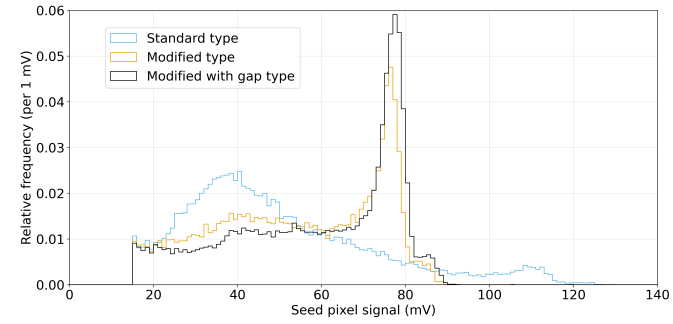
Supplementary material of paper «Characterisation of analogue Monolithic Active Pixel Sensor test structures implemented in a 65 nm CMOS imaging process»

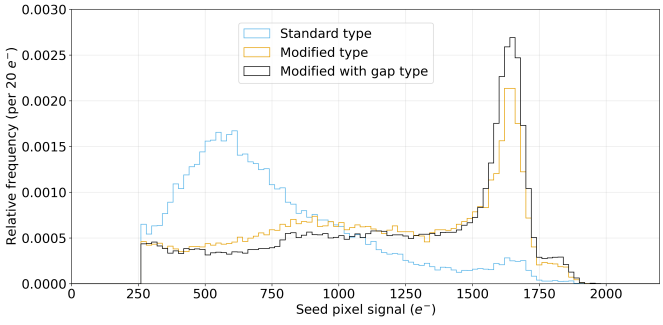
Abstract

Additional plots from measurements using a ^{55}Fe source (Section 1) and a beam test setup (Section 2). Refer to the paper for details.

1. ^{55}Fe measurements

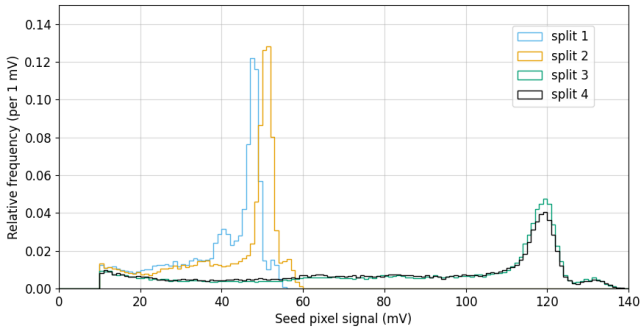


(a)

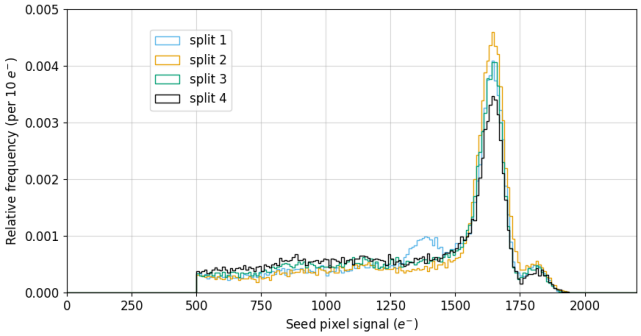


(b)

Figure 1: ^{55}Fe seed signal distribution comparison between different designs, in mV (a) and in electrons (b). APTS with 15 µm pitch, split 4, reference variant, V_{sub} = -1.2 V.

