“Govorun” supercomputer for JINR tasks

M. Zuev on behalf on HybriLIT heterogeneous group

The International Conference Mathematical Modeling and
Computational Physics, 2024 (MMCP2024)
20-25 October 2024

Development of the heterogeneous platform HybriLIT

Cluster HybriLIT **2014**:
Peak performance:
50 TFLOPS double precision
140 TFLOPS single precision

#18 in Top50
Supercomputer "Govorun"
First stage 2018
Peak performance:
500 TFLOPS double precision
1 PFLOPS single precision

#10 in Top50
Supercomputer "Govorun"
Second stage 2019
Peak performance:
860 TFLOPS double precision
1.7 PFLOPF single precision
288 TB UDSS with I/O **>300 Gb/s**
17th in the IO500 list (July 2020)

Russian DC Awards 2020 in "The Best IT Solution for Data Centers"

“Govorun” supercomputer

CPU component

- **21x servers with Intel Xeon Phi**
  Intel Xeon Phi 7290 (72 cores @1.50 GHz), 96 GB RAM
- **76x servers with Intel Xeon Scalable Gen2 (RSC Tornado TDN511)**
  2x Intel Xeon Platinum 8268 (24 Cores @2.90 GHz), 192 GB RAM
- **32x servers with Intel Xeon Scalable Gen2 (RSC Tornado TDN511S)**
  2x Intel Xeon Platinum 8368Q (38 Cores @2.60 GHz), 2 TB RAM

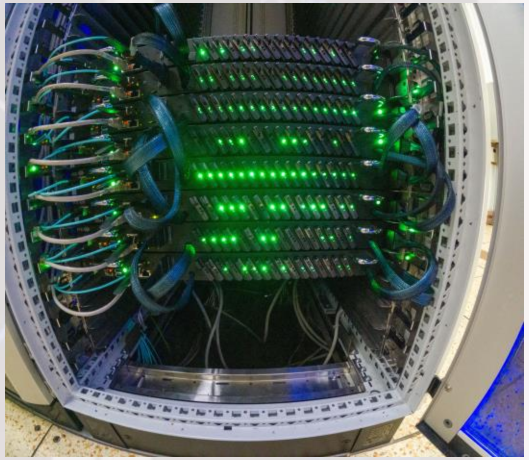
Peak performance: 800 TFLOPS double precision

GPU component

- **5x servers with NVIDIA V100**
  2x Intel Xeon E5-2698 v4 (20 cores @2.20 GHz),
  8x NVIDIA V100 16 GB, 512 GB RAM
- **5x servers with NVIDIA A100**
  2x AMD EPYC 7763 (64 Cores @2.45 GHz),
  8x NVIDIA A100 80 GB, 2 TB RAM

Peak performance:
900 TFLOPS double precision
26 PFLOPS half precision

Storage system: 8.6 PB



Total peak performance

1.7 PFLOPS double precision
3.4 PFLOPS single precision

The CPU component of “Govorun” supercomputer

Current status:

163 hyperconverged compute nodes

8552 compute cores

Total peak performance:

800 TFLOPS double precission

80

RSC Tornado nodes based on Intel Xeon Phi:
Intel Xeon Phi 7190 processors (72 cores)
Intel Server Board S7200AP
Intel SSD DC S3520 (SATA, M.2)
96GB DDR4 2400 GHz RAM
Intel Omni-Path 100 Gb/s adapter

21

32

RSC Tornado nodes based on Intel Xeon Scalable gen 3 (TDN511):
Intel Xeon Platinum 8268 processors (24 cores)
Intel Server Board S2600BP
Intel SSD DC S4510(SATA, M.2),
2x Intel SSD DC P4511 (NVMe, M.2) 2TB
192GB DDR4 2933 GHz RAM
Intel Omni-Path 100 Gb/s adapter

8

Total capacity of Hierarchical Storage: **8.6 PB**

Data IO rate: **300 Gb/s**

14

8

RSC Tornado nodes based on Intel Xeon Scalable gen 2 (TDN511S):
Intel Xeon Platinum 8280 processors (28 cores)
Intel Server Board S2600BP
Intel SSD DC S4510(SATA, M.2),
2x Intel SSD DC P4511 (NVMe, M.2) 2TB / 4x Intel (PMem) 450 GB
192GB DDR4 2933 GHz RAM
Intel Omni-Path 100 Gb/s adapter

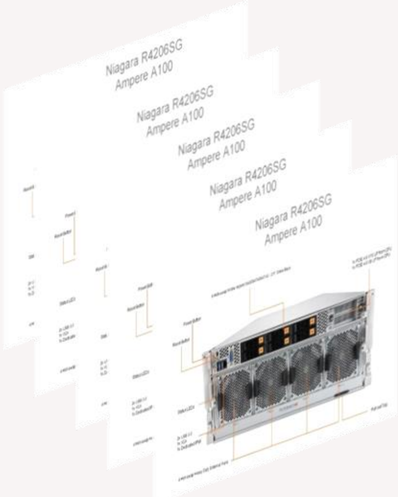
The GPU component of “Govorun” supercomputer

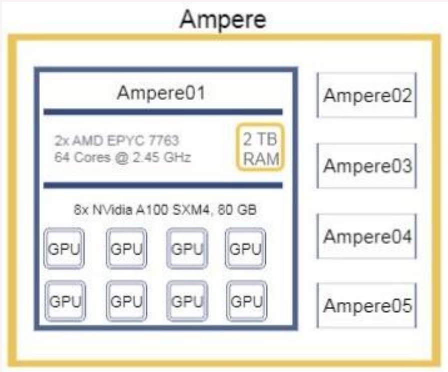
2017

40 NVIDIA V100

+

2023

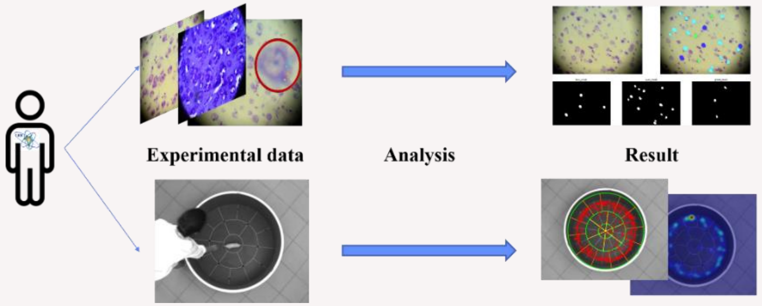




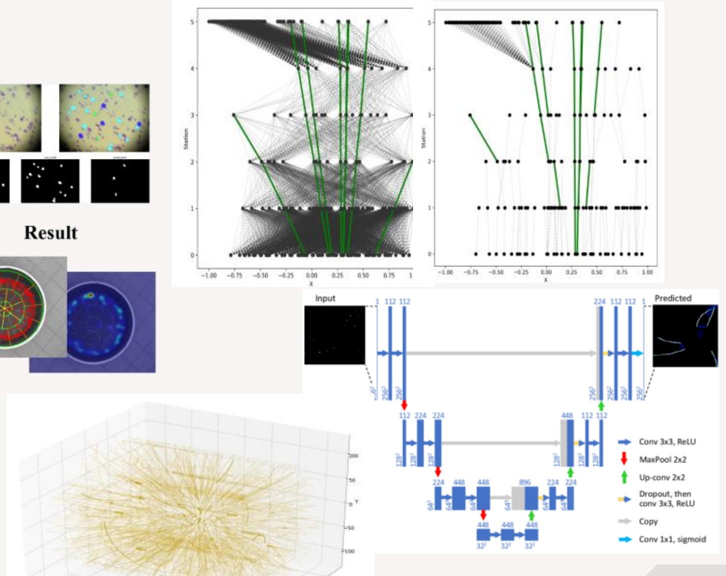
40 NVIDIA A100

Total peak performance of the GPU-component:
900 TFLOPS double precision
26 PFLOPS half precision

The GPU-component gives a users of the supercomputer a possibility to use machine learning and deep learning algorithms for solving applied problems by neural network approach: process data from experiments at LRB in the frame of the Information System for radiation biology tasks; experimental data processing and analysis at the NICA accelerator complex and etc.



Information System for Radiation Biology Tasks



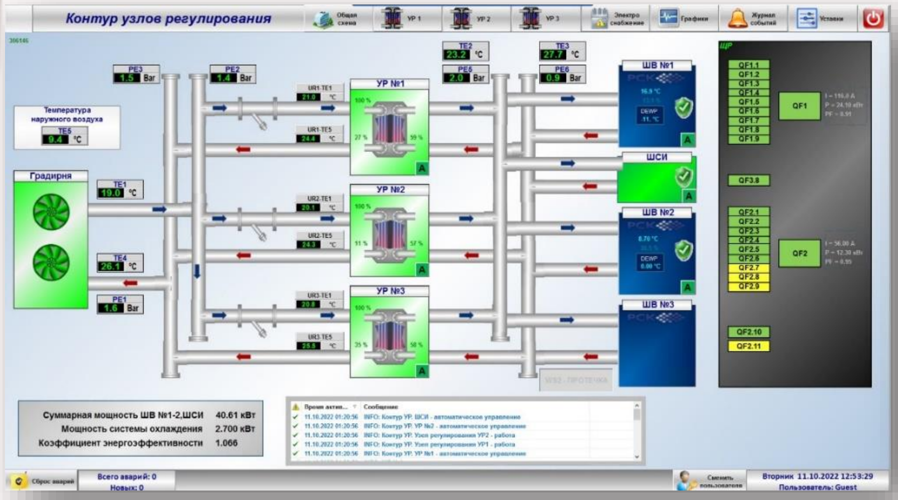
Data Processing and Analysis

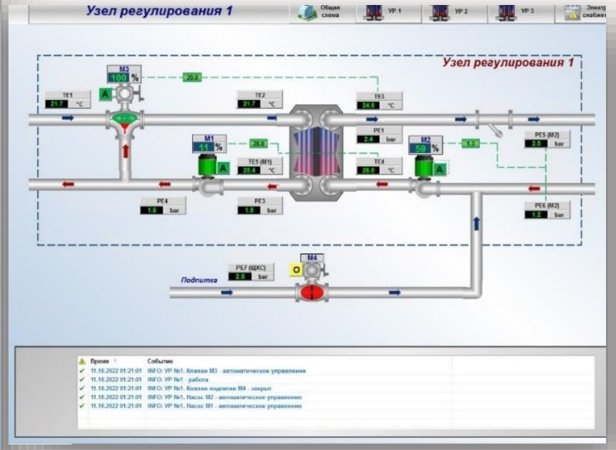
“Govorun” supercomputer. Hot water cooling

