CTAO
Cherenkov Telescope Array Observatory

Production System Status and Development

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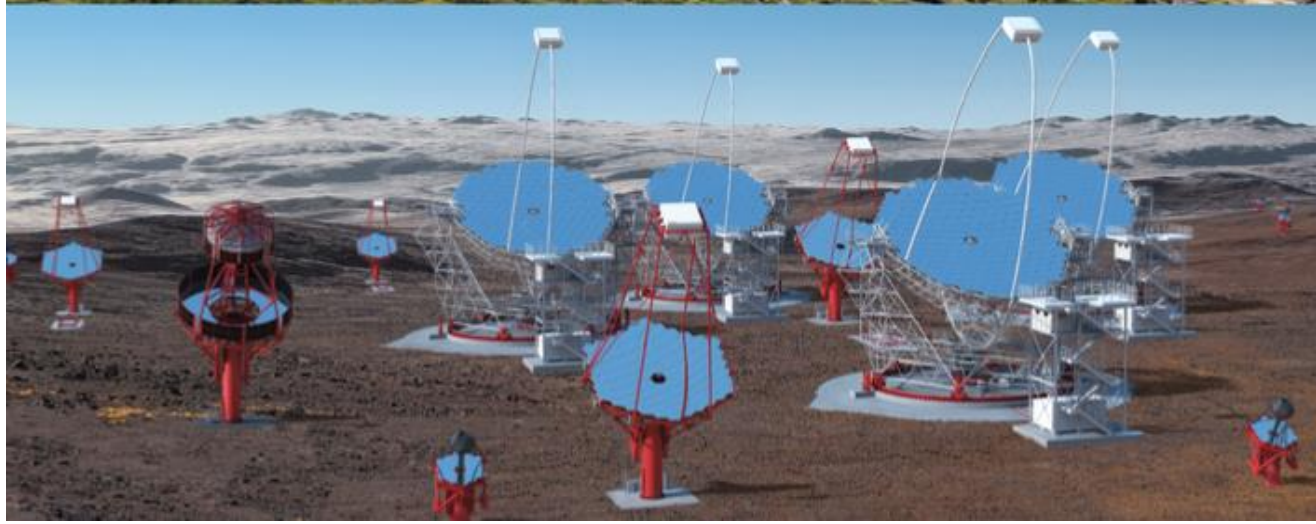
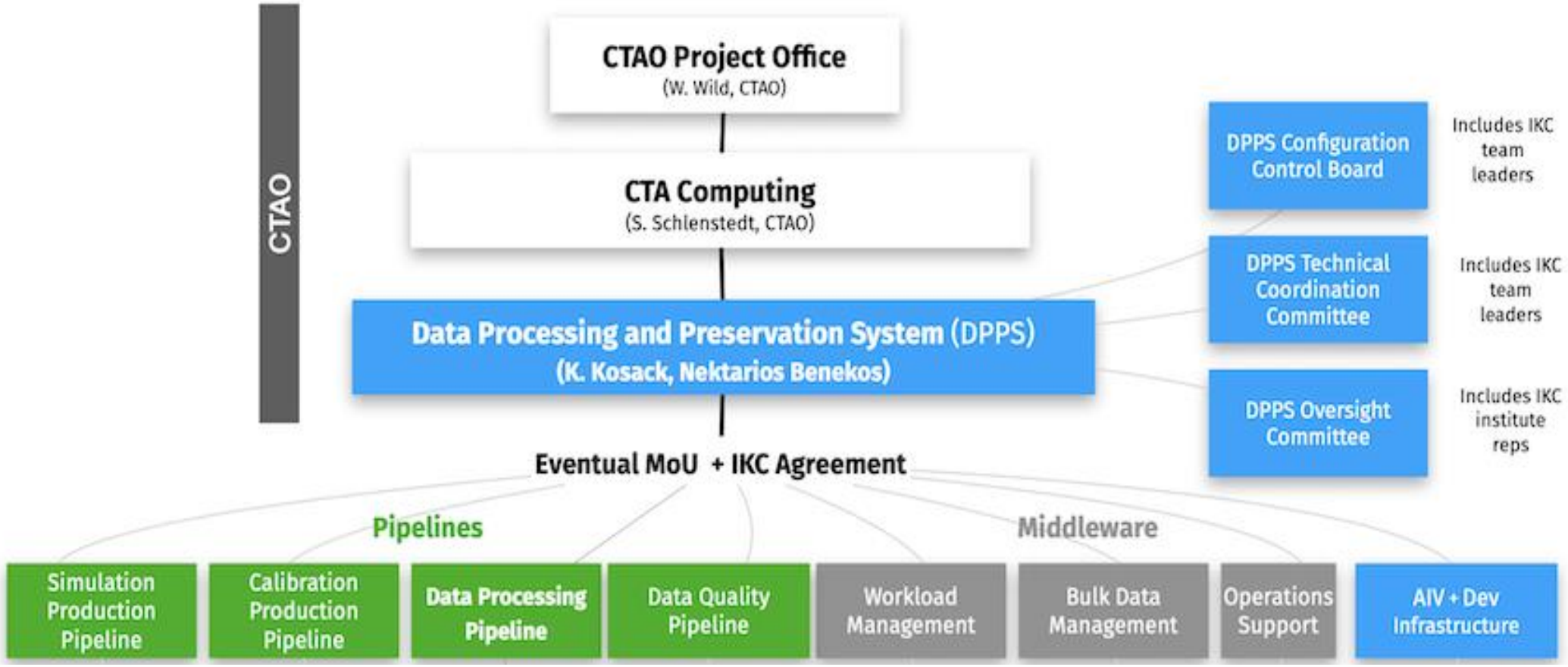
The Cherenkov Telescope Array Observatory

