Infrastructure for GRANIT at the ILL

M. Kreuz

15th of February 2010
GRANIT workshop at “Les Houches”

Overview

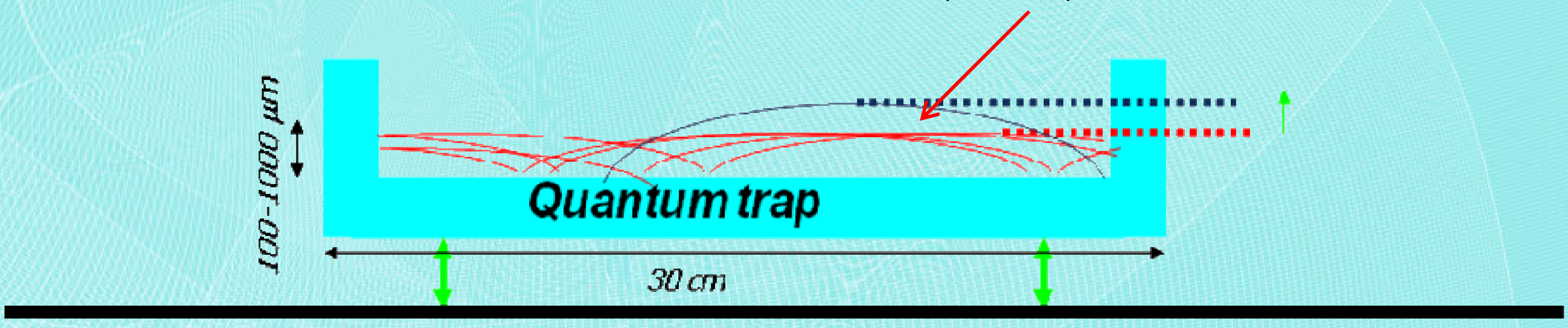
- GRANIT concept
- The ILL reactor
- GRANIT at the ILL
- An intercalated graphite monochromator
- Ultra cold neutron (UCN) production
- First experimental results:
  - Monochromator
  - UCN densities

The GRANIT idea

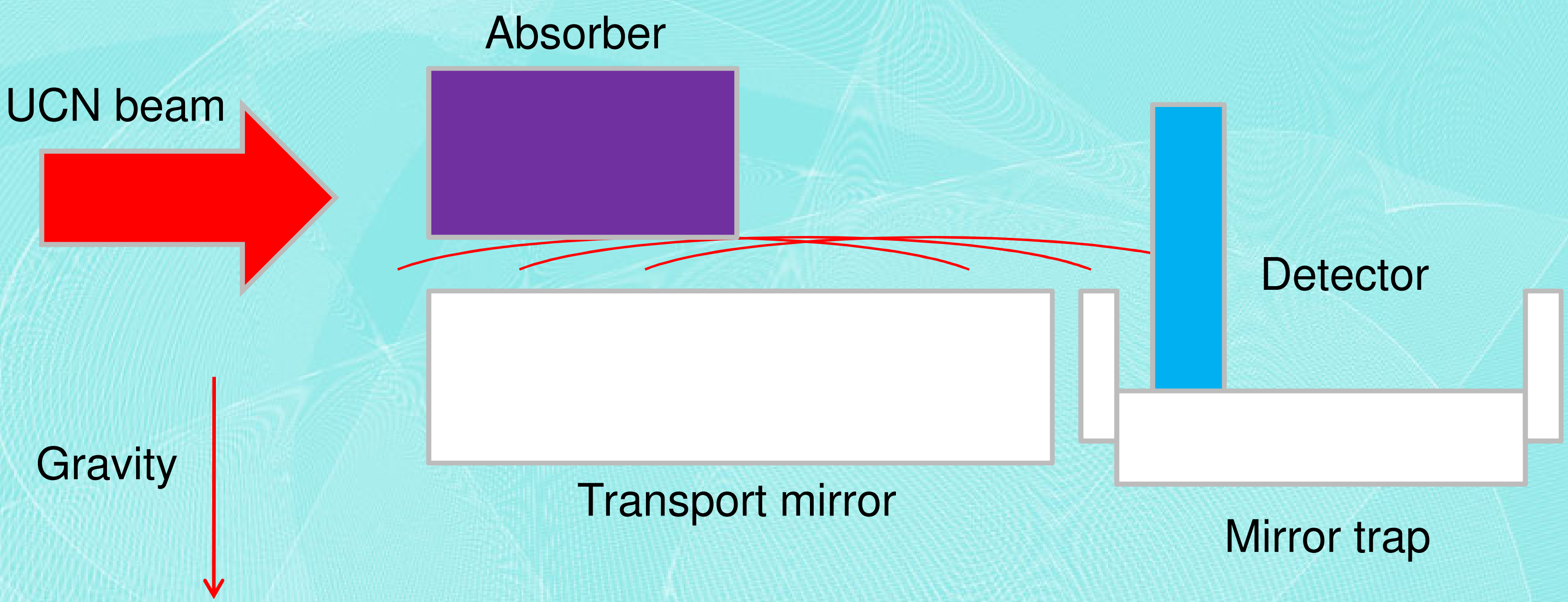
Trapping neutrons between the gravitational field and a mirror potential:

Like children jumping on a trampoline

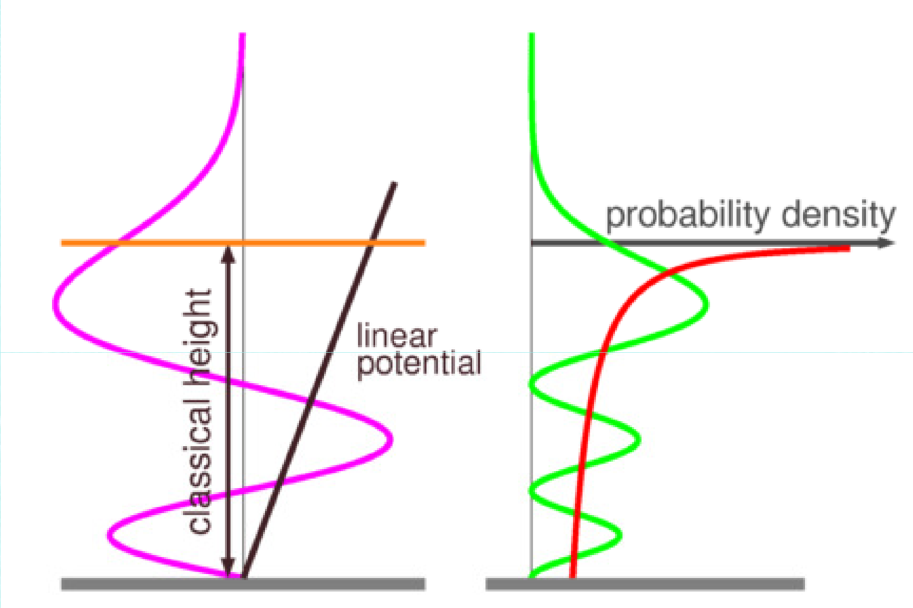
Ultra cold neutrons (UCNs) needed:



GRANIT concept



Quantization in gravitational field



- Neutrons jumping in well defined heights
- Very small vertical energies (peV range)
- Quantization observed at the ILL about 10 years ago on PF2 beam position
- First direct observation of quantization matter in gravitational field

<u>But:</u>

- Experiments are now statistically limited
- Short observation times limit the resolution
- Difficult conditions at PF2 (strong vibrations, magnetic environment, …)

➔ New position, higher statistics and longer observation times needed

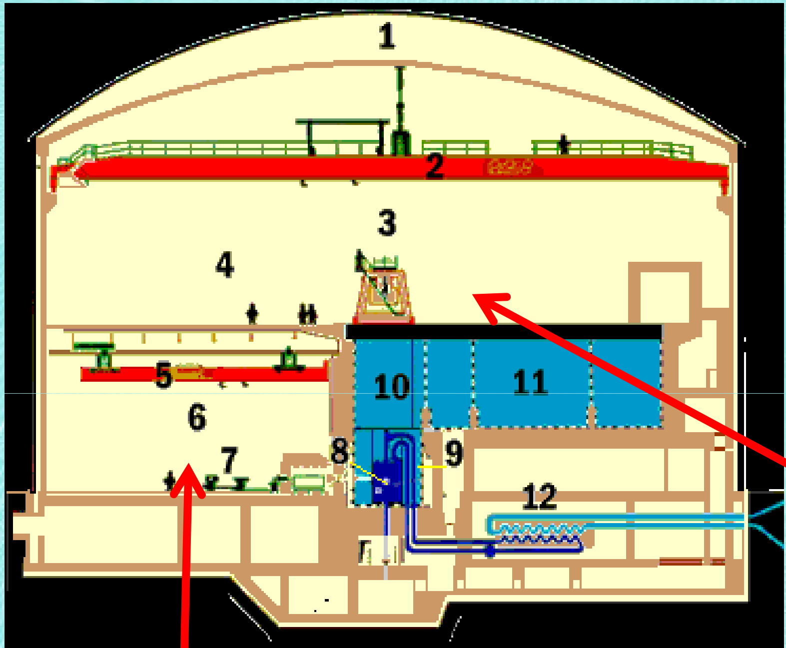
Improvements

Budget: ~1.5M€

- New concept for UCN production
  ➔ **Higher statistics**
- New position at the ILL
  ➔ **Less vibrations, better magnetic environment, less background**
- Storing neutrons in a quantum trap
  ➔ **Longer observation times**
- Inducing resonant transitions between quantum states
  ➔ **Better resolution**
- Clean conditions
  ➔ **Less systematic effects**

The Institute Laue-Langevin (ILL)

The ILL reactor



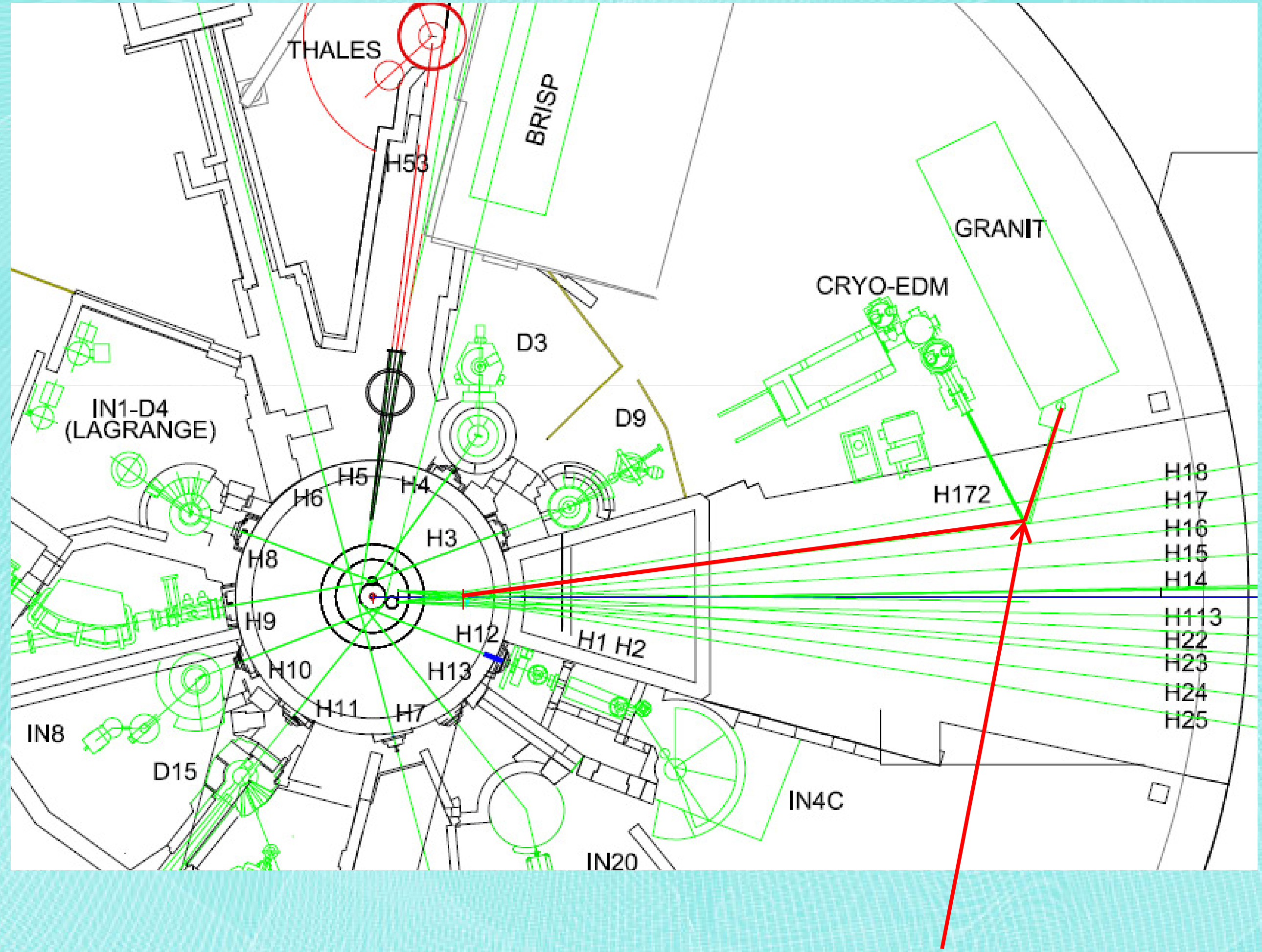
- 1.5×10^{15} n/scm² produced
- 4 cycles of 50d per year
- 2 cold, 1 thermal and 1 hot secondary neutron source
- More than 30 instruments
- ~500 employees
- More than 2000 scientific visitors per year

