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IFDEPS – First Operation Experiences With New Detectors

The Large Pixel Detector for the European XFEL: overview of the system and experience of operation at the FXE beam line

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European XFEL

LPD Introduction

Large Pixel Detector

- Built by Technology Department, Detector Division for the European XFEL
- **1 Megapixel** - 500um pixels
- **4.5MHz frame rate**
- **High dynamic range**, 1 to 1×10^5 photons (12keV) per pixel per pulse. Using parallel gain stages.
- **512 frame memory depth** continuously stores images, overwriting whenever a veto is received.
- Output data rate ~**10GByte/s** per megapixel

The LPD megapixel detector.

The Components

Electronic System Support Group

Feed-through Card

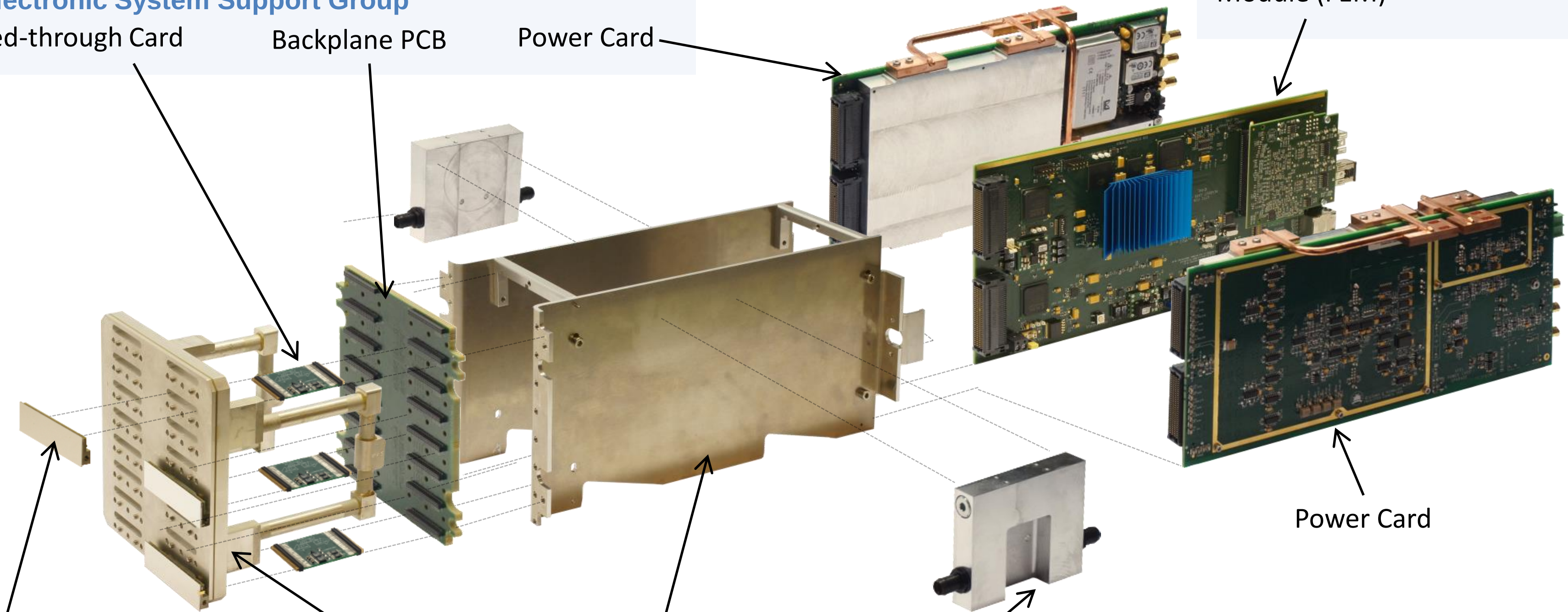
Backplane PCB

Power Card

Electronic System Design Group

Front End DAQ Module (FEM)

Power Card



Detector Tile Hybrid

Sensor and ASICs

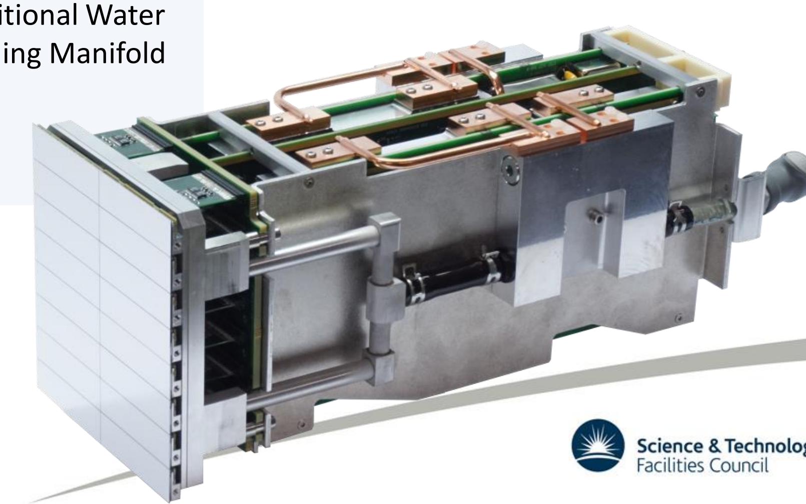
ASIC Design Group, Detector Development Group

Heat Exchanger

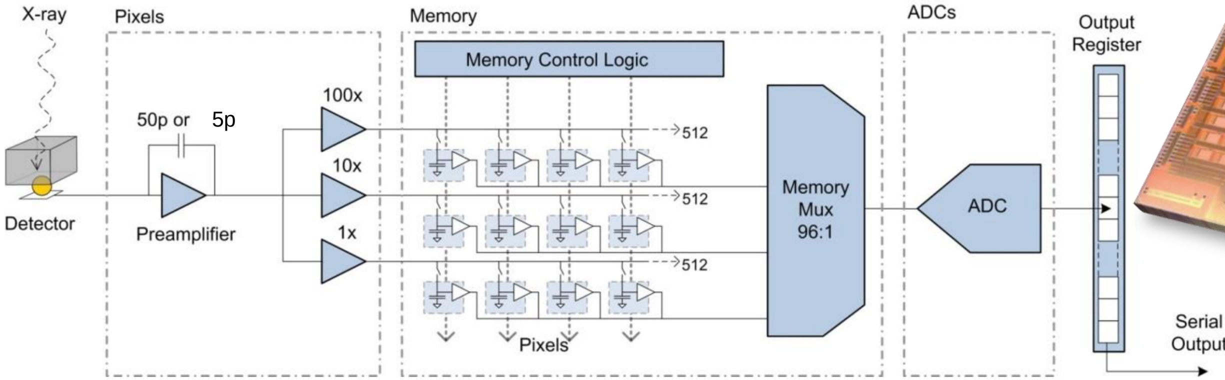
Super-module Frame

Additional Water Cooling Manifold

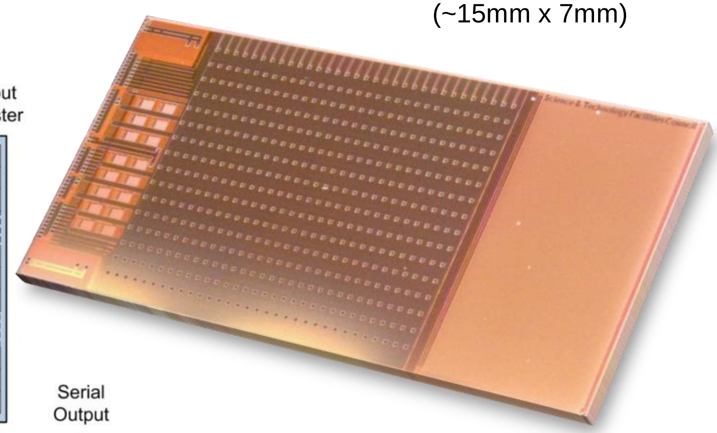
ASD Mechanical Engineering
Technical Systems
Composites and Materials Group



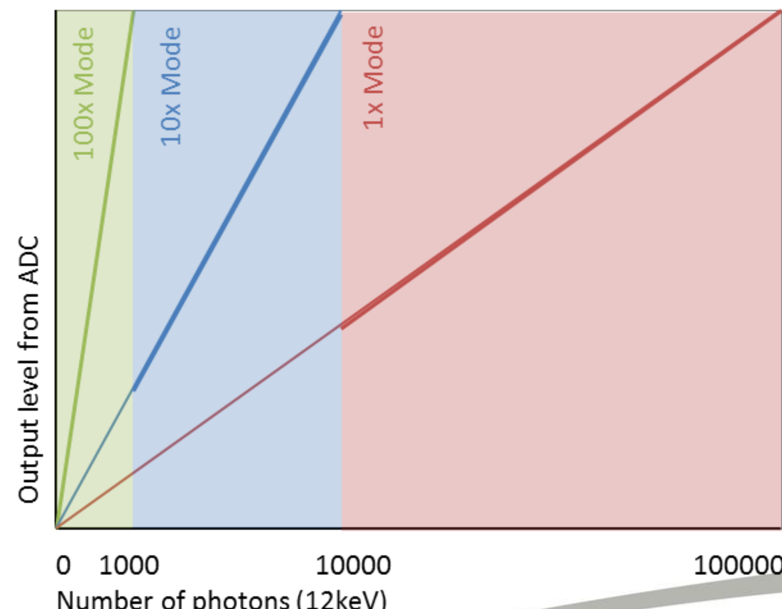
The LPD ASIC



The LPD ASIC
(~15mm x 7mm)



- 512 Channels per ASIC
- Preamplifier with 50pF feedback – 10^5 12keV photons
  - An additional 5pF high gain mode gives sub photon noise performance at the expense of some dynamic range.
- **100x, 10x and 1x parallel gain stages**
  - The best gain for each pixel is selected by the DAQ system during readout.
- **512 frames of memory** for each channel and gain
  - Veto System used to make best use of memory
- 16 ADCs – 12 Bit SAR
- 100MHz LVDS digital output
- Built on IBM 130 nm in 2012



