Nuclear Physics with Neutrons

Facility under construction IREN

06-4-0993-94/2004	Priority of the project: 1
	Status: In-progress

Construction of the IREN Facility

Leader from JINR: W. Furman, I. Meshkov

Participating countries and international organizations: Armenia, Bulgaria, Czech Republic, Germany, Italy, Republic of Korea, Romania, Russia, Ukraine, the USA.

The aim of the IREN project is the construction in JINR of a new basic facility — the brightest in Europe resonance neutron source for investigation in fundamental and applied nuclear physics, by the time-of-flight method in a neutron energy region up to some hundred keV. It is created on the place and in the building of LUE-40+IBR-30 installation removed from operation; thus, the existing infrastructure of eight neutron beams with flight paths from 10 up to 1000 m, an experimental hall and measuring pavilions, is completely used.

The IREN source exploiting a booster principle should provide fast multiplication of initial neutrons produced by an electron beam in the electron-neutron converter. So, its design has to ensure as short time τ as possible for one neutron generation ($\tau \leq 10$ ns) within a subcritical blanket, the total duration of a fast neutron pulse of about 400 ns with the repetition rate of 150 Hz, and neutron yield at a level of 10^{15} n/s. To ensure the lowest neutron background in between pulses, the metallic plutonium was chosen as fuel for which the delayed neutron tail consists of only 6%.

The IREN source consists of three basic parts shown in Fig.1: vertically located electron linear accelerator LUE-200 with the vacuum pipeline for transportation of the beam to the electron-neutron converter which is situated in the center of the multiplying subcritical blanket, containing about 24 kg of highly enriched (more than 95% of ^{239}Pu) metallic plutonium. It is equipped by the closed helium gas cooling system and the additional external air-cooling system.

Comparison of the IREN source with other neutron source aimed for nuclear physics

Neutron source (Laboratory)	$<I_n>$ 10^{15}n/sec	C, 10^7	τ, ns	Δt (at 100 eV),ns
FAKEL (IAE, Russia)	0.003	0.03	50	200
ORELA (ORNL, USA)	0.13	1.5	30	180
LUE-40+IBR-30 (Dubna, shutdown)	0.5	6	1600	4500
LANSCE (LANL, USA)	10	30	125	300
CERN n TOF facility	0.4	5	10	200
GELINA (IRMM,Belgium)	0.05	0.6	1	160
IREN (Dubna, project)	1.0	10	400	430

$$\phi(E_n)=C/E_nL^2$$

General scientific program for IREN source:

Fundamental nuclear physics:

- Search for violation of time invariance with polarized resonance neutron and polarized or aligned nuclear target;
- Study of parity violation in neuron induced reactions (fission, (n,α), (n,p), (n,γ));
- Electromagnetic structure of the neutron;
- Quantum aspects of neutron induced fission;
- Phase transitions in excited compound-nuclei-chaos and order in complex quantum systems.

Applied nuclear physics:

- Nuclear data for astrophysics;
- Nuclear data for technology;
- Isotope and element analysis with resonance neutrons.

