# Upgrade Detector Plans and Options

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for the APS Detectors Group

2 July, 2012

# A brief history…

- Was named Upgrade lead on detectors ~15 months ago
  - Had been at ANL for 3 months…Upgrade had been around longer than me…
  - Told that there would be no significant role in the upgrade for detectors
- However:

**Department of Energy**
Washington, DC 20585

December 21, 2011

Dear Dr. Stephenson:

4. Proper X-ray optics and advanced detectors are crucial for realizing the full potential of new capabilities to be provided by the APS upgrade. APS management is urged to reevaluate the priority of the upgrade path for optics and detectors.

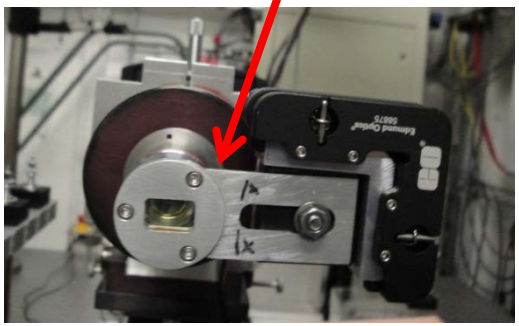
# Began effort to re-evaluate detectors in Upgrade

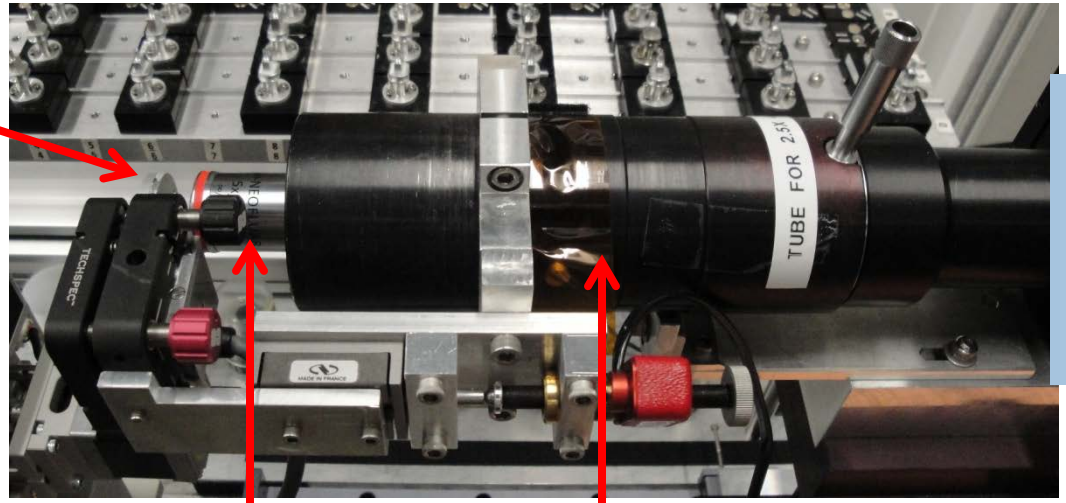
- C. Jacobsen and I started talking
  - C. Jacobsen white paper about development opportunities/status of group
  - Looking for projects with broad impact for Upgrade (multiple beamlines, etc).
- Began to seek input from the community and Upgrade management:
  - Phone conversation with Peter Denes in February
  - Ongoing discussions within Detectors Group
  - Meeting with Upgrade Beamline PIs in March; one-on-one meetings over past 4 months
  - C. Jacobsen presentation to SAC on March 20
  - Meetings with George Srajer and Upgrade management
- Identified possible contributions to the Upgrade:
  - Structured scintillators
  - Fast Integrating Pixel Array Detectors

# Weakness of single-crystal scintillators

Typical microscopy setup at 2BM:

Scintillator converts x-rays to visible light






Hi-res CCD would live here.

