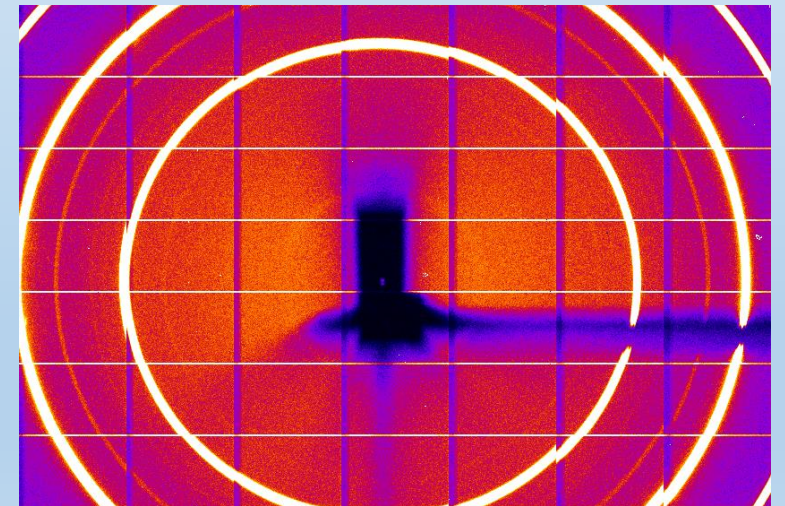




# ANF Octobre 2016

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ImXPAD



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297, Avenue du Mistral  
13600 La Ciotat, France

Tel. : +33 (0)4 42 82 40 91



# PLAN

- ImXPAD
- Un peu d'histoire
- Le pixel hybride
- Nos détecteurs
- Projets spéciaux
- Conclusion

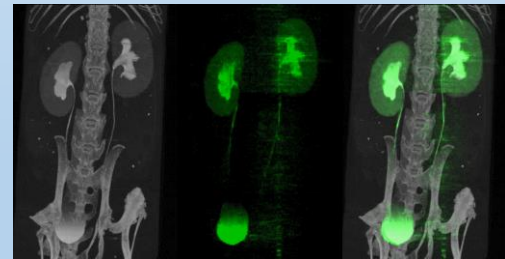
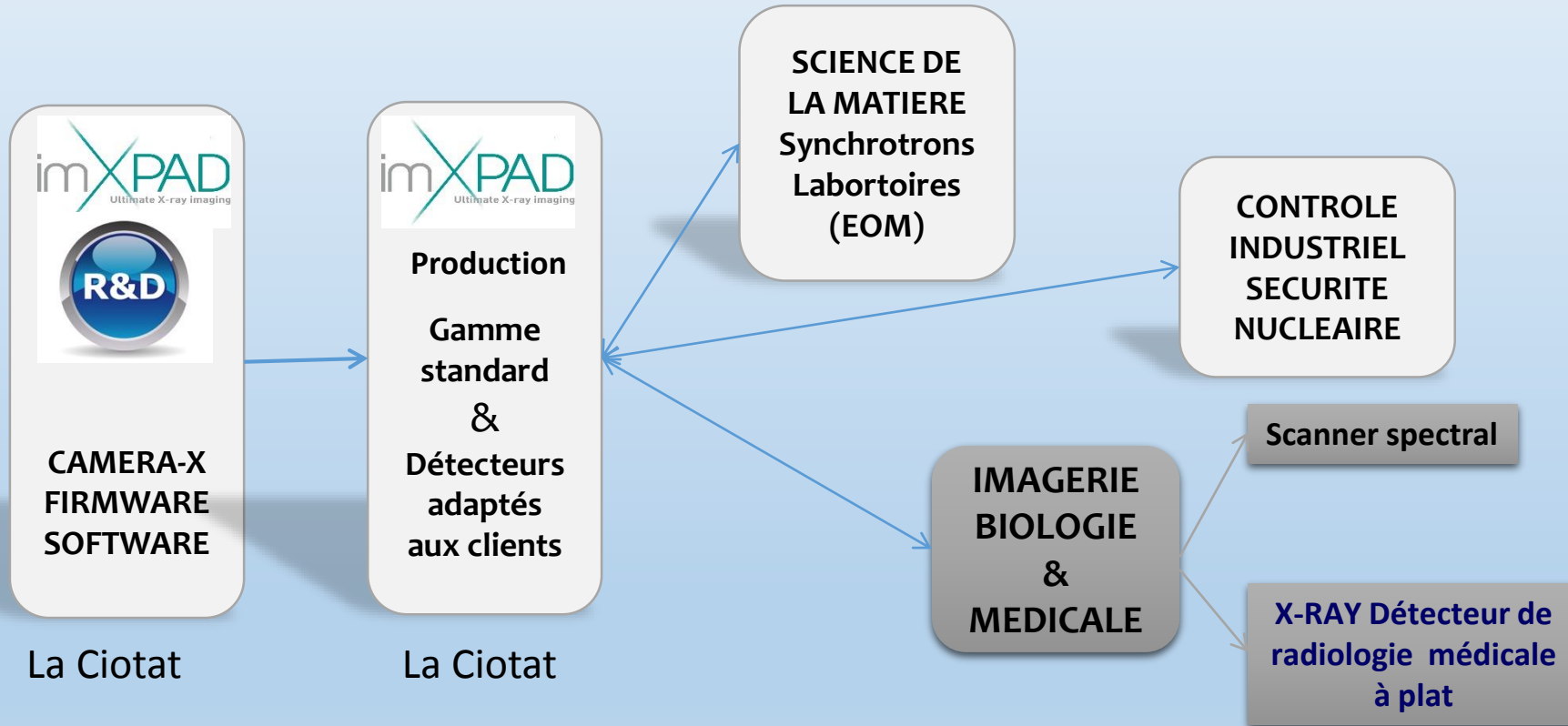
# imXPAD

Ultimate X-ray imaging

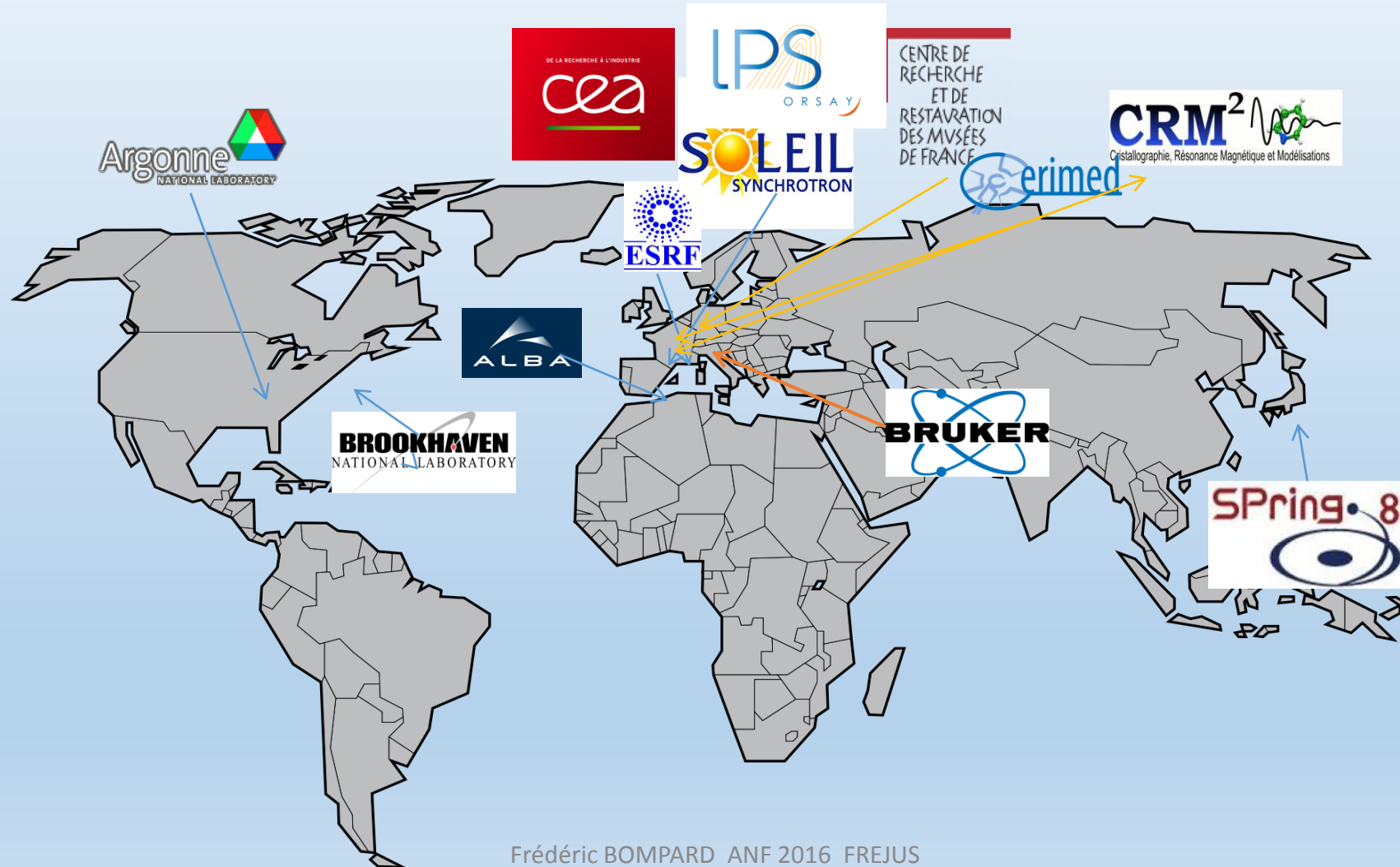


- Est une société Française basée à La Ciotat
- ImXPAD a été créé en 2010 afin de développer et commercialiser des détecteurs de rayon X à pixels hybrides
- Les détecteurs XPAD sont basés sur la technologie des pixels hybrides à comptage de photon.

