Sensors and Cameras for Fast Imaging

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Fast Imaging

10^{-4} sec

- "normal" cameras: 0.1 ms

10^{-6} sec

- Burst mode cameras 1 μs

10^{-8} sec

- Self-triggered cameras: 0.1-10 nsec

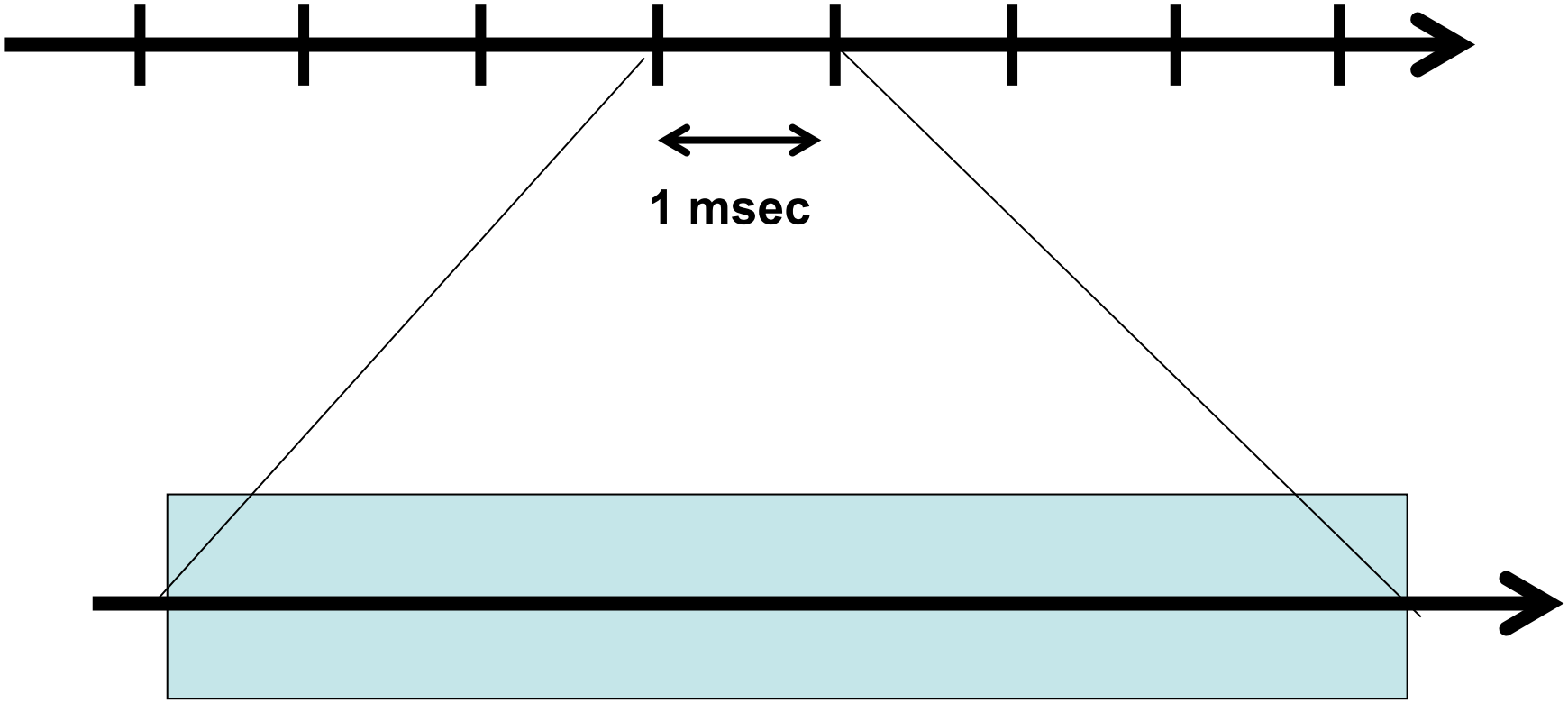
10^{-11} sec

- Streaking cameras: 10 psec

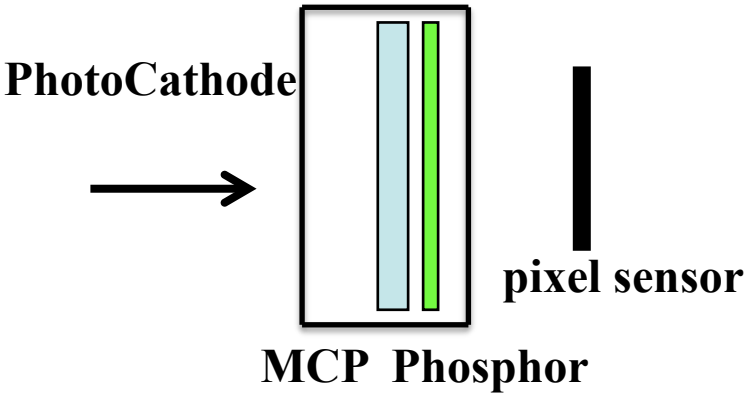
10^{-14} sec

- Repetitive "pump/probe" cameras with lasers : 10 fmsec resolution

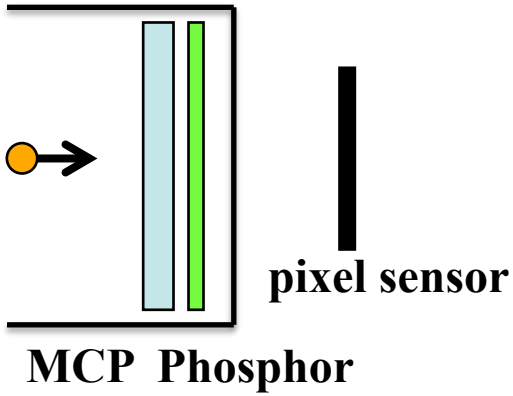
Normally signal is integrated in a slice of time



