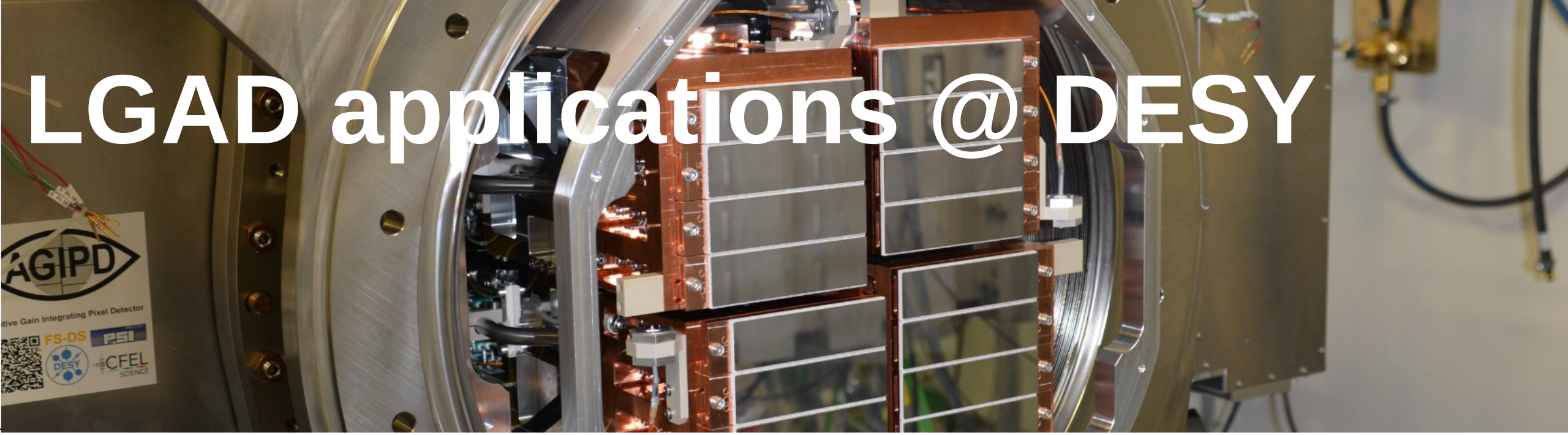


LGAD applications @ DESY

Fast timing for Synchrotron applications

Jonathan Correa
DESY Photon Science Detector Group
Diamond Light Source, Harwell, Nov. 25th 2019

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

DESY.

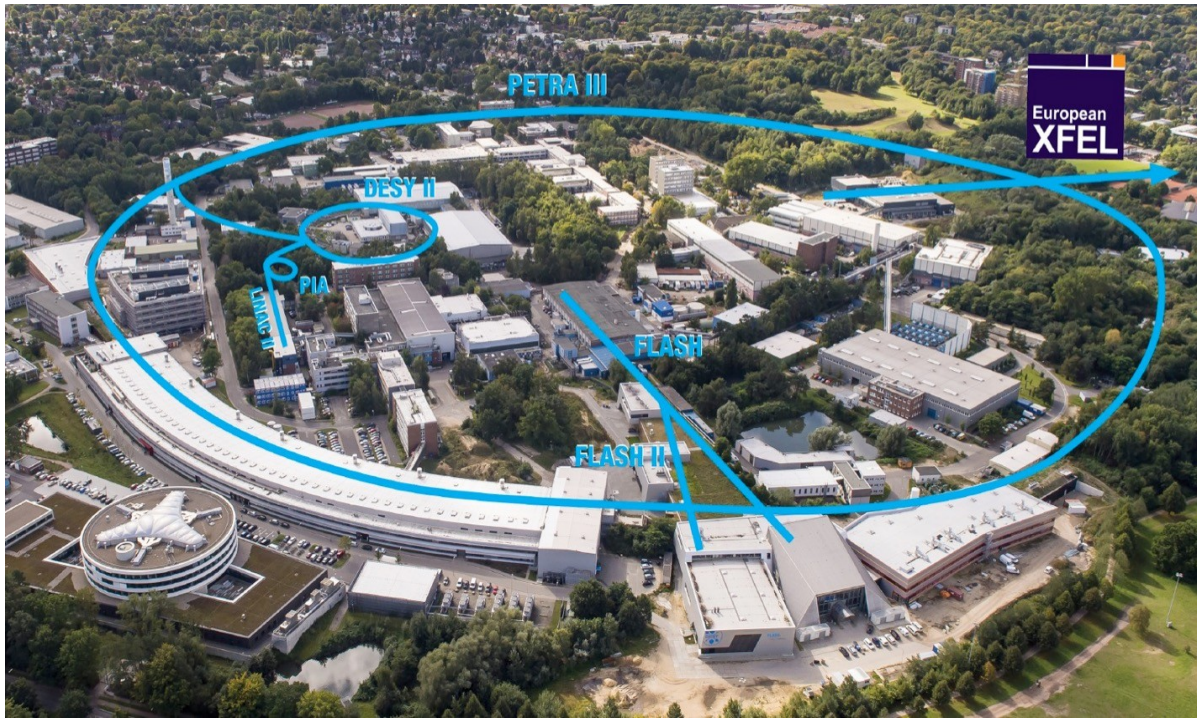
CFEL SCIENCE

DESY

Photon Science is a very broad field

… from Fundamental Physics to Materials Science to Pharmacology …

- e.g. Petra III Synchroton today supports 21 beamlines (more coming …)
  - Bio-imaging
  - Chemical Crystallography
  - Materials Science
  - Spectro-micoscopy down to nanoscale
  - Extreme Conditions Research (pressure, temperature)



- Free Electron lasers open new realms (brilliance, fs timescales)
- European XFEL in Hamburg today supports 6 end stations, facility accommodates 12
- Science:
  - Molecular dynamics (how do chemical reactions evolve?)
  - Detailed studies of materials susceptible to radiation damage “outrun the damage by getting information out fast”

