

LOW GAIN AVALANCHE PHOTODIODE DETECTORS

AT DIAMOND LIGHT SOURCE

Nicola Tartoni

LGAD workshop at Diamond

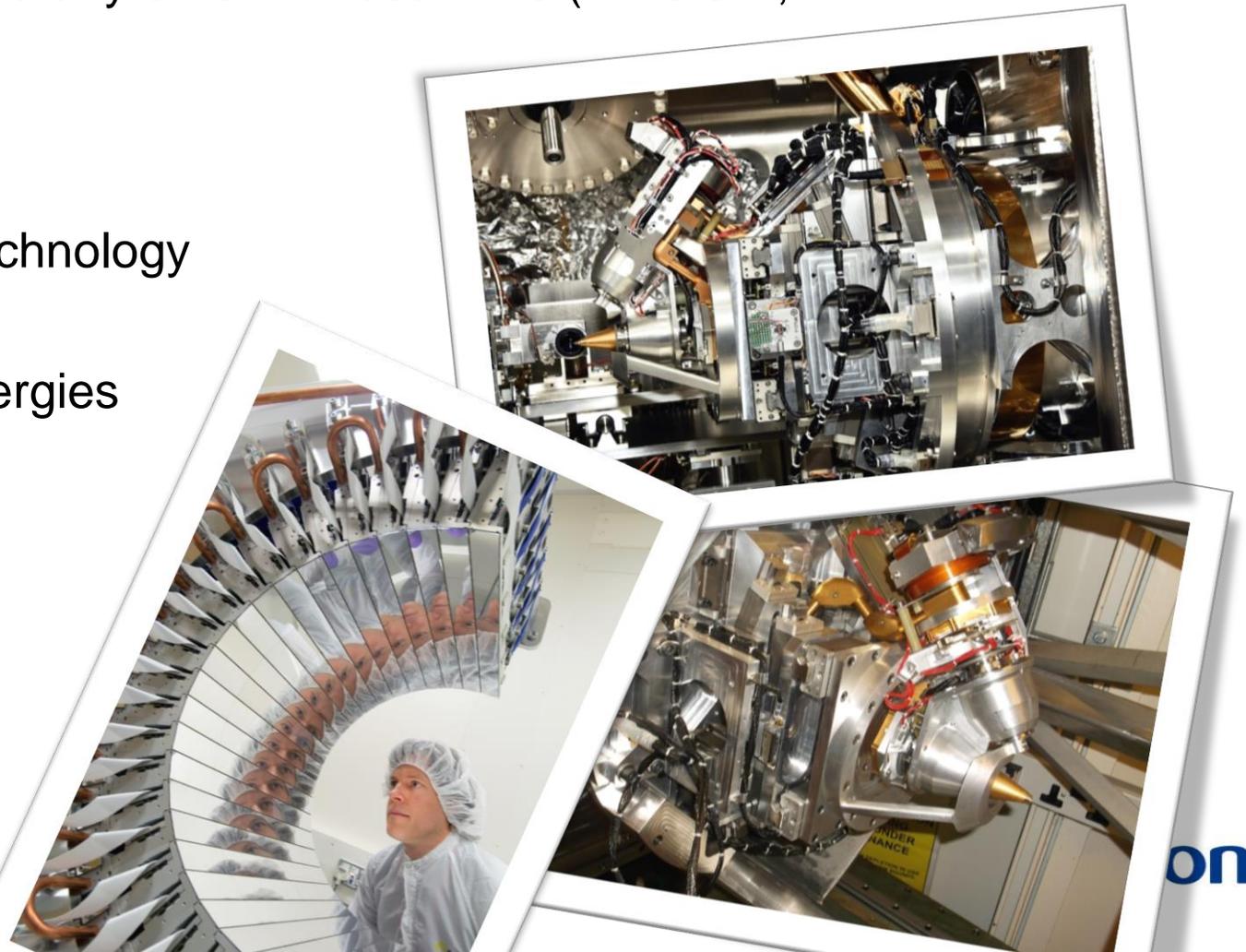


Potentially two major uses of LGADs

- Detection of tender energy X-ray photons
- Detection of X-ray photons in time resolved experiments

I23 – Long-wavelength macromolecular crystallography

- First in-vacuum MX beamline
- Access to wavelengths far beyond any other MX beamline ($\lambda < 5.9 \text{ \AA}$, $E > 2.1 \text{ keV}$)
- Largest area detector for MX
- At the forefront of synchrotron technology
- Many aspects pioneered at I23
 - In-vacuum Pilatus for low energies
 - Sample cooling in vacuum
 - Cryogenic sample transfer
 - Collision prevention system