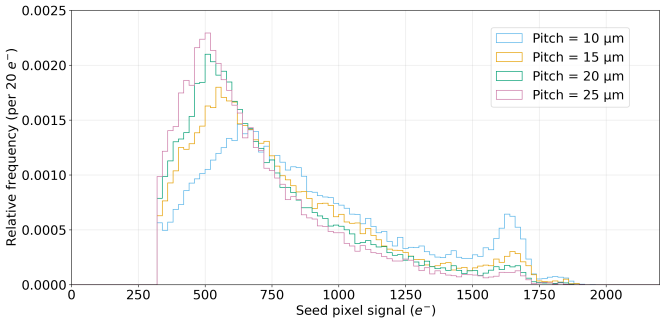


(a)

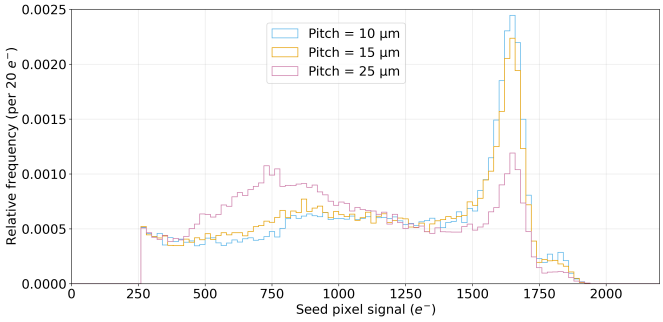


(b)

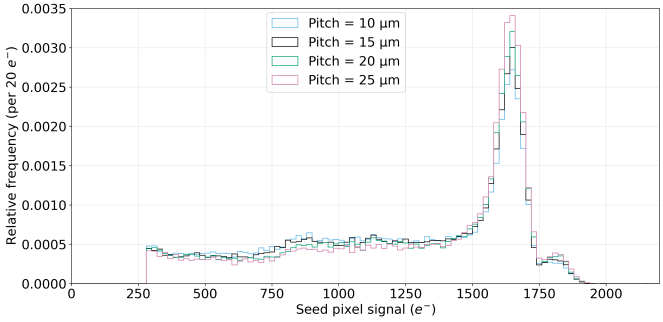
Figure 2: ^{55}Fe seed signal distribution comparison between different splits, in mV (a) and in electrons (b). APTS with 15 µm pitch, modified with gap, reference variant, V_{sub} = -4.8 V.



(a)

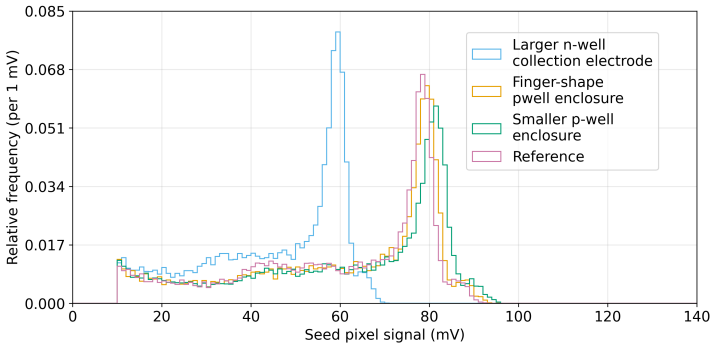


(b)

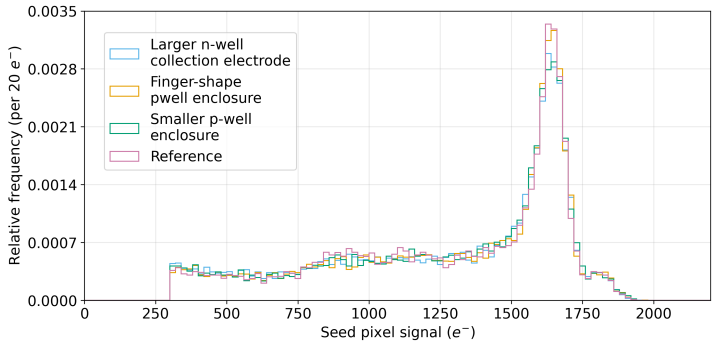


(c)

Figure 3: ^{55}Fe seed signal distribution in electrons compared between different pixel pitches for the standard (a), modified (b) and modified with gap (c) designs. APTS with split 4, reference variant, V_{sub} = -1.2 V.

