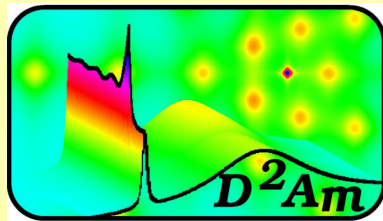


## Improvement in scattering experiments using pixel detectors.



J.F. Bérar, N. Boudet, B. Caillot, C. Mouget  
D2AM-CRG/F, ESRF, Grenoble  
Cristallographie, CNRS, Grenoble



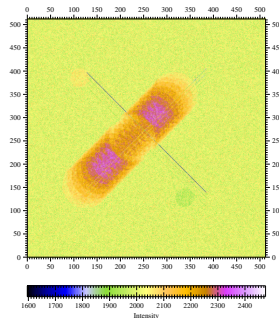
P. Breugon, J.C. Clémens, P. Delpierre,  
I. Koudobine, R. Potheau, I. Valin  
C.P.P.M., IN2P3 - CNRS, Marseille

## Summary.

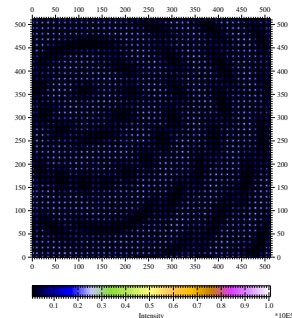
- Synchrotron experiments images and detector developement.
- Pixel detectors.
- XPAD detectors.
- Energy resolution and pixel detectors.
- From detectors data to reciprocal space maps.
- Small detectors : a short term opportunity.

# Synchrotron experiments images concerned by detector developement.

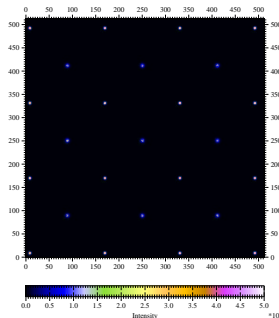
Absorption



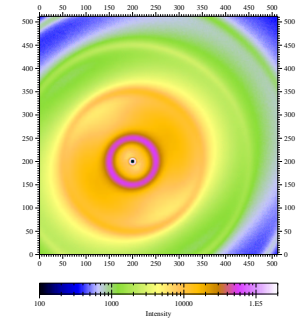
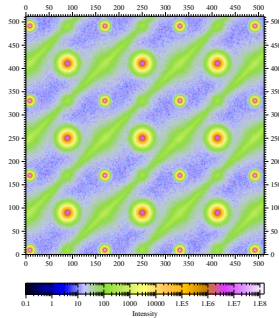
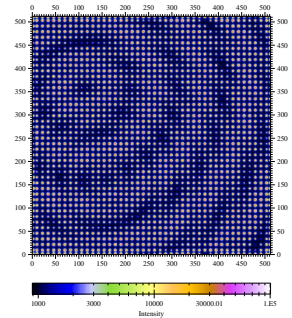
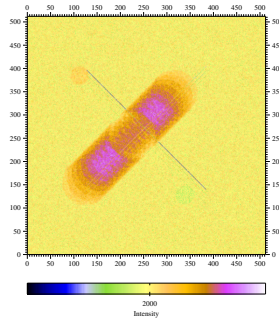
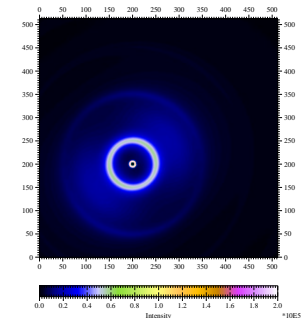
Struct. Cryst.



