STFC's Particle Astrophysics Programme

Patrick Sutton
Cardiff University

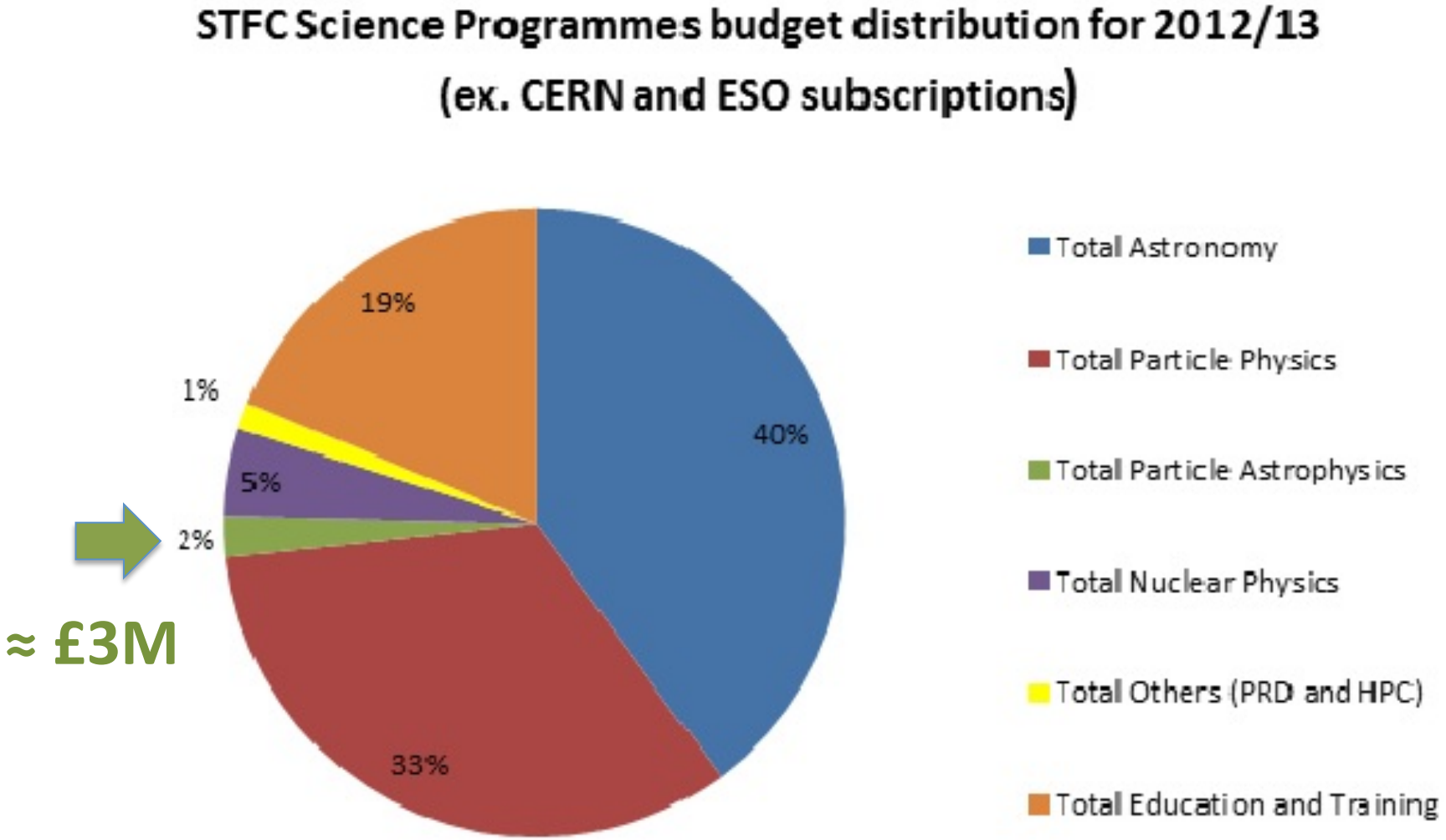
On behalf of the PAAP:
Chamkaur Ghag, Anne Green, Ruth Gregory, Julian Osborne, PS, Lee Thompson

http://www.stfc.ac.uk/2414.aspx

Science Areas

- Particle astrophysics = Astroparticle physics
- **Dark Matter**, **Gamma-ray Astronomy, Gravitational Waves**, cosmic rays, neutrinos & neutrino astronomy, non-astrophysical tests of gravity.
  - Also strong interest in computing, technology development.
  - Much overlap with Astronomy & Particle Physics

