DUNE Offline Computing Model Calculations for 2025

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1 Introduction

This is a projection for DUNE CPU and storage needs intended for use at the Computing Contributions Board meeting in September 2024. It projects needs for 2025 to 2030.

The overall computing model and 2023 projections for DUNE were described in chapters 6-13 of the (Oct. 2022) DUNE Conceptual Design Report [1]. This document provides updates on resource needs for 2024-2025.

The 2025 projection is done using codes at: https://github.com/DUNE/CCB-data/tree/CCB-Jun24/models-2024/ from parameters stored in a json and csv file. We use CPU and storage sizes derived from protoDUNE and simulation experience and apply them to projected numbers of events from the various DUNE detectors.

Changes since the last report [2, 3] include:

- A complete rewrite of the model code to make it more robust and allow more flexibility in plots.
- Delay in the start of ProtoDUNE-2 running at CERN until mid-2024. This moved the need for storage/CPU into mid 2024.
- More data from ProtoDUNE-HD than projected.

- Anticipate need to maintain both ProtoDUNE-HD and ProtoDUNE-VD raw data on disk simultaneously for reprocessing. The previous model assumed 1 year lifetimes for raw data on disk and this has been extended to 3 years. **This leads to a significant increase in the 2025 need which may need to be mitigated by reducing disk access to legacy ProtoDUNE-SP/DP data. See Figures 7, 8, 9 for projections.**
- This report now uses existing data catalog information up to August 2024 in forming a baseline for future projections.
- Switch to HS23-Years as opposed to Core-Years as the main CPU reporting system.
- Revisions to near-term requests based on the 2023 experience including a hold on tape requests from the collaboration during ProtoDUNE activities.
- Enhanced model for splits (Tables 4, 5, 6) between regions in resource provision.

2 Model Summary

Resource requests are based on a processing and storage model that separates different phases of the detectors and includes 5 classifications of activity.

- Physics Data - described by number of events, CPU time/event, storage/event. Physics Data are described by number of events and then transformed into storage and CPU based on measured or estimated performance.
- Simulation - described by number of events, CPU time/event, storage/event. Currently both simulation and reconstruction are combined as a single entity as that is how we currently perform simulation. The model will be extended to support multiple stages in future.
- Test - data taking as part of commissioning. These have a short lifetime and are initially described by PB of storage. They are assumed not to consume large amounts of CPU and to only reside on disk briefly.
- Trigger Primitives (TP) - these are currently described by PB of storage and are assumed not to consume large amounts of CPU.
- Analysis - Analysis is assumed to be use little disk but consume considerable CPU and IO resources. It is currently described by a scaling factor ($\sim 50\%$) relative to Reconstruction and Simulation CPU.

Table 1 summarizes the main detectors and their abbreviations. Smaller prototypes that generate less than 1 PB of data are not explicitly included.

These inputs are then used to calculate storage and CPU needs.

Abbrev.	Detector	Running time
SP	ProtoDUNE Single Phase	2018-2021
DP	ProtoDUNE Dual Phase	2018-2021
Coldbox	Both VD and HD	2018-2024
PDHD	ProtoDUNE-2 Horizonal Drift	2024-2026
PDVD	ProtoDUNE-2 Vertical Drift	2024-2026
2x2	Prototype NDLAr Detector	2024-2026
HD	Far Detector Horizontal Drift	2028-
VD	Far Detector Vertical Drift	2028-
NDLAr + TMS	Near Detector Liquid Argon + Muon System	2030-
SAND	On Axis Near Detector	2030-

Table 1: Detector abbreviations and estimated running times. Simulation campaigns occur earlier.

2.1 Storage replication and retention policies

Disk storage policies are designed to optimize access and minimize CPU inefficiencies due to network transfer speeds. In particular, all recent data samples are planned to have at least one disk copy to avoid the need to access tape. As raw data processing is not I/O bound, one disk copy may be sufficient. Analysis of reconstructed samples is I/O bound so multiple copies located closer to CPU are desirable.

Each type of data has a storage retention policy which includes lifetimes on disk and tape and number of copies on disk and tape. For example, raw data has a very long tape retention policy and 2 tape copies, with a 2-3 year stay of 1 copy on disk. Recent simulated and reconstructed data samples typically have 1 tape copy, 2 disk copies and disk retention times of 1.5-2 years to allow fast analysis. An extended retention time after the end of data taking for the last version of sim/reco is added to allow for extended data analysis.

Simulation and reconstruction from 2018 ProtoDUNE run is still active but is reduced to 1 disk copy.

The model currently does not include any disk headroom allowance for data movement. This will be added in the 2025 version of the model.

2.2 Processing calculations

We assume one processing campaign per year, with all real data reprocessed each campaign. Simulation is assumed to be regenerated once per year.

CPU calculations are now made in HS23 units. Calculations for the ProtoDUNEs and DUNE far detector are based on existing reconstruction and simulation experience. We have much less experience with Near Detector codes so those estimates are less accurate.

We assume ProtoDUNE running in 2024-2025 with startup of DUNE FD commissioning in 2027 (Test stream) and data taking in 2029. A cap of 30 PB/year for raw data (Events, Trigger Primitives and Tests) is imposed by scaling all categories down proportionally when 30 PB is reached.

3 Details of the model

The model is implemented in python. Time series are created for each combination of detector, data type, resource and location. Those time series are then scaled, extended and iterated and the results stored as new time series. The end result is a csv file with a line for each permutation of types and figures summarizing various aggregations of data. Figure 1 shows the steps applied to data and simulation.

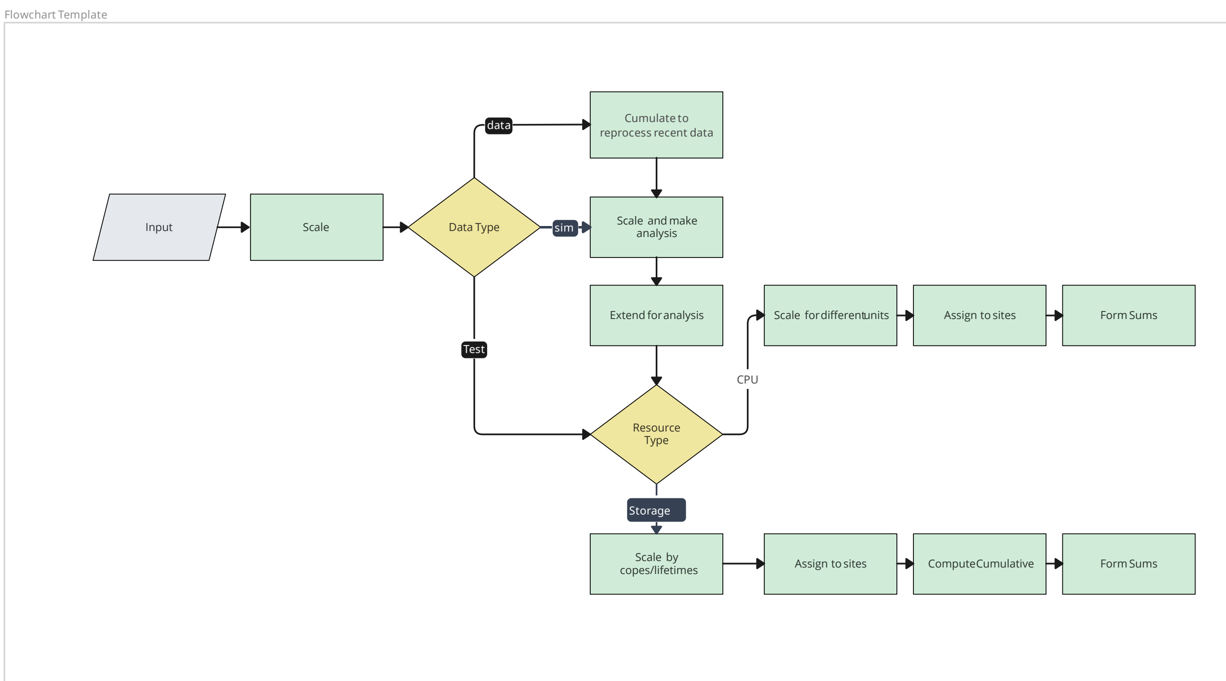


Figure 1: Flow chart of transformations used to transform raw event counts into summaries such as cumulative disk on tape.

