cherenkov telescope array

CTA Computing Model and INFN

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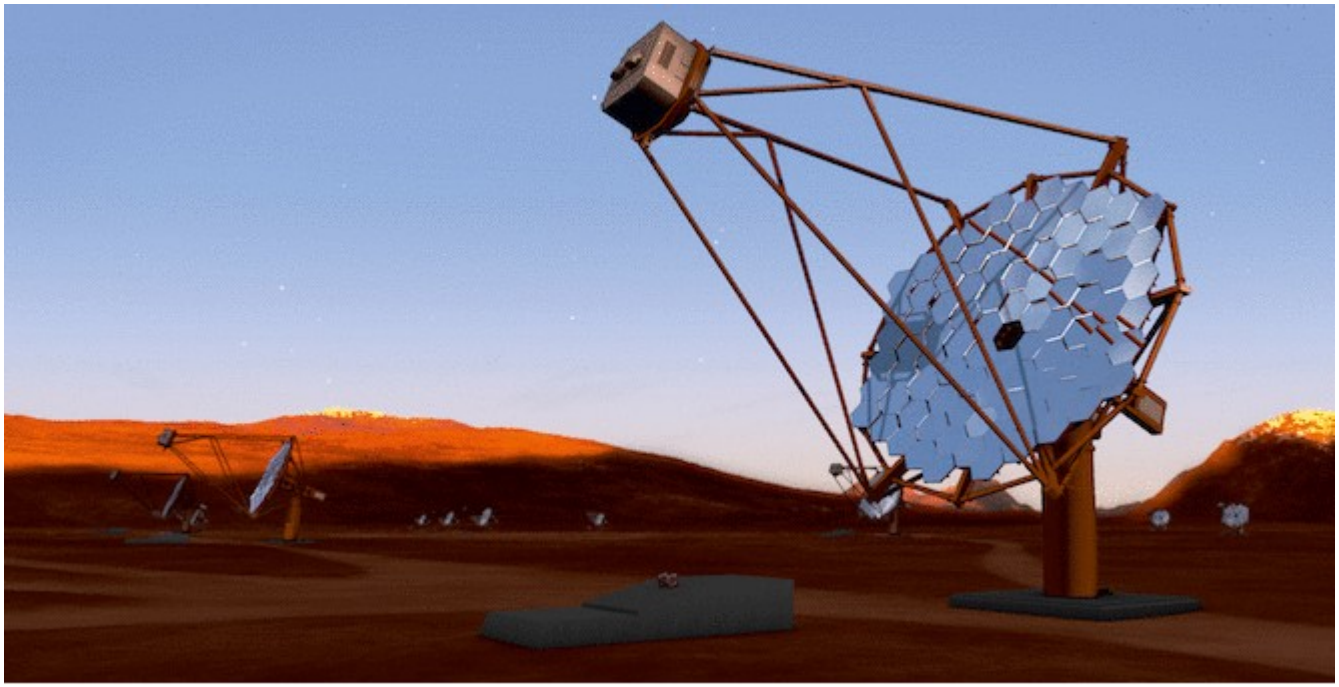
Outline

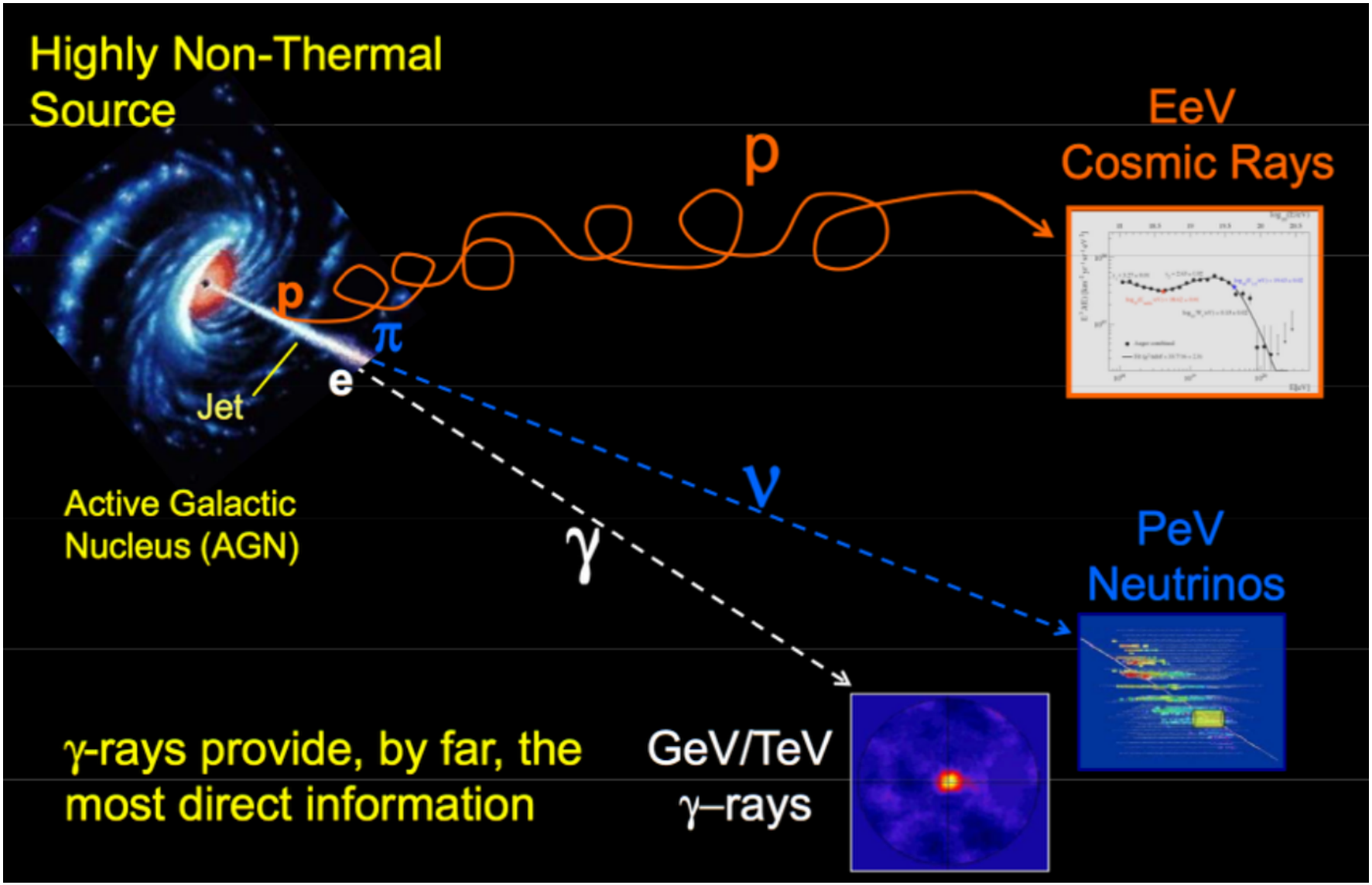
- The Cherenkov Telescope Array (CTA)
- Data Management
  - Data Volume
  - Data Model
  - Computing Model
  - Needed Resources
- Role of INFN
  - present & future

Cherenkov Telescope Array

- Next generation IACT, VHE gamma-rays Observatory
- energy range 20 GeV - 300 TeV
- unprecedented sensitivity (~mCrab @ 1TeV), angular and energy resolutions (~0.05deg, ~8%)
- 3 telescope types, 2 sites (north and south emisphere)
- Worldwide collaboration, 1200 members

