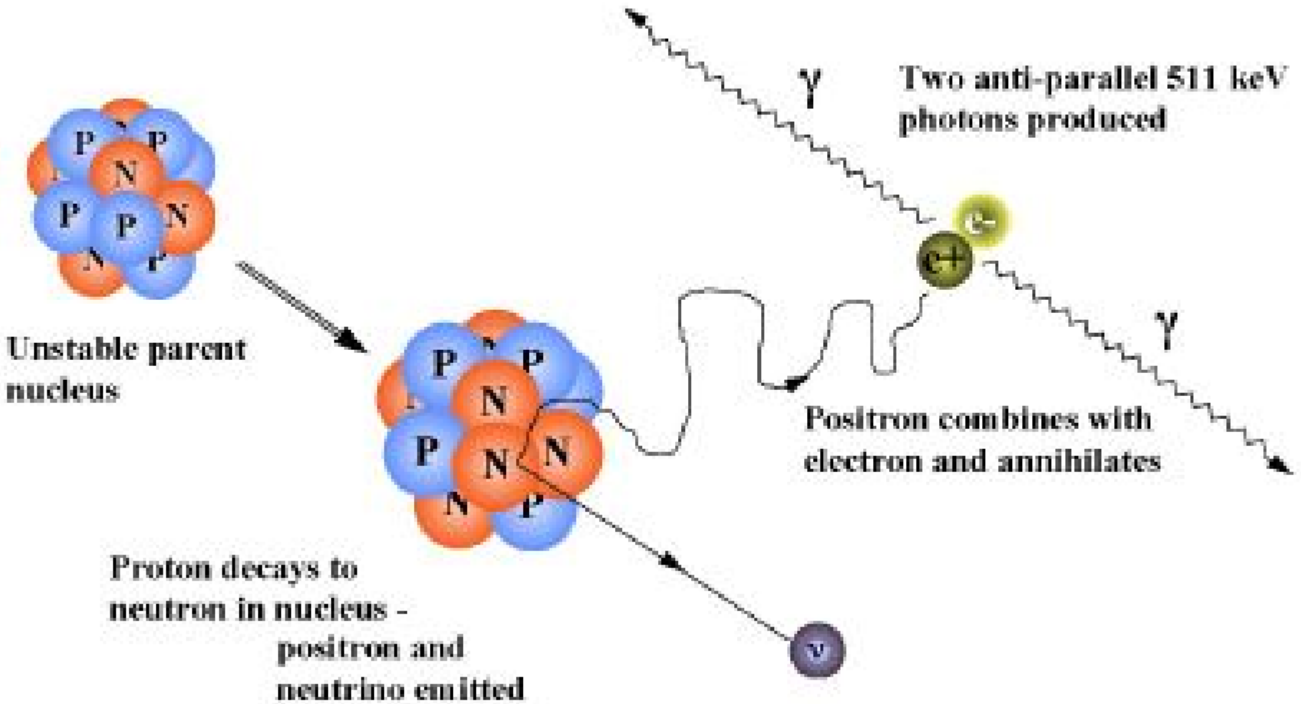
Martin Grossmann :: Center for Proton Therapy :: Paul Scherrer Institute

Introduction to EasyPET Exercise

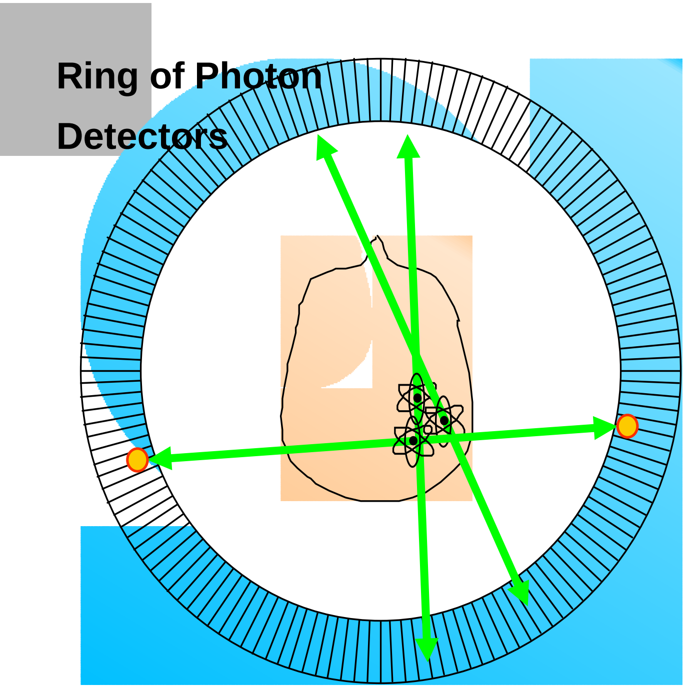
What is PET



Two anti-parallel 511 keV photons produced
γ
γ
e-
e+
Unstable parent nucleus
Positron combines with electron and annihilates
Proton decays to neutron in nucleus - positron and neutrino emitted
ν

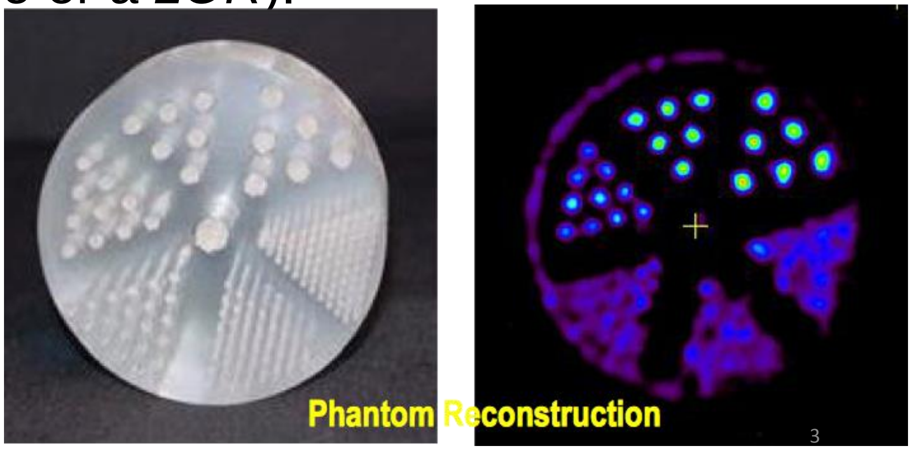
From Martin Purschke!

PET – Positron Emission Tomography



- Radionuclide decays, emitting β^{+}.
- β^{+} annihilates with e^{-} from tissue, forming back-to-back 511 keV photon pair.
- 511 keV photon pairs detected via time coincidence.
- Positron lies on line defined by detector pair (known as a *line of response* or a *LOR*).

- Back-to-back 511KeV photons are detected



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From Martin Purschke!

