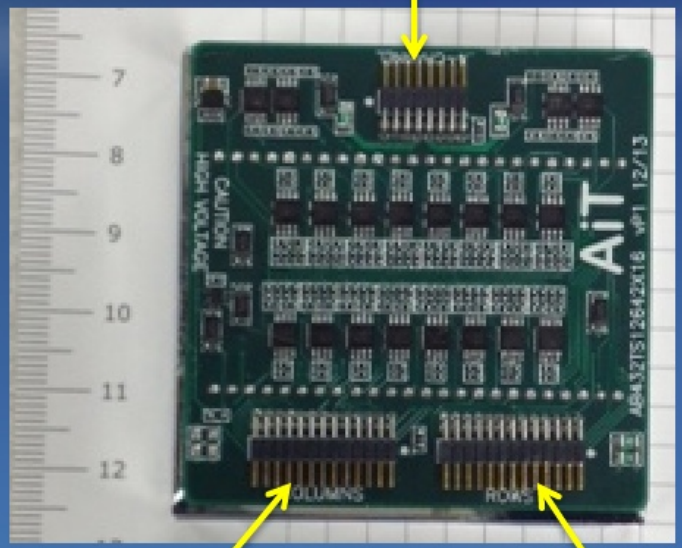
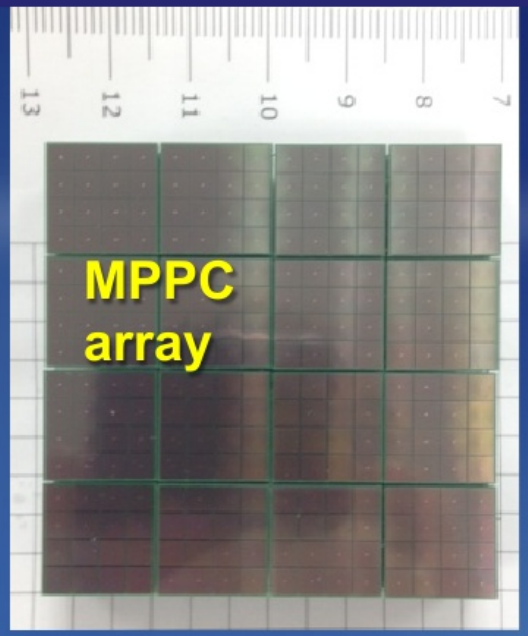
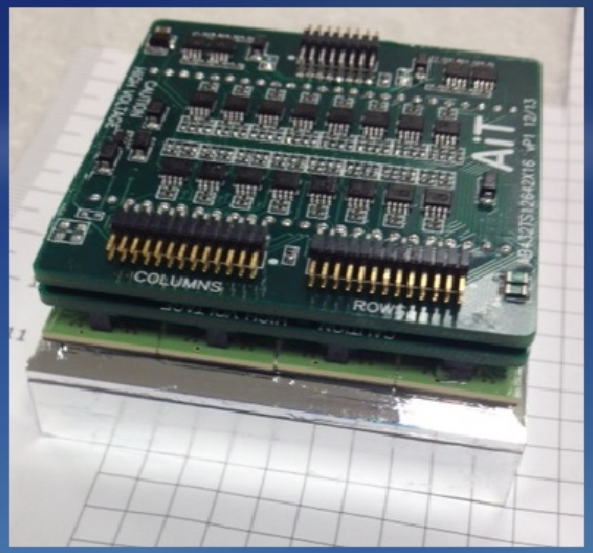
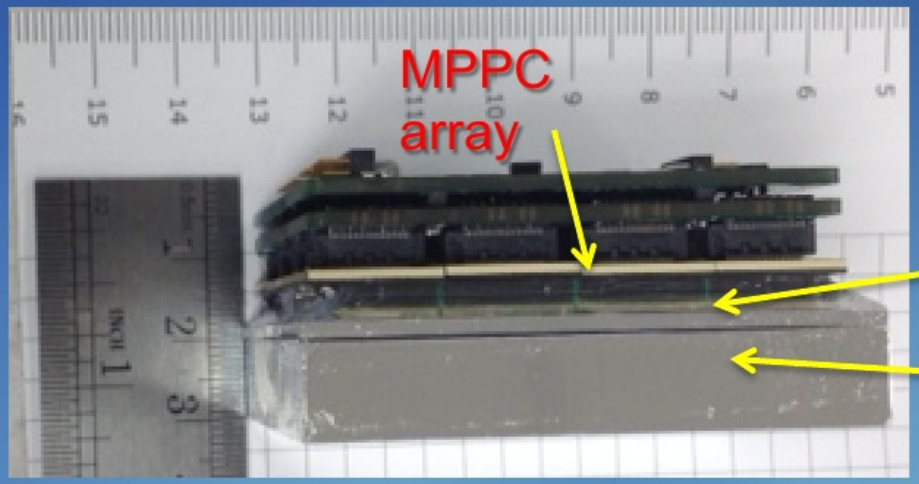
16x16 MPPC module studies with LYSO



Hybrid readout board from AiT Instruments with the row-and-column outputs and a 4ch output.



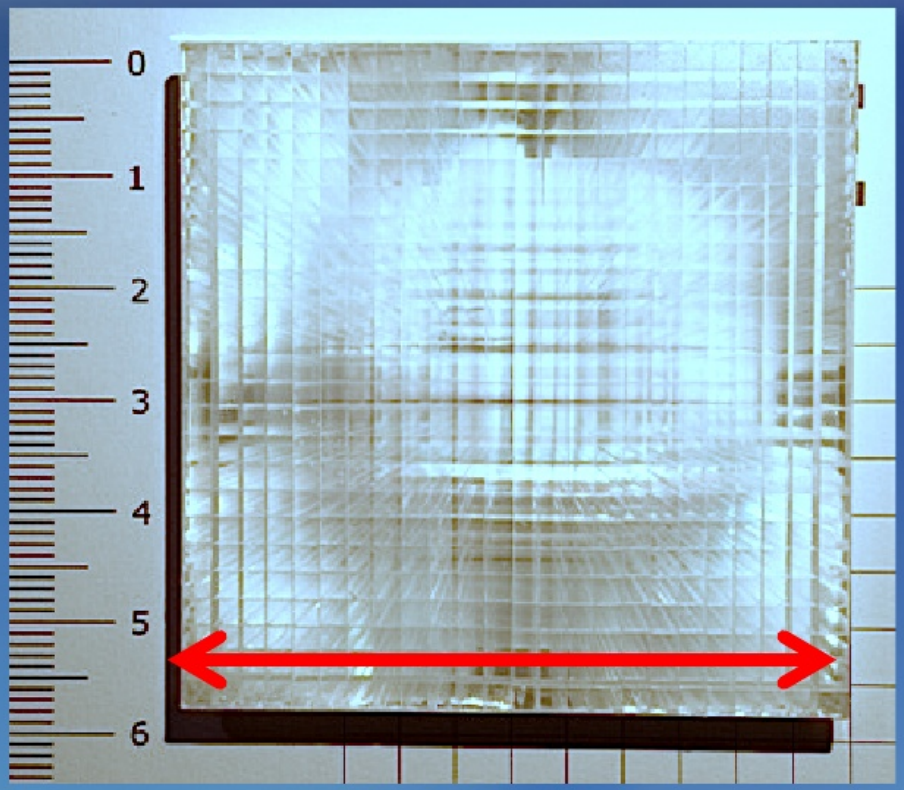




MPPC array was tested with several scintillators and their combinations: pixellated and monolithic. In this example a 1.5mmx1.5mmx10mm LYSO array from Proteus was coupled to the MPPC array via a tapered ~5mm thick light guide, forming very compact detector module of 57mmx57mm active FOV. Silicone optical compound Visilox V-788 was used between all optical surfaces.