Material Science



SAXS

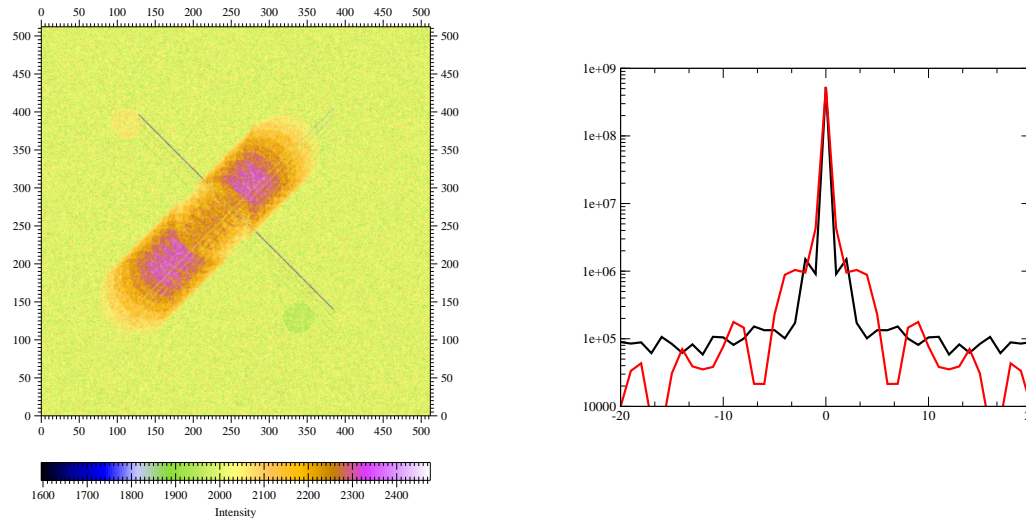


LINEAR or LOG scaled views show that requirements are very different between experiments.

## Absorption images.

Evidence weakly contrasted details using the weakest radiation dose.

In Fourier transform, significant magnitudes near origine

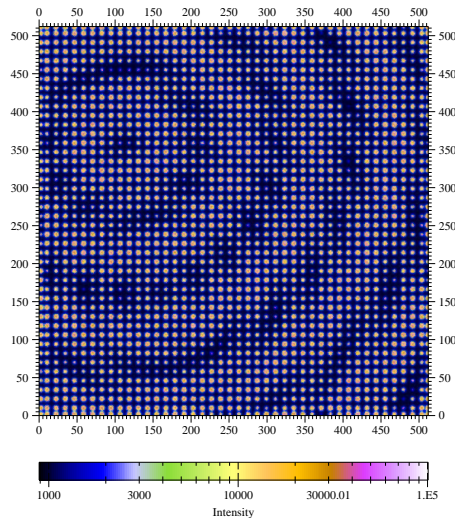


- small details  $\Rightarrow$  expected resolution  $50\mu m$
- $\Delta \approx 0.01 > \sigma \Rightarrow$  counts  $\gg 10^4 \Rightarrow$  14-16 bits
- operate at high energy (80 keV) : high Z sensor needed (GaAs)

**MEDIPIX (CERN)** *Llopart, IEEE-TNS 2002*, **MPEC (Bonn)** *Lindner, NIM 2000*

## Structure collection (Protein crystallography)

Integrate quickly the maximum number of peaks.



