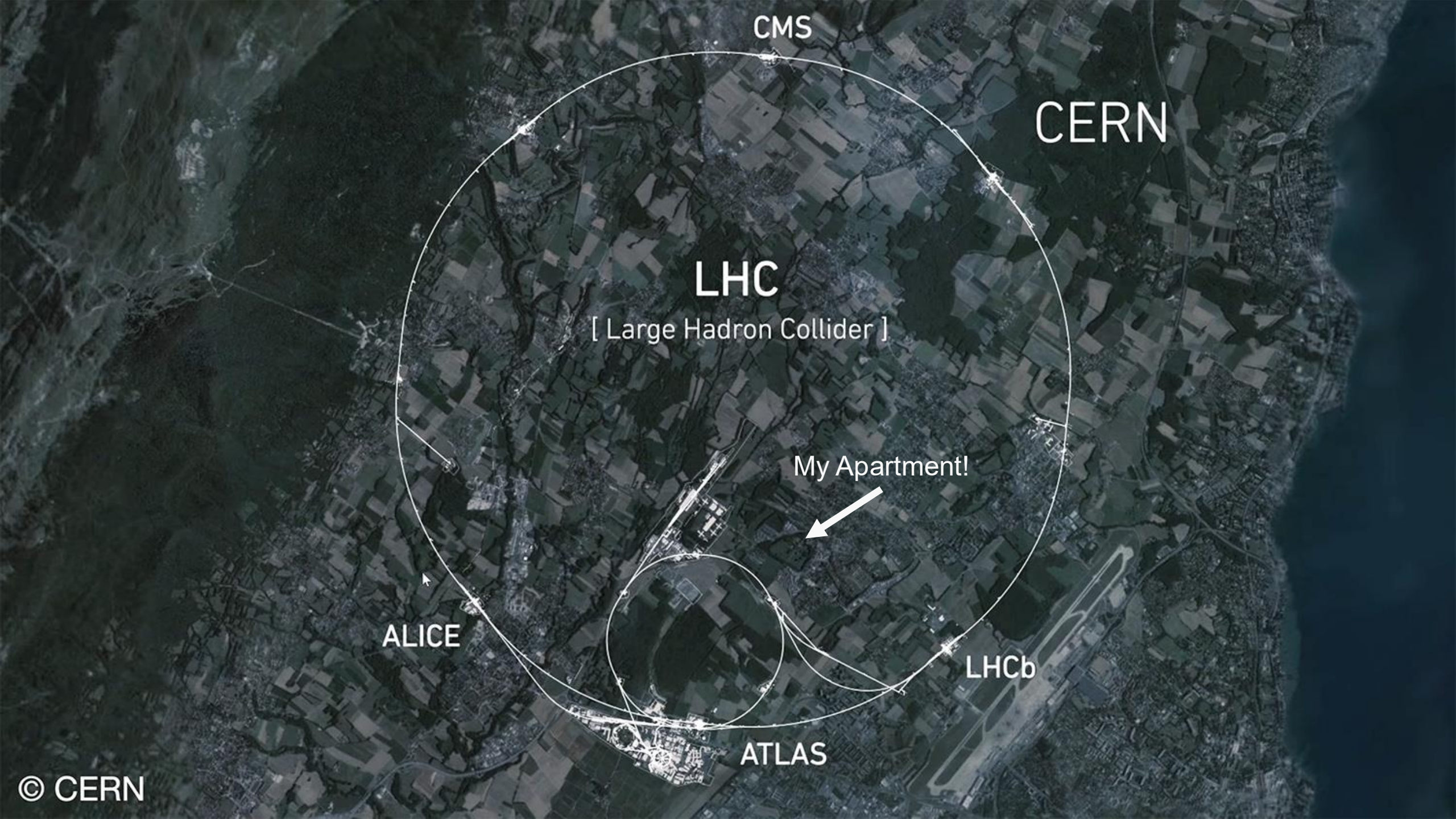


An aerial, high-angle view of a vast data center. The image shows a dense grid of server racks, each with multiple horizontal slots. The racks are arranged in long, parallel rows that stretch far into the distance, creating a strong sense of perspective. The lighting is bright and even, highlighting the metallic surfaces and the organized layout of the facility. The overall color palette is a mix of light grays and off-whites, emphasizing the industrial and technological nature of the environment.

Scientific Data Management at CERN

Luis Antonio Obis Aparicio
19/12/2025



CMS

CERN

LHC

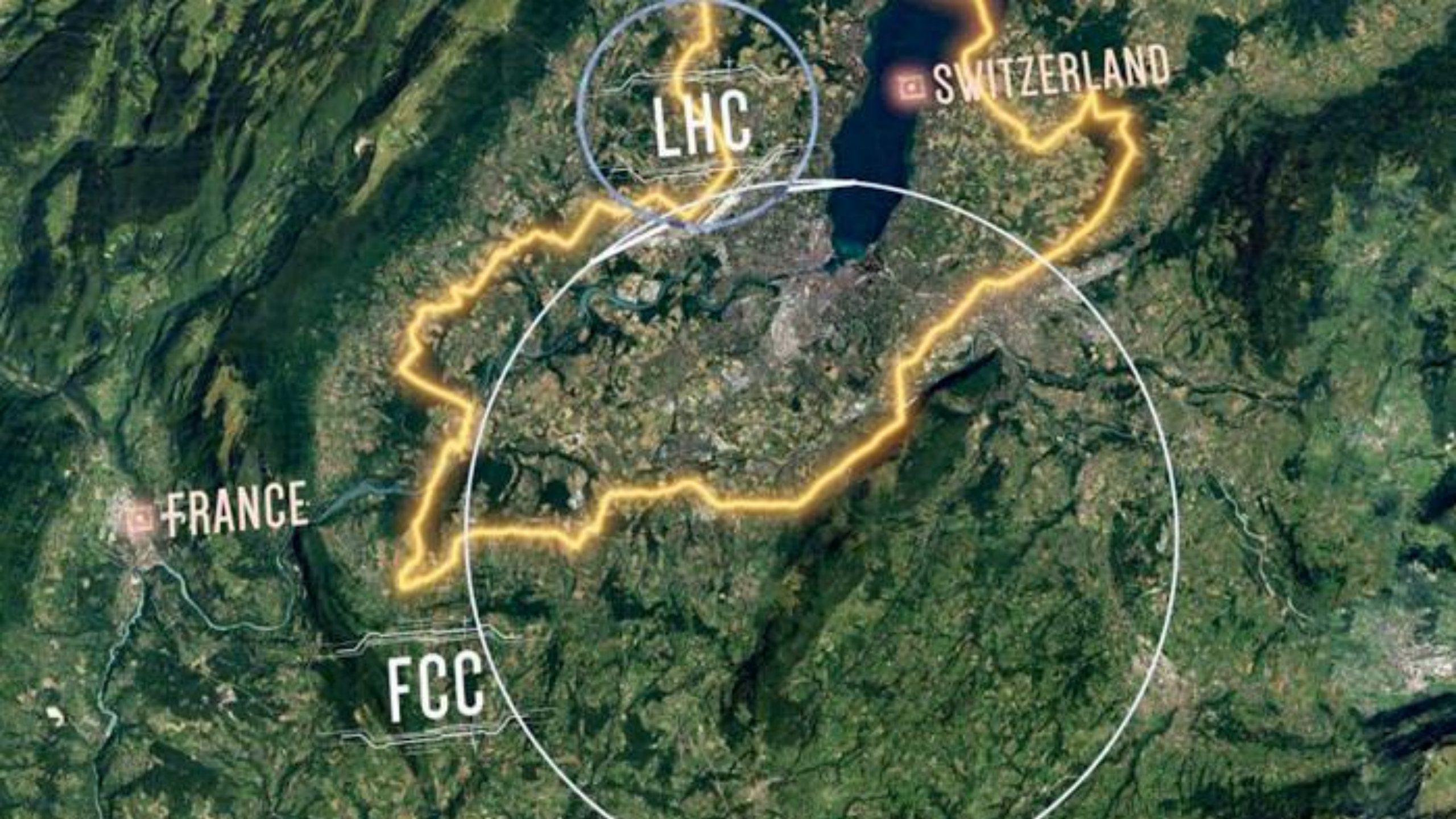
[Large Hadron Collider]

My Apartment!