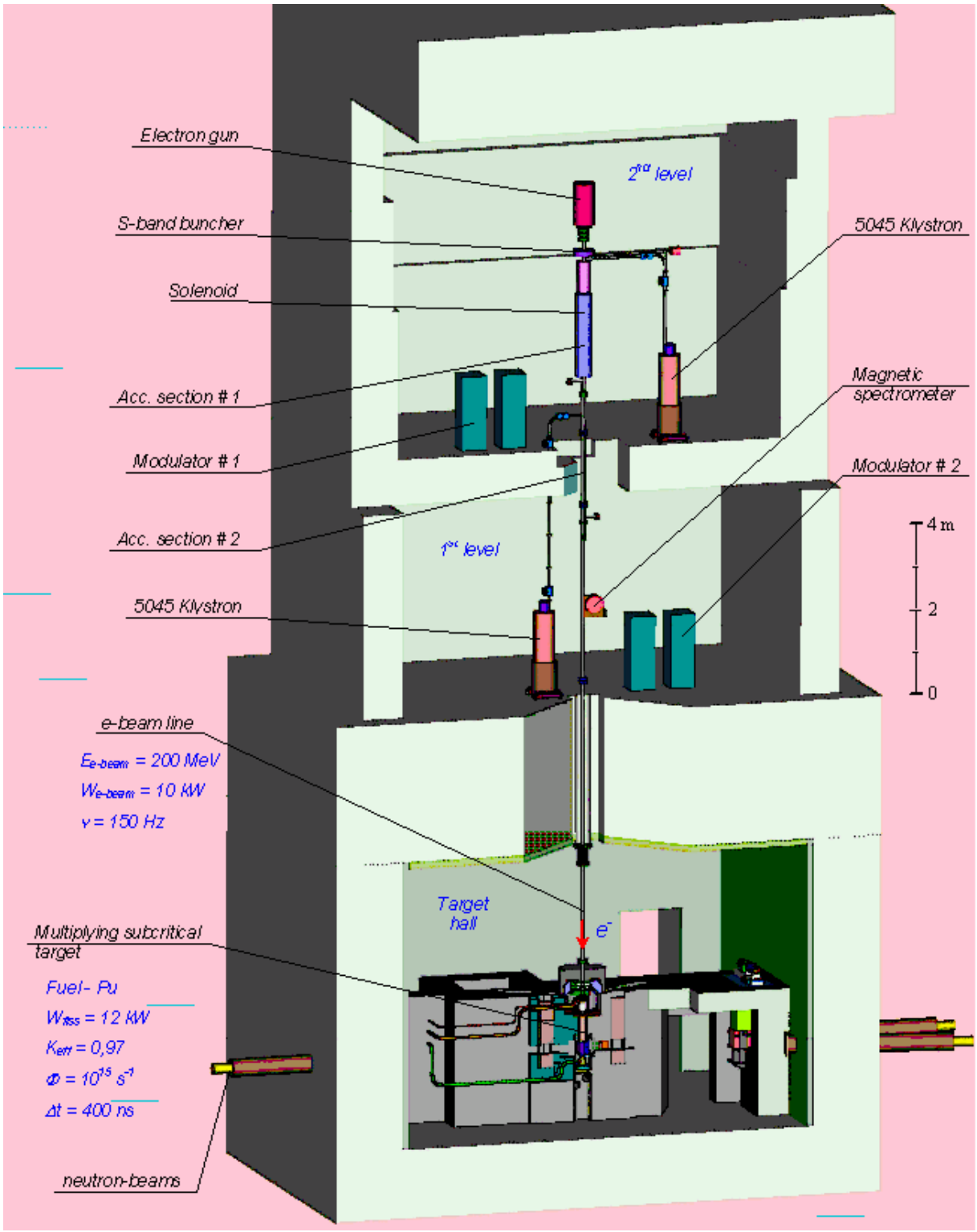

Fig.1. General layout of the IREN source.

Future Experiments at IREN

06-4-1036-2001/2004	Priority: 1
	Status: In-progress

Nuclear Physics with Neutrons — Fundamental and Applied Investigations

Leader from JINR: W. Furman, V. Shvetsov

Participating countries and international organizations: Australia, Austria, Belarus, Belgium, Bulgaria, China, Czech Republic, Egypt, France, Germany, Japan, Latvia, Mongolia, the Netherlands, Norway, Poland, Republic of Korea, Slovak Republic, Romania, the USA, Ukraine.

Fundamental Nuclear Physics

Experimental and methodical developments planned for high-resolution neutron sources (IREN, nTOF, ORELA):

- Tests of the Time-Reversal Invariance:
  - 3-fold correlation (KaTRIn);
  - 5-fold correlation (POLYANA).
- Study of Polarized, Aligned and Unpolarized Nuclei Fission;
- Study of phase transitions chaos-order in excited nuclei by means of (n,2γ) reaction investigation;
- Electromagnetic Structure of the Neutron:
  - electric polarizability and mean-square radius of the neutron.
- Nuclear data for science and technology;
- Isotopic and elemental analysis with resonance neutrons.

Research focused on high flux neutron sources (IBR-2, ILL, JAGUAR, PSI, PIK):

- Parity violation effects in low energy region;
- Neutron spin precession in the nuclear field;
- Investigations of the delayed neutrons on "ISOMER" facility;
- Ultracold Neutron Studies at ILL;
- Quantum Optics of the Long Wavelength Neutrons;
- Direct Measurements of nn-scattering.