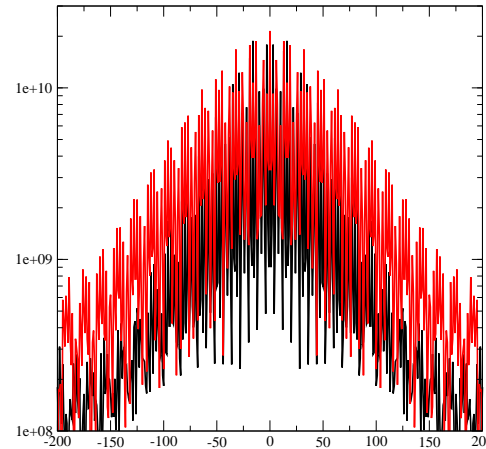
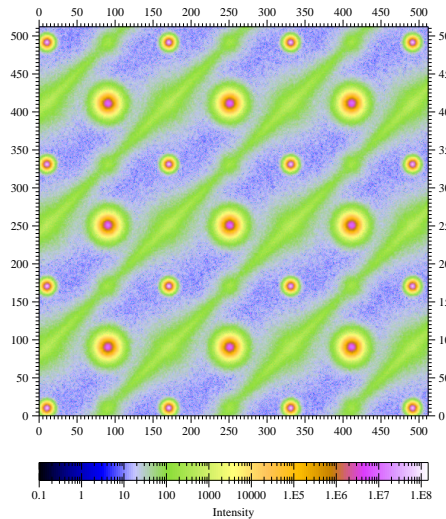
- counts range :  $\approx 10^3$  (diffuse) -  $\approx 10^6$   
 $\Rightarrow$  18-20 bits usefull
  - pixel size  $< \approx$  beam spot size  $\approx 100\mu m$
  - energy range : 10 - 25 keV
- 
- integration (5 pixels) over background  $\Rightarrow$  at less 25 pixels/peak
  - very big surface : a few  $10^6$  pixels required
  - detector motion are restricted :  $2\theta_{center} < \approx 10^\circ$

**PILATUS (PSI)** *Brönninmann, JSR 2002*

## Material Science or Solid state physics

Exploration of reciprocal space, profile shape, diffuse scattering...

The Fourier transform of the image is widely spread.



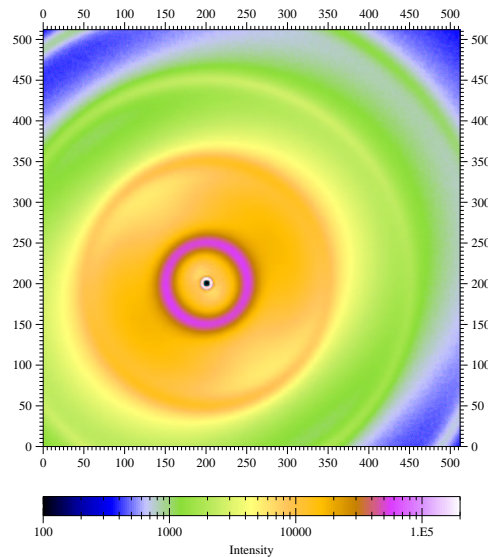
- 5 keV - 25 keV
  - 1 to  $10^9$  photons/s (BM2)
- ⇒ 32 bits usefull

- resolution optimized during experiment by adjusting detector position
- ⇒ pixel size  $\approx 200\mu m > \approx$  beam spot size
- detector has to be fixed on goniometer arm ⇒ mass, connection

**XPAD project (BM02ESRF, IN2P3, CNRS-CEA) Berar, JSR 2001**

## Small Angle Scattering

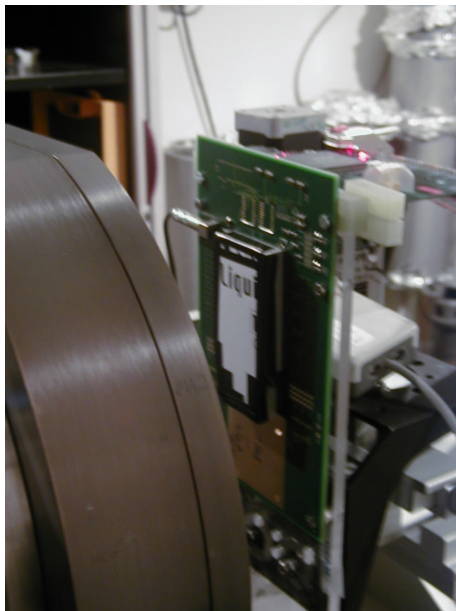
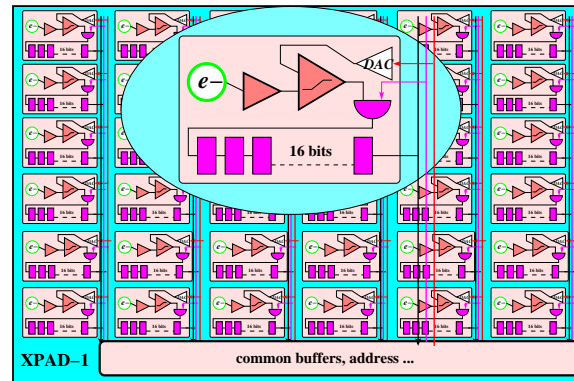
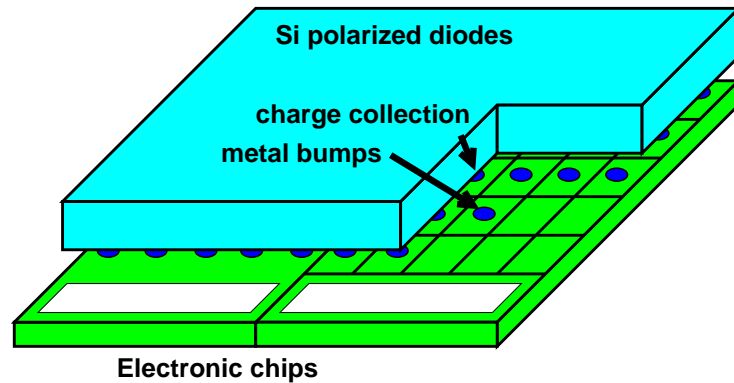
Measure simultaneously data at low and high Q.



