SOLEIL SYNCHROTRON

X-ray beam diagnostics at SOLEIL

Détecteurs pour diagnostique du faisceau de rayons X à SOLEIL

Journées Réseau Semiconducteurs 2026 – IJCLab Orsay

Marie ANDRÄ – on behalf of the Detector Group - SOLEIL

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Outline

- SOLEIL synchrotron + a beamline
- What are X-ray diagnostics and why do we need them?
- Types of X-ray diagnostics at SOLEIL
  - Beam Imagers
  - Position Monitors
  - Intensity Monitors
- Future SOLEIL II & paths of X-ray diagnostics development at SOLEIL

- *Le synchrotron SOLEIL + une ligne de lumière*
- *Qu'est-ce qu'un "diagnostique du faisceau X" et pourquoi en avons-nous besoin?*
- *Types de diagnostiques à SOLEIL*
  - *Imageurs faisceau*
  - *Moniteurs de position*
  - *Moniteurs d'intensité*
- *Développement de futurs diagnostiques faisceau pour SOLEIL II*

SOLEIL: an optimized intermediate energy light source

Source **O**ptimisée de **L**umière d'**E**nergie **I**ntermédiaire du **L**URE

~ 634 M€
Construction budget
(2002-2012)

~ 61 M€
Annuel budget

72% cnrs

28% cea

* Laboratoire d'Utilisation de Rayonnement Electromagnétique / Laboratory of the Use of Electromagnetic Radiation

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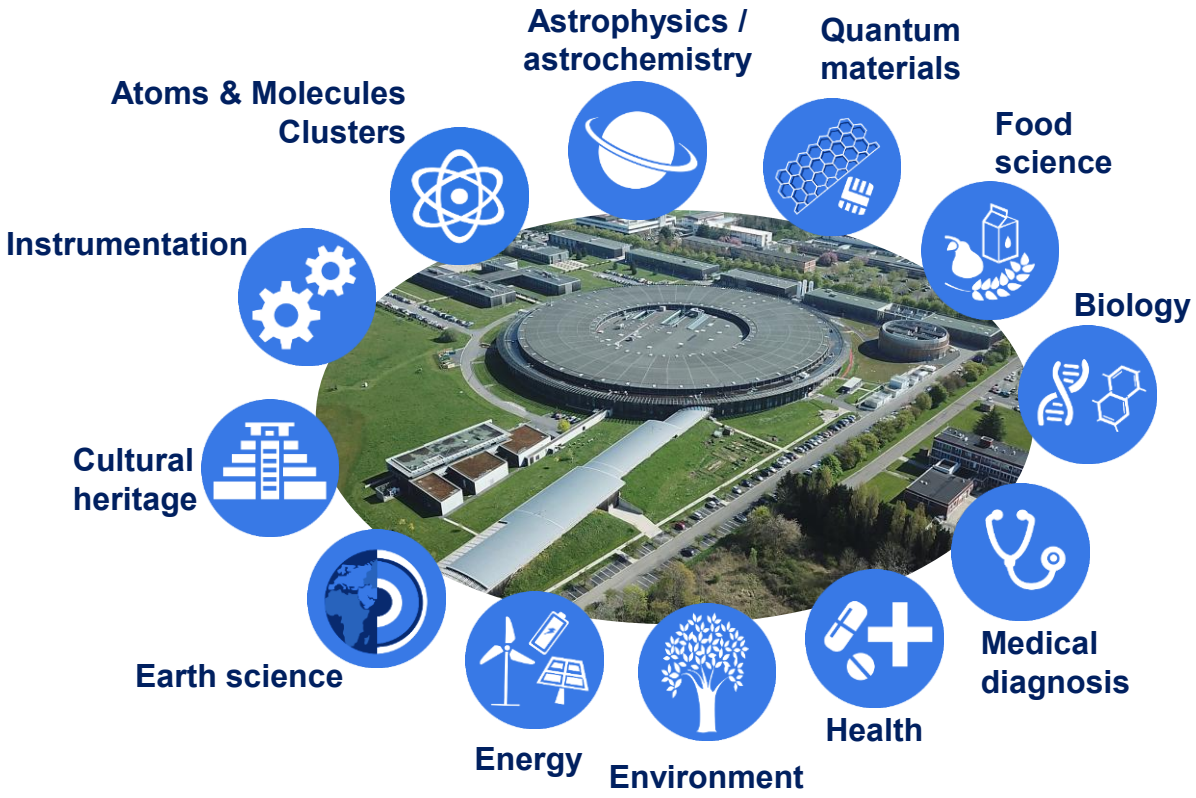
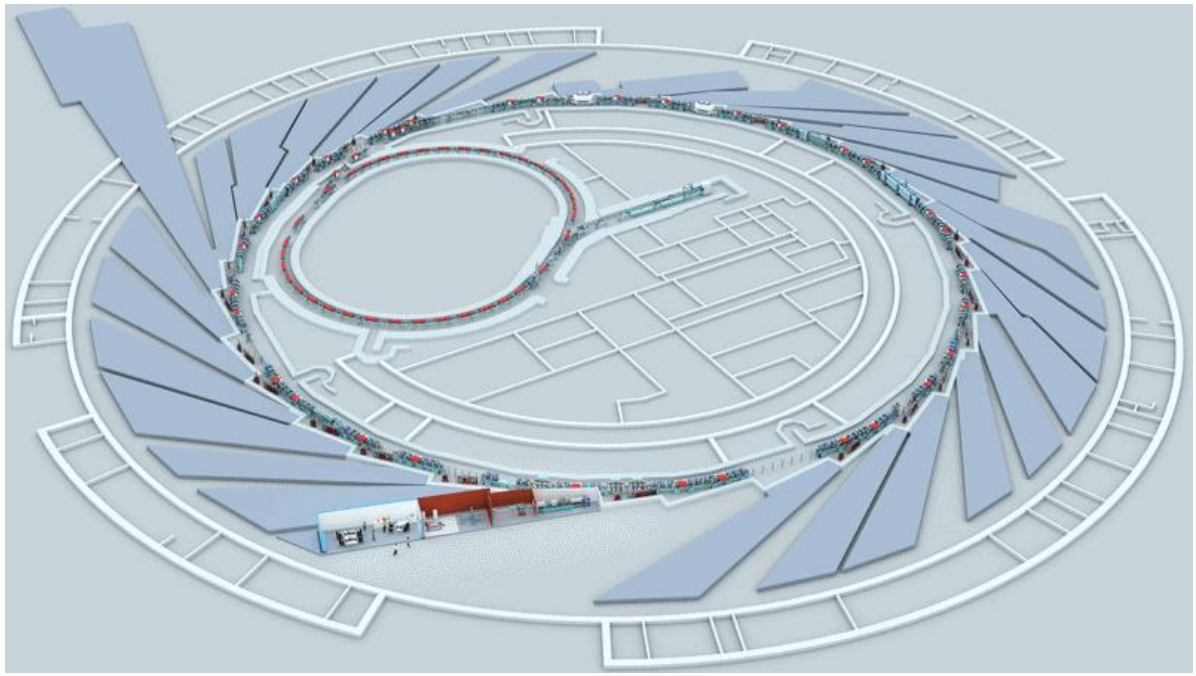
SOLEIL synchrotron





More info and apply for beamtime:
www.synchrotron-soleil.fr

- French national synchrotron
- 29 beamlines
- Energies from 1 meV to 100 keV

- *Synchrotron national français*
- *29 lignes de lumière*
- *Energies de 1 meV à 100 keV*

