Real-time Digital PSD for the Nuclear Materials Identification System

Paul A. Hausladen

Oak Ridge National Laboratory

Richard A. Todd and Adam R. Miller

RIS Corporation

IEEE NSS 2006

Outline

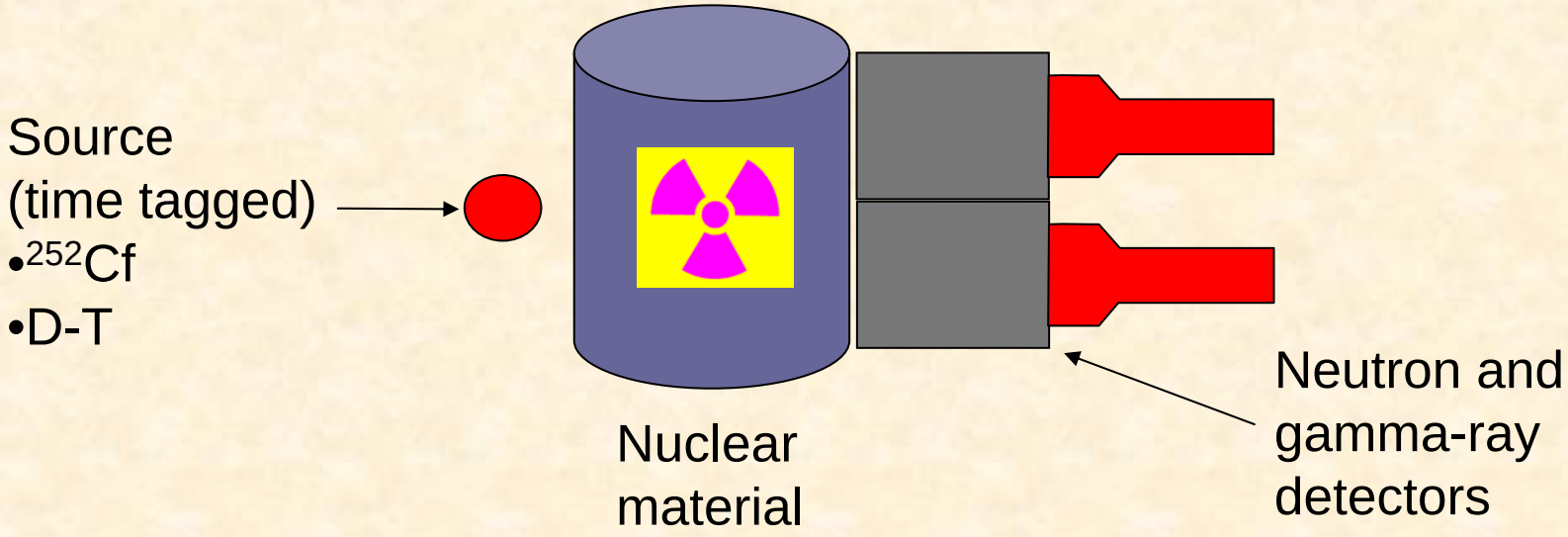
I. **PSD for NMIS**

II. **The need for digital: issues in quality real-time PSD**

III. **Design basis tests**

IV. **The NIM-packaged PSD module**

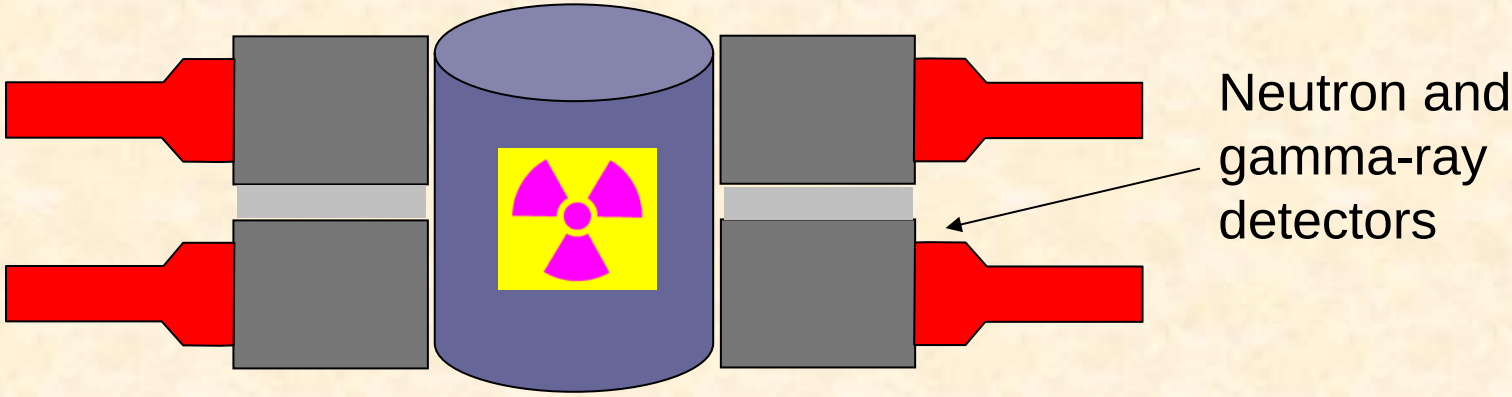
I. (a) Active NMIS measurement

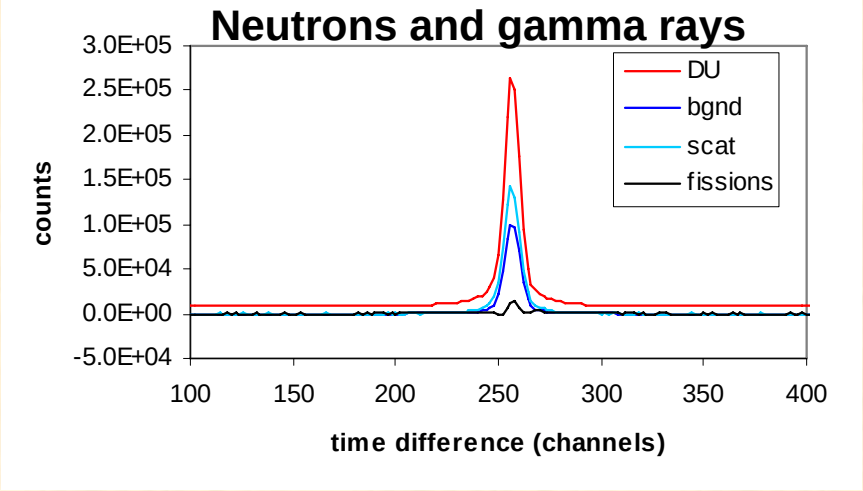


