LLB CRG Inelastic instruments at ILL: from IN6 to SHARP then SHARP$^+$

S. Rodrigues[1], P. Lavie[1], B. Homatter[1], S. Petit[1], Q. Berrod[2], P. Permingeat[1], T. Robillard[1], F. Legendre[1] and *J.-M. Zanotti*[1]

[1] Laboratoire Léon Brillouin , Saclay, France
[2] IRIG/SyMMES , Grenoble, France

DE LA RECHERCHE À L'INDUSTRIE cea

cnrs dépasser les frontières

LLB Orphée Laboratoire Léon Brillouin

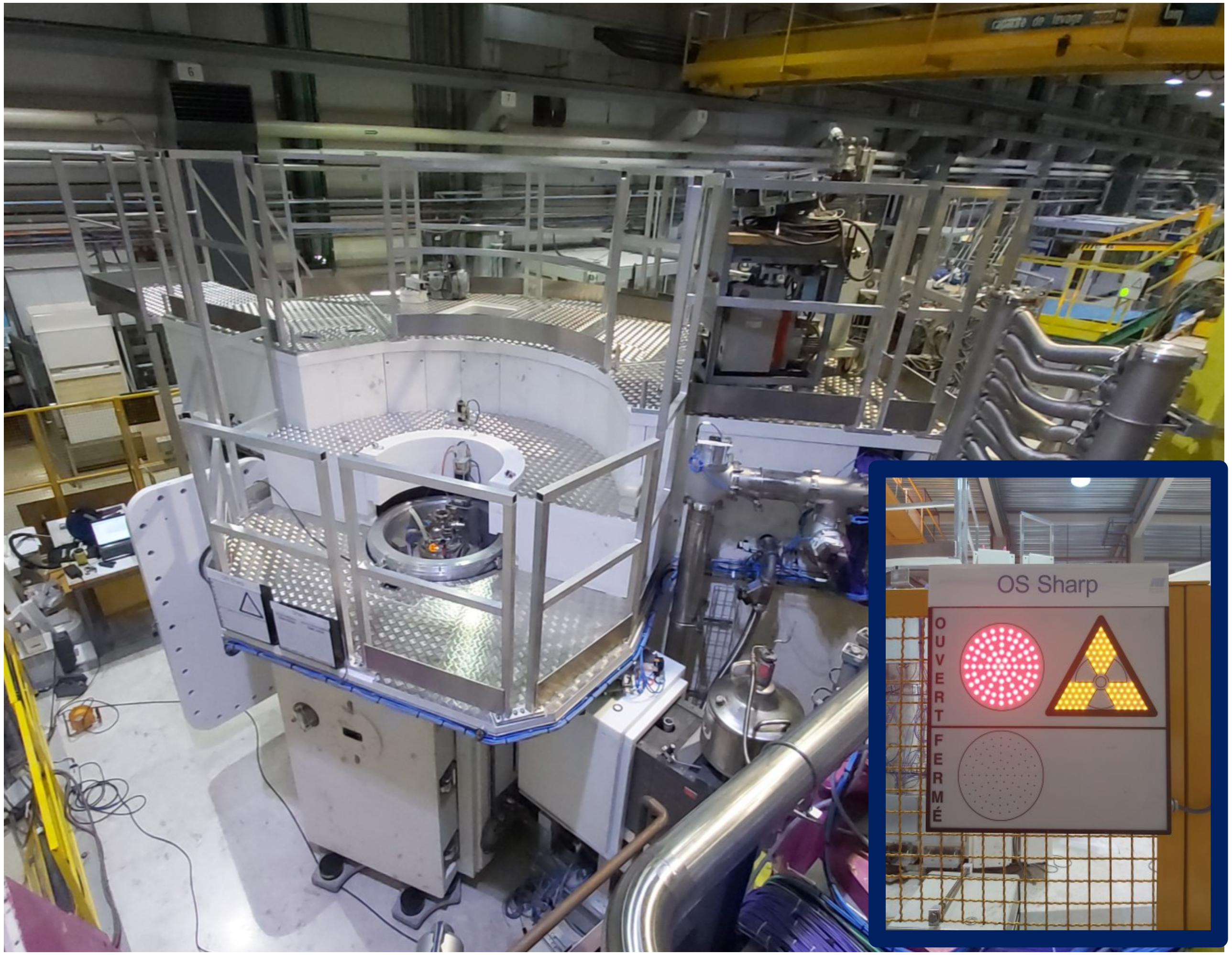
université PARIS-SACLAY

ill NEUTRONS FOR SCIENCE

SHARP (Spectromètre Hybride Alpes Region Parisienne)

Cold time-of-flight inelastic spectrometer by "time focusing" LLB CRG “A” at ILL

March 21 2021 : SHARP Up and Running

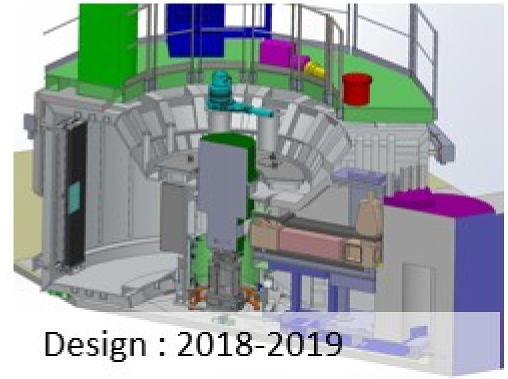


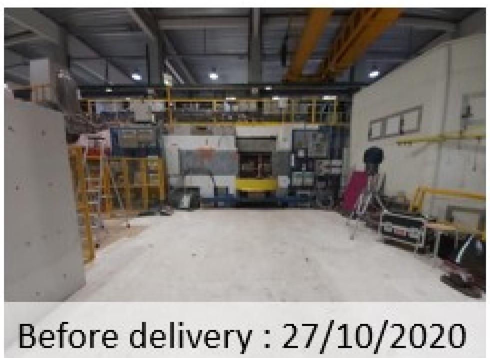
Orphée Laboratoire Léon Brillouin

SHARP (Spectromètre Hybride Alpes Region Parisienne) The Making-Of

NEUTRONS FOR SCIENCE


IN6 : 28/09/2020


Design : 2018-2019


Before delivery : 27/10/2020


Delivery : 30/11/2020


Delivered : 30/11/2020


Detectors : 11/03/2021

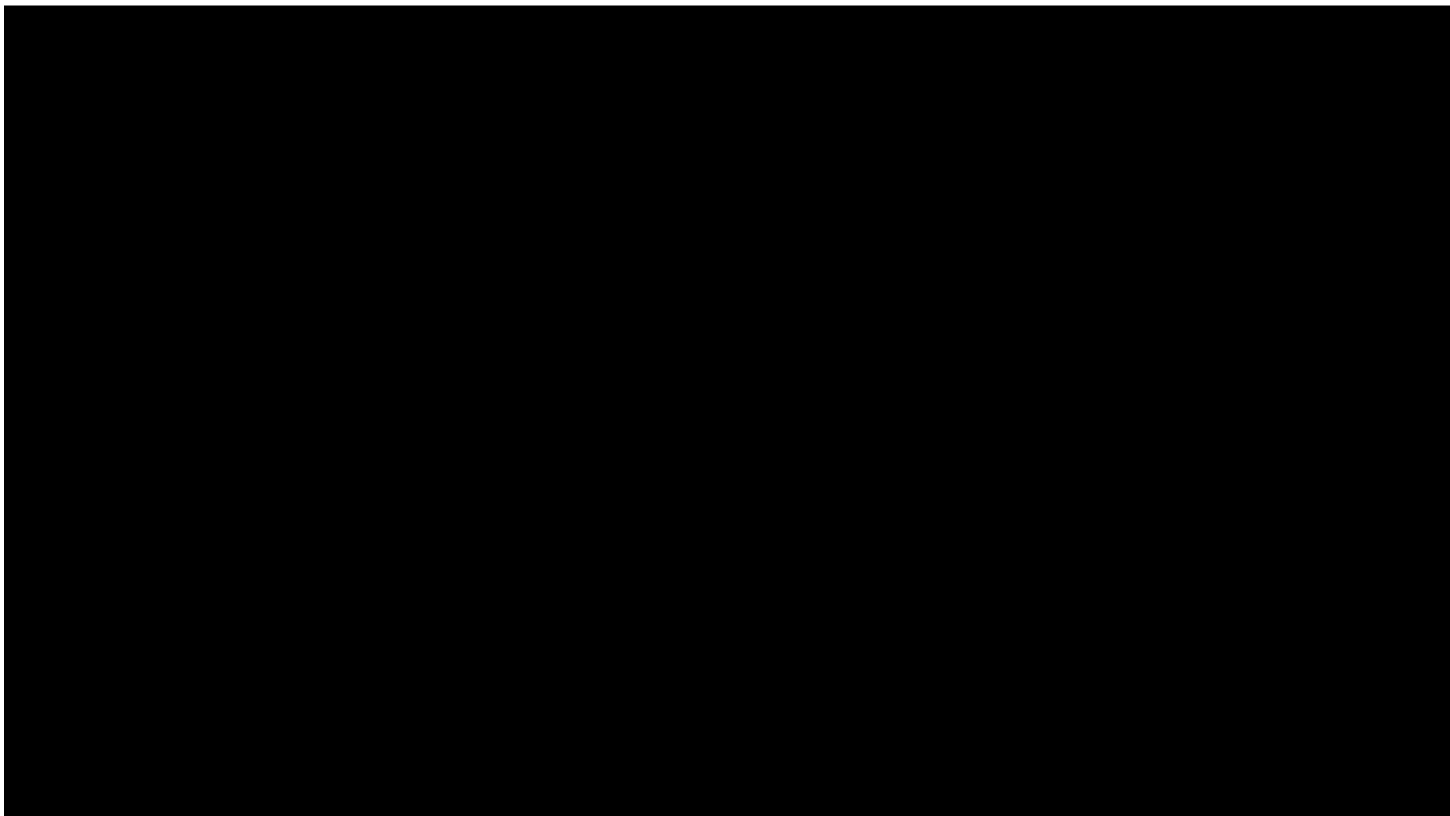

Sample Env. : 19/03/2021

On line : 21/03/2021

SHARP (Spectromètre Hybride Alpes Region Parisienne)
A LLB CRG “A” at ILL

- Cycle 1: January 27 to March 30: Construction & first neutrons (March 21 2021)
- Cycle 2 : May 11 to July 14: Commissioning
- Cycle 3: August 24 to Oct. 13: Back to users granted beam time (50% 2FDN /50 %ILL)

NB: First neutrons in less than 5 months from the delivery of the “naked” chamber

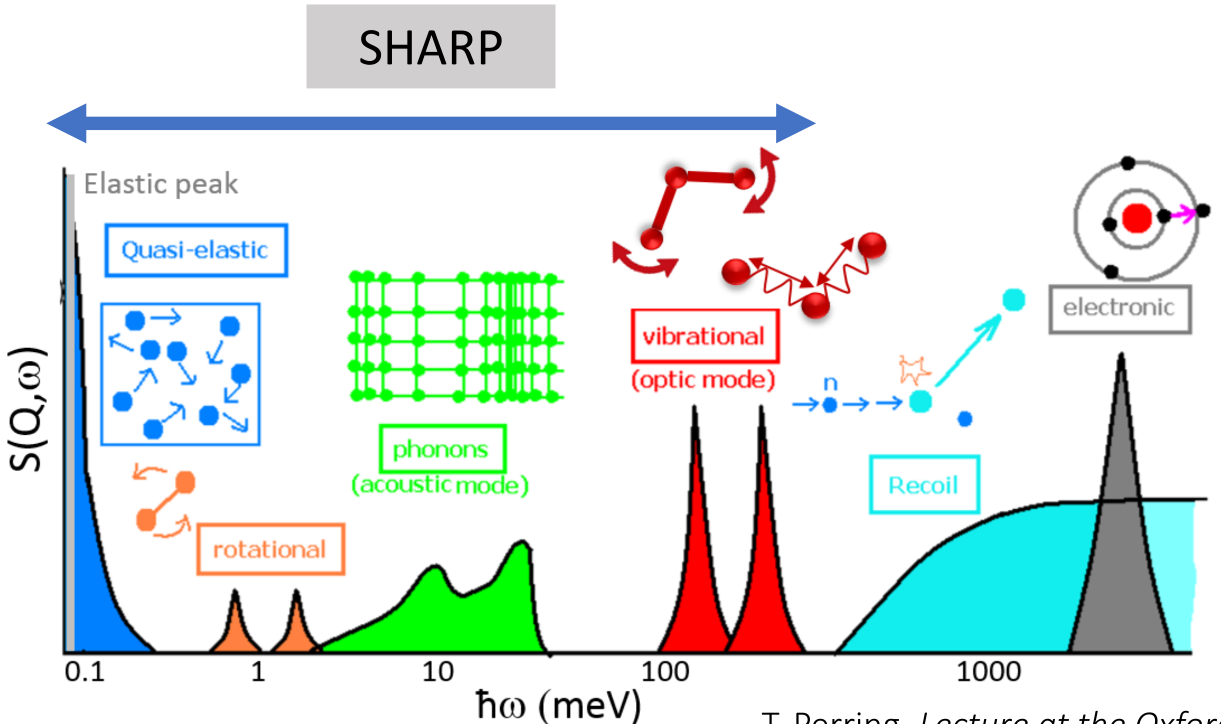


Credit: Amélien Genelle, CEA/DRF/IRIG/SyMMES

Scientific Fields on the SHARP playground

Study of dynamics and relaxation properties in condensed matter:

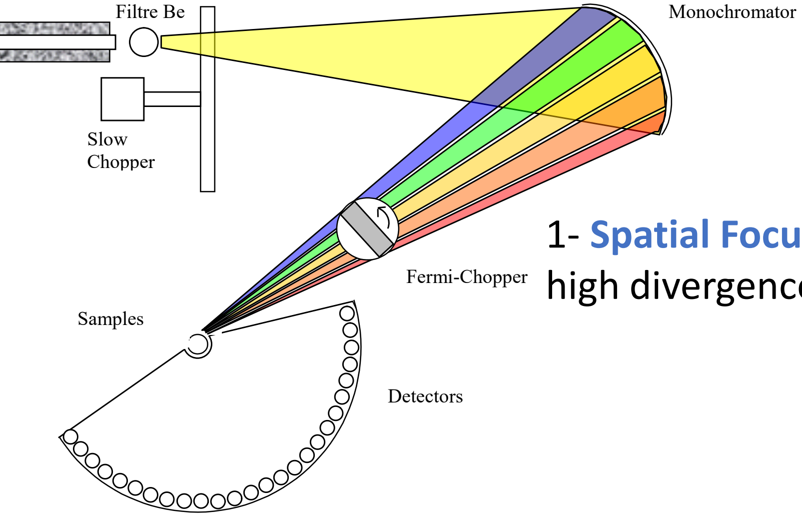
- Dynamics of soft condensed matter such as polymers, proteins, biological membranes and gels
- Local and long range diffusion of liquids, solutions and confined systems
- Vibrational density of states of crystalline and amorphous solids
- Properties of quantum liquids, Fermi and non-Fermi systems
- Phase transitions and quantum critical phenomena in polycrystals and single crystals
- Spin dynamics in high-T_c superconductors
- Properties of crystal field splitting



T. Perring, *Lecture at the Oxford Neutron School* (2007)

Time Focusing Xtal Spectrometers

Mesot, Janssen, Holitzner & Hempelmann, J. Neutron Research, 3, 293-310 (1993).



1- **Spatial Focusing** : focusing Monochromator to fully take advantage of the high divergence of the converging guide.

