

# PIXEL DETECTOR for X-RAY experiments

---

## **PIXEL DETECTOR for X-Rays Experiments**

Jean-Claude CLEMENS  
Centre de Physique des Particules de Marseille

# PIXEL DETECTOR for X-RAY experiments

## SUMMARY

---

- **A CRISTALLOGRAPHY EXPERIMENT**

- Set-up
- Detectors in use and limitations

- **THE D2AM/ESRF PIXEL PROJECT**

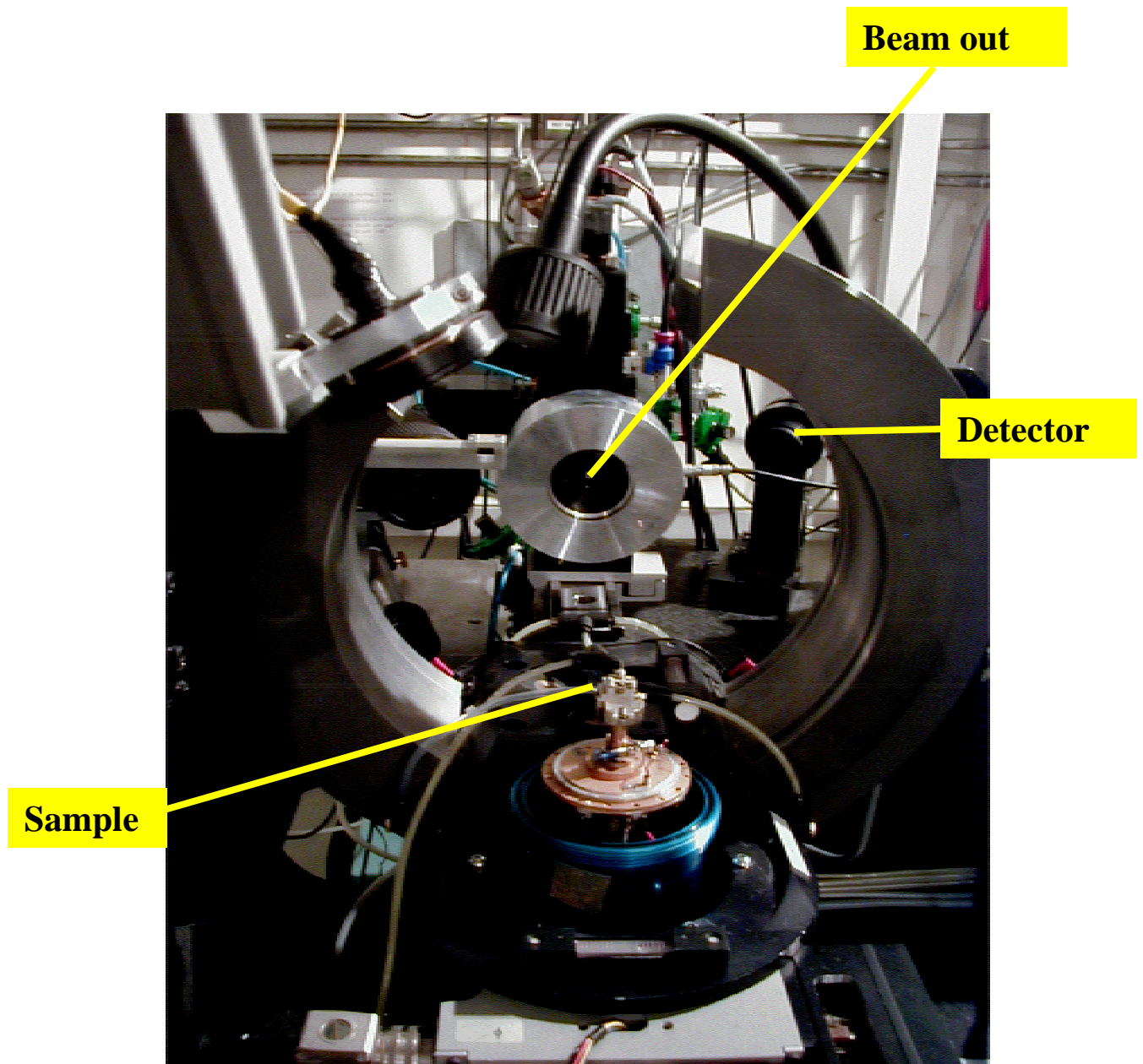
- Main goals for a new detector
- The XPAD chip
- From prototype to final design
- Modules and staves
- Read-out scheme

