DUNE Data Management Experience With Rucio

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For the DUNE Collaboration

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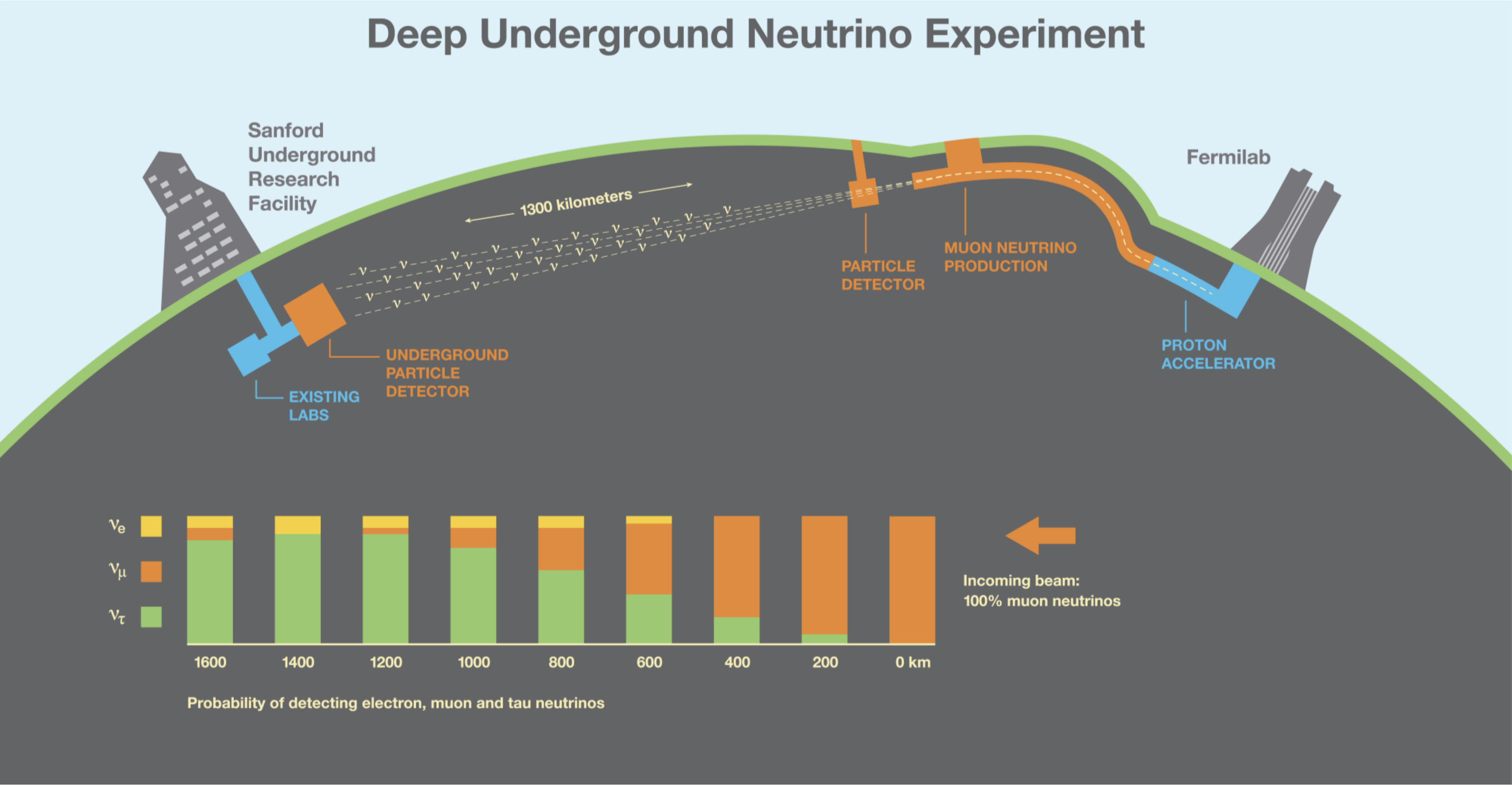
- Description of DUNE Data Model
- DUNE Experience With Rucio
- Plans for Full Rucio-centric Data Management System


