



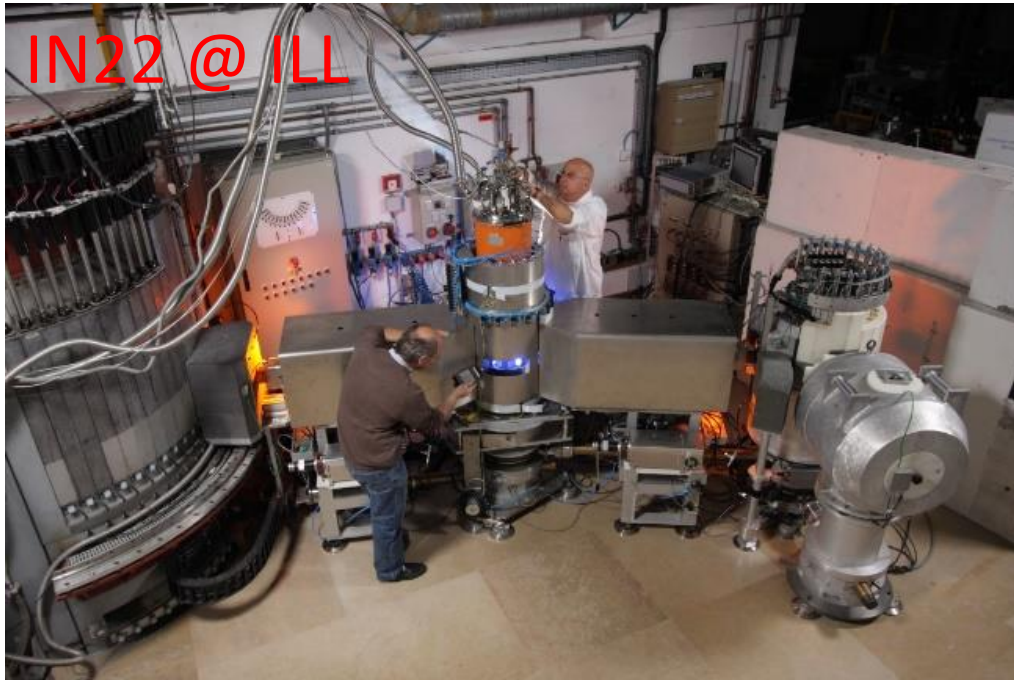
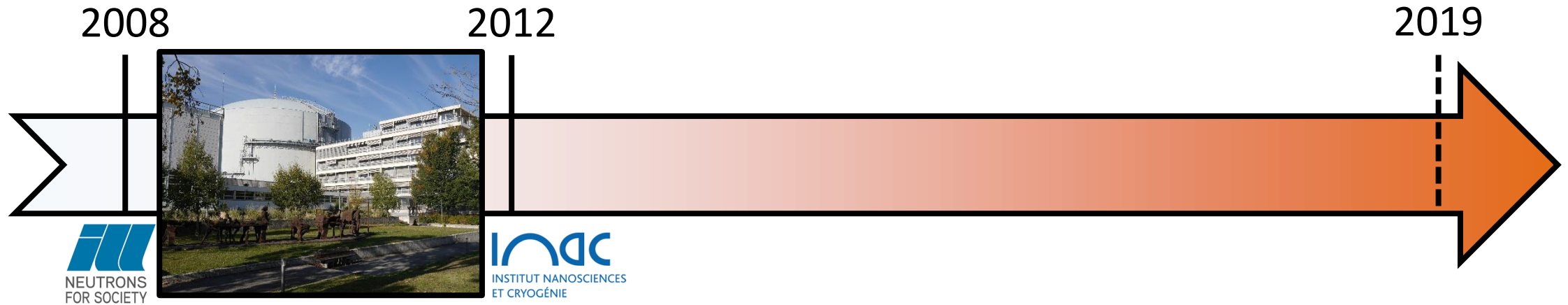
Concours IR2 BAP C no. 19

"Expert en développement d'instrumentation"

Nicolas Martin



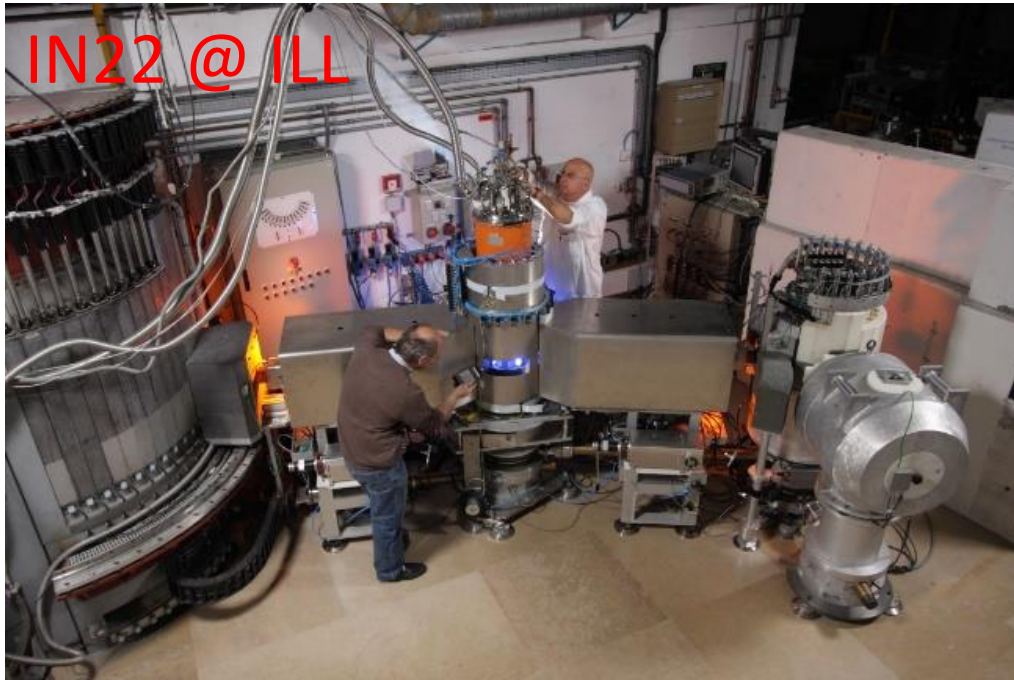
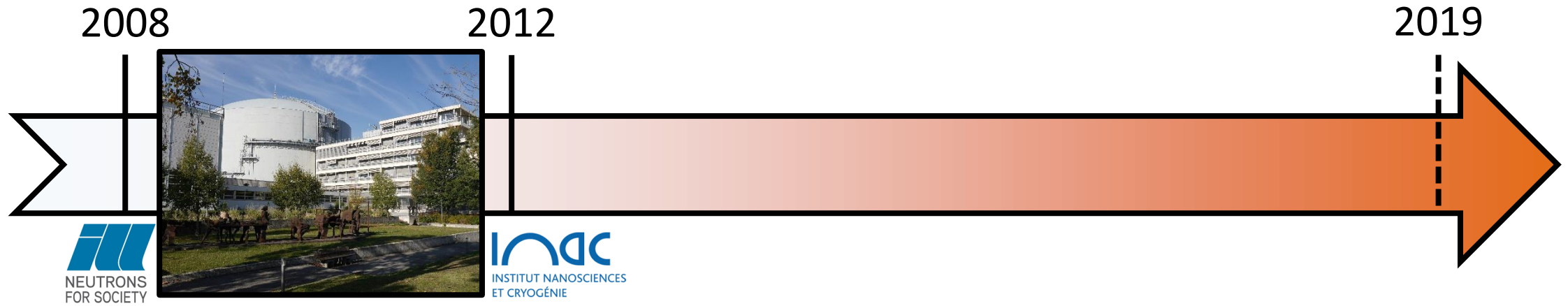
Mon parcours scientifique



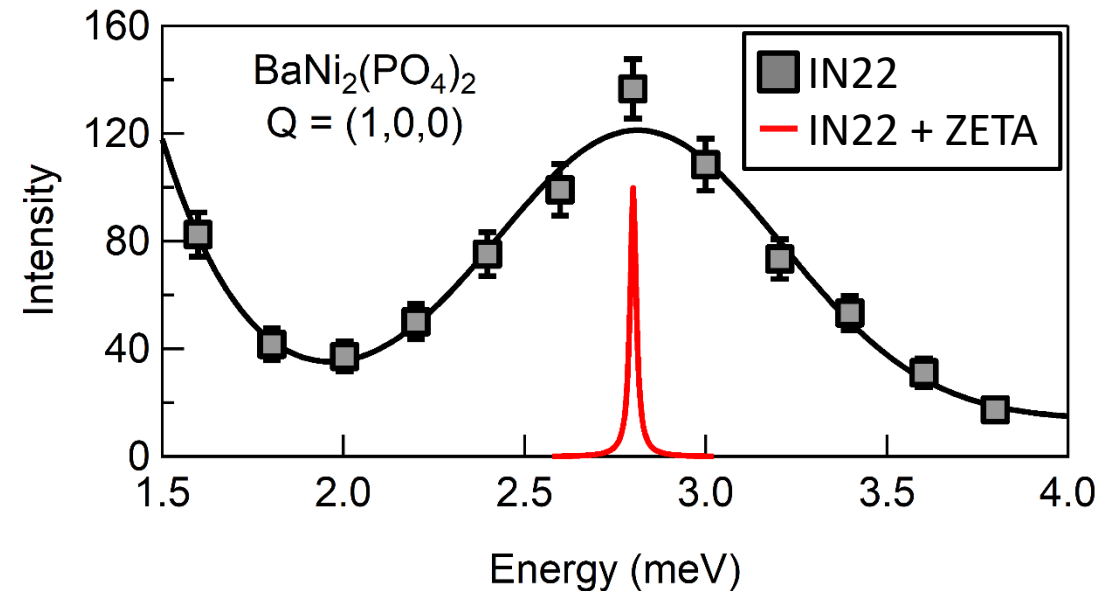
Thèse en Physique des Matériaux (L.-P. Regnault)

- Systèmes magnétiques de basse dimension
- Echo de spin neutronique résonant ("**ZETA**")

Mon parcours scientifique

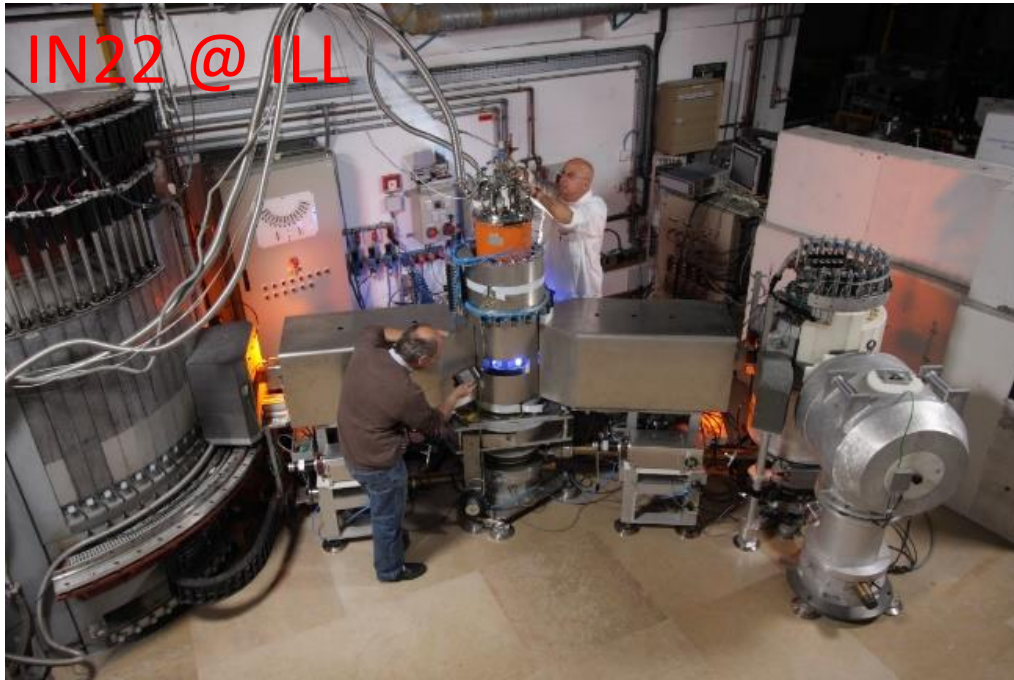
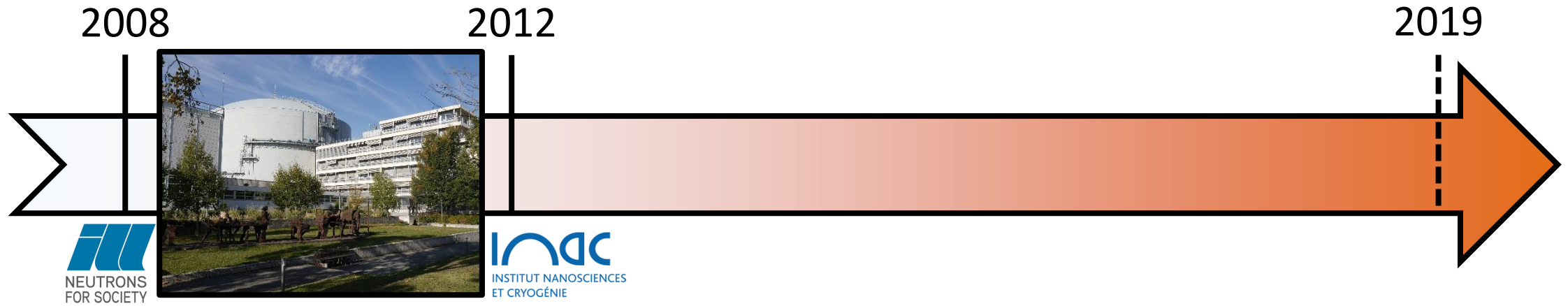


→ Spectroscopie à haute résolution ($\Delta E \approx 10 \mu\text{eV}$)

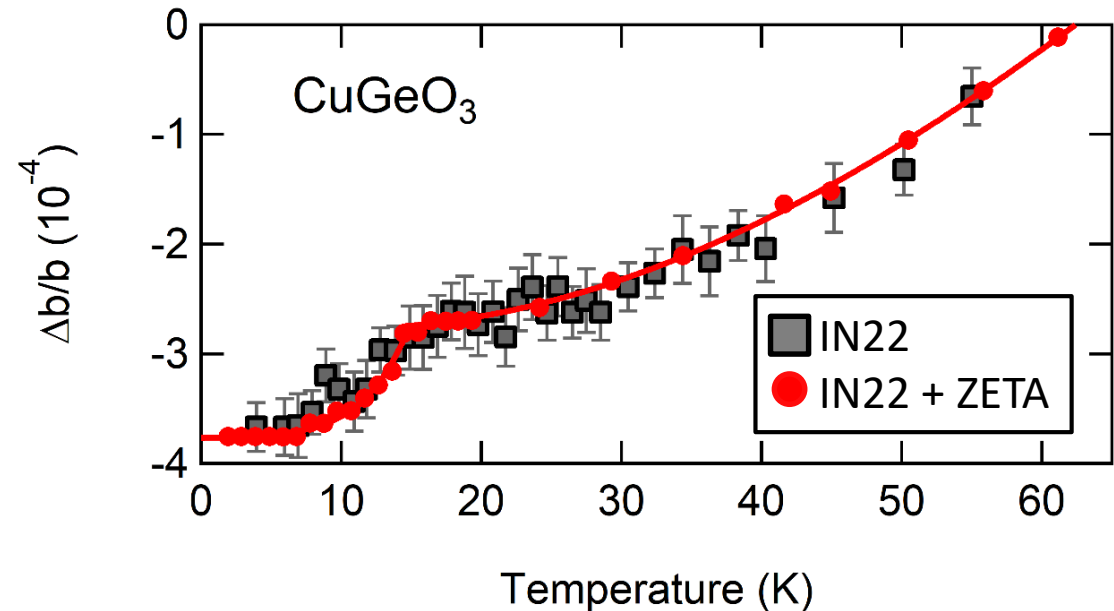


N. Martin (co-auteur), Phys. Rev. Lett. **109**, 097201 (2012)

Mon parcours scientifique

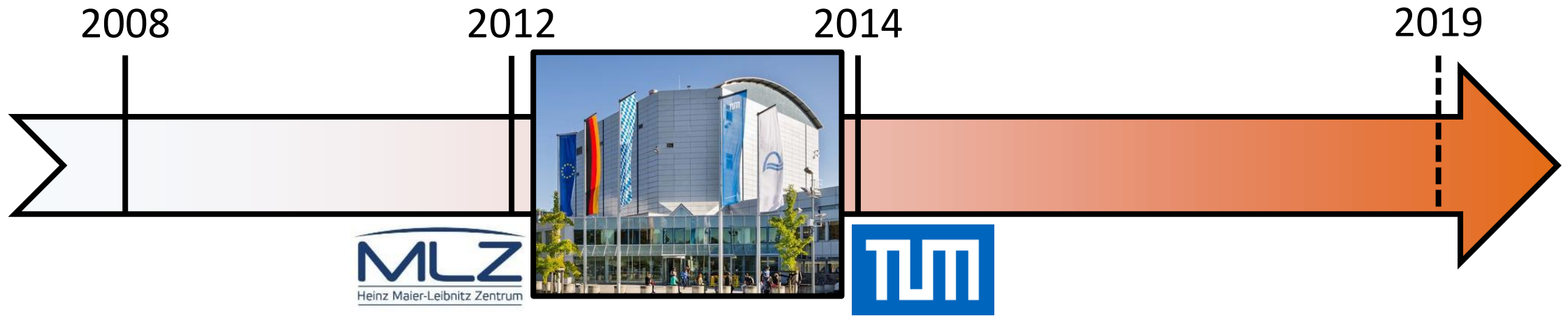


→ Diffraction à haute résolution ($\Delta d/d \approx 10^{-6}$)



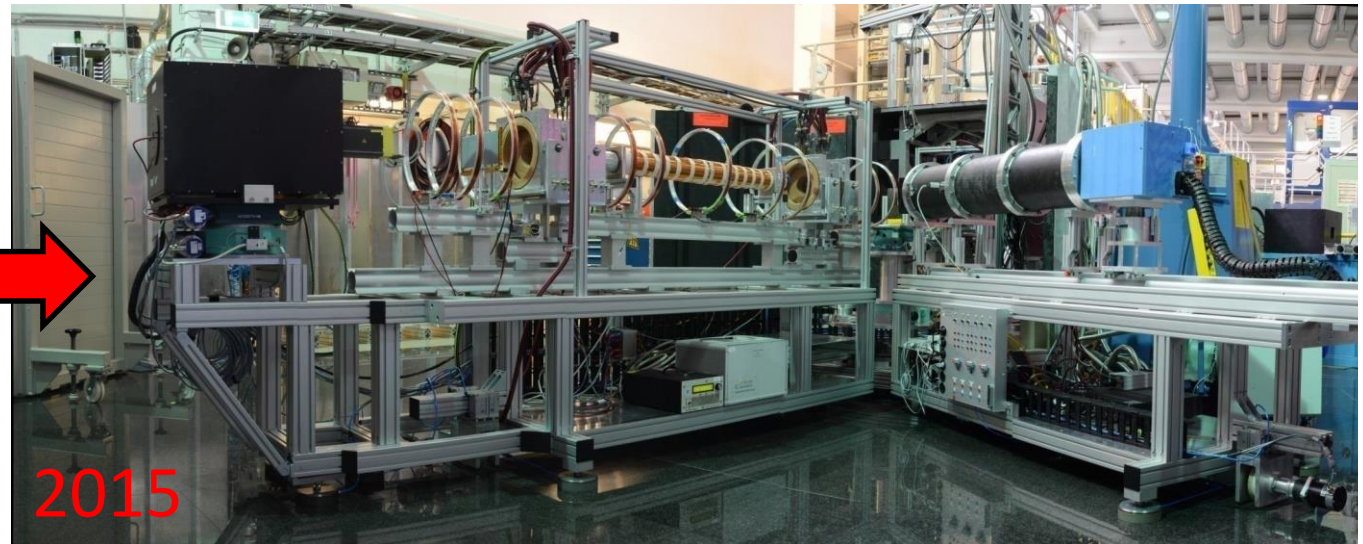
N. Martin *et al.*, Physica B **406** (2011) 2333-2336

Mon parcours scientifique

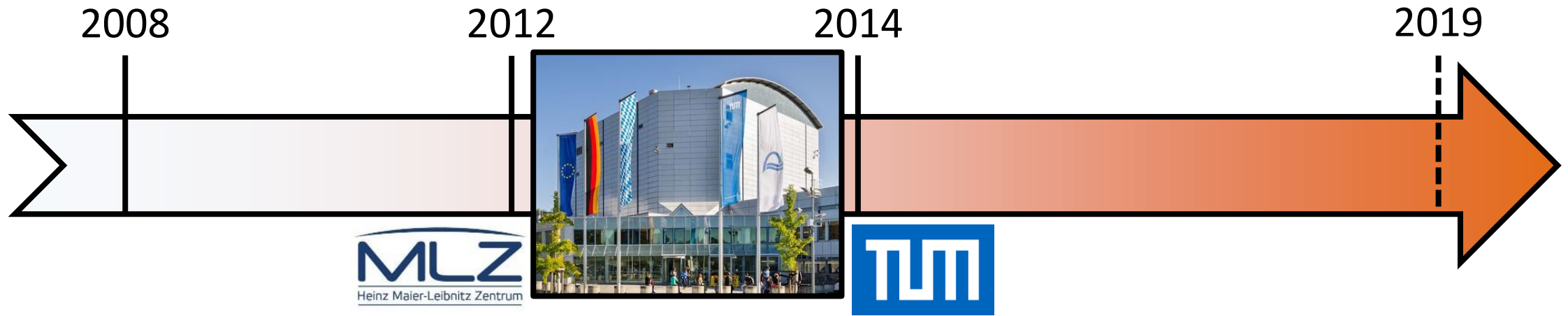


PostDoc #1: Co-responsable de l'instrument RESEDA

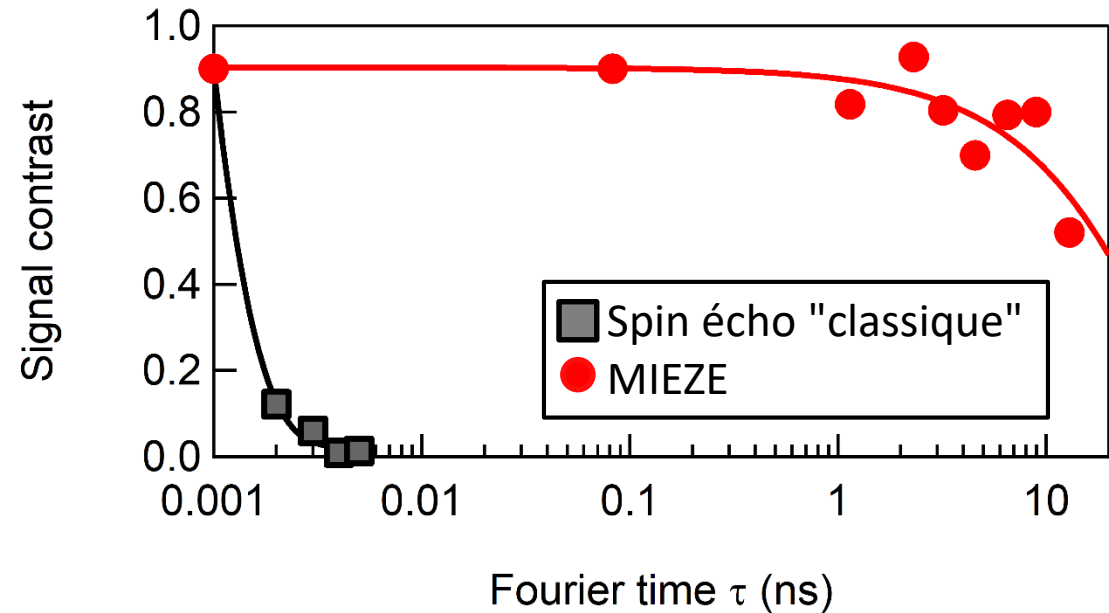
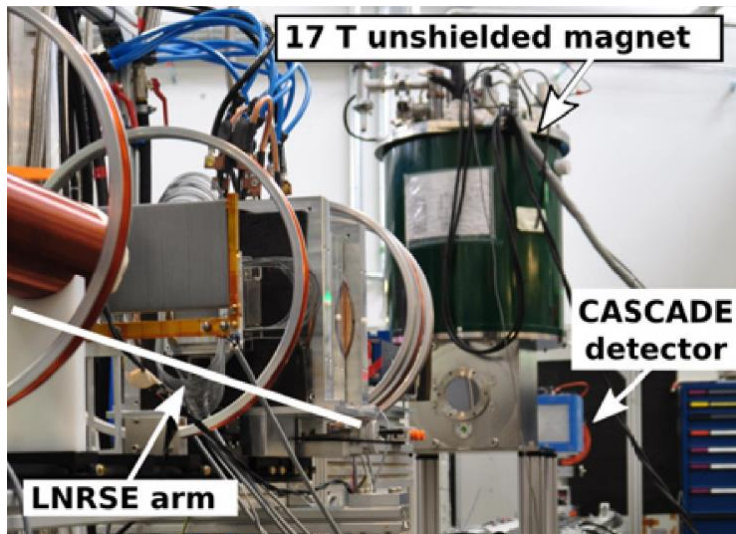
→ "Upgrade" complet de l'instrument (électronique, mécanique, protection biologique et détection)



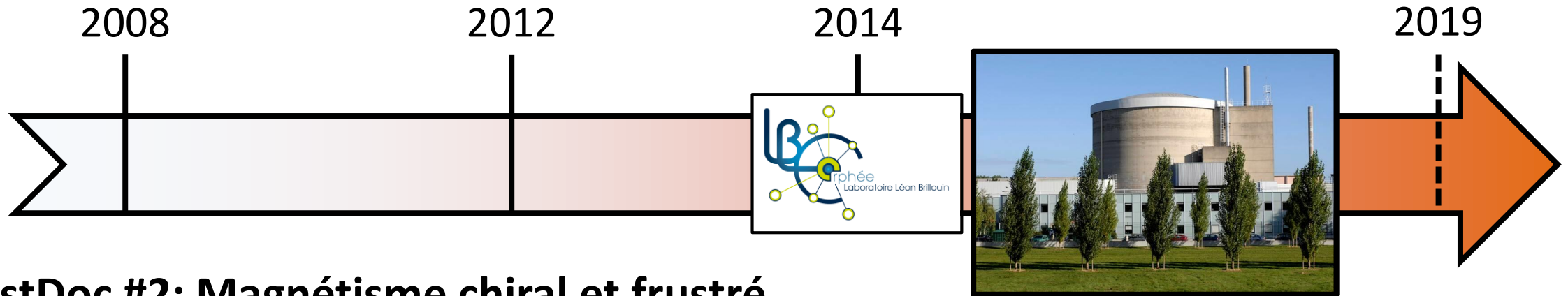
Mon parcours scientifique



→ Mise en place d'une option "**MIEZE**" (écho de spin sous fort champ magnétique)



Mon parcours scientifique



PostDoc #2: Magnétisme chiral et frustré (I. Mirebeau)

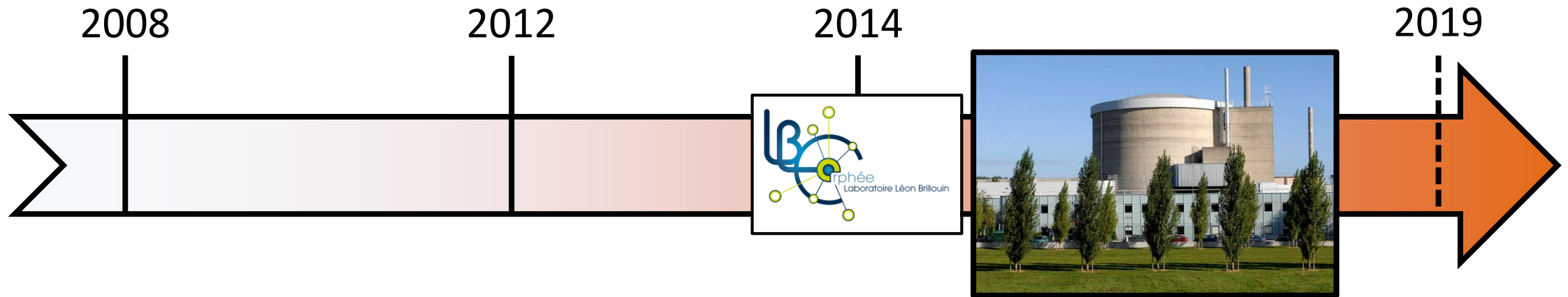
- ✓ Spectroscopie (HAXPES, XMCD)
+ diffraction de poudre sous haute pression en synchrotron
- ✓ Rotation du spin du muon (μ SR)
- ✓ Diffusion neutronique

→ **Diffusion aux Petits Angles**



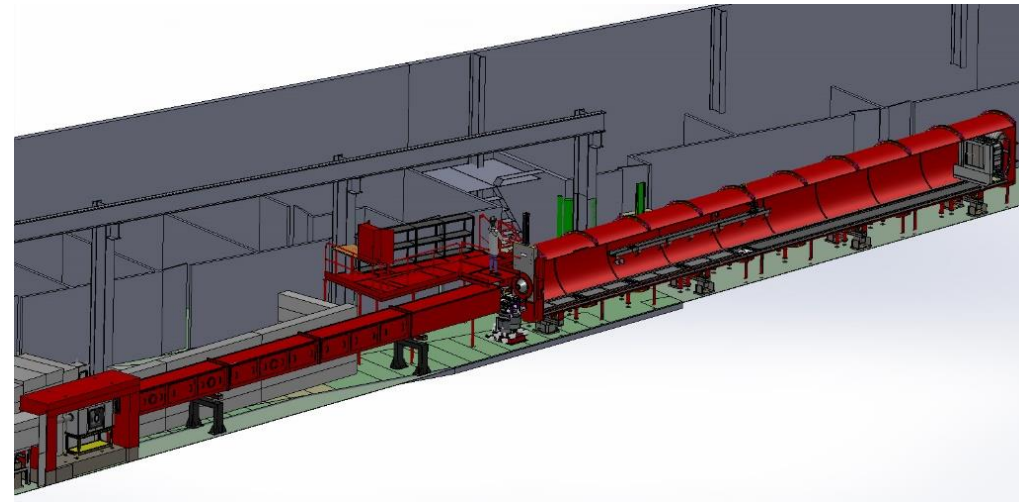
N. Martin et al., PRB **93**, 174405 (2016)
N. Martin et al., PRB **93**, 214404 (2016)
N. Martin et al., PRB Rapid Comm. **96**, 020413 (2017)
N. Martin et al., PRX **7**, 041028 (2017)
N. Martin (co-auteur), PRB **96**, 184416 (2017)
I. Mirebeau, N. Martin et al., PRB **98**, 014420 (2018)
N. Martin et al., PRB Rapid Comm. **99**, 100402 (2019)