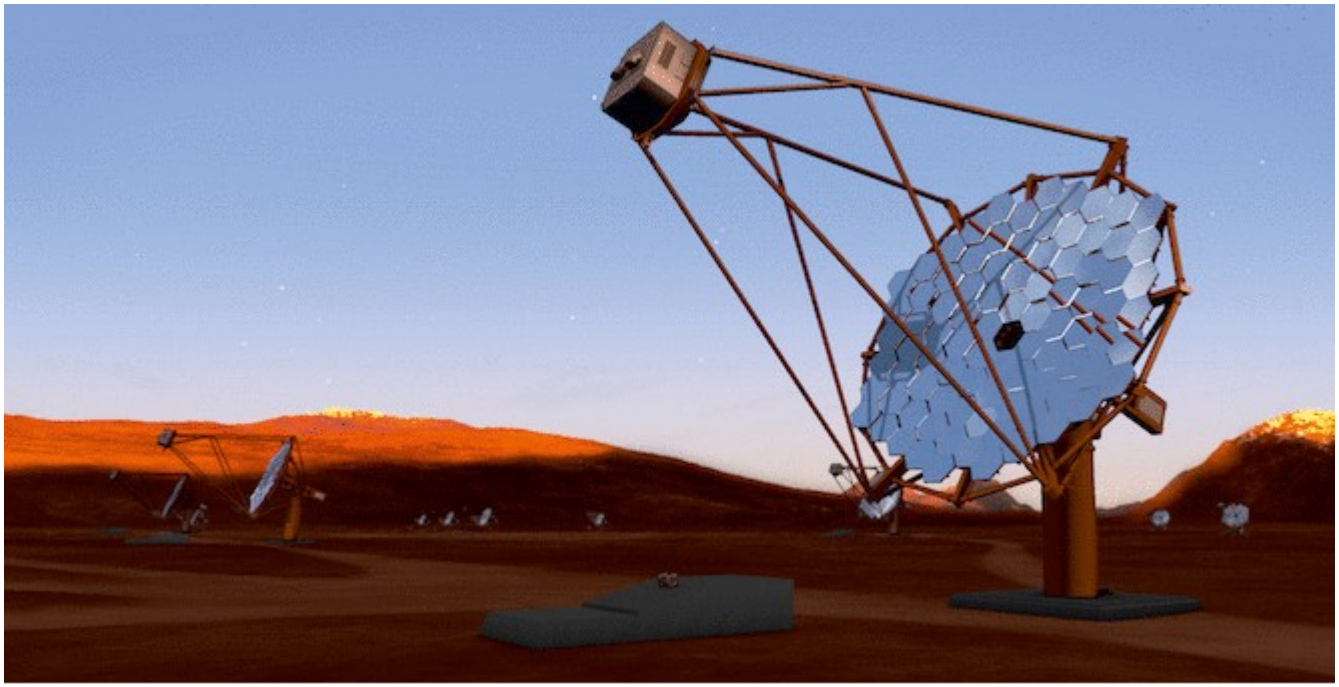


Motivation

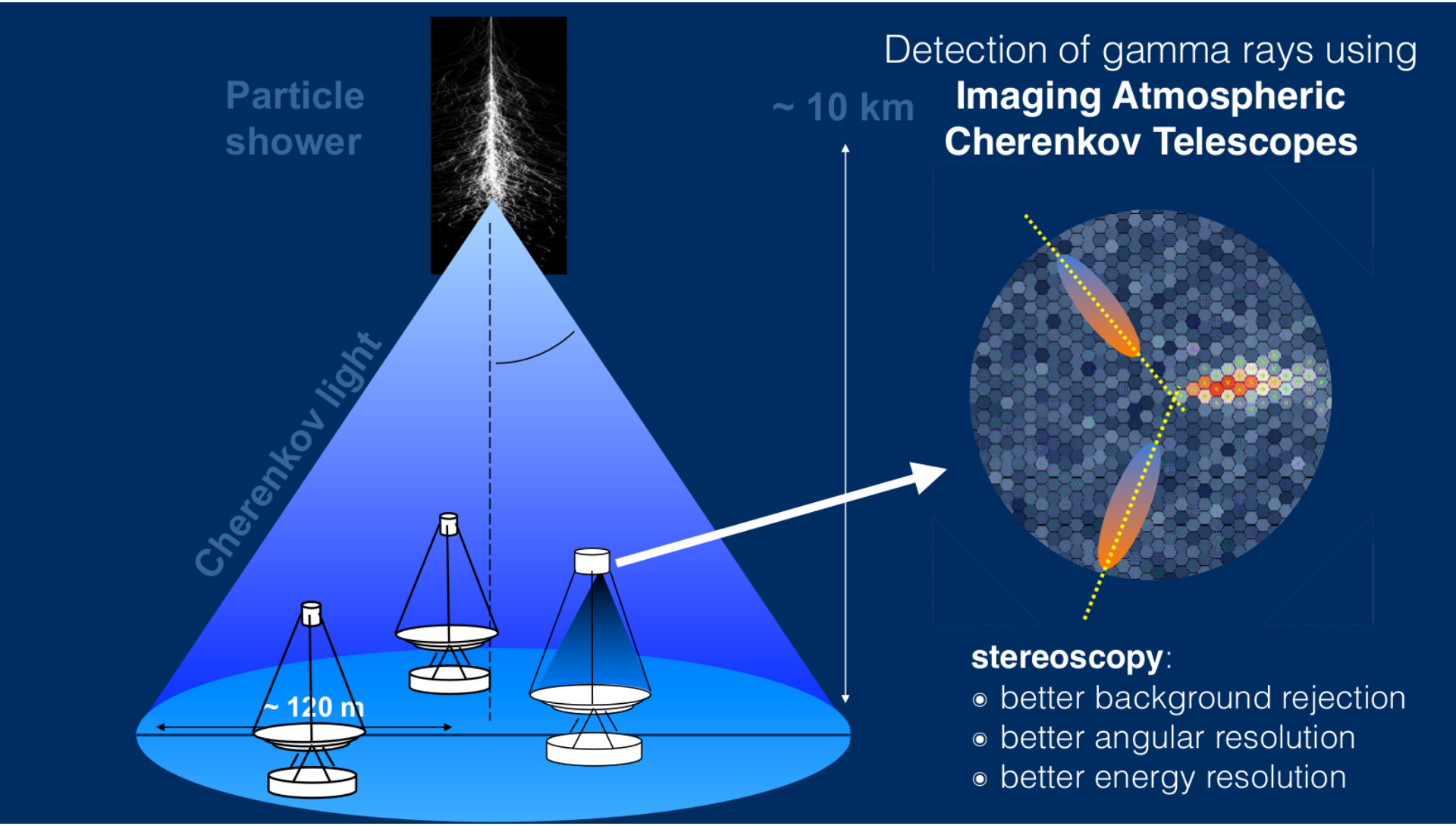

Highly Non-Thermal Source
p
EeV Cosmic Rays
p
π
e
Jet
Active Galactic Nucleus (AGN)
ν
γ
PeV Neutrinos
γ-rays provide, by far, the most direct information
GeV/TeV γ–rays

CTA physics cases

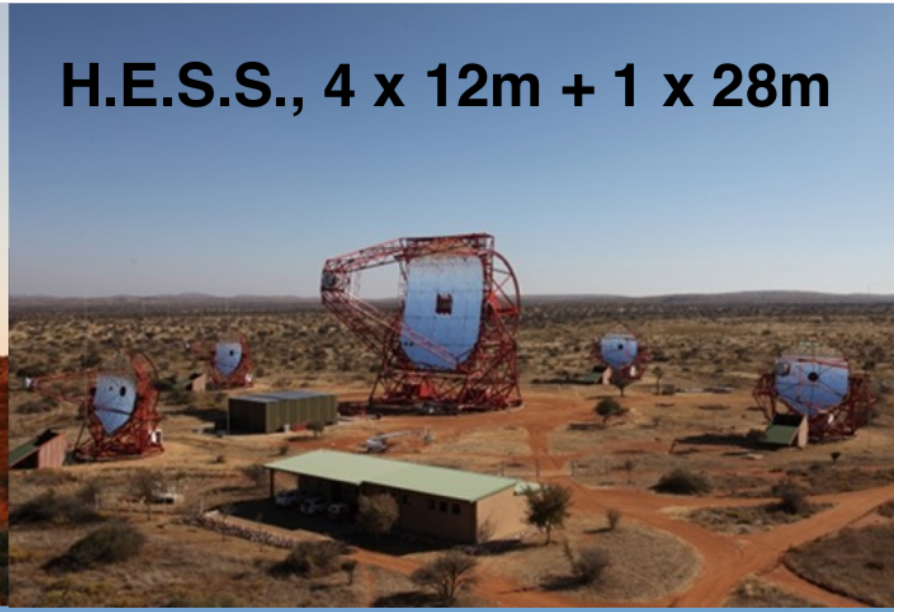
- Fundamental physics: indirect DM search, Axion-like particles, Lorentz Invariance Violation
- Cosmic rays physics (origin, propagation, spectra, ν_τ)
- EM-counterparts of HE-ν and GW
- Transients (GRBs, FRBs)
- Cosmology (EBL)
- HE astrophysics (AGNs, jets, SNR, Pulsars,...)



IACT Technique

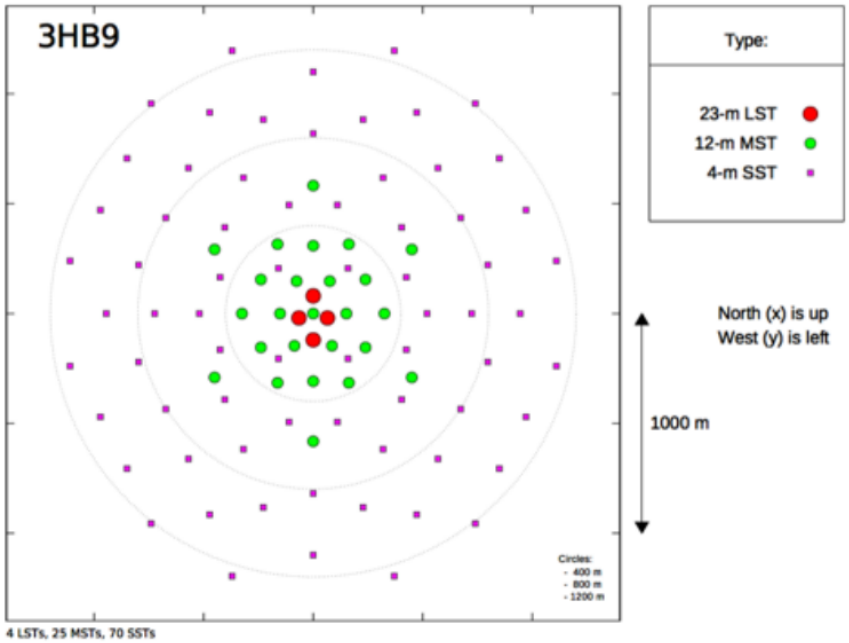


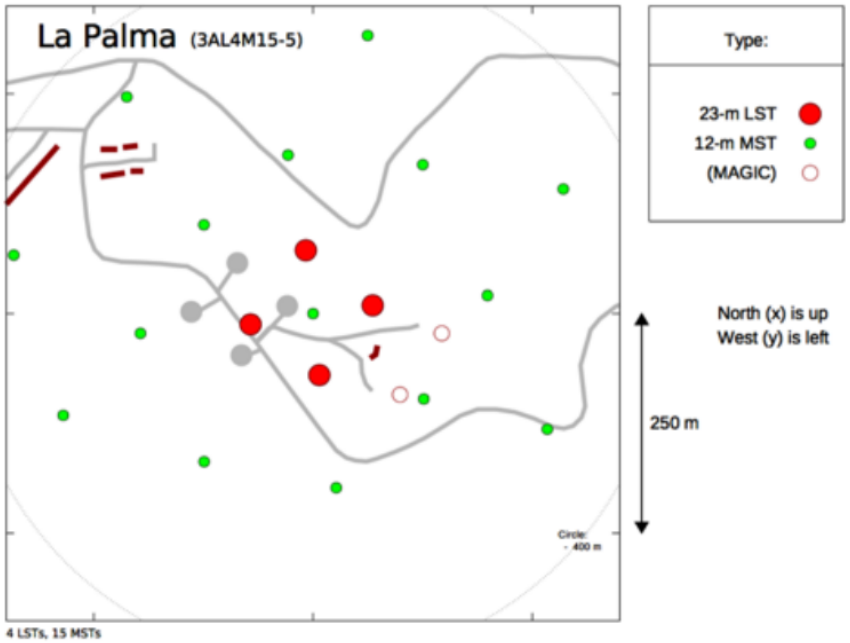
Current Instruments



CTA, North and South Arrays

- N: La Palma (Spain)
- S: ESO site “Paranal” (Chile)

