Behaviour of production VPTs for the CMS Endcap Electromagnetic Calorimeter: VPTs 501-3200

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Abstract

This note reports measurements made on the first 2700 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 2700 Vacuum PhotoTriodes (VPTs) manufactured by RIE (St Petersburg) for the CMS Electromagnetic Endcap Calorimeter.

The appraisal of the VPTs was carried out at RAL and Brunel University during the period January-December 2002. This document describes the results obtained at RAL.

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	Photocathode quantum efficiency at 420nm	≥15%
G	Current gain at zero field	≥ 7
PG	PG = P×G	1.4 – 3.8
F	Excess noise factor	< 4.5
i^a_{max}	Maximum anode current from 0 - 4T	≤ 2 nA
Length	Overall length of VPT	≤ 46mm
Diameter	External diameter of insulating sleeve	26.5-27.2mm

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.

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 characteristics which were seen most frequently were imperfections in the photocathode coating and misalignment of the anode grid with respect to the axis of the VPT. 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. 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”.

A small number of tubes displayed a reddish-brown discolouration of the photocathode. It is notable that three of these had production numbers very close together (bar-code/production-numbers 938/2048, 939/2052, and 953/2049), so that the discolouration may indicate a quickly-corrected anomaly in the manufacturing process.

Characteristic	Number of VPTs (by bar-code)			% of VPTs inspected
	501-1600	1601-3200	All	
Misaligned anode grid	78	384	462	17.1%
Wrinkled anode grid	2	4	6	0.2
Missing photocathode (5-9% of faceplate)	29	6	35	1.3
Missing photocathode (10-19% of faceplate)	25	6	31	1.1
Missing photocathode (20-29% of faceplate)	15	1	16	0.6
Missing photocathode (30-39% of faceplate)	6	0	6	0.2
Missing photocathode (≥40% of faceplate)	4	0	4	0.1%
Uneven photocathode coverage	11	11	22	0.8%
Dark spot on photocathode or faceplate	7	5	12	0.4%
Red-brown discolouration of photocathode	4	0	4	0.1%
Poor or untidy crimping of pins to wires	8	0	8	0.3%
Pin came off during inspection	1	1	2	0.1%
Wire came off during inspection	3	0	3	0.1%
Bloom on photocathode	0	45	45	1.7%
Bloom on grid	0	3	3	0.1%

Table 2. Summary of visual inspection of 2700 production VPTs

The RAL variable-angle test rig

The test rig at RAL is based on a water-cooled magnet providing fields up to 1.8T over an area of approximately 0.5 m^2. The vertical distance between the pole tips is approximately 10cm.

Figure 1 is a photograph of the RAL test rig. The 1.8T magnet, seen on the right of the picture, was formerly used as a bending magnet in a beam line.

The VPTs are held in aluminium cans glued together in rows of eight, with each row attached to the rig by a shaft, so that it may be rotated to present the VPTs at any desired angle to the magnetic field. A stepper motor is used to rotate all of the VPTs simultaneously by means of a system of drive belts.

When the rig is in use, the magnet pole tips are covered with a black cloth to eliminate stray light. The photocathodes of the VPTs are illuminated by blue (430nm) LEDs; each can contains four LEDs, with a frosted perspex diffuser to ensure uniform illumination.

