiation of organs
    - Misdiagnosis

} First vial of new batch for commercial kits

- Sterility
  - Aseptic techniques
  - Routine monitoring for microbiological, particulate and radioactive contamination

Radiopharmacy Quality Control

- Radionuclide Purity
  - Must not exceed 0.1%
- Chemical Purity
  - Aluminium ‘breakthrough’

} first eluate from each generator

- Radiochemical Purity
  - Free $^{99}Tc^{m}$ ($Na^{99}Tc^{m}O_4$)
    - Different bio-distribution
    - Unnecessary radiation of organs
    - Misdiagnosis

} First vial of new batch for commercial kits

- Sterility
  - Aseptic techniques
  - Routine monitoring for microbiological, particulate and radioactive contamination

Radiopharmacy Quality Control

- Radionuclide Purity
  - Must not exceed 0.1%
- Chemical Purity
  - Colorimetry / test paper

} first eluate from each generator

- Radiochemical Purity
  - Free $^{99}Tc^{m}$ ($Na^{99}Tc^{m}O_4$)
    - Different bio-distribution
    - Unnecessary radiation of organs
    - Misdiagnosis

} First vial of new batch for commercial kits

- Sterility
  - Aseptic techniques
  - Routine monitoring for microbiological, particulate and radioactive contamination

Radiopharmacy Quality Control

- Radionuclide Purity
  - Must not exceed 0.1%
- Chemical Purity
  - Colorimetry / test paper

} first eluate from each generator

- Radiochemical Purity
  - Thin layer chromatography / test strip
    - Different bio-distribution
    - Unnecessary radiation of organs
    - Misdiagnosis

} First vial of new batch for commercial kits

- Sterility
  - Aseptic techniques
  - Routine monitoring for microbiological, particulate and radioactive contamination

Radionuclide Calibrator QC

- Daily Quality Control
  - Voltage test
  - Background test
  - Accuracy test
    - Long lived source (^{137}Cs)
  - Relative response
    - Source assayed using several radionuclide settings
- Periodic quality control
  - Linearity
  - Accuracy testing against NPL



Radionuclide Calibrator QC

- Daily Quality Control
  - Voltage test
  - Background test
  - Accuracy test
    - Long lived source ($\tau_{1/2}$=30 years)
  - Relative response
    - Source assayed using several radionuclide settings
- Periodic quality control
  - Linearity
  - Accuracy testing against NPL



Radionuclide Calibrator QC

- Daily Quality Control
  - Voltage test
  - Background test
  - Accuracy test
    - Long lived source (^{137}Cs)
  - Relative response
    - Source assayed using several radionuclide settings
- Periodic quality control
  - Linearity
  - Accuracy testing against NPL



Gamma Camera Quality Control

- Gamma camera – complex device
  - imaging characteristics may deteriorate gradually or
  - fail acutely
- Acute deterioration of performance
  - may become apparent during normal use
- Gradual deterioration of performance
  - unlikely to be evident from normal clinical use
  - **errors** in the interpretation of clinical images

Non-Uniformity Artefacts

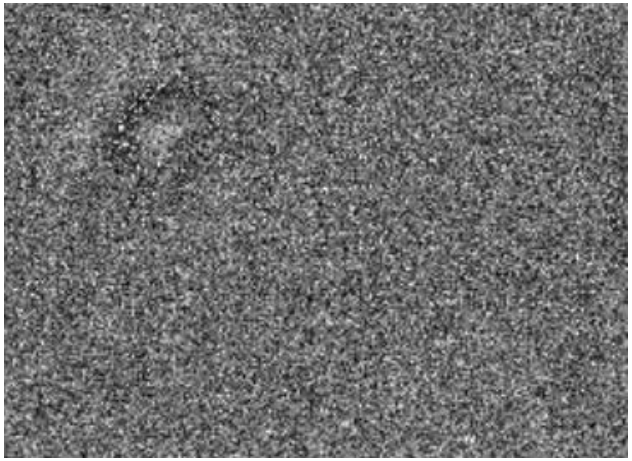
- Scintillation crystal cracked
  - due to mechanical shock
  - during collimator exchange
  - due to thermal shock
- Collimator damaged
  - due to mechanical shock during collimator exchange
  - due to possible mishandling





Non-Uniformity Artefacts

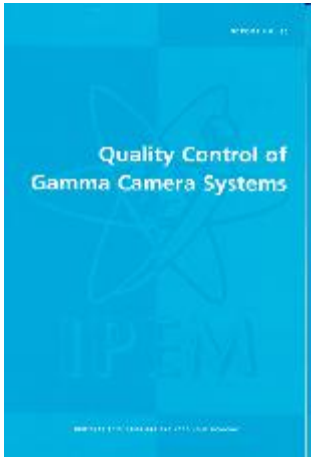
- All values within acceptance limits
- However… image shows a non-uniformity artefact



Parameter Name	Value	Acceptance Criteria
CFOV Integral Uniformity	1.502804373 %	<=3.0
CFOV X-Diff Uniformity	1.428145822 %	<=2.1
CFOV Y-Diff Uniformity	1.289800603 %	<=2.1
UFOV Integral Uniformity	1.502804373 %	<=3.6
UFOV X-Diff Uniformity	1.428145822 %	<=2.3
UFOV Y-Diff Uniformity	1.460370701 %	<=2.3

Gamma Camera Quality Control

- National Electrical Manufacturers Association: "*NEMA Standards Publication NU1-2001 Performance Measurements of Scintillation Cameras*"
  - contains instructions for how to perform and report gamma camera QC tests
  - contains guidelines for analysing the resulting data



- Institute of Physics and Engineering in Medicine Report 86: "*Quality Control of Gamma Camera Systems*"
  - contains the type and frequency of testing gamma cameras in planar and SPECT imaging