- **CONCLUSIONS**

# PIXEL DETECTOR for X-RAY experiments

## EXPERIMENTAL SET-UP

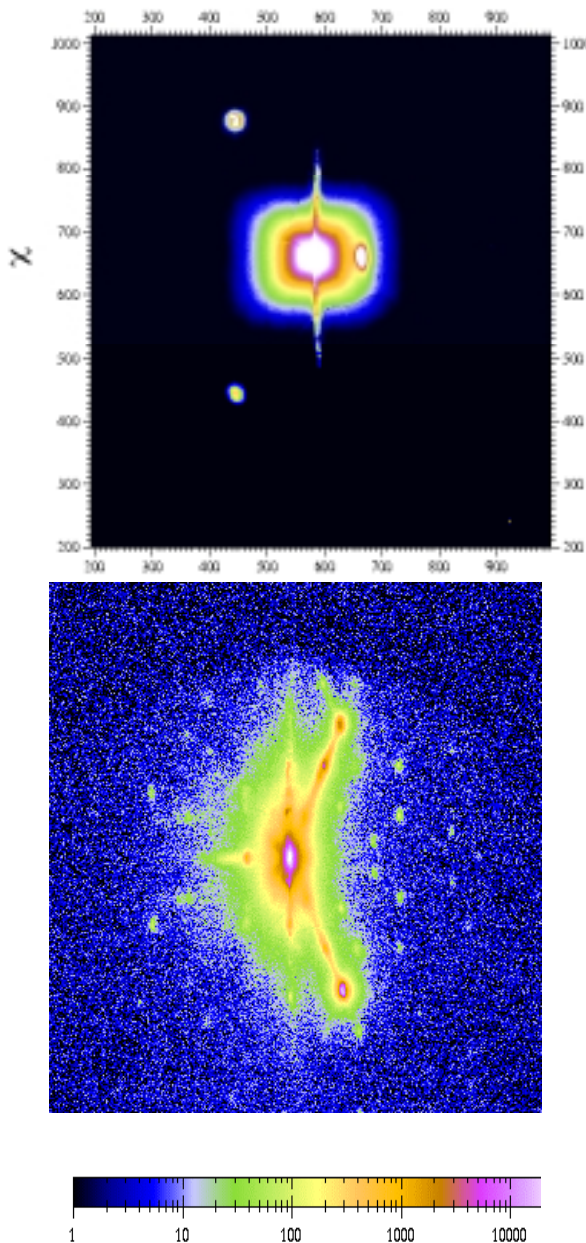
---



Courtesy of J.F. Berar/ESRF

# PIXEL DETECTOR for X-RAY experiments

## CCD DETECTORS



Courtesy of J.F. Berar/ESRF

### Detectors currently in use :

- **Direct illumination CCD**

- High number of charge for 1 X photon > Low dynamic range (100 ph/pixel)
- Small pixels (20 $\mu$ ) / to be compared to the source size (200\*200  $\mu$ m)

- **Phosphor + optical demagnifier+CCD**

- Low statistical accuracy ( due to the 4 transformations)

