Observation of noise in production VPTs at 1.8T

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1. INTRODUCTION

While most of the VPTs supplied by RIE perform satisfactorily in the RAL 1.8T test rig, a minority (less than 10%) display behaviour which makes them unsuitable for use in the CMS experiment. This note describes the behaviour of these VPTs in detail.

2. RAPID CHANGES IN VPT RESPONSE

Some VPTs display rapid changes in response during the course of acceptance testing. This is common at low magnetic fields, but most of the VPTs become stable at fields above 1T. However, a small proportion continue to display this behaviour at 1.8T.

2.1 Response of stable VPTs

Figure 1 shows the expected response of a VPT to a sequence of light pulses. The tube was operated under the standard conditions, in a 1.8T magnetic field with the cathode earthed and the dynode and anode at 800V and 1000V respectively. The upper plot shows the VPT response to a set of 5000 light pulses at a frequency of approximately 80Hz, while the lower plot is a histogram of the response. The plot covers a a period of approximately 1 minute.

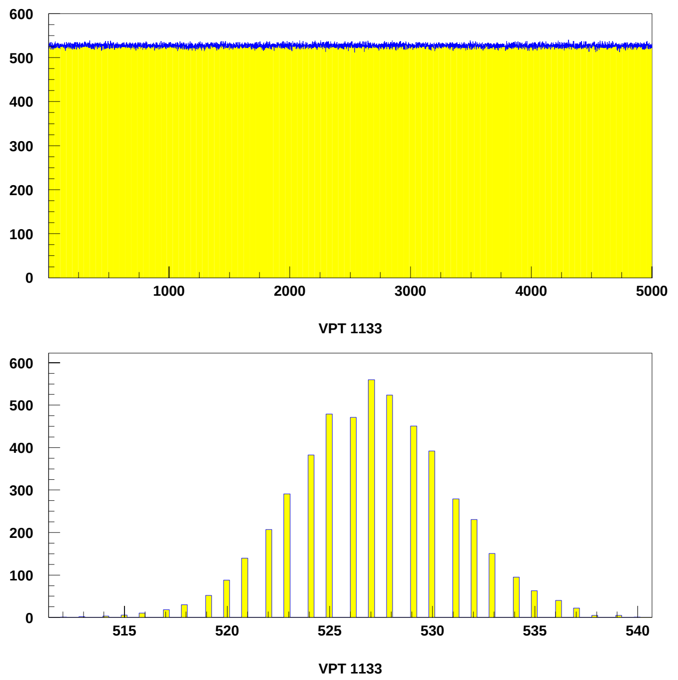

Figure 1. VPT 1133 - constant response to a series of uniform light pulses.

A stable VPT such as this generates a characteristic pattern of response as a function of angle to the magnetic field. Figure 2 shows the complete angle and magnetic-field scans obtained from VPT 1133. The response (shown by solid circles) varies in a periodic manner with angle in a 1.8T magnetic field, and is stable at 15° at fields above 1T. The response at each scan point is Gaussian, as shown in Figure 1, with a Gaussian width of approximately 3 ADC counts.

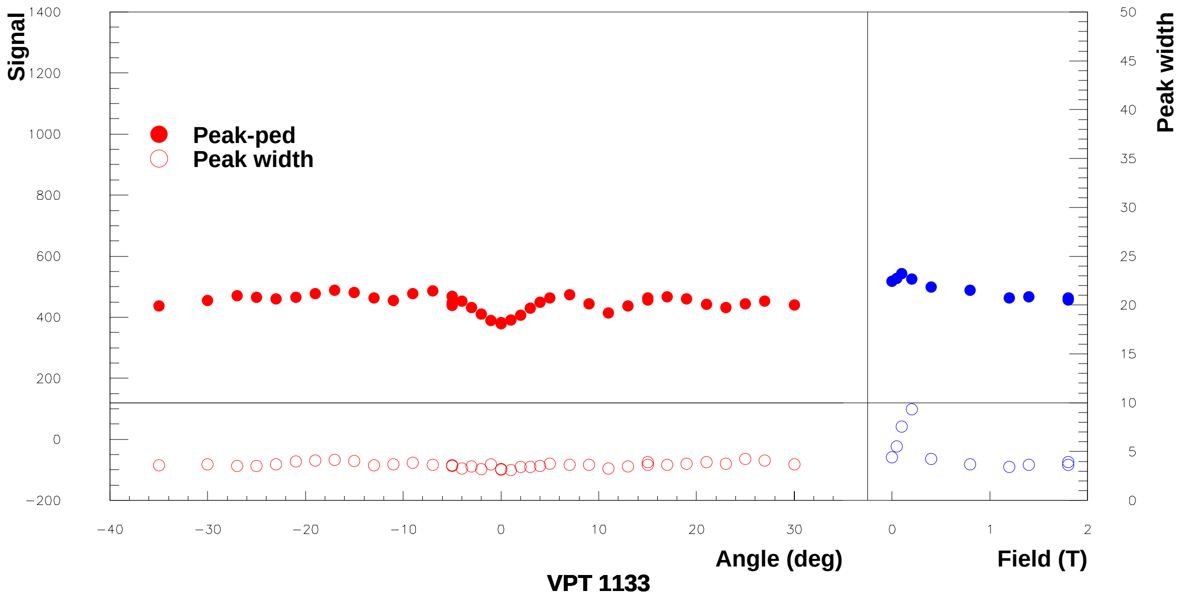

Figure 2. Angle and field scans on VPT 1133.

2.2 Patterns of unstable behaviour

A small fraction of the VPTs delivered so far display unstable behaviour at some angles to the magnetic field. Two patterns of instability have been seen, and are described here.

Some tubes show "spikes" during the data-taking period. Figure 3 shows angle and field scans on VPT 790, taken on 20 January 2003. The measured width of the response indicates that the tube is unstable in the angular range from 9° to 30°. The sequence of 5000 measurements at the 9° scan point is illustrated in Figure 4. There is a spike in the response early in the sequence, and the output of the tube remains variable after the spike. The next scan point, at 11° to the field, is shown in Figure 5 – the delay between scan point is of the order of one minute. It is clear that the VPT has still not returned to normal operation. The data in Figure 6 were taken at 30° to the field, and show the same unstable behaviour. In all cases, the measured pedestal is stable to within a single ADC count throughout the test run.

