PIXSCAN
CT-scanner for
Small Animal Imaging
Based on hybrid pixel detectors

Centre de Physique des Particules de Marseille (CPPM-IN2P3), France
S. Basolo, A. Bonissent, P. Breugnon, J.C. Clemens,
P. Delpierre, B. Dinkespiler, R. Khouri, I. Koudobine, C. Meessen,
M. Menouni, C. Morel, P. Pangaud, E. Vigeolas

CNRS Grenoble & D2am CRG beam-line, France
J.F. Berar, N. Boudet, B. Caillot, C. Mouget

CREATIS, UMR-CNRS-5515, INSERM-U630, Lyon, France
F. Peyrin, D. Sappey-Marinier, S. Valton

Institut de Biologie du Développement de Marseille (IBDM), France
F.Debardieux, F.Mann, G. Rougon

Summary

- Interest of hybrid pixels for X-rays
- Large surface X-ray detector
- Validation with crystallography
- Scanner-CT prototype
- Ongoing work for the final version
- Prospective : PET-CT

Interest of HPS for X-ray imaging

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

- **Photon counting**

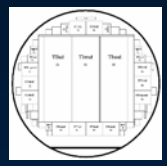
  - **Noise suppression** electronic et physic
  - **Energy selection**
  - **Large dynamic range,** flux et luminosity

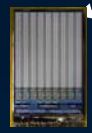
  → **contrast improvement**

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

Building Hybrid Pixel Detectors

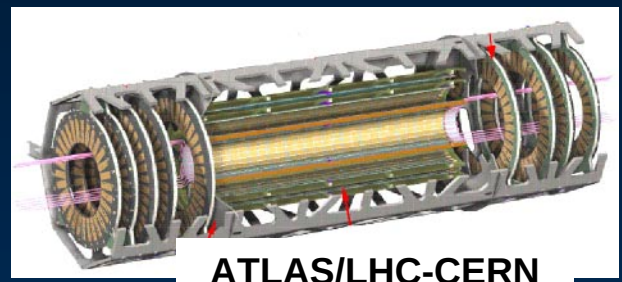
Sensor
Si or **CdTe**
Thickness: 0,3 mm



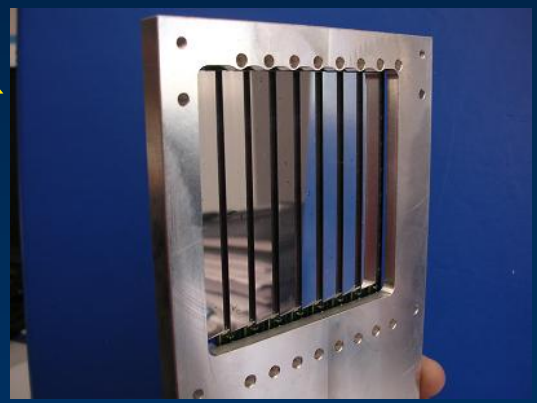


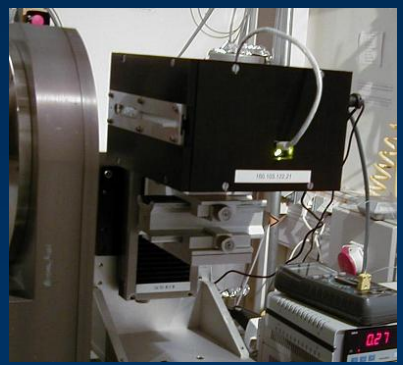
Readout chip
1 complete electronic chain
for each pixel

Photon counting

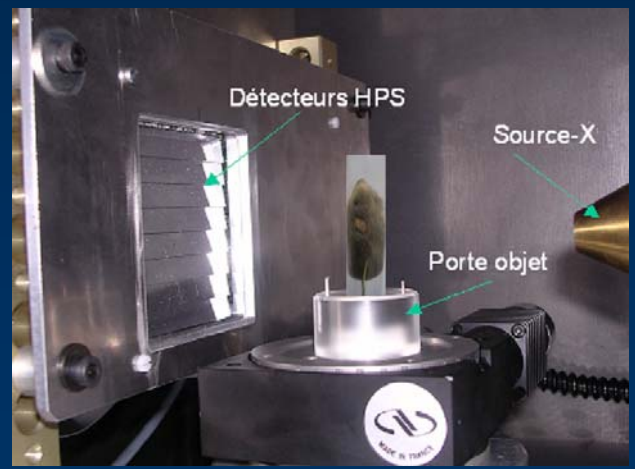


ATLAS/LHC-CERN
70 Millions de pixels





Crystallography
(ESRF, SOLEIL)