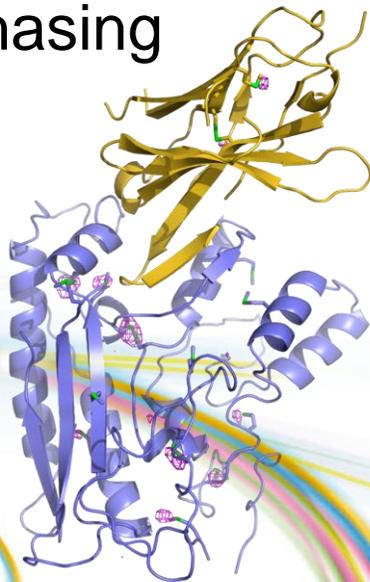


I23 – New opportunities for structural biology

- Unique scientific opportunities exploiting anomalous diffraction from lighter atoms.
- I23 provides access to absorption edges of elements of biological importance such as Ca, K, Cl, S and P

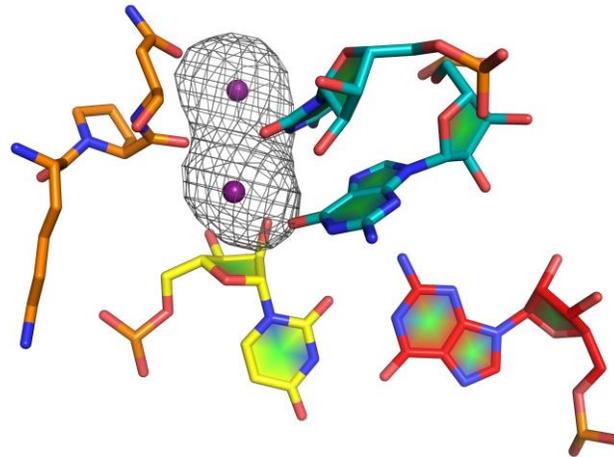


Phasing



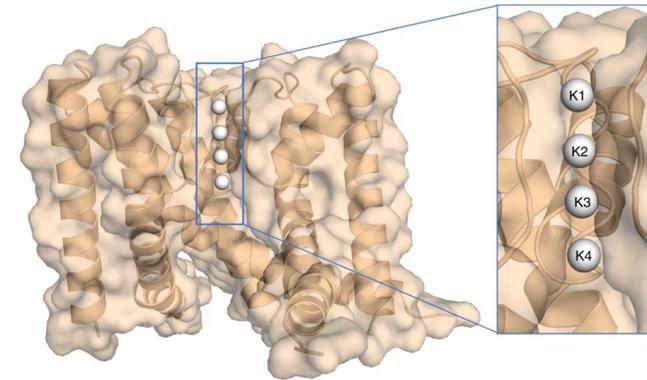
Rudolph et al. Nat. Chem. Biol. 15 (2019) 975.

Ion identification



Rozov et al. Nat. Commun. (2019) 10:2519.

