Laboratory of Nuclear Problems

Alexey Zhemchugov

We still do not know ...

- ... why elementary particles have different mass?
- ... are there any more flavours of quarks and leptons?
- ... the properties of neutrino?
- ... if Standard Model describe all possible phenomena?
- ... why there is much more matter than antimatter?
- ... what is the 'dark matter' is made of?
- ... why quarks are confined inside hadrons and how strong interaction works?

Foundation

- **18 August 1946.** Soviet government approved the proposal of Academician Igor Kurchatov to construct in USSR "the installation M".
- **14 December 1949.** The 480 MeV synchrocyclotron started operation at the Hydrotechnical Laboratory in Dubna, the most powerful accelerator in the world.
- **26 March 1956.** Laboratory of Nuclear Problems of JINR has been founded.

Synchrocyclotron 680 MeV (1949)

M.G.Meshcheryakov

Timeline

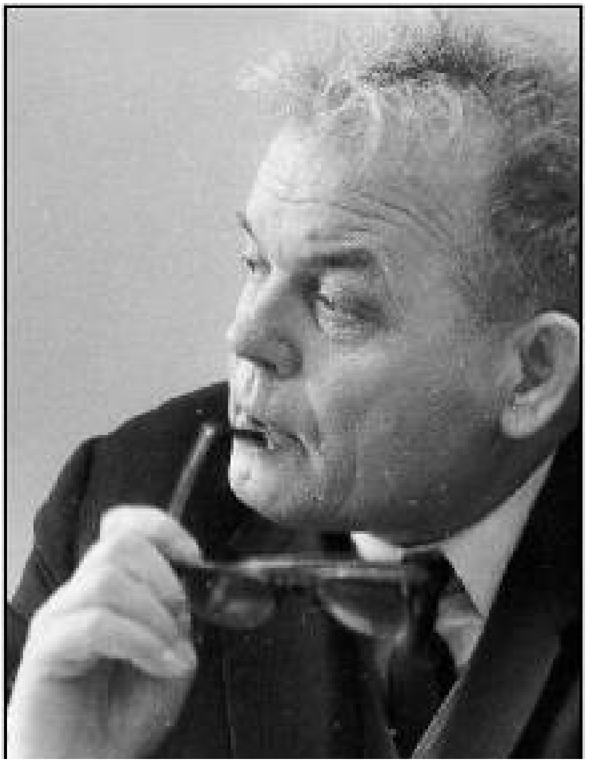
- Since 1949 – experiments at the synchrocyclotron
- Since 1967 – experiments at U-70 (IHEP, Protvino)
- 1979-1984 - synchrocyclotron upgraded to phasotron
- 1982 – 2000 г. – experiment DELPHI at LEP (CERN)
- Since 1992 – participation in the ATLAS experiment at LHC
- 1993 - 2014 - participation in CDF и D0 experiments at FNAL

Radiochemistry, nuclear spectroscopy, accelerator physics and technology, radiation medicine and radiobiology developed at LNP as well

Discoveries

1. Direct deuteron liberation from nuclei by high energy nucleons (1957)
2. Cell self-recovery after lethal irradiation (1957)
3. Discovery of Helium-8 (1959)
4. Radiationless transitions in mesoatoms (1959)
5. Conservation of vector current in weak interactions (1962)
6. Negative pion capture by the chemically bound hydrogen nuclei (1962)
7. Pion double charge exchange (1963)
8. Discovery of muonium in condensed matter (1965)
9. Change of relative intensity of K-series X-rays from mu-mesoatom (1965)
10. Resonant formation of muonic deuterium molecules (1965)
11. Resonant absorption of negative muons by nuclei (1968)
12. Muon spin precession with two frequencies in muonium atom in magnetic field (1969)
13. Capability of one-electron atoms to be a deep donors in semiconductor crystals (1969)
14. Quantum incoherent diffusion of positive muons in solid materials (1972)
15. Proton spin flipping during elastic scattering on protons at high energy (1975)

Great minds of the Laboratory



Mikhail MESHCHERYAKOV

Venedikt DZHELEPOV

Bruno PONTECORVO

Structure of the Laboratory

Particle physics	**Collider physics**	**Intermediate energies**	**Accelerator technology**
Hadron physics	**Multiple hadron production**	**Radiochemistry & nuclear spectroscopy**	**Phasotron & radiation medicine**