$$\nu_X \rightarrow W \rightarrow OF \rightarrow \text{charges}$$

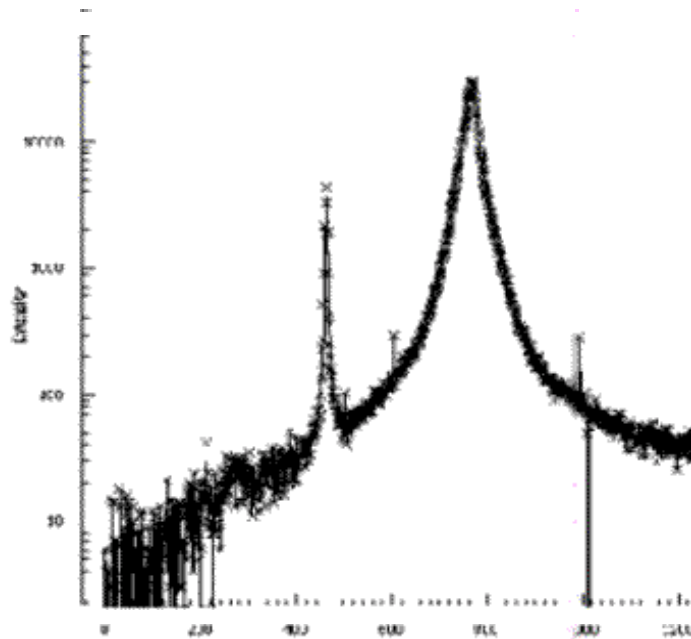
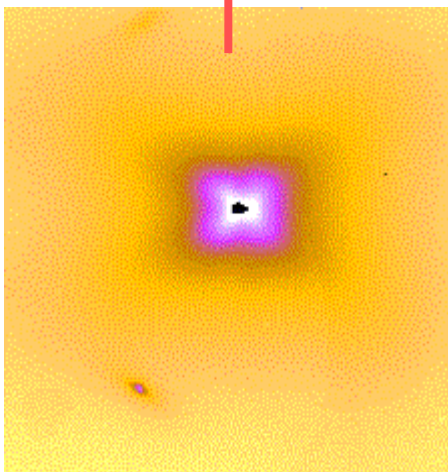
- **In both cases :**

- **Dynamic range not sufficient**  
(~14 bits / satellite peaks could be 1/1000 of peak intensity but well above background)
- **Residual error on ZERO level**  
(see next slide)

# PIXEL DETECTOR for X-RAY experiments

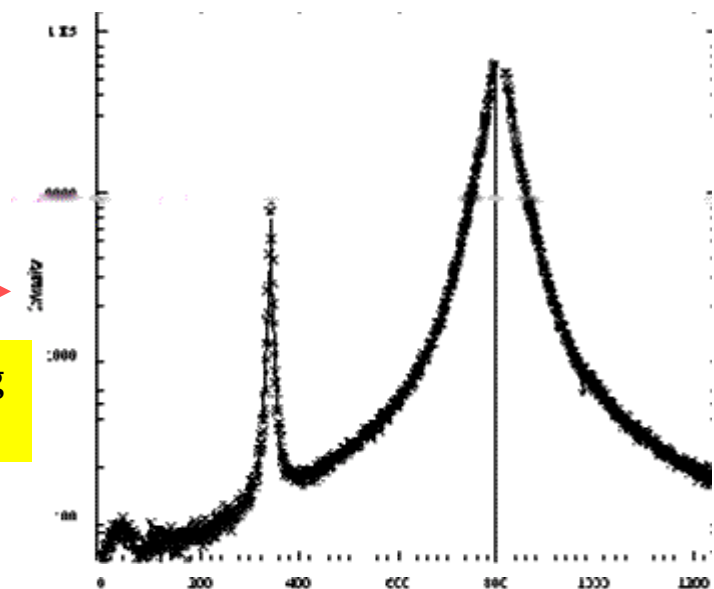
LIMITATIONS ...

Standard acquisition



Courtesy of J.F. Berar/ESRF

Bragg line masking  
(Pb screen)



# PIXEL DETECTOR for X-RAY experiments

The D2AM/ESRF project

---

JF. Berar(bc), L. Blanquart(a), P.Breugnon(a),  
B. Caillot(c), JC.Clemens(a), L. Crest(a),  
P. Delpierre(a), C. Mouget(c), C.Trouilleau(a),  
I.Valin(a)

(a) Centre de Physique des particules de Marseille,  
163 AV. de Luminy, Case 907, Fr-13288 Marseille Cedex 9,  
France

(b) CRG D2AM - ESRF, BP 220, 38043 Grenoble Cedex, France

(c) CNRS Cristallographie, BP 166, 38042 Grenoble Cedex 9, France

# PIXEL DETECTOR for X-RAY experiments

## MAIN GOALS ..

---

### MAIN GOALS OF A PIXEL DETECTOR FOR CRISTALLOGRAPHY

- **X-RAY ENERGY** : 5 to 25 keV

*300  $\mu\text{m}$  thick silicon would be acceptable. ( 100%  $>\mathcal{E}$  > 13 %)*

*Low threshold will be a challenge( 5 keV  $\longrightarrow$  1300 e-)*

- **PIXEL SIZE** : must agree with ESRF source image  $\sim 200 \mu\text{m} \times 200 \mu\text{m}$