Microscope objective

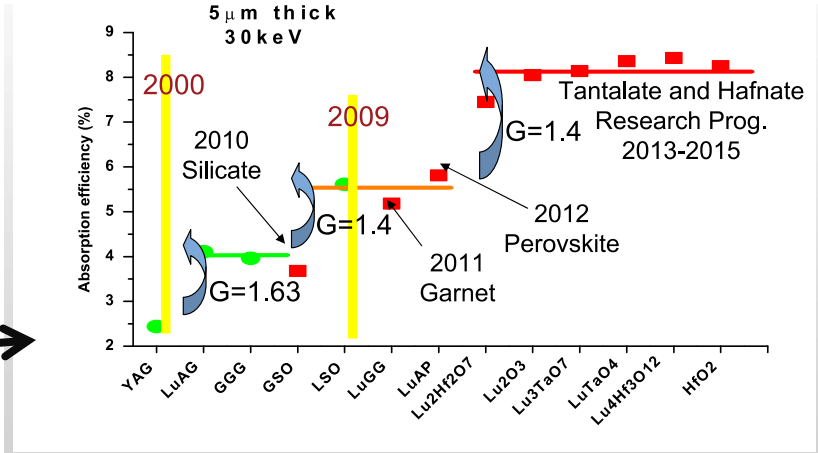
Tube lens

Scintillator trade-off:

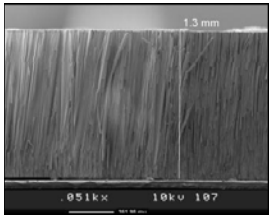
- Need thin scintillator (~few μm) to maintain spatial resolution
- Conversion efficiency is very week; gets worse for high energy applications

# Possible solutions:

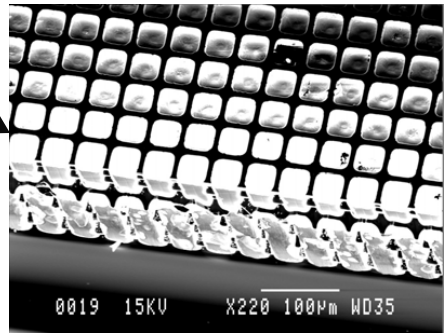
- Single crystals of Hi-z material
  - Efficient at higher energy
  - ESRF effort of Thierry Martin
- Structured scintillator
  - Scintillator with internal structure to limit spread of light
  - Efficiency + spatial resolution:
    - Thick CSI or other materials
    - Spatial resolution defined by structure size
  - Growth Structure – Scintillator grown with columnar structure
    - Has some crosstalk
  - Templated Structure – Substrate with pores filled with CSI
    - Structure limits crosstalk, but trouble filling pores uniformly
    - RISO/KTH and company Scint-X

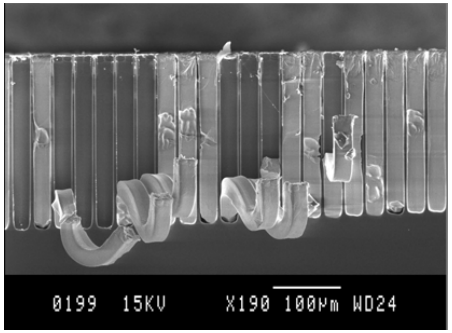



Graphic: T. Martin, APS Detectors Seminar, October, 2010.




1 S.C. Thacker, V. Gaysinskiy, L.E. Ovechkina, S.R. Miller, V.V. Nagarkar, C. Brecher, A. Lempicki, and R.H. Bartram, in Medical Imaging 2008: Physics of Medical Imaging (SPIE, n.d.), pp. 69130Q–69130Q–11.



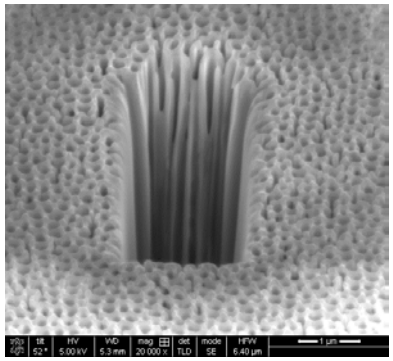




R. Bradford, APS/XSD/DET, APS-U Stakeholders Meeting (2 July, 2012)

1 X. Badel, Electrochemically Ethced Pore Arraus in Silicon for X-Ray Imaging Detectors (Royal Institute of Technology, 2005), pp. 1–81.

