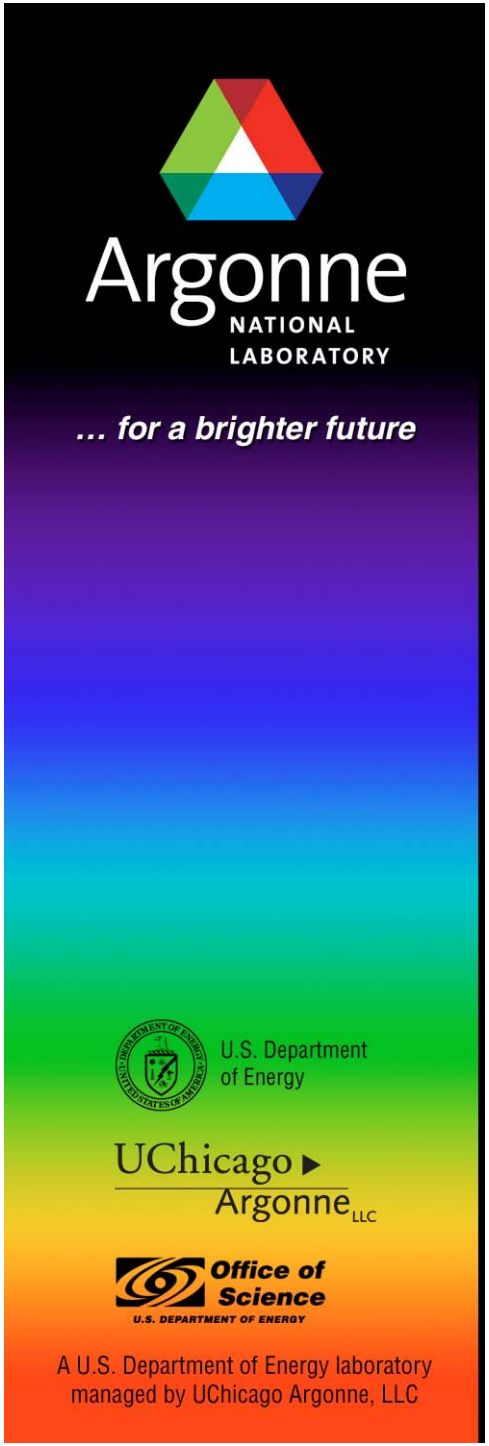


Overview of Detector Development at APS – XSD Beamline Technical Support Group

By: John Weizeorick

weizeor@aps.anl.gov

Argonne National Laboratory

Advanced Photon Source

X-Ray Science Division

Beamline Technical Support Group

Station Identification

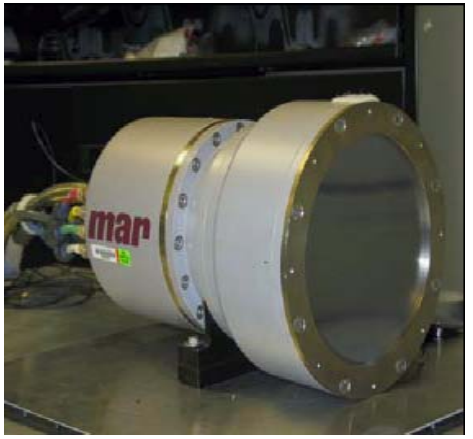
- Beamline Technical Support
  - Who
    - *Patricia Fernandez*
    - *Kevin Beyer* *Lisa Gades* *John Lee*
    - *Troy Lutes* *Tim Madden* *Antonino Miceli*
    - *Diane Morgan* *Steve Ross* *Rick Spence*
    - *John Weizeorick*
  - What
    - *Detector Pool*
    - *Equipment Pool*
    - *Point-of-contact between APS user community and Argonne/APS service groups and contractors*
    - *Provide assistance to beamline staff on construction, upgrade, repair , etc*
    - *Detector development and beamline instrumentation*

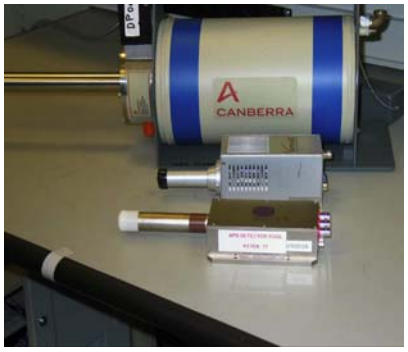
Talk Overview

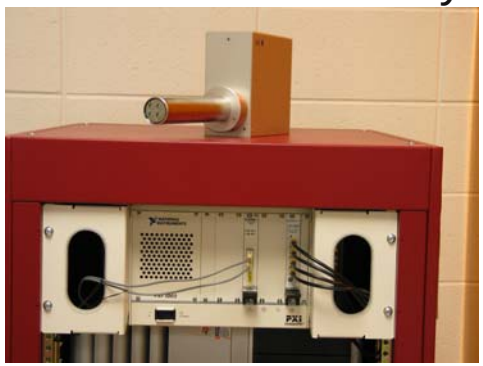
- Detector Pool
- Beamline Technical Support (Value Added)
  - Integrating commercial detectors into beamlines
    - *GE Amorphous Si Detector*
  - Generic Digital Module
  - Generic Amplifier Card
  - Building test stands
- Detector Projects
  - Beam Position Monitor (BPM)
  - Portable Detector System – for characterizing the beam
  - APD Project
  - BESSRC CCD Project
  - Fast CCD Project with LBNL
  - Conclusions

Detector Pool

- **Detectors**
  - Area Detectors
    - *GE Amorphous Silicon Flat Panel*
    - *MAR 165 CCD Detector (2)*
    - *MAR 345 Image Plate (2)*
    - *Bruker 6500 CCD Detector*
  - Microscopy Detectors
    - *CoolSnap and microscopy equipment (2)*
  - Spectroscopy Detectors
    - *SII Nano Technology Vortex 4 Element Si Drift Diode Detector (1)*
    - *SII Nano Technology Vortex SDD (5)*
    - *Ketek Silicon Drift Diode (6)*
    - *Single (2) & multi (2) - element Germanium*
  - ~300 requests per year from entire APS community







Beamline Technical Support – GE Detector

- GE Amorphous Silicon Flat Panel Detector
  - Leased from GE Medical
  - CsI Scintillator (x-ray to optical light)
  - a-Si Array of photodiodes
    - *2048 x 2048 (200 μm pixels)*
  - Frame Rate
    - *8 Hz (2k x 2k)*
    - *30 Hz (1k x 1k binned)*
  - Useful for > 60keV
    - *Powder diffraction*
    - *Diffuse Scattering*
  - Interface with EPICS

Beamline Technical Support – Generic Digital Card

- Generic Digital Card
  - Buffered I/O with Programmable Logic (Altera EPF10K40RC208)
  - Different Modes of operation
    - *Stand alone (18 BNCs – Typically 12 inputs and 6 outputs)*
    - *With eBrick (PC104 running Linux & Epics)*
  - Cash Cow

Beamline Technical Support – Generic Amplifier Card

- Generic Amplifier Card

Beamline Technical Support – Test Stands

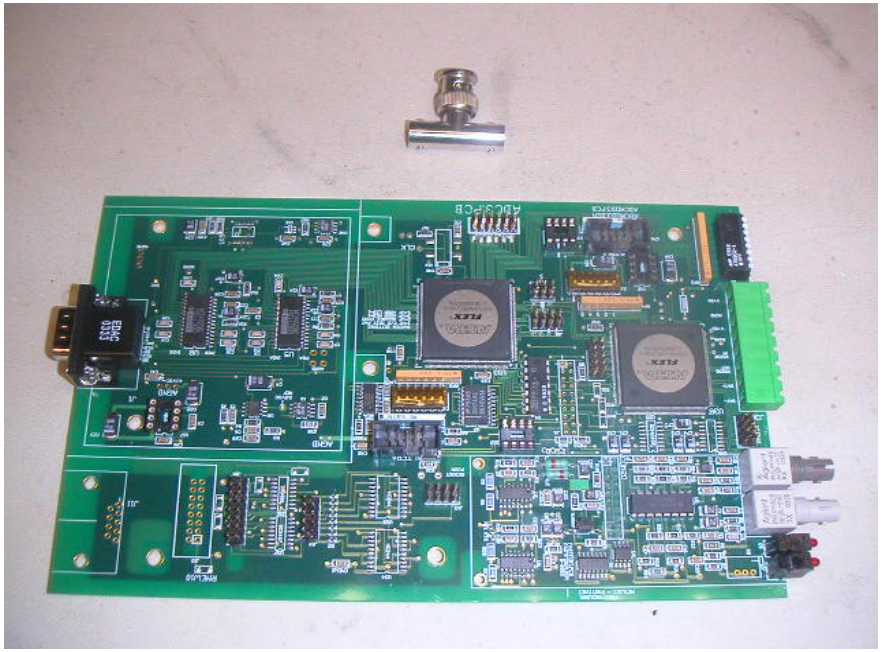
- Building Test Stands
  - Used to Characterize Detectors independent of manufacture specifications
  - Optical Test Stand
    - *Stepper motors*
    - *Integrating Sphere*
  - X-ray Tube Stand

Detector Projects – X-Ray Beam Position Monitor

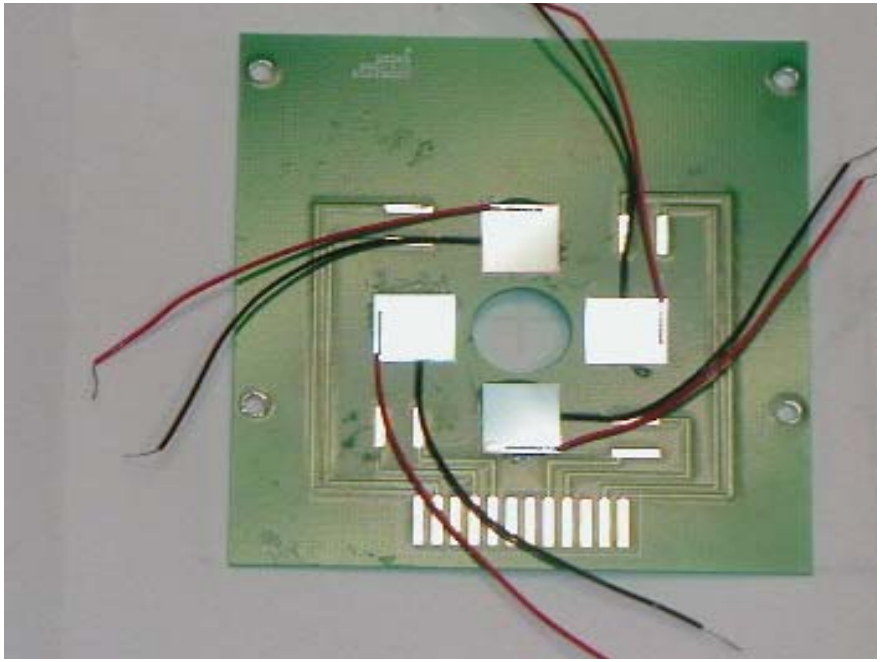
- X-Ray Beam Position Monitor
  - A common problem around the APS – where is my beam?
  - Detector uses Split sensors
    - *Set of 4 photodiodes which detect x-rays and locate beam.*
  - Electrometer detects current, pA noise floor at 1600 Hz. Basically just a very good charge amplifier.
  - Detector's signal given to EPICs, then often combined with feedback control of x-ray mirrors.
  - Installed at ~10 sectors, since 1999.
  - See APS detector pool web-site for users-guide.
    - *http://www.aps.anl.gov/Xray_Science_Division/Beamline_Technical_Support/Detector_Pool/*