Applications: confirmation of receipts, NMC&A

- **NMIS records nanosecond-resolution time distribution of detector counts after source event**
- **Extract number and time distribution of induced fissions to characterize nuclear material**

I. (b) Passive NMIS measurement



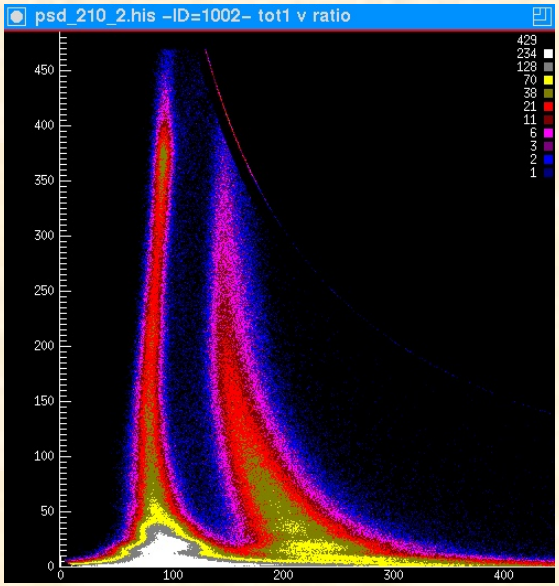


Measurement of DU:

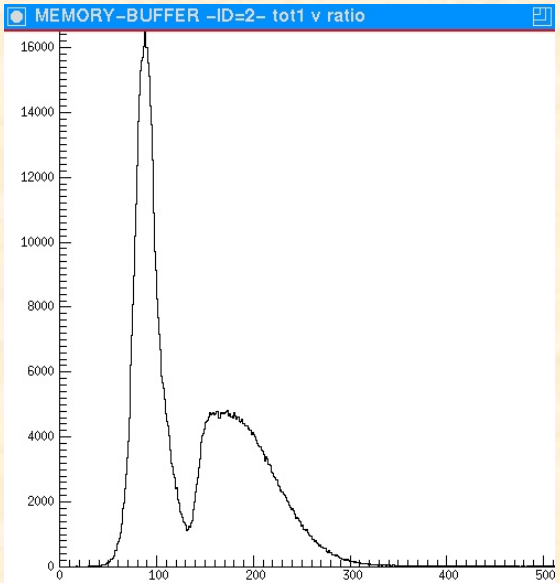
- **Neutrons carry most of information: need PSD**
- **Gamma-ray rate high, neutron rate low: need good PSD with high-rate capability *in real time***