GRANIT position:
On the ground floor

PF2 beam position where the first measurements have been realized
PF2 is still the strongest UCN source with users

GRANIT position

Closer view



Monochromator

H172 neutron guide:

- Cold neutrons
- Curved upwards with R=650m (m=3)
- Critical wavelength: 3.1Å
- Two instruments can share the same guide

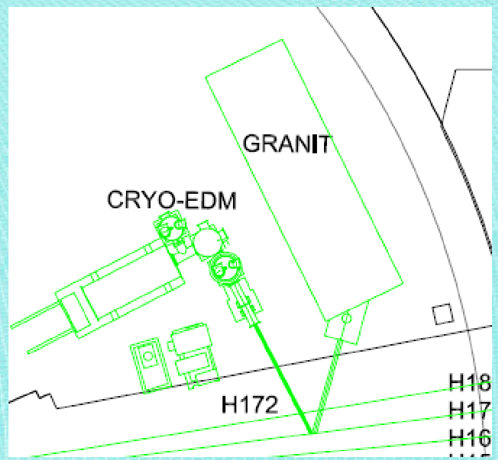
The GRANIT monochromator

8.9Å neutrons for UCN production at high take-off angles:
Intercalated graphite monochromators

ILL optics group

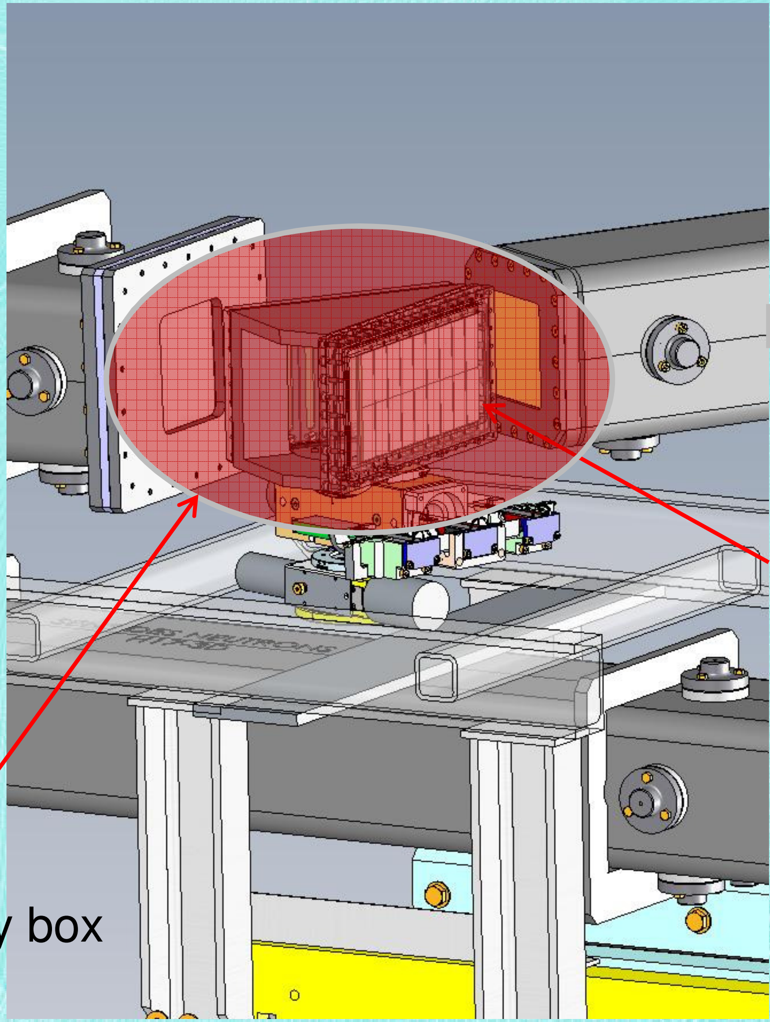
Normal graphite crystals are treated in a Potassium (K) atmosphere
➔ K "seeps" into the crystal structure and increases the grid constant
➔ High take off angles possible: around 61° and 136° depending on the amount of K in the crystals

Two instruments can share the same beam (one after the other)



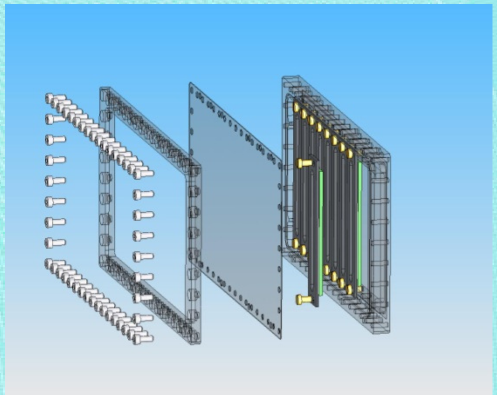
Monochromator mechanics

H172



To GRANIT

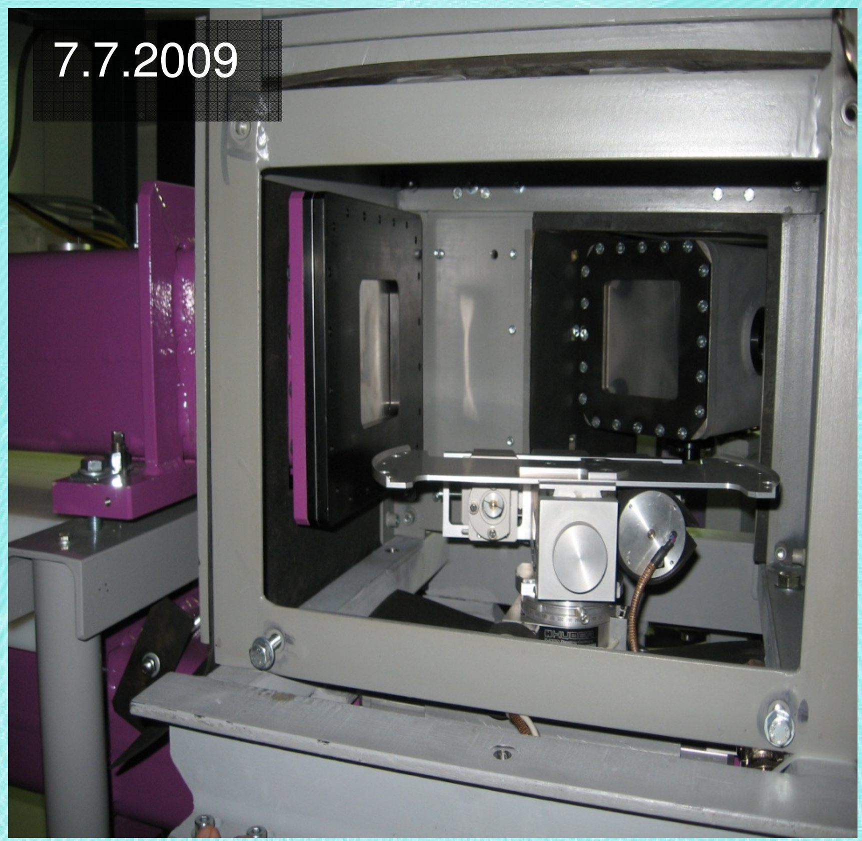
Intercalated graphite crystals in a controlled atmosphere box (Ar)



