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Russia, 188300, Leningrad District , Gatchina, Orlova Roscha

Answer to the recommendation of Subcommittee on Detectors, technical part.

CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

Recommendations of SAC, CREMLIN

- The main message from the committee is that the work should start immediately. Most of the recommendations emphasize that is imperative necessary to urgently organise and prioritise the work that should be done, formulate the strategy and the schedule with priorities matched to resources.

The work was started and supported by the Ministry of science

- It's necessary to establish a detector group in the organizational structure gathering relevant person together: physicists / engineers / software engineers / technicians. It's important to clarify the relationship between the groups and the organisational environment within the Institute. The existing Institute culture should be adapted to the PIK project and to the new priorities. Interfaces and communication between specialists at a low level are important. The cooperation mechanisms between JINR and PNPI should be established on mutual profitable bases.

The detector group is developed and the cooperation is well established. The collaborative project is prepared.

- Write down a schedule. The schedule from the number of planned instruments and level of parallelism (30 instruments is a very large number) is going to be challenging to meet. There is a need to start the work now on all levels.

The schedule is fixed. The 20 instruments are to be build before 2025. The specifications for the instruments is fixed.

Recommendations of SAC, CREMLIN

- Purchase Helium-3 for at least a couple of detectors. So far as the purchasing procedure is time-consuming, the process should be launched as soon as possible.

The purchasing procedure for Helium-3 takes 1.5 years per order. However, the volume of the order is almost unlimited.

- Start to check condition of existing detectors. An audit of what is available, and what condition it is in. There needs to be list of what is available, and what needs upgrading. It is important to check and improve Helium tightness.

The existing detectors (as well as HZG) together with electronics will not be used for the instrument development.

- Electronics and user interface: Consider use of the IBR-2 (JINR, Dubna) system for electronics. Increase collaboration between JINR and PNPI on electronics. Have MWPC electronics for delay technique. Try and put scintillator and Helium-3 readout to use the same system if possible, to make sure that operational requirements are minimised. Note that bearing in mind the users and the user interface is very important from the beginning. This should be thought about now.

The question is still under consideration. Another option is the system which is in operation at synchrotron of Kurchatov institute (KISI).

Recommendations of SAC, CREMLINplus

- Since additional members were added to the detector subcommittee compared with the Cremlin project and the rather long period of time last, it would be useful to listen to a report on the point by point implementation of the recommendations issued by the previous subcommittee in the framework of the Cremlin project.

Recommendations were presented before.

- The SC members need an introduction, briefing, or guidelines on how to communicate with the colleagues at the PIK-facility to receive the information needed to help in their role as a member of the SC.

The communication is to be organized with the help of responsible, namely Evgenii Altynbaev. His task is to report on the questions that rises up and to invite specialists within the requested fields.

- It is important to know all characteristics of the detector inbound with a certain instrument where it will operate. Particularly the choice of detectors at instruments has to be made with the knowledge of expected flux and count rates. It is highly recommendable to review the detector's parameters for each instrument when the parameters of the source become known.

We completely agree and are waiting for the results of the simulation of neutron fluxes for each instrument with a standard samples after the instrument configuration will be finalized.

Recommendations of SAC, CREMLINplus

- From the presentation, it became known that PNPI has a group in charge of the issues related to detectors but the structure and organization of the detector group at the reactor PIK is not clear and it has to be presented. At such a large facility as the PIK reactor, it is mandatory to have a group of sufficient people with knowledge and expertise in neutron detectors. If not already done, it is recommended to build or extend the group by physicists/engineers/software engineers and technicians to perform research and provide professional support in detector technologies.

The neutron detector development department (NDDD) has been established in December of 2020. At the moment it consist of 7 specialists in the field of creation of MWPCs and Li-6 based detectors. The aim of the department is to cooperate with existing departments, namely laboratory of electronics and software (17 specialists) and track detectors department (15 specialists), which are experienced in the different fields of detector development. After the order on detector production will be placed in NRC KI – PNPI, the NDDD will be extended in order to successfully fulfill it.

Recommendations of SAC, CREMLINplus

- As the readout electronics is an integral part of detector systems, the detector group should also discuss it. Because of the long-term operation of the PIK reactor, it is recommended to select modern electronics with long availability of components. To keep the efforts for maintenance and integration into instrument control systems as low as possible, a large diversity of DAQ electronics should be avoided.

The readout electronics is developed for the proportional counters, and delay line MWPCs. At the moment the development of the electronics for charge-division and multi-channel counters is ongoing. The strong collaboration with JINR is established and DAQ is the subject of development within the cooperative project. Also the discussion with CAEN about the standard solutions for charge-division are in process.

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Neutron Detectors in the Russian instrumental program at the reactor PIK: current status and future plans

CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

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Current activities

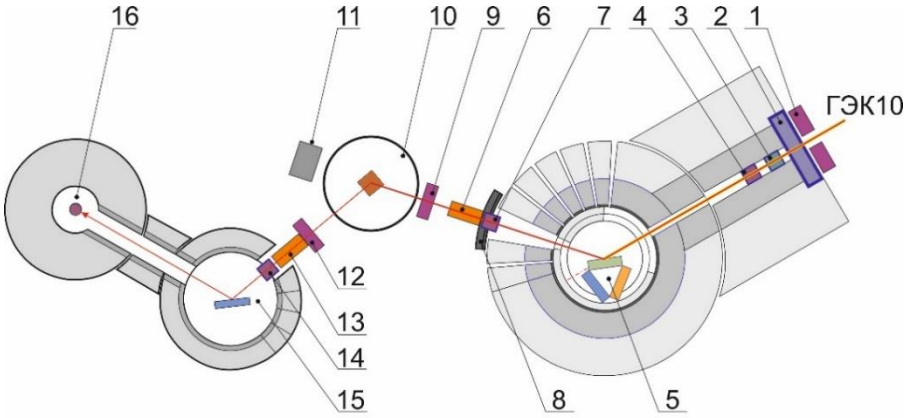
- Manufacturing of the detectors for neutron instruments – ***Founded by Ministry of science of Russian Federation***
- Design of neutron instruments at PIK research reactor – ***Founded by Russian Federation***
- Development of the neutron instruments at PIK research reactor – ***Founded by Russian Federation***
- Research and development of neutron detector systems in accord to the request of PIK research reactor
- Extension of the production capabilities

Instruments at PIK reactor

20 Instruments to be built before 2025:

Condensed matter physics:

1-3. Triple axis spectrometers – IN1, IN2, IN3

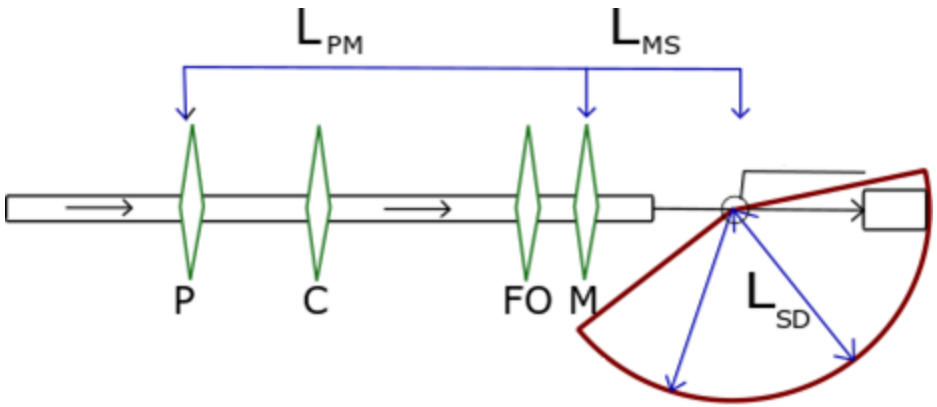


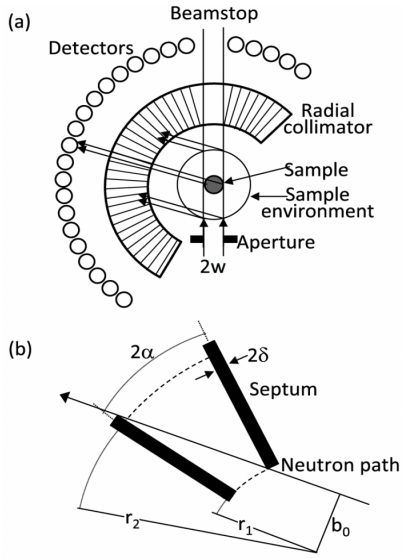
1 Входная щель (VS)
2 Заслонка
3 Фильтр
4 Монитор 1
5 Узел монохроматора
6 Коллиматор
7 Монитор 2
8 Маска
9 Диафрагма
10 Узел образца
11 Ловушка
12 Диафрагма
13 Коллиматор
14 Монитор 3
15 Узел анализатора
16 Узел детектора

