Towards SiPM readout for Phoswich

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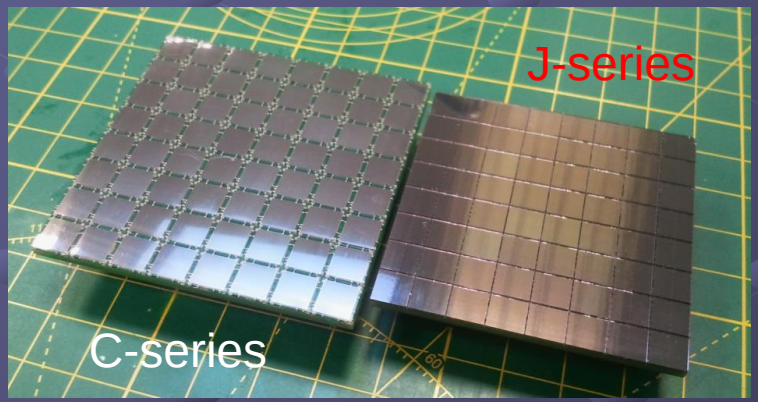
J-Series Family SiPM array 2”x2”

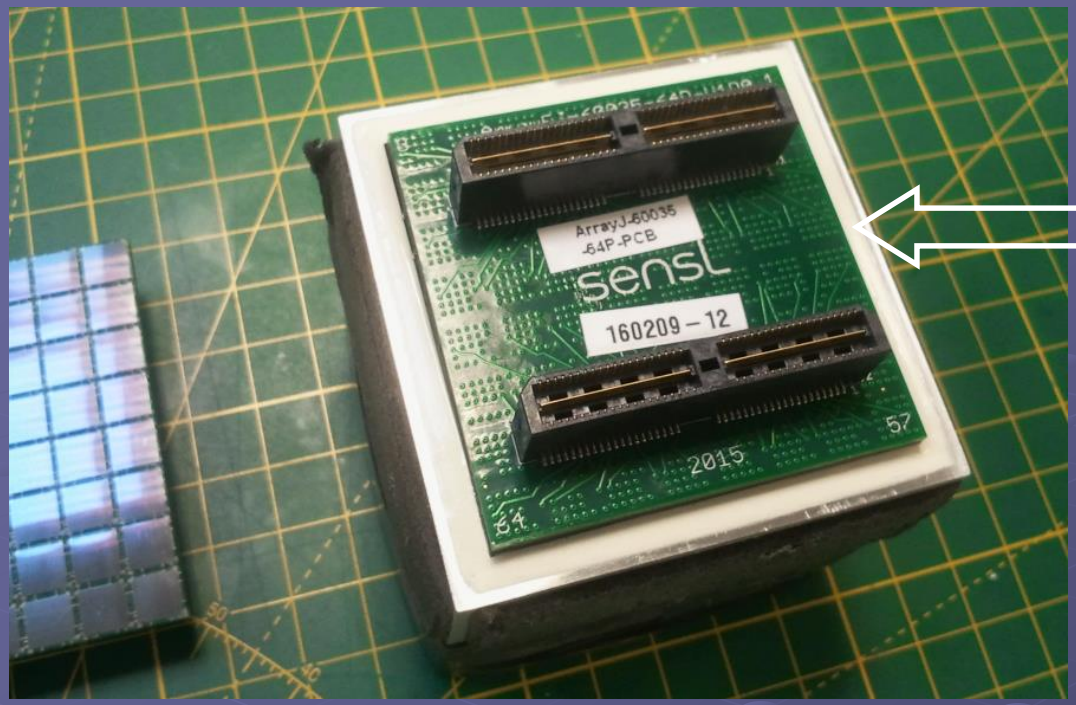
@ York University

The High-Density Fill Factor Silicon Photomultipliers highlights:

- Optimized for high-performance timing applications, such as ToF-PET
- >50 % PDE at 420 nm, facilitated by high-density fill factor microcells
- Ultra-low dark count rates of 35 kHz/mm2 typical
- Signal rise time and the microcell recovery time have been improved, and in addition, the J-Series sensors feature separate fast output terminal
- High breakadown voltage uniformity (+/-250 mV) for J-Series products
- Temperature stability of 21.5 mV/°C, negating the need for active voltage control
- Low bias voltage of <30 V
- Available in a reflow solder compatible TSV chip-scale package that has close to zero deadspace between pixels and is ferrous-metal free
- 3 mm2 and 6 mm2 sensor pixel sizes



sensl.com/products/sipmarrays/arrayj



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J-series array attached to the LaBr3 2”x2”x2” scintillator from Krakow

Increase ~ 15% in Fill Factor and ~ 10% in PDE with respect to C-series SensL array.