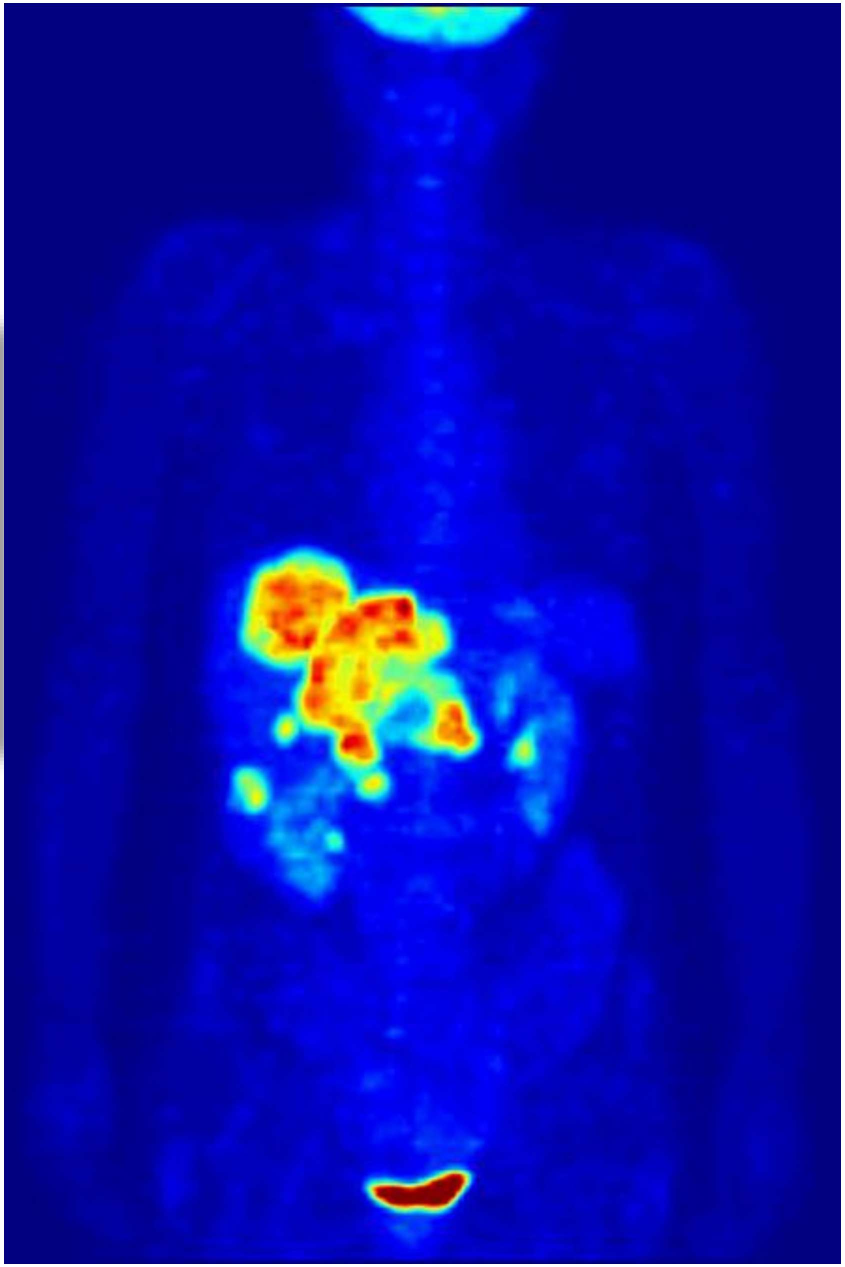
Why PET is so cool

- **PET can be tailored to show *metabolic* processes in tissue**
- **Remember, the *chemical* properties of a radioactive isotope are the same as the stable isotope – it will be used by the body indiscriminately**
- **So you take a molecule that is used in your body for some process – sugar, dopamine, what have you, swap out an atom for a radioactive one**
- **You get "hot spots" where lots of said molecules are used by the body**
- **For example, a tumor that grows uses a lot of energy (sugar), so radioactively tagged sugar will accumulate a lot of activity there**
- **Or tag molecules that the brain burns when it "thinks" – active areas show up as hot spots**
- **Frequently used radiotracers are ^{11}C and ^{18}F (all beta+ = positrons)**

From Martin Purschke!

An Example - ^{18}F

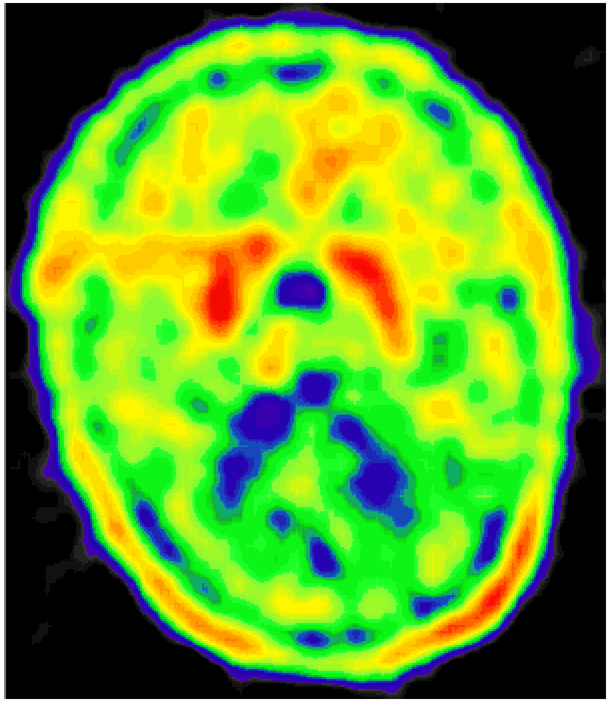
- ^{18}F-FDG - Fludeoxyglucose is one of the commonly used radiotracers
- It is a sugar, so it accumulates where the body burns a lot of energy ("uptake")
- Unusual "hot spots" can point to cancer

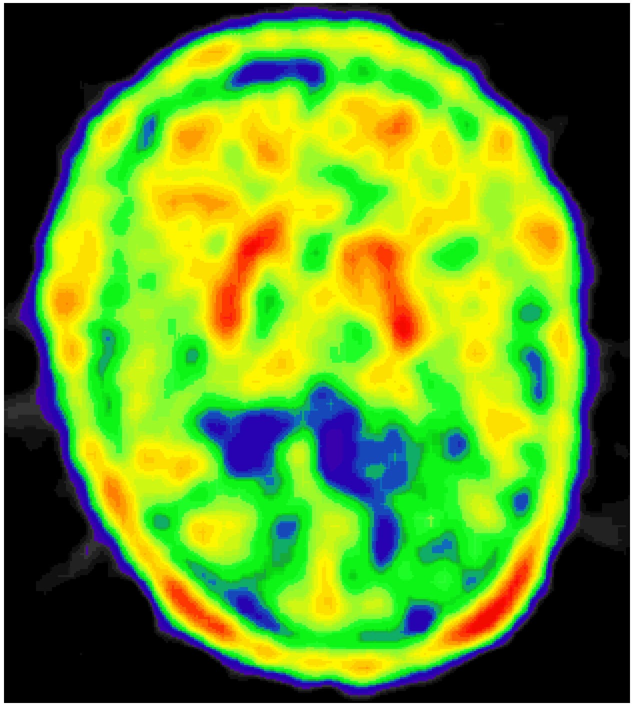


Whole-body PET scan using 18F-FDG to show liver metastases of a colorectal tumor

PET image of the brain

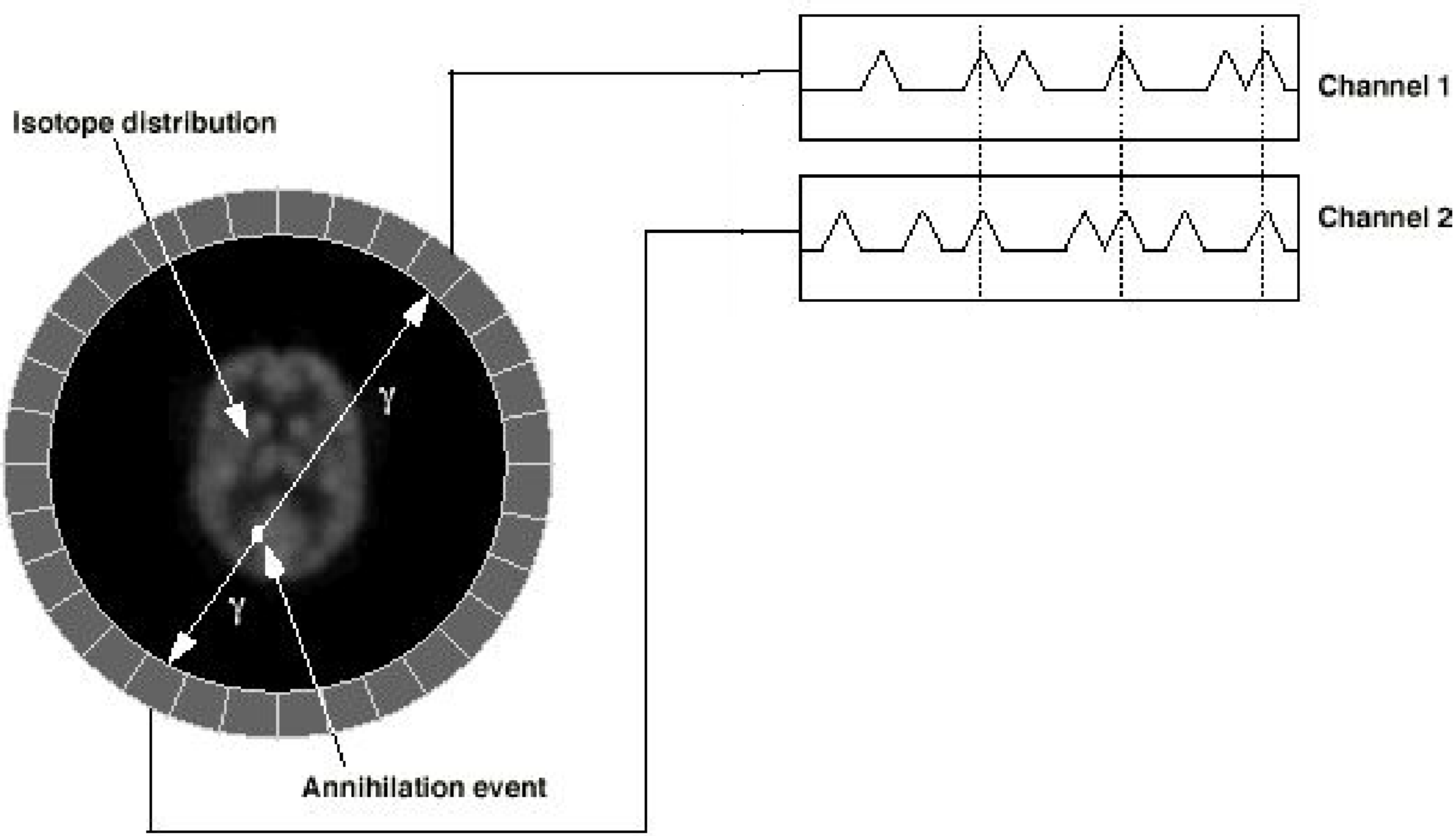
- Dopamine = chemical messenger in our body
- Parkinson's disease: dopamine production in the central brain not properly working
- PET image using dopamine with F^{18} isotope