Mon parcours scientifique

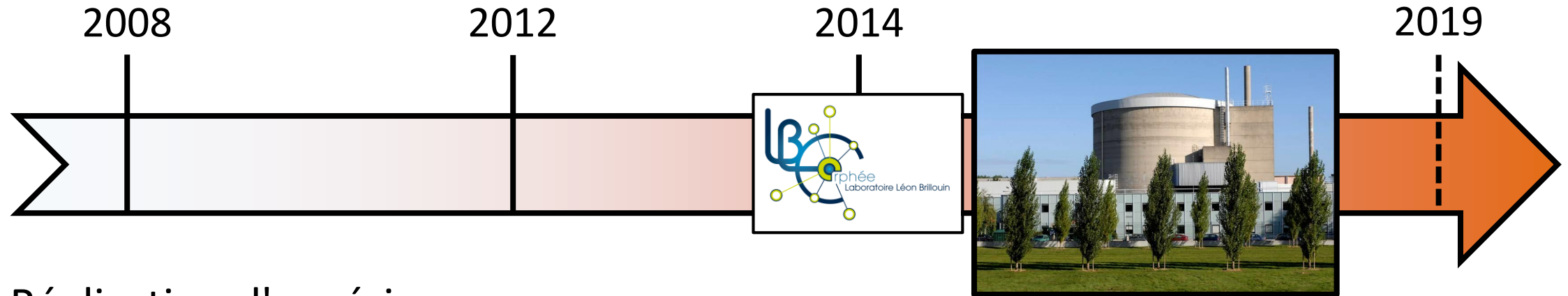


Depuis 2016: Co-responsable de l'instrument PA20

→ Développement des activités en matière "dure" et magnétisme



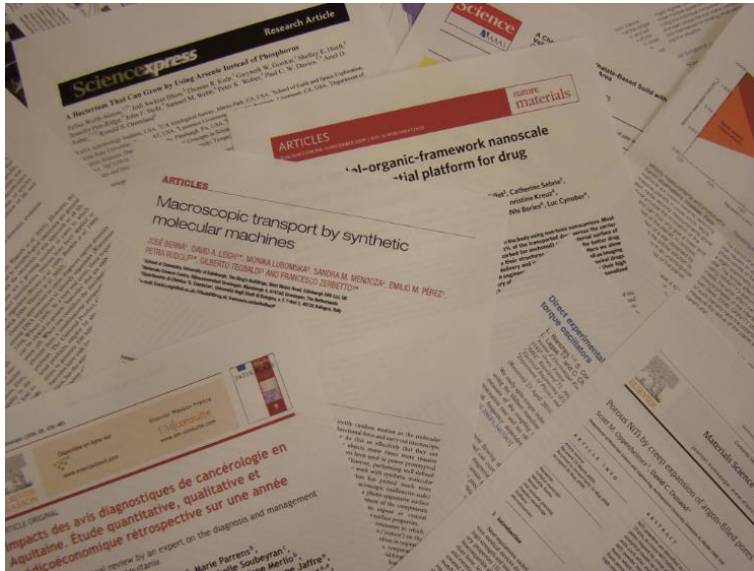
Mon parcours scientifique



- Réalisation d'expériences
- Maintenance de l'instrument
- Gestion des environnements échantillon (*basses températures et forts champs magnétiques*)
- Aide à l'analyse des données
- Développement de cellules pression 30 kbar "compactes" pour la DNPA (*collab. R. Sadykov, Moscou, Russie*)



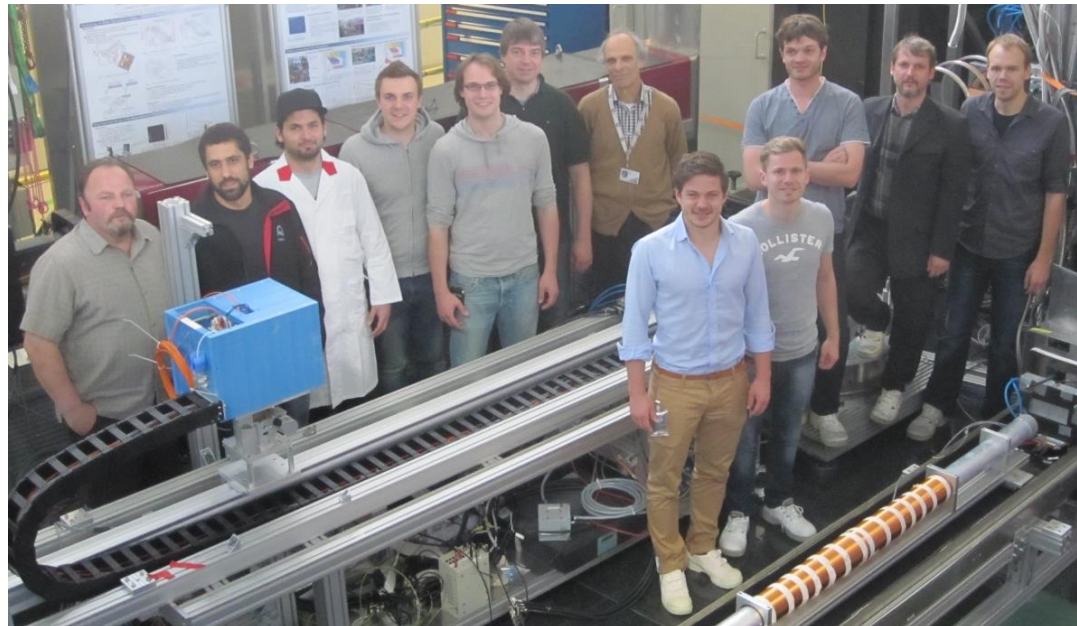
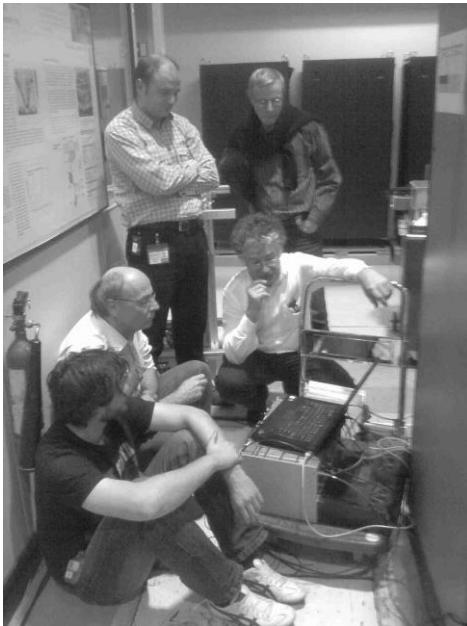
Valorisation des travaux



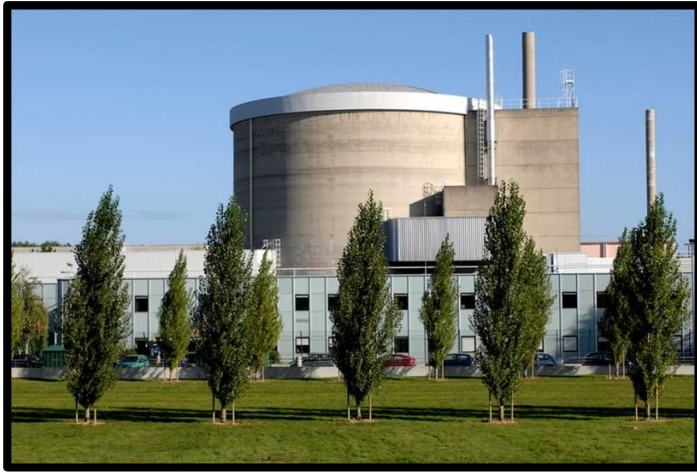
- ✓ **23 publications + 3 en cours de relecture**
 - dont 1 Phys. Rev. X et 5 Phys. Rev. B en 1^{er} auteur
 - ≈ 360 citations (indice h = 10)
- **Magnétisme et instrumentation pour la neutronique**
- ✓ **Invitations en conférences (ECNS 2019) et workshops (WE-Heraeus-Seminar 2020) internationaux + séminaires et réunions thématiques en France**
- ✓ **Relecteur pour l'*American Physical Society* et le *Nature Publishing Group***

Collaborations et encadrement

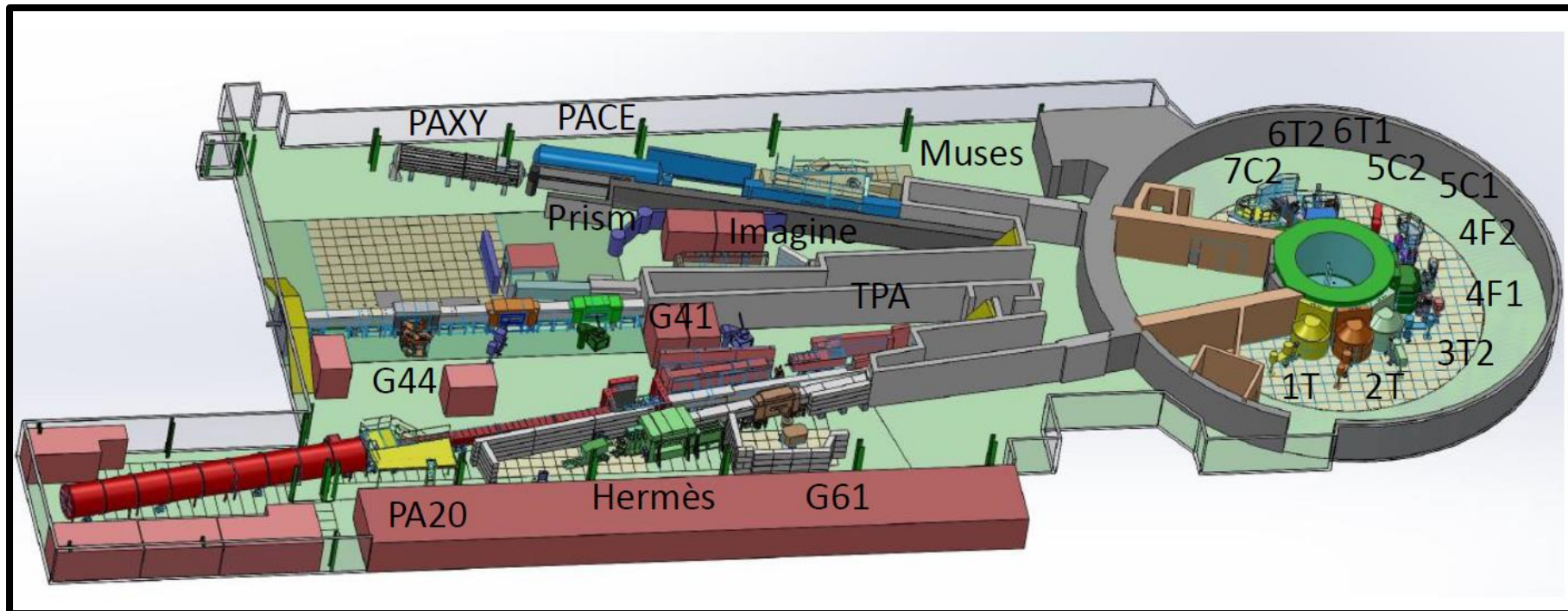
- ✓ **Travail en équipe**
- ✓ **Collaborations** nationales et internationales (*Allemagne, Russie, Japon*)
- ✓ **Accueil d'utilisateurs** "*de la proposition à la publication*"
- ✓ **Encadrement d'étudiants et de jeunes chercheurs** en physique et informatique (*2 niveau Licence, 3 niveau Master et 1 Post-Doc*)



Le Laboratoire Léon Brillouin



- ✓ Centre national de diffusion neutronique
- ✓ 21 instruments (spectroscopie, réflectométrie, diffraction et petits angles)
- ✓ Expertise technique et scientifique internationalement reconnue



Le Laboratoire Léon Brillouin

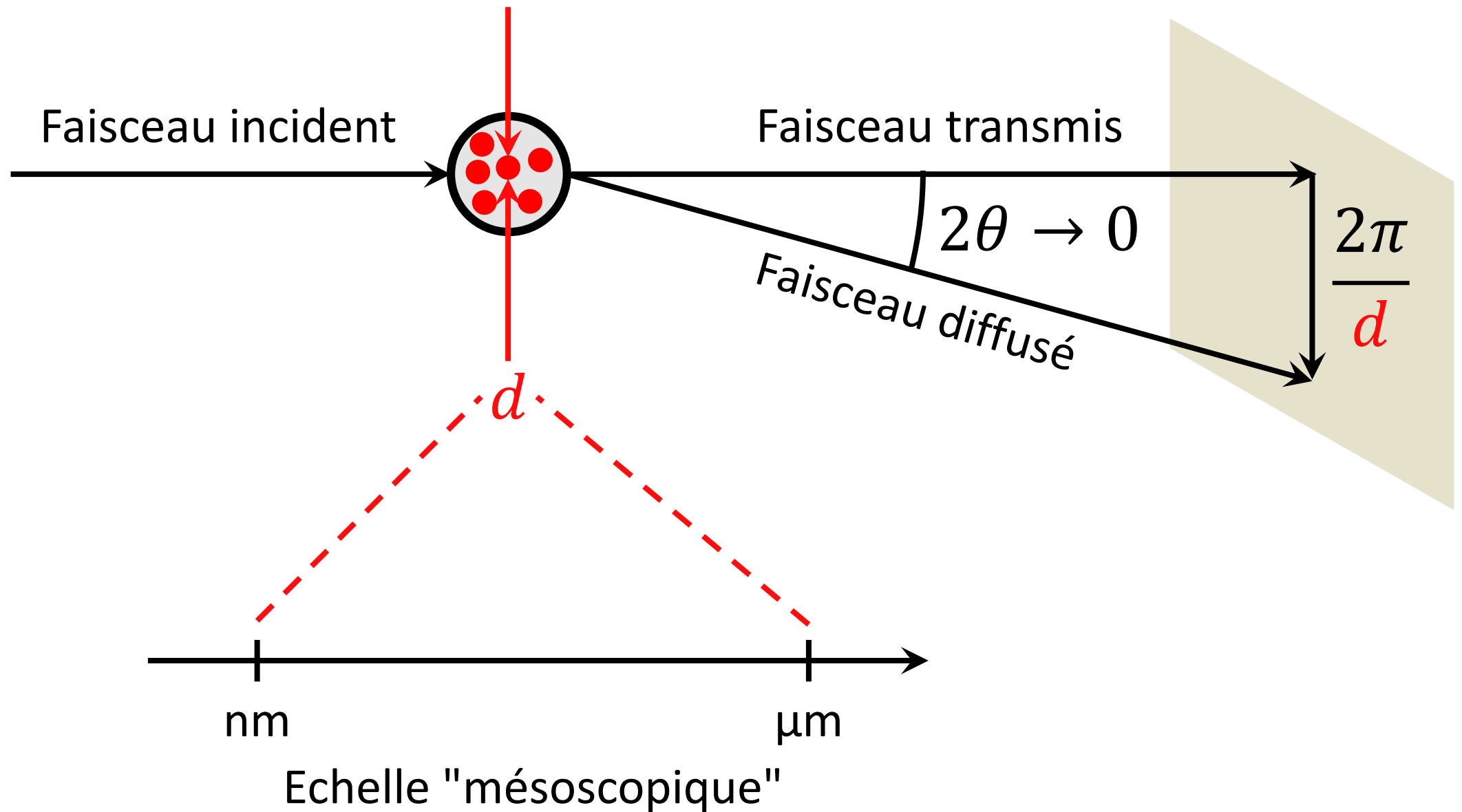


- ✓ **Centre national de diffusion neutronique**
- ✓ **21 instruments** (spectroscopie, réflectométrie, diffraction et petits angles)
- ✓ **Expertise technique et scientifique** internationalement reconnue

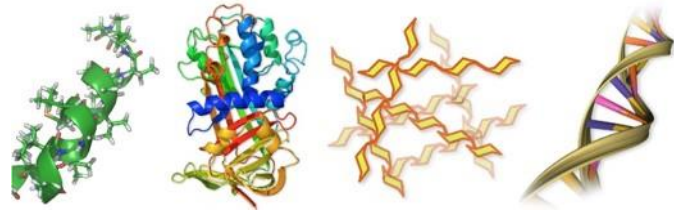
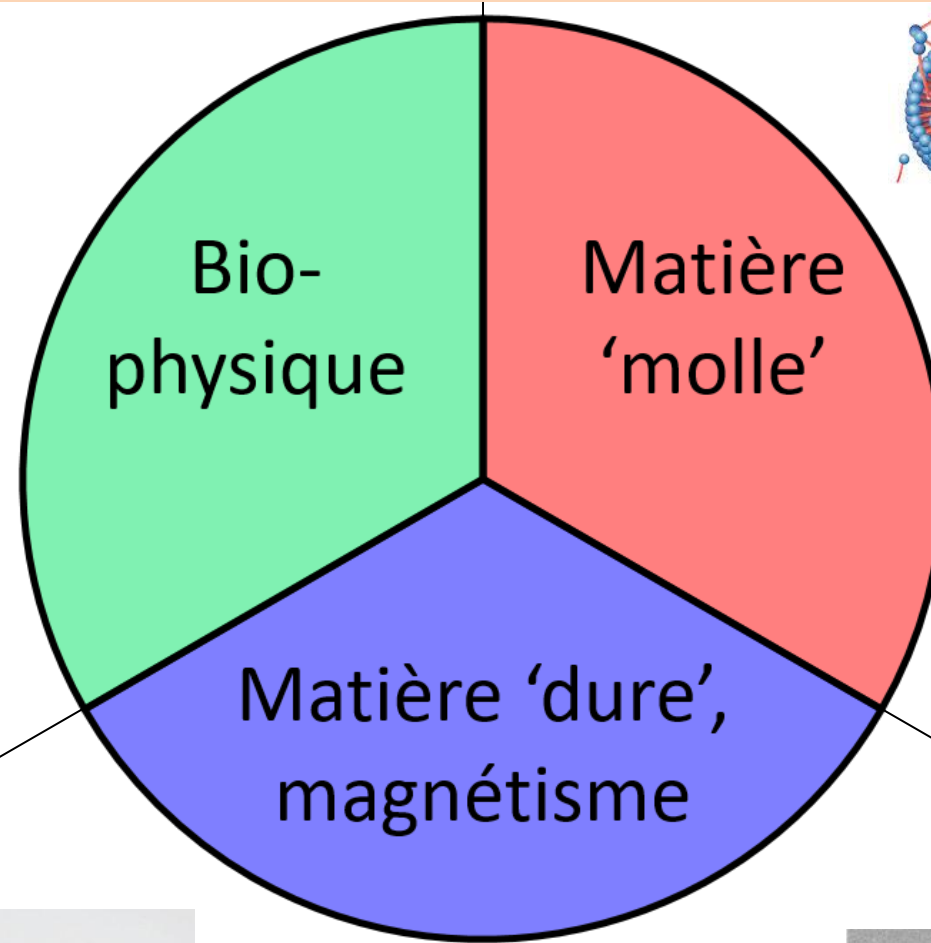
Arrêt du réacteur Orphée le 28 octobre

- ✓ Opportunité de se ré-inventer
- ✓ Mise en place de projets instrumentaux
- ✓ Importance donnée aux "petits angles"

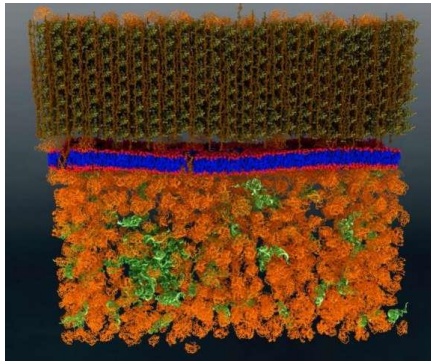
Diffusion des neutrons aux petits angles: une technique universelle



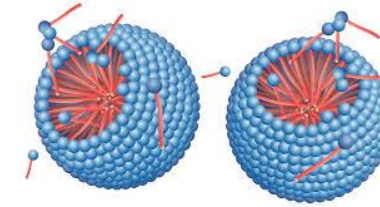
Diffusion des neutrons aux petits angles: une technique universelle



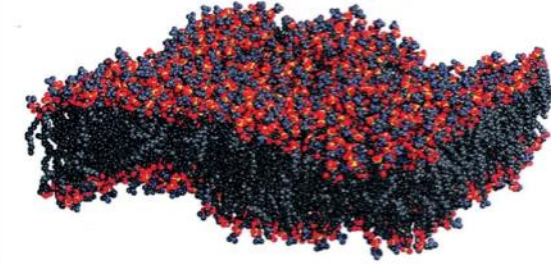
Macro-molécules du vivant



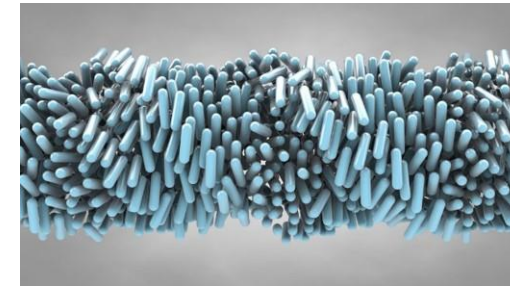
Membranes



Micelles



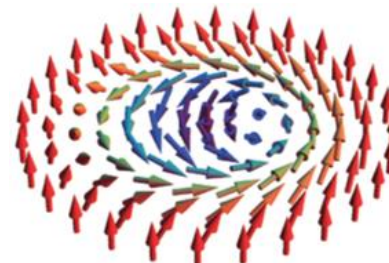
Polymères



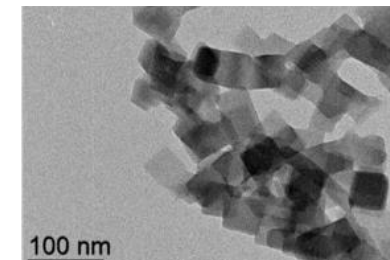
Cristaux liquides



Métallurgie

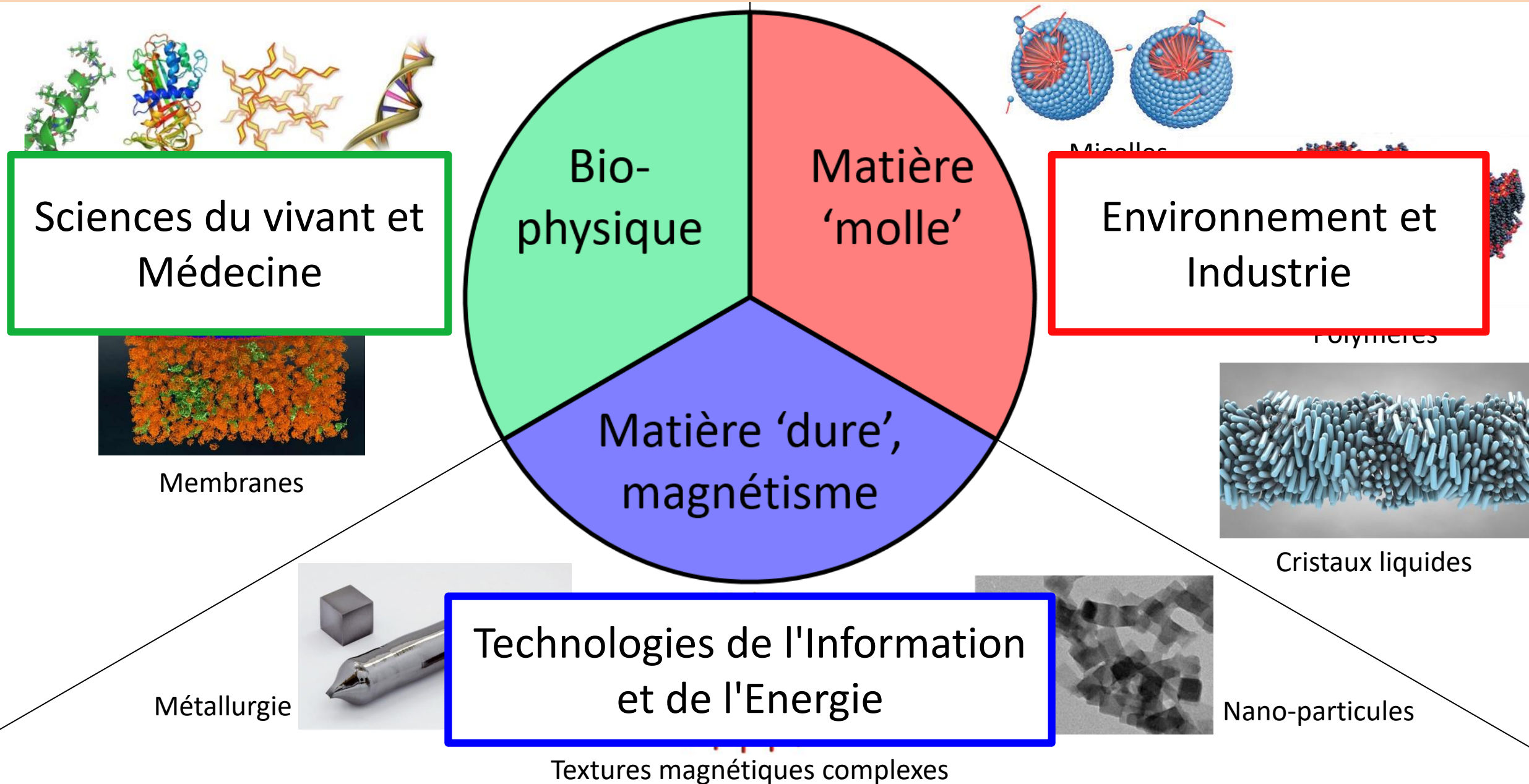


Textures magnétiques complexes

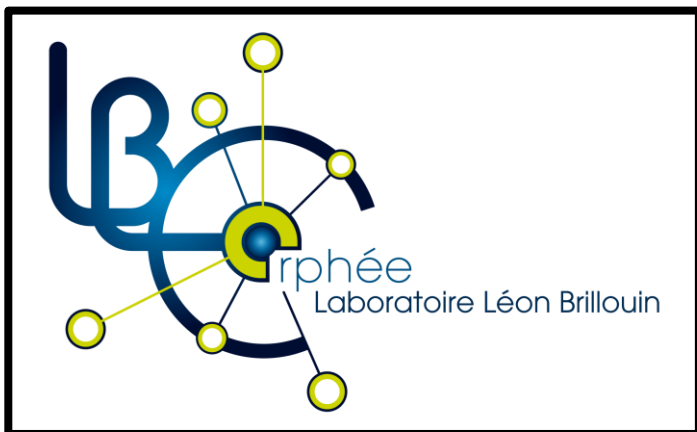


Nano-particules

Diffusion des neutrons aux petits angles: une technique universelle

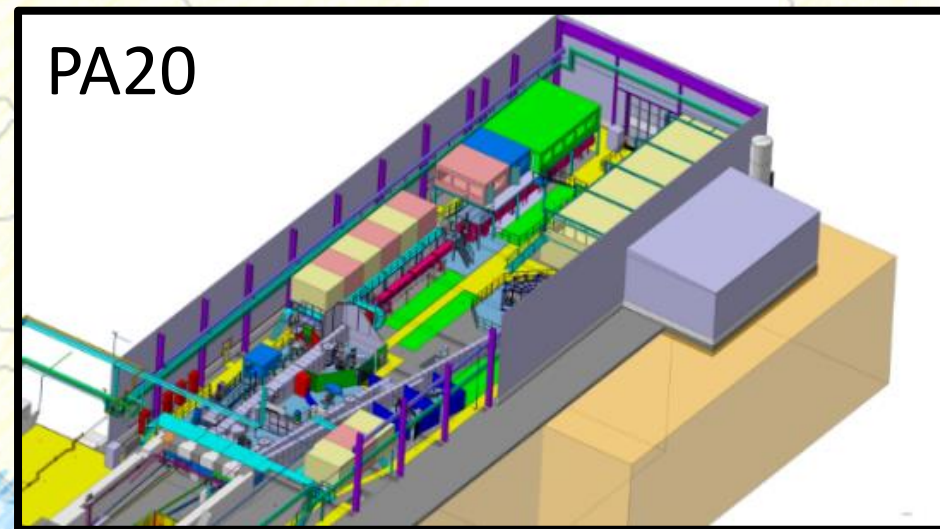


Le LLB du futur: nouveaux horizons, nouveaux défis



PA20 au Paul Scherrer Institut

- ☺ 100 jours/an à la communauté française
- *Accompagnement des utilisateurs sur site*



Le LLB du futur: nouveaux horizons, nouveaux défis

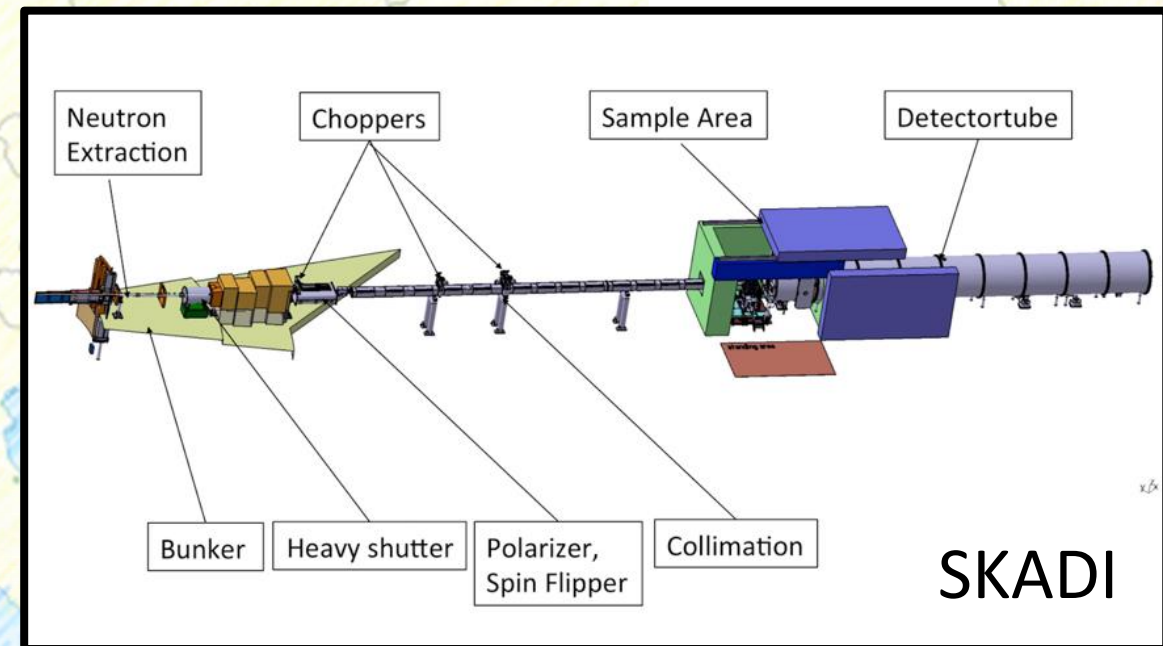


SKADI à la European Spallation Source

☺ $10^{-4} < Q < 1 \text{ \AA}^{-1}$ en "single shot"

