Spatial Resolution and Noise Characteristics of Intensified Active Pixel Sensor Cameras for Vacuum Ultraviolet Imaging

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Abstract

For astronomical observations from space, the acquisition of images in the Lyman Alpha line of hydrogen at 121.6 nm is of great interest. In particular, for solar observations this bright emission line allows diagnostics of different regions of the solar atmosphere as images of the upper chromosphere or the extended corona, in coronagraphic images.

To record the line with high efficiency and good suppression of the overwhelming radiation emitted at longer wavelengths by our star, a preferred solution is to combine a microchannel plate intensifier, which carries a specific photocathode, with a CMOS sensor via a fiber optic coupler. We have built two such intensified active pixel sensor (IAPS) cameras for the Extreme Ultraviolet Imager (EUI) and the Metis instrument of the ESA/NASA mission Solar Orbiter. The entirely new design of the coupling between the intensifier and the sensor involves a conversion and transfer of the image from the photocathode to the imaging device, which may affect the performance of the camera.

The qualification model and the flight and spare models of the Metis Lyman Alpha camera have been subjected to characterization campaigns at the Max Planck Institute for Solar System Research (MPS) in order to determine the intrinsic spatial resolution and the noise characteristics. Each unit under test was mounted inside a specifically built vacuum chamber attached to the reflectometer chamber at MPS for measurements in the VUV using a Lyman-Alpha light source producing a quasi-flat, monochromatic illumination. A set of such measurements taken with the UVDA FS unit are used here to assess the noise level of the camera after careful removal of the small scale disuniformities coming from the intensifier.

Measurements with a series of pinholes located as close as possible to the focal plane of the UVDA QM were performed in order to compare the expected diffraction pattern with the measured one to gain information on the intrinsic spatial resolution of the Metis UVDA camera. Additionally, measurements of the noise (dark thermal noise and MCP dark emission) were also performed.

Flat field pattern and intensifier noise evaluation (UVDA FS)

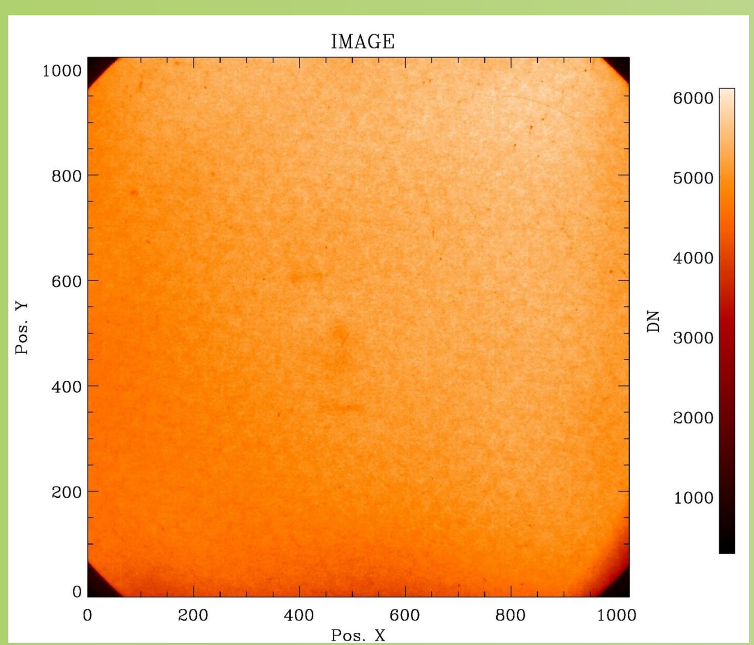


Fig. 1: Single frame taken at V_{MCP} = 750 V and V_{SCREEN} = 4 kV. T_{exp} = 1.1 s, T_{sensor}=−20 °C