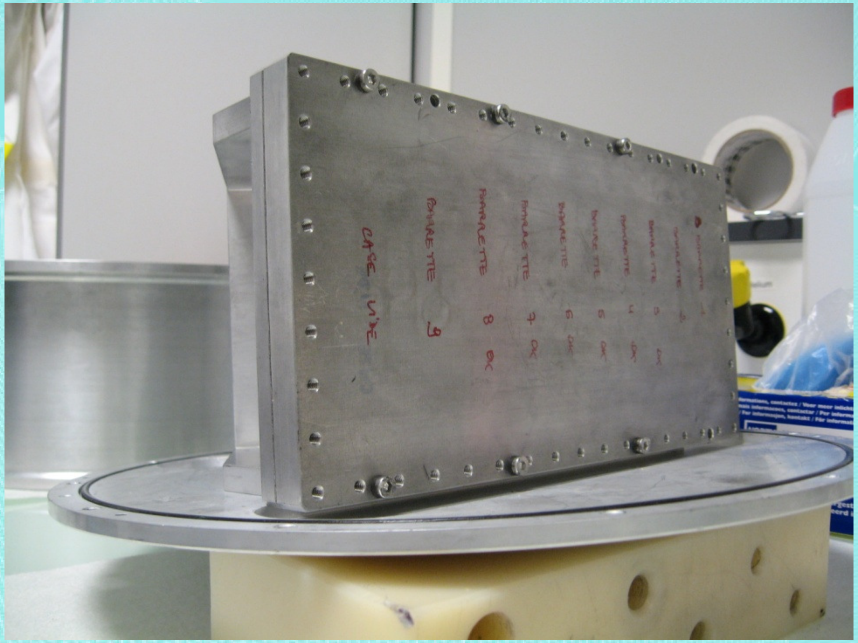
Second safety box (He)

