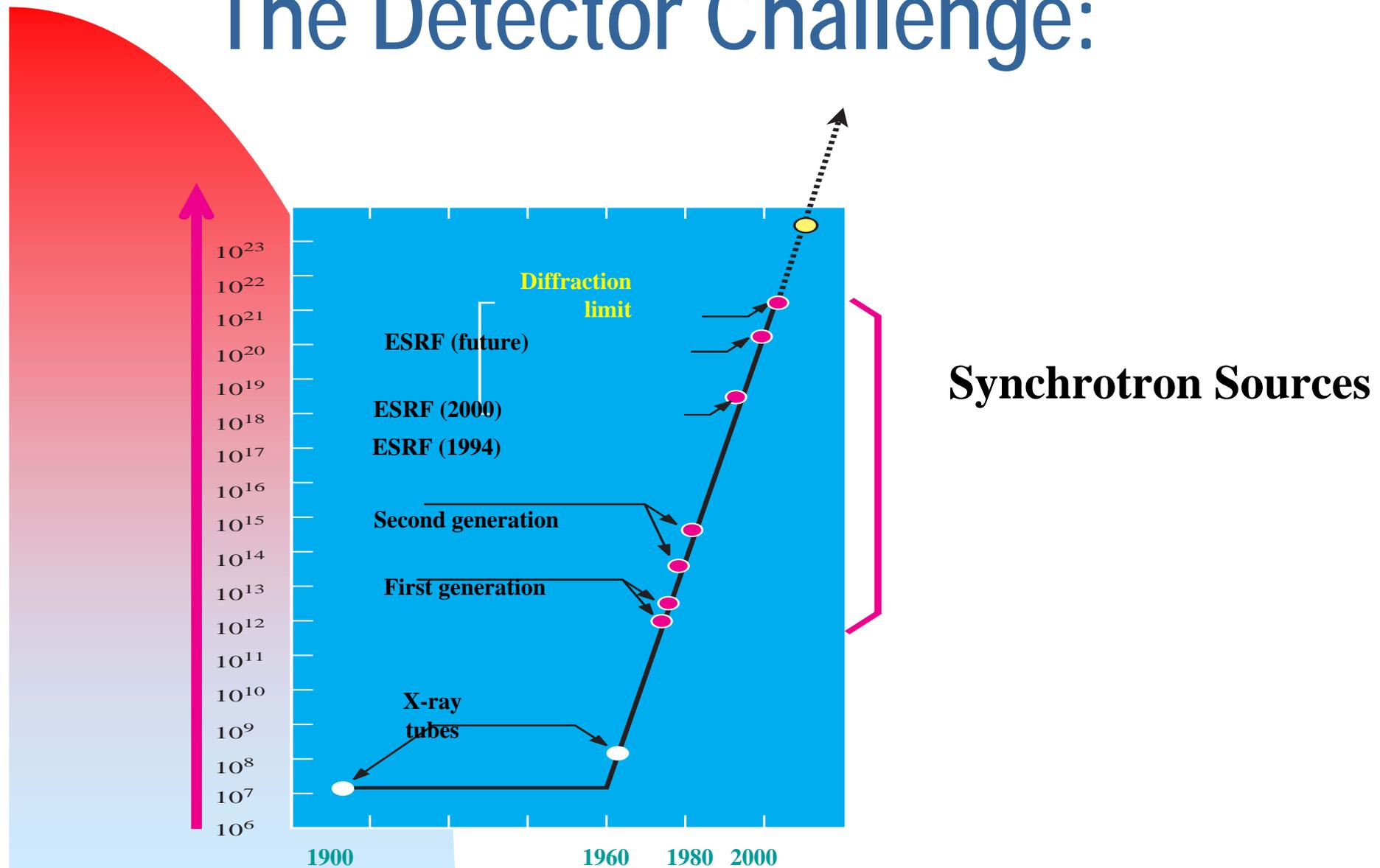


Detectors at Synchrotron Sources now and in the future



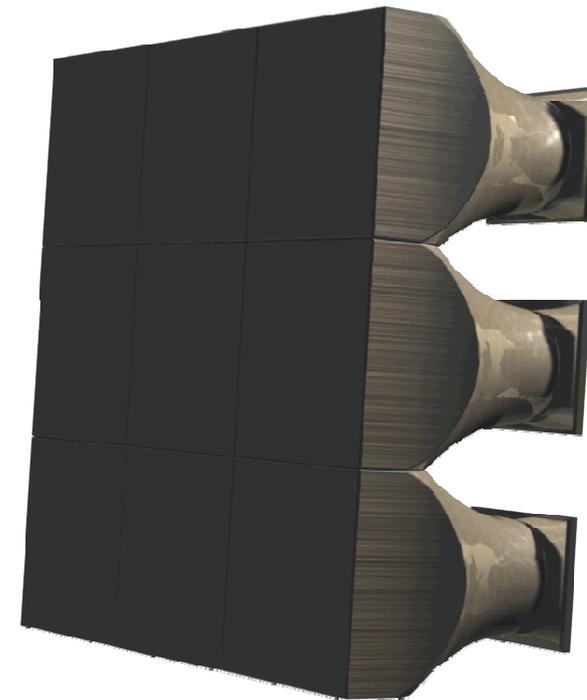
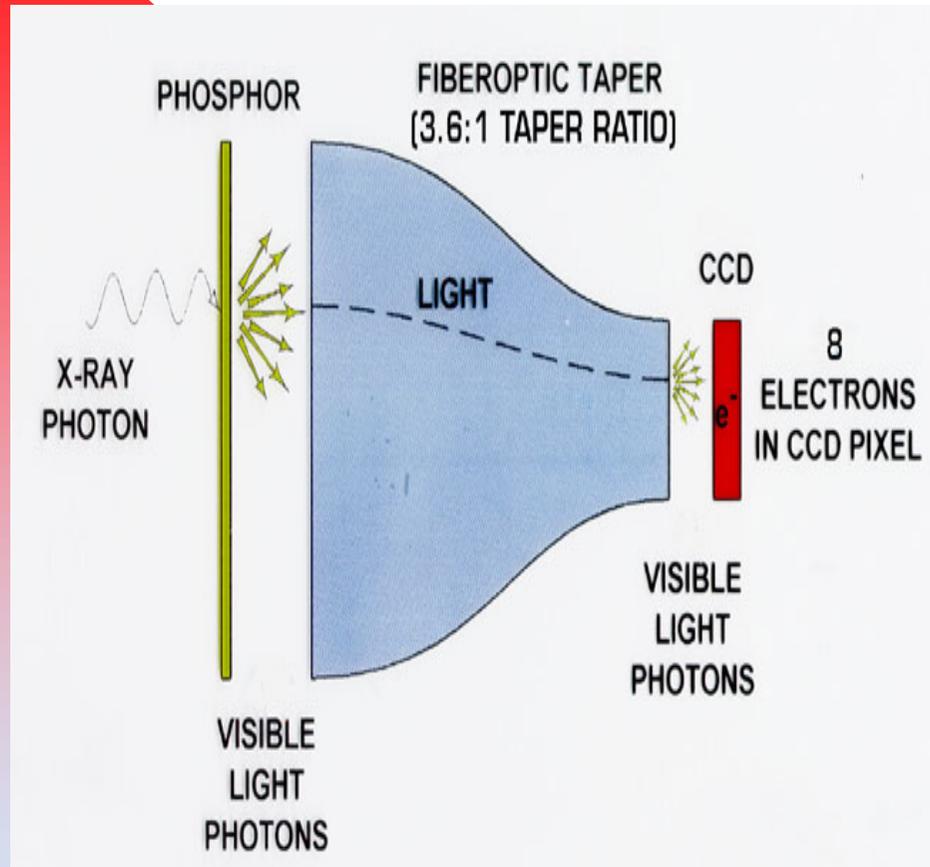
The Detector Challenge:



The Detector Challenge:

- ID1 Anomalous scattering**
- ID2 Small-angle scattering**
- ID3 Surface diffraction**
- ID8 Spectroscopy using polarised soft X-rays**
- ID9 Biology / High pressure**
- ID10 Multipurpose**
- ID11 Materials science**
- ID12 Circular polarisation**
- ID13 Microbeam**
- ID14 Protein crystallography**
- ID15 High energy**
- ID16 Inelastic scattering**
- ID17 Medical**
- ID18 Nuclear scattering**
- ID19 Microtomography - Topography**
- ID20 Magnetic scattering**
- ID21 X-ray microscopy**
- ID22 Microfluorescence**
- ID24 Dispersive EXAFS**
- ID26 Spectroscopy on ultra-dilute samples**
- ID27 Industry**
- ID28 Inelastic scattering**
- ID29 Biology MAD**
- ID30 High pressure**
- ID32 Surface EXAFS - Photoemission**
- BM5 Optics**
- BM16 Powder diffraction**
- BM29 Absorption spectroscopy**

