# REPORT ON THE THEME "INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR" AND PROPOSAL FOR ITS EXTENSION

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LABORATORY OF INFORMATION TECHNOLOGIES

## Main goals of research:

The purpose is to ensure the further development of the network, information and computing infrastructure of JINR for the research and production activities of the Institute and its Member States on the basis of state-of-the-art information technologies in accordance with the JINR Seven-Year Plan of development.

A particular area within the theme is the development of the Multifunctional Information and Computing Complex (MICC) at LIT JINR, presented in a Project form.

## Participating Countries, Institutes and International organizations:

Armenia, Azerbaijan, Belarus, Bulgaria, CERN, China, Cuba, Czech Republic, Egypt, France, Georgia, Germany, Italy, Kazakhstan, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, South Africa, Sweden, Taiwan, Ukraine, USA.

| | Activity | Leaders |
|---|---|---|
| 1. | **Multifunctional Information and Computing Complex (MICC)**<br>MICC engineering infrastructure<br>JINR telecommunication data links and JINR local area network<br>JINR Tier1 and Tier2 centers<br>Cloud Infrastructure<br>HybriLIT platform (HPC) | <br>V.V. Korenkov<br>A.G. Dolbilov<br>V.V. Mitsyn<br>T.A. Strizh |
| 2 | **Information and software support of scientific and production activities at JINR** | P.V. Zrelov<br>V.V. Korenkov<br>I.A. Filozova |
| 3 | **Development of the system of training and advanced training of IT professionals based on the educational and research infrastructure** | V.V. Korenkov<br>T.A. Strizh<br>O.I. Streltsova |

# IT-SERVICES

**Network**

Telecommunication channels, JINR LAN, JINR IXP, JINR LAN Remote Access, Datacenter Network, Device registration, DHCP, DNS, IPDB, Network Registration & Connection, Network Monitoring, Technical Network, WIFI, WLCG Network

**Primary**

Account Management, JINR Certificate Authority, Computer Security Controls, Security Firewall, Single Sign On (SSO), SSH (Secure SHell), VPN, EDUROAM, E-mail, Resources, Portal

**Collaboration**

Audio Conferencing, Eduroam, Indico, Video Conferencing, Webcast and Recording, Project Management, GIT, JINR Disk, JINR Document Server (Invenio)

**Database Services**

Administration Database Service, ADB2, ISS, 1.C EPR, EDS “Dubna”, General Purpose Database Service

## Computer Science &Physics Computing

### Computing

**GRID**

Tier1, Tier2 support, storage support, file transfer, compute element, Grid infrastructure monitoring, VOMS, workload management

**CLOUD**

IaaS
SaaS
PaaS

**HPC**

GOVORUN supercomputer, HybriLIT education and testing cluster, CUDA, MPI, OpenMPI Software and Information Environment

### Applied software

**JINRLIB**

**Software support**

**BigData analytics**

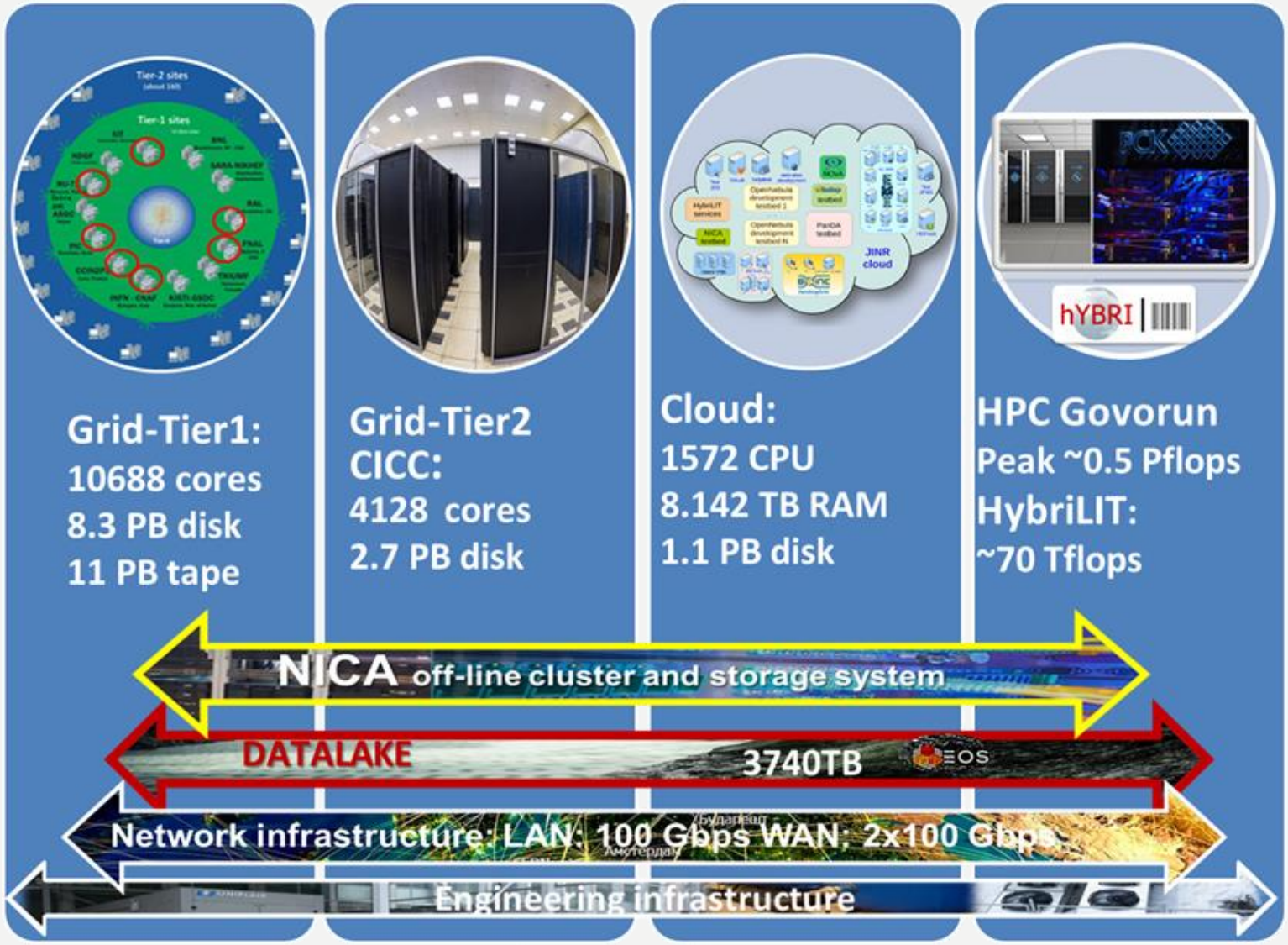
Ecosystem for ML and DL tasks

# MICC NEW COMPONENT

- The "Govorun" supercomputer (a natural development of the HybriLIT heterogeneous cluster) was put into operation
- not initially implied in the MICC project and the JINR 7-Year Plan
- it was the result of requests from scientific groups of JINR Laboratories, primarily BLTP, with the aim of cardinally accelerating complex theoretical and experimental studies in nuclear physics and condensed matter physics underway at the Institute as well as for the development of computing for the NICA megaproject
- supported by the JINR Directors' Grant
- inaugurated on 27 March 2018


## MAIN ACHIEVEMENTS OF THE LAST YEARS: "GOVORUN" HPC

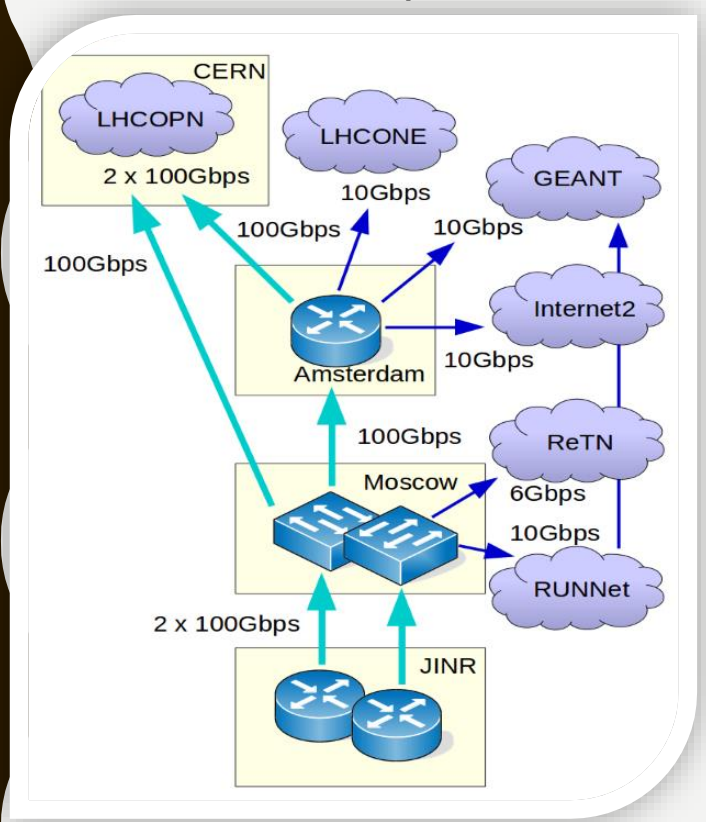
# MULTIFUNCTIONAL INFORMATION AND COMPUTING COMPLEX




- Increase in the total number of compute nodes by **~4** times
- Increase in the disk file system by **~3** times
- Tape robot capacity increase by **2** times
- The Govorun supercomputer with a total peak performance of 1Pflops (single precision) or 0.5 Pflops (double precision) was put in operation

# NETWORK INFRASTRUCTURE

- The external JINR channel was built on the DWDM technology and used a 3x100 Gb/s lambda.
- The main JINR optical data transport medium (backbone) operates at 2x100 Gb/s.
- The multi-site cluster network with a bandwidth 4x100 Gb/s between VBLHEP and LIT was set up.

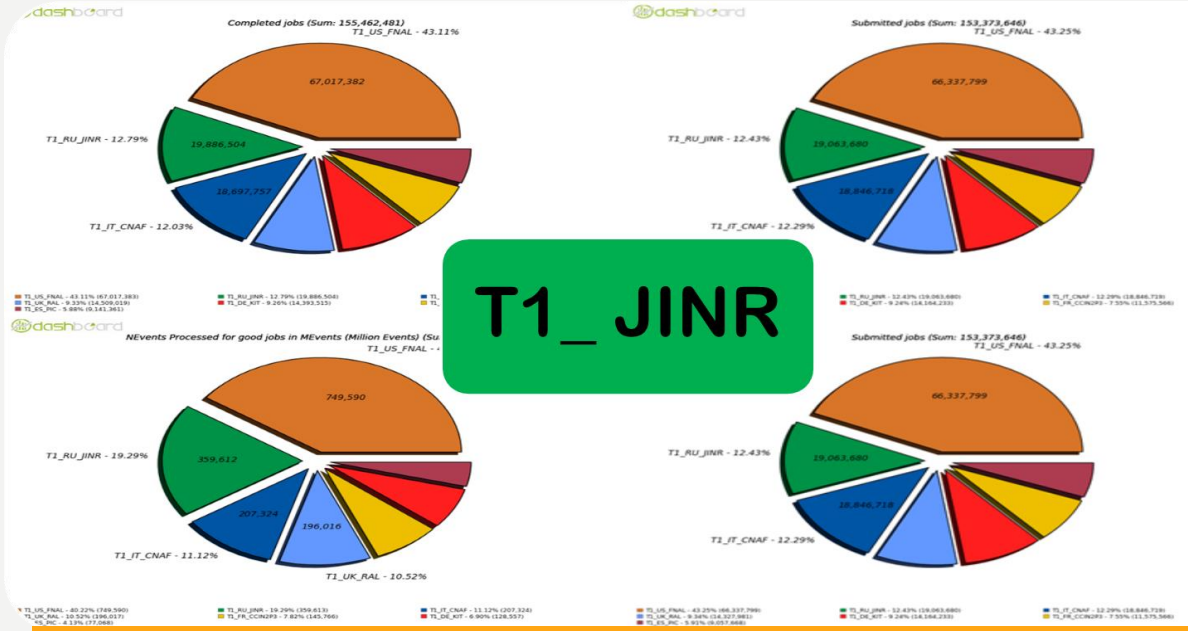



8008 computers & nodes,
Users – 7715,
IP – 14154,
Remote VPN and EDUROAM – 396,
E-library – 1505,
mail.jinr.ru – 2677,
AFS – 369,
VOIP – 131

# ENGINEERING INFRASTRUCTURE

- Cooling system for the Tier-2 modernization (dry cooling)
- Installation of two new transformers (2.5 MW)
- New 100% hot water cooling system for the “Govorun” supercomputer
- Guaranteed power supply using two diesel generators