# Les marchés ImXPAD



# imXPAD dans le monde

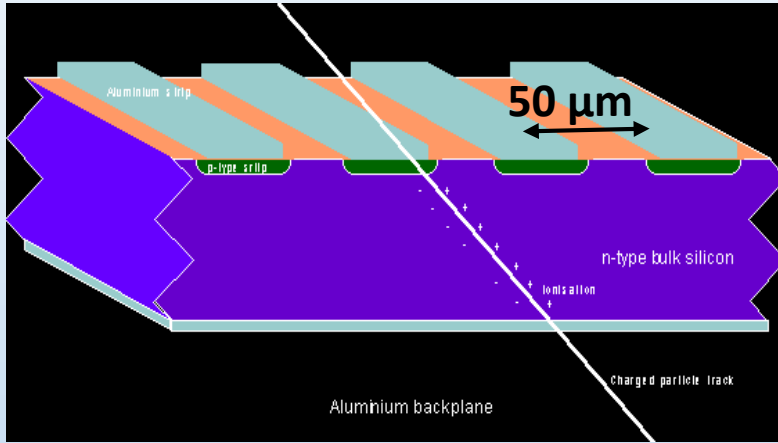




# Un peu d'histoire 😊

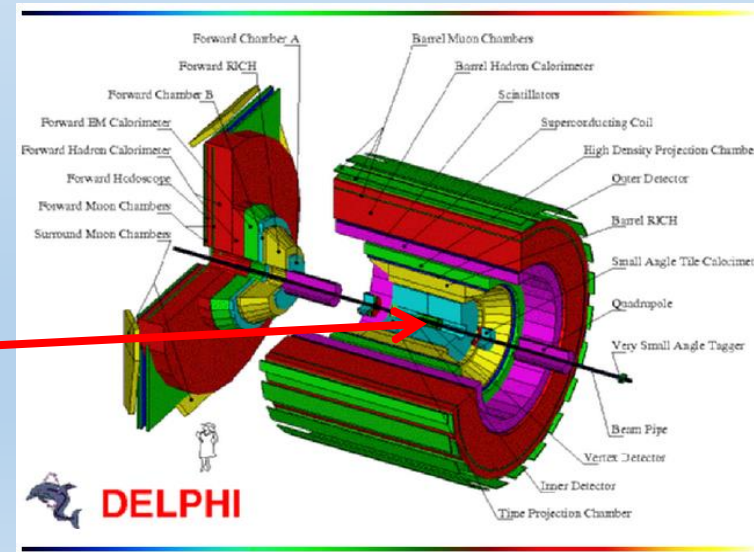
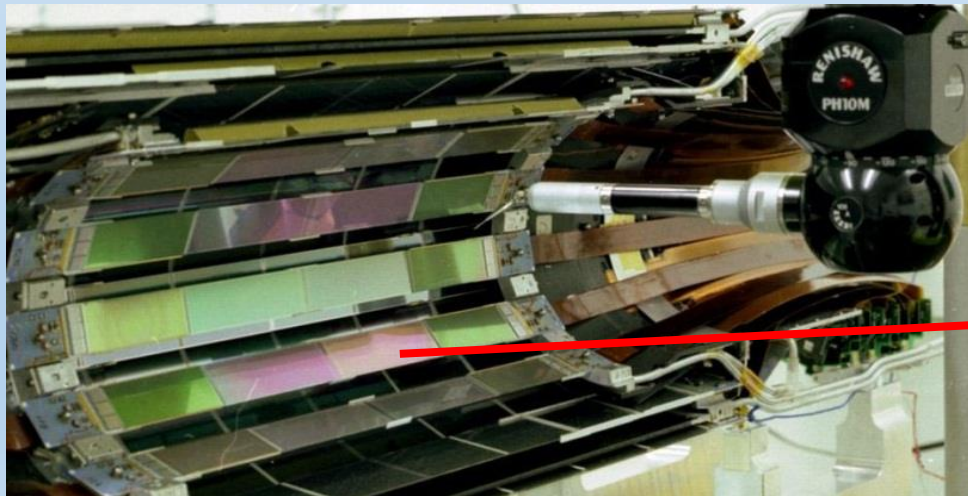
# Détecteur Strip silicium

A la fin des années 1980, il existait des détecteurs strip sensor silicium



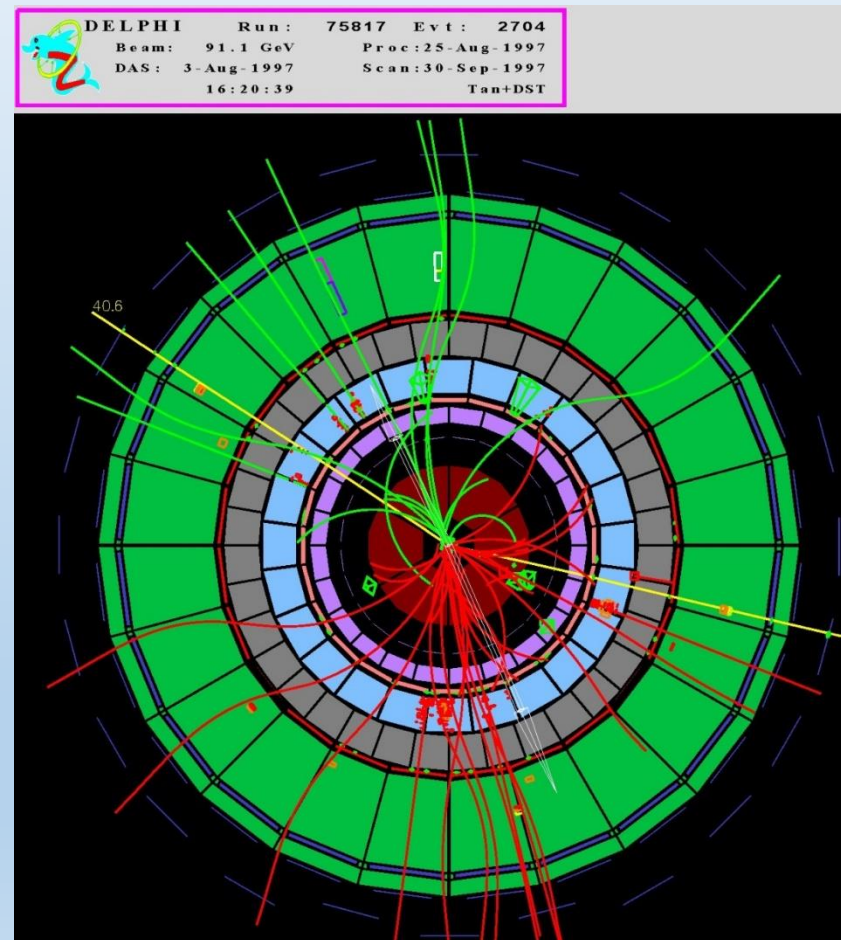
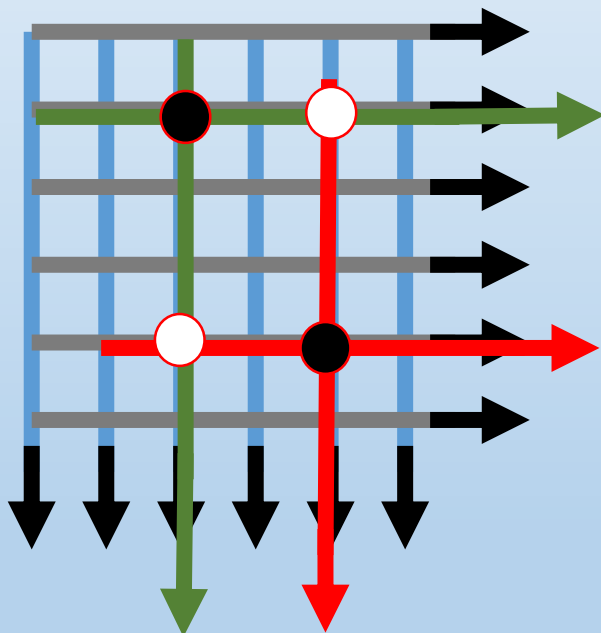
Sensor silicium déplété détecté:

- Particules => électrons et trous
- Photons => charge



# Détecteur Strip silicium

Mais lorsque plusieurs évènements arrivent sur le détecteur à différents angles, Il y avait des ambiguïtés ☹️







# Détecteur pixels hybride

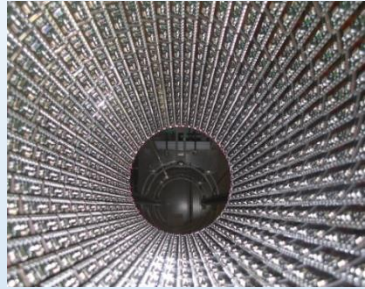
Supprimer les ambiguïtés

Pixéliser le détecteur, avec chaque pixel capable d'indiquer s'il a été touché ou non

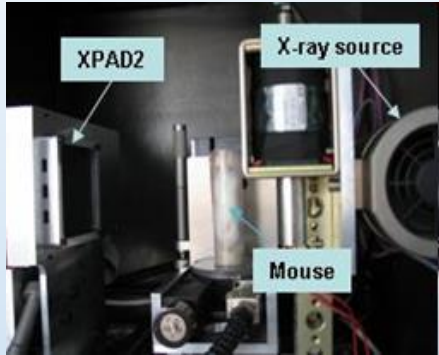
Détecteur à pixel hybride est  
née

# Research & Development on Hybrid Pixels at CPPM

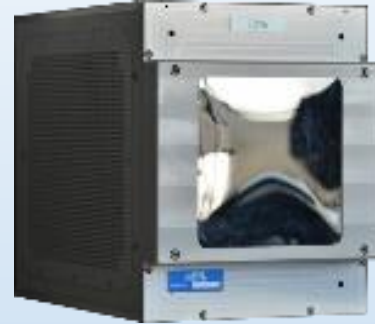
Start of hybrid pixel project



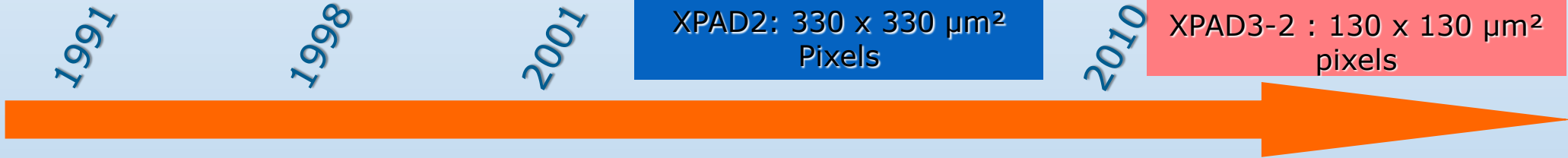
ATLAS: 50 x 400  $\mu\text{m}^2$  pixels