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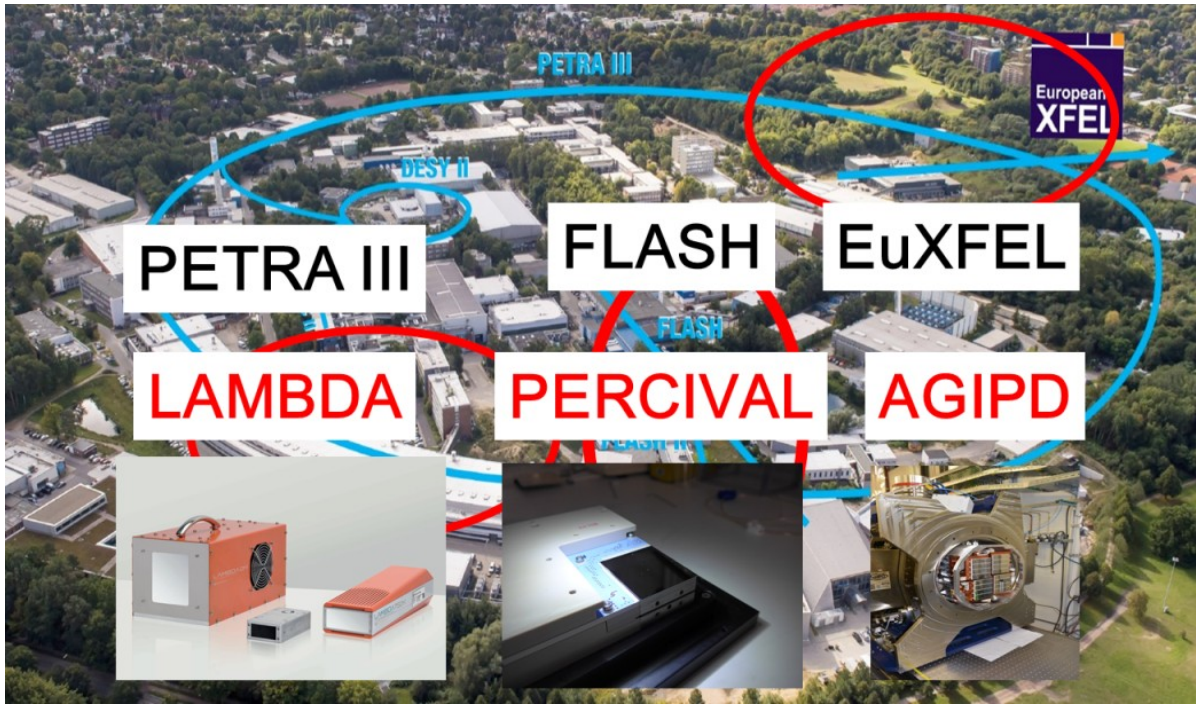

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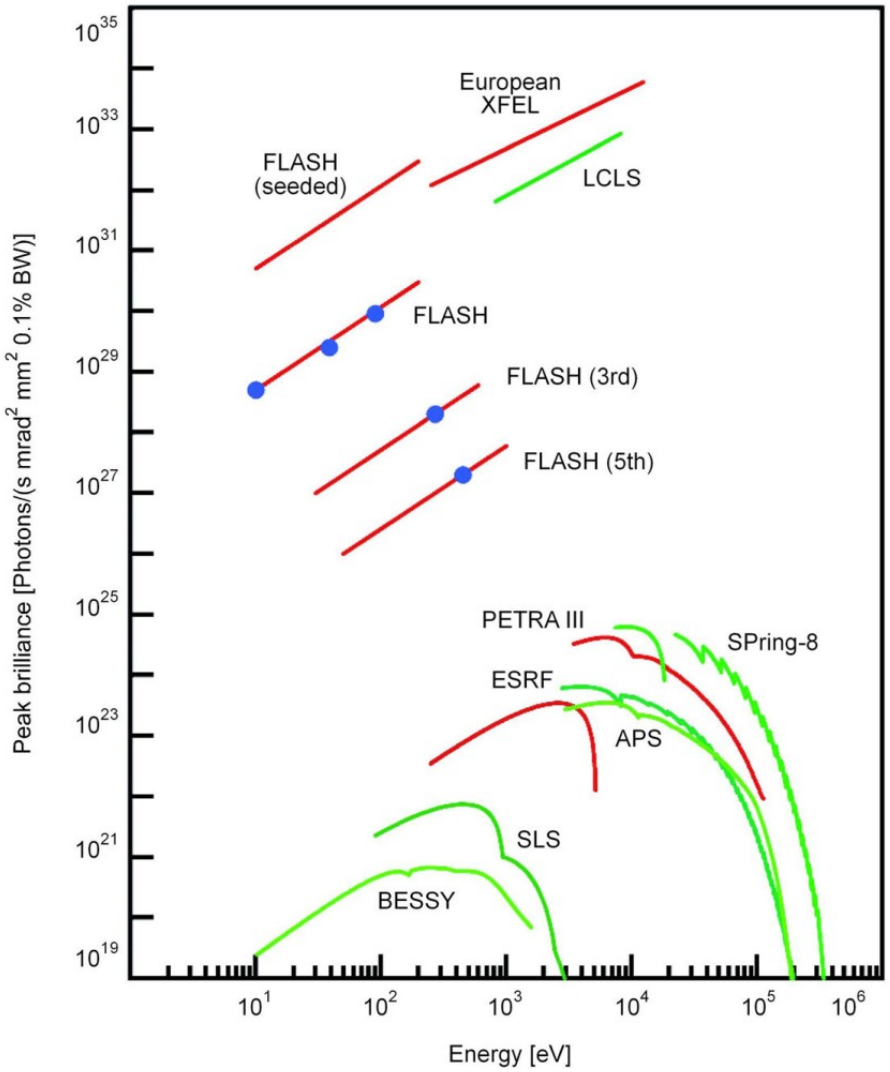
The Hamburg FEL properties

High brilliance and time structure challenges



10^9 !

