Detectors for Light Sources

Contribution to the eXtreme Data Workshop of

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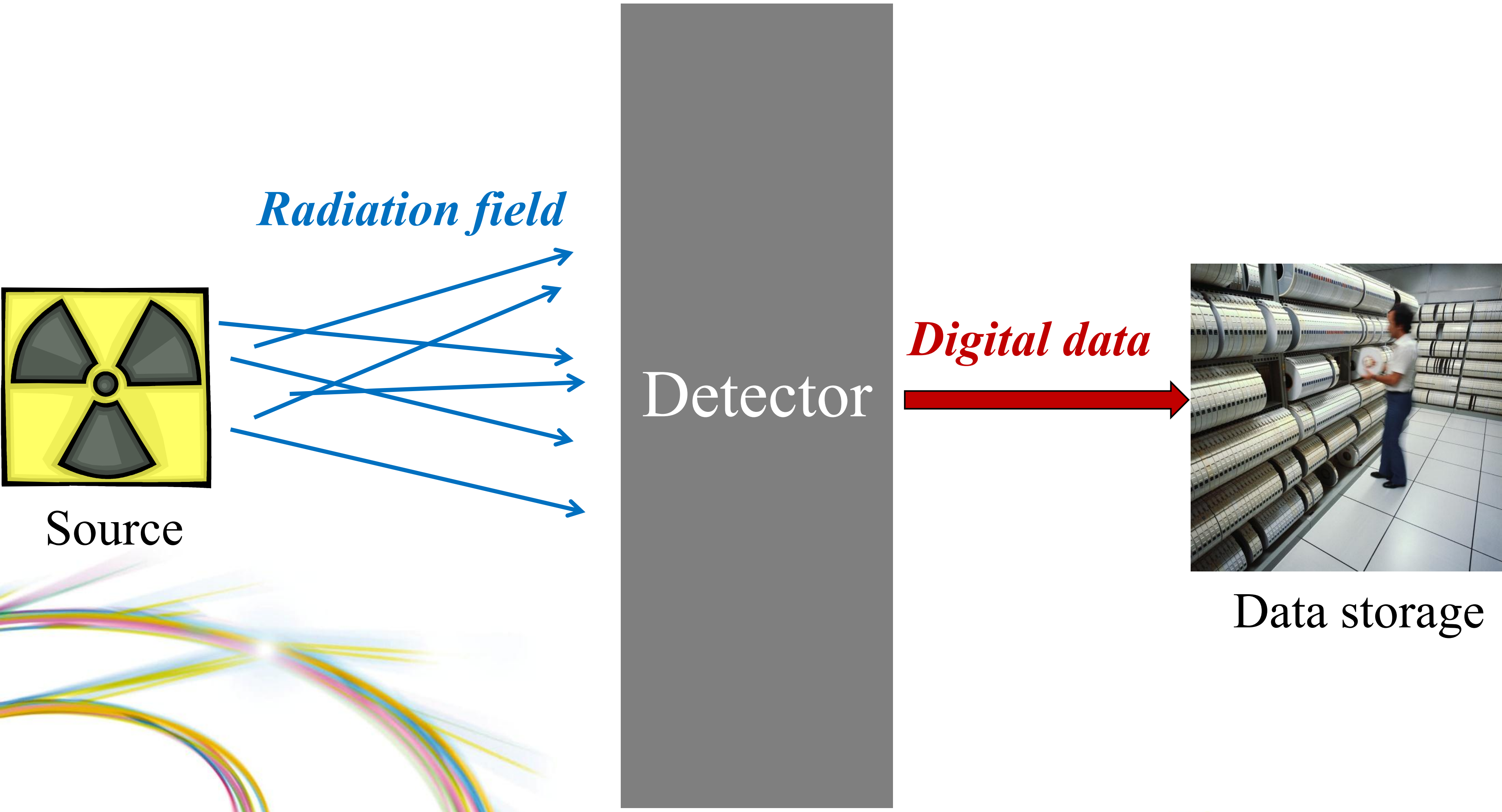
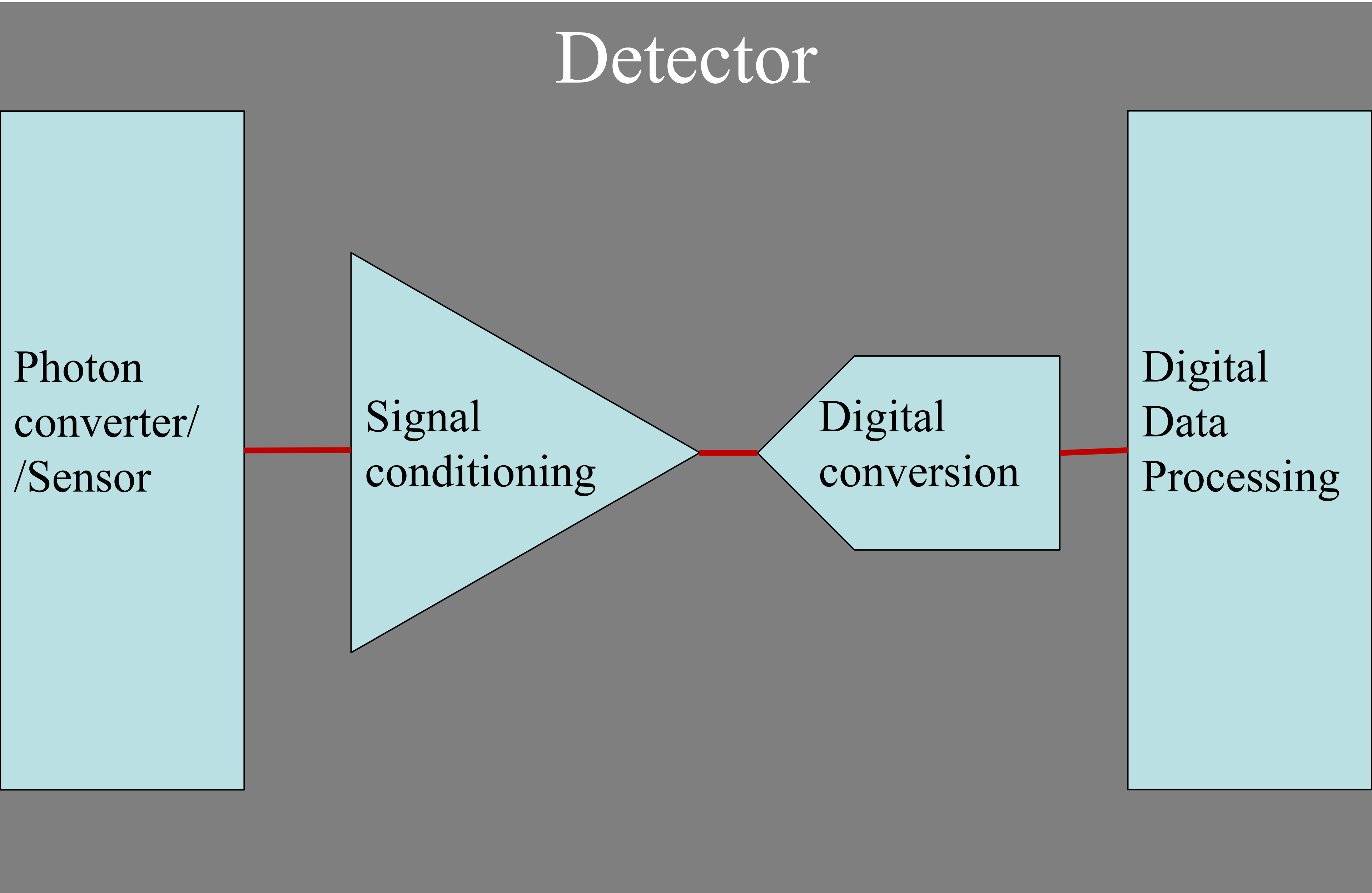
Diamond Light Source

