BRIDGEPORT
INSTRUMENTS, LLC

RADIATION DETECTION - FAST
- SIMPLE
- ECONOMICAL

# Bridgeport Instruments, LLC

### Our Technology In A Nutshell

## 1. Technology

### 1.1 Introduction

**MCA, SiPM, and neutron detectors:** Bridgeport's wholly owned technology encompasses modern multichannel analysers (MCA) for all applications, high-performance SiPM detectors, and neutron detectors for Homeland Security.

**Fresh designs:** All electronics and detector designs have been updated in response to the post-Covid landscape. There are no shortages, and devices and detectors are readily available.

### 1.2 Multichannel Analysers (MCA)

**We offer three classes of analysers**

- **Low speed SiPM/PMT-1000:** Software MCA, 160 kcps throughput
- **High speed SiPM/PMT-2000:** FPGA-assisted MCA, 650 kcps throughput
- **Super speed SiPM/PMT-3000:** FPGA-based MCA, 4000 kcps throughput

**The programmable MCA:** All current MCA have an embedded 32-bit ARM processor, programmable in C. Hence we are able to offer unprecedented levels of customization, as well as many built-in features.

**Our novel approach:** There are many complex operations and calculations embedded in the MCA to make it easier for the business customer to pursue their goals.

**Beyond gain stabilization:** Our MCA use temperature lookup tables for the performance stabilization. Unlike the competition, we stabilize more than the gain. We stabilize 1) the trigger threshold, 2) the maximum measurable energy, and 3) the MCA gain; ie keV/bin.

**Sample vs Background measurements:** The MCA can store a background measurement on board and subtract that background from subsequent sample measurements.

**Poisson Statistics:** Every 50 ms, the ARM processor performs various statistical computations that it uses to decide if an alarm is necessary.

**Sample alarm:** When measuring a background subtracted sample, the MCA reports the statistical likelihood that the sample is more radioactive than the background. The user can set an alarm threshold based on probability (eg 1:1000) rather than a fixed count rate.

**Monitor alarm:** There is an embedded portal monitor algorithm that is suitable for mobile and stationary systems. The processor tracks the slowly changing background. At all times it measures the total counts during the sampling window (typically 4 s) and computes the probability that the observed counts are caused by the known background. The user chooses a probability as an alarm threshold.

**Two-channel logger:** Transient phenomena, such as a quickly passing source can be captured by the built-in 2-channel logger. Each channel records 1020 samples at time increments between 50 ms and 12.8 s. For example, for a portal monitor, one can record net counts and computed alarm probability. When the alarm is issued there is at least an uninterrupted 51 s history available in the logger memory.

**Autonomous operation:** The SiPM/PMT-2000 can acquire data without needing assistance from a host computer. They can be programmed to store data in onboard 32 MB flash memory, which has room for thousands of energy spectra. A device can be deployed unattended together with just a small battery pack. Mount it on a drone, or drop it at a hidden site; collect it after the mission and read back the data in the office.

**RIID:** The processor is powerful enough to perform more complex tasks. For example it can perform the computations necessary for a deep learning multi-layer neural network for radio-isotope identification.

**Secure code updates:** The ARM C-code as well as the FPGA configuration can be updated securely via USB. We use industry standard methods to implement a cryptographically secure process. Encrypted files can be sent to the end user, and the code on the MCA can be updated in situ.

**Open-source client software:** All software outside of the MCA is open source. All MCA and neutron detectors are operated by the MCA Data Server (MDS). The MDS, written in Python, runs on most platforms: Intel and ARM processors, Windows, Linux, Raspberry Pi. The MDS acts as a bridge between the USB detector interface and the local machine or even the Internet. One or more client applications interact with the server via a message protocol (ZMQ) over TCP/IP. This allows the users to communicate with the MCA in any programming language they want.

## 1.3 SiPM

**A new frontier:** Silicon photomultipliers are new optical sensors that can replace the old vacuum photomultipliers in many applications. Bridgeport Instruments has perfected the technology of using SiPM in radiation detectors while reducing the system price considerably.

**Using SiPM in scintillator detectors has many benefits:**

**Precision measurements:** Bridgeport Instruments sells SiPM radiation detector with low noise and high dynamic range. Even on a 3-inch NaI(Tl) equipped with only an economical 4×4 ($5.76\,\mathrm{cm}^2$) SiPM array, we achieve a trigger threshold as low as 11 keV with a maximum measurable energy of 3.2 MeV, for a dynamic range of $> 300{:}1$.