Detector Projects – X-Ray Beam Position Monitor

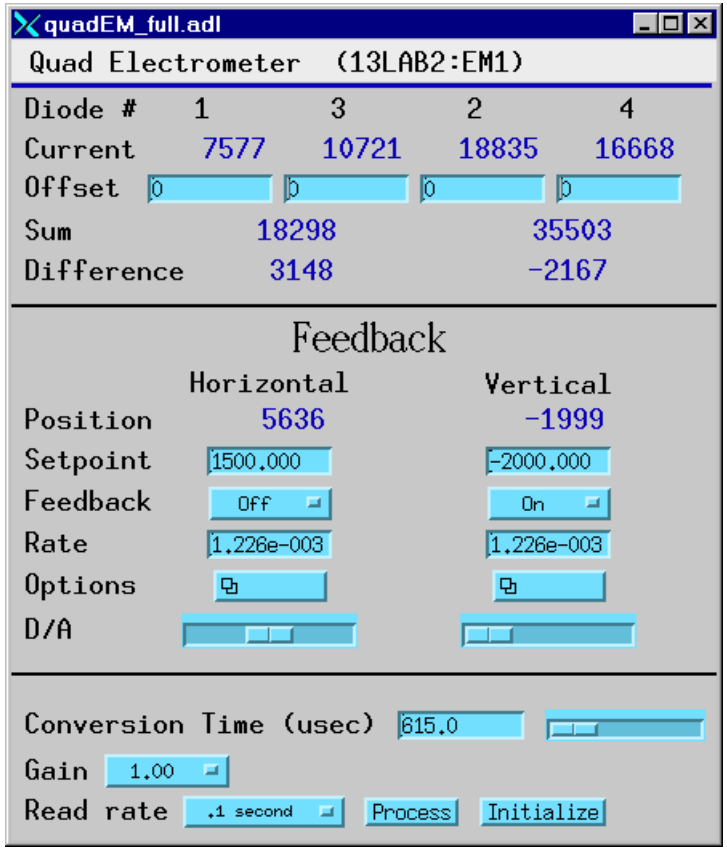
4-channel amplifiers
Ref: Steve Ross



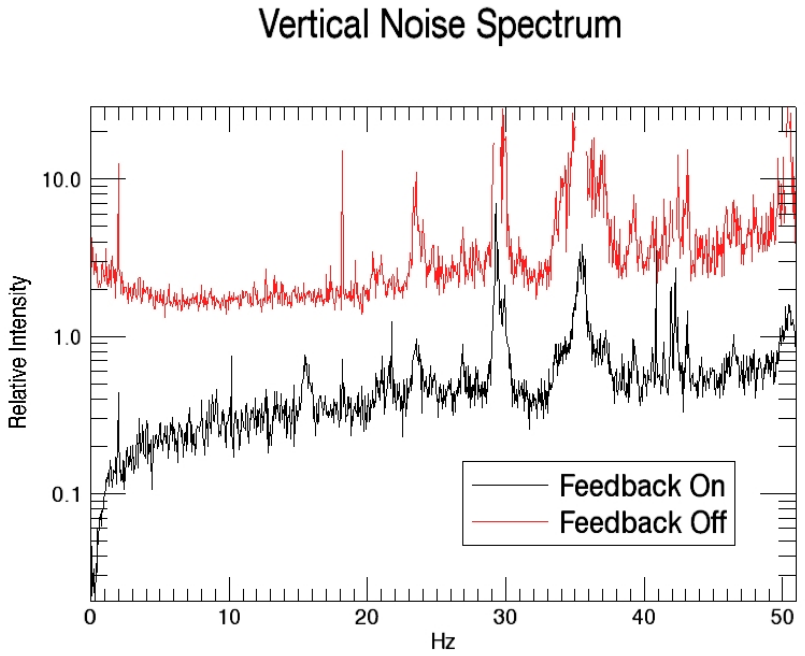
Many permutations of
quad detectors (1999)



Detector Projects – X-Ray Beam Position Monitor



EPICs work courtesy of Mark Rivers/APS/2002

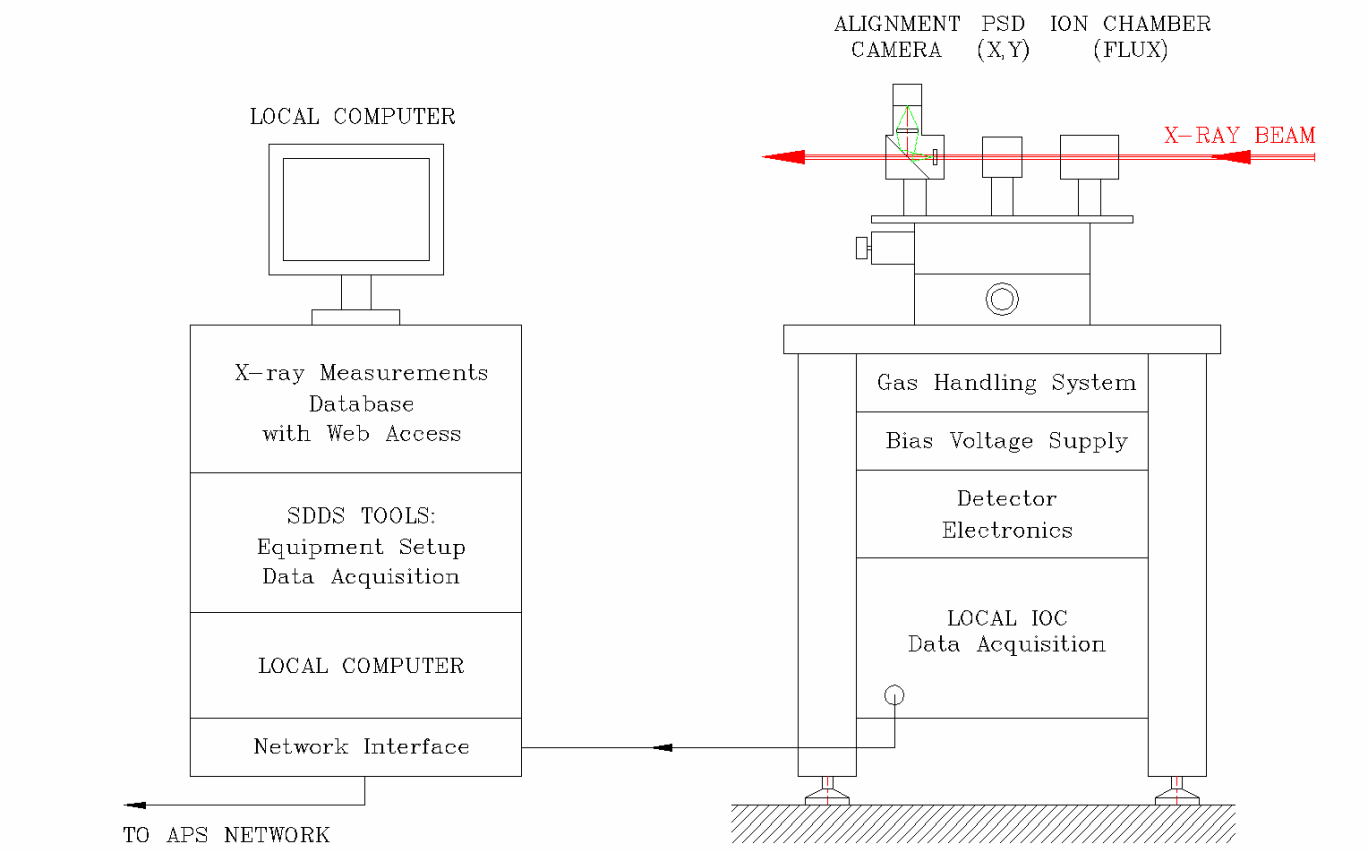


Mechanical jitter power spectral density to 800 Hz

Ref: Jame Ciston CARS, 2003

Detector Projects – Portable Detector System

- **Collaborative project led by APS Diagnostics Group**
  - Measure beamline output ➔ benchmark
  - Measure fluctuations in beam position and size
  - Assist in optimizing steering



Detector Projects – Portable Detector System

- **BTS Contributions**
  - **Ion chamber**
    - *Advanced Design Company/Oxford*
  - **Silicon pin diode detectors**
    - *John Lee (BTS)*
  - **X-ray beam position monitor**
    - *Steve Ross (BTS)*
  - **Coordination**
    - *Lisa Gades (BTS)*

Photo by John Lee

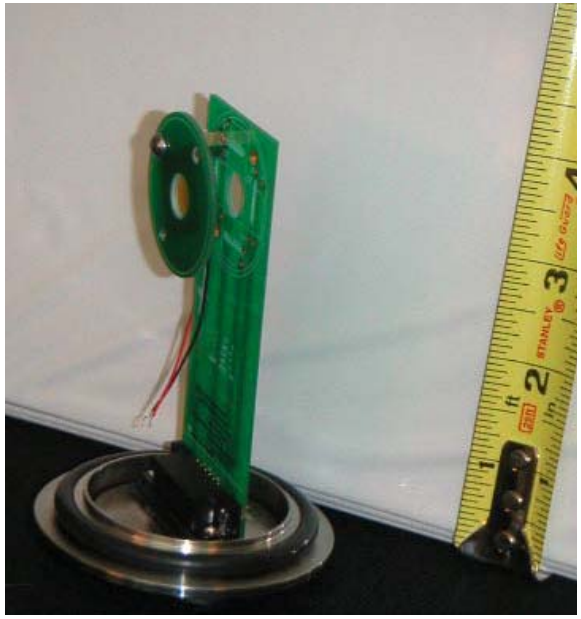


Photo by Steve Ross

Photo by Mark Rivers

Photo by Steve Ross

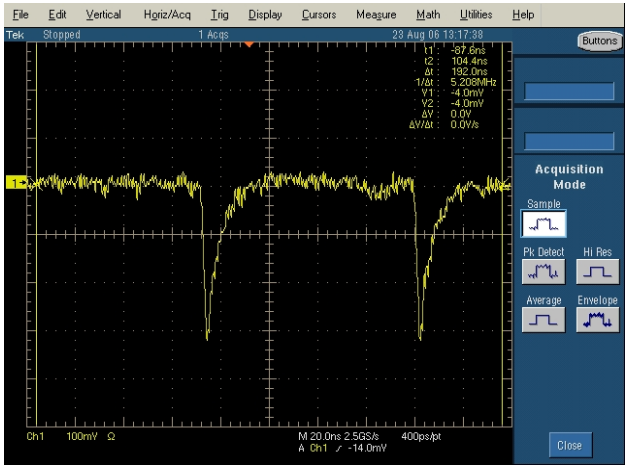
Detector Projects - Avalanche photo diodes and pixel array detectors