diamond

Outline

- Anatomy of detectors
- Computing inside detectors
- Escalation of data volume
- A view of the future: feedback


Radiation field
Source
Detector
Digital data
Data storage


Detector
Photon converter/ /Sensor
Signal conditioning
Digital conversion
Digital Data Processing

•**Photon converter/sensor** *converts X-ray energy to electric charge. X-ray energy can be converted directly to electric charge (e.g. semiconductor detectors) or indirectly (e.g. phosphors + light sensors).*

•**Signal conditioning electronics** *converts the electric charge generated by the sensor to a voltage signal. It improves the signal to noise ratio.*

•**Digital conversion** *converts the voltage signal to digital. Can be analogue to digital converter, discriminators coupled to counters, a combination of various systems.*

Digital Data Processing

•**Digital filters** *improvement of S/N in spectroscopy detectors*

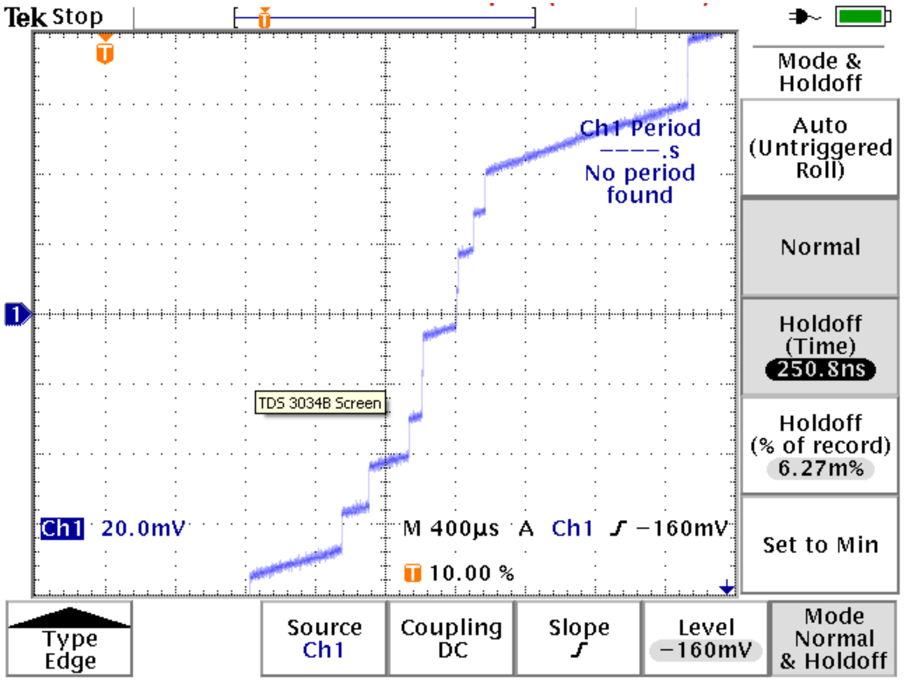
•**Data correction** *dead time correction, flat field correction*