J-series array + LaBr3 2x2x2” vs fast PMT + small LaBr3

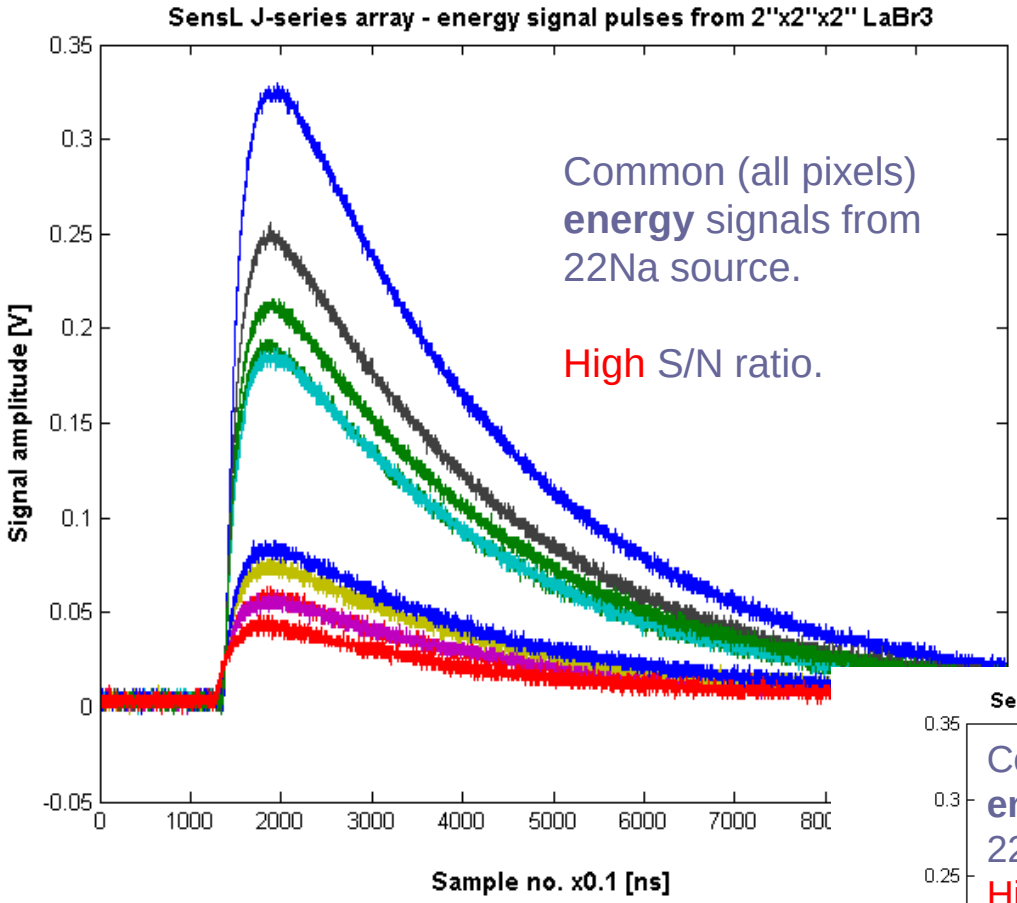
Timing output – 4 pixels

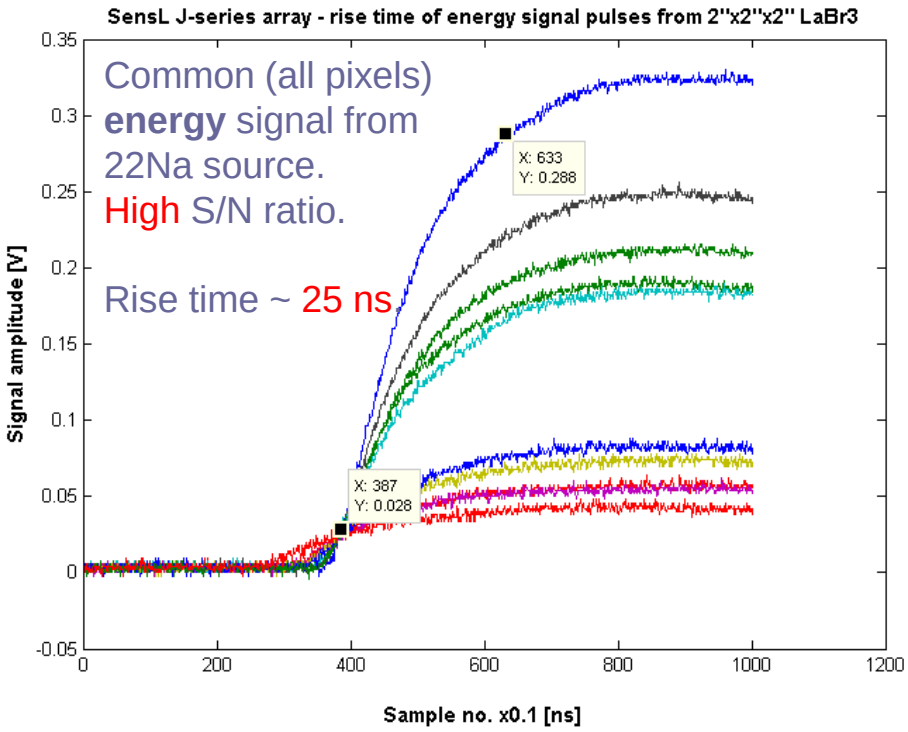
Energy output – 64 pixels

signals sampled @ 10GS/s

SiPM J-series
Energy output signals

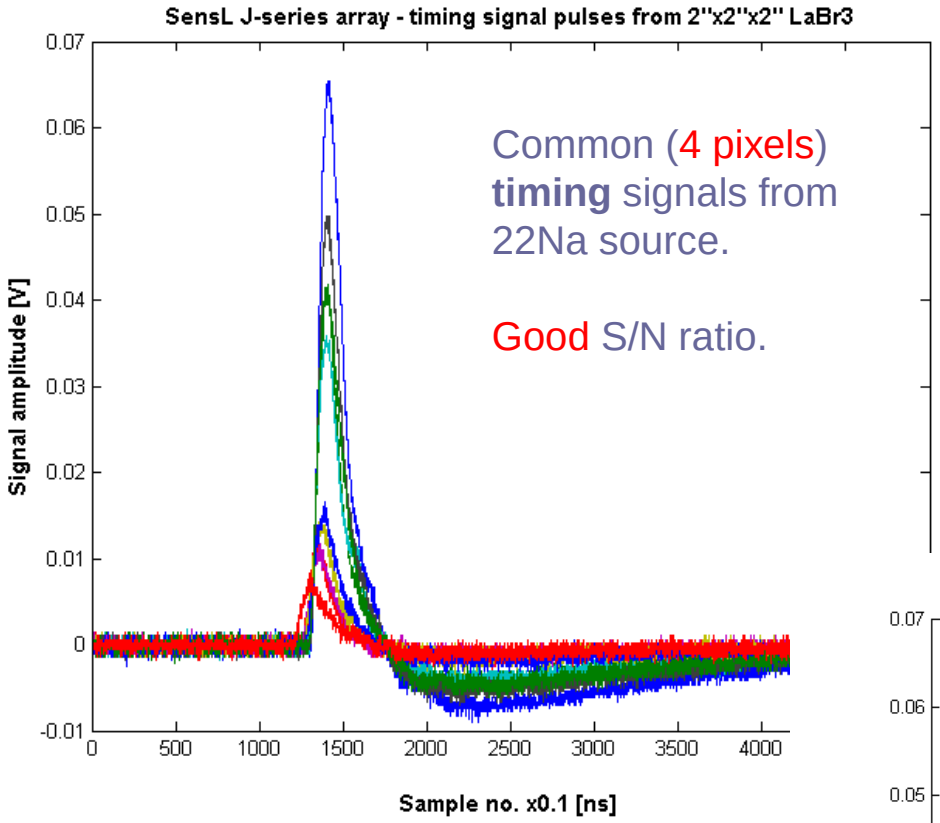
SensL J-series with the LaBr3 2”x2”x2” scintillator. Energy output signals (sum of all 64 pixels).





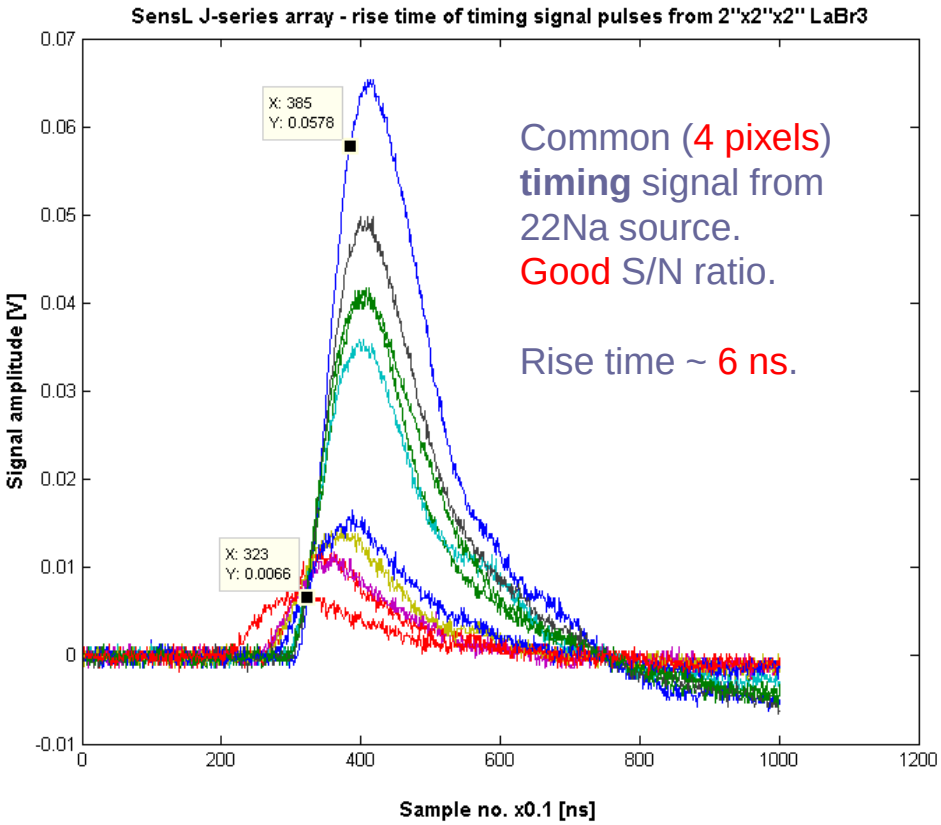
SiPM J-series Timing output signals

SensL J-series with the LaBr3 2”x2”x2” scintillator. Timing output signals (sum of 4 pixels).



Common (4 pixels) **timing** signals from 22Na source.

Good S/N ratio.

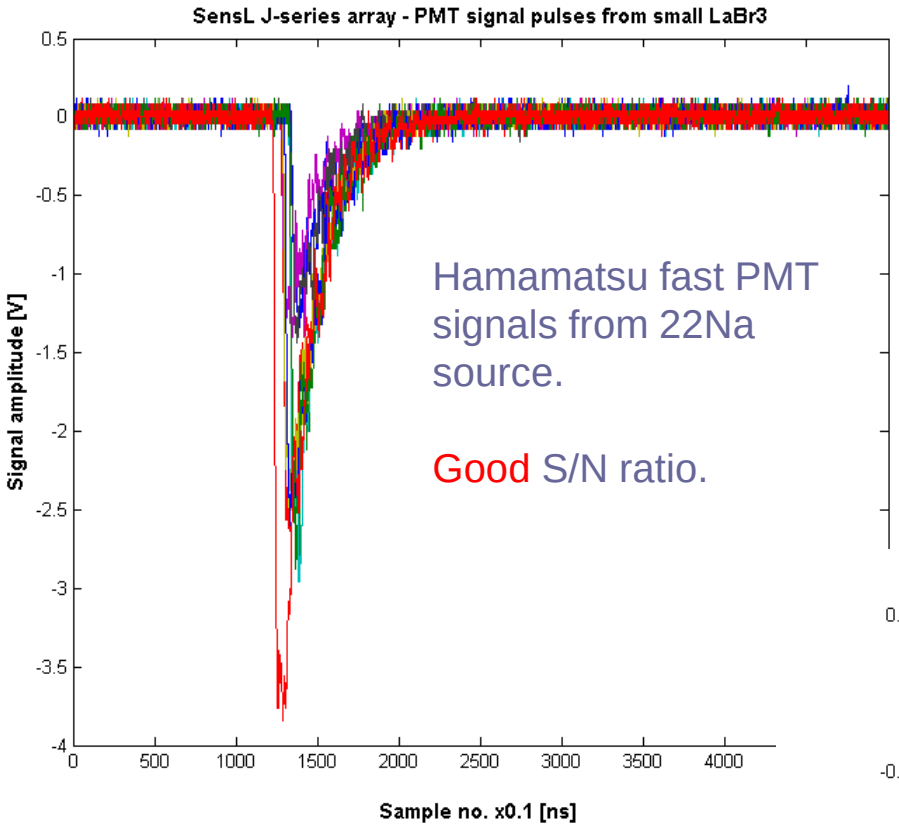


Common (4 pixels) **timing** signal from 22Na source.
Good S/N ratio.

