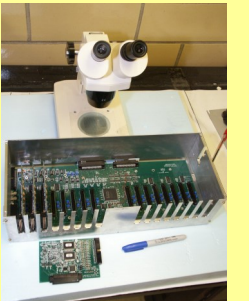
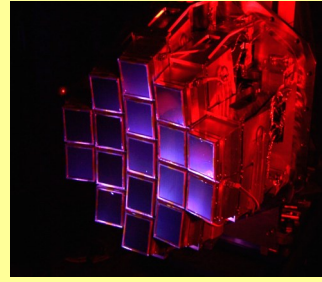


# Multi-Channel Integrated Circuits for the Detection and Measurement of Ionizing Radiation

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## OVERVIEW

The Integrated Circuits (IC) Design Research Laboratory at Southern Illinois University Edwardsville (SIUE) has been collaborating (for several years now) with the Nuclear Reactions Group at Washington University in Saint Louis to develop a family of multi-channel custom integrated circuits for use in research with radioactive ion beams. To date, the collaboration has successfully produced two ASICs (Application Specific Integrated Circuits). Additional details can be found at [www.ee.siu.edu/~gengel/research.htm](http://www.ee.siu.edu/~gengel/research.htm).

The group's first success was an analog shaped and peak sensing chip known as HINP16C (Heavy Ion Nuclear Physics – 16 Channel). The second chip, christened PSD8C (Pulse Shape Discrimination – 8 Channel), was designed to logically complement (in terms of detector types) the HINP16C chip. PSD8C performs pulse-shape discrimination (PSD), and thus particle identification, if the time dependence of the light output of the scintillator depends on particle type. Moreover, PSD8C uses almost all of the same supporting hardware as the HINP16C chip.

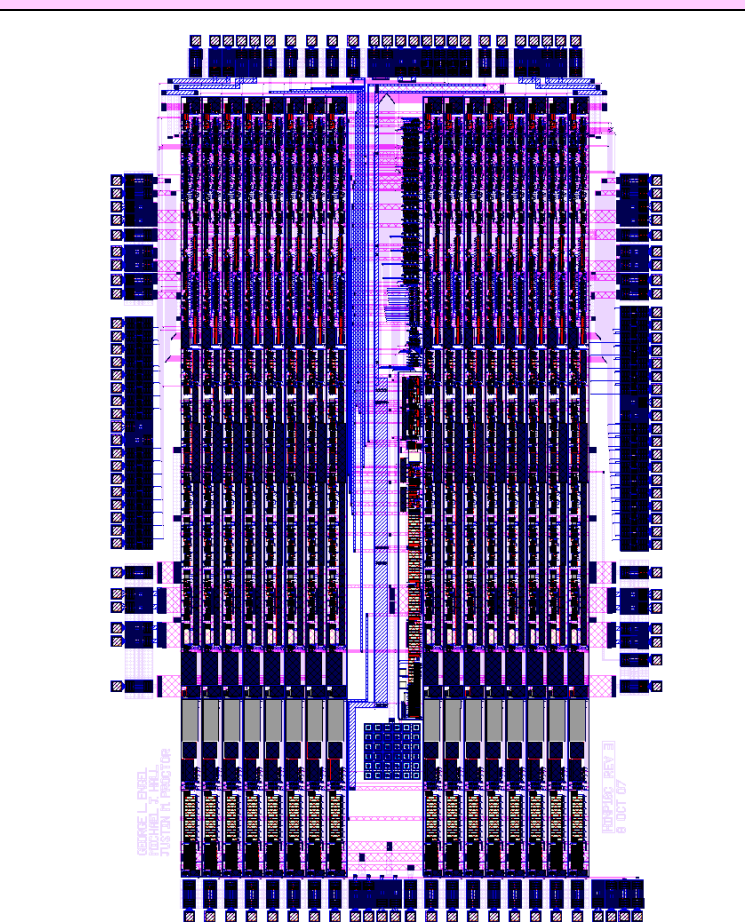
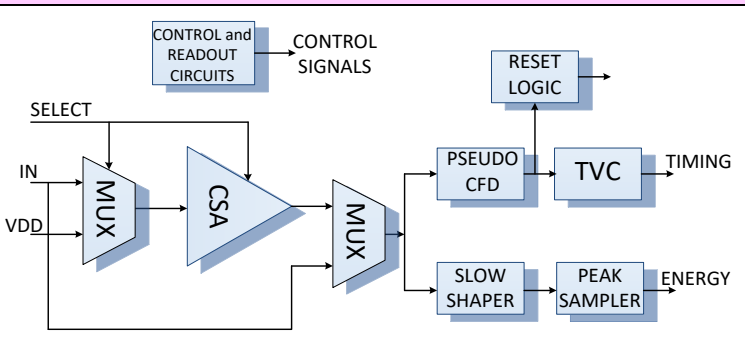
## HINP16C

