Almost 50 years long way from the theoretical hypothesis on the nature and mechanism of generation of masses of the heavy vector fields of the Electroweak Interactions (W,Z bosons) to the direct experimental observation at the Large Hadron Collider in CERN marked in 2012 by the Nobel Prize

What is the next?
At the border of the XX-XXI centuries

Elementary Particle Physics, Nuclear Physics, Astrophysics and Cosmology are developing in a close interrelation as a unique direction of the fundamental research on the edge frontier of the modern nature science = the Fundamental Physics whose goal is search of the primary unique universal laws of Nature which are governing phenomena in both – the micro and macro worlds and relate the deep structure of matter with evolution of our Universe as a whole.
Main Puzzles of Fundamental Physics in the new Millenium

What gave first push to our Universe birth?

Physics of the Big Bang and evolution of the early Universe:

* The Inflation hypothesis (exponentially fast expansion and generation of spectra of inhomogenities)
* Evolution of the Hot Universe
* Nucleosynthesis
* Acceleration of the Universe expanding
Very Broad Scientific International Cooperation in

*Energy & Intensity Frontiers*

Europe, US & Latin America, Asia, South Africa

International labs: CERN (est. 1954) & JINR (est. 1956)
Where is JINR?
JINR’s partners are about 700 institutions located in 60 countries, including about 300 institutions and universities from the JINR Member States
JINR’s Basic Scientific Directions

- High Energy Physics & Relativistic Heavy Ion Physics
- Nuclear Physics
- Condensed Matter Physics
- Radiation Biology & Astrobiology

Main Supporting Activities
- Networking and computing
- Physics instruments and methods
- Training of young specialists
JINR Research Facilities

• Complex Nuclotron-NICA (Mega-Science Project): High density & strong interacting matter search
  • Pulsed reactor IBR-2: Condensed matter & Nuclear physics
  • Accelerators Complex: New heavy elements synthesis
  • Complex of computing & information technologies
  • Accelerators complex: Applied and & medical sciences, proton therapy
High Energy Physics @ JINR
From Synchrophasotron to Nuclotron to NICA

1957 - Synchrophasotron

10 GeV proton accelerator – world leader in energy.

Beginning of era of high-energy physics

V. Veksler – phase stability principle discovery

1993 – Nuclotron

First in the world Superconducting Synchrotron of heavy ions

A. Baldin – start of relativistic nuclear physics era

2019 – NICA

Superconducting collider of heavy ions

Study of baryonic matter at extreme conditions

The JINR 7-year plan for 2010-2016 approved by CPP in 2009:
NICA – the JINR flagship project in HEP
2nd generation Heavy Ion experiments

**STAR/PHENIX @ BNL/RHIC.**
designed for high energy researches ($\sqrt{s_{\text{NN}}} > 20$ GeV),
low luminosity for LES program $L<10^{26}$ cm$^{-2}$s$^{-1}$ for Au$^{79+}$

**NA61 @ CERN/SPS.**
Fixed target, non-uniform acceptance, few energies
(10,20,30,40,80,160A GeV), poor nomenclature of beam species

3rd generation Heavy Ion experiments

**CBM @ FAIR/SIS-100/300**
Fixed target, $E/A=10-40$ GeV, high luminosity

**MPD & SPD @ JINR/NICA.**
Collider, small enough
$\sqrt{s_{\text{NN}}} = 4-11$ GeV, a variety of colliding systems,
$L\sim10^{27}$ cm$^{-2}$s$^{-1}$ for Au$^{79+}$

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

CERN-JINR School 2014
Present and future HI machines

Fixed target: L-limited by detectors
Colliders: scale of $L$, in cm$^{-2}$s$^{-1}$

- RHIC (BNL)
- SPS (NA-49/61, CERN)
- SIS-300 (FAIR)
- NICA (JINR)
- SIS-100 (FAIR)
- Booster (JINR)
- Nuclotron M (JINR)
- AGS (BNL)
- SIS-18 (GSI)
- Nuclotron (JINR)

