LCLS Detector Program
Update

23 April, 2018

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Overview

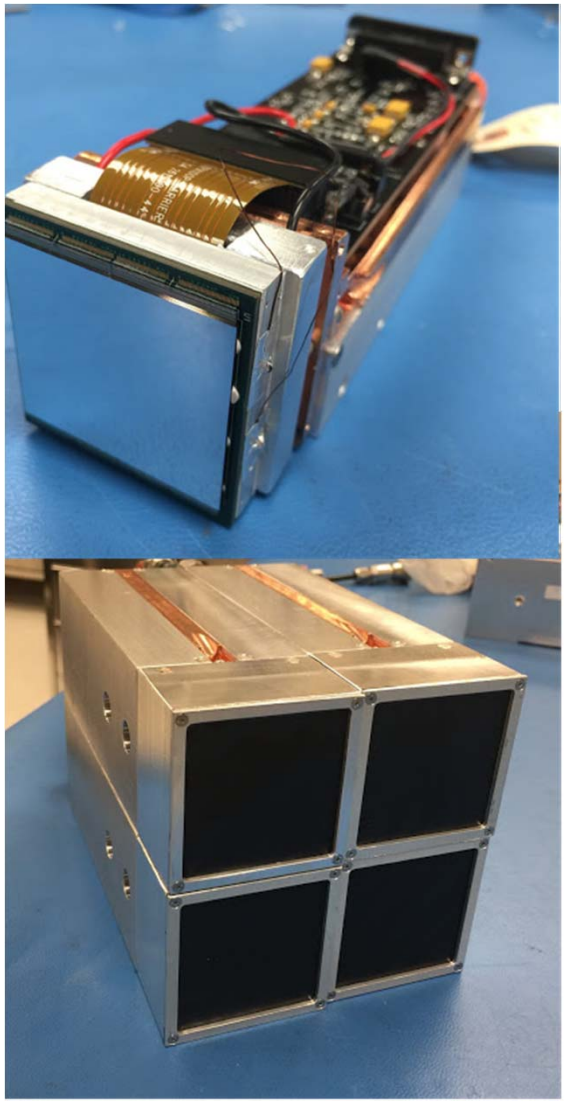
- LCLS Running well with present detector suite ☺
- Heavy development focus on pushing detector technology to match LCLS-II 100kHz rep rates.

- Presented here is a brief summary of the detector program status:
  - Recent development highlights
    - ePix10k LCLS beam test results (February 2018)
    - TES Spectrometer full-string prototype testing (April 2018)
  - Operational status of present detector suite
  - Review of in-work development efforts
  - Phased mapping of development efforts to first-experiments

- *Special thanks to Philip Hart, Kaz Nakahara, and Rebecca Armenta @SLAC, who form the core of the detector effort.*