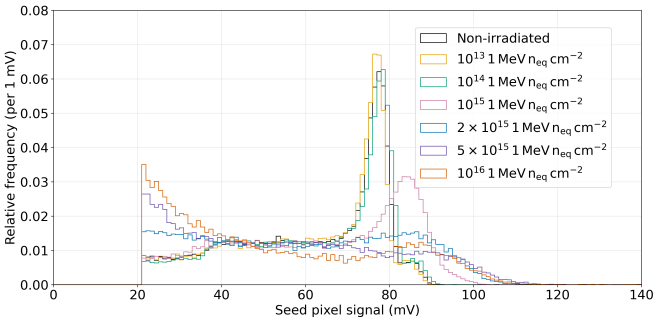


(a)

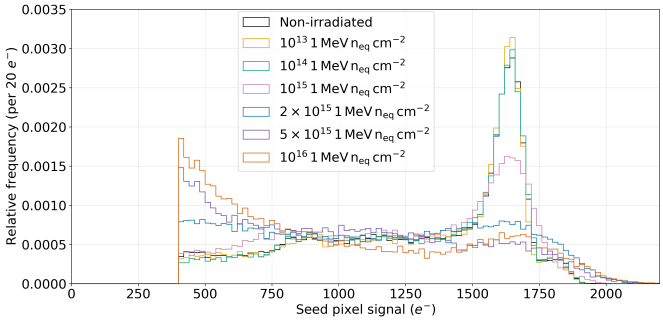


(b)

Figure 4: ^{55}Fe seed signal distribution comparison between different sensor variants: the reference one, the larger n-well collection electrode, the smaller p-well enclosure and the finger-shaped p-well enclosure, in mV (a) and in electrons (b). APTS with 20 µm pitch, modified with gap, split 4, V_{sub} = -1.2 V.

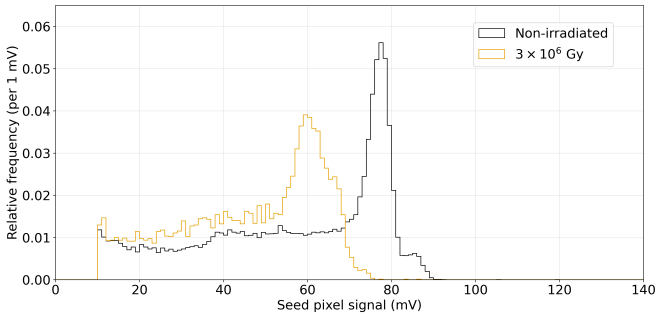


(a)

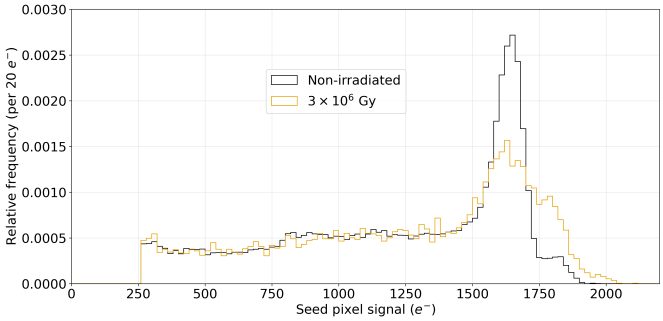


(b)

Figure 5: ^{55}Fe seed signal distribution comparison between different levels of NIEL irradiation, in mV (a) and in electrons (b). For irradiation levels of 2 × 10^{15} 1 MeV n_{eq} cm^{-2} or higher, the measurements have been taken with I_{reset} = 250 pA. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

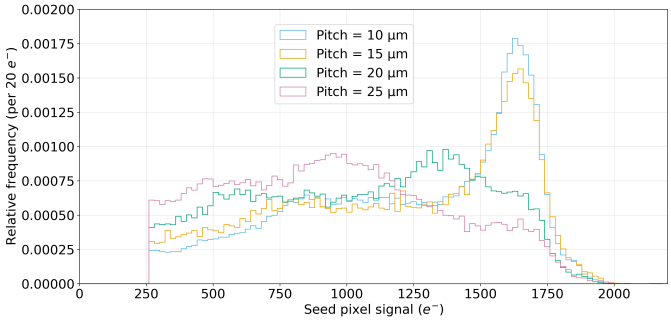


(a)



(b)

Figure 6: ^{55}Fe seed signal distribution comparison between different levels of TID irradiation, in mV (a) and in electrons (b). Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.