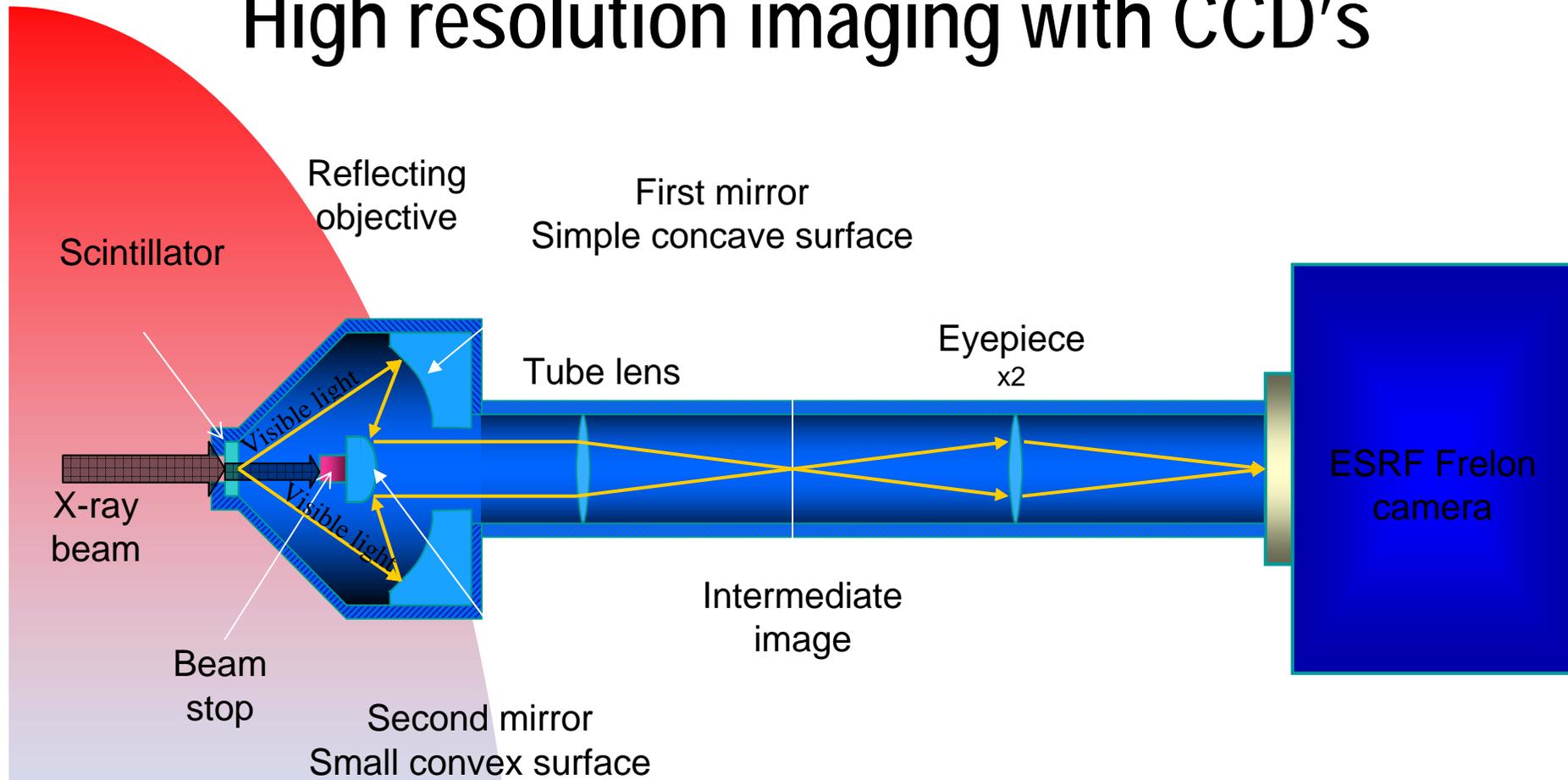
Large area CCD systems, mainly for PX



– Indirect detection
==> losses & spreading

– Integrating detector
==> noise & information loss

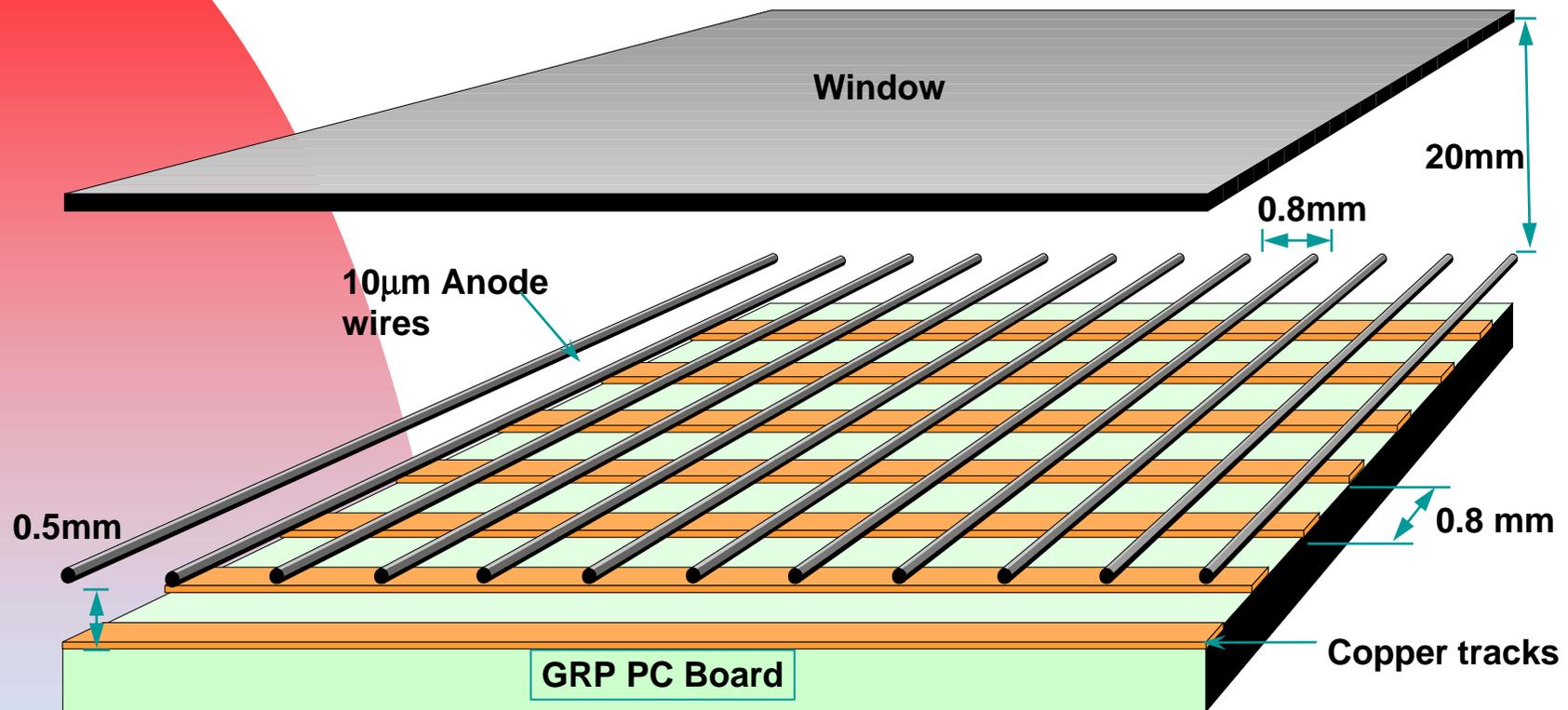
High resolution imaging with CCD's