*330  $\mu\text{m} \times 330 \mu\text{m}$  pixels for prototype*

- **COUNTING RATE** :

*As high as  $10^7$  photons/second/pixel*

- **SENSITIVITY / BACKGROUND** :

*In diffuse scattering, satellites peak counting could be less than 1 ph/s/pixel*

- **REAL TIME STUDIES** : Chemical studies up to 1ms/frame with 100 frames capacity

- **MECHANIC** : Detector will be carried by a goniometer arm (  $\ll 10\text{kg}$ )

# PIXEL DETECTOR for X-RAY experiments

## THE XPAD CHIP

---

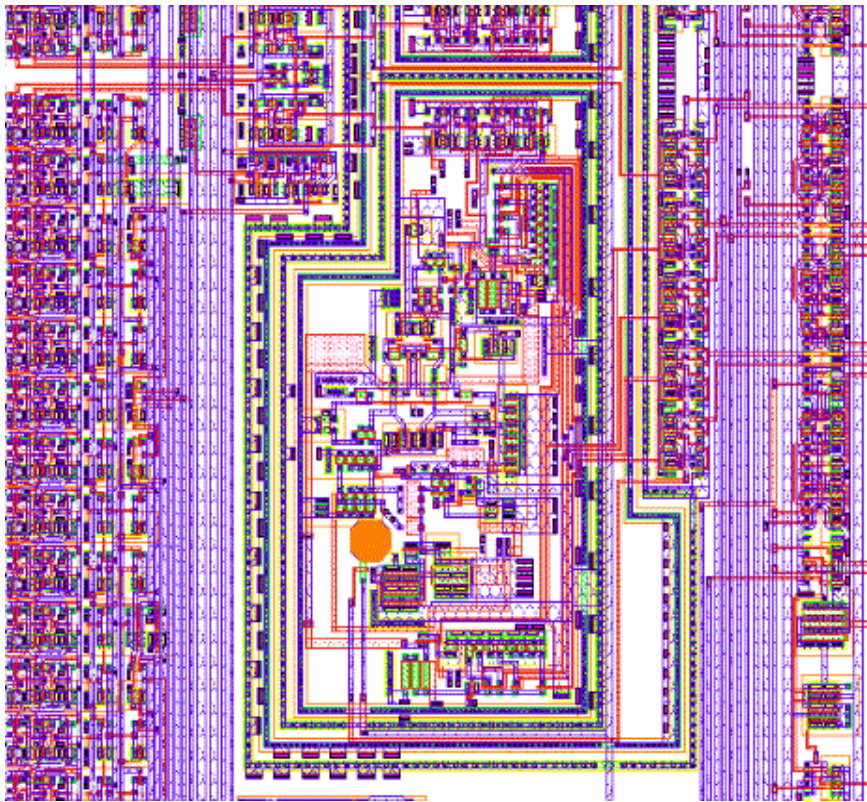
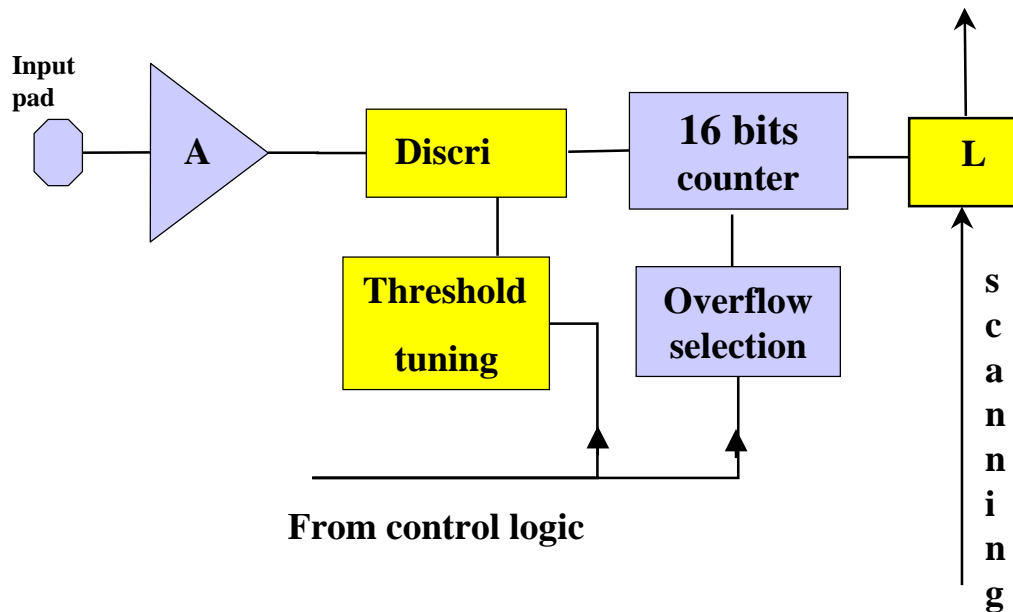
### The XPAD ( X-Ray Pixel with Adaptable Dynamics) chip :