ePix10k Demonstrated

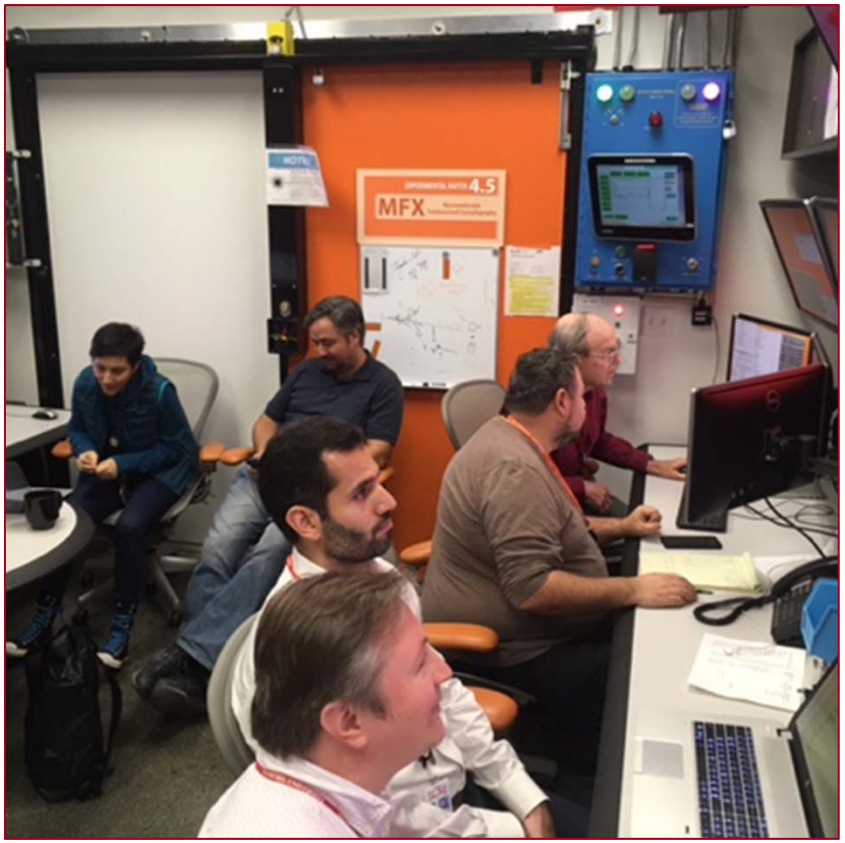
- **New workhorse camera developed by SLAC TID-AIR**, ready to replace aging CSPAD technology.
- Auto-ranging camera, with **single-photon sensitivity**, linear response from zero to 11,000 8keV photons.
- **4x lower noise, 5x higher dynamic range** than CSPAD. Similar 100um pitch.