•**Data formatting** *hystogramming,, image frame*

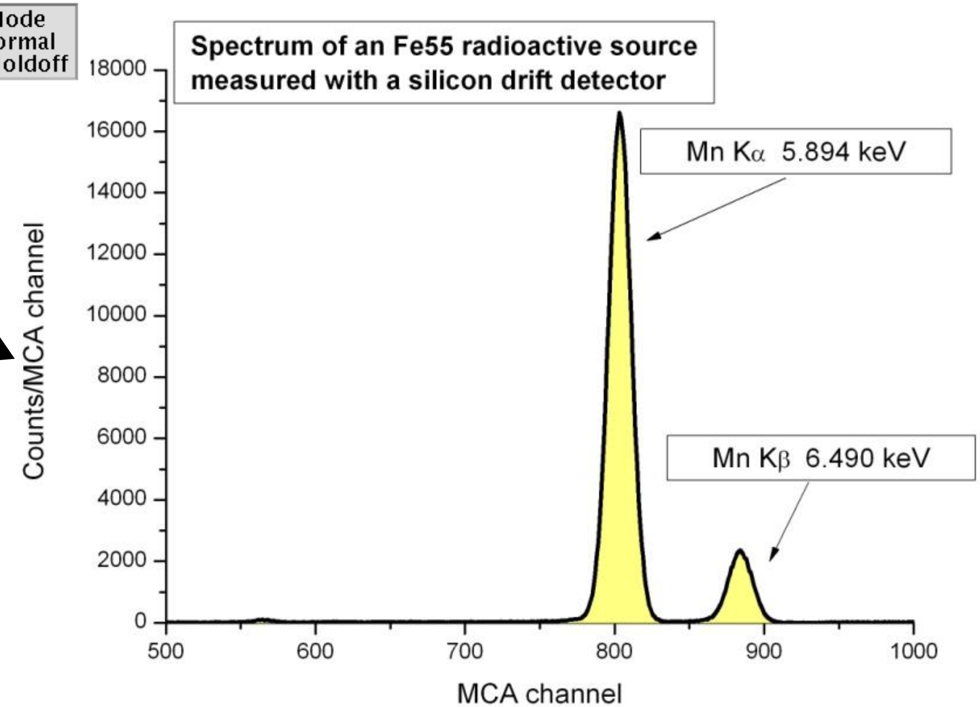
•**Data compression**

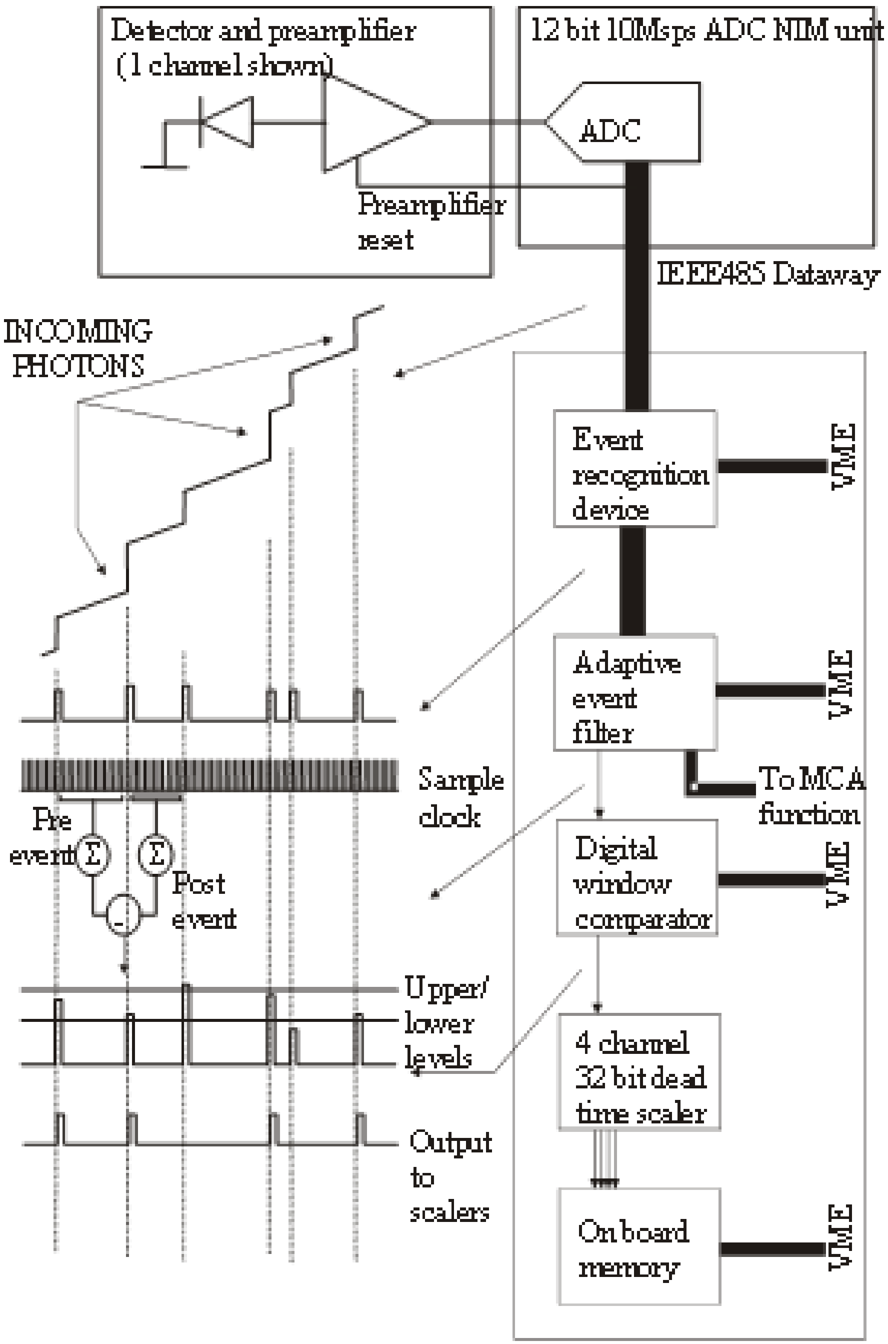
•**Information extraction** *autocorrelation function, peak fitting to deconvolute overlapping peaks*