# APS initiatives

- S. Ross and RMD:
  - Hi-Z materials with grown structure
  - Just awarded Stage 2 SBIR grant
- New LDRD proposal from S. Wang, J. Comamala, T. Cecil (APS), H. Wang (MSD), J. :
  - Templated structure via Anoditic Aluminum Oxide (AAO)
  - Scintillator deposition via melting CSI or other process
  - High marks from XSD group leaders; 2-page proposal submitted.
- Will not seek funding through APS-U



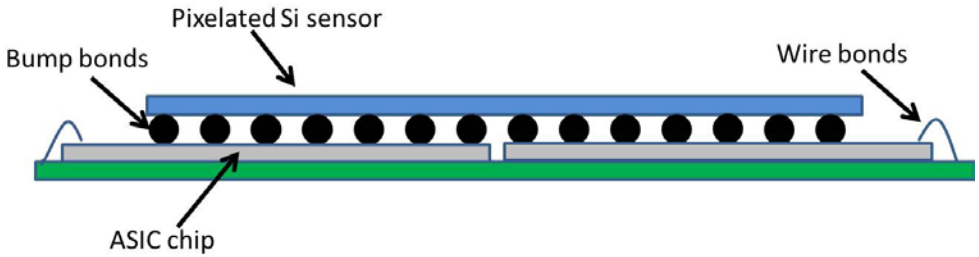
AAO nano-tube array – 30-100 nm etched to 1 μm.

From Steve Wang and Joan Vila Comamala APS, and Hsien-Hau Wang, MSD

# Fast Framing, Integrating Pixel Array Detectors

Pixel array detectors (PADs):
Each pixel of x-ray sensor directly bonded to pixel in Application Specific Integrated Circuit (ASIC).

- Very powerful/flexible design

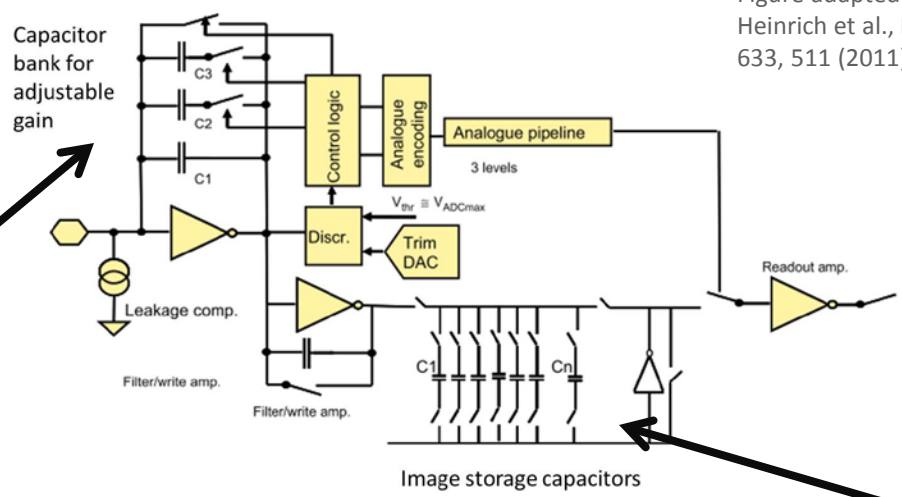



Charge Integrating PADS with internal memory

Beyond limits of counting detectors:

- Pilatus saturates at >1 photon per pixel per beam bunch.
- Integrating detectors can handle 4000 photons per pixel per bunch!
- Gain dynamically set for each pixel by ASIC circuitry
- Suited for high flux applications, but conserves single photon sensitivity!

