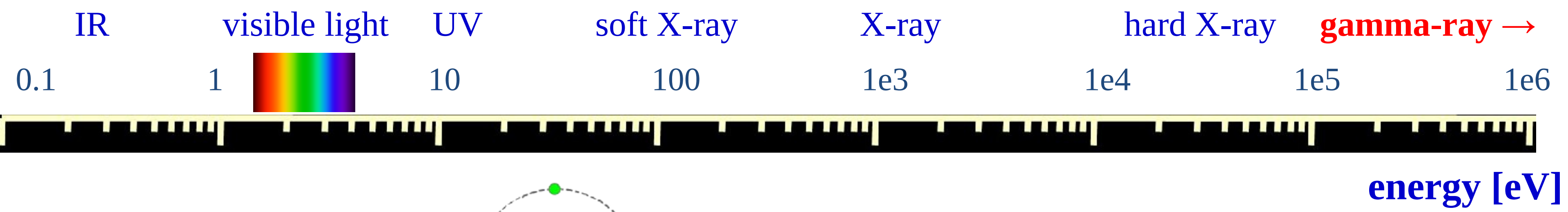
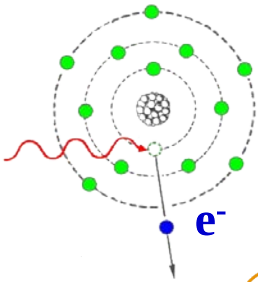
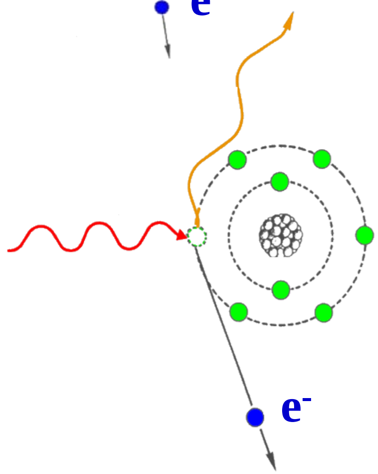
Frontier of gamma-ray spectroscopy

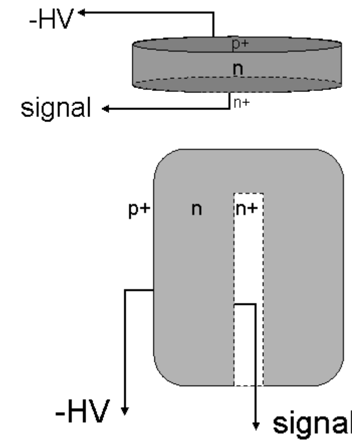


Photoelectric effect



Compton scattering



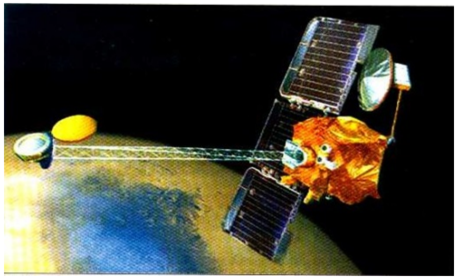


Germanium
semi-conductor detectors

Why imaging gamma-rays?

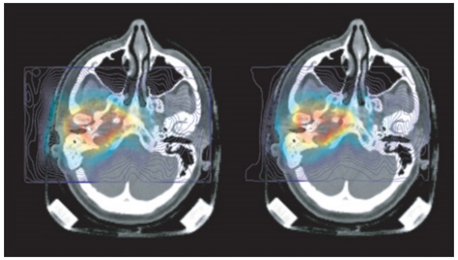
- **High energy astrophysics**

Correlate the detected photon to source object as known from more precise observations in other wavelength



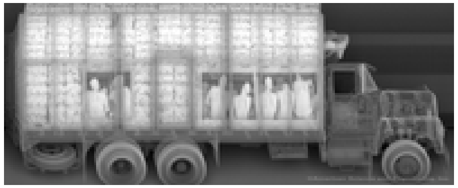
- **Biomedical research**

Precise localization of radioactive tracers in the body
Cancer diagnosis
Molecular targeted radiation therapy
Monitor changes in the tracer distribution → dynamic studies



- **National security**

Nuclear non-proliferation / nuclear counter terrorism
Contraband detection
Stockpile stewardship
Nuclear waste monitoring and management



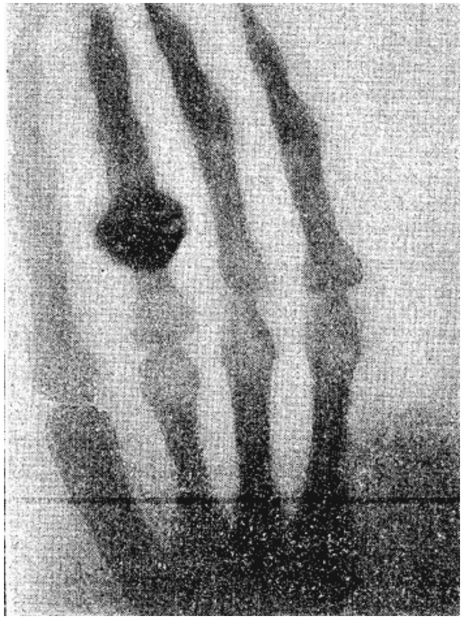
- **Industrial non-destructive assessments**

Determination of the material density distribution between the source and detector

Application of Nuclear Physics

❖ First X-ray image by Wilhelm Conrad Roentgen (1895)

Standard X-ray imaging



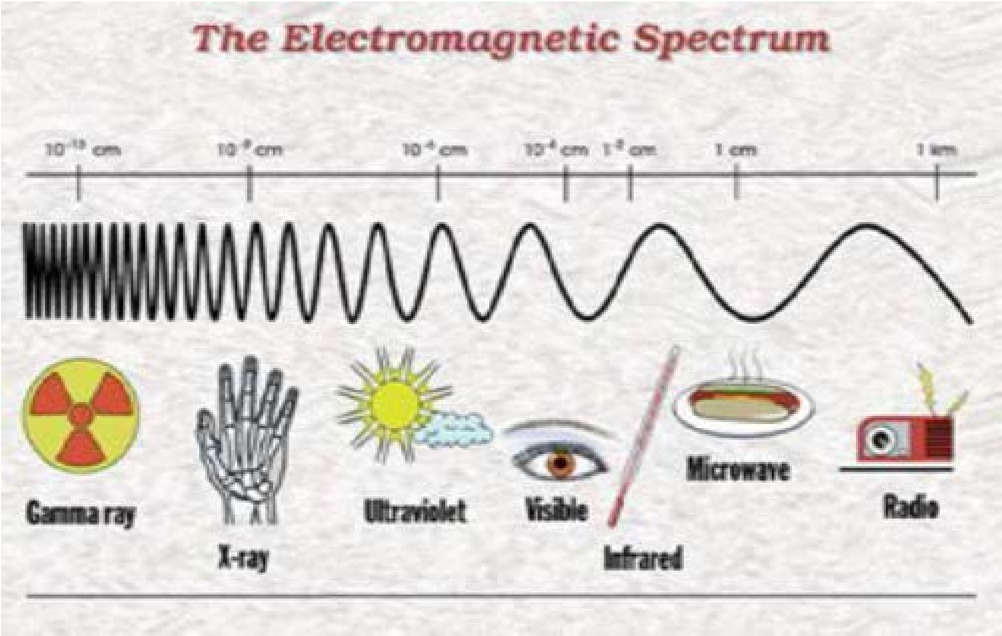
Absorption of X-rays by bones and transmission through soft tissue produces image

- What if we want a 3D image?
- What if we want detailed information on organs, bones and muscles etc?

Nobel Prize 1901

Tomographic Imaging

PET



SPEC

CT

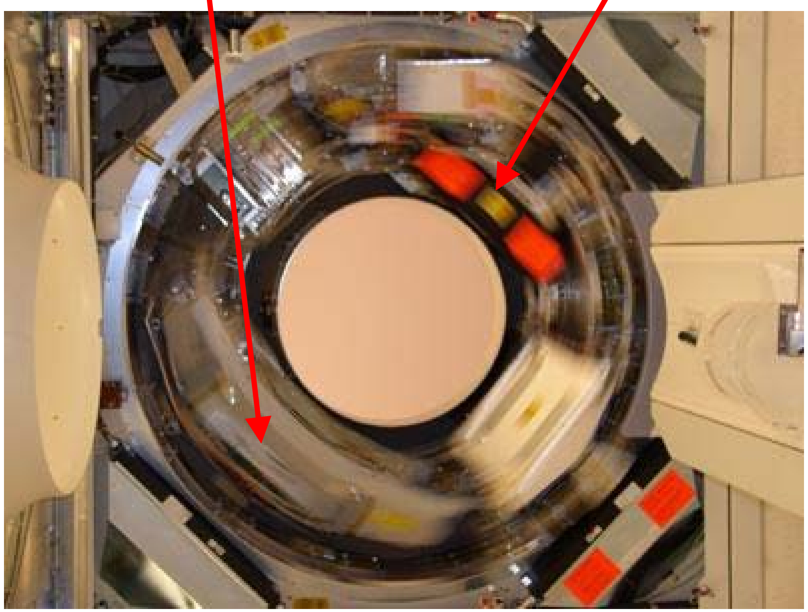
OPTICAL

MRI

Computed Tomography

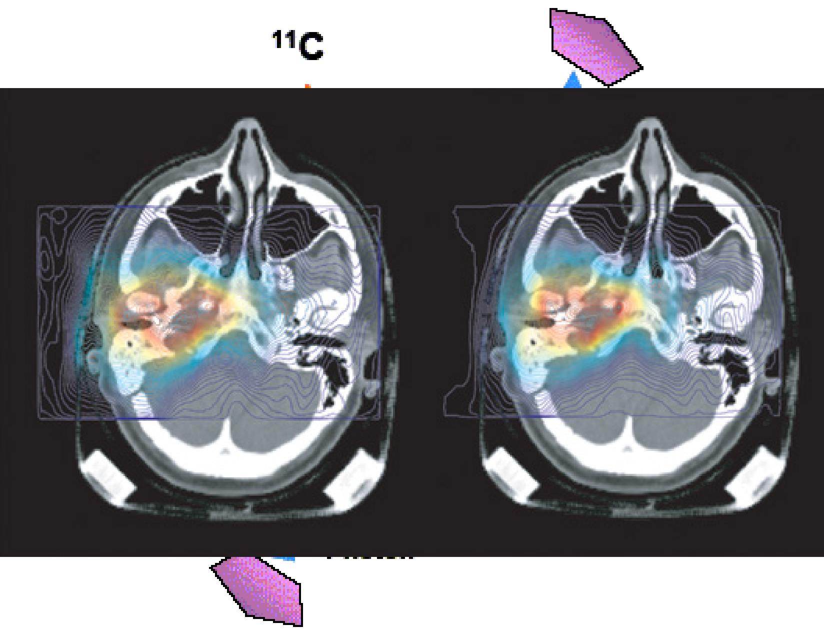
- CT scanning (originally known as CAT)
- X-rays taken at a range of angles around the patient
- Generation of 3D images