IT, design office, workshops, services etc

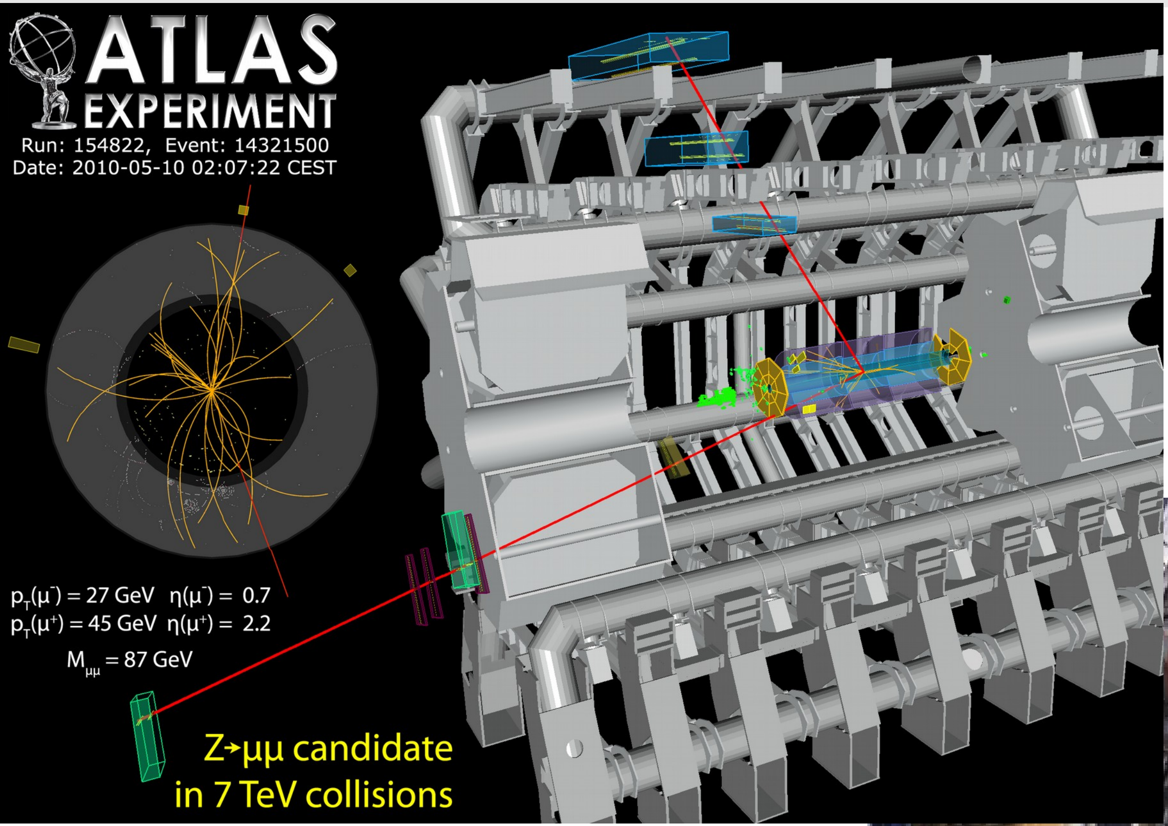
- about 650 employees
- among them about 500 scientific staff

