Picosecond Avalanche Amorphous Selenium Detector

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Outline

- **Amorphous Selenium Inventions**
- **Unipolar Time-Differential (UTD) charge sensing**
- **Multi-Well Selenium Detectors (SWAD, NEW-HARP)**

10.-22.-38
ASTORIA

History of Xerox

- **1938:** Chester Carlson invents a method of transferring images from one piece of paper to another using static electricity, a process dubbed xerography.

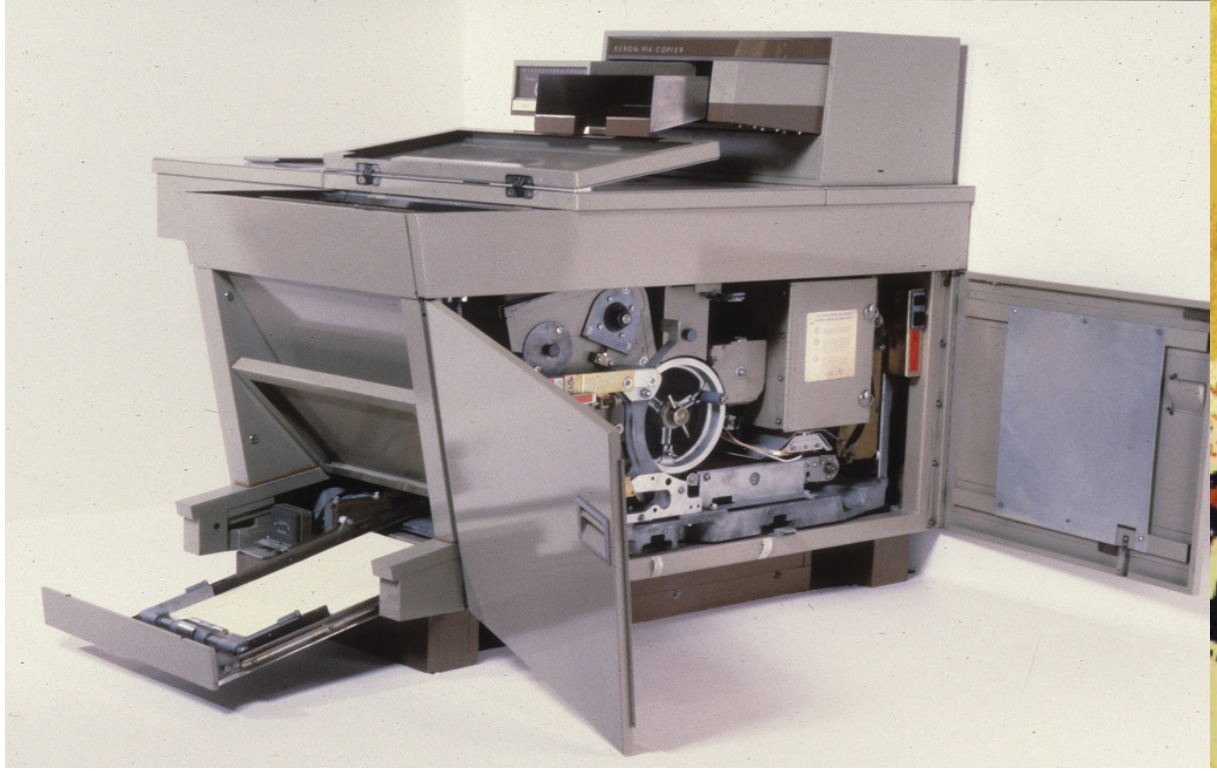
- **1947:** Haloid gets exclusive right to Carlson's patent.

- **1949:** Company introduces the XeroX Copier.

- **1958:** Company changes its name to Haloid Xerox Inc.

- **1959:** Introduction of the Xerox 914, the first automatic, plain-paper copier, proves to be a huge success.


HALOID XEROX
NEW XEROX
914
OFFICE COPIER




HALOID
XEROX
XEROX
914 COPIER
XEROX

Xerography with Selenium

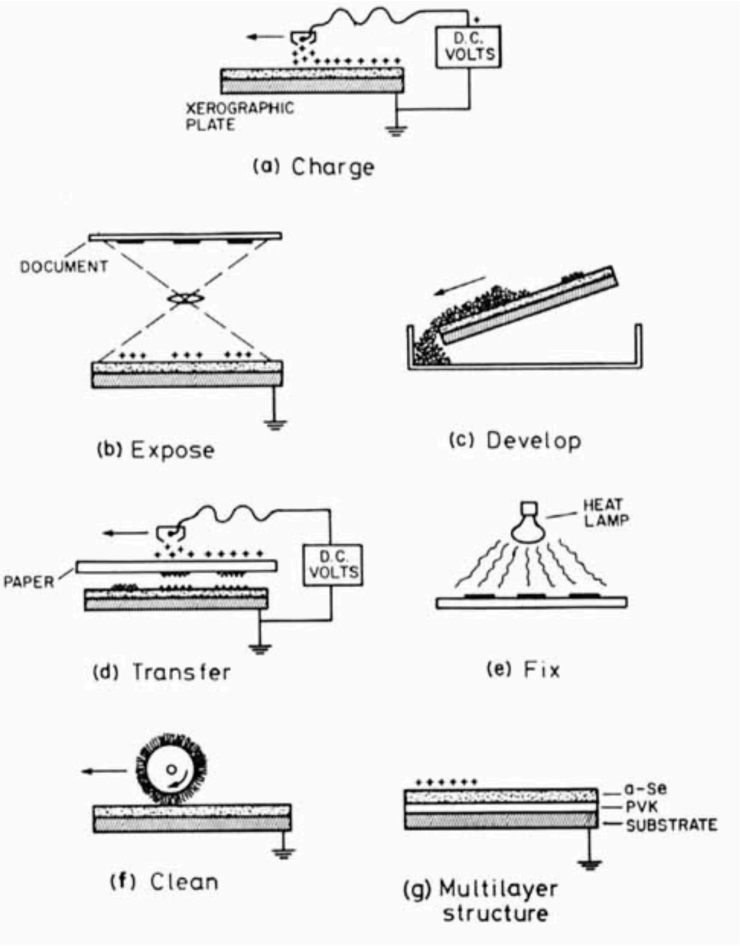


Fig. 2. Basic steps in xerography.

G. Pfister, *Contemp. Phys.* **20**, 449-479 (1979).

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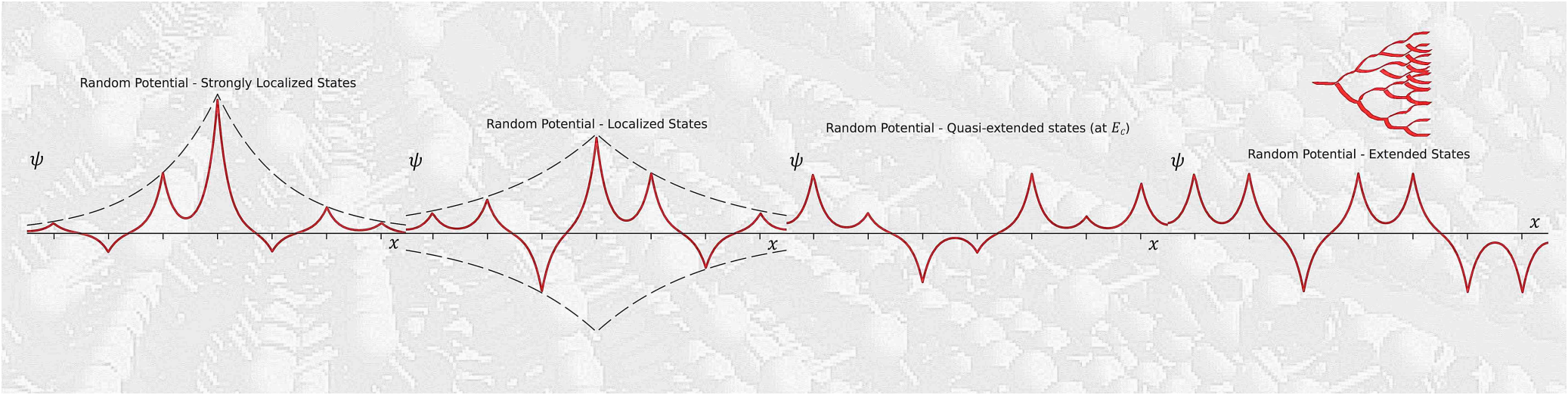
High Resolution X-ray Imaging