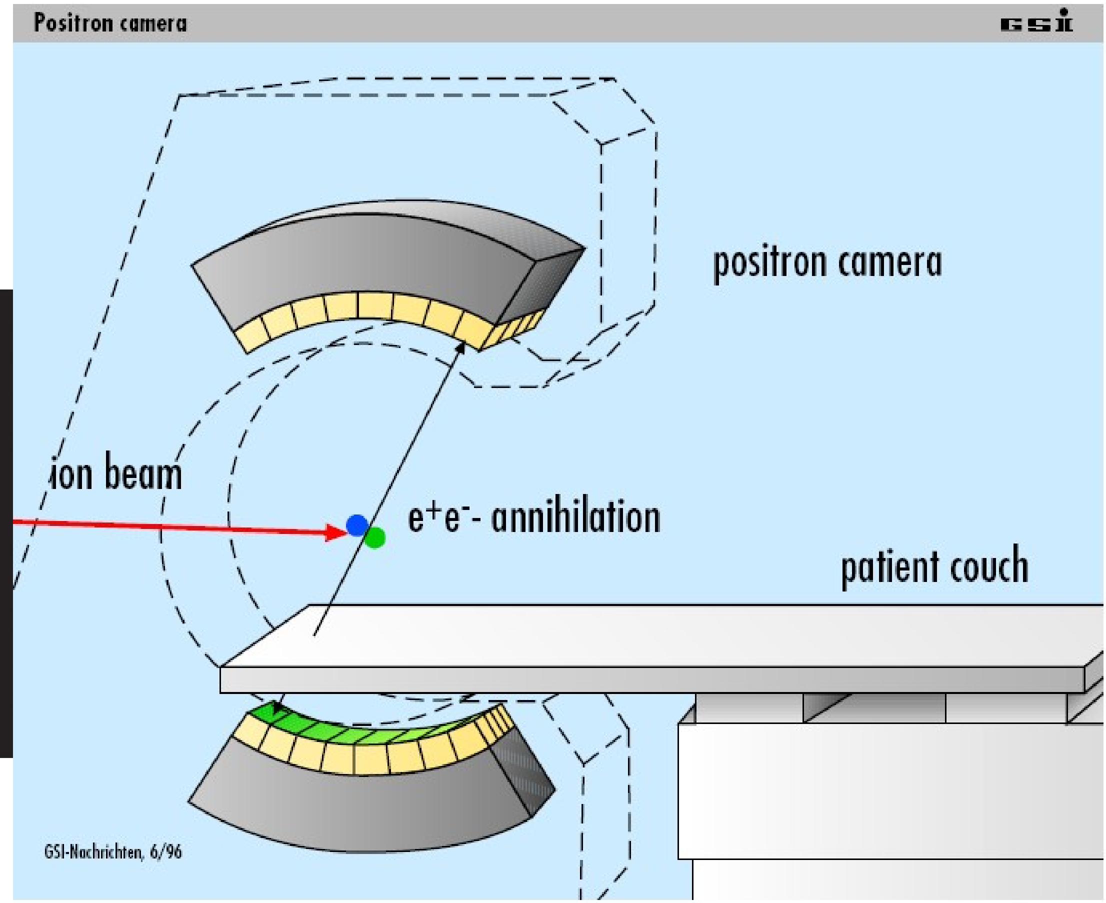
Radiation detector X-ray source



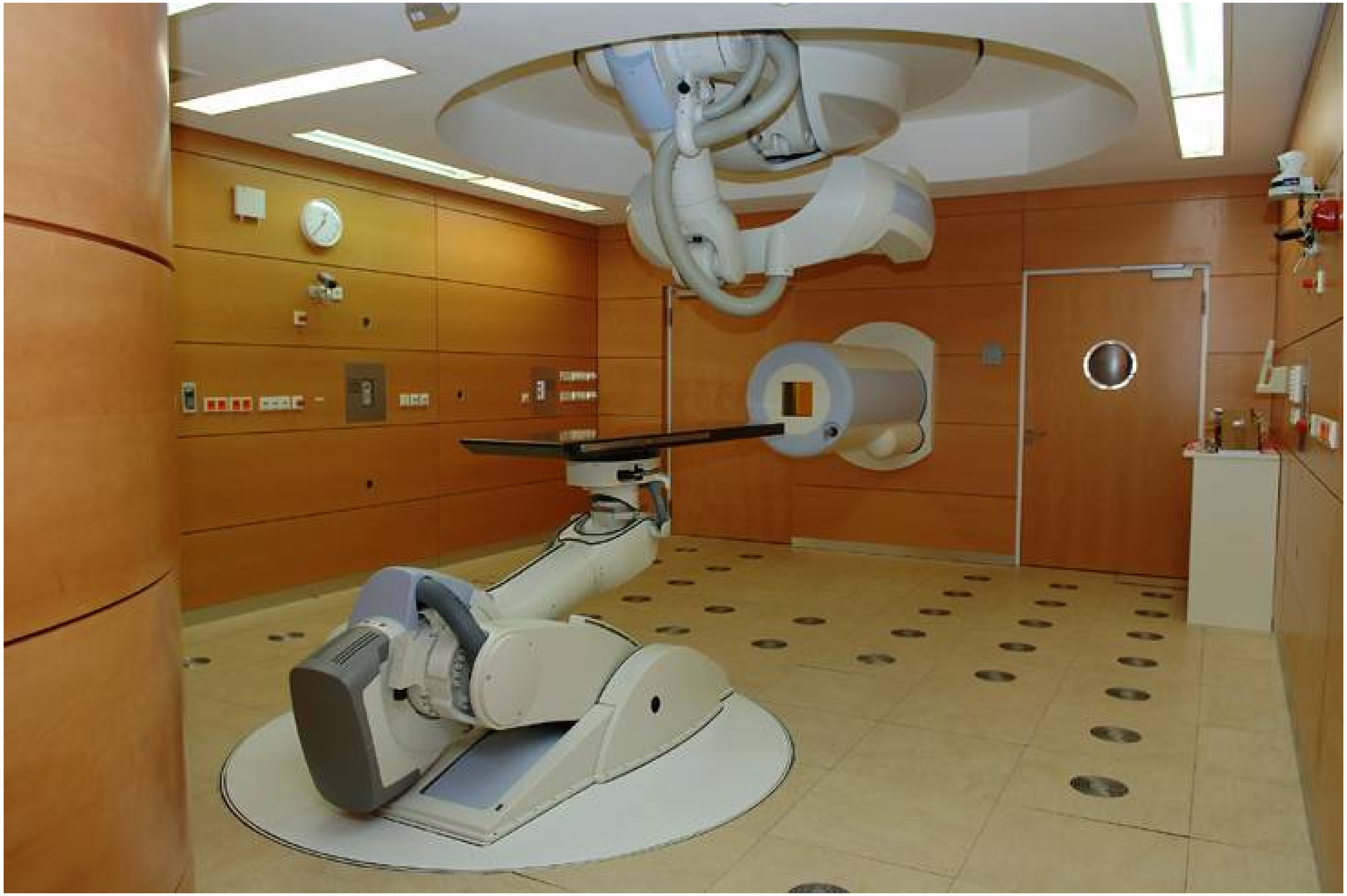
Standard CT-system

Positron Emission Tomography

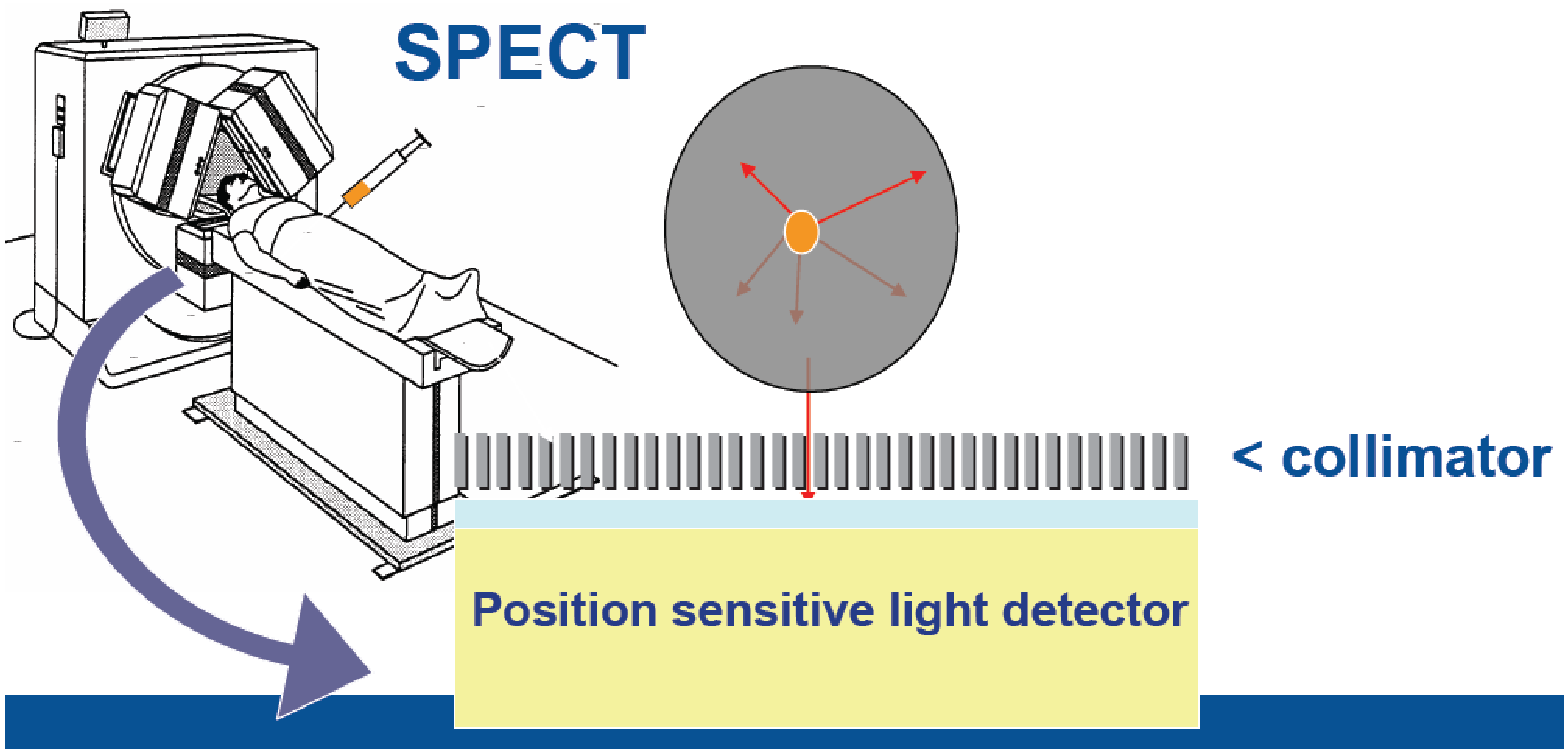




Positron emission tomography

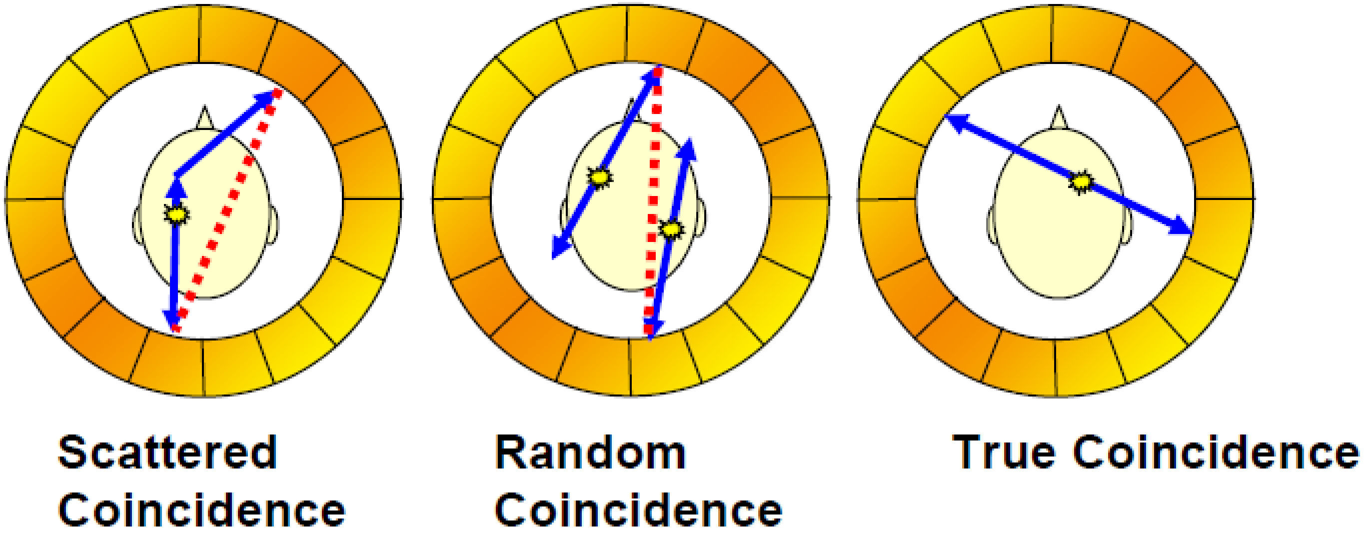


Single Photon Emission Computed Tomography



- Most commonly used tracer in SPECT is $^{99}Tc^{m}$, 140 keV a pure single photon emitter $T_{1/2}$ = 6.02 h.
- Utilizes a gamma-ray camera rotated in small ~3^0 steps around the patient.

The motivation behind the project



- Existing technology relies on BGO scintillator technology

  - Limited position resolution
  - High patient dose requirement.
  - Poor energy resolution only accept photopeak events.
  - Will not function in large magnetic field

- SPECT applications utilizing Compton Camera techniques.

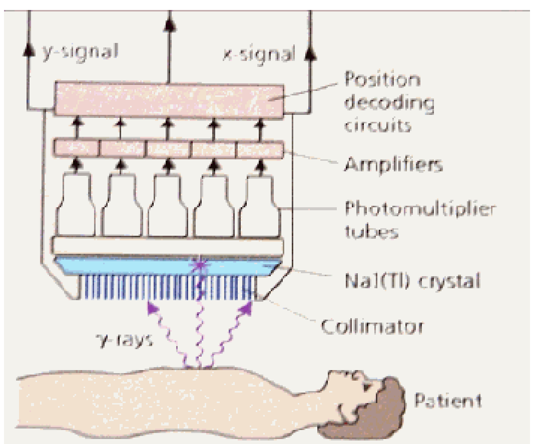
Which γ-ray camera to be used?

Requirements:

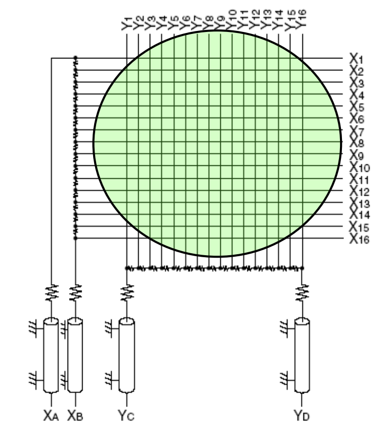