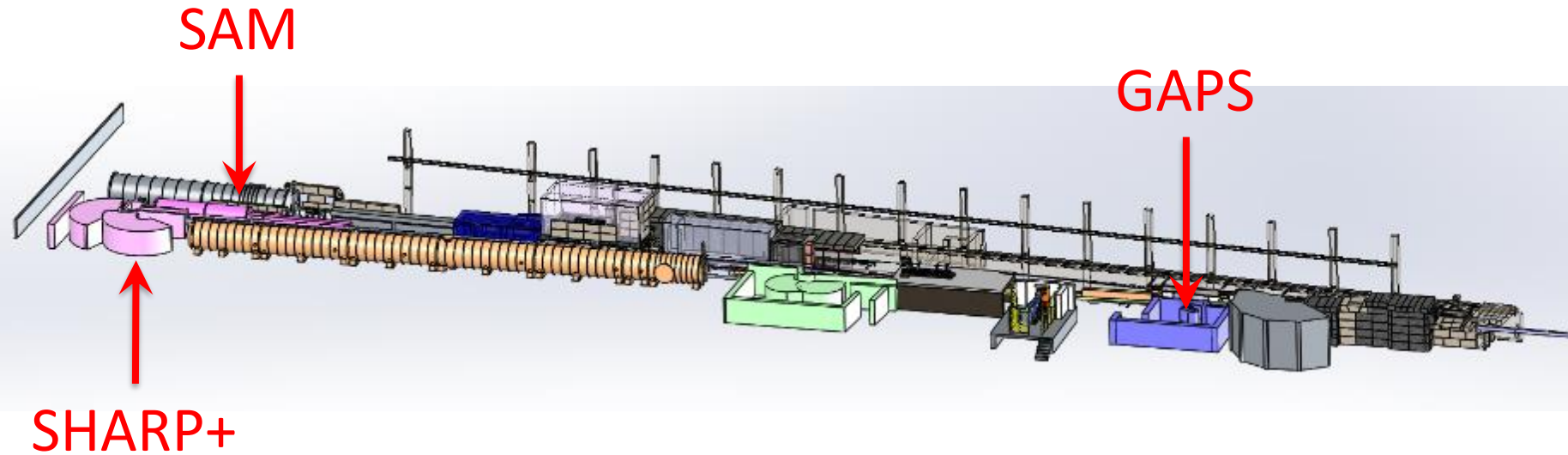
☺ Le flux de l'ESS

→ *Perspectives scientifiques inédites*



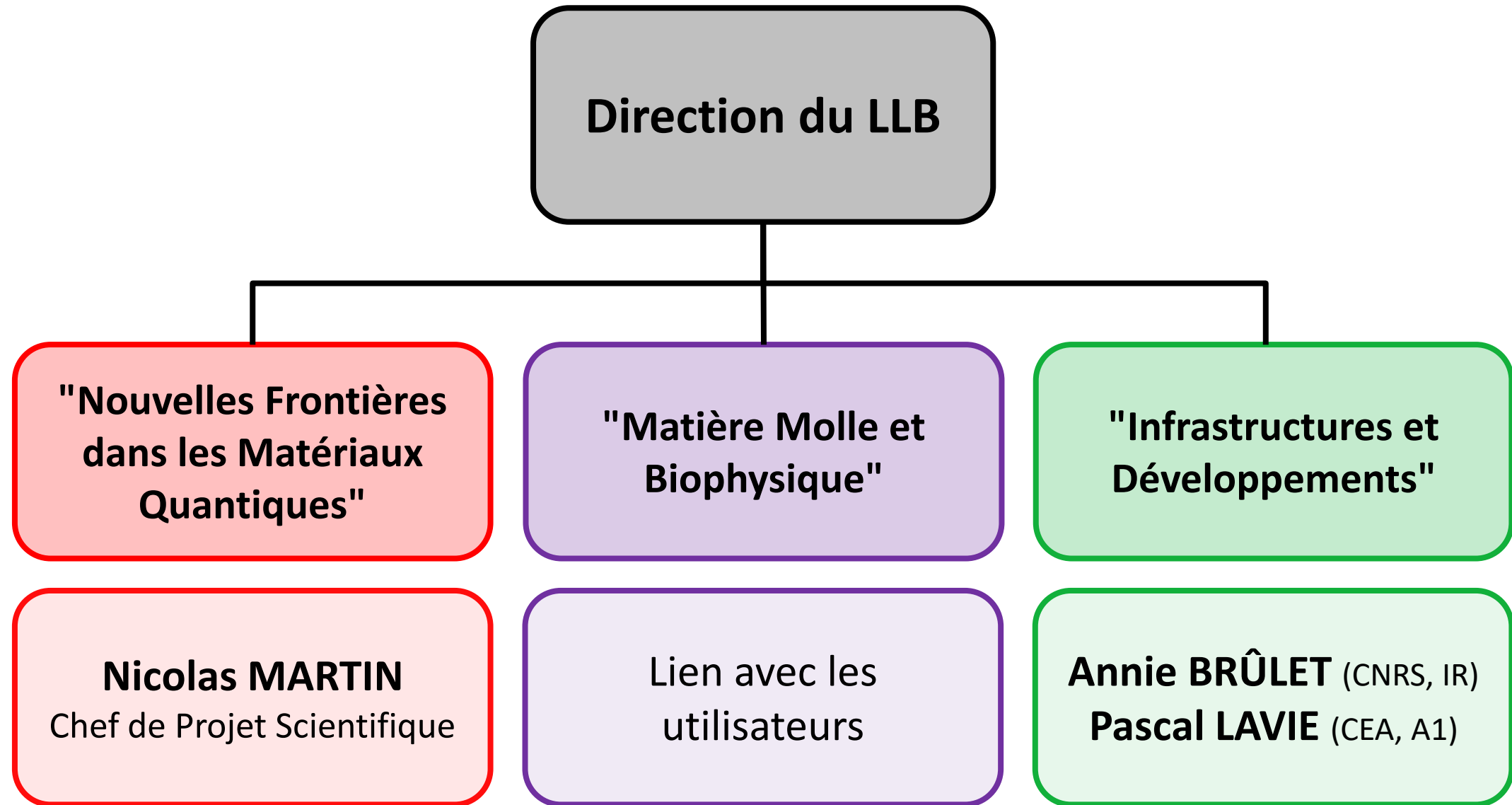
SKADI

Le LLB à l'Institut Laue Langevin

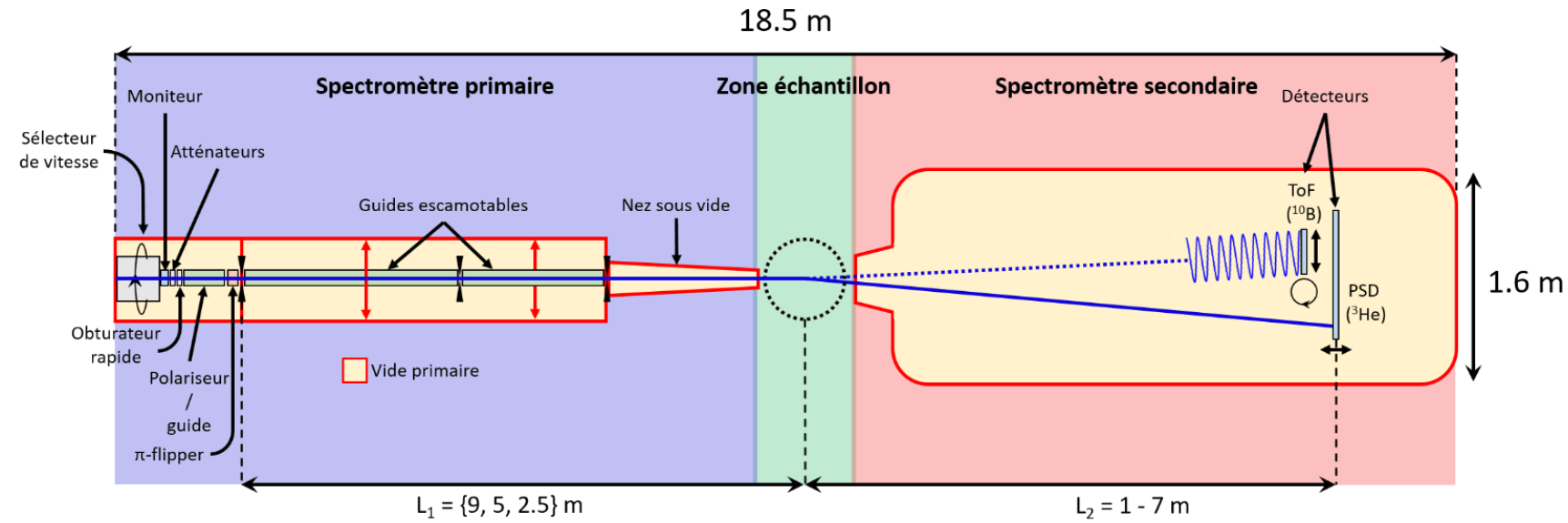


- ✓ Un programme de jouvence lancé fin 2016 ("Endurance 2")
- ✓ Une opportunité pour la communauté française
- ✓ 3 projets portés par le LLB:
 1. Spectromètre à temps de vol **SHARP+**
 2. Spectromètre à trois axes **GAPS** (neutrons polarisés + option **ZETA**)
 3. Diffusion de neutrons aux petits angles **SAM**

Le projet "SAM": équipe projet



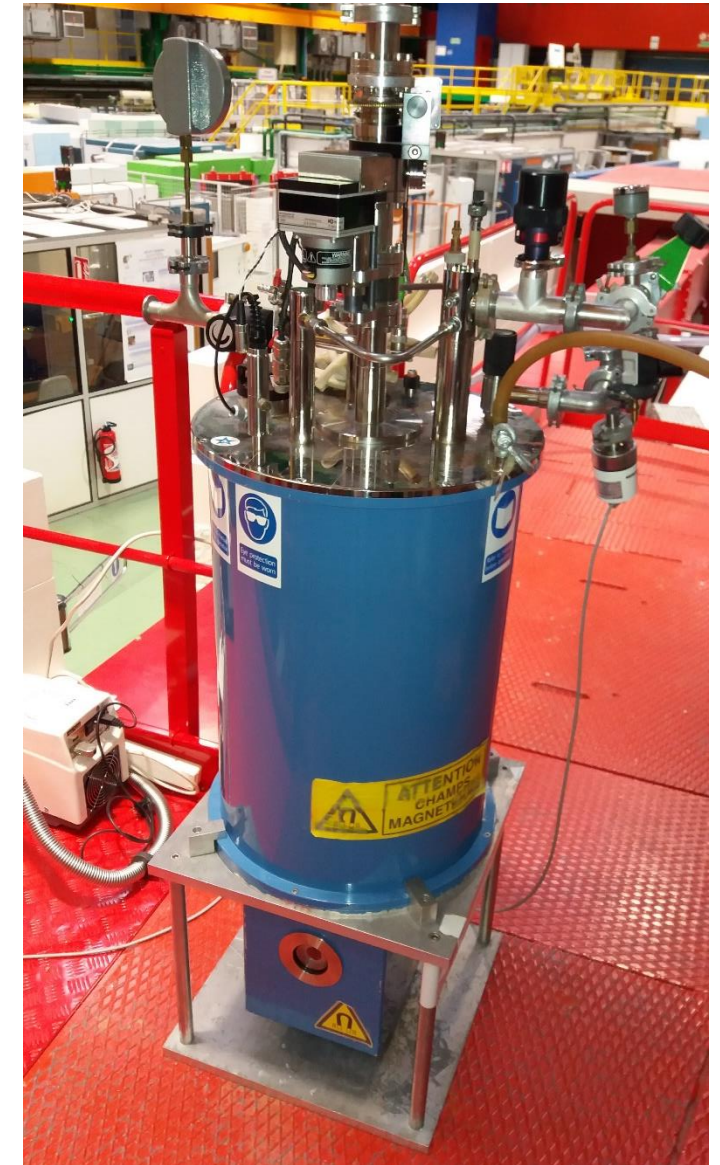
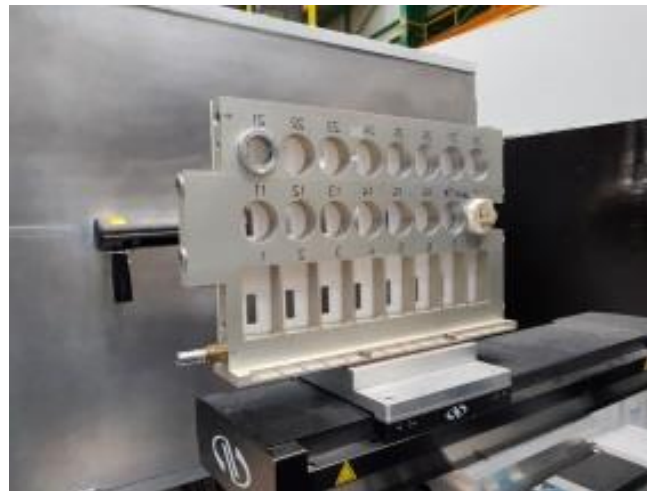
Le projet "SAM": objectifs



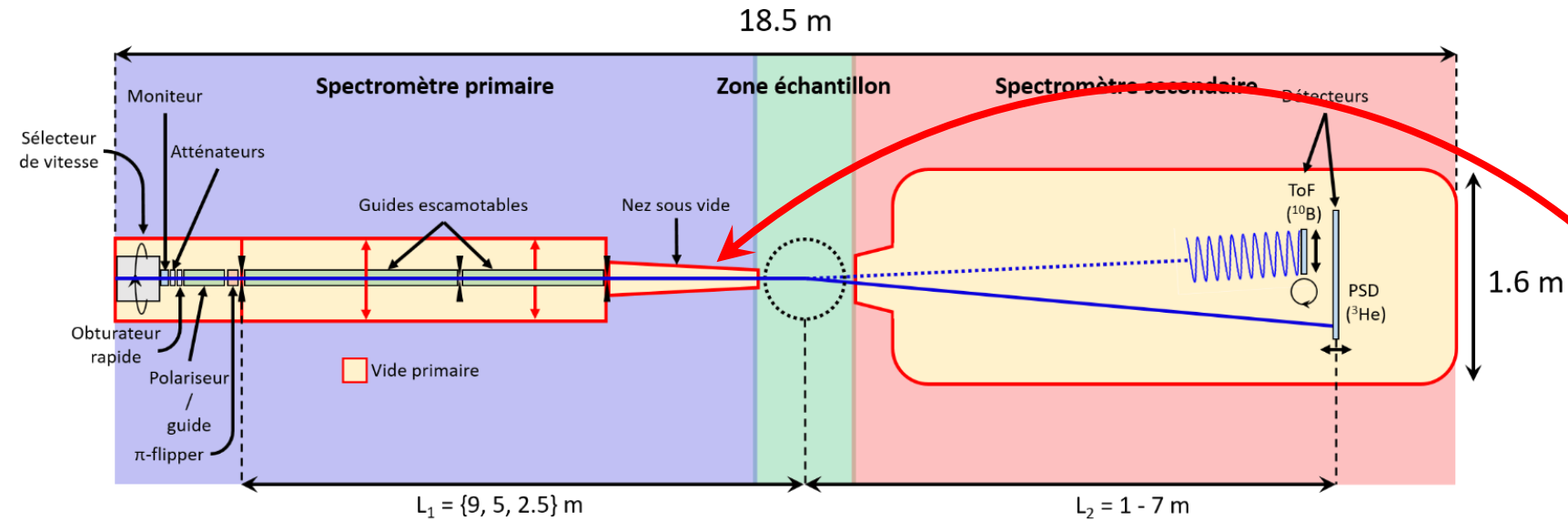
✓ **Un instrument flexible**

✌ Environnements échantillon adaptés à chaque thématique

✌ Neutrons polarisés



Le projet "SAM": objectifs

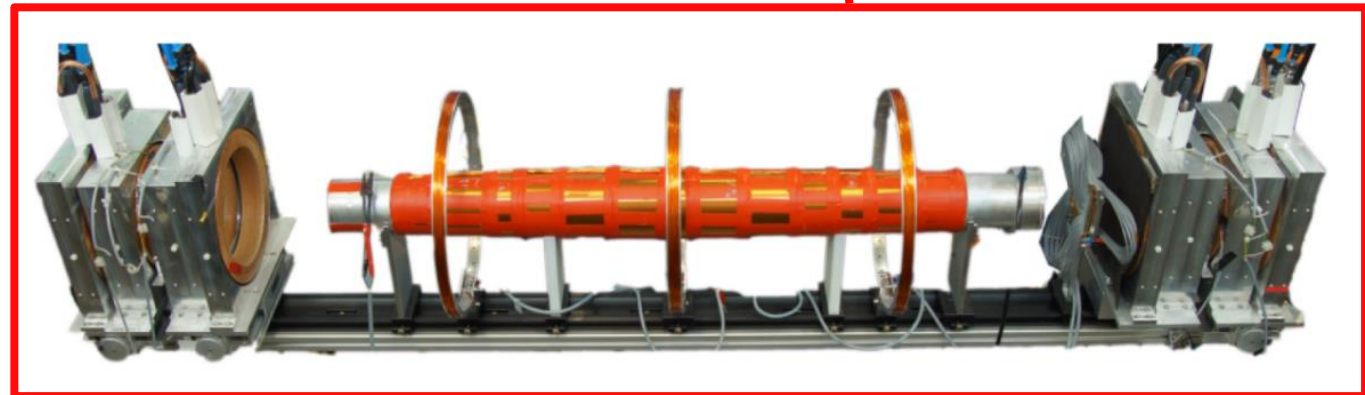


✓ Un instrument innovant

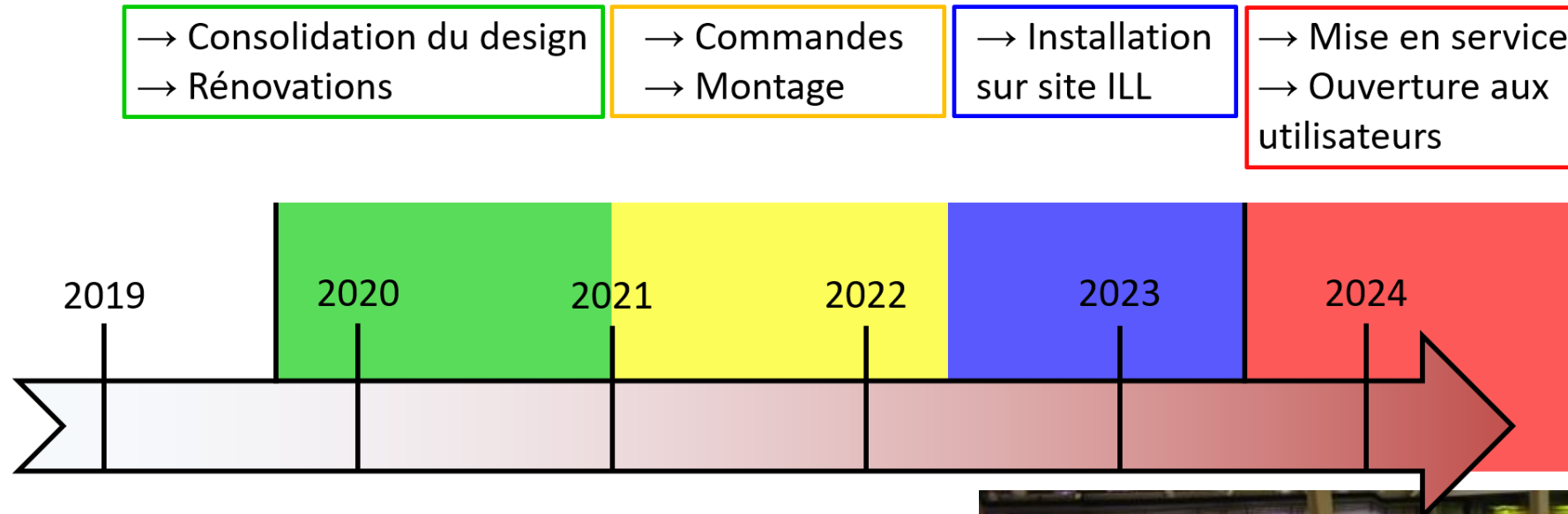
✌ Module "MIEZE":

→ Spectroscopie en conditions extrêmes
(0.1 ps → 100 ns)

→ Mesures stroboscopiques (1 Hz → 1 MHz)



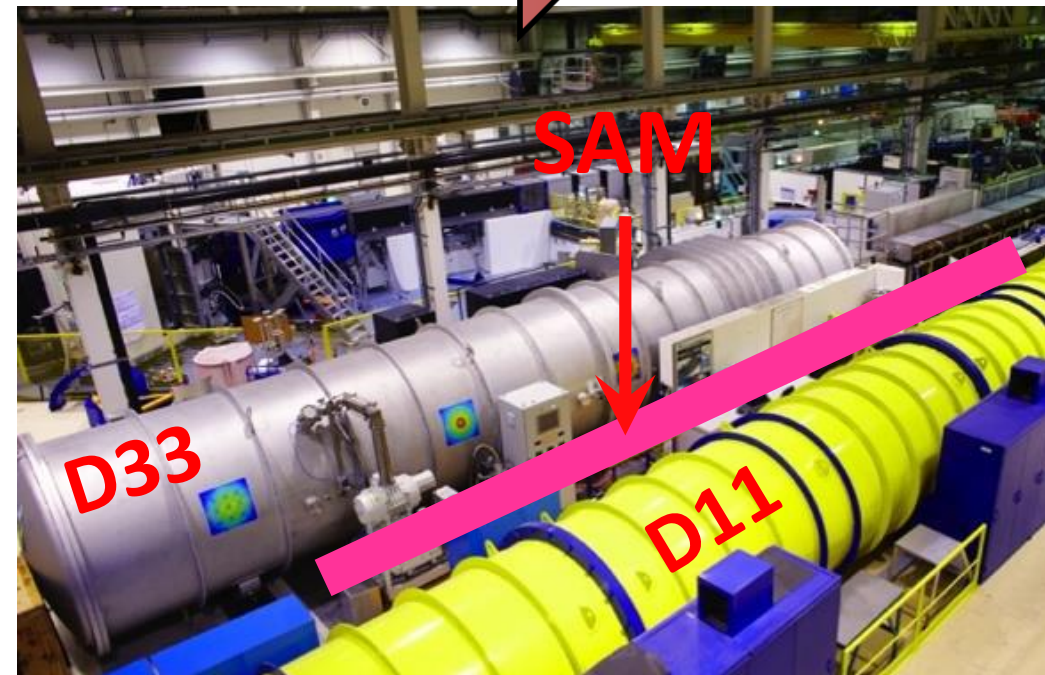
Le projet "SAM": objectifs



✓ **Un instrument disponible dès 2023**

✌ Savoir-faire du LLB en instrumentation

✌ Collaboration étroite avec les équipes de l'ILL



Le projet "SAM": premières étapes

SAM

Plan Projet – SAM.01.002

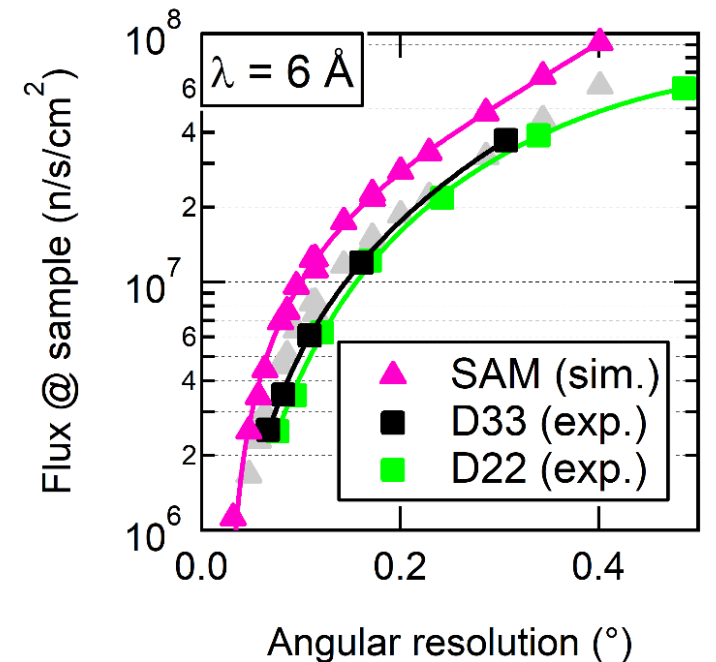
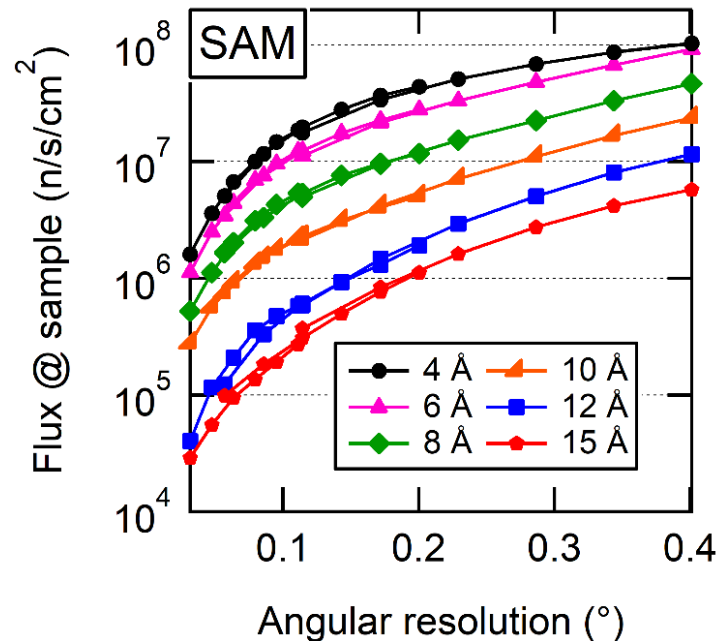
CRG - B

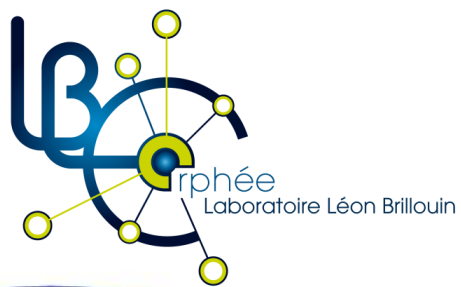


Laboratoire Léon Brillouin, UMR12 CEA-CNRS, Université Paris-Saclay –
Bât. 563 CEA Saclay 91191 GIF-SUR-YVETTE Cedex
Institut Laue Langevin – 71 Avenue des Martyrs, 38042 GRENOBLE Cedex 9

