

# Particle Astrophysics Advisory Panel Update @ IOP Town Hall Meeting

8/4/2025

## •PAAP:

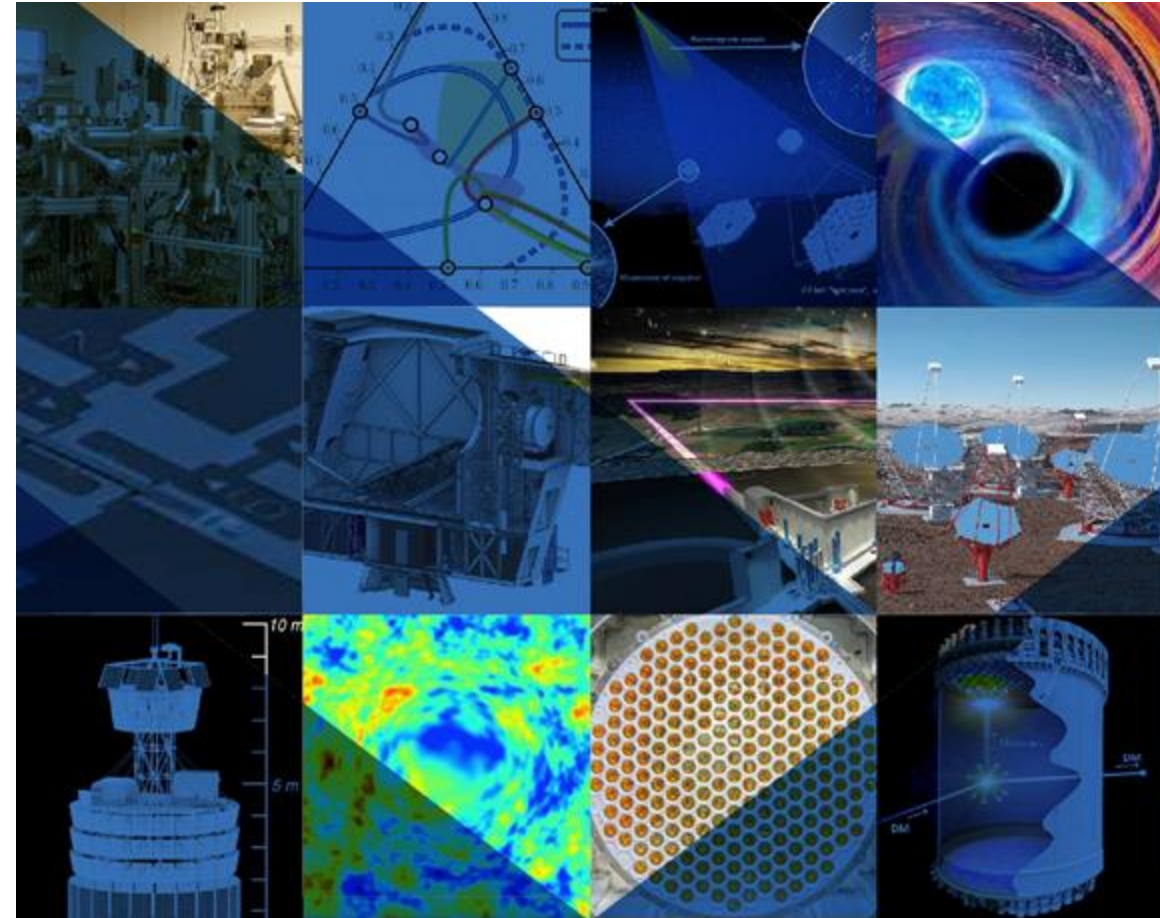
- *Sergey Burdin (Chair, Liverpool)* - Direct (particle-like) Dark Matter searches
- *Garret Cotter (Oxford)* - Gamma-ray Astronomy
- *Djuna Croon (Durham)* - Theory
- *Ed Daw (Sheffield)* - Direct (wave-like) Dark Matter searches & Quantum Technology for Fundamental Physics
- *Teppei Katori (KCL)* - Neutrino Astronomy
- *Laura Nuttall (Portsmouth)* - Gravitational Waves
- *Blake Sherwin (Cambridge)* - Cosmic Microwave Background

## •Science Board representatives:

- *Francesca Di Lodovico (KCL)*, *Anne Green (Nottingham)*,  
*Patrick Sutton (Cardiff)*

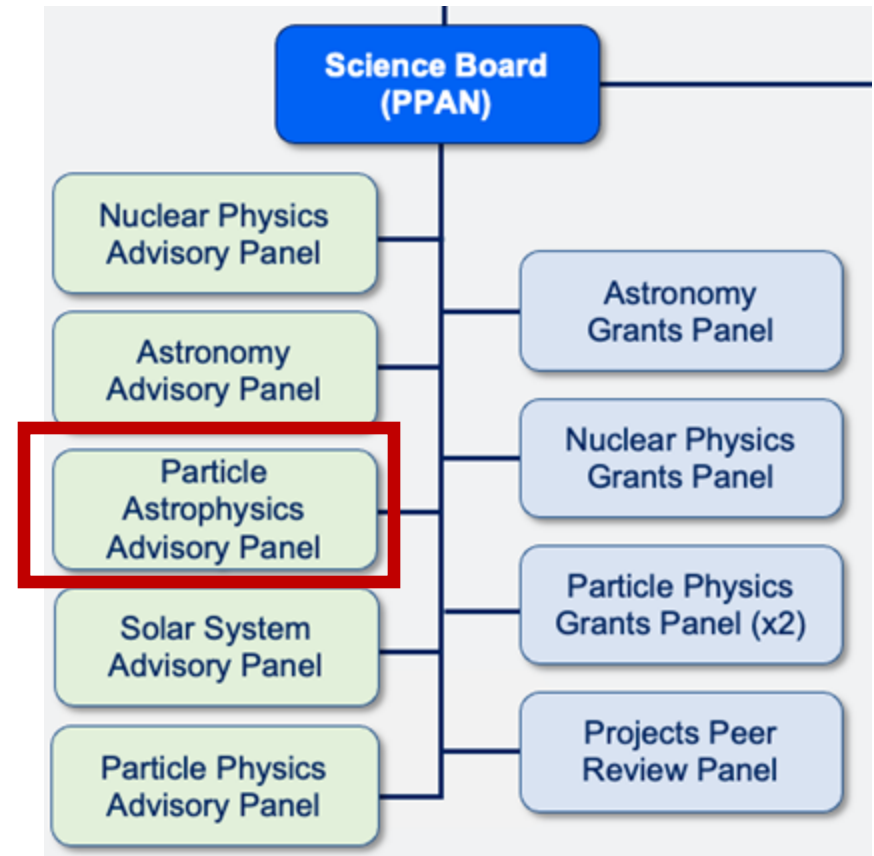
## •STFC:

- *Thomas Gray, Georgina Freeman, Melanie Kidd, Jamie Parkin*



# PAAP role

- One of the 5 Advisory Panels for the Science Board (PPAN)
- Link between SB and the community
  - Establishment of effective route for communication with SB (PPAN) and STFC on strategic programmatic issues
- Overview of activities within Particle Astrophysics
- A science vision and long-term strategy
  - Roadmap
  - Current and future science opportunities
- Technology roadmap for Particle Astrophysics
- Advice to the SB on specific questions as requested
- Links to other advisory panels



# Open Call for PAAP Membership

- <https://www.ukri.org/who-we-are/work-for-us/join-an-advisory-committee-panel-or-network/stfc-particle-astrophysics-advisory-panel-member-vacancies/>
- Closing date: 18 May 2025
- applications from across particle astrophysics, and in particular from individuals with expertise in the areas of:
  - dark matter
  - gravitational waves
  - high energy astrophysics
  - theory and neutrino physics



# PAAP Activities 2024-25

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- In-person meeting in June 2024 in London
- Community survey to prepare the inputs to PPAN Roadmap
- Presentation to the Science Board PPAN in September 2024
- PAAP Roadmap update
  - Timeline updated
  - Format of next input to SB PPAN Roadmap?



# Current Status of UK Particle Astrophysics

Over 400 people in 54 institutes

- 144 academics
- Large communities: Dark Matter, Gravitational Waves, CMB Cosmology

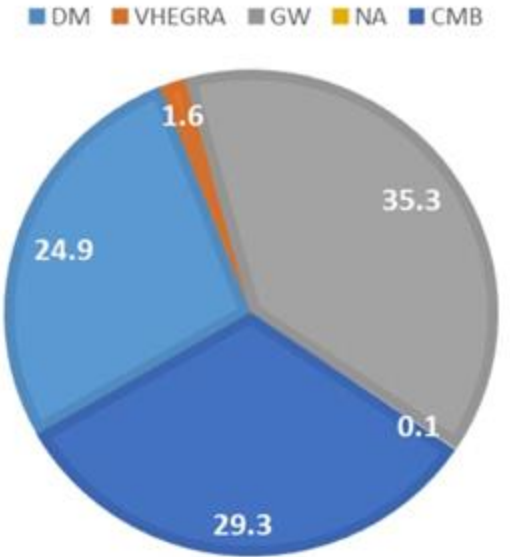
Significant growth in key areas in the last decade

- Gravitational Waves ~3x, Dark Matter ~2x

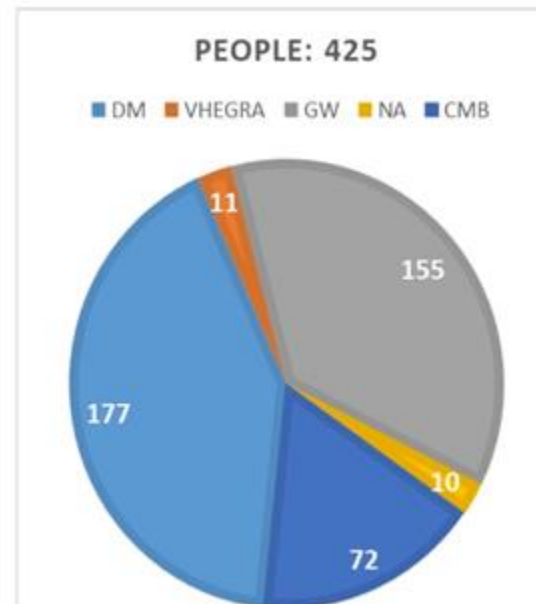
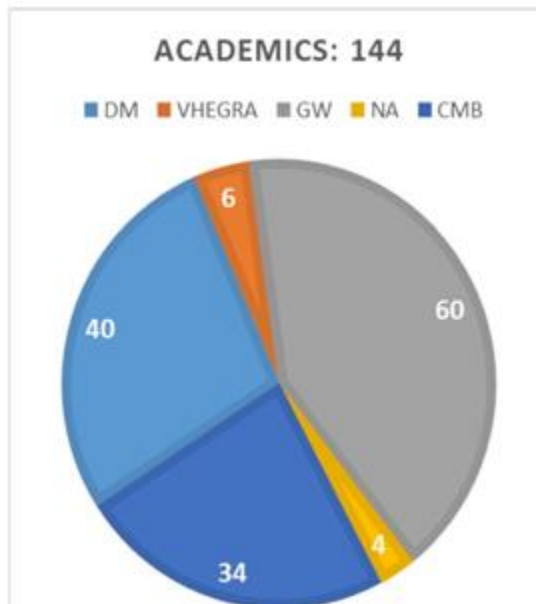
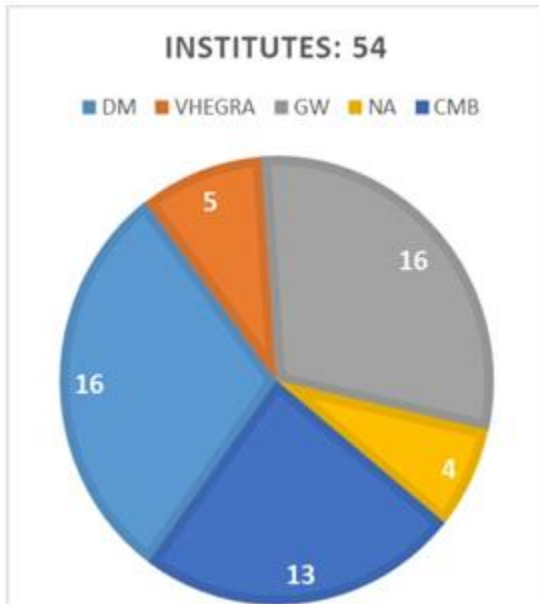
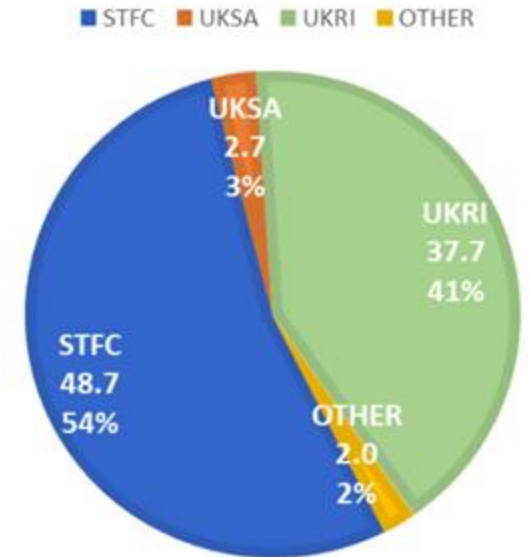
Total funding over ~5 years: £91M

