REANA implementation of ATLAS semi-visible jet analysis

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VRE Bi-weekly meeting

23/01/2024

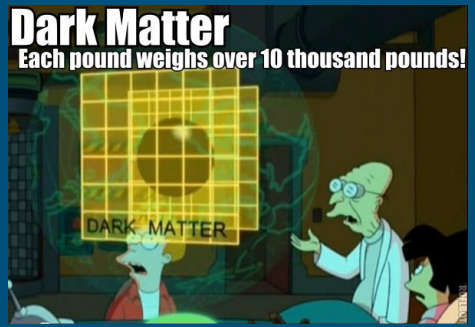
University of Manchester

Hidden Sectors

SM Sector — Connectors / Portals — Hidden Sectors

Z′, SUSY particles, Higgs, Extra Dim, Leptoquarks, CP-odd...

can be strongly or weakly coupled i.e., dark Higgs, dark photon, dark SU(N), Asym DM...



When a Hidden Sector particle is (quasi-)stable, a dark matter candidate can potentially exist

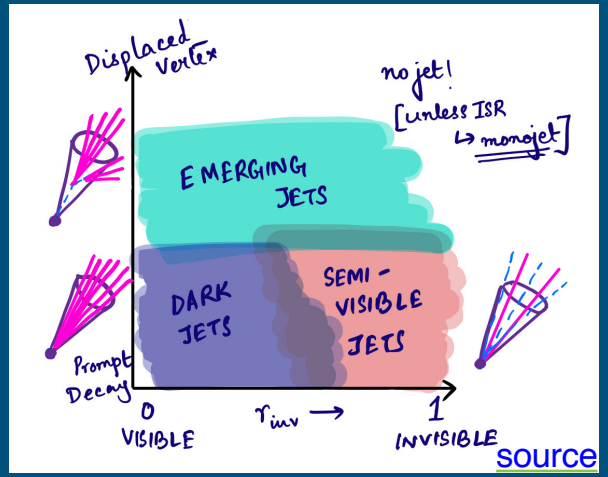
We have not found any concrete sign of new physics … yet!
Looking at unusual topologies and hidden corners of the phase space
→ **signature based searches, using benchmark models.**

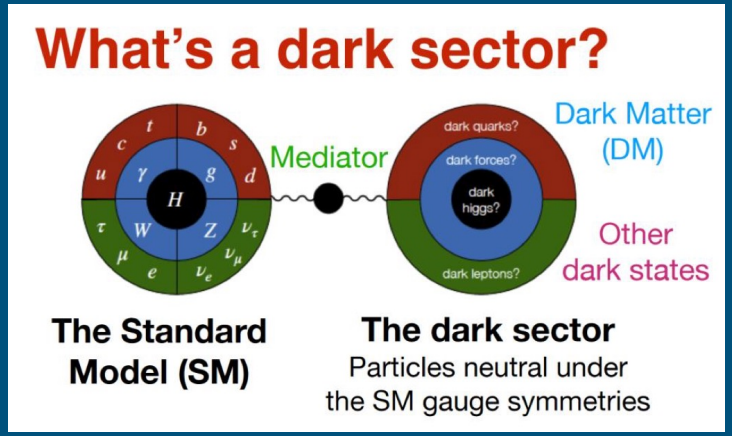
The big picture...

Dark hadrons decaying promptly in a QCD-like fashion,
- fully, or
- partially back to the visible sector

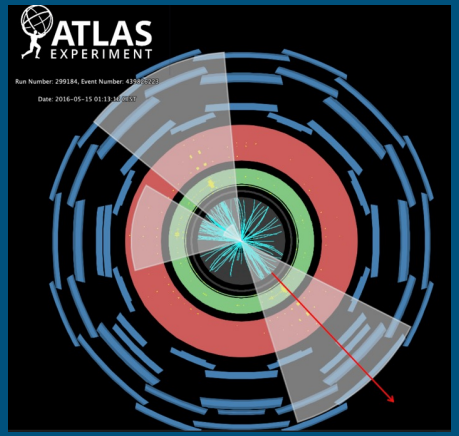
Dark hadrons undergoing displaced decays in a QCD-like fashion