- Excellent resolution $\Delta x = 2$ mm
- Large field of view (**FOV**) = 8x9 cm^2

- Large FOV of ~20 cm diam.
- Low spatial resolution 0.5-1 cm

www.siemens.de



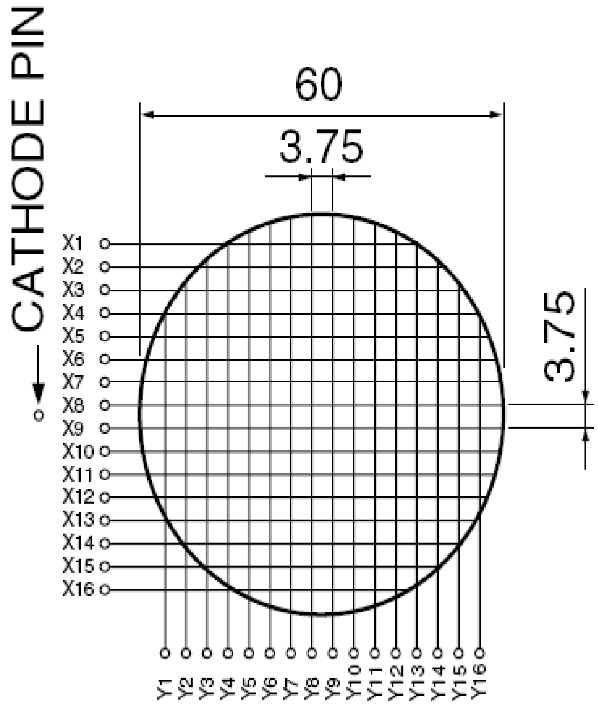
- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm



Gem-imaging.com

Gamma Camera: Individual multi-anode readout

16 wires in X axis and 16 wires in Y axis



ANODE PATTERN
(TOP VIEW)

C.Domingo Pardo, N. Goel, et.al., IEEE, Vol.28, Dec. 2009

LYSO

scintillator

d = 76 mm

t = 3 mm

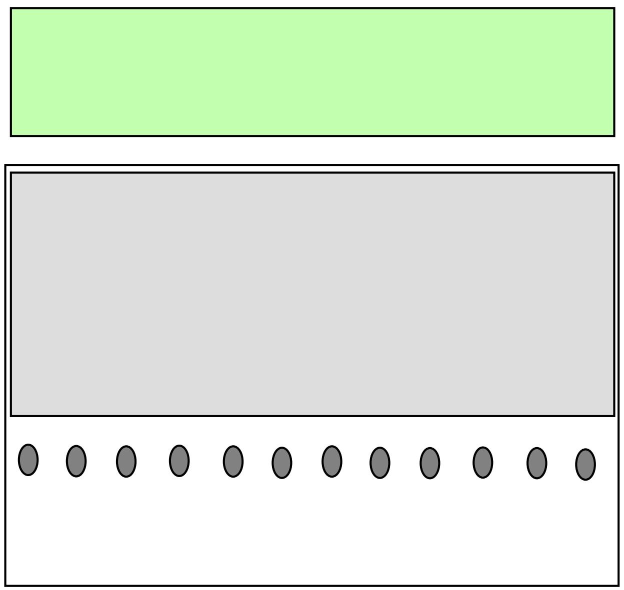
ρ = 7.4 g/cm^3

Hamamatsu R2486 PSPMT

Which γ-ray camera to be used?

Requirements:

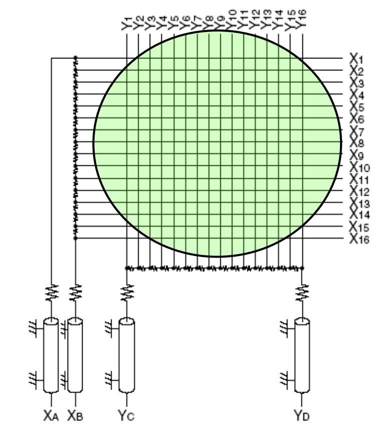
- Excellent resolution Δx = 2 mm
- Large field of view (FOV) = 8x9 cm^2



Scintillator

Position Sensitive PMT

- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm

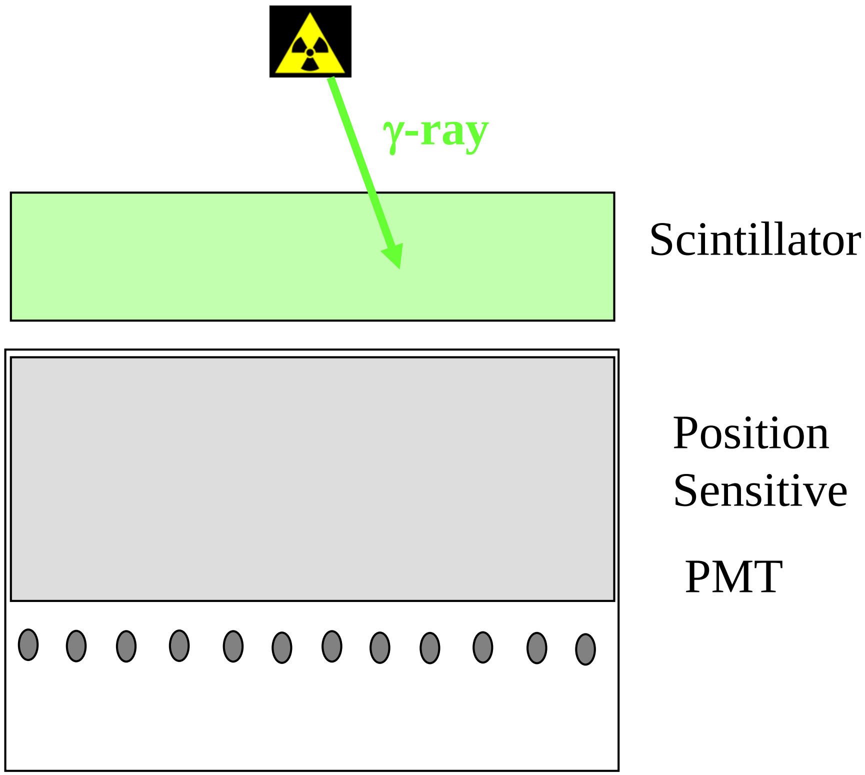


Gem-imaging.com

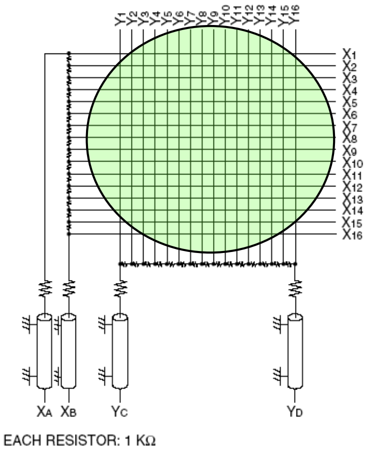
Which γ-ray camera to be used?