- 25\*24 (330 $\mu$ m<sup>2</sup> pixels) matrix
- AMS 0.8  $\mu$  CMOS technology
- 2 stage differential amplifier with pz cancellation (*next slide*)
  - 1st stage with DC feedback
- Differential discriminator
  - 4 bits tunable threshold
  - designed for positive charges but working also with negative pulses  
(*suitable for CdTe detectors*)
- 16 bits counter/pixel
  - Selectable overflow
  - Read-out during data collection
  - 40 MHz read-out possible (simulated at 100 MHz)
- ATLAS F-Ends like Control Logic
- Power consumption
  - 80  $\mu$ W/pixel



# PIXEL DETECTOR for X-RAY experiments

## THE XPAD CHIP



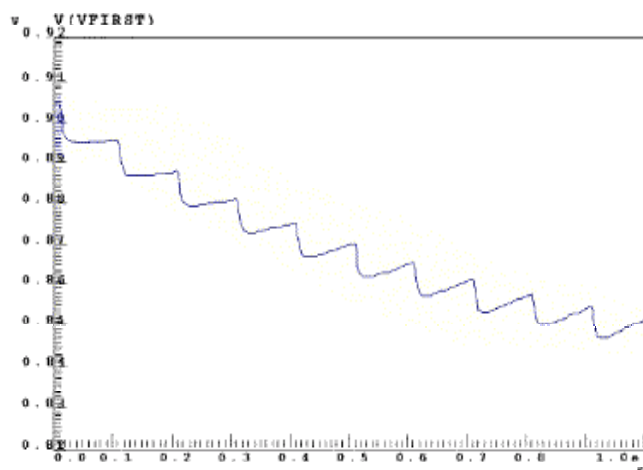
Foreseen scan clock  
33 MHz

Overflow scan  
duration :

18  $\mu$ s for 1 chip

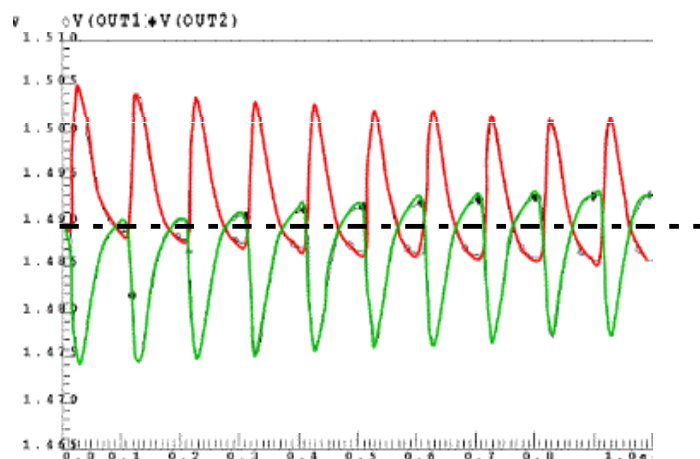
# PIXEL DETECTOR for X-RAY experiments

## THE XPAD CHIP



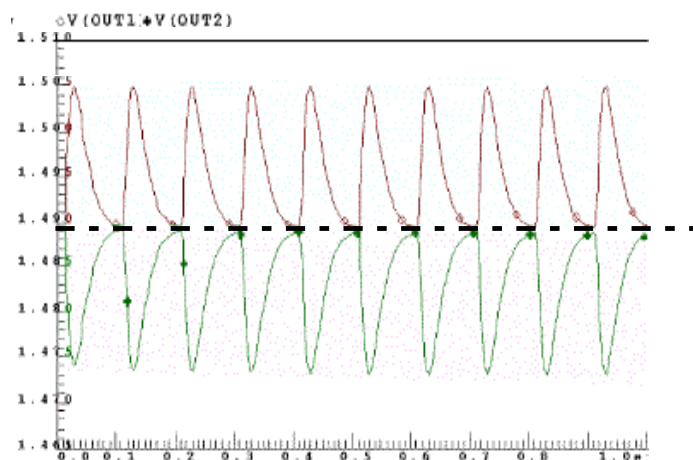
First stage output

$10^7$  imp/s



Second stage differential output :

