UCN Lab At FRM-II

current activities & plans

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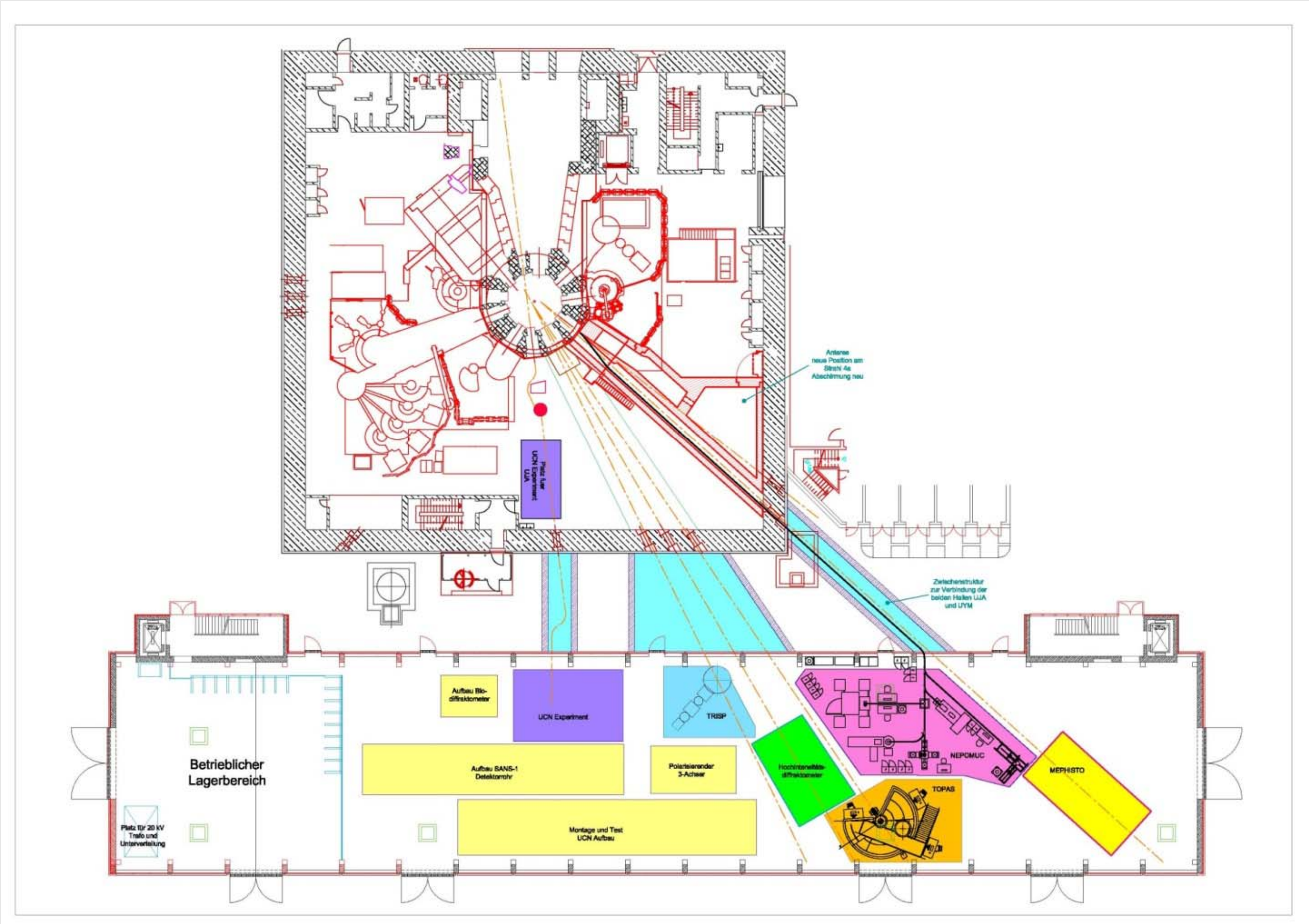
Outline

- Overview
- Neutron EDM
  - Setting up the old EDM apparatus at PSI
  - Development of the new setup
- Neutron Life Time experiment
- UCN Source at FRM-II
  - Overview
  - Current status
- Summary & Outlook

Overview. Munich Research Reactor

East hall Main building Neutron guide hall

Overview. Experimental area



Overview. Main lines of activity

	Currently 2009	Soon 2010÷2015	Future after 2012
Neutron EDM* **	**Setting up experiment at PSI**	**Measurements & development of the new setup**	**Measurements with the new setup at FRM-II**
Lifetime	**Contracting apparatus**	**Setting up & measurements at PSI**	**Measurements at FRM-II**
UCN Source at FRM-II	**Prototyping & paper work**	**Building & running**	**Operating UCN source at FRM-II**

