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Intended for: Collaboration discussions
Web

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Advanced X-ray Methods

For PMI in MFE

Zhehui (Jeph) Wang for **UDA** collaboration

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(email: zwang@lanl.gov)

UDA= Ultrafast Detectors & Applications



Sandia
National
Laboratories



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DARTMOUTH



Dec. 2021

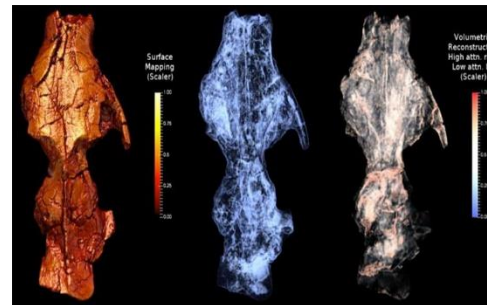
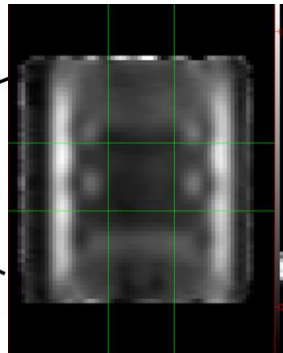
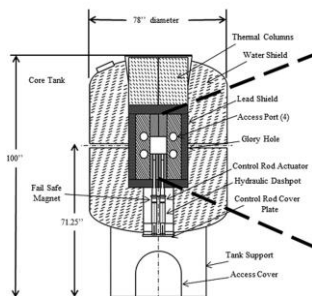
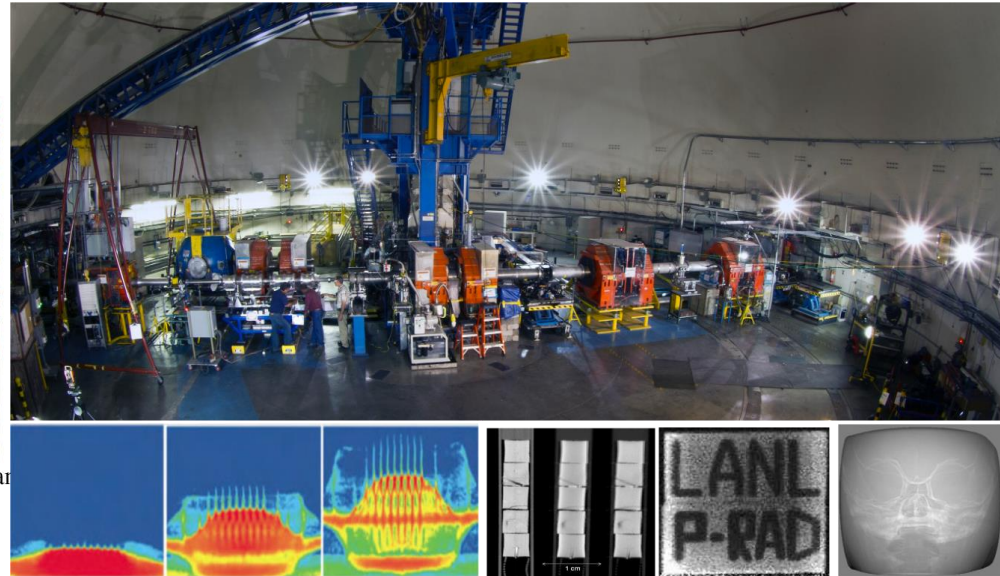
Slide 1

LANL Radiographic imaging

- X-rays, Gamma-rays
- Protons
- Muons
- Neutrons
- Electrons



Figure 1. Aerial view of the Dual Axis Hydrodynamic Test Facility



Perry *et al* (2013)

Nelson *et al* (2018)

Merrill *et al* (2018)

Physics & Technol. of Advanced X-ray imaging

■ X-Ray Sources

- Coherent vs incoherent

■ X-ray Imaging methods

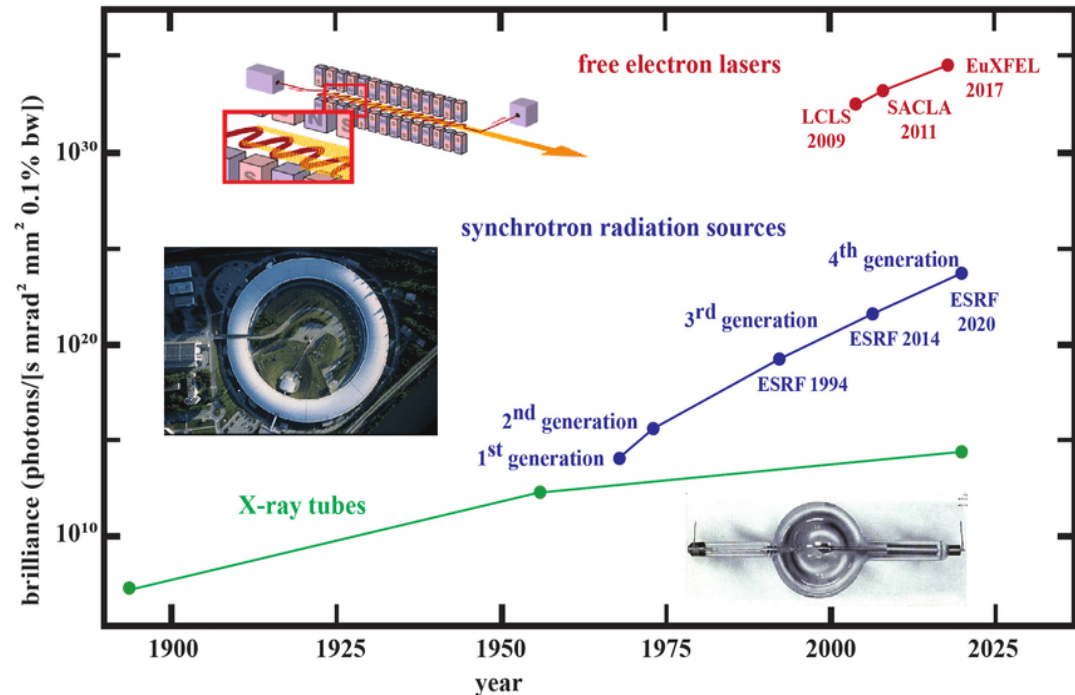
- Propagation, Geometry and Optics

■ X-ray Detector, electronics physics, Noise

■ Data Science & Methods

■ Theory & Interpretation

- X-ray-interaction physics
- Multi-scale multi-physics Simulations



V. Cerantola et al, J. Phys. Cond. Matt. 33 (2021) 274003.



DARTMOUTH

CMOS sensor designs down to pixels



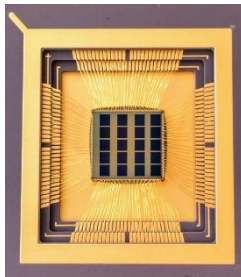
Photon-number-resolving megapixel image sensor at room temperature without avalanche gain