Monochromator pictures

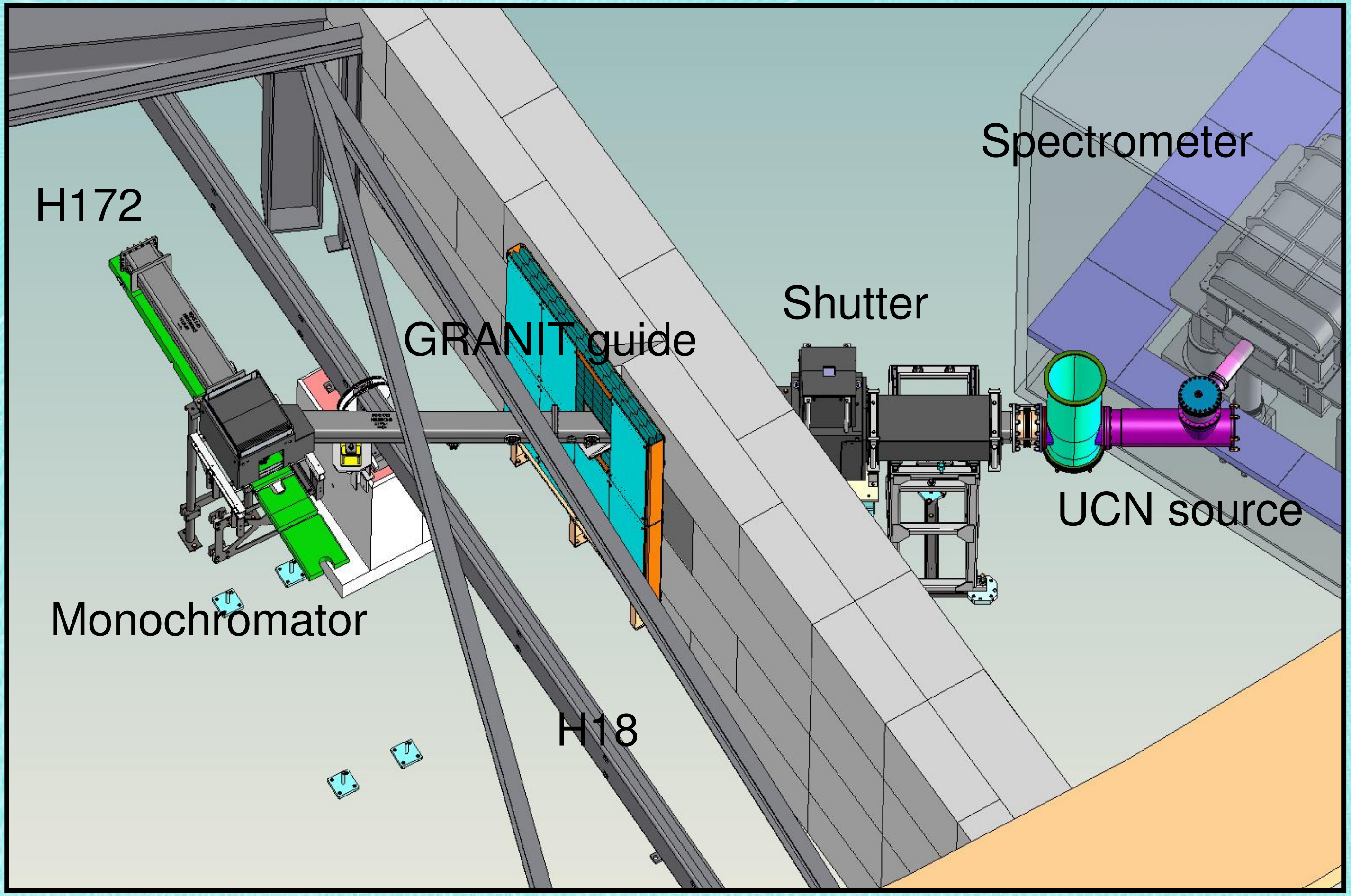
Alignment mechanics



The crystal box

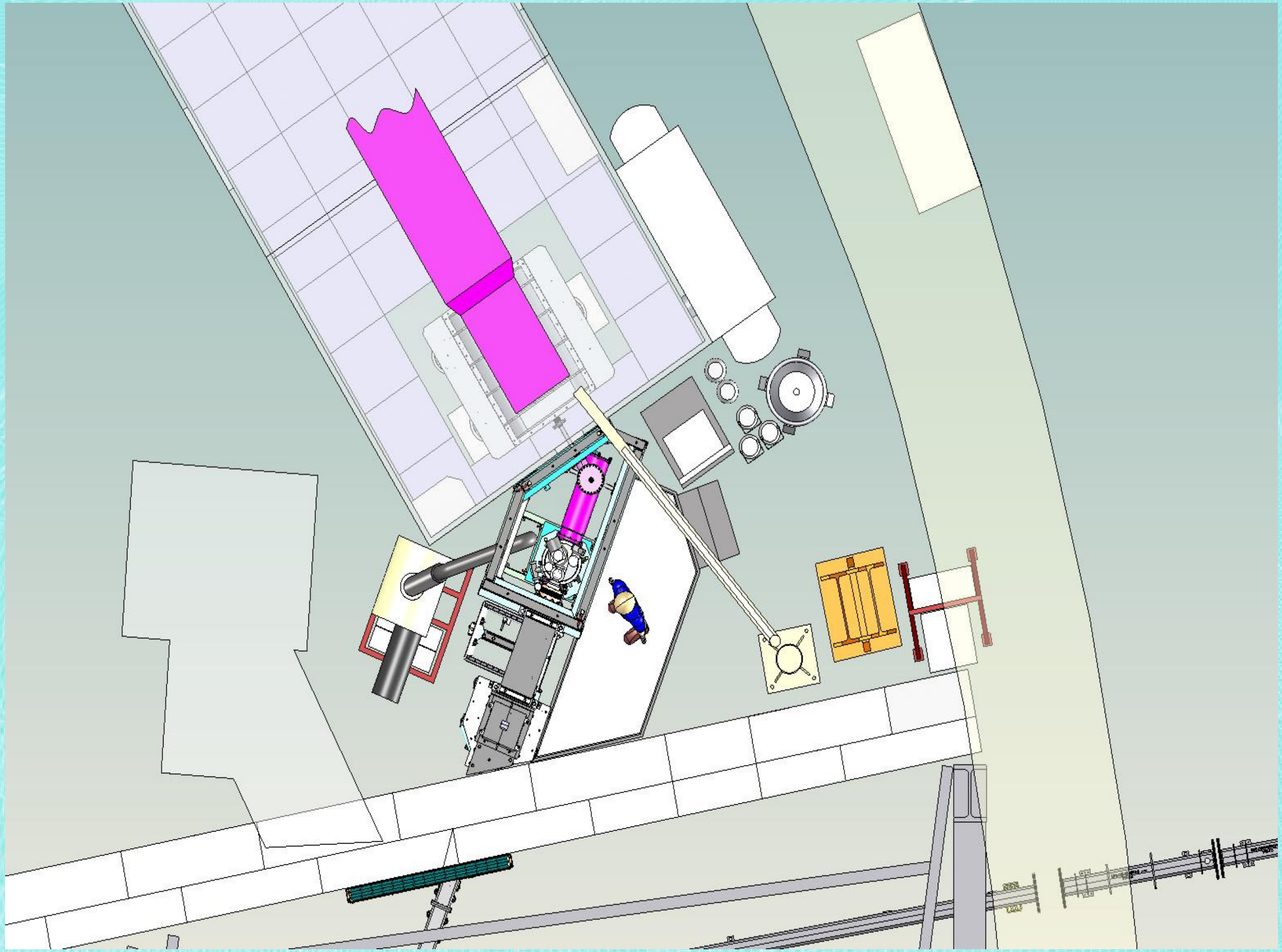


On to the UCN source …

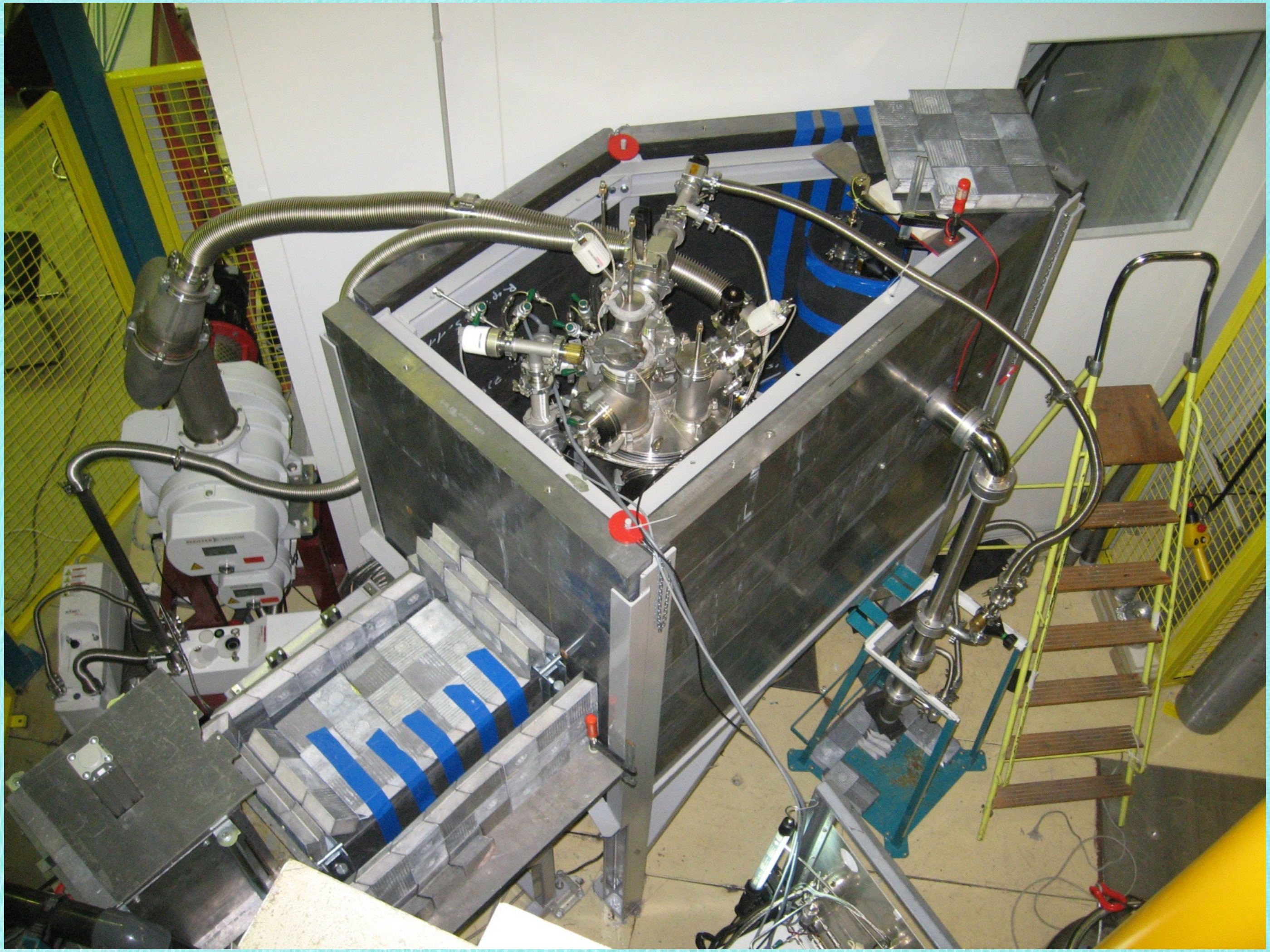


GRANIT guide: m=2 supermirror guide, straight

Design of the source zone



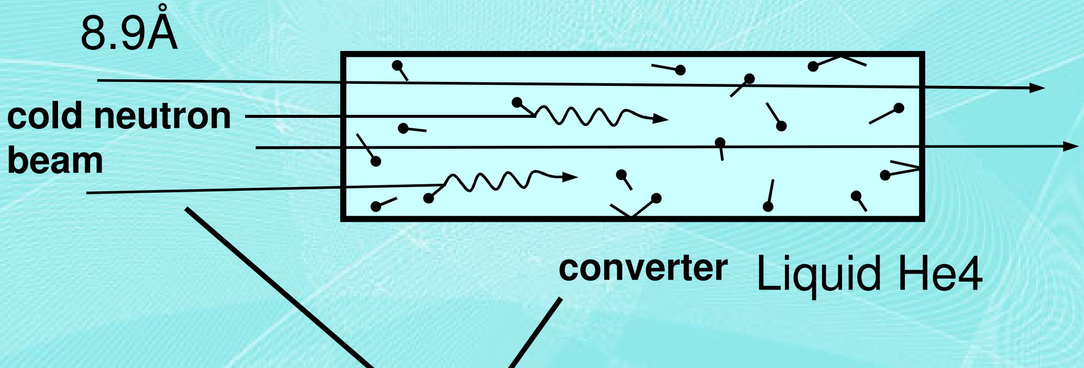
The source zone



Ultra cold neutrons (UCNs)

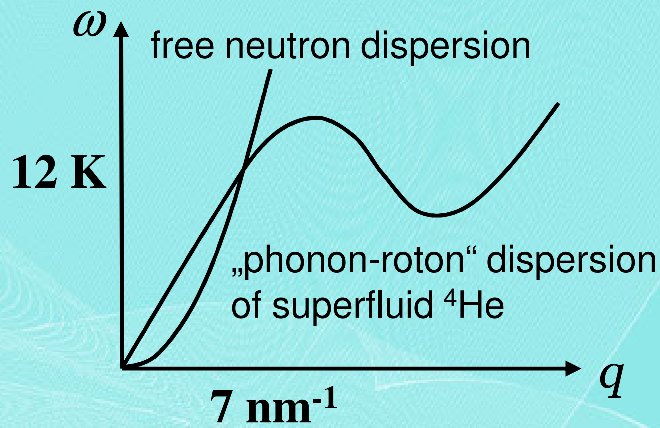
- Ultra cold neutrons = very slow neutrons (velocities <5m/s)
- UCNs are totally reflected from surfaces
  ➔ UCNs can be stored in closed vessels