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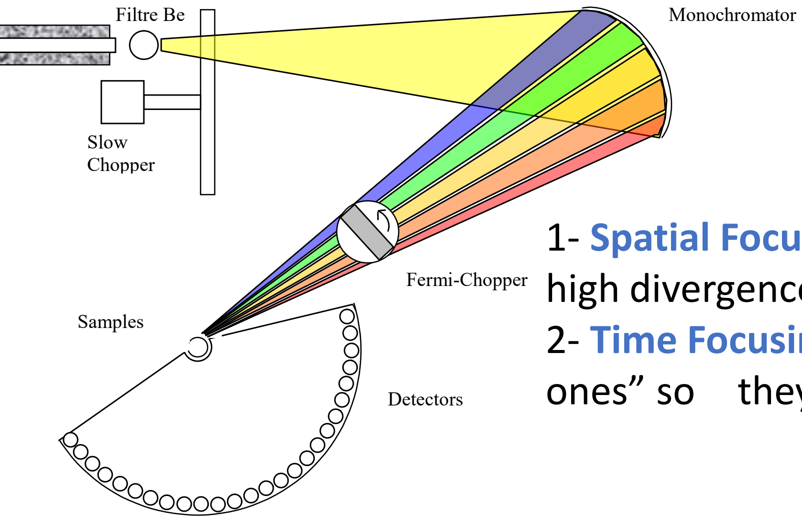

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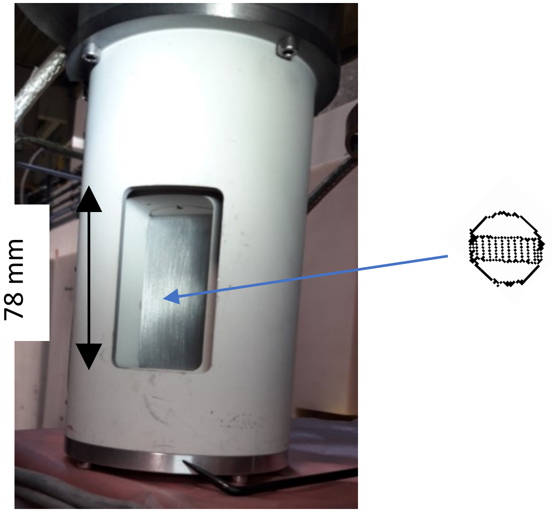
2- **Time Focusing**: Fermi Chopper let the “slow” neutrons start before the “fast ones” so they arrive at the same time at the detector --> good resolution

Fermi Chopper (ν_{Max}=250 Hz)

Slit Package: Stack of Gd and Al. *thick*=25 µm

Collimation = 2.1°



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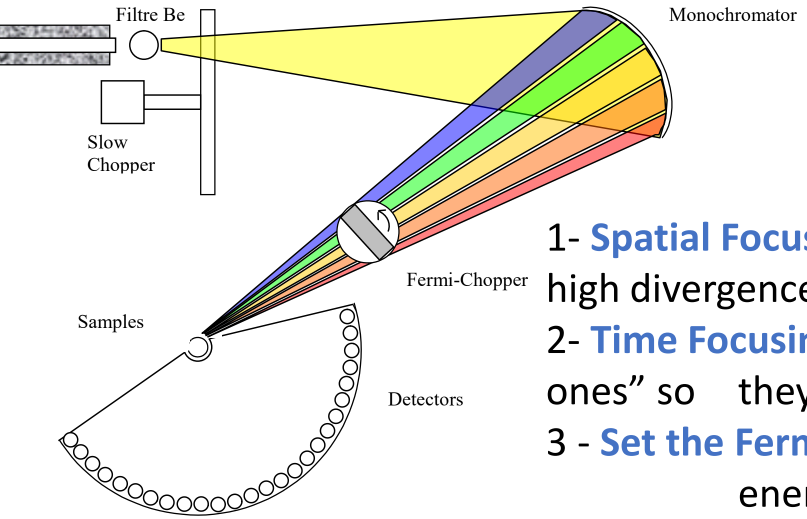

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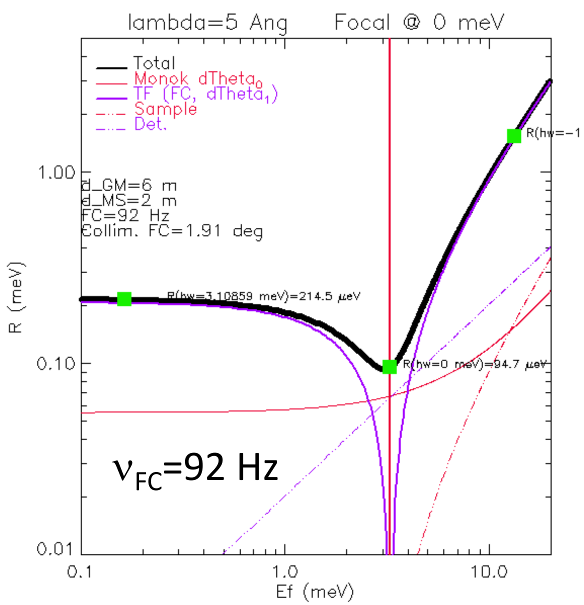
3 - **Set the Fermi chopper speed** to minimise the resolution at the desired energy transfer



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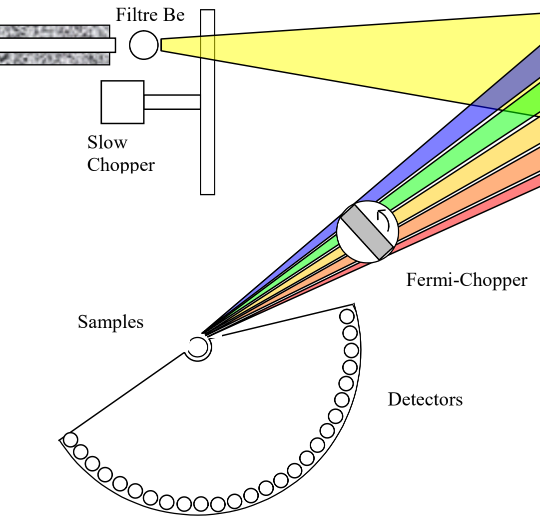

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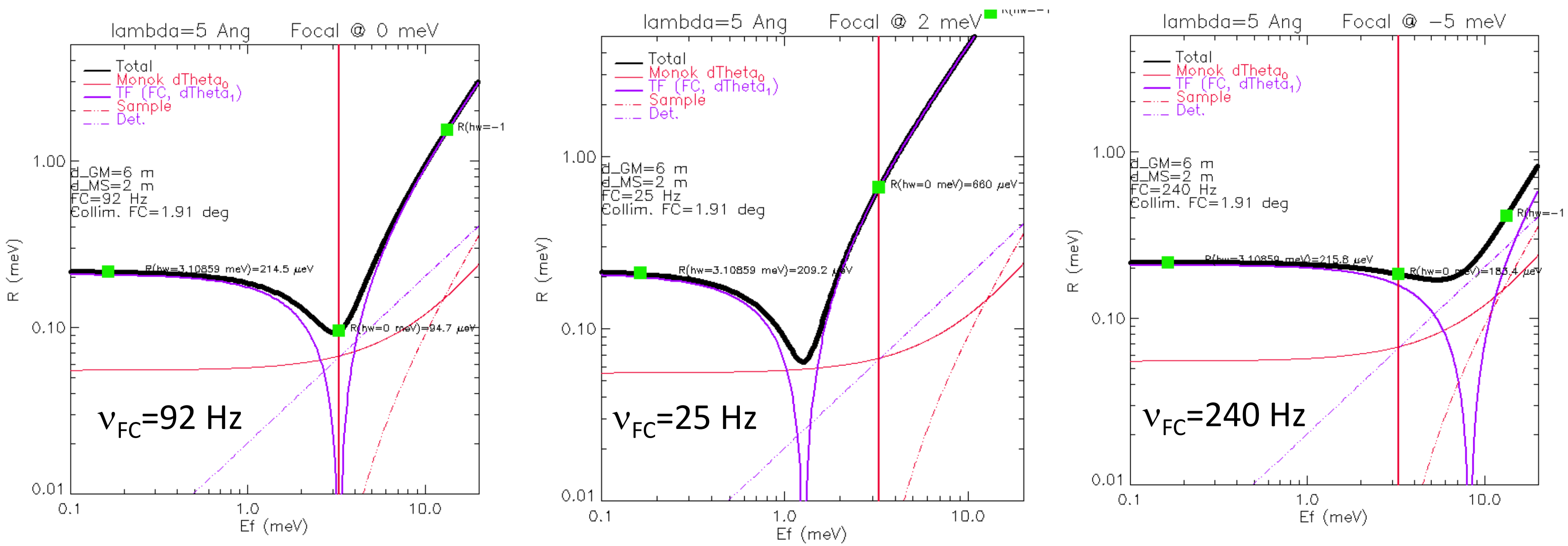
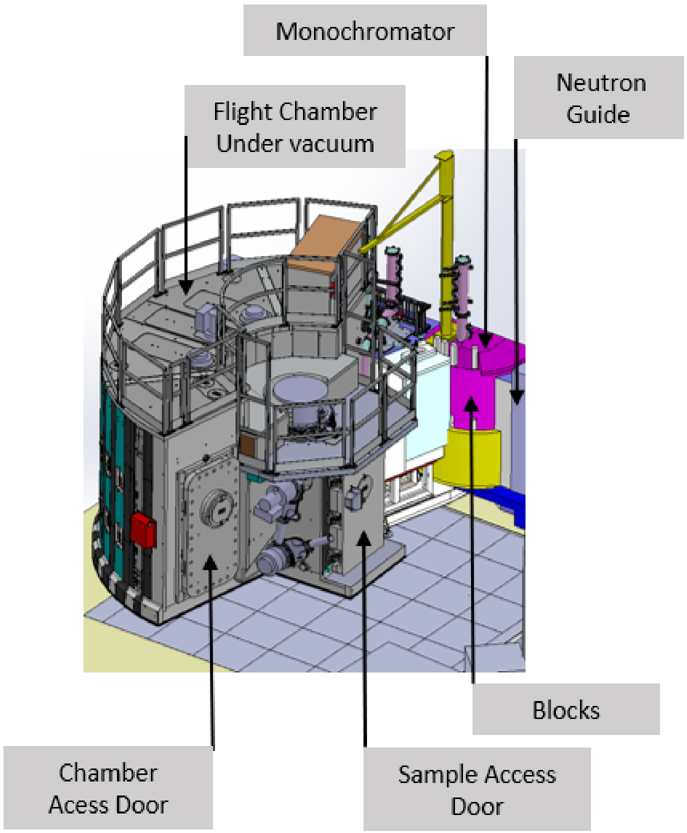
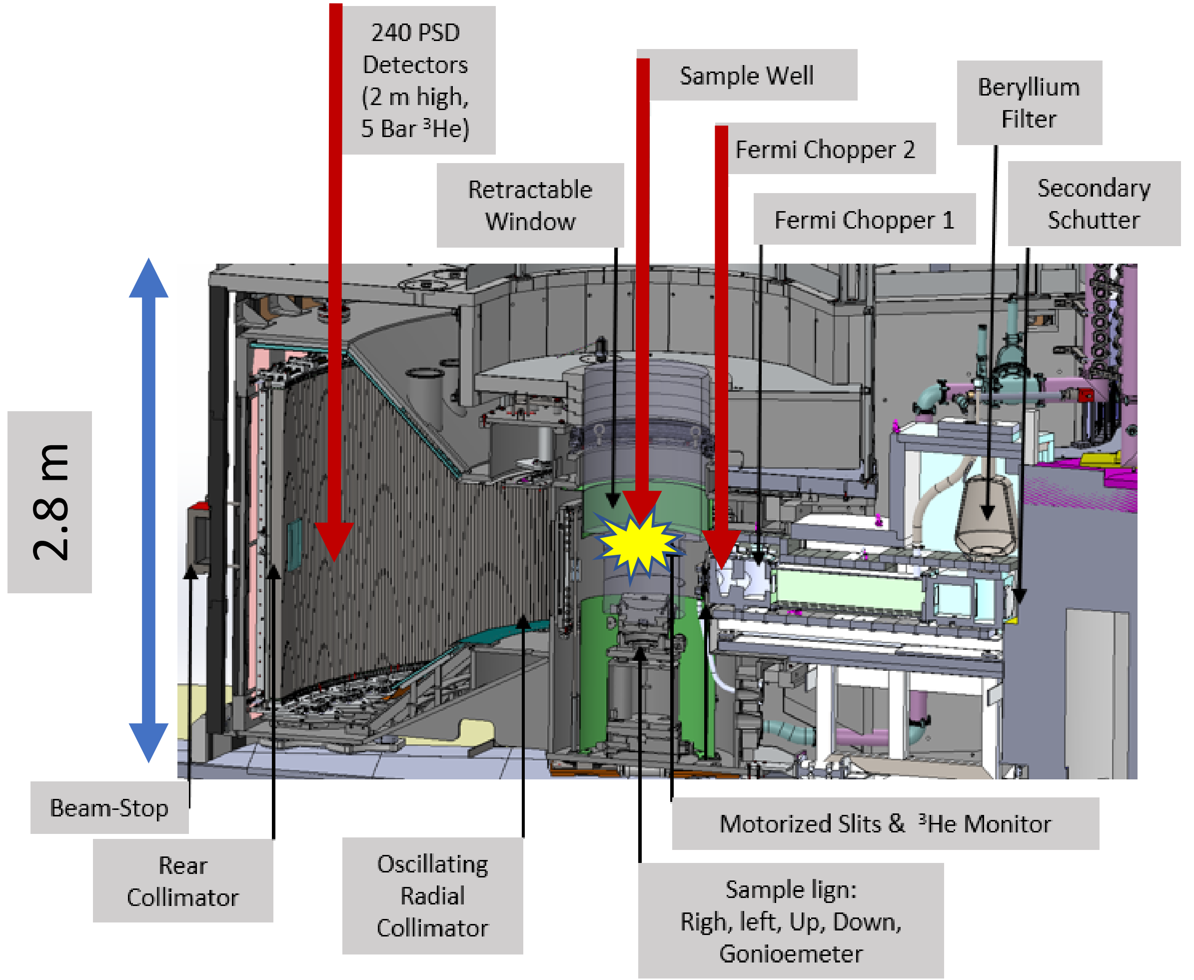


Sharp :
A state of the art ToF Spectrometer





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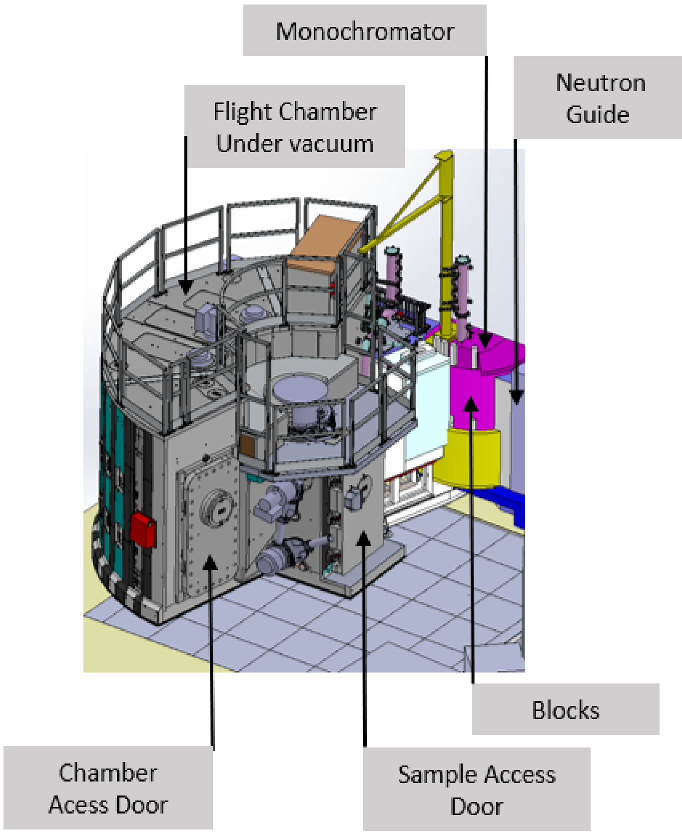

