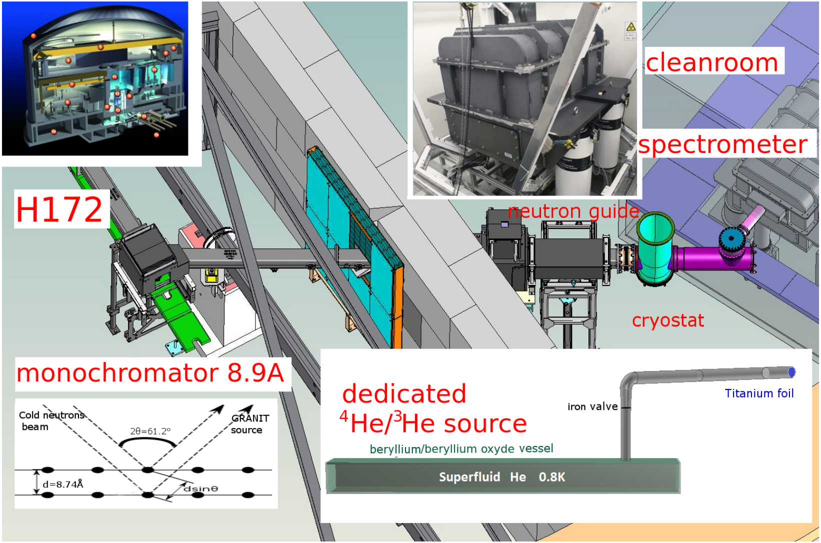
Commissioning of the UCN source for GRANIT

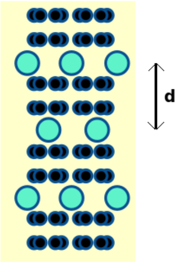
Damien Roulier
PhD Student, Université Joseph Fourier (Grenoble, France)/ILL

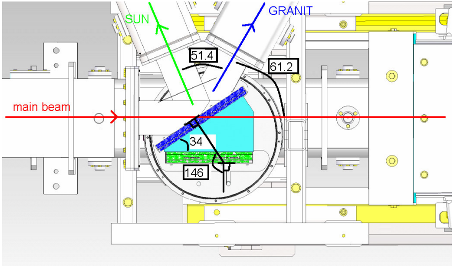
Production of UltraCold Neutrons



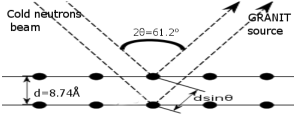
Monochromator

Intercalated Stage2 KC24



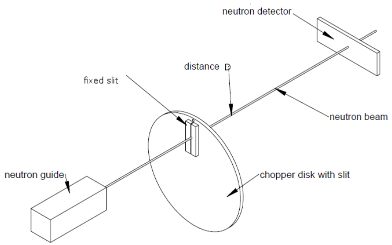


Bragg formula : $2d \times \sin(\theta) = n\lambda$



d(Å)	8.74
θ(deg)	30.6
λ(Å)	8.898044

Cold beam characterization



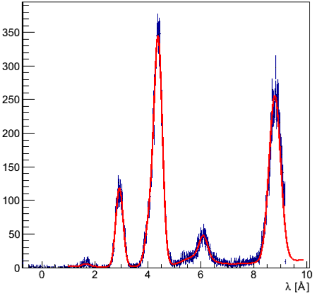
Several time of flight measurements :

- long distance : precise positions of the peaks
- short distance : precise relative intensities of the peaks

Gold foil activation measurement :

- normalization

χ^2 / ndf	1224 / 707
Prob	2.929e-030
Offset	0.002505 ± 0.003685
λ	8.791 ± 0.005
σ_9	-0.2182 ± 0.0022
σ_5	0.1551 ± 0.0017
σ_3	0.1353 ± 0.0018
$Parasit_{1,\lambda}$	4.084 ± 0.014
$Parasit_{1,\sigma}$	0.1673 ± 0.0081
$Parasit_{2,\lambda}$	6.099 ± 0.009
$Parasit_{2,\sigma}$	0.158 ± 0.009
$Parasit_{3,\lambda}$	5.854 ± 0.029
$Parasit_{3,\sigma}$	0.4758 ± 0.0202
$Parasit_{4,\lambda}$	1.668 ± 0.020
$Parasit_{4,\sigma}$	-0.1464 ± 0.0176
A_9	247.8 ± 3.0
A_5	330.6 ± 6.4
A_3	117.1 ± 2.3
$Parasit_{1,A}$	69.21 ± 3.68
$Parasit_{2,A}$	31.93 ± 1.78
$Parasit_{3,A}$	13.97 ± 1.18
$Parasit_{4,A}$	4.129 ± 0.523
Bkg x^2	0.1925 ± 0.0344
Bkg x	-1.011 ± 0.322
Bkg cst	2.191 ± 0.553