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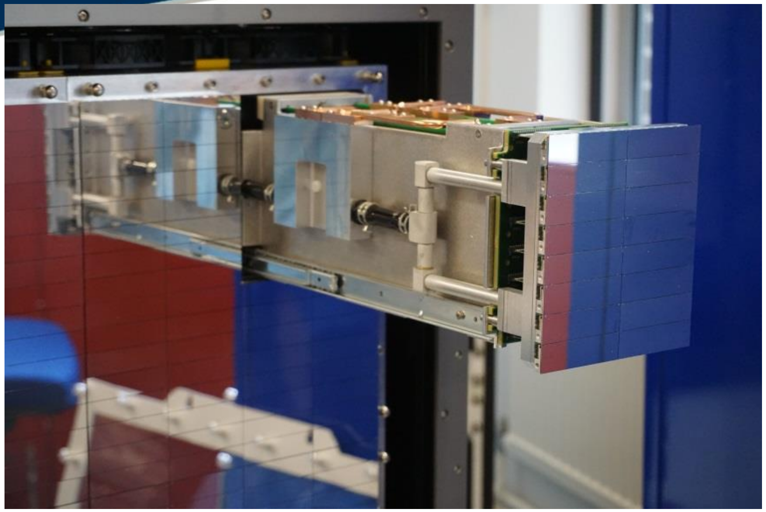
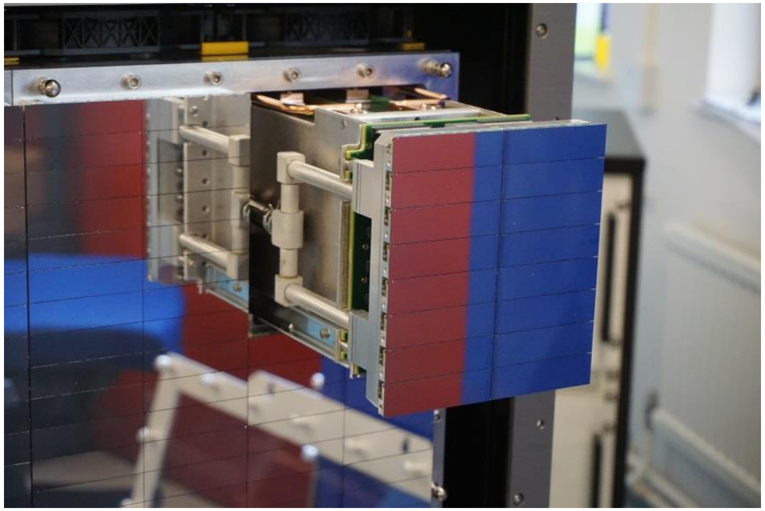
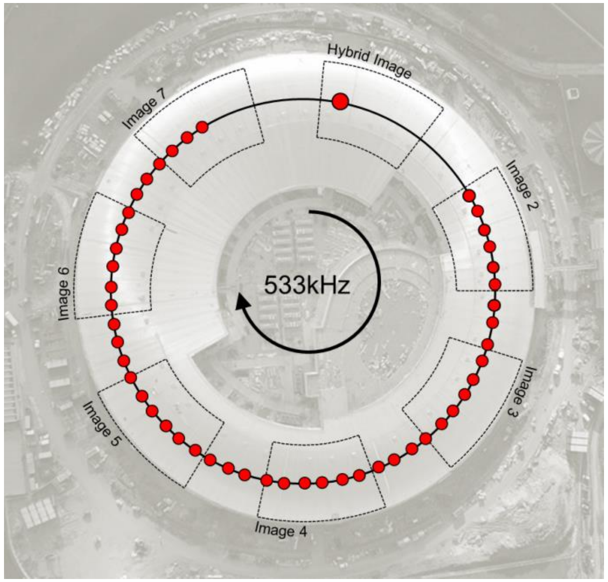
Super-module loading



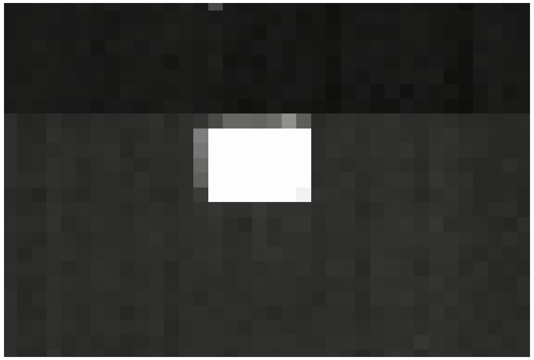


LPD Testing at Diamond

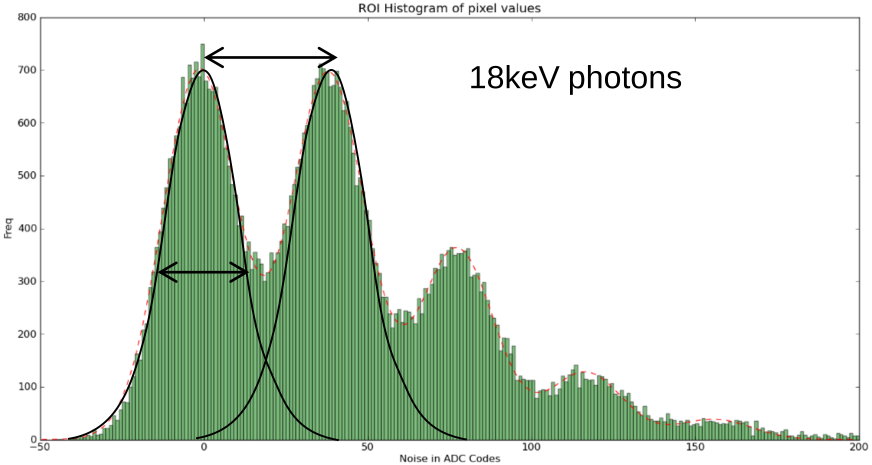
An LPD Super-model setup on B16.



Diamond Hybrid fill mode. Synchronized with LPD running at 3.8MHz



LPD imaging the Diamond Hybrid pulse



High gain mode noise
σ = 0.3 photons (18keV)

- Diamond Hybrid mode a good tool for testing and calibrating high speed detectors at low flux.
- Rest of the fill causes problems. Is an ESRF style 2-4 bunch mode possible?

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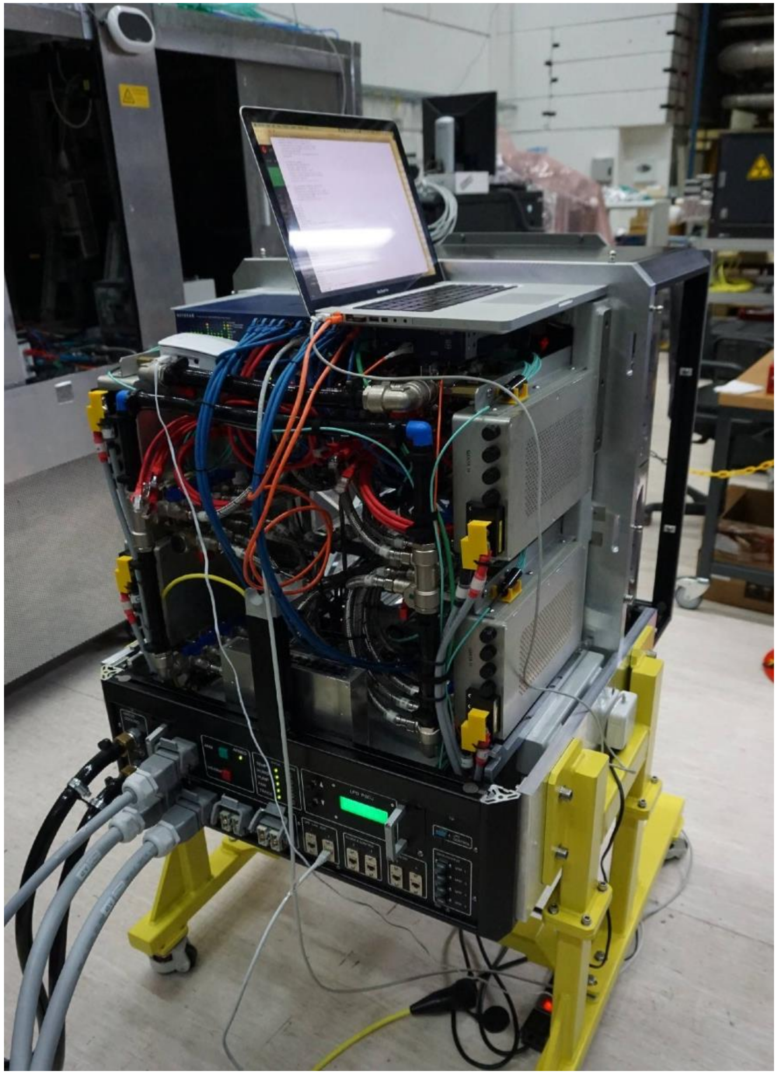
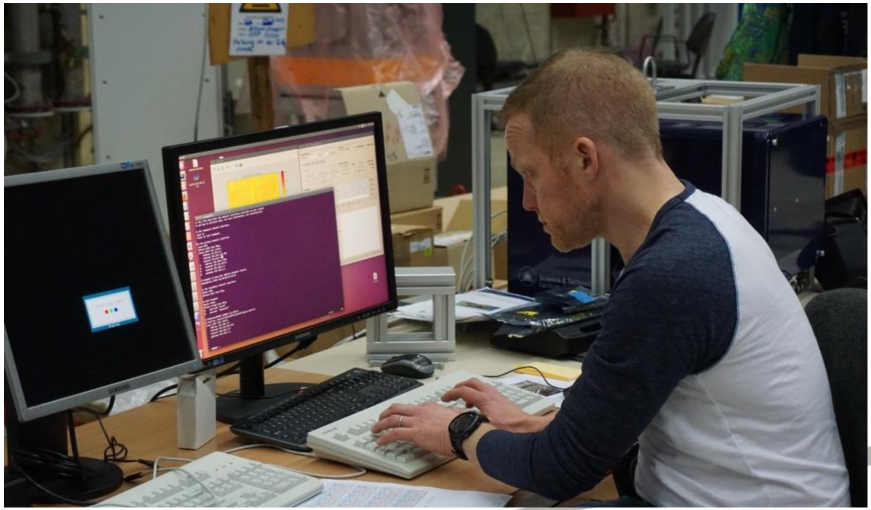
LPD at Hera South

LPD Shipped to Hera South – Feb 27th 2017
Operational at Hera South - March 8th 2017





Integration

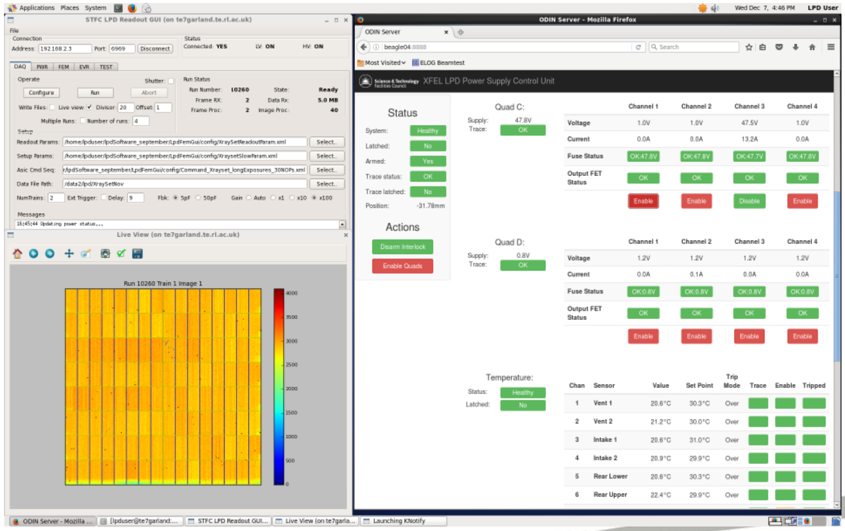
LPD Power Supply

STFC Train Builder

LPD 1M status log data for the month of February 2017

STFC Detector Division

- Experienced in delivering challenging power supplies and cooling
- Designed the Train Builder, Responsible for handling the data from all XFEL detectors
- Software fully compatible with XFEL Karabo. Also triggering and timing with XFEL Clock & Control