Funding c. 2012-13



≈ £3M

Part. Astro. Science Questions

- Multi-messenger Astronomy
  - What is the nature of compact objects?
  - What is the physics behind supernovae and gamma-ray bursts?
  - What are the origins of ultra-relativistic cosmic particles?
  - What role do ultra-relativistic particles play in astrophysical environments?

- Fundamental Physics with Cosmic Messengers
  - What is the nature of Dark Matter?
  - What is the nature of Dark Energy?
  - Does relativity break down under extreme conditions?
  - What are the properties of neutrinos?
  - Are there particles present in the universe which have not yet been detected either directly or indirectly?

Current UK PA Programme

Core PA activity with current STFC support

- Gravitational Wave Astronomy
  - **Adv LIGO, GEO 600**, LISA Pathfinder, ET, eLISA
- Direct Dark Matter Detection
  - Directional detection, **R&D for tonne-scale detectors**: LUX, DMTPC (directional), DEAP, LUX-ZEPLIN (proposal)
- Neutrino Astronomy
  - *(SN neutrino: SNO+, SuperNEMO, LAGUNA (R&D))*
  - VHE, UHE: ANITA, KM3Net, IceCube
- Gamma-ray Astronomy
  - HESS (+Fermi exploitation), **CTA Prototyping**
- Cosmic Rays
- Non-GW probes of Gravity
  - Inverse Square Law, STE-QUEST (ESA M4 candidate)

