

# Report from astroparticle physics

Uli Katz, Univ. Erlangen-Nürnberg  
Chair, Committee for Astroparticle Physics (KAT)  
18 November 2022



## **KAT and astroparticle news**

## What happened recently

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- **APPEC Town Meeting in Berlin** (June 2022), mid-term update APPEC Roadmap
- **Deutsches Zentrum für Astrophysik**: Endorsed September 2022
- **KAT elections** (October 2022)
- **ErUM-Pro** for astroparticle physics and ground-based astronomy
  - Strategy talks with BMBF in May 2022 (new: common strategy document RDS+KAT)
  - Call for proposals mid-October 2022
  - Deadline 15 November 2022
  - New funding period 7/2023-6/2026
- Upcoming: **Wissenschaftsjahr 2023 „Universum“**



Wir haben es geschafft: Das Deutsche Zentrum für Astrophysik - Forschung. Technologie. Digitalisierung. (DZA) kommt in die sächsische Lausitz. Hier geht's zu der Pressemitteilung:

# Deutsches Zentrum für Astrophysik

<https://www.deutscheszentrumastrophysik.de/>

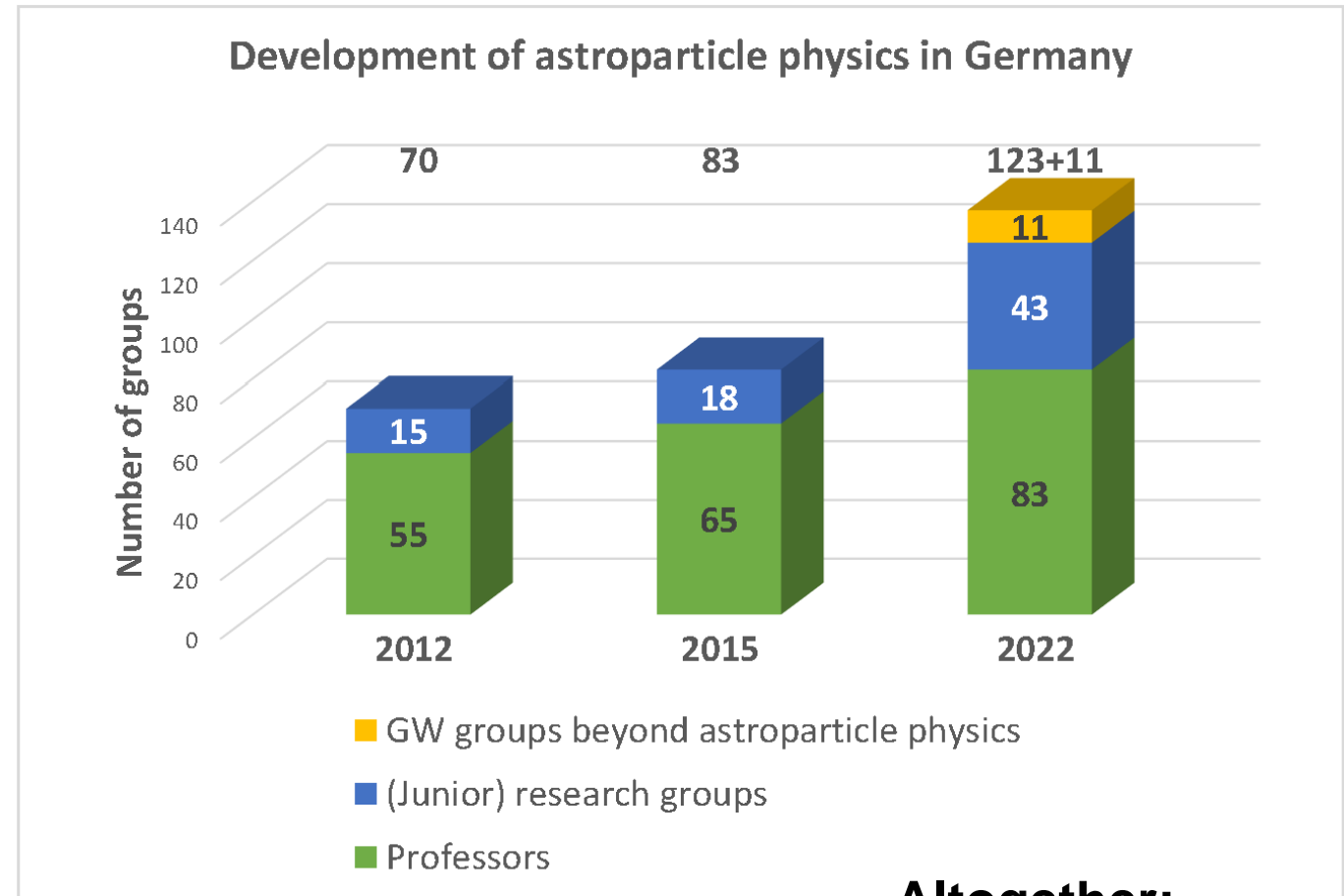


- New national research centre in Lusatia/Saxonia
- Objectives:
  - Astrophysics research (initial focus: Radio astronomy, gravitational waves)
  - Data and computing, green IT (e.g. for SKA data)
  - Technology centre (with low-seismic lab)
- Asymptotically 170 M€ / year
- Founding director: Günther Hasinger
- Opening of ~5 new professorships expected soon

Mission Zentrum Forschung & Transfer Netzwerk Aktuelles

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# Astroparticle physics in Germany



**Altogether:  
~670 scientists  
+ PhD, MSc, BSc  
students**



Thematic constituencies; newly elected members and deputies in **red**:

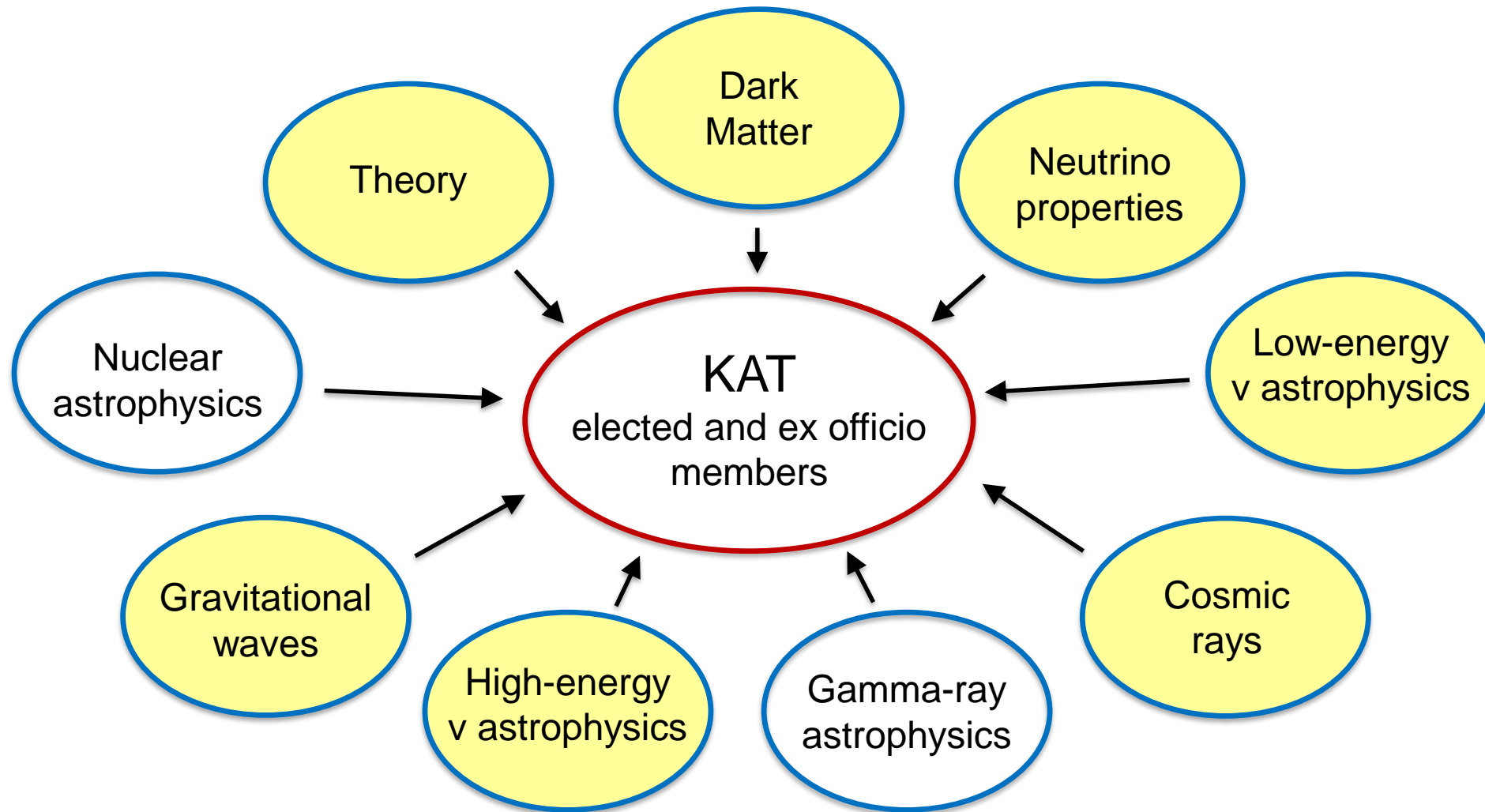
Constituency	Elected	Deputy
Dark Matter	Manfred Lindner → <b>Manfred Lindner</b>	Federica Petricca → <b>Federica Petricca</b>
Neutrino properties	Kathrin Valerius → <b>Kathrin Valerius</b>	Stefan Schönert → <b>Stefan Schönert</b>
Low-energy $\nu$ astrophysics	Achim Stahl → <b>Achim Stahl</b>	Michael Wurm → <b>Michael Wurm</b>
Cosmic rays	<b>Andreas Haungs (Dep.)</b> → <b>Markus Roth</b>	Martin Erdmann → <b>Michael Schmelling</b>
Gamma-ray astronomy	Stefan Funk → <b>Stefan Funk</b>	Jim Hinton → <b>David Berge</b>
High-energy $\nu$ astrophysics	<b>Uli Katz (Chair)</b> → <b>Uli Katz</b>	Elisa Resconi → <b>Marek Kowalski</b>
Nuclear astrophysics	Roland Diehl → <b>Uwe Oberlack</b>	Camilla Hanson → <b>Daniel Bemmerer</b>
Gravitational waves	Karsten Danzmann → <b>Michèle Heurs</b>	Harald Lück → <b>Harald Lück</b>
Theory	Thomas Schwetz-Mangold → <b>Walter Winter</b>	Martin Pohl → <b>Michael Klasen</b>

- Election of chair and deputy chair on 1 Dec 2022 (KAT strategy meeting, Bad Honnef)
- Ex officio members not changed
- KAT “ambassadors” to other committees to be named/confirmed soon.