Major funding from UKRI Infrastructure Fund: GW, Simons, XLZD

SUBJECT AREA: £91M



FUNDING SOURCE: £91M



Thanks to Henrique Araújo for collating the information

# PAAP 2022

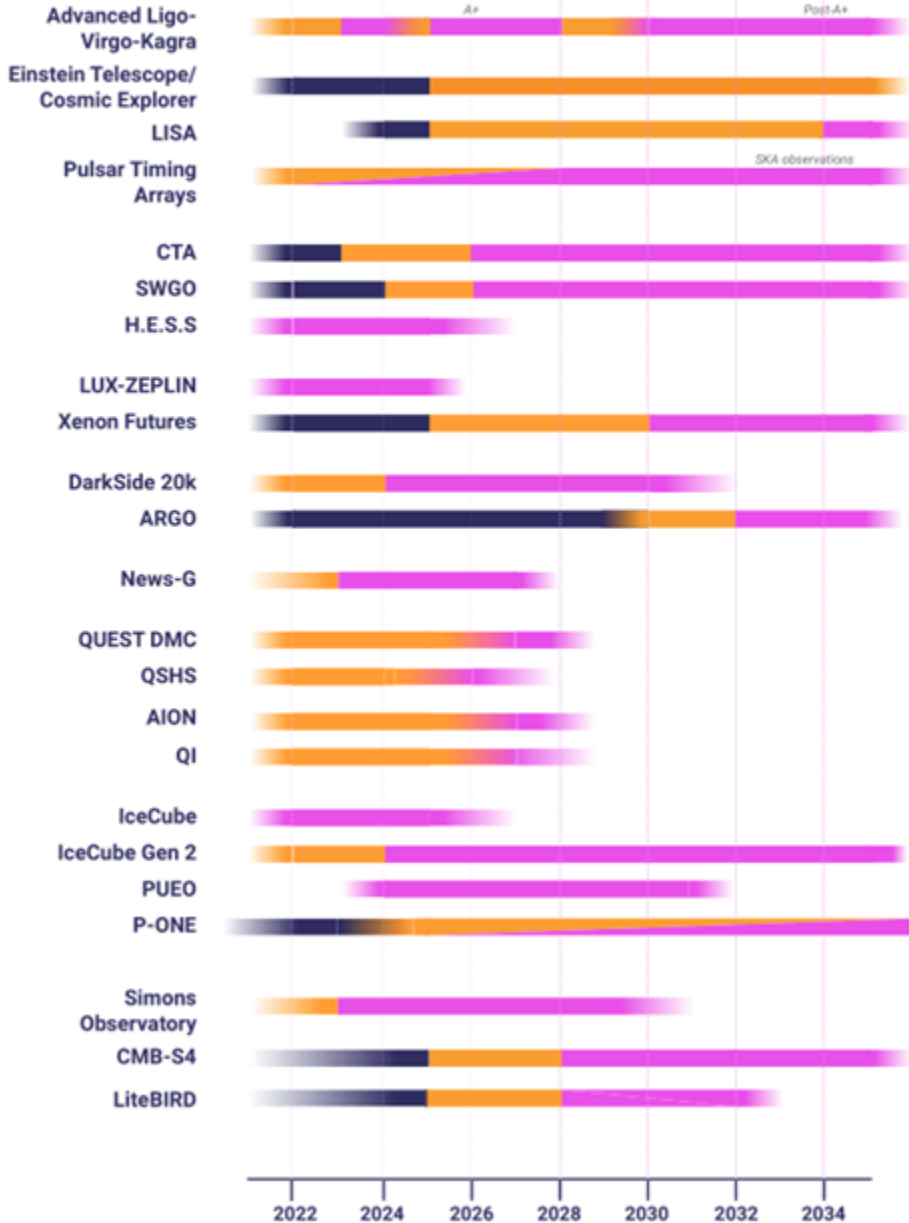
## Gravitational Waves

## VHE Gamma

## Dark Matter

## Neutrinos

## CMB



# Timeline update



# PAAP 2025

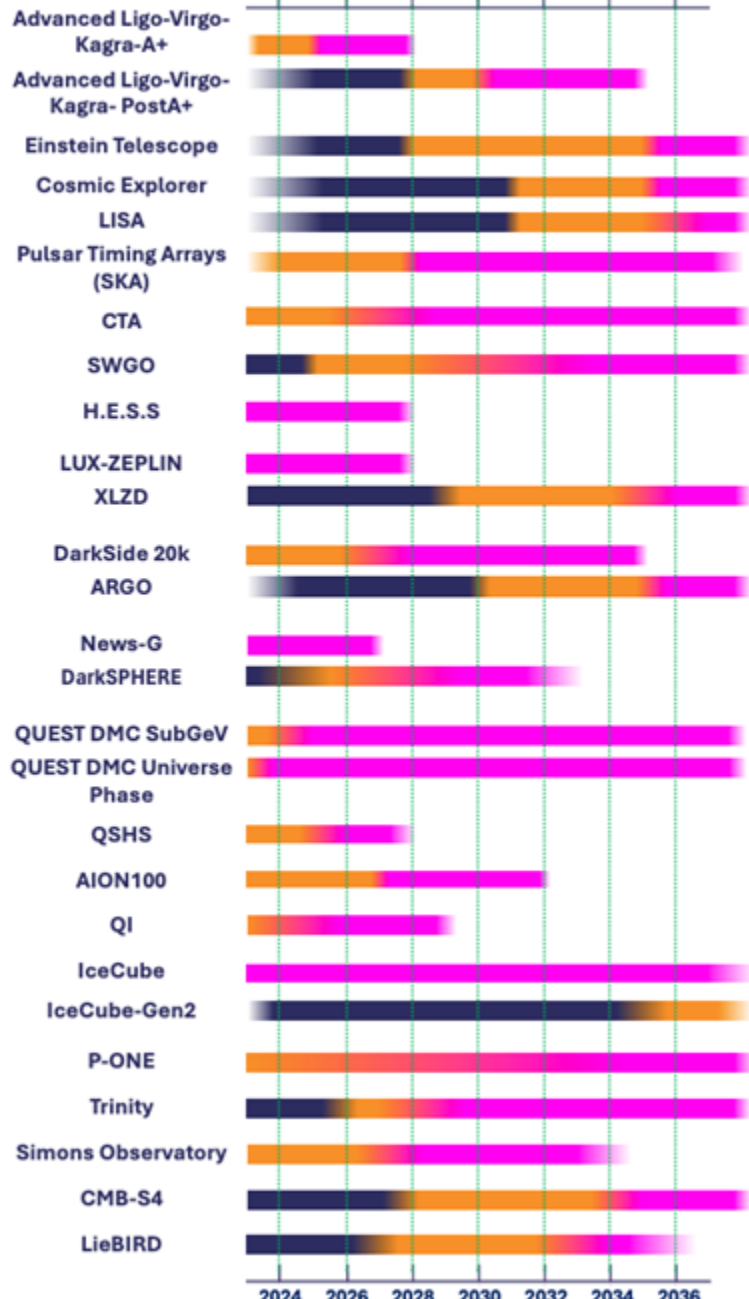
## Gravitational Waves

## VHE Gamma

## Dark Matter

## Neutrinos

## CMB



# Subject Areas

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# Gravitational Waves

## Main projects

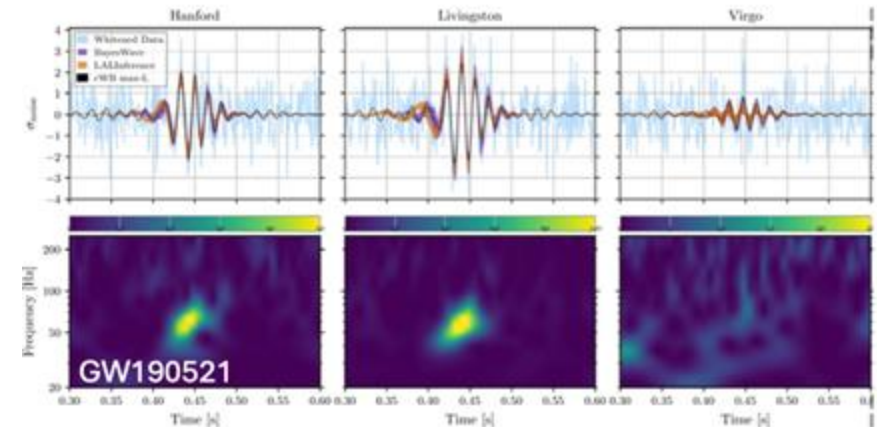
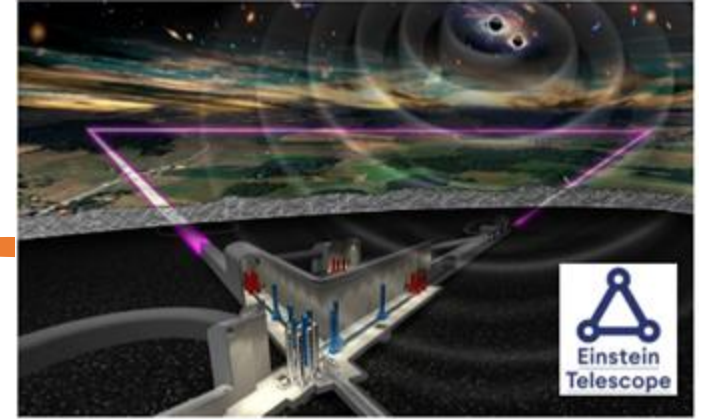
- aLIGO, aLIGO-Virgo-KAGRA (LVK) network → Advanced LIGO plus (A+)
- LISA Pathfinder → LISA (ESA “L-mission”) approved by UKSA
- Pulsar Timing Arrays

## Key results

- aLIGO: UK leadership in operation, upgrade & exploitation