Output of signal conditioning electronics



Output of digital data processing





- Output of preamps continuously sampled
- ADC XpressII: 80 Mhz sampling rate, 14 bits resolution.
- Trigger event
- Adaptive filter
- Correction of the slope
- Correction of artefacts such as reset cross talk
- Reset inhibit signal for each channel

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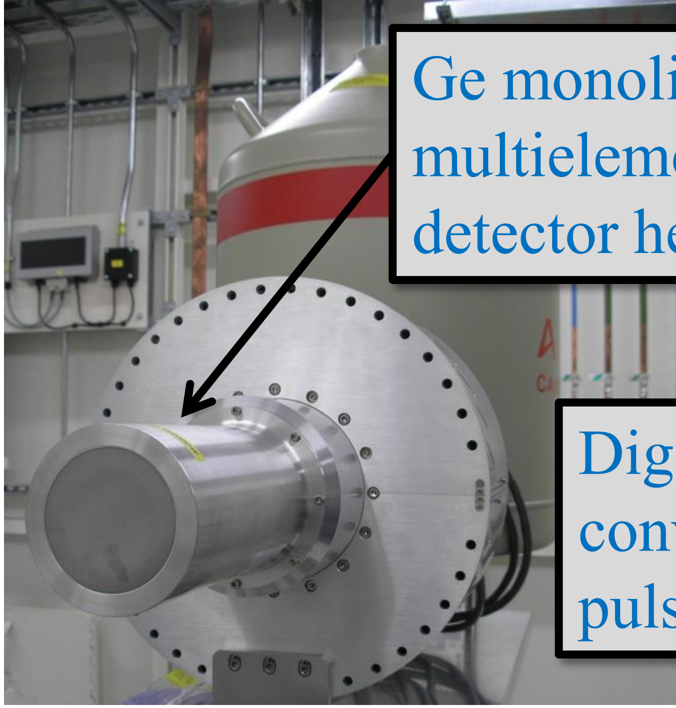


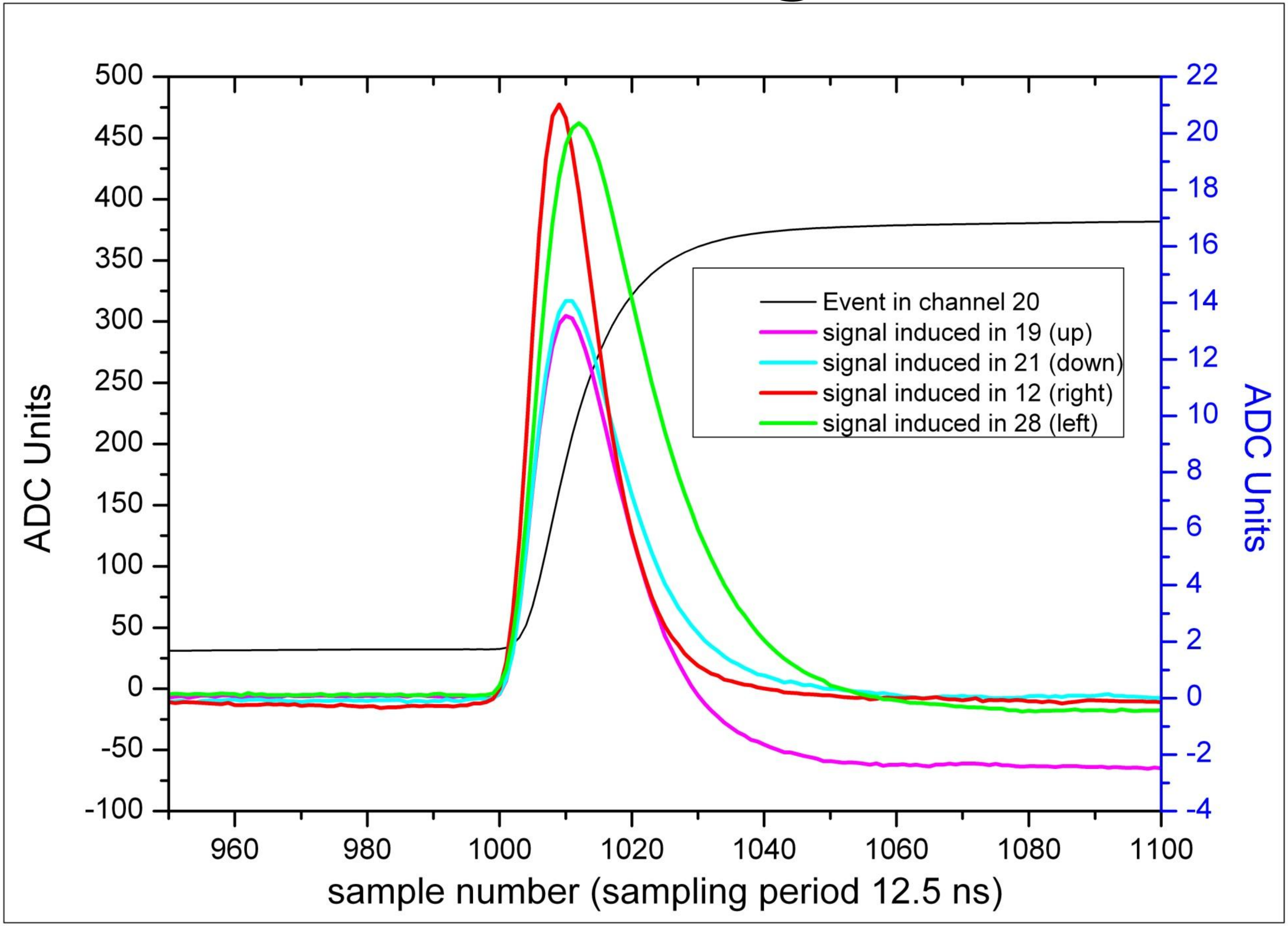
Ge monolithic multielement (8x8) detector head