Two configurations

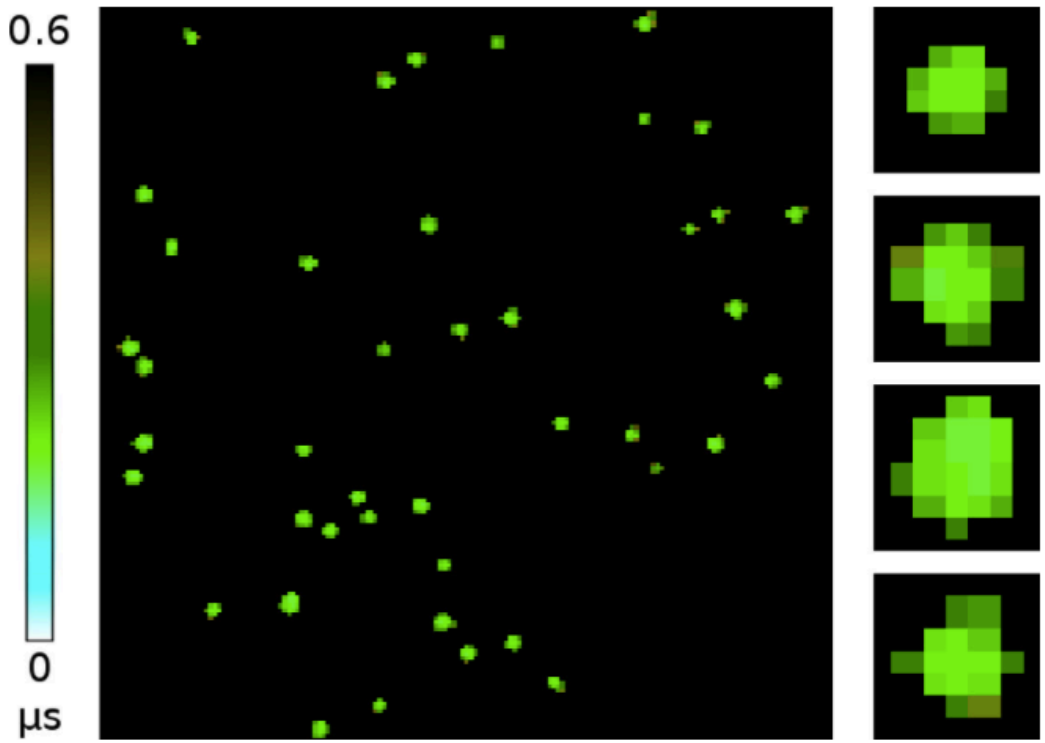


Detection of single photons



Detection of ions

single photon counting



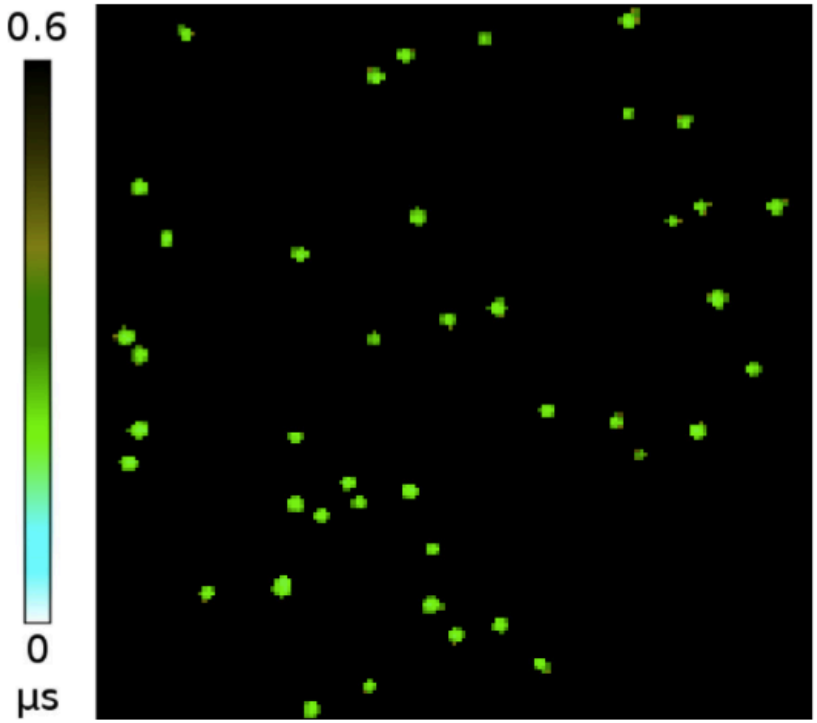
Photon counting phosphorescence lifetime imaging with TimepixCam

Liisa M. Hirvonen, Merlin Fisher-Levine, Klaus Suhling, and Andrei Nomerotski

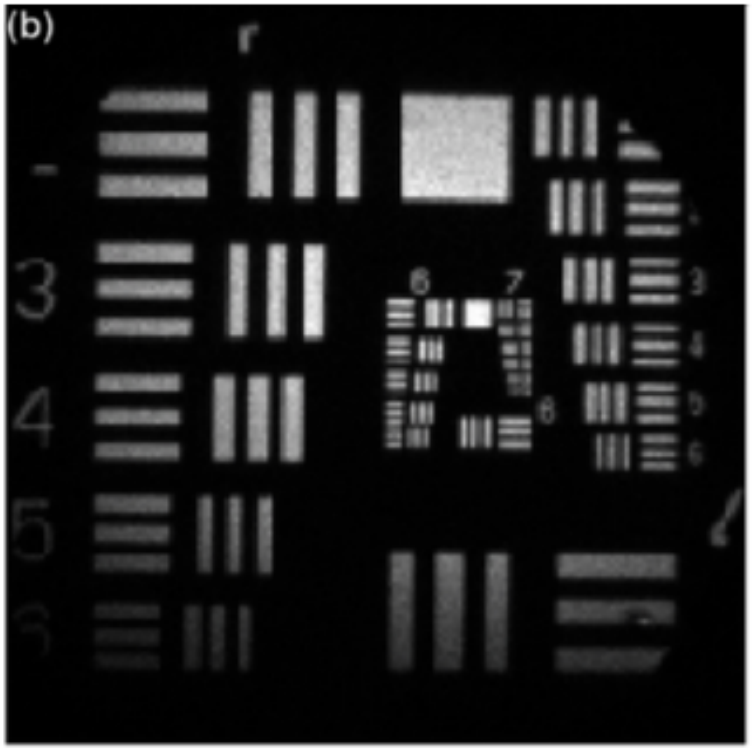
Citation: Rev. Sci. Instrum. **88**, 013104 (2017); doi: 10.1063/1.4973717