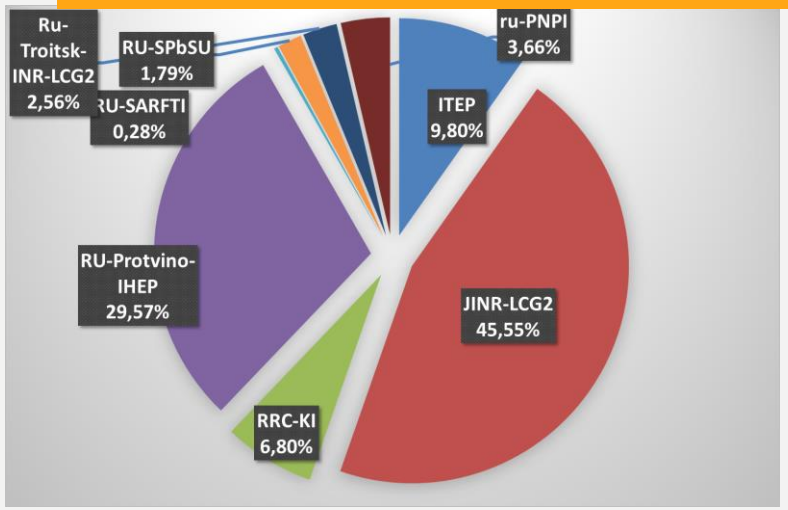
# RESOURCE USAGE 2017-2019

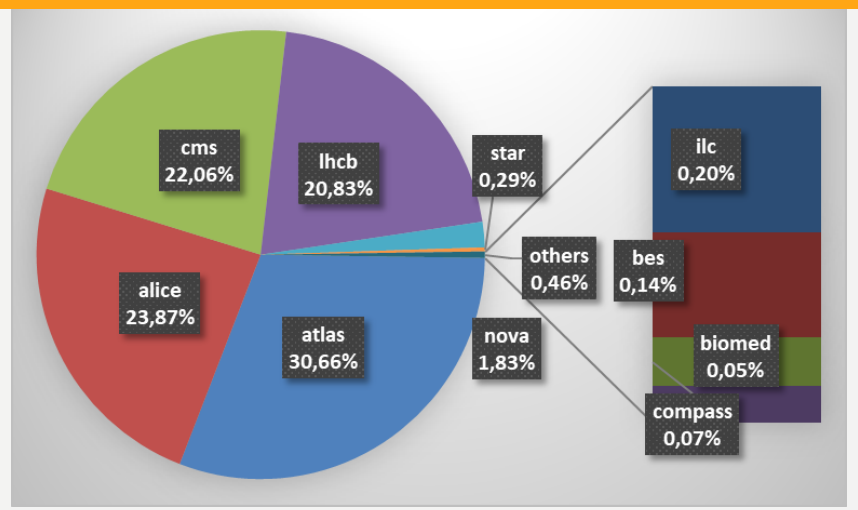


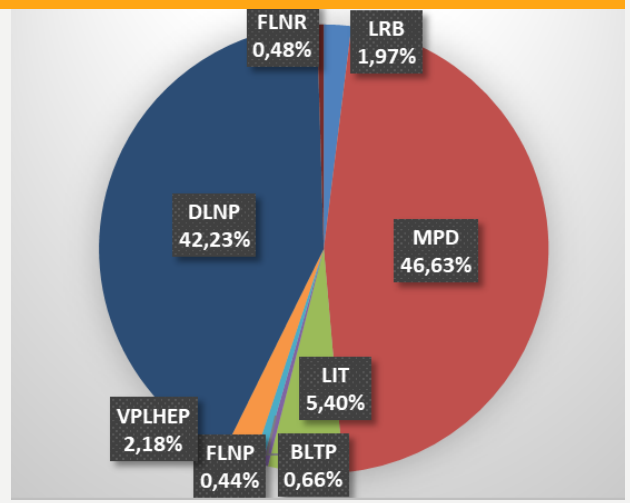

The MICC grid components are Tier1 for CMS at the LHC and Tier2 for Alice, ATLAS, CMS, LHCb, BES, BIOMED, COMPASS, MPD, NOvA, STAR, ILC etc. Tier1 (T1_JINR) was ranked second among other Tier1 centers for CMS by completing over 19.9 million jobs and over 359 billion processed events, which is 19.3% of the total number of CMS events.

Tier2 ensures carrying out computations outside the grid for experiments and local users of JINR Laboratories. More than 11.9 million jobs were processed.

## Tier2 and CICC

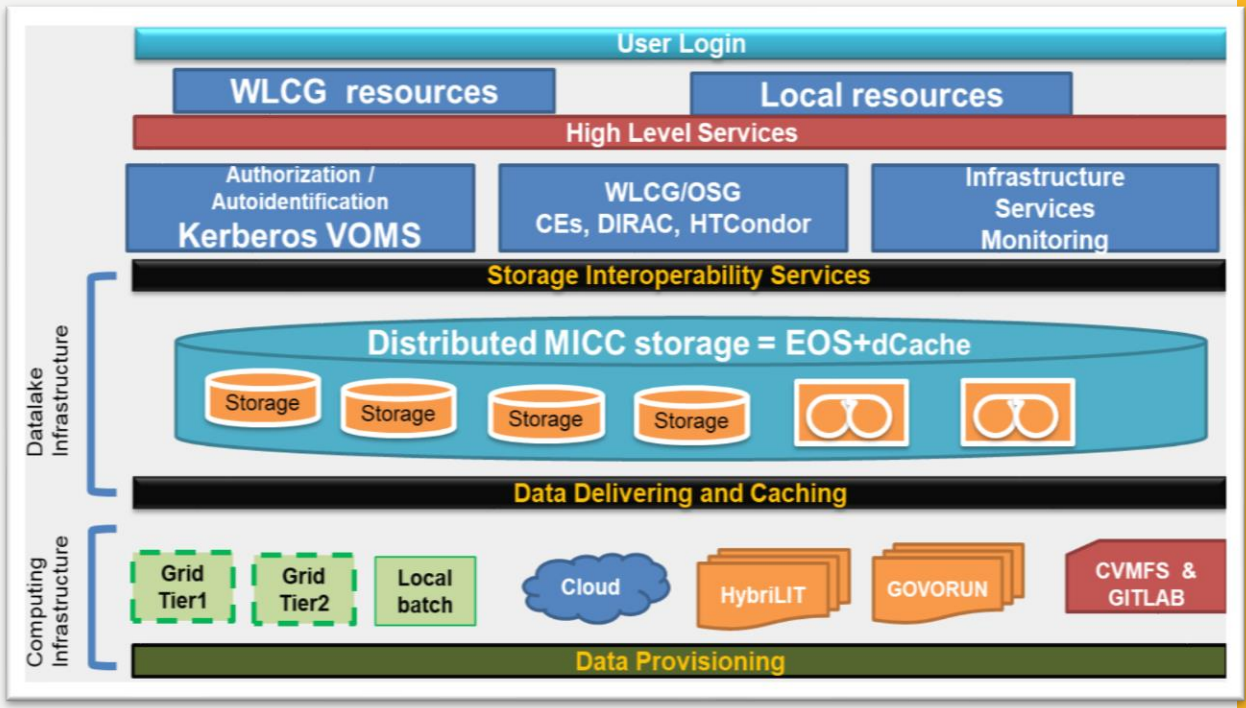


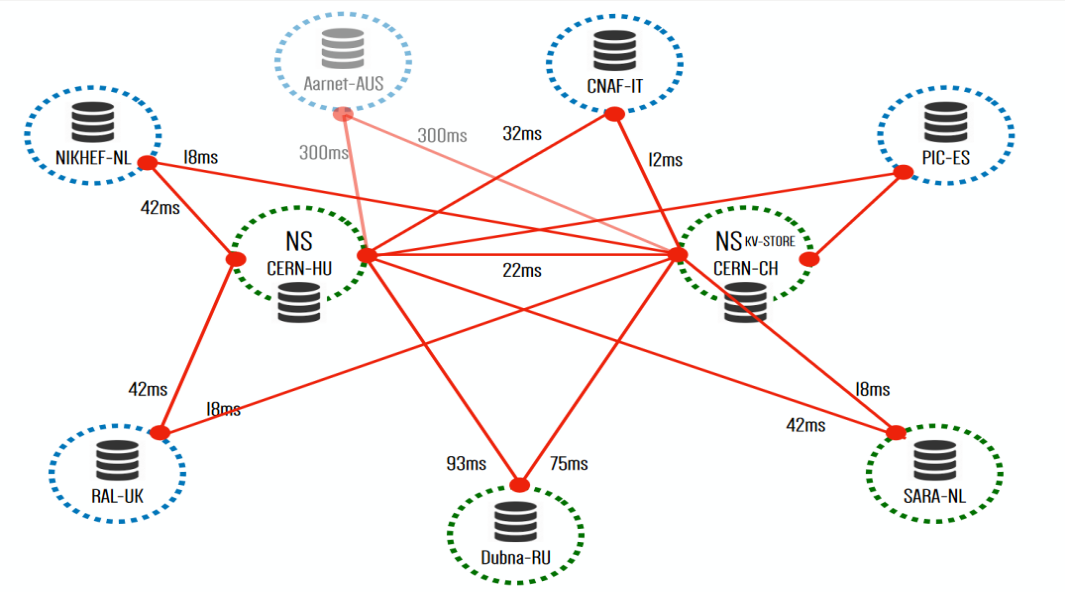



# JINR DATALAKE

- The JINR data lake prototype was built as a distributed EOS storage system.
- EOS was successfully integrated into the MICC structure.
- EOS is used for storing and accessing big arrays of information.
- It can be applied for collective data simulation, storage of raw data gathered from experimental setups, data processing and analysis.

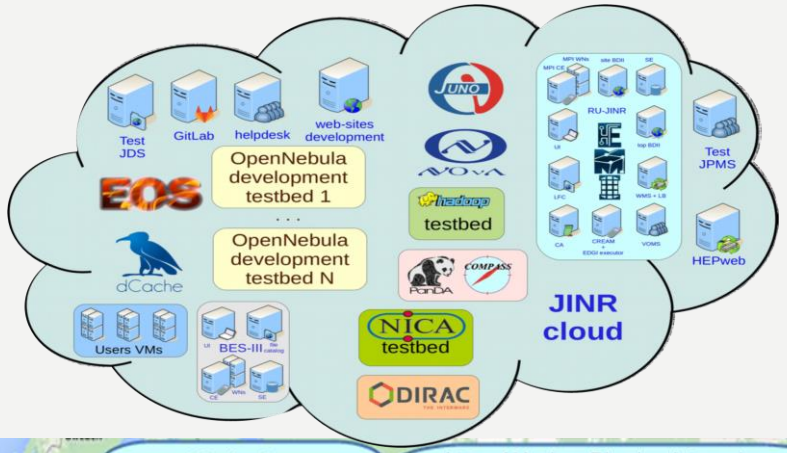



- There is currently 3740TB of disk space available for EOS. NICA experiments have already used EOS for data storage.
- At present, there is ~ 81TB of raw BM@N data and ~84GB of simulated MPD data stored in the EOS instance.
- EOS is visible as a local file system on the MICC working nodes and allows authorized users (by the kerberos5 protocol) to read out and record data.

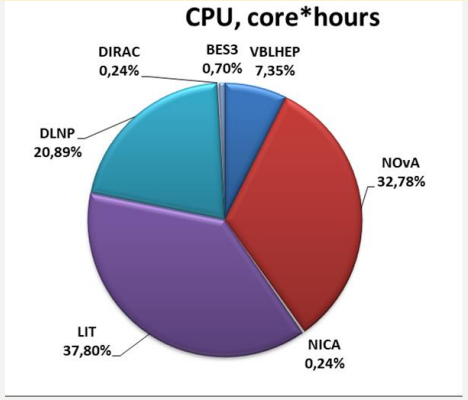


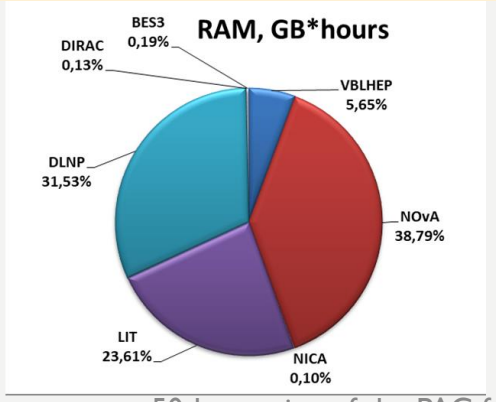
# CLOUD INFRASTRUCTURE

- One of the key components of the JINR cloud infrastructure is a software-defined storage (SDS) based on Ceph
- A new fault-tolerant cloud architecture was designed to optimize the architecture of the cloud storage based on Ceph
- A smart cloud scheduler was developed
- Transformation of the JINR cloud from the IaaS into the Software-as-a-Service (SaaS) platform

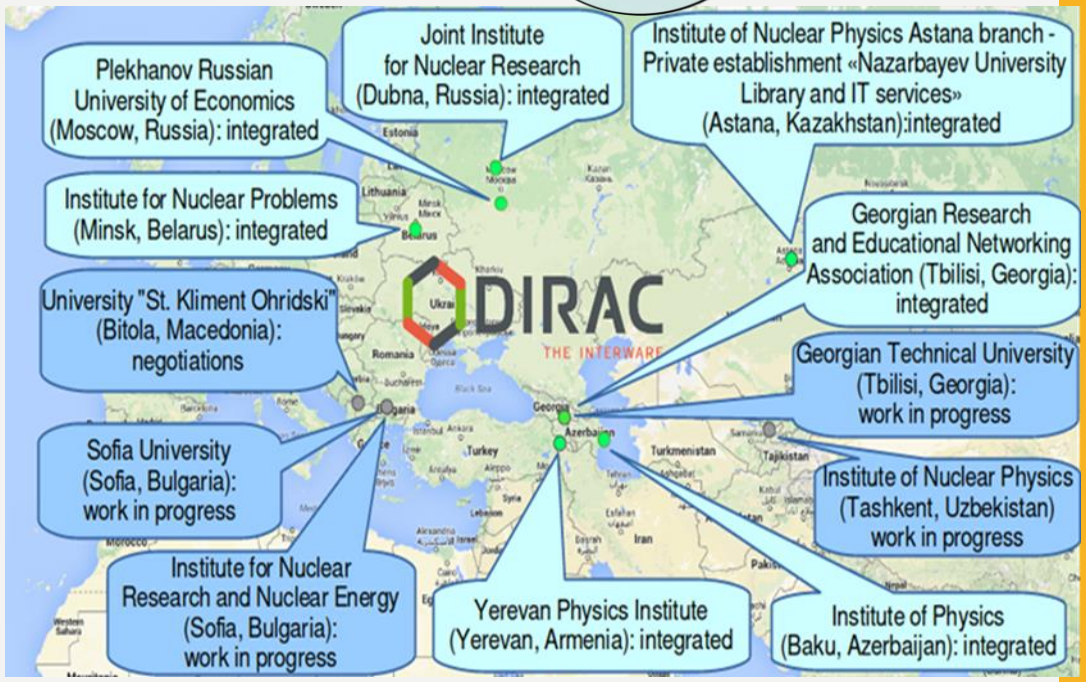



Total CPU cores: 1572: LIT — 972, DLNP: NOvA — 420, JUNO — 96, Baikal-GVD — 84
Total RAM: 8142: LIT: 5020, DLNP: NOvA — 1864, JUNO — 502, Baikal-GVD — 756
Total Ceph-based software defined storage — 1.1PB, effective capacity: ~360 TB due to 3x replication




JINR cloud usage in 2018




Geographical location of cloud infrastructures of the organizations from the JINR Member States involved in the integration of cloud resources.