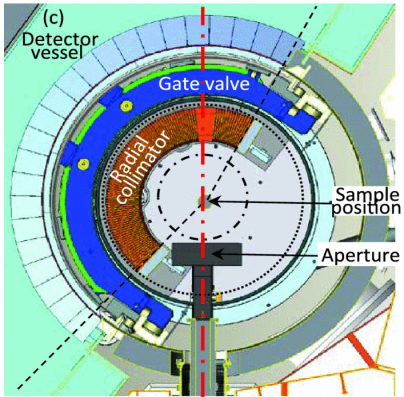
Each instrument requires 3 transmission neutron monitors and one single helium-3 filled counter (100*8 mm^2) as a neutron detector.

Instruments at PIK reactor

4. Time of flight spectrometer – IN4







Before 2025: IN4 requires 1 transmission monitor and 1 square meter surface covered with helium-3 filled detector tubes.

After 2025: The final neutron registration system of IN4 should consist of 2 transmission monitors and 1900 helium-3 filled position sensitive detector tubes (1000*25,4 mm^3).

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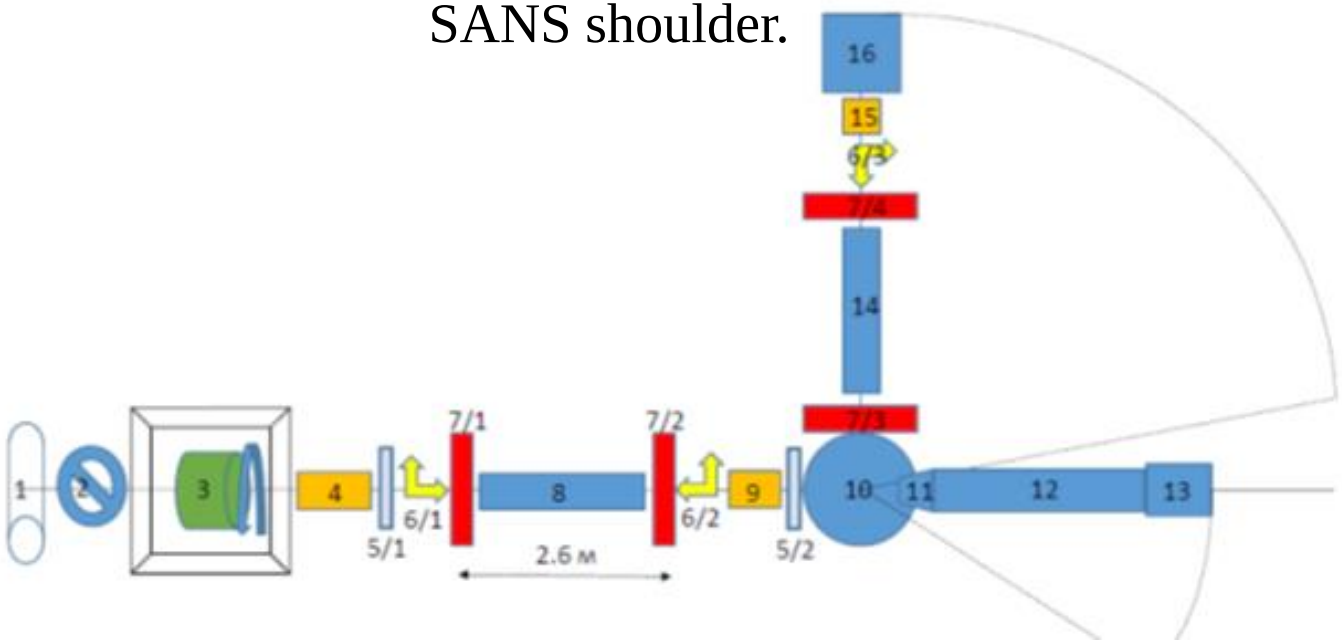
Instruments at PIK reactor

5. Spin-echo spectrometer – SES

SES is designed as an instrument similar to RESEDA, located in FRM-II.

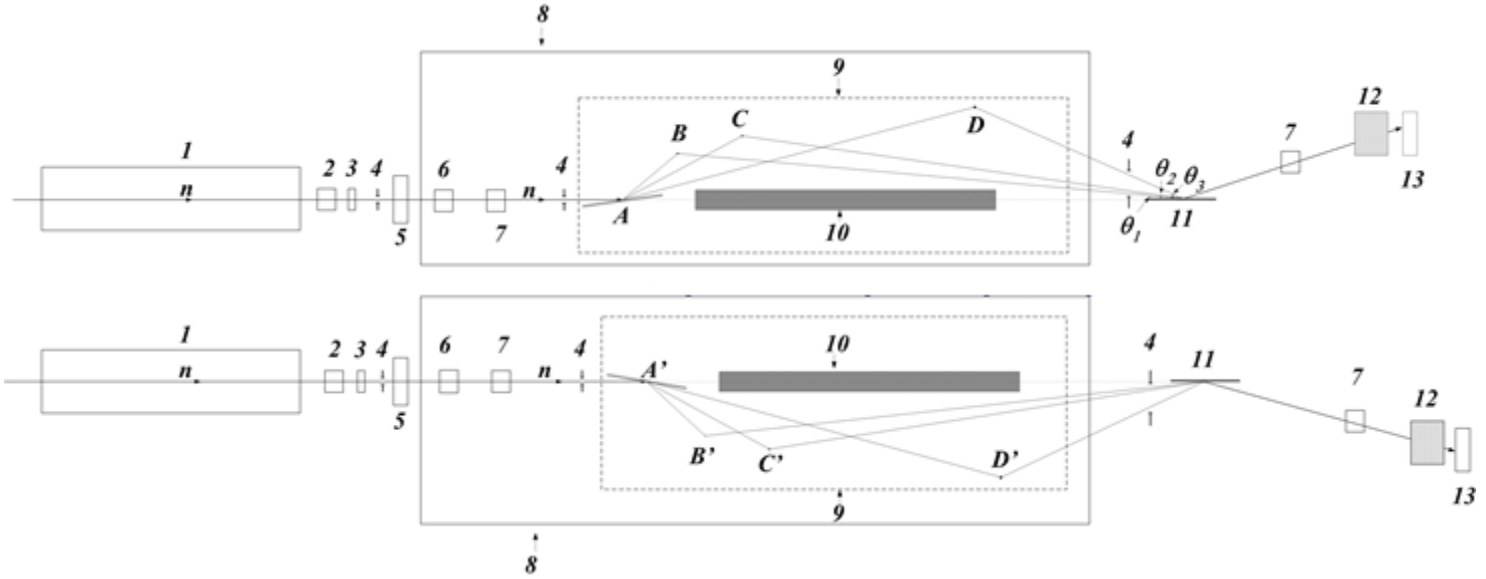
Instrument requires 1 transmission monitor, 1 single helium-3 filled counter for NRSE shoulder and 300*300 mm^2 PSD with 10 micrometers resolution along neutron flight path and 3*3 mm^2 resolution in x and y directions for MIEZE – SANS shoulder.