•Without pole-zero cancellation



•With pz cancellation

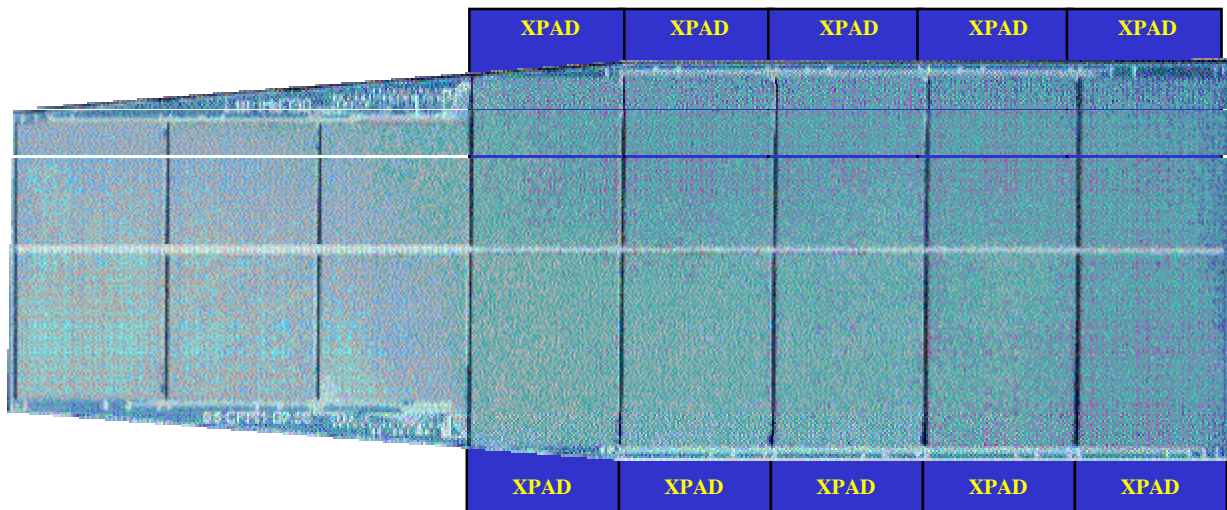
# PIXEL DETECTOR for X-RAY experiments

## DETECTOR PROTOYPES

---

### FROM PROTOTYPES TO FINAL DETECTOR :

- Prototype using old DELPHI detectors :



- 10 XPAD chips will be bump-bonded on 1 detector (TRONICS, 120  $\mu\text{m}$  Pb/lead)
- Cost effective solution but pad input capacitance high
- Active area : 41\*16 mm (small but to be compared with 50\*50 mm CCD)
- 10 of this prototypes expected in Sept. 2000

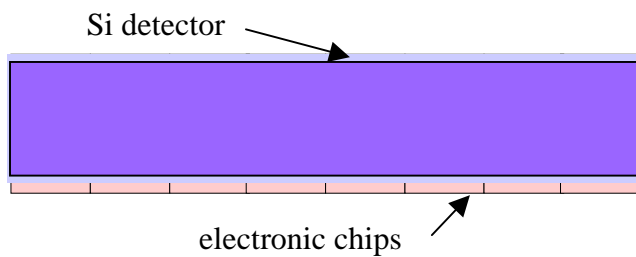
# PIXEL DETECTOR for X-RAY experiments

## DETECTOR DESIGN

---

### MODULE :

=> 8 chips of  $16 \times 8 \text{ mm}^2$  active area (*Note the unusual size*) on one  $64 \times 16 \text{ mm}^2$  Si detector