The instability is repeatable over long periods of time. A similar scan taken on 31 January 2003 is shown in Figure 7. The variation in peak width with angle indicates instability in the same angular range.

Similar spikes can be seen in the output from other VPTs. As an example, Figure 8 shows the complete sequence of data points for an angle scan on VPT 2105, running from -35° to 30°. A burst of noise including several sharp spikes can be seen at angles from -25° to -17°. A further example is shown in Figure 9, which shows an angle scan on VPT 2179.

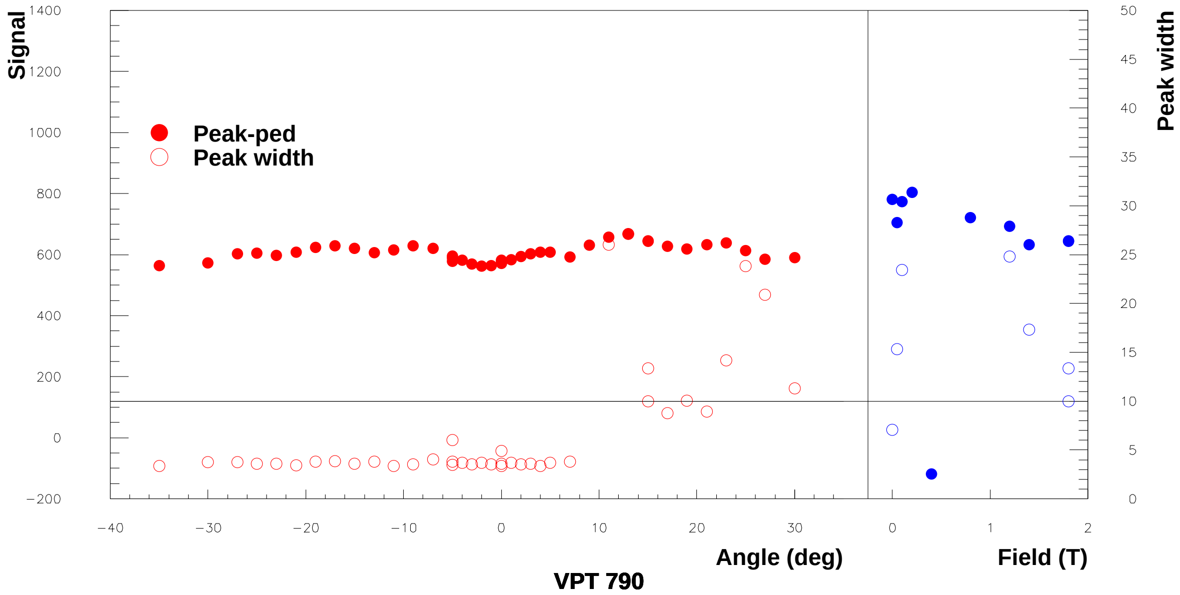

Figure 3. Angle and field scans on VPT 790 on 20 Jan 2003.

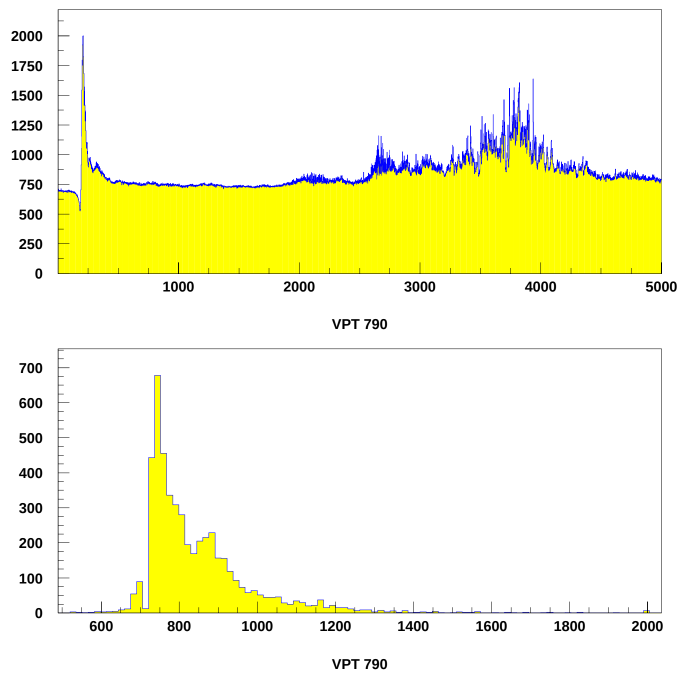

Figure 4. VPT 790 - response to a series of uniform light pulses at an angle of 9° to the magnetic field.

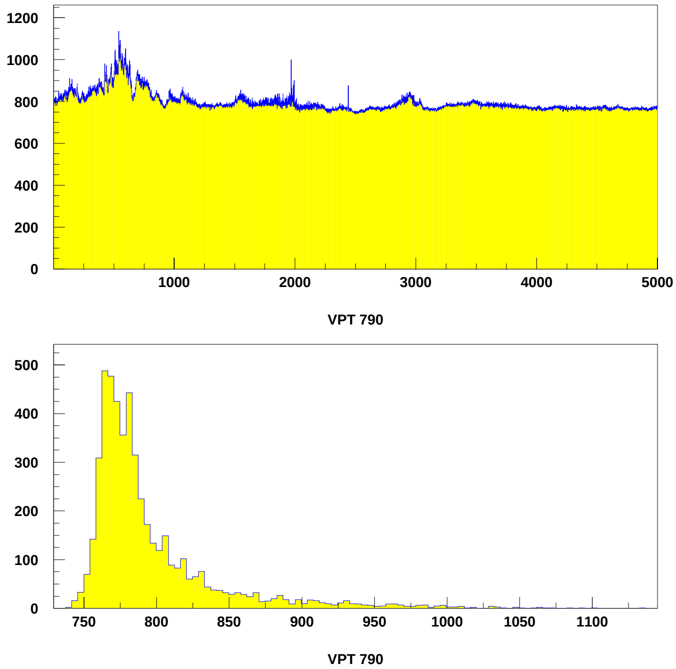

Figure 5. VPT 790 - response to a series of uniform light pulses at an angle of 11° to the magnetic field.

