Progress Report of nEDM collaboration

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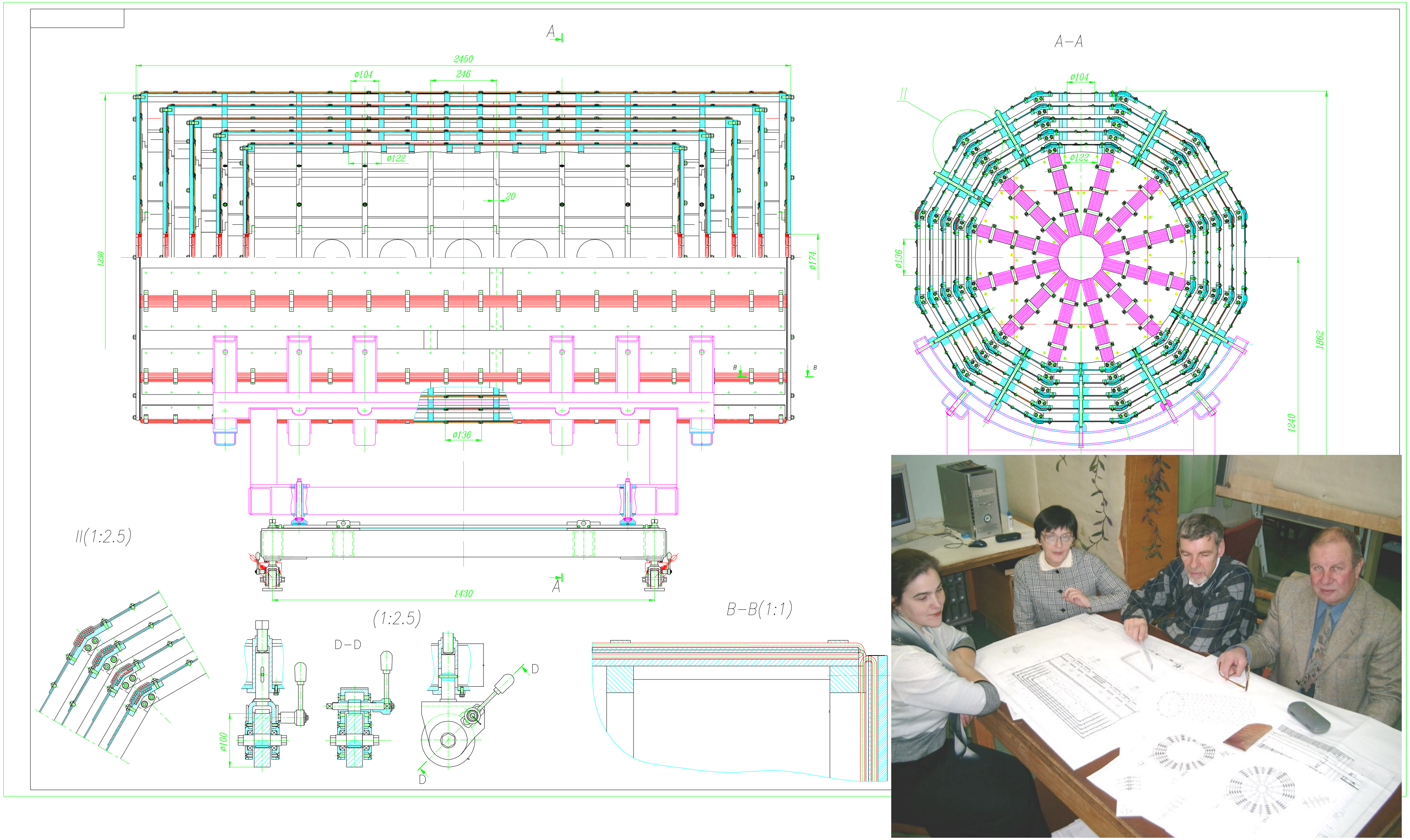
[9]Scientific Research Institute of Optical Materials Technology, St. Petersburg, Russia
[10]Université de Fribourg, Fribourg, Switzerland
[11]University of Messina, Messina, Italy
[12]Vavilov State Optical Institute, St. Petersburg, Russia

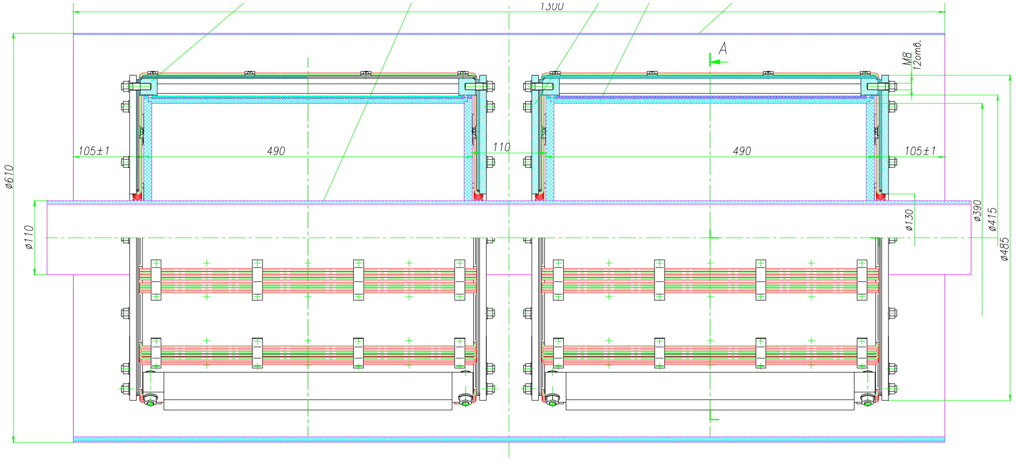
Content

Detailed design of the 5-layer magnetic shielding is finished



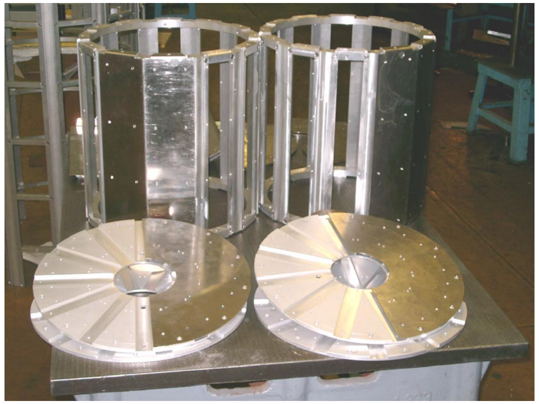
A new test experiment: comparison of permalloy 79NM and CONETIC

The scheme of allocation of magnetic inserts inside of the PSI magnetic shielding



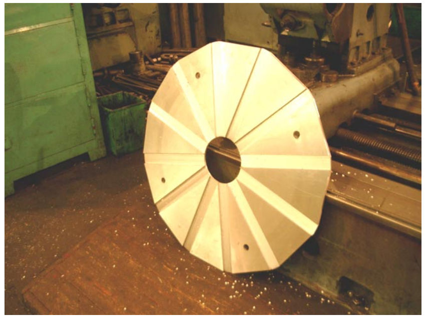
Measurement of a shielding factor before annealing

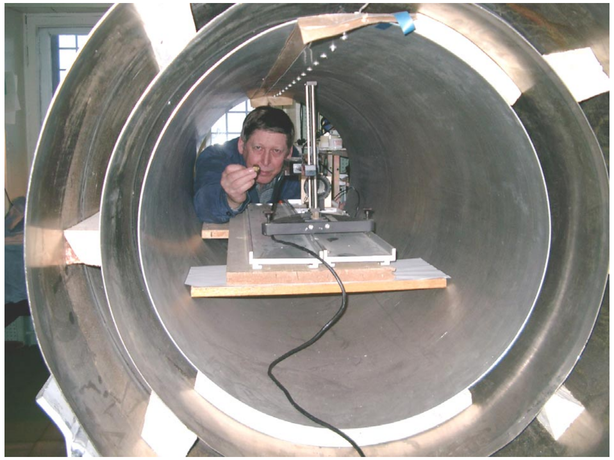
Preliminary assembling before annealing



Manufacturing of support system for magnetic shielding

Manufacturing of covers of magnetic shielding





3 layer magnetic shielding is used to check magnetic properties of materials for new magnetic shielding

Four frames with covers manufactured

Four frames with covers manufactured.
Subsequent stages: joint assembling
and coating by permalloy

Magnetic shielding, design and manufacturing

Results of 2003:

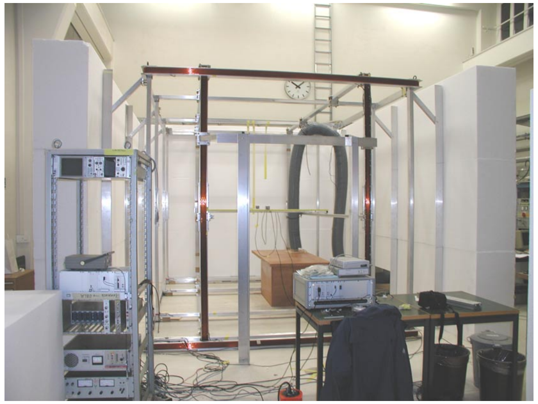
1. A new magnetic shielding has been prepared in order to test the new shield construction and compare permalloy 79NM and CONETIC.
2. Frame details of all 5 shields manufactured. Frames of 4 shields assembled.
3. Support system for the entire shield construction is being manufactured.
4. 1.2 tons of permalloy 79NM are available.

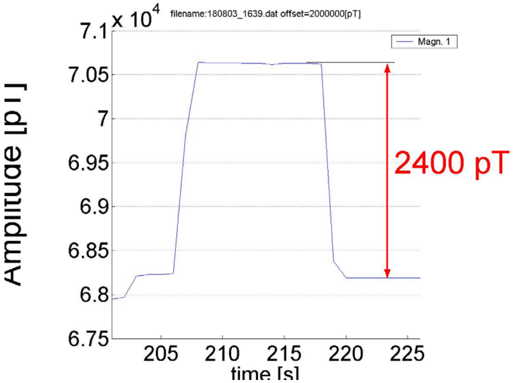
The system of stabilization of external magnetic field was successfully developed at PSI

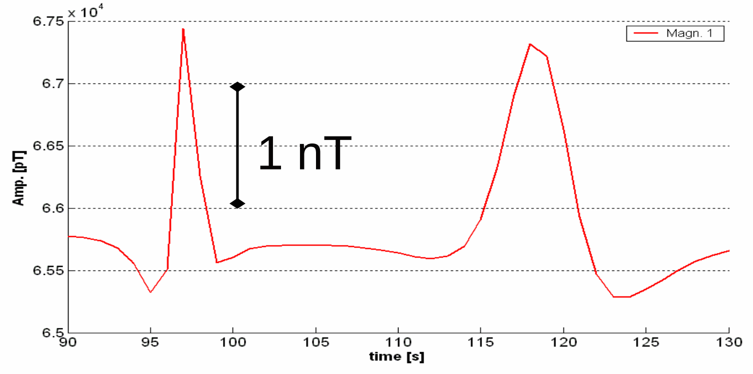
Static:
switch magnet at 7m:

Dynamic:
car drive-by at 11m:

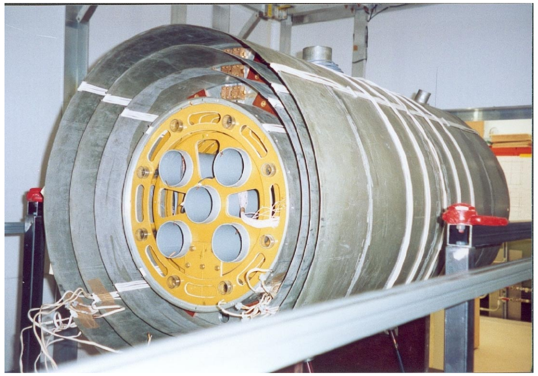
Stabilization off

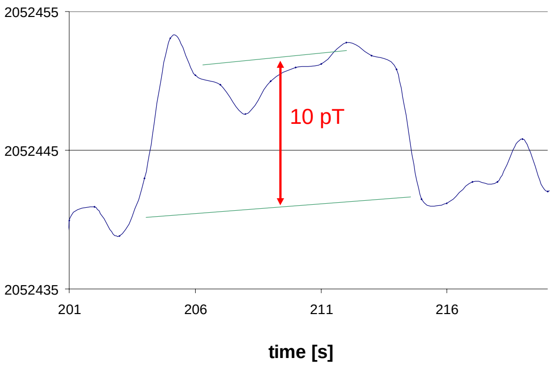


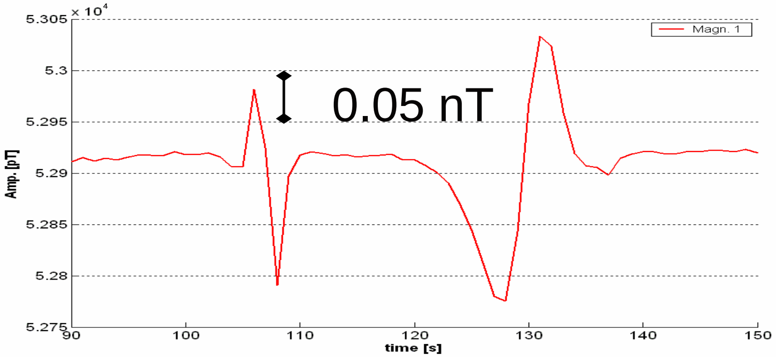




Stabilization on







Integration over ~ 100 s !!