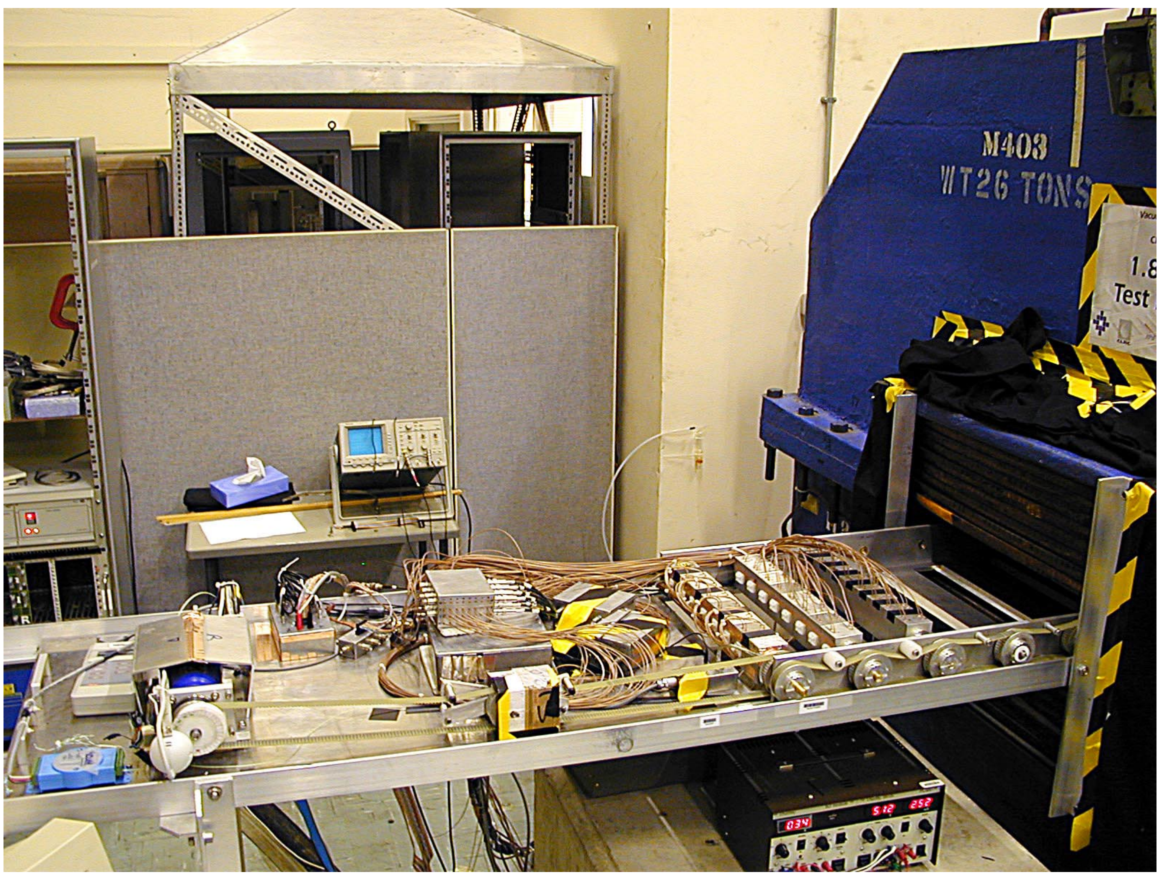

Figure 1. General view of the RAL test rig

Measurements in the RAL 1.8T test rig

Magnetic field scans up to 1.8T

The RAL test rig allows VPTs to be operated at any magnetic field up to 1.8T. A standard part of the testing procedure is to scan the field from 1.8T to 0T with the VPT held at an angle of 15° to the field. After each change of field, a short settling period of about 2 minutes is allowed to ensure that the magnet and the VPTs are stable before starting to pulse the LEDs. 5000 LED pulses are measured at each field point, at a rate of approximately 150Hz. Figure 2 shows the variation in output with field for a typical VPT.