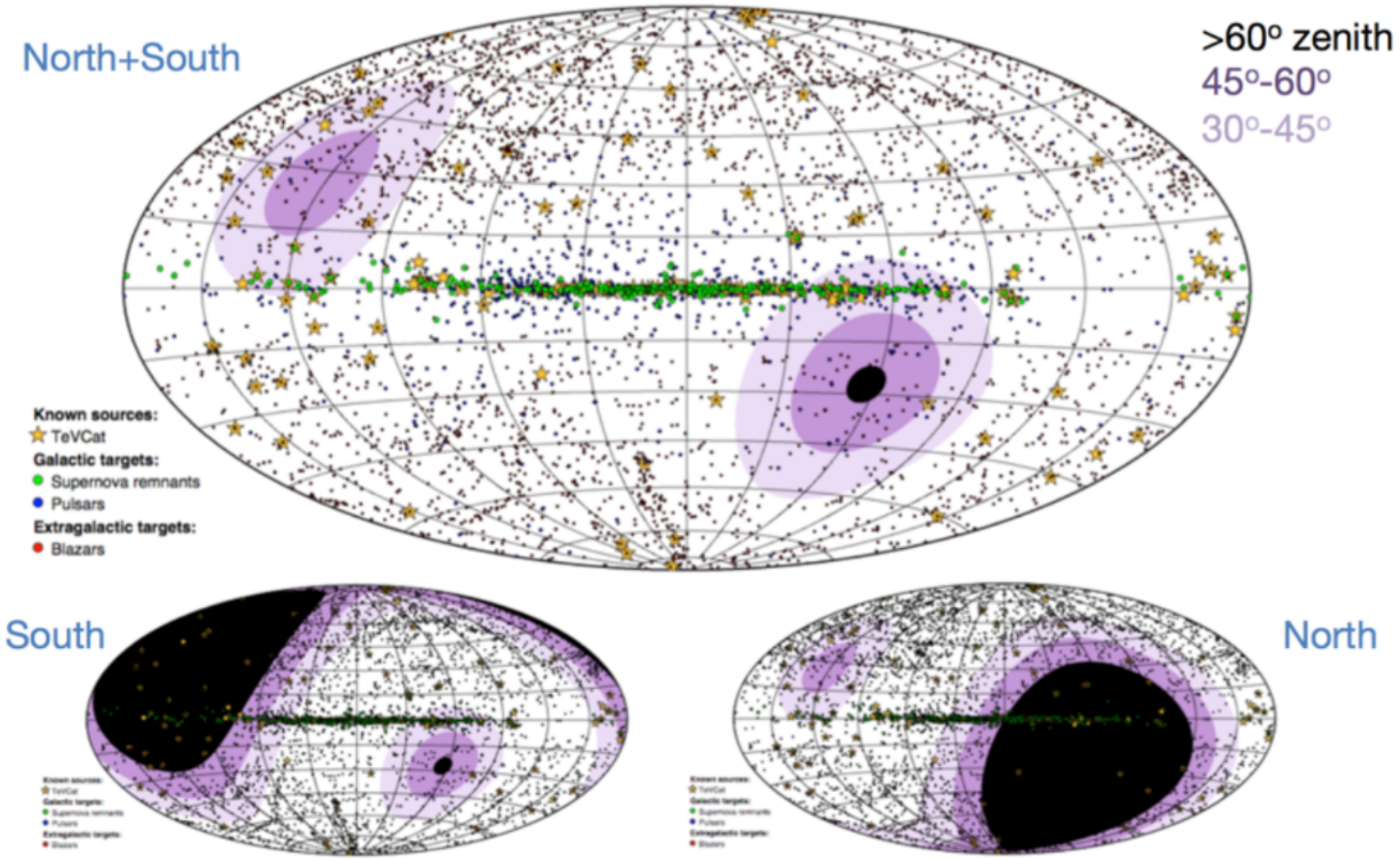




South:
4 LST
25 MST
70 SST

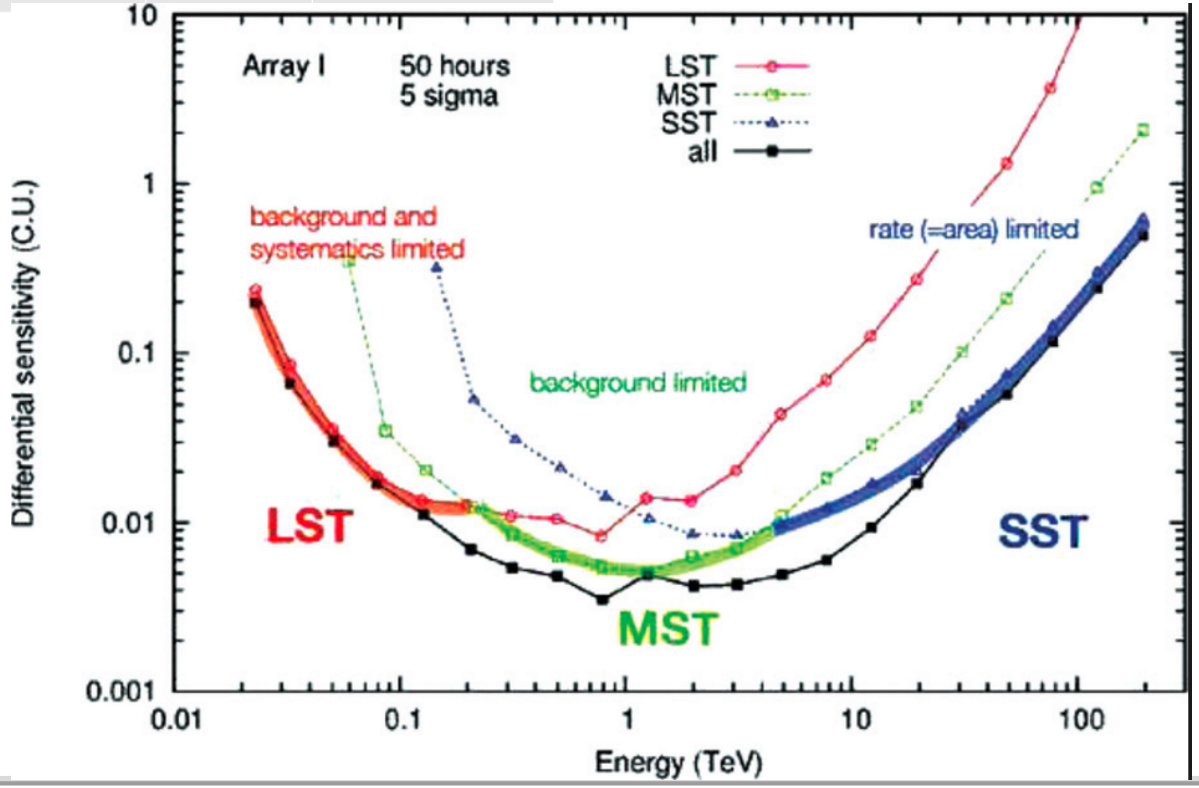
North:
4 LST
15 MST

CTA, North and South Arrays



CTA Telescopes

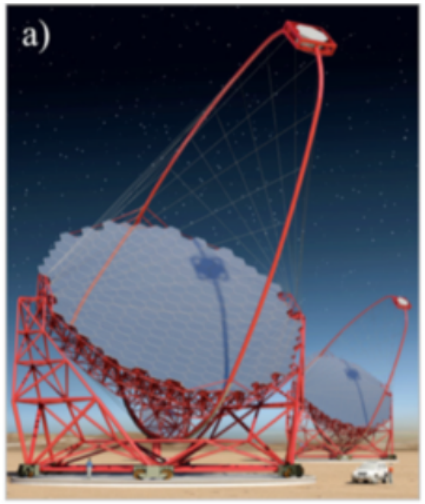
	LST	MST	SST	SCT
# N/S	4/4	15/25	0/70	~25
dish diam. [m]	23	12	4	9.5
fov diam. [deg]	4.5	8	9	8
pixels	1855	1855	2000	11000



CTA Telescopes

INFN contributions:

- LST
  - FEE
  - SiPM
  - structure
  - calbox
- SCT
  - SiPM
- Atmospheric Calibration
- SWAT
- Data

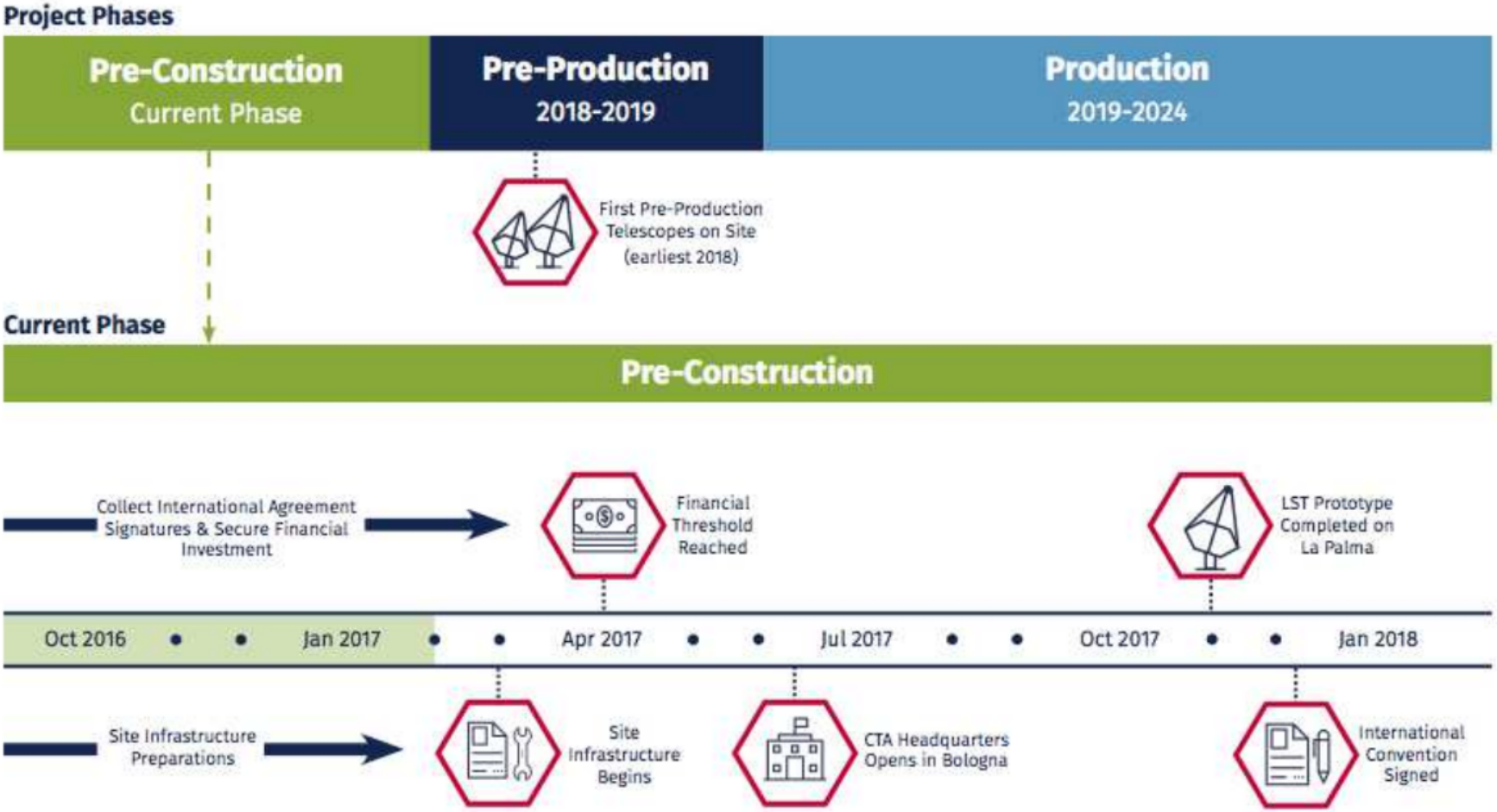


Status of the Project

- Construction Phase 2017 - 2021

Status of the Project

- Construction Phase 2017 - 2021
- **Operation** Phase from **2022**, for **30** years