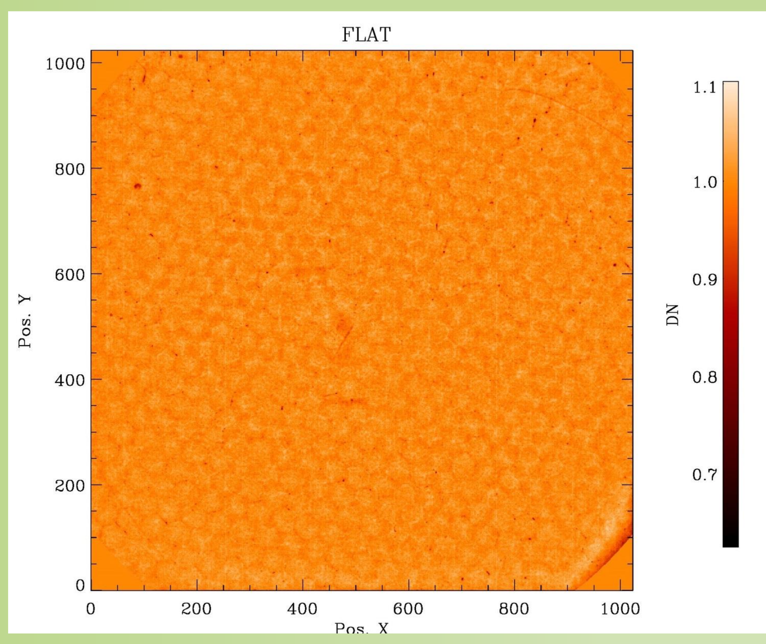


Fig. 2: Flat field pattern (high frequency only) obtained from 850 frames taken with V_{MCP} = 750 V - V_{SCREEN} = 4 kV.; V_{MCP} = 710 V - V_{SCREEN} = 5 kV; V_{MCP} = 690 V - V_{SCREEN} = 6 kV. No difference can be seen between the flats obtained for each setting.

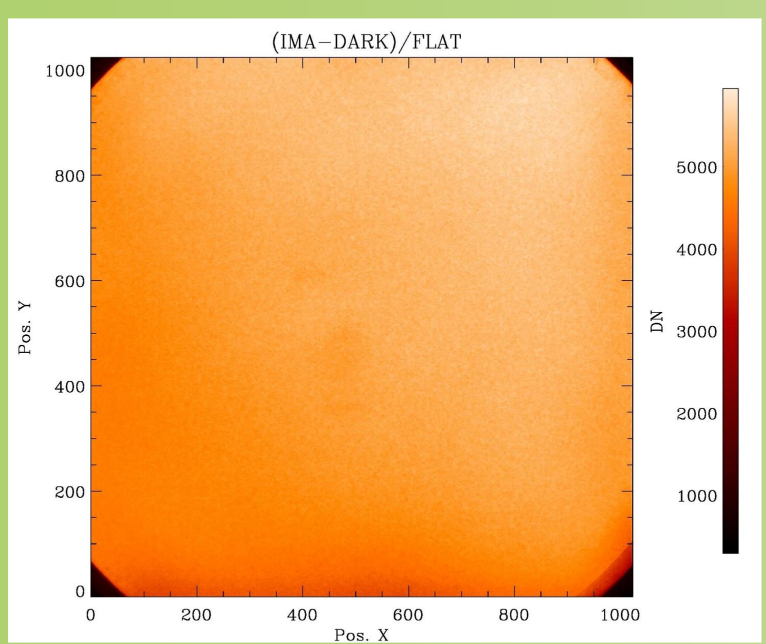


Fig. 3: Dark & Flat Field corrected image

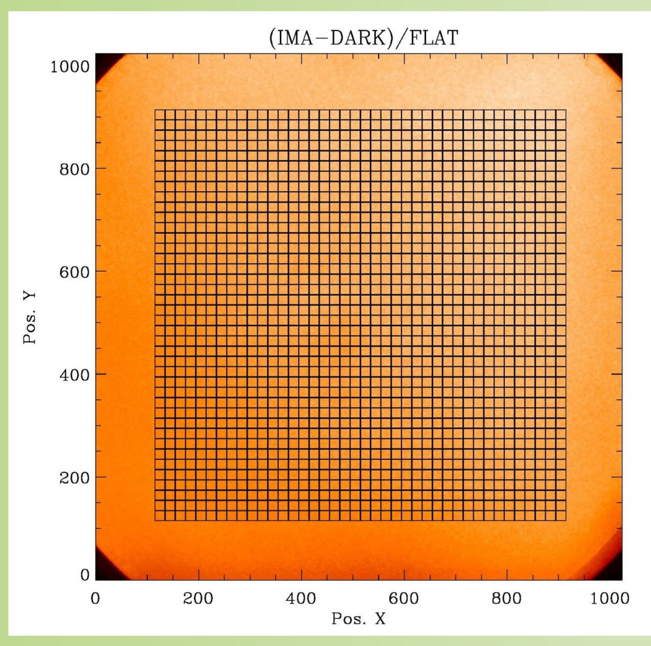


Fig. 4: Corrected image with 20×20 pixel boxes used for the analysis in Figs. 5 and 6.