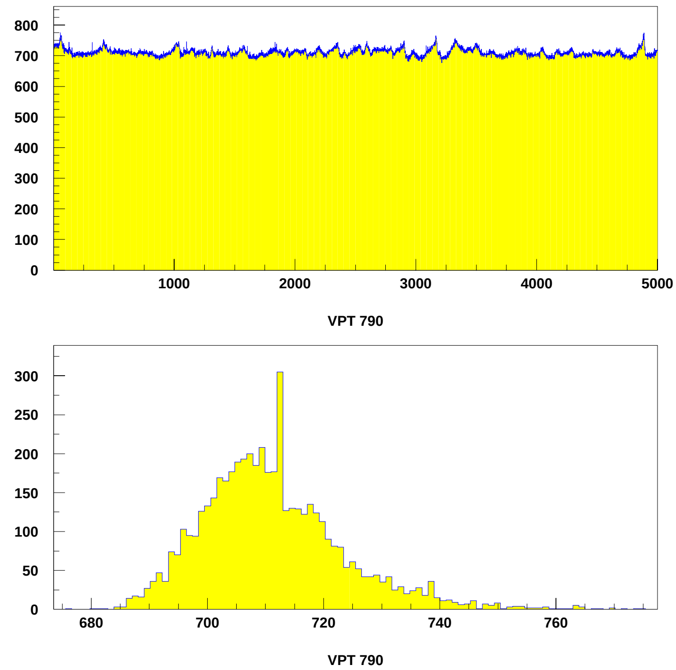

Figure 6. VPT 790 - response to a series of uniform light pulses at an angle of 30° to the magnetic field.

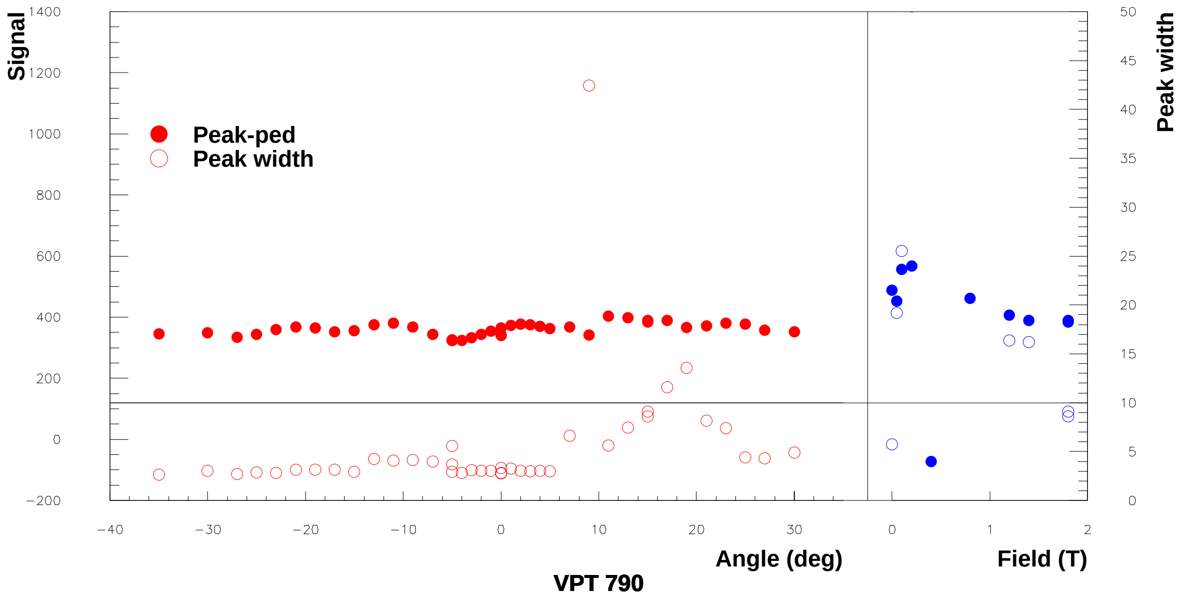

Figure 7. Angle and field scans on VPT 790 on 31 Jan 2003.

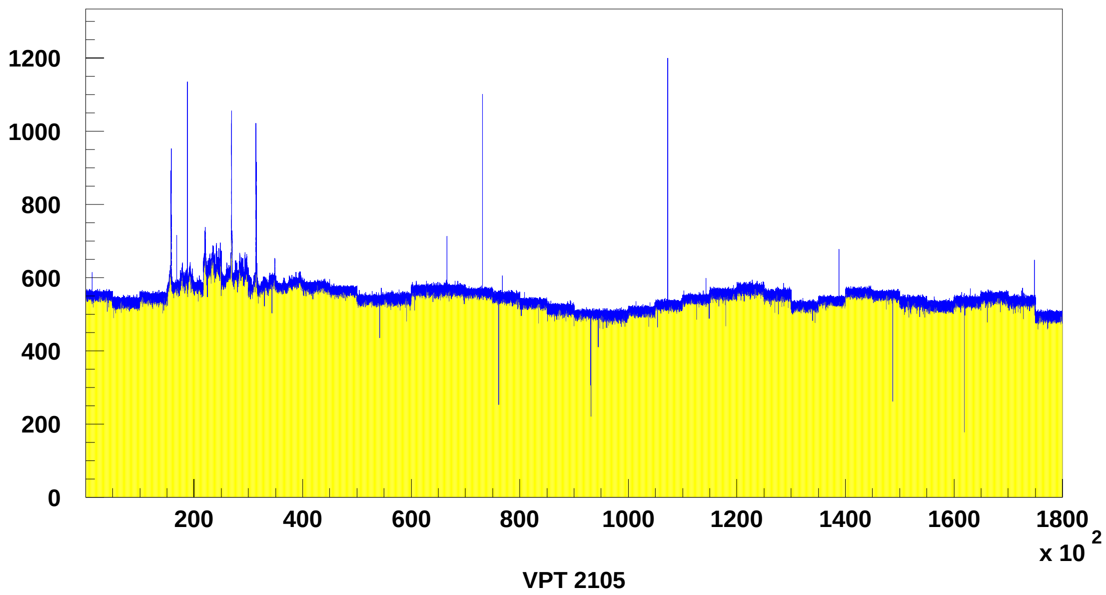

Figure 8. VPT 2105 - complete data sequence for angle scan at 1.8T.