Courtesy of **Analogic Canada**.
(www.analogic.com)



Courtesy of **NHK Japan**
(Inventor: Dr. Kenkichi Tanioka)

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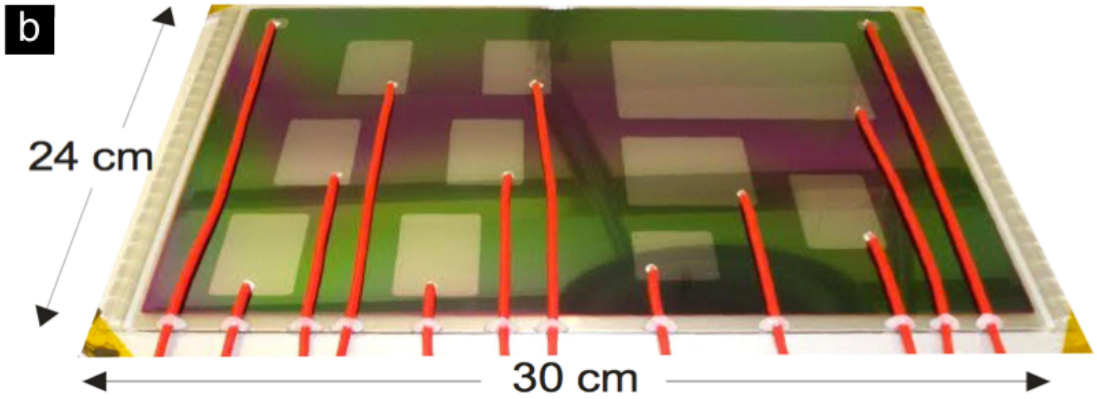
1st Large-Area Avalanche Selenium Imager

Developed by **W. Zhao's Group:**
(https://you.stonybrook.edu/dril/)



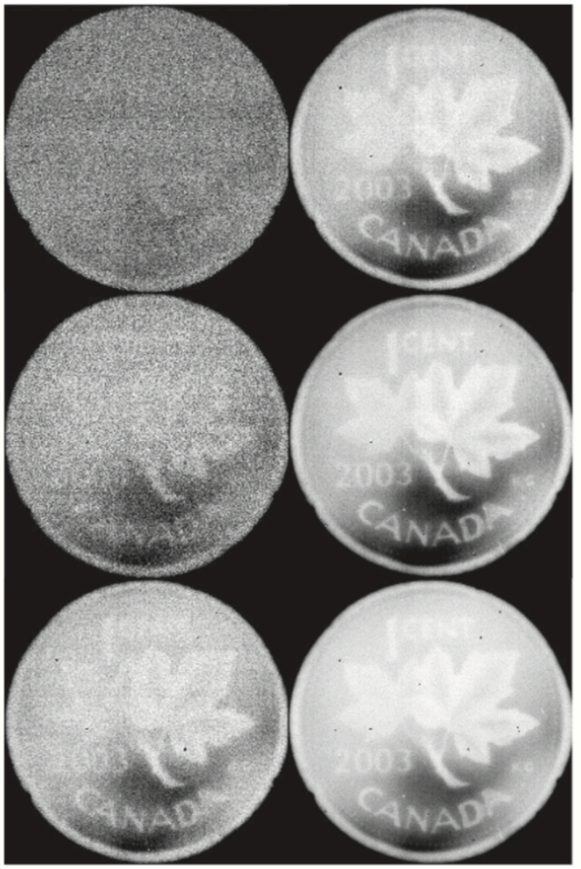


FIG. 8. Images of the tails side of a penny with constant 0.76 mR exposure. Left column from top to bottom E_{Se} = 15, 71, and 95 V μm^{-1}. Right column from top to bottom E_{Se} = 95, 100, and 105 V μm^{-1}.

J. R. Scheuermann, A. H. Goldan et al, Med. Phys. **42**, 1223-1226 (2015)
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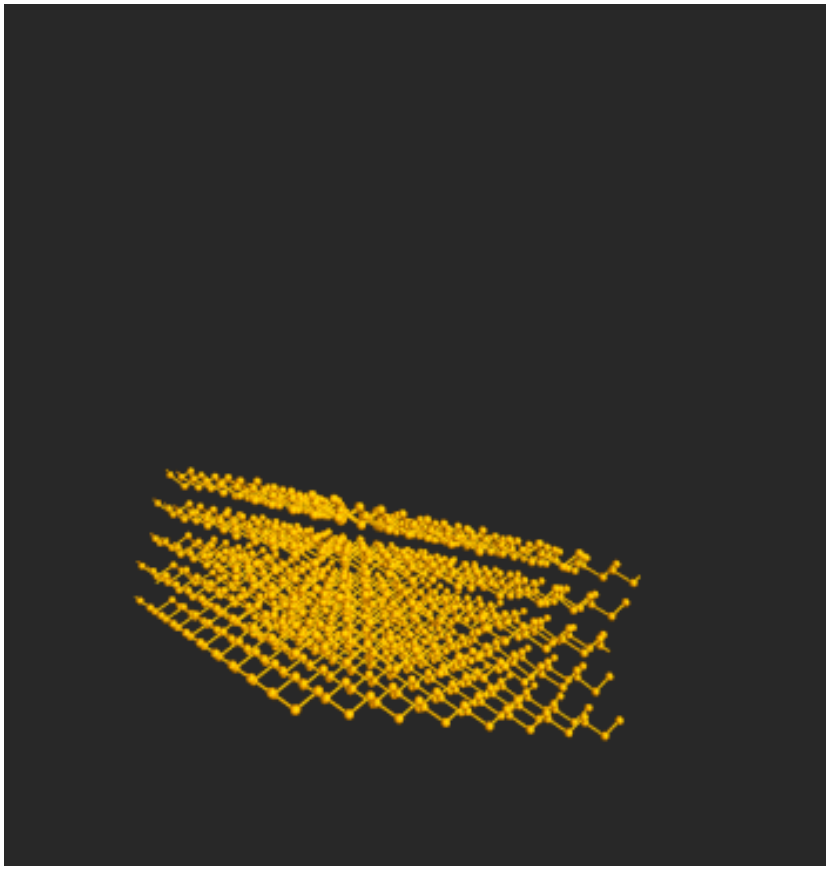
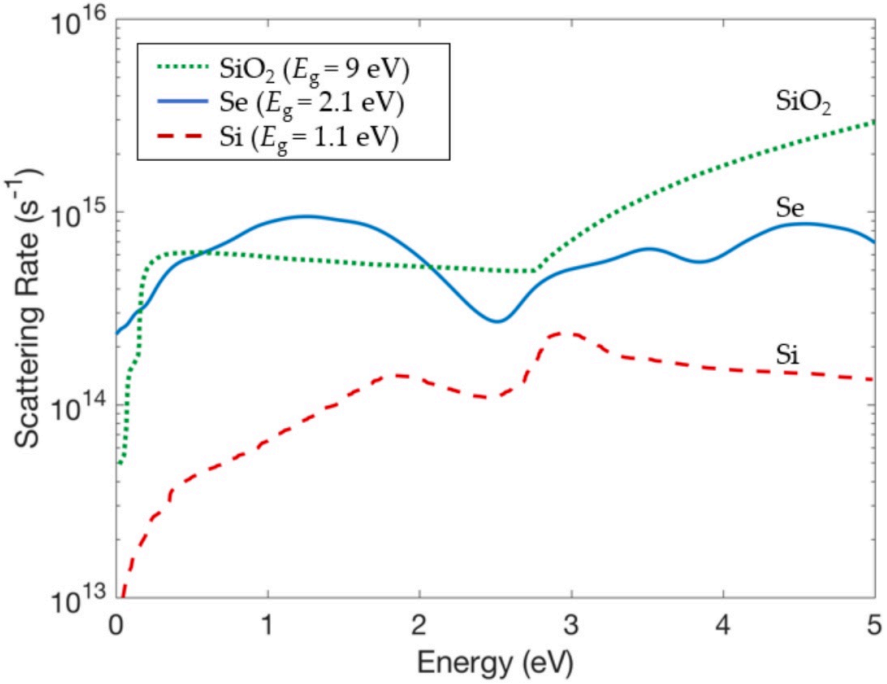
Atomistic and Quantum Mechanical Modeling



$$\frac{\partial f_{\mathbf{k}}(\mathbf{r})}{\partial t} = -\mathbf{F}.\nabla_{\mathbf{p}} f_{\mathbf{k}}(\mathbf{r}) + \frac{\partial f_{\mathbf{k}}(\mathbf{r})}{\partial t}\Big|_{\text{coll}} - \frac{1}{\hbar}\frac{\partial E_{\mathbf{k}}}{\partial \mathbf{k}}.\nabla_{\mathbf{r}} f_{\mathbf{k}}(\mathbf{r}) + s(\mathbf{r}, \mathbf{p}, t),$$



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A. Mukherjee, D. Vasileska, A. H. Goldan, *J. Appl. Phys.* **124**, 025846 (2018).