(a)

Figure 7: ^{55}Fe seed signal distribution comparison between different pixel pitches of a chip irradiated 10^{15} 1 MeV n_{eq} cm^{-2} in electrons. Chiller temperature was 15 °C. APTS with modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

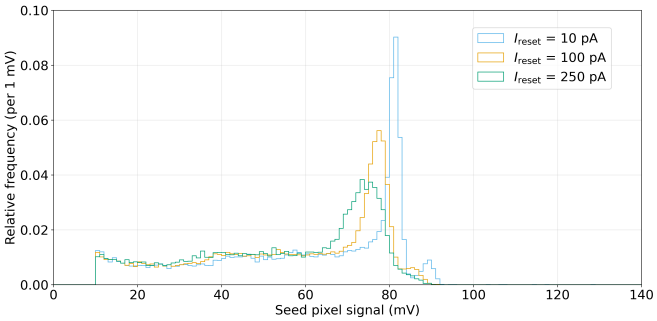


Figure 8: ^{55}Fe seed signal distribution comparison between different I_{reset}. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

2. Beam test results

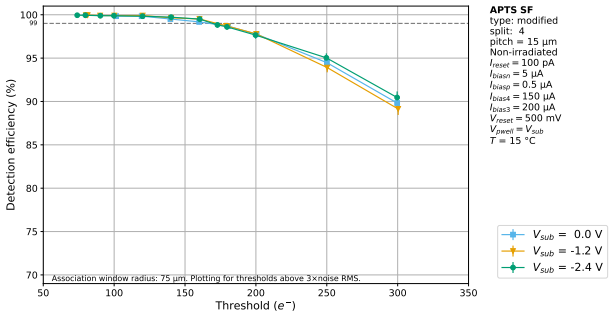


Figure 9: Efficiency comparison between different reverse substrate voltages as a function of the applied seed threshold. APTS with 15 µm pitch, modified, split 4, reference variant.

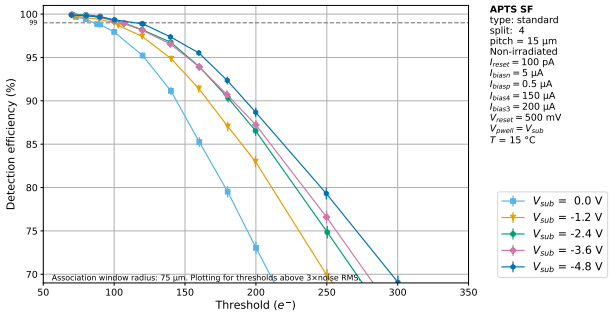


Figure 10: Efficiency comparison between different reverse substrate voltages as a function of the applied seed threshold. APTS with 15 µm pitch, standard, split 4, reference variant.

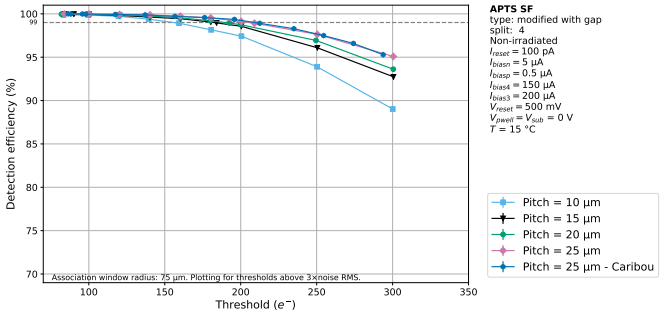


Figure 11: Efficiency comparison between different pitches as a function of the applied seed threshold. APTS with modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