- The next generation **ground-based** observatory for **gamma-ray astronomy** at **very high energy**
- **64 telescopes** located on **two sites**
- Operations expected to start in **2030**
- Observe **extreme cosmic events**:
  - supernovae, neutron stars, black holes …
  - Transient phenomena: Gamma Ray Burst



Paranal (ESO), Chile (South Site)

CTAO Computing Organisation

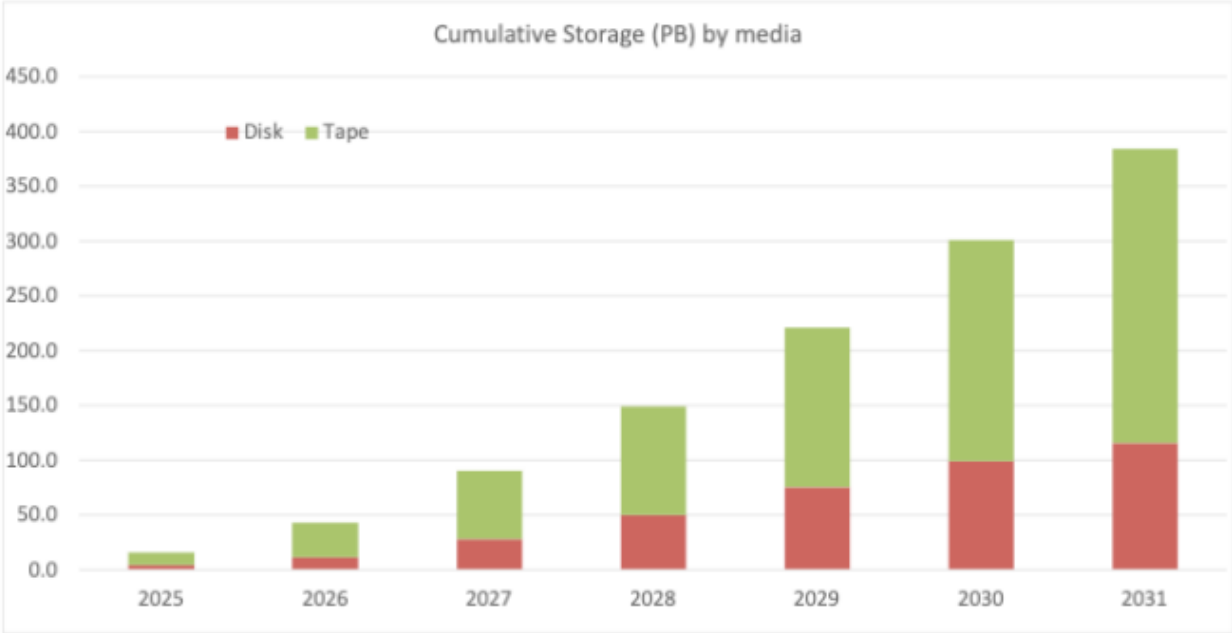


CTAO Computing Model

CTAO will use a ***distributed computing*** **model** using **4 official CTAO Data Centers**:

- CSCS, Lugano (Switzerland)
- DESY, Zeuthen (Germany)
- INAF/INFN, Frascati (Italy)
- PIC, Barcelona (Spain)

Computing resources are expected to grow accordingly.



Year	2025	2026	2027	2028	2029	2030	2031
Annual wall time for simulations (MHS06.hr)	562	562	733	733	733	733	733
Annual wall time for Data pipeline (MHS06.hr)	2	9	15	26	33	35	35
Annual wall time for data reprocessing - one per year (MHS06.hr)	0	283	573	954	1346	1746	2147
Total (MHS06.hr)	564	854	1321	1713	2113	2514	2915
Average Number of cores	3219	4874	7538	9778	12058	14348	16638

Figures from CTAO Swiss Days 2024, Igor Oya, ACADA coll.

DIRAC

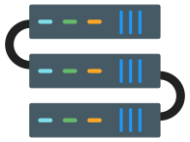
DIRAC is an **open-source** software, first developed for **LHCb**, now a **broad community** uses and contributes to its development.

It is a complete **grid solution** to access **ditributed** and **heterogeneous resources** for computing and storage.

Users

DIRAC
THE INTERWARE

Resources:
Grid, Batch, Cloud, HPC, ...



CTAO usage of DIRAC

CTAO has been using **DIRAC** since 2011 as **Workload Management System**, for **simulations** and **data processing** on the grid.