*** in collaboration with a wide range of institutions

Neutron EDM. Setup at PSI

OILL: Old Sussex-RAL-ILL EDM apparatus has been recently moved to PSI

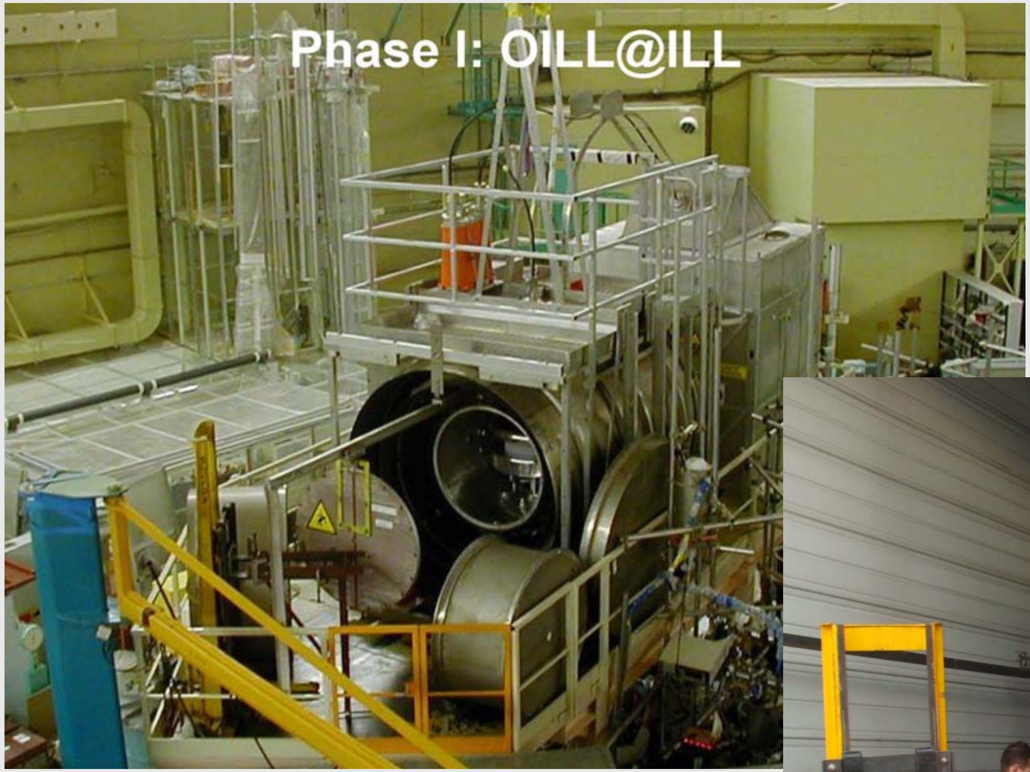
Munich group is mainly involved in setting up the magnetic conditions

Collaborating institutions:

[1]PTB, Physikalisch Technische Bundesanstalt, Berlin, Germany
[2]LPC, Laboratoire de Physique Corpusculaire, Caen, France
[3]JUC, Jagellonian University, Cracow, Poland
[4]HNI, Henryk Niedwodniczanski Institute of Nuclear Physics PAN, Cracow, Poland
[5]JINR, Joint Institute for Nuclear Research, Dubna, Russia
[6]FRAP, Université de Fribourg, Fribourg, Switzerland
[7]ECU, Excellence Cluster Universe, Garching, Germany
[8]ILL, Institut Laue-Langevin, Grenoble, France
[9]LPSC, Laboratoire de Physique Subatomique et de Cosmologie, Grenoble, France
[10]BMZ, Biomagnetisches Zentrum, Jena, Germany
[11]KUL, Katholieke Universiteit, Leuven, Belgium
[12]GUM, Institut für Physik, Gutenberg Universität, Mainz, Germany
[13]IKC, Institut für Kernchemie, Gutenberg Universität, Mainz, Germany
[14]TUM, Technische Universität, München, Germany
[15]PSI, Paul-Scherrer-Institut, Villigen, Switzerland