BeamEnergyScan

Expected region of phase transition at max baryonic density

2018+
2019
2015+

10$^2$
10$^4$
10$^6$
10$^8$
10$^{10}$
10$^{12}$
10$^{14}$
10$^{16}$

$\sqrt{s_{NN}}$, GeV for Au+Au

CERN-JINR School 2014
BASIS: Asymptotic freedom of quarks

N. Bogolyubov, D. Shirkov
D. J. Gross, H. D. Politzer, F. Wilczek
A. Tavkhelidze, B. Struminsky, V. Matveev

But: Strong confining interaction at large distances

BASIS: Asymptotic freedom of quarks and in super-dense matter (inter-particle distances $\sim 1/T$)

Asymptotic freedom; charge anti-screening, confinement

Yukawa coupling; charge screening, deconfinement

super-dense matter could be obtained in heavy ion collisions

the access to “asymptotically free” regime in hard processes
FT experiment area
Nuclotron
Booster
New Linac
Lu 20
Collider

JINR NICA - in the list of international Mega-science projects in RF area

accelerator facility
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)

KRION-6T+HILac (3MeV/u), SPP and LU-20 (5MeV/u)

 Booster (600 MeV/u)

Nuclotron 0,6-4,5 GeV/u

Fixed target experiments area (BM@N, b.205)

NICA Collider (1-4,5 GeV/u, C=503 m)

MultiPurpose detector (MPD)
Booster synchrotron
Main observables @ NICA detector MPD

- Hadron multiplicities (4π particle yields: π, K, p, Λ, Ξ, Ω)
- Event-by-event fluctuations
- BE & FD correlations: Femtoscopy involving π, K, p, Λ, others
- Collective flow for identified hadron species and resonances
- Electromagnetic probes: electrons, photons, vector meson decays
- Hyper Nuclei & other exotic states
Towards the “deconfinement” & mixed phase

- Non-monotonic energy dependence of the \( \frac{K^+}{\pi^+} \) ratio (“Horn”) – onset of deconfinement?

Plateau in the apparent temperature of the kaon spectra (“Step”) – signal of the mixed phase?

CERN-JINR School 2014
NICA Mega-Science Project
International Consortium
6 countries

- Protocol signed by:
  - Belarus, Bulgaria, Germany, Kazakhstan
  - Russia, Ukraine

Dubna, August 08, 2013.
Scientific cooperation @ NICA projects

Belarus
- NC PHEP BSU (Minsk)
- GSU (Gomel)

Germany
- GSI (Darmstadt)
- JLU (Giessen)
- UR (Regensburg)
- Frankfurt/Main Univ.
- FIAS
- FZJ (Julich)
- FAU (Erlangen)

Poland
- Tech. University (Warsaw)
- Warsaw University
- Fracoterm (Krakow)
- Wroclaw University
- INP (Krakow)

Bulgaria
- INRNE BAS (Sofia)
- TU-Sofia
- SU
- ISSP BAS
- LTD BAS
- SWU
- PU (Plovdiv)
- TUL (Blagoevgrad)

Ukraine
- BITP NASU, KSU (Kiev)
- KhNU, KFTI NASU (Kharkiv)

Russia
- INR RAS (Moscow)
- NRC KI (Moscow)
- BINP RAS (Novosibirsk)
- MSU (Moscow)
- LPI RAS (Moscow)
- St. Pet. University
- RI (St. Petersburg)

Australia
- Azerbaijan
- CERN
- China
- France
- Georgia
- Greece
- India

RSA
- UCT (Cape Town)
- UJ (Johannesburg)
- iThemba Labs

Czech Republic
- TUL (Liberec)
- CU (Prague)
- Rzezh, ...

Italy
- Japan
- Moldova
- Mongolia
- Romania
- Serbia
- Slovakia
- USA
Super-Heavy Elements
Super Heavy Elements (DRIBs-III project)

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.

