PARTICLE PHYSICS IN RUSSIA
(midterm report)

Nikolai Tyurin

Plenary ECFA Meeting, 22-23 November

OUTLINE

- Introduction
- Accelerator based activities
- Non-accelerator experiments and facilities
- Participation in new European projects
- New projects in Russia
- R&D on detector technologies
- Computing

Introduction: Organizational Structure

Academy of Sciences

BINP, Novosibirsk

INR, Troitsk

Lebedev, Moscow

National Research Centre "Kurchatov Institute"

Kurchatov Institute, Moscow

PNPI, St.-Petersburg

ITEP, Moscow

IHEP, Protvino

Atomic Energy Corp. Rosatom

VNIIEF, Sarov

VNIITF, Snezhinsk

Universities

Moscow State University

MEPhI Nuclear University

St-Petersburg University

Joint Institute for Nuclear Research, Dubna

Ministry of Science and Education

Introduction: Basic Principles

- Development of the existing and construction of new accelerator and experimental facilities in Russia
- Active participation and partnership in the global and megaprojects LHC, XFEL, FAIR, ILC/CLIC, non-accelerator facilities
- R&D and transfer of technologies from particle physics (accelerators, detectors, …) to other fields, development of interdisciplinary research

Introduction: Structure of Funding (2010-2012)

- NRC KI and RAS via Fundamental Research Programs – *basic support and development of the existing scientific infrastructure*
- Centralized support from MSE of the International Cooperation Projects (Agreements) – *travel mainly*
- RFFR (*grants*) and MSE (*some particular projects*)
- Rosatom – funding FAIR incl. R&D of ITEP and IHEP
  Rosnano – funding XFEL
- Federal Targeted Programs - *construction money*

Introduction: 2013 - 2017

- Particle Physics Program of NRC "Kurchatov Institute"

  - *formulated jointly by all four Institutes: KI, PNPI, ITEP and IHEP, example of coherent planning and future research,*
  - *incl. projects/exps of different scale, part. of RAS, JINR, Universities,*
  - *development of national accelerator facilities is its integral part,*
  - *scientific coordination of Russian participation in the mega-projects,*
  - *should help under the process of resources allocation,*
  - *current status: under consideration*

Institutions, Facilities, Experiments

National accelerator facilities

Proton synchrotron U-70 at IHEP: Kaon decays, Hadron spectroscopy, Exotic hadron matter, Spin physics

e+e- colliders VEPP 4M, VEPP-2000, VEPP-2M at BINP: Hadron spectroscopy, Cros-sections (R value), High precision M(J/ψ), M(ψ), M(τ)

NUCLOTRON (Ions, E=6 GeV/n), **JINR**

1 GeV proton synchrocyclotron, PNPI

1.2 GeV electron synchrotron, LPI

10 GeV proton synchrotron, ITEP
p-LINAC, INR

Abroad accelerator facilities

EUROPE: **LHC (ATLAS, CMS, ALICE, LHCb)**
SPS (COMPASS, OPERA) , PS (DIRAC)
ELSA&MAMI (hadron spectroscopy)
PSI (μ-capture), COSY (WASA, ANKE)

USA : **TEVATRON (D0, CDF)**

RHIC (PHENIX, STAR)
JLAB (CLASS)

JAPAN: **KEKB (BELLE),**
SuperKEKB (BELLEII)
JPARK (T2K, $K^0 \to \pi^0 \nu\nu$)

CHINA: **BEPC II (BES III)**

JINR Dubna

IHEP, Protvino
ITEP, Moscow
KI, Moscow
PNPI, S.Petersburg

INP, Moscow
BINP, Novosibirsk
LPI, Moscow

SINP MSU, Moscow
MEPhI, Moscow

National non-accelerator facilities

BAKSAN, INP: neutrino, astroparticle physics, rare processes

BAIKAL, INP: neutrino astronomy, cosmic rays

Tyan Shan, LPI: cosmic rays, γ-astronomy

TUNKA, SINP MSU: EAS

Nuclear reactors:
- **VVR-M, PNPI:** τ_n , EDM_n
- **Kaliniskaya NPS:** neutrino
- **IR-8, KI; CM-3, VNIIAR**: neutrino

Abroad non-accelerator facilities

Gran Sasso: BOREXINO, DAMA, GERDA, LVD , DARK SIDE
(neutrino, IMP,Double β Decay)

Modane: EDELWEISS (WIMP)
Boulby Mine: ZEPLIN-III (WIMP)
Super NEMO, EXO (Double β Decay)

Double Chooz (neutrino)
Daya Bay (neutrino)

ANTARES, KM3NET (ν astronomy)
ILL (neutrons)

ACCELERATOR BASED ACTIVITIES AND DEVELOPMENT

LHC (high energy frontier studies)

✓ Russian contribution to the LHC:

intellectual, in-kind for accelerator and 4 detectors, data analysis

Overall contribution – 6% (ALICE – 15%), number of PhD authors - 190

✓ Long-term strategy assumes strengthening cooperation with CERN and participation in the future LHC development

✓ Russia plans to become Associate Member State of CERN

- to boost cooperation and exchange of expertise in the field of accelerator physics and technologies

- …….

Upgrade of the LHC (1)

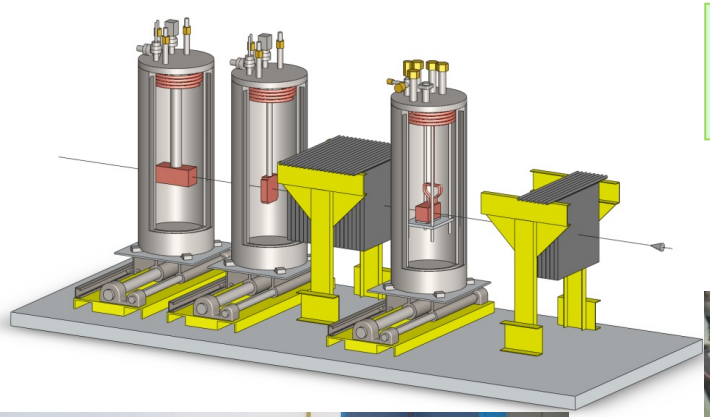
- ✓ Russian institutes formulated and reviewed their intentions (meeting @ NRC KI on 25.10.12). *Concentration on the systems where responsibilities were already delegated to Russian groups, depends on funding and Collaborations' decision*

- ✓ Short-term (LS1) and long-term (HL) plans: in conformity with the ATLAS, CMS, LHCb and ALICE programs

PNPI + US_CMS: production of muon chambers and HV power supply system (2012-2013)

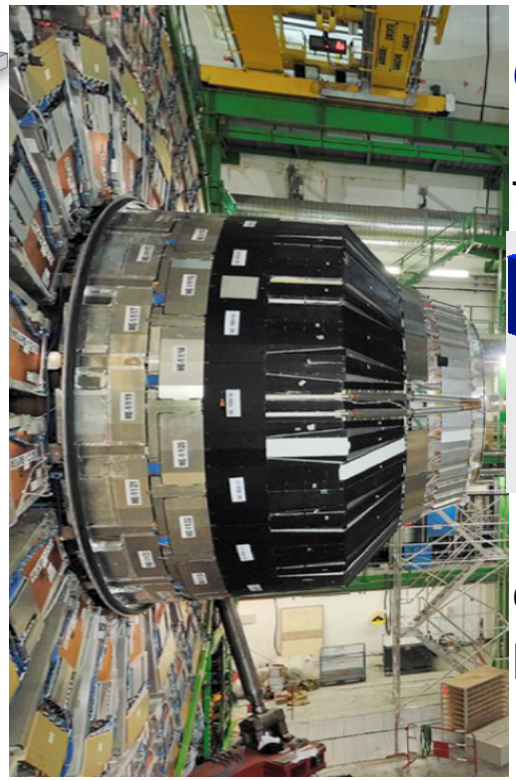
IHEP+CERN: Dump-resistors (77 units) - upgrade to accommodate twice more energy