- 10 keV - 25 keV
  - $10^{-2}$  to  $10^8$  photons/s
- ⇒ 32 bits usefull
- small pixels needed around the beam stop

- Pixel size  $\approx 200\mu m > \approx$  beam spot size
- Real time acquisition with a frame time  $\approx 1ms$  and dead time  $< 1ms$
- The requirements are very similar to the previous ones and are a target in the XPAD project.

## Scheme of pixel detectors



Whole detector consists in :

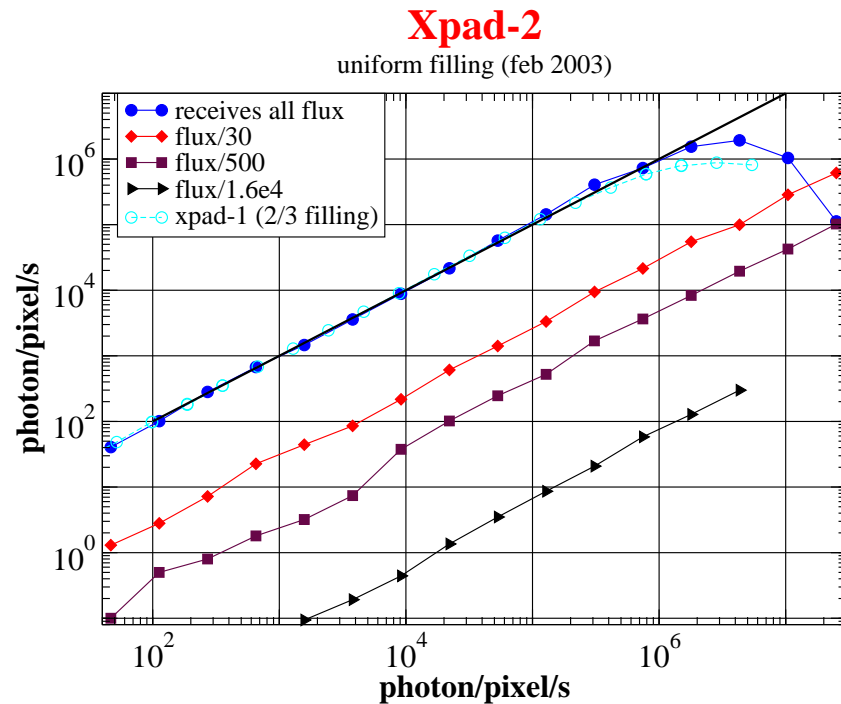
- xpad detector modules
- electronics cards (back plugged).

A 6000 pixel prototype including electronic card at BM2 saxs station.