http://nedm.web.psi.ch/

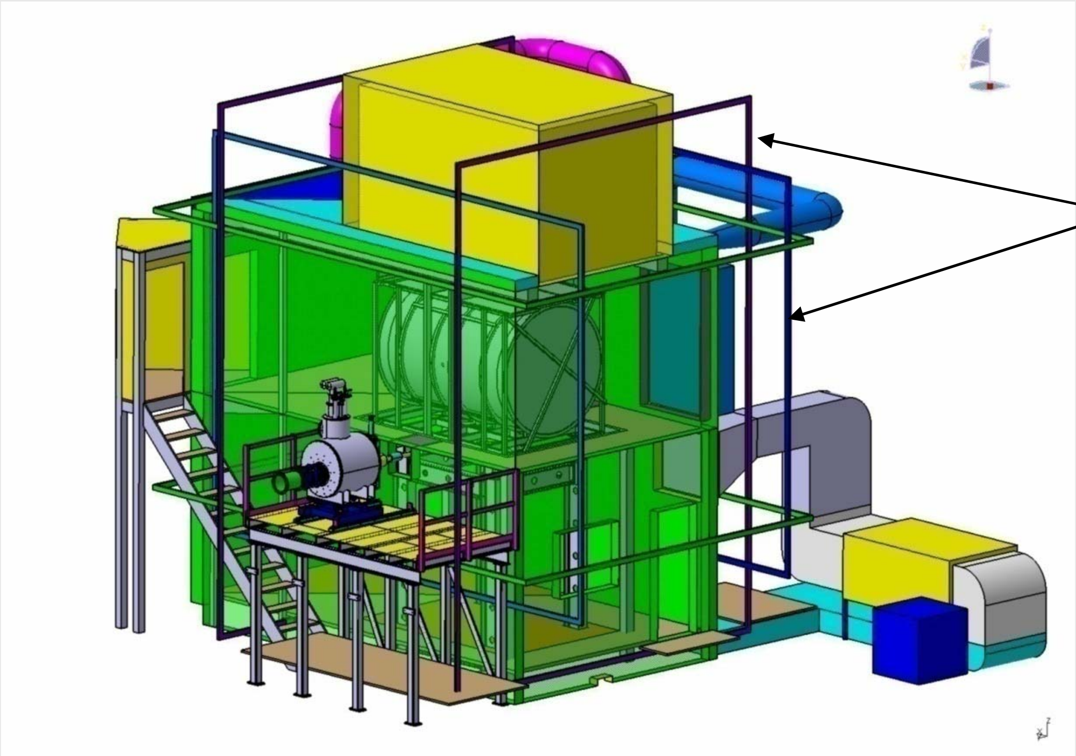
Neutron EDM. Setup at PSI



Most of components has been modernized or replaced with the new ones

The old magnetic shield and vacuum tank is still in use

Neutron EDM. External field compensation

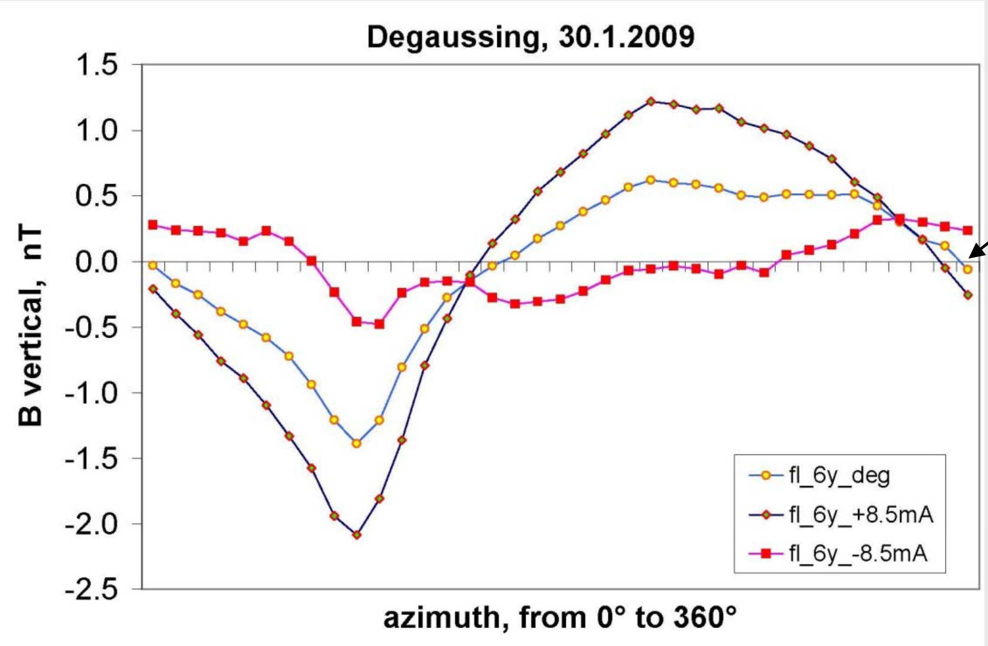


3D compensation coil system for compensation of Earth magnetic field and gradients of external sources.

Stabilization is also foreseen

Status: under construction. To be completed by October 2009

Neutron EDM. Degaussing



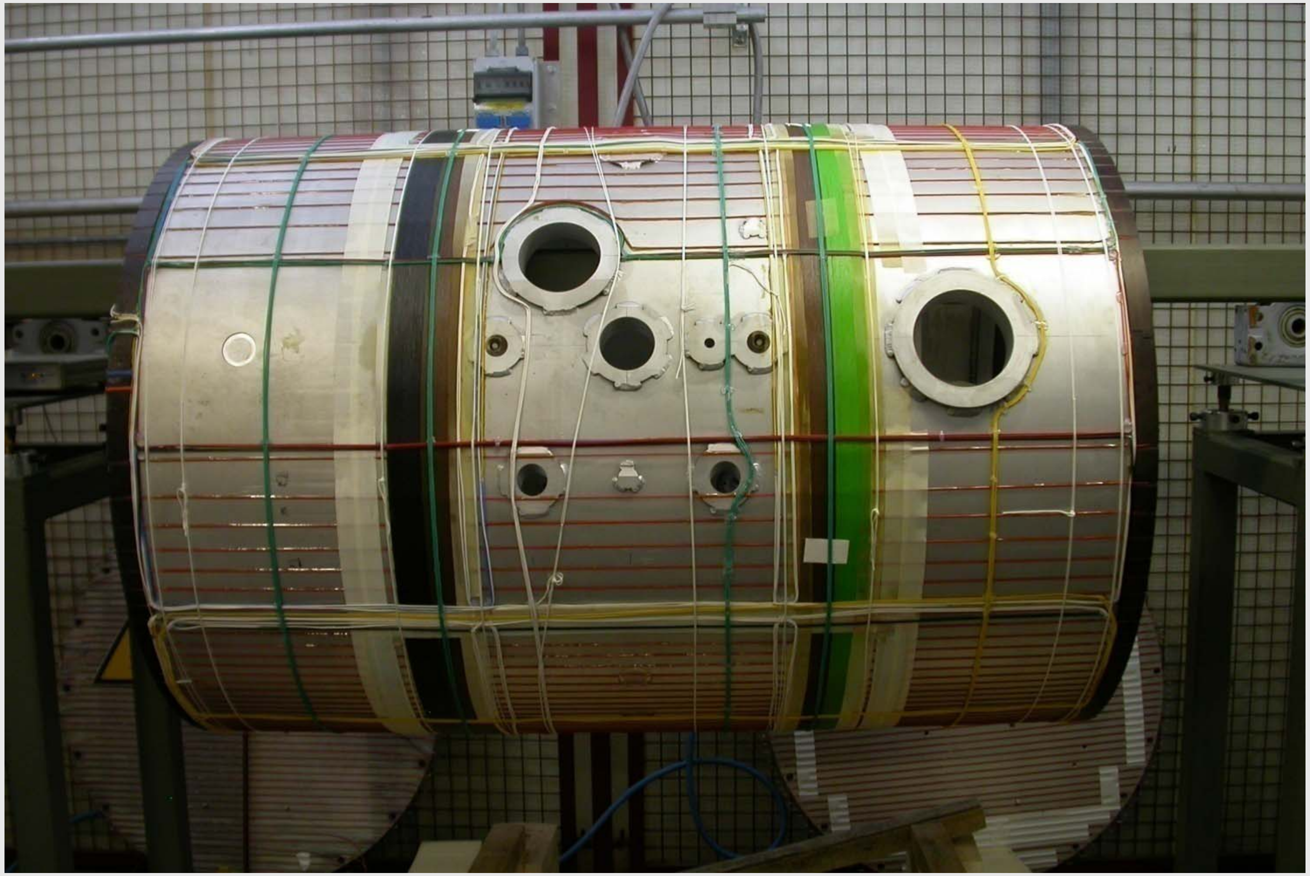
An example of insufficient degaussing of the original OIIL apparatus

A few second current impulse of - 8.5 mA improves considerably the field homogeneity

Remanent vertical magnetic field component at 30 cm distance around vertical axis of the UCN storage cell

A new degaussing system is under construction. The current is increased to 1000 Aw. Additional loop added for most inner layer of the shield