Main uncertainties :

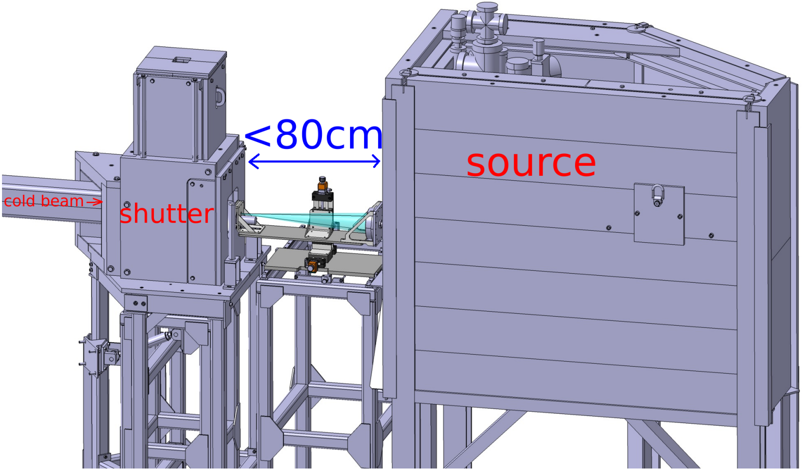
- detector thickness ($\pm$1.3% $\rightarrow \delta\lambda$)
- time resolution (slit opening $\rightarrow \delta\sigma$)

λ (Å)	8.79 $\pm$ 0.11
σ (Å)	0.218 $\pm$ 0.002

Results in agreement with expectation (8.9Å)

New precision TOF measurement (designed for our beam)

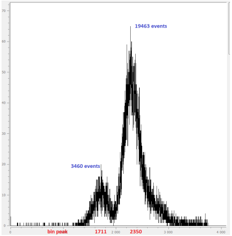
$\Rightarrow$ increased resolution for 8.9Å peak position and σ.


<80cm
source
cold beam
shutter

Gold foil activation

Gold foil activation gives an equivalent beam intensity for 1.8Å neutrons of $\Phi_{gold(1.8Å)} = 6.543 \times 10^8$neutron/cm^2/s (reactor 48MW)

$$\Phi_{true}^{[8.9Å]} = \Phi_{gold(1.8Å)} \times \frac{1.8Å}{8.9Å} \times \left(\sum_{\lambda \in peaks} \frac{p_\lambda}{p_{8.9Å}} \times \frac{\lambda}{8.9Å} \right)^{-1}$$



TOF at closer range : less discrimination between wavelengths for beam divergence

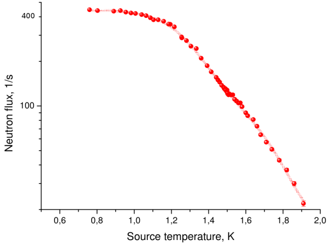
⚠Detector efficiency=f(velocity)

$$\left.\begin{array}{c} \Phi_{true}^{[8.9Å]} = (1.1 \pm 0.1) \times 10^8 \text{ n/cm}^2\text{/s} \\ \sigma_{peak} < 0.218Å \\ \text{Al+Be walls between beam and source :} \\ \times 0.895 \end{array}\right\}, \text{ so } \frac{d\Phi}{d\lambda}\Big|_{8.9Å} = (1.8 \pm 0.2) \times 10^8 \text{ n/cm}^2\text{/s/Å}$$

$\rightarrow$ conversion rate in BeO vessel : $(P = 4.97 \pm 0.38) \times 10^{-8} \times \frac{d\Phi}{d\lambda}|_{8.9Å}$/s/cm^3 (P. Schmidt-Wellenburg et al., 2009)

$\Rightarrow$ we produce 45,000 UCN/s in our 5L vessel

UCN flux versus temperature



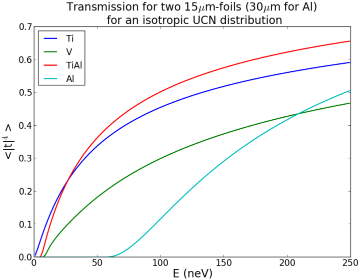
- T> 1.2K : up-scattering in He-II.
- T< 0.9K : losses on the beryllium walls.

Main problem : radiative heat on He-II when the valve is open.

