Astrofisica con Specchi a Tecnologia Replicante Italiana

cta cherenkov telescope array

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Universidade de São Paulo
Instituto de Astronomia, Geofisica e Ciencias Atmosferica

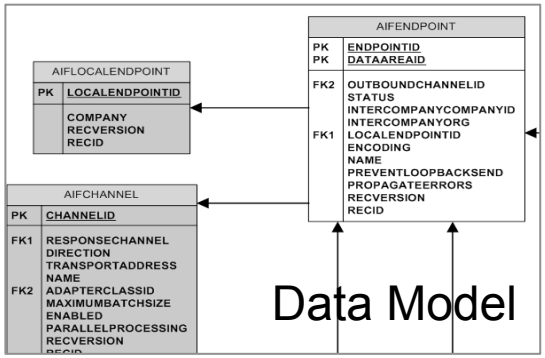
MIUR

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

ASTRI DATA MANAGEMENT.

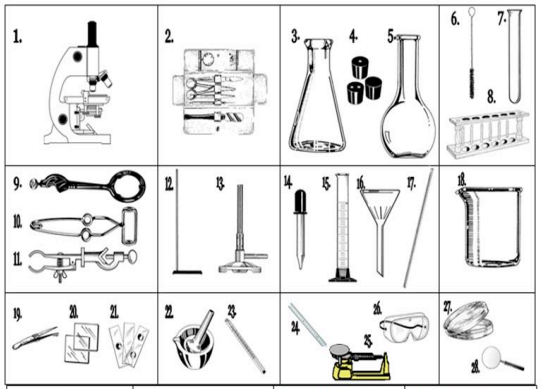
From ASTRI Prototype and Mini-Array to CTA.

L. Angelo Antonelli – INAF-OAR & ASDC
for the ASTRI Collaboration & the CTA Consortium



Data Model

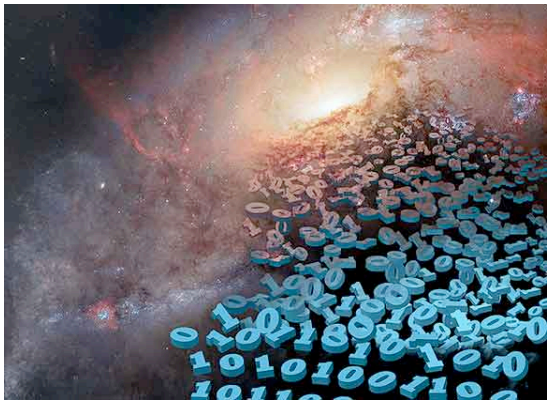
Reconstruction Pipelines



Science Tools

Archive(s)

Simulations



Data Access

ASTRI DATA MANAGEMENT TEAM

DATA RECO & ANALYSIS


Fabrizio Lucarelli


Angelo Antonelli


Denis Bastieri


Saverio Lombardi


Matteo Perri


Andrea Giuliani


Alberto Madonna


Michele Mastropietro


Sara Buson


Sabina Sabatini


Imma Donnarumma


Giovanni Piano

ARCHIVES


Andrea Di Paola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Stefano Gallozzi


Alessandro Carosi


Federica Moscato

MC SIMUL.

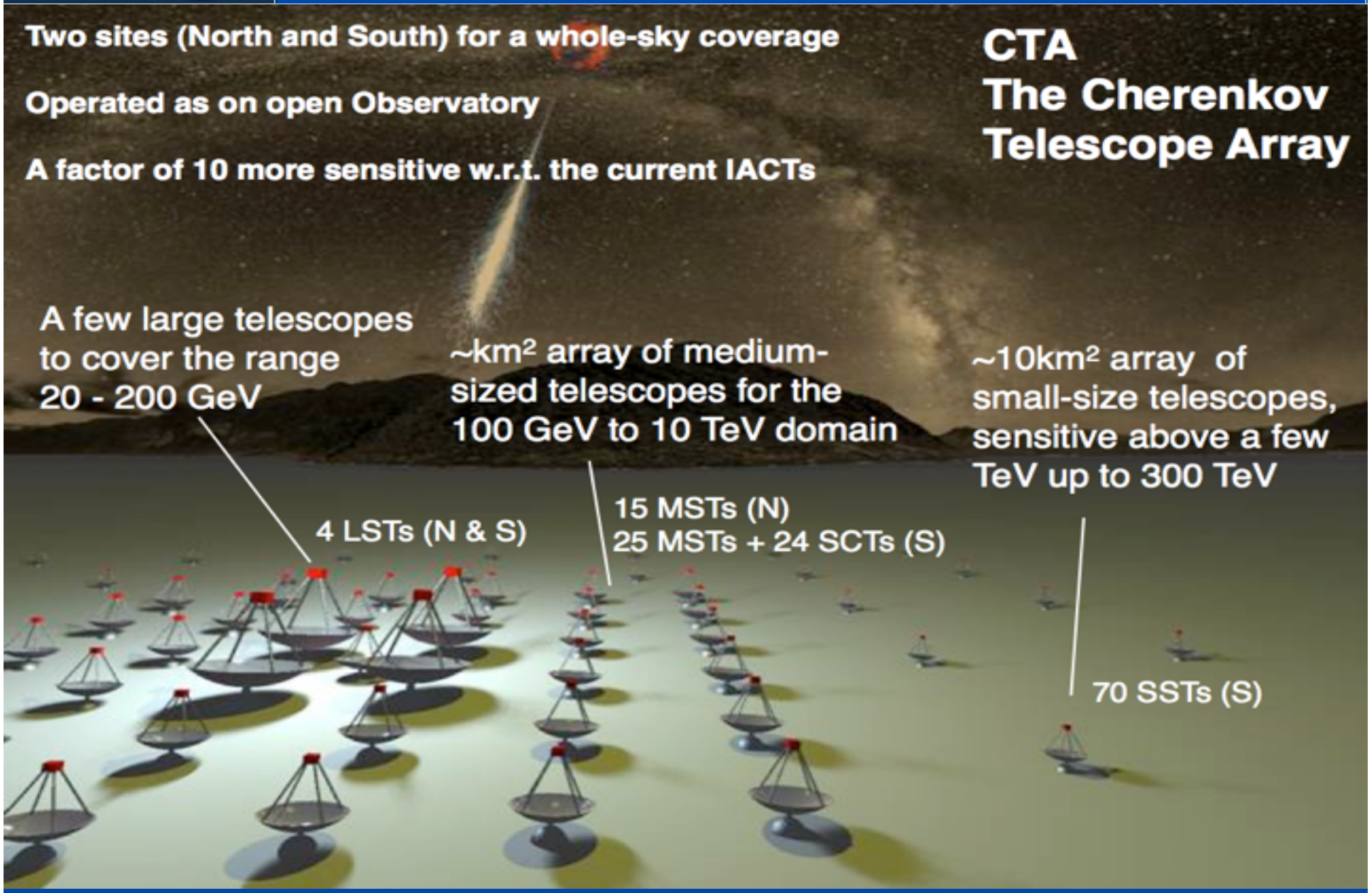

Antonio Stamerra


Ciro Bigongiari


Federico Di Pierro

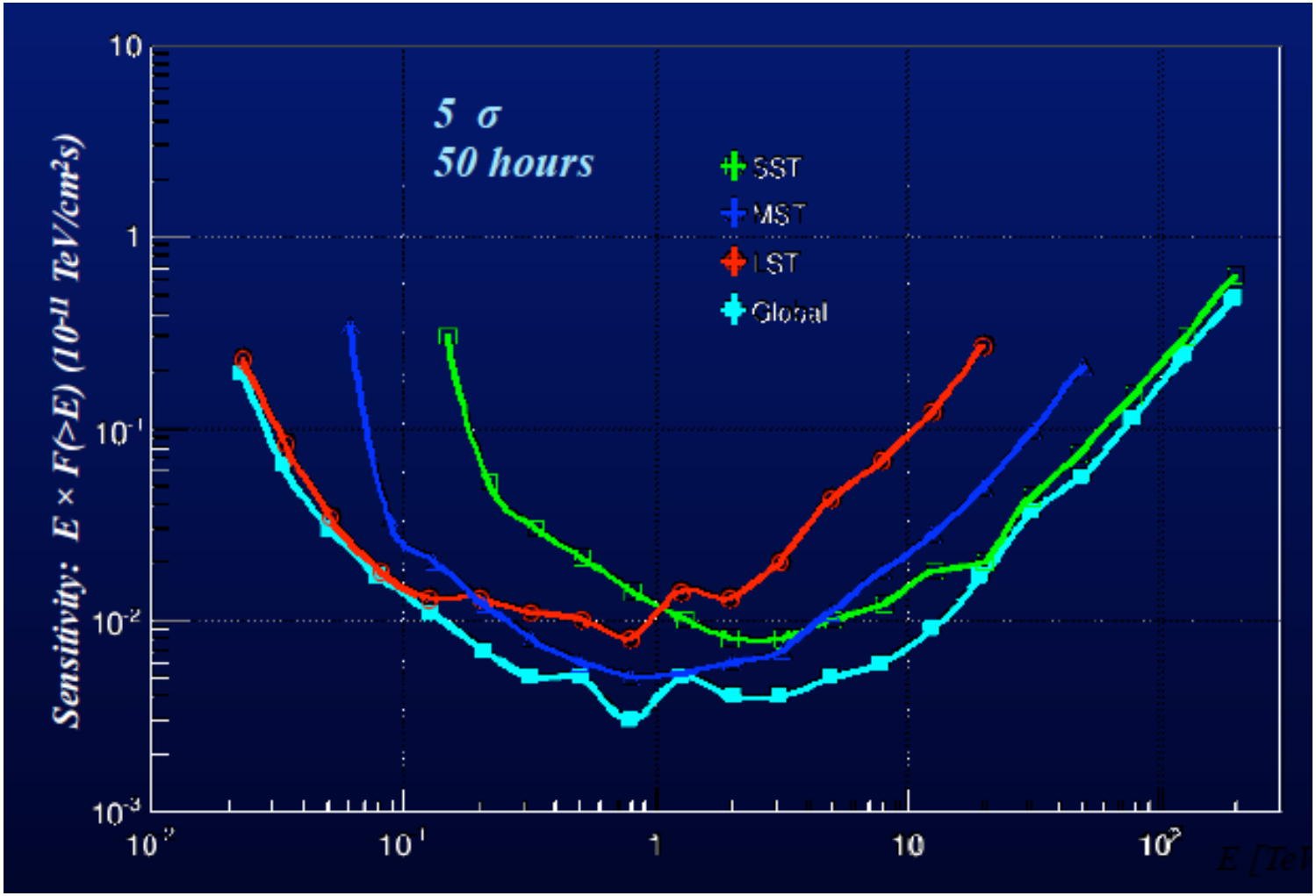
- Introduction: CTA & ASTRI
- Data Analysis Software.
- Archive.

- Introduction: CTA & ASTRI
- Data Analysis Software.
- Archive.


Two sites (North and South) for a whole-sky coverage
Operated as on open Observatory
A factor of 10 more sensitive w.r.t. the current IACTs
CTA
The Cherenkov
Telescope Array
A few large telescopes
to cover the range
20 - 200 GeV
~km² array of medium-
sized telescopes for the
100 GeV to 10 TeV domain
~10km² array of
small-size telescopes,
sensitive above a few
TeV up to 300 TeV
4 LSTs (N & S)
15 MSTs (N)
25 MSTs + 24 SCTs (S)
70 SSTs (S)

The CTA Project in a nutshell.

WHY CTA?



A deeper sensitivity (about a factor 10) on a wider band (from 20-30 GeV to 100 TeV) more then 1000 new gamma ray sources are foreseen to be discovered.

The CTA Project in a nutshell.

WHO IS CTA?