Requirements:

- Excellent resolution $\Delta x = 2$ mm
- Large field of view (FOV) = 8x9 cm^2



- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm

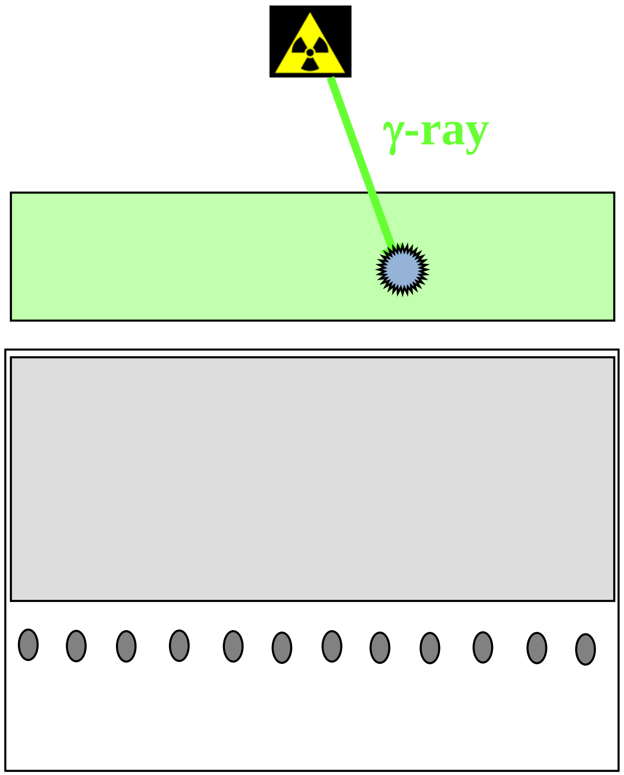


Gem-imaging.com

Which γ-ray camera to be used?

Requirements:

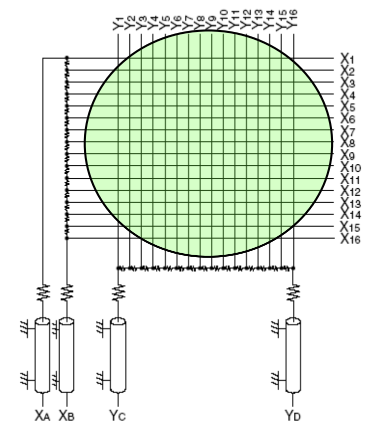
- Excellent resolution Δx = 2 mm
- Large field of view (FOV) = 8x9 cm²



Scintillator

Position Sensitive PMT

- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm

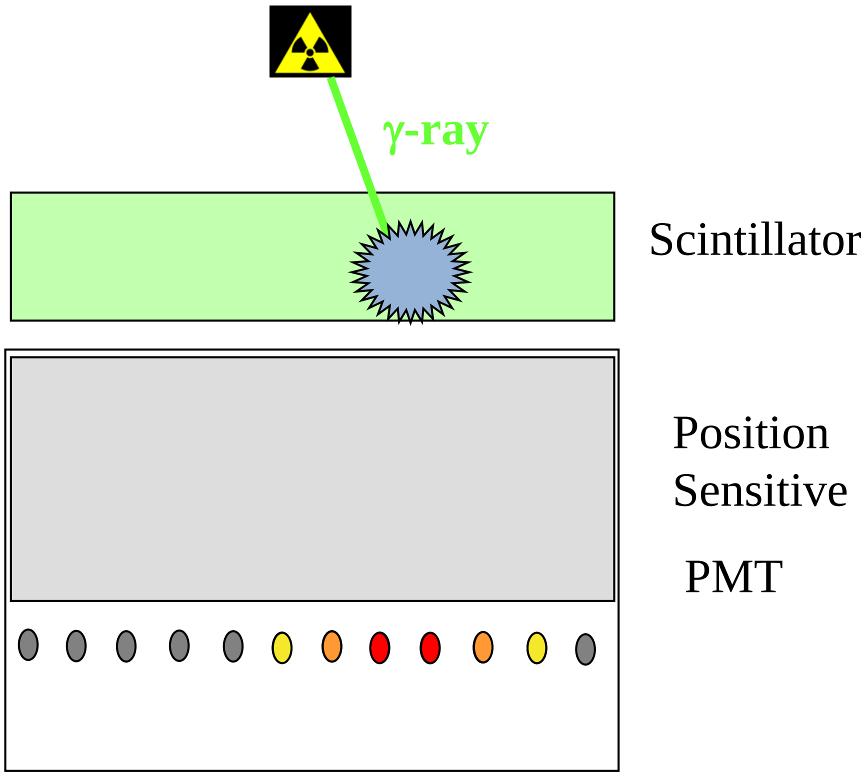


Gem-imaging.com

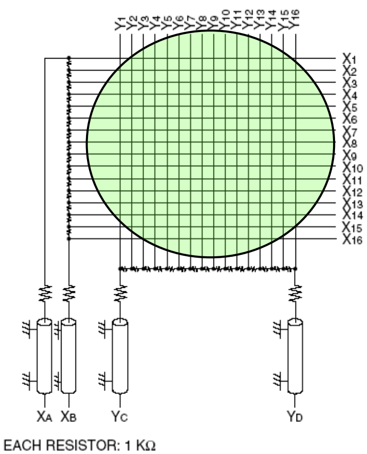
Which γ-ray camera to be used?

Requirements:

- Excellent resolution Δx = 2 mm
- Large field of view (FOV) = 8x9 cm^2



- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm

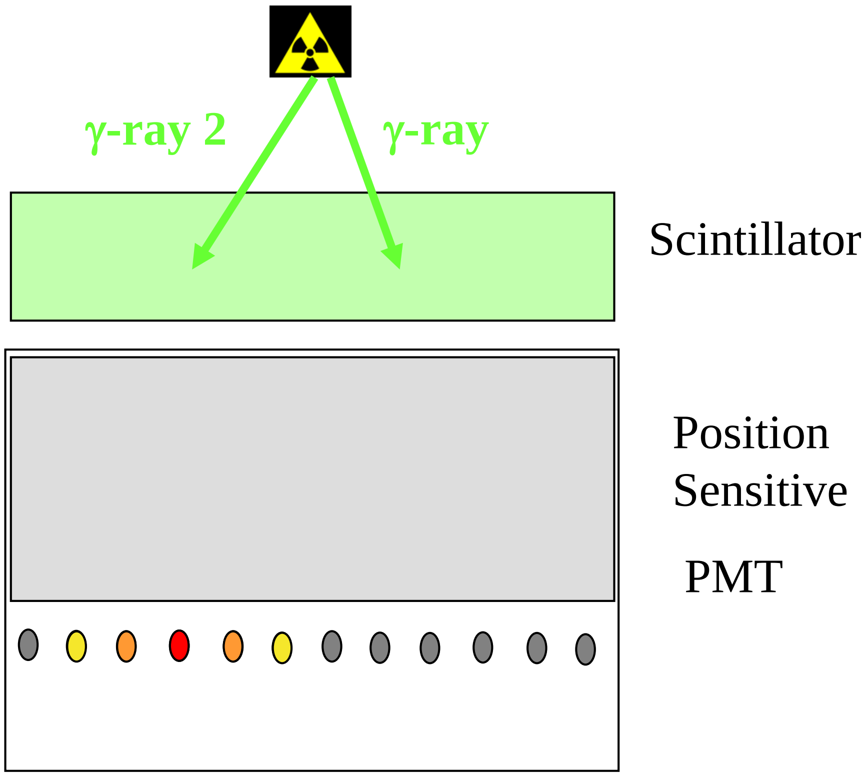


Gem-imaging.com

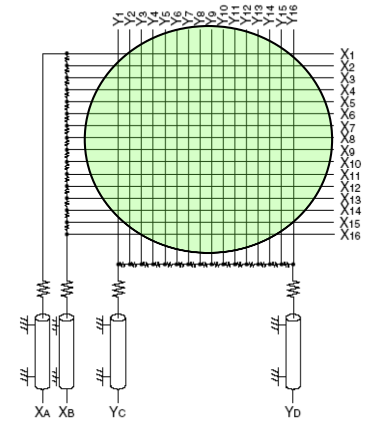
Which γ-ray camera to be used?

Requirements:

- Excellent resolution Δx = 2 mm
- Large field of view (FOV) = 8x9 cm^2

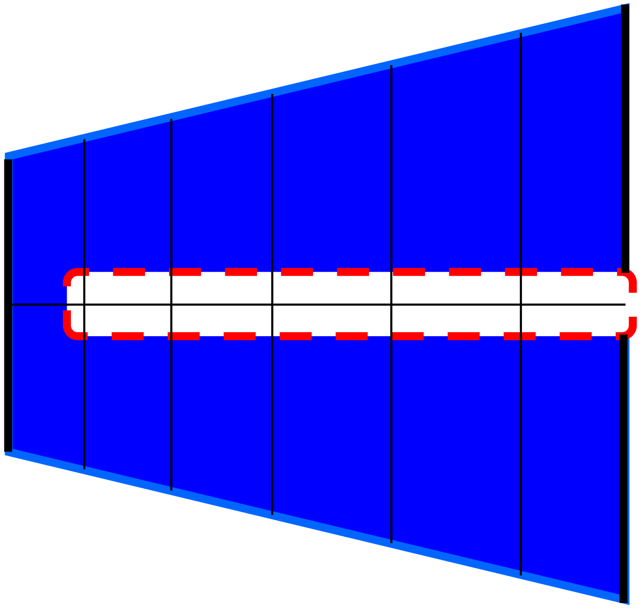


- Small FOV of 3-4 cm diam.
- High spatial resolution 2-3 mm

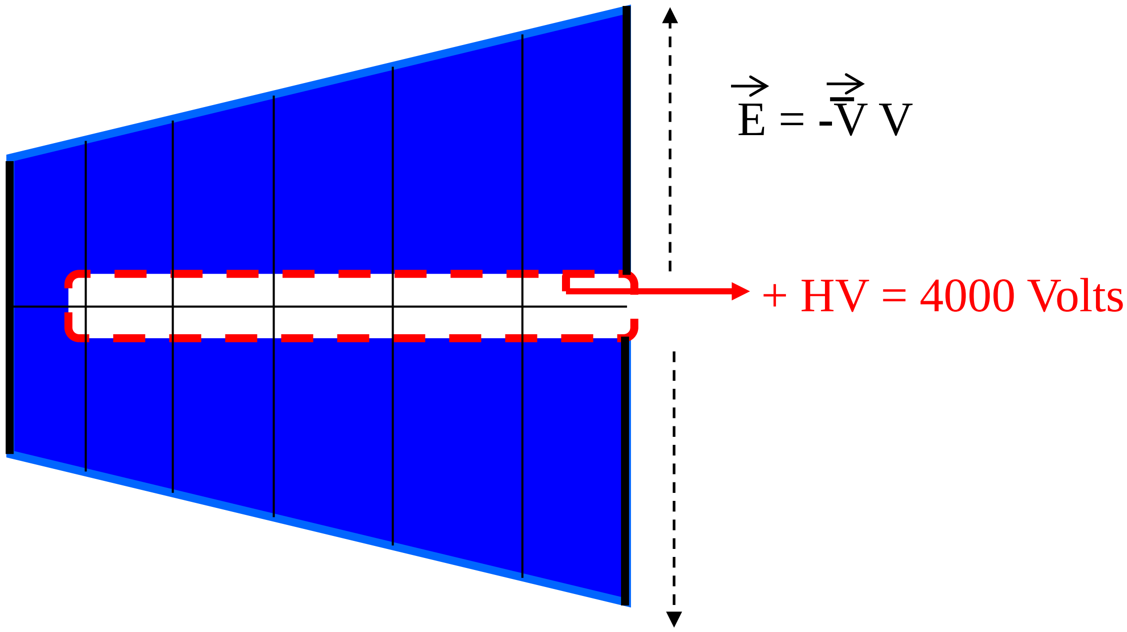


Gem-imaging.com

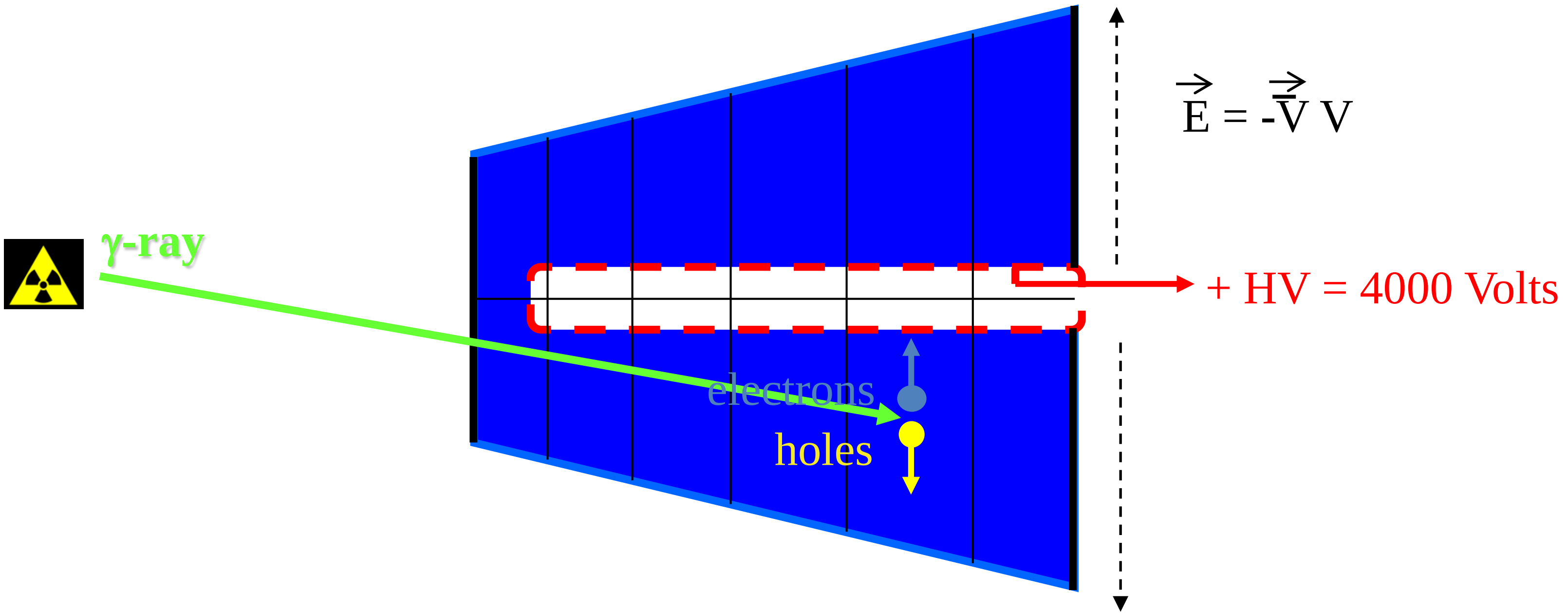
HPGe detector – working principle



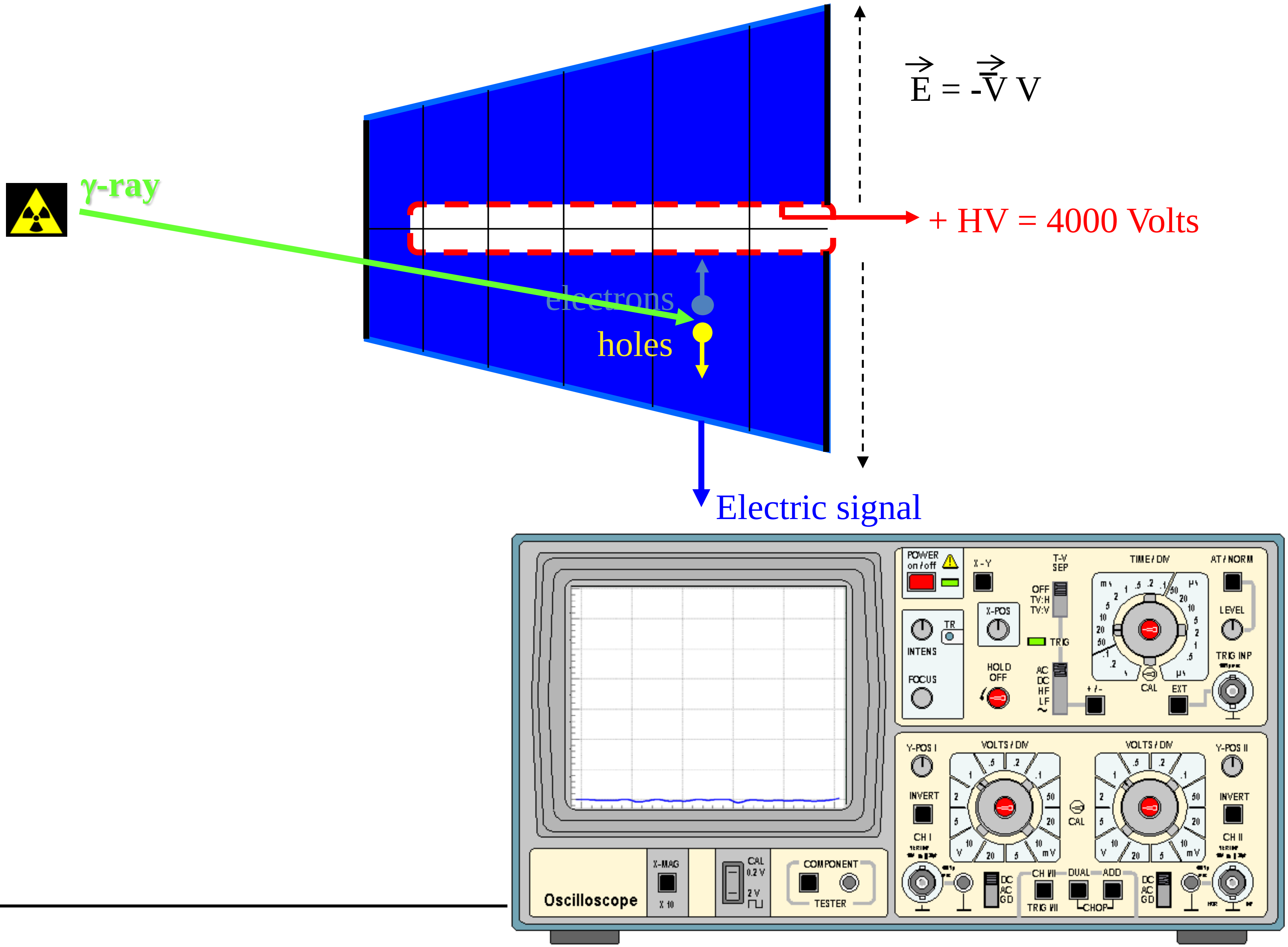
HPGe detector – working principle



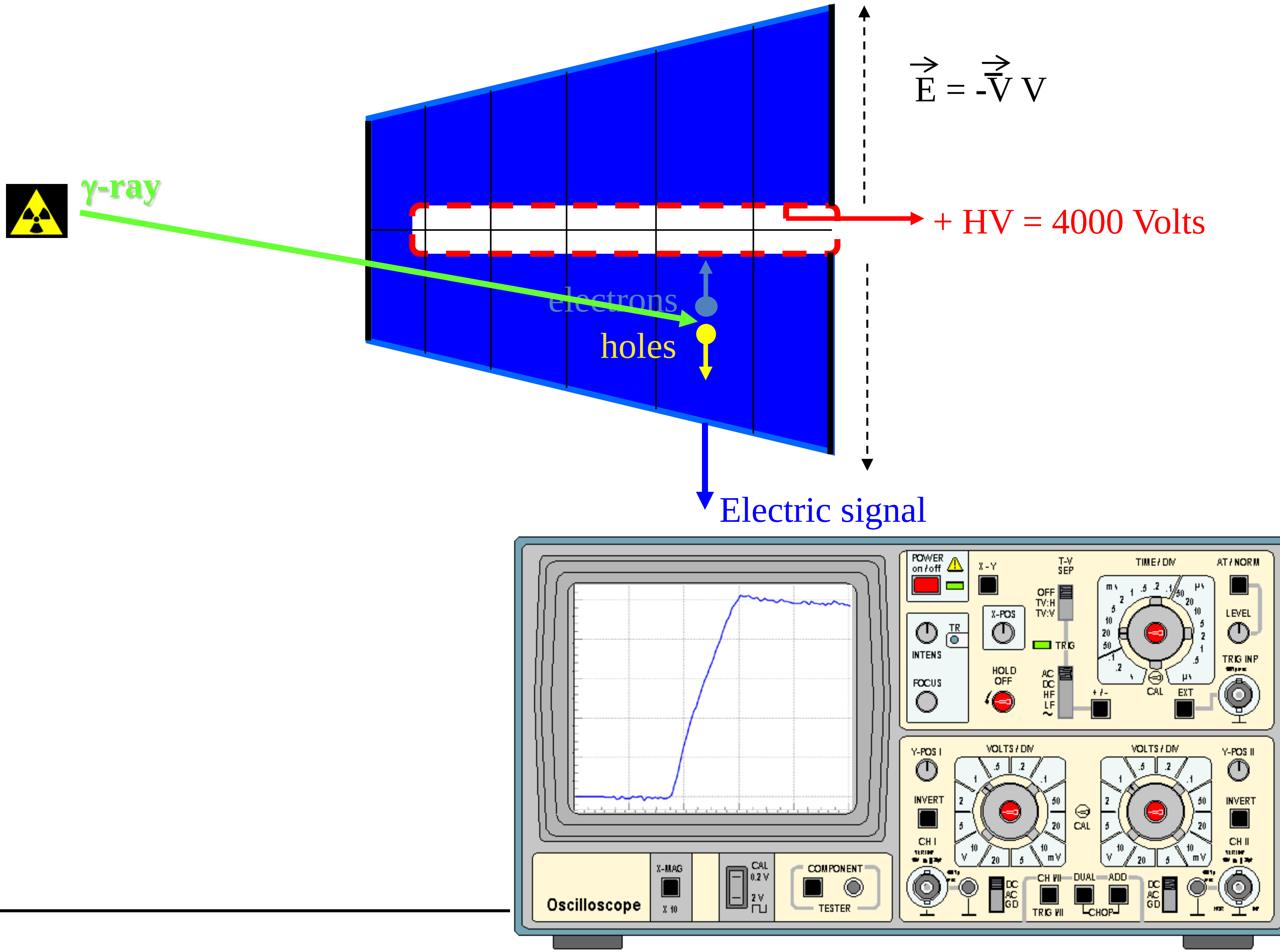
HPGe detector – working principle



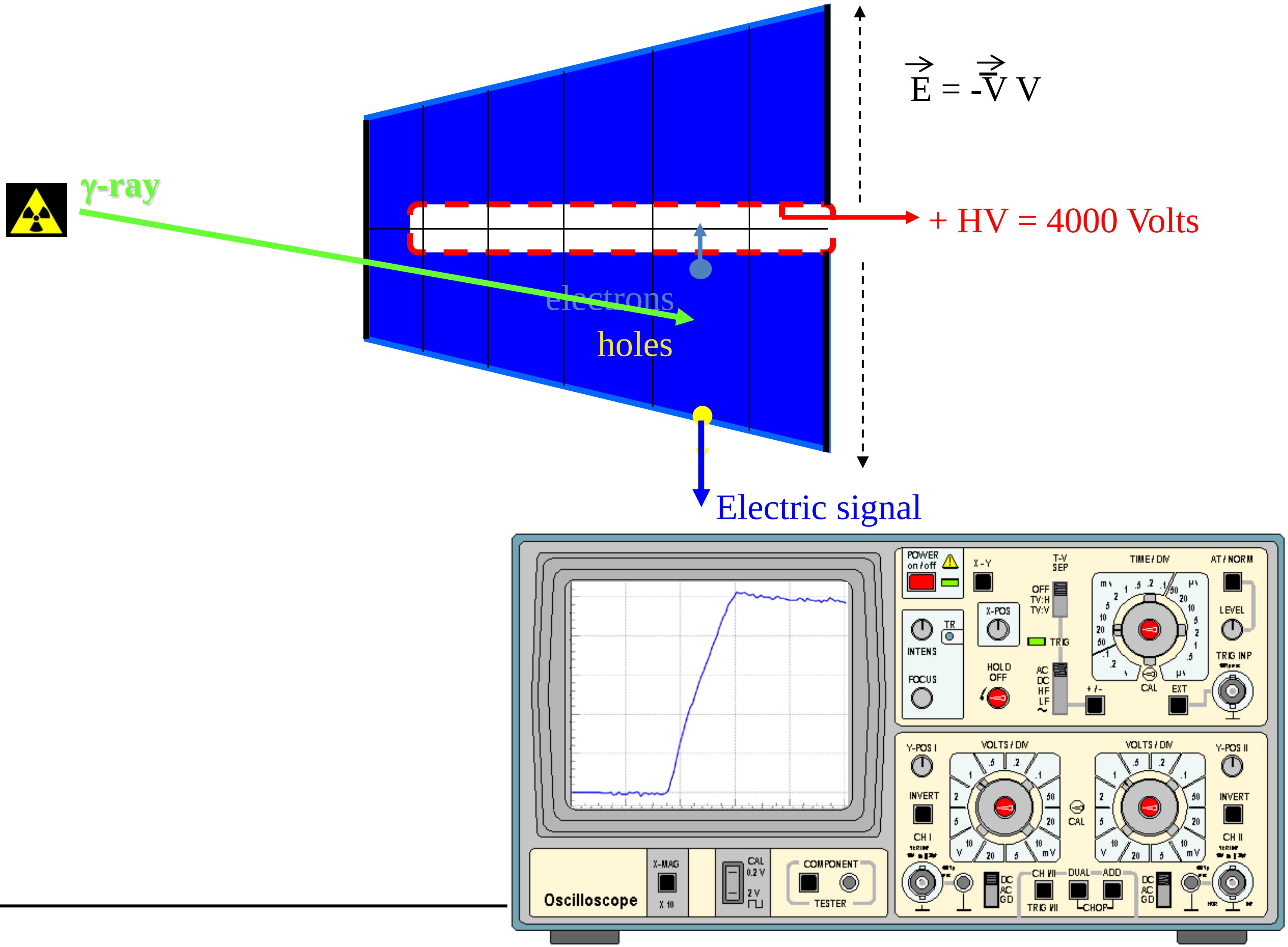
HPGe detector – working principle