Programmatic Review Outcome

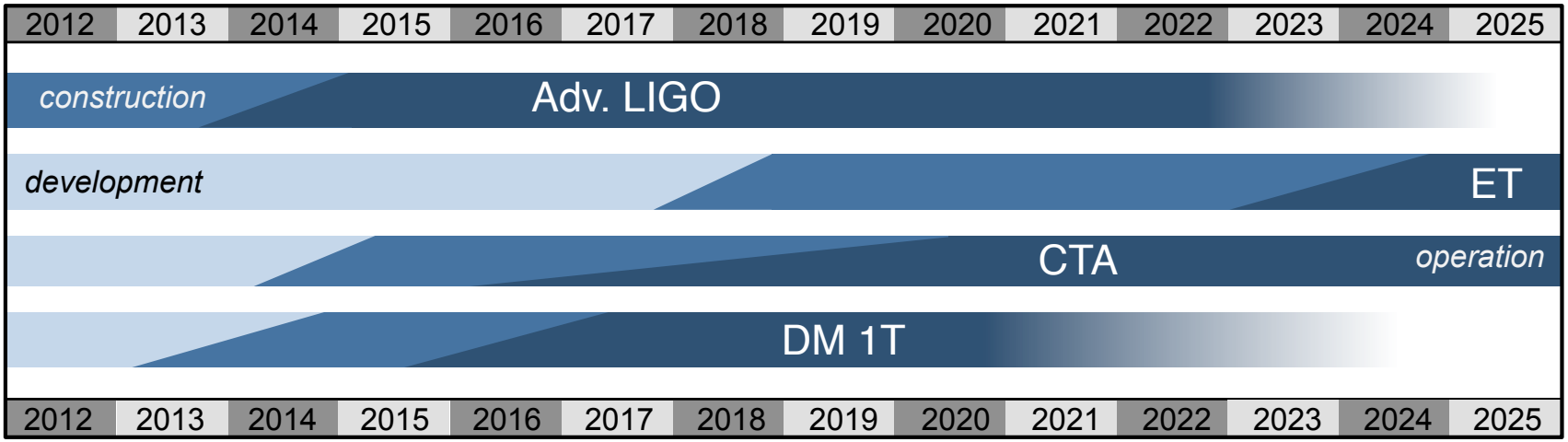
1. • Advanced LIGO

2. • CTA
   • 1T-scale DM detector
   • Einstein Telescope

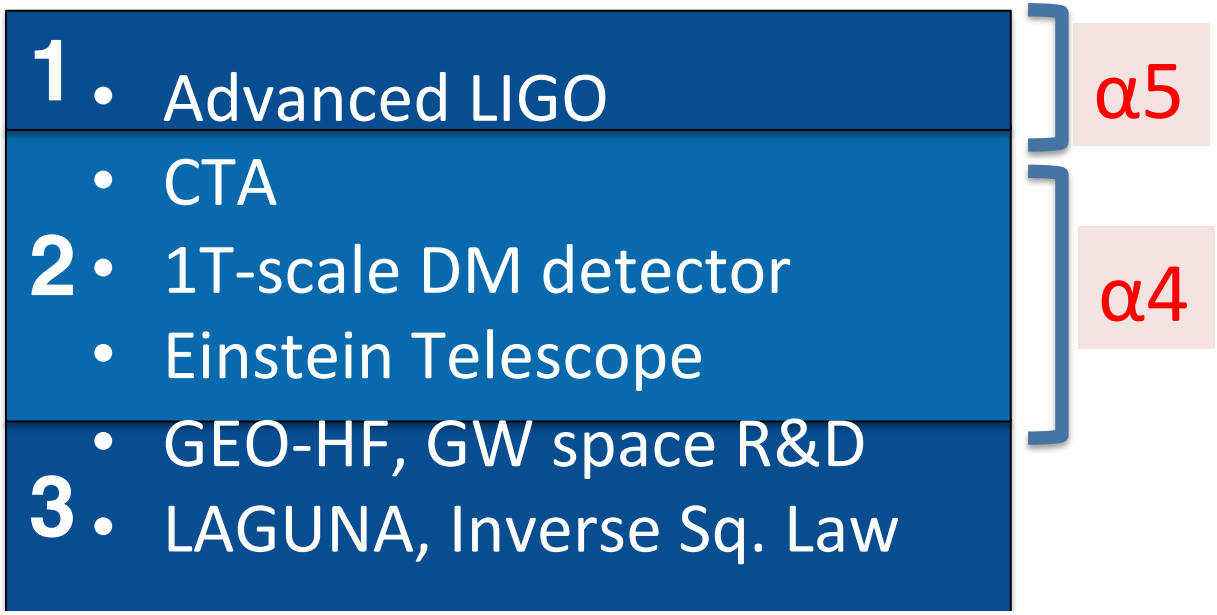
3. • GEO-HF, GW space R&D
   • LAGUNA, Inverse Sq. Law