3.1 Inputs

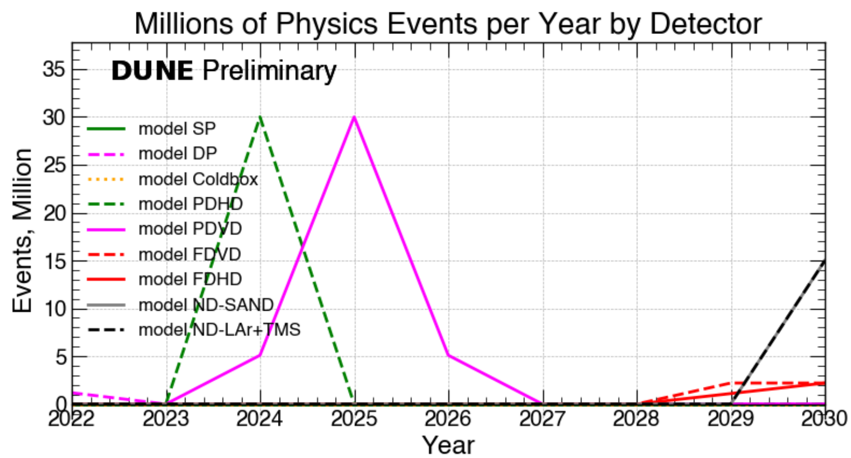
Inputs to the model include projections of events and storage per year by detector and datatype, which are contained in a "timeline file". A master configuration file in json format is used to store detector specific parameters which do not depend on year.

The parameters are stored in NearTerm_2024-09-16-2040.json and NearTerm_2024-09-16-2040_timeline.csv

The calculation starts with numbers of events from the timeline[1] and uses those numbers, with CPU/storage

[1]Event numbers for previous years are back-estimated from the total size of the data from the data catalog and an estimated size/event because the catalog does not report event number totals. Early simulation stored very large events

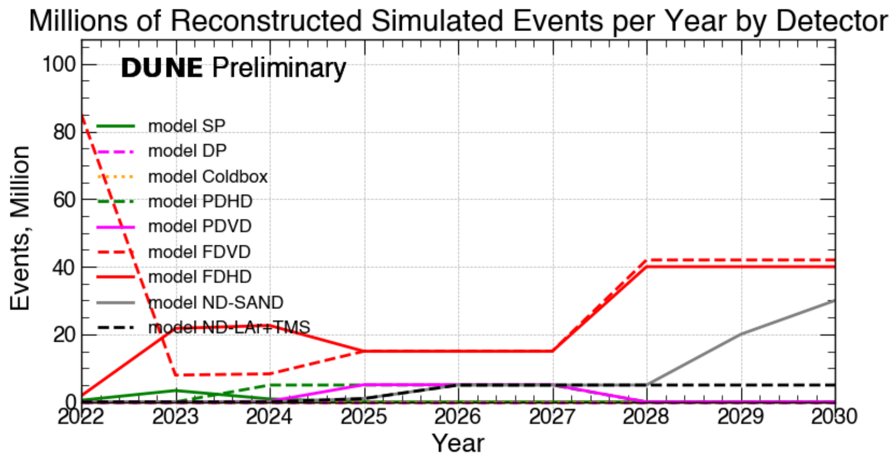
times/event from Table 2 to calculate the annual new storage and CPU use for data taken in that year. Figure/Tables 2 and 3 show the assumptions for numbers of events/year.



Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DP	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
PDVD	0.0	0.0	5.1	30.0	5.1	0.0	0.0	0.0	0.0
FDVD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2
FDHD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.2
ND-SAND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
ND-LAr+TMS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0

Figure 2: Number of raw data events per year, units are Millions.

relative to the current estimated size, leading to an overestimate of the number of events but a correct estimate of disk and tape use.



Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	0.5	3.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0
DP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	0.0	0.0	5.0	5.0	5.0	5.0	0.0	0.0	0.0
PDVD	0.0	0.0	0.2	5.1	5.1	5.1	0.0	0.0	0.0
FDVD	85.1	8.0	8.3	15.0	15.0	15.0	42.0	42.0	42.0
FDHD	1.8	21.8	22.6	15.0	15.0	15.0	40.0	40.0	40.0
ND-SAND	0.0	0.0	0.0	1.0	5.0	5.0	5.0	20.0	30.0
ND-LAr+TMS	0.0	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0

Figure 3: Number of simulated/reconstructed events per year, units are Millions. There was a large simulation campaign in 2022 for the FDVD technical design report.

Those data are then stored with sizes/event `RawDataStore` and `SimDataStore`. See Table 2 for storage estimates per event by detector.

3.2 Simulation/Reconstruction Processing

Processing is modeled by taking the number of events produced in a given year and multiplying by the measured CPU times `RecoDataCPU` and `SimDataCPU` for processing those events. Those data are then assumed to be stored with size `RecoDataStore` and `SimDataStore`.

Reprocessing for detector data is assumed to happen every year and cover `Reprocess` = 3 years for ProtoDUNE and the whole sample for the FD and ND.

New simulation is assumed to happen every year and previous years are not reprocessed.

parameter	units	SP	DP	Coldbox	PDHD	PDVD	FDVD	FDHD	ND-SAND	ND-LAr+TMS
Raw-Data-Store	MB	70	110	30.0	140	110	8000	3750	5	10
Reco-Data-Store	MB	35	35	0	35	20	20	20	10	20
Reco-Sim-Store	MB	220	220	0	220	220	20	20	25	50
Reco-Data-CPU	hr	0.1667	0.1667	0.0	0.1667	0.1667	1.33	1.25	0.0022	0.76
Reco-Sim-CPU	hr	0.75	0.75	0.0	0.75	0.75	0.125	0.125	0.24	4.6
Reco-Data-GPU	hr	0	0	0	0	0	0.1	0	0	0.76
Reco-Sim-GPU	hr	0	0	0	0	0	0.1	0	0	4.6
Analysis-CPU	fraction	0.5	0.5	0.1	0.5	0.5	0.5	0.5	0.25	0.25

Table 2: Per event output size and CPU time parameters used in the model. These values are estimated from running jobs over small numbers of events from protoDUNE and simulation.

3.3 Copies and Retention

Once the data volume generated per year is determined, those data are given retention times and a proposed number of copies. For popular datasets the number of disk copies should be two and disk copies should be retained for 2 years (two reconstruction/simulation cycles) if possible. Due to the large volume of simulation and need for space for raw data from protoDUNE, the number of copies for simulation has been reduced to 1.5 to keep disk demands reasonable.

Raw data has 2 copies on tape with a very long lifetime but a shorter disk lifetime as it is assumed that most users will use the reconstructed samples.

3.4 Analysis

The Analysis model is currently crude. Analysis processing is modeled by scaling the reconstruction and simulation CPU time by a multiplicative factor `AnalysisCPU` $\sim 0.25 - 0.5$ and extending the time by `AnalysisExtend` = 2 years. Analysis use of reconstructed and simulated data is modeled by extending the disk lifetime of those data by the same amount. Currently analysis data samples are assumed to be

Parameters	DiskCopies	DiskLifetimes	TapeCopies	TapeLifetimes
Raw-Data	1	3	2	100
Test	1	0.5	1	1.0
TP	1	0.5	1	100
Reco-Data	2	2	1	15
Reco-Sim	1.5	2	1	15
Analysis-Data	2	5	1	15
Analysis-Sim	2	5	1	15

Table 3: Lifetimes and number of copies for different kinds of data. An exception, we assume protoDUNE raw radata will stay on disk for up to three years for reprocessing. Far detector data are assumed to stay for 2 years.

much smaller than the reconstructed and simulated samples. Figure/Table 14 and 16. shows CPU usage by data type.

3.5 Splitting resources across sites

Resources are assumed to be split as follows:

- Raw data for ProtoDUNE are stored at both CERN and Fermilab
- Reconstructed and simulated data are split between the US (US) and the rest of the Collaboration (Global)

Detector Class	Data Type	US	CERN	Global
PD	Raw-Data	0.5	0.5	0.0
PD	Reco-Sim	0.25	0.0	0.75
PD	Reco-Data	0.25	0.0	0.75
PD	Test	0.5	0.5	0.0
PD	TP	0.5	0.5	0.0
FD	Raw-Data	0.5	0.0	0.5
FD	Reco-Sim	0.25	0.0	0.75
FD	Reco-Data	0.25	0.0	0.75
FD	Test	0.5	0.0	0.5
FD	TP	0.5	0.0	0.5
ND	Raw-Data	0.5	0.0	0.5
ND	Reco-Sim	0.25	0.0	0.75
ND	Reco-Data	0.25	0.0	0.75
ND	Test	0.5	0.0	0.5
ND	TP	0.5	0.0	0.5

Table 4: Assumptions about splits of Disk resources between the US, CERN and Global.