- **Highly configurable.** Gain can be set independently for each pixel, auto-ranging or fixed depending on experiment.
- **Four 135k pixel cameras complete** and ready for service
- **Large-format 2.1 Mp cameras in process** for test in November 2018.



(images courtesy SLAC/TID-AIR, G. Blaj)

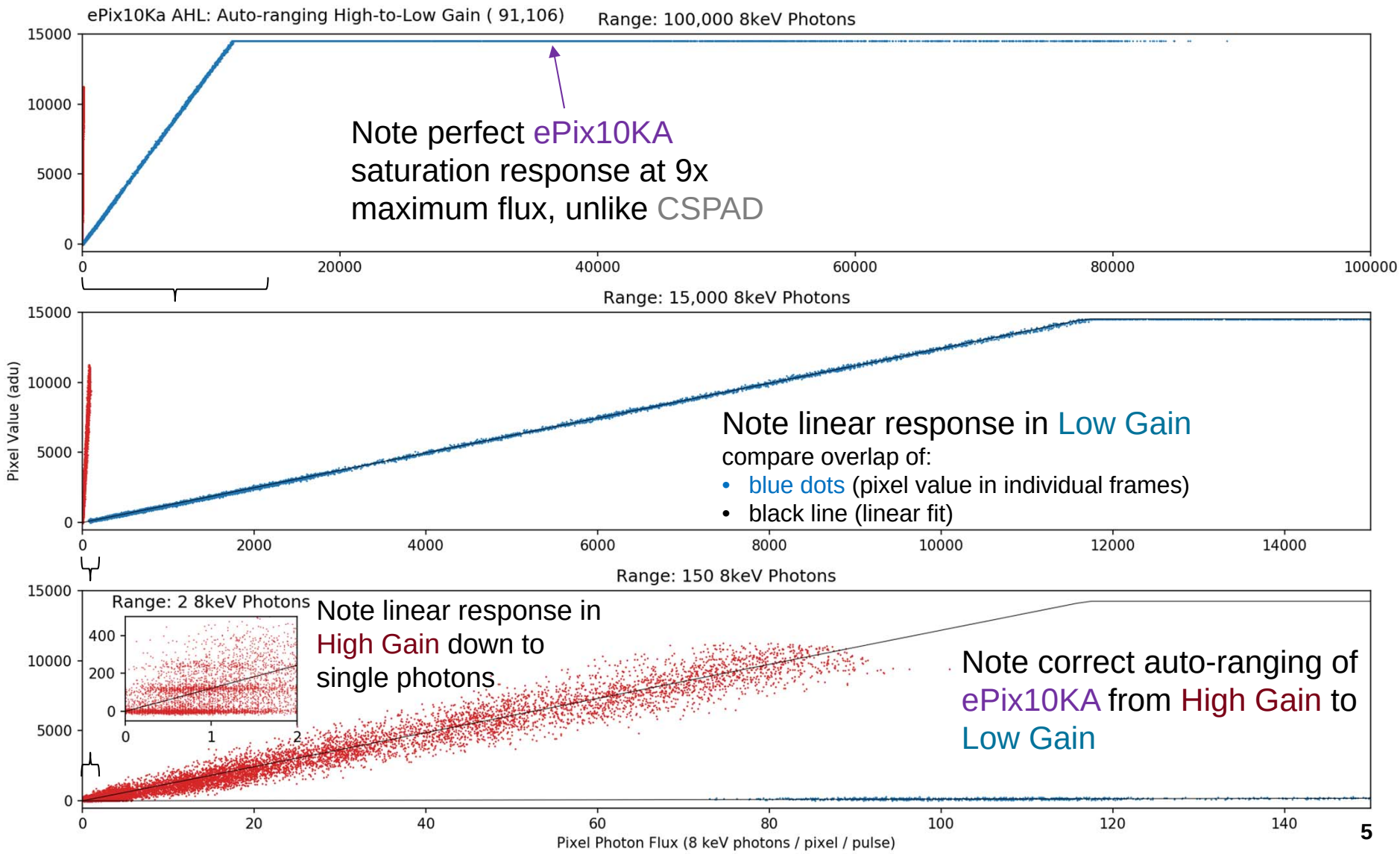
ePix10k Performance Highlights (January Beamtime)