Rise time ~ 6 ns.

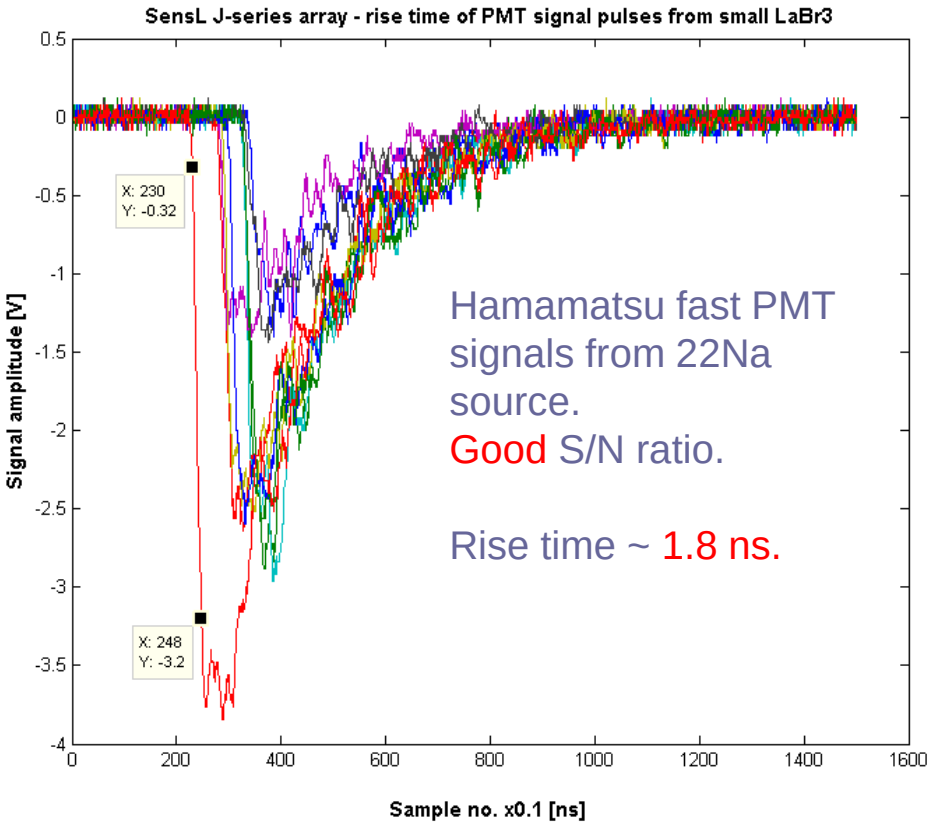
Fast PMT output signals

Hamamatsu fast PMT with small LaBr3 scintillator.
Output signals.



Hamamatsu fast PMT signals from 22Na source.

Good S/N ratio.



Hamamatsu fast PMT signals from 22Na source.
Good S/N ratio.

Rise time ~ 1.8 ns.

Timing performance

PMT (small LaBr3) vs SiPM J-series Energy output

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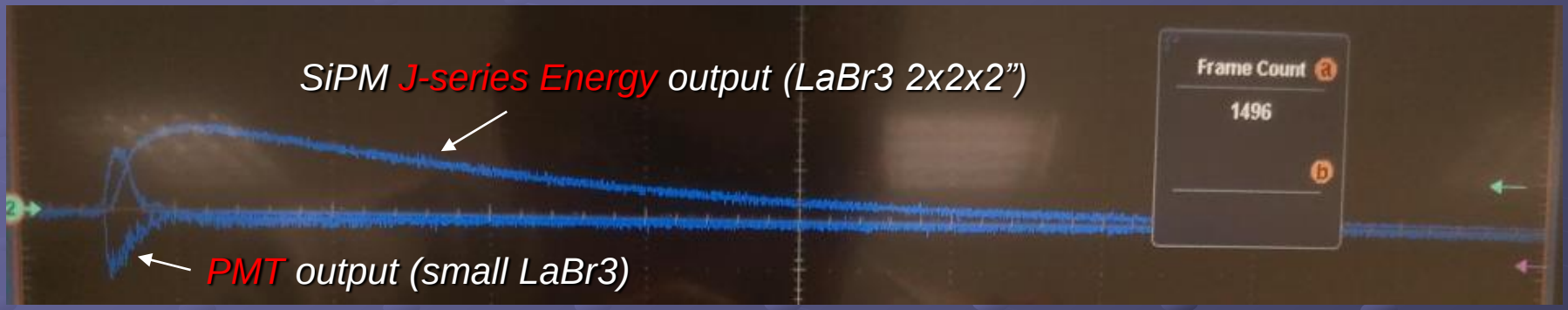
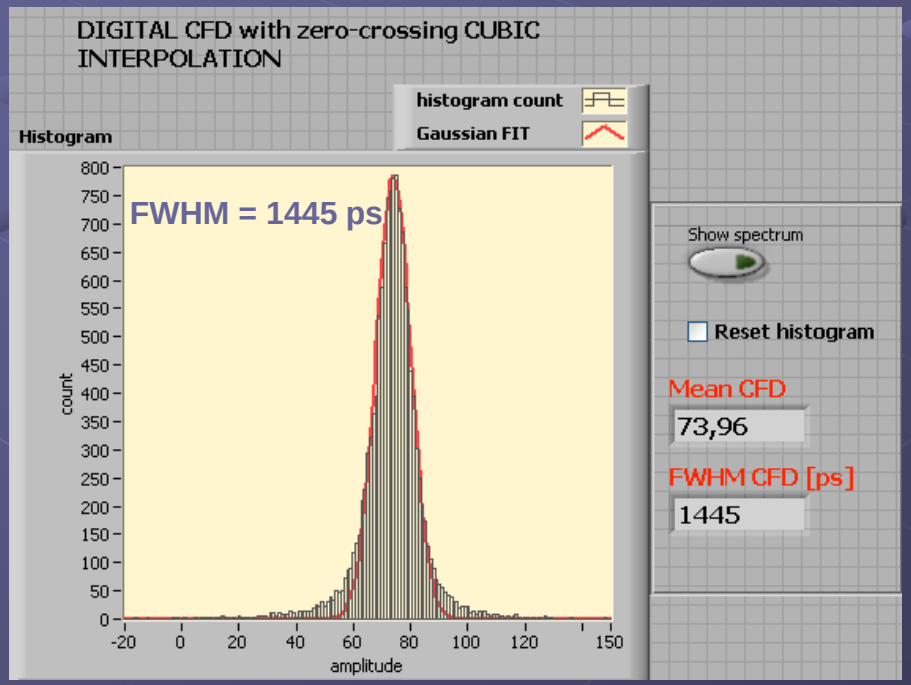
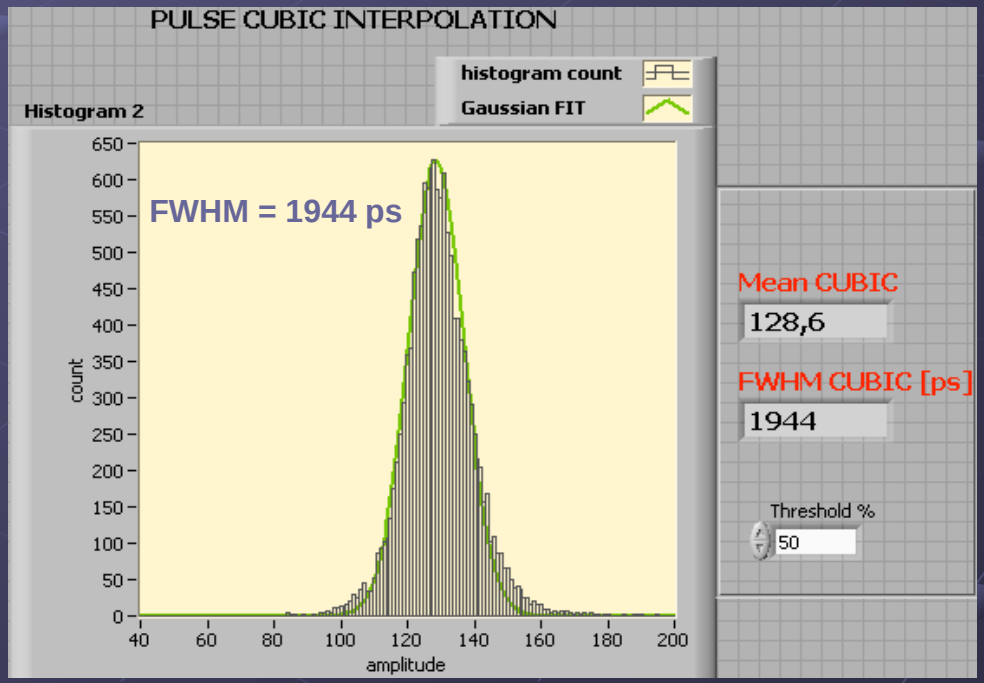
Coincidence timing pulses from 22Na source