Digital conversion and pulse processing

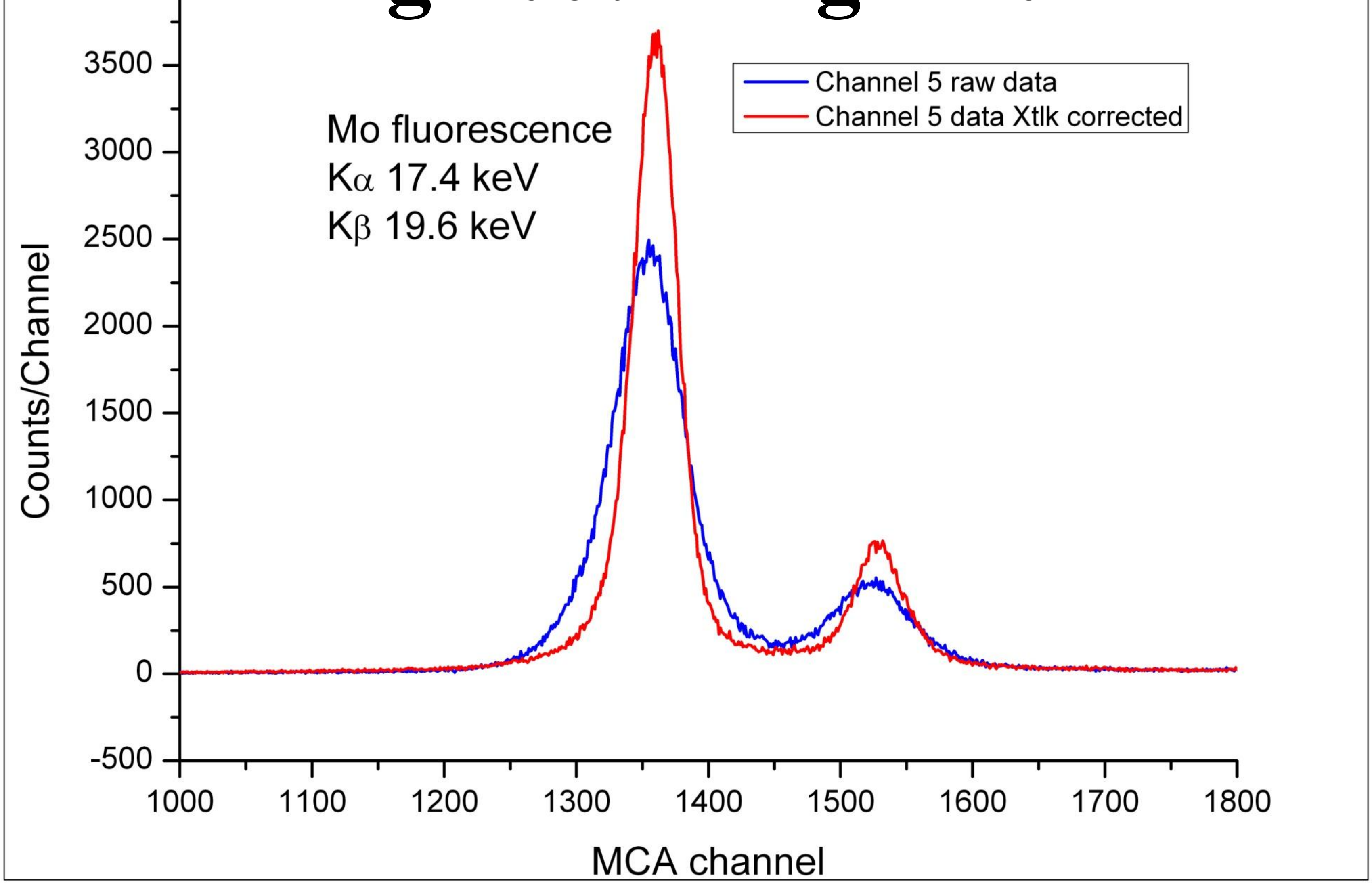
232	238	239	236	243	229	234	218
241	247	237	242	251	233	227	229
233	246	243	240	254	237	236	223
245	241	243	239	246	238	232	227
232	241	243	246	256	235	238	222
227	239	241	243	258	239	228	229
236	237	238	238	250	233	234	220
223	232	229	227	234	224	214	225

Matrix of resolution during a qualification test

Cross talk signals



Impact of cross talk on spectra at high counting rate



X-ray Fluorescence detectors

•X-ray Fluorescence detectors could have hundreds of channels not far in the future.

