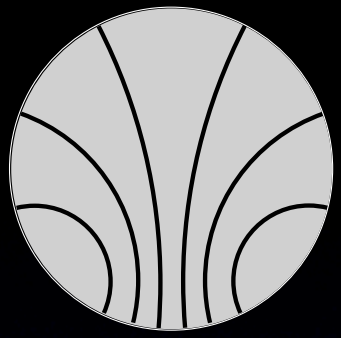

Application of Multi Pixel Photon Counters (MPPC) to PET

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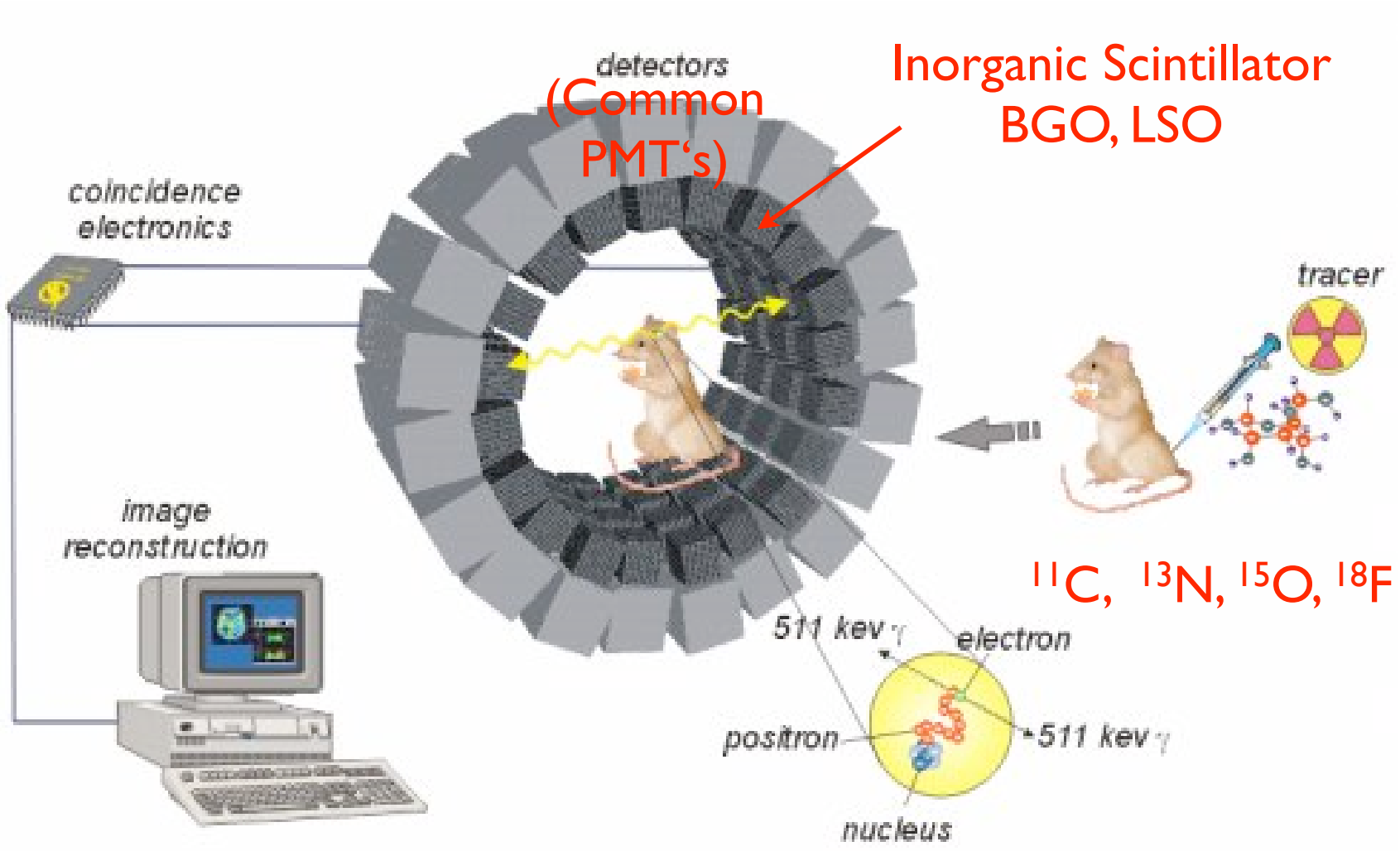
  DESY Hamburg
- Alexander Tadday
  Kirchhoff-Institut für Physik - Universität Heidelberg

