

Regional variation in neutron/gamma pulse-shape discrimination within an organic scintillator



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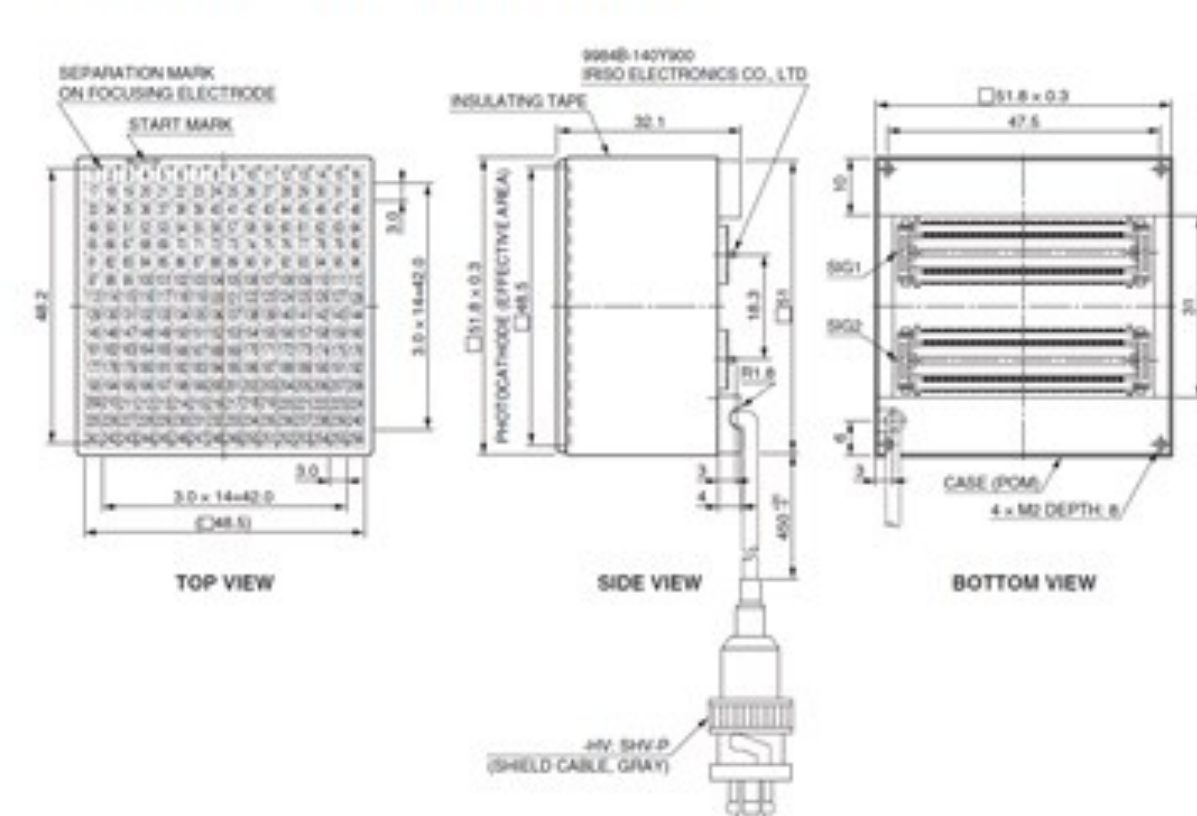
Motivation and Objectives

- Nuclear safeguarding and special nuclear material (SNM) assay require effective means of identifying gamma and neutron events in a mixed field environment
- Established systems use pulse-shape discrimination (PSD) with fast-response organic scintillators to plot events into neutron and gamma plumes, with their degree of separation characterised by a figure of merit (FoM)
- FoM is observed to be worse for events where PSD parameter values are small^[1]; a possible cause is variation in the PSD response within different regions of the scintillator, which is currently not well understood
- Novel examination of how pulse shape varies within a scintillator will allow improved PSD FoM and inform studies seeking to exploit detector geometry^[2-4] or extract interaction position from pulse shape

1. Multi-anode photomultiplier tube (MAPMT) – H13700^[5]



- High quantum and collection efficiencies (33%, 80% typical)
- Low crosstalk (mean 2.8% perpendicular, 0.4% diagonal)
- 256 3x3 mm anodes