Figure adapted from: Heinrich et al., NIM A 633, 511 (2011)

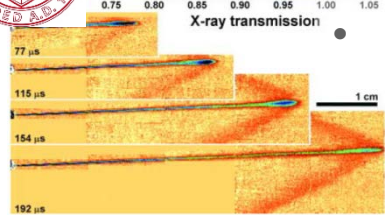



Fastest detector around: Images rapidly stored in capacitors on ASIC – possibly records several hundred images at 6.5 MHz, matching APS beam bunch rate.

# Fast framing PADS and APS-U

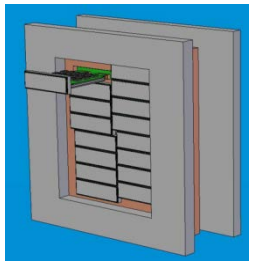
- Currently exploring PAD development as detector component of APS-Upgrade
- Would benefit large timing community at APS:
  - Within APS-U: SPX and associated beamlines, High Flux Pump Probe, (possibly) Wide Field Imaging
  - Complementary: Fluid Dynamics, and Dynamic Compression Sector
- General strategy: Collaborate with existing effort developing fast framing PAD detector suitable for APS

Cornell/Sol Gruner developing Keck PAD:



- Designed with APS timing in mind
- Only buffers 8 frames

Figure from: MacPhee, et al., Science 225 (2002), 5558, 1261.
Koerner and Gruner, J. Synchrotron Rad. (3022) 18, 157-164.



DESY, Paul Scherrer Institute and University of Hamburg:

- AGIPD detector for XFEL
- Buffers 352 frames, but optimized for XFEL timing

Figures from:
http://haslylab.desy.de/instrumentation/detectors/projets/agipd/presentations/e128845/AMarrasAGIPD_Status_Nov2011_v2.0.pdf