Light 07 workshop 23-28.09.07
Ringberg Castle, Tegernsee

Outline

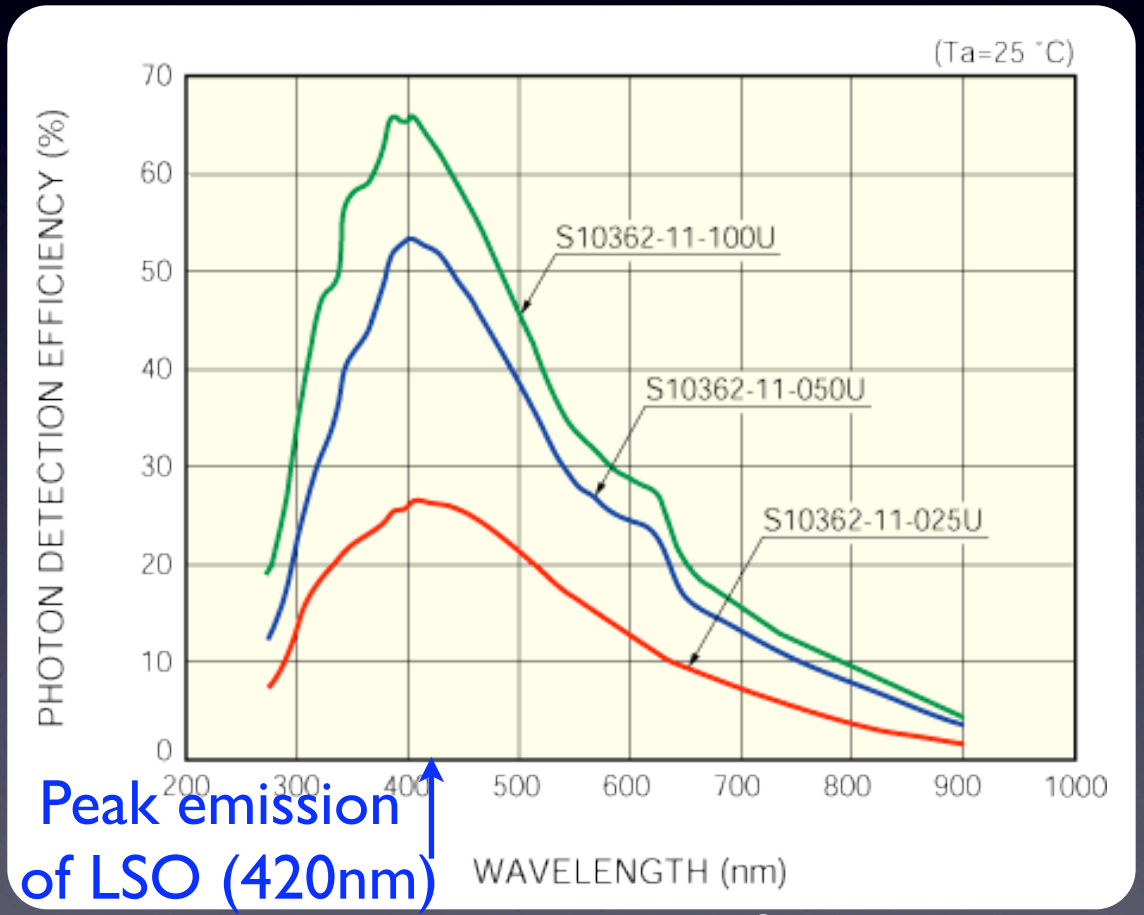
- Introduction to Positron Emission Tomography (PET)
- Why use Multi Pixel Photon Counters (MPPC)?
- Background reduction
- Setup
- Results

Introduction to PET



Why use MPPC's

- Scintillation light from LSO is blue
  - MPPC has high sensitivity in the blue range



Source: Hamamatsu

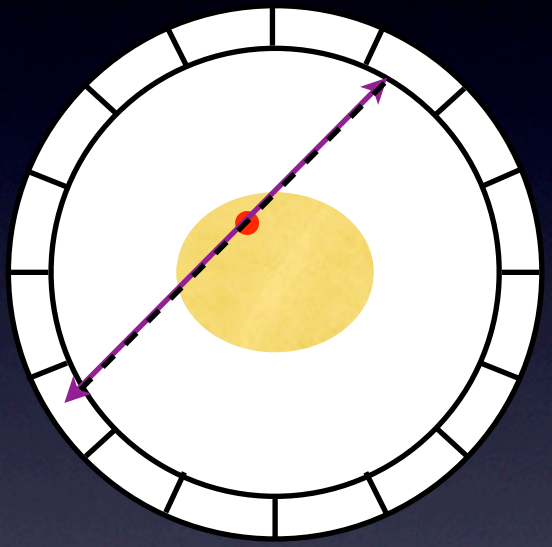
Why use MPPC's

- Spatial Resolution
  - Small size
    ➥ possibility to study single crystal readout with size from 1×1-3×3mm^2
- Fusion of PET and MRI (small PET detector contained in MRI)
  - Not sensitive to magnetic fields
- High gain, low operation voltage