Applied research

- Ecology:
  - biomonitoring of heavy metal pollutions at Central Russia, South Ural, Europe, Republic of Korea, China, Macedonia, Turkey, USA, Great Britain;
  - food quality testing;
  - workplace monitoring at fertilizer plants in Russia.
- Materials science:
  - studying the impurities at artificially grown diamonds;
  - analysis of archeological ceramic samples.
- Biotechnologies:
  - development of the pharmaceuticals based on the blue-green alga Spirulina platensis.
- Design, construction and calibration of the neutron detectors for planetary physics;
- Design and creation of the novel-type neutron detectors.

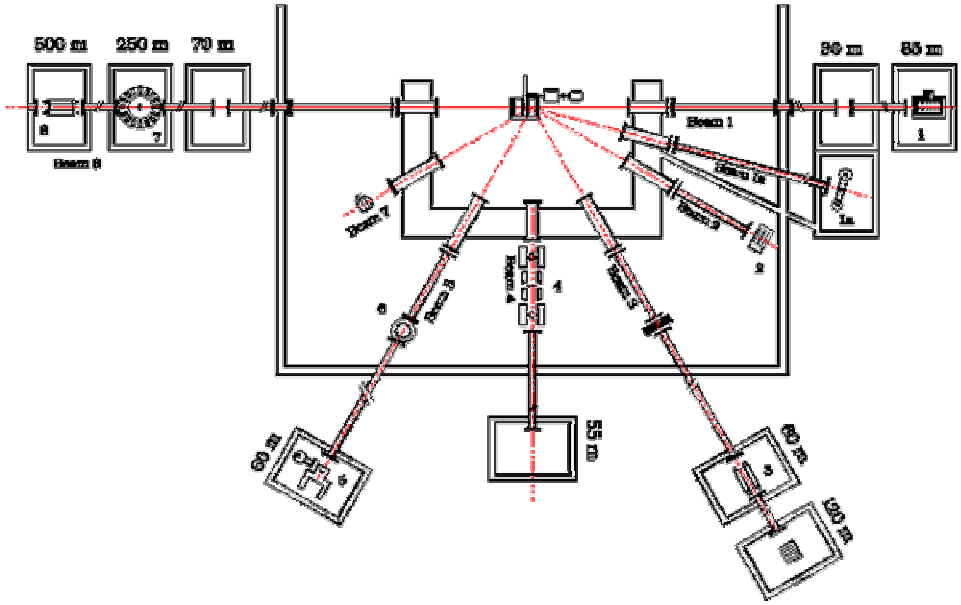

Fig.2. IBR-30/IREN experimental halls and pavilions plan view.

1 – beam #1: PARKS facility for (n,p), (n,α) reactions studies; 2 – beam #2: test beam; 3 – beam #3: PARUS facility for experiments on neutron/gamma multiplicity measurements; 4 – beam #4: POLYANA facility for experiments with polarized neutrons/nuclei; 5 – beam #5: AFFAAS facility for studies of angular correlations of fission fragments from resonance neutron induced fission of the aligned nuclei; 6 – beam #6 (250 m flight path): UGRA time of flight spectrometer for elastic neutron scattering measurements at keV energies; beam #6 (500 m flight path): ROMASHKA facility for experiments on neutron/gamma multiplicity measurements; 7 – beam #7: test beam.