Upgrade of the LHC (2): HL-LHC



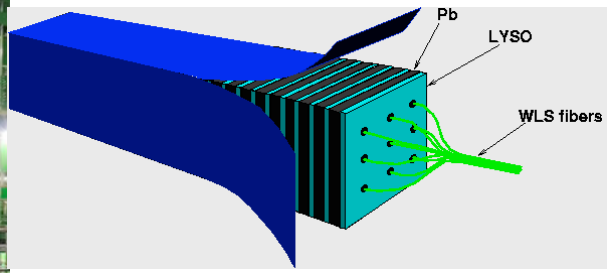
Li-Ar Calorimetry studies at 70 GeV accelerator at IHEP (**ATLAS** Collaboration)

LHCb Central Tracking R&D + prototyping based on scintillator fibres (+ IHEP, ITEP)



CMS experiment:

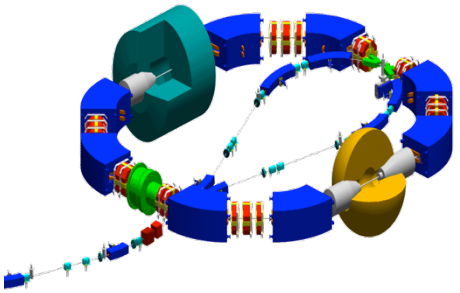
- solution for upgrade of forward Ecal

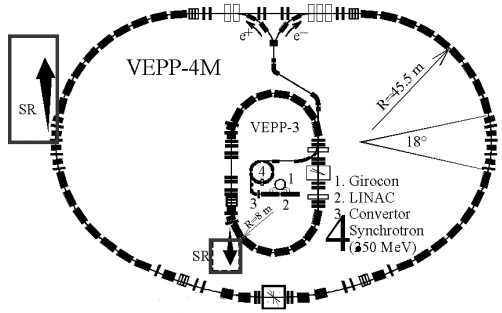


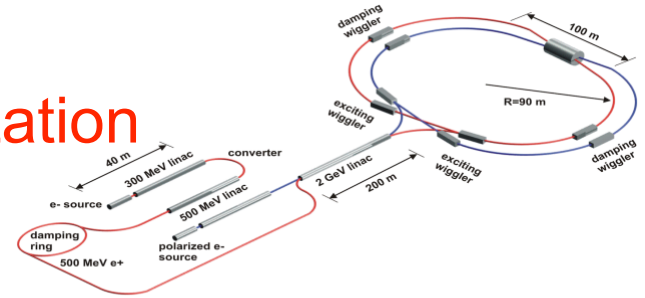
- radiation studies – calculations, prognostics, proposals, neutron monitors

Flavor Physics at Budker INP

- **Collaborations:**
  - LHCb, BELLE, BaBar, Super-KEKB,Super-B, BES-III
- **Domestic programs (with e^+e^- colliders):**
  - VEPP-2000 (SND and CMD-3 detectors)
    - In operation since 2009; E_{cm}=0.3÷2 GeV
  - VEPP-4M (KEDR detector):
    - Large energy region E_{cm} = 2÷11 GeV
    - High precision energy resolution and tagging
  - Planning stage: Super –Tau/Charm factory
    - L > 10^{35} cm^{-2} s^{-1}, longitudinal polarization





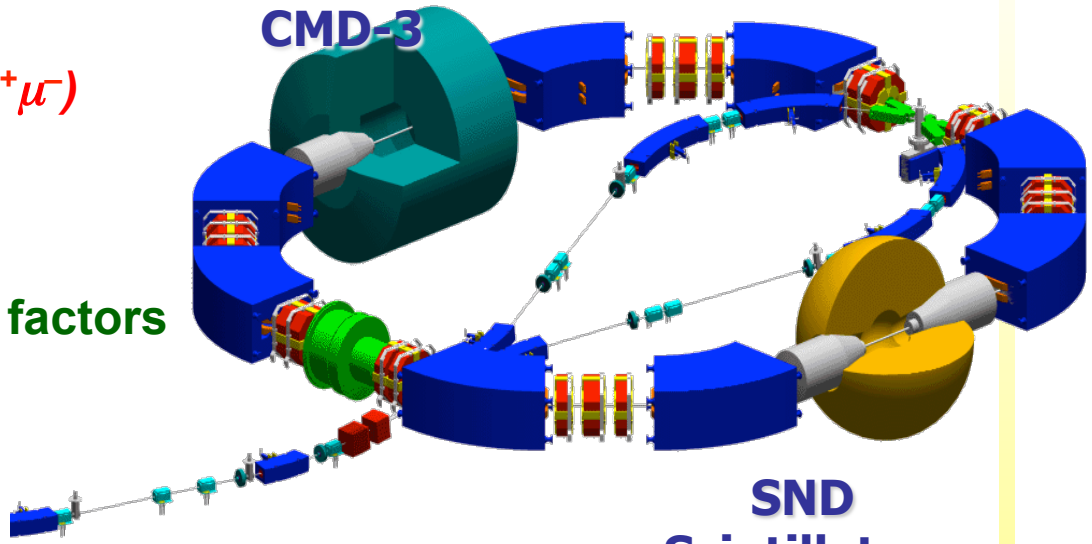


VEPP-2000 Collider

60 pb-1 in the region 2E=1.0-1.9 GeV in 2011-12 , analysis in progress

Round beams, 2 x 1000 MeV
(1x1 bunch)

- **Study of hadronic cross sections** $e^+e^- \to 2h, 3h, 4h \ldots, h= \pi, K, \eta, \ldots$
- **Precision measurement of** $R=\sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$
- **Study of light vector mesons excitations:** $\rho', \rho'', \omega', \varphi', ..$
- **Nucleon electromagnetic form factors and search for *NN- resonances***
- **Two-photon physics**
- **High order QED processes**