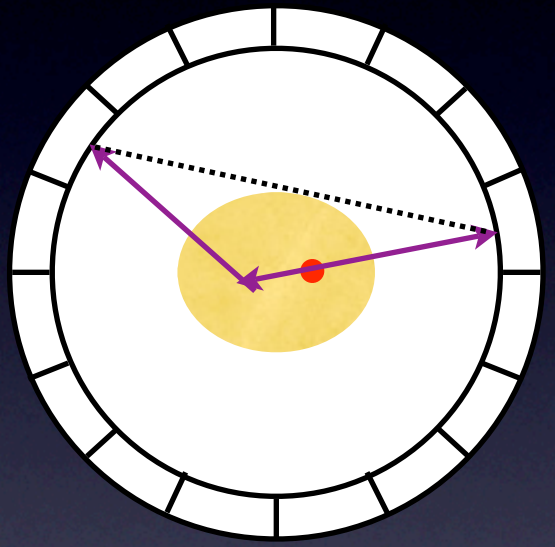
Reduction of Background

Energy Resolution

True coincidence



Scattered coincidence



Annihilation point

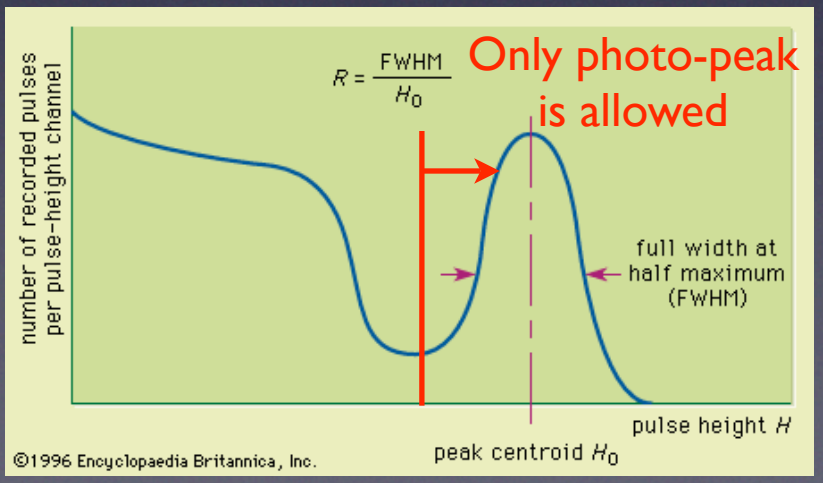
Gamma ray

Line of response

Why is energy resolution crucial for PET?

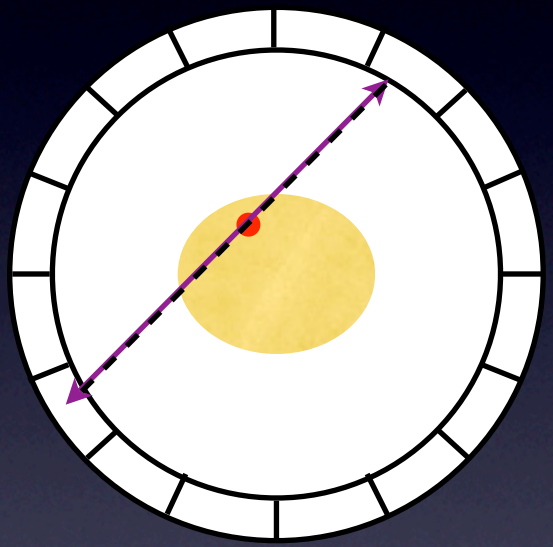
Cut scattered events but keep true events

➥ need good energy resolution

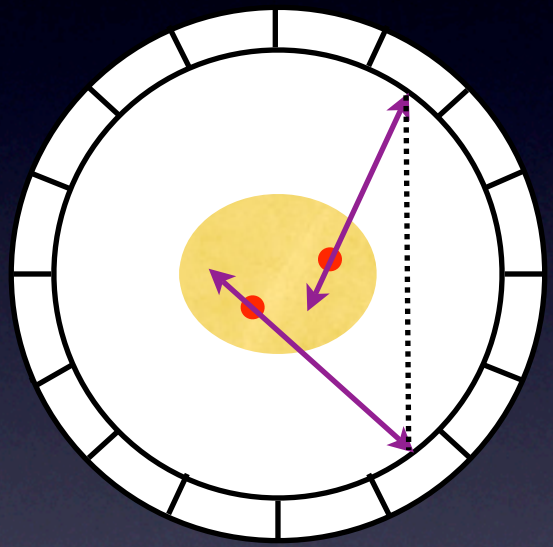


Timing Resolution

True coincidence



Random coincidence



Annihilation point

Gamma ray

Line of response

Keep coincidence window as small as possible to reduce Random coincidences

➥ need good timing resolution

Time of Flight PET

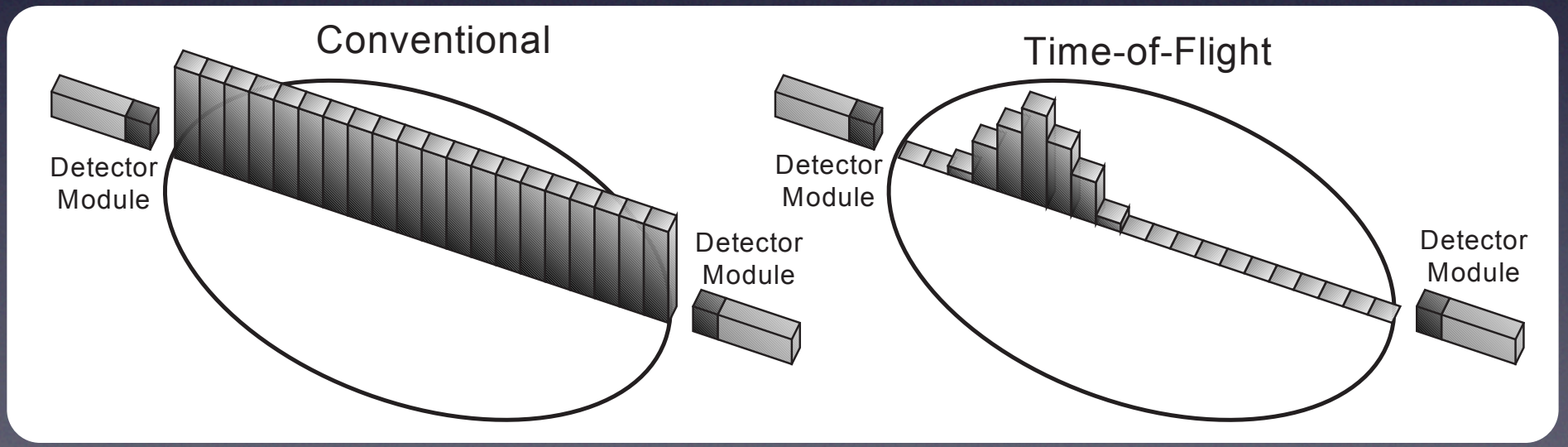
- Accuracy of position measurement is: (for Δt = 500ps)