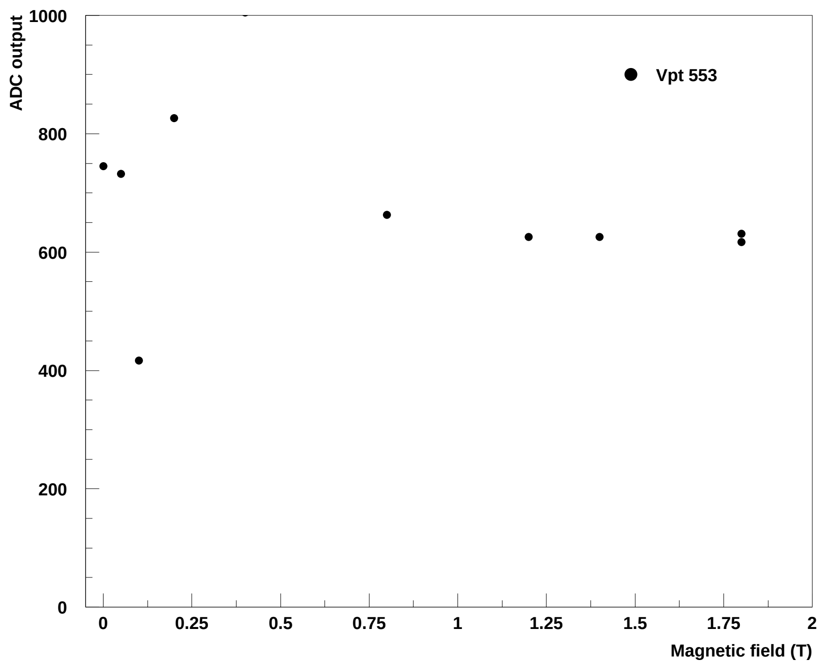

Figure 2. Examples of magnetic field scan on a typical VPT.

The VPT in this figure (bar code 553) exhibits a significant instability in the anode pulse size at low field. The pulse width also increases substantially in this field range. Many VPTs display similar behaviour at fields below 1T; a minority are unstable at 1.8T, and have been analysed in a separate report [3].

Angular scans on the VPTs at 1.8T

In the CMS endcap detector, the VPTs will be operated at a range of angles from 7° to 24° to the magnetic field. In the RAL test rig, the devices can be placed at any desired angle with respect to the 1.8T field. In the standard angle scan, measurements are taken at angles from 30° to -35°; after every movement, a short settling period is allowed so that any induced instabilities in the VPTs can decay before taking data. Again, each measurement consists of 5000 LED pulses. Figure 3 shows the variation in output with angle for a typical VPT.

The periodicity shown in this figure is seen in all of the VPTs supplied by RIE, and is dependent on the alignment of the anode grid with respect to the axis of rotation. The orientation of all the grids has been determined at RAL, and in the standard measurement procedure the grid lines are aligned with the axis of rotation.

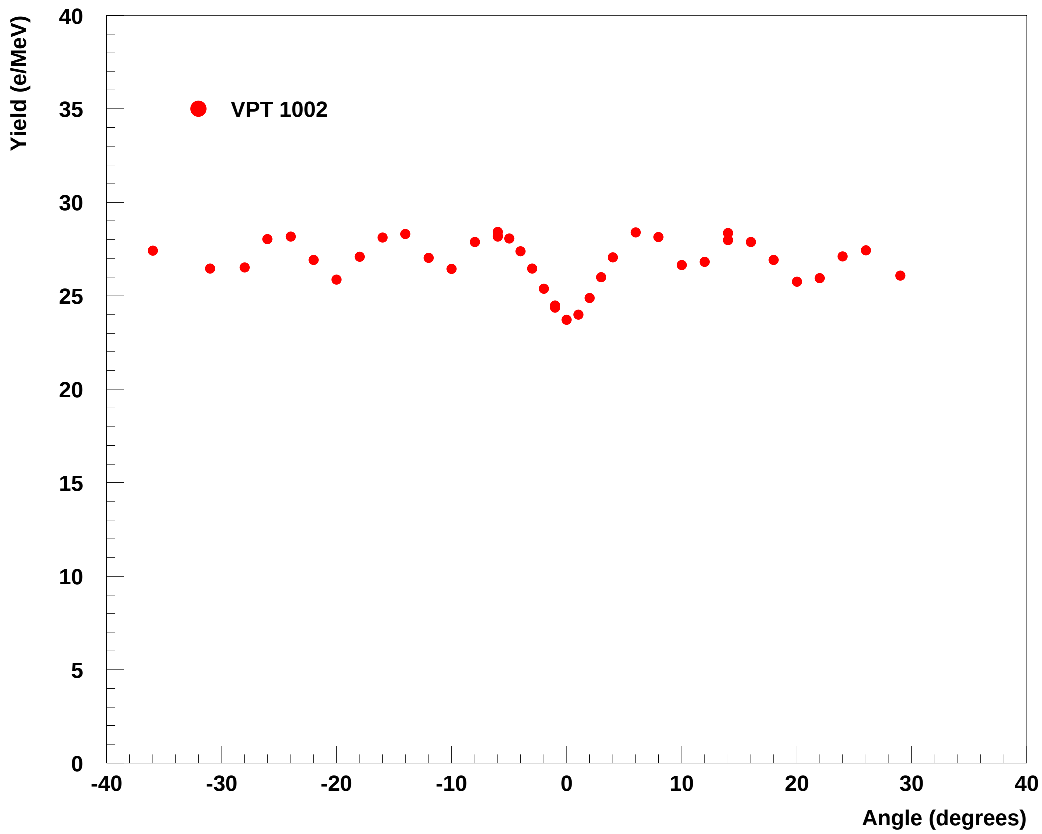

Figure 3. Angular scan at 1.8T on a typical VPT.