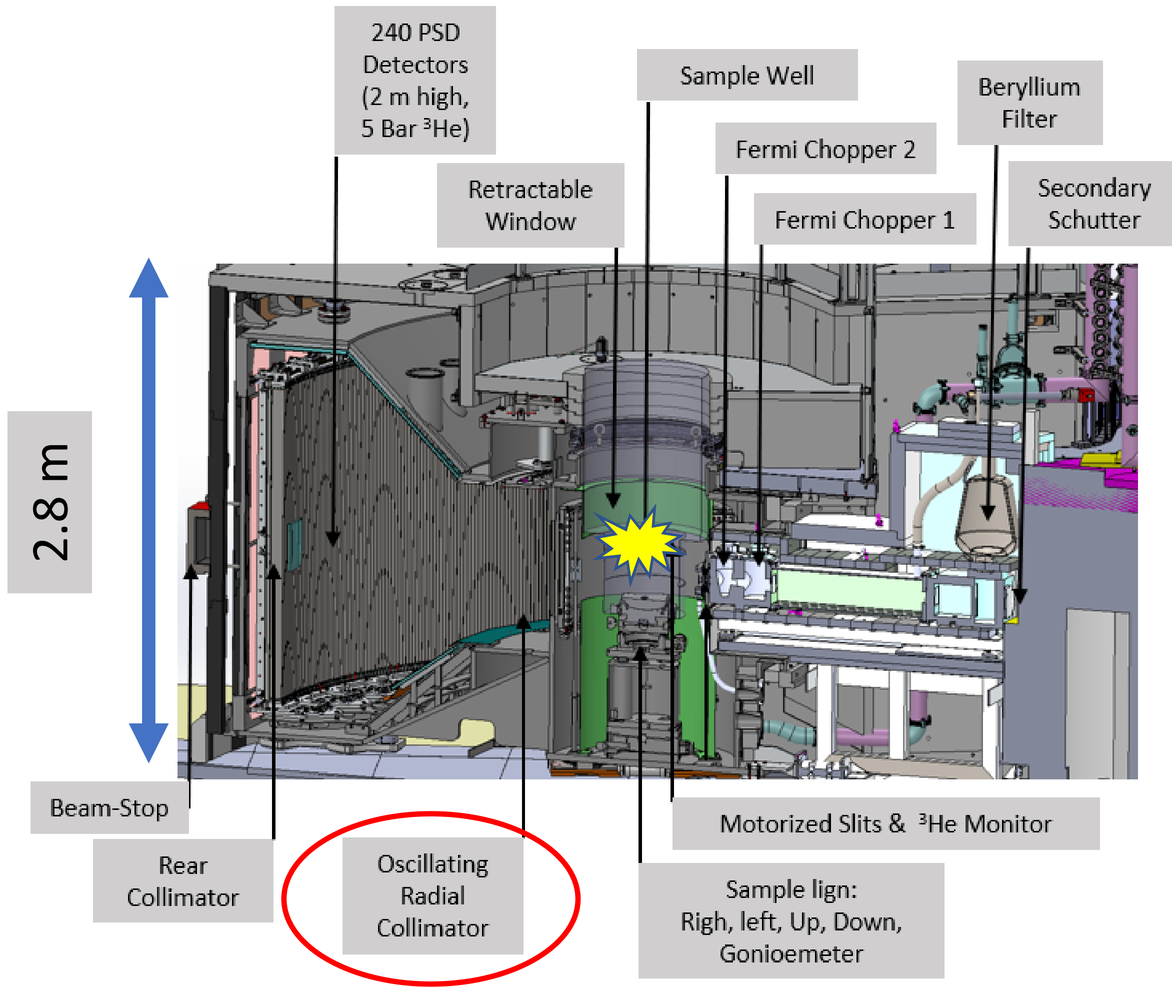

More on « time-of-flight » :

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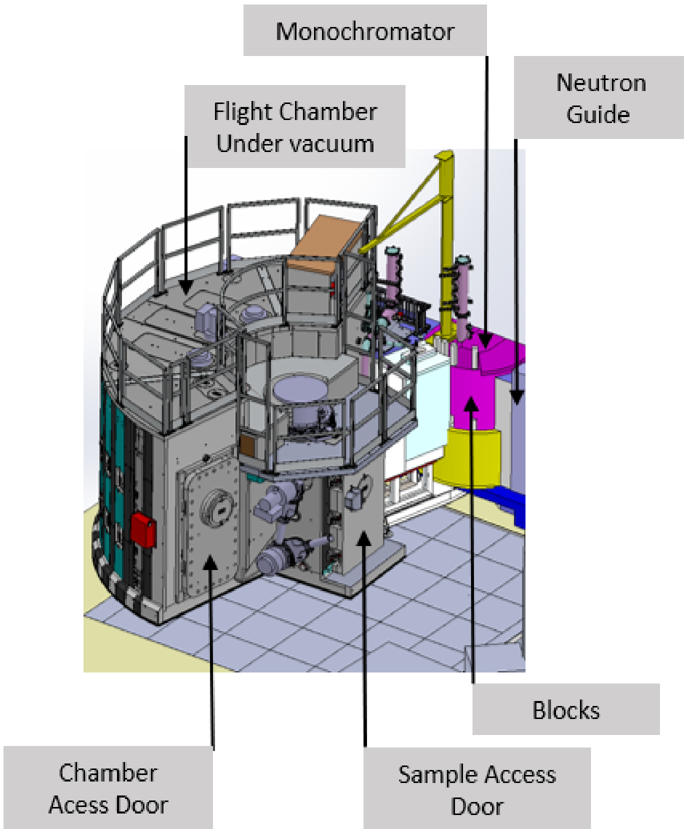

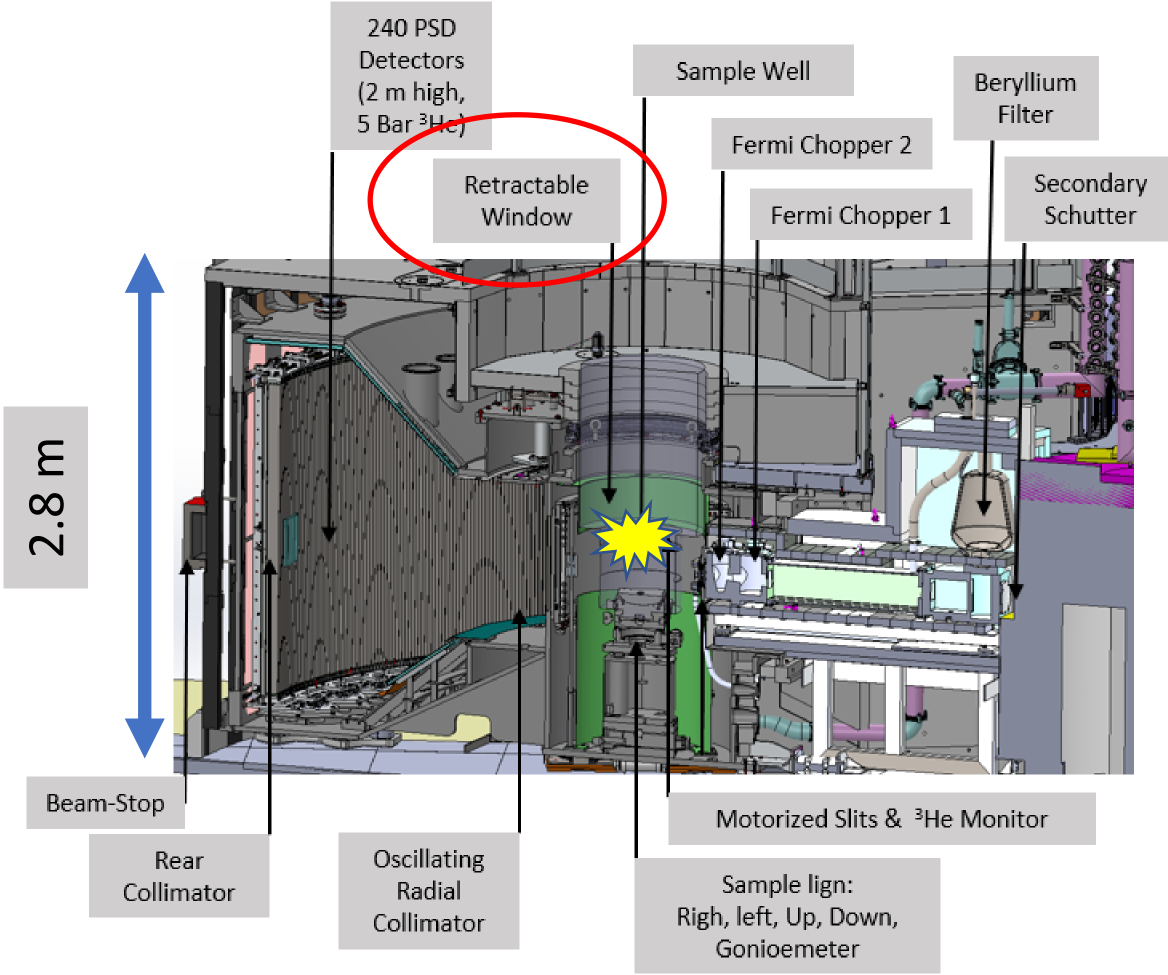

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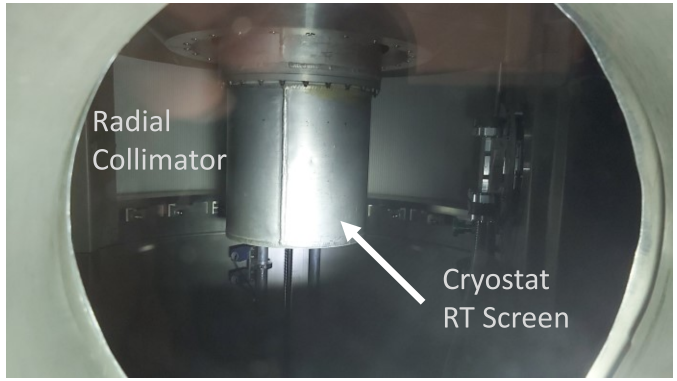
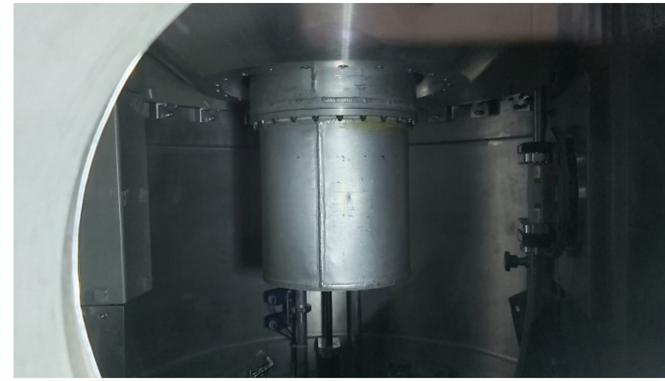
Detector chamber under vacuum but Sample environment under controlled atmosphere: Retractable Window





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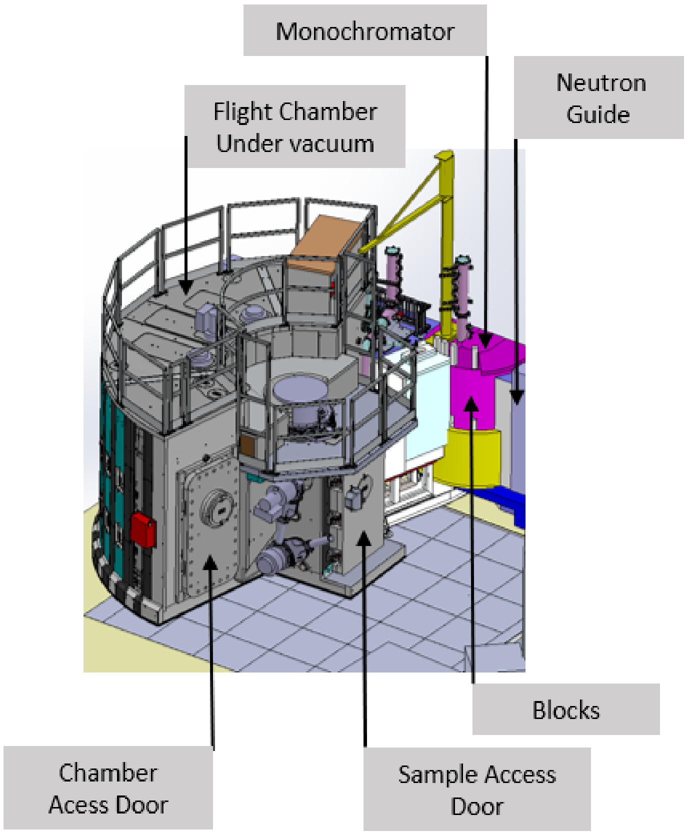