Ion occupancies

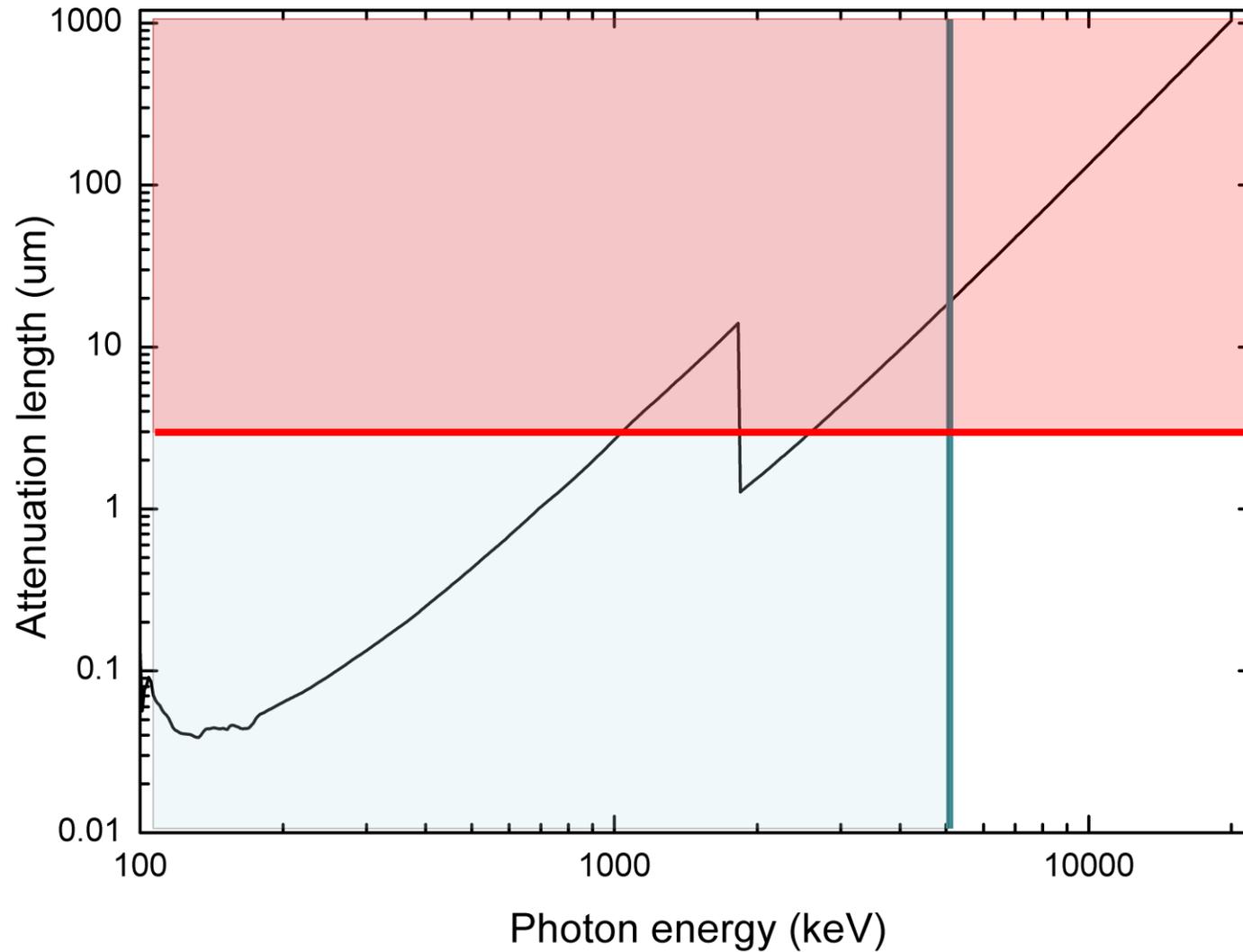


Langan et al. Nat. Commun. (2018) 9:4540.

