JINR: Current Activities and Prospects

Victor Matveev,
Dubna, December 3, 2014

RF-JINR-China-EU Forum.
International mega-science projects: growth points for Fundamental science and innovations.
Collaboration and perspectives of Russian and Chinese mega-projects
The agreement on the establishment of JINR was signed on 26 March 1956 in Moscow.
# Founders

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<tbody>
<tr>
<td>G. Flerov</td>
<td>V. Veksler</td>
<td>I. Frank</td>
<td>M. Meshcheryakov</td>
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<tr>
<td>V. Dzhelepov</td>
<td>N. Bogoliubov, D. Blokhintsev</td>
<td>B. Pontecorvo</td>
<td>H. Hulubei</td>
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<tr>
<td>L. Infeld</td>
<td>H. Niewodniczanski</td>
<td>L. Janossy</td>
<td>G. Najakov</td>
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<td>H. Niewodniczanski</td>
<td>B. Pontecorvo</td>
<td>H. Hulubei</td>
<td>Wang Ganchang</td>
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</table>
JINR has at present 18 Member States:

- Armenia
- Azerbaijan
- Belarus
- Bulgaria
- Cuba
- Czech Republic
- Georgia
- Kazakhstan
- D. P. Republic of Korea
- Moldova
- Mongolia
- Poland
- Romania
- Russian Federation
- Slovakia
- Ukraine
- Uzbekistan
- Vietnam

Participation of Egypt, Germany, Hungary, the Republic of South Africa and Serbia in JINR activities is based on bilateral agreements signed on the governmental level.
The agreement on the establishment of JINR was signed on 26 March 1956 in Moscow.

- 18 Member States
- 6 Associated Members States
- about 700 research partners in 60 countries
- staff members ~ 4500
- Doctors and PhD ~ 1200

JINR – a Centre of Broad International Partnership on the Russian Land

Three Pillars of JINR:

- Great experience and world-wide recognized traditions of scientific schools.
- Large and unique park of basic facilities for fundamental and applied research.
- Status of an international intergovernmental organization.
Committee of Plenipotentiaries

- Scientific Council
  - PAC for Particle Physics
  - PAC for Nuclear Physics
  - PAC for Condensed Matter Physics

- Directorate

- Finance Committee
  - Science & Technology Council
  - 7 Laboratories
  - University Centre
  - Office of Administration
JINR’s Science Policy


Road Map (2006-2017)

I.

Fundamental Science

Basic Scientific Directions

- High Energy Physics
- Nuclear Physics
- Condensed Matter Physics

Innovative activities

Education programme

Special Economic Zone “Dubna” Public-Private-Partnership

UC, DIAS-TH International Univ. “Dubna”
The results of the researches carried out at the Institute can be used solely for peaceful purposes for the benefit of mankind.
**JINR basic facilities**

**Nuclotron-M – NICA/MPD /SPD**
Superconducting ion and polarized particle accelerator and ion collider
Physics of ultrarelativistic heavy ions, high energy spin physics
Applied research

**Cyclotron complex U400, U400M**
Acceleration of heavy ions up to 50 MeV/u
Synthesis of super-heavy elements
Applied research

**Impulse reactor IBR-2M and Source of resonance neutrons IREN**
5 GHz pulses with 1,5 GW power and $10^{16}$ neutrons/cm$^2$sec
Accelerator driven neutron beam of 50 GHz up to $10^{13}$ neutrons/sec
Nuclear physics with neutrons, Condense matter physics
Applied research

**JINR’s Phasotron**
2 μA proton beam with the energy 660 MeV
Complex for Hadron Therapy
Applied research
JINR’s Large-Scale Basic Facilities

Particle Physics and High-Energy Heavy-Ion Physics

**Nuclotron-NICA**

- accelerated heavy ions $A \sim 200$
- beam intensity $\sim 10^9$ ion/cycle (0.2-0.4 Hz)
- at kinetic energy $\sim (1,0-4,5)$ GeV/u for Au$^{79+}$

**NICA/MPD:** Heavy Ion Collider with:

- maximum collision energy of $\sqrt{s_{NN}} = 11$ GeV
- average luminosity $\sim 10^{27}$ cm$^{-2}$ s$^{-1}$ (for Au$^{79+}$)
- polarized proton beams with energy $\sqrt{s} \sim 26$ GeV

Experimental study of hot and dense strongly interacting QCD matter and spin physics.
For the last decade JINR has become one of the leading scientific centres in the world in low energy heavy-ion physics.

