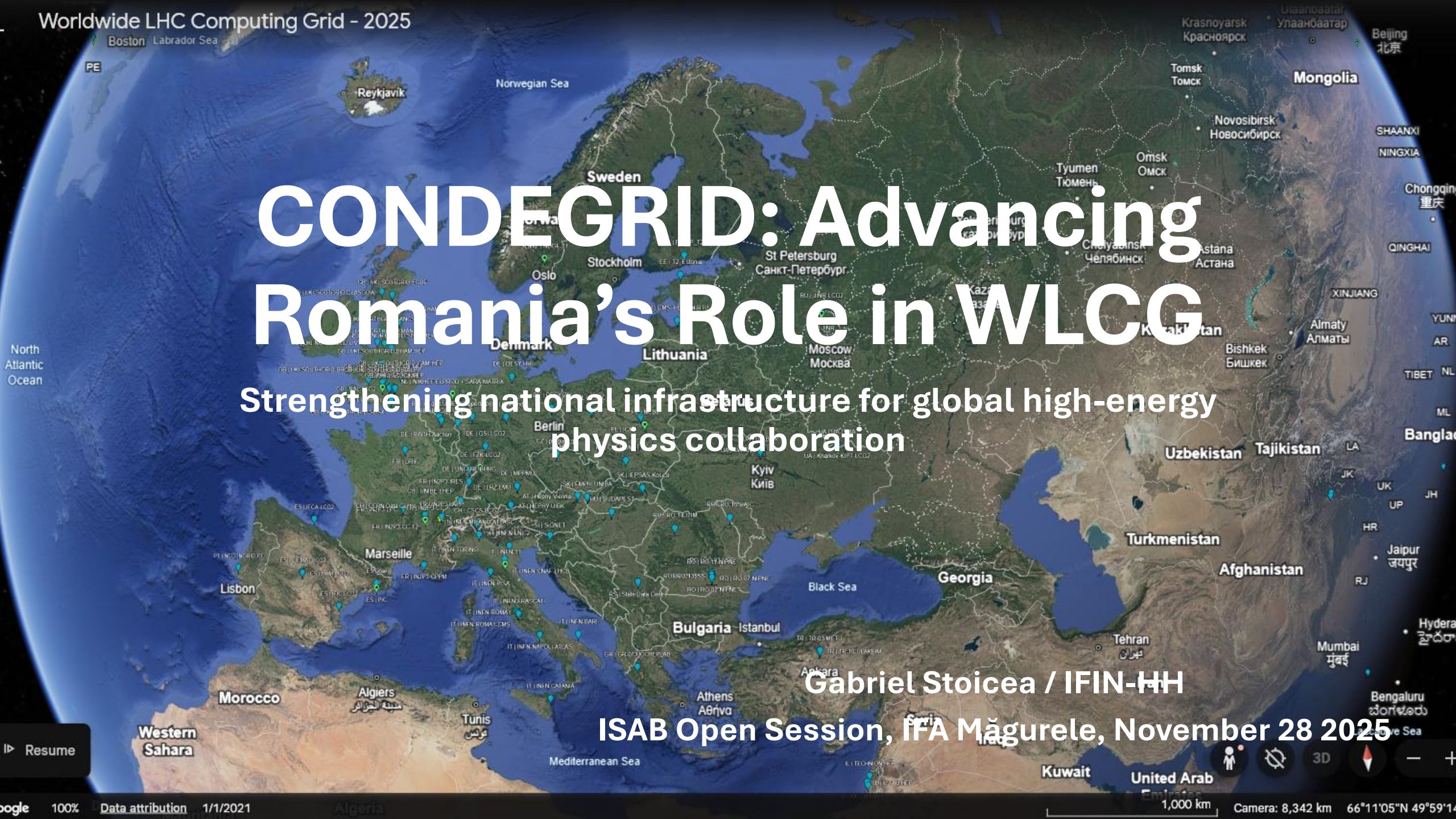


CONDEGRID: Advancing Romania's Role in WLCG

Strengthening national infrastructure for global high-energy physics collaboration

Gabriel Stoicea / IFIN-HH

ISAB Open Session, IFA Măgurele, November 28 2025

Overview & Motivation

The LHC Data Challenge

- The Large Hadron Collider (LHC) produces hundreds of petabytes of data annually from proton–proton collisions.
- Even after filtering out 99% of uninteresting events, the experiments still generate ~200 PB per year that must be stored and analyzed.
- CERN alone can provide only about 20% of the required computing and storage capacity, so global collaboration is essential.

What is WLCG?

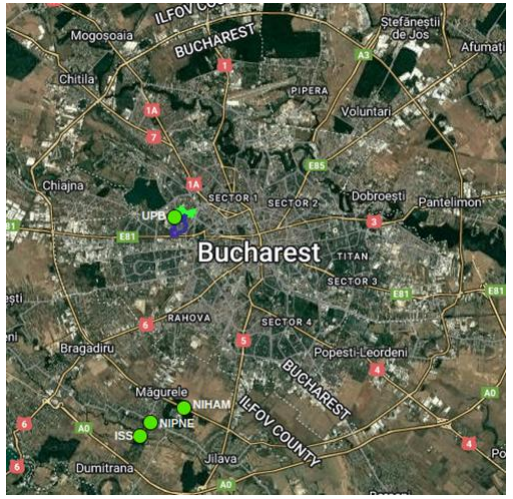
- The Worldwide LHC Computing Grid (WLCG) is a distributed computing infrastructure linking 170+ sites across 42 countries.
- It combines ~1.4 million CPU cores and 1.5 exabytes of storage, enabling near real-time access to LHC data for over 12,000 physicists worldwide.
- WLCG runs over 2 million tasks per day, with global transfer rates exceeding 260 GB/s

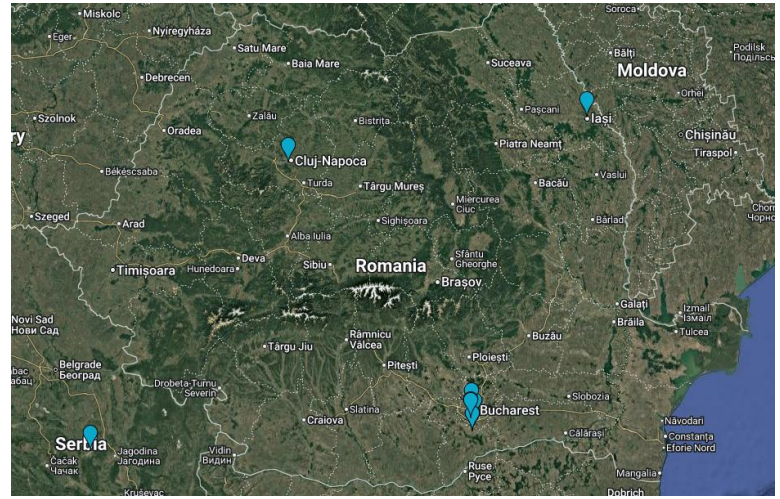
Why It Matters

- Without WLCG, analyzing the LHC's unprecedented data volumes would be impossible.
- The grid ensures that discoveries like the Higgs boson and future physics breakthroughs are supported by robust, scalable computing.