ALICE

LHCb

ATLAS



LHC

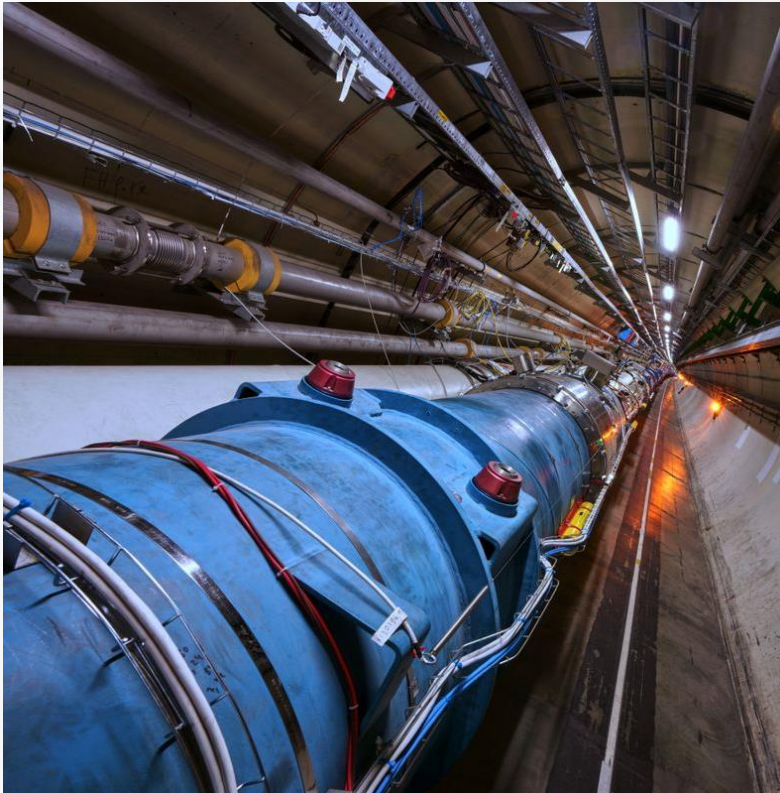
SWITZERLAND

FRANCE

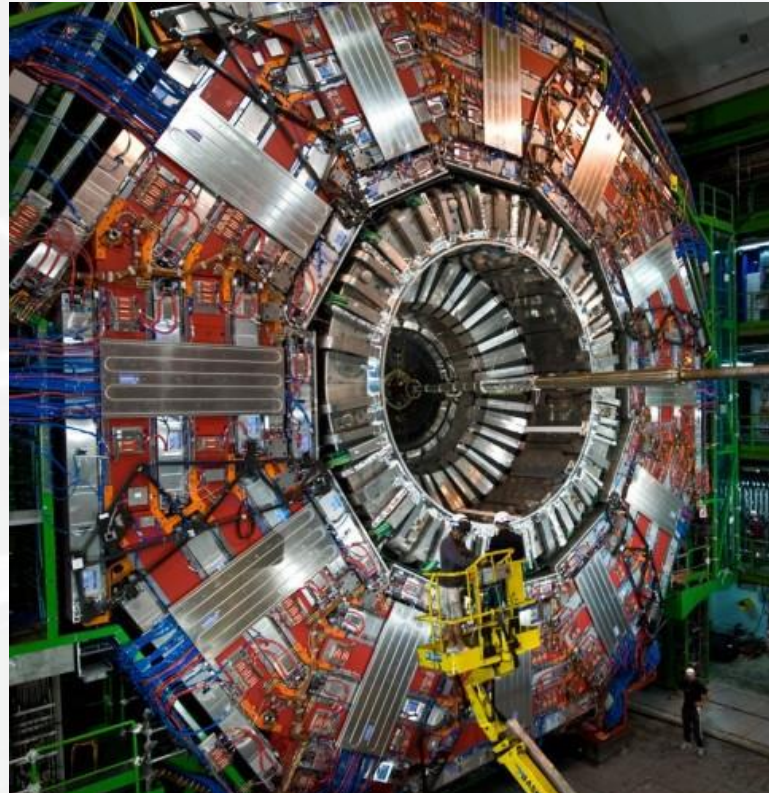
FCC

CERN Technologies

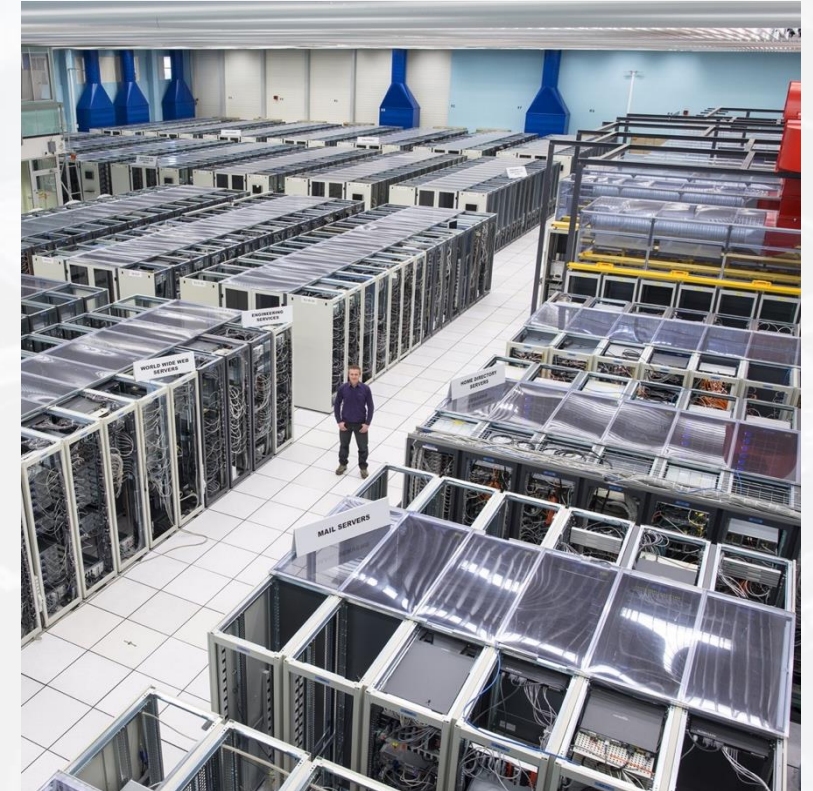
Accelerators



Detectors



Computing



Computational Resources

Meyrin Data Center (CERN):

- Built in **1972**.
- Approx. **450k processor cores**, **10k servers**, **200k disks (HDD)**.
- 90% of resources managed via **OpenStack**.



Computational Resources

Prevezin Data Center (CERN):

- Recently Built.
- In commissioning.
- Mostly used for **compute**.