✓ Rédaction du plan projet

✓ Simulations neutroniques et optimisation du design global de l'instrument

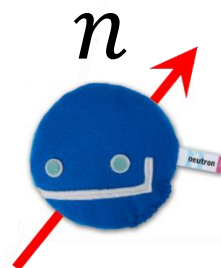




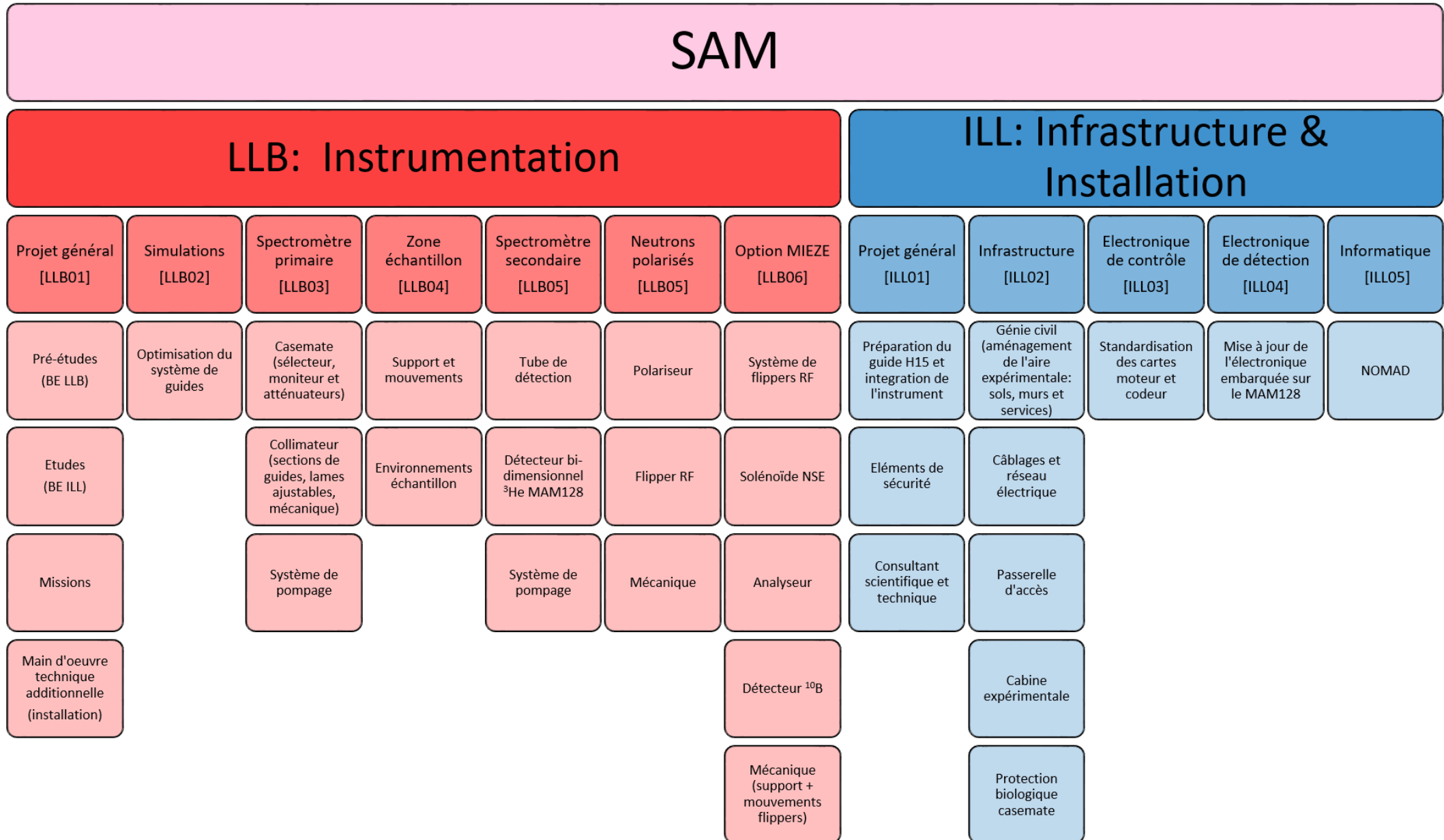
Concours BAP C IR no. 19

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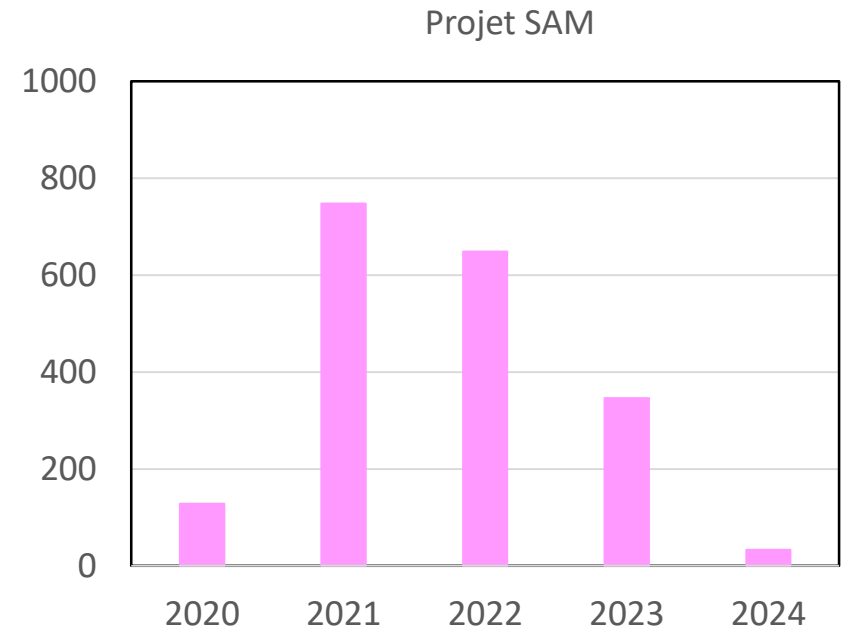
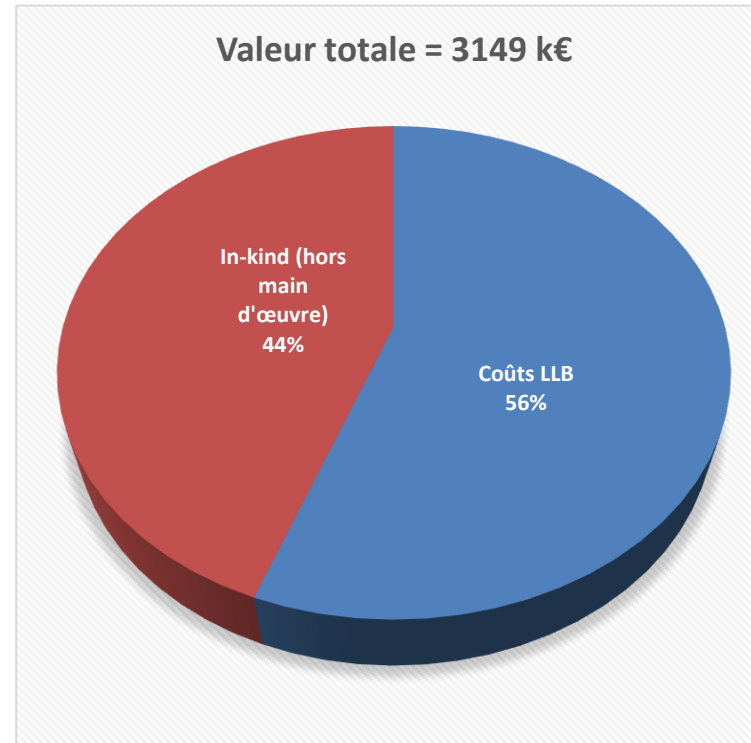
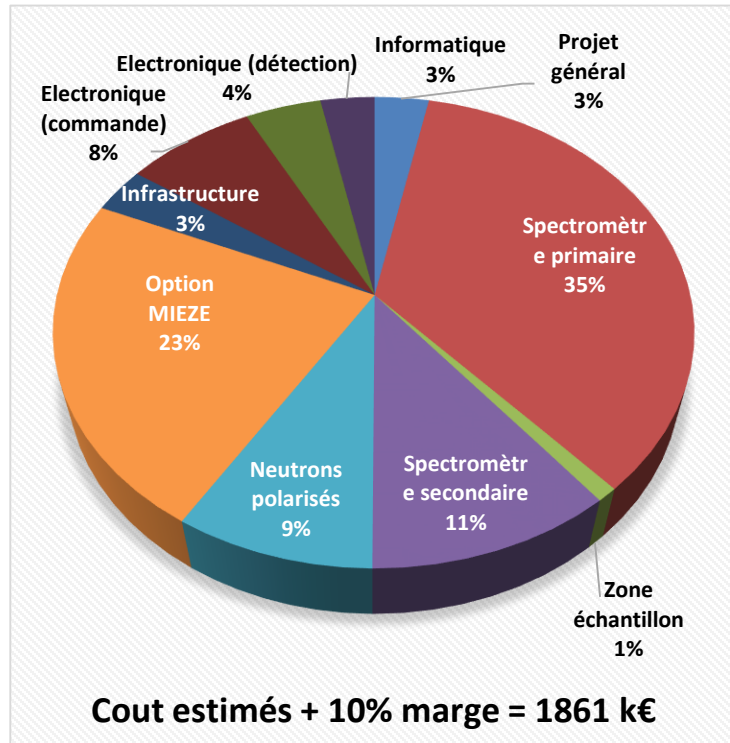
Nicolas Martin



Le projet "SAM": structure de répartition des travaux



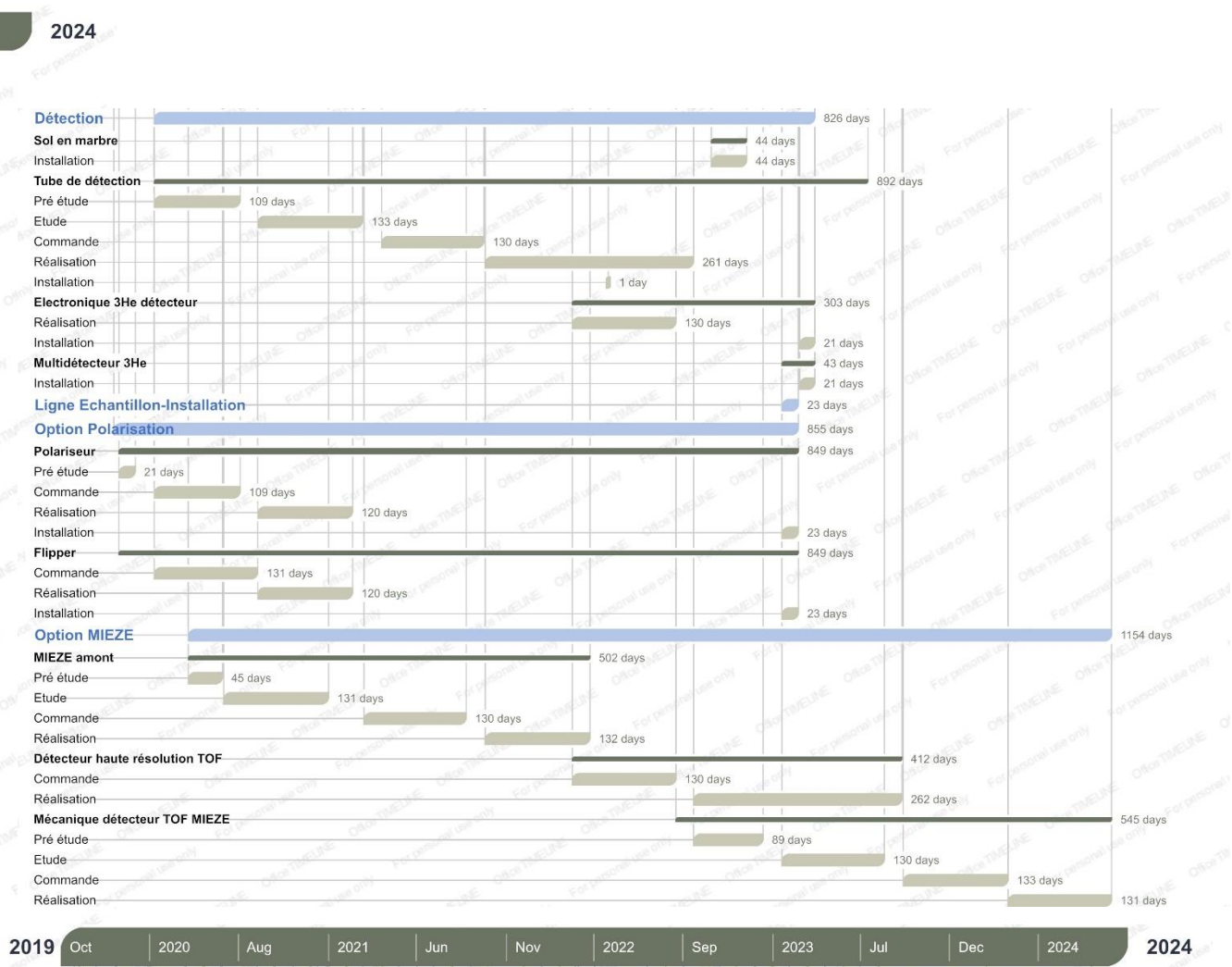
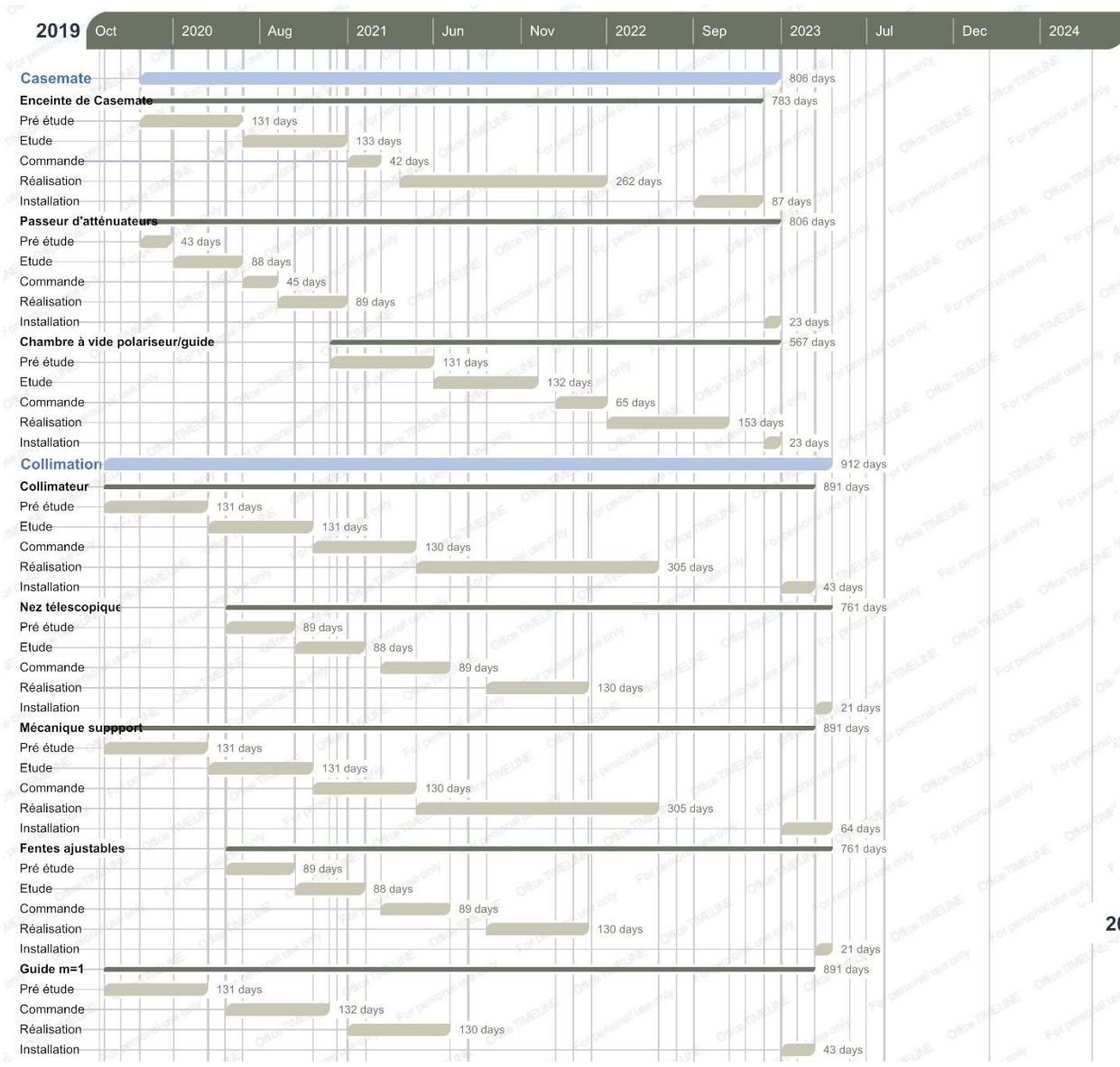
Le projet "SAM": estimation des coûts



Répartition des coûts par "workpackage"

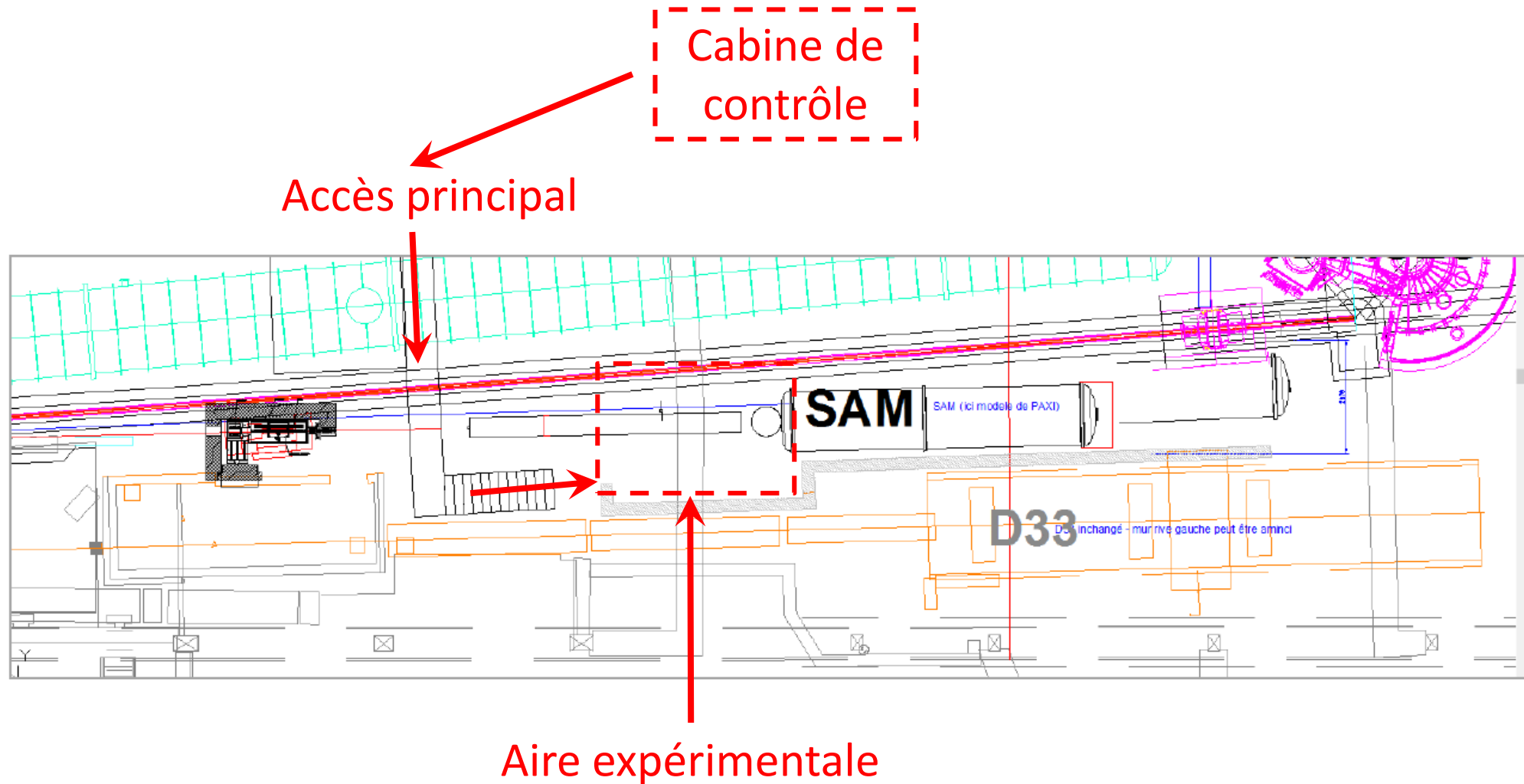
Profil de dépenses

Le projet "SAM": planning prévisionnel détaillé



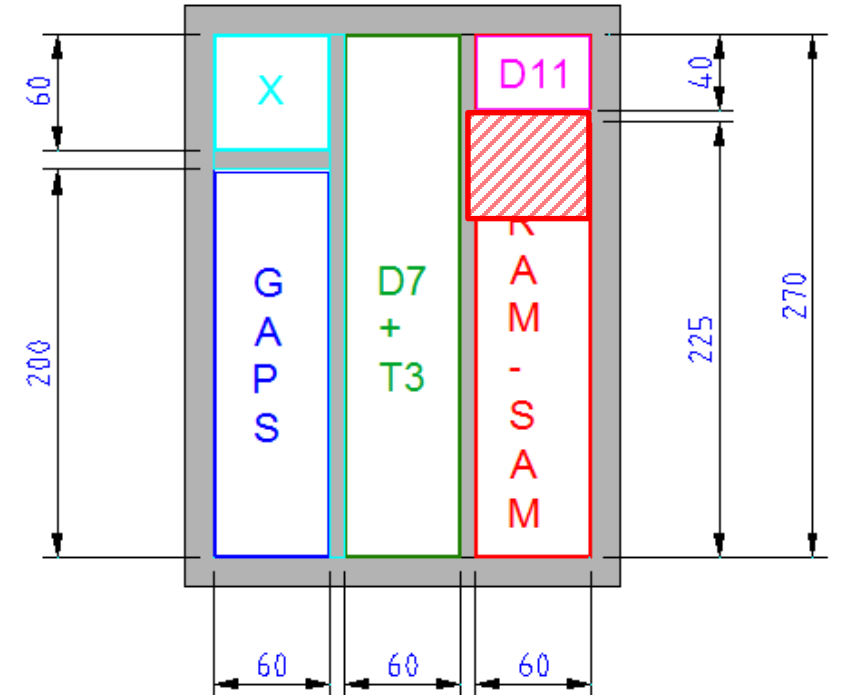
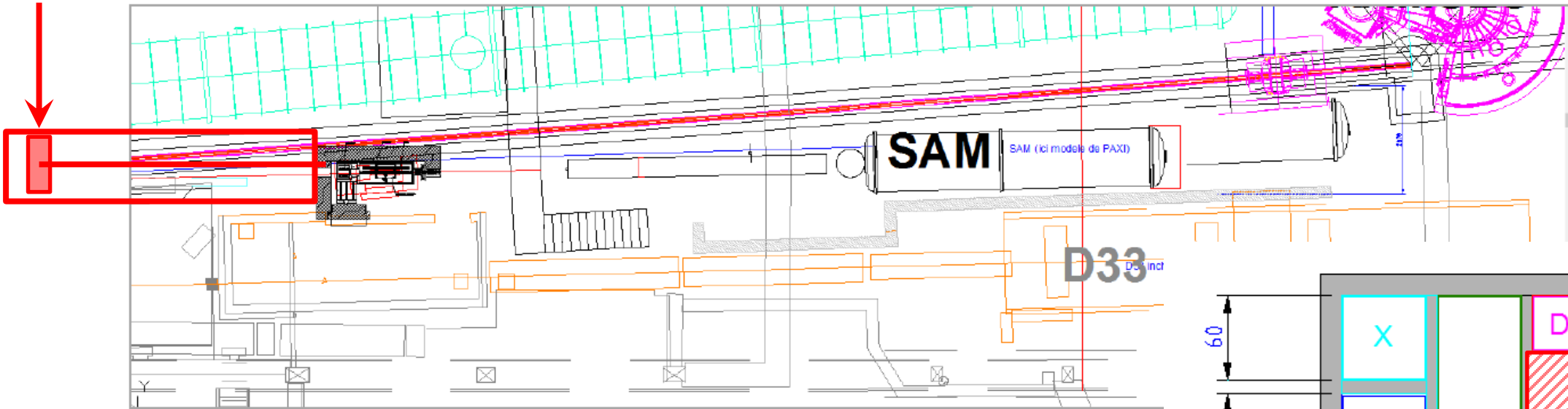
2019 Oct | 2020 Aug | 2021 Jun | Nov | 2022 Sep | 2023 Jul | Dec | 2024 **2024**

L'instrument "SAM": emplacement dans le hall des guides ILL



L'instrument "SAM": branche de guide H153b

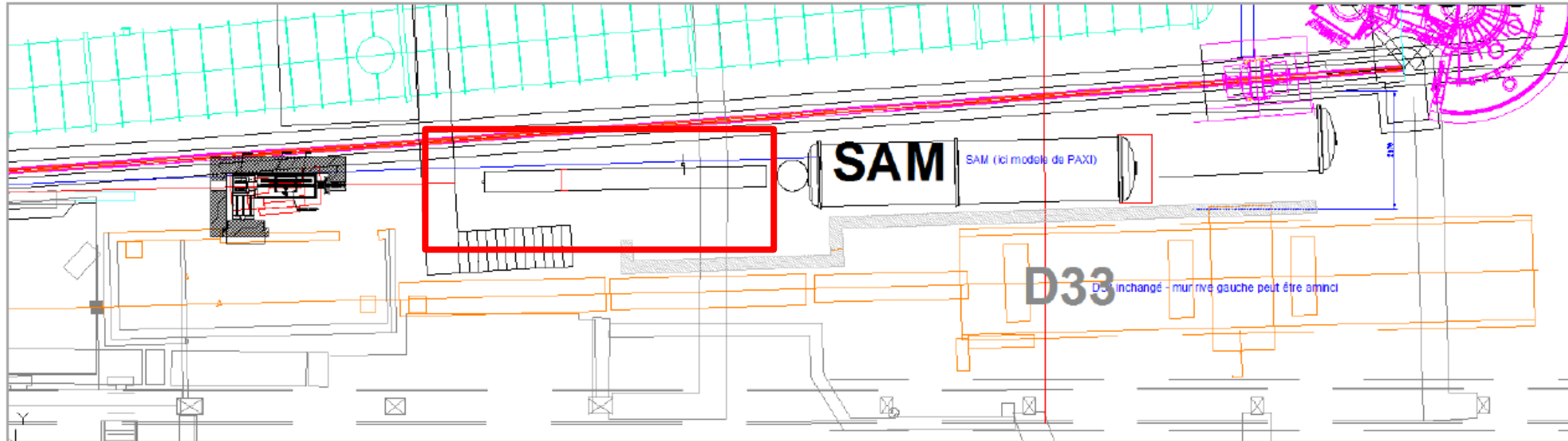
Split "RAM-SAM"



1. Guide:

- $m = 1$
- Réduction de la section $60 \times 40 \rightarrow 35 \times 35 \text{ mm}^2$
- Pas de "vue directe"

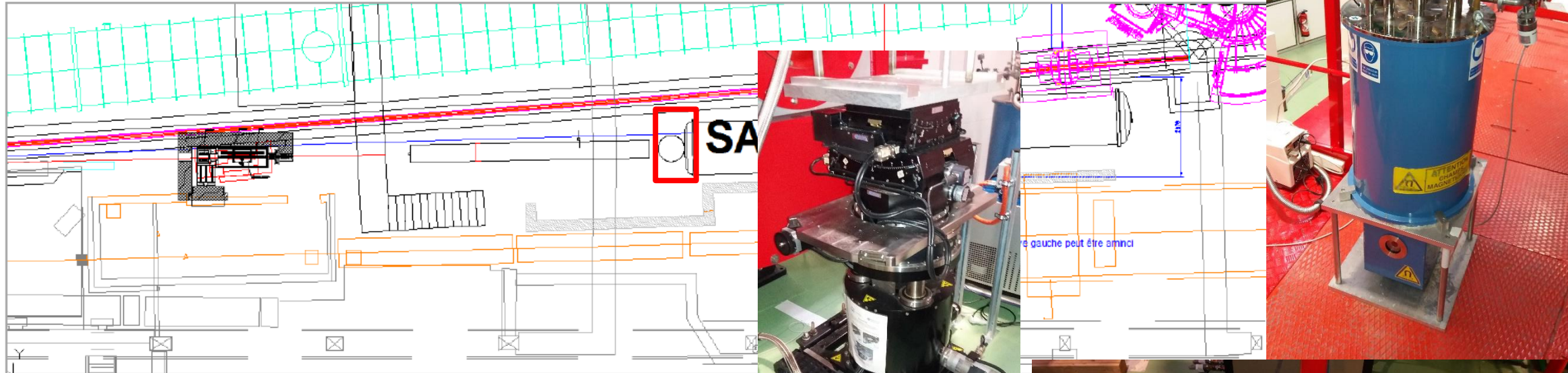
L'instrument "SAM": collimateur



3. Collimateur:

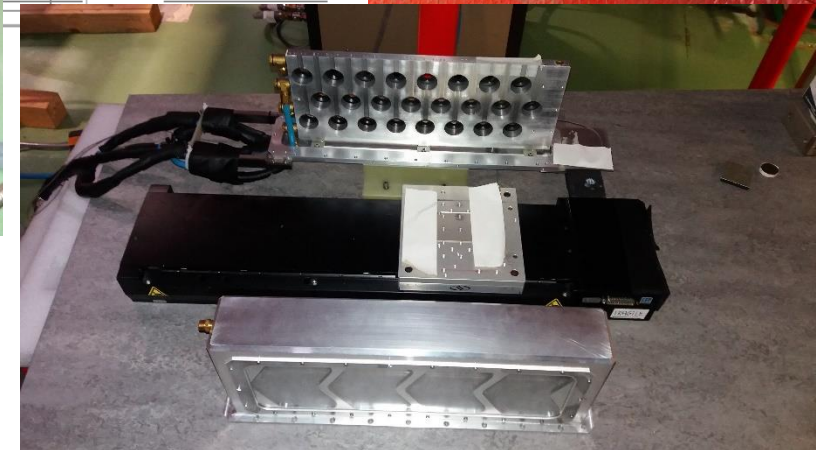
- Longueur totale ≈ 9 m
- 2 guides amovibles (4 et 2.5 m), section 35×35 mm²
- Fentes ajustables (4 lames, cf. PA20)
- Champ de guidage (polarisation)

L'instrument "SAM": zone échantillon

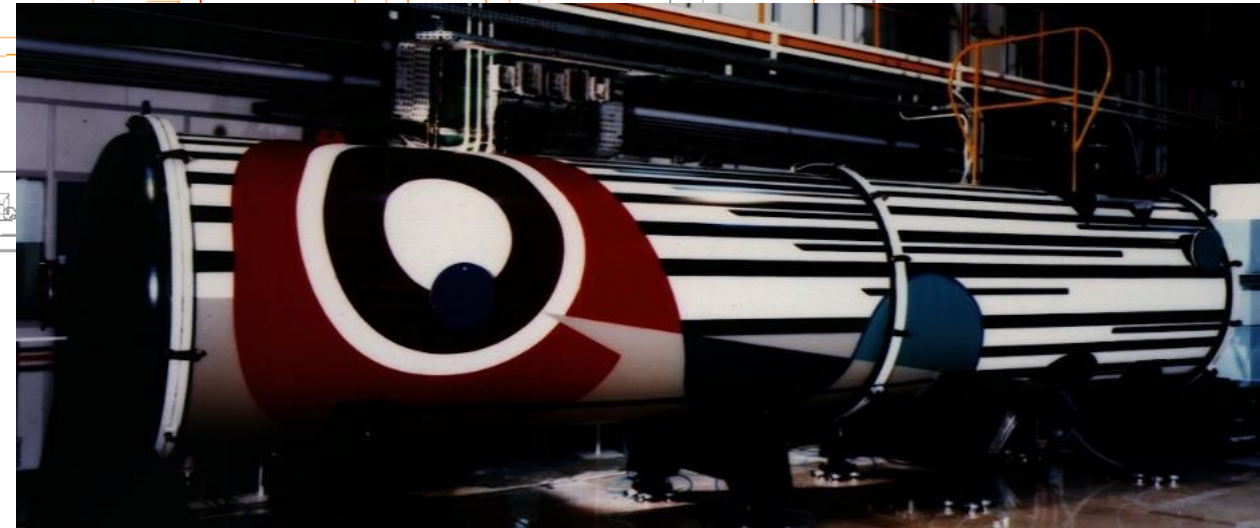
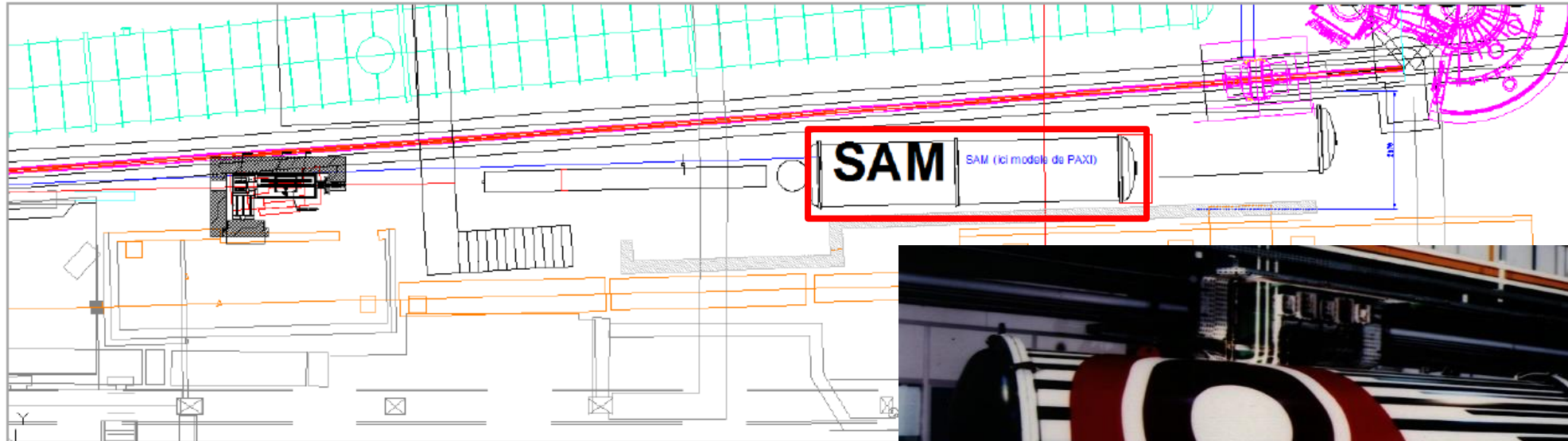


4. Ligne échantillon + environnement

- Table PA20
- Passeur "2D", cryo-aimant, hautes-pressions, etc.
- *Protection radiologique à étudier*
- *Possibles interférences avec les guides et instruments voisins*