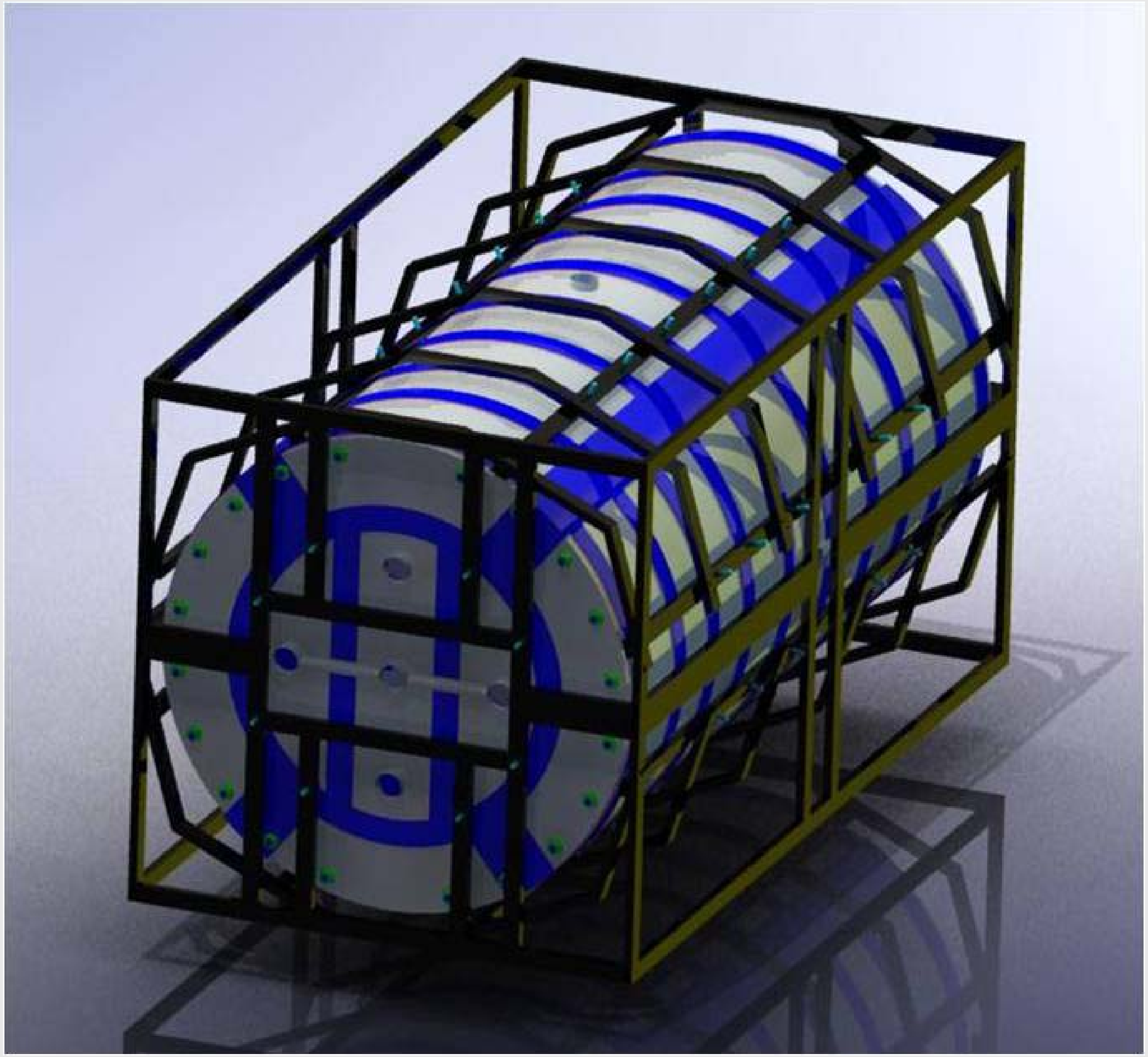
Neutron EDM. Correction coils



OILL vacuum tank

The original set of 8 correction coils is improved. 24 coils are available now for fine tuning of magnetic field inside of the tank

Neutron EDM. New Magnetic Shield



R&D research is in progress for the new magnetic shield.

It will have:

dimensions about 3x3x6 meters

5 layers of μ-metal

radial shielding factor 50000

Neutron Life Time. PENeLOPE

In progress *(in collaboration with PSI)* / **Talk by Stefan Materne**

Precision goal

$$\Delta\tau_n \sim 0.1 \text{ s}$$

- magnetic trapping:
  no systematic errors due to wall collisions
- no zero-field regions:
  spin-flip probability < 10^{-5} for 1500 s storage time
- removal of marginally trapped UCN, which introduce systematic errors
- good statistics: up to 10^8 stored UCN with next generation UCN sources
- detection of decay protons:
  online measurement of exponential decay curve
- additional counting of surviving neutrons:
  second, independent measuring principle
- intense study of systematic effects possible

error	value
Statistics (after 40 days)	0.03 s
neutron spin-flip	< 0.01 s
marginally trapped UCN	< 0.03 s
UCN scattering on rest gas	< 0.07s
time variation of UCN distribution	-
total (quadratic sum)	**0.08 s**

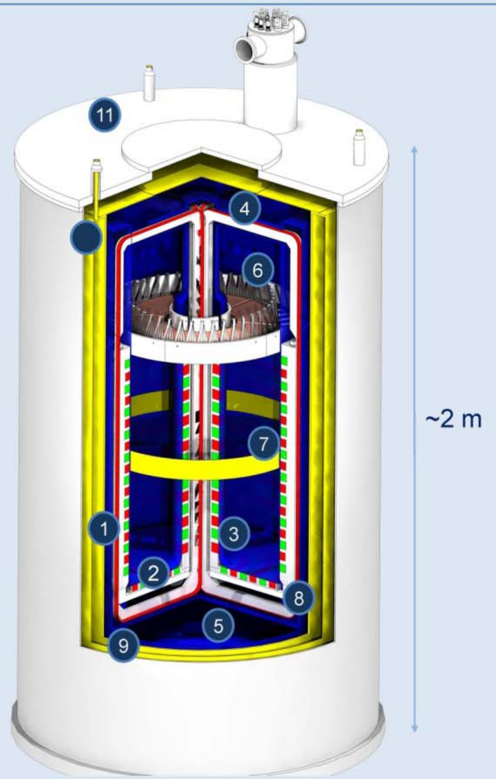
Experimental setup

- trap height: 1.1 m
- outer radius: ~ 0.5 m
- storage volume: ~700l

- 42 superconducting storage coils
- racetrack coils for zero-field suppression
- focusing coils for proton collimation