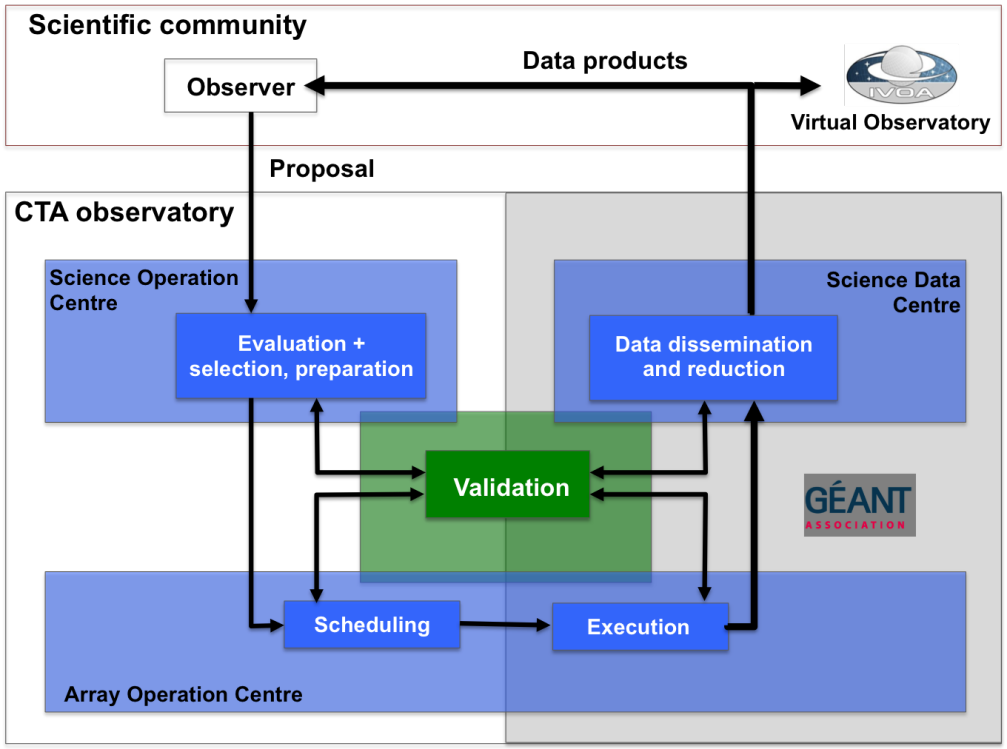
Data Management

Data Management tasks:

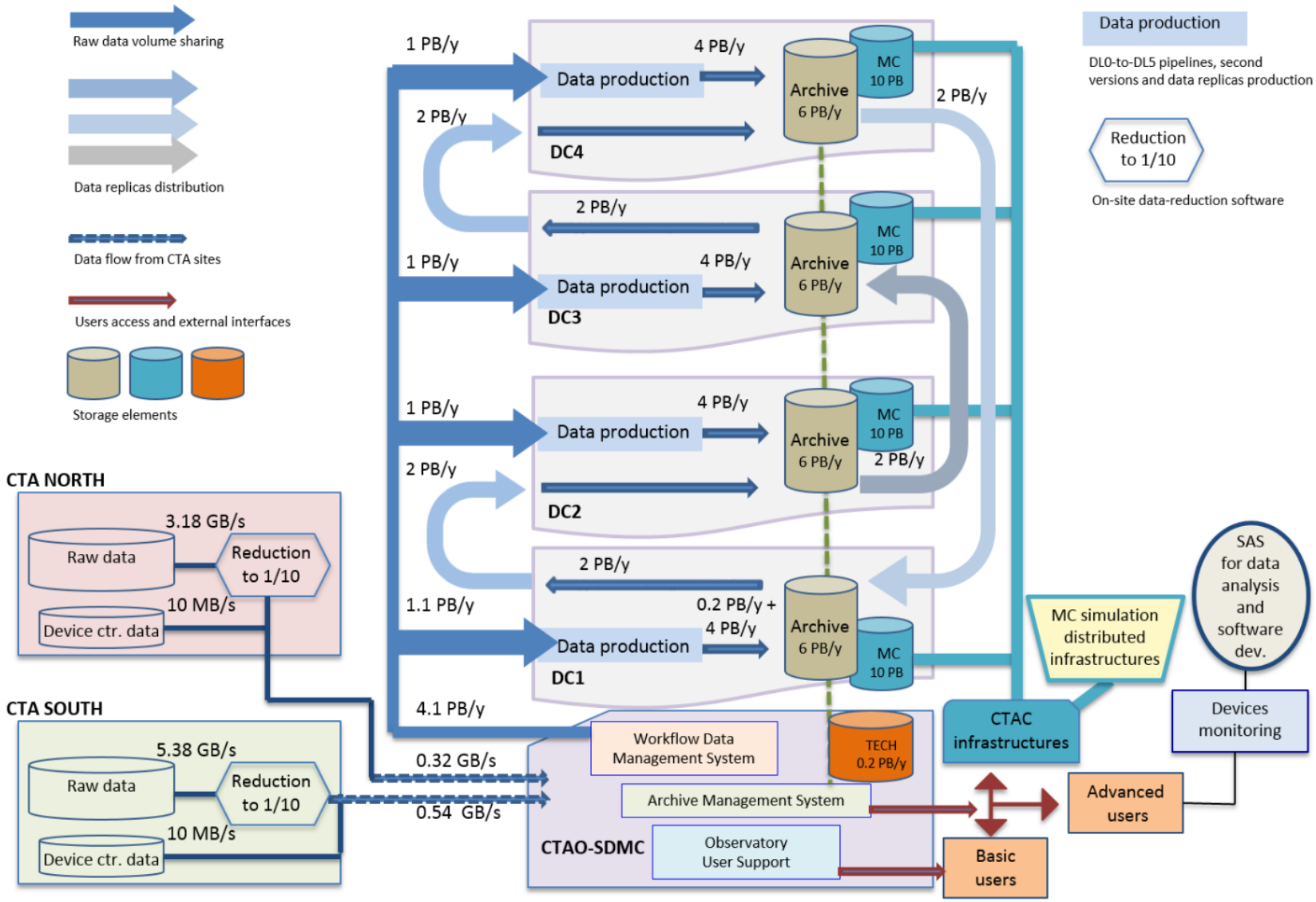
- treatment and flow of data from remote telescopes
- *big data* archiving and processing
  - high data rate
  - large computing power
- open data access

Contexts: **CTAC** and **CTAO**

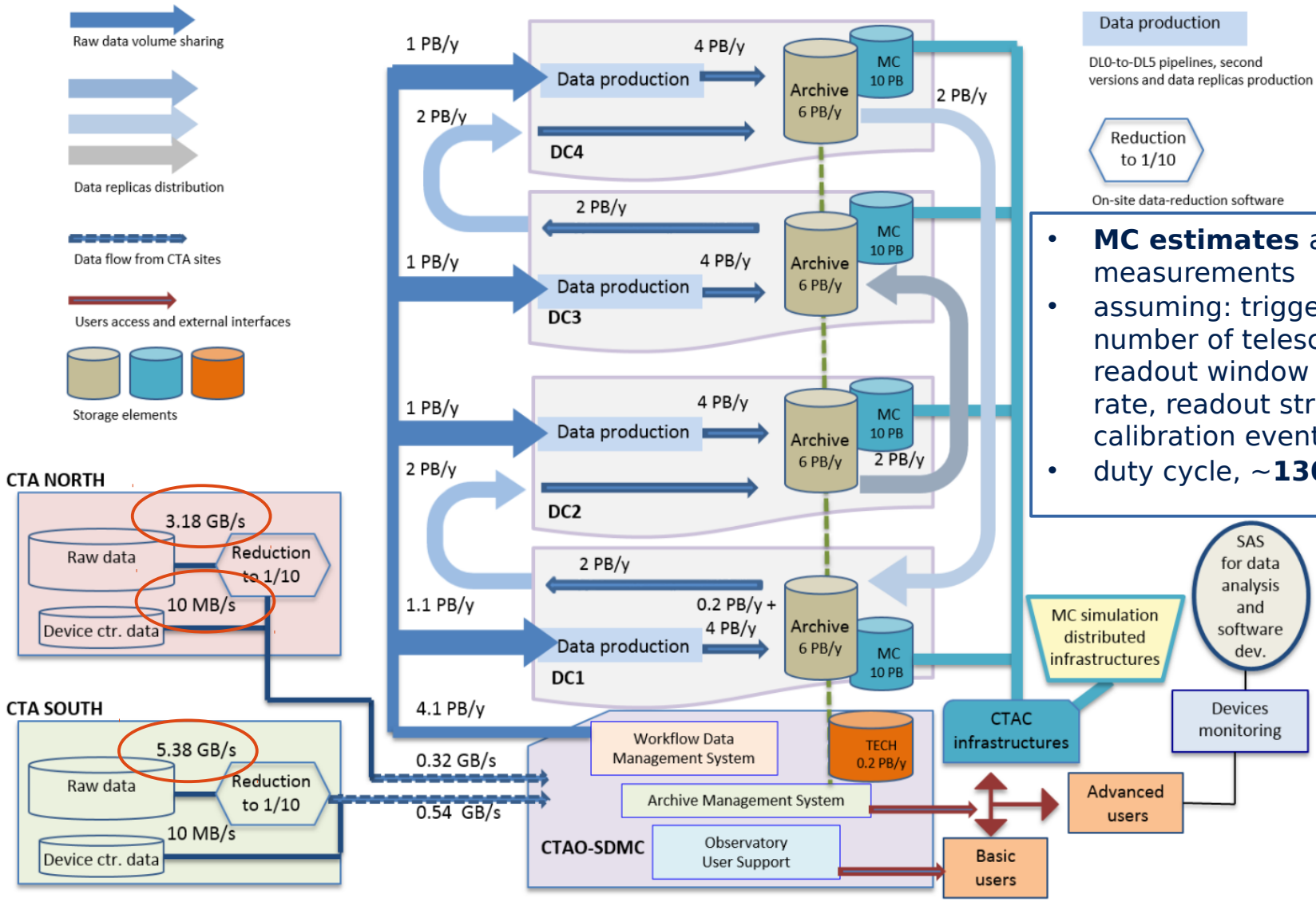
- guest observers, archival users, advanced users