Small Animal Imaging

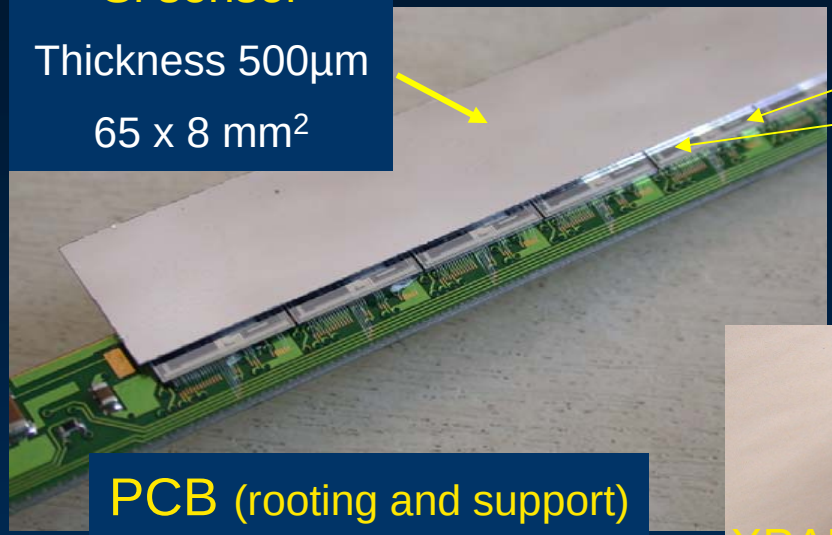
clemens@cppm.in2p3.fr

X-ray detector

Si sensor

Thickness 500µm

65 x 8 mm^2



XPAD2

Pixels 330 x 330 µm^2

15-bit Counter

linear until 10^6 ph/sec/pixel

PCB (rooting and support)

XPAD2's

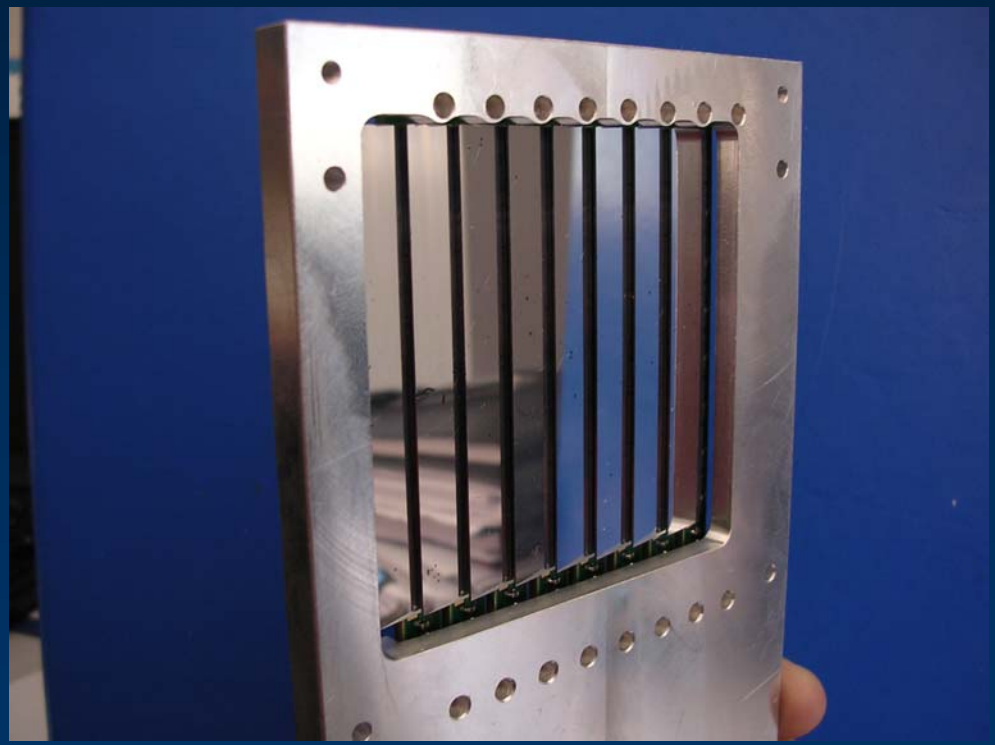
1. **Readout of pixel counter overflows during exposure**
2. **Addition** in an external 16-bit counter
   => Dynamic range: 2.10^9
3. **Storage in memory chips**
   => 423 images