U400 and U400M isochronous cyclotrons are combined into the accelerator complex – project DRIBs which deals with the production of beams of exotic light neutron-deficient and neutron-rich nuclei in reactions with light ions.

Number of observed decay chains

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<tr>
<th>Element</th>
<th>118</th>
<th>116</th>
<th>115</th>
<th>114</th>
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<td>26</td>
<td></td>
<td>Fe</td>
<td>Iron</td>
<td>26</td>
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</tbody>
</table>

- **112**: Chemical identification in 2006
- **113**: Discovered at JINR in 2003
- **114**: Discovered at JINR in 1999
- **115**: Discovered at JINR in 2003
- **116**: Discovered at JINR in 2000
- **118**: Discovered at JINR in 2001
The IBR-2M pulsed reactor of periodic action is included in the 20-year European strategic programme of neutron scattering research.

### Parameters

- **Fuel**: PuO$_2$
- **Active core volume**: 22 dm$^3$
- **Cooling**: liquid Na
- **Average power**: 2 MW
- **Pulsed power**: 1500 MW
- **Repetition rate**: 5 s$^{-1}$
- **Average flux**: 8·10$^{12}$ n/cm$^2$/s
- **Pulsed flux**: 5·10$^{15}$ n/cm$^2$/s
- **Pulse width**: (fast / therm.) 215 / 320 μs
- **Number of channels**: 14

Fundamental and applied research in condensed matter physics and related fields — biology, medicine, material sciences, geophysics, engineer diagnostics — aimed at probing the structure and properties of nanosystems, new materials, and biological objects, and at developing new electronic, bio- and information nanotechnologies.
Milestones in Condensed Matter Physics for the YEARS 2010-2016

- IBR-2M: operation at design parameters of the reactor
- Realisation of the full-scale cryogenic complex
- Complex of modern neutron spectrometers
- Wide international user policy

Condensed Matter Physics at IBR-2M (priority directions)

- Nanosystems and Nanotechnologies
- Biomedical Research
- Novel Materials
- Engineering Diagnostics. Earth Sciences
Network and telecommunication
2009: two important projects completed

1. JINR - Moscow 20Gbps telecommunication channel was put into operation.
2. Increase of the JINR Central Information and Computing Complex performance up to 2400 kSI2K and the disk storage capacity up to 500 TB

At present, JINR site is one of the 10 best sites of the worldwide Grid infrastructure (WLCG)
~ 4 million Jobs (using ~166 million normalized CPU time) were executed during the first eight months of 2014.

Local users (no grid)

Normalized CPU time share: JINR Laboratories and experiments in 2014.
CERN – participation in 15 projects, including 3 LHC experiments: ATLAS, CMS, ALICE with the total contribution of 25 M Swiss francs.

The JINR physics teams in ATLAS, CMS and ALICE are working on several important physics analysis subjects and strongly participating in preparation for the data taking.
A vitally important task is attracting of young people from all the Member States to science.

EDUCATIONAL PROGRAMME

JINR UNIVERSITY CENTRE

More than 400 students and postgraduates from Member States are trained at the UC.

Chairs: MSU, MIPT, MEPI, MIREA, others

JINR is a school of excellence for the Member States!

“Dubna” International University

The UC offers graduate programmes in the fields of:

- Elementary Particle Physics
- Nuclear Physics
- Theoretical Physics
- Condensed Matter Physics
- Technical Physics
- Radiobiology

Dubna International Advanced School on Theoretical Physics
JINR Educational Program in 2014

By the beginning of 2014/2015 academic year 226 graduate students have taken part in various JINR educational programs. The JINR PhD program is currently being updated according to a new “Law on Education in RF” and according to the goals of the JINR seven-year plan.

International Student Practice (ISP)

In total 139 students from 9 JINR Member States have participated in three stages of ISP-2014 (129 last year): ARE-24, Belarus-8, Bulgaria-2, Czech Republic-23, Poland-22, Romania-13, Slovakia-9, South Africa-32, Serbia-5

JINR Summer Student Program (SSP)

http://students.jinr.ru

In 2014 JINR UC has launched the Summer Student Program. The main distinction of SSP from ISP is a selection of participants on a competitive basis. In 2014 the SSP was organized in the field of accelerator physics and information technologies. 30 applications were received and 8 participants in SSP from ARE, Poland, Czech Republic and Russia were selected by VBLHEP and LIT. In 2015 SSP the scientific fields will be extended to include all JINR research areas.
JINR Outreach Activity in 2014

The programs for the teachers from JINR Member States at CERN and JINR started in November 2009. Up to now 5 programs at CERN (193 participants) and 5 programs at JINR (212 participants) have been held. This year the University Center received 122 applications from 5 Member States to participate in the 6th Russian Language Teacher Program at CERN.