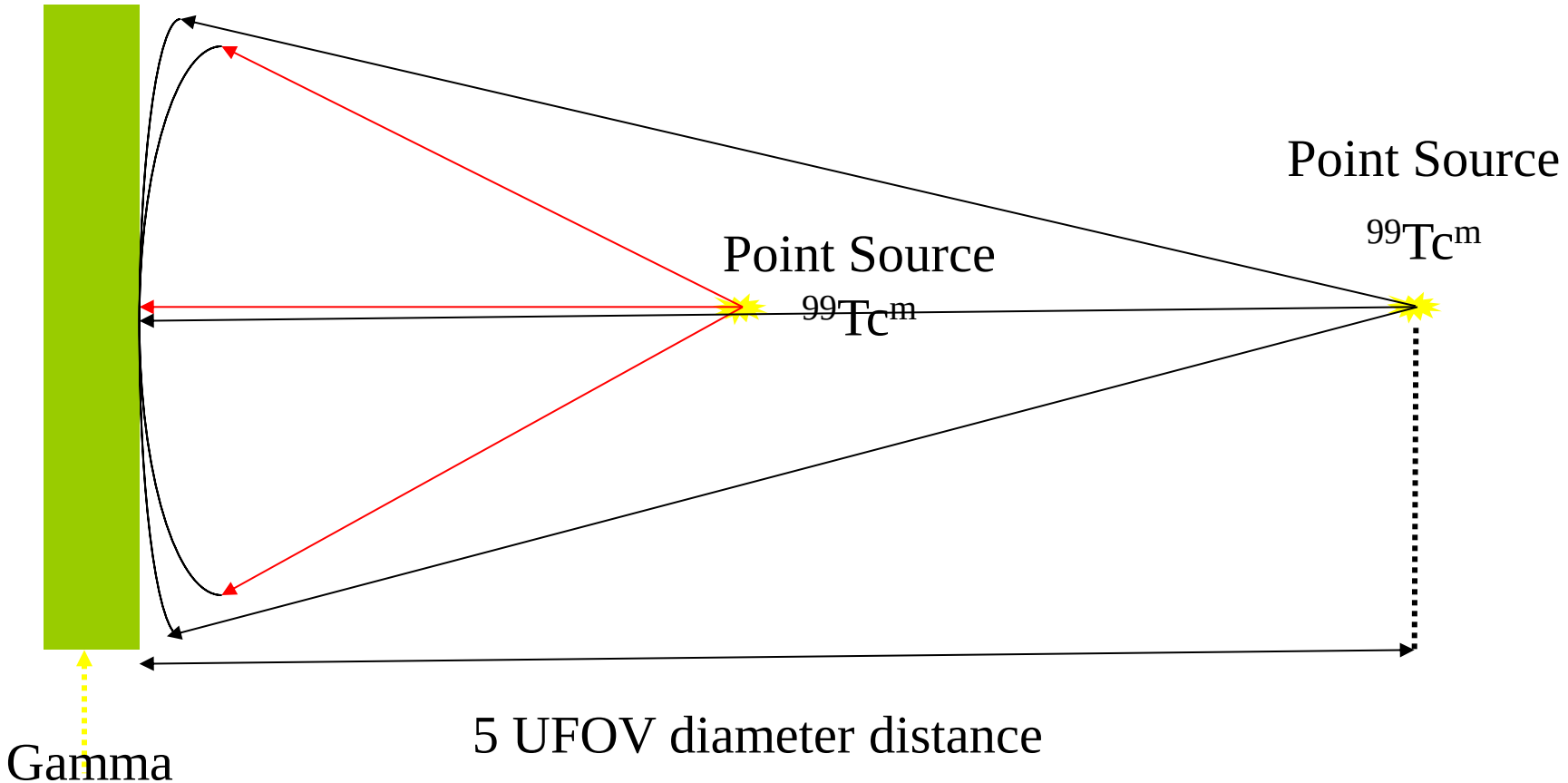
Gamma Camera Quality Control

- Purpose of quality control in Nuclear Medicine Imaging
  - to detect changes in performance which might degrade the accuracy of clinical images
  - to avoid image artefacts due to camera malfunction
- Factors contributing to final image quality
  - uniformity
  - resolution (spatial & energy)
  - centre of rotation (SPECT)
- The data is checked
  - visually
  - analysed to generate quantitative values characterising performance

Uniformity

- Most sensitive parameter to changes due to variations in
  - photopeak location
  - photomultiplier tube performance
  - energy and linearity correction
- Most important quality control test
  - should be performed daily
- Performed to
  - provide uniform image in response to a uniform flux of radiation
  - verify components are functioning properly

Intrinsic Uniformity [2]

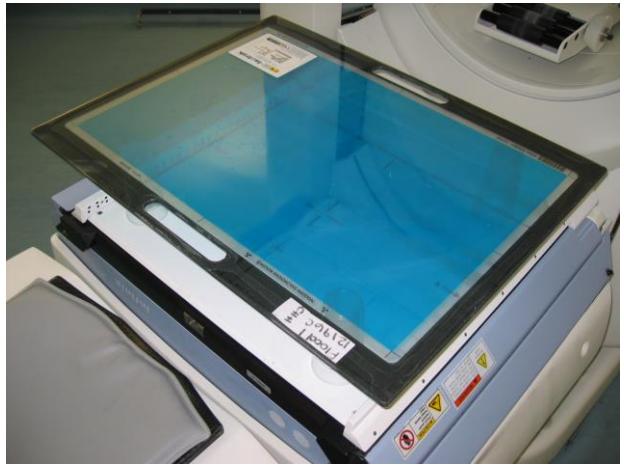


Intrinsic Uniformity

- *Advantages*
  - inexpensive technique
  - low radiation burden to users
  - system evaluated with the isotope that will be used for the majority of clinical studies
- *Disadvantages*
  - collimator not evaluated
  - time consuming to orientate the detector heads (on dual-headed systems)
  - increased risk of damage to the exposed crystal

Extrinsic Uniformity

- Measurement performed:
  - on a daily basis
  - generic assessment of uniformity
  - to check collimators for defects
- Extrinsic uniformity measurements performed:
  - using a ^{57}Co flood source
  - using a $^{99}Tc^{m}$ sheet source
  - acquiring 4,000,000 counts





Extrinsic Uniformity

- *Advantages*
  - collimator does not need to be removed
  - simultaneous acquisition for both detectors
  - reduced time
- *Disadvantages*
  - expensive
  - needs to be replaced every 1-2 years
  - high-energy contaminants
    - (i.e. ^{56}Co and ^{58}Co)

Centre of Rotation (C.O.R)

- Accurate C.O.R:
  - important for high quality SPECT
- Alignment between mechanical and electronic C.O.R essential
  - otherwise – ring artefacts & blurring
- Performed to maintain ability to resolve details in clinical SPECT studies
- Aims to quantify the lateral shift of the C.O.R

PET Quality Control

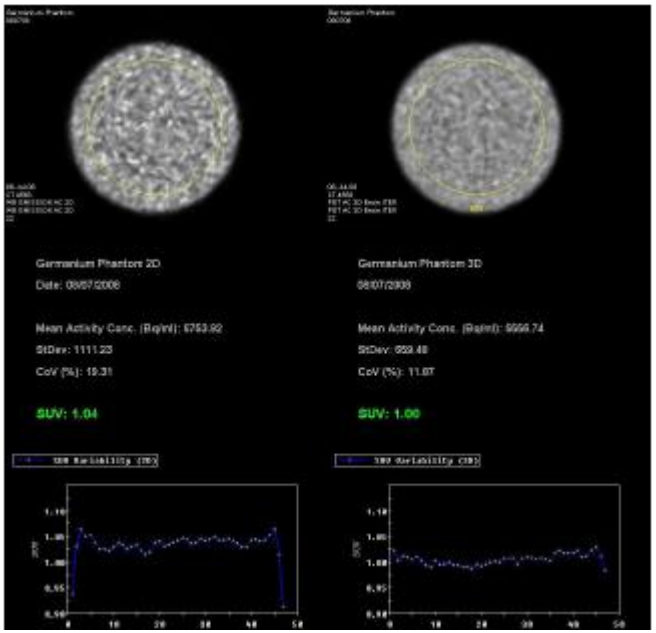
- Detector performance
  - aka blank scan or daily QC
- Provides
  - overall assessment of PET detector response
  - identifies electronic drift or faulty detectors
- ^{68}Ge uniform cylinder ($\tau_{1/2}$=271 days)
  - positioned/scanned at the centre of scanner's FOV
  - review for defective detectors



