The core software and simulation activities for data analysis at the Pierre Auger Observatory
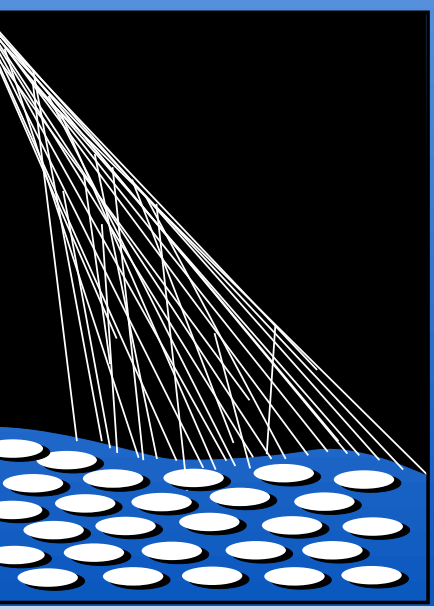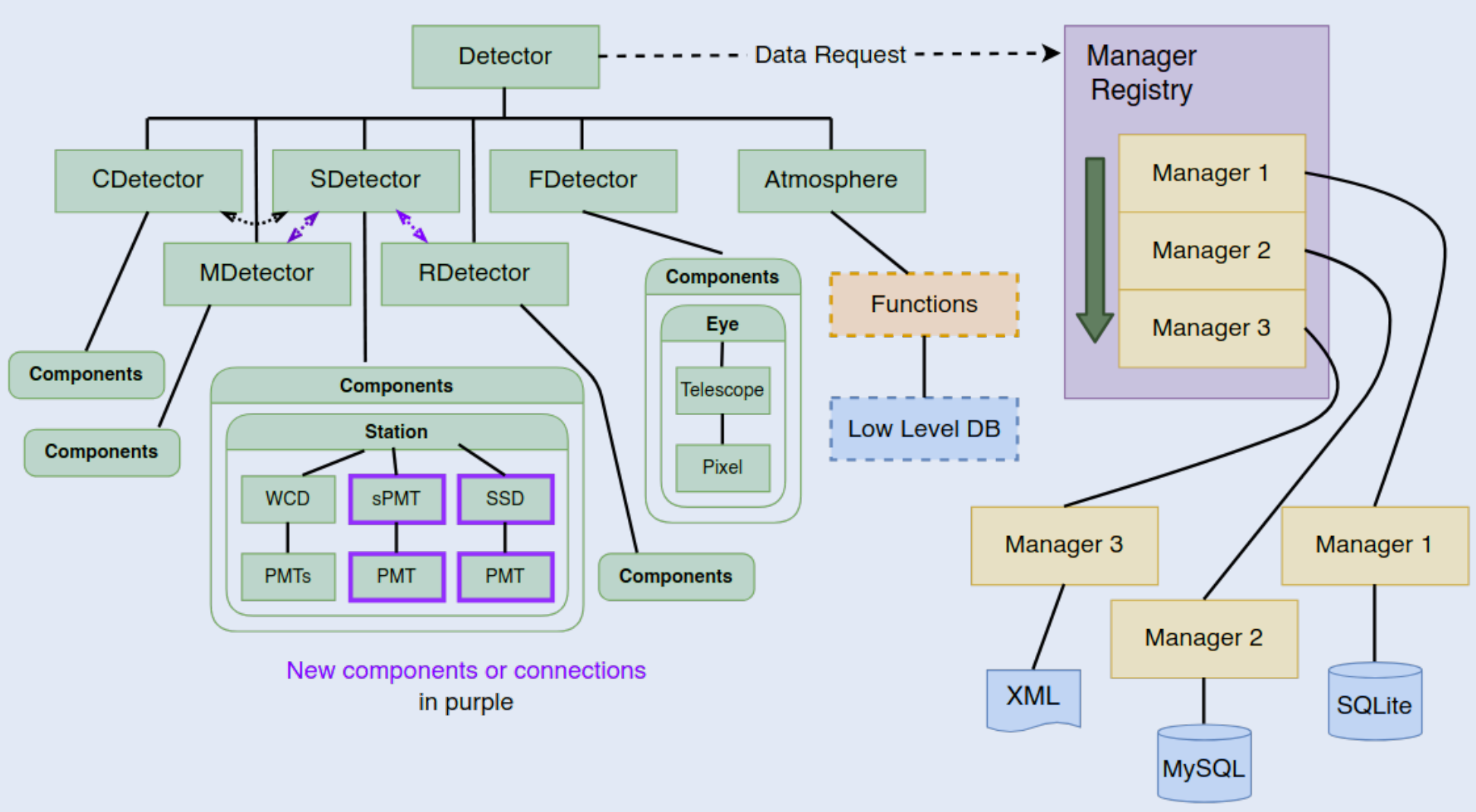
Eva Santos[1], for the Pierre Auger Collaboration[2]