Short history of WLCG in Romania

- One of the oldest groups of Tier-2s on the Grid, joined as early as 2005: NIHAM, ISS, NIPNE and UPB
- Decades of growth, operational experience and innovation
  - Fast adoption of new technologies
- Long history of collaboration with ALICE, ATLAS and LHCb
  - Romanian Federation is the 4th largest contributor of computing resources for the ALICE experiment





Project Objectives

Main Goal:
Strengthen RO-LCG's integration into the WLCG infrastructure by improving service quality for ALICE, ATLAS, and LHCb, and supporting the computational strategy for Run 4.

Specific Objectives:

- **O1. Maintain Tier-2 Contribution:**
  Fulfill MoU commitments and sustain RO-LCG's role as a medium-size Tier-2 site.
- **O2. Improve Efficiency:**
  Enhance technical and financial performance through better service reliability, optimized resource management, and coordinated human resources.
- **O3. Deepen WLCG Integration:**
  Align with WLCG strategic directions and expand collaboration for HL-LHC readiness.
- **O4. Adopt New Technologies:**
  Develop and implement advanced computing paradigms and software tools, both in-house and with CERN.
- **O5. Build Human Capacity:**
  Recruit, train, and retain a stable pool of qualified specialists for grid operations and development.
- **O6. Increase Visibility:**
  Promote RO-LCG achievements through outreach, strategic partnerships, and engagement with RDI communities and funding bodies.

Technical Architecture

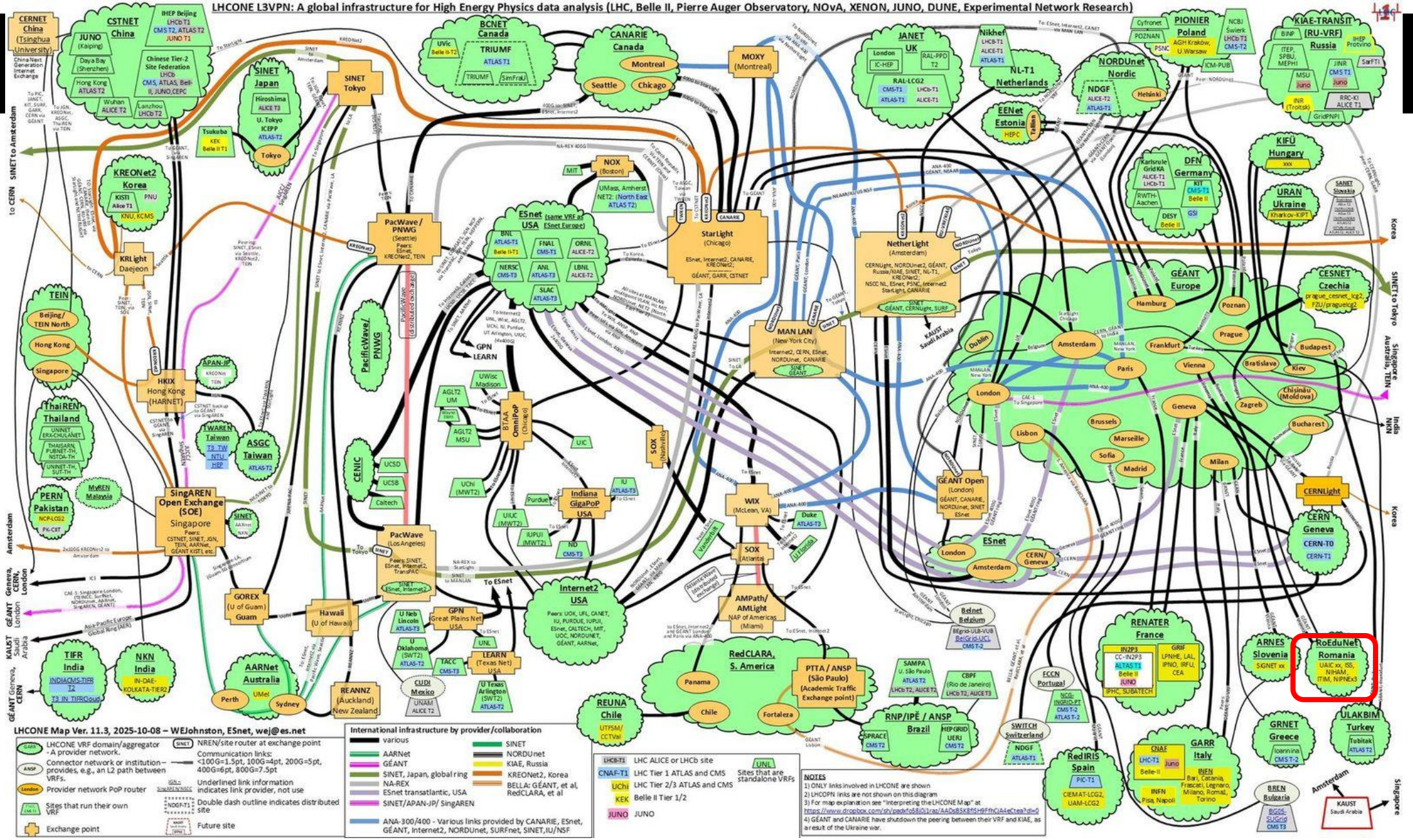
Infrastructure Overview

- **Federated Tier-2 Sites:**
  RO-13-ISS (P1), RO-14-ITIM (P2), RO-16-UAIC (P3), RO-03-UPB (P4), RO-07-NIPNE (CO)
  Integrated into WLCG, supporting ALICE, ATLAS, and LHCb
- **Middleware & OS Stack:**
  - Rocky Linux 9, Alma Linux 8, OpenStack 2025.1
  - EGI middleware, ARC, HT-Condor
  - EOS upgraded to Diopside 5.3.15 with QuarkDB
  - JAliEn middleware with TTL-based adaptive scheduling