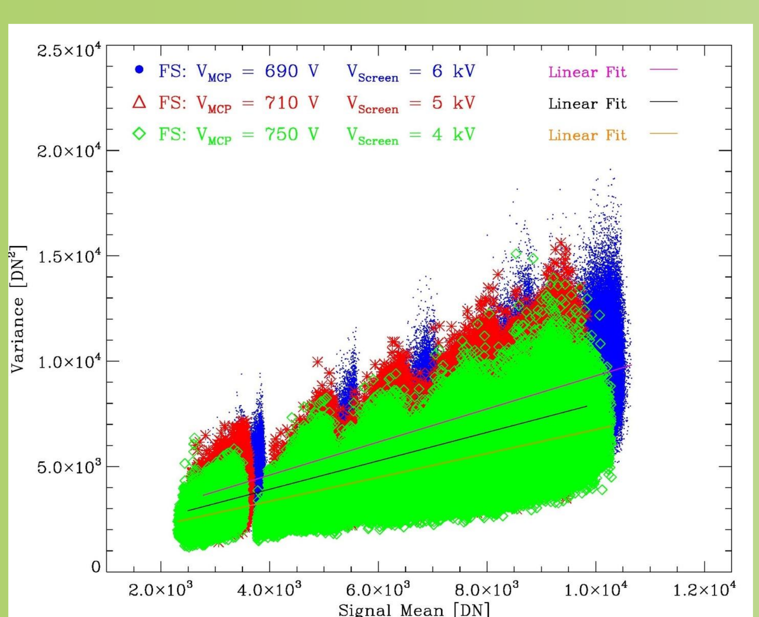


Fig. 5: Variance (spatial) vs. Mean Signal. Analysis performed in 20×20 boxes (Fig. 4). FS unit. Data were dark and flat corrected.

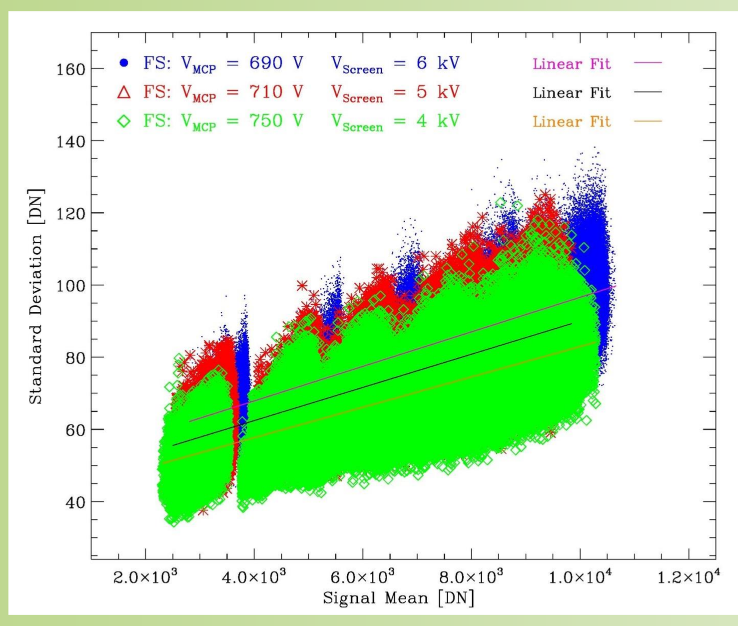


Fig. 6: Standard Deviation (spatial) vs. Mean Signal. Analysis performed in 20×20 boxes (Fig. 4). FS unit. Data were dark and flat corrected.