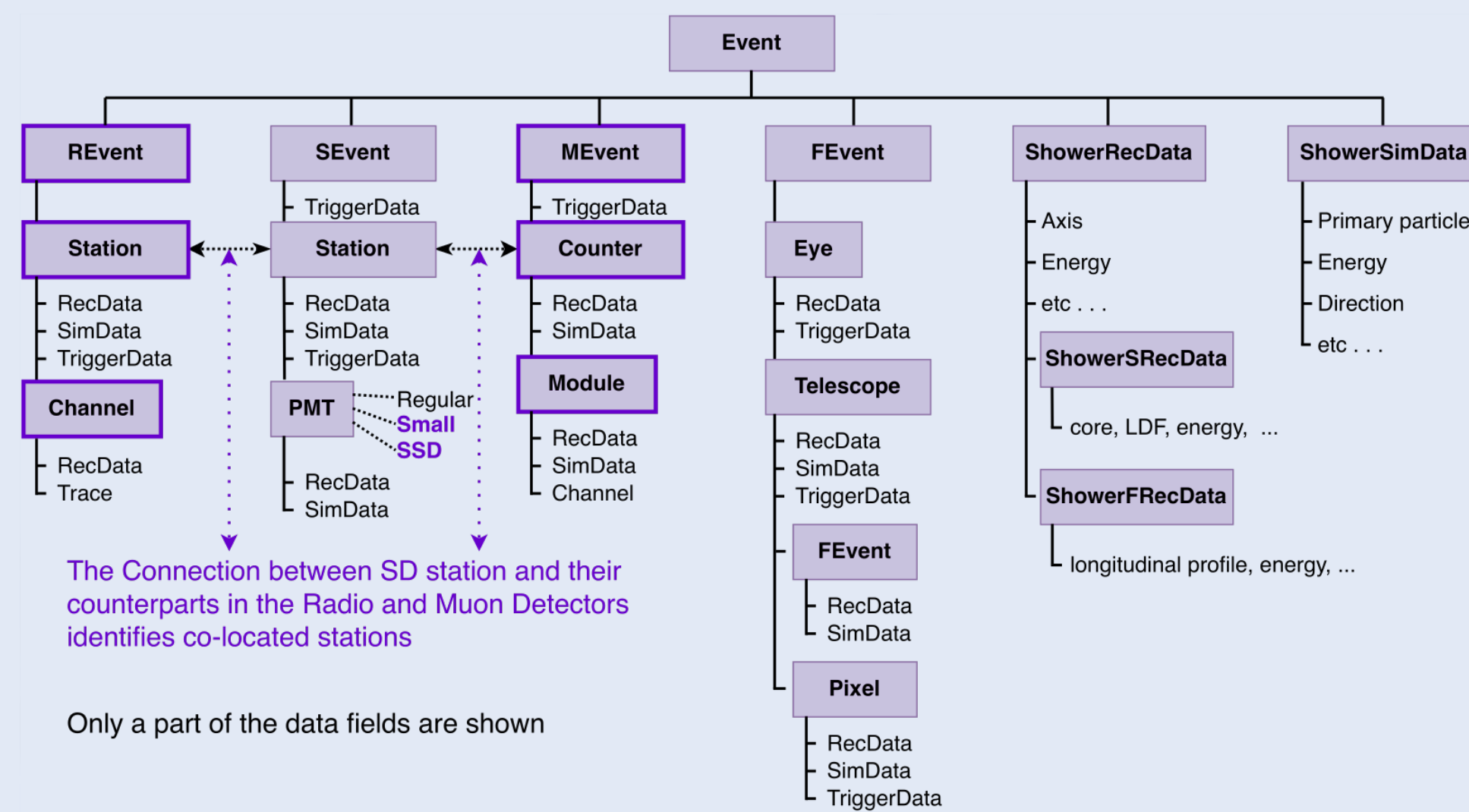[1]FZU - Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic

[2]Observatorio Pierre Auger, Av. San Martín Norte 304, 5613 Malargüe, Argentina
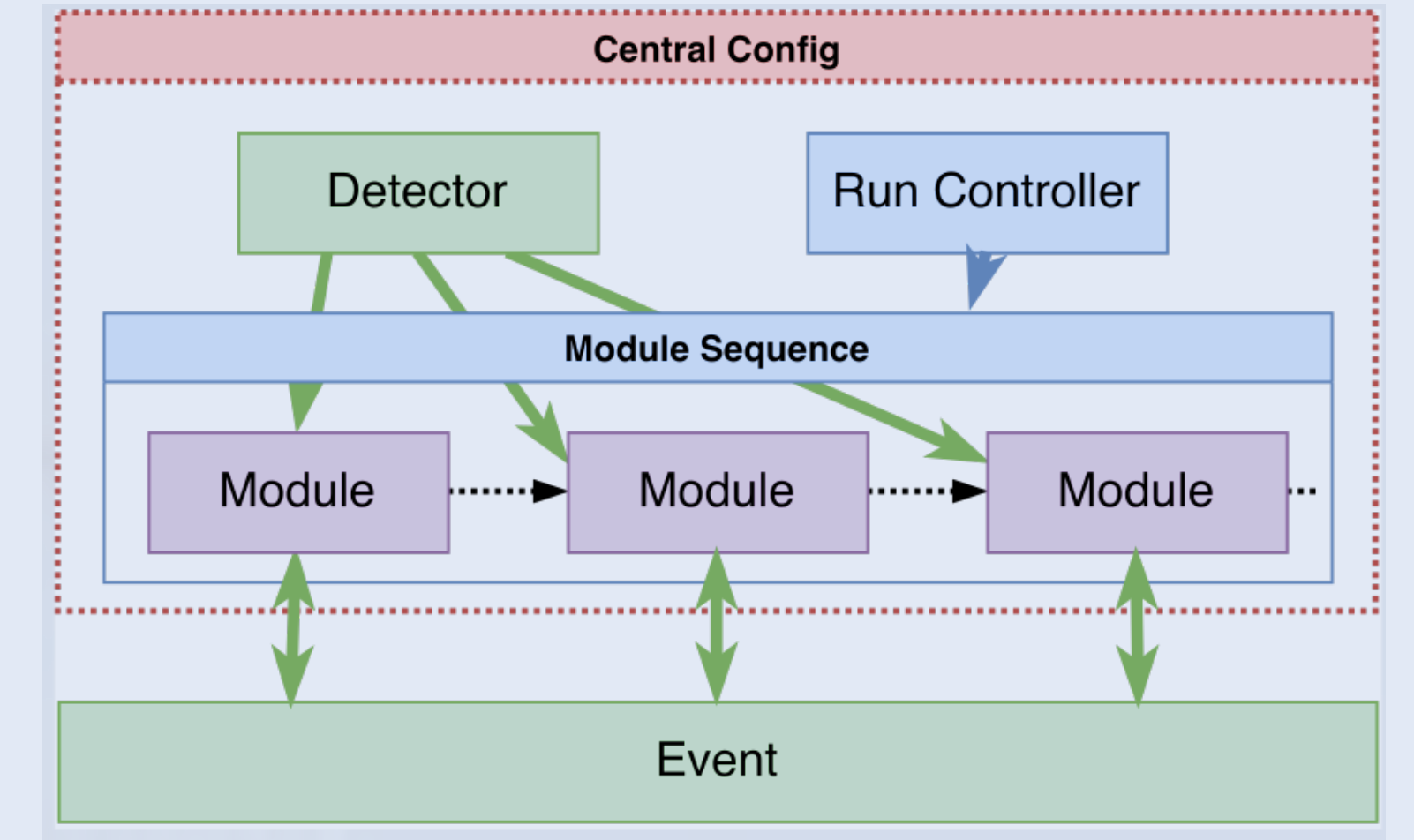
Detector structure