SUV Stability & Image Quality

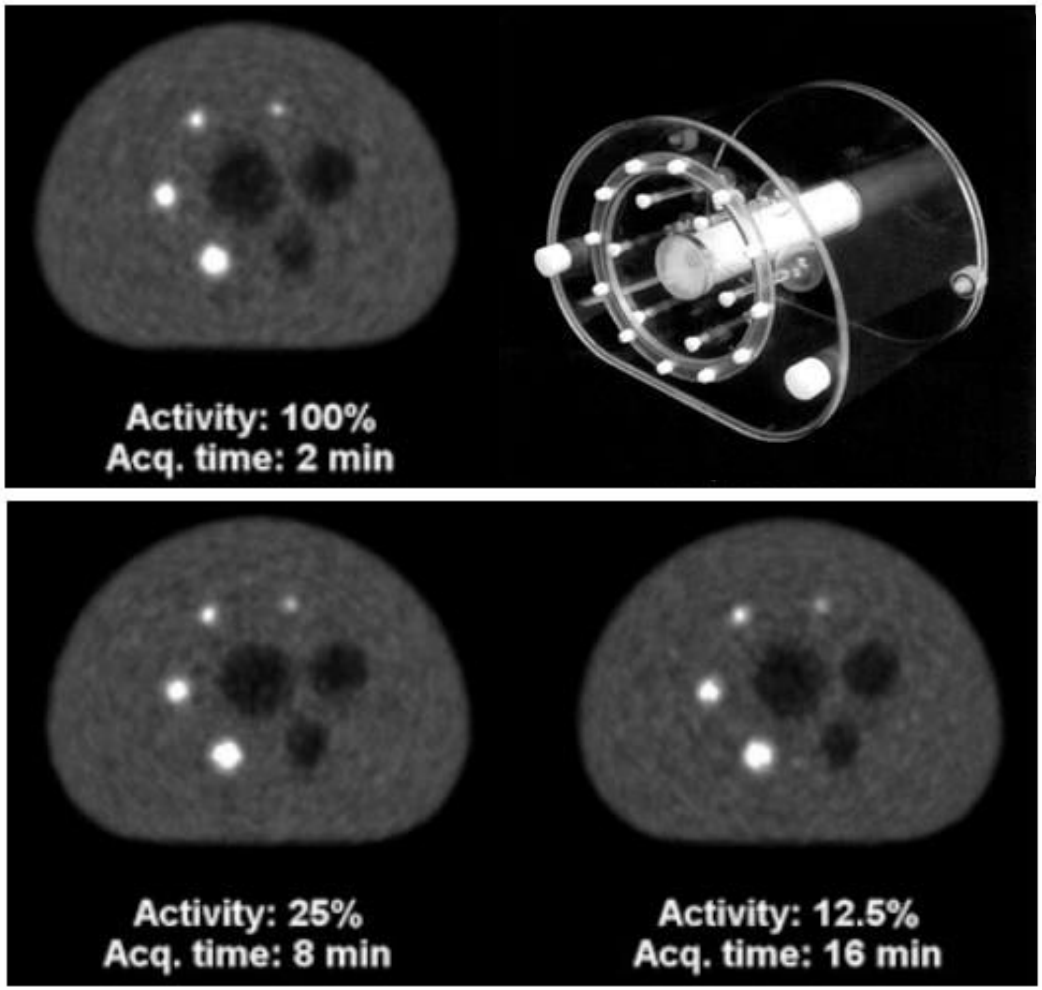
- SUV stability
  - ^{18}F of known activity
  - use uniform phantom
  - ensures correct quantitation





SUV Stability & Image Quality

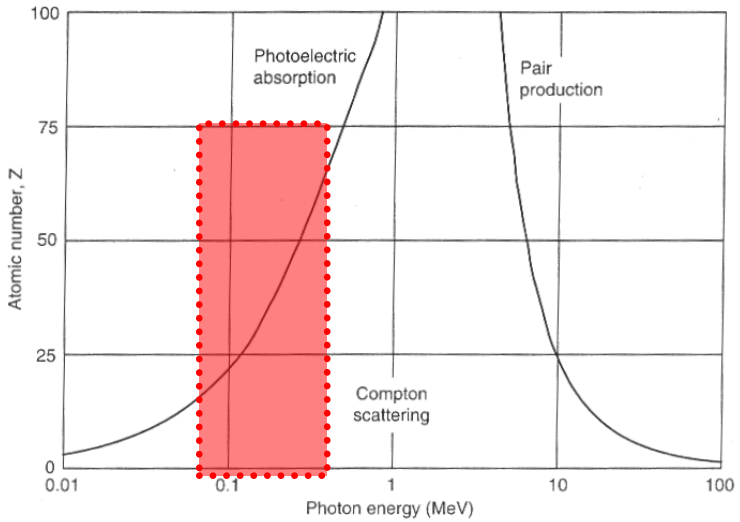
- SUV stability
  - ^{18}F of known activity
  - use uniform phantom
  - ensures correct quantitation
- Image quality
  - NEMA IQ phantom
  - assesses
    - contrast
    - noise



Radiation Detectors

Radiation Detectors

- Human senses unable to detect ionising radiation
  - reliance on devices to detect and quantify
- Detection of radiation is achieved via
  - ionisation in gases
  - Ionisation and excitation in certain solids/liquids
- Interaction mechanisms (Nuclear Medicine)
  - Photoelectric
  - Compton Scatter
- Typical isotopes
    - Tc^{99m} - 140keV
    - I^{123} - 159keV
    - In^{111} - 171 & 247keV
    - I^{131} - 363keV
    - F^{18} - 511keV



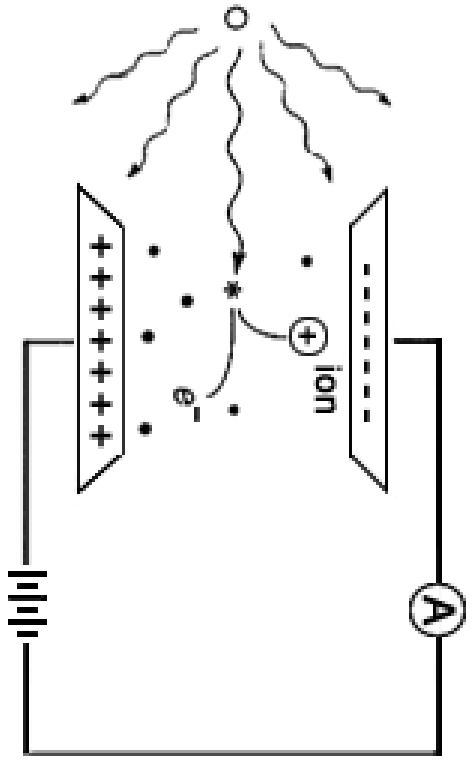
Detector Types

- Radiation detectors are classified by their material/detection method:
  - Gas detectors
    - Ionisation chamber
    - Proportional counter
    - Geiger-Muller (GM) counters
  - Scintillation detectors
    - Organic
    - Inorganic
  - Semiconductor detectors
  - … many others!



Gas-Filled Detectors

- Volume of gas between two electrodes
  - with voltage applied between electrodes
- Ion pairs produced
  - by incident radiation in the gas
- Positive ions (cations) are attracted
  - to the negative electrode (cathode
- Electrons (anions) are attracted
  - to the positive electrode (anode)
- Electrical **current** is measured
  - with electrometer

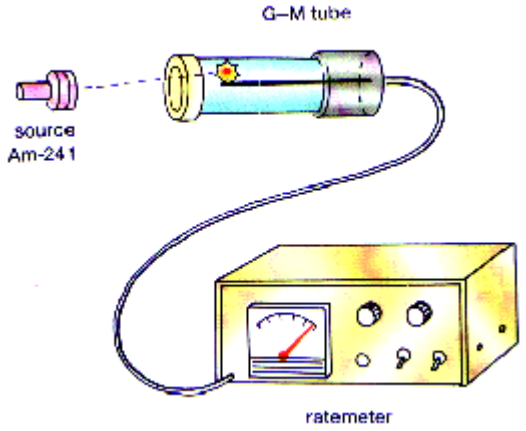


Hull and East Yorkshire Hospitals NHS Trust

Gas-Filled Detectors

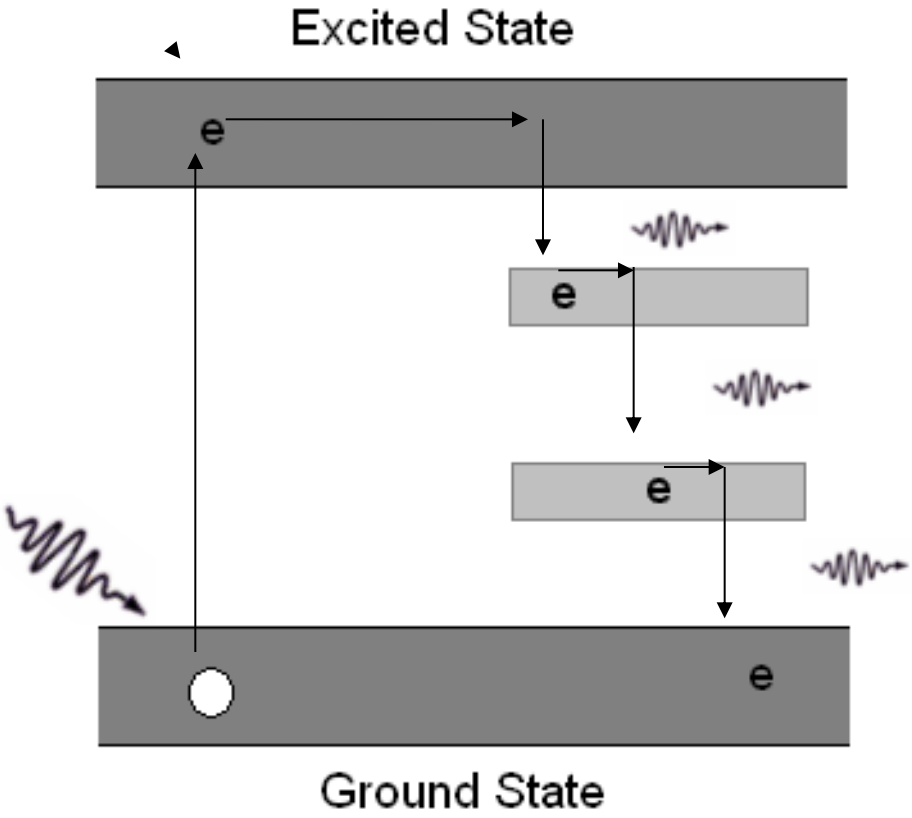
- Radionuclide calibrators
- Contamination monitors
  - large detection area
  - Filled with a noble gas (e.g. Xe, Ar)
  - detects β and γ radiation
- Geiger-Mueller Tube
  - small detection area
  - very sensitive
  - detects β and γ radiation