Suppression factor ≥ 200

The system of stabilization of external magnetic field was successfully developed at PSI

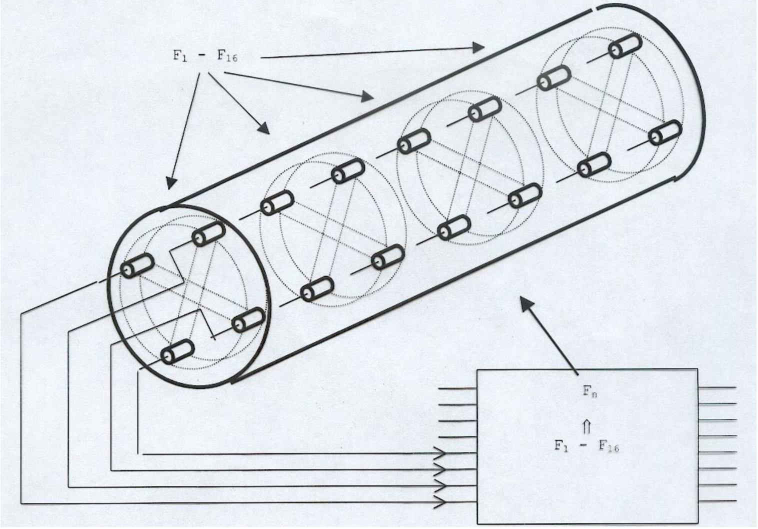
Results:

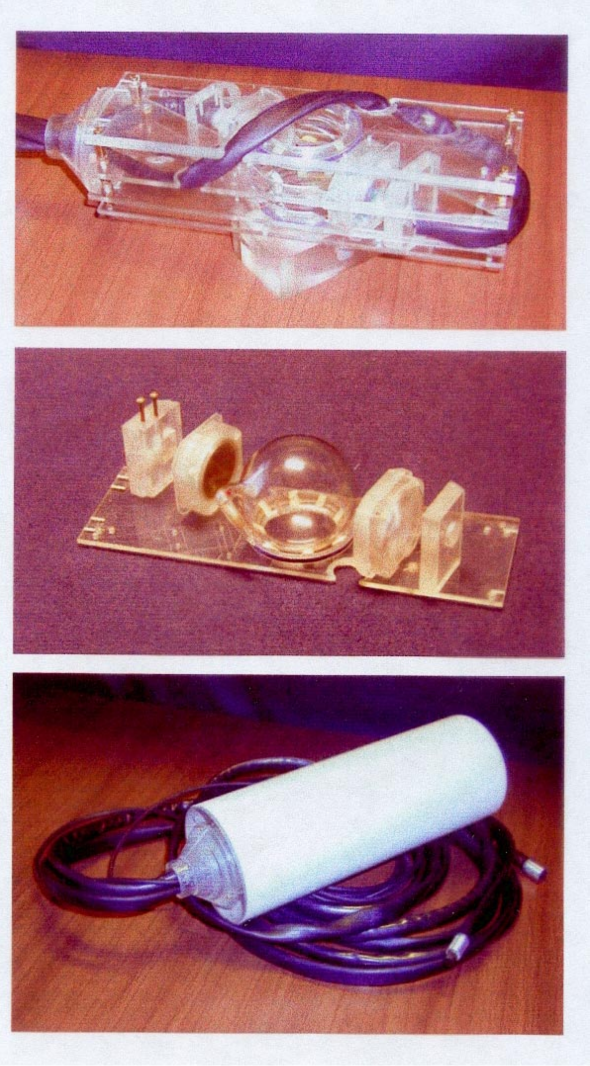
- for certain positions of the feedback sensor the suppression is better than 200
- this applies for both, static sources (e.g. magnets) as well as moving sources (vehicles)
- the exact location of these points depends on the geometry of the external coil system as well as on the properties of the shielding and of the stabilization system

Cs-magnetometers (lamp version)

Preparation of 16 Cs-magnetometers at IPTI and VSOI

The scheme of
16 Cs-magnetometers





5 new Cs-magnetometers are in the process of assembly. There are N.Dovator and S.Dmitriev near the installations.

Cs-magnetometers (lamp version)

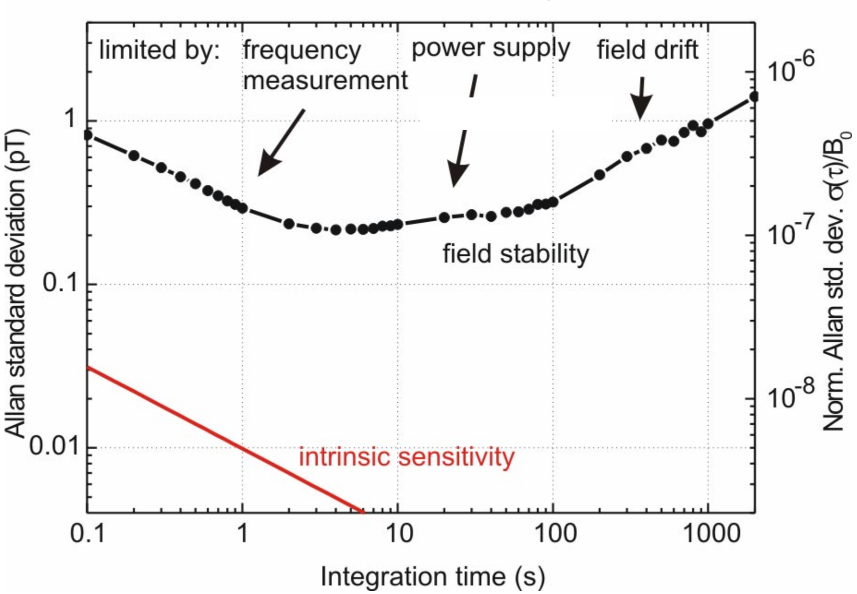
Results of 2003:

5 new magnetometers, for which all necessary elements are available, are in the process of manufacturing. The new design provides for full optical isolation of magnetometers allowing to avoid high-voltage noise. An additional light guide has been added to the scheme. In order to reduce the costs a new design of one Cs-lamp for 4 magnetometers has been developed and put into manufacturing.

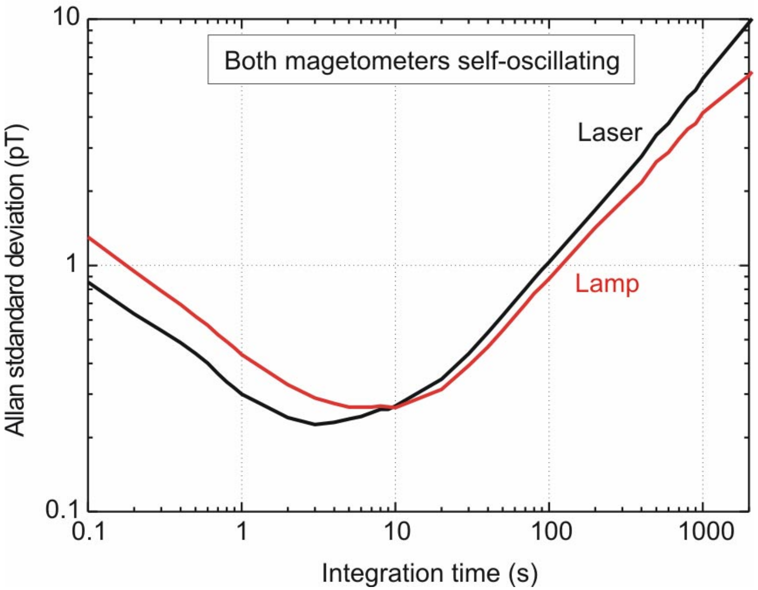
The FRAP laser-pumped magnetometer

Fribourg measurements: recent results

Phase-locked laser magnetometer



Laser vs. lamp magnetometer



current work in collaboration with Pazgalev:

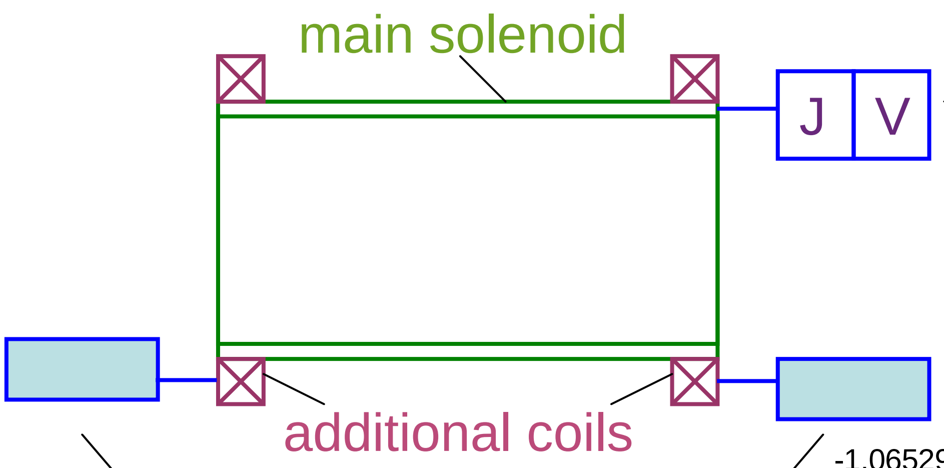
- self-oscillating mode of operation of laser magnetometer
- comparison of lamp and laser pumped magnetometers

The FRAP laser-pumped magnetometer

Results:

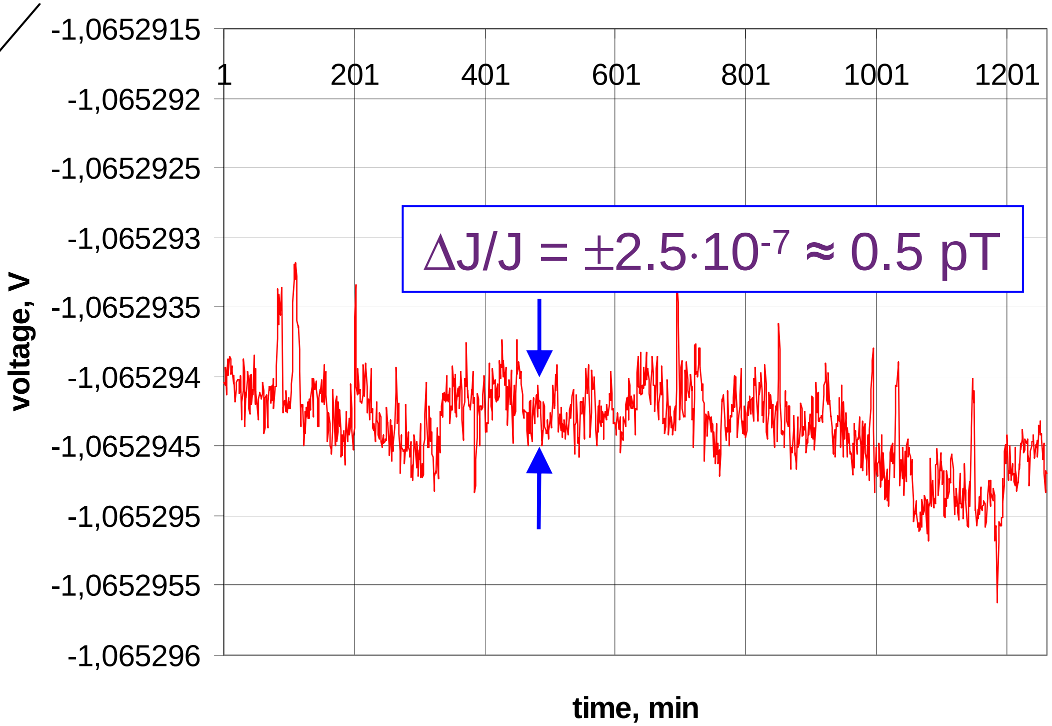
- intrinsic sensitivity = noise-equivalent B field: 30% better with laser device.
- current noise studies in Fribourg shield are not limited by intrinsic sensitivity, but by field drifts (long times), power supply stability (intermediate times), frequency measurement (low times).
- Note right scale on top left picture: power supply is very good, but limits performance to 10^{-7}
- Fribourg shield better than current PSI shield regarding shielding factor, but is worse regarding field gradients
- laser and lamp magnetometers are compared, both in the same shield. Basically same results, differences due to gradient and noise

