# *CMS компьютинг*
## Кореньков В.В.

Семинара памяти И.А.Голутвина

08.08.2024

# Golutvin & CMS Computing

- RDMS-CMS Computing (1994-
- Golutvin I., Korenkov V., Pose R., Tikhonenko E. CMS computing support at JINR// JINR D11-98-122 Dubna, 1998
- WLCG, RDIG, grid in JINR
- RDMS CMS Tier2 cluster
- Tier1 for CMS in JINR
- Symposium Nuclear Electronics and Computing (NEC) in Varna and Montenegro
- GRID conferences in Dubna (2004-2013)

# Развитие компьютерной инфраструктуры ОИЯИ с 1994-2004 год
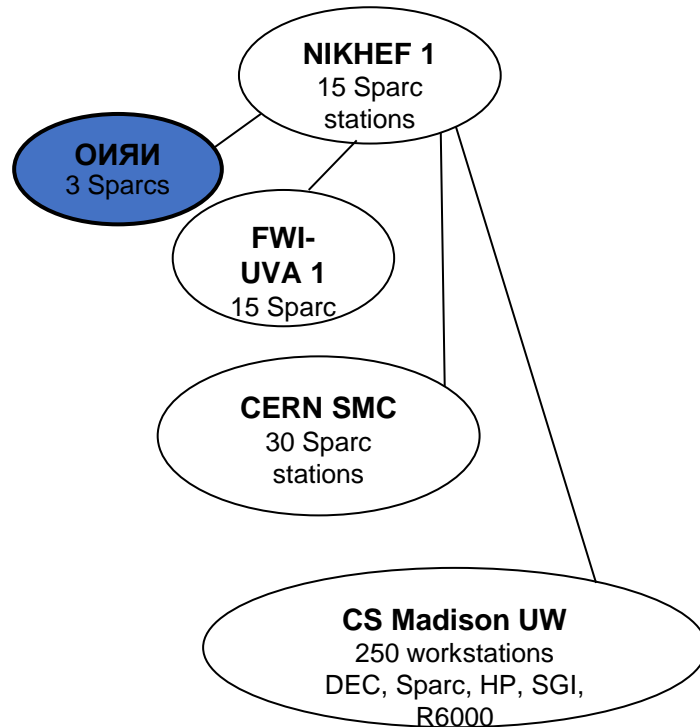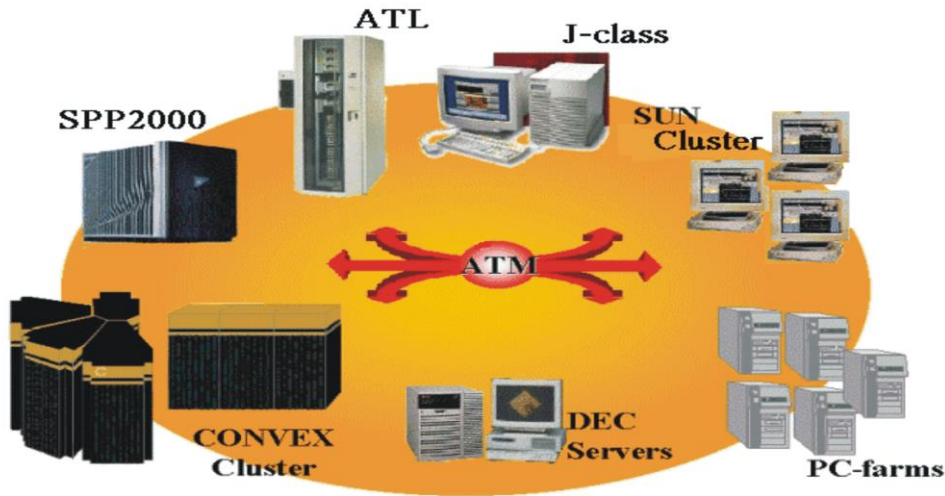
# CMS Computing - directions of Activities (1994-2003):

- *support of current versions of CMS SW;*
- *PC farms development;*
- *participation in CMS M.-C. events production runs;*
- *preparation for participation in DC04;*
- *www-informational support of RDMS activities.*

# CMS High Level Trigger production run at JINR LIT PC farm in 2000 and 2001



**CMS**

**CERN**

**JINR**

**SINP MSU + RCC MSU**

**LPI**

**ITEP**

**RRC - LHC**
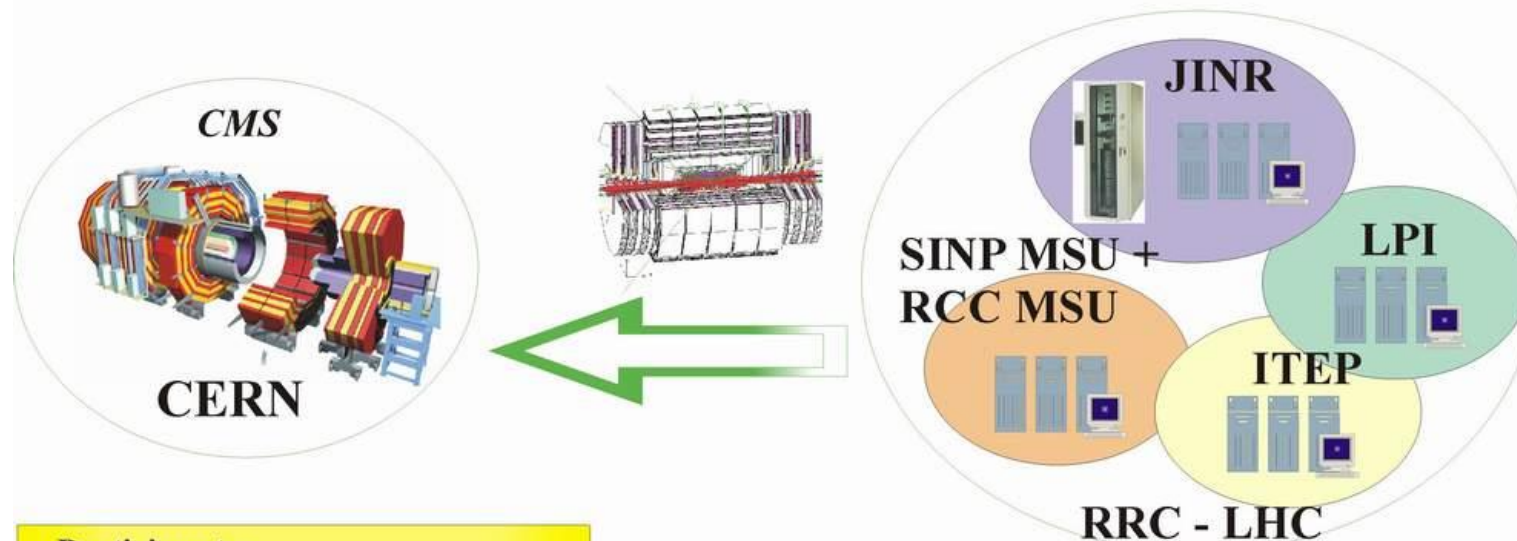
**Participants:**
CERN;
INFN (Italy);
FNAL, Caltech, Univ.of Florida,
   UC Davis (USA);
Bristol (Gr.Britain);
HIP (Finland);
IN2P3 (France);
Russian institutes (SINP MSU+RCC
MSU, ITEP, LPI), JINR.

**CMS HLT production run:**
**October, 2000** - 40000 events (68 GB)
**May, 2001** - 75000 events (75GB)
500 events ~ 42-45 hours CPU time at PC of 500 MHZ;
resulting file for 500 events ~ 0.85 GB.

The total number of events generated at JINR
transferred to CMS data base at CERN

«**Грид** - это система, которая:

· координирует использование ресурсов при отсутствии централизованного управления этими ресурсами

· использует стандартные, открытые, универсальные протоколы и интерфейсы.

· обеспечивает высококачественное обслуживание»

(Ian Foster: "What is the grid? ", 2002 г.)

## Модели грид:
- ❖ **Distributed Computing**
- ❖ **High-Throughput Computing**
- ❖ **On-Demand Computing**
- ❖ **Data-Intensive Computing**
- ❖ **Collaborative Computing**

Междисциплинарный характер грид: развиваемые технологии применяются в физике высоких энергий, космофизике, микробиологии, экологии, метеорологии, различных инженерных и бизнес приложениях.