## XPAD detectors

	XPAD1	XPAD2	XPAD3
pixel size		330 x 330 $\mu m$	$\approx 150 \mu m$
xpad chips		24 x 25 pixels, AMS 0.8 $\mu m$ CMOS	IBM.25
counting depth		16 bits internal + 16 bits external (overflow)	
energy range		5 to 25 keV	
sensor	Si 300 $\mu m$ (Delphi)	Si 500 $\mu m$	
time constant	208 ns with detector	<i>to be measured</i>	
modules	5 * 2 chips	5 x 2 or 8 x 1 chips	
detector	1 module	up to 8 modules <i>expected</i>	2003
electronic connection	reduced parallel wires	back plugged ethernet	

## Counts detected in neighbouring pixels



Delphi detectors

Overall dead time  $0.21\mu s$

Xpad chip dead time  $< 0.10\mu s$ .

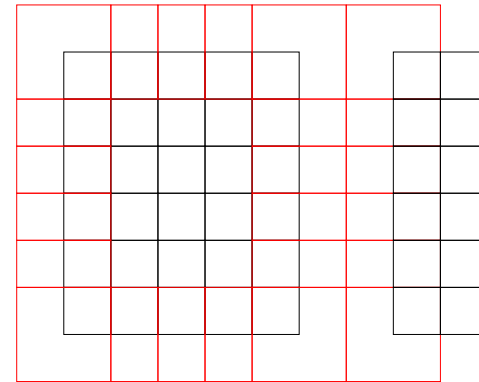
No blooming effect.

The new detectors improve efficiency at high energy,  
and will reduce the capacity allowing higher counting rates.

## Dead area

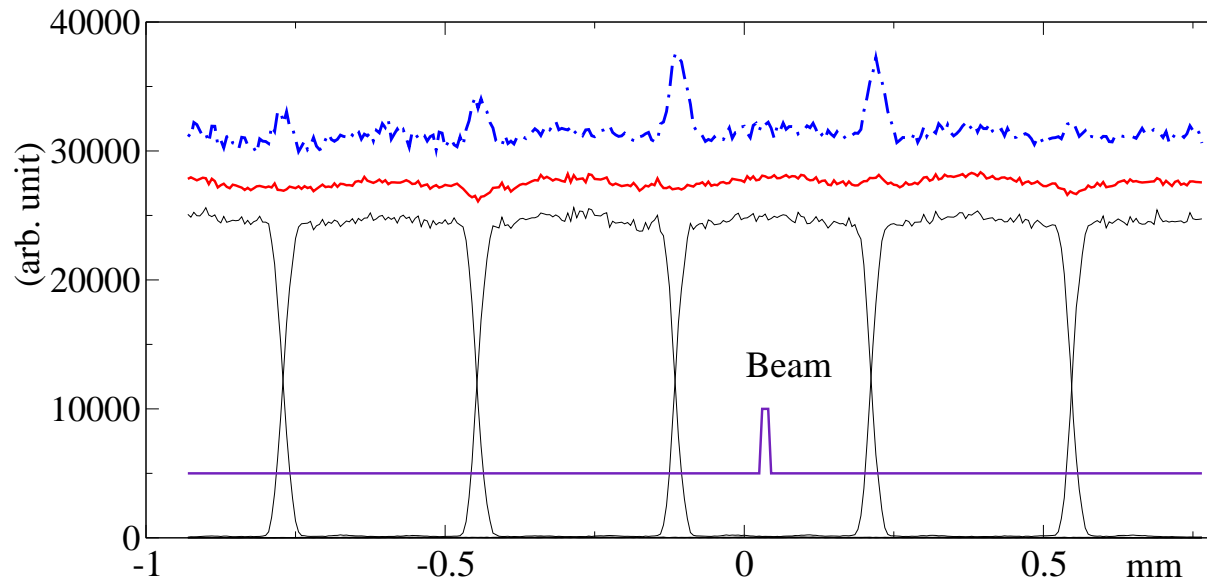
- **Within modules** No dead area

Pixels at the border of the chip are connected to pixel diode with an increased surface to avoid dead area associated with the packing of chips on the detector : mechanical border, guards ring...