- 5 auto-ranging and fixed gain modes work as designed.
- Range exceeds design specs (8keV photons):
  - High gain: 110 photons
  - Medium gain: 330 photons
  - Low gain: 11,000 photons
- Noise below requirement @67e-
- Single-photon sensitivity demonstrated
- Negligible cross-talk, consistent saturation response.
- Straightforward integration with DAQ/data infrastructure.
- Forward-looking measurements toward higher-rate devices also conducted. Provides path to 25kHz rep rates and beyond.

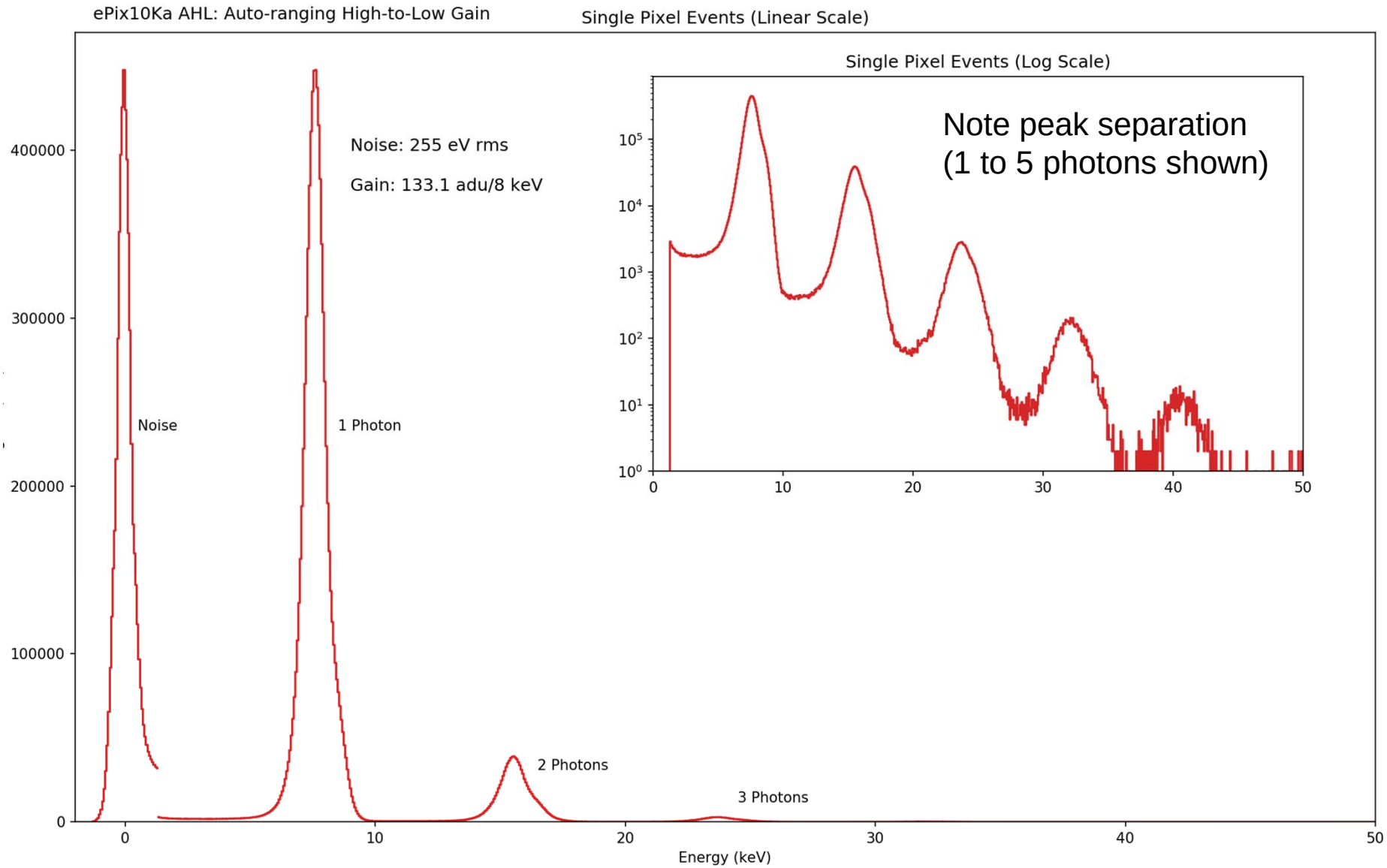


On-beam test at LCLS/MFX, January 23, 2018

ePix10Ka Auto-ranging High-to-Low Gain: Single Pixel Response



ePix10Ka Auto-ranging High-to-Low: Spectrum at Low Photon Flux



ePix10Ka for LCLS-II

- Critical for LCLS-II Cu LINAC:
  - 4-16 keV with Si sensor
  - 16-25 keV with high-Z sensor
- Core detector for LCLS-II Superconducting LINAC:
  - Path to high-rate, high dynamic range area detectors:

$ePixHR_{planar}$
- 5 kHz at first light

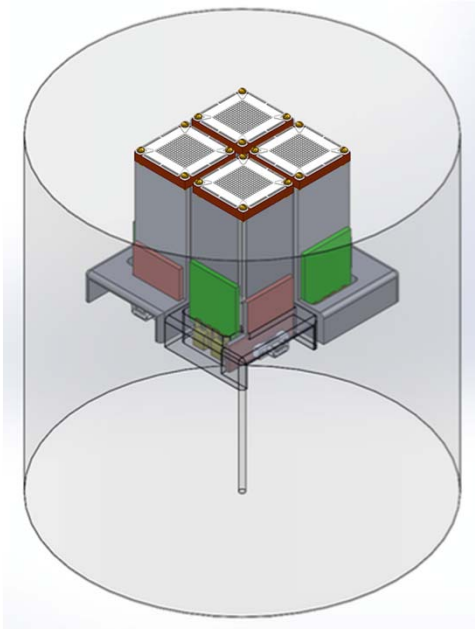
$ePixHR_{2.5D}$
- 25 kHz after 3 years

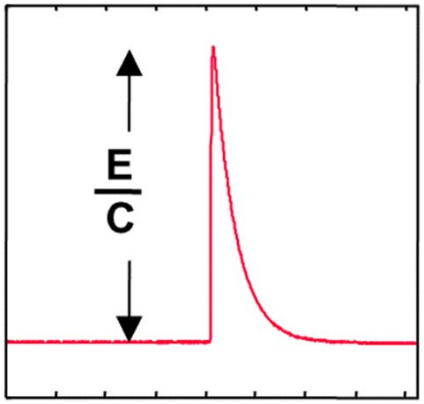
ePixUHR
- 100kHz

ePix10KT (tender)
- Optimized for 2-5 keV
- Noise < 50 e-, Range > 30 MeV

TES Spectrometer Development

- **Superconducting spectrometer for x-ray science.** Builds on maturing technology now used in more than a dozen astronomical and x-ray scientific applications, including synchrotron sources at SLAC and elsewhere.
- **Medium-resolution SXR spectroscopy from a broadband sensor array** with 0.5eV energy resolution at 1keV, 10kHz rep rate.
- **Up to three orders of magnitude gain in efficiency** over existing grating spectrometer**.**
- **LCLS-II first light** development by Stanford, SLAC/TID-AIR, CU, NIST.





(images courtesy SLAC/TID-AIR)

(SLAC, NIST, CU)

Transition-Edge Sensor (TES) Spectrograph

Science: 0.5eV (goal) energy resolution for NEH 2.2 Liquid Jet Endstation; broadband response for x-ray fluorescence. Extension of TES spectrometers successfully deployed at synchrotron light sources, adapted to fast-pulse science.

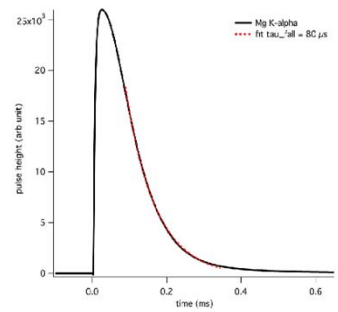
Schedule: First install at LCLS: Mid-2020. Commissioning for first light in 2021

Status: Fast pixel demonstrated at 1eV energy resolution. **Full-string test of prototype hardware conducted at NIST in April 2018**. X-ray pulses observed at T = 40mK, noise sources identified and characterized for refinement of firmware algorithms. Next round of TES sensor designs coming out of fab in the next weeks.

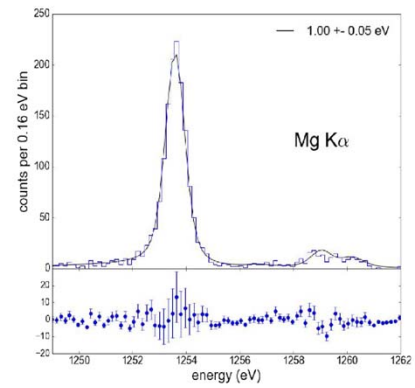
Best Result:

212x106 (2-square) 4-bar, 10% Rn
1.00 eV at Mg (1.25 keV)
Tau_fall = 80 μs

VdV = 1.1 eV
Expect ~ 0.7 eV at low E (when detector is linear)