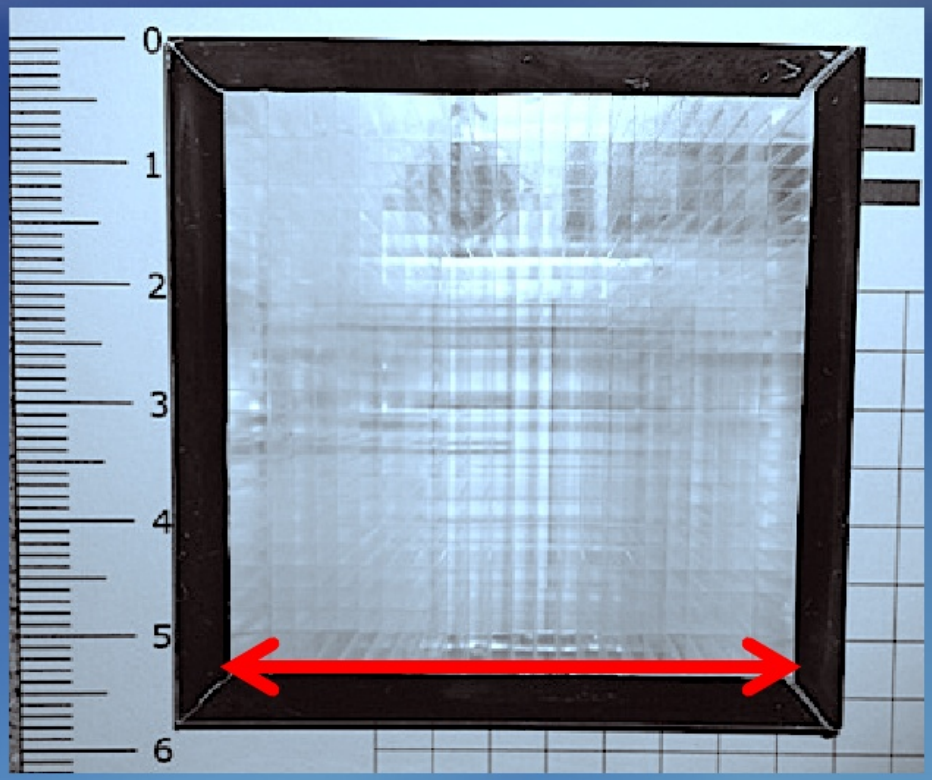
Tapered Light Guide from Proteus/Agile

Front



57.2mm

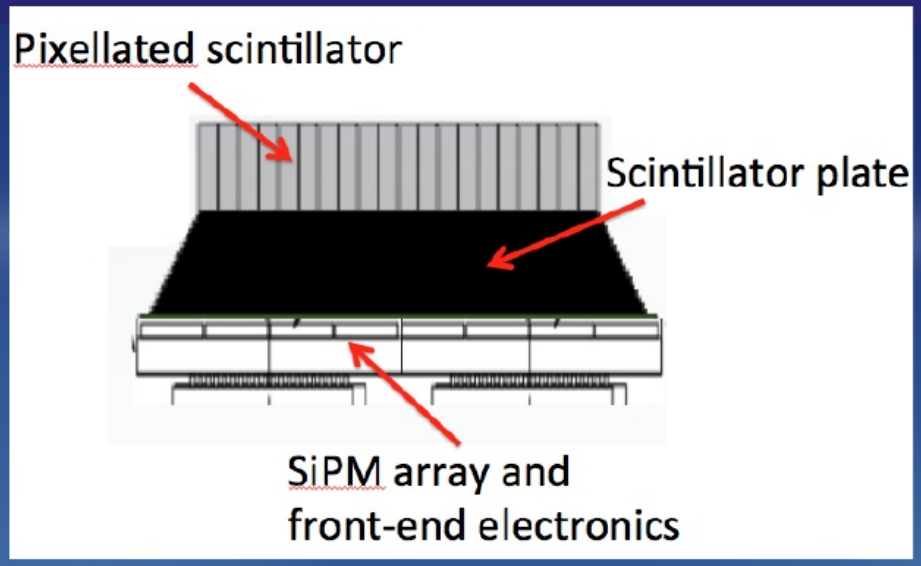
Back

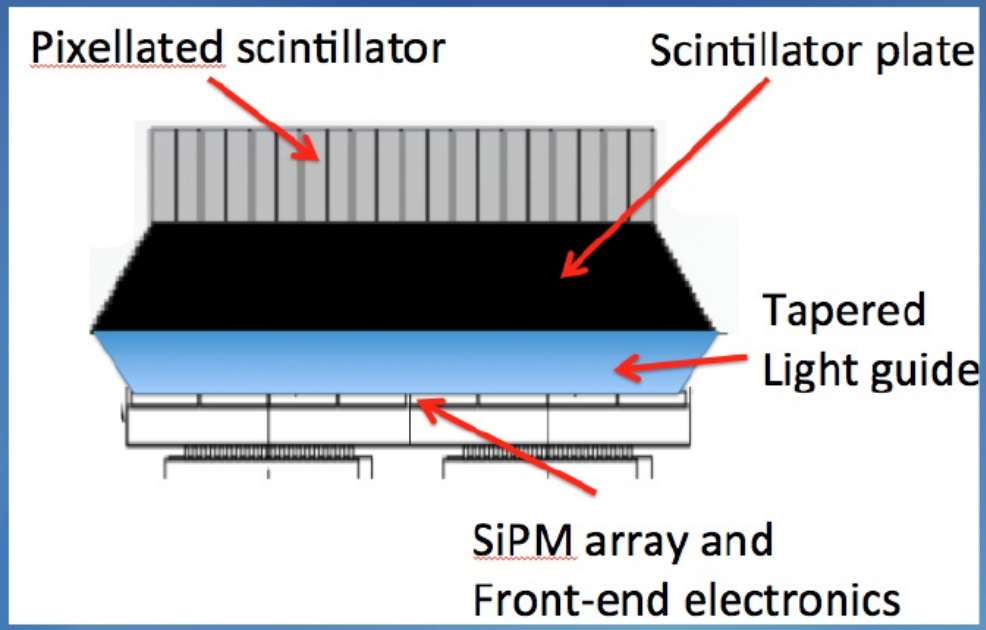


~47mm

Prototype of a compact tapered light guide made from an array of interlocking pieces. Front side 57.2mm x 57.2 mm, back side ~ 47mm x 47mm. 5.15mm thick.

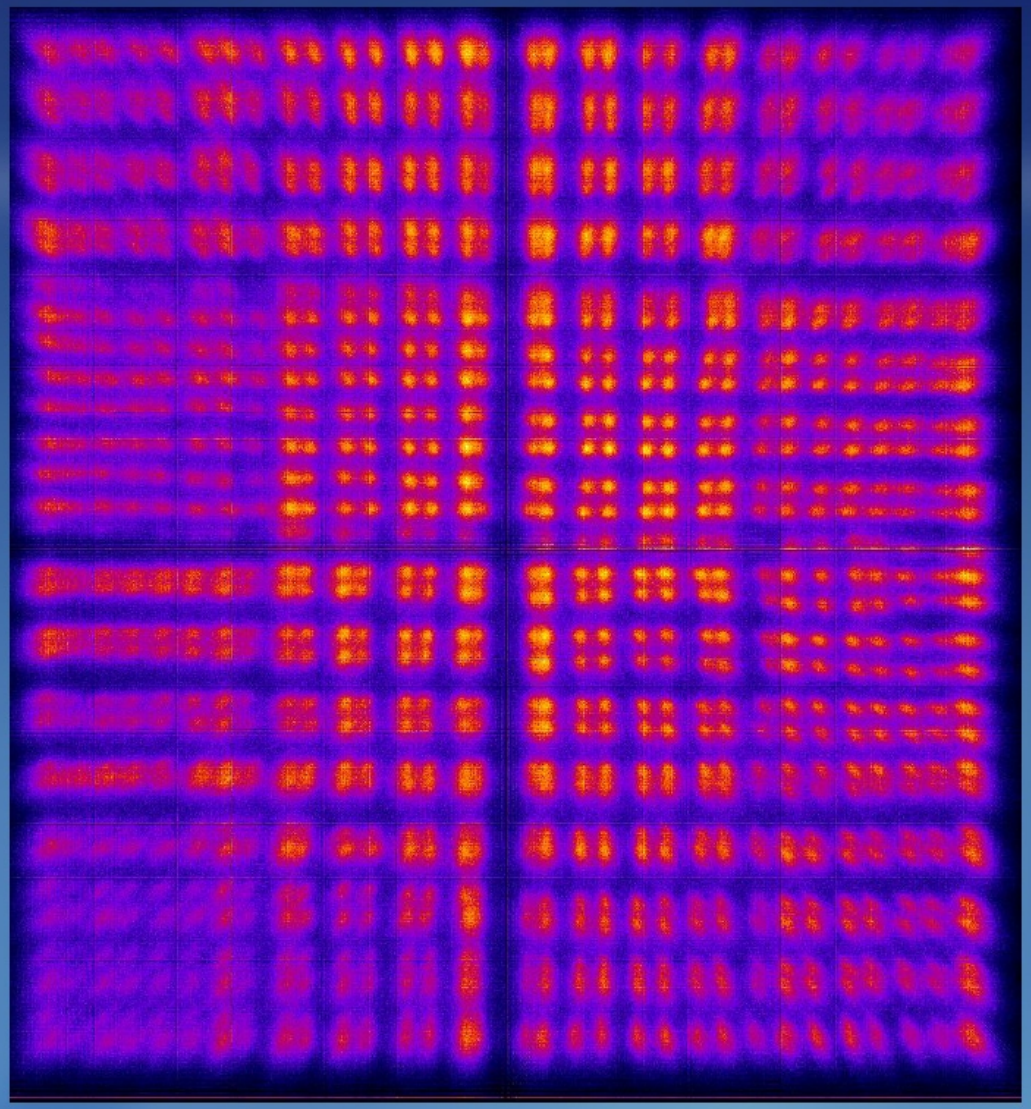
Hybrid detector module designs





Top: original hybrid design. Bottom: the new configuration using tapered light guide to increase active field of view of the PET detector module, while keeping the same photodetector size.

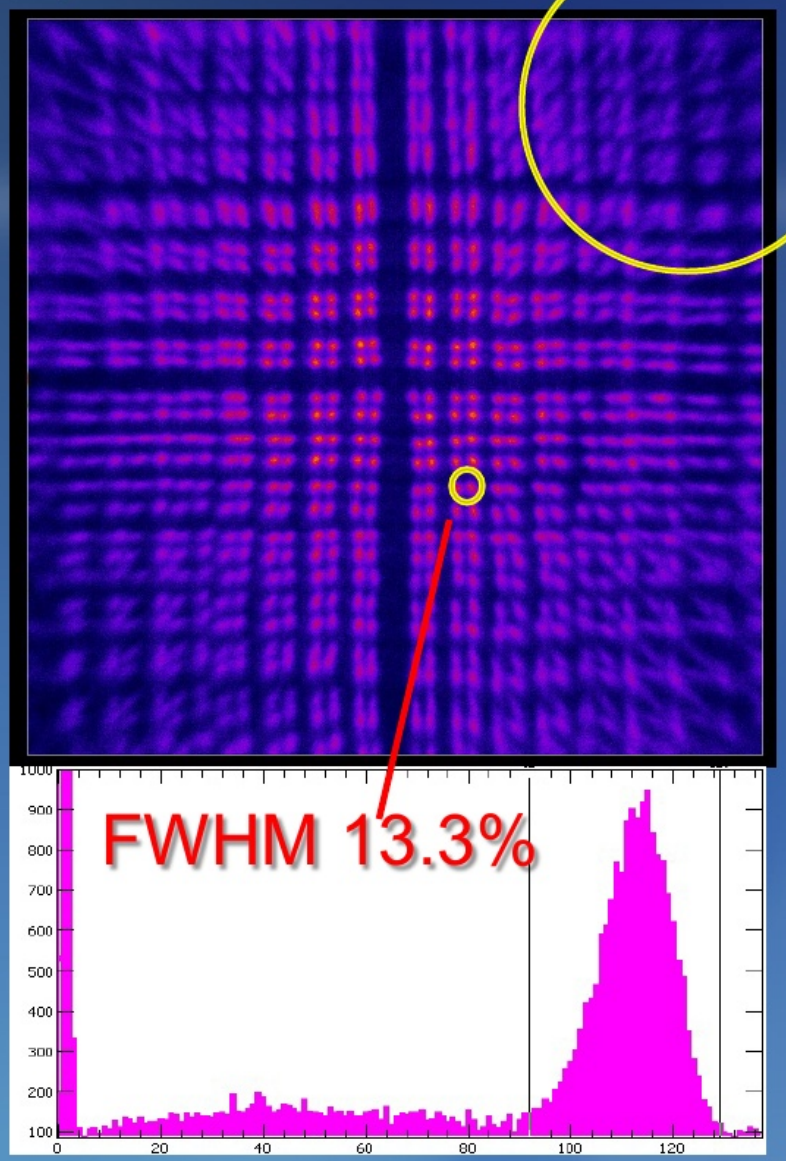
Scintillator coupled directly to the MPPC array