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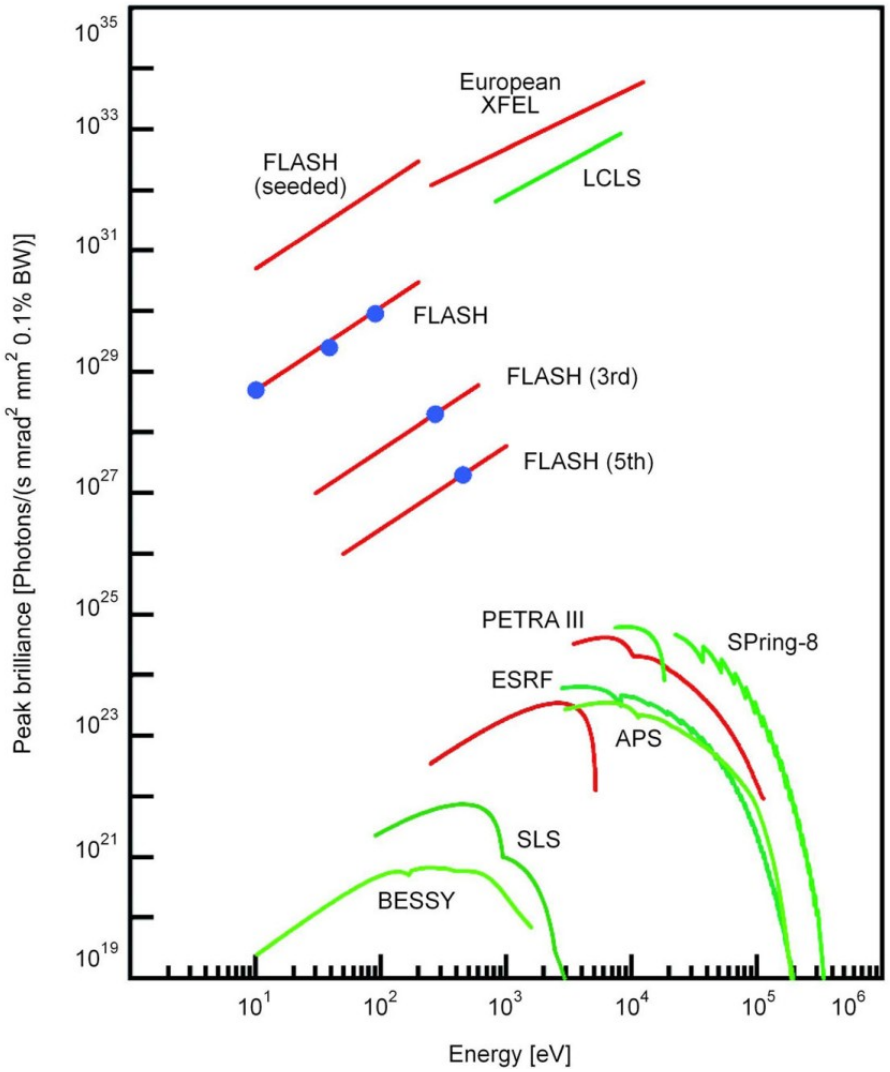

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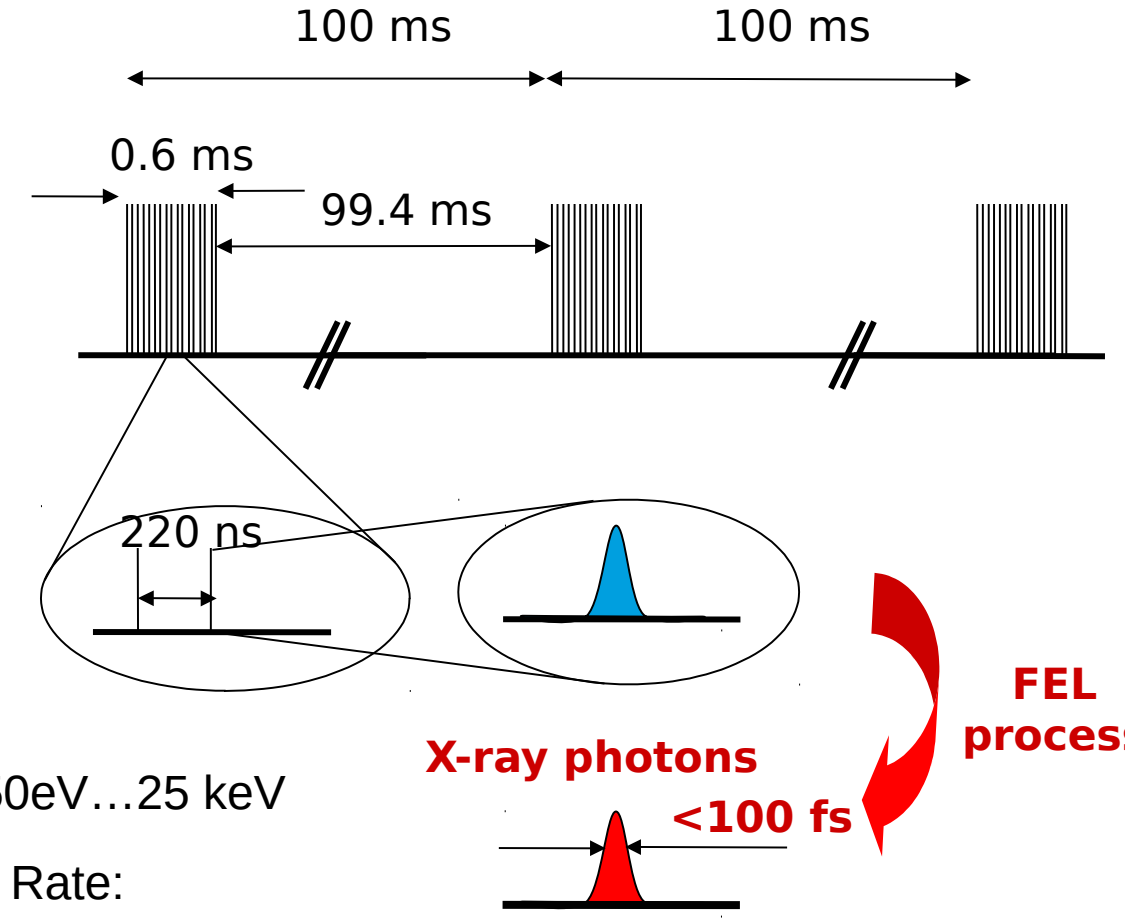


