Development of a Large Area, High Resolution, MR-Compatible PET Detector Module

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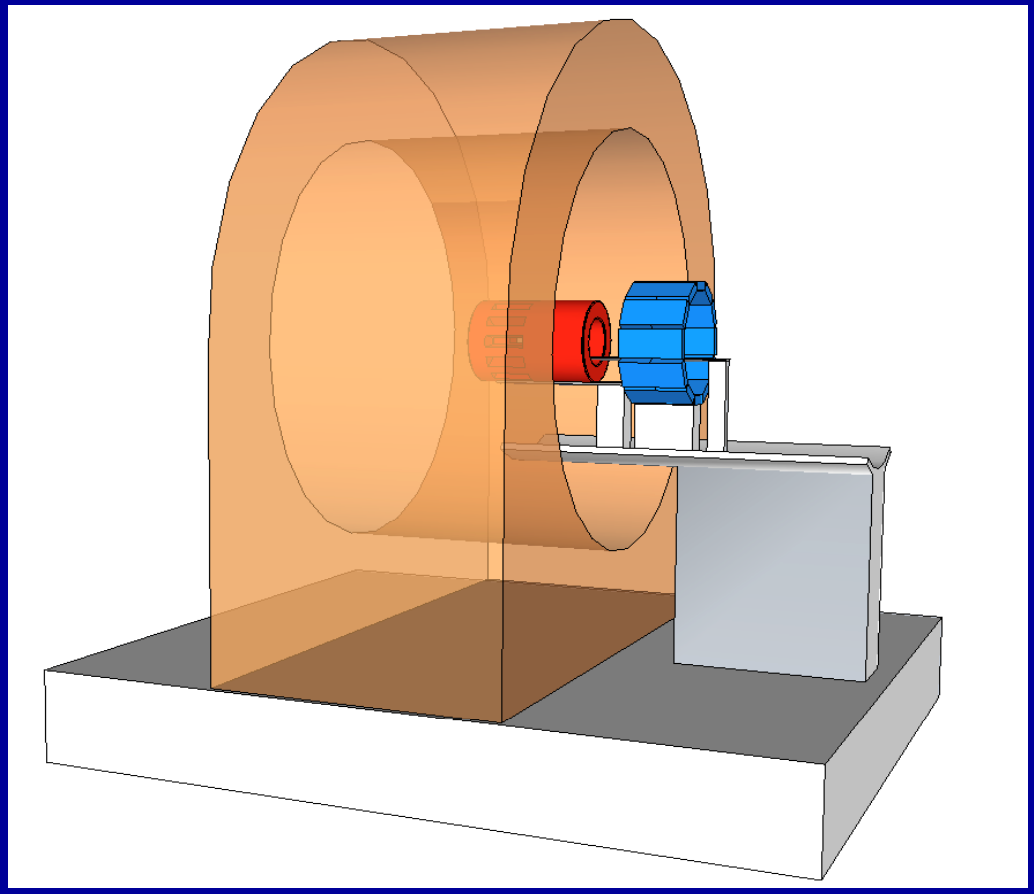
Project Goals

Long-term Goal: Construction of a large FOV (axial and trans-axial) PET-MRI insert for the pre-clinical imaging of animals rat to rabbit size in a 3T MRI.

Goal of this Investigation: Development of an MR-compatible, large area detector module from which we will construct the PET scanner component of our PET-MRI insert. Specifically, test the necessity for cooling/temperature stabilization.

Pre-Clinical PET-MRI Insert



PET Scanner: Ring of twelve MR-compatible modules (4.4cm x 9.2cm).
Diameter= 15.3cm; axial extent= 9.2cm

MRI Coils: Two phased array coils (Nova Medical).
Rat (8cm diameter) and rabbit (12cm diameter) coils.