CTAO is **contributing** to the **DIRAC core development** of the **"Production System".**

A DIRAC software **extension** is currently being developed, called **CTA-DIRAC.**

CTAO Computing Infrastructure

We run **CTA-DIRAC** prototype on CTAO **infrastructure**:

- **DIRAC services** and **databases** deployed on 10 VMs distributed on 3 sites CSCS, DESY-ZN and PIC
- Configured to submit on the **4 official CTAO Data Centers**
- Currently used for **running** MonteCarlo **simulations**
- **OpenSearch** server, providing **Kibana/Graphana** dashboards for monitoring

CTAO Computing Infrastructure

CTAO **Test Cluster**:

- provides **VMs** and a **Kubernetes** cluster
- used to test **deployment** and **integration** of the subsystems:
  Data Management (Rucio), **Pipelines** (Simulations, Calibration, Processing, …) and
  Workload Management (DIRAC)
- A **Docker Compose pipeline** in **Gitlab CI** is developed, it is currently running WMS–BDMS (DIRAC-RUCIO) integration

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DIRAC workflow management is based on the **Transformation** and **Production systems.**

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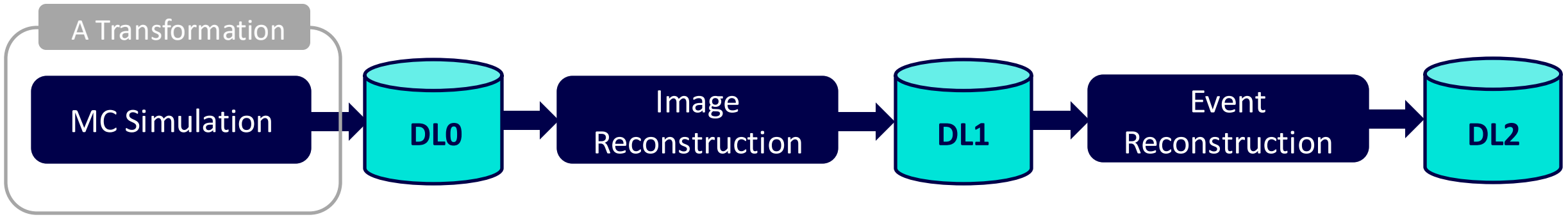
- A **Transformation** is a set of similar tasks applied to a specific set of data
  - **Tasks description** template and rules
  - **Query on metadata** to select input/output data