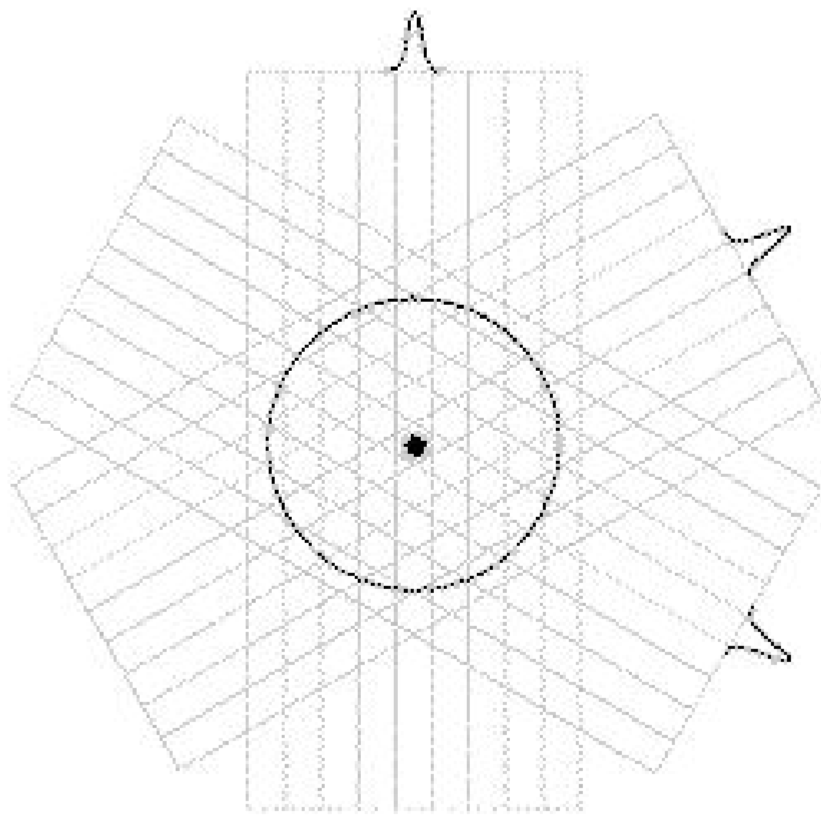
[F-18]fluoro-L-DOPA, 13. November 1997, Grossmann Martin

Coincidence detection



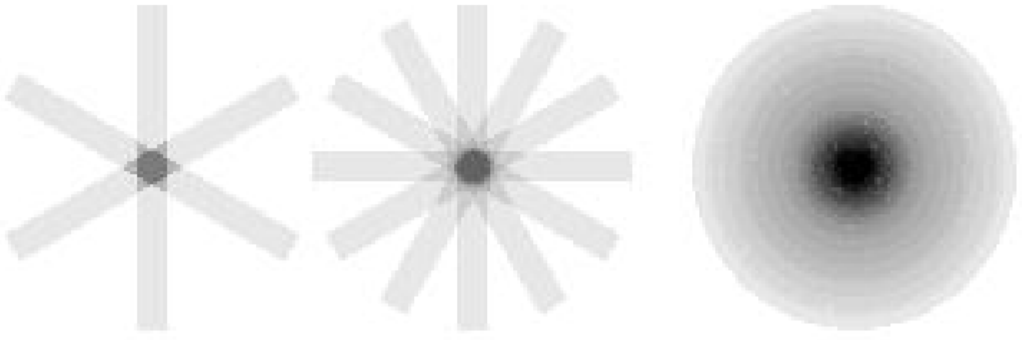
2D PET image

- LOR (lines of response) arranged into sets of 1-dimensional parallel projections



