OSCARS
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Funded Project

XRootD and FTS in the MADDEN Multi-RI Data Lake

Principal Investigator: Federica Legger, INFN Torino
Project team members: N. Avdeev (INFN Torino), M. Jansson (UCLouvain), L. Lavezzi (INFN Torino), A. Tanasijczuk (UCLouvain)

XRootD and FTS Workshop
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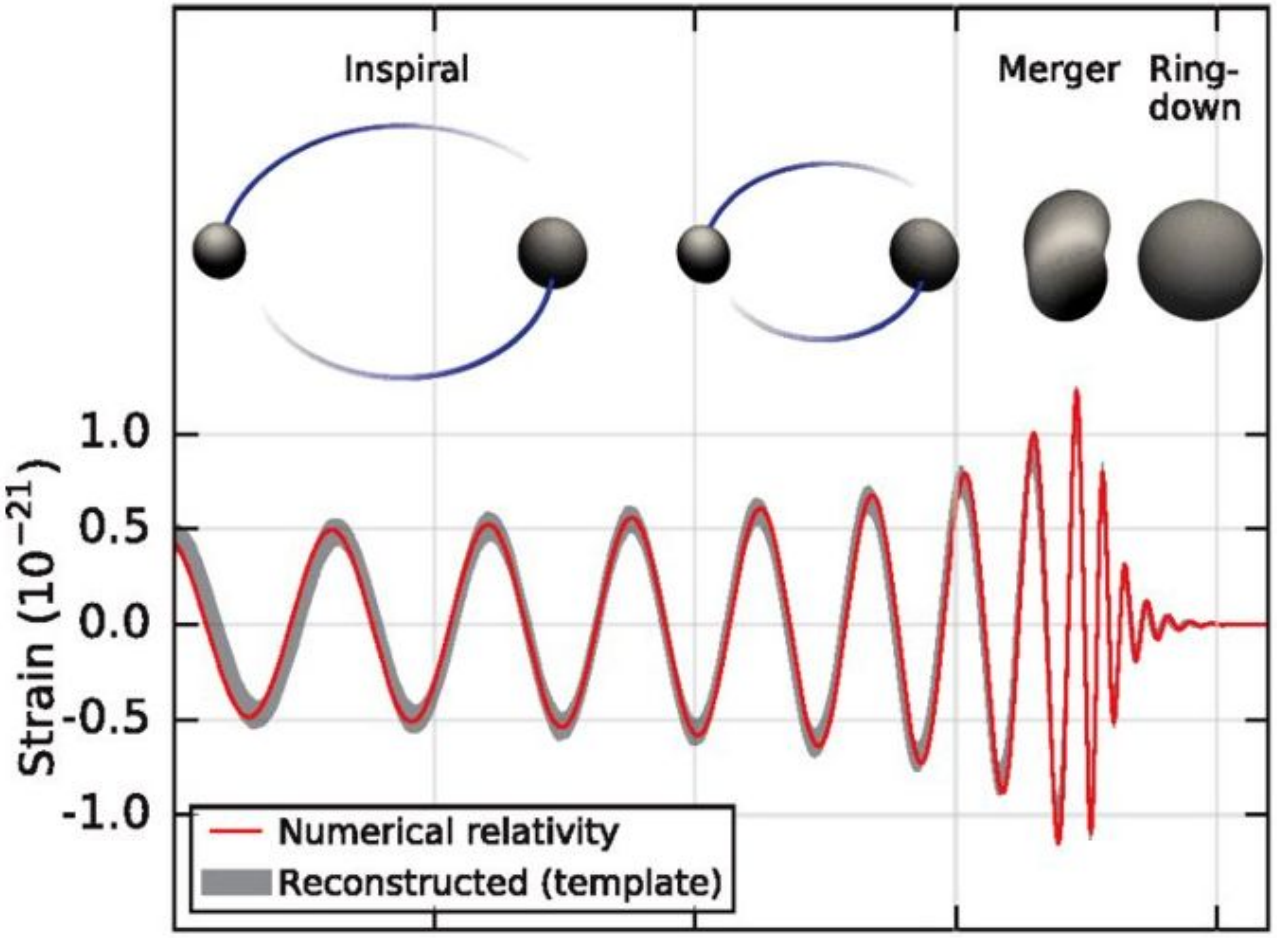
CNRS Delegation Rhône-Auvergne

Funded by the European Union

GW community



- Gravitational waves - "ripples" in the fabric of space and time, created by acceleration of massive cosmic objects (like black holes)
- Predicted by A. Einstein in 1916; detected by Ligo and Virgo in 2015

