

Multi-Input Readout Systems for ³He/BF₃ Position Sensitive Neutron Detectors

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Nbrick: a system for neutron position measurements

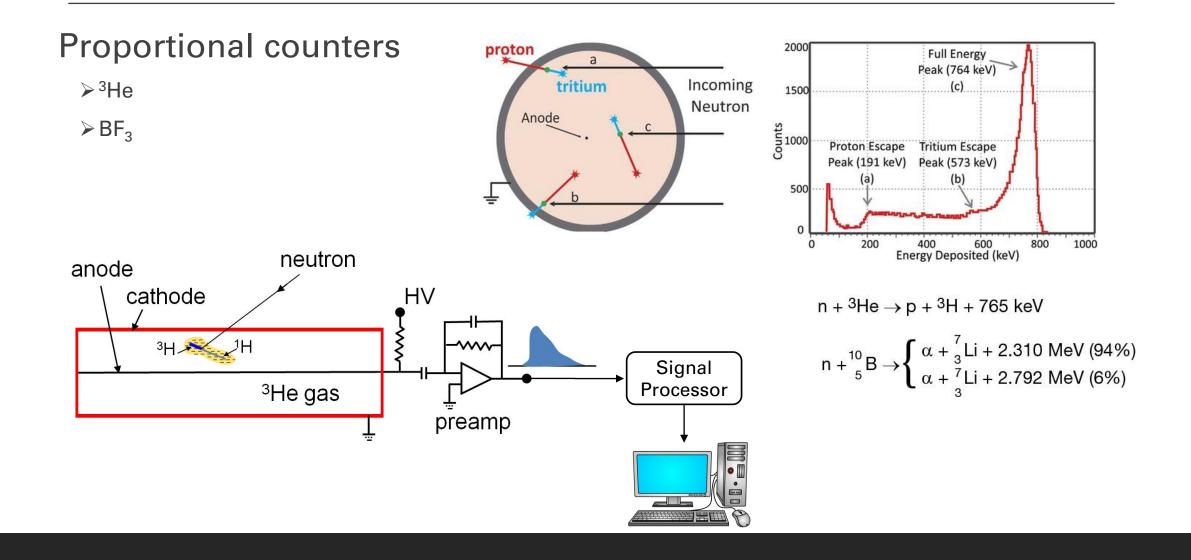
Details of the electronics

Qualification and use cases

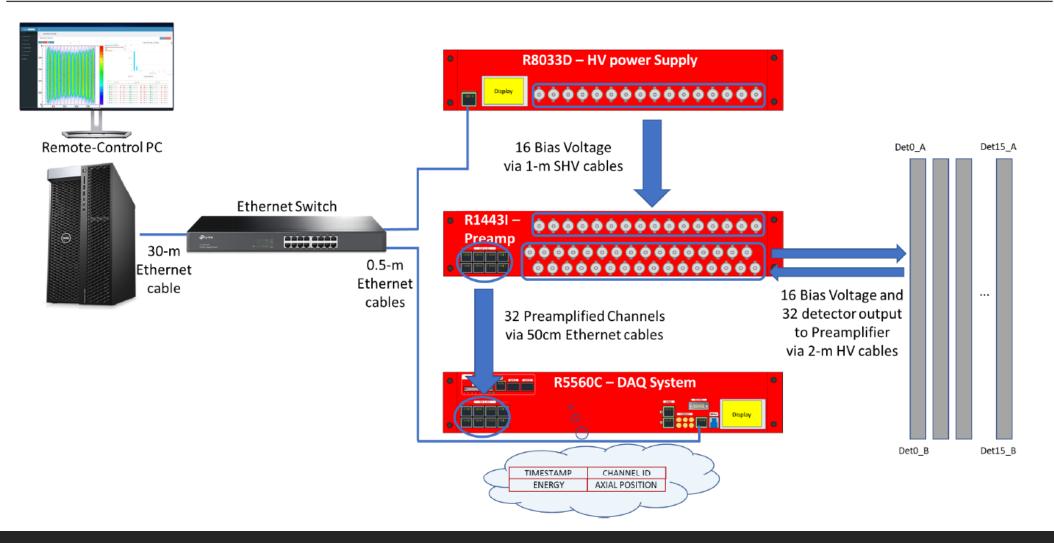
Possible upgrades : n/gamma discrimination