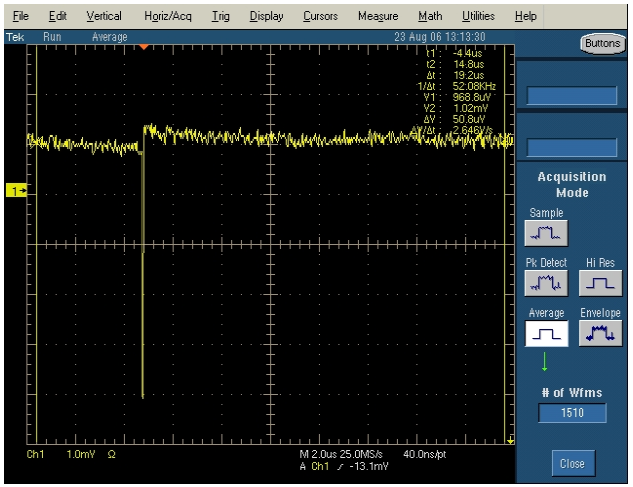
- APS - Single element APD detectors for various time resolved experiments at the APS.
- $50K/yr 2006 LDRD for Pixel array development (PAD), working with Cornell/CHESS.
  - Build camera around existing detectors
  - CMOS MOSIS run, step towards learning CMOS design.
- Participating with HEP's 2006 LDRD on Silicon Photomultipliers
- $100K 2006 SBIR phase I to Voxtel Inc. for APD array development (APD-PAD), spec's being worked now.
  - 300 um thick
  - Nanosecond fast
  - CMOS processing
- This fall, we will send in another SBIR with RMD Inc. for APD arrays.
  - High gain
  - May cover 4" wafer

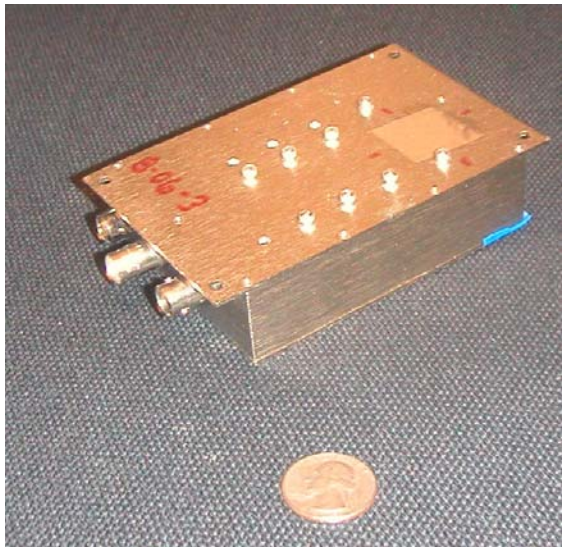
Detector Projects – single element APD

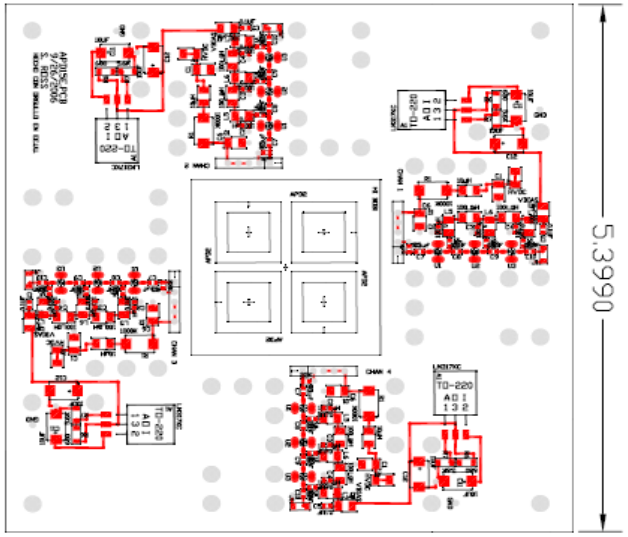
- APS “Box” design #1
  - Meets needs of several sectors, 24 bunch mode, 10-20 MHz counting
  - Building for detector pool,
  - May work 324 bunch mode.
- Now adding a EPICs/E-Brick/DAC based discriminator.
- Also small array – N x 2 array

~4ns leading, 12 ns falling, but can be tweaked



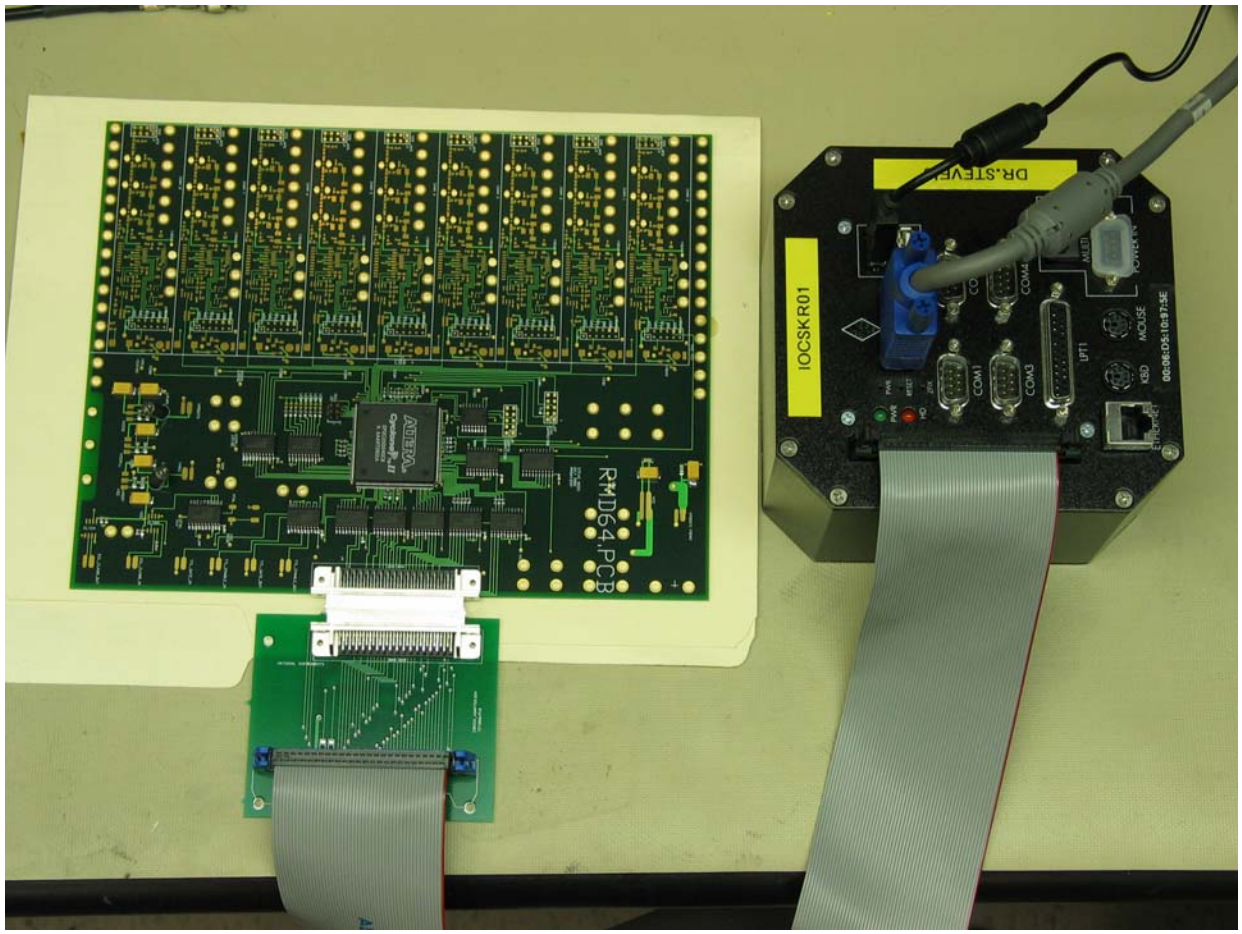






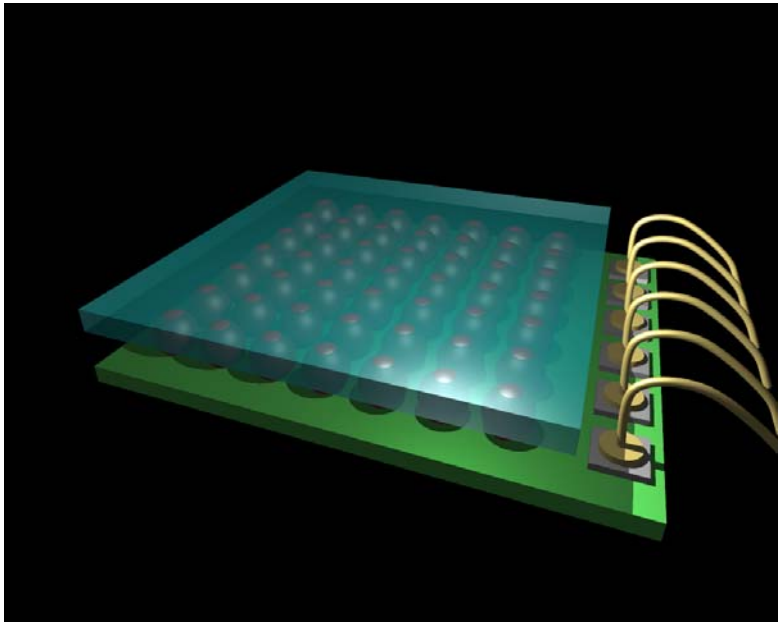
Detector Projects – multi element APD

- 3x3 APD array
- Use eBrick for DAS



Detector Projects – Pixel Arrays

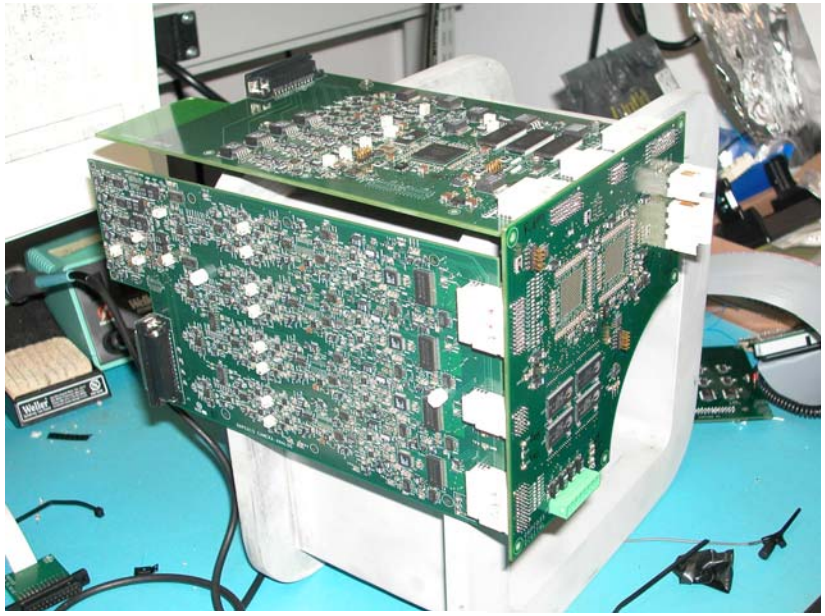
- Pixel Arrays
  - PAD (gain x 1)
  - APD (gain x 10^{2-3})
  - SiPM (gain x 10^{6})
- Different detectors, different uses on beamlines, but from engineering point of view common architecture similar issues, require similar tools.
  - (1) X-ray stopping layer
  - (2) Bonding
    - *Bump bonding, wire bonding, SOI*
  - (3) CMOS, Bi-CMOS readouts