**Small volume:** SiPM measure only 0.3 mm in thickness and replace a 12-20 cm long assembly of vacuum PMT plus high voltage unit. Given that the most popular NaI(Tl) scintillator size is a 5 cm long cylinder, the space saving is enormous.

**Easy to gain stabilize:** Unlike vacuum PMT, SiPM are silicon devices with very predictable temperature behavior. They also do not have a long thermal relaxation time constant. Hence, gain stabilization, becomes simple and very economical to implement.

**Complete integration with the MCA:** Our MCA include the power supply for the SiPM, the embedded ARM processor performs all necessary voltage adjustments, as well as the gain stabilization without requiring assistance from a host computer. In fact, the MCA plugs directly onto a SiPM carrier board, so that the entire electronics stack is only 1.3 cm tall.

**Demountable crystals:** The SiPM-detector systems are designed to let an end user change out a broken crystal in the field. Just four screws need to be undone and a new crystal can be swapped in. No longer does the user lose the entire expensive detector, just because of a cracked NaI(T) crystal.

**Ideal for drone flights:** In a SiPM-based NaI(Tl) detector, equipped with our MCA, practically all the weight and size is in the scintillator itself, ie the radiation detecting element. With only 75 mW to 250 mW power consumption, and no need for a host computer, battery weight is minimized.

**Low background counting:** When measuring weak radioactive contamination in soil or food, users often rely on shielding the sample from environmental radiation to improve the minimum detectable activity. The shielding is made of lead and usually very heavy. The much smaller size of a SiPM detector helps to dramatically reduce the size, weight and cost of the shielding – and it makes the measurement apparatus much more portable.

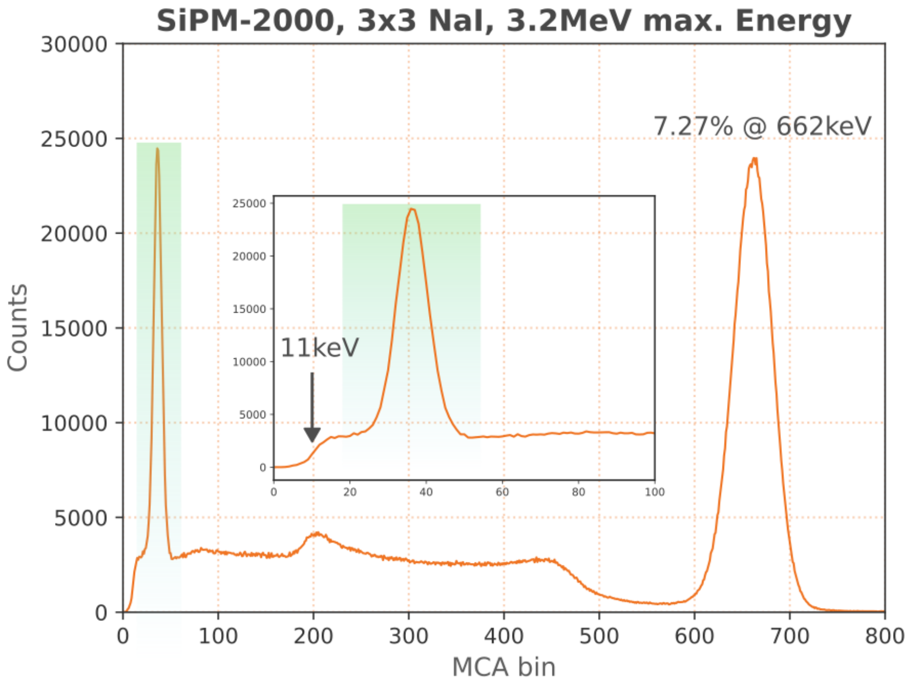

Fig. 1: The performance of an SiPM-2000 with a very economical SiPM array on an Alpha Spectra 3-inch NaI(Tl) crystal.

## 1.4 Neutron Detectors

**Smart neutron detectors:** The neutron detectors share many of the characteristics of the MCA, since they all use one of our MCA without modification, save perhaps for dedicated FPGA firmware.

- **High efficiencies:** Used widely as vehicle mount and in portal monitors
- **No special electronics:** Uses COTS PMT-2000 MCA
- **No difficult to source substances:** Only ZnS(Ag) and $^{10}$B; no helium, no $^{6}$Li
- **No hazardous substances:** No pressurized gases, no Li-metal, no BF$_3$
- **Proven stability:** In a study of deployed detectors, we found no loss of performance over a period of 6 years.
- **High performance:** Minimal instrument dead time (<5μs per event) using the embedded neural network for real time neutron/gamma separation
- **Improvements:** Further improvement is possible by implementing deep-learning multilayer neural networks in the FPGA of a PMT-3000. Considerable improvements may be achieved without changing the hardware, chemistry or method of production.
- **Easy to assemble and scalable:** A team of only 3 employees can assemble 300 detectors/year.