Electronics for magnetic field generation



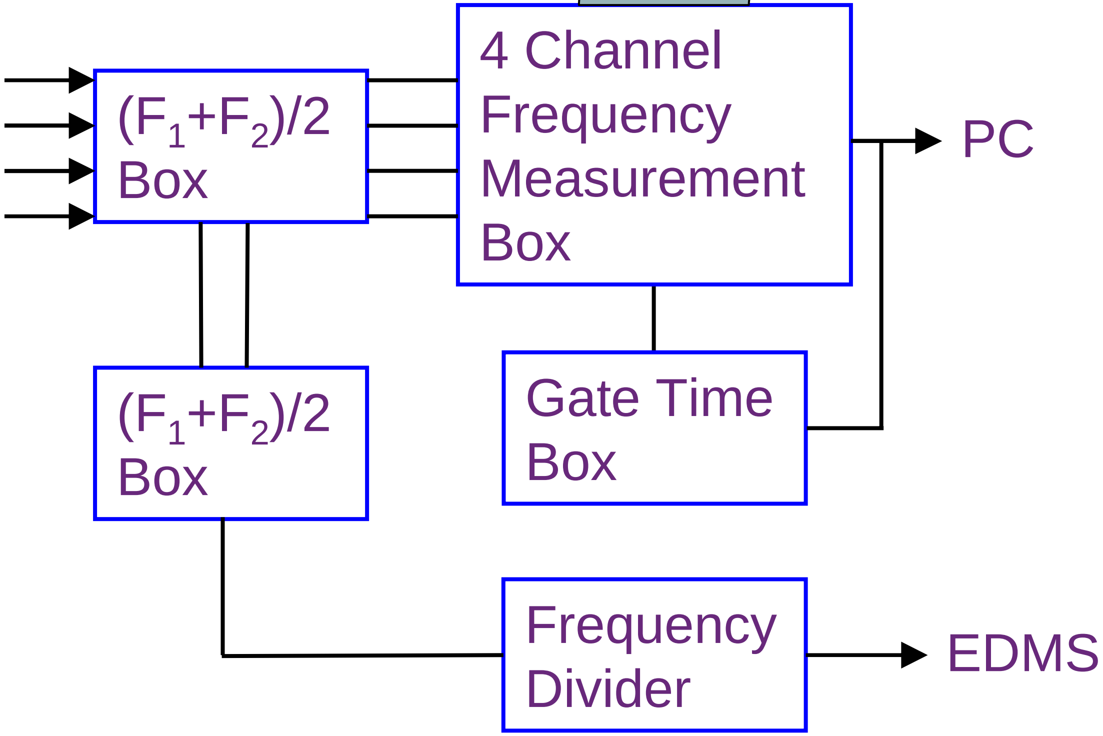
PNPI

PNPI



$\Delta J/J = \pm 2.5\cdot 10^{-7} \approx 0.5$ pT

Electronics for stabilization system of neutron resonance conditions



$(F_1+F_2)/2$ Box

4 Channel Frequency Measurement Box

PC

$(F_1+F_2)/2$ Box

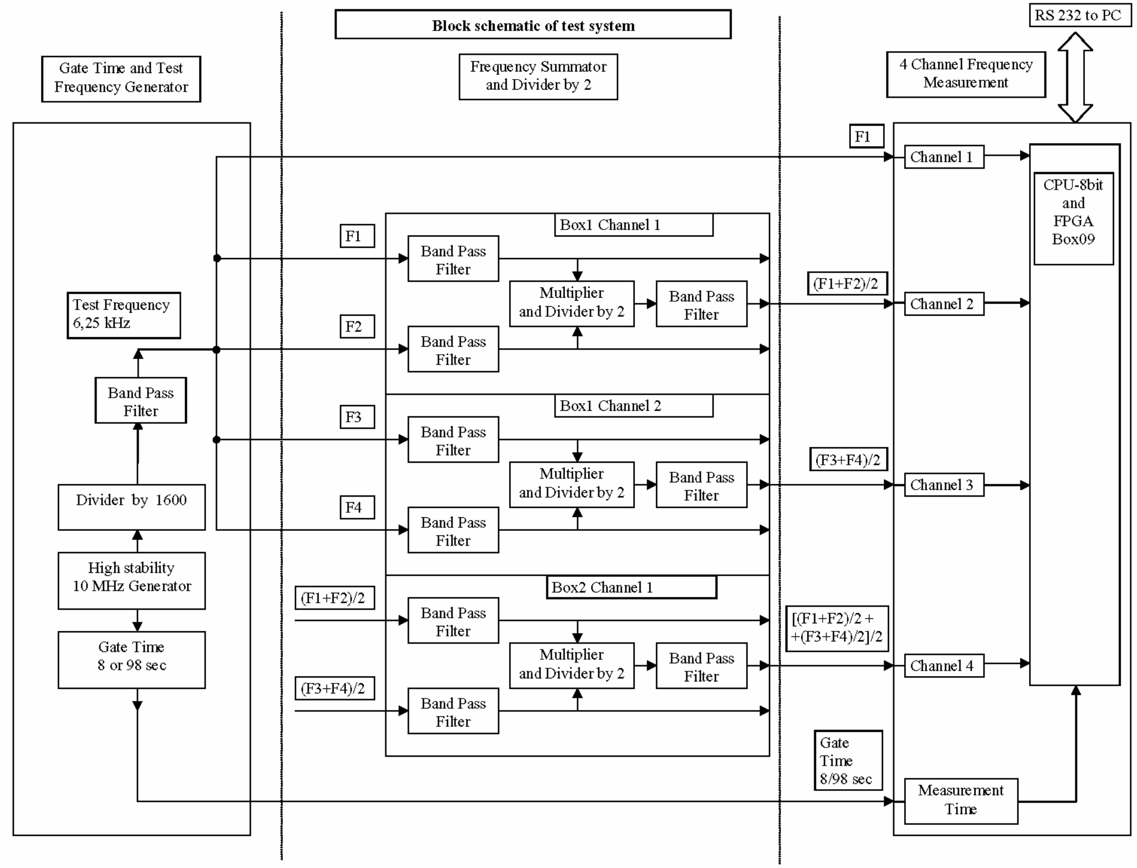
Gate Time Box

Frequency Divider

EDMS

Electronics for stabilization system of neutron resonance conditions

Test of generation of average Cs-frequency

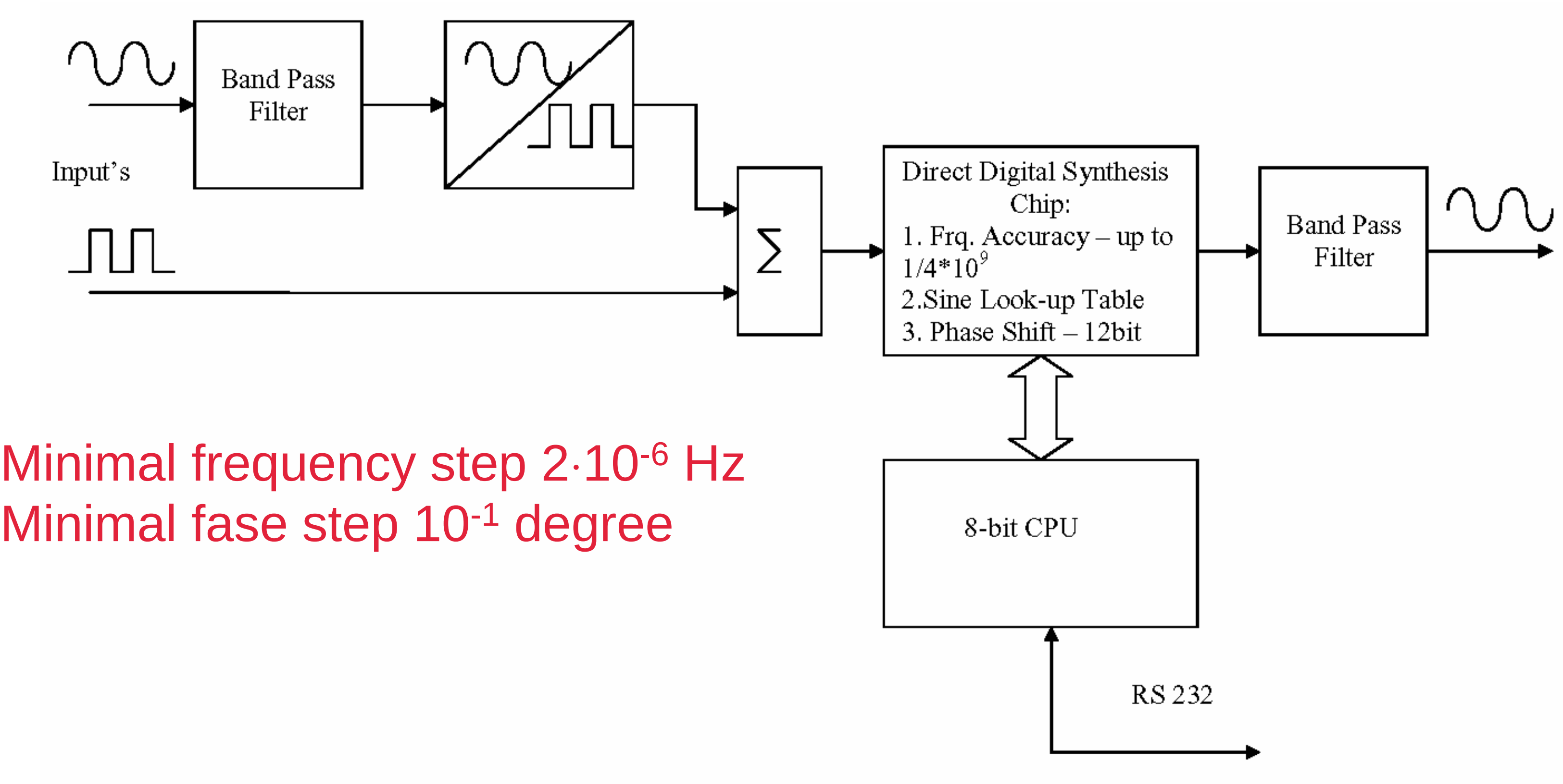


V.Solovei, I.Savelieva, V.Marchenkov (from left to right)

The average Cs-frequency was reproduced with accuracy 10^{-9}

Divider of Cs-frequency into the neutron one

Scheme of divider



Minimal frequency step $2{\cdot}10^{-6}$ Hz
Minimal fase step 10^{-1} degree

The model of this device was developed and checked in spring 2003 during the test measurement at PSI. The full test will be done in spring 2004.

Electronics for magnetic field generation

Results:

Three current power supplies have been produced so far by PNPI. One – for the main solenoid – with a stability $\Delta J/J = 10^{-7}$, and the other two – for alignment coils – with a stability $\Delta J/J = 2.5 \cdot 10^{-7}$. It was shown in test experiment at PSI that the parameters of the produced equipment meet the requirements of the set task.

Another power supply for the main solenoid was produced at University of Messina (Italy) which also fulfills the stability requirements of the experiment.

The Task 5a (electronics for magnetic field generation) may be considered as completed, taking into account that the final stability of magnetic field will be determined by the SMF and SRC systems.

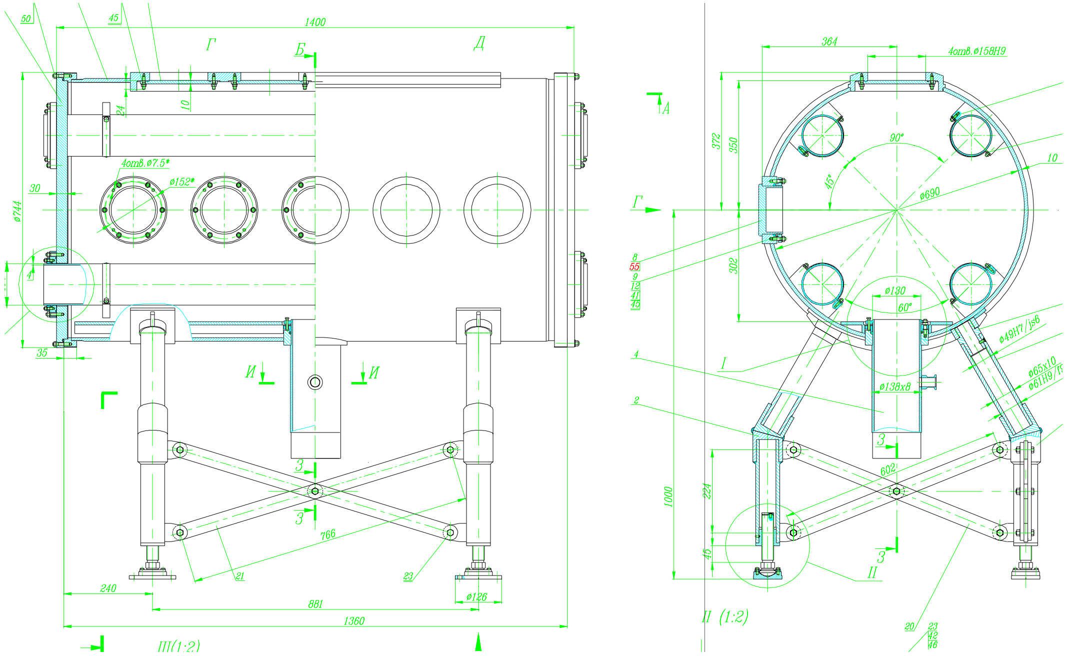
Electronics for stabilization system of neutron resonance conditions

Results:

PNPI with the help of VSOI has developed an electronics set for measuring the frequency of 4 Cs-magnetometers and for synthesizing this frequency into the neutron one. The set includes: two four-channel units for frequency measurement, three units for frequency summing and dividing, the unit for the dividing of Cs-frequency into the neutron one, and also the Gate Time unit. This set has been tested in a laboratory with a frequency generator.