- max. storage field: > 2 T
- min. storage field: >> 10^{-3} T

$$E_{UCN} < 110 \text{ neV}$$

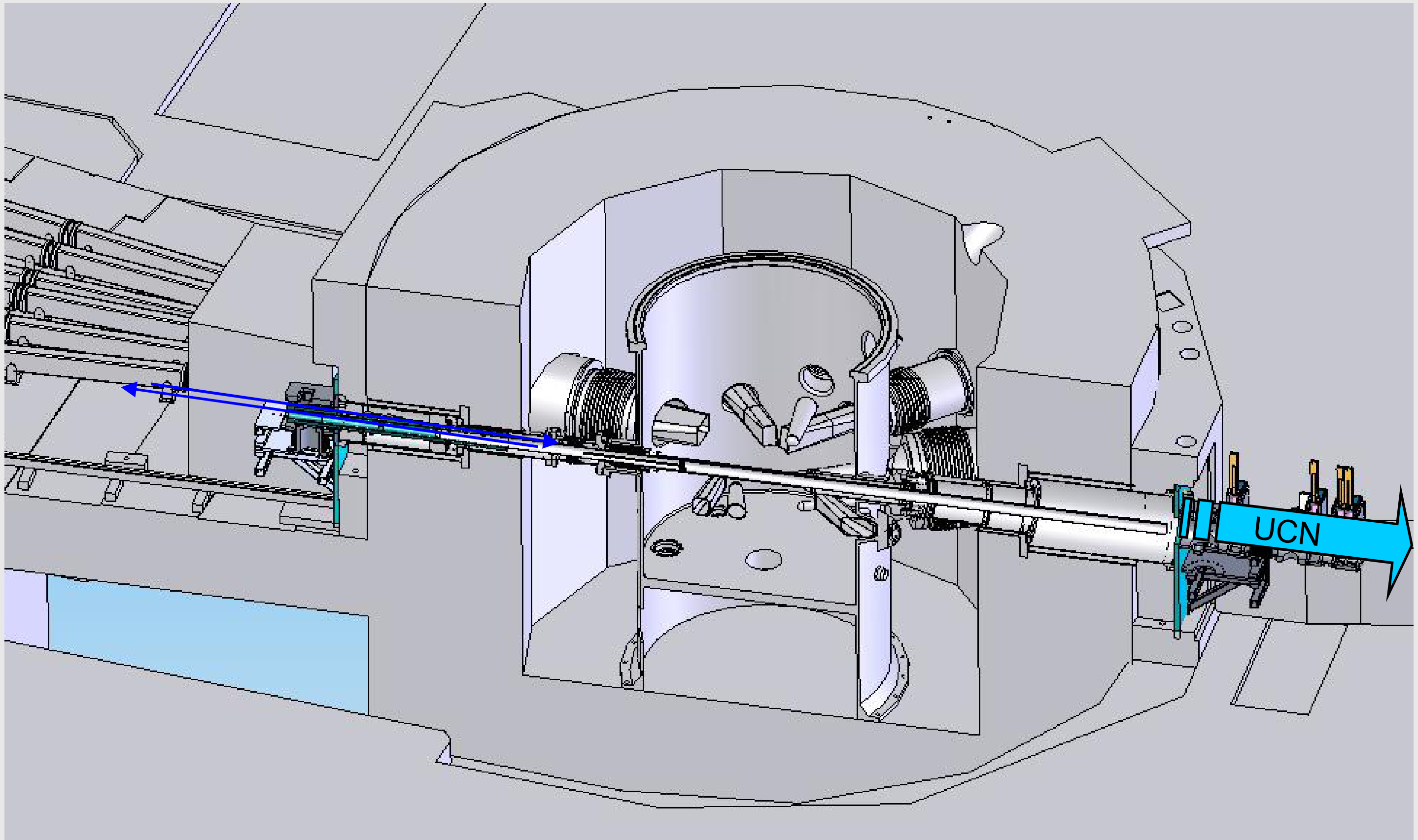


1. outer storage coils
2. bottom storage coils
3. central storage coils
4. racetrack coils
5. UCN buffer volume
6. proton detector
7. absorber
8. UCN entrance slit
9. liquid He cryostat
10. liquid N_2 radiation shield
11. vacuum tank