$$\Delta x = \frac{c}{2}\Delta t = 7.5cm$$

- ➥ No gain in spatial resolution but noise variance decreases

$$f = \frac{D}{\Delta x} = \frac{2D}{c\Delta t}$$

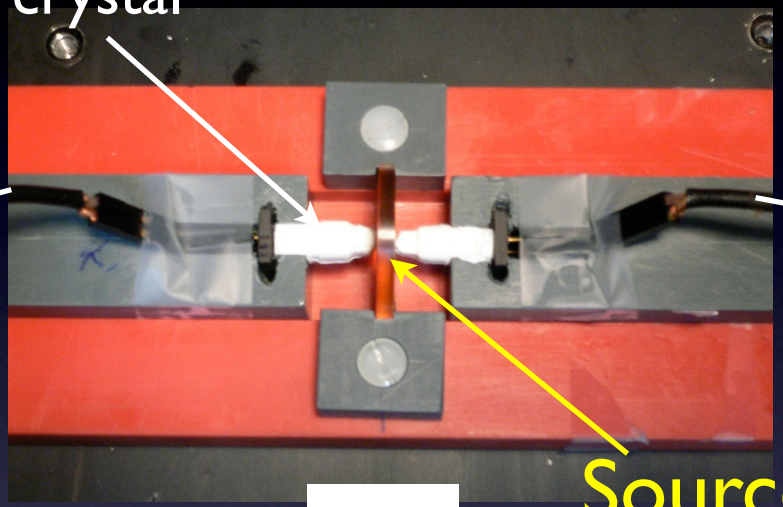
D: Size of emission source



Advantages of Improved timing accuracy in PET Cameras using LSO Scintillator, W.W. Moses LBNL-51788

Setup

Scintillating crystal



Source Na^{22}

&

Gate ≈160ns

QDC

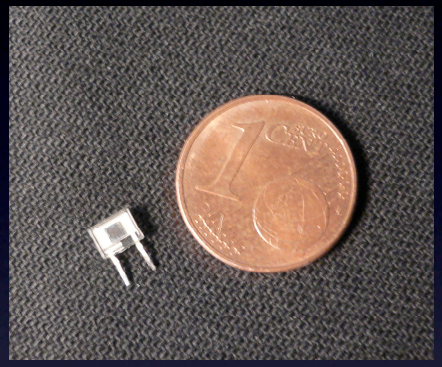
LeCroy
Model 1182
250pC FSR

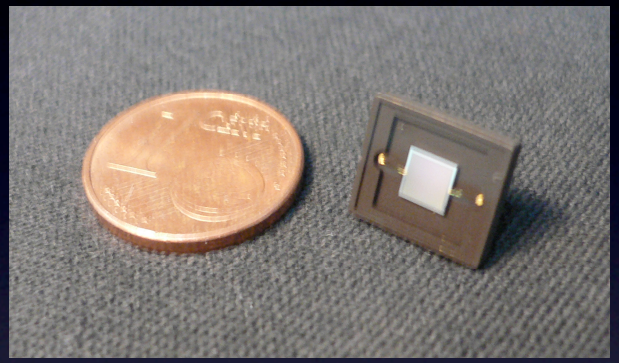
Computer

Used Scintillators

Crystal	Size	Peak emission	Decay time
LSO (Lutetium Orthosilicate), Hilger Crystals	$1\times1\times15mm^3$ $3\times3\times15mm^3$	420nm	40ns
LFS (Lutetium Fine Silicate), Lebedev Institute	$3\times3\times15mm^3$	blue	similar to LSO

Readout with MPPC's from Hamamatsu





Pixels	Active area	Operating voltage	Dark rate 0.5 pixels	Dark rate 1.5 pixels	Gain 10^5
400	$1\times1mm^2$	76V	220k - 250kHz	9k - 10kHz	7.4 - 7.5
3600	$3\times3mm^2$	70V	3.2 - 3.3 MHz	320k - 330kHz	7.4 - 7.5