Radiation in Medical Imaging

	Modality	Energies
X-ray imaging	Mammography	25 kVp, ~18 keV
transmission	Radiography (chest)	150 kVp
	Fluoroscopy	150 kVp
	X-ray CT	150 kVp
Nuclear Medicine	Scintigraphy	80 – 140 keV
emission	SPECT	60 – 511 keV
	PET	511 keV

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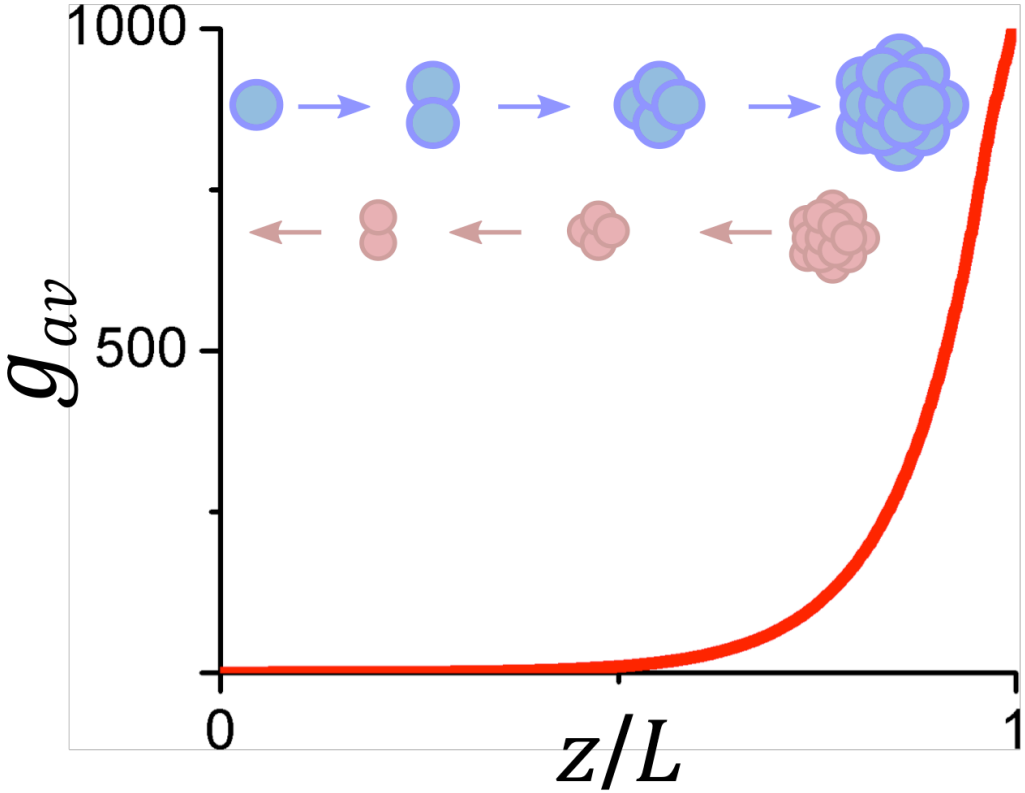
Avalanche Gain in a-Se: Slow Collection



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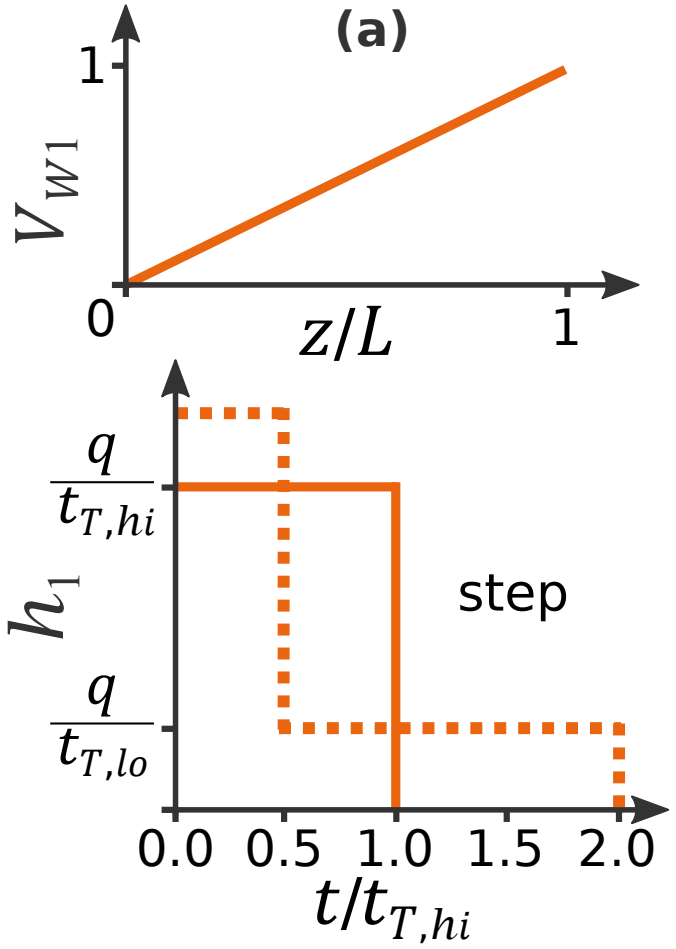
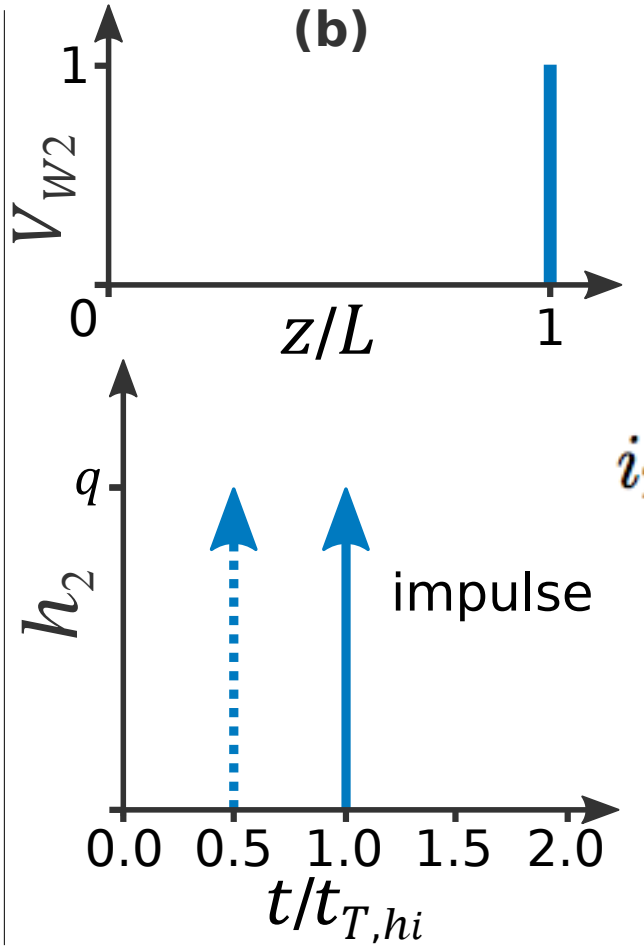
Unipolar Time-Differential (UTD) sensing