# “GOVORUN” SUPERCOMPUTER

100% liquid cooling in a ’hot water’ mode, engineering infrastructure for the ultra high dense scalable and energy-efficient cluster solution. Equipment racks, additional redundancy, automated monitoring and control system


GPU component based on NVIDIA DGX-1 Volta


CPU component based on the novel Intel architectures (Intel Xeon Phi and Intel Skylake processors)

Joint project of BLTP and LIT under support of the JINR Directorate. Named after Nikolai Nikolaevich Govorun, with whom the development of information technologies at JINR has been connected since 1966

- Unique heterogeneous and hyper-converged system
- Multipurpose high-performance system with direct hot liquid cooling of all system components
- The most energy-efficient system in Russia (PUE = 1,03)
- First 100% hot liquid cooling of Intel® Omni-Path interconnect
- Record power density – up to 100 kW per 42U cabinet

# SOME TASKS SOLVED ON THE BASIS OF HYBRILIT

## FNLP

1. Calculations of nucleation kinetics and cluster growth in the binary system
2. Modeling an oscillating sample for the experiment on studying the interaction of a neutron wave with a substance moving with extreme acceleration
3. Numerical calculation of the interaction of the neutron wave packet with an oscillating potential barrier
4. Kinetics of dissolution and growth of clusters in fullerene solutions
5. Simulating the experiment on the precise measurement of the time dependence of loss coefficients on the speed of neutrons in a magnetic field
6. Experimental and model study of the dynamics of the IBR-2 pulsed reactor (IBR-2M)
7. Calculations for the FLUKA package. Calculations of biological protection.
8. Simulating the experiment on the precise measurement of the dependence of the loss coefficient on the speed of neutrons with gravitational spectroscopy
9. Research on disperse systems and complex fluids in the volume and on interphase boundaries
10. Transport of neutrons and gamma-quanta in heterogeneous environments. Monte Carlo calculations.
11. Modernization of the air heat exchanger of the IBR-2 pulsed reactor. Modeling and computing of temperature fields of 52 air heat exchange tubes in the COMSOL package.

## FLNR

1. Modeling of the kinetics of excitation and relaxation of dielectrics irradiated with fast heavy ions
2. Modeling of thermal conductivity in alumina irradiated with high-energy fast heavy ions
3. Modeling of the threshold for the formation of tracks of fast heavy ions in Si3N4
4. Study of reactions involving light stable and exotic nuclei, as well as heavy and super-heavy nuclei
5. Microscopic description of processes of fusion, decay, transmission of nucleons and clusters in low-energy nuclear reactions
6. Analysis of the interaction of light weakly bound nuclei within stationary and nonstationary approaches
7. Simulation of radiation interactions with complex biological geometries
8. Calculations of biological protection with large amounts of data using software packages such as FLUKA, GEANT4, COMSOL, within the SHE project implementation
9. Study of optical, electrical and magnetic properties of nanostructured materials
10. Modeling of the distribution of neutron and gamma fields in the GALS physical cabin
11. Studies of light exotic nuclei on the boundary of nucleon stability

http://hlit.jinr.ru/en/heterogeneous-cluster-hybrilit/users_publications_eng/

# JINR MICC MONITORING

1. Monitoring the states of all MICC nodes and services - from the supply system to the robotized tape library
2. Global real time survey of the state of the entire computing complex
3. In case of emergency, alerts are sent to habilitated persons via e-mail, SMS, etc.
4. 1250 hosts under observation
5. 10 295 services controlled in real time

# Built up Multifunctional Information and Computing Complex (MICC)

- is a fault-tolerant infrastructure with electrical power storage and distribution facilities with an expected availability of 99.995%
- supports and uses a large variety of architectures, platforms, operating systems, network protocols and software products
- provides means for the organization of collective development
- supports the solution of problems of various complexity and subject matter
- enables management and processing of data of huge volumes and structures (Big Data)

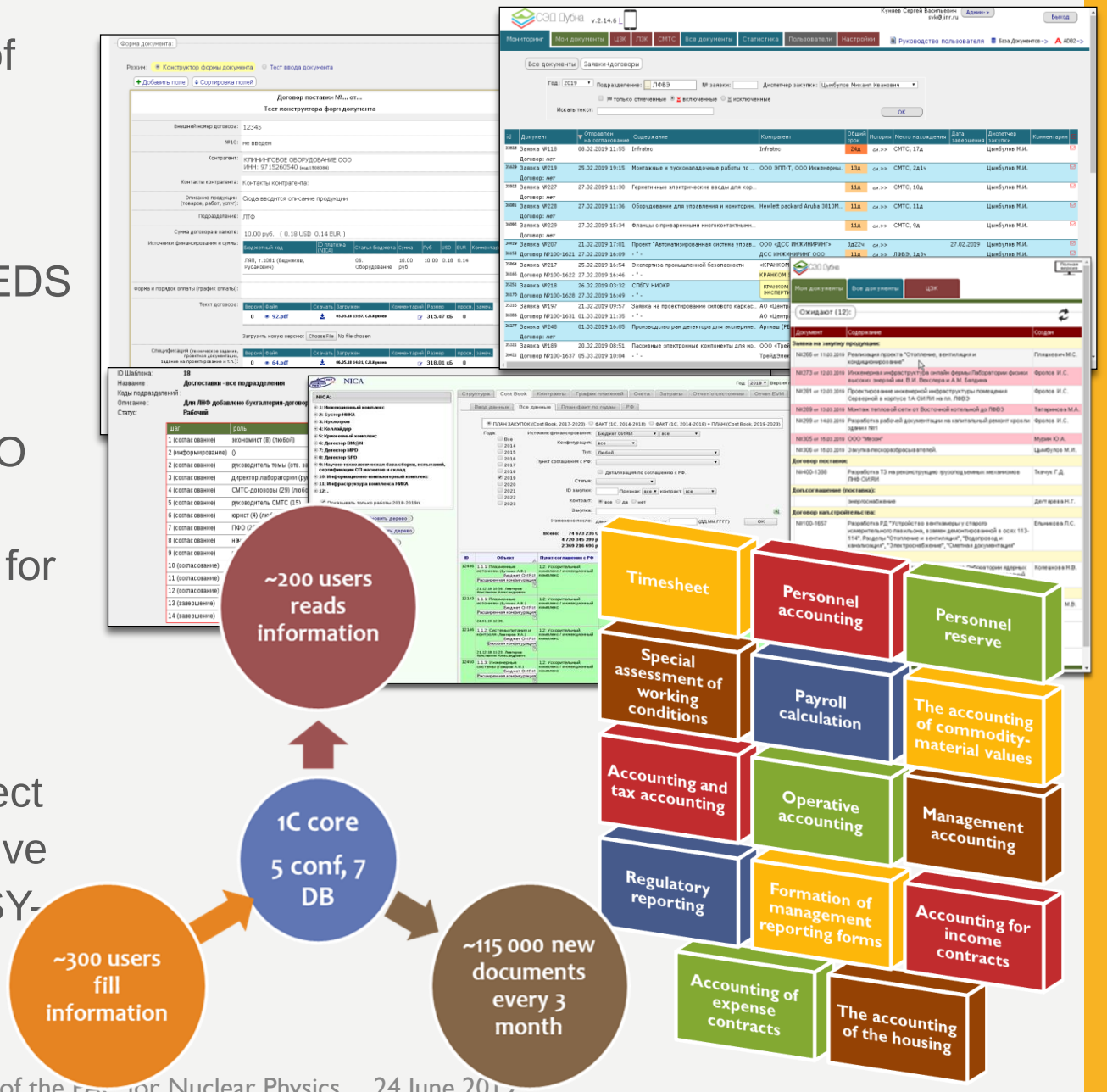
For the period of 2017-2019, the project staff members have been co-authors of 132 publications of the ATLAS collaboration, 198 publications of the CMS collaboration, which are not included in the list of publications, and have published 56 articles in referred journals (53 with young staff as co-authors).

Two PhDs were prepared.

The reference "Computations were held on the basis of the HybriLIT heterogeneous computing platform (LIT, JINR)" was made in more than 60 articles.

# JINR CORPORATIVE INFORMATION SYSTEM

- The data exchange between the elements of JINR CIS through the universal exchange gateway was established. At present, the following subsystems are involved in the exchange through the gateway: 1C, ADB2, EDS “Dubna”, PIN, ISS, Document Base, HR.
- All the given systems, except for 1C, were transferred to authentication through the SSO (Single Sign-On) system.
- A reduced version of EDS “Dubna” adapted for mobile devices was developed and put into operation.
- The development of the JDS information services is carried out within the JOIN2 project (Just anOther INvenio INstance). Collaborative research in this field is regulated by the DESY-JINR Cooperation Agreement.



# EDUCATIONAL PROGRAM ON THE HYBRILIT PLATFORM

- parallel programming technologies as well as IT-solutions and tools necessary for the effective use of HPC platforms.
- courses on C/C ++, MPI, OpenMP, CUDA, OpenCL as well as on hybrid technologies MPI + OpenMP, MPI + CUDA, etc., specialized software such as ROOT, PROOF, application programs COMSOL Multiphysics, MATLAB, etc.
- regular training of IT-specialists at the department of System Analysis and Management of Dubna University - the courses on "Computing System Architectures", "Architectures and Computing System Technologies", "Mathematical Models in Physics"
- lectures on parallel programming technologies was given at the AS Belarus, at the Institute of Physics of ANAS (Azerbaijan), at Sofia University in Bulgaria, Mongolian State University

During the 2014-2018 time period, on the basis of the platform, 41 tutorials and lectures were held; more than 341 people from JINR and 218 people from the JINR Member States took part in them.

