Behaviour of production VPTs for the CMS Endcap Electromagnetic Calorimeter: VPTs 501-11600

16 September 2005

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Abstract

This note reports measurements made on the first 11100 production Vacuum PhotoTriodes (VPTs) manufactured by RIE (St Petersburg) for the CMS Electromagnetic Endcap Calorimeter.

Introduction

This document describes a series of measurements made on the first 11100 production Vacuum PhotoTriodes (VPTs) manufactured by RIE (St Petersburg) for the CMS Electromagnetic Endcap Calorimeter.

The VPT specification

Some of the technical specifications of the VPTs which are incorporated into the contractual agreement with the manufacturers are summarised in Table 1. A more detailed and definitive statement of the requirements can be found in [1].

Quantity	Meaning	Range
P	Quantum efficiency at 420nm	at least 15%
G	Current gain at zero field	at least 7
PG	PG = P·G	1.4 to 3.8
F	Excess noise factor	less than 4.5
i^a_{max}	Maximum anode current from 0 - 4T	at most 2 nA
L	Overall length of VPT	at most 46mm
D	External diameter of insulating sleeve	26.5 to 27.2mm

Table 1. Technical specification of VPTs. Measurements are to be made with anode and dynode voltages of 1000V and 800V respectively relative to the photocathode, using blue LEDs with a peak emission of wavelength 420nm.

Delivery of VPTs

Figure 1 shows the VPT delivery rate as a function of time from 25 September 2000 to the present. The current delivery rate is close to the revised schedule.

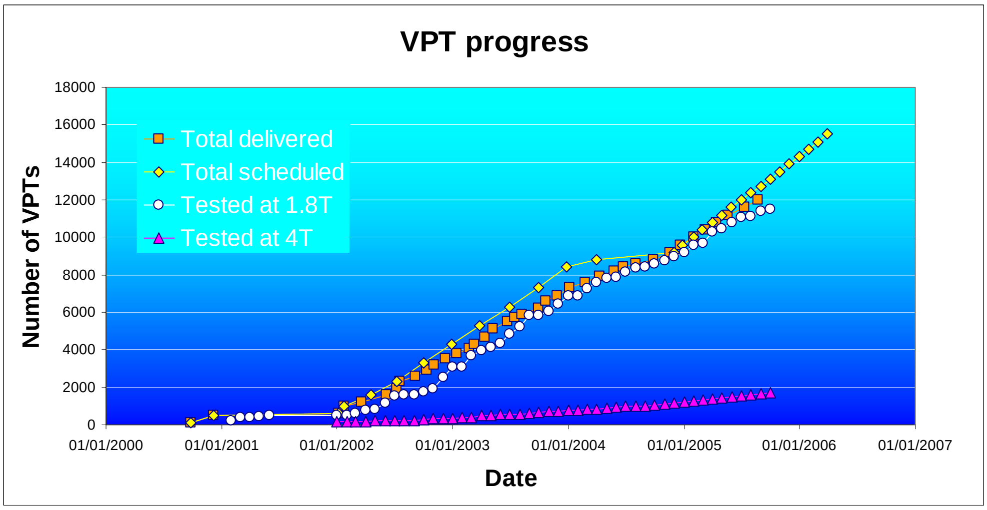

Figure 1. VPT delivery and testing

Visual inspection of VPTs

All of the VPTs received have been inspected visually, to detect obvious defects or anomalies in their photocathodes, anode grids, or other aspects of their appearance. Table 2 summarises the results.

The feature which is most often seen is a misalignment of the anode grid with respect to the axis of the VPT. Almost 20% of the VPTs appear to have some misalignment of the grid, This rate has been reduced to about 3% for VPTs with bar-codes above 9600, though there is an indication that the rate is rising again in the most recent VPTs. The operation of the VPTs seems to be unaffected by the grid position: however, there is a concern that it might affect the long-term robustness of the devices and this will continue to be monitored at RAL. The fraction of VPTs with off-centre grids is shown as a function of bar-code in Figure 2.

The other characteristics which were seen most frequently were various imperfections in the photocathode coating. The entries given as "Missing photocathode" refer to crescent-shaped areas of the faceplate which appeared to have no photocathode coating – in these cases, the approximate size of the missing area has been estimated by eye. Detailed measurements of the photocathode response confirm [2] that the quantum efficiency of these devices is very low in the "missing" regions. A small number of VPTs showed more random variations in the thickness of the photocathode layer; these are recorded as "Uneven photocathode coverage". Photocathode defects were observed more frequently in VPTs 5901 to 8600, but have been less frequent in more recent batches.

