Improved Detection System Description and New Method for Accurate Calibration of Micro-Channel Plate based Instruments and its use in the Fast Plasma Investigation on NASA's Magnetospheric MultiScale Mission

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The Fast Plasma Investigation (FPI) on NASA's Magnetospheric MultiScale (MMS) mission employs 16 Dual Electron Spectrometers (DESs) and 16 Dual Ion Spectrometers (DISs) with 4 of each type on each of 4 spacecraft to enable fast (30 ms for electrons; 150 ms for ions) and spatially differentiated measurements of the full 3D particle velocity distributions. This approach presents a new and challenging aspect to the calibration and operation of these instruments on ground and in flight. The response uniformity, the reliability of their calibration and the approach to handling any temporal evolution of these calibrated characteristics all assume enhanced importance in this application, where we attempt to understand the meaning of particle distributions within the ion and electron diffusion regions of magnetically reconnecting plasmas.

Traditionally, the micro-channel plate (MCP) based detection systems for electrostatic particle spectrometers have been calibrated using the plateau curve technique. In this, a fixed detection threshold is set. The detection system count rate is then measured as a function of MCP voltage to determine the MCP voltage that ensures the count rate has reached a constant value independent of further variation in the MCP voltage. This is achieved when most of the MCP pulse height distribution (PHD) is located at higher values (larger pulses) than the detection system discrimination threshold. This method is adequate in single-channel detection systems and in multi-channel detection systems with very low crosstalk between channels. However, in dense multi-channel systems, it can be inadequate. Furthermore, it fails to fully describe the behavior of the detection system and individually characterize each of its fundamental parameters.

To improve this situation, we have developed a detailed phenomenological description of the detection system, its behavior and its signal, crosstalk and noise sources. Based on this, we have devised a new detection system calibration method that enables accurate and repeatable measurement and calibration of MCP gain, MCP efficiency, signal loss due to variation in gain and efficiency, crosstalk from effects both above and below the MCP, noise margin, and stability margin in one single measurement. More precise calibration is highly desirable as the

instruments will produce higher quality raw data that will require less post-acquisition data-correction using results from in-flight pitch angle distribution measurements and ground calibration measurements. The detection system description and the fundamental concepts of this new calibration method, named threshold scan, will be presented. It will be shown how to derive all the individual detection system parameters and how to choose the optimum detection system operating point. This new method has been successfully applied to achieve a highly accurate calibration of the DESs and DISs of the MMS mission. The practical application of the method will be presented together with the achieved calibration results and their significance. Finally, it will be shown that, with further detailed modeling, this method can be extended for use in flight to achieve and maintain a highly accurate detection system calibration across a large number of instruments during the mission.