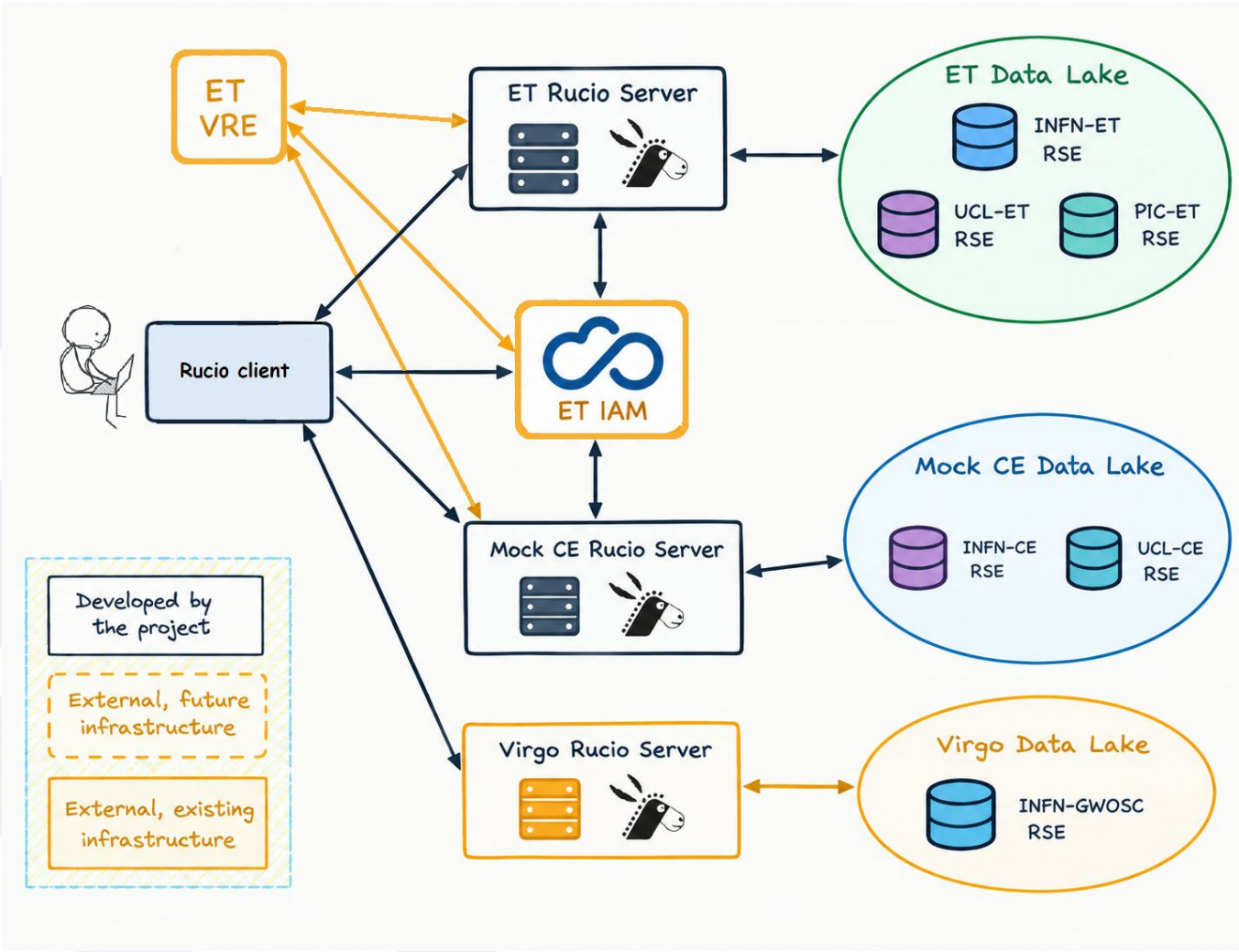
GW community

- March–Oct 2024 (Virgo): ~57,000 files, ~3.2 TB (strain + environment). 1 event per 2-3 days in LVK (LIGO, Virgo, Kagra)
- Einstein Telescope is the future third generation GW detector: ET expected amount ~10 TB/year (strain) and ~50-100 PB/year (raw). Several hundreds events per day

Rucio infrastructure used in MADDEN

MADDEN main Objectives:

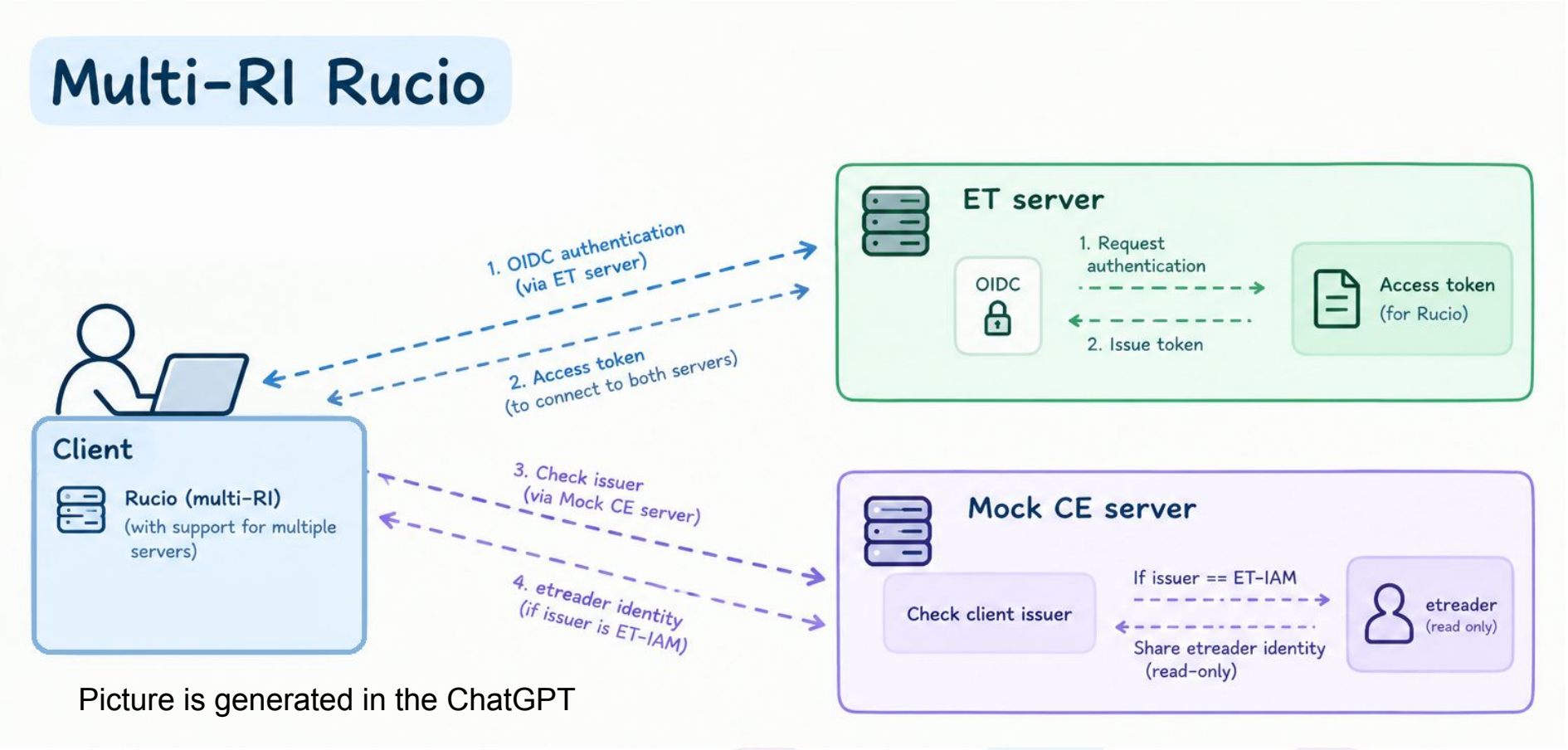
- **<u>Showcase Rucio for Distributed Data Management for ET and CE community</u>**
- **<u>Build multi Research Infrastructure (multi-RI) Rucio Data Lake</u>** integrated with ET Indigo Identity and Access Management and Virtual Research Environment from partner project ETAP*
- **<u>Provide POSIX view of Rucio catalog</u>**: RucioFS or CVMFS plugin
- Improve metadata support for GW use case
- Set up technology demonstrator for LVK(LIGO, Virgo, Kagra)