Results: Energy Resolution

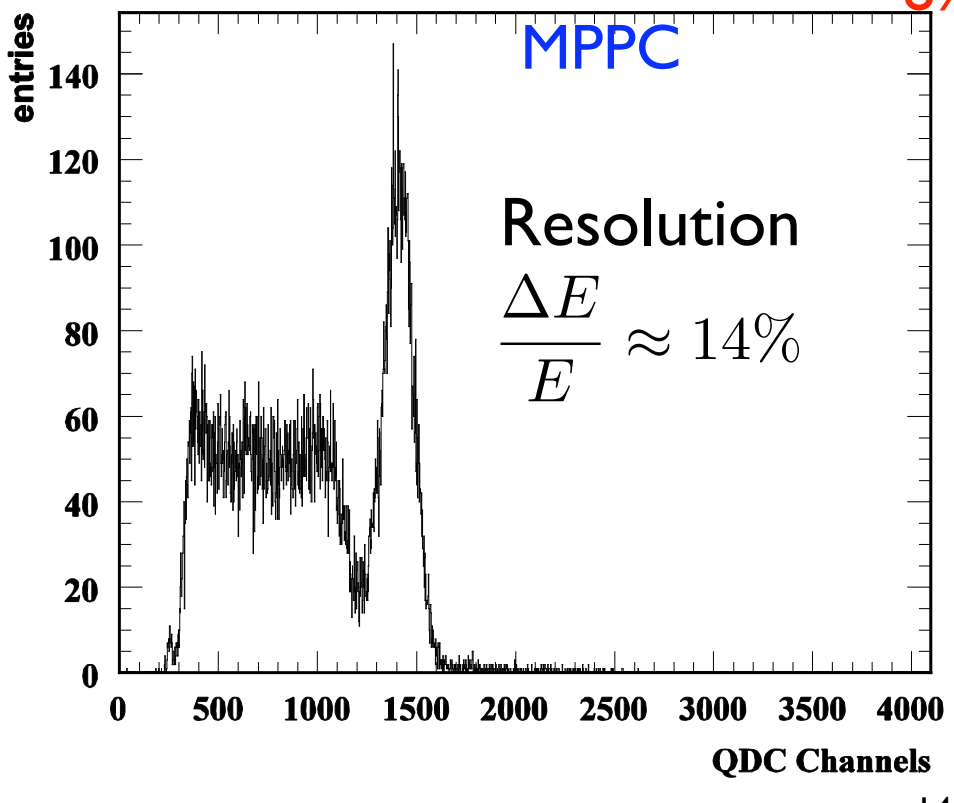
1×1×15mm³ LSO with 1×1mm² MPPC

$$\left(\frac{\sigma(E)}{E}\right)^2 \approx \left(\frac{1}{\sqrt{N}}\right)^2 + (\Delta_{intr}(E))^2 + \left(\frac{\sigma_{noise}}{E}\right)^2$$

blue sensitive MPPC

~8% for LSO

negligible



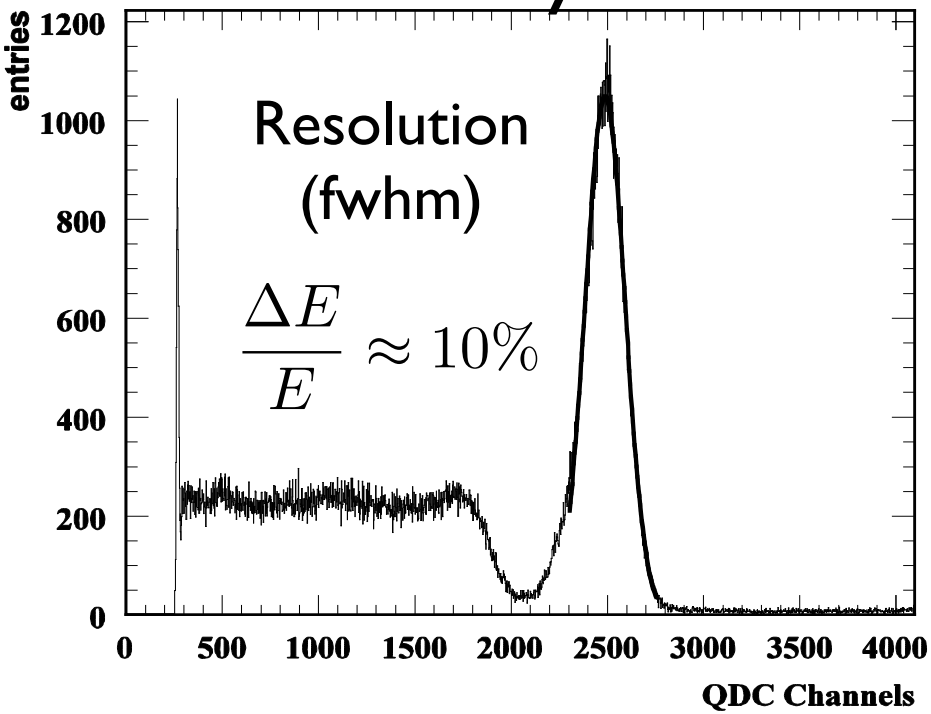
Energy resolution of 14% (fwhm) was measured

Coupling between crystal and MPPC is main systematic error ≈10%

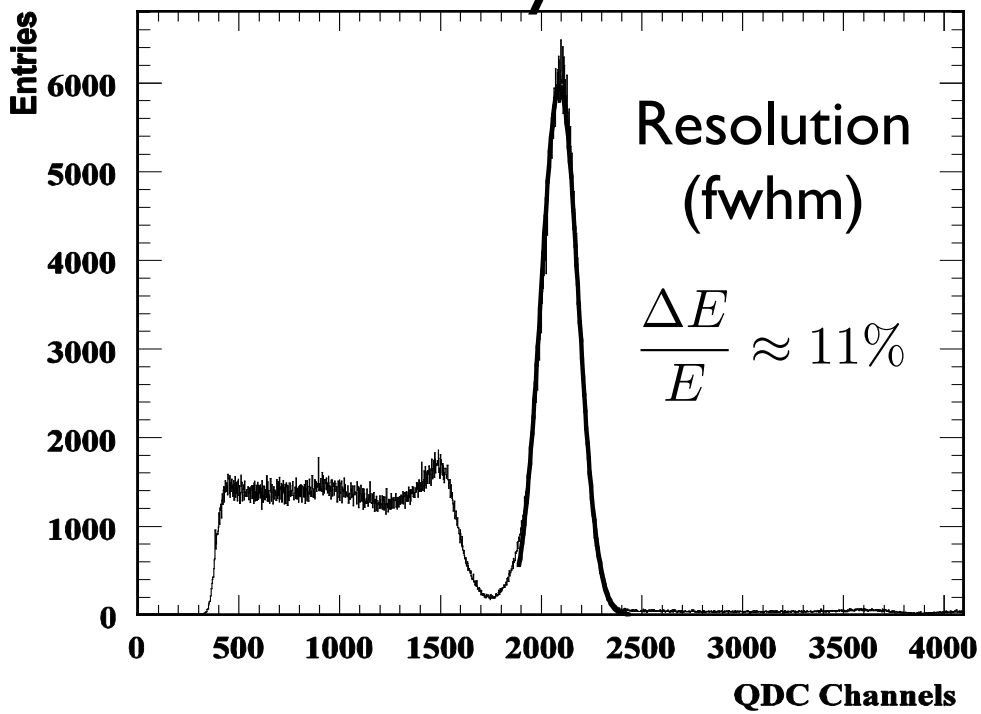
Improvement possible!