2 different digital timing algorithms: Digital CFD vs Pulse Interpolation





Timing performance c.d.

PMT (small LaBr3) vs SiPM J-series Timing output

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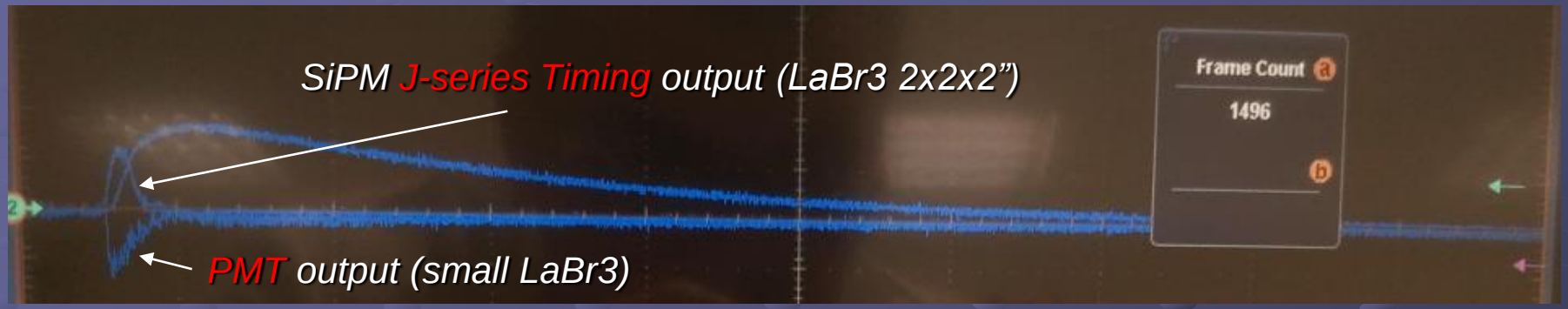
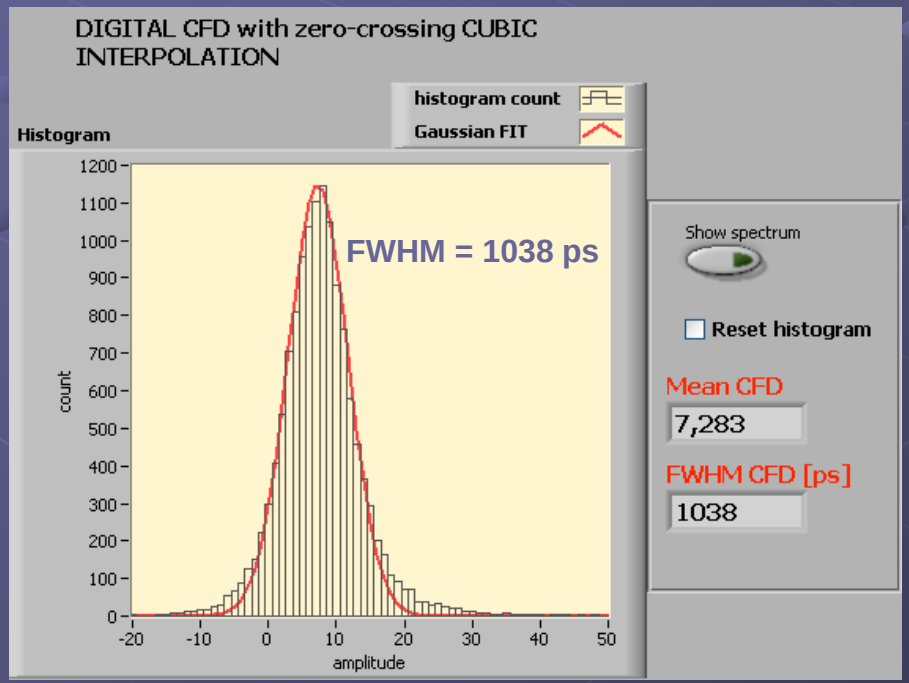
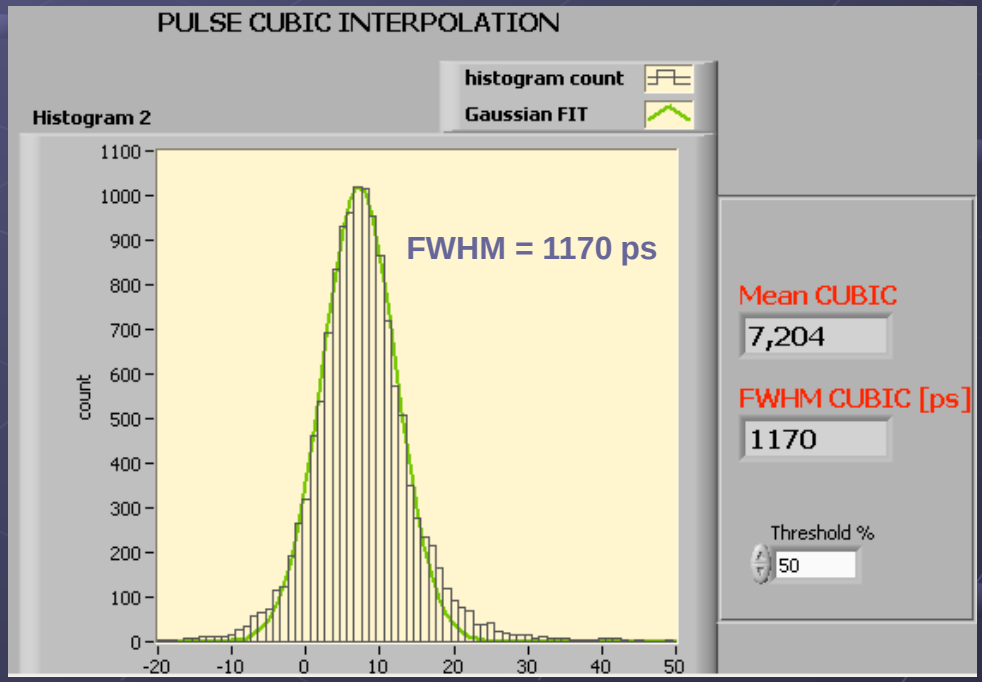
Coincidence timing pulses from 22Na source



2 different digital timing algorithms: Digital CFD vs Pulse Interpolation





Timing performance c.d.