Equipment for Neutron Counting

Neutron detection



Nbrick: neutron position measurements







- Fast, specifically designed for neutron detectors in collaboration with ILL-France
- 32 input channels with 16 independent HV lines (one for each position-sensitive tube)
- Rate capability: >100kHz per tube
- Differential outputs on RJ45 connectors rise time <20ns, decay time 1µs
- Total gain: 2.25 V/pC
- Cross talk < 1%
- Resolution ⁽¹⁾: ~20 keV (with full scale range 36 MeV)
- Input residual Noise: about 0.8 fC

(1) measured with a CAEN 2745 digitizer with DPP-PHA FW with trapezoidal filter parameters (Rise Time = 2 us, Flat Top = 0.6 us, Tau = 0.95 us)

R5560C Digital Signal Processor

- 32 channels, 14-bit @125 MS/s Flash ADC Module
- Online Signal Processing → Energy, Time, Position, PSD (Coming Soon)
- Differential inputs on RJ45 connectors for direct coupling to R1443
- Cost-effective installation and minimum noise pick-up thanks to standard Ethernet CAT5/6e cables
- USB3.0 / 1 Gbps Ethernet Readout



Signal Processing

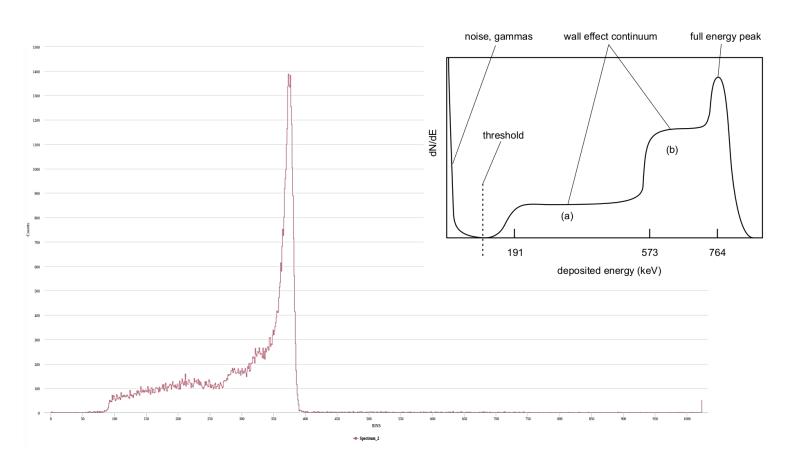
- Thanos Software Remote High Voltage control and DAQ
- Waveforms inspection
- Trigger-less acquisition: each channel is self-triggered (digital timing filter and discriminator)
- On board coincidences
- **Resistive Charge Division** to reconstruct position
- List Mode: output files with time stamped energy (or position) list
- Energy Spectrum of each single tube side
- **Image reconstruction** of the neutron flux

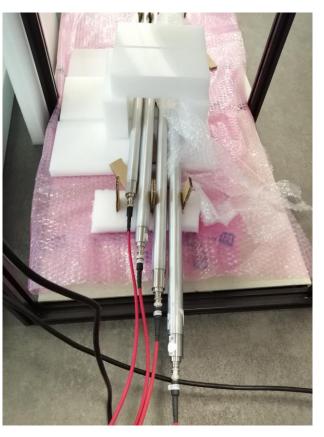
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Total charge collection

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Energy Spectrum of moderated neutrons by Thanos software