Instruments at PIK reactor

6. Reflectometer with vertical scattering plane – HARMONY

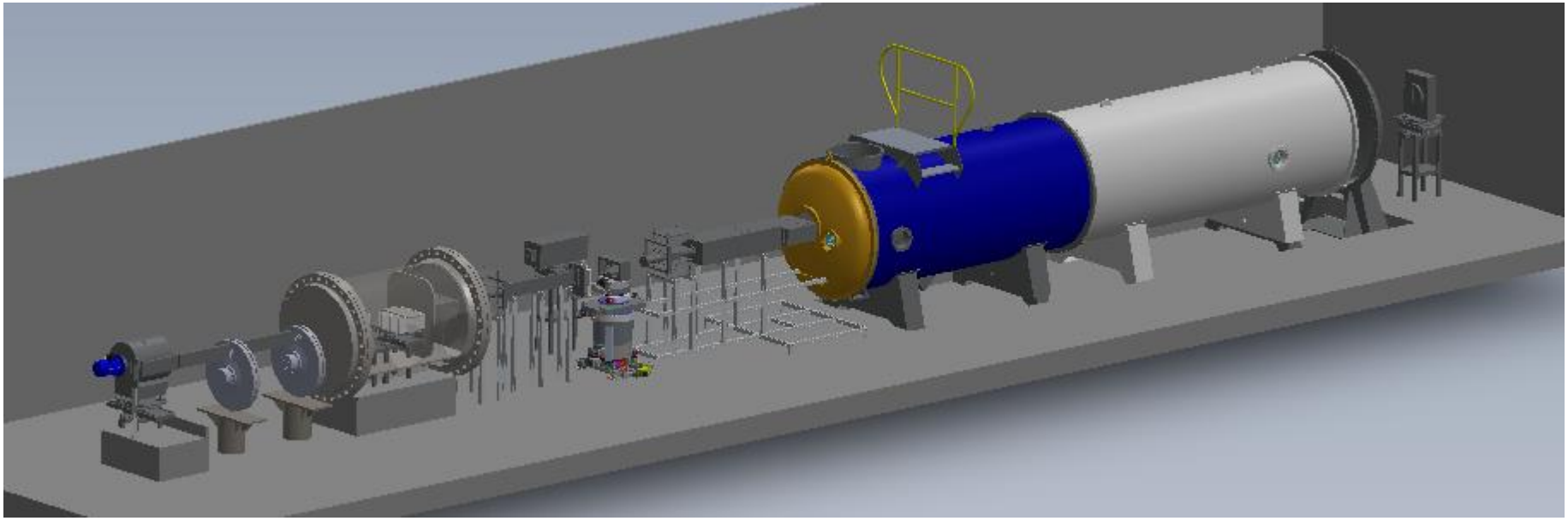
Instrument requires 1 transmission monitor, 500*250 mm^2 PSD 3*2 mm^2 resolution in x and y directions.



Instruments at PIK reactor

7. Reflectometer with horizontal scattering plane – SONATA

Instrument requires requires 1 single helium-3 filled counter as a neutron monitor (or transmission monitor), 300*500 mm^2 PSD with 1.5*5 mm^2 resolution in x and y directions. Additionally the multi-blade PSD with boron-10 converter 100x130 mm^2 with 0.5x3.5 mm^2 resolution in x and y directions is proposed by WP7 of CREMLINplus.



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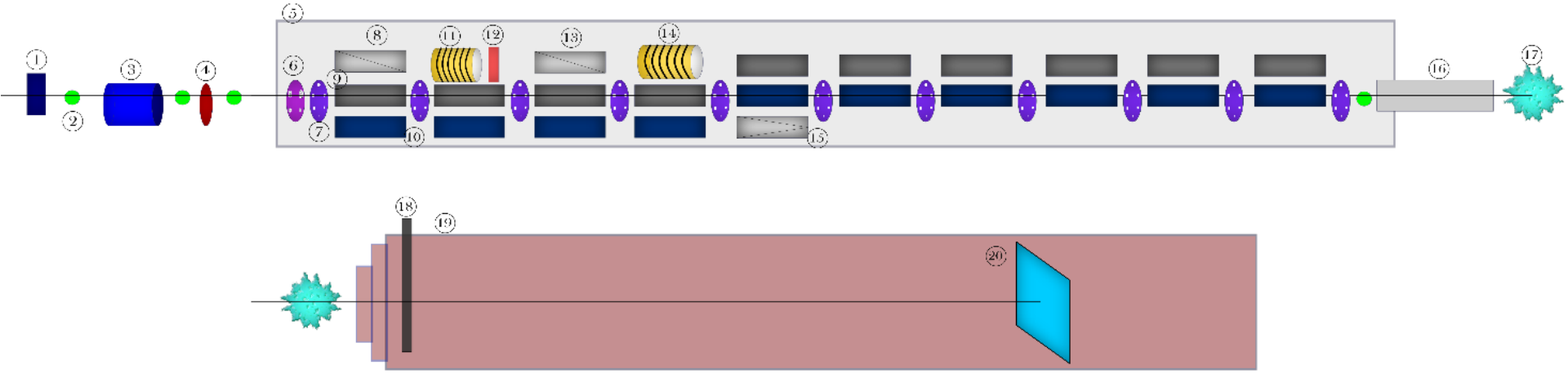
Instruments at PIK reactor

8. Polarized small-angle diffractometer (SANS) – Tenzor

Instrument requires requires 4 single helium-3 filled counters as a neutron monitors (or transmission monitors), 1000*1000 mm^2 PSD with 8*8 mm^2 resolution in x and y directions. After 2025 additional and 100*100 mm^2 PSD with 10 micrometers resolution along neutron flight path and 3*3 mm^2 resolution in x and y directions for MIEZE option will be requested.



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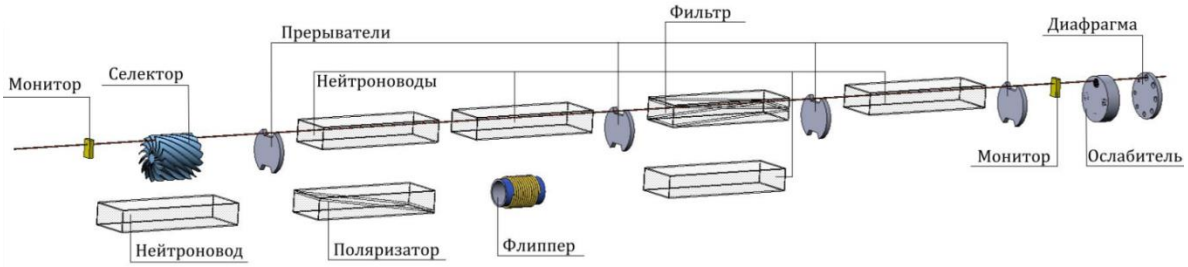
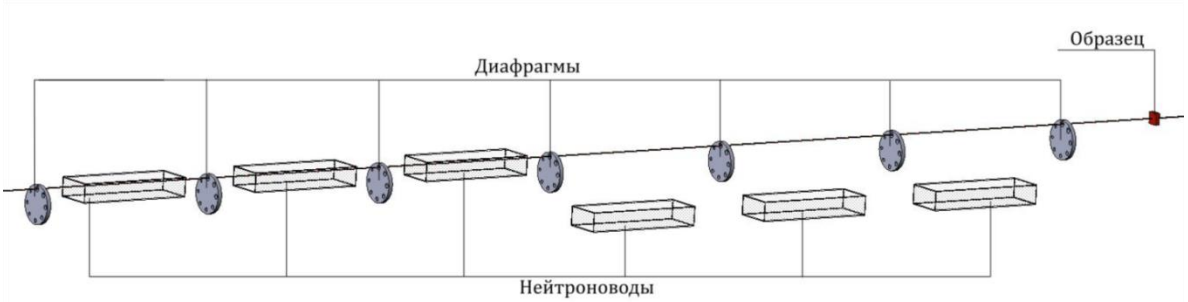
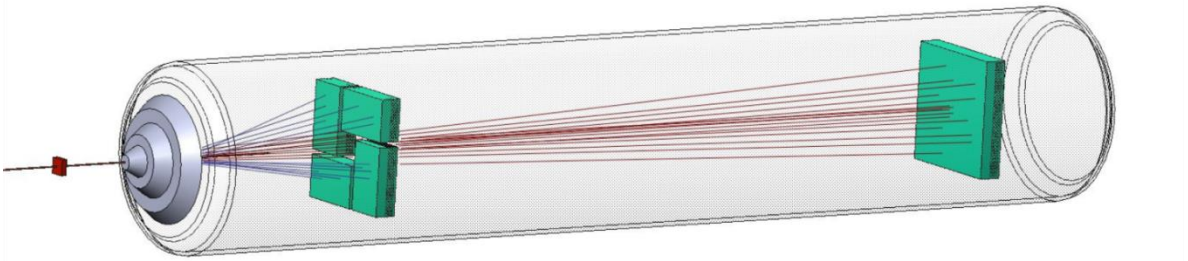
Instruments at PIK reactor