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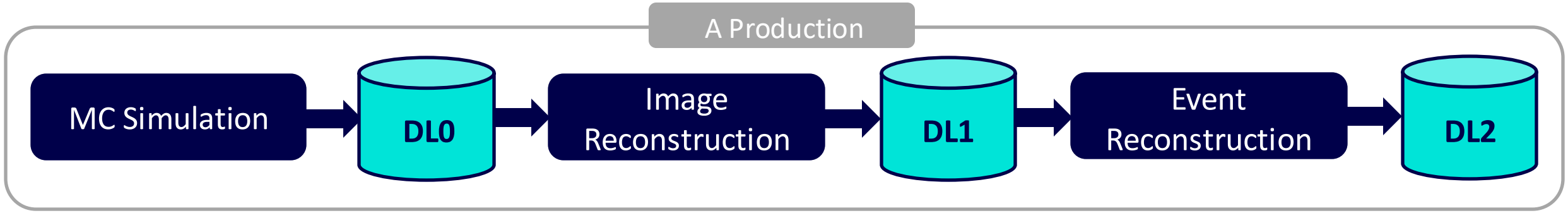
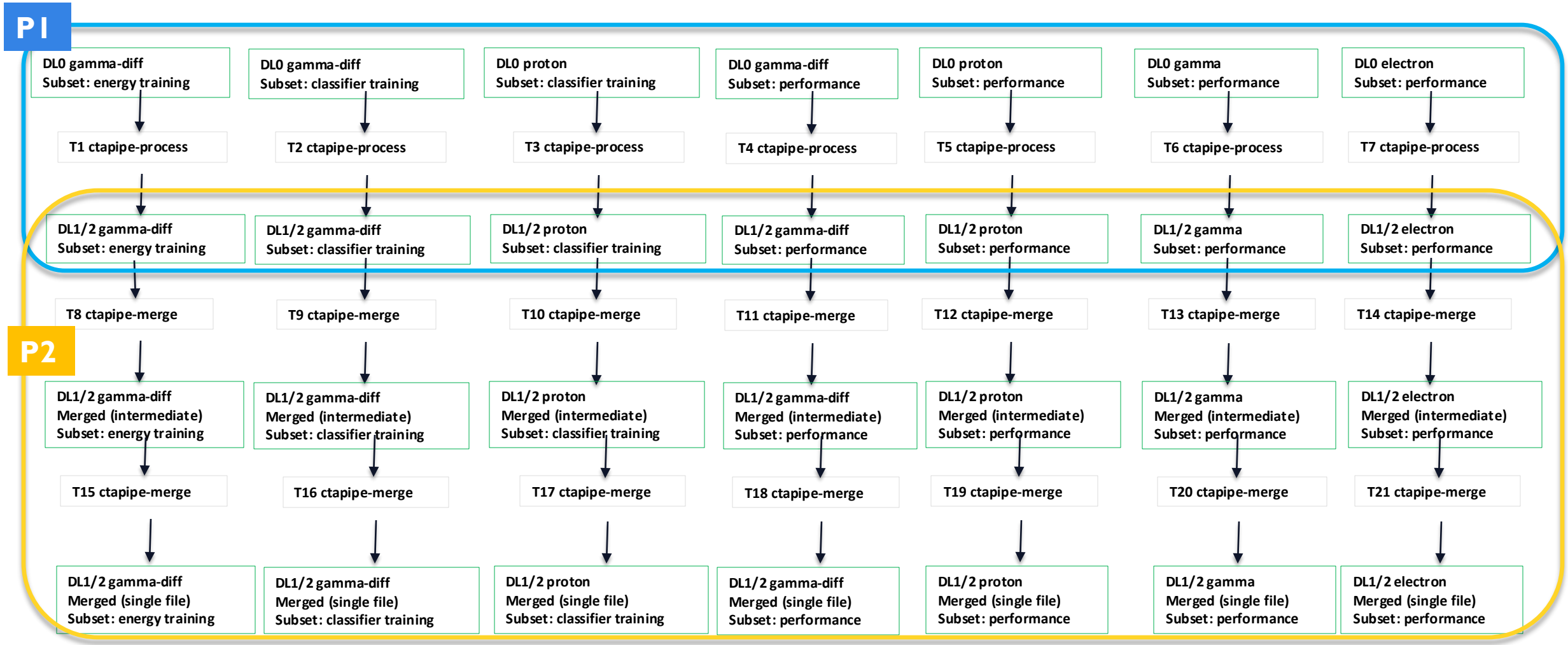
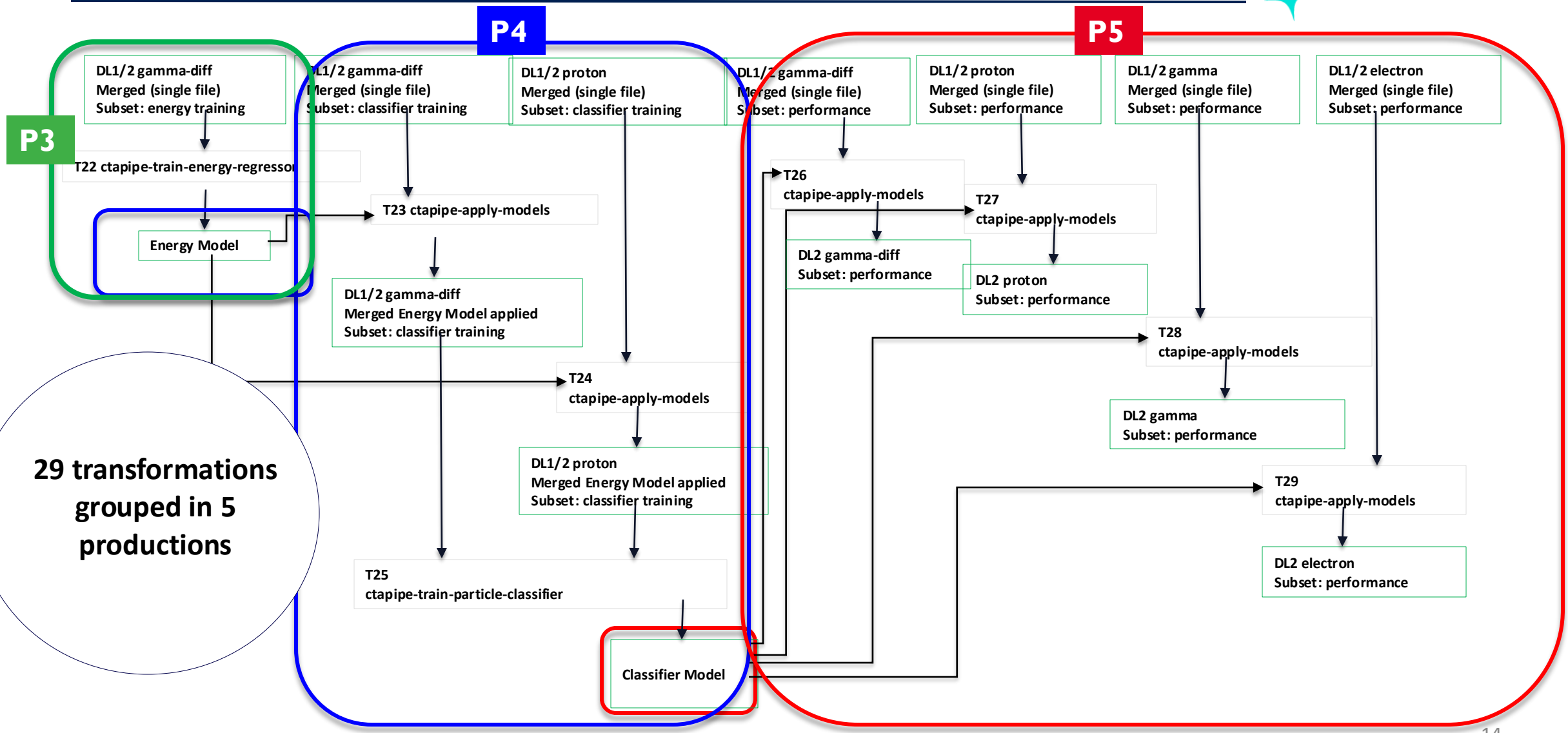
- A **Production** is a set of Transformations
  - **Data driven**: the **transformations are connected** when input and output data correspond