Deep Underground Neutrino Experiment
Sanford Underground Research Facility
1300 kilometers
Fermilab
PARTICLE DETECTOR
MUON NEUTRINO PRODUCTION
PROTON ACCELERATOR
UNDERGROUND PARTICLE DETECTOR
EXISTING LABS
ν
ν_e
ν_μ
ν_τ
1600
1400
1200
1000
800
600
400
200
0 km
Incoming beam: 100% muon neutrinos
Probability of detecting electron, muon and tau neutrinos

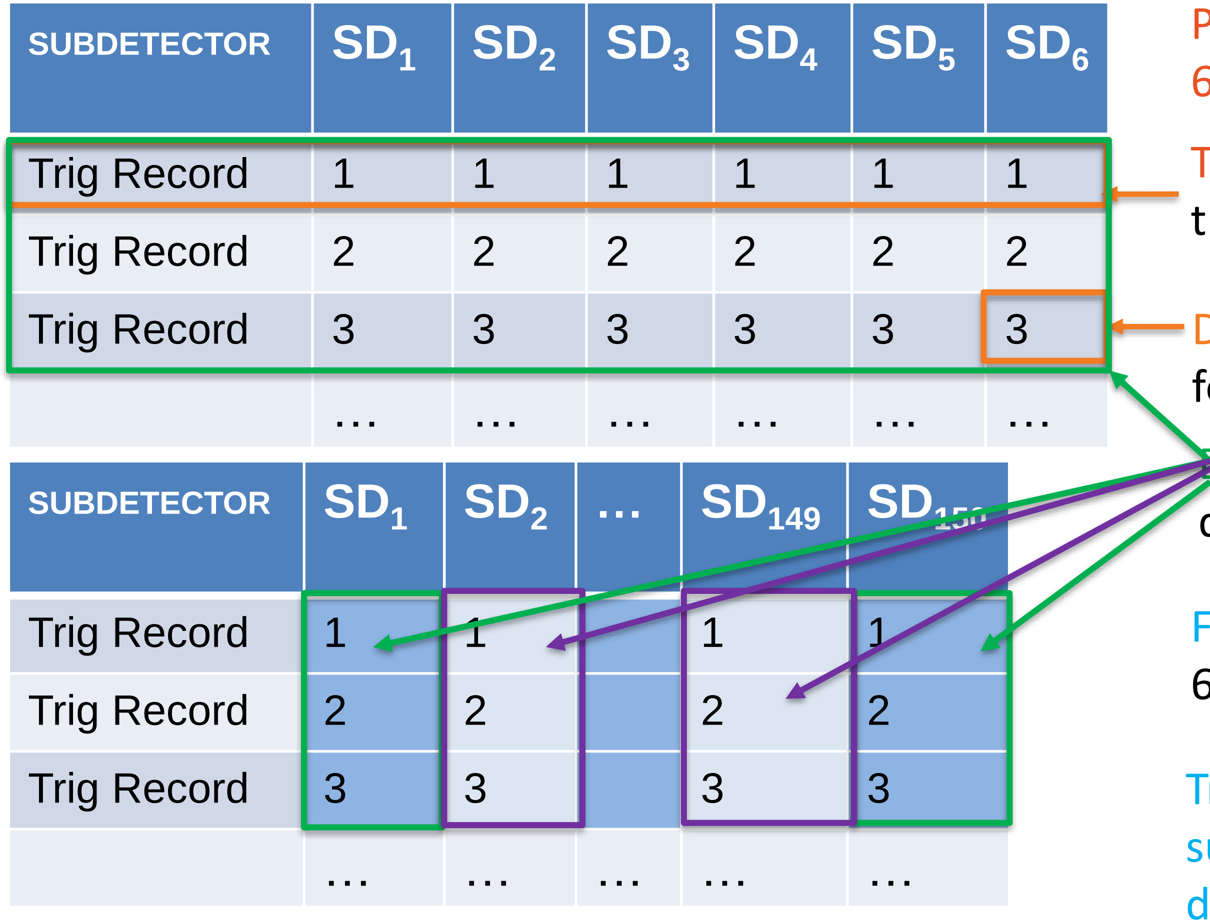
What is Rucio

- Data Management software developed originally by ATLAS experiment
- Other large scientific collaborations (CMS, LSST, DUNE among others) have picked it up.
- Rule-based declarative system-–tell it where you want the data and Rucio will get it there
- Uses FTS3 for file transport
  - Can also use Globus Online