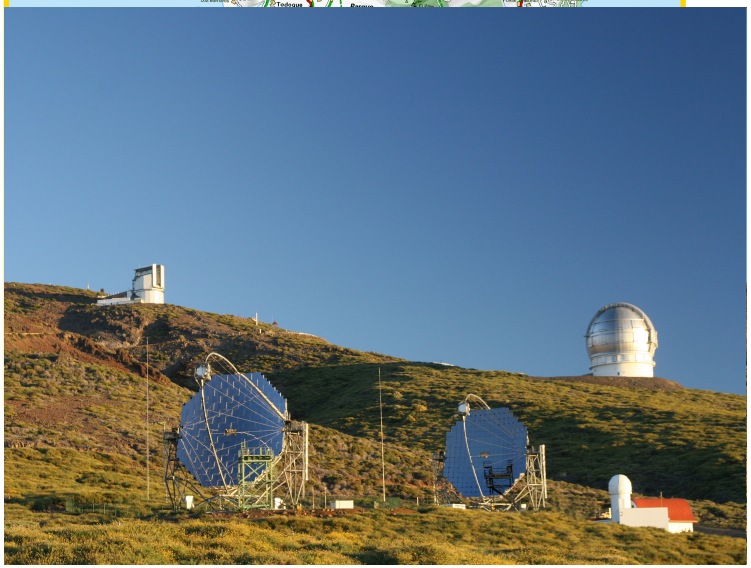
CTA is an ESFRI Project

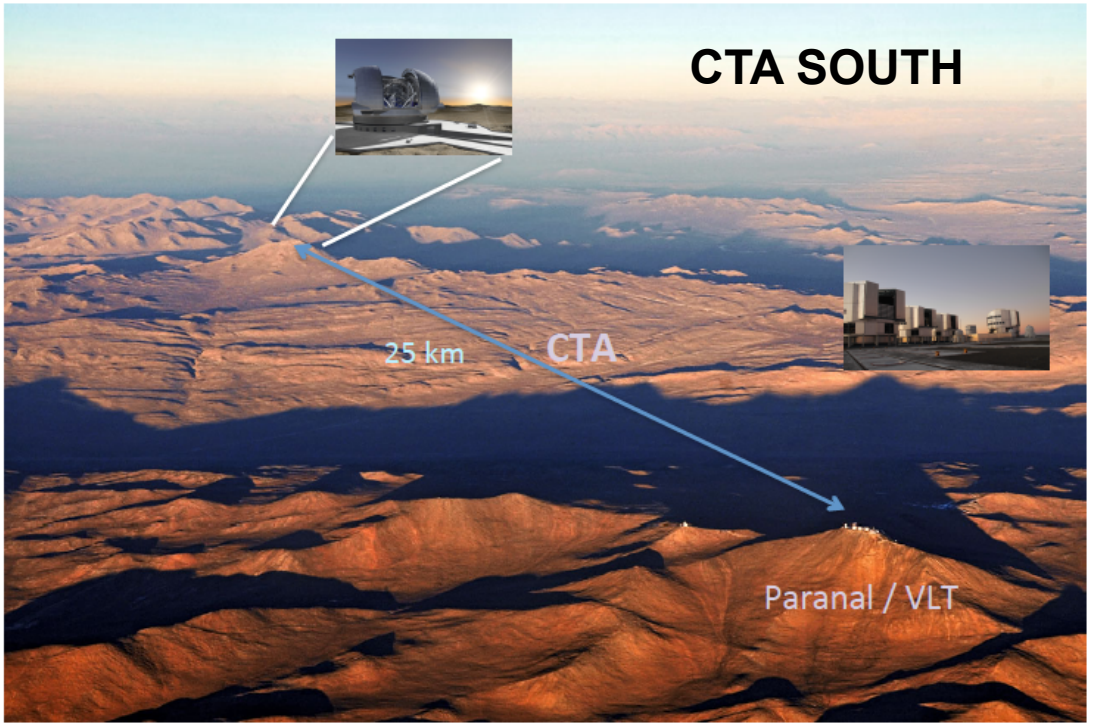
31 countries, ~1200 participants, ~180 institutes, ~400 FTE

The CTA Project in a nutshell.

WHERE CTA?

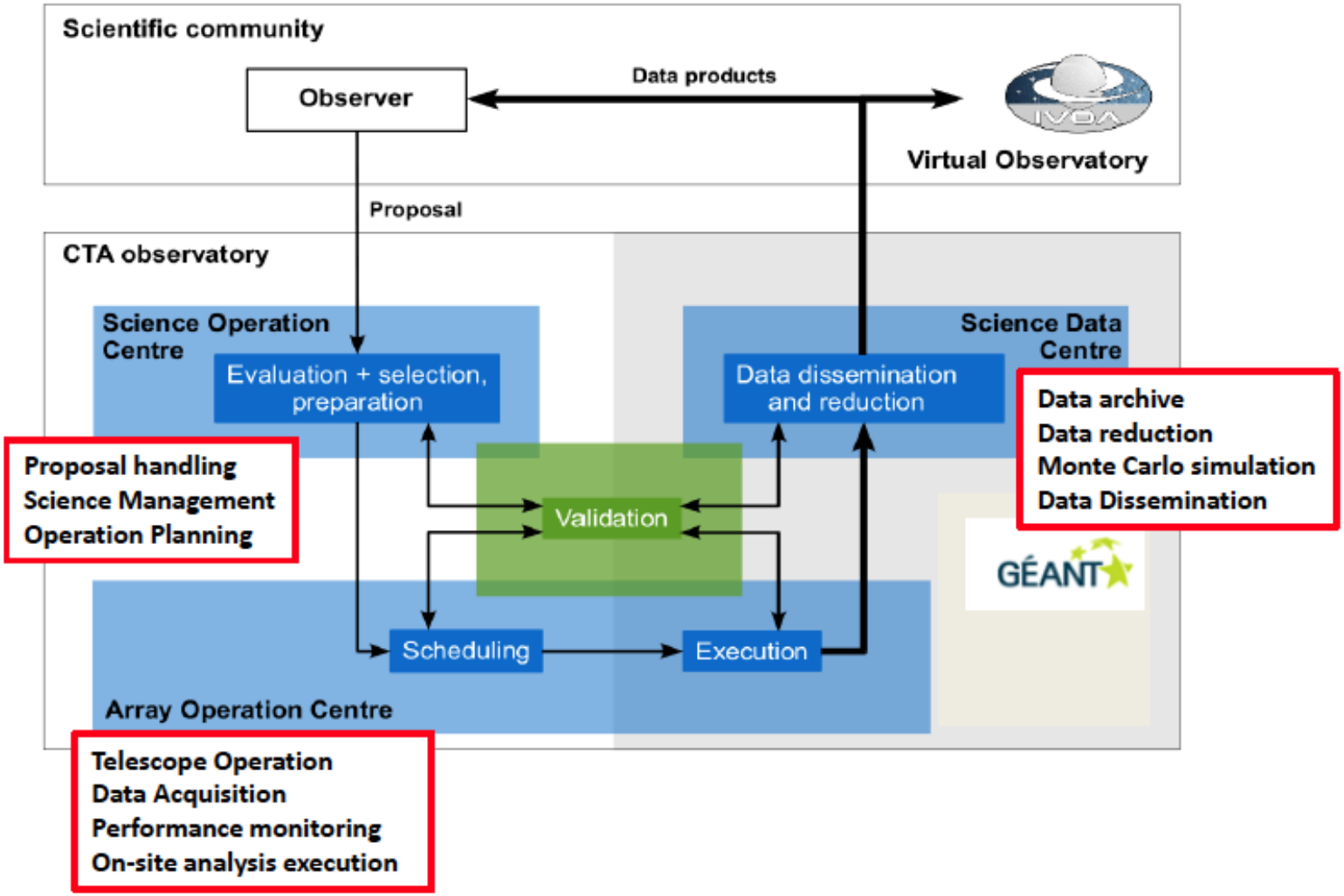
CTA NORTH



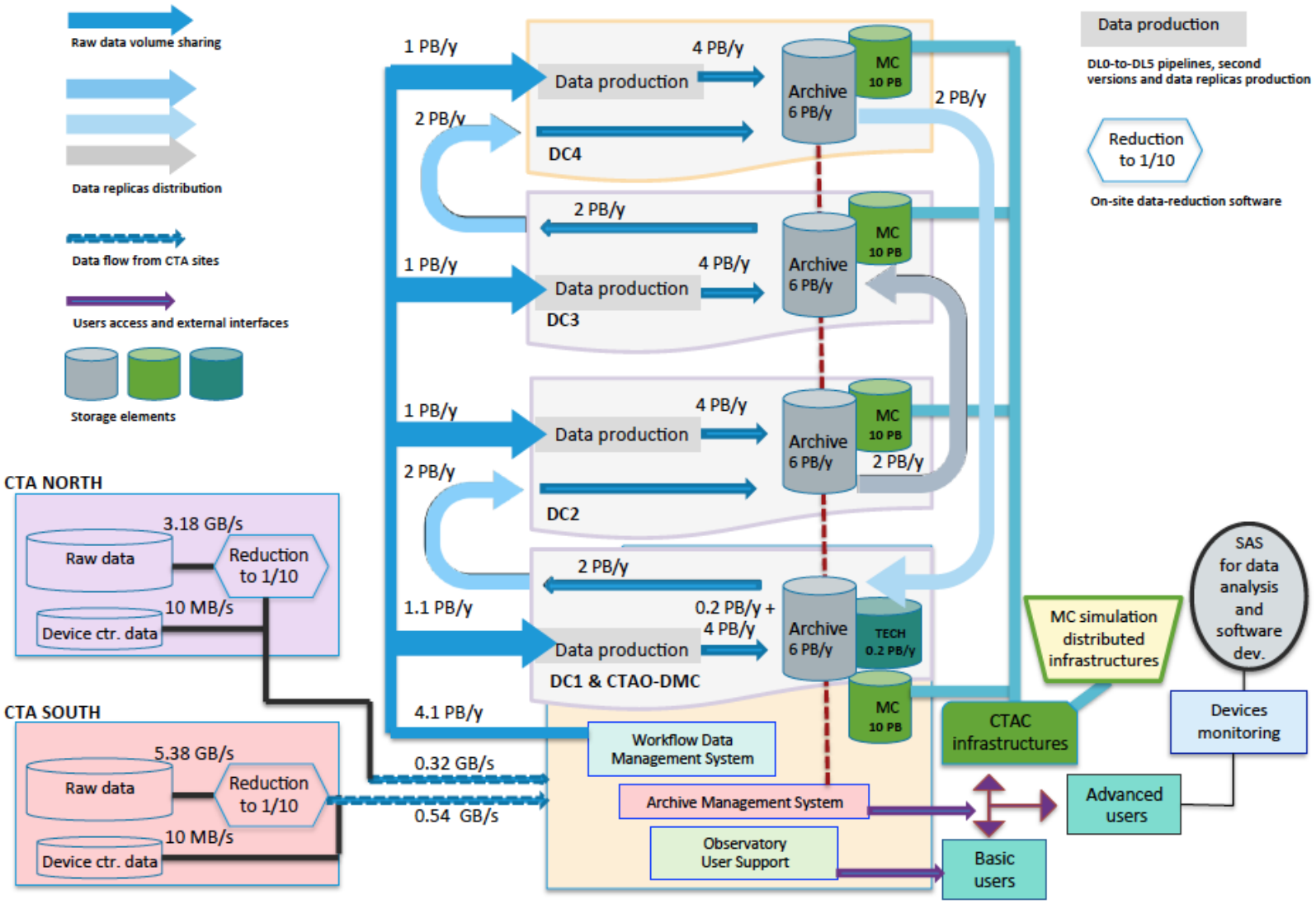


CTA as an Open Observatory

CTA will be a PB project operated as an observatory open to a large scientific community.



CTA Data Flow



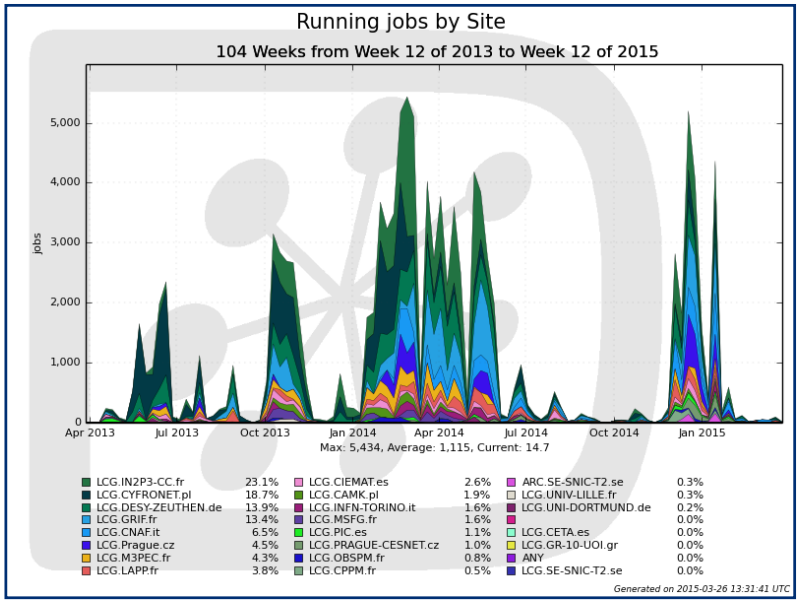
MC Production 2014-2015

- **About 20 centres** currently support the CTA VO. They are classified as:
  - ***Production centres*** if they provide CPU only **-> *used for MC production***
  - ***Analysis centres*** if they provide both CPU and storage resources **–> *used for MC production and Data Analysis***

CPU usage by Centre

- **Total used 2014: 94 M HS06**
- **87% CPU for MC production**
- **13% CPU for Users Analysis (7 active users)**
- **(2.6 M executed jobs in 2014)**
- **Total pledged 2015: 143 M HS06**

50% FRANCE; 20% POLAND; 14% GERMANY
8% ITALY; 4% SPAIN; etc.



Storage resources at 6 Analysis Centres

- **Total pledged 2015: 1.4 PB**
- **About 400 TB more disk than in 2014**

Centre	Allocated Disk 2014 (TB)	Pledged Disk 2015 (TB)	Used Disk (TB)
CYFRONET-LCG2 (**PL**)	448	600	206
DESY-ZN (**DE**)	336	336	204
IN2P3-CC (**FR**)	190	270	98
GRIF (**FR**)	50	120	61
IN2P3-LAPP (**FR**)	60	100	51
INFN-T1 (**IT**)	30	110	15
Total	**1004**	**1426**	**635**

Without data compression: prototypes and the final array.