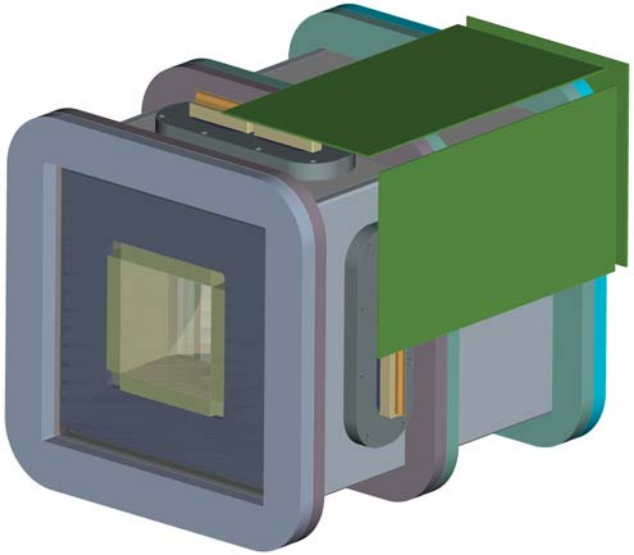


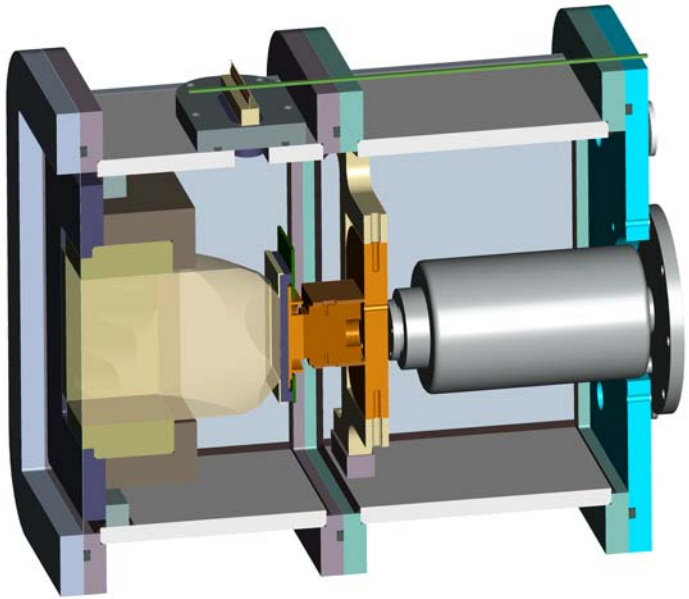
Ref: Gruner et.al.

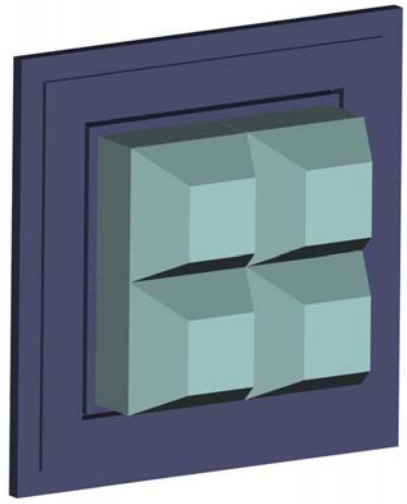
Detector Projects - Bessrc CCD

- **BESSRC CCD Detectors**
  - CCD X-ray detector
  - Single CCD and **2x2 Mosaic** of CCDs
  - 1.75 Demagnification Fiber-Optic Taper
  - Kodak KAF-4320E CCDs
    - 2084 x 2084, 24mm pixels
    - QE of .65
  - Readout in .2 sec (5 fps)



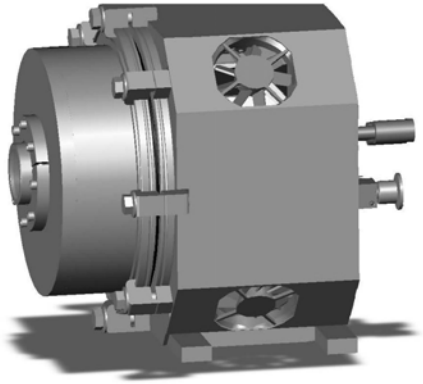






Detector Projects – Fast CCD

- **Fast CCD X-ray Detector Project**
  - LBNL and ANL Collaboration
  - Produce Two CCD x-ray detectors (demonstrator)
  - Expected completion in 2007



- **LBNL**
  - Howard Padmore & Peter Denes
  - Two custom ICs based on SNAP ICs
    - Custom CCD
    - Custom Readout IC (fCRIC)
  - Building the assembly
  - Mechanical Housing

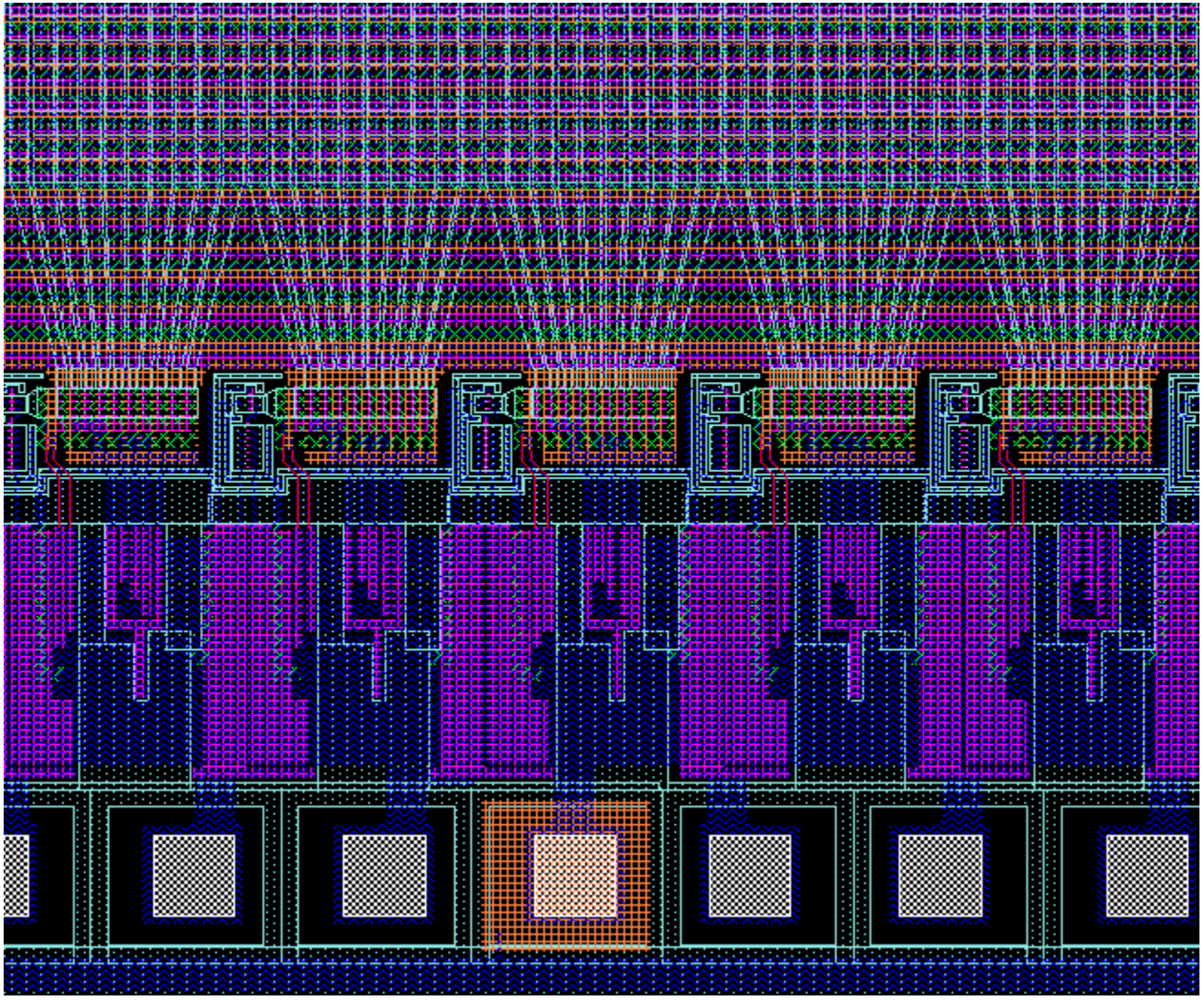
- **APS – XSD**
  - Design Readout Electronics
    - *Interface Module*
    - *Data Module*
    - *Clock Driver Module*
  - Provide computer with commercial frame grabber
  - Develop Software

Detector Projects – Fast CCD - Custom ICs from LBNL

- Fast CCD IC
  - 480 x 480 (30um pixels)
  - Back-illuminated CCD
    - *Good quantum efficiency (QE) for phosphor coupled x-ray cameras*
  - Thick substrate of 200-300 um (Fully Depleted)
    - *Direct detection of X-Rays*
  - Added Almost Column-Parallel Readout
    - *Split Top and Bottom of CCD with one output for 10 columns*
      - 96 analog outputs
    - *Readout time of 2.4 msec / frame = max of 416 frames/sec*
    - *192 Mbytes/sec*
- Custom Readout IC to perform ADC on 96 analog outputs
  - Low power Pipeline ADCs
  - Low noise (~ 10 electron read noise)
  - Large Dynamic Range of 14+ bits
  - Conversion Rate of 1usec/pixel
  - 4 Serial LVDS output