Imaging with photon counting

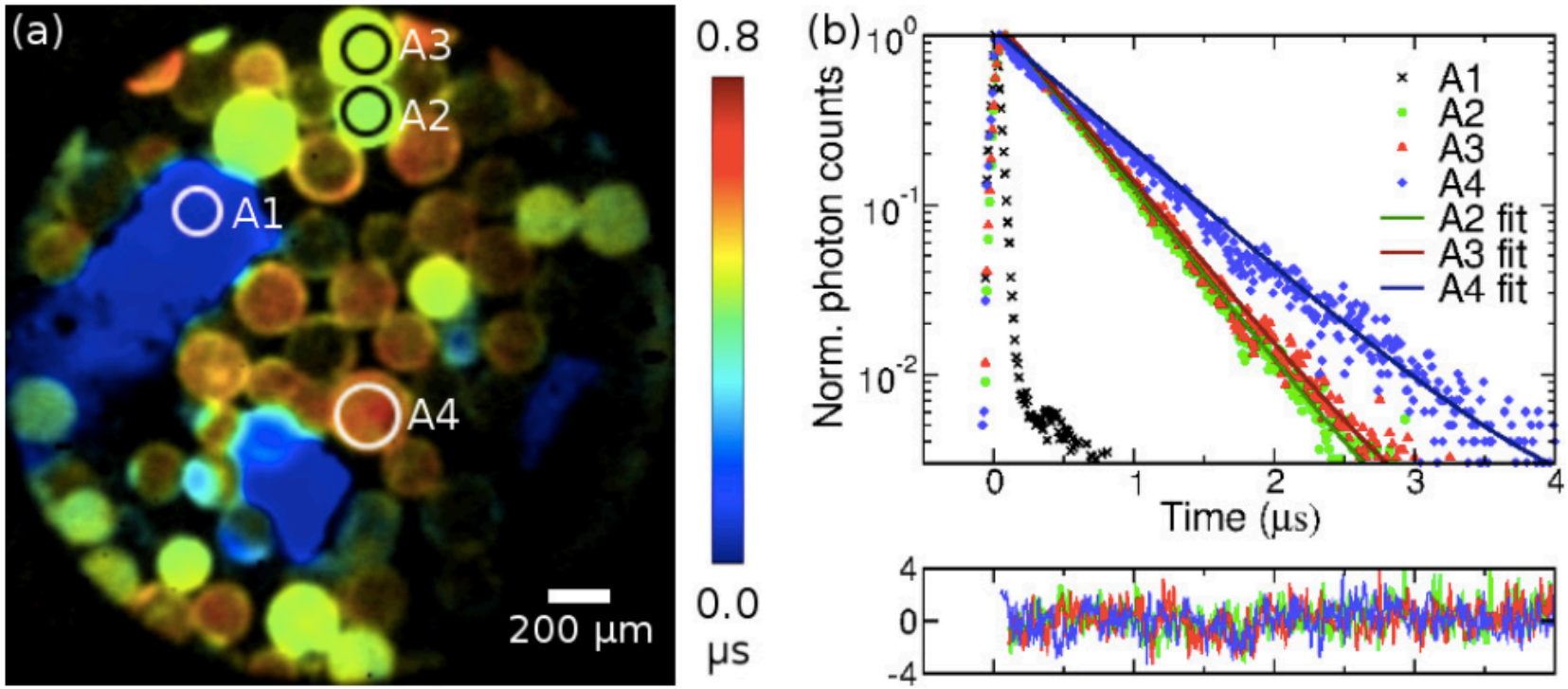
Single frame



Integrated image



Lifetime imaging with 10 ns timing



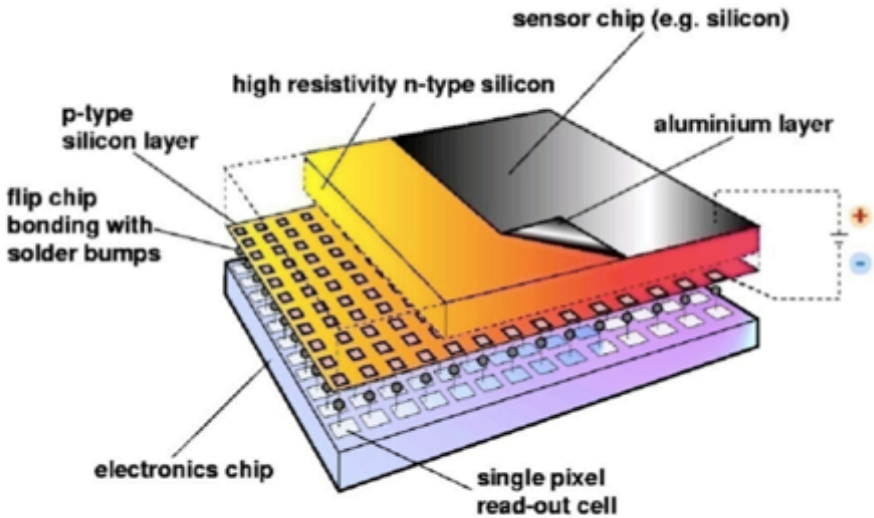
TimepixCam & Tpx3Cam

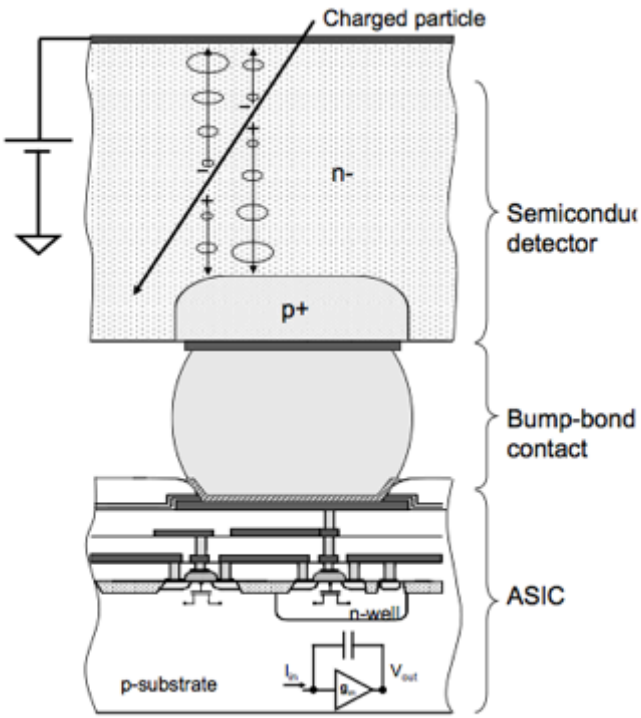
- Optical cameras with 10 and 1 ns time resolution

- Use hybrid pixel approach – developed for particle and x-ray detection

[29] M. Fisher-Levine and A. Nomerotski, "Timepixcam: A fast optical imager with time-stamping," J. Inst. **11**(3), C03016 (2016).
[30] A. Nomerotski, Z. Janoska, I. Chakaberia, M. Fisher-Levine, P. Takacs, and T. Tsang, "Characterization of TimepixCam, a fast imager for time stamping of optical photons," J. Inst. **12**(1), C01017 (2017).