Computational Resources

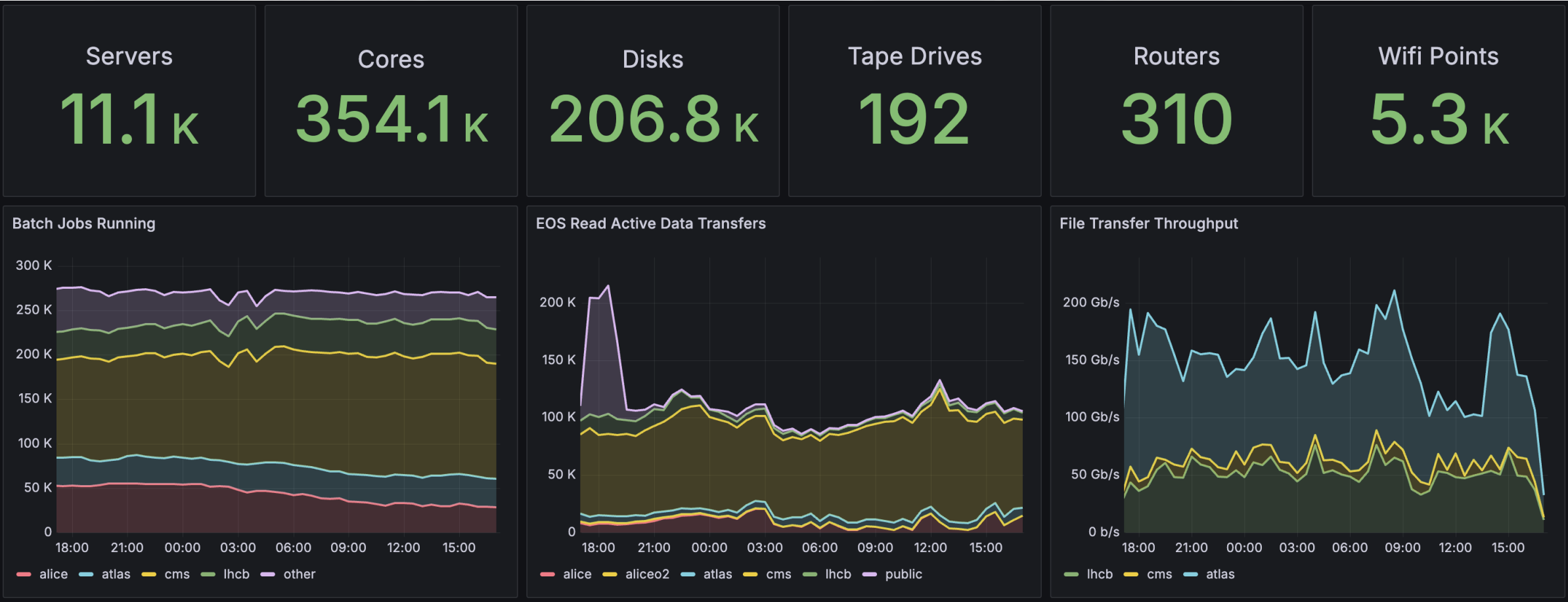
WLCG: Worldwide LHC Computing Grid

- More than 170 computing centers in 42 countries.
- 1.4 Million cores, 1500 Petabytes stored worldwide.
- Tier 0: Meyrin / Preveessin DC.
- Tier 1: 13 academic institutions in Europe, Asia and America.
- Tier 2: More than 150 institutions.



Computational Resources

<https://monit-grafana.cern.ch/d/000000473/it-overview?orgId=1>



CERN Data Storage

LHC Data Production (simplified):

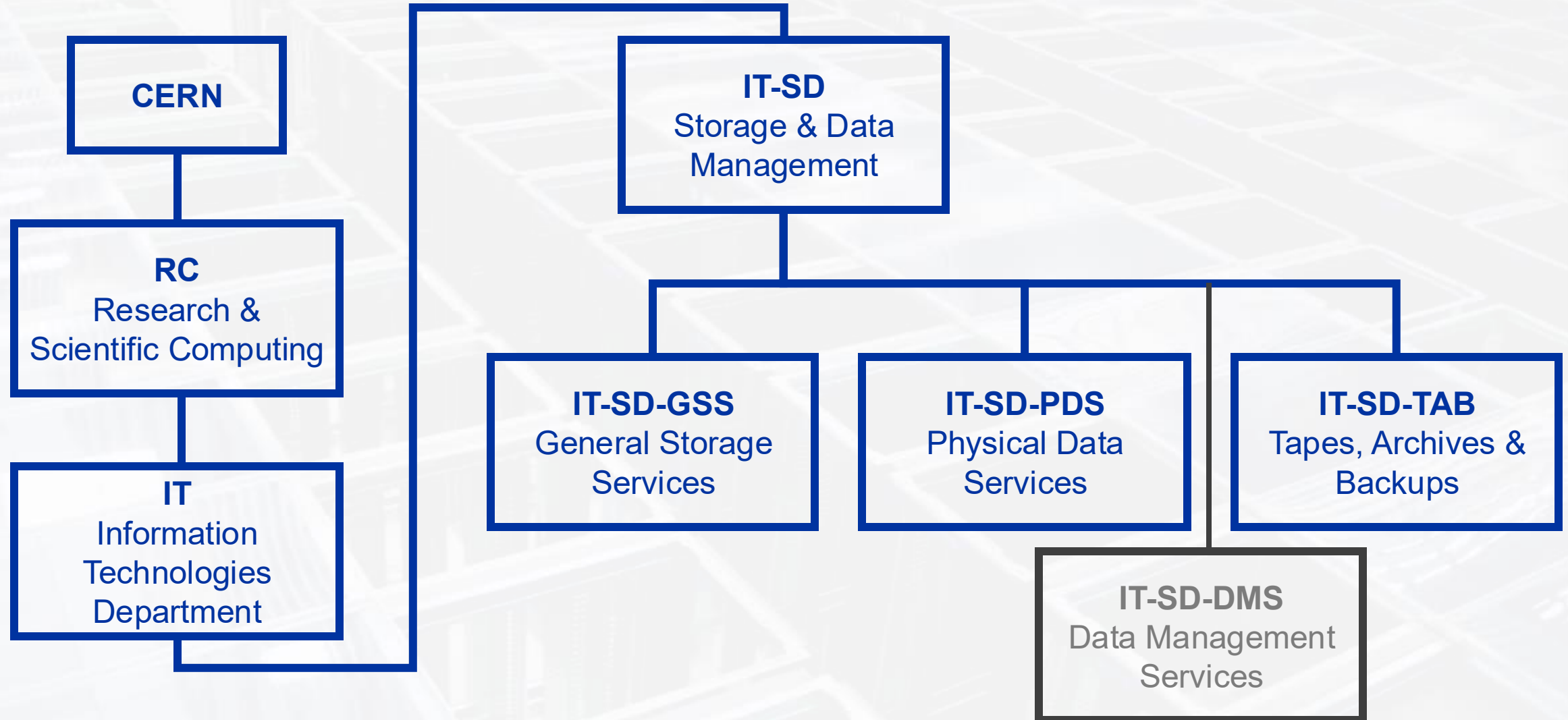
- **~40 MHz** collision rate.
- **~1 PB/s** of raw data rate if all data was captured.
- Level 1 trigger (L1) reduces rate to **~100 kHz**.
- High level trigger (HLT) reduces rate to **~1-3 kHz**.
- Average ingest rate of **~30 GB/s** to the tier 0 data center.

The CERN Storage and Data Management Group

Manage and develop all storage and data management services

- Data services for large LHC experiments and small and medium experiments (SME).
- General purpose data storage for the organization (CERNBox, etc.)
- Archival services (tape) for physics data and the backup service.
- Multiple storage technologies using **disk** and **tape**.