$$i_2(t) = -t_{T,hi}\,\frac{\mathrm{d}}{\mathrm{d}t} i_1(t)$$

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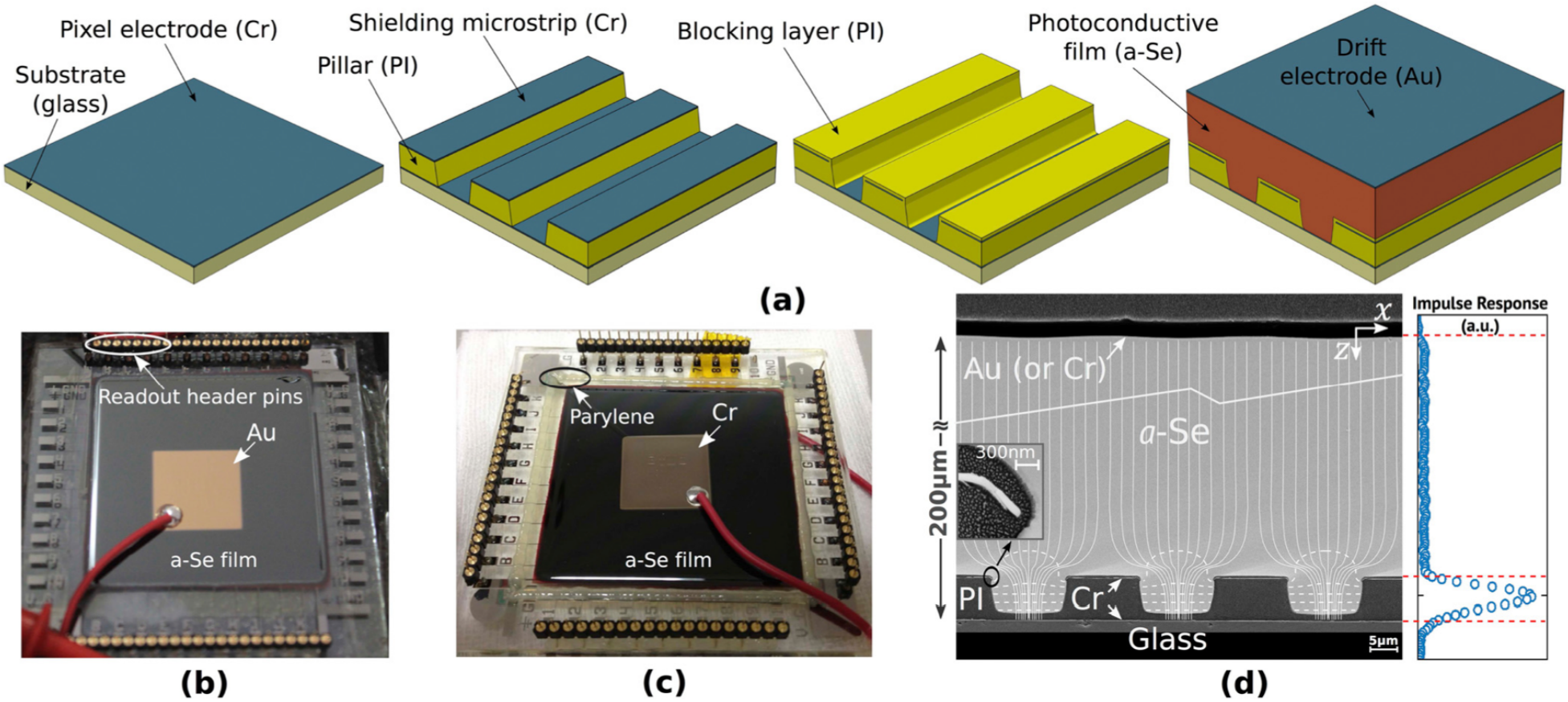
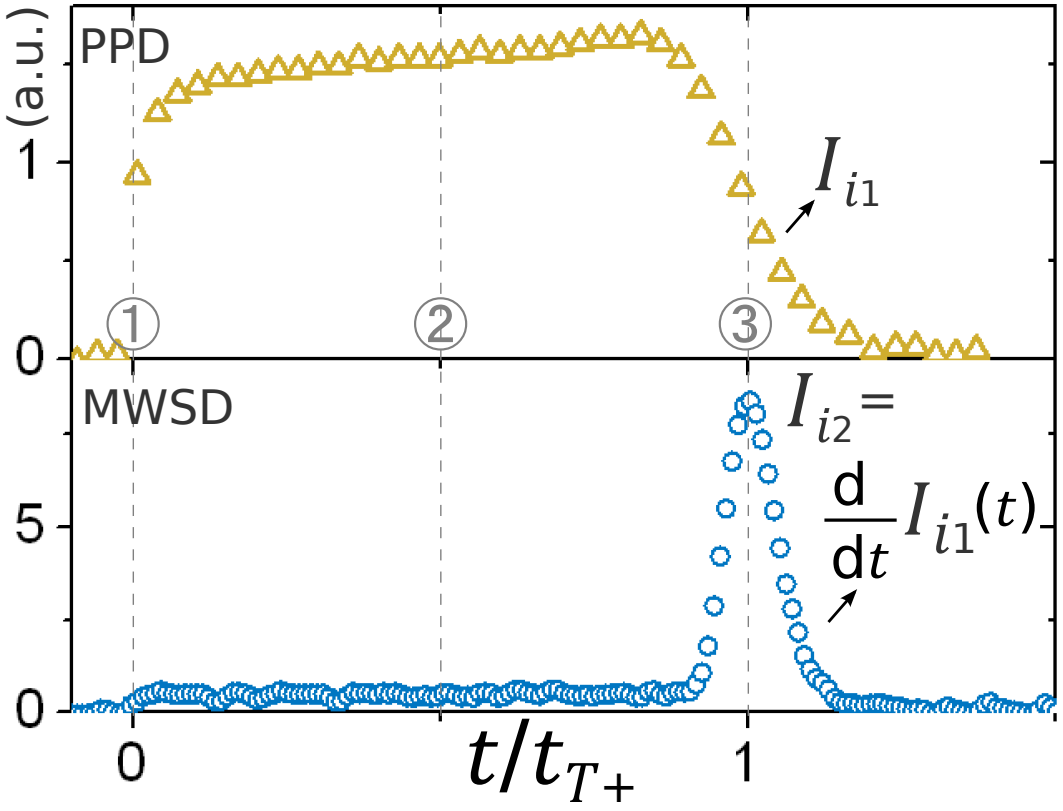
Multi-Well Detectors



A. H. Goldan, J. A. Rowlands et al, *J. Appl. Phys.* **113**, 224502 (2013).

Multi-Well Detectors

Excitation = 5ns laser pulse tuned to λ=337nm.



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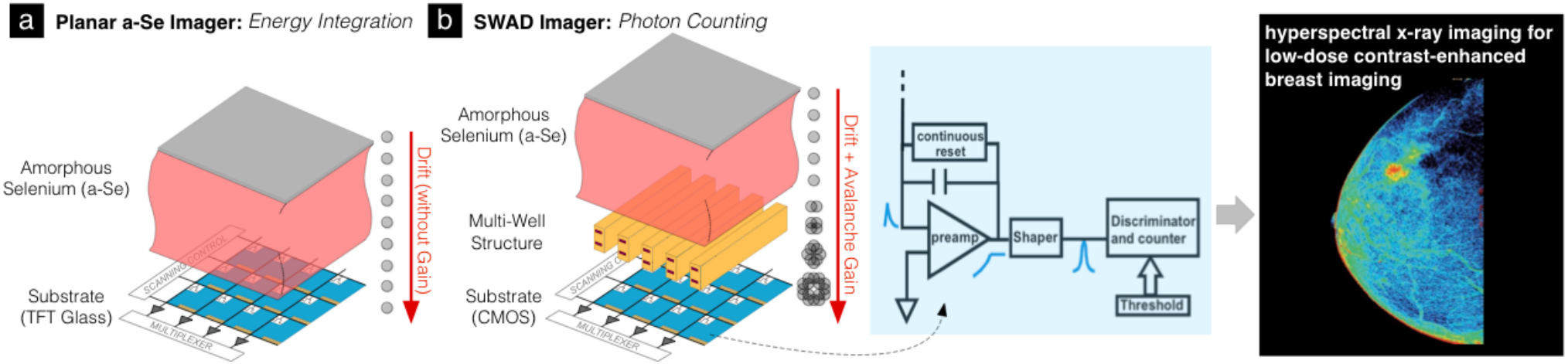
X-ray Photon Counting Detectors