JIAJU MA,* SALEH MASOODIAN, DAKOTA A. STARKEY, AND ERIC R. FOSSUM

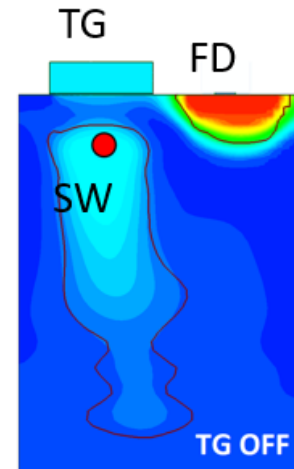
Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire 03784, USA

*Corresponding author: jiaju.ma@dartmouth.edu

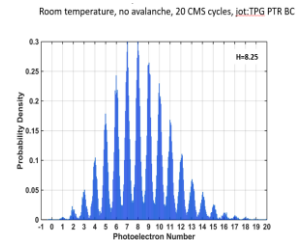
Received 7 July 2017; revised 22 October 2017; accepted 23 October 2017 (Doc. ID 301901); published 29 November 2017



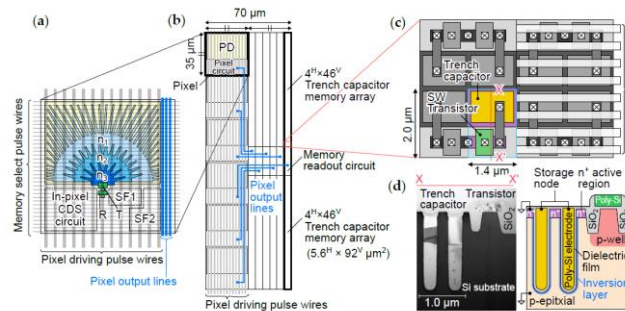
20-Mpixel SPDA



~0.2e⁻ rms noise



Quantized PE

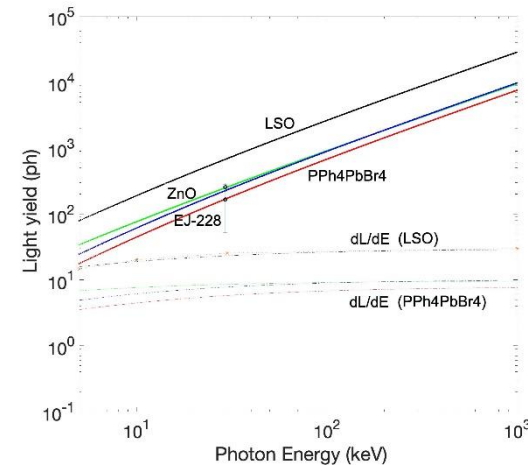
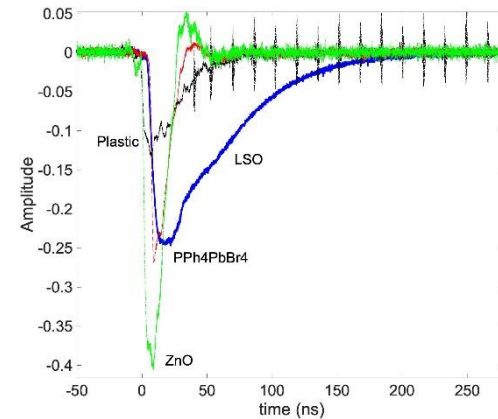
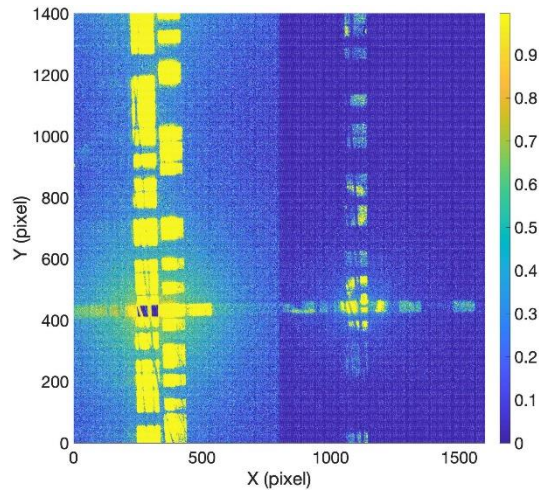
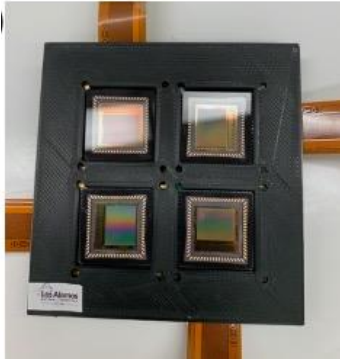


100 M fps+ capability

Suzuki et al, Sensor 20 (2020) 1086

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Large FOV: Billion-pixel X-ray cameras (BiPC-X)



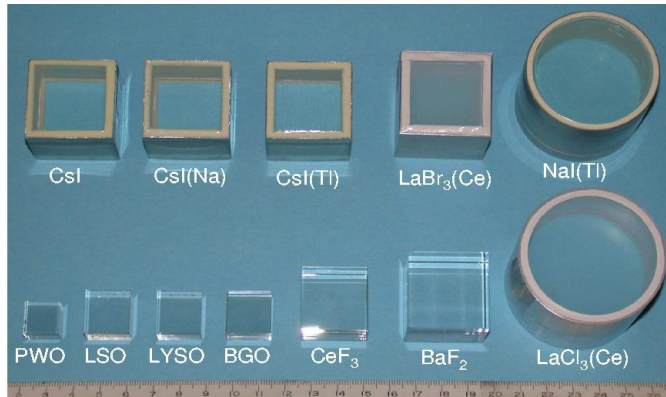
Wang *et al*, Rev. Sci. Instrum. 92 (2021) 043708