PUE ~ 1,06

Power usage effectiveness

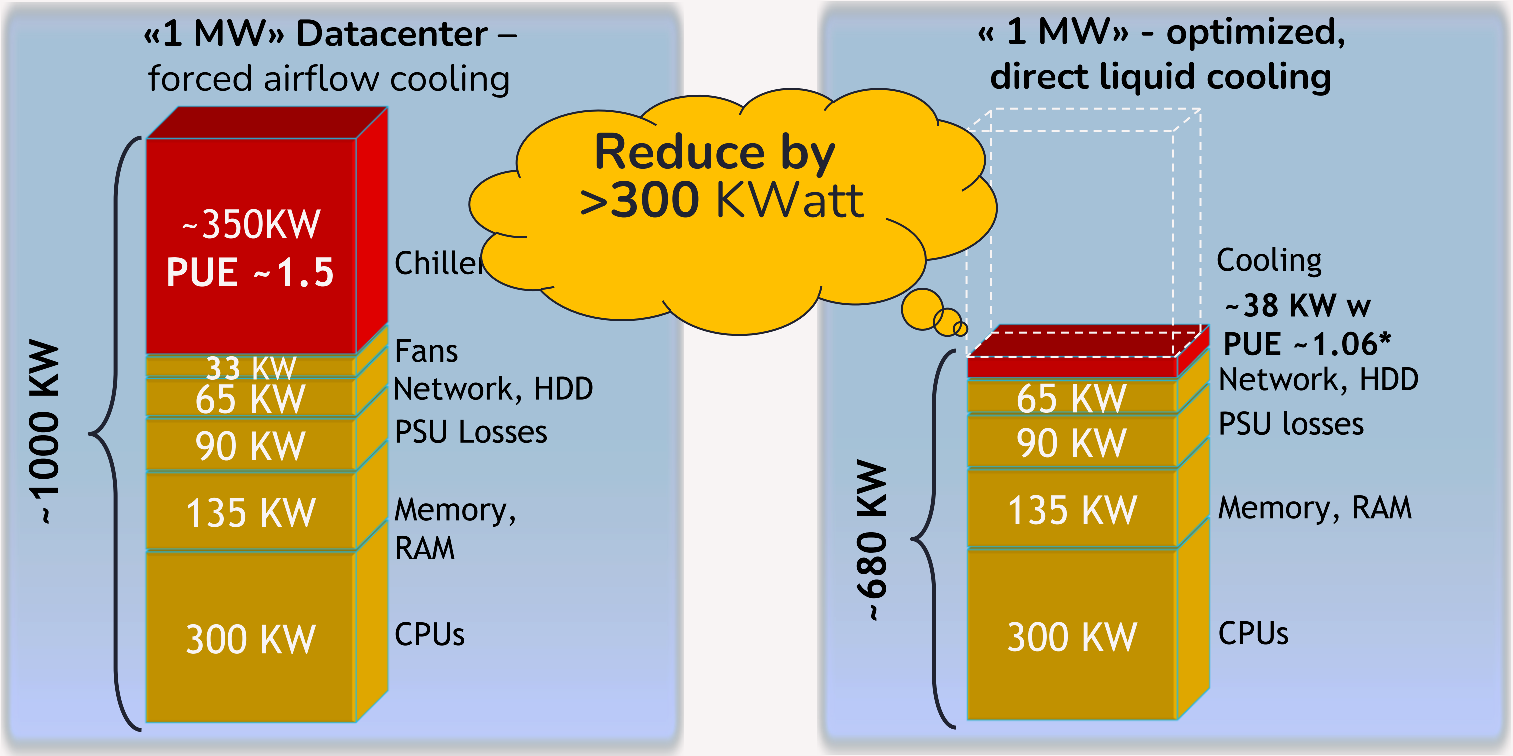
The supercomputer receives water cooled to a temperature of **45 degrees**. Having passed through the entire circuit in the supercomputer, water heated to **50 degrees** returns to the heat exchanger, where it is cooled, transferring thermal energy to the hydraulic circuit of the dry cooling tower.

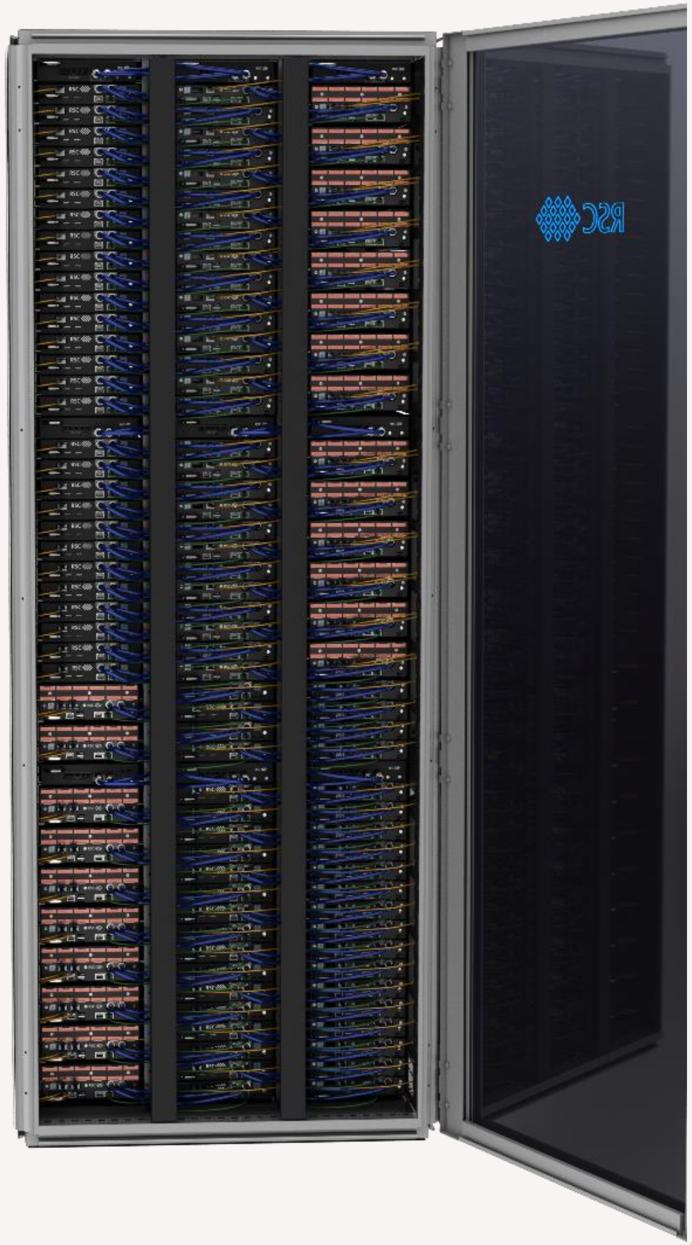




The cooling system has a smooth performance adjustment, which allows you to increase or decrease the power of the cooling system in accordance with the actual load. This allows you to significantly reduce energy consumption at partial load.

Reason for liquid cooling: 1 MW datacenter example





Cooling is a major optimization option in datacenter

Additional benefits:

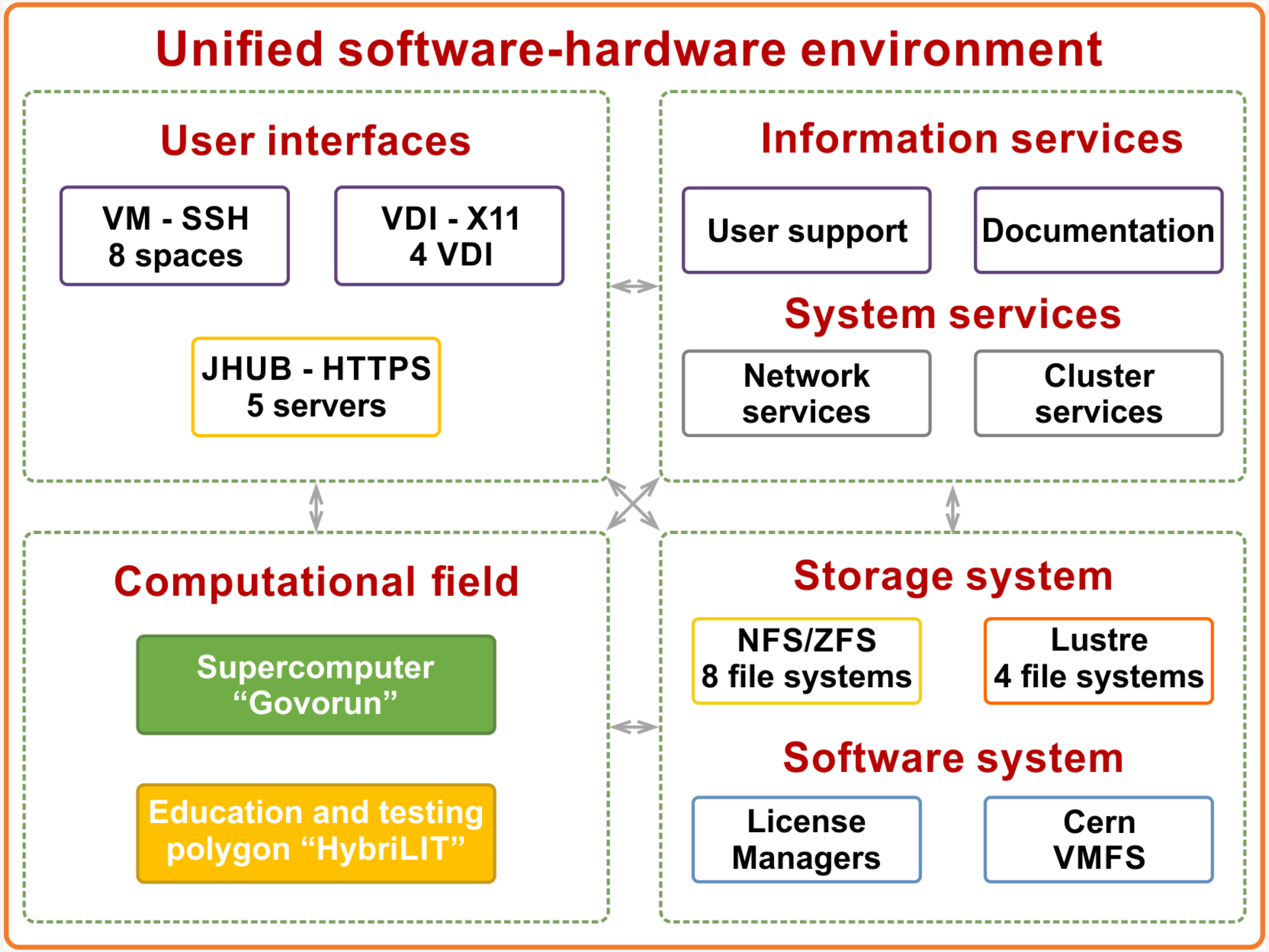
1) Compact design enabled
2) Top bin CPU even in dense blade package
3) More reliability

Liquid cooling for supercomputers

Top500 Rank	System	Cooling technology	Top500 Rank	System	Cooling technology
1	Frontier	Direct cold water cooling	11	Explorer-WUS3	Airflow cooling
2	Fugaku	Direct cold water cooling	12	Adastra	Direct cold water cooling
3	LUMI	Direct cold water cooling	13	JUWELS Booster Module	Direct warm water cooling
4	Leonardo	Direct warm water cooling	14	Pre-Eos 128 Node DGX SuperPOD	Direct cold water cooling
5	Summit	Direct cold water cooling	15	HPC5	Airflow cooling
6	Sierra	Direct cold water cooling	16	Voyager-EUS2	Airflow cooling
7	Sunway TaihuLight	Airflow cooling	17	Setonix – GPU	Direct cold water cooling
8	Perlmutter	Direct cold water cooling	18	Discovery 5	Direct cold water cooling
9	Selene	Airflow cooling	19	Polaris	Airflow cooling
10	Tianhe-2A	Airflow cooling	20	SSC-21	Airflow cooling

Liquid cooling systems take **12 positions** among the first 20 places in the list of the Top500 most productive supercomputers in the world.

