AtlasPix3.1 Rate Limitations
Using X-Ray tube

Theoretical Limits

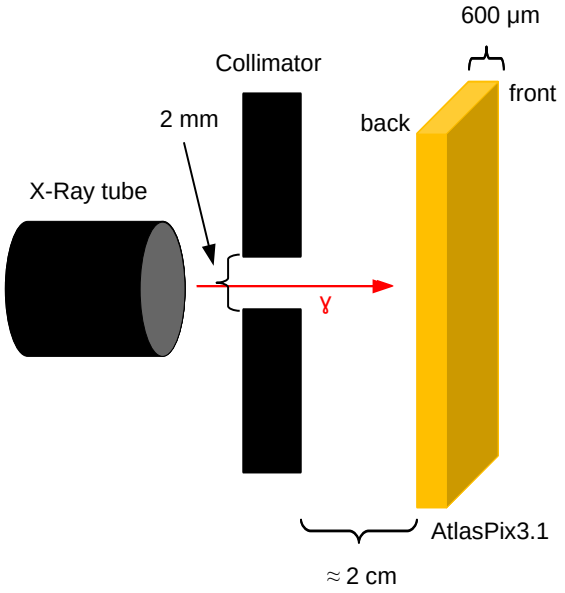
- State Machine:

Readout mode	external clock [MHz]	timerend	FSM [MHz]	TS clock [MHz]	maximum rate [MHz]
untriggered	600	1	30	120	7.3
untriggered	400	0	40	80	9.8

- 1Gbit/s Ethernet connection between FPGA and PC:
  - 3 × 64bit → 5 MHz
  - 1 × 64bit → 15 MHz

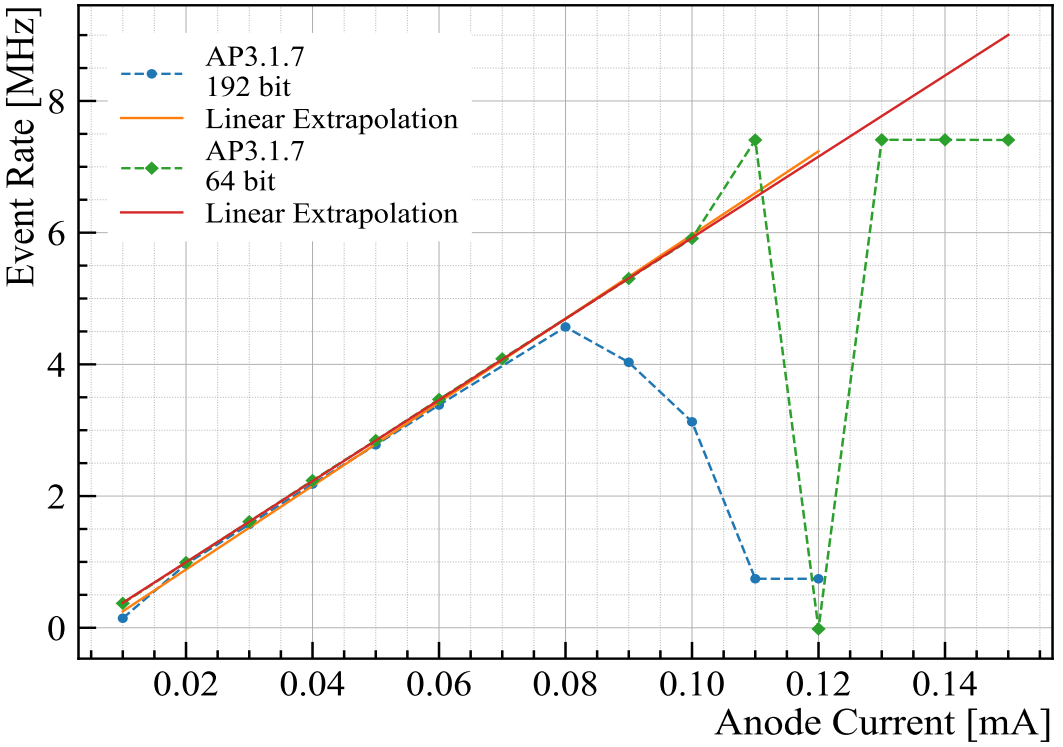
Setup

- Used standard GECCO readout (3×64 bit/hit) & reduced data / hit (64bit/hit: col, row, 40bit TS)
  - 600 MHz external clock
  - FSM 30 MHz (timerend = 1)
- X-Ray irradiation from the backside with different collimator
- Calculate rate from TS1:
  R = #Events / (TS1[last] – TS1[first])