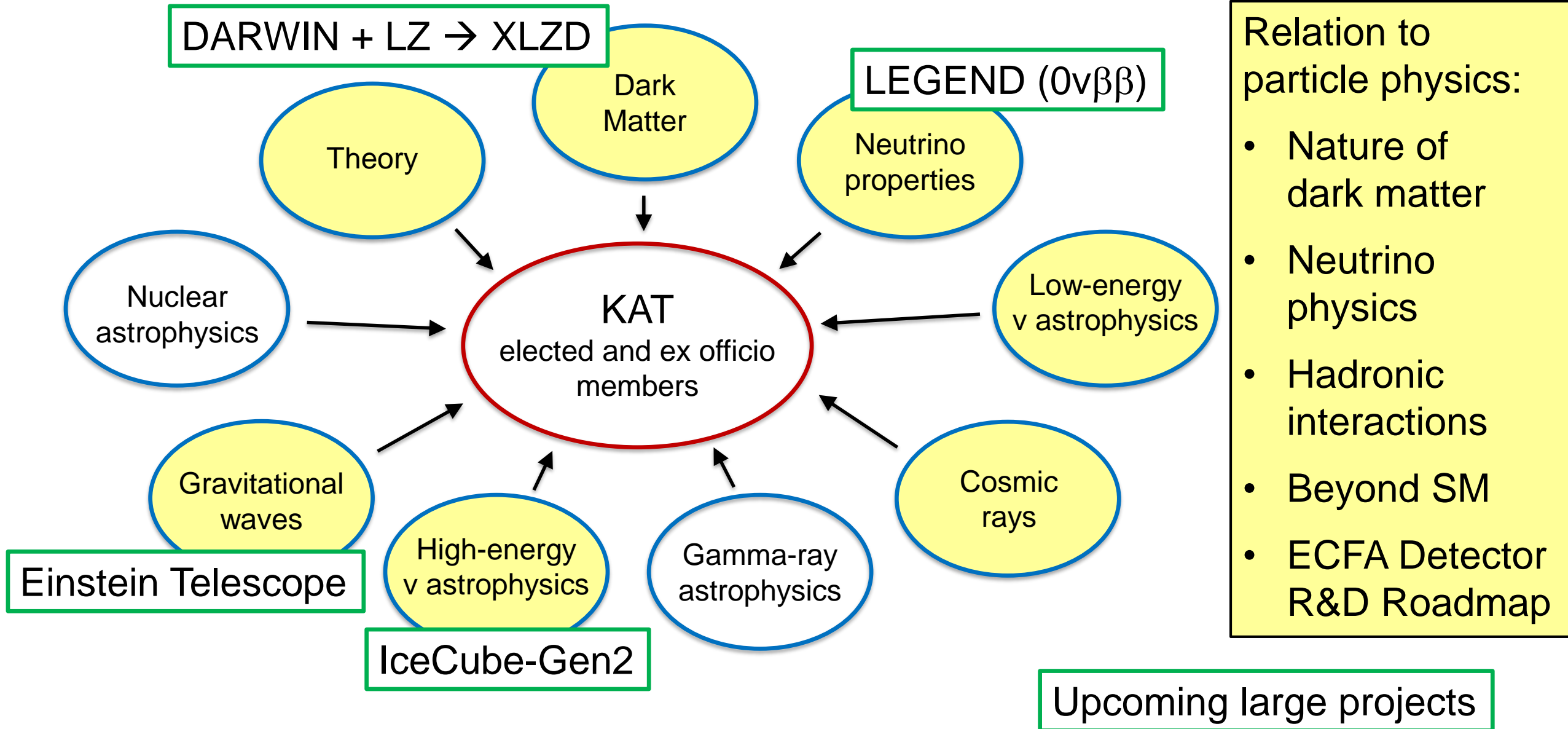
## **Some links between astroparticle and particle physics**





Relation to particle physics:

- Nature of dark matter
- Neutrino physics
- Hadronic interactions
- Beyond SM
- ECFA Detector R&D Roadmap