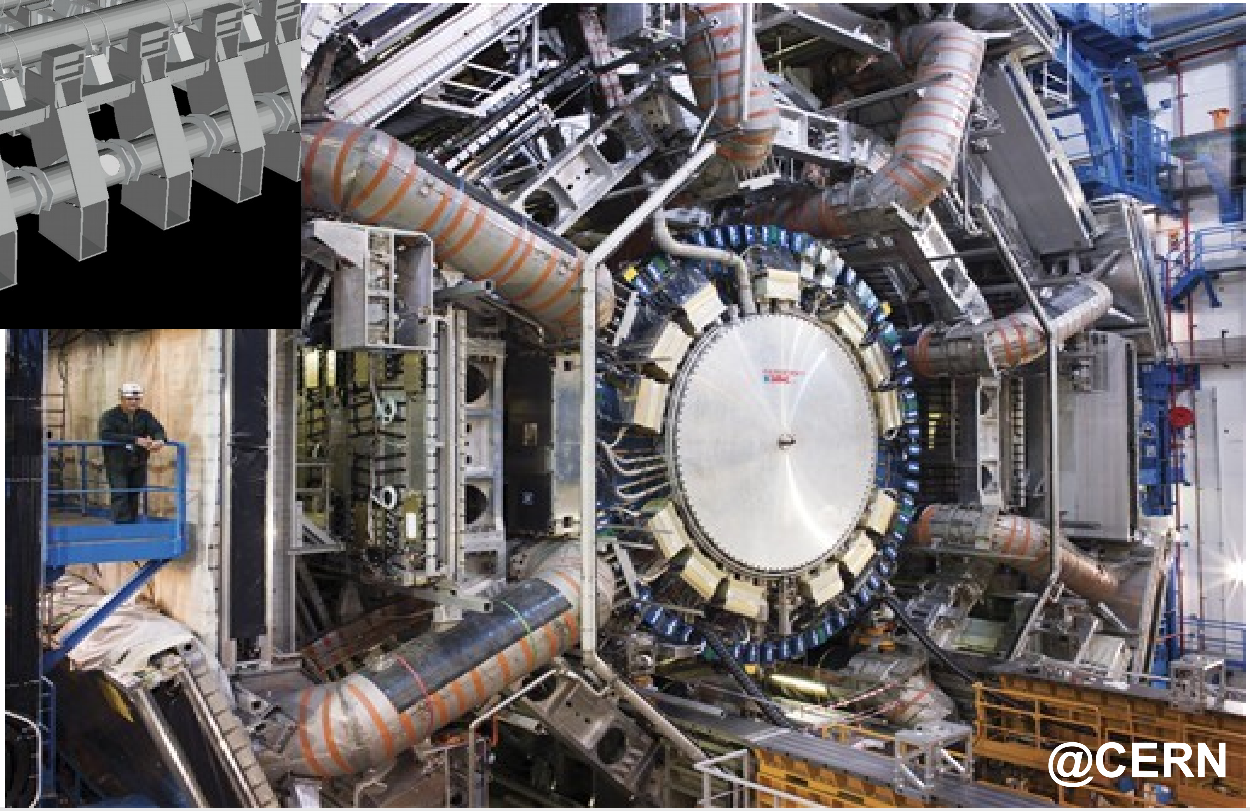
Fundamental research

Main directions

- **Physics at LHC**
  - ATLAS
- **Neutrino physics**
  - OPERA, BOREXINO, Daya Bay, BAIKAL-GVD, NEMO, GERDA, TGV, GEMMA, JUNO, NOVA
- **Strong interaction and QCD**
  - QCD tests: BES-III, ANKE, DIRAC
  - Spin physics: COMPASS, SPD @ NICA
- **Relativistic nuclear physics**
  - MPD @ NICA, PANDA @ FAIR

ATLAS at LHC


ATLAS
EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST
$p_T(\mu^-)$ = 27 GeV $\eta(\mu^-)$ = 0.7
$p_T(\mu^+)$ = 45 GeV $\eta(\mu^+)$ = 2.2
$M_{\mu\mu}$ = 87 GeV
Z→μμ candidate
in 7 TeV collisions


@CERN

ATLAS experiment

Main goals:

- Search for Higgs boson
- Tests of Standard Model at energies > 2 TeV
- Top quark properties
- Physics beyond Standard Model (supersymmetry etc)
- many more ...