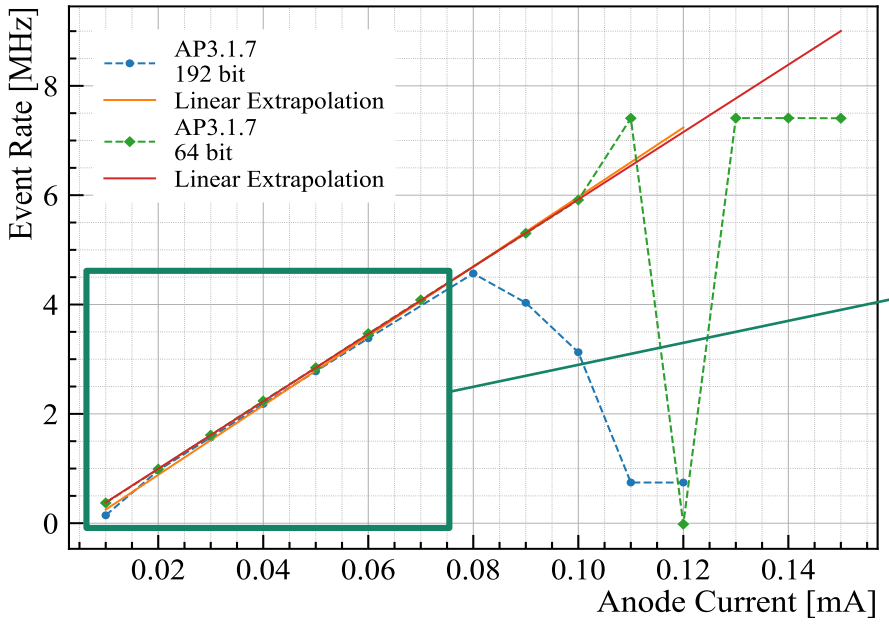


Rate Limitation - Data Format

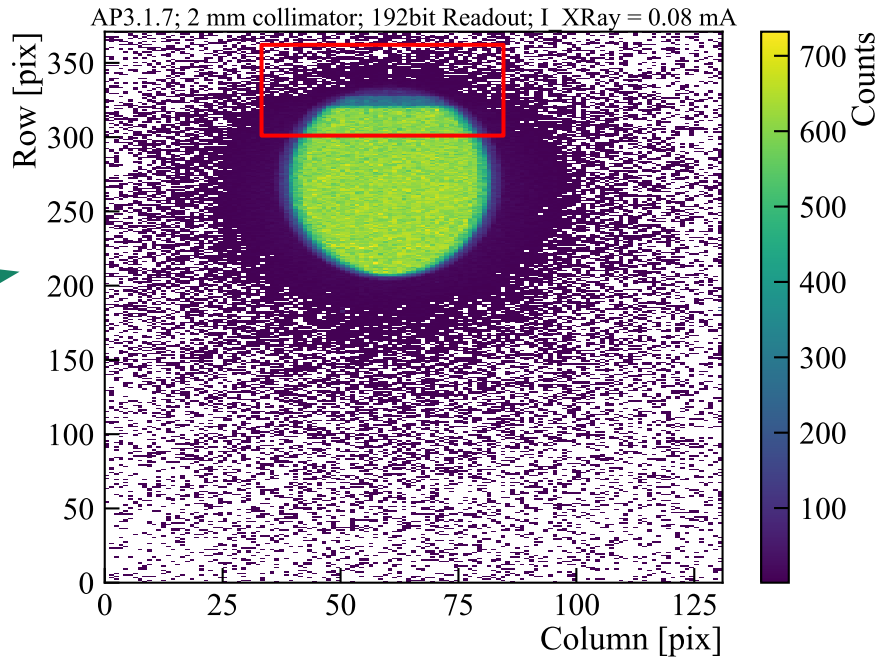
- 3 × 64 bit: R_{max} = 4.5 MHz
  - ➔ Ethernet
- 1 × 64 bit: R_{max} = 6.0 MHz
  - ➔ FSM