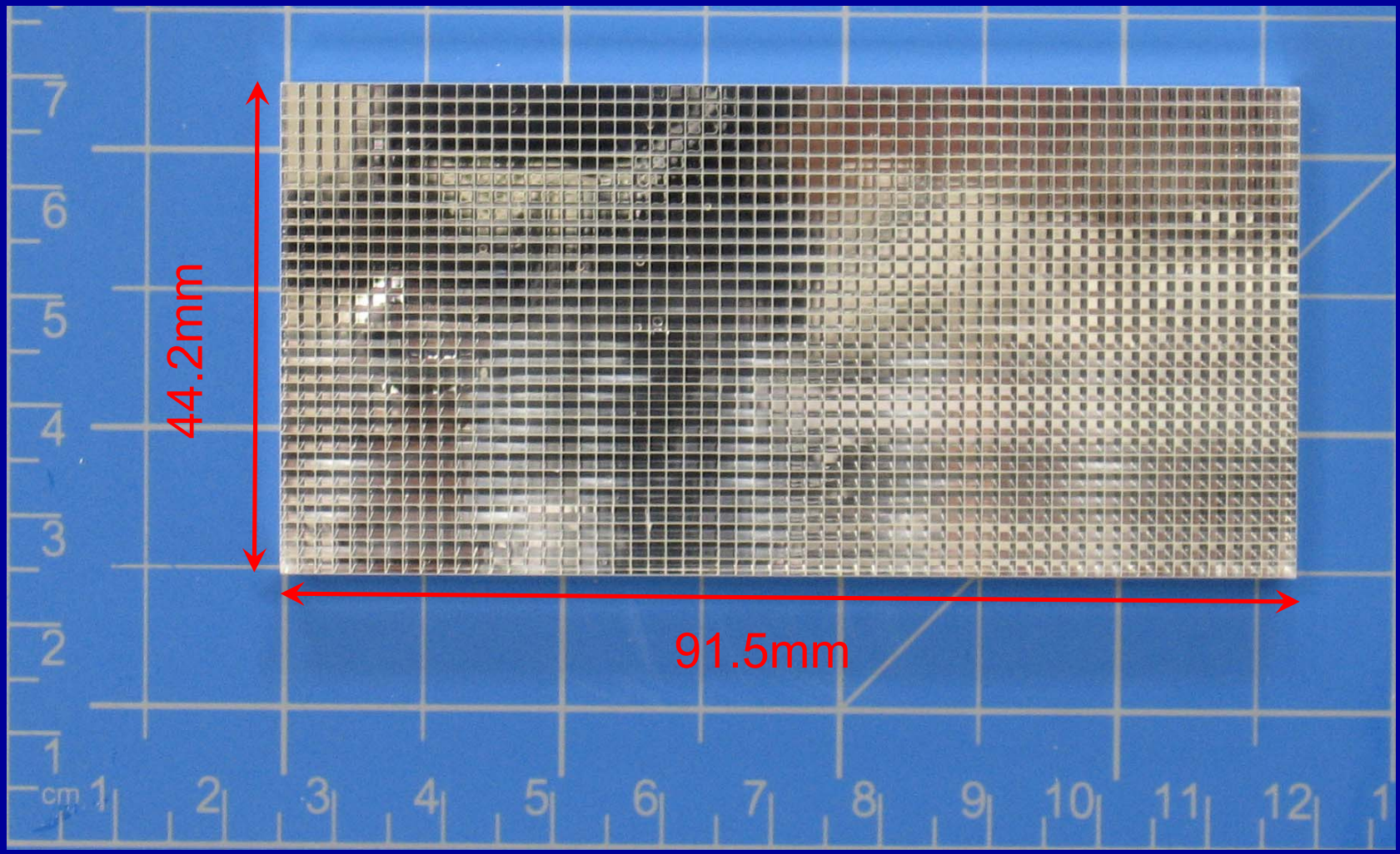
Module Components

Scintillator Array

58x28 LYSO (1.5x1.5x10mm)

Pitch= 1.57mm

Proteus Inc.