Manufacturing of vacuum chamber of EDM spectrometer

Vacuum chamber design



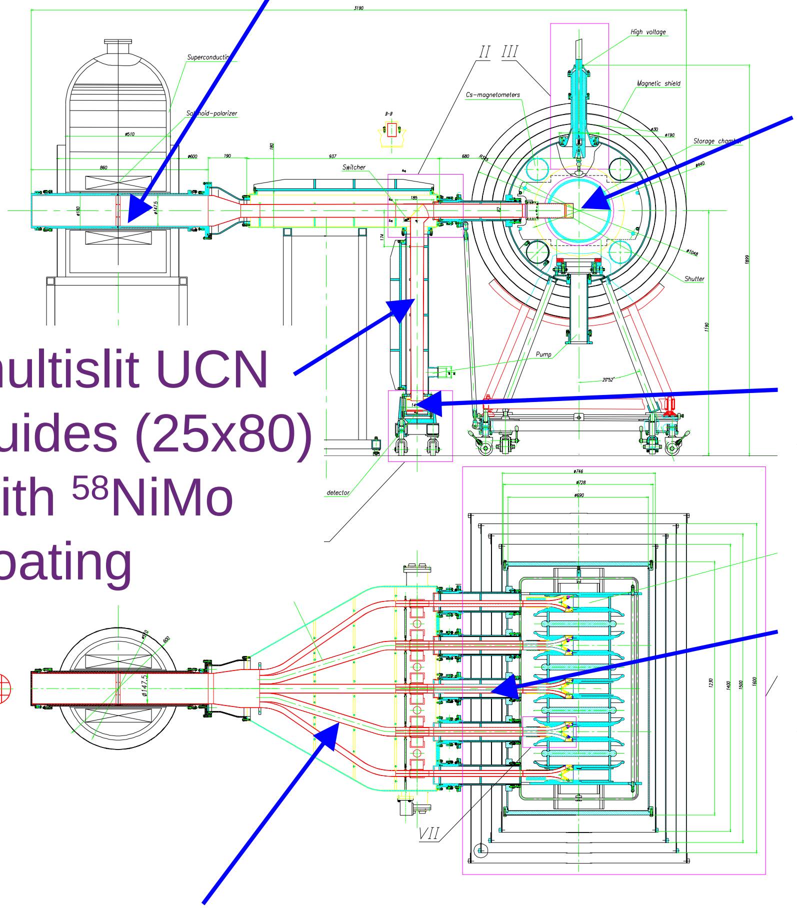
Vacuum test at PNPI workshop

Manufacturing of vacuum chamber is finished

Chamber on the support

The people who are responsible for manufacturing and quality

Neutron guide coatings, UCN trap coatings



high polished cylindrical UCN guide (∅120) with ^{58}NiMo coating

BeO coated traps, Be coated electrodes

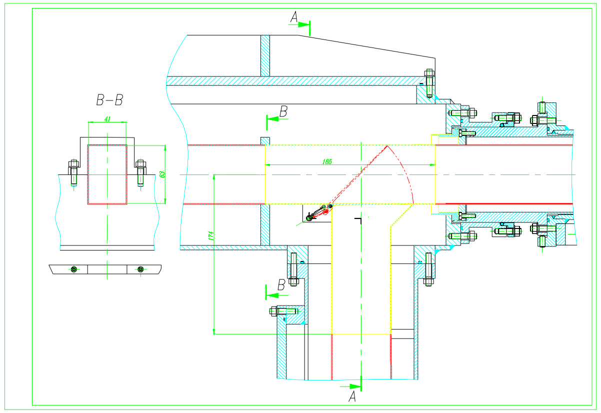
multislit UCN guides (25x80) with ^{58}NiMo coating

Si-UCN detectors with ^{6}LiF coating

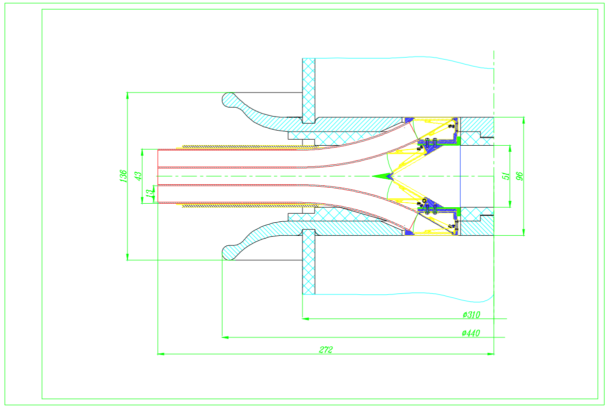
multislit UCN guides (25x80) with Be coating

rectangular UCN guides (80x80) with Be coating

shutter system



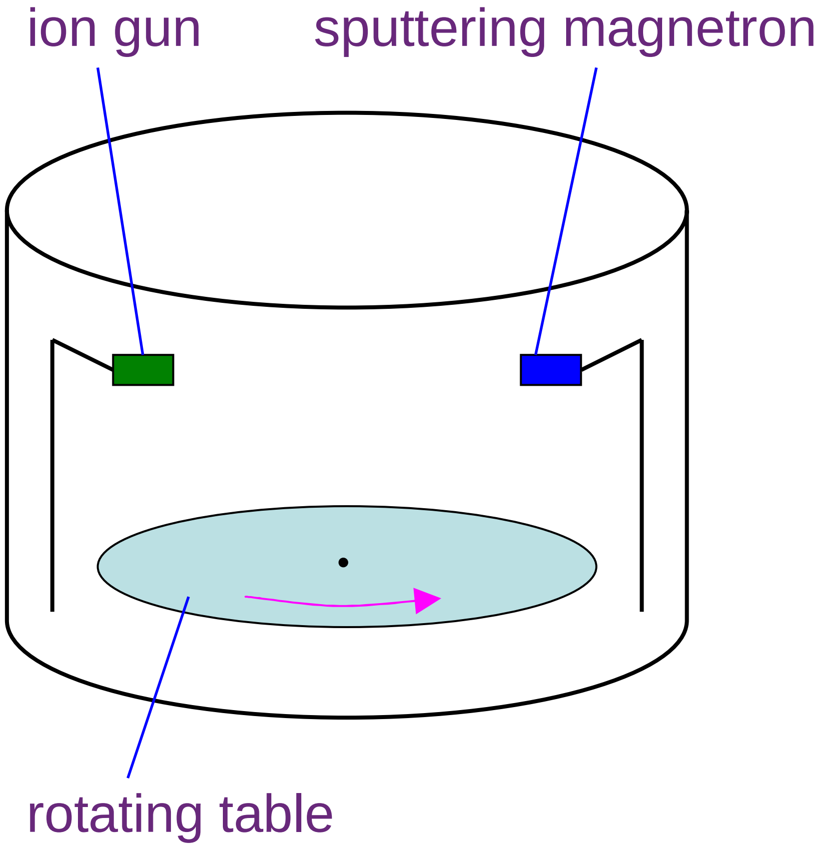
distributing valves



trap valves

Progress Report, February 2004

Coating facilities at PNPI (installation for coating of flat surface of UCN guides and electrodes ($Ni^{58}Mo$, Be) and cylindrical surface of UCN trap (BeO)).

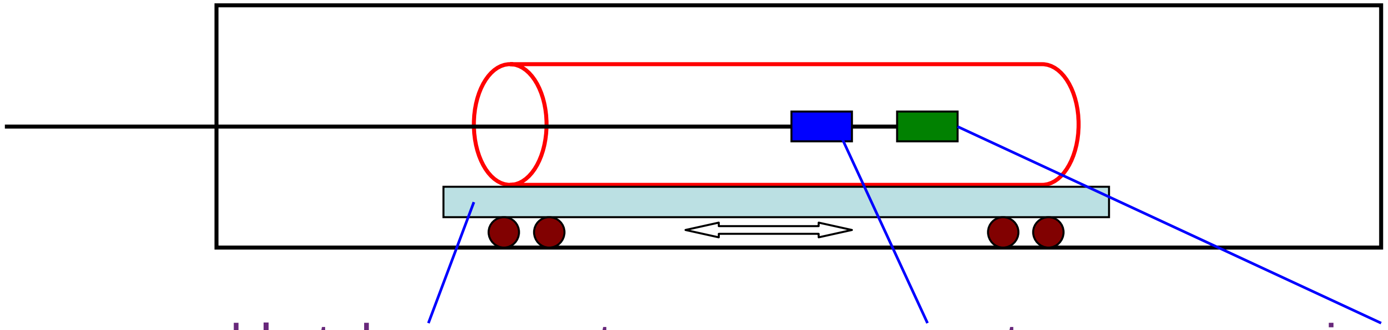

ion gun

sputtering magnetron

rotating table


Near installation
A.Kharitonov, E.Siber, O.Rozhnov

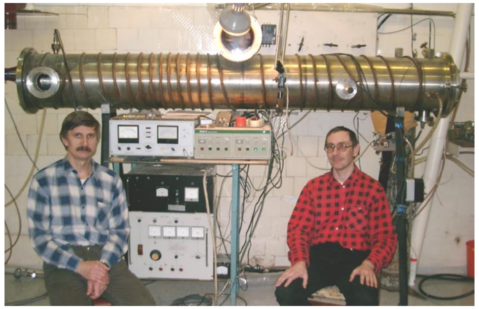
Coating facilities at PNPI (installation for coating of cylindrical UCN guides inside ($Ni^{58}Mo$, Be))



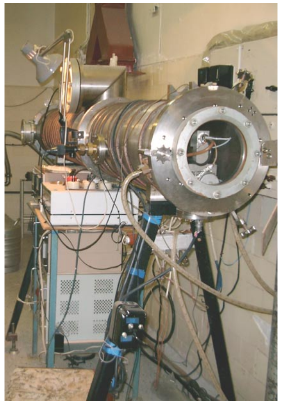
moveable tube support

magnetron

ion gun

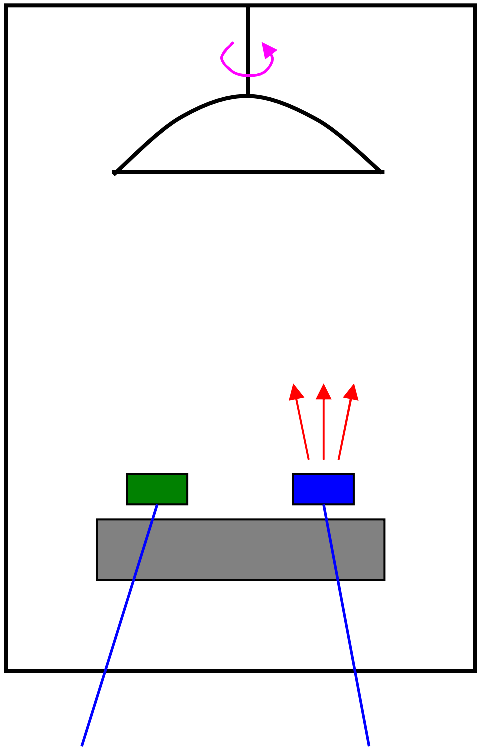


Near installation
M.Lasakov, A.Vasiliev



Coating facilities (installation for sputtering of highly absorbing materials (^{6}LiF, B, …))

