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Stability and homogeneity: key detector characteristics for good quality high-yield experimental data.

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The high coherence, high peak power and short pulses duration of modern light sources (e.g. X-ray Free-Electron Lasers - XFELs) are particularly well suited for time-resolved pump-probe and coherent diffraction studies.
In many pump-probe experiments small differences in signal produced by ground and excited states have to be detected and resolved. Poisson statistics dictates that ˜ 1 million of photons are needed to resolve an effect with 1/1000 precision. This requires detector systems with tremendous dynamic resolution and sources capable to provide either pulses with high intensity and moderate repetition rate or very high repetition rate with moderate intensity.
The typical approach is to average many frames. However source, pump-laser and sample instability make blind averages not really useful. It is therefore critical to preserve the information of each single pulse: comprising beamline and accelerator diagnostics, laser to FEL timing, and detector. Data can then be sorted out, binned and correlated, before the averaging procedure.
Further even when the detector is capable of better-than-Poisson performance for a single image, it's not guaranteed that the detector error will be smaller than the summed Poisson statistics when many frames will be averaged. Non-gaussian non-ergodic processes can dominate the error limiting the achievable resolution.
Detector stability and homogeneity are equally important for X-ray Photon Correlation Spectroscopy (XPCS), where in addition small pixel and single photon resolution are needed.
Deep understanding of the detection system and careful calibration are necessary for good quality high yield data. While these techniques have been used since long time in the High-Energy and Particle Physics communities, they are relatively new in the field of Photon Science. Examples of applications and optimization will be presented.

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