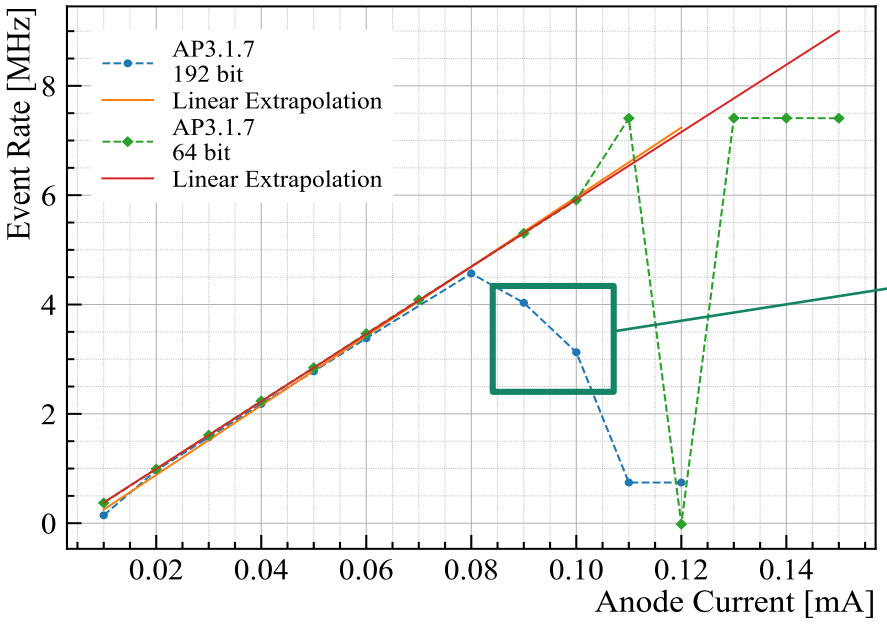
Rate Limitation - Data Format

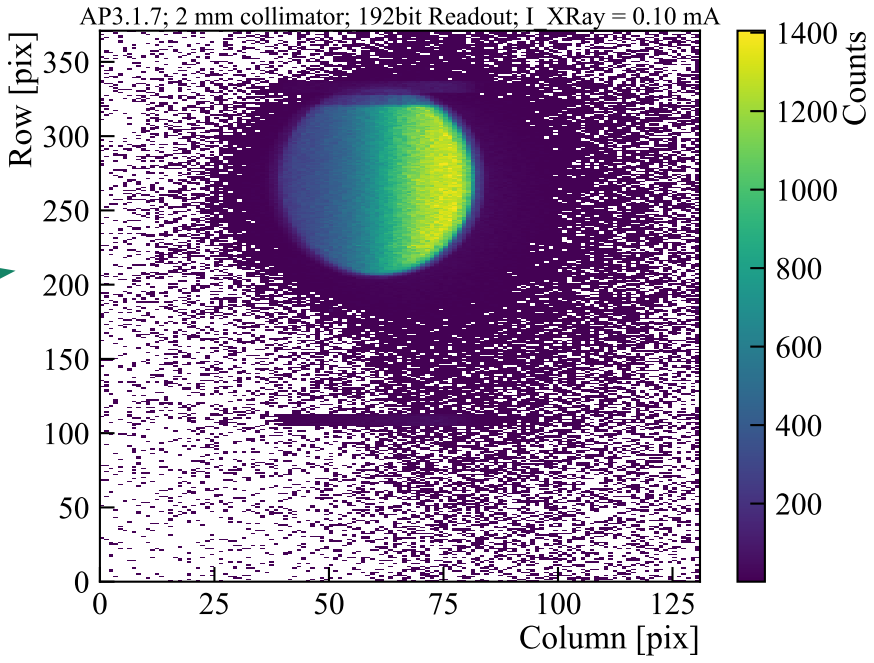


PCB cutout



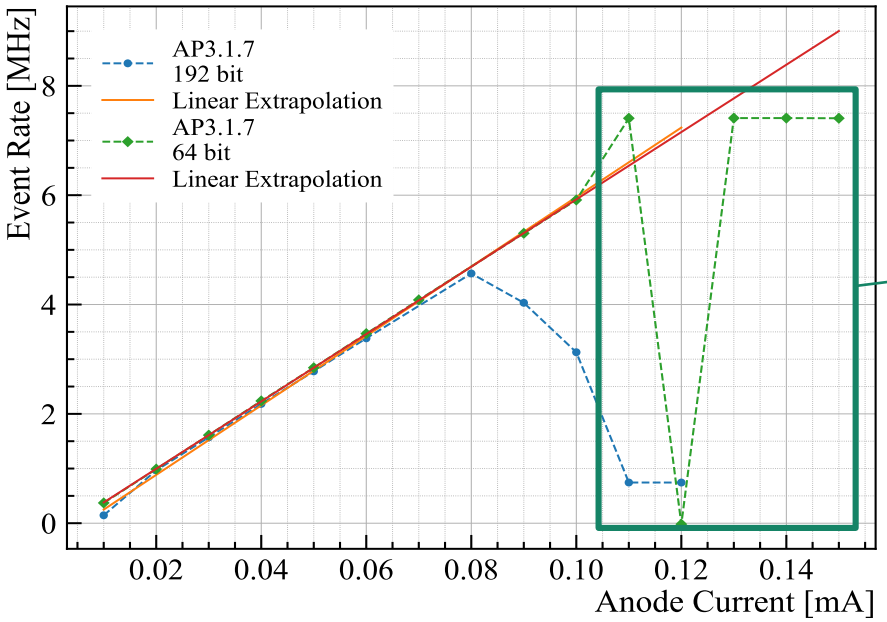
Rate Limitation - Data Format

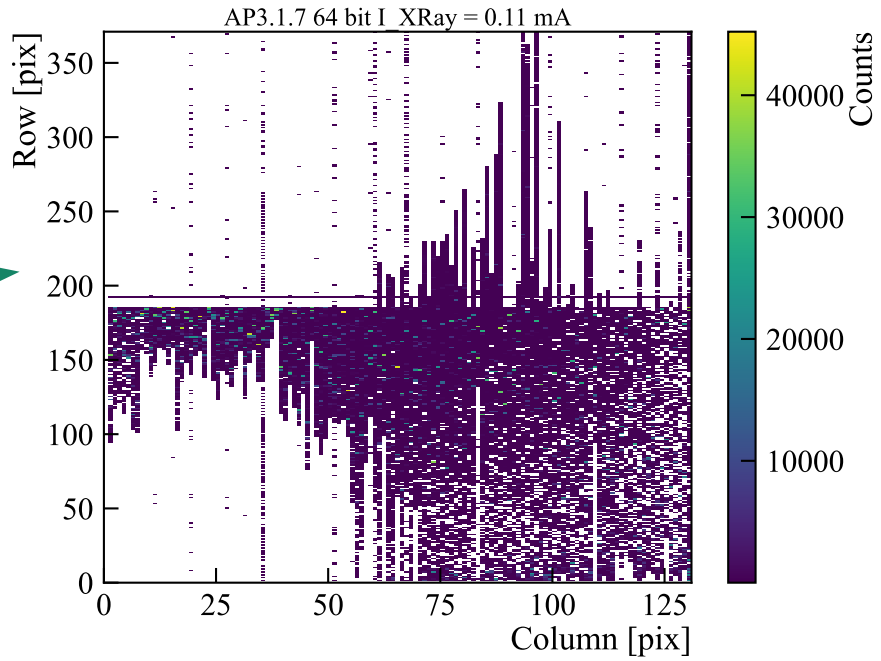




