Evaluation of Four Photomultiplier Candidates for the SD

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1.0 Introduction

We have performed comparative evaluation tests of four photomultipliers, possible candidates to be used on the Surface Detector tanks, namely Photonis XP 1802, Hamamatsu R5912, ElectronTube 9353, and FEU125.We obtained each tube on loan from the manufacturer for evaluation.

For the time being we have concentrated our efforts on

1. Tube gain at nominal voltage, photoelectron peak features and gain uniformity across the photocathode
2. Gain variation with temperature
3. Magnetic field sensitivity

The light source is a picoseconde laser beam (Yag at 1060nm) at double and triple frequencies of 530nm and 353 nm. A silice fibre allows one to send the light to a particular point on the photomultiplier photocathode. Photomultiplier signals are integrated in a charge sensing ADC, with known charge calibration, whose gate is generated by a signal delivered by a photodiode detector with a direct view of part of the laser beam.

2.0 Photomultiplier gain

Except for the FEU125, the single photoelectron peak is well separated above pedestal as shown in Figure 1, which allows us to check the electronic gain. We confirm the constructor's value to 10%, namely a gain of 10^7 at a voltage of 1530 volts (Hamamatsu and Photonis), and 1750 volts for the Electron Tube, device which becomes unstable at 2000 volts.

The gain uniformity across the photocathode surface has also to been studied, as shown in Figure 2. We have limited our test to one radius. The plot clearly exhibits good uniformity within 10% over a diameter of the order of 20 centimetres.

Figure 3 is an example of singles counts (in Hz) versus the applied voltage in the case of the Photonis XP1802, with a threshold low enough to see the photoelectron peak, the stability region is well within the requirements.

Photocathode efficiencies have been checked at 404 nm using a Hg lamp and wavelength separator. We obtained results compatible with the values given by the manufacturers, the latter being more precise than ours. This test was more difficult in the case of the FEU125, where we compared the response to the Hamamatsu response with the same illumination. We derive a smaller efficiency by at least a factor 1.5

In the case of the FEU125, the single photoelectron peak could not be seen, and as we did not try other methods to get the electronic gain, we cannot quote a value. The gain uniformity is satisfactory over diameter of the order of 10 centimetres, a smaller area given the smaller photocathode surface of this tube. We then had a problem with the photomultiplier's basis and we have stopped the tests on the FEU125.

3.0 Gain variation with temperature

Documentation appearing in standard text books on photomultipliers tells us that the gain variation should be rather small in the temperature range appropriate for the tanks in real situations. Nevertheless we had the opportunity to do a check extending somewhat the range of temperature to enhance the effect.

This has been done with Photonis XP 1802 and ElectronTube 9353. While preparing the test with Hamamatsu R5912, we observed a gain drop by a factor 10, the tube was sent back to Hamamatsu, the gain drop was recovered and stays unexplained.

Results are shown in Figure 3, and we do observe a small variation, which appears to be higher on ElectronTube 9353. Data acquisition process was repeated several times.

As the refrigerator used for the temperature test had a spurious magnetic field of 2 Gauss, we had to shield the PMT with mu-metal.

4.0 Magnetic field sensitivity

When installed in the refrigerator, before cooling, we could see the tube's response vary with a magnetic field perpendicular to the tube axis, both horizontal.

With the Photonis XP 1802 and ElectronTube 9353, working at a high gain,

1. Below 1 Gauss, we could not observe a significant effect
2. Between 1 Gauss and 2 Gauss the gain decreases by a factor 10.

5.0 Conclusion

Three tubes have satisfactory working responses, it seems reasonable to install them on the tanks of the Engineering array in order to gain more experience with them., and in particular to study the long term stability under real conditions.