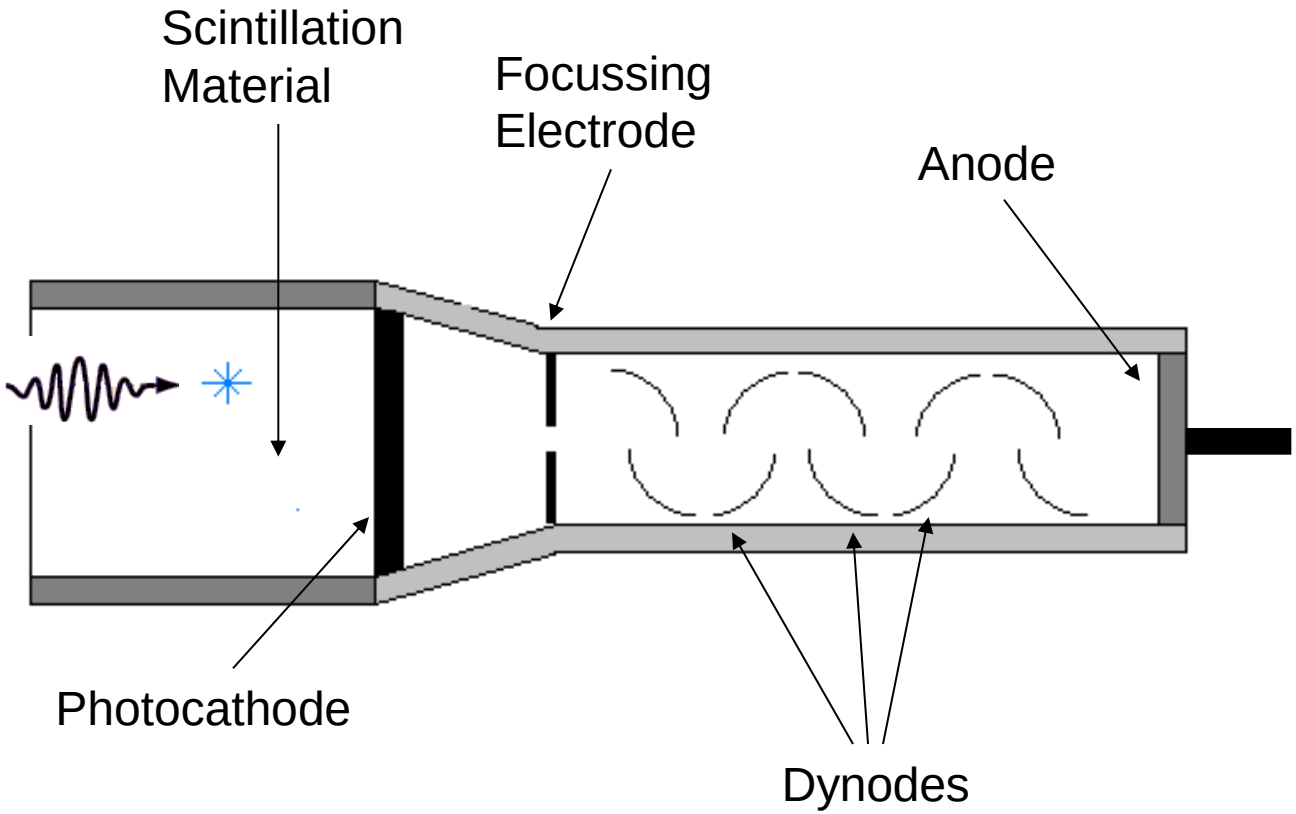


Scintillation Detectors

- Consist of
  - Scintillation crystal
  - Photomultiplier tube
  - Associated electronics
- Incoming radiation
  - Excites atoms of crystal
- Electrons
  - excited (excess energy)
  - release excess energy (photons)



Scintillation Detectors



Scintillation Detectors

- CoMo monitor
  - large area detector
  - plastic scintillator
  - can detect alphas



Scintillation Detectors

- CoMo monitor
  - large area detector
  - plastic scintillator
  - can detect alphas
- Sample counter
  - very sensitive
  - energy discrimination
  - assays blood samples



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  - localisation of nodes



Scintillation Detectors

- CoMo monitor
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  - can detect alphas
- Sample counter
  - very sensitive
  - energy discrimination
  - assays blood samples
- Sentinel node probes
  - localisation of nodes
- Gamma Camera
  - energy and positional discrimination



Radiation Dose

Radiation Dose

- Absorbed Dose (J/kg)
  - amount of energy deposited per unit mass (kg)
  - dose to an organ or tissue
  - unit is the Gray (Gy)
- DOSE TO A CERTAIN PLACE IN THE BODY

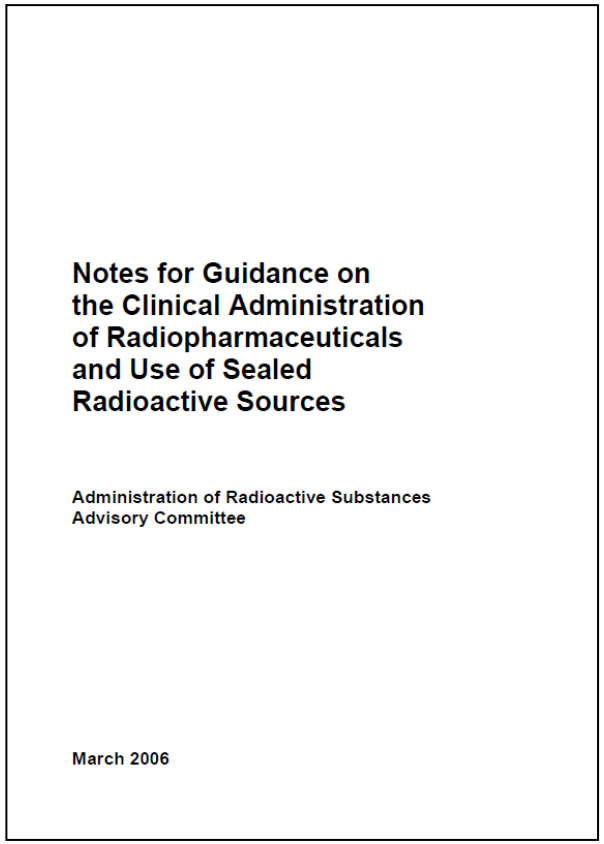


RADIATION ↓ TISSUE

- Effective Dose (J/kg)
  - Unit is the Sievert (Sv)
  - This gives us the risk of contracting cancer from the exposure
- THIS IS THE OVERALL DOSE TO THE WHOLE BODY