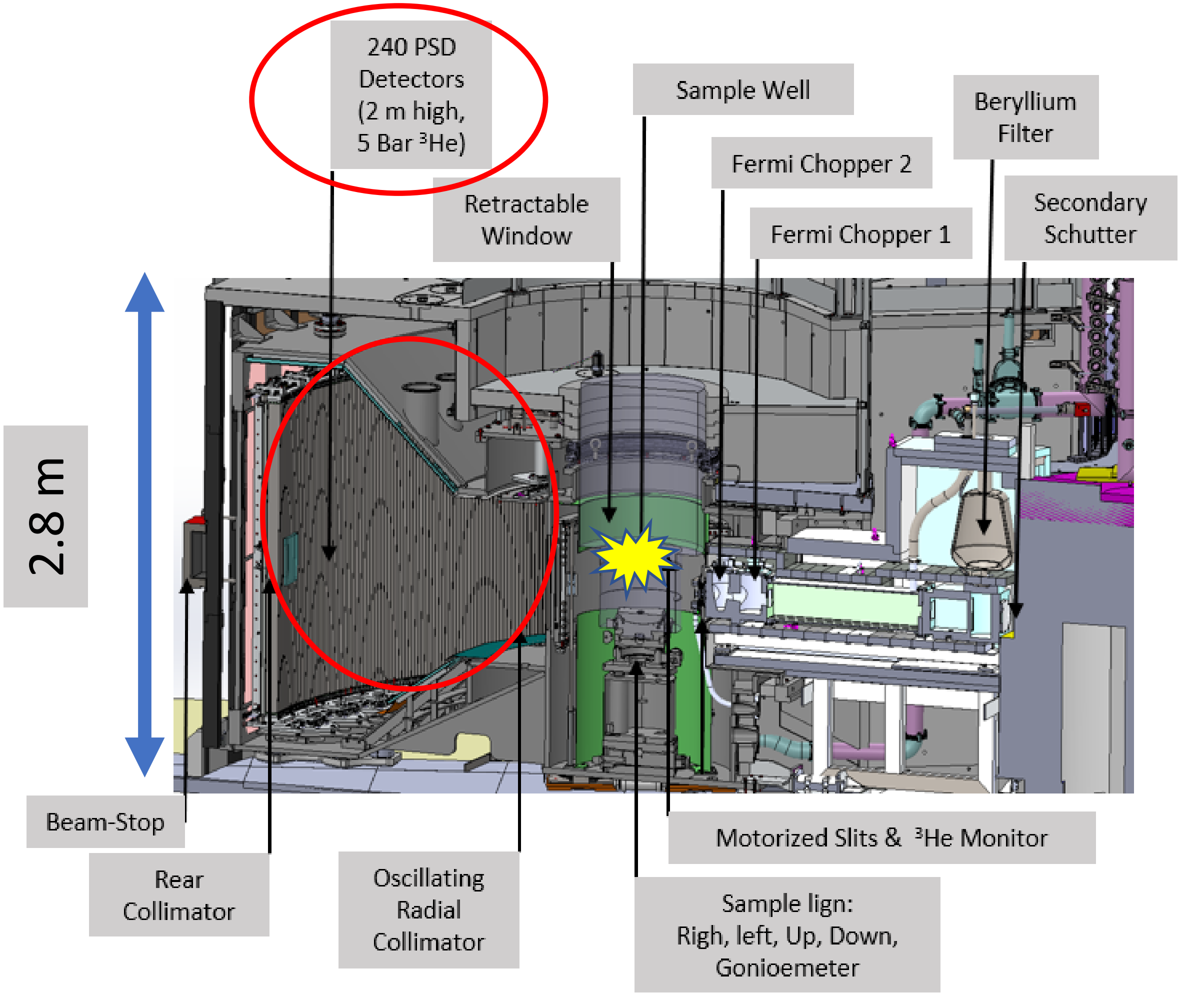

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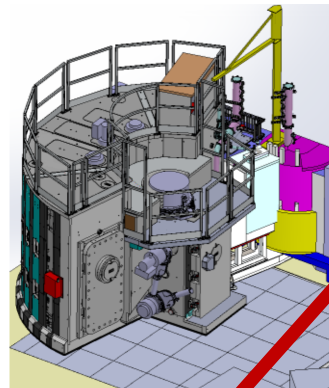
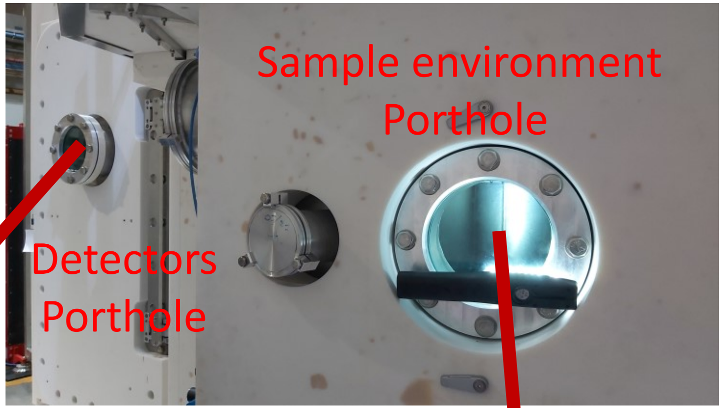
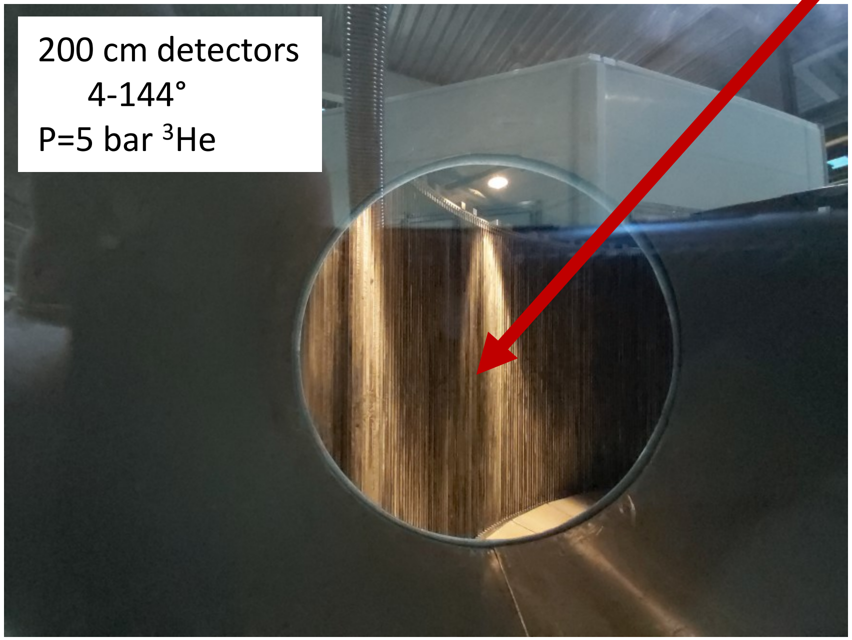
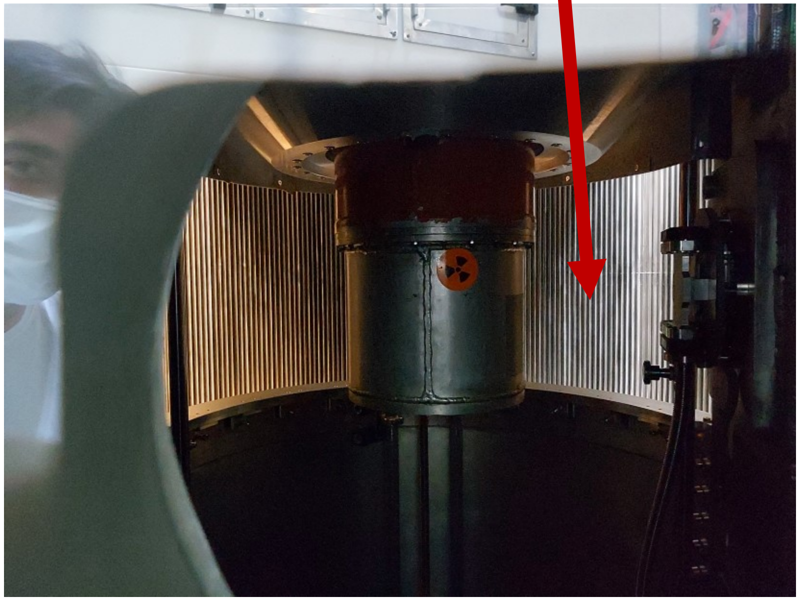
240 Position Sensitive Detectors 4-144° and Rear Collimator (No cross talks)









Elementary Mechanisms in Gas Separation using Zeolite Membranes

W. Kellouai, M. Plazanet, P. Judeinstein & B. Coasne

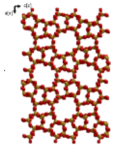
Orphée Laboratoire Léon Brillouin

Funding: 2FDN Fédération française de Diffusion Neutronique

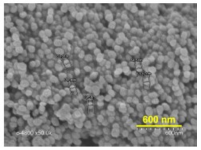
October 4-8 2021 (2FDN Beam Time)

cea cnrs LIPhy cnrs Université Grenoble Alpes

Separation of small molecules: CH_4 and CO_2.
Zeolite separate gazes according to their size, concentration and diffusivity.



Alumino-silicates
Pores < 8 Å



Samples: M. Drobek & A. Julbe, Institut Européen des Membranes, Montpellier

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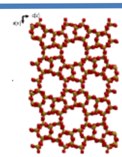

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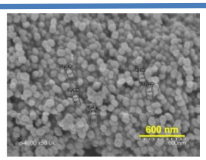

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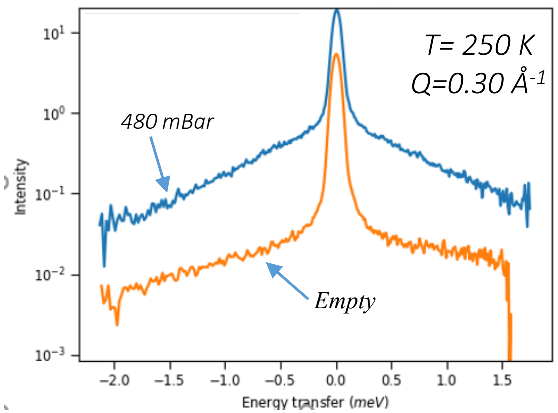
1- Jump diffusion of confined CH_3 (self)



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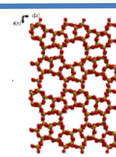

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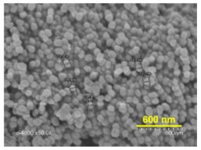

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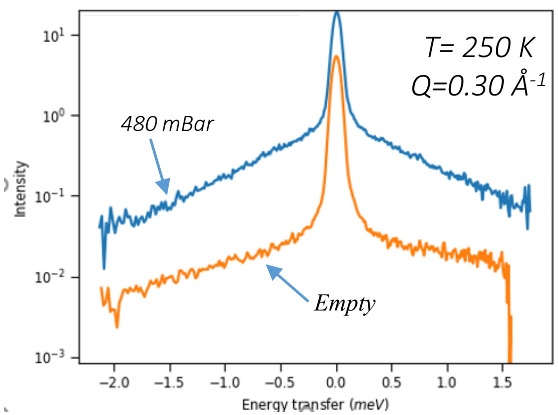
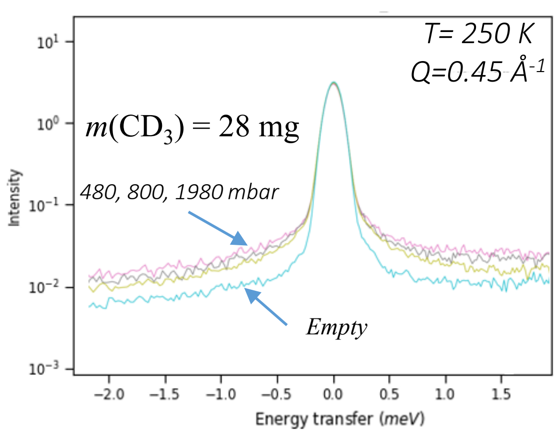


2- Jump diffusion of confined CD_3 (collective)



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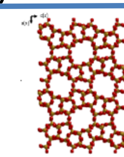

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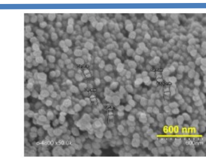

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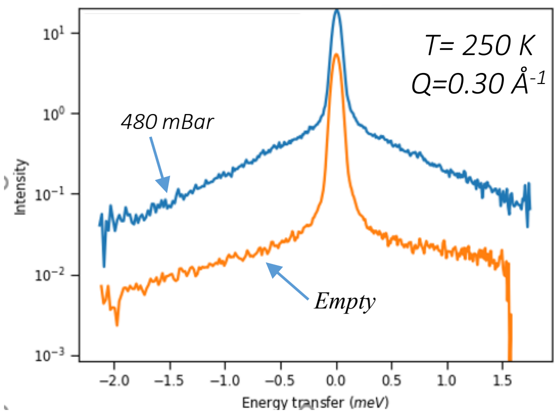
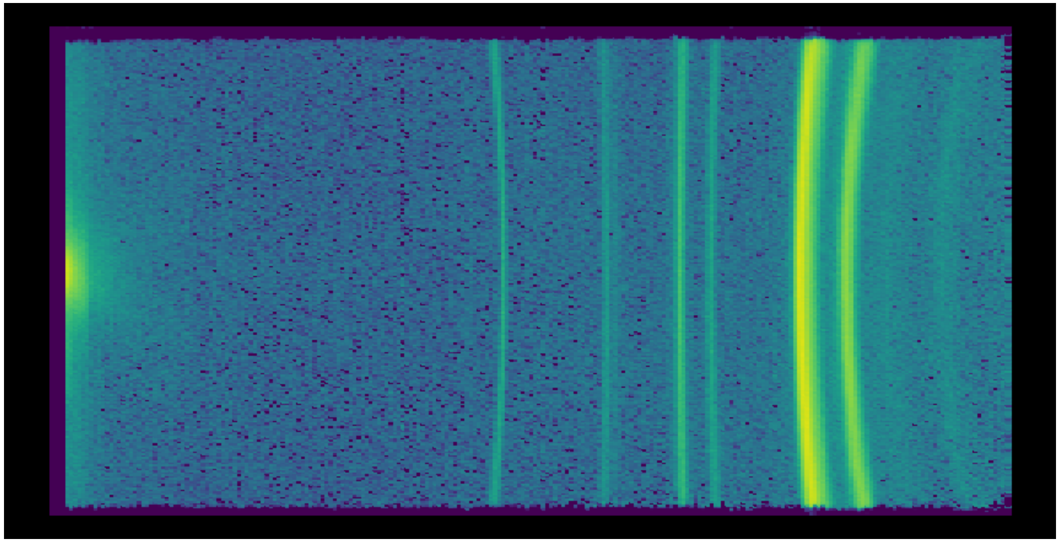
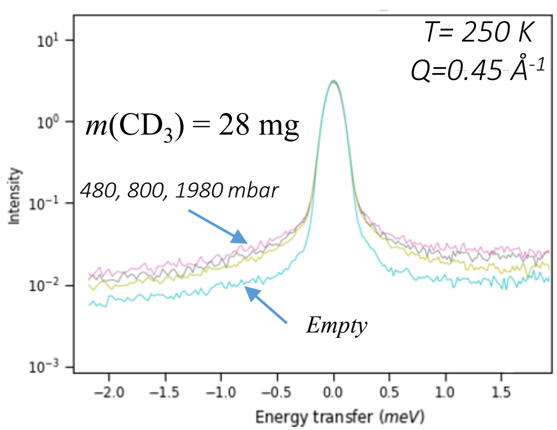


SHARP (240 PSD): Diffraction signal



2- Jump diffusion of confined CD_3 (collective)



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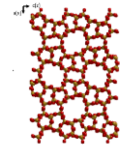

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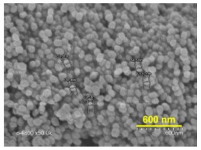

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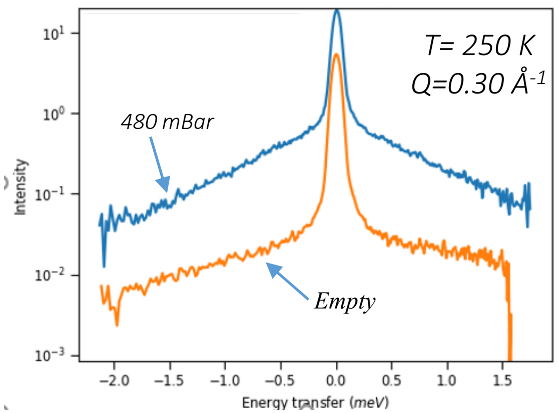