**Виртуальные организации (VO)**
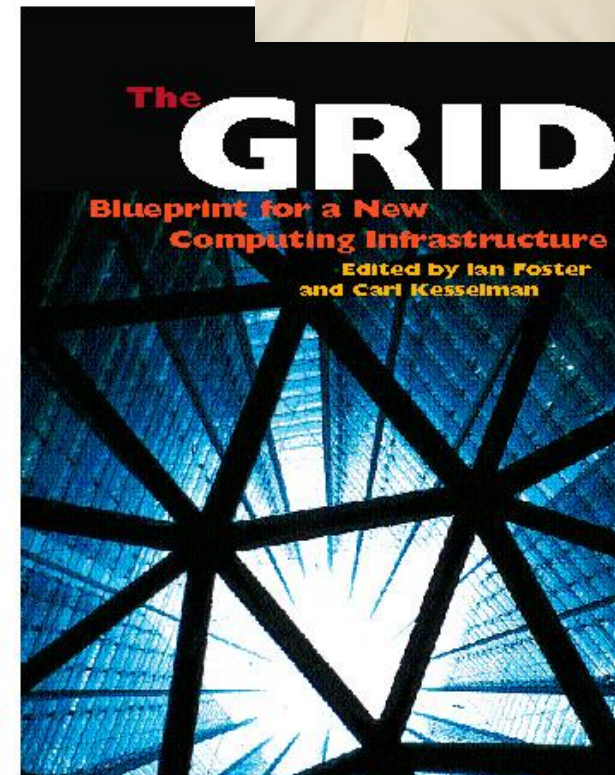
# Tier Structure of GRID Distributed Computing: Tier-0/Tier-1/Tier-2
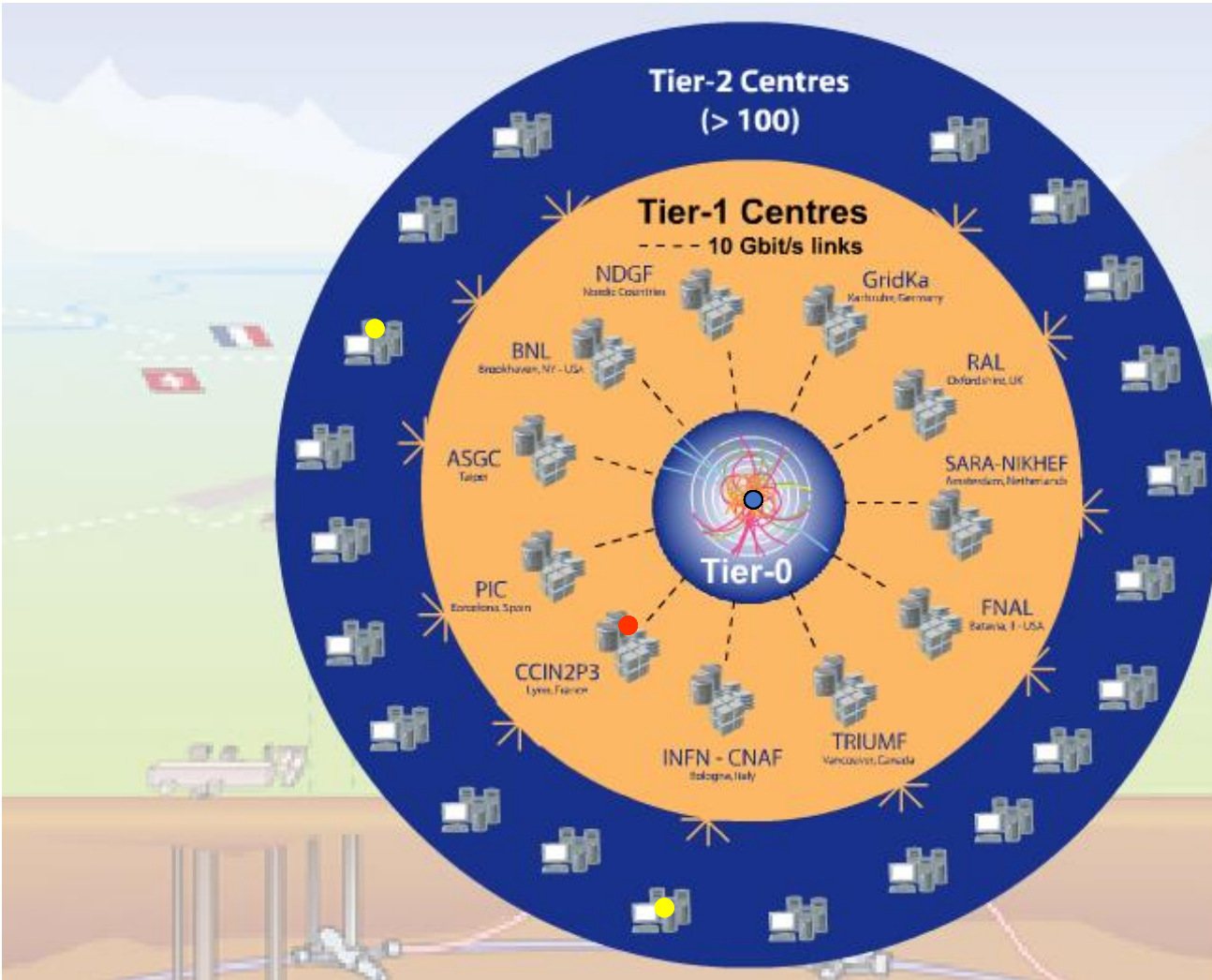


**Tier-0 (CERN):**
- accepts data from the CMS Online Data Acquisition and Trigger System
- archives RAW data
- the first pass of reconstruction and performs Prompt Calibration
- data distribution to Tier-1

**Tier-1 (11 centers):**
- receives a data from the Tier-0
- data processing (re-reconstruction, skimming , calibration etc)
- distributes data and MC to the other Tier-1 and Tier-2
- secure storage and redistribution for data and MC

**Tier-2 (>200 centers):**
- simulation
- user physics analysis

# Развитие распределенной грид-инфраструктуры RDMS CMS



Обсуждение предложения о развитии распределенных компьютерных коммуникаций на основе GRID-технологии в России.
В.А.Ильин, Е.М.Сухарев и И.А.Голутвин
Москва, 2001 г.



В.А.Ильин (МГУ), В.В.Кореньков и И.А.Голутвин после совещания по компьютингу CMS. Женева, 2003

# Конференция по управлению данными 2002 год, Дубна

# *Grid activities as a basis of RDMS CMS participation in CMS computing at a running phase of LHC*
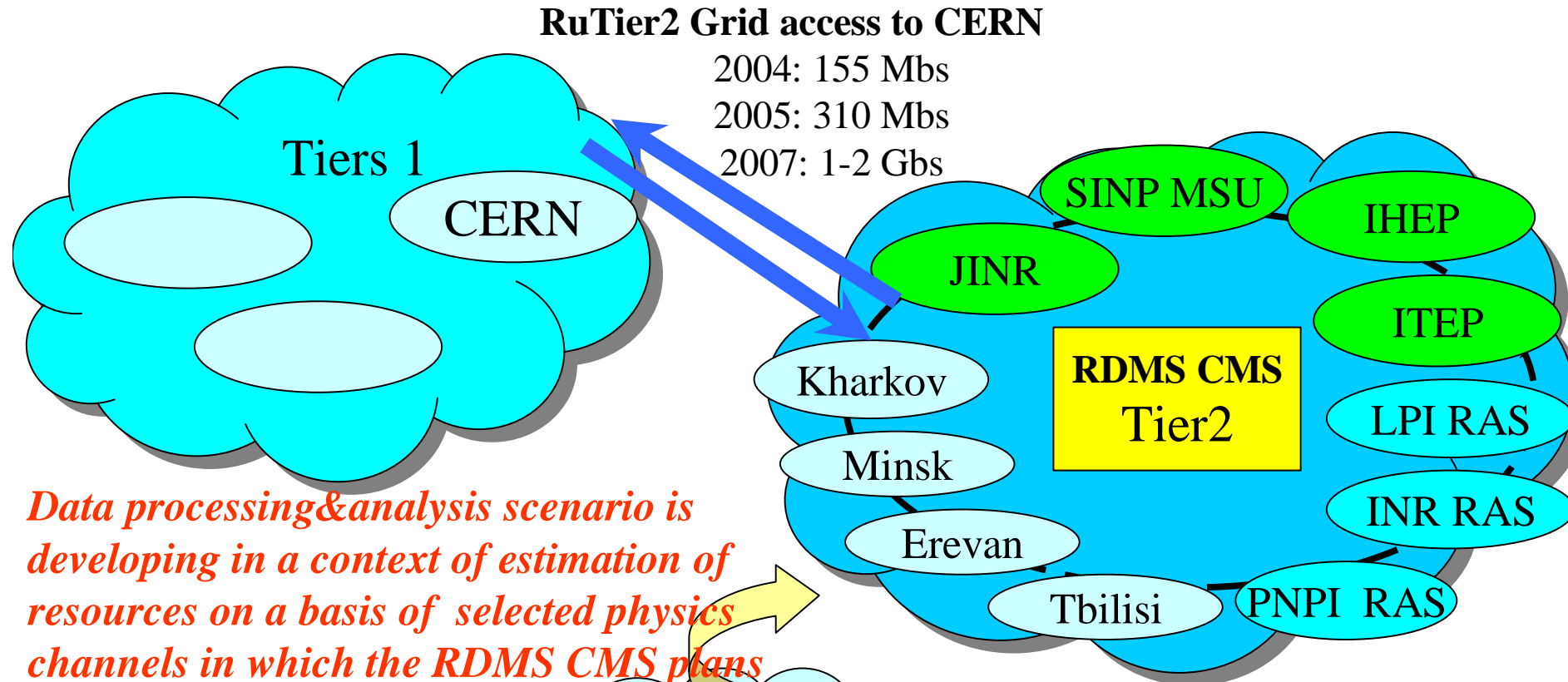
**RDMS institutes participate in the following European Grid projects:**