Computing model at a glance

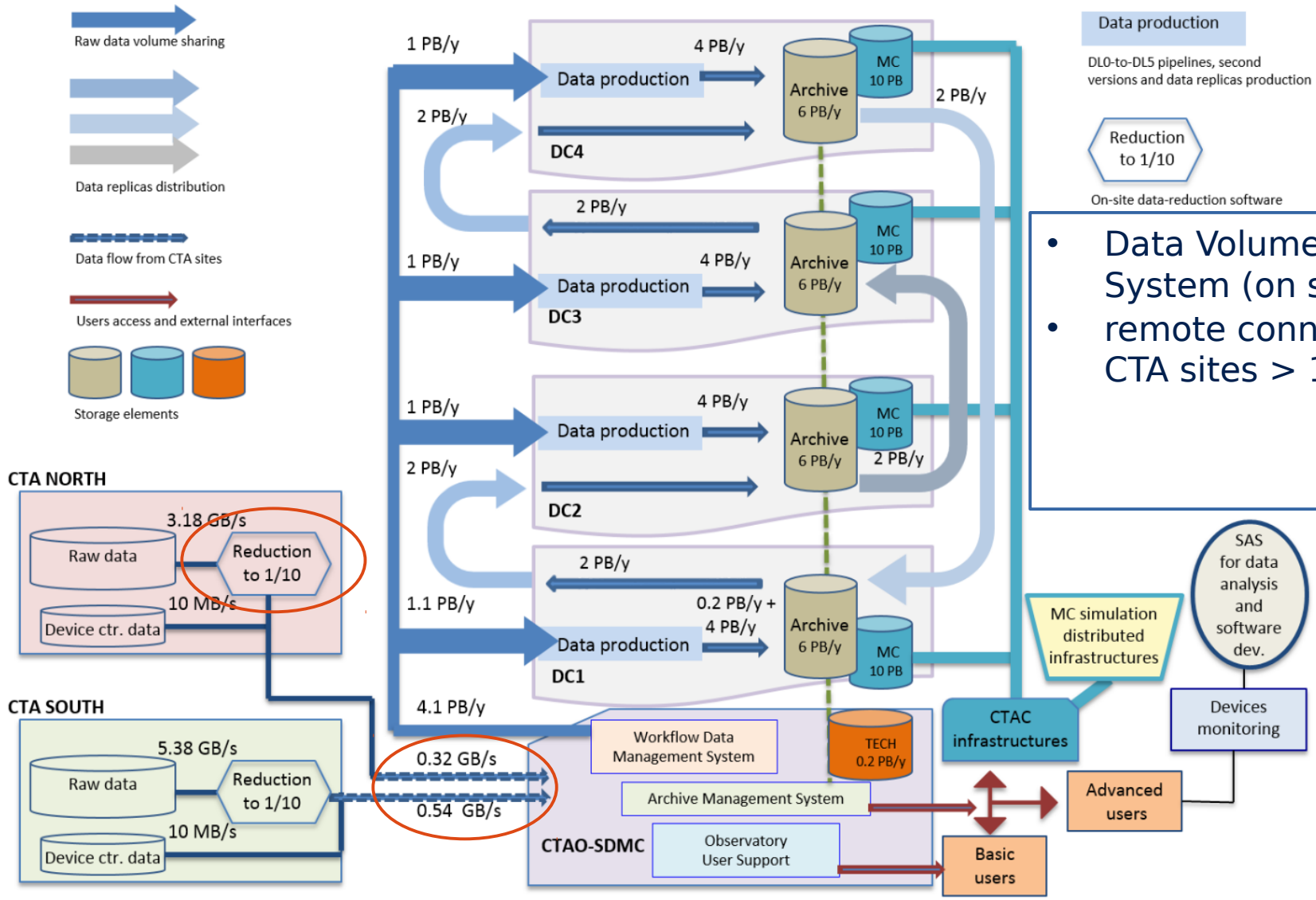


Data production rate



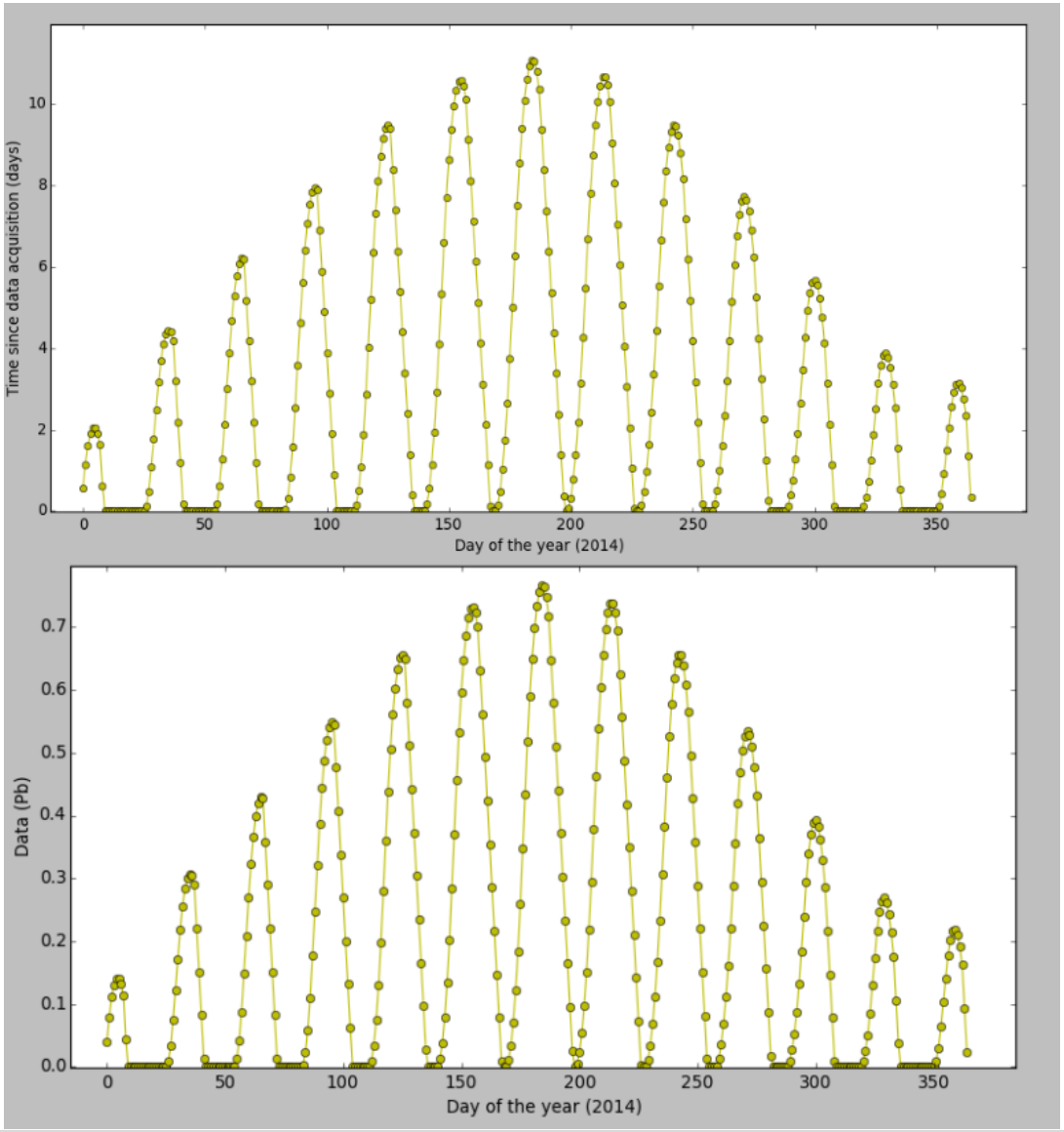
- **MC estimates** and site measurements
- assuming: trigger scheme, number of telescopes, pixels, readout window and sampling rate, readout strategy, calibration events, etc...
- duty cycle, ~**1300 h/y**

Data transfer from remote sites



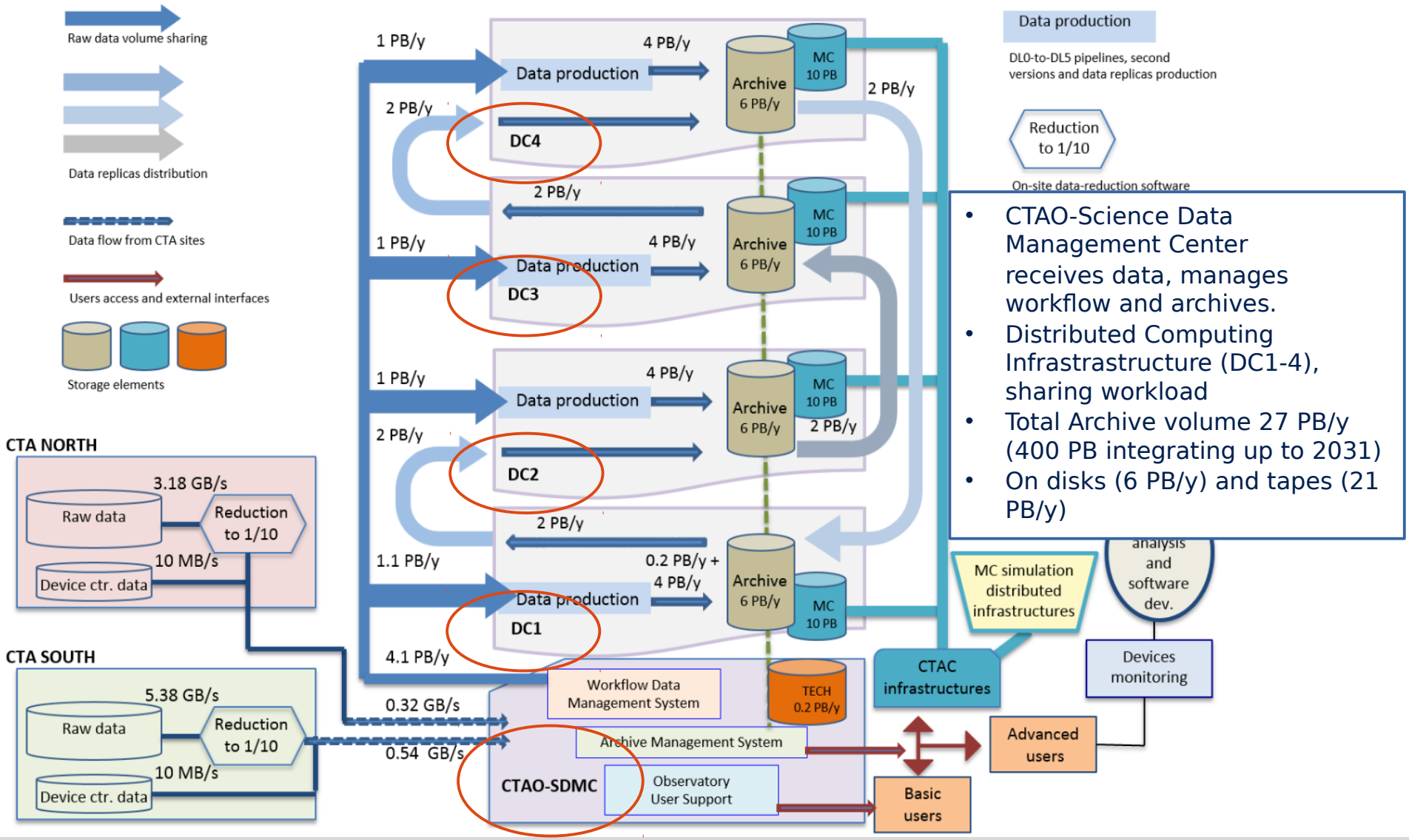
- Data Volume Reduction System (on site), 1/10
- remote connection to CTA sites > 1Gb/s