9. Chopped small-angle diffractometer (SANS) – Membrana







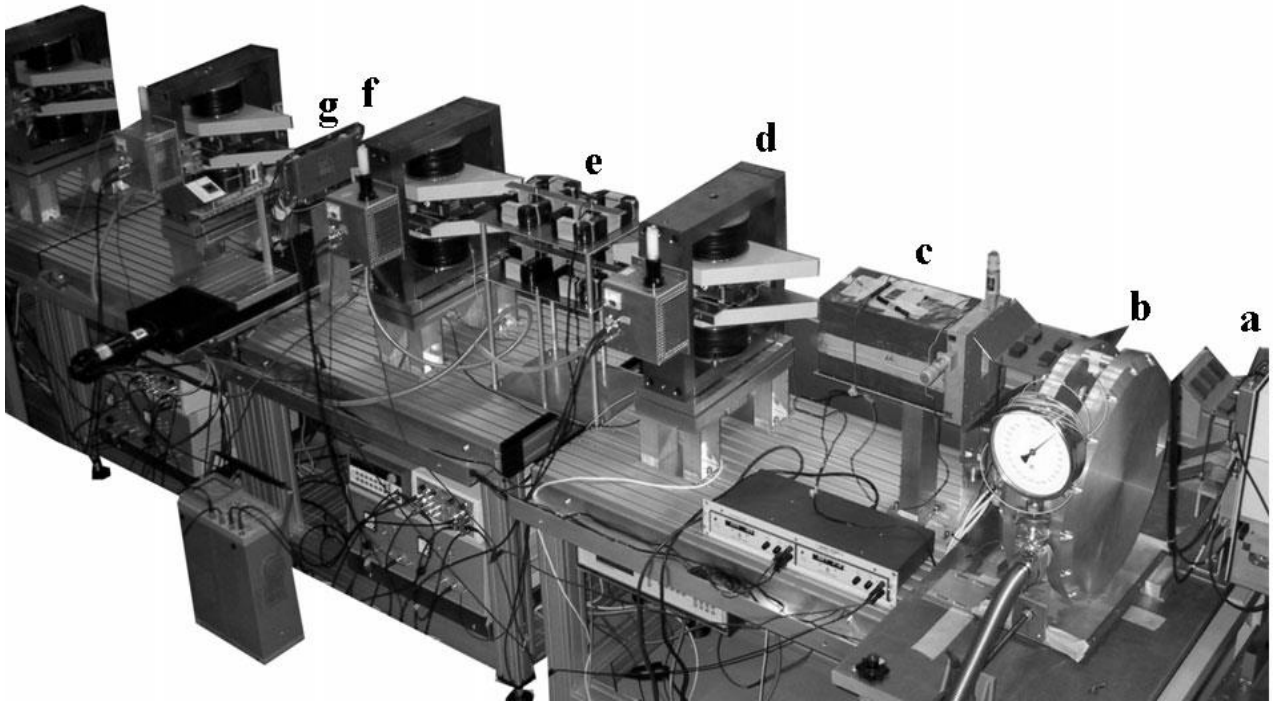
Before 2025: Instrument requires requires 2 single helium-3 filled counters as a neutron monitors (or transmission monitors), 1000*1000 mm^2 PSD with 8*8 mm^2 resolution in x and y directions.

After 2025: Instrument requires 4 additional 500*300 mm^2 PSD with 5*5 mm^2 resolution in x and y directions as a front detector.

Instruments at PIK reactor

10. Spin-echo SANS – SESANS

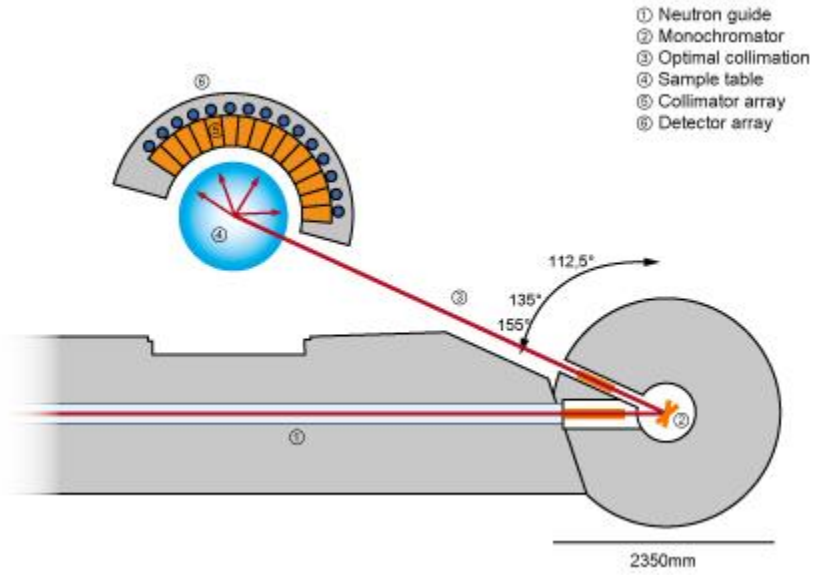
Before 2025 instrument requires 1 transmission monitor and single helium-3 filled counter as a detector. After 2025 single counter is to be replaced with 300*300 mm^2 PSD with 5*5 mm^2 resolution in x and y directions.



Instruments at PIK reactor

11. High resolution powder diffractometer – D1

Instrument requires 1 transmission monitor and 80 single helium-3 filled counters as a detector.