# Dark Matter

## Main projects

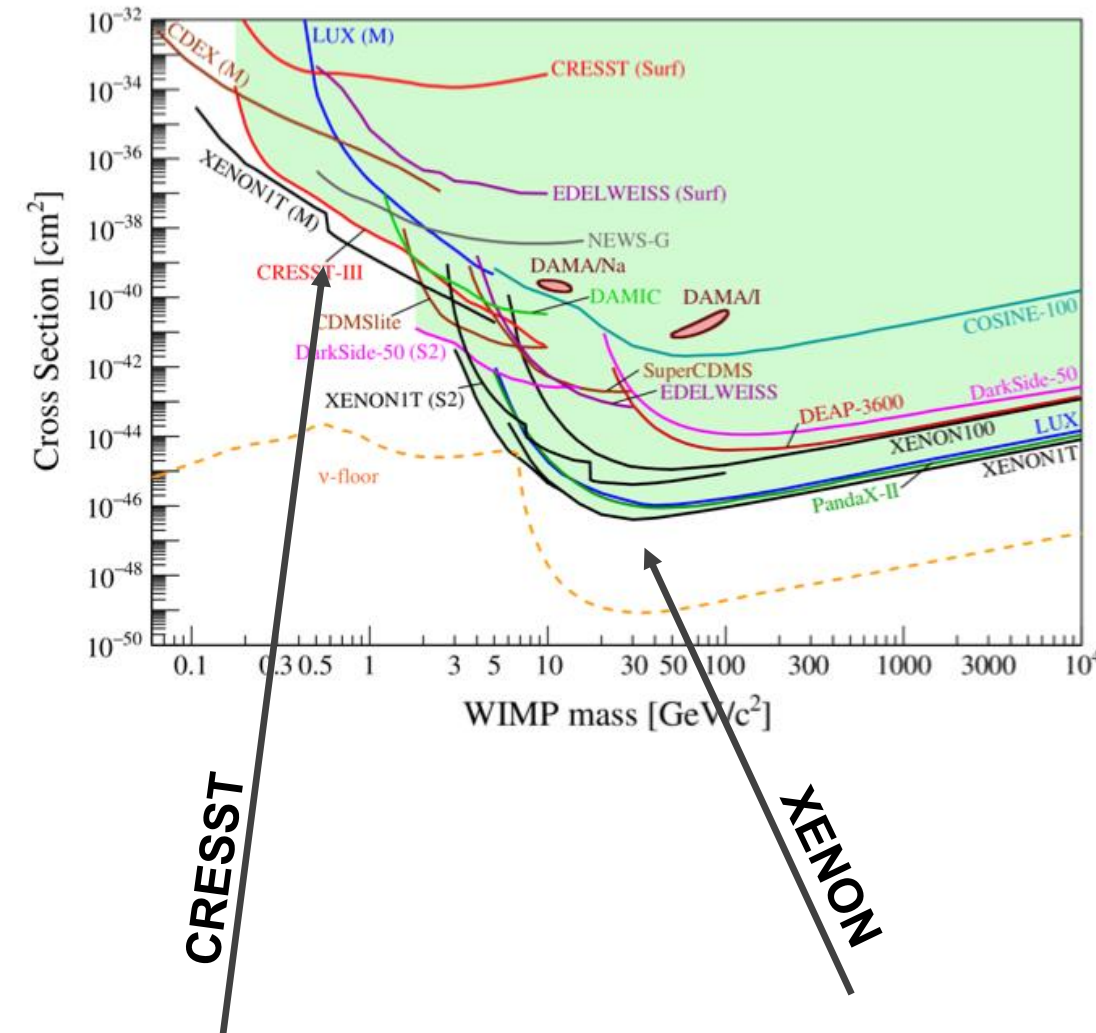
- **XENON** (XENON100 → XENON1T → XENONnT)
- **DARWIN** → **XLZD**
- **CRESST**

## Major results

- XENON1T
  - Leading limits: generic WIMPs, other searches
  - Interesting excess (ca.  $3\sigma$ ) at low recoil energy
- CRESST
  - Lowest thresholds for nuclear recoils
  - Leading sensitivity to low-mass dark matter

## Future plans

- DARWIN+LZ → **XLZD**
  - Operation of XENONnT, design of XLZD
  - First XLZD data ca. 2027
- Upgrade to **CRESST-III**: 300 channels