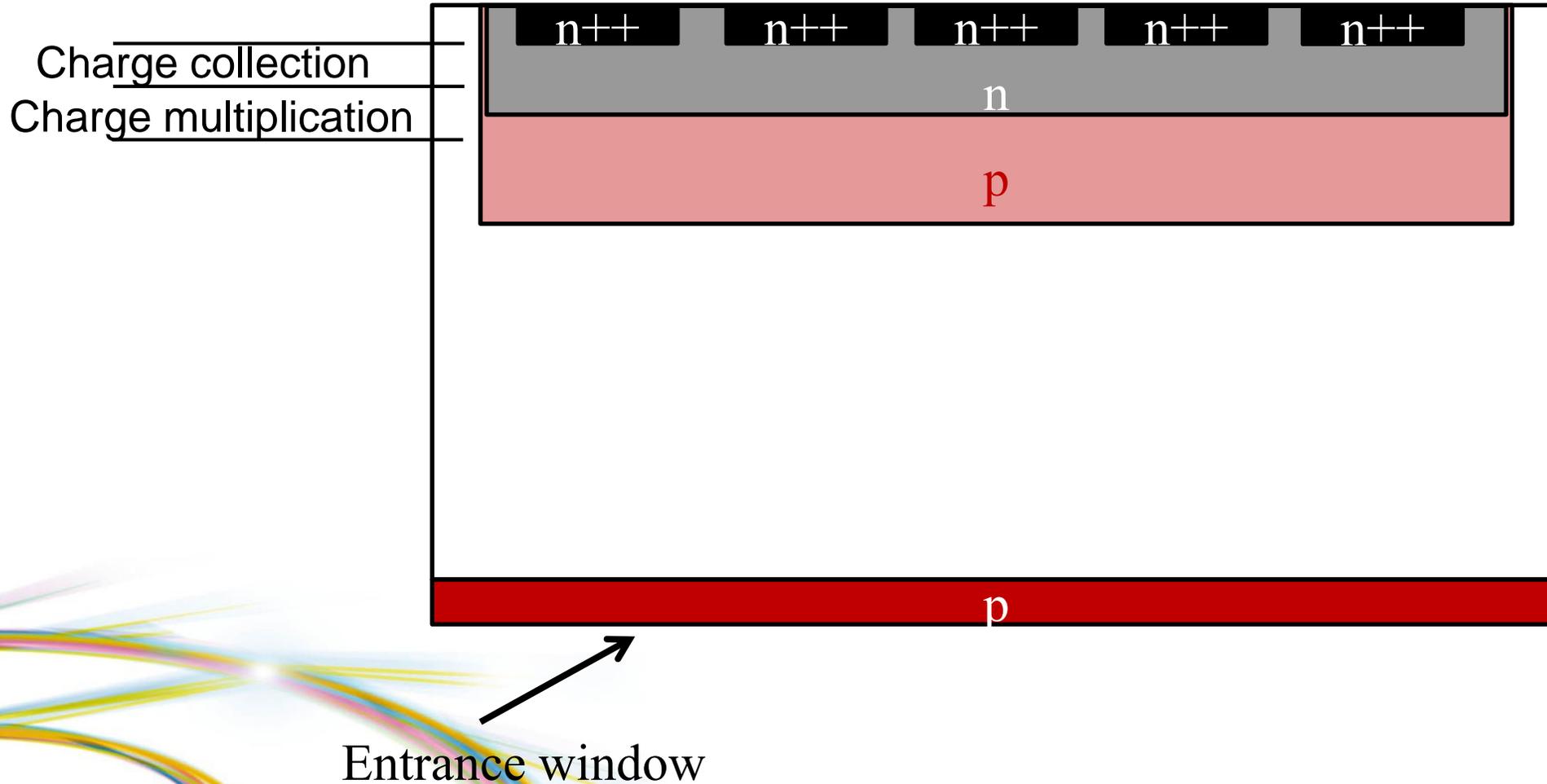
Other use cases of tender X-ray photons

- Medipix3 photon counting detector for I20 spectrometer (wish to go down to 2 keV)
- Medipix3 photon counting detector for I16 polarimeter (down to 2.5 keV)

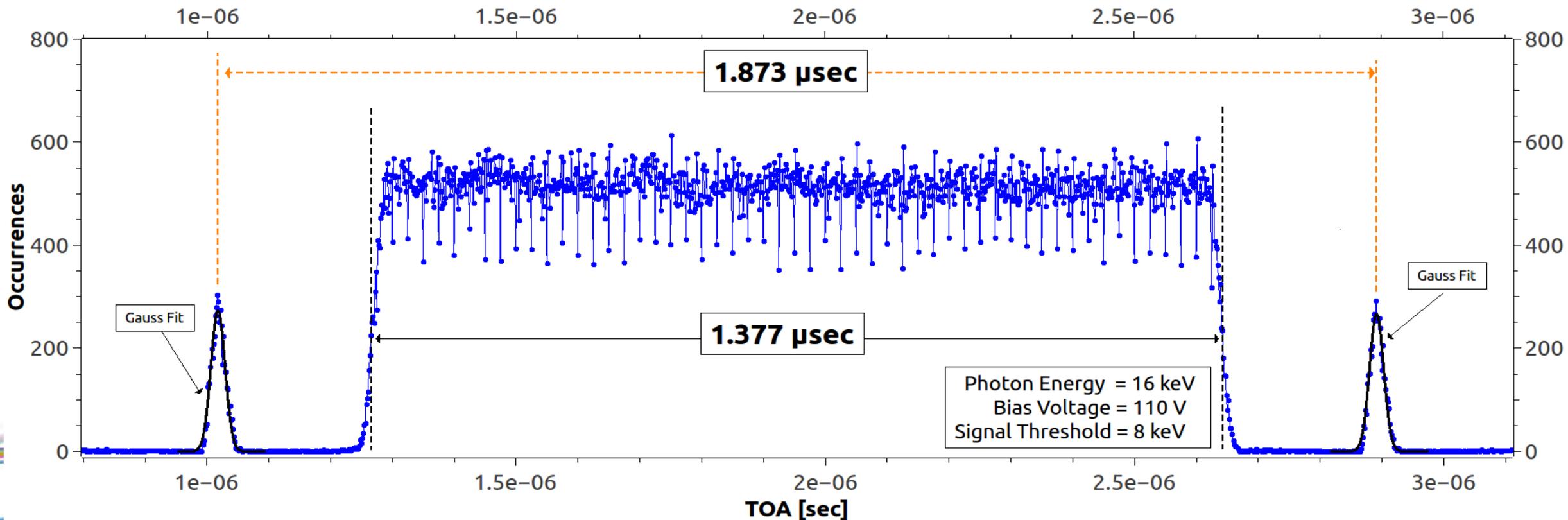
Photons attenuation length in Si



Some naive ideas...