Software and hardware structure and services of the HybriLIT heterogeneous computing platform



Software and information environment of the Platform

Information Level

HybriLIT web-site
http://hlit.jinr.ru/

HybriLIT user support project
https://pm.jinr.ru/

HybriLIT user support telegram
https://web.telegram.org/k/#-1752786710

Indico
https://indico.jinr.ru/

GitLab
https://gitlab-hybrilit.jinr.ru/

Jupyter Book
http://studhub.jinr.ru:8080/jjbook
http://studhub.jinr.ru:8080/books

Software Level

Testbed for quantum computing

Cirq, PennyLane, Qiskit, QuTiP

ML/DL/HPC ecosystem

Development component
https://studhub.jinr.ru
https://studhub2.jinr.ru

Component for carrying out resource-intensive calculations
https://jhub1.jinr.ru
https://jhub2.jinr.ru

Component for HPC on the HybriLIT platform nodes and data analysis
https://jlabhpc.jinr.ru/

HLIT-VDI

Virtual Desktop Infrastructure

Parallel computing software

Open MPI, CUDA, Intel

Licensed software packages

Comsol Multiphysics, Maple, Wolfram Mathematica, Matlab

Application Packages

GROMACS
Java
LAMMPS
PandaRoot
Python
REDUCE
ROOT
Cmake
FairRoot
FairSoft
FLAIR
FLUKA
GEANT4
Quantum ESPRESSO

BIOHLIT

BIO Dashboards
Datasets
CVAT

NICA

MPD Event Display
Parametric Database
DIRAC interware integration

System Level

Scientific Linux 7.9 (operating system)

xCAT (OS deployment tool)

Puppet (configuration management tool)

FreeIPA (auth system)

SLURM (workload manager)

NFS (network file system)

Lustre (parallel file system)

CernVM-FS (software distribution service)

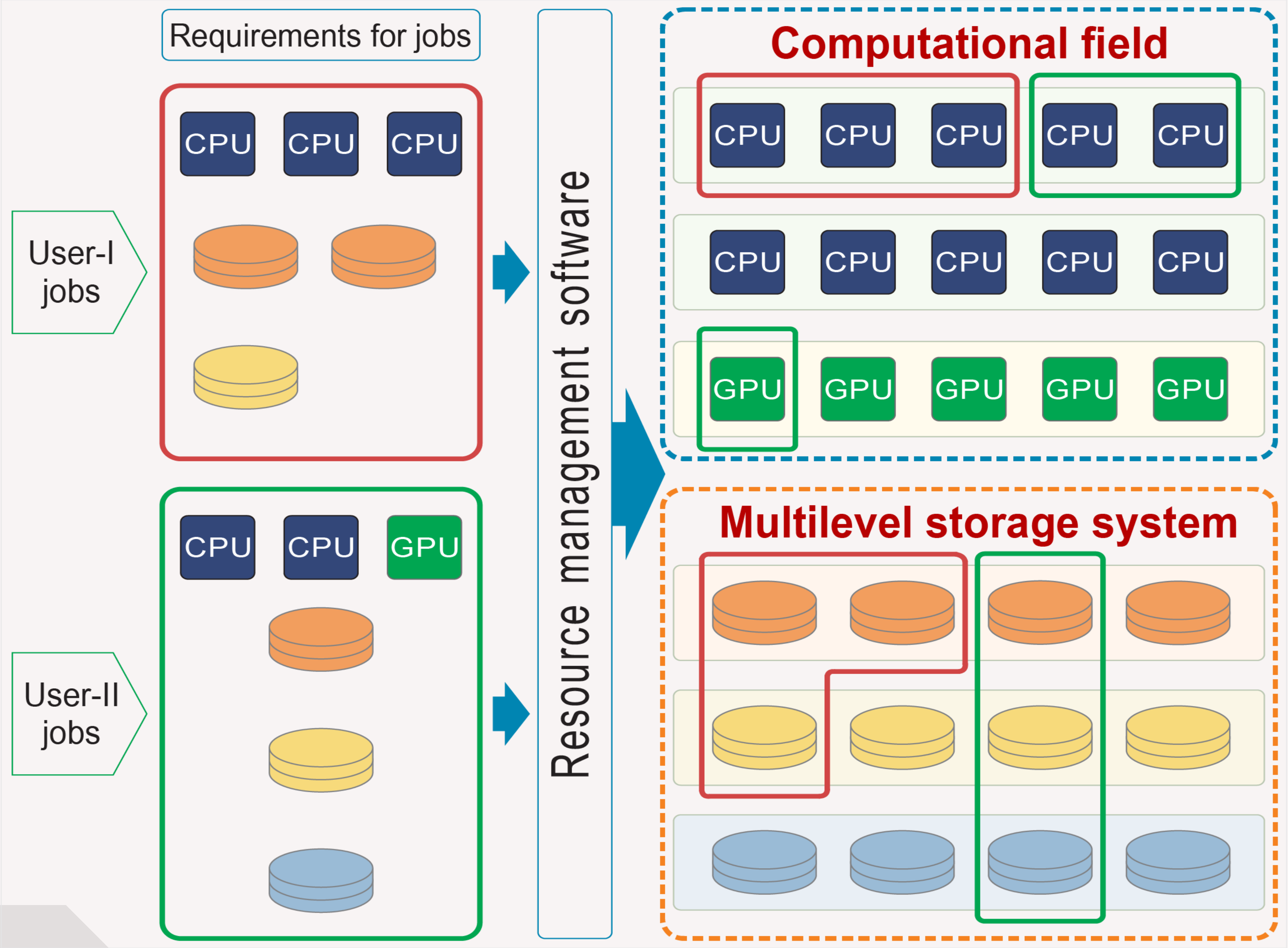
FlexLM/MathLM (licence manager system)

Modules (software environment tool)

Monitoring

Home-HLIT
Monitoring HLIT-VDI
РСК БазИС
Computing Resources' Statistics

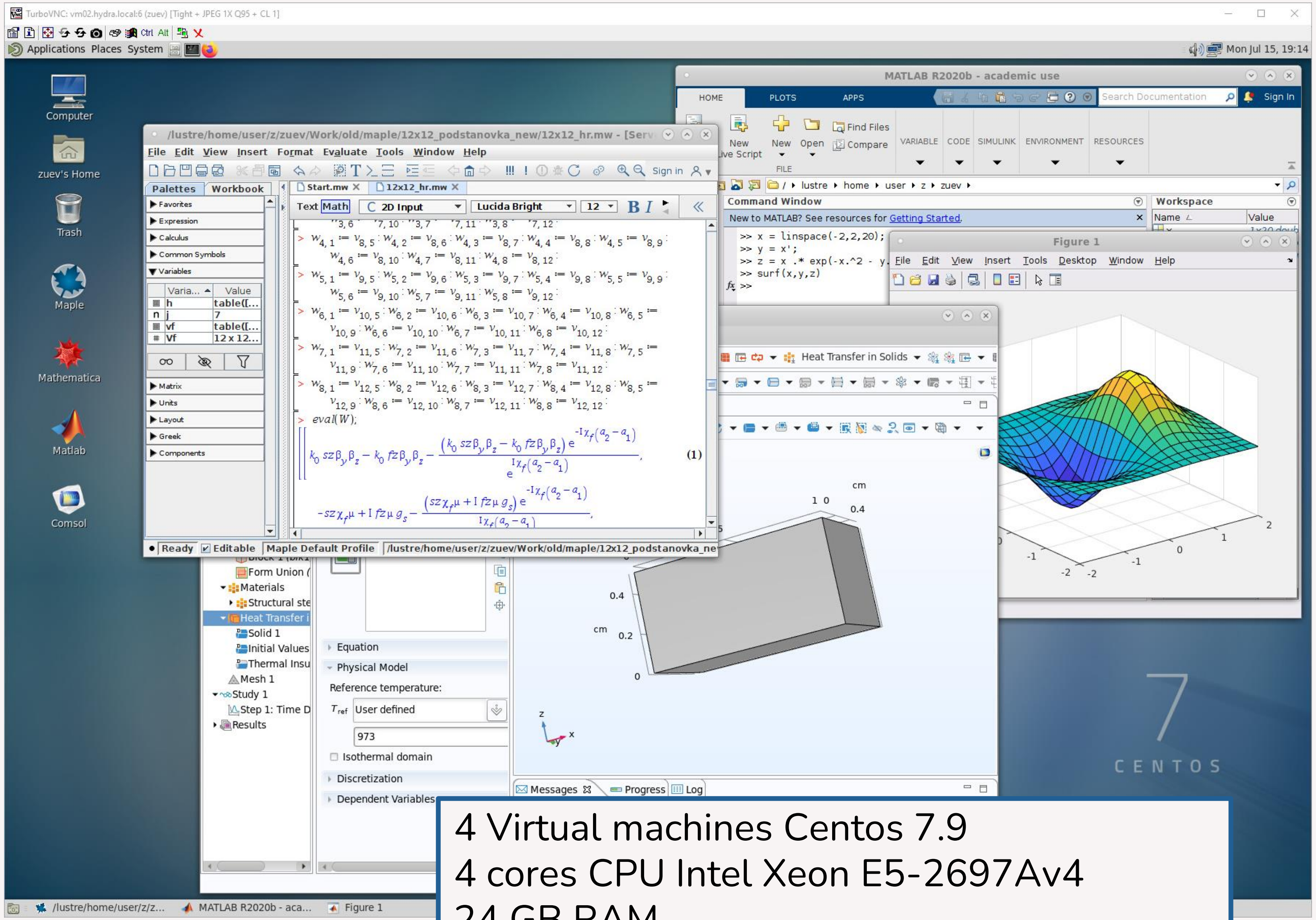
Orchestration and hyperconvergence



“Govorun” supercomputer has unique properties for the flexibility of customizing the user’s job. For his job the user can allocate the required number and type of computing nodes and the required volume and type of data storage systems.

This property enables the effective solution of different tasks, which makes “Govorun” supercomputer a unique tool for research underway at JINR.