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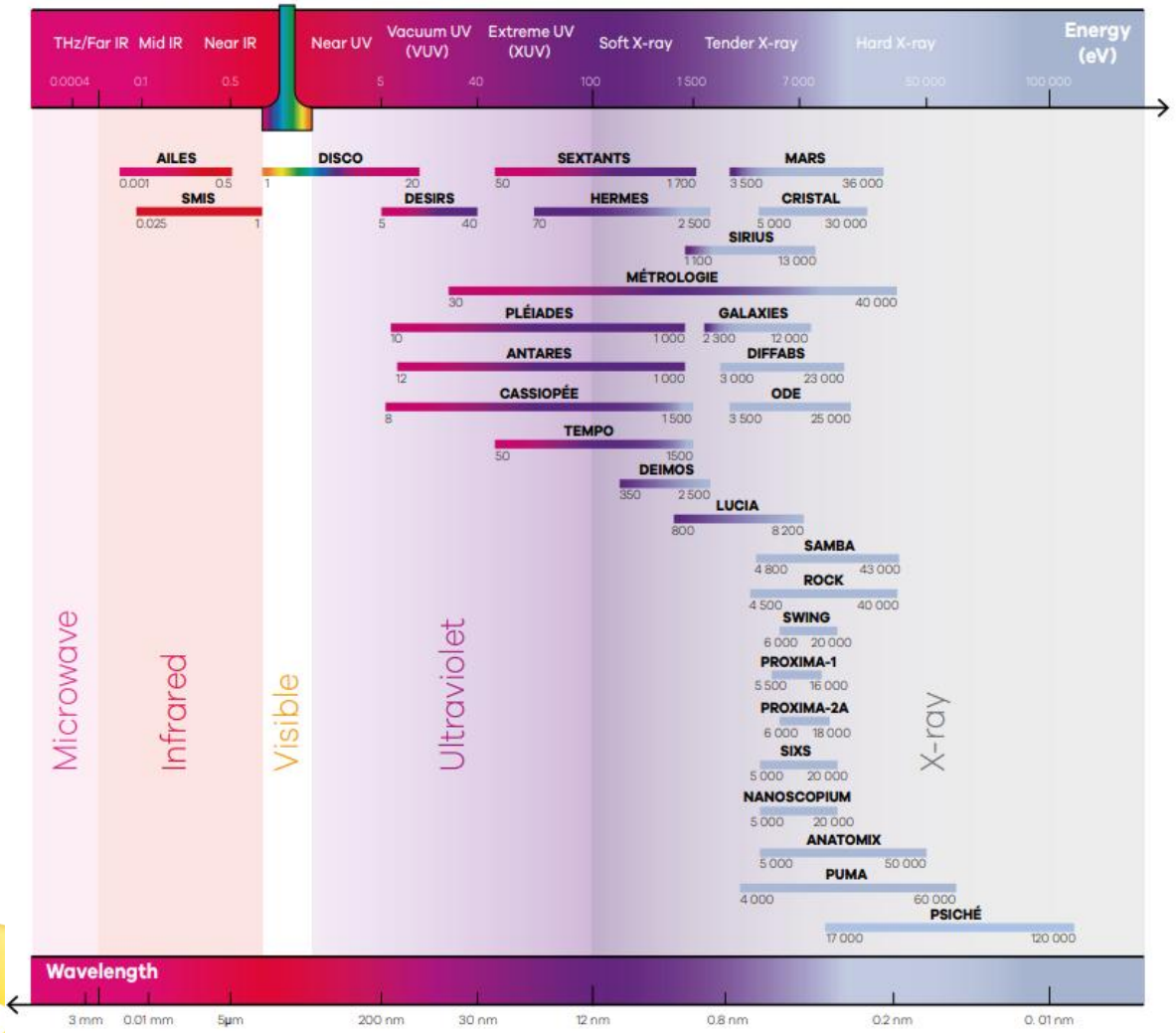
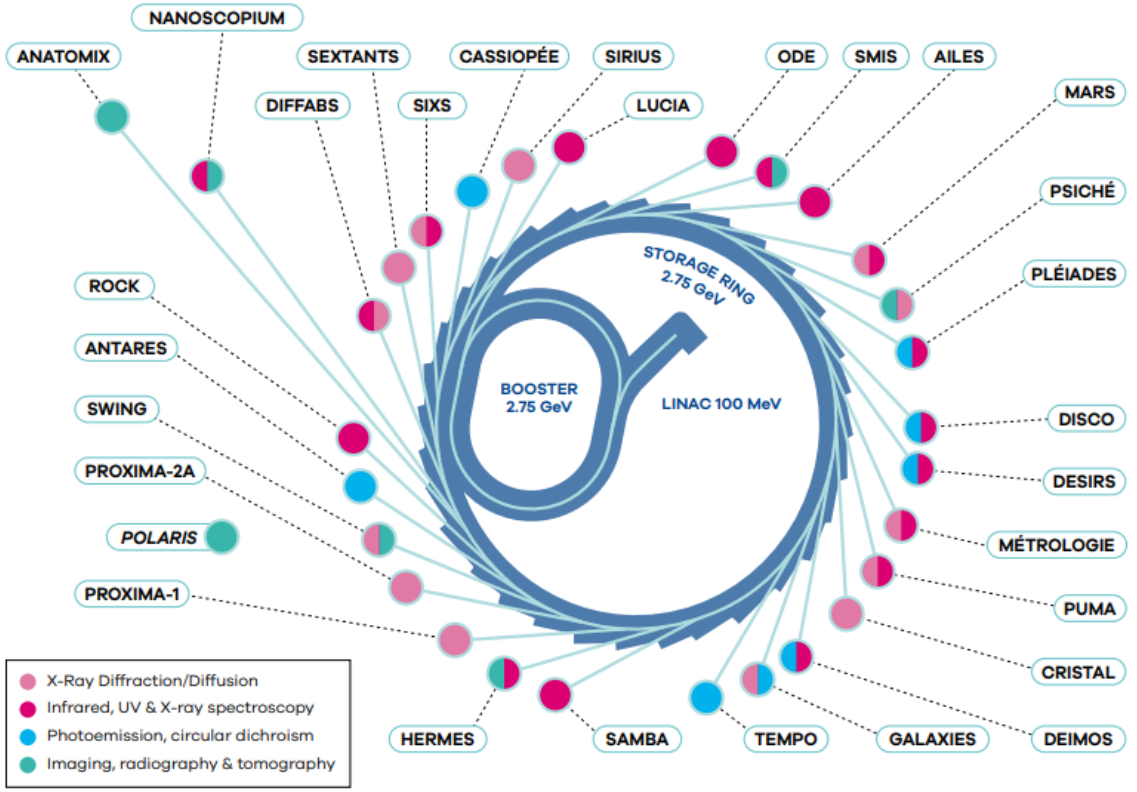
SOLEIL's beamlines / *Lignes de lumière à SOLEIL*