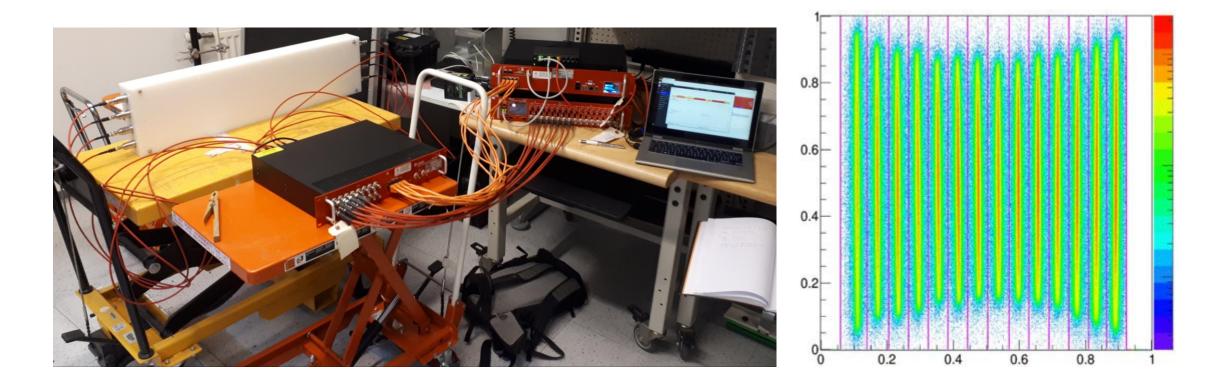




Use case: neutron flux measurements

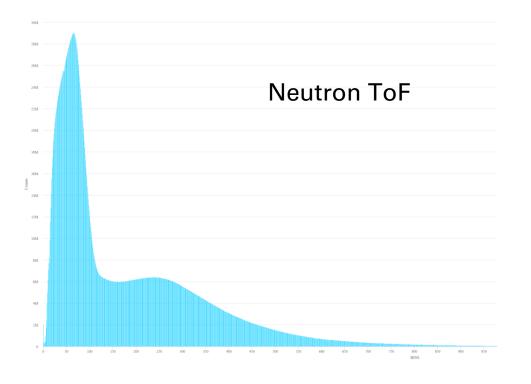
IRSN – France: readout system for 8 position sensitive ³He tubes

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Use case: Small Angle Neutron Scattering

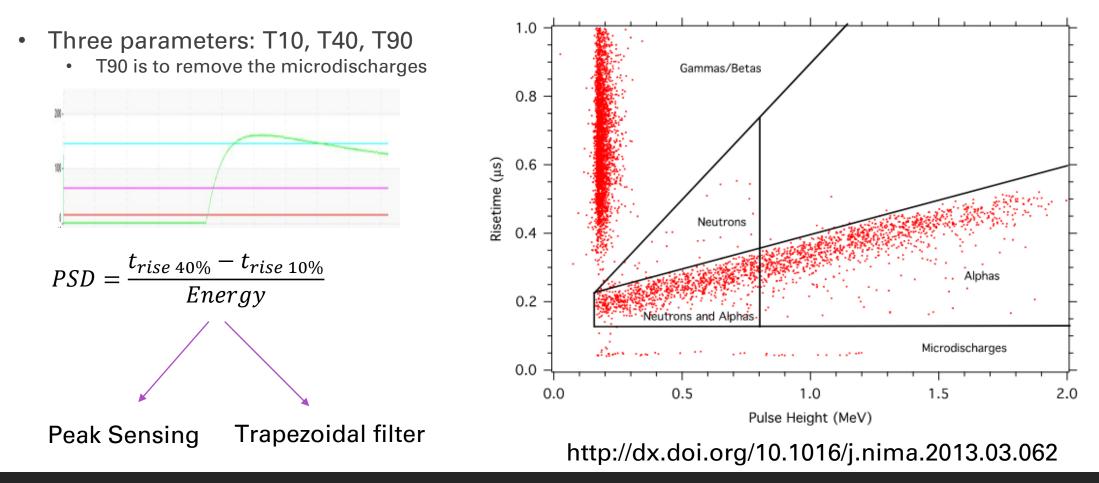
Loki @ ESS/RAL-ISIS: 3He tubes readout by more than 30*R5560 synchronized and interfaced with pre-existing systems