- **ALTERA prog. device**
- **ETHERNET interface**
- Monitoring by **PC**

Large surface X-Ray PixelDetector

8 modules tiled

6,8 x 6,5 cm^2 HPS Detector



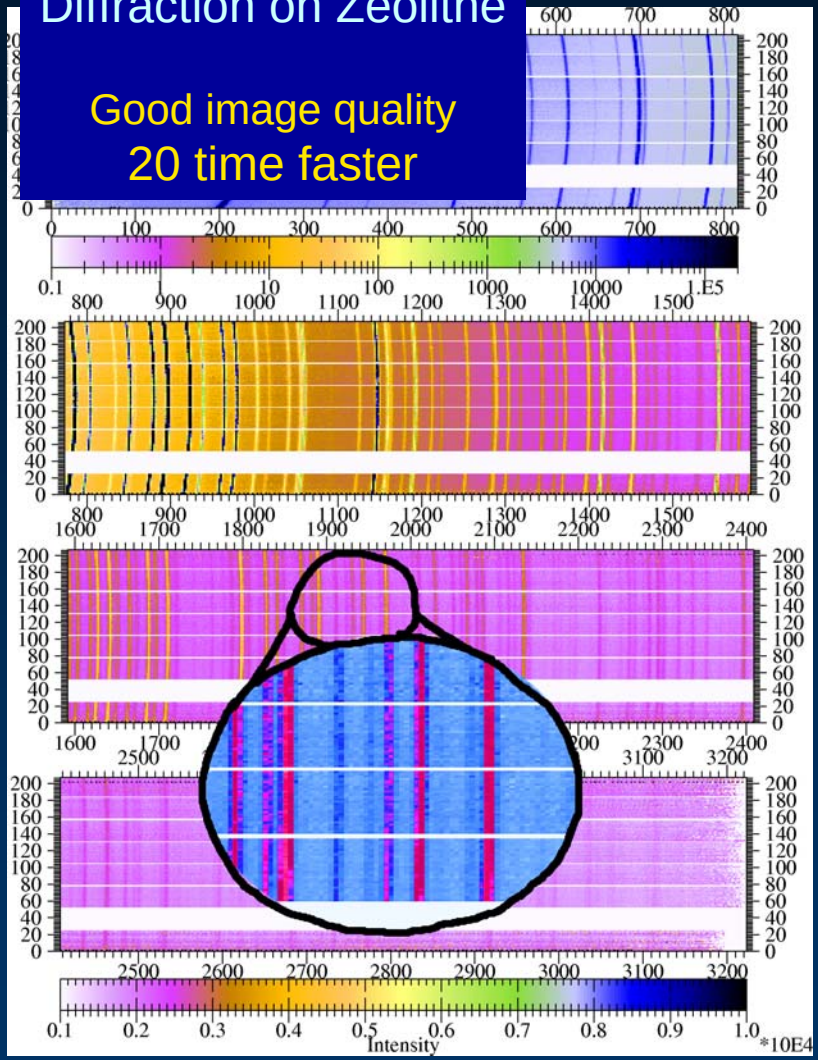
Pixels size: 330 x 330 μm^2

400 images, 2 ms gap

Crystallography

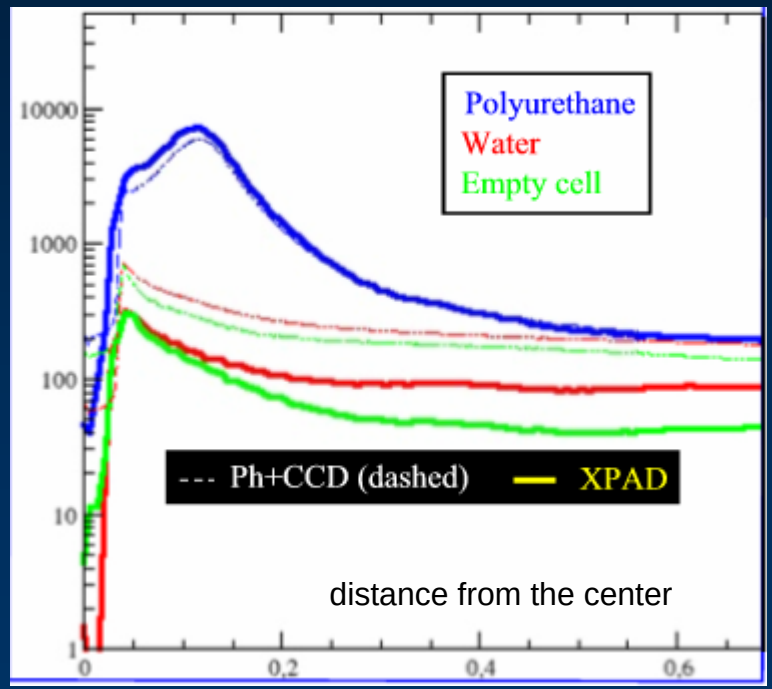
XPAD / Slit + PM
Diffraction on Zéolithe