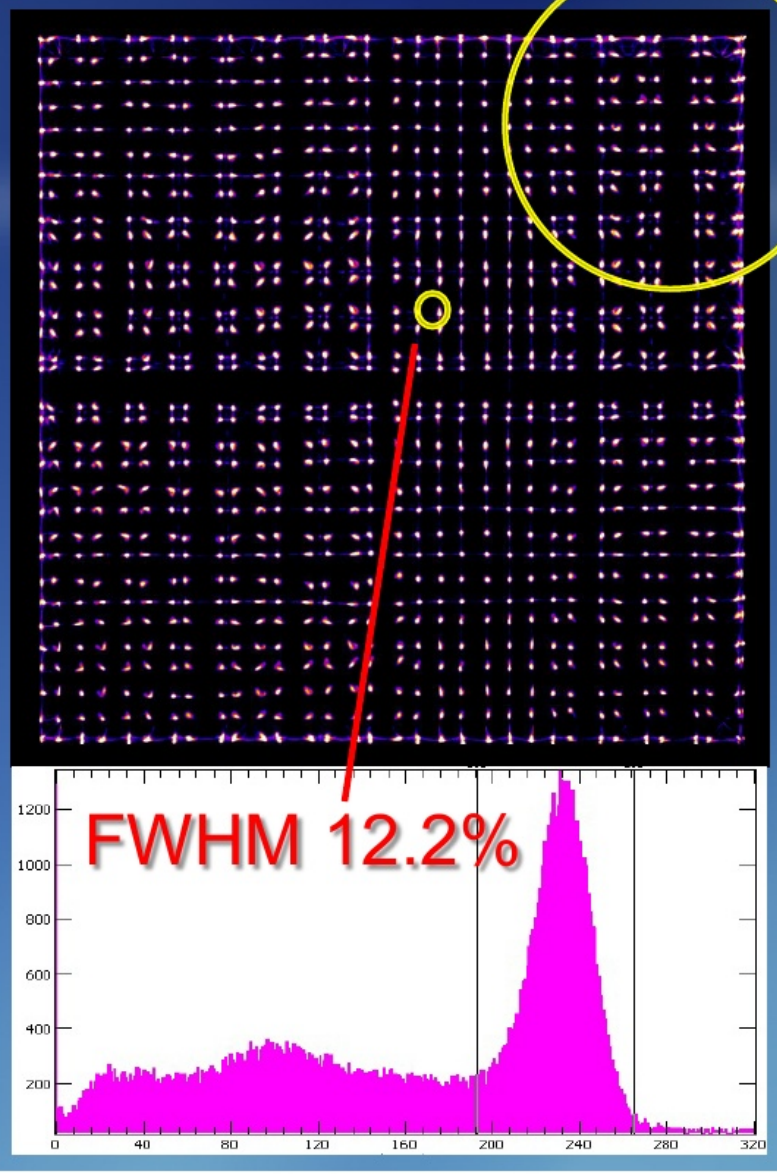
Temperature: 23.5 deg C, bias: 65.9 V. 270 ns ADC gate. Row image using 4ch charge division readout.

Scintillator coupled directly to the MPPC array

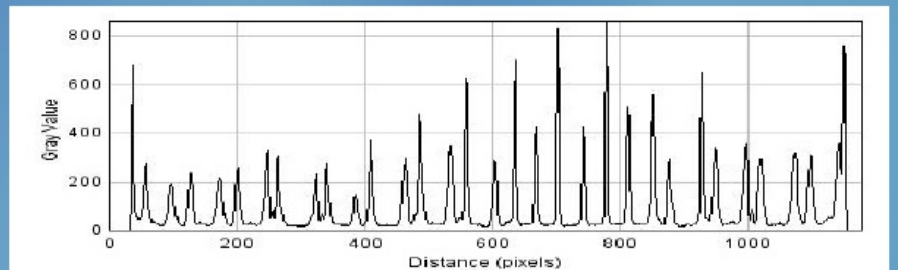
4 ch



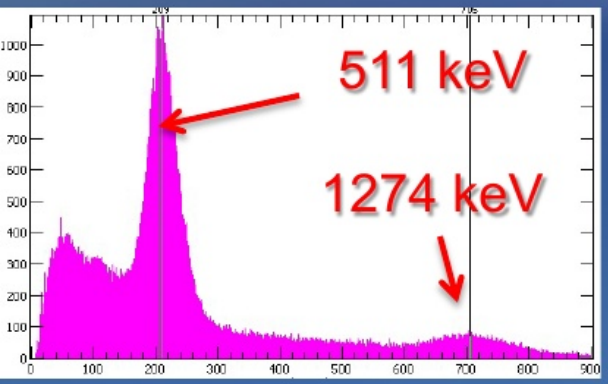
Row-and-column



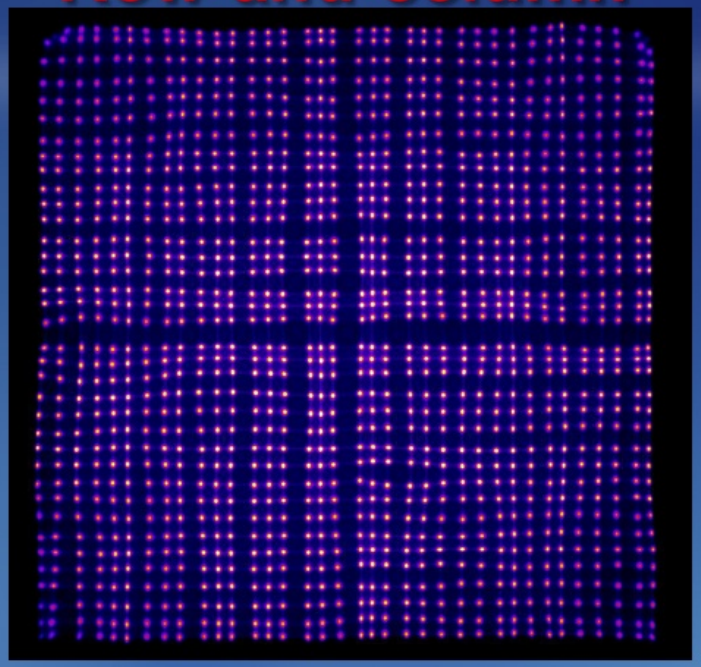
Temperature: 14.7 deg C, bias: 67.2 V. 170 ns ADC gate. Row images using 4ch charge division readout (left) and row and column readout (right).



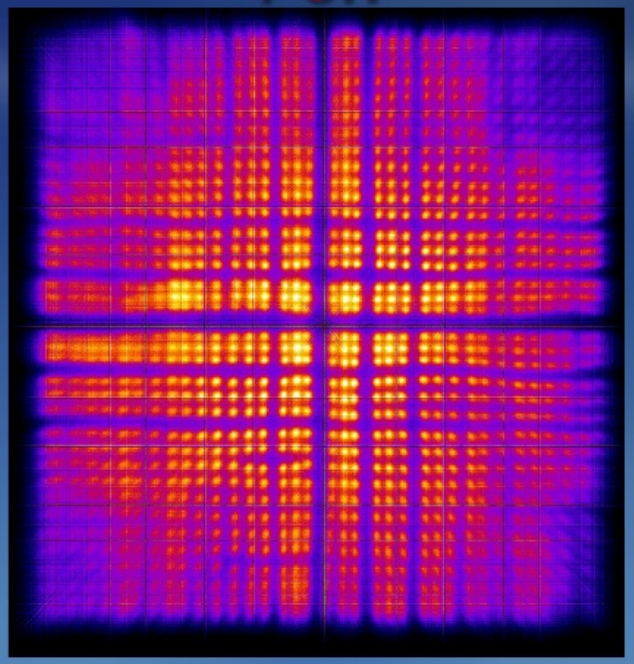
Pixellated 1.5mm scintillator array coupled to the MPPC array via tapered light guide