3×3×15mm³ LSO & LFS with 3×3mm² MPPC's

LSO Crystal



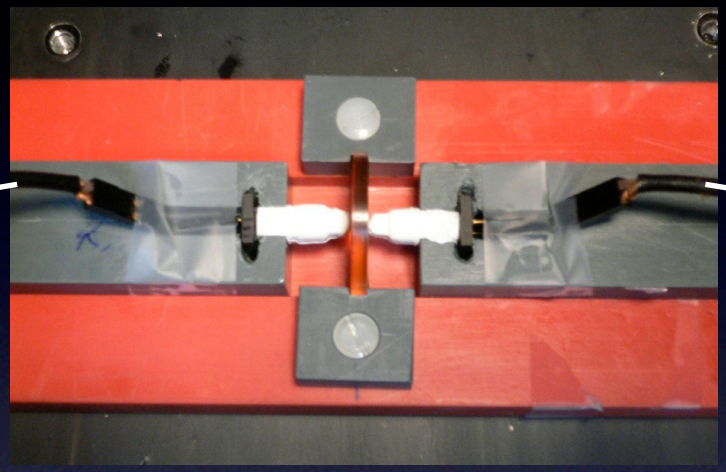
LFS Crystal



LSO and LFS are equal within systematics ~3%
Typical value with "traditional" Photomultiplier tube (511key) : 10%

Timing Measurement

Setup



No Preamplifiers needed!
Direct evaluation with oscilloscope

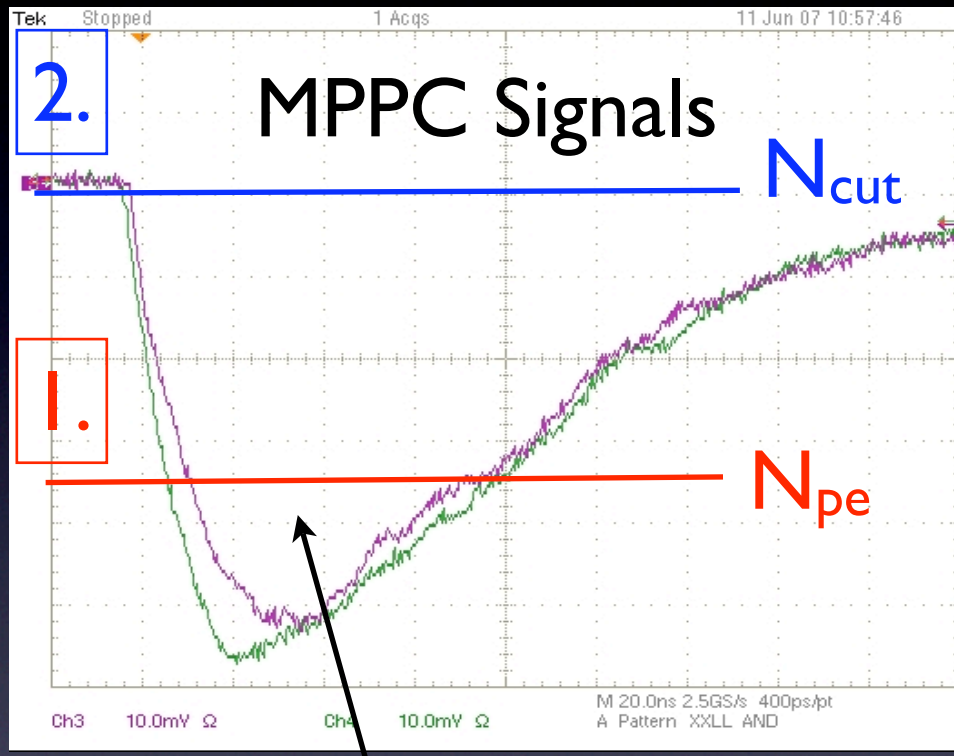
Oscilloscope

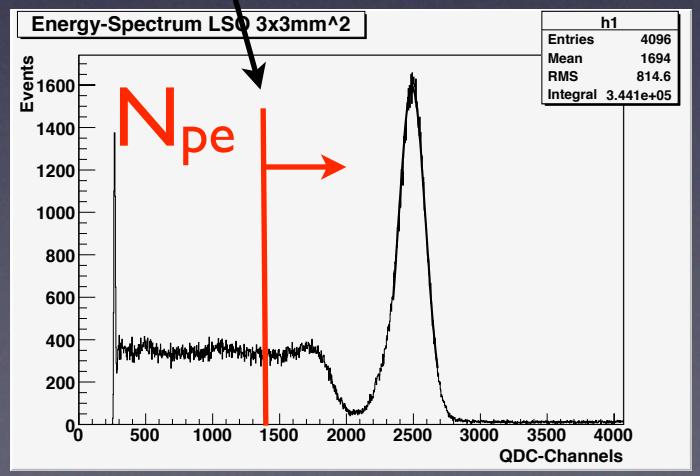
Oscilloscope: Tektronix Model 7204, Bandwidth 4GHz, 20GS/s
⇒Time resolution 50ps