- **Between modules**  $\approx 1$  pixel/column  $\Rightarrow 4\%$  XPAD2  $\rightarrow 1\%$  XPAD3

## Charge sharing



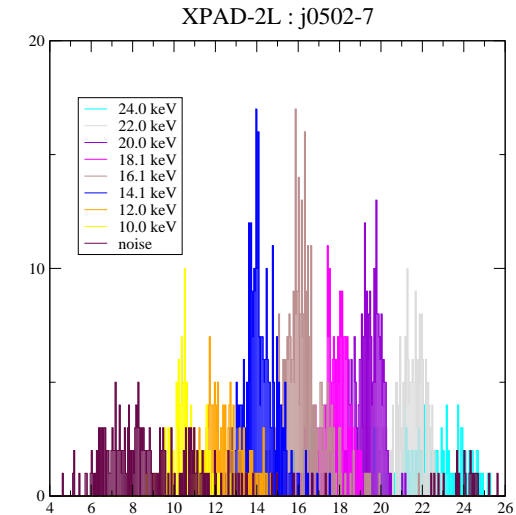
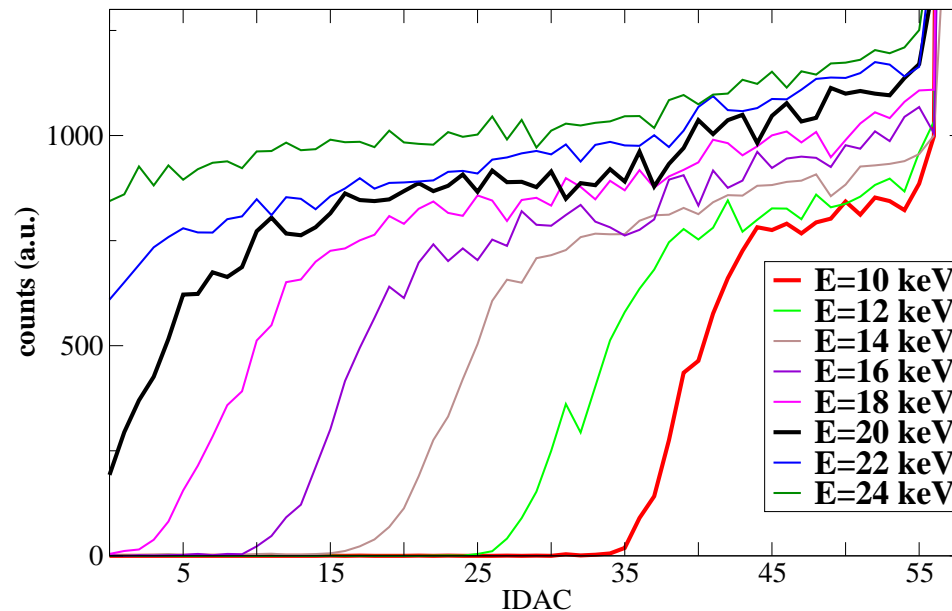
The adjustment of the threshold levels allows to obtain a flat response.

The charge sharing between neighbouring pixel is near  $60 \mu m$ .

This effect is a **physical limitation of pixel size**  
associated with absorption process.