Detector Class	Data Type	US	CERN	Global
PD	Raw-Data	0.5	0.5	0.0
PD	Reco-Sim	1.0	0.0	0.0
PD	Reco-Data	1.0	0.0	0.0
PD	Test	0.5	0.5	0.0
PD	TP	0.5	0.5	0.0
FD	Raw-Data	0.5	0.0	0.5
FD	Reco-Sim	0.5	0.0	0.5
FD	Reco-Data	0.5	0.0	0.5
FD	Test	0.5	0.0	0.5
FD	TP	0.5	0.0	0.5
ND	Raw-Data	0.5	0.0	0.5
ND	Reco-Sim	0.5	0.0	0.5
ND	Reco-Data	0.5	0.0	0.5
ND	Test	0.5	0.0	0.5

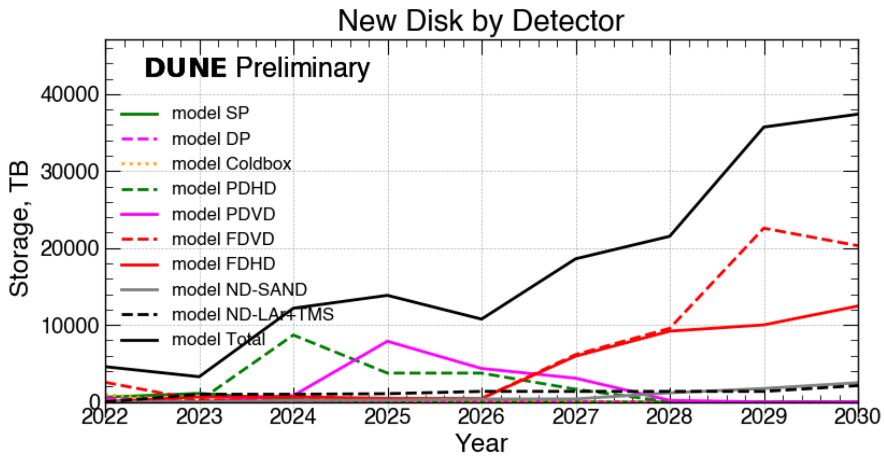
Table 5: Assumptions about splits of Tape resources between the US, CERN and Global.

Detector Class	Data Type	US	CERN	Global
PD	CPU	0.4	0.1	0.5
FD	CPU	0.5	0.0	0.5
ND	CPU	0.5	0.0	0.5

Table 6: Assumptions about splits of CPU resources between the US, CERN and Global.

4 Resource use projections

In this section we show projected resource needs by detector, data type, resource type and site.



Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	620	1113	293	0	0	0	0	0	0
DP	408	82	82	0	0	0	0	0	0
Coldbox	936	41	151	0	0	0	0	0	0
PDHD	8	143	8697	3750	3750	1650	0	0	0
PDVD	0	5	824	7887	4352	3087	204	0	0
FDVD	2553	238	249	450	450	6150	9560	22578	20302
FDHD	54	652	678	450	450	5950	9200	10013	12465
ND-SAND	0	0	200	237	387	387	1187	1750	2500
ND-LAr+TMS	0	1000	1000	1075	1375	1375	1375	1375	2125
Total	4582	3278	12178	13849	10764	18599	21526	35717	37393

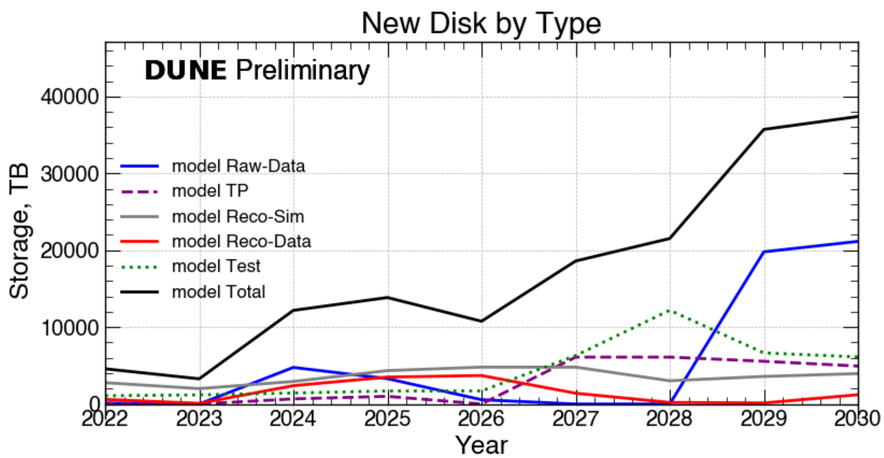
Figure 4: New Disk per year by detector. This includes multiple copies where need but not longer lifetimes.

5 Longer term projections

This section shows the projected resources past the startup of the far detectors in 2028-29.

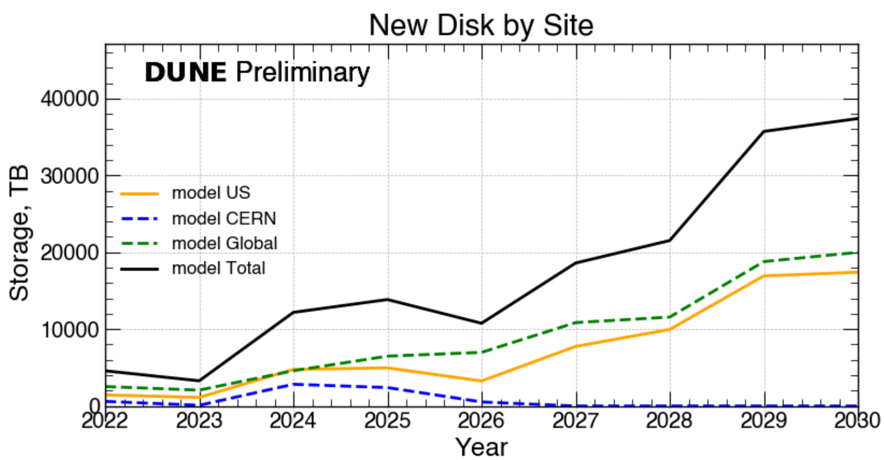
The estimates for storage are dominated by the far detector while CPU is likely dominated by the near detectors

In this section we show projected resource needs by detector, data type, resource type and site.



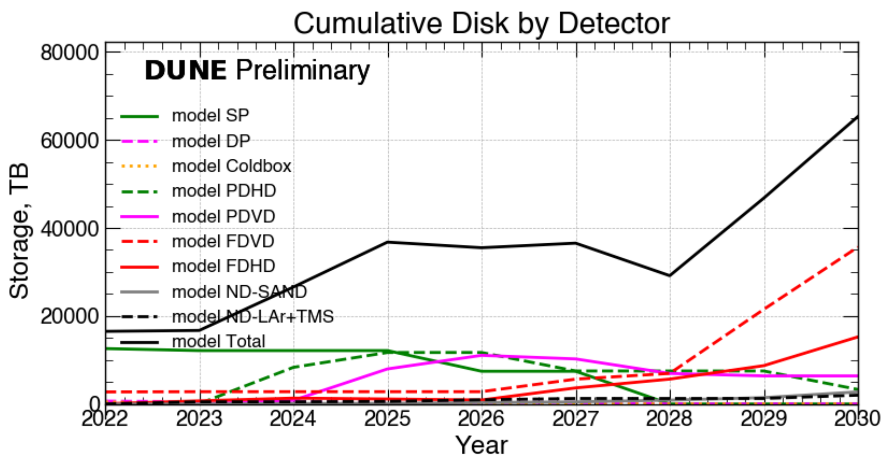
DataTypes	2022	2023	2024	2025	2026	2027	2028	2029	2030
Raw-Data	130	0	4761	3300	561	0	0	19794	21156
TP	0	0	668	1000	0	6100	6100	5558	4939
Reco-Sim	2773	2004	2931	4345	4795	4795	3022	3585	3960
Reco-Data	603	82	2386	3504	3708	1404	204	132	1208
Test	1075	1190	1430	1700	1700	6300	12200	6646	6129
Total	4582	3278	12178	13849	10764	18599	21526	35717	37393

Figure 5: New Disk per year by data type. This includes multiple copies where need but not longer lifetimes.