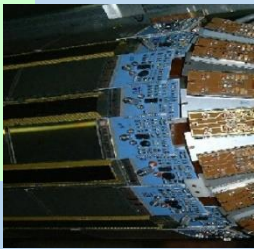
XPAD2: 330 x 330  $\mu\text{m}^2$  Pixels



XPAD3-2 : 130 x 130  $\mu\text{m}^2$  pixels



DELPHI:  
World premiere



XPAD1: first hybrid pixel detector for X-ray applications



XPAD3 : 130 x 130  $\mu\text{m}^2$  pixels

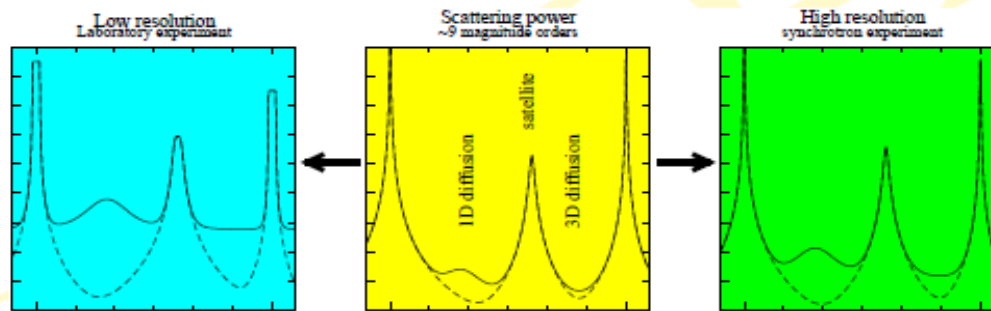


# Pourquoi utiliser les pixels hybrides en crystallography

First need => Large dynamic range

## De nouveaux détecteurs, pourquoi ?

intensité intégrée maximale	Bragg $N F^2$ $N^2 F^2$	Satellites $N_d N_c f^2$ $N_d N_c^2 f^2$	diffus 1D $N = N_d N_c$ $N_d N_c^{5/3}$	diffus 3D $N_d N_c$
-----------------------------------	-------------------------------	--	---	------------------------



☞ La résolution accroît la dynamique requise.

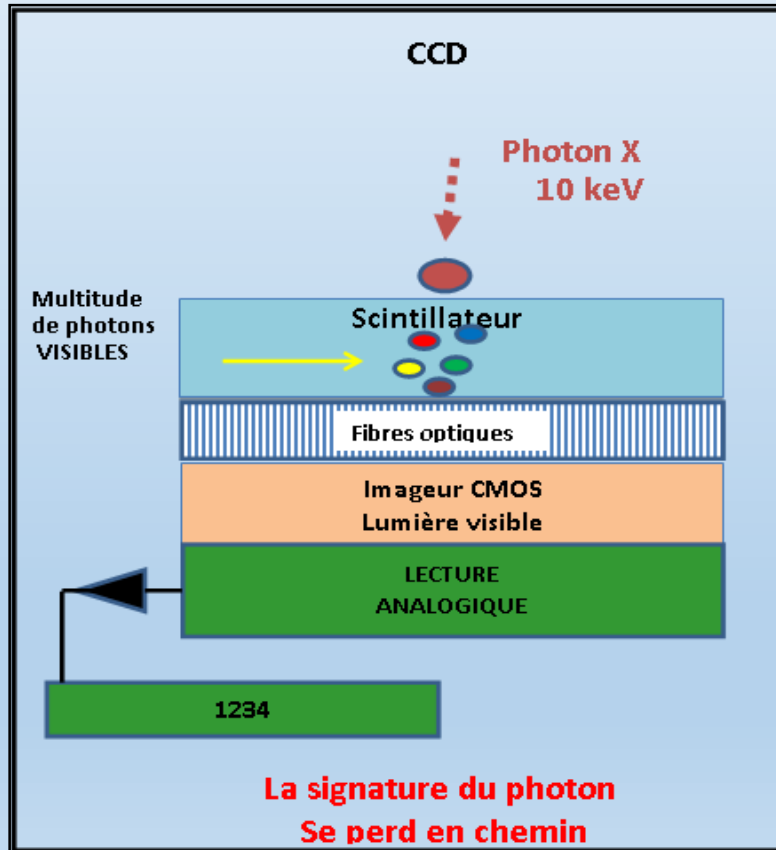
☞  $I_{Bragg} > 10^9 \nu/s$  (BM2@ESRF) → saturation ou atténuation.

☞  $F \propto \sqrt{I} \rightarrow \sqrt{\text{dynamique}(I)}$ .

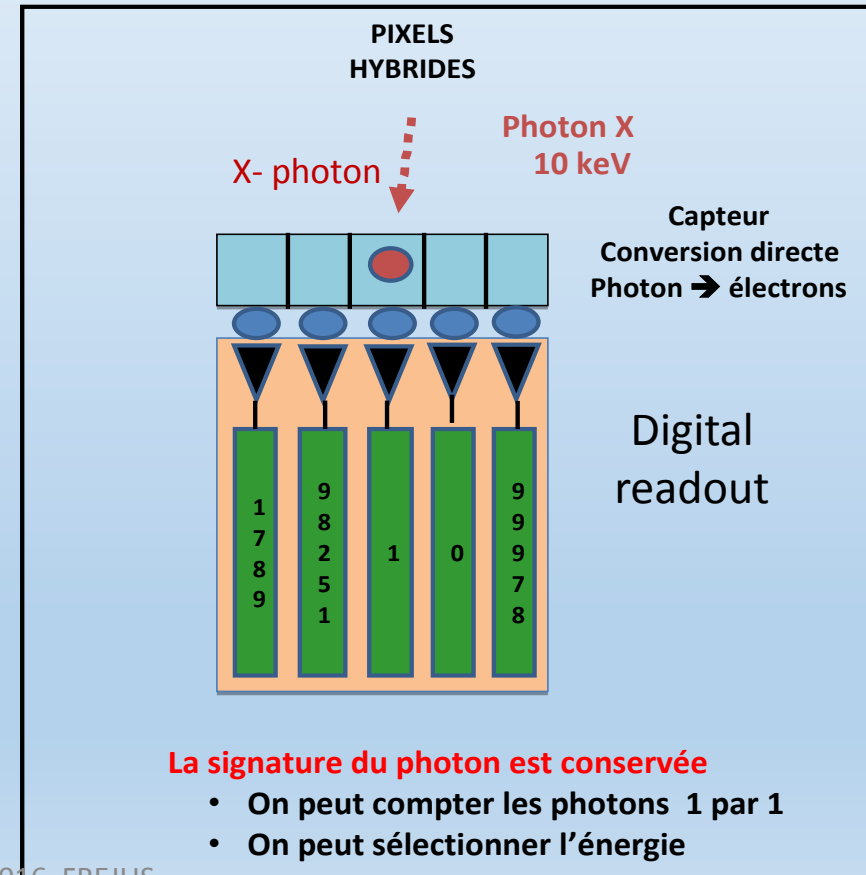
- High dynamic range
- No noise
- Time resolved experiment
- Fluorescence elimination (energy threshold)

# CCD vs Pixels

Les détecteurs CCD et CMOS convertissent les Rayon X en visible et cumulent le bruit et le signal



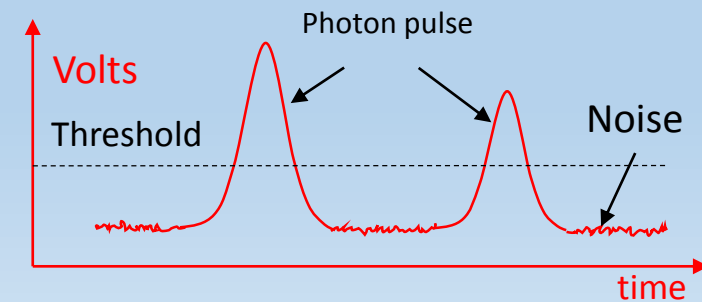
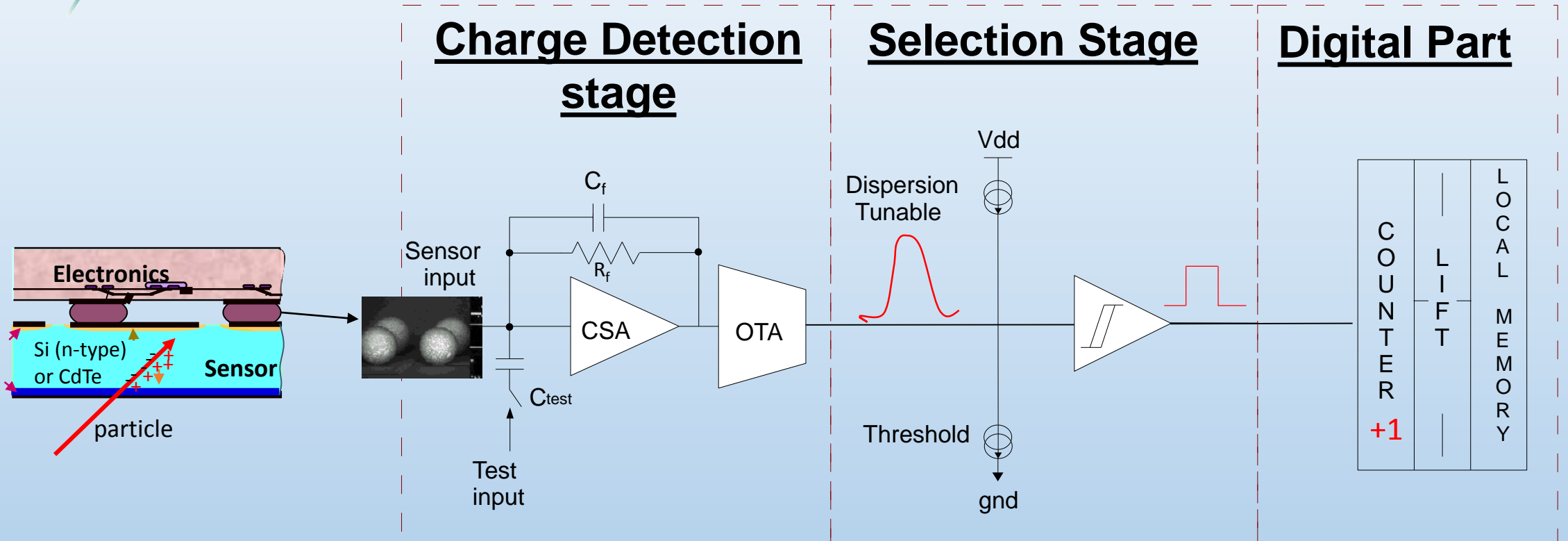
Les détecteurs pixels convertissent directement les rayons X et les numérisent dans les pixels