Personnel Summary / Total: 4.53 FTE

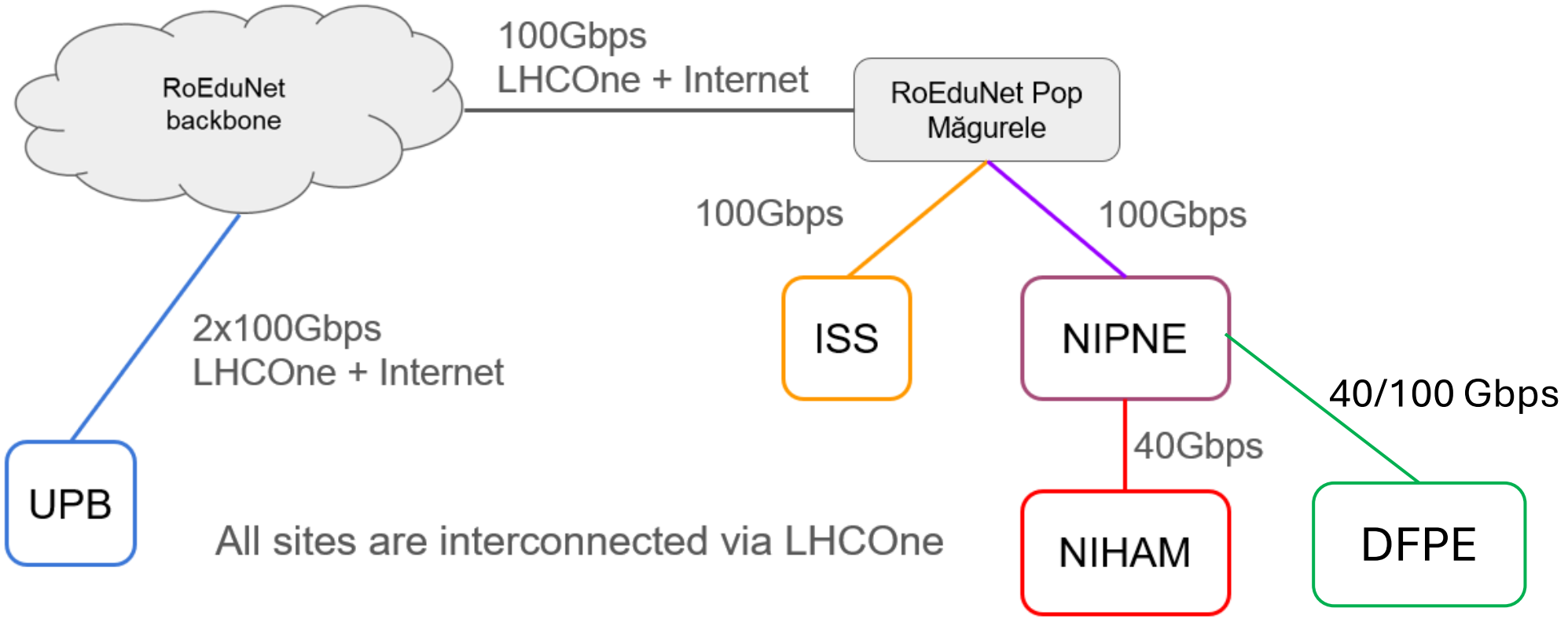
Category	Count	Notes / Roles
Physicists	7	Senior researchers supporting ALICE, ATLAS, LHCb
Engineers & Technical Staff	16	Site admins, network operators, IT specialists, software developers
Postdocs	1	Dr. Eng. contributing to technical development
PhD Students	3	Active in Grid computing, middleware optimization, experiment support
Master Students	2	Training in Grid/Cloud technologies
Administrative Staff	1	Economist handling financial management
Total Personnel	**30**	Distributed across RO-LCG federation sites (IFIN-HH, ISS, ITIM, UAIC, UPB)

Technical Architecture



Technical Architecture

RO-LCG Network connectivity



Technical Architecture P1 - ISS

Compute resources:

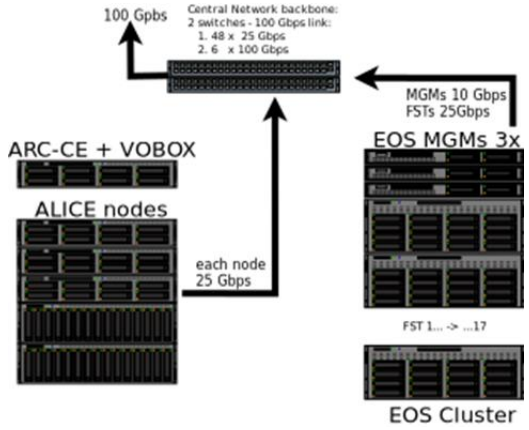
- 1384 cores (2768 threads)
- 4.5 GB RAM/thread

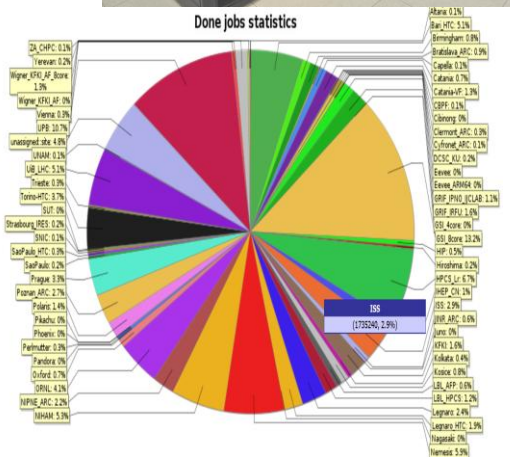
Storage resources:

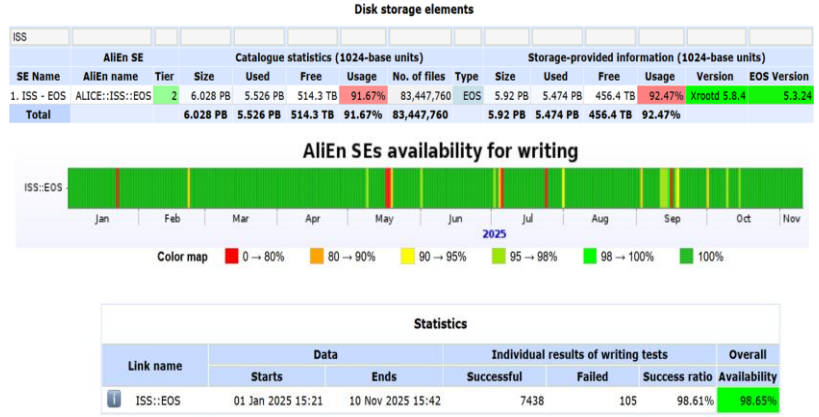
- EOS cluster
  - redundant 3x manager nodes
- 6 PiB storage (over 25 Gbps connected 17 nodes)

Network resources:

- 100 Gbps upstream, local 25 Gbps network







http://alimonitor.cern.ch

- High computing contribution/cost ratio
- Over 1.73M done jobs in last year
- 82.19 % jobs efficiency (cpu time/wall time) over last year
- 98.6% availability and success ratio of our storages
- 65 PB data transfer in the last year, 91% storage space occupied
- Storage capacity (6 PB) will increase until the end of this year with another 1.2 PB

GRID purchases in 2025 and future upgrades

- Storage capacity upgrade (auction ongoing)
  - 3 x 4U storage servers, each server with 600 TB storage capacity and 2 x 25 Gbps network connection