II. (a) Why digital?

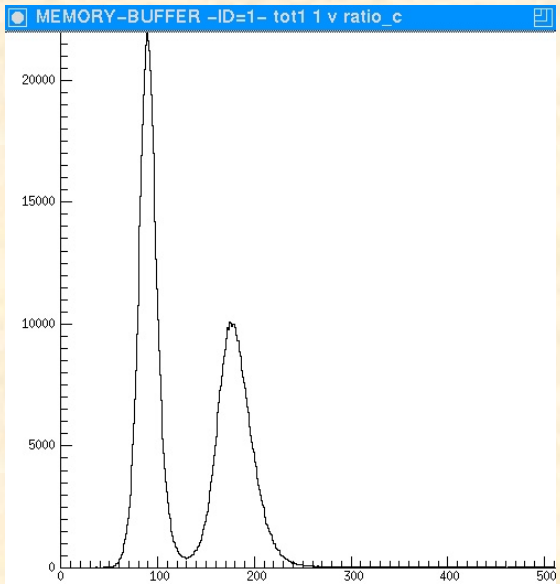
Pulse height



Slow to total ratio



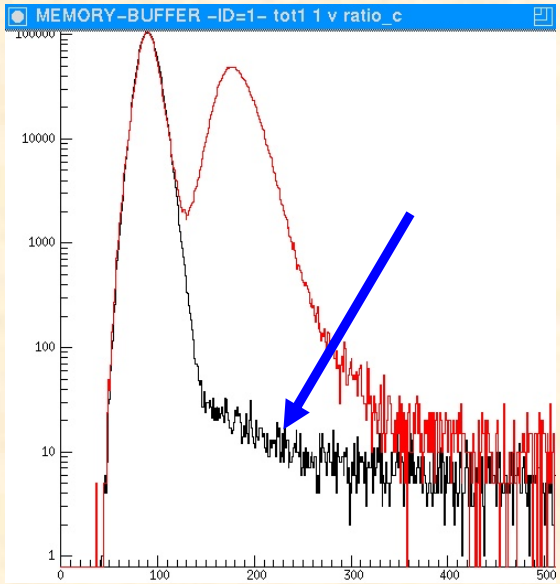
Slow to total ratio



corrected ratio

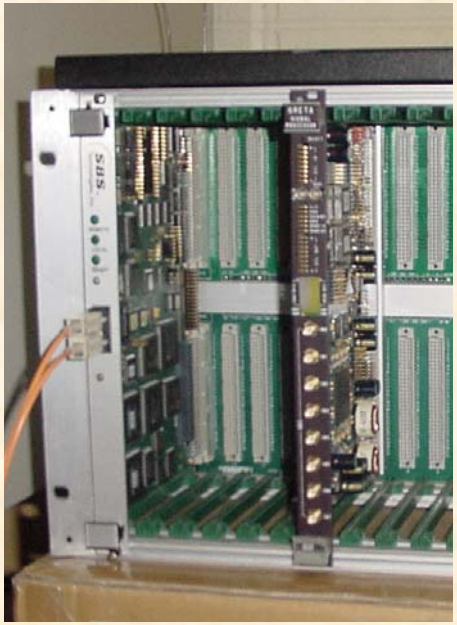
- **Recall: origin of PSD is different amounts of fast (~3 ns) and slow (~270 ns) light that depends on dE/dx**
- **Can't change statistical uncertainty in number of fast and slow photoelectrons**
- **Can change systematic problems, e.g. inherently a 2D problem so decision needs to be 2D**