The HINP16C chip produces sparsified analog pulse trains for both linear (pulse height) and timing (relative to an external reference) and allows the user to choose from one of two internal charge sensitive amplifier (CSA) gains. The chip may also be used with an external amplifier.

A shaper and peak sampler are implemented in the linear branch, and a pseudo constant-fraction discriminator along with a time-to-voltage converter are implemented in the logic/timing branch. The internal plus external gain options and the preparation of both pulse height and timing pulse trains with synchronized addresses (suitable for pipelined ADCs) make the chip suitable for a wide variety of applications.

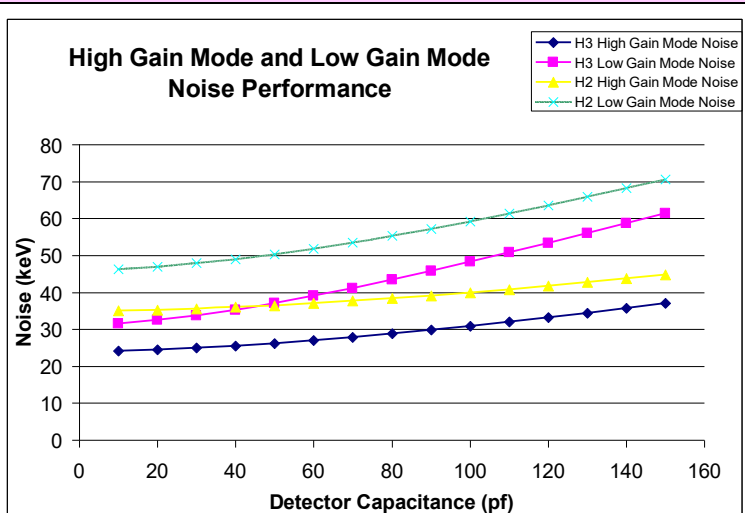
To learn more about HINP16C (Rev.2) please refer to:

G.L. Engel, M. Sadasivam, M. Nethi, J.M. Elson, L.G. Sobotka, R.J. Charity (2007) A Multi-Channel Integrated Circuit for Use in Low- and Intermediate-Energy Nuclear Physics - HINP16C, *Nucl. Instr. Meth. A*, 573, 418-426

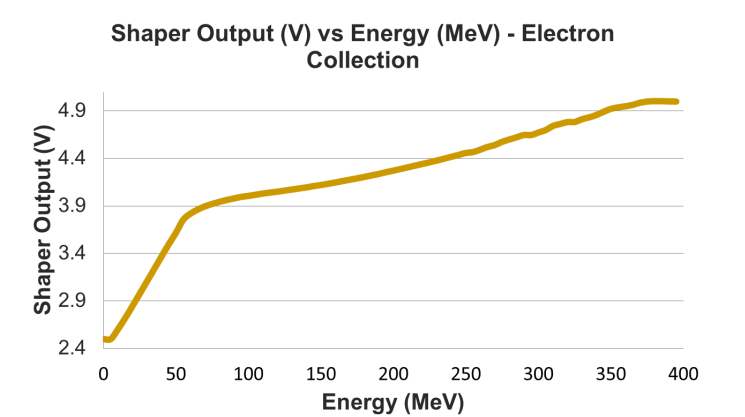


HINP16C-Rev 3 layout. The biasing and circuits used for configuring the IC as well as for readout are located in the center ("common" channel) of the chip. Eight channels lie to the left of this "common" area, and eight channels lie to the right.