- The European Pulsar Timing Array had its second data released, and announced evidence for discovery of a gravitational wave background based on its analysis
- Leading contributions to GW science
  - Most up-to-date LVK catalogue of GW observations (GWTC-3)
  - First clear discoveries of neutron star – black hole binaries (GW200105, GW200115)
  - First confirmed observation of an intermediate-mass black hole (GW190521)

## Future Projects

- Next-generation observatories to realise transformative potential of GW astronomy:
  - Einstein Telescope & Cosmic Explorer: the UK is uniquely well-placed to contribute to both
- Next-Gen GW project



# Gamma-Ray Astronomy

## Main Projects

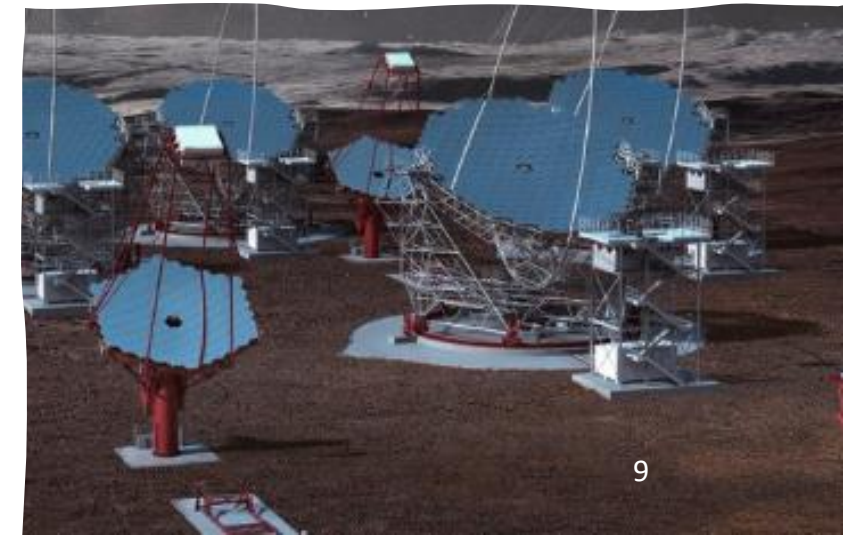
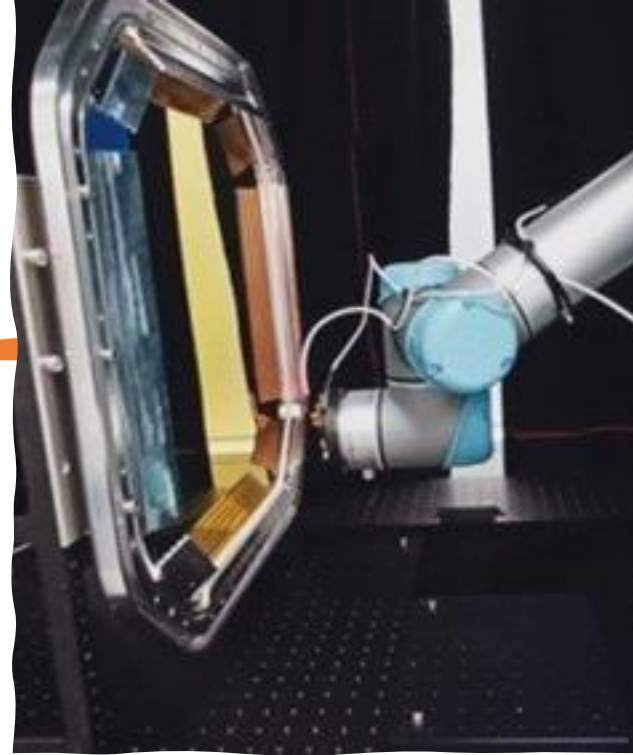
- HESS, (MAGIC, VERITAS) → CTA design and construction (camera for Small-Sized Telescopes @CTA-South)
- Limited involvement in Southern Wide-field Gamma-ray Observatory (SWGGO)
- Science exploitation of Fermi and HESS funded mostly from non-STFC sources