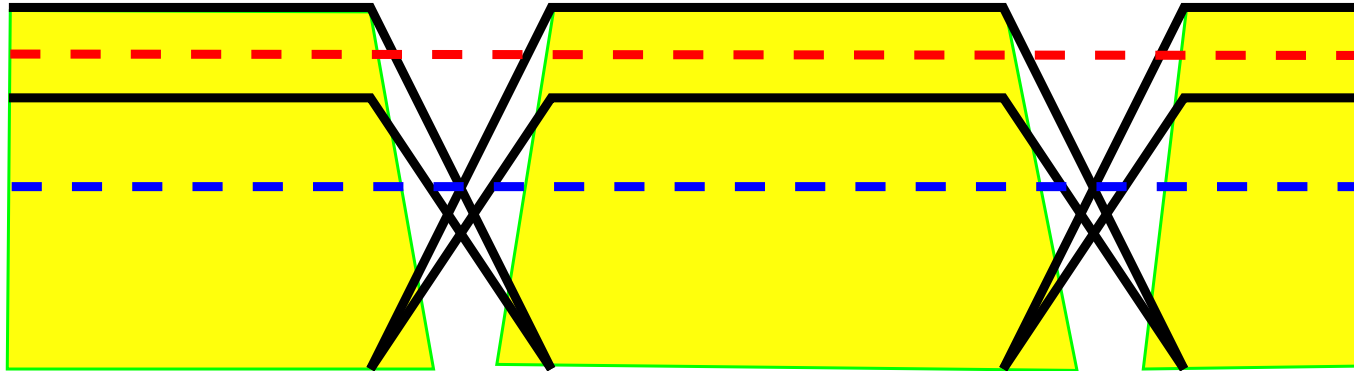
There is no significative influence of the bias field in the diode.

## Energy resolution



- Noise of the whole detection system :  $110 e^- \approx 400\text{eV}$ .
- Threshold edge : 6 bits register/pixel (4 bits/XPAD1) + 8 bits common
- Dispersion  $> 1000e^-$ , XPAD1  $\Rightarrow 300 e^-$ , XPAD2L  $\Rightarrow 60e^-$ , XPAD2C
- Due to dispersion tails  $\Rightarrow 15$  unadjustable pixels ( $< 3\%$ , XPAD2L).

## Energy resolution versus flat pixel detectors



- **Removing fluorescence**

Due to charge sharing on pixel borders rejecting  $E - 1keV$  create dead zones on this border with size  $d \approx 60\mu m$

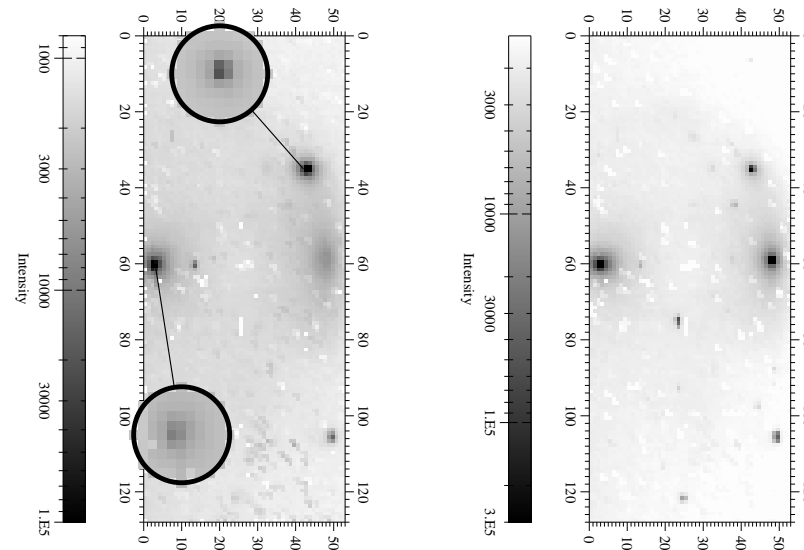
$\Rightarrow$  restricted to pixel size  $D > d$  : dead area  $\propto 2d/D$

- **Removing harmonics** needs a energy window with upper edge

More complicated :  $2E$  photons in the border zone are counted as  $E$  photons

