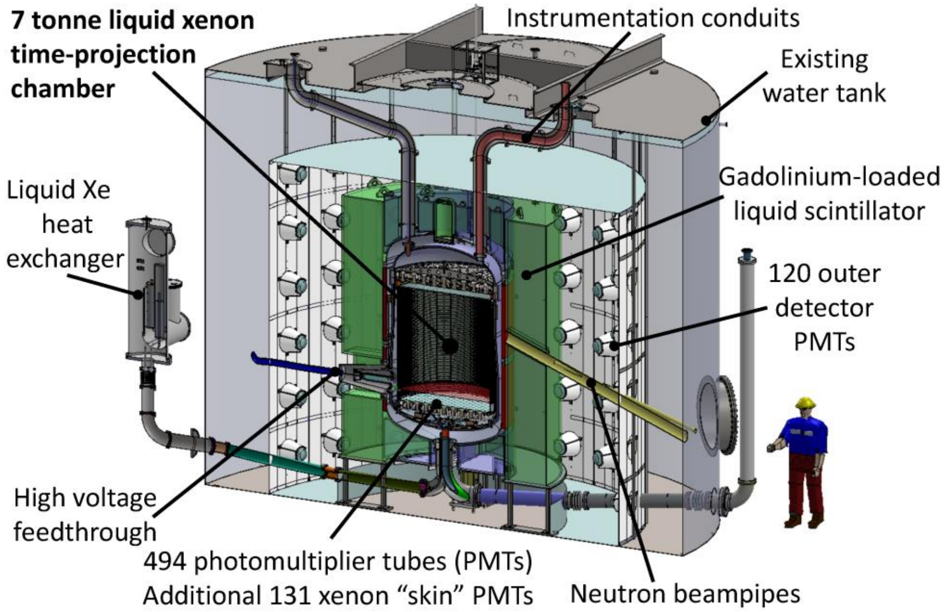
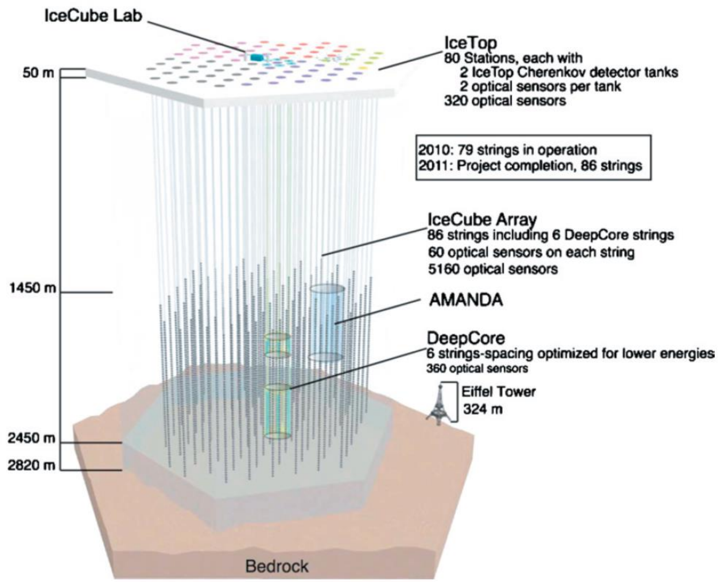
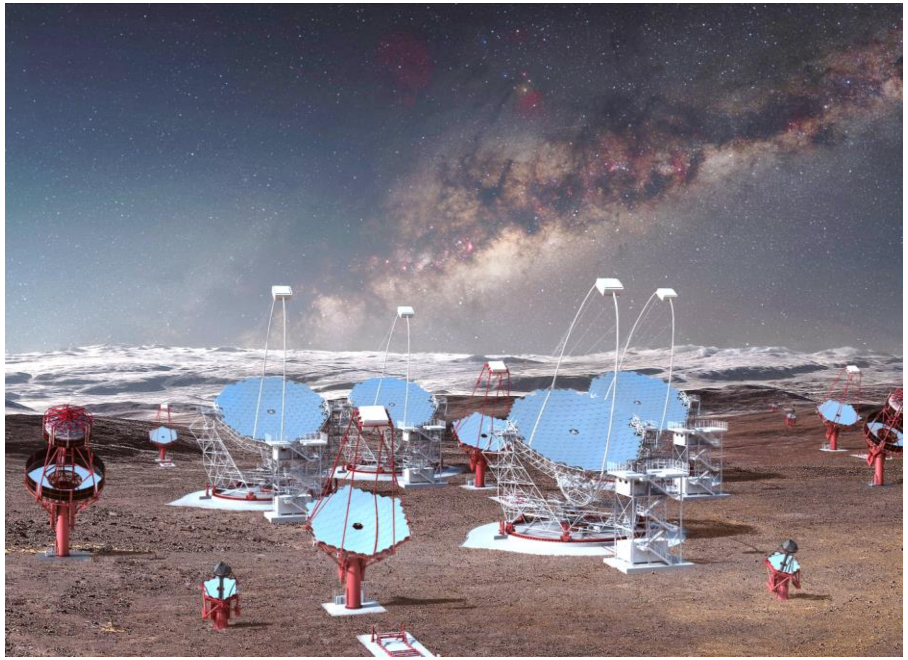
Particle Astrophysics IRIS Computing