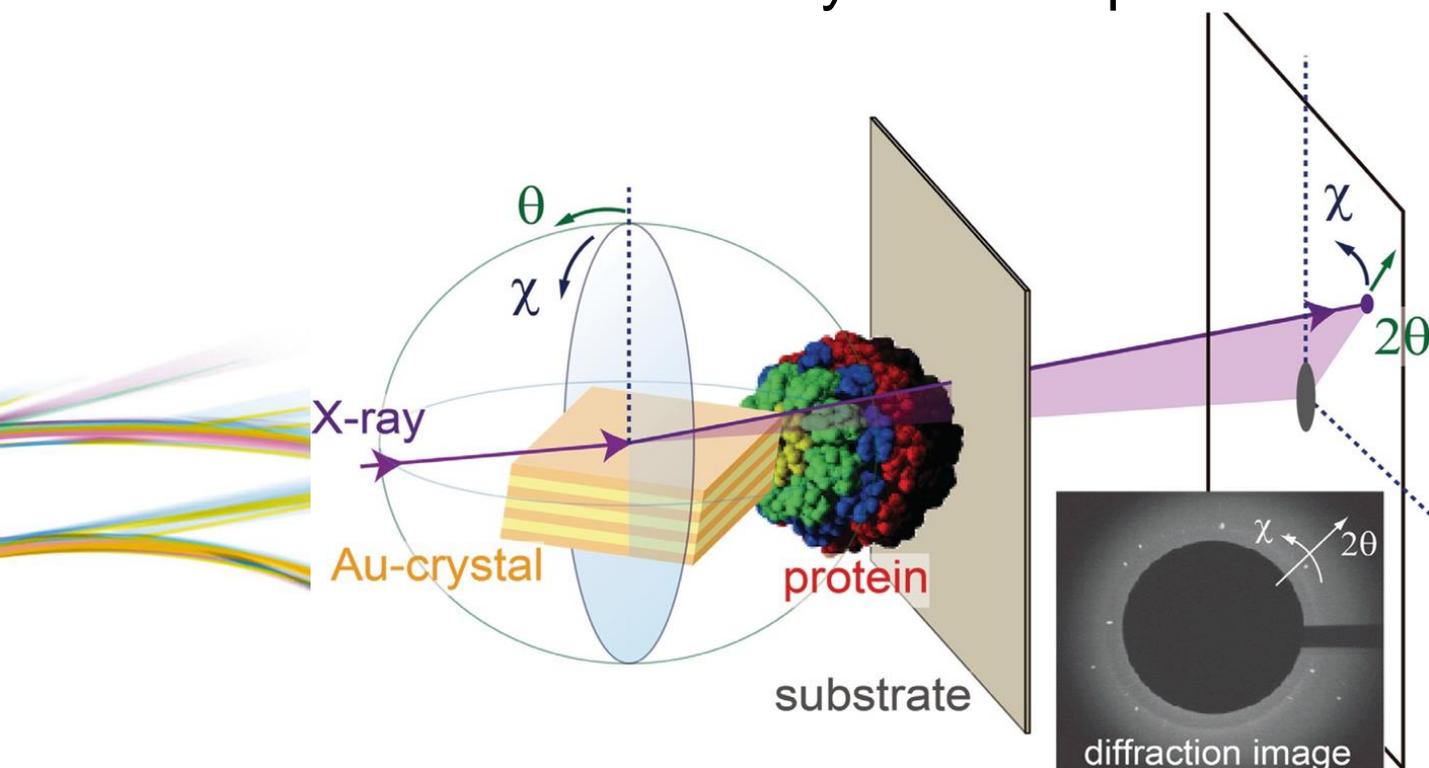


TIMEPIX3 FOR TIME RESOLVED EXPERIMENTS



DXT- DIFFRACTED X-RAY TRACKING

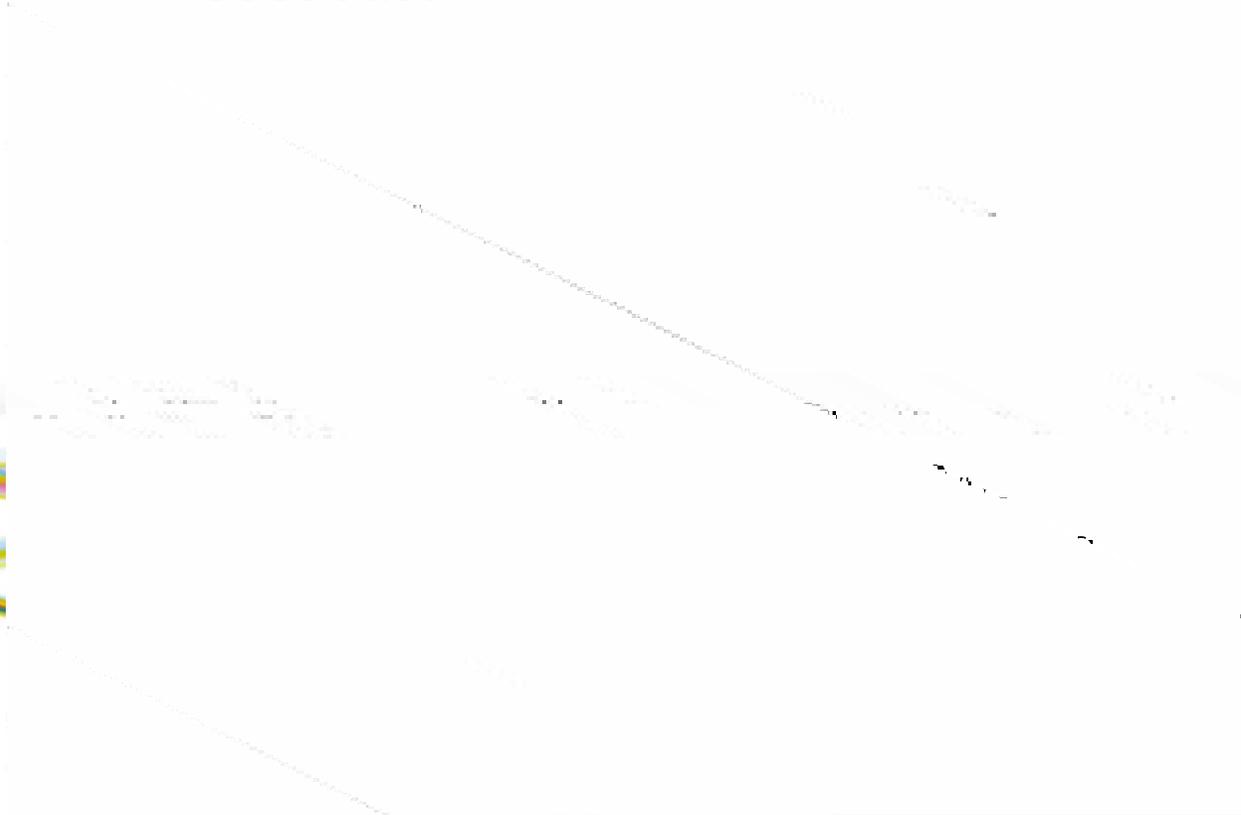
- User experiment performed in B16 @ DLS – previously performed only at SPring-8 on a dedicated beamline
- Detector positioned with sensitive area just outside the direct beam
- One-shot dynamic experiment