Factors Affecting Patient Dose

- Administered activity
  - Diagnostic Reference Levels (ARSAC)
- Effective Half-Life
- Biodistribution
  - Radiochemical/nuclidic purity
  - pathology
  - drugs
- Type of radioactive decay
- Energy of emissions



Patient Dosimetry

- Need to account for
  - tissue radiosensitivity
- Use ICRP weighting factors to determine
  - effective dose

Organ	ICRP
Gonads	0.08
Bone marrow (red)	0.12
Lung	0.12
Breast	0.12
Thyroid	0.04
Bone Surfaces	0.01
Remainder	0.12
Colon	0.12
Stomach	0.12
Bladder	0.04
Liver	0.04
Oesophagus	0.04
Skin	0.01
Salivary Glands	0.01
Brain	0.01

Radiopharmaceuticals and Doses

Radiopharmaceutical	Route	Typical Activity	Effective Dose (mSv)	Clinical Use
$^{99}Tc^{m}$-HDP	IV	600 MBq	3	Bone Imaging
$^{99}Tc^{m}$-MAG3	IV	100 MBq	0.7	Renal Imaging
^{201}Tl (thallous chloride)	IV	80 MBq	11	Myocardial Perfusion
^{123}I (sodium iodide)	Oral	400 MBq	5	Thyroid metastases
$^{99}Tc^{m}$-labelled red cells	IV	800 MBq	6	Cardiac blood pool
$^{99}Tc^{m}$-labelled white cells	IV	200 MBq	2	Localisation of infection

Radiation Protection in Nuclear Medicine

Protection of the Patient IR(ME)R

- Referral criteria
- Justification (ARSAC license holder)
- Patient identification procedures
- Labelling of syringes/vials
- Checking of activity prior to administration
- Thyroid blocking
- Conception, pregnancy, breast feeding

Protection of the Patient – MARS78

- ARSAC certification of
  - medical and dental practitioners
- Certificates
  - last for 5 years
  - specific to individual practitioner
  - specific to individual site
  - named radiopharmaceuticals and uses
- ARSAC Notes for Guidance

Pregnancy

- Departmental policy to check for pregnancy
  - in female patients of child bearing age
- Notices in departments
  - “Please inform technicians if you may be pregnant”
- Does the risk to the patient from failure to diagnose and treat outweigh the radiation risk to the foetus?
  - Clinical benefit to the mother may be of indirect benefit to the unborn child

Conception: Advice to Males

- Diagnostic administrations:
  - no evidence that pre-conceptual irradiation of males can cause any abnormality in their offspring (Doll R et al)
  - no need to avoid conception for males undergoing routine diagnostic studies
- Therapeutic administrations:
  - possible appearance of larger quantities of such radionuclides in sperm
  - avoid conception for 4 months

Conception: Advice to Females

- Diagnostic radiopharmaceuticals ($\tau_{1/2} < 7$ days)
  - No need to avoid pregnancy (ARSAC Notes for Guidance)
- Diagnostic uses of longer lived radiopharmaceuticals
  - ^{131}I-MIBG (tumour imaging): 2 months
  - ^{131}I (thyroid metastases): 6 months
- Therapy
  - ^{131}I (≤800 MBq thyrotoxicosis therapy): 6 months
  - ^{32}P (≤200 MBq polycythemia therapy): 3 months
  - ^{89}Sr (≤150 MBq bone metastases therapy): 24 months

Breast Feeding

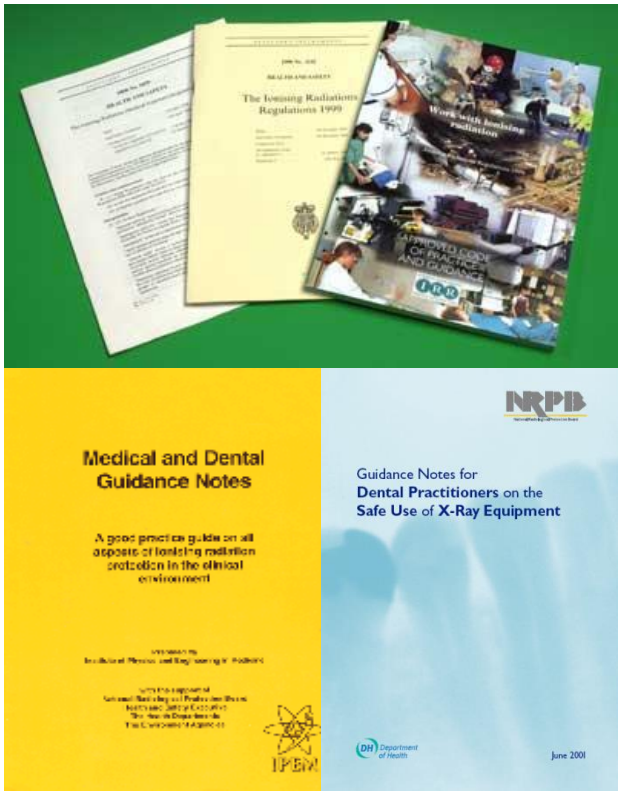
- Can the test be delayed?
- Mother to express breast milk prior to test
- Advise to stop breast feeding for time depending upon radiopharmaceutical
  - Any quantity of I131-iodide: STOP
  - 3 MBq of ^{32}P-phosphate: STOP
  - 80 MBq $^{99}Tc^{m}$-MAA: 12 hours
  - 800 MBq $^{99}Tc^{m}$-pertechnetate: 48 hours

Protection of Staff and MoP – IRR99

- Time, Distance, Shielding
  - handling techniques to reduce time
  - forceps
  - syringe Shields
- Contamination
  - surfaces in rooms to be smooth and non-absorbent
  - isolators
  - protective clothing
  - no eating/drinking in rooms where unsealed sources used
  - wash hand basins close to exit of rooms
  - routine contamination monitoring
  - room surfaces and staff leaving controlled areas

Statutory and Non-Statutory Guidance

- Health & Safety Executive
  - IRR99 - Approved code of Practice
  - Work with ionising radiations
- IPEM
  - Medical & Dental Guidance Notes



Principles of Radiation Protection

- ALARP – ***A***s ***L***ow ***A***s ***R***easonably ***P***racticable
  - Staff doses should be maintained ALARP
- Prior risk assessments
- Optimisation of protection in working areas
- Delineation of areas (controlled/supervised)
  - Avoidance of accidental entry

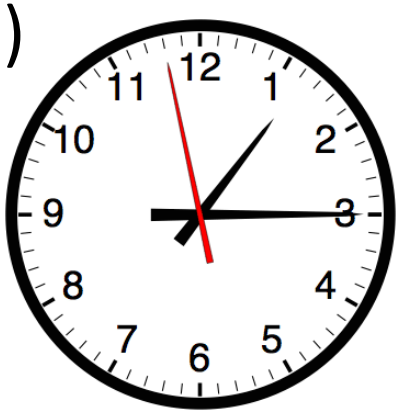
Principles of Radiation Protection

- Classification of radiation workers
- Information and training of staff
- Monitoring of exposures
- Monitoring of working environment



Radiation Protection of Staff

- ***Time***
  - Proximity of uptake rooms, toilets, scanner
  - Patient-free areas and access for staff
  - Working procedures (local rules)
  - Training
  - Automation

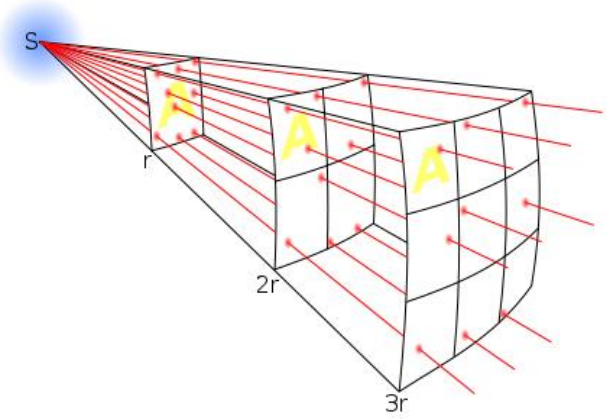


Radiation Protection of Staff

- ***Time (continued)***
  - Prepare every process very carefully and perform all tasks as swiftly as possible
  - Examine, explain, answer questions ***BEFORE*** injection
  - Spend only as long as necessary with patients
  - Staff rotation