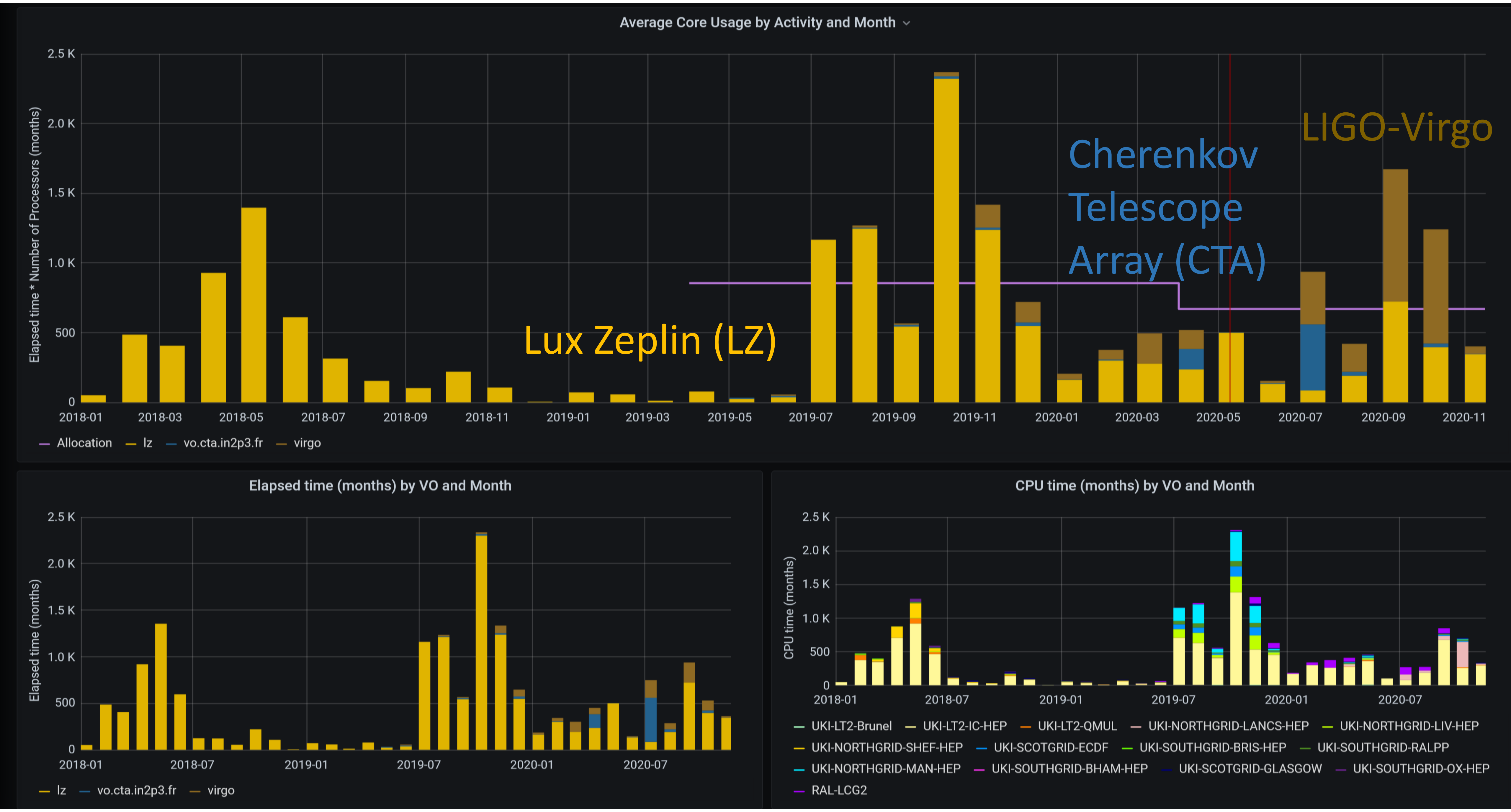
Stephen Fairhurst



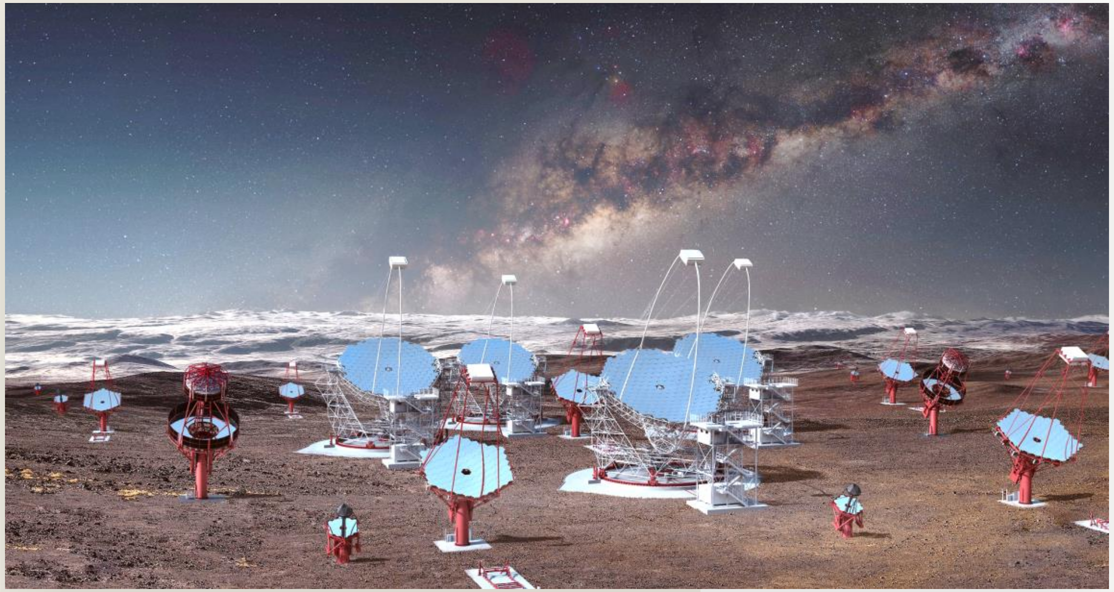


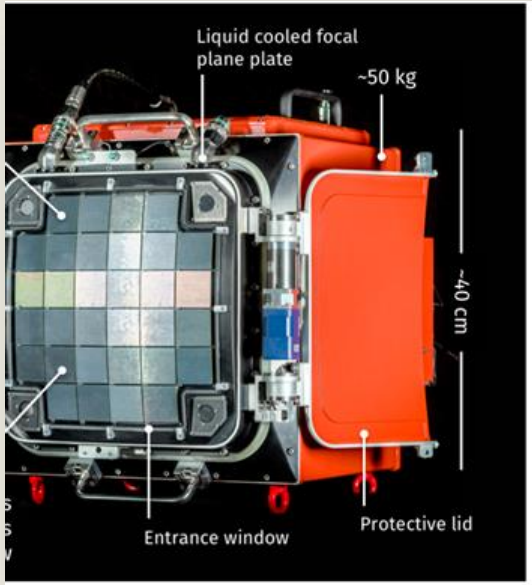


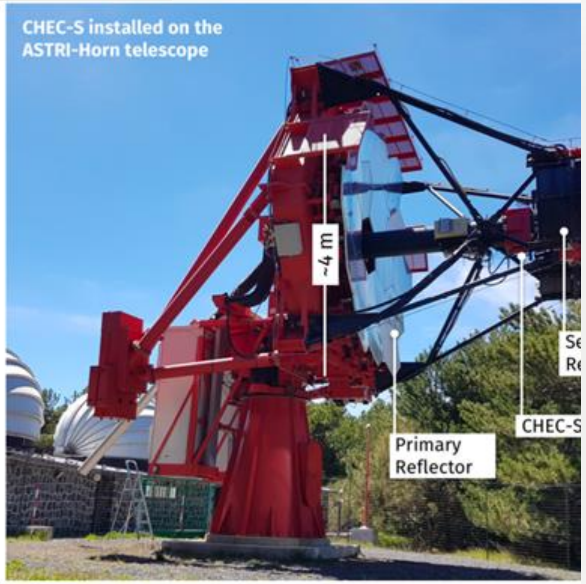
Particle Astrophysics



Average Core Usage by Activity and Month
Elapsed time * Number of Processors (months)
0
500
1.0 K
1.5 K
2.0 K
2.5 K
2018-01
2018-03
2018-05
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
Allocation
lz
vo.cta.in2p3.fr
virgo
Lux Zeplin (LZ)
Cherenkov
Telescope
Array (CTA)
LIGO-Virgo
Elapsed time (months) by VO and Month
Elapsed time (months)
2018-01
2018-07
2019-01
2019-07
2020-01
2020-07
lz
vo.cta.in2p3.fr
virgo
CPU time (months) by VO and Month
CPU time (months)
UKI-LT2-Brunel
UKI-LT2-IC-HEP
UKI-LT2-QMUL
UKI-NORTHGRID-LANCS-HEP
UKI-NORTHGRID-LIV-HEP
UKI-NORTHGRID-SHEF-HEP
UKI-SCOTGRID-ECDF
UKI-SOUTHGRID-BRIS-HEP
UKI-SOUTHGRID-RALPP
UKI-NORTHGRID-MAN-HEP
UKI-SOUTHGRID-BHAM-HEP