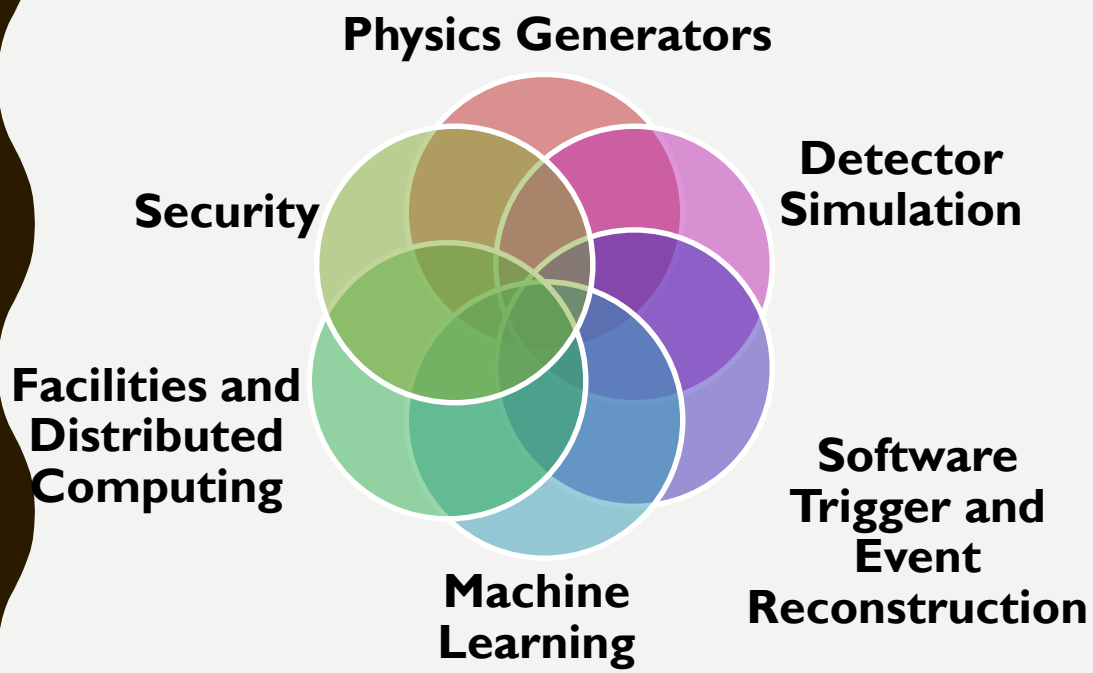
IT School for Young Scientists "Modern IT Technologies for Solving Scientific Problems" (27-28 May 2019, North Ossetian State University)

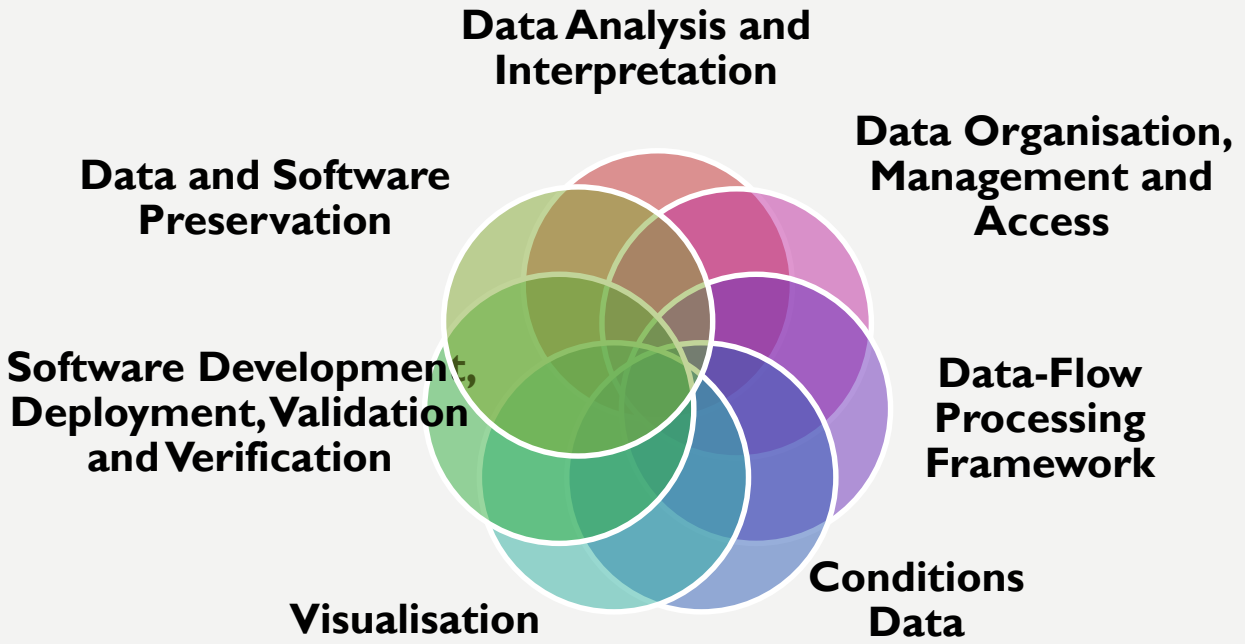
Parallel programming technologies and high performance computing within the HybriLIT computing platform. (2 Apr 2019, Tver State University)

Tools and libraries for data analysis and machine learning tasks (14 May, Tver State University)

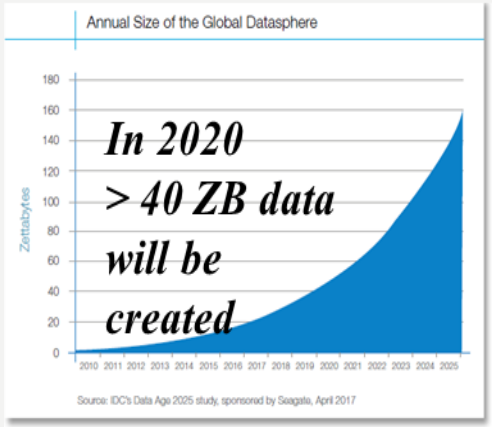
Workshop on parallel programming technologies (26-30 November 2018, at Pilsen and Prague)

# CHALLENGE: R&D OF SOFTWARE TO ACQUIRE, MANAGE, PROCESS AND ANALYZE LARGE AMOUNTS OF DATA TO BE RECORDED




# BIG DATA + HPC (HPDA - HIGH PERFORMANCE DATA ANALYSIS)




*The annual data production follows the exponential law.*

Square Kilometer Array radio telescope (SKA) > 20 Pb/Day (estimation)


CERN Large Hadron Collider
> 20 Pb/Year, > 200 Pb stored

**Science**

# MAIN STAGES OF THE MICC DEVELOPMENT IN 2020-2023

- Development and improvement of the JINR telecommunication and network infrastructure.
- Stage-by-stage modernization of the JINR MICC engineering infrastructure.
- Modernization and development of the IT infrastructure of the NICA project.
- Extension of the performance and capacity of storage systems of the Tier1 data processing center for the CMS experiment.
- Modernization and development of the resources of the Tier2/CICC integral component, which provides support for the experiments using the grid environment and cooperating with physical groups in JINR, as well as for non-grid JINR users and its Member States (MPD/NICA, BESIII, LRB, FLNR, DLNP, BLTP, FLNP).
- Extension of the cloud component in order to enlarge a range of services provided to users as well as to create an integrated cloud environment for experiments of JINR (NICA, ALICE, BESIII, NOvA, Daya Bay, JUNO, etc.) and its Member States using the containerization technology.
- Enlargement of the HybriLIT heterogeneous platform with the Govorun supercomputer.
- Significant extension of resources of the MICC components to meet requirements of neutrino experiments.
- **Development of a unified system for computing resource management aimed at big data processing.**
- **Development of a unified data management system for all MICC components (JINR Data Lake).**

# NETWORK INFRASTRUCTURE

1. Development of external telecommunication channels
2. Development of the JINR local area network
3. Development of the network infrastructure of the MICC and the NICA megaproject

The work on expanding the bandwidth of the external optical channel will consist of several successive stages:

☐first stage: continuation of the modernization of the existing channel-forming telecommunication equipment and 100 Gbps transponders;

☐second stage: scaling of the Moscow (MGTS-9) telecommunication segment on the MPLS (MultiProtocol Label Switching) and VRF (Virtual Routing Forwarding) technologies;

☐third stage: optimization of the high-speed data transfer routes with participants of high-energy physics collaborations via the networks GEANT, LHCOPN, LHCONE, etc.

| | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| External Channel | 2x100Gbps | 4x100Gbps | 4x100Gbps | 6x100Gbps |
| Backup Network | 2x100Gbps | 2x100Gbps | 2x100Gbps | 2x100Gbps |
| MultiSite Cluster | 4x100Gbps | 4x100Gbps | 8x100Gbps | 8x100Gbps |

# ENGINEERING INFRASTRUCTURE

The MICC guaranteed power supply system development plan presupposes:

☐Creation of a power supply system for four air-cooling modules and cabinets for the network and computing equipment of the MICC complex;

☐Development and installation of the power supply system of the hall on the 4th floor;

☐Elaboration of the project and connection of an additional source of power supply from the Dubna HPS (hydroelectric power station) to provide the MICC with the power supply of the first category;

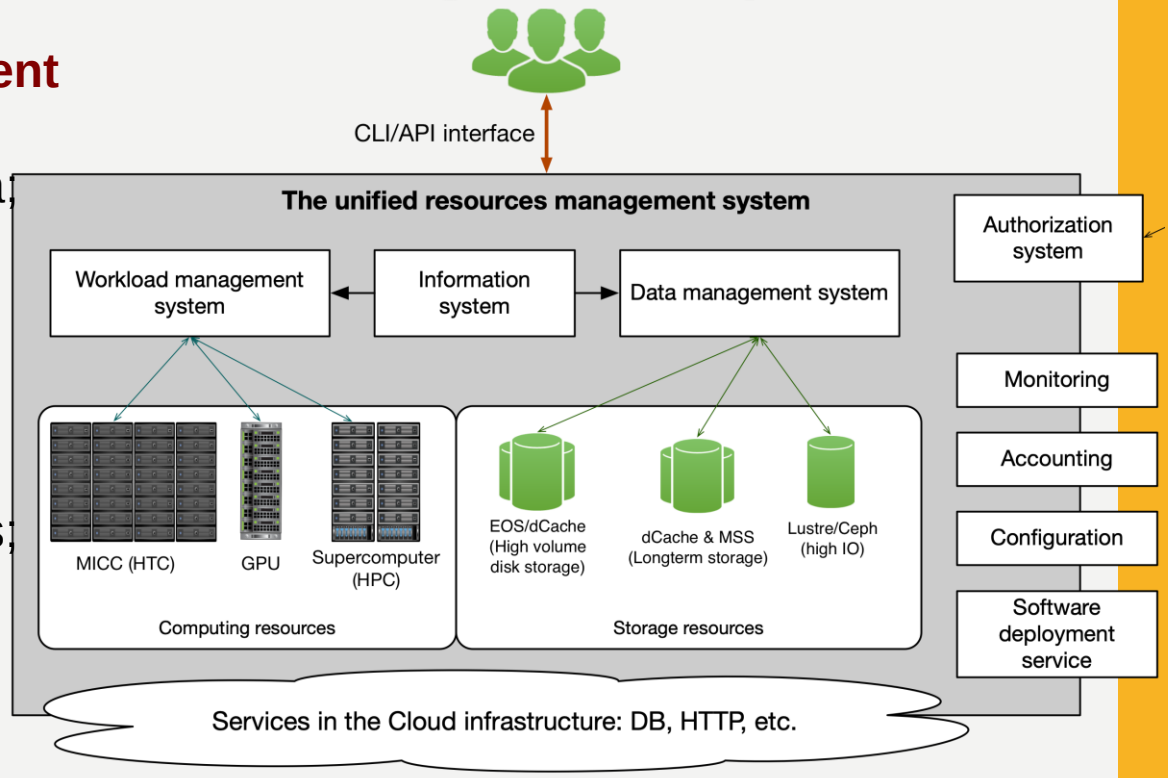
☐Completion of the reconstruction of the power supply and control of air handling units

| | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| Power consumption | 500 kVA | 600 kVA | 800 kVA | 1000 kVA |
| Cooling system | 300 kW | 500 kW | 650 kW | 800 kW |

# MICC unified resource and data flow management system

**The main objectives of a unified resource management system are:**

- to provide the ability to process large amounts of data;
- to provide the possibility to organize massive computing tasks;
- to optimize the efficiency of the use of computing and storage resources;
- to effectively monitor the resource loading;
- to consolidate the accounting for the use of resources;
- to provide a unified interface of access to resources.




**The data flow management system should provide:**

- an interface for the formation of jobs, chains and groups of jobs;
- a database for storing job definitions;
- a job generation system based on certain parameters;
- the preparation of input data through the data management system of the MICC unified resource management system; the selection of suitable computing resources;
- sending jobs to the load management system of the MICC unified resource management system;
- control over their implementation.

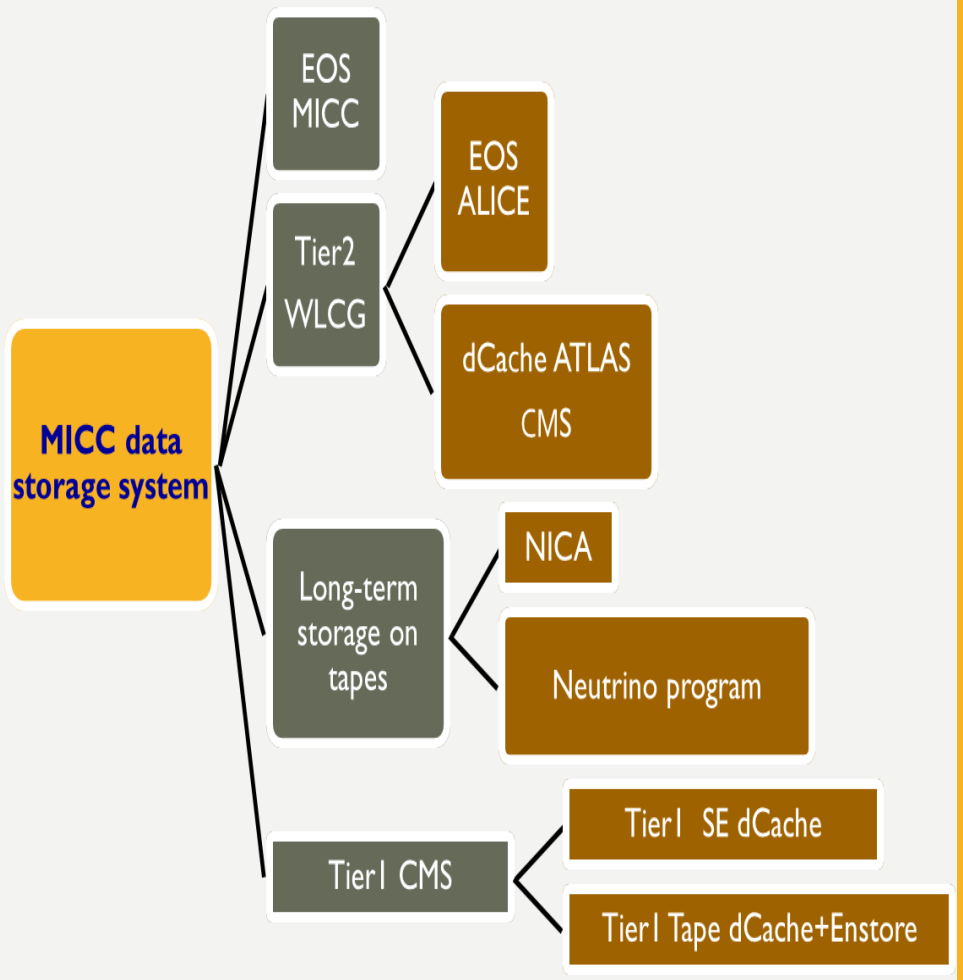
**For experiments the system should provide:**

- the ability to ensure an isolated interface for each experiment;
- the possibility to form a chain of data processing in accordance with the experiment computing model;
- processing on available computing resources.