Network: raw data transfer



- Transfer of raw data from remote sites
- maximum daily volume must be transfered within 10 days
- moonless nights (~1300 h)
- required > 1Gb/s link
- figures for CTA-S

Distributed Computing model



- CTAO-Science Data Management Center receives data, manages workflow and archives.
- Distributed Computing Infrastrastructure (DC1-4), sharing workload
- Total Archive volume 27 PB/y (400 PB integrating up to 2031)
- On disks (6 PB/y) and tapes (21 PB/y)

Data Model

Data Level	Short Name	Description	Data reduction factor
Level 0 (DL0)	RAW	Data from the Data Acquisition hardware/software.	
Level 1 (DL1)	CALIBRATED	Physical quantities measured in each separate camera: photons, arrival times, etc., and per-telescope parameters derived from those quantities.	1-0.2
Level 2 (DL2)	RECONSTRUCTED	Reconstructed shower parameters (per event, no longer per-telescope) such as energy, direction, particle ID, and related signal discrimination parameters.	10^{-1}
Level 3 (DL3)	REDUCED	Sets of selected (e.g. gamma-ray-candidate) events, along with associated instrumental response characterizations and any housekeeping (technical summary) data needed for science analysis.	10^{-2}
Level 4 (DL4)	SCIENCE	High Level binned data products like spectra, sky maps, or light curves.	10^{-3}
Level 5 (DL5)	OBSERVATORY	Legacy observatory data, such as CTA survey sky maps or the CTA source catalog.	10^{-5} - 10^{-3}

DL0, low level:
- EVT, TECH, CAL
- permanently archived
- Array level trigger (individual telescope trigger rate ~10 kHz)
- compressed on site
- **Monte Carlo**

DL1-2, mid level:
- EVT, TECH, CAL
- camera/array level
- accesible advanced users

DL3-5, high level:
- with dedicated IRF
- science tools

Data Model

Data Level	Short Name	Description	Data reduction factor
Level 0 (DL0)	RAW	Data from the Data Acquisition hardware/software.	
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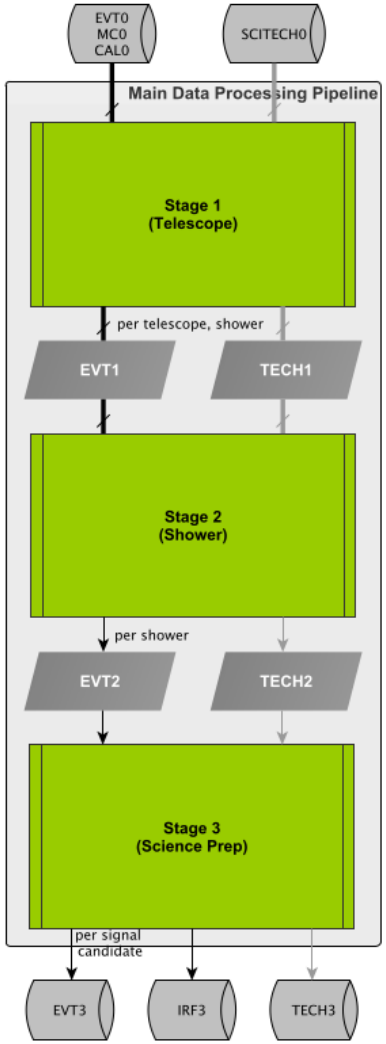
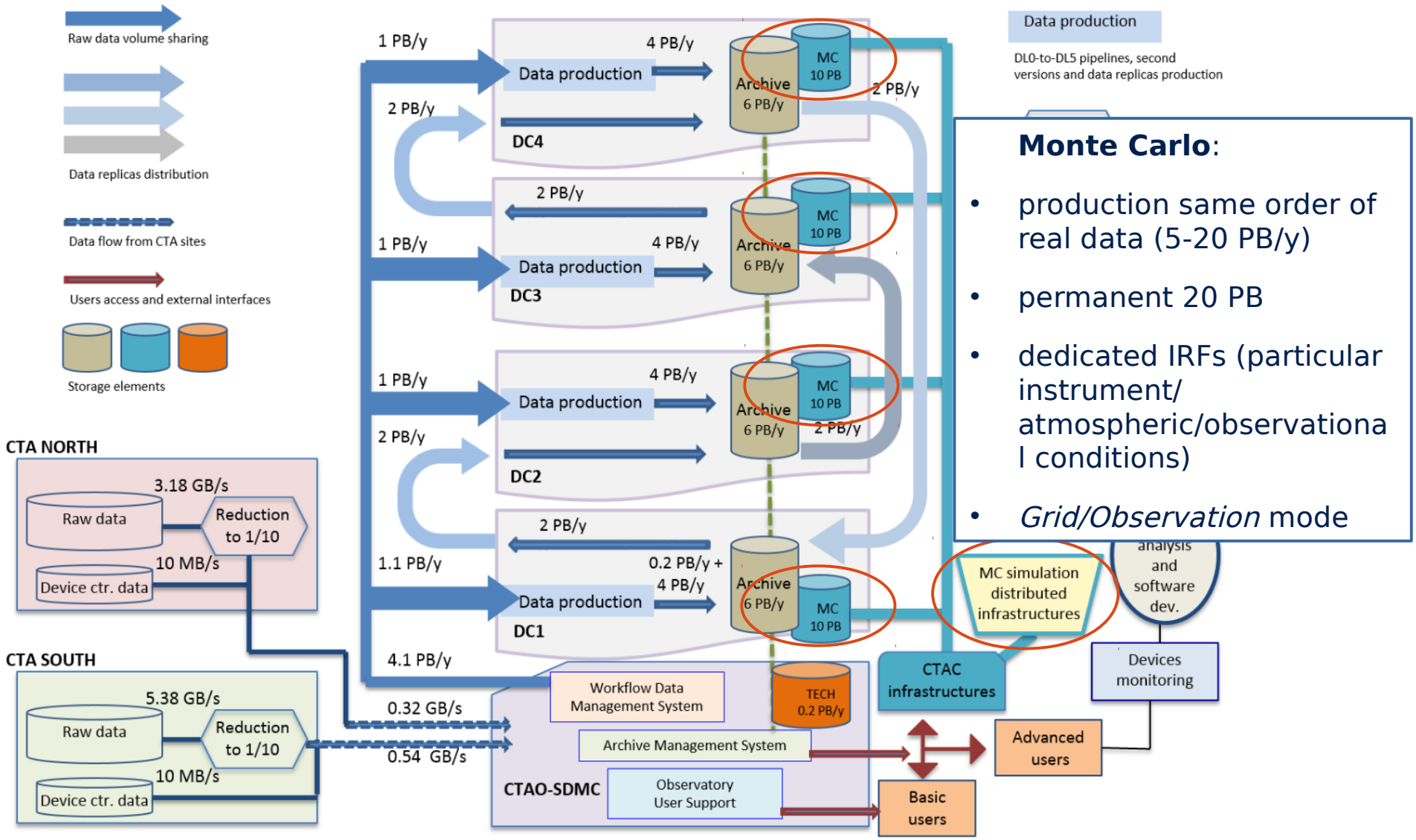


Data processing pipelines

- Different types of **pipelines**
  - Monte Carlo production
  - Reconstruction
  - High level analysis
- 3 different levels of recon/analysis pipelines:
  A. **real time**: 30s, monitor operations, transients, re-scheduling, sensitivity not worse than factor 3 w.r.t. off site
  B. **on site**: offline, results within 10h, sensitivity not worse than factor 2 w.r.t. off site
  C. **off site**: CTA DCs, best performance, dedicated MC, within 2 months
- High level of parallelization required, different architectures
- Level A. or B. will provide on site Data Volume Reduction

MC Data volume



Monte Carlo:

- production same order of real data (5-20 PB/y)
- permanent 20 PB
- dedicated IRFs (particular instrument/ atmospheric/observational conditions)
- *Grid/Observation* mode

Global data volume needs

- **Data rate and volume**:
  - Raw: 8.56 GB/s for 1300 h/y -> 40 PB/y (raw, minimal reduction) -> 4 PB/y (after level A/B onsite reduction)
  - DL2 = 3.4 PB/y
  - DL3-4-5 = 0.65 PB/y

  1 reprocessing/year

  Archive 2 most recent versions
  - TECH = 100 TB/y

TOTAL ~ 12 PB/y

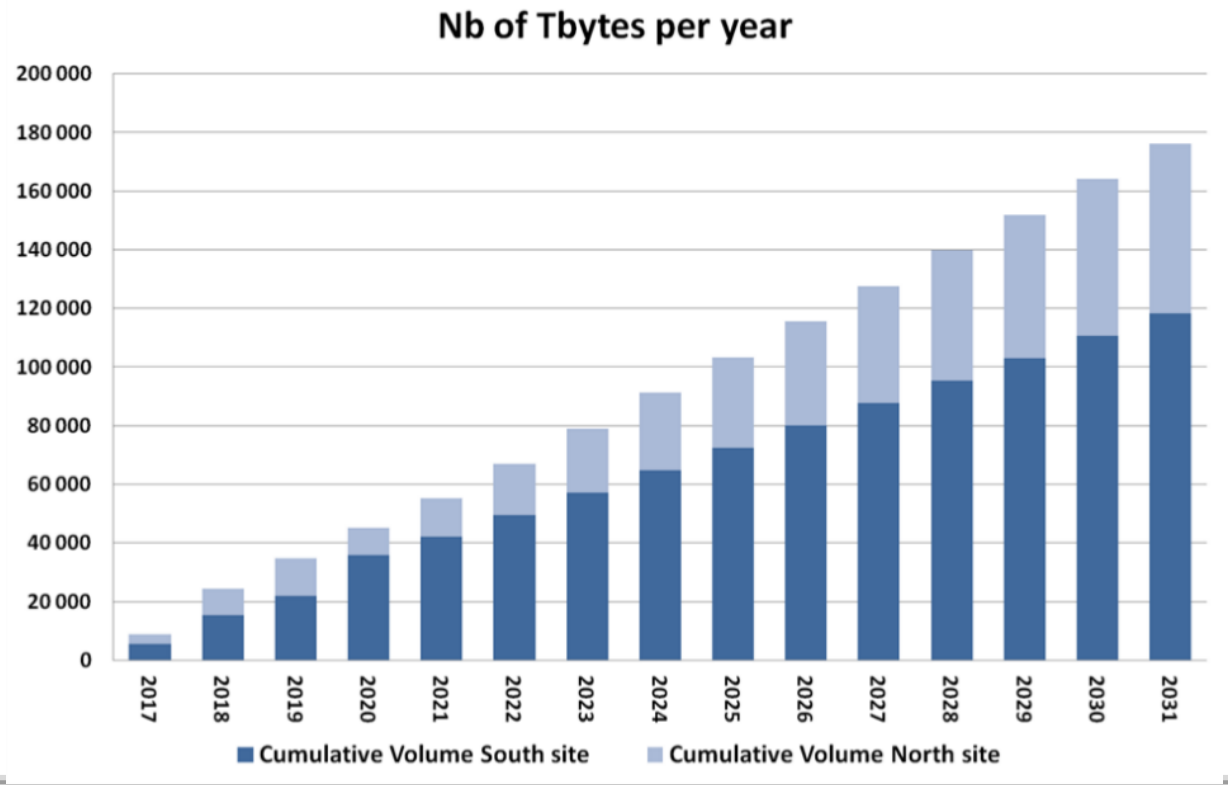
- Standard operations (not including special simulations, analysis, Advanced Users,...)
- **Construction Phase** (5 y), *current schedule: +1 y shift w.r.t. tables' labels...*