BEAMLINE ENERGY RANGES



ANALYTICAL TECHNIQUES



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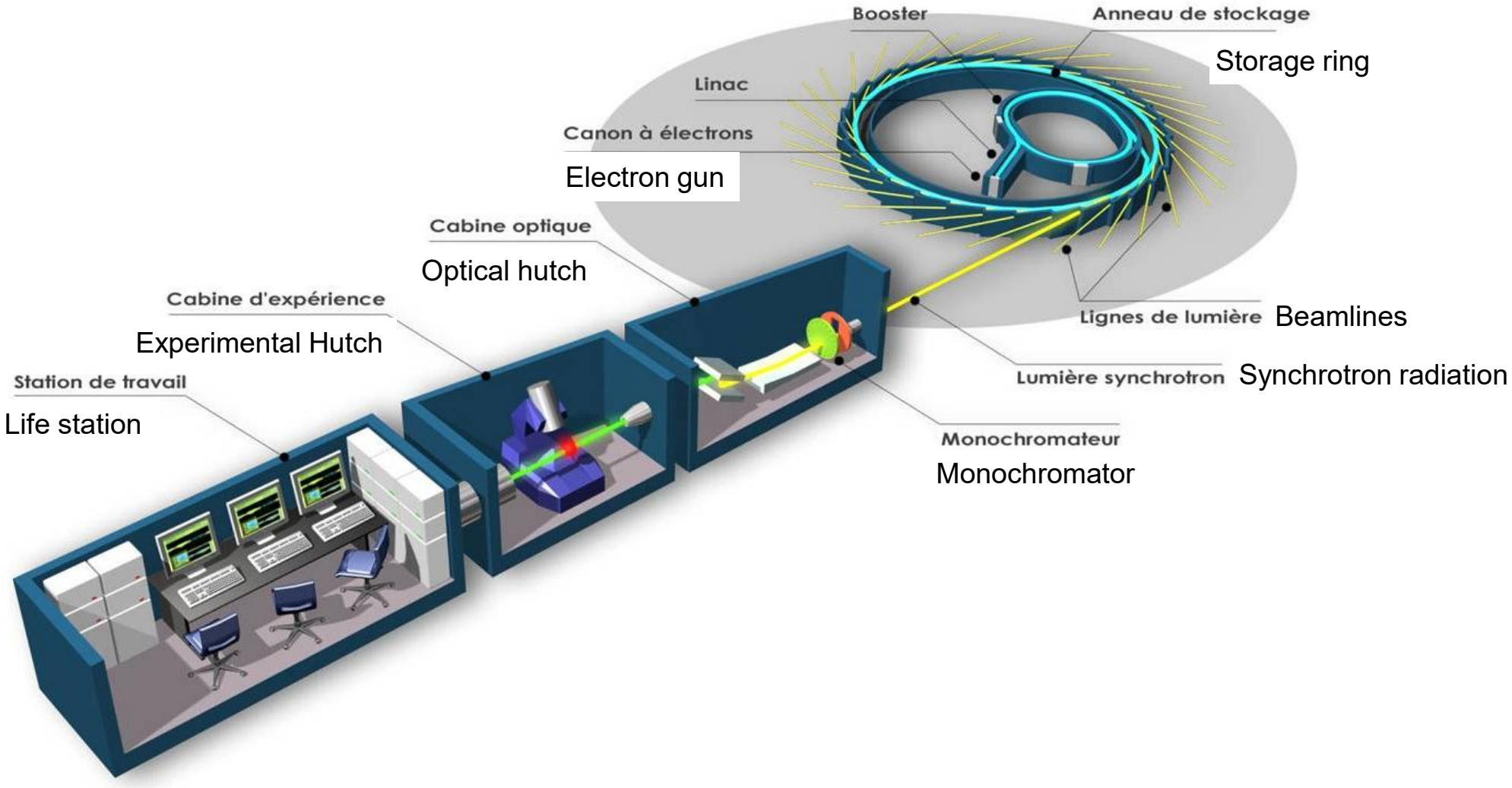
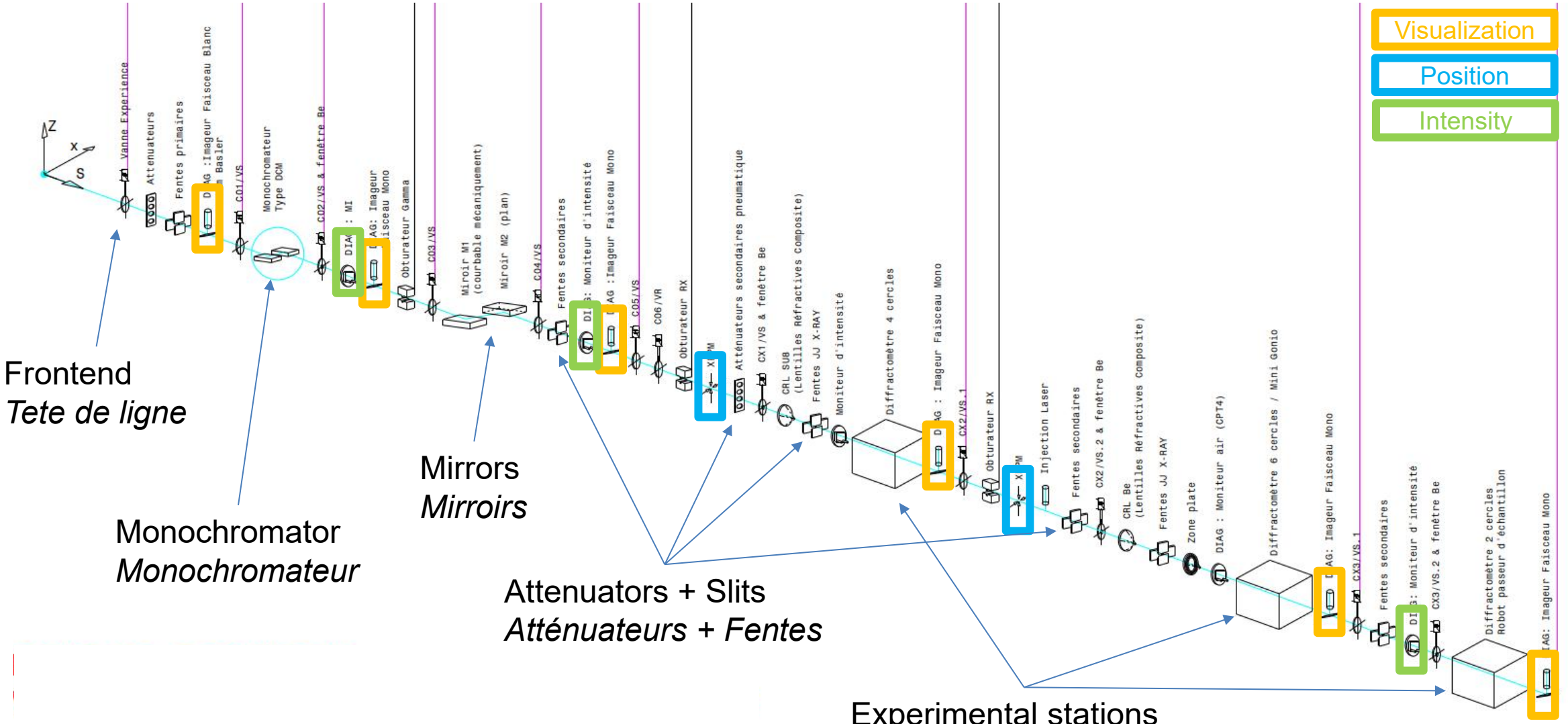
Beamline organisation / *L'organisation d'une ligne de lumière*

