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The XENON1T Computing Scheme

1st International Rucio Community Workshop

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CERN

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The XENON1T Collaboration

What are we doing:
Looking for particle Dark Matter with 3.5 tons of liquid xenon in a dual phase time projection chamber (TPC)

*A worldwide collaboration:**
- 25 institutes
- 155 members

* Latest count: February 2018

Collaboration Meeting in January 2018 (Florence)

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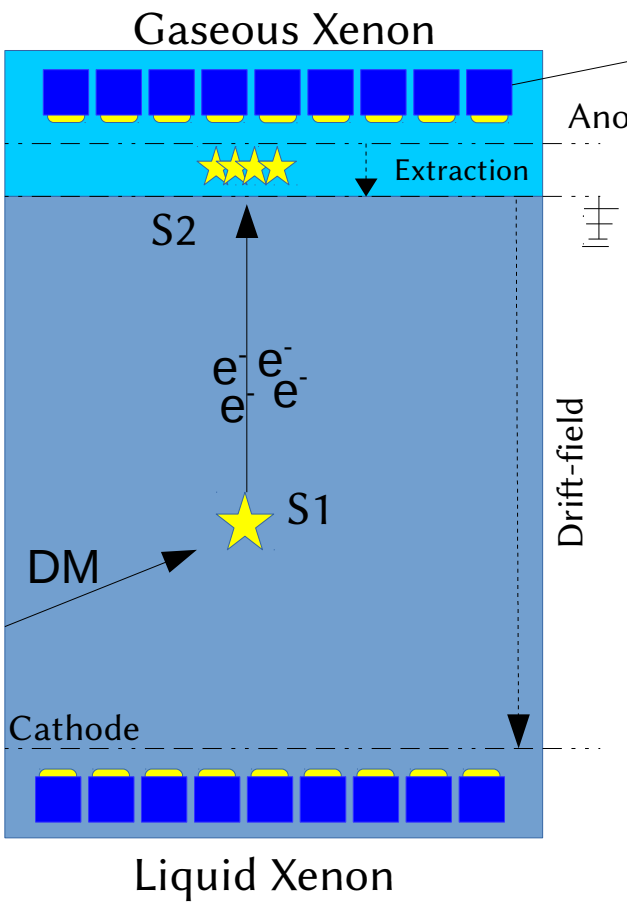
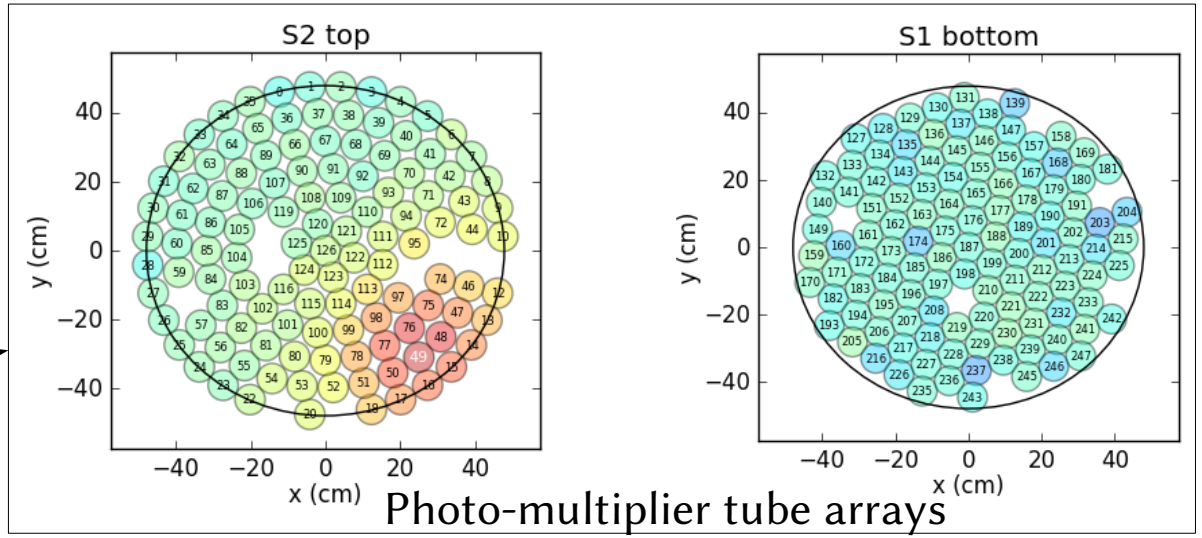
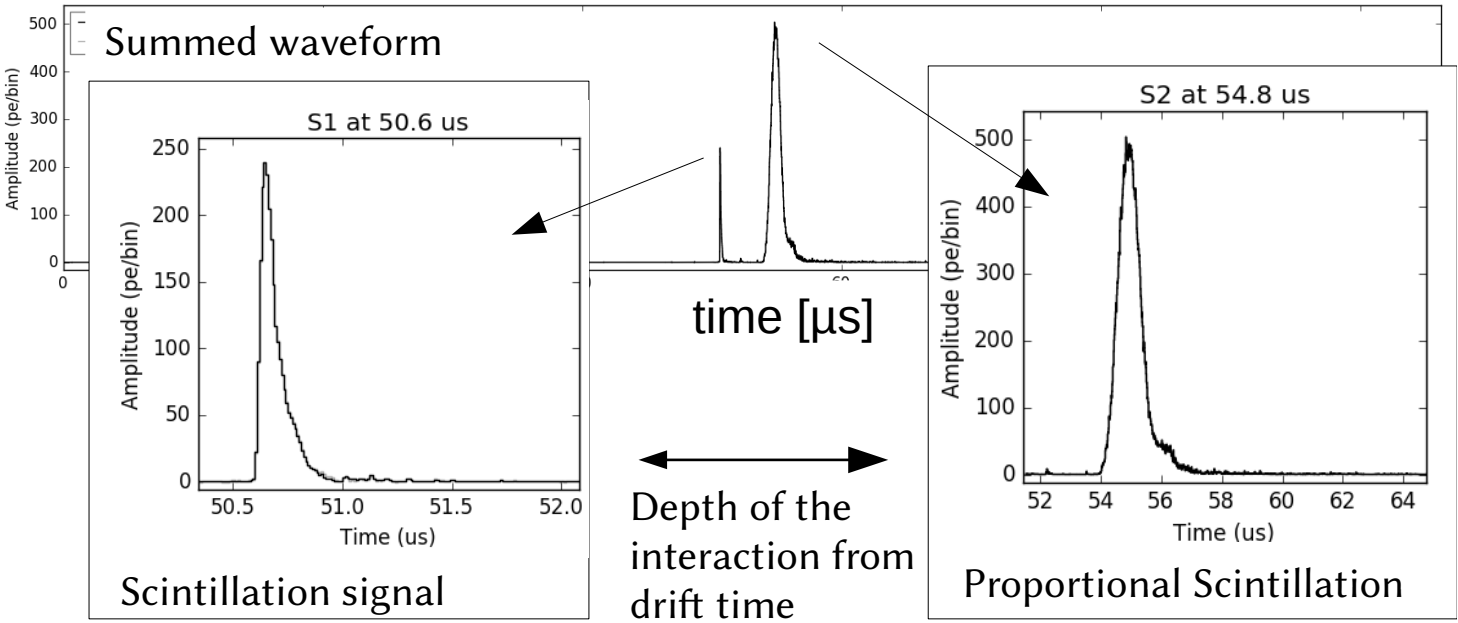
The XENON Dark Matter Experiment (I)