DUNE Data Management Currently

- Two ProtoDUNE detectors at CERN, each 5% of full detector size
- ~10 PB of data accumulated thus far
  - Roughly half raw data, half reconstruction output products, small amount of MC. Event size ~60MB
- 36 compute sites around the world
- 13 disk only sites, 4 disk+tape sites.
- Data streamed via xrootd from the closest location.
- Very similar to other experiments that use the grid.

DUNE Data Terms



SUBDETECTOR	SD_1	SD_2	SD_3	SD_4	SD_5	SD_6
Trig Record	1	1	1	1	1	1
Trig Record	2	2	2	2	2	2
Trig Record	3	3	3	3	3	3
	…	…	…	…	…	…

SUBDETECTOR	SD_1	SD_2	…	SD_{149}	SD_{150}
Trig Record	1	1		1	1
Trig Record	2	2		2	2
Trig Record	3	3		3	3
	…	…	…	…	…

ProtoDUNE 6 subdetectors
60 MB compressed

Trigger record: Output of the DAQ for a single trigger

Data Unit: 1 Subdetector for 1 trigger record

Data Object: Collection of data units

Full DUNE: 150 subdetectors
6GB/readout (5 ms)

Trigger records will be split by subdetector across many different data objects.
The MANIFEST tells us what is where.

Unique DUNE data challenges

- Subdetectors from the same *trigger record* may end up in multiple files
- Time slices from the same *trigger record* may end up in multiple files.
- In case of supernova burst readout we will have to split both by subdetector and by time slices, and get it out fast.
- Exploring the HDF5 format to store the data
- Exploring non-file-based object stores in general.
- DUNE far detector output 30PB per year, plus more from near detector
- Working with signed JSON Web Tokens (JWT) for authentication.