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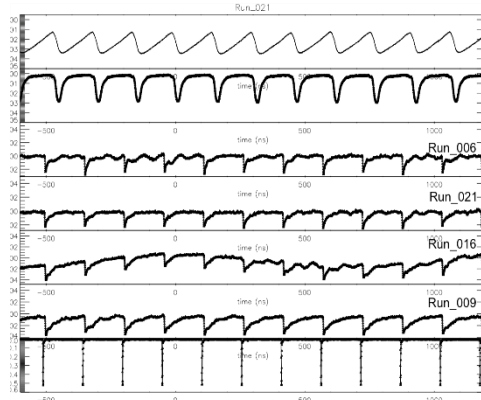
Dec 2021

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Multiple Fast Scintillator Candidates

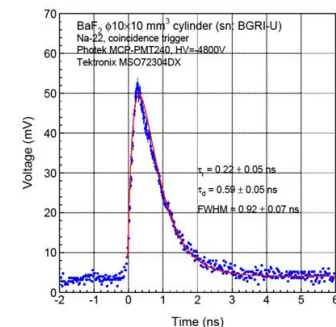


	LYSO:Ce,C ^a	ZnO:Ga	BaF ₂ :Y	YAP:Yb	LuAG:Ce	LaBr ₃ :Ce
Density (g/cm ³)	7.4	5.67	4.89	5.35	6.76	5.29
Melting Points (°C)	2050	1975	1280	1870	2060	783
X ₀ (cm)	1.14	2.51	2.03	2.77	1.45	1.88
R _M (cm)	2.07	2.28	3.1	2.4	2.15	2.85
λ ₁ (cm)	20.9	22.2	30.7	22.4	20.6	30.4
Z _{eff}	64.8	27.7	51.6	31.9	60.3	45.6
dE/dX (MeV/cm)	9.55	8.42	6.52	8.05	9.22	6.9
λ _{peak} ^a (nm)	420	380	300 220	350	520	360
Refractive Index ^b	1.82	2.1	1.5	1.96	1.84	1.9
Normalized Light Yield ^{a,c}	100	6.6 ^e	1.7 4.8	0.19 ^e	35 ^f 48 ^f	153
Total Light Yield (ph/MeV)	30,000	2,000 ^e	2,000	57 ^e	25,000 ^f	46,000
Decay Time ^a (ns)	40	<1	600 0.5	1.5	820 50	16
Light Yield in 1 st ns (photons/MeV)	740	610 ^e	1200	28 ^e	240	2,200
40 keV Att. Length (1/e, mm)	0.185	0.407	0.106	0.314	0.251	0.131



LYSO + PMT 1
Fast plastic + PMT 2
Diamond (Quadrant A)
Diamond (Quadrant B)
Diamond (Quadrant C)
Diamond (Quadrant D)
APS timing pulses

Xie *et al*, NIMA 927 (2019) 287



Hu *et al*, NIMA 950 (2020) 162767



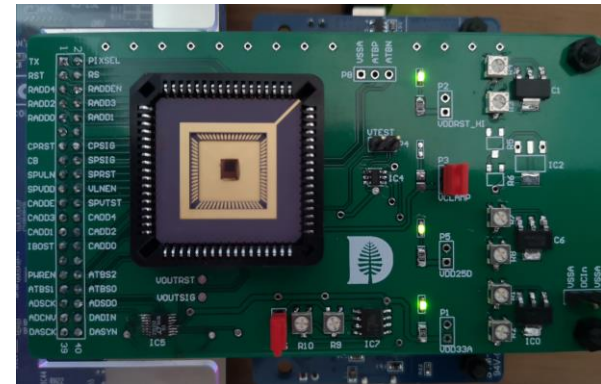
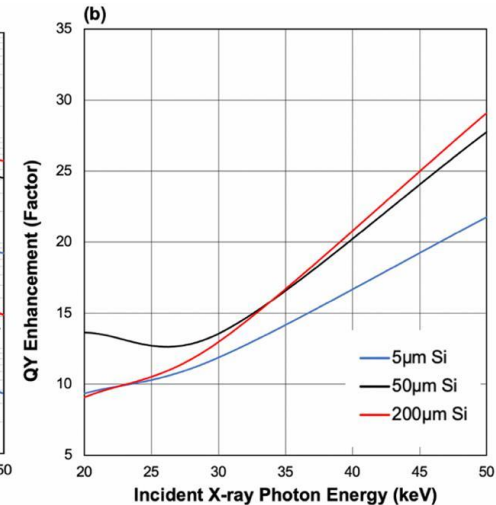
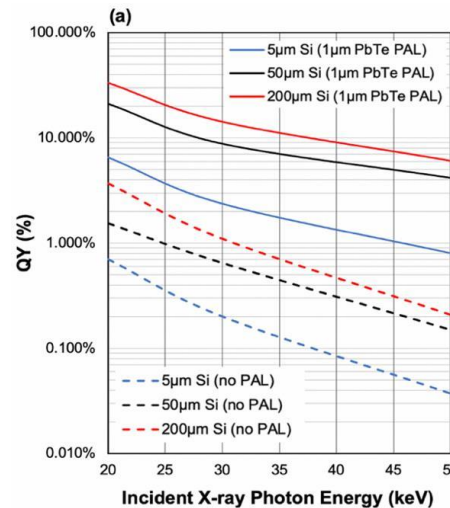
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PAL layer integration with CMOS sensor