ASTRI => ~0.8 TB/Night
=>**~0.3PB** per year

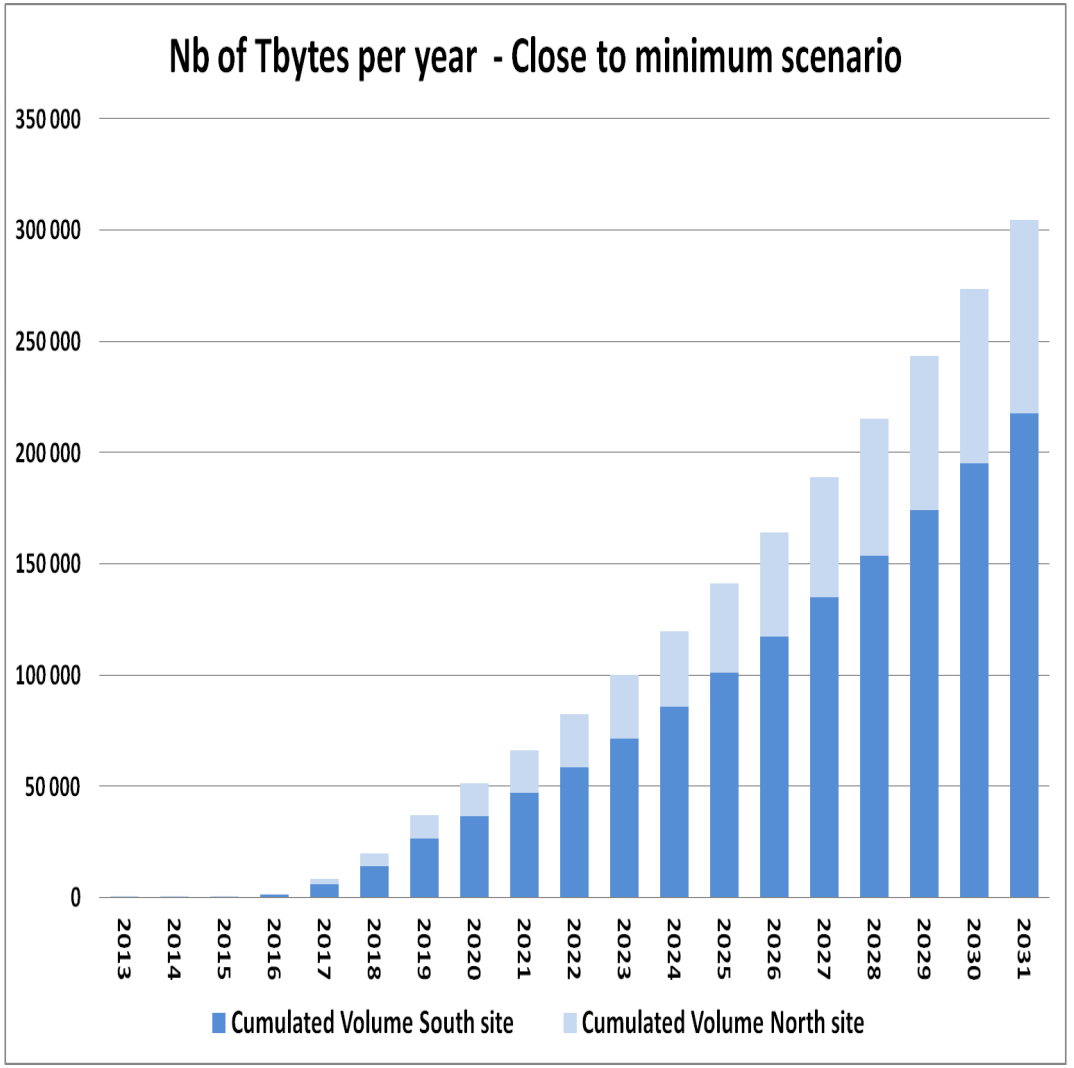
MA/SST => ~3TB/night
=>**~1PB** per year

CTA => ~24TB/Night
=>**~10PB** per year

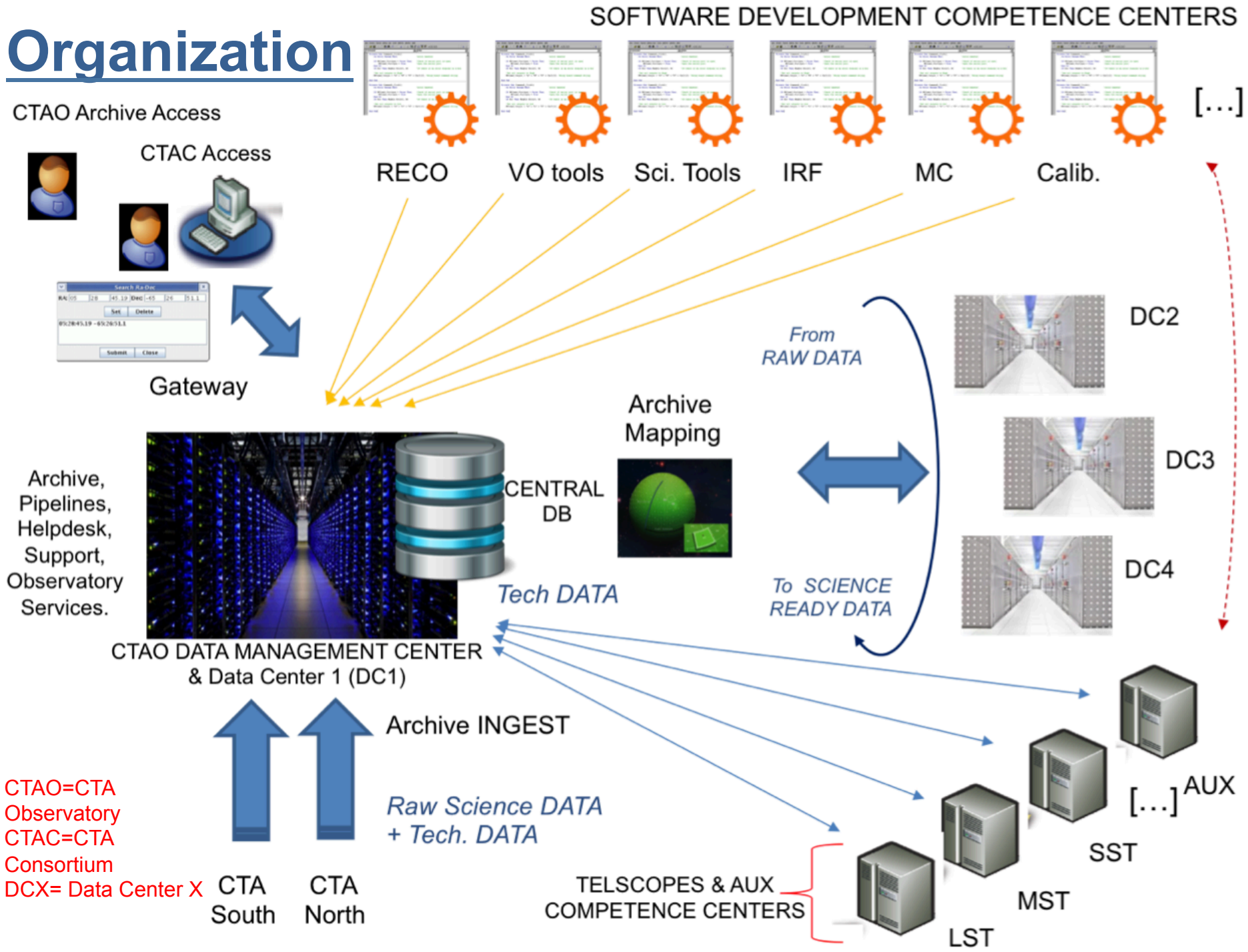
Thus **10 PB per year** including calibs, reduction and MC simulation data.

this is the OPTIMISTIC SCENARIO
The pessimistic one >100PB/year !

The CTA Archive system must store, manage, preserve and provide easy access (IVOA Access) to a such huge amount of data for a long time.

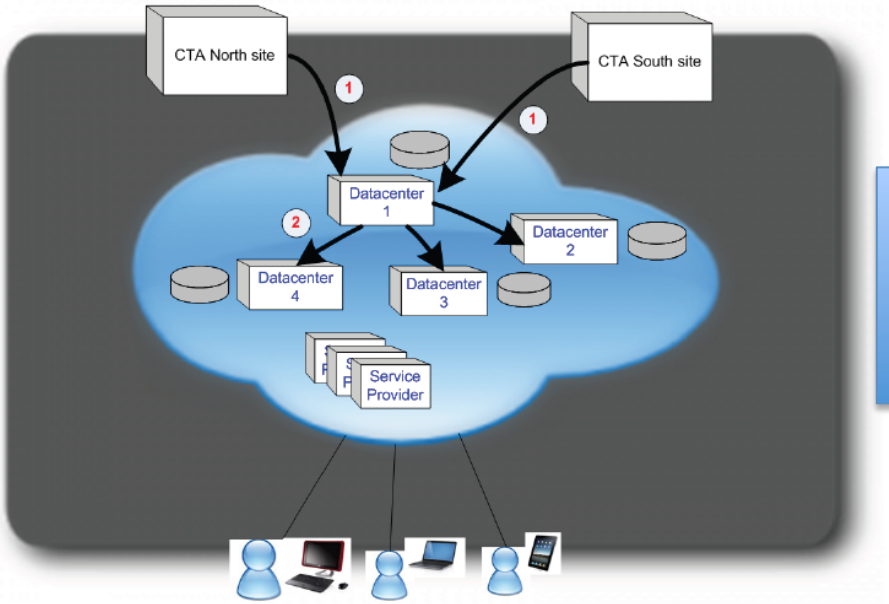


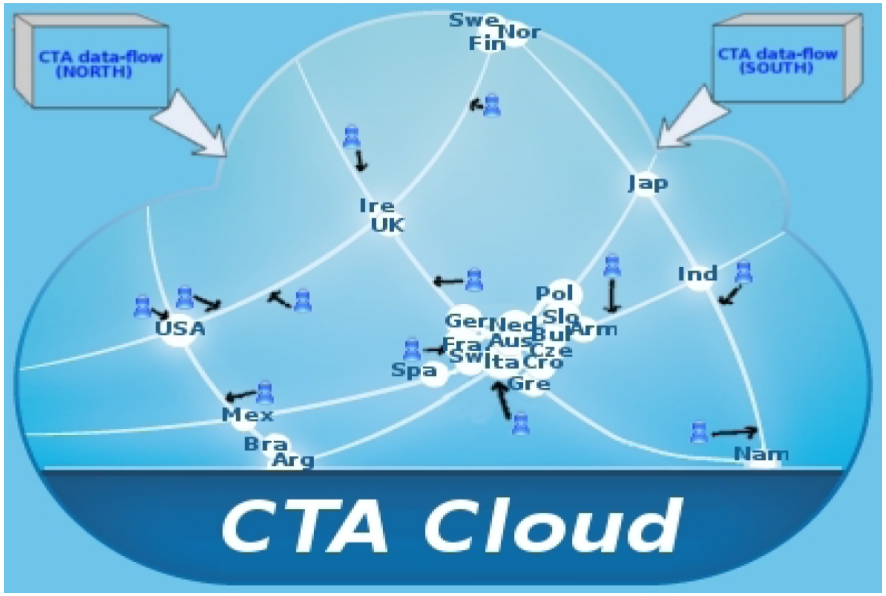
Organization



Toward CTA Preproduction: Distributed Archive System

(from CTA-DATA-TDR, v1.0, January 19, 2015)





- High Performance Storage System (massive I/O)
- High Throughput Storage System (optimized transfer _vs_ minimize latency)
- Long-term durable, persistent data storage
- High level of availability, low access latency

- Secure access to data (different level of access)
- Linear scalability (dimension increase with time)
- Hardware No-Single Point of Failure (no-SPOF)
- High Performance and fault tolerant DB (handle BigData)
- Minimize costs (costs _vs_ benefits)

To manage all this data-flow we identified a **Distributed Archive System** as a cloud resource composed by several storage entities (NODES).