Each signature has a distinctive feature:
-> Dark jets: unique substructure
-> Emerging jets: displaced objects
-> Semi-visible jets: substantial missing energy

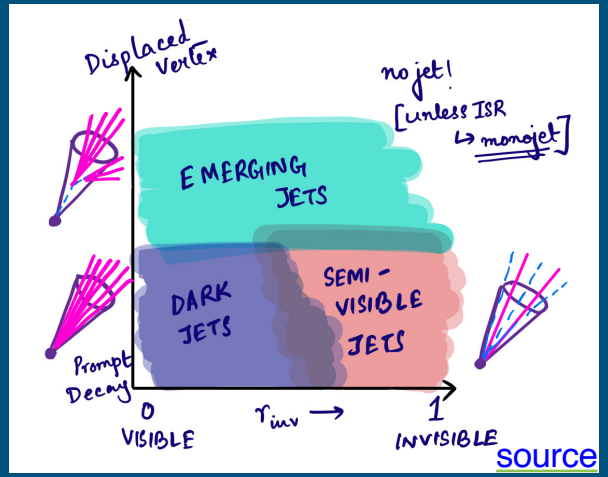




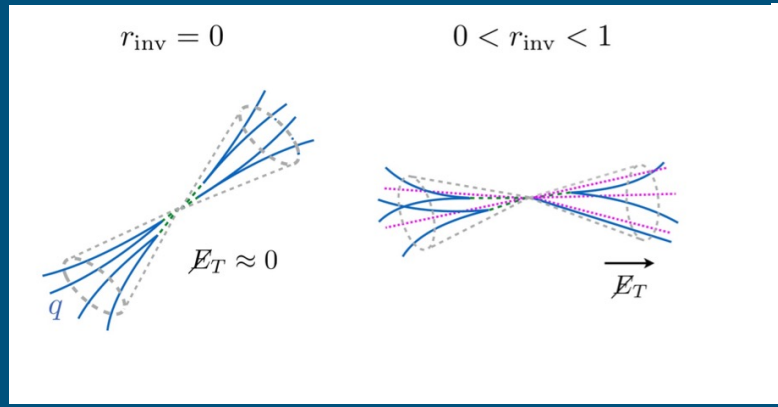
Semi-visible jets

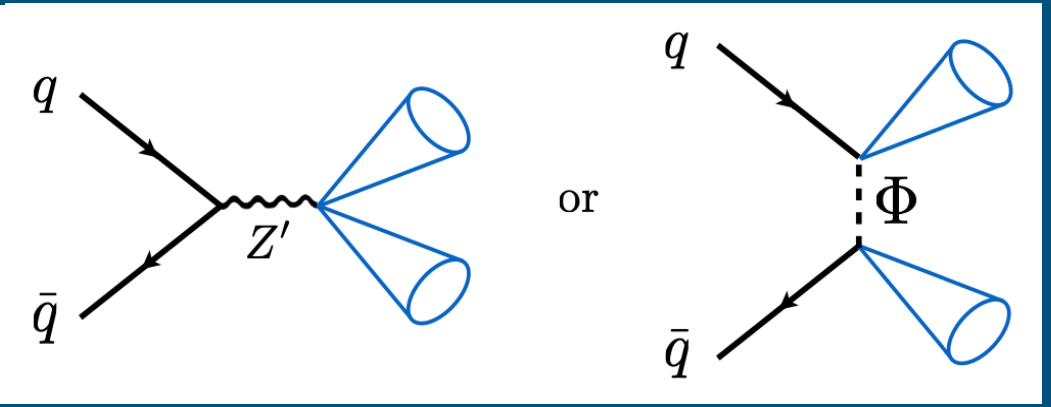


Assume dark sector quarks interact with QCD
→ Some dark hadrons decay back to SM
→ Some dark hadrons are stable and invisible



Jets with missing energy aligned along one of the jet direction!