The CERN Storage and Data Management Group

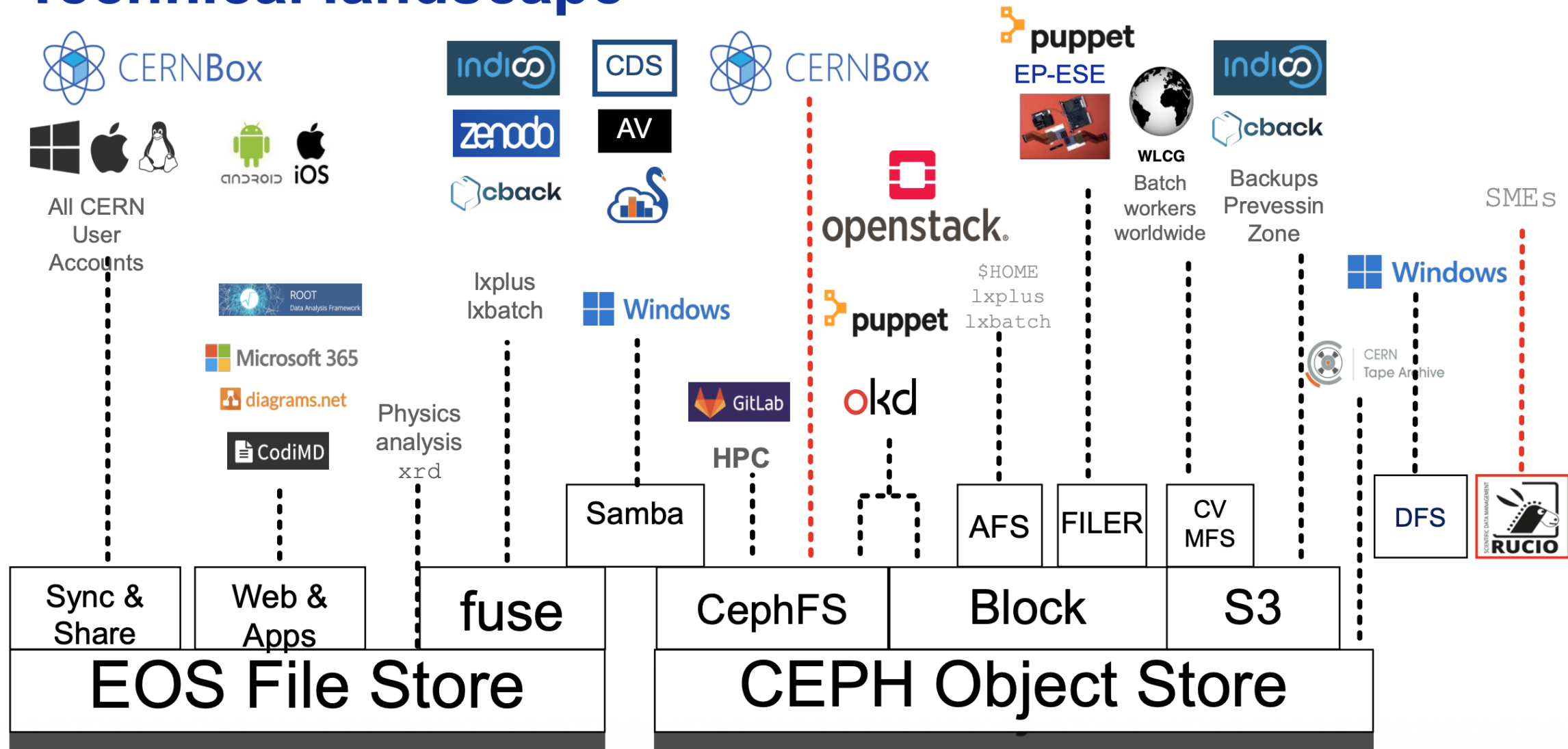


IT-SD-GSS General Storage Services

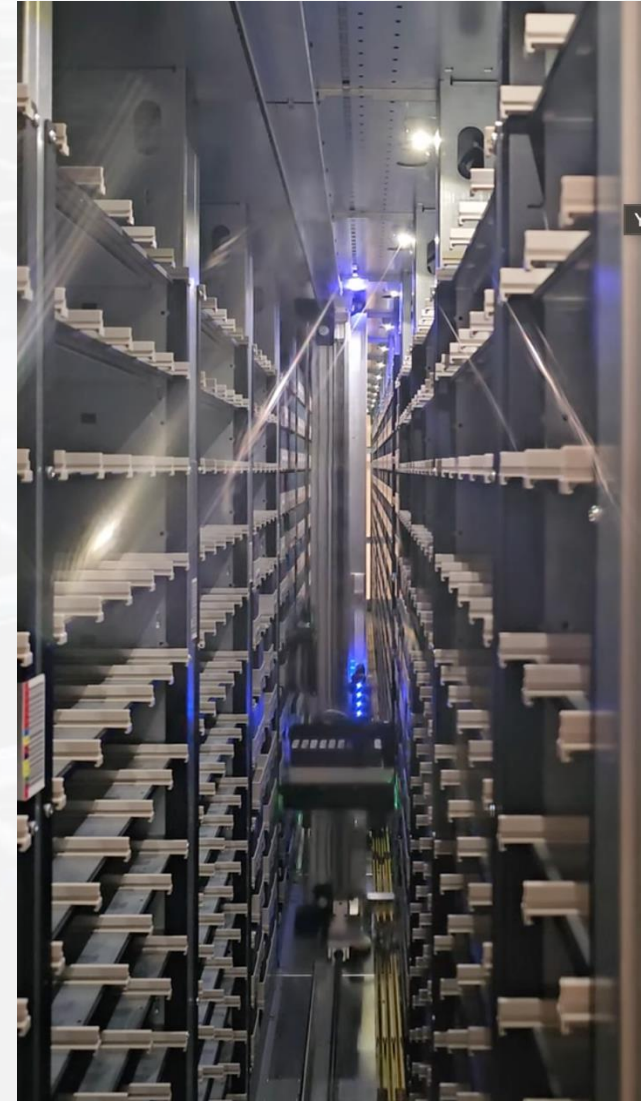


IT-SD-GSS General Storage Services

Technical Landscape

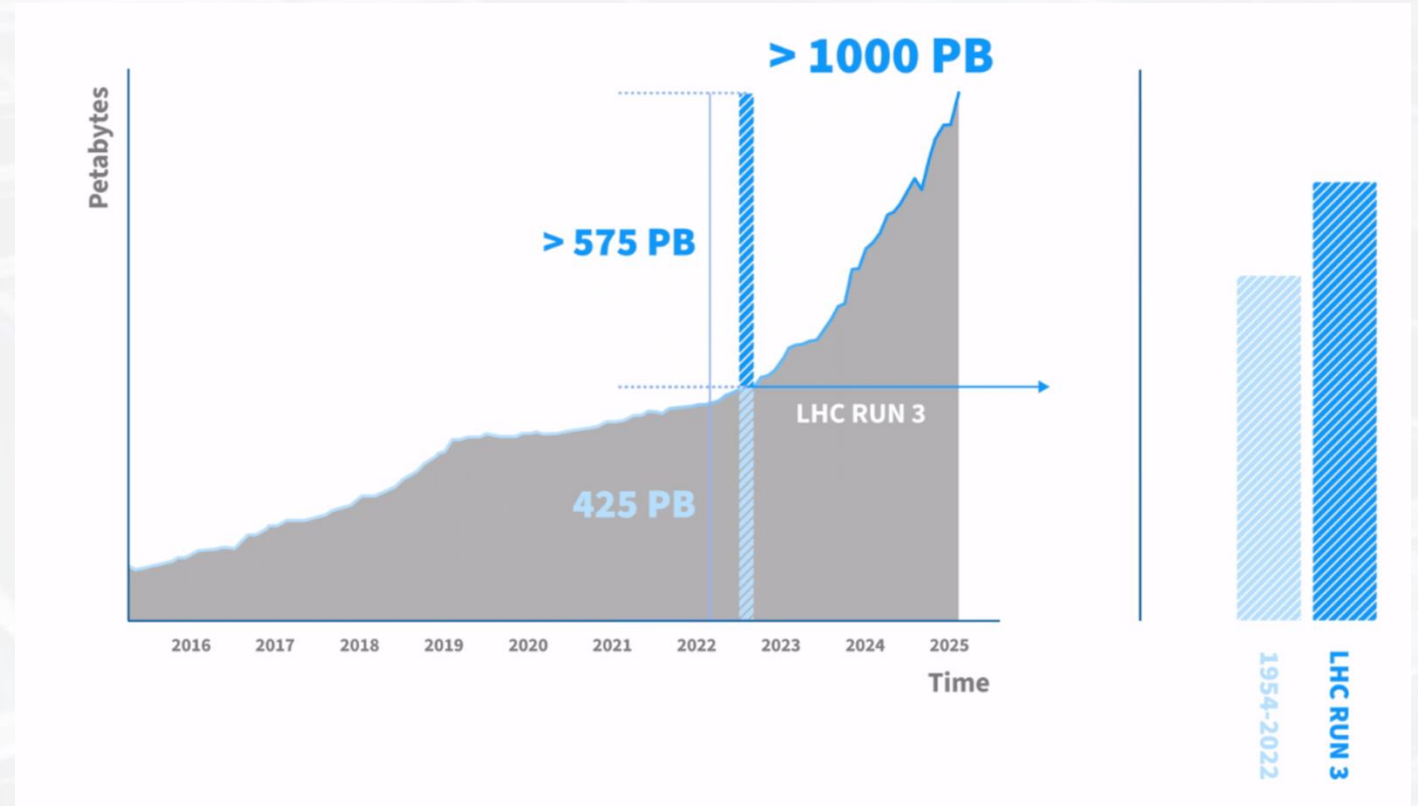


CTA: CERN Tape Archive



CTA: CERN Tape Archive