“Row drain” due to blocked FIFO & corrupted data

Rate Limitation - Data Format

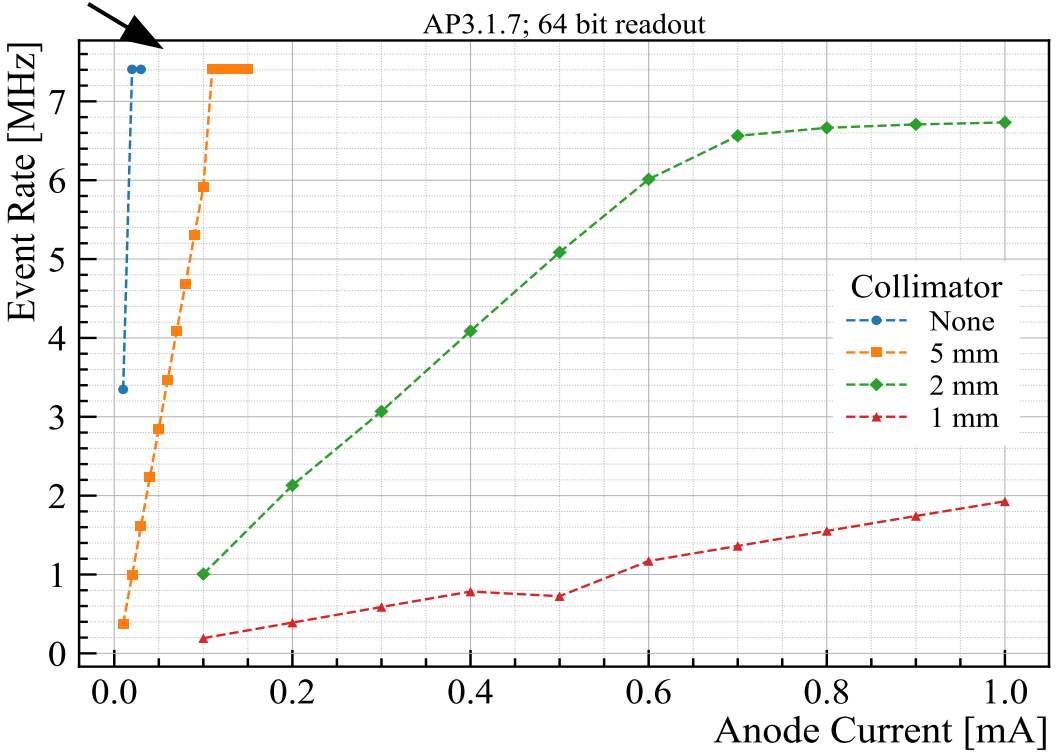




Break down of readout at 6.6 MHz
➔Sensor oscillating
7.5 MHz event rate

Rate Limitation - Collimator

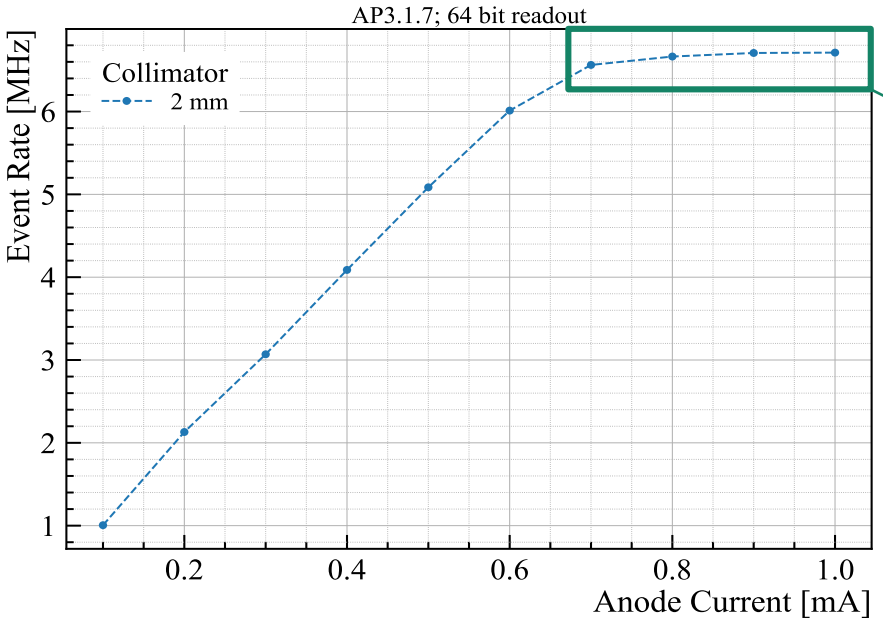