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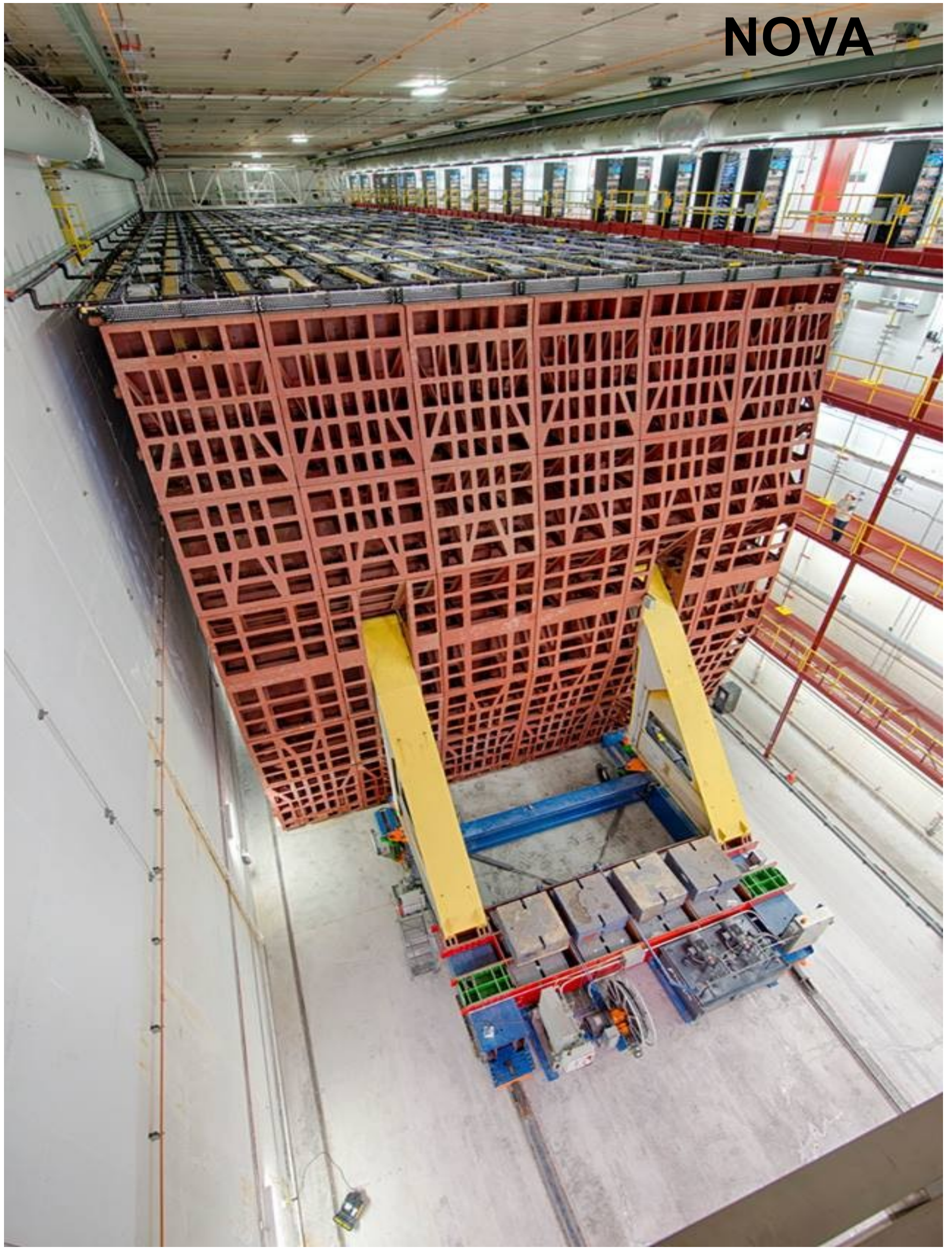
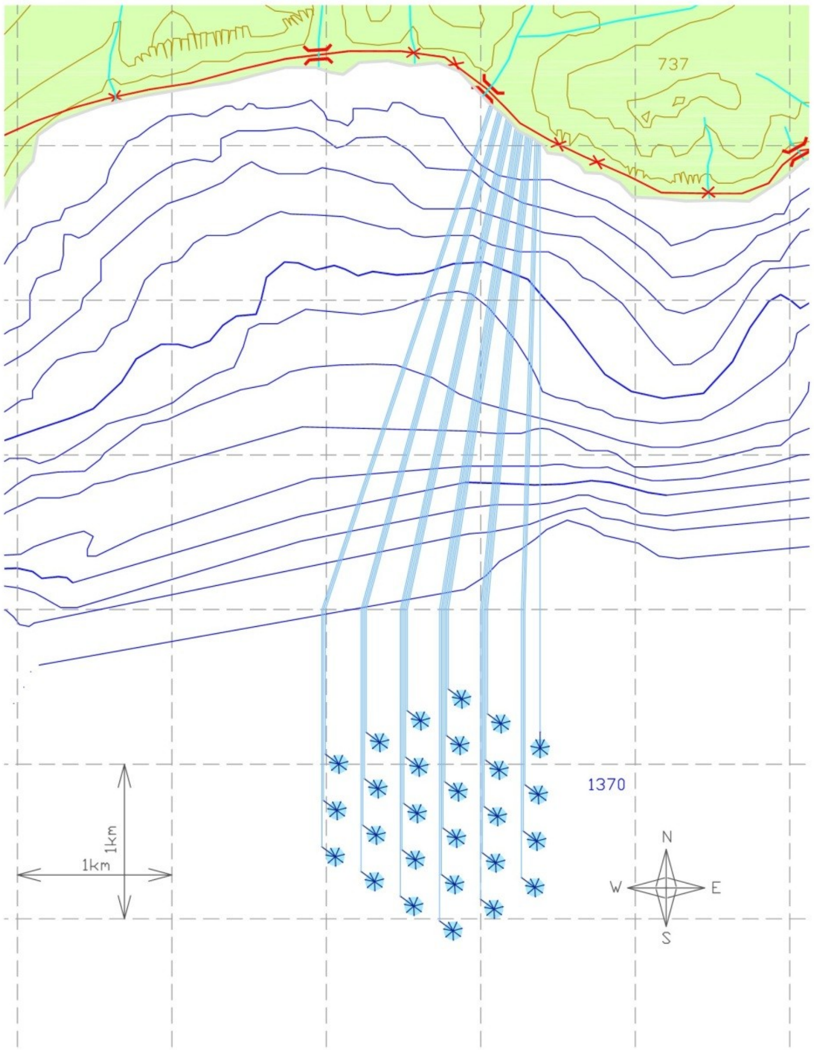
The principal source of experimental data for the next 20 years!