Ratio reduced only by  $\propto d/D \Rightarrow$  **optics are more efficient!**

## Diffuse scattering by a quasicrystal



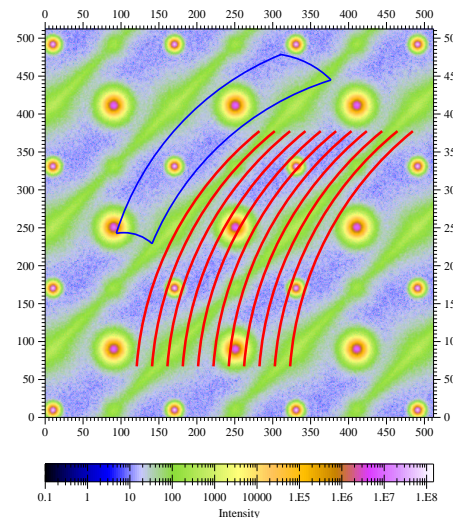
$\omega$  fixed image and  $\omega$  integration on  $0.1^\circ$  image revealing diffuse scattering and Bragg peaks.

On integrating image, the highest peak is near counter saturation rate as it cross the Ewald sphere within a few part of the exposure!

*Similar image can be obtained using CCD : uses attenuator for beam intensity and collects near 1000 images to be summed*

## From detector to Reciprocal space intensities

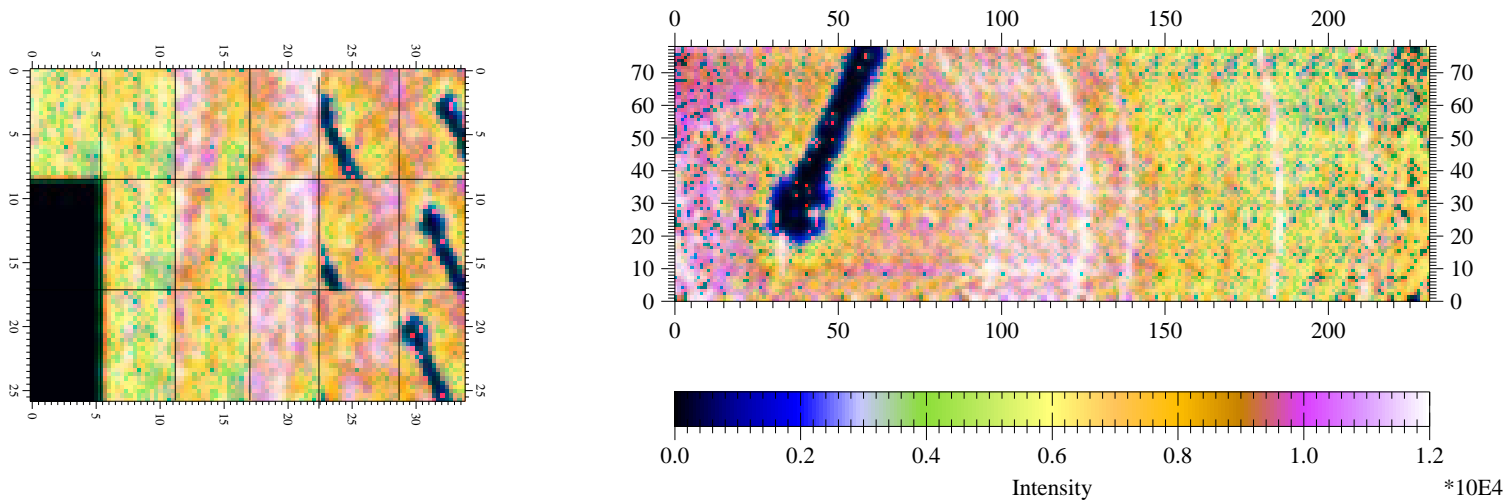
Due to the curvature of the Ewald sphere, a detector does not appear as a line ( $\omega$  fixed) or a simple shape ( $\omega$  integration) on simulated image but looks like elliptic figures.



The mapping of reciprocal space can not be done using single exposure and data reconstruction using 100's images is needed.

## Modules : a short term opportunity

Modules can be used for various application, using them instead of slits and scintillator, powder pattern can be collected in an efficient way.



Due to the dynamical range and their wide collection surface, **modules** are the best available detectors for data collection needing a very good signal to noise as in fluorescence measurement :  $\approx 10^4$  counting chains / modules.