Radiation Protection of Staff

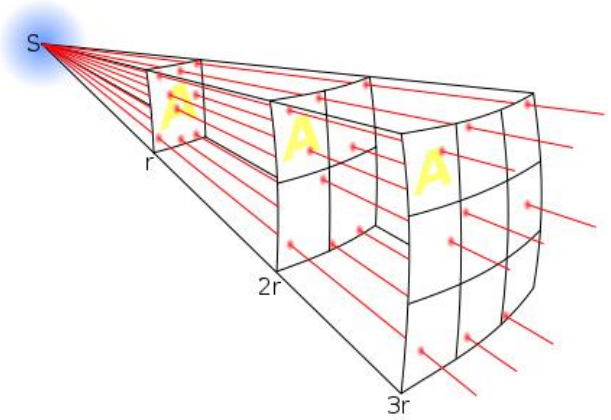
- ***Distance***



  - make use of $1/r^2$ law
  - avoid staying beside patient unnecessarily
  - use intercom to communicate with patient
  - direct patients rather than escort them

Radiation Protection of Staff

- ***Distance (continued)***



  - use remote viewing
  - use long tongs (remote handling tools)
  - draw-up with spinal needles
  - use trolley to carry doses

Radiation Protection of Staff

- ***Shielding***
  - Rest area more active than scanner area
  - Vial and syringe shields
  - Shielding for waste and other active items
  - Lead glass windows on cameras
  - Lead mobile screens for positrons and γ-rays

Radiation Protection *from* Patients

- No restrictions for diagnostic procedures
  - Exceptions:
    - > 10MBq ^{111}In-white blood cell studies
    - > 120MBq ^{111}In-octreotide
    - > 200MBq ^{67}Ga-citrate,
    - > 30MBq ^{131}I
    - > 150MBq ^{201}Tl-thallous chloride
    - > 800MBq ^{99}Tc^{m} myocardial perfusion agents
    - Assessment of exposure and contamination risk



- Routine restrictions for therapeutic administrations
  - Contamination – hygiene procedures
  - External irradiation - close-contact restrictions

Procedures in Wards

- Contamination
  - ward staff will be protected if they follow standard hygiene procedures (e.g. gloves/aprons)
  - handling & storage instructions should bedding/clothing become contaminated
- External irradiation
  - no special precautions usually required
  - risk assessment if patient requires intensive nursing

Keeping & Disposal of Radioactive Substances



- EPR certificates for
  - use of radioactive materials
  - storage/disposal of radioactive materials
- Properly designed stores
- Stock Records
- Reports to be sent to the Environment Agency
  - solid waste for incineration
  - solid waste to landfill
  - aqueous waste to drains

Transport of Radioactive Materials

- Controlled under
  - Carriage of Dangerous Goods 2009 Regulations
- Staff involved
  - must be trained
- Vehicles
  - need to be marked
  - have emergency kits and instructions

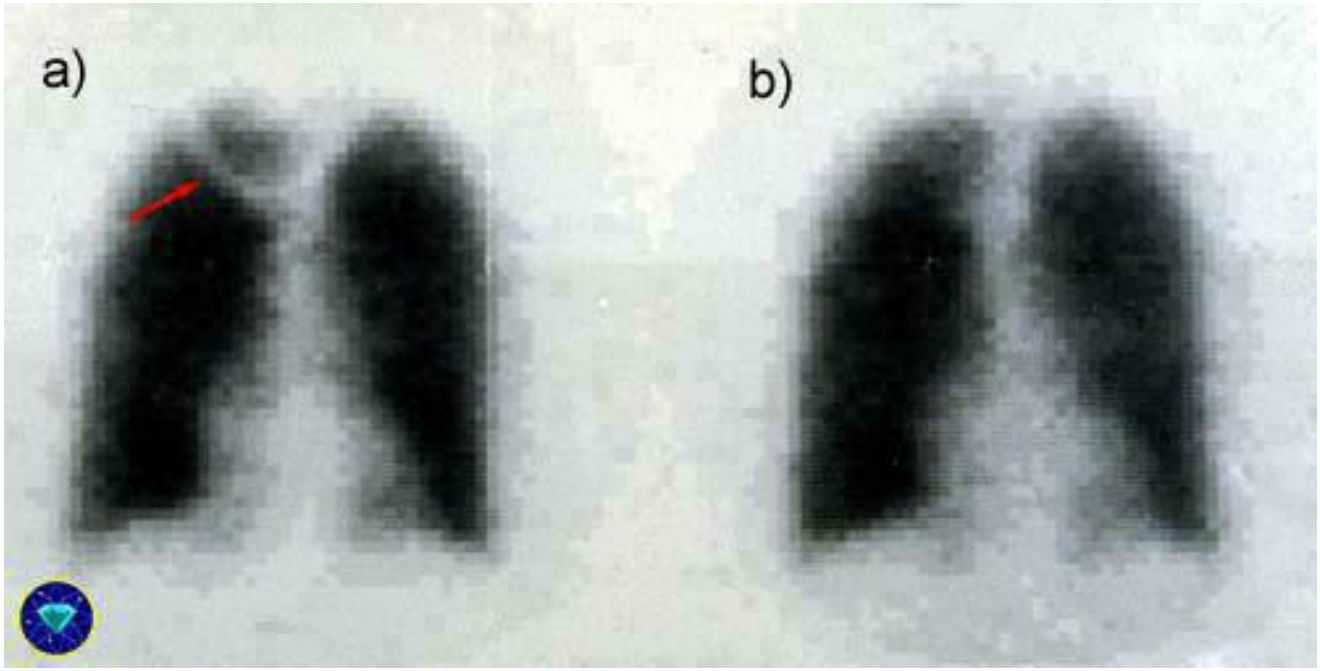


Artefacts in Nuclear Medicine

Artefact

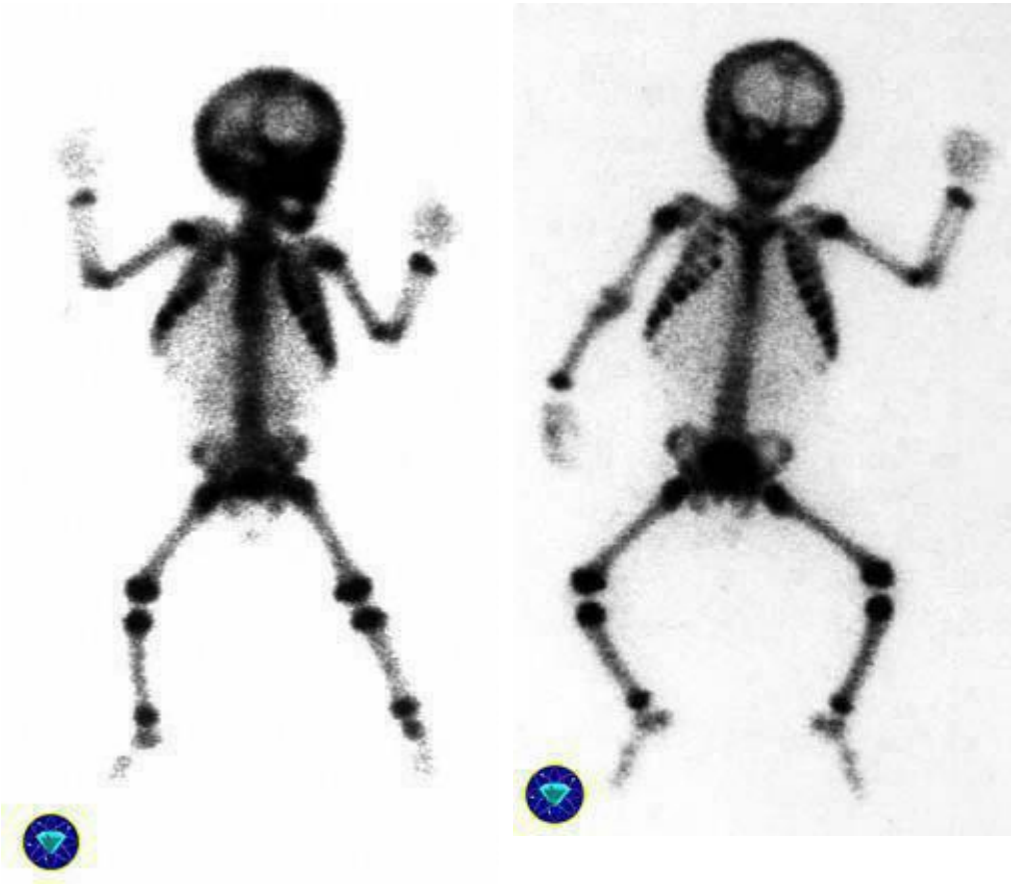
- A structure that is not naturally present
  - introduced during preparation or investigation
- Need for constant vigilance
  - before and during scanning