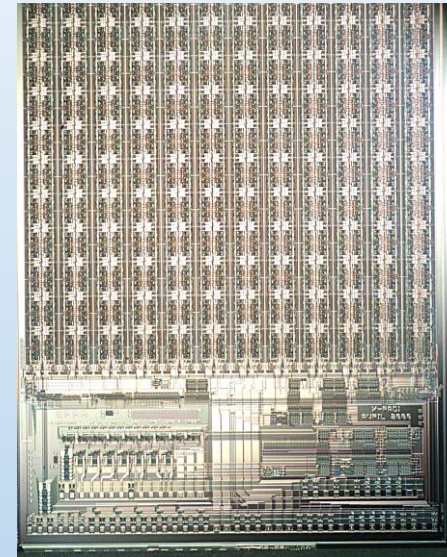
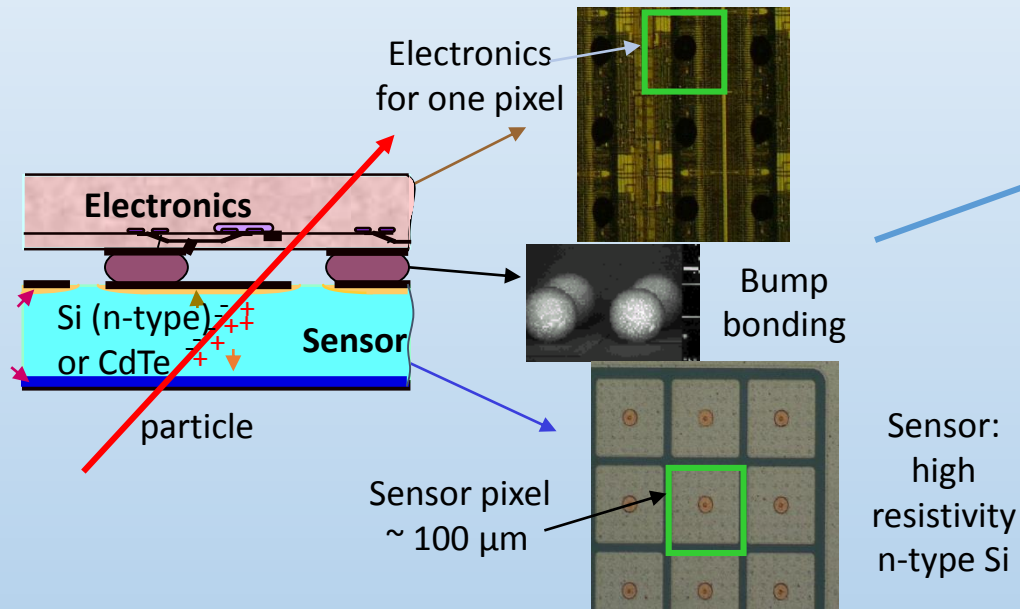


# Le pixel hybride

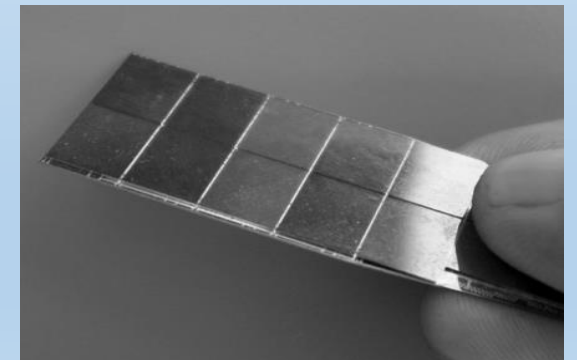
# Le pixel



# Grande surface

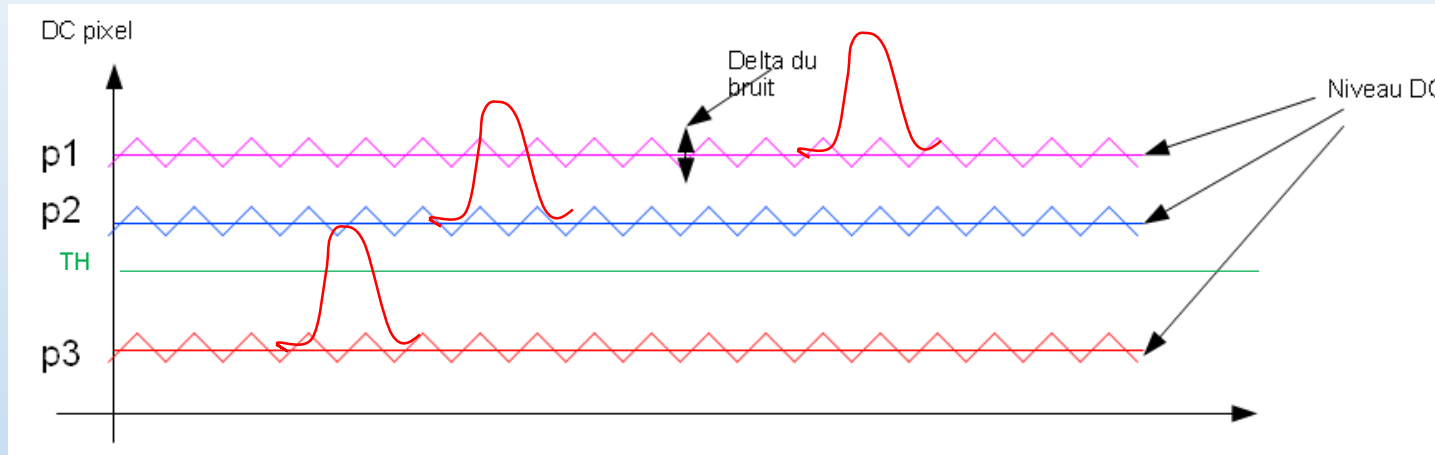


(now 10 million)  
small size  
to preserve yield

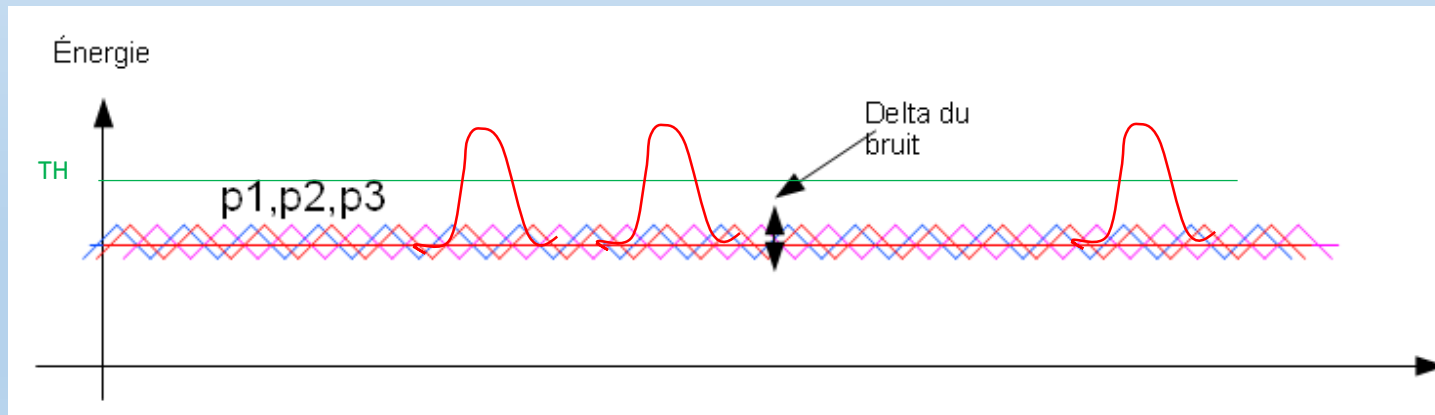


# La calibration

Matrice non calibrée



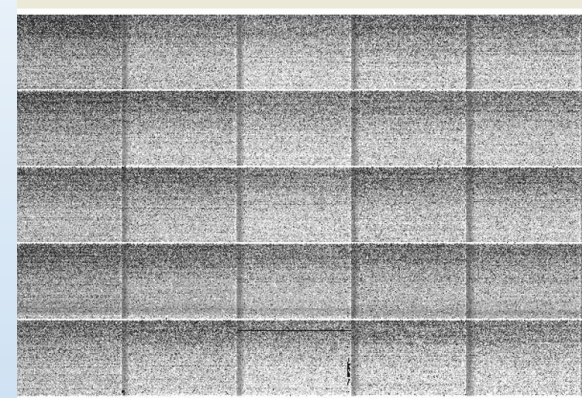
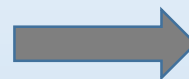
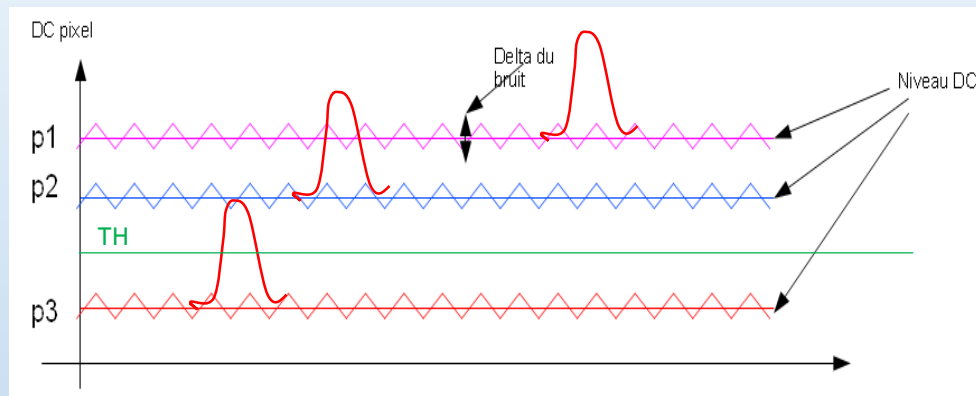
Matrice calibrée