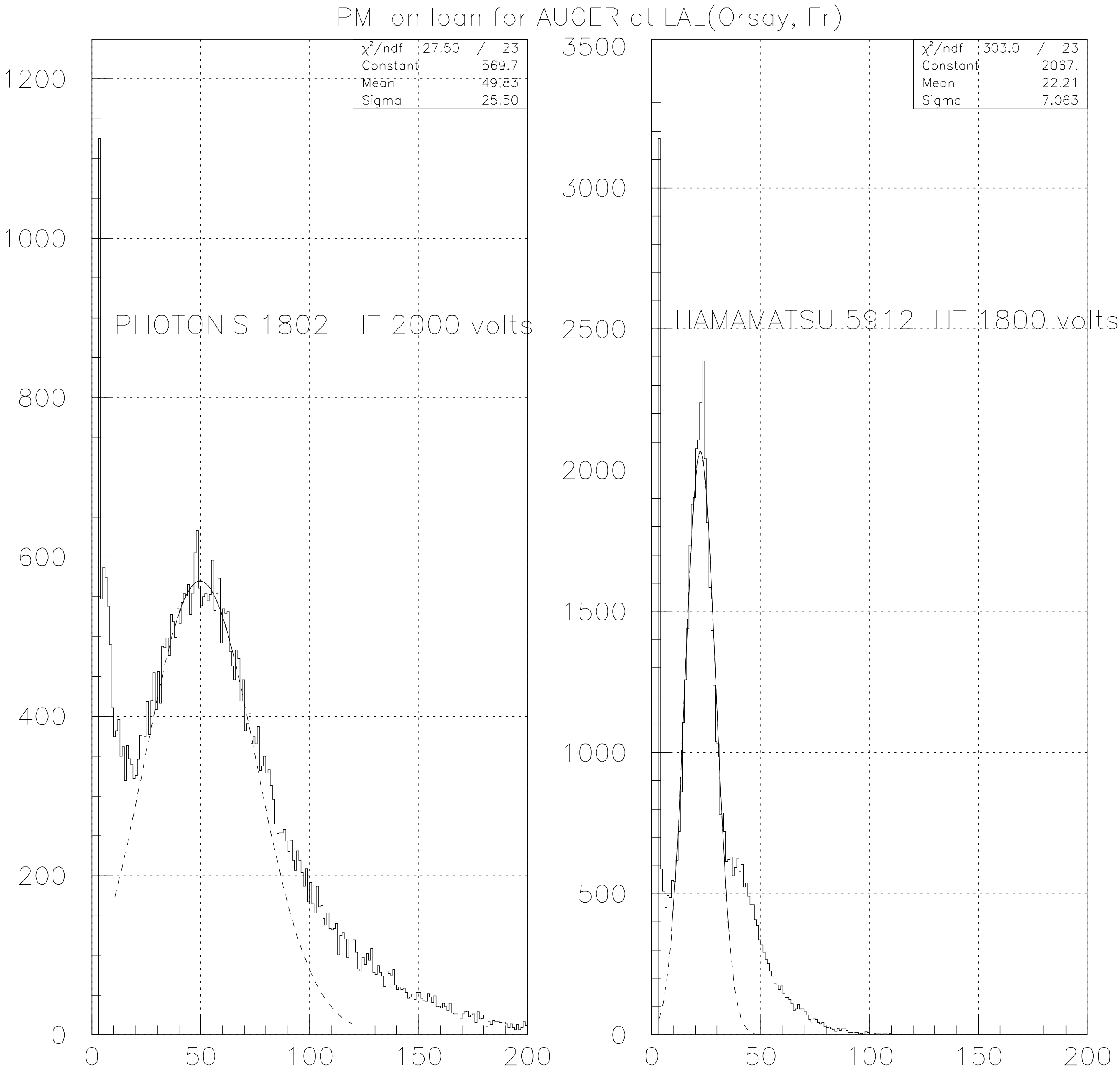

FIGURE 1. Single photoelectron pulse height spectra for PHOTONIS XP1802 (left side) and HAMAMATSU R5912 (right side)