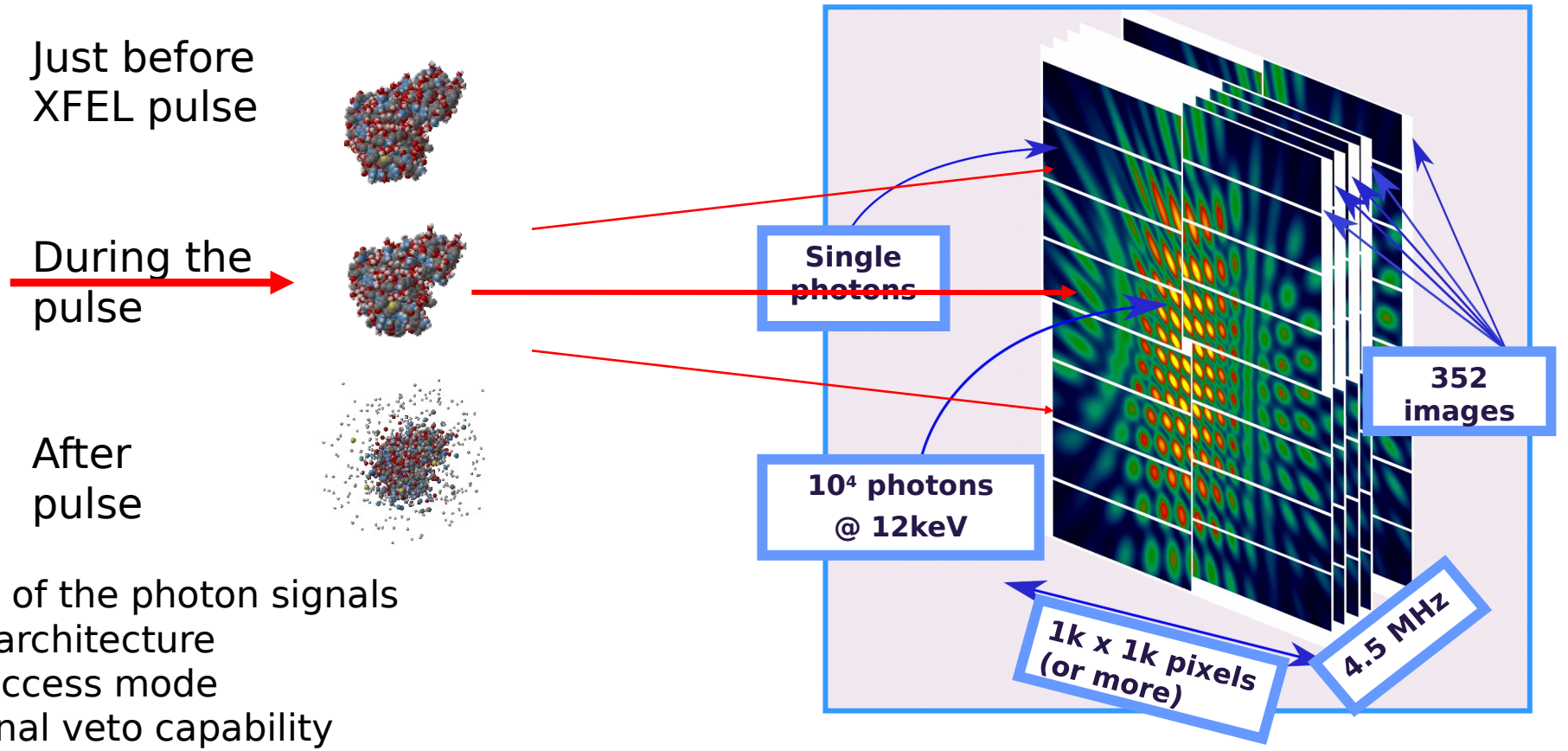
Ey=50eV…25 keV

max. Rate:

- 4.5 MHz XFEL

AGIPD for Single Molecule Imaging

Scientific Case

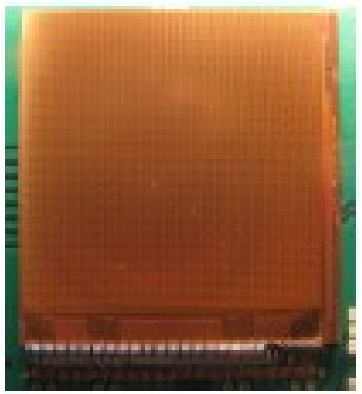


- Time structure of the photon signals
  - Pipelined architecture
  - Random access mode
    - External veto capability
- High radiation dose at small angles: 10^4 photons/(pixel shot)
- over 3 years: 1 GGy @sensor
  - Radiation damage of silicon sensor
  - Radiation damage of underlying electronics (≫10 MGy)
    - Radiation hard design

- 500 µm silicon sensor
- 200 µm square pixels
- Vacuum compatibility
- Detector with central hole