LPD Software – transparent to XFEL Karabo

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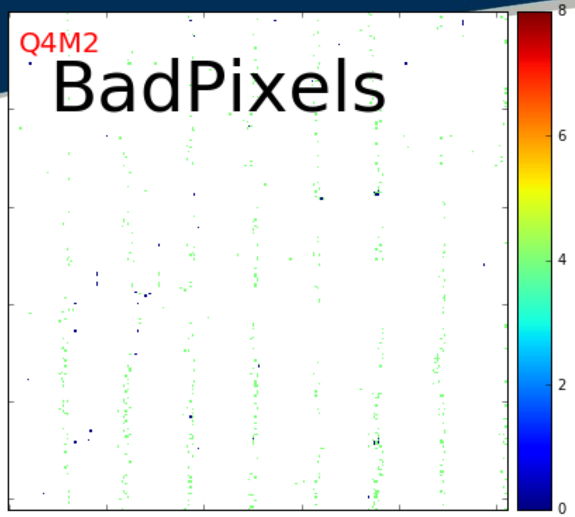
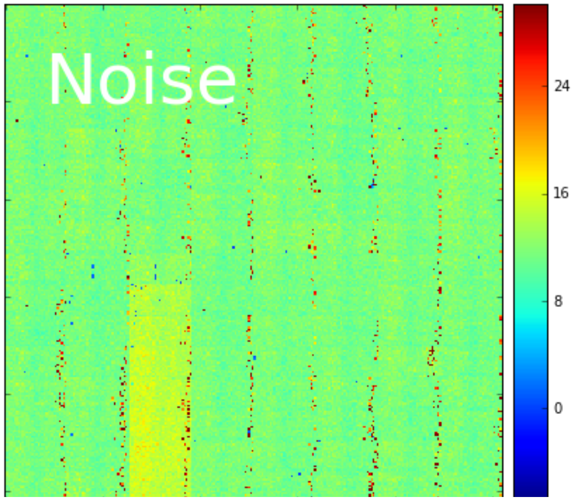
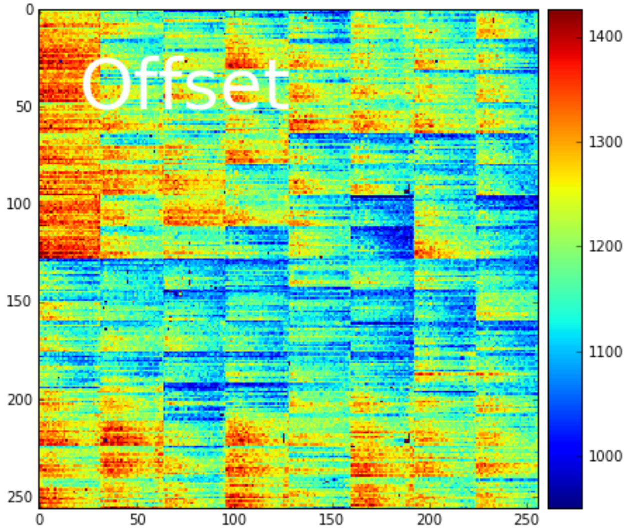
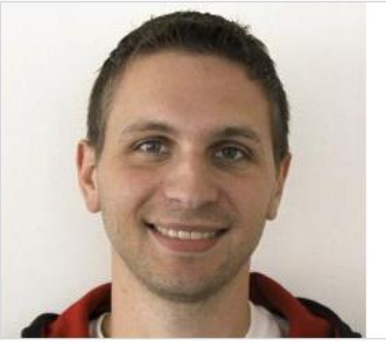
Early Calibration Efforts









Credit: **Philipp Lang.** Detector Scientist LPD lead at XFEL

Noise (ADU)	100x, 5pF	10x, 5pF	1x, 5pf
Q1M1	11.81	3.71	2.51
Q1M2	11.72	3.69	2.5
Q1M3	17.23	7.24	2.42
Q1M4	11.73	3.74	2.54
Q2M1	15.25	9.88	8.34
Q2M3	11.7	3.71	2.51
Q2M4	12.09	3.78	2.52
Q3M2	12.98	6.19	4.69
Q3M3	18.02	11.17	10.39
Q3M4	11.72	3.69	2.53
Q4M1	30.26	20.97	21.39
Q4M2	18.21	4.61	2.65
Q4M3	11.63	3.69	2.52
Q4M4	11.67	3.7	2.53

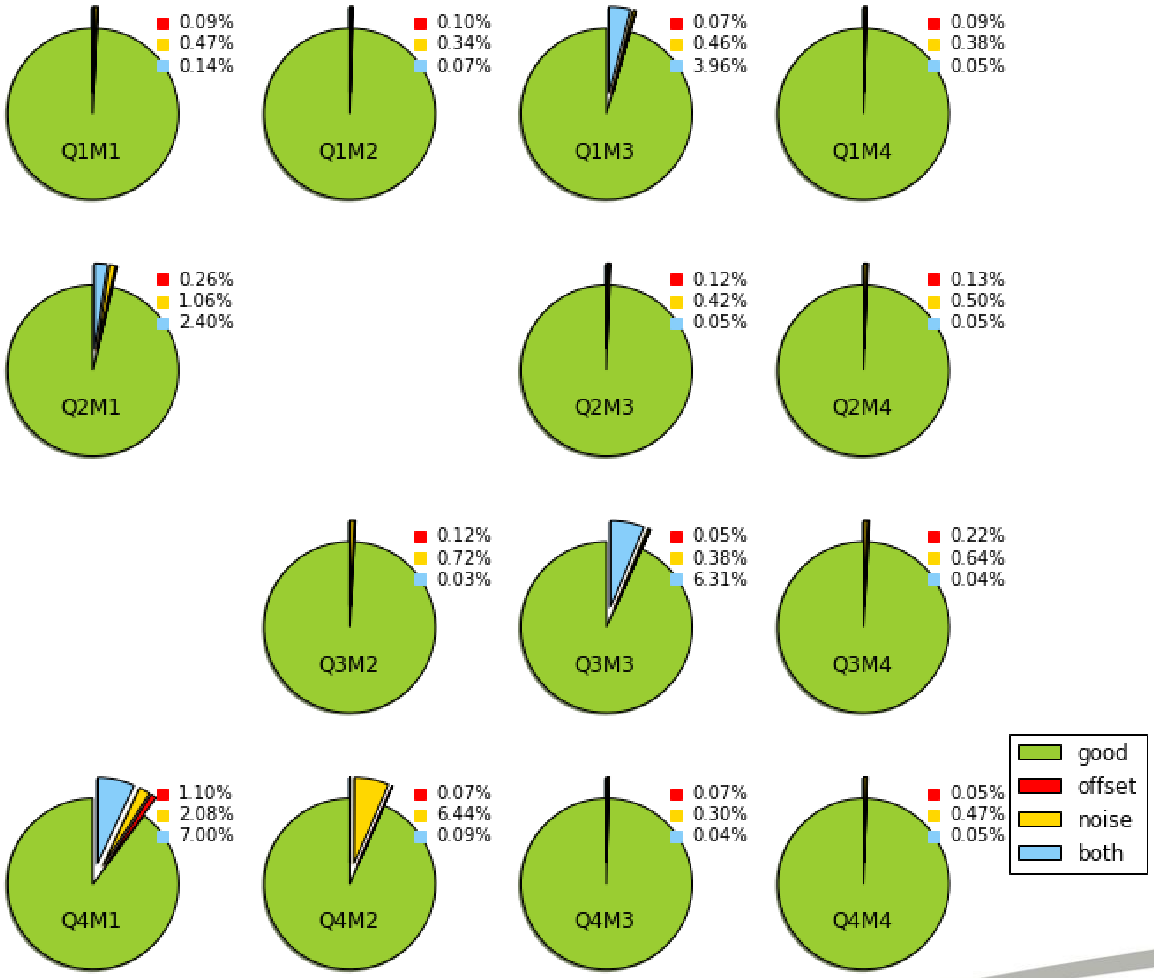
- Automated tested within the Karabo control environment.
- Updates detector calibration database
- Keeps track of detector health

Early Calibration Efforts

Credit: **Philipp Lang.** Detector Scientist LPD lead at XFEL

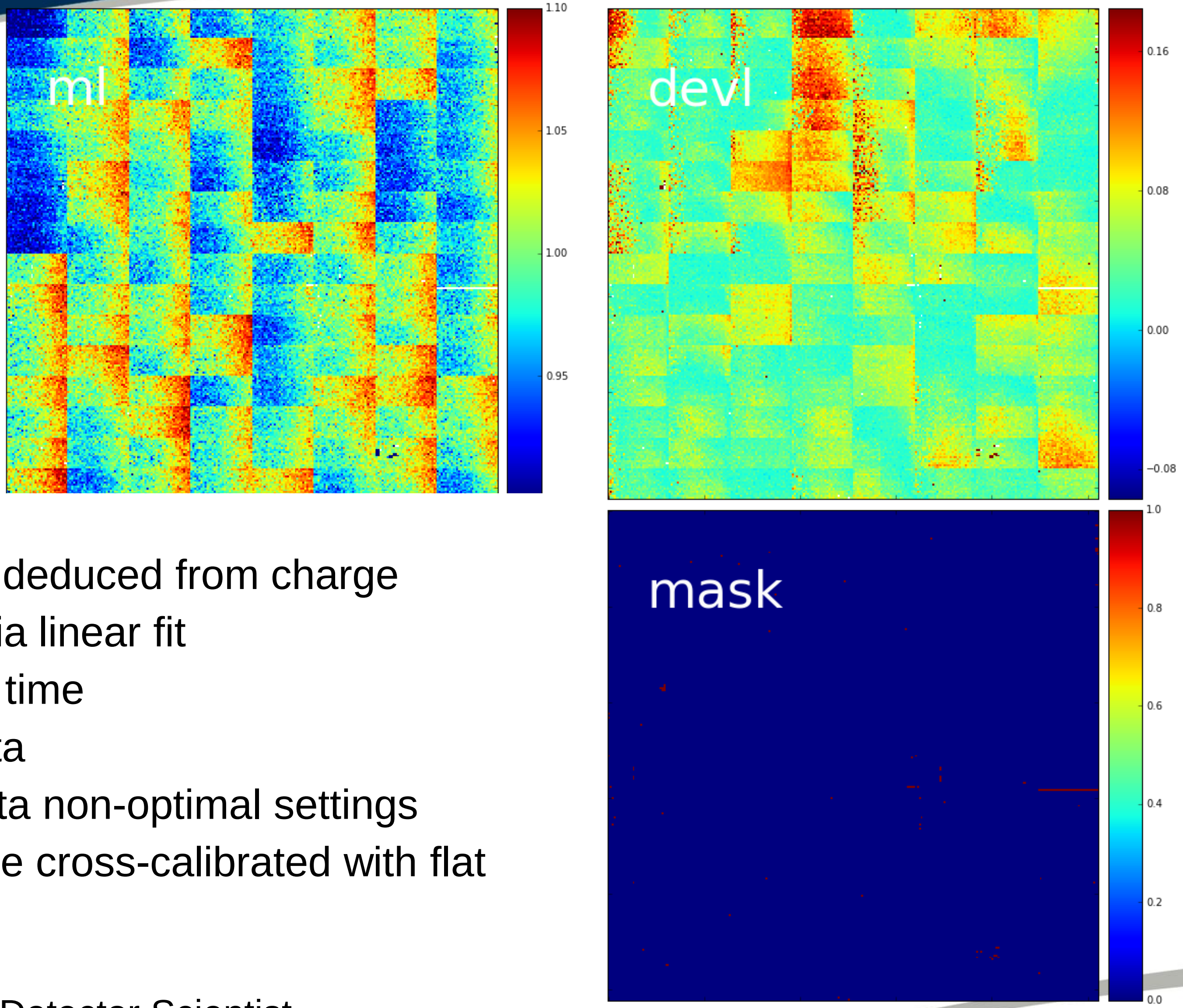
Dark Image Deduced Bad Pixels – High Gain