Many thanks to Prof Yuji Sasaki (University of Tokyo) and Dr Hiroshi Sekiguchi (SPring-8)

DXT- DIFFRACTED X-RAY TRACKING

- Most of time spent to limit the background
- Part of the detector sensitive area shielded
- Several protein sample tested
- Continuous exposures with different duration (between 1 and 10

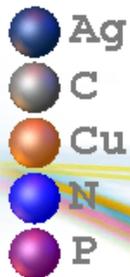
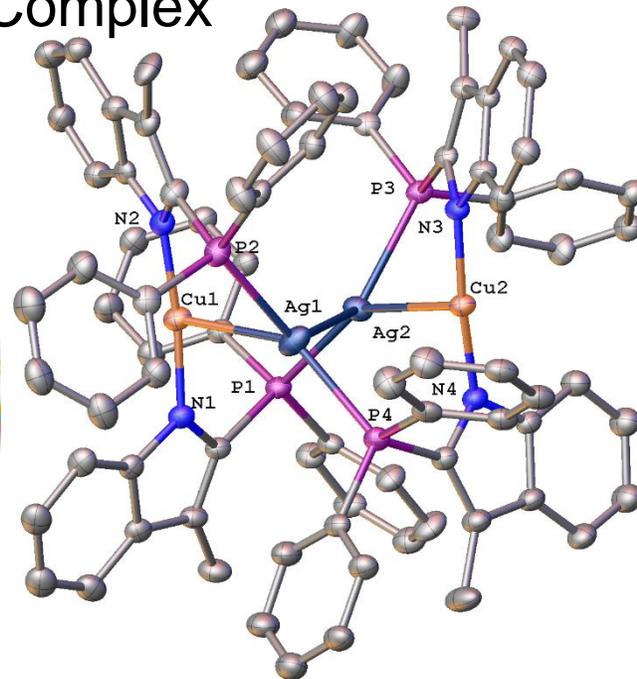
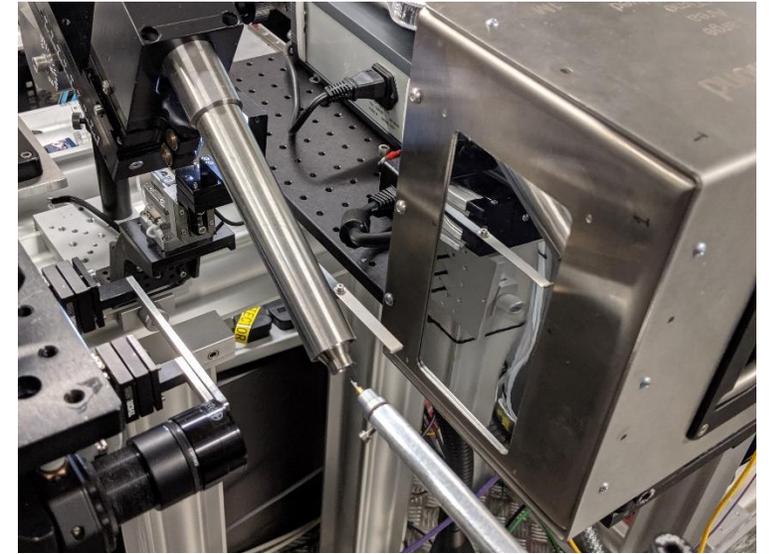


RESULT:

- 3 s exposure
 - Frame duration is not fixed: possibility to change frame duration using event timing without need to perform another exposure
- 1200 frames of 50.5ms

TIME-RESOLVED CRYSTALLOGRAPHY

- User experiment performed in I19 @ DLS
- Detector positioned with sensitive area in direct beam path using beamstop
- Pump-and-probe experiment using pulsed laser (femtosecond)
- Monochromatic beam
- Sample: AgCu Complex