Scientific-engineering group at UC

The scientific-engineering group at the University Center was created to implement training programs for engineering physicists. UC will be ready to offer such programs for the Member States Universities starting from the spring of 2015.
## JINR (Web of Science)

### 2011-2013

- Total number of publications: **2618**
- Total number of citations: **20370**
- h-index: **47**
- Budget (2012): **126** million USD

### 2013

- Total number of publications: **852**
- Total number of citations: **1291**
- h-index: **13**
- Budget (2013): **143.2** million USD

## CERN (Web of Science)

### 2011-2013

- Total number of publications: **3127**
- Total number of citations: **27093**
- h-index: **55**
- Budget (2012): ≈ **1206** million USD

### 2013

- Total number of publications: **1116**
- Total number of citations: **2264**
- h-index: **16**
- Budget (2013): ≈ **1264** million USD
Cooperation with National Research Center “Kurchatov Institute”

Cooperation and Common Participation in LHC Experiments

- XFEL and FAIR projects. NRC KI – coordinator of RF participation in those European megaprojects. JINR is responsible for delivery and development of many key accelerator and detector technologies in the FAIR and XFEL projects.

- Information Technologies: Tier-2 and Tier-1 Centers for International Experiments

- Superconducting technologies and cryogenics: currents leads for NICA, large cryogenics systems for LHC

- Detector technologies for Particle Physics

- Neutron Physics (PIK – IBR-2)

- Theoretical Physics
The Special Economic Zone in Dubna
(Nucleophysical Technologies)
SEZ main specialization

Nanotechnologies
- COPPER MICROTBUES
- METALLIC NEEDLES

Radiation medicine
- Hadron therapy

IT and Telecommunication
- Safety systems
At JINR an advanced technology has been developed to produce nuclear membranes by using unique multicharged ion cyclotrons.

On the basis of this technology the nuclear membranes can be produced from various polymeric films.
The Joint Institute for Nuclear Research and Chinese scientific centres and universities have resumed their fruitful and mutually beneficial cooperation.
Cooperation with China

JINR Vice-Director in 1959-1962
Academician Wang Ganchang

LHE, JINR, 1960. From left to right: V.Veksler (USSR), Din Datsao (CPR), Kim Hi In (PDRK), Nguyen Din Ty (SRV), A.Mihul (SRR).
2006: Russian Year in China
2007: Chinese Year in Russia
JINR-China negotiations are in progress

September 2006
JINR-CHINA COOPERATION

Chinese young scientists on a visit to the JINR Laboratory of Nuclear Reactions. The Leader of the group - Dean of the Physics department of Beijing University Professor Jangling Je.

From left to right: Leading engineer Yu.Gue (China), Academician V.Kadyshhevsky (JINR), post-graduate Ty.Song (China)

S.Krupko and Professor Yangling Je
Agreement Between Institute of Theoretical Physics of CAS and BLTP JINR Since 2010

**Nuclear Theory:** fusion reactions, nuclear structure and properties of superheavy nuclei  
**Few body systems:** high-precision spectroscopy of light atoms  
**Elementary Particle Physics:** high-precision calculations for experiments at electron-positron colliders, QCD and hadron structure  
**Modern Mathematical Physics:** integrable systems, quantum groups, supersymmetry & gravity

**Joint Workshops on Nuclear Physics:**  
2010 (Dubna), 2011 (Beijing), 2012 (Dubna), 2013 (Beijing), 2014 (Dubna)  
**Organizers:** BLTP and Key Laboratory of Frontiers in Theoretical Physics (KLFTP-ITP)

**Collaboration**  
KLFTP, Beijing University, China Institute of Atomic Energy, Institute of Modern Physics, Institute of High Energy Physics, Chern Institute of Mathematics, Nankai University, Wuhan University

- **2 PhD students** in BLTP from Shanghai Jiatong Uni. (2 months) and Wuhan Uni. (1 year as JINR fellow)  
- **1 BLTP researcher** – 1 year research fellowship at KLFTP