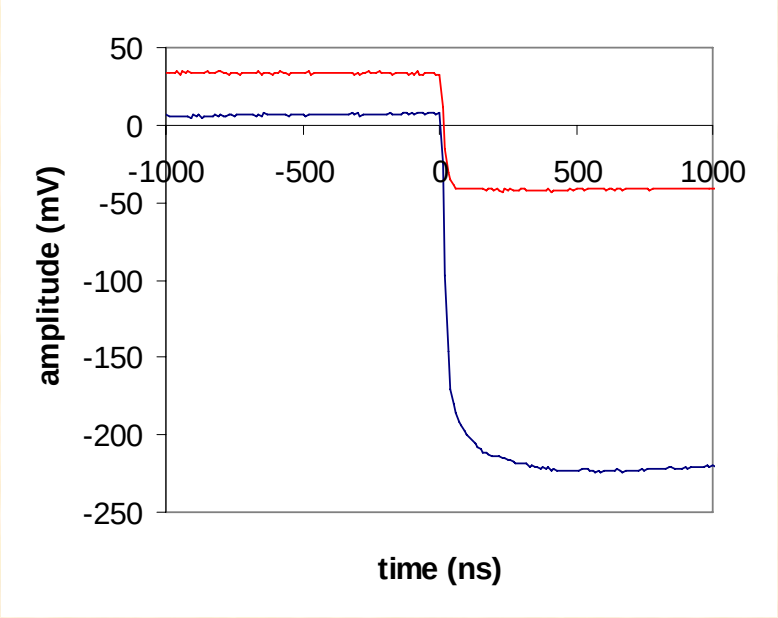
II. (b) Why digital (cont.)



- **Limits in gamma-ray rejection largely determined by pileup**
- **Discriminator level for second event depends on size of initial event**
- **Easier to identify aberrant pulses when the whole time dependence is digitized**

III. (a) Design basis tests

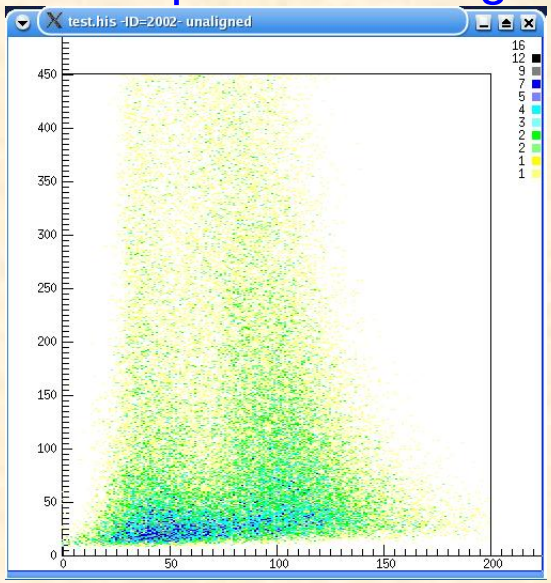




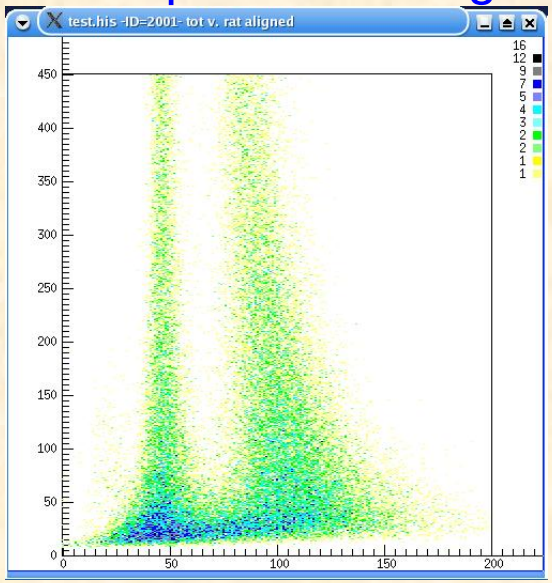
- **Tests performed with a large (25 x 25 x 8 cm) liquid cell**
- **Preamplified signal digitized with free-running 100 MS 12-bit ADC (GRETA prototype board from LBL) and stored to disk**
- **ADC traces analyzed offline to identify computationally simple analysis appropriate for FPGA implementation**