- Full 3D and energy reconstruction!
- Data taking: 24/7 (including calibrations)
- S1 and S2 allow signal discrimination for electronic recoil (ER) and nuclear recoil (NR)
- Data taking rate: ~ 5 Hz

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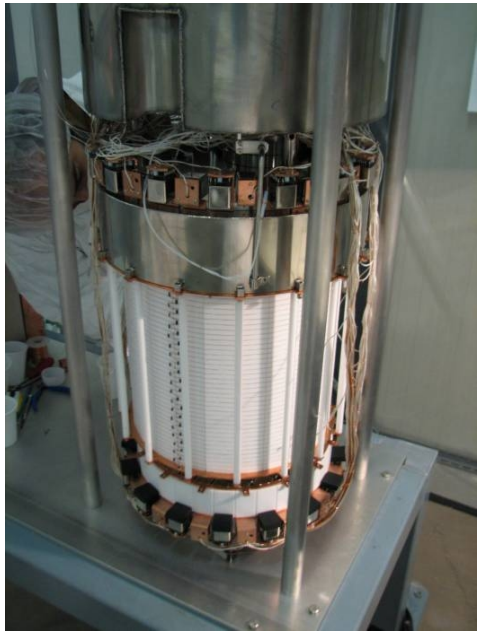
The XENON Dark Matter Experiment (II)

XENON10

Lifetime: 2005-2007
Mass: 25 kg
Height: 15 cm
PMTs: 89

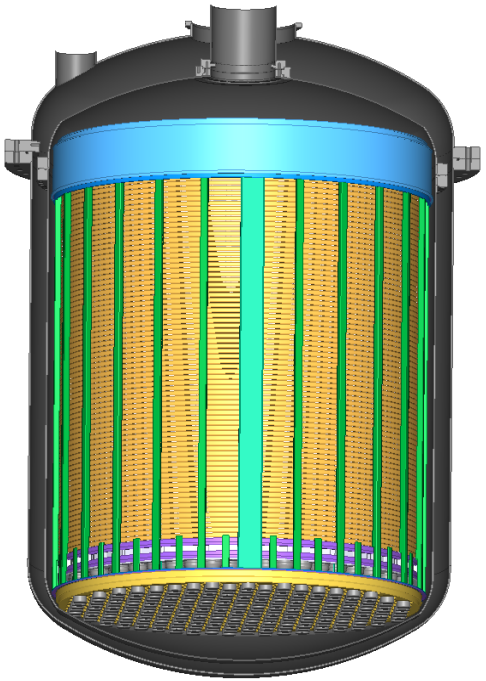


XENON100

Lifetime: 2008-2016
Mass: 161 kg
Height: 30 cm
PMTs: 242

XENON1T

Lifetime: 2012-2018
Mass: 3200 kg
Height: 100 cm
PMTs: 248



XENONnT

Lifetime: 2019-20??
Mass: ~8000 kg
Height: 144 cm
PMTs: 476

Continuously improved in sensitivity!

But also improved in:
- Data handling
- Computing
- Analysis

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From XENON100 to XENON1T

	What we did in XENON100	What we do in XENON1T
Raw data storage	Dedicated disk space at the LNGS	Dedicated GRID endpoints at: • European Grid Interface (EGI) • Open Science Grid (OSG)
Raw data processing	A few reprocessing campaigns at the LNGS	Several reprocessing campaigns on EGI and OSG
Data analysis	Processed data sets were available at the LNGS: • For analysis • Download to institutes or analysts computers	Center for data analysis at Research Computing Center (RCC) Chicago: • Reduced data sets available • Jupyterhub server for analysts
GRID usage	Monte Carlo production	Processing, storage and Monte Carlo
Software & Tools	C++/ROOT Homemade tools (e.g. for reprocessing)	• Python 3 • Jupyter notebooks • Homemade tools & Rucio
Tape storage	LNGS	Center for High Performance Computing (PDC, Stockholm)
Network		Update to LHCOne network (ongoing)

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The XENON1T Raw Data Overview

	Calibration (electronic/nuclear recoil)						Science data
Source	Kr83m	Rn220	AmBe	LED	Th228	Neutron Generator	DM
Total size [TB]	40	85	67	30	3	12	332
Total lengths [h]	791	1141	802	245	13	51	10705

Data sets: 17141
Total time: 13748 hours
Total events: 830 M events
Total size: >571 TB

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The XENON1T Data Workflow: Data at Three Stages:

I Raw data uploaded to Rucio

Tools:
PAX,
CAX, RUCIAX

Raw data:
- Waveforms

II Processing on OSG and EGI

Tools:
PAX,
CAX, DAG
Man

"Processed files"
- Contain reduced information
- Much smaller
- No waveforms
- Re-created when important changes in PAX are made in reprocessing campaigns

III Second processing on RCC Chicago

Tools:
CAX, HAX

"Minitrees"
- Created from processed files
- Stored on RCC Chicago for the analyst
- Contain corrections (e.g. for drift time)
- Do not need a heavy reprocessing campaign

Analysts:
- Work with minitrees mainly
- Can define own minitrees for variables of interest from processed files
- Look at waveforms with a waveform watcher

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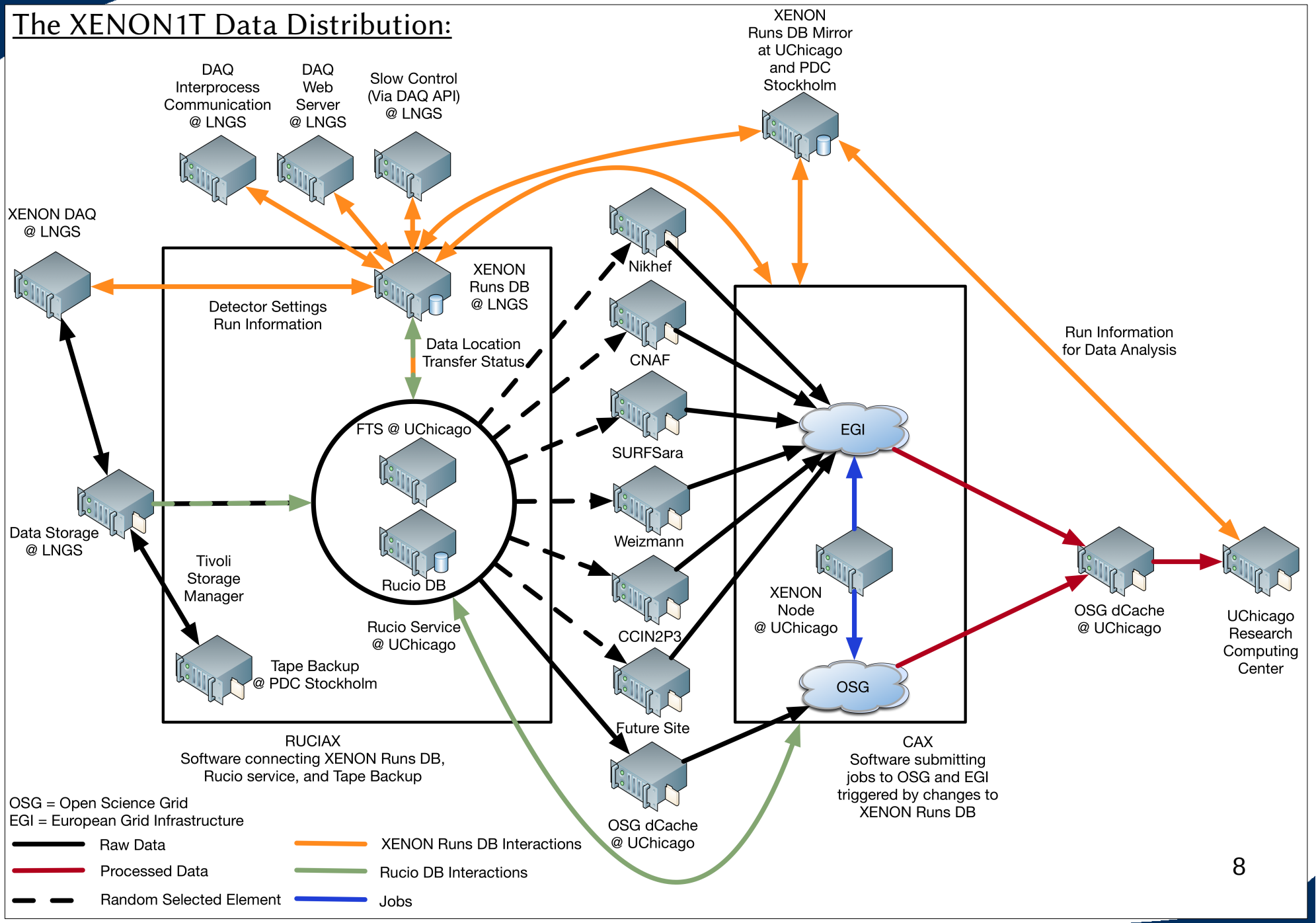
The XENON1T Data Distribution:



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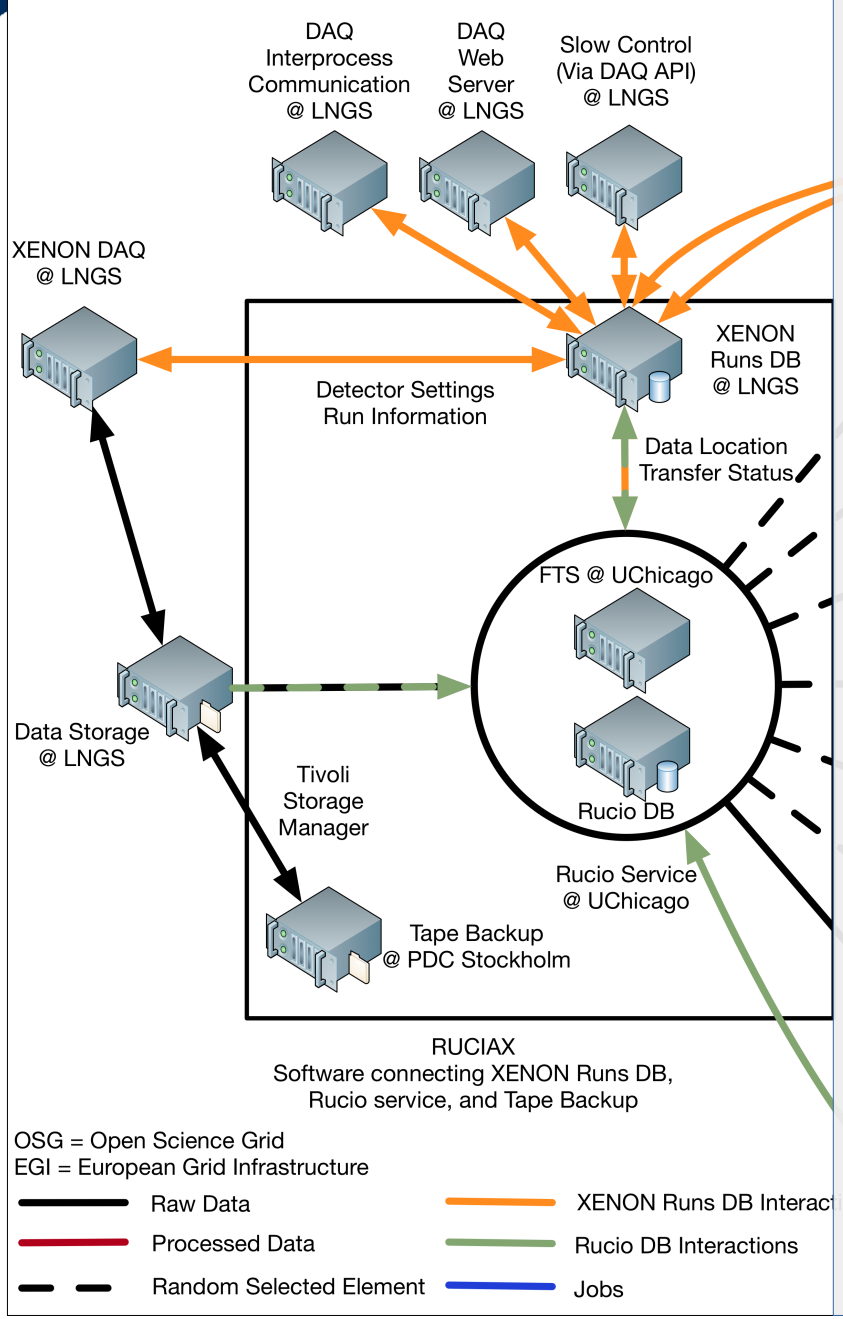
The XENON1T Data Distribution:



A Rucio server (VM) handles raw data transfers to several Rucio Storage Elements (RSE)

But data handling needs: RUCIAX and Rucio:

- Upload and download raw data
  - Uploads run from LNGS only
  - Analysts download small junks of raw data
    We "hide" Rucio command line interface from analysts
- Set and change transfer rules for many raw data sets if necessary
- Update the XENON runDB (@LNGS) regularly
- Remove uploaded raw data from LNGS data storage

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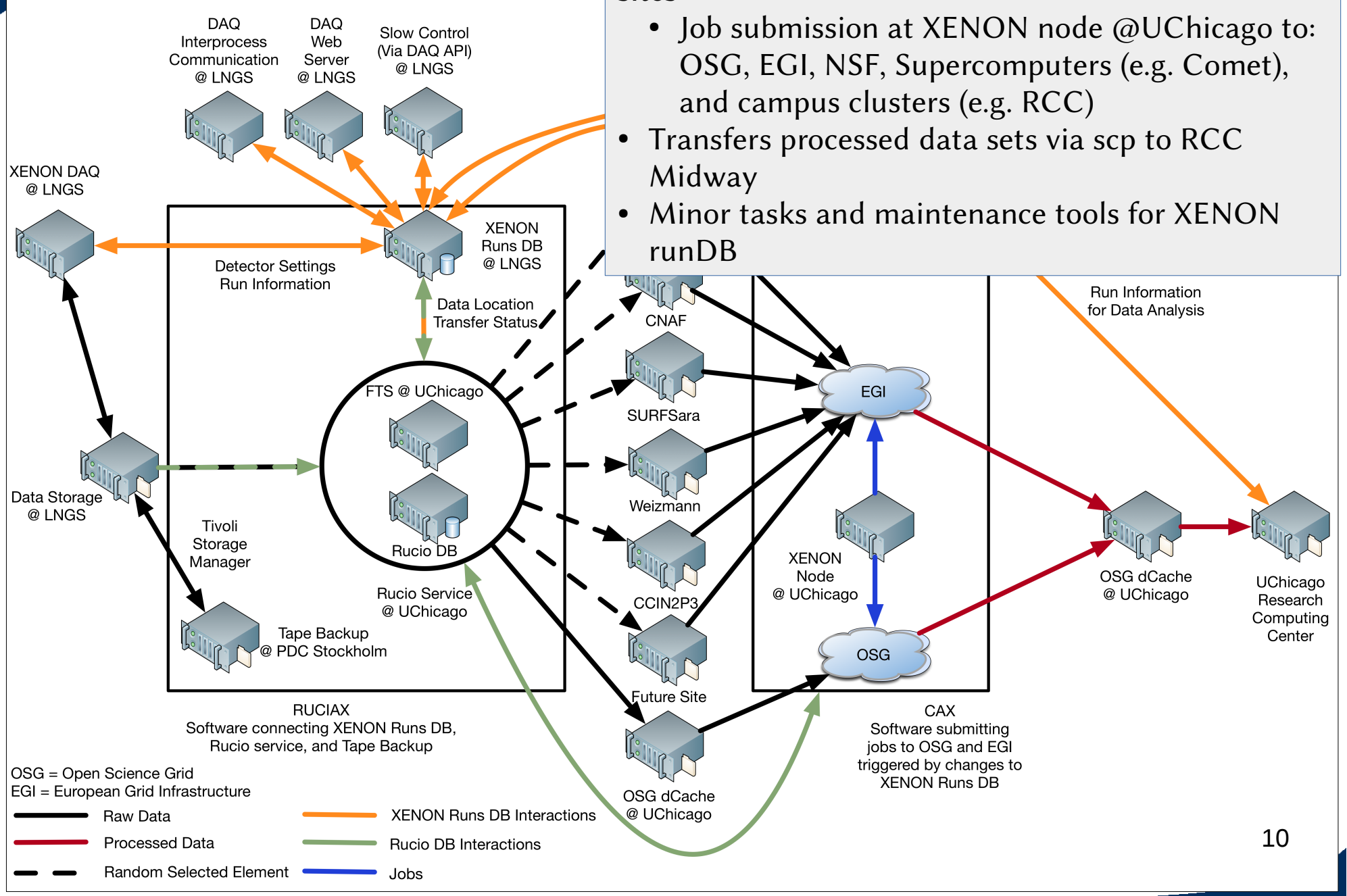
CAX (several tasks):