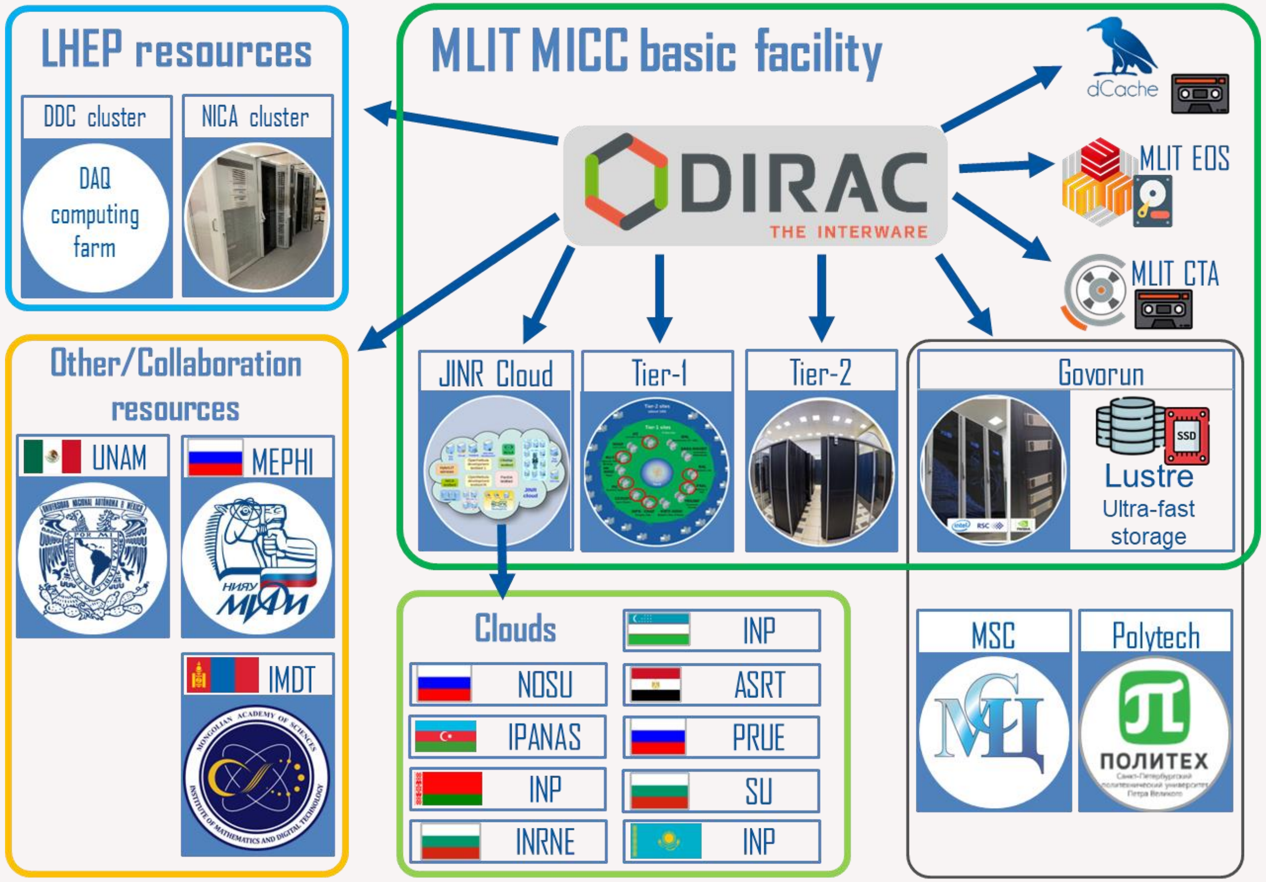
HLIT-VDI Remote Desktop

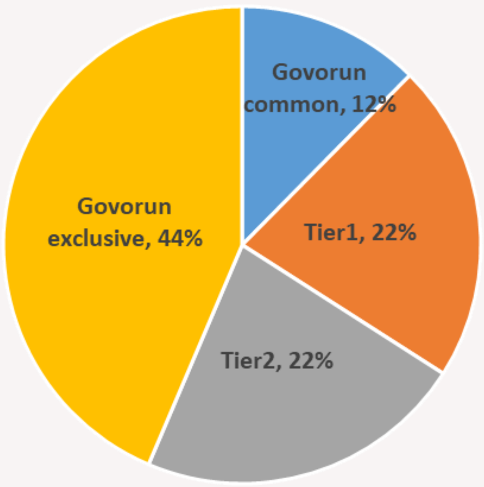


Users have the opportunity to work with mathematical and physical software (Matlab, Mathematica, Maple, COMSOL, Geant4, ROOT) through a graphical user interface (GUI).

4 Virtual machines Centos 7.9
4 cores CPU Intel Xeon E5-2697Av4
24 GB RAM
Nvidia Tesla M60, 8 GB

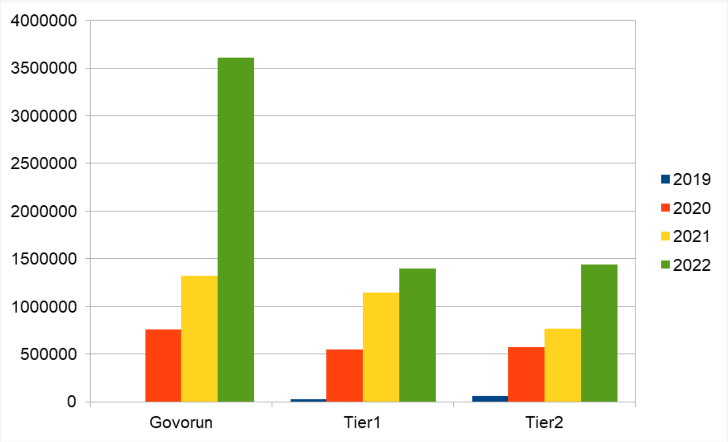
Heterogeneous distributed computing environment





Share of the use of different MICC components for MPD tasks in 2022: "Govorun" resources are the most efficient for MPD tasks.

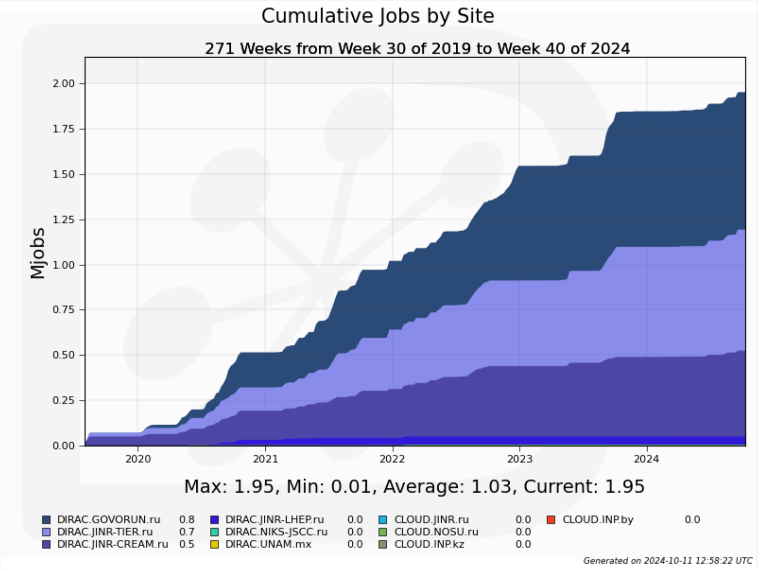
Increase in the share of the MICC computing resources on the DIRAC platform in normalized CPU HEP-SPEC06 days

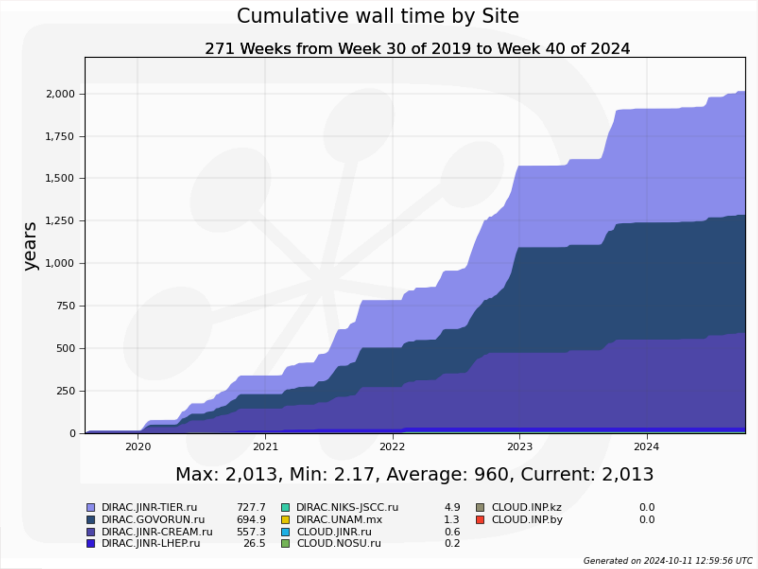


Summary statistics of using the DIRAC platform for MPD tasks in 2019-2024

36	1.412 B	568	1.95 M	2013	1.6 PB	10	500 M
data generation campaigns	events generated	events reconstructed	jobs completed	total computation time(years)	MPD data produced	data analysis campaigns	events analyzed

Heterogeneous distributed computing environment for the MPD experiment



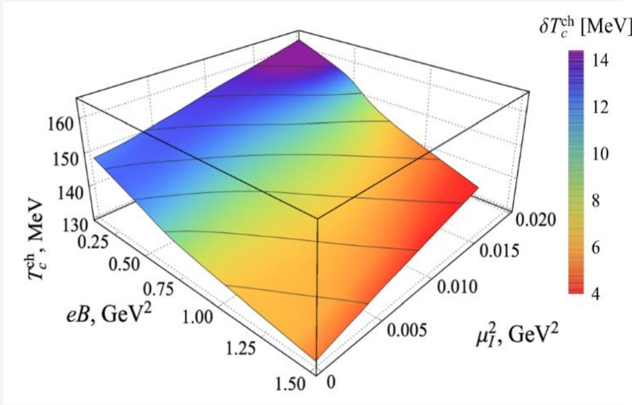


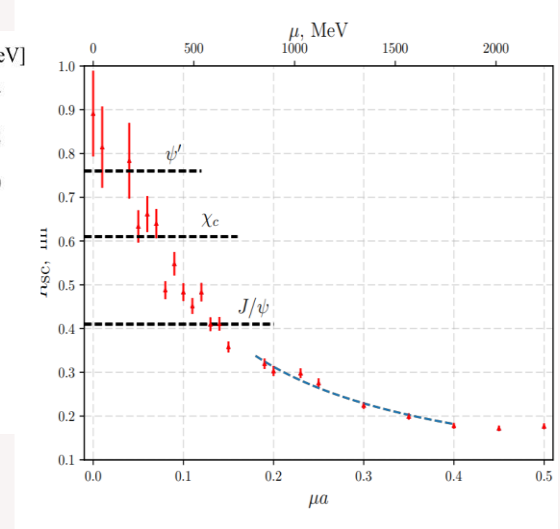
Available resources of the DIRAC platform for the MPD experiment:

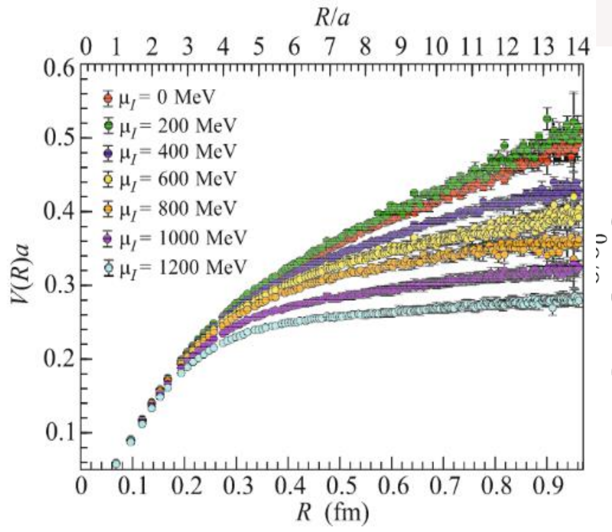
- **“Govorun”** supercomputer: up to **4,864** cores in the latest production
- **Tier1**: **1,500** cores
- **Tier2**: **1,000** cores
- **Clouds** (JINR and JINR Member States): **~500** cores
- **NICA offline cluster**: **1,000** cores (limit for users)
- **UNAM** (Mexico University): **100** cores
- National Research Computer Network of Russia (**NIKS**, now resources from SPBTU and JSCC): **672** cores.