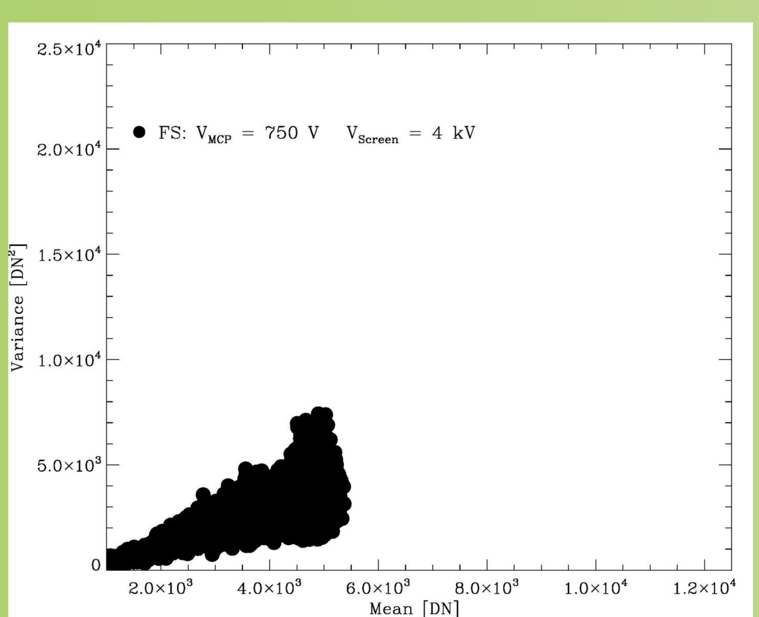


Fig. 7: Variance (along time) vs. Mean Signal. Analysis performed in all pixels. FS unit. Data were dark corrected only.

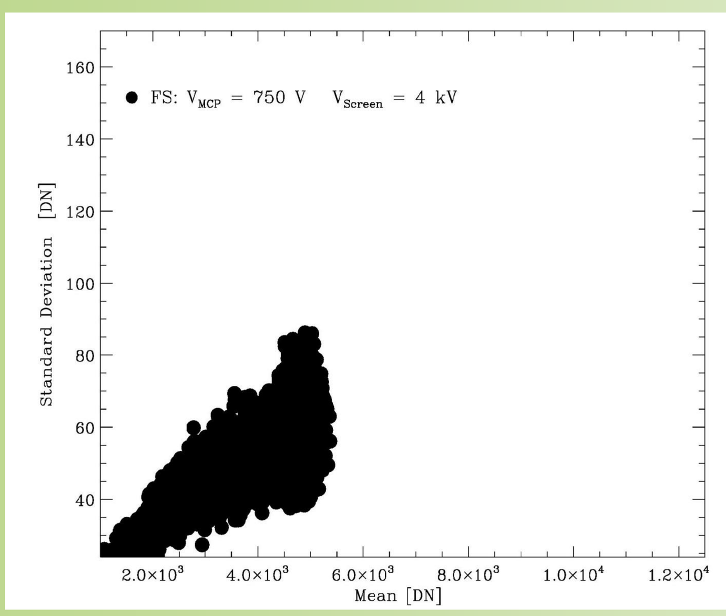
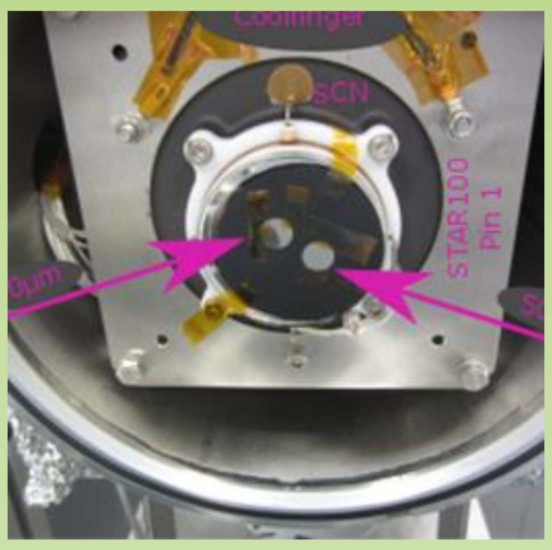
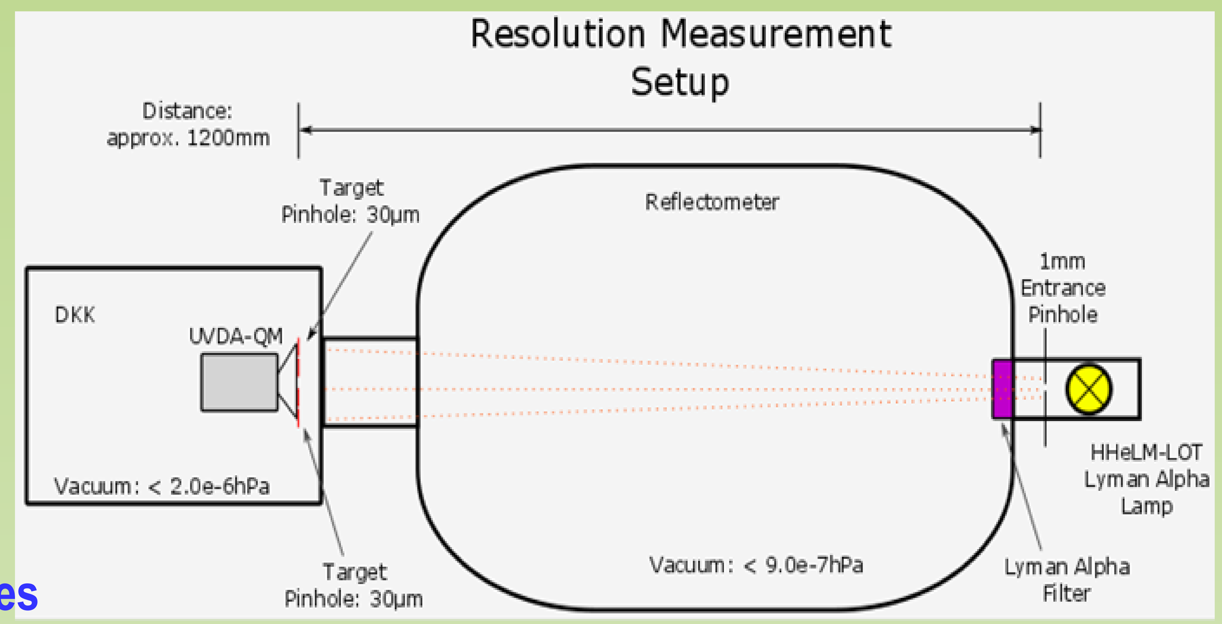