Oscillation

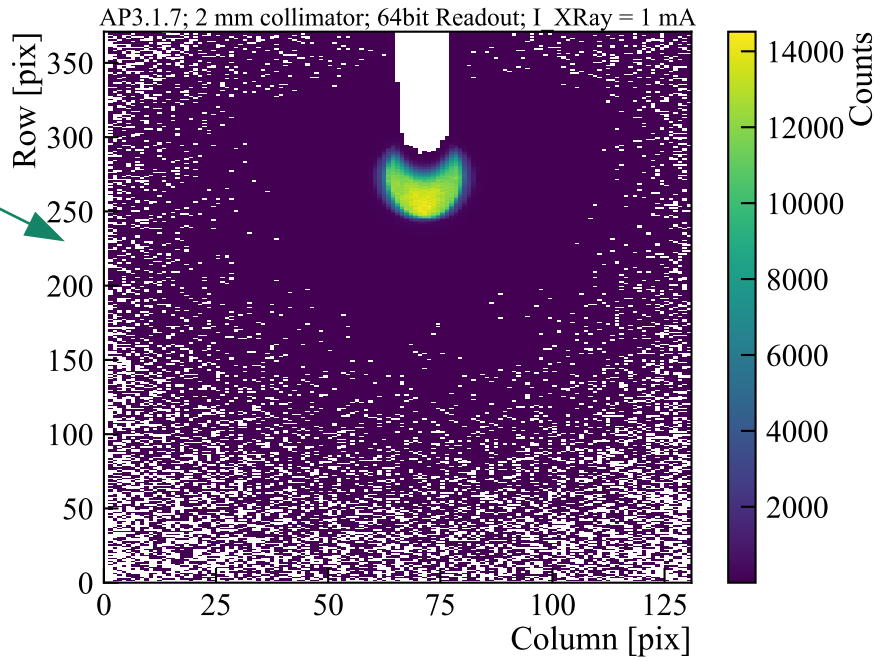


Collimator	maximum Rate
None	lower limit: 3.3 MHz
5 mm	lower limit: 6.0 MHz upper limit: 6.6 MHz
2 mm	6.7 MHz (column drain)
1 mm	above measurement range

Limited by step size of X-Ray tube for larger collimator sizes