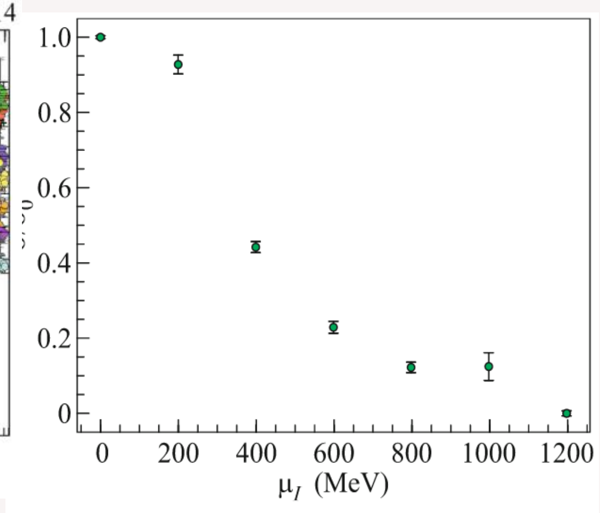
The mass production **storages** integrated into the Dirac File Catalog are **1.5 PB** in size.

“Govorun” supercomputer for QCD tasks









The resources of “Govorun” supercomputer were used to study the properties of quantum chromodynamics (QCD) and Dirac semimetals in a tight-binding mode under extreme external conditions using lattice modeling. The given study entails the inversion of large matrices, which is performed on video cards (GPU), as well as massive parallel CPU calculations, to implement the quantum Monte-Carlo method:

– The influence of the magnetic field on the confinement/deconfinement transition and the chiral transition at finite temperature and zero baryon density were investigated using the numerical modeling of lattice QCD with a physical quark mass.

– Quantum chromodynamics with non-zero isospin density taking into account dynamical u- d-, s- quarks in the Kogut-Susskind formulation was studied.

– The potential of the interaction between a static quark-antiquark pair in dense two-color QCD was investigated, and the confinement/deconfinement phenomenon was studied.

– The effect of the non-zero chiral chemical potential on dynamical chiral symmetry breaking for Dirac semimetals was studied.

– The influence of the external magnetic field on the electromagnetic conductivity of quark-gluon plasma was investigated.

The results are published in the articles:

1. V. V. Braguta, M. N. Chernodub, A. Yu. Kotov, A. V. Molochkov, and A. A. Nikolaev, Phys. Rev. D 100 (2019), 114503, DOI: 10.1103/PhysRevD.100.114503, arXiv:1909.09547

2. V.V. Braguta , A.Yu. Kotov, A.A. Nikolaev, JETP Lett. 110 (2019) no.1, 1-4, DOI: 10.1134/S0021364019130083 (JETP Letters, 110 (2019) no.1, 3-6)

3. N. Astrakhantsev, V. Bornyakov, V. Braguta, E.M. Ilgenfritz, A.Y. Kotov, A. Nikolaev, A. Rothkopf, PoS Confinement2018 (2019), 154, DOI: 10.22323/1.336.0154

4. V. V. Braguta, M. I. Katsnelson, A. Yu. Kotov, and A. M. Trunin, Phys.Rev. B100 (2019), 085117, DOI: 10.1103/PhysRevB.100.085117 , e-Print: arXiv:1904.07003

5. N. Yu. Astrakhantsev, V. G. Bornyakov, V. V. Braguta, E.-M. Ilgenfritz, A. Yu. Kotov, A. A. Nikolaev, A. Rothkopf, JHEP 1905 (2019) 171, DOI: 10.1007/JHEP05(2019)171,e-Print: arXiv:1808.06466

6. https://arxiv.org/abs/1902.09325

7. http://arxiv.org/abs/1910.08516

"Govorun" supercomputer for nuclear physics tasks

- Study of the structure of light exotic, heavy and superheavy nuclei and reactions with them.
- Simulations and data processing for the experiments with exotic nuclei
- Relativistic molecular and periodic quantum-chemical calculation of superheavy elements and their compounds
- Study of changes in the Periodic Law in the region of extremely heavy elements. Study of the electronic structure of elements at the end of the 7th and beginning of the 8th periods.
- Study of radiation safety of heavy ion accelerators at FLNR JINR using Monte Carlo simulation
- Modeling the radiation environment of the DC-140 accelerator complex using the FLUKA software package
- Modeling the kinetics of excitation and relaxation of dielectrics irradiated by fast heavy ions

For calculations of electronic properties of superheavy elements. an on-demand computing system was created. It containing **380 physical cores** (760 logical cores) and **80 TB** file storage managed by the NFS file system. Intensive calculations were carried out on this system using AMS, DIRAC, KANTBP, etc. software. During the past year, over **11,800 tasks** were solved, on which over **3,800,000 core hours** were spent.

The results are presented in the next publications:

1. A.A. Kotov, Y.S. Kozhedub, D.A. Glazov, M. Ilias, V. Pershina, V.M. Shabaev // ChemPhysChem. 2023. **24**. C. E202200680;
2. A. Ryzhkov, V. Pershina, M. Ilias, V. Shabaev // Phys. Chem. Chem. Phys. 2023. **25**. C. 15362;
3. I. M. Savelyev, M. Y. Kaygorodov, Y. S. Kozhedub, A. V. Malyshev, I. I. Tupitsyn, and V. M. Shabaev // Phys. Rev. A **107**, 042803;
4. V.A. Zaytsev, M.E. Groshev, I.A. Maltsev, A.V. Durova, V.M. Shabaev // Int. J. Quant. Chem. 2023. C. e27232.

ML/DL/HPC ecosystem

Component for HPC and data analysis

VM with JupyterHub and SLURM [**https://jlabhpc.jinr.ru**]

- ❑ Intel Xeon Gold 6126 (24 Cores @ 2.6 GHz)
- ❑ 32 GB RAM

Development component

JupyterLab Server [**https://studhub.jinr.ru**]
[**https://studhub2.jinr.ru**]

- ❑ 2x Intel Xeon Gold 6152 (22 Cores @ 2.1 GHz)
- ❑ 512 GB RAM

Component for carrying out resource-intensive calculations

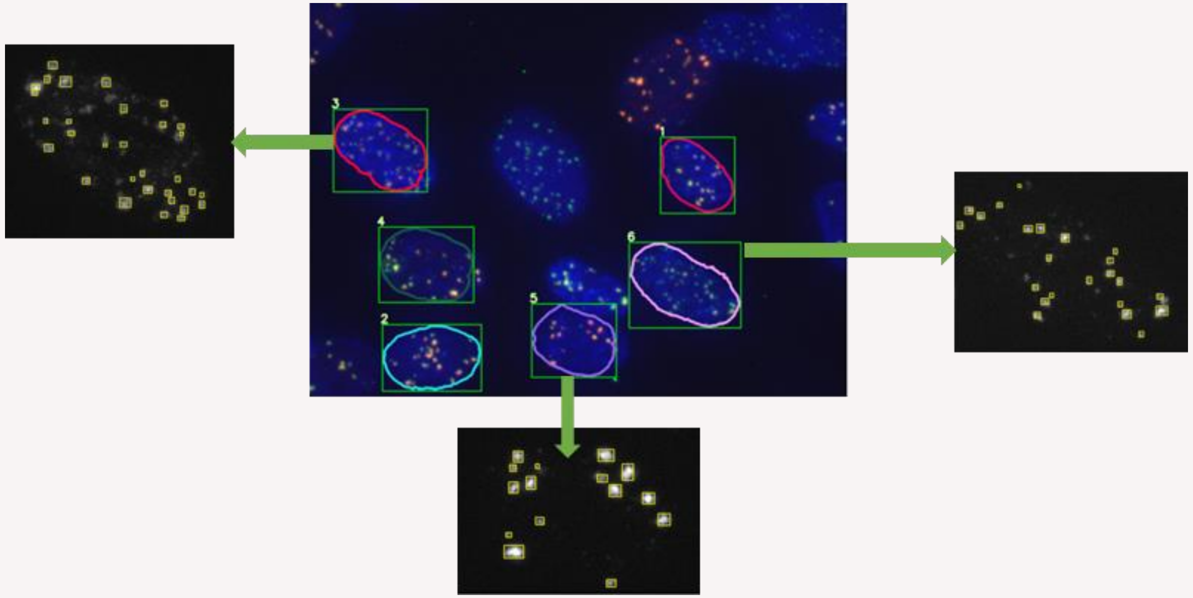
Server with NVIDIA Volta [**https://jhub1.jinr.ru**]
[**https://jhub2.jinr.ru**]

- ❑ 2x Intel Xeon Gold 6148 (20 Cores @ 2.4 GHz)
- ❑ 4x NVIDIA Tesla V100 SXM2 32 GB HBM2
- ❑ 512 GB RAM

BIOHLIT information system for radiobiological studies

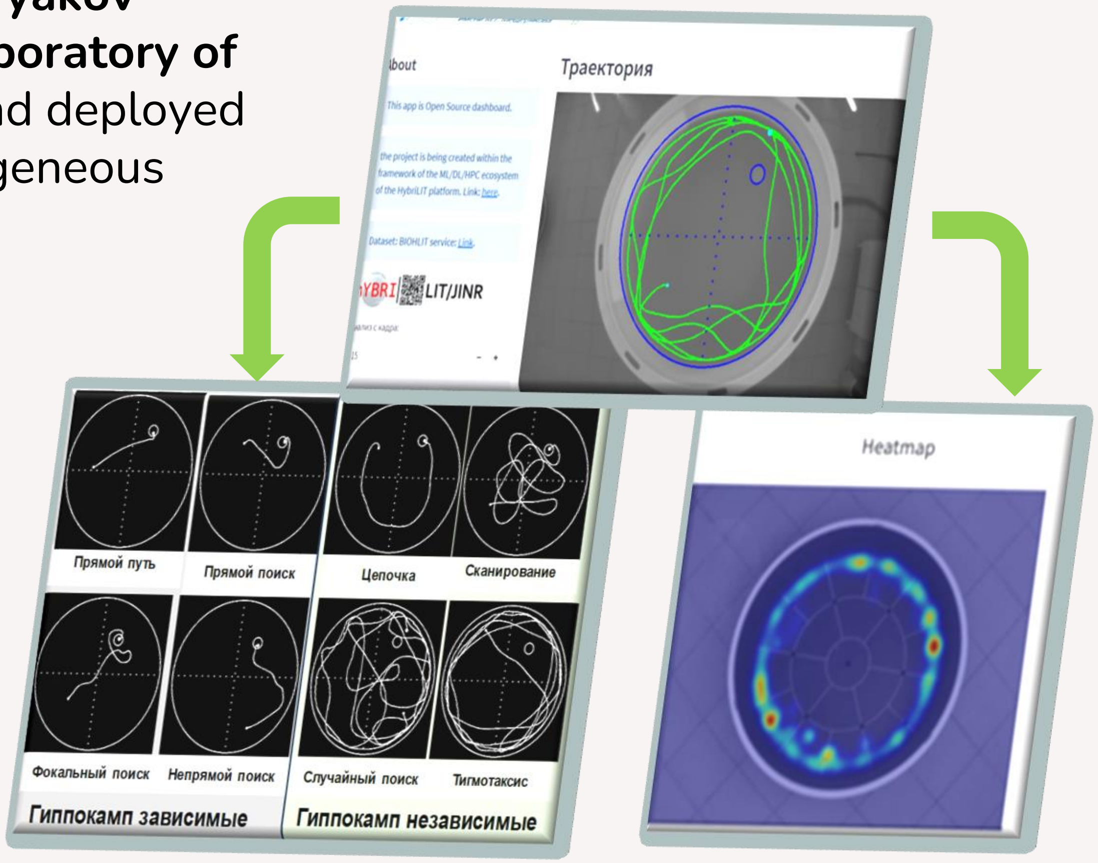
Within the framework of the joint project between **Meshcheryakov Laboratory of Information Technologies (MLIT)** and **the Laboratory of Radiation Biology (LRB)**, the web services are developed and deployed based on the ML/DL/HPC ecosystem of the HybriLIT Heterogeneous Computing Platform.