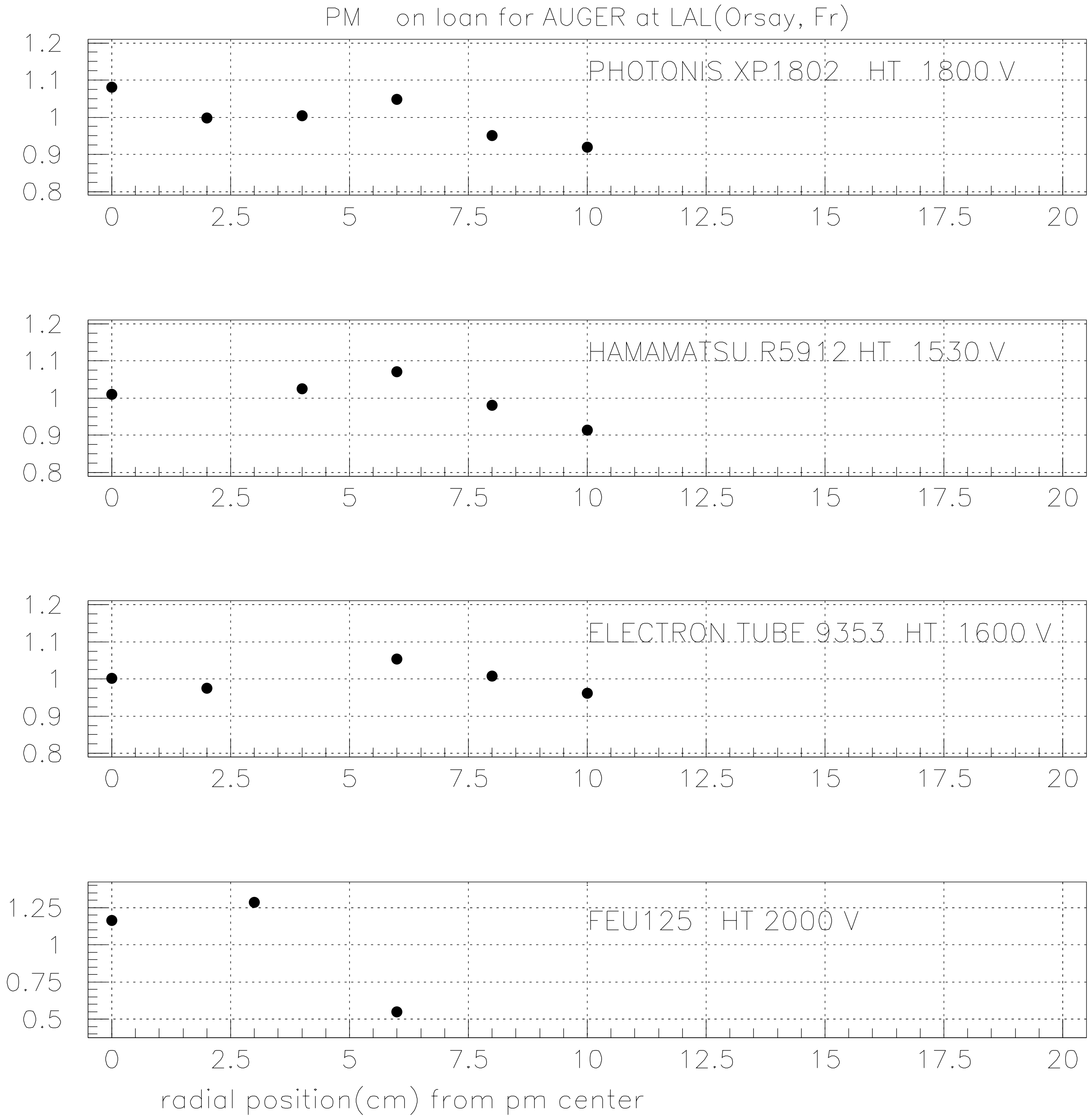

FIGURE 2. Photomultiplier gain along the photocathode radius for the four tubes, respectively from top to bottom: Photonis XP 1802, Hamamatsu R5912, ElectronTube 9353, and FEU125