Processing Workflow Example (½)



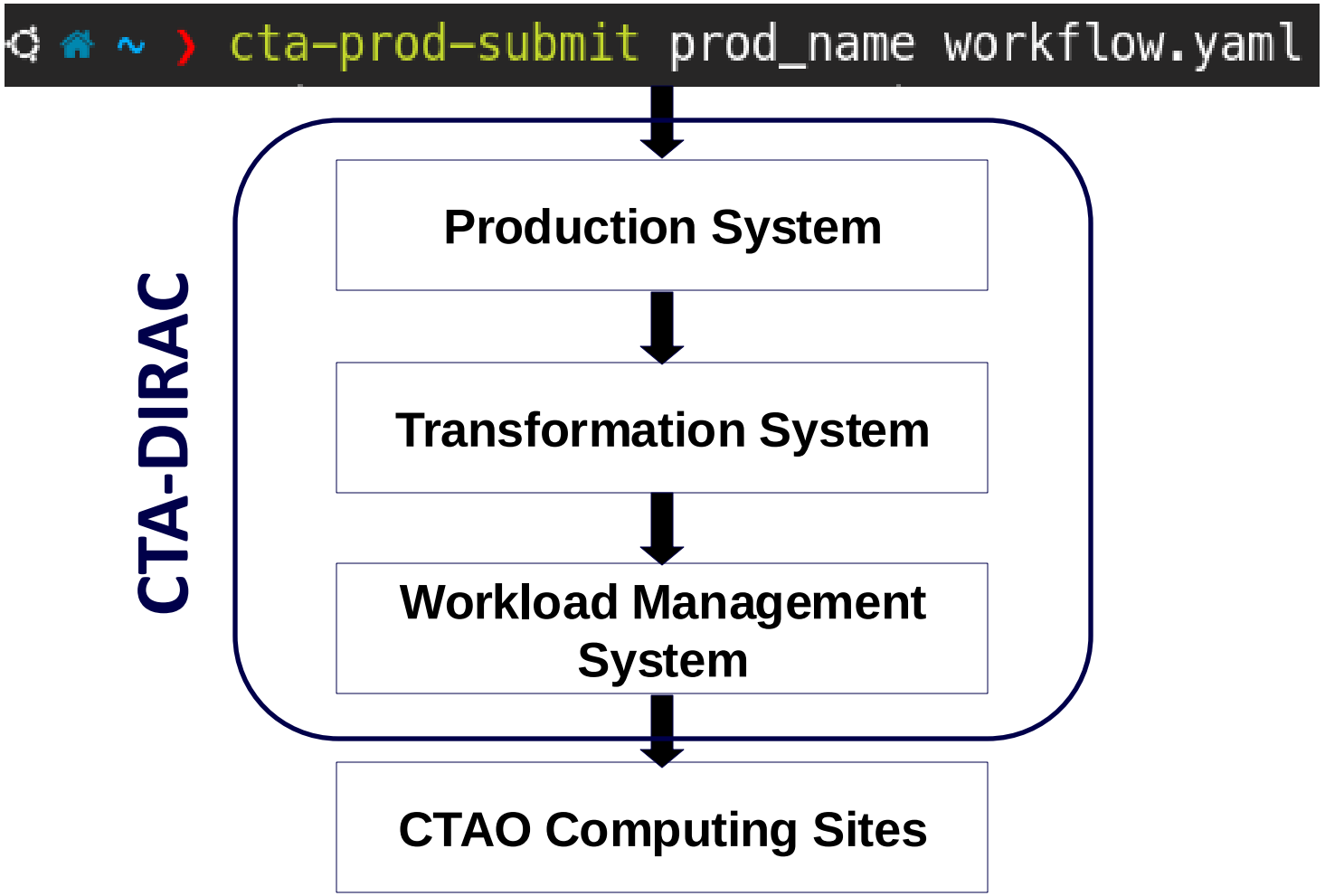
Processing Workflow Example (2/2)