# RESOURCES OF TIER1 AND TIER2 BY YEAR

In terms of hardware, a linear increase in the characteristics of Tier1, Tier2/CICC is planned in accordance with the figures in the LIT Seven-Year Plan. The fulfillment of the given figures will ensure the required level of resources for all LHC collaborations at Tier1 and Tier2 in JINR.

| Year / component | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| Tier1 CPU, kHS06 | 160 | 200 | 240 | 300 | 350 |
| Tier1 disk, TB | 8000 | 8800 | 10880 | 13100 | 16100 |
| Tier1 MSS, TB | 20000 | 25000 | 30000 | 35000 | 42000 |
| Tier2 CPU, kHS06 | 96 | 110 | 130 | 150 | 170 |
| Tier2 disk, TB | 5000 | 5500 | 6000 | 6500 | 7000 |
| EOS ALICE, TB | 980 | 1200 | 1400 | 1800 | 2000 |
| EOS MICC, TB | 4000 | 10000 | 30000 | 50000 | 60000 |
| MSS/MICC | - | 10000 | 20000 | 30000 | 40000 |




HS06 is an official CPU performance metric to be used by WLCG sites since 1 April 2009.

# JINR CLOUD RESOURCES

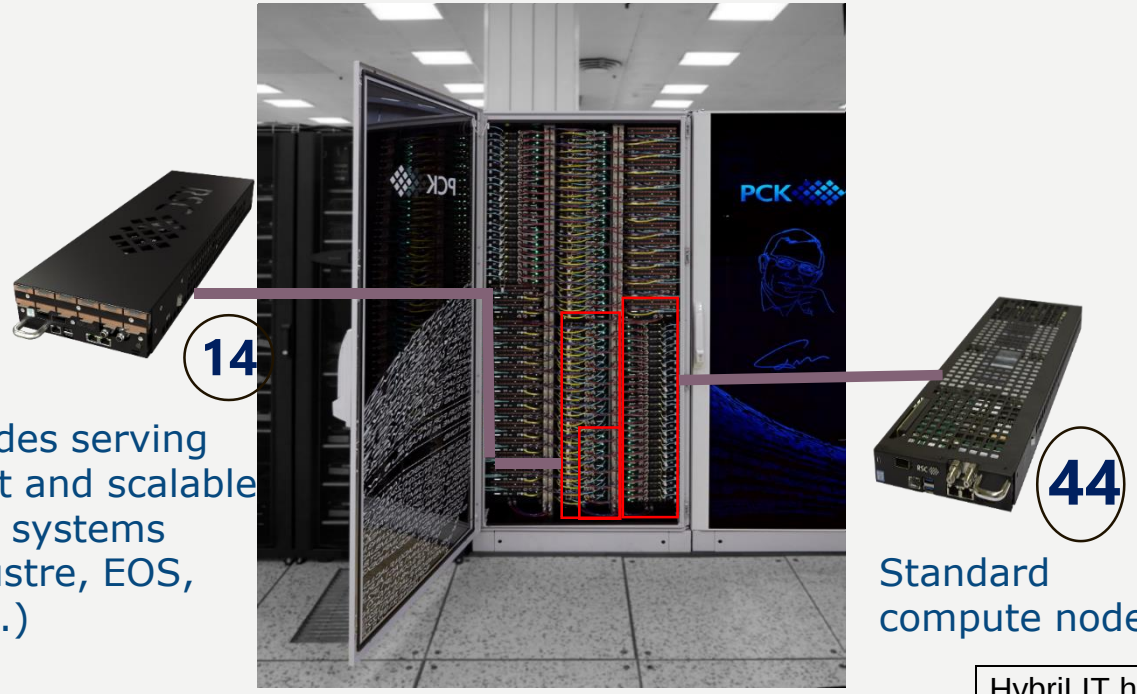
| | Parameter | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| **LIT** | Total number of CPU cores | 1636 | 2000 | 2400 | 2800 | 3200 |
| | Total amount of RAM, TB | 8.61 | 10 | 12 | 14 | 16 |
| | Total amount of storage, PB | 1.27 | 1.5 | 2 | 2.5 | 3 |
| **Baikal-GVD** | Total number of CPU cores | 384 | 684 | 984 | 1284 | 1584 |
| | Total amount of RAM, TB | 3.75 | 6.75 | 9.75 | 12.75 | 15.75 |
| | Total amount of storage, PB | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
| **JUNO** | Total number of CPU cores | 1096 | 2096 | 3096 | 4096 | 5096 |
| | Total amount of RAM, TB | 16.5 | 32.5 | 48.5 | 64.5 | 80.5 |
| | Total amount of storage, PB | 0.63 | 1.13 | 1.63 | 2.13 | 2.63 |
| **NOvA** | Total number of CPU cores | 540 | 660 | 780 | 900 | 1030 |
| | Total amount of RAM, TB | 2.50 | 3.14 | 3.78 | 4.42 | 5.06 |
| | Total amount of storage, PB | 0.32 | 0.388 | 0.488 | 0.588 | 0.688 |
| **Total** | Total number of CPU cores | 3656 | 5440 | 7260 | 9080 | 10910 |
| | Total amount of RAM, TB | 31.36 | 52.39 | 74.03 | 95.67 | 117.31 |
| | Total amount of storage, PB | 2.42 | 3.42 | 4.72 | 6.02 | 7.32 |


The LIT and DLNP directorate agreed to establish a joint working group on writing a proposal about the dedicated project for developing computing facilities at JINR for neutrino experiments the Institute participates in.

**LIT contribution:** engineering infrastructure (electricity, UPS, cooling, network, racks, manpower)

**DLNP contribution:** computing and storage resources (CPUs/GPUs&disks)

# EXTENSION OF THE HYBRILIT HETEROGENEOUS PLATFORM INCLUDING THE GOVORUN SUPERCOMPUTER




In 2019, the JINR Directorate has allocated a grant of 2500 k$ to the extension of the Govorun supercomputer, which will allow increasing the performance by more than 200 TFlops for double-precision operations and by more than 400 TFlops for single-precision operations, as well as increasing the volume of ultrafast storage to 288 TB.

The total enlargement in the performance of CPU and GPU components will amount to 90 TFlops for double-precision operations per year.

| HybriLIT heterogeneous platform. GOVORUN supercomputer. | **2020** | **2021** | **2022** | **2023** |
|---|---|---|---|---|
| Performance of the CPU-component (Tflops, for double-precision operations) | 260 | 320 | 380 | 450 |
| Performance of the GPU-component (Tflops, for double-precision operations) | 330 | 360 | 390 | 420 |
| Total performance of the supercomputer (Tflops, for double-precision operations) | 590 | 680 | 770 | 870 |

It is noteworthy that the enlargement of the supercomputer performance above the plan will be defined by user needs, including the needs of the NICA megaproject and the neutrino program, and elaborated due to the financial support from the budgets of experiments, joint grants and other sources.

# PLANS FOR THE DEVELOPMENT OF THE CORPORATE INFORMATION SYSTEM

**Within the development of the JINR corporate information system (CIS) in 2020-2023 it is planned:**

- To develop the electronic document system EDS “Dubna”, the project management system APT EVM for NICA, the systems ADB2, ISS, “Document Base”, HR LHEP taking into account the requests of end users and the recommendations of the coordination group on the development of databases, electronic document management and information security, with the concept of the cloud SaaS platform of the unified administrative and business information system at JINR.
- To develop a personnel information and analytics system for recording the participation of LIT employees in projects and themes.
- To maintain the systems EDS “Dubna”, APT EVM for NICA, ADB2, ISS, “Document Base”, PIN, HR LHEP.

**The main work on the development of the JDS infrastructure in 2020-2023 is:**

- To unify metadata formats
- To update the software platform on a regular basis
- To develop the project technical documentation
- To develop the functionality of the JOIN2 software platform: participation in the back-end and front-end development
- To support the collections “Authorities”

# DEVELOPMENT OF THE SYSTEM FOR TRAINING AND RETRAINING IT SPECIALISTS

## Training courses, tutorials and lectures

**HybriLIT group**
**leading scientists from JINR and its Member States**

**Leading manufacturers of modern computing architectures and software**

**Parallel programming technologies**

OpenMP
MPI
OpenCL
NVIDIA CUDA

**Tools for debugging and profiling of parallel applications**

Intel Cluster Studio

**Work with packages of applied software**

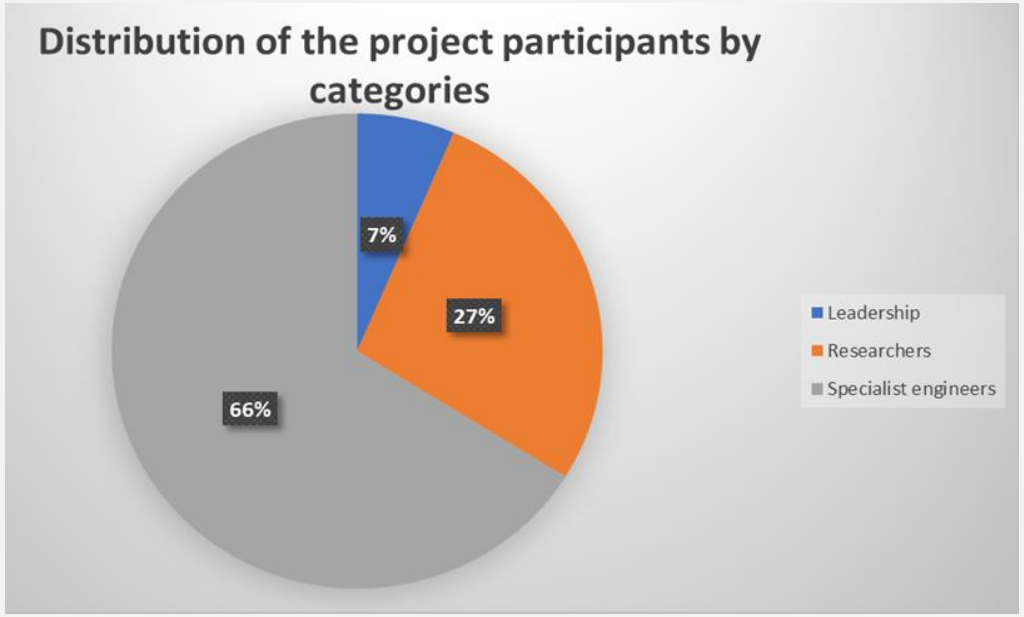
COMSOL MULTIPHYSICS
ROOT Data Analysis Framework
MATLAB
Wolfram Mathematica
GEANT4
Maple

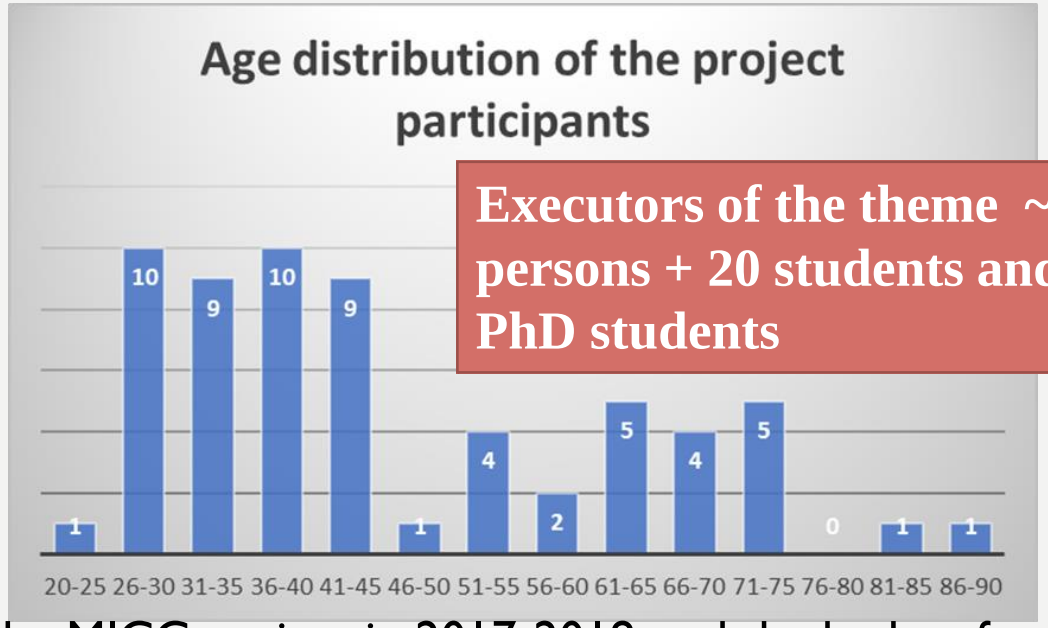
**Frameworks and tools for ML/DL tasks**

jupyterhub
TensorFlow
scikit learn
NumPy

- Regular courses on modern IT technologies both for the Institute staff and students and young scientists from the JINR Member States within activities organized by the JINR University Centre;
- Special courses from leading software developers;
- Special courses and seminars within conferences and schools organized by JINR;
- Special courses organized in the JINR Member States within international cooperation programs.