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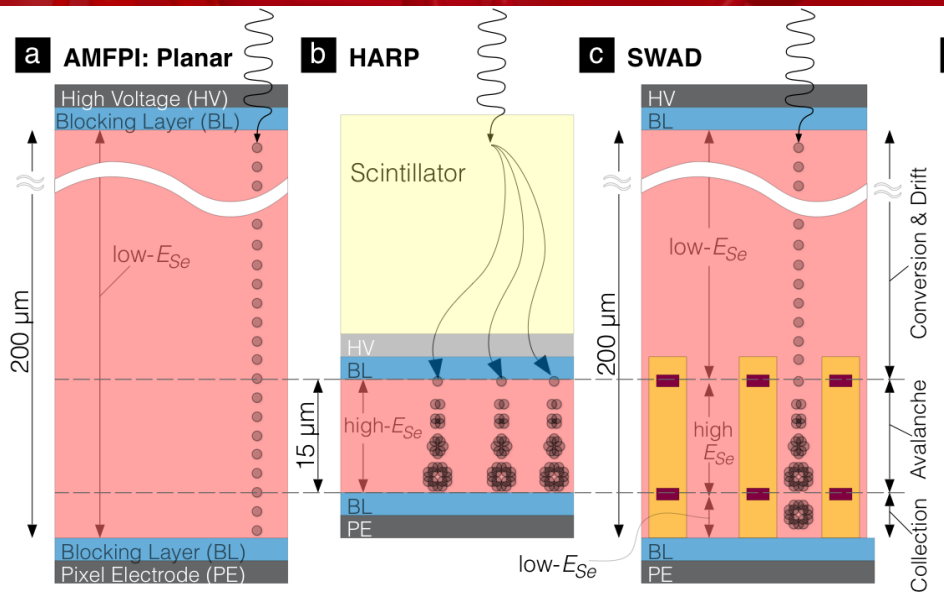
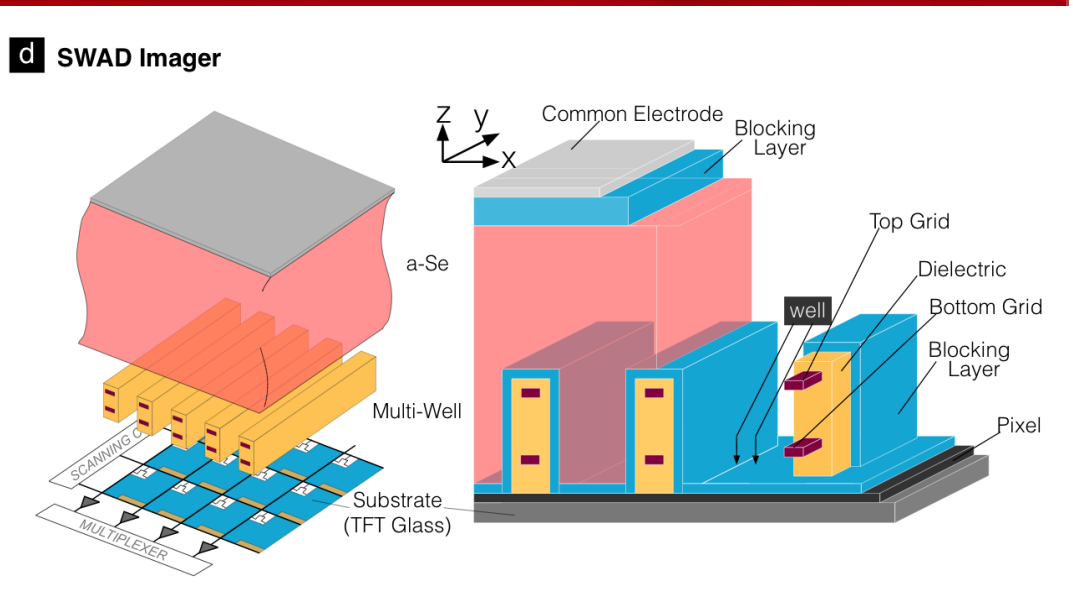
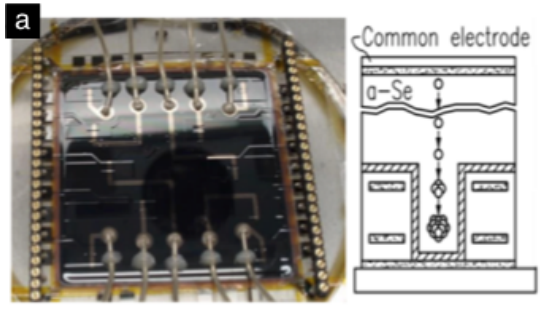
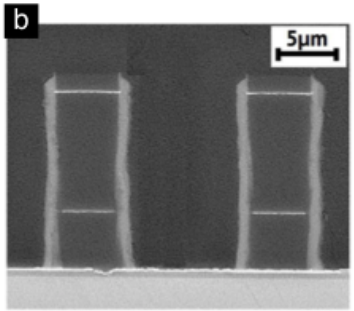
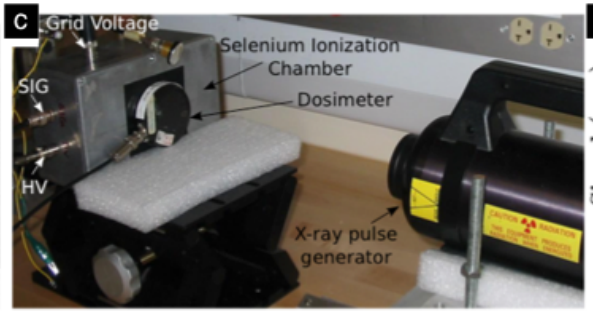
SWAD: field-Shaping multi-Well Avalanche Detector

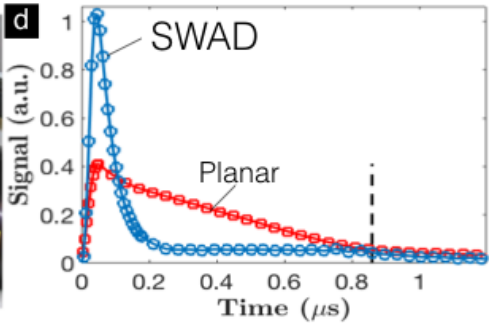












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A. H. Goldan, W. Zhao, *Med. Phys.* **40**, 010702 (2013).

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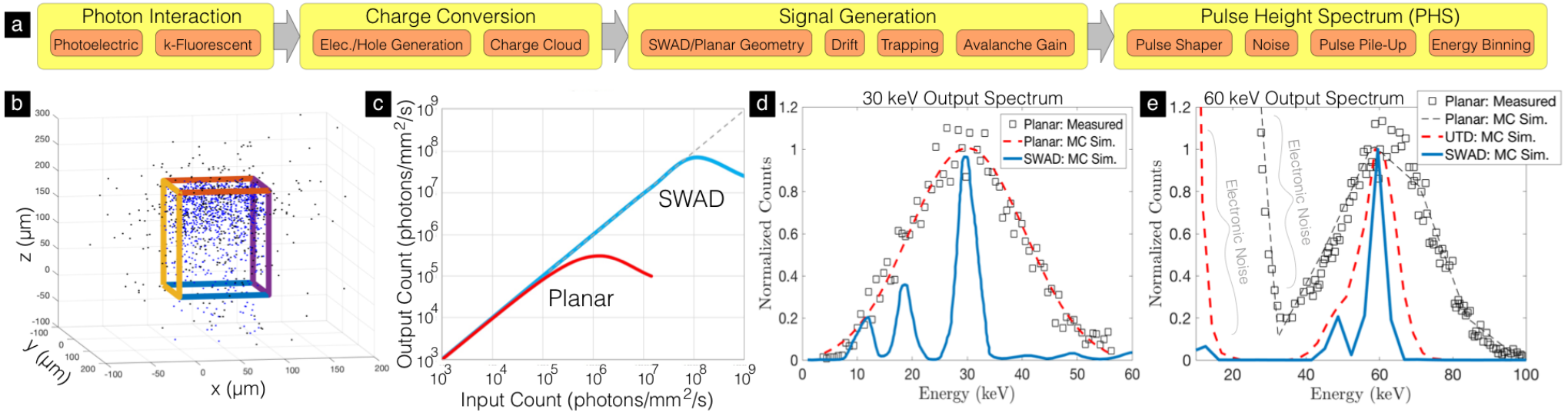
SWAD: Pulse-Height Spectra



J. Stavro, A. H. Goldan and W. Zhao, *J. Med. Imag.* **5**, 043502 (2018).
J. Tanguay et al, *Proc. SPIE* **10573**, 105734V (2018).