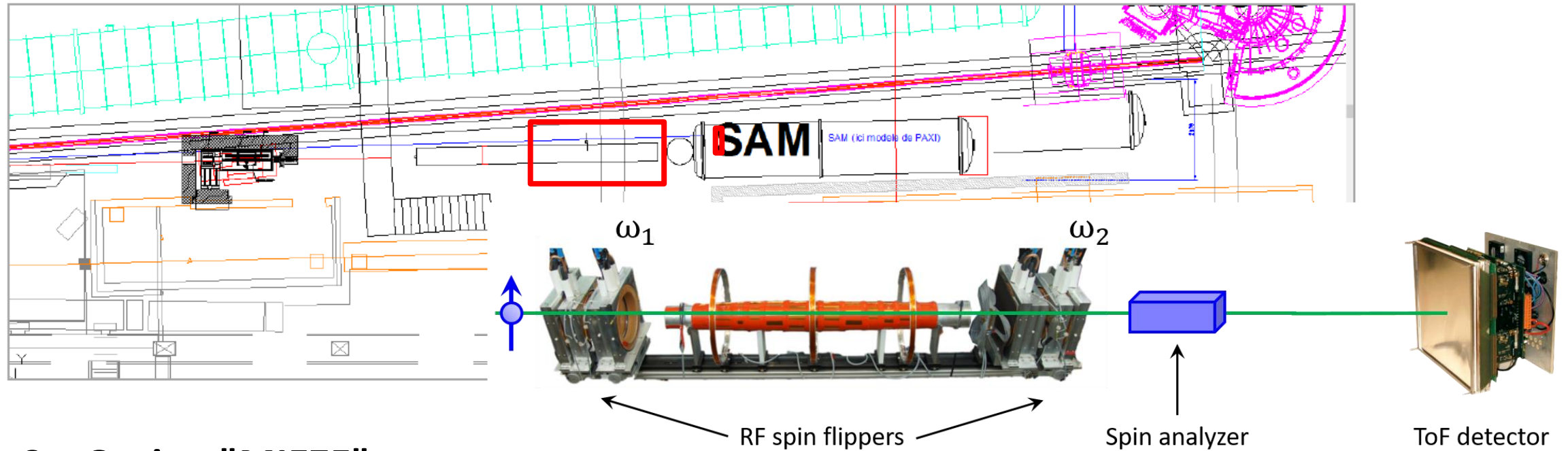
L'instrument "SAM": spectromètre secondaire



5. Enceinte détecteur

- Tube + détecteur "MAM128" PAXY
- Amovible en fonction de l'environnement échantillon
- Accès arrière (maintenance détecteur)

L'instrument "SAM": option "MIEZE"



6. Option "MIEZE"

- Flippers RF + analyseur en fin de collimateur
- Détecteur temps de vol (10B), 10 x 10 cm², dynamique ≈ 10 MHz
 - *BaroTron, SoNDe, CASCADE, ProxiVision, NovaScientific??*

Equipements "tabletop" du LLB

PPMS 9 T

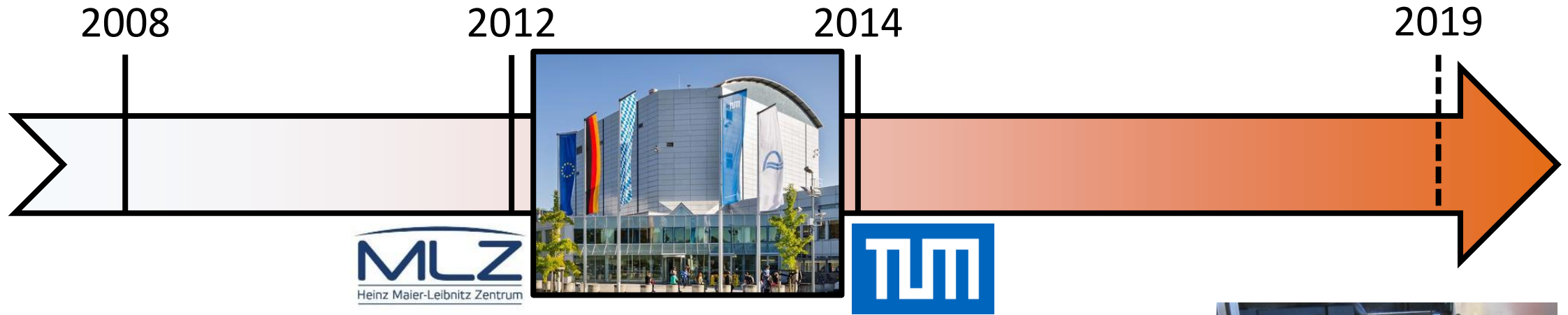
- Magnétométrie, transport et chaleur spécifique
- Options haute-température, pression, *etc.*



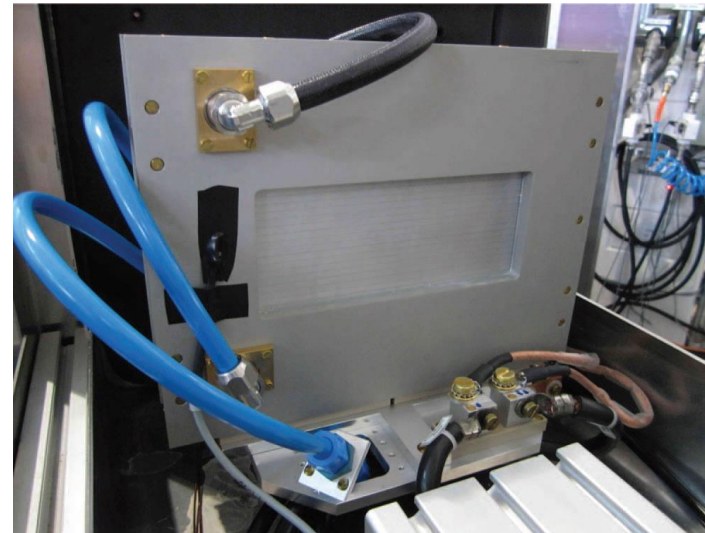
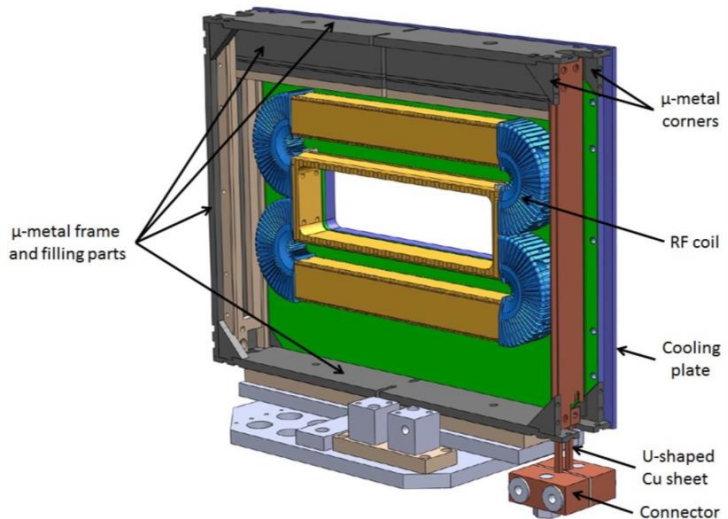
Diffusion de rayons X aux petits angles (SAXS)



Exemple de développement instrumental

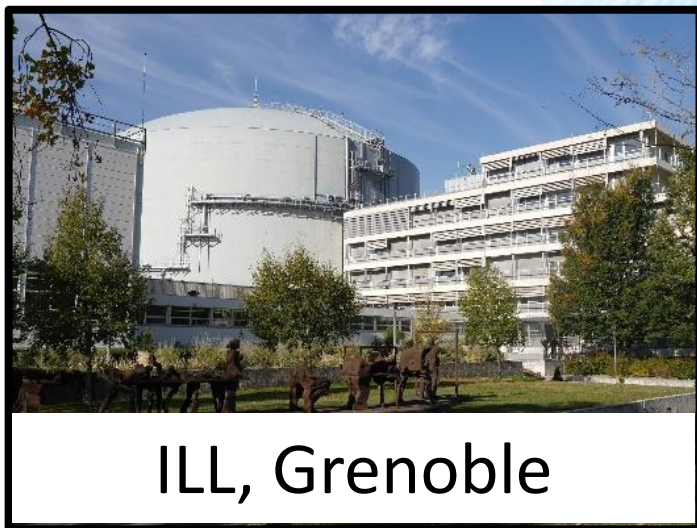


→ Conception d'un nouveau type de flipper radiofréquence

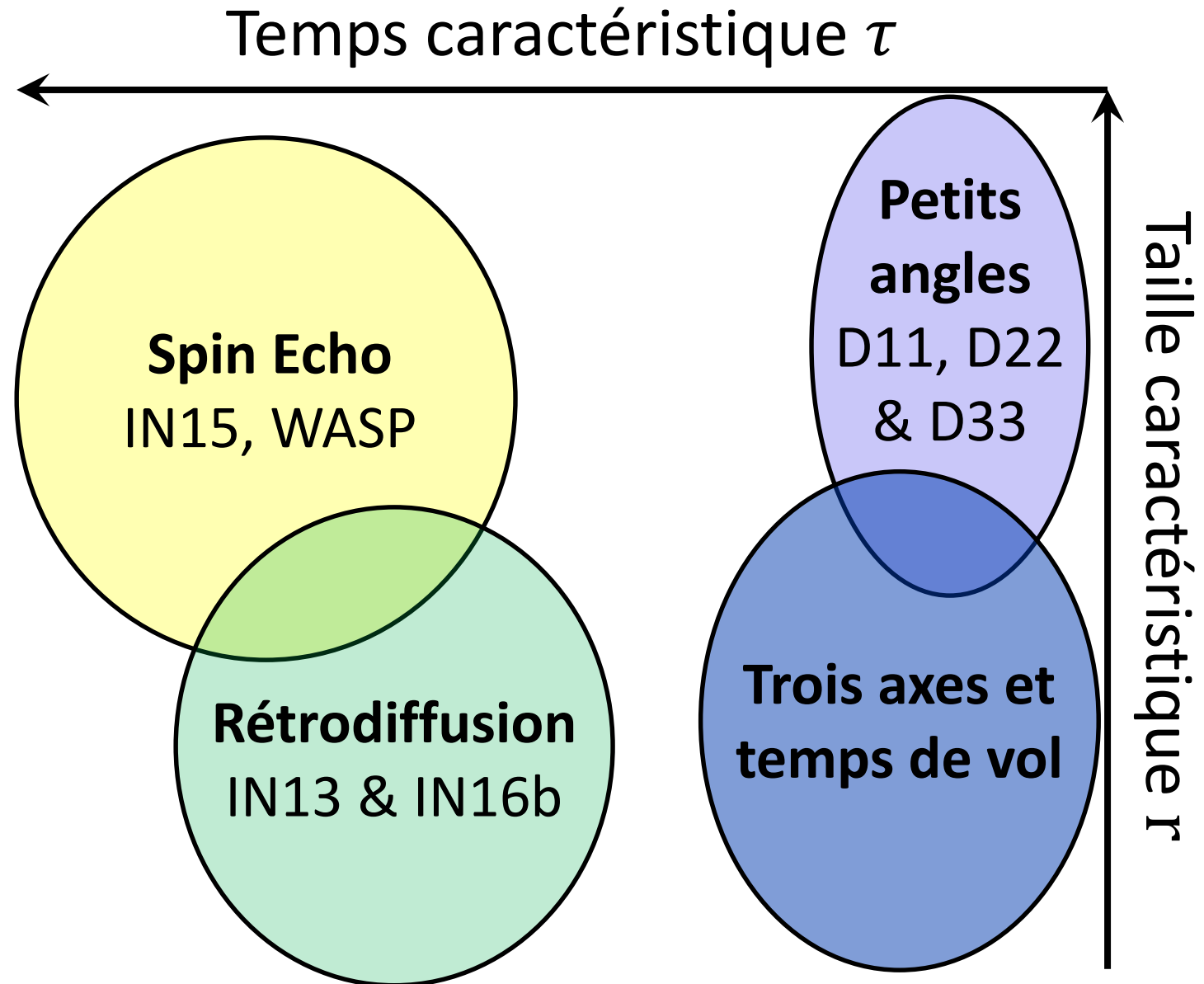


N. Martin et al., Rev. Sci. Instrum. **85**, 073902 (2014)

Le LLB du futur: nouveaux horizons, nouveaux défis



Le projet "SAM": performances et synergie



Le projet "SAM": performances et synergie

Temps de corrélation τ

Conditions "extrêmes":

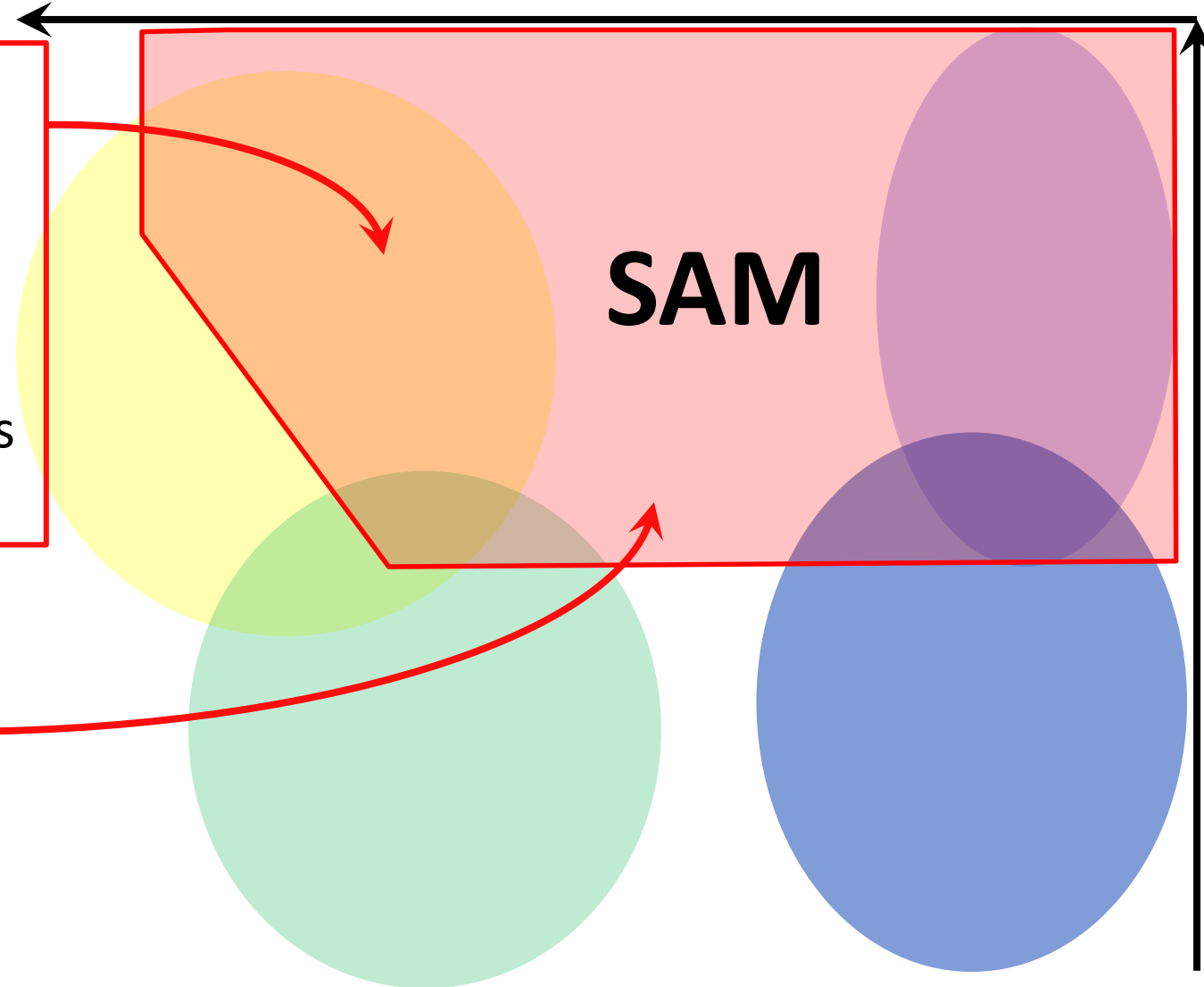
- ✓ Forts diffuseurs incohérents (H)
- ✓ Matériaux ferromagnétiques
- ✓ Forts champs magnétiques
- ✓ *etc.*

Faibles diffuseurs:

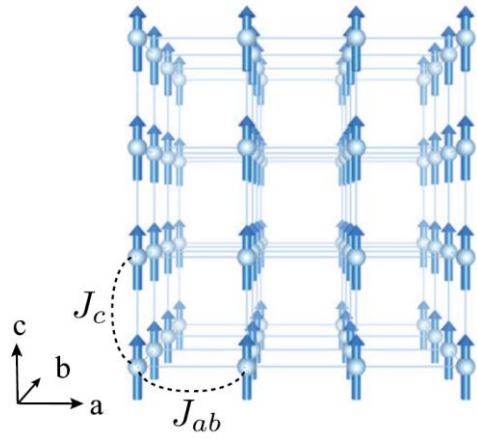
- ✓ Flux important sur l'échantillon

SAM

Taille caractéristique r

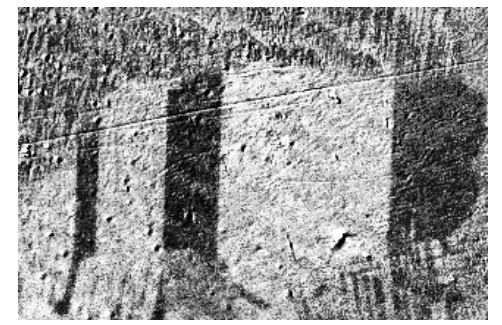
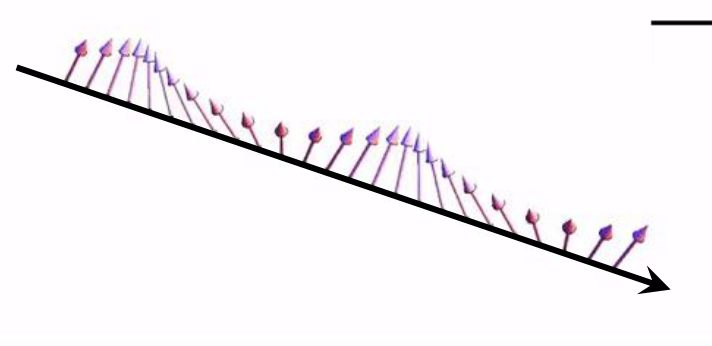
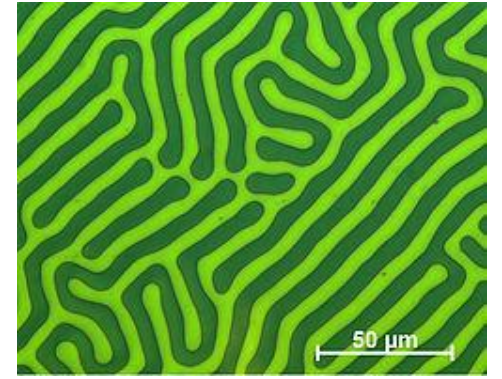
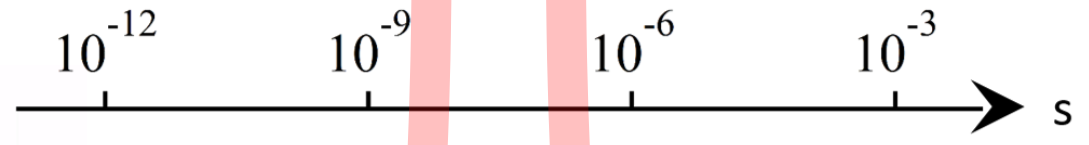
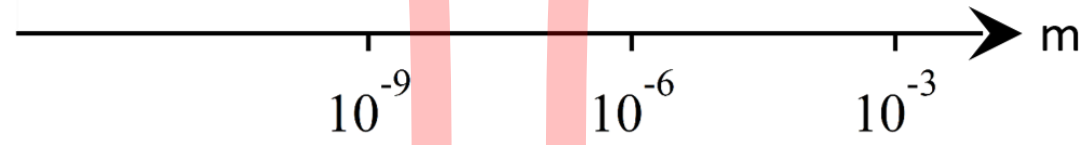


Echelles d'espace et de temps en magnétisme



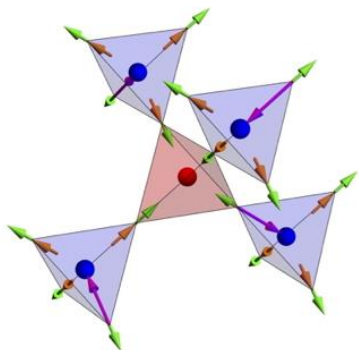
Microscopique
'Quantique'

Macroscopique
'Classique'

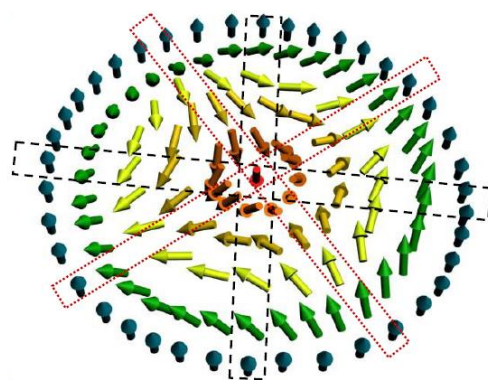


Le magnétisme à l'échelle mésoscopique: de nouveaux objets

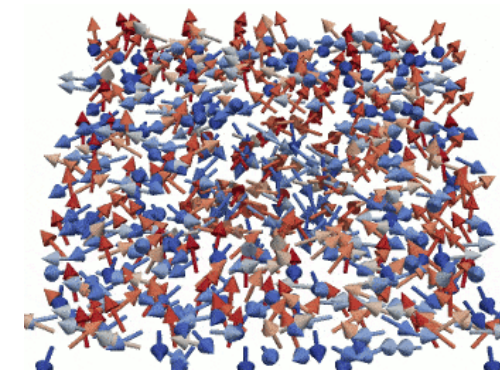
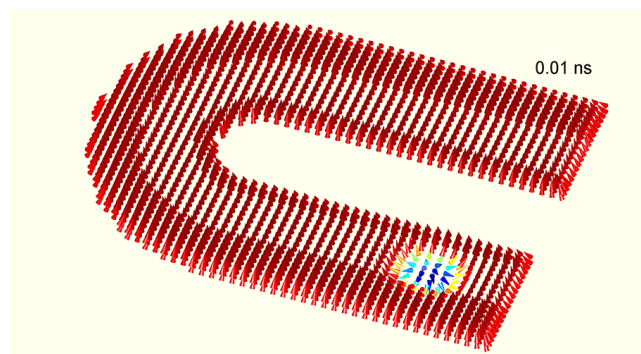
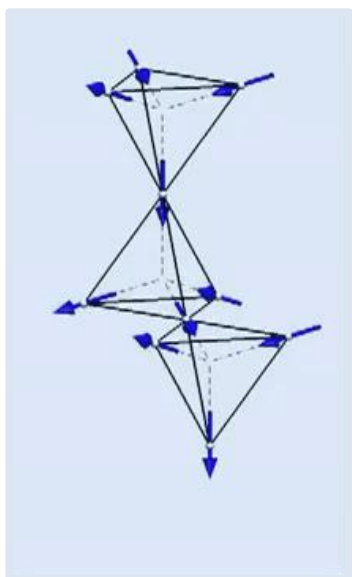
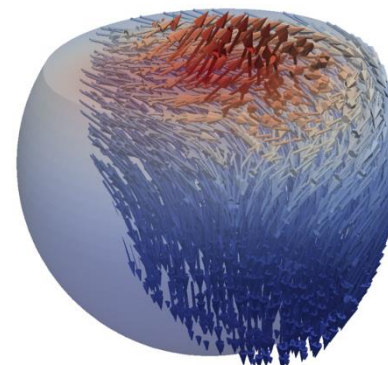
Monopoles



Skymions

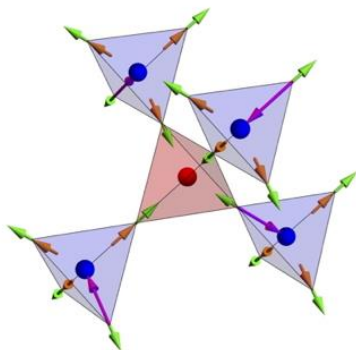


"Hérissons"

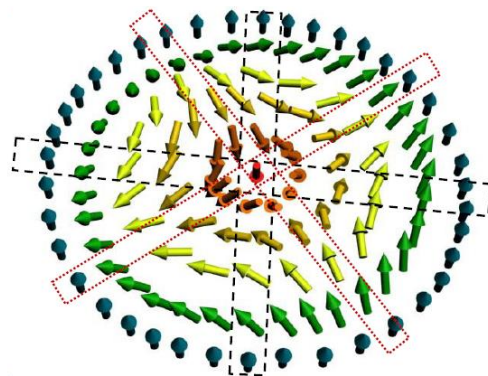


Le magnétisme à l'échelle mésoscopique: de nouveaux objets

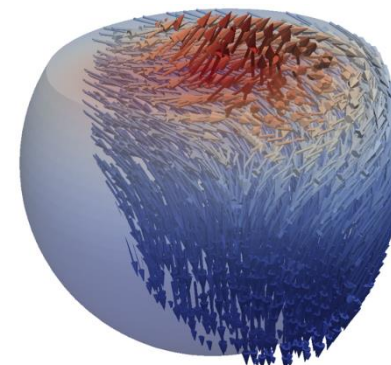
Monopoles



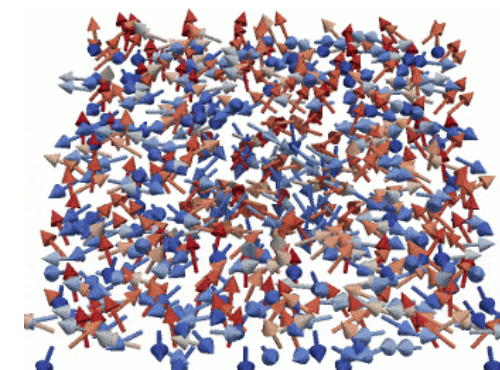
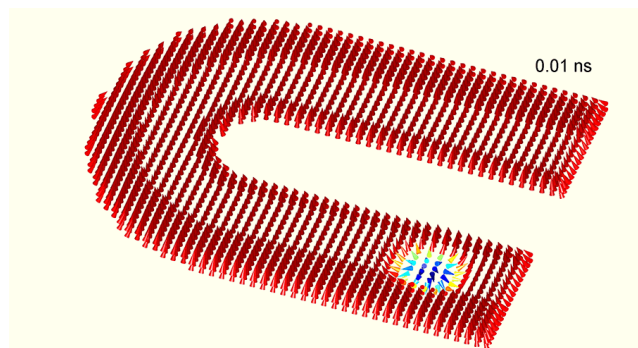
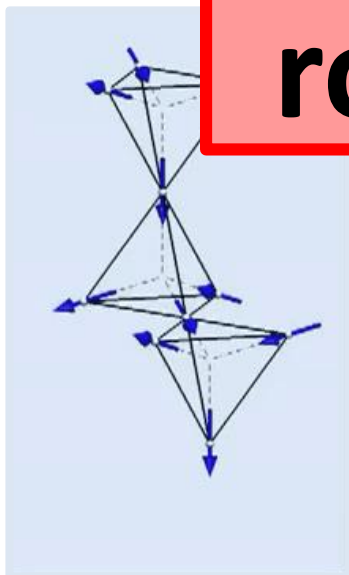
Skyrmions



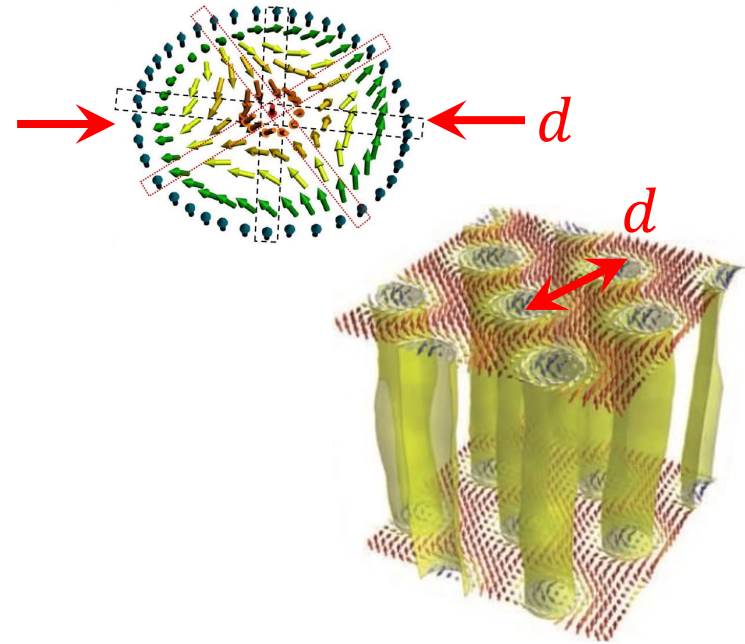
"Hérissons"



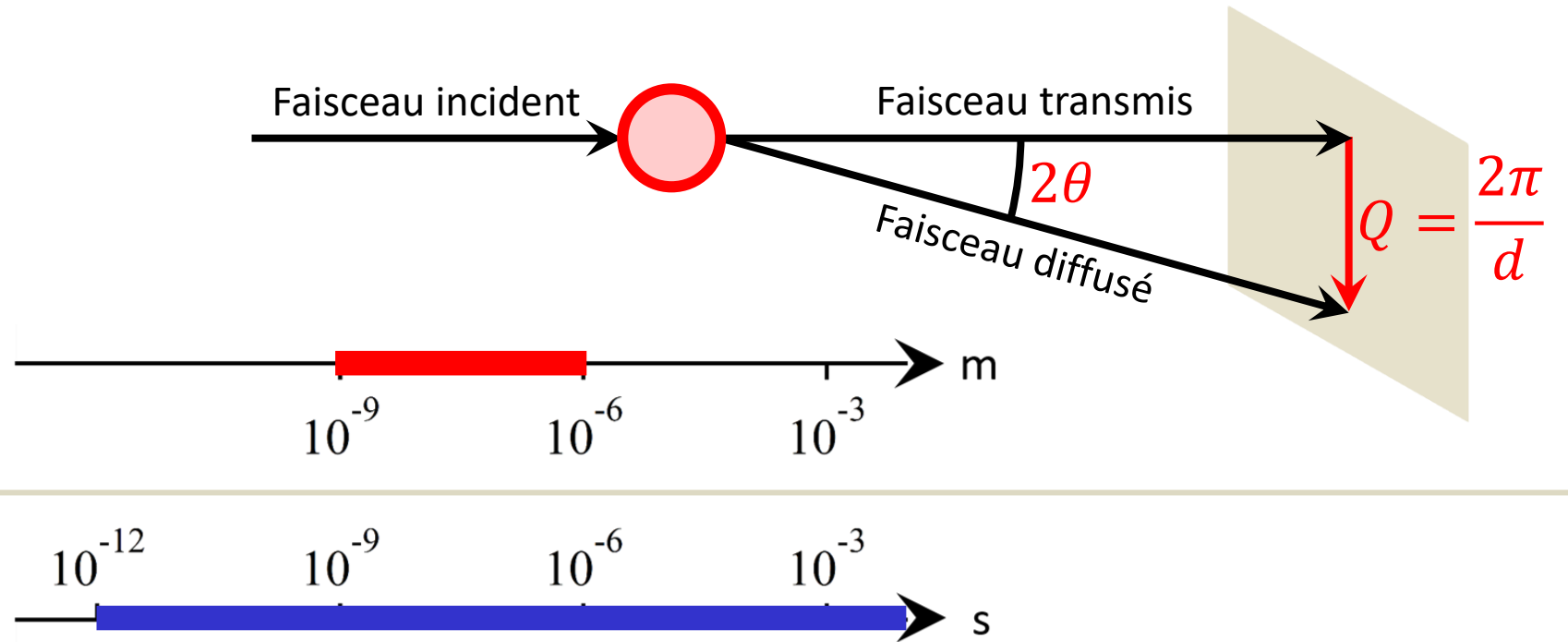
"There's plenty of room in the middle!"