Rucio Care and Feeding

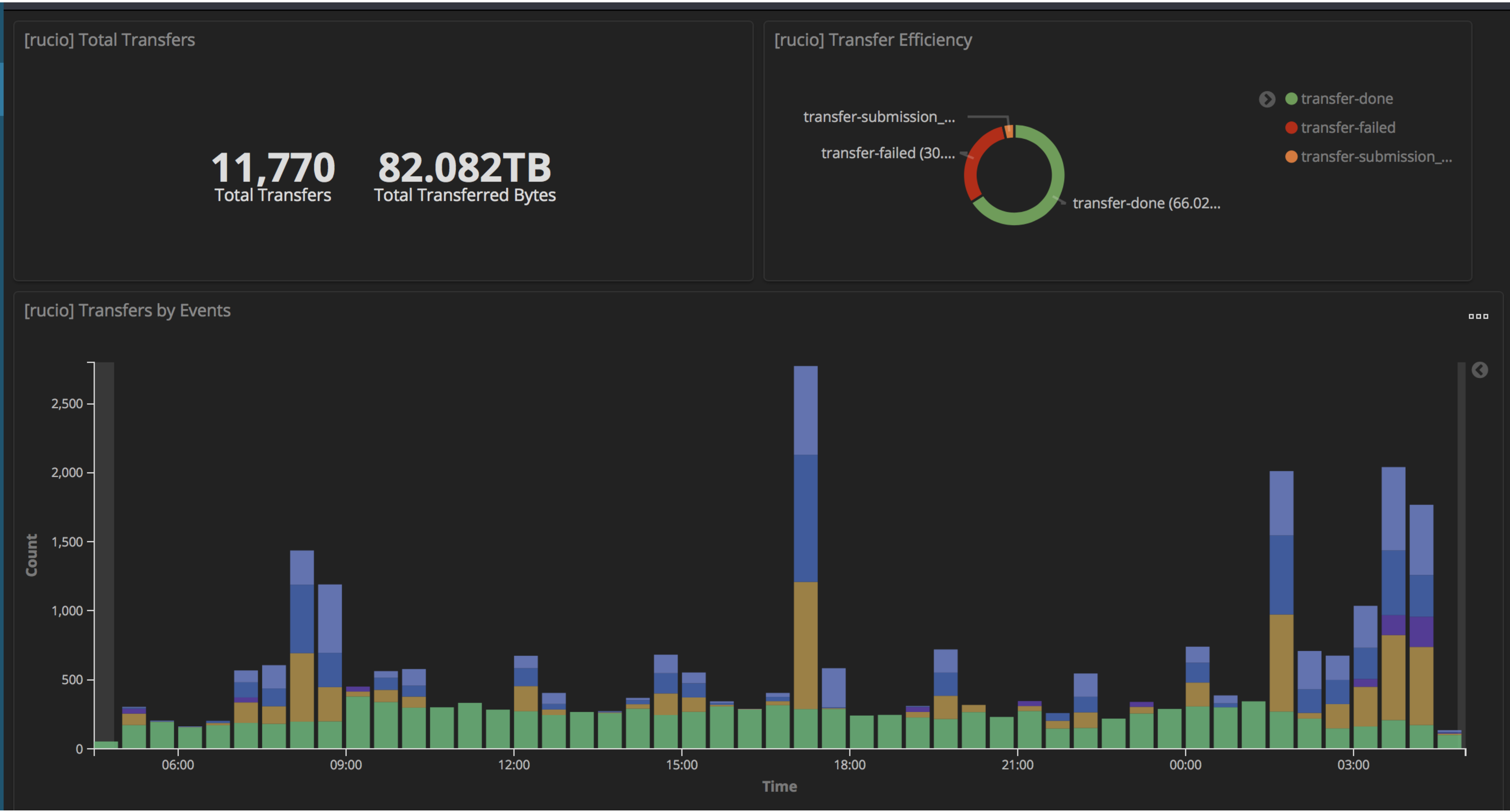
- DUNE has been running Rucio since Fall of 2018.
- Fermilab Scientific Data Storage Dept.
  - Rucio server deployed as a containerized application
  - soon to change to deployment on Fermilab's OKD cluster
    - Use shared Helm configuration to configure the various containers
  - Using Postgres DB on back end
  - Manages all schema and software upgrades.
- DUNE Data Management Team
  - Rucio clients to move data from point A to point B. (asking for help if things get stuck)
  - Creation and declaration of new Rucio replicas
  - Onboarding new remote Rucio storage elements
  - Interaction with remote sites for transfer

Current Rucio status:

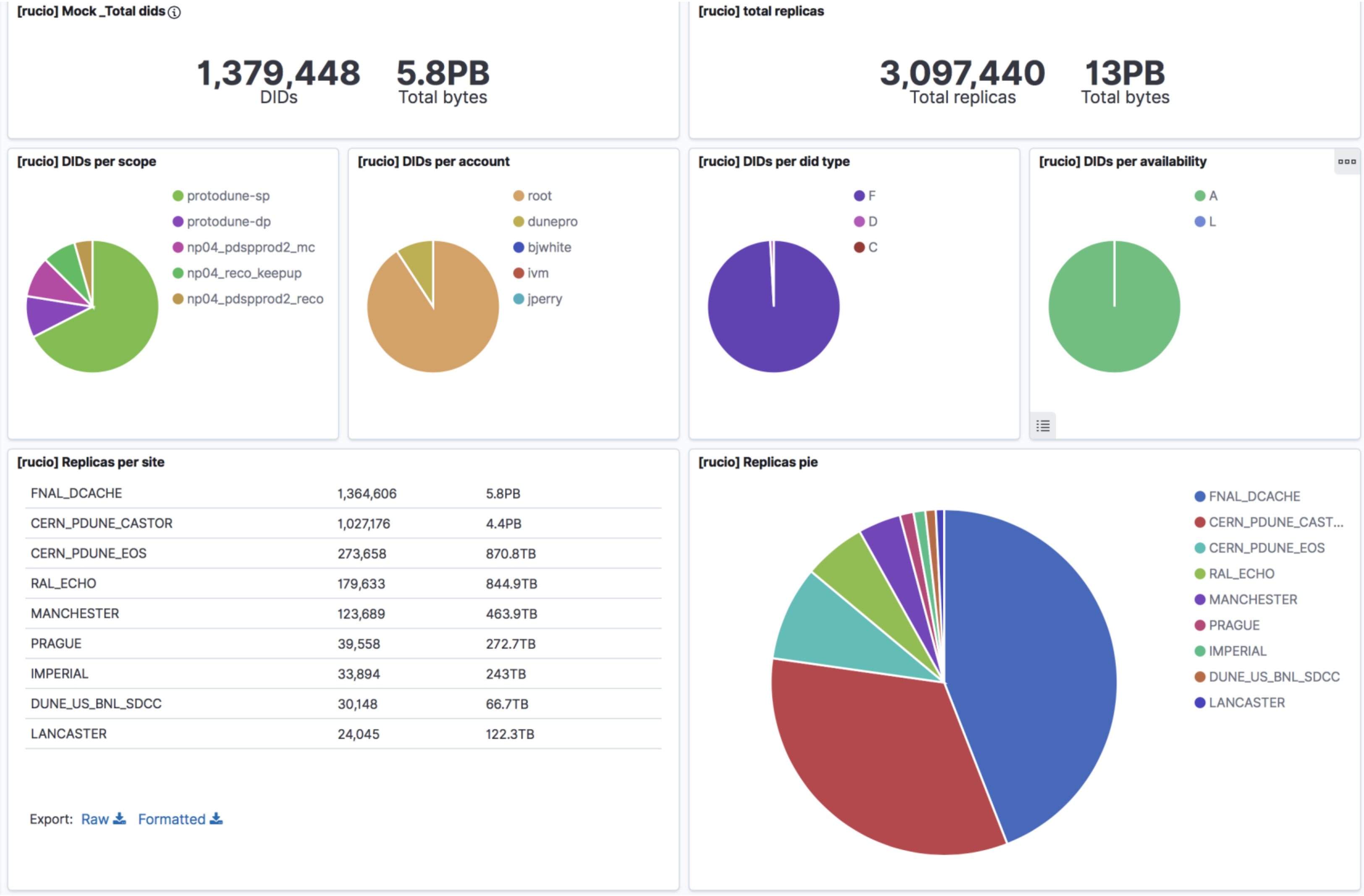
- Ingest of ProtoDUNE raw data still done with legacy system.
- Legacy system gets data from CERN EOS to CERN Castor and FNAL dCache/Enstore Tape
- Declared to Rucio once it gets to Fermilab
  - One dataset per run, Large containers of related data sets
  - Different detector types are different scopes
    Rucio is used to send it everywhere else.
- Rucio is also used to manage limited disk space on CERN EOS
- We use legacy system to tell us what it is, and where it is
  - (But not for much longer)
- We have 17 commissioned Rucio Storage Elements (RSE)
- 13 PB under Rucio management, 1379448 DID’s, 3097440 replicas as of 20 July 2020.

Monitoring: Transfers

- Rucio Kibana Monitoring. Shows queued, failed, submitted, done.