- The source can last a long time at 0.7K (but short valve opening time)
- Measurements are possible at 1.3K (less UCNs, but longer valve opening time)

Extraction window

Analytical calculation :

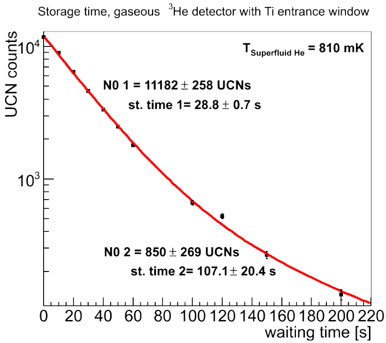


Extraction window :

1. was 30μm AlMg3
2. changed to 15μm Ti (same for our gaseous UCNs detectors)
3. transmission tested at PSI (courtesy of B. Lauss) for $\geq$ 140neV UCNs

$\Rightarrow$ softer UCNs transmitted and detected

UCN storage time



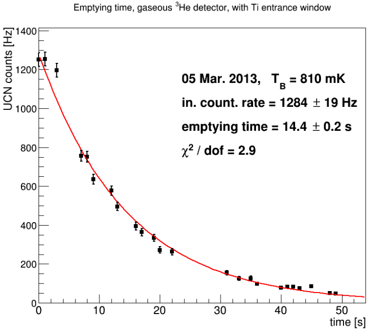
Protocol :

1. accumulate UCN in the source (2min)
2. close cold beam shutter
3. wait *x* seconds
4. release UCNs towards extraction
5. integral count

	Ti	Al
τ	30.4 ± 0.7s	21.3 ± 0.4s

$\Rightarrow$ softer UCNs are available

UCN emptying time



Protocol :

1. accumulate UCN in the source (2min)
2. close cold beam shutter
3. wait *x* seconds
4. release UCNs towards extraction
5. live countrate

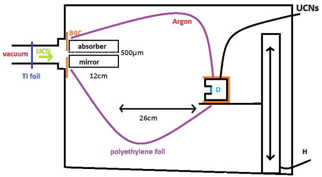
Waiting time (s)	Emptying time (s)
0	14.4 ± 0.2
50	18.6 ± 0.6
100	23.8 ± 1.4

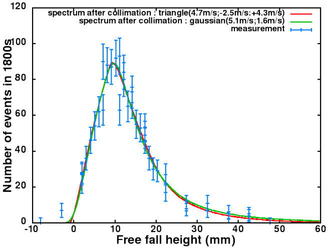
$\tau_{emptying} < \tau_{storage} \Rightarrow$ the source can work in accumulation mode

UCNs velocity spectrum

Free fall of the UCNs horizontally collimated :

$$h = \frac{g}{2}\left(\frac{d_{freefall}}{v_{UCN}}\right)^2$$



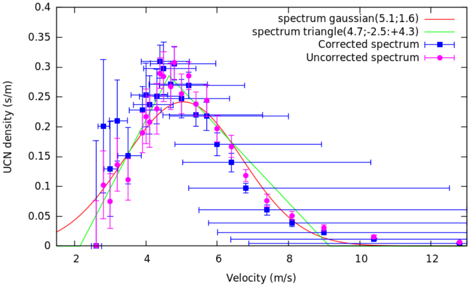


The velocity spectrum is assumed Gaussian or triangular after the collimation, transformed by a simulation of the experiment, then fitted to the measurement.

Velocity spectrum reconstruction

Corrections :

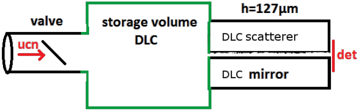
- UCN losses in Ar
- Detector geometry (large window size, "shadowing")
- Reflection on detector window (Ti)

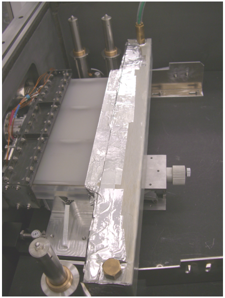


The **mean velocity** of our UCNs in this mode is $5.1 \pm 0.1 m/s$, but the spectrum is quite wide.

Collimation ⇒ less statistics ⇒ valve alway open ⇒ no accumulation of soft UCNs ⇒ "high" mean velocity

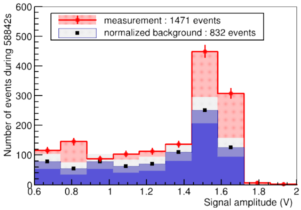
The GRANIT spectrometer : first setup





T_{source}=1.35K,
$(10.9 \pm 1.5) \times 10^{-3}$UCN/s
at the exit of the extraction slit.