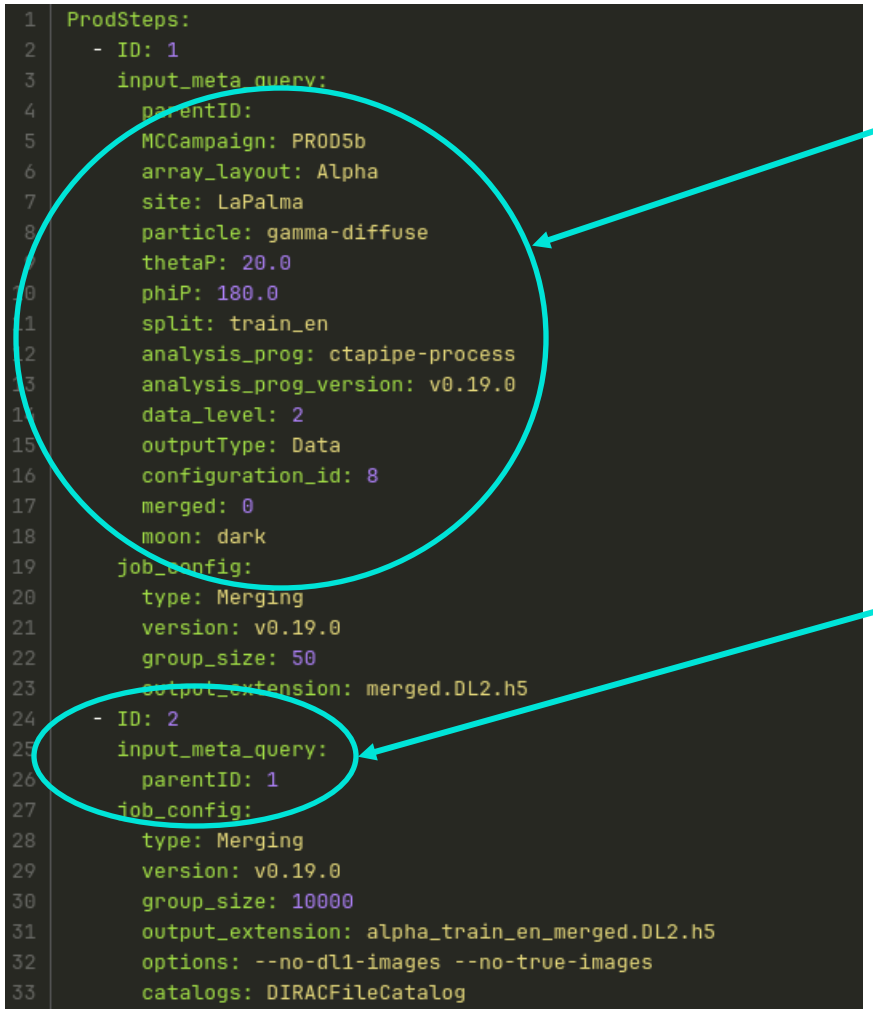
29 transformations grouped in 5 productions

Workflow Submission Interface

- We have developed in CTA-DIRAC an **interface to submit productions** using **YAML** files.
- It **automatically builds the queries on metadata**.



Workflow YAML description



```yaml
ProdSteps:
  - ID: 1
    input_meta_query:
      parentID:
      MCCampaign: PROD5b
      array_layout: Alpha
      site: LaPalma
      particle: gamma-diffuse
      thetaP: 20.0
      phiP: 180.0
      split: train_en
      analysis_prog: ctapipe-process
      analysis_prog_version: v0.19.0
      data_level: 2
      outputType: Data
      configuration_id: 8
      merged: 0
      moon: dark
    job_config:
      type: Merging
      version: v0.19.0
      group_size: 50
      output_extension: merged.DL2.h5
  - ID: 2
    input_meta_query:
      parentID: 1
    job_config:
      type: Merging
      version: v0.19.0
      group_size: 10000
      output_extension: alpha_train_en_merged.DL2.h5
      options: --no-dl1-images --no-true-images
      catalogs: DIRACFileCatalog
```

- Transformation **input/output** defined by **metadata**
- Specify **parent/child** transformation connections to possibly add **extra metadata** specifications

Figure: YAML description of a **Production**

Workflow CWL description

```yaml
cwlVersion: v1.2

class: CommandLineTool
label: run MC simulation with dirac_prod_run
baseCommand: dirac_prod_run

inputs:
    setup_path:
        type: File
        inputBinding:
            prefix: --file
            position: 10
    start_run_number:
        type: int
        inputBinding:
            prefix: --start_run
            position: 1
            separate: true
    run_number:
        type: int
        inputBinding:
            prefix: --run
            position: 2
            separate: true
    moon:
        type: string?
        inputBinding:
            position: 3
```

Figure: CWL description of a **Transformation**

COMMON WORKFLOW LANGUAGE

CWL is a **standard** for **describing workflows**.

- Composed of several steps (command line / expressions)
- A CWL runner (cwltool) parses the steps describe in YAML and runs the workflow

(=> New version of DIRAC (DiracX) will use CWL natively to describe jobs/transformations/productions => see A. Boyer poster)

Manage Transformations Failures

CTAO submits **complex workflows** on a **distributed environment**
➡ very **rare** that such **workflows end without manual intervention.**