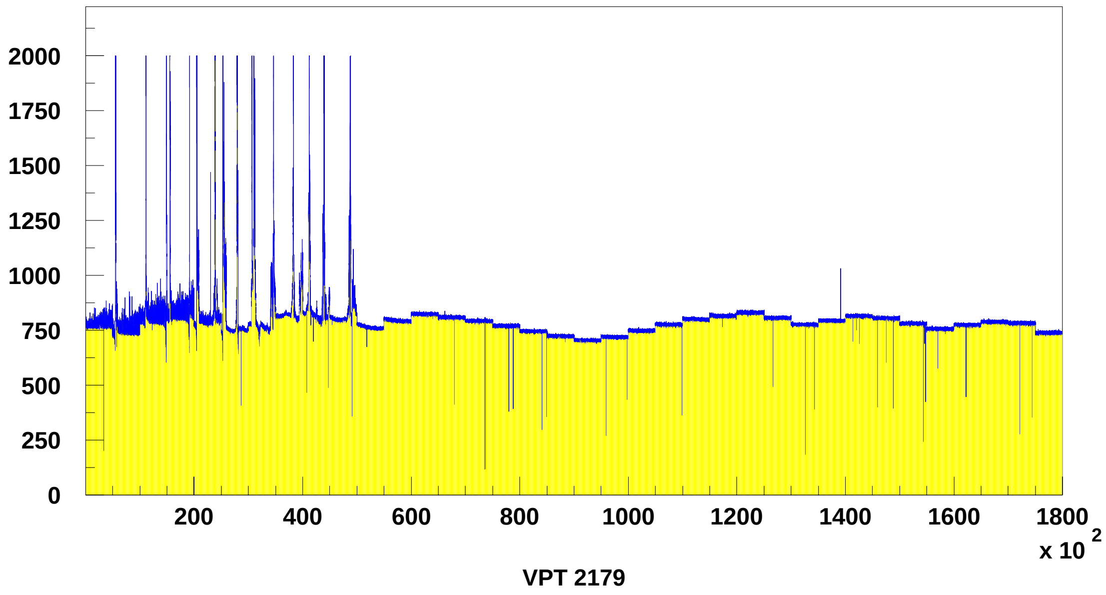

Figure 9. VPT 2179 - complete data sequence for angle scan at 1.8T.

The second instability pattern closely resembles the "spike" behaviour, except that no large spike is seen. In other respects, the tube response is very similar. As an example, Figure 10 shows the angle and field scans on VPT 1639. The instability at angles from 13° to 30° is similar to that seen in the scans described above. However, the behaviour does not originate from a visible spike. The raw data sequence corresponding to the angle scan is shown in Figure 11. The noisy region is clearly visible, but there is no obvious spike.

We conclude that the two types of instability have the same cause, but that in some cases the "spike" occurs in the interval between data-taking periods, either when the VPTs are being rotated to a new angle, or during the waiting period after rotation, which is intended to allow the VPTs and test rig to stabilise. As evidence for this, Figure 12 shows another raw data sequence from VPT 790. No spike is seen in this figure, but a raw data sequence from the same VPT shown in Figure 4 clearly displays a spike.

3. EFFECT OF VARYING OPERATING VOLTAGES

3.1 Description of voltage scans

A number of test runs have been carried out at operating voltages different from the standard (V_A/V_D = 1000V/800V). Three non-standard voltage settings were used: 1000V/850V, 800V/600V and 750V/600V. In each test run, a batch of VPTs was loading into the test rig, and a set of four angle- and field-scans were taken using the four selected voltage settings. the VPTs were not remove from the rig, or disturbed in any way, between scans.

In these tests, reducing the anode voltage had the effect of reducing the incidence of spikes. An example is shown in Figure 13-Figure 16, which illustrate the behaviour of VPT 2179 at various voltage settings. There is a strong suggestion that the VPT is more stable at the lower operating voltages. The raw data sequences at the non-standard voltage settings are shown in Figure 17-Figure 19. These figures show that the VPT still generates spikes at the reduced voltage settings, but that they are much smaller.

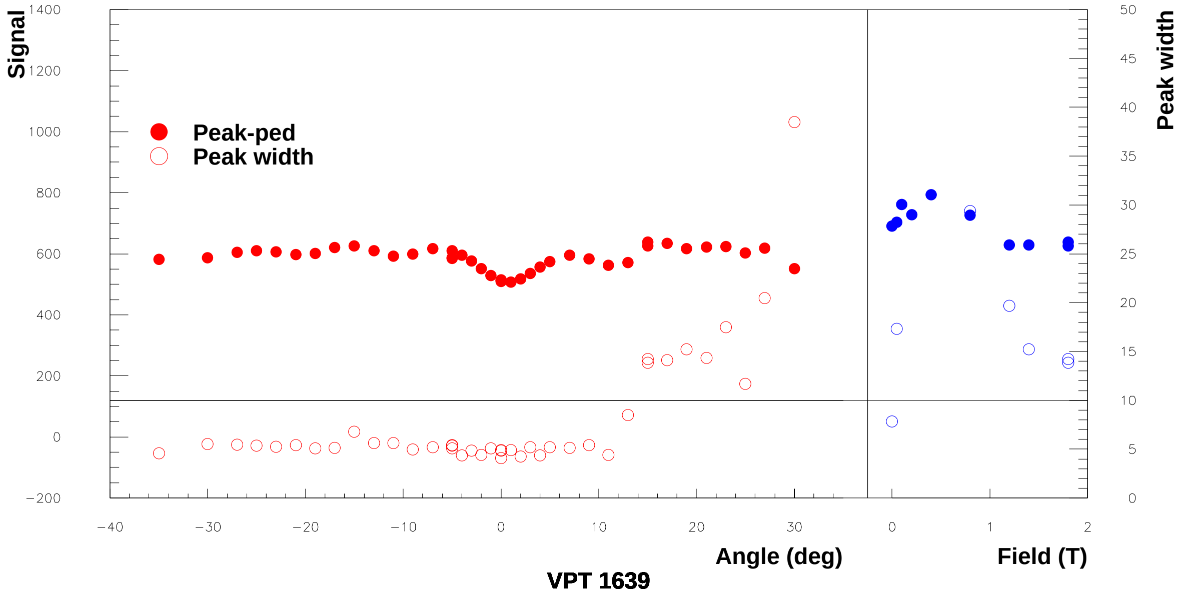

Figure 10. Angle and field scans on VPT 1639.