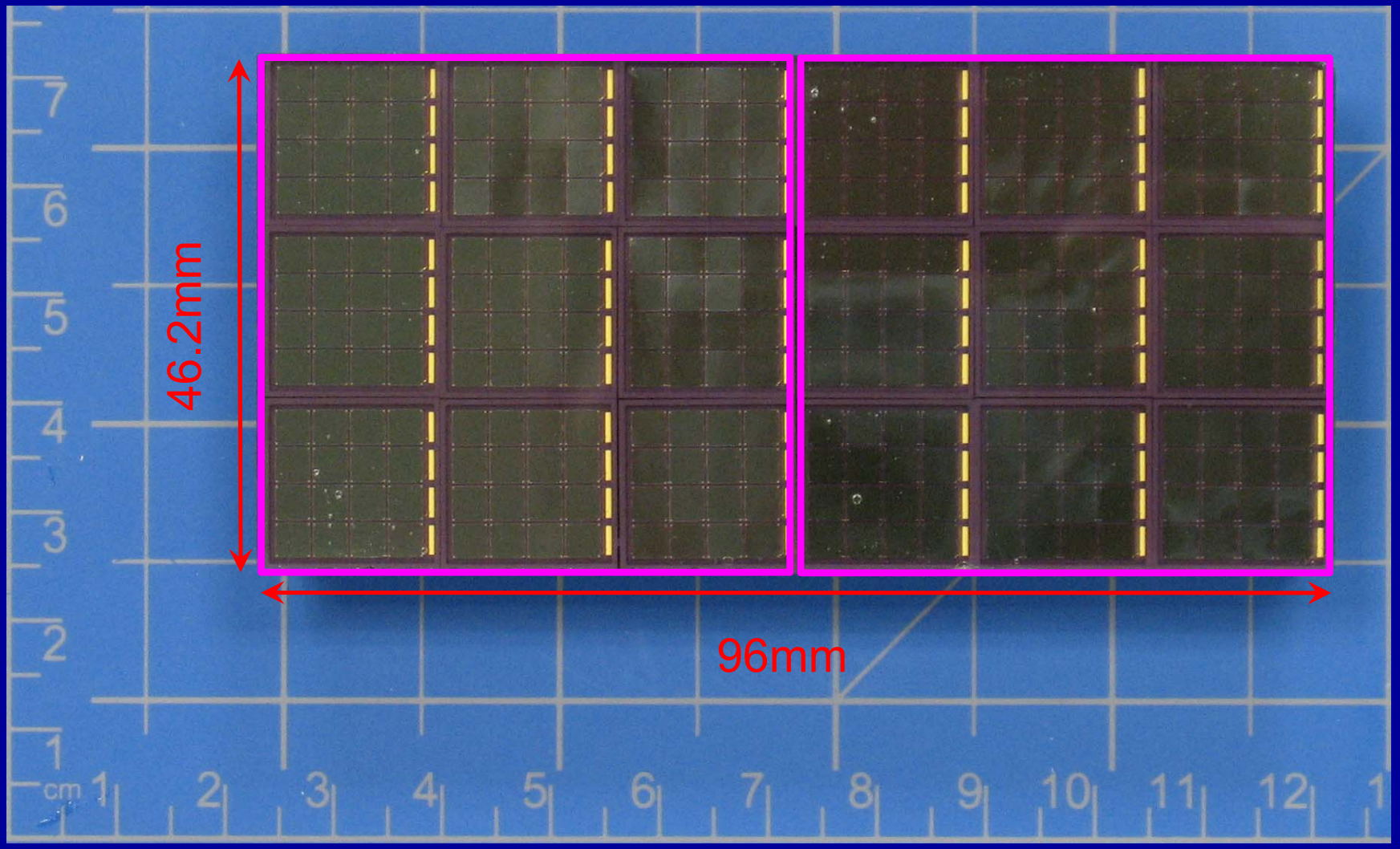
Module Components

Silicon Photomultiplier Array

2 x ArraySL-4p9 SensL Technologies, LTD.

Each Unit: 12x12 3.05x3.05mm pixels (4774 Microcells)

Gain= 2.4x10^6 (at room temperature and standard bias)

