Initial PET Measurements for the SAFIR project

Christian Ritzer for the SAFIR collaboration
Outline

- The SAFIR Project
- Introduction to MRI & PET
- Testsetups for SAFIR and Measurement Results
- Summary & Outlook
The SAFIR Project

Small Animal = mice & rats
→ inner diameter 130 mm

Fast = PET image acquisition time <5 s
→ high activity (500 MBq)
→ low dead time

Insert = for Brucker BioSpec 70/30
→ 200 mm outer diameter
→ simultaneous image acquisition for MRI

Quantitative Kinetic Neuroimaging
The SAFIR Project

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- Electronics compartment 1
- Sensor compartment
- Electronics compartment 2
- Cylindrical design
- 24 identical detector

Very fast PET insert to make unknown processes in the brain visible
Introduction to Magnetic Resonance Imaging

Basics:

- Based on nuclear magnetic resonance (NMR)
- Combined with spatial encoding

- 3 em-fields: B0 (7T & static)
  - Gradient fields (~100mT & dynamic)
  - HF (300MHz signal)
- Gradients to „distort“ the static field → spatical encoding
- Many sequences, but mainly sensitive to Water
Introduction to Positron Emission Tomography (PET)

Phantom or Animal

\[ ^{18}\text{F} \quad ^{15}\text{O} \quad ^{11}\text{C} \]

\[ \text{CH}_2\text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \quad \text{OH} \]

Scintillator + SiPM

Signal Processing
Introduction to Positron Emission Tomography (PET)

\[ e^+ - e^- \text{ annihilation} \rightarrow \text{photon pairs (511keV)} \]

lines between interactions form an image

\((^{18}\text{FDG}) = \text{sugar}\)
Combining PET & MRI

Advantages of PET
- Functional imaging
- High sensitivity

Advantages of MRI
- Anatomical imaging
- High spatial resolution
- Very good soft tissue contrast

Challanges
- MR-compatible electronics
  non-magnetic & no HF emission
- Spatial constraints for the detector

Weissler et al. 2015 (DOI 10.1109/TMI.2015.2427993)
Detection of Gamma Rays

Scintillator
- LYSO-crystals
  - decay time: ~42 ns
  - light output: ~30000 photons/MeV
  - rad length: ~1.15 cm
- crystal dimensions: 2.1×2.1×12 mm³
- 2.2 mm pitch
- 8x8 arrays, with one-to-one coupling

Photodetector
- Hamamatsu "MPPC", pixel size: 2×2 mm²
- Expected singles rate up to 10 kHz/mm²
Test Setup

Components
- 2 matrices with 2 SiPMs
- 16 channels of each SiPM are used
- 1 ASIC „PETA6“
- Power + Clock
- Some electronics for data transfer

Main objectives
- Understand the ASIC
- Obtain reference values for timing resolution & energy resolution
- Test calibration routines
- Verify analysis software
Measured Energy Spectrum

Energy resolution is limited by SiPM (intrinsic resolution is ~10% FWHM)

Photo peak (15.2% FWHM)

secondary peak (1275keV from $^{22}$Na)
Measured Coincidence Timing Spectrum

Difference of arrival times (227ps FWHM, from fit)

Timing resolution is limited by scintillation material
Comparison to Simulation

Red = Simulation
Black = Data

Good agreement, but Compton spectrum is different

(different data set)
Comparison to Simulation

Red = Simulation
Black = Data

Good agreement, systematically less events (-6%)
(structure due to source position)
(different data set)

Missalignment of source?
Towards a PET Insert

Improvements
- MR compatible!
- Many more readout channels 144 (432)
- Gigabit Fibre Connection (compared to USB2)
- Power converters → less input power

Main objectives
- Develop firmware for FPGA
- Verify MR compatibility
- Test synchronisation of boards
- Replicate results from simple setup
Energy Spectrum - Projection

One readout channel not working
Similar to the spectrum from the small setup slightly better energy resolution

Energy Spectrum

Photo peak (14.7% FWHM)
Summary & Outlook

- Basic detector concept works well
- Very good timing resolutions and fair energy resolution
- Firmware is currently under development + some improvements in the hardware
  (Boards are already tested in the MRI)
- Next up we will build the first ring with 12 boards
SAFIR collaboration

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Thank you for the attention!
Questions?