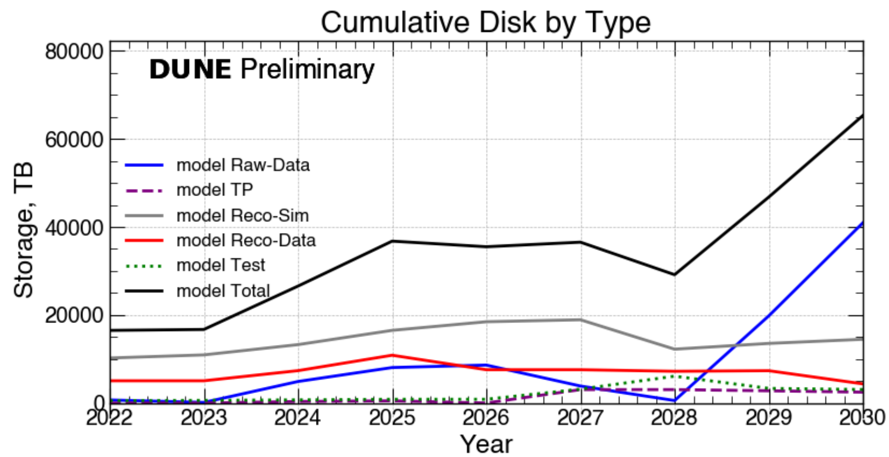
Locations	2022	2023	2024	2025	2026	2027	2028	2029	2030
US	1447	1117	4759	4962	3256	7749	9956	16929	17404
CERN	602	95	2829	2400	530	0	0	0	0
Global	2532	2065	4588	6487	6977	10849	11569	18787	19988
Total	4582	3278	12178	13849	10764	18599	21526	35717	37393

Figure 6: New Disk per year by site. This includes multiple copies where need but not longer lifetimes.



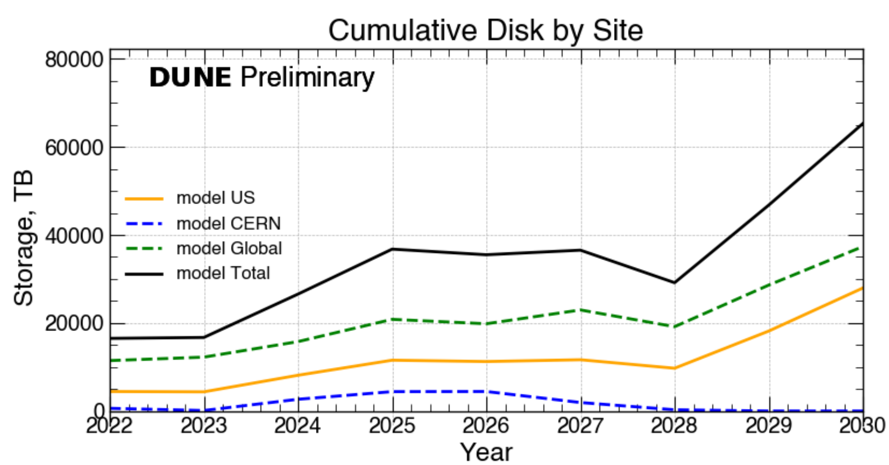
Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	12587	12132	12132	12132	7435	7435	0	0	0
DP	652	485	485	355	355	355	0	0	0
Coldbox	468	20	75	0	0	0	0	0	0
PDHD	4	71	8323	11700	11700	7500	7500	7500	3300
PDVD	0	2	824	7961	11050	10239	6939	6378	6378
FDVD	2736	2792	2792	2792	2792	5642	6942	21513	35651
FDHD	54	707	1331	1128	900	3650	5650	8708	15241
ND-SAND	0	0	100	137	325	475	875	1437	2750
ND-LAr+TMS	0	500	500	575	950	1250	1250	1250	2000
Total	16504	16713	26565	36782	35508	36547	29156	46787	65320

Figure 7: Cumulative Disk by detector.



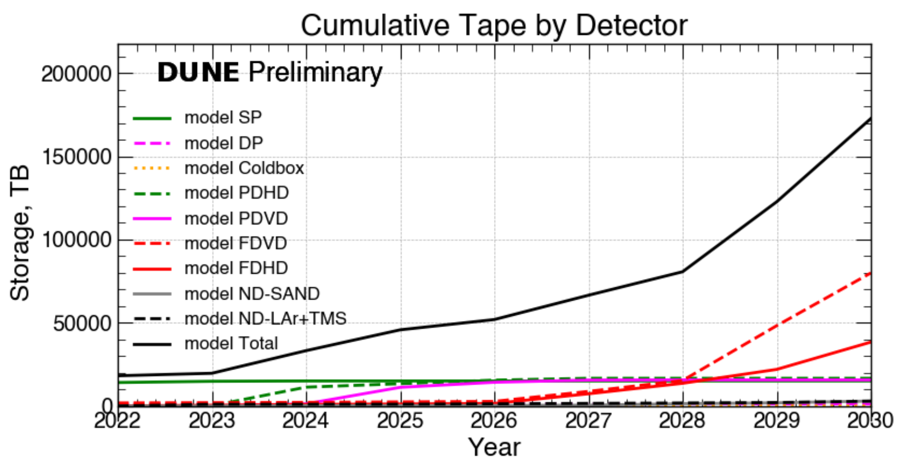
DataTypes	2022	2023	2024	2025	2026	2027	2028	2029	2030
Raw-Data	687	130	4891	8061	8622	3861	561	19794	40951
TP	0	0	334	500	0	3050	3050	2779	2469
Reco-Sim	10227	10935	13269	16511	18469	18919	12233	13545	14483
Reco-Data	5052	5052	7356	10860	7567	7567	7212	7344	4352
Test	537	595	715	850	850	3150	6100	3323	3064
Total	16504	16713	26565	36782	35508	36547	29156	46787	65320

Figure 8: Cumulative Disk by data type.



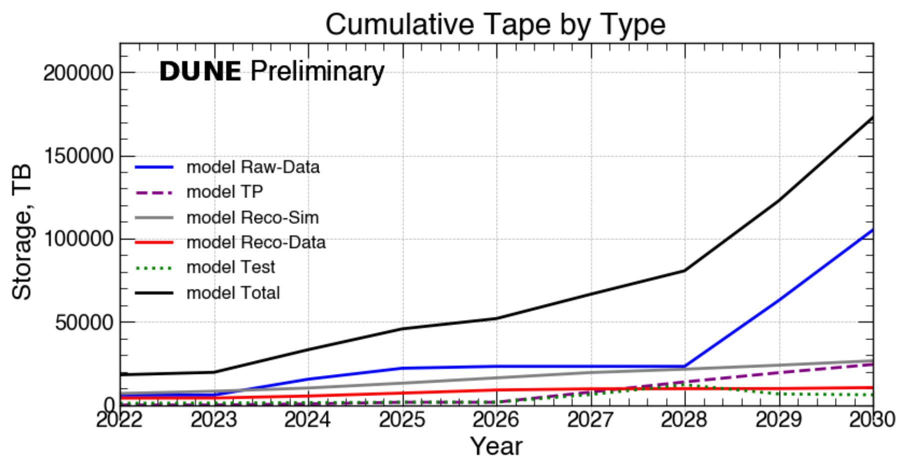
Locations	2022	2023	2024	2025	2026	2027	2028	2029	2030
US	4432	4359	8126	11548	11245	11652	9716	18171	27951
CERN	612	112	2670	4405	4436	1930	280	0	0
Global	11459	12240	15768	20828	19827	22964	19158	28616	37369
Total	16504	16713	26565	36782	35508	36547	29156	46787	65320

Figure 9: Cumulative Disk by site.



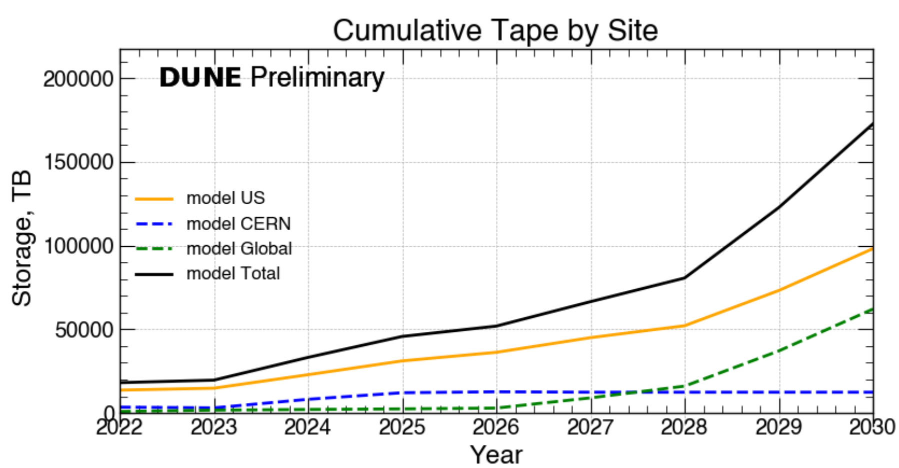
Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	14083	14825	15021	15021	15021	15021	15021	15021	15021
DP	1255	1167	1208	1208	1208	1208	1208	1208	1208
Coldbox	936	41	151	0	0	0	0	0	0
PDHD	8	143	11297	13368	15518	16618	16618	16618	16618
PDVD	0	5	1264	11187	14235	15559	15661	15661	15661
FDVD	1824	1983	2149	2449	2749	8749	15289	48240	79916
FDHD	36	471	924	1224	1524	7324	13624	21974	38376
ND-SAND	0	0	200	225	350	475	1400	1900	2950
ND-LAr+TMS	0	1000	1000	1050	1300	1550	1800	2050	2900
Total	18145	19639	33217	45735	51908	66507	80624	122675	172654

Figure 10: Cumulative Tape by detector.