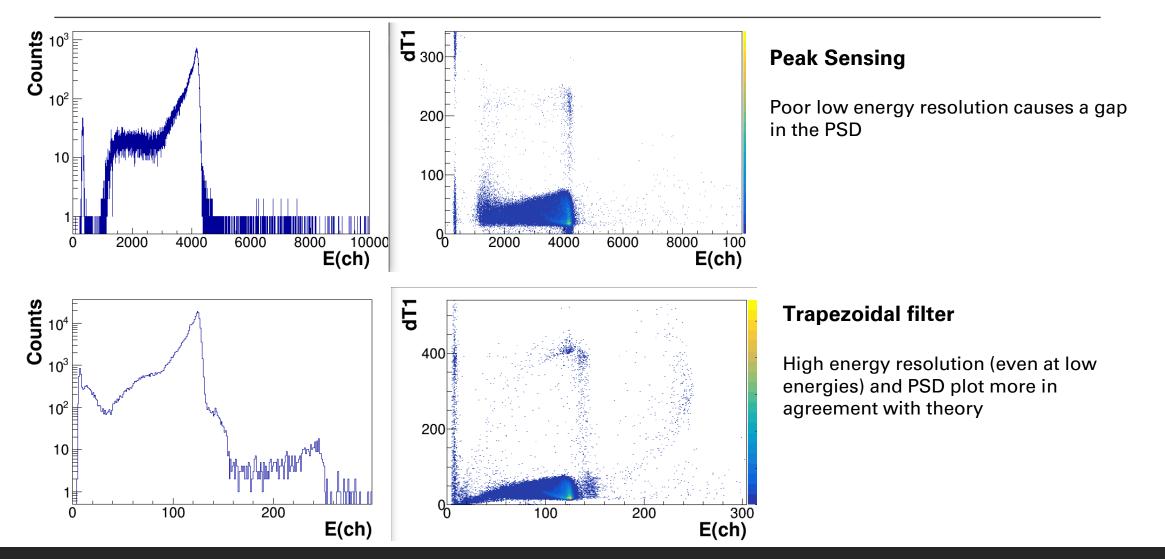
Next steps: gamma/n Pulse Shape Discrimination

• Plasma diagnostic need: PSD at event frequency < 100 Hz – no pileup issues



Preliminary results from PSD algorithms

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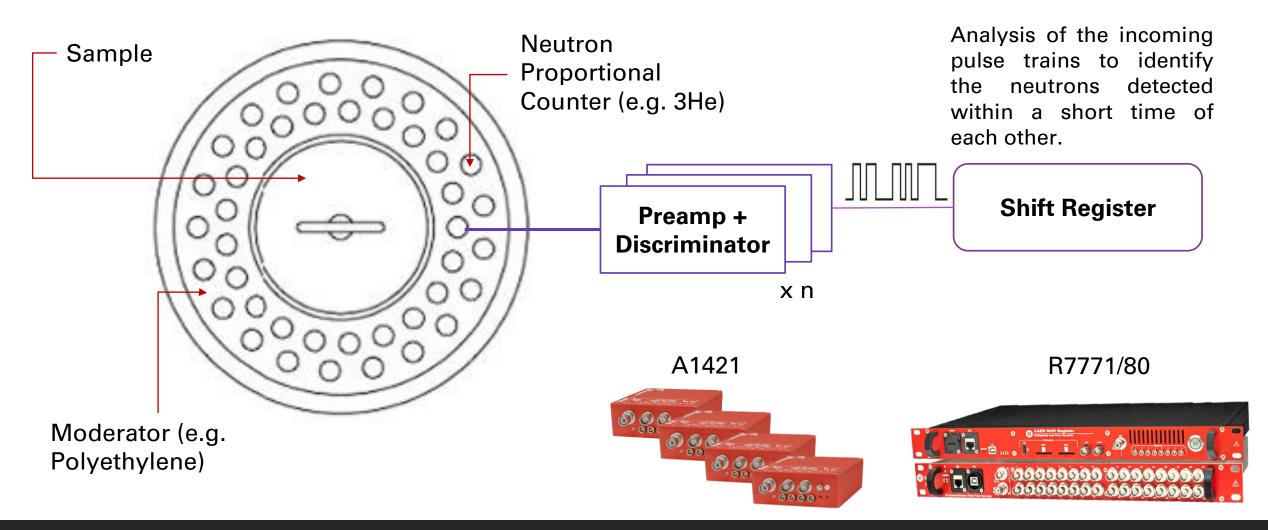