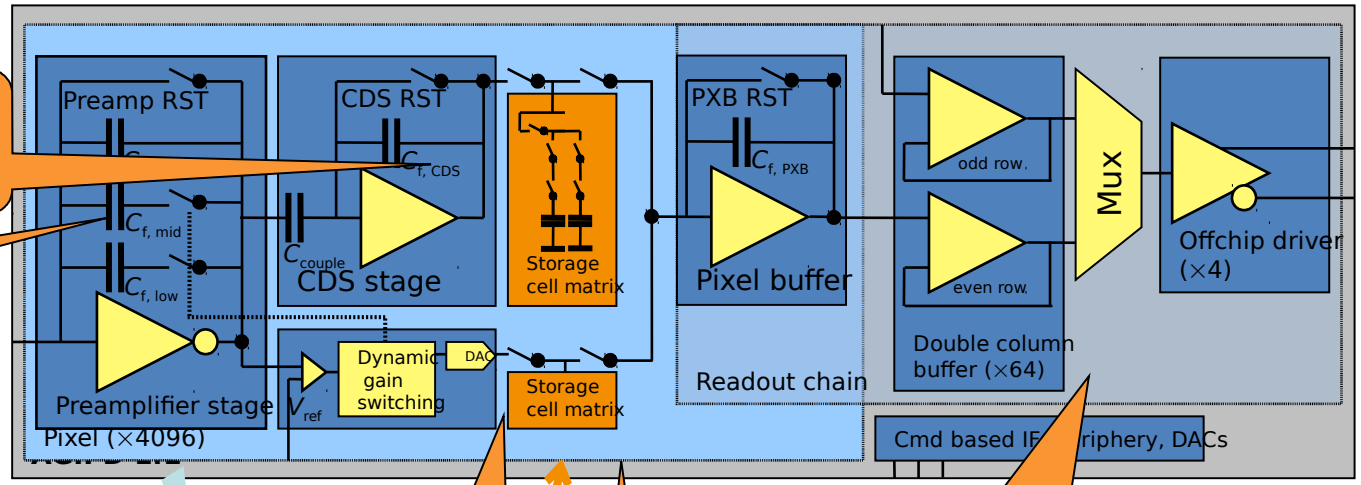
AGIPD 1.1

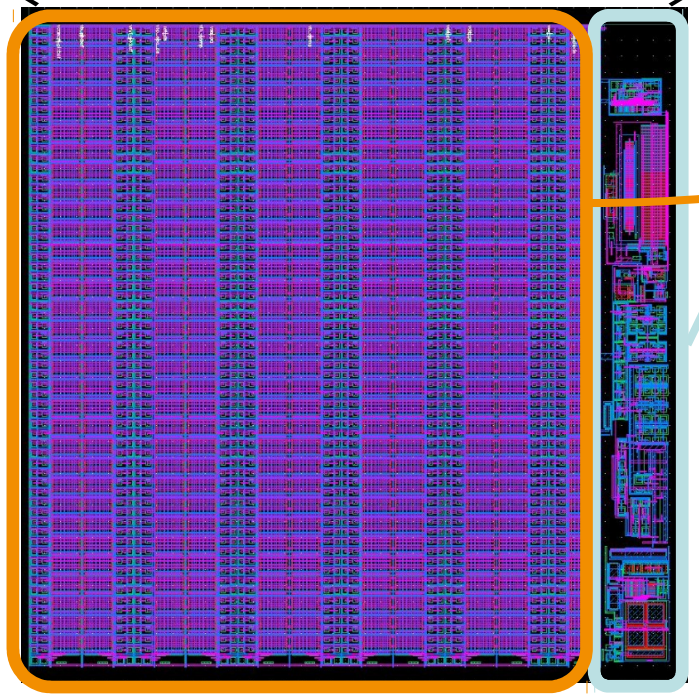
The ASIC design



Correlated double sampling

Adaptive gain
C_f=60fF, 3pF, 10pF





Analogue encoding of gain

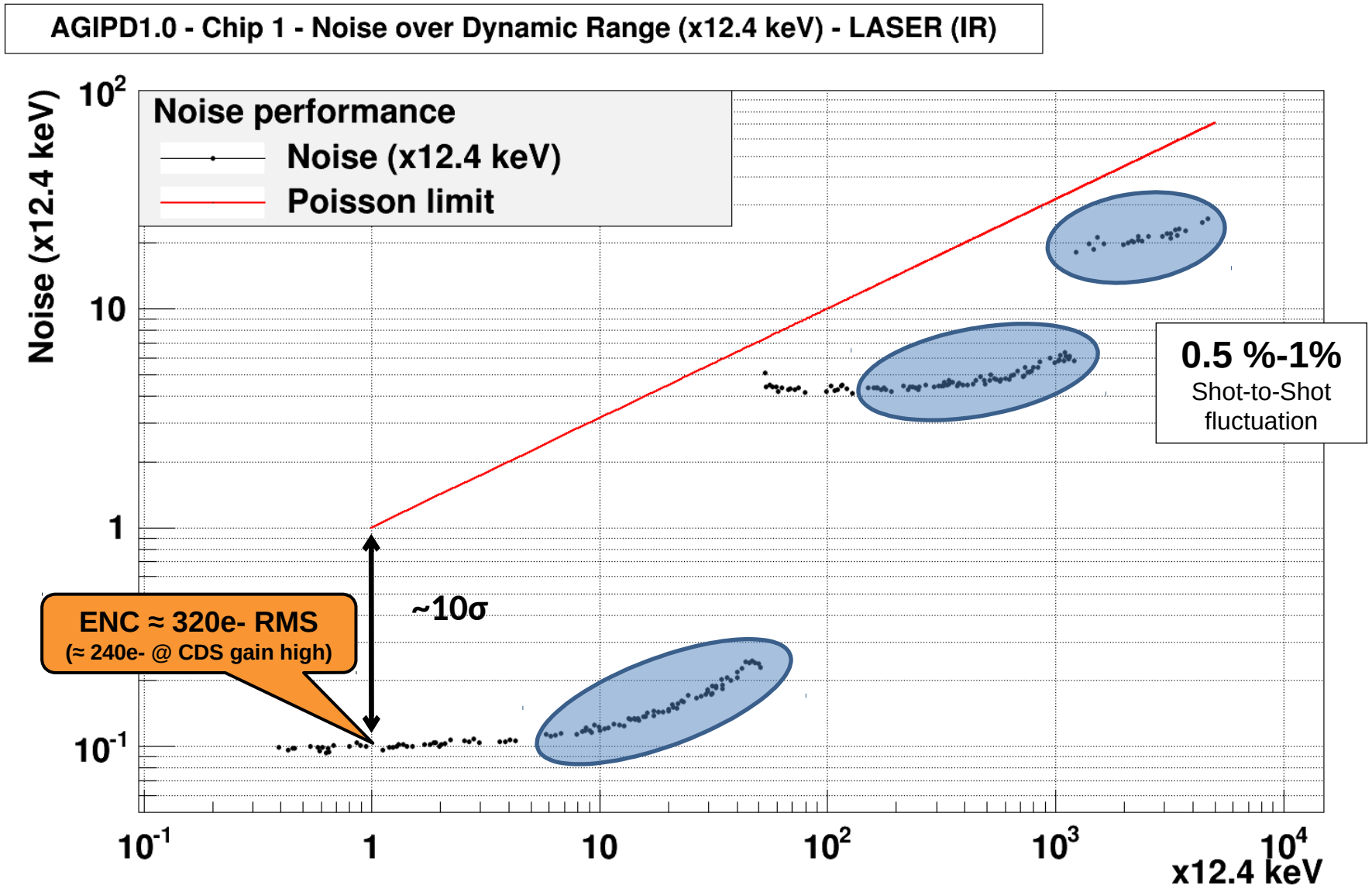
Analogue RAM for 352 images

Interleaved row Double column readout

Command based control via serial IF

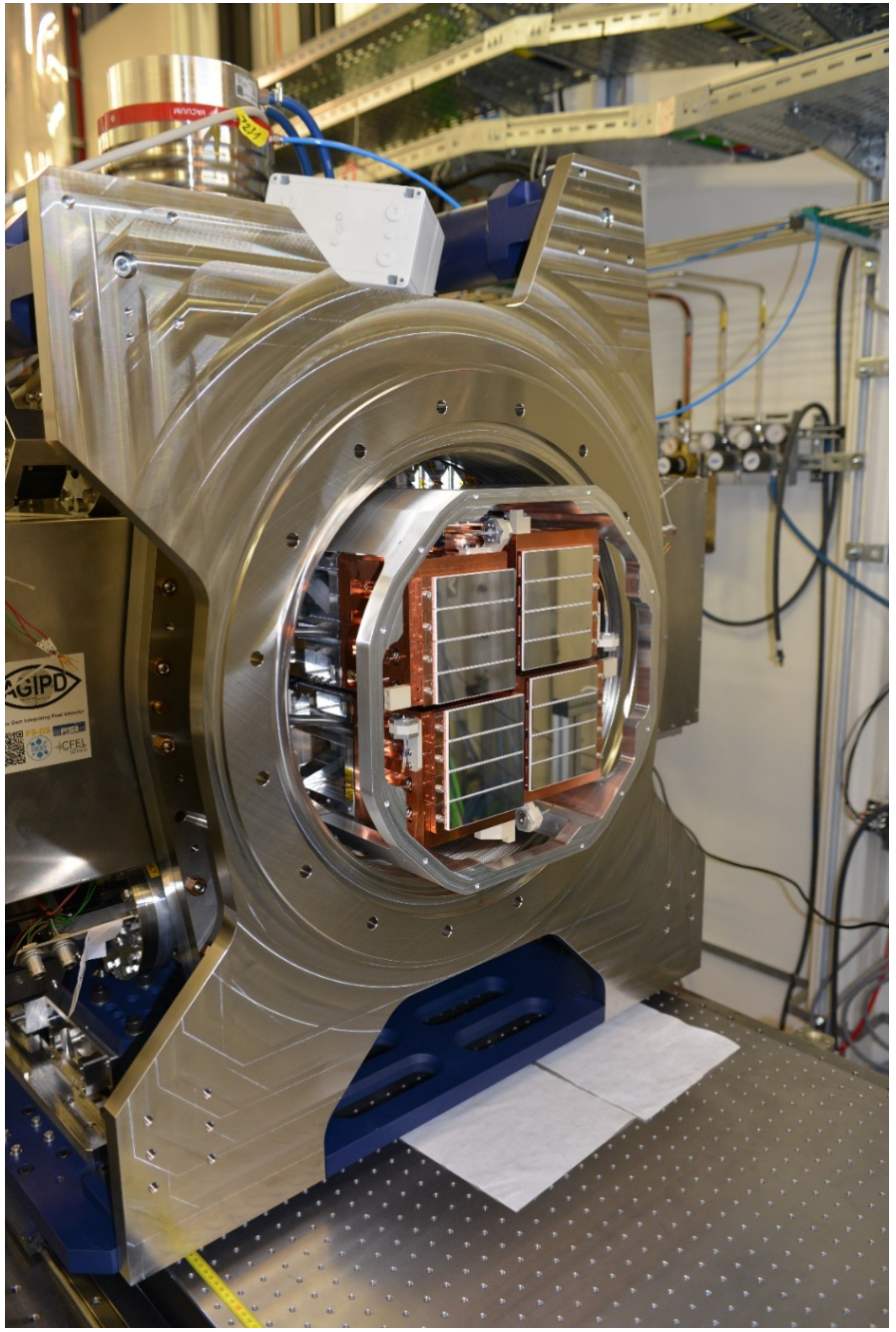
AGIPD Detector Noise

Characterisation

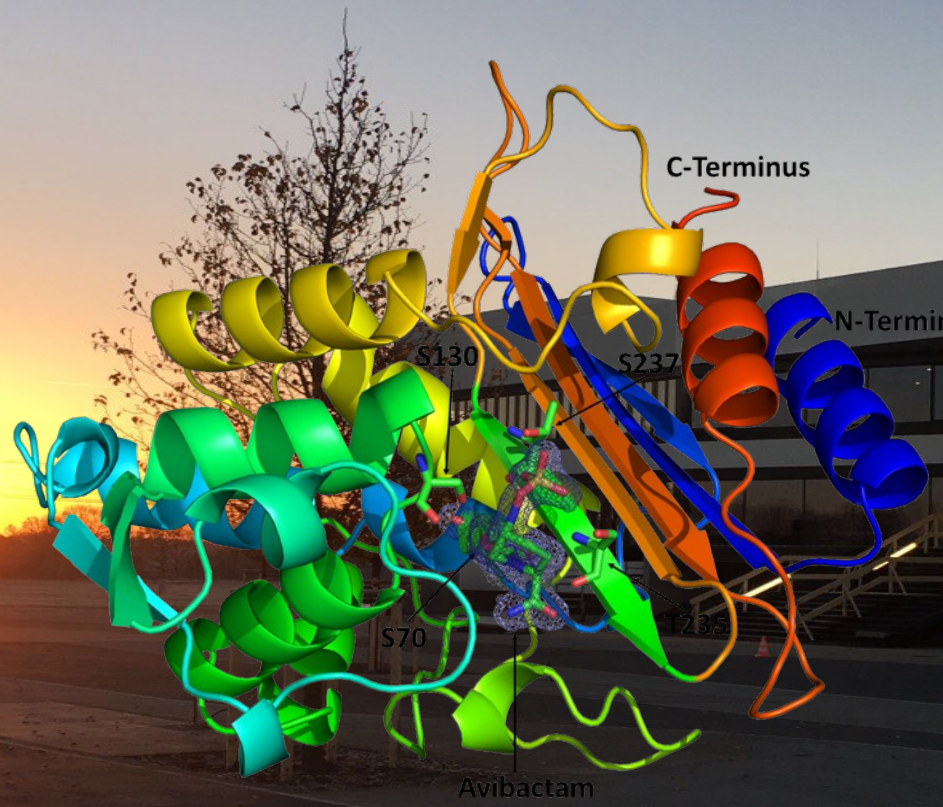


AGIPD successfully commissioned

… and producing Data



Resolved structure of
CTX-M-14 β-lactamase