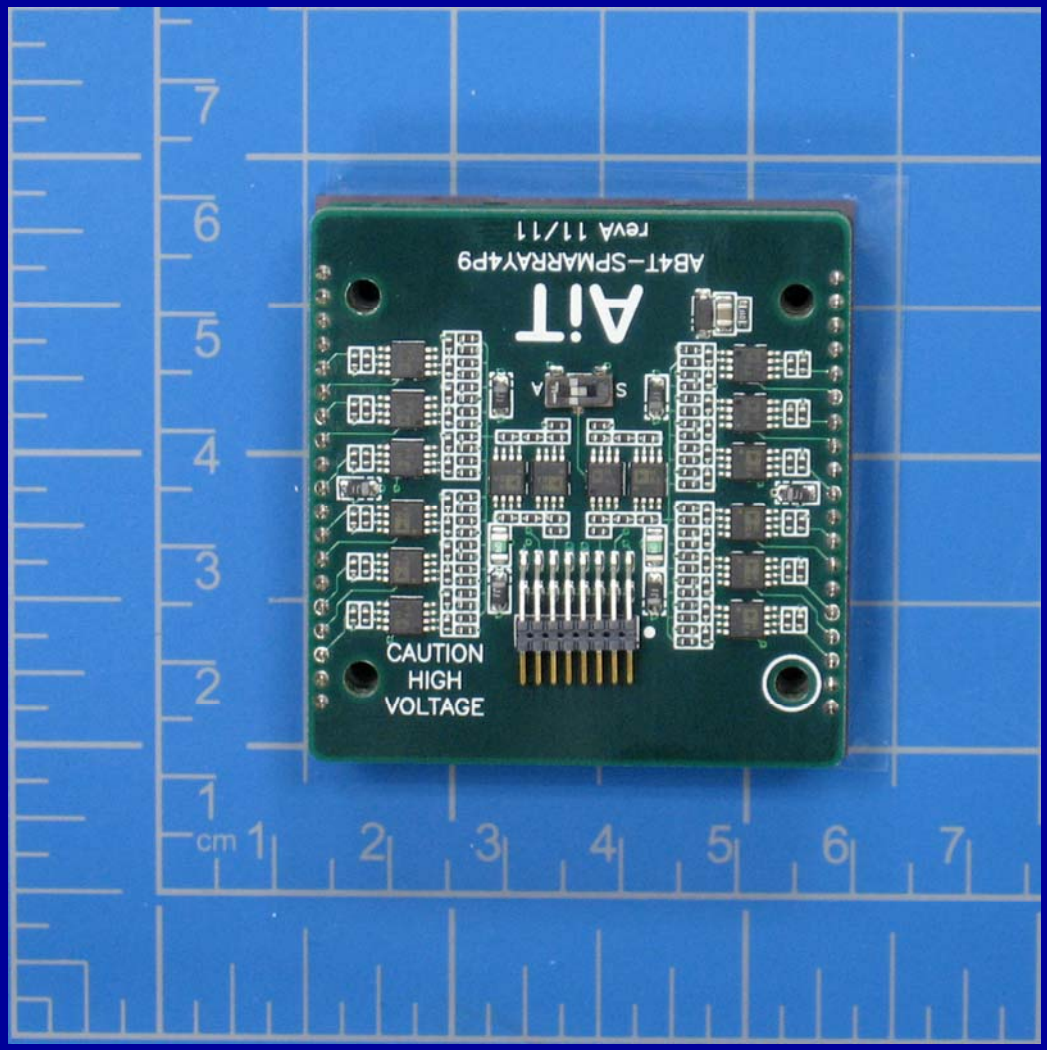


Module Components

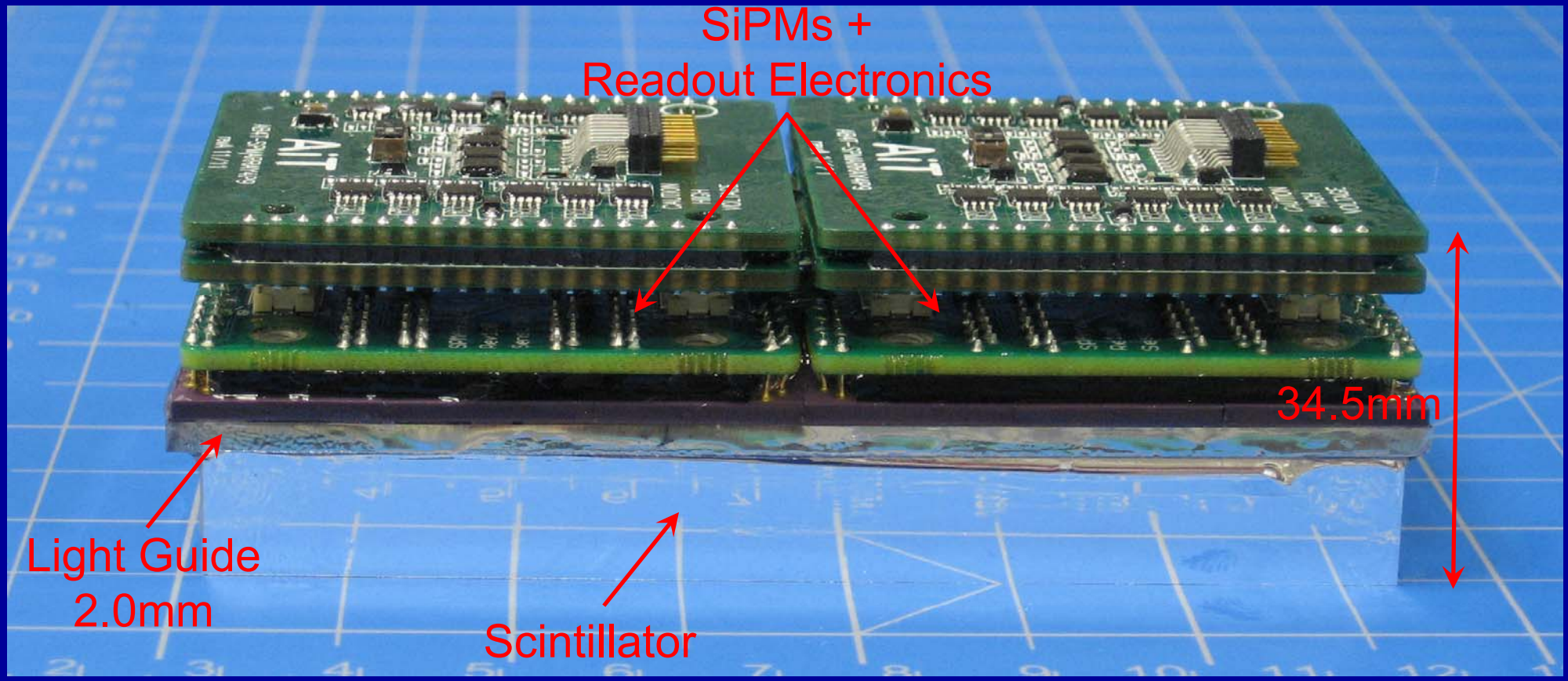
Silicon Photomultiplier Array Readout

4 Output Channels (Multiplex Readout)

AiT Instruments



MR-Compatible PET Detector Module



DAQ System

Detector Module

SiPM Interface Module

FPGA-Based ADC

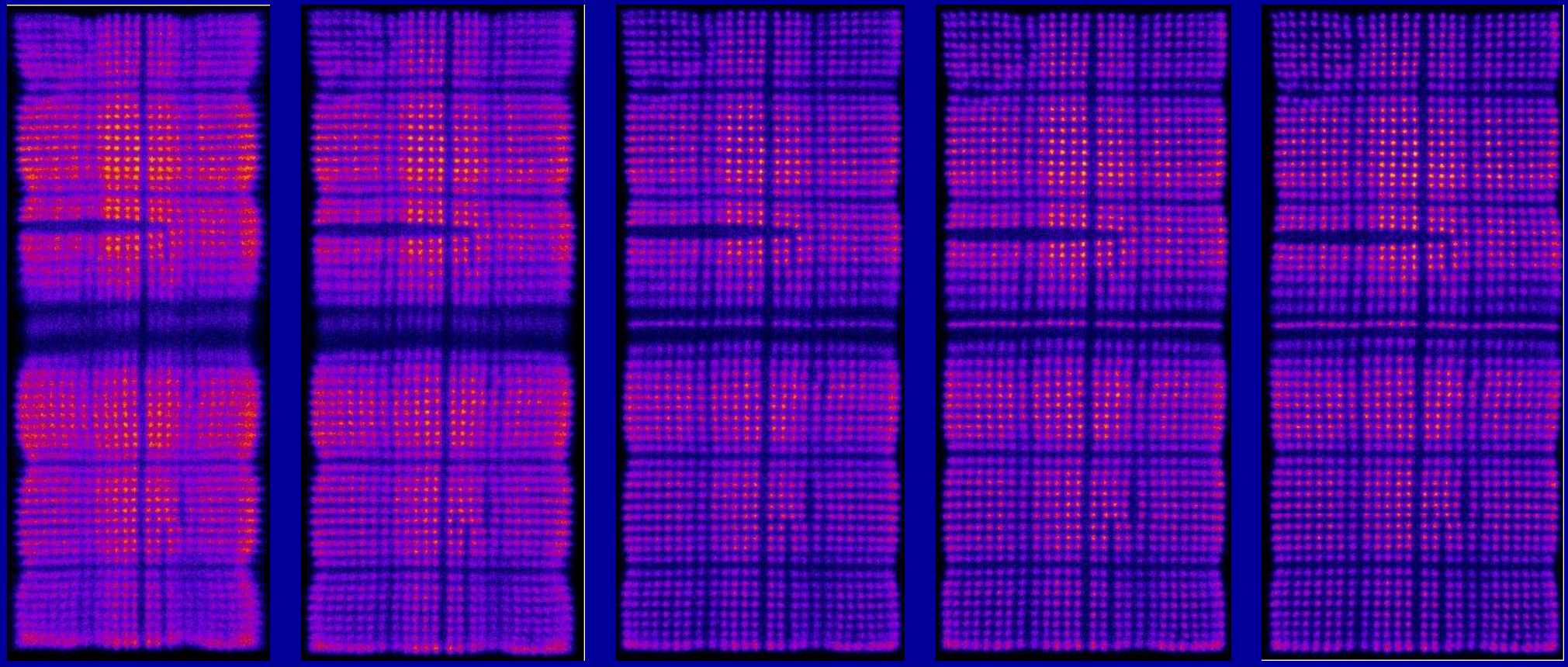
Sum signals from the Interface Module discriminated and or'd in NIM modules, then converted to TTL pulses used to trigger ADC.

Test Procedures

- Detector placed in temperature controlled unit.