Why Hybrid-Pixel Detectors?



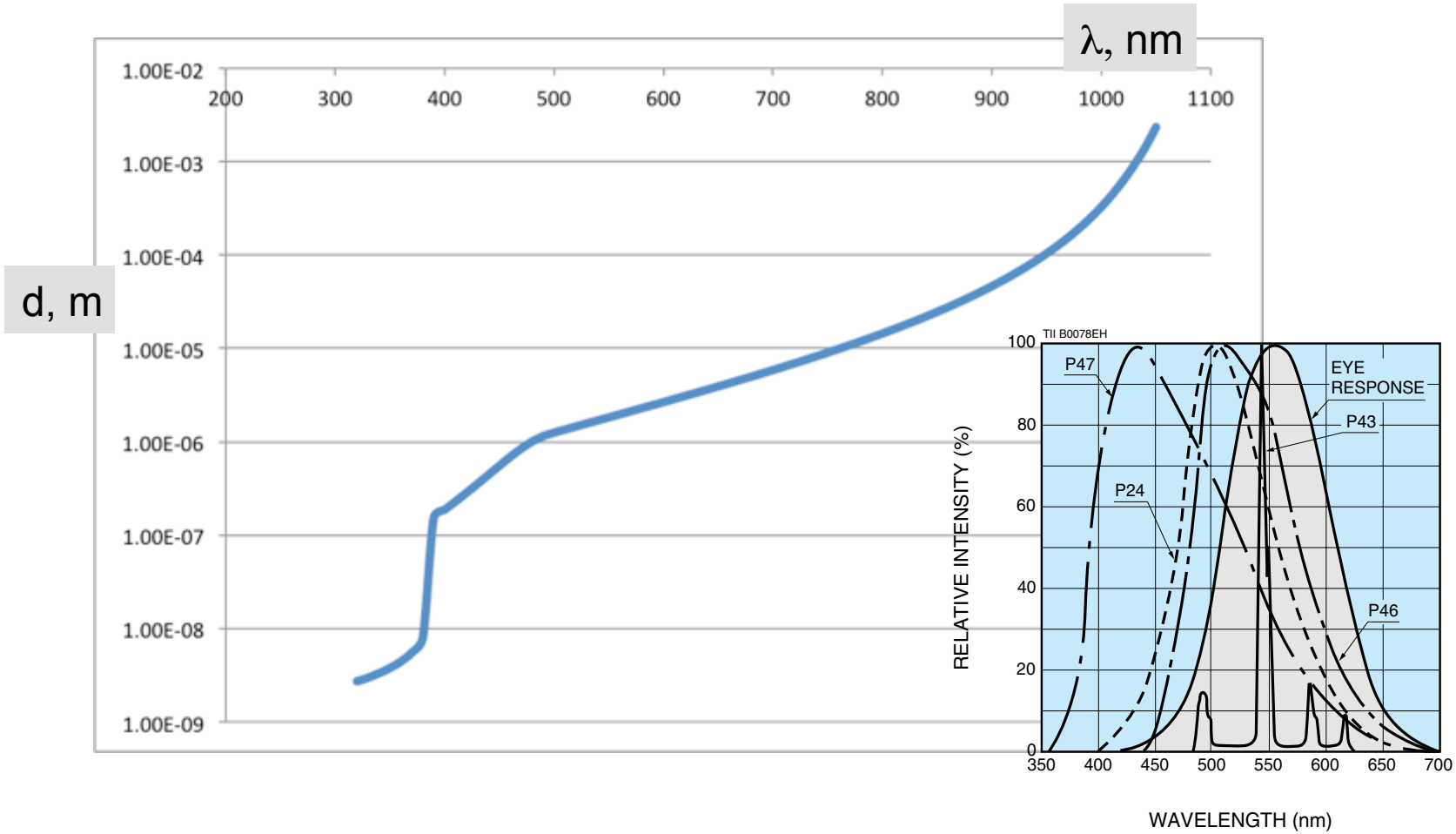


Fill factor is 100% (away from periphery)
Sensor and ASIC can be optimised separately
Full depletion of sensor allows prompt charge collection
It is relatively straightforward to achieve extremely high SNR – “noise free imaging”
Sensor material can be changed – or replaced by e.g. MCP, Gas gain grid, etc
Standard CMOS can be used allowing on-pixel signal processing