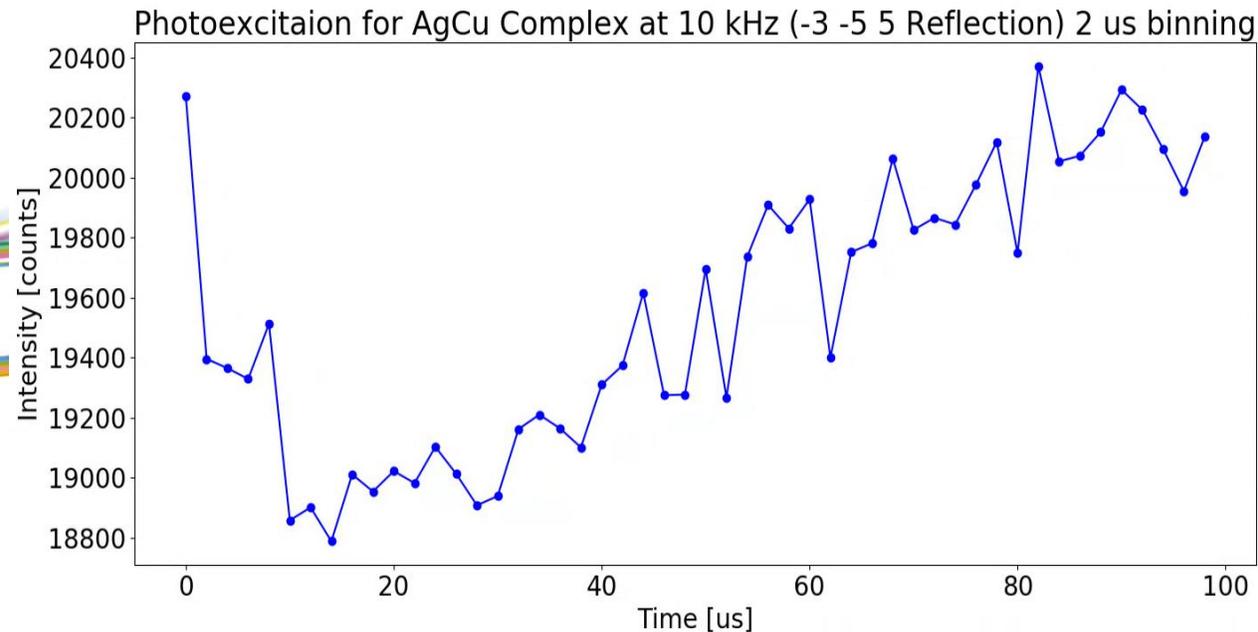
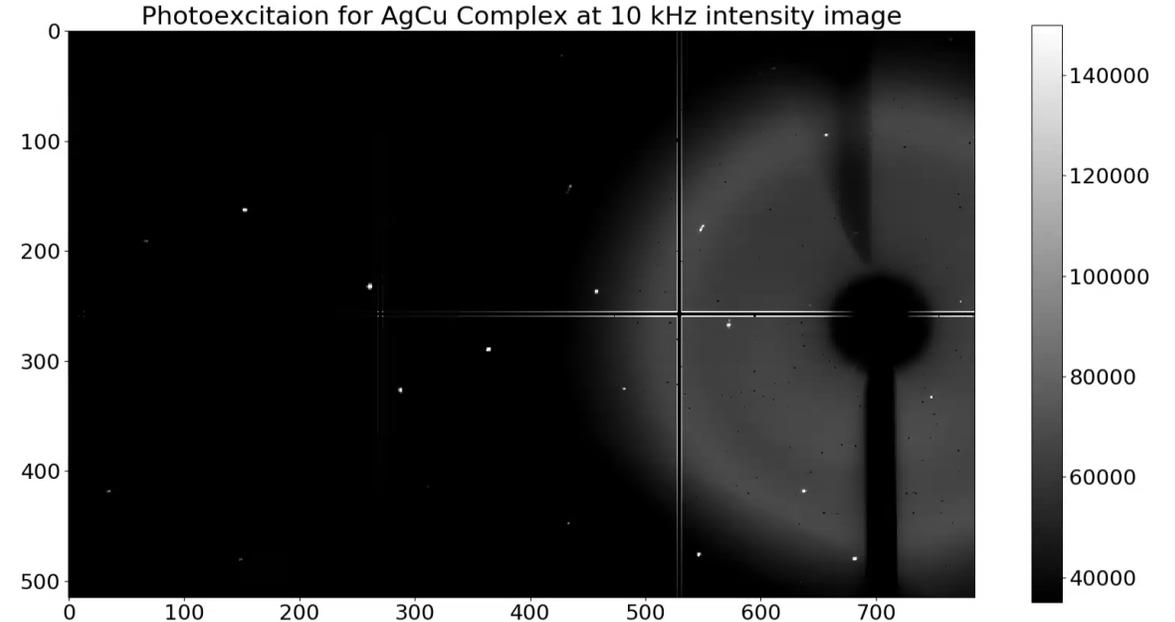


*Many thanks to
Dr Mark Warren
and all I19's team*



TIME-RESOLVED CRYSTALLOGRAPHY

- 1000 s continuous exposure with laser pump at 10 kHz: continuous probe, periodic pump
- Pump signal (trigger) timestamped by detector on same time base of events to realign data in processing
- Data driven readout → no downtime!