DRIBs (I,II,III) – Dubna Radioactive Ion Beams

<table>
<thead>
<tr>
<th>Element</th>
<th>Number of observed decay chains</th>
</tr>
</thead>
<tbody>
<tr>
<td>118</td>
<td>3</td>
</tr>
<tr>
<td>116</td>
<td>26</td>
</tr>
<tr>
<td>115</td>
<td>4</td>
</tr>
<tr>
<td>114</td>
<td>43</td>
</tr>
<tr>
<td>113</td>
<td>2</td>
</tr>
<tr>
<td>112</td>
<td>8</td>
</tr>
</tbody>
</table>

CERN-JINR School 2014
MAss-Separator of Heavy Atoms - “MASHA”

Mass-separator “MASHA” at the beam of U-400M

Detection of mercury isotopes at the focal plane

Mass measurement of $^{283}$Cn in reaction $^{48}$Ca+$^{238}$U started

Hot catcher
6 new heaviest elements

2013

48 new isotopes

118
116
115
113
111
110
109
108
107
106
105
104

105/266
0.37 h
105/267
1.2 h
105/268
1.2 d
105/270
23 h

104/267
1.3 h
104/267
1.3 h

118/294
0.9 ms
117/294
14 ms
117/294
78 ms
116/290
7 ms
116/291
18 ms
116/292
18 ms

115/287
32 ms
115/288
87 ms
115/289
0.22 ms
115/290
16 ms

114/286
0.13 ms
114/287
0.48 ms
114/288
0.8 ms
114/289
2.8 s

113/282
7.3 ms
113/283
0.1 s
113/284
0.48 s
113/285
5.5 s
113/286
20 s

112/282
0.8 ms
112/284
0.1 s
112/285
20 s

111/278
4.2 ms
111/279
0.17 s
111/280
3.6 s
111/281
26 s
111/282
0.2 s
111/283
5.5 s
111/284
9.00 s

110/279
0.2 s
110/279
9.70 s

109/274
0.46 s
109/275
9.7 s
109/276
0.72 s
9.71 s
109/277
9.7 s

108/275
0.19 s
9.30 s
108/276
9.55 s

107/270
61 s
107/271
9.8 s
107/272
9.8 s
107/274
53 s
8.20 s

106/271
1.9 min
8.54 s
106/271
9.02 s

GANIL (Caen, France)

RIAR (Dimitrovgrad, Russia)

Vanderbilt University (Nashville, USA)

FLNR, JINR (Dubna)

ORNL (Oak-Ridge, USA)

LLNL (Livermore, USA)

ANL (Argonne, USA)

GSI (Darmstadt, Germany)

TAMU Cyclotron Institute (Texas USA)

GANIL (Caen, France)

RIAR (Dimitrovgrad, Russia)

Vanderbilt University (Nashville, USA)
Two new elements in the Table
What is beyond 118 element?

Heaviest target: $^{249}\text{Cf} \rightarrow Z_{\text{max}} = 118$

- Heavier projectiles ($^{50}\text{Ti}$, $^{54}\text{Cr}$, $^{58}\text{Fe}$, $^{64}\text{Ni}$)
- Heavier targets ($^{251}\text{Cf}$, $^{254}\text{Es}$ -???)
- Symmetric reactions: $^{136}\text{Xe} + ^{136}\text{Xe}$, $^{136}\text{Xe} + ^{150}\text{Nd}$, $^{150}\text{Nd} + ^{150}\text{Nd}$;
- Nucleon transfer reactions ($^{136}\text{Xe} + ^{208}\text{Pb}$, $^{238}\text{U} + ^{248}\text{Cm}$).