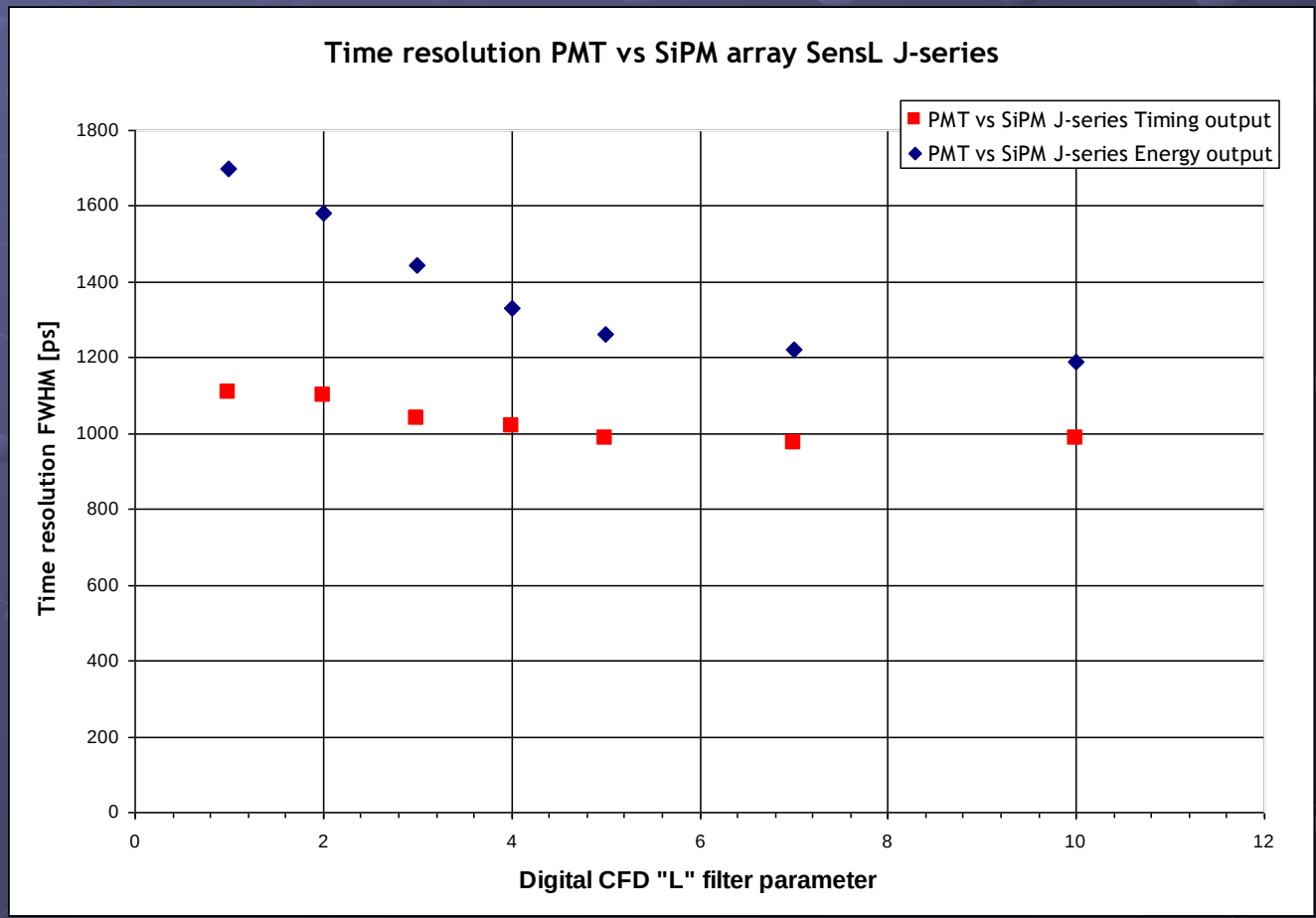
@ York University

Because of high sampling rate of digitizing oscilloscope (10 GS/s), we have „oversampled" signals (sampled with higher frequency than required). This however allowed us to improve S/N, thus improving also the time resolution.

The total time resolution formula for single detector

$$\sigma^2_{time} = [t_{rise}/(S/N)]^2 + \sigma^2_{t,digitization} + \sigma^2_{t,LaBr3}$$

The improvement in terms of timing resolution by „averaging" consecutive samples **is strongly visible especially for energy (slow) signal.**

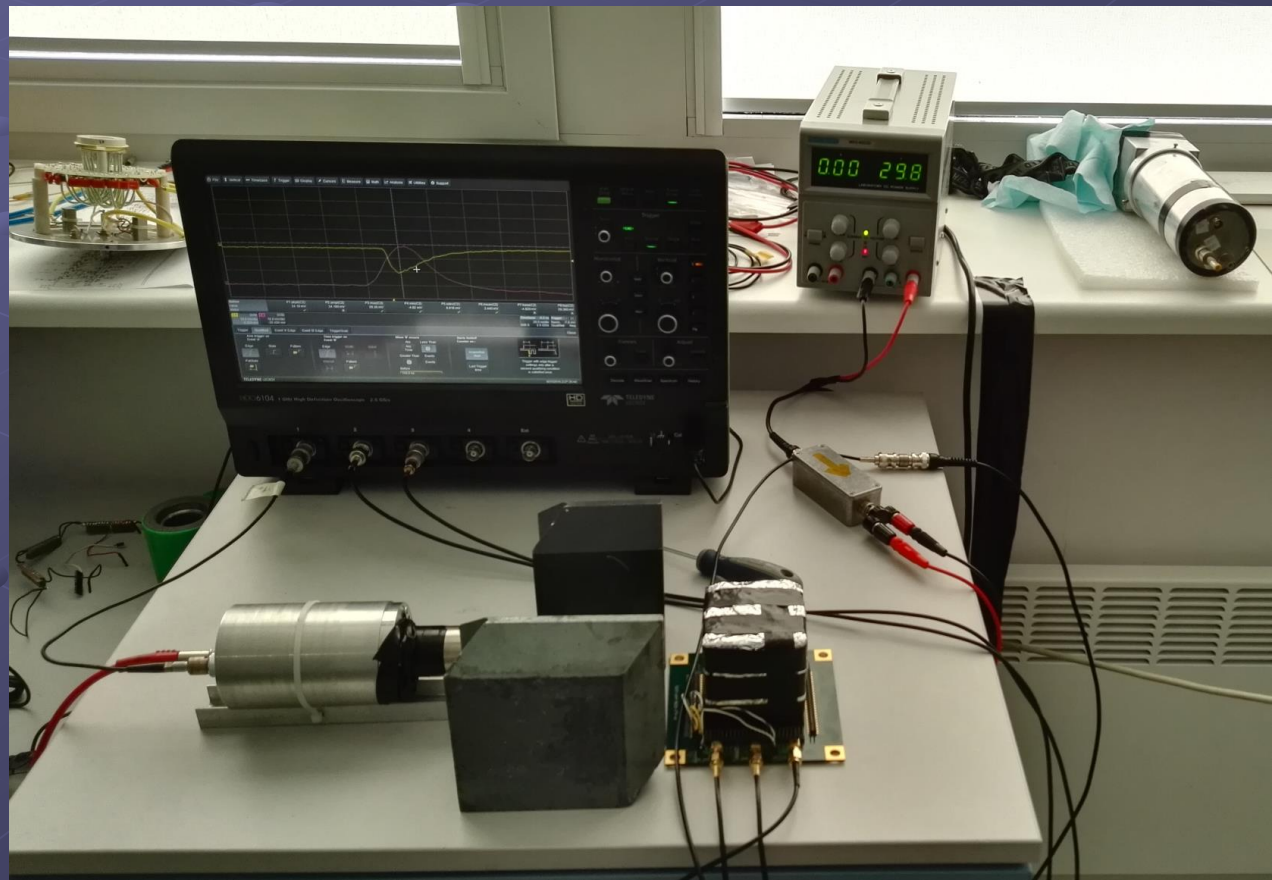


Setup with SiPM J-series in Krakow – sensor array delivered by York

After the first measurements of **2x2x2" LaBr3 coupled J-series SiPM array** at York,we would like to contribute in exploring their potential for PARIS.
We have prepared a dedicated setup to be able to continue tests to measure timing and energy with different crystals: LaBr3, NaI, Phoswich…?