Detector Projects – Fast CCD

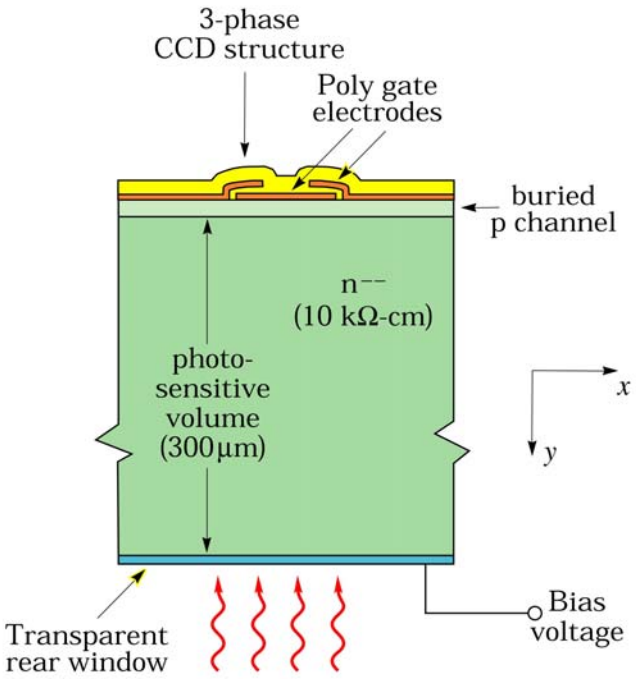
- Almost Column-Parallel Readout



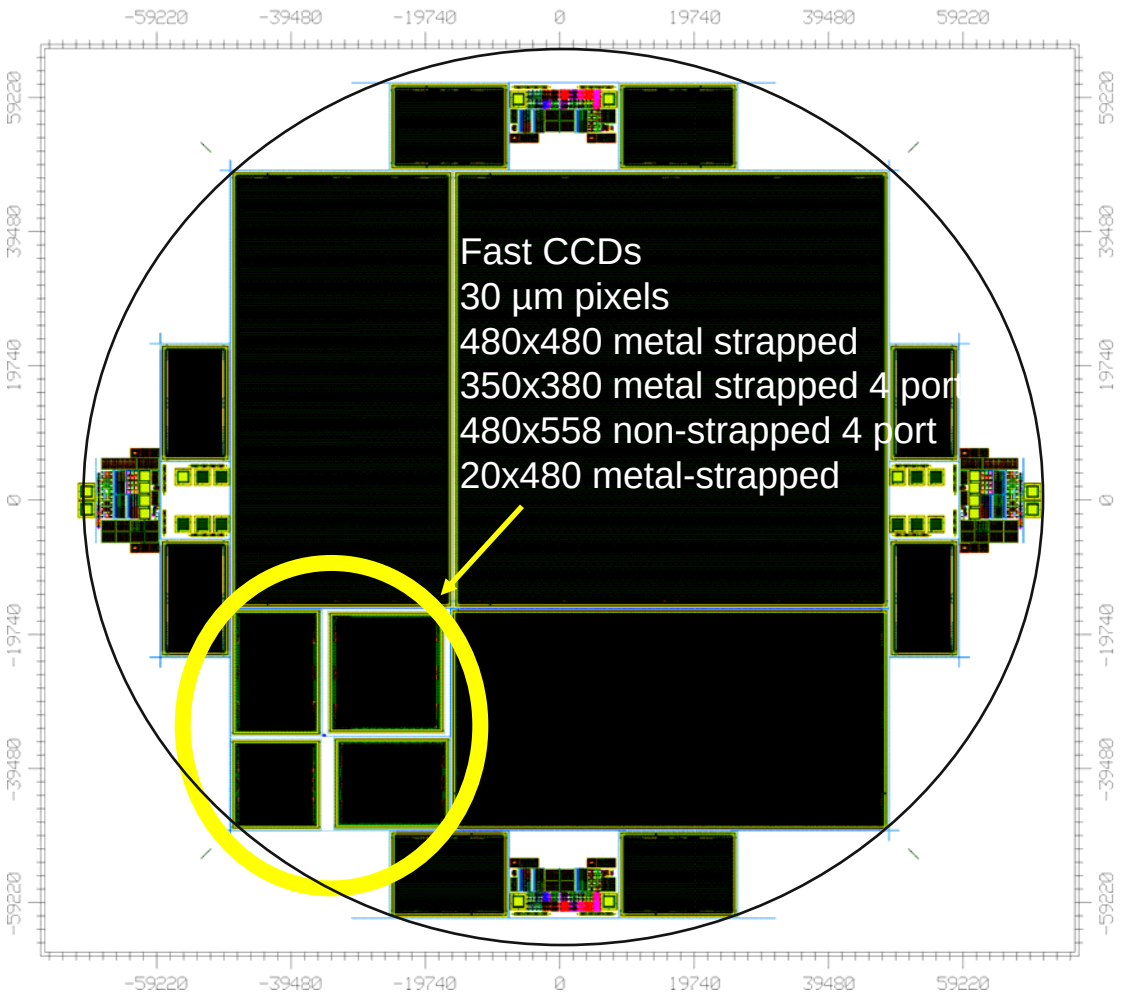
P. Denes

Detector Projects – Fast CCD

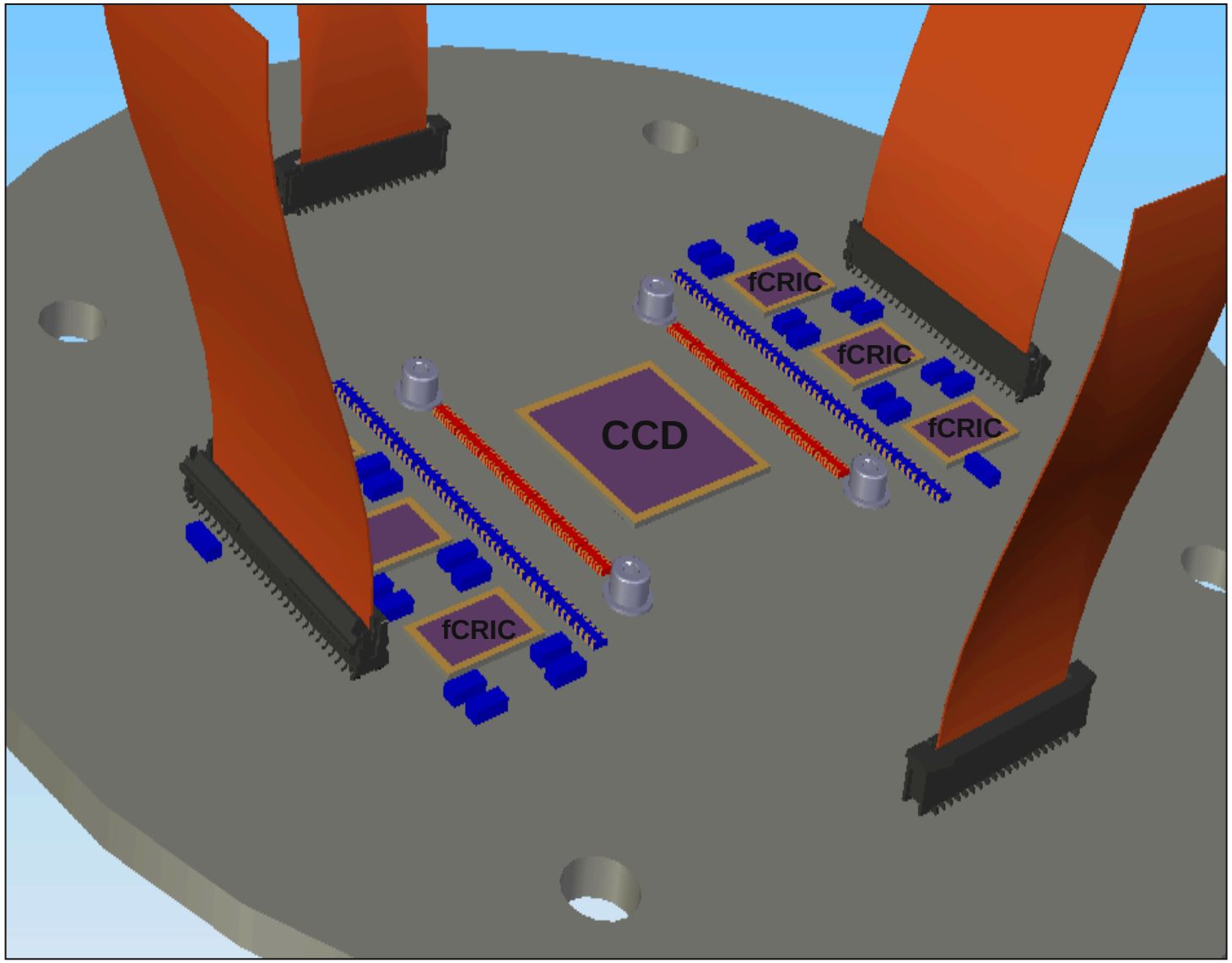
- SNAP Pixel



- SNAP 6-inch wafer



Detector Projects – Fast CCD – LBNL Assembly



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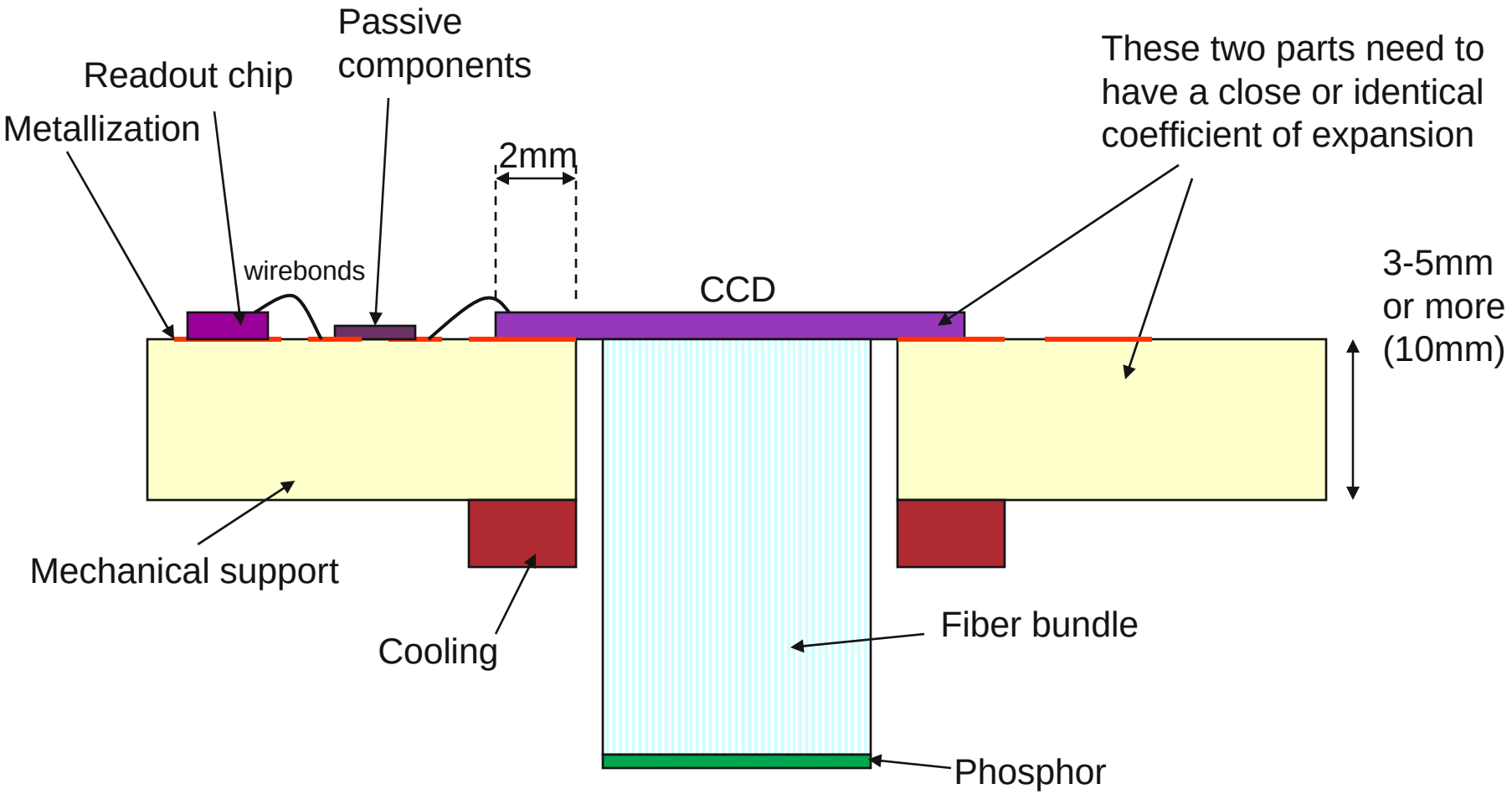
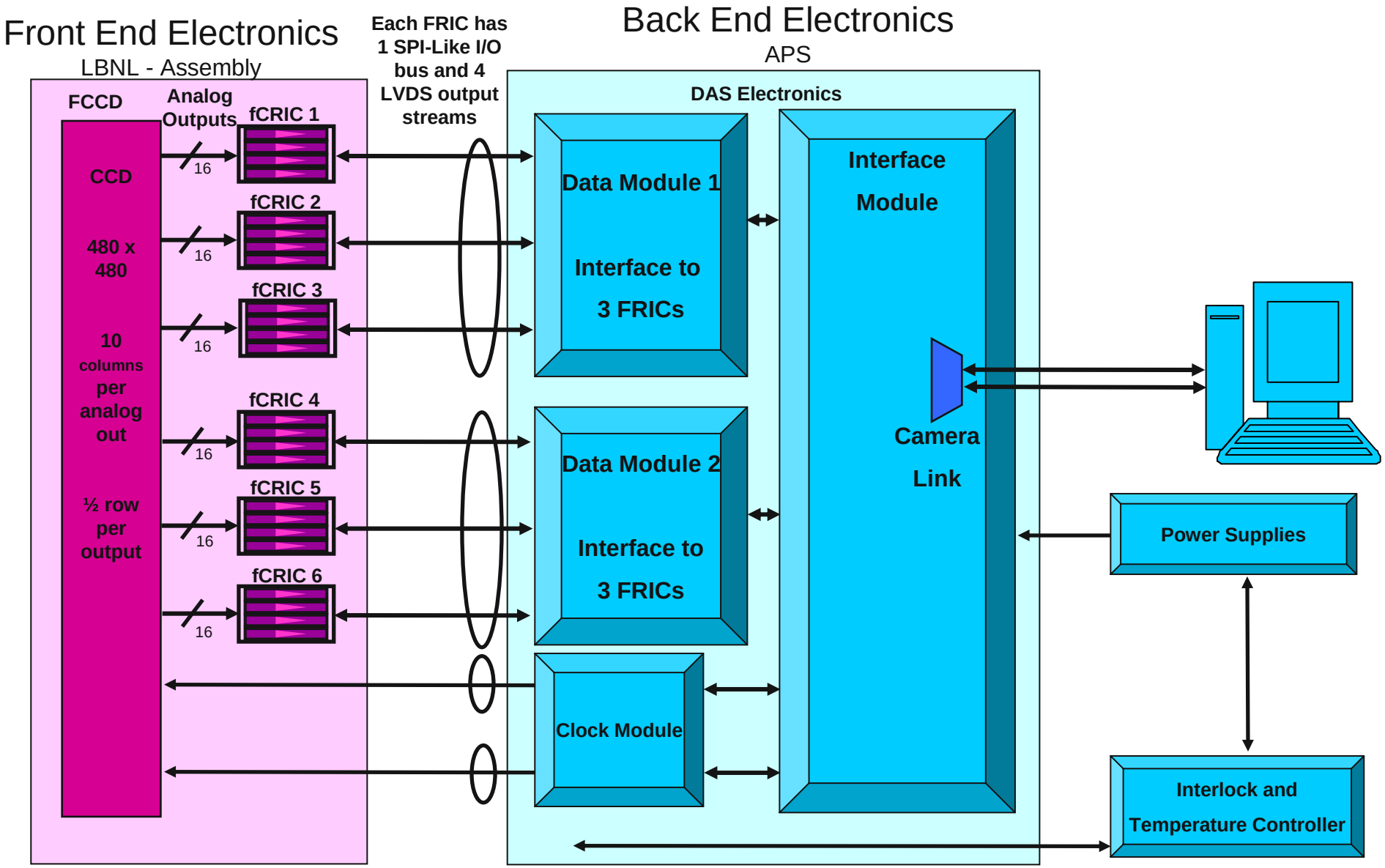
Detector Projects – Fast CCD – LBNL Assembly