Preparation to study $^{48}\text{Ca} + ^{251}\text{Cf}$ reaction (Spring 2014)
Russian Information Agency has recently published the result of widely distributed questionnaire about most significant discoveries by Russian researchers over last two decades. The list of those discoveries is opening with SHE synthesis at JINR.
**Super-Heavy Elements Factory – «SHEF»**

<table>
<thead>
<tr>
<th>Increased</th>
<th>Intensity beam &amp;</th>
<th>Beam time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today: $\sim 5 \cdot 10^{19}$</td>
<td>With SHEF: $1.5 \cdot 10^{21}$</td>
<td>factor: 30</td>
</tr>
<tr>
<td>~ 7000 h/year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Production**

- Super-Heavy Elements Factory – «SHEF» 2014

**With SHEF:**

- New accelerator
- $10$-$20$ pµA
- $1.5 \cdot 10^{21}$
- ~ 7000 h/year

**Today:**

- $\sim 5 \cdot 10^{19}$

**Factor:** 30

- fission reactors are the best source of low energy antineutrinos
- muon-neutrinos can be produced by allowing pions to decay in flight
- the Sun is a “most copious source of neutrinos”
- cosmic rays striking the Earth’s atmosphere should produce a significant flux of neutrinos from pion decay
- high-energy neutrinos produced by astrophysical objects would provide information not available from cosmic rays

B. Pontecorvo:
- proposed the first (radiochemical) method of neutrino detection and possibility of reactor experiments.
- was the first who came to an idea of \( \mu - e \) universality of the weak interaction.
- proposed the experiment with accelerator neutrinos to prove that \( \nu_\mu \) and \( \nu_e \) are different particles.
- was the first who came to idea of neutrino oscillations and proposed many experiments to check it.
New frontier

A lot more to learn

- Majorana or Dirac masses? \(\rightarrow 2\beta 0\nu\)-decays
- Absolute mass scale \(\rightarrow\) Katrin + cosmology + \(2\beta 0\nu\)
- Direct or inverse chierarhy \(\rightarrow\) Long baseline accelerator and reactor neutrino experiments
- CP-violation \(\rightarrow\) Long baseline accelerator experiments
- Electromagnetic properties \(\rightarrow\) Search for neutrino magnetic moment
- Sterile neutrinos?

JINR is an important player in nearly all of this

NEMO \(\rightarrow\) SuperNEMO, GERDA \(\rightarrow\) GERDA/Majorana
Daya Bay \(\rightarrow\) JUNO, NO\(\nu\)A
GEMMA
DANSS
60 years of reactor neutrino physics

1953 – first experiment at Hanford

2008 - Precision measurement of $\Delta m_{12}^2$. Evidence for oscillation

2003 - First observation of reactor antineutrino disappearance

1995 - Nobel Prize to Fred Reines at UC Irvine

1980s & 1990s - Reactor neutrino flux measurements in U.S. and Europe

1956 - First observation of (anti)neutrinos

Past Reactor Experiments
- Hanford
- Savannah River
- ILL, France
- Bugey, France
- Rovno, Russia
- Goesgen, Switzerland
- Krasnoyark, Russia
- Palo Verde
- Chooz, France

KamLAND

Daya Bay
Double Chooz
Reno
Experiments at Kalinin NPP

Fundamental and Applied Research:

- Search for Neutrino Magnetic Moment
- Measurement of Neutrino Fluxes and Spectra
- Search for Sterile Neutrino States
M. Markov, 1960:
"We propose to install detectors to determine the direction of charged particles deep in a lake or in the sea and with the help of Cherenkov radiation" Proc. 1960 ICHEP, Rochester, p. 578.
Neutrino Astronomy

Among others, underwater/under-ice detectors are special
Main advantage: large scale.

Multi-purpose

- Neutrino physics (in future) – mass hierarchy, CP-violation
  - With atmospheric neutrinos
  - Very long baseline experiments

- Search for dark matter: annihilations in the Earth and Sun
  \[ X + \bar{X} \rightarrow \pi^\pm + \cdots \rightarrow \nu, \bar{\nu} \]

- Search for exotica (magnetic monopoles, quark nuggets, violation of Lorentz-invariance...)

- Cosmic ray physics

- Environmental studies

- Many more
Neutrino Astronomy

Proof of Principle: BAIKAL

Newsmaker

The IceCube Neutrino Observatory

- Total of 86 strings and 162 IceTop tanks;
- Full operation with all strings since May 2011.