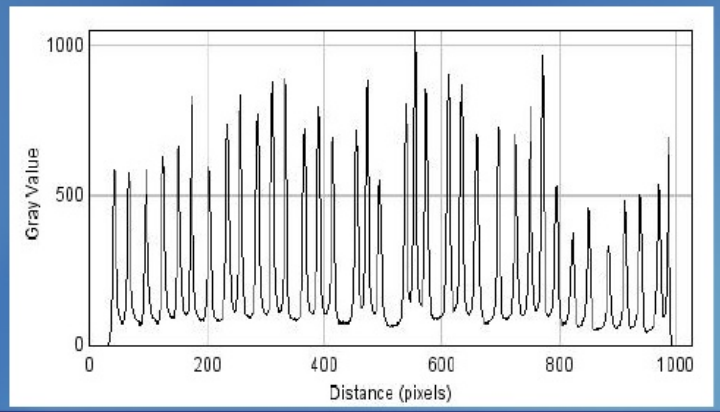


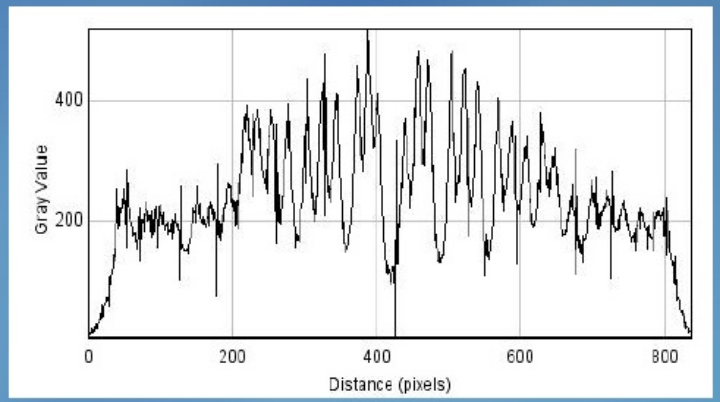
Row-and-column



4 ch

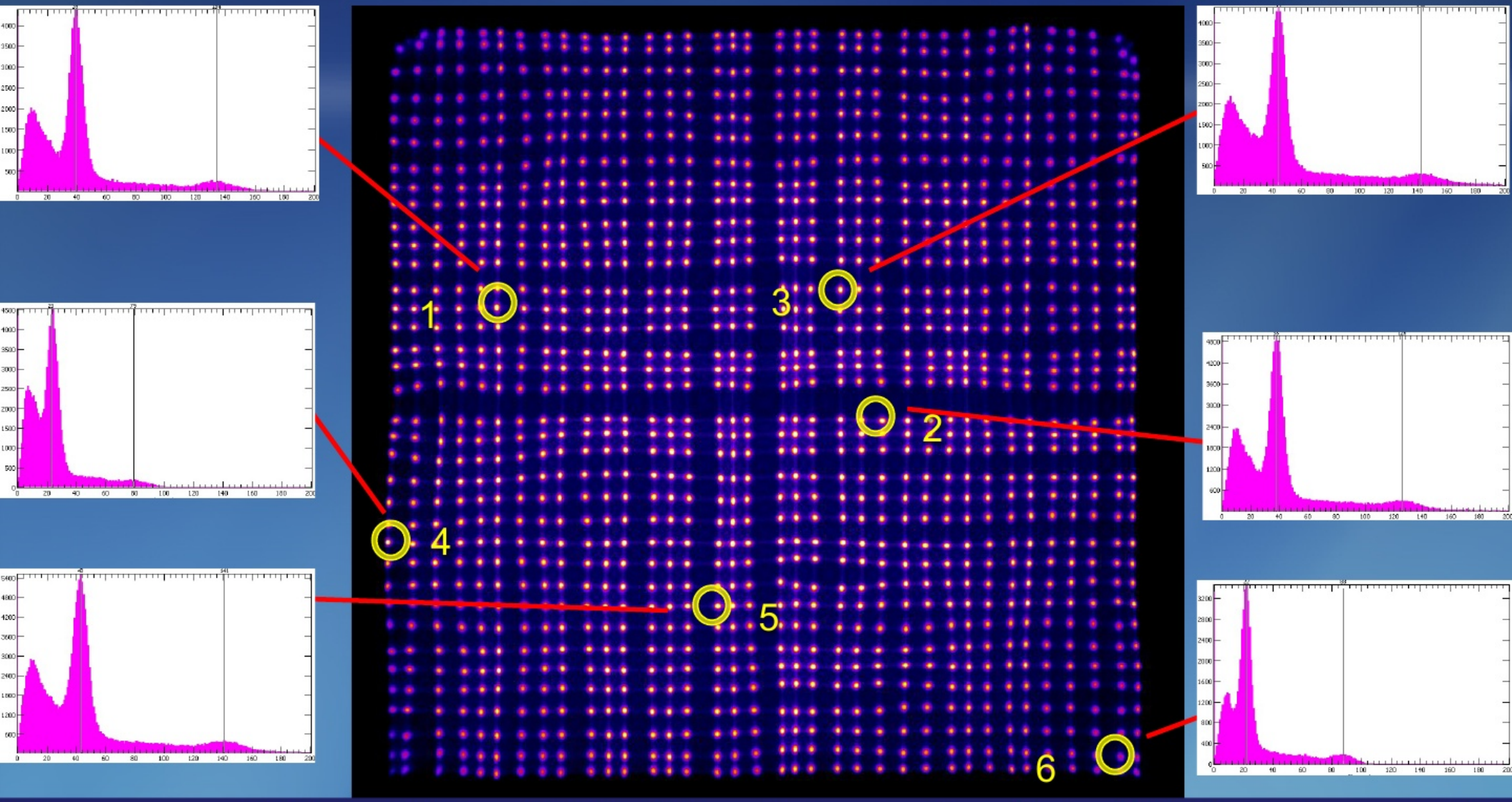






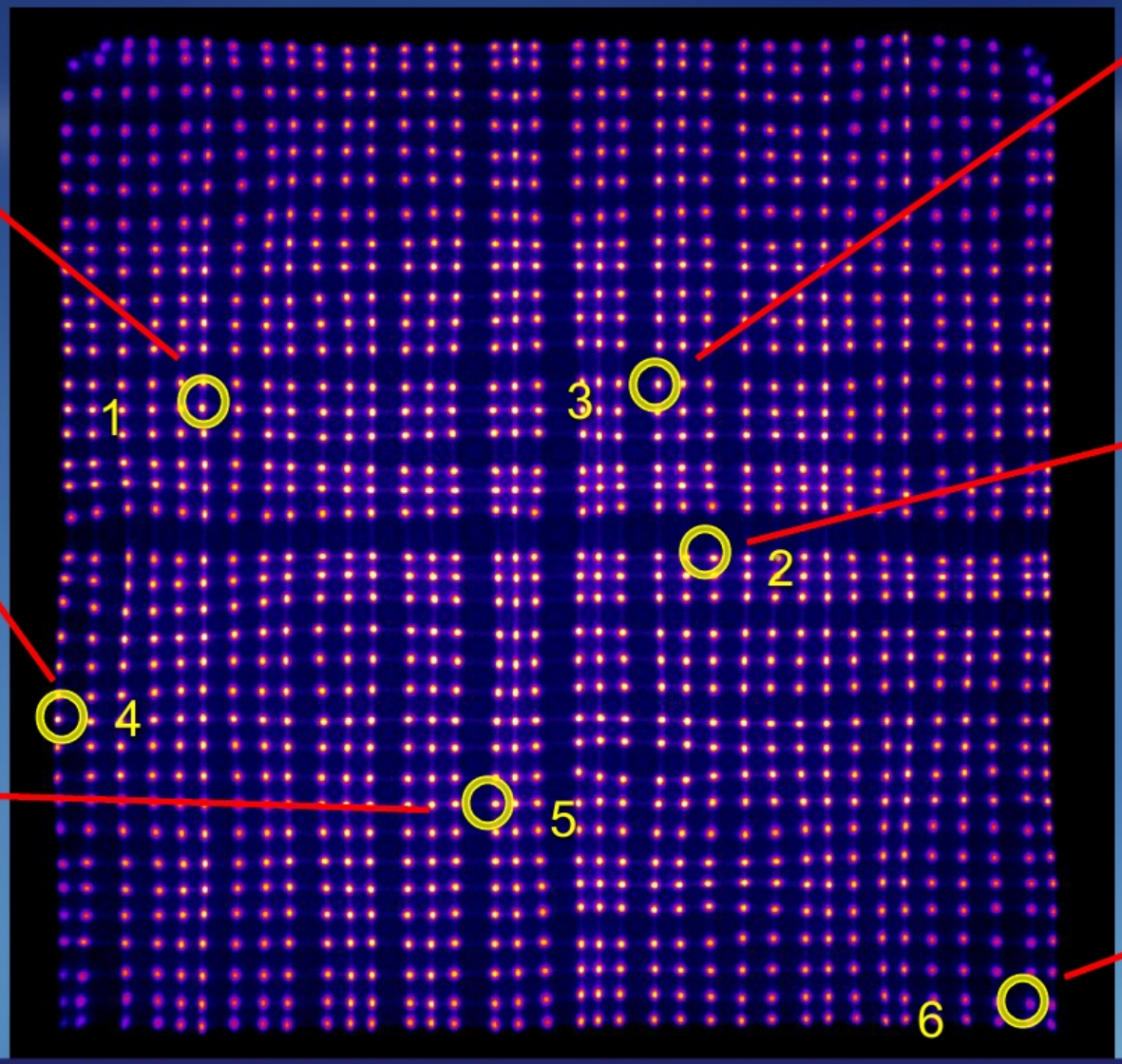
Comparison between the row-and-column (left) and 4 channel charge division readout (right). 14.7 deg C. Bias 65.9V, ADC gate widths 170 nsec. Example of the single pixel energy spectrum. Energy resolution: 15.0% FWHM @511 keV. Row images and plots through a selected pixel row.

Pixellated 1.5mm scintillator array coupled to the MPPC array via tapered light guide



Temperature: 23.5 deg C, bias: 65.9 V. 270 ns ADC gate. Six selected LYSO pixels across the surface of the detector module. Shown energy spectra. Maximum gain variation is of about factor 2 – including the SiPM, scintillator, and light guide contributions, as well as geometry (edges).

Pixellated 1.5mm scintillator array coupled to the MPPC array via tapered light guide