Neutrino physics



BAIKAL-GVD


737
1370
1km
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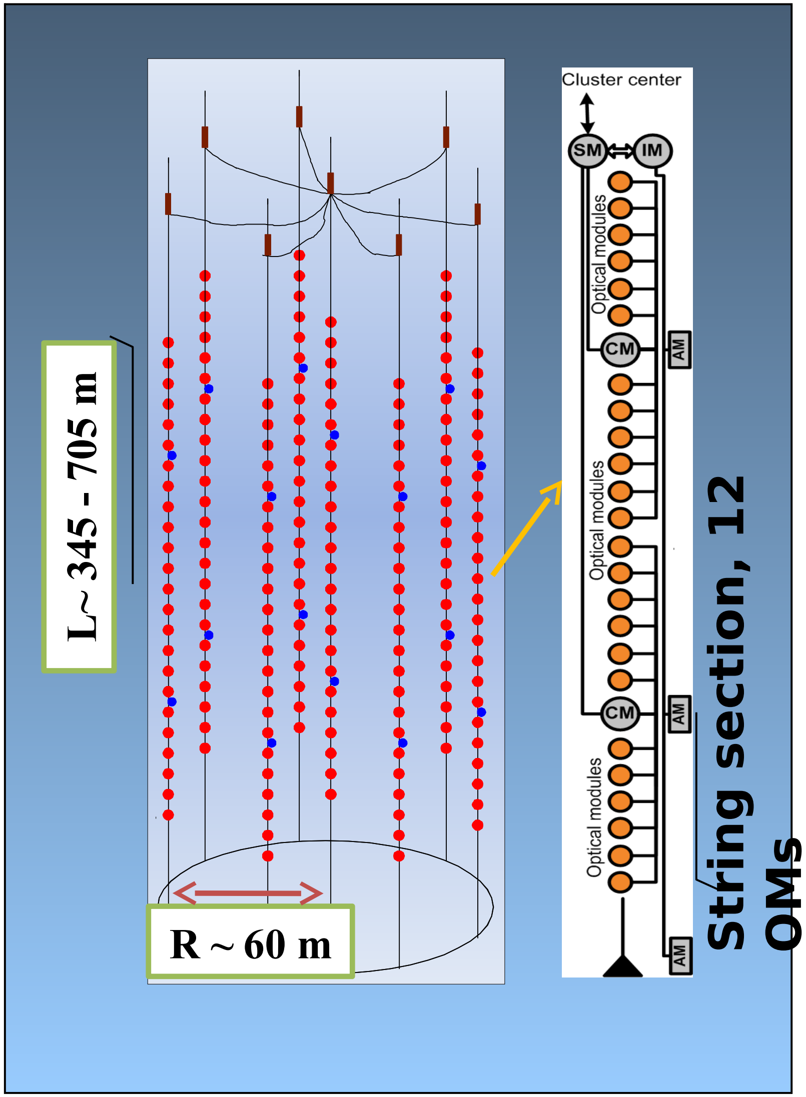

L~ 345 - 705 m
R ~ 60 m
Cluster center
SM
IM
CM
AM
Optical modules
String section, 12 OMs