Good image quality
20 time faster

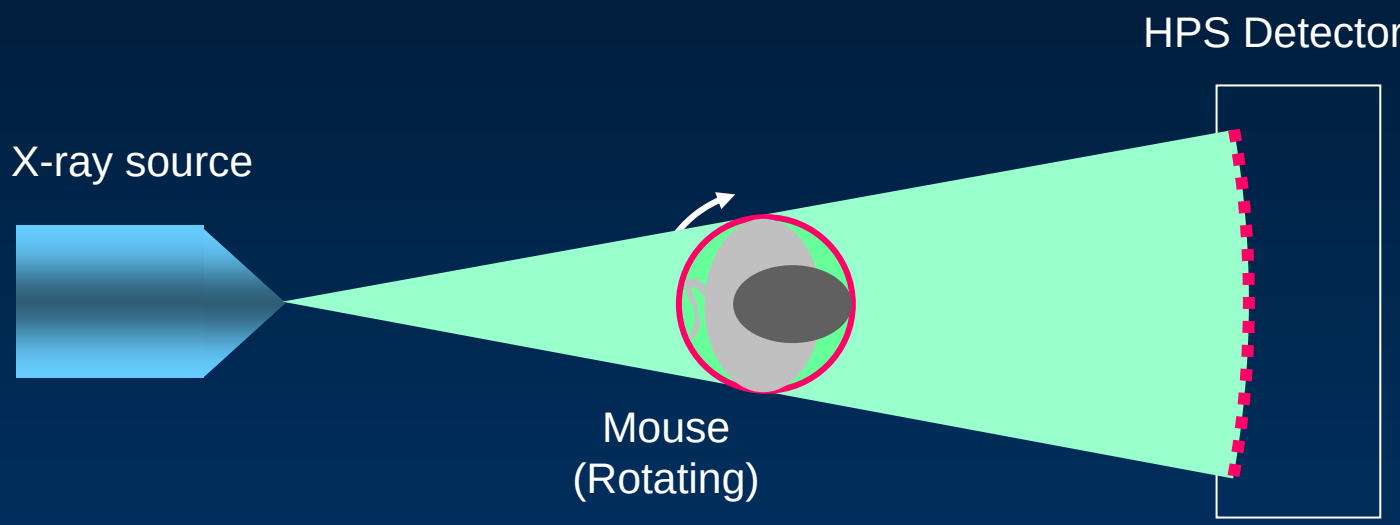


XPAD / Ph + CCD
Small angle diffusion

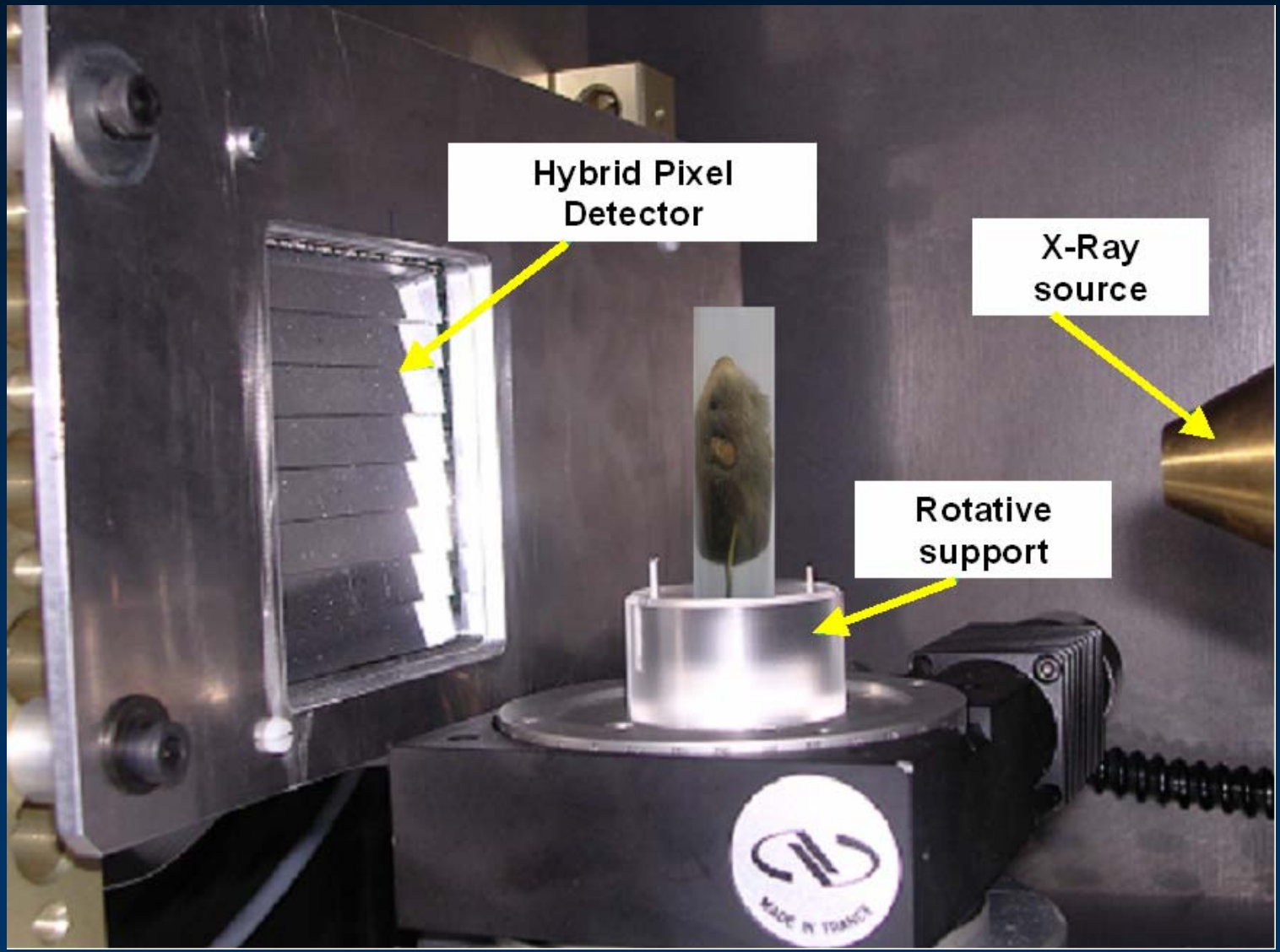
Much better separation between air/water
(No noise)