UKI-SCOTGRID-GLASGOW
UKI-SOUTHGRID-OX-HEP
RAL-LCG2

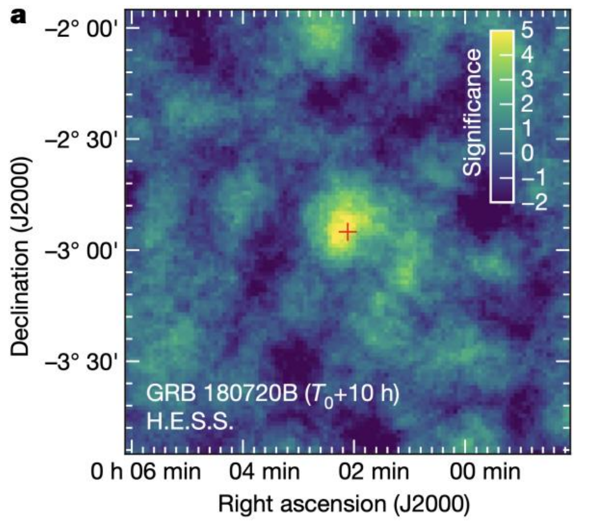


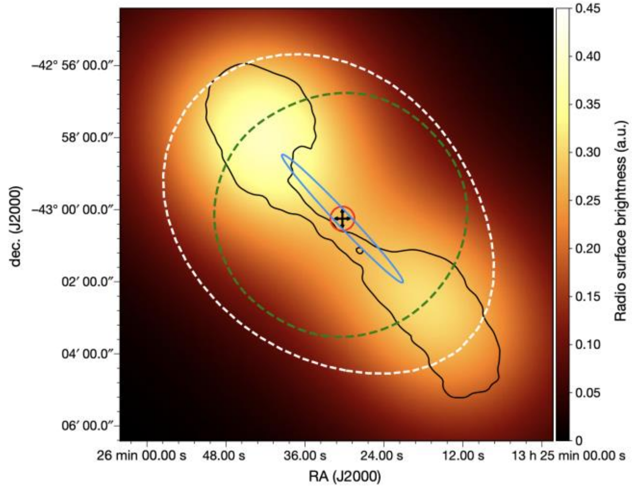




Cherenkov Telescope Array: Very High Energy Gamma-ray astronomy

- CTA – the next generation gamma ray astronomy in the energy range from 20 GeV to over 100 TeV
- CTA is transformational – order-of-magnitude improvement in sensitivity plus substantial gains in angular resolution and energy range
- CTA science has an exceptionally broad range –spanning all three of STFC's science challenges
- **Construction of CTA is planned to begin 2021**





Gamma-ray astronomy – ongoing science exploitation activities

- First ground-based detection of GRB’s
- STFC science goal synergies - transients, Rubin Observatory, SKA, GW (EM counterparts) and multimessenger
- CTA will have 10 x sensitivity, faster slew times, capability to quickly tile GW error boxes with sub-arrays