Slew rates:
This pixel = 2.2 A/sec @ 1.25 keV
Fastest pixels ~ 4.5 A/sec



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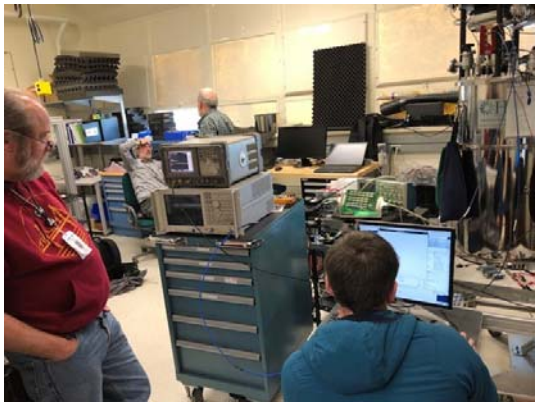
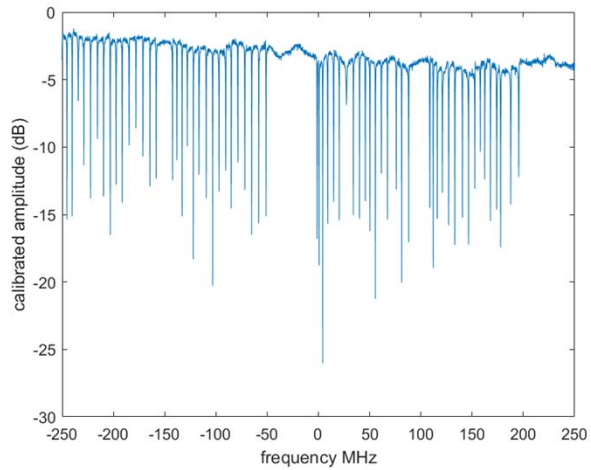




Photos from TES testing at NIST Quantum Sensors Laboratory, 4/3/18

Operational LCLS Detector Suite

Detector Type	Format	Pixel Pitch	Uses	Comment
CSPAD *- Workhorse, becoming obsolete with ePix10k availability*	140kpix	110μm	XPP, XCS, MFX, CXI	19 units, 2 need repair
	0.5Mpix (quad)	110μm	MEC	4 units, 3 in test, 1 good
	2.3Mpix	110μm	XPP, XCS, MFX, CXI	3 units
ePix100	0.5Mpix	50μm	XPP, XCS, MFX, CXI, MEC	10 units, 3 in test
ePix10k	0.13Mpix	100μm	XPP, XCS, MFX, CXI, MEC	4 units
pnCCD	1Mpix	75μm	AMO, SXR	1 unit
Rayonix MX170	16Mpix	44μm	XPP, MFX	1 unit
Jungfrau	1Mpix	75μm	XPP, XCS, MFX	1 unit
	0.5Mpix	75μm	XPP, XCS, MFX	1 unit