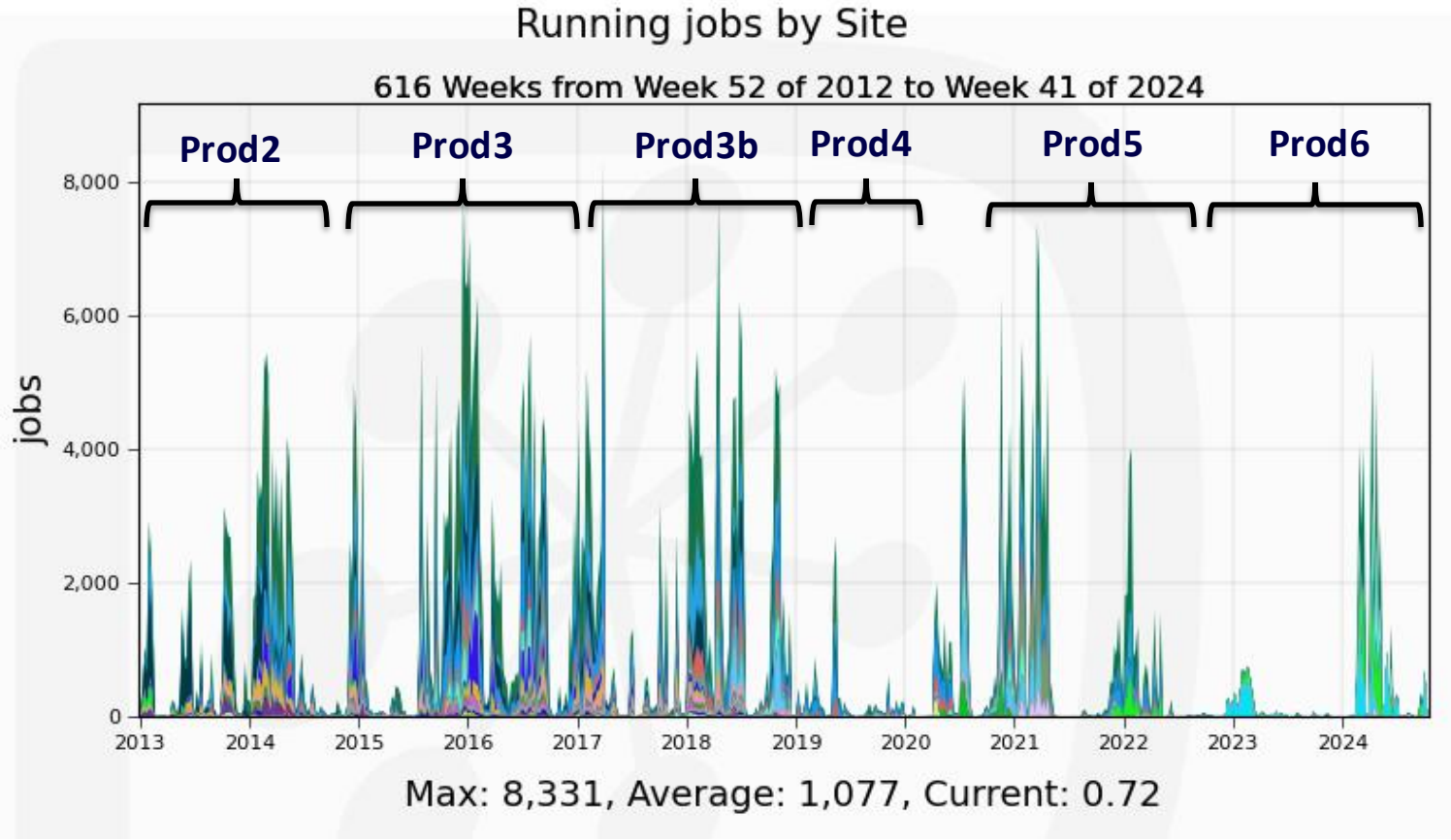
DIRAC already have a **mechanism** for this purpose, but it doesn't fit exactly our needs
➡ we have **developed** an **agent in CTA-DIRAC to manage failures in Transformations**.

This agent:

- manages most **"infrastructure" related failures and errors**
- **already used** during **Simulation campaigns**.
- will be **improved** to manage a **broader range of failures** (software environments, …)
- will try **generalized** to be integrated directly in DIRAC.

Large-Scale Productions

Massive **simulation campaigns** are run since 2011 to produce the response functions of the telescopes.



Large-Scale Productions

CTAO consumed **120 million HS06 hours** in **2024** (~100 MHS06.h per year on average).

It performs **heavy data transfers.**

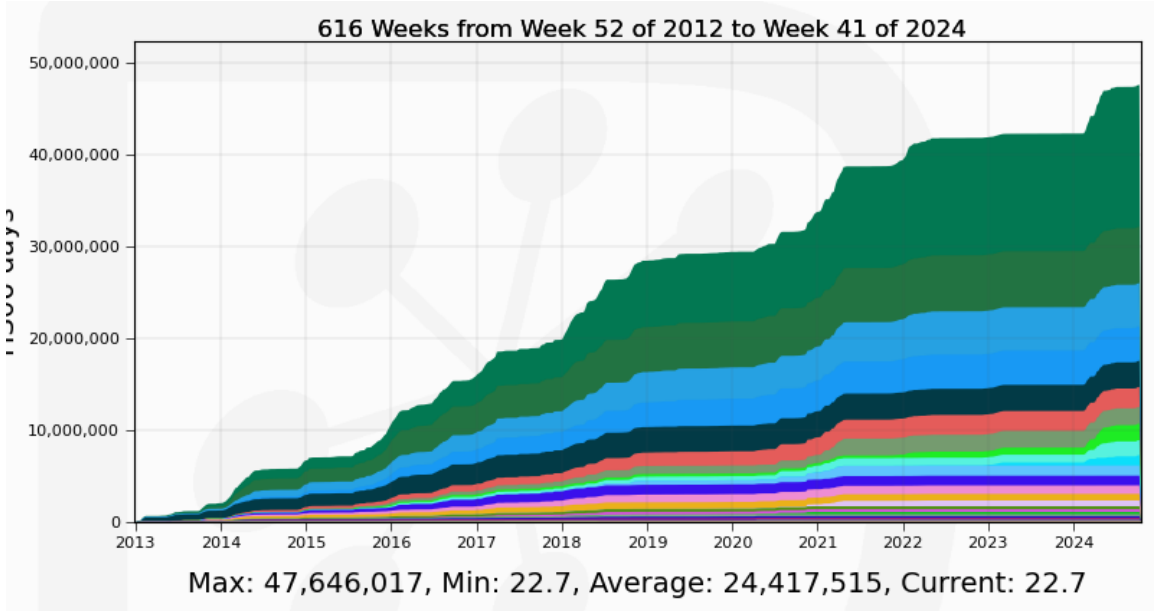


Fig: Cumulative normalized CPU used (HS06 days)