In some batches of VPTs (with bar-codes from 5900 to 8600) there has been a significant increase in the number of tubes with poor crimping of the pins onto the leads. While this does not affect the performance of the VPTs, it is time-consuming for staff at RAL to re-crimp the pins on such VPTs before they can be tested. The most recent batches, with bar-codes from 8601 to 11600, have much better crimping.

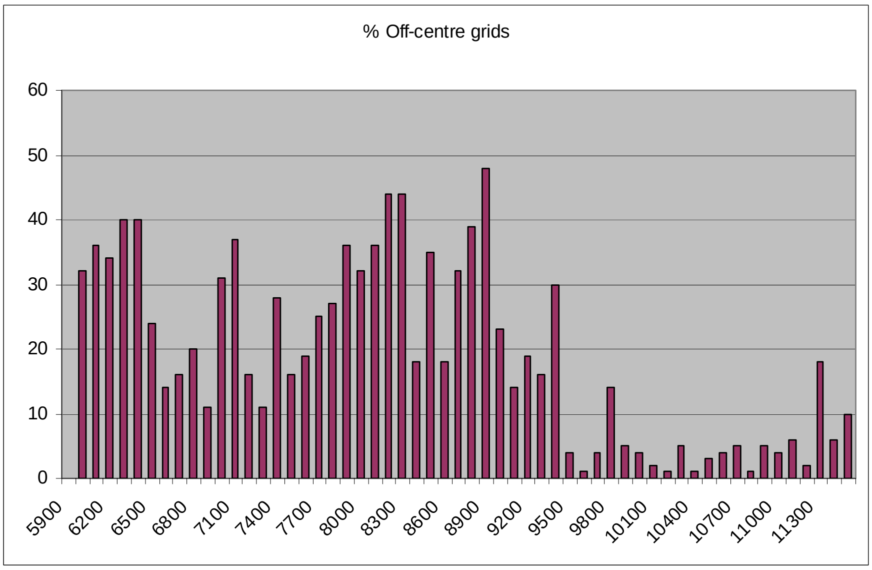

Figure 2. Fraction of VPTs with off-centre anode grids as a function of bar-code

Characteristic	Number of VPTs (by bar-code)						% of VPTs inspected
	501-1600	1601-3200	3201-5900	5901-8600	8601-11600	All	
Misaligned anode grid	78	384	435	744	344	1985	17.9%
Wrinkled anode grid	2	4	1	5	6	18	0.2%
Missing photocathode (5-9% of faceplate)	29	6	7	29	8	79	0.7%
Missing photocathode (10-19% of faceplate)	25	6	1	4	2	38	0.3%
Missing photocathode (20-29% of faceplate)	15	1	1	1	0	18	0.2%
Missing photocathode (30-39% of faceplate)	6	0	0	0	0	6	0.1%
Missing photocathode (‡40% of faceplate)	4	0	0	0	0	4	0.1%
Uneven photocathode coverage	11	11	8	8	12	50	0.5%
Dark spot on photocathode or faceplate	7	5	8	21	16	57	0.5%
Red-brown discolouration of photocathode	4	0	0	0	0	4	0.1%
Poor or untidy crimping of pins to wires	8	0	2	181	10	201	1.8%
Pin came off during inspection	1	1	1	0	0	3	0.1%
Wire came off during inspection	3	0	1	1	1	6	0.1%
Bloom on photocathode	0	45	25	163	81	314	2.8%
Bloom on grid	0	3	0	0	6	9	0.1%

Table 2. Summary of visual inspection of 9500 production VPTs

Measurements in the RAL 1.8T test rig

11000 of the production tubes have so far been tested in the RAL test rig. Figure 3 shows the distribution of anode pulse heights measured in a 1.8T magnetic field; the quantity plotted is the mean pulse height over the angular range 8 -25 to the magnetic field. For comparison, results obtained from the pre-production batch are also shown. The measured pulse heights have been converted into the expected experimental yield of electrons per MeV of energy deposited in the CMS calorimeter.

Figure 4 shows the correlation between the mean pulse height in the 1.8T magnetic field and the quality factor *PG* supplied by the manufacturer. The correlation between the manufacturer's measurements at 0T and the RAL measurements at 1.8T is striking.