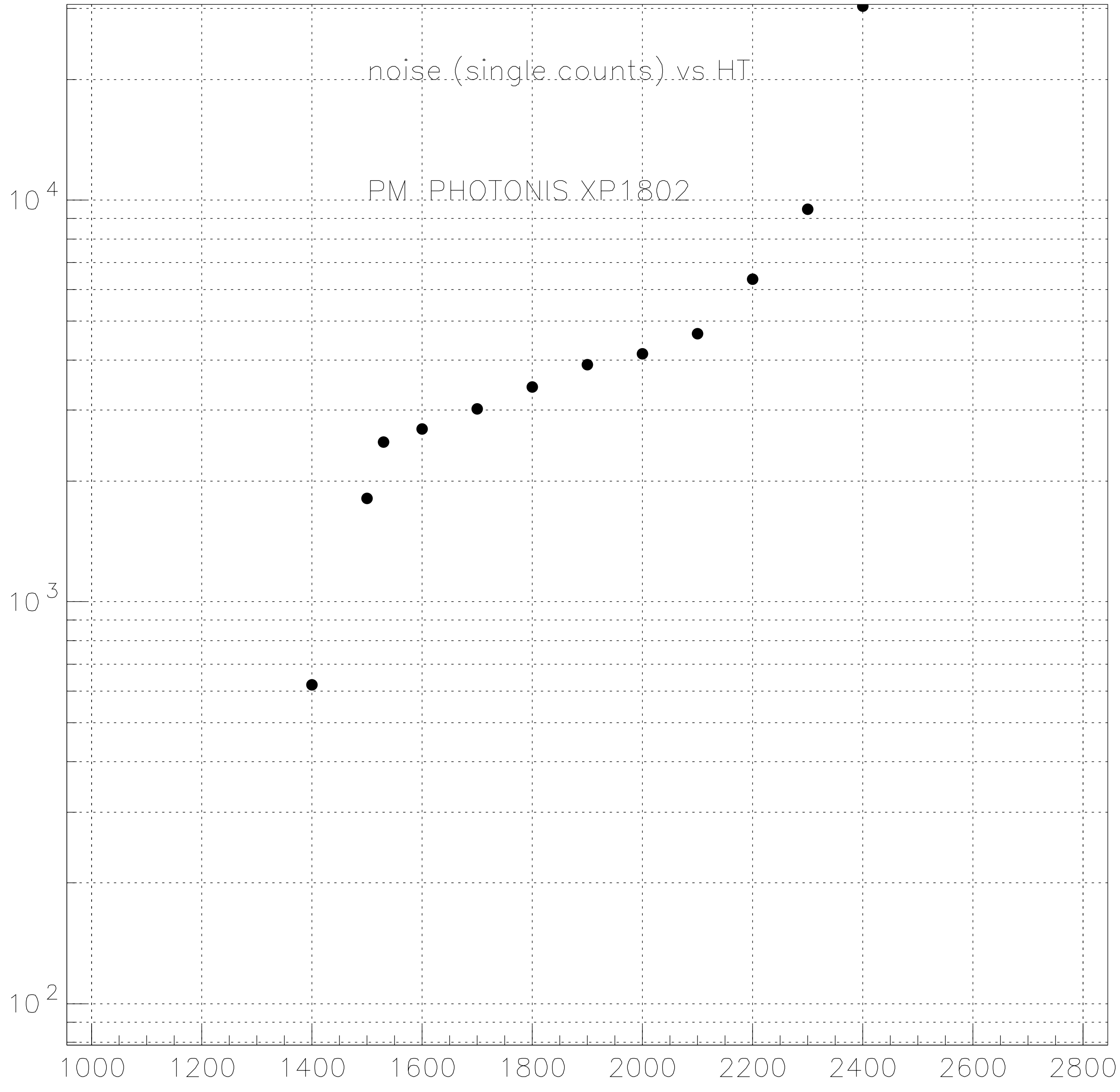

FIGURE 3. Single counting rate versus the applied voltage for the PM Photonis XP1802