- for 2026 we plan to purchase a new computing and storage server

Technical Architecture P2 - ITIM

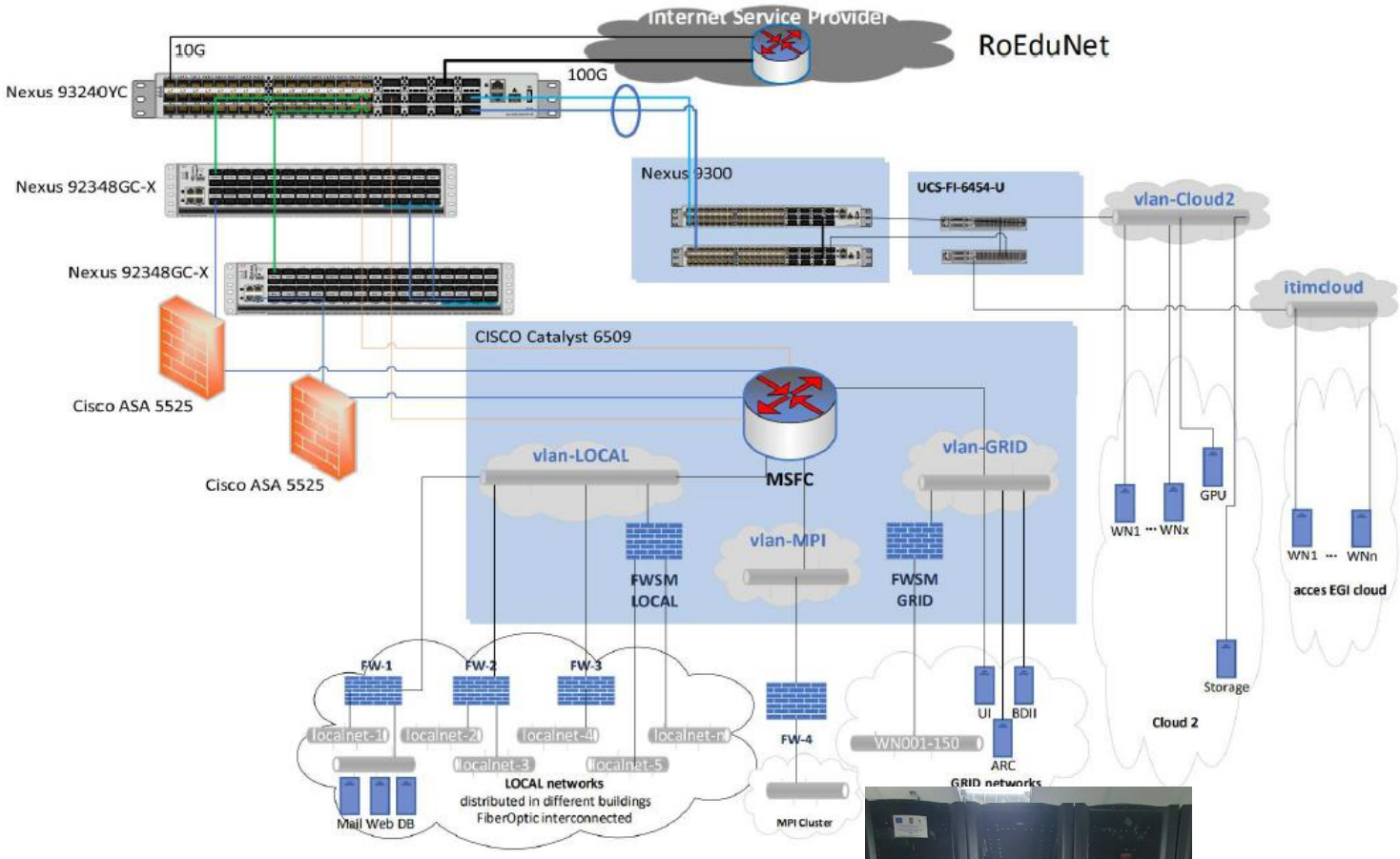
Compute resources:

- 79 computing nodes / 1580 cores
- 2 GB/core and 4 GB/core
- 1 TB/node storage

Network resources:

- 100 Gbps upstream to RoEduNet

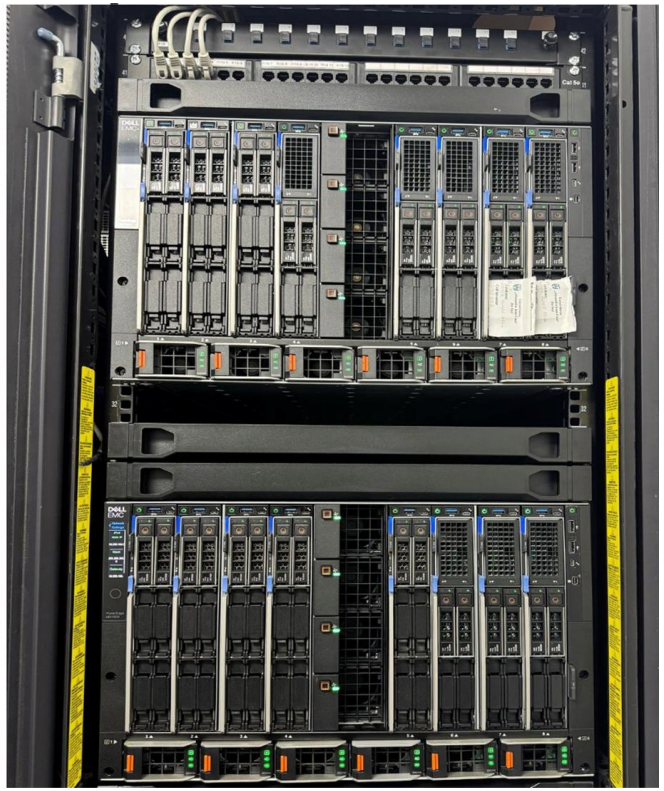
- Over 1.62M done jobs in 2025
- Over 3.5M hours CPU time over this year



Technical Architecture P3 - UAIC

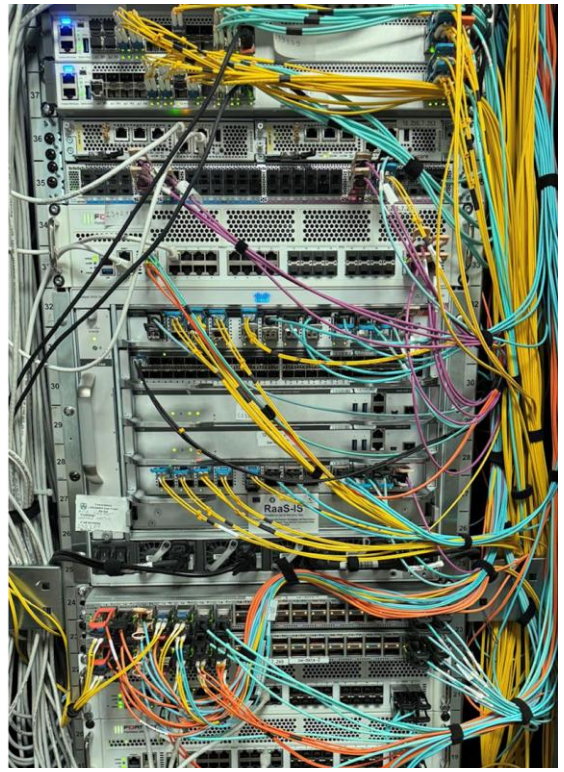
Compute

The infrastructure consists of 28 blade servers with a total of 932 processor cores, 1,864 hyperthreads, and 4 TB of RAM



Networking

Uplink:
2x 100Gbps to RoEduNet -> Geant
Downlink:
2 x 40/100 Gbps to every blade system and 2x10/25Gbps to every server