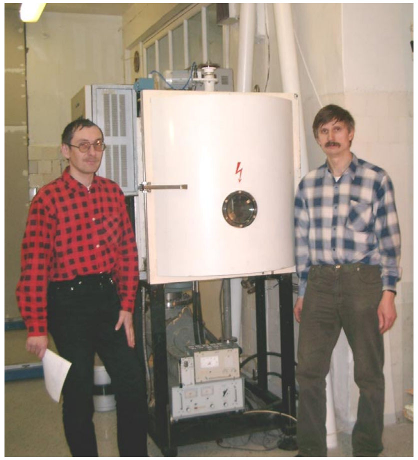
Scheme of installation



ion gun

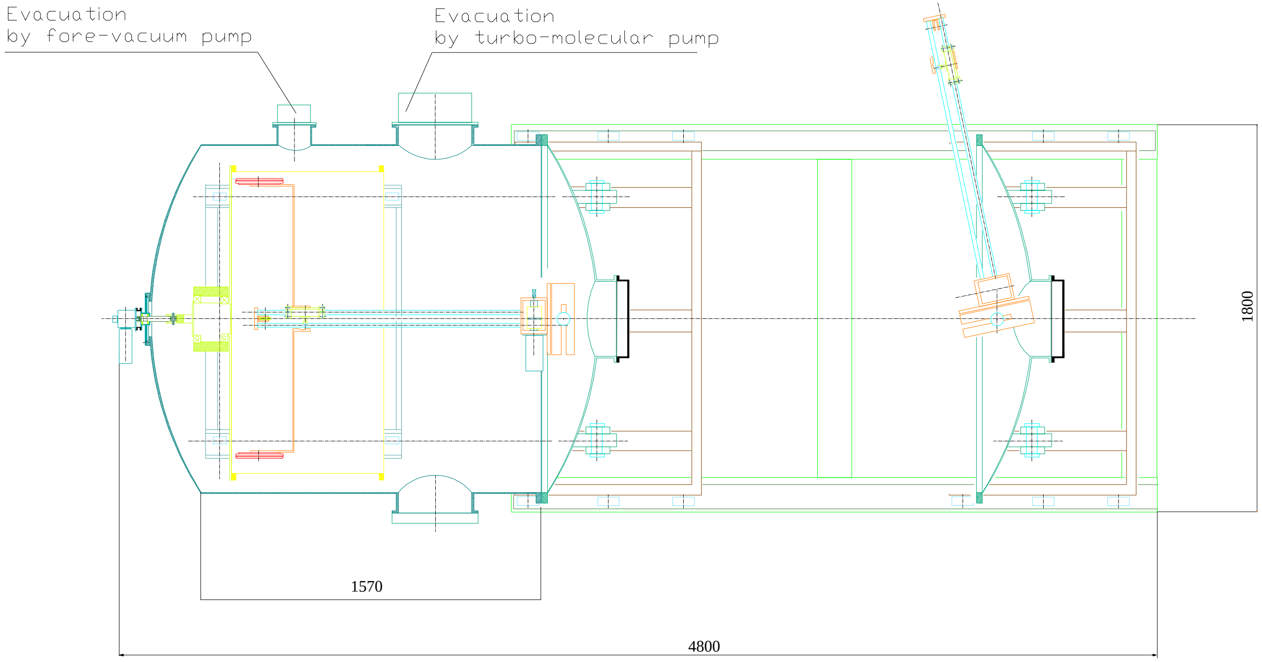
high frequency magnetron

Installation for sputtering of strong absorbing materials



Near installation M.Lasakov, A.Vasiliev

PNPI-PSI coating facility in stage of preparation (universal installation for coating of large surface: trap for UCN source)



Scheme

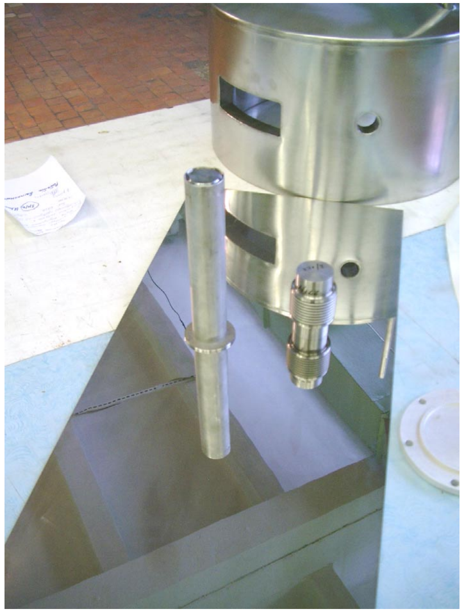
Vacuum chamber is ready

This facility is mainly developing for PSI UCN source, but can be used for some tasks for EDM experiment. Free oil pumping vacuum system will be used for other installation as well.

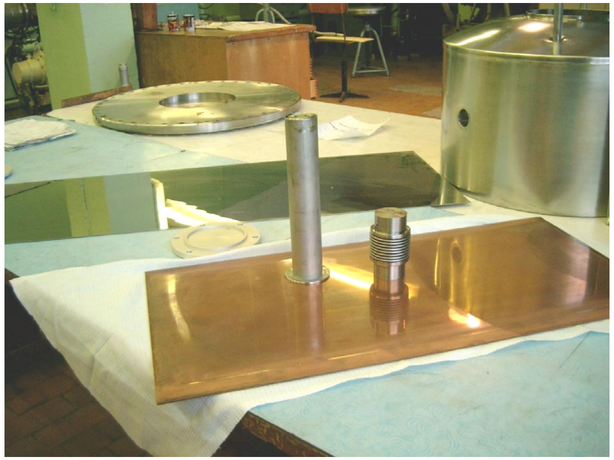
Polishing facilities at PNPI

Zone of polishing facilities

Samples of polishing



Stainless steel polished plate 300x1000 mm^2

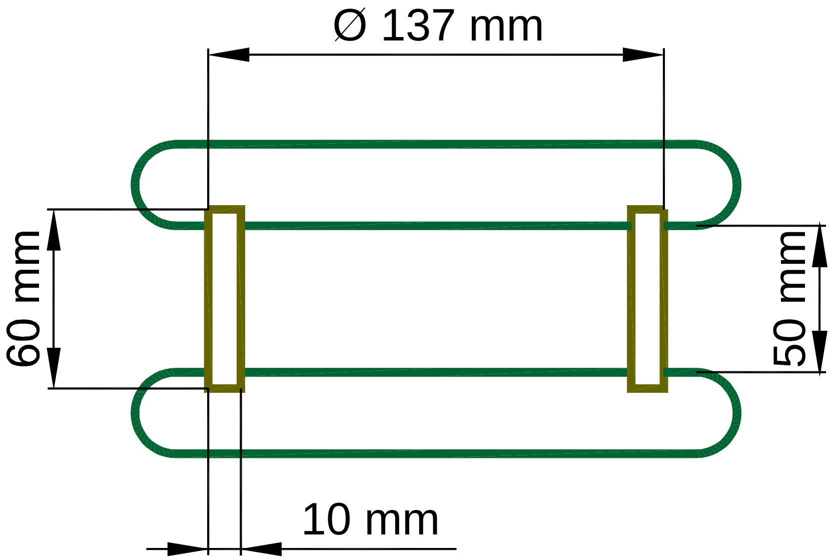


Preliminary polished chromium copper plate

UCN traps, high-voltage test at PNPI

SiO_2 - Al_2O_3 - MgO

$\rho > 10^{16}$ Ohm·cm
$J_{leakage} < 0.25$ nA
E = 31 kV/cm



Dimensions of the minor test sample (diameter – 137 mm). The main moulding has a diameter of 310 mm.

Glass-ceramic mouldings produced by centrifuging of glass in the liquid phase

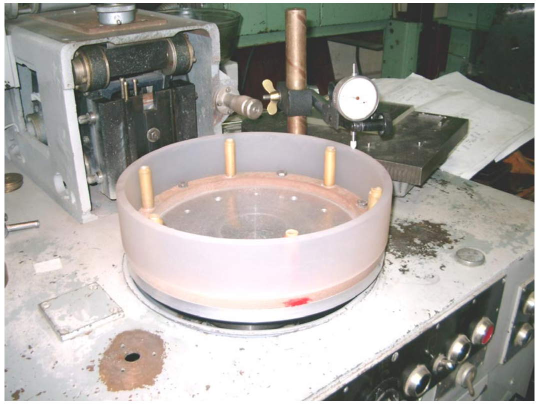
Preparation of glass-ceramics UCN chambers at SRIOMT

Melting and pouring

Preparation of cylindrical surface and
end surface with accuracy 0.1 mm

Preparation of glass-ceramics UCN chambers at SRIOMT

Technical control

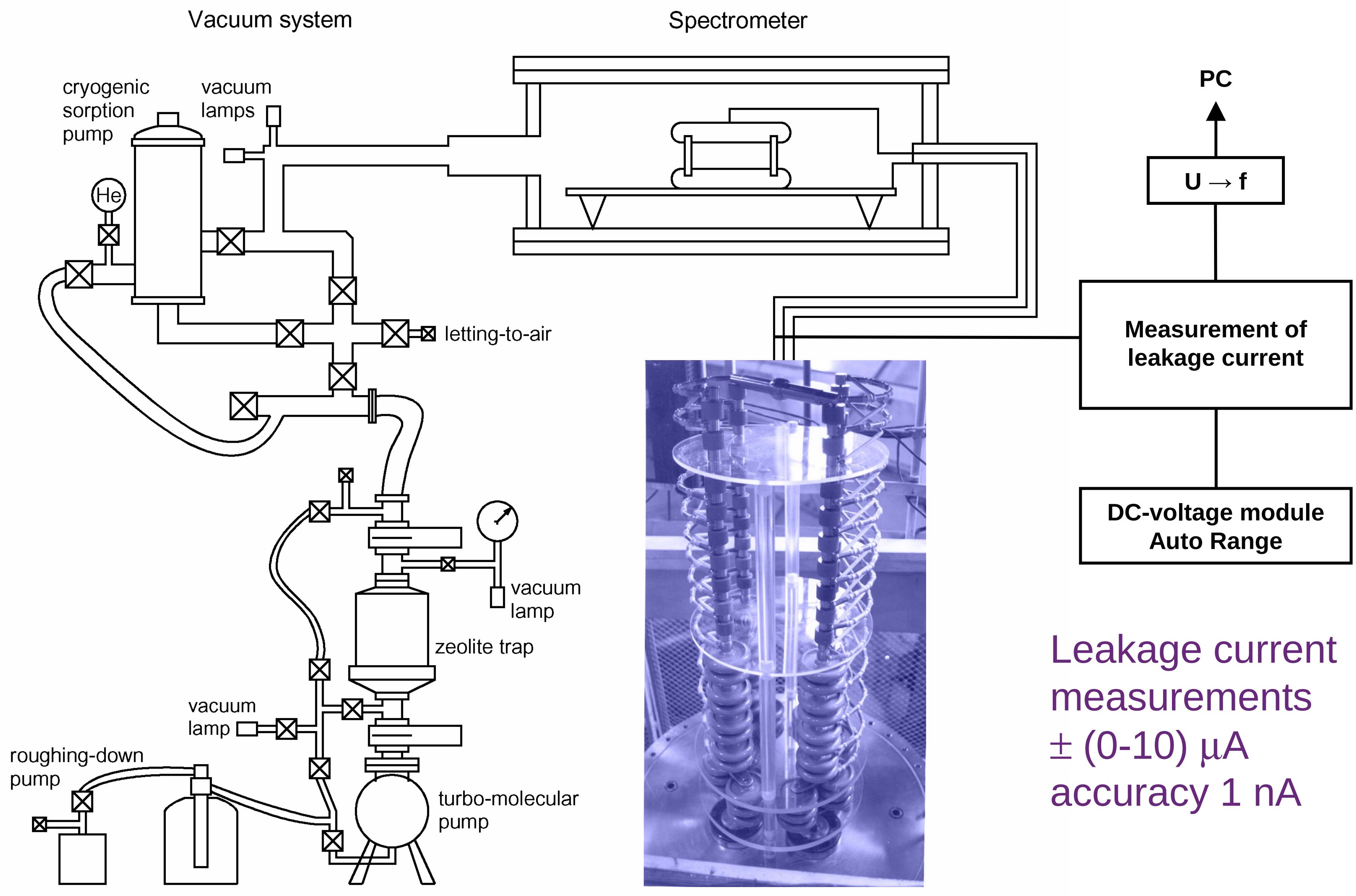


SRIOMT team handing over the first chambers to PNPI: B.Lodygin, M.Bakaev, A.Serebrov, A.Zhilin, Yu.Borisov, A.Shashkin, O.Dymshits (from left to right)

High-voltage test at PNPI

Preparation for the high-voltage test,
a test assembly of glass-ceramics with electrodes