Fig. 8: Standard Deviation (along time) vs. Mean Signal. Analysis performed in all pixels. FS unit. Data were dark corrected only.



32 µm (left) and 57 µm pinholes



Pinhole measurements: Camera resolution (UVDA QM)

- the theoretical diffraction pattern is convolved with a model PSF profiles of a given FWHM,
- the obtained profile is resampled to the detector resolution element (pixel size times taper magnification),
- the obtained profile is convolved with the sensor cross-talk profile (if there is a relevant cross-talk),
- the obtained profile is ccompared to the measured pinhole profile,
- the process is repated with a different FWHM odel PSF profile until a match with the observations is found.

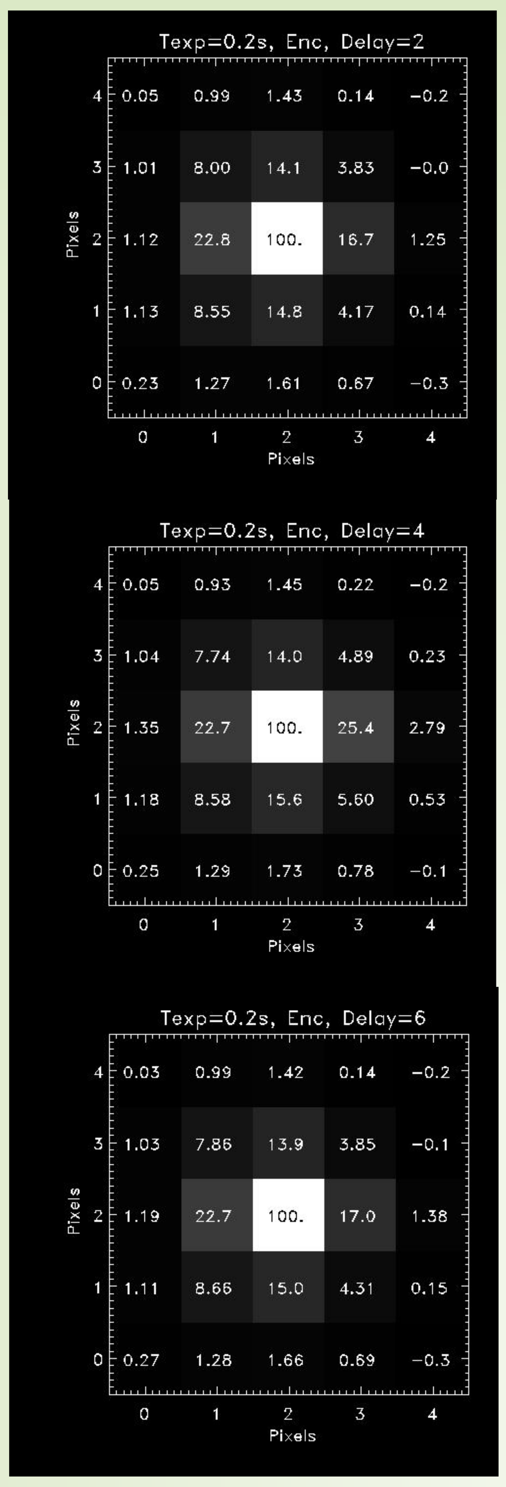


Fig. 10: Star1000 spatial cross-talk for different settings. Sub-pixel scanner measurements on BB unit