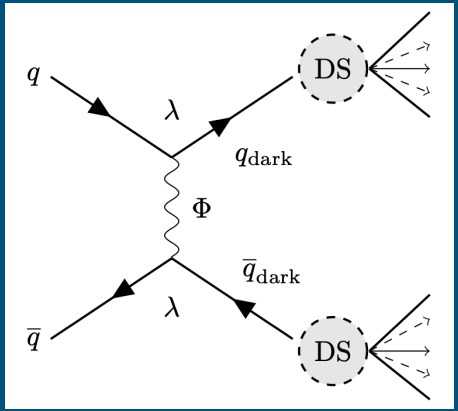
R_{inv} = #stable dark hadrons / #all dark hadrons

t-channel production mode

ATLAS Full Run-2 search for semi-visible jets (t-channel)

Signal model parameters:

1. M_ϕ = Mass of scalar bi-fundamental mediator
2. r_{inv}
3. M_d = Mass of dark hadrons

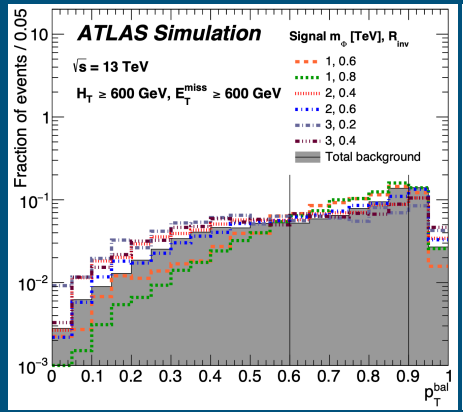


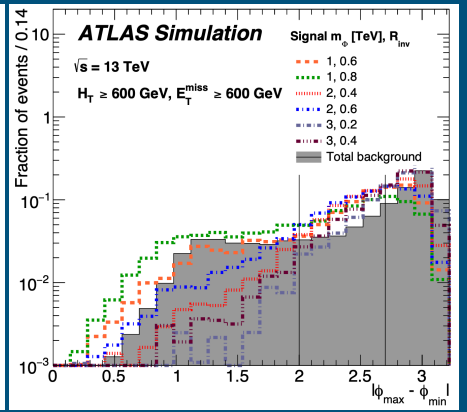
Background samples: W/Z+jets, ttbar, singletop, multi-jet, diboson

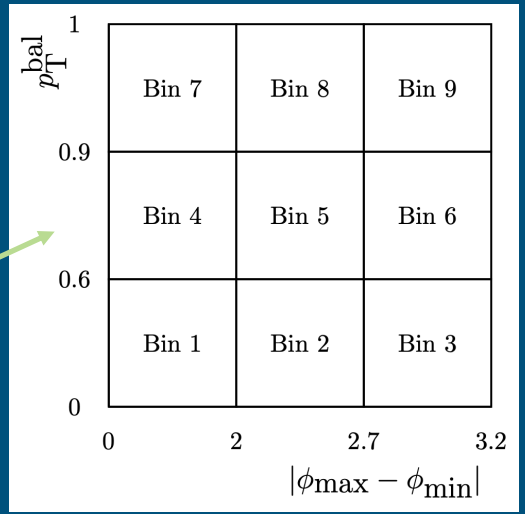
The signal events typically have high missing energy

Partially data-driven method, simultaneously fit signal region and three control regions to obtain scale factors for each bg process