Detector Projects – Fast CCD – Block Diagram



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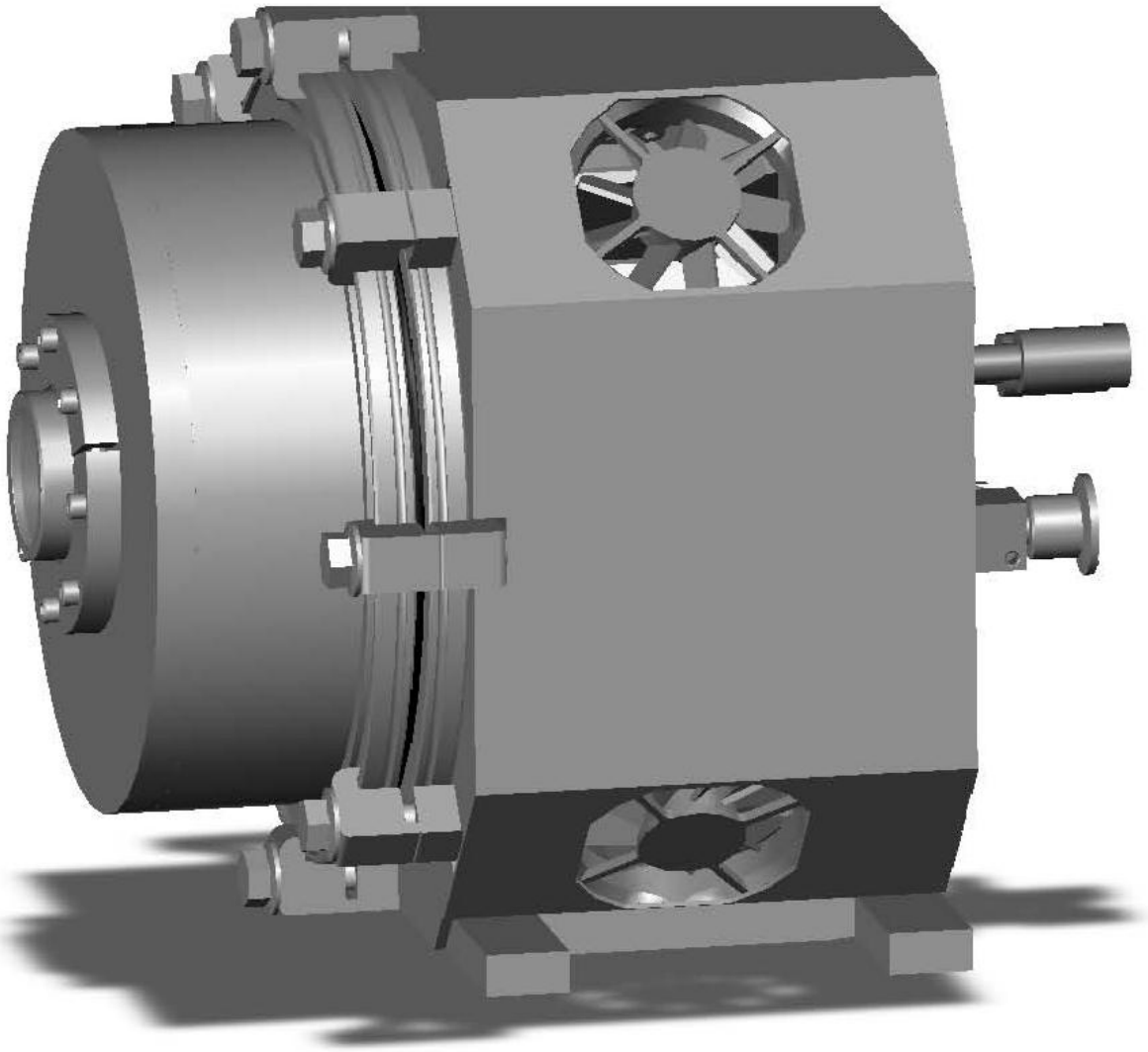

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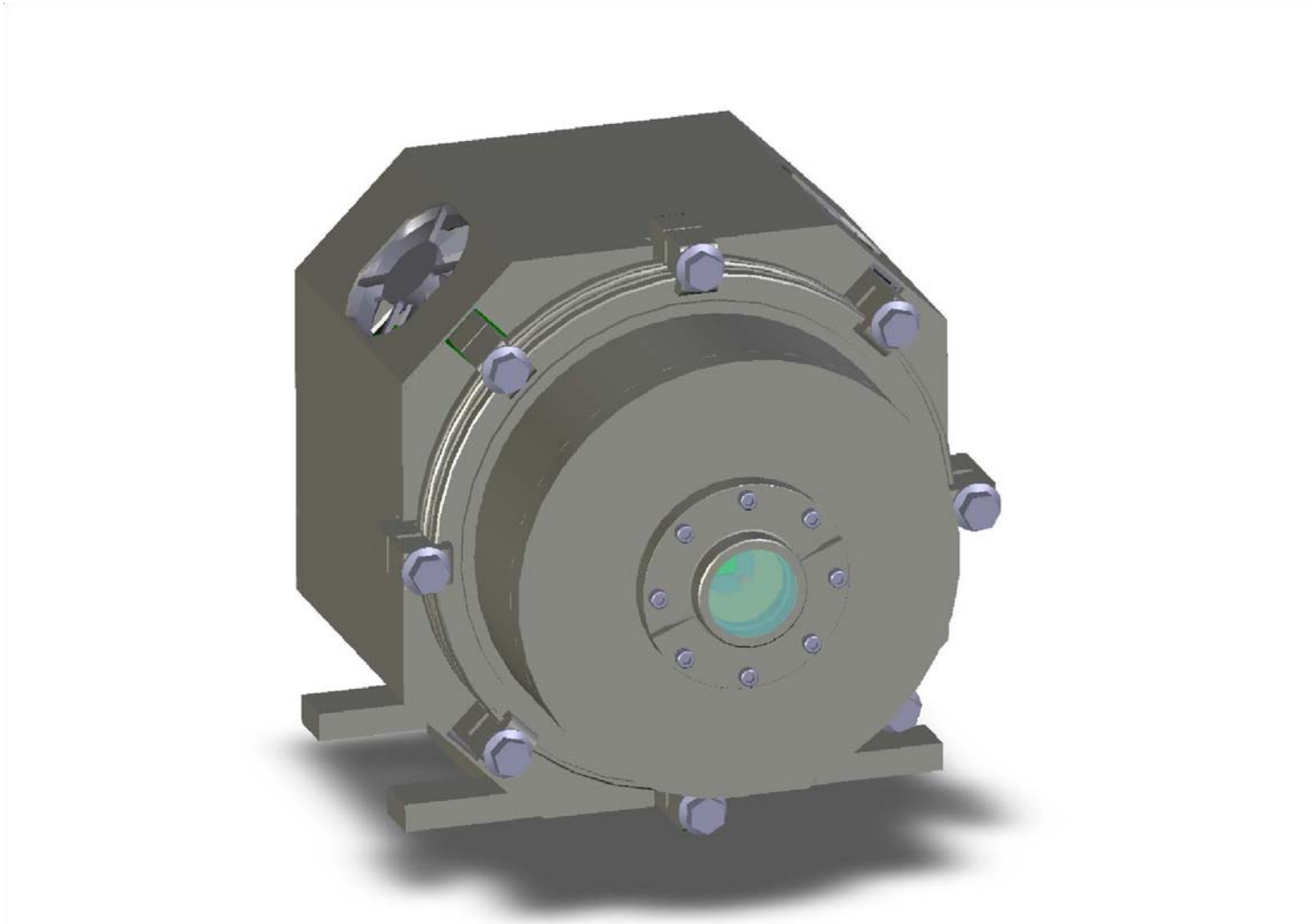
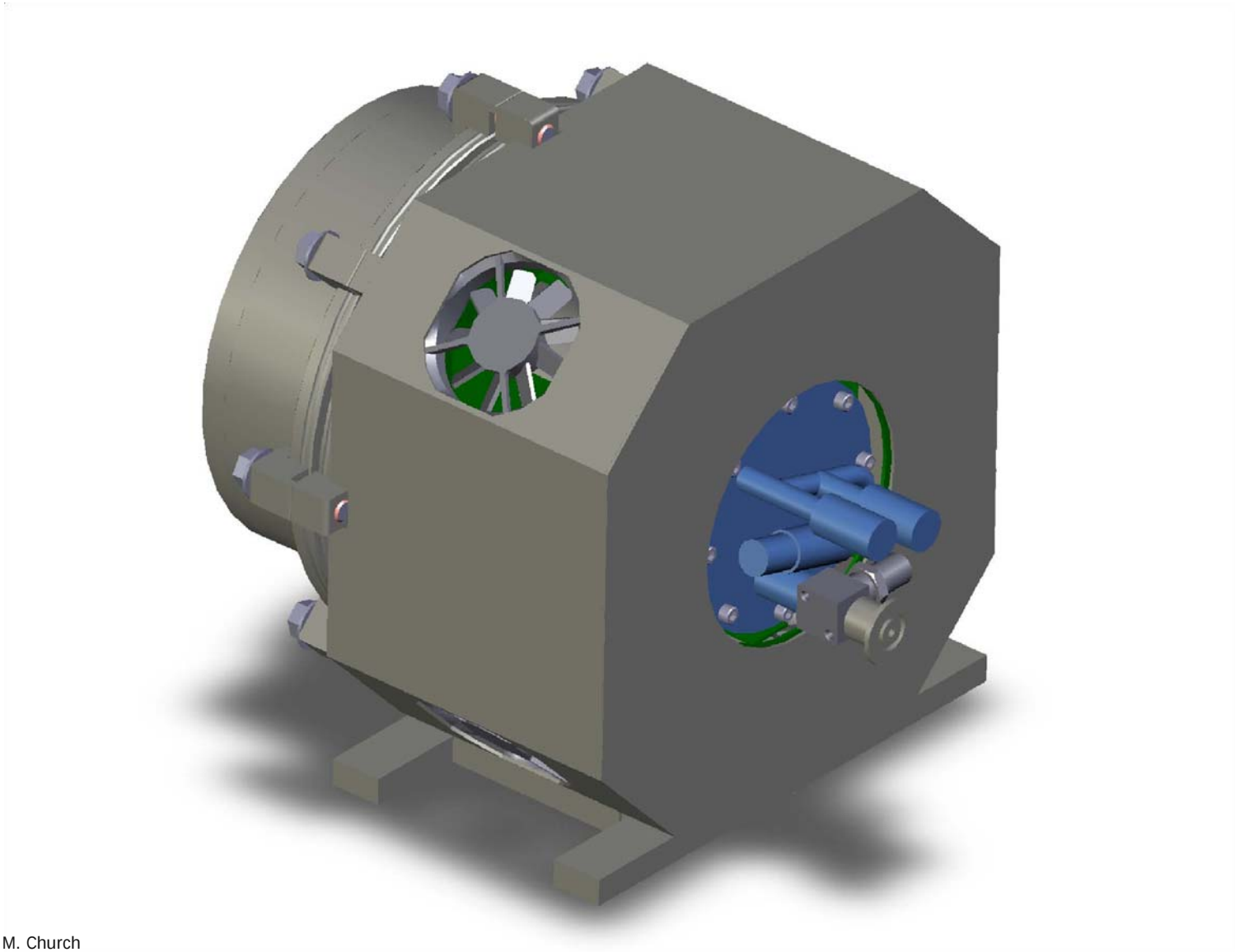