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Neutron counting challenges

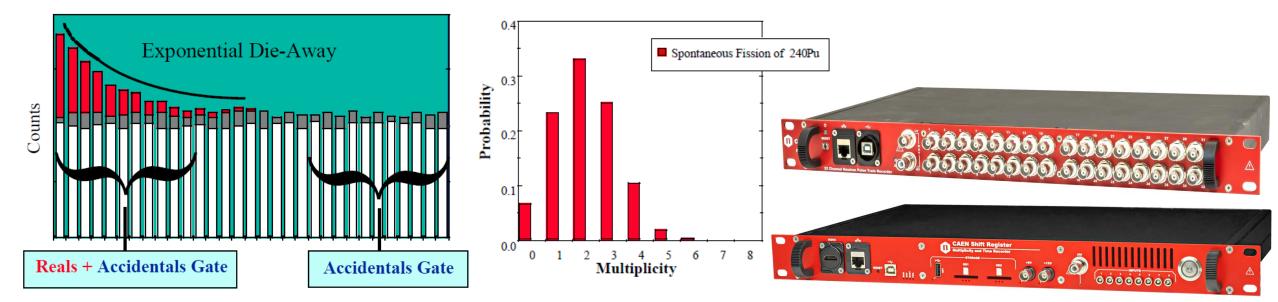
- Nuclear Safeguards → Assay of fresh fuel materials (²³⁸Pu, ²⁴⁰Pu, ²⁴²Pu, ²³⁹Pu, ²³⁵U, ²³⁸U) for non-proliferation and security purposes
- Non-destructive **quantification** of Pu and U mass inside a high-density sample (Spontaneous Fission or Active Interrogation)
- γ-rays by the fissile element drawn into a background due to ligther elements (already present or products of the fission)
- Most n would come from (α ,n) reactions induced by lighter elements \rightarrow Random
- Fission produces **multiple n simultaneously** → **Neutron Coincidence Counting**
- Distribution of the number of n emitted in coincidence → **Multiplicity**

Neutron Coincidence Counting



Shift Register operation

- Trains of pulses \rightarrow Identification of n events within a certain gate from the triggering event
- Probability of coincidence n counts decays as an exponential
- **Rossi-Alpha** distribution takes into account coincident and random n
- **Multiplicity** distribution takes into account the number of coincident $n \rightarrow$ Fissile material signature





All-in-one system for ³He/BF₃ neutron detectors

- ✓ Tested in real scenarios: position reconstruction, spectroscopy, timing.
- Performances are satisfactory for both Research and Security applications
- Ongoing support and upgrades
- ✓ Open to discuss your needs and wishes!

Neutron Counting Electronics for Nuclear Safeguards

- ✓ Particular attention to robustness, reliability, ease of use
- ✓ Validated by IAEA and currently in use

Thank you for your attention

Any question/curiosity? y.venturini@caen.it

Backup slides

32-ch N-brick rackmount solution

Readout of up to 16 position-sensing tubes



High Voltage for detector bias

16-ch Rack-mount Programmable HV Power Supply(+4KV, 3mA)

Charge Sensitive Preamplifier

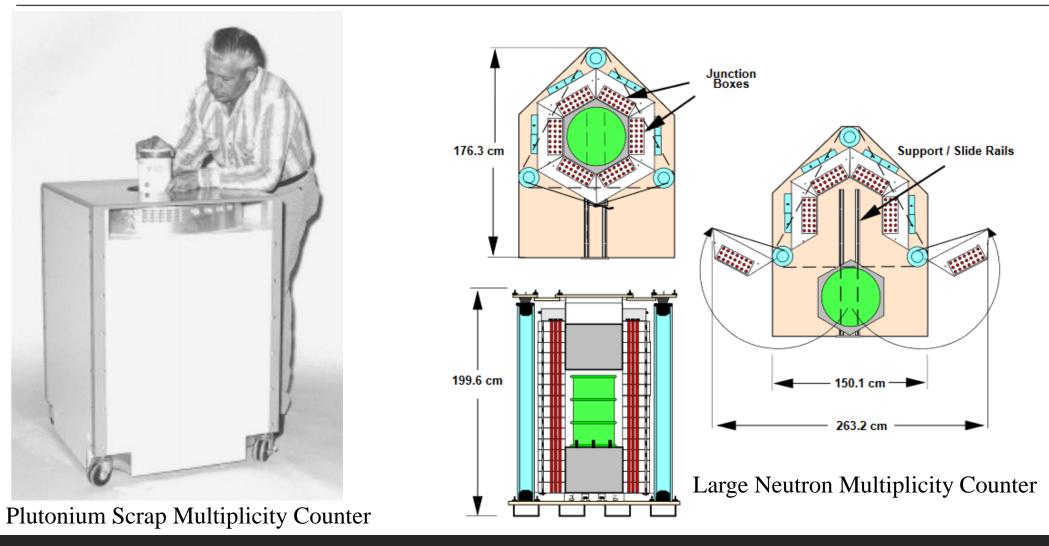
32-ch Preamplifier unit with 16 independent High Voltage distribution and decoupling lines

Digital Signal Processor 32-ch, 14-bit @125MS/s Flash ADC with online signal processing algorithm

Neutron counting for Nuclear Safeguards

Neutron Coincidence Counting

n



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Preamplifier and discriminator

Full chain in a box

- 1 Ch, compact size **preamp + shaper + discriminator**
- Gain: 30 mV/fC on HiZ
- Shaping: 120 ns rise time + 460 ns fall time
- Analog and **TTL output**
- Fast recovery time suitable for **passive** as well as for **active** interrogation measurements.