High-voltage test at PNPI

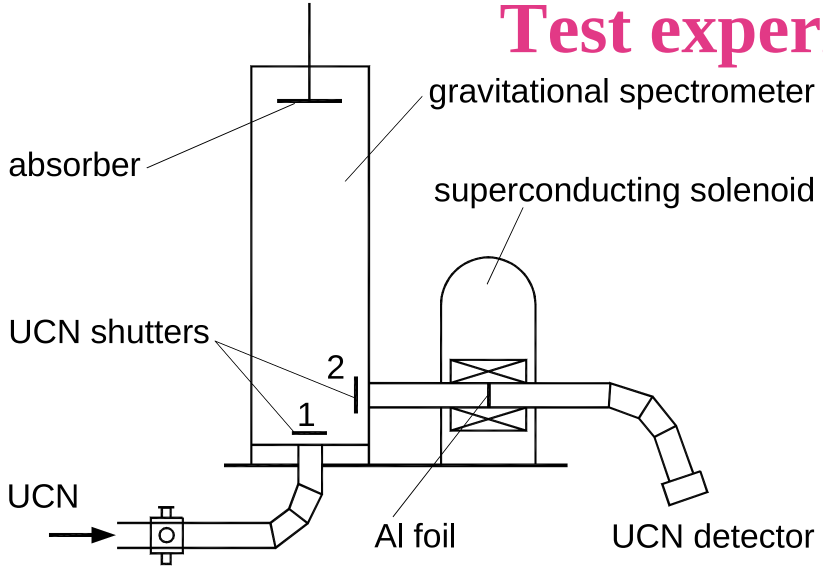


Leakage current measurements
± (0-10) µA
accuracy 1 nA

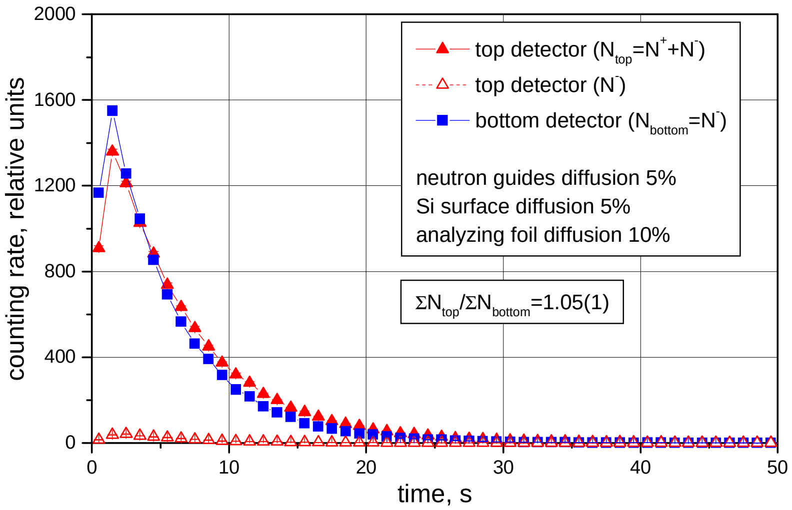
Results of high-voltage test experiment

The high-voltage tests have shown that the electrostatic intensity of 31 kV/cm can be obtained. This value is by 2 times greater than the best results in the PNPI experiment, and by 3 times – than in the ILL experiment.

Si UCN detector with analysis of polarization. Test experiment at ILL

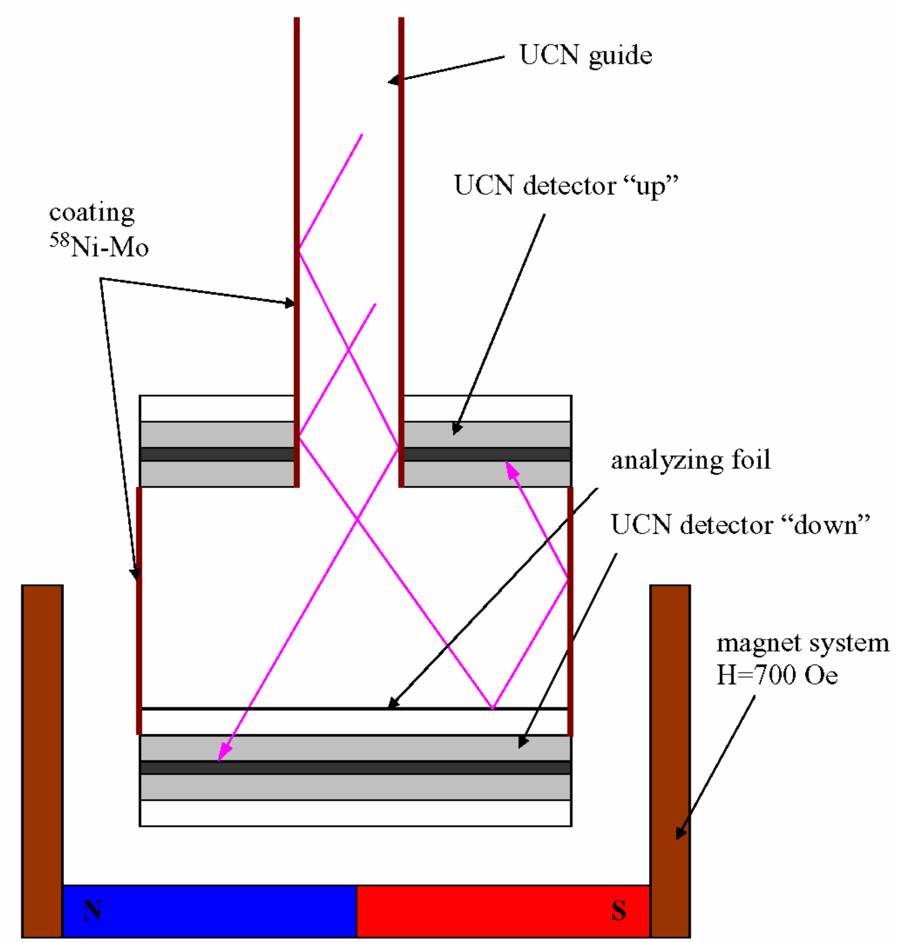


The scheme of test experiment at ILL



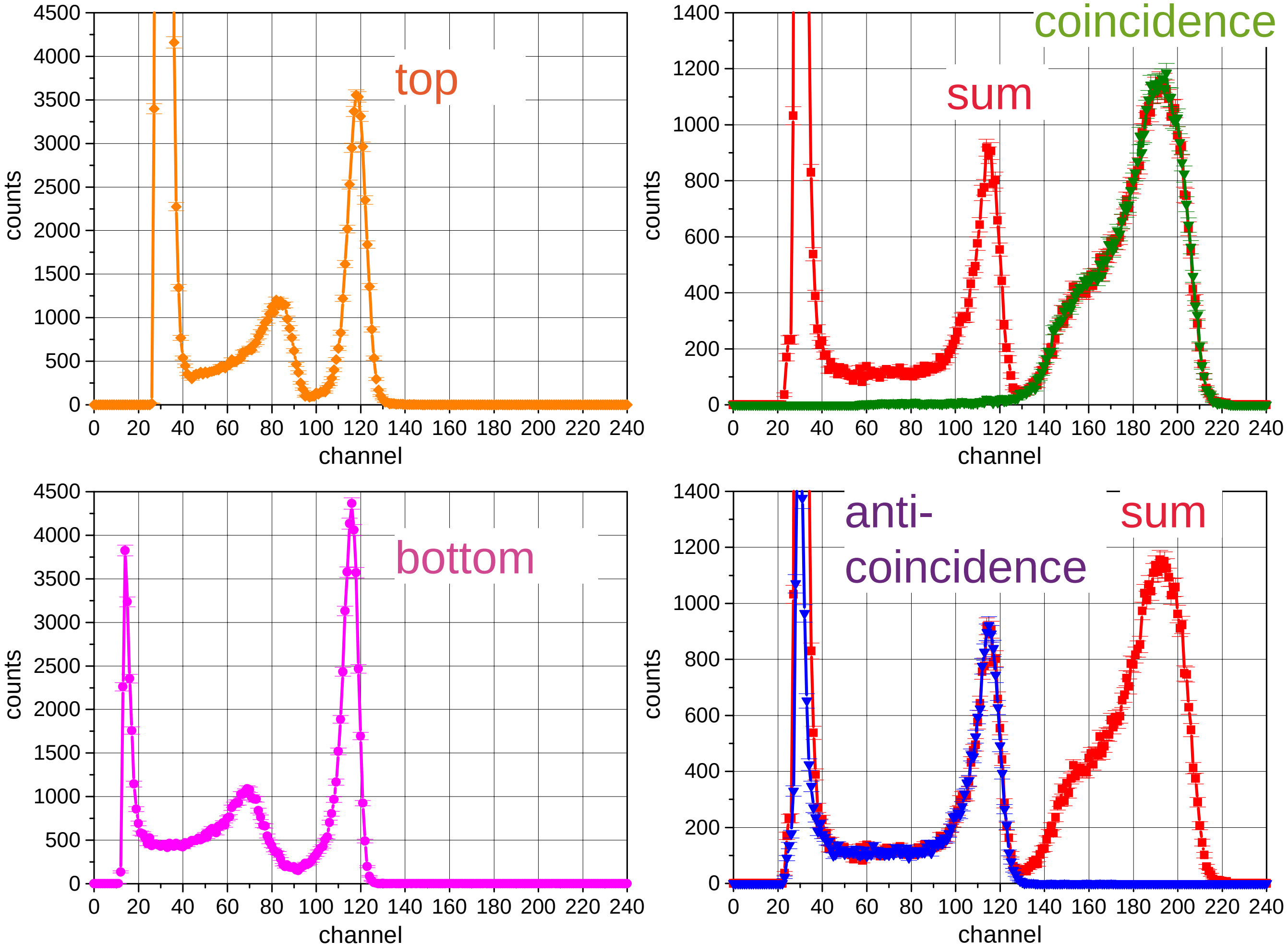
The process of a simultaneous detection of both spin components

Scheme of the UCN detector for the polarization analysis



Si UCN sandwich type detector

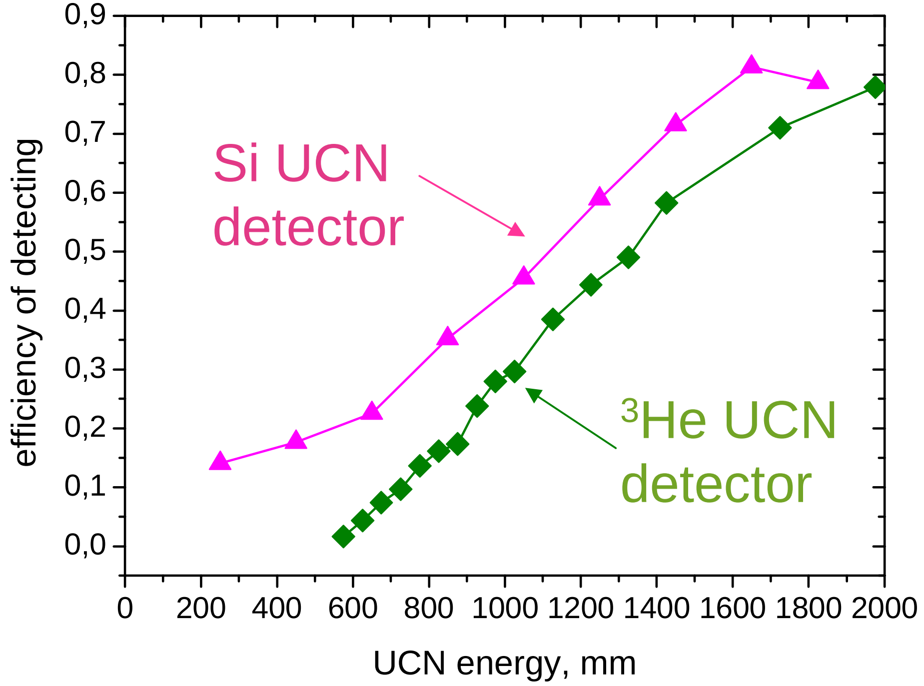
Si UCN detector was tested at ILL



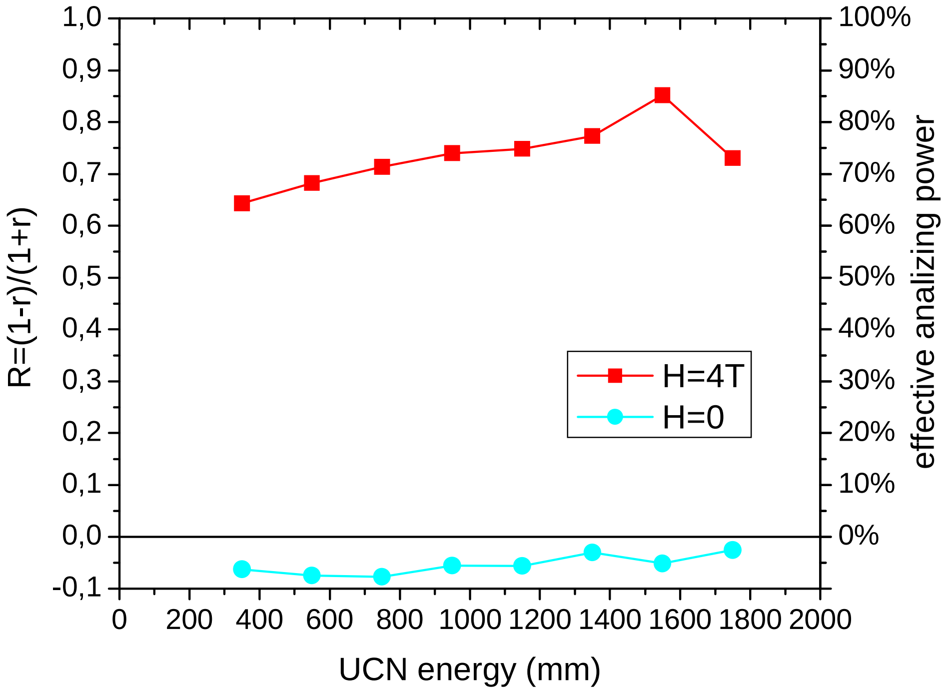
Si UCN detector with analysis of polarization