Year	2017	2018	2019	2020	2021
Cumulative raw data volume(PB)	4	10	12	15	19
Cumulative event data volume(PB)	4.5	12	17	25	35
Monte-Carlo data volume(PB)	5	12	17	20	20
Technical data volume(PB)	0.01	0.04	0.09	0.16	0.26
Cumulative Data (PB)	**9**	**24**	**35**	**45**	**55**

Global data volume needs

- Construction Phase (5 y), **Operation Phase** (here: 10 y, foreseen: 30y)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Cumulative raw data volume(PB)	23	27	31	35	39	43	47	51	55	59
Cumulative event data volume(PB)	47	59	71	83	96	108	120	132	144	156
Monte-Carlo data volume(PB)	20	20	20	20	20	20	20	20	20	20
Technical data volume(PB)	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3
Cumulative Data(PB)	**67**	**79**	**92**	**104**	**116**	**128**	**141**	**153**	**165**	**177**



Computing needs

Computing needs in construction and operation phases (in **10^9 HS06 · s**)

Year	2017	2018	2019	2020	2021
Data pipeline needs	19.7	59.1	98.5	138	177
Simulation needs	360	360	360	360	360
Re-processing needs	0	19.7	78.8	177	315
Cumulative needs	**380**	**439**	**537**	**675**	**853**

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Data pipeline needs	197	197	197	197	197	197	197	197	197	197
Simulation needs	360	360	360	360	360	360	360	360	360	360
Re-processing needs	493	690	887	1084	1281	1478	1675	1872	2070	2267
Cumulative needs	**1050**	**1247**	**1444**	**1641**	**1838**	**2035**	**2232**	**2430**	**2627**	**2824**

1 core ≈ 10 HS06 , 1 core in 1 y ≈ 10 · 3600 · 24 · 365 ≈ 315 MHS06 · s

Requirements:

- **Data reduction**: to process one day of raw data in less than one day
  = ~ 2100 cores
- **Monte Carlo**: to process the annual MC production in less than one month
  = ~ 14000 cores. Using Off-peak periods or/and CTACG.

Computing needs

Computing needs in operation phase (in **number of cores**)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total average	3329	3954	4579	5204	5829	6454	7079	7704	8329	8954
Peak (simulation)	13899	13899	13899	13899	13899	13899	13899	13899	13899	13899
Peak (daily data process)	2083	2083	2083	2083	2083	2083	2083	2083	2083	2083
Peak (reprocess-ing)	4753	5323	5703	5975	6178	6337	6464	6567	6654	6727
Daily data process + reprocessing	6836	7406	7786	8058	8262	8420	8547	8651	8737	8954

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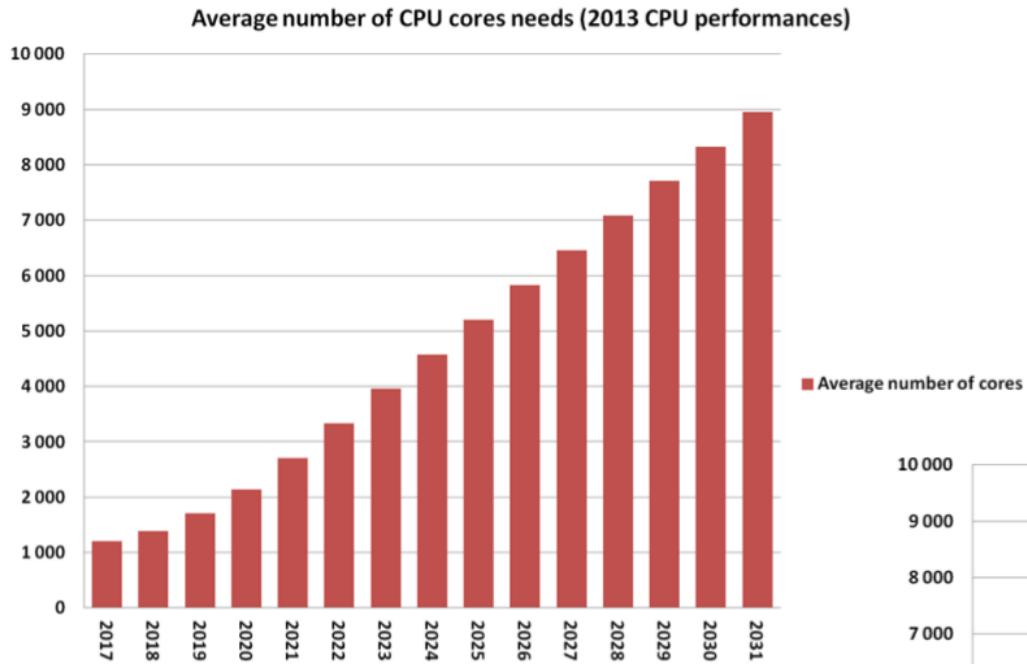
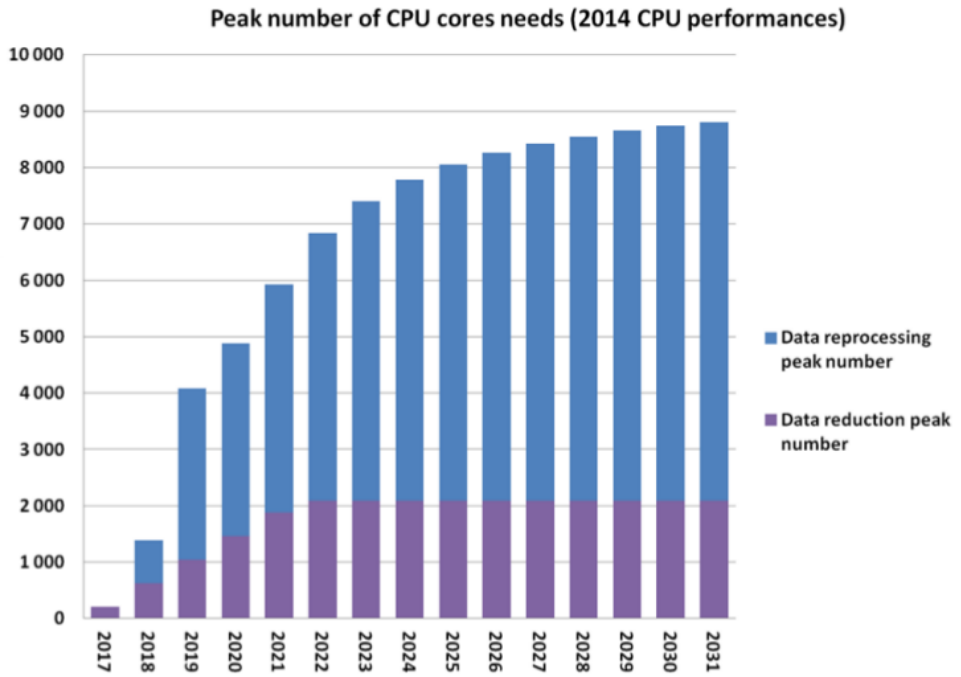
Computing needs

Computing needs in operation phase (in **number of cores**)





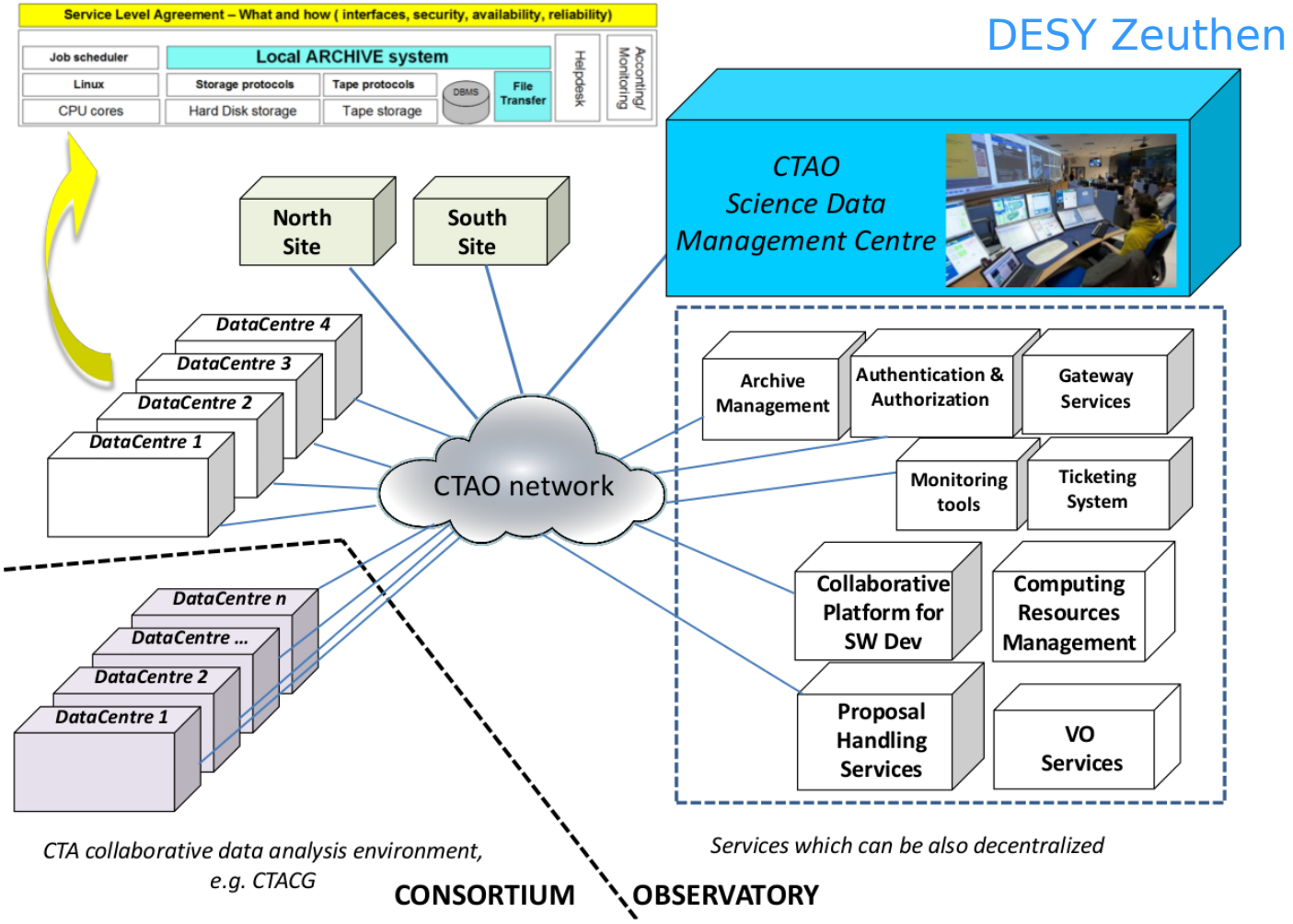
Resource needs summary

Year	2017	2018	2019	2020	2021
Storage capacity (PB)	9	24	35	45	55
Computing (Billion HS06.sec)	380	439	537	675	853
CPU cores (Peak number)	1204	1392	4083	4880	5931