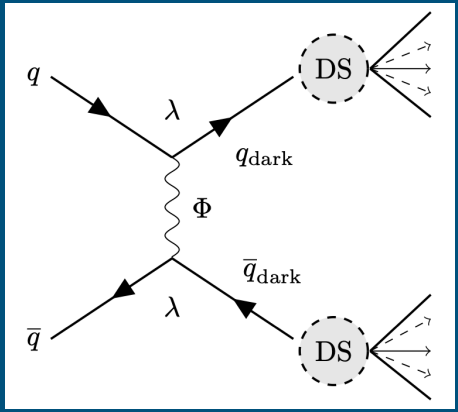
Two key observables used to design a 9 bin grid: Yield in each bin treated as an observable

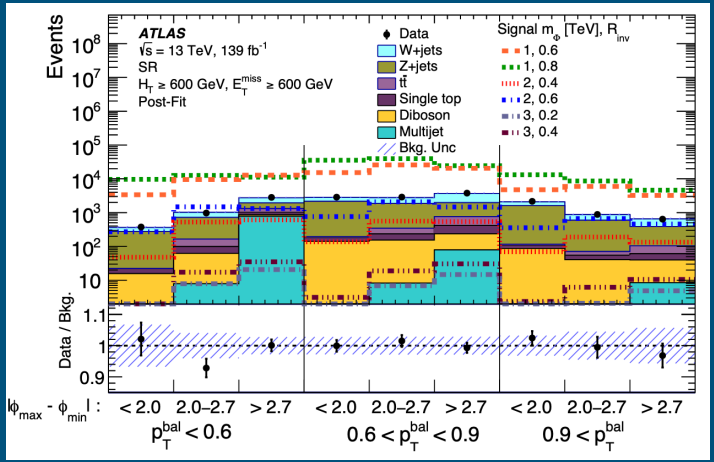


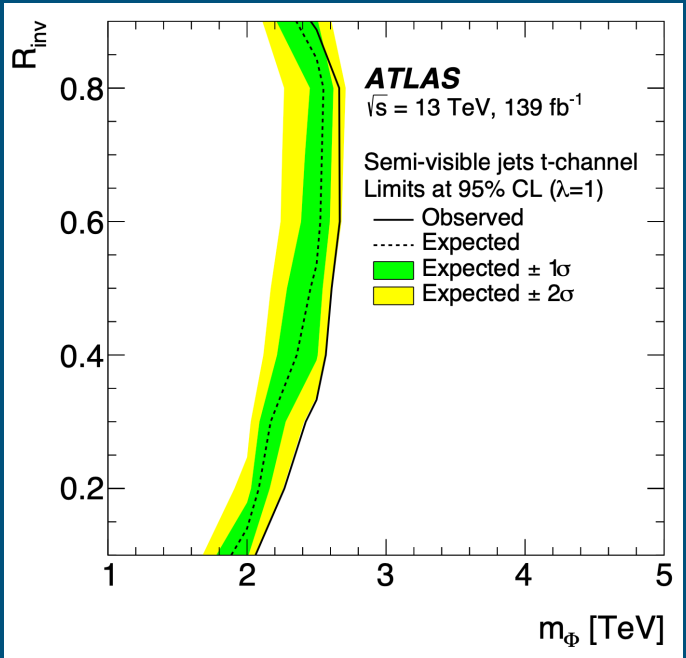




ATLAS Full Run-2 search for semi-visible jets (t-channel)







Phys. Lett. B 848 (2024) 138324

Search for non-resonant production of semi-visible jets using Run 2 data in ATLAS

The ATLAS Collaboration

Semi-visible jets, with a significant contribution to the event's missing transverse momentum, can arise in strongly interacting dark sectors. This results in an event topology where one of the jets can be aligned with the direction of the missing transverse momentum. A search for semi-visible jets produced via a t-channel mediator exchange is presented. The analysis uses pp collisions with an integrated luminosity of 139 fb^{-1} and a centre-of-mass energy of 13 TeV, collected with the ATLAS detector during Run 2 of the LHC. No excess over Standard Model predictions is observed. Assuming a coupling strength of unity between the mediator, a Standard Model quark and a dark quark, mediator masses up to 2.7 TeV can be excluded at the 95% confidence level. Upper limits on the coupling strength are also derived.