# HUMAN RESOURCES AND FINANCIAL SUPPORT




**Executors of the theme ~ 90 persons + 20 students and PhD students**

13 700.3 kUSD from the JINR budget were spent on the MICC project in 2017-2018, and the budget for 2019 is planned in the amount of 8 705.5 kUSD (total expected 22 405.8 kUSD) The main funds were spent on the implementation of tasks and the expansion of the MICC computing powers planned by the project. Financial support for the implementation of the project is based on the LIT budget for 2017-2019.

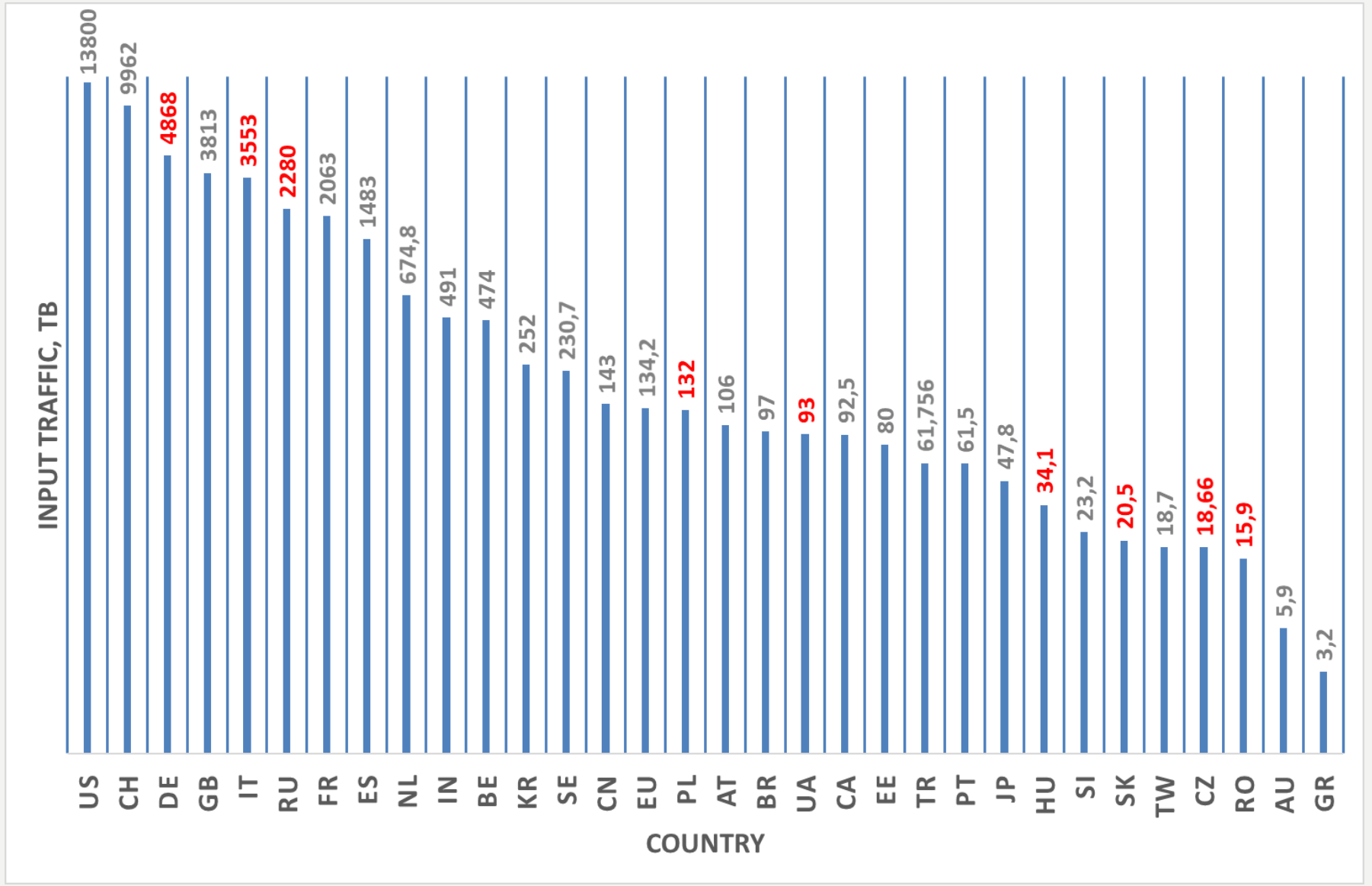
| | Total costs (k$) | Proposals of the Laboratory on the distribution by years (k$) | | | |
|---|---|---|---|---|---|
| | | 2020 | 2021 | 2022 | 2023 |
| Main units of equipment, work towards its upgrade, adjustment etc. | 28 582.3 | 6 747.0 | 6 990.3 | 7 160.0 | 7 685.0 |
| Materials | 640.0 | 160.0 | 160.0 | 160.0 | 160.0 |
| Computer communication | 110.0 | 20.0 | 30.0 | 30,0 | 30.0 |
| Travel expenses | 535.2 | 133.8 | 133.8 | 133.8 | 133.8 |

# Conclusion:

We ask the Programme Advisory Committee for Nuclear Physics to **agree with the continuation of the theme**: “Information and Computing Infrastructure of JINR"
and the Project
"Multifunctional
Information and Computing
Complex (MICC)"
within the theme
**for the period 2020-2023 with first priority**.

# Thank you for your attention!

# TRAFFIC 2017-2019 BY COUNTRIES >3 TB

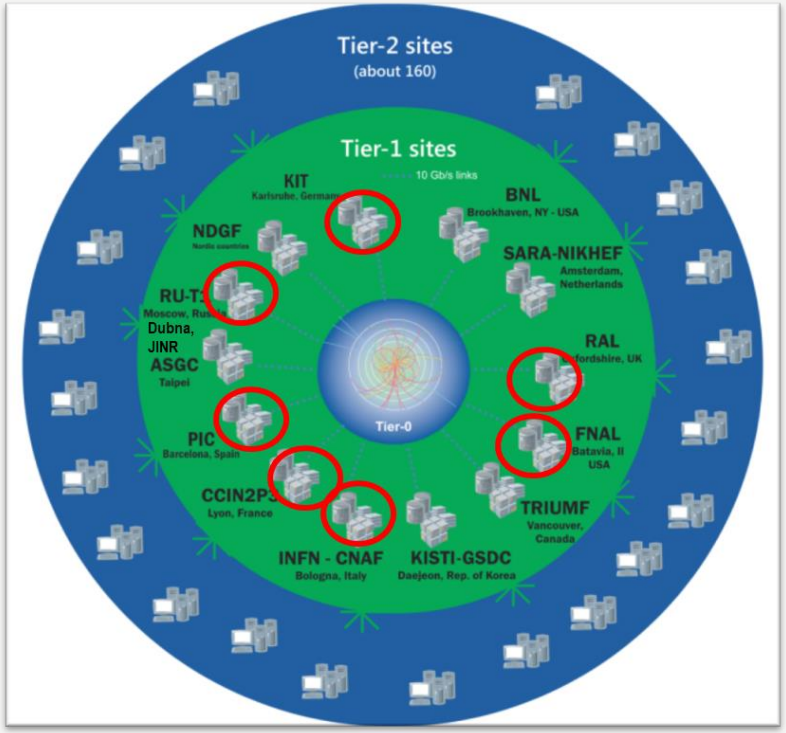


| | | | | |
|---|---|---|---|---|
| 1 | Fermi National Accelerator Laboratory | US | FNAL | 949 |
| 2 | European Organization for Nuclear Research | SE | CERN | 569,13 |
| 3 | Istituto Nazionale di Fisica Nucleare | IT | INFN | 404,18 |
| 4 | Massachusetts Institute of Technology | US | MIT | 221,16 |
| 5 | Rutherford Appleton Laboratory | GB | RAL | 192,34 |
| 6 | Курчатовский Институт | RU | KIAE | 150,72 |
| 7 | Institut National de Physique Nucleaire | FR | IN2P3 | 130,53 |
| 8 | Karlsruhe Institute of Technology | DE | KIT | 114,54 |
| 9 | India CMS | IN | INDIACMS | 109,96 |
| 10 | Imperial College London | GB | ICFDDI | 85,87 |
| 11 | Rechen-und Kommunikationszentrum Aachen | DE | RWTH-Aachen | 82,65 |
| 12 | Deutsches Elektronen-Synchrotron | DE | DESY | 61,91 |
| 13 | Universit degli Studi di Bari Aldo Moro | IT | RECAS-NET | 58,84 |
| 14 | University of California San Diego | US | UCSD | 57,25 |
| 15 | University of Florida | US | UFL | 36,08 |
| 16 | Sao Paulo Regional Analysis Center | BR | SPRACE | 30,54 |
| 17 | University of Wisconsin Madison | US | UWM-US | 29,29 |
| 18 | Indiana University-Purdue University at Indianapolis | US | IUUAI | 29,1 |
| 19 | University of Chicago | US | UCHIKAGO | 26,94 |
| 20 | UltraLight collaboration of experimental physicists | US | UltraLight | 25,5 |
| 21 | Consorci Institut de Fisica Altes Energies | ES | PIC | 25,16 |
| 22 | Institute of High Energy Physics | CN | IHEP-CN | 24 |
| 23 | Centro de Investigaciones Energeticas | ES | CIEMAT | 23,72 |
| 24 | Commissariat a lEnergie Atomique | FR | FR-CEA | 20,07 |
| 25 | Institute for High Energy Physics | AT | OEAW-NET-HEPHY | 18,77 |
| 26 | Институт Ядерных исследований РАН | RU | INR-TROITSK | 18,76 |
| 27 | Universite Libre de Bruxelles | BE | RESULB | 15,23 |
| 28 | University of Nebraska-Lincoln | US | UNL | 14,92 |
| 29 | Korea Research Institute of Standards and Science | KR | KREONET | 14,08 |
| 30 | Narodowe Centrum Badan Jadrowych | PL | NCBJ | 13,09 |
| 31 | Institute of Chemical Physics and Biophysics Estonia | ES | KBFI | 10,75 |
| 32 | University of Texas at Arlington | US | UTARLINGTON | 9,84 |
| 33 | University of British Columbia | CA | UBC | 8,9 |
| 34 | University of Manchester | GB | UKHEP-MAN | 8,64 |
| 35 | Infraestruturas Nacionais de GRID | PT | INGRID | 7,85 |
| 36 | University of Glasgow | GB | GLANET | 7,71 |
| 37 | Centro Svizzero di Calcolo Scientifico | CH | CSCS | 7,32 |
| 38 | Science Park Watergraafsmeer Amsterdam | NL | SARA | 6,22 |
| 39 | Kyungpook National University | KR | KNU-NET-KR | 6,07 |
| 40 | Estonian Educational and Research Network | EE | EE-EENET | 5,97 |
| 41 | Nordic Data Grid Facility | DK | NDGF | 5,89 |
| 42 | Brookhaven National Laboratory | US | BNL | 5,53 |
| 43 | Electric Power Research Institute | US | EPRI | 5,42 |
| 44 | Boston University | US | BOSU | 5,16 |
| 45 | Taiwan Academic Network | TW | TANET | 4,83 |
| 46 | Brunel University Network | GB | BRUNEL | 4,65 |
| 47 | National Institute for Physics and Nuclear Engineering | RO | NIPNE | 4,57 |
| 48 | University of Tokyo | JP | U-TOKYO | 4,45 |
| 49 | Bergische Universitaet Wuppertal | DE | WUPPERNET | 3,81 |
| 50 | Институт физики высоких энергий | RU | IHEP | 3,57 |
| 51 | Nordic Data Grid Facility | SE | NORDUNET | 3,53 |
| 52 | University of Western Ontario | CA | SHARCNET | 3,46 |
| 53 | Институт Теоретической и Экспериментальной физики | RU | ITEP | 3,38 |
| 54 | Comenius University Bratislava | SK | COMUNI-NET | 3,18 |
| 55 | Albert-Ludwigs-Universitaet Freiburg | DE | UNI-FREIBURG | 3,12 |

# THE WORLDWIDE LHC COMPUTING GRID

**WLCG:**

An International collaboration to distribute and analyse LHC data Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists




The mission of the WLCG project is to provide global computing resources to store, distribute and analyse the ~50-70 Petabytes of data expected every year of operations from the Large Hadron Collider.