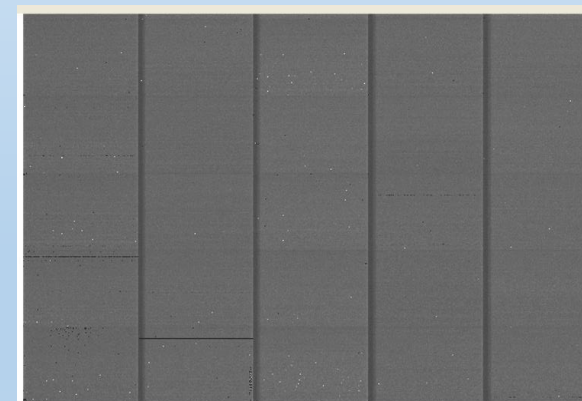
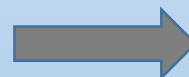
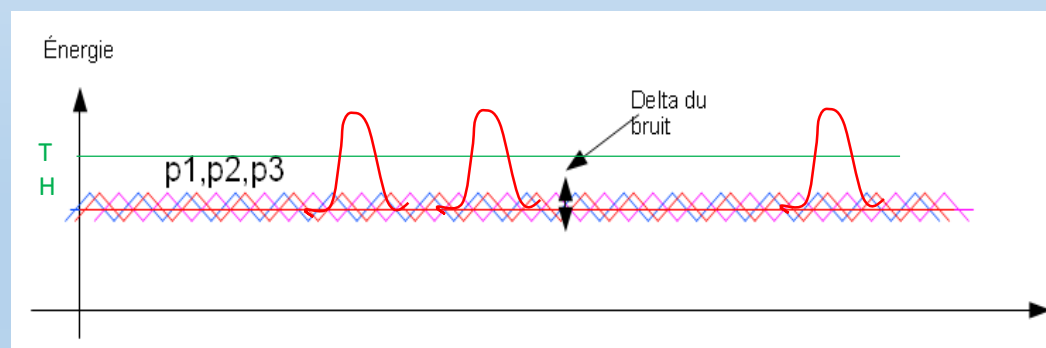


# La calibration

Matrice pas calibrée

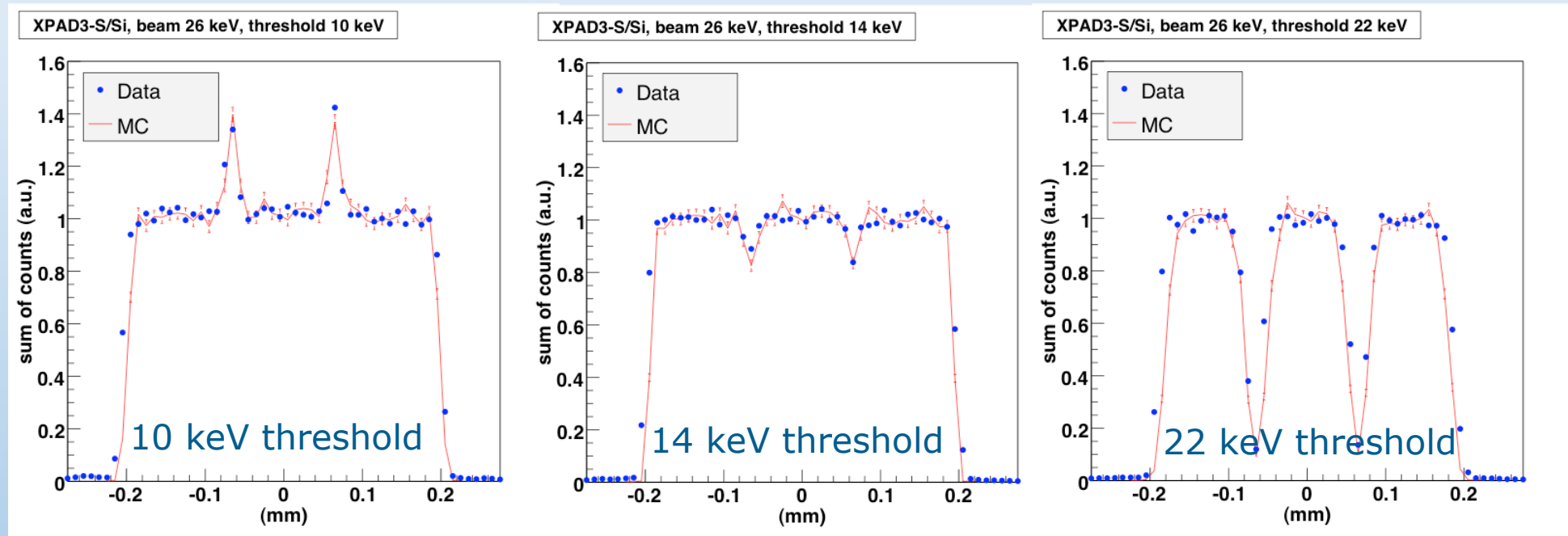


Matrice calibrée



# Study of charge sharing with XPAD3 Si and CdTe

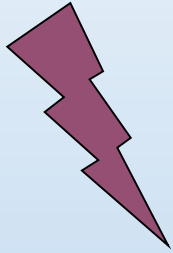
Beam of  $E_0 = 26$  keV



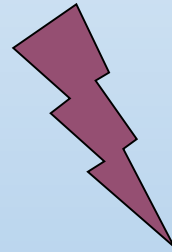
Cassol *et al.*, Nucl. Instrum. Meth. A **633** (2011) 111

## what we do not have with CCD's or CMOS pixels (APS)

- Photon counting:



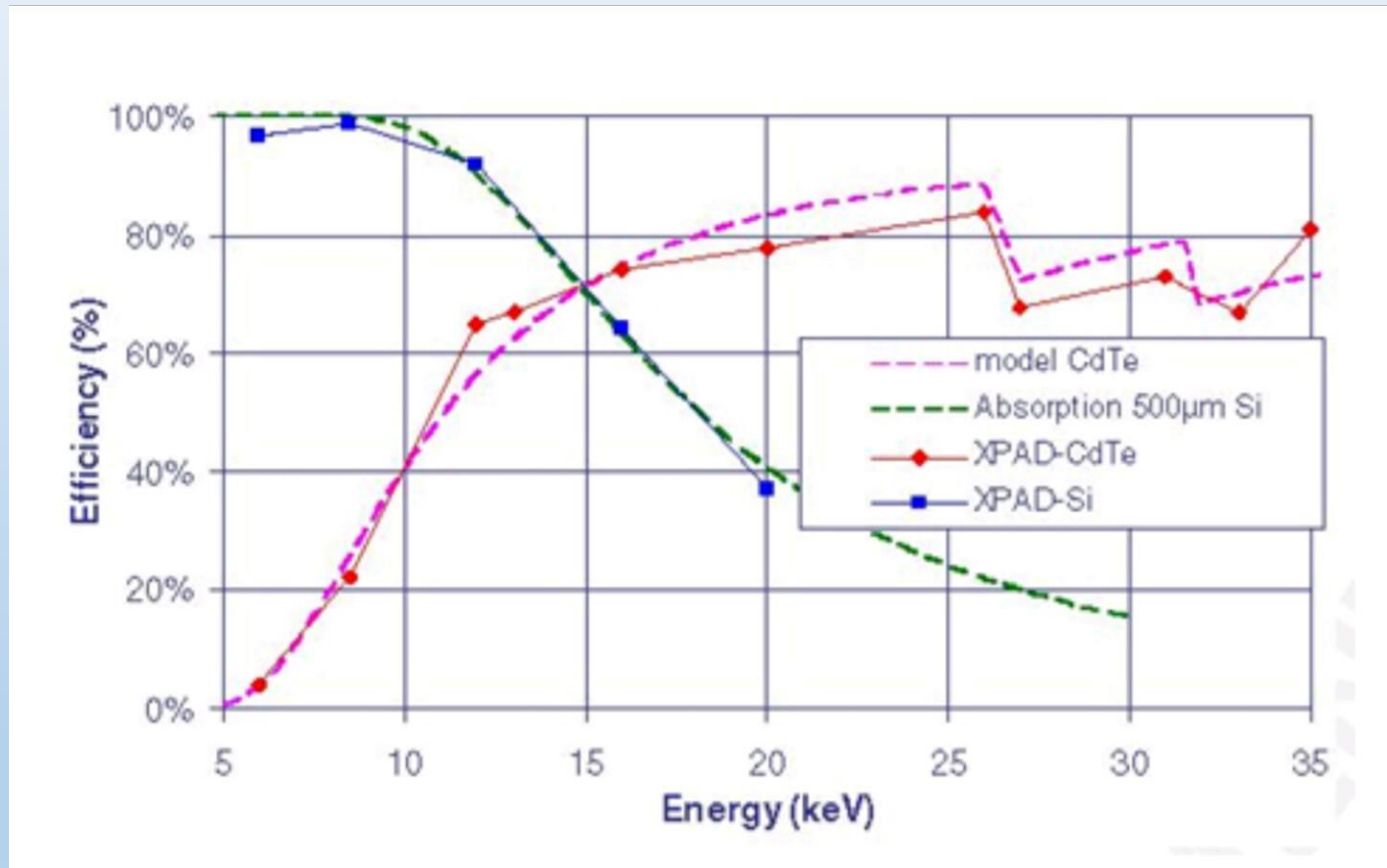
- **noise suppression** electronic et physic
- **Energy selection**