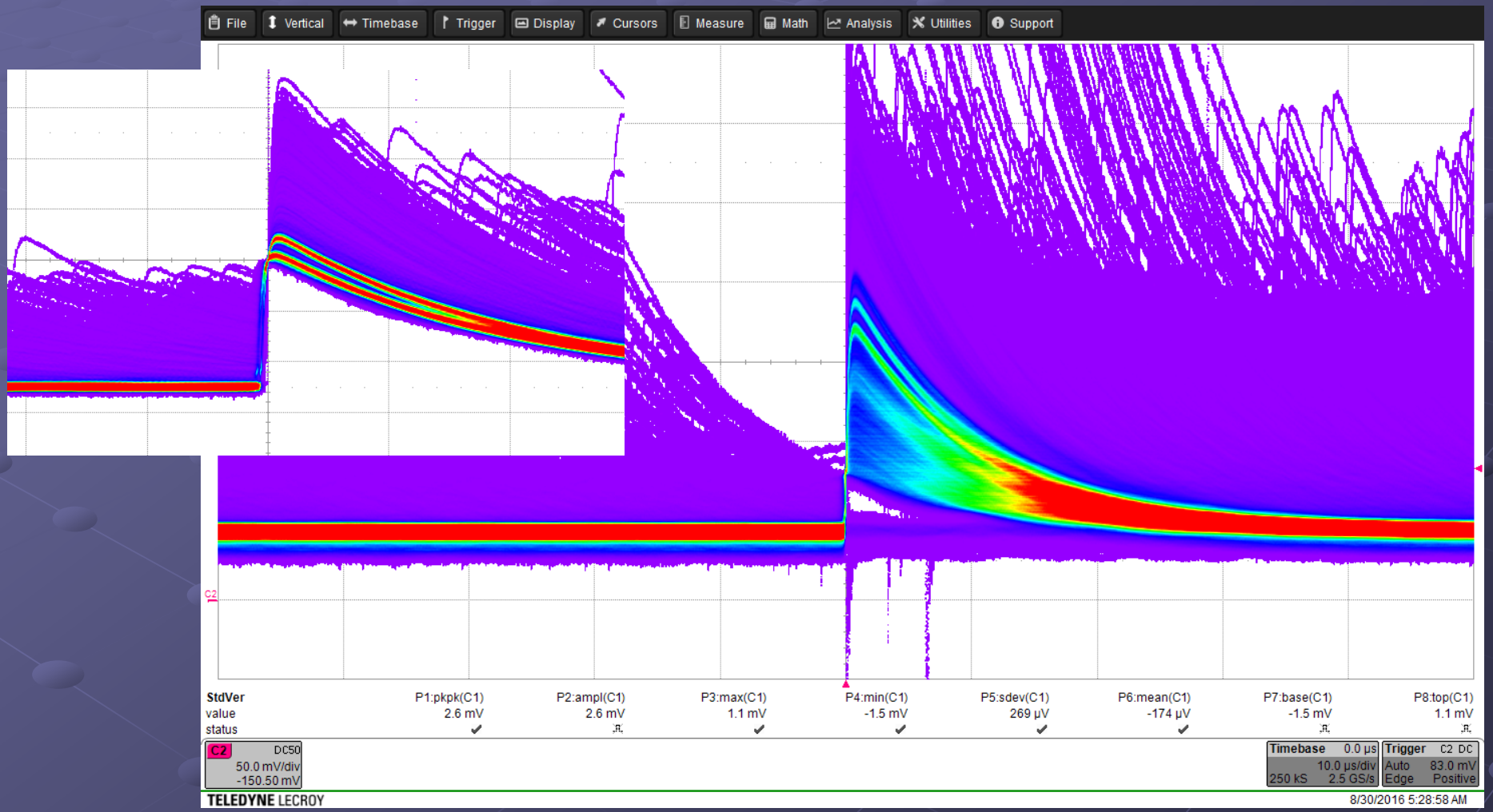
The Oscilloscope used in Krakow is Lecroy HDO6104 1GHz, 12-bit, 2.5 Gs/s.

As a **reference for timing we are using a small LaBr3** (2mm in diameter) by York.
This scintillator has been coupled to a fast, small-size PMT exploited in RFD detector.



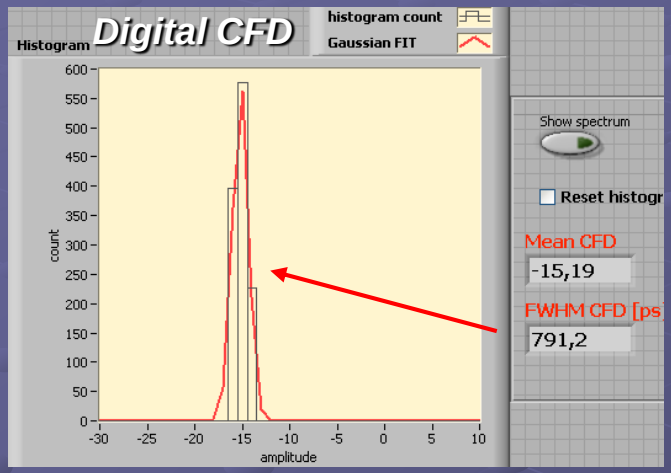
Setup with SiPM J-series in Krakow – quick energy signal check with Co-60

A fast verification of **2x2x2" LaBr3** read out by **all of the pixels (sum of all outputs) J-series SiPM** array with a **Co-60 source**.
More precise measurements woule be required at very stable, but not necessarily low temperature.

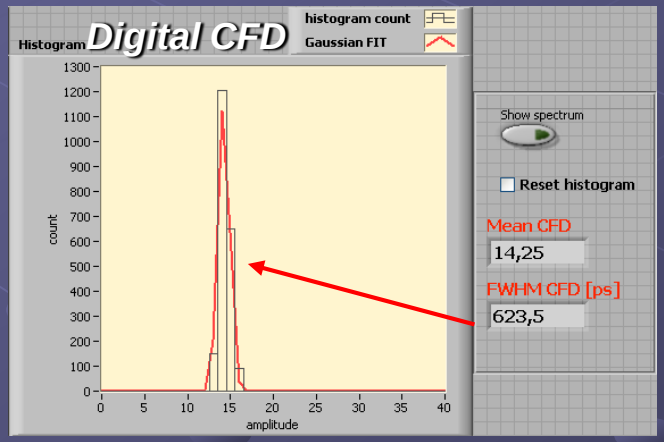


Setup with SiPM J-series in Krakow – timing measurements equipment limits

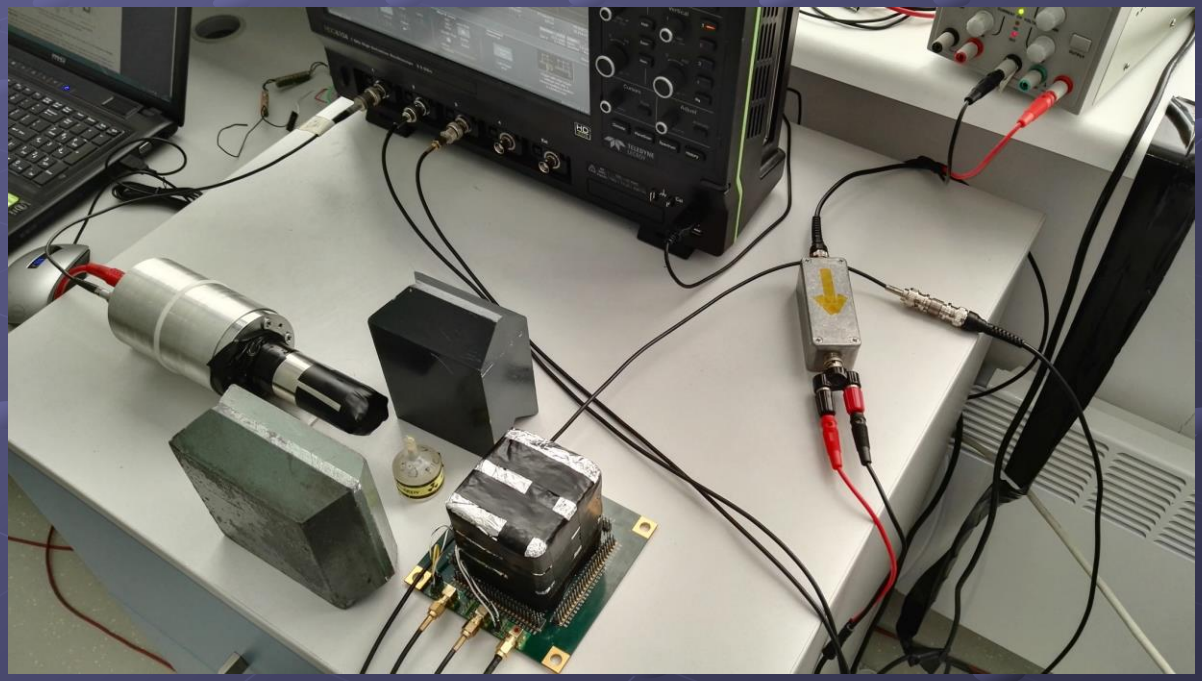
Timing (coincidence) measurements have been performed using mostly Na-22 a also Co-60 sources.
The contribution of the system itself (limited sampling rate, power supply noise etc.) has beed measured.