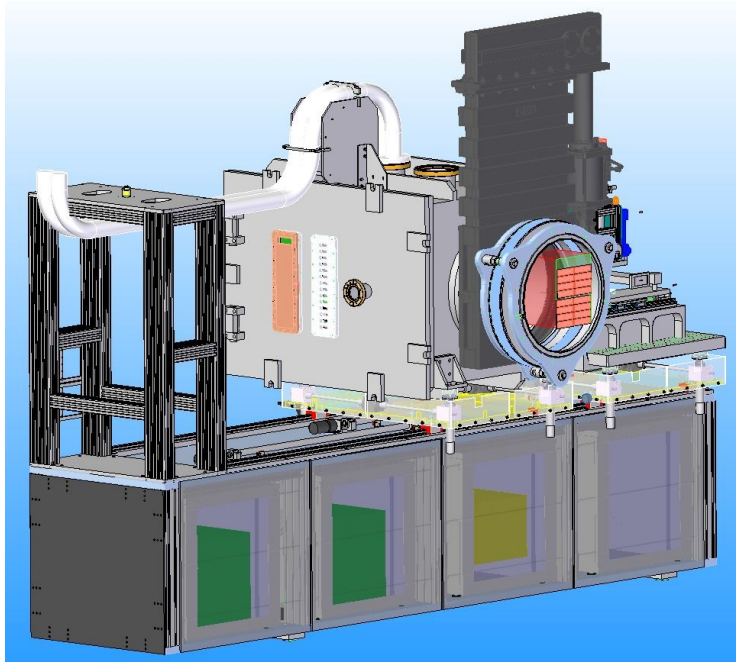
XFEL-2012 collaboration

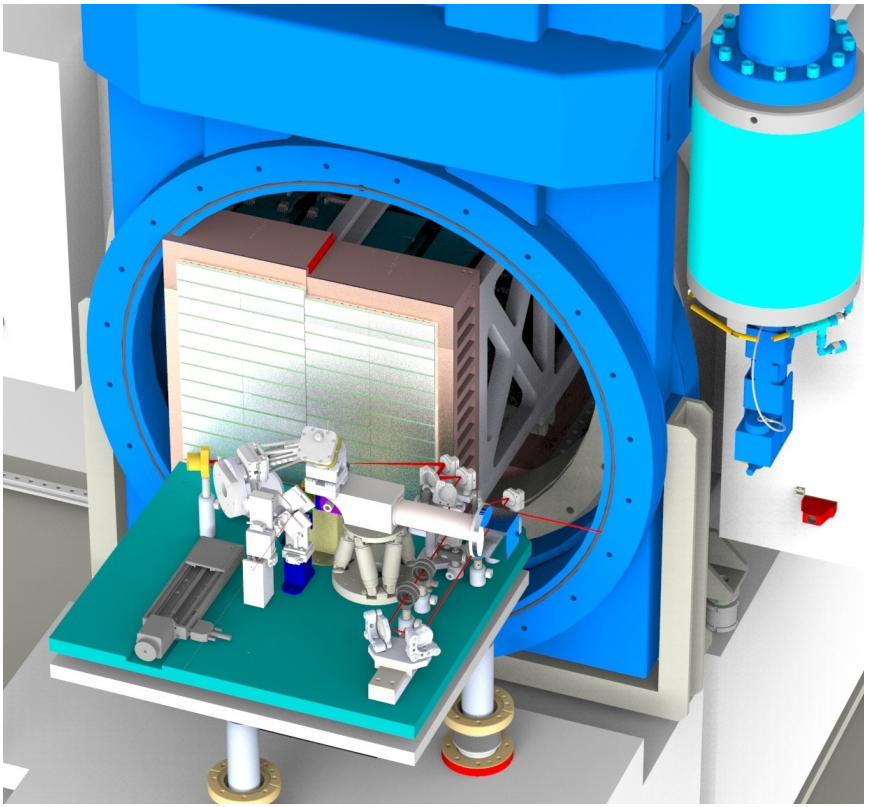
“Megahertz serial crystallography” Nat Communications 9(1), 4025 (2018)

doi:10.1038/s41467-018-06156-7

AGIPD @ HiBEF

Higher Photon Energies





The HiBEF (Helmholtz International Beamline for Extreme Fields) experiment @ EuXFEL needs a 1Mpix detector for **E_{ph}≥25keV**

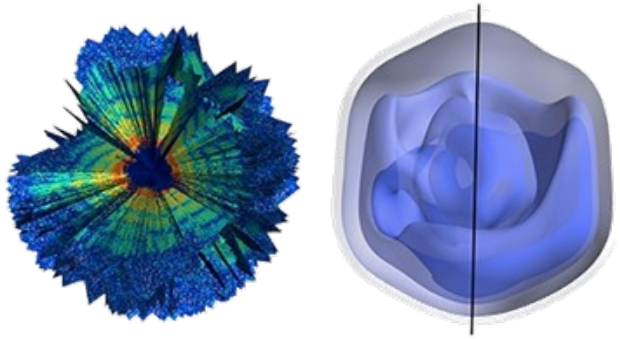
- The existing AGIPD detector collects positive charges (holes)
  - Easier to realise radiation hard sensors
  - Slower – less demanding to handle large charges (circuit wise)
- AGIPD is not suitable for experiments with photons above ~15keV
  - The Silicon sensor gets inefficient ~15keV
- High-Z Semiconductors, esp. GaAs promise efficient sensors for E_{ph}≥25keV
- Composite (III/V) Semiconductors feature relatively short charge carrier lifetimes
- Collection of Electrons (i.e. the fast component) is required

Working at the Soft X-Ray regime

Science Challenges – two examples

- Water window offers unique view of biological systems:
  Between Carbon and Oxygen edges, water is transparent but carbon absorbs
- 282 eV to 533 eV photons