- ❖ **EDG  (European Data-Grid)**

- ❖ **LCG (LHC Computing Grid)**

- ❖ **EGEE (Enabling Grid for E-science in Europe)**

# Main tasks of support for CMS computing in LIT JINR (2004-2010)

- *Development and maintenance computer infrastructure JINR for CMS activities (communication, LAN, Clusters, data storage);*

- *Installation and support of basic Software (OS, batch systems, file system NFS, AFS, translators, graphics systems...), documentation and user support;*

- *Installation and support of up-to-date versions of CMS Software;*

- *participation in LCG (LHC Computing GRID) and EGEE projects;*

- *development of JINR-segment RDMS Tier-2 cluster, optimization of data access;*

- *development of CMS condition DB, off-line interface;*

- *participation in CMS Data Challenge production;*

- *informational support of RDMS activities.*

# Development of RDMS CMS computing model



**RuTier2 Grid access to CERN**
2004: 155 Mbs
2005: 310 Mbs
2007: 1-2 Gbs

Tiers 1

CERN

SINP MSU

IHEP

JINR

ITEP

**RDMS CMS Tier2**

Kharkov

LPI RAS

Minsk

INR RAS

Erevan

Tbilisi

PNPI  RAS

*Data processing&analysis scenario is developing in a context of estimation of resources on a basis of  selected physics channels in which the RDMS CMS plans to participate.*

**Collaborative centers:**
    **RCC MSU, RRC KI**

**Institutes in Russia**: IHEP, ITEP, JINR, SINP MSU (as 4 basic centers), LPI RAS, INR RAS, PNPI RAS
**Collaborative RDMS Institutes:**
ErPhI (Armenia), HEPI (Georgia) KIPT (Ukraine), NCPHEP (Belarus)