**Performance:** In fig. 2 we show the neutron detection efficiency in response to a $^{252}$Cf source surrounded by 4 cm of high density polyethylene (HDPE), at 2 m distance from the front face of the detector. We use the convention that 1 ng of $^{252}$Cf emits 2300 neutrons per second.

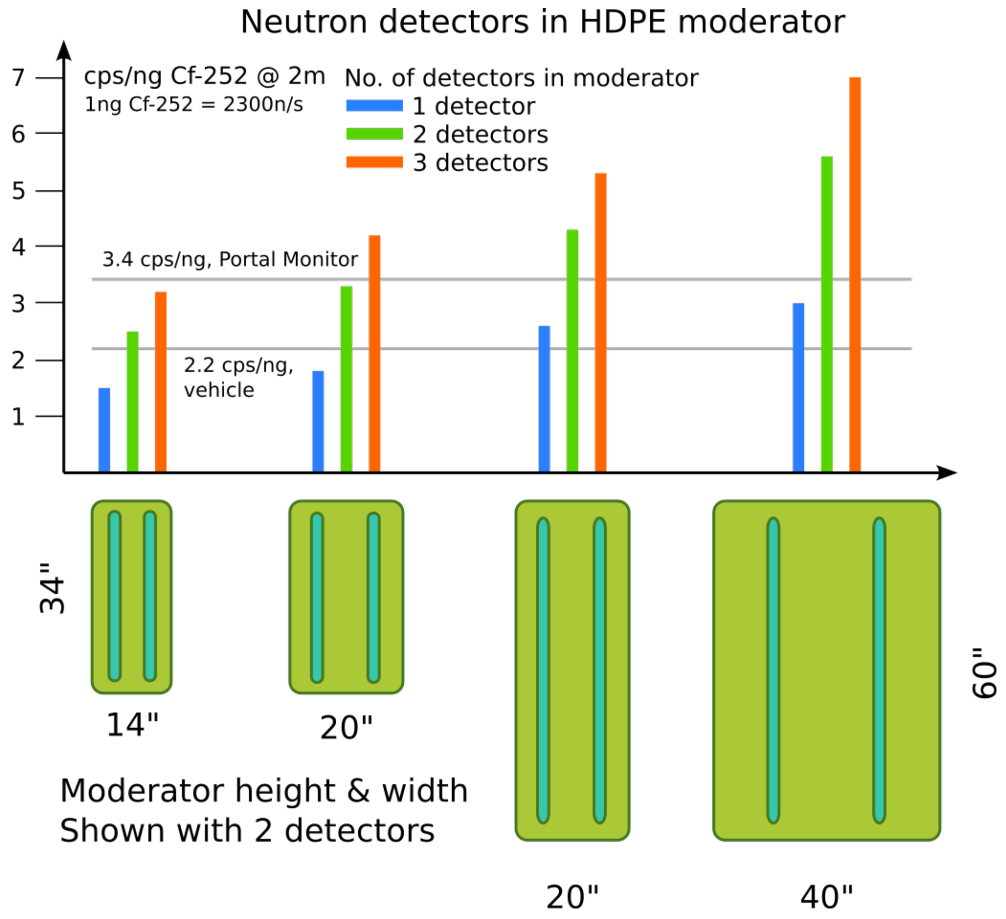

Fig. 2: The performance of neutron detectors of 24-inch and 48-inch length in moderators of different sizes.

**Vehicle mounted:** For portable applications, the moderator has typical source-facing size of 34"×14" (86×36 cm). We show the sensitivity of the entire neutron detection system is one, two, or three individual detector tubes are placed in that moderator. Increasing the moderator width from 14" to 20" (50 cm) increases the system efficiency considerably, while adding negligible cost.

**Full-size Portal Monitor:** On the right we show the system response when 48-inch neutron detector tubes are place in a full-length 60" (152 cm) HDPE moderator. As was the case for the vehicle mounted system, the system sensitivity increases substantially when the moderator is widened to 40" (102 cm)

**Performance vs cost:** In both cases, just two neutron detector tubes create a system that exceeds critical performance specifications. Systems using Bridgeport neutron detectors cost a fraction compared to what is otherwise available on the market.