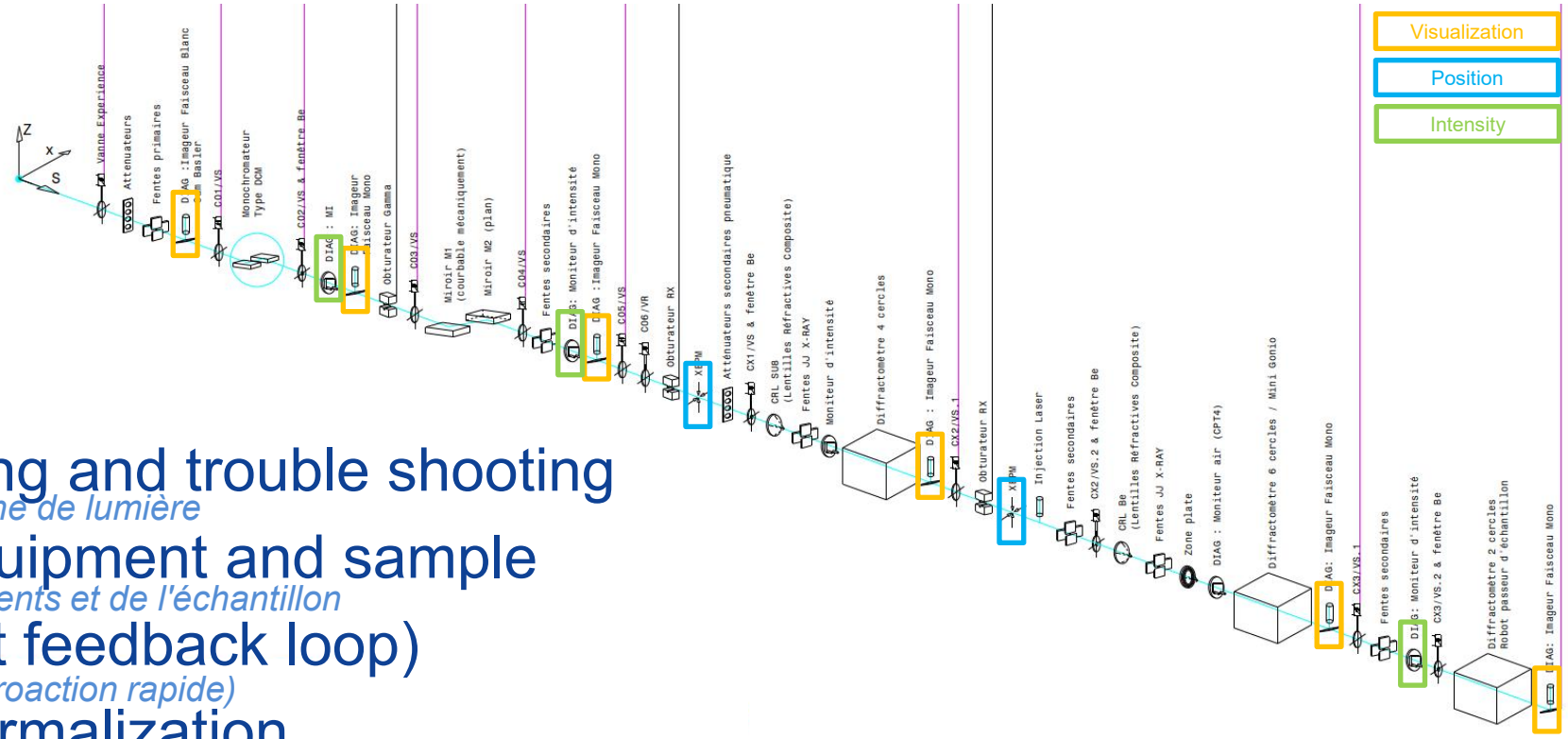


La ligne Cristal Beamline

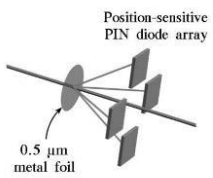


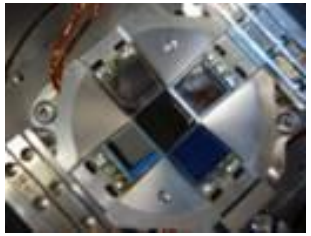
Why X-ray beam diagnostics? / *Pourquoi des diagnostiques?*

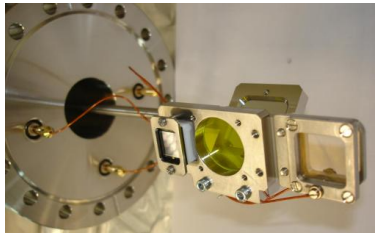
- Beam visualization
  Visualisation du faisceau
- Position monitoring
  Surveillance de la position
- Intensity monitoring
  Surveillance de l'intensité

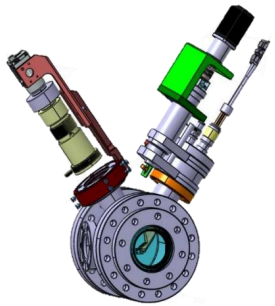


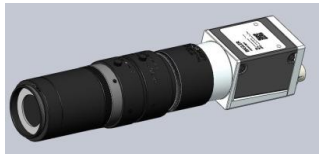
- Beamline commissioning and trouble shooting
  Mise en service et dépannage de la ligne de lumière
- Alignment of optics, equipment and sample
  Alignement des optiques, des équipements et de l'échantillon
- Beam stabilization (fast feedback loop)
  Stabilisation du faisceau (boucle de rétroaction rapide)
- Reference and data normalization
  Référence et normalisation des données

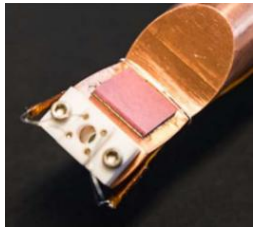


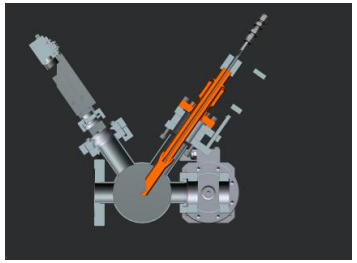












[C. Menneglier et al., Proc. MEDSI'18, Paris, France](); [Desjardins et al. JSR (2014) 21]()

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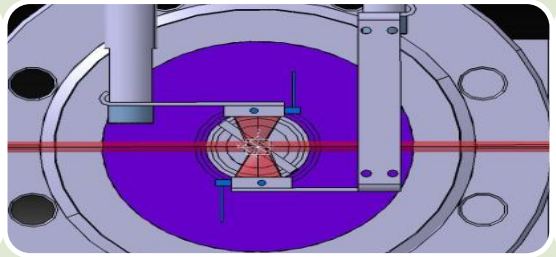
Types of Diagnostic Systems at Soleil

Beam imager

- (Multilayer +) Scintillator + camera

Imageurs faisceau

- *(Multi-couche +) scintillateur + caméra*



Intensity monitor

- Photodiodes, direct / scattering
- Gold mesh
- PMT, ion. Chamber

Moniteurs d'intensité

- *Photo diodes, direct / diffusion*
- *Grille d'or*
- *Chambre d'ionisation*

Position monitor

- Duolateral diamond PSD
- 4 Q-diode
- Alkire: fluo to 4 diodes

Moniteur de position

- *PSD diamant duo-latéral*
- *diodes 4Q*
- *Alkire : fluo vers 4 diodes*

Electronics

- Low current amplifiers

Electronique

- *Amplificateurs à faible courant*

- Femto
- Locum
- Keithley
- Novelec
- Ontrac

Beam Imagers

Imageurs faisceau

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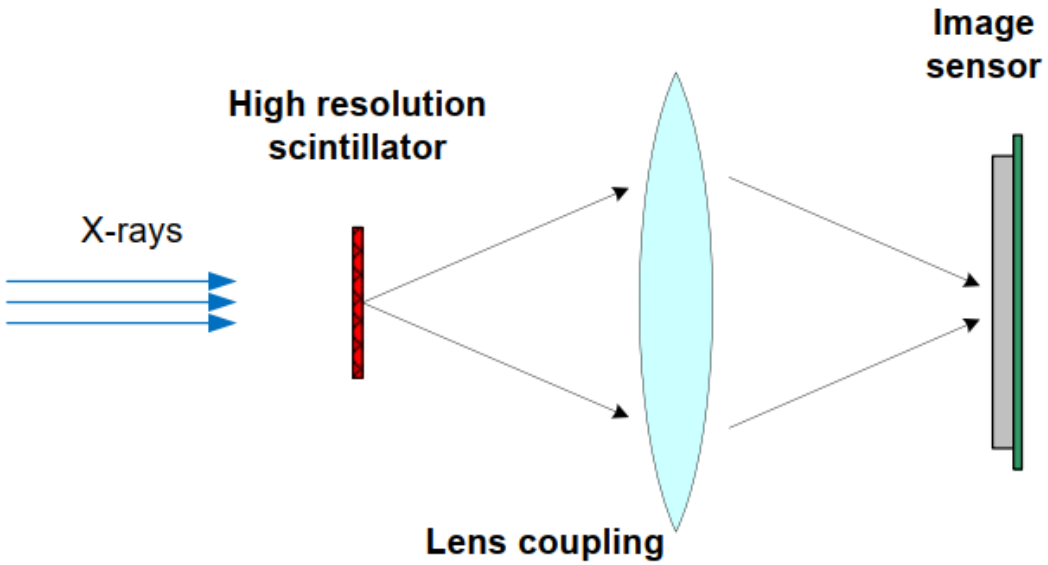
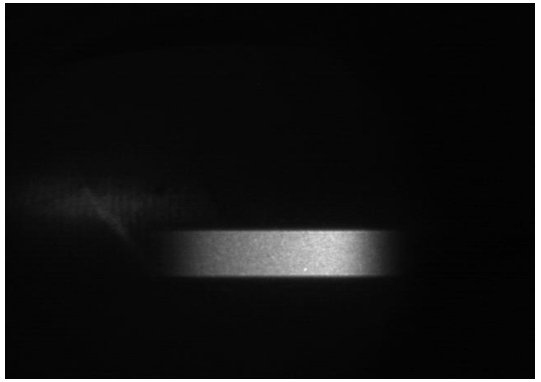
Beam Visualization / *Visualisation du faisceau*