- Big milestone recently: 1 Exabyte of data on tape!
- In the next 3 years: store one exabyte per year!
- Some interesting blog [posts](#) / [videos](#)



Distributed file systems: EOS



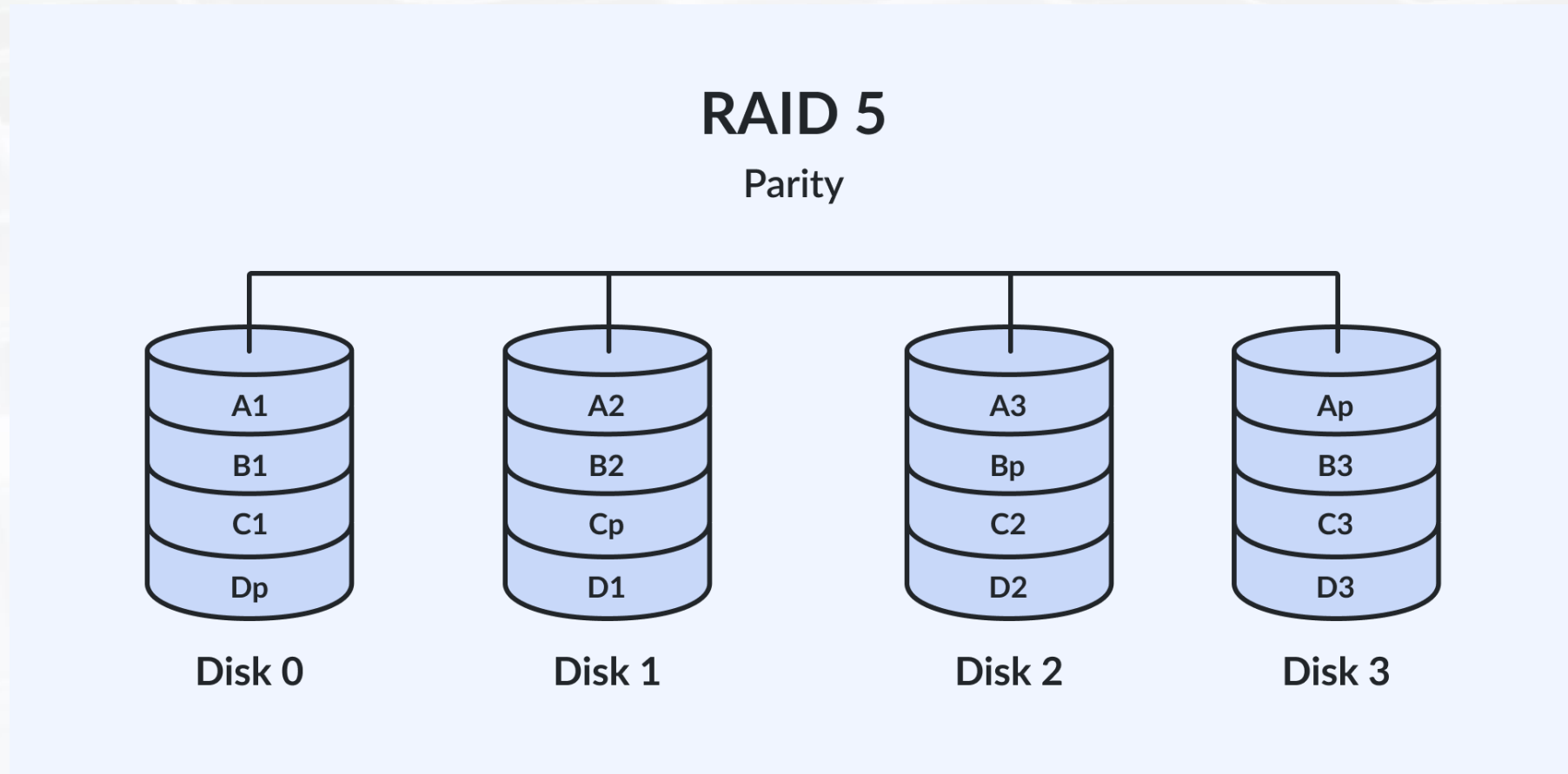
Distributed file systems: EOS

- The problem: Store ~1PB of data.
- The solution: buy a few of these!