Allows to handle several and different tasks on many sites:

- Job submission at XENON node @UChicago to: OSG, EGI, NSF, Supercomputers (e.g. Comet), and campus clusters (e.g. RCC)
- Transfers processed data sets via scp to RCC Midway
- Minor tasks and maintenance tools for XENON runDB

The XENON1T Data Distribution:



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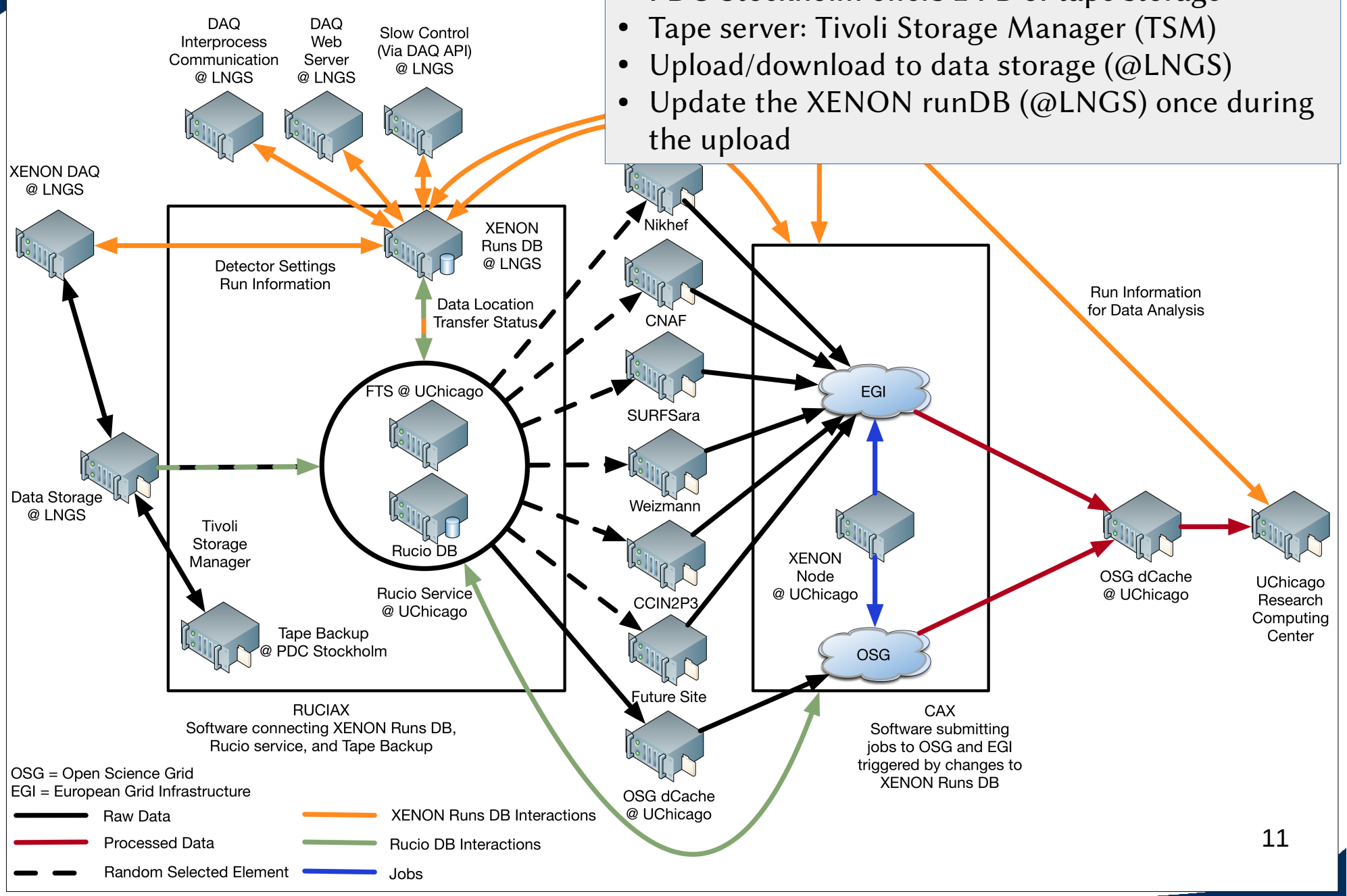
CAX-TSM:

Handles the tape backup with PDC Stockholm

- PDC Stockholm offers 2 PB of tape storage
- Tape server: Tivoli Storage Manager (TSM)
- Upload/download to data storage (@LNGS)
- Update the XENON runDB (@LNGS) once during the upload

The XENON1T Data Distribution:



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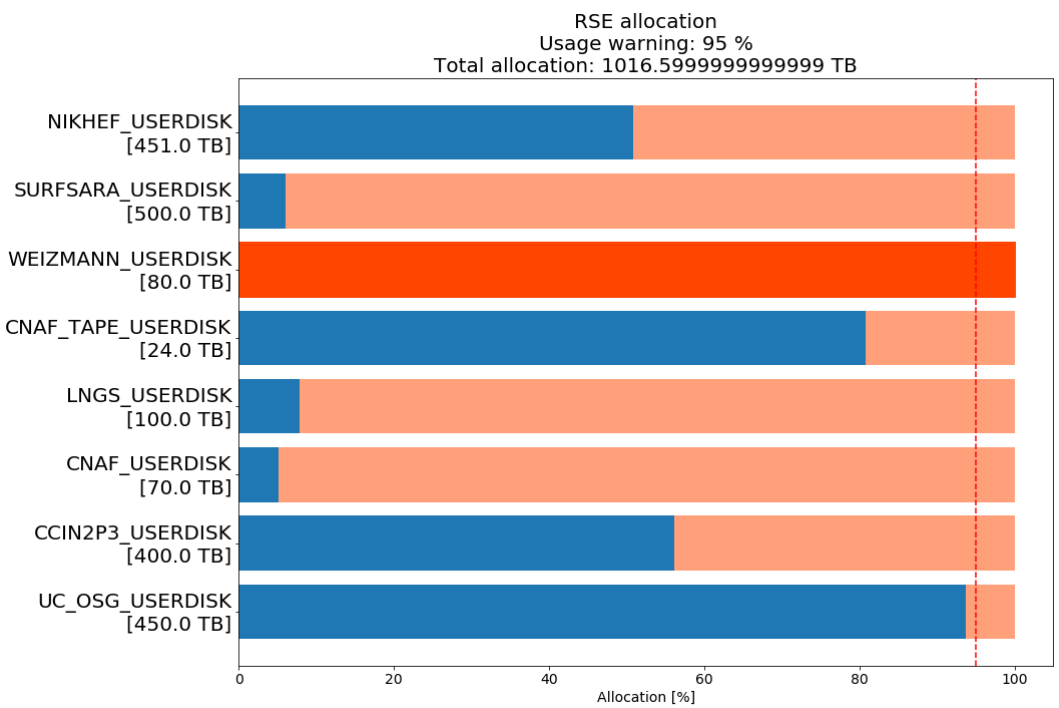
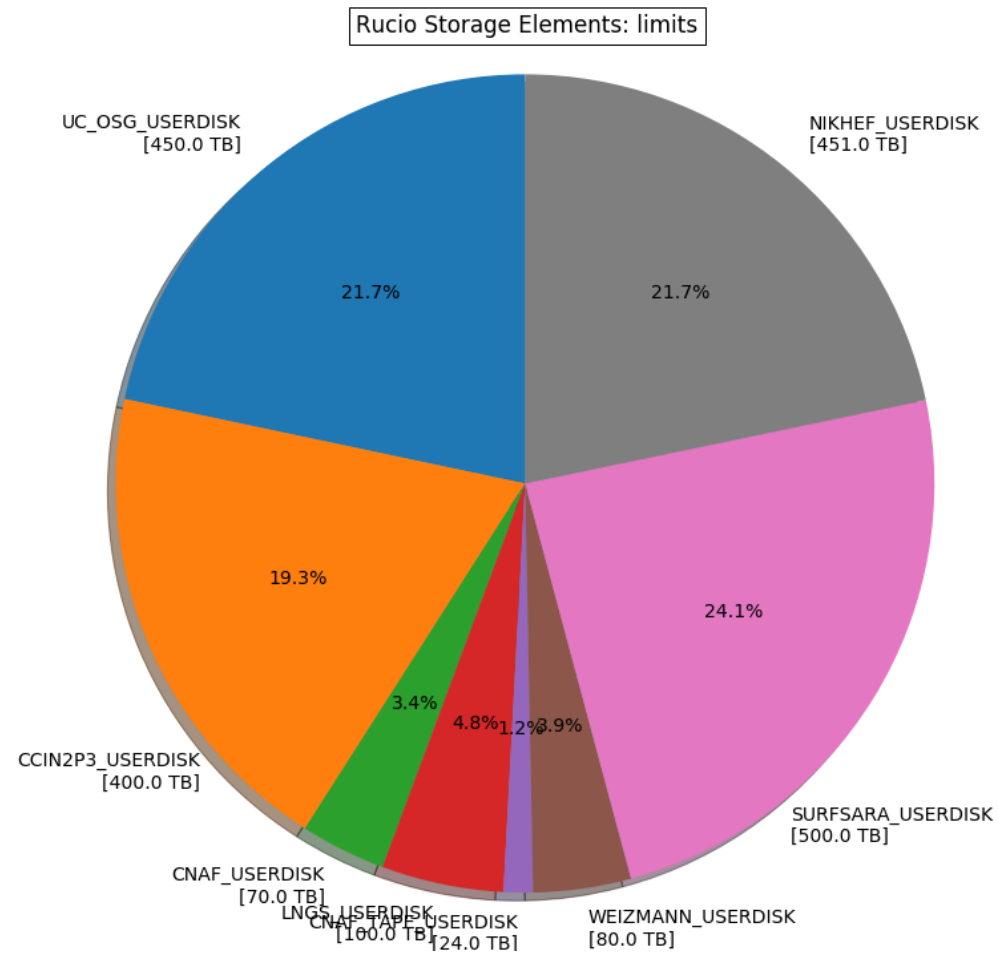
The XENON1T Disk Allocation and Requirement

- Data have two copies:
  - US: OSG dCache at UChicago (hold only relevant data)
  - Europa: One of several computing centers
- Tape copy in Stockholm
  Independent from Rucio





- In total: ~2 PB available
- Distributed worldwide
- Connected to computing centers