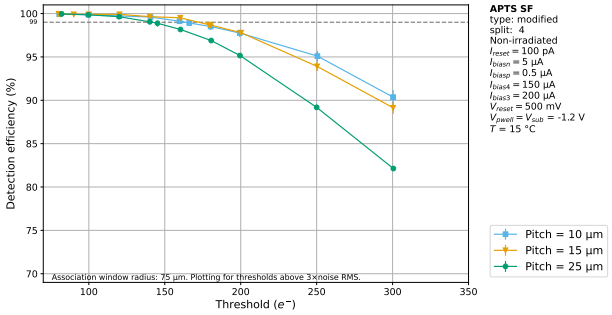


Figure 12: Efficiency comparison between different pitches as a function of the applied seed threshold. APTS with modified, split 4, reference variant, V_{sub} = -1.2 V.

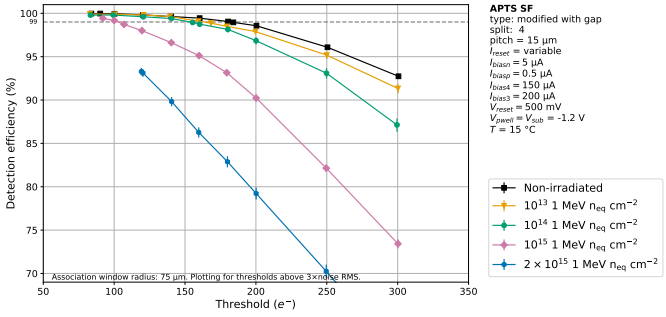


Figure 13: Efficiency comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

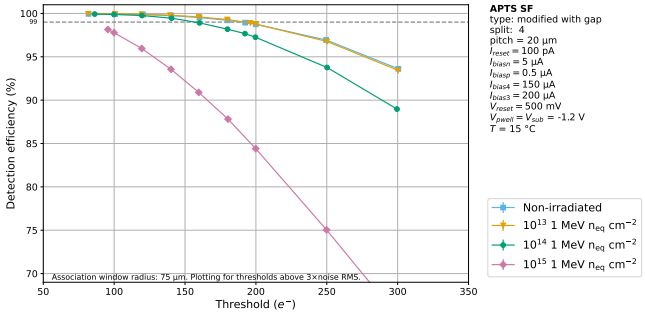


Figure 14: Efficiency comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 20 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

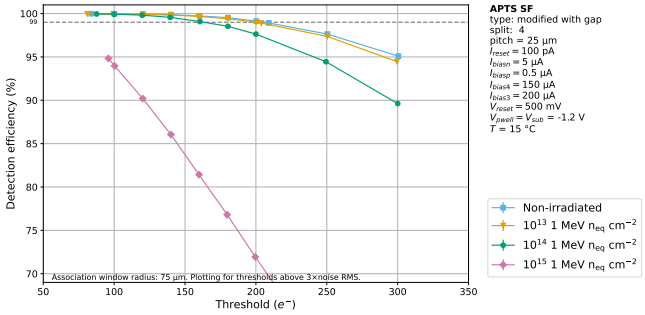


Figure 15: Efficiency comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 25 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

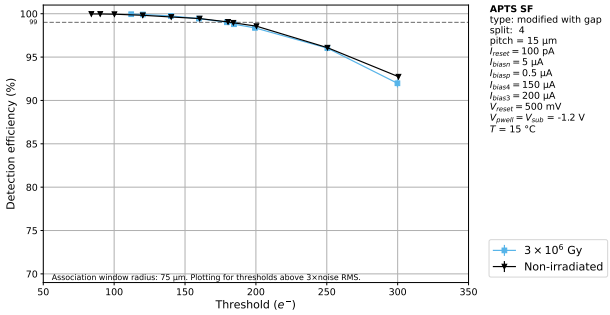


Figure 16: Efficiency comparison with TID irradiatiad APTS as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