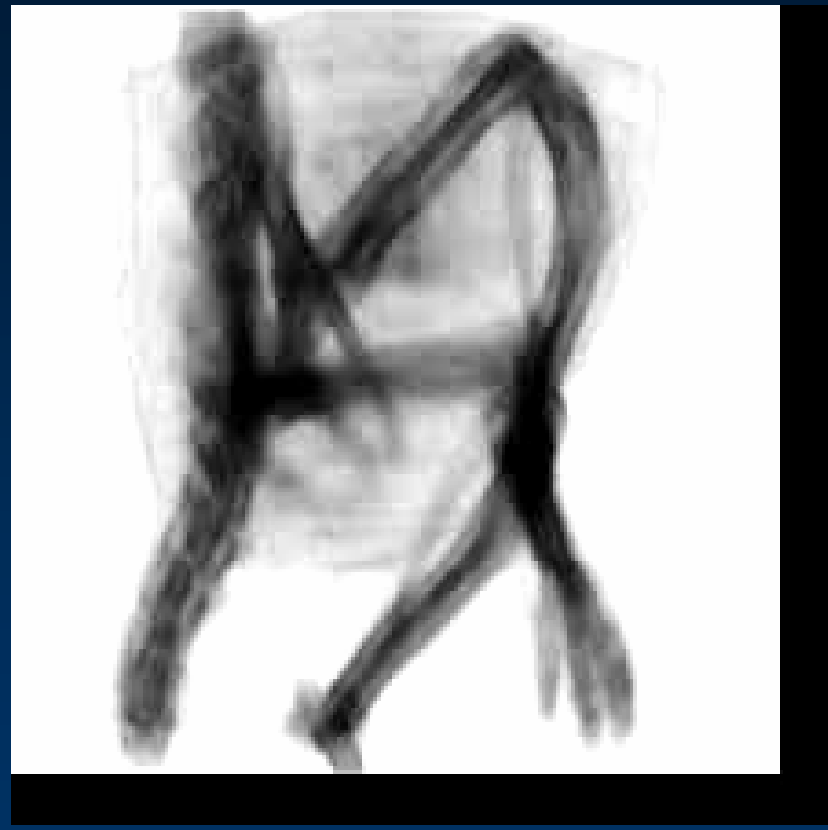
Small Animal CT-scanner



PIXSCAN Prototype



PIXSCAN Prototype

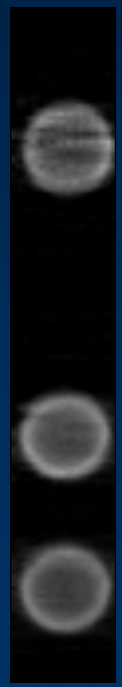


Tomographic images

Cone beam tomographic reconstruction by FDK algorithms
(collaboration with CREATIS, Lyon, France)

360 projections (1 per degree)

Phantom => geometry



One slice

Ongoing work for the next CT-scanner

Goals :