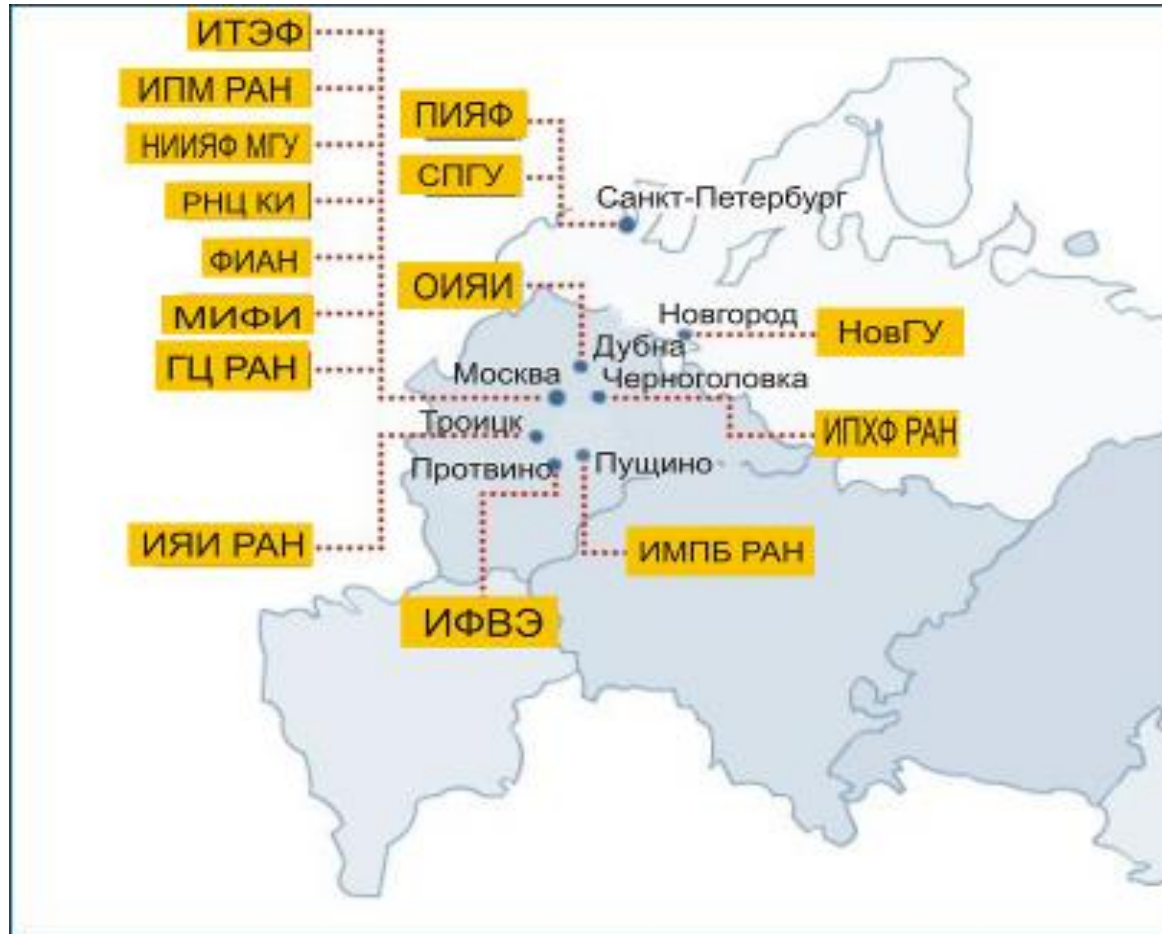## RDMS CMS computing centers

JINR is a part of Worldwide LHC Computing Grid
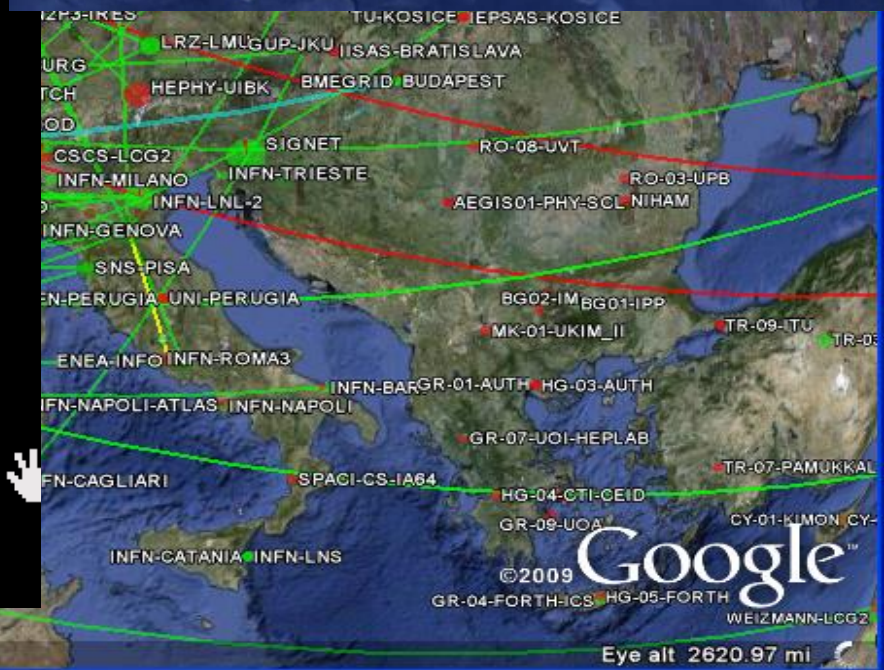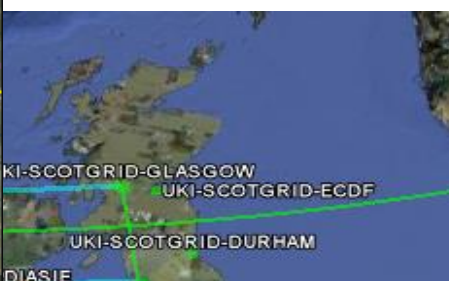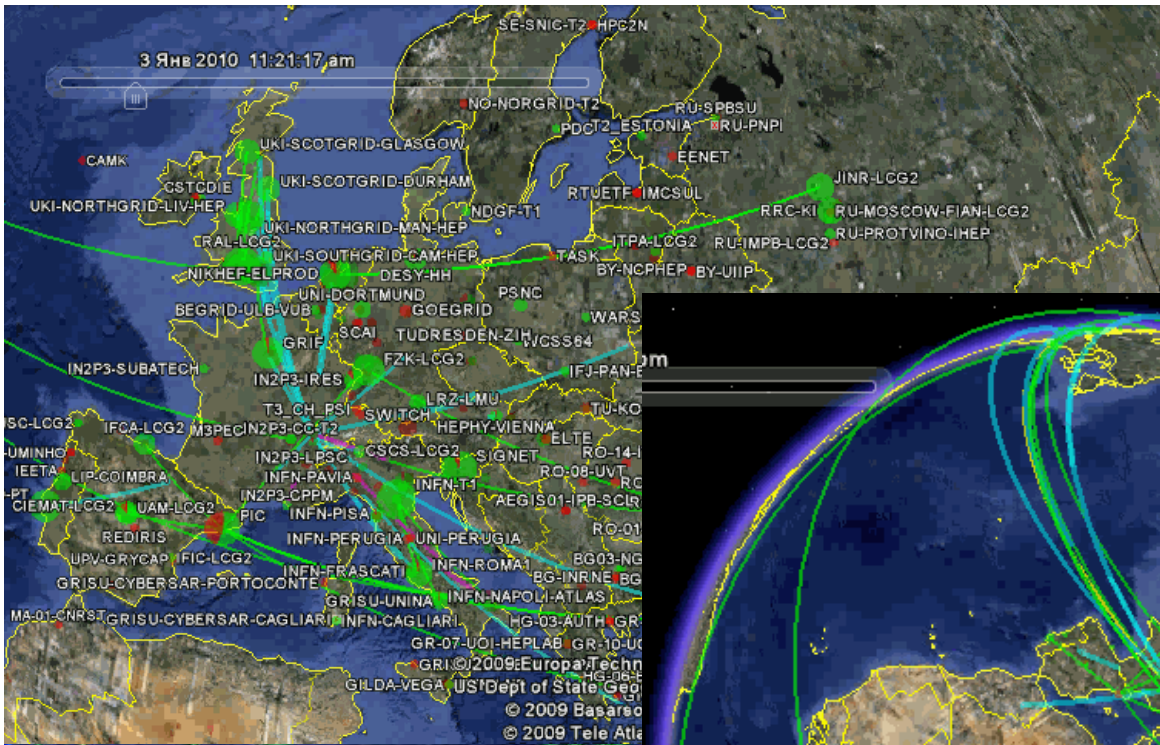
# Russian Data Intensive Grid infrastructure (RDIG)

The Russian consortium RDIG (Russian Data Intensive Grid), was set up in September 2003 as a national federation in the EGEE project.
In 2010 the RDIG infrastructure comprises 12 Resource Centers with > 3000 CPU and > 5000 TB of disc storage.



*RDIG Resource Centres:*
– ITEP
– JINR-LCG2 (Dubna)
– RRC-KI
– RU-Moscow-KIAM
– RU-Phys-SPbSU
– RU-Protvino-IHEP
– RU-SPbSU
– Ru-Troitsk-INR
– ru-IMPB-LCG2
– ru-Moscow-FIAN
– ru-Moscow-MEPHI
– ru-PNPI-LCG2 (Gatchina)
– ru-Moscow-SINP
- Kharkov-KIPT (UA)
- BY-NCPHEP (Minsk)
- UA-KNU
-- UA-BITP

На торжестве по поводу получения Нобелевской премии за открытие бозона Хиггса директор ЦЕРНа Рольф Хойер прямо назвал **грид-технологии одним из трех столпов успеха** (наряду с ускорителем LHC и физическими установками).

**Без организации грид-инфраструктуры на LHC было бы невозможно обрабатывать и хранить колоссальный объем данных, поступающих с коллайдера, а значит, совершать научные открытия.**

*Сегодня уже ни один крупный проект не осуществим без использования распределенной инфраструктуры для обработки данных.*

# WLCG Tier1 center in Russia

- Proposal to create the LCG Tier1 center in Russia (official letter by Minister of Science and Education of Russia A. Fursenko has been sent to CERN DG R. Heuer in March 2011).

- The corresponding point to include in the agenda of next 5x5 meeting Russia-CERN (October 2011)

  - for all four experiments ALICE, ATLAS, CMS and LHCb

  - ~10% of the summary Tier1 (without CERN) resources

  - increase by 30% each year

  - draft planning (proposal under discussion) to have prototype in the end of 2012, and full resources in 2014 to meet the start of next working LHC session.

- Discussion about distributed Tier1 in Russia for LHC and FAIR

# Tier1 center

**March 2011 - Proposal to create the LCG Tier1 center in Russia** (official letter by Minister of Science and Education of Russia A. Fursenko has been sent to CERN DG R. Heuer):

    NRC KI for ALICE, ATLAS, and LHC-B
    LIT JINR (Dubna) for the CMS experiment

***The Federal Target Programme Project*: «Creation of the automated system of data processing for experiments at the LHC of Tier-1 level and maintenance of Grid services for a distributed analysis of these data»**

*Duration:* **2011 – 2013**

**September 2012 – Proposal was reviewed by WLCG OB and JINR and NRC KI Tier1 sites were accepted as a new "Associate Tier1"**

**Full resources - in 2014 to meet the start of next working LHC session.**

**ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE**
**EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH**
Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

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Prof. Victor Matveev
Director of Joint Institute for Nuclear Research
Joliot-Curie 6
141980 Dubna, Moscow Region, Russia

Votre référence/Your reference:
Notre référence/Our reference:

Subject: Acceptance of the proposal to build Tier 1 centres in Russia

Geneva, October 12, 2012

Dear Directors,

As you know, the proposals from the National Research Centre – "Kurchatov Institute" and the Joint Institute for Nuclear Research, Dubna, to build Tier 1 centres for LHC data analysis were discussed in the recent WLCG Overview Board held on September 28. I am very happy to report that the proposals were well received by the members of the board, and that the decision was made to accept the Russian sites as a new "Associate Tier 1". This decision will be noted in the formal minutes of the meeting.

The next step is now to proceed to signing the WLCG Memorandum of Understanding. The WLCG project office will assist in drafting this MoU, which should be signed by the relevant funding agencies for the two Russian Institutes, or their designated agents.

I am at your disposal for any assistance or to provide further details of the process.

Yours Sincerely,

Dr. Ian Bird
LHC Computing Grid Project Leader
IT Department
CERN

# CMS Computing at JINR

- ✓ the first RDMS CMS web-server (in 1996);

- ✓ full-scale CMS software infrastructure support since 1997

- ✓ JINR CMS Tier2 center is one of the most reliable and productive CMS Tier2 centers worldwide (in the top ten best) the most powerful RDMS CMS Tier2 center