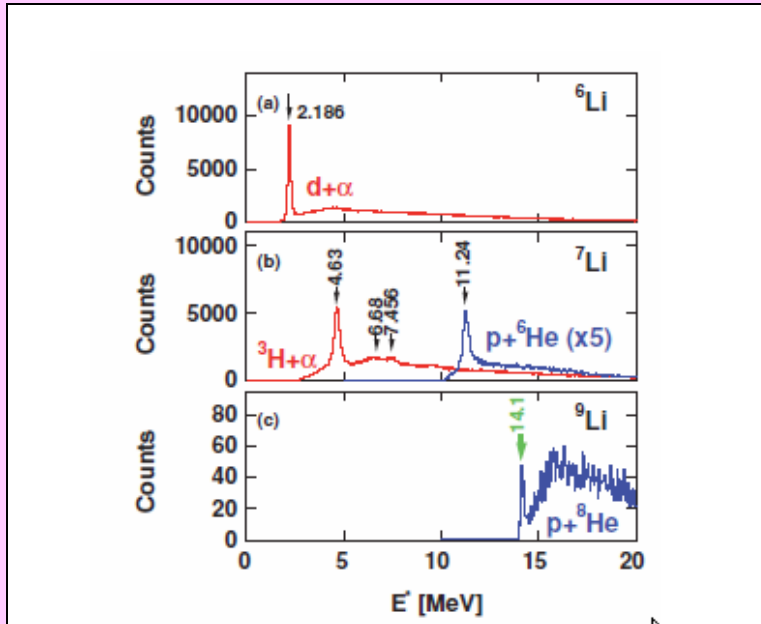
The IC is 4 mm x 6.4 mm. HINP16C is packaged in a 14 x 14 mm, 128 lead thin quad flat pack. The chip's power consumption is about 800 mW.



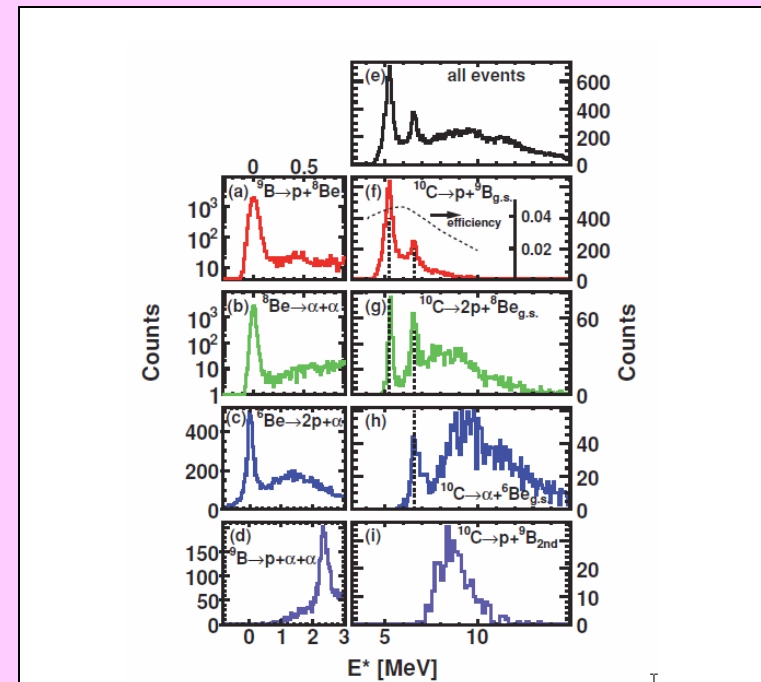
HINP16C (Rev 3) has improved resolution and linearity characteristics.