Detecting DNA repair foci in cell nuclei



Our web service allows to process the group of fluorescent images with minimal operator's involvement and automate the analysis of radiation induced DNA double-strand breaks.

Trajectory analysis



The developed web service allows one to study spatial learning, behavioral reactions and memory of small laboratory animals exposed to irradiations.

Study the dynamics of magnetization in a Phi-0 Josephson Junction

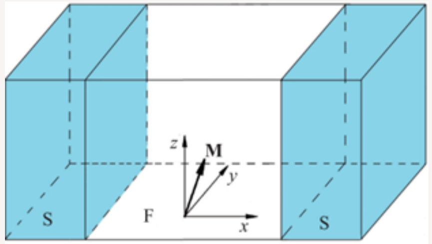
The dynamics of the magnetic moment M of the system under consideration is described by the Landau-Lifshitz-Gilbert equation:

$$\frac{dm_x}{dt} = -\frac{1}{1+M^2\alpha^2}\{m_y H_z - m_z H_y + \alpha[m_x(M,H) - H_x]\},$$

$$\frac{dm_y}{dt} = -\frac{1}{1+M^2\alpha^2}\{m_z H_x - m_x H_z + \alpha[m_y(M,H) - H_y]\}$$

$$\frac{dm_z}{dt} = -\frac{1}{1+M^2\alpha^2}\{m_x H_y - m_y H_x + \alpha[m_z(M,H) - H_z]\},$$

$M = [m_x, m_y, m_z]$ are the magnetic moment components; the effective field components $H = [H_x, H_y, H_z]$ depend on the Josephson phase difference ϕ and are defined as follows:



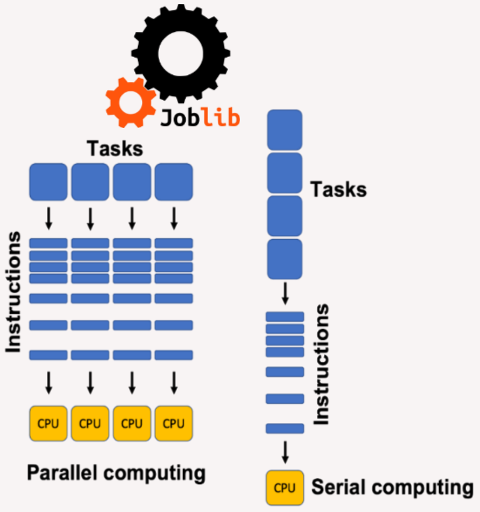
$$H_x(t) = 0,$$

$$H_y = Gr\sin(\phi(t) - t m_y(t)),$$

$$H_z(t) = m_z(t).$$

The equation for the Josephson phase difference $\phi(t)$ is determined from the equation for the electric current I flowing through the Josephson junction, measured in units of the critical current I_c :

$$\frac{d\phi}{dt} = -\frac{1}{w}\left(\sin(\phi - r m_y) + r\frac{dm_y}{dt}\right) + \frac{1}{w}I,$$



Calculations for different values of parameters

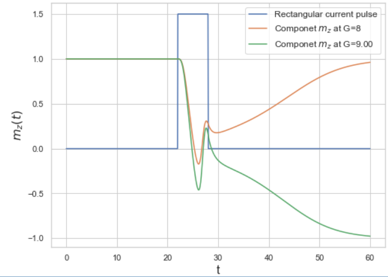
To analyze the possibility of reversing the magnetic moment of the ϕ_0-Josephson junction at different values of the parameters, we will carry out calculations for G=8.9.

```
from scipy.integrate import solve_ivp
from functools import partial
```

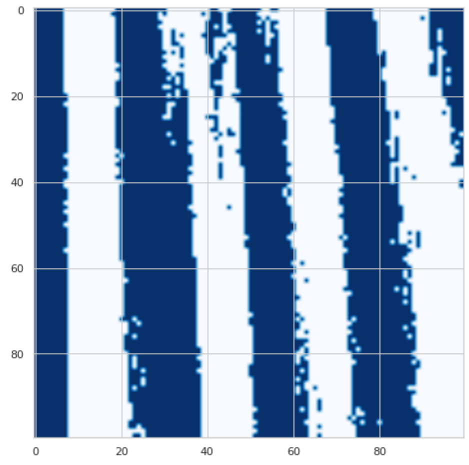
```
G=9
f = partial(my_sfs,  G=G, r=r, alpha=alpha, \
                As=As, t_s=t_s, delta_t=delta_t)
#t_e = np.arange(0, 25, 0.0001)
t_e=np.linspace(0,60,1000)

s0 = np.array([0, 0, 1, 0])
sol_2=solve_ivp(f,[0,60],s0, t_eval=t_e) # method = 'Radau'
```

```
plt.figure(figsize = (8, 6))
plt.plot(t_e,y_I,  label= 'Rectangular current pulse')
plt.plot(sol_1.t, sol_1.y[2], label= 'Componet $m_z $ at G=8' )
plt.plot(sol_2.t, sol_2.y[2], label= 'Componet $m_z $ at G=%4.2f' %G)
plt.xlabel('t', size=16)
plt.ylabel('$m_z(t)$', size=16)
plt.legend(fontsize=12)
plt.show()
```




```
#plt.figure(figsize = (8, 6))
fig, ax1 = plt.subplots(figsize=(8, 8))
# mask out the negative and positve values, respectively
#Zpos = np.ma.masked_less(alpG[:,:,0], 0)
Z1 = Zc.reshape(N, N)
plt.imshow(Z1, interpolation='bilinear', cmap='Blues')
#plt.contourf(X, Y, Zc, 100)
#fig.colorbar(Zc, ax=ax1)
plt.show()
```



Define a function called by each process

```
from joblib import Parallel, delayed
import numpy as np
```

```
def funk_parall(k):
    i=k%N
    j=k//N
    mz_sol=0
    G=G0+delta_G*i
    alpha=alpha0+delta_alpha*j
    f = partial(my_sfs, G=G, r=r, alpha=alpha, \
                As=As, t_s=t_s, delta_t=delta_t)
    t_e=np.linspace(0,60,1000)
    s0 = np.array([0, 0, 1, 0])
    sol_i=solve_ivp(f,[0,60],s0, t_eval=t_e) # method = 'Radau'
    if sol_i.y[2][999] < 0:
        mz_sol= -1
         # alpGxy[i+j*N,2] =- 1
    return mz_sol
```

Serial mode calculation

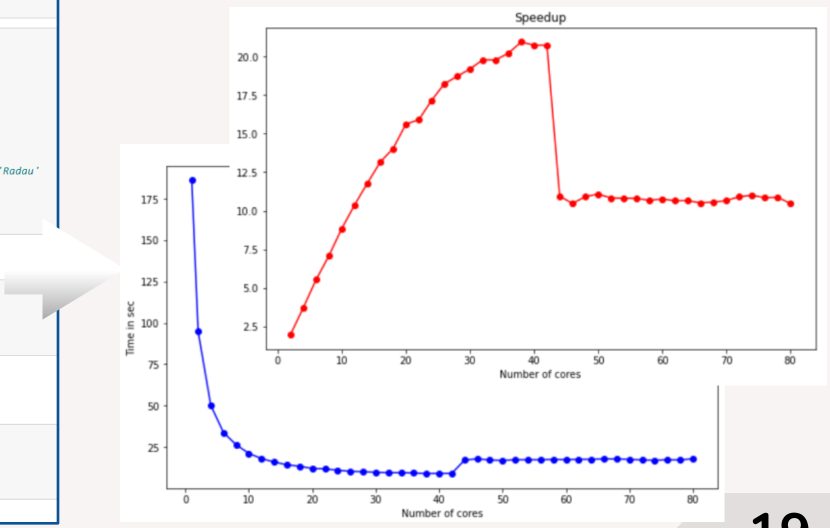
```
t0 = time.time()
rez= Parallel(n_jobs=1)\
    (delayed(funk_parall)(k) for k in range(N*N) )
t1 = time.time()
print(f'Execution time {t1 - t0} s')
```

```
Execution time 159.9254457950592 s
```

Computing in Parallel Mode

```
t0 = time.time()
rez= Parallel(n_jobs=6)\
    (delayed(funk_parall)(k) for k in range(N*N) )
t1 = time.time()
print(f'Execution time {t1 - t0} s')
```

```
Execution time 34.51503801345825 s
```



Software modules for modelling superconductor/magnetic hybrid nanostructures

http://studhub.jinr.ru:8080/jjbook, http://studhub.jinr.ru:8080/books

As part of a joint project between **MLIT** and **the Laboratory of Theoretical Physics (BLTP)** on modelling hybrid superconductor/magnetic nanostructures, a package of tools in the form of Jupyter Notebook, which are posted in the format of electronic publications **Jupyter Book** on the Platform resources has been developed.

Математическая постановка задачи

Динамика магнитного момента m рассматриваемой системы описывается уравнением Ландау-Лифшица-Гильберта [1], которое в нормированных единицах покомпонентно имеет вид :

$$\frac{dm_x}{dt} = \frac{\Omega_F}{1+m^2\alpha^2}\left[h_y(m_z - \alpha m_x m_y) - h_z(\alpha m_x m_z + m_y) + \alpha h_x(m_y^2 + m_z^2)\right],$$

$$\frac{dm_y}{dt} = \frac{\Omega_F}{1+m^2\alpha^2}\left[-h_x(\alpha m_x m_z + m_z) + h_z(m_x - \alpha m_y m_z) + \alpha h_y(m_x^2 + m_z^2)\right],$$

$$\frac{dm_z}{dt} = \frac{\Omega_F}{1+m^2\alpha^2 + \Omega_F \alpha \epsilon k(m_x^2 + m_y^2)}\left[\alpha\epsilon[\sin(Vt - km_z) + V](m_x^2 + m_y^2) - \right.$$

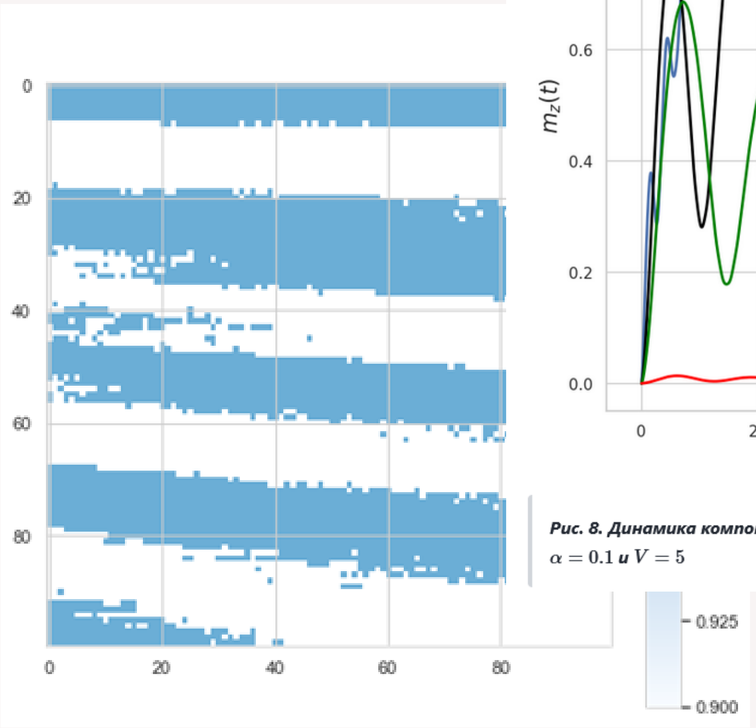
```python
# Зафиксированные физические параметры
alpha = 0.1
k = 0.05
OmegaF = 0.5
V = 5
# Параметры численного счеты
t0 = 0
tf = 120
nt = 600000
```