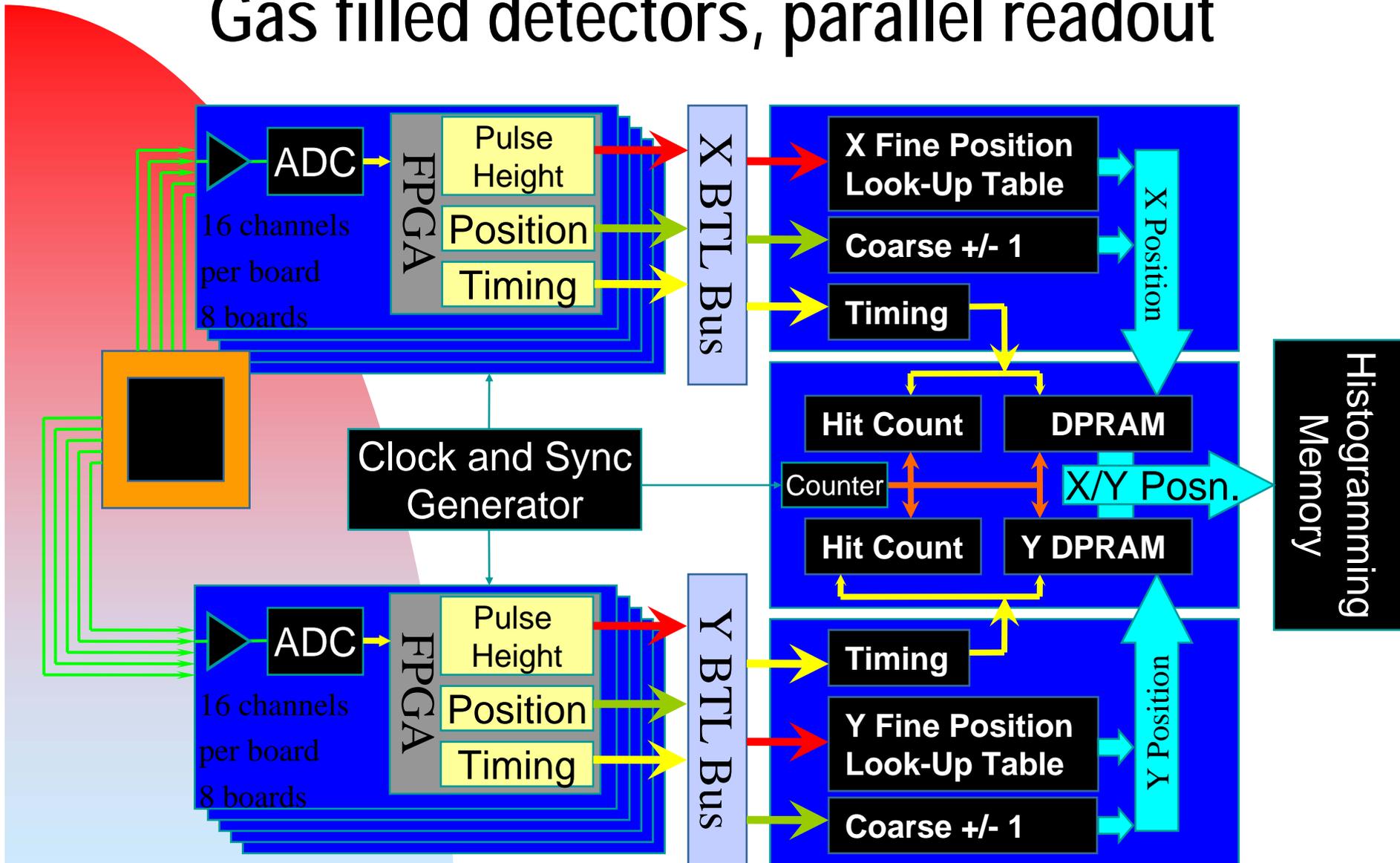
Scintillator is very inefficient

Full tomo dataset in 10 sec.

Gas filled detectors, parallel readout

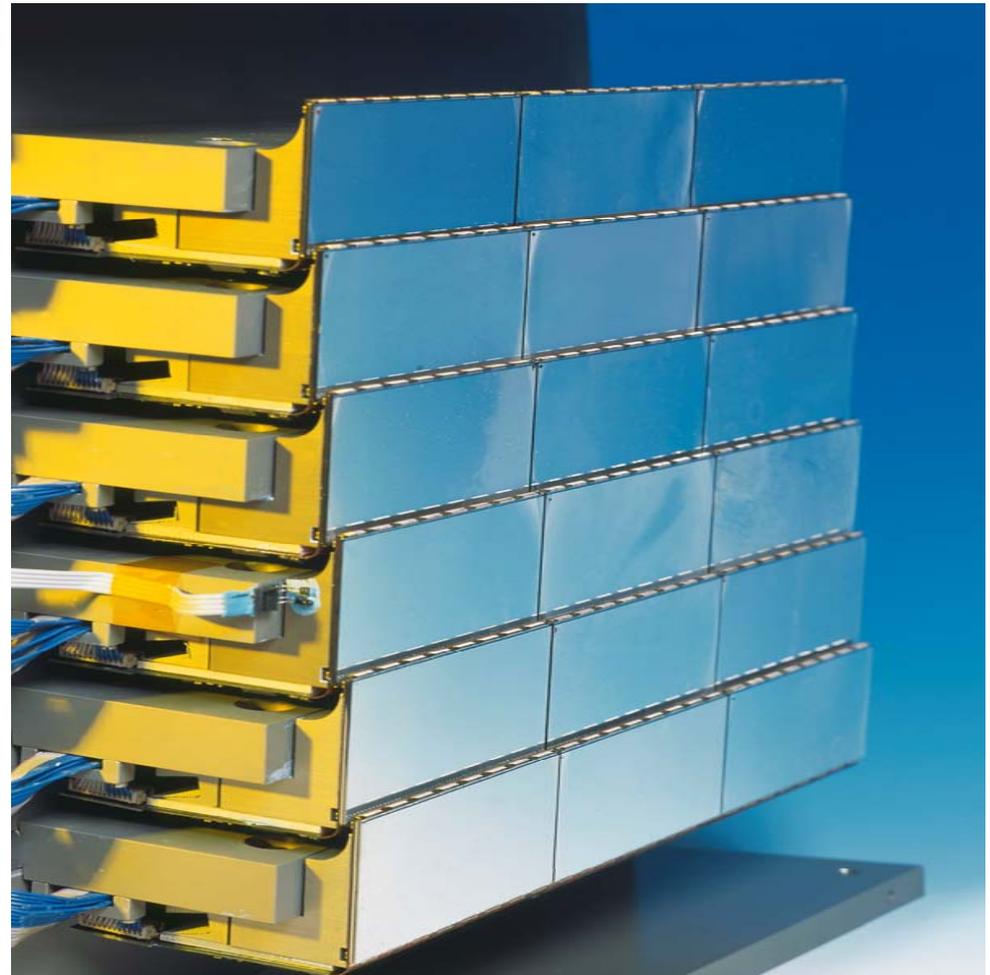
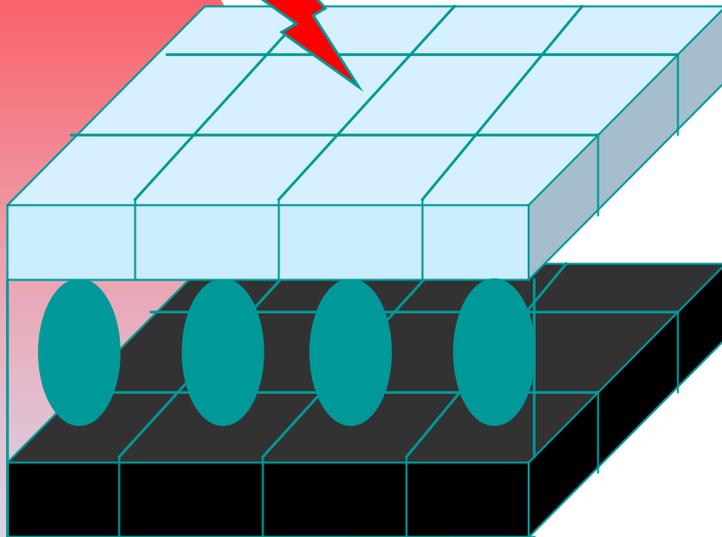