Small LaBr3 signal only



Timing output from 4 pixels (a sum)

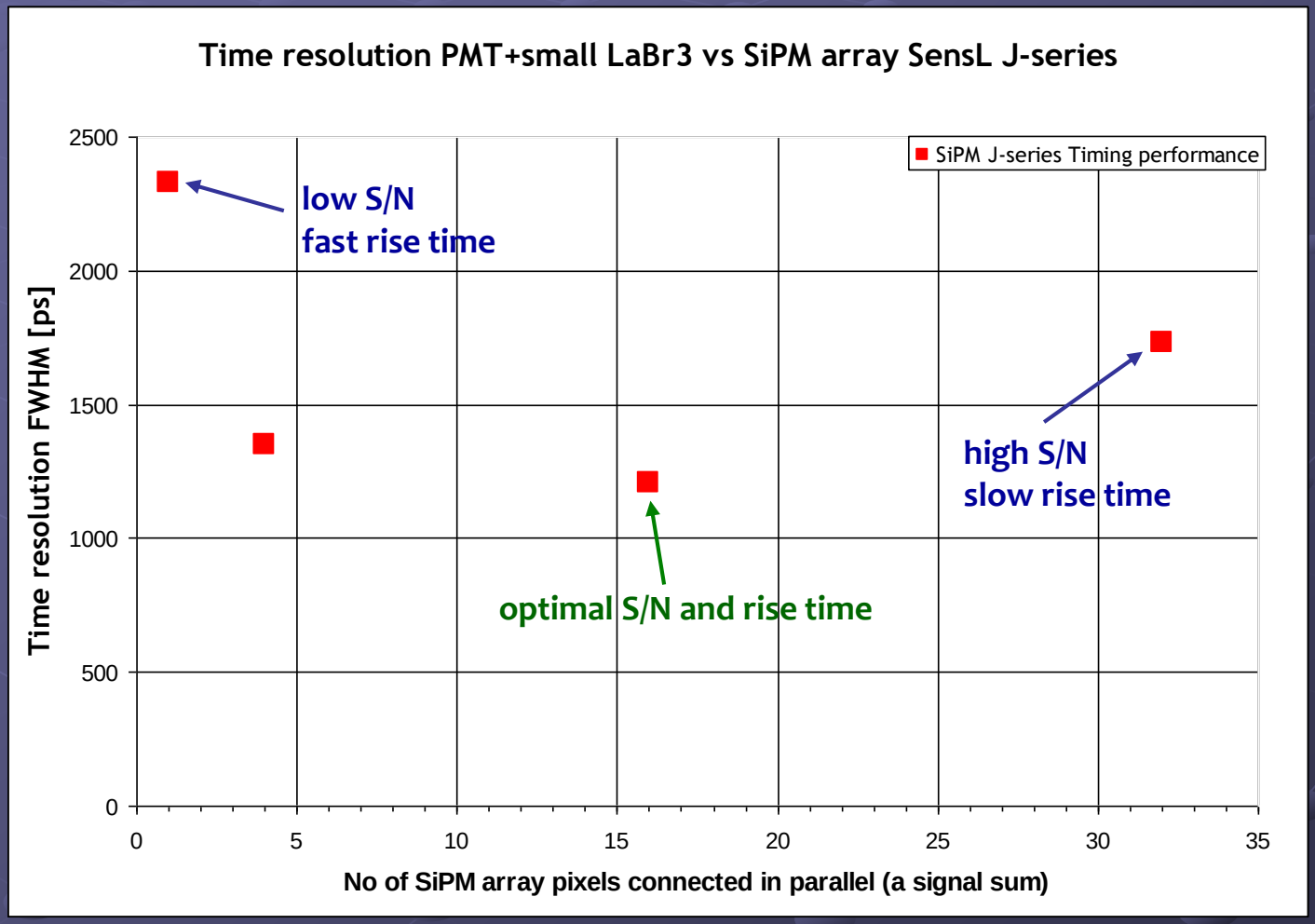


For the system limit measurements, the same signal (delayed) was provided to both LeCroy channels

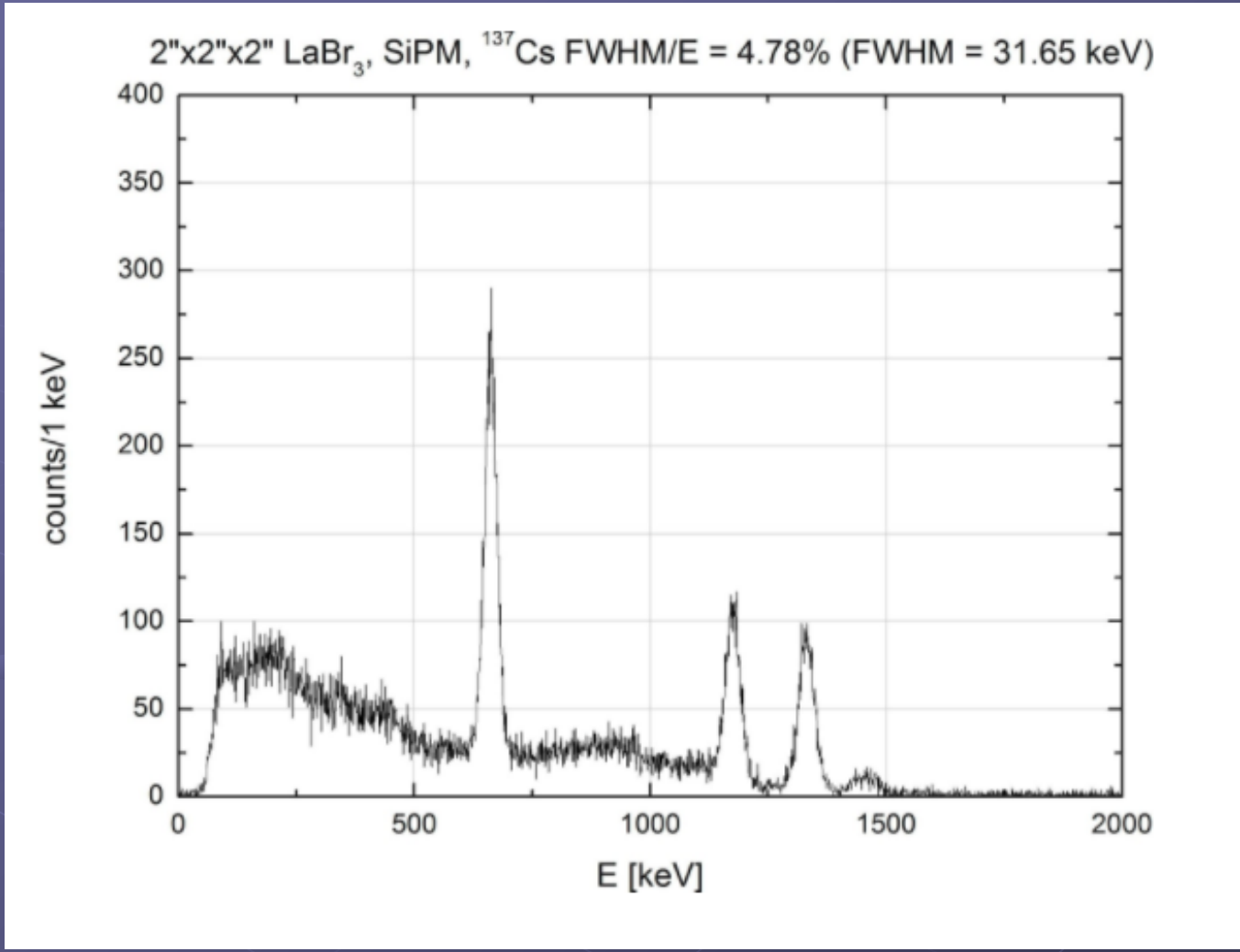
Setup with SiPM J-series in Krakow – detector timing measurements

Timing (coincidence) measurements have been performed using NA-22 source.