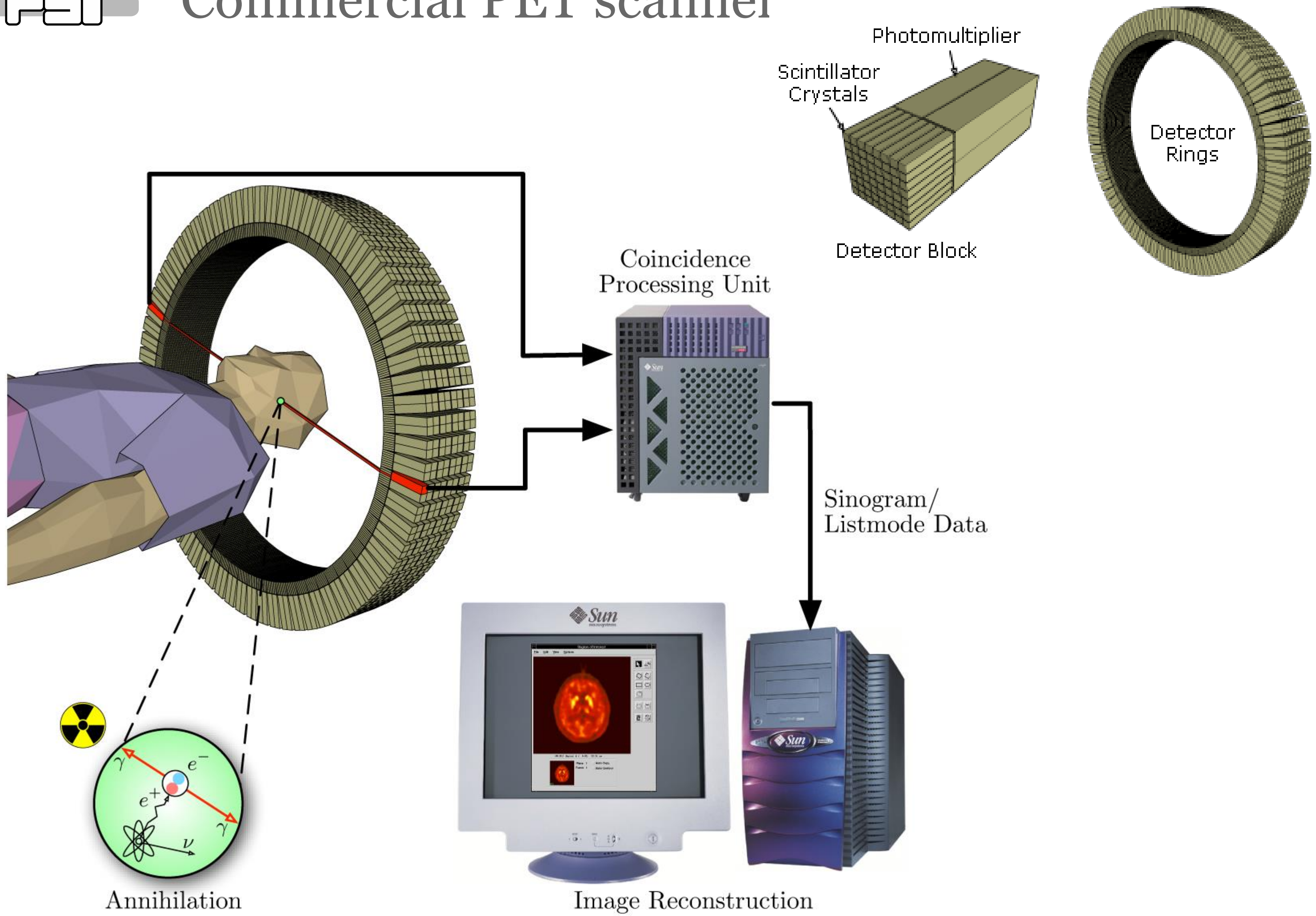
2D PET image

- Back-Projection allows to reconstruct original source distribution



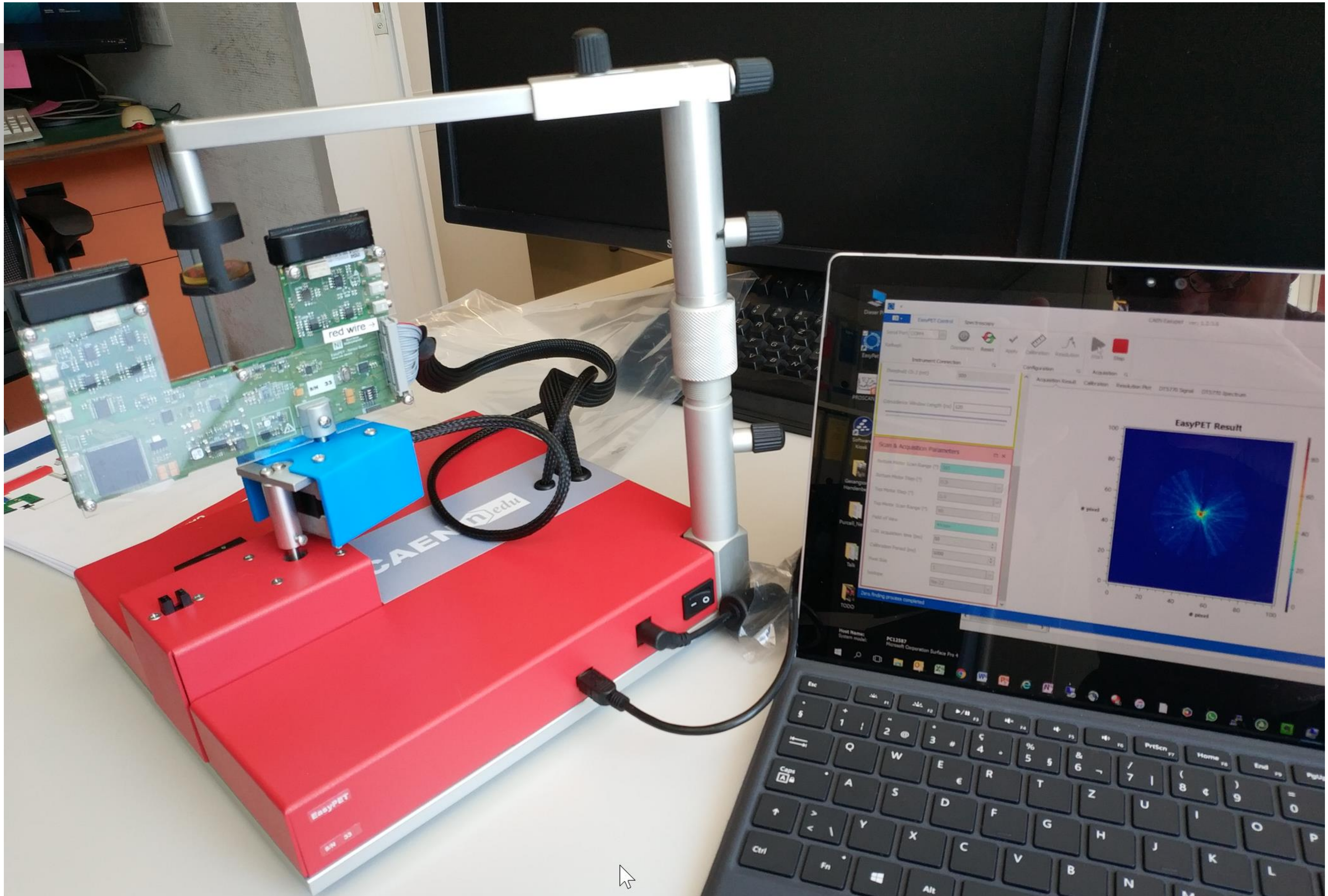
Commercial PET scanner

Commercial PET scanner



EasyPET

- 2 detectors moving around the target



LySO Crystals

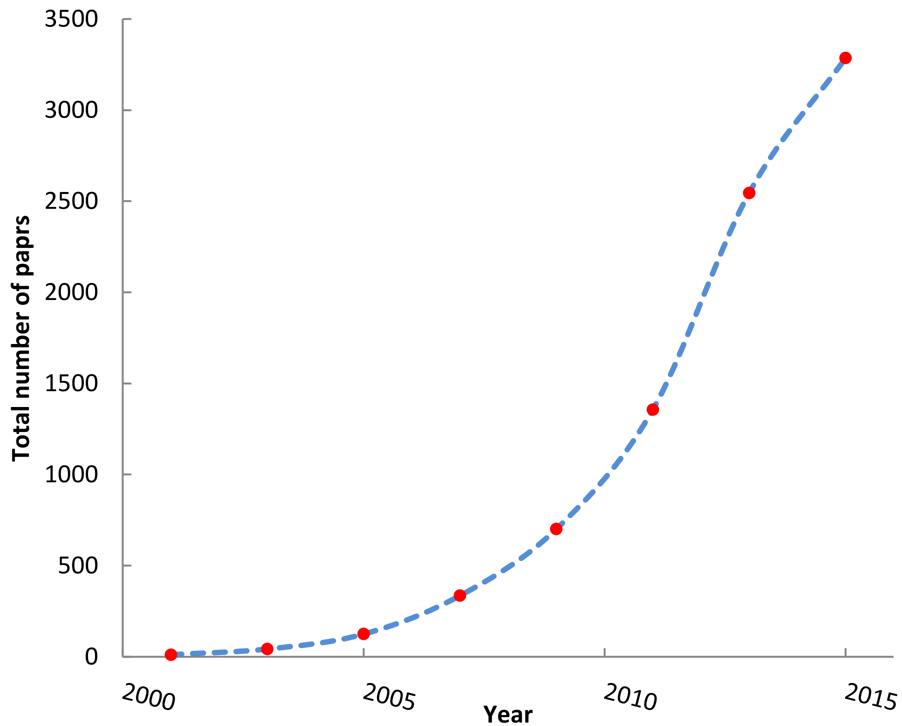
- Lutetium-yttrium oxyorthosilicate $Lu_{2(1-x)}Y_{2x}SiO_5$
- Scintillator crystal

Silicon Photo Multiplier - SiPM

- Solid state photon detectors
- High gain, low voltage («bias»)
- Very compact
- Compatible with magnetic resonance imaging MRI

Silicon Photo Multiplier - SiPM

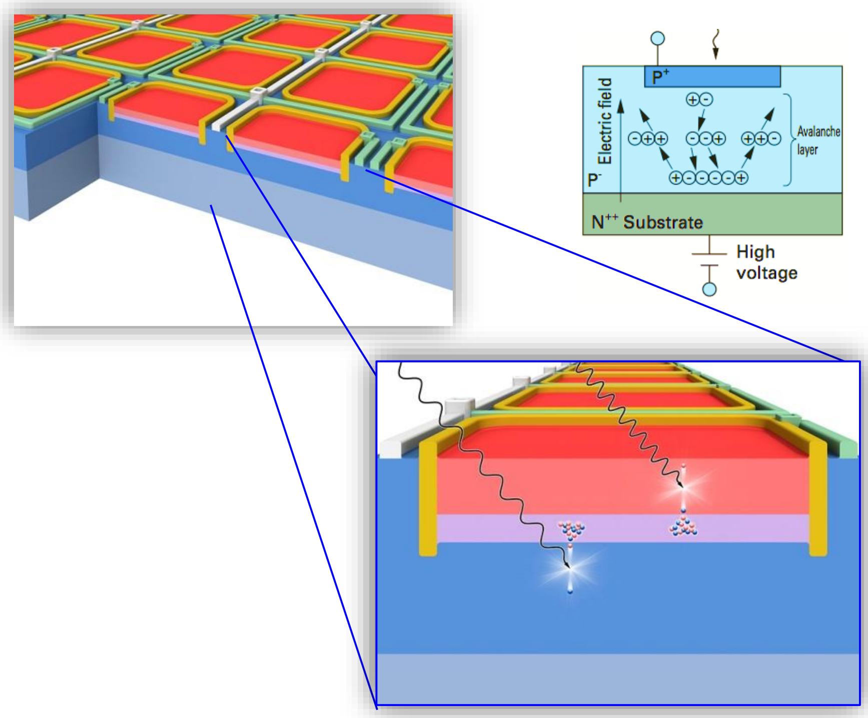
- Many institutes/companies are involved in SiPM production
  - **CPTA,** Russia
  - **Amplification Technologies** , USA
  - **Novel Device Laboratory** (NDL), China
  - **Excelitas tech.** (formerly Perkin-Elmer)
  - **National Nano Fab Center,** Korea
  - **MePhi/Pulsar Enterprise**, Russia
  - **Zecotek**, Canada
  - **Hamamatsu HPK**,, Japan
  - **FBK-AdvanSiD**, Italy
  - **ST Microelectronics**, Italy
  - **MPI-HLL,** Germany
  - **Philips**, Germany
  - **KETEK**, Germany
  - **SensL**, Ireland
  - **RMD**, USA



Papers on Google Scholar about «SiPM»

Silicon Photo Multiplier - SiPM

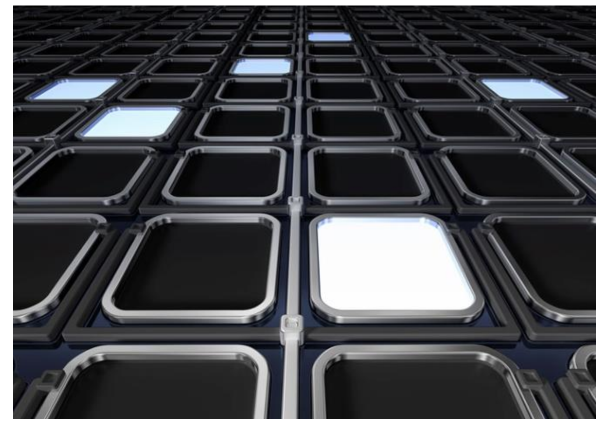
- SiPM is a High density (up to 104/mm2) matrix of diodes with a common output, working in Geiger-Müller regime
- Common bias is applied to all cells (few % over breakdown voltage)
- Each cell has its own quenching resistor (from 100kΩto several MΩ)
- When a cell is fired an avalanche starts with a multiplicative factor of about 10^5-10^6
- The output is a fast signal (t_{rise}~ ns; t_{fall} ~ 50 ns) sum of signals produced by individual cells
- SiPM works as an analog photon detector