* https://oscars-project.eu/projects/etap-einstein-telescope-analysis-portal

Multi-RI Rucio

- **OIDC authentication on ET and CE servers:**

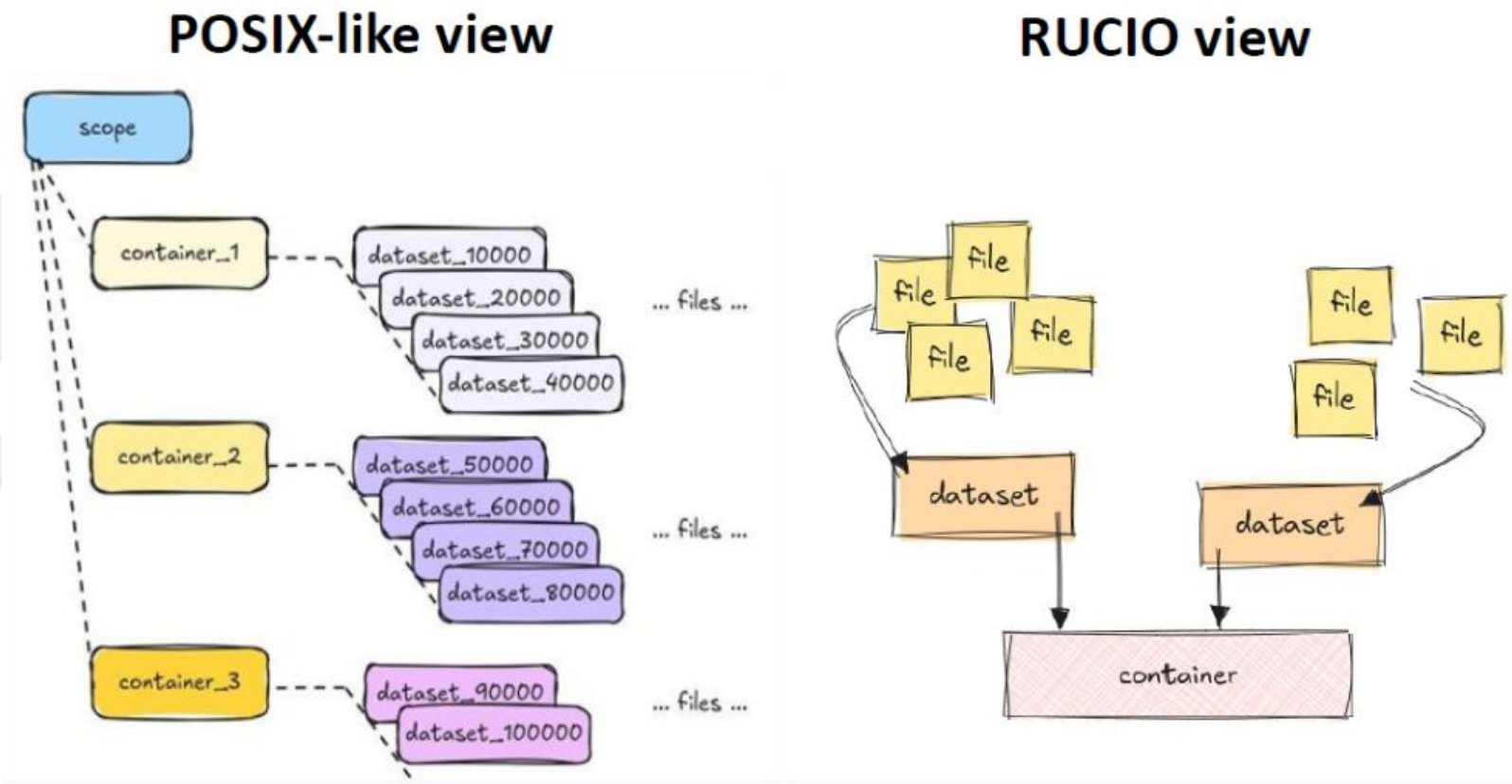


Picture is generated in the ChatGPT

- **<u>Why do we need it?</u> - It is convenient for ET users to have direct read-only access to CE data**
- Simultaneous access to multiple Rucio instances
- OIDC for auth
- Running Rucio commands at more than one Rucio server