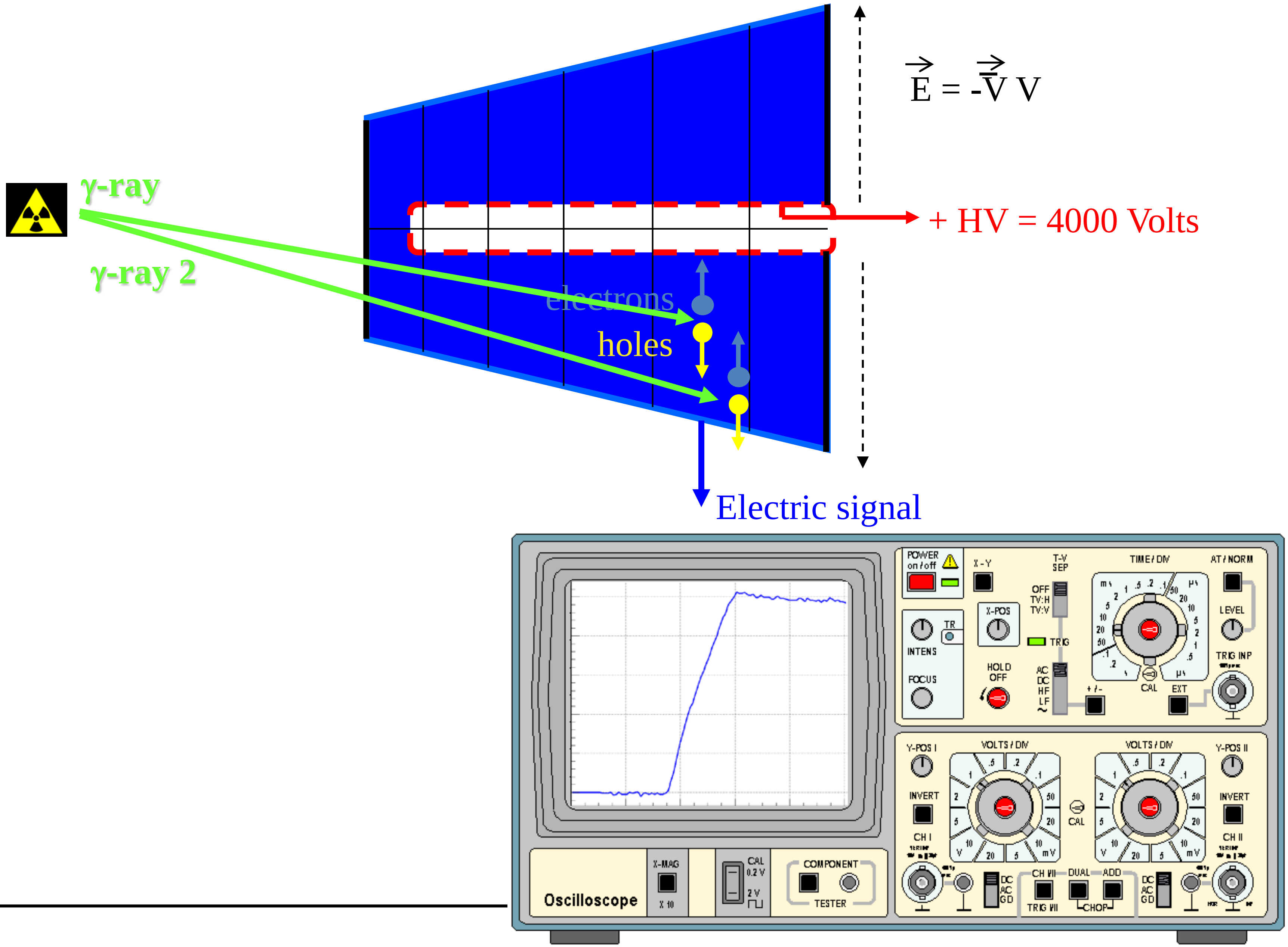
HPGe detector – working principle



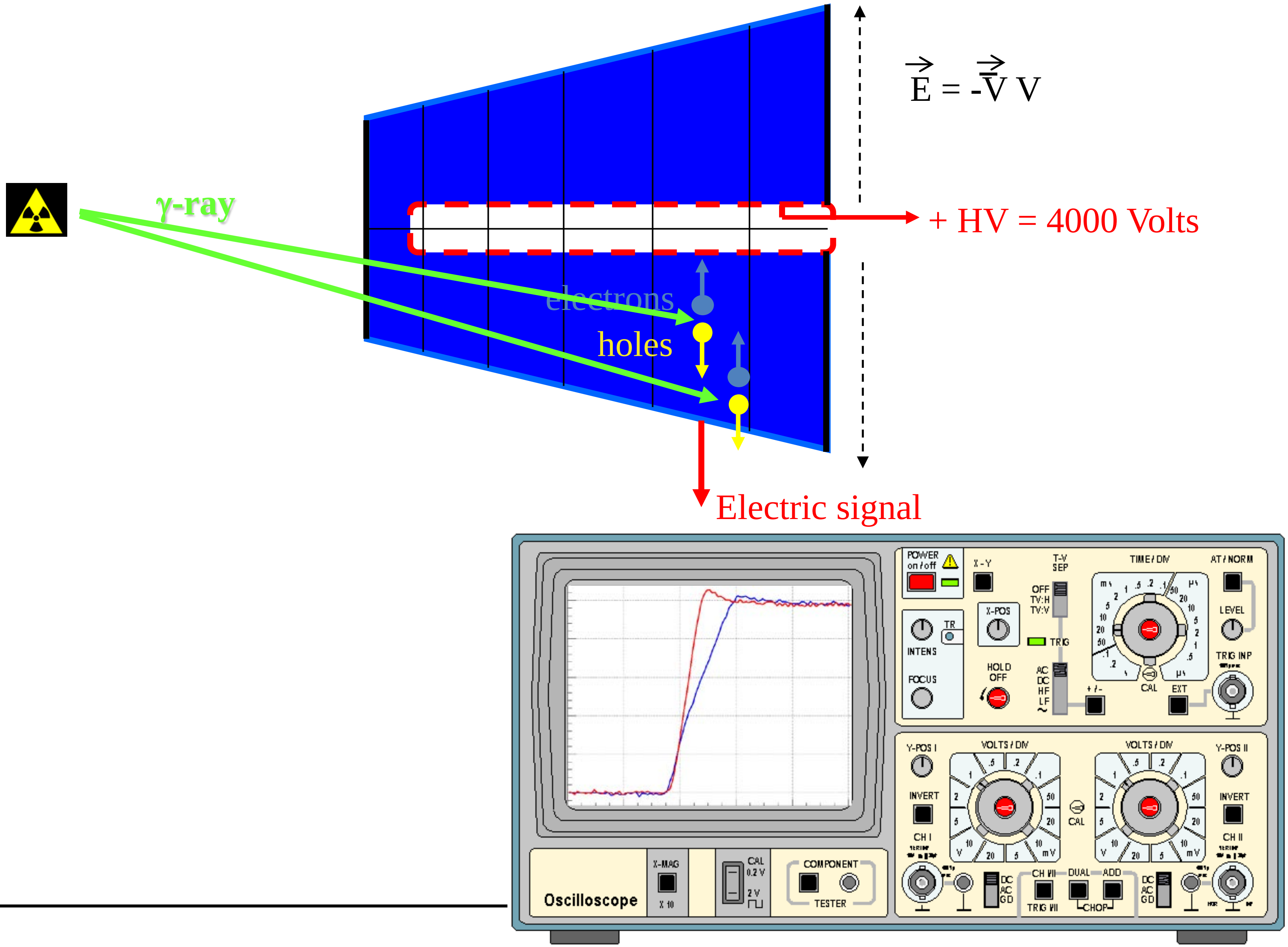
HPGe detector – working principle



HPGe detector – working principle

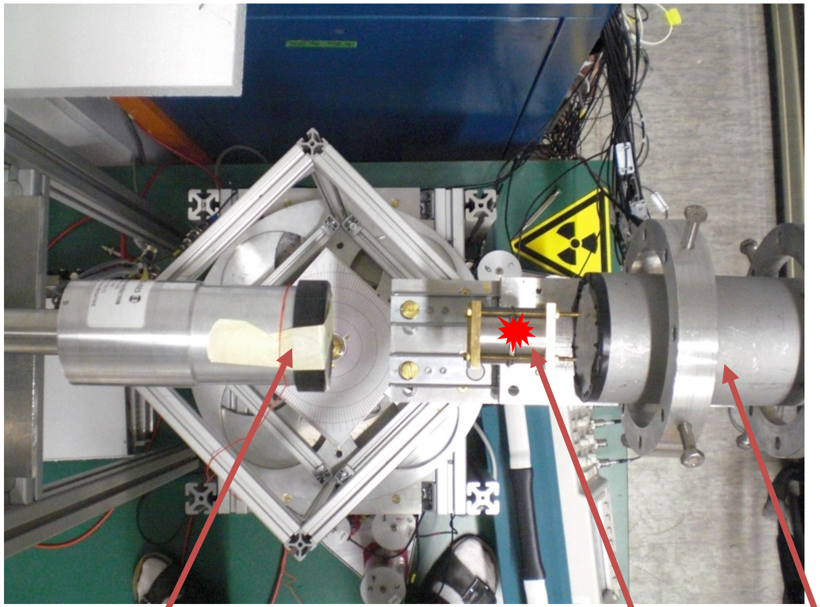


HPGe detector – working principle

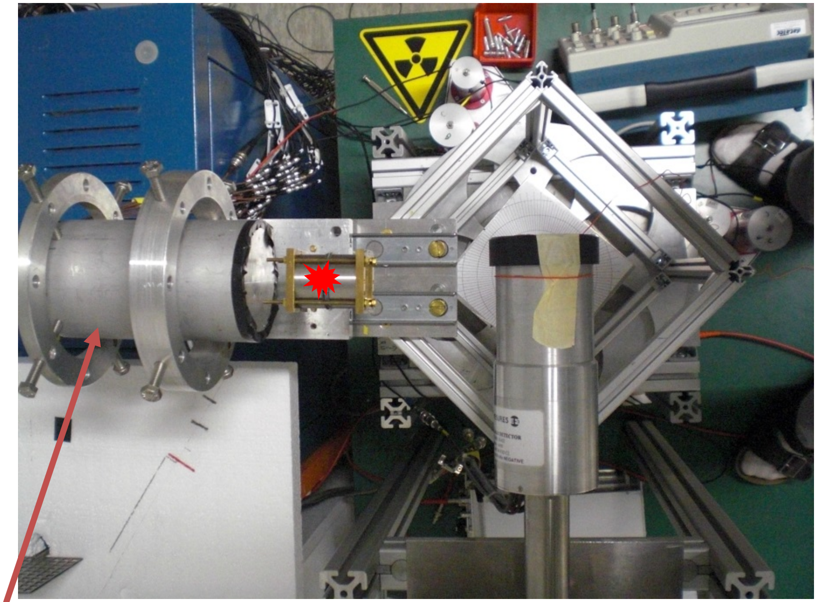


Characterization of planar HPGe detector

Front view



Side view



Planar Ge

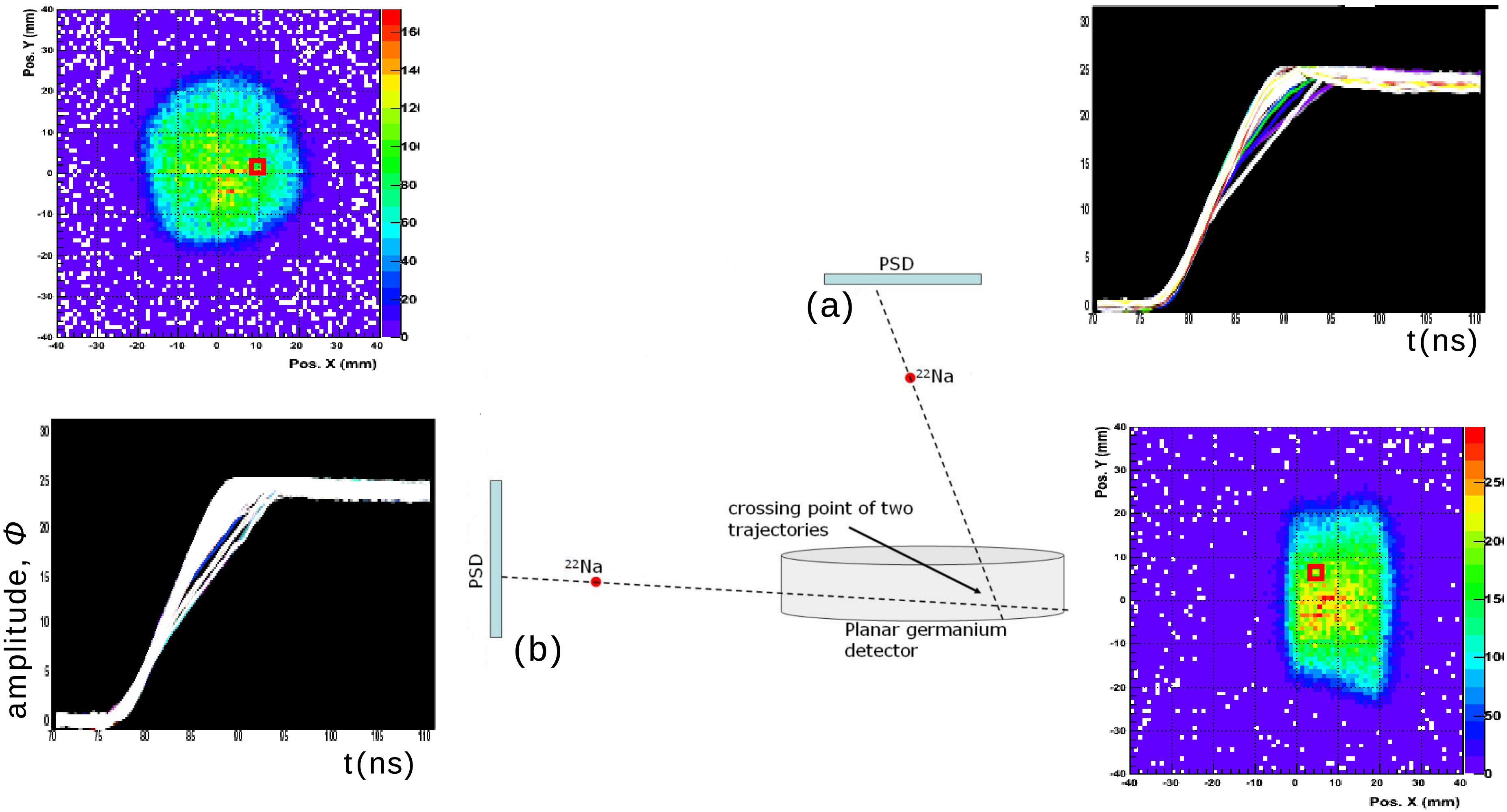
^{22}Na

Position sensitive detector

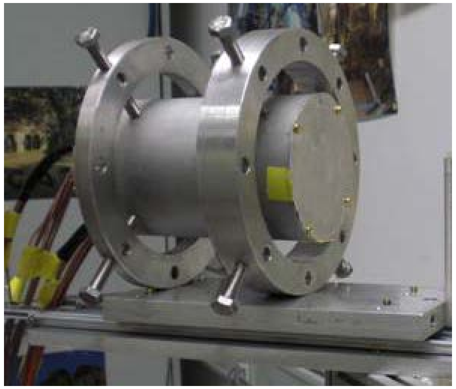
d = 4 cm

t = 2 cm