First neutrinos of cosmic origin

February, 2014
Arrival directions

**Water, volume ~ km³**

- Are there cosmic neutrinos indeed?
- Neutrinos from Galaxy or outside?
- Most likely from Galaxy, then
  - Point sources?
  - Galactic center (black hole)?
  - Fermi bubbles?

Key: angular resolution → water, not ice!

There must be hard gammas as well: both

\[ \pi^+ \rightarrow \mu^+ + \nu_\mu (\bar{\nu}_\mu), \text{ and } \pi^0 \rightarrow \gamma \gamma \]

HiScore, HAWK, CTA

---

**All this is within reach of Baikal GVD**

**Gigaton Volume Detector (Lake Baikal)**

- 10368 photo-sensors at 216 strings
- 27 subarrays (clusters with 8 strings)
- String: 4 sections, 48 photo-sensors
- Active depths: 600 - 1300 m
- To Shore: 4 - 6 km
- Instrumented water volume
  \[ V = 1.5 \text{ km}^3 \]
  \[ S = 2 \text{ km}^2 \]
- Angular resolution
  - Muons: 0.25 degree
  - Showers: 3.5-5.5 degree

---

**Good company: GVD, IceCube, KM3Net**

From left to right: Christian Spiering, Maarten de Jong, Tyce DeYoung, Zhan-Arys Djilkibaev, Juan-Jose Hernandez-Rey, Paschal Coyle, Olga Botner, Uli Katz.

October 15, 2013, München, MoU signing.
Future of Daya Bay is JUNO, aimed at neutrino mass hierarchy. Apart from the mass hierarchy, with JUNO it would be possible to look for SN-neutrinos, geo-neutrinos, sterile neutrinos and may be even CP-violation ...

**Reach physics goals**
- Supernova neutrinos (less than 20 events so far)
  - $\bar{\nu}_e + p \rightarrow n + e^+$, $\sim$ 3000 correlated events
  - $\bar{\nu}_e + ^{12}\text{C} \rightarrow ^{12}\text{B} + e^+$, $\sim$ 10-100 correlated events
  - $\nu_e + ^{12}\text{C} \rightarrow ^{12}\text{N} + e^-$, $\sim$ 10-100 correlated events
  - $\nu_x + ^{12}\text{C} \rightarrow ^{12}\text{C}^* + \nu_x$, $\sim$ 600 correlated events
  - $\nu_x + p \rightarrow \nu_x + p$, single events
  - $\nu_x + e^- \rightarrow \nu_x + e^-$, single events
- Geoneutrinos
  - 10 times more than recorded by BOREXINO and KamLAND
  - Difficult on systematics
  - Background to reactor antineutrinos

**Tasks to be solved**
- Large detector (20 kt of LS):
  - design, mechanics, chemistry, stability
- Energy resolution $3% / \sqrt{E}$ (1200 p.e./MeV)
  - Highly transparent LS
  - High light yield
  - High (80%) PMT coverage
  - High QE PMT (40-50%) → a number of new problems to solve

**JINR possible contribution:**
- Intelligent HV system
- PMT protection against Earth magnetic field
- Construction of a dedicated laboratory for large PMT tests and LS studies
- $\mu$-veto based on OPERA plastic scintillator
- Detector design
- Simulation and reconstruction
- Data analysis
NOvA (NuMI Off-Axis $\nu_e$ Appearance) — a new generation accelerator long baseline experiment for study $\nu_\mu \rightarrow \nu_e$ oscillations.

The goal is to precisely measure the parameters of the neutrino mixing matrix, the neutrino mass hierarchy and CP violation effects in the lepton sector.

The NOvA apparatus consists of a Near Detector (220 ton) on the Fermilab site where the $\nu_\mu$-s are produced, and a Far Detector (14 kton) 810 km distant, both filled with liquid scintillator, have similar construction and situated 14 mrad off-axes to the $\nu$ beam. Detectors will be ready to reach full data-taking capability in 2014. The following 6 years of data taking are optimized for running with $\nu$ and $\bar{\nu}$ beams.
Neutrino history in Dubna — B. Pontecorvo and M. Markov!