0.94
14.8%

0.99
15.2%

0.57
18.1%

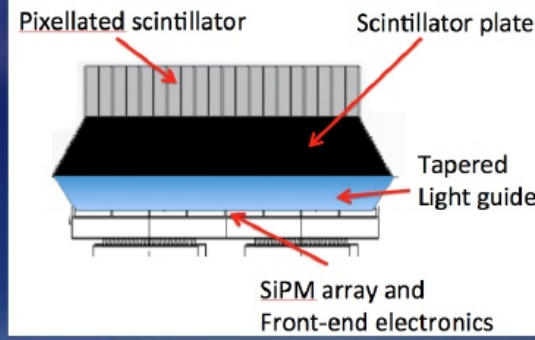
0.95
15.2%

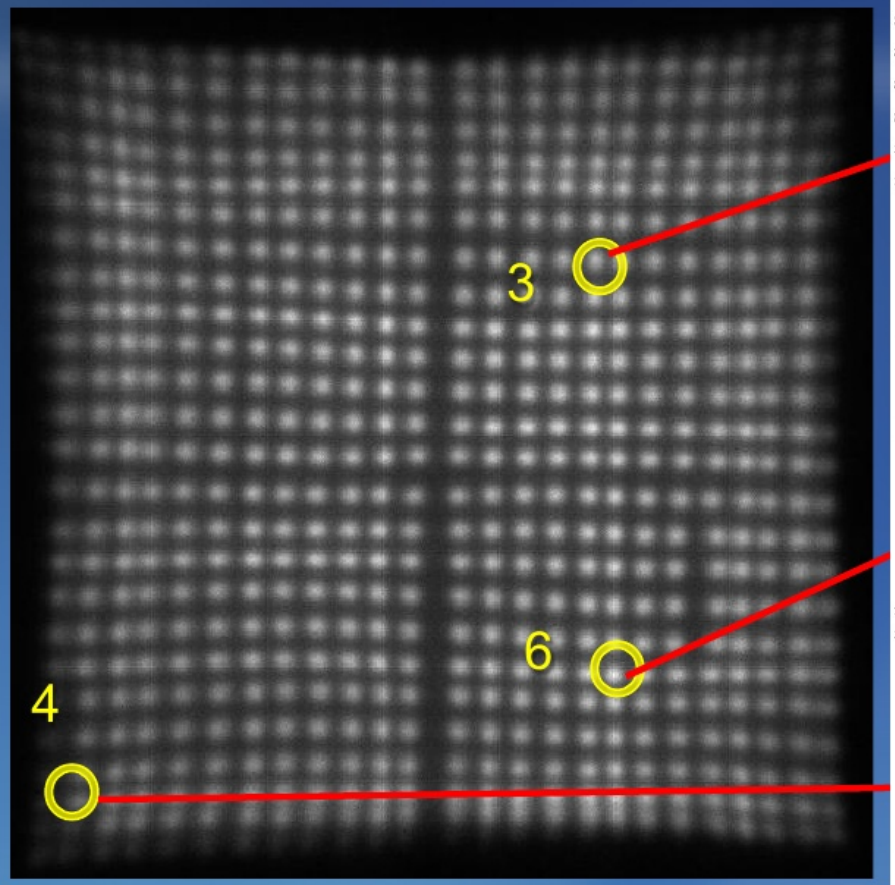
1.00
15.7%

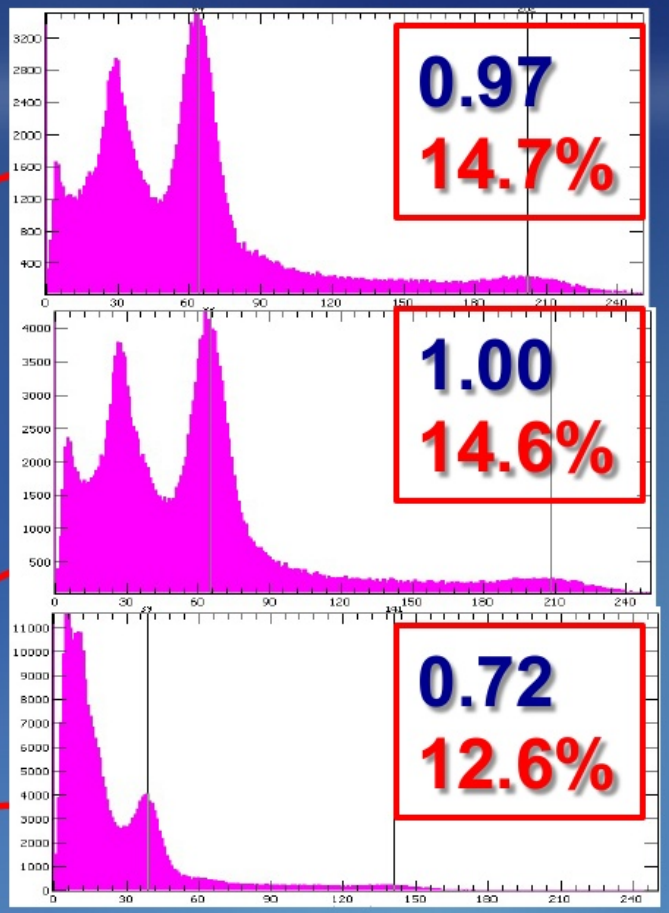
0.65
15.3%

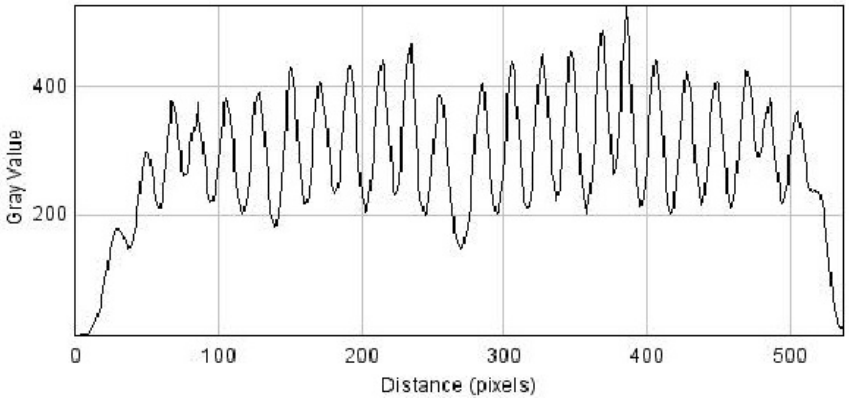
Temperature: 23.5 deg C, bias: 65.9 V. 270 ns ADC gate. AC coupling of the signals to ADC. Six selected LYSO pixels across the surface of the detector module. Shown energy resolution and relative amplitude values. Maximum gain variation is of about factor 2 – including the SiPM, scintillator, and light guide contributions, as well as geometry (edges).

Pixellated 1.5mm scintillator array coupled to the MPPC array via 9.5mm thick monolithic scintillator and tapered light guide – hybrid module.



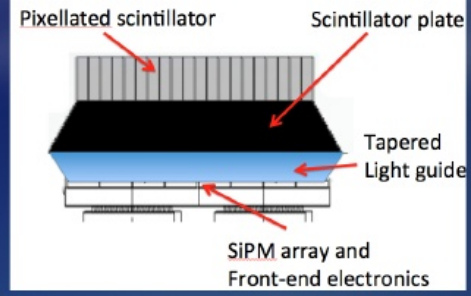


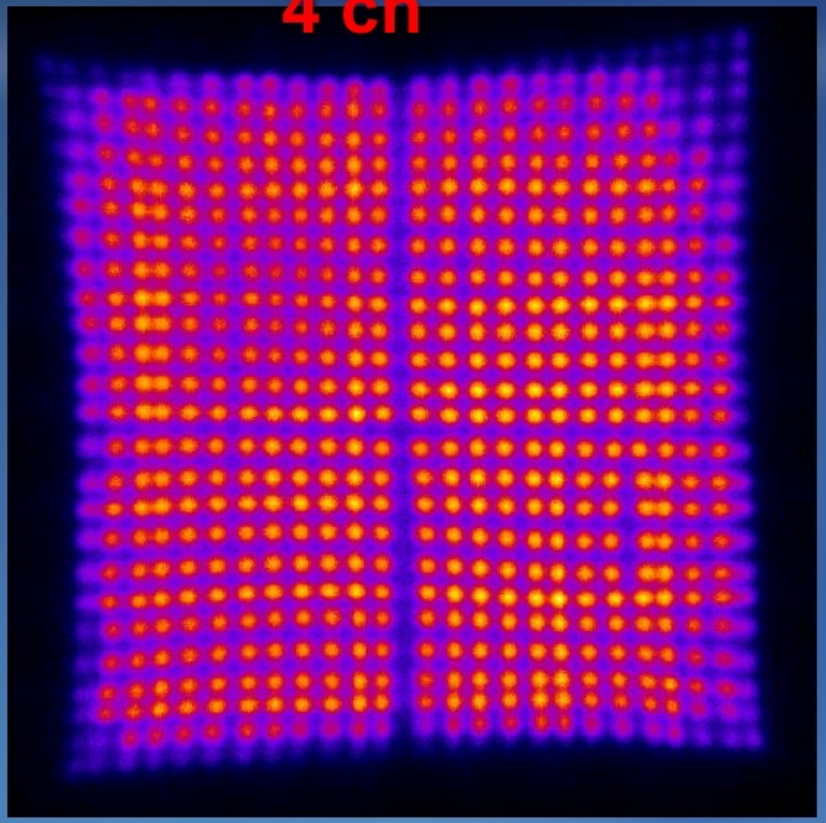


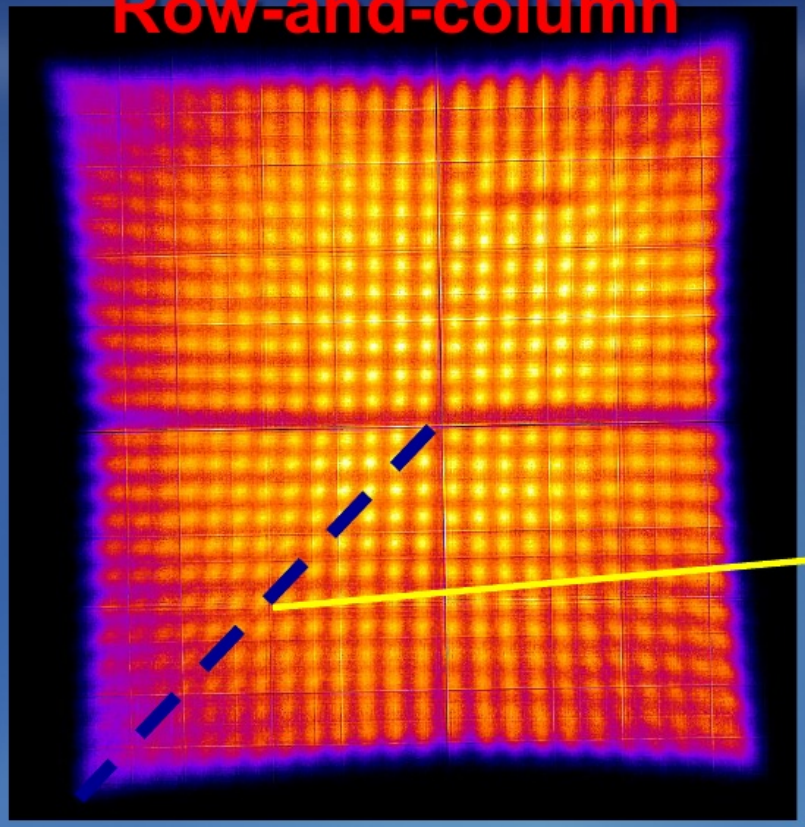


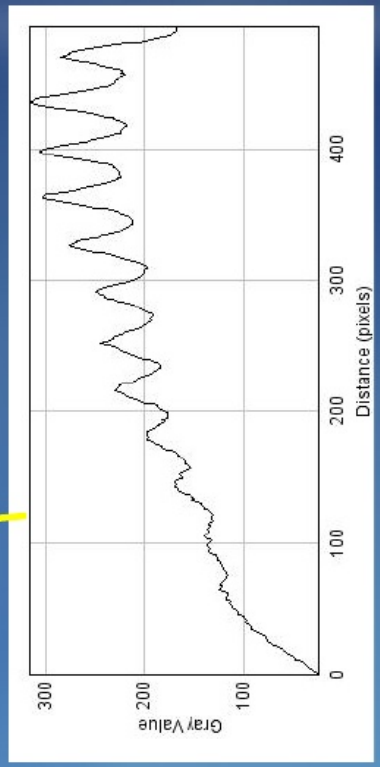
Temperature: 14.7 deg C, bias: 66.6 V. 170 ns ADC gate. AC coupling of the signals to ADC. F factor 0.05. Three selected LYSO pixels across the surface of the detector module. Shown energy resolution FWHM @ 511 keV and relative amplitude values.

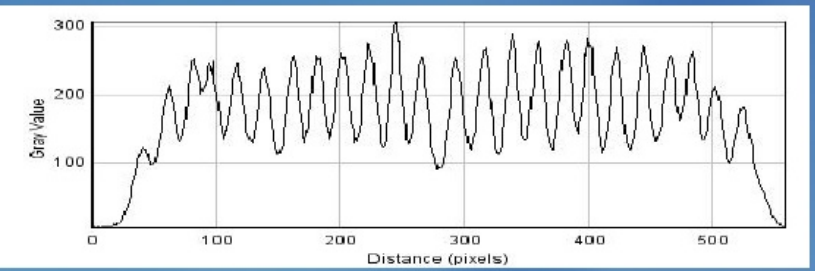
Pixellated 1.5mm scintillator array coupled to the MPPC array via 9.5mm thick monolithic scintillator and tapered light guide – hybrid module.