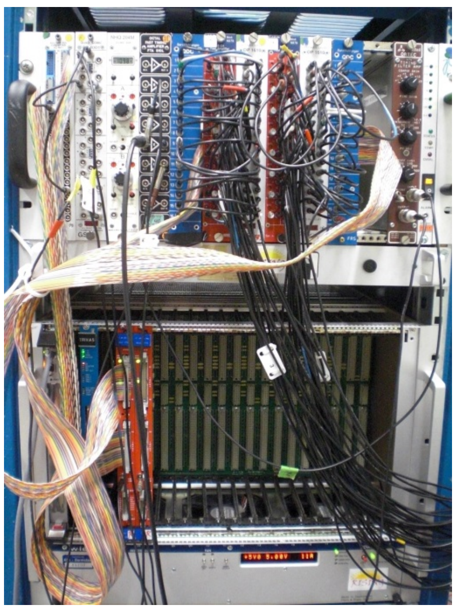
Intensity distribution for photopeak events



Outlook

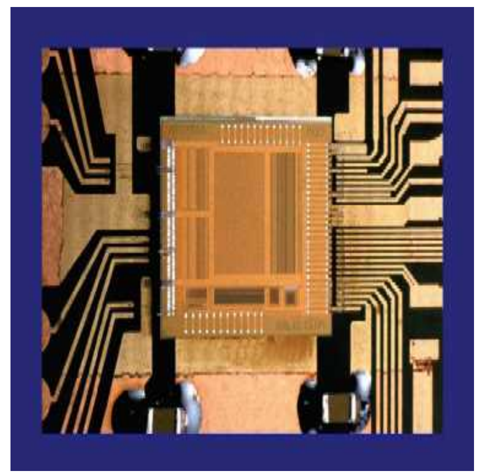


The GSI system uses conventional NIM and VME electronics, which makes it not easily portable, not easily scalable and rather expensive if one wants to build many of these devices.
However, this drawback could be overcome thanks to the increasing technology of electronics, e.g. a new acquisition system based on ASIC, FPGA, etc. technologies. This would also make the system more suitable for medical applications.