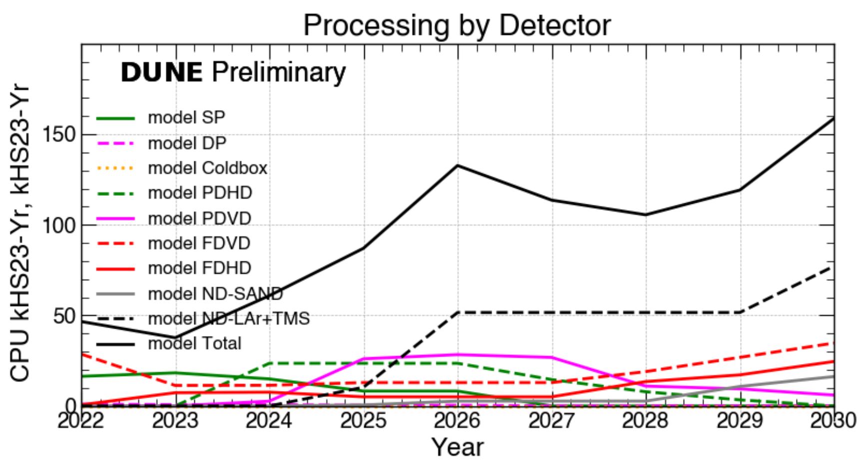
DataTypes	2022	2023	2024	2025	2026	2027	2028	2029	2030
Raw-Data	5970	5970	15492	22092	23214	23214	23214	62804	105116
TP	0	0	668	1668	1668	7768	13868	19426	24366
Reco-Sim	6928	8265	10219	13116	16313	19510	21525	23915	26555
Reco-Data	4171	4213	5406	7158	9012	9714	9816	9882	10486
Test	1075	1190	1430	1700	1700	6300	12200	6646	6129
Total	18145	19639	33217	45735	51908	66507	80624	122675	172654

Figure 11: Cumulative Tape by data type.



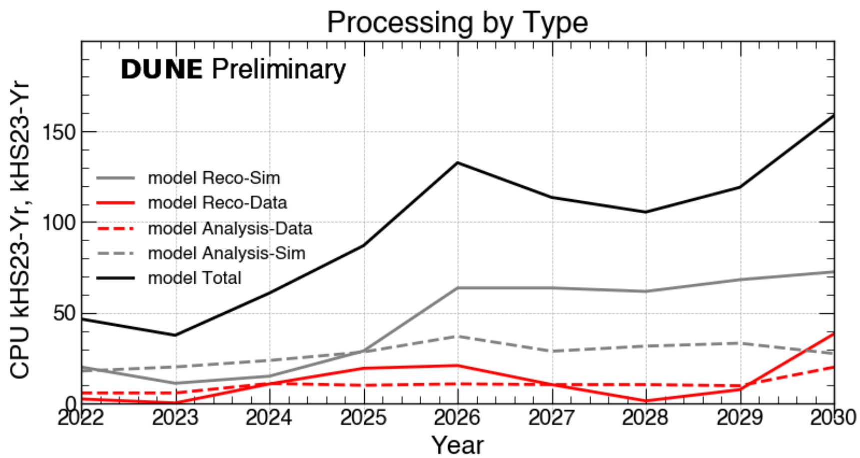
Locations	2022	2023	2024	2025	2026	2027	2028	2029	2030
US	13692	14831	22884	31130	36255	45016	52126	73151	98140
CERN	3522	3080	8195	12130	12691	12441	12441	12441	12441
Global	930	1727	2137	2474	2962	9049	16057	37082	62071
Total	18145	19639	33217	45735	51908	66507	80624	122675	172654

Figure 12: Cumulative Tape by site.



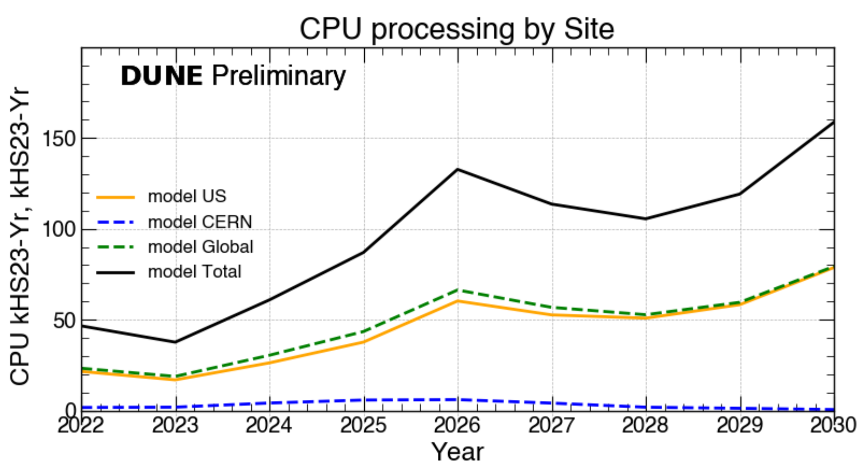
Detectors	2022	2023	2024	2025	2026	2027	2028	2029	2030
SP	16.3	18.3	14.9	8.2	8.2	0.0	0.0	0.0	0.0
DP	1.0	0.7	0.7	0.4	0.4	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	0.0	0.0	23.5	23.5	23.5	14.6	7.8	3.4	0.0
PDVD	0.0	0.0	2.7	26.0	28.3	26.8	11.0	9.4	6.0
FDVD	28.6	11.3	11.4	12.9	12.9	12.9	19.0	26.8	34.7
FDHD	0.6	7.3	7.6	5.0	5.0	5.0	13.5	17.2	24.6
ND-SAND	0.0	0.0	0.0	0.5	2.7	2.7	2.7	10.8	16.2
ND-LAr+TMS	0.0	0.0	0.0	10.3	51.6	51.6	51.6	51.6	77.1
Total	46.6	37.6	60.9	87.0	132.7	113.6	105.5	119.1	158.6

Figure 13: CPU kHS23-Yr resources by detector by year.



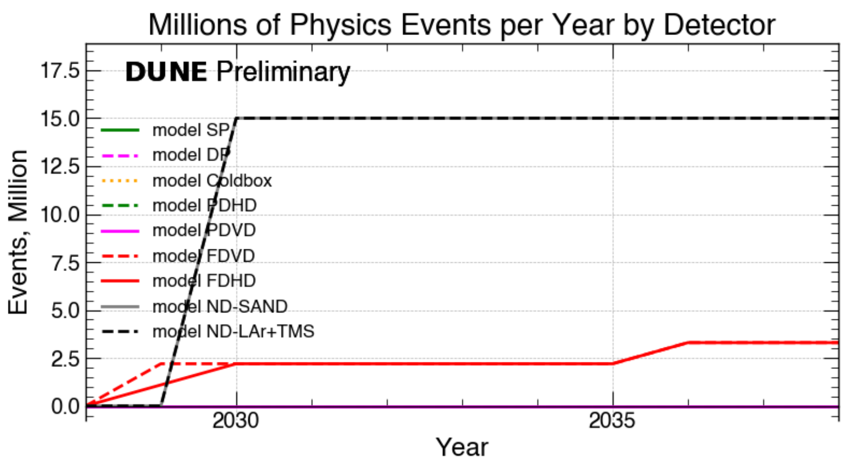
DataTypes	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reco-Sim	20.2	11.2	15.1	29.0	63.7	63.7	61.8	68.3	72.6
Reco-Data	2.6	0.4	10.8	19.5	21.0	10.5	1.5	7.7	38.4
Analysis-Data	5.9	5.9	11.1	10.1	10.9	10.5	10.5	9.9	20.1
Analysis-Sim	18.0	20.2	23.8	28.4	37.1	28.9	31.7	33.3	27.6
Total	46.6	37.6	60.9	87.0	132.7	113.6	105.5	119.1	158.6

Figure 14: CPU kHS23-Yr resources by data types by year.