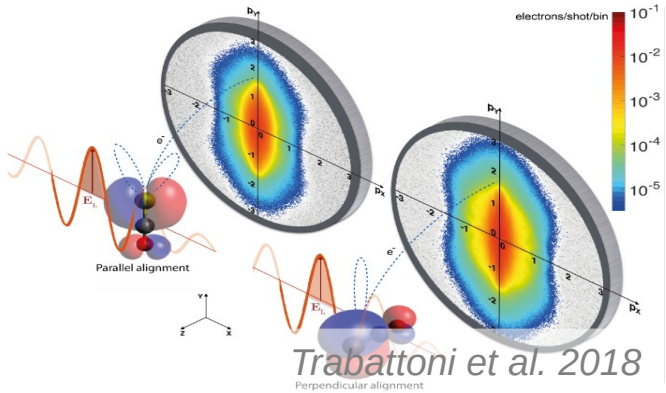
Imaging bio-systems



Soft X-rays *Ekberg et al. 2015*

- Laser-Induced Electron Diffraction:
  re-scattered electrons can give simultaneous access to sub-100pm-spatial and sub-fs temporal resolution
- Sweet spot for these measurements is around 500 eV electron energy
  (plus few keV acceleration from optics)

Molecular dynamics



Trabattoni et al. 2018

~ keV electrons

Entrance Window and others

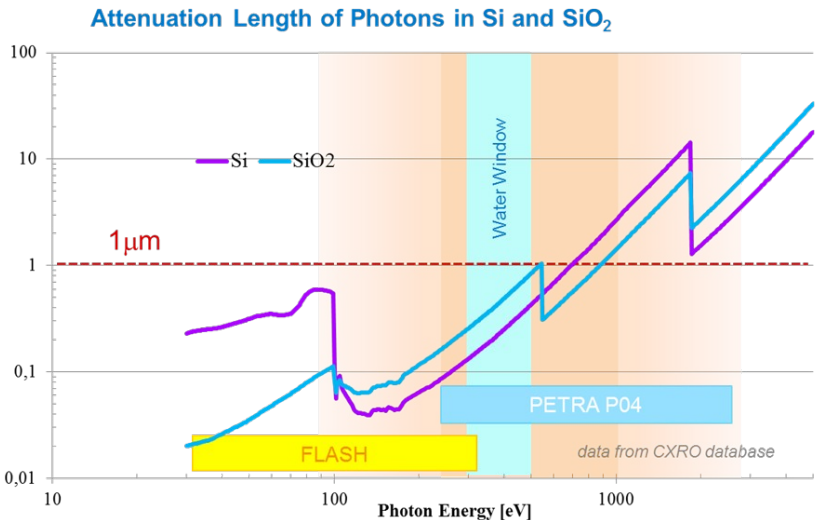
Necessary to optimise performance for soft X-rays, UV light, as well as low-energy charged particles

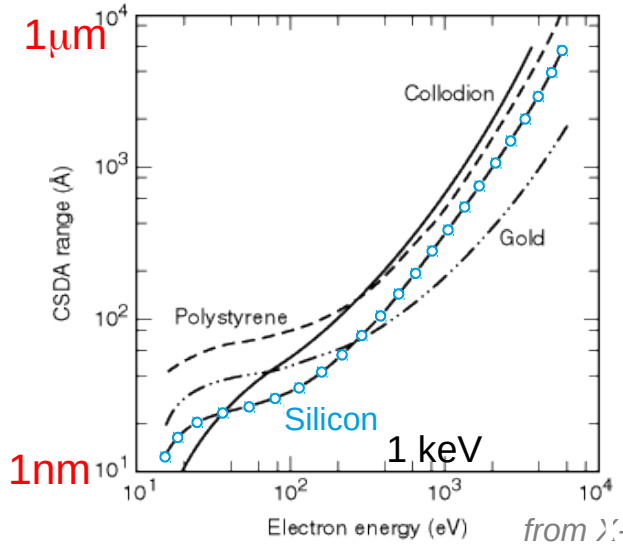
- Attenuation lengths in Si / SiO2 at or below 100nm for soft X-rays
- Attenuation lengths for few-keV electrons in Si are on the order of 10s of nm

- Interaction must happen in active Si, and generated charge cloud must reach the circuitry

Requires:

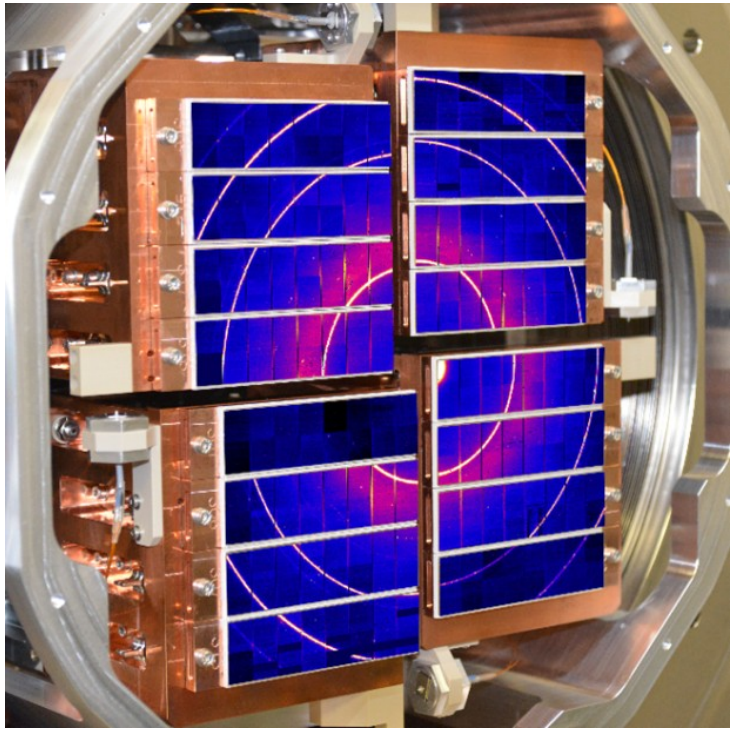
- Negligible passive layer
- Negligible traps
- Optimized geometry of electric field at surface of sensor





from X-ray Data Booklet

Summary and Conclusions



- Challenges at FELs are somewhat different that at Synchrotron radiation sources:
  - Very high brilliance
  - Complex time structures

- AGIPD:
  - First 1M systems are a success story
  - Evolution into larger (4M), more compact (new readout) systems with broad sensor range (e-collecting for high-Z/HIBEF)

- AGIPD coupled to LGADs:
  - Would allow the extension of the photon energy range towards the soft X-ray
  - A gain factor of ~10 could be enough
  - Special attention to be paid to the entrance window thickness
  - Due to relatively large pixel size, fill factor might not be an issue