α5

α4



Programmatic Review Outcome

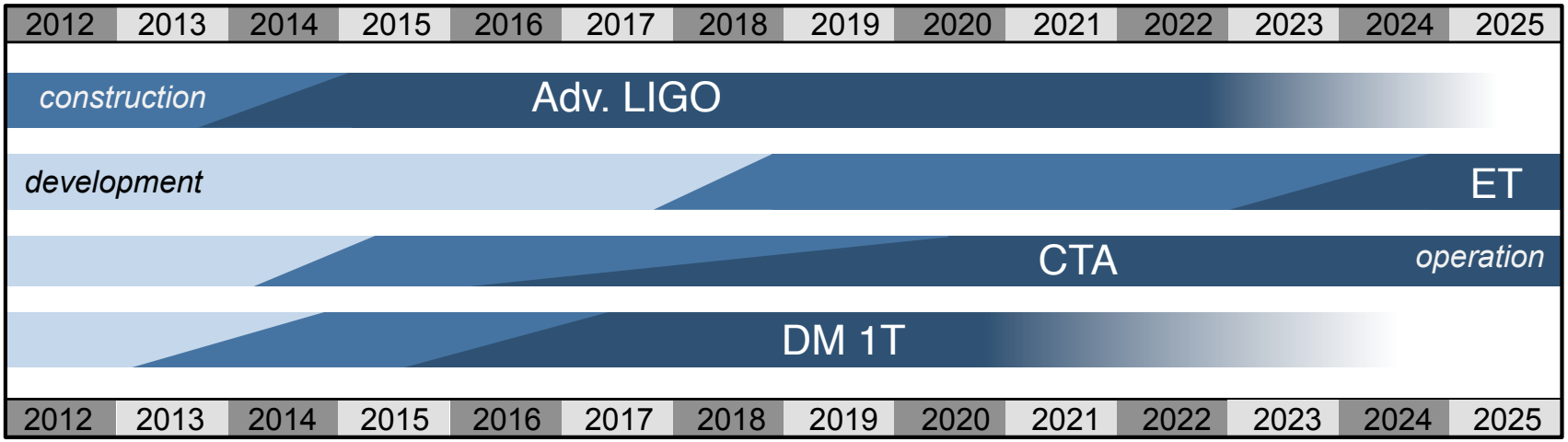


R15 - We recommend that maintaining involvement in gravitational wave, dark matter, and high energy gamma ray experiments be a priority for the sake of the diversity of the UK programme.

Programmatic Review Outcome

1. Advanced LIGO
2. CTA
   - 1T-scale DM detector
   - Einstein Telescope
3. GEO-HF, GW space R&D
   - LAGUNA, Inverse Sq. Law

focus on these three



Direct Dark Matter Searches

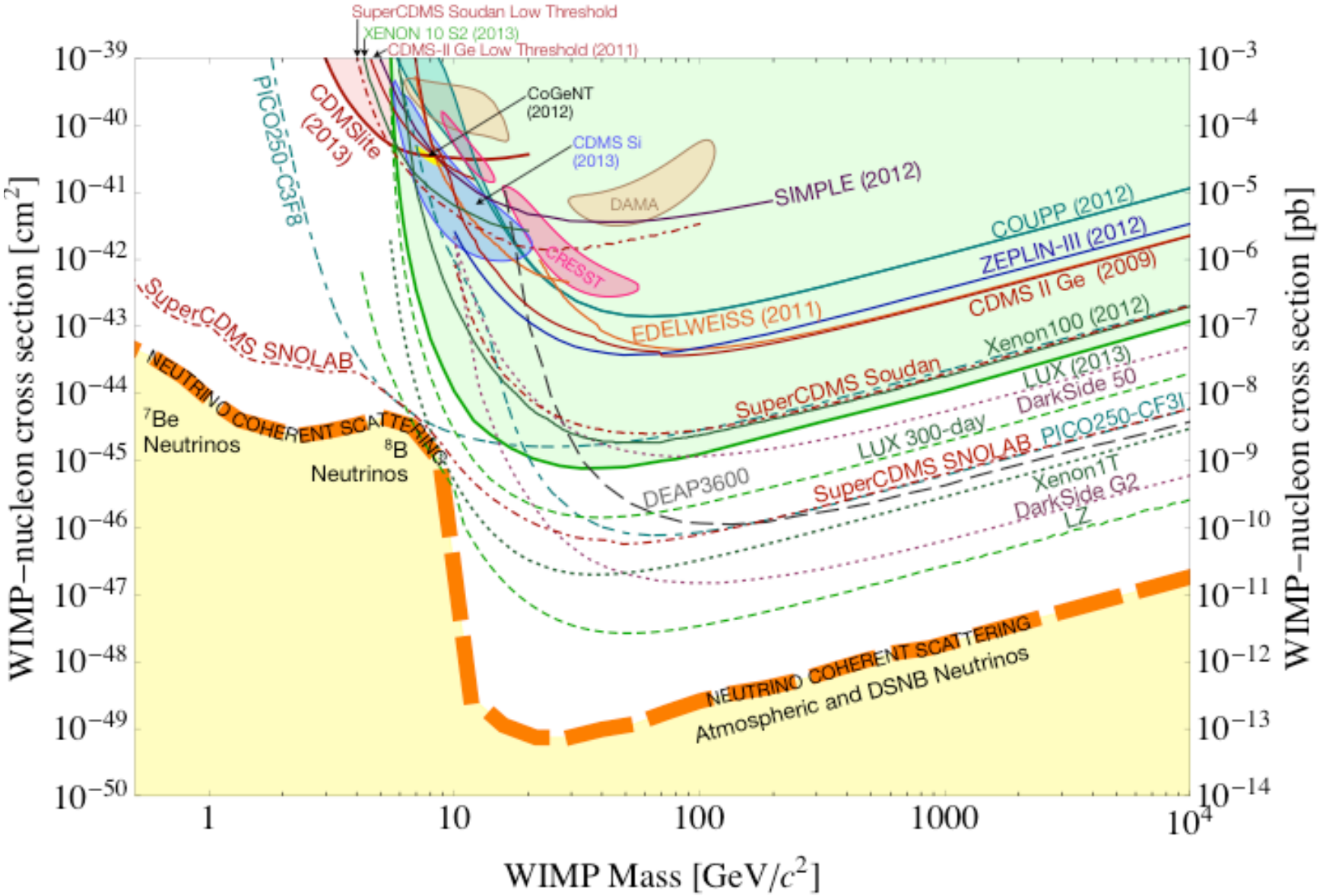
- Strongly endorsed in recent US P5 report.
  - **"R19: Proceed immediately with a broad second generation (G2) dark matter direct detection program ..."**
  - http://science.energy.gov/~/media/hep/hepap/pdf/May 2014/P5MayHEPAP-Ritz.pdf
- Strong endorsement in STFC's Programmatic Review.