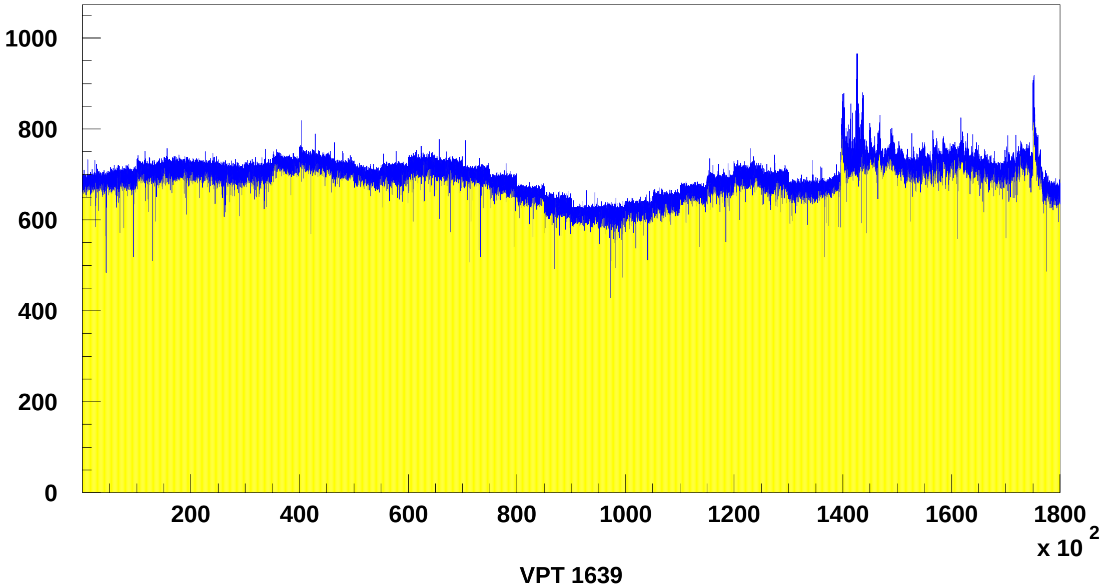

Figure 11. VPT 1639 - complete data sequence for angle scan at 1.8T.

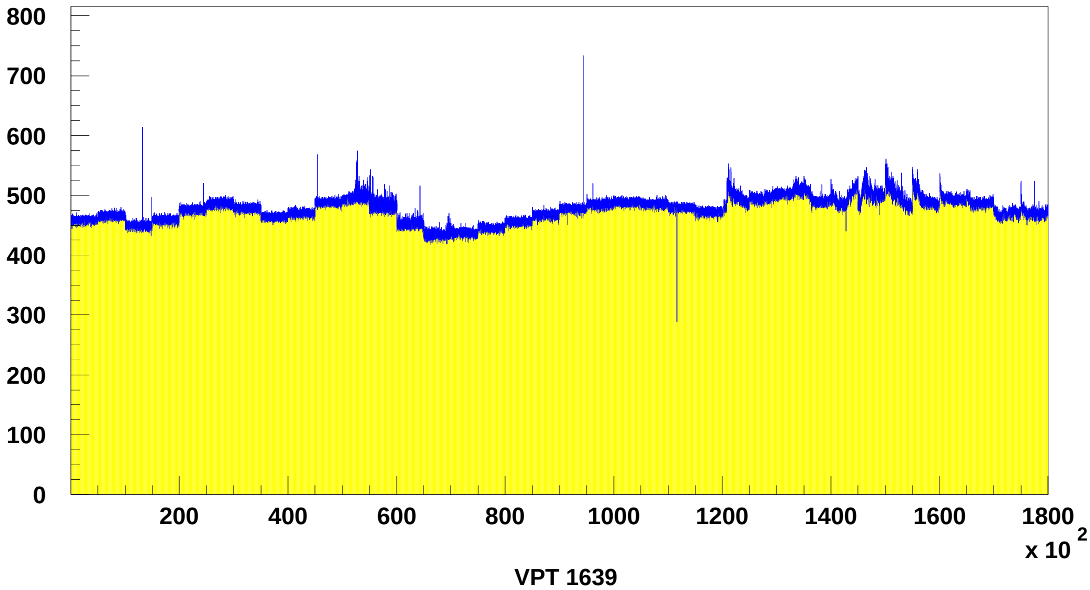

Figure 12. VPT 790 - complete data sequence for angle scan at 1.8T, on 24 Jan 2003.