**contrast  
improvement**

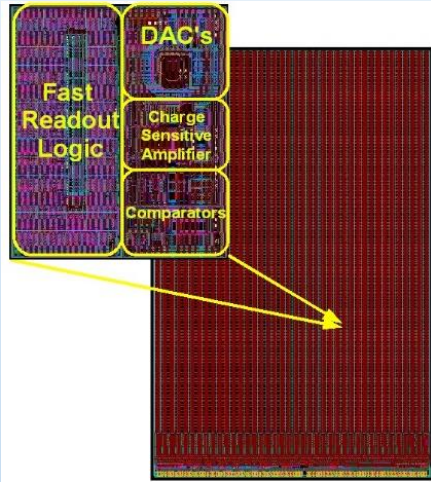
- **Very fast data acquisition (< 2 ms)**
- **Choice of the sensor substrate (Si, CdTE, AsGa)**
- **Maximum efficiency =>Dose reduction**

# Efficacité des différents sensors

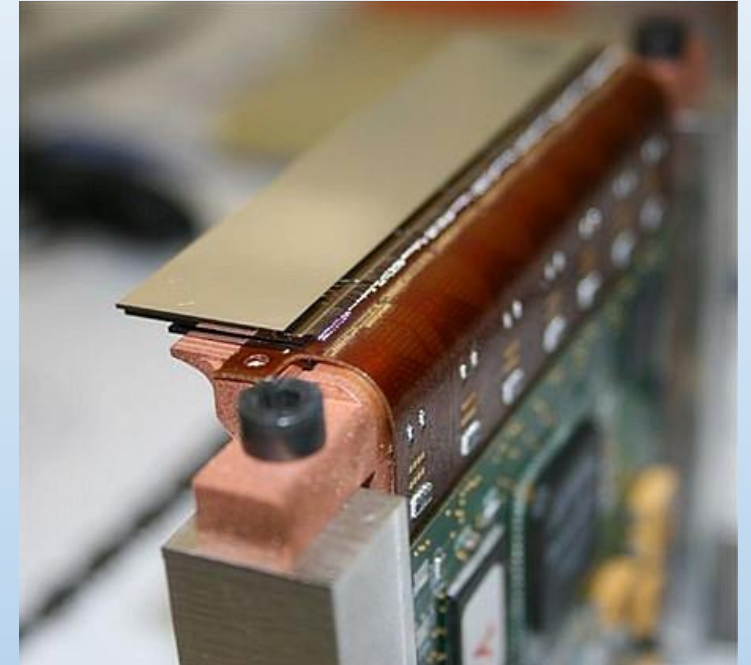


# Nos détecteurs

# XPAD 3.2

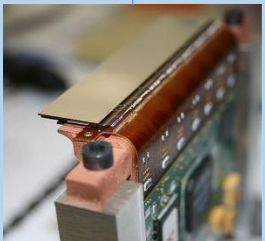
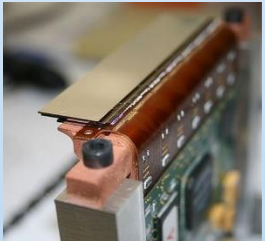
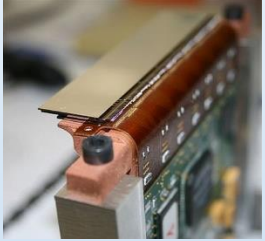


- Pixel size  $130 \times 130 \mu\text{m}^2$
- Programmable threshold range:
  - Si 5 to 30 keV
  - CdTe 6 to 60 keV
- No limit for the dynamic  $> 32\text{bits}$  (12 bits counter and overflow)
- Maximum count rate  $10^6 \text{ ph/pixel/s}$
- Fast readout 1.2ms
- Fast gate 150 ns (time resolve experiment)
- Noise suppression



# Construire un détecteur XPAD Grande surface

Module XPAD



n

Carte électronique  
Pour un module XPAD



n

Centralisation des  
données



XPAD SERVER

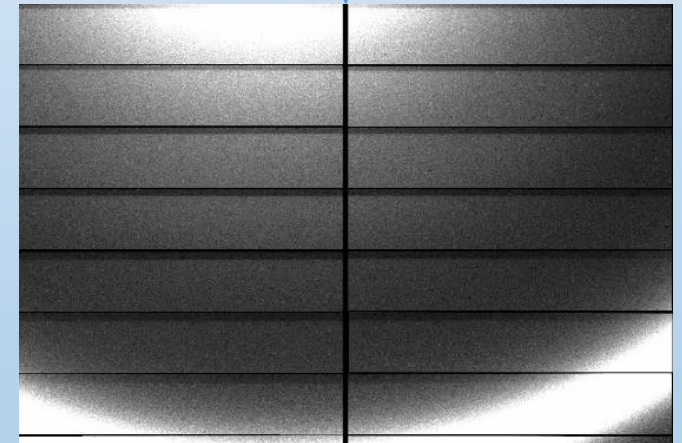
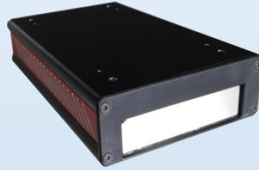
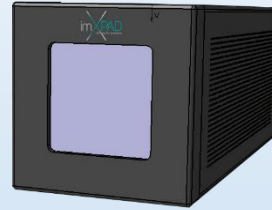


Image S1400 => 20 modules

# OUR PRODUCTS



**S70/C70**



**S270/C270**



**S540/C540**



**S1400**

## HYBRID PIXEL PHOTON COUNTING DETECTORS

Detector	Active area (cm <sup>2</sup> )	Number of pixels
S10/C10	1.5 x 1	9 600
S70/C70	7.5 x 1.5	67 200
S270/C270	7 x 7.5	268 800
S540/C540	12 x 7.5	537 600
S700/C700	8.5 x 15	672 000
S1400/C1400	15 x 15	1 344 000



# XPAD DETECTORS

- Can be build with Si or CdTe sensor
- High frame rate: 250 fps continuous whatever the size  
and **700 fps by bunch of 900 images**
- **Gating mode and Stacking mode**
- All detectors flat or tiled with overlap (no dead area between the modules)
- Air cooling (possibility of water cooling)

# Firmware du détecteur XPAD

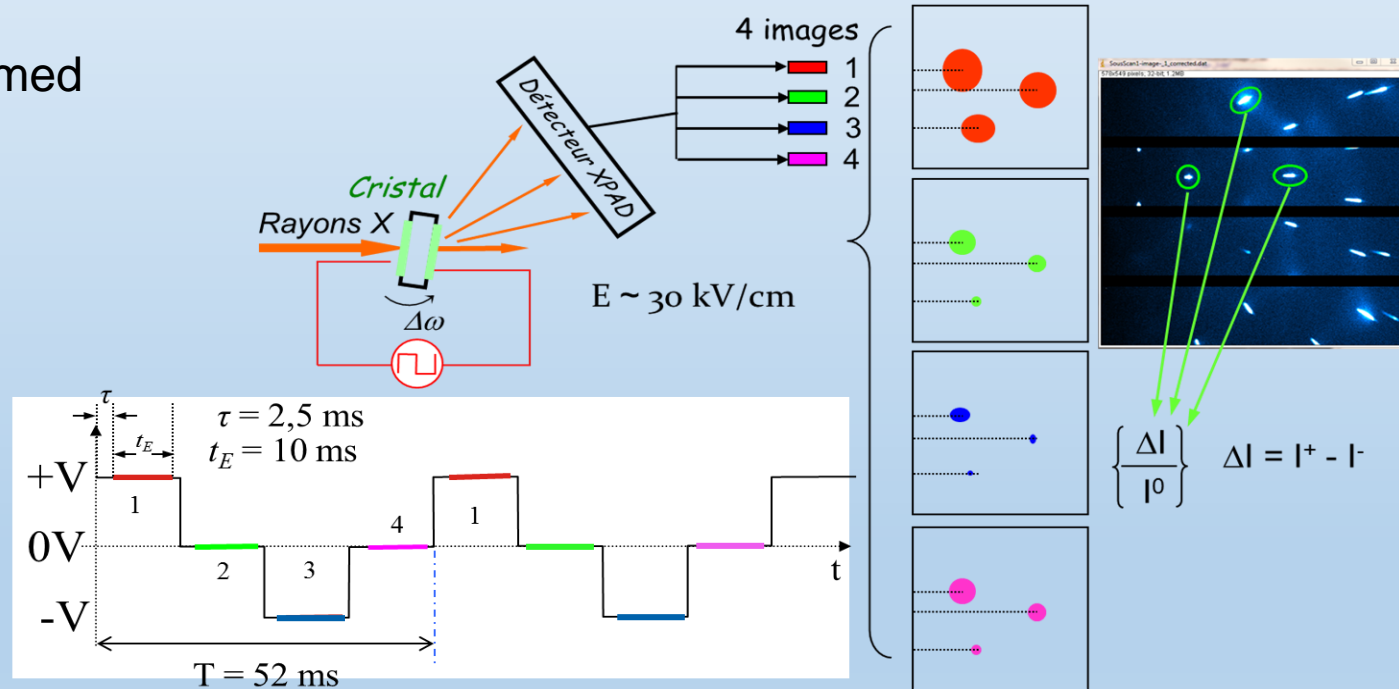
- Modes d'acquisition:
  - Mode Standard : 32 bits de résolution
  - Mode Detector Burst : 12 bits de résolution
    - 980 images
    - Jusqu'à 700 images/s quelque soit la taille du détecteur
  - Mode Computer Burst: : 12 bits de résolution
    - Nombre d'images illimitée
  - Stacking : 16 ou 32 bits
    - 480 slots en 32 bits et 980 slots en 16 bits
  - Single bunch : 16 ou 32 bits de résolution
    - Minimum gate 150 ns

# Stacking mode

Addition of images by stack performed completely by the detectors (NOT SOFTWARE)