Расчет при $G = 3\pi$

```python
G3 = 3*np.pi
```

```python
f = partial(my_sfs, G=G3, alpha=alpha, k=k, OmegaF=OmegaF, V=V)
t_e = np.linspace(t0, tf,nt)

s0 = np.array([0, 1, 0])
sol_G3 = solve_ivp(f, [t0, tf], s0, t_eval=t_e, method='RK45',
                   rtol=1e-8, atol=1e-9)
```



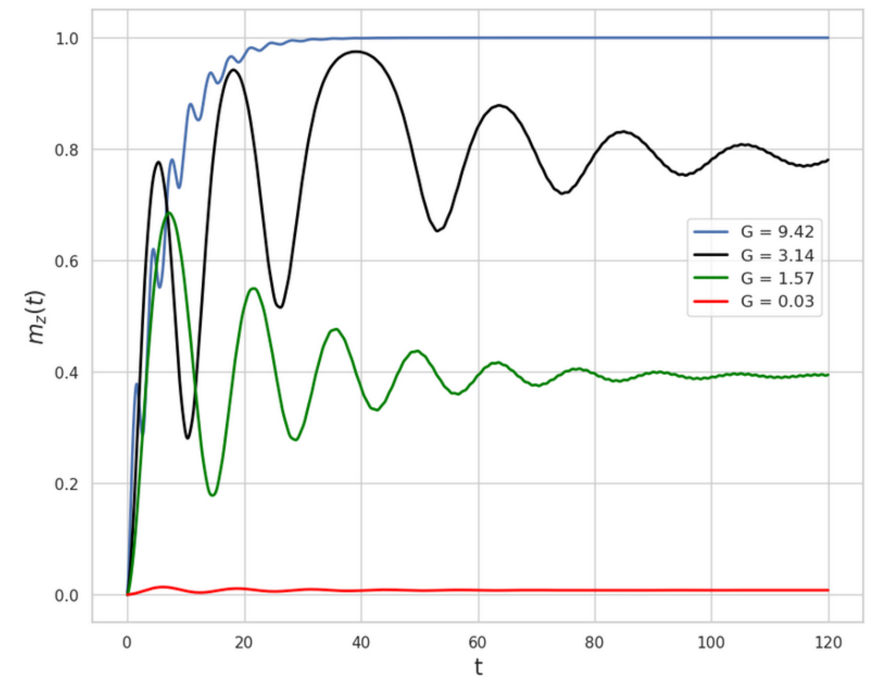


Рис. 8. Динамика компоненты m_z в зависимости от величины параметра G при $k = 0.05$, $\alpha = 0.1$ и $V = 5$

Testbed for quantum computing

While quantum computers are not available for widespread use, various simulators of quantum computing on classical computers are being developed.
These are libraries on various programming languages or frameworks that allow to create, transform, optimize and effectively simulate quantum circuits. Thus, they allow user to completely control the behavior of a quantum system.

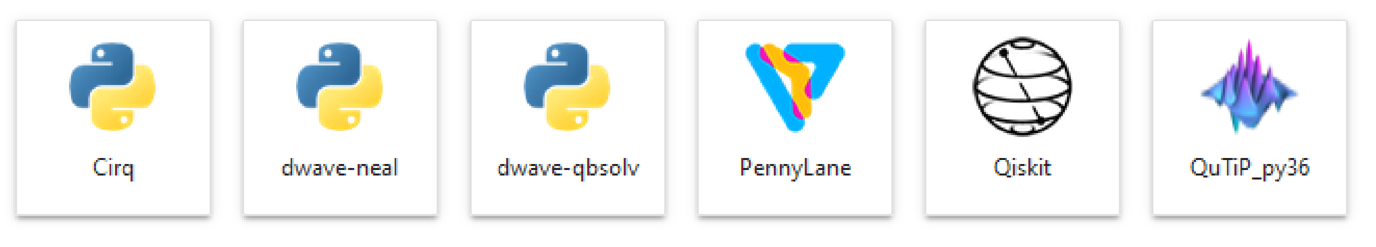
The work is organized in two modes:

- using task scheduler (in SLURM queue mode)

  The main advantages:
  - the ability to perform multi-node computations using MPI technology;
  - the use of resources of the entire Platform.

- in interactive mode via web-browser

  The main advantages:
  - the ability to visually develop algorithms, visualize quantum circuits;
  - available Python language materials can significantly speed up research.



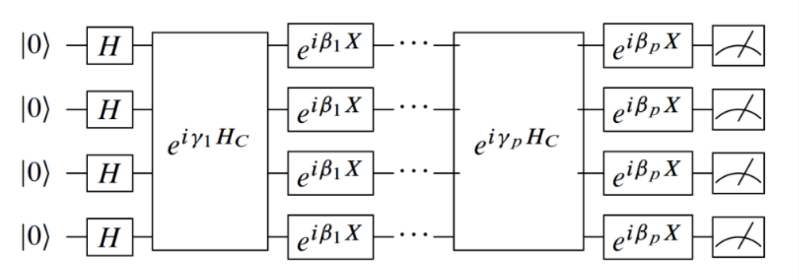
Testbed for quantum computing. Working in interactive mode. Cirq library

https://quantumai.google/cirq

Searching for the state with the lowest energy in the Ising model with a longitudinal magnetic field using the quantum approximation optimization algorithm (QAOA).

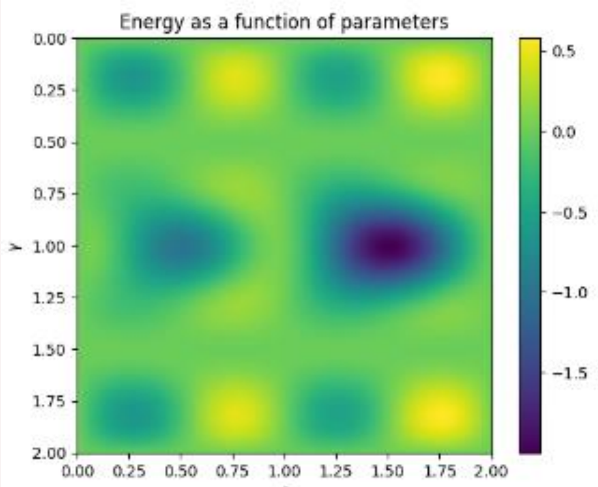
The solution to the problem is to find a pair of parameters γ, β, at which the energy value $\mathcal{E}(\gamma, \beta)$ will be minimal.

The problem statement is presented in detail in the work *Yu. Palii, A. Bogolubskaya, and D. Yanovich: Quantum Approximation Optimization Algorithm for the Ising Model in an External Magnetic Field // PEPAN, V. 55, N. 3. Pp. 600-602, 2024.*



A quantum circuit to the variation ansatz of QAOA

$$|\psi(\gamma,\beta)\rangle = \underbrace{U(\beta_p, B)U(\gamma_p, \mathcal{H})}_{p} \ldots \underbrace{U(\beta_1, B)U(\gamma_1, \mathcal{H})}_{1} H^{\otimes n}|0\rangle^{\otimes n}$$



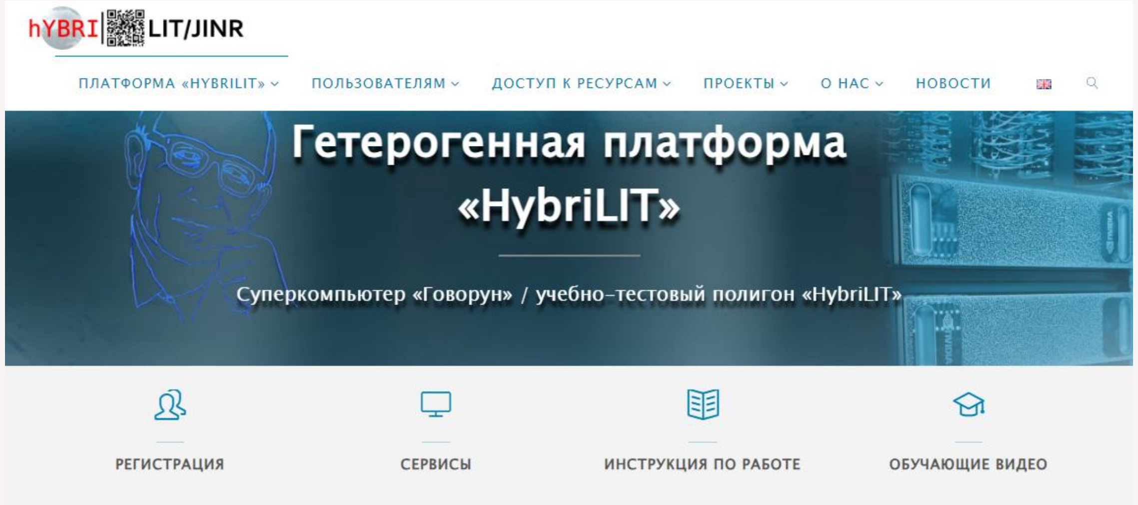
Coincidence of state vector search and sampling search.

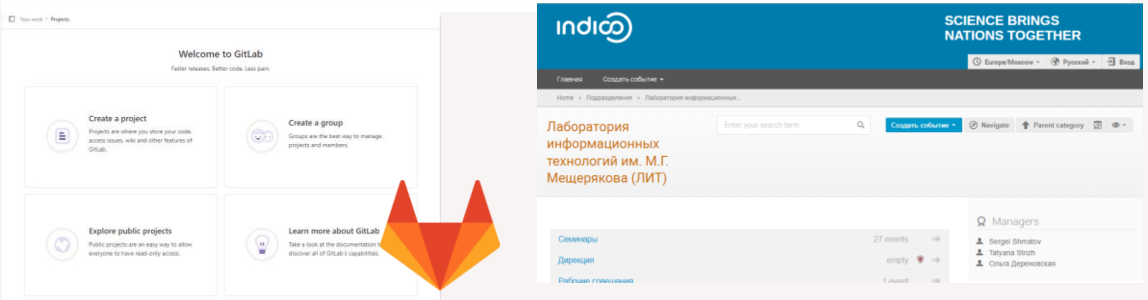
The optimized **qsim simulator** integrated into Cirq is written in C++ and uses SIMD instructions for vectorization, OpenMP for CPU calculations, and CUDA for GPU calculations.