Results:

detecting efficiency



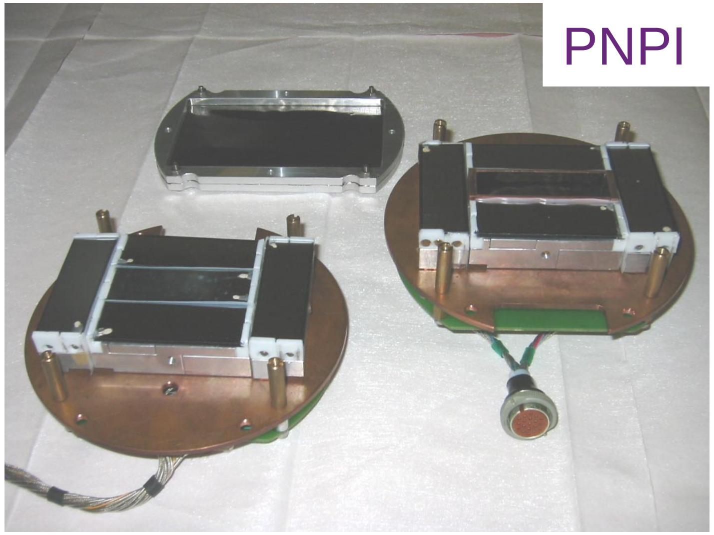
analyzing power

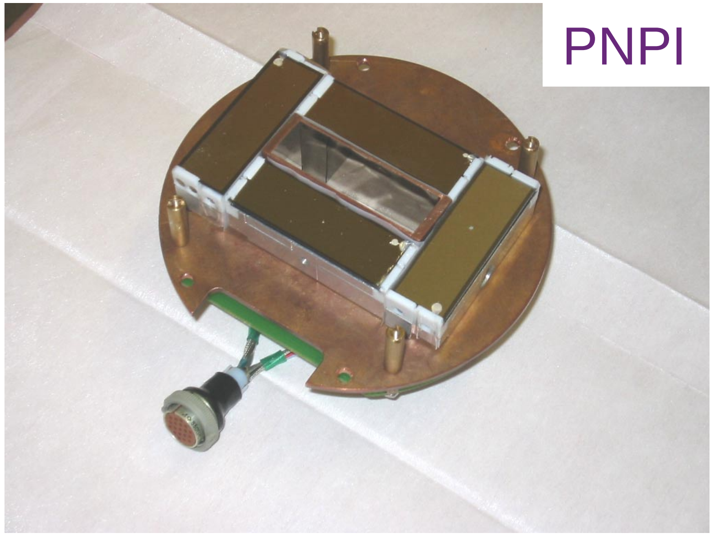


$r=N_{up}/N_{down}$

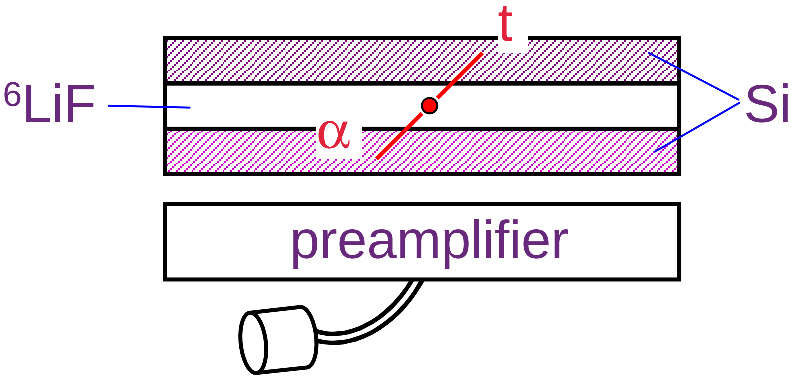
Si UCN detector construction

UCN (Si-^{6}LiF) detectors of PNPI production





UCN sandwich type detector



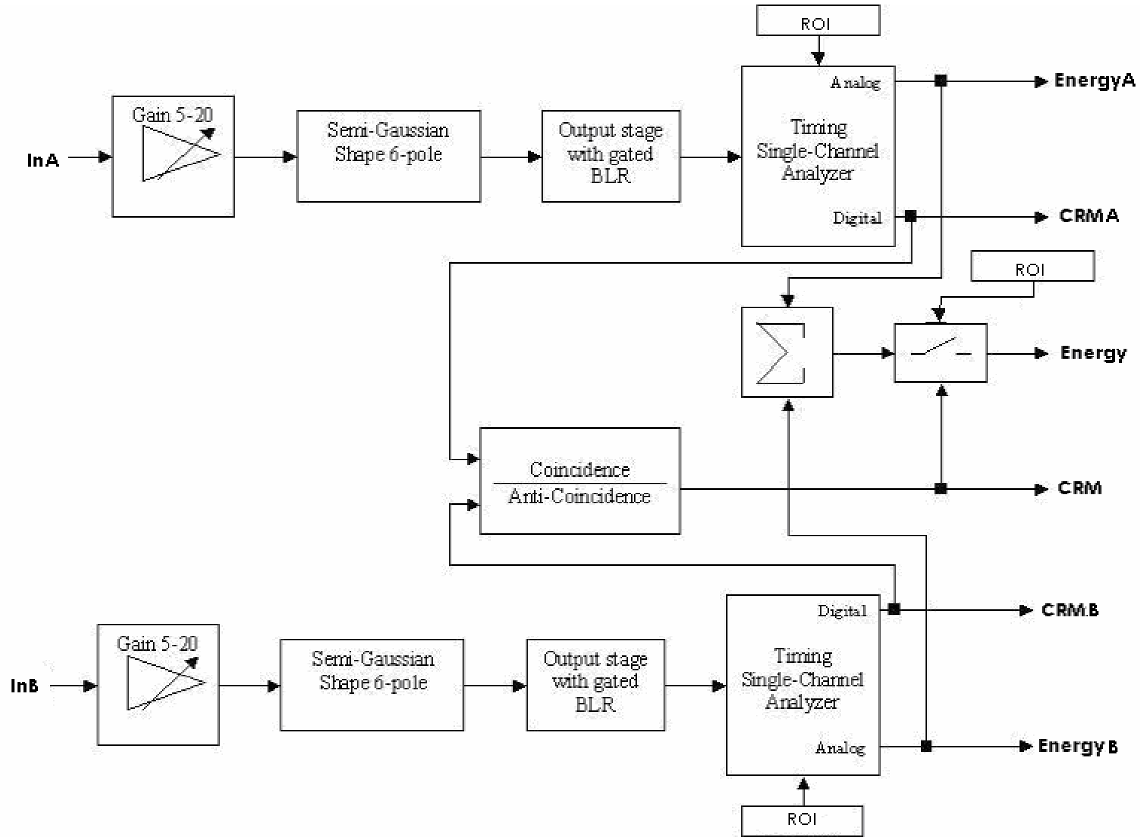
S = 2×6 = 12 cm^2 (each piece)

Si UCN detector without analysis of polarization

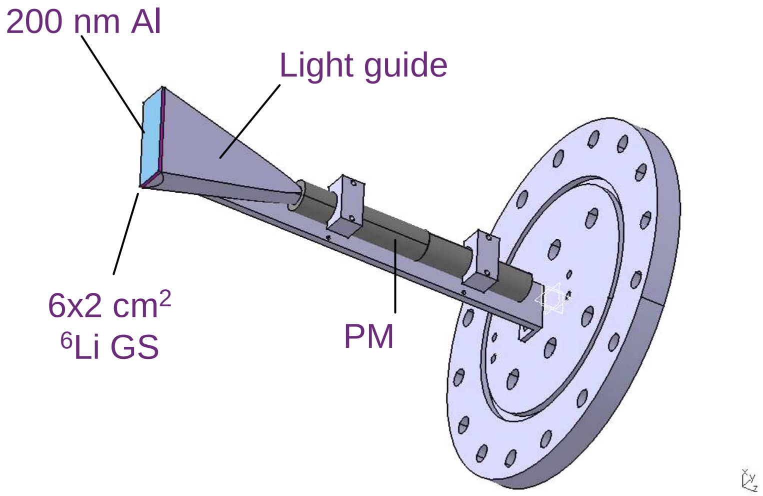
Si UCN detector on the wafer 78 mm diameter

Si UCN detector electronics

Electronics for UCN detector
(with possibility of energy summing of α and t,
analysis of coincidence and anticoincidence)