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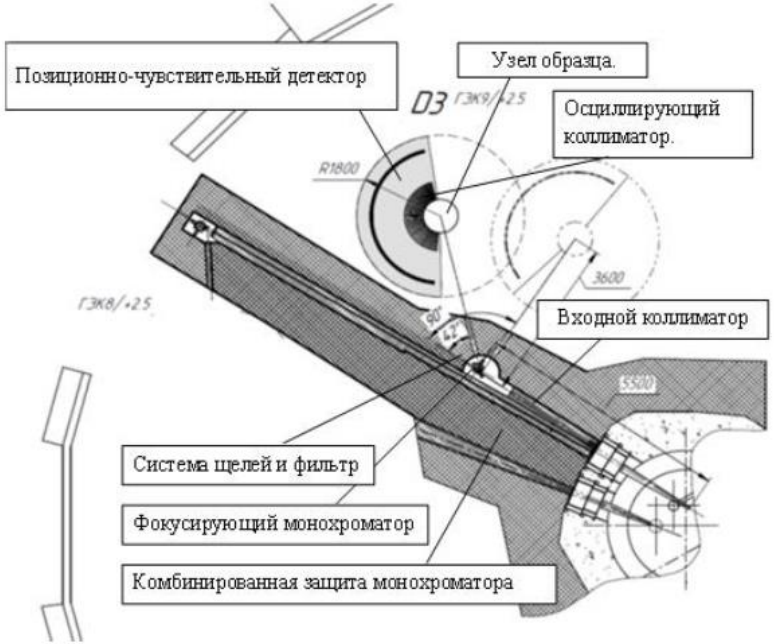
Instruments at PIK reactor

12. High intensity powder diffractometer – D3

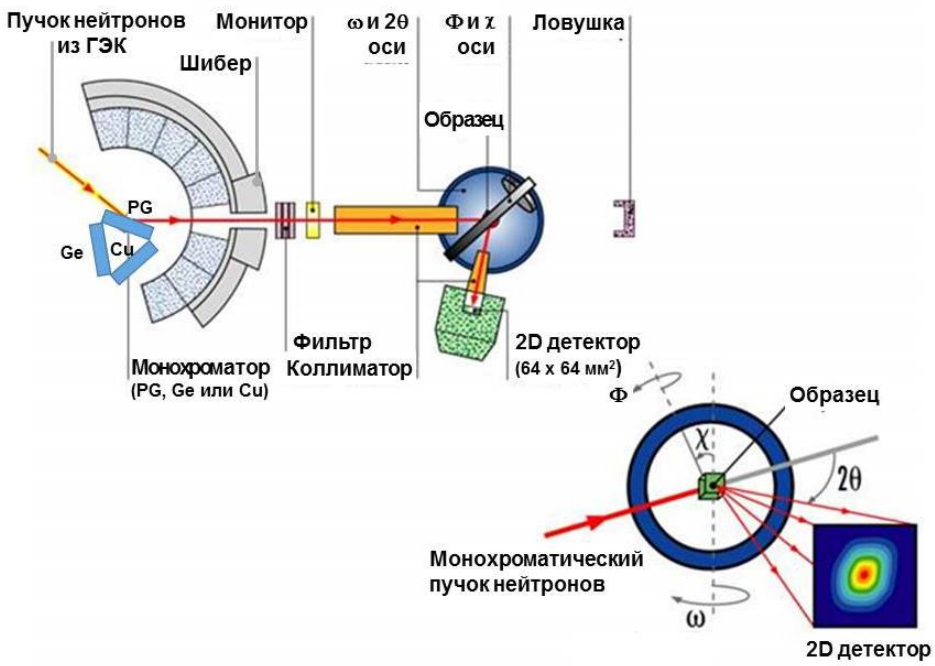
Instrument requires 1 transmission monitor and 72 position sensitive helium-3 filled counters, 900 x 8 mm^2 in size, 5 mm resolution along the counter.



Instruments at PIK reactor

13. Single-crystal diffractometer – DC1

Instrument requires 1 transmission monitor and 256x256 mm^2 PSD with 2*2 mm^2 resolution in x and y directions.



Instruments at PIK reactor

20 Instruments to be built before 2025:

Fundamental physics:

1. Neutron EDM – DEDM requires 250x250 mm^2 PSD with 2*2 mm^2 resolution in x and y directions

2-7. Others… - Liquid scintillators and charged particles detectors.

Overall request of PIK

Detectors to be built before 2025:

- Transmission monitors – ~20 pieces
  - MWPC PSD – 4 detectors
- CD based counters – 4 detectors, 572 counters
- Single proportional counters – 100 counters
  - CASCADE detectors – 1 detector

… Detectors for charged particles

Detectors to be built after 2025:

- MWPC PSD – 5 detectors
- CD based counters – 1 detector, 1900 counters
  - CASCADE detectors – 1 detector

Conclusions

The research reactor PIK might become a basement for intense collaboration in the field of development of most effective solutions for neutron instrumentation.

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Thank you for your attention!

Directions for detector development

1. Renovation of the production line for MWPC PSD.

2. Development of the CD based counters and proportional counters.

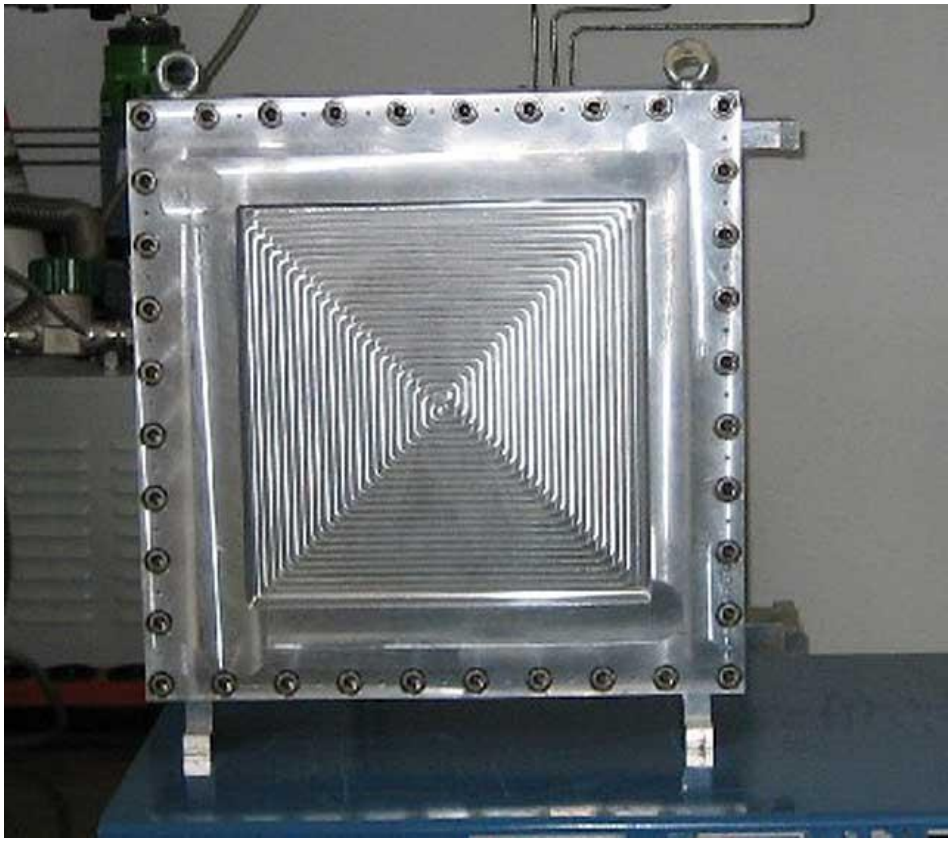
3. Development of the scintillator based proportional and position sensitive counters with low gamma sensitivity.

4. Development of the electronics.

Manufacturing of MWPC PSD

In 2019 the delay line MWPC neutron detector is designed to be installed on SANS instrument of IR-8 reactor in Moscow in 2020.

- Sensitive area: 600x600 mm^2
- Spatial resolution: 3x3 mm^2
- Gas pressure: 3.5 bar
- Count rate: 150 kHz per pixel / 150 kHz overall.
- Efficiency: ~65% for 1 angstrom.