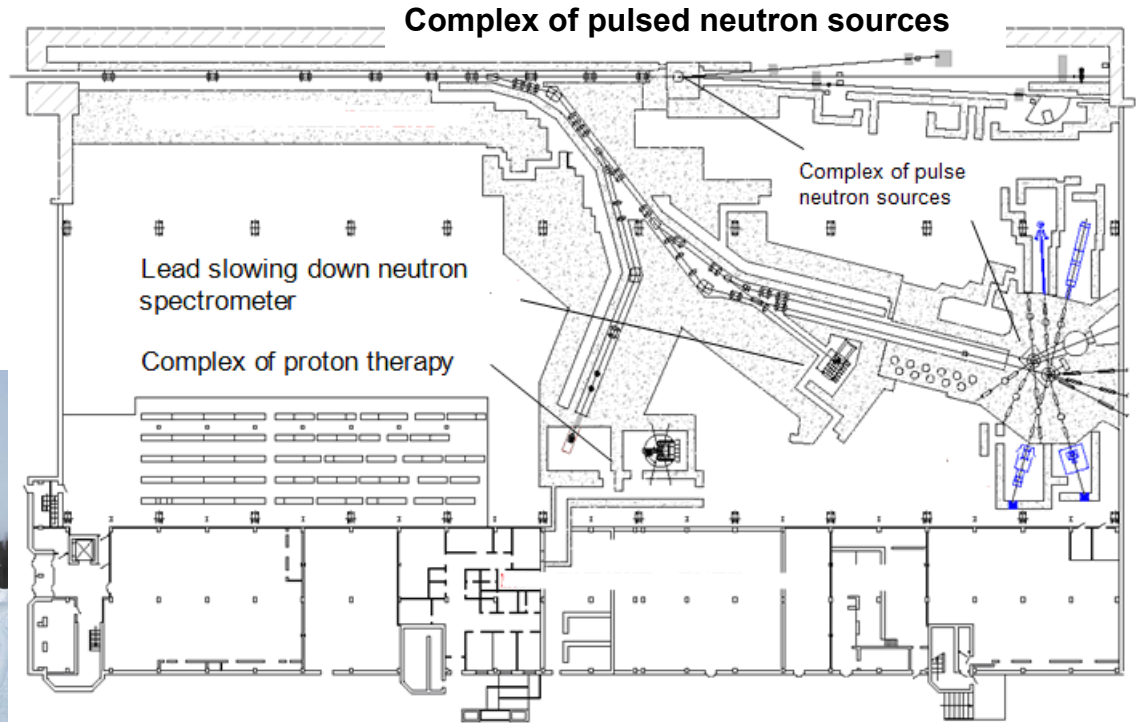
Present status: $\xi=0.14!$

$L=2\times10^{31}\ cm^{-2}\ c^{-1}$

Luminosity will be increased by 10 times after new positron injector commissioning (2013)

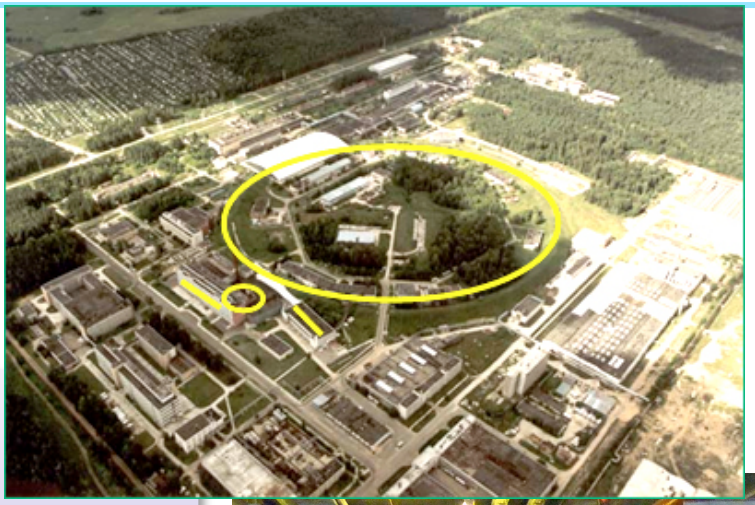
The Neutron complex @ proton LINAC of INR RAS

Parameter	Designed	2012	Nearest future	Probable upgrade
Energy, MeV	600 H^+, H^-	209 H^+, H^-	502 H^+, H^-	1000 H^+, H^-
Pulse current, mA	50	15	16	20
Repetition rate, Hz	1÷100	1÷50	1÷100	1÷100
Pulse duration, μs	0.25÷100	0.25÷200	0.25÷200	0.25÷200
Average current, μA	500	120	300	500



IHEP: U-70 accelerator

- Operation ~ 3000 h per year
- Max proton beam intensity $1{,}2 \cdot 10^{13}$ ppp
- U-70 upgrade - to increase intensity up to $3 \cdot 10^{13}$ ppp and operation reliability

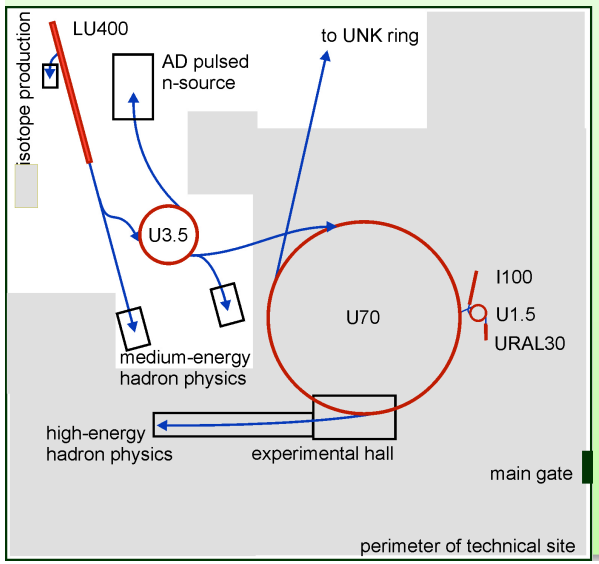


✓ **Facility for proton radiography**

✓ **$_{12}C^{+6}$ beam: 34,1 GeV/u, $5 \cdot 10^9$ ipp (2012)**

450 MeV/u beam for therapy (radiobiology - 2012)

❑ Facility for intense hadron beams (OMEGA)



- New RFQ-DTL 400 MeV Linac
- New 3,5 GeV booster (25 Hz)
- Megawatt power beams

<u>The two major goals:</u>

- Basic&Applied research

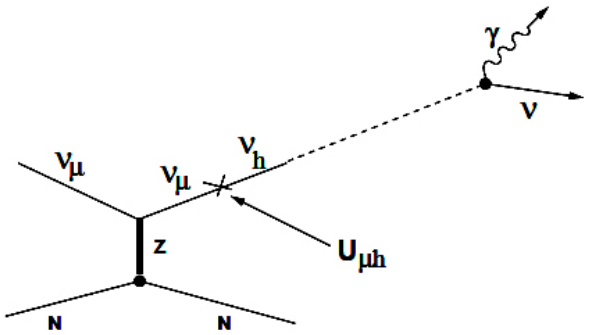
- Higher Intensity p-beams for U-70

INR, MEPhI joined the R&D

IHEP: physics at U-70

- **Hadron spectroscopy** (VES, SVD, HYPERON)
- **Rare kaon decays** (ISTRA+, OKA)
- **Polarization** (PROZA, FODS)
- **Nuclear effects** (SPIN)
- **Physics with light ions**

Experimental setup OKA (IHEP-INR-JINR) - 2010, separated kaon beam



The results of LSND, KARMEN and MiniBooNE could be explained by heavy neutrino ν_h with following properties:

$40\ MeV/c^2 < m_h < 80\ MeV/c^2$;

$10^{-11}\ s < \tau_h < 10^{-9}\ s$;

$10^{-3} < |U\mu h|^2 < 10^{-2}$.

● Heavy neutrino ν_h with $m_h < 300\ MeV/c^2$ has been searched for in kaon decays at **ISTRA+ and OKA**. The upper limit on a mixing matrix element $|U\mu h|^2$ for radiatively decaying ν_h from $K^- \rightarrow \mu^- \nu_h$ ($\nu_h \rightarrow \nu\gamma$) has been obtained in the following parameter region:

$30\ MeV/c^2 < m_h < 80\ MeV/c^2$;

$10^{-11} s < \tau_h < 10^{-9}\ s$.