- Temperature monitored with probe in contact with edge of SiPM.
- Detector irradiated by three Na-22 sources (5uCi each).
- SiPMs biased at 30.6V.
- Data acquired at 9.2, 11.8, 14, 17.8 and 21.6°C for 900s each.
- Pixel map, energy spectra and pixel profile obtained for each data acquisition.

- Magnetic field test performed in Siemens 3T Verio.
- One measurement.
- Detector removed from temperature control unit, so temperature was not controlled over course of measurement.

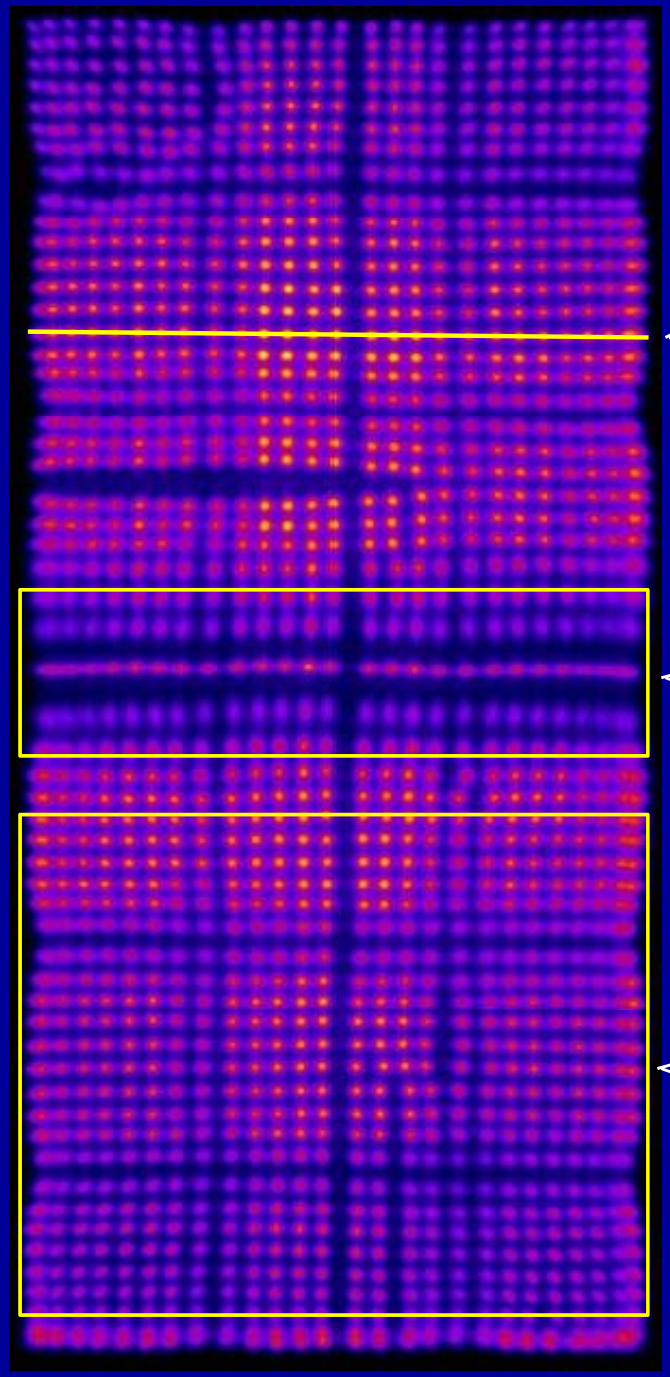
Results (Pixel Maps)