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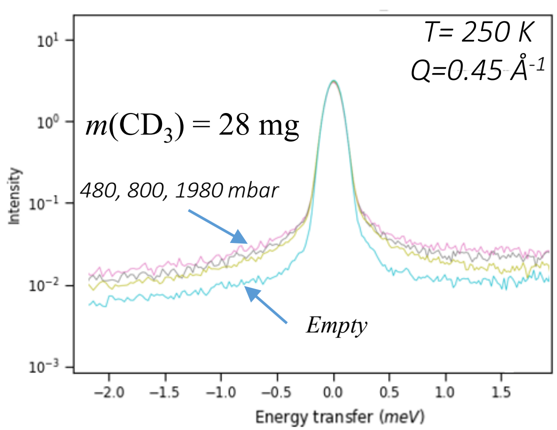
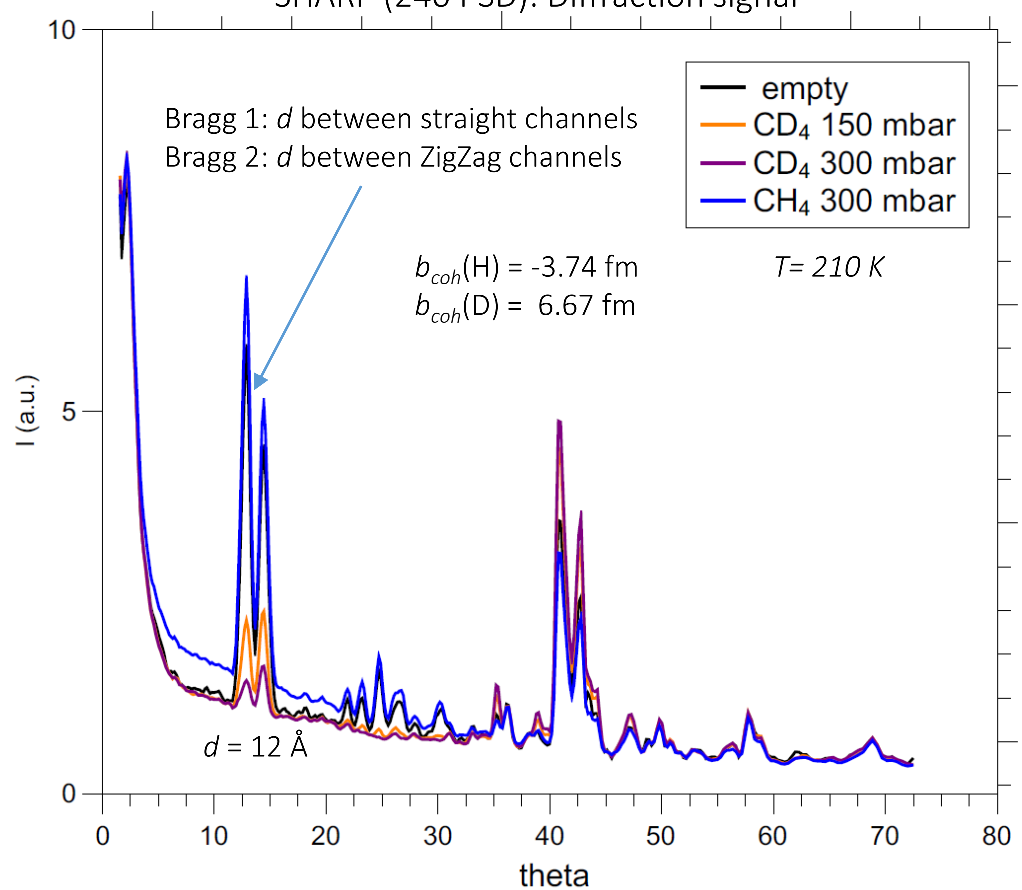
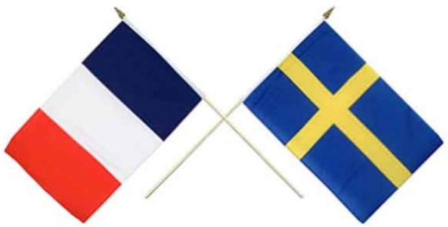


3- Modulation of the Bragg peaks upon CD_4 or CH_4 insertion

SHARP (240 PSD): Diffraction signal



Funding



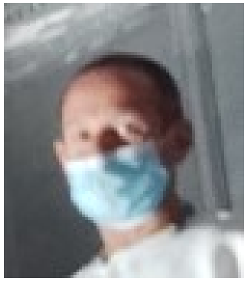
● French-Swedish (CEA - CNRS - Swedish Research Council) agreement for design, construction of neutron spectrometers. Protocol initiated within the framework of the European Spallation Source.

● Conception
● Design
● Building de of the instrument

● Vacuum System of the ToF Chamber
● Detectors Electronics
● Nuclear related regulations and safety

● Funding for sample “lift”

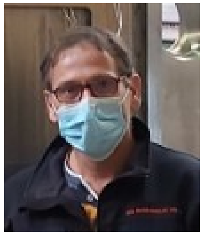
The Actors: professionalism, expertise and involvement

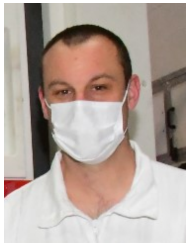

Nicolas Pautrieux


Pablo Abad

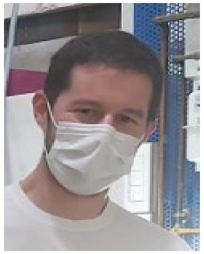

Sylvain Rodrigues


Frédéric Legendre

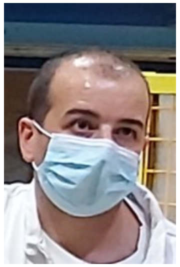

Pascal Lavie


Benoît Homatter


Quentin Berrod


Thomas Robillard


JMarc Zanotti


Pascal Lachaume


Franck Cécillon


Christophe Monon


Franck Rey


Emmanuel Courraud


Martin Platz

But also:

- **Bureau d'étude :** L. Didier, P. Permingeat, B. Giroud
- **Hall :** B. Jarry
- **Aménagement :** P. Coggo
- **Mécanique / Usinage :** J. Beaucourt, F. Lapeyre, O. Tessier
- **Détecteurs :** J.-C. Buffet, B. Guérard, J. Marchal, F. Pinet, J. Pentenero, S. Cuccaro
- **SCI :** J.-M. Delpierre, J. Blanc-Pacques, S. Sallaz-Damaz
- **Vide :** E. Iampasona, A. Girault
- **Automatismes :** C. Mounier, B. Sornin
- **Electronique & DAS :** P. Mutti, Y. Le Goc
- **Monochromateur :** P. Courtois
- **Sécurité :** I. Perbet, G. Bonnet
- **Radio-Protection :** F. Rencurel, S. Grimaud, P. Cochet
- **Administratifs :** A. Verdier, S. Même, O. Sineau, E. Colas, P. Combrisson
- **Service Commercial CEA :** A. Rozier, C. Berthon
- **Planning :** M. Plassard
- **Groupes Spectroscopie :** B. Farago, S. Petit
- **CEA/DRF & IRAMIS :** H. Desvaux, F. Daviaud, M. Faury, V. Berger
- **CNRS INP & DAS :** **E.** Lacaze, E. Solal, S. Ravy
- **Management :** E. Eliot, G. Chaboussant, A. Menelle, C. Alba-Simionesco, A. Brulet, H. Schober, M. Johnson, J. Estrade, J. Jestin

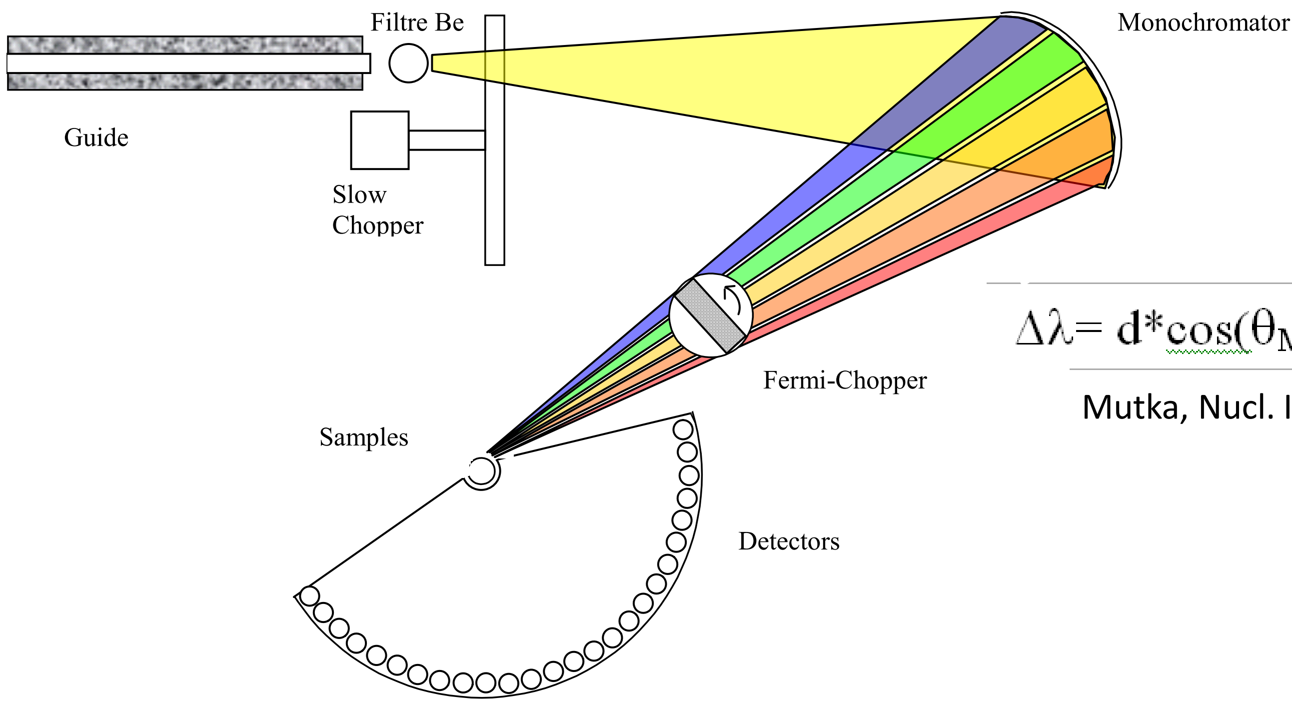
From SHARP to SHARP$^+$
Future LLB CRG A Instrument

G. Manzin[1] --> S. Roux[1] (Project Engineer)
G. Pastrello[1] (Mechanical Design Responsible)
M. Koza[1] (ILL Scientific Advisor)
J.-M. Zanotti[2] (Scientific Responsible)

[1] Institut Laue Langevin , Saclay, France
[2] Laboratoire Léon Brillouin , Saclay, France

Xtal Spectrometers

Mesot, Janssen, Holitzner & Hempelmann, J. Neutron Research, 3, 293-310 (1993).



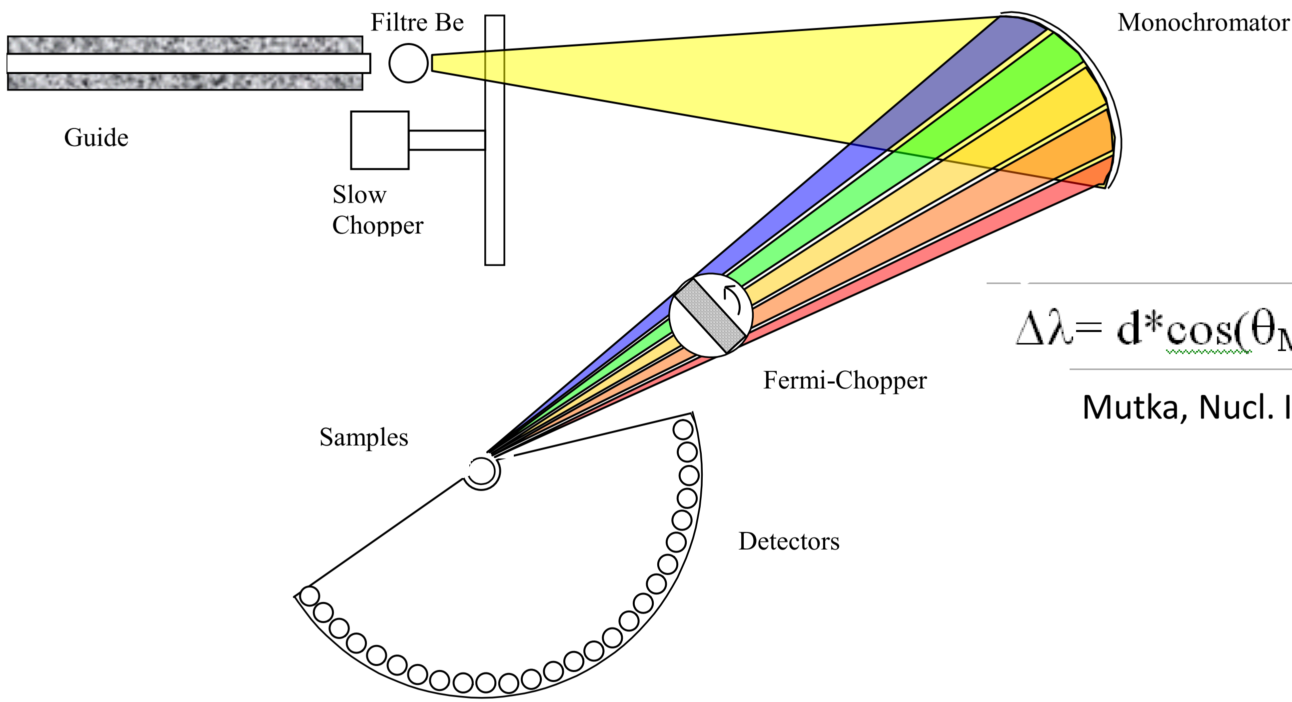
$$\Delta\lambda = d*\cos(\theta_M)*W*\sin(\theta_M)\left| 1/d_{GM} - 1/d_{ME} \right|$$

Mutka, Nucl. Inst. & Meth. A, 338, 144-150 (1994).

- **d GM ≠ d MS: Time Focusing (TF)** **---> large λ band: High flux**

Xtal Spectrometers

Mesot, Janssen, Holitzner & Hempelmann, J. Neutron Research, 3, 293-310 (1993).



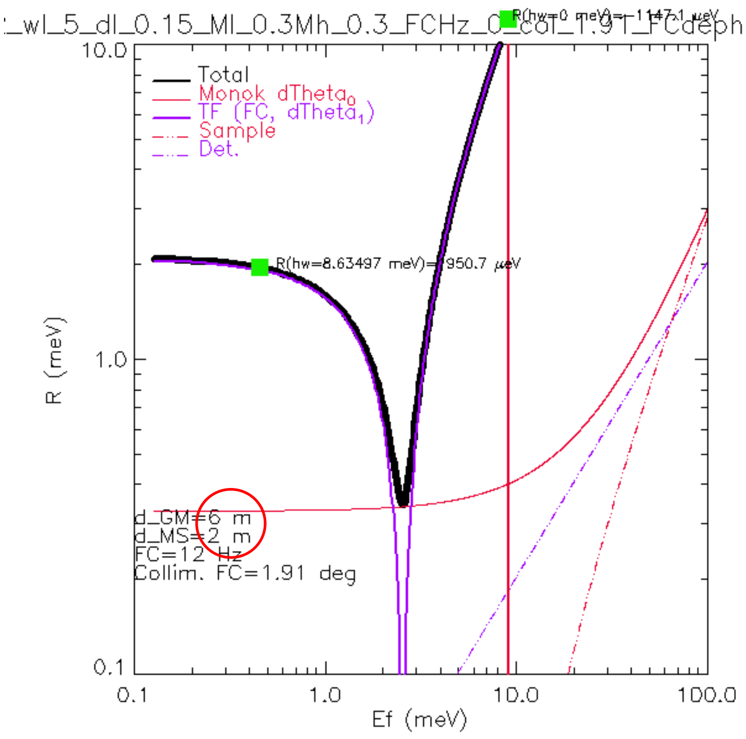
$$\Delta\lambda = d^*\cos(\theta_M)^*W^*\sin(\theta_M)\left|\,1/d_{GM} - 1/d_{ME}\right|$$

Mutka, Nucl. Inst. & Meth. A, 338, 144-150 (1994).