- Detector structure is slowly changing
- Structure follows detector hierarchy
- Atmosphere is also part of the detector
- Managers as abstraction for data access
  - Configurable

Event structure

The Connection between SD station and their counterparts in the Radio and Muon Detectors identifies co-located stations

Only a part of the data fields are shown

- Structure parallel to detector
- Mostly write-only
  - Delete only when unavoidable
- Not all fields shown

Control flow

- Application
  - Sequence of steps encapsulated as modules
- Run Controller
  - Configures sequence; Schedules execution
- Central Config
  - Detector; Run Controller; modules
- Detector
  - Detector is read-only
- Event
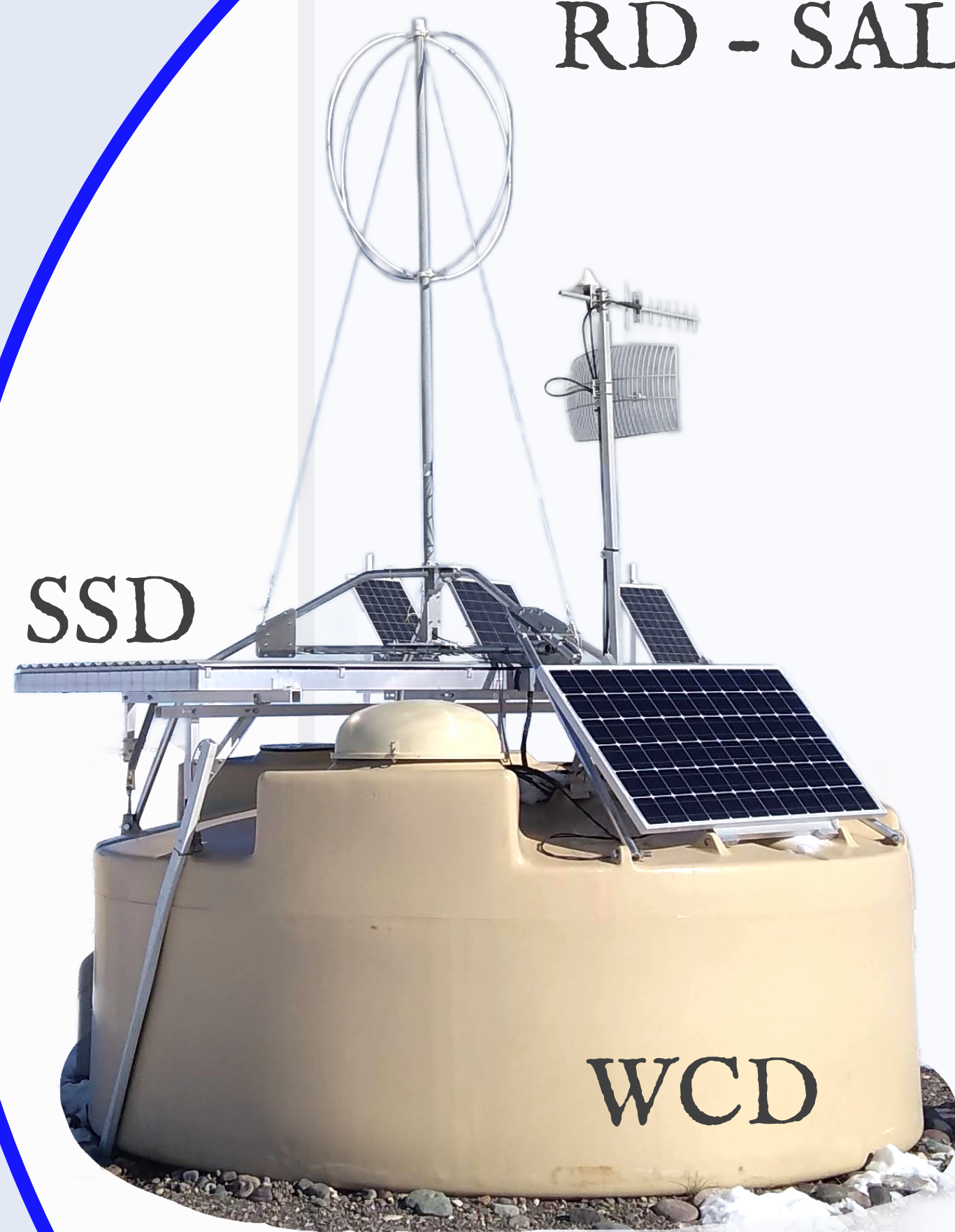 - Transports information between modules