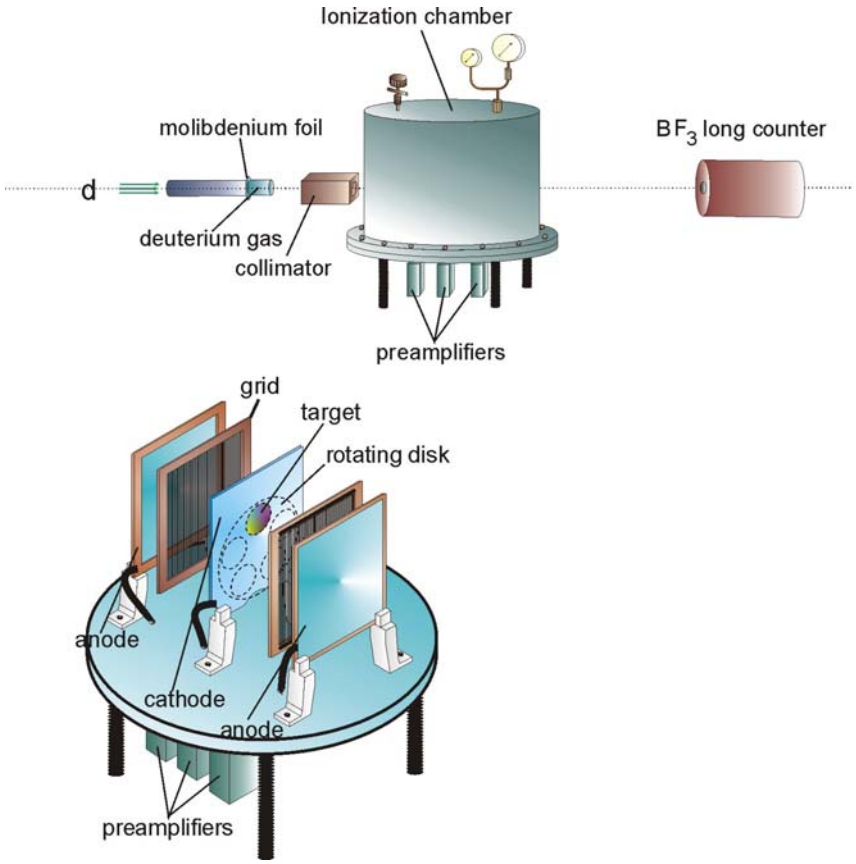

Fig.2. Sketch of ionization chamber used at PARKS facility for (n,p), (n,α) reactions cross-section measurements (bottom left corner) and scheme of the experiment (top).

Applied Research

06-4-1036-2001/2004	Priority of the project:
	Status: Data taking

REGATA (Russian–European GAte To Asia)

Leader from JINR: M. Frontasyeva

Participating countries and international organizations: Bulgaria, China, Czech Republic, Mongolia, Poland, Republic of Korea, Romania, Russia, Slovak Republic, Turkey, Ukraine, Vietnam.

Increased concern in air pollution with toxic heavy metals in industrialized countries has lead to establishing the international programme "Atmospheric Heavy Metal Deposition in Europe: — *estimations based on moss analysis*". The data from the regular surveys for heavy metal concentrations in mosses are an invaluable resource for international negotiations on heavy metal pollution. These data allow both spatial and temporal trends in heavy metal concentration/deposition to be examined, and the areas where there is high deposition of heavy metals from long-range transport to be identified. The Task Force on Heavy Metals was established by the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (UNECE — CLRTAP) as a response to the concern over the accumulation of heavy metals in ecosystems, and their impacts on the environment and human health.

The moss survey objectives are to characterize qualitatively and quantitatively the regional atmospheric deposition pattern of heavy metals in Europe, to indicate the location of important heavy metal pollution sources and to allow retrospective comparison with similar studies repeated every 5 years. Content of heavy metals in moss is closely correlated to atmospheric deposition, and conversion to absolute deposition rates by calibration against metal content in the bulk precipitation data is rather straightforward.

Since 1995 Department of NAA FLNP JINR has been involved in the European programme reporting results to the **European Atlas** from the moss survey 1995/1996 (1) and 2000/2001 (2). The Department of NAA FLNP initiated similar biomonitoring projects in Turkey, China and South Korea. Two more Asian JINR member-states — Mongolia and Vietnam — revealed interest in biomonitoring studies in collaboration with the Dubna team.

Instrumentation: a combination of instrumental epithermal activation analysis (ENAA) using radioanalytical complex REGATA at the reactor IBR-2, FLNP JINR in Dubna and atomic absorption spectrometry (AAS) in participating countries provides data for concentrations of about 40 chemical elements (Al, **As**, Au, Ba, Br, Ca, **Cd**, Ce, Cl, Co, **Cr**, Cs, **Cu**, Dy, Eu, **Fe**, Hf, **Hg**, I, In, La, Lu, Mg, Mn, Na, Nd, **Ni**, **Pb**, Rb, Sb, Sc, Se, Sm, Ta, Tb, Th, **V**, W, Yb, **Zn**) that substantially exceeded the requested number of elements (marked as bold) normally presented in the European Atlas. Not all the above trace elements are strictly relevant as air pollutants, but they come from the multi-elemental analyses with insignificant extra cost, and most of them can be used as air-mass tracers. By applying multivariate statistical analysis to the data sets, it is possible to uncover the character and the origin of pollution sources within an area under investigation, as well as those sources affecting this area through long-range atmospheric transport.