An hardware/software entity

Storage Node (SN)
+
Distributed File System (DFS)
+
Distributed Database (DD)
+
Distributed Computing (DC)

INDIGO - DataCloud

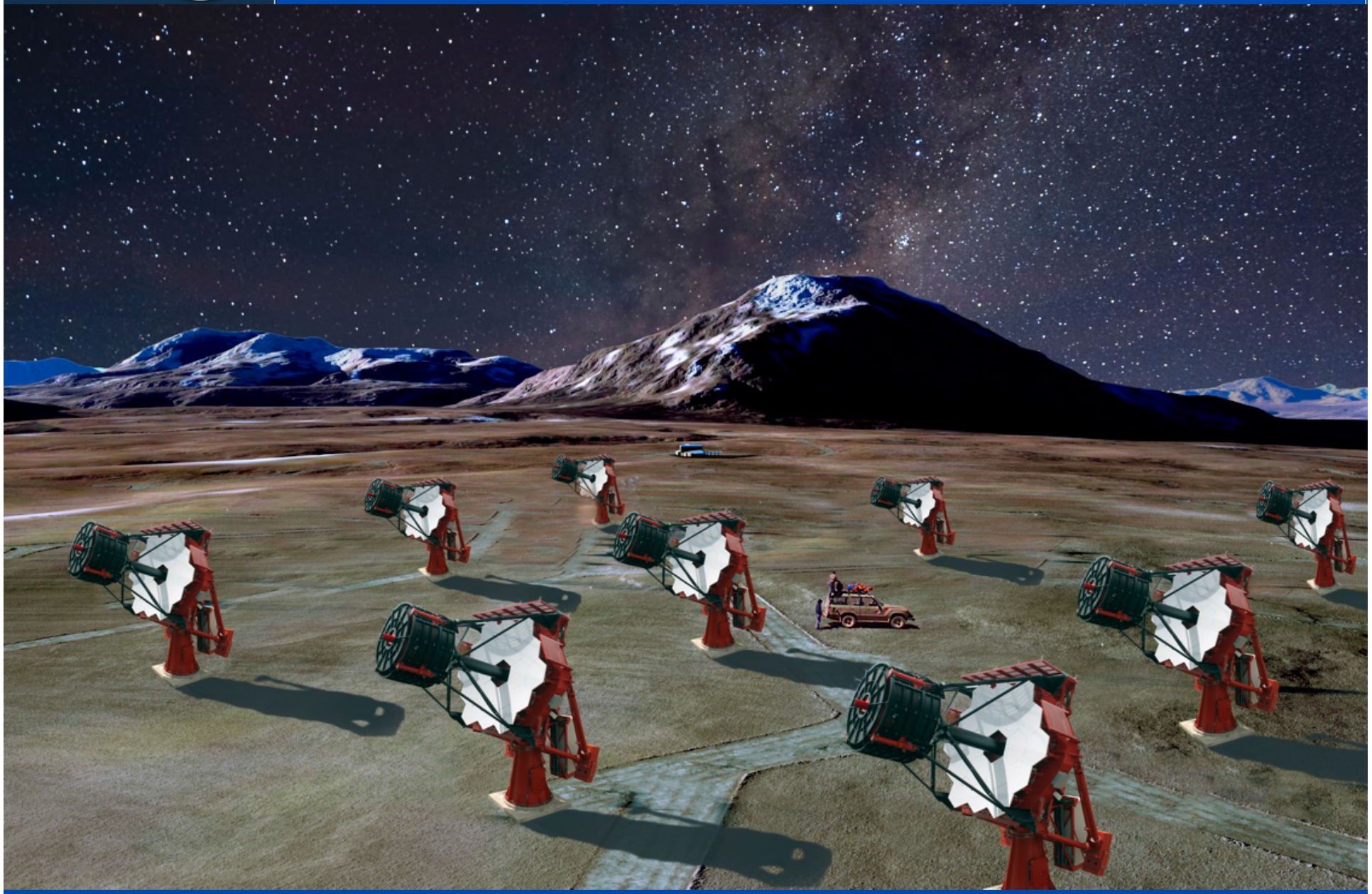
This is the "building-block" for a scalable distributed cloud storage.
We are developing the ASTRI prototype Archive as single SB.
→ several SBs → network of distributed resources (**CTA Cloud**) →
fault toleracy, geographical distribution (and commitment) for CTA partners.

Project ASTRI in a nutshell

- Project funded in 2010-2014 by the Italian MIUR “Progetto Bandiera” (> 40 FTE)
- Now the project continues with the support of MIUR (“Progetto Bandiera extension”) and MISE (“Industrial Astronomy” program) with the participation of Universities from South Africa and Brazil
- End-to-end SST-2M prototype:
  - Validation and commissioning of the telescope via Cherenkov astronomical observation
- End-to-end implementation of a mini-array (# 9) of SST-2M (pre-production) at the CTA southern site:
  - Validation and commissioning of the array (including trigger and SW) via Cherenkov astronomical observations, first CTA scientific data
  - Aiming at the construction of 35 out of the 70 SST units of the CTA southern array

ASTRI SST-2M Prototype

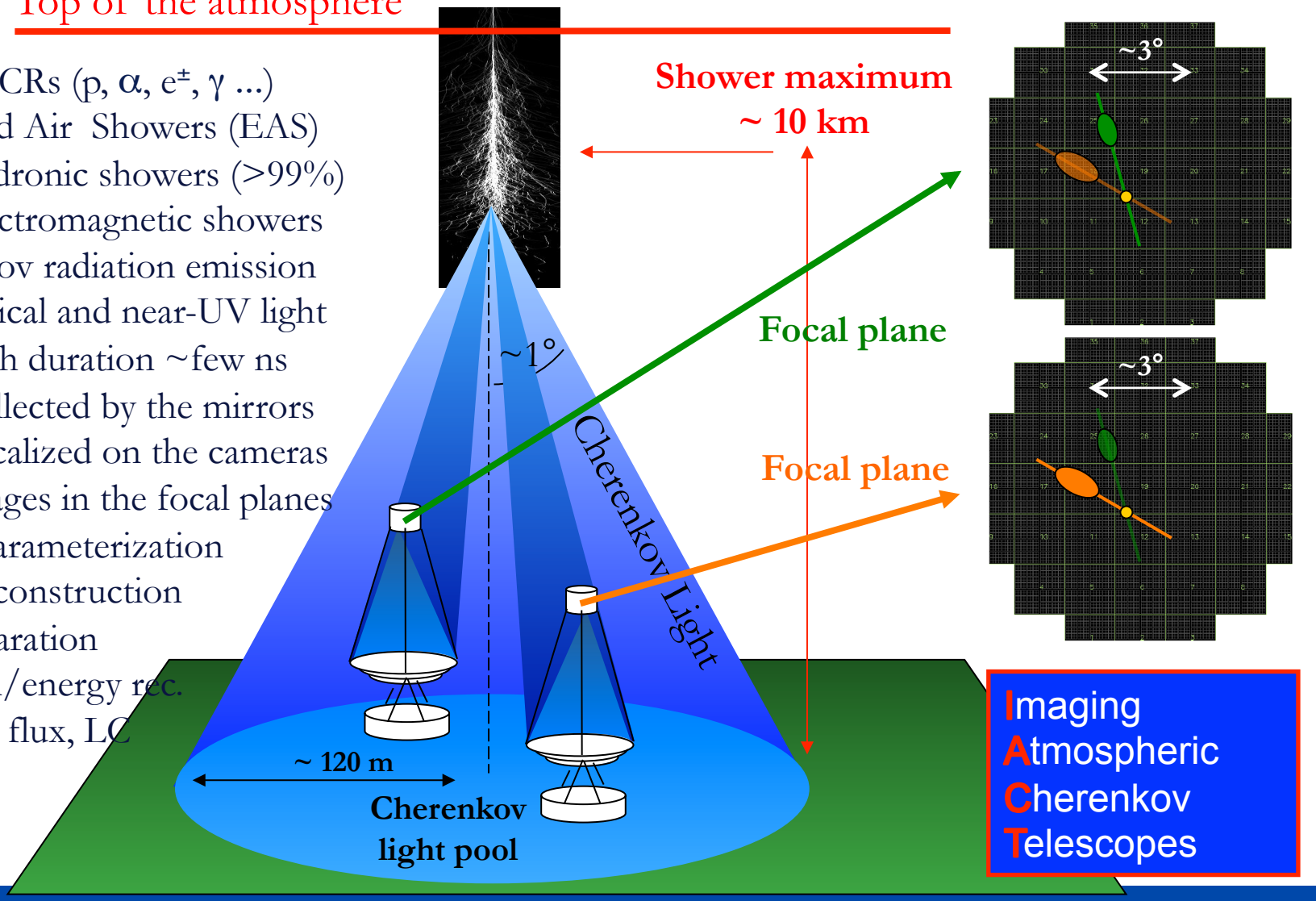
ASTRI/CTA Mini Array



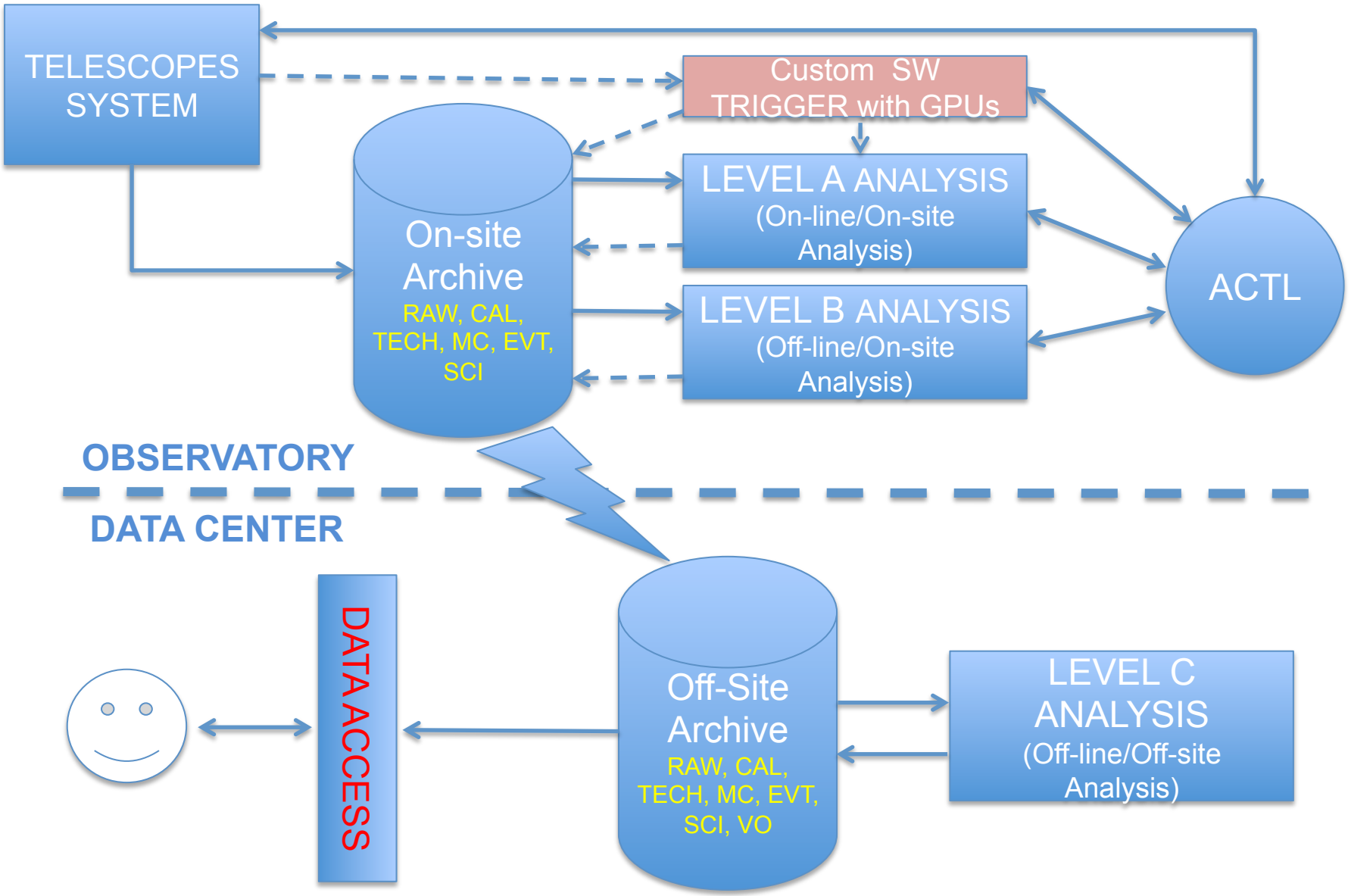
- Introduction: CTA & ASTRI
- Data Analysis Software.
- Arc