Artefact 1



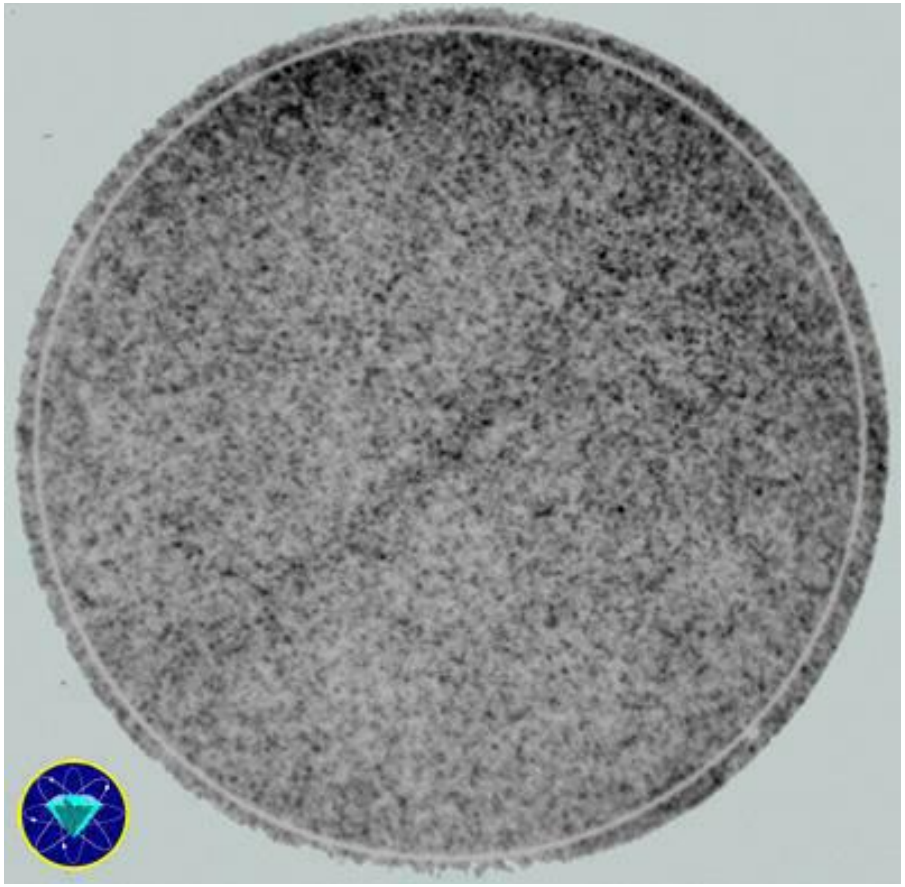
Lungs with a) metal chain round the neck
b) after it has been removed.

Artefact 2



- “Wrong” collimator
- General purpose
- High resolution

Artefact 3



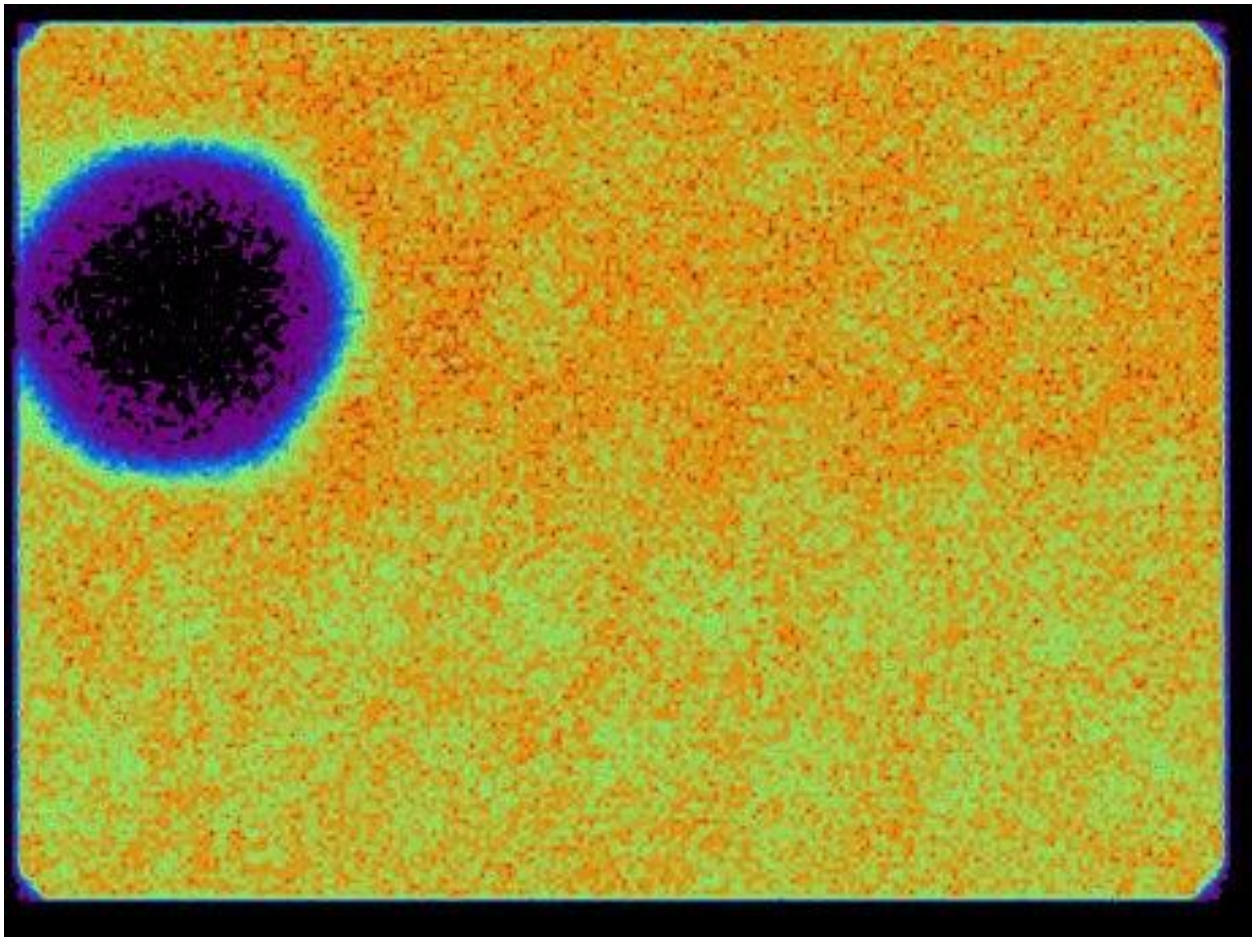
- Crack in crystal
  - the window was left open overnight!