Int. Workshop on Part. Physics with Slow Neutrons, 2008, Grenoble

UCN source. Overview

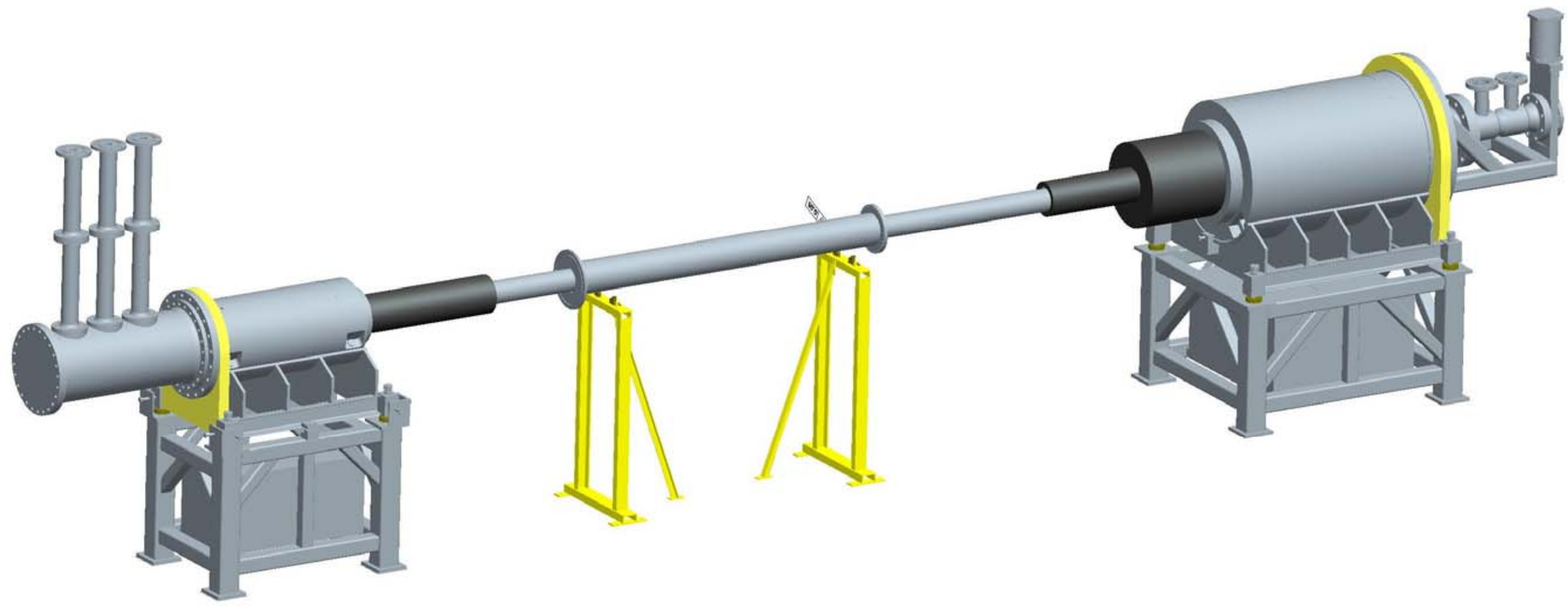
Cryogenics & Mechanics Ø155mm UCN



Location in the beam tube SR6

UCN source. Overview

Mockup of SR6 at East hall for prototyping and tests



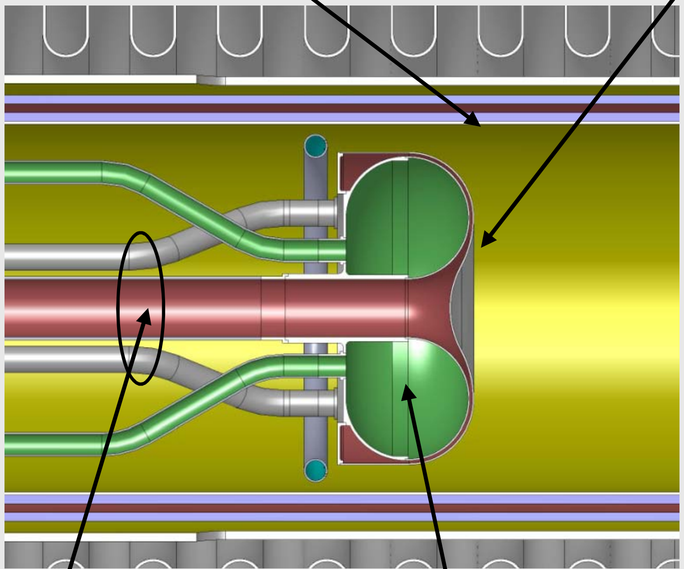
Start of mockup building in July 2009

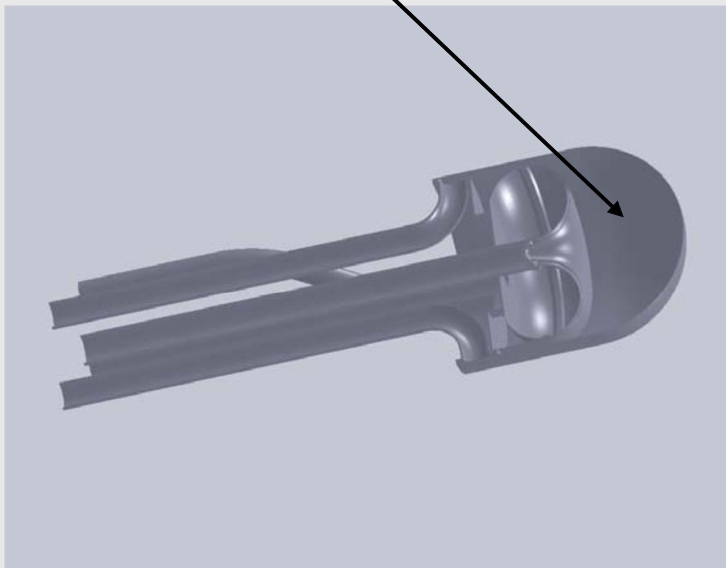
UCN source. UCN converter

In-pile tube is a UCN guide

D_2 is frozen on the outer surface

Option: D_2 is contained





5K He loop

H_2 pre-moderator

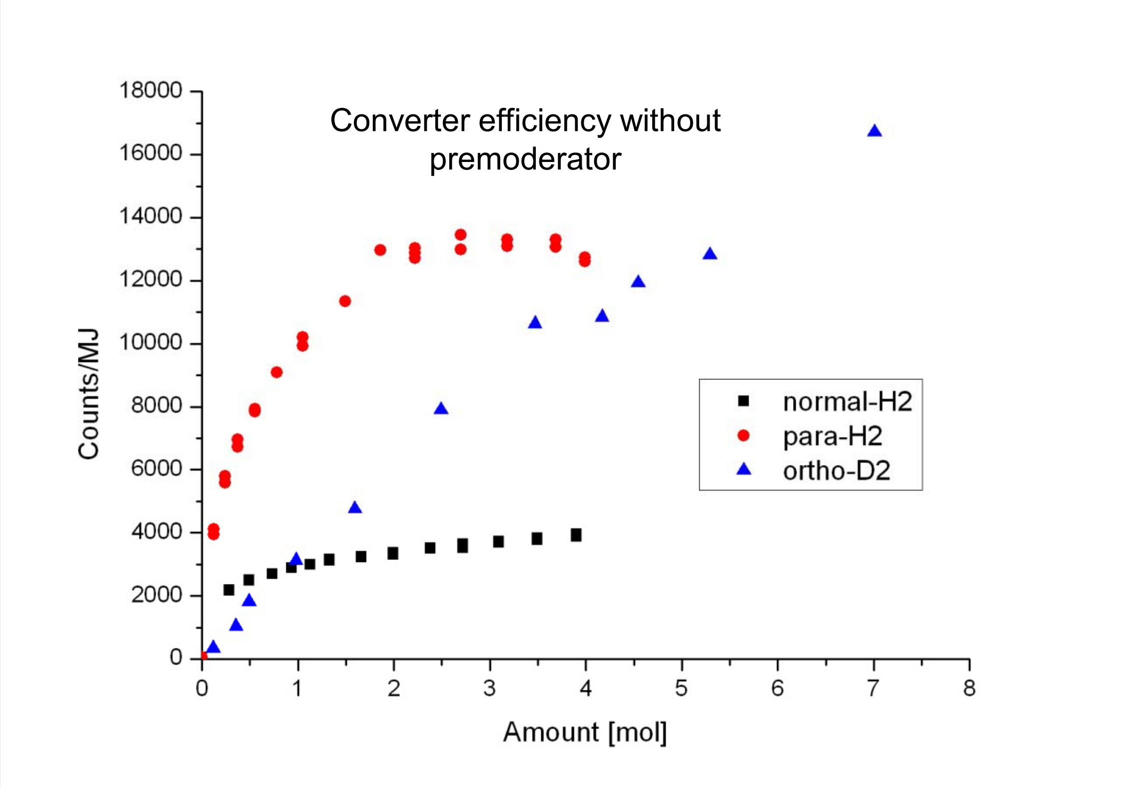
Status: prototype production

Plans: extensive tests in 2009 - 2010