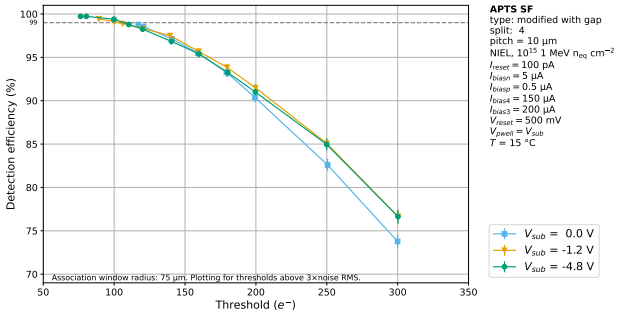


Figure 17: Efficiency comparison between different substrate reverse biases as a function of the applied seed threshold for a NIEL irradiation level of 10^{15} 1 MeV n_{eq} cm^{-2}. Chiller temperature was 15 °C. APTS with 10 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

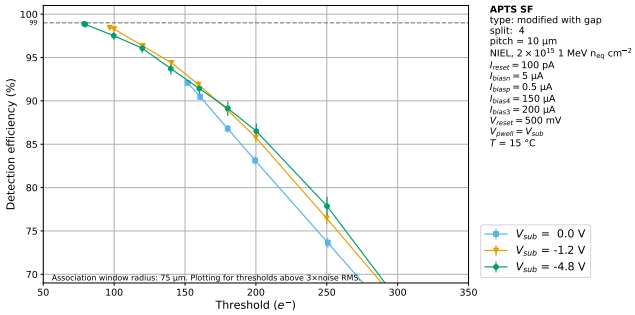


Figure 18: Efficiency comparison between different substrate reverse biases as a function of the applied seed threshold for a NIEL irradiation level of 2×10^{15} 1 MeV n_{eq} cm^{-2}. Chiller temperature was 15 °C. APTS with 10 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

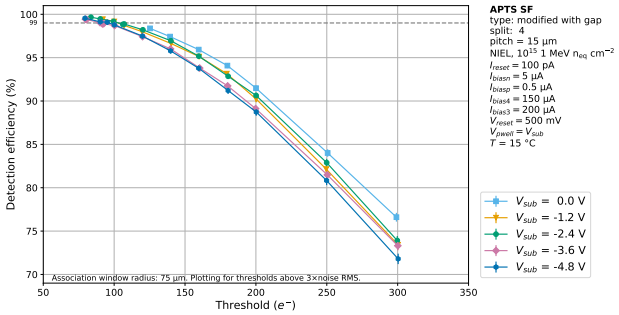


Figure 19: Efficiency comparison between different substrate reverse biases as a function of the applied seed threshold for a NIEL irradiation level of 10^{15} 1 MeV n_{eq} cm^{-2}. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

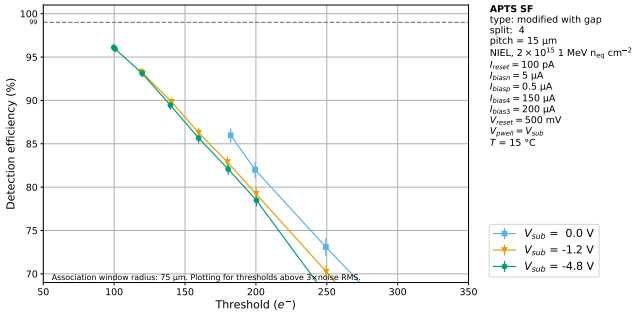


Figure 20: Efficiency comparison between different substrate reverse biases as a function of the applied seed threshold for a NIEL irradiation level of 2×10^{15} 1 MeV n_{eq} cm^{-2}. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

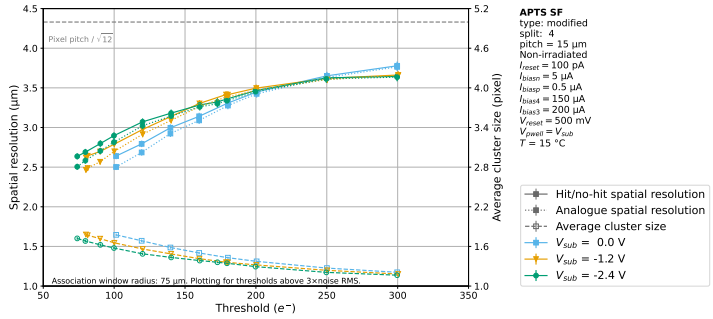


Figure 21: Resolution comparison between different reverse substrate voltages as a function of the applied seed threshold. APTS with 15 µm pitch, modified, split 4, reference variant.