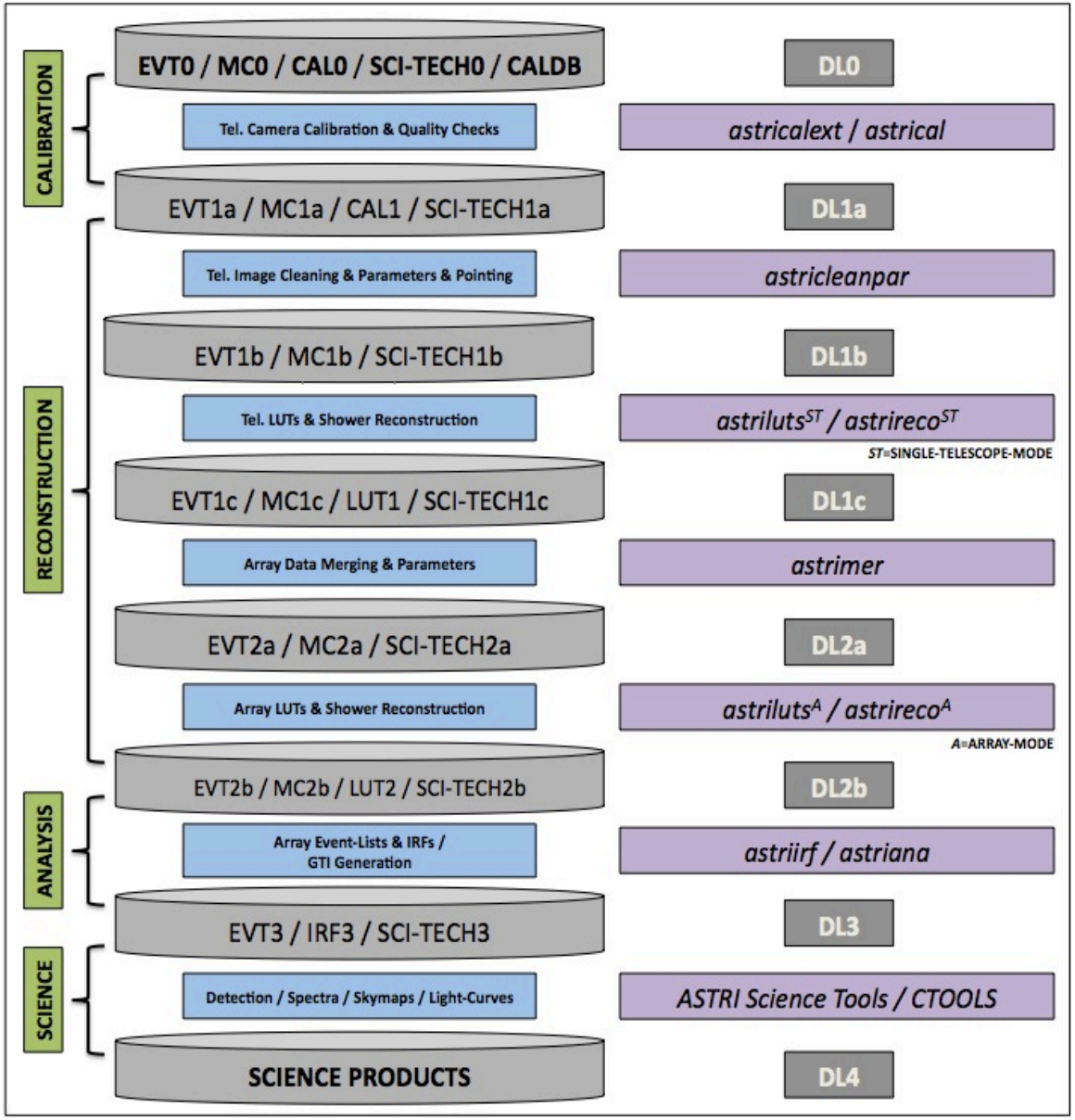
Imaging Air Cherenkov Technique

- Primary CRs (p, α, $e^{\pm}$, γ ...)
- Extended Air Showers (EAS)
  - Hadronic showers (>99%)
  - Electromagnetic showers
- Cherenkov radiation emission
  - optical and near-UV light
  - flash duration ~few ns
- Light collected by the mirrors
- Light focalized on the cameras
- EAS images in the focal planes
- Image parameterization
- Array reconstruction
- γ/h separation
- direction/energy rec.
- γ signal, flux, LC



ASTRI Prototype/Mini-Array Computing Model



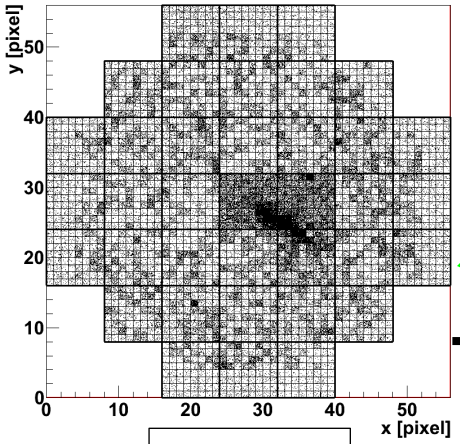


The ASTRI SST-2M Prototype and Mini Array Data Pipeline

- follows the general design and data model scheme defined in CTA Data Management
- manages **FITS data** (from DL0 to DL3) adopting CFITSIO/ CCFITS libraries;
- is written in **C++** (Unix environment) / **CUDA7** (for GPU/ARM coding);
- is developed in independent software modules linked by pipelines written in **Python**;
- will make use of *ad hoc* and official CTA Science Tools for final scientific results production (DL4).

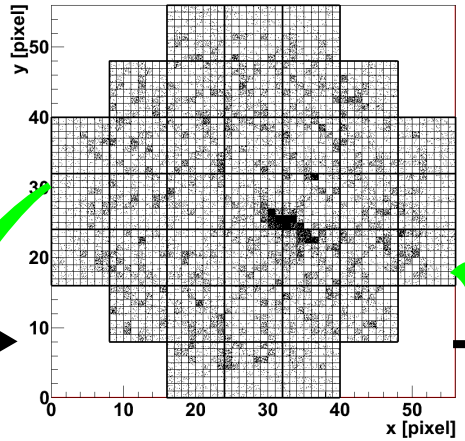
ASTRI SST-2M Prototype Data Reco & Analysis SW Status

DL0

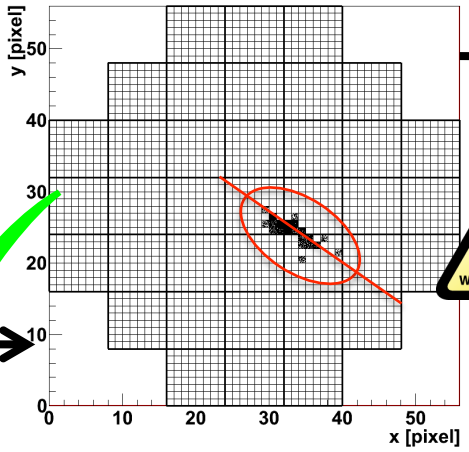


ADC Units

DL1a



DL1b/c



DL2a/b

(Event Lists + GTI and corresponding IRFs

WORK IN PROGRESS

DL3

Event Lists and corresponding IRFs

WORK IN PROGRESS

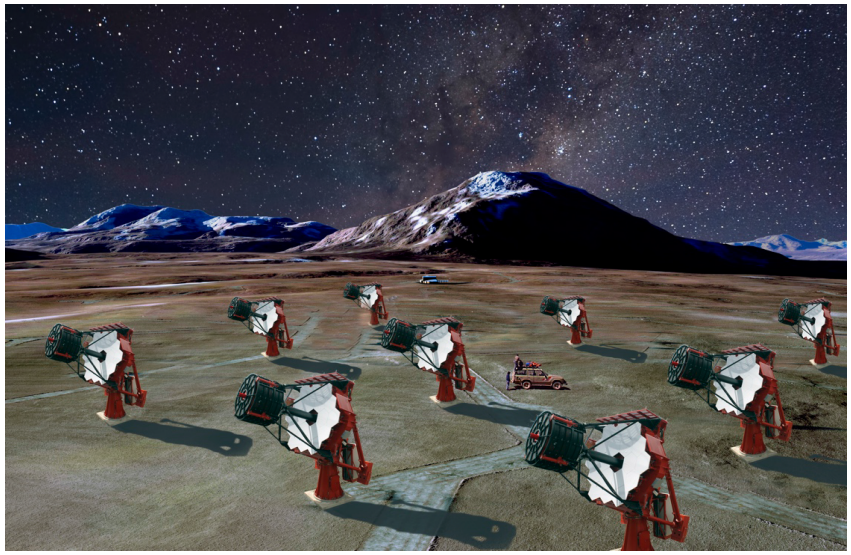
DL4

(SCIENCE PRODUCTS)

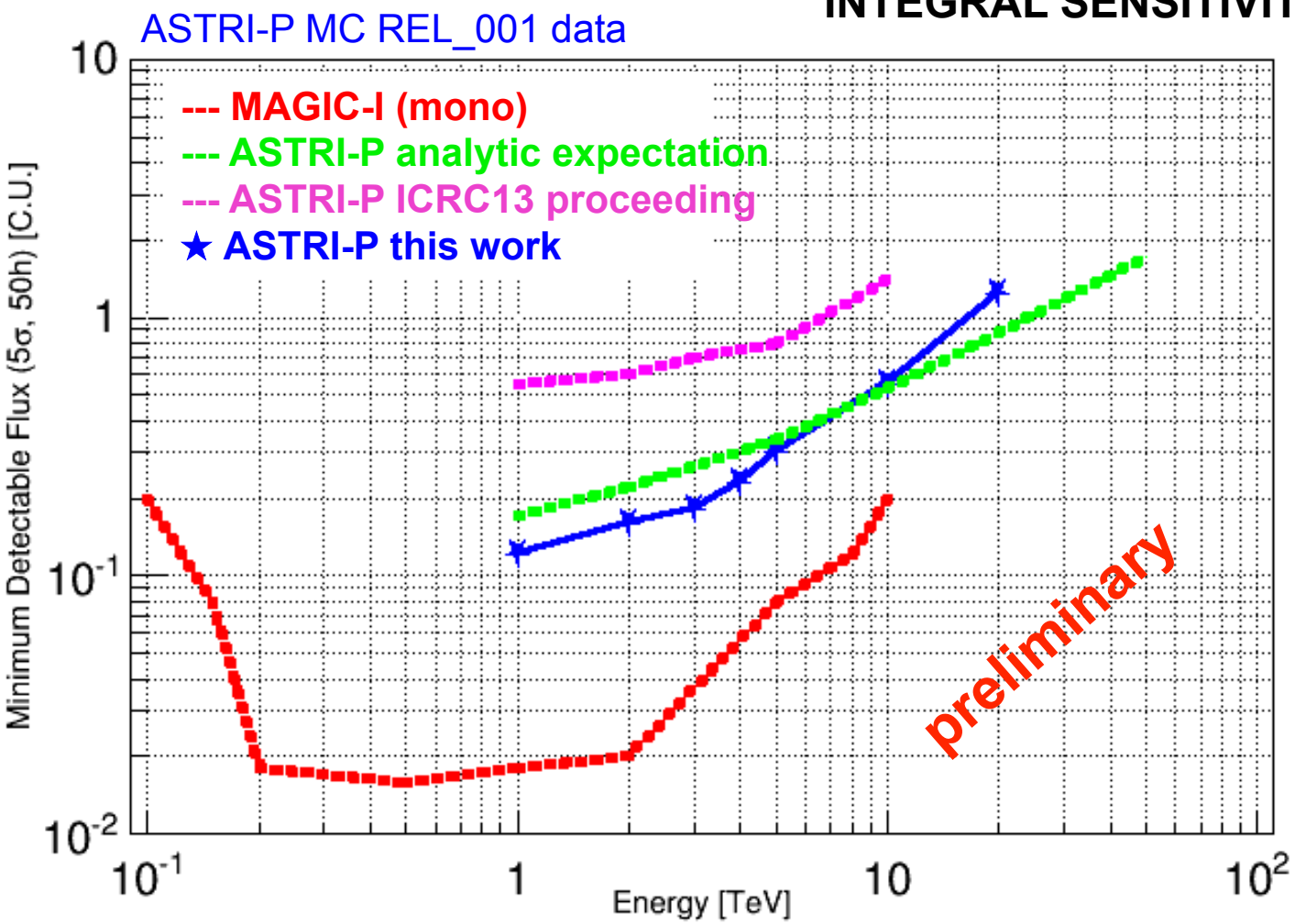
WORK IN PROGRESS

DL5

(OBSERVATORY PRODUTS)



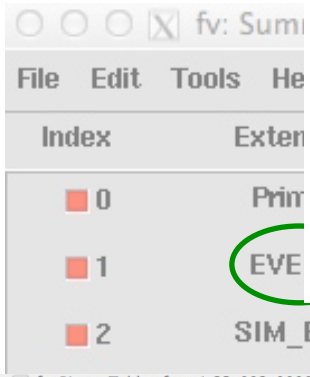
INTEGRAL SENSITIVITY

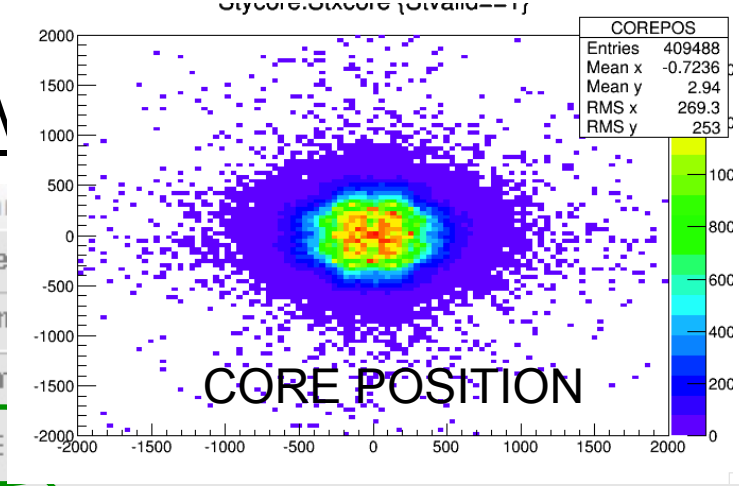


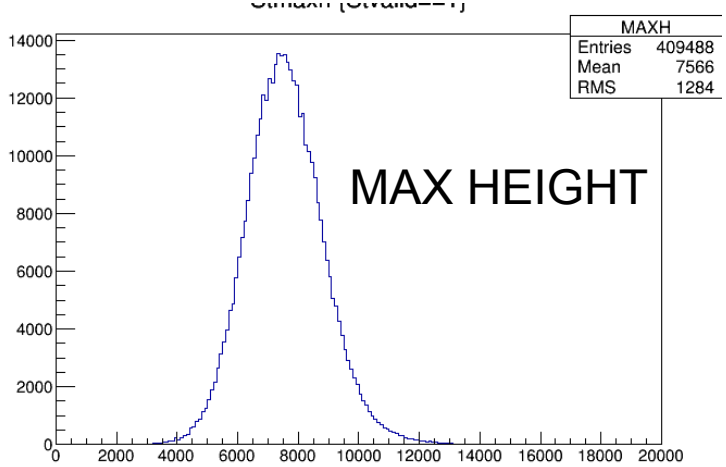
A-W RECONSTRUCTION (DL1c➔DL2a) Status

STEREO RECON.