**Joint publications 2009-2013:**  
Phys. Rev. A(C) – 12 papers, EPJA(C) – 4 papers, Conference Proceedings - 5

**Grants** RFBR-NSFC – 2
Collaboration with Frank Laboratory of Neutron Physics since 1990

Measurements of total, partial and differential cross sections of (n,p), (n,α) reactions for various isotopes

Main workteam
- FLNP JINR: Yu.M.Gledenov, M.V.Sedysheva
- Peking University: Zhang Guohui, Chen Jinxiang
- NUM, Mongolia: G.Khuukhenkhuu
- UL, Lodz, Poland: P.Szalanski
- ORNL, USA: P.E.Koehler
- LNP JINR: V.A.Stolupin

Identical detectors produced in FLNP JINR installed at
- Van de Graaff accelerator EG-4.5 in IHIP PU, Beijing
- Van de Graaff accelerator EG-5 in FLNP JINR, Dubna

Output: more than 40 publications in
JINR at BES-III experiment (IHEP, Beijing)

- The BES-III experiment in Beijing is the world's best facility to test Standard Model and QCD with high precision in tau-charm domain.
- No hardware contribution.
- Main activities of JINR group:
  - preparation of physics program
  - software development
  - physics analysis
- JINR group members:
  - DLNP senior staff - 6, PhD students - 3
  - BLTP senior staff - 4
  - LIT senior staff - 5, PhD students - 2, graduate students - 2

JINR group is currently one of the main software developers in BES-III
Upgrade of the Technical Design Baseline of the HITFiL injector cyclotron

A new accelerator complex Heavy Ion Therapy Facility in Lanzhou is under construction at the IMP, LanZhou, P.R.China. In this project, a 7MeV/u $^{12}$C$^{5+}$ cyclotron is selected as the driving accelerator providing 10μA, $\varepsilon=20$ π mm.mr, $\Delta W/W \leq \pm 1\%$ carbon beam. It is conceived as an injector for the HITFiL synchrotron, which accelerates carbon ions to the energy 300MeV/u for tumors treatment.

Daya Bay experiment - Precise $\sin^2 2\theta_{13}$ measurement

Institute of High Energy Physics (Beijing) + 20 other institutions/universities from China within collaboration.

JINR contribution:
- PPO production (1.5 tons) for liquid scintillator
- Plastic scintillator muon veto option offered
- MC simulation and data analysis

Main results:
- Discovery of non-zero $\theta_{13}$, Precise $\sin^2 2\theta_{13}$ measurement

Main publications:
Cooperation in Mega-Science Projects: NICA, SHE, C-tau, EAST, HIAF, Daya-Bay, BEPC

JINR Partners in China

- Institute for Plasma Physics (ASIPP)
- Institute of High Energy Physics of the Chinese Academy of Sciences), Beijing — IHEP CAS
- China Institute of Atomic Energy, Beijing — CIAE
- Institute of Modern Physics of the Chinese Academy of Sciences, Lanzhou — IMP CAS
- HuaZhong Normal University;
- Institute of Particle Physics, Wuhan — HZNU
- University of Science and Technology of China, Hefei — USTC
The First ASIPP-JINR Workshop on Energy S&T and the Applications
ASIPP, Hefei, January 23-25, 2014

The implementation of this mega-science project is an important activity for strengthening the Chinese-Russian cooperation in scientific and technology and strongly meets the interests of the both Parties. The ASIPP expressed a strong interest to participate in construction of the NICA.

This activity will encourage the expansion of comprehensive Chinese-Russian cooperation in priority areas of science, technology and engineering.

The ASIPP and JINR Directorates address to the respected ministries of their countries to support this fruitful cooperation and create the corresponding dedicated partnership Programme China-Russia.
Subcommission notes active cooperation between RF, JINR and China in megascience program and especially beneficial cooperation between JINR and China scientific centers (ASIPP, IHEP CAS, IMP CAS, Tsinghua University, USTC) in NICA and EAST megaprojects. Scientific program of the NICA had been recognized as highly perspective for participation of China centers. Sides agreed to perform required agreement procedures to prepare signature of the Memorandum on the Governmental level providing China participation in the NICA megaproject.
Unique Dubna technologies of fast-cycling superconducting magnets tested during several tens of Nuclotron runs and chosen as basic for accelerator complexes NICA and FAIR

Common European Research infrastructure for Heavy Ion High Energy Physics: NICA + FAIR
Cooperation with Italy

The Joint Institute for Nuclear Research has been maintaining scientific contacts with Italian physicists since the JINR establishment.
Cooperation with Italy

BOREXINO collaboration

OPERA collaboration
Conclusions

• Being a world leader in some domains of Nuclear Physics (e.g., synthesis of superheavy elements) and visible partner in major world projects (Tevatron, RHIC, LHC, ILC, FAIR, XFEL and others) JINR now proposes its home facilities (NICA) and services to become available for wider scientific community.