First limits on t-channel production mode from ATLAS!

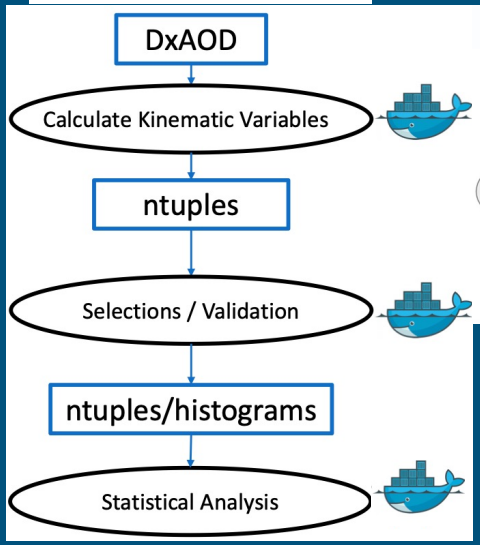
Potential for reinterpretation

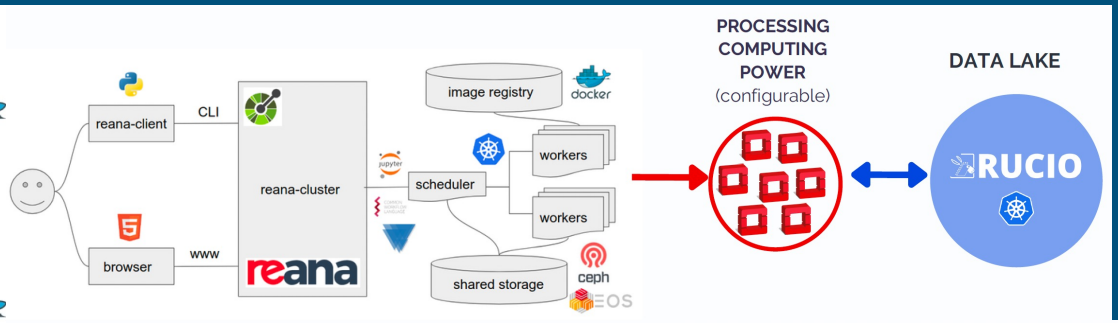
Semi-visible jet t-channel search has fairly inclusive selections
→ ALLOWS TO PROBE OTHER MODELS WITH SIMILAR FINAL STATES

VRE@CERN

https://vre-hub.github.io/

Open source analysis platform being developed @CERN
→ access to all the digital content needed to develop, share and reproduce analyses in compliance with FAIR (findable, accessible, interoperable, reproducible) principles.





From the Reana client:
- authenticate via IAM to Rucio with a side-car container
- get data from distributed storage

→ the analysis can be reproduced fully and **independently from local storage**

Following implementation guidelines similar to Z′ analysis [talk by J. Little.]

Checking files available on rucio-vre

$ docker pull ghcr.io/vre-hub/vre-rucio-client:latest

$ docker run --user root -e RUCIO_CFG_CLIENT_X509_PROXY=/tmp/x509up -e RUCIO_CFG_AUTH_TYPE=x509_proxy -e RUCIO_CFG_ACCOUNT=<username> -v ~/.globus/usercert.pem:/opt/rucio/etc/client.crt -v ~/.globus/userkey.pem:/opt/rucio/etc/client.key -it --name=rucio-client ghcr.io/vre-hub/vre-rucio-client

$ [root@471be78934af user]# ls /tmp/x509*
/tmp/x509up_u0

If exists, then:
$ cp /tmp/x509up_u0 /tmp/x509up

else directly:
$ voms-proxy-init --voms escape --cert /opt/rucio/etc/client.crt --key /opt/rucio/etc/client.key --debug --out /tmp/x509up