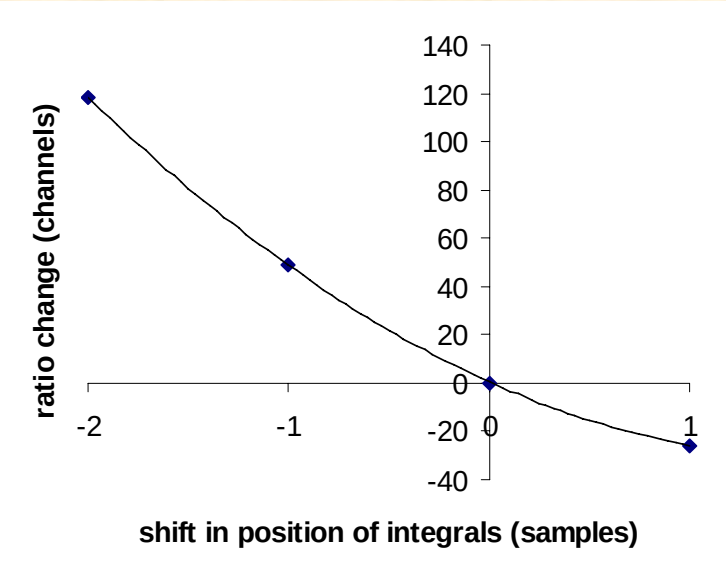
III. (b) Interpolated timing

Sample-rate timing



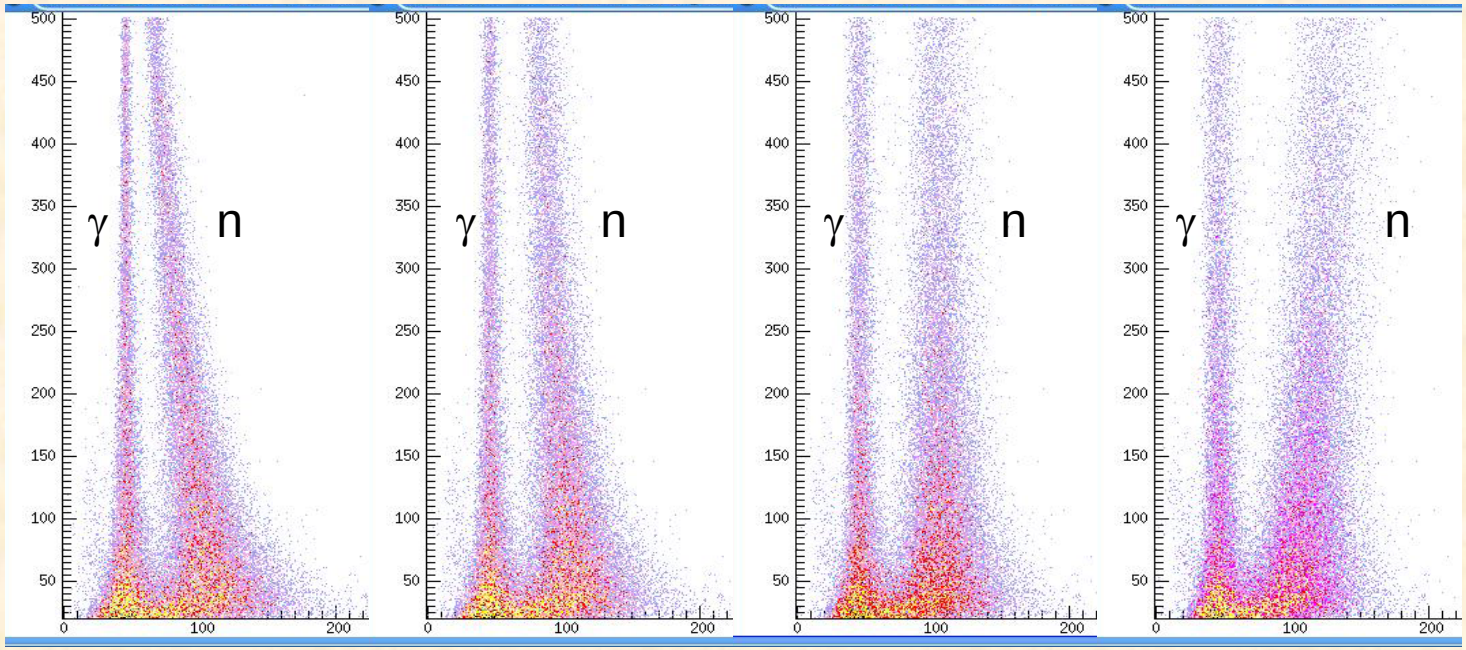
Interpolated timing





- **Algorithm to extract detector timing more important than the PSD algorithm**
- **At 100 MSs^{-1}, close to 2 ns CFD timing for big detectors**
- **200 MSs^{-1} will give some improvement and more versatility for faster-rise detectors**