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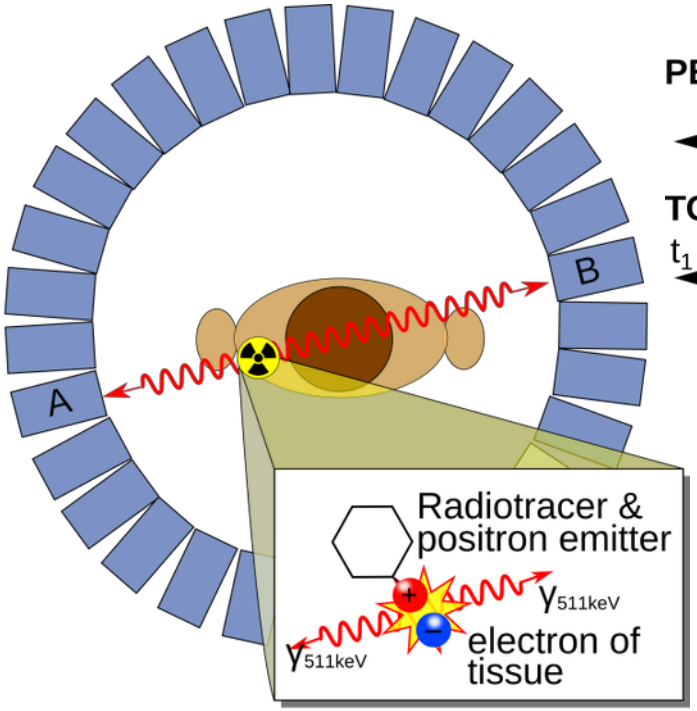
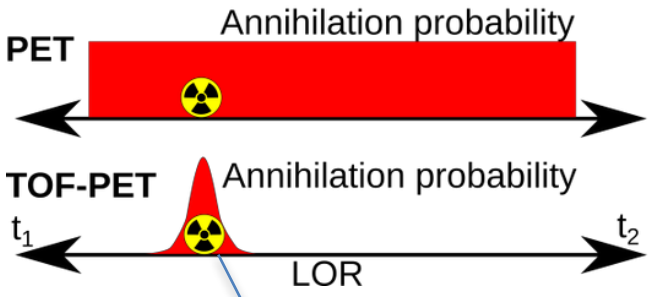
Time-Of-Flight (TOF) PET



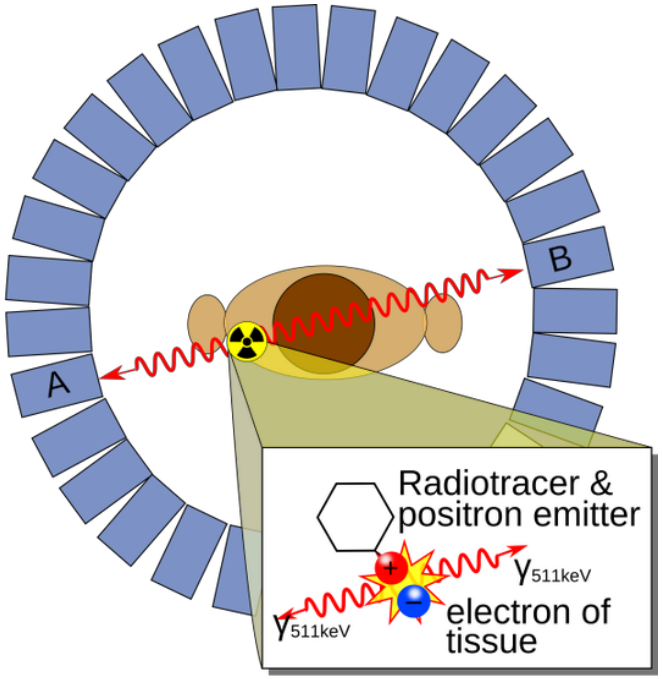


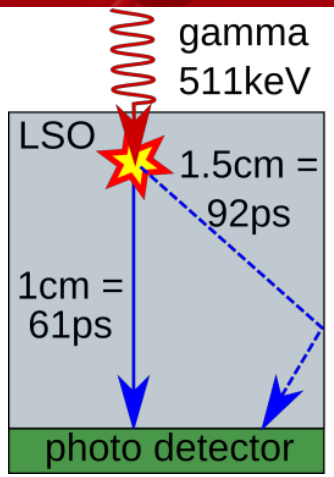
$$\Delta t = \frac{2\Delta x}{c}$$

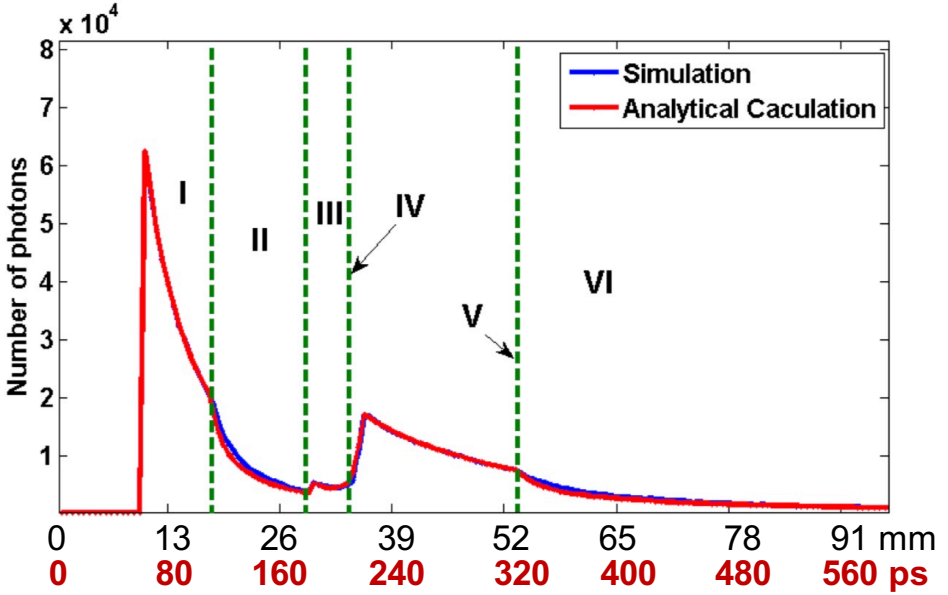
- ✓ Increase SNR
- ✓ Improve lesion detectability
- ✓ Reduce scanning time or radiotracer activity by an amount proportional to the SNR gain
- ✓ Thereby increasing patient throughput or reducing patient radiation dose.

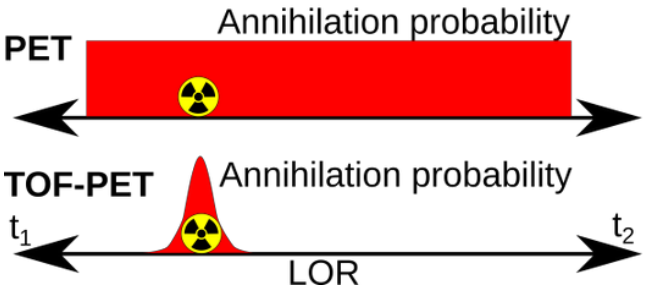
$$\frac{SNR_{TOF}}{SNR_{Non-TOF}} = \sqrt{\frac{D}{\Delta x}} = \sqrt{\frac{2D}{c \cdot \Delta t}}$$