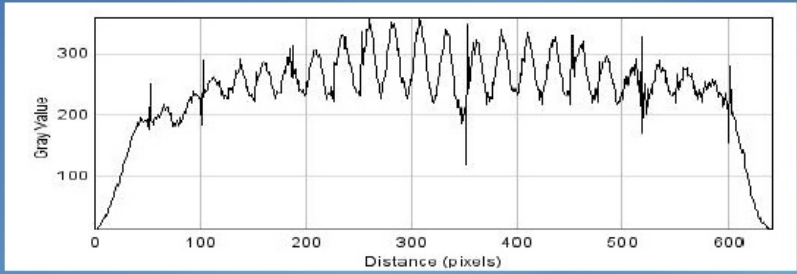






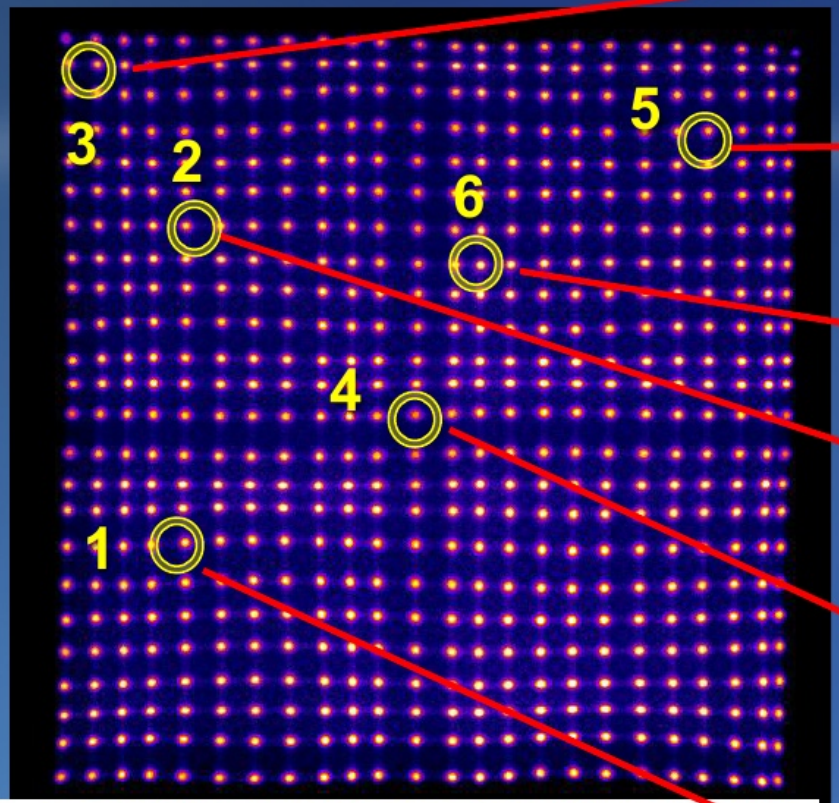


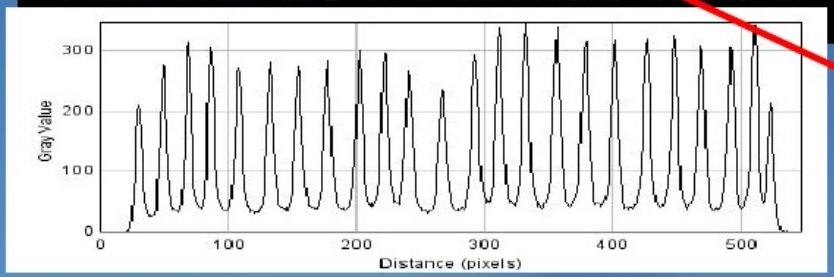


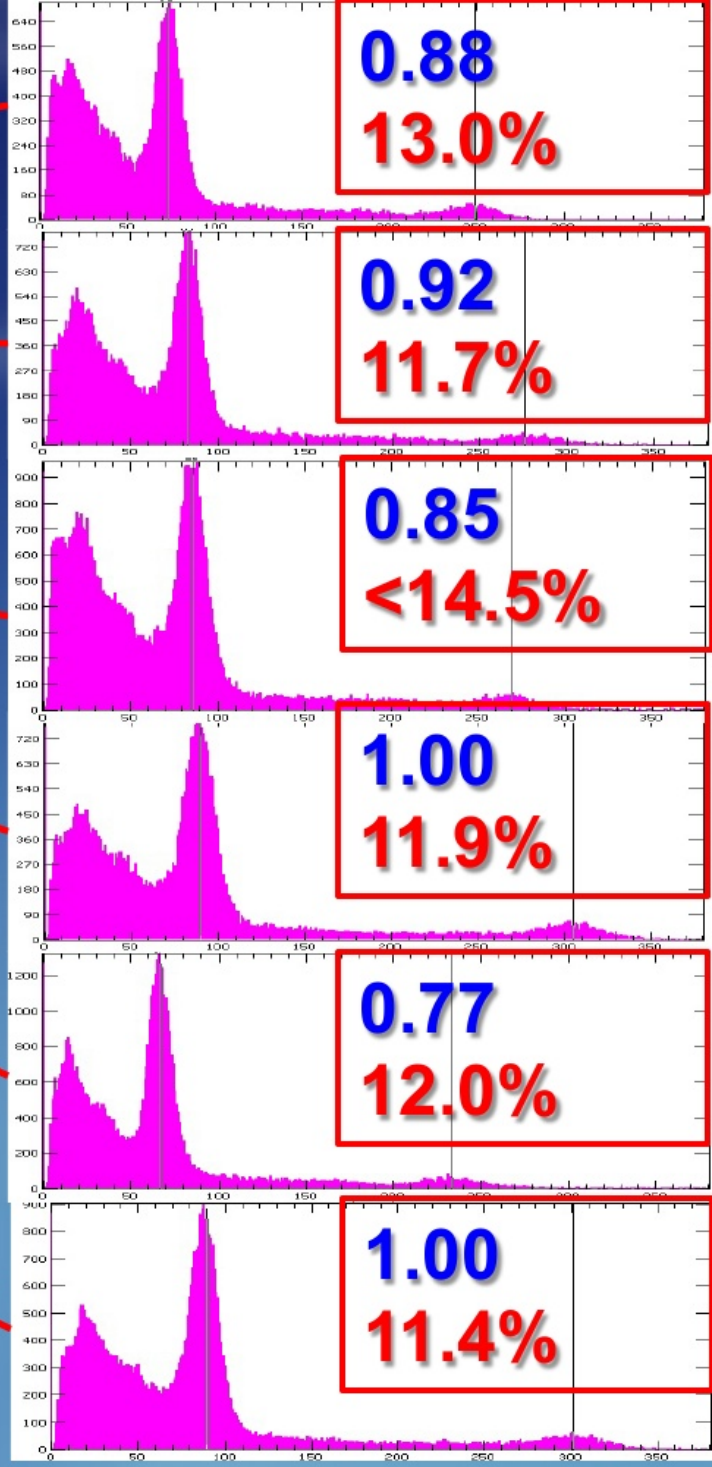


Temperature: 14.7 deg C, bias: 67.2 V. 170 ns ADC gate. AC coupling of the signals to ADC. F factor 0.05. Shown row images and profiles.

24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via 1.65mm thick acrylic window

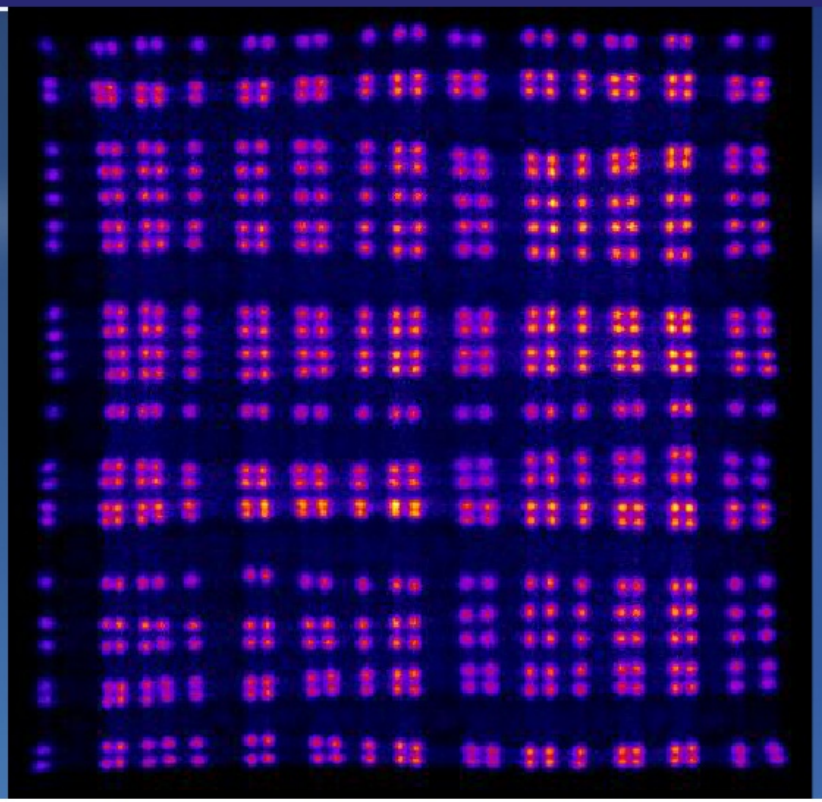


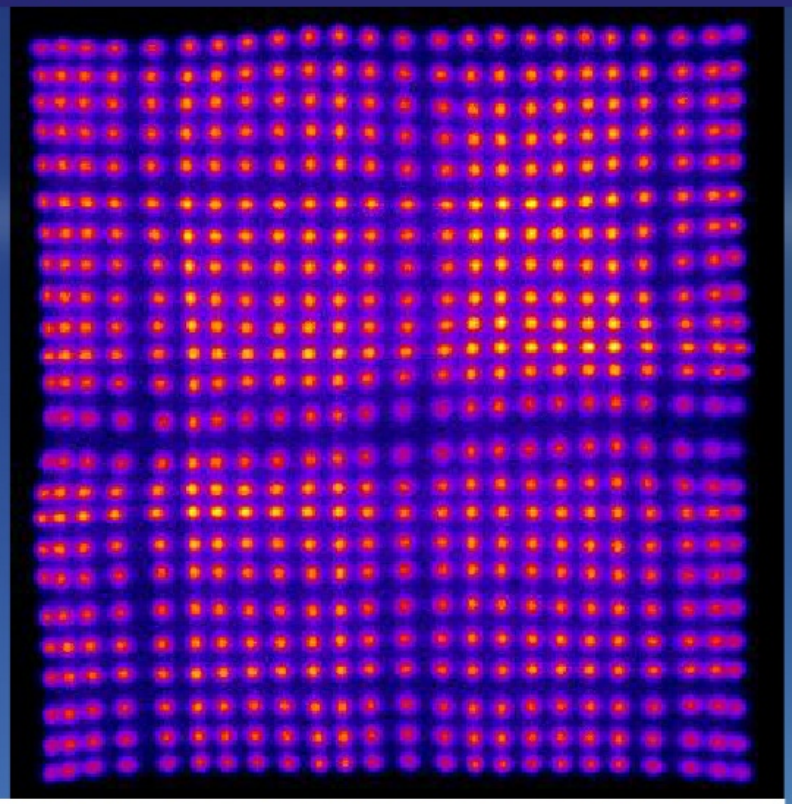


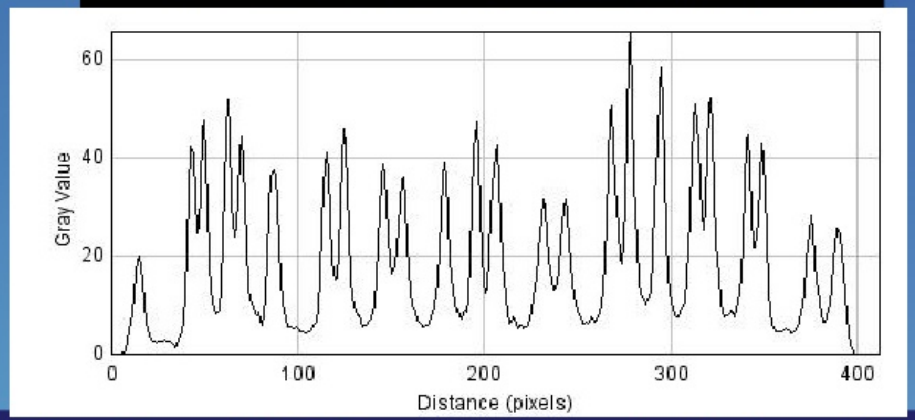


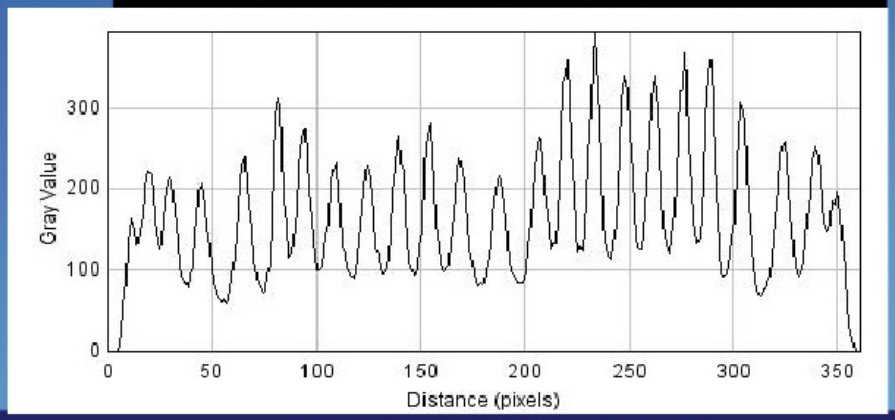
Six selected 1mm LYSO pixels across the LYSO array placed in the central part of the MPPC module. Shown FWHM energy resolution and relative @511 keV values. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via tapered light guide