Neutrino physics

Main goals

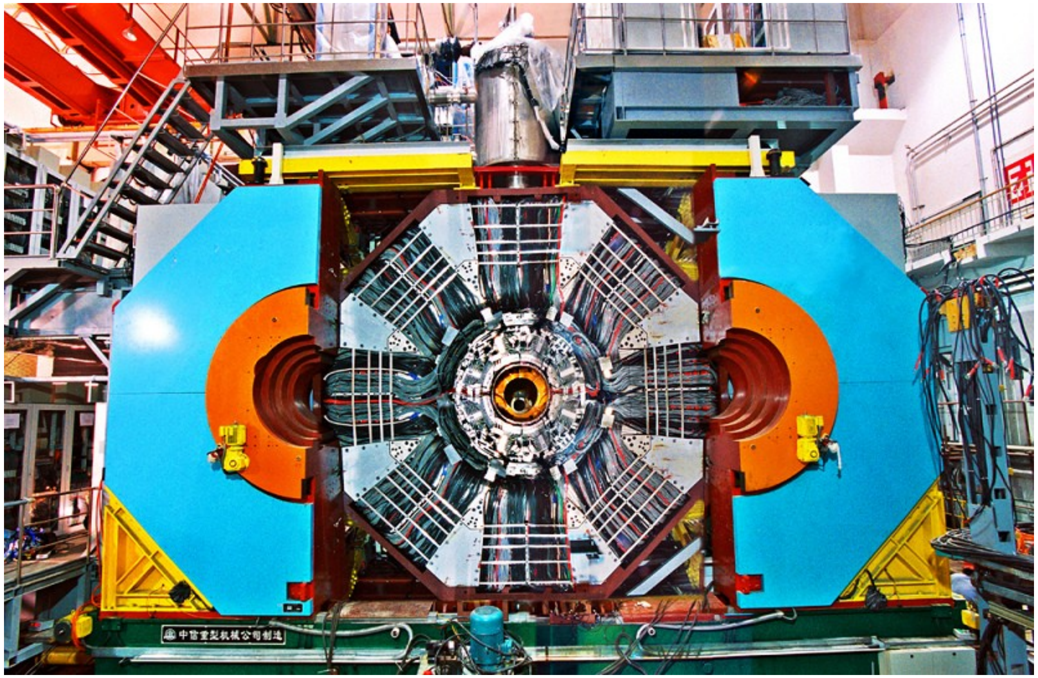
- Direct observation of $\nu_\mu \rightarrow \nu_\tau$ (OPERA)
- Measurement of θ_{13} $\Rightarrow$ search for CP-violation in lepton sector (DayaBay)
- Search for neutrinoless 2β decay (NEMO, GERDA, TGV)
- Neutrino magnetic moment (GEMMA-2)
- Neutrino astronomy and astrophysics (BAIKAL-GVD)
- Neutrino mass hierarchy (Juno, Nova)

Strong interaction

Main goals:

- Precision tests of QCD $\Rightarrow$ nuclear forces, hadronization, confinement
- Hadron spectroscopy and search for exotic particles
- Nucleon structure and «spin crisis»
- Dense nuclear matter and formation of quark-gluon plasma

BES-III and COMPASS



BES-III
Beijing, China

COMPASS @ CERN

Accelerator technology and applied research

- Observation: particle and nuclear physics stimulates high technology
- Accelerators ⇐⇒ vacuum and cryogenic technology, superconducting magnets, automation
- Detectors ⇐⇒ ultrafast electronics, semiconductors, novel materials, high precision combined with the huge size
- Computing: LHC gives 10000 TB of data per year ⇒ grid-technologies
- Nuclear technology: radiation medicine, material science, industrial accelerators

Cyclotrons constructed at LNP in recent years

- **Russia,** Tver, industrial cyclotron **RIC-30**

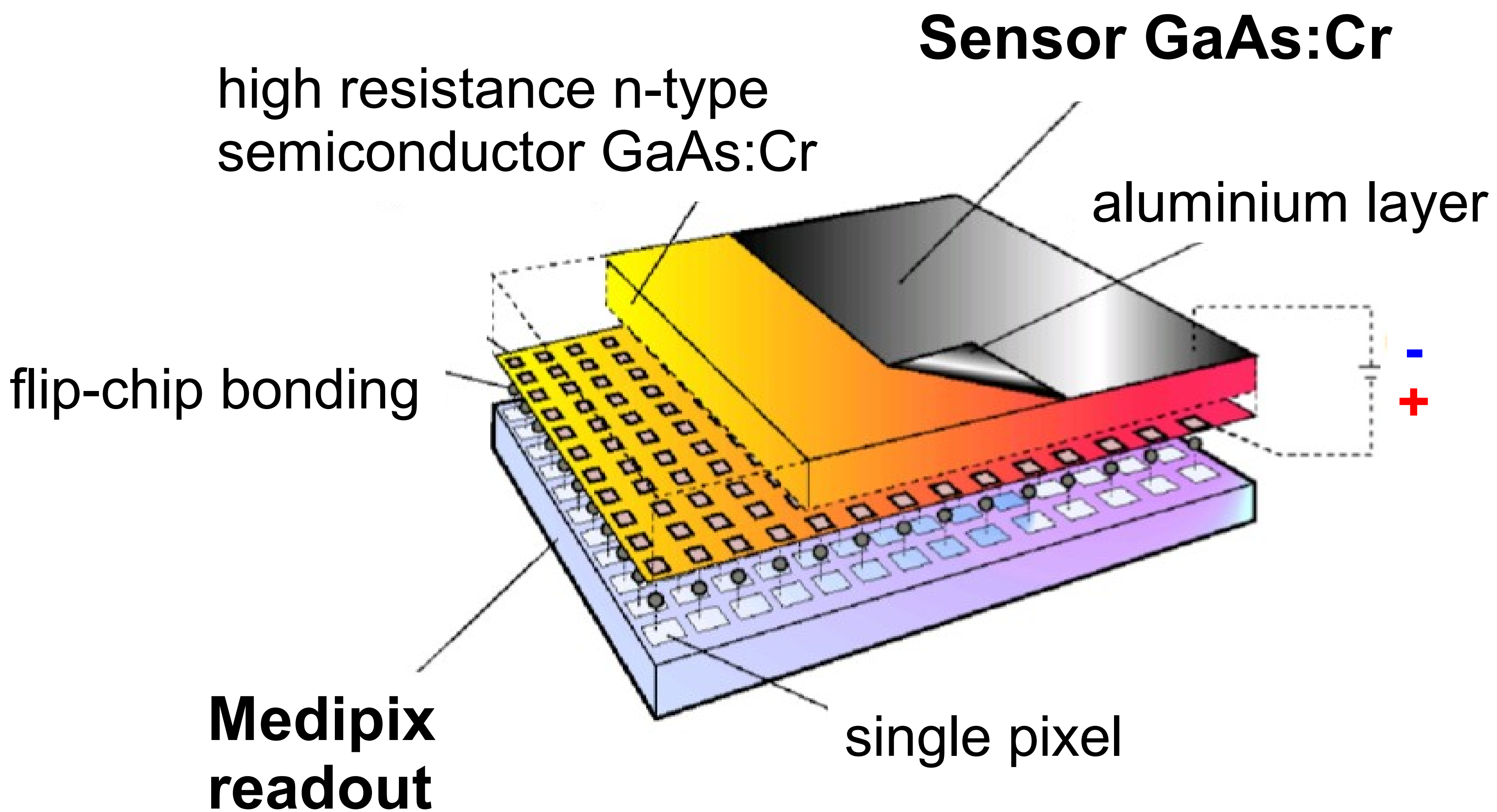
- **Uzbekistan,** Tashkent, Cyclotron **U-150**