- ASTRI







Binary 11 cols X 50000 rows

Header Hist Plot All Select

fv: Binary Table of astri_23_002_00001_R_009999_001_0201.lv2a[1] in /astri03/data1/lombardi/ASTRI/ASTRI_ANALYSES/ANALYSIS_REL002_ARRAY/SIM/DL2a/MC2a/gamma_ptsrc/arrayconf_1/teltype_1/rf1/test/

File Edit Tools Help

Select / All / Invert	STVALID 1L	STXDIR 1E [deg]	STYDIR 1E [deg]	STXCORE 1E [m]	STYCORE 1E [m]	STMAXH 1E [m]	STMINDIR 1E [deg^2]	STMINCORE 1E [m^2]	STMINMAXH 1E [m^2]	STIP 1E [m]	EVTNUM 1J	NTRIGTEL 1J	TRIGTEL 1J	TELTYPE 1J	NUSEDTEL 1J
Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	T	1.116531E-01	5.010708E-02	6.028513E+02	1.422729E+02	0.000000E+00	2.414397E-17	1.697185E-09	0.000000E+00	6.194120E+02	1106	7	13	1	2
2	T	1.116531E-01	5.010708E-02	6.028513E+02	1.422729E+02	0.000000E+00	2.414397E-17	1.697185E-09	0.000000E+00	6.194120E+02	1106	7	1	1	2
3	T	1.180399E-01	-2.722386E-01	1.090776E+03	7.164079E+01	0.000000E+00	6.684230E-17	2.523765E-09	0.000000E+00	1.093126E+03	3507	3	13	1	2
4	T	1.180399E-01	-2.722386E-01	1.090776E+03	7.164079E+01	0.000000E+00	6.684230E-17	2.523765E-09	0.000000E+00	1.093126E+03	3507	3	15	1	2
5	T	-7.600708E-02	-4.709019E-02	4.399545E+02	-3.393379E+02	0.000000E+00	5.765386E-20	0.000000E+00	0.000000E+00	5.556169E+02	5303	10	16	1	2
6	T	-7.600708E-02	-4.709019E-02	4.399545E+02	-3.393379E+02	0.000000E+00	5.765386E-20	0.000000E+00	0.000000E+00	5.556169E+02	5303	10	15	1	2
7	T	-1.253837E-01	1.279560E-01	3.071549E+02	-4.125042E+02	0.000000E+00	8.248764E-02	2.842357E+05	0.000000E+00	5.142994E+02	5308	11	16	1	4
8	T	-1.253837E-01	1.279560E-01	3.071549E+02	-4.125042E+02	0.000000E+00	8.248764E-02	2.842357E+05	0.000000E+00	5.142994E+02	5308	11	15	1	4
9	T	-1.253837E-01	1.279560E-01	3.071549E+02	-4.125042E+02	0.000000E+00	8.248764E-02	2.842357E+05	0.000000E+00	5.142994E+02	5308	11	1	1	4
10	T	-1.253837E-01	1.279560E-01	3.071549E+02	-4.125042E+02	0.000000E+00	8.248764E-02	2.842357E+05	0.000000E+00	5.142994E+02	5308	11	13	1	4

Go to: Edit cell:

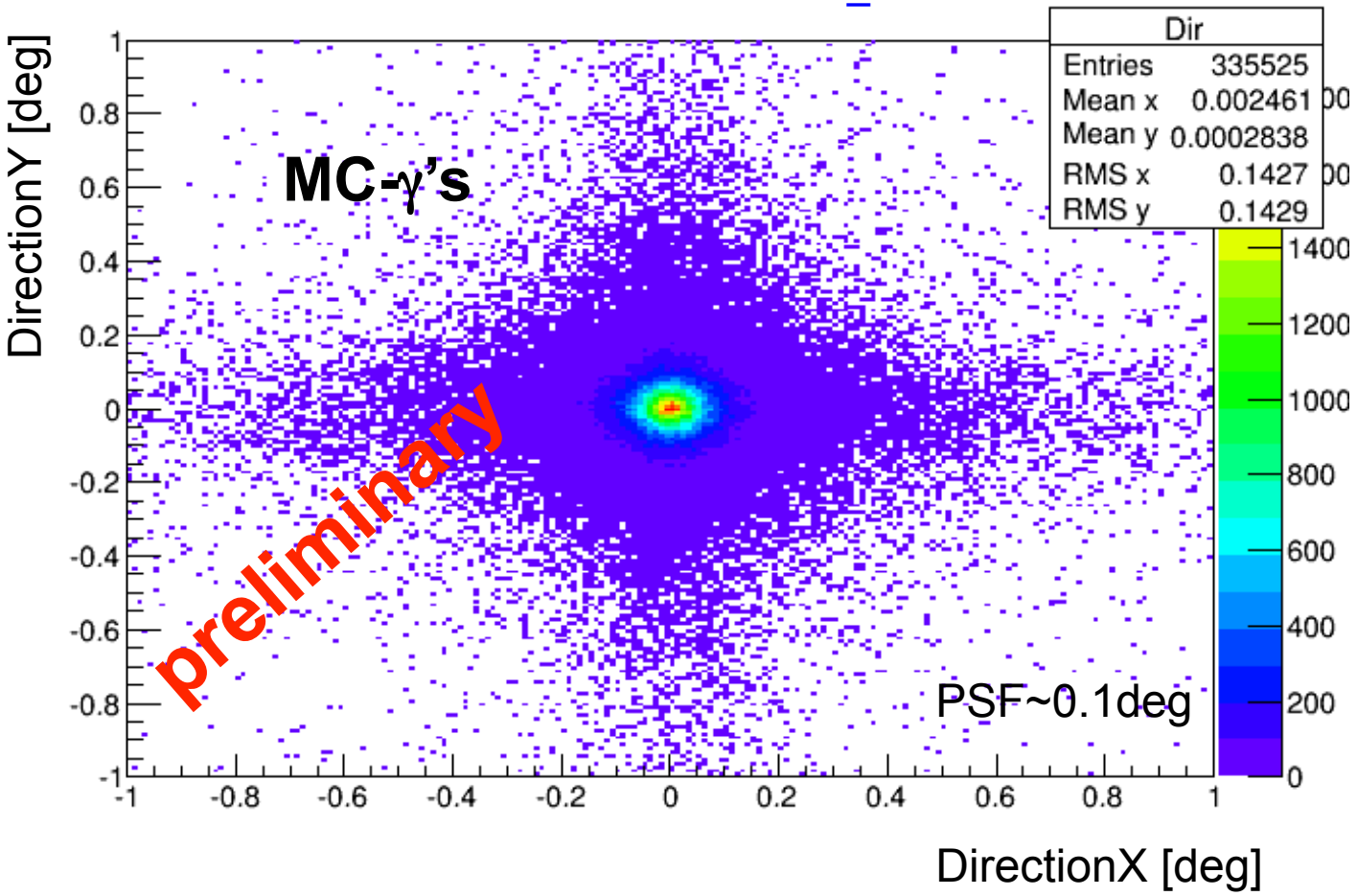
STEREO PARAMETERS

ARRAY INFORMATION

STEREO RECON.

DIRECTION ESTIMATION

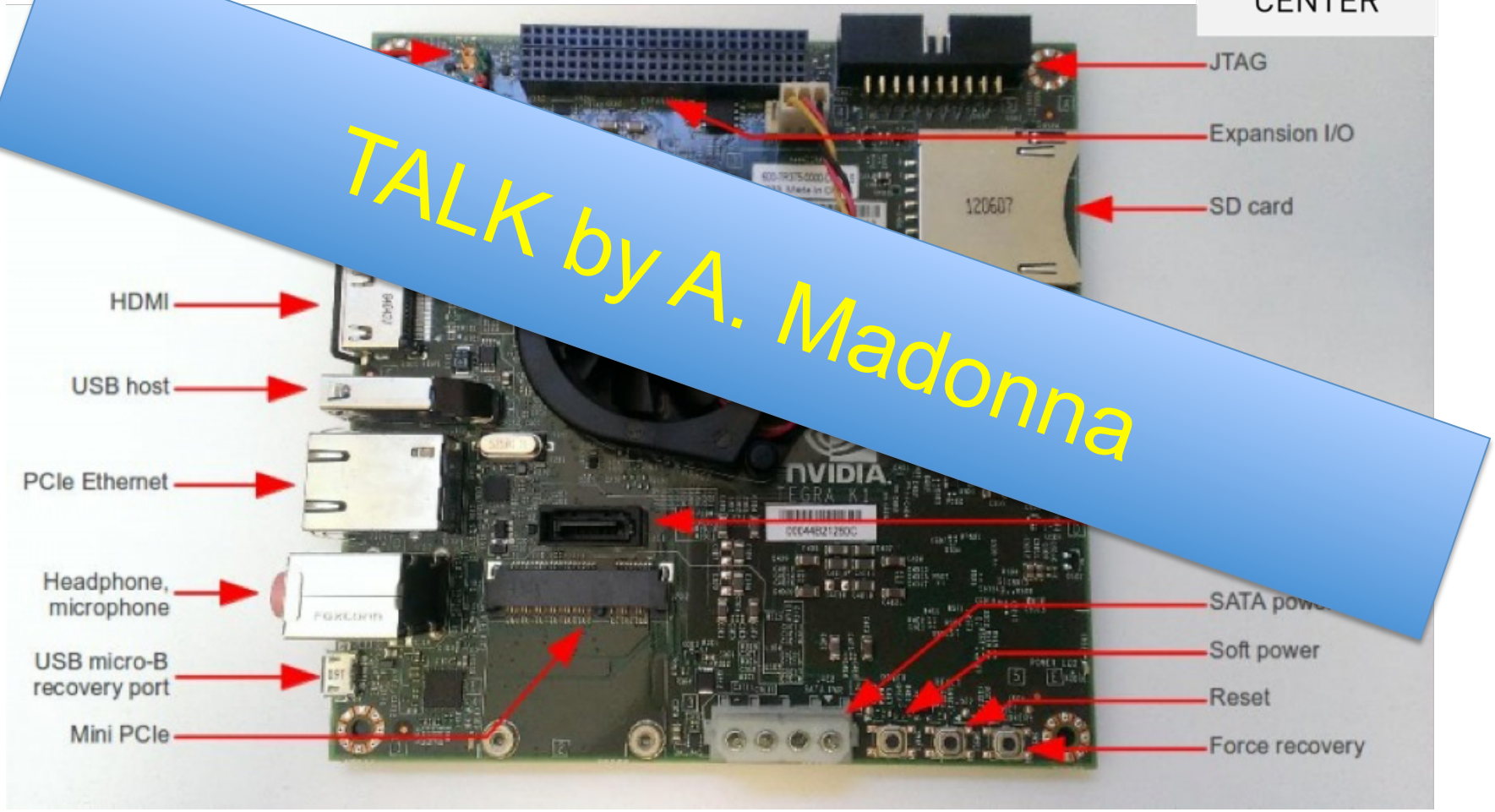
ASTRI-MA MC REL_002 data



Jetson TK-1

192 cores @ 192$

NVIDIA GPU RESEARCH CENTER



TALK by A. Madonna

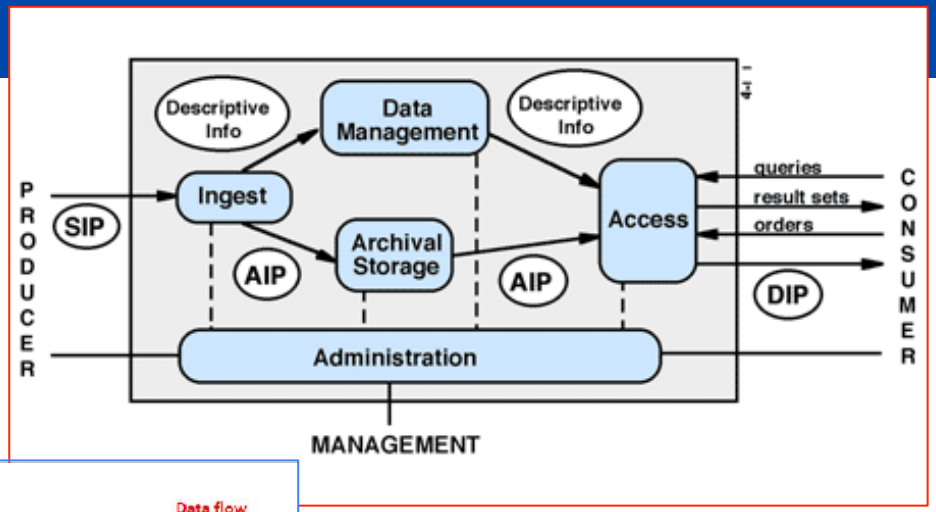
- Data reduction in <6 W (real-time) on Jetson TK1:
  - calibration (ADC → phe)
  - cleaning (single core)
  - image parametrization
- Photon list (img. parms → *E*, *hadronness*, *direction*)
  - via Breiman RF: running on Shark
  - distributed on GPU (K40)
  - test on DNN on-going