Images are multiplexed and summed by the hardware of the detector

Dead time between 2 images : 1.2ms



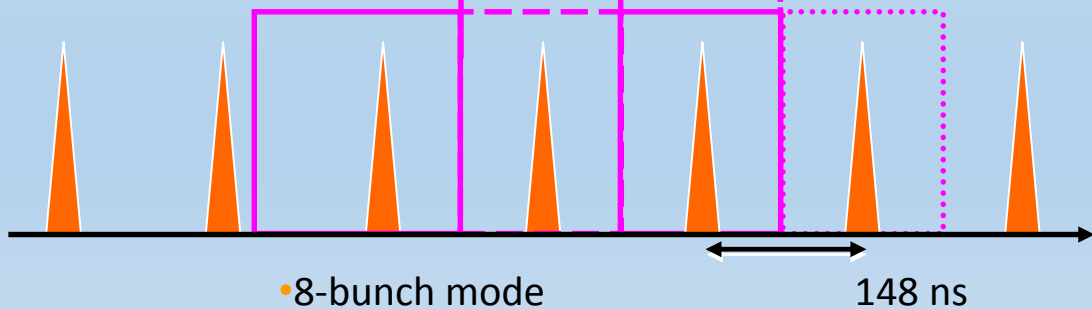
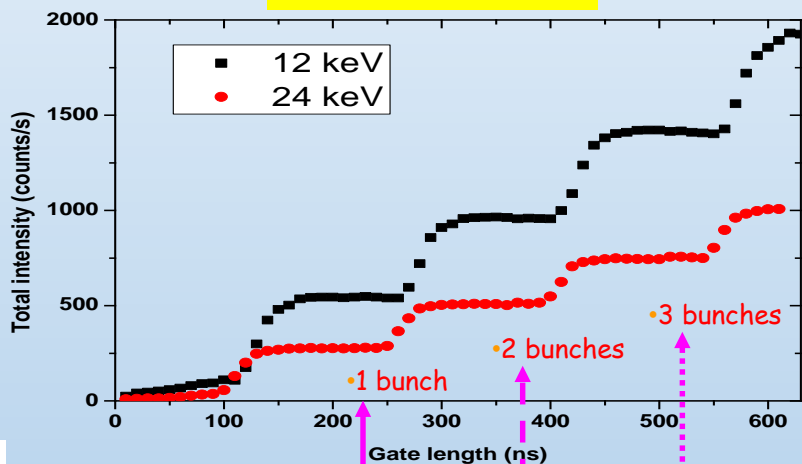
Time resolved experiment at CRM2 Laboratory (Nancy France)

# GATING MODE : Time resolved performances

Experiment done on CRISTAL SOLEIL beamline June 2010 (S.Hustache, K.Medjoubi, JC Clemens )