Summary of RAL 1.8T measurements

2700 of the production tubes have so far been tested in the RAL test rig. Figure 4 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 5 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.

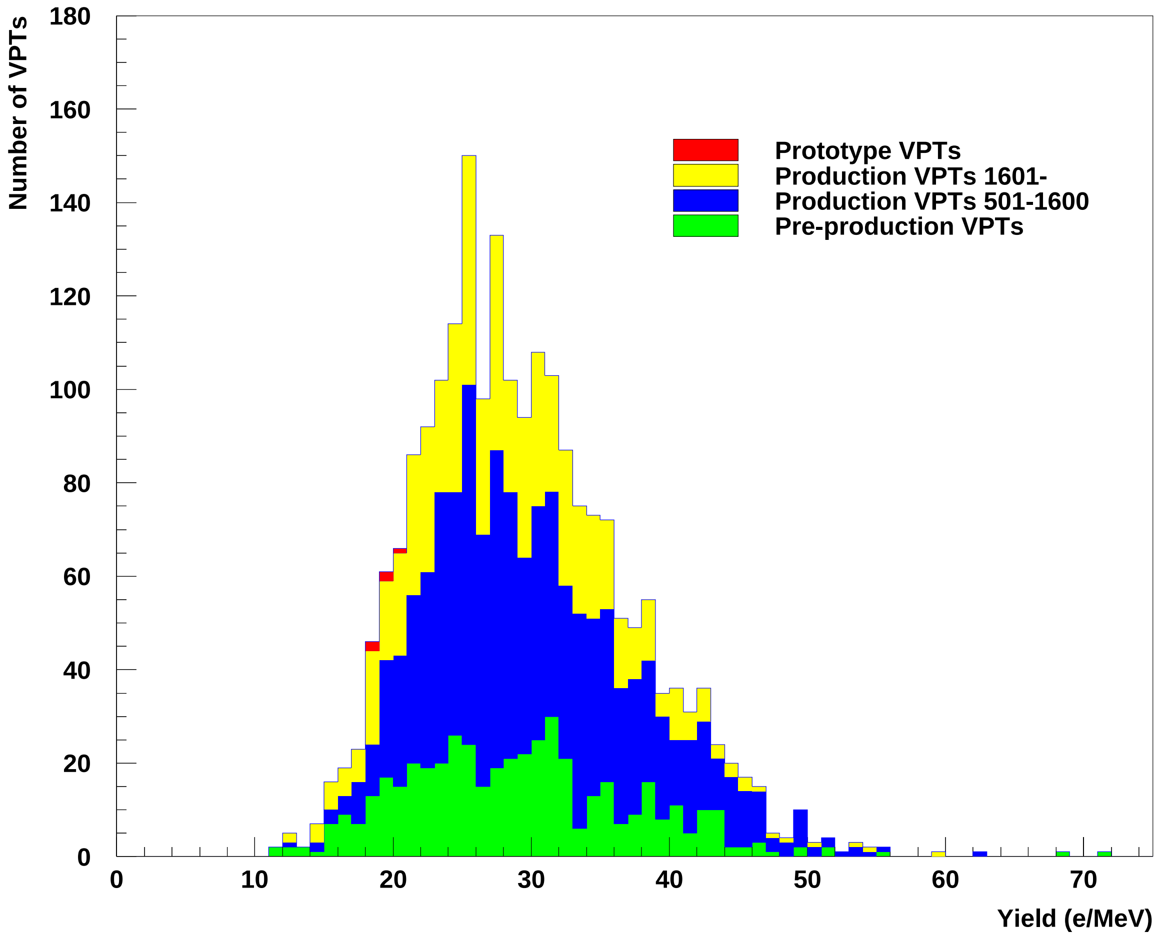

Figure 4. Mean anode pulse height over the angular range 8°-25° in a 1.8T magnetic field.