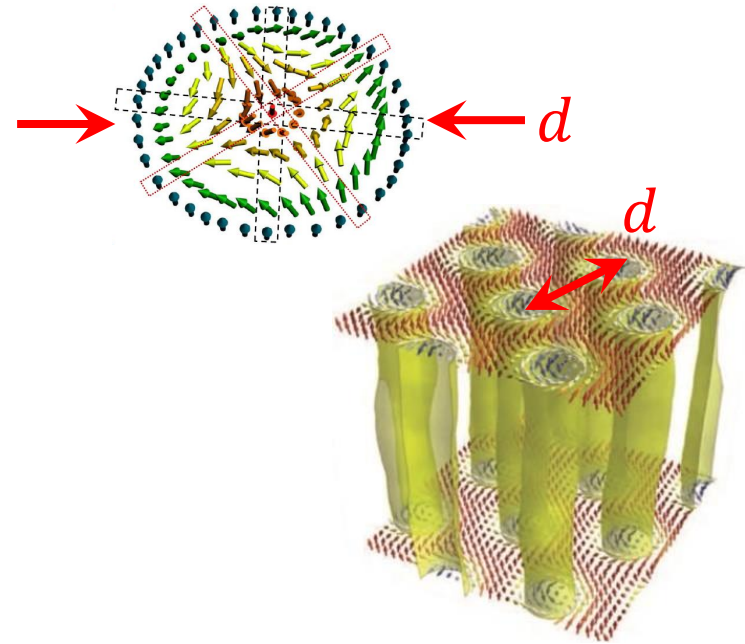
Le magnétisme à l'échelle mésoscopique: avec quels outils?



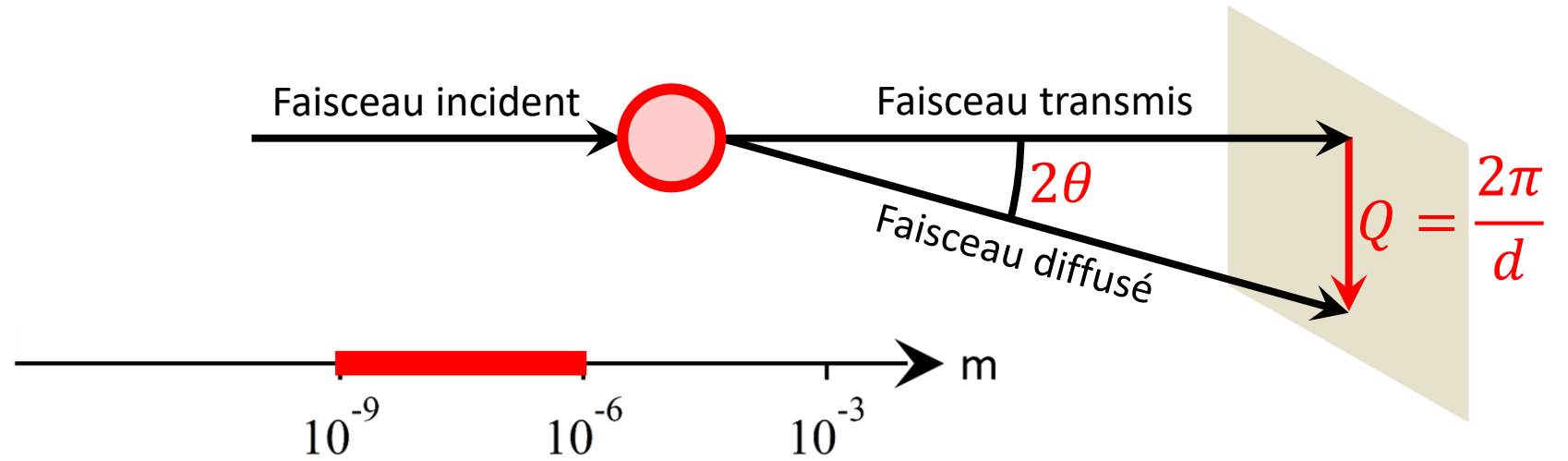
Diffraction de rayonnements aux petits angles (SANS/SAXS)



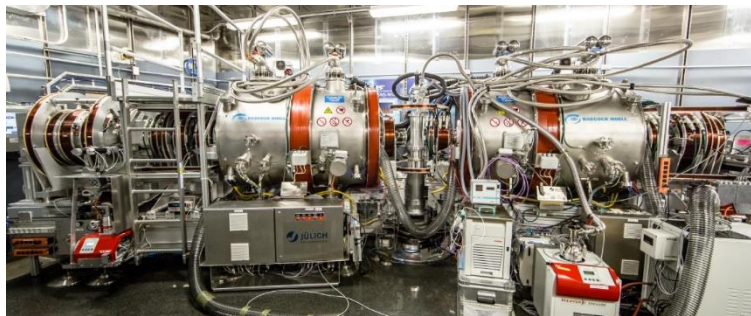
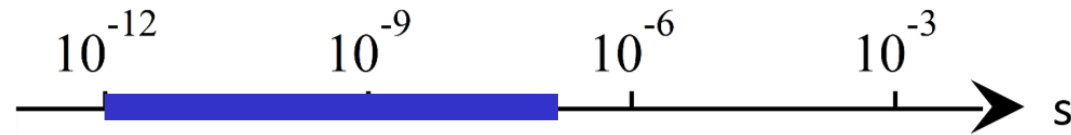
Le magnétisme à l'échelle mésoscopique: avec quels outils?



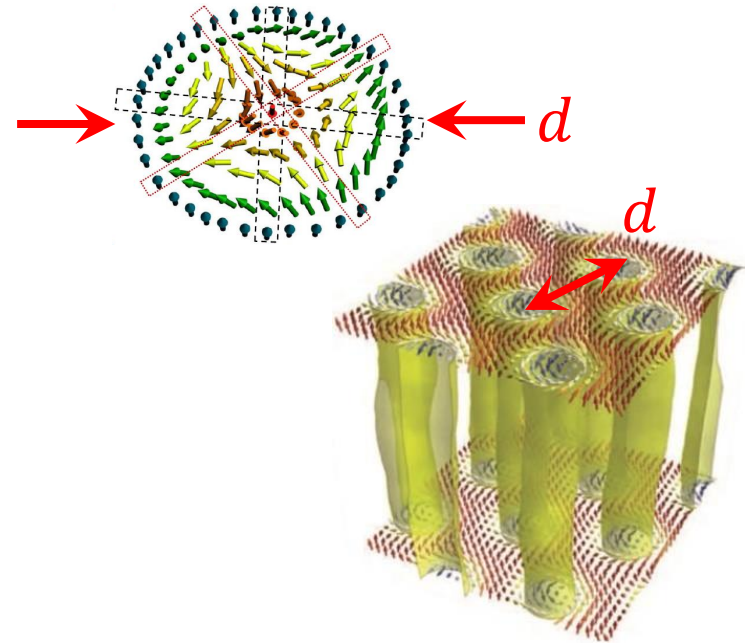
Diffraction de rayonnements aux petits angles (SANS/SAXS)



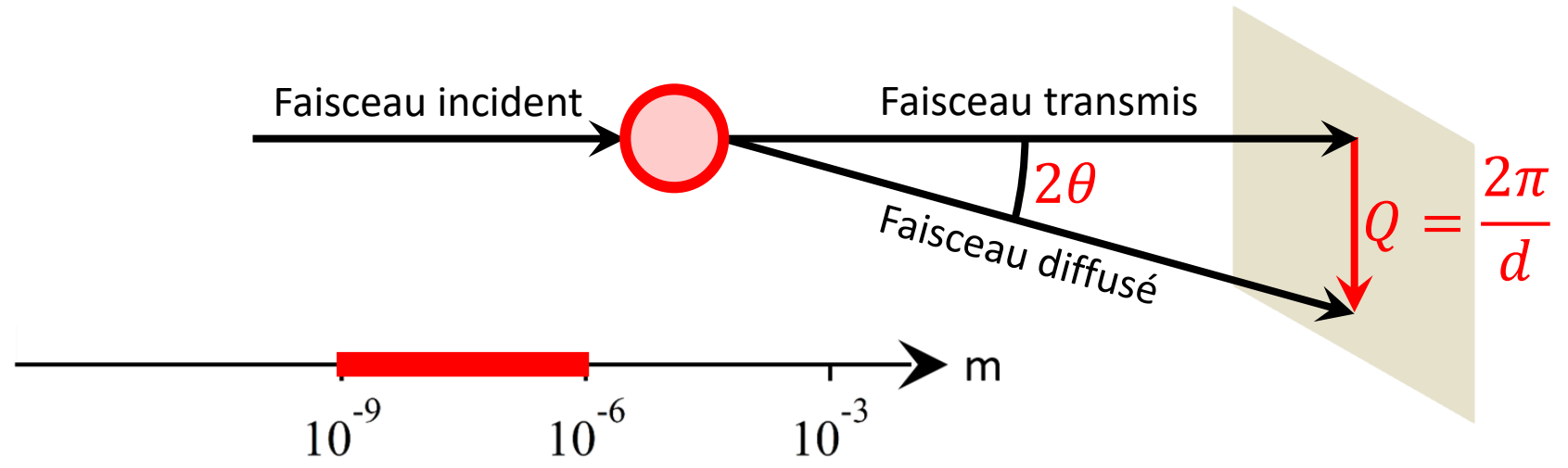
Spectroscopie neutronique
(Q et ω)



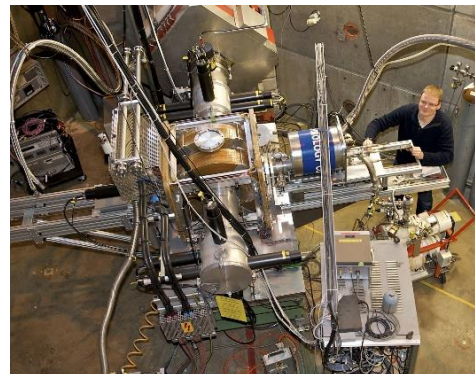
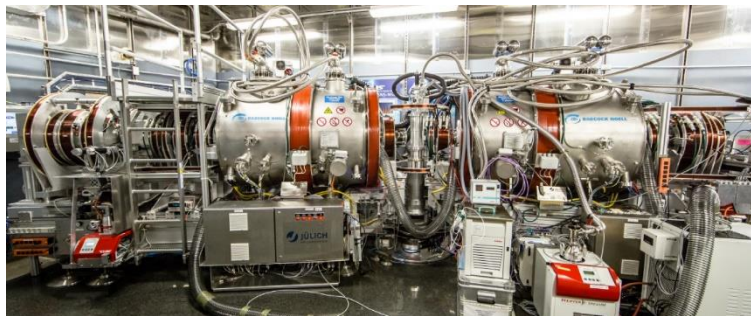
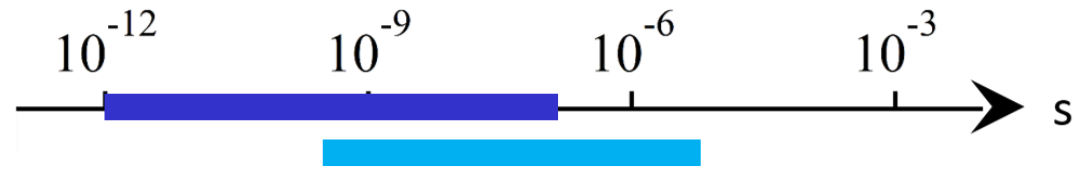
Le magnétisme à l'échelle mésoscopique: avec quels outils?



Diffraction de rayonnements aux petits angles (SANS/SAXS)

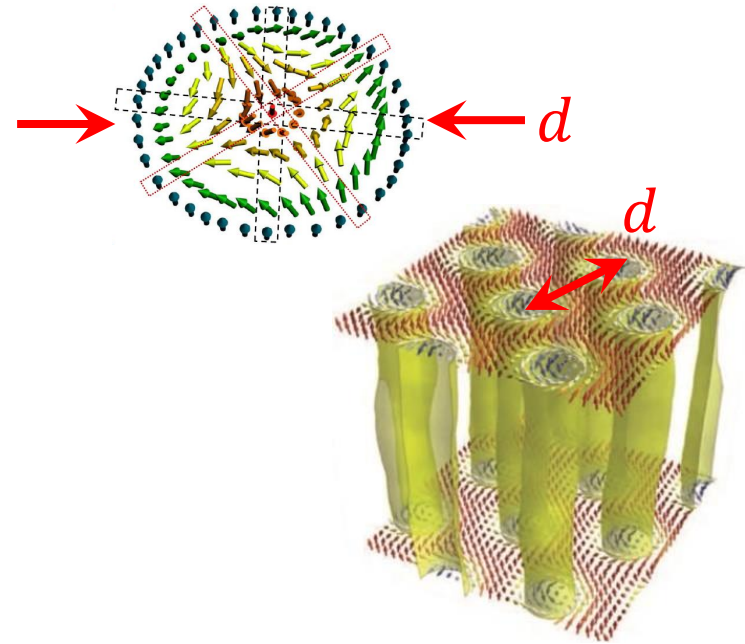


Spectroscopie neutronique (Q et ω)

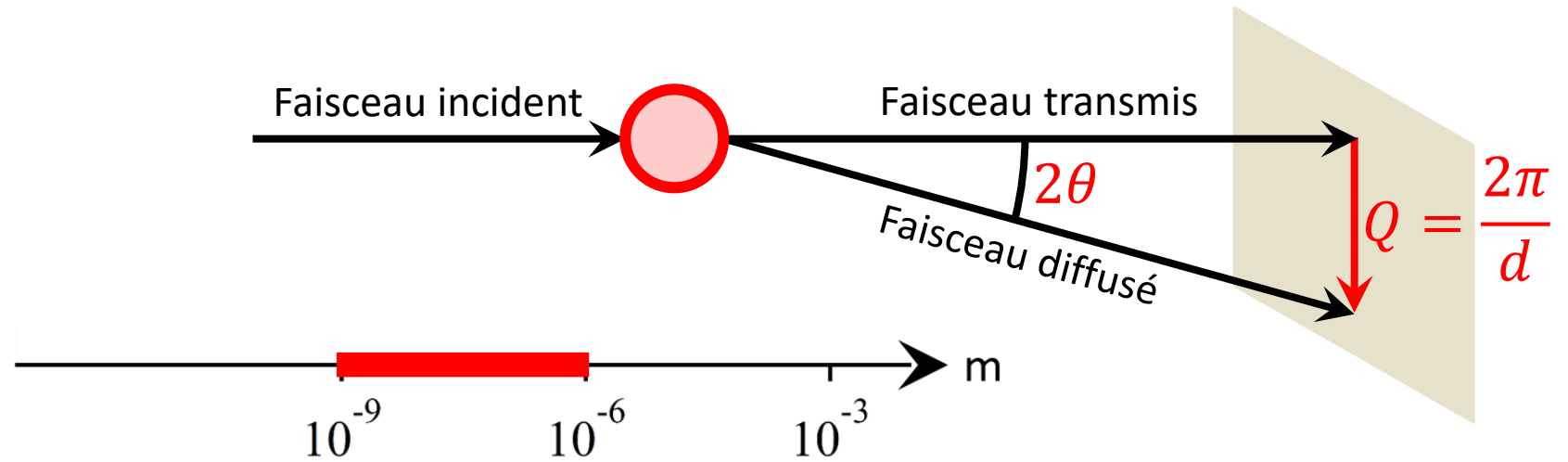


Rotation du spin du muon

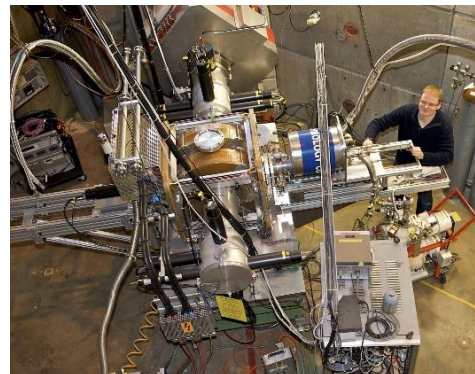
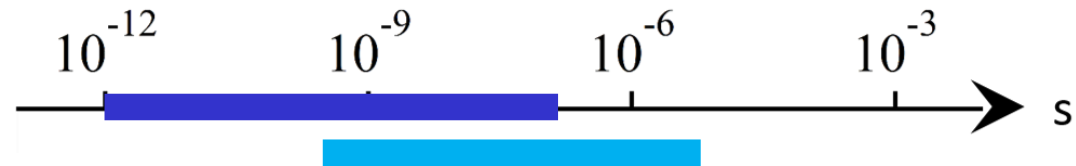
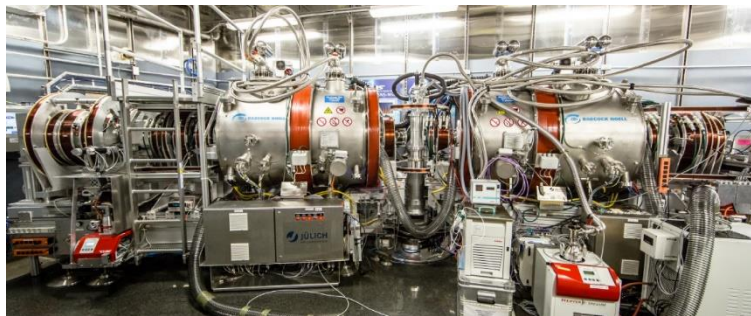
Le magnétisme à l'échelle mésoscopique: avec quels outils?



Diffraction de rayonnements aux petits angles (SANS/SAXS)

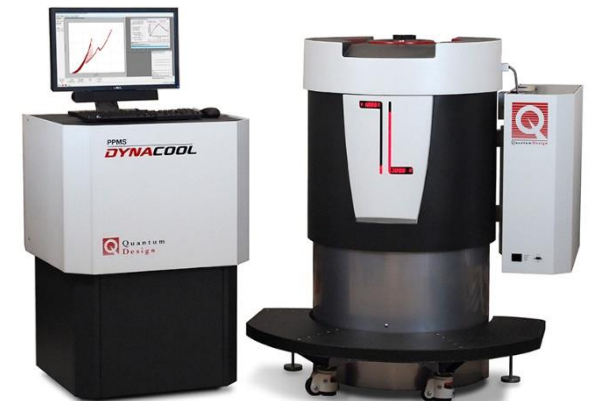


Spectroscopie neutronique
(Q et ω)

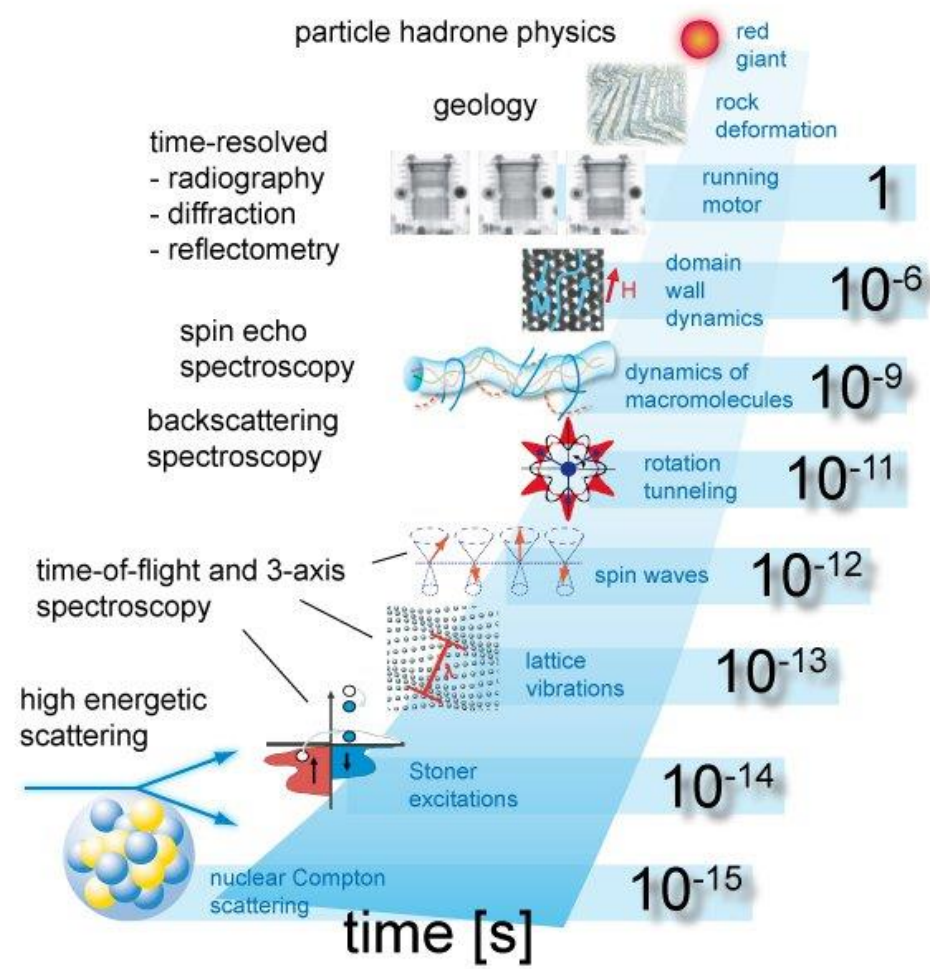
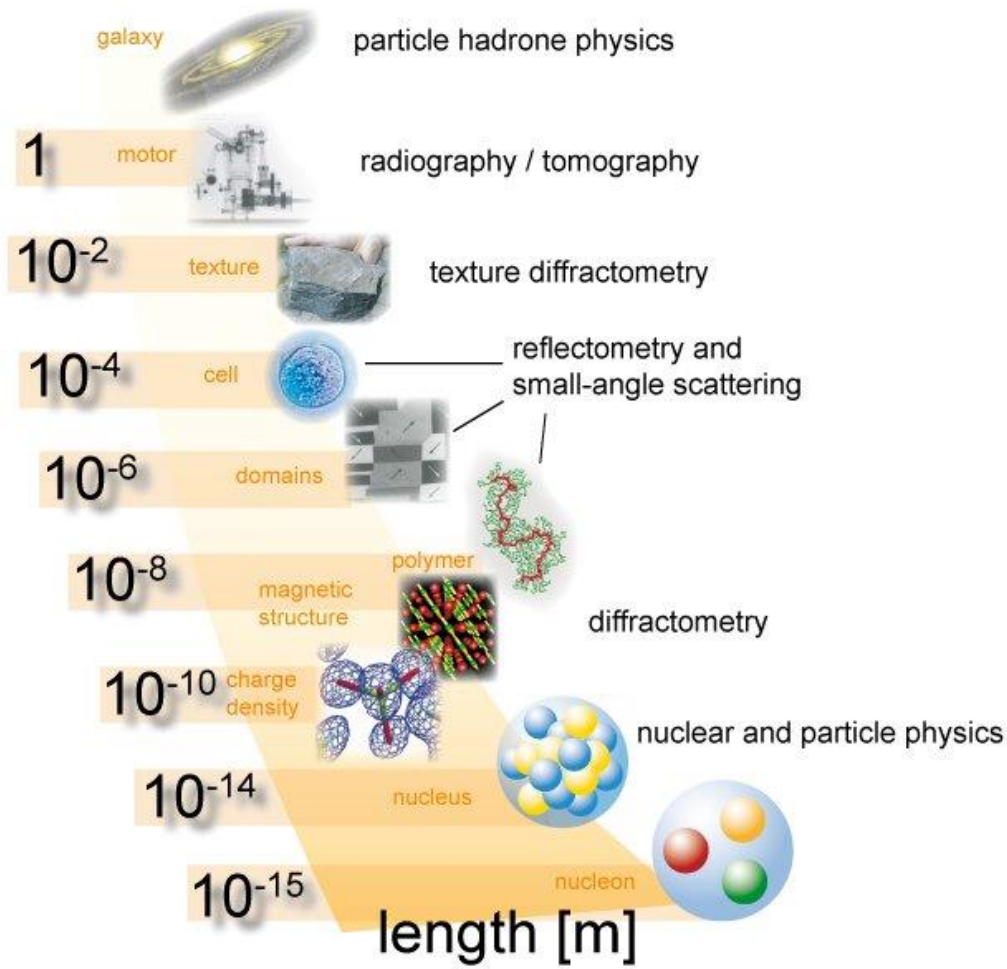


Rotation du
spin du muon

Magnétométrie



Spectroscopie neutronique – espace (Q,ω)



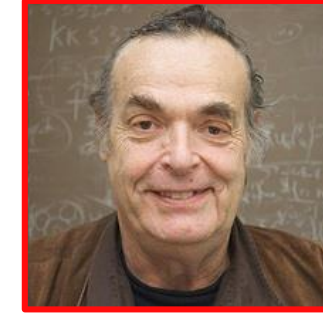
Spectroscopie MIEZE – principes (1)

- Quasi-elastic spectroscopy @ sub- μeV resolution

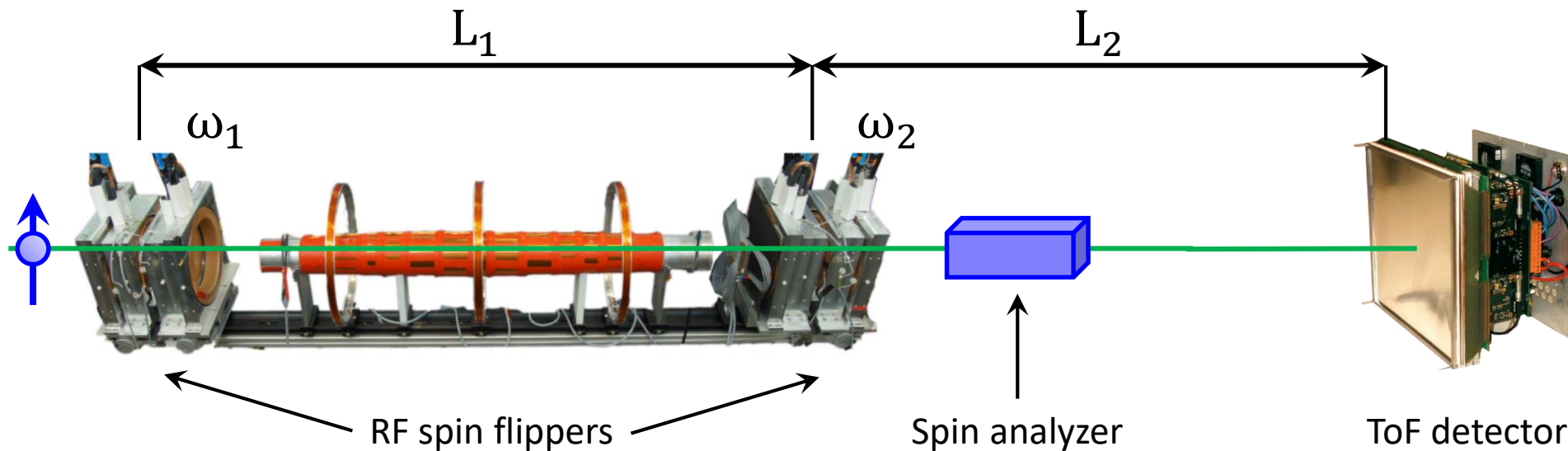
The incoming polarized neutron beam is manipulated by a pair of radio-frequency (RF) spin flippers running at frequencies ω_1 and $\omega_2 \rightarrow$ oscillation of neutrons' spin at a frequency $\omega_M = 2 \cdot (\omega_2 - \omega_1)$



R. Gähler, ILL



R. Golub, HMI
(now NYC University)



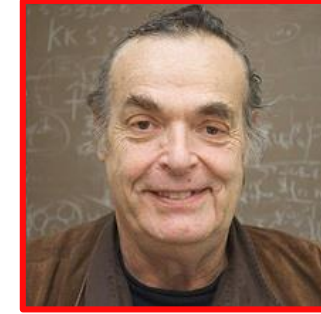
Spectroscopie MIEZE – principes (2)

- Quasi-elastic spectroscopy @ sub- μeV resolution

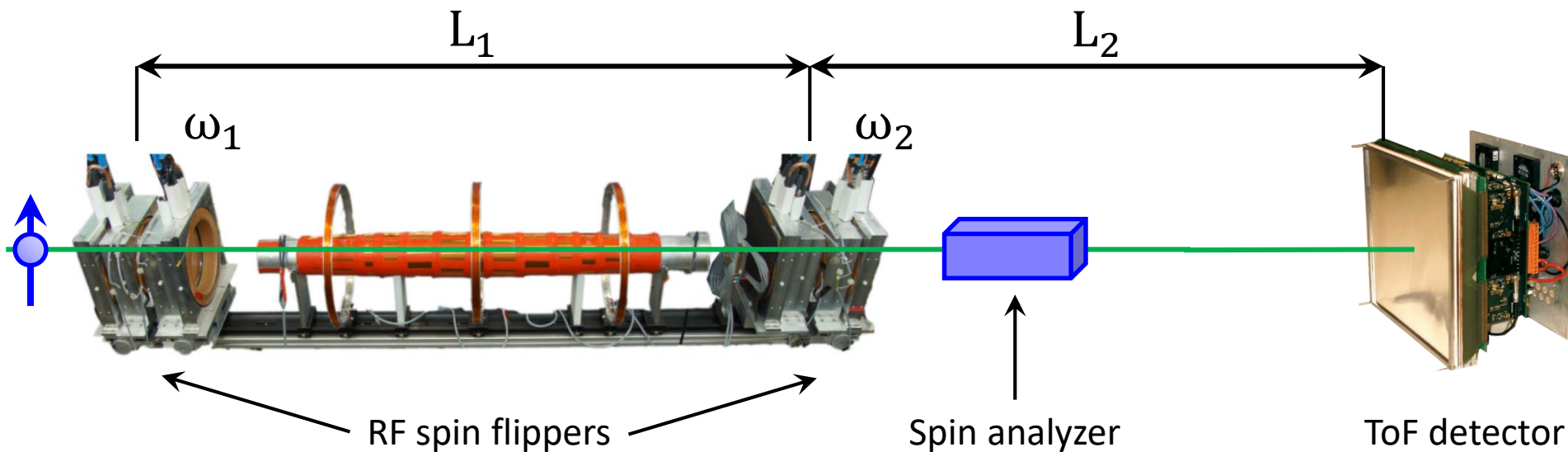
This time-dependent precession is converted into an **intensity modulation** by the spin analyzer.