- 10 times less than expected
- background significant (fast neutrons in reactor building)



Perspective

Simulations with STARucn (B. Clément) :

- show many more UCNs available for measurements (theoretically better source features)
- helped identify possible causes of losses
- helped design improvements

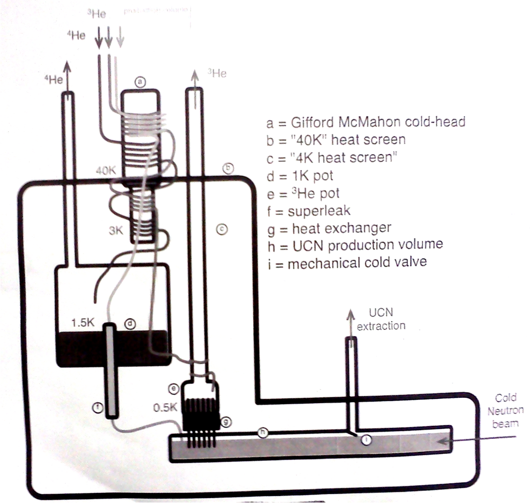
Perspective :

- cold beam : ok, to be confirmed with precise TOF
- cryogenics : more reliable
- conversion volume : to be replaced by sapphire
- extraction : improved, to be replaced by sapphire
- storage volume : to be replaced by copper

$\Rightarrow$ with our efforts, we are confident to improve significatively the number of UCNs available for the GRANIT spectrometer

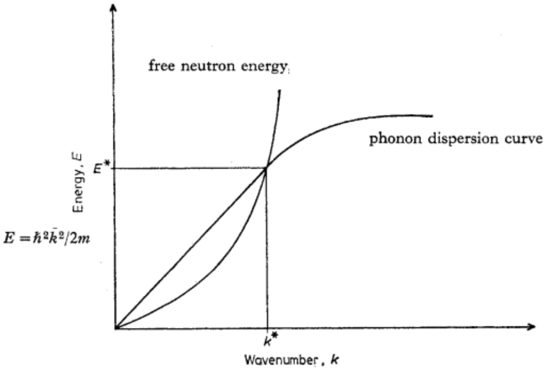
Thank you

Cryostat



^{3}He
^{4}He
^{4}He
^{3}He
a = Gifford McMahon cold-head
b = "40K" heat screen
c = "4K heat screen"
d = 1K pot
e = ^{3}He pot
f = superleak
g = heat exchanger
h = UCN production volume
i = mechanical cold valve
40K
3K
1.5K
0.5K
UCN
extraction
Cold
Neutron
beam

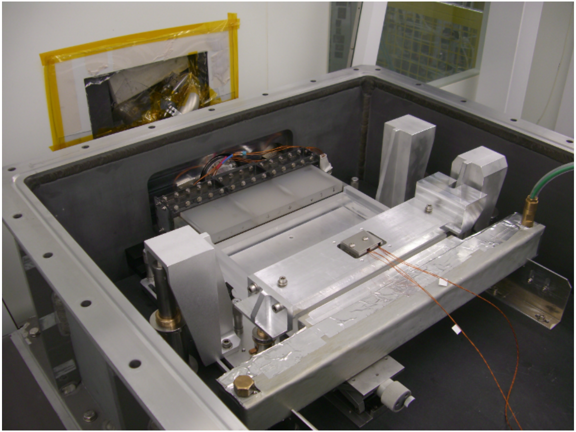
Phonon exchange



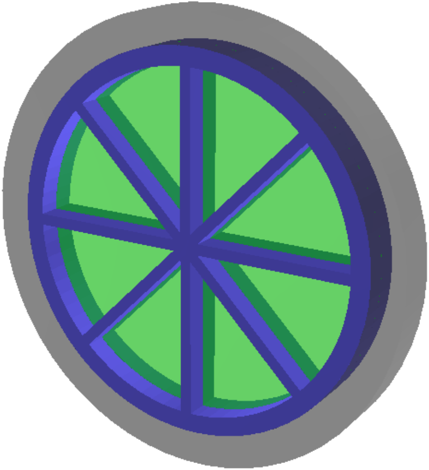
Conservation of energy and momentum in coherent scattering of UCN from phonons.

$$P = 4.97 * 10^{-8} \frac{\mathring{A}}{cm} \frac{d\phi}{d\lambda}|_{8.9\mathring{A}}$$

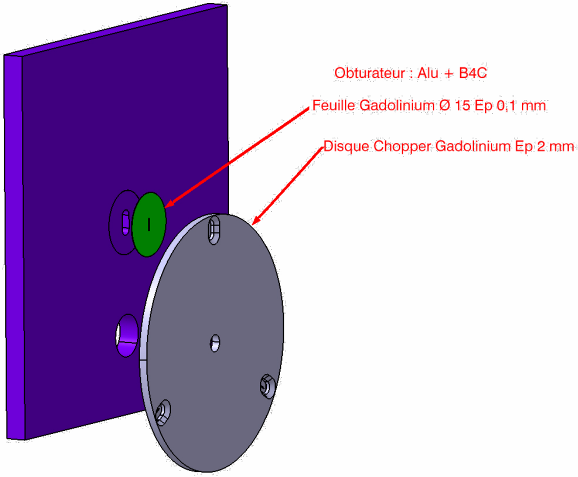
Inside the spectrometer



Holding system for extraction window



New TOF chopper and slit



New TOF detector