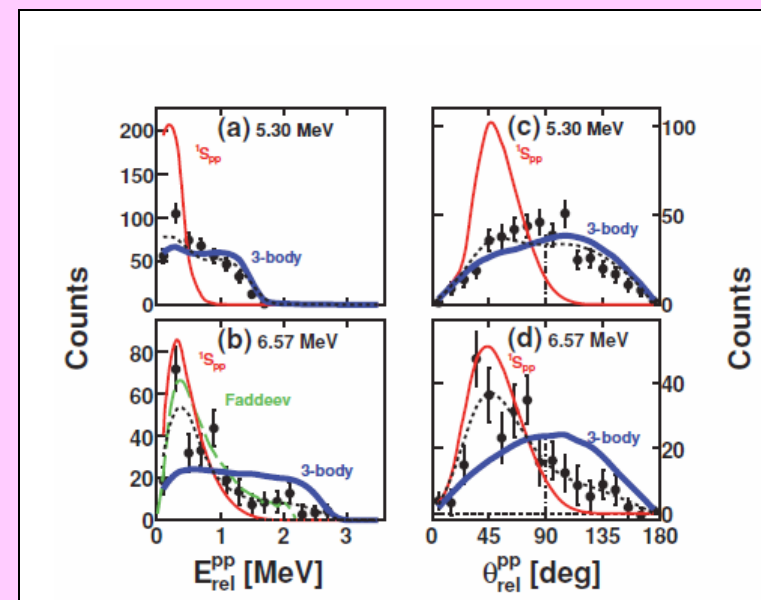
HINP16C (Rev. 4) is expected to be fabricated Fall 2010 and will have a single gain but with an extended dynamic range mode.



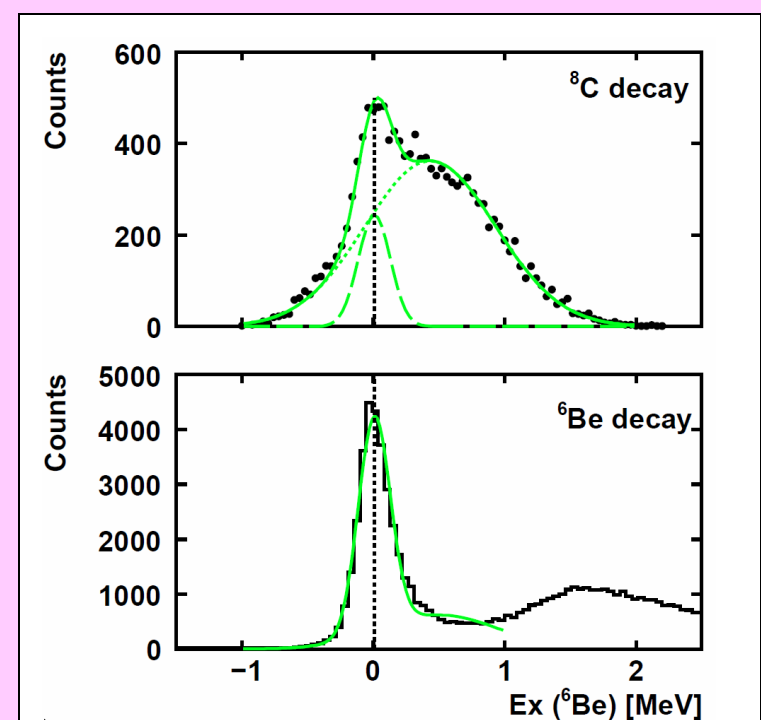
Particle-particle correlations leading to Li isotopes from a study of the continuum structure of n-rich light nuclei.



Reconstructed excitation energies from (left) 2-, 3- and (right) the 4-body correlations from our study of the continuum structure of <sup>10</sup>C study.



The 2p relative energy and angle from two excited states in <sup>10</sup>C which decay directly to the ground state of <sup>8</sup>Be.



Results for the study of <sup>6</sup>Be and <sup>8</sup>C.