- bad pixels are pixels that:
  - exceed offset thresholds
  - exceed noise thresholds
- most modules have less than 1% bad pixels
  - exception: Q1M3,Q3M3, Q4M1



Early Calibration Efforts

Relative Gain



- Relative gain deduced from charge injection run via linear fit
  - 2 days run time
  - 3 TB of data
  - Current data non-optimal settings
  - Needs to be cross-calibrated with flat fields

Credit: **Philipp Lang**. Detector Scientist LPD lead at XFEL

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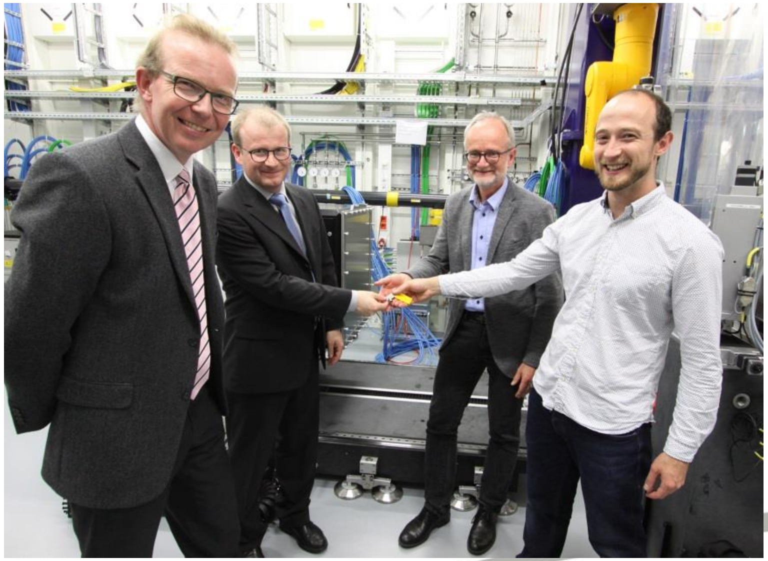
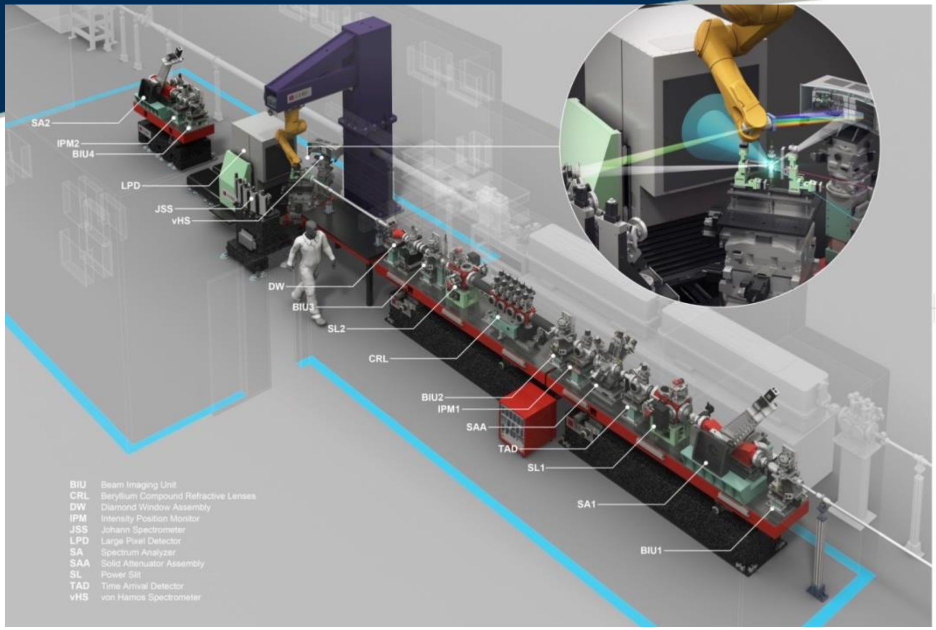
LPD 1M Final Installation

Delivery of LPD to the XFEL experimental hall



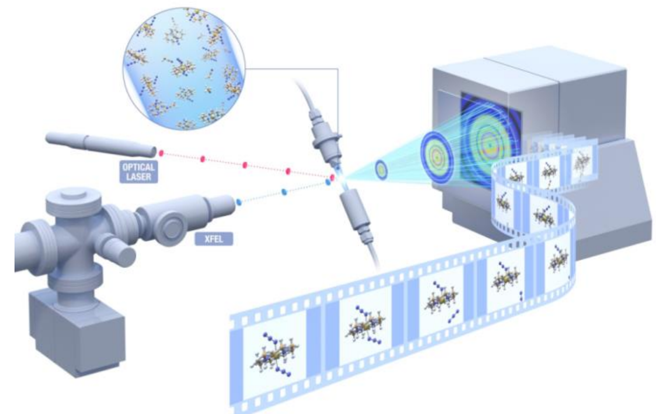
LPD mounted at FXE

LPD @ FXE



FXE – Femtosecond X-ray Experiments

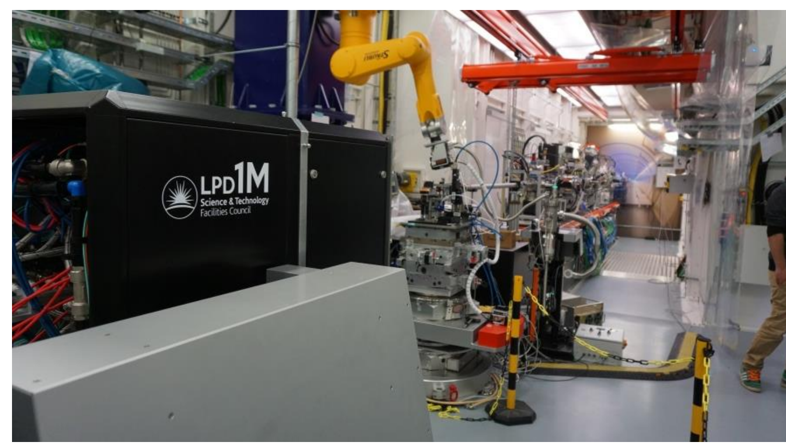
Ultrafast photo-induced processes
in liquids and solids



Christian Bressler

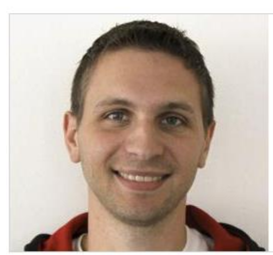
Andreas Galler

Dmitry Khakhulin



Frederico Alves Lima

Peter Zalden



LPD Lead: Philipp Lang

….and more!

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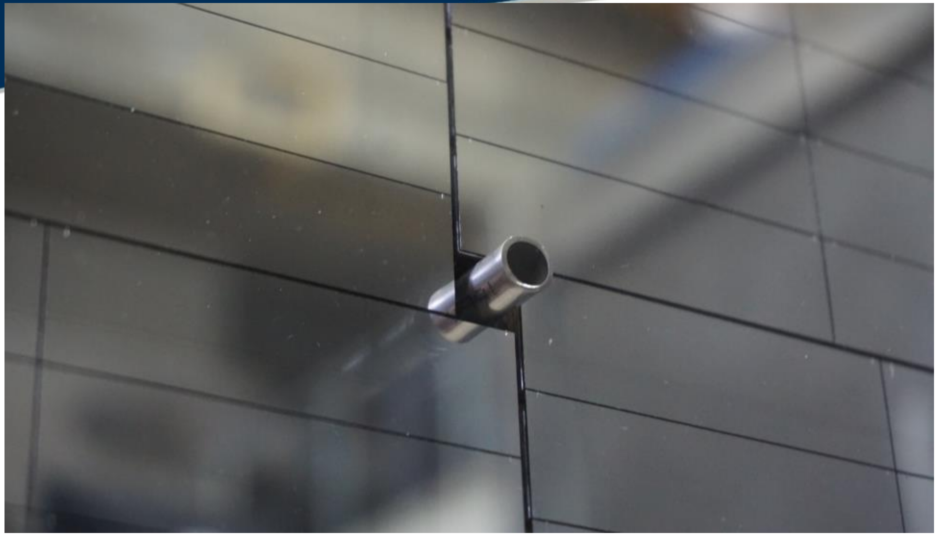
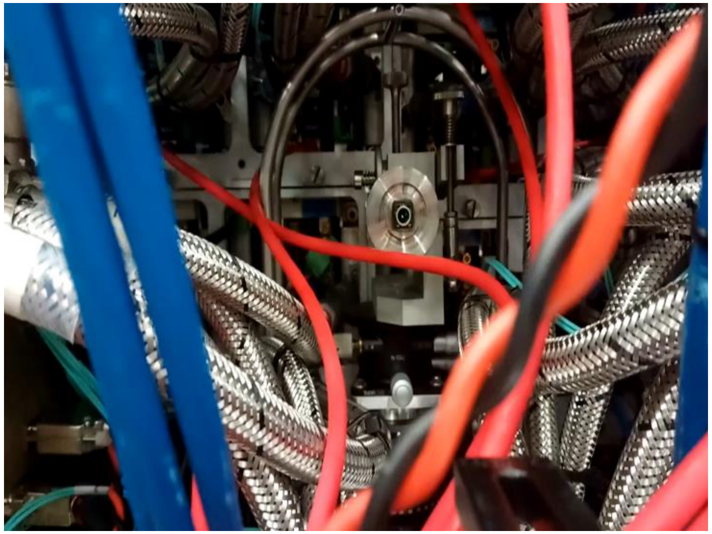
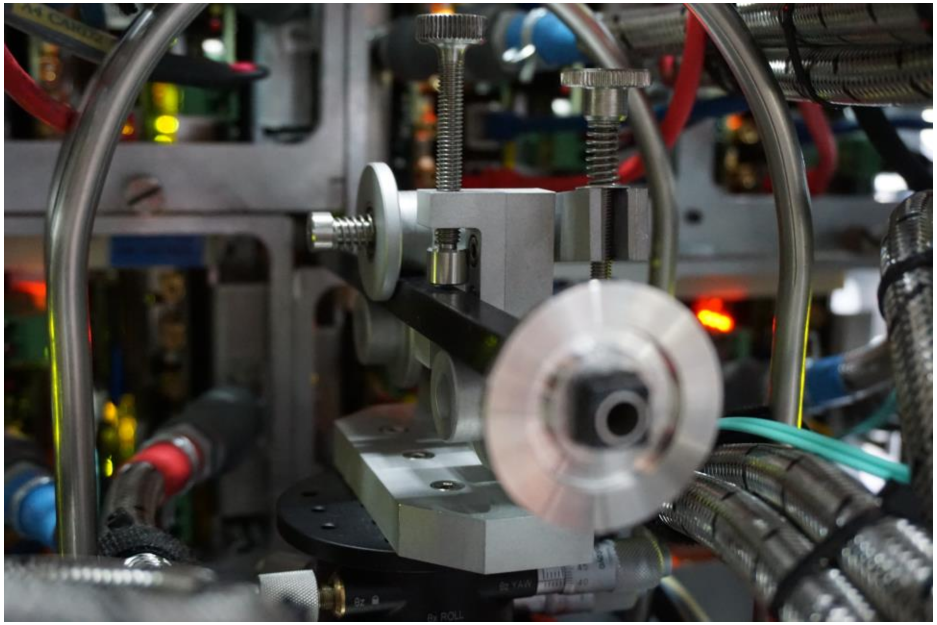
1st LPD Commissioning Beam Time