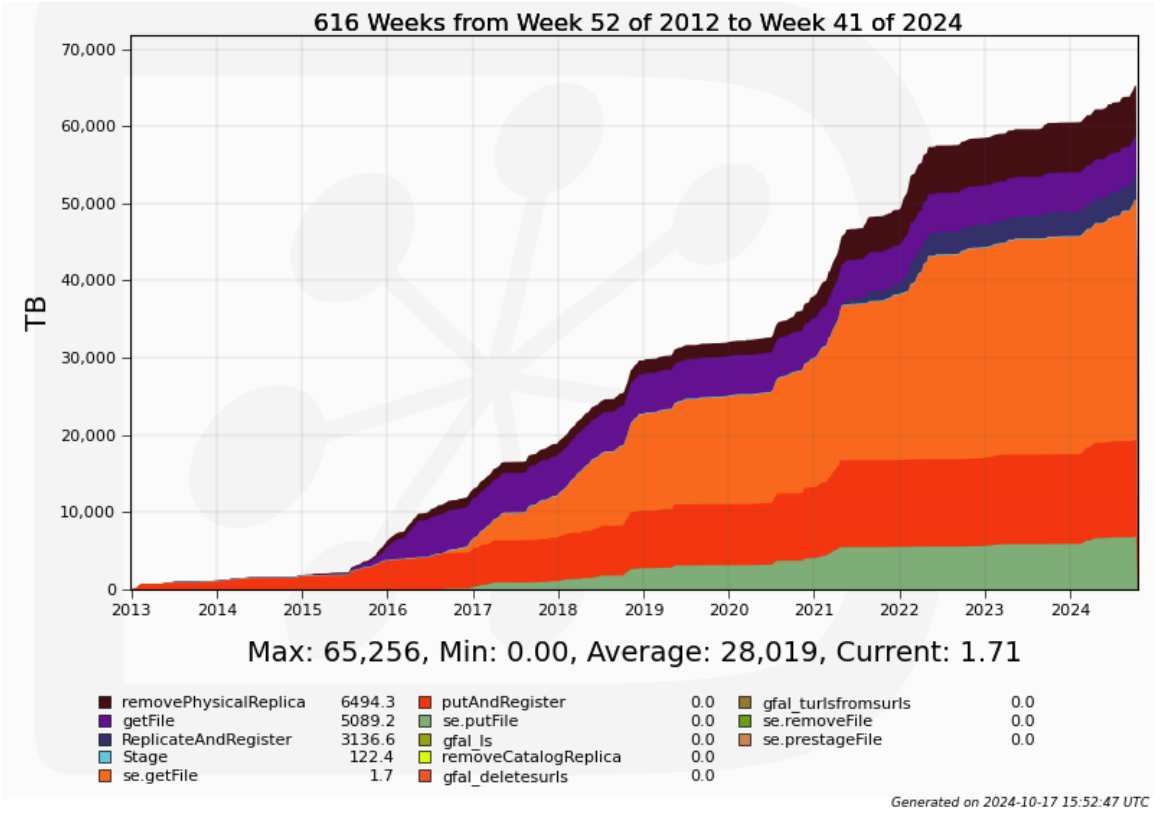


Fig: Cumulative transfered data by Operation Type

Conclusion

- We are **successfully operating a DIRAC** instance for CTAO to **run MC Simulations** using the **DIRAC Production and Transformation systems** for several years
  - We now use the **4 official CTAO data centers**

- The **integration** of **CTA Computing subsystems** (Workload, DataManagement, Pipelines softwares) has started

- We have developed a **user interface in CTA-DIRAC** to easily **configure and submit complex workflows** through the **DIRAC Production System** using **YAML description**.

- We have introduced a support for **CWL** description in **CTA-DIRAC** to submit **workflows** through the **Transformation System**.

- We have **developed a DIRAC agent** to **manage failures** in **Transformations**.

Plans

- Continue the **integration** of **CTA-DIRAC** and the **other subsystems**
  - especially with the Bulk Data Management System (e.g. Rucio)
- **Improve** the **failures management** in workflows
- Continue **CTA-DIRAC team participation** to the **DiracX** (see F. Stagni's talk) **development**
- CTAO has **planned to deploy** the softwares on **Kubernetes**
  - Preliminary tests have been done and we are **waiting for DiracX** which will provide **Helm charts**
- We are preparing to be ready for the **processing of the 1st Large Size Telescope (LST) data**

Thank you for your attention !

CTAO

www.ctao.org