Monitoring: File size and location



[rucio] Mock _Total dids ⓘ

1,379,448 DIDs

5.8PB Total bytes

[rucio] total replicas

3,097,440 Total replicas

13PB Total bytes

[rucio] DIDs per scope

[rucio] DIDs per account

[rucio] DIDs per did type

[rucio] DIDs per availability

[rucio] Replicas per site

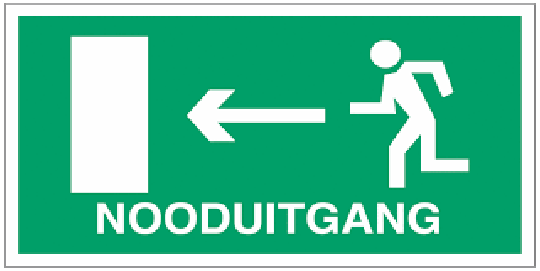
FNAL_DCACHE	1,364,606	5.8PB
CERN_PDUNE_CASTOR	1,027,176	4.4PB
CERN_PDUNE_EOS	273,658	870.8TB
RAL_ECHO	179,633	844.9TB
MANCHESTER	123,689	463.9TB
PRAGUE	39,558	272.7TB
IMPERIAL	33,894	243TB
DUNE_US_BNL_SDCC	30,148	66.7TB
LANCASTER	24,045	122.3TB

Export: Raw Formatted

[rucio] Replicas pie

Use Case: Vacating a Storage Element

- Given notice we had to get ~500TB off of a storage element
- Had 1 month notice initially.
- All of data in question was data that existed in at least one or two other places
- Used rucio list-dataset-replicas to
  - Identify which datasets were there now.
  - Identify at least one other site where that dataset is *not*
- Then make one rule per dataset (886 datasets in all)
- And sit back and wait.
- Transfers were kicked off on 23 Jan, finished on 1 Feb.
- And then we learned we really had 6 months to get out