- Last weekend 4th and 5th March. 2x 12 hour shifts
- Main goals
  - Perform **timing calibration** – sync detector and machine
  - Trial some flat field setups and gather data for **gain corrections**.
  - Take diffraction reference images to verify **positional calibration**.

Beam Pipe Alignment





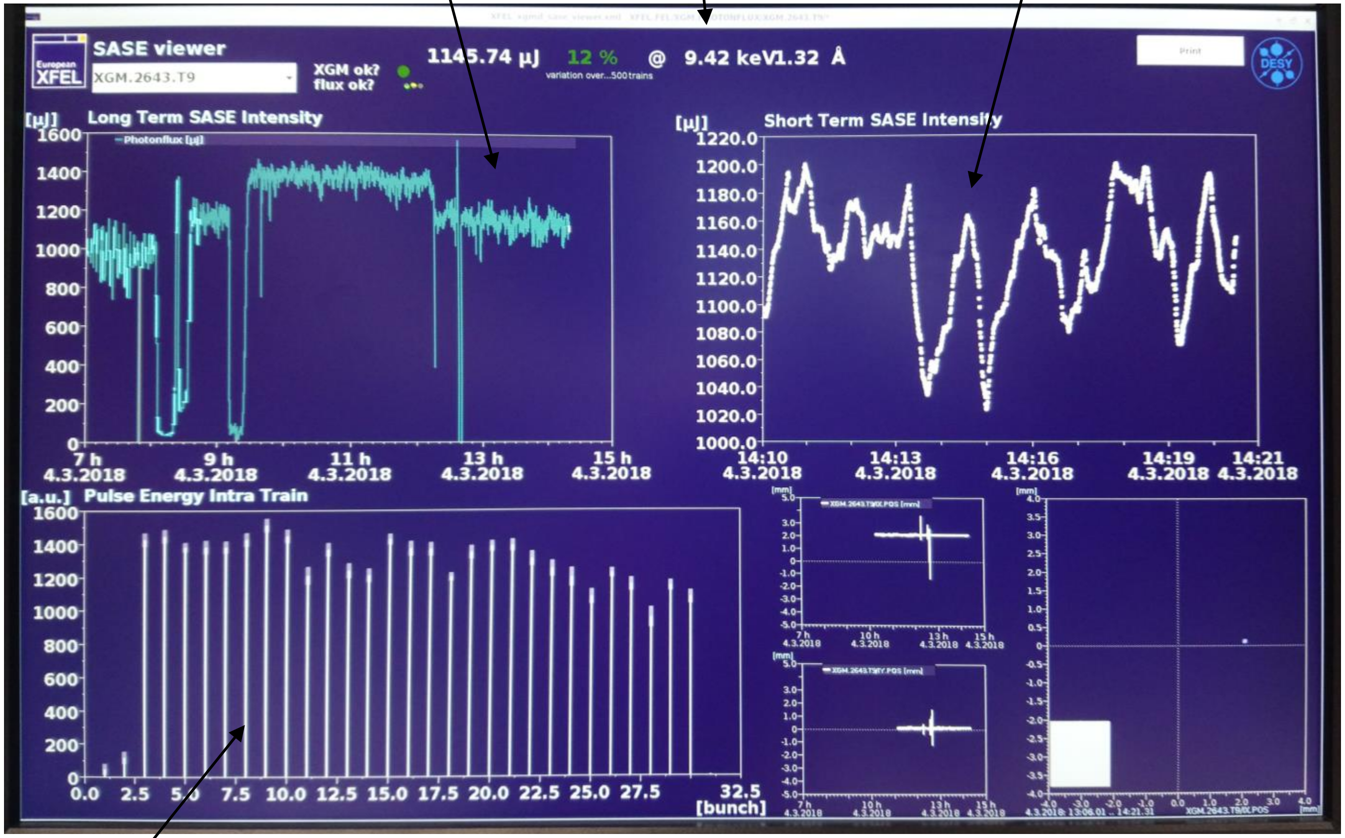


Machine Setup

Long timescale stability
Uptime was good

9.42keV

Short term stability
i-zero needed for good calibration



30 pulses per train – spaced 4 LPD images apart

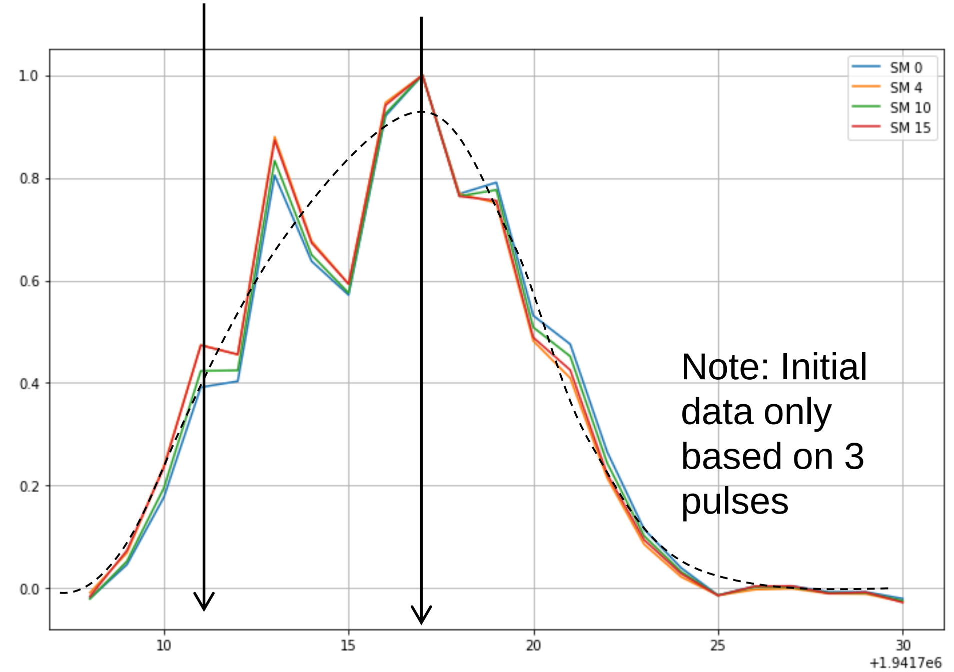
LPD First Commissioning time at FXE

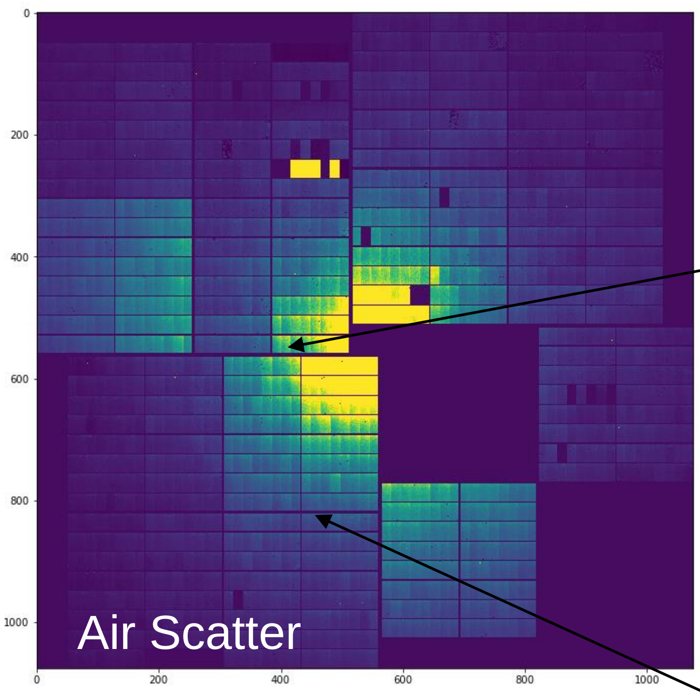
Step 1 – Timing calibration

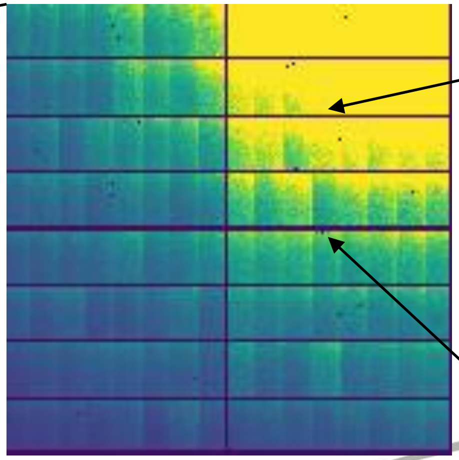
- 4.5MHz = 222nsec from pulse to pulse but only 90nsec for integration. The rest is reset.
- Bad pulse timing can lead to image artefacts and increased noise