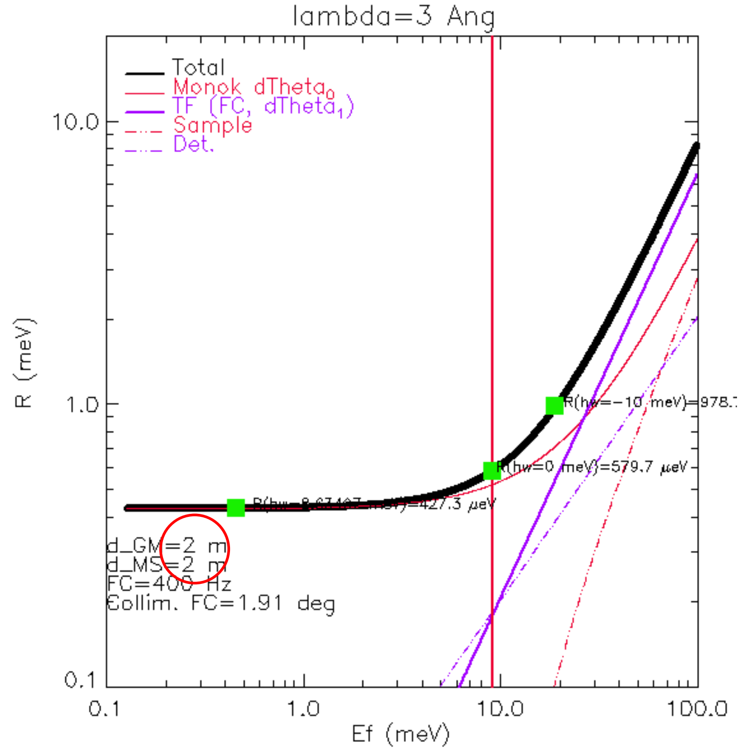
- d GM ≠ d MS: Time Focusing (TF) ---> large λ band: High flux
- d GM = d MS: Monochromatic Focusing (MF) ---> narrow λ band: Good resolution on an extended ω range

Time *vs* Monochromatic Focusing

Time focusing (IN6 like)



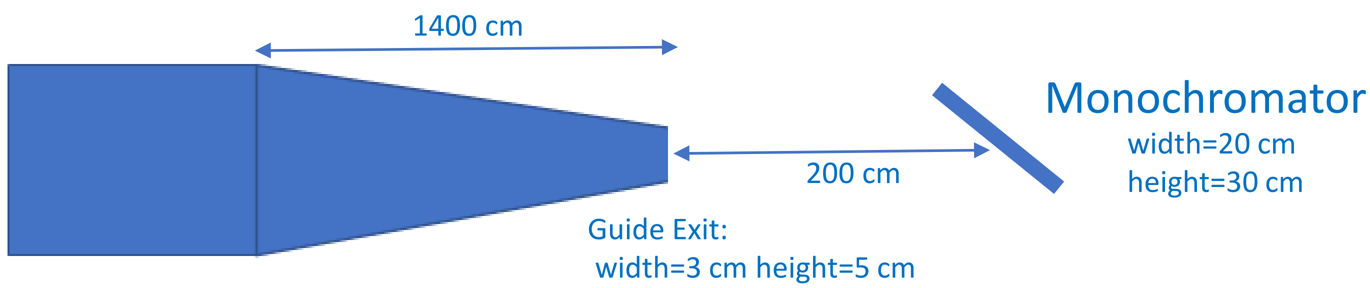
Monochormatic focusing (IN5 like)



Swintching from from Monochromatic to Time Focusing

NB: Distance Monochromator to sample = 2 m

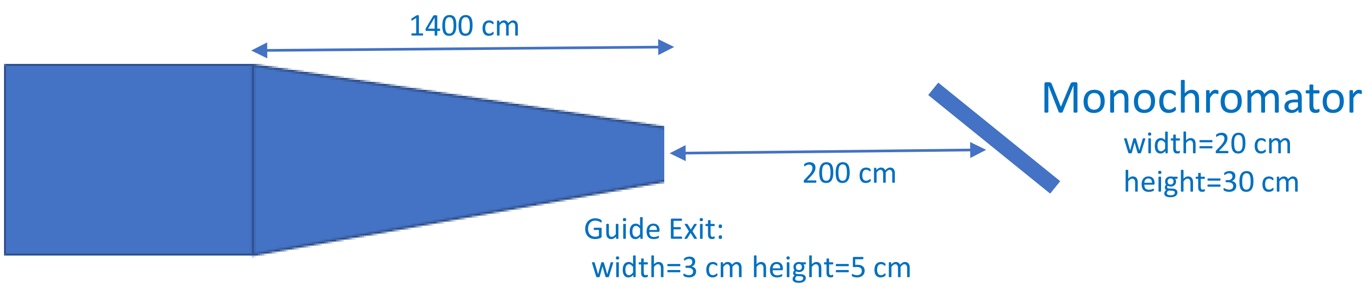
- Distance guide to monochromator: 2 m --- > **Monochromatic Focusing**



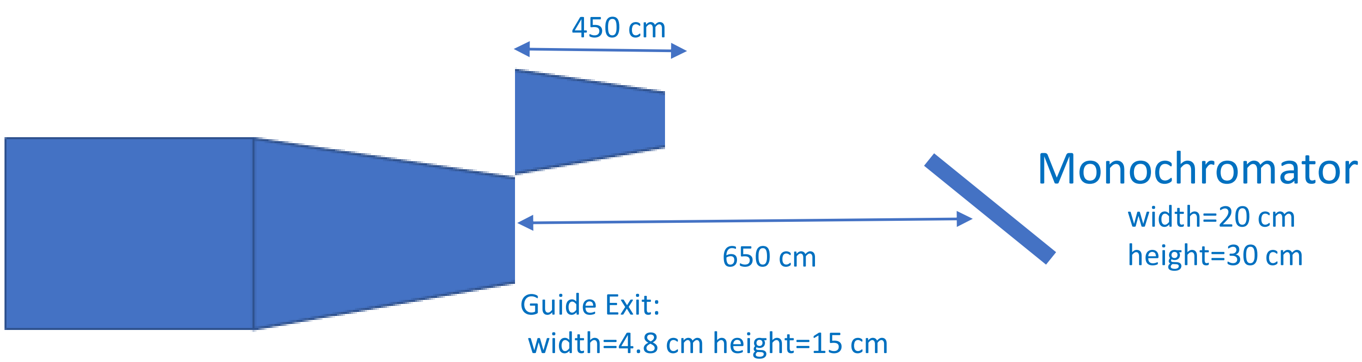
Swintching from from Monochromatic to Time Focusing

NB: Distance Monochromator to sample = 2 m

- Distance guide to monochromator: 2 m --- > **Monochromatic Focusing**



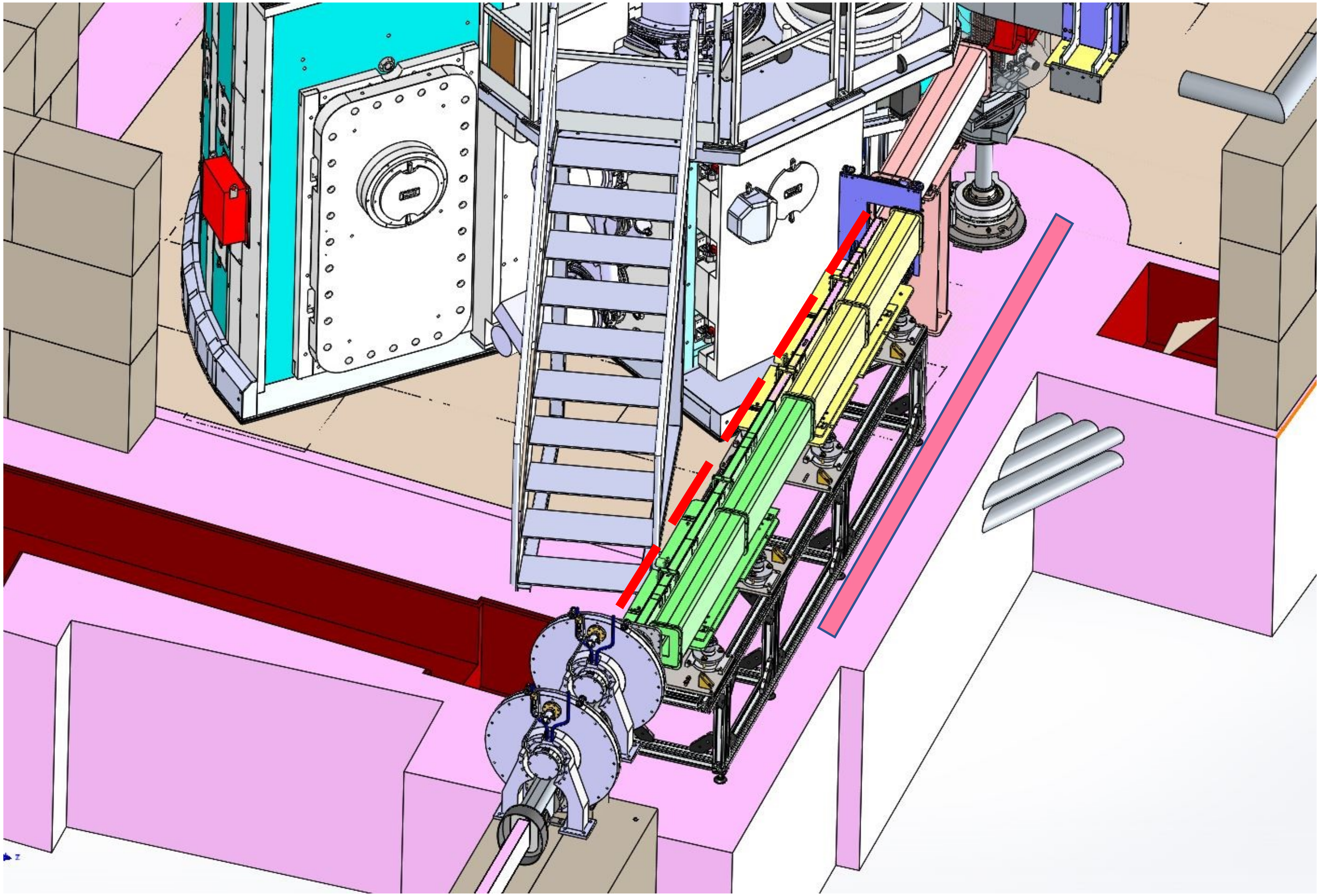
- Set by a 4.5 m retractable guide section at the end of the 14 m elliptic guide: distance monochromator to sample: 4.5+2 = 6.5 m -- > **Time Focusing**



NB: The length of the retractable section has been optimized on a FC speed criterium (ratio).

Swintching from from Monochromatic to Time Focusing

NB: Distance Monochromator to sample = 2 m



Courtesy Sébastien NICOLLE, SEI@ILL

French community scientific Fields
High resolution needed

IN6-Sharp

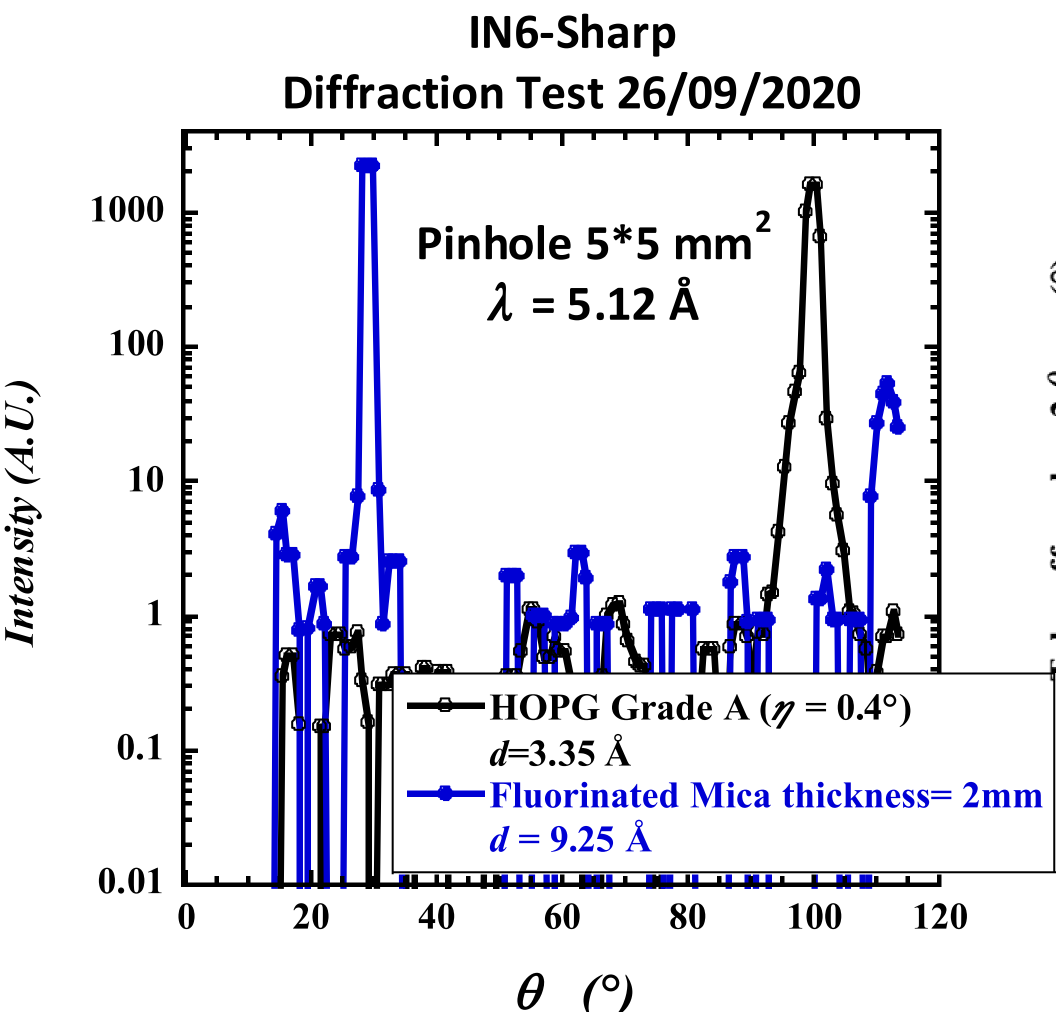
Scientific Activity

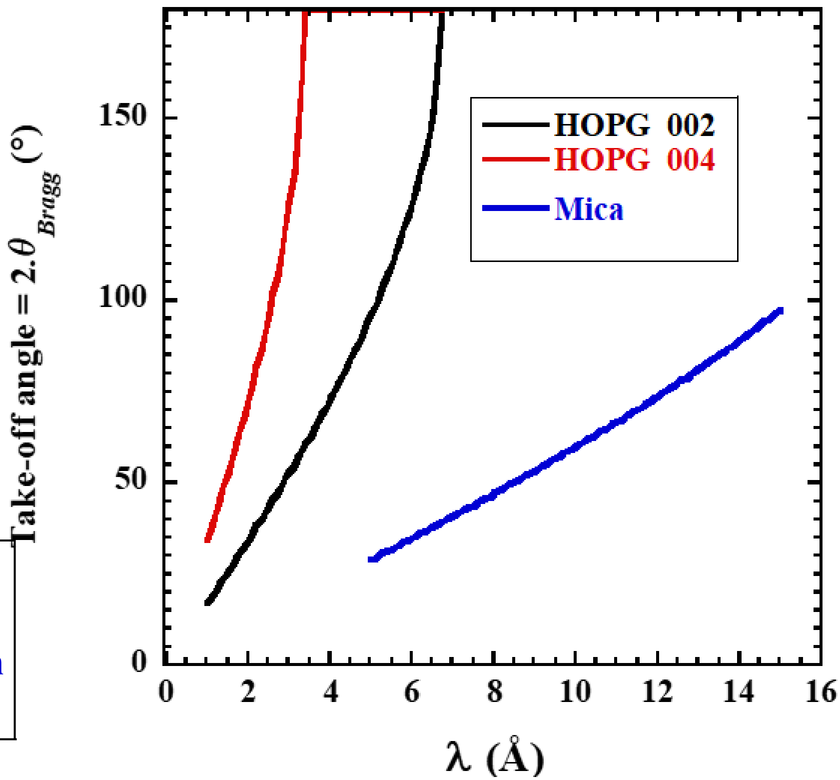
2018 -2020

College	ILL beam time (days)	%	CRG beam time (days)	%	Total	Total
#1: Applied Materials	6	100%	0	0%	6	2%
#4: Magnetic excitations	29	33%	59	67%	88	29%
#6: Liquids/Glasses	21	30%	48	70%	69	23%
#7: Spectroscopy in solid state physics & Chemistry	75	68%	36	32%	111	36%
#8: Biology	0	0%	5	100%	5	2%
#9: Soft Matter	9	33%	18	67%	27	9%
Total	**140**	**46%**	**166**	**54%**	**306**	**100%**