•A typical X-ray Fluorescence map (e.g. elemental analysis) contains over 10,000 MCA spectra.

•The MAIA detector (Brookhaven development) has implemented on the fly data processing as well as piping data to analysis packages for near real time data analysis.

"The ability to rapidly stream the data to an external processing system, to store the data in efficient file formats and incorporation of some degree of automation is highly desirable"
(Fred Mosselmans I18 PBS)

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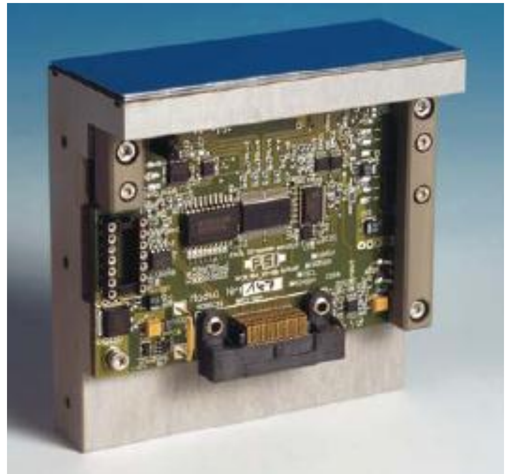
- **Mosaic of 9 CCD sensors**
- **Pixel size**: 51 um x 51 um
- **No. of Pixels:** 6144 x 6144
- **ADC depth:** 16 bits
- **Read-out time:** 1.1 s
- **Image size:** 72 MB
- **Binned image size:** ~20 MB
- **Data set per sample:** ~ 300-400 images
- **“Volume” of a data set:** ~ 6-8 GB

Single module
8x2 chips
172 µm x 172 µm pixels

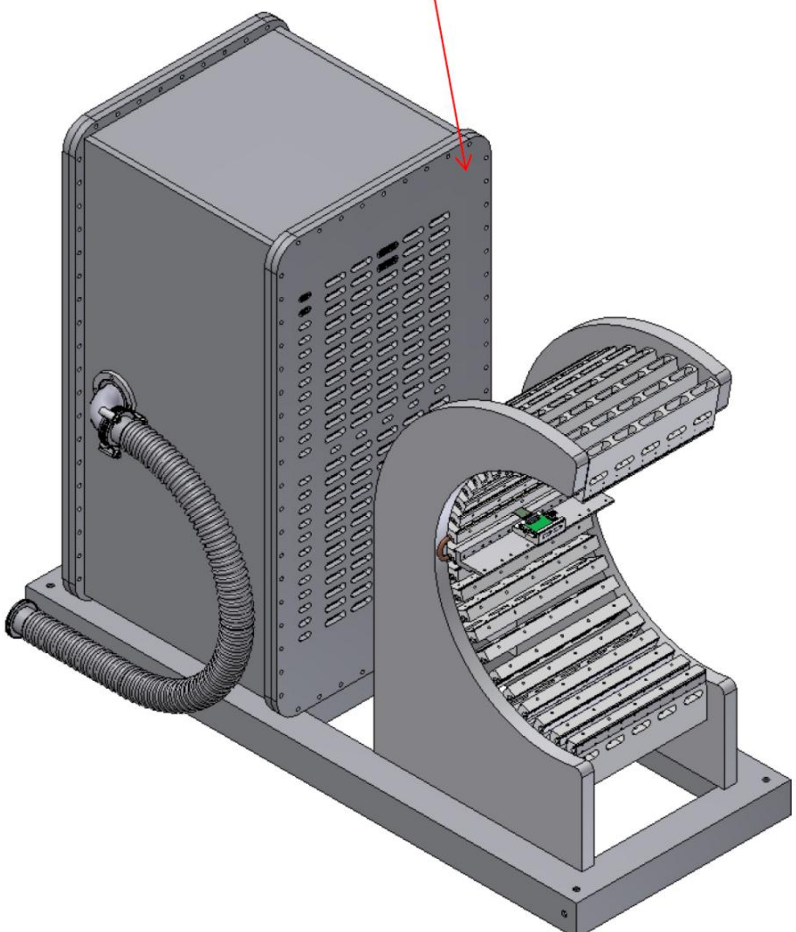


P6M
5x12 modules
~ $43x45\ cm^2$

- **Hybrid detector, 60 monolithic silicon sensors,**
- **Pixel size:** 172 um
- **No. of Pixels:** 2463 x 2527
- **Counter depth:** 20 bits
- **Frame rate:** 12 fps
- **Image size (Tif 32 bits):** ~23 MB
- **Compressed image: ~** 6 MB
- **Data set:** ~ 1800 images
- **"Volume" of a data set:** 11 GB
- **P6M recently upgraded to 25 fps**
- **Future development P6M to 100 fps**

Pilatus 12M

Detector for long-wavelength macromolecular crystallography beamline I23.



- In-vacuum detector (10^{-7} mbar)
- 120 P100k modules in semi-cylindrical geometry
- 24 banks, 5 modules wide
- Delivery spring 2013.