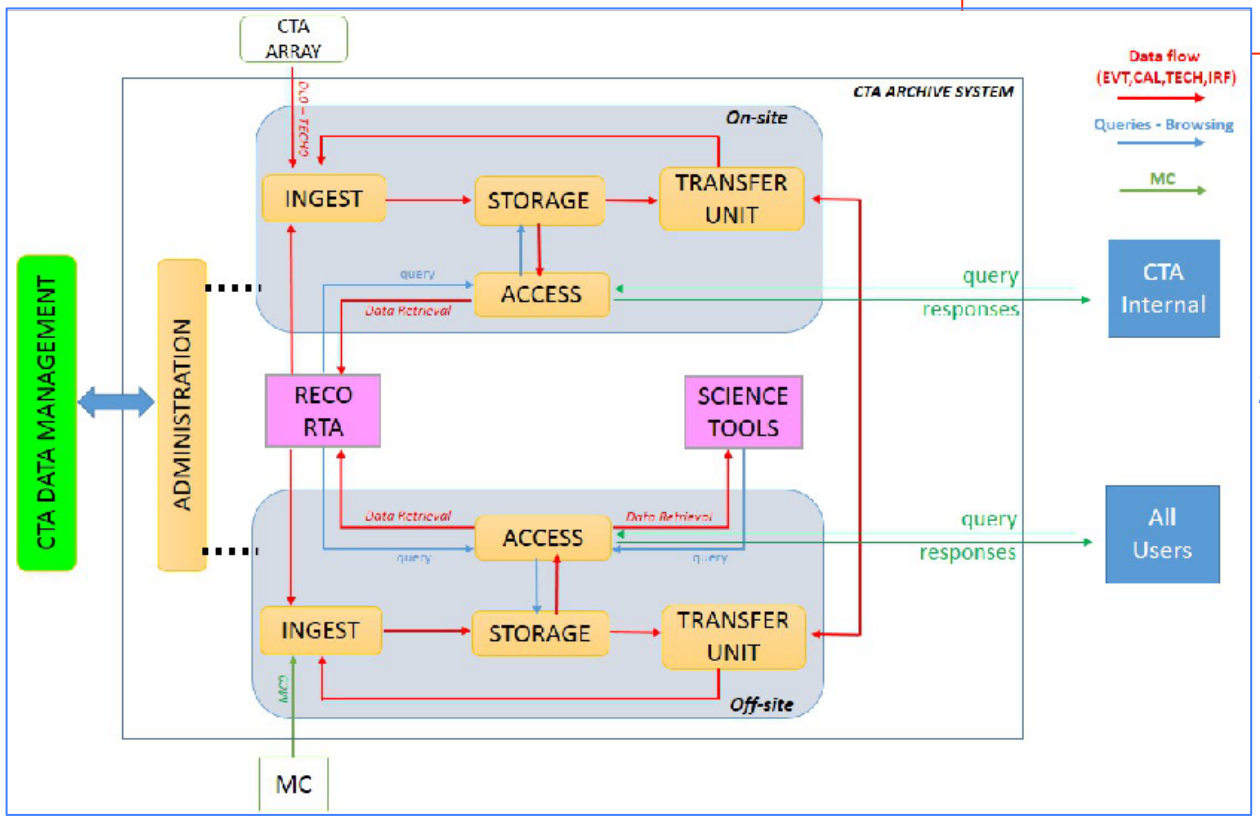
- 2kPxl × 4 B/Pxl × 1kHz = 8 MB/s
- 30 s batches = 240 MB
- 5 s I/O (FITS → input data; output data → FITS)
- 10 momenta ~ 20 kFLOP/Pxl ~ 40 GFLOP/1kEvt
  ~ 3J/1kEvt
- cleaning/clustering ~ 10 s on 1 core
- Average current over 30 s (2 batches): 0.43 A
- Average power over 30 s (2 batches): 5.2 W
- 2 kEvt/s on current version (twice the reqs)
- Expected 4 kEvt/s on TX1 (same power, but some tweaks)

- Introduction: CTA & ASTRI
- Data Analysis Software.
- Archive.

CTA Archive

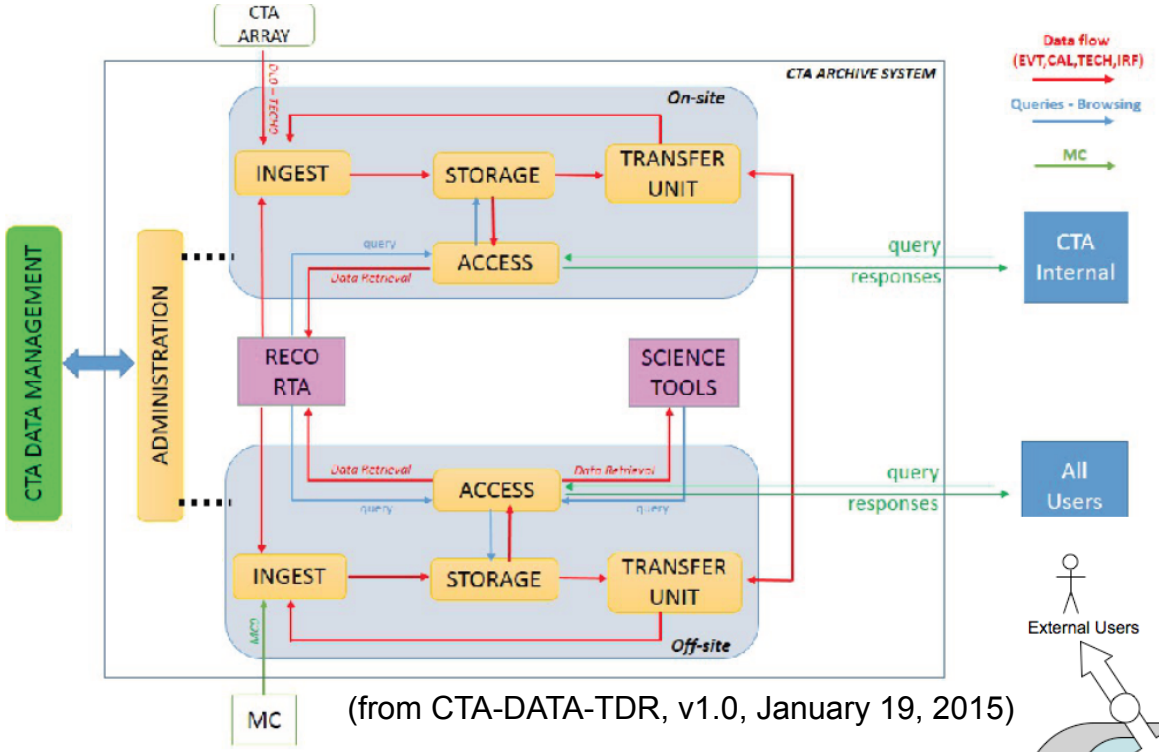
1 – Reference Model: OAIS





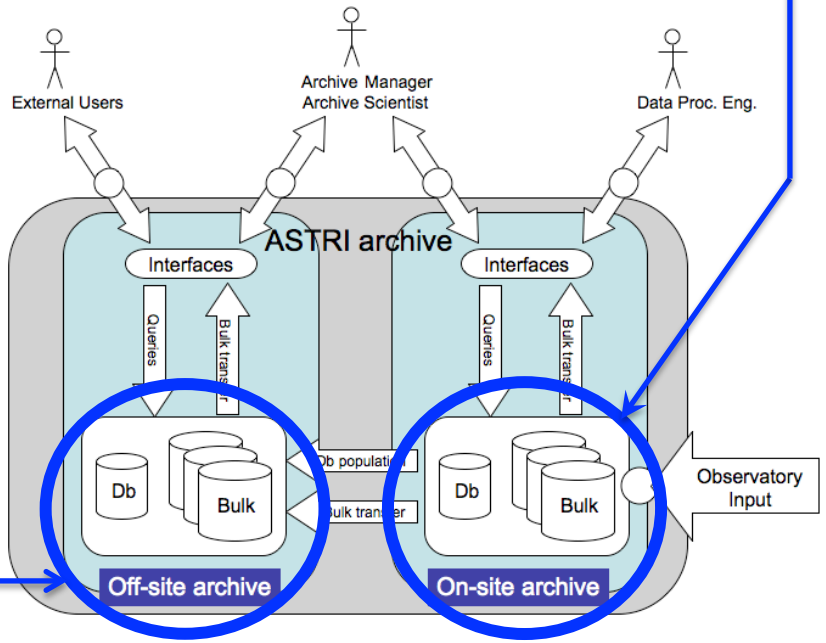
2 – CTA Archive Organization

CTA Archive System Concept Design & ASTRI

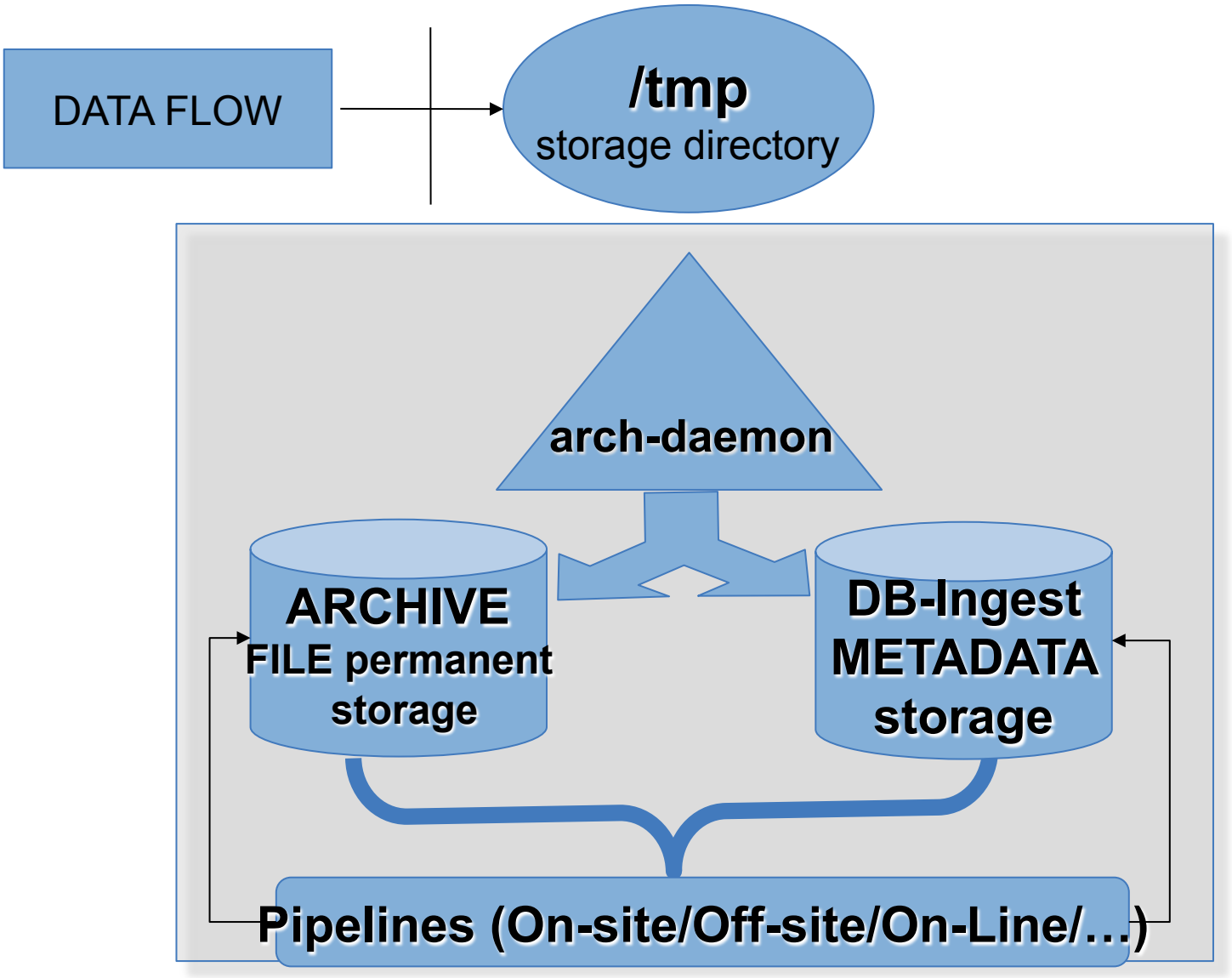


(from CTA-DATA-TDR, v1.0, January 19, 2015)