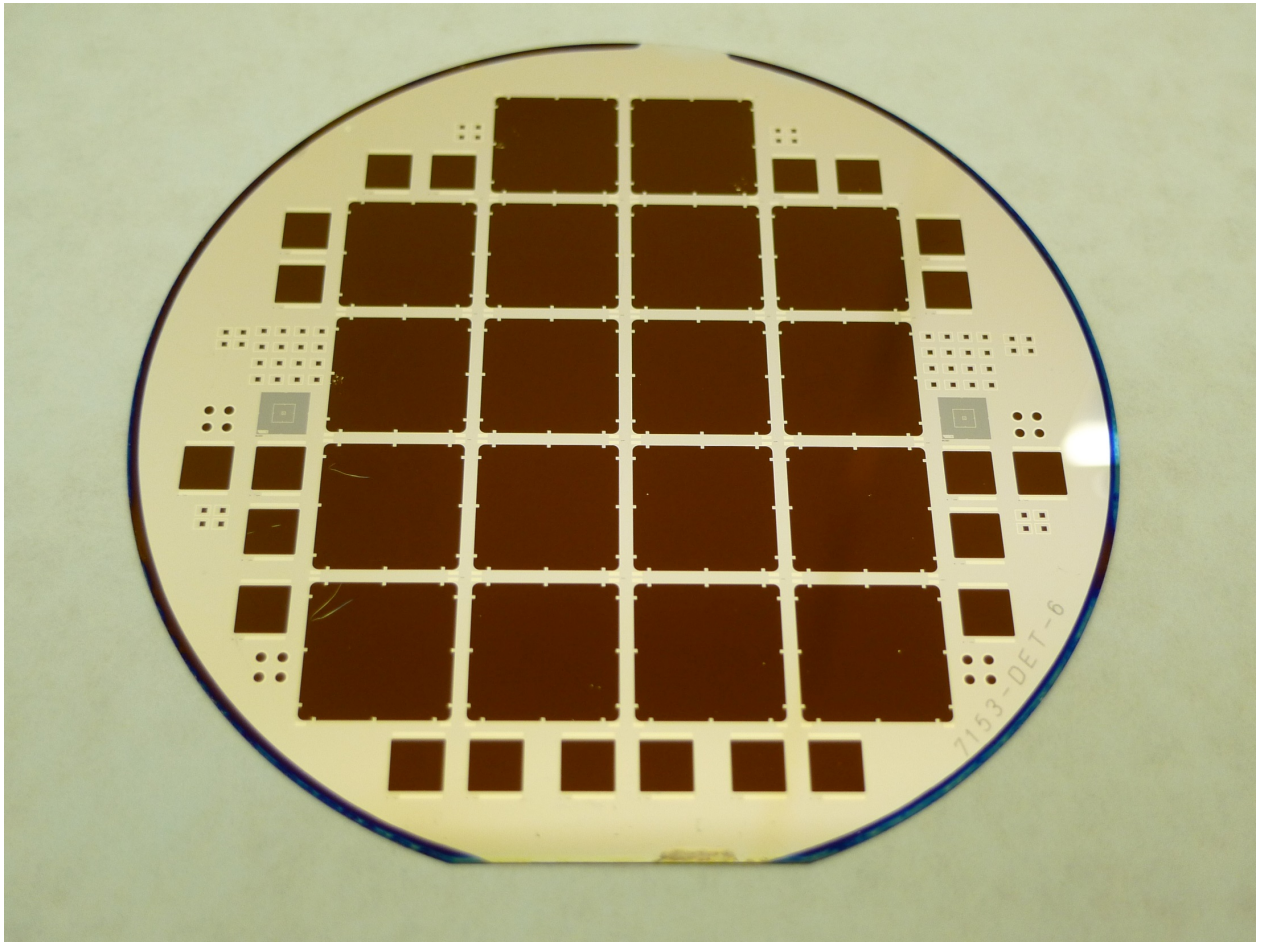
M.Campbell

Photon absorption in silicon

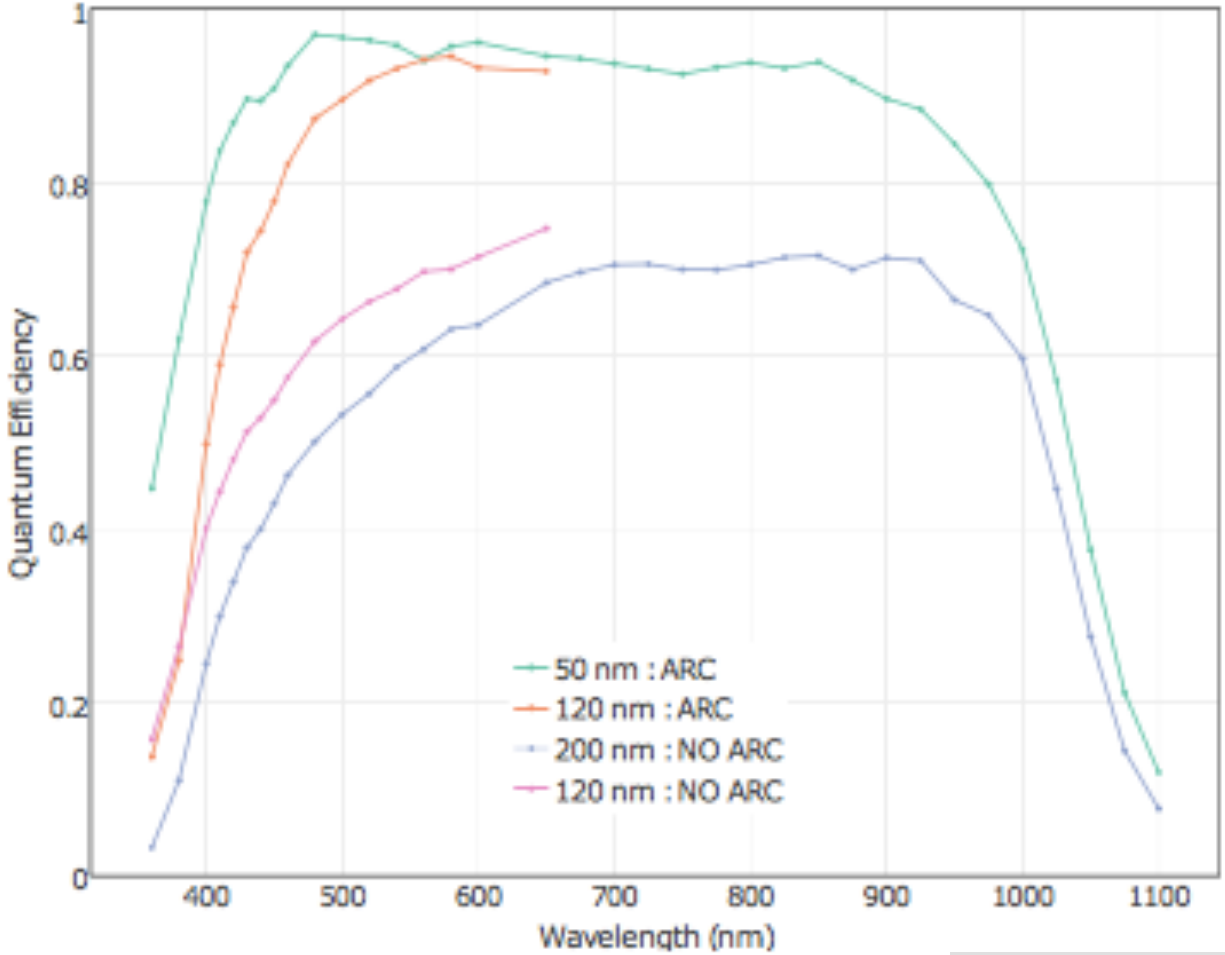
- Blue photons are absorbed near the surface (~0.25 um for 430 nm, P47 max emission)
- Others penetrate deeper (~1 um for 500 nm, ~10 um for 800 nm)