• We are glad to invite partners from NRC KI, China, Germany, Italy, Egypt, Romania, France, Hungary, and others to join NICA at JINR and also other scientific activities building real international collaboration!
Welcome to JINR (Dubna)
THANK YOU!
International Mega-science Projects:
Growth Points for Fundamental Science and Innovations
Collaboration and Perspectives of Russian and Chinese Mega-projects

Ministry of Science and Technology,
People's Republic of China

Inst. of Plasma Physics, CAS
Inst. of HEP, CAS
Inst. of Modern Physics, CAS

Univ. of Science and Technology
Tsinghua Univ.
Peking Univ.
Fudan Univ.
Guanzhou Univ.

Germany (FAIR)
Italy (INFN, Univ.)
Hungary
France (IN2P3, CNRS)

NRC KI
B.P.Konstantinov
Petersburg Nuclear Physics Institute

Egypt
• Nuclear physics and particle physics;
• Plasma physics;
• Neutron reactors;
• Superconducting technologies and low temperature cryogenics;
• New energetics, power saving technologies;
• Information technologies;
• Radiobiology, astrobiology and radiation medicine;
• Future facilities
European commission on Russian mega-science projects (May-Dec 2013)

The fact that NICA/JINR are part of the EU research infrastructures landscape has already been recognized by ESFRI. The Expert Group (EG) recommends that the NICA project be fully taken into account in the forthcoming discussions on the next update of the ESFRI Roadmap. The EG encourages JINR to continue actively develop new and extended cooperation with potential European partner institutions. The exceptional opportunities available in Dubna to young scientists and engineers should be more widely promoted.

HORIZON - 2020

08 Aug’13: Representatives of 13 countries, 6 signed (Belarus, Bulgaria, Germany, Kazakhstan, RF, Ukraine). China and South Africa – discussions are going.

The Parties have agreed to inform their Governments about the Meeting on Prospects for Collaboration in the Mega-Science Project “NICA Complex” and to express their interest in preparing corresponding multilateral Agreement and in taking steps for approval by their countries

Germany (BMBF, GSI) – Test Facility for SC magnets and Si tracker Lab; MoU, 16M€

China (ASIPP) – to the HTSC current leads, SC magnets, vacuum systems; MoU

USA (FNAL) – to the NICA collider stochastic and electron cooling systems; MoU, ~1M$

CERN – to the MPD elements, etc (drift chambers, MM systems…); MoU, ~2MCHF

Rep. of South Africa – cryostats, diagnostics for SC ion source, cryogenics. MoU, ~1M$
5. The Parties have agreed to inform their Governments about the Meeting on Prospects for Collaboration in the Mega-Science Project “Complex of Superconducting Rings for Heavy Ion Colliding Beams” – the NICA Complex and to express their interest in preparing a corresponding multilateral Agreement and in taking steps towards its approval by their countries.

Signed:

E. Kozlov
for the State Committee of Science and Technology of the Republic of Belarus

L. Kostov
for the Nuclear Regulatory Agency of the Republic of Bulgaria

B. Vierkorn–Rudolph
for the Federal Ministry of Education and Research (BMBF) of the Federal Republic of Germany

I. Zuev
for the Atomic Energy Committee of the Ministry of Industry and New Technologies of the Republic of Kazakhstan

N. Bonehaw
for the Ministry of Education and Science of the Russian Federation

A. Povalko
for the State Agency for Science, Innovation and Informatization of Ukraine

B. Grynyov
for the Joint Institute for Nuclear Research

V. Matveev

Representatives of 13 countries
Parties agreed to join their efforts in the construction of both FAIR & NICA in:

- construction of cryogenic facility at LHEP JINR to provide the assembly & the cold tests of superconducting magnets for the NICA synchrotrons & 175 quadrupole modules for FAIR SIS100