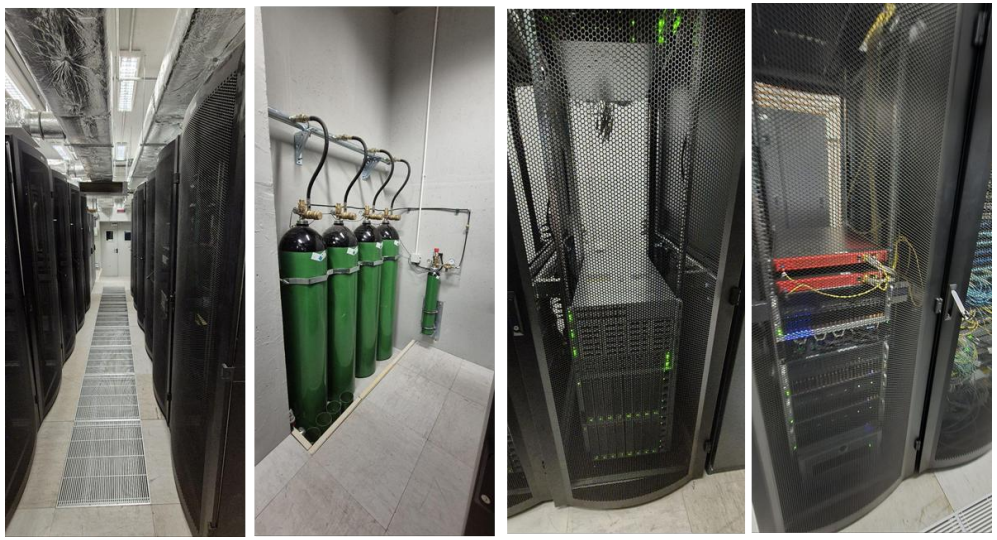


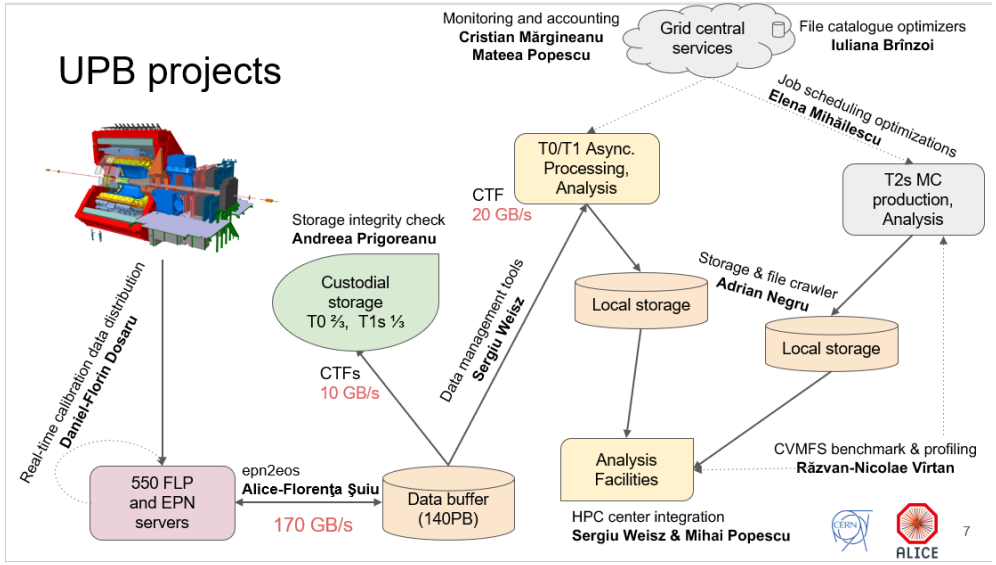
RO-16-UAIC 2025

Upcoming Delivery
- **1 × UCS-X 9508 Chassis**
- **2 × UCSX-S9018 Switches**
- **1 × UCS X210c M8 Server**

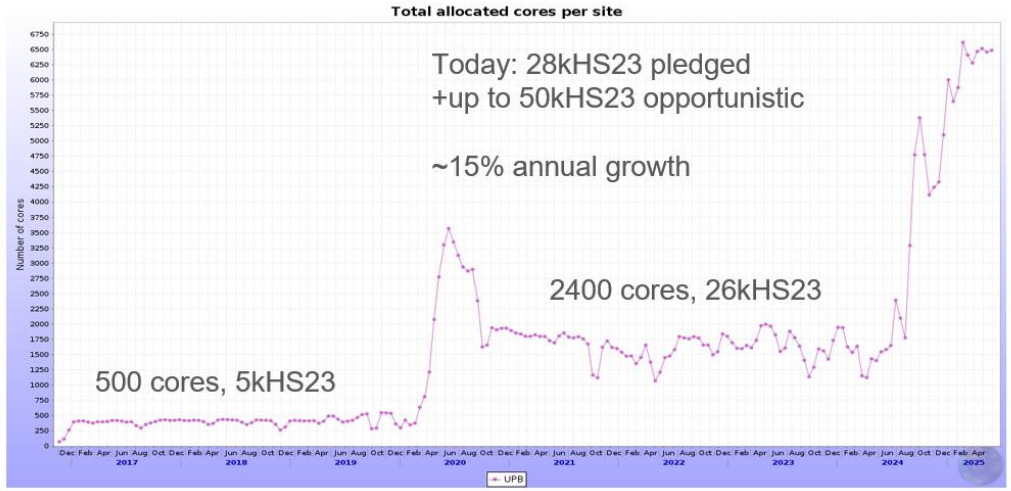
Primary activity: Maintaining the grid site at optimal operating parameters and implementing the necessary security and debugging packages.

Technical Architecture P4 - UPB

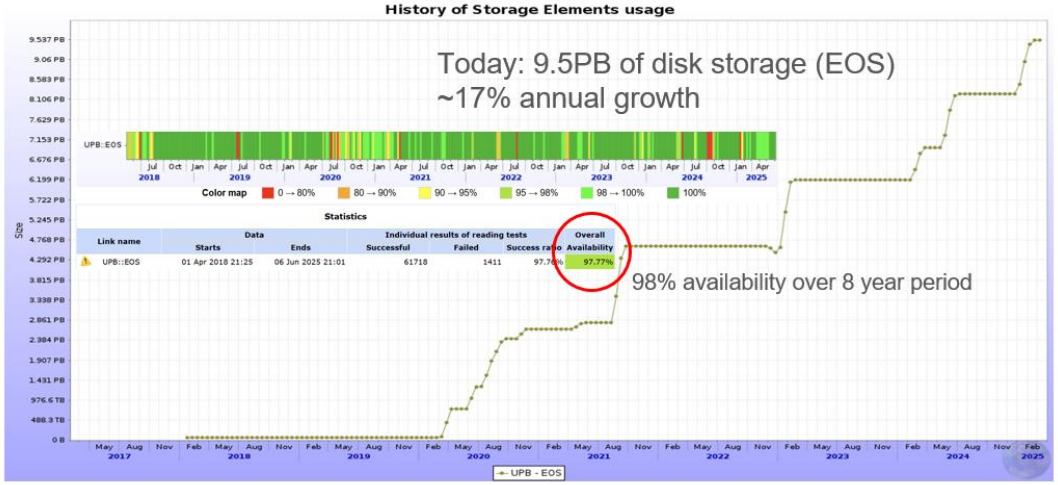




UPB evolution - compute resources



UPB evolution - storage resources



Technical Architecture CO – IFIN-HH (RO-07-NIPNE / DFCTI + DFPE)