Thin window sensors

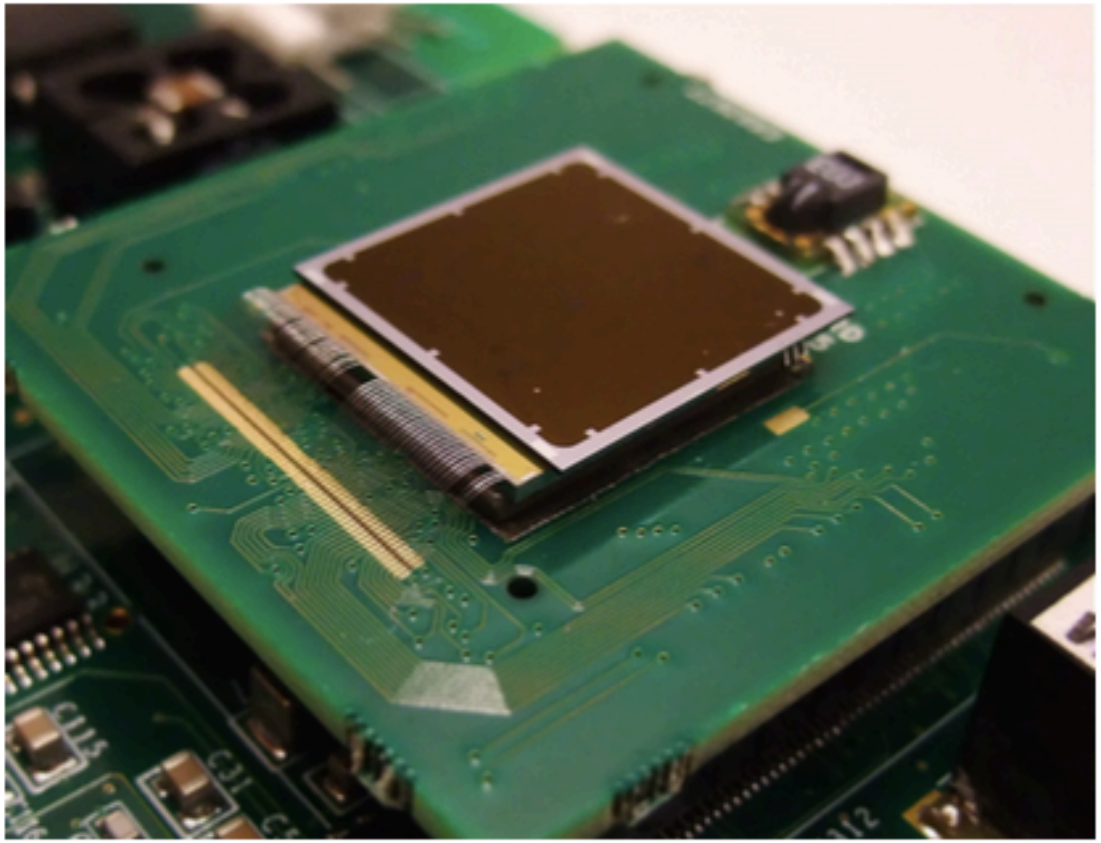


Quantum Efficiency



Wavelength, nm

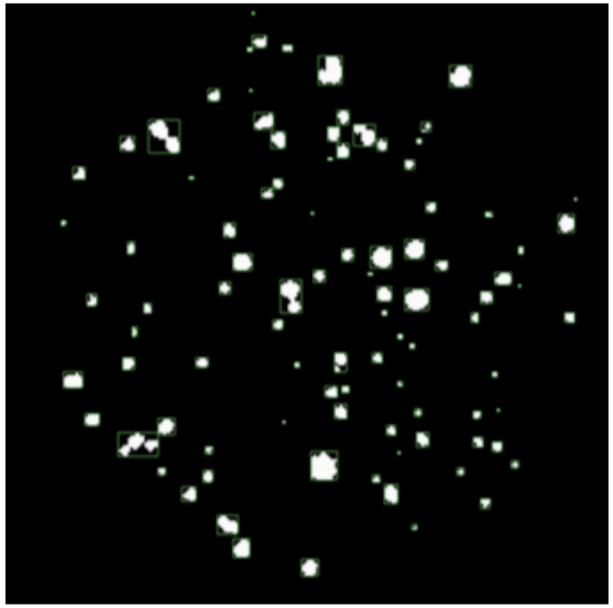
TimepixCam



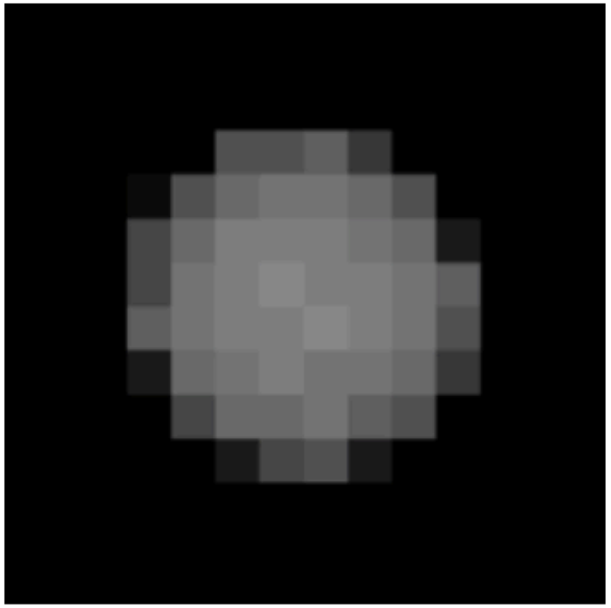
(a) The new sensor in TimepixCam.

Ions in BNL Chemistry with TimepixCam

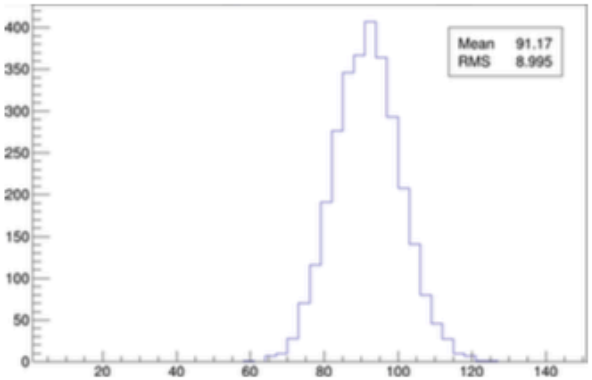
- BNL imaging MS group: Matt Kershis, Amanda Muraca & Mike White
- Use Timepix optical sensor since Mar 2015



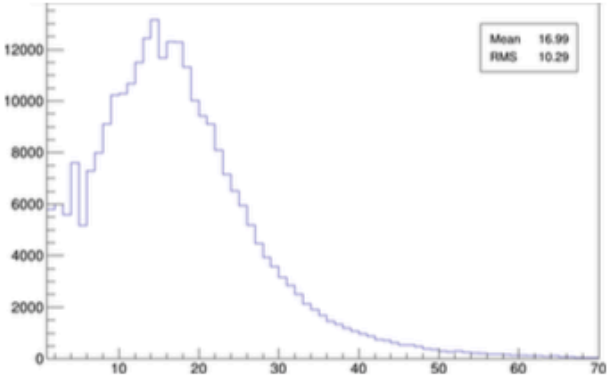
(a) Typical frame showing ion hits and the results of the cluster finding algorithm.