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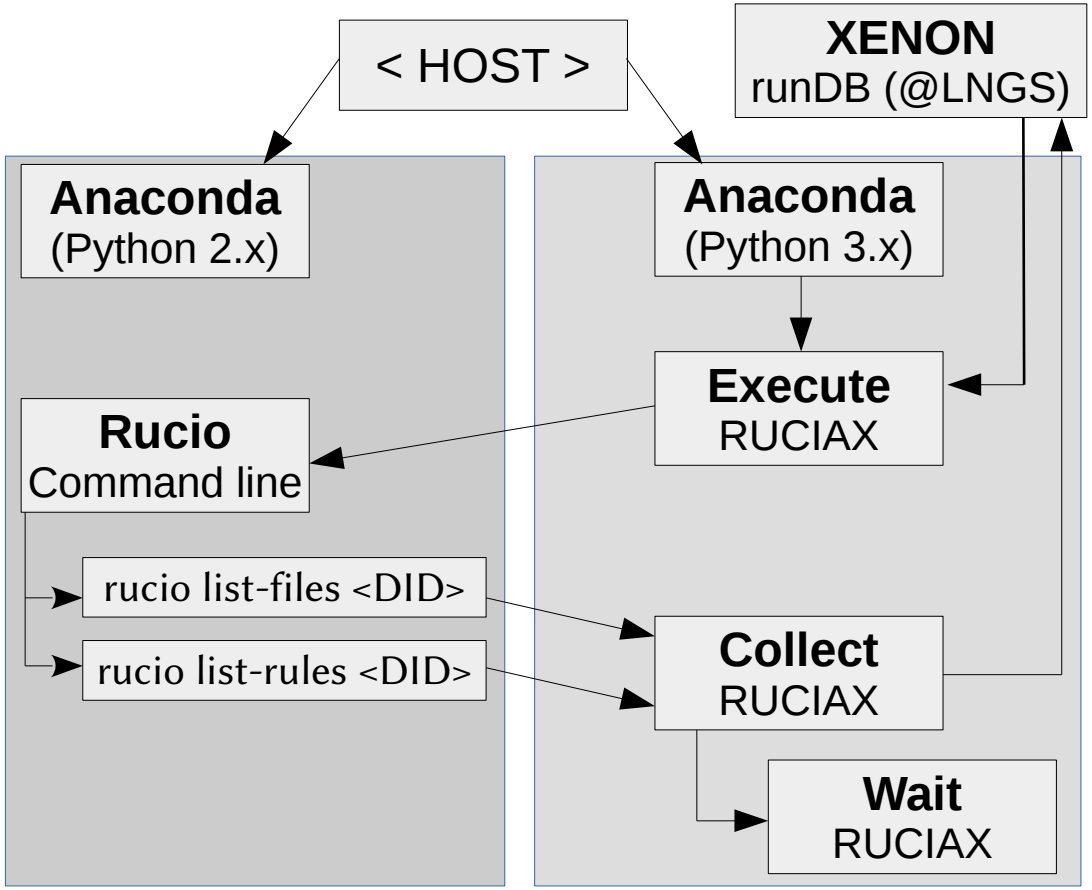
The Toolbox

RUCIAX, CAX, CAX-TSM are

- Part of the same toolbox CAX (Github)
  -> Several experts develop different parts
- Serve different purpose based on "tasks" (CAX) or applications (RUCIAX, CAX-TSM)
- Language: Python 3.x

We needed to overcome the "language barrier" to talk to Rucio with RUCIAX



Several configurations but:

- Mounted: cvmfs at several hosts to provide all our software tools
- Anaconda manages different Python versions
- Offers: CAX, RUCIAX, CAX-TSM, Rucio

For example:
RUCIAX is executed to update XENON runDB locations

Heavy usage of Rucio command line interface (CLI)

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The XENON1T Data Acquisition

The XENON runDB (@LNGS) keeps track on meta information:

- Trigger information
- Time stamps
- Source
- Data locations and transfer status
- …

A web interface allows us to check for:

- Data transfers status (Rucio and non-Rucio)
- Data processing status

Storage | Comments | JSON

Raw data

xe1t-datamanager

Type: raw **Status:** transferred
Location: /data/xenon/raw/180224_0427

tsm-server

Type: raw **Status:** transferred
Location: /data/xenon/tsm/180224_0427

rucio-catalogue

Type: raw **Status:** transferred
Location: x1t_SR001_180224_0427_tpc:raw [LNGS_USERDISK, UC_OSG_USERDISK]

Processed data

login

Type: processed **Status:** transferred
Pax version: v6.8.0
Location: /xenon/xenon1t_processed/pax_v6.8.0/180224_0427.root

midway-login1

Type: processed **Status:** transferred
Pax version: v6.8.0
Location: /project2/lgrandi/xenon1t/processed/pax_v6.8.0/180224_0427.root


```
{
    "location": "x1t_SR001_180224_0427_tpc:raw",
    "checksum":
    ":1204afbb:aaddddb3:b0cfa37c:3f5648b7:6a16339
    "creation_time": {
        "$date": 1519452310627
    },
    "status": "transferred",
    "host": "rucio-catalogue",
    "rse": [
        "LNGS_USERDISK",
        "UC_OSG_USERDISK"
    ],
    "type": "raw",
    "rule_info": [
        "LNGS_USERDISK:2018-03-01_07:49:03",
        "NIKHEF_USERDISK:STUCK",
        "UC_OSG_USERDISK:valid"
    ]
},
```

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Outlook: XENONnT (I):

We expect a larger data amount:

- Higher data taking rate
- More channels (TPC, MuonVeto, NeutronVeto) NEW

→ **~1.5 PB/year** raw data in XENONnT

Xenon1T	size**	XENONnT	size**	Comments
Raw data	25 GB	Raw data	50 GB → Conservative estimate: --> 4x reduction	Upload to GRID and tape
Processed data	2 GB	Reduced data	12.5 GB	first level processing NEW: • Purge raw data from GRID after successful first level processing • Keep reduced data in Rucio for reprocessing campaigns
Minitrees	22 MB	Processed data	1 GB*	second level processing: Keep processed data in Rucio for minitree creation
		Processed data	11 MB*	Minitrees for the analysts

Changes in PAX, HAX, job submission and bookkeeping

*Assume Xenon1T reduction

** Example numbers for illustration

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Outlook: XENONnT (II):

Update: Software

- Independent tool in Python 2.x to handle:
  - the extended data structure (reduced and processed data in Rucio)
  - RucioAPI instead of CLI
  - the tape storage (CLI for TSM)

- Independent tool for job submission
  - Job submission is adjusted according to reduced and processed data sets

- CAX to handle tasks (similar to XENON1T)

RestAPI for XENON runDB access

Update: Requirement on data safety (& tape)

- Keep latest raw data in Rucio on dedicated tape storage.
- Move older raw data to PDC/Stockholm

Allow quick first level reprocessing if necessary

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Summary:

Successful established:
XENON1T takes still data!