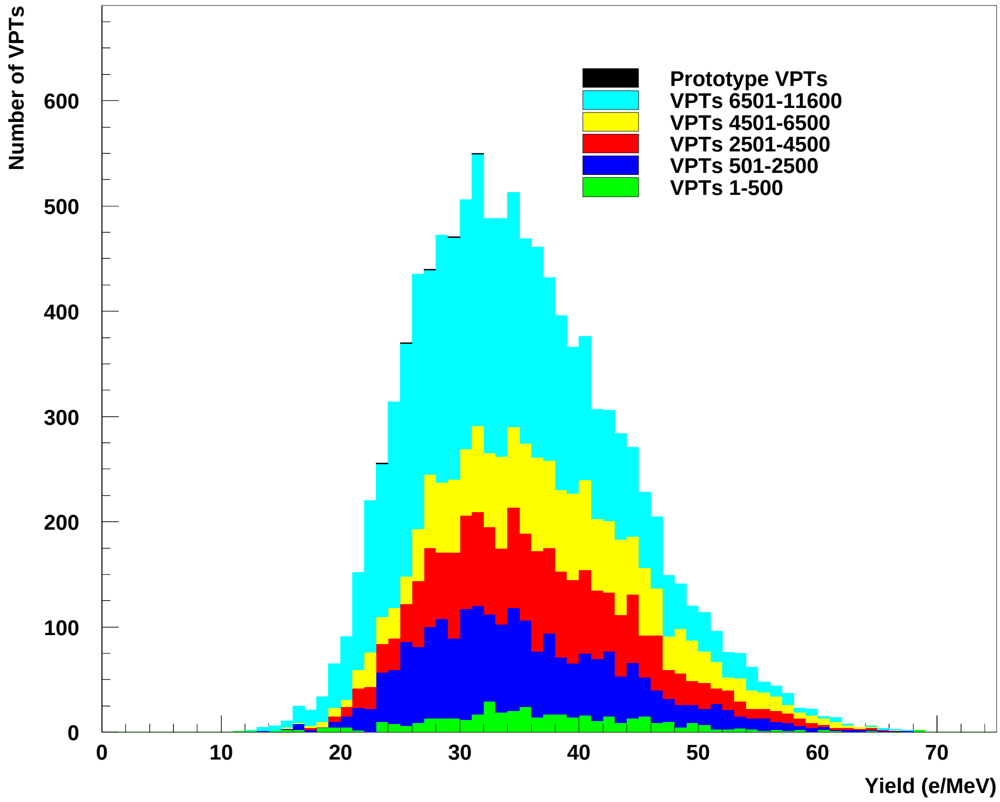

Figure 3. Mean anode pulse height over the angular range 8 -25 in a 1.8T magnetic field.

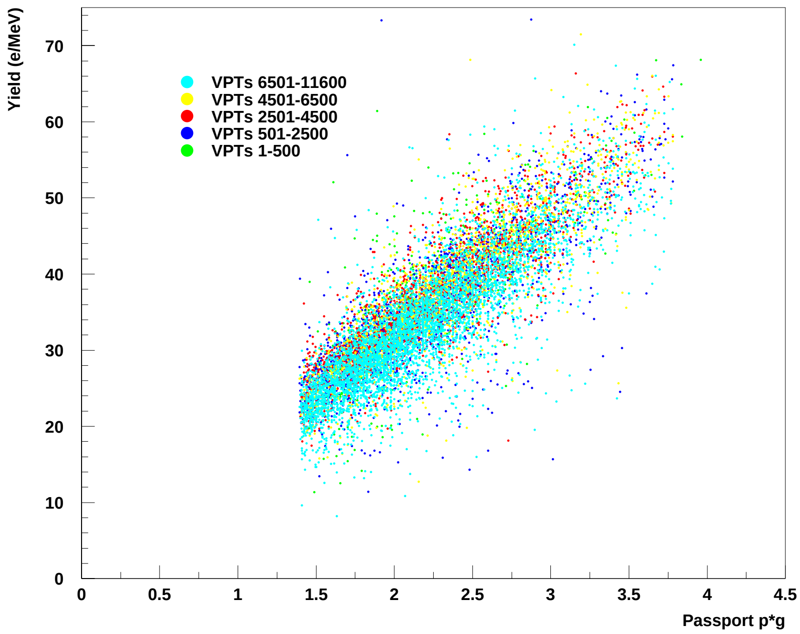

Figure 4. VPT response at 8 -25 and 1.8T v quality factor *PG*

Summary and Conclusions

The first 11100 production VPTs supplied by RIE have been subjected to a variety of measurements at RAL and Brunel University. The parameters supplied in the VPT passport are found to correlate well with these measurements.

The recent VPT batches have not suffered from the crimping problems observed previously. The fraction of VPTs with misaligned anode grids remains low, though there is some indication that the rate may be increasing in VPTs with bar-codes above 11300. This trend should be investigated and rectified.

References

[1] ‘Technical specification of vacuum phototriodes for the endcap electromagnetic calorimeters of the Compact Muon Solenoid (CMS) experiment’, 11 May 2001.

[2] ‘Uniformity measurements across the photosensitive area of CMS ECAL photodetectors’, N. Godinovic et al, CMS NOTE in preparation.

[3] ‘Observation of noise in production VPTs at 1.8T: VPTs with bar-codes 1501-10400’, B W Kennedy, 22 April 2005.