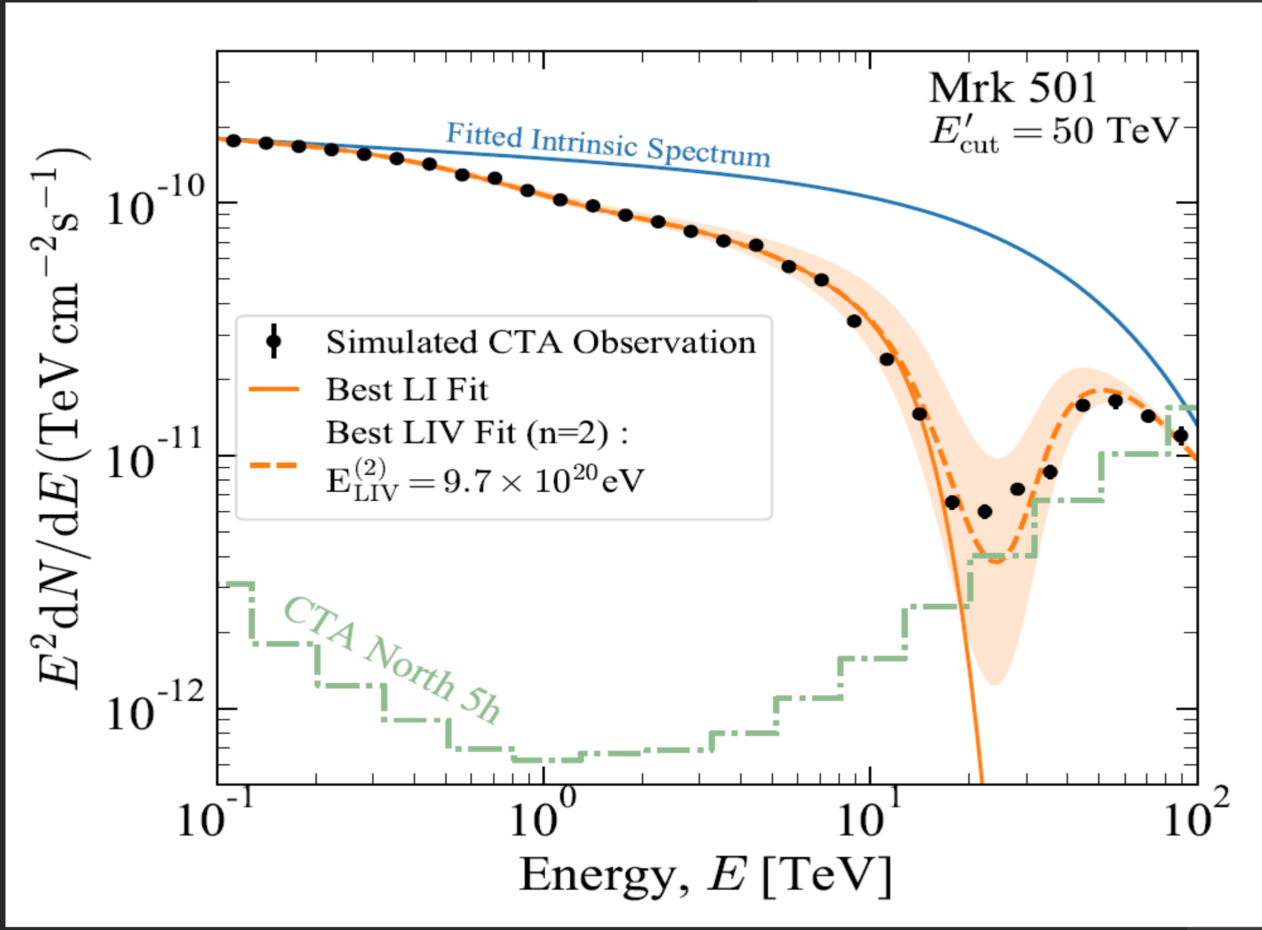
Abdalla et al. 2019, Nature, 575, 464

- First detection of TeV emission from kpc-scale jet (Cen A)
- STFC science goal synergies – SKA AGN science, black hole jet formation, particle acceleration, AGN impact on galaxy evolution
- CTA will have higher sensitivity, higher energy range extending to 300 TeV, sharper angular resolution

Abdalla et al. 2020, Nature, 582, 356

Gamma-ray astronomy – ongoing science exploitation activities
Lorentz Invariance Violation