Lower panel shows the reconstructed (3-particle) 2p $\alpha$  excitation energy from the neutron stripping of a <sup>7</sup>Be beam. The upper panel shows the 2p $\alpha$  correlation from the 5-particle (4p $\alpha$ ) data set from the n stripping of <sup>9</sup>C. For the latter, all 6 2p $\alpha$  correlations are plotted and a gate on the 5-particle correlation has been used to select the ground state of <sup>8</sup>C. The fits indicate that <sup>8</sup>C is essentially a pure 2p-2p

## PSD8C

PSD8C greatly simplifies the pulse-processing electronics needed for large arrays of scintillation detectors. Because PSD8C employs (user-controlled) multi-region charge integration, particle identification is incorporated into the basic design. Each channel on the chip also contains a time-to-voltage converter which provides relative time information.

The pulse-height integrals and the relative time are all stored on capacitors and are either reset, after a user controlled time, or sequentially read out if acquisition of the event is desired. Each of the three pulse-height sub-channels consists of a gated integrator with eight programmable charging rates and an externally programmable gate generator that defines the start (with 4 time ranges) and width (with 4 time ranges) of the gate relative to an external discriminator signal. The chip supports three triggering modes and two TVC time ranges.

To learn more please see:

G.L. Engel, M.J. Hall, J.M. Proctor, J.M. Elson, L.G. Sobotka, R. Shane, R.J. Charity (2009) Design and Performance of a Multi-Channel, Multi-Sampling, PSD-Enabling Integrated Circuit, *Nucl. Instr. Meth. A*, 612, 161-170