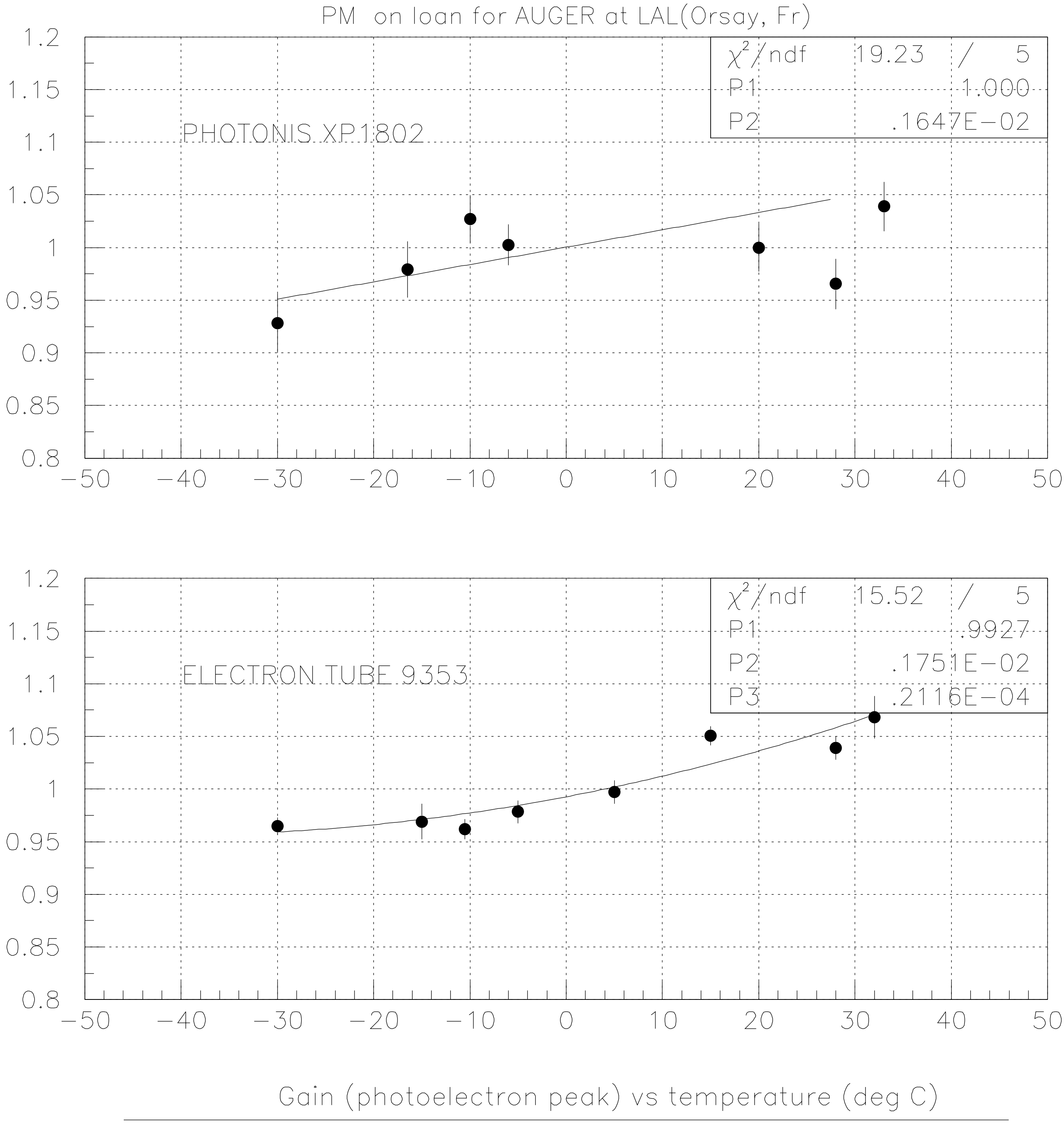

FIGURE 4. Photomultiplier gain variation with temperature: top Photonis XP 1802, bottom ElectronTube 9353