Development of a Novel Time-based Method for Discrimination of Photon and Neutrons in LUPIN REM Counter

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1) Introduction

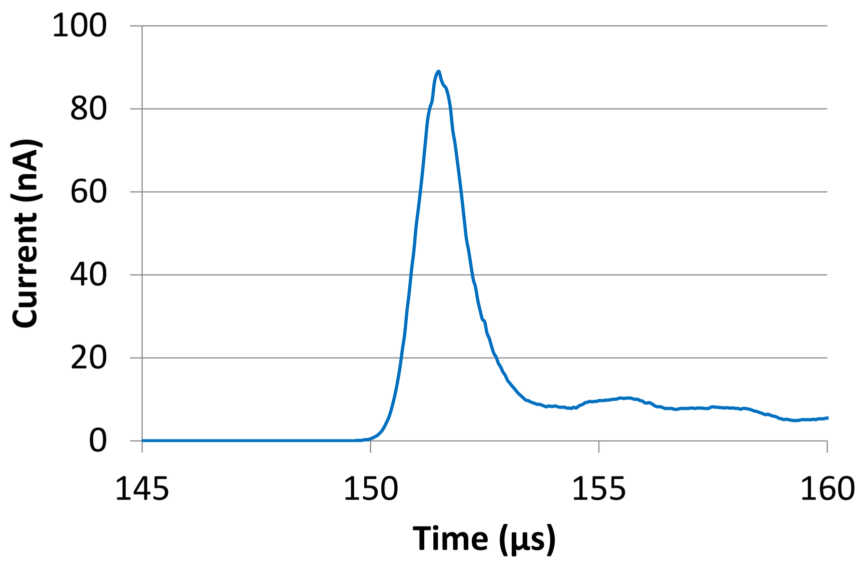
The LUPIN-II is a neutron Rem counter designed to work in Pulsed Neutron Fields (PNFs). It is based on a BF_3 proportional counter and uses a LOGAMP and a unique acquisition method to enable it to work in PNFs.

This method consists of sampling the current with an ADC converter at a rate of 10 MHz and acquiring for a set time window (of the order of ms). The current is then digitally integrated to find the total charge and converted into neutron interactions dividing by the expected charge per neutron. H*(10) is calculated with a calibration coefficient.

The working principle means that photons present a significant problem, as the signal they produce will also be integrated. This can be compensated for by using a time-based discrimination method: The photon peak is excluded from the acquisition while the neutron component is integrated as normal, therefore providing a more accurate value for the H*(10).

This discrimination method was tested through simulation and in two experimental campaigns.

Figure 1. Single neutron acquisition



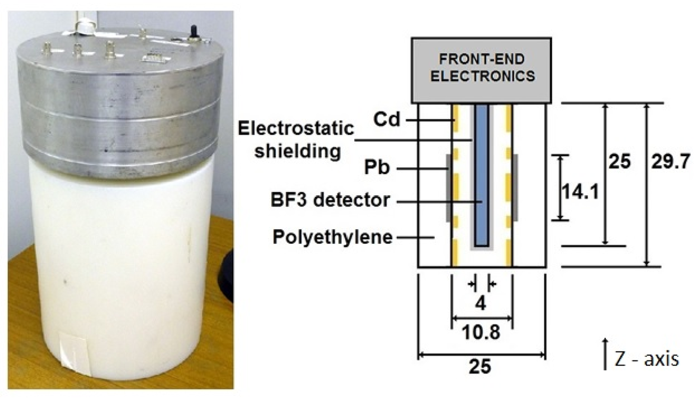


Figure 2. The LUPIN-II detector (all dimensions in cm)

2) Simulation

Simulations were executed with Geant4 version 10.0 and with the QGSP_BERT_HP physics list. The LUPIN-II moderator was modelled and neutrons were detected by counting α particles originating inside the sensitive volume by the $^{10}B(n,\alpha)$ reaction. The time taken from creation of the neutron to detection was recorded. The radiation field consisted of neutrons with of energy 700 keV. The neutrons were generated at a random heights along the z axis of the moderator (see Fig 2).