- ✓ CMS Regional Operation Center are functioning in JINR since 2009
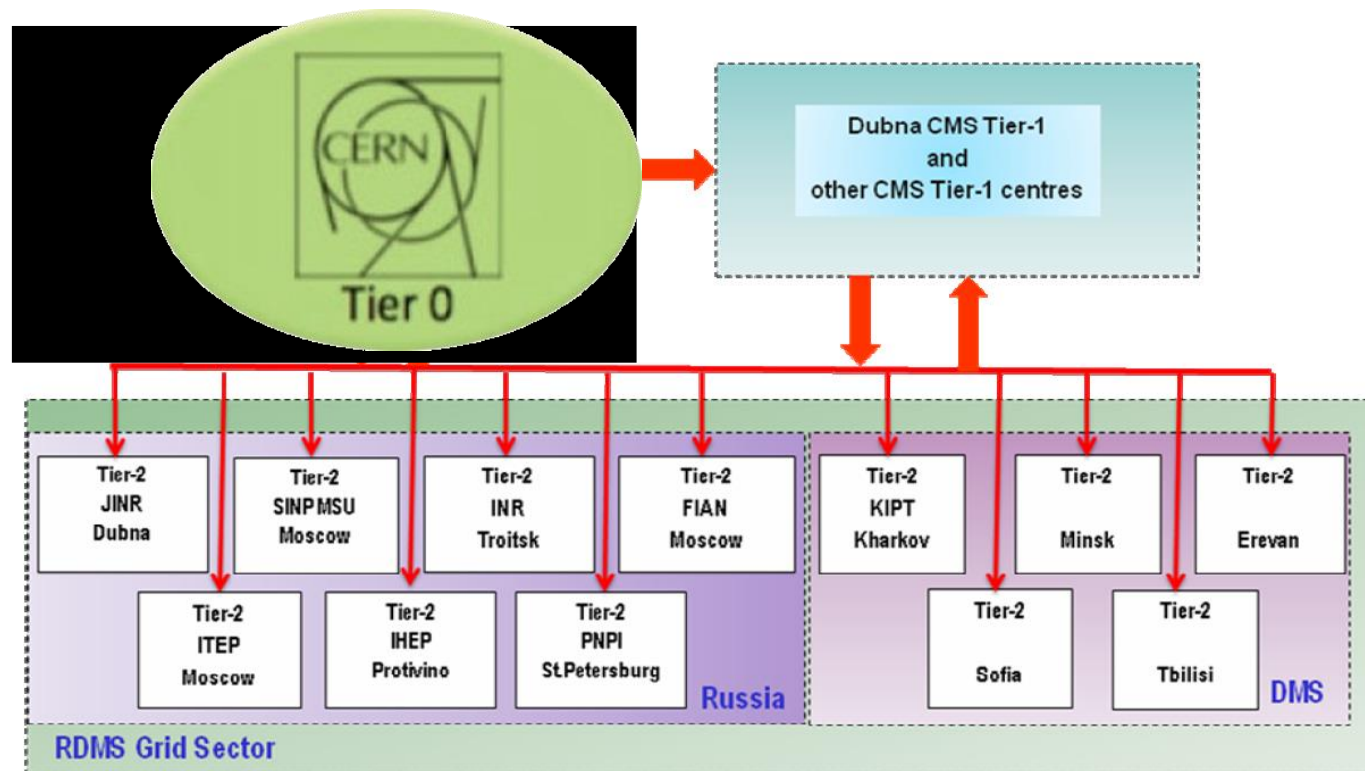


**The core services needed for WLCG Tier-1 are**
✓ computing service, a storage service, information service.

**The primary Tier-1 tasks can be divided into**
- ✓ recording raw data from CERN and storing them on tape;
- ✓ recording processed data from CERN and storing them on disk;
- ✓ providing data to other Tier-1 / Tier-2;
- ✓ reprocessing raw data;
- ✓ event simulation calculations.

# JINR CMS Tier-1 progress

| | 2012 (done) | 2013 | 2014 |
|---|---|---|---|
| CPU (HEPSpec06) | 14400 | 28800 | 57600 |
| Number of core | 1200 | 2400 | 4800 |
| Disk (Terabytes) | 720 | 3500 | 4500 |
| Tape (Terabytes) | 72 | 5700 | 8000 |

- Disk & server installation and tests: **done**
- Tape system installation: **done**
- Organization of network infrastructure and connectivity to CERN via GEANT: **done**
- Registration in GOC DB and APEL: **done**
- Tests of WLCG services via Nagios: **done**

# JINR CMS Tier-1 progress

| | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|
| CPU (HEPSpec06) Number of core | 28800 | 57600 | 69120 | 82944 |
| | 2400 | 4800 | 5760 | 6912 |
| Disk (Terabytes) | 3500 | 4500 | 5400 | 6480 |
| Tape (Terabytes) | 5700 | 8000 | 9600 | 10520 |
| Link CERN-JINR | 10 | 10 | 40 | 40 |

- Disk & server installation and tests: **done**
- Tape system installation: **done**
- Organization of network infrastructure and connectivity to CERN via GEANT: **done**
- Registration in GOC DB and APEL: **done**
- Tests of WLCG services via Nagios: **done**

# Tier1 center JINR for the CMS experiment
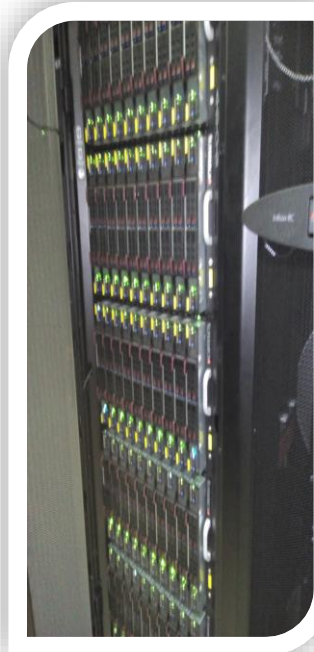


**Current configuration**
- **6000 cores**
- **6 PB disks**
- **11 PB tapes**
- **100% R/A**
- **70 TB per day**

Grid Tier-1 is one of the 7 centres in the world intended for large-scale processing of experimental and event-modeling data coming from the centres of Tier-0 (CERN), as well as Tier-1 and Tier-2 of the Worldwide Computing Grid

**WLCG:** **a**n 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
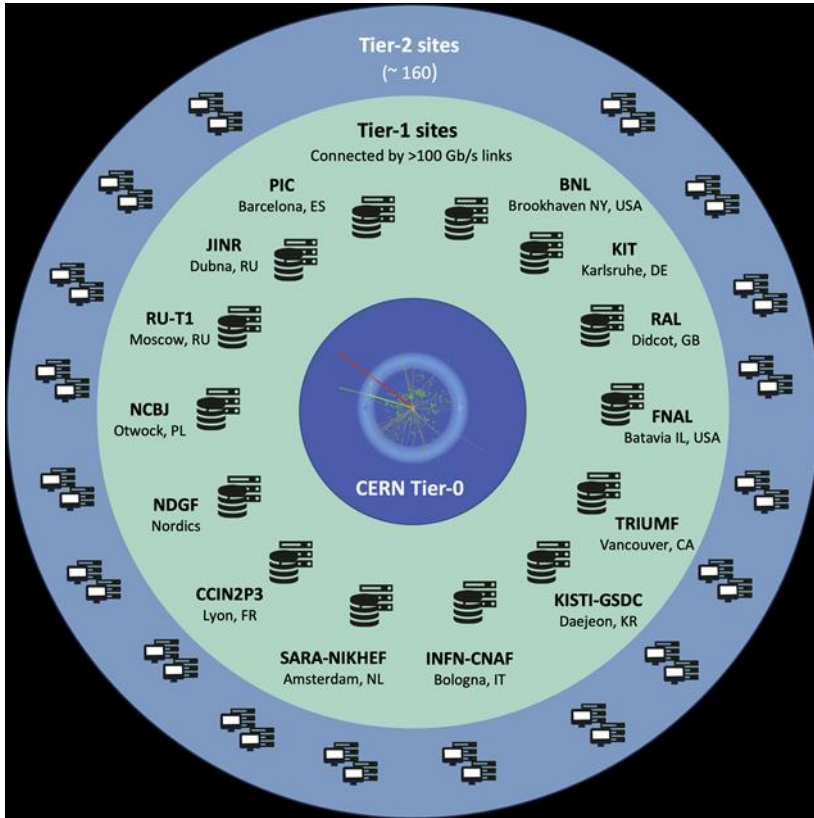


The mission of the WLCG project is to provide global computing resources to store, distribute and analyze the ~250-300 Petabytes of data expected every year of operations from the Large Hadron Collider.