- UCNs are used for precision particle physics experiments (neutron lifetime, …)
- UCNs are also used for GRANIT (storage in the gravitational trap, observation time, etc.)

UCN source concept



$$\rho_{\mathrm{UCN}} = P\tau_{\mathrm{storage}}$$

R. Golub, J.M. Pendlebury, PL 53A (1975) 133

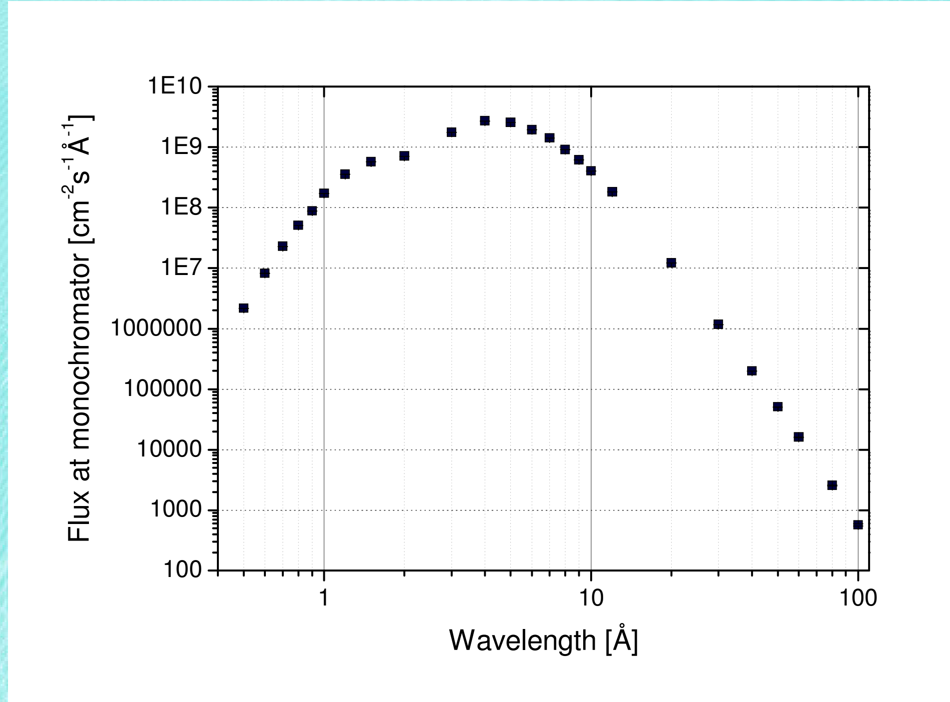


- **Absorption cross section $\sigma_{abs} = 0$**
- **0.7 K: $\tau_{storage} \approx 500$ s (due to phonon absorption)**

  0.5 K: $\tau_{storage} \approx 800$ s
- **Above ~1K all created will be destroyed by phonons**
  ➔ UCN production not possible