Example of bad timing ✗

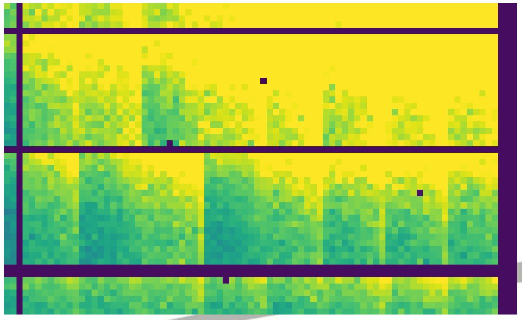
Optimised Pulse Arrival Time ✓







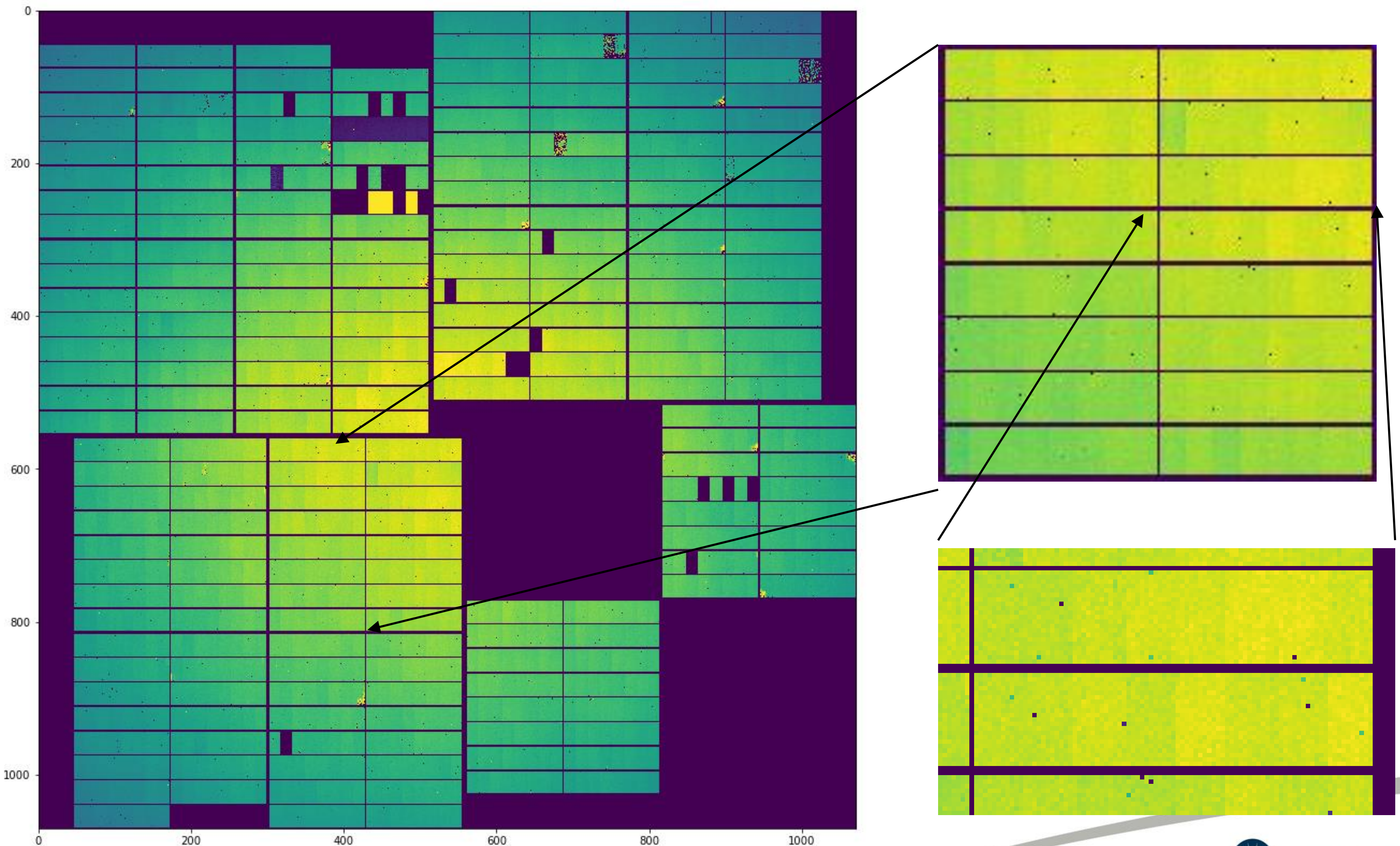
Poor uniformity with bad timing



Flat Field Tests

Flat(ish) field from copper fluorescence

Approx. 50-100 photons per pixel with good timing



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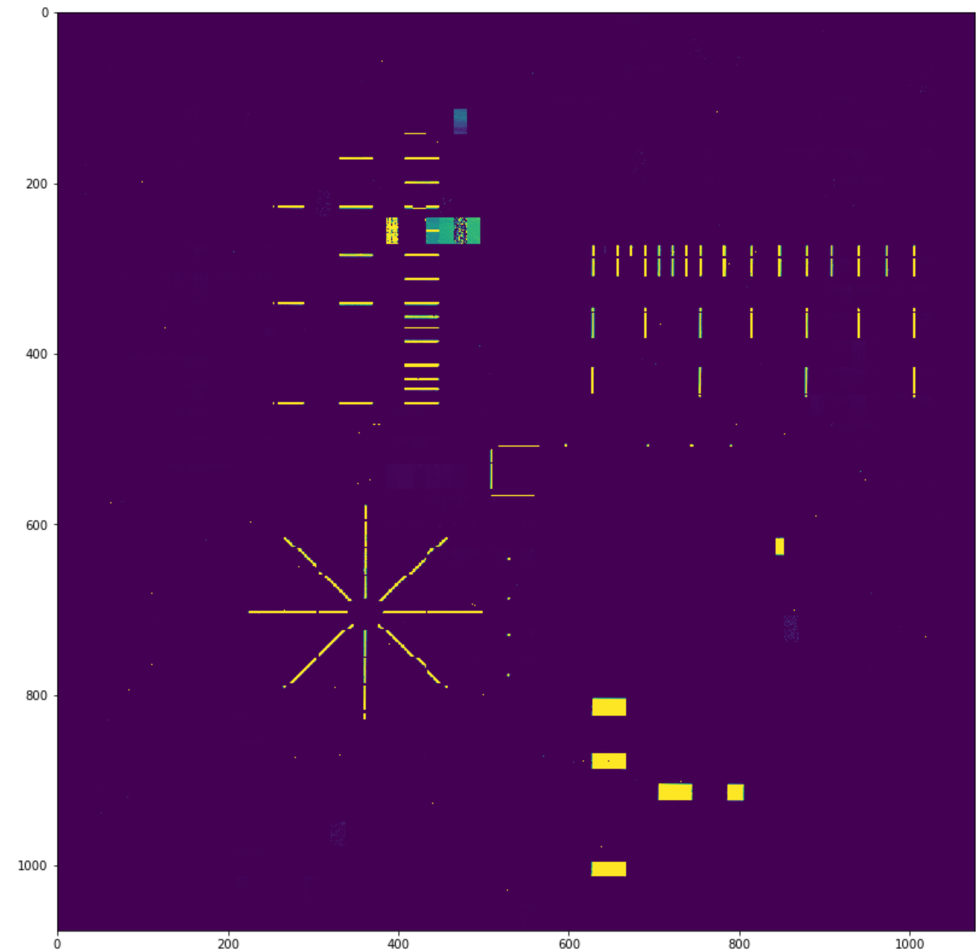
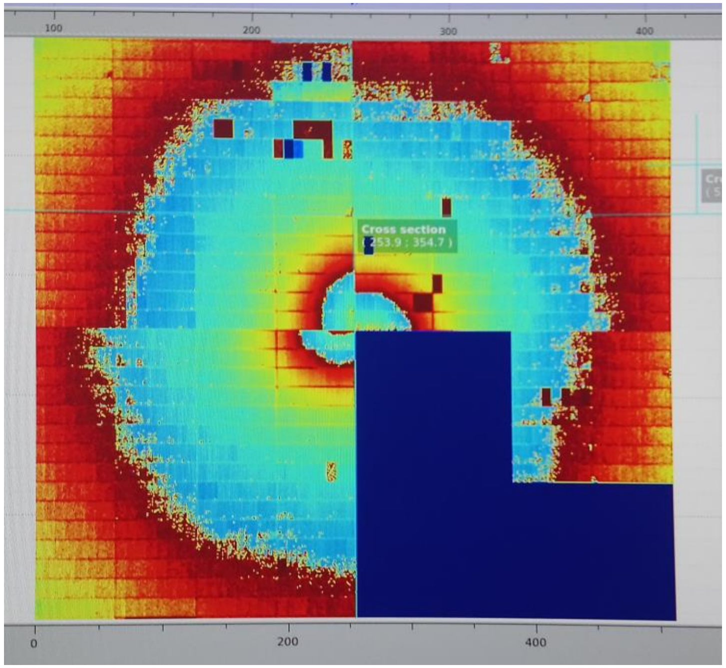
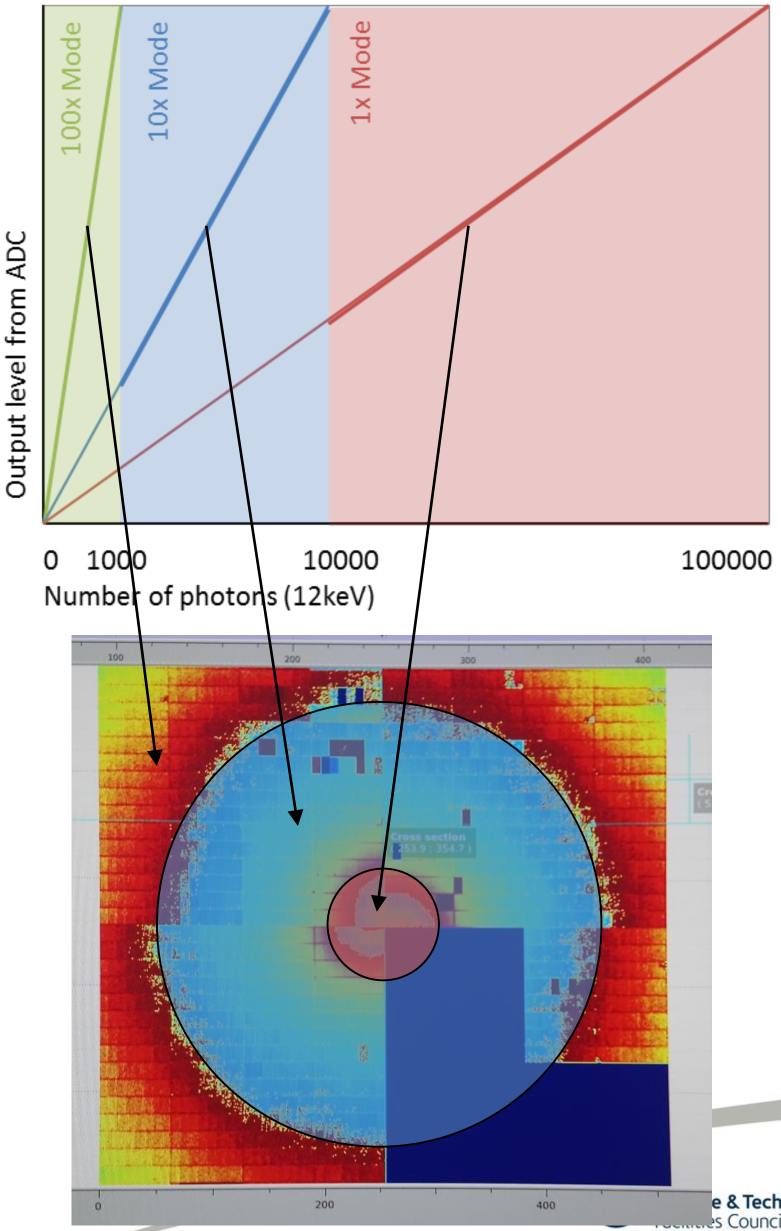
Flat Field With Mask