**WLCG computing enabled physicists to announce the discovery of the Higgs Boson.**

**170** sites

**42** countries

**> 12k** physicists

**~1.6 M** CPU cores

**~2 EB** of storage (**1 EB** - **CERN**)

> **2.5** million jobs/day

**100-400** Gb/s links



**Tier0 (CERN):** data recording, reconstruction and distribution

**Tier1:** permanent storage, re-processing, analysis

**Tier2:** Simulation, end-user analysis

*Worldwide LHC Computing Grid - 2023*
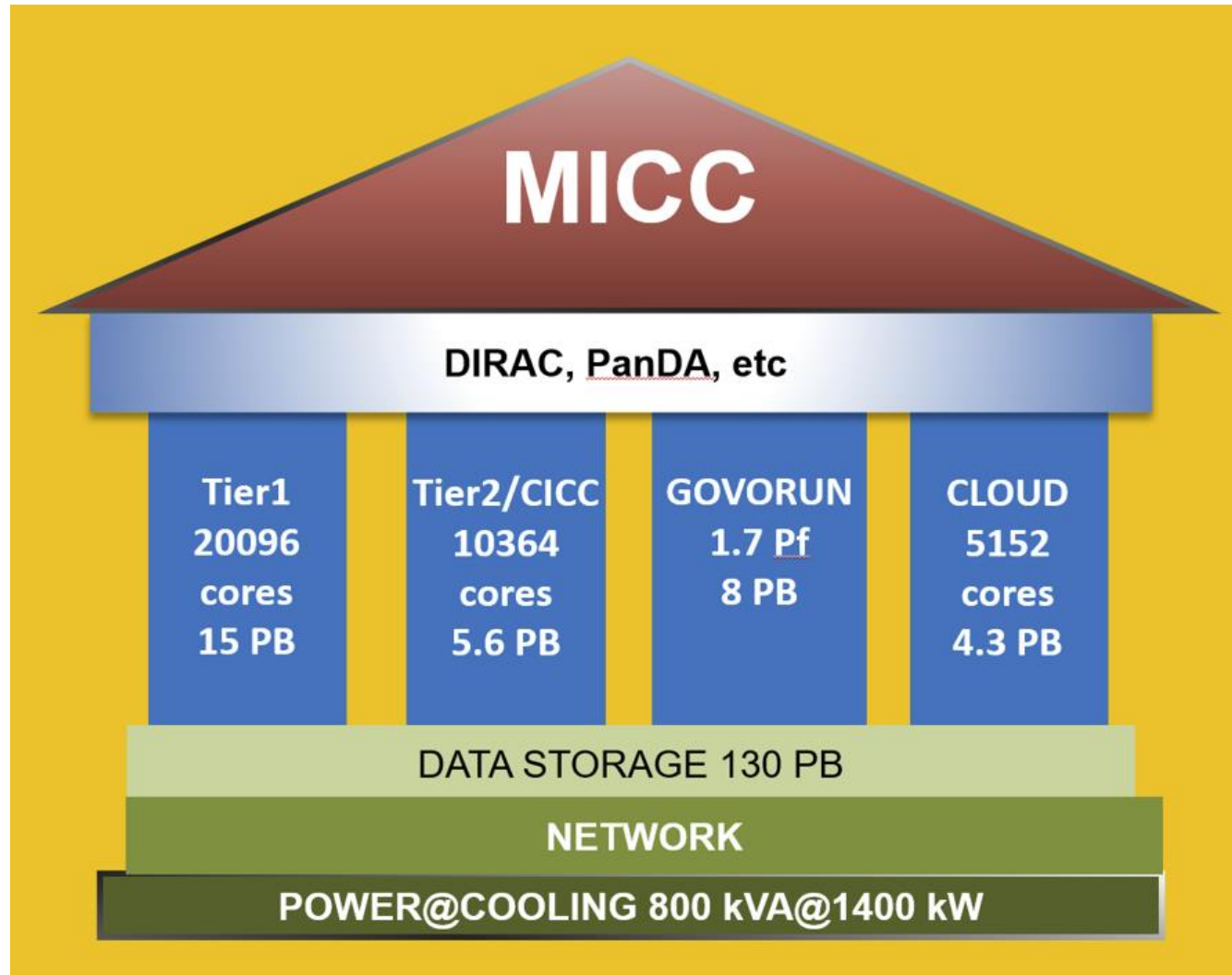
**4 advanced software and hardware components**

- ➤ Tier1 grid site
- ➤ Tier2 grid site
- ➤ hyperconverged "Govorun" supercomputer
- ➤ cloud infrastructure

**Distributed multi-layer data storage system**

- ➤ Disks
- ➤ Robotized tape library

**Engineering infrastructure**

- ➤ Power
- ➤ Cooling

**Network**

- ➤ Wide Area Networkr
- ➤ Local Area Network

**The main objective of the project is to ensure multifunctionality, scalability, high performance, reliability and availability in 24x7x365 mode for different user groups that carry out scientific studies within the JINR Topical Plan**
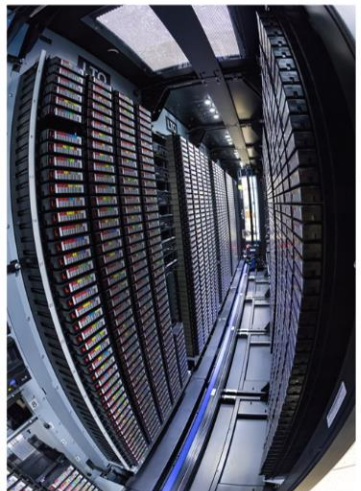
**Distribution of the incoming and outgoing traffics by the JINR MICC in 2020-2023 (TB)**
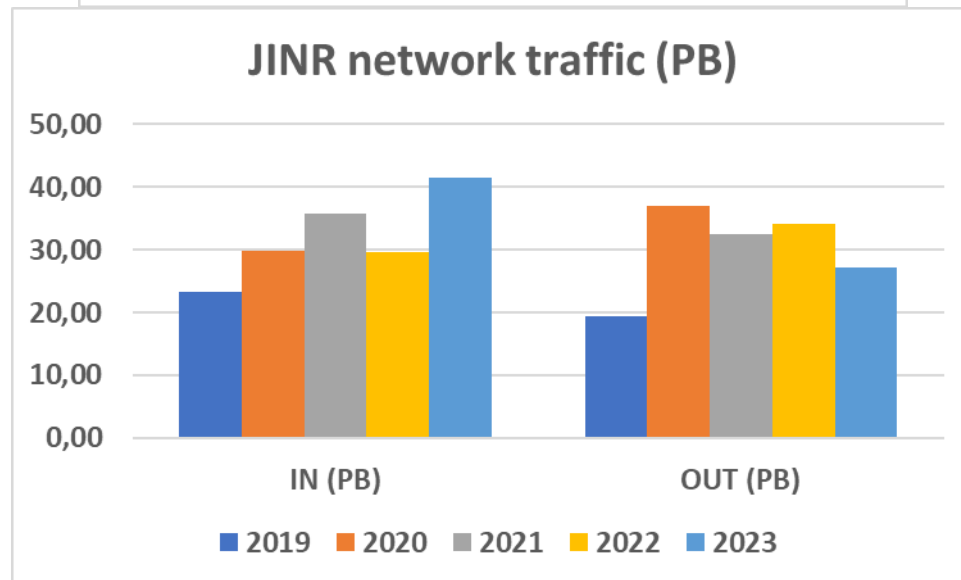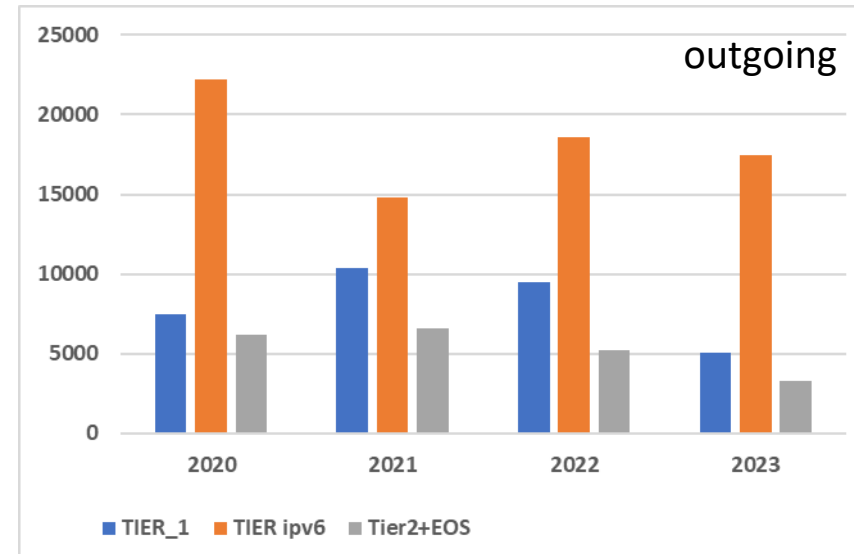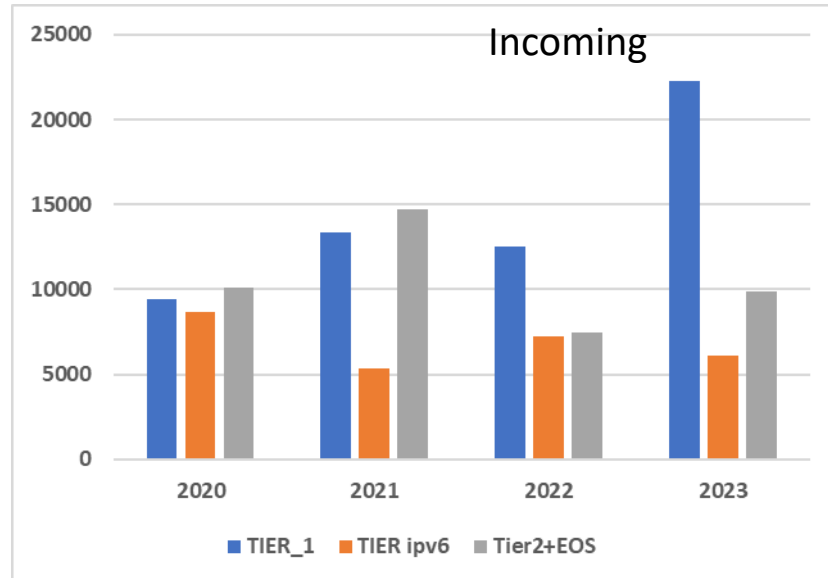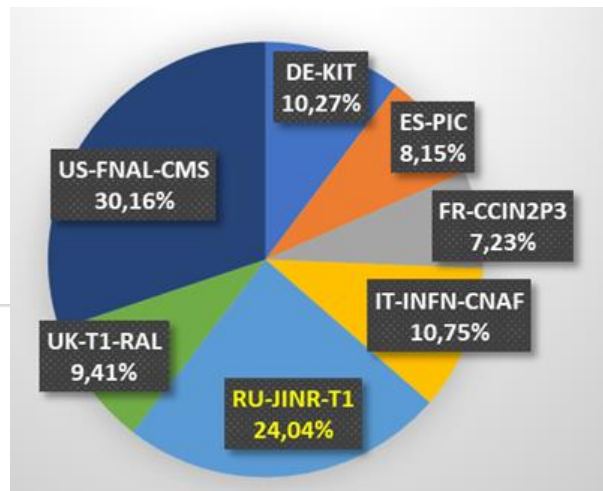