**WLCG computing enabled physicists to announce the discovery of the Higgs Boson on 4 July 2012.**

**nearly 170 sites,**
**42 countries**
**1 000 000 cores**
**1 EB of storage**
**> 3 million jobs/day**
**10-100 Gb links**

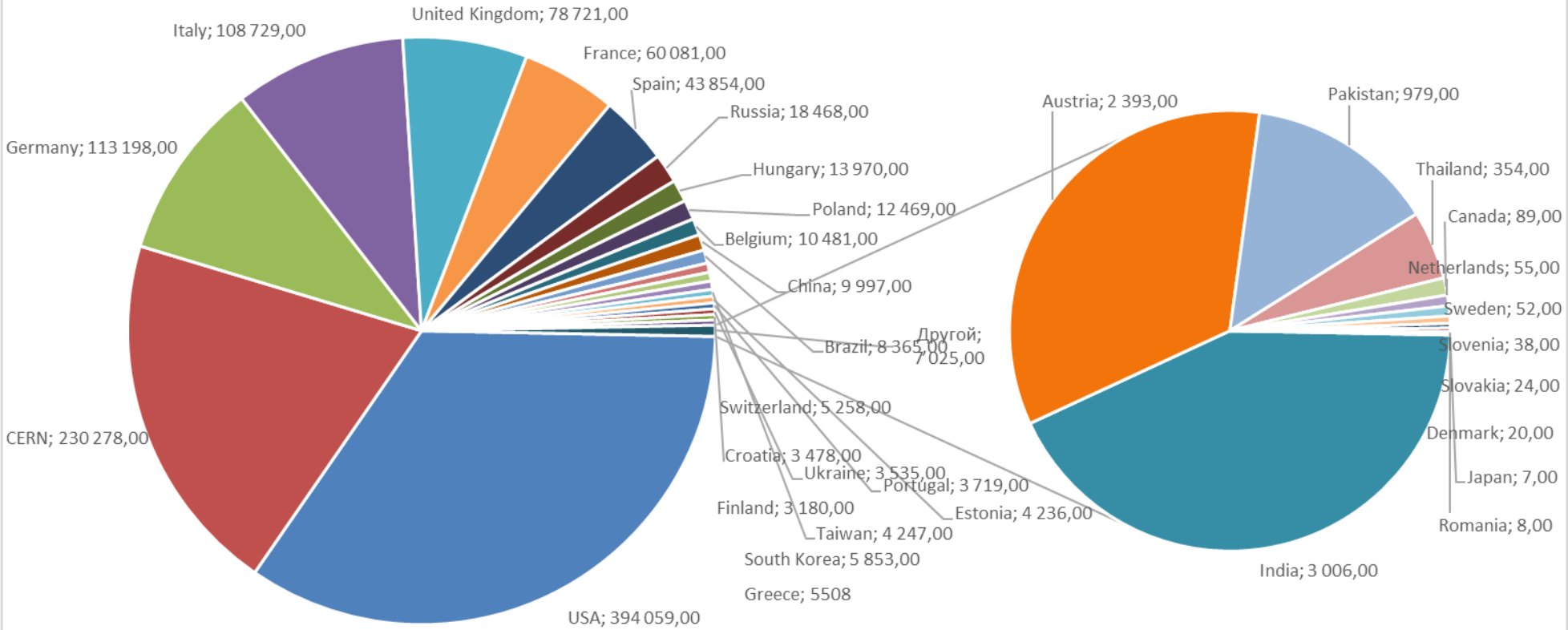
*Worldwide LHC Computing Grid - 2019*

**Tier-0 (CERN):** data recording, reconstruction and distribution

**Tier-1:** permanent storage, re-processing, analysis

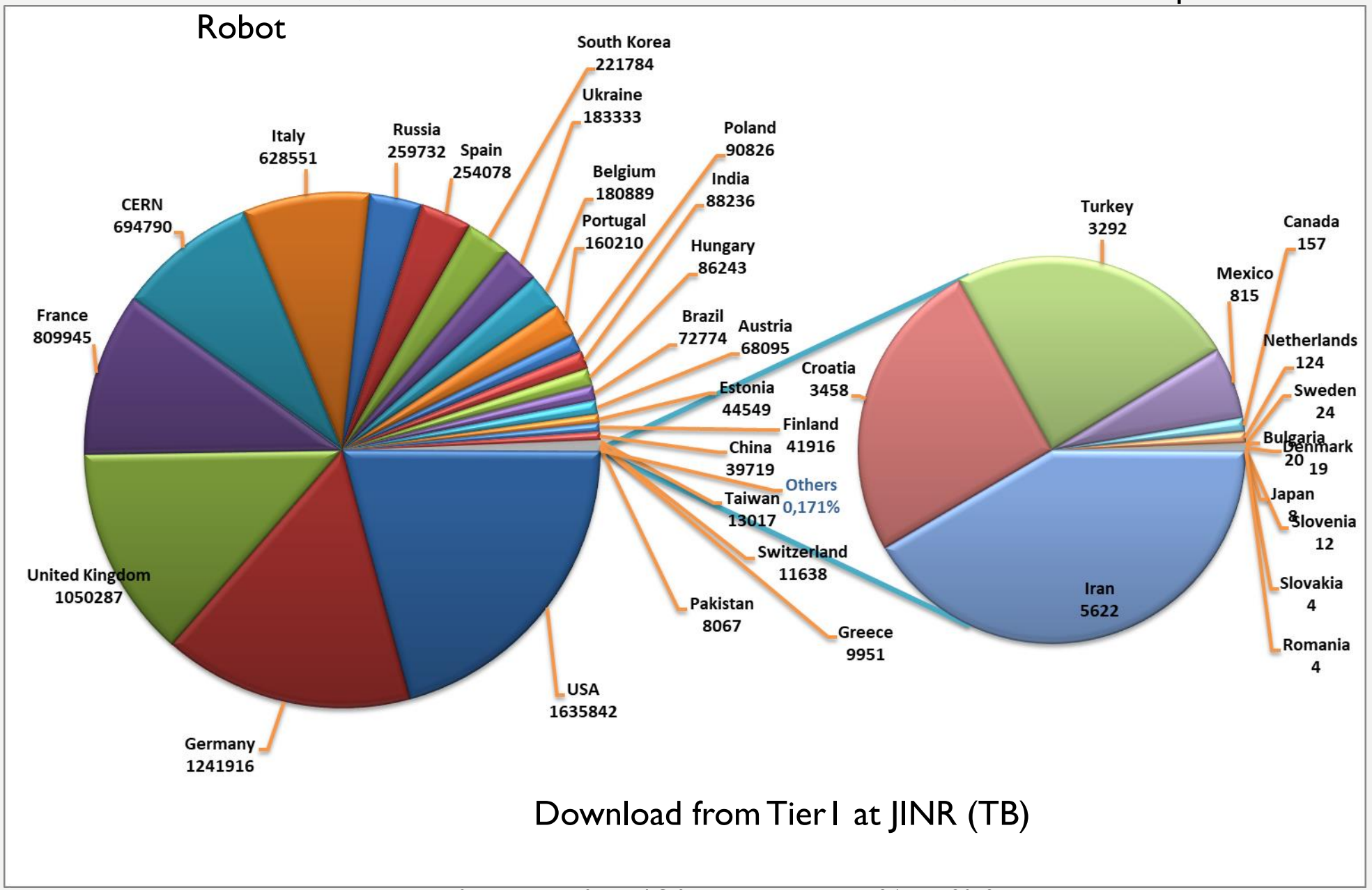
**Tier-2:** Simulation, end-user analysis

# In 2019 loaded was 16,8 PB to T1 DISK and 0,969 PB to T1 Tape Robot




Load to Tier1 at JINR (TB)

# In 2019 36,4PB was downloaded ftom T1 Disk and 3,5PB from T1 Tape Robot



# GOVORUN SUPERCOMPUTER IN HPC RATINGS

The Govorun hyper-converged system allows all of its nodes with SSD drives to act as storage and compute nodes at the same time. The RSC software stack BasIS and the RSC Tornado hardware architecture support Software Defined Storage of different types (Luster, EOS, BeGFS, etc.)

**IO-500**

This is the official *ranked* list from ISC-HPC 2018. The list shows the best result for every given combination of system/institution/filesystem (i.e. multiple submissions from the same system are not shown; only the most recent is shown). The full list is available here.

| # | information | | | | | | io500 | | |
|---|---|---|---|---|---|---|---|---|---|
| | system | institution | filesystem | storage vendor | client nodes | data | score | bw GiB/s | md kIOP/s |
| 1 | Oakforest-PACS | JCAHPC | IME | DDN | 2048 | zip | 137.78 | 560.10 | 33.89 |
| 2 | ShaheenII | KAUST | DataWarp | Cray | 1024 | zip | 77.37 | 496.81 | 12.05 |
| 3 | ShaheenII | KAUST | Lustre | Cray | 1000 | | 41.00* | 54.17 | 31.03* |
| 4 | JURON | JSC | BeeGFS | ThinkparQ | 8 | | 35.77* | 14.24 | 89.81* |
| 5 | Mistral | DKRZ | Lustre2 | Seagate | 100 | | 32.15 | 22.77 | 45.39 |
| 6 | Sonasad | IBM | Spectrum Scale | IBM | 10 | zip | 24.24 | 4.57 | 128.61 |
| 7 | Seislab | Fraunhofer | BeeGFS | ThinkparQ | 24 | | 16.96 | 5.13 | 56.14 |
| 8 | Mistral | DKRZ | Lustre1 | Seagate | 100 | zip | 15.47 | 12.68 | 18.88 |
| 9 | Govorun | Joint Institute for Nuclear Research | Lustre | RSC | 24 | zip | 12.08 | 3.34 | 43.65 |
| 10 | EMSL Cascade | PNNL | Lustre | | 126 | | 11.12 | 4.88 | 25.33 |
| 11 | Serrano | SNL | Spectrum Scale | IBM | 16 | | 4.25* | 0.65 | 27.98* |
| 12 | Jasmin/Lotus | STFC | NFS | Purestorage | 64 | zip | 2.33 | 0.26 | 20.93 |

The Govorun is ranked on the **9**th position in the edition of **26.06.2018** of the **IO500** list, i.e. a new industry benchmark for HPC storage systems:
https://www.vi4io.org/io500/list/18-06/start

Редакция №28 списка Top50 от 03.04.2018

| № | Название<br>Место установки | Узлов<br>Проц.<br>Ускор. | Архитектура:<br>кол-во узлов: конфигурация узла<br>сеть: вычислительная / сервисная / транспортная | Rmax<br>Rpeak<br>(Тфлоп/с) | Разработчик<br>*Область применения* |
|---|---|---|---|---|---|
| 12<br>new | «имени Н.Н. Говоруна<br>сегмент DGX»<br><br>ЛИТ,<br>ОИЯИ | 5<br>10<br>40 | 5: CPU: 2x Intel Xeon E5-2698v4, 512 GB RAM<br>Acc: 8x NVIDIA Tesla V100<br><br>QDR Infiniband / Gigabit Ethernet / 10 Gigabit Ethernet | 175.13<br>319.0 | NVIDIA<br>IBS Platformix<br><br>*Наука и образование* |
| 18<br>new | «имени Н.Н. Говоруна<br>сегмент SKYLAKE»<br><br>ЛИТ,<br>ОИЯИ | 40<br>80<br>н/д | 40: CPU: 2x Intel Xeon Gold 6154, 192 GB RAM<br><br>Intel OmniPath / Fast Ethernet / Gigabit Ethernet | 102.12<br>138.24 | Группа компаний РСК<br><br>*Наука и образование* |
| 45<br>new | «имени Н.Н. Говоруна<br>сегмент KNL»<br><br>ЛИТ,<br>ОИЯИ | 21<br>21<br>н/д | 21: CPU: 1x Intel Xeon Phi 7290, 112 GB RAM<br><br>Intel OmniPath / Fast Ethernet / Gigabit Ethernet | 46.73<br>72.58 | Группа компаний РСК<br><br>*Наука и образование* |

All computing components of the Govorun supercomputer were included in the Top50 list of the most powerful supercomputers in the CIS countries:
http://top50.supercomputers.ru/archive/2018/04

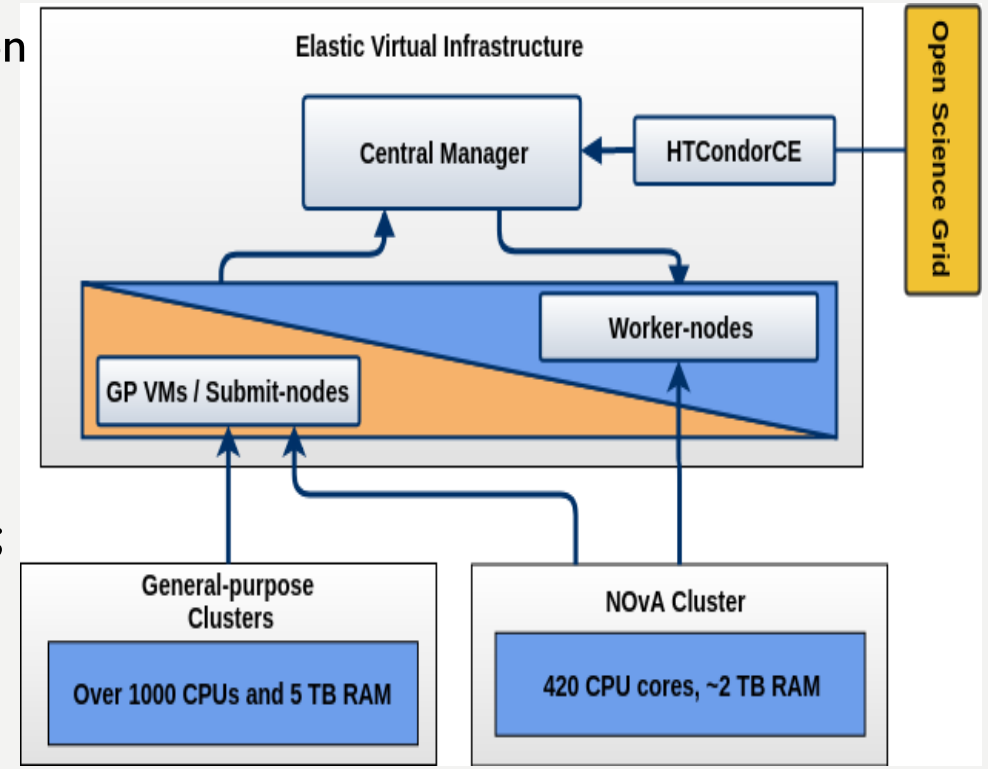
The peak performance of the supercomputer is **1 PFlops** for single-precision operations
and
**0.5 PFlops** for double-precision operations.