## Key results

- Successful production/deployment of the first fully-operational camera for SSTs (Sicily, 2019)

## Future Projects

- **CTA** is the priority for the UK community



# Neutrino Astronomy

## Main Projects

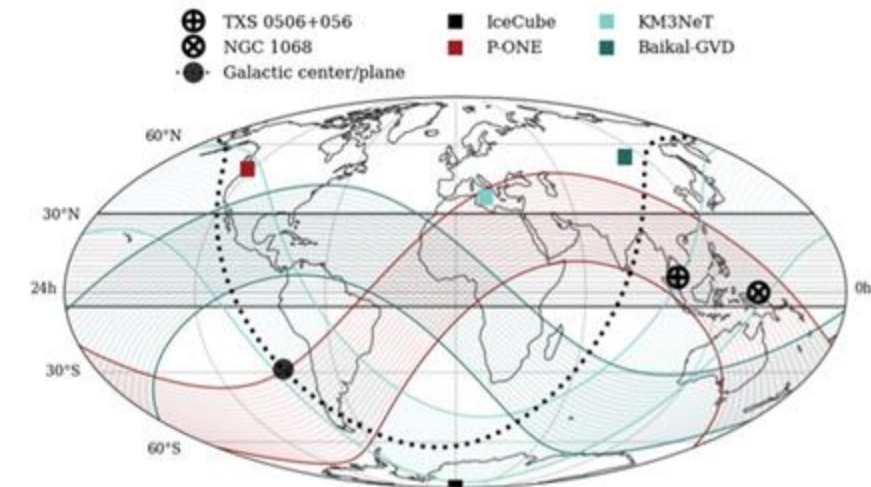
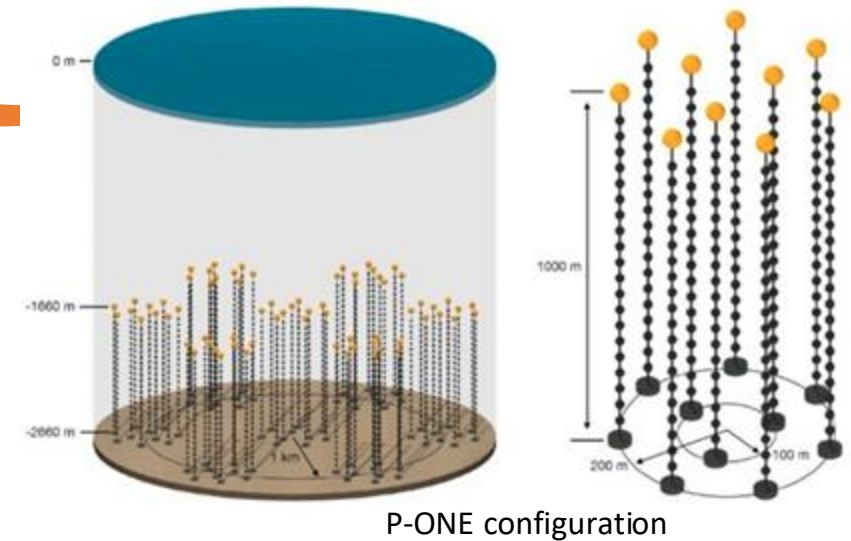
- IceCube/IceCube-Gen2, ANITA/PUEO, P-ONE, KM3NeT, Trinity – small involvements, mostly non-STFC funded
- UK High-Energy Neutrino (UHEN) consortium is working towards consolidating the UK effort to achieve critical mass in one project

## Key results

- Neutrinos are only high-energy particles to explore the deep universe
- Various observations:
  - IceCube: New high-energy neutrino sources, TXS0506+056 (blazar), NGC1068 (radio galaxy), Milky Way galactic plane
  - KM3NeT: The highest energy neutrino detected ( $\sim 220$  PeV)

## Future Projects

- Consolidation of the UK community is in progress around P-ONE (Canada)
- **Neutrino Astronomy is an important part of development of multi-messenger astronomy in the UK**