Gas filled detectors, parallel readout



Detectors for now and the future

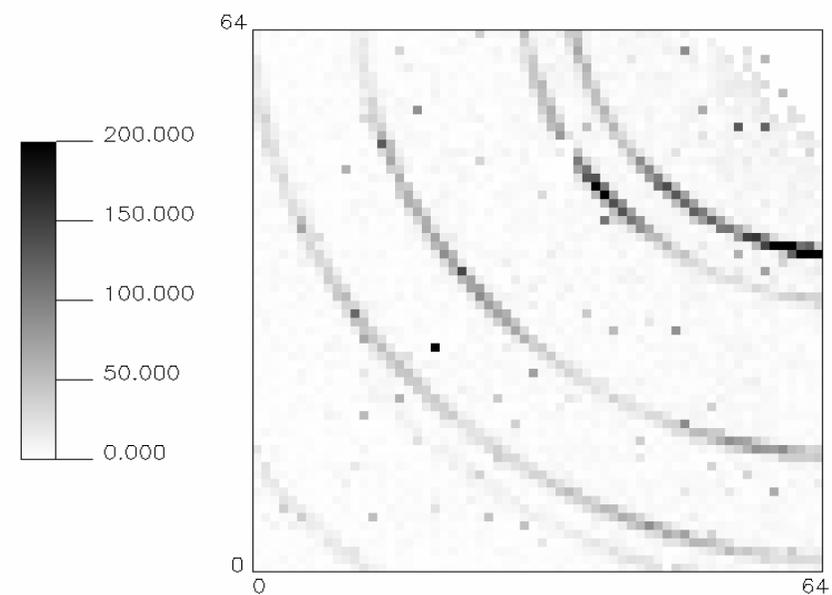
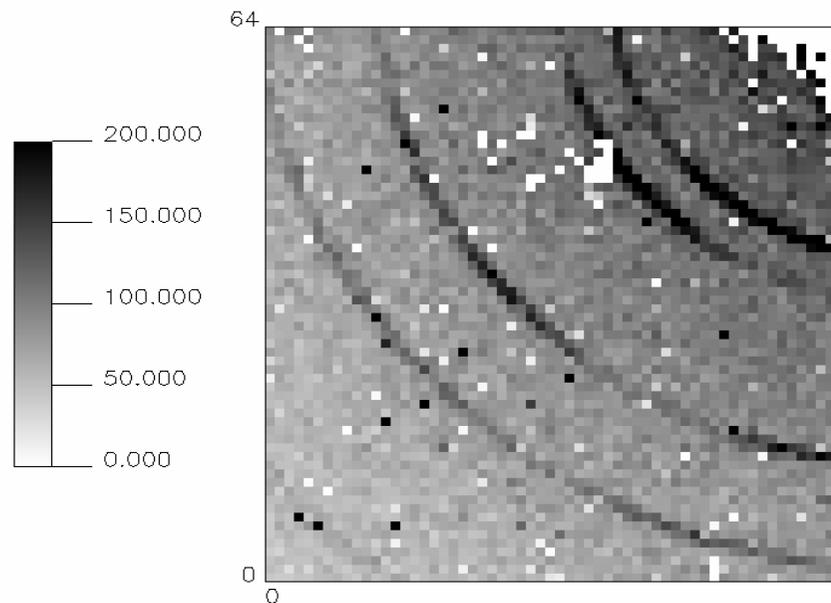
X-ray photon



Really low noise:



L. Tlustos, Medipix Collaboration, CERN, 2002



Heinz Graafsma; ESRF-France

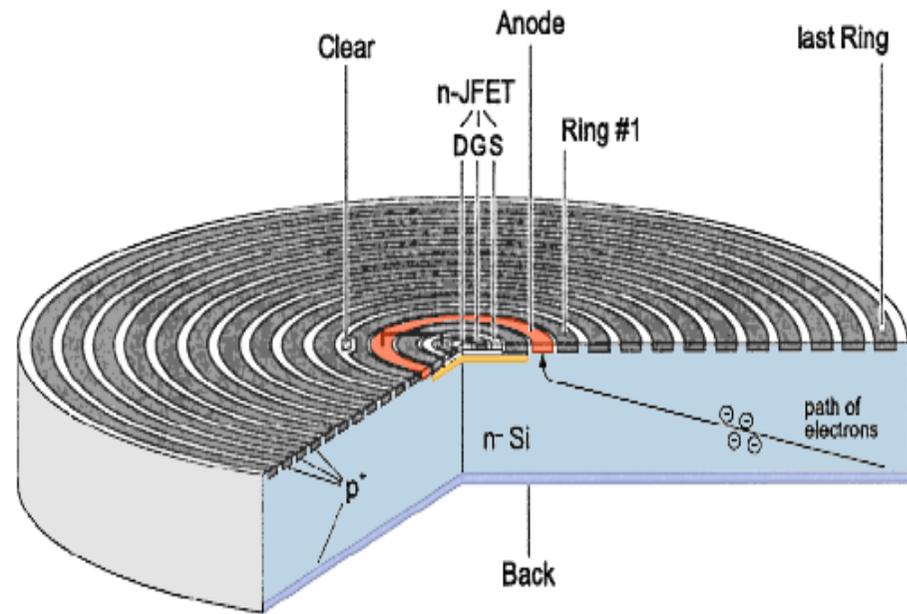
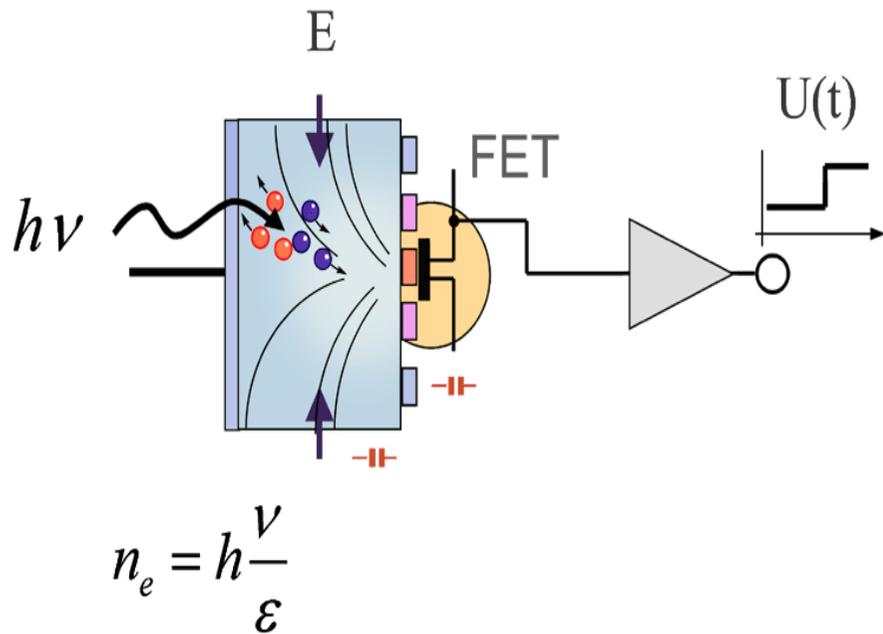
PSD-7; Liverpool; 14 September 2005

Problems to overcome:

- **Radiation tolerance**
- **Charge sharing**
- **Yield**
- **4 side-butting (3D connectivity)**
- **High Z sensors (GaAs, CdZnTe)**
- **This can all be overcome by enough critical mass → COLLABORATION!**
- **Limited energy resolution**

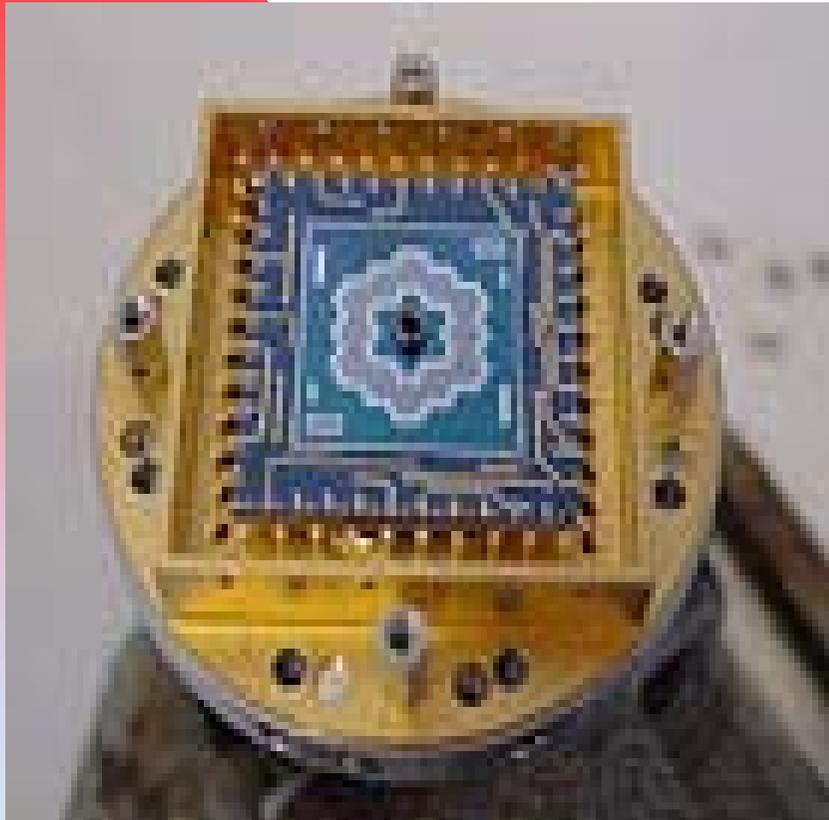
Energy Resolving Detectors

Silicon Drift Detectors:



Energy Resolving Detectors

Silicon Drift Detectors:

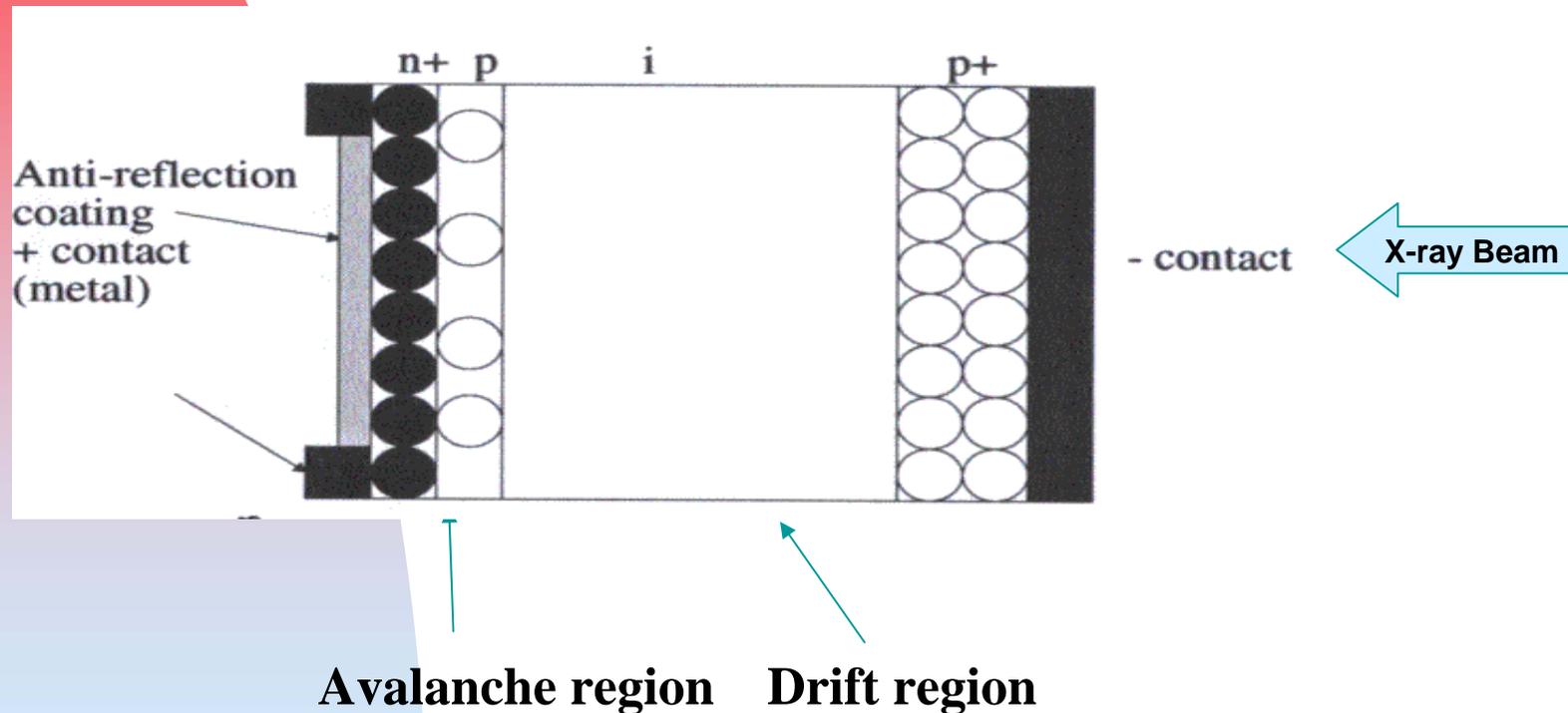


Advantages:

- energy resolution 130 eV
- Fast: 100 kcps per pixel
- 2D systems possible
- Large drive by space research
- Well adapted to 12 keV and lower.
- Advanced technology
- Canberra and MPI-Munich/Milan poly technique

Fast Detectors: AVALANCHE PHOTODIODE

Real device
“Reach-Through” APD



AVALANCHE PHOTODIODE

- Energy range : $3 \text{ keV} < E_{\text{X-ray}} < 30 \text{ keV}$ (limited by thickness)
- Counting rate: $\sim 10^7 \text{ cps}$
- Dark noise: $\sim 0.01 \text{ cps}$
- Energy resolution: $\sim 20 \% @ 24\text{keV}$
 $\sim 39\% @ 12\text{keV}$
- **Time resolution: $\sim 1 \text{ ns}$**

AVALANCHE PHOTODIODE



Head = APD + Pre-amplifier



•Hamamatsu

- 5x3mm² 135 μm available
- $\phi=3\text{mm}$ 135μm (proto)

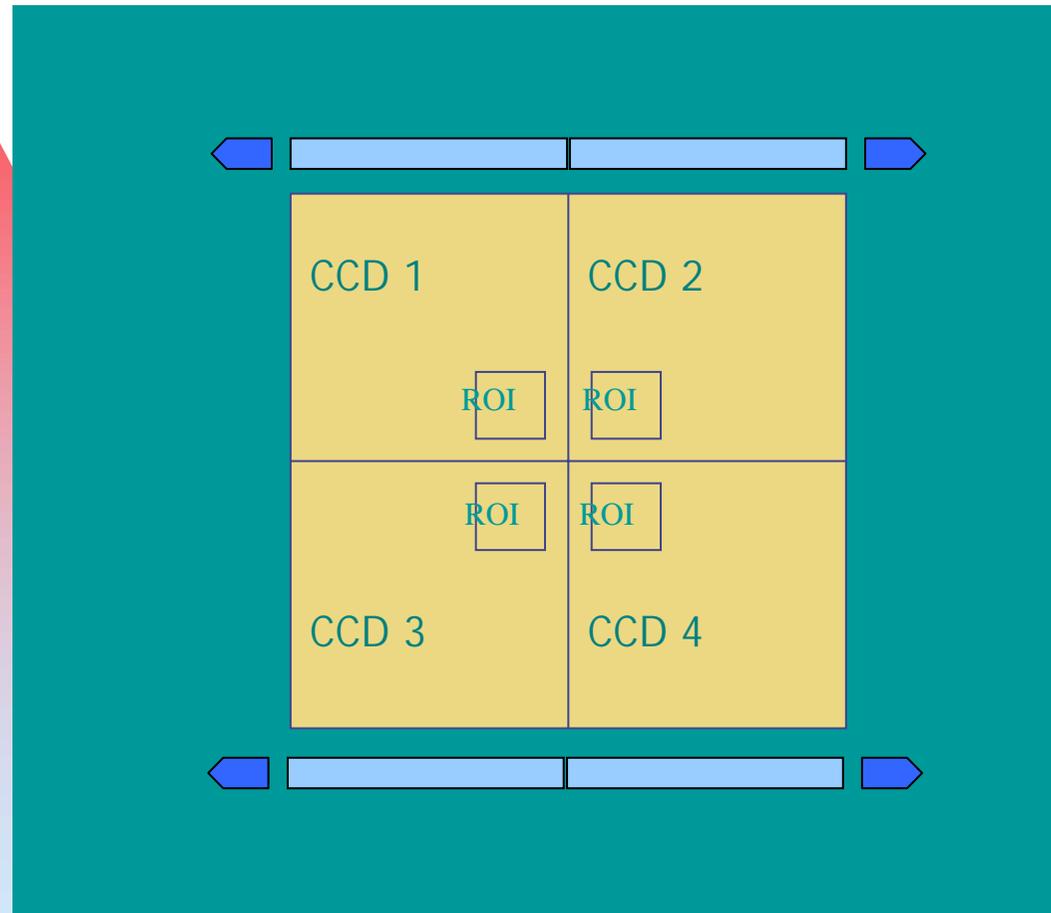
•EGG

- 5x5mm² 110μm
- 10x10mm² 110 μm

Acquisition system : ACE (APD Controller Electronic)

- Principle of use: amplitude (mV) \Leftrightarrow energy(eV)
 - ◆ 1 counter, 2 thresholds (high and low) for level discrimination
 - ◆ Counter with low level only = integral counter.
 - ◆ Counter with low-high level = counter in energy range.