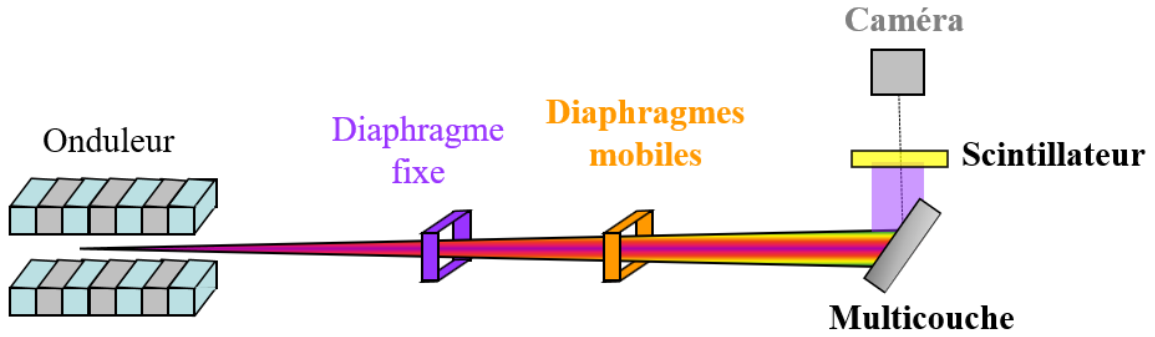




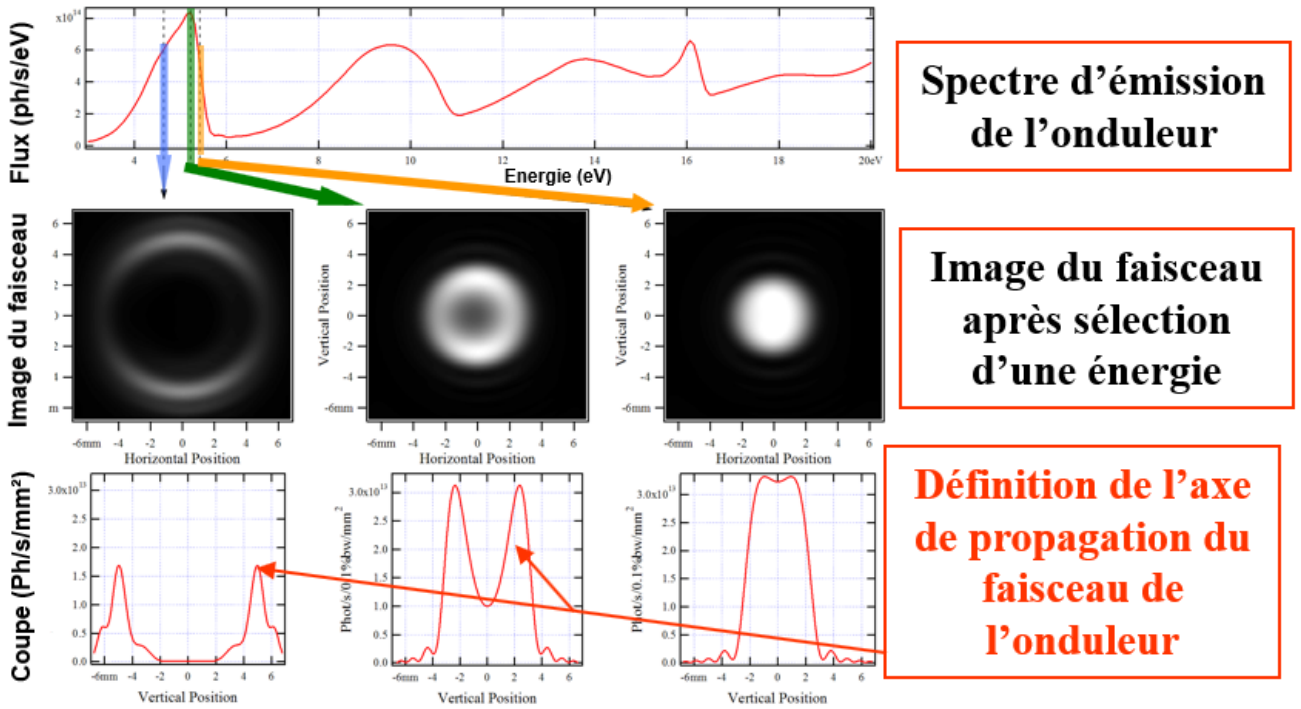
- Visualize the shape and profile of the beam
  Visualiser la forme et le profil du faisceau
- Design constraints ***Contraintes de conception***
  - Scintillator type *Type de scintillateur*
  - Optical resolution *Résolution optique*
  - Cooling *Refroidissement*
  - Mechanical design *Conception mécanique*
  - Vacuum compatibility *Compatibilité avec le vide*

DiagOn imaging system

- Main purpose: **white** beam imager
  - Undulators alignment
  - Diaphragm alignment
  - Undulator diagnostic



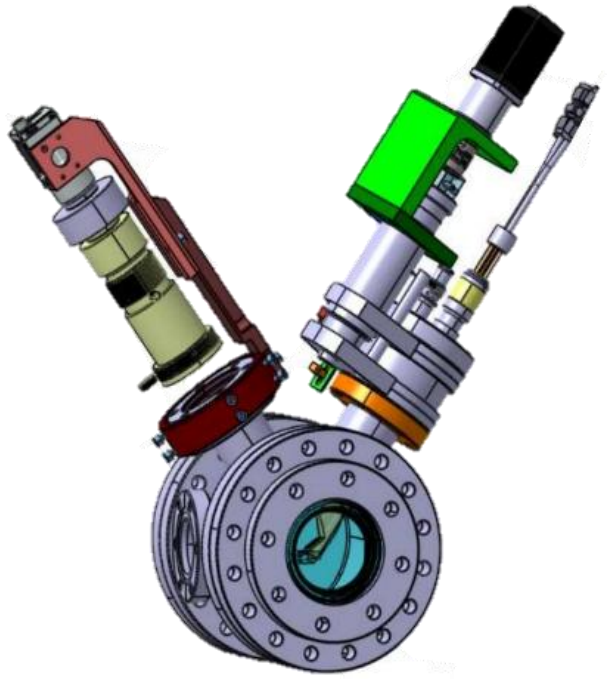
Flux en sortie de l'onduleur HU640 de la ligne DESIR (Simulé par O. Chubar)



Spectre d'émission de l'onduleur

Image du faisceau après sélection d'une énergie

Définition de l'axe de propagation du faisceau de l'onduleur



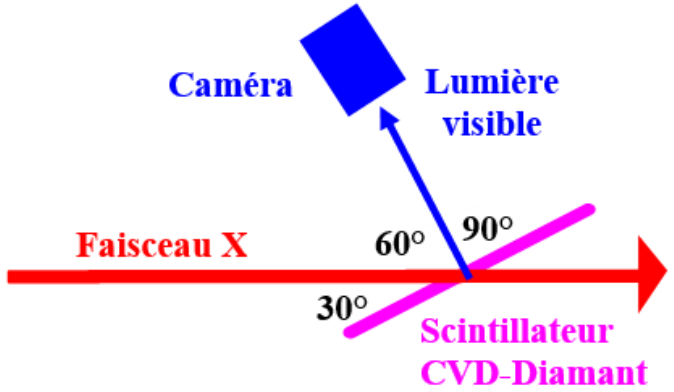
Desjardins et al., IEEE NSS 2008,10.1109/NSSMIC.2008.4774883

Scintillator + Camera

- **Ceramic**: Designed for hard & soft Xray beamlines (undulator & BM)
  pour lignes X durs et mous
- **Diamond**: Designed for hard Xray white beam, undulator sources
  pour lignes X durs, faisceau blanc, sources ondulateur
- **YAG:Ce / LuAG:Ce / YAP:Ce**: Designed for monochromatic hard & soft Xray
  pour faisceau monochromatique, X durs et mous

Scintillator	Beam *Faisceau*	Power *Puissance* [W]	dP [W/mm²]	Dimension
Ceramic	white	343	1	Few cm²
Ceramic	pink	30	30	1 mm²
YAG:Ce	mono.	< 1	< 1	mm² to cm²
Diamond	white	90	72	1.5 x 0.8 mm²