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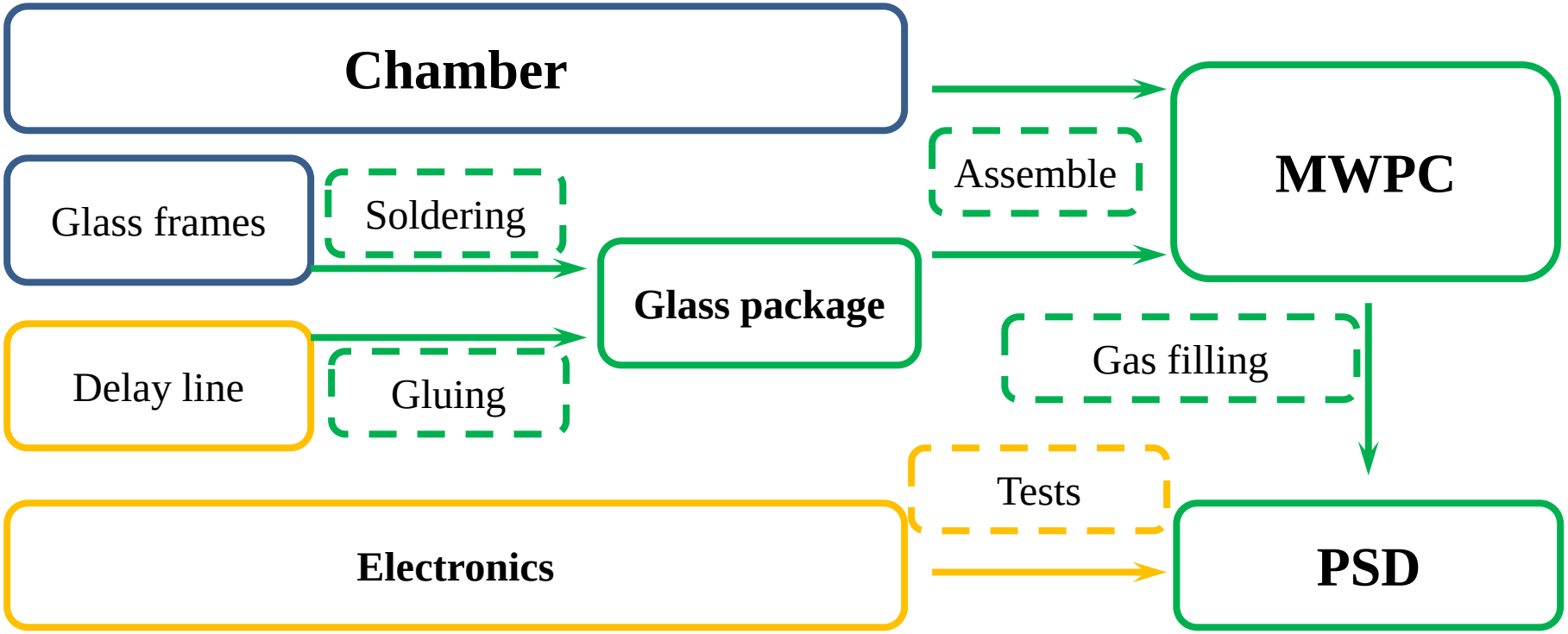
MWPC PSD for SANS

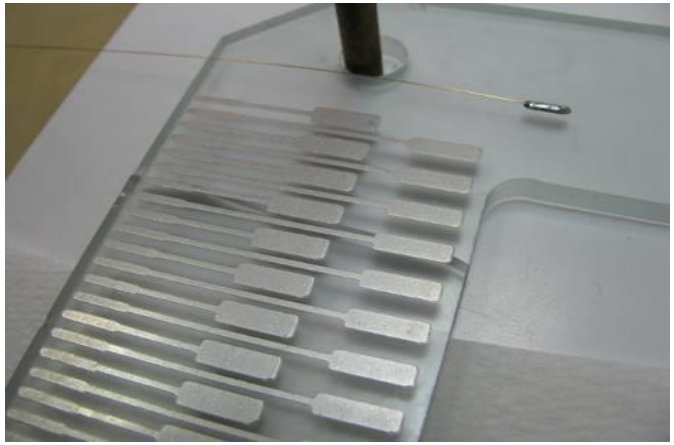


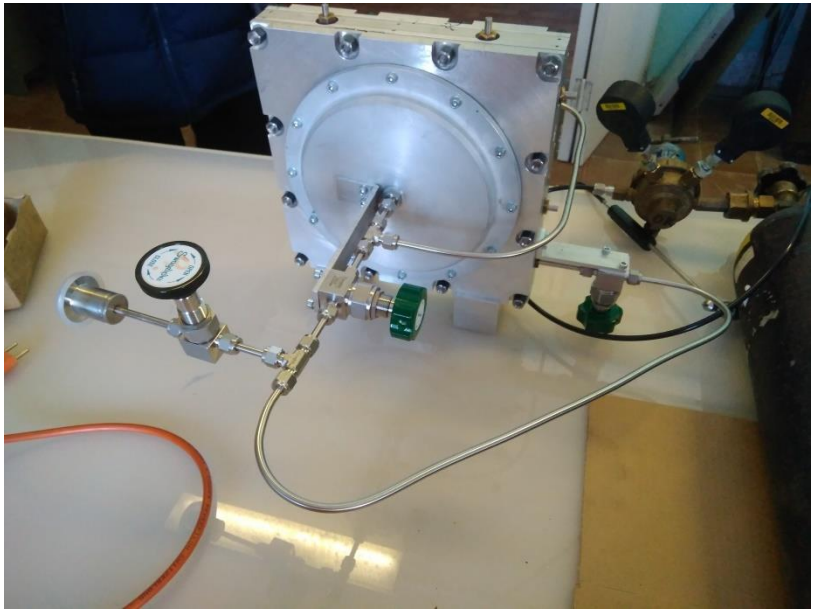
Manufacturing of neutron monitors

In 2019 the neutron monitors have been created on the basis of:

1. Delay line based MWPC neutron detector:

- Sensitive area: 100x100 mm^2
- Spatial resolution: 2x2 mm^2
- Gas pressure: 1 bar
- Count rate: 150 kHz per pixel / 150 kHz overall.
- Efficiency: >0.01% for 1 angstrom.
- Transmission: 99% for 1 angstrom



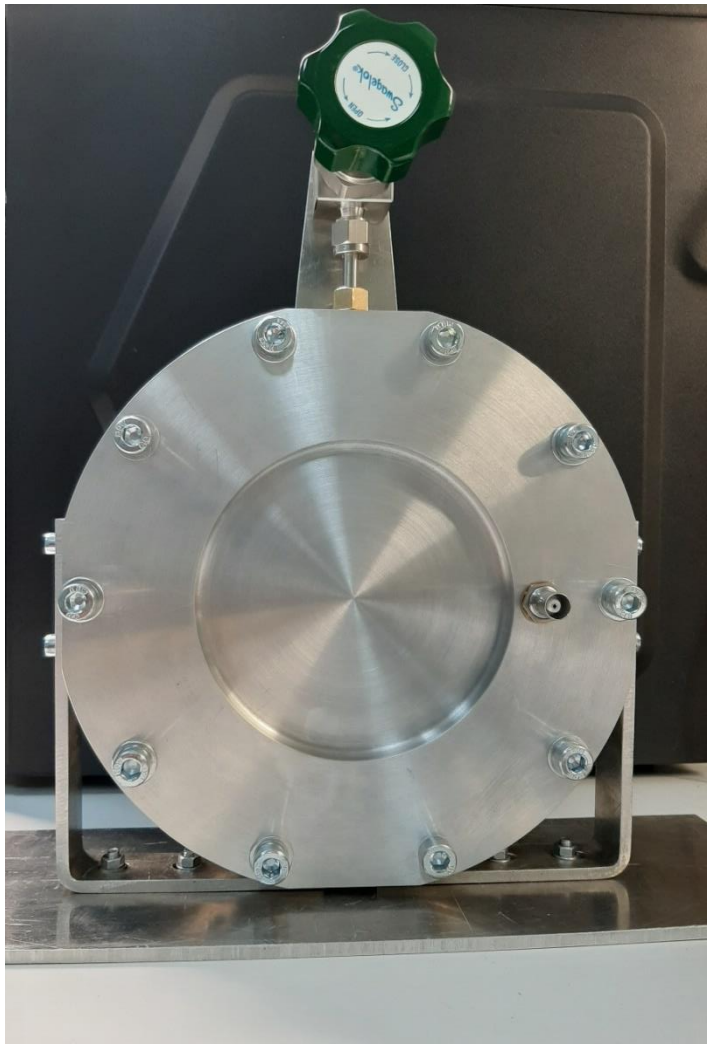


Manufacturing of neutron monitors

In 2019 the neutron monitors have been created on the basis of:

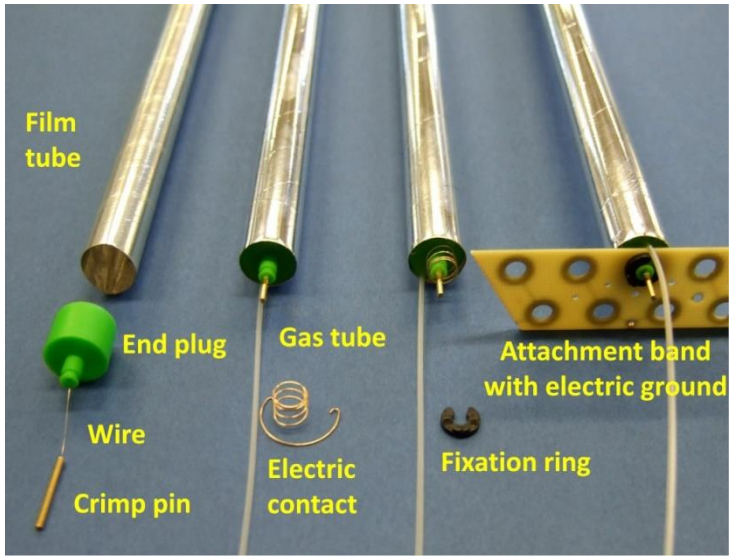
2. Proportional U-235-based counter:

- Sensitive area: 100x100 mm^2
- Gas pressure: 1 bar
- Count rate: ~1 MHz.
- Efficiency: >0.1% for 1 angstrom.
- Transmission: 98% for 1 angstrom.
- Voltage: ~300 V



CD based counters

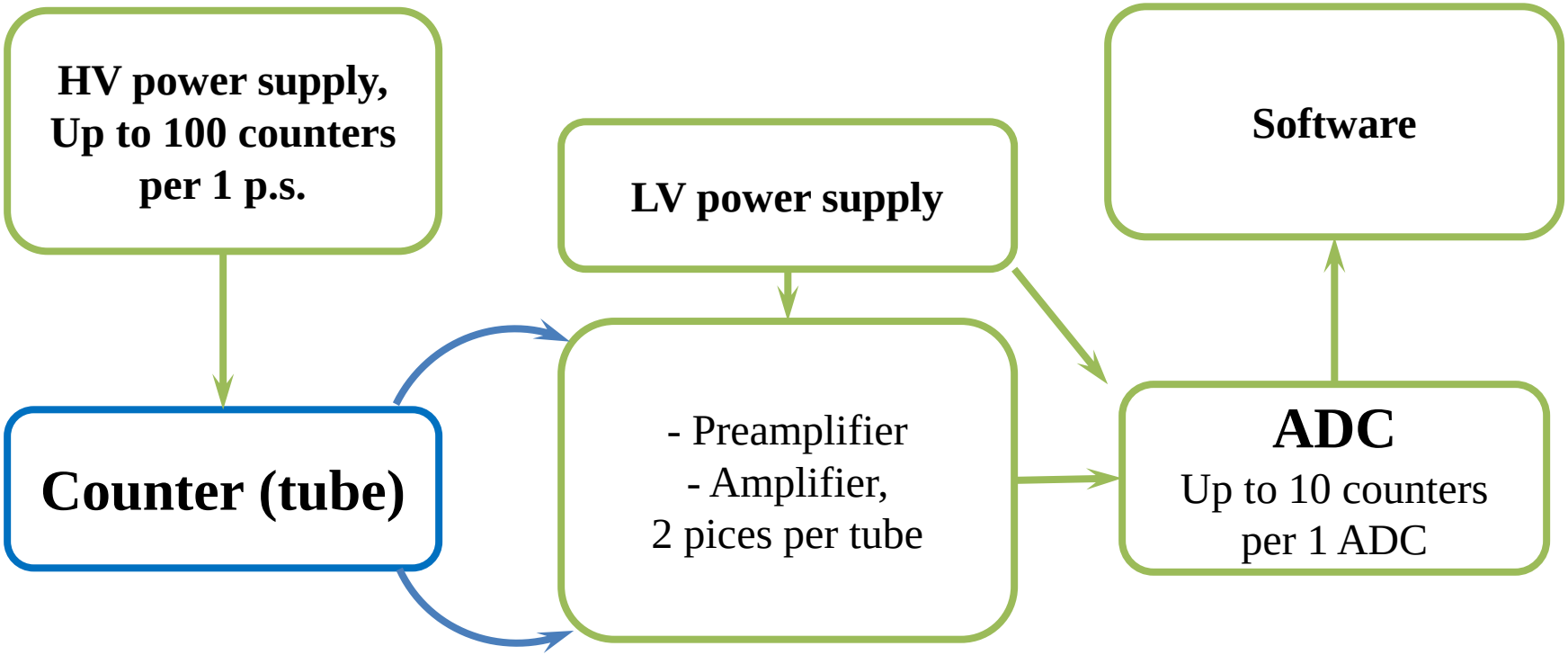
In 2019 the counters to be used as CD based PSD have been developed and manufactured in collaboration with commercial partner. Warranty period – 8 years.



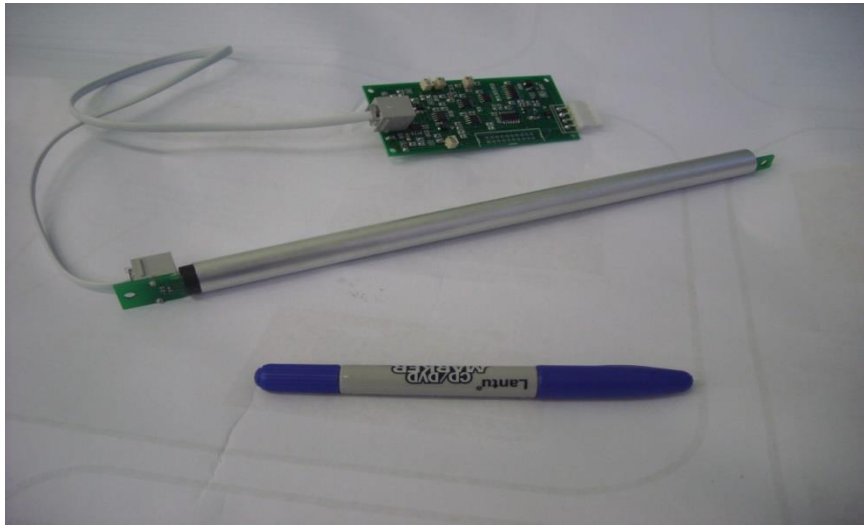
Parameters

- Sensitive area: 1000x10 mm^2
- Gas pressure: 10 bar
- Efficiency: ~75% for 1 angstrom.