2FDN community: need for high resolution i.e. $\lambda > 6.0$ Å

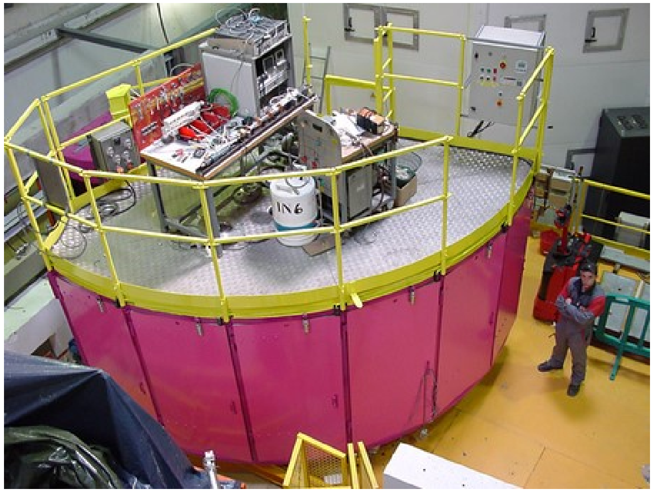
Fluorinated Mica tests
IN6-Sharp (Sept. 2020)

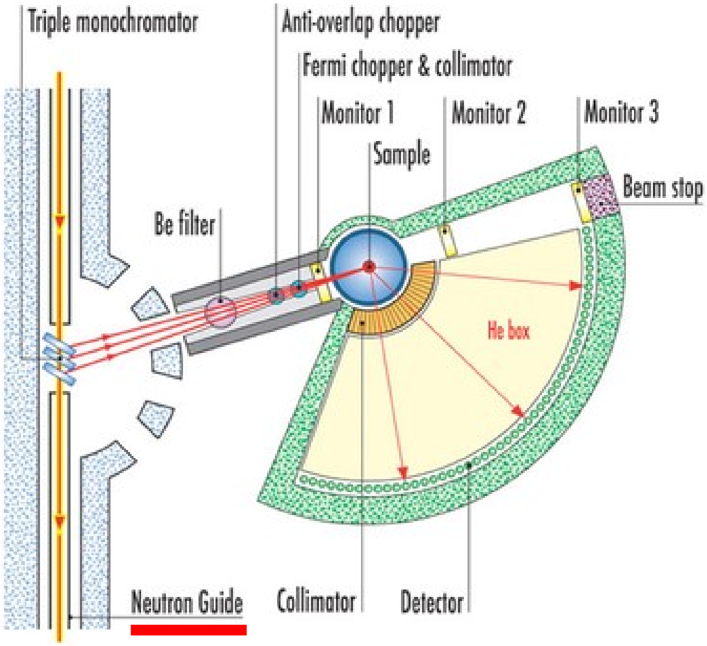




- Pinhole diffraction (IN6-Sharp) : Expected Bragg peak detected at *d* = 9.25 Å
- No detectable natural mosaicity. Confirmed by P. Courtois (Monok Service ILL) test.
- First Xray Reflectivity test P. Courtois (Monok Service ILL) good.
- SHARP⁺ funded by ILL: so far a second monochromator not in the scope.

IN6: a cold time-of-flight inelastic spectrometer "time focusing"



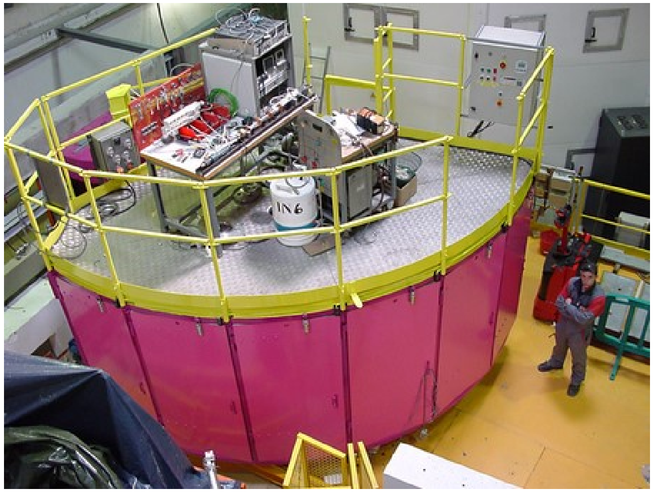
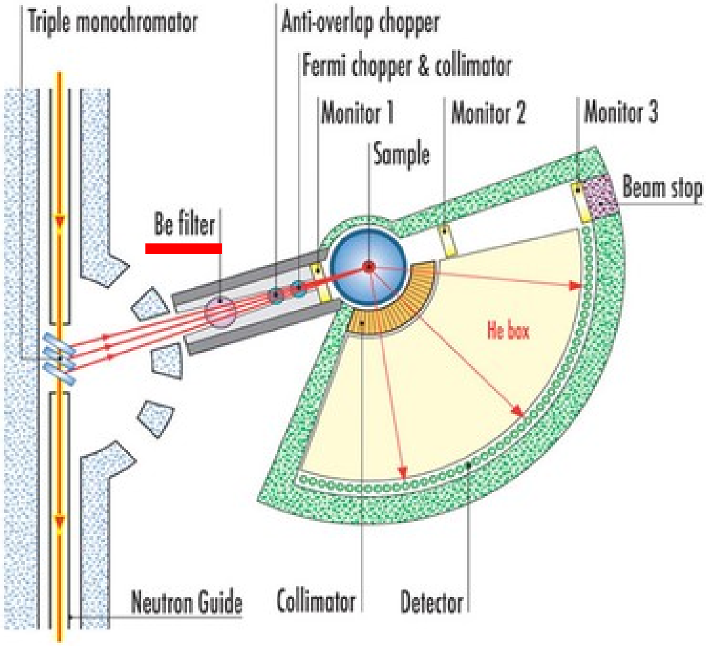


1- Sharing the H15 guide with D7 and D11:
not a guide end: 4 wavelengths.

4 incident wavelengths	
Incident wavelenght	Energy Resolution
4.1 Å	170 µeV
4.6 Å	120 µeV
5.1 Å	70 µeV
5.9 Å	50 µeV

https://www.ill.eu/instruments-support/instruments-groups/instruments/in6

IN6: a cold time-of-flight inelastic spectrometer "time focusing"

2- **Beryllium Filter** (T= 77 K)

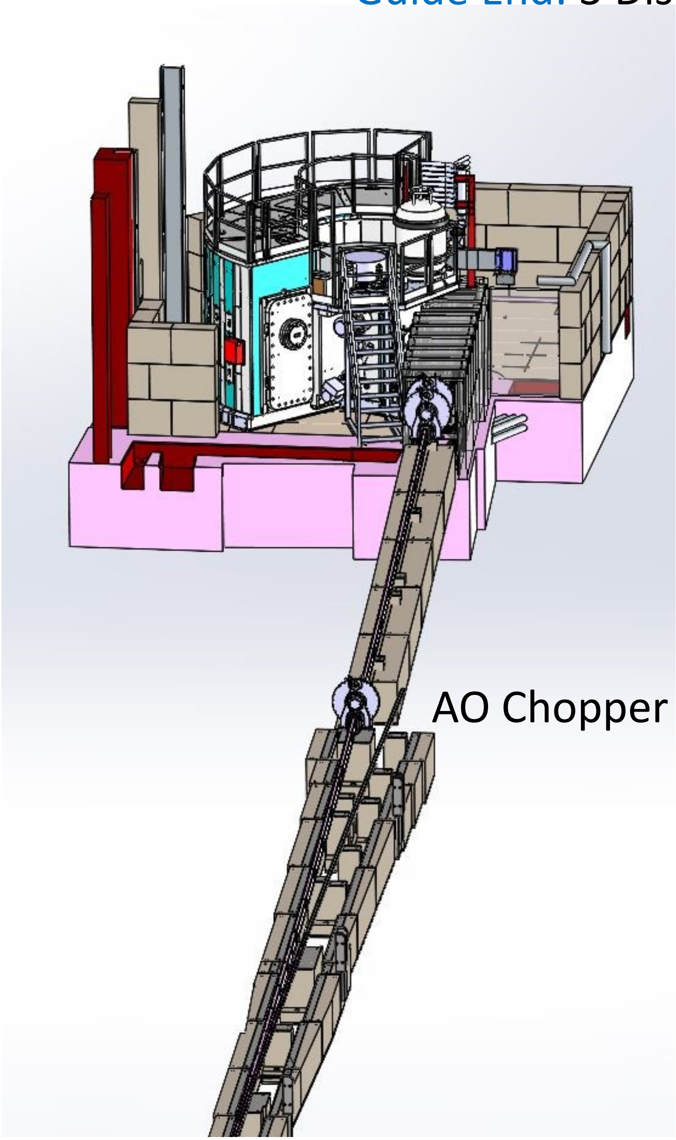
1- Sharing the H15 guide with D7 and D11:
not a guide end: 4 wavelengths.

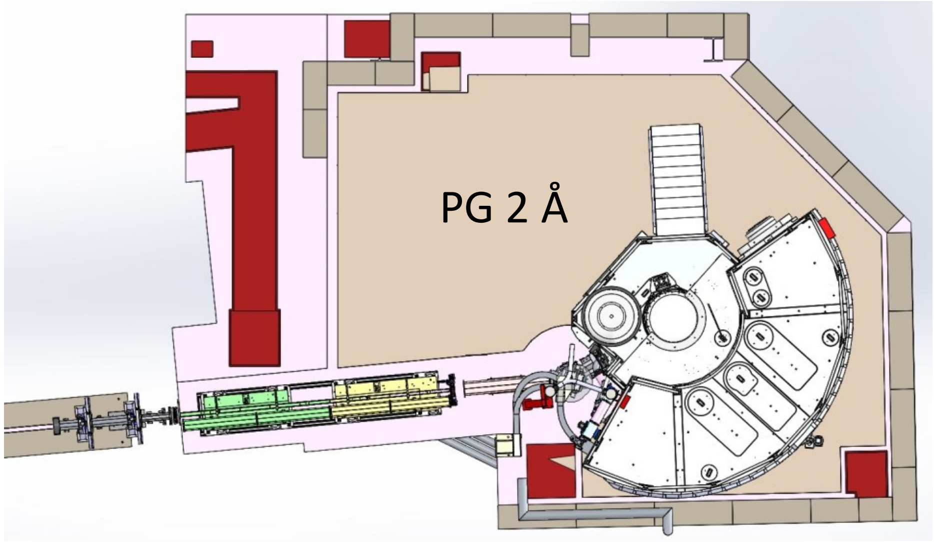
4 incident wavelengths	
Incident wavelenght	Energy Resolution
4.1 Å (not bolow)	**170 µeV**
4.6 Å	120 µeV
5.1 Å	70 µeV
5.9 Å	50 µeV

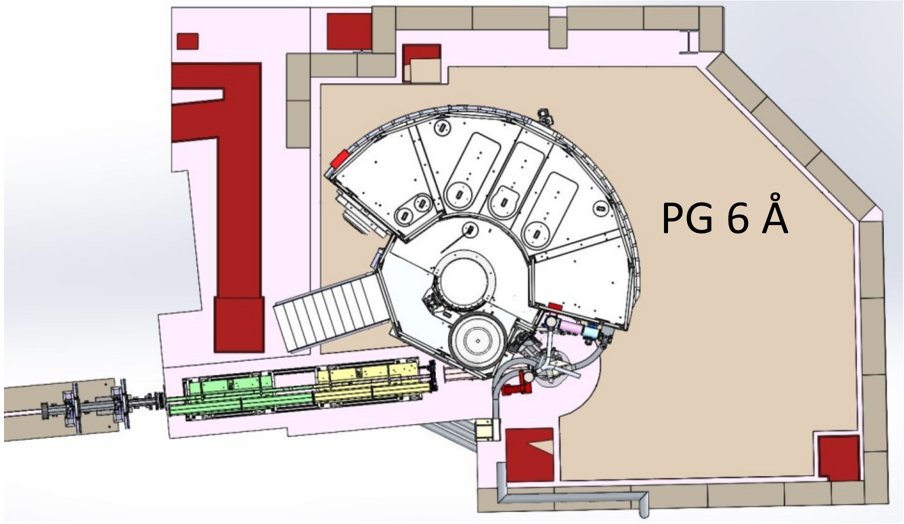
https://www.ill.eu/instruments-support/instruments-groups/instruments/in6

Design to optimize Flux and offer extended Incident lambda: No Beryllium filter (save 15-20% flux)