- Assumption 2 x 180 deg in different orientations, 0.1 deg oscillation → 3600 images
- Image size: 12.0 MB
- Estimated data set size:
  12.0 MB x 3600 ~ 43.2 GB
- 48 samples in 24 hours
- Over 2 TB per day

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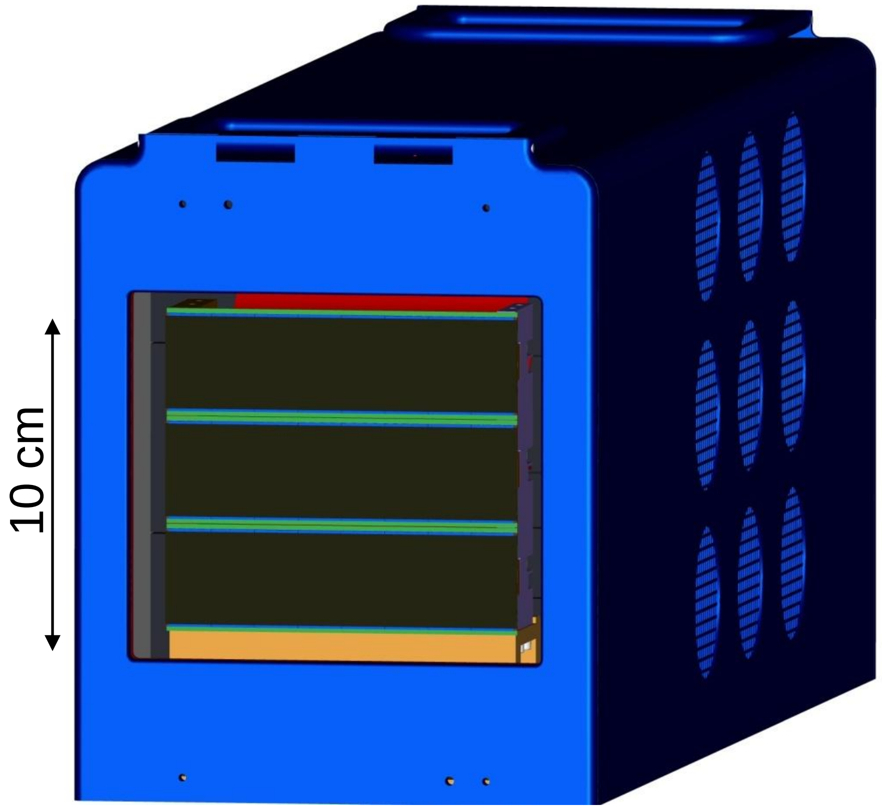
EXCALIBUR

Enhanced **X**-ray **CA**mera for **L**ive **I**maging and **BUR**st mode operation

DLS/STFC Development project

Mode	Counting
Pixels	55 µm
Read-out time	500 µs
Sensor	Silicon (300 µm)
Area	11 cm x 10 cm (3M pixels)
ASIC	MEDIPIX3
Frame rate in continuous mode	100 images/s @ 12bit ~0.6 GBytes/s
Frame rate in « Burst » mode	1000 images/s @ 12bit ~ 6 GBytes/s vers RAM



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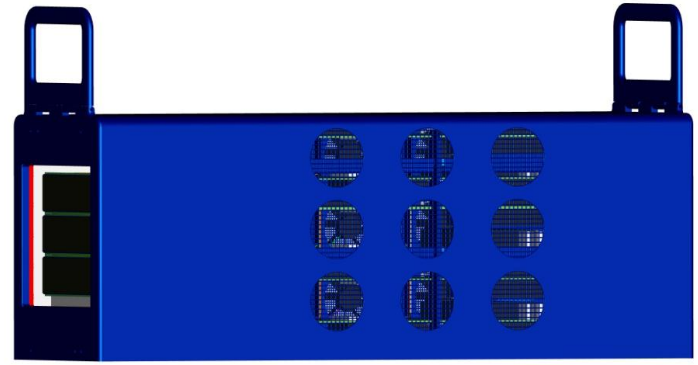
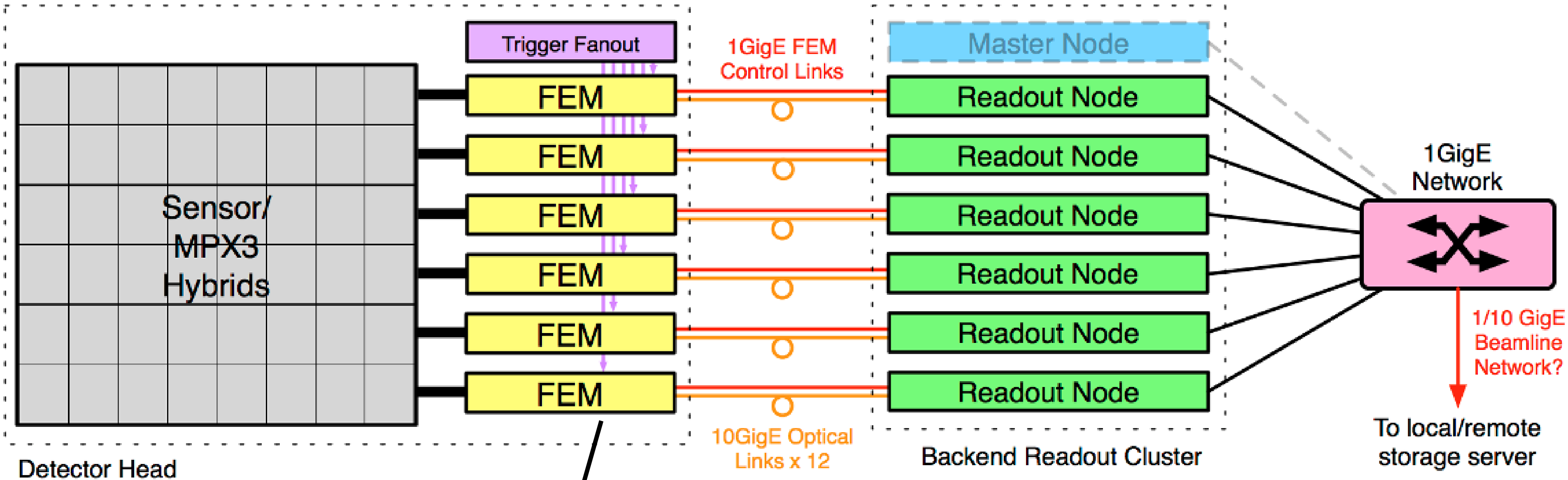
EXCALIBUR