(b) Enlarged image of an ion hit, with pixel timecode represented by the grayscale.

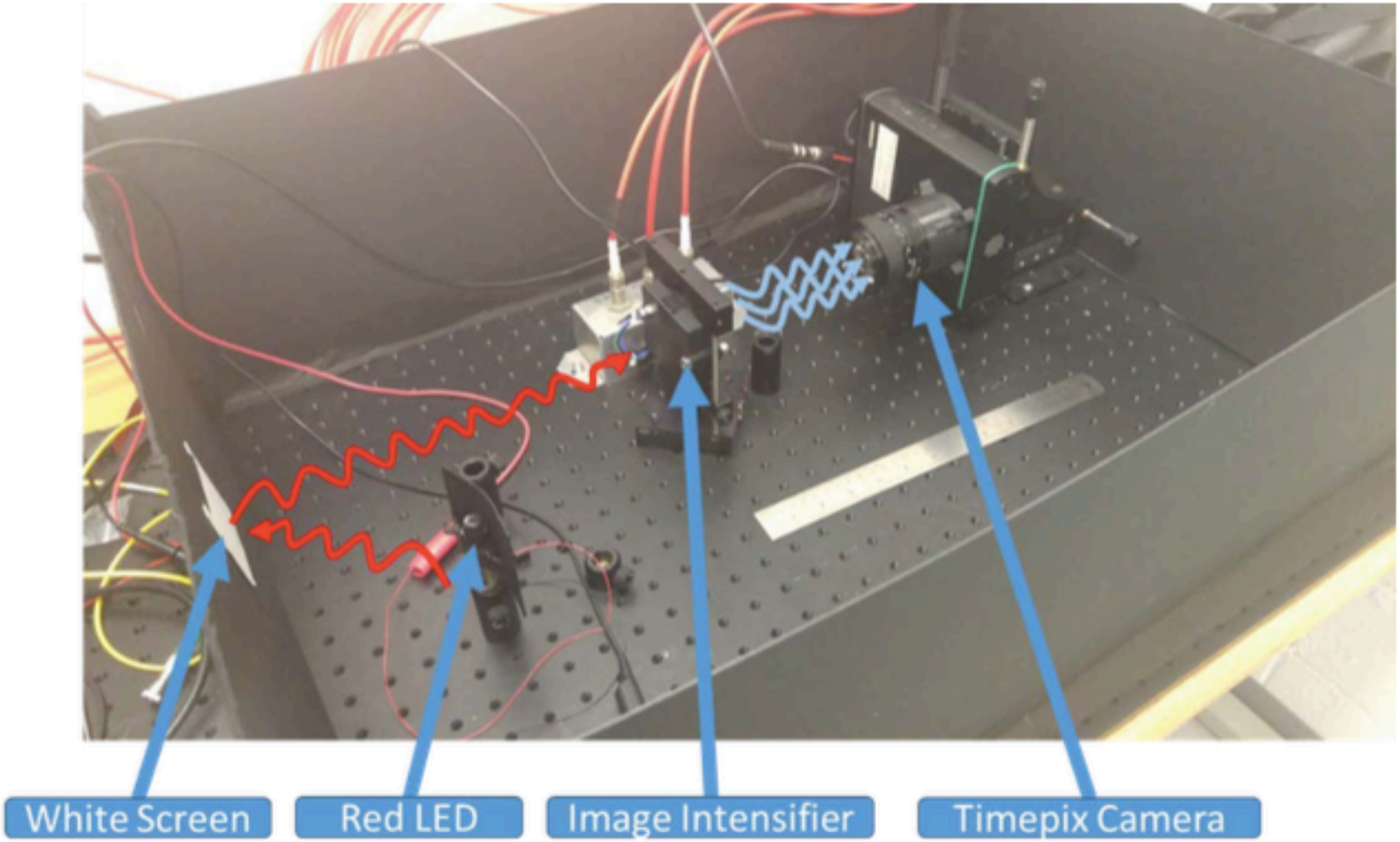


(c) Historgram of number of ions recorded per frame.



(d) Histogram of cluster sizes. The spike at 4 pixels is due to the geometric favourability. The peak lies at 15 pixels per cluster.