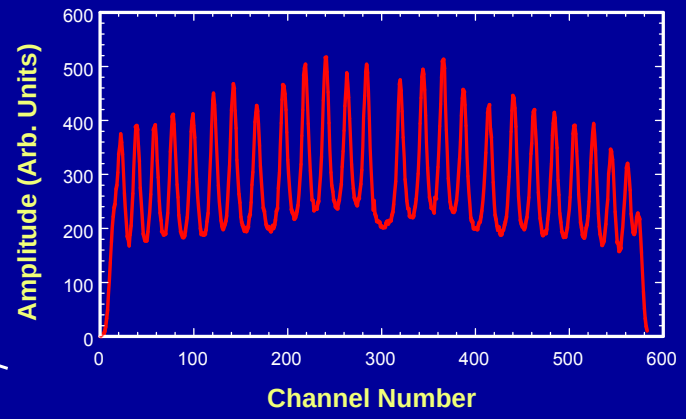


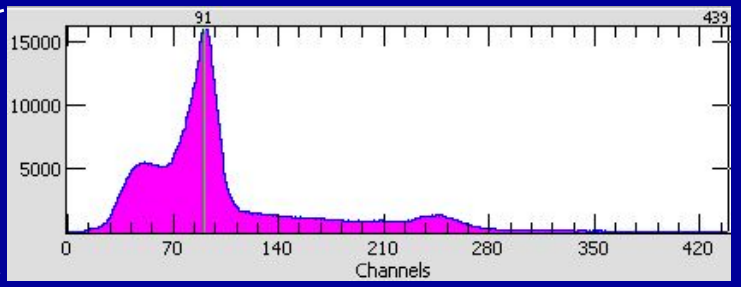
21.6°C	17.8°C	14.0°C	11.8°C	9.2°C
OV= 3.18v	OV= 3.24v	OV= 3.29v	OV= 3.35v	OV= 3.42