Rate Limitation – 2 mm Collimator



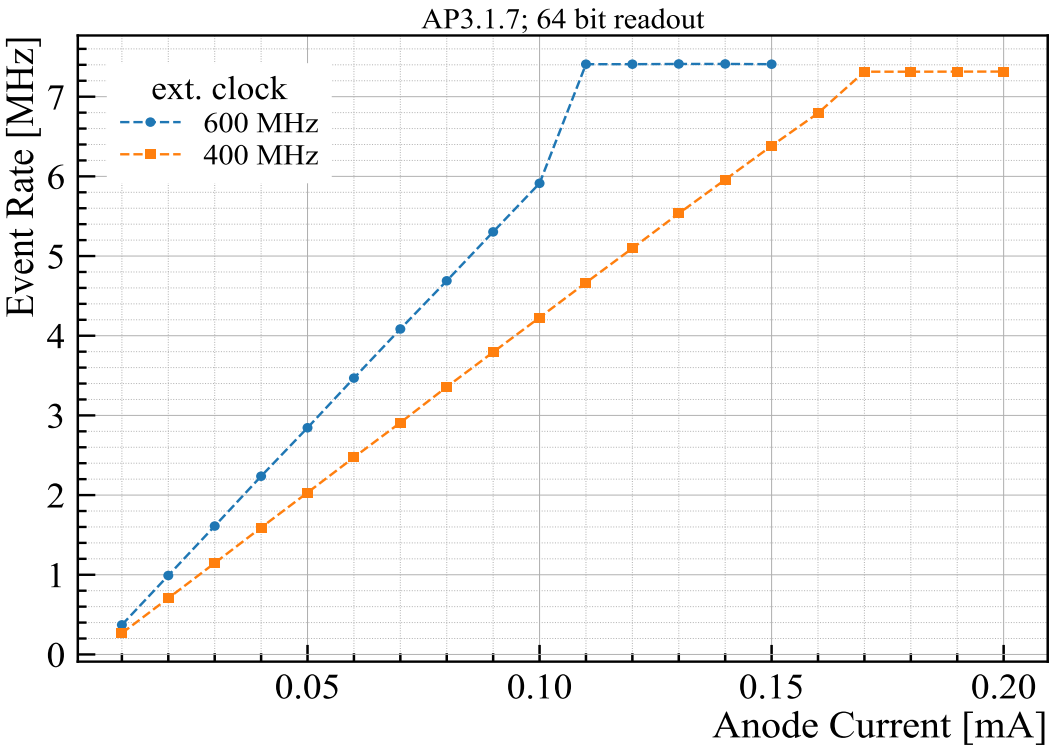


Rate saturation due to column drain
R = 6.7 MHz

Rate Limitation - FSM

- 600 MHz: R_{max} = 6.0 MHz (30 MHz FSM)
- 400 MHz: R_{max} = 6.8 MHz (40 MHz FSM)