Beam estimation by T. Moreno

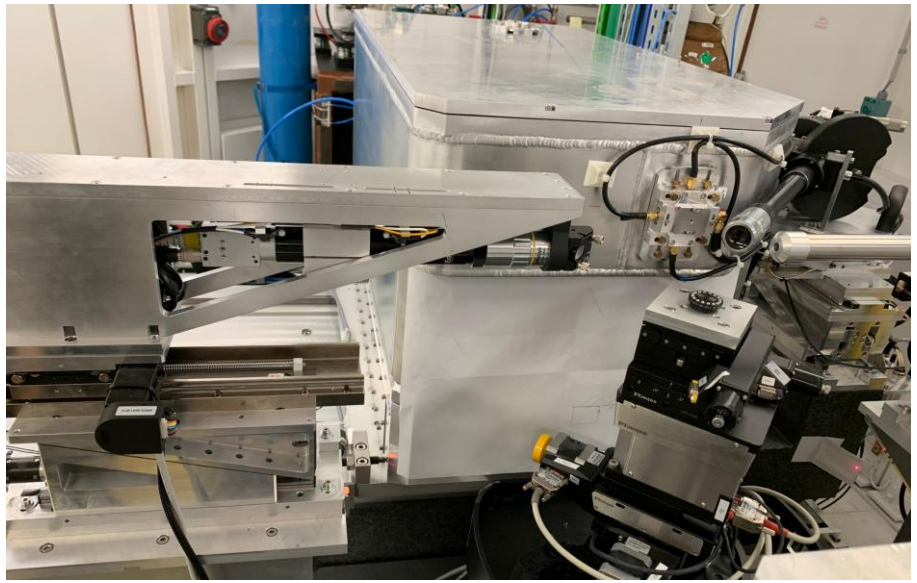


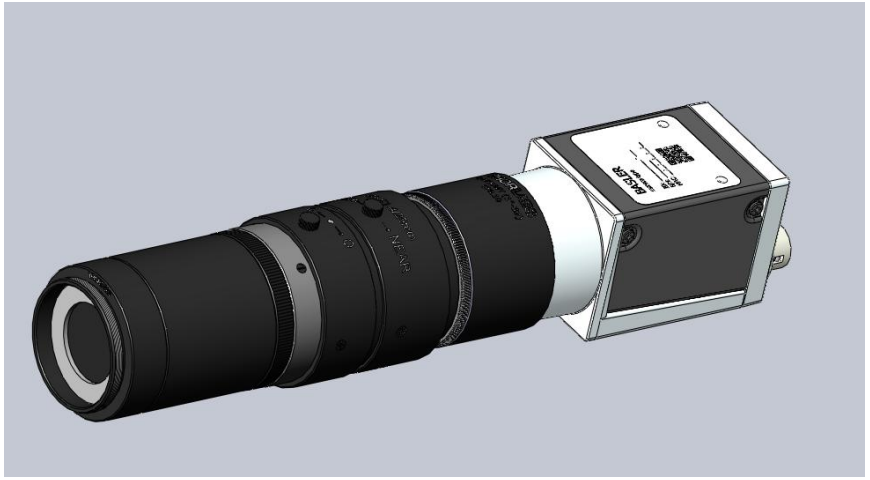
High magnification vizualizer

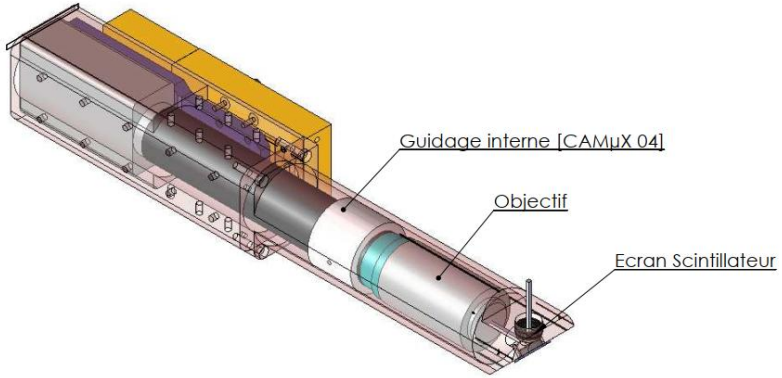
- Designed for beam size < mm², hard Xray

Conçu pour des faisceaux de taille < mm², rayons X durs

Optical characteristics	
Scintillator	Clear polished YAG:Ce / LuAG:Ce 20µm thick
Résolution	< 1 µm
Optical magnification	x0,5 to x20







Position Monitors

Moniteurs de position

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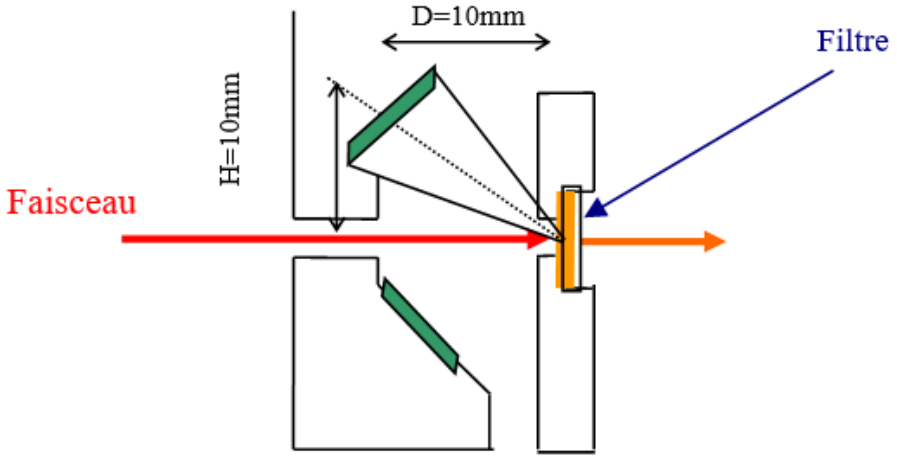
Xray Beam Position Monitors

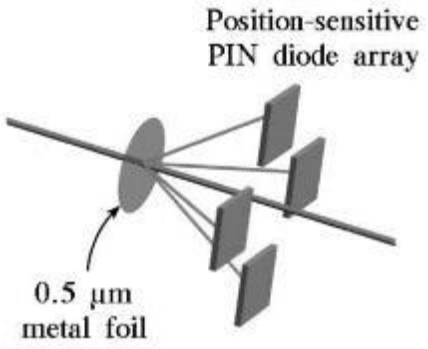
Indirect detection

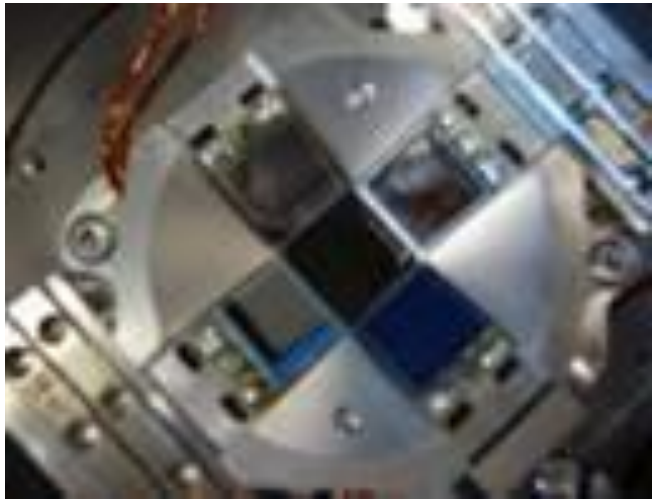
- Scatterer (e.g. Kapton foil) + 4 photo diodes
  - Alkire design
- + low current amplifier + electronics for readout



Détection indirecte

- *Diffuseur (p.ex., feuille de Kapton) + 4 photodiodes*
  - *Conception d'Alkire*
- *+ amplificateur de faibles courants + électronique de lecture*