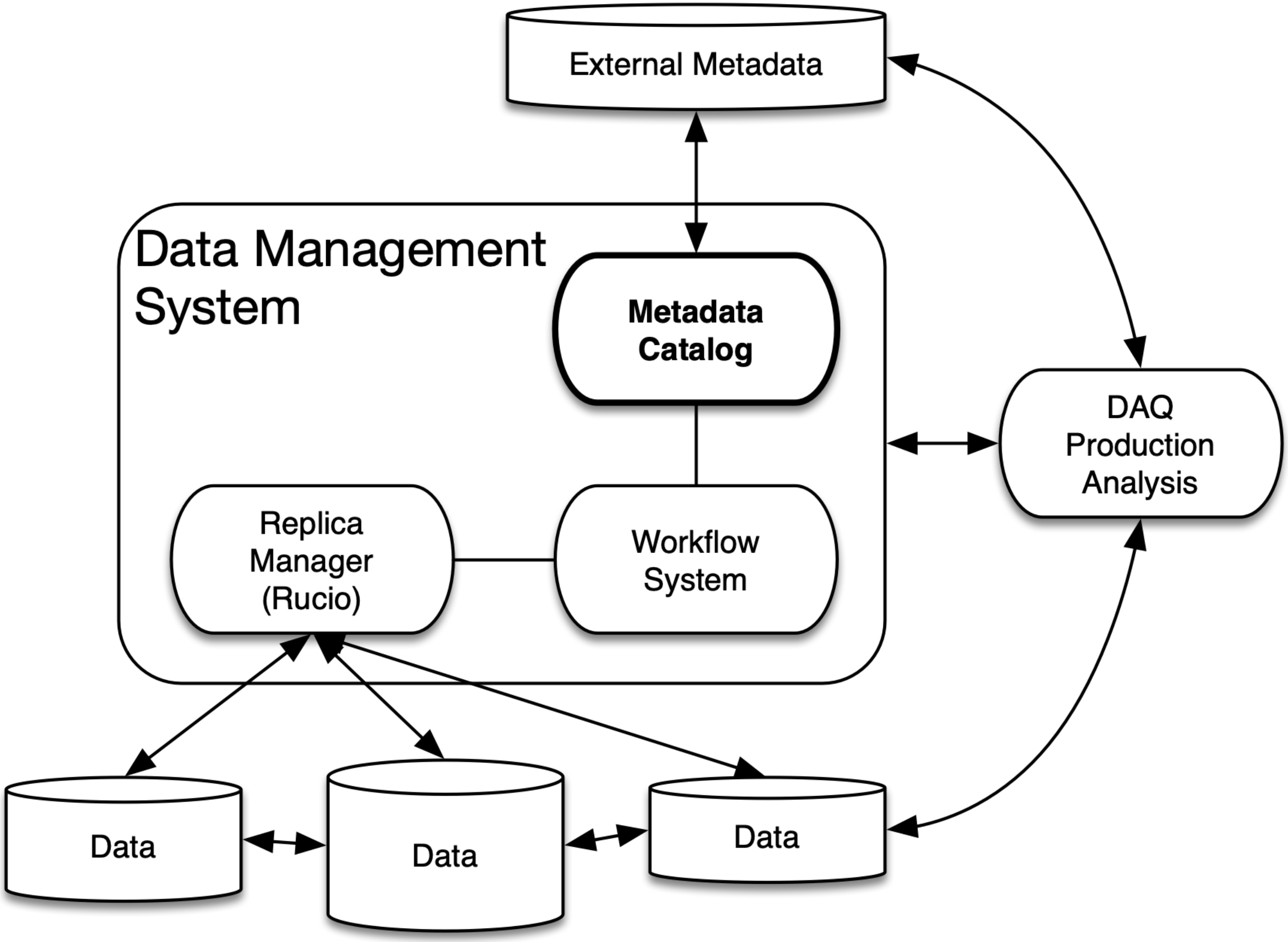
Rucio features we know we need

- Quality of Service
  - Better way to know when a file is online or on tape.
  - Detection of condition when Fermilab dCache has the file in online storage and prefer that as a source.
- Deterministic vs. non-deterministic
  - “Deterministic” is for disk sites—files stored in a hashed path
  - “Non-deterministic” used on tape sites—human-readable path constructed from metadata fields
    - Pending a new feature to serve the path to Rucio.
- Lightweight client for REST API
  - Stock client has lots of dependencies

Changes needed to use Rucio in reco/analysis workflow

- We are using Rucio for data movement
  - Need to change our data delivery system so we use the Rucio file location info—and use Rucio to deliver the file location.
- Need to replace 3 main functions of monolithic legacy system
  - Replica manager (Where is the file)-> Rucio
  - File Provenance (Metadata)
  - Data Delivery / project tracking
- Three projects needed to get there:
  - New Data Ingest service replacing legacy data transfer system.
  - New Metadata service replacing legacy metadata “MetaDB”
  - New Data Delivery Client service for workflow management

DUNE Data Management Architecture



External Metadata

Data Management System

Metadata Catalog

DAQ Production Analysis

Replica Manager (Rucio)