Hamamatsu flat panel type multianode PMT assembly – H13700



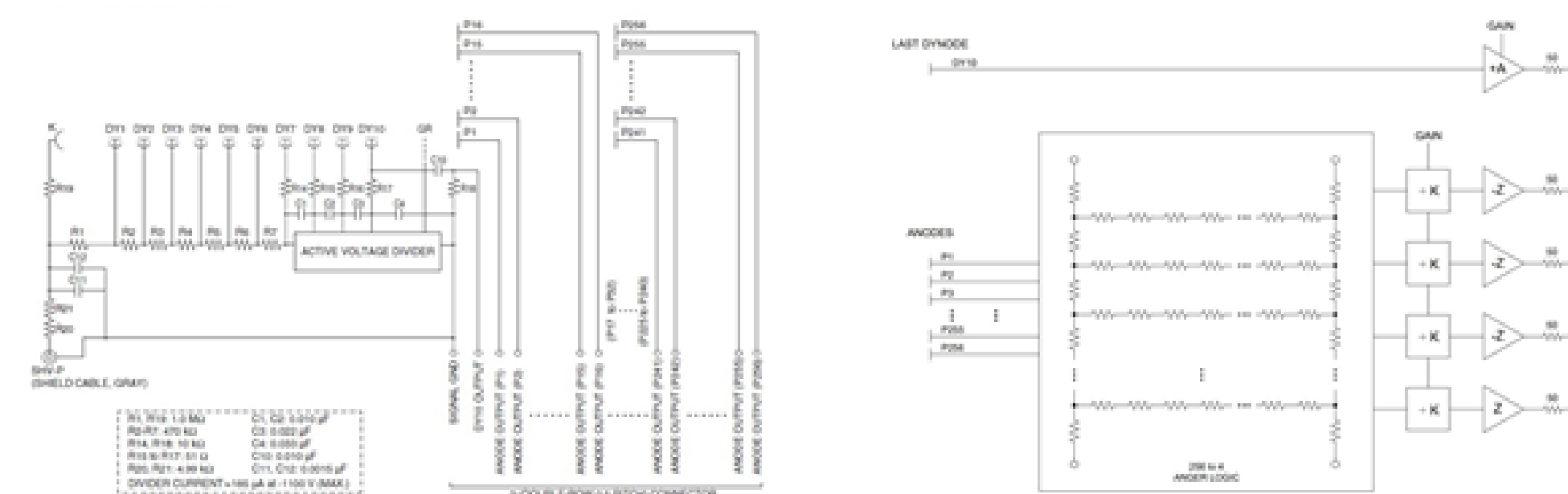
2. Anger logic readout circuit – SIB71256^[6]



- Anode charge divided across resistive network
- 256 anode outputs reduced to 4 Anger logic outputs
- Anger logic gives coordinate information
- Separate last dynode output

$$X_{\text{pos}} = (V_1 + V_{16} - V_{241} - V_{256}) / (V_1 + V_{16} + V_{241} + V_{256})$$

$$Y_{\text{pos}} = (V_1 + V_{241} - V_{16} - V_{256}) / (V_1 + V_{16} + V_{241} + V_{256})$$