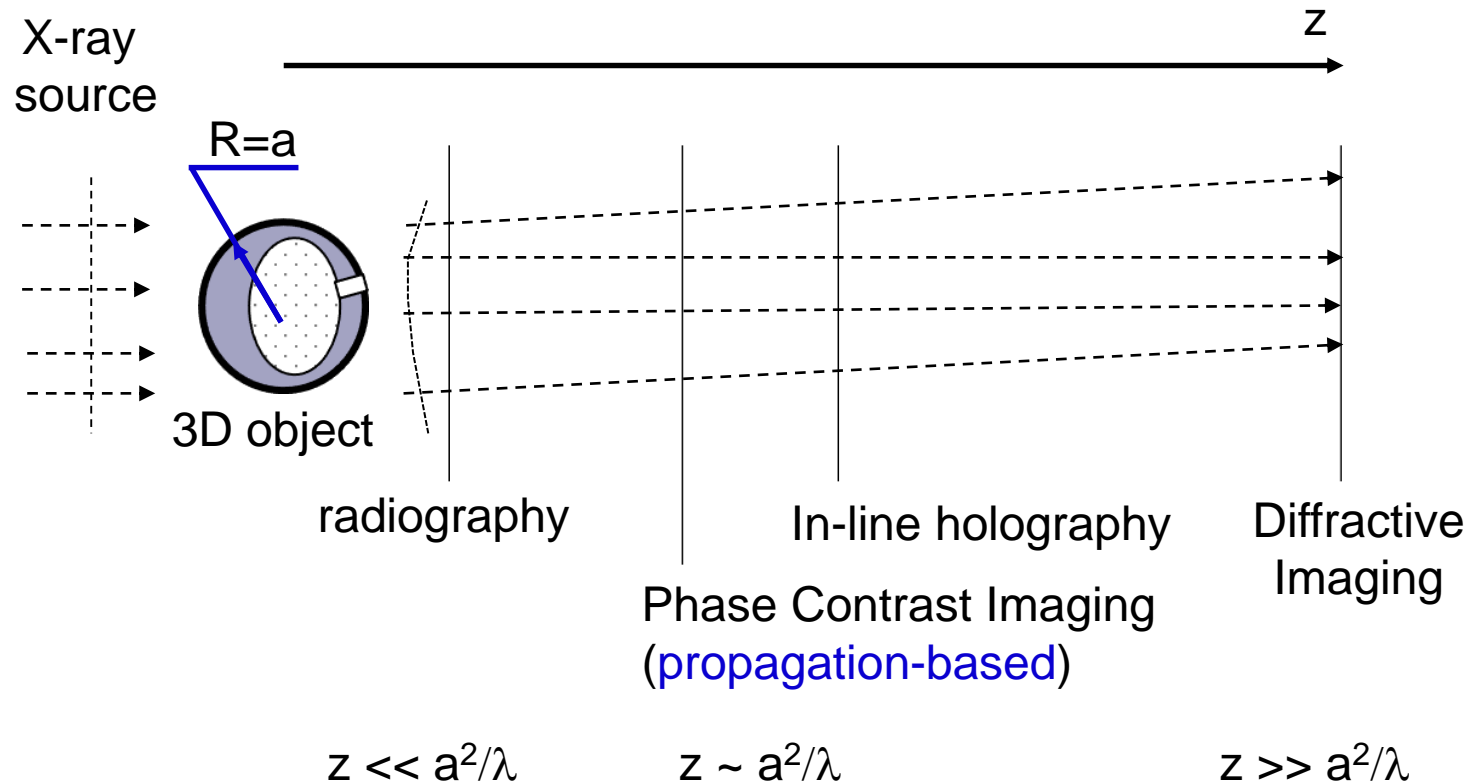
Pixel-level hybridization

Lee *et al*, Instruments 5 (2021) 17

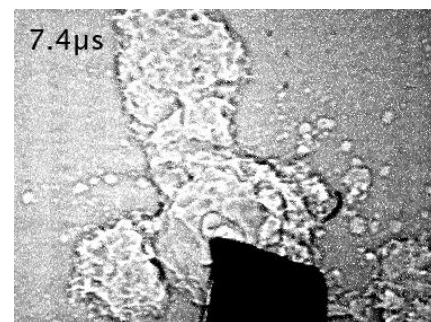
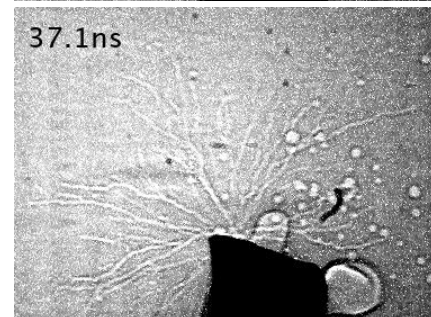
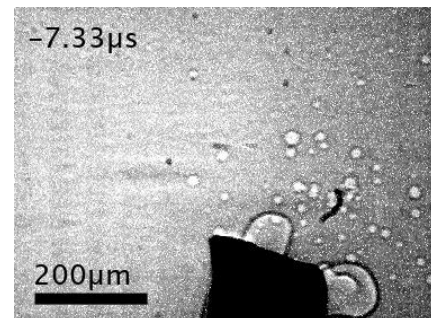
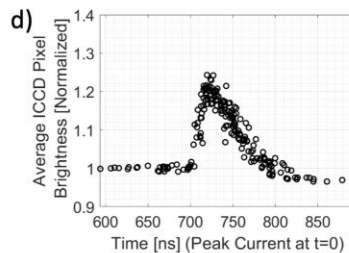
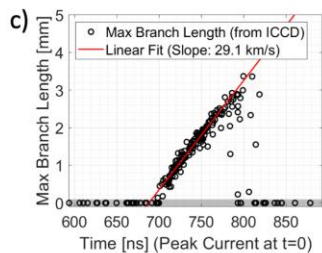
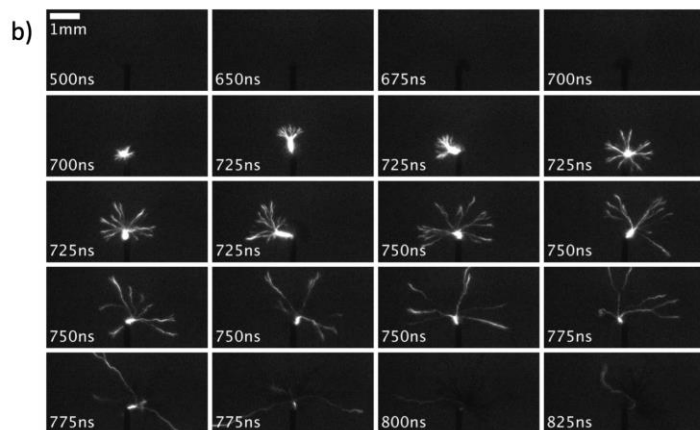
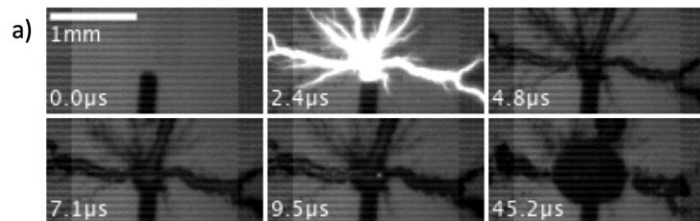