Общий входящий трафик ОИЯИ, включая сервера общего назначения, Tier1, Tier2, СК «Говорун» и облачные вычисления, составил в 2023 году 41,5 ПБ, общий исходящий – 27,5 ПБ.
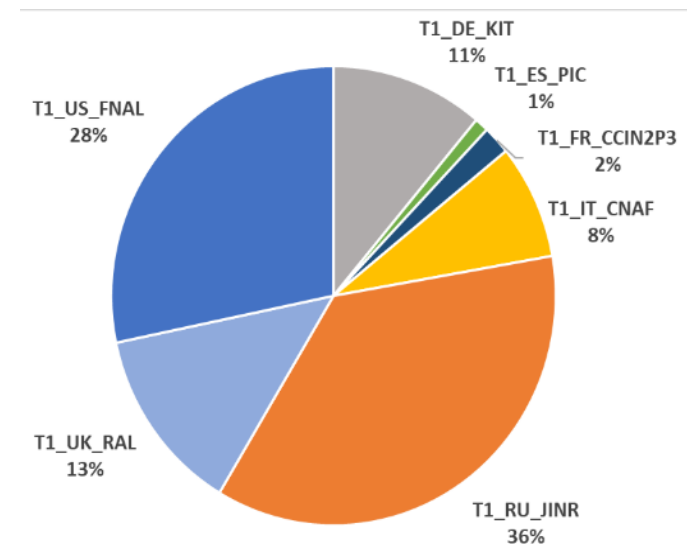
# JINR Tier1 for CMS

- **20064** cores
- **360** kHS06
- **15 PB** disks
- **103 PB** tapes
- **100%** reliability and availability

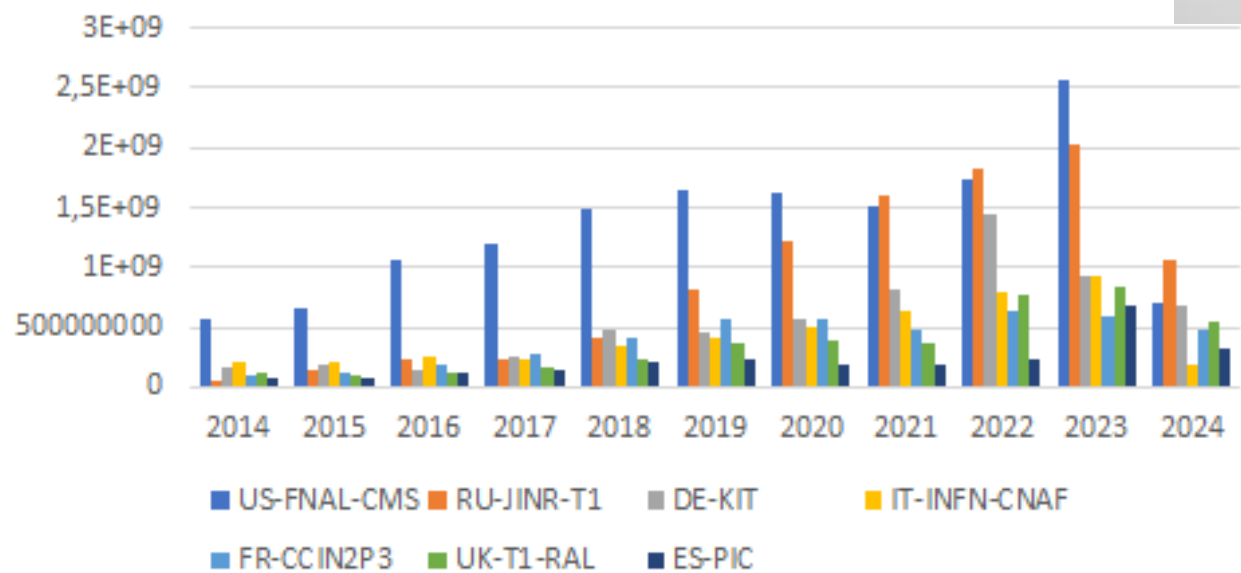Accounting - 2014_1 to 2024_8 normcpu for CMS TIER1 and Year

Вклад мировых Tier1 центров в обработку экспериментальных данных CMS за 2023 год:



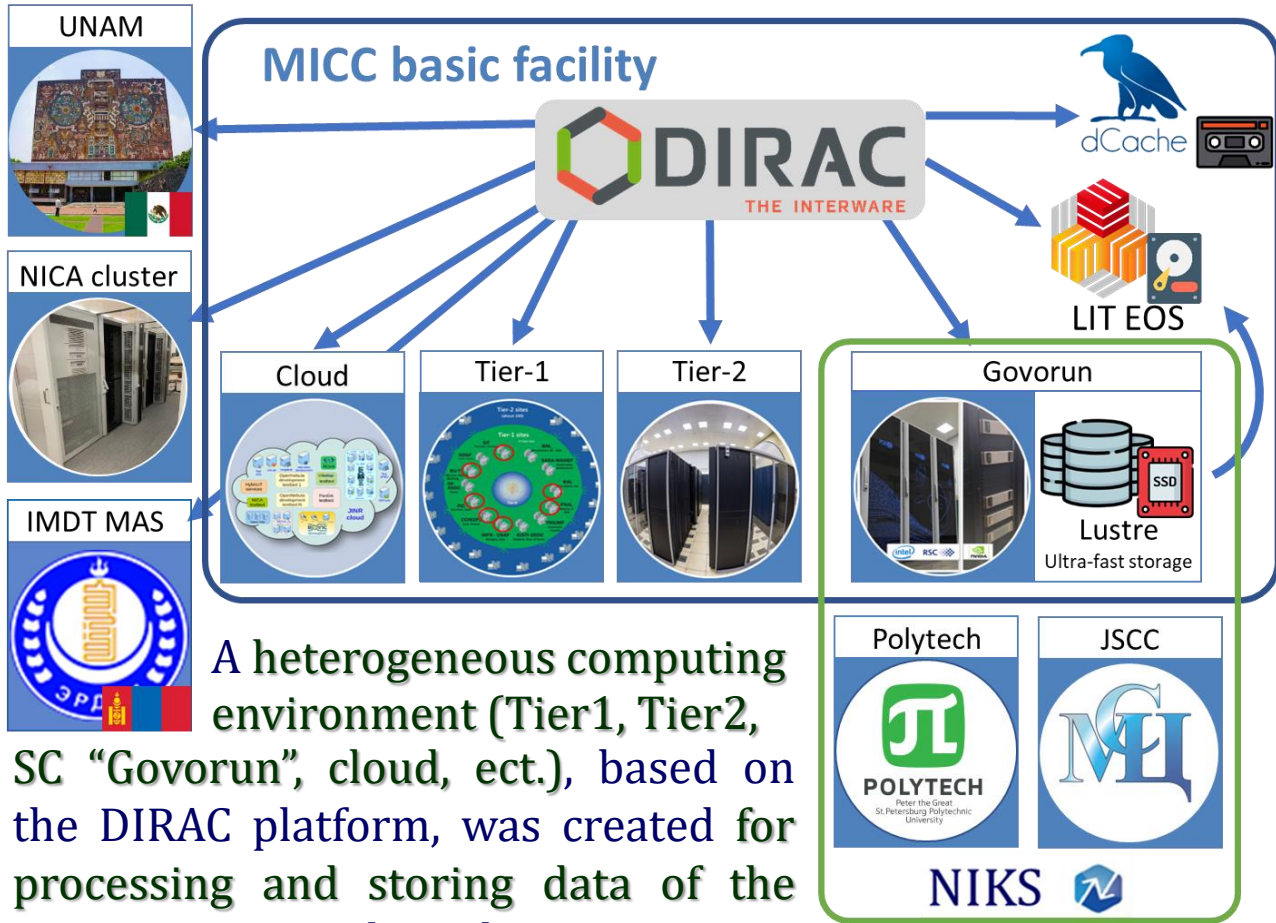Количество обработанных событий эксперимента CMS за 2023 год



| Tier1 CMS | 2024 | % |
|---|---|---|
| **RU-JINR-T1** | **1,066,487,239** | **26,48** |
| US-FNAL-CMS | 699,418,243 | 17,36 |
| DE-KIT | 690,138,246 | 17,14 |
| UK-T1-RAL | 560,611,382 | 13,91 |
| FR-CCIN2P3 | 487,329,004 | 12,09 |
| ES-PIC | 325,997,642 | 8,07 |
| IT-INFN-CNAF | 198,473,663 | 4,91 |