- **Poland,** Cracow, Cyclotron **AIC-144**

- **Belgium,** Louvain-la-Neuve, IBA, medical cyclotron **C235**

- **Research projects:** medical cyclotron **C250**, superconducting cyclotron

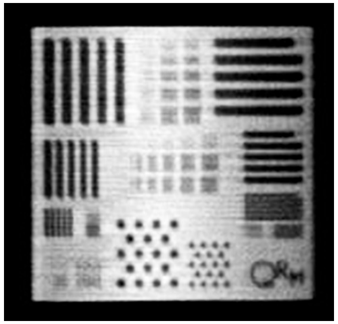
Hybrid pixel detectors

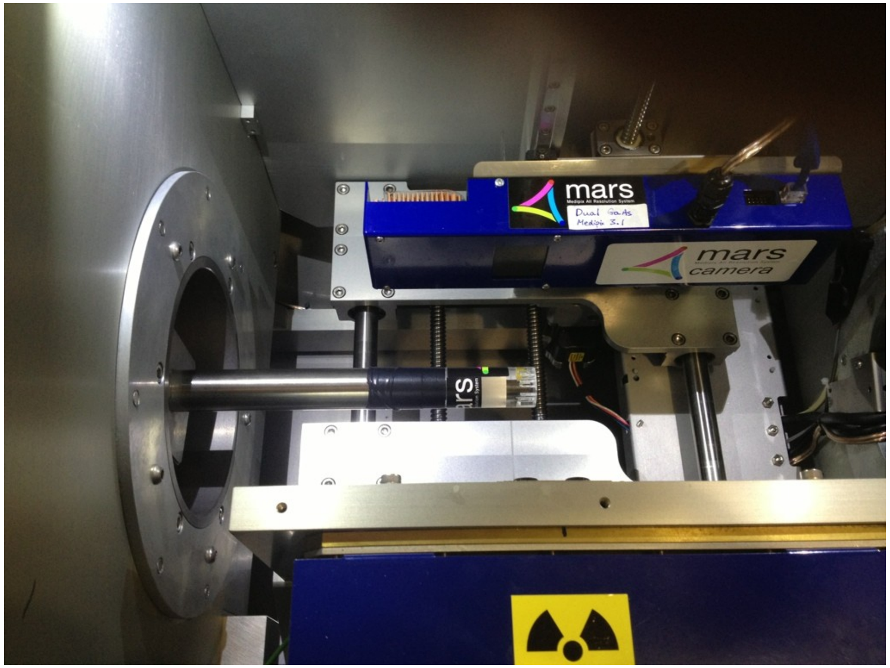


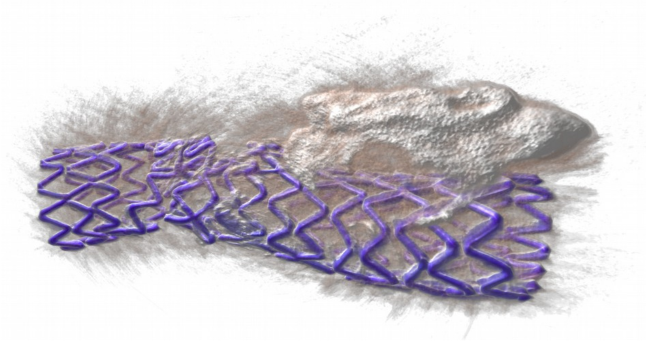
JINR joined Medipix collaboration in 2016