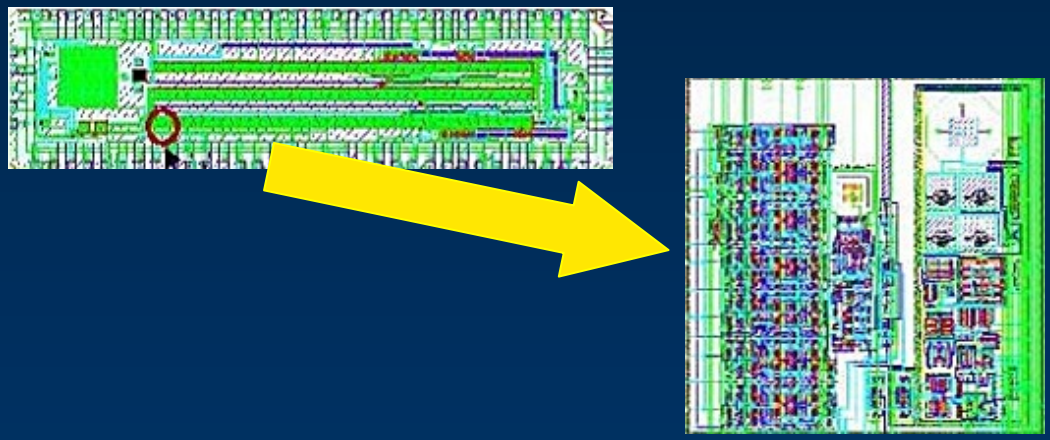
- Pixel size = 125 µm
- Energy selection => double threshold
- Dynamic range ~ infinite
  - ➢ Continuous readout during exposure
  - ➢ Noise suppression
- Time gap between images < 1 msec => very fast image transfer
- Dose reduction
  - ➢ Efficiency > 95% at 50 keV (for CdTe and gap < 1 msec)
- Gamma (511 keV) absorption < 2% => 300 µm CdTe

XPAD3

New chip, the **XPAD3**, technology 0,25 µm

- 125 µm,120 x80 pixel matrix
- Double threshold (windowing)
- Radiation hard
- 12-bit counter/pixel + overflow
- Fast image reading :1000 Frame /s

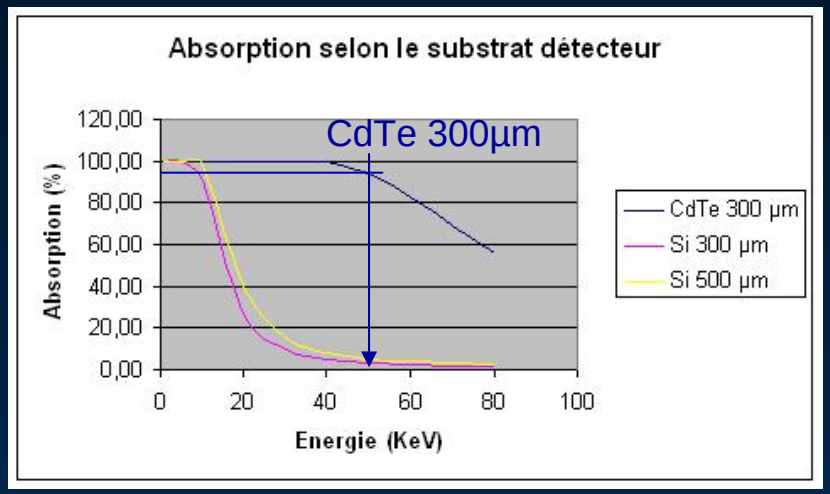
120 cells test chip done : Good analog and digital results