Image Intensifier + TimepixCam



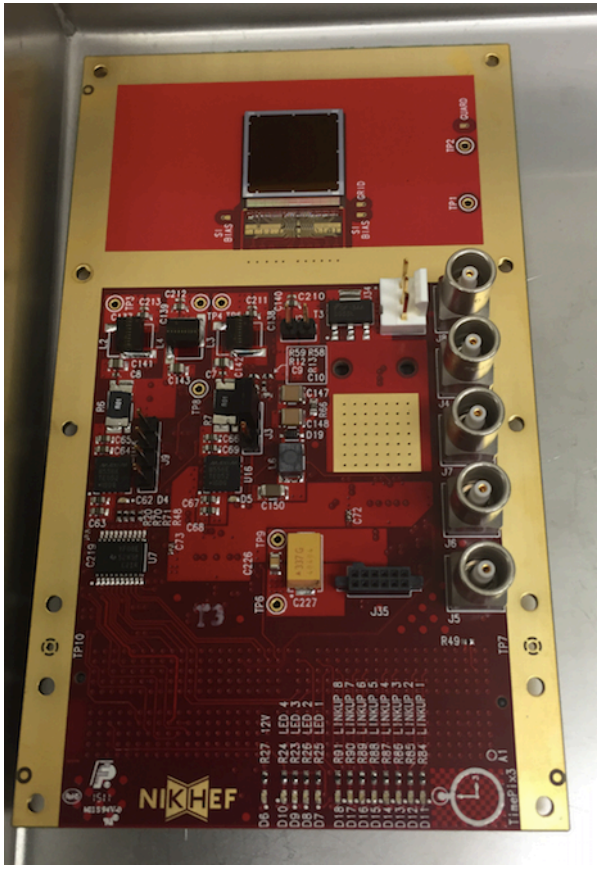
Better ASIC: Timepix3

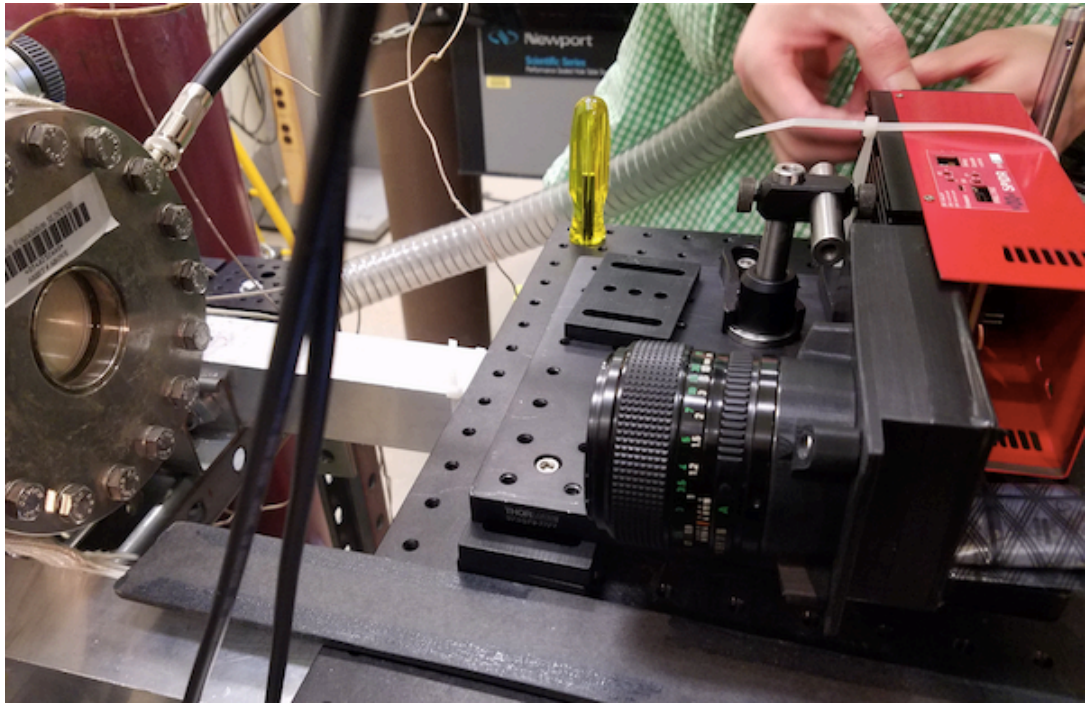
- Next generation of time stamping ASIC
  - 1.5 nsec timing resolution
  - multihit capabilities (pixel deadtime = 500 nsec)
  - High throughput (80 Mpix/sec)

Timepix vs Timepix3

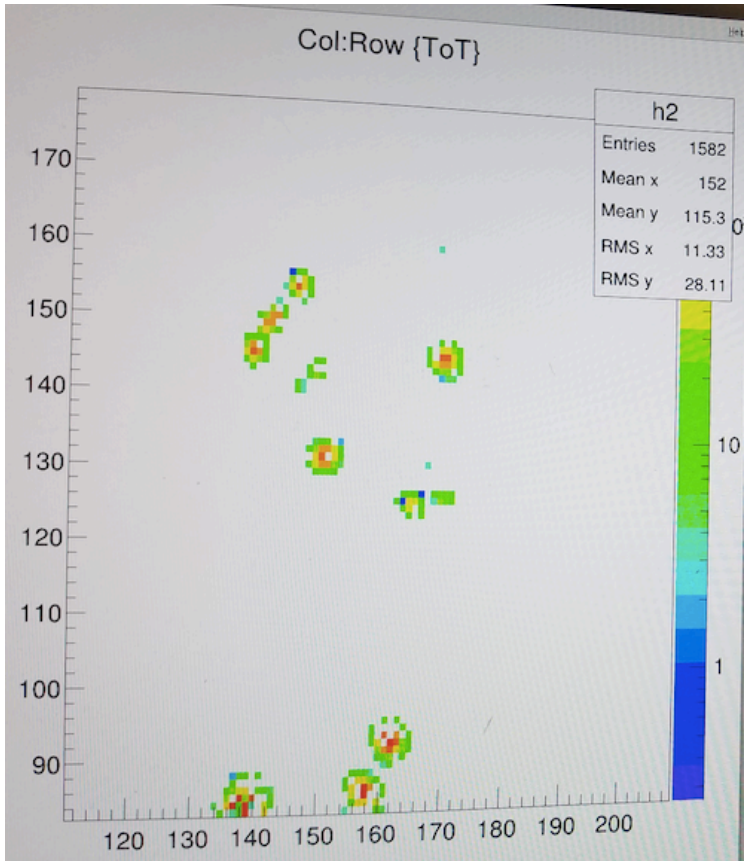
	Timepix (2006)	Timepix3 (2013)
Pixel arrangement	256 x 256	
Pixel size	55 x 55 μm^2	
Technology	250nm CMOS	130nm CMOS
Acquisition modes	1) Charge (iTOT) 2) Time (TOA) 3) Event counting (PC)	1) Time (TOA) AND Charge (TOT) 2) Time (TOA) 3) Event counting (PC) AND integral charge (iTOT)
	Trigger-less	
Readout Type	1) Frame based	1) Data driven (DD) 2) Frame based (FB)
Zero suppressed readout	NO	YES
Dead time per pixel	> 300 µs readout time of one frame	> 475 ns Pulse measurement time + packet transfer time
Minimum timing resolution	10 ns	1.562 ns
TOT Energy resolution	~300-600 e^-_{FWHM}	
Minimum detectable charge	>750 e^-	>500 e^-
Collection Polarity	e^- and h^+ (with leakage current compensation up to ~2nA/pixel)	
Radiation hardness	<250 krad	Expected <200 Mrad (still to be measured)

Tpx3Cam





Ions in Tpx3Cam in SBU



Freeman Dyson

“New directions in science are launched by new tools much more often than by new concepts”