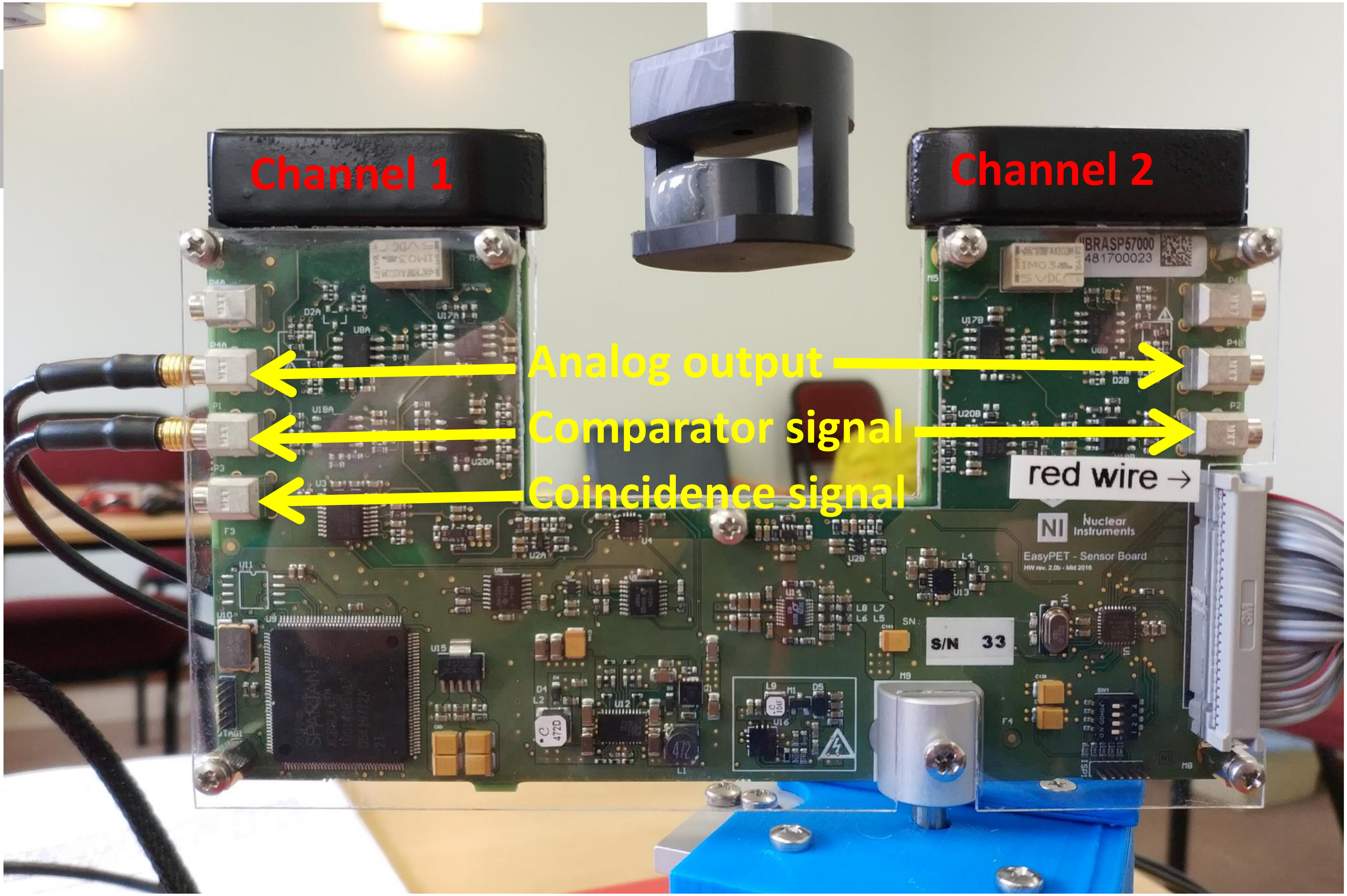
Silicon Photo Multiplier - SiPM

- SiPM can be seen as a collection of binary cells, fired when a photon is absorbed
- Counting cells provides information about the intensity of the incoming light

- Dark Count Rate (DCR)
  - Avalanche induced by thermal effects
  - Depends on
    - Temperature
    - Sensor technology
    - Bias voltage
- Detector counts even without radioactive source



EasyPET PCB

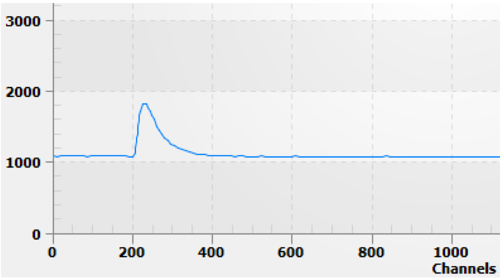

Channel 1
Channel 2
Analog output
Comparator signal
Coincidence signal
red wire →
Nuclear Instruments
EasyPET - Sensor Board
S/N 33

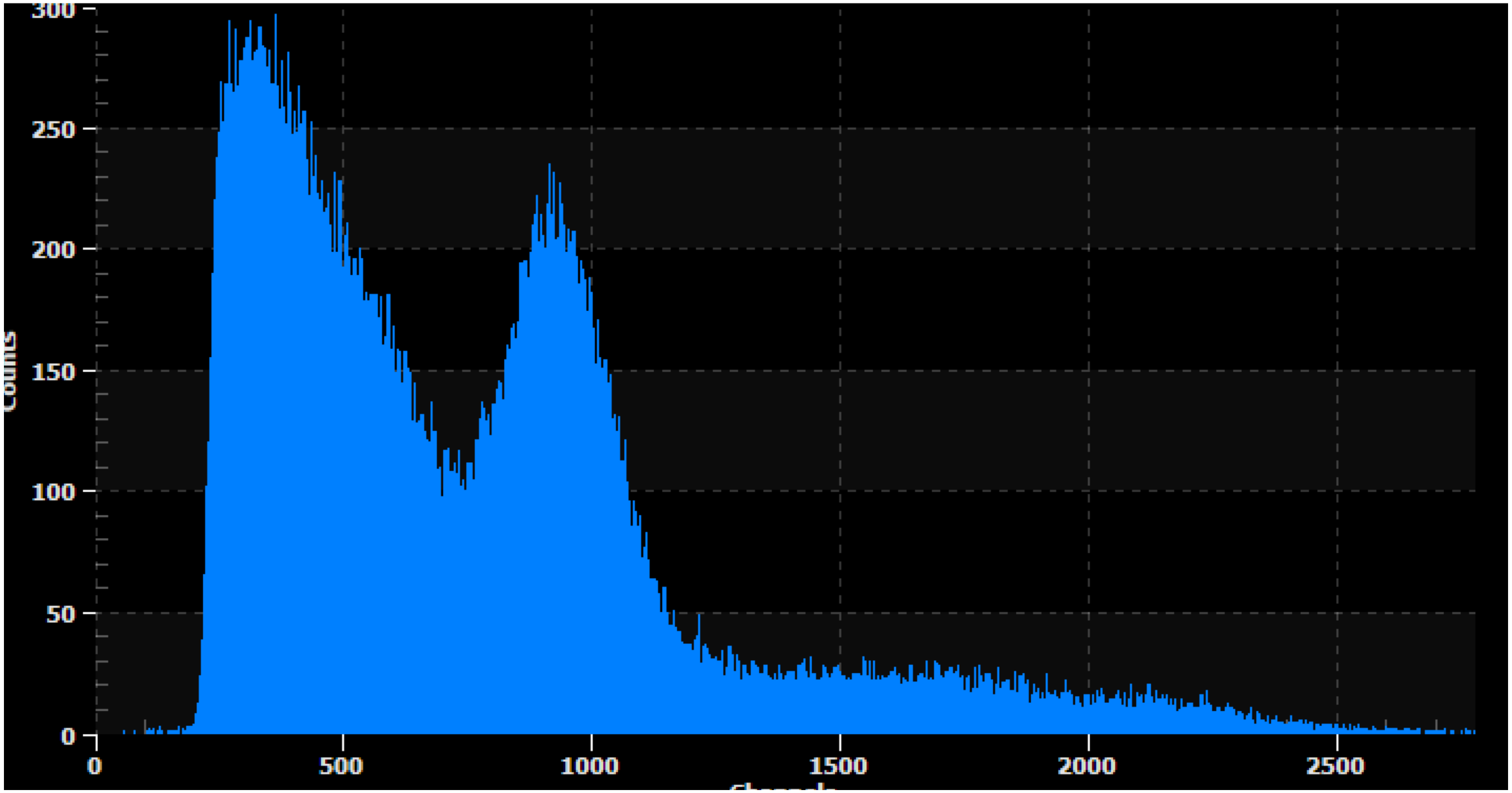
DT5770 Multi Channel Analyzer (MCA)