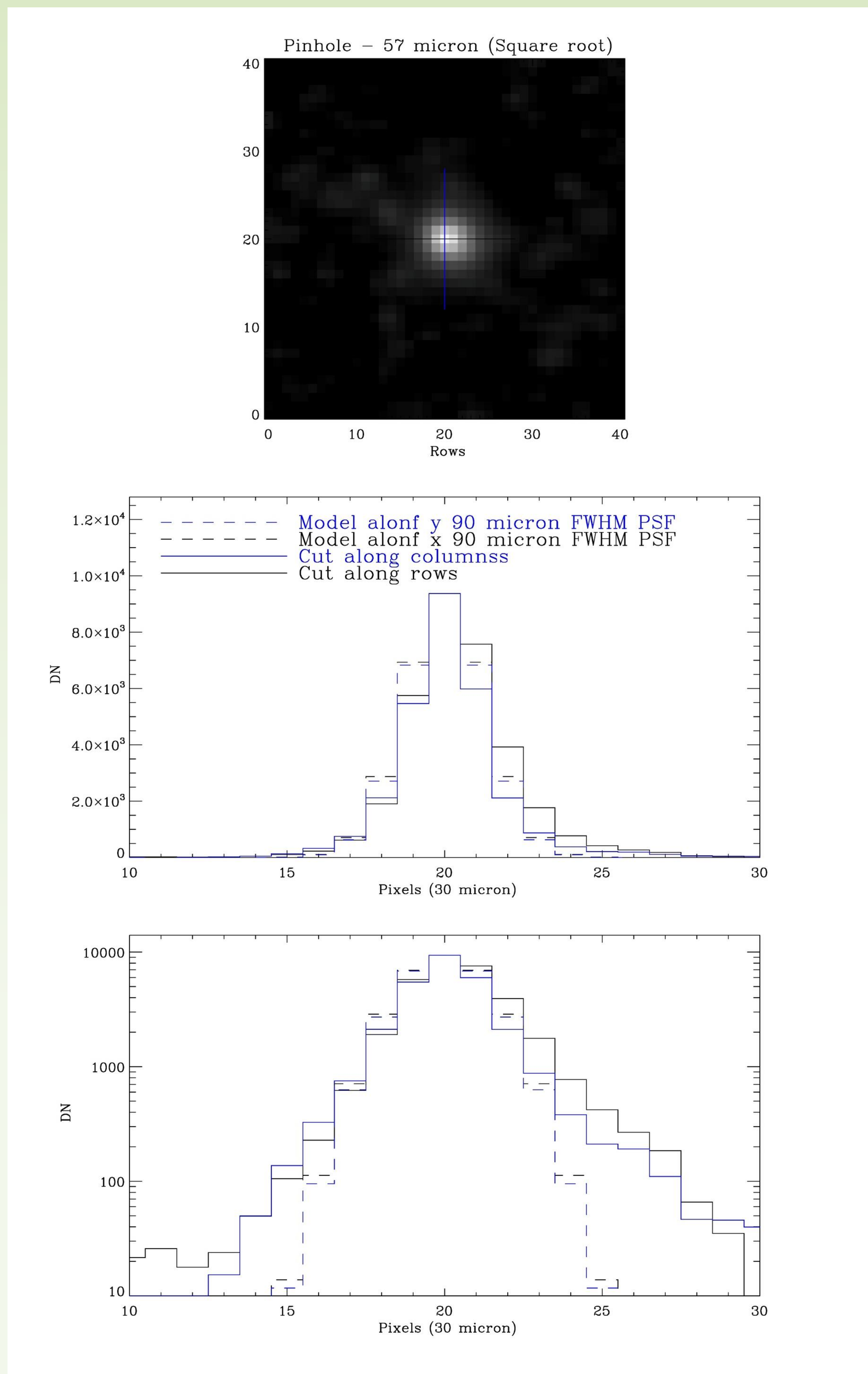


Fig 11: Comparison between measured profiles of the diffraction spot created by the 57 µm pinhole and the modeling for a 90 µm PSF convolved with the expected diffraction pattern and rebinned and convolved with the APS cross talk profile. Notice that the profiles are over plotted "by eye" but that