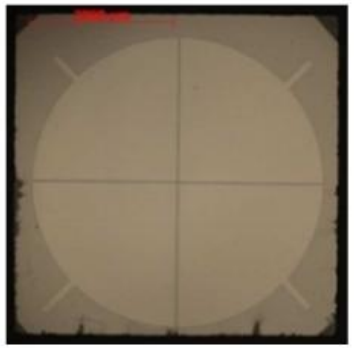


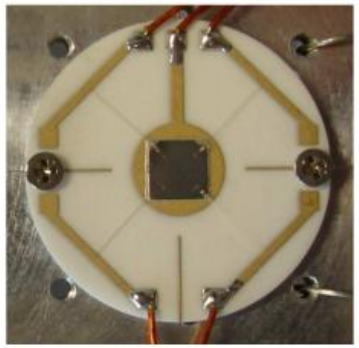
Alkire et al, JSR (2000) 7

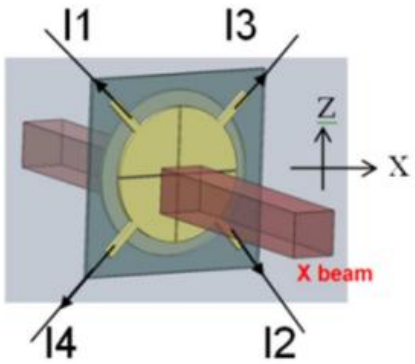
XBPMs / Position Sensitive Detectors

Direct detection

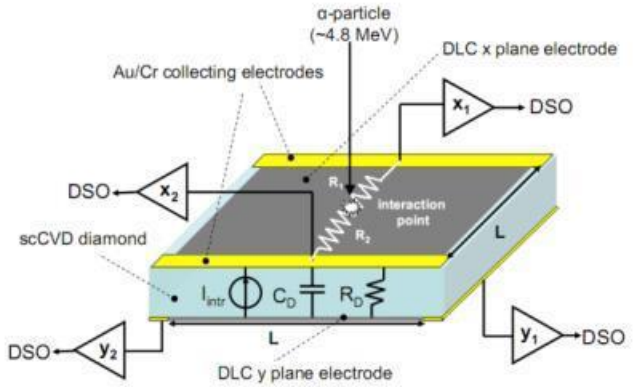
- Silicon or diamond or SiC
- 4 Quadrant design







- Duo-lateral / resistive design



[Desjardins et al, JSR (2014) 21](#) ; [Desjardins et al, JSR (2018) 25](#)

Intensity Monitors

Moniteurs d’intensité

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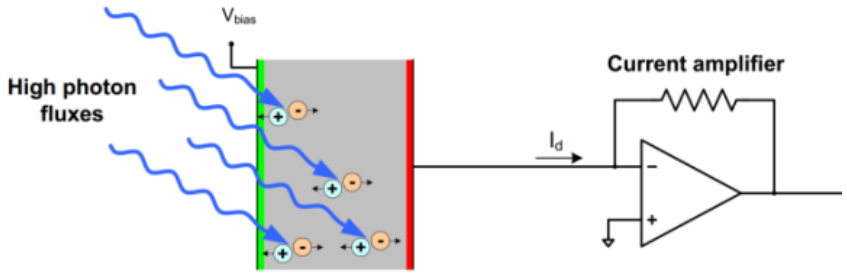
Intensity Monitor

- Direct measurement
  - Photodiode
  - Diamond
  - (PSD)
- Scattering / fluo. measurement
  - Foil + photodiode
  - (QBPM)



- *Mesure directe*
  - *Photodiode*
  - *Diamant*
  - *(PSD)*
- *Mesure par diffusion / fluorescence*
  - *Feuille + photodiode*
  - *(QBPM)*

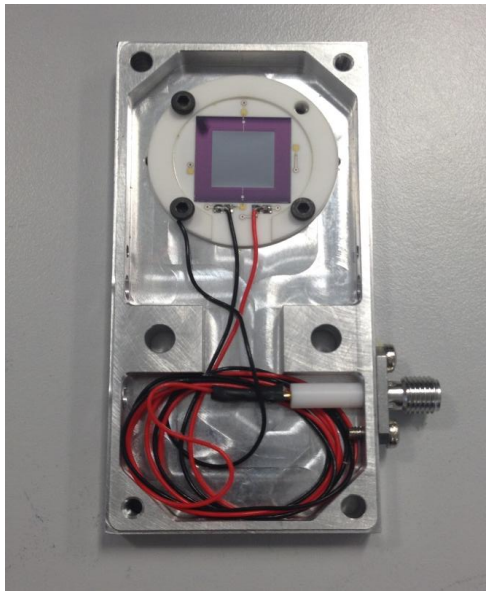
- Readout current electrometer
  - *Femto* current to voltage amplifier
    - Digitalisation
  - *Keithley 486* current monitor
- ~100 devices
  - At all beamlines

- *Électromètre à lecture de courant*
  - *Amplificateur à transimpédance Femto*
    - *Numérisation*
  - *Moniteur de courant Keithley 486*
- *~100 appareils*
  - *Sur toutes les lignes de lumière*

Examples of Intensity monitors

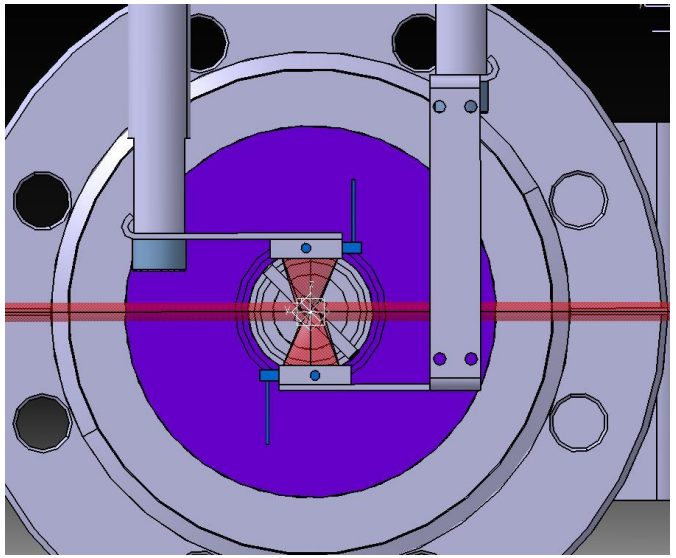
Direct photo diode

Diode photoélectrique directe



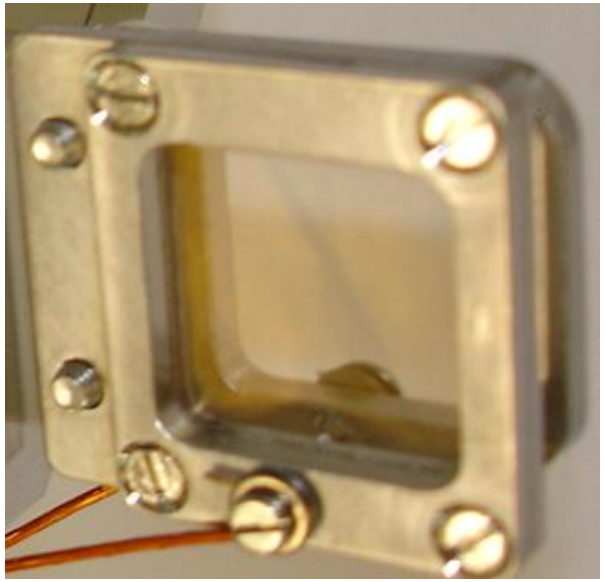
Scattering

Diffusion



Gold mesh (for soft X-rays)

Grille d'or (pour X mou)



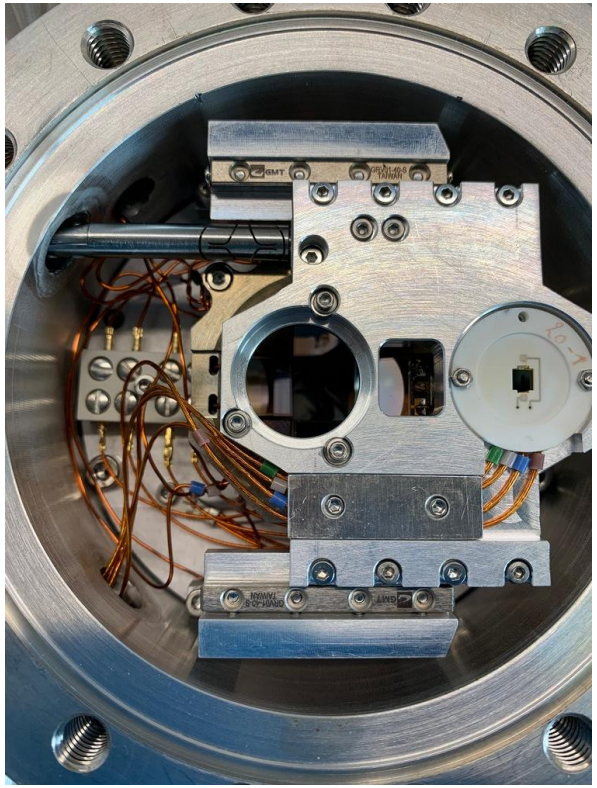
+ readout electronics (e.g. Keithley)