XENON1T:

- RUCIAX, CAX-TSM, CAX as part of the CAX toolbox handling several tasks regarding data management and processing
- Allocated disk space at the moment ~1 PB (multiple copies, 7 RSEs worldwide)

Developments already started

XENONnT:

- Dedicated tools for data management and processing
- The RUCIAX successor will be in Python 2.x (access RucioAPI)
- Independent PDC tape storage will be integrated in tape storage handling on dedicated RSEs
- Data processing is extended by another intermediate step: "Reduced raw data" ⟶ Safe processing time and disk space
- Reduced raw data and processed data will be distributed by Rucio
- PAX, HAX (and more!) tools of XENON1T will be used again

Schedule:
"End of the year"

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Thank you for your attention!

&

Stay tuned: XENON1T announces new results soon:
- Twitter: https://twitter.com/xenon1t
- Blog: https://www.xenon1t.org

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Backup: An overview on our science runs campaigns (average)

Data sets: 17141
Total time: 13748 hours
Total events: 830 M events
Total size: 571 TB

Source	Kr83m	Rn220	AmBe	LED	Th228	Neutron Generator	DM
<Rate> [Hz]	27.75	44.28	9.37	329	51	24	9.83
<Event size> [Mb/event]	0.848	0.68	2.55	0.13	2.97	2.65	1.87
<Events/dataset>	96918	137674	31384	164180	51231	81894	23705
<Size> [MB]	48806	64381	79305	18435	71748	216126	29685
Total size [TB]	40	85	67	30	3	12	332
Total lengths [h]	791	1141	802	245	13	51	10705

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Backup: Details on Processing:

- Raw data sets are organized in zip files of 100 events each
- DAGMan handles job submissions based on single zip files

Run <run number>
- file_001.zip
- file_002.zip
- file_....zip

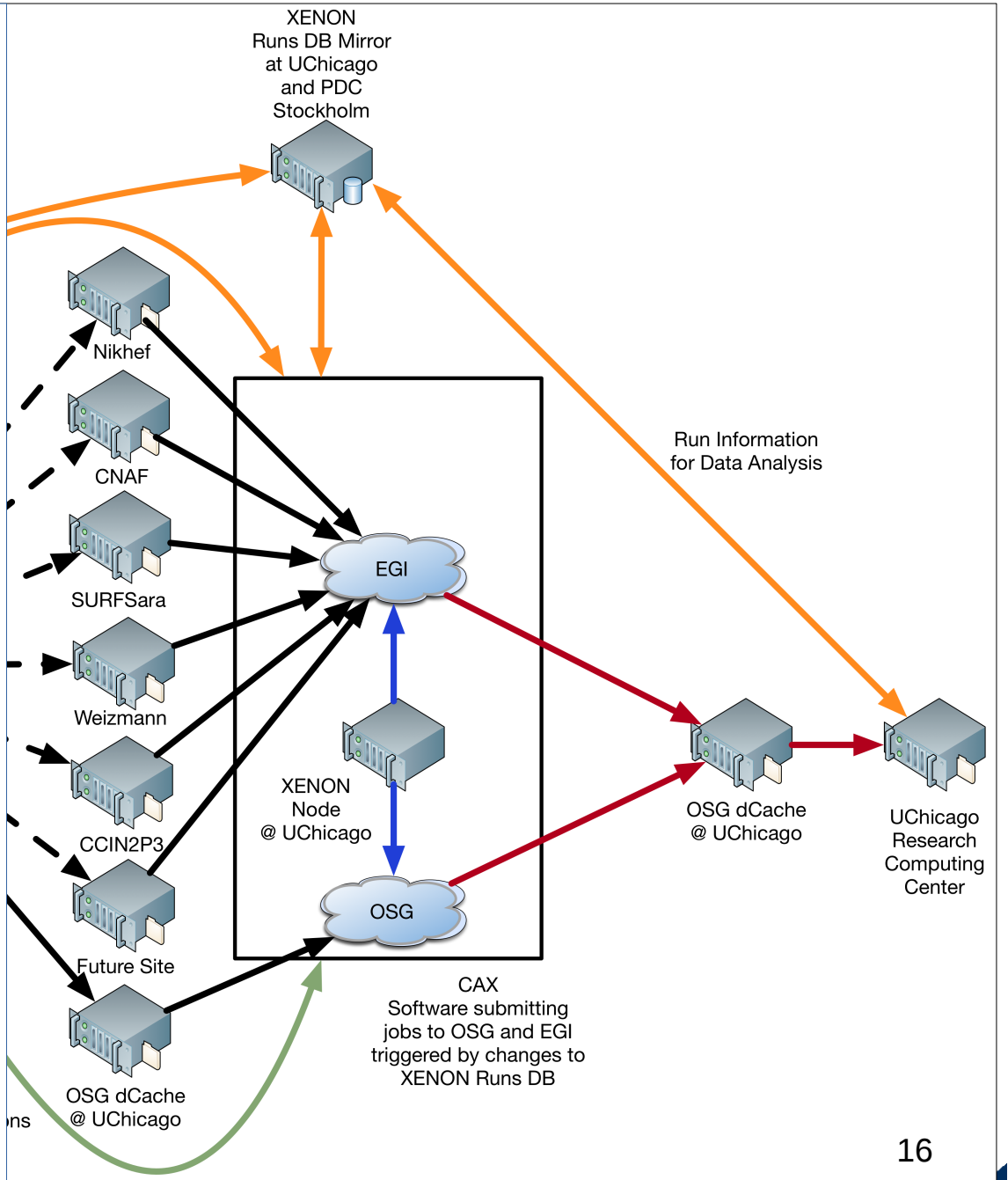
Processing: PAX
At our connected computing centers

OSG worker nodes

Merge

Run <run number>
- file_001.root
- file_002.root
- file_....root

File: run_number.root
- CAX moves it to RCC Chicago
- Create minitrees for analyst



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Backup: XENON1T at the LNGS