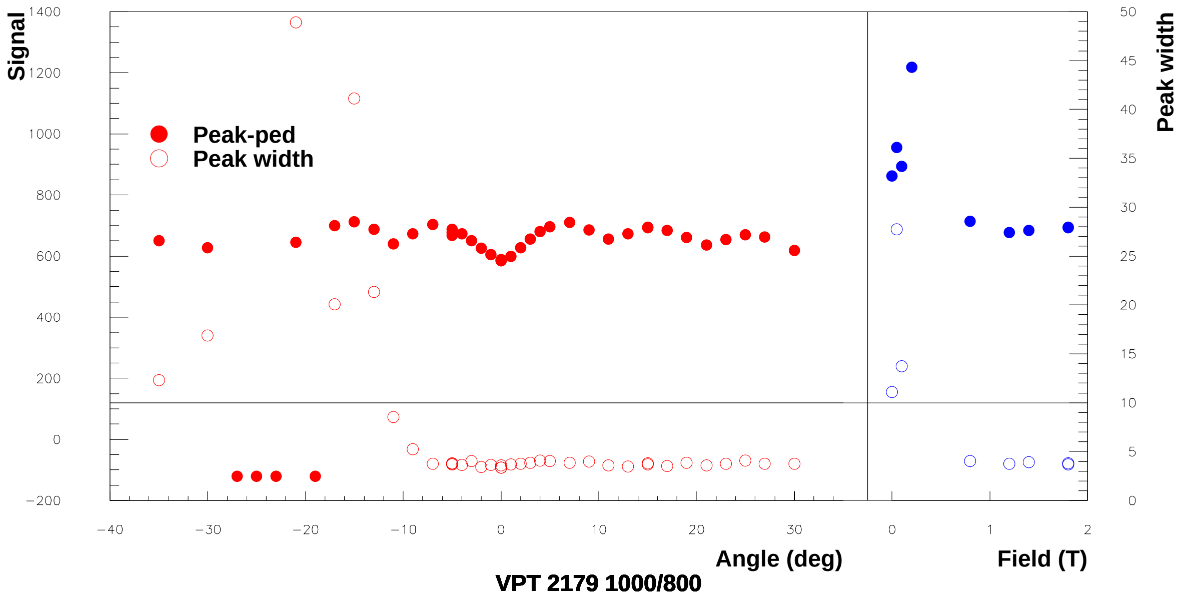

Figure 13. Angle and field scans on VPT 2179, V_A/V_D = 1000/800.

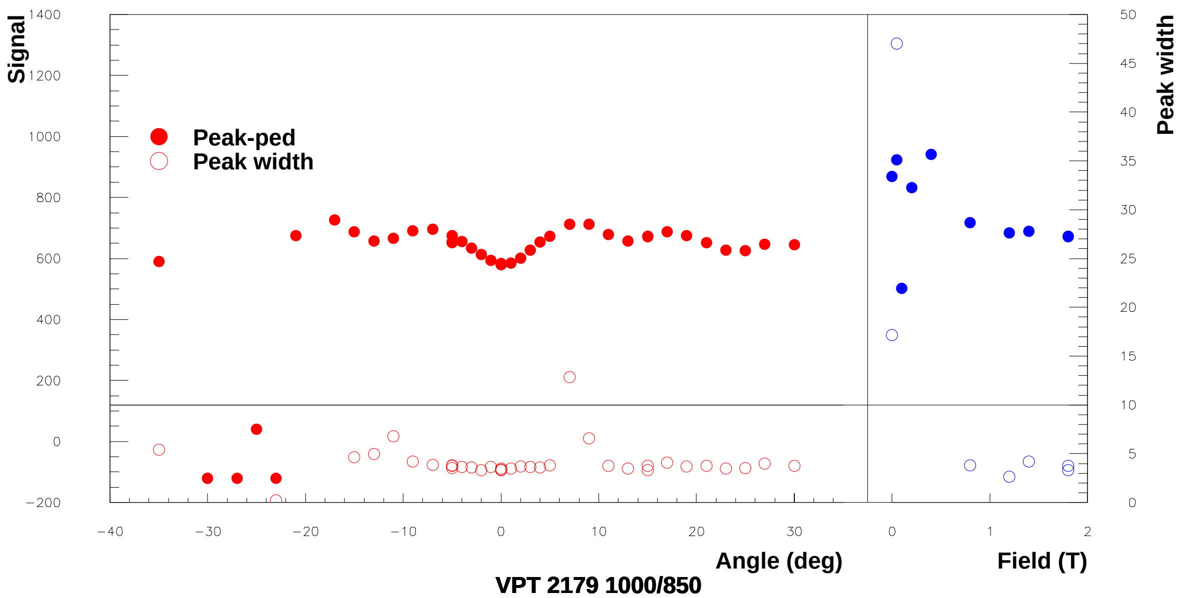

Figure 14. Angle and field scans on VPT 2179, V_A/V_D = 1000/850.

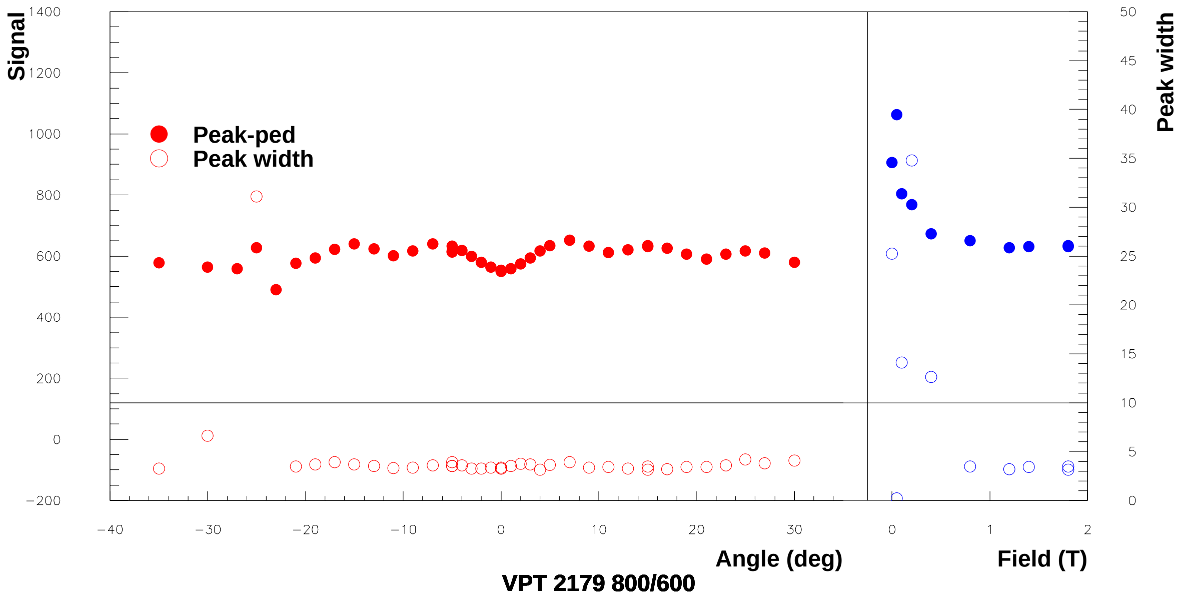

Figure 15. Angle and field scans on VPT 2179, V_A/V_D = 800/600.