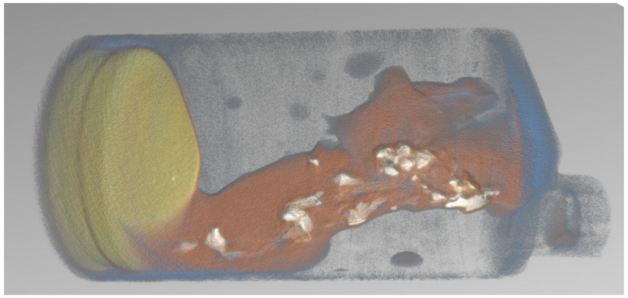
MARS-CT

- Manufactured by MARS Bioimaging Ltd., New Zealand
- Fully-functional microCT equipped with two GaAs:Cr+Medipix3 detectors
- Spatial resolution about 30 um
- X-ray energy up to 120 keV
- Sample size up to Ø 10 cm X 30 cm

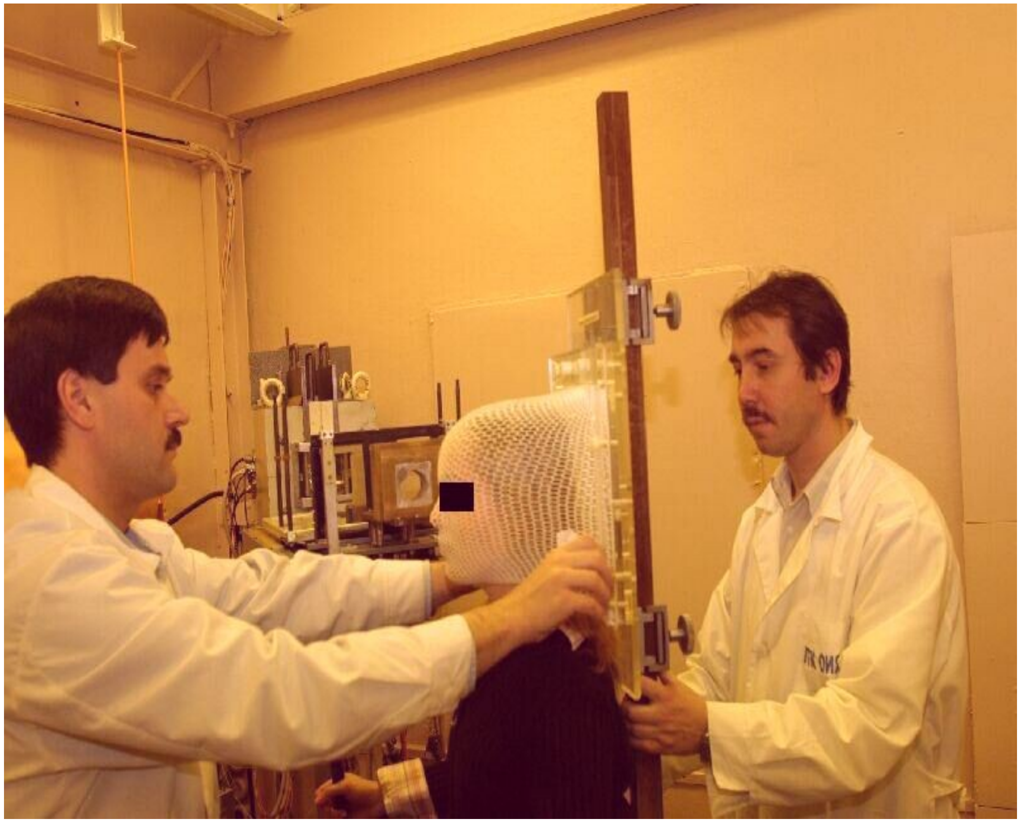








Radiation medicine



- Research on methods of proton therapy
- Cancer treatment by Phasotron beams
- Design and construction of specialized medical cyclotrons (collaboration with IBA)

Also

- Novel imaging detectors for CT and X-ray diagnostics

Welcome to the Laboratory of Nuclear Problems!