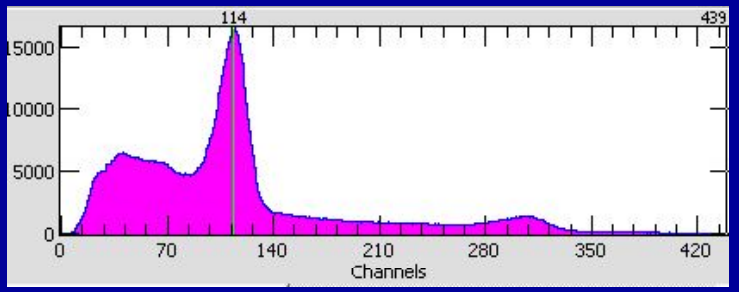
Bias Voltage= 30.6v

Results



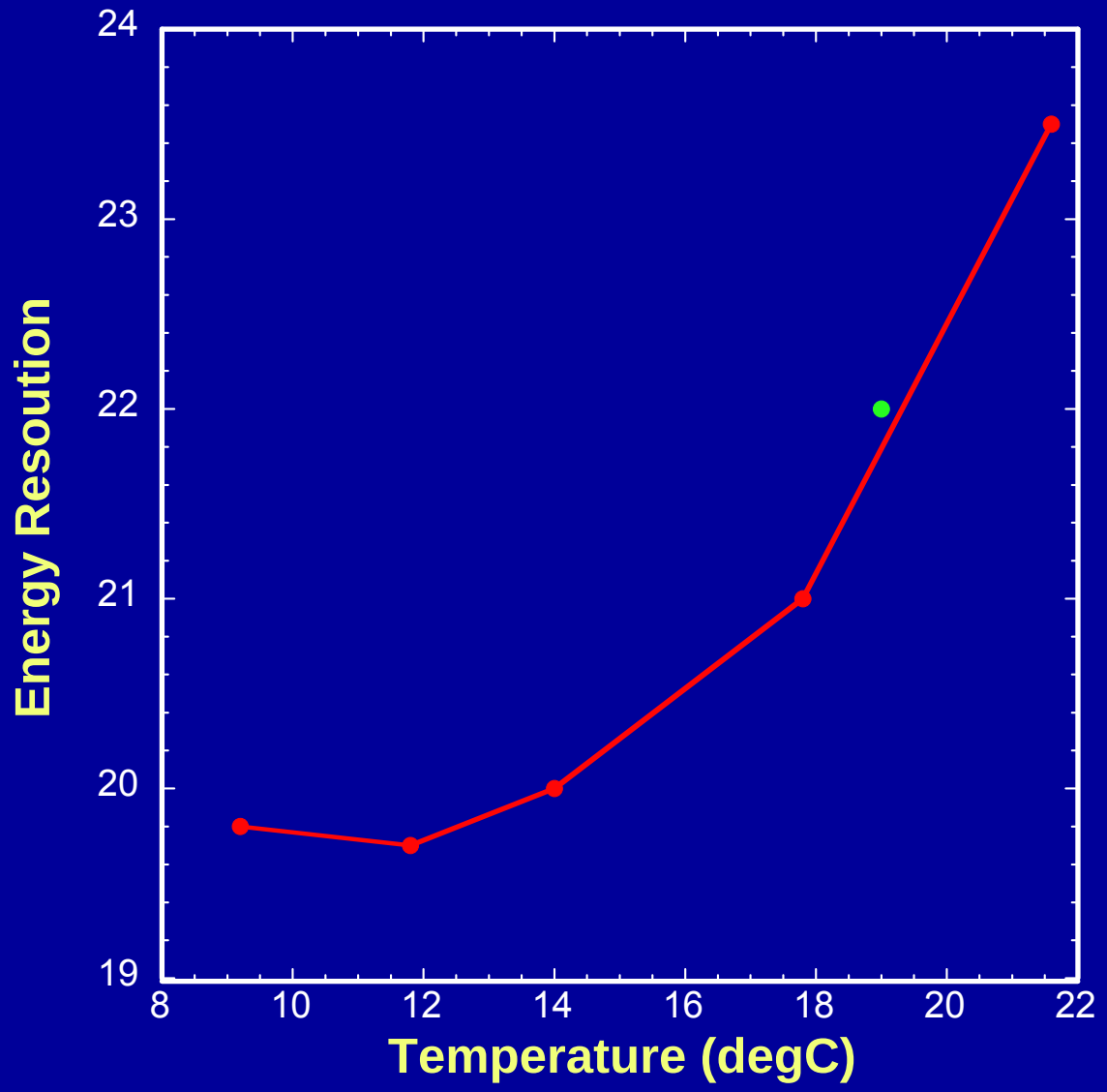






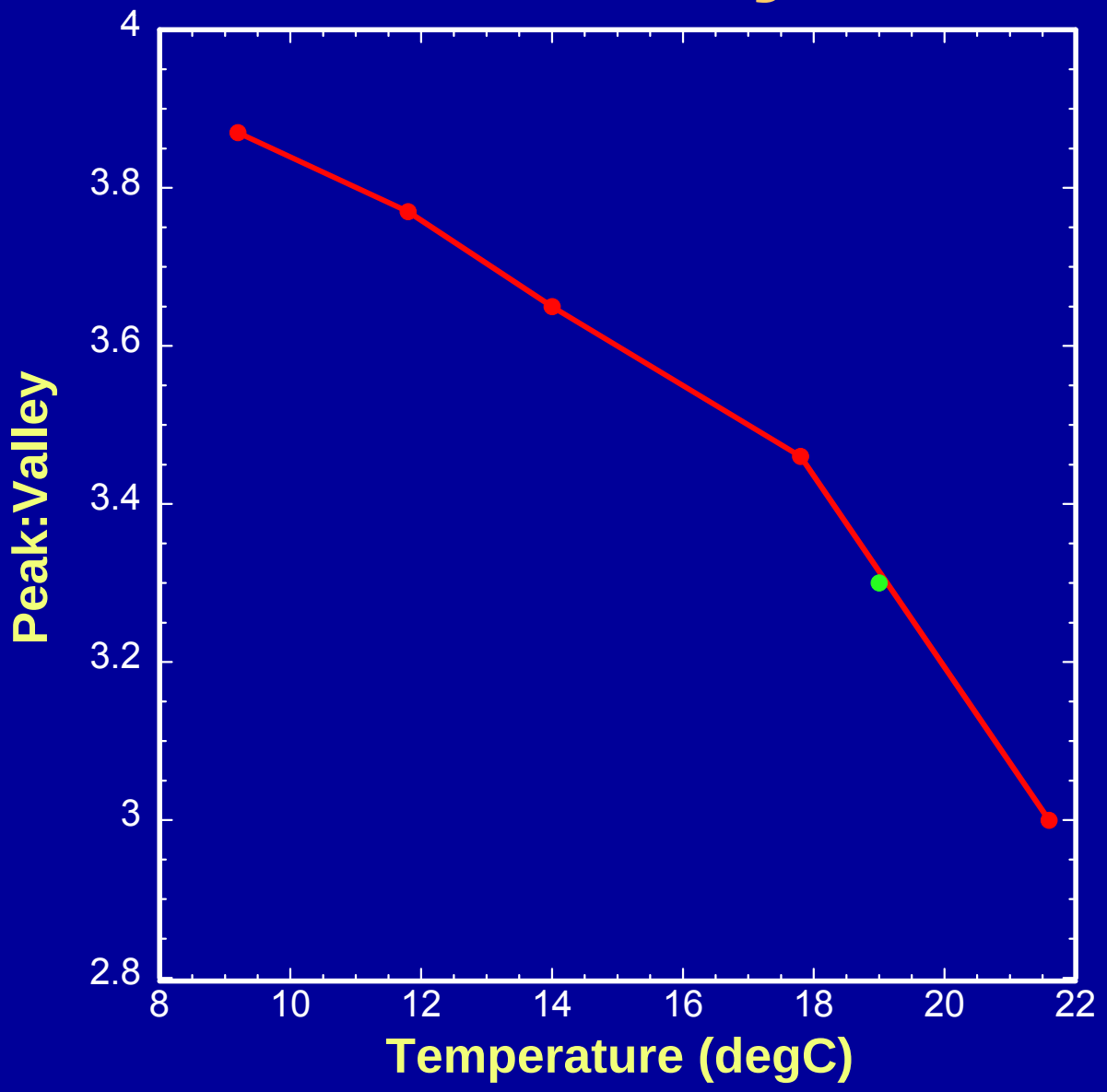
Temperature= 12°C

Results (Energy Resolution)