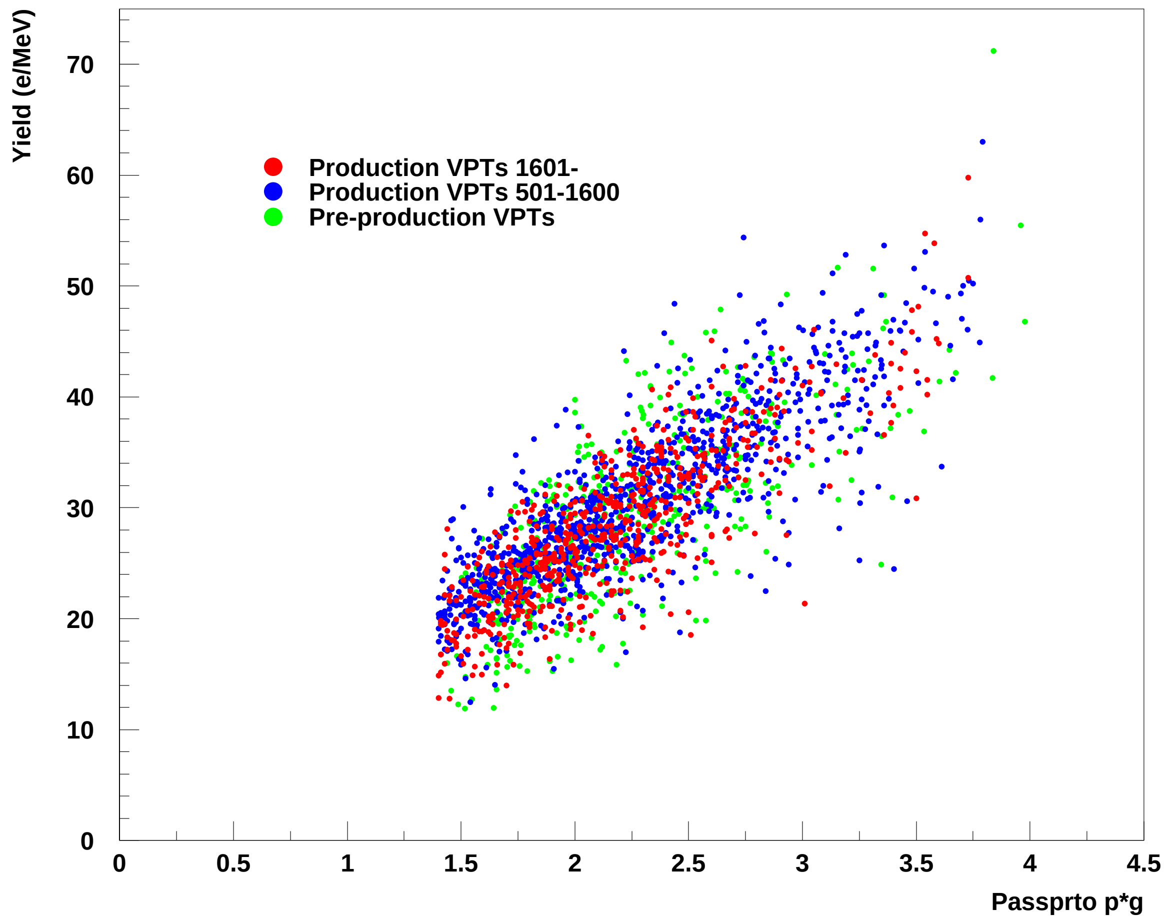

Figure 5. VPT response at 8°-25° and 1.8T v quality factor *PG*

Summary and Conclusions

The first 2700 production VPTs supplied by RIE have been subjected to a variety of measurements at RAL and Brunel. The data supplied in the VPT passport is found to correlate well with these measurements.

References

[1] 'Technical specification of vacuum phototriodes for the endcap electromagnetic calorimeters of the Compact Muon Solenoid (CMS) experiment', May 11 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', B W Kennedy, 10 February 2003