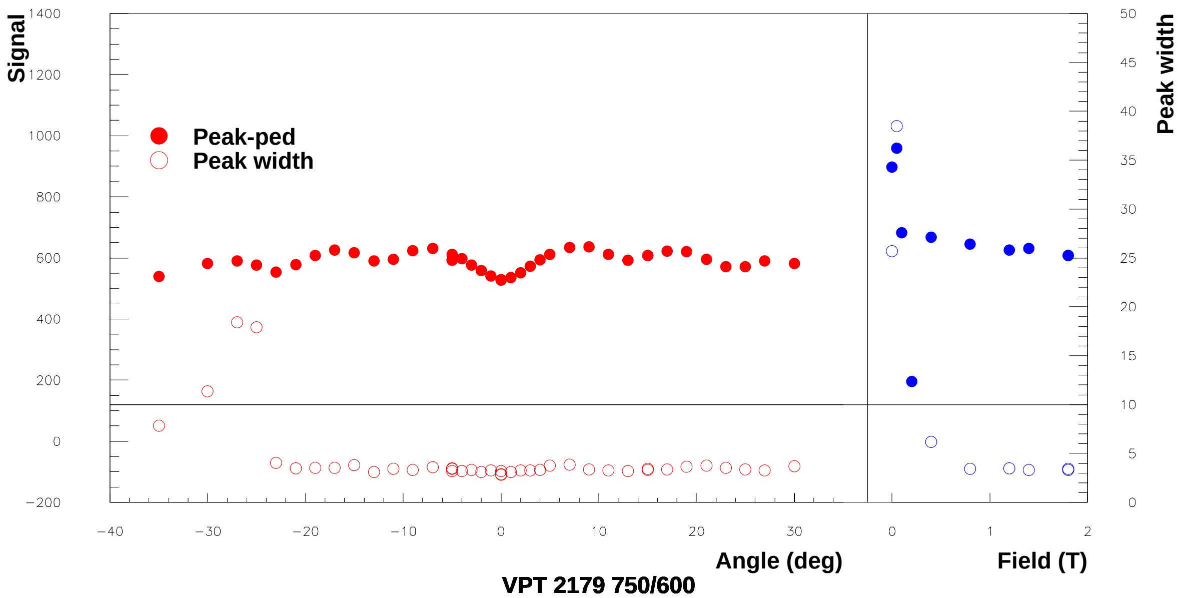

Figure 16. Angle and field scans on VPT 2179, V_A/V_D = 750/600.

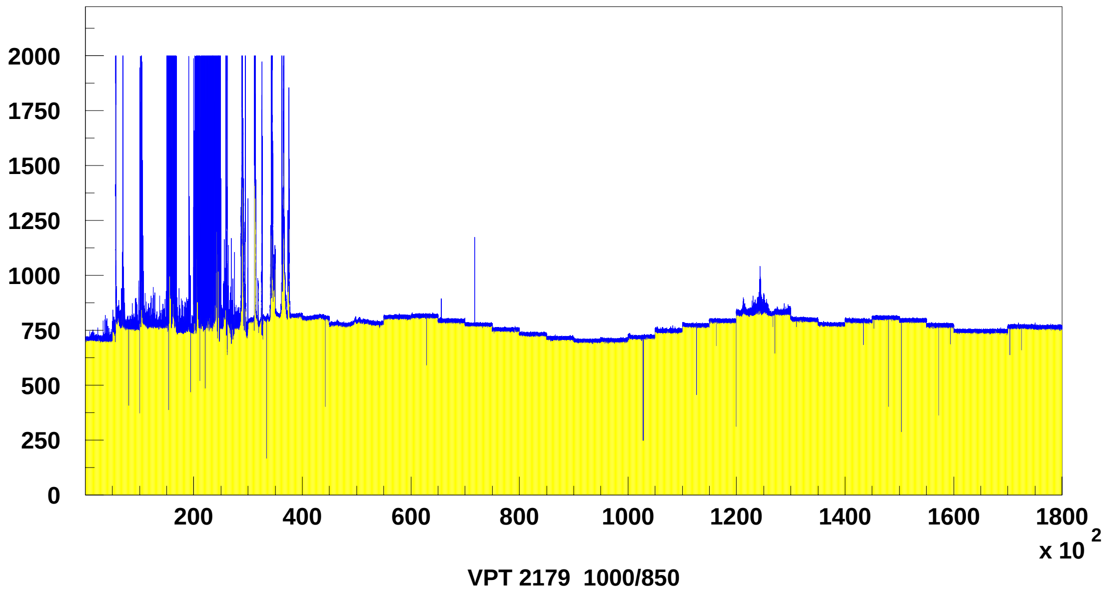

Figure 17. VPT 2179 - complete data sequence for angle scan at 1.8T, at 1000/850 voltage setting.