Fast parallel readout CCD's



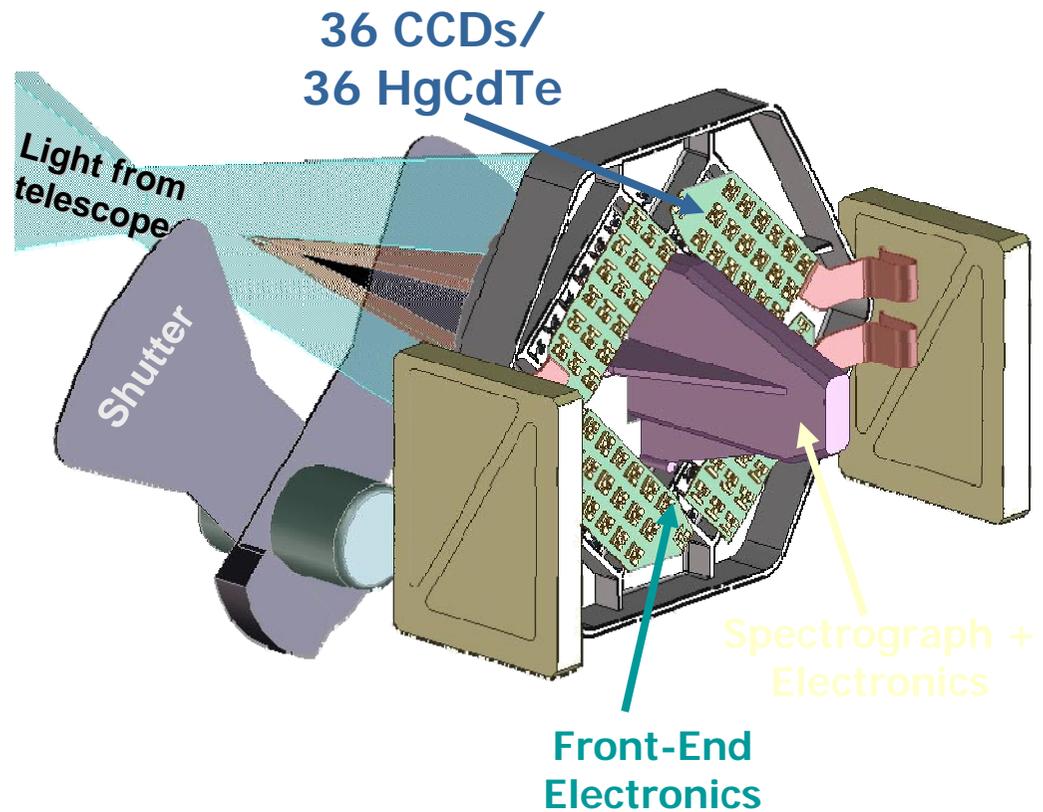
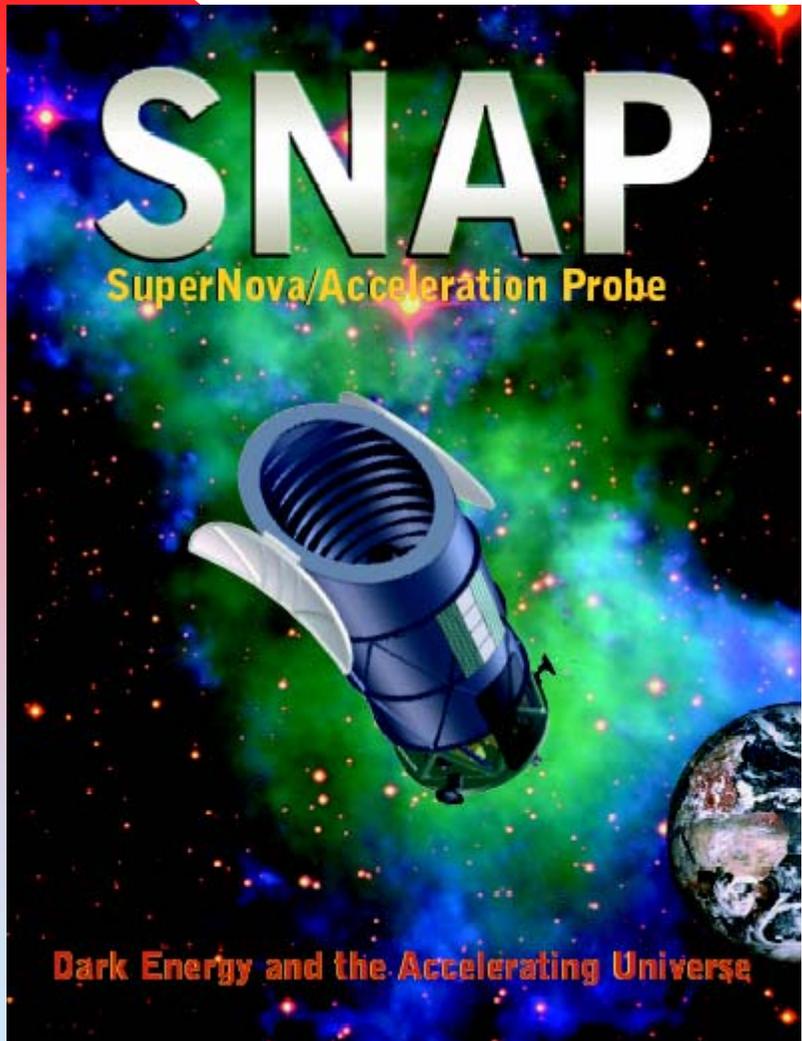
Fast CCD-based Systems for Detection of X-rays and Electrons

H. A. Padmore¹, C. Bebek², M. Church¹, P. Denes³, J. Glossinger¹,
S. Holland², H. von der Lippe³ and J. P. Walder³

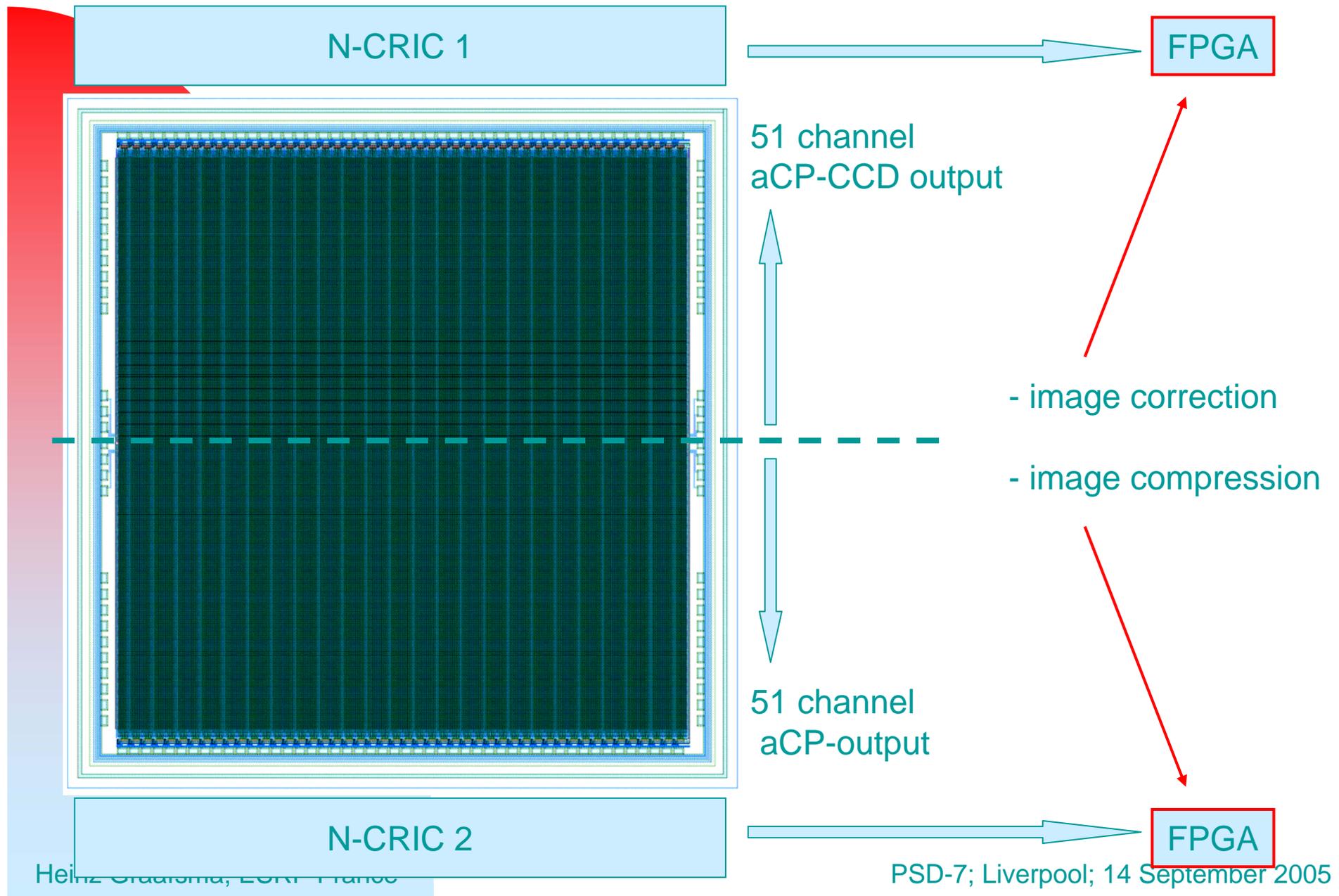
Lawrence Berkeley National Laboratory
¹ ALS, ² Physics and ³ Engineering Divisions