About 55 years ago the idea of neutrino oscillation was born in Dubna!

Bruno Pontecorvo:
“The oscillations are very simple trick: 1–2–3 and ... all OK!”

The beginning of neutrino astrophysics ...

M.A. Markov had proposed for the first time to define incoming directions of a cosmic ray charged particle in water by means of its Cherenkov radiation. The first realization of this idea was the Baikal neutrino telescope NT-200. This is foundation of the IceCube success of today!
Opening of the monument to Bruno Pontecorvo and Venedict Dzhelepov at Dubna on 20 September 2013
**Condensed Matter Physics**

**IBR-2** is included in the 20-year European strategic research program in the field of neutron scattering.

**Nanosystems and Nanotechnology**

**Fe (3-5 нм)**

**Cr (1-2 нм)**

**Biomedical research**

**New materials**

**Diagnostics. Earth science.**
Upgraded IBR-2
Pulsed reactor with fast neutrons

- mean power \(2 \text{ MW}\)
- pulse frequency \(5 \text{ Hz}\)
- pulse width for fast neutrons \(200 \mu\text{s}\)
- thermal neutrons flux density on the moderator surface: \(10^{13} \text{n/cm}^2/\text{s}\)
- maximum in pulse: \(10^{16} \text{n/cm}^2/\text{s}\)

and spectrometer complex
IBR-2

2578 hours for physical experiments, 12 cycles:
7 – water moderator, 6 – cryogenic moderator

- 195 proposals received for realization in 2013 during two calls
- 70% accepted for realization according to recommendations of Expert Committees
- 118 visits in the FLNP

[Diagram showing distribution of countries and research fields]
THEORETICAL PHYSICS @ JINR

Main fields of research

- Theory of Elementary Particles and Fields
- Nuclear Theory, Nuclear Structure and Dynamics
- Theory of Condensed Matter and New Materials
- Modern Mathematical Physics

Research and Education Project
“Dubna International School of Theoretical Physics (DIAS-TH)”

Conferences and Schools
Every year (> 1000 participants)
DIAS-TH and Helmholtz Schools
(> 20 countries represented)

Educational Activity
Lectures courses at JINR UC, DIAS-TH, Moscow U., Dubna U., MPTI, etc.
JINR Central Information and Computing Complex

Grid users

JINR CICC
Normalised CPU time share: JINR Laboratories and experiments in 2013.
Total CPU time - 4 580 752

JINR-LCG2 Normalised CPU time (2013)

About 5 million jobs were executed

JINR CICC
Jobs executed for JINR Laboratories and experiments in 2013:
226 832

JINR-LCG2 takes a 4-th place among the Tier2 sites worldwide serving all the LHC experiments

Site serving all LHC experiments

Local users (no grid)
CMS Tier-1 prototype

- Engineering infrastructure (uninterrupted power supply, climate-control);
- High-speed reliable network infrastructure with dedicated reserved data link to CERN (LHCOPN);
- Computing system and storage on the base of disk arrays and tape libraries of high capacity;
- Reliability and accessibility 100%
International Student Practice (ISP)

In total 129 students from 9 JINR Member States were participated during three stages of ISP-2013: ARE, Belarus, Bulgaria, Czech Republic, Poland, Romania, Slovakia, South Africa, Ukraine

JINR Summer Students Program (SSP)

In 2014 JINR UC launches the Summer Student Program. Main distinction SSP from ISP is a selection of participants on a competitive basis. A special web-site to coordinate this Program is already opened and we plan to start collecting applications for SSP-2014 by the mid of March.