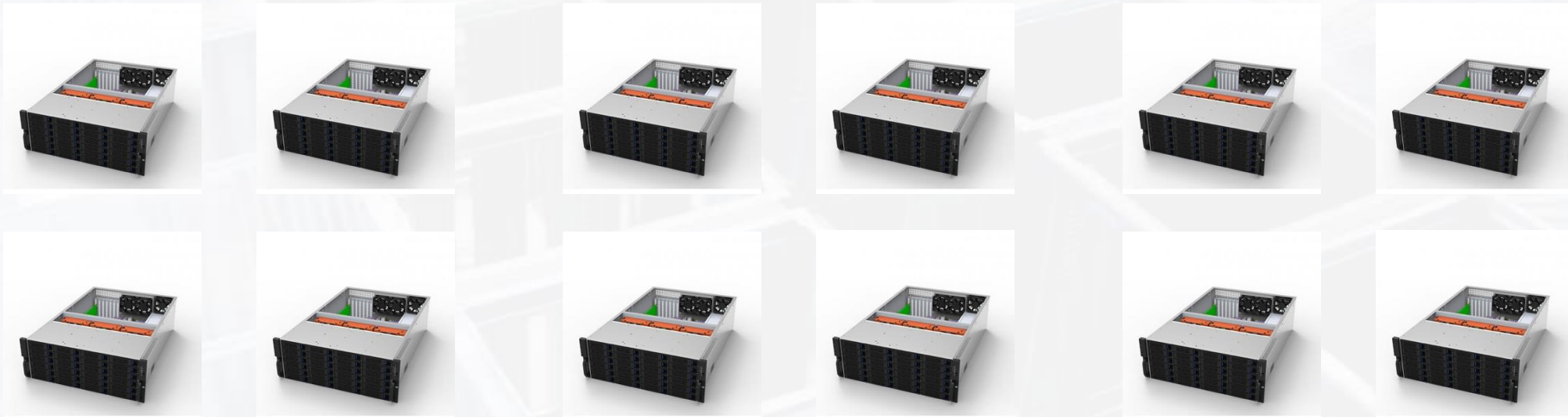
Distributed file systems: EOS

- RAID: Redundant array of inexpensive disks



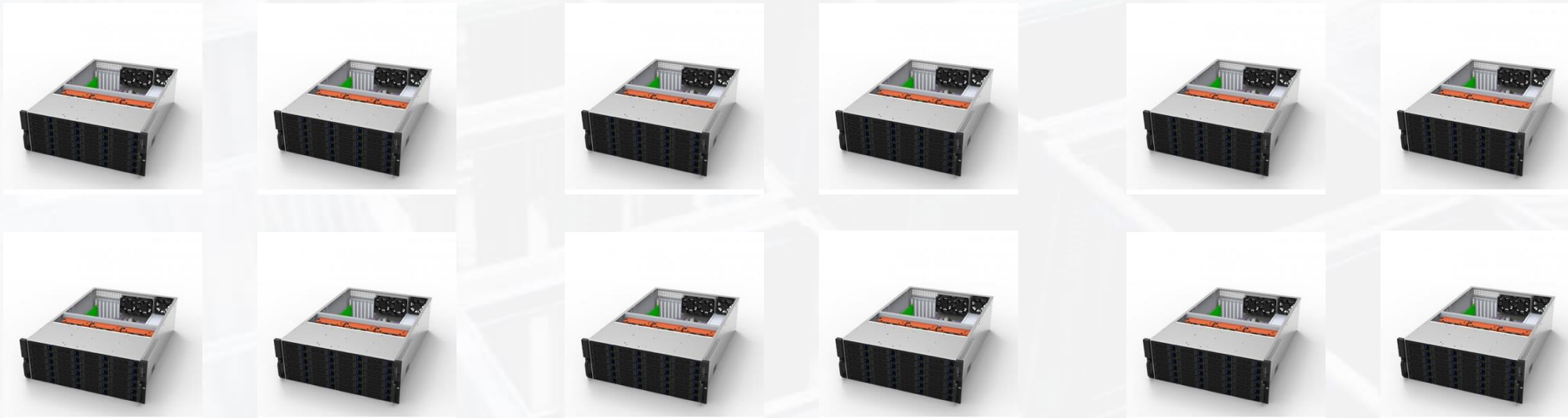
Distributed file systems: EOS

- New problem: Store $\sim 1\text{EB}$ of data.
- Solution: Buy 1000s of these but it gets more complicated...



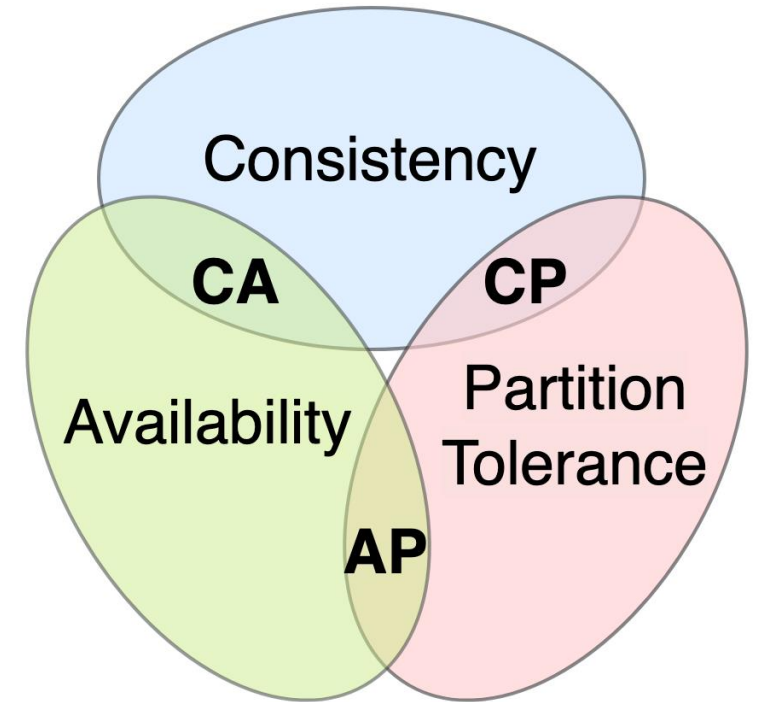
Distributed file systems: EOS

- New problems appear how to distribute files, how to sync the servers, how to optimize for read/write performance...

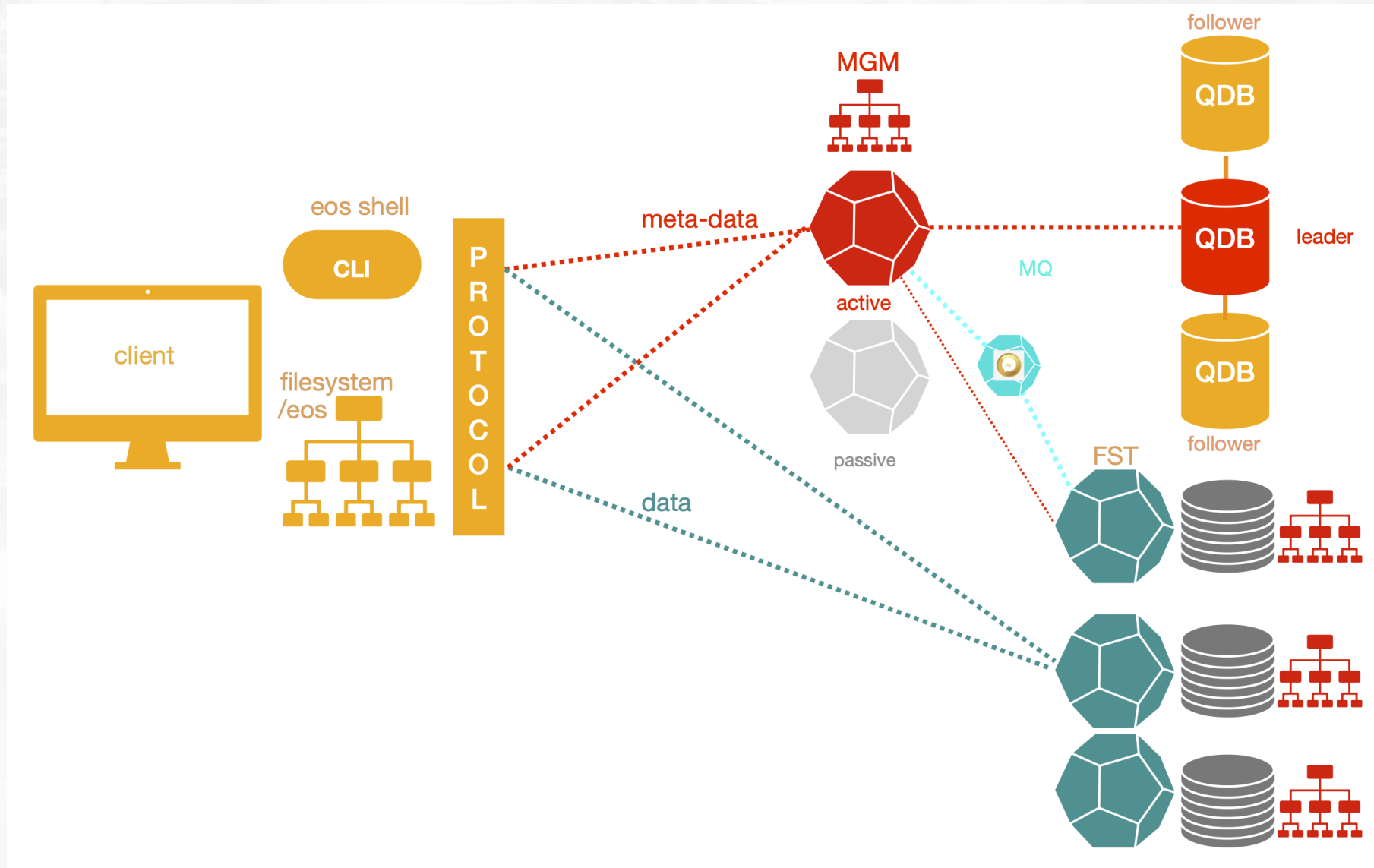


Distributed file systems: EOS

- **CAP** Theorem: can only pick two.
- Any distributed system must guarantee partition tolerance (**P**).
- AP example: DNS
- CP is what we need for our distributed storage systems