Timing Measurement

1. Define coincidence threshold N_{pe}
2. Define timing threshold N_{cut}

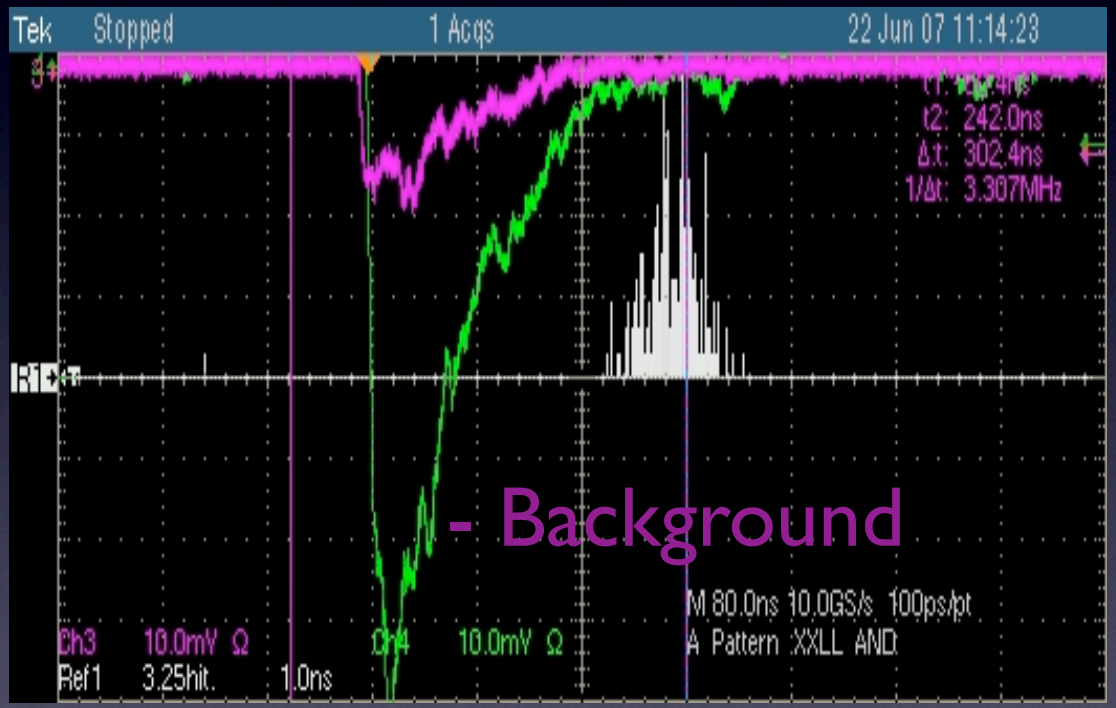
$$S_1 > N_{pe} \wedge S_2 > N_{pe}$$
$$\Delta t = t_1(N_{cut}) - t_2(N_{cut})$$



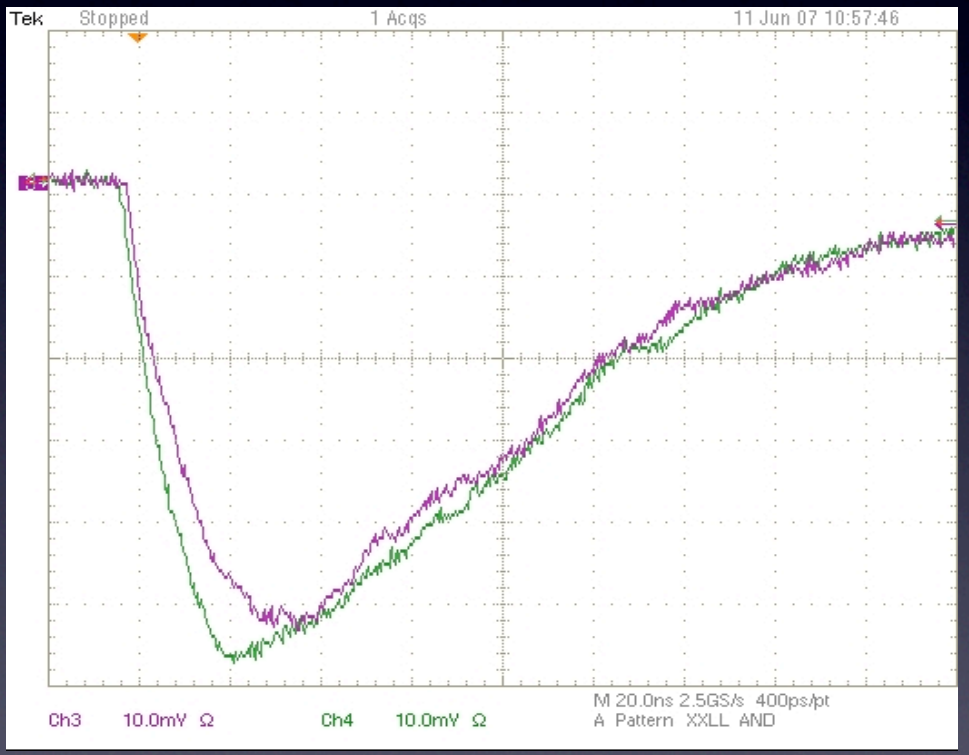


Timing Measurement

"Background event"