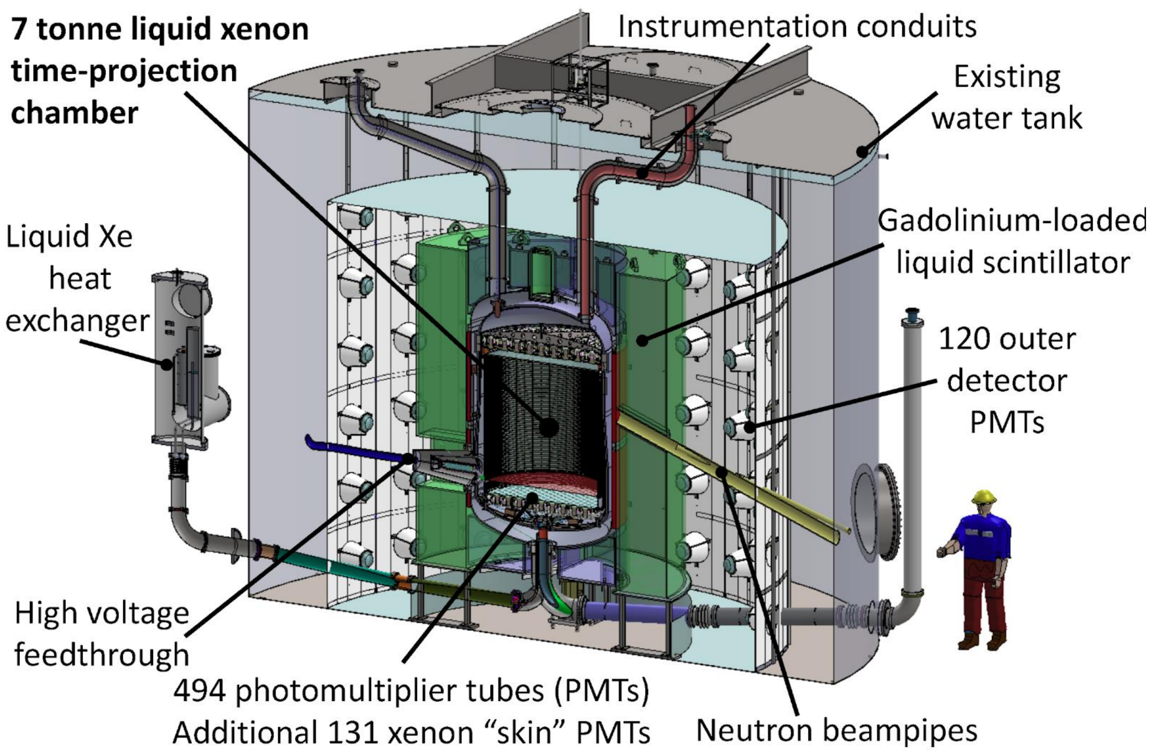
- Consequence of quantum gravity theories
- Clear imprint on blazar spectra at the highest energies
- Important science contribution from CTA Small-Sized Telescopes (SST) to which UK is contributing
- See CTA paper: https://arxiv.org/abs/2010.01349 for this and other fundamental physics measurements possible with CTA



Lux Zeplin Dark Matter experiment

- Next-generation dark matter direct detection experiment. Largest & most sensitive DM experiment to date.
- 1 mile underground, SURF, USA; ultra-radio pure materials & Xe; active veto system for background suppression & in-situ characterisation.
- Rich non-WIMP physics program: astrophysical neutrinos, DM-electron scattering, rare decays of 136Xe and 124Xe,
- LXe TPCs is leading technology in search for WIMPs.
- LZ status:
    - Received DOE "CD-4 approval" late August 2020, marking end of construction;
    - Commissioning activities underway, full science run will start in 2021.

The LZ Detector



"The LUX-ZEPLIN (LZ) experiment"
https://doi.org/10.1016/j.nima.2019.163047

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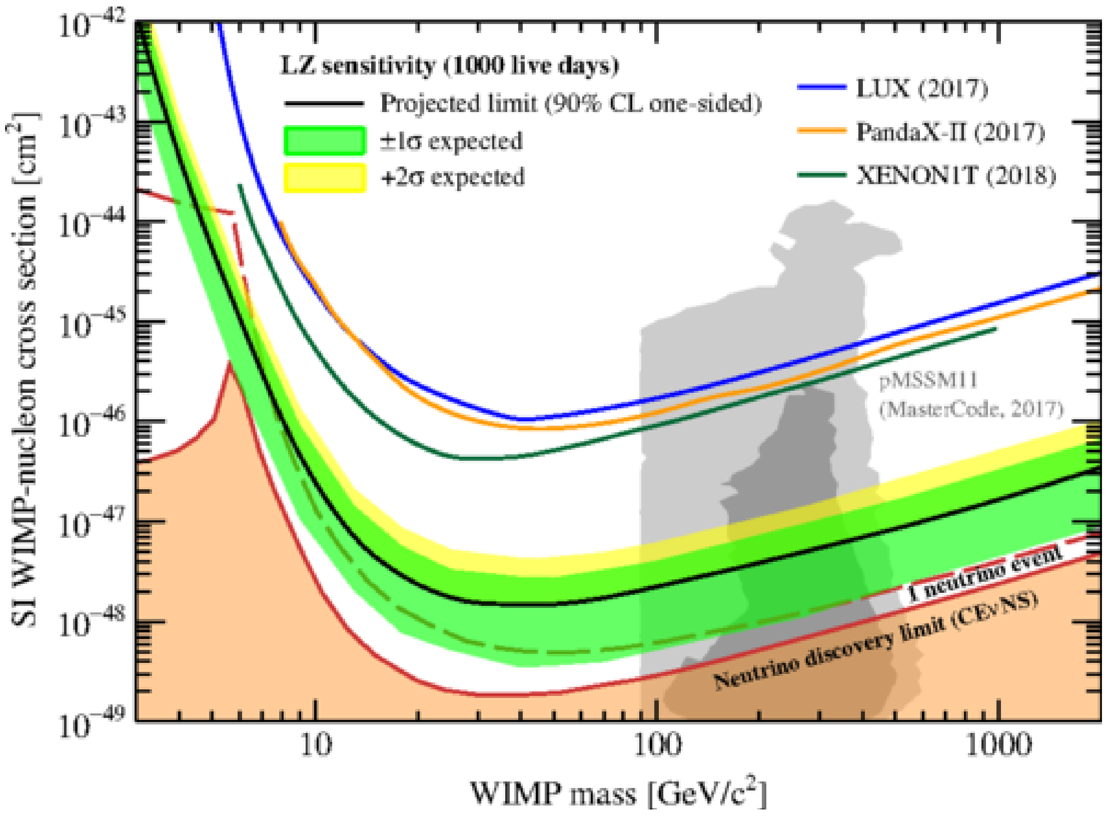
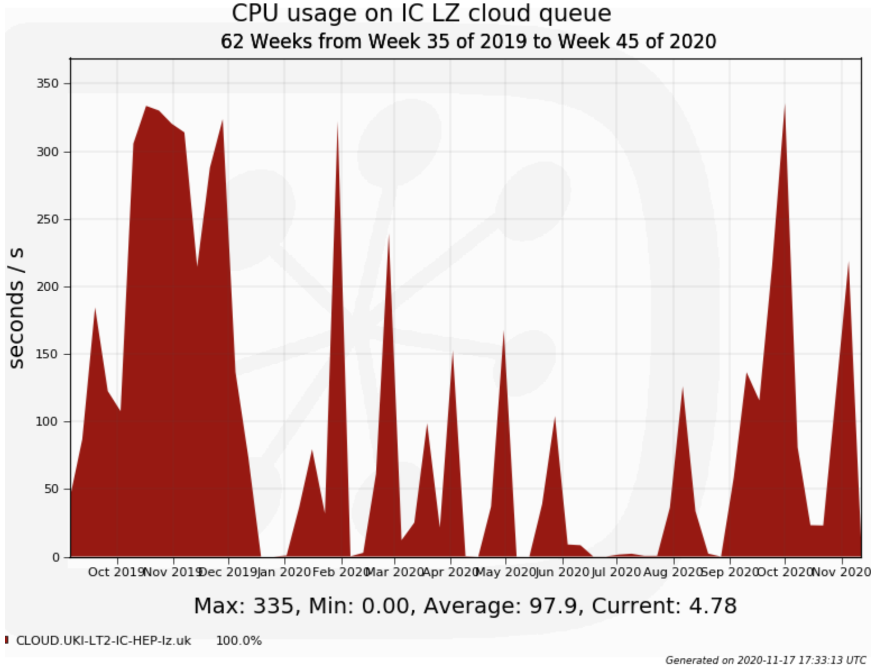