- ***ASTRI On-site archive*: *temporarily* contains DL0 data files (EVT0/CAL0/ TECH0) and products of the *in situ* OPA and DOPA.**



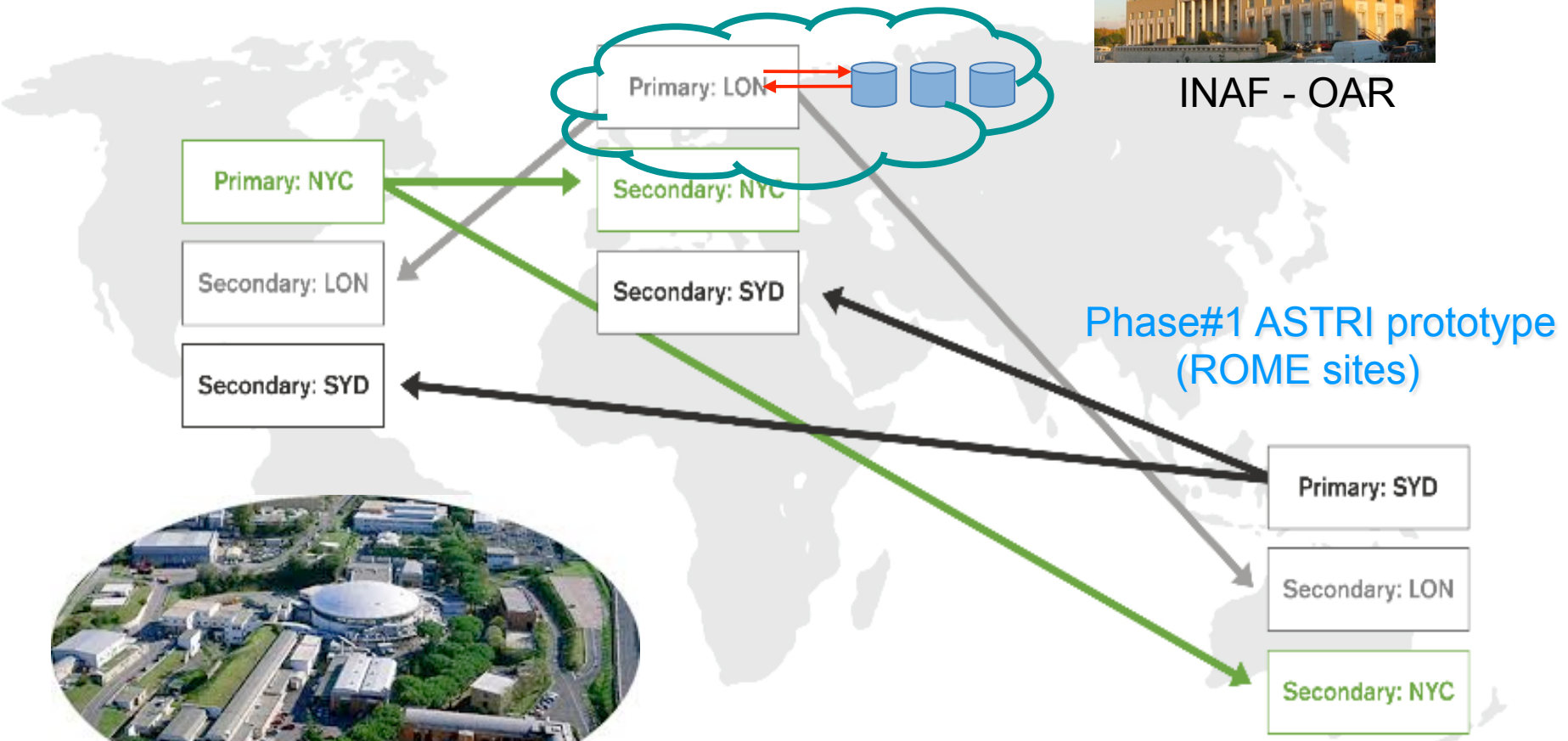
- ***ASTRI Off-site archive*: contains all RAW data, data reco products and high-level science products**


DATA FLOW
/tmp
storage directory
arch-daemon
ARCHIVE
FILE permanent
storage
DB-Ingest
METADATA
storage
Pipelines (On-site/Off-site/On-Line/…)

ASTRI ARCHIVE SYSTEM Deployment Phases

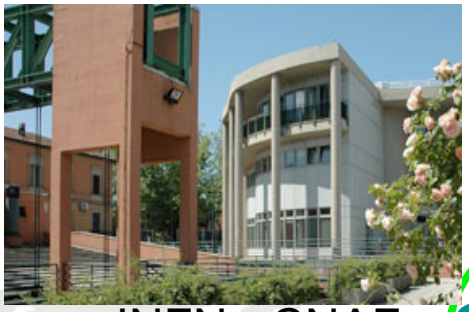
DATA CENTERS

INAF - OAR



INFN - LNF

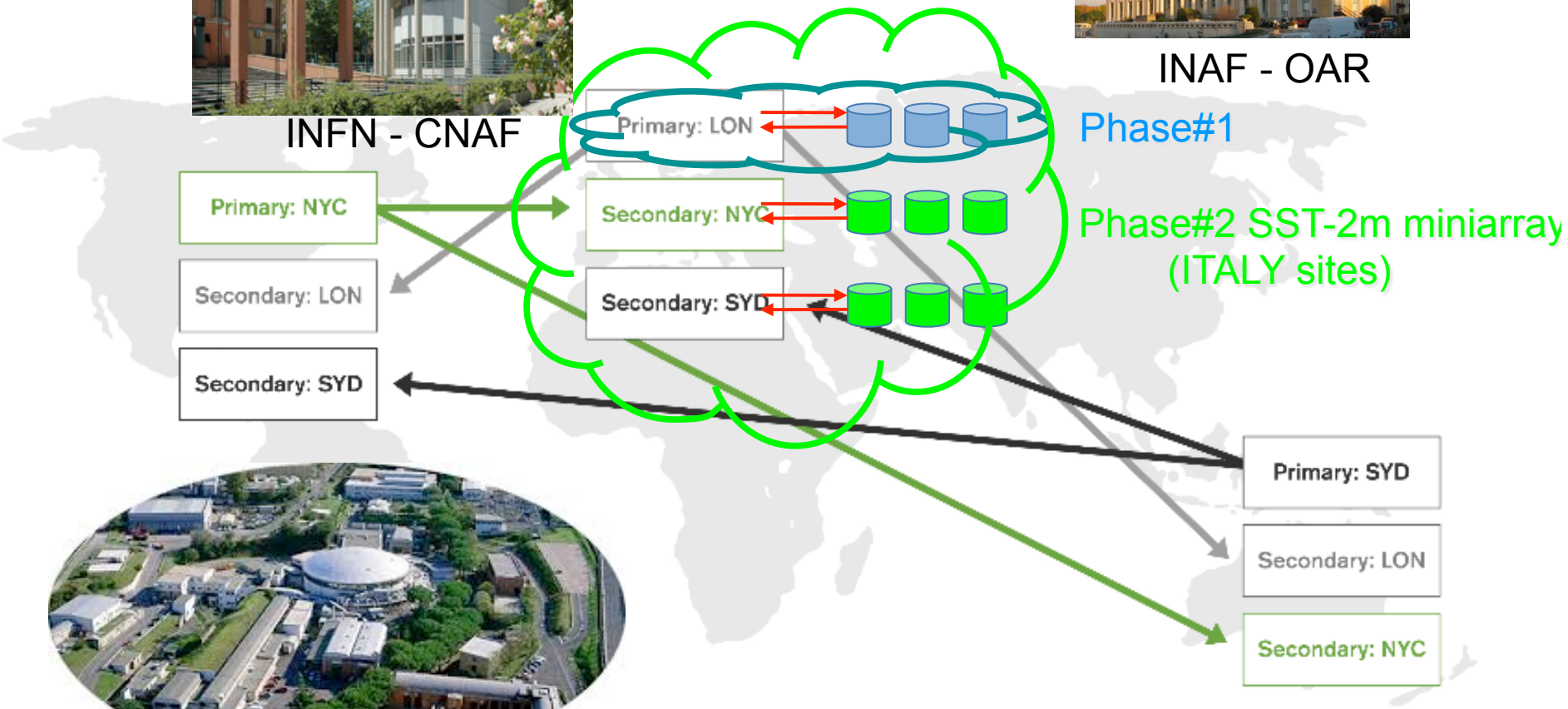
ASTRI ARCHIVE SYSTEM Deployment Phases



INFN - CNAF

DATA CENTERS

INAF - OAR

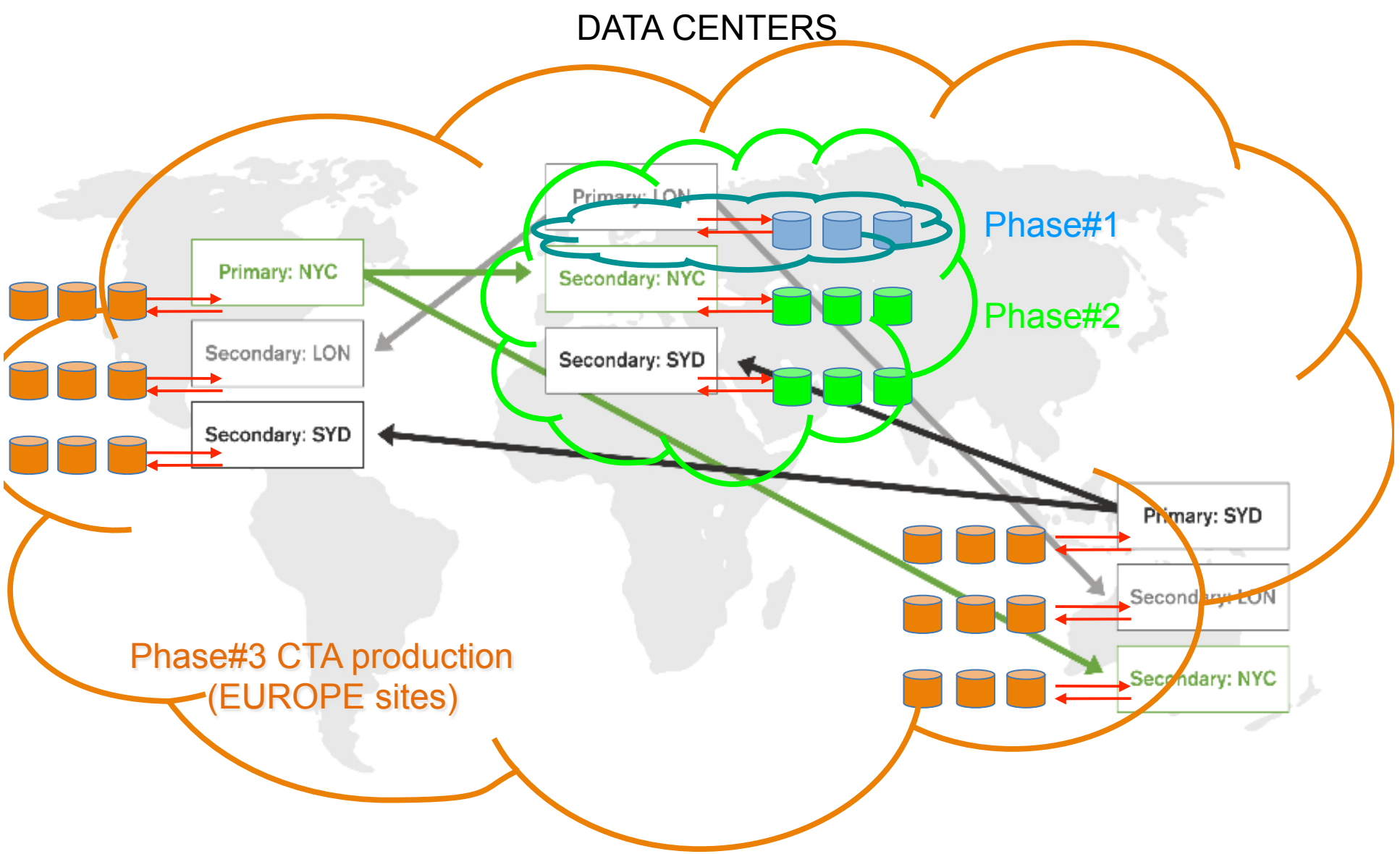


Phase#1

Phase#2 SST-2m miniarray (ITALY sites)

INFN - LNF

ASTRI ARCHIVE SYSTEM Deployment Phases



LEV-A: first prototype of the CTA archive is going to be realized in order to archive and manage all data products coming from the CTA/ASTRI SST-2M prototype.The CTA/ASTRI SST-2M archive system will provide full access to several archive users to the whole data set in order to archive, reduce, analyse and publish scientific data in a PI-oriented platform.

LEV-B: the second level is an archive system prototype capable of efficiently manage (for archiving and data-processing activities) data coming from several telescopes (mini-array) with several and (possibly) different kind of cameras technologies.

LEV-C: CTA Archive core. It is the final prototype version totally compliant with CTA requirements.

- The ASTRI Project is now moving from the prototype construction phase to the CTA pre-production phase.
- A complete data analysis and archiving system is under construction.
- Several solutions are tested in order to be suitable and finally selected for CTA.