CD based PSD


HV power supply,
Up to 100 counters
per 1 p.s.
LV power supply
Software
Counter (tube)
- Preamplifier
- Amplifier,
2 pices per tube
ADC
Up to 10 counters
per 1 ADC

ZnS (Ag) / Li^6F based counters



In 2019 the detector system for powder neutron diffractometer has been developed and manufactured to be installed on IR-8 reactor in Moscow in 2020. The detector system consist of 160 SiMP-based counters with sensitive area 5x50 mm^2.

Parameters of the counters:

- Sensitive area (5-300)x(2-50) mm^2
- Efficiency 75% for 1.8 angstrom
- Gamma sensitivity < 10^{-5}
- Count rate – 1 MHz per counter

- Low dark noise
- Possible assembling with lack of the blind area
- Do not require high voltage

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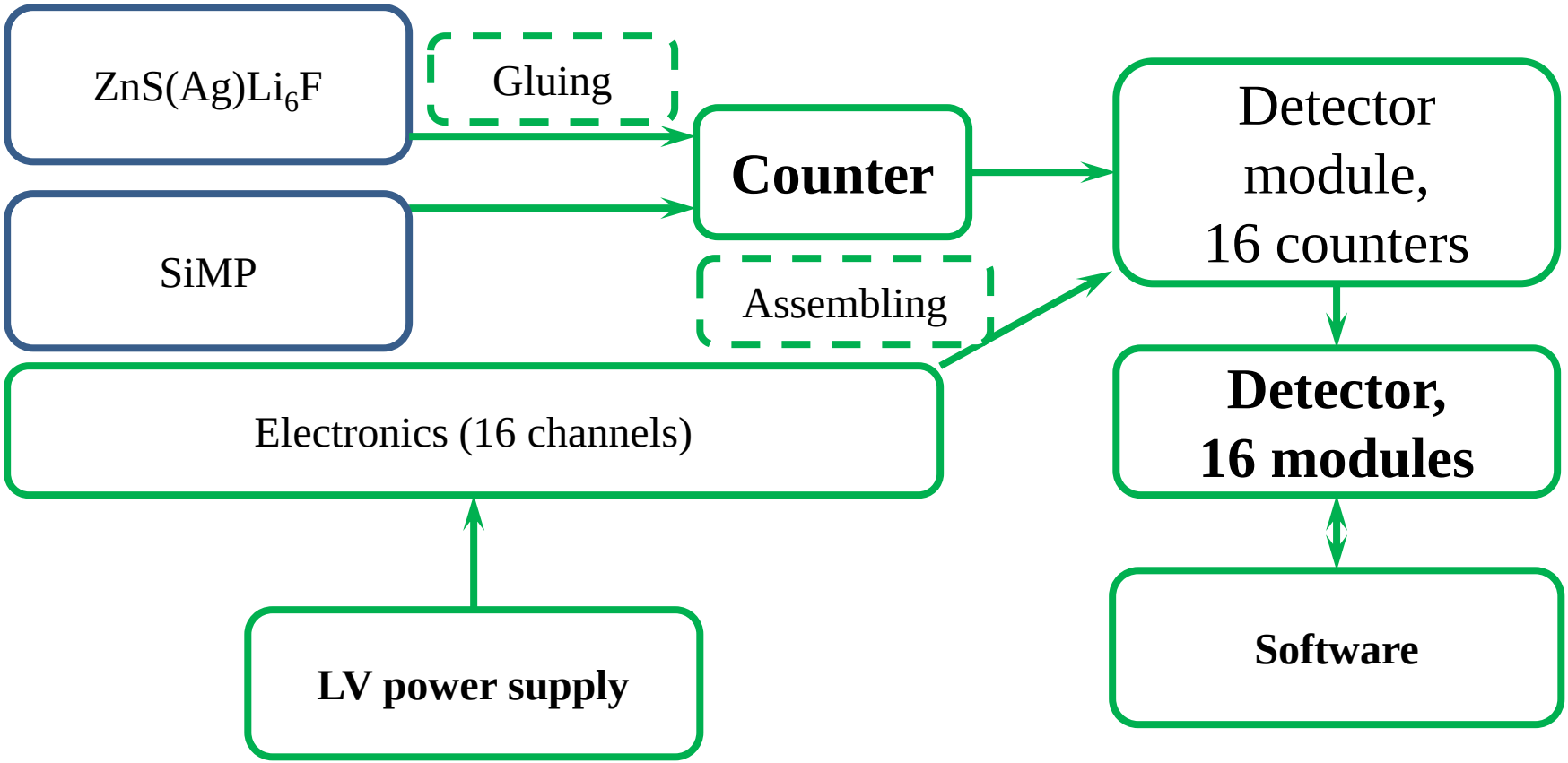
ZnS (Ag) / Li^6F based counters



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WP3 (Collaboration with PIK):

Coordination of work WP3-WP7

Sergey Grigoriev

Purpose of the meeting

The main “purpose of this meeting is to align WP3 -WP7- activities (*in the field of neutron detectors*) and ensure a proper communication flow” (Martin Sandhop).

The meeting will achieve its goals by exchange of ideas and views of different parties (bodies) involved in the process:

- **NRC KI – PNPI** as the main partner within WP3 (Vladimir Voronin),
- **WP3** coordinating team (Stefan Mattauch),
- **WP7** coordinating team (Christian Schmidt),
- **CREMLINplus** coordinating team (Martin Sandhop),
- **Detector SubCommettee**: chair and members (Victor Bodnarchuk).

WP3 Tasks:

- Task 3.1: High-brilliance cold neutron source
- Task 3.2: Bi-spectral neutron extraction system
- Task 3.3: Development of advanced Very Cold Neutron Source
- Task 3.4: General blueprint for the instrumentation at PIK
- Task 3.5: Prototype of advanced polarized neutron diffractometer for PIK reactor
- Task 3.6: Establishing the scientific advisory committees at PIK
- Task 3.7: Instrument-specific education and training programs for engineers and scientists
- Task 3.8: User System
- Task 3.9: Support strategic coordination

WP7 Tasks:

- **Task 7.1: Development CMOS technologies for high-rate silicon trackers**
- **Task 7.2 Development new methods for effective integration of MAPS sensors**
- **Task 7.3 Next-generation neutron detectors**
- **Task 7.4 Training and school for young scientists on particle detection technologies**

WP7 Task 7.3:
Next-generation neutron detectors

1) "The primary focus of the activities within this task is the joint development and construction of a high resolution detector to a piloting example instrument at PIK."

2) The primary aim of this task is the development of a cost effective, small area detector with position resolution of a few mm.

3) **"**The recent advances in Boron-10 detector technology will be used to focus on a design around these requirements. This will build upon the results from the recent H2020 BrightnESS project. The key specifications of the chosen application will be verified, and a detailed design done. This task will then construct this detector for a PIK instrument. This will be done in an open and collaborative fashion between all institutes involved."

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WP7 Task 7.3:
Next-generation neutron detectors

Deliverables

D7.1 Neutron detector requirements (M3)

……

D7.4 Test of key neutron detector specifications (M24)

……

D7.5 Neutron detector design (M30)

…….

D7.9 Constructed Neutron detector for PIK (M30)

NRC KI – PNPI position with respect to neutron detectors within CREMLINplus project

- PNPI had not initiated the topic of neutron detectors within CREMLINplus project. It was initiative of the ESS team.

- WP3 (and team of PNPI working on the topic “Cooperation with PIK”) is not focused on the neutron detectors

- NRC KI – PNPI has received 30 kEu within the WP7 and neither had nor have at present any plans to invest the own money.

WP7 Task 7.3:
Next-generation neutron detectors

Deliverables

D7.1 Neutron detector requirements (M3) - NRC KI – PNPI

D7.4 Test of key neutron detector specifications (M24) – ESS

D7.5 Neutron detector design (M30) - ESS

D7.9 Constructed Neutron detector for PIK (M30) - ESS

Purpose of the meeting:

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