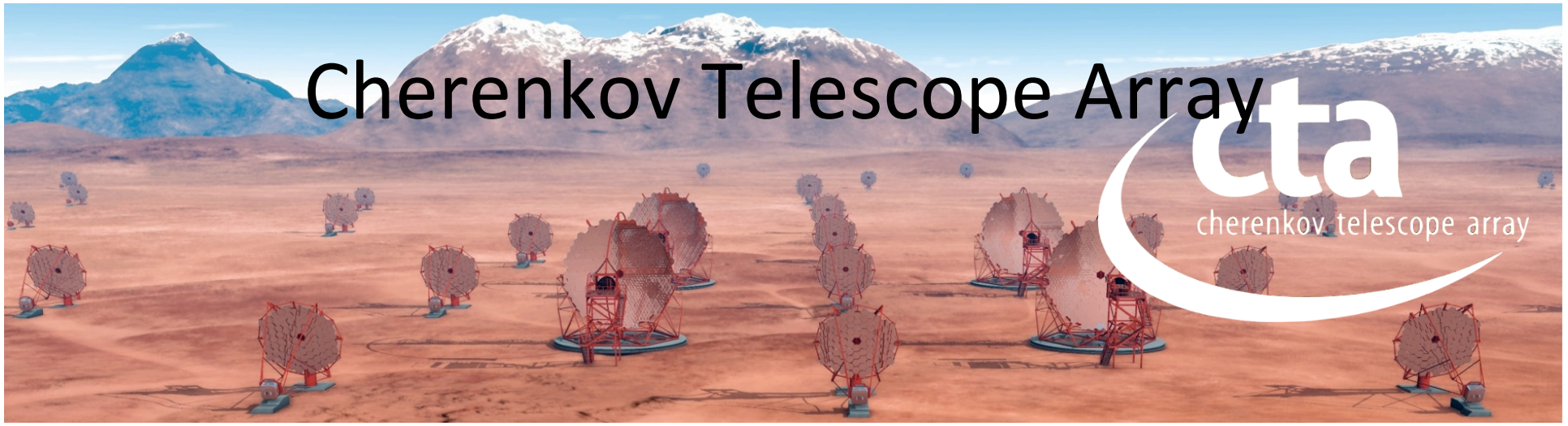
- **UK focus on LUX-ZEPLIN:** strong participation with significant UK leadership roles and track record in pioneering world-leading technology.
  - UK Participants: Daresbury, Edinburgh, Imperial, Liverpool, Oxford, RAL, Sheffield, UCL
  - Total Cost: $70M
  - STFC support for R&D, proposal for LZ participation under review (~£6M).