- **CCDs for synchrotron radiation x-ray research**
- **Development of optical CCDs at LBNL**
- **Column Parallel CCDs**
- **Status report**

**Thick, deeply depleted, back illuminated CCDs
and CMOS CCD readout used in SNAP**



Prototype (almost) Column Parallel CCD Readout Structure



“New” developments summary

- Pixel Detectors: Asics and sensors
- Silicon Drift Detectors
- Avalanche Photodiodes
- Parallel readout CCD's

- Plus others: high resolution phosphors, flat panel imagers, diamond detectors, ...

Characteristics of XFEL radiation

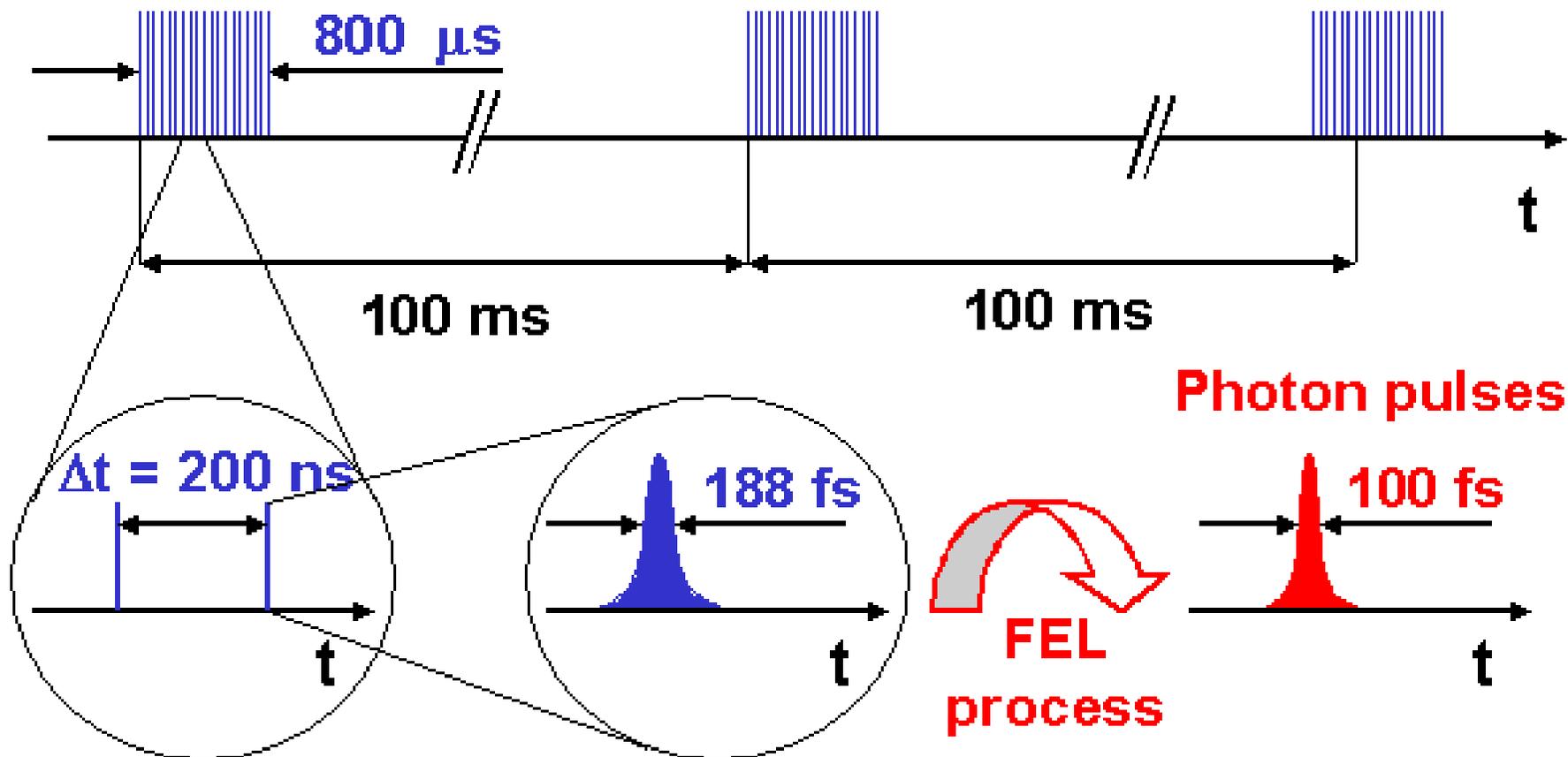
- Photon energy X-rays: 3 up to 15 keV
soft X.: 200 up to 2000 eV
- Photon per pulse 10^{12} up to 10^{14}
- Divergence <1 up to few 10 μ rad
- Source appearance $\sim 100 \mu\text{m}$ (diffraction limited)
- Bandwidth $\sim 0.1 \%$

- Pulse duration **100 – 300 fs (probably decreasing)**
- Repetition rate Macro-Bunch (MB): 10 – 120 Hz
single bunch within MB: $\sim 10\text{MHz}$

- Short pulse high energy radiation from spontaneous emission
- Photon energy 100 – 400 keV
- Photons per pulse $\sim 10^8 / 0.1\%bw$

Accelerator time pattern

Electron bunch trains
(with up to 4000 bunches à 1 nC)