Artefact 4



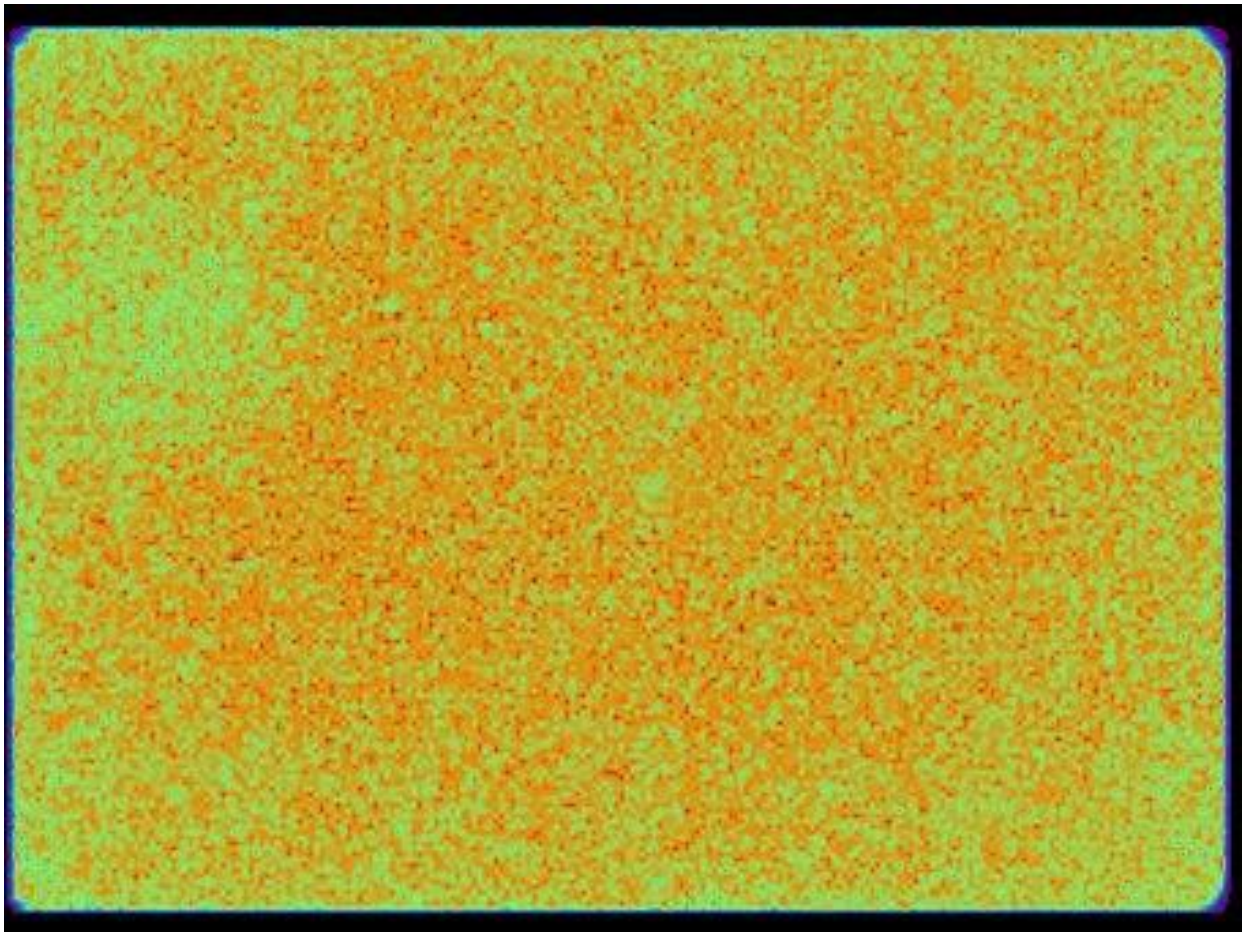
Patient wearing belt

Artefact 5



Photomultiplier tube not working

Artefact 6



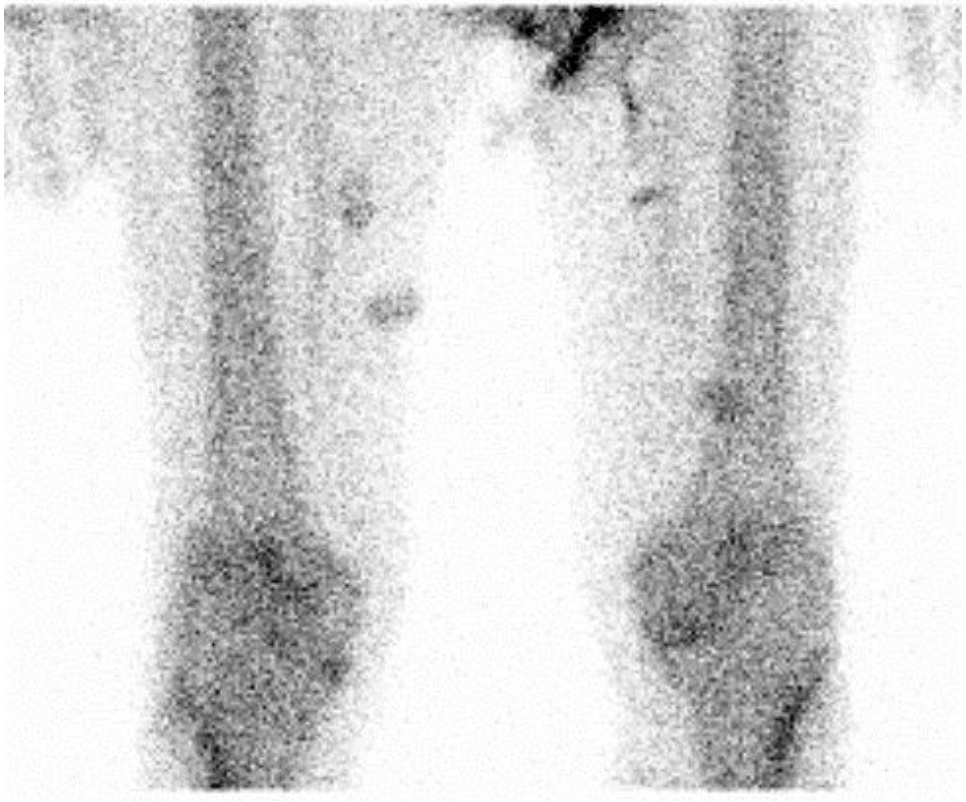
Non-uniformity artefact

Artefact 7



Patient with leg catheter

Artefact 8



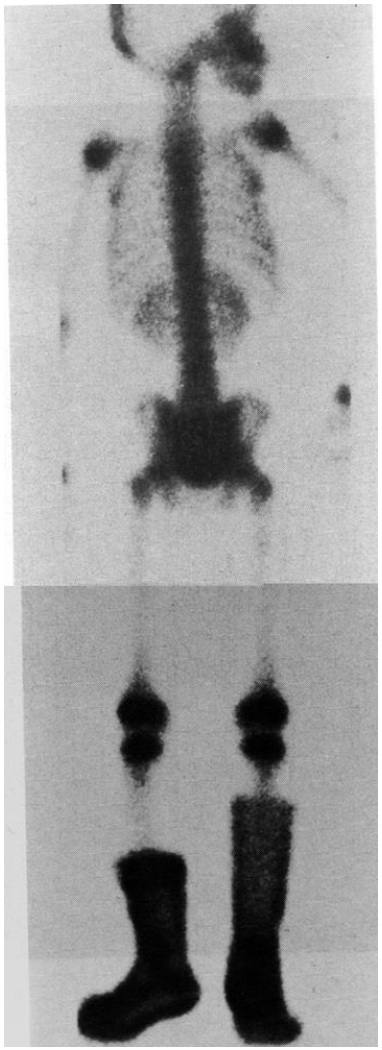
Urinary contamination

Artefact 9



- Extravasation
  - Can obscure joints
  - Always administer on opposing side to suspected joints
  - Always use a venflon or butterfly
  - Radiation necrosis in therapy doses

Artefact 10



- Contamination
  - Imaging for metastases from Ca prostate
  - Urine “spillage” onto floor
  - Patient mopped up spill with only available absorbent material

End of Part 2: Thank you for listening