# DIRAC-based distributed heterogeneous environment



**MICC basic facility**

UNAM
NICA cluster
IMDT MAS

DIRAC — THE INTERWARE

dCache
LIT EOS

Cloud | Tier-1 | Tier-2 | Govorun
Lustre — Ultra-fast storage

Polytech | JSCC
NIKS

A **heterogeneous computing environment (Tier1, Tier2, SC "Govorun", cloud, ect.)**, based on the DIRAC platform, was created **for processing and storing data of the experiments** conducted at JINR.
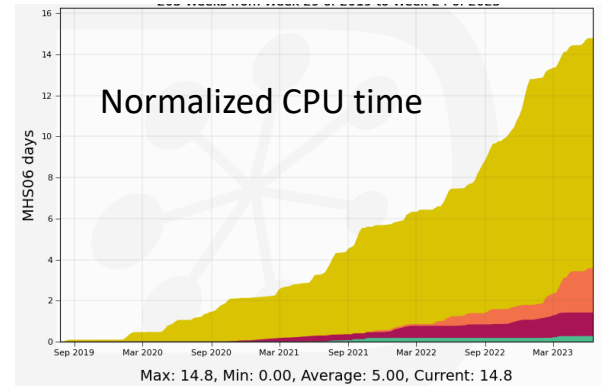
The distributed infrastructure is used by the **MPD, Baikal-GVD, BM@N, SPD.**
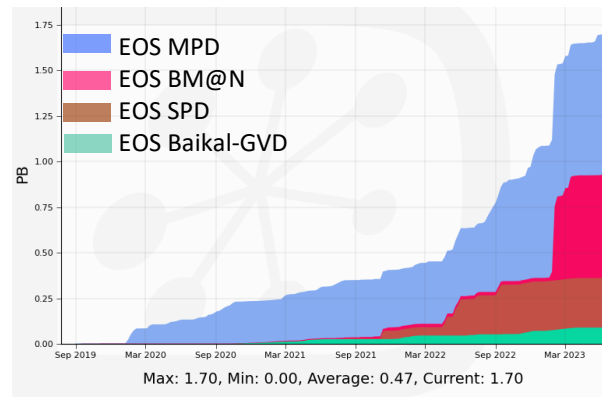
Use of DIRAC platform by experiments in 2019-2022

BM@N 6%
Baikal-GVD 11%
SPD 14%
MPD 69%

- MPD
- SPD
- Baikal-GVD
- BM@N
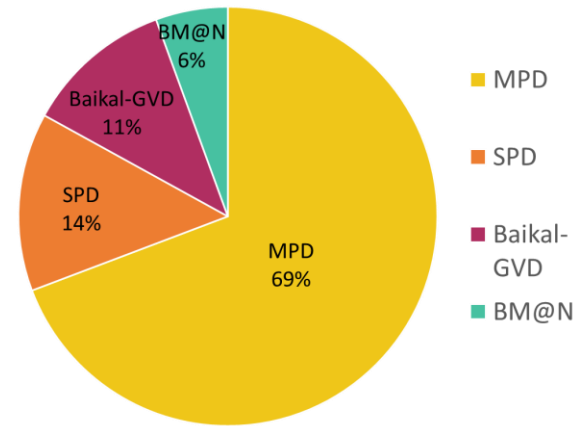
Total Number of executed jobs

Normalized CPU time

Max: 14.8, Min: 0.00, Average: 5.00, Current: 14.8

The major user of the distributed platform is the MPD experiment

Data processed by experiments

- EOS MPD
- EOS BM@N
- EOS SPD
- EOS Baikal-GVD

Max: 1.70, Min: 0.00, Average: 0.47, Current: 1.70

Summary statistics of using the DIRAC platform for MPD tasks in 2019-2022

| 31 data generation campaigns | 1.283 B events generated | 440M events reconstructed | 1.5M jobs completed | 1557 years total computation time | 1.3 PB MPD data produced |

NEC'2015
XXV International Symposium
on Nuclear Electronics & Computing

# GRID-conferences

Joint Institute for Nuclear Research
Meshcheryakov Laboratory of Information Technologies

# GRID2023
## 3-7 July 2023

10th International Conference
"Distributed Computing and Grid Technologies in Science and Education"

10th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2023)

# Семинары памяти М.Г. Мещерякова, Н.Н. Говоруна

**Дорогой Игорь Анатольевич!**

**Коллектив Лаборатории информационных технологий
от всей души поздравляет Вас с ЮБИЛЕЕМ!**

Позвольте в этот день отметить Ваш огромный вклад
в экспериментальные исследования в области физики
элементарных частиц, особенно в развитие эксперимента CMS
на Большом адронном коллайдере, на котором было совершено
открытие бозона Хиггса.
Ваши научные исследования хорошо известны научной общественности
и получили самое широкое признание как в нашей стране, так и за рубежом.
Ваше сотрудничество с нашей Лабораторией имеет продолжительную
и богатую историю. Особенно нам приятно отметить Ваши совместные
работы с Николаем Николаевичем Говоруном в области развития методов
онлайн-обработки экспериментальных данных. Ваши пионерские разработки
в области создания ядерной электроники на транзисторах существенно
улучшили работу сцинтилляционных и черенковских счётчиков.
Ваш большой талант Ученого и Организатора, Ваш опыт и практические
знания и готовность взять на себя ответственность позволили
Вам стать руководителем коллаборации RDMS CMS.
На этом посту Вы успешно и эффективно решали задачи по координации
работы физиков России и стран-членов ОИЯИ в составе международной
коллаборации CMS, что сыграло важную роль в получении
фундаментальных результатов.
В этот день особо хотелось бы подчеркнуть не только Вашу научную и
организационную деятельность, но и Ваши прекрасные человеческие
качества, сочетающие умение быть эффективным и требовательным
руководителем с отзывчивостью и готовностью помочь в трудную минуту.
Ваша энергичность, отзывчивость и высокий профессиональный
уровень снискали заслуженное уважение и авторитет среди
Ваших коллег, учеников и друзей!

**Дорогой Игорь Анатольевич,
примите в день Вашего Юбилея искренние пожелания
крепкого здоровья,
бесконечной творческой энергии,
новых идей, счастья и благополучия!**
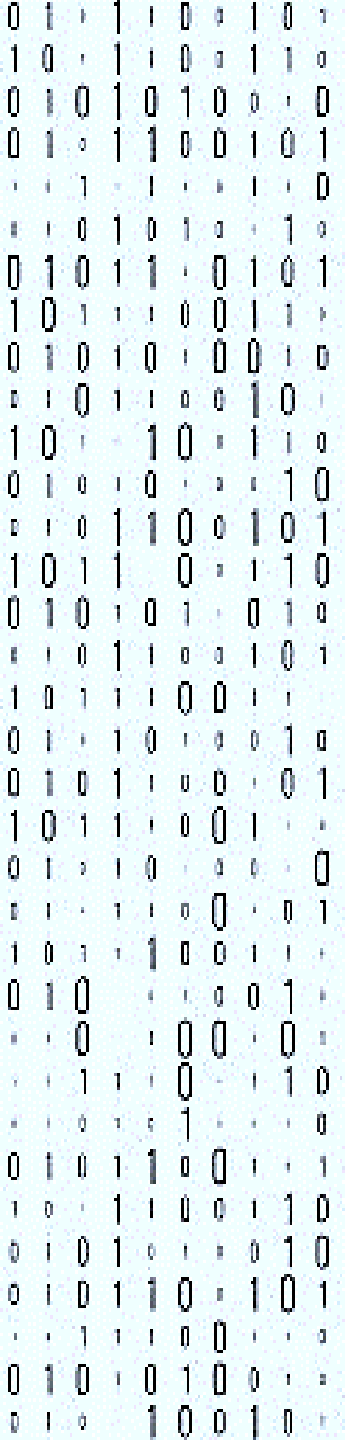
# Игорь Анатольевич Голутвин
# Светлая память