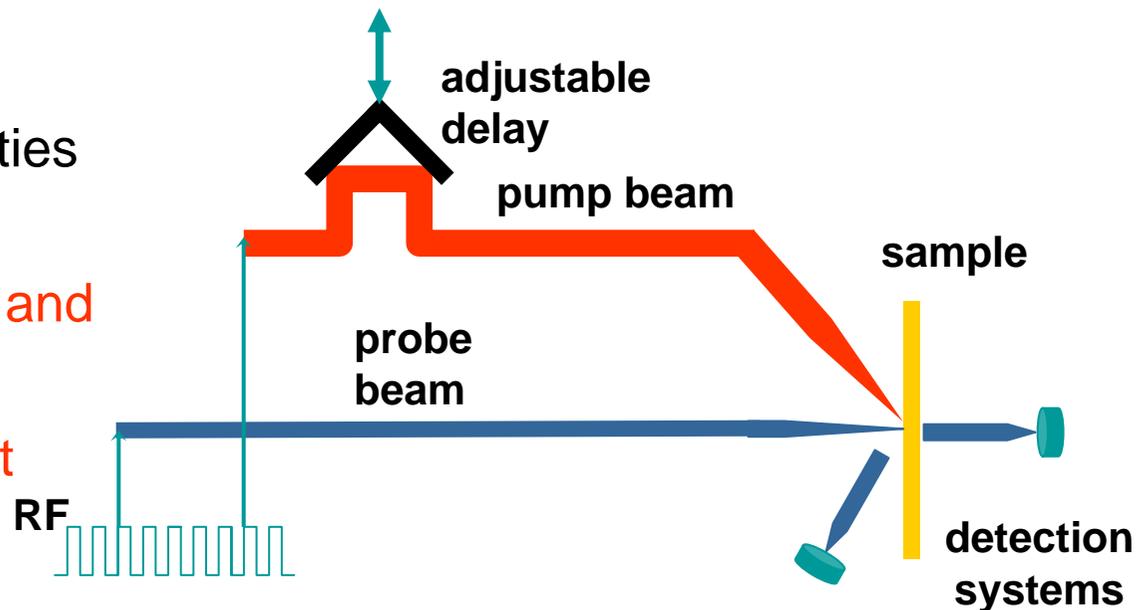


Time-resolved pump-probe experiments

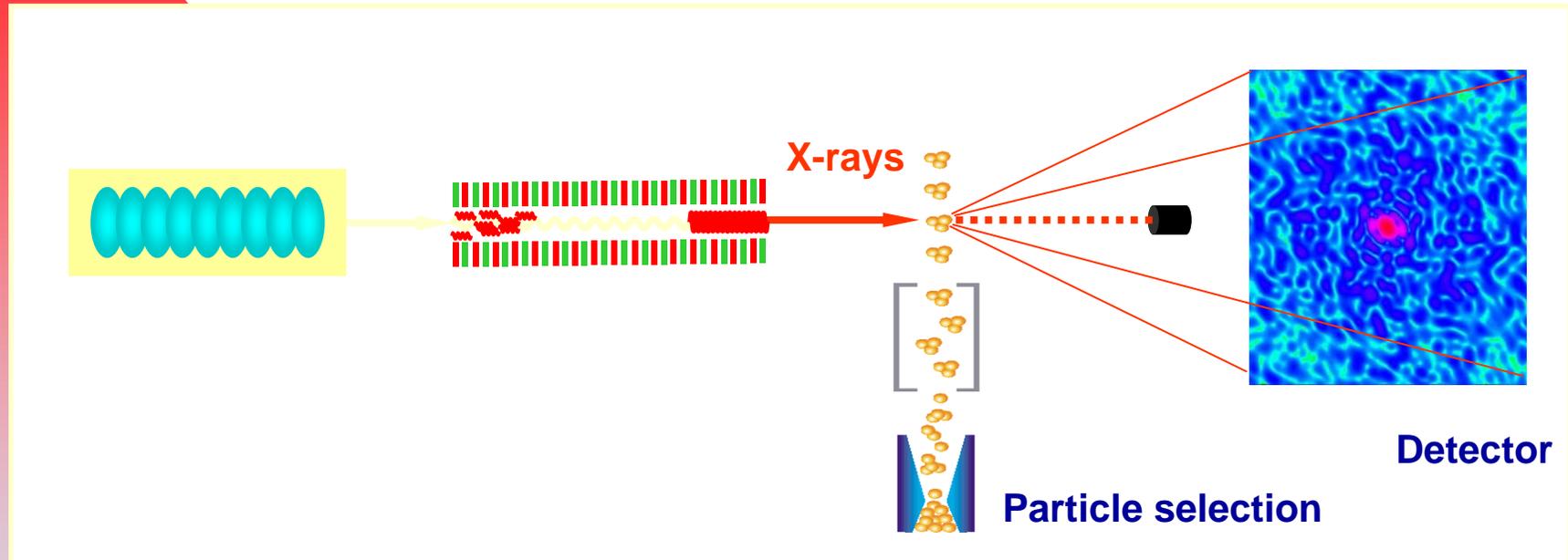
- Use X-rays and optical laser to pump/probe the investigated system. Both systems will be referenced timewise to the RF signal of the accelerator.
 - ◆ Laser-to-RF jitter
 - ◆ X-ray-to-RF jitter
 - ◆ Path length instabilities

- ⇒ Time delay of Pump and Probe varies (\sim ps)
- ⇒ determines overall Δt

A solution:
Sample data at pump/probe frequency



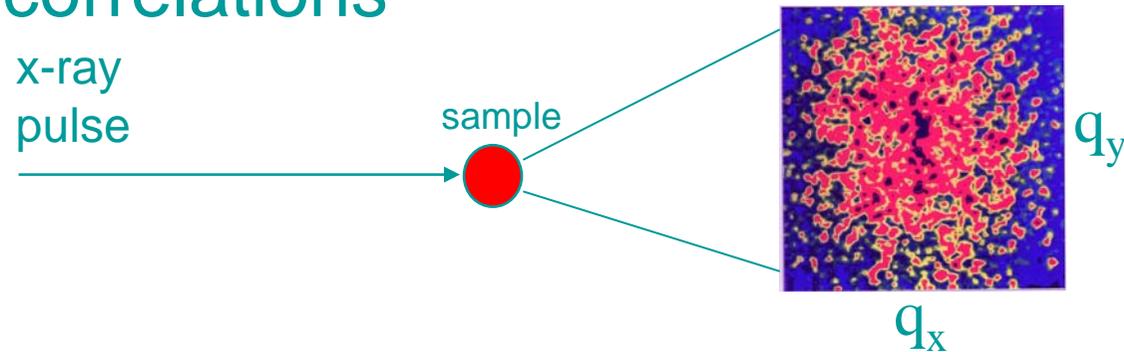
Single molecule diffraction



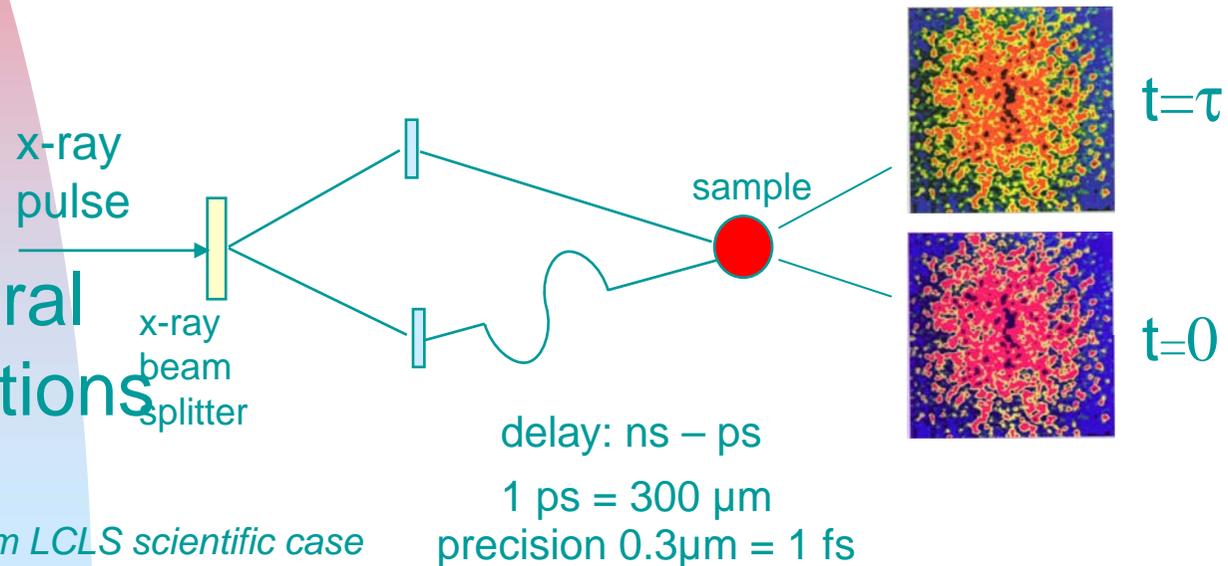
- structure solution without phases by collecting slices in q -space,
- accumulation of identical orientations, followed by crystallographic procedures
- 3D structure solution by oversampling and reconstruction methods

X-ray photon correlation spectroscopy

- Spatial correlations



- Temporal correlations



From LCLS scientific case

Summary of requirements

■ General

- ◆ Single-photon counting detectors seem impossible
- ◆ Energy resolution (10%) for background suppression
- ◆ High quantum efficiency
- ◆ Very low noise due to dark current
- ◆ Homogeneity and distortions must be minimized

■ Data acquisition

- ◆ Enable readout/storage at repetition rate
- ◆ Correlate with photon beam parameters and diagnostics
- ◆ Software integrated into data acquisition system

■ Time related requirements

- ◆ Fast readout → 10 – 100 Hz
- ◆ Noise due to readout must not exceed dark current

Conclusion

Detector developers will have a lot to do in the years to come