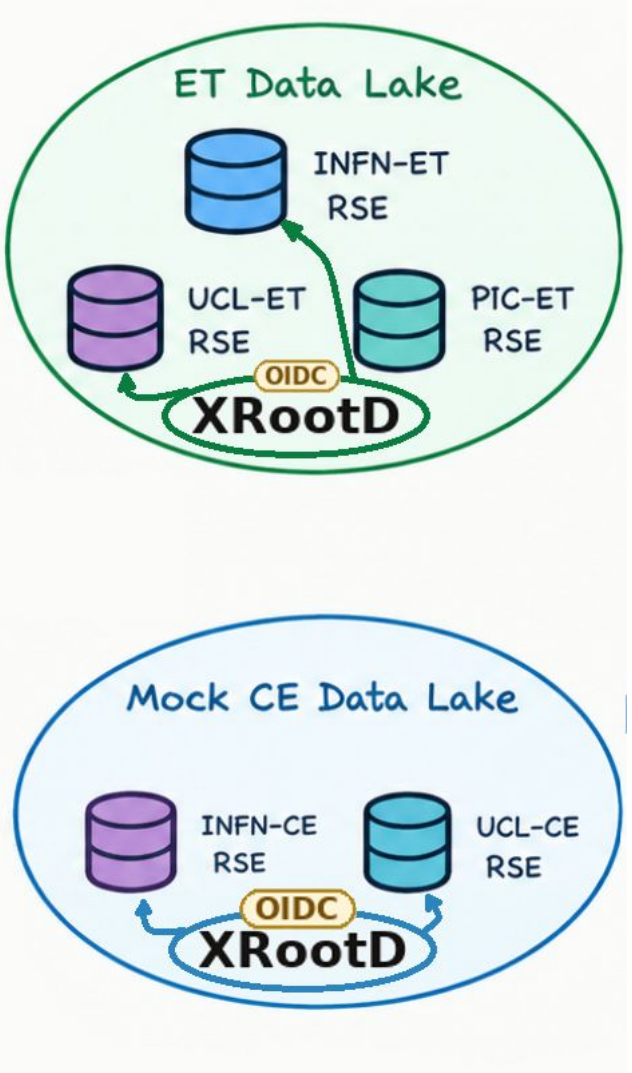
POSIX-like view Rucio

- **Objective:**
  - **Provide a read-only POSIX-like view with minimal Rucio changes**
- **Why do we need it?**
  - Many GW users expect a familiar POSIX interface for analysis
  - It is more convenient to find data files
- **How can we solve this?**
  - **RucioFS**
  - **CVMFS plugin for Rucio**

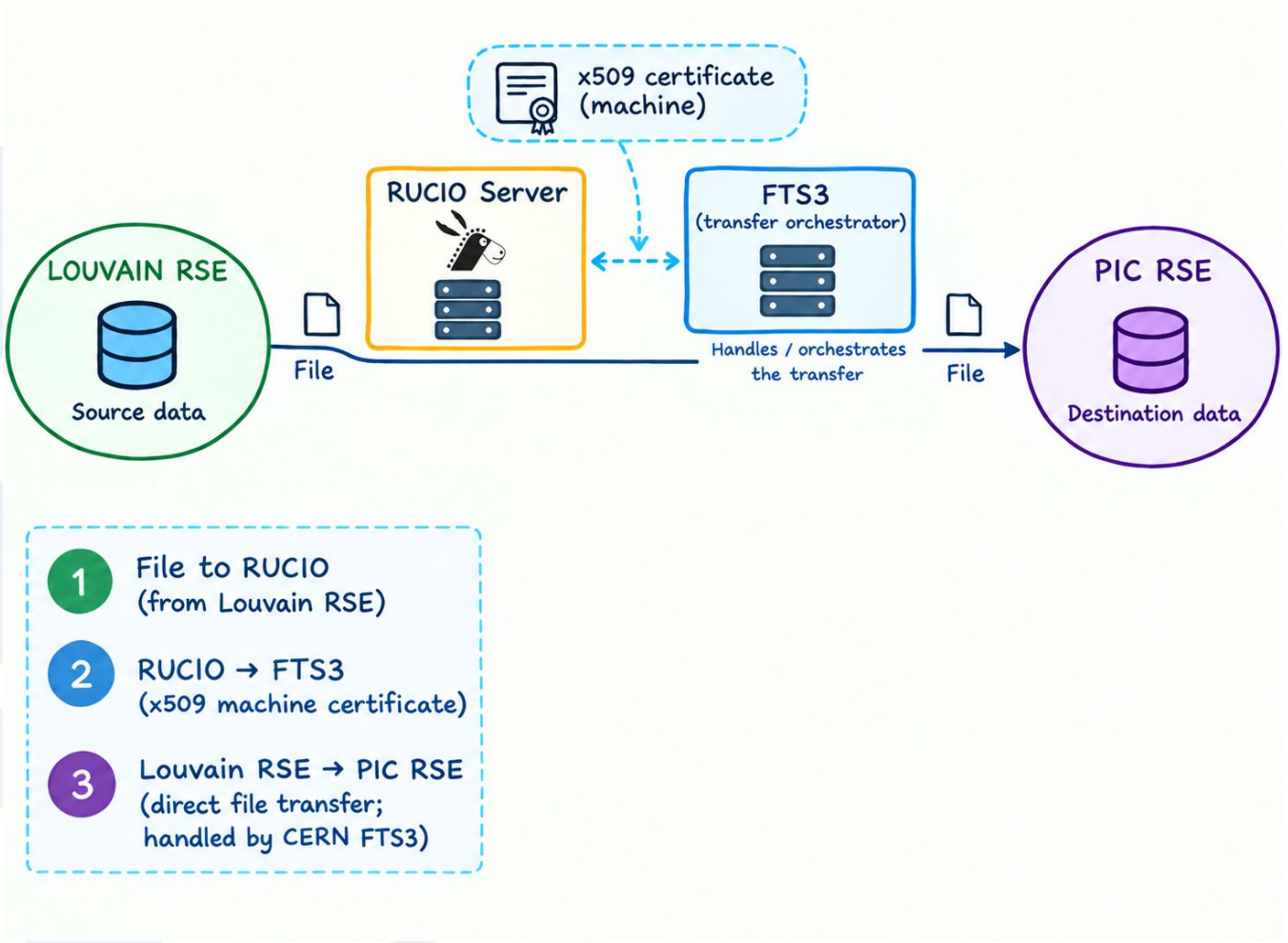


XRootD

- **XRootD manages 4 RSE**: INFN-ET, INFN-CE, UCL-ET, UCL-CE
- All RSEs configured for **x509 and OIDC authentication**
- **Louvain RSEs:**
  - **Integration into OSDF**: Dedicated storage operated as an OSDF Origin (powered by Pelican Platform with XRootD underlying layer) for sharing .gwf data.
  - **XRootD process created by Pelican** is also used as the RSE endpoint for Rucio.
  - **ET MDC Setup**: Adopted the LVK OSDF model for ET Mock Data Challenge simulation data (**public read access)**.
  - **MADDEN**: Reusing the same XRootD layer, but **MADDEN requires private read/write access**, creating a policy conflict with ET MDC public read rules.