- Analyze pulses
- Accept signal and trigger input
- Readout with PC

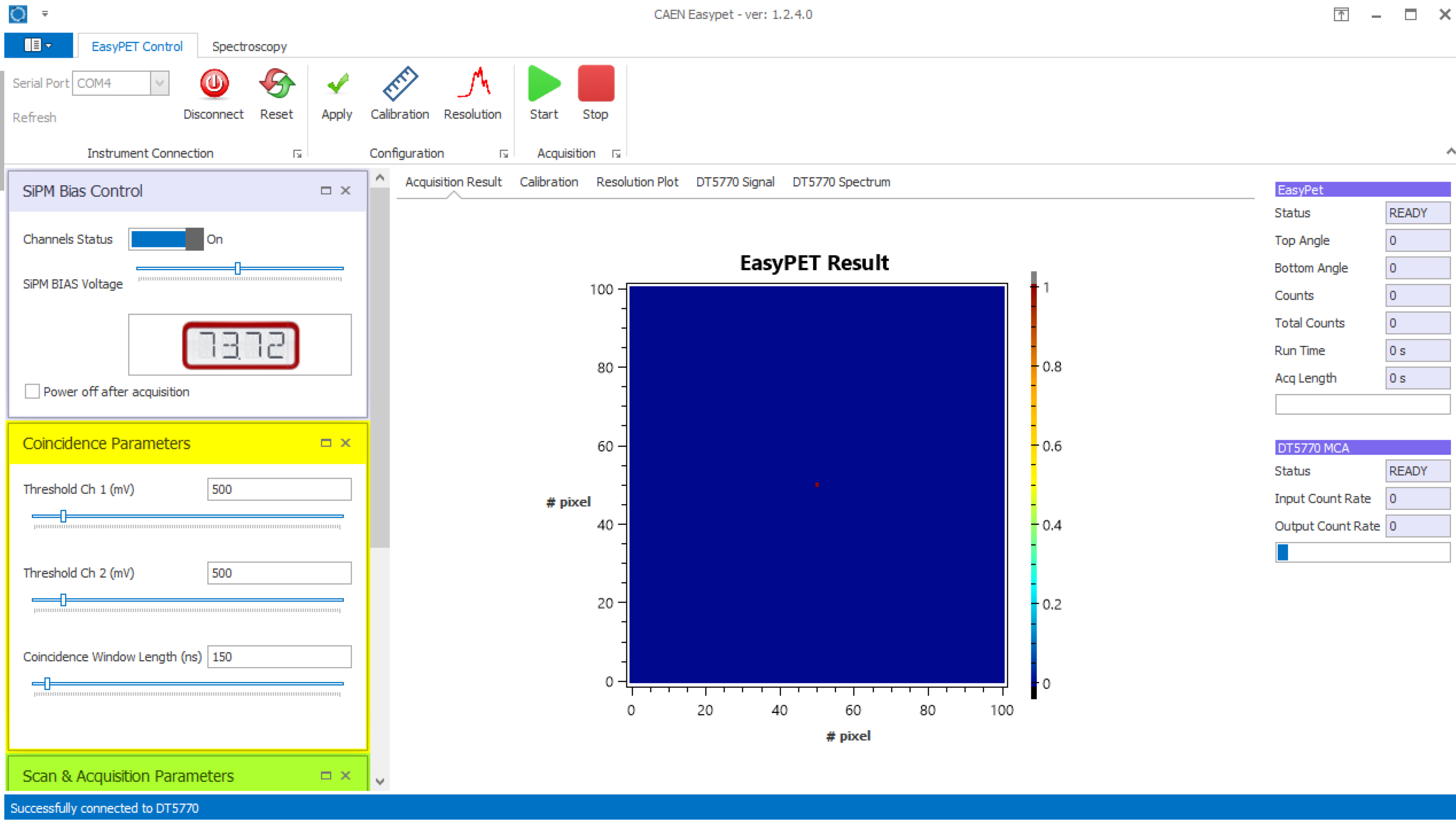
Multi Channel Analyzer (MCA)

- Look at individual pulses
- Acquire spectrum



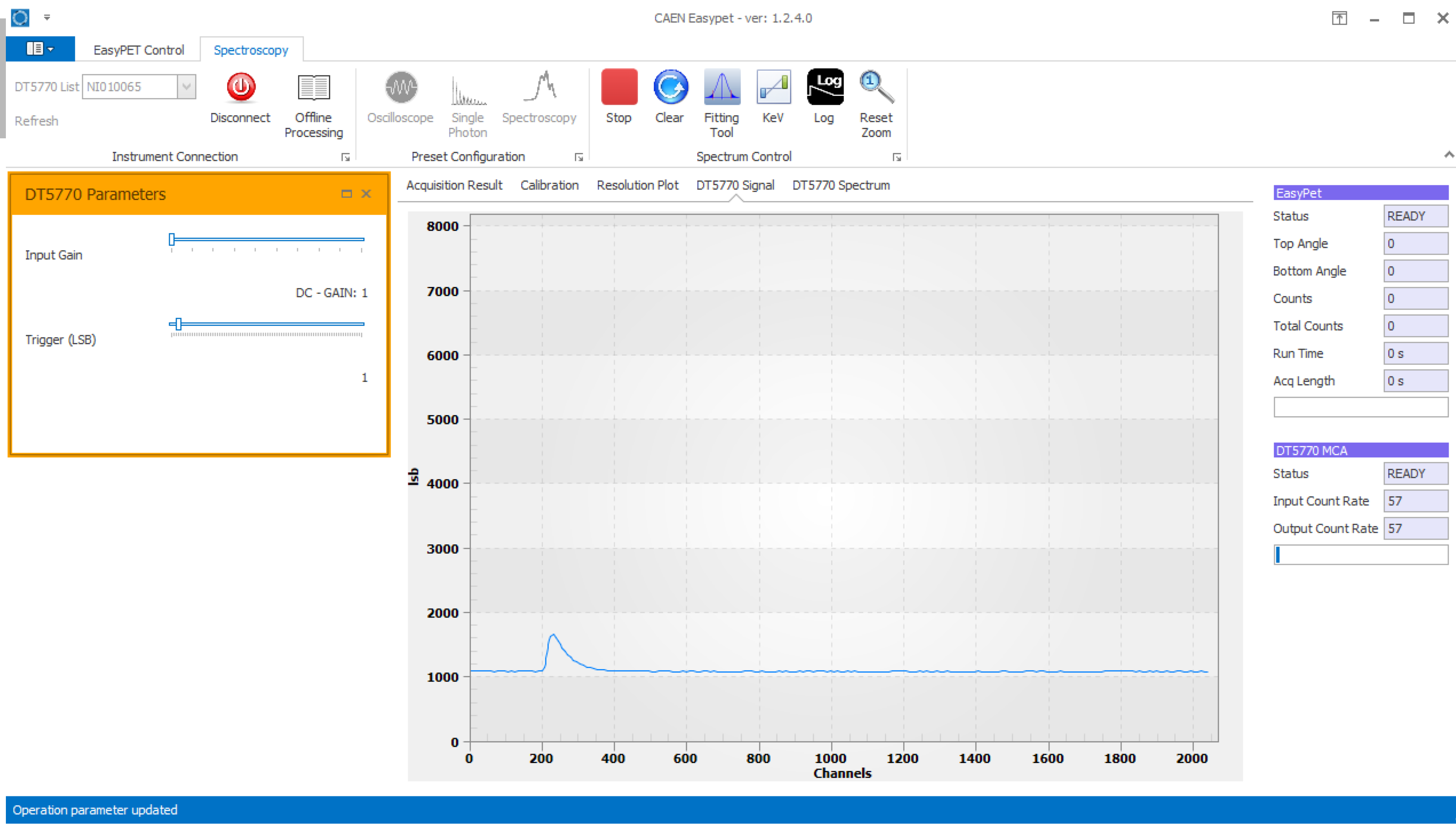


EasyPET GUI



CAEN Easypet - ver: 1.2.4.0
EasyPET Control
Spectroscopy
Serial Port
COM4
Refresh
Disconnect
Reset
Apply
Calibration
Resolution
Start
Stop
Instrument Connection
Configuration
Acquisition
SiPM Bias Control
Channels Status
On
SiPM BIAS Voltage
7372
Power off after acquisition
Coincidence Parameters
Threshold Ch 1 (mV)
500
Threshold Ch 2 (mV)
500
Coincidence Window Length (ns)
150
Scan & Acquisition Parameters
Acquisition Result
Calibration
Resolution Plot
DT5770 Signal
DT5770 Spectrum
EasyPET Result
pixel
pixel
EasyPet
Status
READY
Top Angle
0
Bottom Angle
0
Counts
0
Total Counts
0
Run Time
0 s
Acq Length
0 s
DT5770 MCA
Status
READY
Input Count Rate
0
Output Count Rate
0
Successfully connected to DT5770