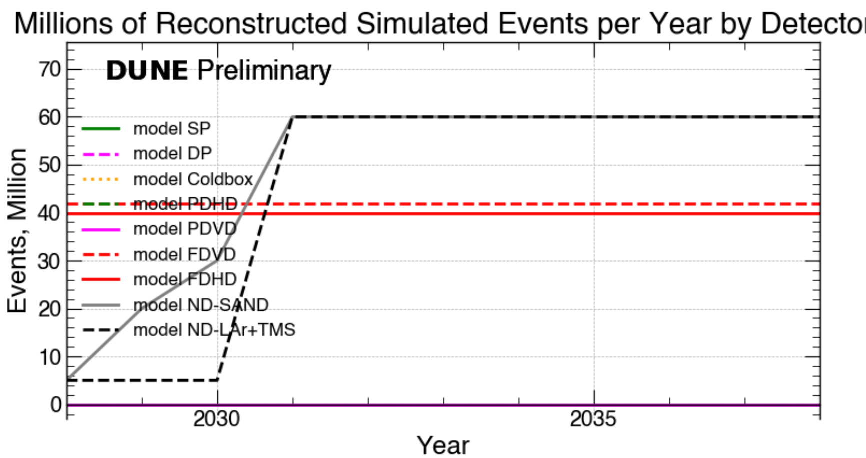
Locations	2022	2023	2024	2025	2026	2027	2028	2029	2030
US	21.6	16.9	26.3	37.7	60.3	52.7	50.9	58.3	78.7
CERN	1.7	1.9	4.2	5.8	6.0	4.1	1.9	1.3	0.6
Global	23.3	18.8	30.4	43.5	66.3	56.8	52.7	59.6	79.3
Total	46.6	37.6	60.9	87.0	132.7	113.6	105.5	119.1	158.6

Figure 15: Projected CPU use by location. Units are CPU kHS23-Yr



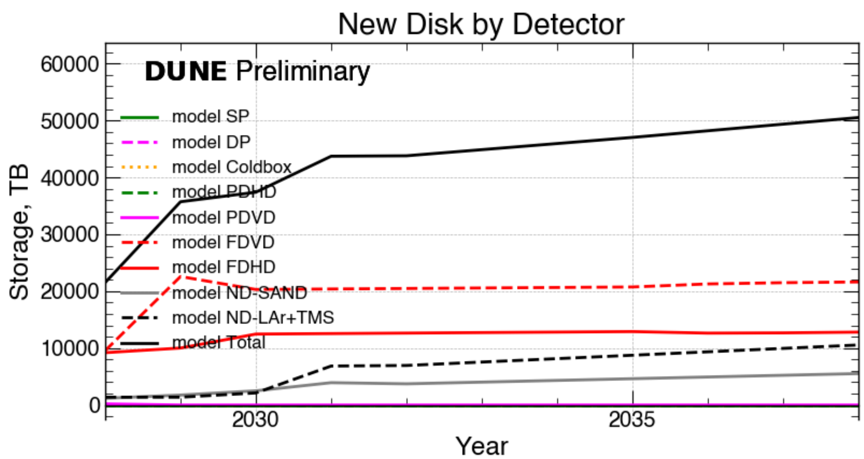
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDVD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FDVD	0.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	3.3	3.3	3.3
FDHD	0.0	1.1	2.2	2.2	2.2	2.2	2.2	2.2	3.3	3.3	3.3
ND-SAND	0.0	0.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
ND-LAr+TMS	0.0	0.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0

Figure 16: Number of raw data events per year, units are Millions.



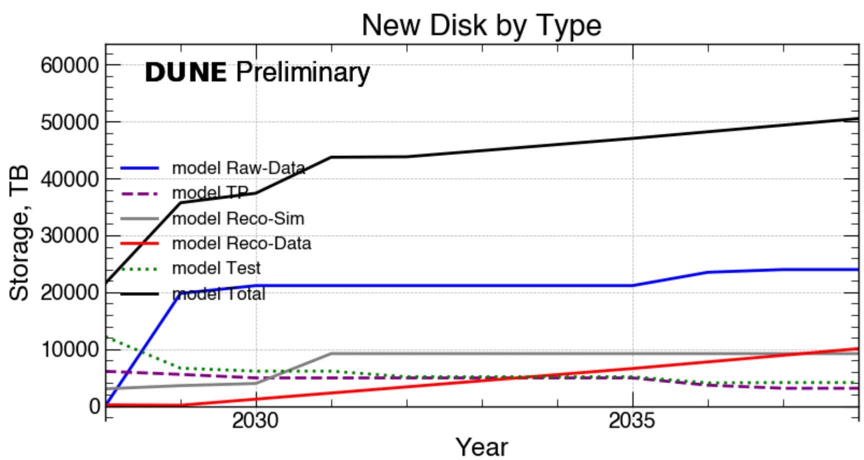
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDVD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FDVD	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0
FDHD	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
ND-SAND	5.0	20.0	30.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
ND-LAr+TMS	5.0	5.0	5.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0

Figure 17: Number of simulated/reconstructed events per year, units are Millions. There was a large simulation campaign in 2022 for the FDVD technical design report.



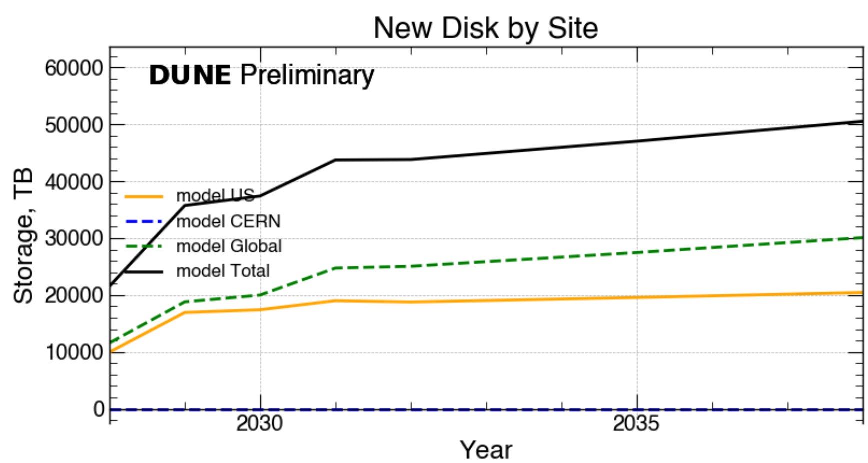
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	0	0	0	0	0	0	0	0	0	0	0
DP	0	0	0	0	0	0	0	0	0	0	0
Coldbox	0	0	0	0	0	0	0	0	0	0	0
PDHD	0	0	0	0	0	0	0	0	0	0	0
PDVD	204	0	0	0	0	0	0	0	0	0	0
FDVD	9560	22578	20302	20390	20478	20566	20654	20742	21277	21496	21628
FDHD	9200	10013	12465	12553	12641	12729	12817	12905	12634	12679	12811
ND-SAND	1187	1750	2500	3925	3725	4025	4325	4625	4925	5225	5525
ND-LAr+TMS	1375	1375	2125	6850	6950	7550	8150	8750	9350	9950	10550
Total	21526	35717	37393	43718	43794	44870	45946	47022	48187	49351	50515

Figure 18: New Disk per year by detector. This includes multiple copies where need but not longer lifetimes.



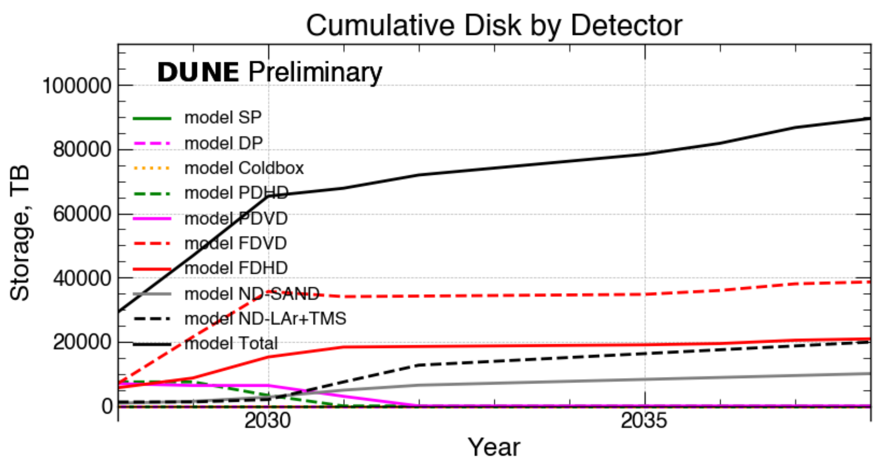
DataTypes	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Raw-Data	0	19794	21156	21156	21156	21156	21156	21156	23501	23976	23976
TP	6100	5558	4939	4939	4939	4939	4939	4939	3661	3124	3124
Reco-Sim	3022	3585	3960	9210	9210	9210	9210	9210	9210	9210	9210
Reco-Data	204	132	1208	2284	3360	4436	5512	6588	7752	8916	10080
Test	12200	6646	6129	6129	5129	5129	5129	5129	4061	4124	4124
Total	21526	35717	37393	43718	43794	44870	45946	47022	48187	49351	50515

Figure 19: New Disk per year by data type. This includes multiple copies where need but not longer lifetimes.