The below results of timing resolution are for the set of both detectors: small-size LaBr3+PMT + SiPM J-series SensL 8x8 pixels array.



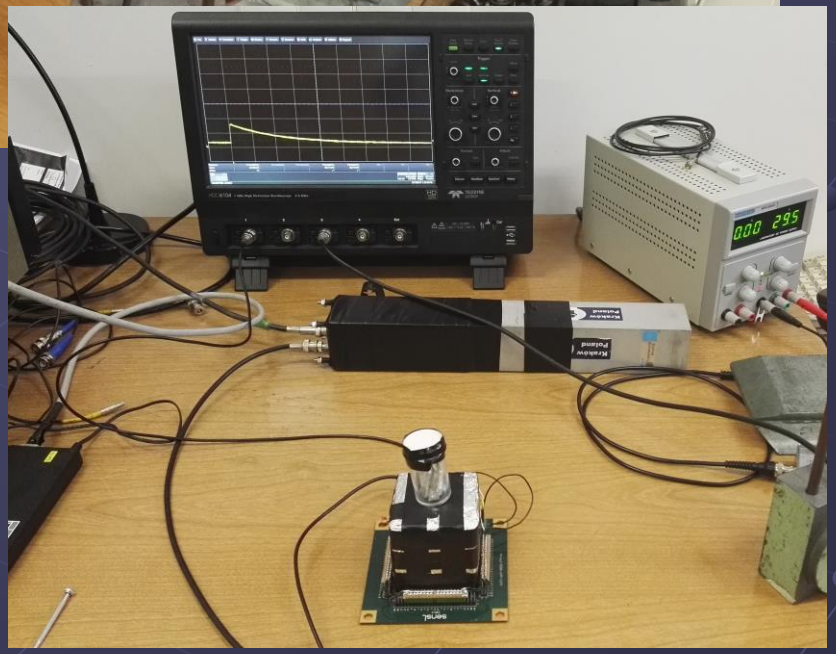
Setup with SiPM J-series in Krakow – energy measurements first results



by Michał Ciemała

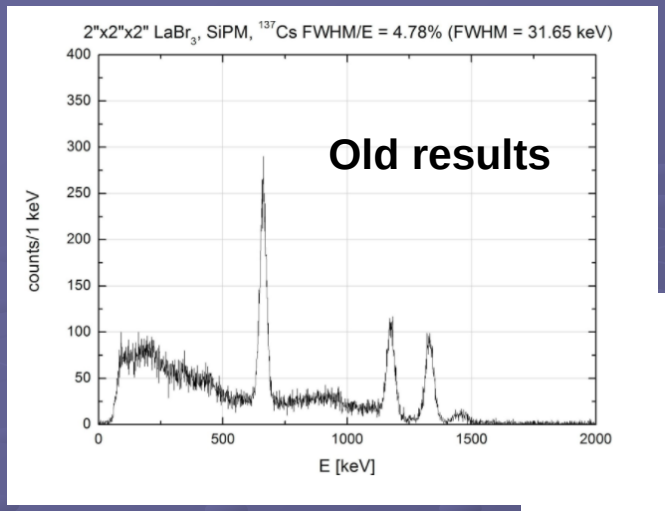
In order to fine tune and improve results, we decided to prepare a shielding box

Shielding box

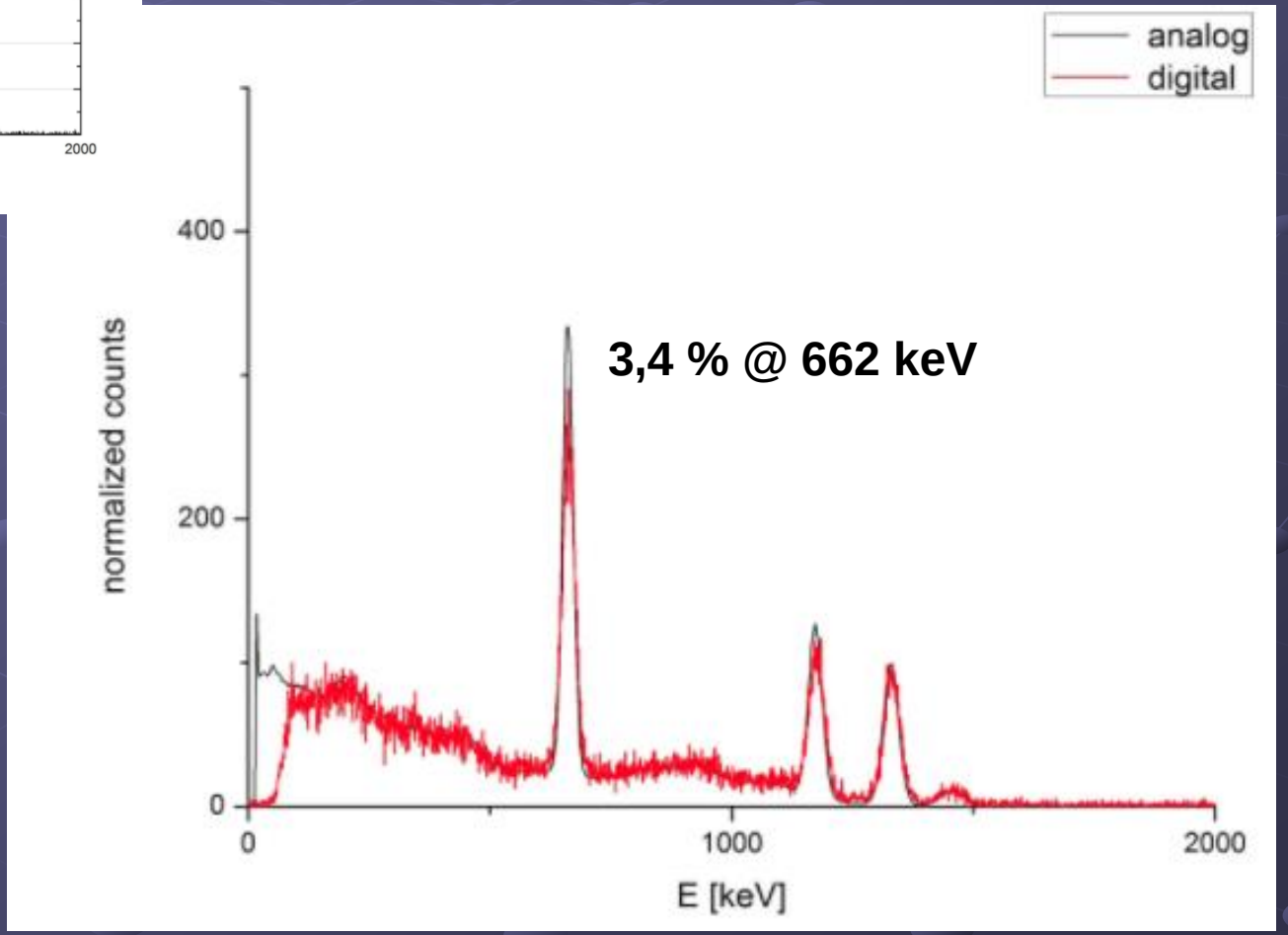


In order to assure optimal conditions for fine characterization of the SiPM array, we have produced a shielding box with proper cabling, to limit the influence of environmental interferences and more stable temperature conditions for the timing and energy measurements.

Setup with SiPM J-series in Krakow – energy improved results



For the digital data, when setting optimal integration pulse area it is possible to obtain ~3.4 % FWHM/E for 662 keV, very similar to results achieved with MCA with shaping amplifier (Ortec 671).



by Michał Ciemała

Conclusions

SiPM technology has a potential to replace PMT but requires some new development in terms of electronics and readout

- Time resolution of the 2x2x2” LaBr3 vs small LaBr3+PMT is ~1 ns
- Energy resolution for 2x2x2” LaBr3 is comparable to analog ~3,4%

- Energy and Timing performances are strongly influenced by on # of pixels connected together
- Energy pulse duration for 64 pixels is ~ 1 us
- Signal rise time and pulse duration dependence on # of pixels connected, can be minimized by designing low-impedance preamplifiers for each array pixel

- Limited sampling rate of the oscilloscope HDO6104 (2.5 GS/s) is being a limiting factor for very precise timing evaulation

Collaboration

University of York
University of Milano
INFN Milano
IFJ PAN