+ électronique de lecture (p.ex., Keithley)

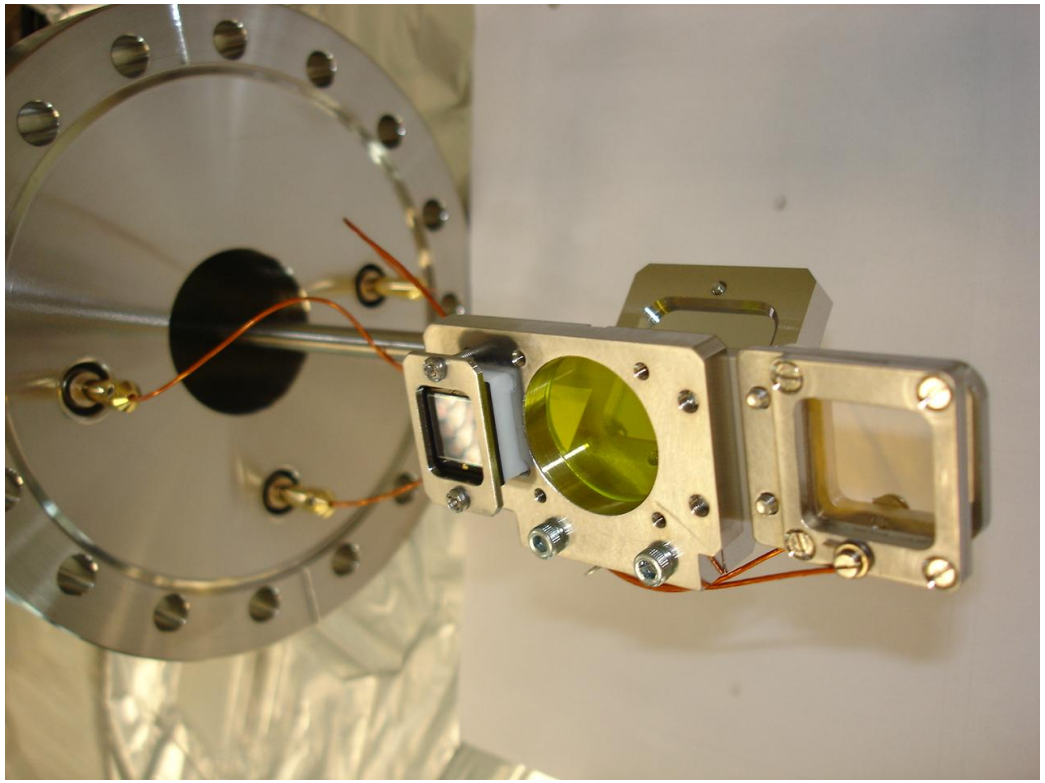
Wait, there is more

- Ionisation Chamber
- Current on mirrors
- Frankenstein's Monsters

QBPM + PSD Diamond



PYG : Photodiode / YAG / Gold mesh



From SOLEIL SYNCHROTRON to SOLEIL II La science éclaire l'avenir Science lights up the future

Roadmap & Developments

SOLEIL II
La science éclaire l'avenir
Science lights up the future

Diagnostic Systems at SOLEIL and SOLEIL II

What for? Monitor the beam's intensity, position & shape
→ for equipment & sample alignment, reference & data normalization

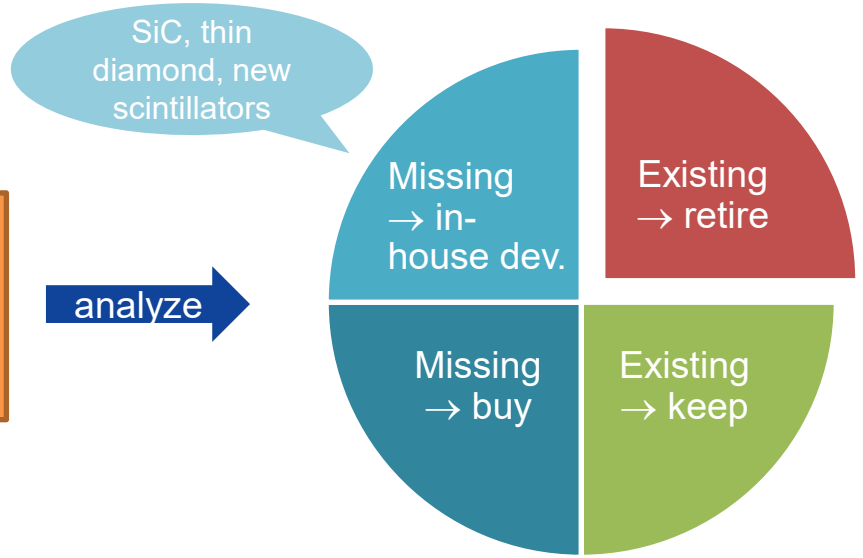
Pourquoi? *Surveiller l'intensité, la position et la forme du faisceau → pour l'alignement de l'équipement et de l'échantillon, pour références et pour normaliser les données*

Today / *Aujourd'hui*
- 368 devices installed
- 13 different types, highly customized

Beam imager
Beam position
Intensity monitor

Matching electronics

analyze



condense

Goal / *Objectif*
- Few default systems
- Easy to manage & maintain
- Ensure flexibility

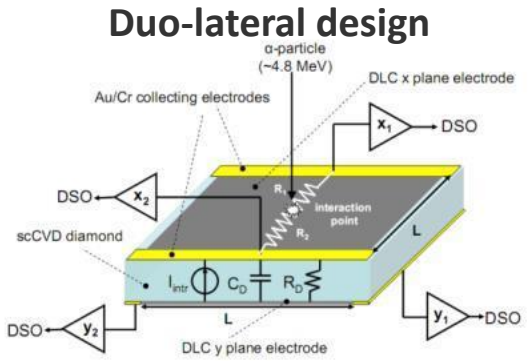
49 new + 90 updated diagnostics to be installed

New developments required for soft X-rays + spatial resolution

Roadmap: Keep review drop new
368 diagnostics devices: 266 + 90 -12 + 49 ➔ **405**
Ca 1 M€ and 3 developments

Approaches for soft X-ray diagnostics

Thin Diamond rXBPM



- 12 + 14 new devices on 18 beamlines
- ➢ Need to reproduce **3-5 µm thin** rXBPMs
- ➢ Master resistive carbon deposition
- C2N, CINEL, CEA, Lumin, BNL, DiamFab

Desjardins et al, JSR (2014) 21

SiC (r)XBPM + Electronics

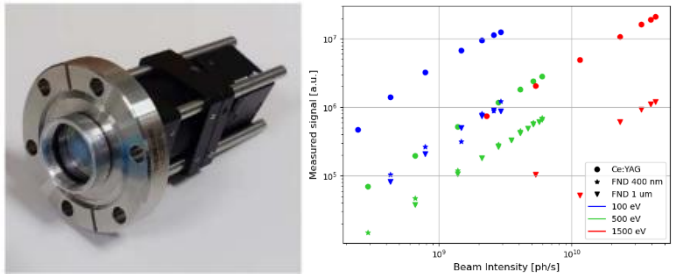
- Radiation hard
- Testing 220nm thin membranes with 4Q or rXBPMs by SENSIC
- Combined with (fast feedback) **electronics** from STLAB

Trovato et al, (2025), JACoW, 14th IBIC

FIBIEX

Await funding

FND-based in-situ beam imager for EUV and soft X-rays



- Based on fluorescent nanodiamonds
- Semi-transparent for soft X-rays
- Thin electrosprayed layers
- Negligible afterglow

Y. Y. Hui et al., RSC Adv., 2025, 15, 1011-1019
H.-C. Lu et al., 2020, ACS Appl Mater Interfaces, 12, 3

Questions ?


dank je
gràçie
спасибо
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