It was determined that 0.4% of the neutrons were detected in from 0-2 µs. This is the approximate width of a pulsed photon peak (depending on the field), and thus the probability of a neutron and photon peak occurring simultaneously is small.

This simulation was verified with results from a clinical linac (Figs 3 and 4). The longer tail in the experimental plot is due to stray neutrons.

Figure 3. Histogram of time from creation to detection of neutrons

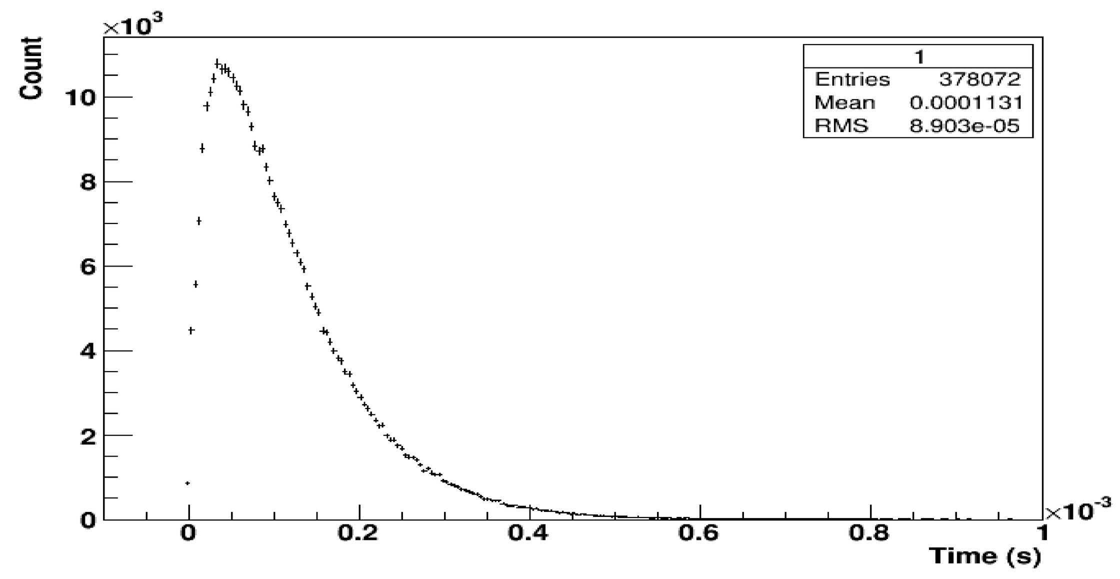
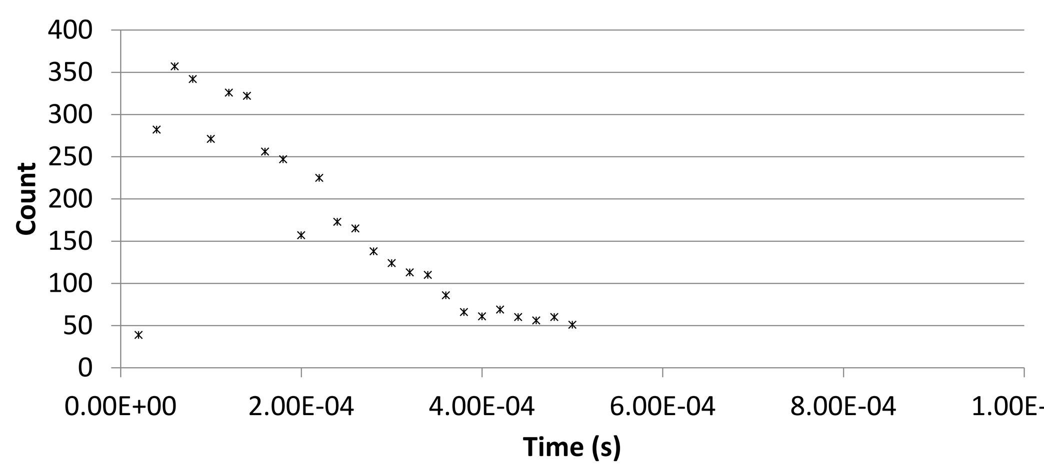


Figure 4. Results obtained with 15 MV field from clinical linac (see section 4)



3) Experiments at PSI

Experiments were performed at the Paul Scherrer Institut in Villigen, Switzerland. This is a Free-Electron Laser facility and therefore provided a mixed pulsed photon and neutron field. The results showed an over-estimation of the H*(10) per burst, but this was able to be corrected by a subtraction of the gamma peak based on the time resolution.