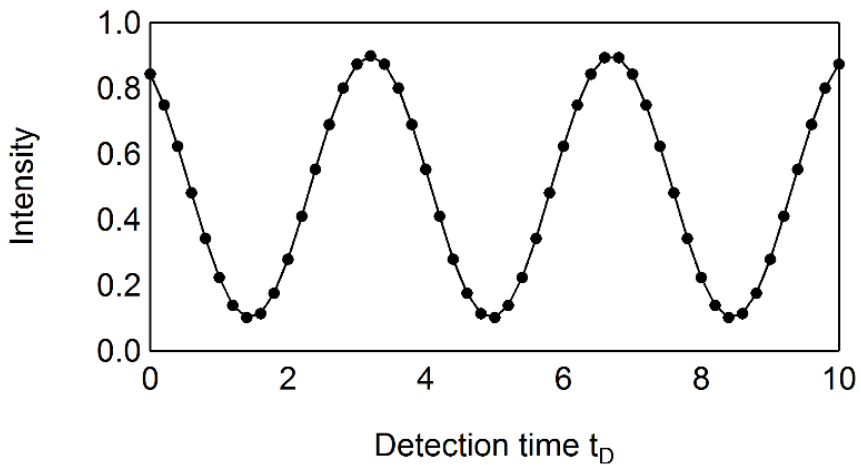
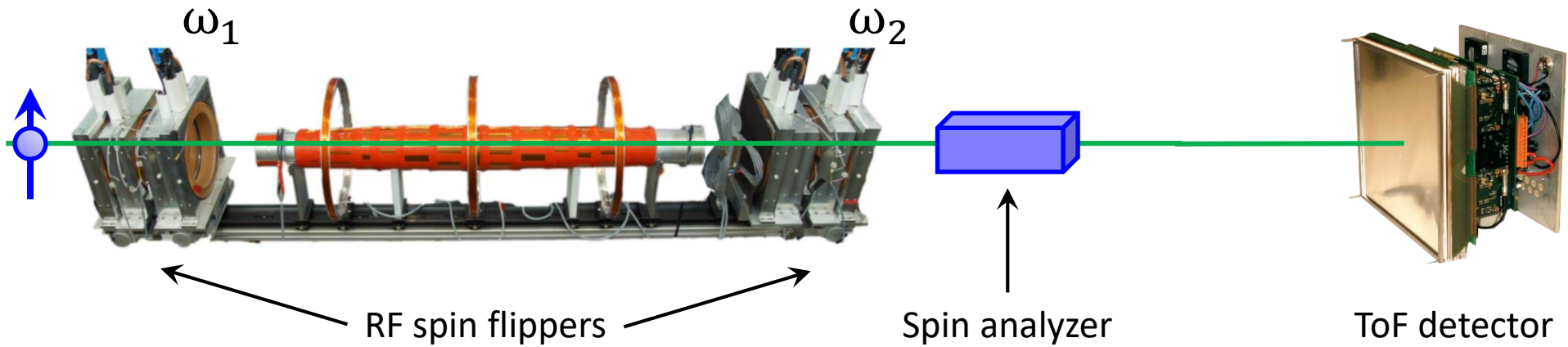
R. Gähler, ILL



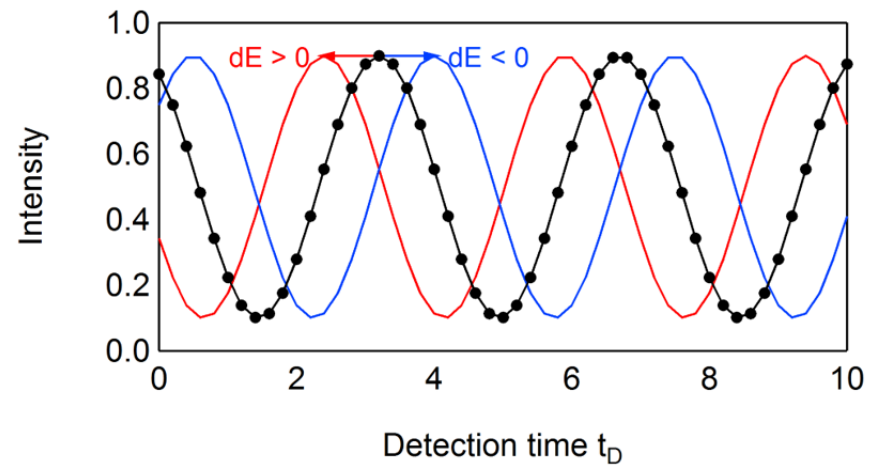
R. Golub, HMI
(now NYC University)



Spectroscopic MIEZE – principes (3)

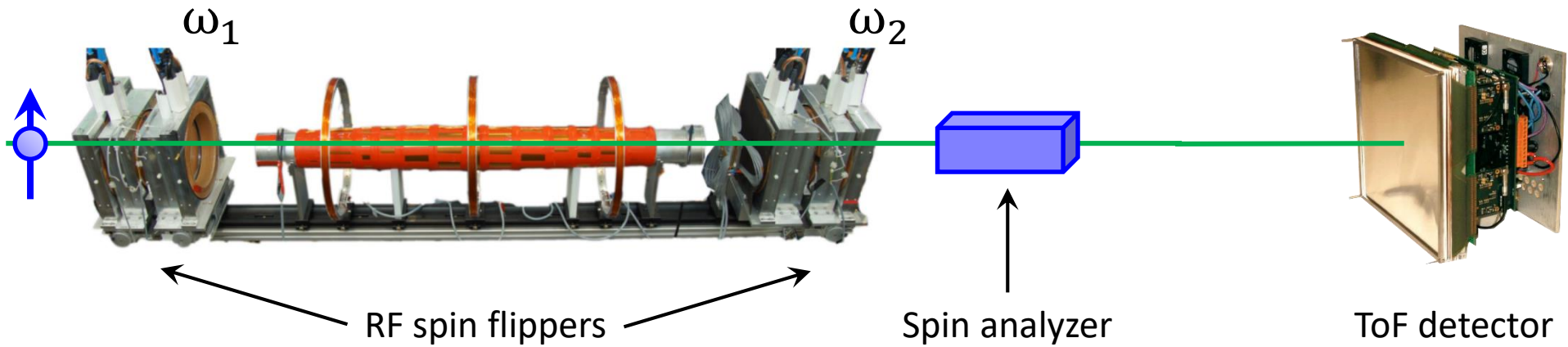


No scattering → harmonic intensity modulation at the detector

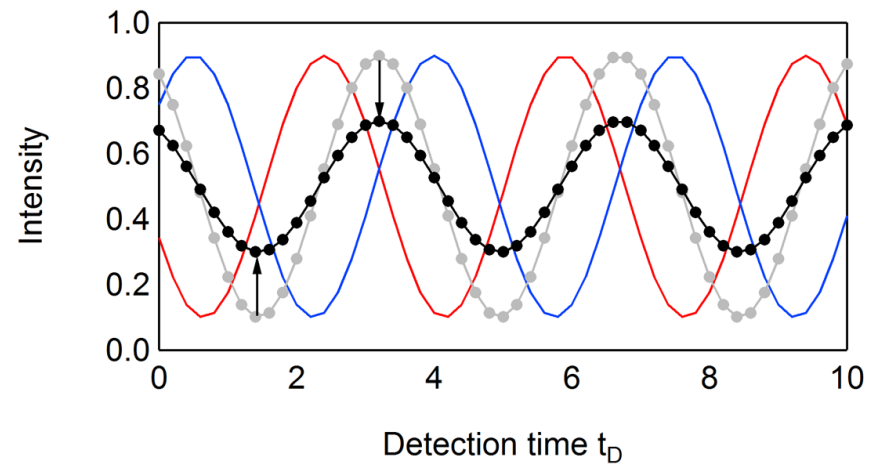


Quasi-/inelastic scattering process at the sample → distribution of neutron propagation time

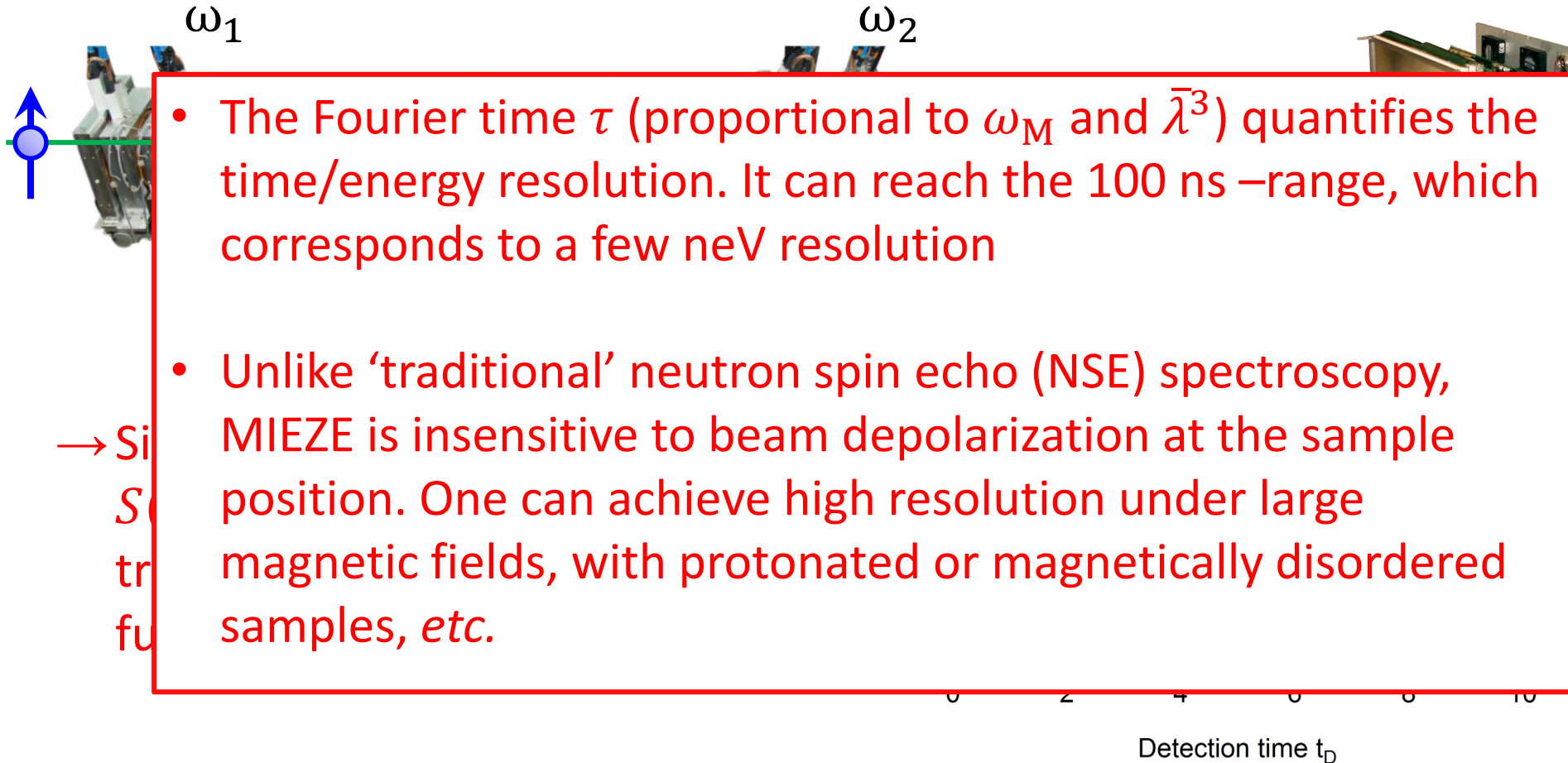
Spectroscopie MIEZE – principes (4)



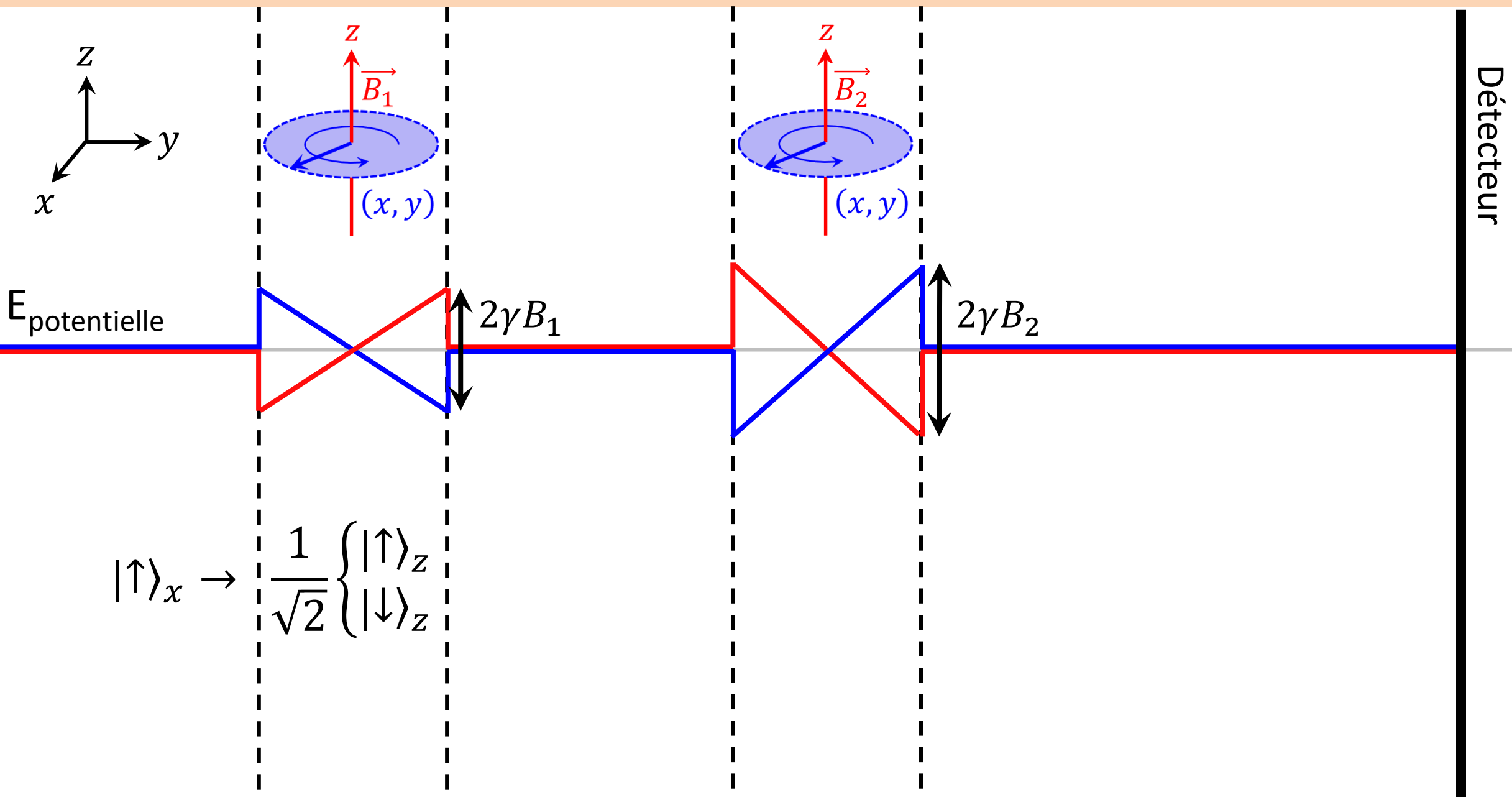
→ Signal contrast proportional to $S(q, \tau)$ i.e. the time-Fourier transform of the scattering function $S(q, \omega)$



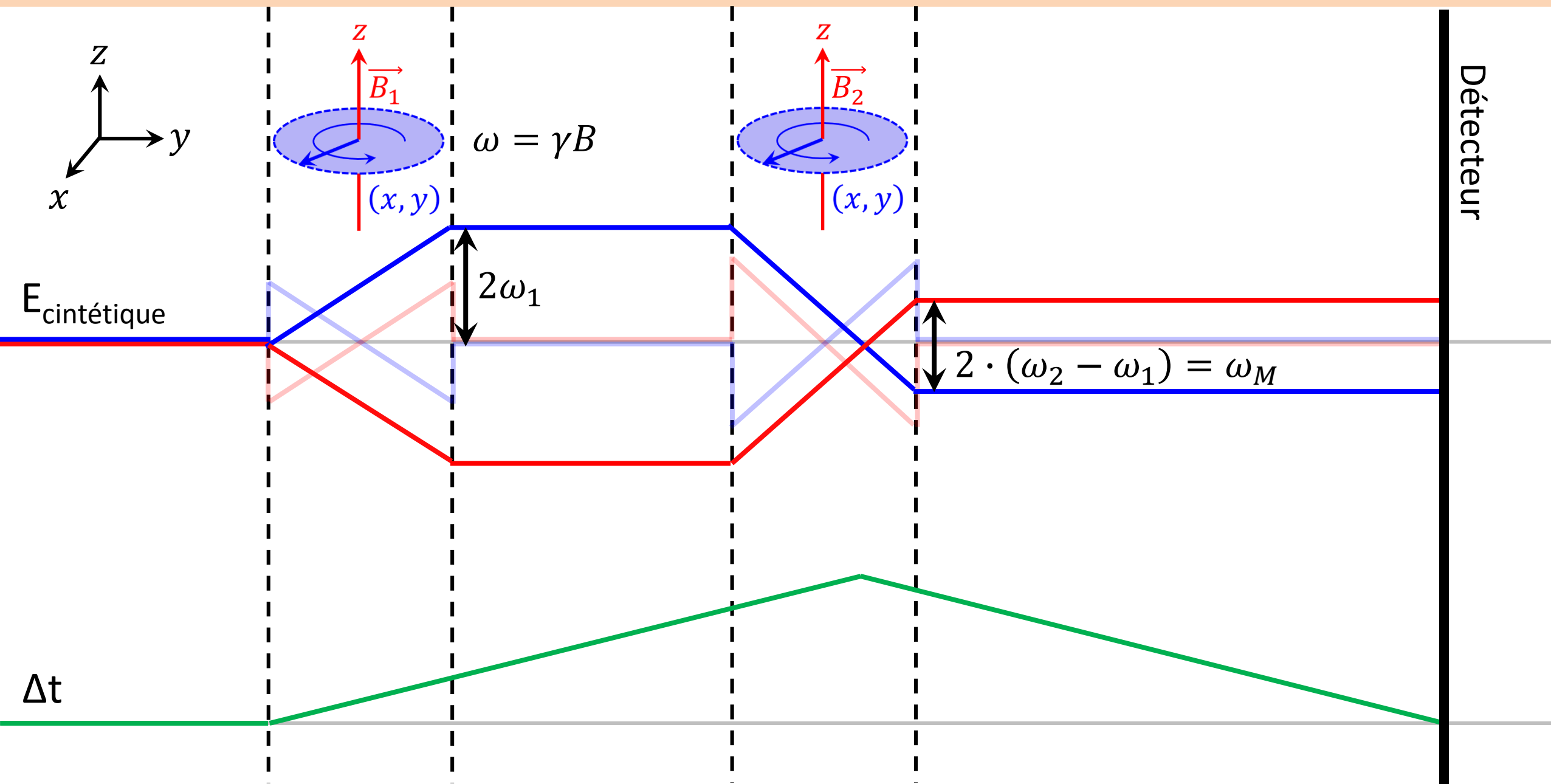
Spectroscopie MIEZE – principes (4)



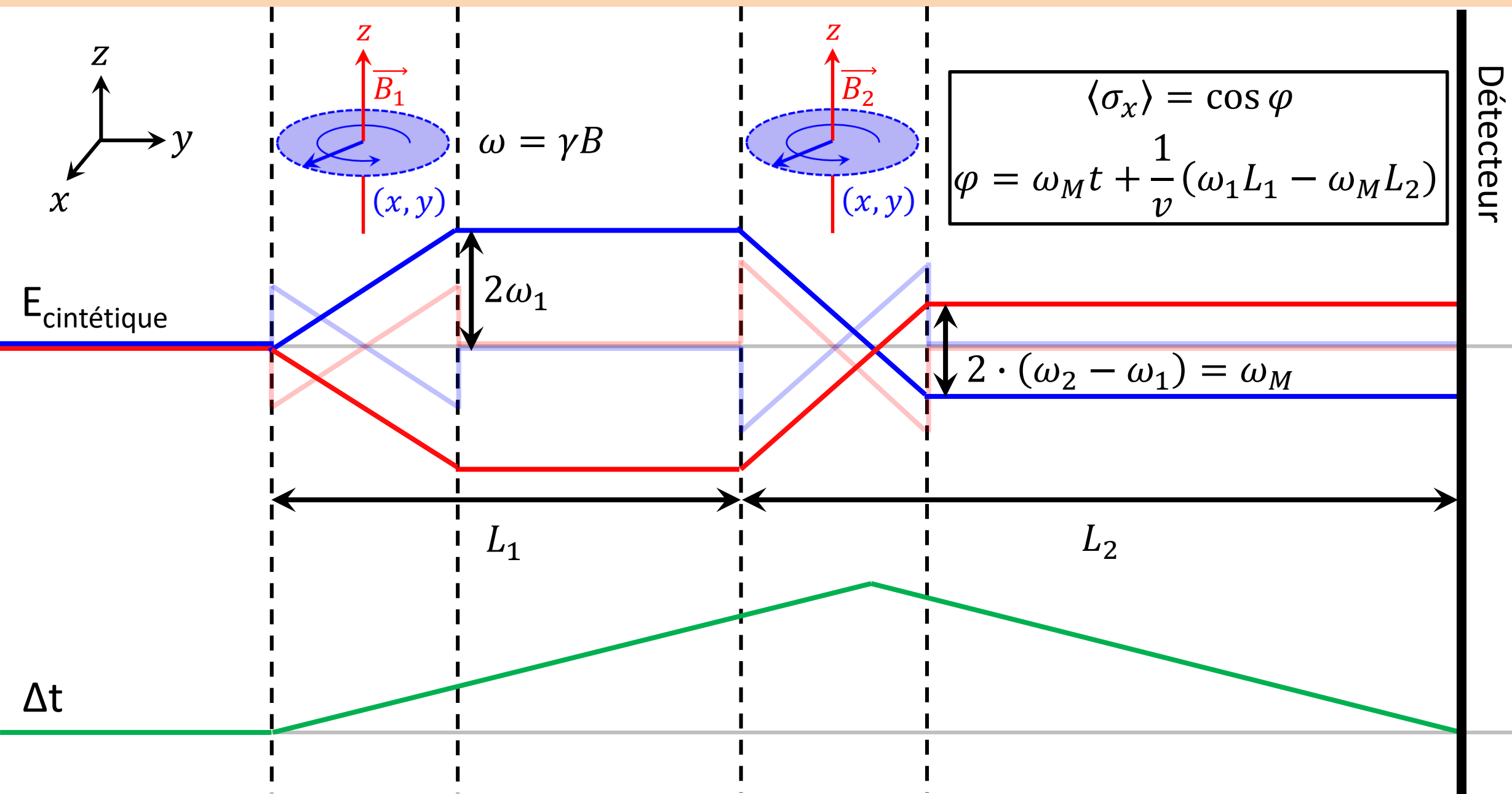
La spectroscopie "MIEZE" – description semi-classique



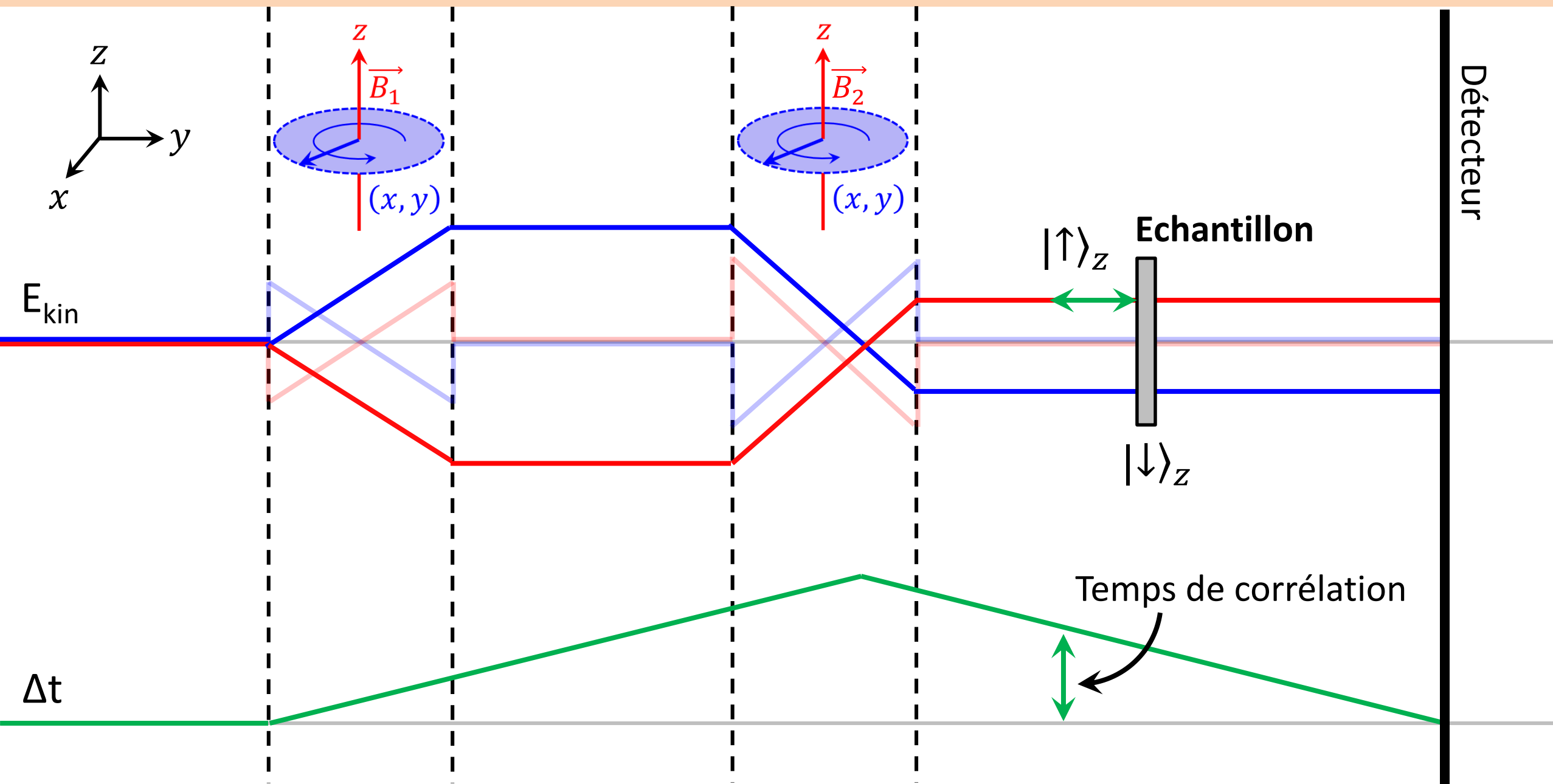
La spectroscopie "MIEZE" – description semi-classique



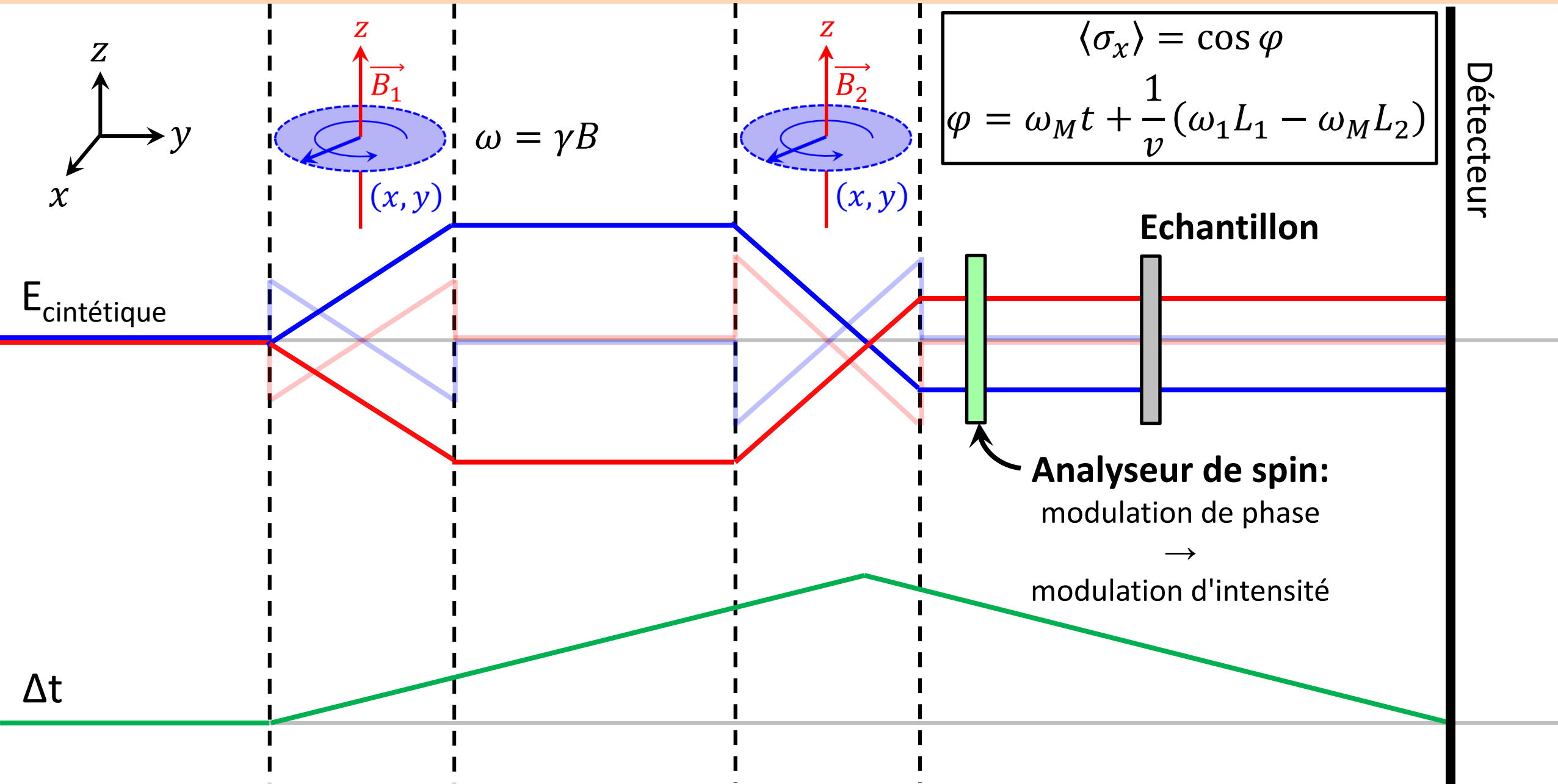
La spectroscopie "MIEZE" – description semi-classique