Most advanced Russian developments of GIS (geographical information system) technologies for the purposes of environmental monitoring are widely used for interpretation of the distribution of heavy metals over examined territories. The program GRINVIEW from the geographical information system software package GIS-INTEGRO with raster and vector graphics was used to generate raster-based pollution contour maps for the elements of interest for the entire studied area. This system is supplied with interfaces for all international standard GIS: ARC-Info, MAP-Info, etc.

Our “home-made” Atlases are produced in addition to mapping provided by the UNECE ICP. Examples of maps constructed using GRINVIEW are given in Fig.1.

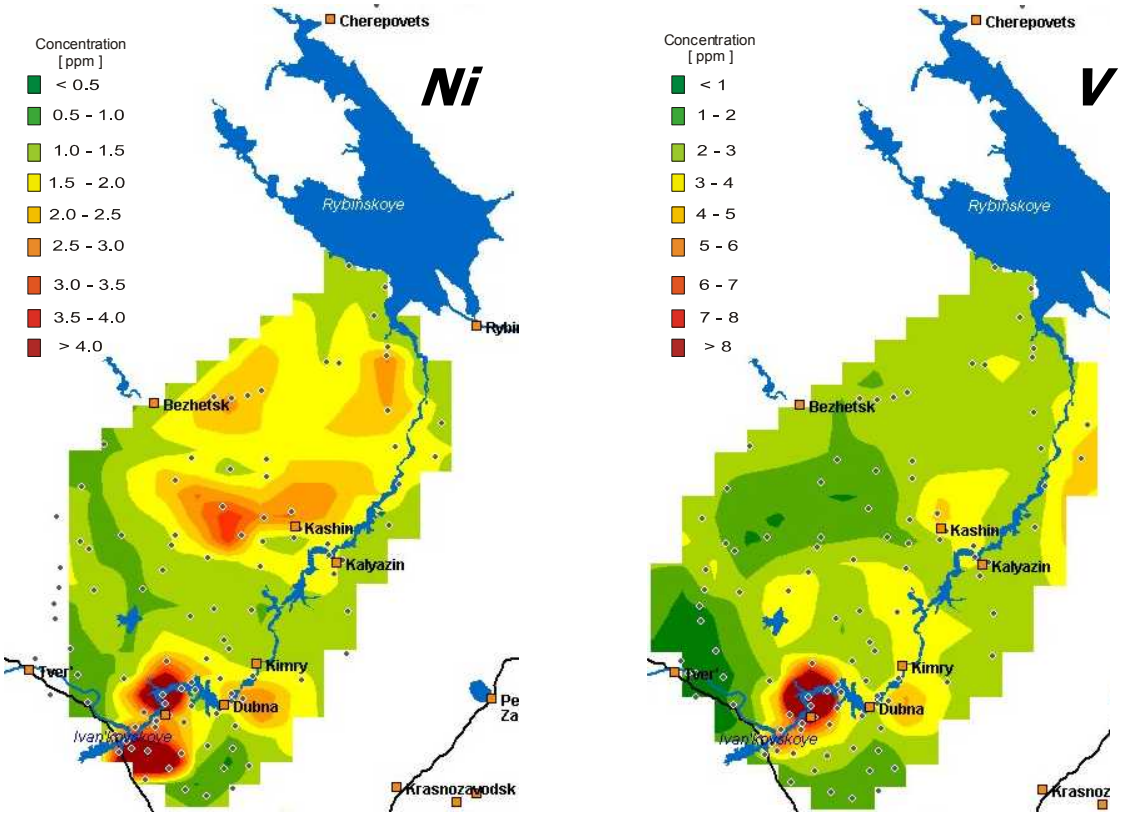

Fig.1. Distribution maps of nickel and vanadium in Central Russia (16).

The Department of NAA FLNP educates and trains young specialists from many countries in nuclear analytical technique to study environmental pollution as part of the framework for current international projects.