Lessons learned

20 years of Offline experience:

- Clean design and investment in testing infrastructure pay off
- From the beginning consider the need of the end-user
- Choose data formats carefully: event data, detector/slow control, and configuration

AugerPrime

RD - SALLA antenna

SSD

WCD

- RD - Radio Detector
- SSD - Surface Scintillator Detector
- UMD - Underground Muon Detector
- UUB - Upgraded Unified Board
- Small PMT
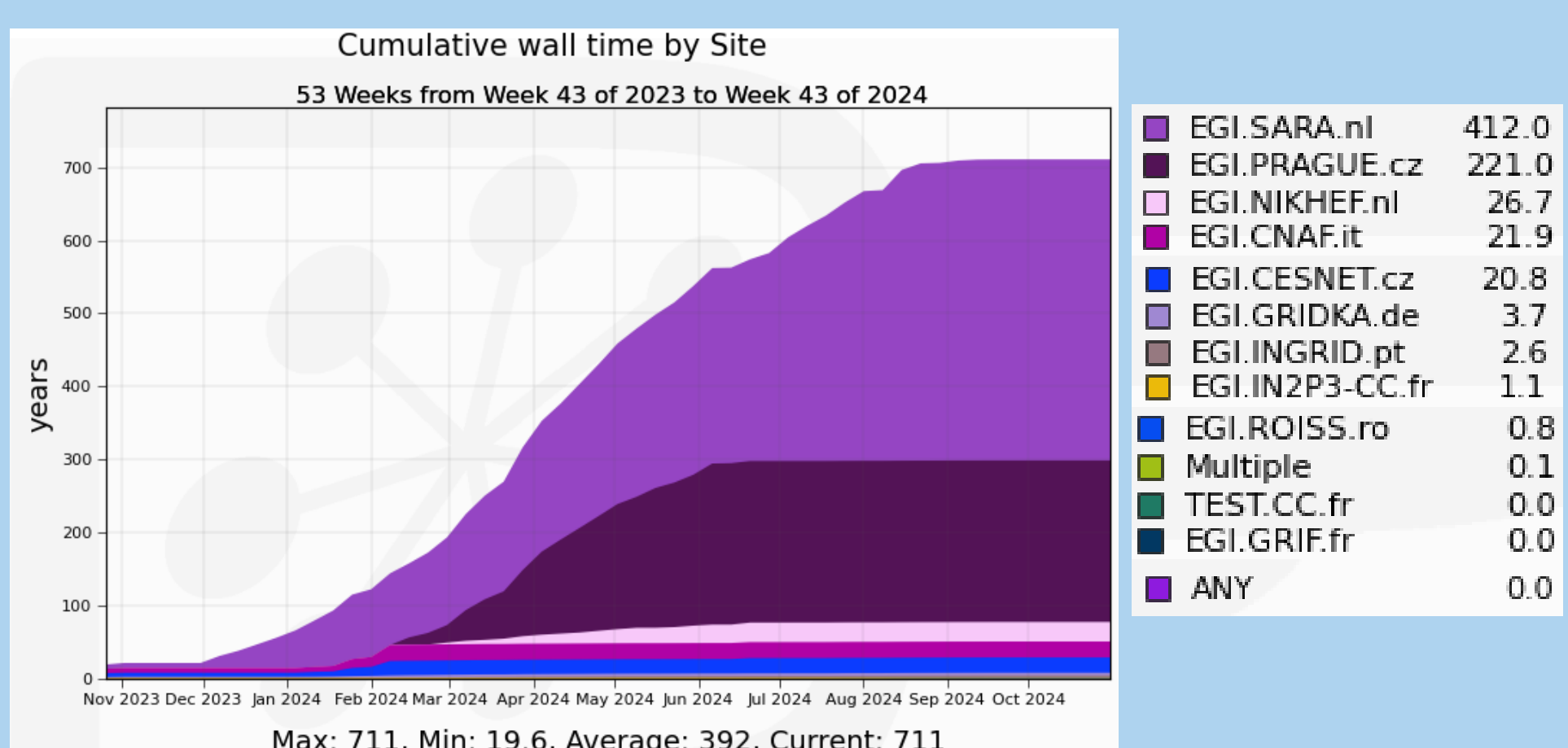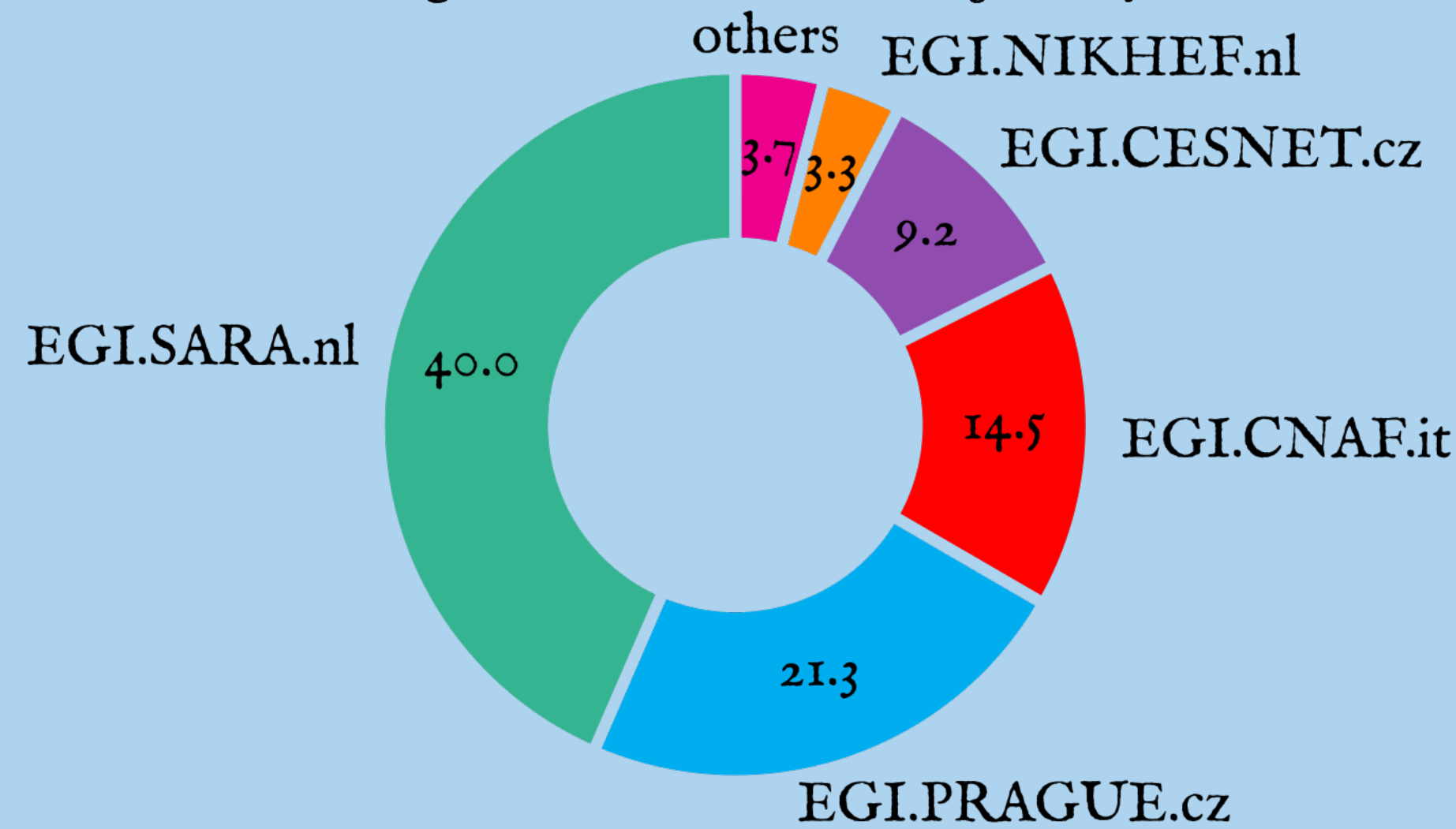
AugerPrime components implemented in Offline