- **RO-07-NIPNE** part of RO-LCG Federation – member in WLCG collaboration
- Computing resources dedicated to 3 LHC VOs: ALICE, ATLAS, LHCb
- Storage resources dedicated to 3 LHC VOs: ALICE, ATLAS, LHCb(EOS+dCache)
- 2 different resource managers: HTCondor fair-share policies
- Single core and multicore queues (ALICE and ATLAS - 8core)
- Ansible for upgrades
- Top-BDII, VOBOX and VOMS (eli-np.eu,ronbio,etc)
- dCache storage used for Romanian ATLAS diskless sites
- 100Gbps uplink network
- 2 locations DFCTI: “computing room” and “storage room” with 100Gbps link interconnectivity + 1 location DFPE Data Center: 40 / 100Gbps links to DFCTI Data Center

Upcoming

Network

- Upgrade IFIN-HH back-up connection to 100Gbps

Storage

- New storage equipment to be installed

- **~7000** CPU(**~1000** CPU belongs to ATLAS Bucharest Group / DFPE)
- Blade + ”pizza boxes”16, 20, 32 cores/server

Achievements & Metrics in 2025

WLCG Storage Space Accounting

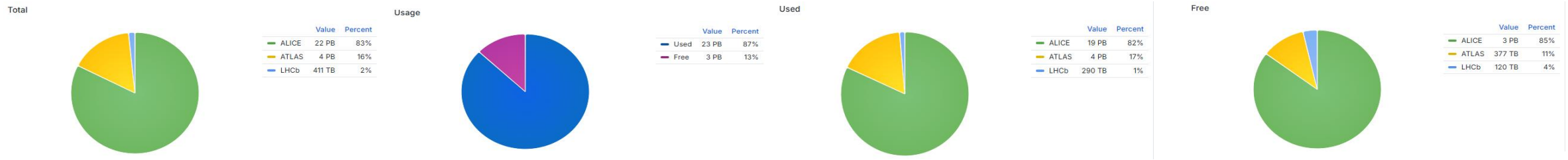
VO: ALICE + ATLAS + LHCb | Tier: All | Country: RO | Federation: RO-LCG | Medium: Disk | Site: All | Service: All | Area: All

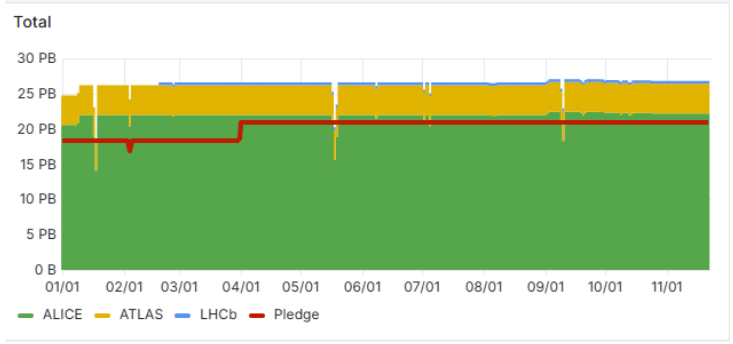
Group By: vo | Binning: 1d

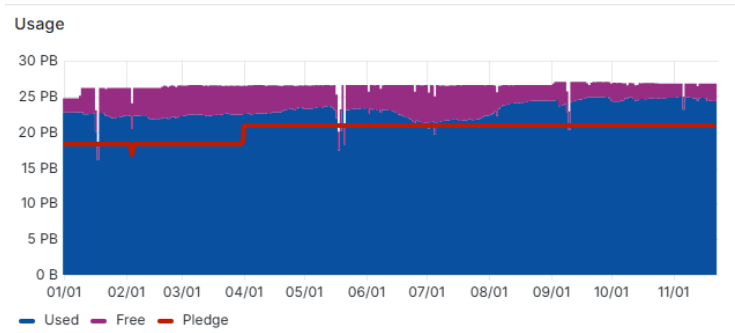
Table View

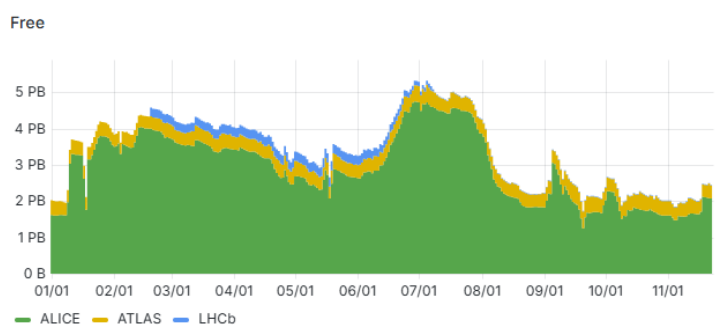
Summary

vo	Used	Free	Total
ALICE	19.0 PB	2.9 PB	21.9 PB
ATLAS	3.8 PB	377.5 TB	4.2 PB
LHCb	290.3 TB	120.2 TB	410.6 TB









Achievements & Metrics in 2025

Tier2 — Total number of jobs by Country and Quarter (LHC VOs)

Country	Jan 2025 — Mar 2025	Apr 2025 — Jun 2025	Jul 2025 — Sep 2025	Oct 2025 — Dec 2025	Total	Percent
United Kingdom	12,811,577	11,368,220	10,227,082	6,405,413	**40,812,292**	**22.52%**
United States	10,073,978	11,222,253	10,054,330	6,038,299	**37,388,860**	**20.63%**
Germany	6,788,986	7,348,233	7,310,170	4,273,102	**25,720,491**	**14.19%**
France	4,632,467	5,552,987	4,003,040	1,932,128	**16,120,622**	**8.89%**
Czechia	1,504,436	1,942,539	2,240,104	1,856,584	**7,543,663**	**4.16%**
Poland	1,646,769	1,631,340	2,298,377	843,624	**6,420,110**	**3.54%**
Italy	1,661,138	1,859,011	2,076,786	698,359	**6,295,294**	**3.47%**
Japan	2,168,059	1,646,253	1,689,398	629,959	**6,133,669**	**3.38%**
Romania	1,569,079	1,746,246	1,778,244	830,957	**5,924,526**	**3.27%**
Switzerland	2,864,446	2,902,470	0	0	**5,766,916**	**3.18%**
Canada	1,877,641	1,534,691	1,177,673	696,451	**5,286,456**	**2.92%**
Spain	1,463,232	1,442,591	1,050,541	810,055	**4,766,419**	**2.63%**
Israel	937,818	1,237,309	1,154,837	479,828	**3,809,792**	**2.1%**
Latin America	175,025	354,070	1,005,404	824,684	**2,359,183**	**1.3%**
Russian Federation	283,513	545,015	291,433	147,166	**1,267,127**	**0.7%**
Turkey	487,770	193,860	35			
Slovakia	293,522	222,514	19			
Belgium	228,972	147,605	12			
Portugal	214,368	82,782	11			
Taiwan	140,619	74,997	8			
Brazil	47,812	75,652	1			
Finland	52,355	156,289	8			
"Korea, Republic of"	114,708	44,813	11			
Hong Kong SAR	15,376	118,598	10			
Hungary	71,616	68,863	6			
Estonia	23,028	138,473	6			
Austria	39,010	54,161	4			
Ukraine	22,689	27,965	2			
Thailand	2,870	2,077				
Total	**52,212,879**	**53,741,877**	**47,92**			
Percent	**28.81%**	**29.65%**	**26**			