# Direct Dark Matter (Particle-like) Searches

## Main Projects

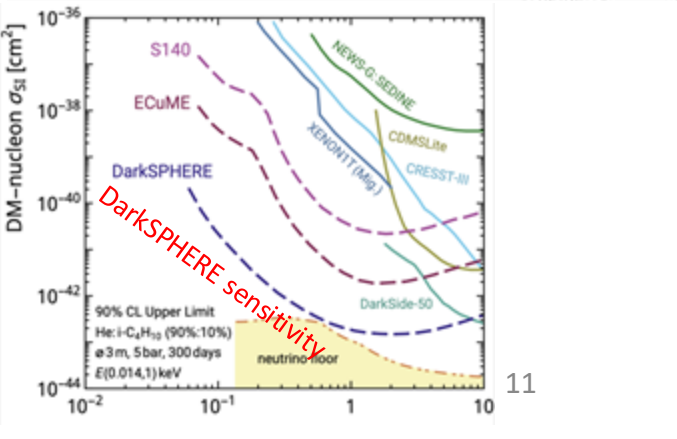
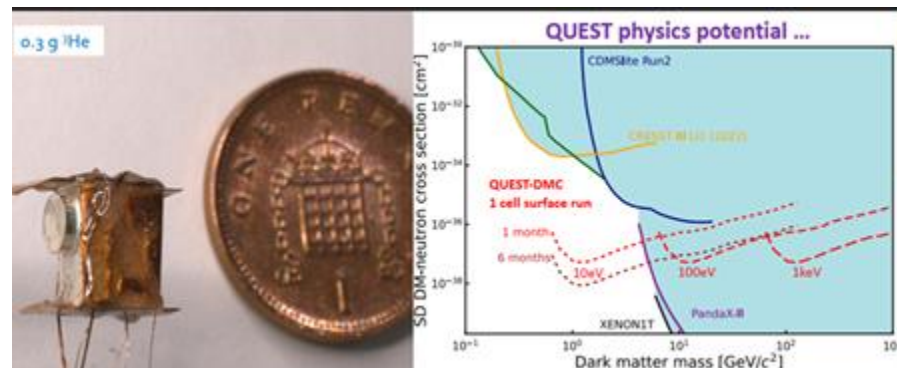
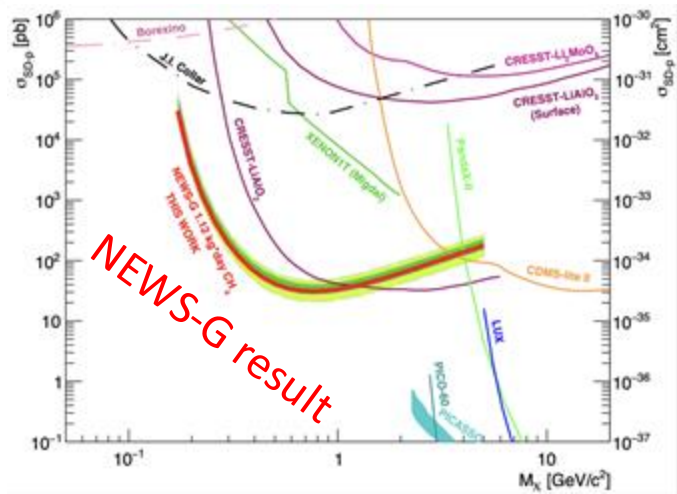
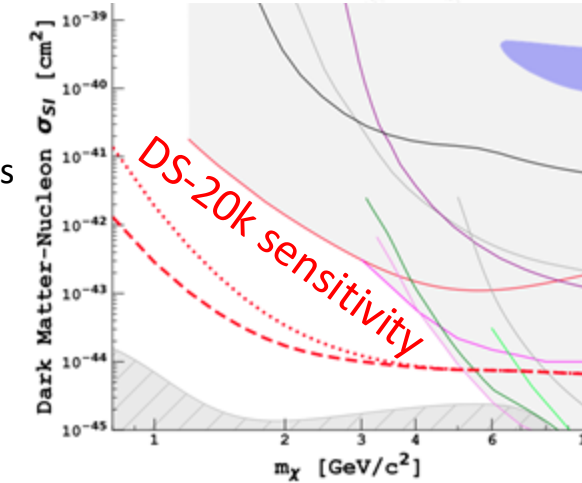
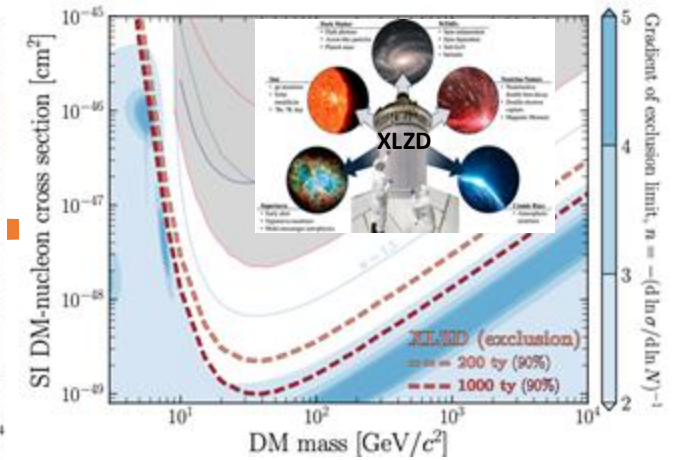
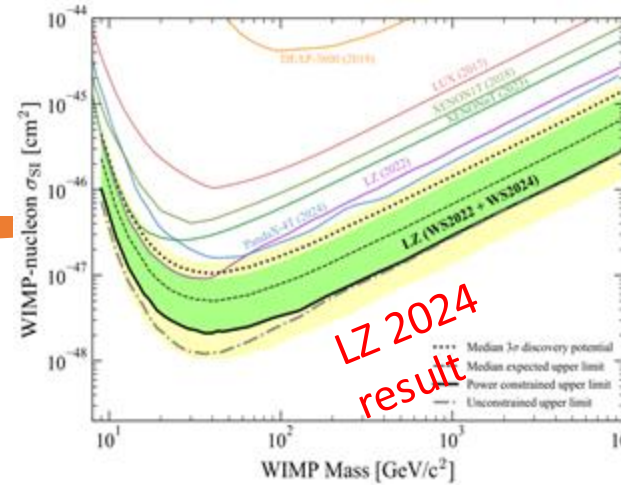
- LXe programme: ZEPLIN @Boulby → LUX @SURF → LUX-ZEPLIN (LZ) @SURF
- LAr programme: DEAP-3600 @SNOLAB → DarkSide-50, DarkSide-20k @LNGS
- Gas detectors: NEWS-G @SNOLAB; MIGDAL @RAL
- QUEST-DMC – superfluid  $^3\text{He}$  particle-like dark matter detector, nanowire readout.

## Key results

- LZ leads search for both spin-independent and spin-dependent interactions above 10 GeV
- DarkSide-50 leads on SI interactions in low-mass region  $\sim 1\text{-}3$  GeV
- NEWS-G leads on SD (proton) interactions in 0.2-1 GeV

## Future Projects

- **Major new underground facility at Boulby** is the paradigm-shifting opportunity
- **XENON+LUX+ZEPLIN+DARWIN = XLZD**: Rare Event Observatory for DM &  $\nu$  physics
  - Xenon Futures (R&D) → XLZD@Boulby (UKRI IF)
- Further opportunity for mid-class projects under review
  - SOLAIRE – LArTPC with Silicon photosensors
  - DarkSPHERE – Next-generation NEWS-G
  - QUEST-DMC – QTFP project