For the whole region:

$|U\mu h|^2 < 5 \cdot 10^{-5}$ for Majorana type of ν_h

$|U\mu h|^2 < 8 \cdot 10^{-5}$ for the Dirac case

NON-ACCELERATOR EXPERIMENTS AND FACILITIES

Institutions, Facilities, Experiments

National accelerator facilities

Proton synchrotron U-70 at IHEP: Kaon decays, Hadron spectroscopy, Exotic hadron matter, Spin physics

e+e- colliders VEPP 4M, VEPP-2000, VEPP-2M at BINP: Hadron spectroscopy, Cros-sections (R value), High precision M(J/ψ), M(ψ), M(τ)

NUCLOTRON (Ions, E=6 GeV/n), **JINR**

1 GeV proton synchrocyclotron, PNPI

1.2 GeV electron synchrotron, LPI

10 GeV proton synchrotron, ITEP

Abroad accelerator facilities

EUROPE: **LHC (ATLAS, CMS, ALICE, LHCb)**
SPS (COMPASS, OPERA) , PS (DIRAC)
ELSA&MAMI (hadron spectroscopy)
PSI (**μ**-capture), **COSY (WASA, ANKE)**

USA : **TEVATRON (D0, CDF)**
RHIC (PHENIX, STAR)
JLAB (CLASS)

JAPAN: **KEKB (BELLE),**
SuperKEKB (BELLEII)
JPARK (T2K, $K^0 \to \pi^0 \nu\nu$)

CHINA: **BEPC II (BES III)**

JINR Dubna

IHEP, Protvino
ITEP, Moscow
KI, Moscow
PNPI, S.Petersburg

INP, Moscow
BINP, Novosibirsk
LPI, Moscow

SINP MSU, Moscow
MEPhI, Moscow

National non-accelerator facilities

BAKSAN, INP: neutrino, astroparticle physics, rare processes

BAIKAL, INP: neutrino astronomy, cosmic rays

Tyan Shan, LPI: cosmic rays, γ-astronomy

TUNKA, SINP MSU: EAS

Nuclear reactors:
- **VVR-M, PNPI:** τ_n , EDM_n
- **Kaliniskaya NPS:** neutrino
- **IR-8, KI; CM-3, VNIIAR**: neutrino

Abroad non-accelerator facilities

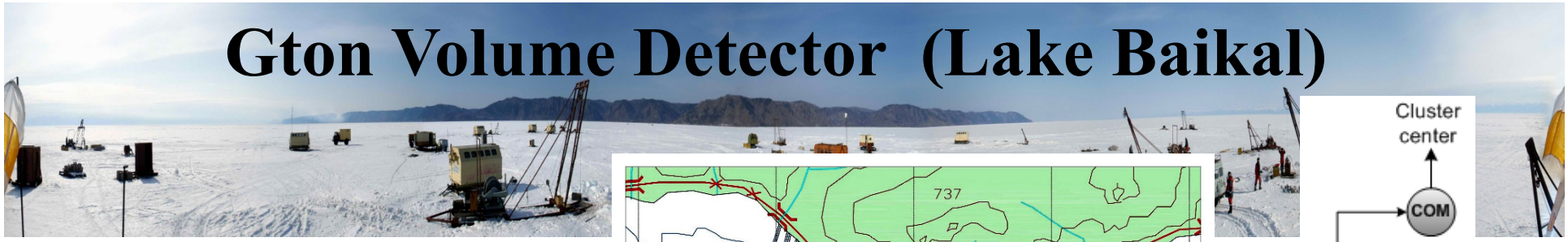
Gran Sasso: BOREXINO, DAMA, GERDA, LVD , DARK SIDE (neutrino,WIMP,Double β Decay)

Modane: EDELWEISS (WIMP)
Boulby Mine: ZEPLIN-III (WIMP)
Super NEMO, EXO (Double β Decay)

Double Chooz (neutrino)
Daya Bay (neutrino)

ANTARES, KM3NET (ν astronomy)
ILL (neutrons)

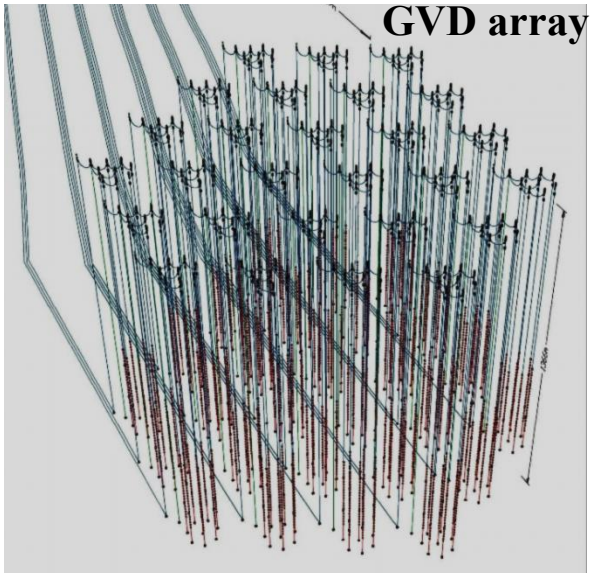
Gton Volume Detector (Lake Baikal)

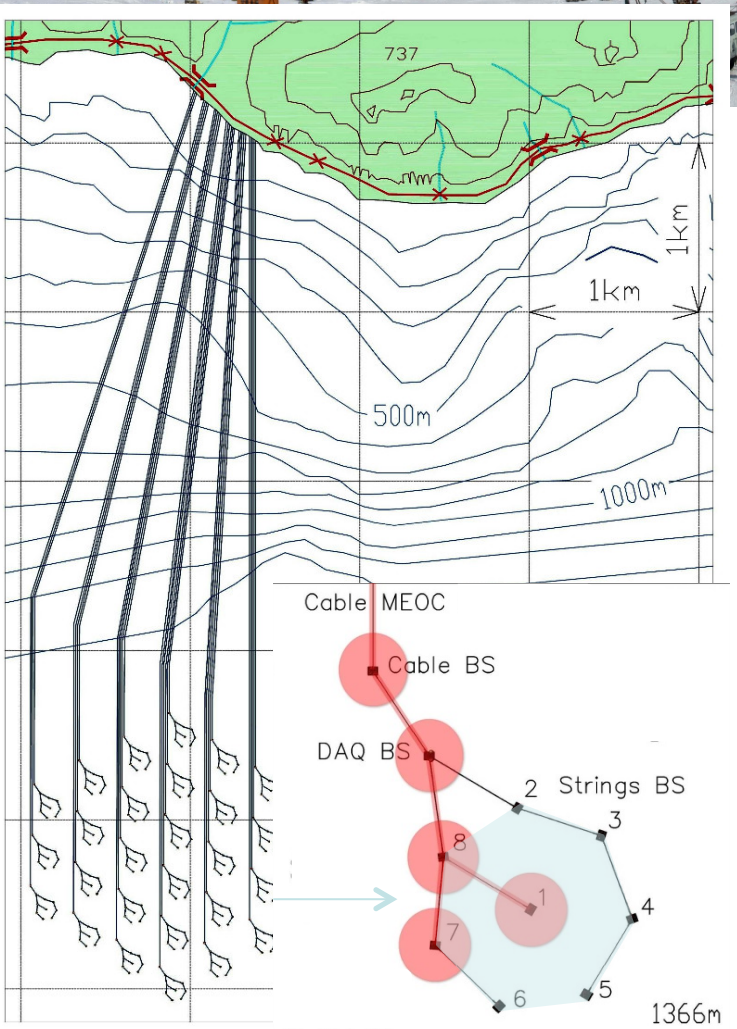


10368 optical sensors
27 subarrays (clusters with 8 strings)
String: 4 sections, 48 optical sensors
Depths: 600 – 1300 m
To Shore: 4 – 6 km