Distributed file systems: EOS



Data Management with Rucio

- Rucio is an open-source data management software used by many in the HEP community including ATLAS and CMS experiments.
- Provides an abstraction over all files and datasets.
- Used to configure data policies: which files go where, how many copies, etc. via rules



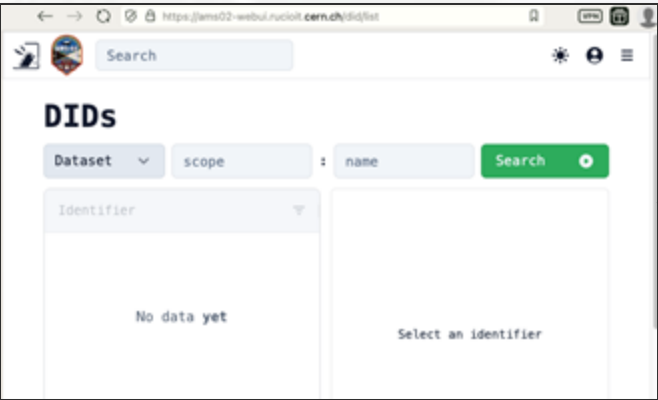
Data Management with Rucio



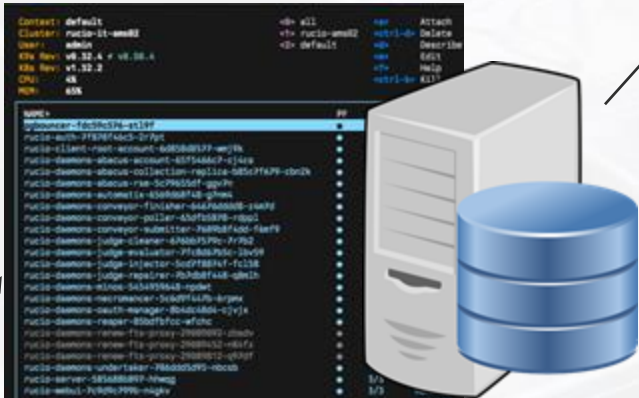
Data Management with Rucio



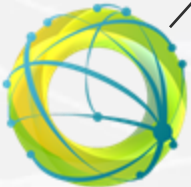
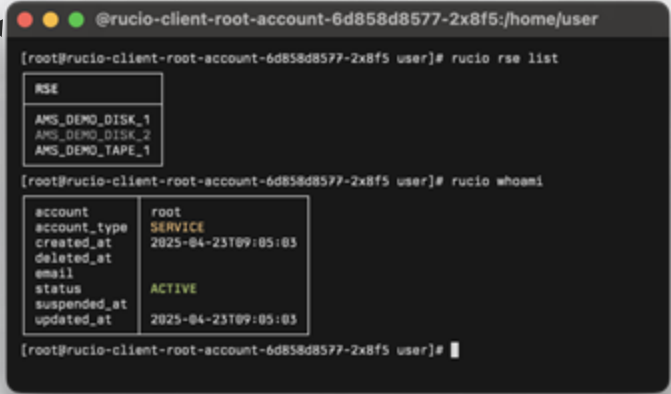
Rucio WebUI
<https://ams02-webui.rucioit.cern.ch>



Rucio Server
<https://ams02-server.rucioit.cern.ch>



Rucio CLI



eosams02.cern.ch
/eos/ams/MC/AMS02/...

fts3-public.cern.ch
amsmc service account



CERN
Tape Archive

eosctapublic.cern.ch
/eos/ctapublic/archive/ams/group

Data Management with Rucio

- My work during 2025: **Rucio as a service for SMEs.**
- The problem: setting up Rucio is very complex, not worth it for small and medium experiments.
- There is significant overlap between Rucio deployments: work towards creating reusable components with low operational overhead.

Data Management with Rucio

- Rucio for SMEs is **confirmed to become a CERN production service** in 2026 for CERN SMEs.
- Some of our users: AMS, SHIP, NA62, ...
- Technologies used: Kubernetes, Argo-CD, ...
- Isolated deployments: one DB, one cluster per client

Data Management with Rucio

Context: default [RW]