**Pixel size  $250 \times 250 \mu\text{m}$**

**$64 \times 32$  matrix**

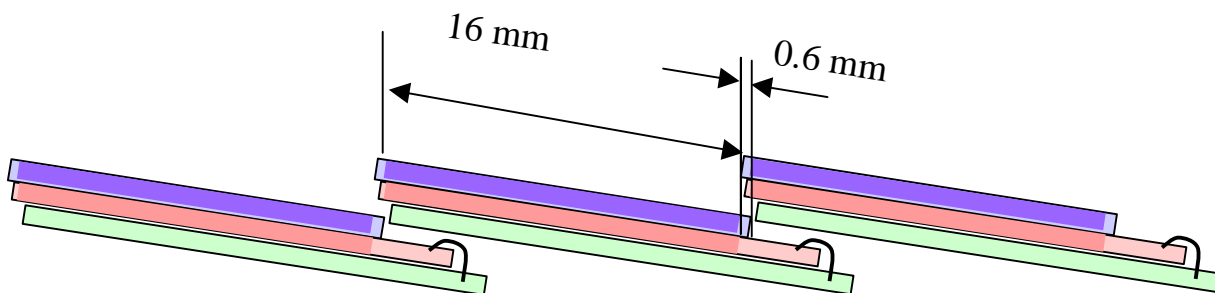
**2048 pixels/chip**

**16kpixels**

### SUPPORT :

=> 4 modules on an ceramic

**64kpixels**



Support's arrangement

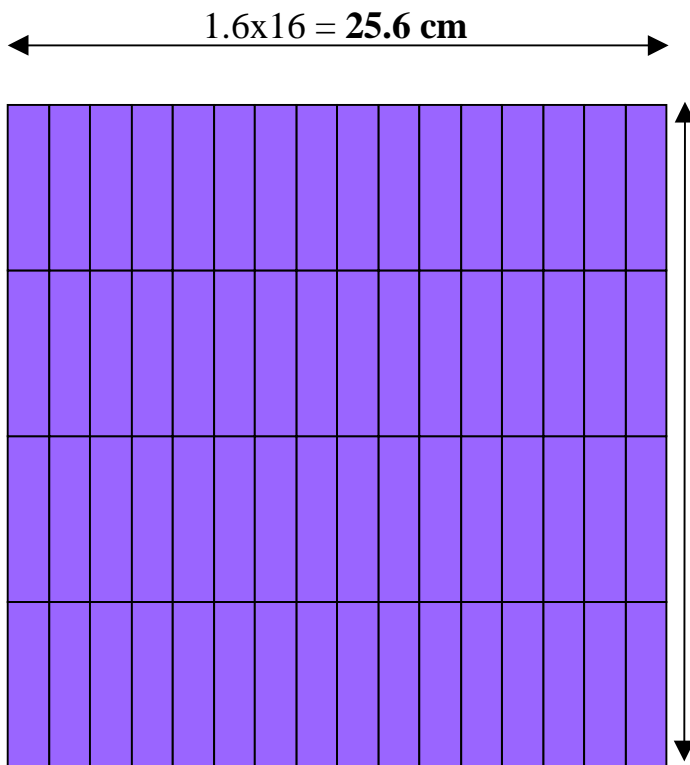
# PIXEL DETECTOR for X-RAY experiments

## DETECTOR DESIGN

---

### DETECTOR :

16 staves of 4 modules ( 512 chips)



### Dead area problem :

=> Overlap along the small dimension of the module :