D. S. Akerib *et al.*, “Projected WIMP sensitivity of the LUX-ZEPLIN dark matter experiment”, https://doi.org/10.1103/PhysRevD.101.052002

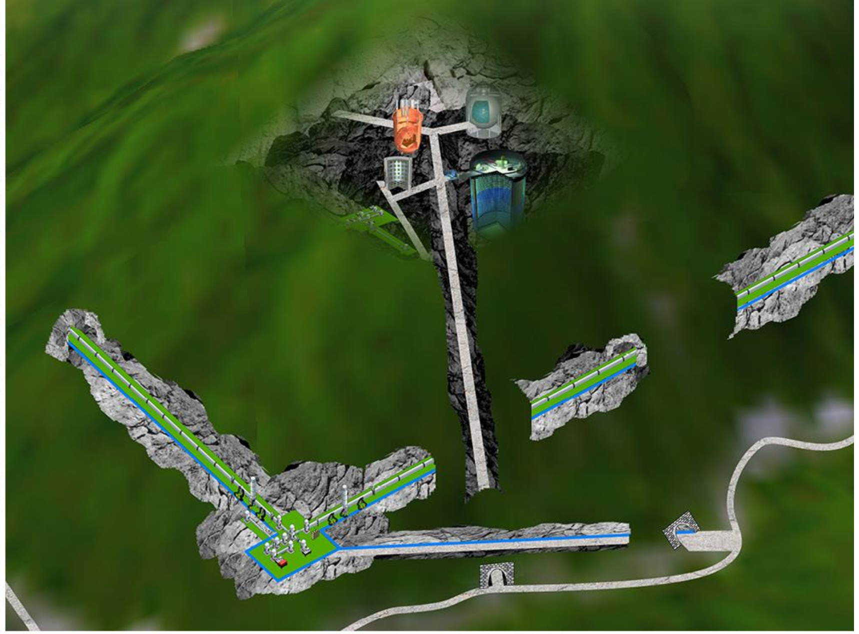
Lux Zeplin: IRIS Computing

- In September 2019 LZ received additional IRIS computational and storage resources:
  - 300 high memory (10GB) job slots;
  - 300 TB of storage
  - Usage of new resource significantly improved job efficiency



- The CPUs have been used for simulations for LZ Final Mock Data Challenge
  - Typically for calibration sources — the most demanding simulations due high rate and high energy
  - The mock data is then used to exercise the full LZ analysis chain ensuring LZ will be physics ready from day one
  - Constitutes an important contribution to preparations for data taking given most of the activity when LZ turns on will involve calibration sources
  - Over the next year such simulations will be required to interpret first data

D. S. Akerib *et al.*, "Simulations of events for the LUX-ZEPLIN (LZ) dark matter experiment", https://doi.org/10.1016/j.astropartphys.2020.102480