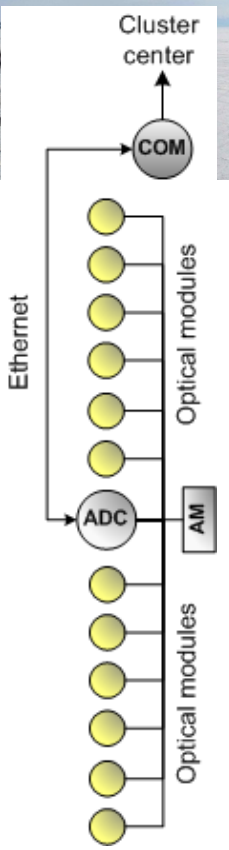
Instrumented water volume
V= 1.5 km^3 S = 2 km^2

Angular resolution
Muons: 0.25 degree
Showers: 5-7 degree

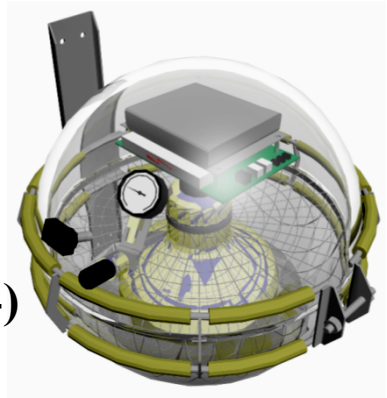




1st GVD cluster: 8 strings (2014)
- Installed strings and cable stations



Section: basic detection unit



Optical module

Gigaton Volume Detector (GVD) in Lake Baikal

Objectives:

- km3-scale 3D-array of photo sensors
- flexible structure allowing an upgrade and/or a rearrangement of the main building blocks (clusters)
- high sensitivity and resolution of neutrino energy, direction and flavor content

Central Physics Goals:

- Investigate Galactic and extragalactic neutrino "point sources" in energy range > TeV
- Diffuse neutrino flux – energy spectrum, local and global anisotropy, flavor content
- Transient sources (GRB, …)
- Dark matter – indirect search
- Exotic particles – monopoles, Q-balls, nuclearites, …

Complementary to ANTARES/KM3NeT

Physics program of the Baksan Neutrino Observatory of the INR RAS

Laboratories

Baksan Underground Scintillation Telescope (BUST)

Investigations of cosmic rays in the Earth's surface and underground

……

Gravitational collapses in the Galaxy:

≤0.088/year (90%CL)

(ΔT = 29 years)

……

CARPET-3

Andyrchy EAS array

Gallium-Germanium Neutrino Telescope (GGNT)

SAGE

Measurement of Solar neutrino flux

……

$64.4^{+3.7}_{-2.9}$ SNU

(ΔT = 20.6 years)

……

Search for sterile neutrino

Low Background Researches (LBL)

Investigations of rare decay processes (double β-decay, dark matter search)

……

Kr-78: $T_{1/2}(2K, 2\nu+0\nu)=$

$(9.2^{+5.5}_{-2.6} \pm 1.3) \cdot 10^{21}$ yr

(year2011)

……

COLLABORATIONS

GERDA (Ge-76)

AMoRE (Mo-100)

Geophysics and Gravity (LGG)

Investigations of process in the Earth and search for GV in the Galaxy

……..

Laser Interferometer

Geo Physical Laboratories I and II

Optical–Acoustic Gravitation Antenna (OGRAN)

Reactor antineutrinos

A measurement of θ_{13} neutrino mixing angle

High statistic measurements of the positron spectrum from inverse beta-decay reaction at Chooz nuclear plant in France (in the framework of Double-Chooz project, NRC KI)

$$\sin^2 2\theta_{13} = 0.109 \pm 0.030\ (\text{stat.}) \pm 0.025\ (\text{syst.})$$

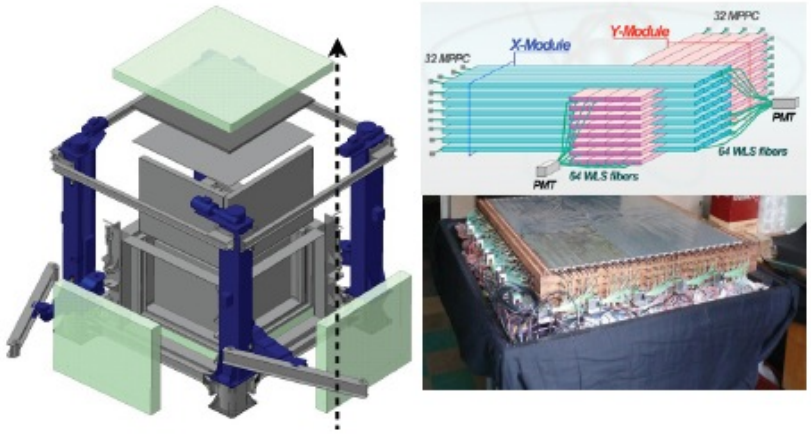
A search of the sterile neutrinos in the nuclear reactor experiments

Kalininskaya NPS

DANSS, Russia (2013)

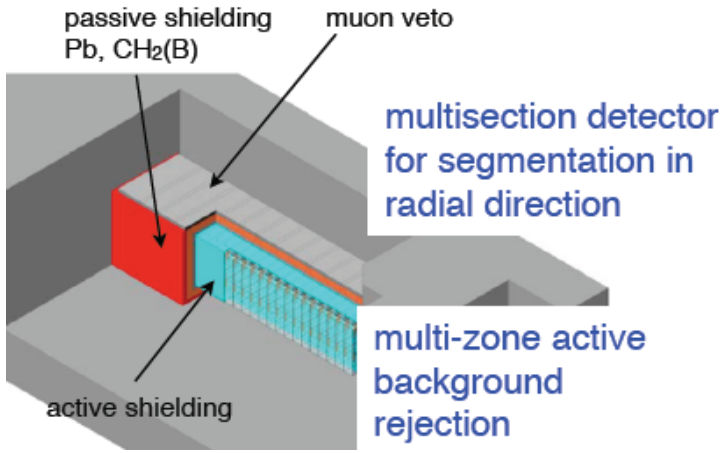
$\delta m^2 = (0.01\text{-}8)\,eV^2$

$\sin^2(2\theta) > 0.02$



Research reactors CM-3 (NIIAR) and PIK (PNPI)

Neutrino4, Russia



PARTICIPATION IN NEW EUROPEAN PROJECTS

XFEL – participation of Russian Labs

✓ Partnership project for Russia, coordination – NRC KI, shareholder of European XFEL GmbH – “Rosnano” corp.
contribution – 307M Euro (~ 25%)