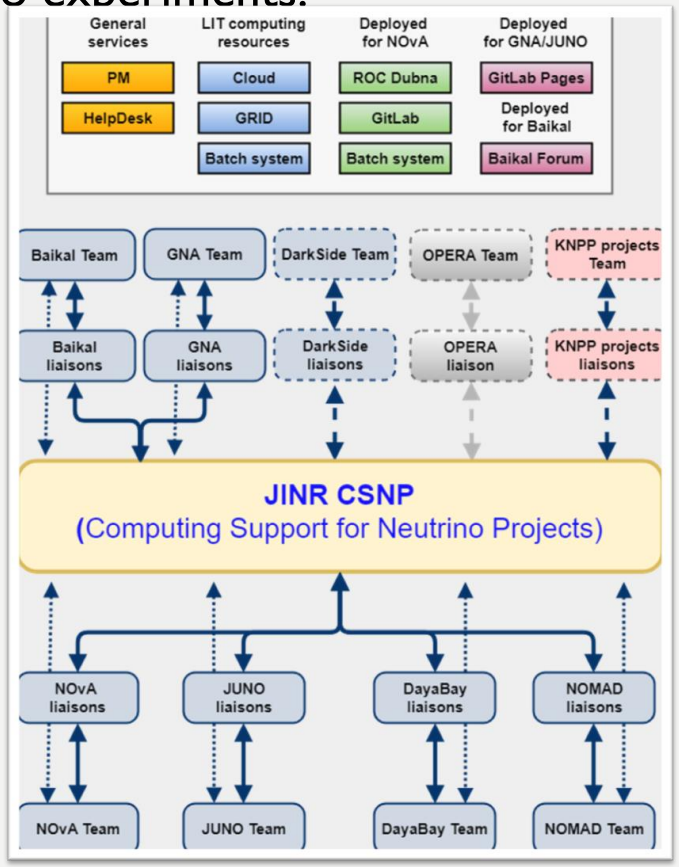
# COMPUTING SUPPORT FOR NEUTRINO PROJECTS

Modern large-scale neutrino experiments generate huge amounts of data, and the amount of computing resources needed to process and analyze these data is approaching the scales of LHC experiments. Cloud technologies make it possible to combine traditional (in the HEP domain) Grid systems with other modern software tools, which do not fit in the Grid computing model.

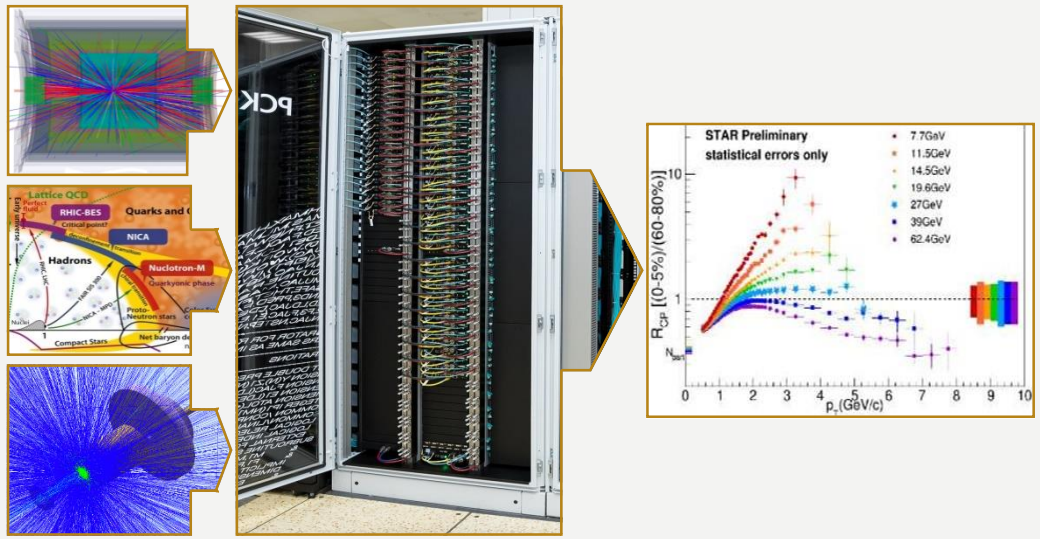
The NOvA experiment was first to start using the JINR cloud and now has the largest amount of dedicated resources in the cloud, followed by Baikal-GVD, JUNO and other neutrino experiments.

- HTCondor - production and analysis, job processing;
- JupyterHub - data visualization;
- Personal virtual machines - traditional interactive applications;
- GitLab CI - automated software testing and deployment.



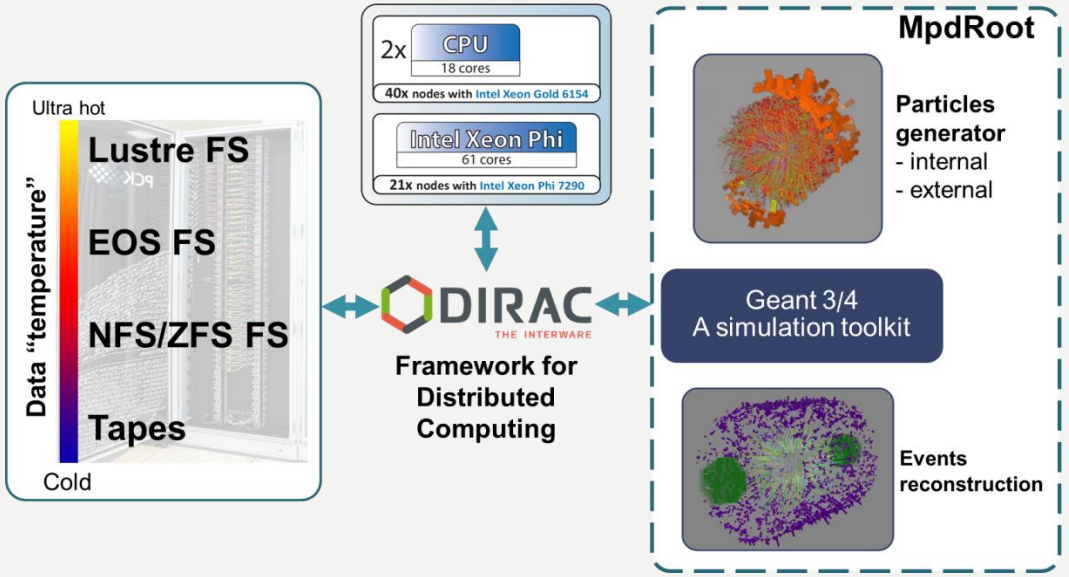



# GOVORUN SUPERCOMPUTER FOR THE NICA MEGAPROJECT





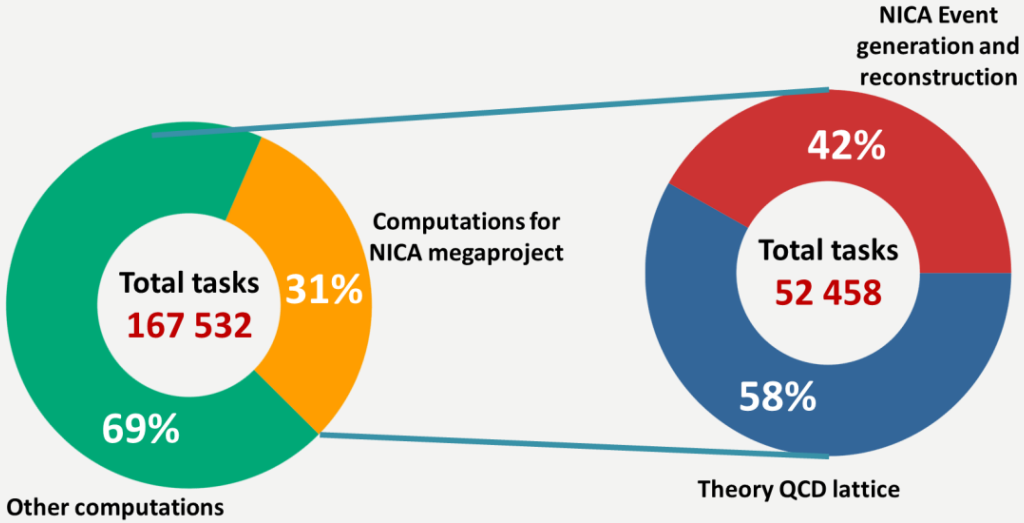


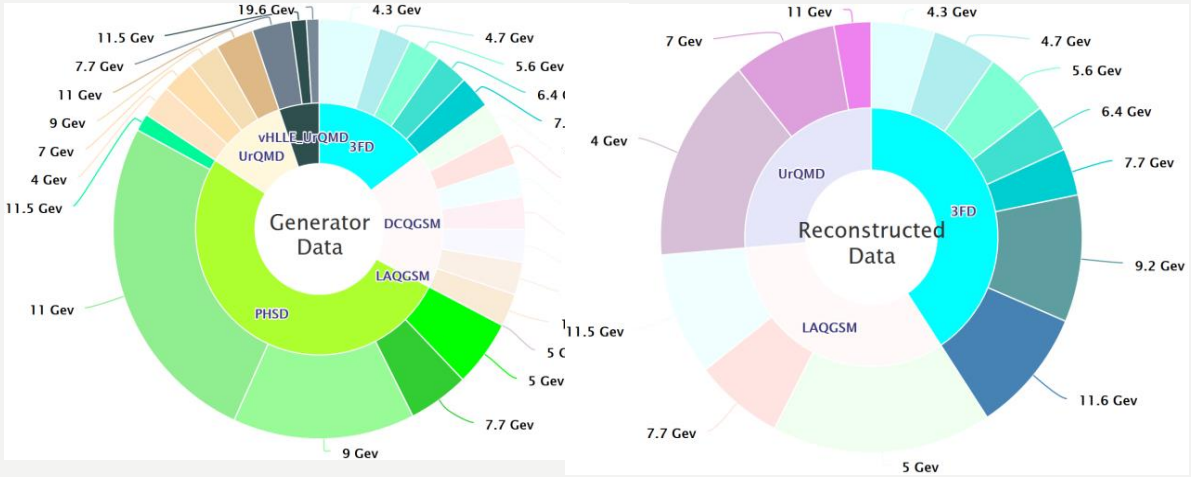



At present, the Govorun supercomputer is used for both theoretical studies and event simulation for the MPD experiment of the NICA megaproject. To generate simulated data of the MPD experiment, CPU computing components of the Govorun supercomputer, i.e. Skylake (2880 cores) and KNL (6048 cores), are used; data are stored on the ultrafast data storage system (UDSS) under the management of the *Lustre file system* with a subsequent transfer to cold storages controlled by the *EOS* and *ZFS* file systems. UDSS currently has five storage servers with 12 SSD disks using the NVMe connection technology and a total capacity of 120 TB, which ensures low time of access to data and a data acquisition/output rate of 30 TB per second.

The *DIRAC* software is used for managing jobs and the process of reading out/recording/processing data from various types of storages and file systems.

# STATISTICS OF USING ALL COMPONENTS OF THE SUPERCOMPUTER FOR THE NICA MEGAPROJECT




Since commissioning, more than 164,000 tasks were performed on the Govorun supercomputer. One third of them refer to computing for the NICA megaproject. Moreover, more than half are theoretical calculations carried out on all computing components of the supercomputer. More than 40% directly relate to the event generation and reconstruction for the MPD experiment.

By June 2019 over 75 million events for the MPD experiment have already been generated using the *UrQMD* generator. At present, almost 6.5 million events have been reconstructed. The CPU component and UDSS are used for the solution of these problems.

# INFORMATION SECURITY

Currently, the JINR information security system is built on the Intrusion Detection Systems (IDS) technology.

Due to the growing number of threads to information security, the system needs to be upgraded. To increase the efficiency of the system it is planned:

- to introduce a system service for the analysis of DPI (Deep Packet Inspection) data packages using a specialized gateway;
- to adapt the 6-tier structure of information security control at JINR diversified to:
  1) available public network,
  2) networks of computing complexes such as Tier-1, Tier-2, MICC, NICA,
  3) JINR Management network,
  4) access control network,
  5) networks of research physical installations,
  6) particularly important networks (IBR, NICA, etc.).

Functional capabilities of the ungraded security system should include the following components:

- centralized access control in real time;
- account management (including on target devices);
- providing a single entry point in the system Single Sign-On (SSO);
- activity tracking and record of sessions (such as RDP, SSH, Telnet, VNC, etc.);
- generating statistics and reports on user actions.