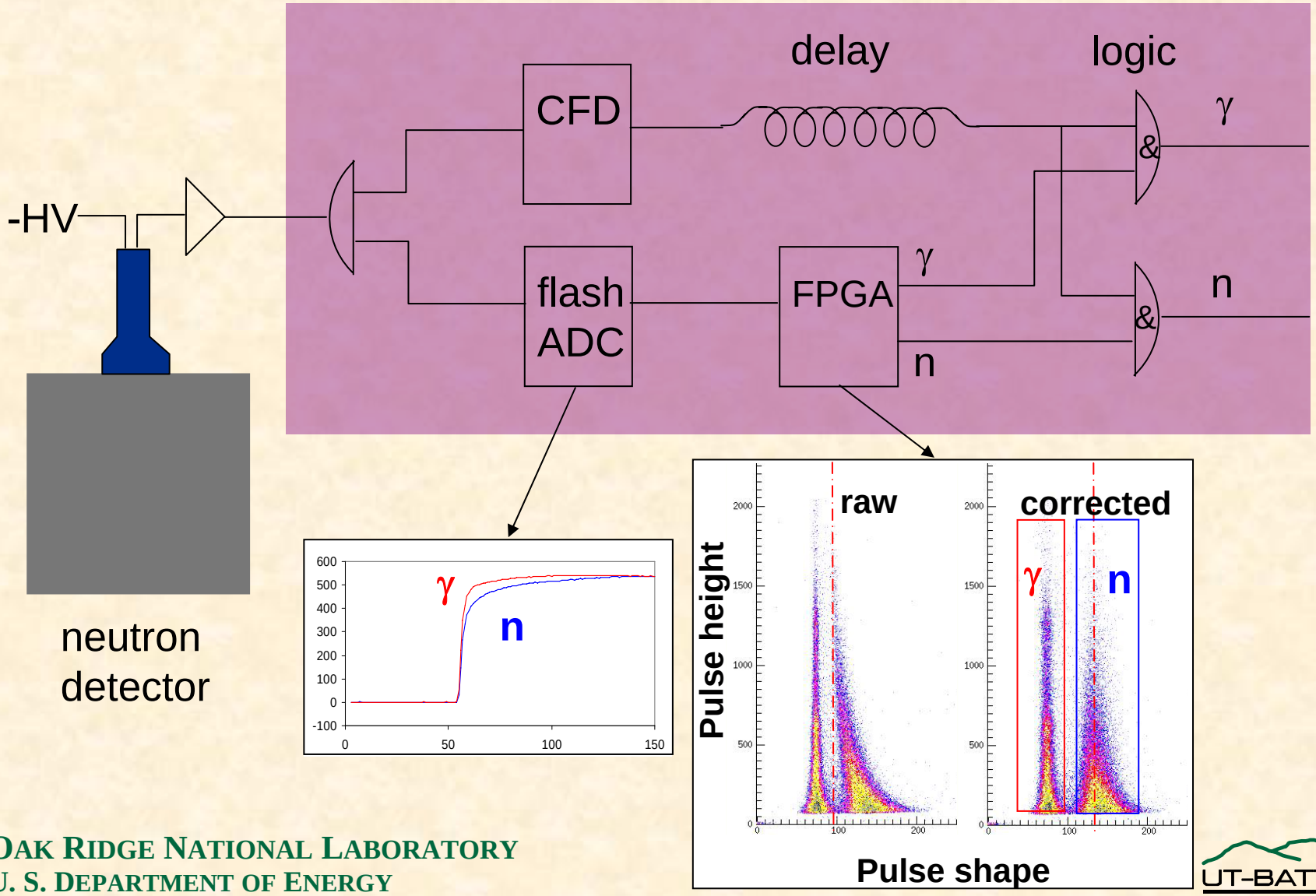
III. (c) Corrected pulse shape



Over corrected | Uncorrected | Optimally corrected | Over corrected

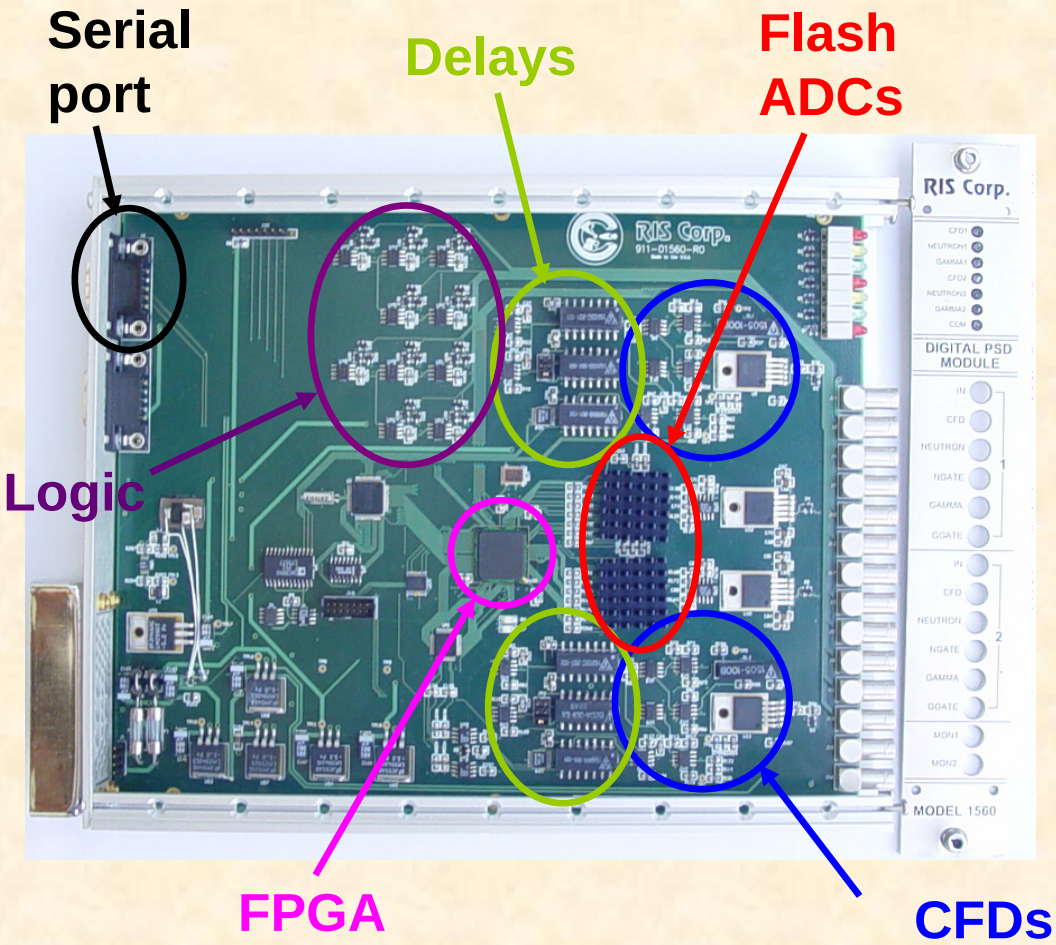
- **Pulse-height dependence of pulse shape for neutrons originates in different values of dE/dx as scattered proton stops**
- **Can be removed in FPGA by one multiplication and one subtraction**