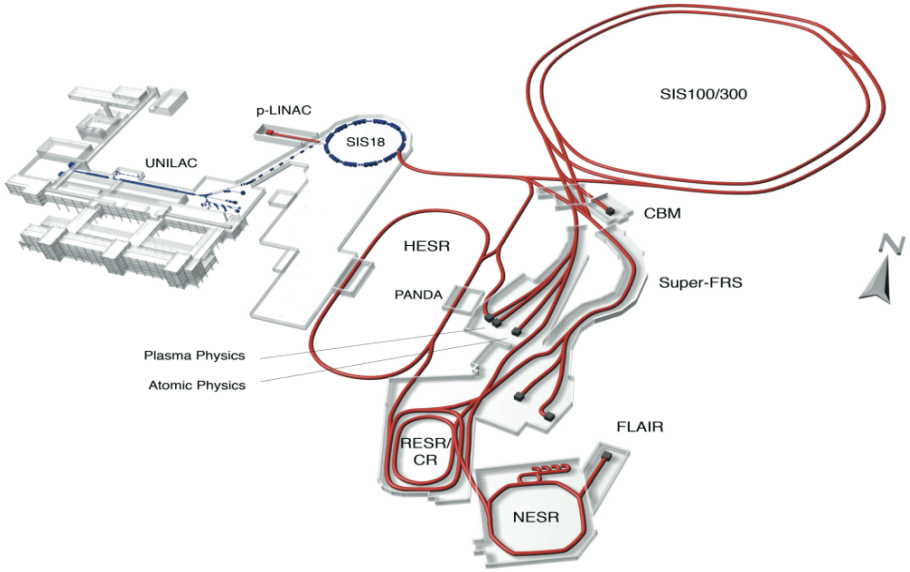
✓ Design and construction of the accelerator systems – *in the framework of Accelerator Consortium (DESY + …)*

✓ BINP, INR, IHEP, NIIEFA, JINR, …

✓ Fields of activities – cryomodules, main dumps, diagnostics, magnets …

✓ Physics research (NRC KI, …)

Russia in FAIR



Start version - 1'200M Euro
Russia – strategic partner
Contribution – 178M Euro (17.5%)
Rosatom – shareholder of FAIR GmbH
FAIR Research Centre was founded in Russia *(funded by Rosatom and Helmholtz Association by 50%)*

Four Pillars of Physics at FAIR

APPA (**A**tomic, **P**lasma **P**hysics and **A**pplications) *incl. HEDgeHOB*

CBM (**C**ompressed **B**aryonic **M**atter) experiment

NUSTAR (**Nu**clear **S**tructure, **A**strophysics and **R**eactions)

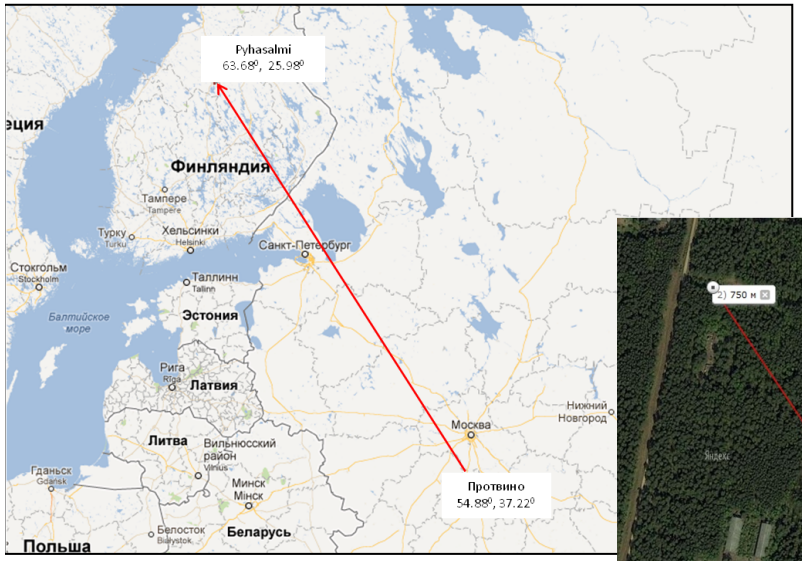
PANDA (Anti**p**roton **An**ihilation at **Da**rmstadt) experiment

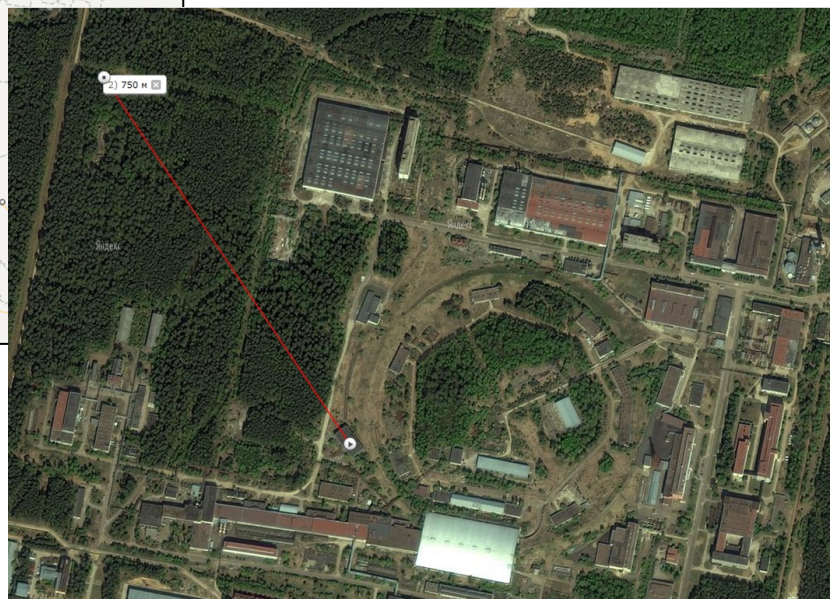
PANDA	IHEP, ITEP, PNPI, JINR, MEPhI, BINP, NRC KI
CBM	ITEP, PNPI, JINR, SINP MSU, MEPhI
HEDgeHOB	ITEP, Lebedev, IHEP
NUSTAR	NRC KI, PNPI, JINR, VNIIEF

Accelerator - contributions from NIIEFA, BINP and JINR (45M Euro)

LAGUNA – LBNO (European ν-program)

- Russian Labs expressed interest (NRC KI, PNPI, INR, JINR)
- Opportunity to provide ν-beam to Pyhasalmi from U-70?
  Such a facility – part of European scientific infrastructure ?





Distance L=1160 km
Beam power P= 450 kWt

Near detector
depth - 20 m
distance 700-750 м

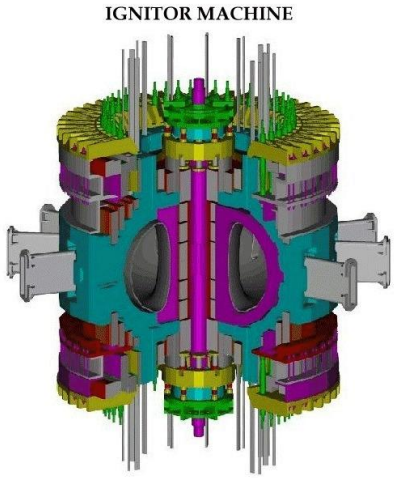
Under study

MEGA-PROJECTS IN RUSSIA

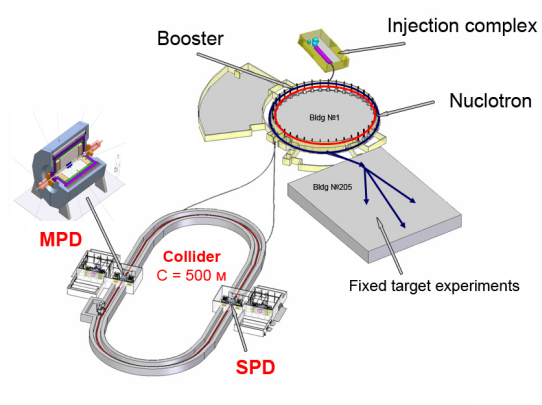
At the date there are three approved mega-projects:

- PIK

- IGNITOR



- NICA



Heavy-Ion Collisions and Dense Matter Physics (NICA)

Main targets of NICA/JINR (2017):

- *studying hot and dense baryonic matter*

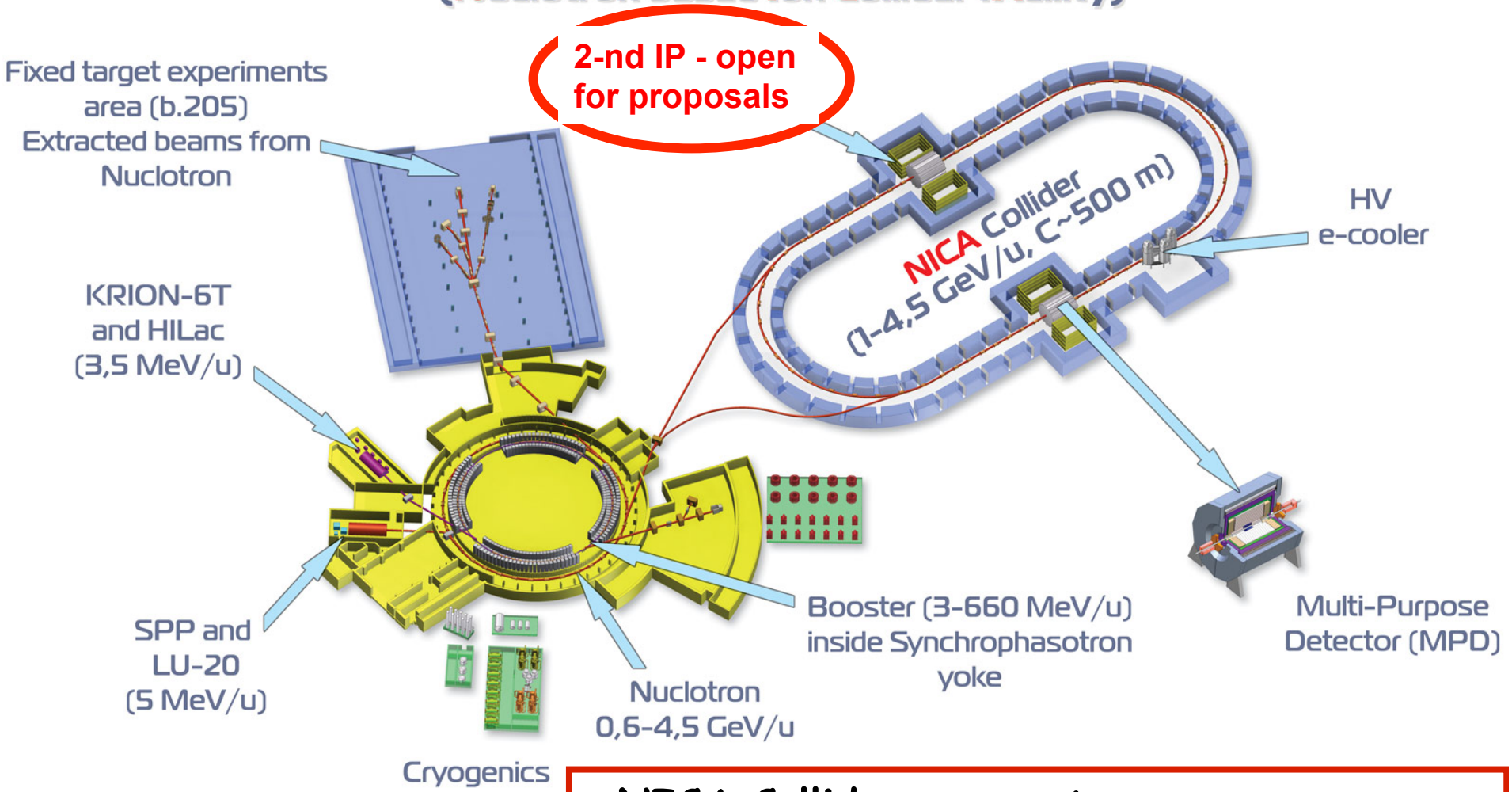
& nucleon spin structure,

polarization phenomena

- *development of accelerator facility providing intensive beams of relativistic ions from* ***p*** *to* ***Au*** *& polarized protons and deuterons with max energy up to* $\sqrt{S_{NN}}$= ***11 GeV (Au^{79+})*** *and* ***26 GeV (p)***

Superconducting accelerator complex NICA

(Nuclotron based Ion Collider fAcility)



NICA Collider parameters:

Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV

Beams: from p to Au

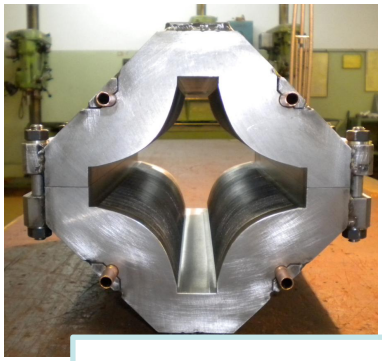
Luminosity: $L \sim 10^{27}$ (Au), 10^{32} (p)

Detectors: MPD; Waiting for Proposals

NICA – physics and modern SC-technologies

- Unique capabilities for studying a variety of phenomena in a large unexplored region of the QCD phase diagram