Detector Projects – Fast CCD



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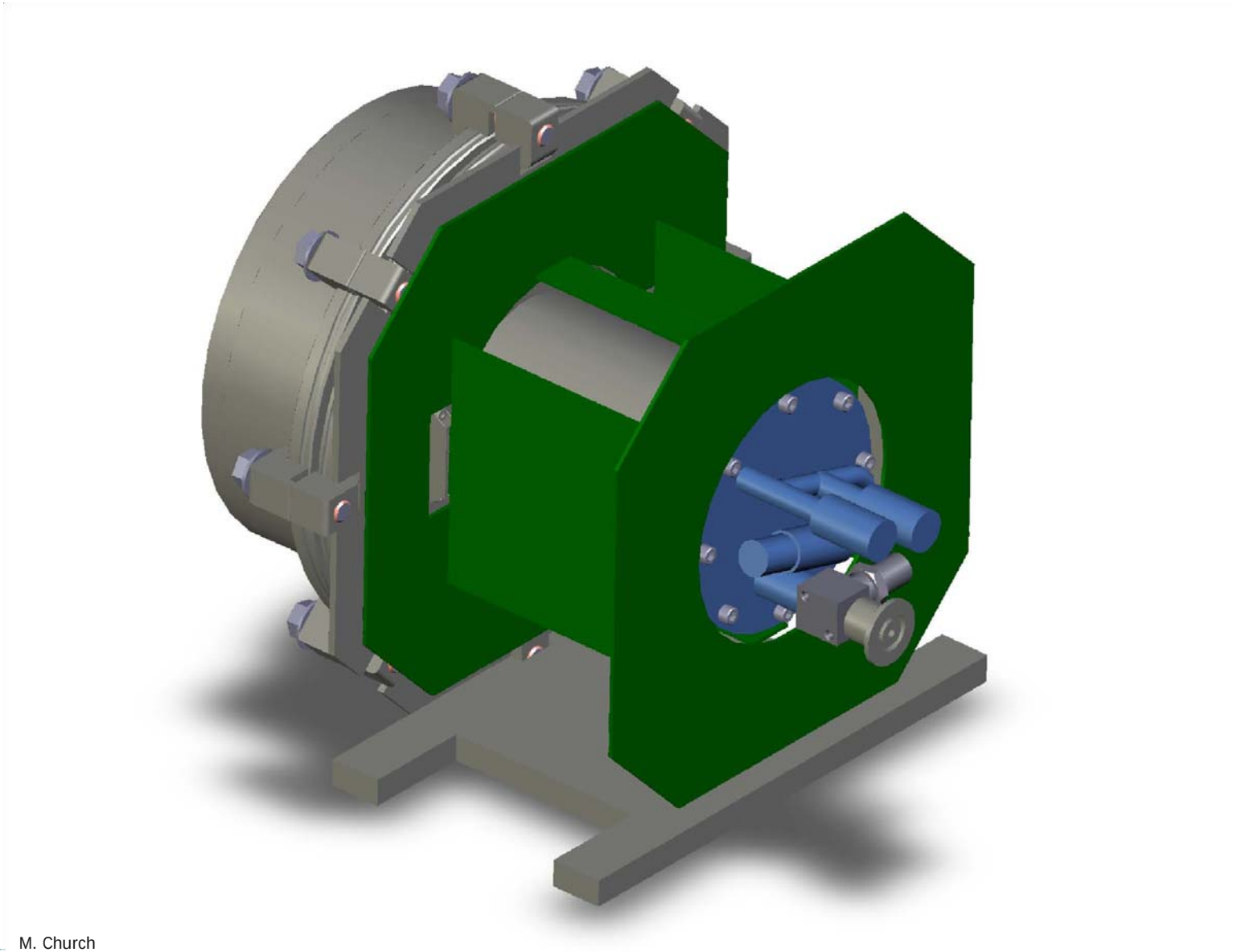
Detector Projects – Fast CCD



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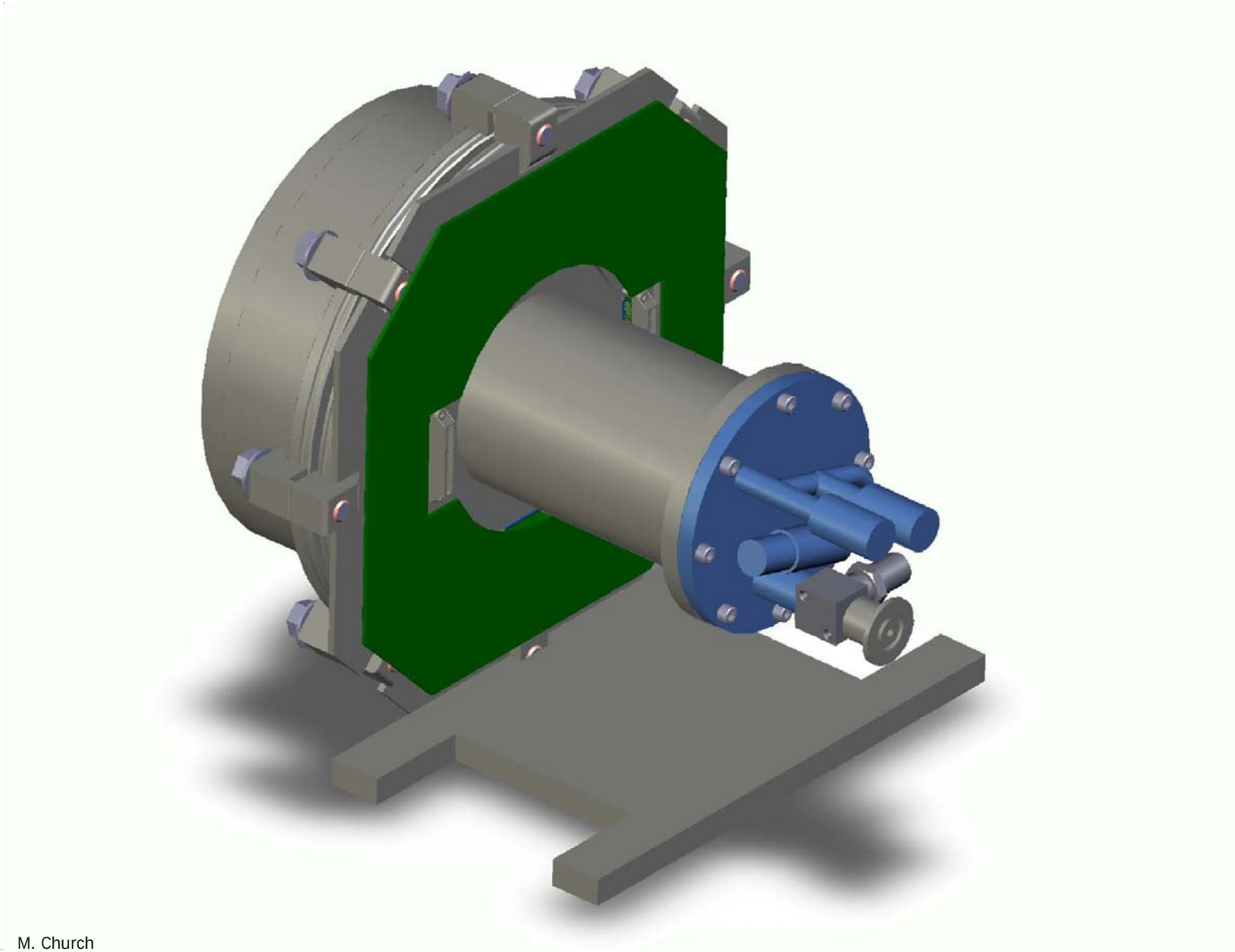
Detector Projects – Fast CCD