Tier2 — Sum CPU Time Hours used (h)hours) by Country and Quarter (LHC VOs)

Country	Jan 2025 — Mar 2025	Apr 2025 — Jun 2025	Jul 2025 — Sep 2025	Oct 2025 — Dec 2025	Total	Percent
United States	262,335,424	326,108,518	303,226,717	175,778,413	**1,067,449,072**	**31.8%**
United Kingdom	153,009,854	178,737,082	176,551,168	99,615,130	**607,913,234**	**18.11%**
Germany	71,048,554	72,710,923	94,618,310	71,225,168	**309,602,955**	**9.22%**
France	72,830,438	78,983,721	67,386,146	32,011,695	**251,212,000**	**7.48%**
Italy	40,754,377	63,863,673	70,603,879	13,537,255	**188,759,184**	**5.62%**
Latin America	3,056,387	12,457,563	33,497,783	71,868,400	**120,880,133**	**3.6%**
Spain	29,887,150	33,091,159	33,969,542	20,120,723	**117,068,573**	**3.49%**
Czechia	20,124,906	36,042,276	33,363,083	18,300,099	**107,830,363**	**3.21%**
Romania	26,633,790	29,824,186	27,866,229	14,060,369	**98,384,574**	**2.93%**
Poland	11,405,353	18,510,877	26,543,856	12,204,011	**68,664,097**	**2.05%**
Japan	20,737,995	20,514,501	20,823,816	6,077,398	**68,153,710**	**2.03%**
Israel	16,893,815	16,480,433	19,332,297	9,783,226	**62,489,772**	**1.86%**
Canada	19,228,501	14,807,217	14,967,226	8,774,094	**57,777,039**	**1.72%**
Belgium	17,456,444	15,430,186	14,641,413	8,813,977	**56,342,020**	**1.68%**
Switzerland	29,439,066	19,363,761	0	0	**48,802,827**	**1.45%**
Russian Federation	8,785,555	8,670,132	9,798,348	5,308,246	**32,562,281**	**0.97%**
Hungary	6,264,448	5,080,946	6,160,119	3,985,542	**21,491,055**	**0.64%**
Slovakia	5,289,045	3,167,558	4,289,416	3,136,104	**15,882,123**	**0.47%**
Estonia	1,734,862	6,438,103	5,122,179	0	**13,295,145**	**0.4%**
Portugal	2,505,408	1,968,640	3,165,774	1,782,578	**9,422,400**	**0.28%**
Austria	2,418,832	2,424,079	1,974,415	253,989	**7,071,315**	**0.21%**
"Korea, Republic of"	1,896,099	1,858,123	1,827,577	1,113,457	**6,695,257**	**0.2%**
Taiwan	2,130,834	1,579,661	1,541,448	816,403	**6,068,346**	**0.18%**
Finland	1,077,754	1,798,804	2,025,431	766,536	**5,668,525**	**0.17%**
Brazil	0	10,225	2,473,977	2,358,949	**4,843,152**	**0.14%**
Ukraine	832,064	692,185	718,099	444,523	**2,686,870**	**0.08%**
Hong Kong SAR	51,568	10,121	0	0	**61,689**	**0%**
Thailand	195	7,313	14,527	5,862	**27,897**	**0%**
Turkey	7,212	0	121	0	**7,333**	**0%**
Total	**827,835,929**	**970,631,967**	**976,502,899**	**582,142,147**	**3,357,112,942**	
Percent	**24.66%**	**28.91%**	**29.09%**	**17.34%**		

Achievements & Metrics in 2025

Tier2 — Sum Wallclock Time (cores * hours) by Country and Quarter (LHC VOs)

Country	Jan 2025 — Mar 2025	Apr 2025 — Jun 2025	Jul 2025 — Sep 2025	Oct 2025 — Dec 2025	Total	Percent
United States	357,596,688	443,971,594	417,457,551	238,366,262	**1,457,392,094**	**32.94%**
United Kingdom	195,779,413	212,194,342	202,821,763	115,235,915	**726,031,434**	**16.41%**
Germany	109,044,449	114,067,009	143,529,972	83,911,002	**450,552,433**	**10.18%**
France	83,520,687	92,009,081	77,581,853	35,746,468	**288,858,088**	**6.53%**
Italy	55,399,425	90,465,941	93,974,575	18,757,740	**258,597,680**	**5.85%**
Czechia	24,496,689	50,403,314	55,303,376	32,884,773	**163,088,152**	**3.69%**
Spain	42,798,310	42,613,619	47,139,955	25,922,205	**158,474,089**	**3.58%**
Romania	37,590,097	41,778,468	39,956,414	21,045,005	**140,369,984**	**3.17%**
Latin America	4,370,270	13,715,358	37,402,259	76,049,403	**131,537,290**	**2.97%**
Poland	15,219,863	23,891,598	33,027,130	14,958,222	**87,096,813**	**1.97%**
Belgium	24,938,352	22,124,056	21,573,343	12,545,803	**81,181,553**	**1.84%**
Japan	21,403,239	20,927,355	21,823,049	6,451,234	**70,604,878**	**1.6%**
Switzerland	41,947,816	28,101,051	0	0	**70,048,867**	**1.58%**
Israel	18,053,378	19,214,721	20,332,303	10,782,061	**68,382,463**	**1.55%**
Canada	19,907,109	15,413,911	15,800,779	9,634,899	**60,756,698**	**1.37%**
Russian Federation	11,042,705	11,605,070	12,579,970	6,867,757	**42,095,501**	**0.95%**
Hungary	9,013,963	7,773,262				
Turkey	5,975,796	6,425,827				
Brazil	5,704,693	7,241,014				
Slovakia	5,932,477	3,857,412				
Estonia	2,046,682	9,272,944				
Portugal	3,930,482	2,918,245				
Taiwan	3,659,052	2,861,398				
"Korea, Republic of"	2,732,917	2,923,323				
Austria	2,645,621	2,639,973				
Finland	1,350,795	2,461,447				
Ukraine	1,208,781	1,176,945				
Hong Kong SAR	53,635	11,362				
Thailand	1,734	17,365				
Total	**1,107,365,116**	**1,292,077,005**	**1,29**			
Percent	**25.03%**	**29.21%**				

Tier2 — CPU Efficiency (%) by Country and Quarter (LHC VOs)