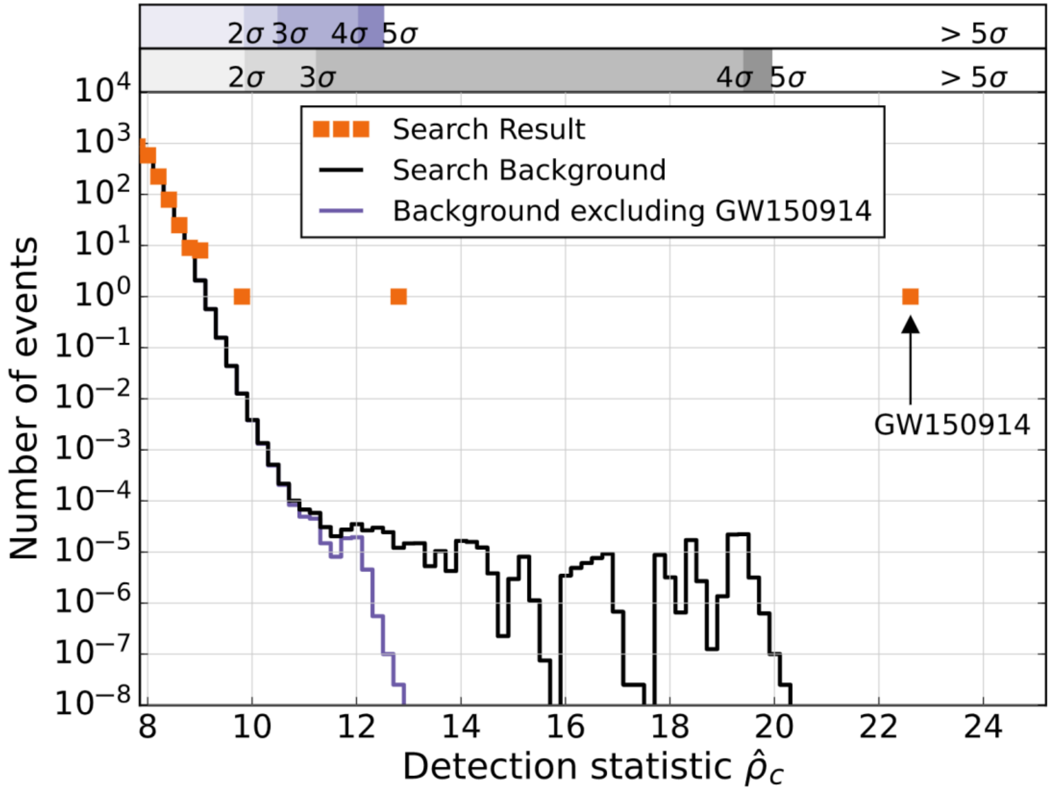


International Gravitational Wave Network (IGWN): LIGO, Virgo and KAGRA

- Third Observing Run from April 2019 to March 2020
- Over 50 real-time public alerts of observations
- Publications of exceptional events and a catalogue of events from first half of run
- Fourth observing run, with improved sensitivity, expected to begin mid-2022

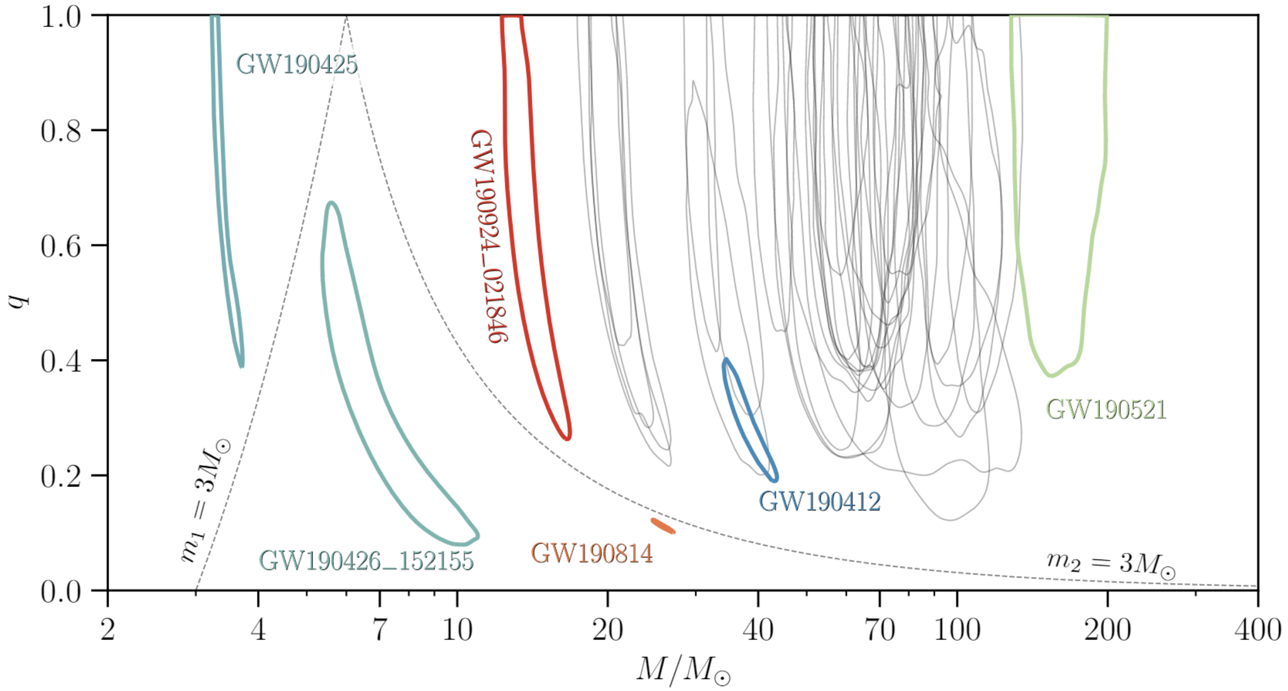
Gravitational Wave computing on IRIS

- Detection: identification of events in the data
- Filtering many thousands of waveform templates against months of data to identify signals
    - Time-shifted analysis to estimate backgrounds
    - Simulation campaigns to evaluate sensitivity
- Embarrassingly parallel computing
- Data, software hosted via CVMFS
- Job submission from dedicated GW nodes (at Caltech, Cardiff)



From: Abbott et al, "Binary Black Hole Mergers in the first Advanced LIGO Observing Run", https://doi.org/10.1103/PhysRevX.6.041015