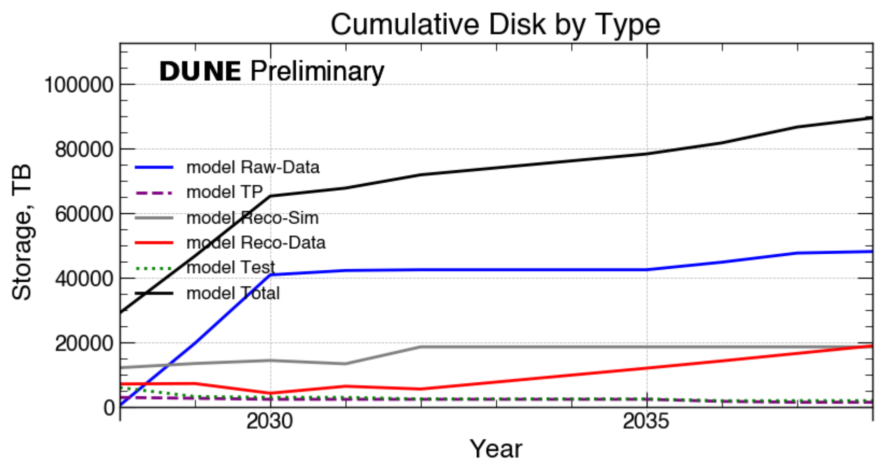
Locations	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
US	9956	16929	17404	18986	18755	19023	19292	19561	19853	20144	20435
CERN	0	0	0	0	0	0	0	0	0	0	0
Global	11569	18787	19988	24732	25039	25846	26653	27460	28334	29207	30080
Total	21526	35717	37393	43718	43794	44870	45946	47022	48187	49351	50515

Figure 20: New Disk per year by site. This includes multiple copies where need but not longer lifetimes.



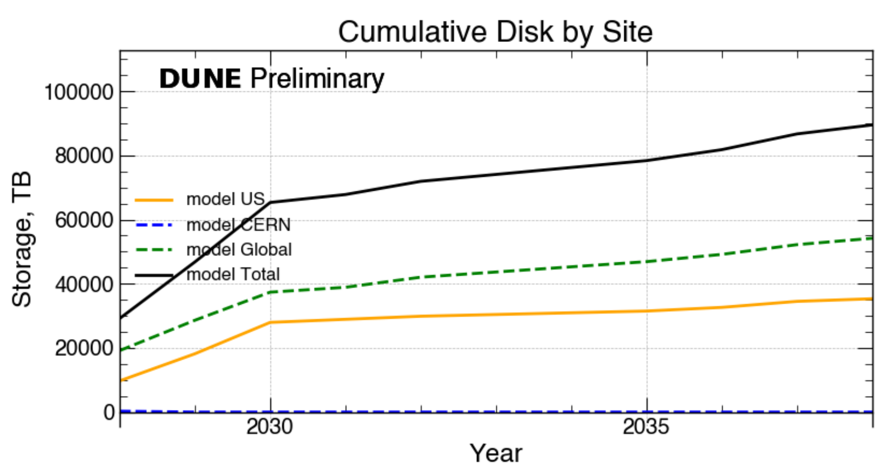
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	0	0	0	0	0	0	0	0	0	0	0
DP	0	0	0	0	0	0	0	0	0	0	0
Coldbox	0	0	0	0	0	0	0	0	0	0	0
PDHD	7500	7500	3300	0	0	0	0	0	0	0	0
PDVD	6939	6378	6378	3012	0	0	0	0	0	0	0
FDVD	6942	21513	35651	34041	34217	34393	34569	34745	35965	38032	38619
FDHD	5650	8708	15241	18339	18515	18691	18867	19043	19435	20480	20896
ND-SAND	875	1437	2750	4925	6475	7075	7675	8275	8875	9475	10075
ND-LAr+TMS	1250	1250	2000	7475	12700	13900	15100	16300	17500	18700	19900
Total	29156	46787	65320	67792	71907	74059	76211	78363	81776	86687	89491

Figure 21: Cumulative Disk by detector.



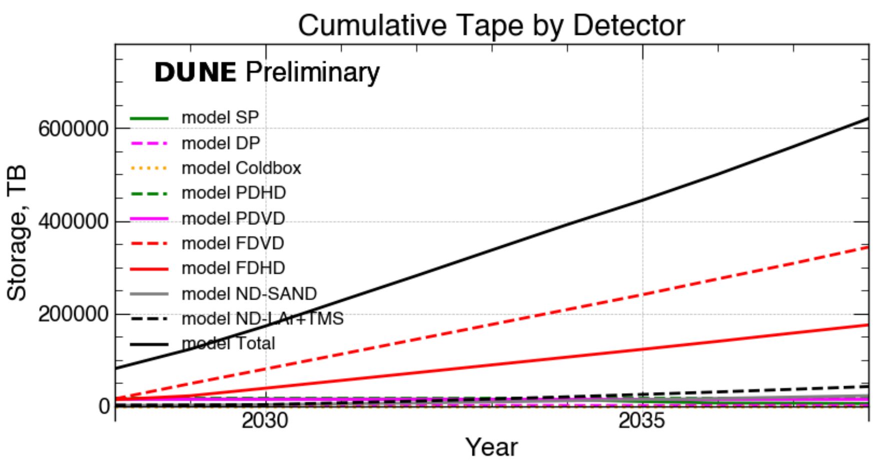
DataTypes	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Raw-Data	561	19794	40951	42312	42537	42537	42537	42537	44882	47703	48178
TP	3050	2779	2469	2469	2469	2469	2469	2469	1830	1562	1562
Reco-Sim	12233	13545	14483	13442	18692	18692	18692	18692	18692	18692	18692
Reco-Data	7212	7344	4352	6504	5644	7796	9948	12100	14340	16668	18996
Test	6100	3323	3064	3064	2564	2564	2564	2564	2030	2062	2062
Total	29156	46787	65320	67792	71907	74059	76211	78363	81776	86687	89491

Figure 22: Cumulative Disk by data type.



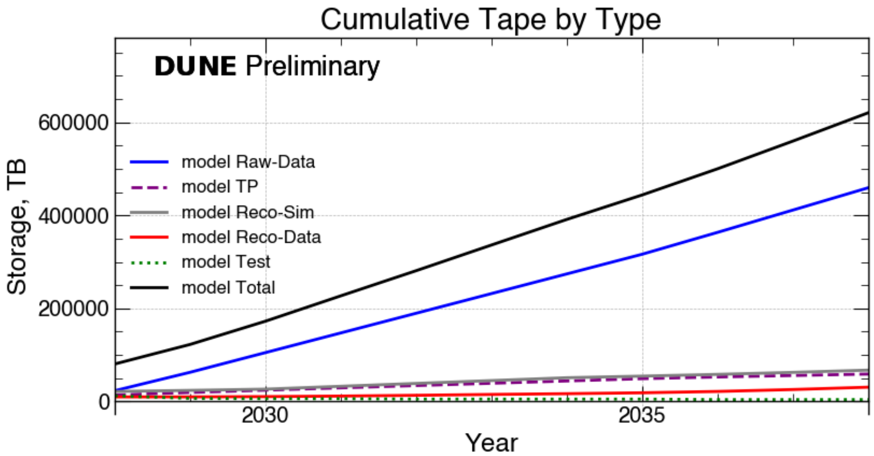
Locations	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
US	9716	18171	27951	28909	29869	30407	30945	31483	32630	34503	35323
CERN	280	0	0	0	0	0	0	0	0	0	0
Global	19158	28616	37369	38883	42038	43652	45266	46880	49146	52183	54167
Total	29156	46787	65320	67792	71907	74059	76211	78363	81776	86687	89491

Figure 23: Cumulative Disk by site.