Detector Development Projects

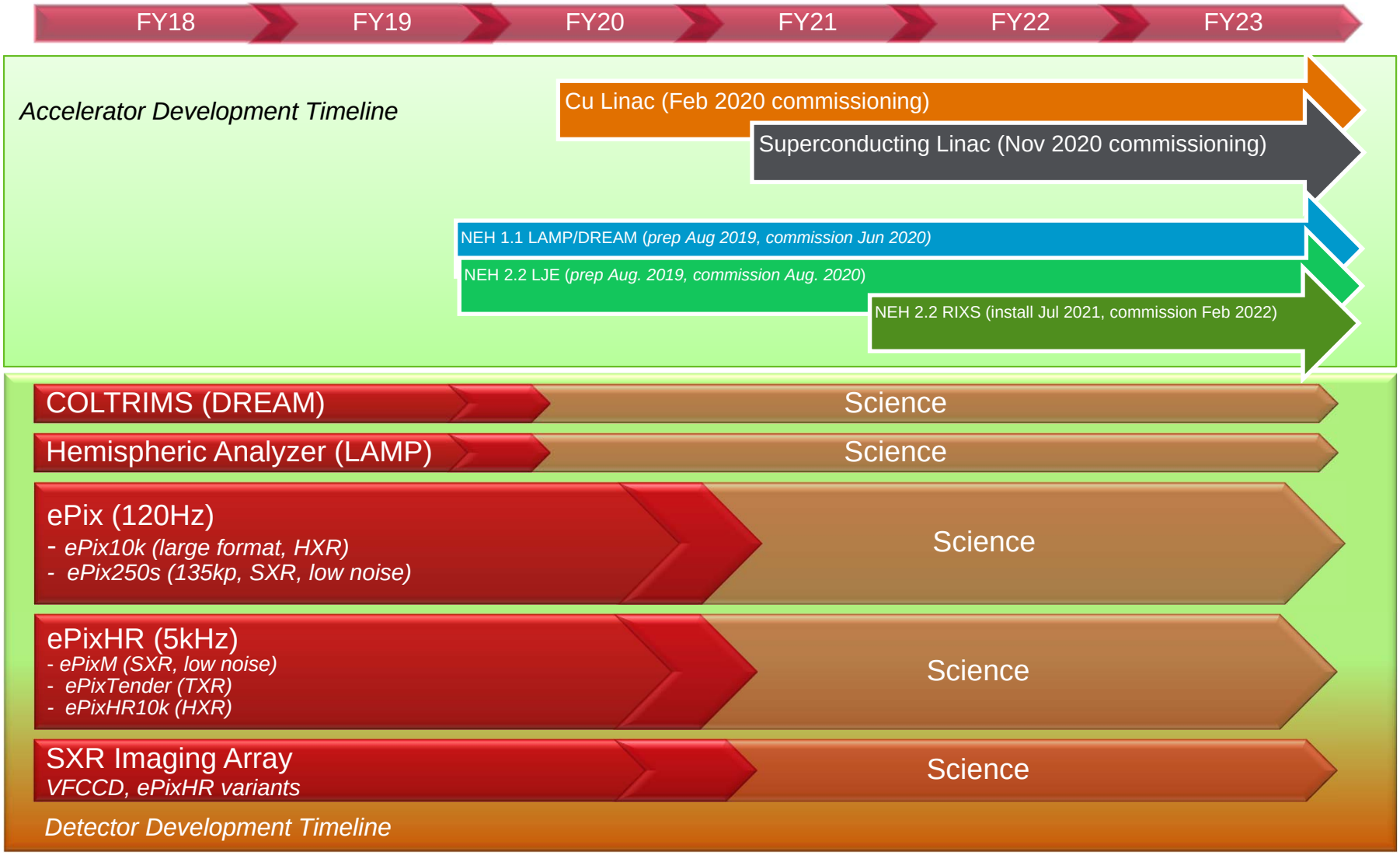
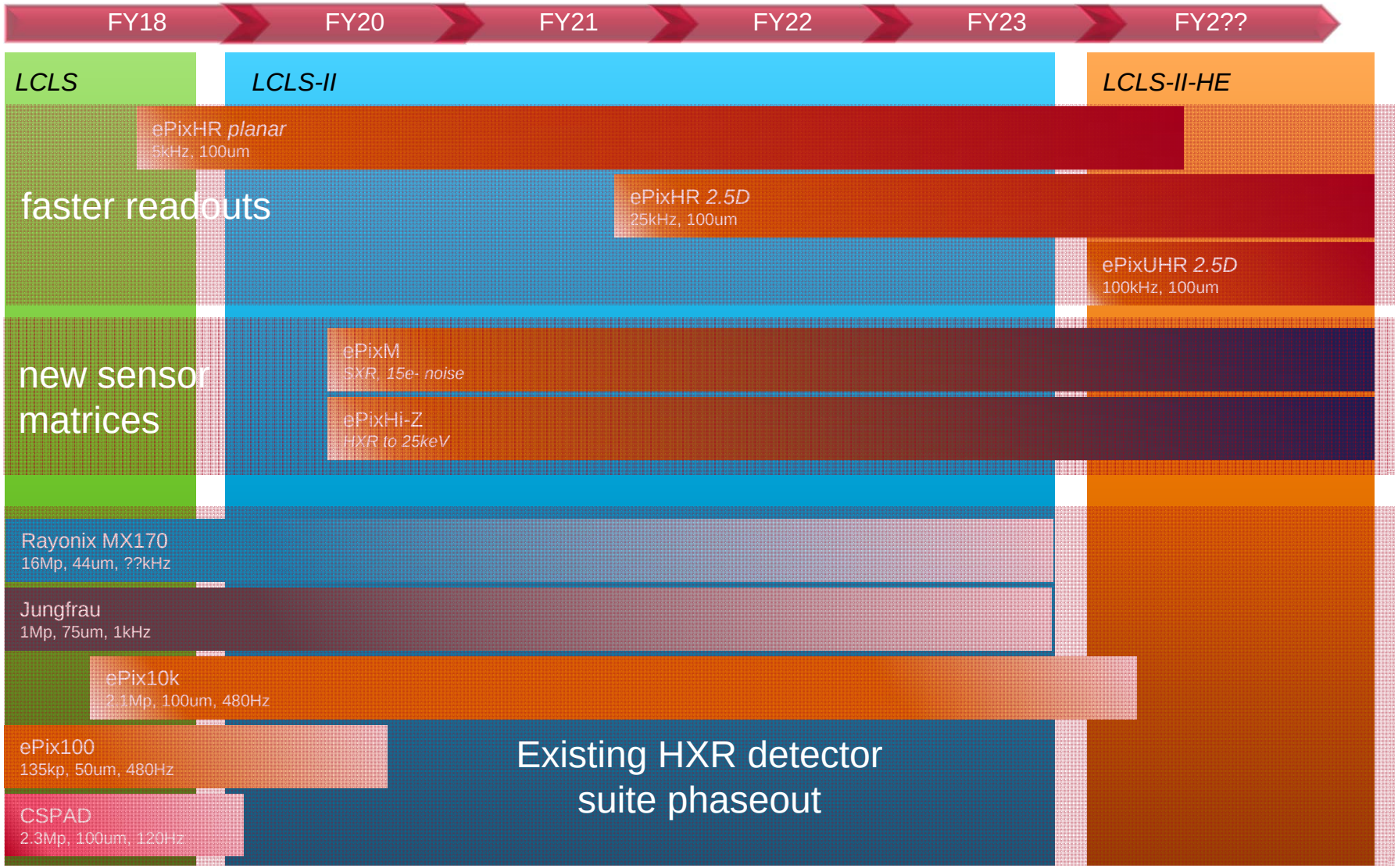
Application	Project	Partners	Comment
Spectroscopy	TES Spectrometer	SLAC, NIST, CU	0.5eV resolution, LCLS-II first light
	RIXS CCD	Commercial/custom	first-light test in Run17
Scattering/imaging tender/hard	ePixHR	TID-AIR	High speed evolution of ePix ASIC, 5kHz @ first light, path to 25kHz.
	ePix10k	TID-AIR	Demonstrate low-noise, gain switching, high-speed detector unit cell, working.
	Jungfrau	PSI (COTS)	2KHz rep rate (NIH grant, adapting 4Mp for vacuum use)
Scattering/imaging soft	ePixM	TID-AIR	Monolithic, high-speed detector for SXR, 15e
	VFCCD	LBL	5-10kHz, 1Mp phase II, firs
Particle detection	Tixel	TID-AIR	Time of arrival, time over threshold, momentum spectroscopy.

Map to 'First Experiments' (WiP)

Science	Early Science Detector	Next-gen
Tracking time-resolved Acetylene isomerization (*DREAM*) date?	RoentDek COLTRIMS MCP, *commercial, low-risk*	TBD
Time-resolved multi-edge photoelectron-photoion spectroscopy (*LAMP*)	LAMP w/ new hemi *in-hand, low risk*	Tixel
XPP Coincidence Catalysis (TXI)	VFCCD, ePixM	TBD
Single Particle Imaging (TXI)	ePixTender, ePixM, or VFCCD	
Time-resolved RIXS on Mn model clusters (LJE)	Existing VLS	TES Spectrometer (target first light)
Emergent Properties in Complex Materials (RIXS)	RIXS CCD	
X-ray Photon Correlation Spectroscopy of fluctuating charge/spin dynamics (RIXS)	ePixM/250s or VFCCD	
Hard X-ray Scattering and Spectroscopy (XPP/FEH)	ePix10k	ePixHR

Green: Meets early science requirement. *Blue: Meets extended performance goal*

Phased Development and Deployment



Long View Toward LCLS-HE (HXR)