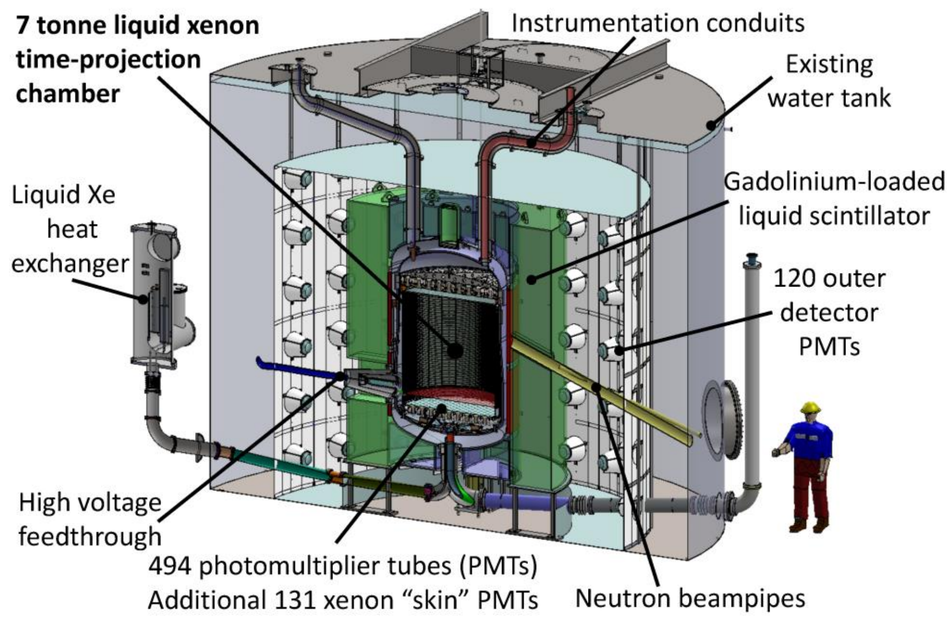
Gravitational Wave computing on IRIS

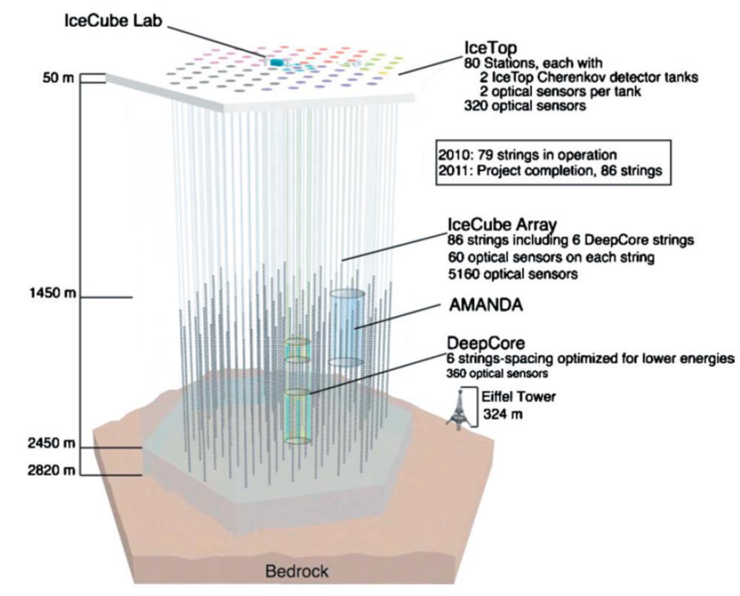


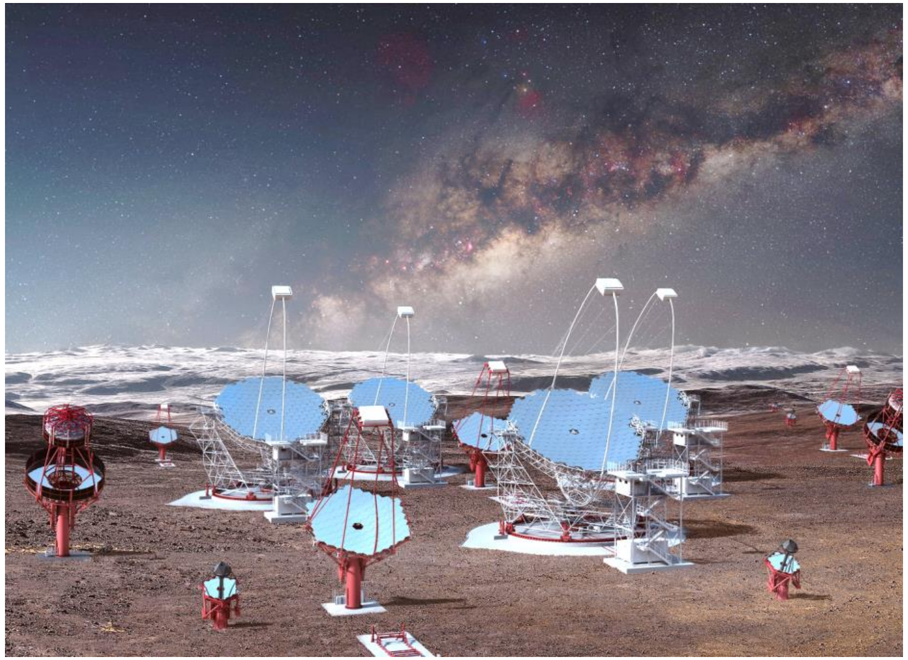
From: Abbott et al, "GWTC-2: Compact Binary Coalescences Observed by LIGO and Virgo During the First Half of the Third Observing Run", e-Print: 2010.14527 [gr-qc]

Parameter estimation: Understanding observed events

- Stochastic samplers used to explore multi-dimensional parameter space
- Typically run for several days on a single node
- Increasing use of parallelization to reduce (wall-)time to get results


7 tonne liquid xenon time-projection chamber
Instrumentation conduits
Existing water tank
Liquid Xe heat exchanger
Gadolinium-loaded liquid scintillator
120 outer detector PMTs
High voltage feedthrough
494 photomultiplier tubes (PMTs)
Additional 131 xenon “skin” PMTs
Neutron beampipes


IceCube Lab
IceTop
80 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
320 optical sensors
2010: 79 strings in operation
2011: Project completion, 86 strings
IceCube Array
86 strings including 6 DeepCore strings
60 optical sensors on each string
5160 optical sensors
AMANDA
DeepCore
6 strings-spacing optimized for lower energies
360 optical sensors
Eiffel Tower
324 m
50 m
1450 m
2450 m
2820 m
Bedrock



Thanks.