EasyPET GUI



CAEN Easypet - ver: 1.2.4.0
EasyPET Control
Spectroscopy
DT5770 List
NI010065
Refresh
Disconnect
Offline Processing
Instrument Connection
Oscilloscope
Single Photon
Spectroscopy
Preset Configuration
Stop
Clear
Fitting Tool
KeV
Log
Reset Zoom
Spectrum Control
DT5770 Parameters
Input Gain
DC - GAIN: 1
Trigger (LSB)
1
Acquisition Result
Calibration
Resolution Plot
DT5770 Signal
DT5770 Spectrum
lsb
Channels
EasyPet
Status
READY
Top Angle
0
Bottom Angle
0
Counts
0
Total Counts
0
Run Time
0 s
Acq Length
0 s
DT5770 MCA
Status
READY
Input Count Rate
57
Output Count Rate
57
Operation parameter updated

Handling radioactive sources

Handling radioactive sources

Handling radioactive sources

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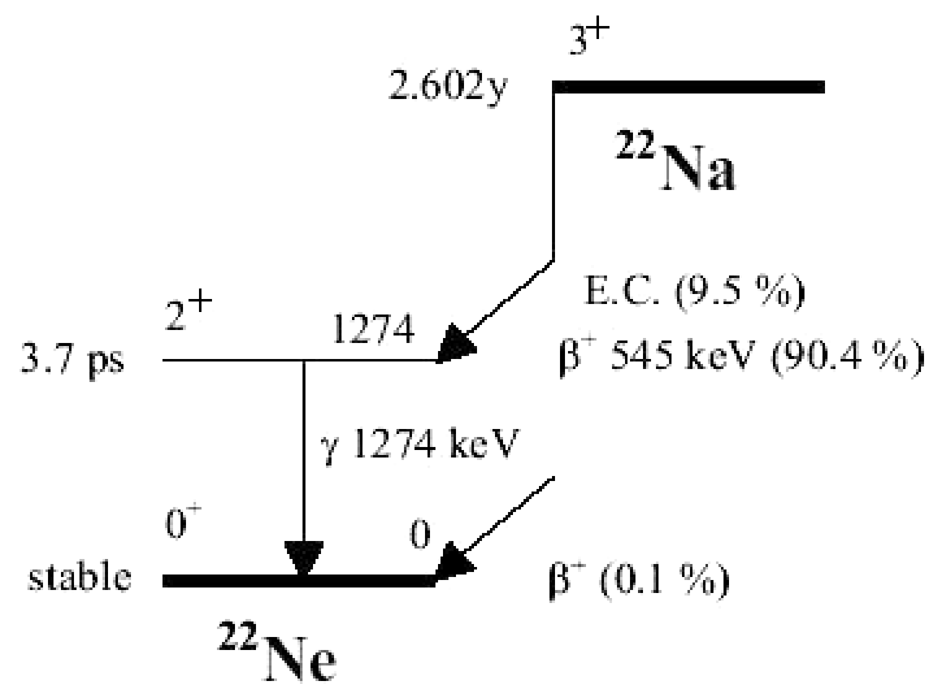
Handling radioactive sources

- **Let your instructor do most of the source handling!**
- Minimize the time you are handling the sources directly
- Maximize your distance from the sources during the experiment
- When not needed store the sources in the lead castle (small desk in the corner)

Na^{22}

- Sealed sources of Na^{22}
- β^+ emitter
- 12 µCi activity
- Emission of 511 keV from positron annihilation
- Emission of 1274 keV from Ne^{22} in excited state



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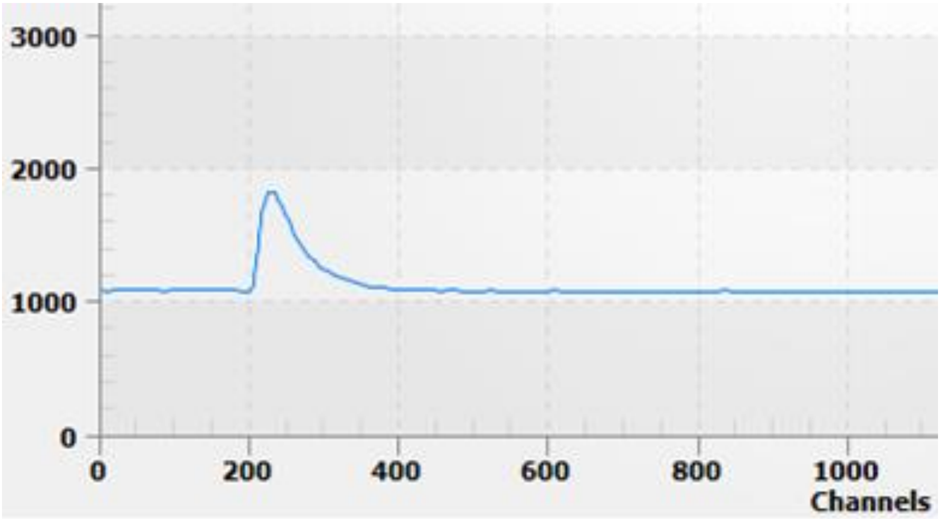
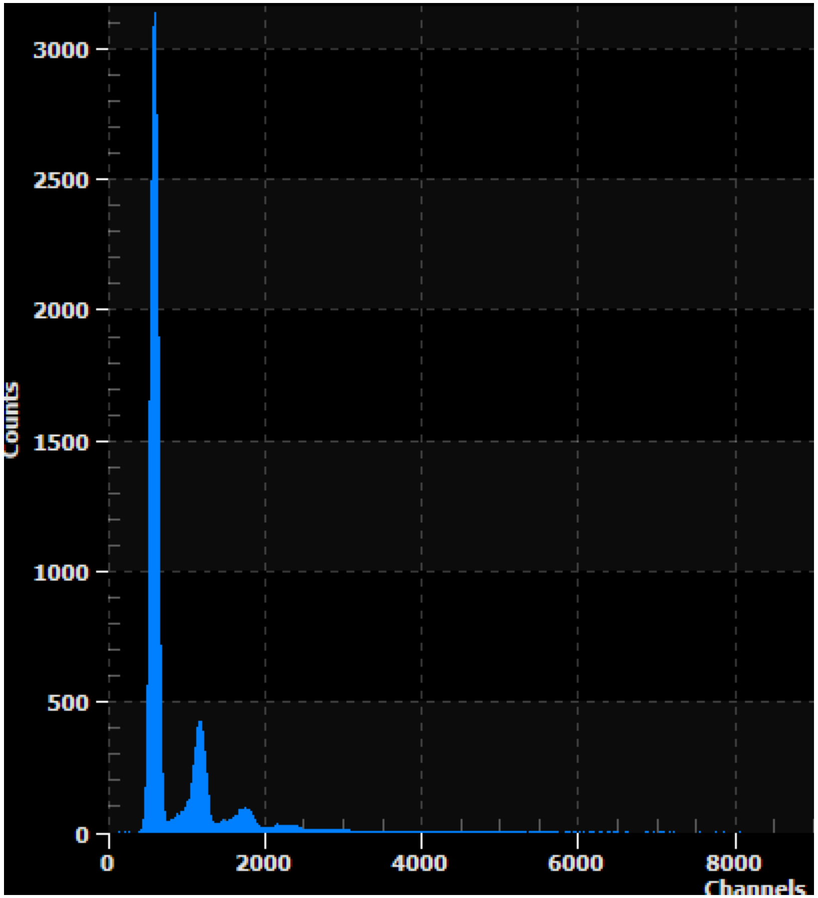
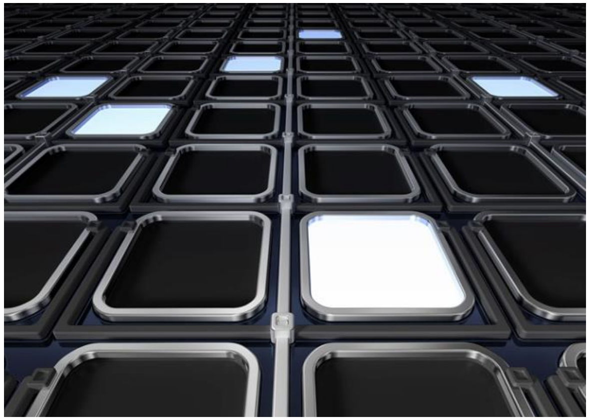
EXERCISE