UCN source. Results from TRIGA Mainz

22000

11 mol

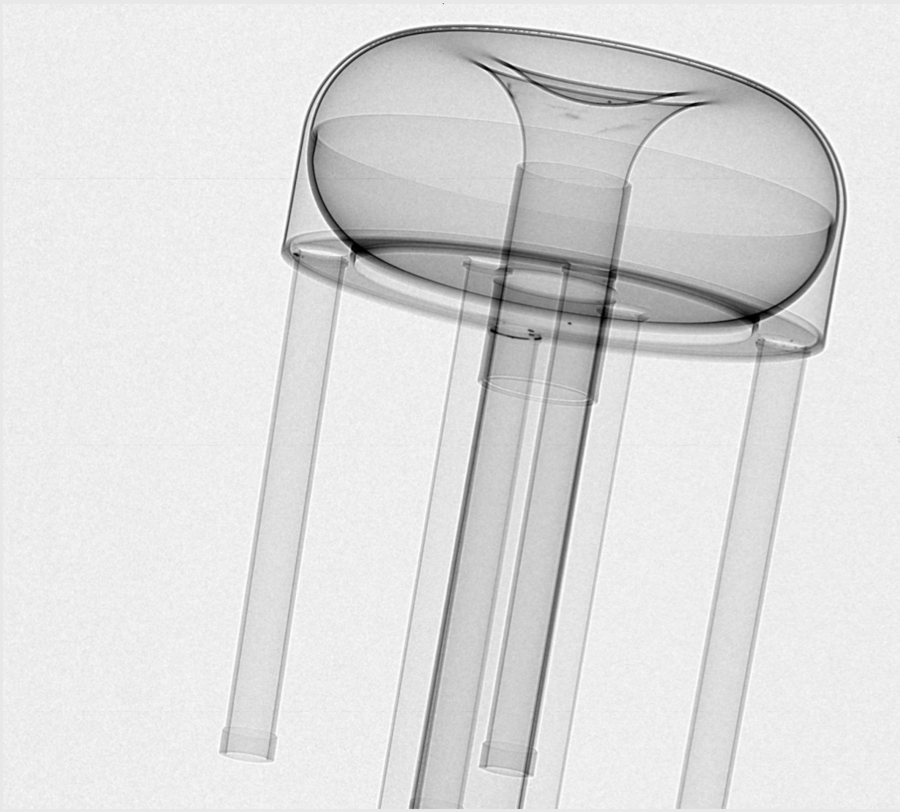


Para-H_2 is a possible candidate as a UCN converter

UCN source. UCN converter

Instrument: ANTARES@FRM-II

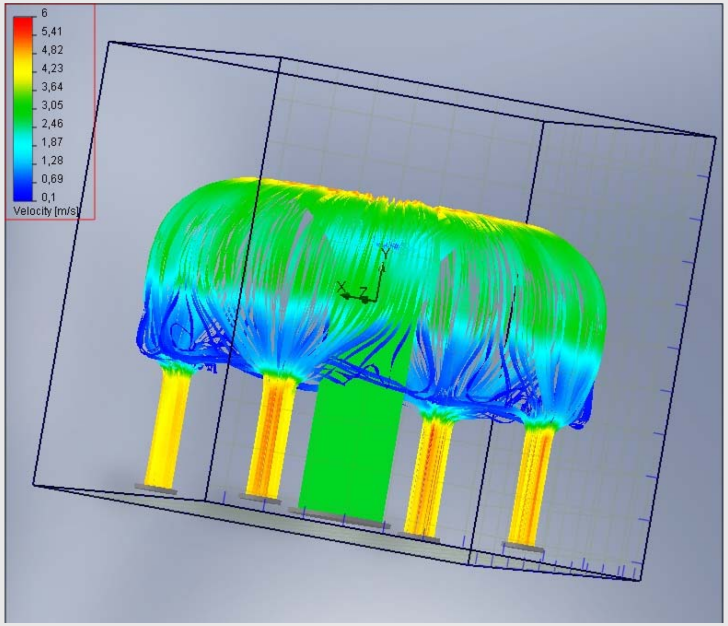
http://einrichtungen.physik.tu-muenchen.de/antares/



Neutron tomography image

UCN source. Cooling efficiency calculations

Cooling He velocity profile



Nuclear heating:

Al - 1.8 W/cm^3
D_2 - 0.09 W/cm^3
H_2 - 0.05 W/cm^3

Project of 2000

Al - 2.2 W/cm^3
D_2 - 0.11 W/cm^3

Total cooling power 500 W @4.2K

He mass flow	100 g/s
He pressure	3 bar
Pressure drop	0.09 bar
Temperature increase	0.2 K
Heat transfer coeff.	500 W/m^2/K