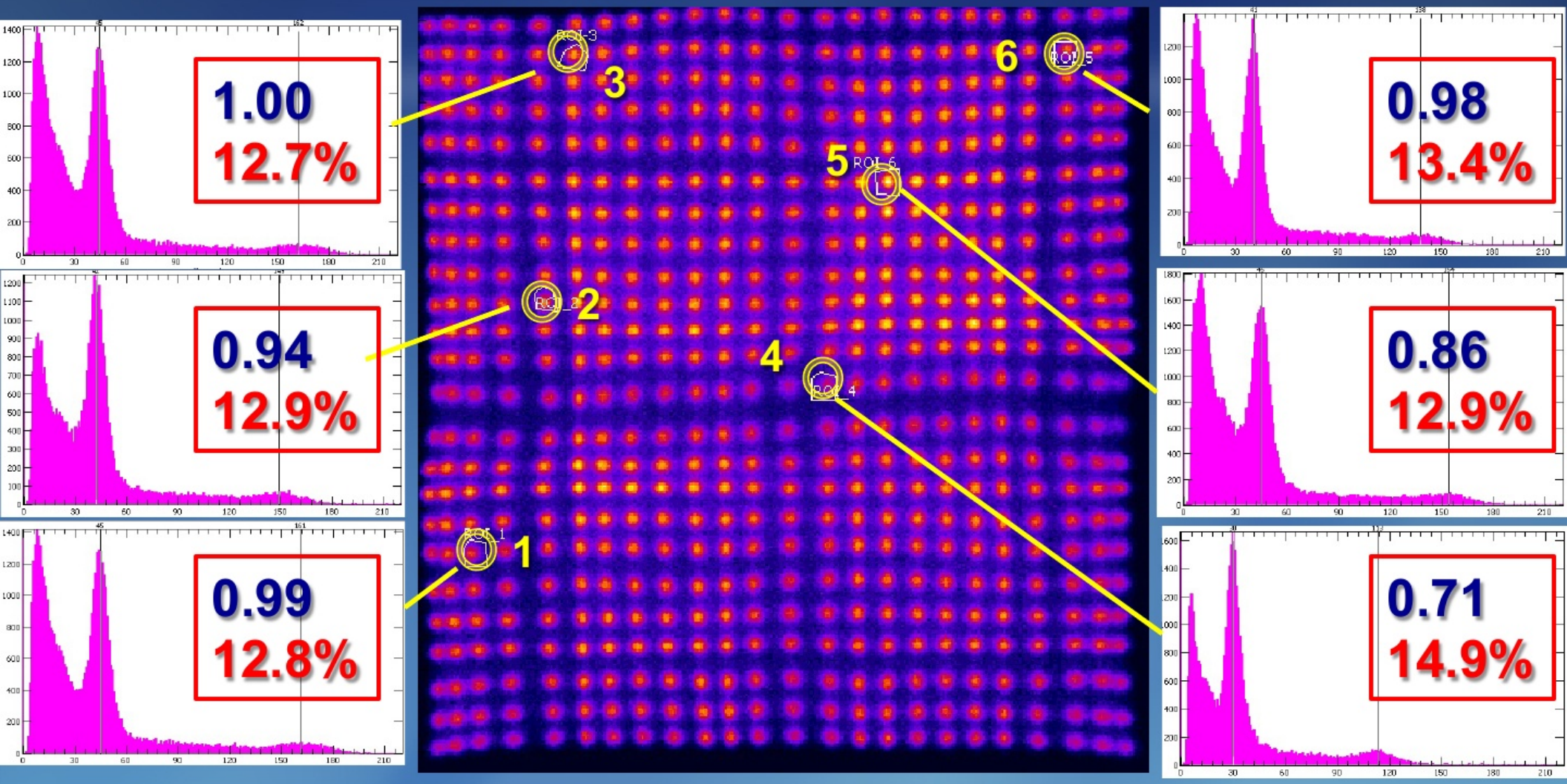






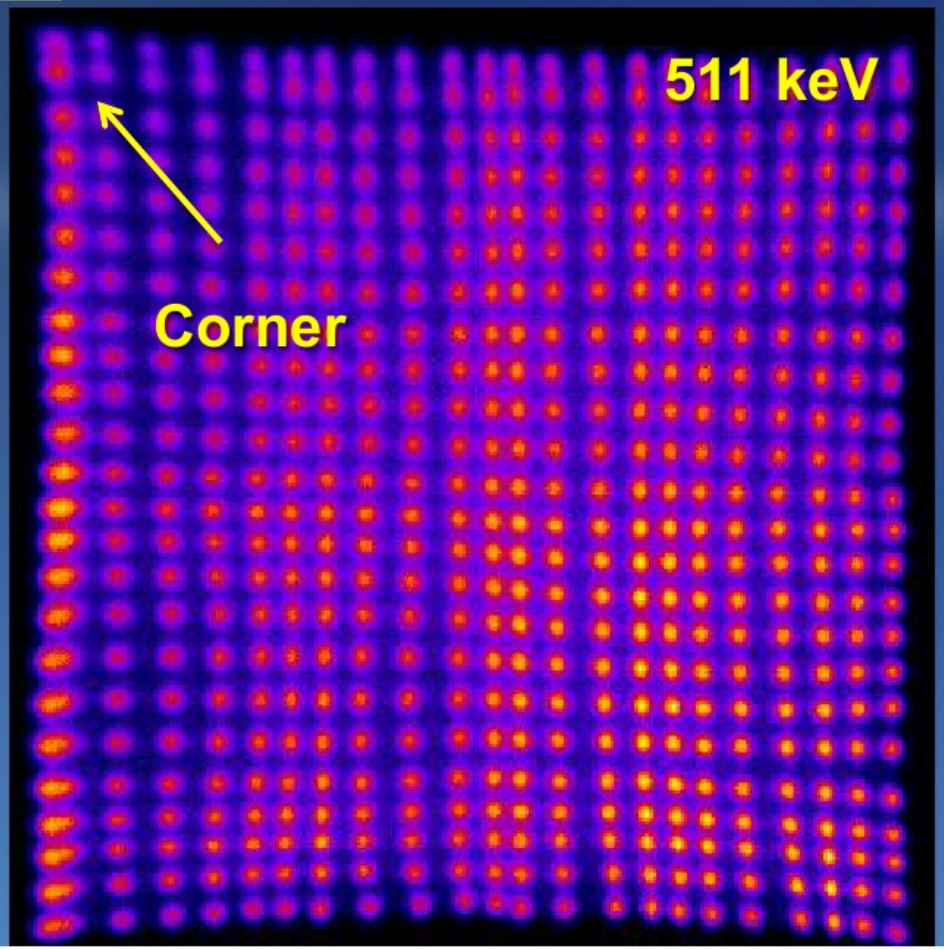
The 1mm LYSO array coupled directly to the tapered light guide (left) and through the additional 1.65 mm window (right). The LYSO array was placed in the central part of the MPPC module. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

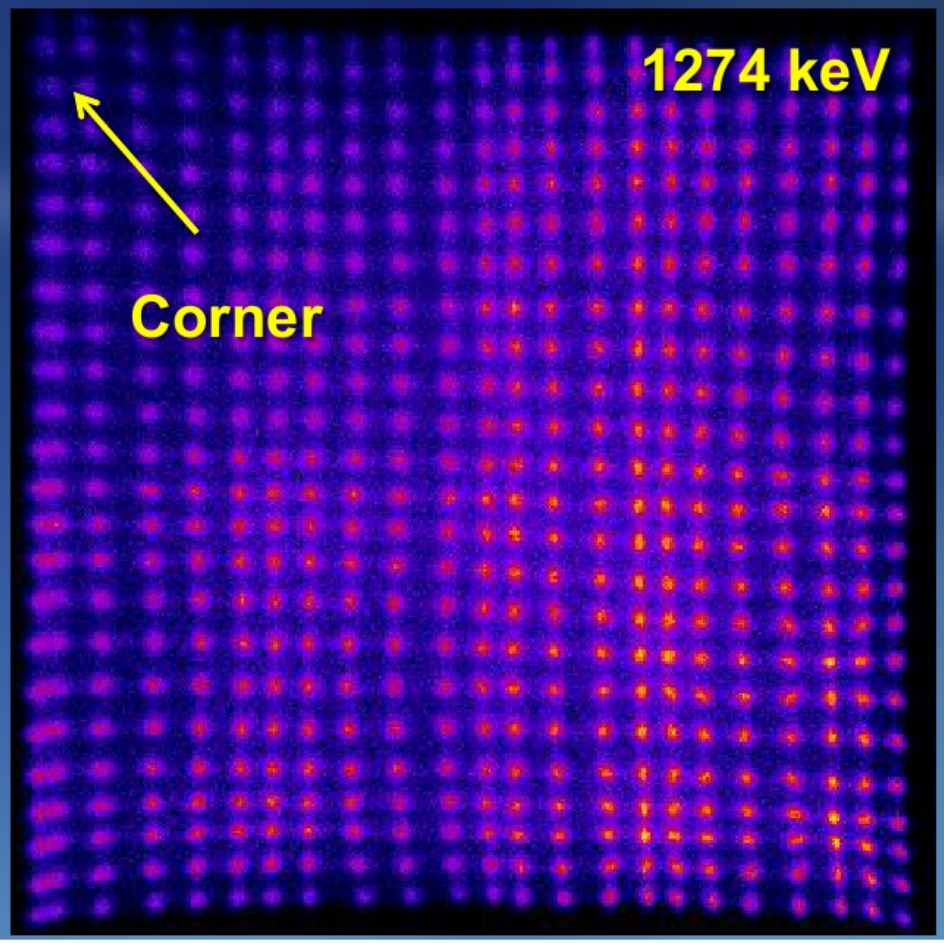
24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via 1.65mm window and tapered light guide - center