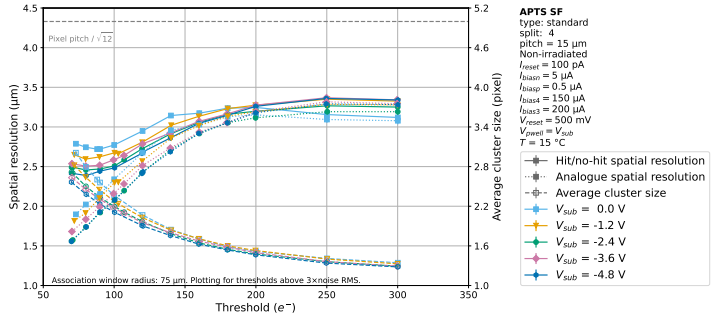


Figure 22: Resolution comparison between different reverse substrate voltages as a function of the applied seed threshold. APTS with 15 µm pitch, standard, split 4, reference variant.

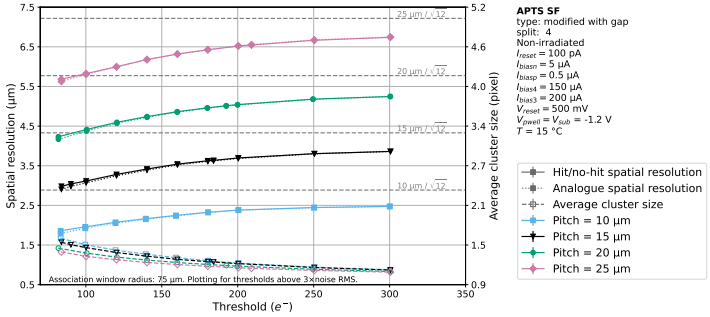


Figure 23: Resolution comparison between different pitches as a function of the applied seed threshold. APTS with modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

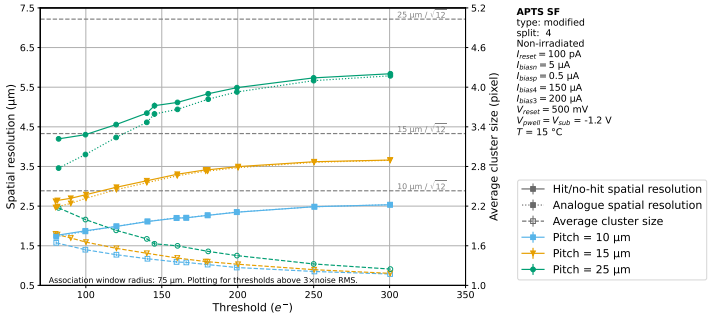


Figure 24: Resolution comparison between different pitches as a function of the applied seed threshold. APTS with modified, split 4, reference variant, V_{sub} = -1.2 V.