# Direct Dark Matter (Wave-like) Searches

## Main Projects

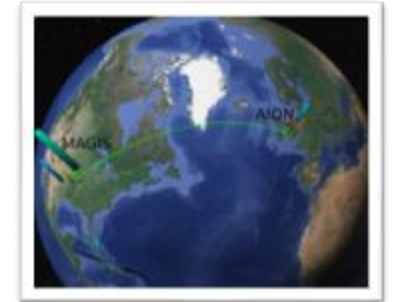
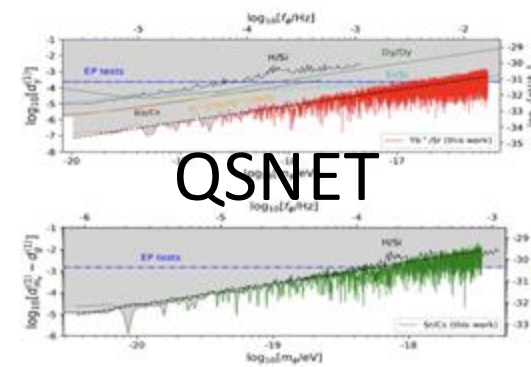
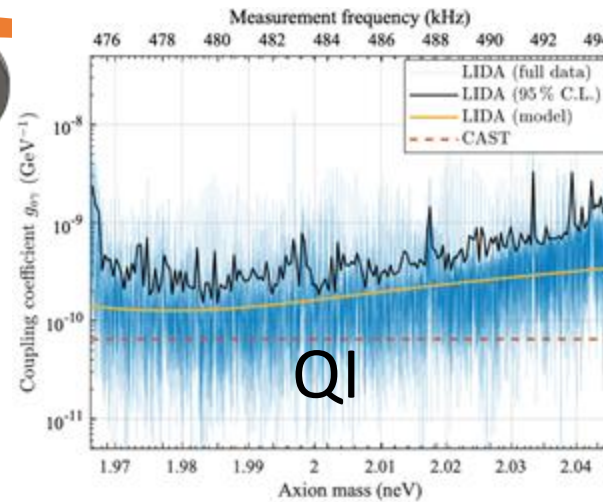
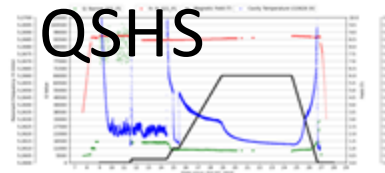
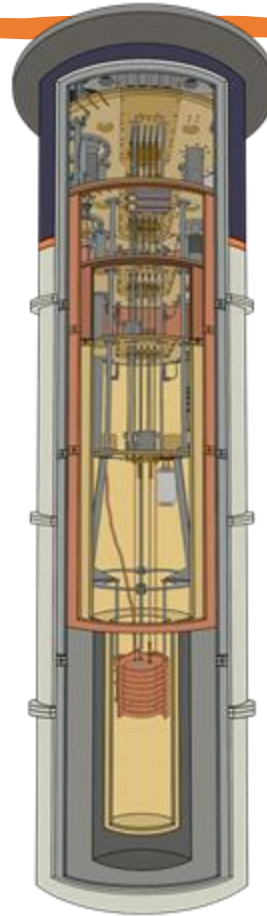
- **QSHS** – ultra-low-noise search for **QCD axion / wave-like dark matter**.
  - **First axion search using QSHS will happen in 2025!**
- **AION** – atom beam interferometry for **ultra-light axion / mid band gravitational waves**.
- **QI** – precision optical and squeezed light interferometry for **ultra-light halo or produced axions/ALPS**, probes of semiclassical gravity and quantum gravity.
- **QSNET** - a network of clocks for measuring the stability of fundamental constants. Comparison between two clocks → constraints on **ultralight dark matter**.

## Key results

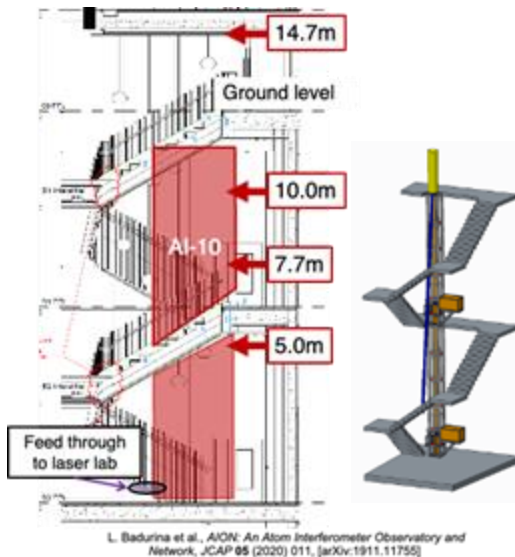
- An important demonstration of the feasibility of sensor technologies at or around the quantum limit in sensitivity and allowing to probe phenomena that do not produce high energy by-products detectable in conventional general purpose particle detectors.
- Part of the Quantum Technologies for Fundamental Physics initiative
- **The QTFP community grew significantly since the initial funding and became an important part of the UK scientific landscape.**

## Future Projects

- As part of the Quantum Technologies for Fundamental Physics initiative these projects depend on future funding of this initiative.
- **To benefit from the initial investment, STFC/RCUK should provide sustained support, and encourage further cross-linking between EPSRC and STFC funded groups that share common interests.**
- **It is essential to identify sources for its continuous funding and support within the STFC core program.**



AION



**ADMX Niobium Tin coated niobium tuning rod superconducting in a 6T magnetic field!**

# Cosmic Microwave Background

## Main Projects

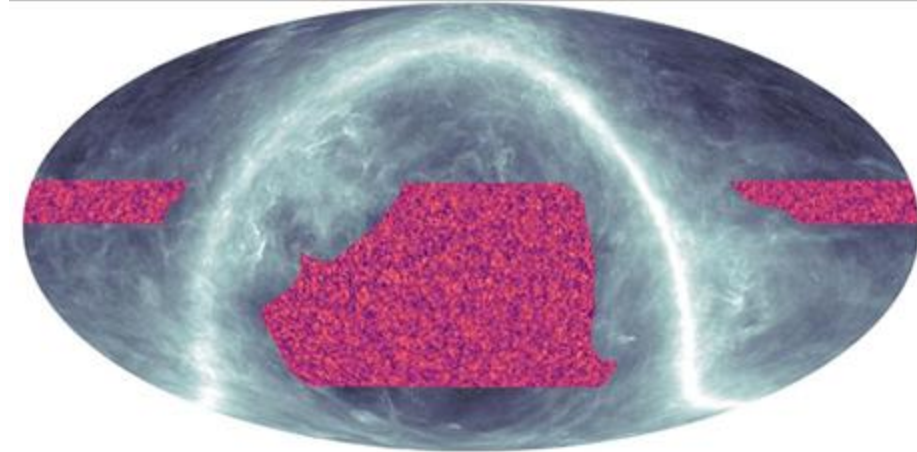
- Significant UK involvement has been funded by UKRI Infrastructure Fund into the Simons Observatory
  - Two small-aperture telescopes (SATs) in 2026
- New involvement in Japanese-led LiteBIRD satellite (inflationary GW), initial funding from the UKSA
- Atacama Cosmology Telescope (ACT)

## Key results

- The analyses of CMB power spectrum and lensing spectrum with Planck and AdvACT
  - Precise tests of  $\Lambda$ -CDM and inflation
  - Neutrino masses and  $N_{\text{eff}}$  / number of light relics
  - Recently: UK co-led ACT power spectrum and lensing analysis
  - Simons Observatory
    - Two SATs and LAT are taking data
    - 3<sup>rd</sup> SAT is due soon

## Future Projects

- LiteBIRD: uncertainty due to withdrawal of KEK
- CMB-S4: uncertainty due to issues with NSF polar operations