- Complementary to the RHIC, CBM/FAIR, SPS/CERN experimental programs

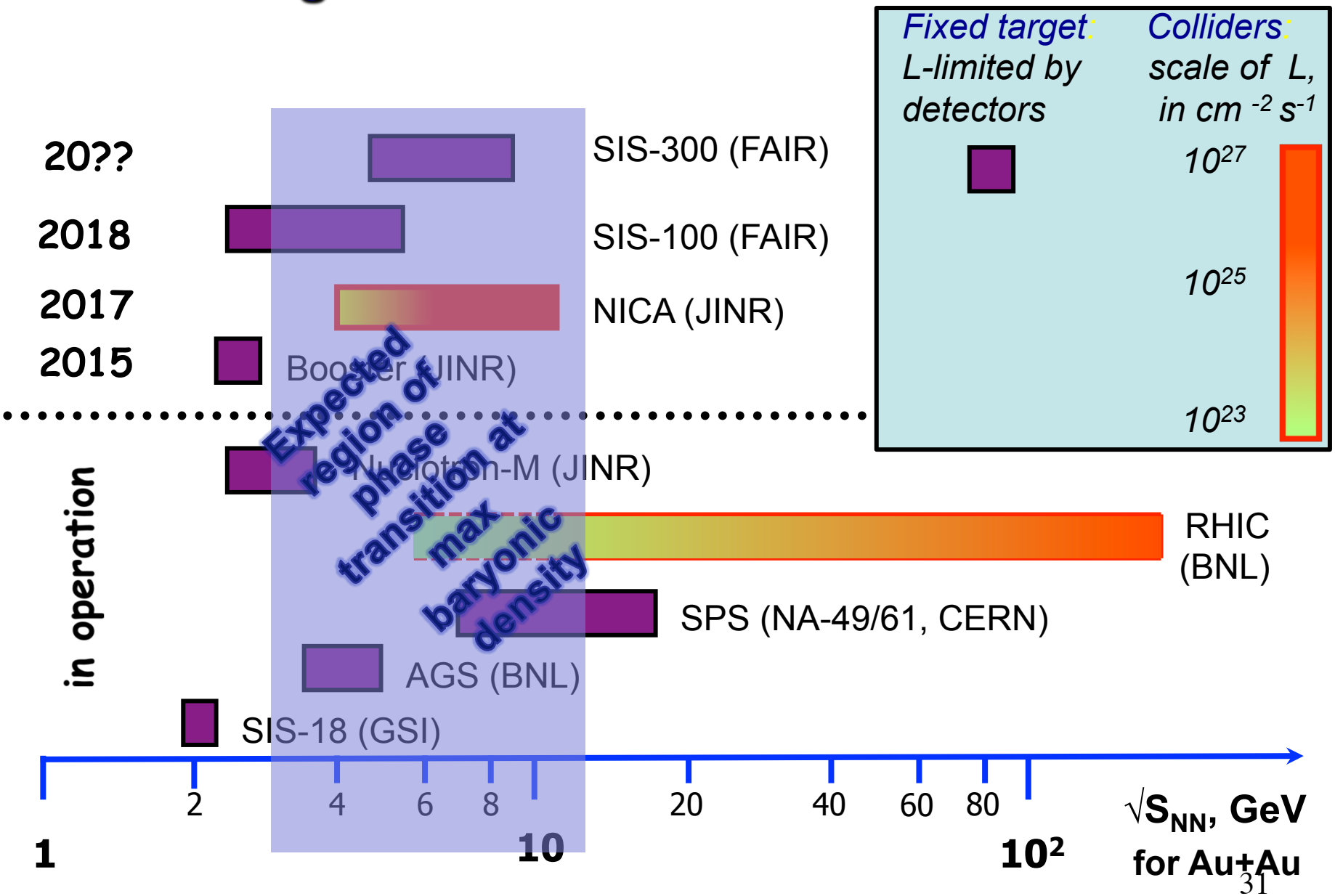


Quadrupole and curved Dipole magnet for booster

Dipole magnet for NICA collider

Collider and MPD (stage – I) - 2017

Existing & Future HI Machines



From V.Kekelidze, JINR

An Analogue Hadron Calorimeter for ILC experiments

In the frame of CALICE collaboration (31 institutions from USA, EUROPE, RUSSIA and JAPAN) a hadron calorimeter prototype was constructed (2005-2007) and tested at beams at DESY, CERN and FNAL (2006-2012).

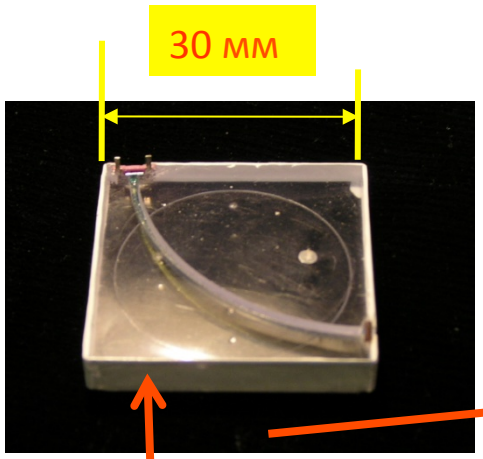
The prototype comprises 7608 scintillator tiles readout with novel developed in Russia photo-sensors SiPM's.

Photo-detectors were manufactured by MEPhI and Pulsar.

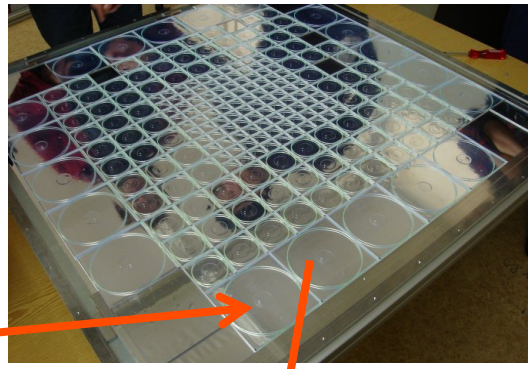
Tile production, selection of photo-sensors and final test of assembled detector cells were performed at ITEP.

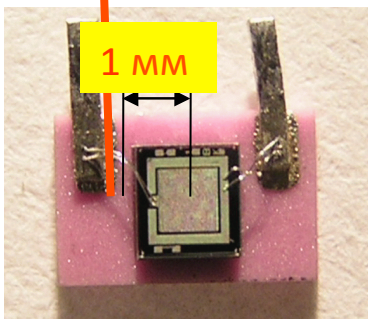
R&D on engineering prototype is in progress

Tile

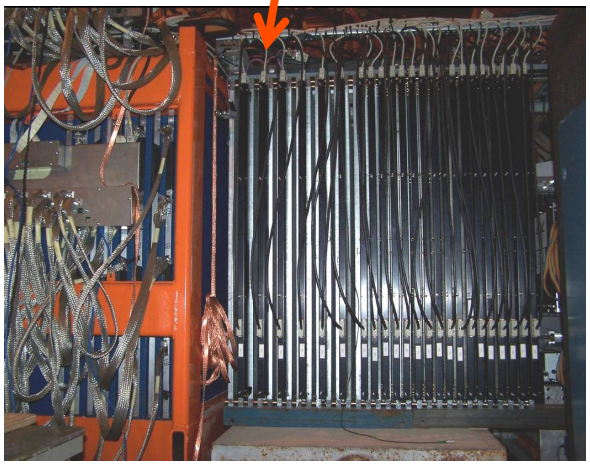


Calorimeter plane





SiPM



Assembled calorimeter

RDIG
Russian Data Intensive Grid

Russian participation in WLCG

9 Russian sites participate in the data analysis for four LHC experiments in the World-wide LHC Computing Grid:

NRC KI, JINR, IHEP
ITEP, PNPI, SINP MSU, INR, StPSU, FIAN
provided by Russian Data Intensive Grid (RDIG-RuTier2)

2012/2011: *CPU increase - 40%; DISK increase - 56%*

RuTier-2 CPU consumed in Russia – 4%

RuTier1 proposal:

September 2012 – WLCG Overview Board accepted the JINR and NRC KI proposal to create the LCG Tier1 centers:

- **for all four experiments ALICE, ATLAS, CMS and LHCb**
- **~10% of the summary Tier1 (without CERN) resources**
- **two sites: CMS at JINR**
  ATLAS, ALICE, LHCb at NRC KI
- **production starts in autumn 2014**
- **production testbed autumn 2013 – autumn 2014**

- **Scientific expertise** (decision making):
  - Topical Councils of RAS (neutrino, accelerators, fundamental interactions, …),
  - WGs at MSE (annual reviews and funds planning),
  - International Scientific Policy Committee at NRC KI and WGs

- **Education** – chairs and educational centers at MSU, St-PU, MEPhI, MPhTI + other universities and research institutes

- **Outreach** – on personal basis mainly,
  regular Sunday scientific program “Stories from the Future” led by Prof.M.V.Kovalchuk (“5” TV ch.)

Summary

- There are plans on development of the accelerator and non-accelerator facilities in Russia.
  Mega-project NICA at JINR was approved

- Experiments abroad are an essential part of Particle Physics program
  - actively involved in the LHC
  - partnership in XFEL and FAIR
  - interest in number of exps in US, Japan, Europe

- Russia plans to become Associate Member of CERN.
  Working on the way to maximize the synergy between Russian Particle Physics program and EPPS

Many thanks to my Colleagues from Dubna, Troitsk, Moscow, Novosibirsk, St-Petersburg and Protvino who provided the information and some slides for this presentation