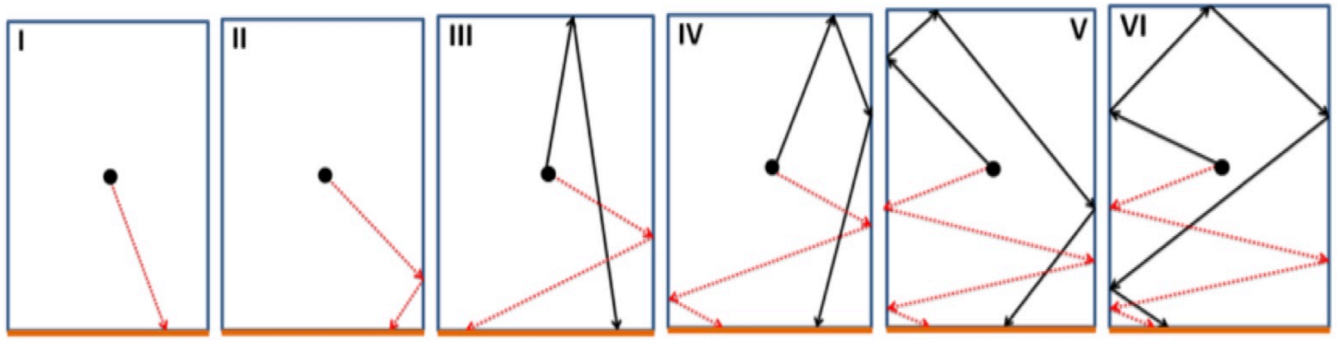
TOF-PET





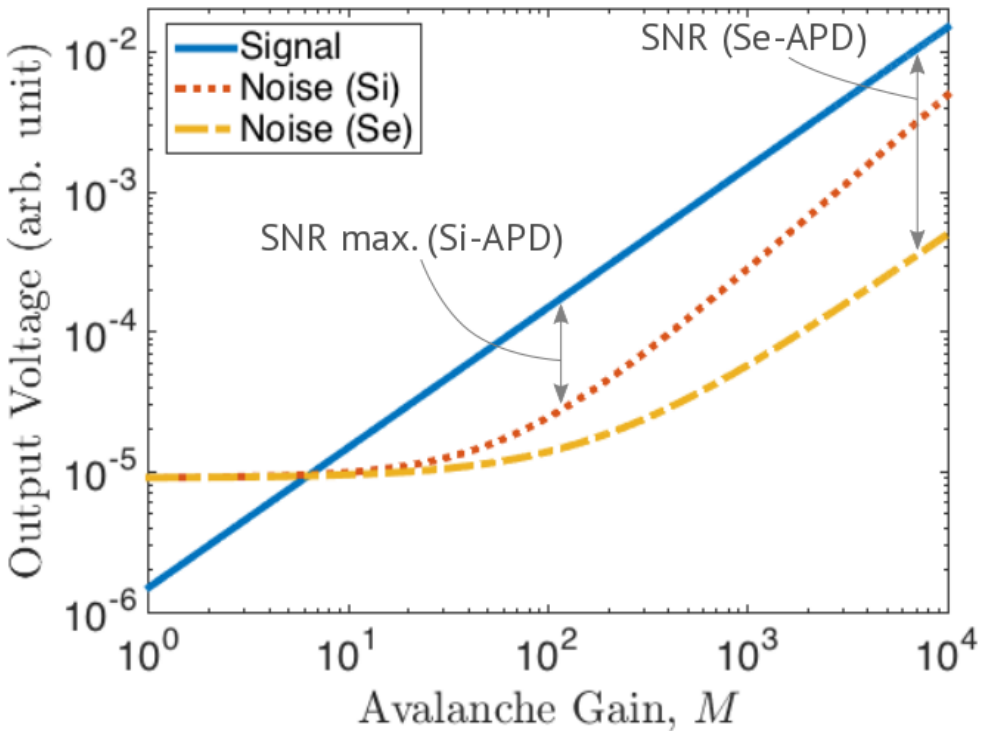


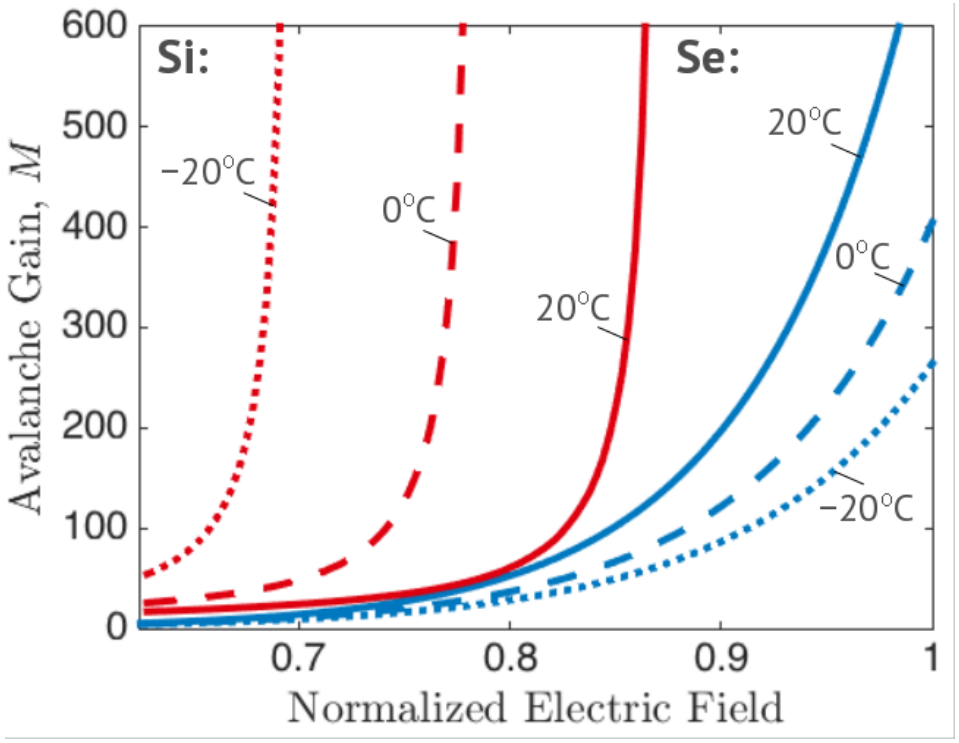




X. Yang *et al*, *Phys. Med. Biol.* **58** (2013).

Silicon vs. Selenium





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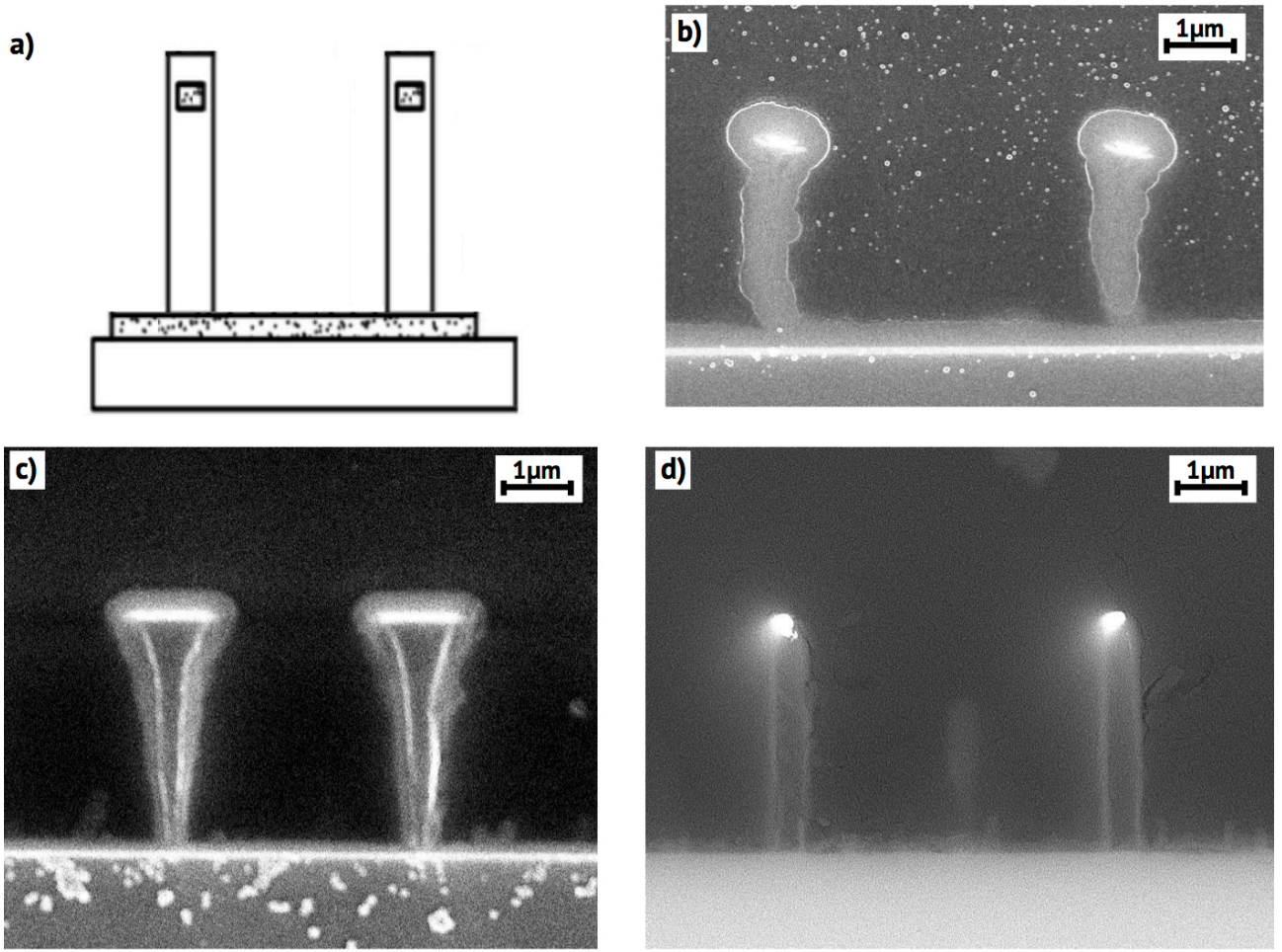
Nano-Scale Frisch Grids