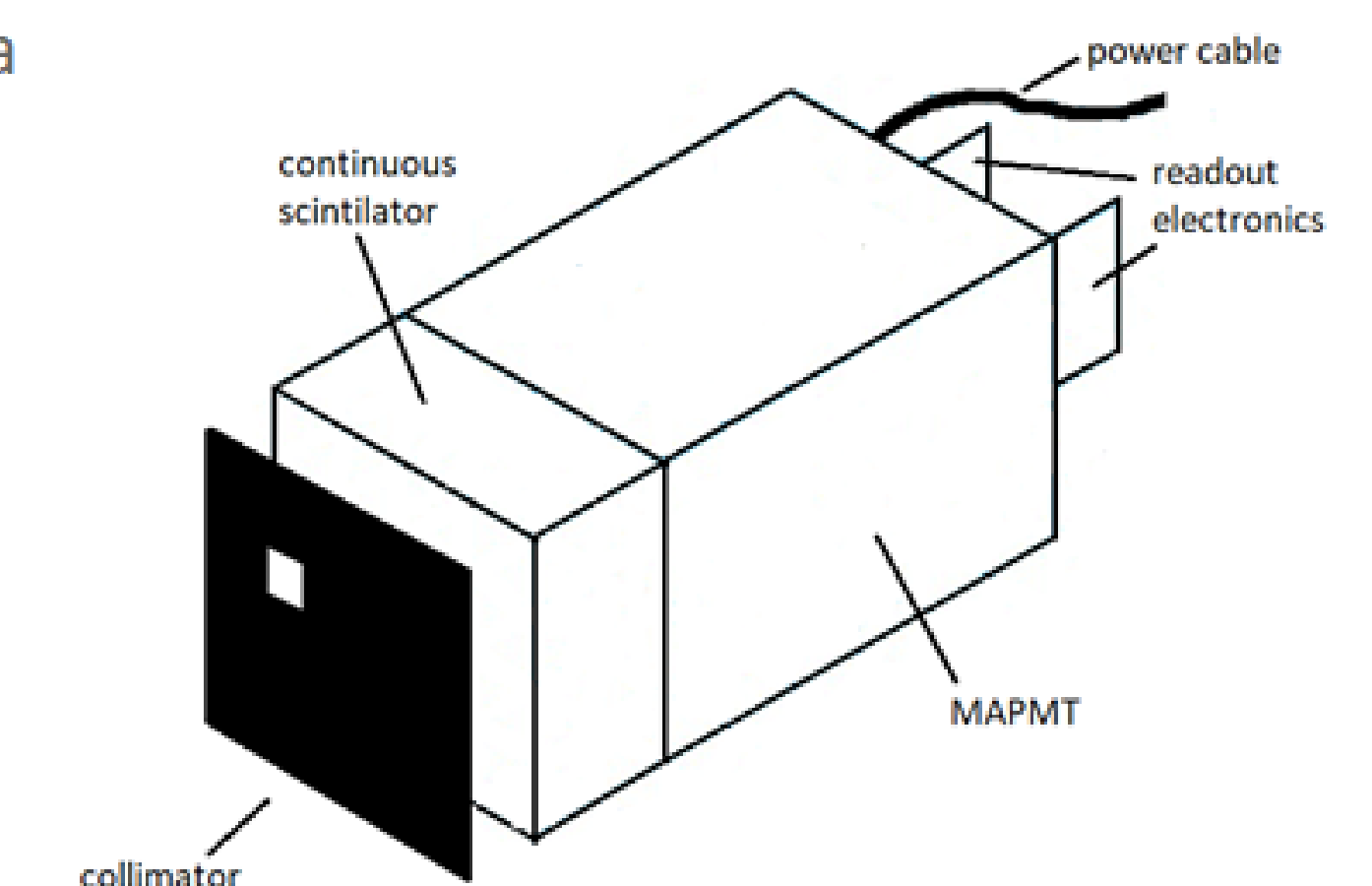


Hamamatsu flat panel type multianode PMT assembly – H13700; Vertilon SIB71256

3. Novel application of MAPMT (H13700) with continuous organic scintillator (EJ-276)



- H13700's 256 anodes would allow a very granular view of light behaviour within the scintillant
- Multiple anodes allow separate readings of the same event at different positions within a continuous scintillator
 - PSD FoM
 - Peak amplitude
 - Rise/die-away times
- Anger logic resistive network yields coordinate information



4. Current and future research methodology using Vertilon sensor-interface boards (SIBs)



Anger logic readout SIB71256

- CURRENT WORK**
- Lead-polythene collimator with 1x1 pixel (3x3 mm) aperture controls interaction location
 - Cs-137 gamma calibration source
 - Cf-252 mixed-field source
1. Calibrate detector energy channels
 2. Position aperture at known coordinate position
 3. Measure Anger logic output for each interaction location
 4. Perform mixed-field PSD using last dynode output

Custom manual selection SIB

- FUTURE WORK**
- Lead-polythene collimator with 1x1 pixel (3x3 mm) aperture controls interaction location
 - Cf-252 mixed-field source
1. Position aperture at known coordinate position
 2. Measure and compare PSD response across detector regions
 - Connect up to 4 anodes to MFA inputs 1:1
 3. Repeat for different interaction locations

References:

- [1] S. A. Pozzi et al., "Correlated neutron emissions from 252Cf", Nucl. Sci. & Eng., Vol. 178: pp. 250-260, 2014.
- [2] F. Begin et al., "New shapes for liquid scintillation detectors used in neutron spectrometry", Nucl. Instr. & Meth. A, Vol. 562: pp. 351-357, 2006.
- [3] C. S. Sosa et al., "Energy resolution experiments of conical organic scintillators and a comparison with Geant4 simulations", Nucl. Instr. & Meth. A, Vol. 898: pp. 77-84, 2018.
- [4] C. S. Sosa et al., "Improved neutron-gamma discrimination at low-light output events using conical trans-stilbene", Nucl. Instr. & Meth. A, Vol. 916: pp. 42-46, 2019.
- [5] Hamamatsu flat panel type multianode PMT assembly – H13700
- [6] Vertilon SIB71256