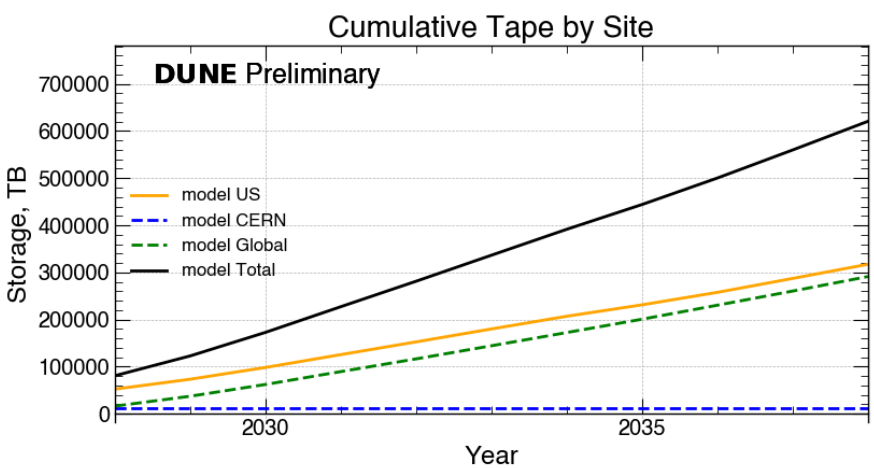
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	15021	15021	15021	15021	15021	14640	13579	9600	6428	6090	5347
DP	1208	1208	1208	1208	1208	1208	1152	1063	975	900	859
Coldbox	0	0	0	0	0	0	0	0	0	0	0
PDHD	16618	16618	16618	16618	16618	16618	16618	16618	16618	16618	16618
PDVD	15661	15661	15661	15661	15661	15661	15661	15661	15661	15661	15661
FDVD	15289	48240	79916	111900	143928	176001	208117	240277	274381	307926	343049
FDHD	13624	21974	38376	55076	71819	88607	105438	122313	139600	157505	175046
ND-SAND	1400	1900	2950	4900	6500	8750	11150	13700	16400	19250	22250
ND-LAr+TMS	1800	2050	2900	6800	10500	15000	19800	24900	30300	36000	42000
Total	80624	122675	172654	227187	281259	336487	391518	444135	500365	559953	620833

Figure 24: Cumulative Tape by detector.



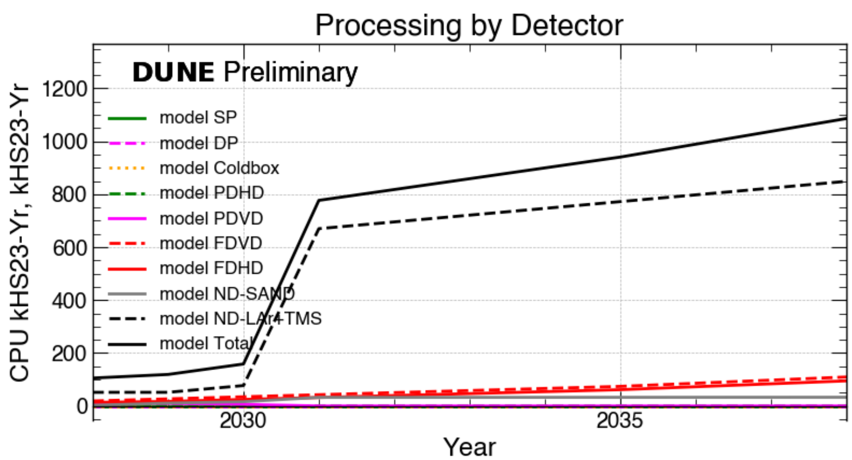
DataTypes	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Raw-Data	23214	62804	105116	147428	189741	232053	274365	316678	363681	411635	459589
TP	13868	19426	24366	29305	34244	39183	44123	49062	52724	55848	58972
Reco-Sim	21525	23915	26555	32695	38835	44975	51115	54564	58316	62607	67410
Reco-Data	9816	9882	10486	11628	13308	15144	16784	18701	21582	25738	30737
Test	12200	6646	6129	6129	5129	5129	5129	5129	4061	4124	4124
Total	80624	122675	172654	227187	281259	336487	391518	444135	500365	559953	620833

Figure 25: Cumulative Tape by data type.



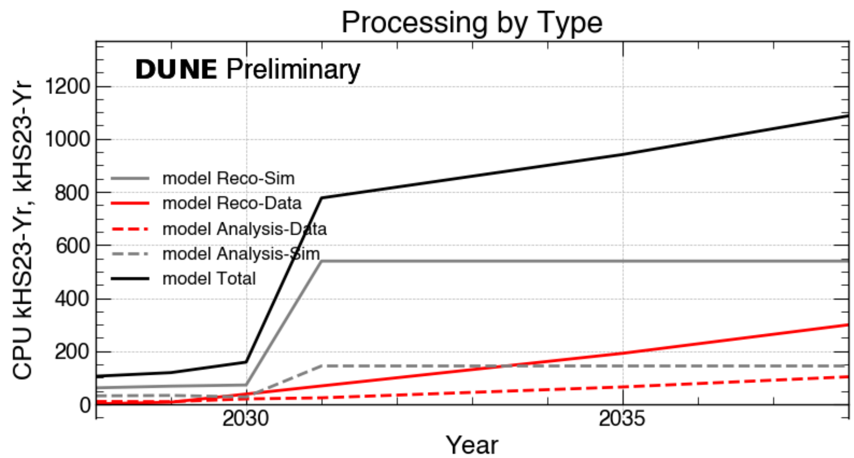
Locations	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
US	52126	73151	98140	125407	152443	179866	206824	231098	257583	287171	317219
CERN	12441	12441	12441	12441	12441	12441	12441	12441	12441	12441	12441
Global	16057	37082	62071	89338	116374	144179	172252	200595	230341	260340	291172
Total	80624	122675	172654	227187	281259	336487	391518	444135	500365	559953	620833

Figure 26: Cumulative Tape by site.



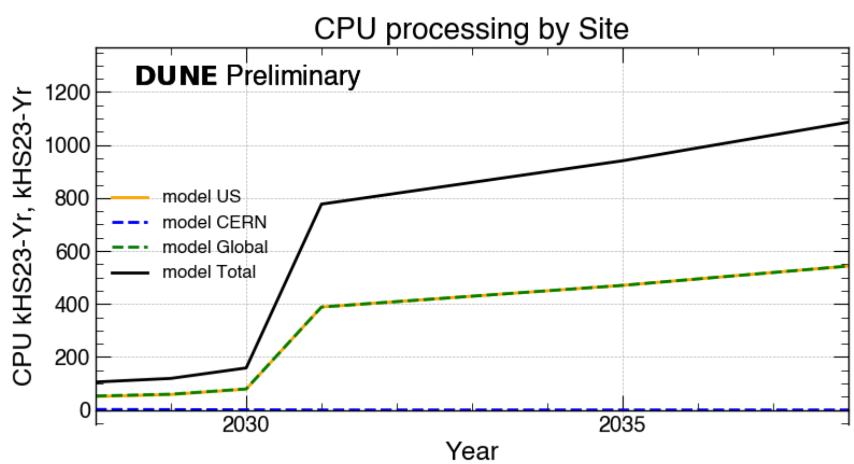
Detectors	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coldbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDHD	7.8	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PDVD	11.0	9.4	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FDVD	19.0	26.8	34.7	42.6	50.5	58.3	66.2	74.1	85.9	97.7	109.5
FDHD	13.5	17.2	24.6	32.0	39.4	46.8	54.2	61.6	72.7	83.8	94.9
ND-SAND	2.7	10.8	16.2	32.4	32.5	32.6	32.7	32.7	32.8	32.9	33.0
ND-LAr+TMS	51.6	51.6	77.1	670.0	695.6	721.1	746.7	772.3	797.8	823.4	848.9
Total	105.5	119.1	158.6	777.0	817.9	858.8	899.7	940.6	989.2	1037.7	1086.3

Figure 27: CPU kHS23-Yr resources by detector by year.



DataTypes	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Reco-Sim	61.8	68.3	72.6	539.3	539.3	539.3	539.3	539.3	539.3	539.3	539.3
Reco-Data	1.5	7.7	38.4	69.1	99.8	130.5	161.2	191.9	227.6	263.4	299.2
Analysis-Data	10.5	9.9	20.1	24.3	34.5	44.7	54.9	65.2	77.9	90.7	103.5
Analysis-Sim	31.7	33.3	27.6	144.3	144.3	144.3	144.3	144.3	144.3	144.3	144.3
Total	105.5	119.1	158.6	777.0	817.9	858.8	899.7	940.6	989.2	1037.7	1086.3

Figure 28: CPU kHS23-Yr resources by data types by year.



Locations	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
US	50.9	58.3	78.7	388.5	408.9	429.4	449.9	470.3	494.6	518.9	543.1
CERN	1.9	1.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Global	52.7	59.6	79.3	388.5	408.9	429.4	449.9	470.3	494.6	518.9	543.1
Total	105.5	119.1	158.6	777.0	817.9	858.8	899.7	940.6	989.2	1037.7	1086.3

Figure 29: Projected CPU use by location. Units are CPU kHS23-Yr

References

[1] **DUNE** Collaboration, A. Abed Abud *et al.*, "DUNE Offline Computing Conceptual Design Report," arXiv:2210.15665 [physics.data-an].

[2] H. Schellman, "DUNE Offline Computing Model Calculations for 2024." https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=29925.

[3] P. Clarke, "Computing Contribution Board (CCB) Minutes for February 2024." https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=30302.