Cluster: rucio-it-ams02

User: admin

K9s Rev: v0.50.12

K8s Rev: v1.32.2

CPU: 3%

MEM: 56%

<0> all

<1> external-dns

<2> monitoring

<3> kube-system

<4> rucio-ams02

<5> default

<a> Attach

<ctrl-d> Delete

<d> Describe

<e> Edit

<?> Help

<shift-j> Jump Owner

<ctrl-k> Kill

<l> Logs

<p> Logs Previous

<shift-f> Port-Forward

<z> Sanitize

<s> Shell

<o> Show Node

<f> Show PortForward

<t> Transfer

<y> YAML



NAME↑

PF

READY

STATUS

RESTARTS

CPU

%CPU/R

%CPU/L

MEM

%MEM/R

%MEM/L

IP

NODE

AGE

pgbouncer-7b5449f49f-7gmc8

●

1/1

Running

0

18

7

3

11

9

4

10.100.5.181

rucio-it-ams02-c5743kni6ch6-node-3

23d

redis-6c556f5b94-t66l4

●

1/1

Running

1

6

n/a

n/a

10

n/a

n/a

10.100.6.157

rucio-it-ams02-c5743kni6ch6-node-5

48d

rucio-auth-7488cc67d9-cz7wm

●

3/3

Running

0

3

0

0

690

31

15

10.100.5.231

rucio-it-ams02-c5743kni6ch6-node-3

22d

rucio-client-root-account-779c78ddcb-9sqs9

●

1/1

Running

0

1

n/a

n/a

9

n/a

n/a

10.100.8.73

rucio-it-ams02-c5743kni6ch6-node-6

22d

rucio-daemons-abacus-account-f86c588f4-vfpks

●

1/1

Running

0

2

0

0

86

86

34

10.100.2.48

rucio-it-ams02-c5743kni6ch6-node-1

34m

rucio-daemons-abacus-rse-57898c46f8-sb28c

●

1/1

Running

0

1

0

0

86

43

17

10.100.6.16

rucio-it-ams02-c5743kni6ch6-node-5

34m

rucio-daemons-automatix-5bc7d5d755-fg6fq

●

1/1

Running

9

1

0

0

88

35

17

10.100.6.110

rucio-it-ams02-c5743kni6ch6-node-5

21d

rucio-daemons-conveyor-finisher-84fc96dfbf-vln2r

●

1/1

Running

0

11

1

0

167

33

8

10.100.4.109

rucio-it-ams02-c5743kni6ch6-node-0

34m

rucio-daemons-conveyor-poller-74dbf95947-gzgzv

●

1/1

Running

0

1

0

0

110

44

5

10.100.2.224

rucio-it-ams02-c5743kni6ch6-node-1

34m

rucio-daemons-conveyor-submitter-568666fd4f-7jqs2

●

1/1

Running

0

1

0

0

116

46

11

10.100.8.114

rucio-it-ams02-c5743kni6ch6-node-6

34m

rucio-daemons-judge-cleaner-58fdf9f5f-7wgkm

●

1/1

Running

0

1

0

0

110

22

2

10.100.6.188

rucio-it-ams02-c5743kni6ch6-node-5

34m

rucio-daemons-judge-evaluator-65b798c494-j5kkv

●

1/1

Running

4

2

0

0

2459

61

40

10.100.8.174

rucio-it-ams02-c5743kni6ch6-node-6

20d

rucio-daemons-judge-injector-f6bf85d4c-mg4zd

●

1/1

Running

4

1

0

0

116

5

2

10.100.2.33

rucio-it-ams02-c5743kni6ch6-node-1

21d

rucio-daemons-judge-repairer-74dbc5c58c-p67kx

●

1/1

Running

3

304

60

15

245

12

4

10.100.5.5

rucio-it-ams02-c5743kni6ch6-node-3

20d

rucio-daemons-minos-7844696d5d-wkhlp

●

1/1

Running

0

1

0

0

109

109

43

10.100.1.215

rucio-it-ams02-c5743kni6ch6-node-2

34m

rucio-daemons-necromancer-96989b58f-jtd8c

●

1/1

Running

0

1

0

0

109

109

36

10.100.1.246

rucio-it-ams02-c5743kni6ch6-node-2

34m

rucio-daemons-oauth-manager-5974764bfb-fxcmf

●

1/1

Running

6

1

0

0

101

202

50

10.100.6.129

rucio-it-ams02-c5743kni6ch6-node-5

21d

rucio-daemons-renew-fts-proxy-29312652-qgcdc

●

0/1

Completed

0

0

0

0

0

0

0

10.100.6.196

rucio-it-ams02-c5743kni6ch6-node-5

12h

rucio-daemons-renew-fts-proxy-29313012-n62gp

●

0/1

Completed

0

0

0

0

0

0

0

10.100.4.222

rucio-it-ams02-c5743kni6ch6-node-0

6h35m

rucio-daemons-renew-fts-proxy-29313372-2grbd

●

0/1

Completed

0

0

0

0

0

0

0

10.100.6.251

rucio-it-ams02-c5743kni6ch6-node-5

35m

rucio-daemons-undertaker-646ddd7749-fpgv7

●

1/1

Running

5

1

0

0

111

222

55

10.100.1.83

rucio-it-ams02-c5743kni6ch6-node-2

21d

rucio-database-summary-29296800-hswcw

●

0/1

Completed

0

0

n/a

n/a

0

n/a

n/a

10.100.2.83

rucio-it-ams02-c5743kni6ch6-node-1

11d

rucio-database-summary-29306800-sskl9

●

0/1

Completed

0

0

n/a

n/a

0

n/a

n/a

10.100.4.163

rucio-it-ams02-c5743kni6ch6-node-0

4d12h

rucio-it-register-dumps-29312640-qgdwc

●

0/1

Completed

0

0

n/a

n/a

0

n/a

n/a

10.100.6.153

rucio-it-ams02-c5743kni6ch6-node-5

12h

rucio-psql-database-cleanup-29313400-dp67v

●

0/1

Completed

0

0

n/a

n/a

0

n/a

n/a

10.100.4.190

rucio-it-ams02-c5743kni6ch6-node-0

7m10s

rucio-server-74857f9b9c-56xhj

●

3/3

Running

0

4

0

0

770

34

16

10.100.2.234

rucio-it-ams02-c5743kni6ch6-node-1

6d1h

rucio-server-74857f9b9c-bcbmp

●

3/3

Running

0

3

0

0

754

34

16

10.100.1.210

rucio-it-ams02-c5743kni6ch6-node-2

6d1h

rucio-server-74857f9b9c-gzmfz

●

3/3

Running

0

4

0

0

731

32

16

10.100.6.4

rucio-it-ams02-c5743kni6ch6-node-5

6d1h

rucio-server-74857f9b9c-lwwgw

●

3/3

Running

0

3

0

0

741

33

16

10.100.5.190

rucio-it-ams02-c5743kni6ch6-node-3

6d1h

rucio-server-74857f9b9c-vlw7l

●

3/3

Running

0

4

0

0

770

34

16

10.100.8.242

rucio-it-ams02-c5743kni6ch6-node-6

6d1h

rucio-tools-register-redis-95c64fc94-nt2bv

●

1/1

Running

0

2

n/a

n/a

32

n/a

n/a

10.100.6.109

rucio-it-ams02-c5743kni6ch6-node-5

22d

rucio-ui-5d755f7646-vjzbr

●

2/2

Running

0

1

n/a

n/a

503

n/a

n/a

10.100.6.249

rucio-it-ams02-c5743kni6ch6-node-5

22d

rucio-webui-7448c5f8bf-4sshv

●

3/3

Running

0

1

n/a

n/a

131

n/a

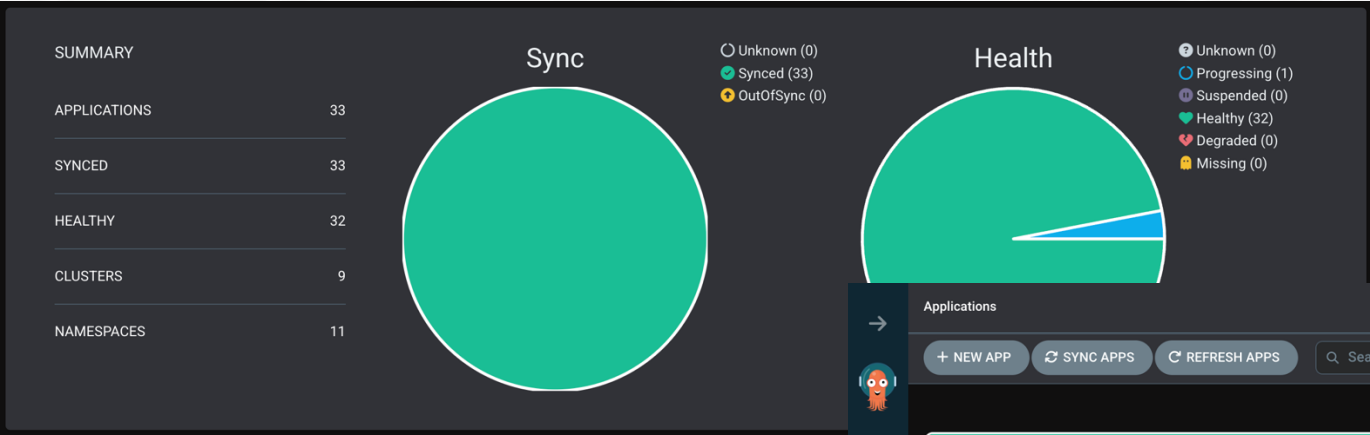
n/a

10.100.6.100

rucio-it-ams02-c5743kni6ch6-node-5

9d

Data Management with Rucio



Applications

+ NEW APP

SYNC APPS

REFRESH APPS

Search applications...

Sort: name ▼ Items per page: all ▼

☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/argo-cd/applications	master	♥ Healthy	⋮
	Name:	applications	Destination:	in-cluster/argocd		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/argo-cd/arg...	master app=argocd argocd.argopr	♥ Healthy	⋮
	Name:	argocd	Destination:	in-cluster/argocd		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-in-cluster	Destination:	in-cluster/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-ams02	Destination:	rucio-it-ams02/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-eosc	Destination:	rucio-it-eosc/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-fcc	Destination:	rucio-it-fcc/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-na62	Destination:	rucio-it-na62/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-ntof	Destination:	rucio-it-ntof/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮
	Name:	external-dns-rucio-it-opendata-dev	Destination:	rucio-it-opendata-dev/external-dns		✓ Synced	
☆	Project:	default	Source:	https://gitlab.cern.ch/rucio-it/rucio-k8s.git/external-dns	master app=external-dns	♥ Healthy	⋮

Data Management with Rucio

- How does it work from an experiment point of view?
- Experiment registers files using our tools or uses our automatic registration service from filesystem dumps.
- Files are tagged with metadata based on location, filename, etc. and match against existing replication rules.
- Files are transferred following rules: moved to tape, from DAQ to EOS, etc.
- A Rucio Web interface is provided to have an overview of the data.

The End!

- Thank you very much for your attention!