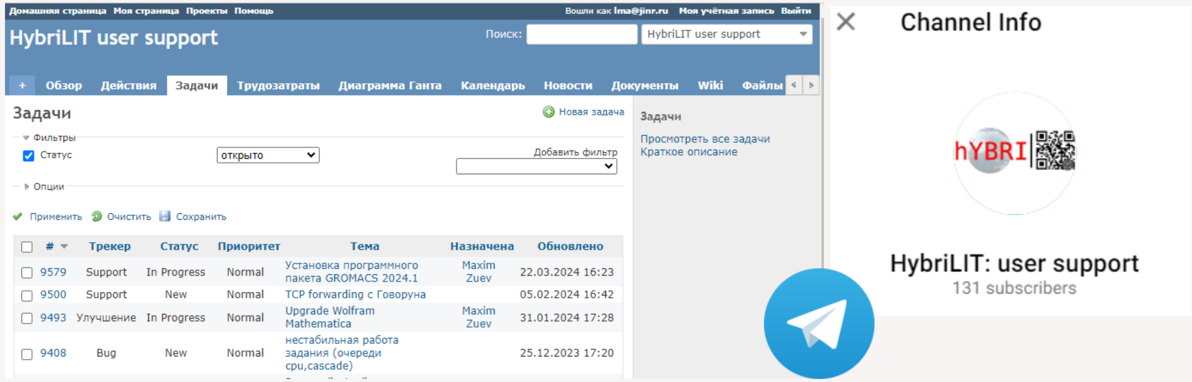
During the computations, the task on the **3x3x3** lattice took up **~1 ТБ RAM CPU** and **~1.5 ГБ RAM GPU**.

Ising Model 3x3x3 lattice 27 qubits	**AMD EPYC 7763, 128 threads**	**Intel Xeon Platinum 8368Q, 128 threads**	**NVIDIA A100, cuStateVec**
Computation time	3 h 20 min	3 h 10 min	14 min 35 sec

Information level





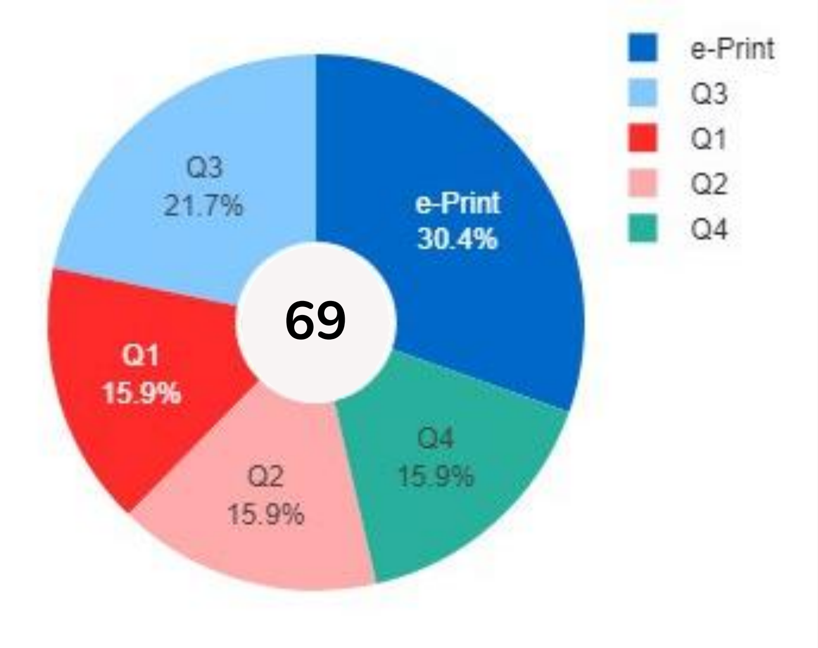


- **The website** provides a detailed description of the platform: hardware and software structure, characteristics of computing resources, and examples for working with installed application software
- **GitLab** collaborative development service provides the opportunity for the users of the platform to jointly develop application software and work with their own Git repositories.
- The **Indico** software platform is used to support the organization of conferences, seminars and meetings, including in a hybrid format.
- HybriLIT team provides user support and resolves issues related to the work process on the platform via **JINR Project Management Service**.
- To consult and resolve user questions regarding work on the Platform, the **HybriLIT user support** service is used, available in the JINR Project Management Service environment.
- A streaming channel **HybriLIT user support** on the **Telegram social network** is being used to promptly inform users

84 processed user requests (in 2023) via **PM HybriLIT user support**

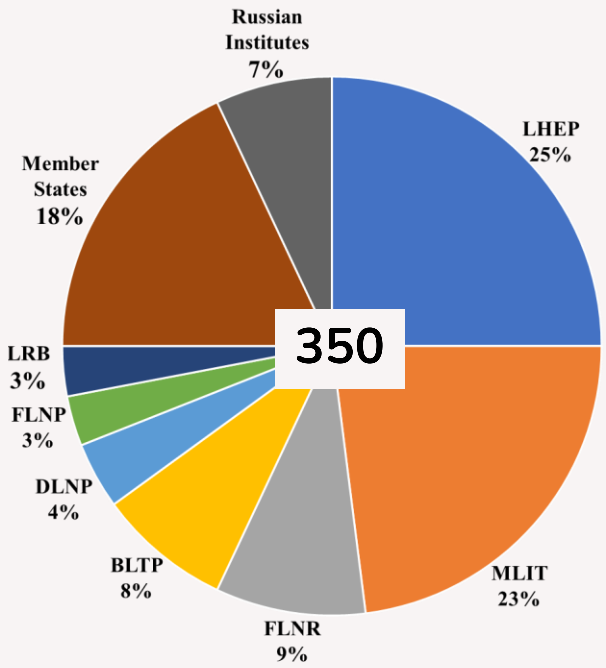
41 events conducted (in 2023) via the **Indico** system

Using of the “Govorun” supercomputer in 2023



Over the past year, users of the heterogeneous HybriLIT platform published **69** articles in various fields:

- physics of elementary particles and the atomic nucleus,
- high energy physics,
- biophysics and chemistry,
- neural network approach, methods and algorithms of machine learning and deep learning (ML/DL), etc.



Research results obtained using the supercomputer resources since 2018 are presented in **336** publications. Two of them were prepared in Nature Physics:

- M. Kircher,..., **O. Chuluunbaatar** et al. Kinematically complete experimental study of Compton scattering at helium atoms near the threshold. Vol. 16. № 4. Pp. 756-760
- **BM@N Collaboration**. Unperturbed inverse kinematics nucleon knockout measurements with a 48 GeV/c carbon beam. Vol. 17. Pp. 693-699

Within 2023, all groups of “Govorun” SC users completed **640,861 jobs on the CPU** component, which corresponds to 16 million core hours, and **7,808 jobs on the GPU** component, which corresponds to 45,400 GPU hours. The average load of the **CPU component** was **96.4%**, while the **GPU component** load was **91.2%**.

Educational activities on the Platform

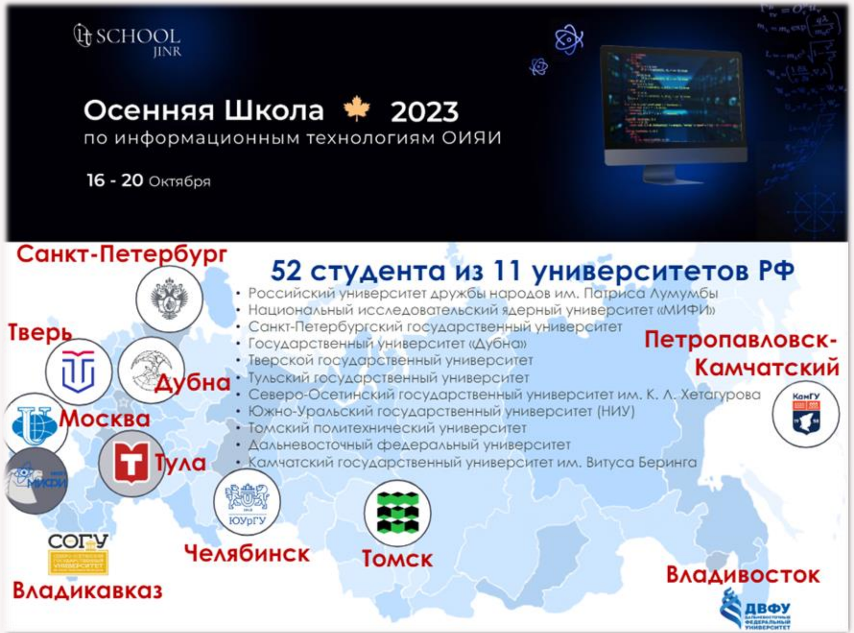
Platform resources are used as a base platform for studying new IT technologies and for training IT specialists. The International School on Information Technologies of JINR is held annually at LIT; it is aimed at attracting young specialists to solving JINR tasks using modern information technologies.

The **Dubna State University** regularly conducts training courses in such disciplines as:

- "Architecture and technologies of high-performance systems",
- "Parallel distributed computing",
- "Languages and technologies of data analysis",
- "High-performance computing technologies".

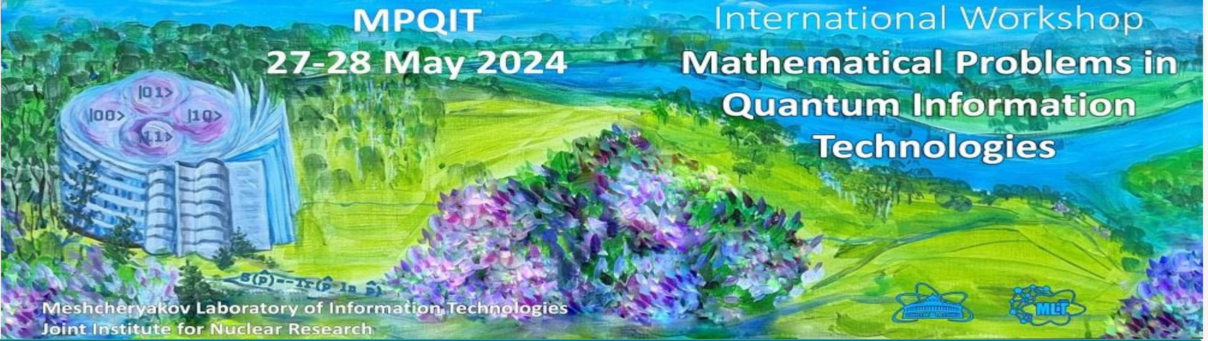
Over the past academic year (2022-2023), **380 students** participated in these courses.

"Software tools for mathematical calculations" course attended by **40 students** was held at **Tver State University**.



https://itschool.jinr.ru

Training courses, lectures, tutorials



The main focus was on the mathematical aspects of diverse problems in fundamental and applied quantum technologies, such as

- quantum information theory,
- quantum communications,
- quantum computing, simulation, and quantum algorithms.

More than **60** participants from

Armenia,	Great Britain,	India,	Romania,
Belarus,	Georgia,	Kazakhstan,	Serbia,
Bulgaria,	Egypt,	Moldova,	the Czech Republic

Russia was represented by specialists from Voronezh, Kazan, Moscow, St. Petersburg, Tver, Chelyabinsk and Dubna.

32 reports (9 from JINR)

JINR School of Information Technologies

it SCHOOL JINR

7-11 October 2024

- Distributed and high-performance computing for experimental and theoretical research at JINR;
- Mathematical modeling and numerical methods;
- Modern methods and technologies for information processing and analysis;
- JINR Digital EcoSystem;
- Support and development of the JINR Multifunctional Information and Computing Complex (MICC);
- Engineering infrastructure: automation and monitoring.

Thank you for your attention!

Heterogeneous platform “HybriLIT”

http://hlit.jinr.ru/