- FTS was connected to ET Rucio server for xRIDGE
- At this point (for xRIDGE) ET uses https://fts3-pilot.cern.ch:8446 CERN instance for FTS transfers
- Future plans: connect mock CE server to FTS? use OIDC authentication for FTS transfers?



- **xRIDGE`26 (see CHEP26 Giovanni Guerrieri (CERN) From quarks to quasars: unifying the universe through scalable computing *)** is a data challenge which builds directly on the DAC series (Data Analysis Challenge)

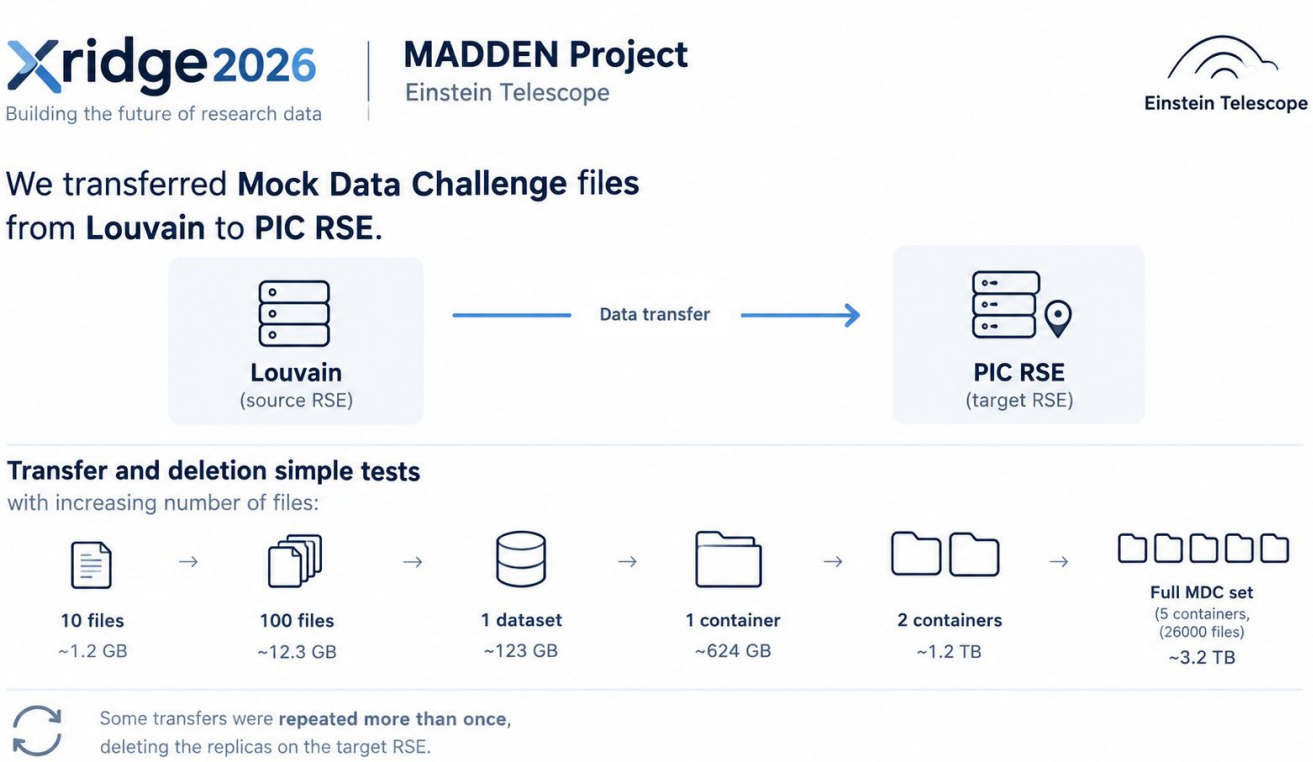
- **main goal of xRIDGE** is to test abilities of multiple Rucio/FTS instances to transfer, manage and analyze different amounts of data. Our goal was to make first time check up of our infrastructure.

- It unites **ET**, SKAO, CTAO, EOSC Federation and FCC for shared data and analysis challenges in a domain-aware environment