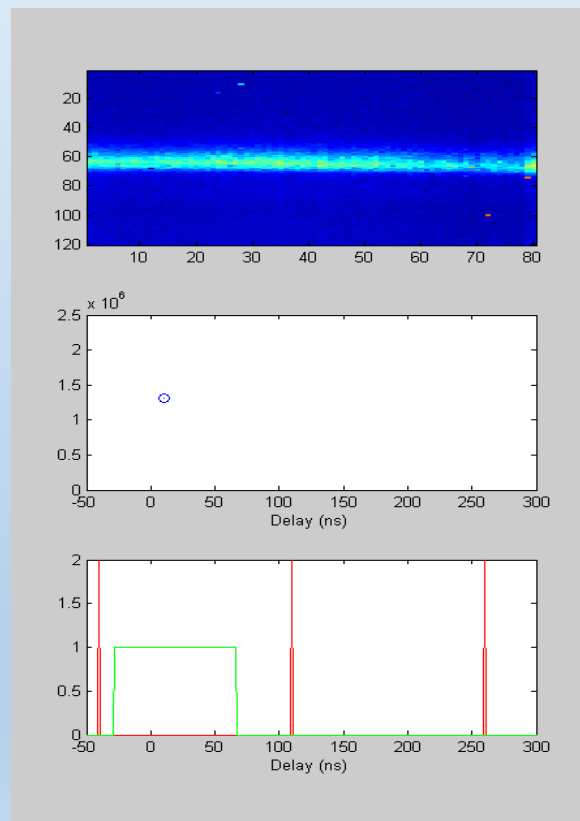
- Repetition rate : 847 kHz

- XPAD S540



- One-bunch

Repetition rate = 1 kHz, gate=90ns,  
500 gates (?) accumulated, step delay=10ns



Electronics shutter

# Triggers détecteur XPAD

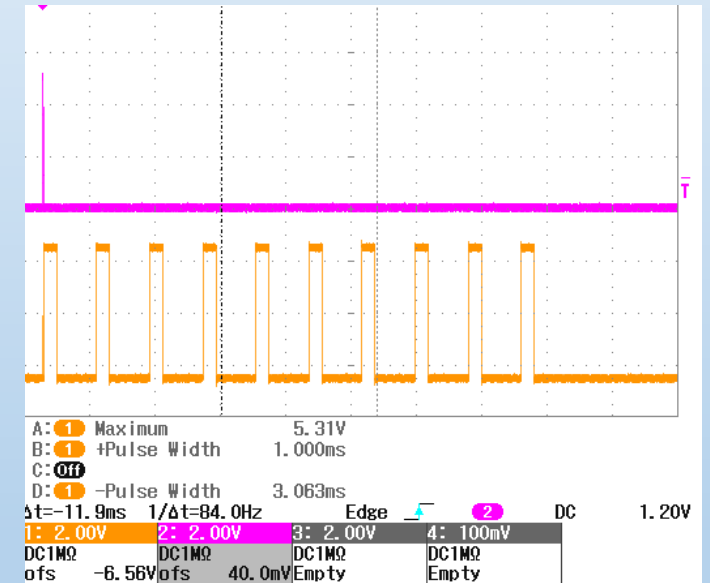
## Multi Trigger



Synchro

Busy counter

## First Trigger

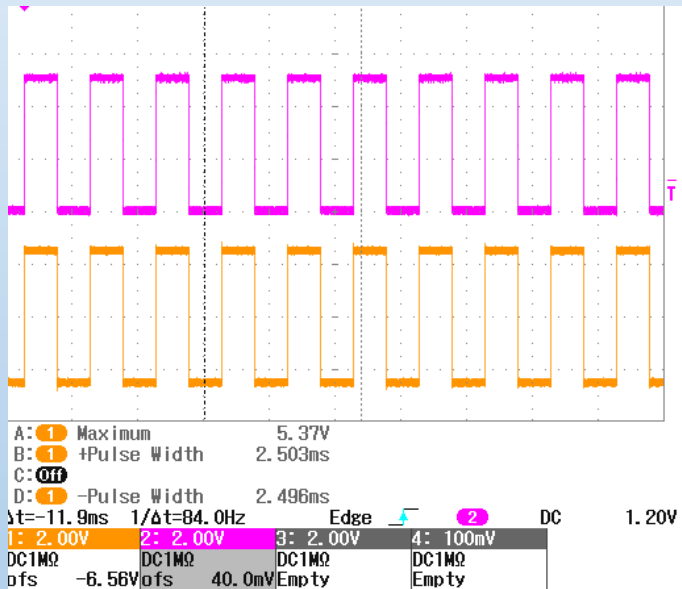


Synchro

Busy counter

# Triggers XPAD détecteur

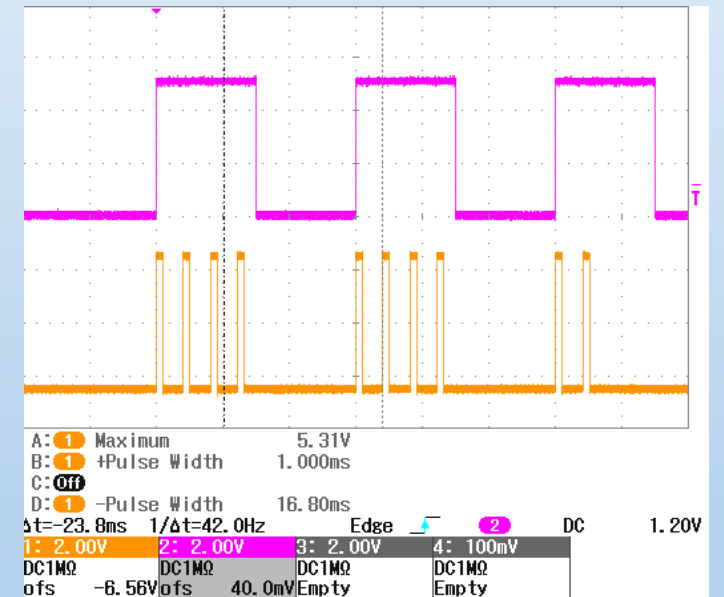
## External Gate



Synchro

Busy counter

## Level Trigger

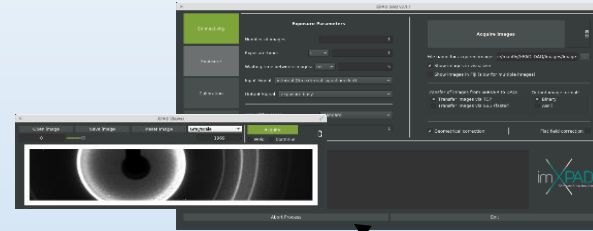


Synchro

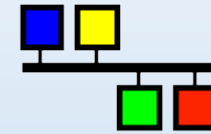
Busy counter

# ImXPAD SOFTWARE

ImXPAD DAQ Client



**EPICS**



ADXpad

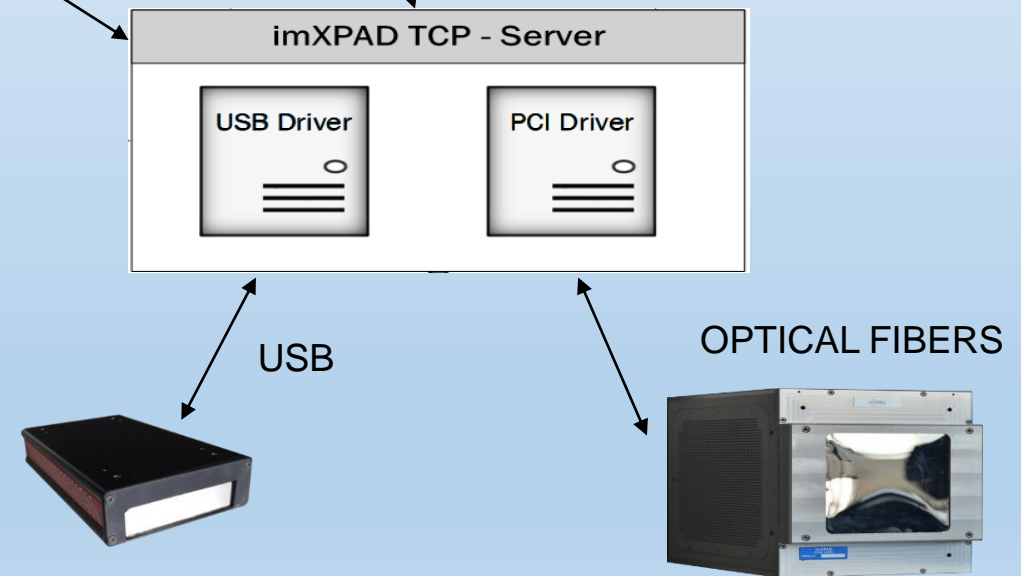


ImXPAD camera

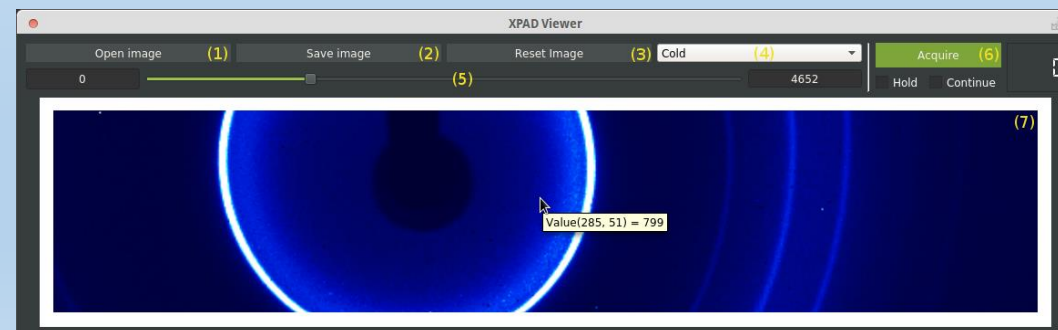
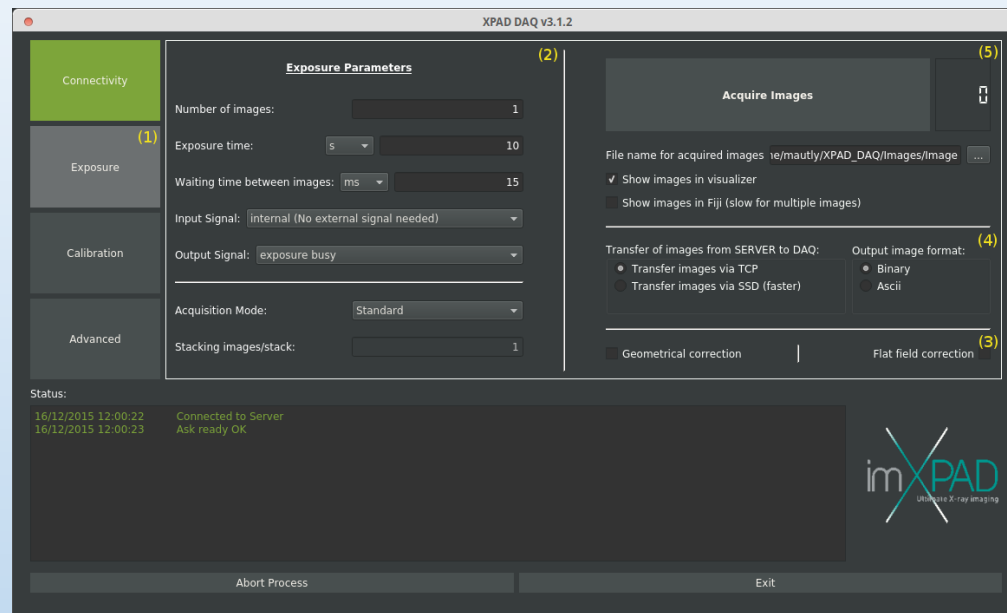
All XPAD detectors are controlled via a **client - server** architecture.

imXPAD supports open source control devices:

- EPICS (ADXpad)
- LIMA / TANGO



# ImXPAD GUI SOFTWARE





## SPECIAL PROJECTS REALIZED

### ImXPAD can develop custom design detectors

Examples:

- **WOS**: WAX Open for SAX (vacuum tube through the detection area)
- **CIRPAD**: Circular XPAD detector

# WOS S700: Wax Open for Sax



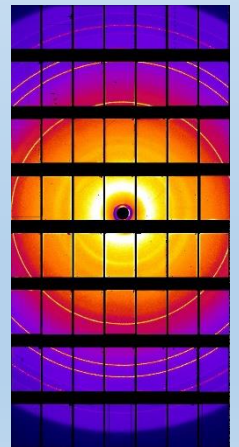
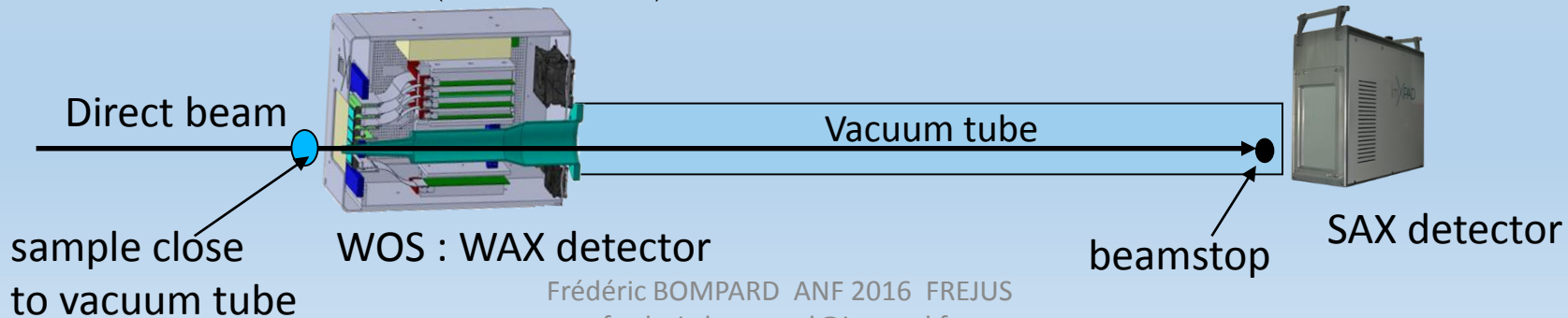
## WAX detector

vacuum tube placed next to the sample to avoid diffusion of the beam between the WAX detector and the SAX detector allowing simultaneous detections



Silver behenate (ESRF GRENOBLE)

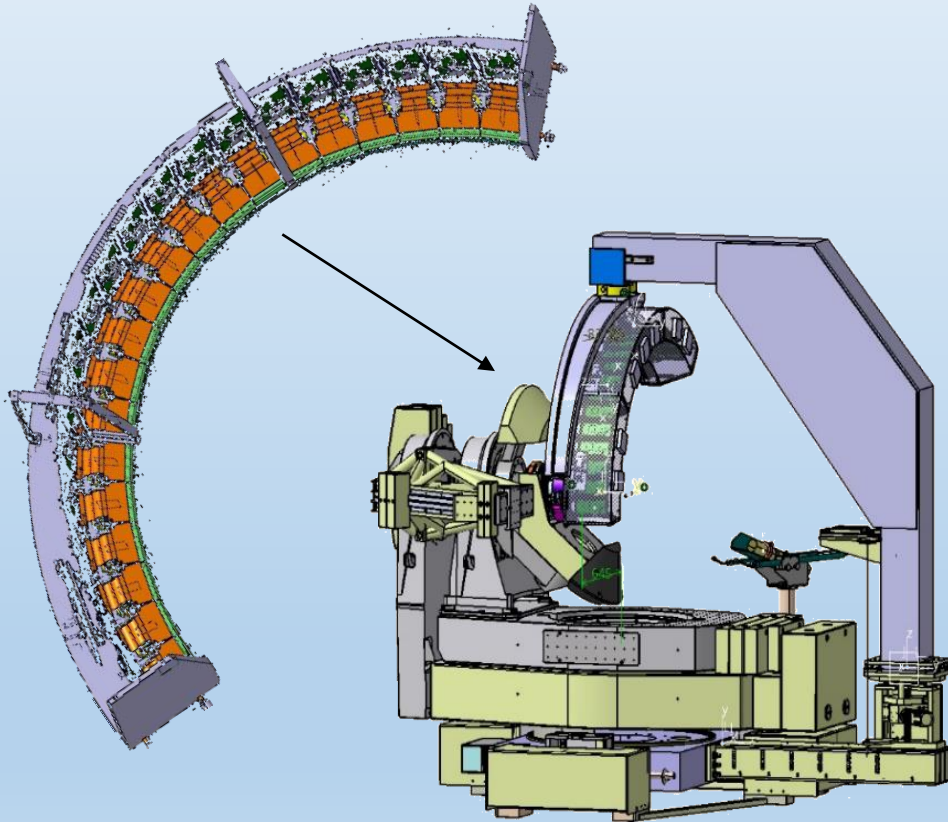
- Active area 15 x 9 cm<sup>2</sup>
- Si or CdTe sensor
- 10 modules (or more)



# CirPAD

Design with SOLEIL SYNCHROTRON Collaboration

Circular detector rotating to cover a spherical surface



**Pixels number : 1 344 000 (11600 x 120) pixels**

**Active area : Radius 64.5 cm**

**Angle 135 width 1.5 cm**

**Angular resolution : 0.0115°**

**Total dead area : 1% total area**

**Numbers of modules : 20**

# Conclusion

- Les besoins évoluent (énergies plus élevées, pixels plus petits, ..) et c'est un véritable challenge pour nous fournisseurs de s'adapter car cela exige de faire de nouveaux circuits électroniques qui sont très couteux.
- Par contre, le fait de pouvoir s'adapter à cette évolution et aux différentes applications permet d'affirmer que ce type de détecteur a un avenir très prometteur.

# Thank you



We are looking forward to answering your questions