Complete XPAD3 : Design under work

1 x 1,5 cm^2 ⟶ First version to be submitted in sept. 2005

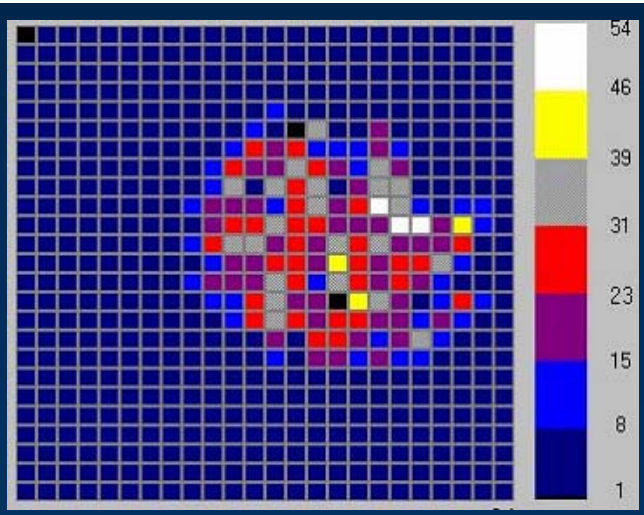
Sensor => CdTe



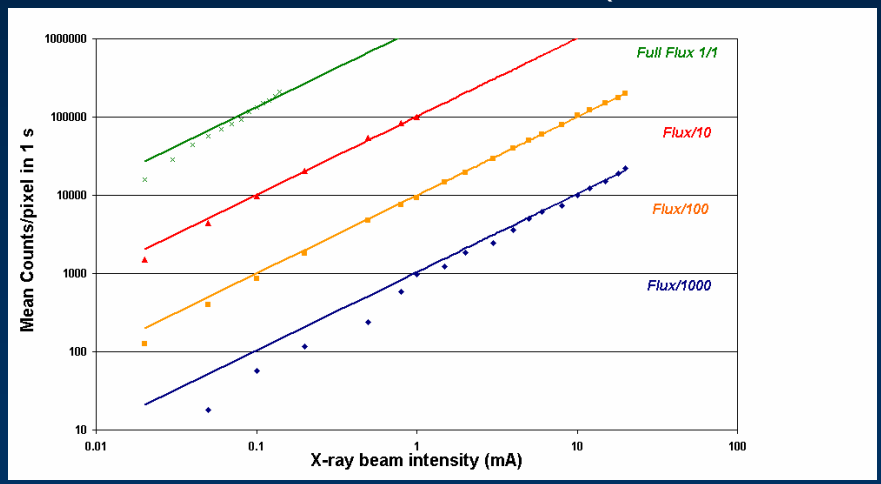
CdTe or CdZnTe

- Strong absorption / thin thickness
  => 95% efficiency at 50 keV
- Radiation hard

Bump-bonding =>
Collaboration with **LETI** (Grenoble, France)



CdTe / XPAD1
Co^{57} **(122 KeV)**



CdTe sensor on XPAD2
Linear over 4 decades of incident flux
(see poster from R. Franchi)

clemens@cppm.in2p3.fr

PET-CT

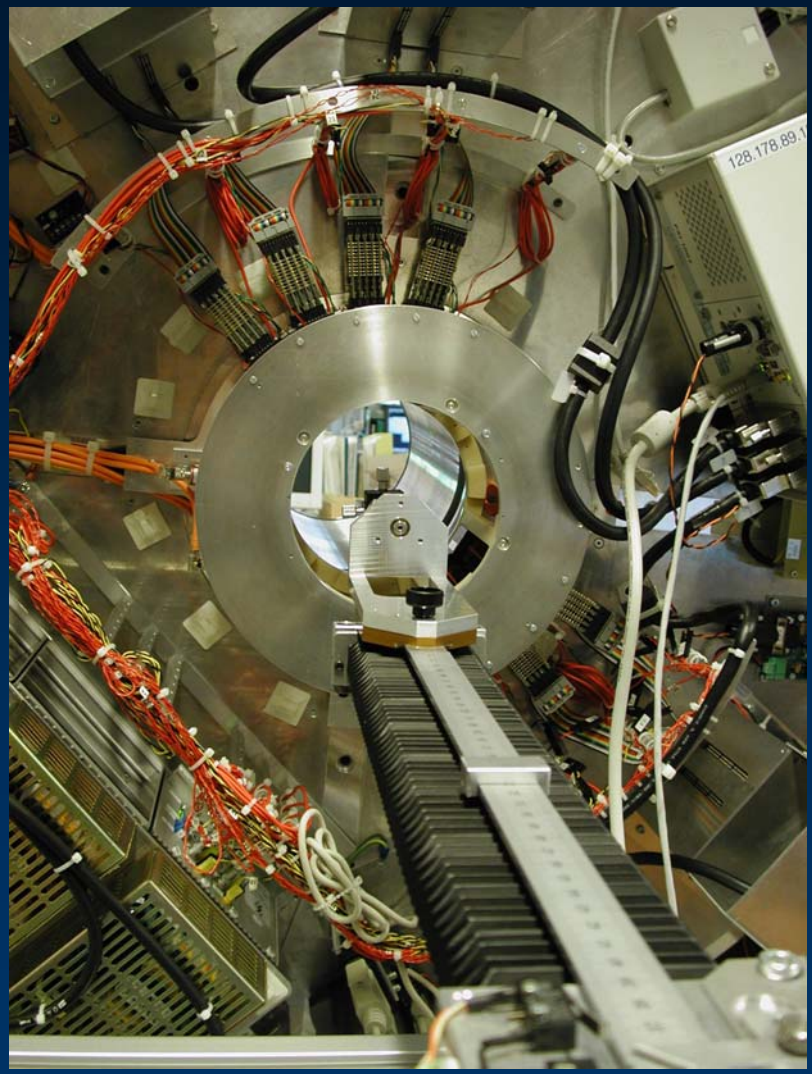
PET + CT-scan simultaneous imaging
several CT images during the PET