Yue *et al*, (2021)

Geometries of Advanced X-ray imaging

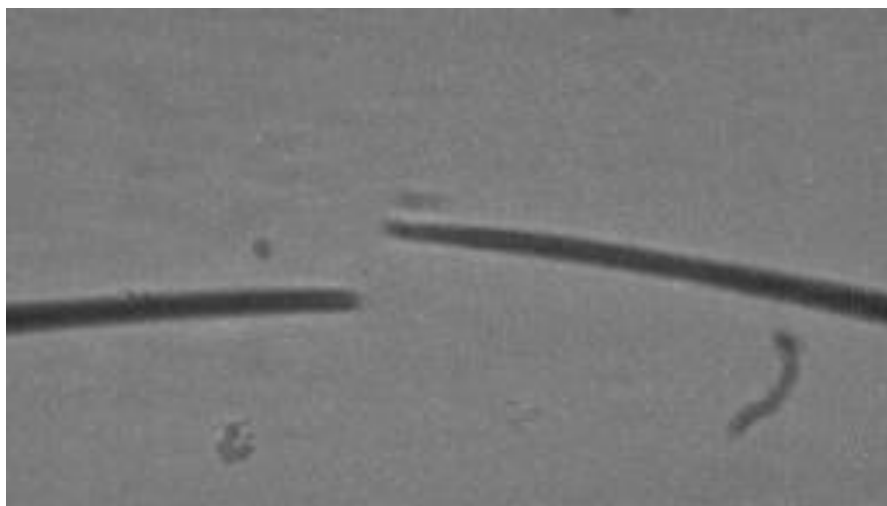


Ultrafast lightning in water

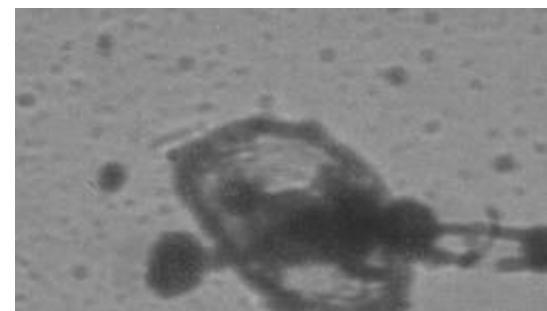
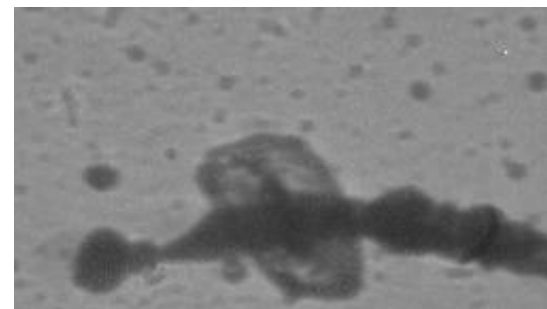
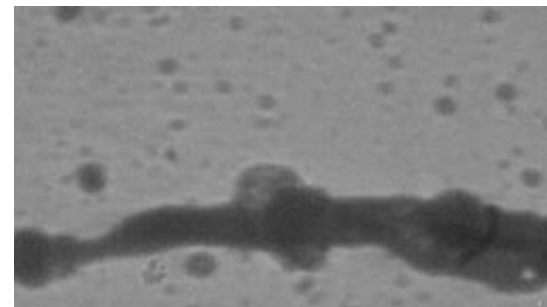


‘ultrafast
lightning
in H₂O’

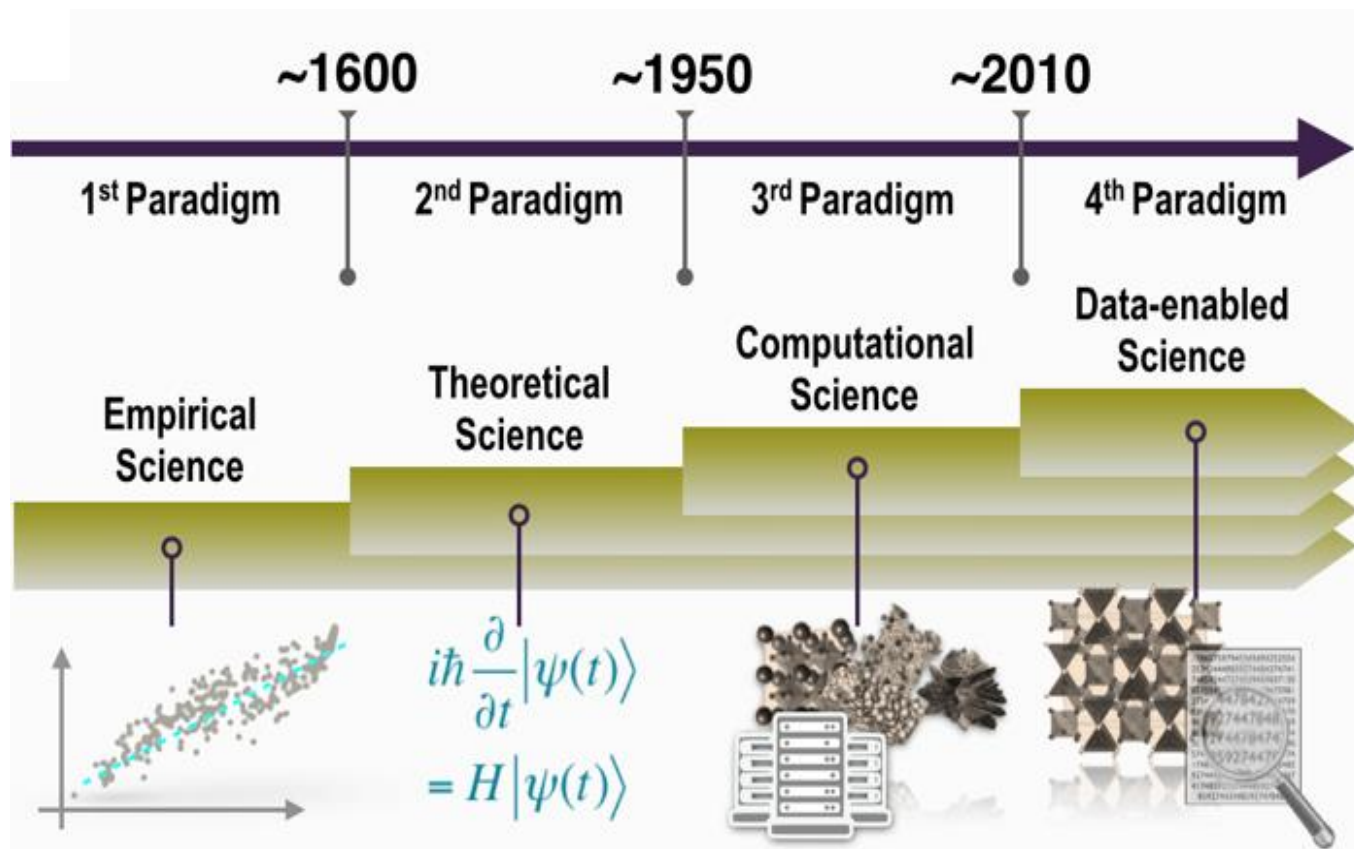
In need of 3D information: X-ray experiment @ APS