results have been verified by 2-D Gaussian fitting of the pinhole image.

Resolution vs Screen and MCP Voltages – without 1 mm field stop

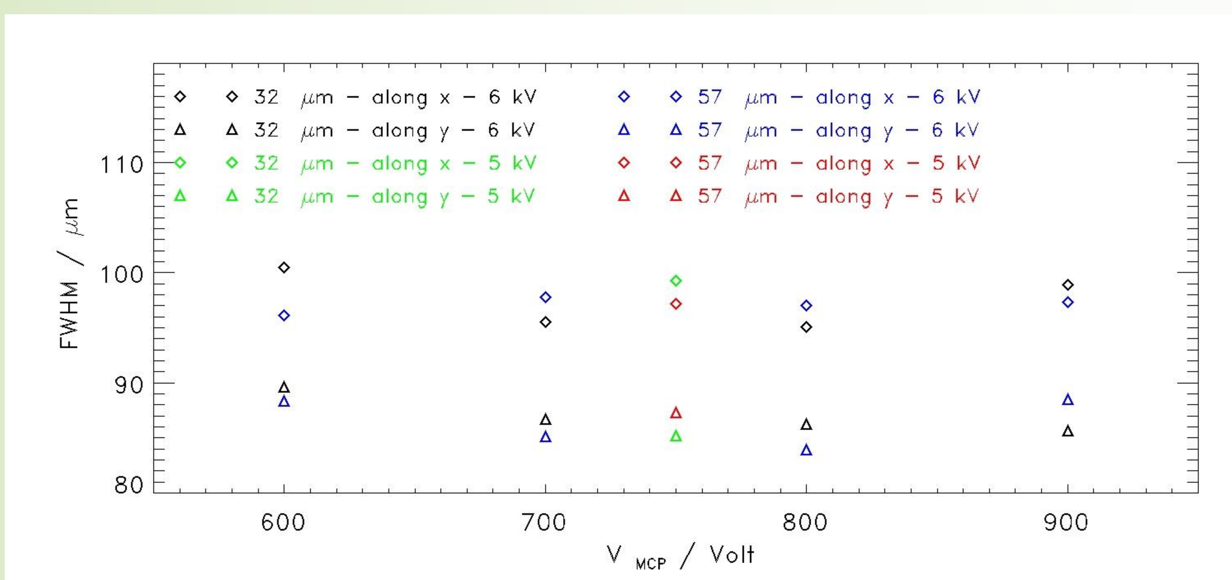


Fig. 12: FWHMs of the pinhole images (2-D Gaussian fit) obtained at different voltages of the Screen and of the MCP.

Results along rows and columns are shown.