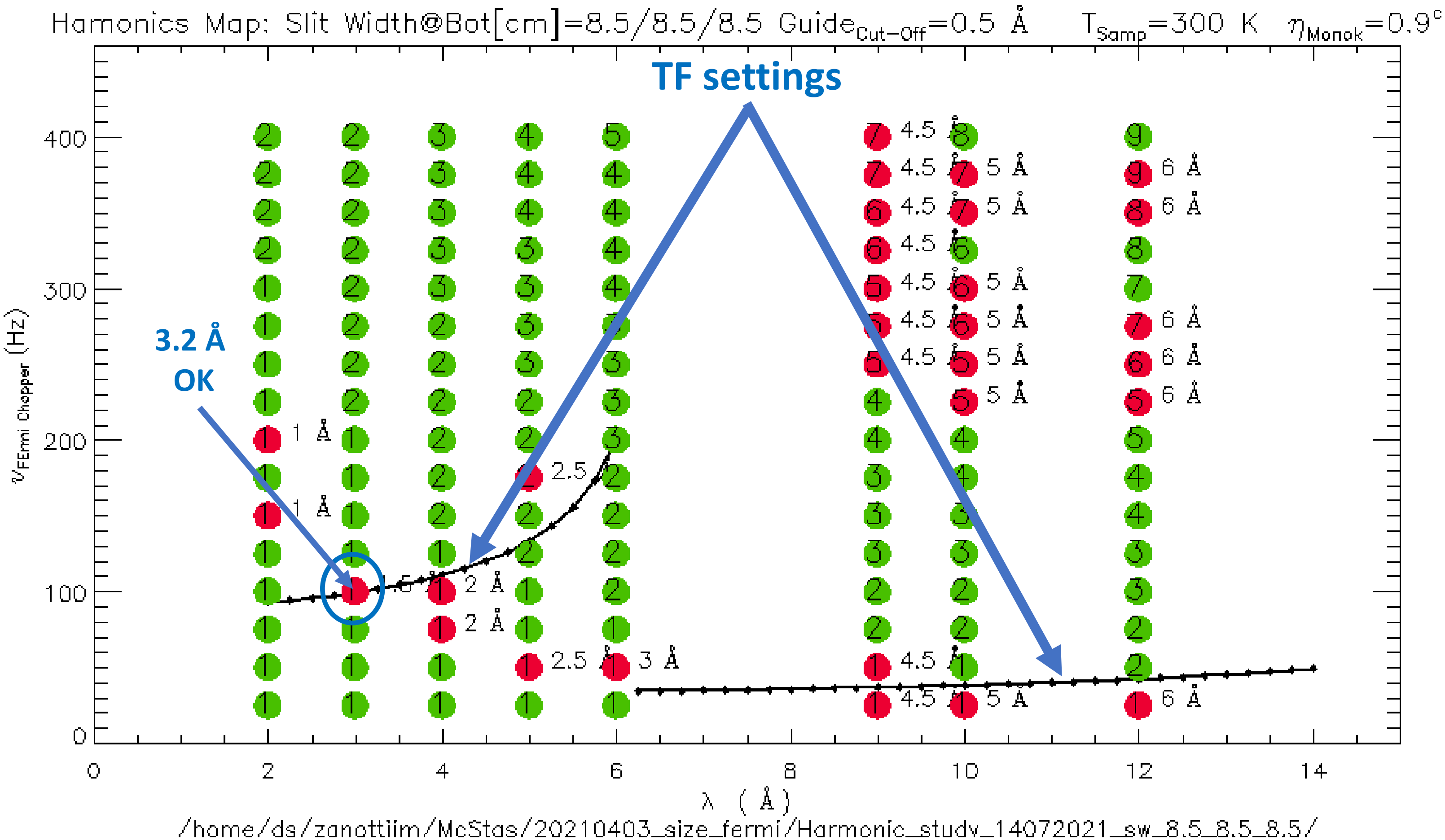
Guide End: 3 Disk chopper cascade to remove harmonics







Extended Q and resolution range
Compromise at will between flux and resolution



Extended Q and resolution range
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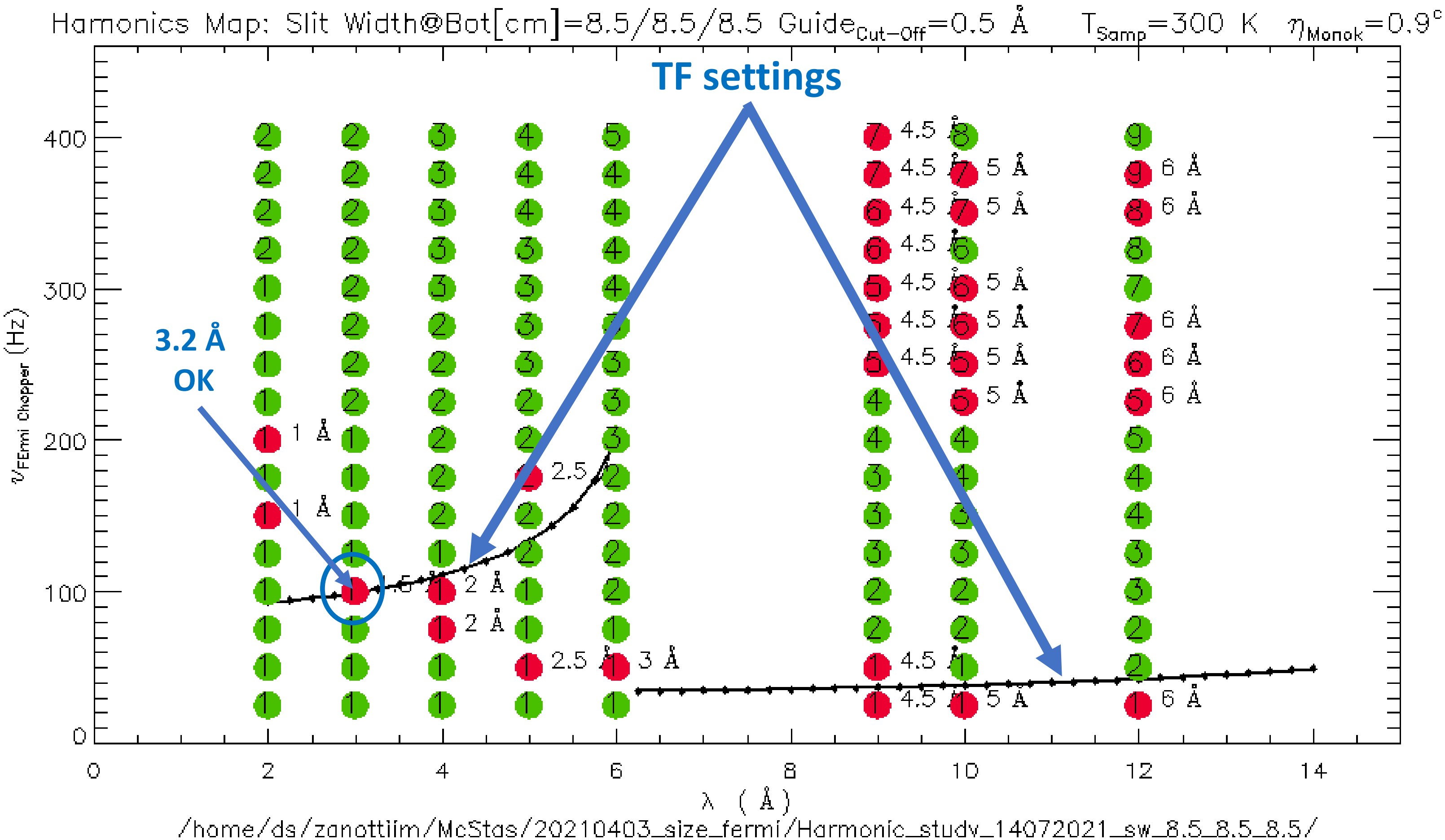


Monochromatic Focusing mode key for experiments at λ > 6 Å

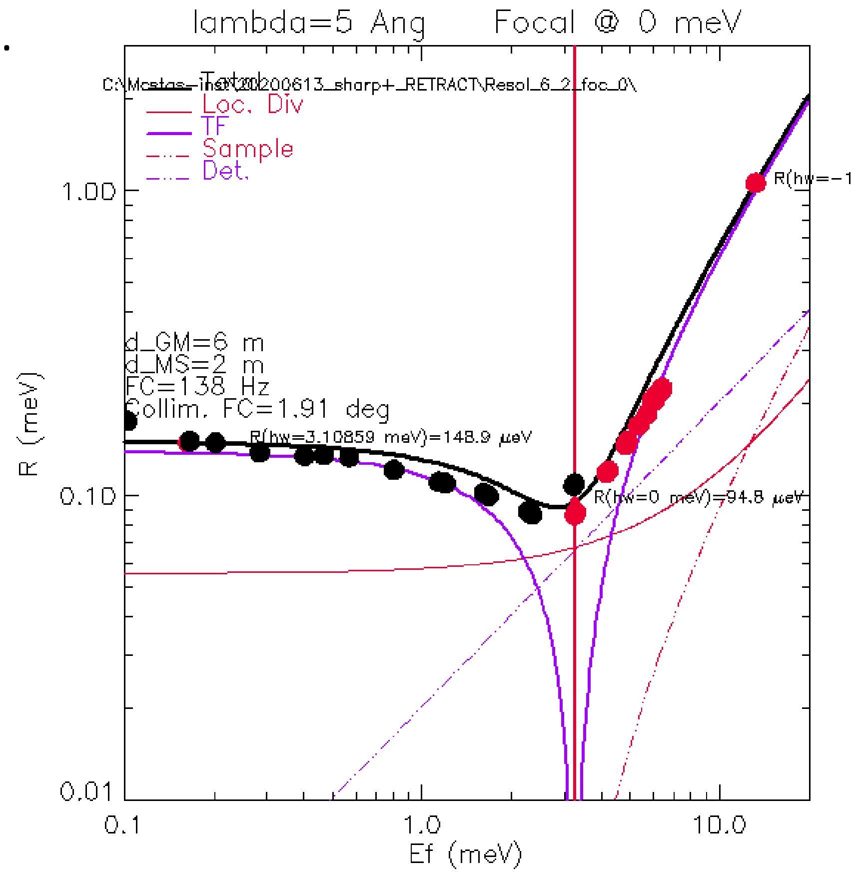
i.e. reach high resolution

At all steps and for all elements
McStas simulation challenged *by* Analytical Calculation

1- McStas model seems quite accurate.

Here McStas points (●, ●) *vs* analytical calculation of *R(ω)*.

2- Resolution well reproduced so flux estimate meaningful.



The future of SHARP: SHARP$^+$

Counting rate at least 10 compared to IN6

An "Hybrid" Spectrometer with a 4.5 m retractable guide nose

1- Nose OUT : "IN6 like" **(Time-Focusing Mode) --> Improved energy resolution on a narrow desired energy range.**

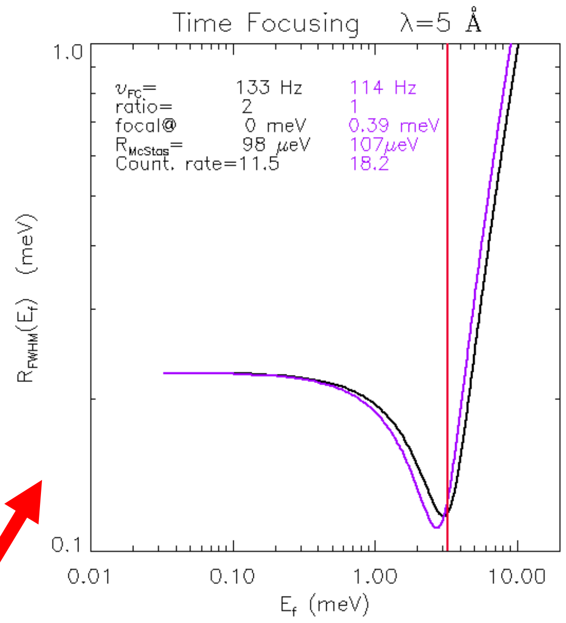
2- Nose IN : "IN5 like" **(Monocromatic Mode) --> constant energy resolution on extended energy transfer range.**

Monochromatic Focusing ("IN5 like")

λ (Å)	Sample Temp. (K)	ν_{FC} (Hz)	AO Chopper Ratio	R (μeV)	Flux @ Samp. (10^5 n/cm2/s)	Solid Angle ratio	P(^{3}He) Gain	Xtal Refectivity	$T_{Windows}$	Counting Rate (10^5 n/cm^2/s)
5	30	5	1	116	5.87	3.65	1.05	0.88	0.95	18.8
5	300	5	2	116	2.88	3.65	1.05	0.88	0.95	9.2

Time Focusing ("IN6 like")

λ (Å)	Sample Temp. (K)	ν_{FC} (Hz)	AO Chopper Ratio	R (μeV)	Flux @ Samp. (10^5 n/cm2/s)	Solid Angle ratio	P(^{3}He) Gain	Xtal Refectivity	$T_{Windows}$	Counting Rate (10^5 n/cm^2/s)
5	30	133	1	99	4.73	3.65	1.05	0.88	0.95	15.2
5	300	133	2	99	3.6	3.65	1.05	0.88	0.95	11.5
5	300	114	1	107	5.68	3.65	1.05	0.88	0.95	18.2



The future of SHARP: SHARP$^+$
Counting rate at least 10 compared to IN6

Focusing Monochromators (20*30 cm^2)	/	Wavelength	/	Energy Resolution
HOPG	/	2.0 - 6.3 Å	/	1.20 meV – 0.070 meV
Fluorinated Mica (project)	/	6.0 - 12 Å	/	0.12 meV – 0.025 meV
Fermi Speed		50-400 Hz		

An Hybrid^2 Spectrometer with a 4.5 m retractable guide nose

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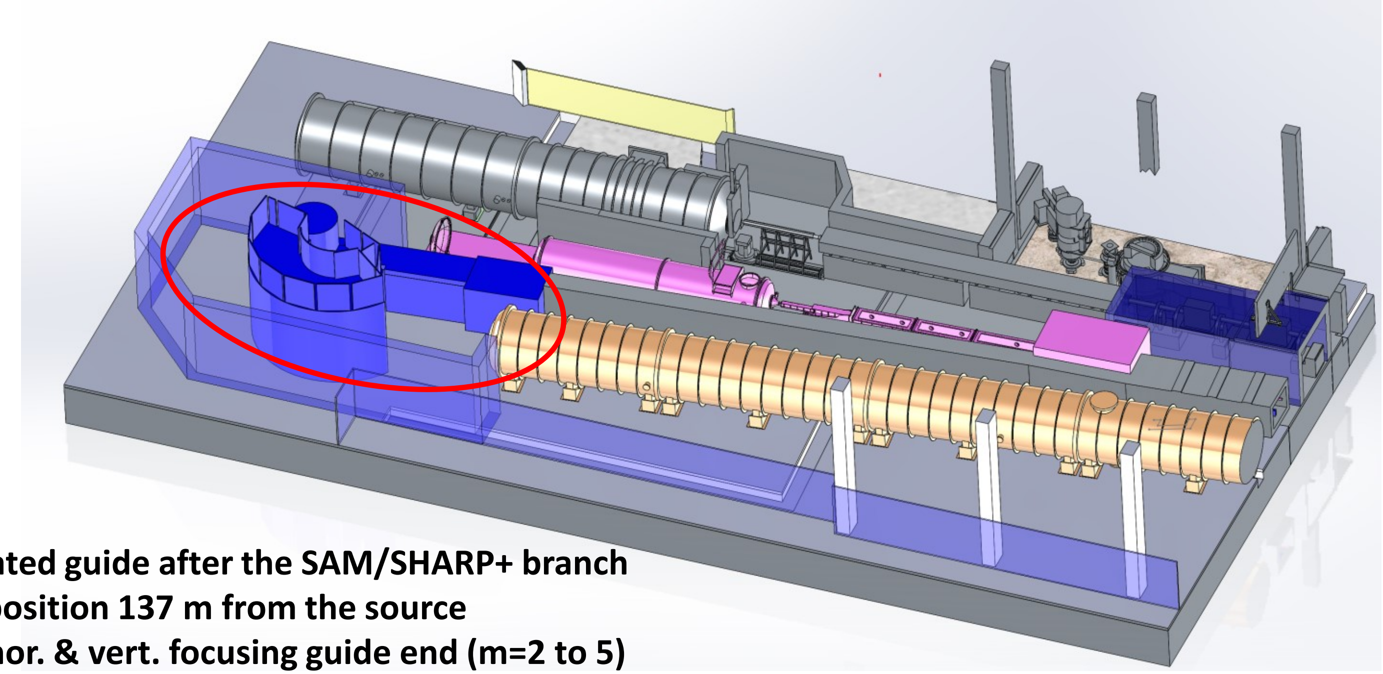

*** A 60 m dedicated guide after the SAM/SHARP+ branch**

*** A guide-end position 137 m from the source**

*** Elliptic 14 m hor. & vert. focusing guide end (m=2 to 5)**

*** No Be Filter but instead 3 anti-harmonics 200 Hz disk choppers cascade**

*** Brand new 400 Hz Fermi Chopper**

SHARP$^+$
Outlook

March 24 2022

April 2 2024