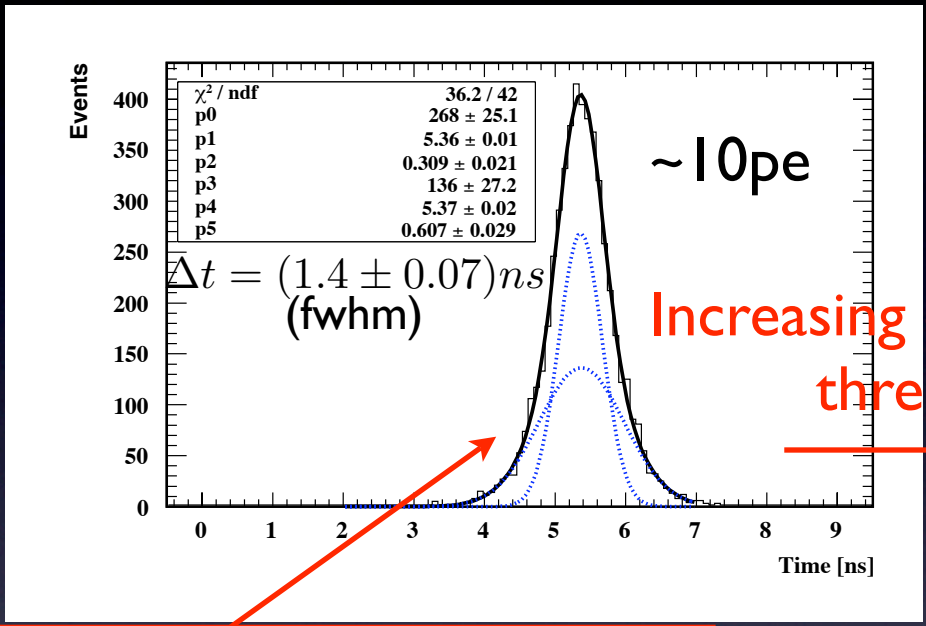
"Photoelectric event"



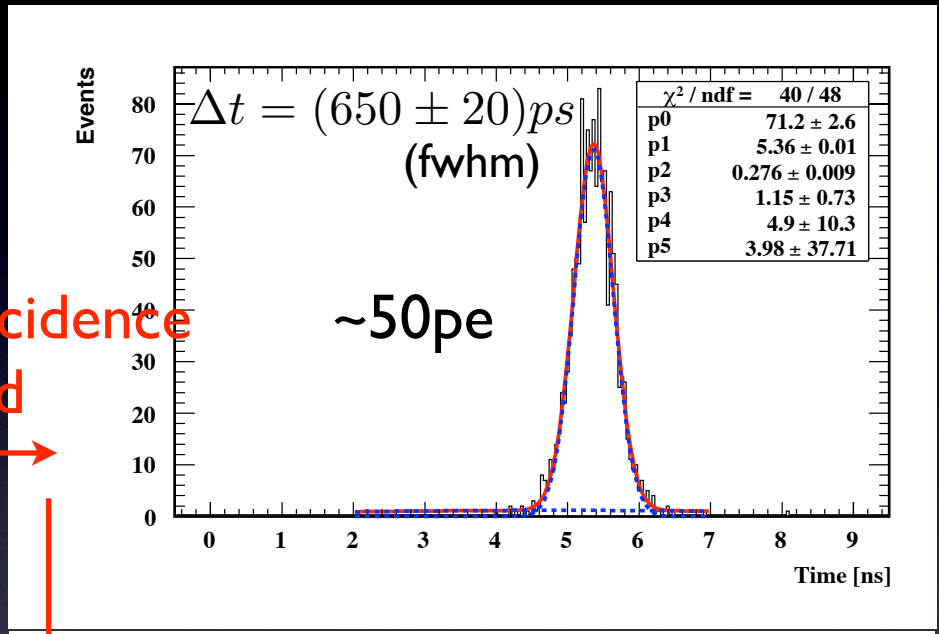
A Background is superimposed and ruins the timing

➥Need to go to high coincidence threshold

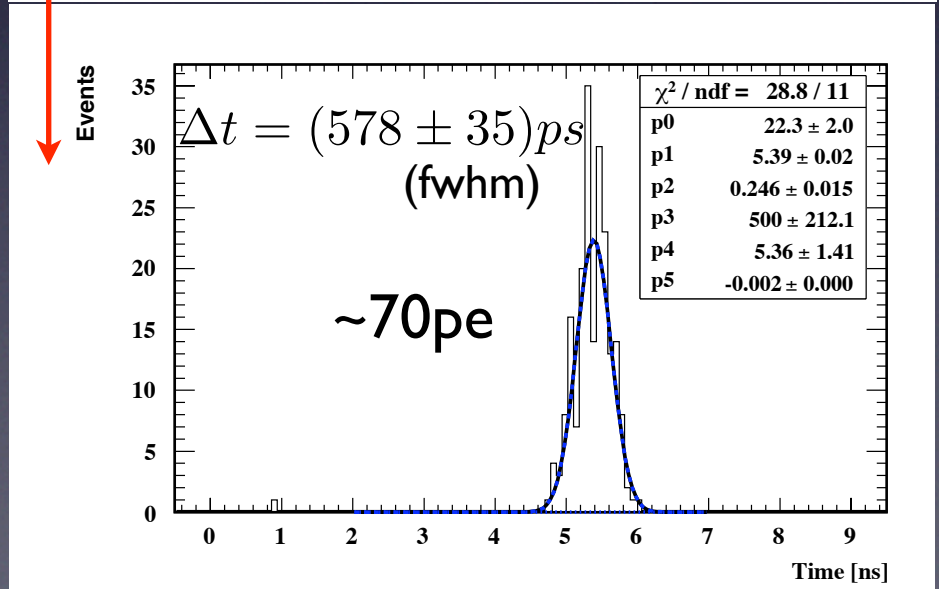
Results Timing



Increasing coincidence threshold



Background worsens timing from 700ps to 1.4ns



Conclusion & Outlook

- MPPC's show very promising properties for the application of Geiger Mode Avalanche Photodiodes in PET
  - Energy Resolution: 10% (fwhm)
  - Timing Resolution: 580ps (fwhm)
- More studies needed
  - Which Crystal LSO, LFS
  - spatial resolution of matrix
  - Build a prototype and verify the concept

End of Presentation
Thank you for your attention!