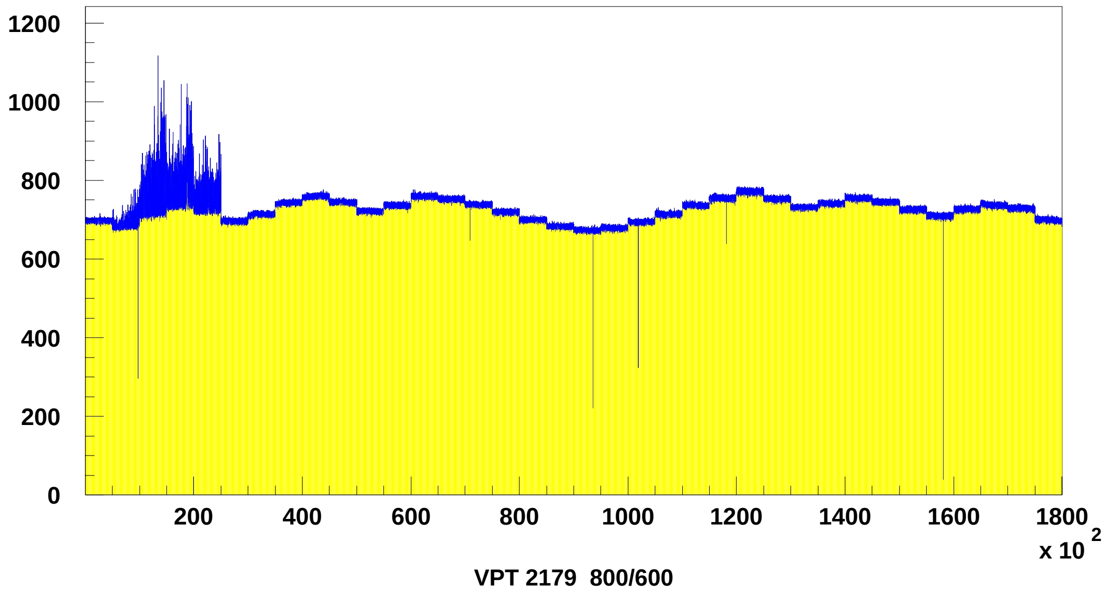

Figure 18. VPT 2179 - complete data sequence for angle scan at 1.8T, at 800/600 voltage setting.

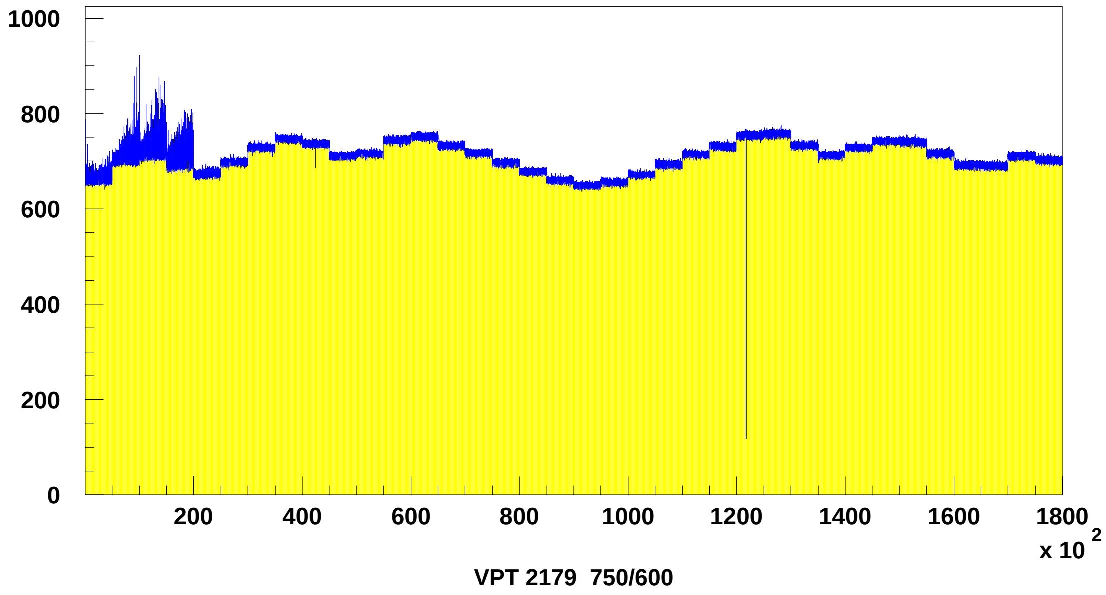

Figure 19. VPT 2179 - complete data sequence for angle scan at 1.8T, at 750/600 voltage setting.

3.2 Analysis of voltage scans

In order to measure the effect of changing the voltage setting, a "noisy" angle point is defined as a response measurement with a peak width greater than 10 ADC counts. A crude measure of noise is then given simply by the number of "noisy" points in a standard angle scan.

Table 1 summarises the result of the voltage scan for a sample of VPTs which display spikes in their raw data sequence. Some of the tubes were scanned more than once. There is a clear indication in this table that a reduction in the operating voltage of the tubes from 1000/800 to 800/600 produced a substantial reduction in the number of "noisy" points. Reducing the voltage between anode and dynode (from 1000/800 to 1000/850) produced a smaller effect.

VPT	**Number of noisy points in angle scan at given voltage setting**			
	1000/800	1000/850	800/600	750/600
790	9	5	2	2
790 repeat	2	2	1	0
790 repeat	6	3	0	0
790 repeat	1	2	0	0
790 repeat	3	2	0	0
790 repeat	3	0	0	0
790 repeat	3	2	0	0
1503	9	4	1	1
1560	4	1	0	0

1635	3	0	0	0
1638	2	0	0	0
1641	3	0	1	1
1700	10	12	2	8
1742	3	1	0	0
1745	5	11	2	0
1981	2	2	0	1
2020	5	0	0	0
2036	1	0	0	0
2105	5	0	0	0
2105 repeat	4	0	1	1
2174	3	1	0	0
2179	8	7	1	3
2252	0	2	0	0
2256	11	16	13	8
2304	8	14	12	13
2373	11	11	6	4
2395	7	5	4	2
2413	4	1	0	0
2436	5	5	2	1
2557	2	1	0	0
2830	5	0	0	0
3065	5	8	2	2
3089	4	0	0	0
3117	1	1	1	1

Table 1. Number of noisy points measured for VPTs showing spikes, as a function of applied voltage.

4. CONCLUSIONS

While most of the VPTs supplied by RIE have given satisfactory results in the 1.8T test rig, a small fraction, less than 10%, show noisy behaviour, characterised by sharp "spikes" in the tube response to a pulsed light source. The severity of this noise can be reduced, though not eliminated, by running the VPTs at reduced voltage.

The extremely rapid onset of the spikes, typically rising to a maximum in a single sampling period of the test system (less than 12ms), and the behaviour as a function of applied voltage, strongly suggest that they arise from discharges within the VPTs. The fact that the noise is repeatable when VPTs are tested more than once also supports this conclusion.

VPTs showing this behaviour are unsuitable for installation in the CMS detector.