UCN densities

Best neutron source today: PF2 at the ILL → ~ 30n/cm³

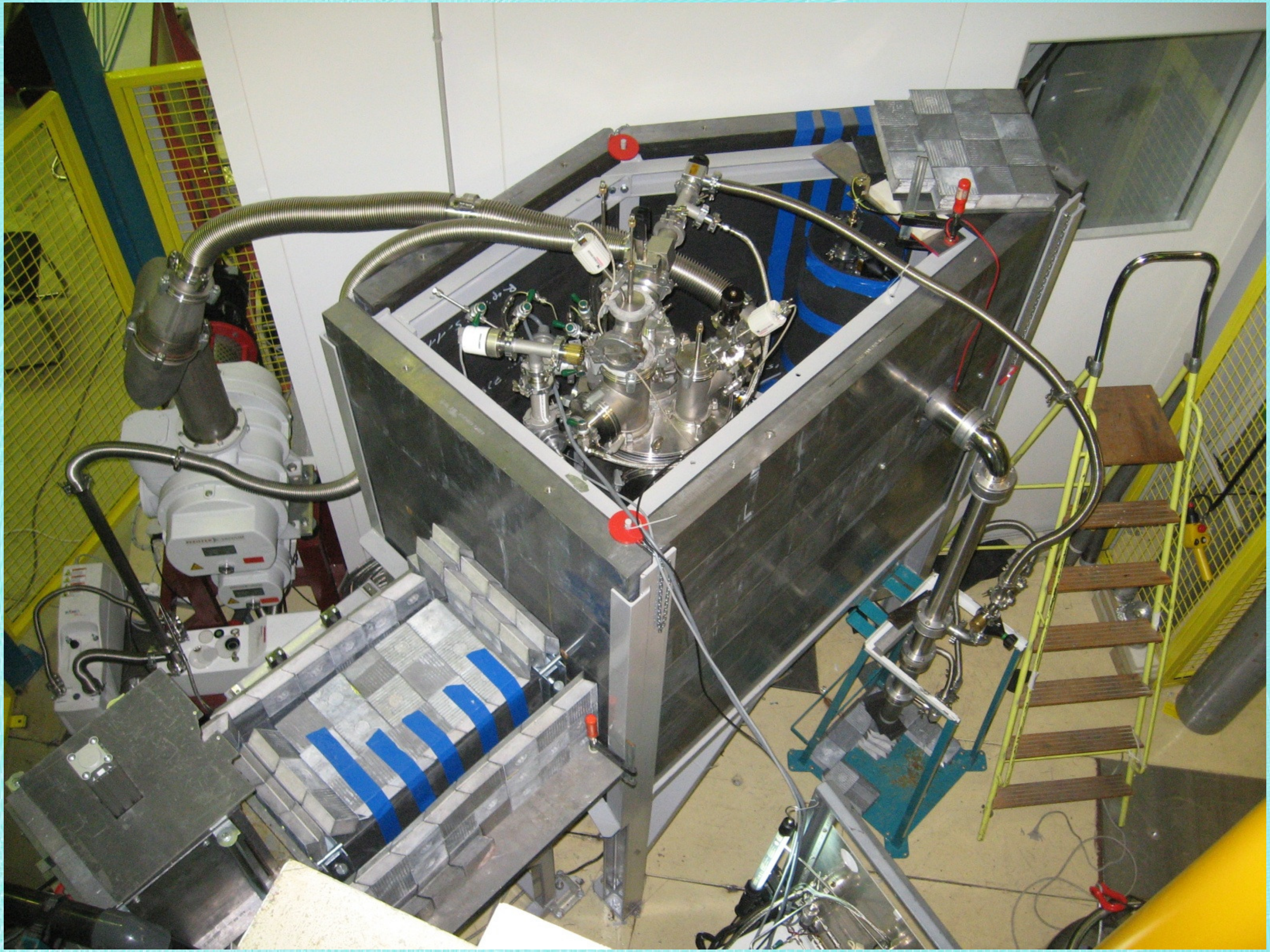


Simulation K. Andersen

Simulation:
Projected flux gives densities in the order of 1000-3000n/cm³

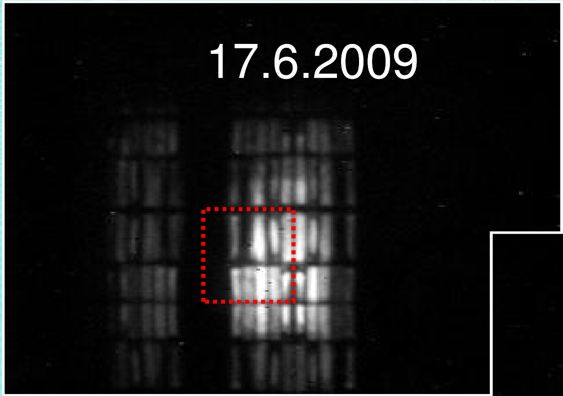
Reality:
Later

UCN source SUN-1



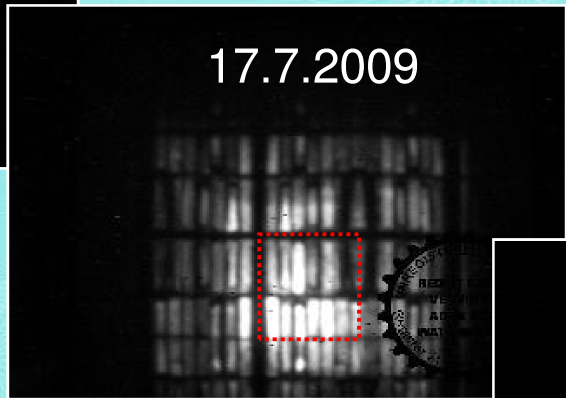
Experimental results

Monochromator images



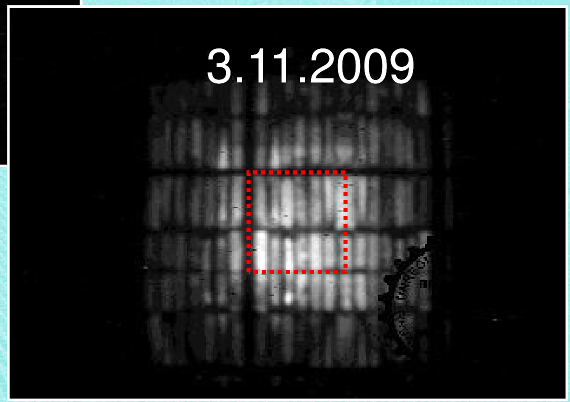
3.1×10^{8} n $cm^{-2}s^{-1}$

Monochromator turned



5.9×10^{8} n $cm^{-2}s^{-1}$

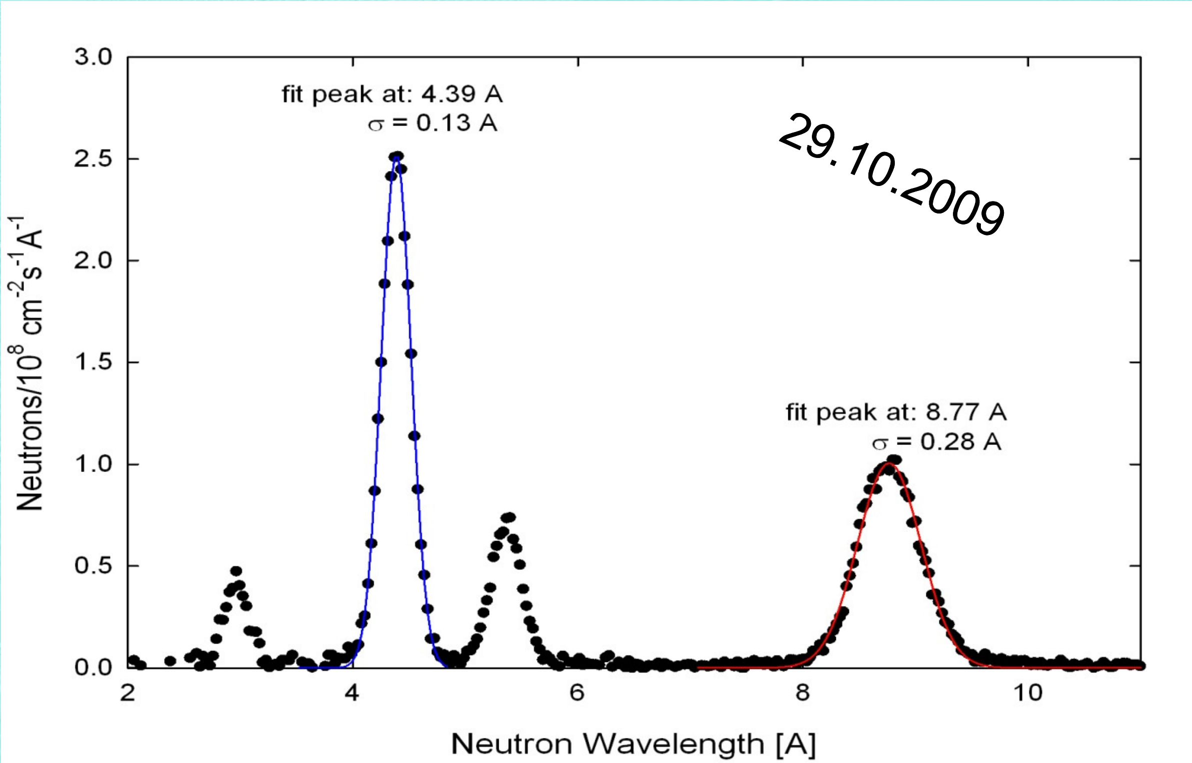
Crystals readjusted



7.2×10^{8} n $cm^{-2}s^{-1}$

F. Piegsa, O. Zimmer, et al.

Flux at 8.9Å



F. Piegsa et al.

Result: 1.0×10^8 n $cm^{-2}s^{-1}Å^{-1}$ @ 8.8 Å

Expected: 2.7×10^8 n $cm^{-2}s^{-1}Å^{-1}$ @ 8.9 Å (50% refl.)

Difference can be explained by uncertainty of the neutron spectrum

Expected UCN density

Reminder: PF2 density

- ~30 n/cm^3
- Best working source so far
- Used by a world wide user community

Possible gain factor of 30 in statistics due to the new source concept

UCN source SUN-1

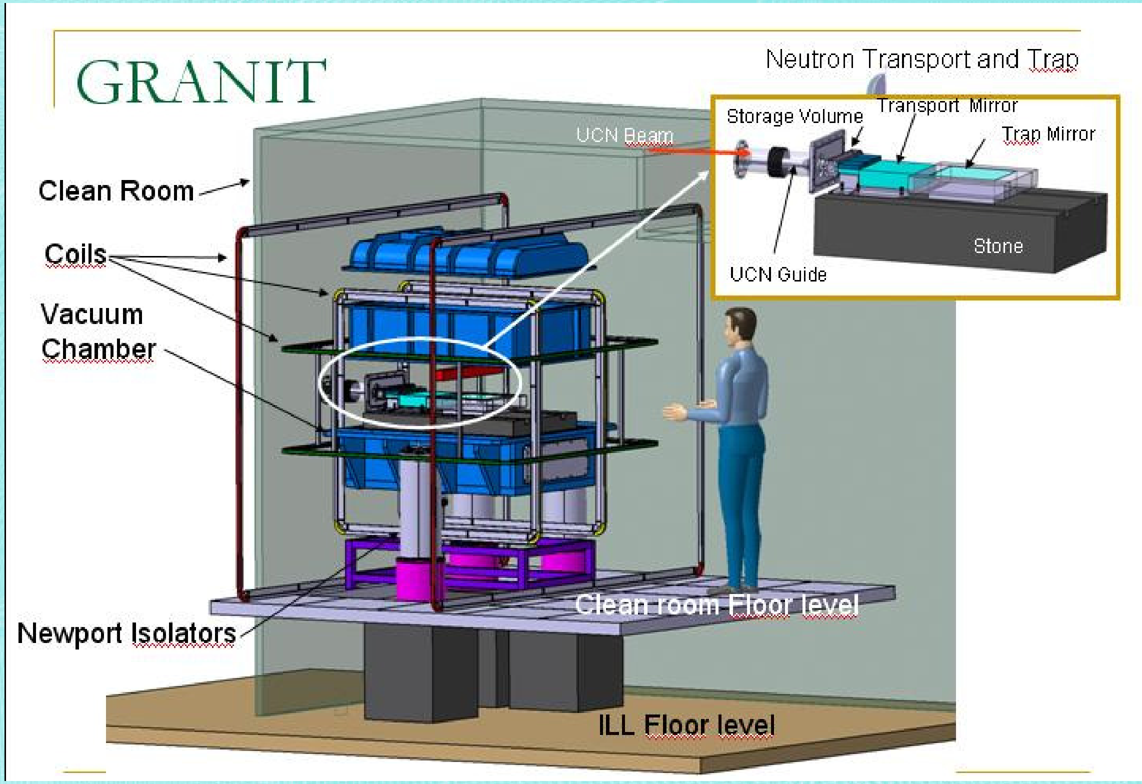
- Production rate (calculated using the measured flux): P=5n/cm^{3}s
- Projected storage time in BeO vessel: ~200s