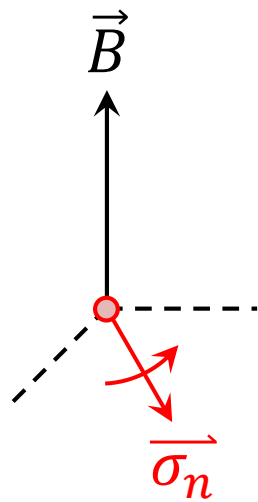
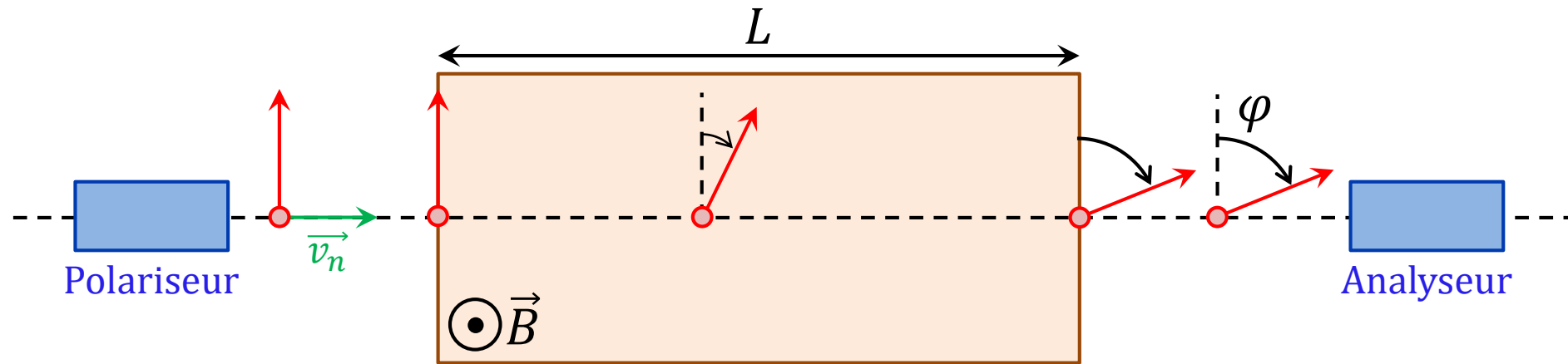
La spectroscopie "MIEZE" – description semi-classique



La spectroscopie "MIEZE" – description semi-classique

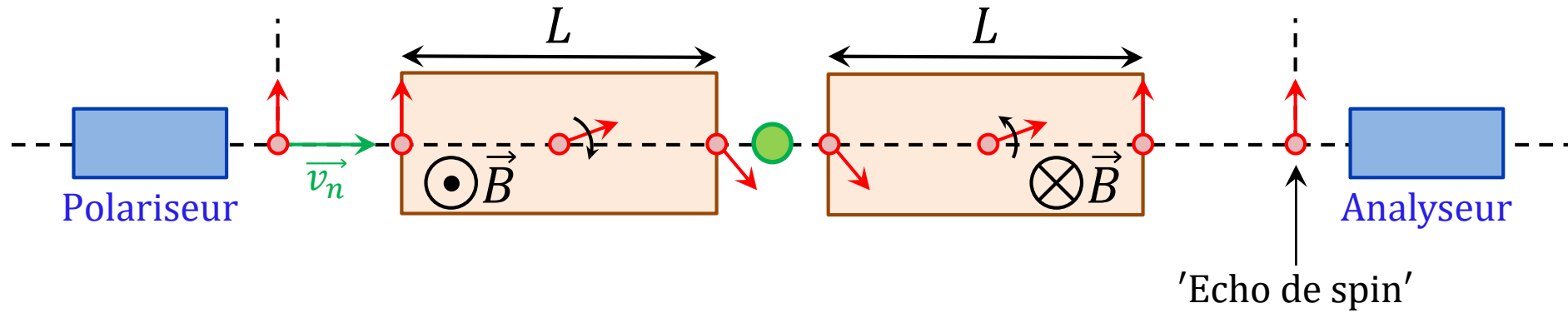


Précession de Larmor



$$\varphi = \underbrace{\gamma_n \cdot B}_{\text{Fréquence de Larmor}} \cdot \underbrace{\frac{L}{v_n}}_{\text{Temps de vol du neutron}}$$

Echo de spin neutronique – cas élastique

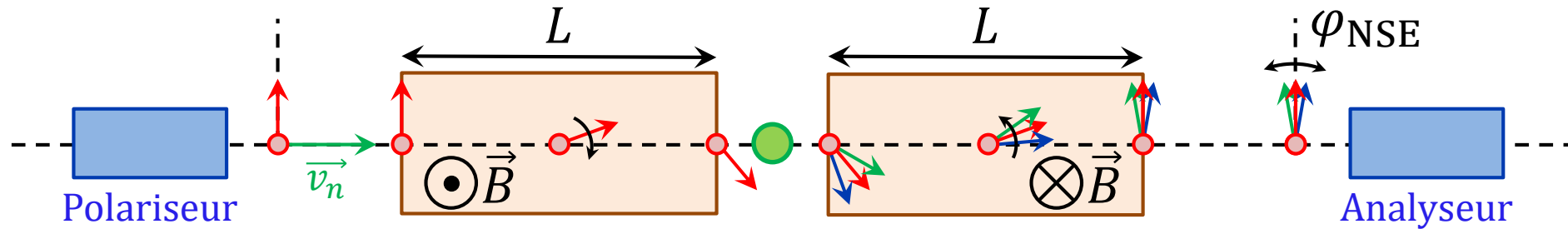


$$\varphi_{\text{NSE}} = \boxed{\gamma_n B L} \cdot \left(\frac{1}{v + \delta v} - \frac{1}{v} \right) = 0$$

Intégrale de champ magnétique

$\delta v = 0$
(diffusion élastique)

Echo de spin neutronique – cas quasi-élastique



$$\varphi_{\text{NSE}} = \gamma_n BL \cdot \left(\frac{1}{v + \delta v} - \frac{1}{v} \right) \neq 0$$

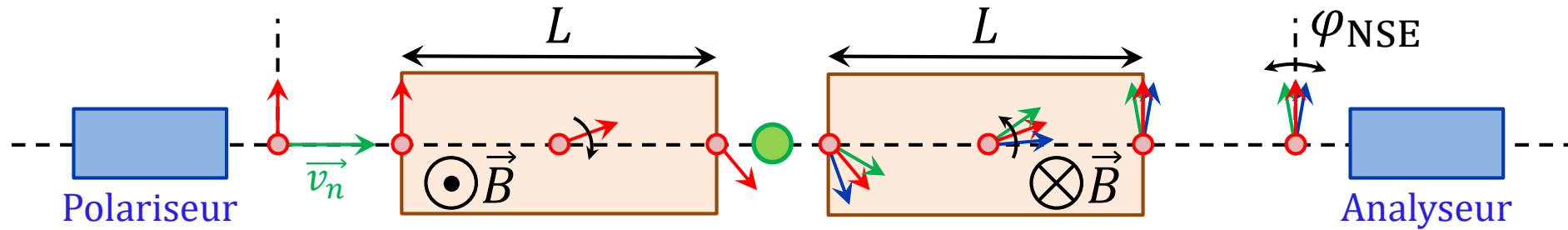
$$\xrightarrow{\delta v \ll v} \quad \boxed{\gamma_n BL} \cdot \frac{\delta v}{v^2} = \frac{\hbar \gamma_n BL}{m_n v^3} \cdot \boxed{\omega}$$

Transfert d'énergie neutron-échantillon

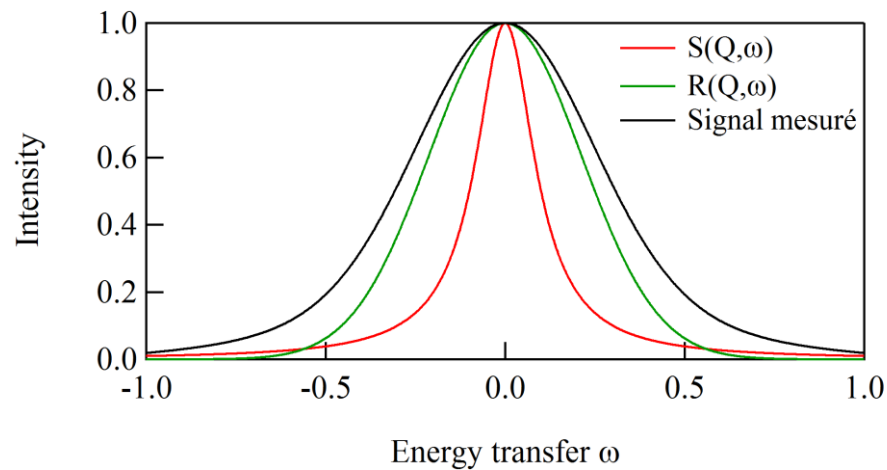
Intégrale de champ magnétique

Temps de Fourier τ

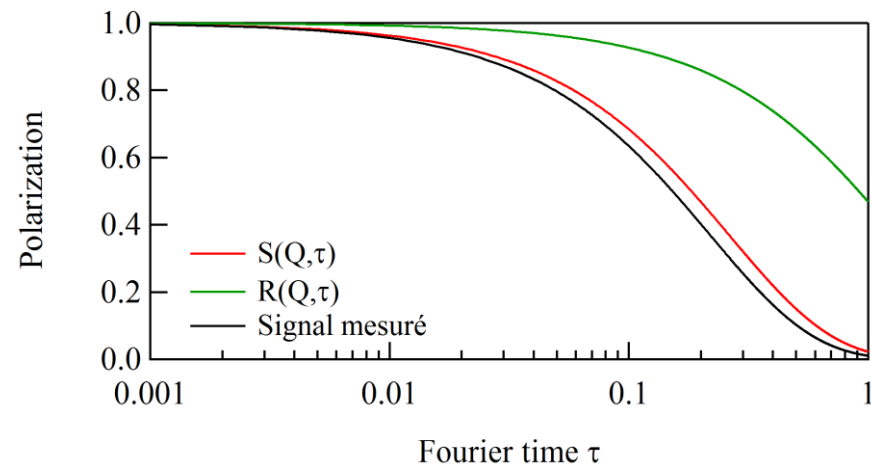
Echo de spin neutronique – quantité mesurée



$$P_{NSE} = \langle \cos \varphi_{NSE} \rangle = \int \cos(\tau \cdot \omega) \cdot S(Q, \omega) \cdot d\omega \equiv S(Q, \tau)$$

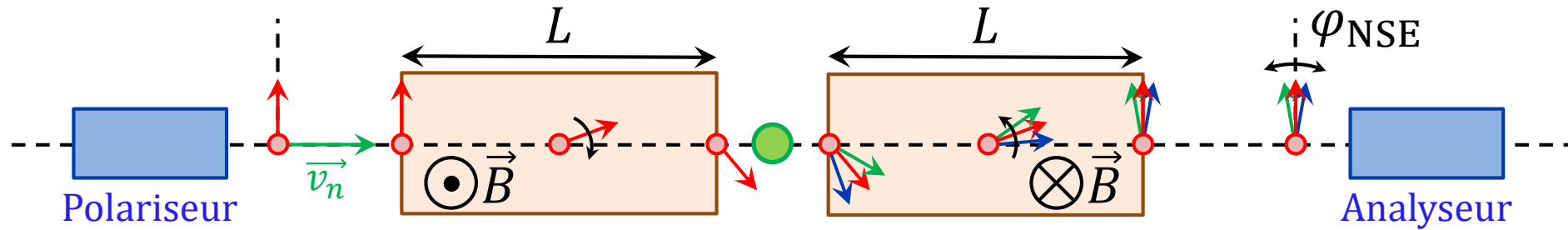


Signal mesuré: $S(Q, \omega) * R(Q, \omega)$
 → déconvolution



Signal mesuré: $S(Q, \tau) \cdot R(Q, \tau)$
 → division

Echo de spin neutronique – avantages

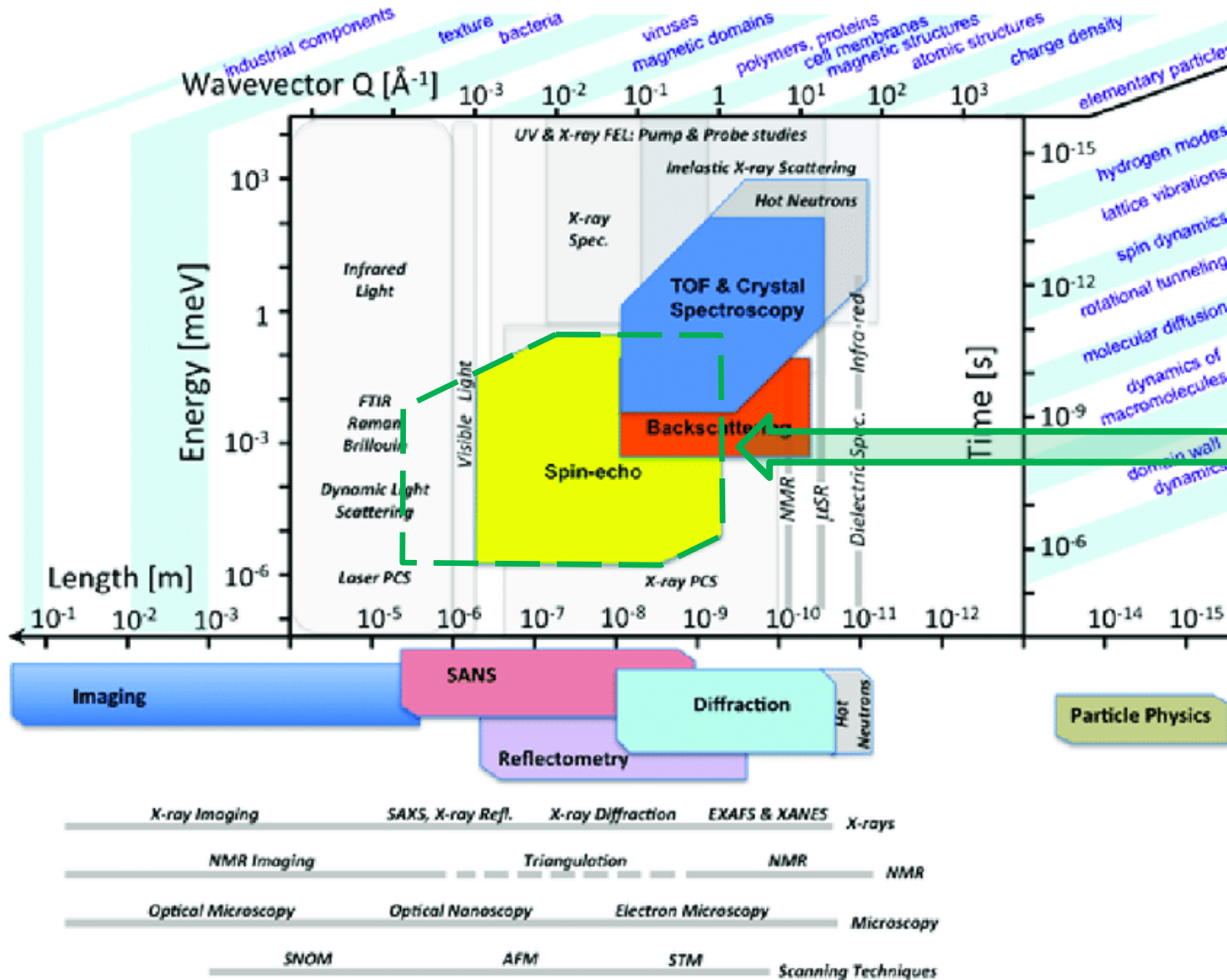


$$P_{NSE} = \langle \cos \varphi_{NSE} \rangle = \int \cos(\tau \cdot \omega) \cdot S(Q, \omega) \cdot d\omega \equiv S(Q, \tau)$$

- **La condition d'écho de spin est *indépendante* de la longueur d'onde:** travail avec des faisceaux modérément monochromatisés ($\frac{\Delta\lambda}{\lambda} \approx 10\text{-}20\%$).
- **Meilleure résolution en énergie** atteignable en diffusion neutronique
- Donnée par le temps de Fourier $\tau = \frac{\hbar\gamma_n BL}{m_n v^3}$

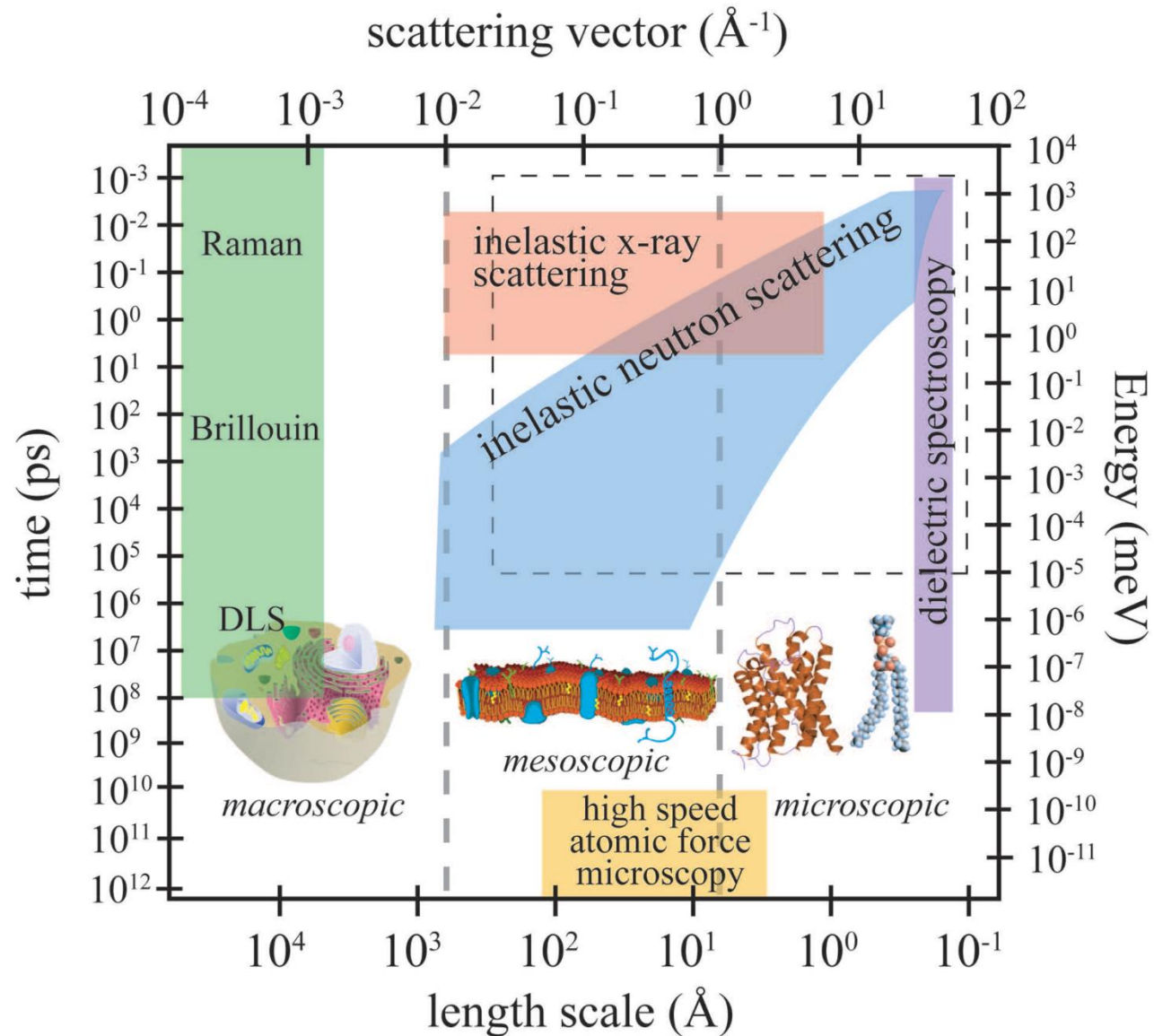
e.g. IN15 @ ILL : $(BL)_{\max} = 2.7 \cdot 10^5 \text{ G} \cdot \text{cm}$, $\lambda = 25 \text{ \AA} \rightarrow \tau_{\max} \approx 500 \text{ ns} \leftrightarrow \delta E \approx 1 \text{ neV}$

Spectroscopie MIEZE dans l'espace (Q, τ)

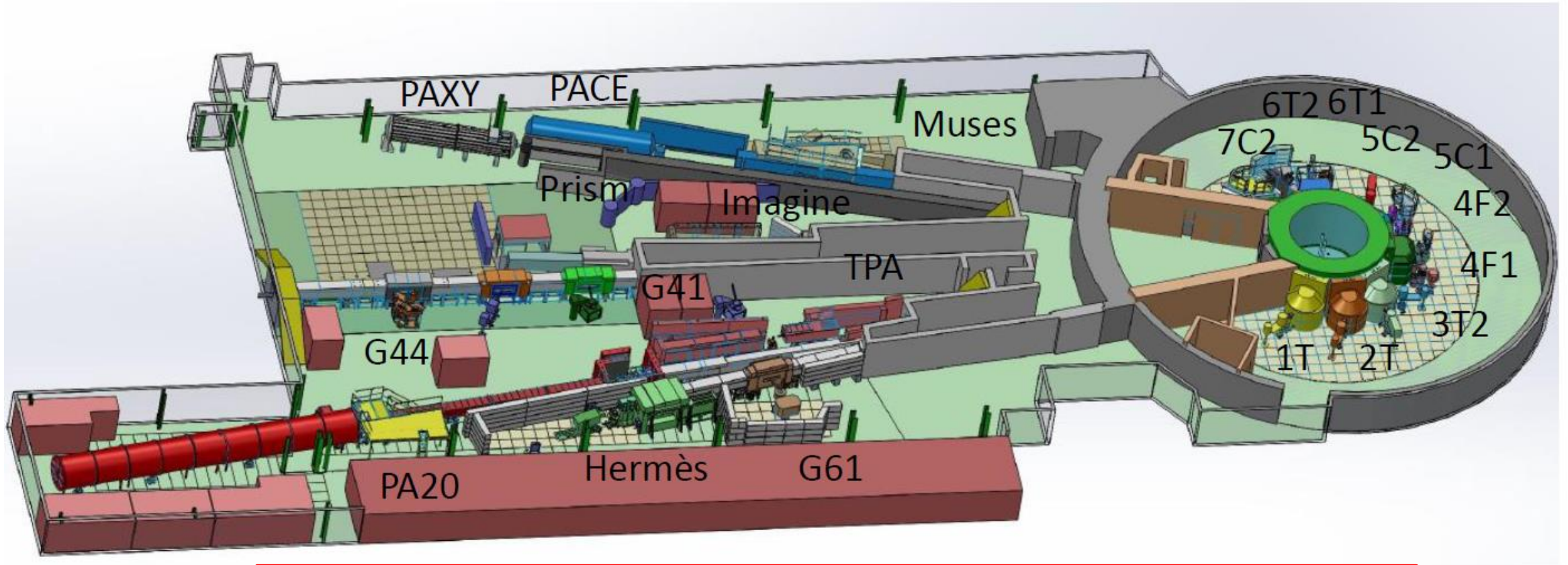


MIEZE:
SANS + H et P

Spectroscopie MIEZE dans l'espace (Q,τ)



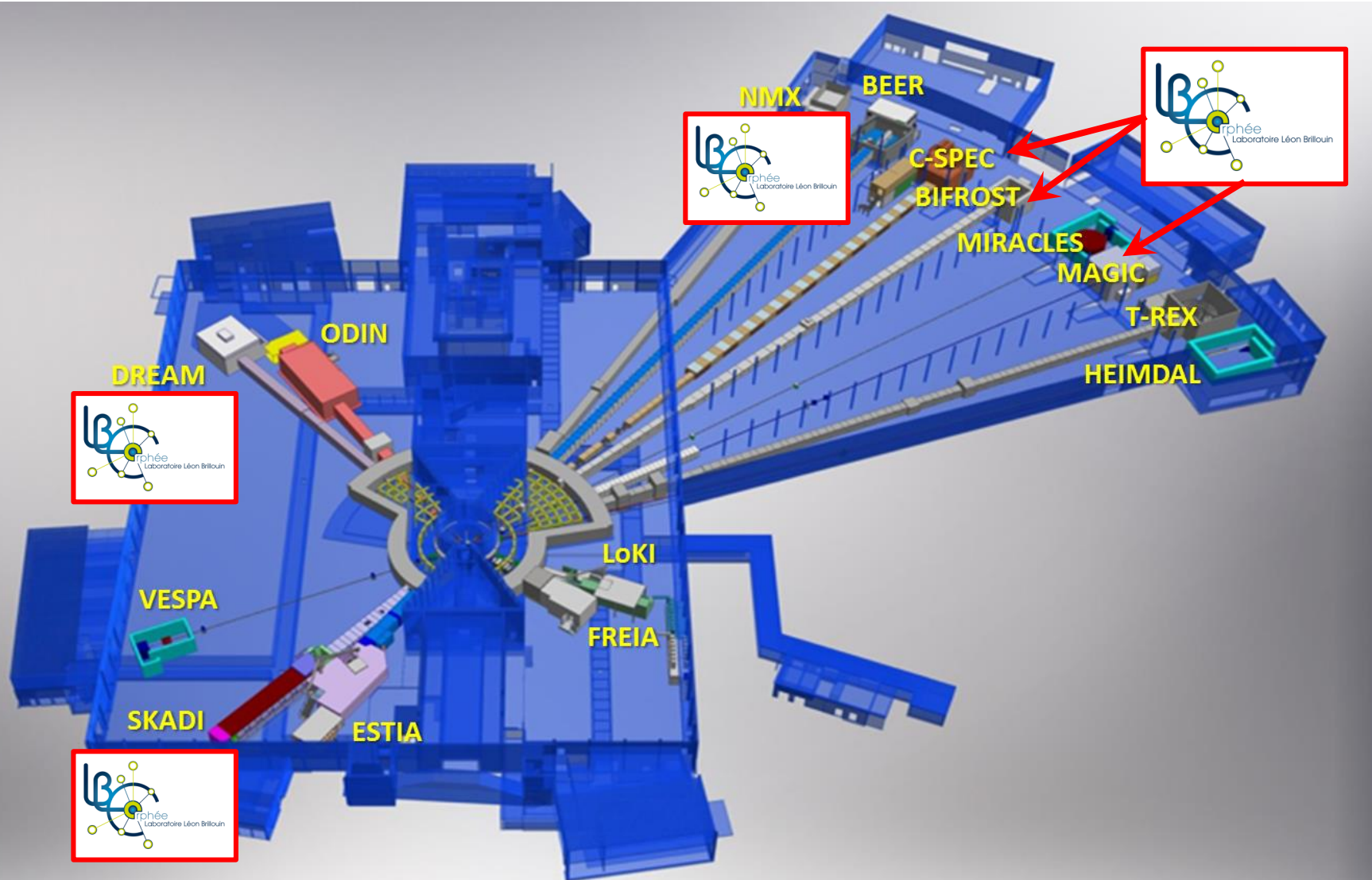
Laboratoire Léon Brillouin: instruments



21 instruments

- 9 diffractomètres
- 4 petits-angles
- 2 réflectomètres
- 4 spectromètres trois-axes
- 1 spin echo
- 1 station d'imagerie

European Spallation Source: instruments et contributions françaises



French contributions

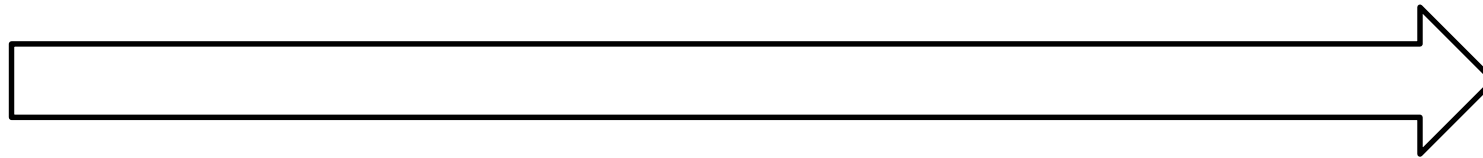
- MAGIC (60 %):**
 - Polarized single-crystal diffraction
- C-SPEC (50 %):**
 - Cold ToF, direct geometry
- SKADI (50 %):**
 - SANS
- DREAM (24 %):**
 - Powder diffraction
- BIFROST (22 %):**
 - ToF, indirect geometry
- NMX (14 %):**
 - Diffraction for biophysics

Le développement instrumental...

'The development of a new method -whenever its precision, sensitivity, or resolution is better than everything that existed before- leads to new science.'



Heinz Maier-Leibnitz
ILL director (1967-1972)



Rudolf Mößbauer
ILL director (1972-1977)



Decision to build in parallel IN11-NSE (based on a 3 pages hand-written proposal! cf. F. Mezei) and IN10-BSS (perceived as less interesting than NSE)

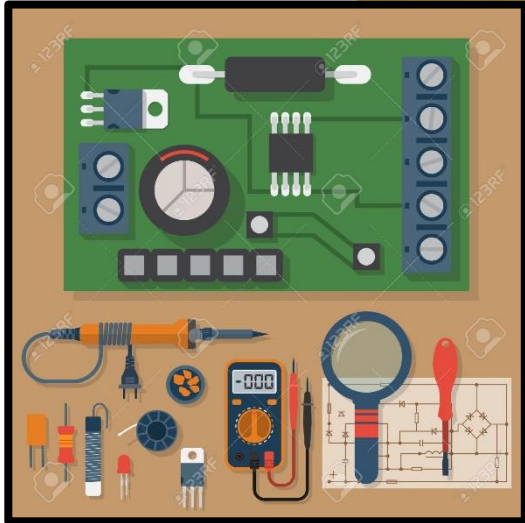
L'ingénieur de recherche: un rôle pivot

Solution
instrumentale

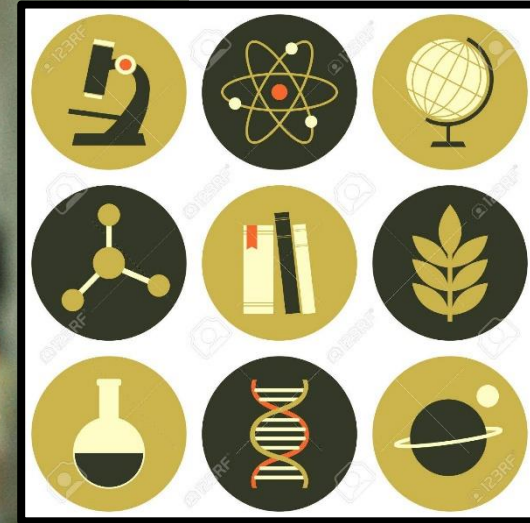
Physique
"nouvelle"



L'ingénieur de recherche: un rôle pivot



Maîtrise des aspects techniques et instrumentaux



Compréhension des problèmes scientifiques