- preparation of clean area at LHEP JINR for the assembly and test of silicon tracking detectors for BM@N, MPD & CBM

- stimulation of joint research & educational programs for young scientists
Test Facility for SC magnets of NICA and FAIR: excellent collaboration of JINR and Germany (BMBF) – around $15 \text{ MEuro}$ investments from BMBF to NICA

The 1-st arm has been put in operation in Aug’14. 1\textsuperscript{st} cold test of the Booster magnet made few days ago.
China Institutes and Industry could contribute to NICA:
- high-temperature superconducting current leads (HTSC) for 100A-20 kA;
- high-vacuum systems and UHV elements;
- power supplies;
- compact screw compressors, cryogenic lines;
- copper bus for coils of magnets, trim coils for large detector MPD;

Overall contribution - around 10 M$ (incl. R&D). Optimal scheme for China's real participation in the NICA: organization of the Joint Research Program in China funding these Contracts for Chinese Institutions.

**JINR could contribute to Chinese mega-projects:**
- superconducting hollow cable and coils for different magnet systems;
- Design/construction/testing of compact cyclotron for medical purposes and for industrial purposes (track membrane, isotopes);
- Large cryogenics

Exchange in both directions (CAS, MOST and JINR) for:
- education, practice, scientific research.
- Engineers training and getting valuable experience at NICA.
<table>
<thead>
<tr>
<th>N</th>
<th>Item for in-kind contribution</th>
<th>Number</th>
<th>Period of delivery</th>
<th>Required funding</th>
<th>China partner (supplier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High-temperature superconducting current leads (HTSC) for 100-1000A and 10-20 kA (for Test Facility, collider, Booster)</td>
<td>24 pairs</td>
<td>2015-2019</td>
<td>1.5 M$</td>
<td>ASIPP, Industry</td>
</tr>
<tr>
<td>2</td>
<td>Vacuum systems and elements (cryostats with thermal shields, vacuum chambers); - cryogenic lines</td>
<td>~ 100</td>
<td>2015-2019</td>
<td>1.3 M$</td>
<td>ASIPP, IMP CAS, USTC</td>
</tr>
<tr>
<td>3</td>
<td>Power supplies (10-15 kA, 25/250V) + (100-1000 A, 25/250V) with ultra precise feed-back. Large transformers (&gt;1MW)</td>
<td>3 + 20 2-4</td>
<td>2015-2018</td>
<td>3.2 M$</td>
<td>ASIPP, Industry</td>
</tr>
<tr>
<td>4</td>
<td>MPD detector (TOF: mRPCsystems, end-caps, gas system, electronics, etc). Trim coils supporting rings and basic support of MPD, moving system.</td>
<td>-</td>
<td>2015-2018</td>
<td>~ 3.2 M$</td>
<td>IHEP, ASIPP, USTC, Tsinghua Univ., Hefei Univ., MP CAS, others</td>
</tr>
<tr>
<td>5</td>
<td>“Warm” magnets for beam channels from Nuclotron to collider (335 m in total): - Dipole magnets - Quadrupole magnets And power supplies for those channels.</td>
<td>28 (2m) 50 (0.5m)</td>
<td>2016-2019</td>
<td>~ 4.3 M$</td>
<td>IMP CAS, ASIPP, Industry</td>
</tr>
<tr>
<td>6</td>
<td>Theoretical physics, International Scientific cooperation (student and PhD programs, Engineering practice, workshops, Round tables, etc)</td>
<td></td>
<td>2015-2020</td>
<td>200 k$/year (total 1 M$)</td>
<td>IHEP, Tsinghua Univ., ASIPP, Beijing Univ, Fudan Univ., IMP CAS, ...</td>
</tr>
</tbody>
</table>

**Total**: 2015-2020 ~ 17 M$
A low energy proton beam (25-400 MeV) was shaped to test electronic equipment for operation in space.

Scheme of experiment of low energy proton beam formation

Around 100 patients are treated per year on Phasotron proton medical beams. In total ~ 1400 patients have been treated since 2000.
“DVIN” detector for drugs and explosives

On the basis of the technique, a unique method of tagged neutrons is used

The advantages of the technique:
- High sensitivity to the element content of the substance (up to 50 elements)
- 3D-imaging of the objects
- The possibility to determine the spatial location of objects inside a closed volume
- Big scanning depth for closed volumes (up to 1.5m deep)