*** https://indico.cern.ch/event/1471803/contributions/6967825/**

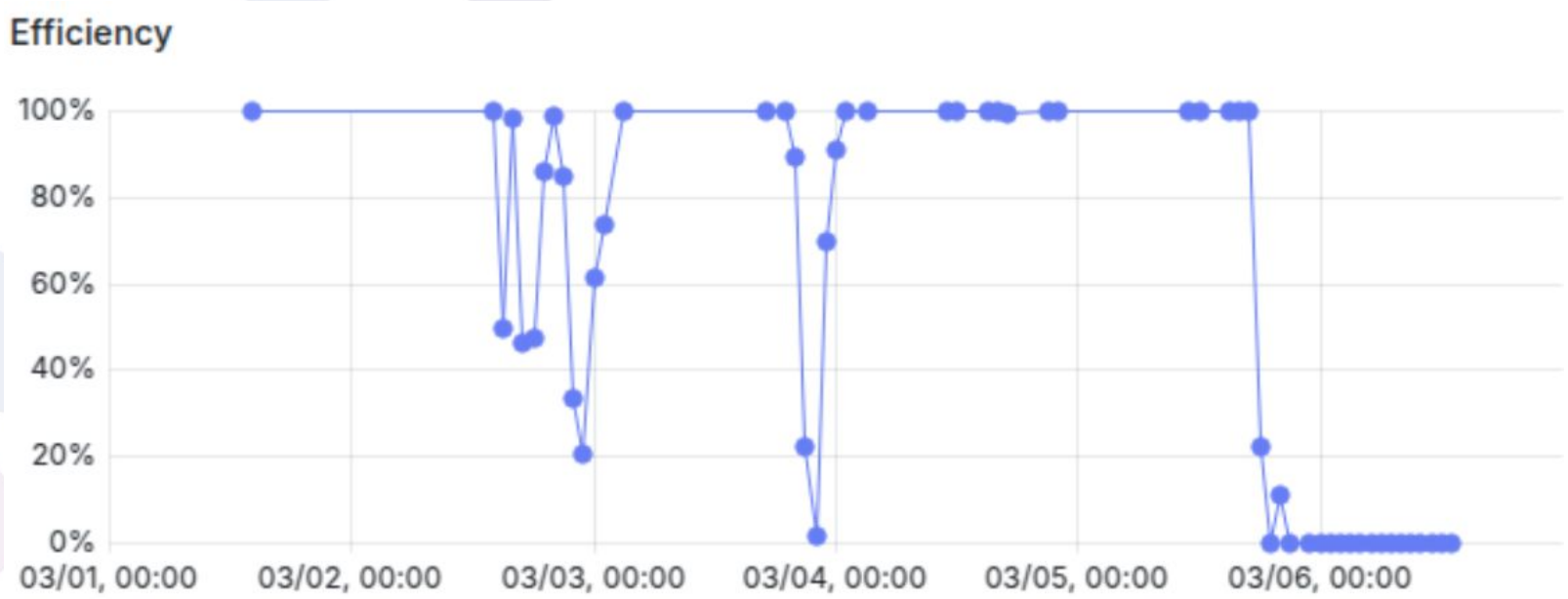
xRIDGE 2026. ET setup

- We transferred Mock Data Challenge files from Louvain to PIC RSE.
- Transfer and deletion simple tests with increasing number of files: 10 files (~1.2 GB), 100 files (~12.3 GB), 1 dataset (~123 GB), 1 container (~ 624 GB), 2 containers (~1.2 TB), full MDC set (5 containers (26000 files)) (~3.2 TB). Some transfers were repeated more than once, deleting the replicas on the target RSE.
- **Special thanks to Steven Murray for help of setting up FTS! :)**