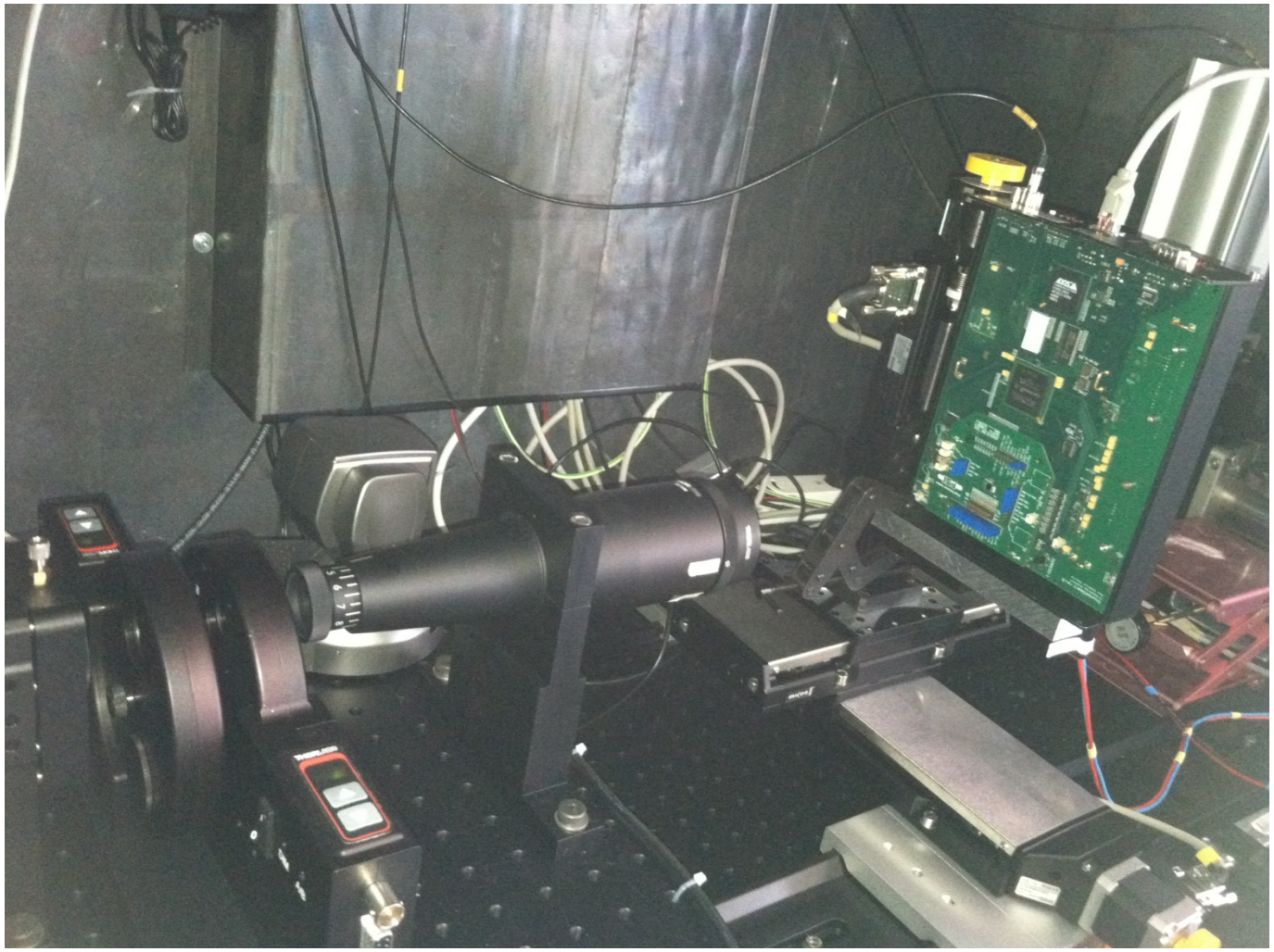
# Current Status

- Have been in communication with Cornell and PSI/DESY since March
  - Approached both groups via phone in March
  - Submitted plan to APS-U in late April requesting travel funds to help evaluate each group
    - Need to evaluate both efforts: technical, project management (cost, timeframe), personal
- Had very good visit with PSI/DESY June 11-20
  - Visited both sites; lots of interest in APS invovlement
  - General overview of project structure; technical overview of detector
  - Bench tests of their ASIC at APS timing structure
- Cornell:
  - Had phone conversation with Sol Gruner, but were unable to find dates for site visit this summer
  - Will continue to evaluate via other avenues that are available

# General Information

- Who visited:
  - Myself, Dave Kline, and Chris Jacobsen
- Collaboration:
  - DESY: Liaison to XFEL, design of ASIC periphery, mechanical systems, and readout electronics, calibration, etc.
  - PSI: Design of ASIC pixel logic, bump bonding
  - Hamburg: Design of silicon sensor
- Status/Timeframe:
  - Have produced 4 prototype systems to optimize ASIC with 5$^{th}$ produced this summer
  - First complete modules within 1 year
  - Detector ready for XFEL beam 15 December, 2015