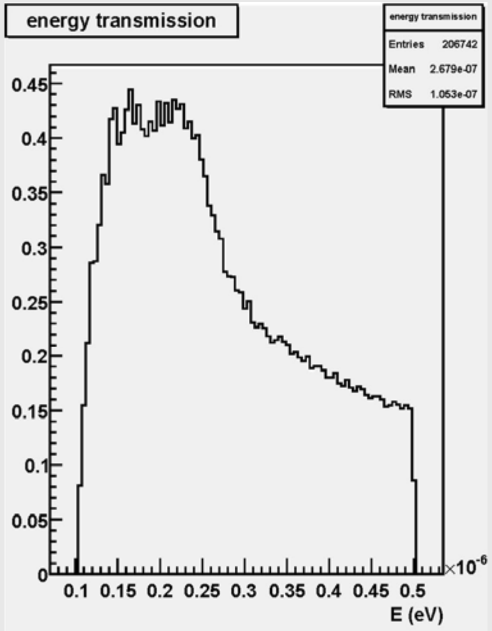
Status: Two 500 W refrigerators will be purchased soon

Plans: installation & test of the refrigerators in East hall by 2010

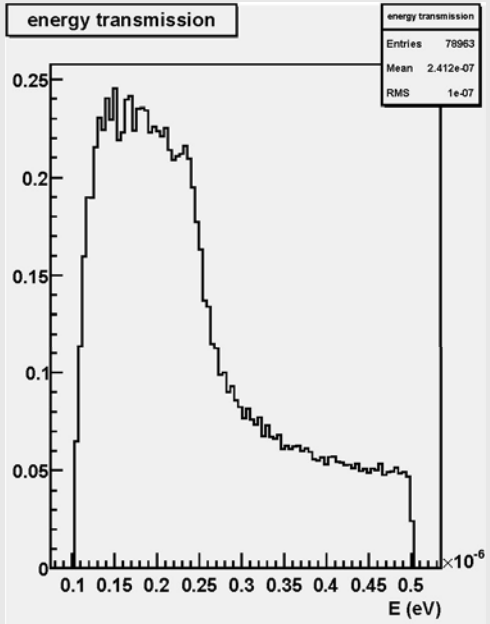
UCN source. Guide performance calculations

Transmission of 40m guide with open end, Ø = 125 mm

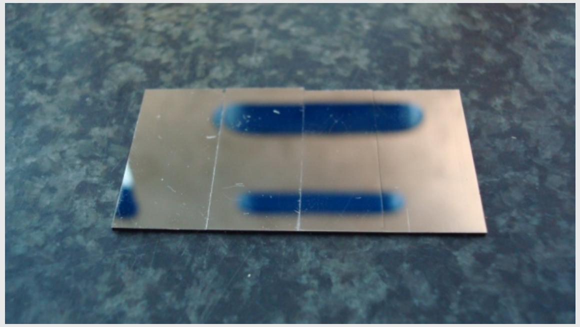
η = 1.25·10⁴ , f = 0.01



η = 2.5·10⁴ , f = 0.02



Replication technique



Loss probability μ ~ 2η

$$\bar{\mu}(E) = 2\eta\left\{\frac{V}{E}\sin^{-1}\left(\frac{E}{V}\right)^{1/2} - \left(\frac{V}{E}-1\right)^{1/2}\right\}$$

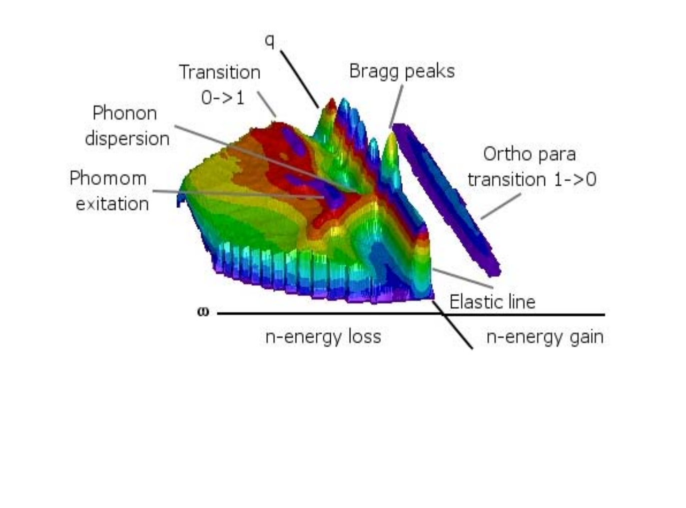
V = 250 neV

f – diffuse reflection probability

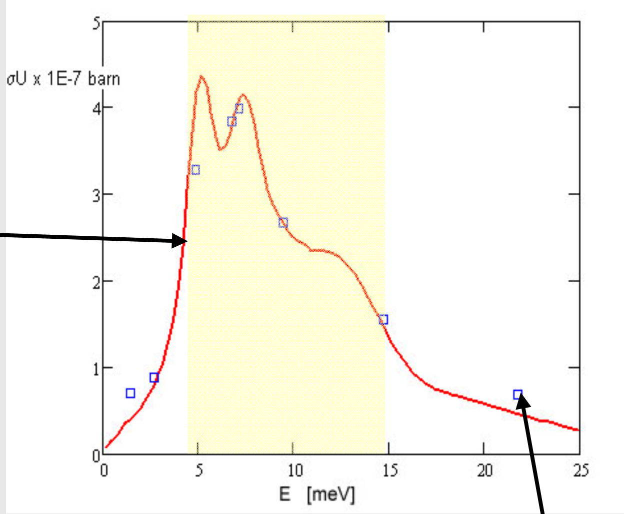
Talk by Klaus Schreckenbach : **Transmission measurements of UCN guides by UCN capture activation analysis of vanadium**

UCN source. TOFTOF measurements at ILL

TOFTOF data example
(in collaboration with TOF-HR group of the ILL)



UCN production cross section



F. Atchison et al., PRL 99, 262502 (2007)

Talk by Helmut Schober: **Time-of-Flight inelastic neutron scattering on D2, a key tool to understand the down-conversion properties and loss channels of a D2-UCN source**

Summary & Outlook

	Current 2009	Soon 2010÷2015	Future after 2012
EDM limit, e·cm	* $2.9 \cdot 10^{-26}$	$5 \cdot 10^{-27}$	*** $5 \cdot 10^{-28}$
Lifetime accuracy, s	** ± 0.8	± 0.1	< ± 0.1
UCN Source, ucn/cm^3	~10 (ILL)	~10^3 (PSI)	up to 10^4 (FRM-II)

* Sussex-RAL-ILL ** PDG *** with the new apparatus

Progress mainly due to reduction of systematical errors

Thanks