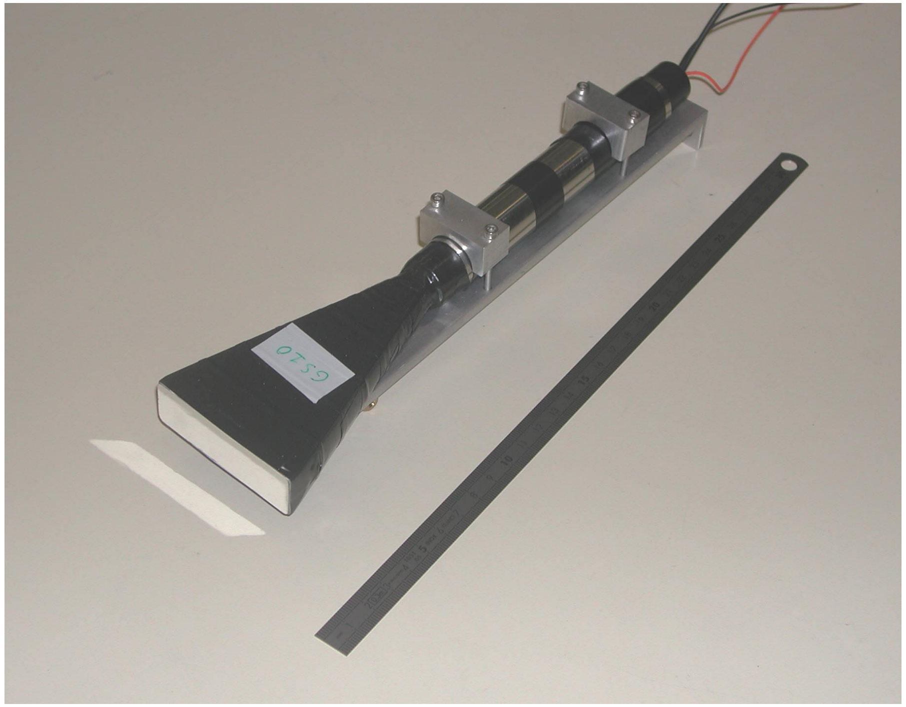


^{6}Li doped GS-UCN detectors



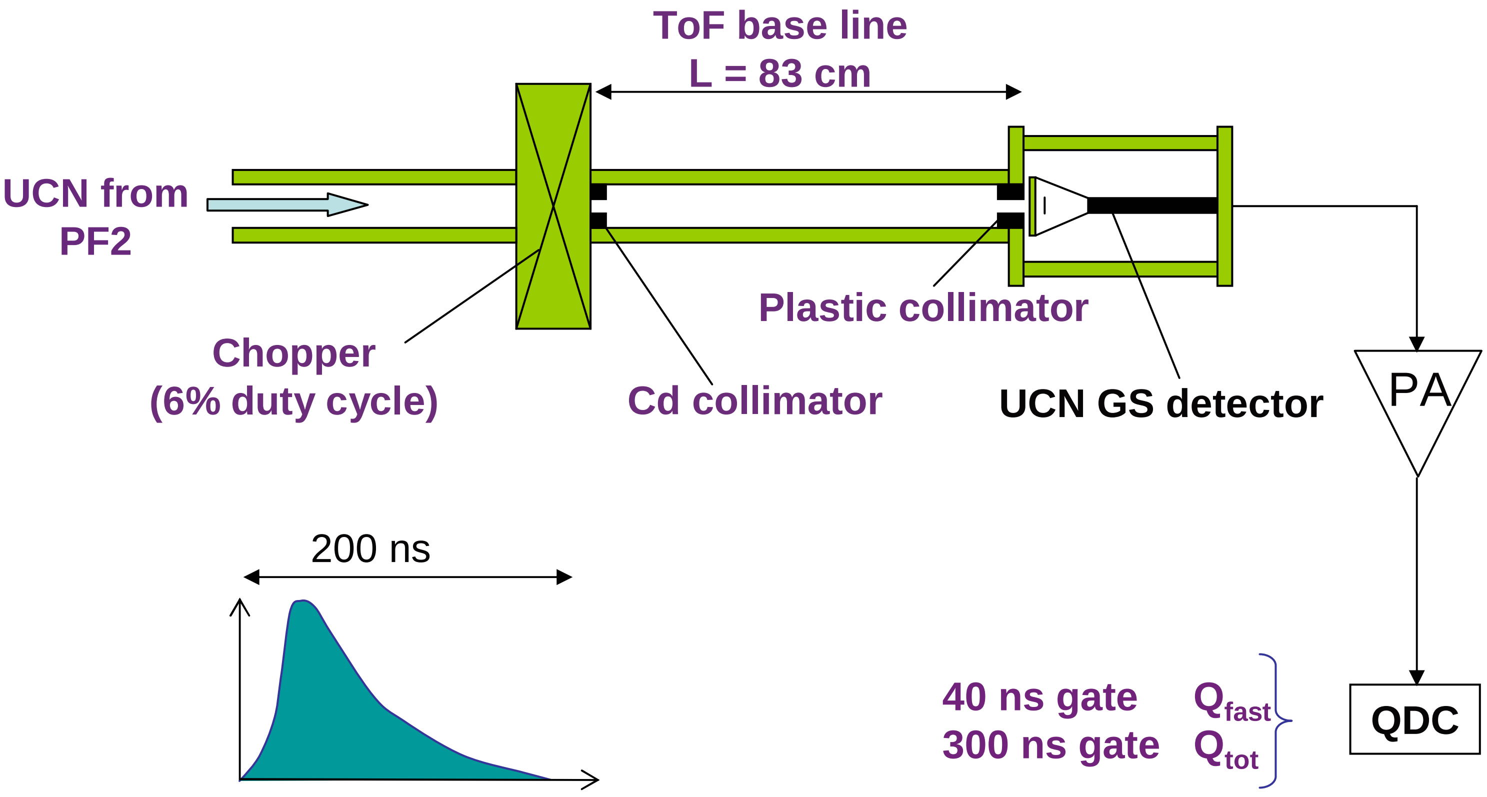
GS type	Thickness (μm)	^{6}Li Oxide weight (%)
GS1	500	0.45
GS10	250	1.35
GS20 / GS3	250 / 250	17 / ≈ 0

- 200 nm dead layer
- Fast (fall times < 150 ns)
- Low critical velocity
- Low γ sensitivity
- Radiation hard
- Simple and cheap



Test experiment at ILL

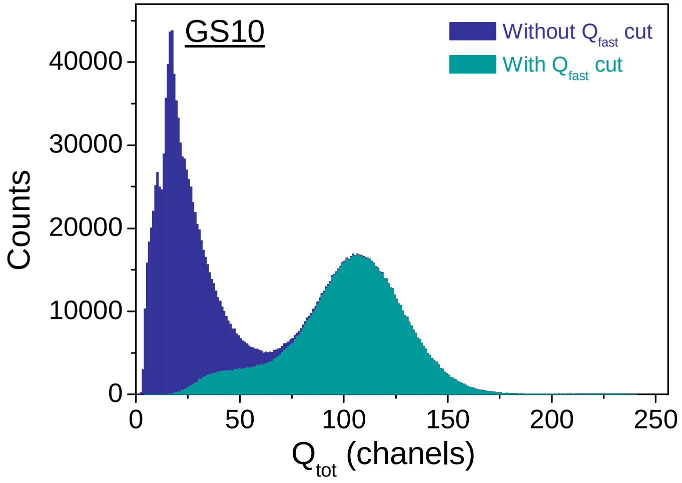
- **Experimental setup**



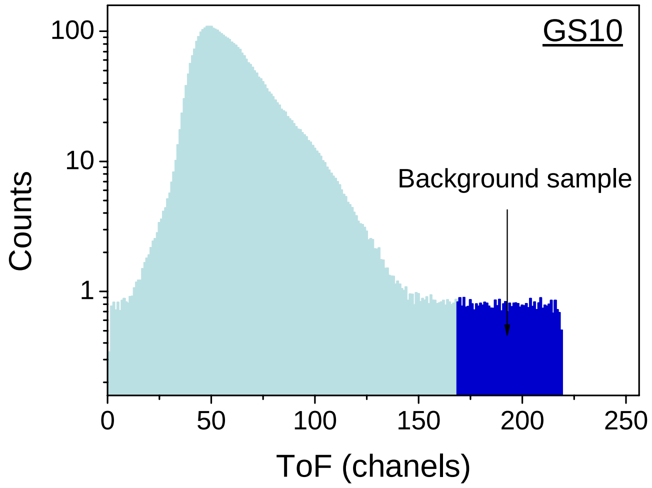
•Typical charge signal from UCN

Charge selection and velocity distribution

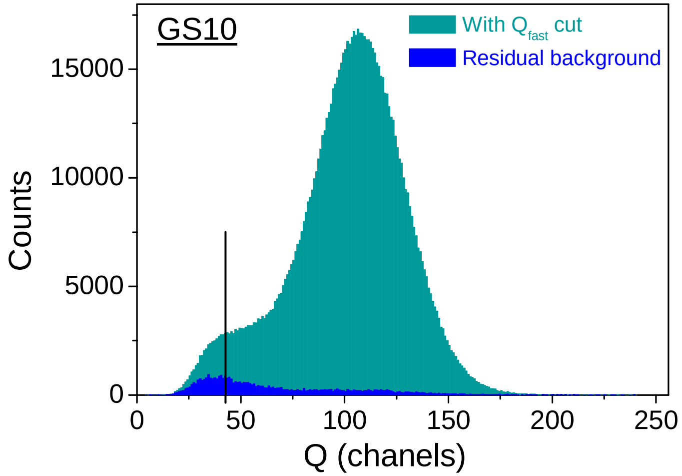
- Charge selection



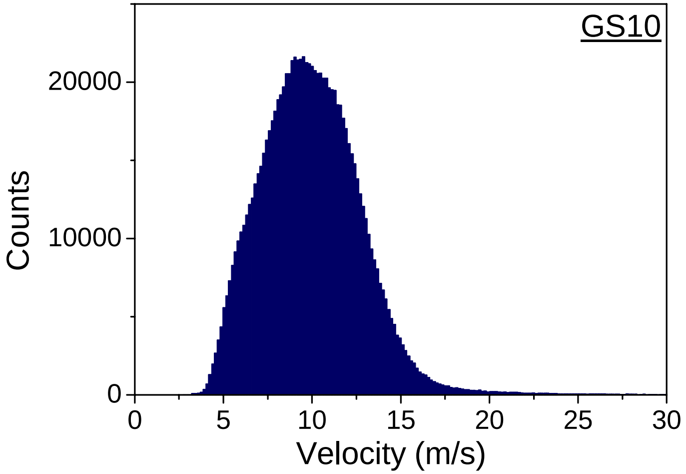
- ToF measurement



- Background measurement



- Velocity distribution



- Cut at 3 σ → 95 % of UCN, background < 1.5 counts / s

Timetable of nEDM project

№	Task	2004		2005		2006	
		1-6	7-12	1-6	7-12	1-6	7-12
1	General and detailed design of EDM spectrometer	▨	▨				
2	Magnetic shielding	▨	▨				
2a	Magnetic test experiments at PSI and stabilization of external magnetic field						
3a	Cs-magnetometers (lamp version)	▨	▨	▨			
4a	Stabilization of MF	▨	▨	▨	▨	▨	
4b	Stabilization of RC	▨	▨	▨			
5a	Electronics for MF generation	▨	▨				
5b	Electronics for SRC	▨	▨				
5c	Divider of Cs-frequency into the neutron one	▨	▨				
6a	Vacuum housings	▨	▨	▨			
6b	Vacuum equipment				▨	▨	
6c	Assembly of EDM spectrometer at PNPI		▨	▨	▨		
7a,b	Neutron guides and coatings	▨	▨	▨	▨		
7c	Improvement of vacuum equipment and coating facilities at PNPI		▨				
8a,b	UCN traps, HV test	▨	▨	▨			
9	HV power supply	▨	▨	▨	▨		
10a	Si detector	▨	▨	▨			
10b	Scintillation UCN detector	▨	▨				
10c	GEM UCN detector	▨	▨				
11	Superconducting solenoid	▨	▨	▨			
12	DAQ system		▨	▨	▨		
13	Database management		▨	▨	▨		
14	Monte-Carlo simulations	▨	▨	▨	▨	▨	
15	Platform and assembly			▨	▨	▨	
16	Measurements					▨	▨

The main results of 2003

1. The new design of magnetic shielding is worked out. Test experiment for comparison of permalloy 79NM and CONETIC as material for internal layer of magnetic shielding is prepared. The manufacturing of magnetic shield is started.
2. The development of stabilization system of external magnetic field is practically finished. The system of demagnetization of magnetic shielding is produced and tested.
3. Electronics for generation of magnetic field in EDM spectrometer was developed at PNPI and tested with PSI magnetic shielding.The first set of electronics for stabilization of resonance conditions and synthesis of neutron frequency is developed and tested in laboratory conditions.
4. The vacuum chamber of EDM spectrometer is manufactured and the He leak test was successfully done.
5. Upgrade of coating and polishing facilities for preparation of neutron guide system of EDM spectrometer has been carried out at PNPI.

The main results of 2003

6. The technology of preparation of glass-ceramics UCN chamber was developed at SRIOMT.
7. The high-voltage test has been carried out at PNPI. It was shown that electrostatic intensity of 31 kV/cm can be obtained. This value is by 2 times greater than the best result in PNPI experiment and by 3 times than in ILL experiment.
8. The Si UCN detector with analysis of UCN polarization was developed at PNPI and tested at ILL. It has been shown that the detector efficiency is about 80% in its working point and analyzing power is about 75-80%. Development of scintillation UCN detector and GEM UCN detector are in progress.

Present status of R & D experiments for EDM spectrometer

1. The possibility to stabilize resonance conditions inside the EDM spectrometer by means system of magnetometers was shown in the test experiment at PSI. The use of shaking effect allows to obtain necessary shielding factor. The problem of preparation of reproducible magnetic field configuration due to development of method of demagnetization was shown in this test experiment. The possibility of external magnetic field stabilization was also demonstrated. (Proposal, Progress Report February 2003.)

2. The problems of high sensitivity of Cs-magnetometer were solved long time ago in E.Alexandrov's laboratory (VSOI, IPTI). It was demonstrated in the test experiment at PSI again. The laser-pumped Cs-magnetometer was developed by A.Weis in FRAP and the high sensitivity of this device was demonstrated also. (Progress Report July 2003.)

3. Electronics for field generation (current power supplies) were worked out at PNPI, MU and checked in the test experiment at PSI. It satisfies requirements of the experiment. (Progress Report July 2003.)

4. Electronics for measurement of Cs-frequency and generation of neutron frequency are worked out at PNPI and checked in the laboratory. (Progress Report July 2003, present Report.)

Present status of R & D experiments for EDM spectrometer

5.The problem of high strength of electric field has been solved successfully due to usage of special glass-ceramics. The best strength of electric field was reached in the PNPI test experiment. (Progress Report February 2003, Progress Report July 2003.)

6.The special glass-ceramics was worked out at SRIOMT. This glass-ceramics solved also the problem of strength of multichamber construction. (Progress Report July 2003, present Report.)

7.High voltage power supply , which satisfies the requirements of the EDM experiment was developed a long time ago at PNPI. (Proposal.)

8.The question of UCN polarization with simultaneous improvement of UCN intensity was studied in the test experiment at ILL. The possibility to obtain 100% polarization and the factor of improvement of UCN intensity equal to 3.8 times was shown. The way for practical realization of this task is in progress. (Proposal, Progress Report February 2003.)

Present status of R & D experiments for EDM spectrometer

9. The problem of the Si UCN detector with the analysis of UCN polarization was studied in the test experiment at ILL. It has been shown that the detector efficiency is about 80% in its working position and analyzing power is about 75-80%. Both parameters are good enough but they can be improved by some additional efforts. Electronics for Si UCN detector were worked out at PNPI and checked in the test experiment at ILL. (Progress Report July 2003, present Report.)

10. The versions of scintillation and GEM detector are in progress. (Progress Report July 2003, present Report.)

11. The problem of preparation of UCN guides i.e. polishing, coating and so on was developed a long time ago at PNPI, and even some improvements have been done recently. (Present Report.)

Conclusion

Thus the main part of R & D phase of the project is fulfilled. The phase of realization of the project has been started already.