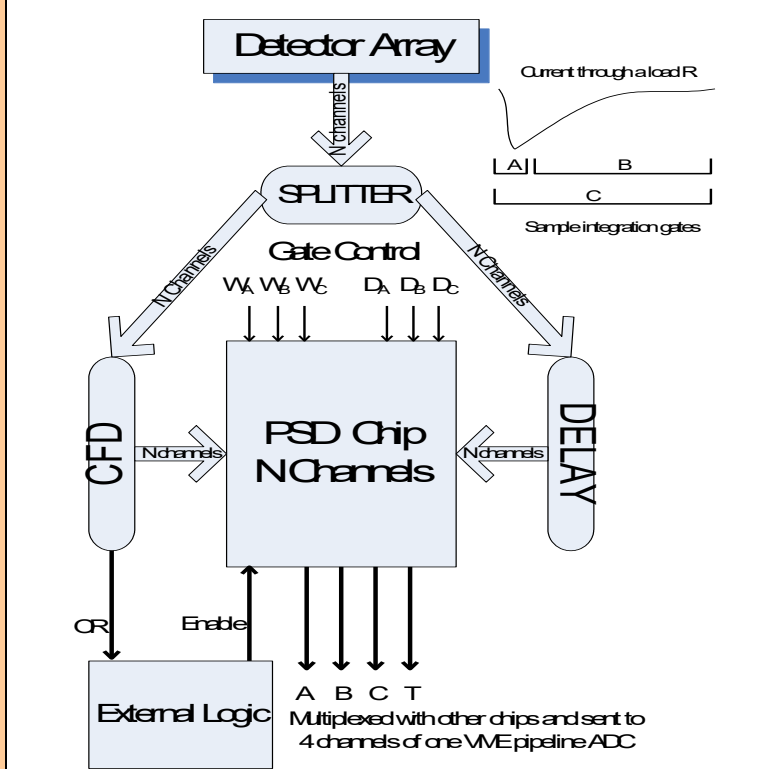
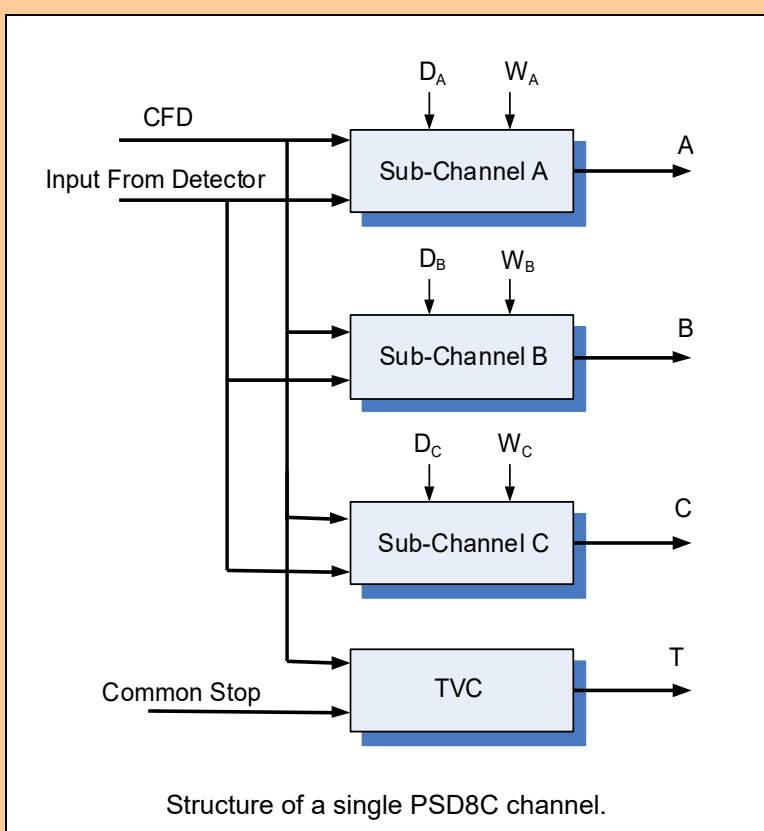
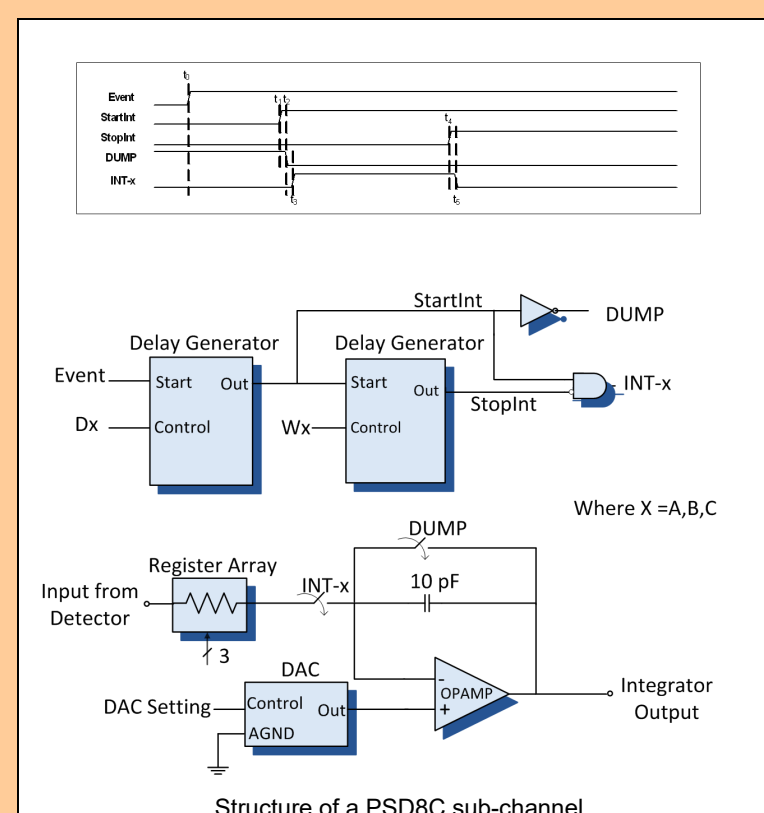