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Storage capacity (PB)	67	79	92	104	116	128	141	153	165	177
Computing (Billion HS06.sec)	1050	1247	1444	1641	1838	2035	2232	2430	2627	2824
CPU cores (Peak number)	6836	7406	7786	8058	8262	8420	8547	8651	8737	8954

Distributed Computing Model

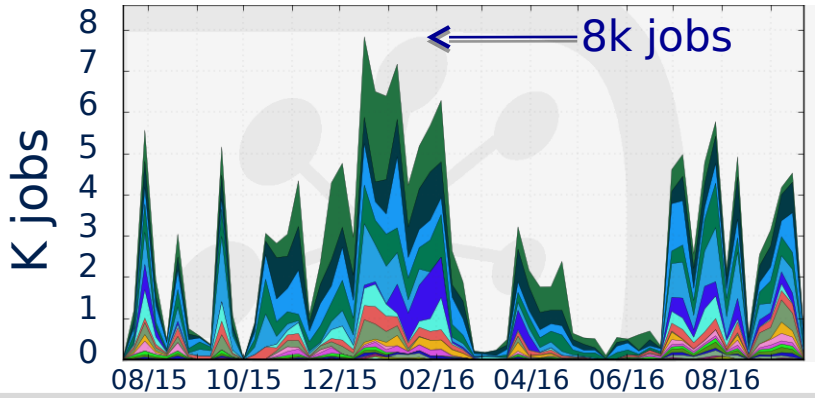
- Proposed solution, tradeoff between economy of scale and sustainability:
  4-7 Data Centres



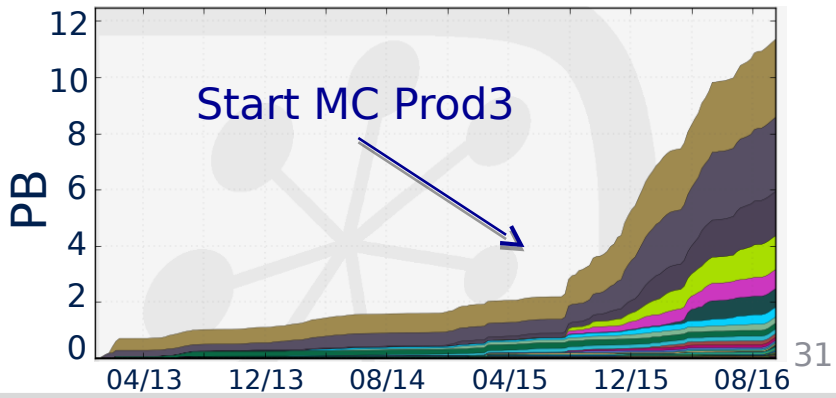
CTA Computing Grid

- Since 2008 the CTAC partners distributed computing resources are linked with Grid e-infrastructure (also *cloud* resources)
  - 19 sites, 7 countries, ~12000 logical CPUs, ~3.5 PB
- **DIRAC** as Workload Managment System and Data Managment System
- last years MC massive productions and their analysis
  - 360 M HS06 CPU hours (10% for users analysis)
  - 11 PB transferred data (2 PB currently on disk/tape)
  - 25 M files registered in the DIRAC File catalog

Running jobs by site during last MC campaign



Transferred data by destination



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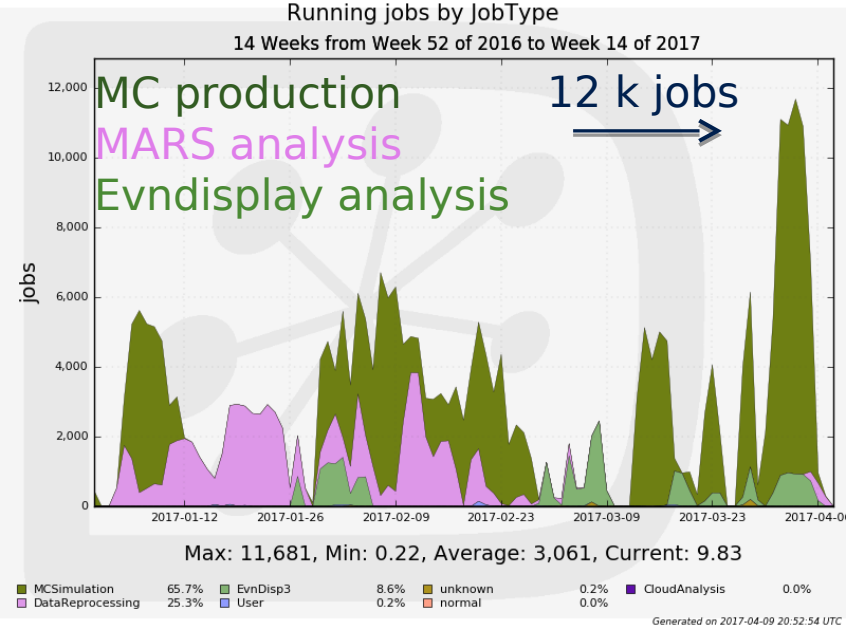
- **DIRAC** as Workload Managment System and Data Managment System
- MC massive productions and their analysis
  - 2017 Activities (Prod3b)

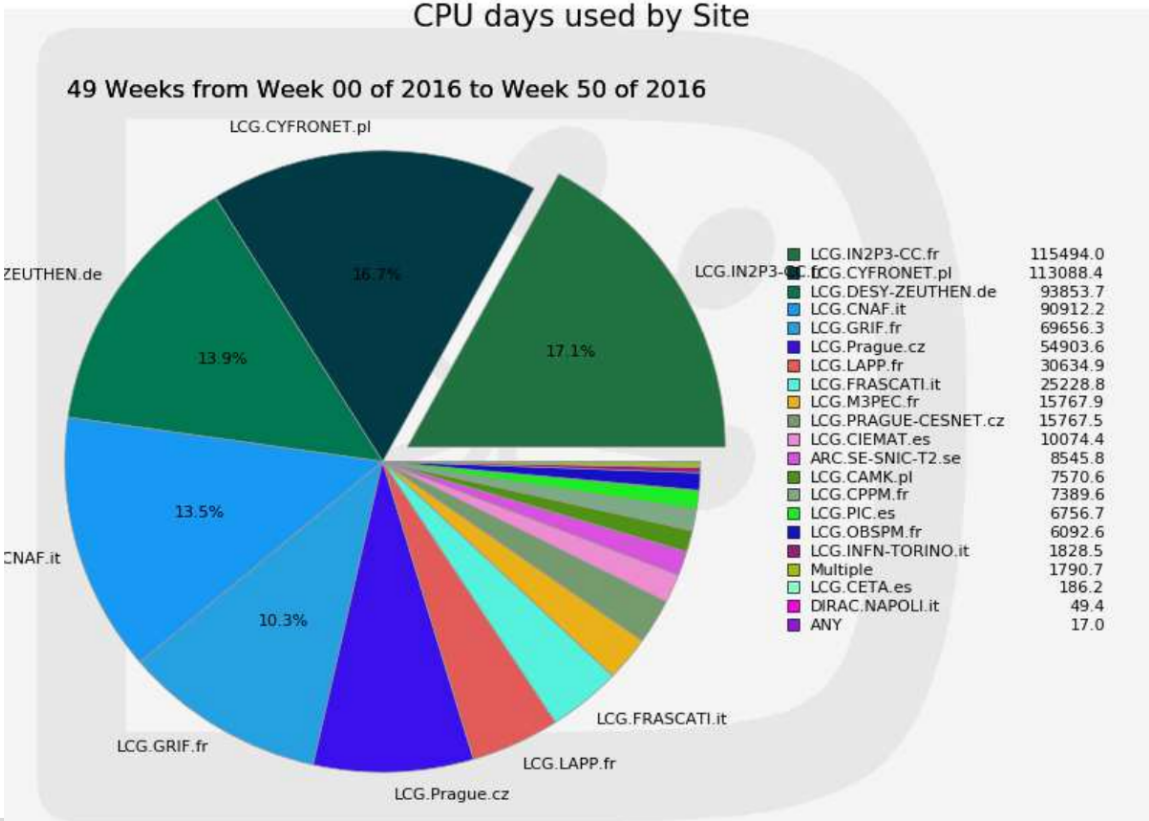


Site	Availabl e Disk (TB)	Used Disk (TB)	Total Disk (TB)
CYFRONET-LCG2	37	592	628
DESY-ZEUTHEN	44	1012	1056
IN2P3-CC	29	325	354
GRIF (LPNHE+CEA)	23 (0+23)	210 (120+90)	233 (120+113)
IN2P3-LAPP	9	109	118
INFN-T1	0	486	486
Total	142	2734 (95%)	2875

430 TB Prod2 data on tape
(at CC-IN2P3, CNAF and DESY)

INFN contributions to CTA (Computing)

- **Presently** CNAF resources for:
  - **CTA Computing Grid** (CE, SE) (4th contributor Storage and CPU)
  - **INFN users** community (10 TB)
- additional contributions to Grid from INFN Frascati, To, Na



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- **Presently** CNAF resources for:
  - **CTA Computing Grid** (CE, SE) (4th both Storage and CPU)
  - **INFN users** community (10 TB)
- additional contributions to Grid from INFN Frascati, To, Na

2017

- Disk = 496 TB, Tape = 120 TB;
- Computing power = 4000 HS06;

2018

- Disk = +300 TB
- *and merging with MAGIC resources (296 HS06, 65/150 TB disk/tape)*

2019

- Disk = +200 TB, CPU = +1000 HS06

- **Future/parallel**: ongoing discussion concerning *Data Centre option*

Conclusions

- CTA will be an amazing instrument
- CTA will produce a huge amount of data that has to be processed and archived
  - high storage and computing needs
- CTA baseline Computing Model foresees 4 Data Centres
- INFN is already significantly contributing to CTA Computing Grid