Workflow System

Data

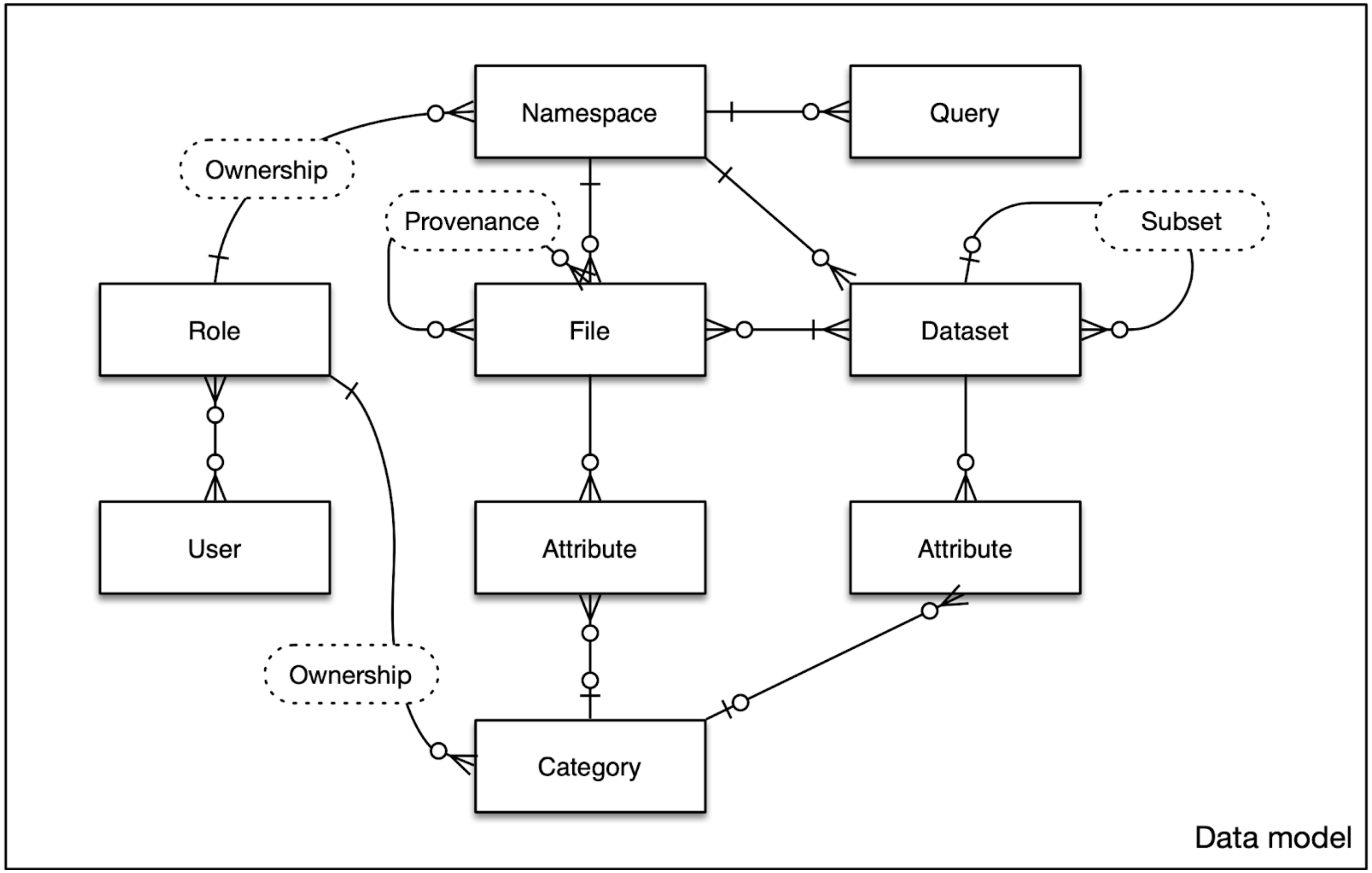
Data

Data

Data Ingest

- Still in planning phase
- Replace legacy system with:
  - Process that scans the newly created files on the DAQ buffer disks
  - @ ProtoDUNE, Far Detector(s), Near Detector
- Declare file location to Rucio, metadata to metadata service
- Use FTS3 to do 3rd party transfer to FNAL and from FNAL to elsewhere, under Rucio control.

Metadata Server: MetaDB



Data model

- Metadata sets very similar to Rucio model
- Requirements are complete
- Reference implementation in testing

Data Delivery / Workflow Management

- Users are used to :
  - Defining a dynamic data set
  - Running a project across the whole data set:
    - Each job says “give me the next file”
    - Each job notifies the project manager when it’s processed successfully.
    - Recovery jobs can be generated.
- Rucio has fixed data sets.
  - Some important ones we will declare “immutable”
  - Others we will declare “monotonic” to which you can add but not delete
- Metadata server API will allow queries of the metadata plus user callouts to the conditions database.
- “Workflow Management” in this case is very low level—much simpler than Dirac or WMAgent for instance. DUNE will eventually choose a higher level workflow manager which interfaces to this.

Conclusions:

- Rucio is working well for DUNE to date
- No known issues keeping us from scaling up to full DUNE
- Goal to have Rucio-centric data management in place by next run of ProtoDUNE (ProtoDUNE II) early 2022
- Thanks to Rucio core developers, site admins all over the world, and DUNE Data Management team.