~ 100 kfps



Why ML?



Pilania *et al*, J Mat. Sci 54 (2019) 8361

What ML can do?

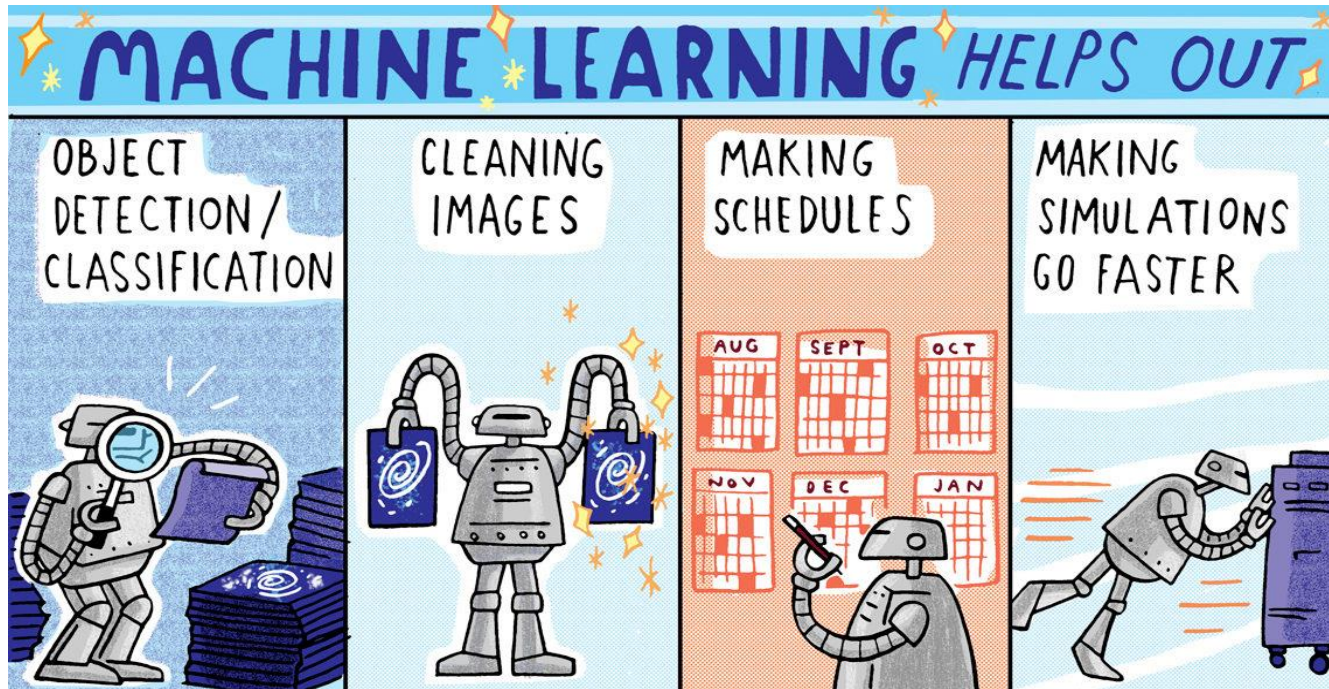
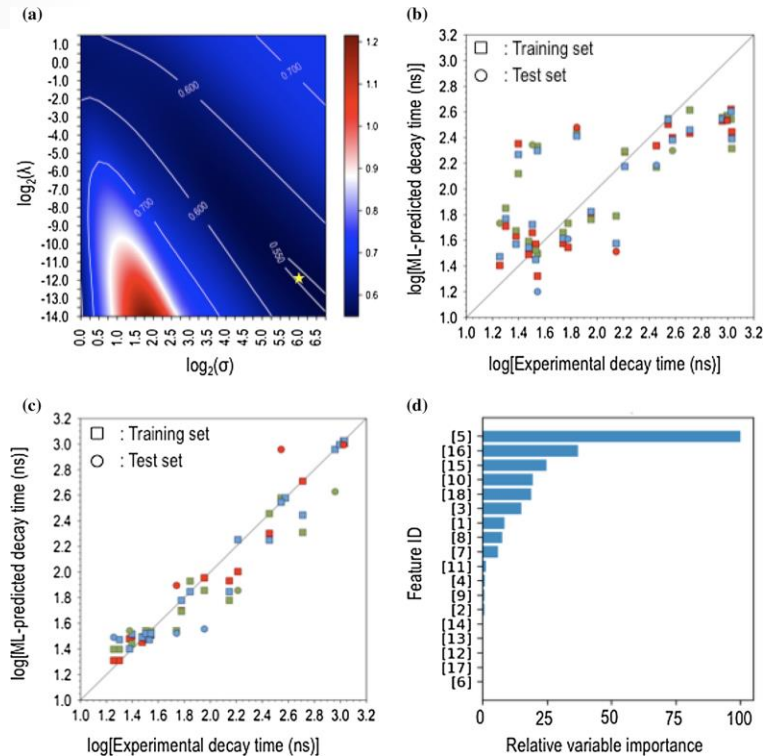