Country	Jan 2025 — Mar 2025	Apr 2025 — Jun 2025	Jul 2025 — Sep 2025	Oct 2025 — Dec 2025	Total
Japan	96.89%	98.03%	95.43%	94.25%	**96.54%**
Hong Kong SAR	96.15%	89.08%	0.33%	0%	**94.77%**
Canada	95.49%	95.14%	93.56%	88.48%	**93.65%**
Latin America	65.57%	91.68%	89.92%	95.23%	**92.62%**
Israel	93.08%	85.05%	94.64%	90.38%	**90.86%**
Austria	91.43%	91.82%	88.63%	92.03%	**90.78%**
France	87.21%	86.02%	87.26%	89.5%	**87.14%**
Slovakia	88.87%	81.85%	85.42%	83.85%	**85.39%**
United Kingdom	76.5%	83.69%	85.72%	84.89%	**82.51%**
Poland	73.78%	78.21%	80.26%	81.14%	**78.85%**
Russian Federation	79.57%	74.9%	77.86%	77%	**77.35%**
Finland	79.79%	73.16%	73.34%	76.12%	**74.8%**
United States	73.05%	72.7%	72.05%	72.94%	**72.64%**
Italy	72.34%	69.97%	74.84%	73.72%	**72.49%**
Estonia	84.76%	69.43%	72.82%	0%	**72.44%**
Germany	66.81%	64.71%	71.89%	85.59%	**72.37%**
Hungary	69.5%	65.36%	74.12%	82.44%	**71.8%**
Portugal	63.74%	67.46%	75%	77.82%	**70.53%**
Switzerland	70.27%	68.99%	0%	0%	**69.79%**
Romania	70.74%	70.21%	69.48%	67.01%	**69.66%**
Belgium	69.76%	69.55%	67.59%	70.23%	**69.2%**
"Korea, Republic of"	69.38%	63.56%	71.04%	72.75%	**68.6%**
Ukraine	68.83%	58.81%	63.41%	70.87%	**64.81%**
Czechia	76.48%	67.33%	53.34%	52.66%	**60.69%**
Spain	60.25%	70.02%	54.23%	59%	**59.37%**
Taiwan	54.31%	51.74%	62.02%	45.67%	**53.92%**
Thailand	11.27%	42.11%	49.84%	37.06%	**43.54%**
Brazil	0%	0.14%	33.04%	63.1%	**20.04%**
Turkey	0.12%	0%	0%	0%	**0.03%**
Total	**74.33%**	**74.62%**	**74.69%**	**76.77%**	**74.96%**

Achievements & Metrics in 2025

Availability & Reliability

Site	Availability	Reliability
ISS	98.60%	98.60%
NIHAM	99.88%	99.88%
NIPNE	95.23%	95.59%
UPB	97.43%	98.39%

Site	Availability	Reliability
RO-07-NIPNE	84.29%	84.52%
RO-14-ITIM	96.31%	96.31%
RO-16-UAIC	95.52%	95.52%

Site	Availability	Reliability
LCG.NIPNE-07.ro	86.44%	86.81%

Collaboration & Impact

International & National Collaboration

- **Integration with WLCG:**
  RO-LCG Federation fully embedded in the Worldwide LHC Computing Grid, supporting ALICE, ATLAS, and LHCb.
- **Partnerships:**
  Active collaboration with CERN, NGI_RO Operations Centre, and Romanian NREN (RoEduNet/ARNIEC) for networking and security.
  Engagement with major IT industry partners (Cisco, Dell, NVIDIA, Lenovo, HPE, Oracle, Supermicro).
- **Educational Outreach:**
  - Courses at Technical University of Cluj Napoca (Grid & Cloud computing).
  - Outreach in high schools (Cluj, Magurele, Bucharest).
  - Events: Researchers' Night (Magurele, Bucharest), student program "Different School: Know more, be better!".
  - UPB teaching >100 Master students annually in parallel/distributed systems and Grid security.

Visibility & Impact

- Strengthened Romania's role in HL-LHC computing strategy.
- Dissemination through workshops, CERN collaborations, peer-reviewed publications, and technical reports.
- Enhanced national and international recognition of Romanian contributions to large-scale scientific computing.

Challenges & Solutions

Key Challenges

- **Infrastructure Bottlenecks**
  - Growing data volumes from Run 3 and HL-LHC preparations
  - Need for scalable storage and compute resources
- **Middleware & Technology Updates**
  - Continuous upgrades (EOS, QuarkDB, JAliEn, OS migrations) require stability and compatibility
  - Transition to IPv6 and containerized deployments
- **Resource & Financial Constraints**
  - Balancing pledged capacity with available funding
  - Procurement delays and cost optimization needs
- **Human Resources**
  - Recruitment and retention of skilled specialists
  - Avoiding fragmentation across sites and teams
- **Visibility & Outreach**
  - Ensuring Romania's contributions are recognized internationally
  - Expanding training and dissemination activities

Solutions Implemented

- **Infrastructure Scaling**
  - Expanded disk storage to ~19 PB for ALICE (Tier-2 leader)
  - Delivered 135M CPU hours (6th globally among Tier-2s)
  - Upgrading network links (IFIN-HH will upgrade until end of the year the backup link to RoEduNet from 10 Gbps to 100 Gbps)
- **Technology Integration**
  - EOS upgraded with QuarkDB synchronization for faster, stable storage
  - TTL-based adaptive scheduling algorithms deployed in JAliEn
  - IPv6 support and OpenStack 2025.1 virtualization upgrades
- **Resource Optimization**
  - Collaboration via Steering Committee for efficient procurement and cost control
  - Benchmarking with HEPScore to align with WLCG standards
- **Human Capacity Building**
  - Training programs at universities (Cluj, UPB) and outreach in schools
  - 100 Master students annually exposed to Grid/Cloud technologies
- **Visibility Enhancement**
  - Active participation in CERN workshops, WLCG meetings, and international collaborations
  - Outreach events (Researchers' Night, "Different School") and industry partnerships (Cisco, Dell, NVIDIA, Lenovo, HPE)

Future Outlook - Expected Outcomes for 2026

- Stable and optimized operation of the RO-LCG infrastructure at or above pledged capacity levels.
- Successful commissioning and benchmarking of new resources.
- Enhanced software tools and technology adoption for ALICE and related VOs.
- Increased international visibility through scientific publications and presentations.
- Continued training and capacity development of technical personnel.
- Full compliance with the WLCG MoU and 2026 SLA commitments.

Acknowledgments

Evaluation & Guidance

- Annual review by the **International Scientific Advisory Board**
- Ensures scientific excellence and alignment with WLCG strategy

Institutional Support

Backed by Romanian national institutions:

- **IFIN-HH** (National Institute for Physics and Nuclear Engineering - Magurele)
- **ISS** (Institute of Space Science - Magurele)
- **ITIM** (Institute of Isotopic and Molecular Technologies – Cluj Napoca)
- **UAIC** (Alexandru Ioan Cuza University - Iasi)
- **UPB** (University Politehnica of Bucharest)

Funding & Infrastructure

- Financed by the **National Research Authority** through **IFA** (Institute of Atomic Physics) Măgurele
- High-speed network connectivity provided by **RoEduNet** (Romanian Education Network)