Figure 5. Sample acquisition showing resolution of photons and neutrons

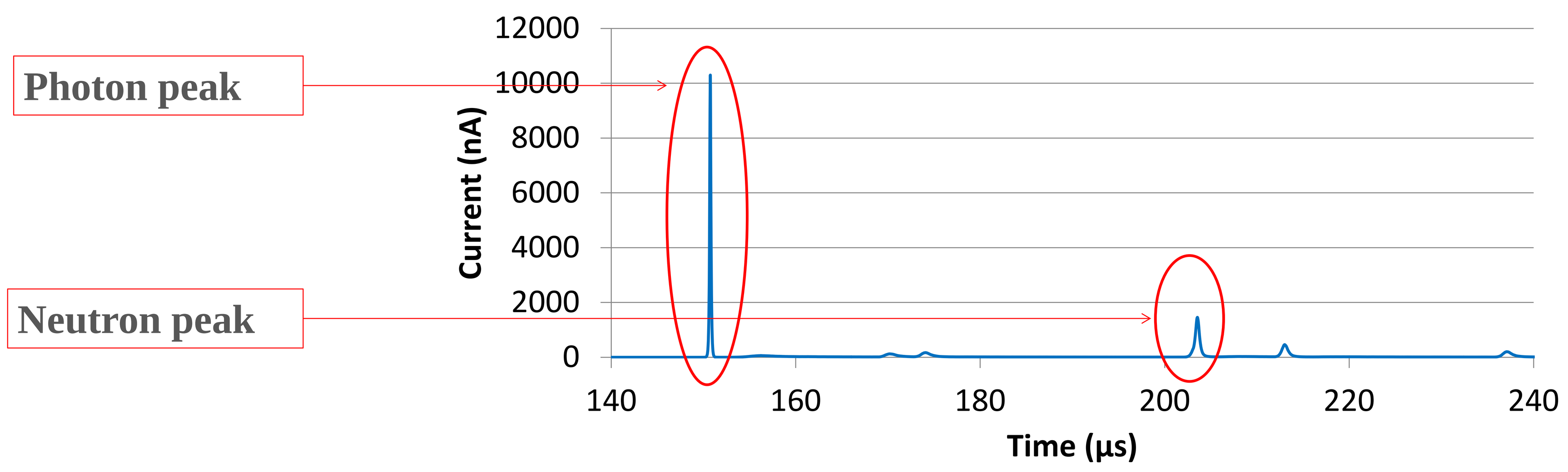


Table 1. Effect of time-based discrimination

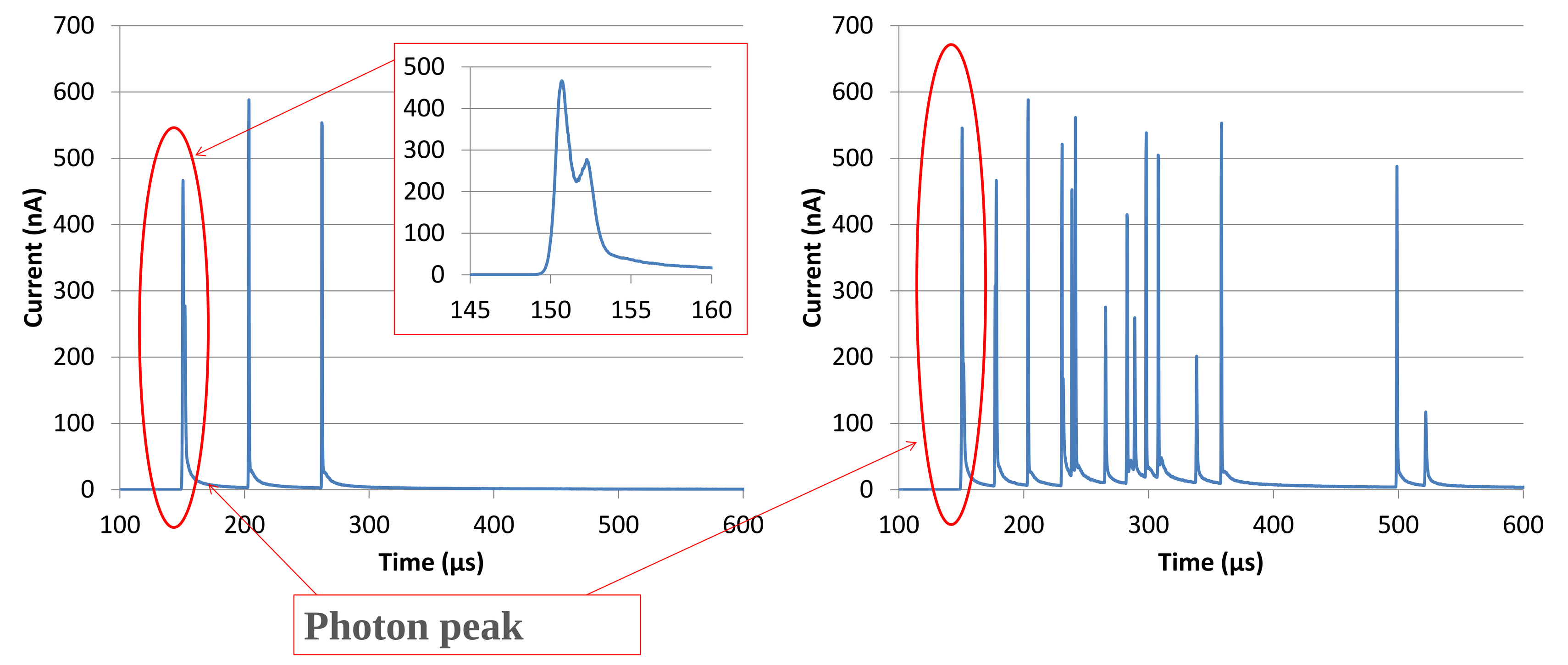
Position	Expected Photon Component (Low/Medium/High)	H*(10) dose per burst without discrimination (nSv/burst)	H*(10) dose per burst with discrimination (nSv/burst)
Pre- Bunch Compressor	Low	11.4 ± 2.2	10.1 ± 1.8
Post- Bunch Compressor	High	16.5 ± 2.7	7.8 ± 1.8
Dump-Front	Medium	29.7 ± 3.6	25.3 ± 3.3
Dump-Lateral	Medium	20.5 ± 3.0	17.8 ± 2.8

4) Experiments at Clinical Linac

A second series of experiments was performed at Instituto Nazionale dei Tumori in Milan, Italy. Using a Varian 'True Beam' clinical linac, the photon and neutron component was measured for 6, 10 and 15 MV fields. The time between linac pulses was 28 ms for the 6 MV field and 60 ms for the 15 MV field, due to the low dose rate used for the measurement. The method previously used to discriminate the photons was again applied.

The results took the same form as the previous measurement: a photon peak followed by neutrons. An interesting aside was that the shape of the photon peak (thought to be due to the linac parameters) made it easily distinguishable from the neutrons. This was not observed in the 15 MV measurement which, along with the increased production of neutrons, meant the neutron and photon peaks were not resolvable.

Figure 6. Sample acquisitions of 6 MV (Left) and 10 MV (Right) fields. A close up of the photon peak shows a shape distinctly different from a neutron (Fig. 1), probably related to the fine time structure of the linac pulse.



For these results, the photon peak corresponded to a value of 3 neutrons. Thus, for this field, the detector output was modified by 3 neutrons/burst to compensate.

6) Conclusion

- **From the agreement between the simulated and experimental data, it is clear that this is an effective method for discrimination between photons and neutrons in the LUPIN-II Rem counter, except in a field where the photon peak overlaps the neutron peak.**

References

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