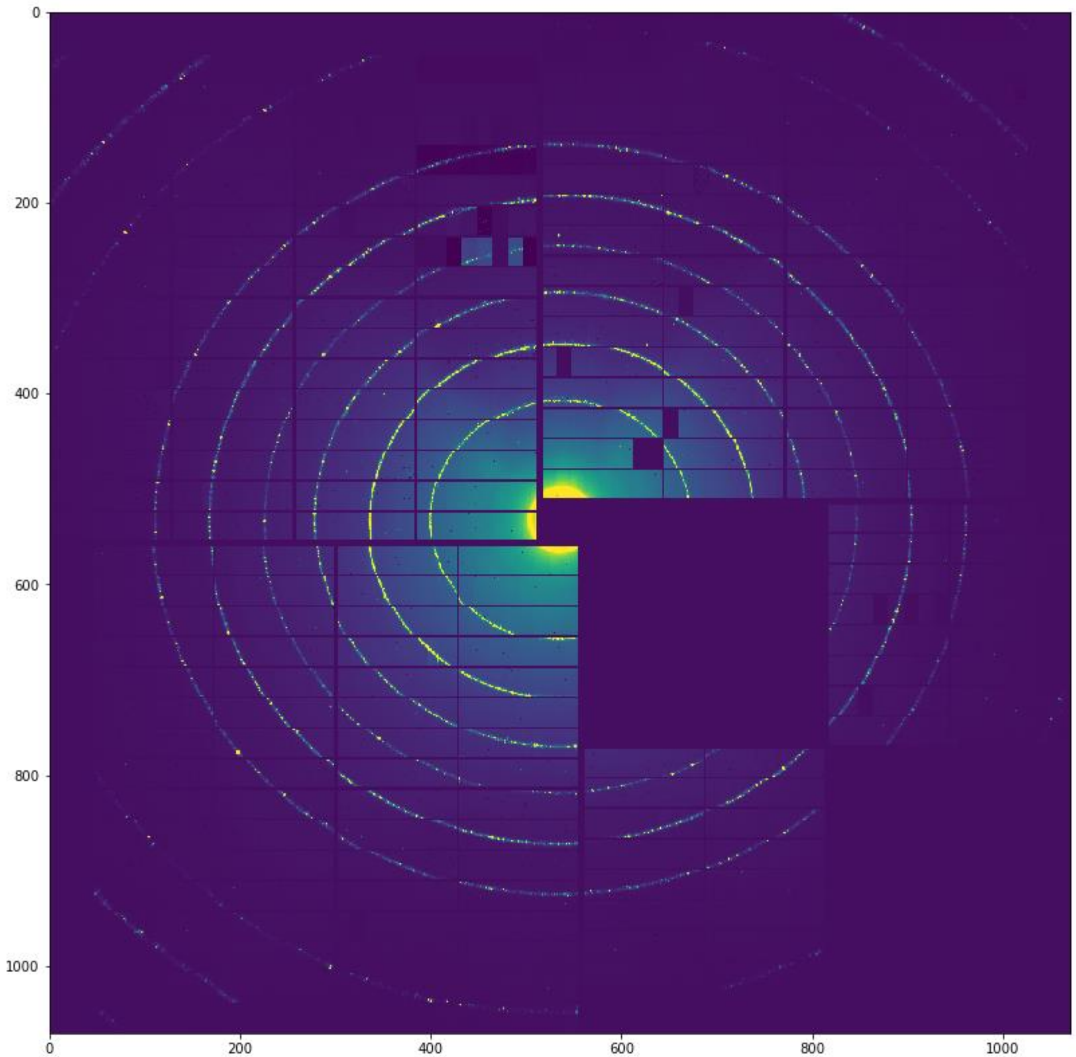
Dynamic Range Sweep

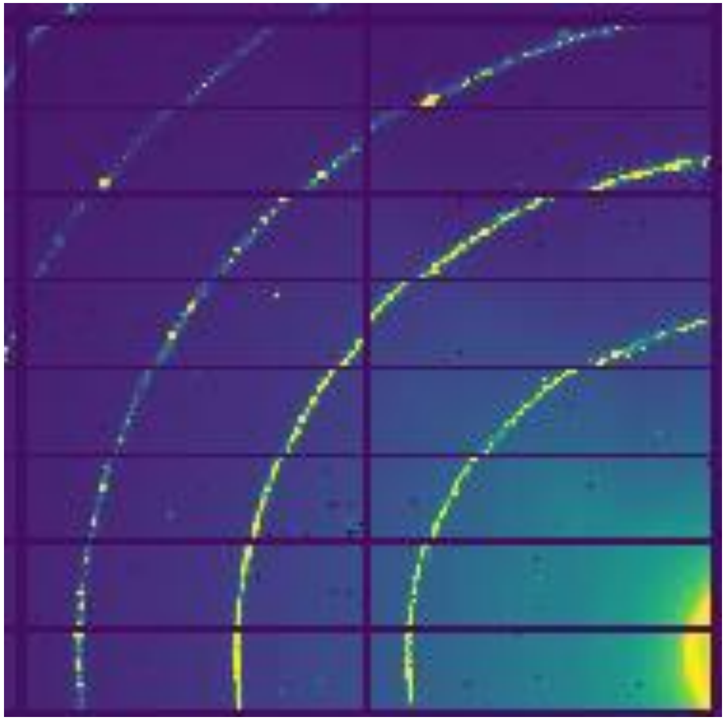


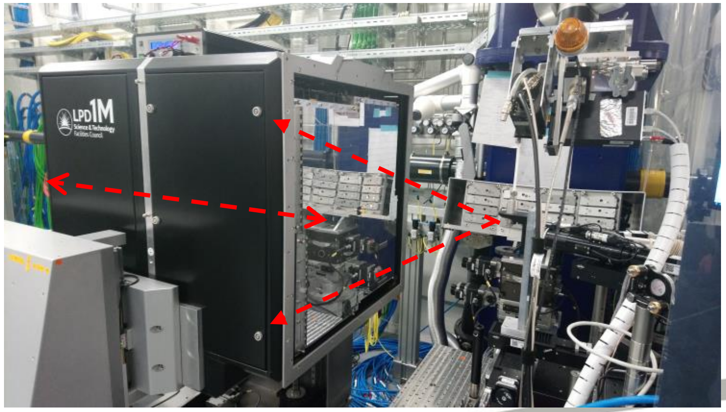


- Stressed full dynamic range using full beam intensity with various scattering or diffracting configurations
- Auto gain selection performed by in detector DAQ.

LaB6 Diffraction – Alignment Calibration







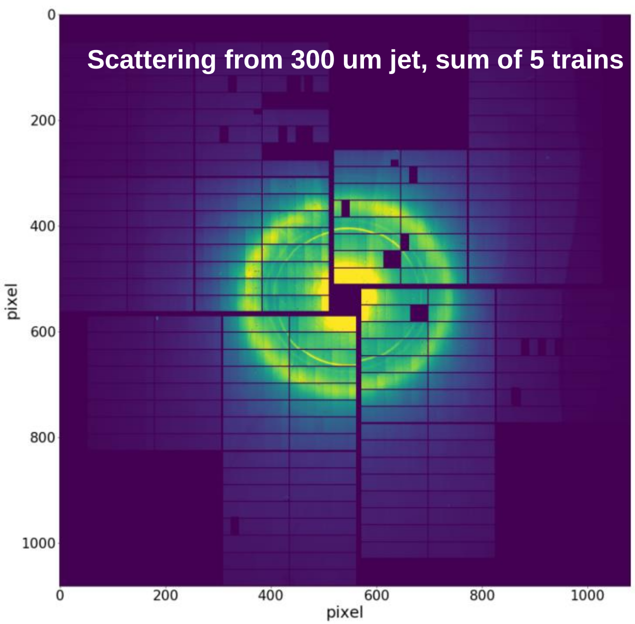
Data analysis to be continued…

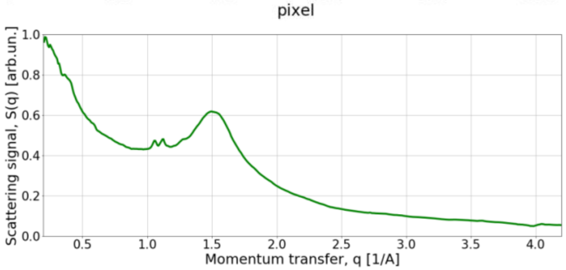
Pump-probe Scattering on Cu-complex solution in THF (Experiment #2052)

28.09. – 02.10.2017 Grigory Smolentsev (PSI)

- 30 bunches/train, 9.3 keV, ~100uJ/pulse, focused to ~20 um

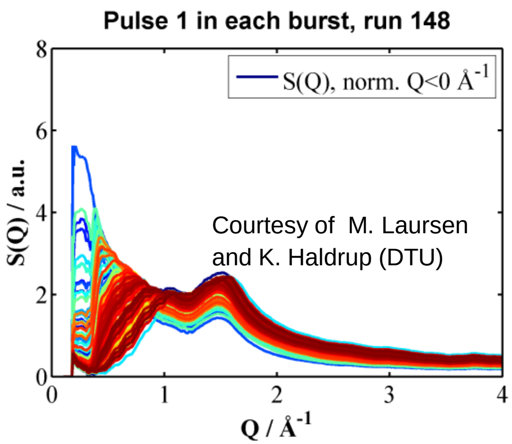
Laser-induced difference scattering in the first pulse of the train