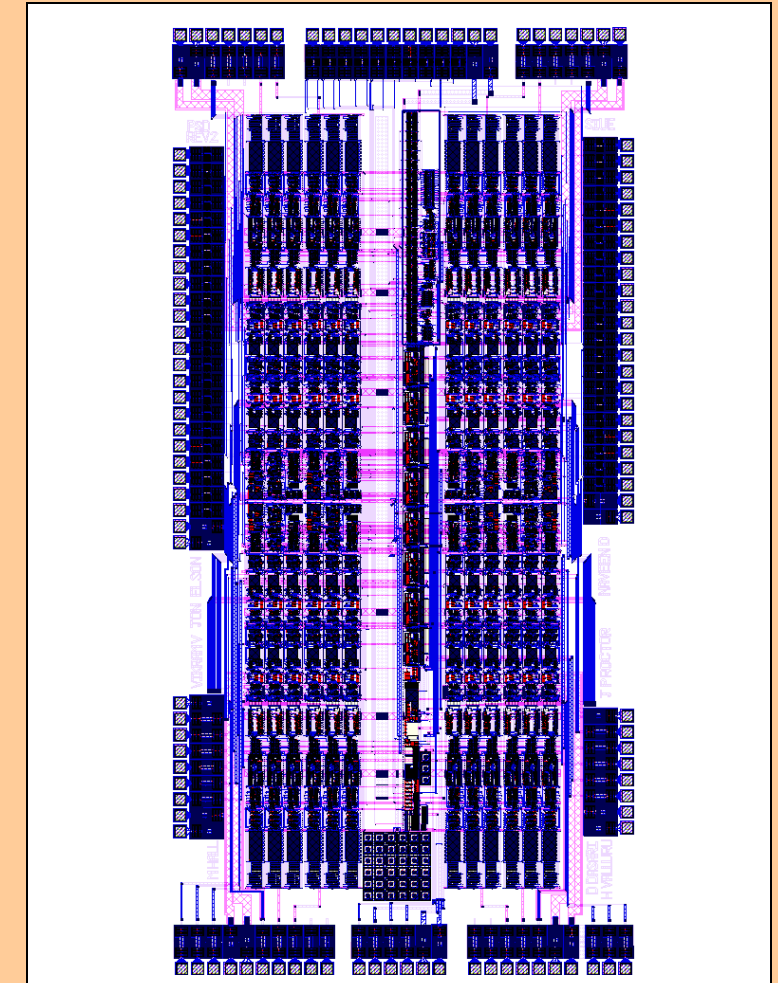
Illustration of typical system employing PSD IC. For the current PSD8C chip, N = 8.



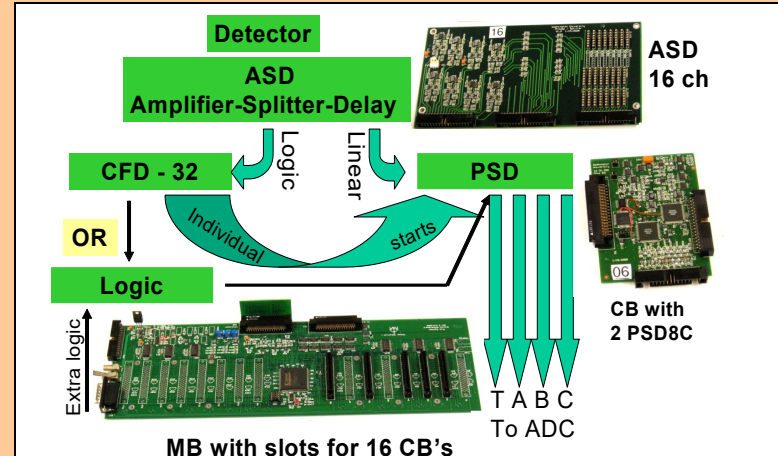
Structure of a single PSD8C channel.