Illustration by Sandbox Studio, Chicago with Corinne Mucha

DFT Computations: Costly and slow

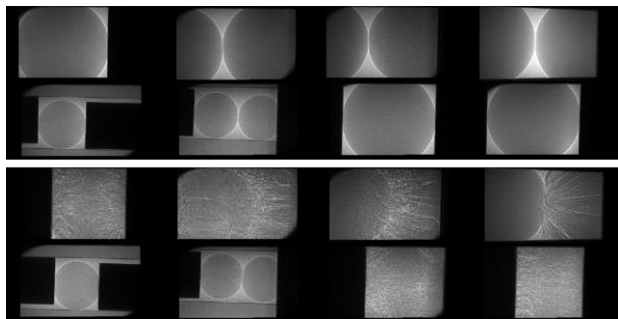


Los Alamos
NATIONAL LABORATORY
EST. 1943

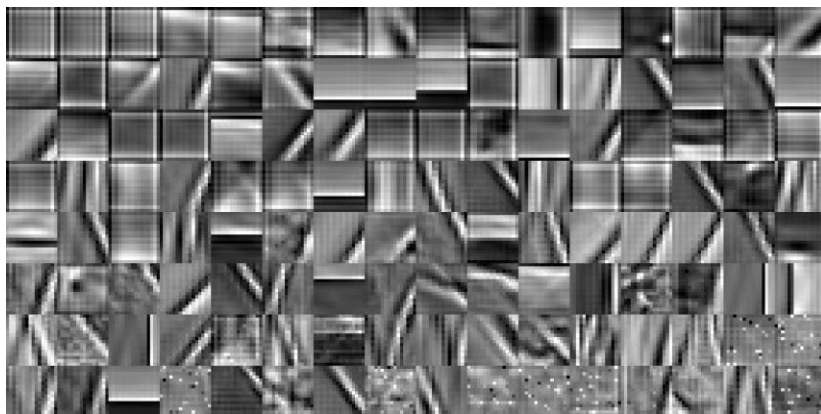
zwang@lanl.gov Slide 13



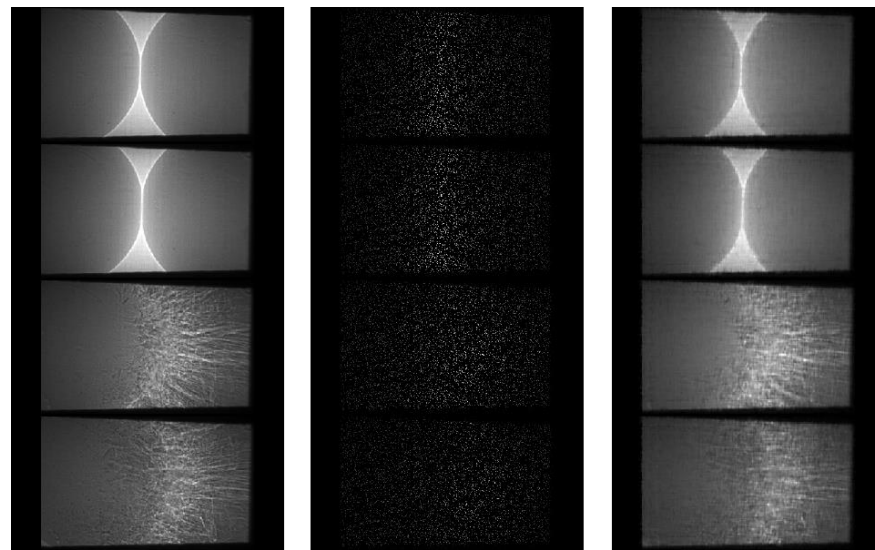
Implementation of Sparse imaging principle



Experiments



Feature extraction



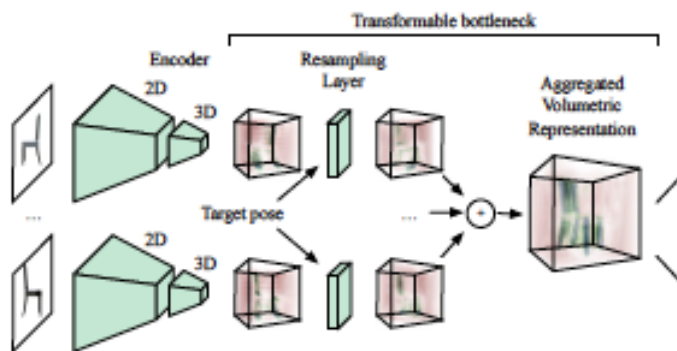
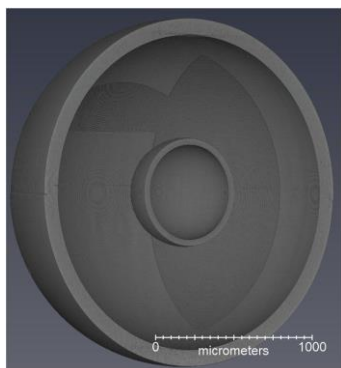
(a)

(b)