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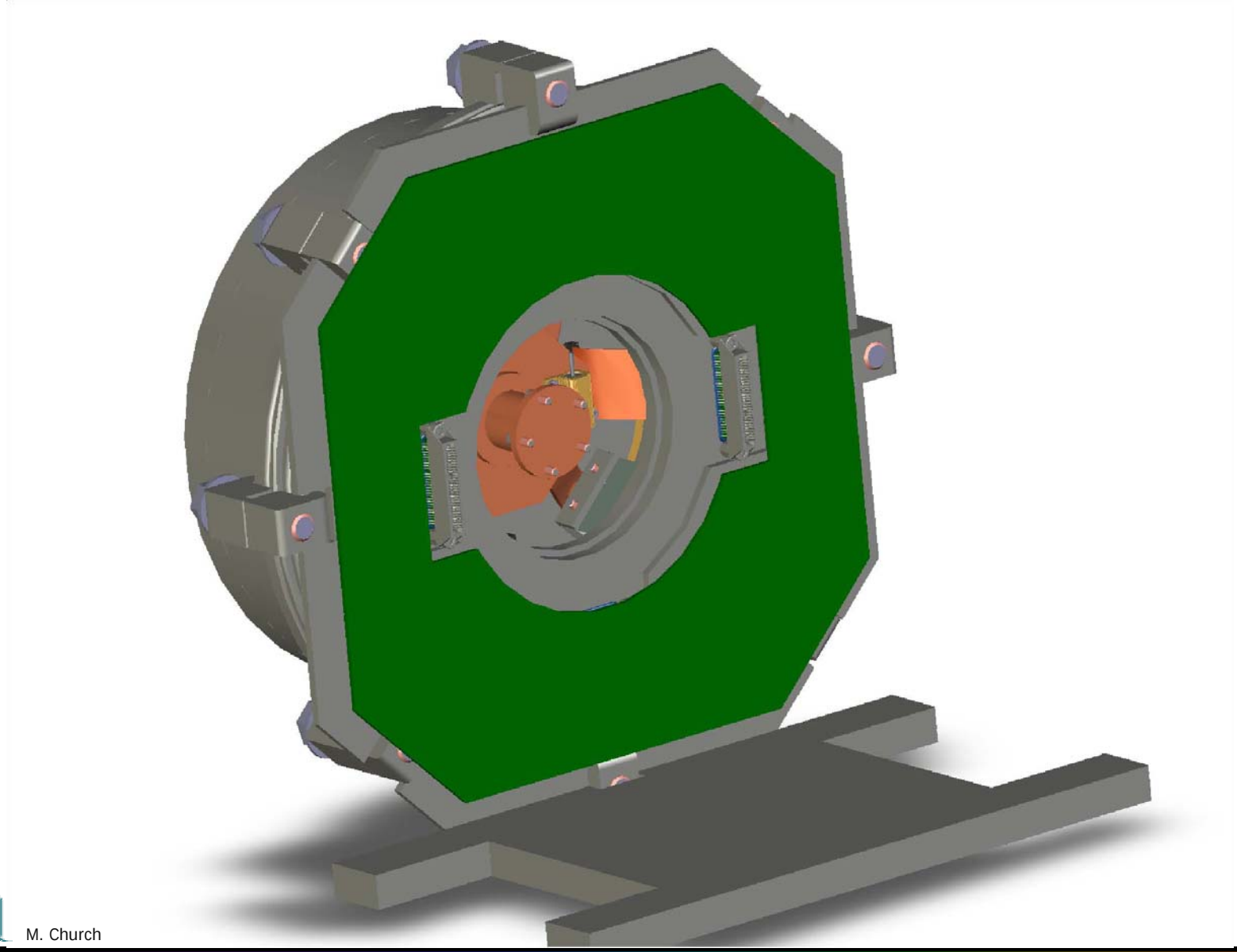
Detector Projects – Fast CCD



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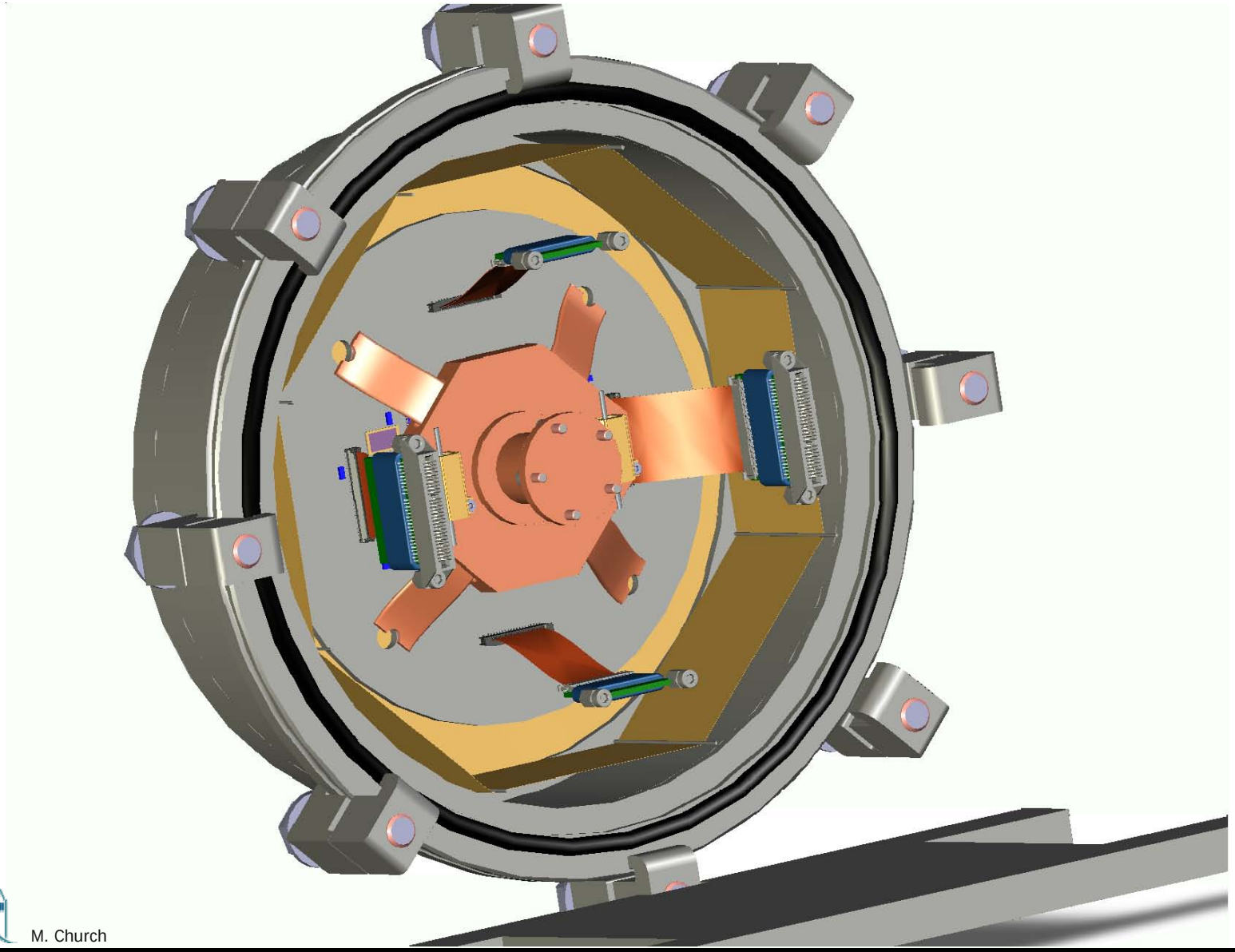
Detector Projects – Fast CCD



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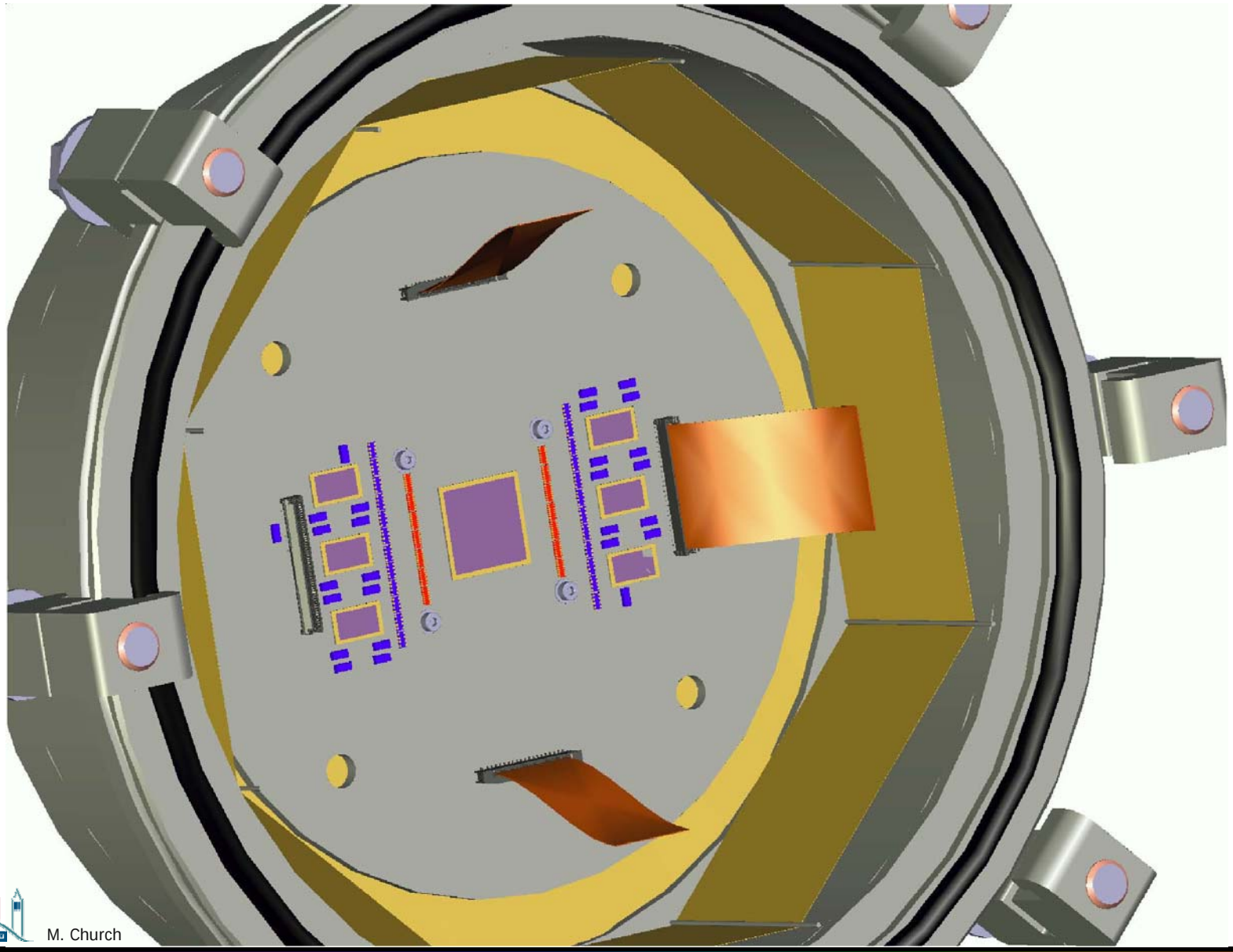
Detector Projects – Fast CCD



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Detector Projects – Fast CCD - Future Projects

- FCCD Project is a stepping stone to bigger and better detectors
  - Design Larger CCDs (1k x 1k or 2k x 2k)
    - *Do our own wafer run?*
  - Use large CCDs to make a large x-ray detector
    - *Mosaic of CCDs*
  - Increase readout speed
    - *More columns*
    - *Faster ADCs*

Conclusions

The End