ACT lensing map

# Theory

## Large and prominent community in astroparticle theory

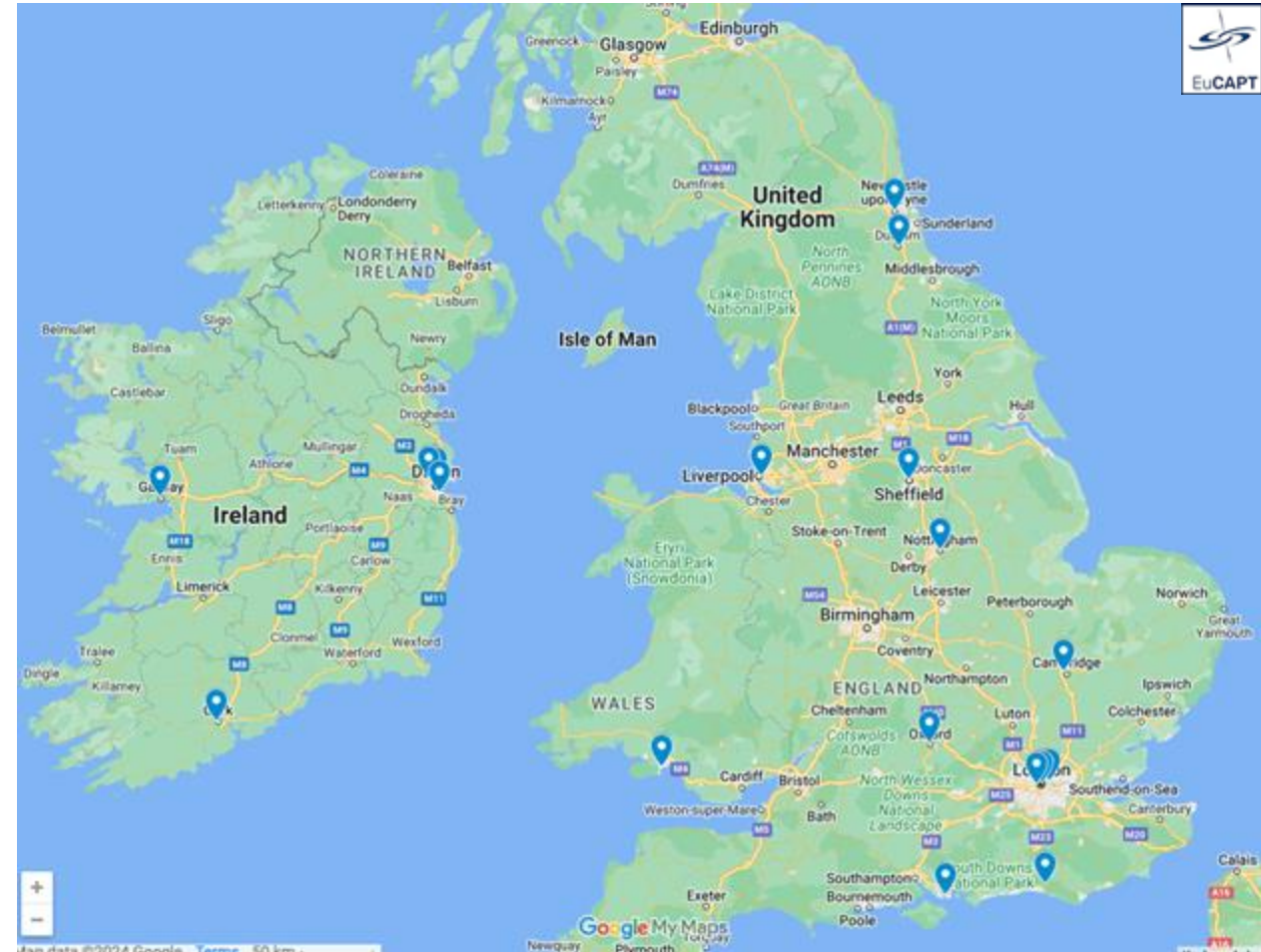
- 16 UK institutes in European Consortium for Astroparticle Theory (EuCAPT)
- Areas: Particle phenomenology and cosmology, cosmic-rays, neutrinos, gravitational waves, general relativity

## Key results

- Major UK involvement at leadership level to EuCAPT
- New theoretical effort in the QTFP programme
  - E.g., DM, GW

## Future Projects

- A strong theory community and links with experiments are essential for success of the UK experimental programme

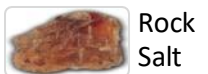


## STFC Boulby Laboratory Development

The UK's deep underground science facility operating in a working polyhalite & salt mine in NE England

Current facilities are almost full and new projects (inc possible next gen DM projects) now seeking space for operation.

**2 stage facility expansion proposed.** Excavation for Stage 1 expansion (5 x size of current lab) now underway.



Rock Salt



Polyhalite



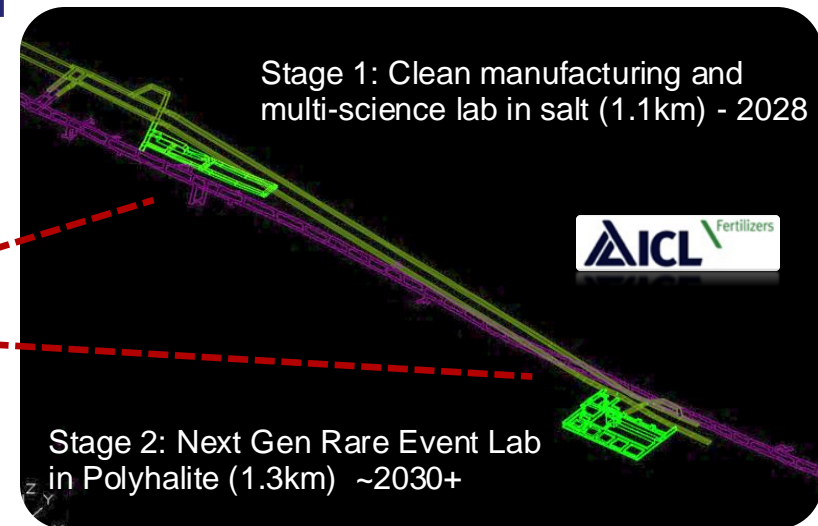
Current Boulby Facility



Factor  $\sim 10^6$  reduction in cosmic ray flux vs. surface



Current multidisciplinary deep underground science facility



Excavation for stage 1 expansion underway

A **QUIET** place in the Universe

# Summary

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- Significant growth of UK Particle Astrophysics community
- Updated timeline for PAAP projects
- Significant progress and many highlights in PAAP subject areas and related infrastructure
- Uncertainties and lack of funding start affecting projects

# BRIGHT FUTURE OF HUMANITY