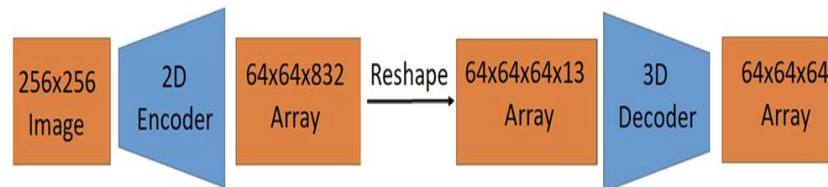
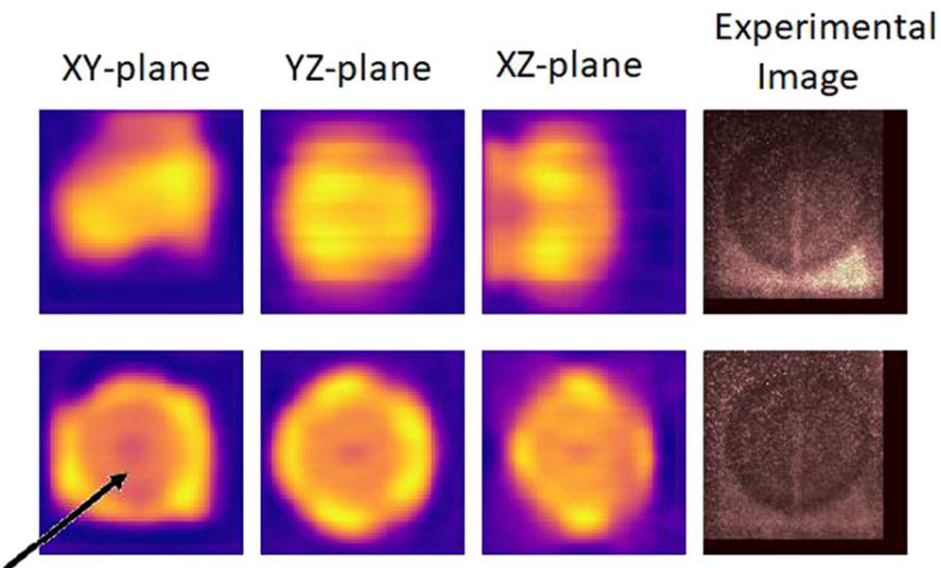
(c)

Validation

3D reconstruction example

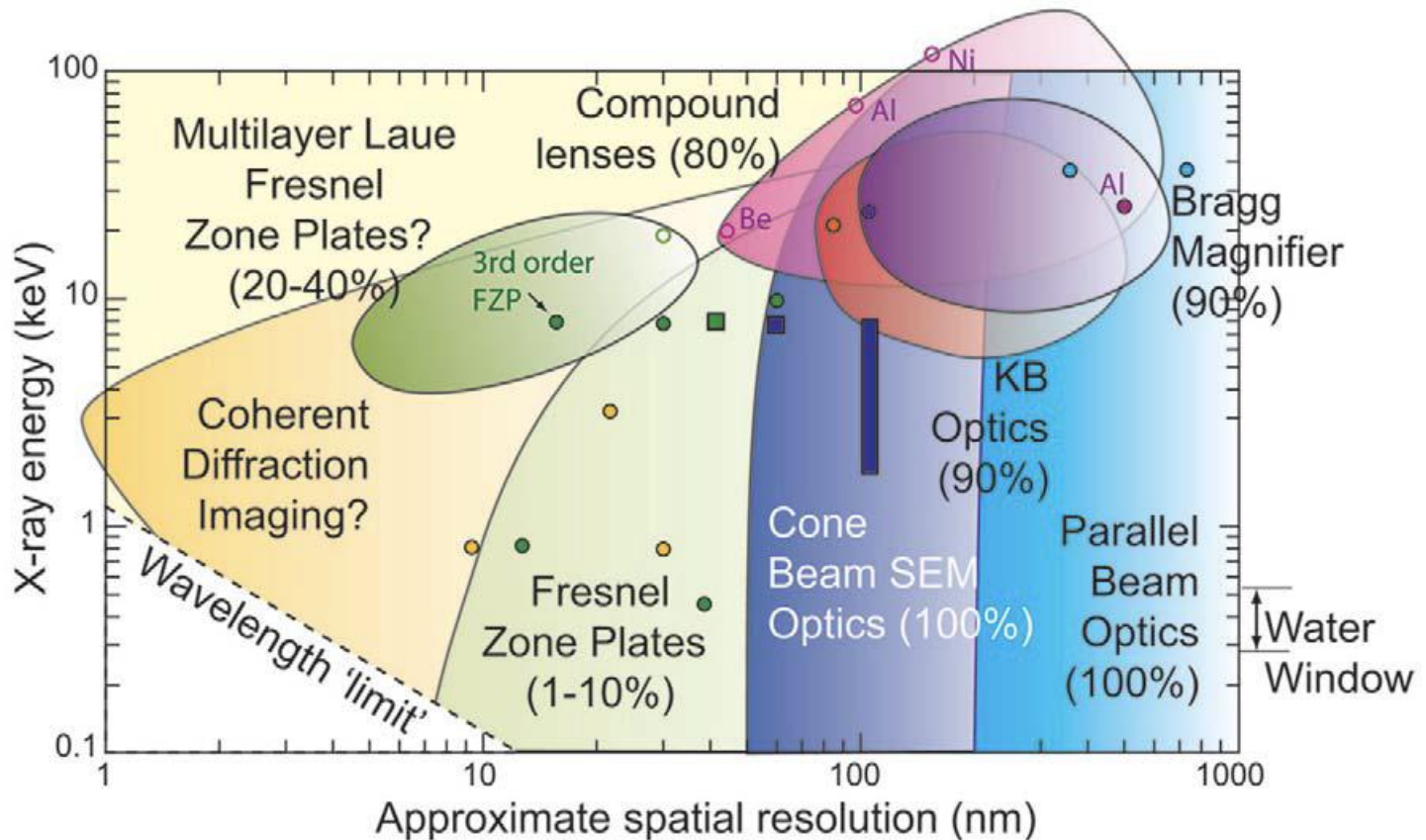


Olszewski *et al*, (2019)



Wolfe *et al*, Rev. Sci. Instrum 92 (2021) 033547

Sub-micron resolutions



Withers (2007)

Summary

- **Flash X-ray radiography (WWII)**

- With Roots in Flash photography

- **Recent trends** (hard-ware driven)

- Increasing number of probes (protons, neutrons, muons, ...)
- CMOS technology & device physics (legacy of the Moore's law)
- Material discoveries (scintillators)
- Hybrid approach (PAL concept)

- **Emergent opportunities** (data-driven)

- data science, machine learning
- New applications for PMI