IV. (a) Simplified block diagram of real-time Digital PSD module



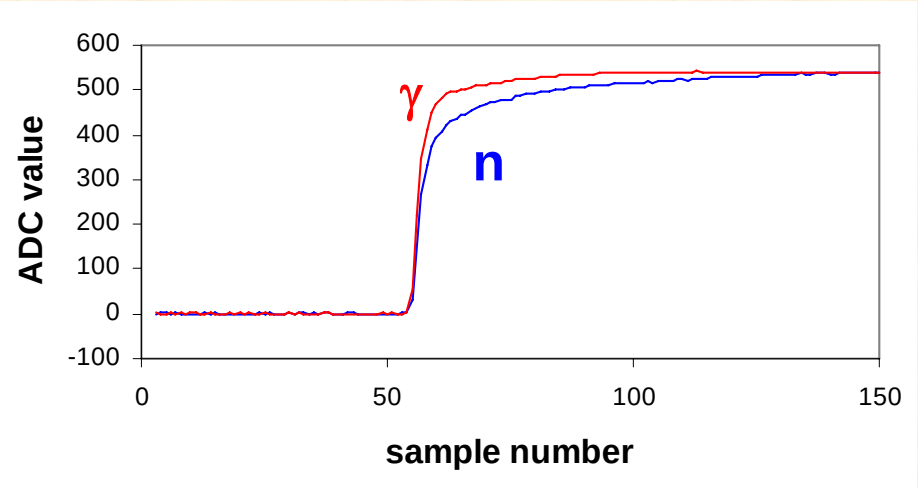
IV. (b) RIS 1560 DPSD module

http://www.ris-corp.com/



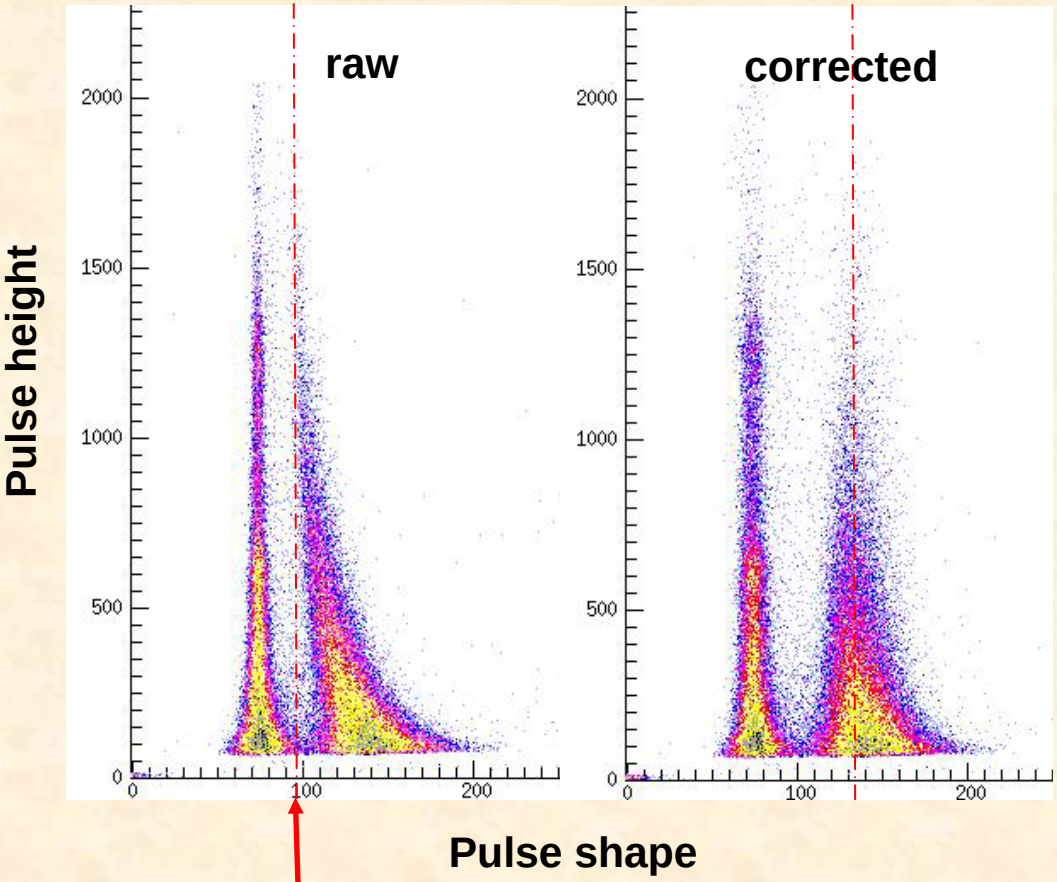
Xilinx Virtex II XC2V1000-5
(1M gates)

IV. (c) Status of RIS 1560 DPSD



- **Hardware debugged and tested with neutron sources, presently at 100 MSs^{-1}**
- **Off-line analysis of raw data confirms performance of hardware**
- **Real-time PSD calculation needs final debug**

IV. (d) PSD data from RIS 1560 DPSD



Without correcting for dependence of pulse shape on pulse height, will lose high energy neutrons

- **Offline analysis shows good PSD (module producing high quality data)**
- **Correction of pulse shape for pulse height working as intended**
- **Pending demonstration at 100 MSs^{-1}, existing hardware will be clocked at 200 MSs^{-1}**