Single Pulses

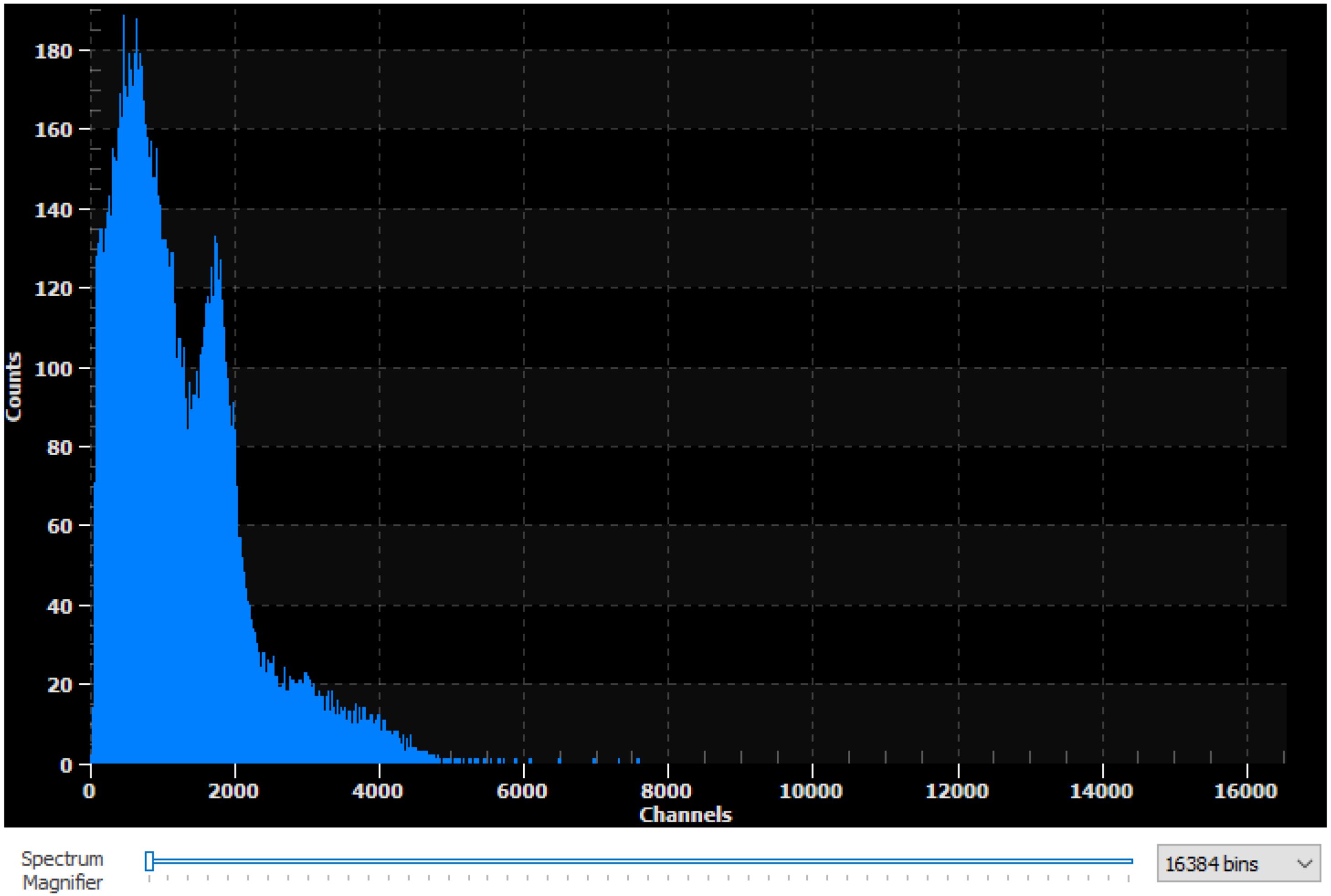


Multi Photon Spectrum

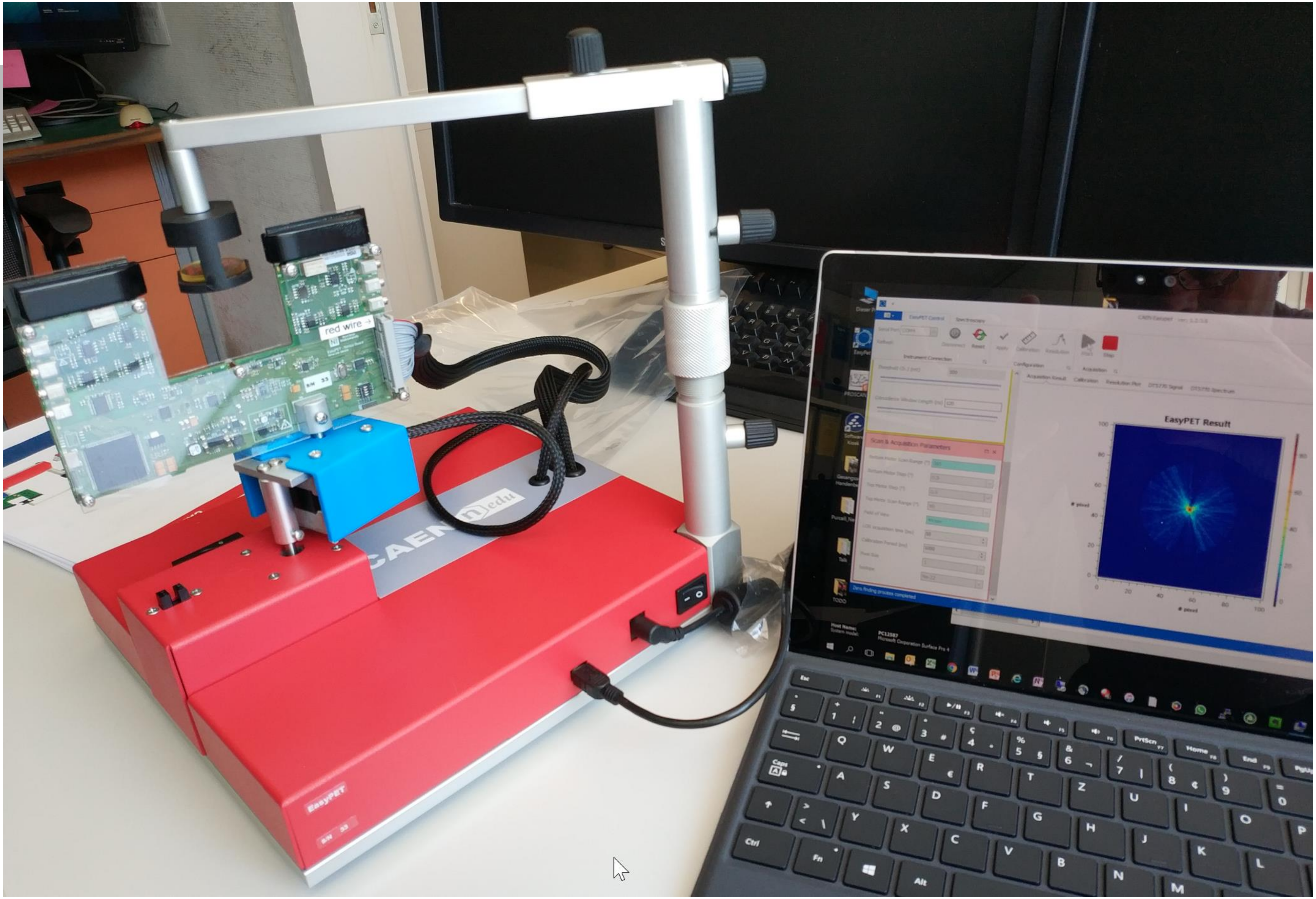




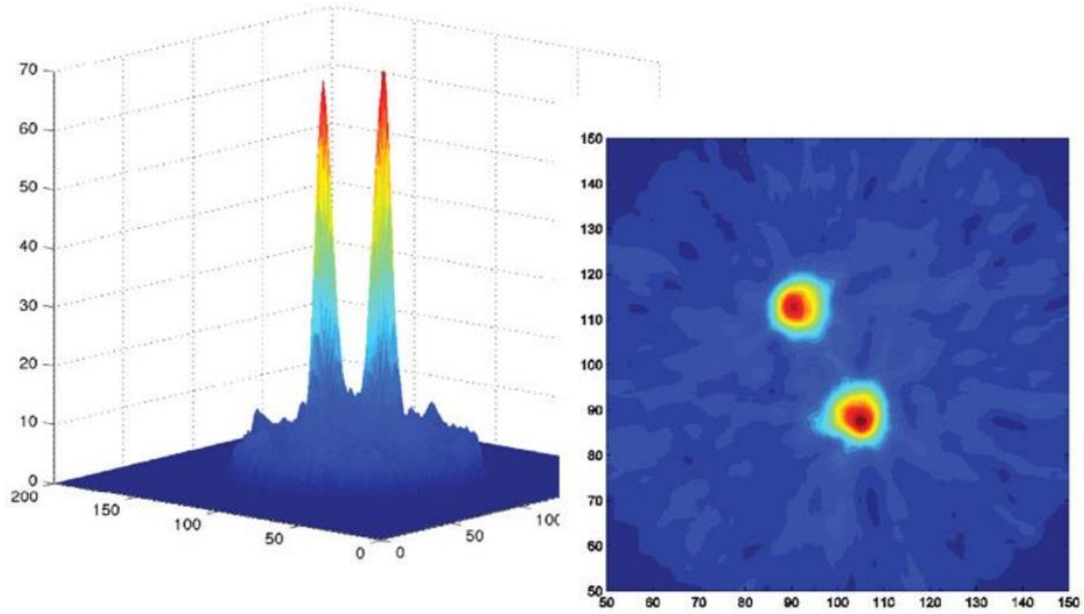
Gamma Spectrum



PET image



Two sources resolution



^{22}Na sources, 5 µCi, 2.7 mm Ø and 9 mm apart.

Seminar Room PG 57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