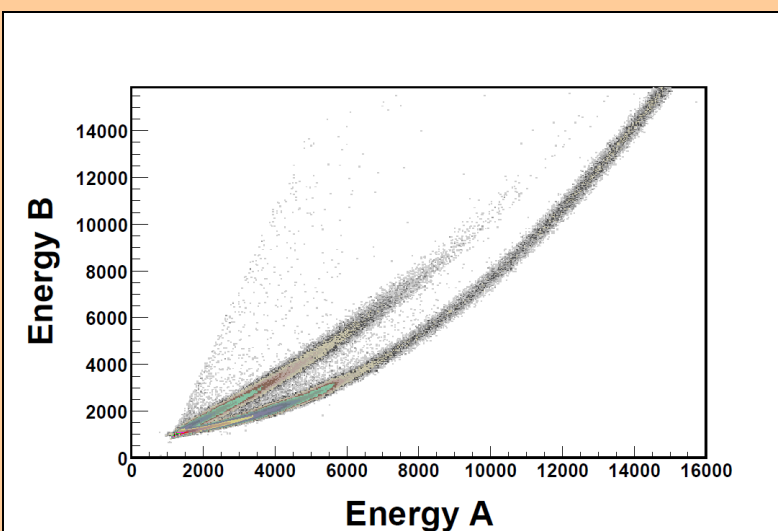
Structure of a PSD8C sub-channel



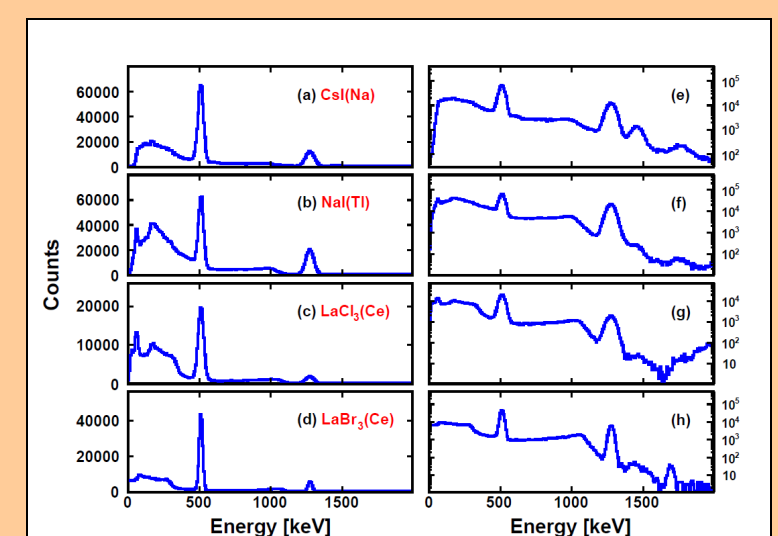
Layout of PSD8C (Rev. 2.0). IC is 2.75 mm x 5.7 mm. PSD8C is packaged in a 14 x 14 mm, 128 lead thin quad flat pack. Power consumption is 65 mW in low-bias mode.



Present implementation strategy and components: CB (with two PSD8C chips), MB (capable of servicing 16 CB's), and the ASD (with an amplifier, splitter and delay – for the linear branch.) PSD chipboards are being modified (summer 2010) to include on-board ADCs.



PSD map taken with a BC501A liquid scintillator detector. The abscissa captures the integral with a prompt gate of 400 ns duration, while the ordinate is the integral resulting from an equal length gate starting approximately 100 ns after the start of the prompt gate. The bottom locus corresponds to gamma rays while the top to neutrons. For an energy reference, the Compton edge of <sup>137</sup>Cs has an abscissa channel value of 2850.



<sup>22</sup>Na spectra taken using the prototype PSD system. From top to bottom the spectra are from a) CsI(Na) (3"x3"x4"), b) NaI(Tl) (2" diameter x 3"), c) LaCl<sub>3</sub>(Ce) (1" dia. x 1"), and d) LaBr<sub>3</sub>(Ce) (1" dia. x 1"). Spectra are shown with both linear and logarithmic ordinates. The trigger rate for these data was approximately 1kHz and the gate widths were approximately: a) 600 ns, b) 2000 ns, c) 300 ns, and d) 125 ns. In some cases external (i.e. <sup>40</sup>K) and internal (likely  $\alpha$ -emitters) background features as well as the sum peak are observed.