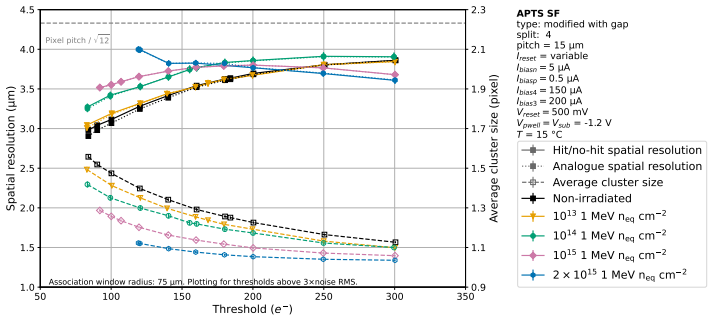


Figure 25: Resolution comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

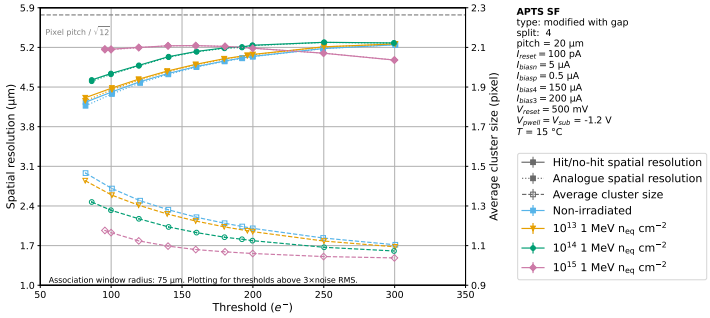


Figure 26: Resolution comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 20 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

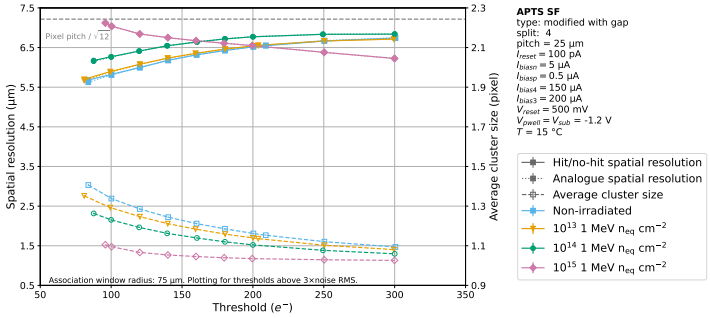


Figure 27: Resolution comparison between different NIEL irradiation levels as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 25 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

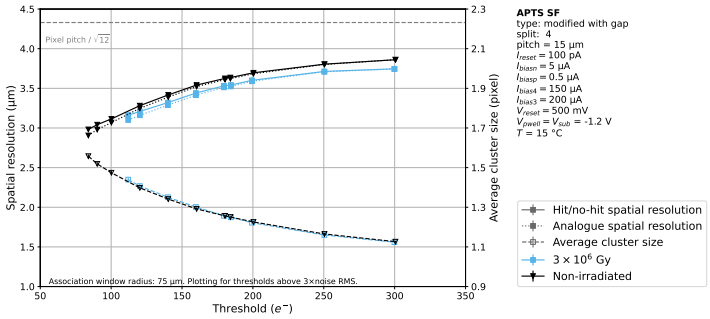


Figure 28: Resolution comparison with TID irradiatiad APTS as a function of the applied seed threshold. Chiller temperature was 15 °C. APTS with 15 µm pitch, modified with gap, split 4, reference variant, V_{sub} = -1.2 V.

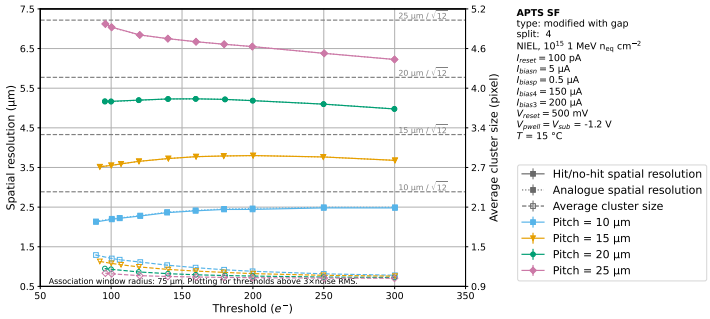


Figure 29: Resolution comparison between different pitches as a function of the applied seed threshold for a NIEL irradiation level of 10^{15} 1 MeV n_{eq} cm^{-2}. Chiller temperature was 15 °C. APTS with modified with gap, split 4, reference variant, V_{sub} = -1.2 V.