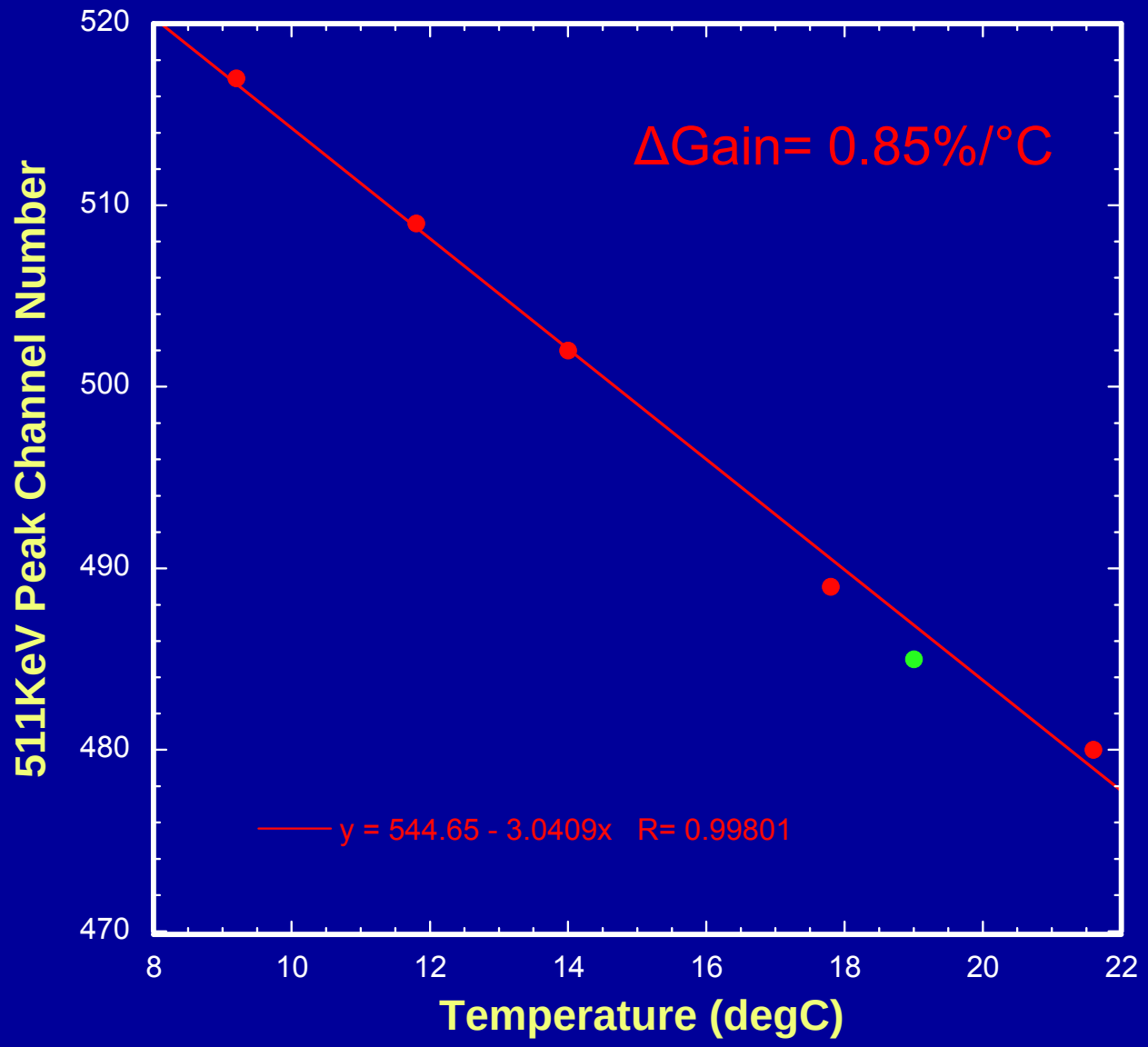
Green dot shows data point when unit was exposed to 3T magnetic field (average temperature during acquisition).

Peak-to-Valley Ratio



Green dot shows data point when unit was exposed to 3T magnetic field (average temperature during acquisition).

Results (511KeV Peak Channel)



Green dot shows data point when unit was exposed to 3T magnetic field (average temperature during acquisition).

Discussion and Conclusions

- Successfully constructed and tested large area (4.6cmx9.6cm), SiPM-based PET detector module. Building block for MR-compatible PET systems.
- Energy resolution improved (23.5% to 19.8%) over temperature range tested.
- Peak-to-valley ratio increased from 2.9 to 3.9 over temperature range.
- 511KeV peak position increased by ~7.5% over temperature range (gain increase by ~8%).
- Performance changes due to increase in gain and reduction in noise caused by temperature decrease.
- Magnetic field produced no measurable change in the parameters measured.
- Moderate cooling/temperature control (10-14°C) necessary for improved performance.
- Next step is to construct twelve modules for the MR-compatible PET component of our pre-clinical MRI-PET scanner insert.

Acknowledgements

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