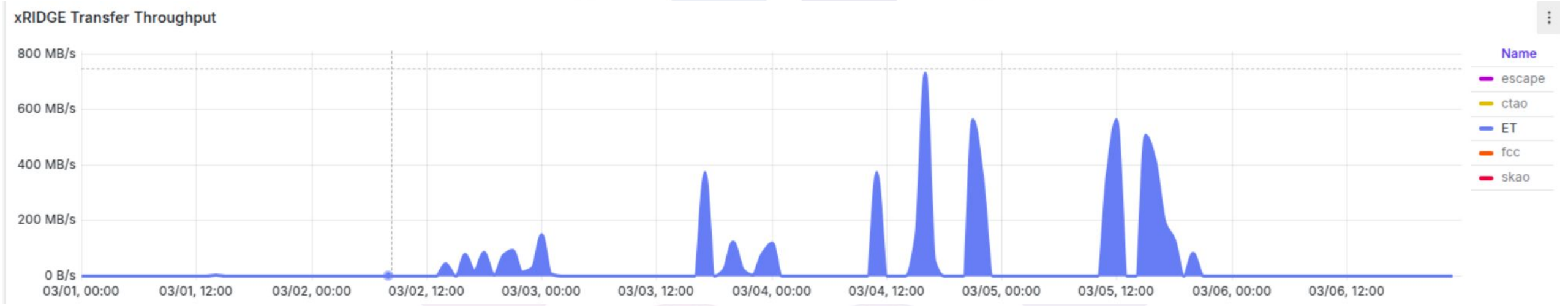


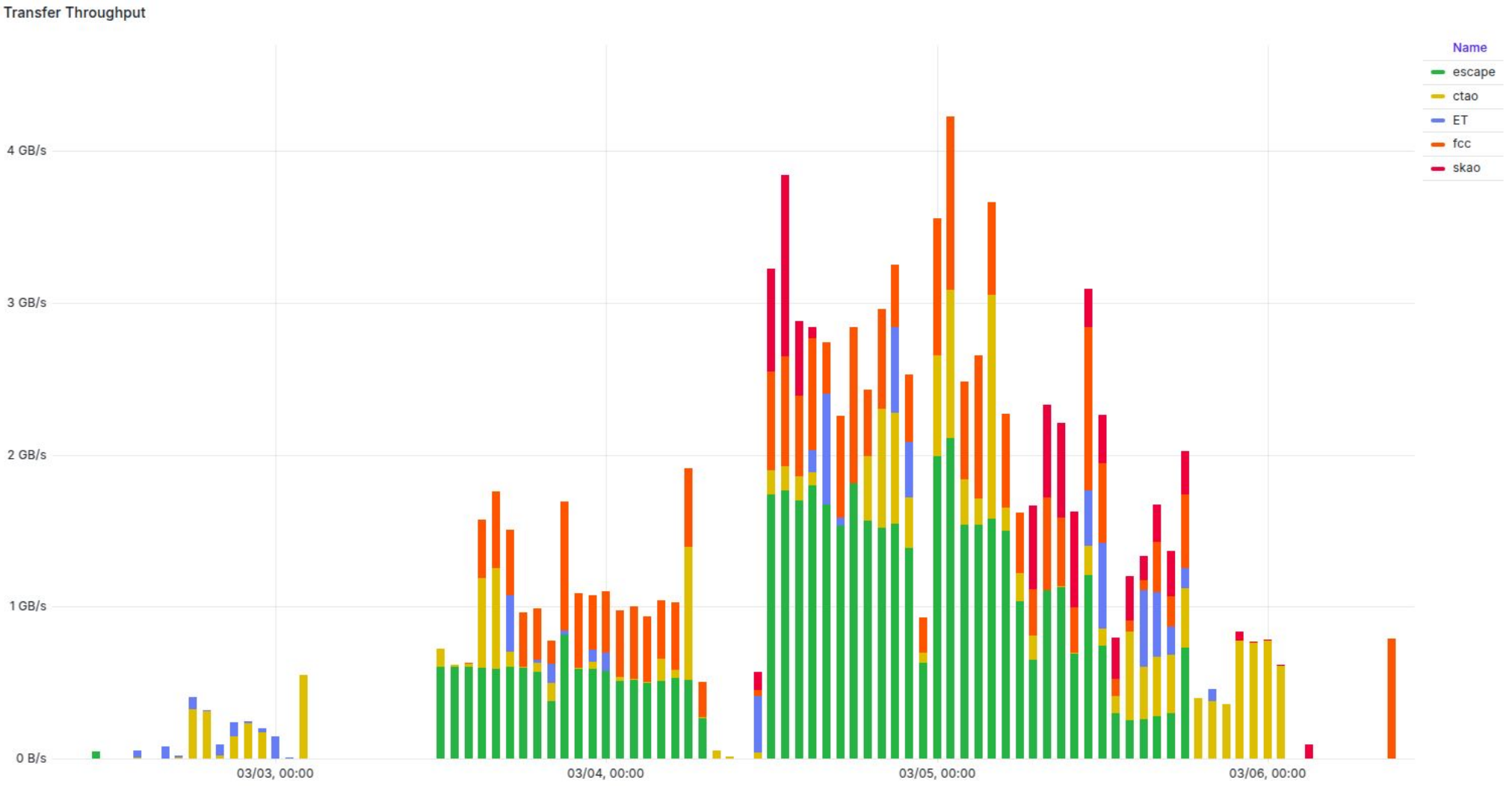
xRIDGE 2026. ET results

- Peak speed of transfer was 732–800 Mb/sec (default limits)
- Encountered Louvain-side origin failures during peak transfers(HTTP 404/454 and packet loss).
- **Is there a dedicated advanced monitoring service for XRootD storage elements to storage directly during high-load transfers?**



xRIDGE 2026. ET results




Transfer Throughput
Name
escape
ctao
ET
fcc
skao
4 GB/s
3 GB/s
2 GB/s
1 GB/s
0 B/s
03/03, 00:00
03/04, 00:00
03/05, 00:00
03/06, 00:00

What do you think?
Any thoughts, suggestions or feedback are welcomed!

Looking for my next postdoc position

Get in touch: naavdeev.astro@gmail.com

OSCARS
Thank you

Multi-RI Rucio

- How does it look like?
  - Original Rucio - Access to only one server
  - Multi-RI Rucio - access to several servers

```
[root@00db07ffcad6 etc]# rucio whoami

Please use your internet browser, go to:

    https://et-rucio-server.to.infn.it/auth/oidc_redirect?oTnsR3waxuZWRJEaKkxysCr_polling

and authenticate with your Identity Provider.
In the next 3 minutes, Rucio Client will be polling
the Rucio authentication server for a token.
--------------------------------------------
suspended_at : None
status     : ACTIVE
created_at : 2025-04-08T13:01:41
account    : avdeev
account_type : USER
email      : nikita.avdeev@to.infn.it
deleted_at : None
updated_at : 2025-04-08T13:01:41
```

```
[root@rucio-client bin]# rucio whoami
Result from ET server.

Please use your internet browser, go to:

    https://et-rucio-server.to.infn.it/auth/oidc_redirect?HZKsZu8cs9rFLm3ZQdIyPaD_polling

and authenticate with your Identity Provider.
In the next 3 minutes, Rucio Client will be polling
the Rucio authentication server for a token.
--------------------------------------------
suspended_at : None
account    : avdeev
status     : ACTIVE
account_type : USER
created_at : 2025-04-08T13:01:41
email      : nikita.avdeev@to.infn.it
deleted_at : None
updated_at : 2025-04-08T13:01:41
Result from CE server.
suspended_at : None
account_type : USER
email      : defaultemail@et-gw.eu
created_at : 2025-07-29T12:25:29
account    : etreader
status     : ACTIVE
deleted_at : None
updated_at : 2025-07-29T12:25:29
```

Multi-RI Rucio command examples

- How does **commands which run on several servers** look like?

```
[root@00db07ffcad6 user]# rucio-mri rse list
Result from ET server.
LOUVAIN
PIC
TORINO
Result from CE server.
LOUVAIN_CE
TORINO_CE
```

- How to use **command only on one server**?

```
[root@00db07ffcad6 user]# rucio-mri \
> --config /opt/rucio/etc/rucio_CE.cfg \
> rse list
LOUVAIN_CE
TORINO_CE
```

Current status: Multi-RI client part was added to Rucio starting with version 39.2.0.

RucioFS

- **RucioFS is a POSIX-like FUSE-based filesystem.**
- https://github.com/rucio/fuse-posix
- Caching mechanism was implemented
- user/passwd and x509 authentication are supported
- OIDC authentication support: work in progress
- Future plans: full scalability and performance tests and adding metadata support

Rucio

```
bash-5.1# rucio did list --filter type=all test:*
+-----------------------------+--------------+
| SCOPE:NAME                  | [DID TYPE]   |
|-----------------------------+--------------|
| test:test_LOUVAIN_CE.txt    | FILE         |
| test:test_TORINO_CE.txt     | FILE         |
| test:test_upload9004.txt    | FILE         |
+-----------------------------+--------------+
```

RucioFS

```
bash-5.1# cd ruciofs
bash-5.1# ls
torino_ce  torino_et        Rucio server
bash-5.1# cd torino_ce/
bash-5.1# ls                Scope
MDCv2  atanasi  avdeev  avdeev-test-data  avdeev.test1  avdeev.t
est2  lavezzi  legger  mjansson  playcock  test
bash-5.1# cd test/
bash-5.1# ls                DID
test_LOUVAIN_CE.txt  test_TORINO_CE.txt  test_upload9004.txt
```