Preamplifier + Discriminator for n detectors

- A1421 is specifically designed for neutron detectors as ³He or BF₃ tubes in counting applications
- 1 Ch, compact size preamp + shaper + discriminator
- Gain: 28 V/pC, Sensitivity: 1 V/pC
- Output signal total duration: 700 ns
- Analog and TTL output → match with R7771/80 Shift Registers
- Fast recovery time suitable for **passive** as well as for **active** interrogation measurements.



Preliminary picture - mechanical t.b.d.

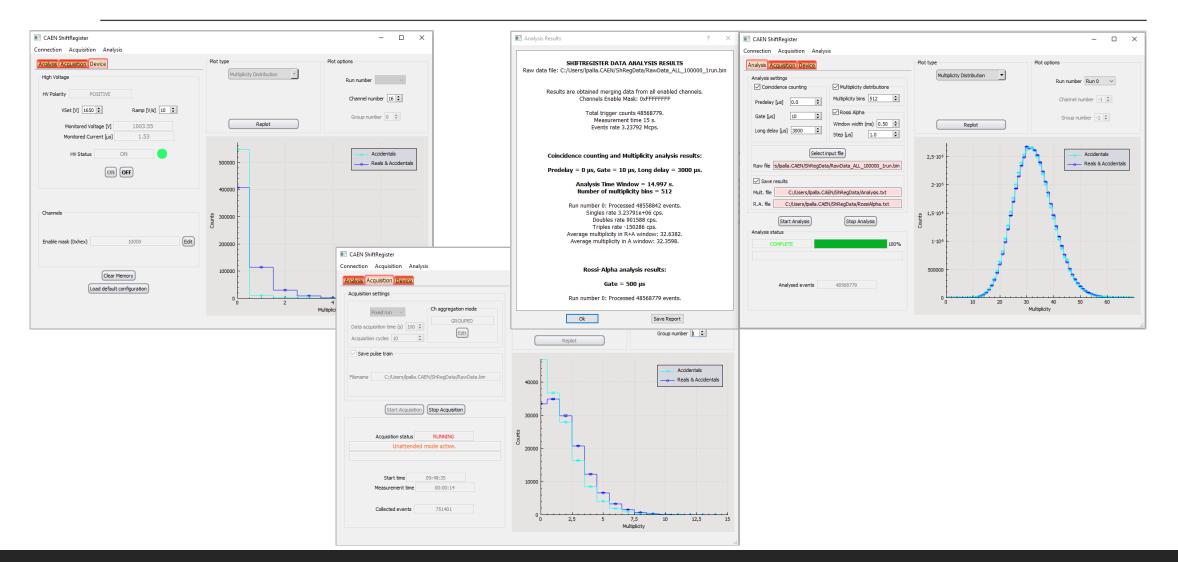
R7771 - 32-Ch Neutron Pulse Train Recorder

- 32 inputs on BNC connectors (TTL, 1 $k\Omega$)
- 10 ns time stamp resolution



- 10 ns of pulse pair resolution and minimum pulse width detection
- Rossi-Alpha and multiplicity distribution
- Possibility to recall pulse trains for off-line analysis (files in INCC format)
- High Voltage for detectors bias and Low Voltage for preamp power
- 10/100 Ethernet and USB 2.0 interfaces

CAEN Shift Register Software



R7780 - 8-Ch Unattended Monitoring System

- Multiplicity, Time recorder and Shift Register adopted as IAEA UDL1
- 8 inputs on LEMO connectors (TTL, 50 Ω)
- 10 ns time stamp resolution



- Unattended operation with data logging capability (two removable SD cards and USB stick)
- Redundant storing mechanism implemented for higher reliability in unattended operation
- Special video output (HDMI) to monitor the state-of-health of the device
- Time-stamped lists saved to PTR-32 compatible file format and compliant to INCC software package
- 10/100 Ethernet and USB 2.0 interfaces