$ rucio list-rses

$ rucio list-files ATLAS_LAPP_SP:final_histos.root

Initialising reana-vre

Put the following code in your directory under reana-vresetup.sh

#if on lxplus

```
source /afs/cern.ch/user/r/reana/public/reana/bin/activate

export REANA_SERVER_URL=https://reana-vre.cern.ch
export REANA_ACCESS_TOKEN=<your token>

voms-proxy-init --voms escape --cert ~/.globus/usercert.pem --key ~/.globus/userkey.pem --out
/tmp/x509up_u1000

reana-client secrets-add --env VONAME=escape \
                         --env VOMSPROXY_FILE=x509up_u1000 \
                         --file /tmp/x509up_u1000 \
                         --env RUCIO_USERNAME=susinha \
                         --env RUCIO_RUCIO_HOST=https://vre-rucio.cern.ch \
                         --env RUCIO_AUTH_HOST=https://vre-rucio-auth.cern.ch --overwrite
```

--overwrite is important for when one of the SECRETS already exist, and you still want to run everything using a bash script

Running semi-visible jet analysis

This is the REANA implementation of semi-visible jets t-channel analysis: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2022-37/

The workflow is split into 3 steps (== 3 docker images, that run one after the other in the REANA-VRE instance):

1. object and trigger selections using AnalysisTop package (part of AnalysisBase public docker image)
2. flat ntuple analyser
3. fitting mechanism via TRExFitter package (part of StatAnalysis public docker image)

The workflow is run within the reana-vre(.cern.ch) platform → `GitHub link to repository`

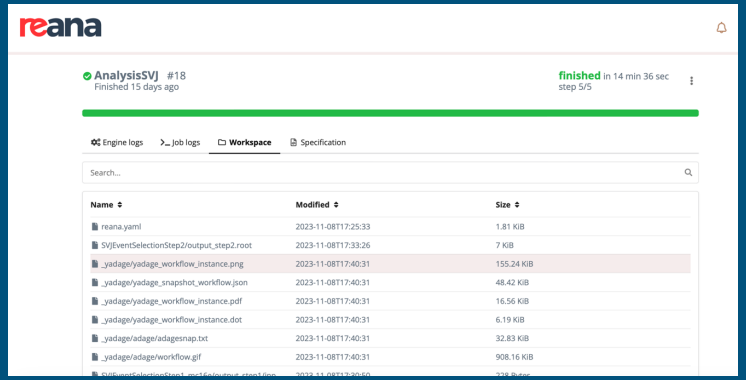
To run the code:

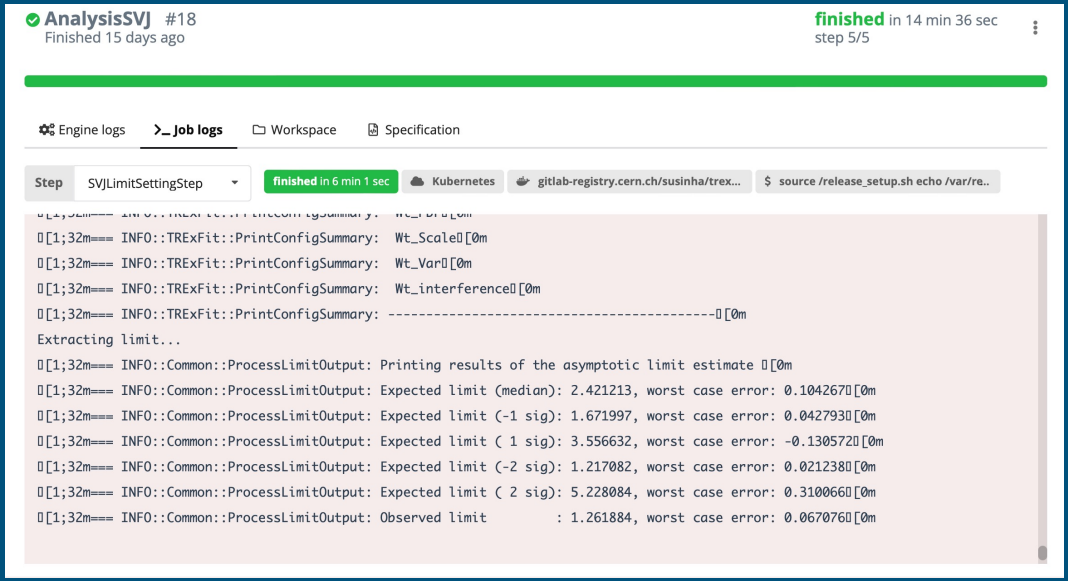
```
$ git clone git@github.com:susinha1702/svj-tchannelreana.git

$ cd svj-tchannelreana/
```