$$\sim 0.6 \text{ mm} / 16 \text{ mm} = \mathbf{3.8 \%}$$

**dead area**

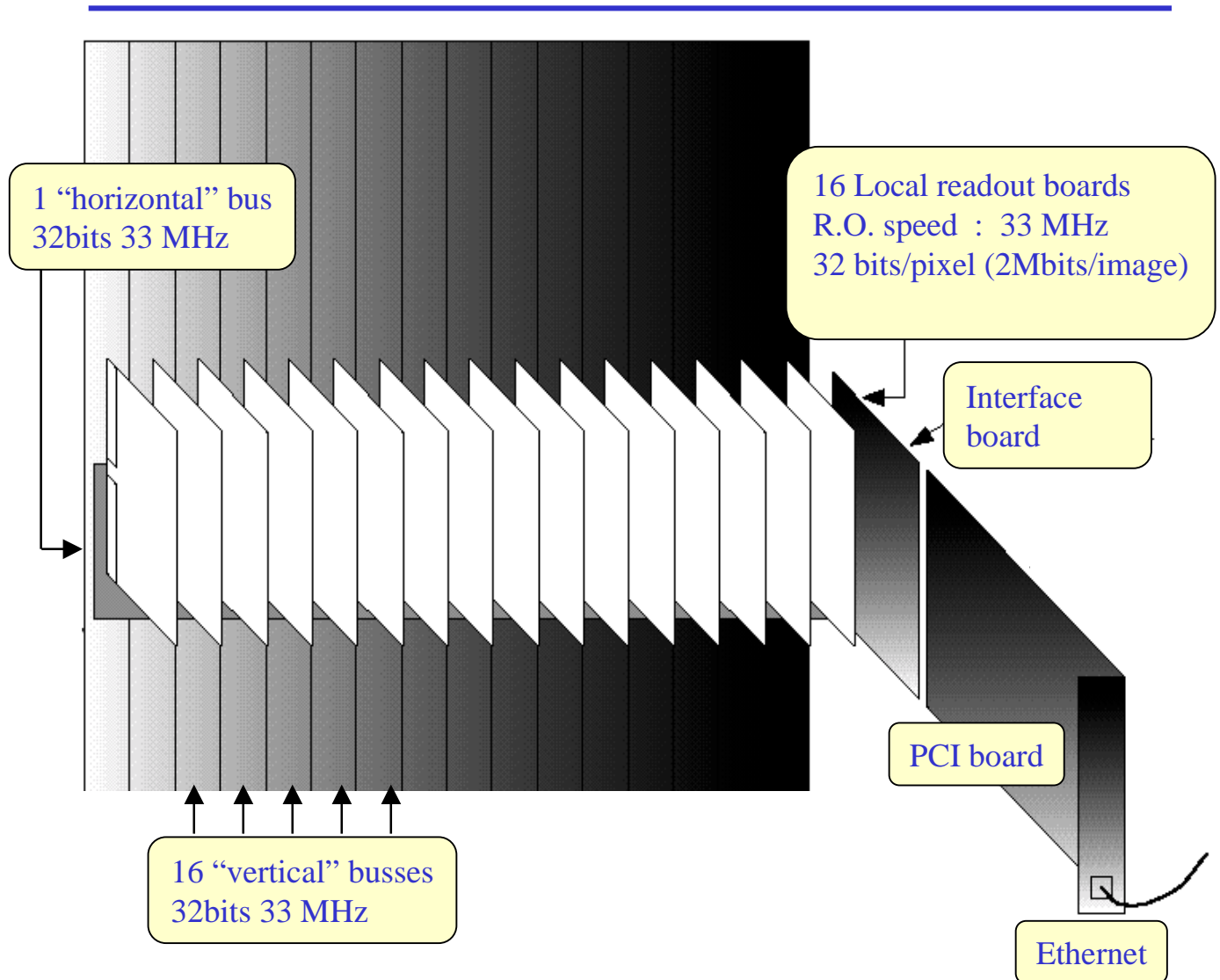
=> Overlap along the long dimension of the module :

$$\sim 6 \text{ mm} / 256 \text{ mm} = \mathbf{2.3 \%}$$

**No overlap in Z allows 4 modules in 1 ceramic  
(32 chips)**

# PIXEL DETECTOR for X-RAY experiments

## GLOBAL READ-OUT SCHEME



- **Data scan every 5 ms** ( 1 overflow every 6.4 ms at  $10^7$  ph/s  
 $1\text{ ms} < \text{Scan duration} + \text{data handling} < 4\text{ ms}$  )
- **Complete image recording after exposure : 3ms**
- **Local memory storage : 128 images**
- **Expected read-out via Ethernet : 3 to 30 images/s**



# PIXEL DETECTOR for X-RAY experiments

## CONCLUSIONS

---

- First results of XPAD (without detector) in the next month

- Hybridations foreseen in August 2000

*At this moment we will have an usable detector for cristallography experiments*

- Studies of this prototype in real conditions :

*Threshold, counting rate, radiation problems? ...*

- Few chips to be hybridized with CdTe detectors (and AsGa)

*Efficiency improvement ( at 30 keV , 100  $\mu$ m CdTe = 3 mm Si)*

- Electronic final design during next year