VO Auger

- DIRAC Interware
  - Grid job management
  - File Catalog
- VOMS server
- Registration portal
- CVMFS
  - Software distribution
- $\sim$ 2 PB disk space
  - 1.7 PB disk occupancy
- $\sim$ 30 members
- 8 countries
- 13 sites

VO Auger statistics

2024 - Astrophysics VOs
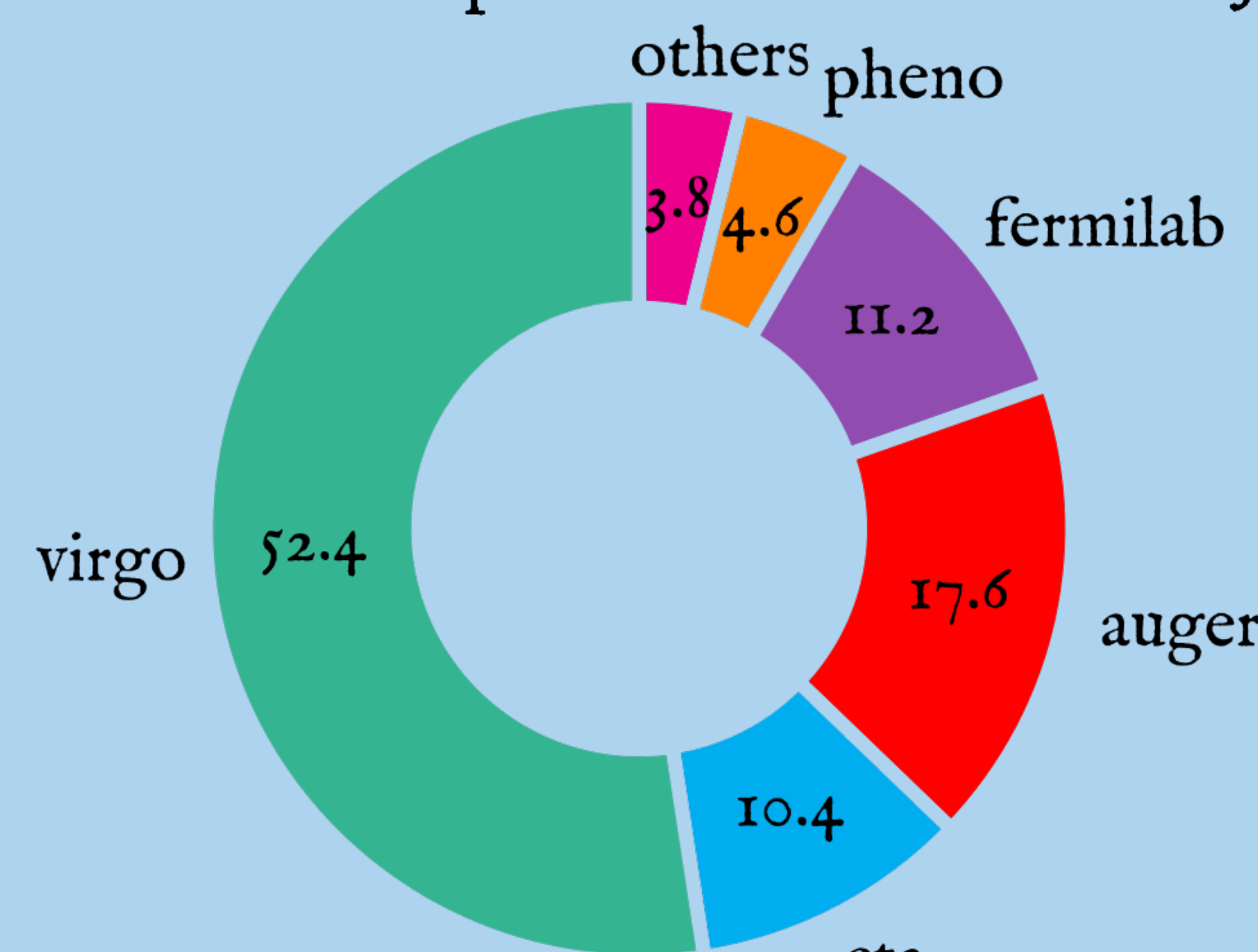Percentage of Total Number of Jobs by Site

others — 3.7
EGI.NIKHEF.nl — 3.3
EGI.CESNET.cz — 9.2
EGI.CNAF.it — 14.5
EGI.PRAGUE.cz — 21.3
EGI.SARA.nl — 40.0

Cumulative wall time by Site
53 Weeks from Week 43 of 2023 to Week 43 of 2024

	years
EGI.SARA.nl	412.0
EGI.PRAGUE.cz	221.0
EGI.NIKHEF.nl	26.7
EGI.CNAF.it	21.9
EGI.CESNET.cz	20.8
EGI.GRIDKA.de	3.7
EGI.INGRID.pt	2.6
EGI.IN2P3-CC.fr	1.1
EGI.ROISS.ro	0.8
Multiple	0.1
TEST.CC.fr	0.0
EGI.GRIF.fr	0.0
ANY	0.0

Max: 711, Min: 19.6, Average: 392, Current: 711

Astrophysics VOs

2nd largest Astroparticle EGI user*

2024 - Astrophysics VOs
Normalized elapsed time - HEPSCORE23

others — 3.8
pheno — 4.6
fermilab — 11.2
auger — 17.6
cta — 10.4
virgo — 52.4

*Excluding VO LHCb contribution

Reference libraries

Shower simulations

- CORSIKA /CoREAS
  - $\log_{10}(\mathrm{E/eV}) = 14.0 - 20.2$
  - 4 hadronic species: H, He, O, Fe
  - 3 ultra-heavy elements: Te, Pt, U
  - Neutral particles: γ, ν_e, ν_τ
  - EPOS-LHC; Sibyll 2.3d; Sibyll*; QGSJetII-0.4

Auger Offline sim & rec

- CORSIKA /CoREAS as input
- Multi-hybrid reconstruction
- Different output file formats
- Hybrid time-dependent simulations