$ source runReana.sh #script containing all the REANA workflow setup and running instructions

```
(reana) [susinha@lxplus788 reana]$ source runReana.sh
==> Verifying REANA specification file... /afs/cern.ch/work/s/susinha/reana/reana.yaml
  -> SUCCESS: Valid REANA specification file.
==> Verifying REANA specification parameters...
  -> SUCCESS: REANA specification parameters appear valid.
==> Verifying workflow parameters and commands...
==> SUCCESS: File /reana.yaml was successfully uploaded.
==> SUCCESS: File /specs/steps.yml~ was successfully uploaded.
==> SUCCESS: File /specs/steps.yml was successfully uploaded.
==> SUCCESS: File /specs/workflow.yml was successfully uploaded.
==> SUCCESS: File /specs/workflow.yml~ was successfully uploaded.
==> SUCCESS: AnalysisSVJ has been queued
```





Status as of Dec 2023:

Files uploaded on rucio-vre and can be accessed via same authentication. Run successful and sensible limit extraction using reana-vre instance

Current issues with accessing rucio-vre files

Trying to upload new files in Jan 2024 using same instructions shown before for signal model, and faced with following error:

```
Remote VOMS server contacted succesfully.

Loading CA Certificate /etc/grid-security/certificates/8a21c0da.0.
Loading CA Certificate /etc/grid-security/certificates/35105088.0.
Loading EACL namespace (signing_policy) /etc/grid-security/certificates/8a21c0da.signing_policy.
VOMS AC validation for VO escape succeded.
=== VO escape extension information ===
VO        : escape
subject   : /DC=ch/DC=cern/OU=Organic Units/OU=Users/CN=susinha/CN=839783/CN=Sukanya Sinha
issuer    : /DC=org/DC=terena/DC=tcs/C=IT/ST=Roma/O=Istituto Nazionale di Fisica Nucleare/CN=voms-escape.cloud.cnaf.infn.it
attribute : /escape/Role=NULL/Capability=NULL
timeleft  : 11:59:58
uri       : voms-escape.cloud.cnaf.infn.it:15000

Created proxy in /tmp/x509up.

Your proxy is valid until Sun Jan 21 00:07:26 UTC 2024
[root@f06441bf1023 user]# rucio list-rses
2024-01-20 12:07:37,276 ERROR   ConnectionError: HTTPSConnectionPool(host='vre-rucio-auth.cern.ch', port=443): Max retries exceede
d with url: /auth/x509_proxy (Caused by SSLError(SSLError(1, '[SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed (_ssl.c:8
77)'),))
2024-01-20 12:07:37,401 ERROR   ConnectionError: HTTPSConnectionPool(host='vre-rucio-auth.cern.ch', port=443): Max retries exceede
d with url: /auth/x509_proxy (Caused by SSLError(SSLError(1, '[SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed (_ssl.c:8
77)'),))
2024-01-20 12:07:37,515 ERROR   ConnectionError: HTTPSConnectionPool(host='vre-rucio-auth.cern.ch', port=443): Max retries exceede
d with url: /auth/x509_proxy (Caused by SSLError(SSLError(1, '[SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed (_ssl.c:8
77)'),))
2024-01-20 12:07:37,517 ERROR   Cannot connect to the Rucio server.
```