3 modules
3M pixels (11 x 10 cm)
8x2 MPX3/module
1 FPGA card / row of 8 MPX3s



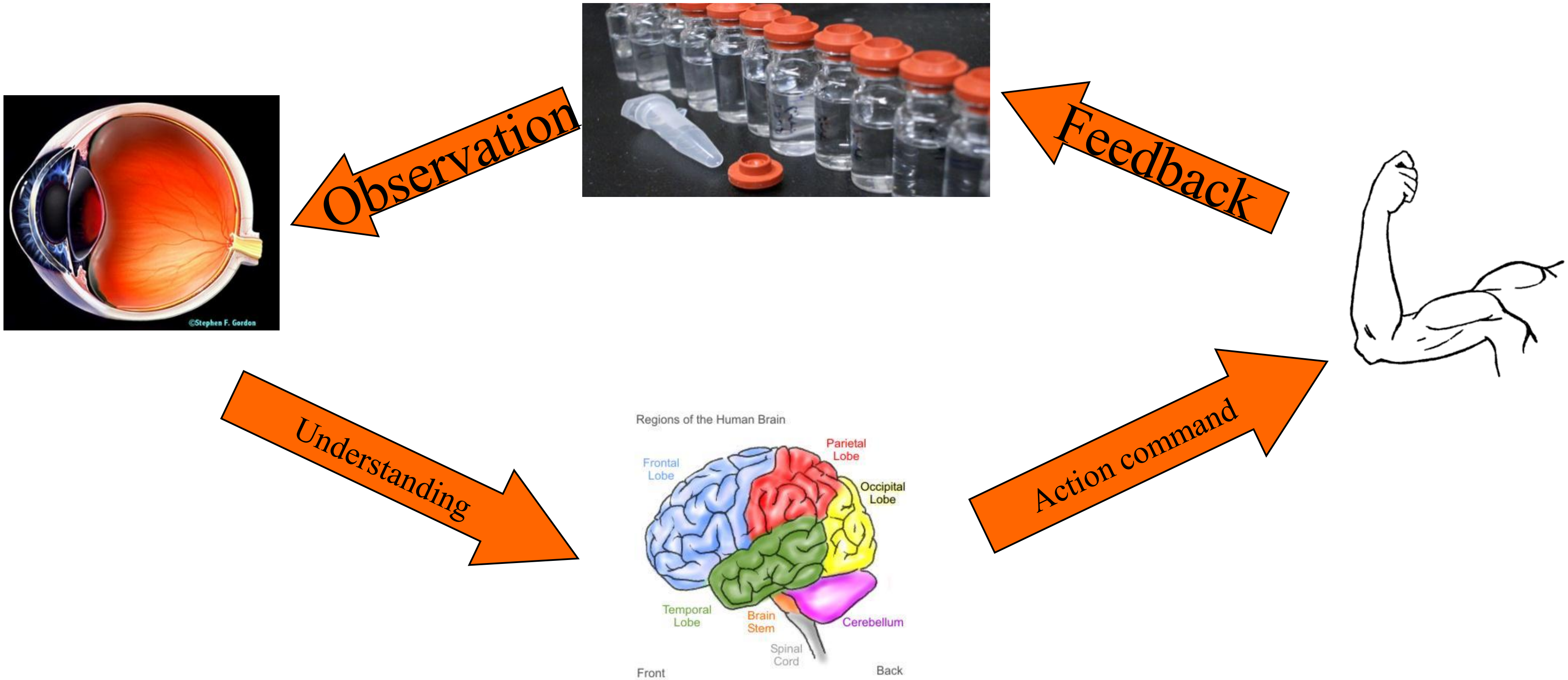


Front-End Module (FEM) FPGA card

Readout backend: 6 Linux nodes

- Buffering, local storage & processing of image data
- Interface to EPICS for DAQ & control

Connect a brain to your eye



An "intelligent" board can open up a completely new realm for detectors:

THE DETECTOR WILL DRIVE THE EXPERIMENT!

- Real time calculation (e.g. autocorrelation function)
- Pattern recognition
- Variable integration time as a function of photon flux
- Feedback to the diffractometer, sample environment, other instruments

- **Detectors in 20 years will no longer look the same because of the computing power that will be embedded.**

- **Detector and beam line scientists and users look forward to future developments in computing.**

Thank you!