New!
Programs at CERN and JINR started in November 2009 for the teachers from JINR Member States. Up to now 5 programs at CERN (193 participants) and 4 programs at JINR (176 participants)

New department “Development of the modern education programmes” was created at JINR University Center. One of the goals of this department is a creation of the educational programs to include current scientific data into the educational process, conduct virtual and online laboratory research based on information and communication technologies

UC continues organizing the video-conferences to promote achievements of modern science
Particle Physics (JINR outside)

JINR @ CERN, BNL, Fermilab, GSI/FAIR, KEK, China

Bright ex.: DISCOVERY OF HIGGS—THE STANDARD MODEL TRIUMPH—HIGHEST ACHIEVEMENT OF MANKIND

JINR contribution: in ATLAS & CMS (experiments)

In theory:

- Transfer of spontaneous symmetry breaking phenomenon in condensed matter physics (N.N. Bogolyubov) to elementary particle physics.
- New quantum number of quarks (color) introduction.
- Renormalization principle in Quantum Field Theory.
- Renormalization group and “Asymptotic freedom” phenomenon.
Collaboration in Particle Physics
JINR @ CERN, BNL, Fermilab, GSI/FAIR, KEK, China

I. **CERN (LHC):** LHC development – consolidation of SC magnets; CMS, ALICE and ATLAS – data taking & analysis; *upgrade* of all 3 detectors – moderate *additional resources*;

II. **CERN (SPS):**

    COMPASS – finished 1st phase. Detector modification to measure GPD (DVCS) and polarized/unpolarized D-Y;
    NA61 – neutrino and heavy-ion programs;
    NA62 – measurement of extremely rare decays ($K^+ \rightarrow \pi^+\nu\nu$);
    DIRAC – lifetime measurement of $\pi\pi$ and $\pi K$ atoms completed at PS; collaboration formed to continue at SPS;

III. **BNL (RHIC):**

    STAR - energy scan HI program and physics with polarized beams
    (important experience for future research at NICA)

IV. **Fermilab:** **NovA** neutrino program – in progress, Mu2e ($\mu \rightarrow e$) – in discussion

V. **GSI, FAIR (SIS-18/100/300):** HADES – on the beam
    CBM, PANDA – in preparation

VI. **J-PARC & KEK:** COMET ($\mu \rightarrow e$), in progress

VII. **China:** Daya Bay Neutrino program new results in sin2Theta_13
CO-OPERATION AGREEMENT

between

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

and

THE JOINT INSTITUTE FOR NUCLEAR RESEARCH (JINR)

concerning

Scientific and Technical Co-operation in High-Energy Physics

2010

Done at Geneva on 28 January 2010, in two copies in the English language.

For the European Organization for Nuclear Research (CERN)

For the Joint Institute for Nuclear Research (JINR)

Prof. Rolf-Dieter Heuer

Prof. Alexei N. Sissakian

3.2 Possible projects at the date of this Agreement include:

- the commissioning and operation of the Large Hadron Collider (“LHC”) at CERN, including the ALICE, ATLAS and CMS experiments using the LHC;
- upgrades of the Nuclotron and the construction, commissioning and operation of the NICA collider project at JINR, including the MPD and SPD experiments using NICA;
- upgrades of the LHC injector chain, including the Linac4, SPL and PS2 projects;
Strategy for Particle Physics

Future major facilities in Europe, Russia and elsewhere require collaboration on a global scale.

**CERN & JINR** combine the framework within which to organize a global particle & heavy ion physics accelerator projects in Europe & Russia, and should also be the leading partners in global particle & heavy ion physics accelerator projects elsewhere. Possible additional contributions to such projects from CERN’s & JINR’s Member and Associate Member States should be coordinated with CERN & JINR.

Strategy comprises high priority items for large-scale scientific activities which could/should be organised as international projects.

FHC: 80-100 km tunnel infrastructure in Geneva area – design driven by pp-collider requirements with possibility of e+e− (TLEP) and p−e (VLHeC)

15 T ⇒ 100 TeV in 100 km
20 T ⇒ 100 TeV in 80 km.

CLIC near CERN

International Linear Collider (ILC): Site Specific Design

JAPAN

The background photo shows a similar site image, but not the real site.
To realise our ambitious scientific plans based on the home and out of JINR large scale facilities and to fully exploit their excellent physics capabilities we suggest:

- coherent and strong efforts of JINR member-states in all regions;
- long term stability and support in all regions;
- careful adjustment of schedules for these facilities.
THANK YOU!