UK Dark Matter Base

- **Boulby:** important UK infrastructure to underpin dark matter searches.
  - Material screening at world-class sensitivity levels.
  - Training ground for our grad students and post-docs.
  - Hosting dark matter work in the UK funded by international partners.
  - Vital infrastructure for direct DM searches and any other experiments requiring ultra-low background radioactivity.

Dark Matter Landscape





- **27 nation effort (1000+ scientists)** to build a global observatory for the highest energy photons (20 GeV – 300 TeV)
  - 120 Cherenkov telescopes of three types on two sites
    - LST/MST/SST (23/12/4 m diameter)
  - Up to 1' resolution, 7 degree FOV, several km^2 collection area.
  - Explore cosmic particle acceleration, probe extreme environments, search for dark matter, axions, Lorentz invariance violations, …
- **Status**
  - Preparatory phase, Construction 2015-2020
  - ≈£185M price tag; STFC support for R&D

UK Role in CTA

- 10 UK institutes, current STFC funded grouping:
  - Durham, Leicester, Liverpool, Oxford
- Current UK Roles:
  - Project Scientist
  - Leader of SST (small-size telescope) sub-project, a system of 70 x 4 m telescopes
  - Lead in mirror test facilities and outreach
  - Leadership of CHEC prototype camera

Advanced LIGO

- Status
  - Fully funded, with STFC support.
  - Two 4 km interferometers for direct detection of gravitational waves
  - Under construction in the US, first science ops. 2015.
  - First detections likely c. 2016-18.
    - rate of detected compact binary coalescences 0.4-400 yr^{-1}

UK Role in Advanced LIGO

- Institutions
  - Birmingham, Cambridge, Cardiff, Glasgow, RAL, Sheffield, Southampton, Strathclyde, UWS
  - ~100 researchers
- UK roles & contributions
  - co-chair 2 of 4 search groups, several members of Executive Committee & other leadership roles.
  - development of low-noise suspension technology

PAAP Recent & Current Activities

- Input to government (BIS) consultation on capital investment 2015-2020:
  - LUX-ZEPLIN (Boulby upgrades, xenon purchase)
  - CTA (hardware construction, e.g SSTs)
  - Advanced LIGO upgrades (suspensions & optics for x3 sensitivity increase).

- Roadmap updates.

Other PA-related Activities

Long baseline neutrino experiments:

- covered by Paul Newman's talk

Neutrinoless double beta decay experiments

- covered by Paul Newman's talk

HE neutrino astonomy

- KM3NeT: UK contribution by Sheffield (calibration work package)
- IceCube: UK participation from Oxford (theory & interpretation)
- IceCube-PINGU: Manchester and QMUL.
- not currently STFC supported

Other PA-related Activities

Space-based GW detection

- Selected for ESA L3 mission (launch 2034)
- UK institutes: Glasgow, Birmingham, Imperial, Birmingham, Cardiff, Cambridge, Southampton (LISA Pathfinder flight hardware, data analysis techniques)
- UKSA support for LISA Pathfinder

Cosmic Rays

- past support of Auger, current LOFAR (Chilbolton station)

Summary & Comments

- Current highest priorities: GWs, DM, CTA.
  - Aligned with ApPEC priorities.
  - Major developments in all three fields expected over next few years.
- UK achieves very strong impact for modest overall funding level.
- Need expanded funding to maintain diversity of PA programme.