CVMFS plugin

- **<u>CVMFS provides a mechanism for distributing files globally across computing centers.</u>**
- CVMFS plugin reproduces Rucio structure in POSIX like way (**without distributing real files!!!**). Image of real DID file is .json file with metadata of this file
- **<u>CVMFS plugin has two parts</u>**:
  - Initial export of existing Rucio catalogue to CVMFS.
  - Keep Rucio catalogue synchronized in CVMFS.
- Future plans: full scalability and performance tests, adding multi-RI, adding **FTS event messages** support

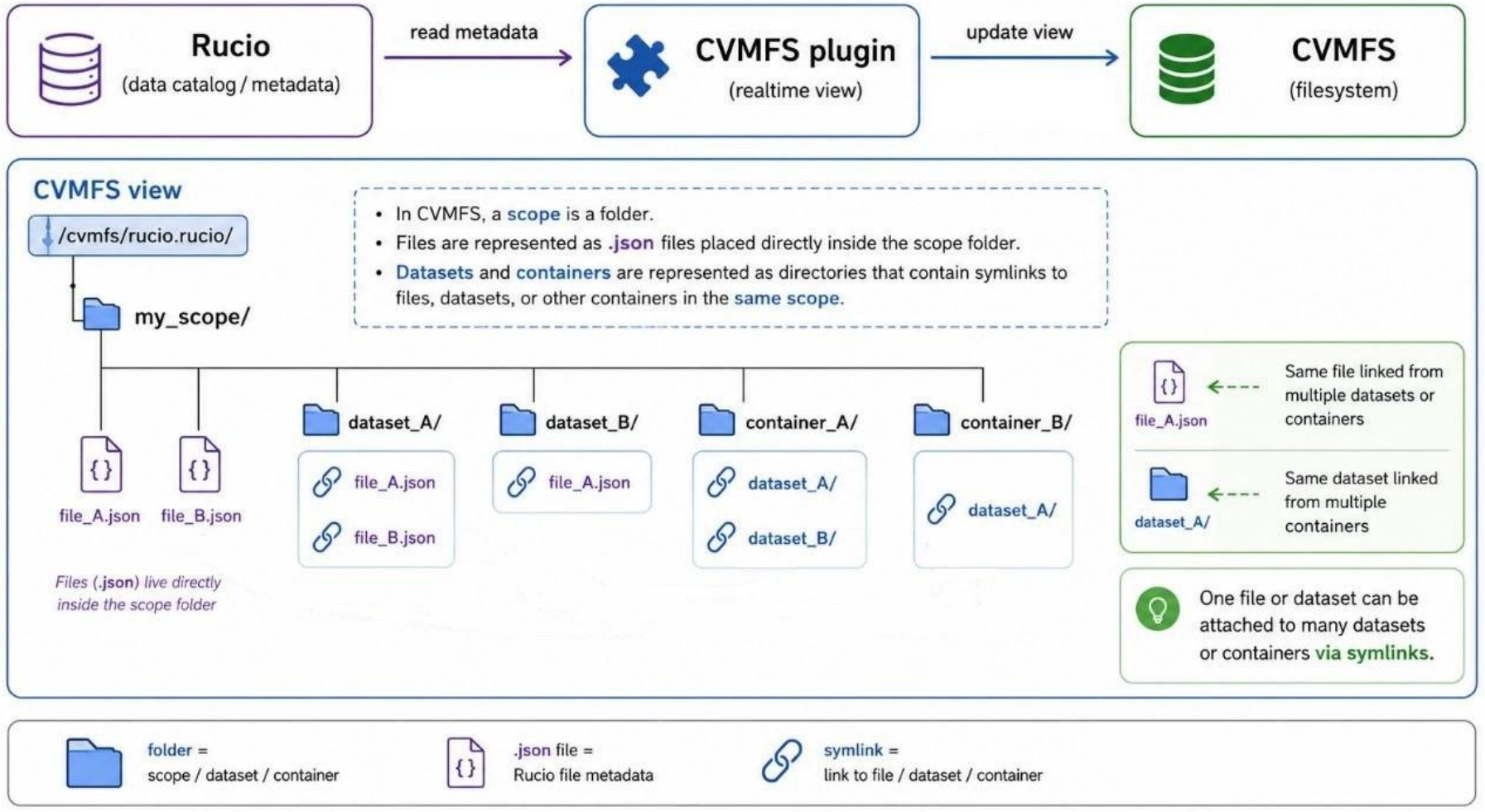
scope

Images of DIDs

```
][rucioadmin_ce@et-rucio-test ce-rucio-setup]$sudo ls /cvmfs/rucio.rucio/avdeev/
BHnew1           GWcontainer          GWset5              NSNS9.txt.json       test_file1000.txt.json
BHNS1.txt.json   GWcontainer1000      GWset7              some_file4.txt.json  test_upload_on_test_server11.txt.json
BHNS4.txt.json   GWdataset            GW_test1.txt.json   some_file5.txt.json
BHNS.txt.json    GWfile1000.txt.json  NSNS7.txt.json      some_file6.txt.json
```

CVMFS plugin

- Data structure on CVMFS side



Picture is generated in the ChatGPT

CVMFS plugin

- Example of .json file:


```
[
  {
    "rse": "TORINO_CE",
    "path": [
      "davs://et-rucio-test.to.infn.it:1094//data1/rse_torino_ce/avdeev/0c/c0/some_file6.txt"
    ]
  },
  {
    "rse": "LOUVAIN_CE",
    "path": [
      "davs://ingrid-osdf2.cism.ucl.ac.be:8443/et-gw/PUBLIC/rucio-tests/torino_ce/avdeev/0c/c0/some_file6.txt"
    ]
  },
  {
    "scope": "avdeev",
    "name": "some_file6.txt",
    "bytes": 17,
    "adler32": "3ca20685",
    "created_at": "2026-06-27 18:52:57.004527"
  },
  {
    "gps_time": "1465737211"
  }
][rucioadmin_ce@et-rucio-test ce-rucio-setup]$
```