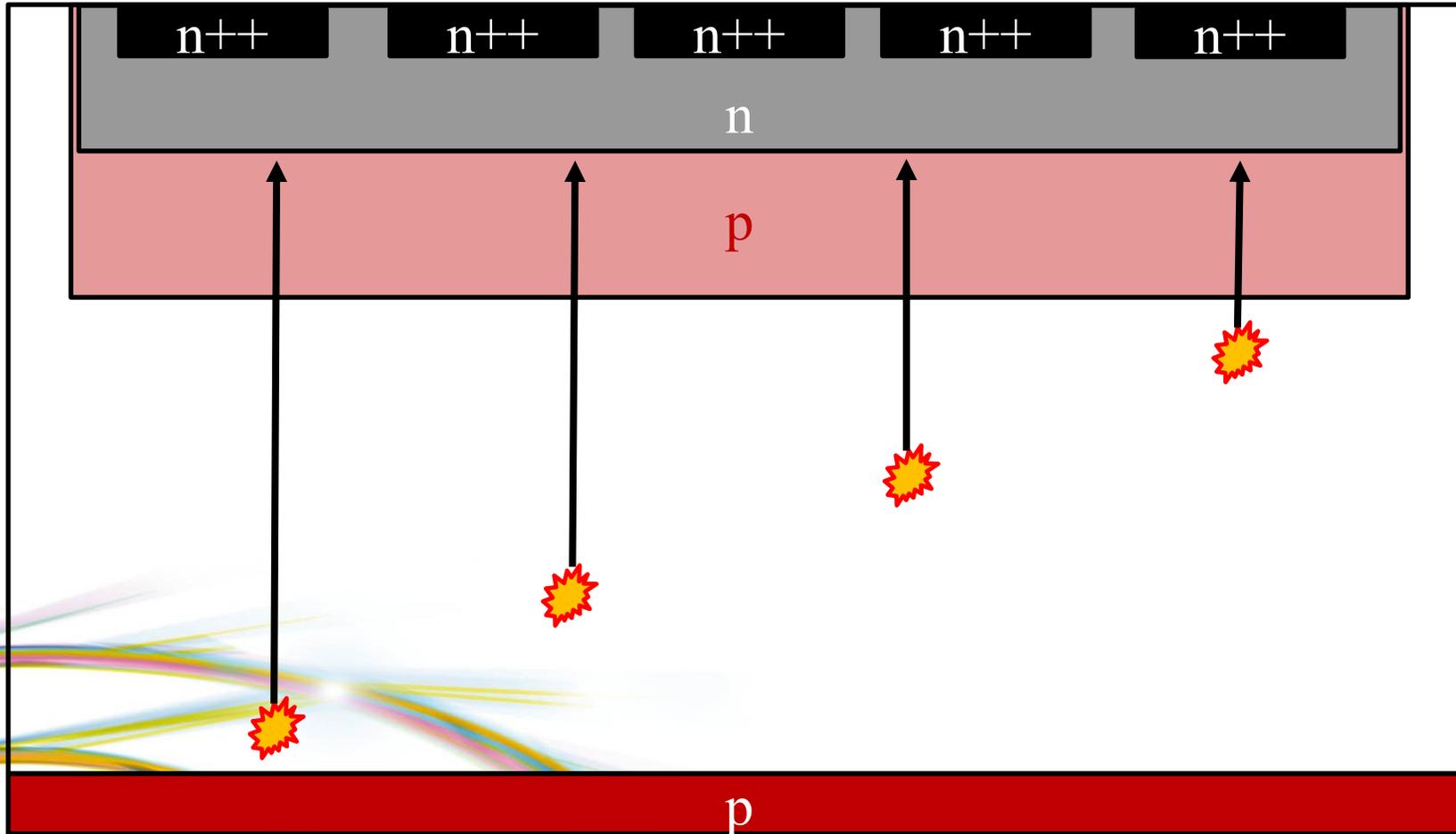
ADVANTAGES:

- ✓ μs regime easily accessible
- ✓ Data collection is 50x faster than the current imaging detector
- ✓ Samples are less exposed hence less subjected to radiation damage

TIMEPIX3 MAIN CHARACTERISTICS

Pixel arrangement	256 x 256
Pixel size	55 x 55 μm^2
Chip active area	1.98 cm^2
Total chip area	2.29 cm^2
Dead time per pixel	475 ns
Measurable time interval	409.6 μs
Timing resolution	1.56 ns
Minimum detectable charge	500 e-
Readout Type	1) Frame Based Zero Suppressed 2) Data Driven Zero Suppressed

Signal latency depends on interaction depth



Electron saturation velocity in Si:

$\sim 10^7$ cm/s

Latency spread in 500 μ m
thick sensor:

At least 5 ns

A long way but... let's start!

Thank you!