Anatomic image
+ **functional** image (tumors)

Without positioning problems

PET data correction
for **absorption** and
for movements
during PET exposure

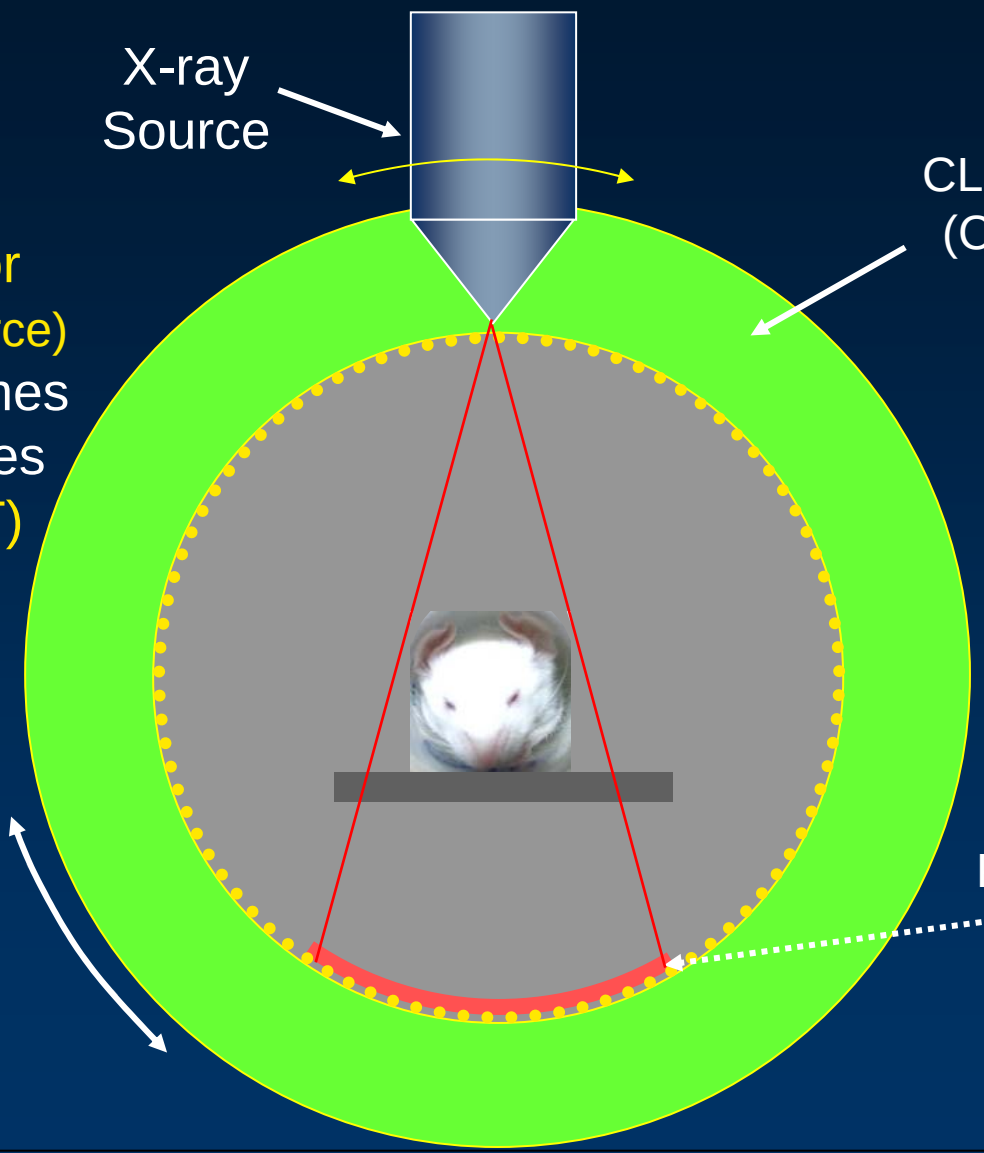
CLEARPET



CLEARPET
from Lausanne
(C. Morel)

To be installed
at Marseille (CPPM)

PIXSCAN in the ClearPET



The full detector
(and the X-ray source)
rotate several times
to take CT images
during the PET)

Conclusion

A large surface X-Ray Hybid Pixel Detector has been built

It is in use for :

Crystallography:

- saving a factor of 20 / slit + PM scan
- Noise improvement / CCD

CT-scan (PIXSCAN):

- 400 images separated by 2 ms
- Starting tomographic images

New chip in submicronic technology under design for a pixel size of 125 µm and CdTe sensor

Plans:

- First version PIXSCAN (Silicium) June 2006
- Final PIXSCAN (CdZnTe) End 2006
- Simultaneous PET-CT Mid. 2007

Mouse tomographic image