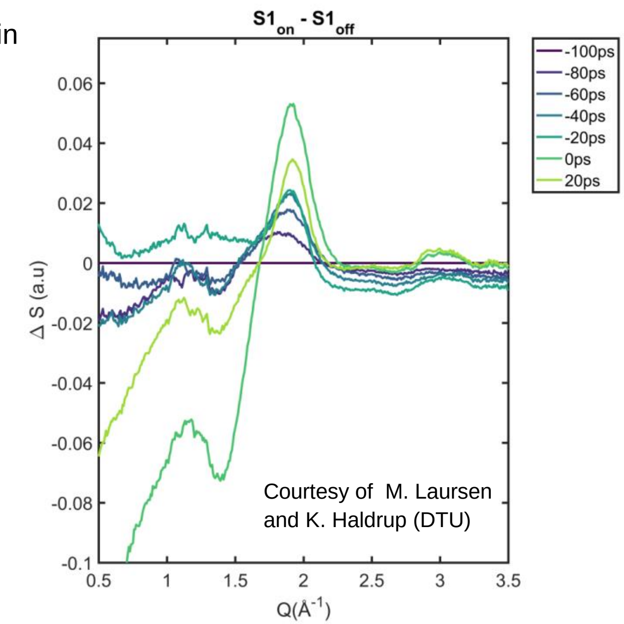


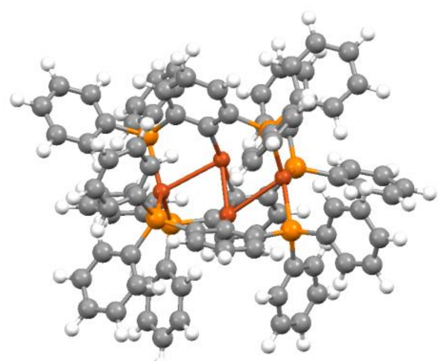


- Stability of scattering from train to train

1st pulse in the train





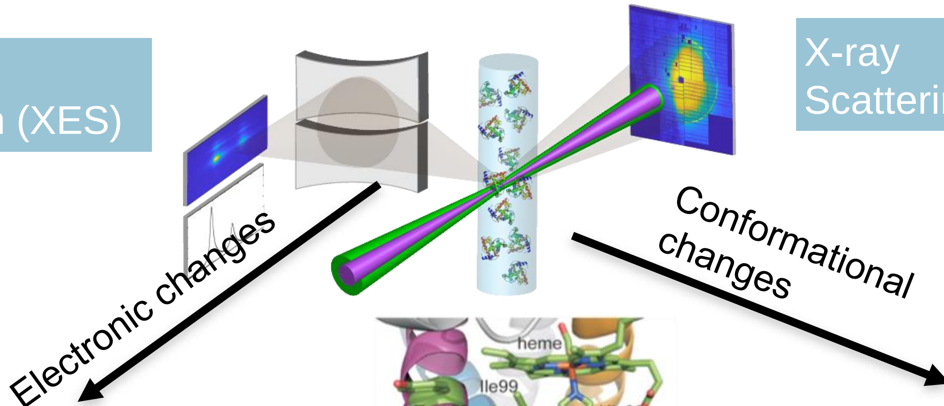


Cu_4 cluster inside

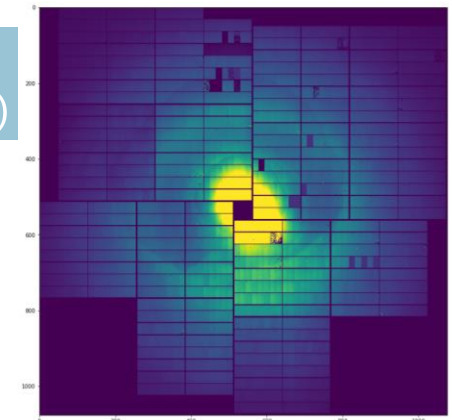
Correlated spin and structural dynamics in the recombination of nitric oxide (NO) to deoxy-Myoglobin in physiological media (Experiment #2072)

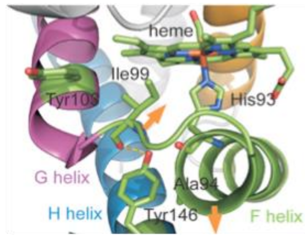
23.11. – 27.11.2017 Dominik Kinschel (EPFL)

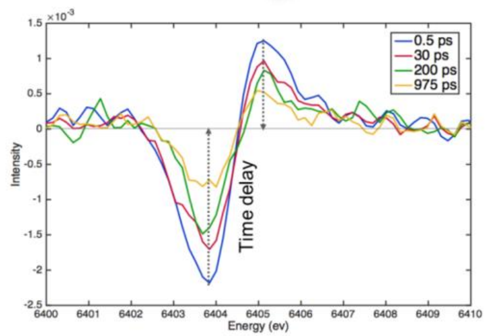
X-Ray Emission (XES)



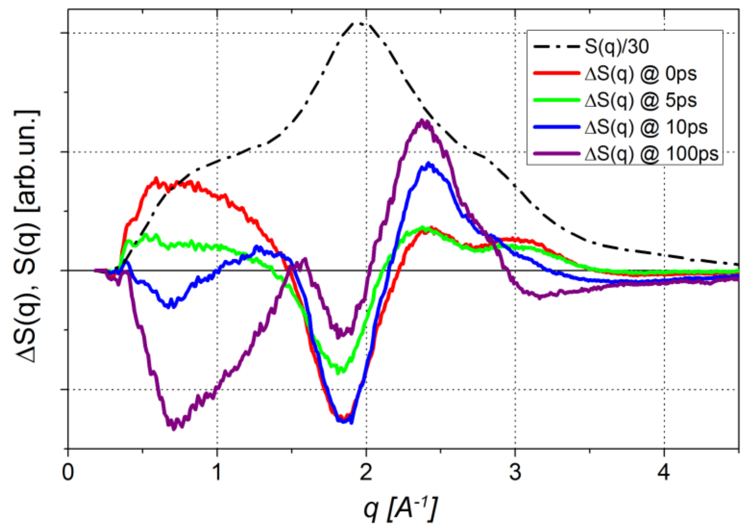
X-ray Scattering (XDS)







- LPD XFEL, 15 min collection, 1st pulse of train



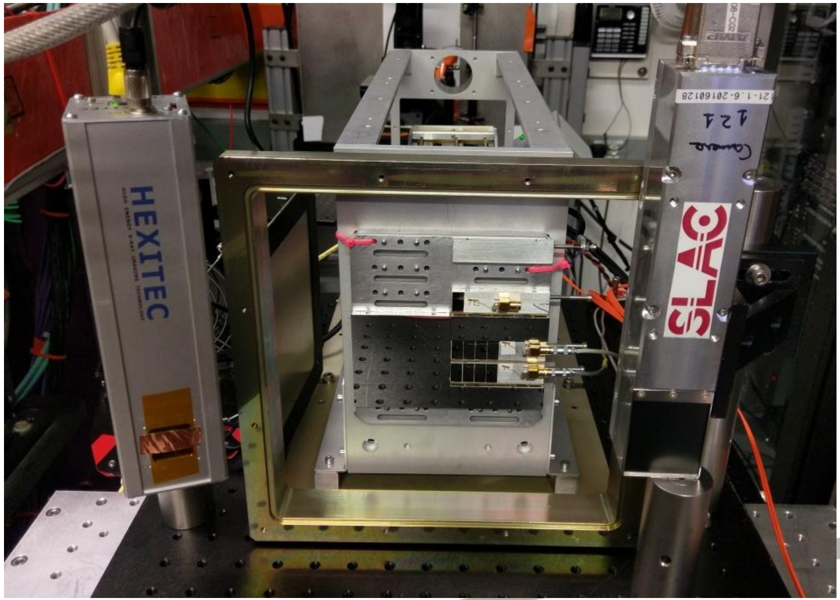
Feedback from users

- No major detector artefacts spotted
- LPD used most the time, good reliability
- Data saved to storage very effectively
- Live data fast feedback more of a challenge – but mostly available.

Requests

- More live data. E.g. Integrated curves, image measurables (ROI ratios, sums etc)
- More robust beam pipe alignment

What Next For LPD



Current work

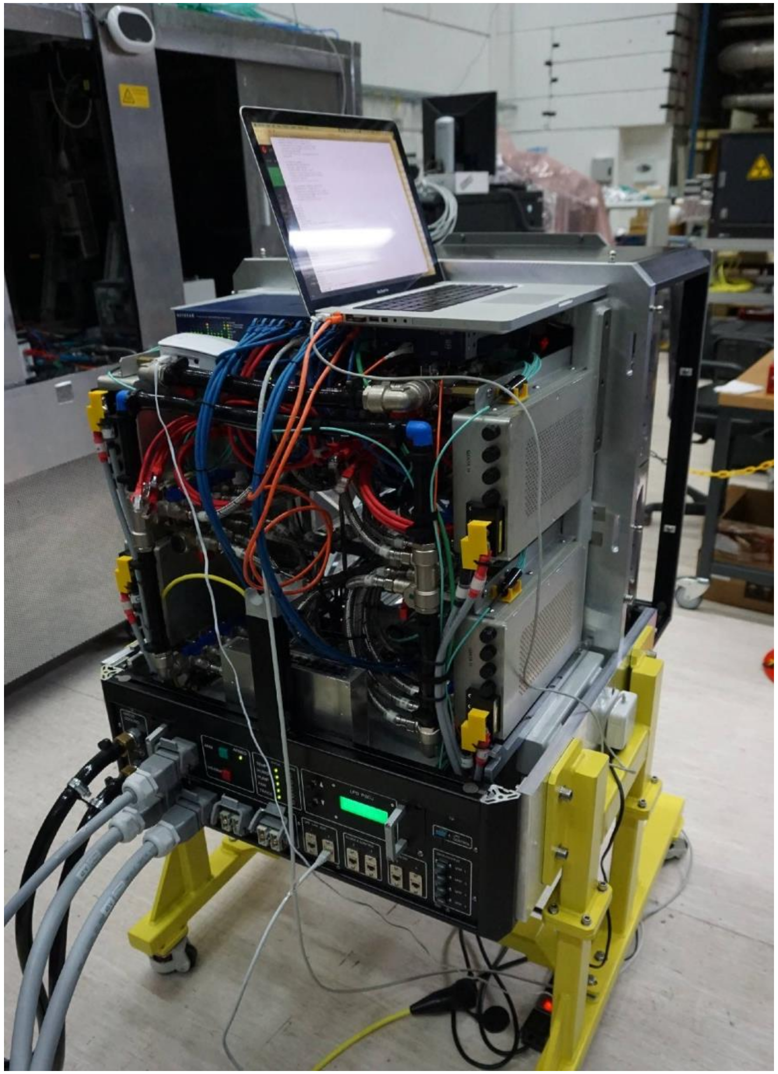
- Spare Parts for the 1M system – work has started to supply 100% spares
- Support agreement for 5 years

Opportunities

- Good potential for LPD ASIC V3 – Upgrade to fit within the current LPD ecosystem.
- Demand for a ¼M or 1/16M system – Smaller, more flexible to adapt to experimental demands.
- GaAs and high flux CZT – Allow LPD to be used at higher energies or greater dose

LPD in 10 years?

- **LPD should still be working**! built with 10 year operation in mind. But only ever at 4.5MHz
- **European XFEL will move to 1MHz** continuous. How would LPD look?
- New challenges – More power, More data, Smarter electronics
- LPD uses too much power 12kW – effort needed to avoid scaling this.
- **Innovation in interconnect** may hold alternative options to the conventional Hybrid detector
- **DAQ (FPGAs) to move off detector head.**



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