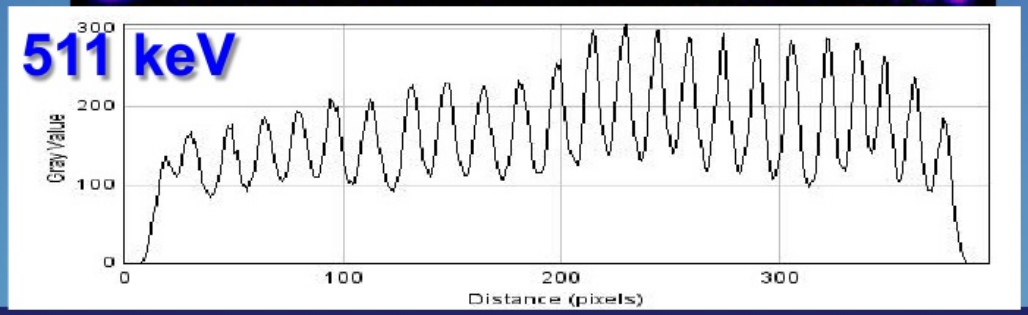


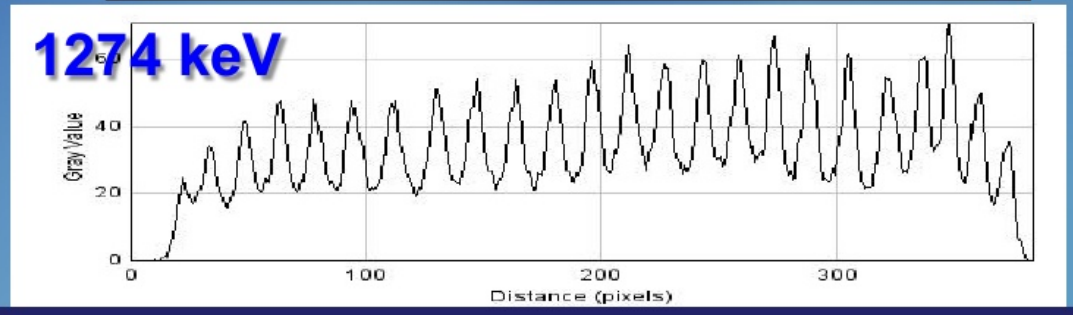
Six selected 1mm LYSO pixels across the LYSO array placed in the central part of the MPPC module. Shown FWHM energy resolution and relative @511 keV values. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via 1.65mm acrylic window and tapered light guide - corner



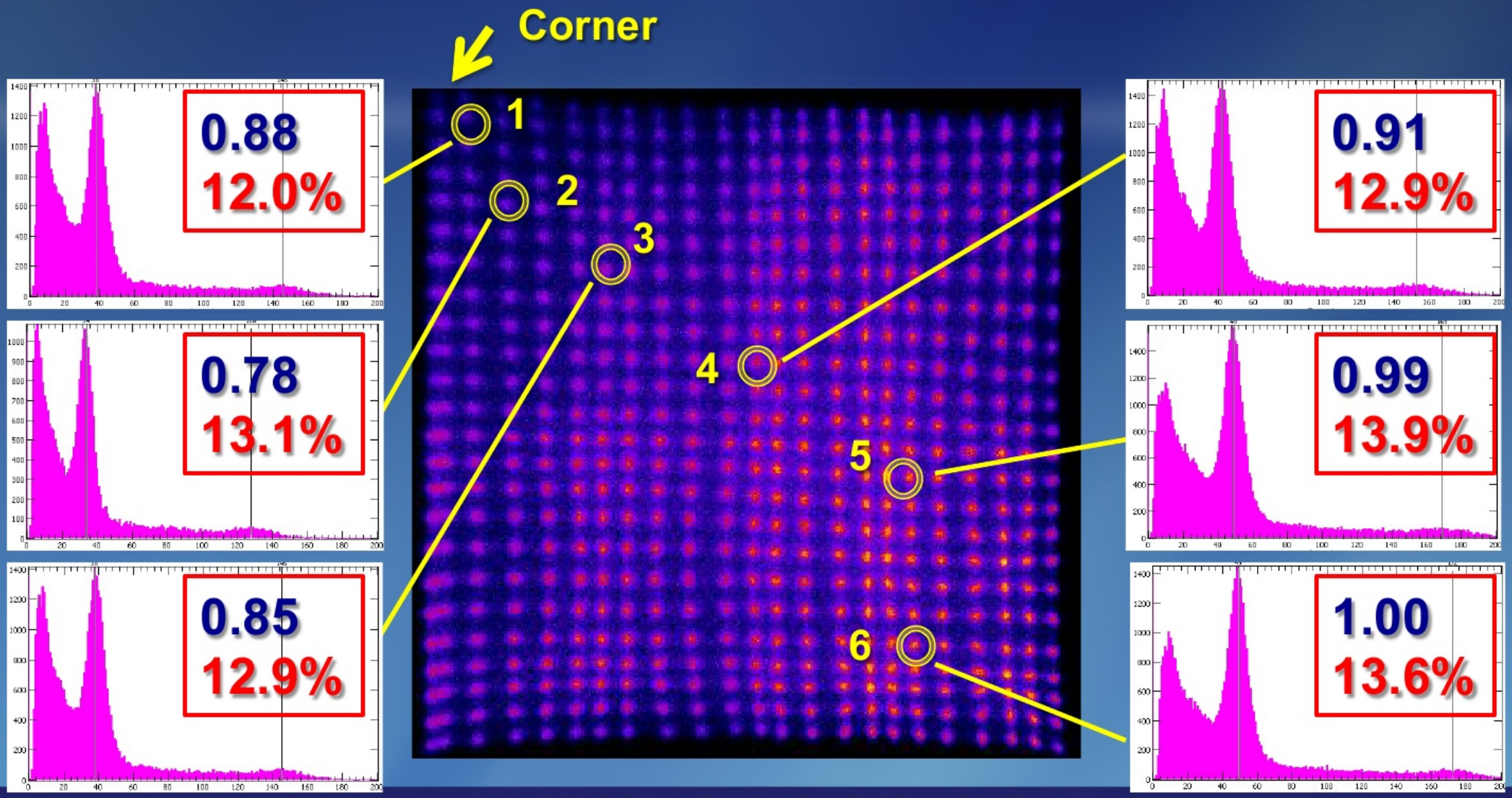






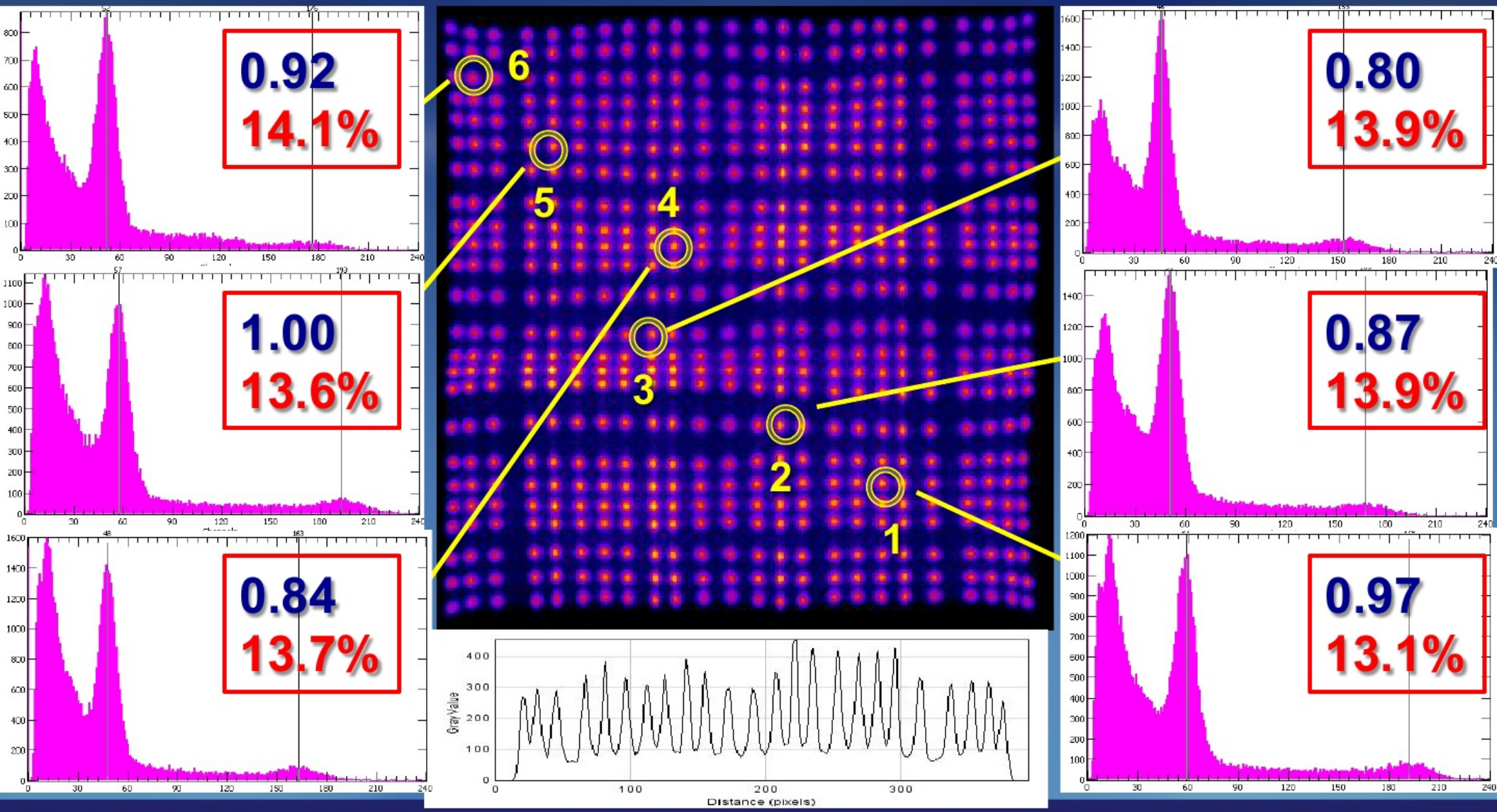
Left: image and example column profile @ 511 keV. Right: image and example column profile @ 1274 keV. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via 1.65mm acrylic window and tapered light guide - corner



Six selected 1mm LYSO pixels across the LYSO array placed in the corner of the MPPC module. Shown FWHM energy resolution and relative @511 keV peak values. 1274 keV photopeaks were used to correct for energy zero shift due to diode circuitry in the row and column readout. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

24x24 1.0mm x 1.0mm x 10mm LYSO array coupled to the MPPC array via 1.00mm microscope glass window and tapered light guide – center



Six selected 1mm LYSO pixels across the LYSO array placed in the center of the MPPC module. Shown FWHM energy resolution and relative @511 keV peak values. 1274 keV photopeaks were used to correct for energy zero shift due to diode circuitry in the row and column readout. Temperature: 22.0 deg C, bias: 66.9 V. 170 ns ADC gate. 0.025 truncation factor. AC coupling of the signals to ADC.

Summary for the LYSO study with the 16x16 MPPC array

- Row-and-column readout can separate down to 1.0mm LYSO pixels, also with tapered light guide
- 4ch readout is not capable to separate 1.5mm pixels in the corner regions
- Energy resolution is better than 14-15% FWHM @ 511 keV when using tapered light guide
- Lower temperature provides only small performance improvement but improves operational stability (gain is sensitive to temperature)
- Adding monolithic scintillator in a hybrid configuration does not worsen energy resolution