➔ **Expected density (in the BeO vessel):**

~ 1000n/cm^3

Beware: extraction into vacuum is a challenge

UCNs ➔ the spectrometer



The GRANIT spectrometer will be described in detail by F. Vezzu

Project team

LPSC:

Project leader: K. Protasov

Scientist: D. Rebreyend

Techn. project leader spectrometer: F. Vezzu

Project leader: V. Nesvizhevsky

Tech. project leader: M. Kreuz

Scient. Advisor: T. Soldner

Calculations:

M. Thomas

Electronics:

F. Nagali (CNRS)

Design:

H. Barrias

B. Giroud

UCN source:

O. Zimmer

F. Piegsa

S. Mironov

Monochromator:

C. Menthonnex

P. Mutti

Detectors:

B. Guérard

A. Gagarski (PNPI)

T. Kuzmina (Khl)

Accounting: G. Stieffenhofer

Programming: *L.A. Grigorieva (PNPI)*

Theory:

A.Yu Voronin (Lebedev Institute)

A. Meyerovitch (Rhode Island University)

Installation on level C:

R. Gandelli / J. Aléo

B. Jarry

Diamond coatings: *L. Pinard (LMA)*

Magnetic system: *S. Bäßler (University of Virginia)*

Conclusion

- First neutrons (8.9Å) on the source in 2009
- Guide and monochromator are installed and tested
- The source is being finalized at the moment ➔ first UCNs expected in summer 2010
- First GRANIT measurements expected in autumn 2010