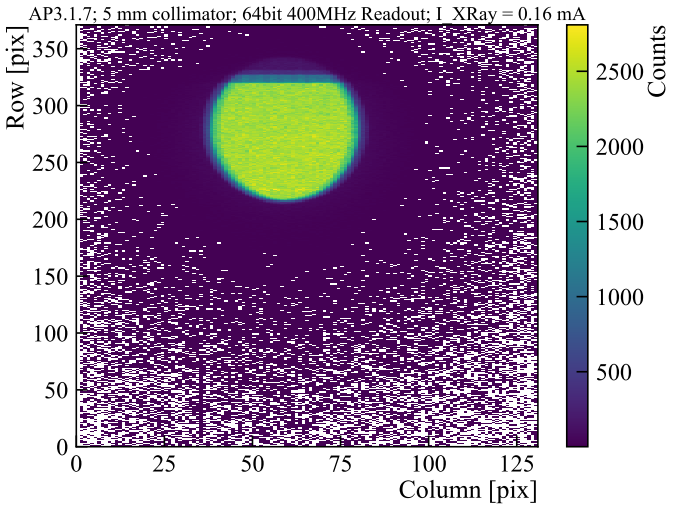
➔ Rate not limited by FSM?



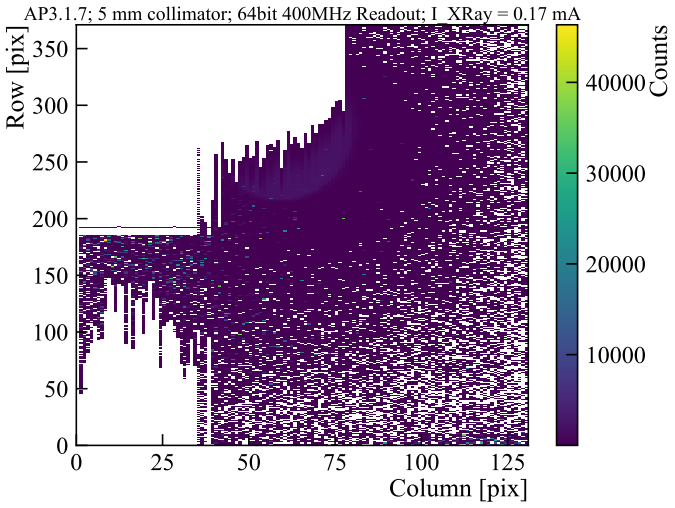
Rate Limitation – Column Drain

- 7.5 MHz limit could be a column drain effect
- ➔ 400 MHz readout is not oscillating

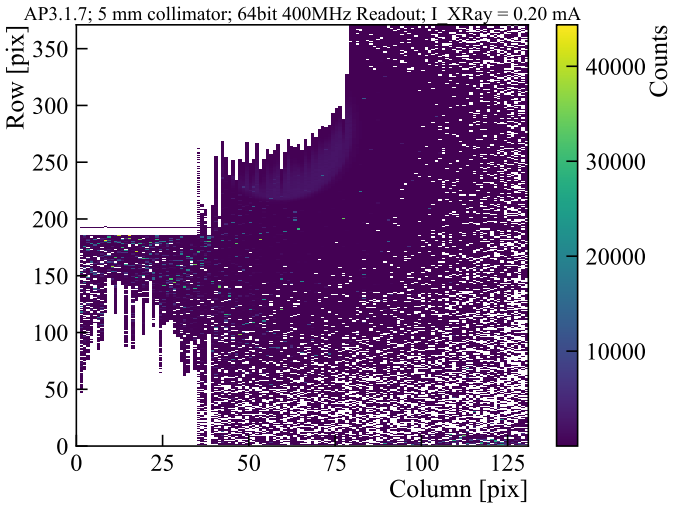
6.8 MHz



7.5 MHz



7.5MHz



Summary

- Determined event rate limitations of AP3.1
- Limited by the step size of the photon rate
- Readout could be limited by column drain effects
- To-do: Measure 2 mm & no collimator with 30 MHz FSM

FSM	Theoretical limit	5 mm collimator	2 mm collimator
30 MHz	7.3	6.0 – 6.6 MHz	6.7 MHz
40 MHz	9.8	6.8 – 7.5 MHz	