?

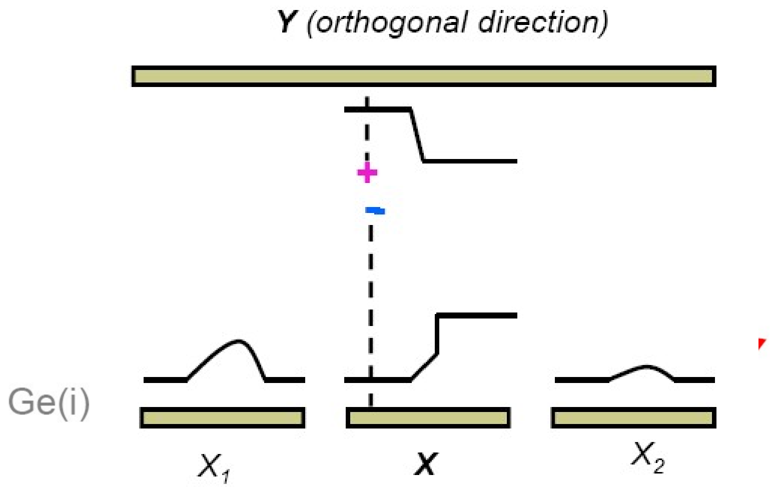
APV25 chip (from CERN CMS experiment)

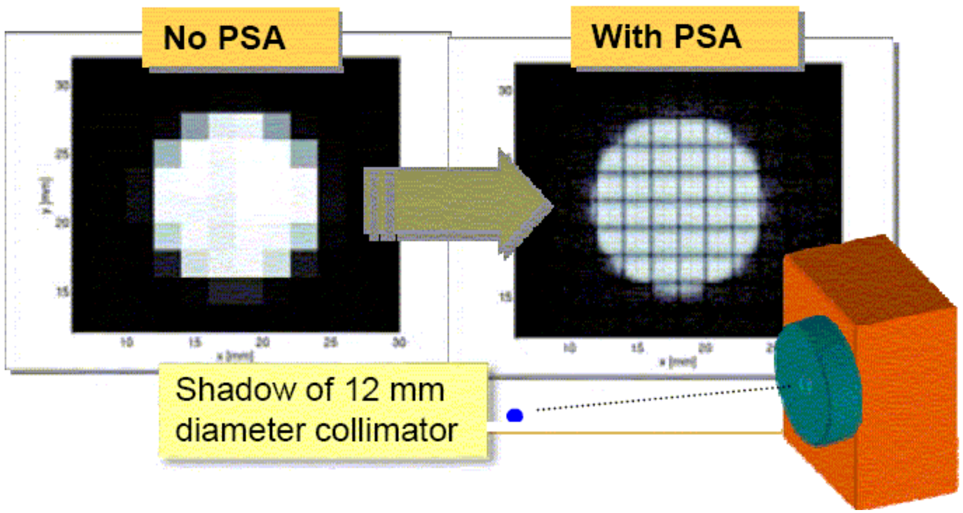


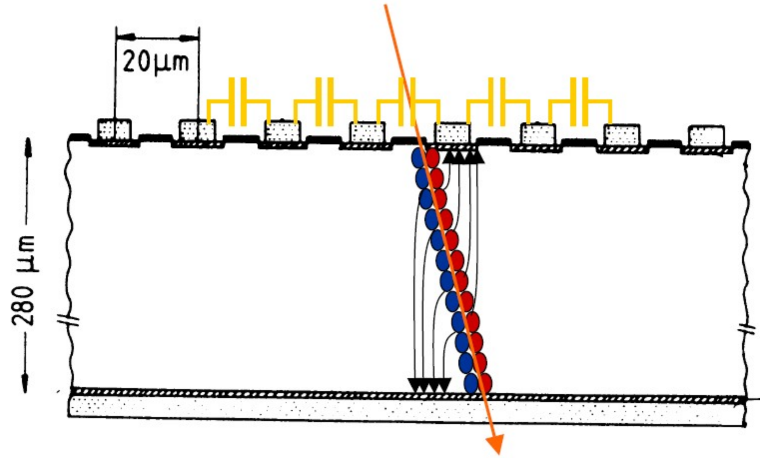
128-channel analogue pipeline chip

M.J. French et al., NIMA 466 (2001) 359

Position Extraction in Planar Detectors

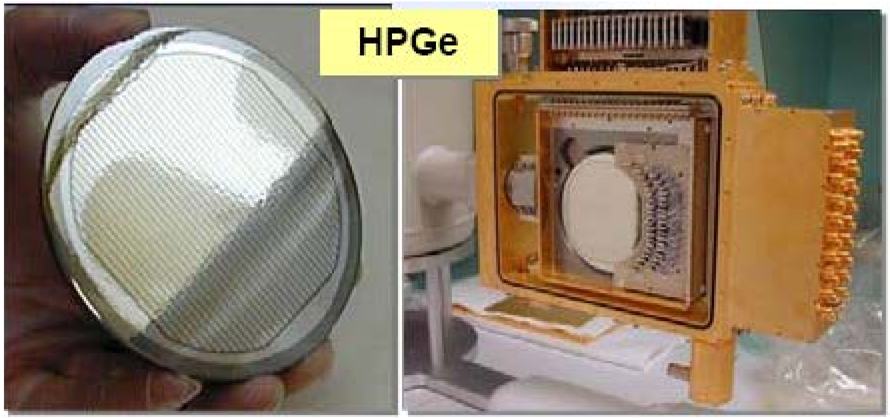




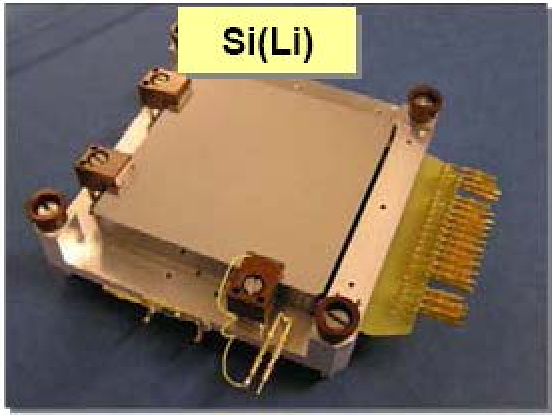


Position resolution of <0.5mm achieved at 122 keV in all three dimensions.

LLNL- Double Sided Strip Detectors (DSSD) built of high-purity Ge and Li-drifted Si for gamma-ray imaging applications
(Ethan Hull, LLNL, Paul Luke, LBNL, and Davor Protic, Research Center Juelich, Germany)



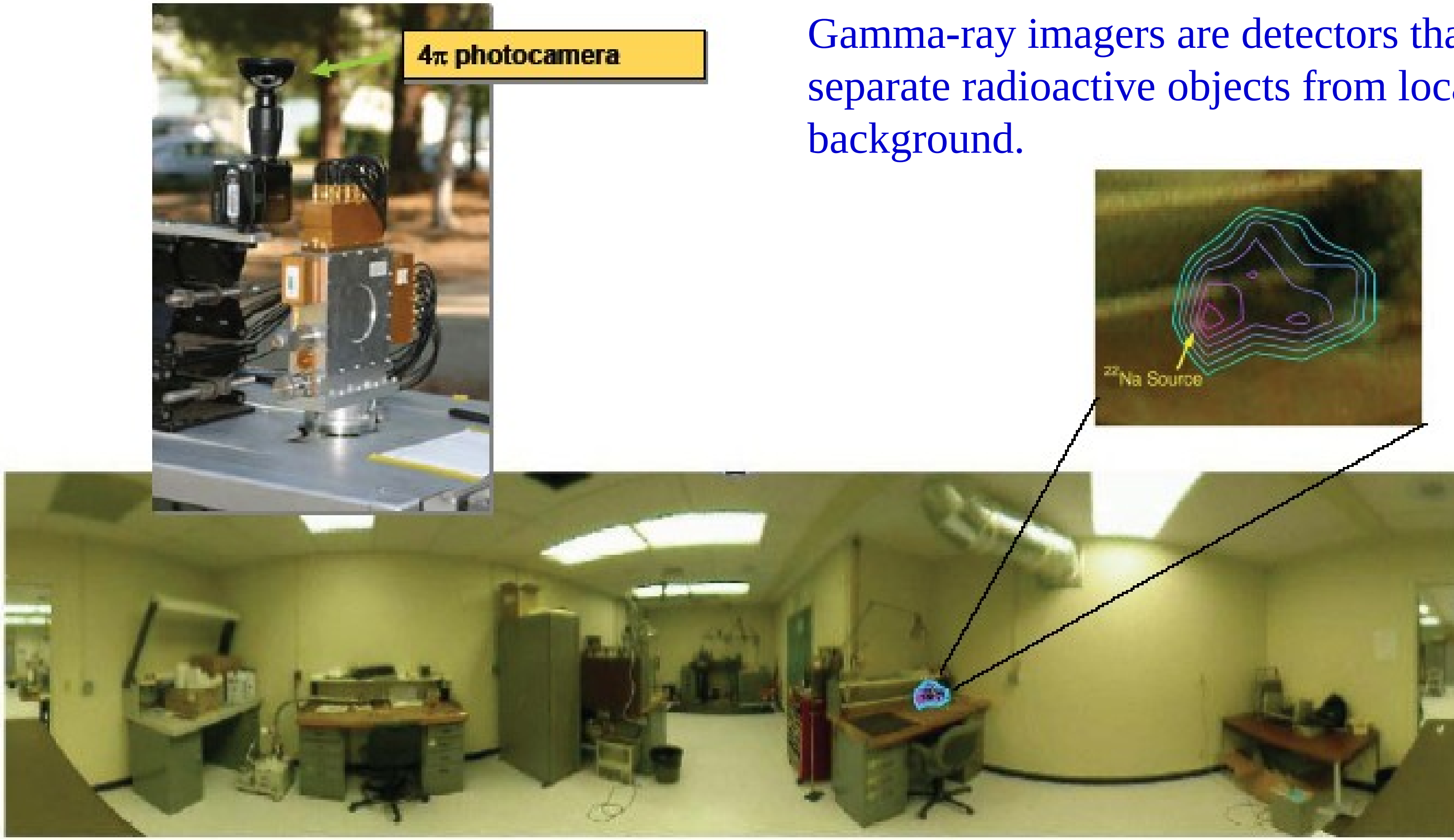
2x38 strip DSSD HPGe detector with 2 mm pitch and 11mm thickness



2x32 strip DSSD Si(Li) detector with 2 mm pitch and 10mm thickness

Gamma-Ray Imaging

Gamma-ray imagers are detectors that separate radioactive objects from local background.



Conventional detectors accept gamma-rays from all directions and can be overwhelmed by local backgrounds.