# ASIC Testing



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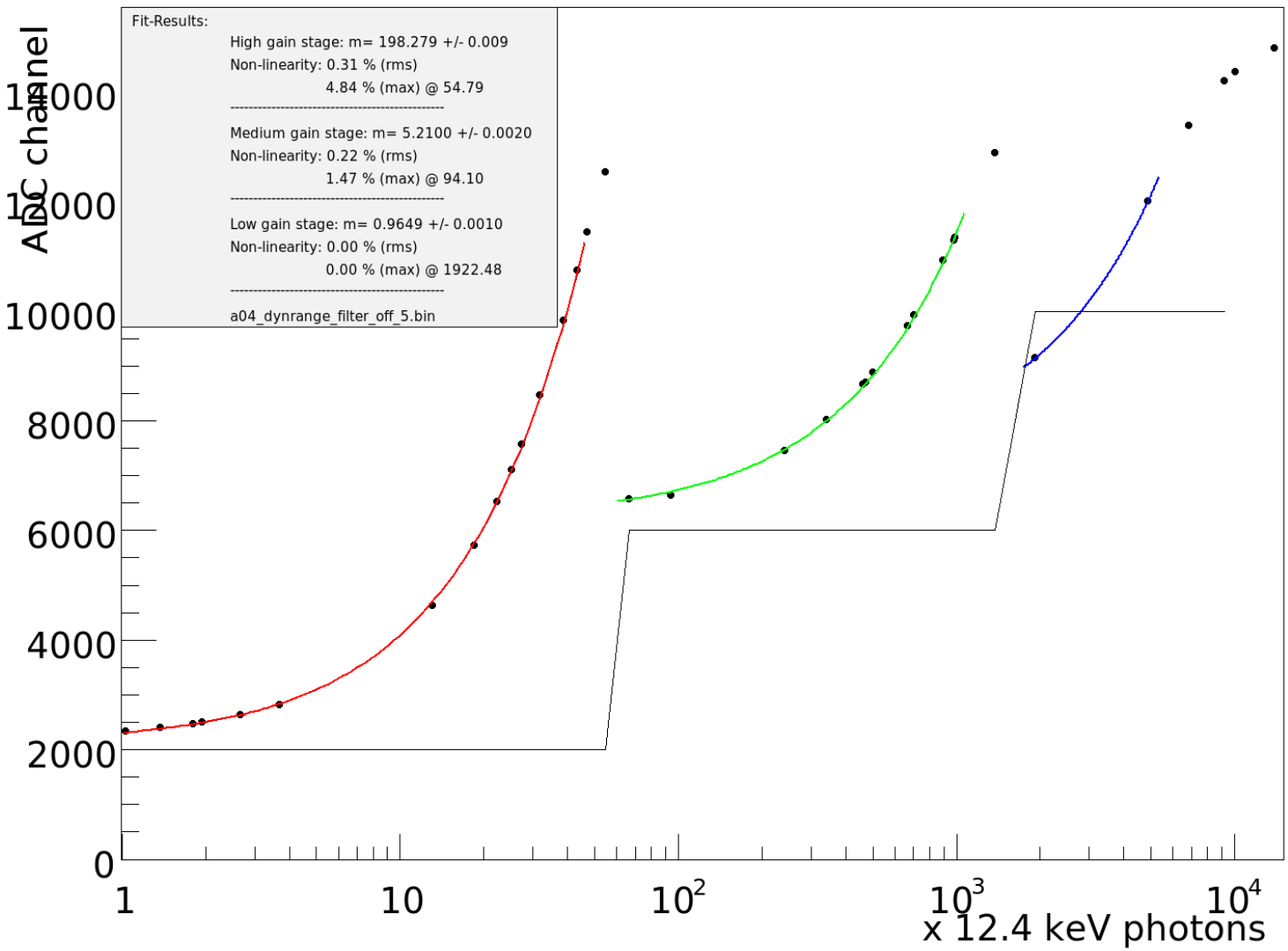
AGIPD0.4: Linearity measurement by IR-Laser (x12.4 keV photons / 150 ns cycle / VrefDS=600 mV / CDS gain LOW)




Graphic courtesy of D. Greiffenberg

# Thoughts:

- Groups were very open with information and very personable
- APS contributions:
  - Calibration: Have to correct all storage cells for leakage
  - Testing: Possibility to use new Detectors Testing Beamline
  - FPGA code, software
  - Commissioning at XFEL
- XFEL detector really optimized for XFEL experiments, in ways that we may not want
  - Ex. 2-meter wide geometry
- Interest in developing special detector for synchrotron community
  - Could be lead by APS
  - H. Graafsma enthusiastic about this idea

# Conclusions

- Making progress on detector initiatives in support of APS-U
  - Structured scintillator – will proceed with SBIR and LDRD proposals
  - Fast framing PAD
- Currently evaluating collaborative options for Fast Framing PAD:
  - Successful visit to DESY/PSI
    - No technical showstoppers at this point – looks feasible for delivery on timeframe of APS-U
    - Possibility of strong APS contribution to international effort
  - Will continue to communicate with Cornell
- Future plans:
  - Will begin working to WBS and budget after SRI
  - Seeking further input from community
  - Project review (with optics) tentatively August 20, 2012