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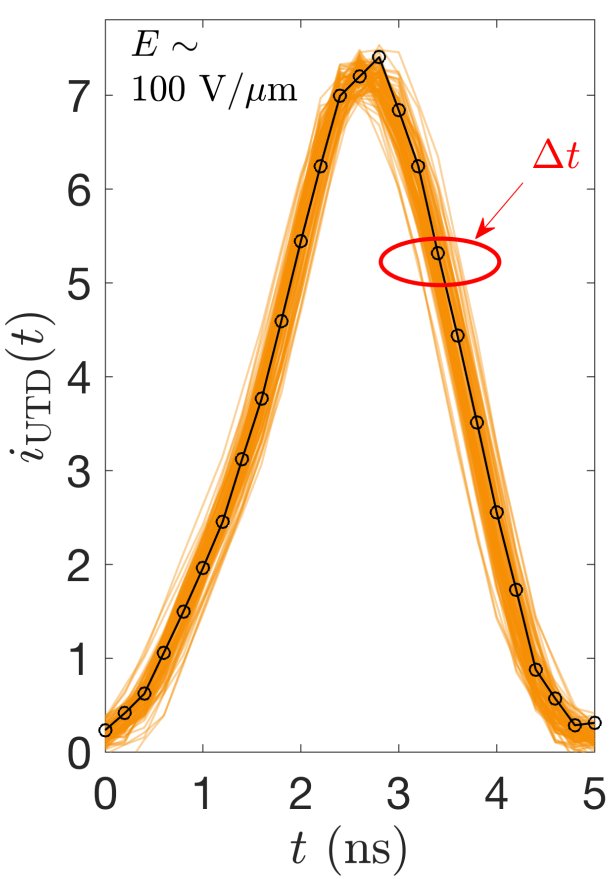
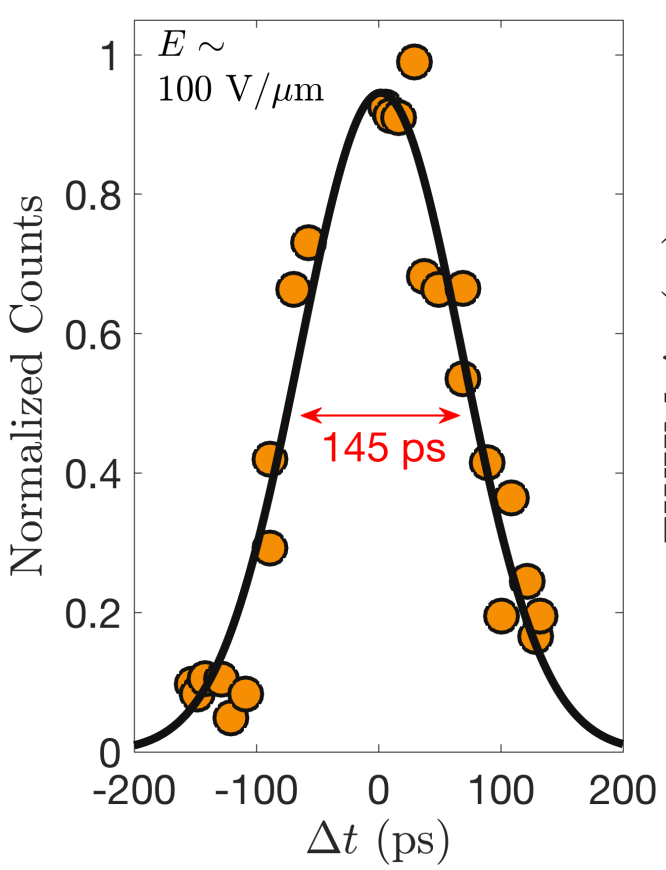
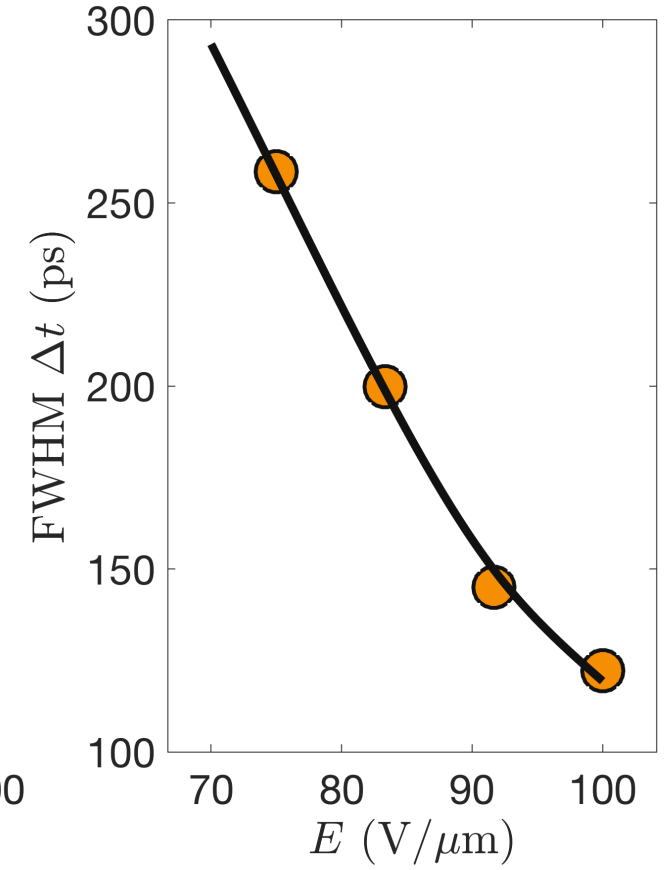
Picosecond Time-Resolution







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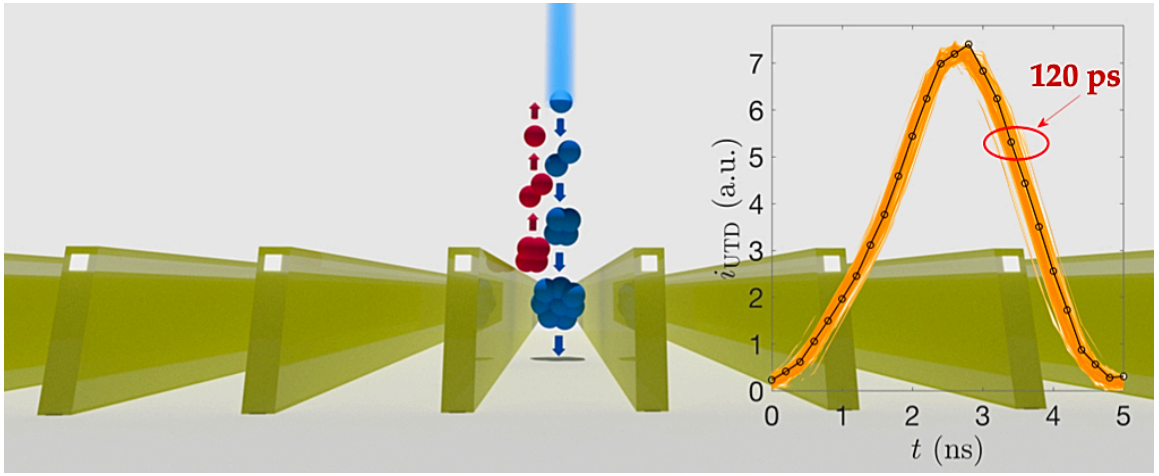
Conclusions

- Amorphous Selenium has tremendous potential as high-sensitivity, large-area, and low cost radiation detector.

- We have reinvented the detector structure using multi-well pixel geometry (with embedded micro- and nano-scale Frisch grids) to obtain avalanche gain and picosecond timing resolution.



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Acknowledgements

- Prof. Wei Zhao
- PhD Students
  - Andrew LaBella
  - Atreyo Mukherjee

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NIH National Institutes of Health
Turning Discovery Into Health

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Thank you!
Questions?