# Neutrino properties

## Main projects

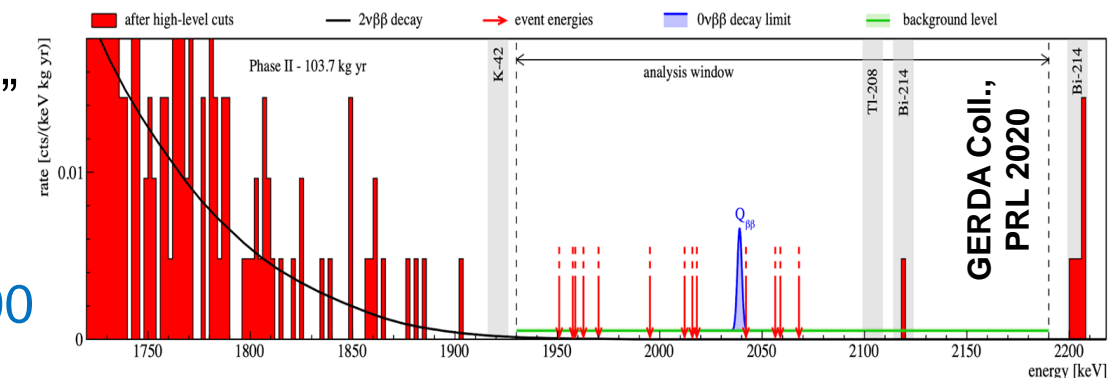
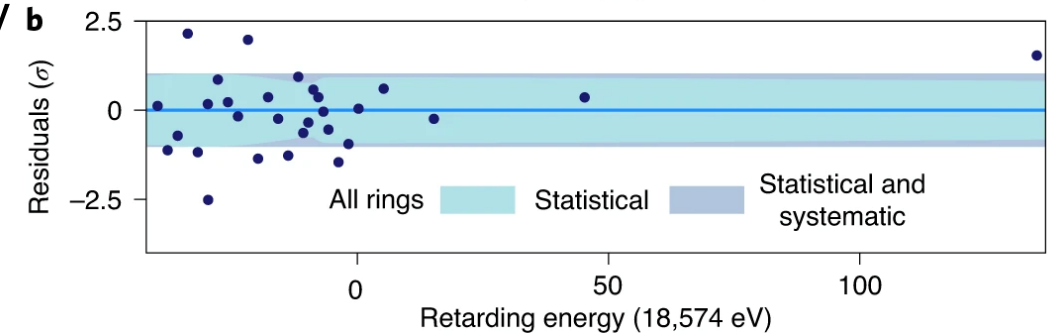
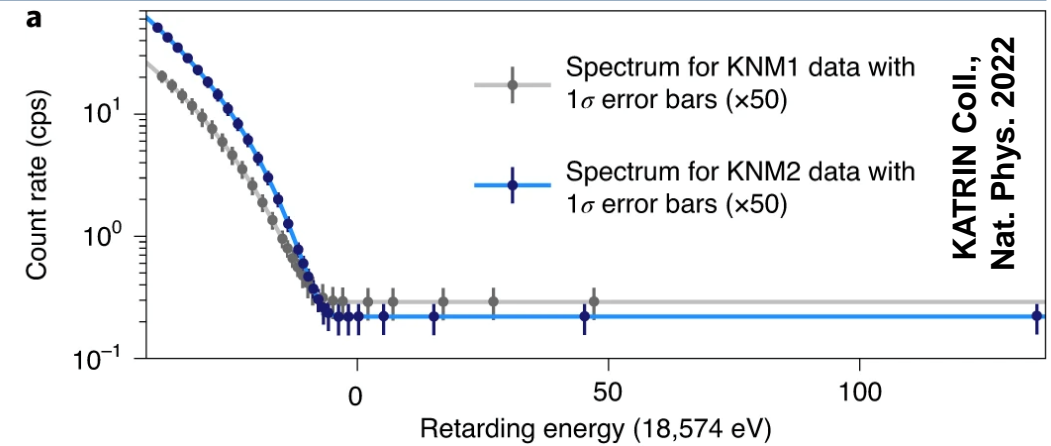
- **KATRIN**: direct neutrino-mass measurement
- **GERDA, LEGEND**: search for  $0\nu\beta\beta$  decay
- Coherent scattering and NSI search: ongoing (**CONUS**) and in prep. (**NUCLEUS**)

## Major results

- First direct sub-eV neutrino mass limit:  $m_\nu < 0.8$  eV
- Physics analyses beyond the neutrino mass
- First background-free search for  $0\nu\beta\beta$  decays
- First  $T_{1/2}$  sensitivity beyond  $10^{26}$  yr

## Future plans

- Exploit full KATRIN sensitivity of 0.2 eV
- 2024+: full-spectrum detector upgrade “TRISTAN”
- **LEGEND-200** @ LNGS start data taking 2022
- **LEGEND-1000**: successful DOE Review 2021
- R&D towards: **Project-8**, **ECHo-100k**, **CONUS-100**



# Low-energy neutrino astrophysics

## Main projects

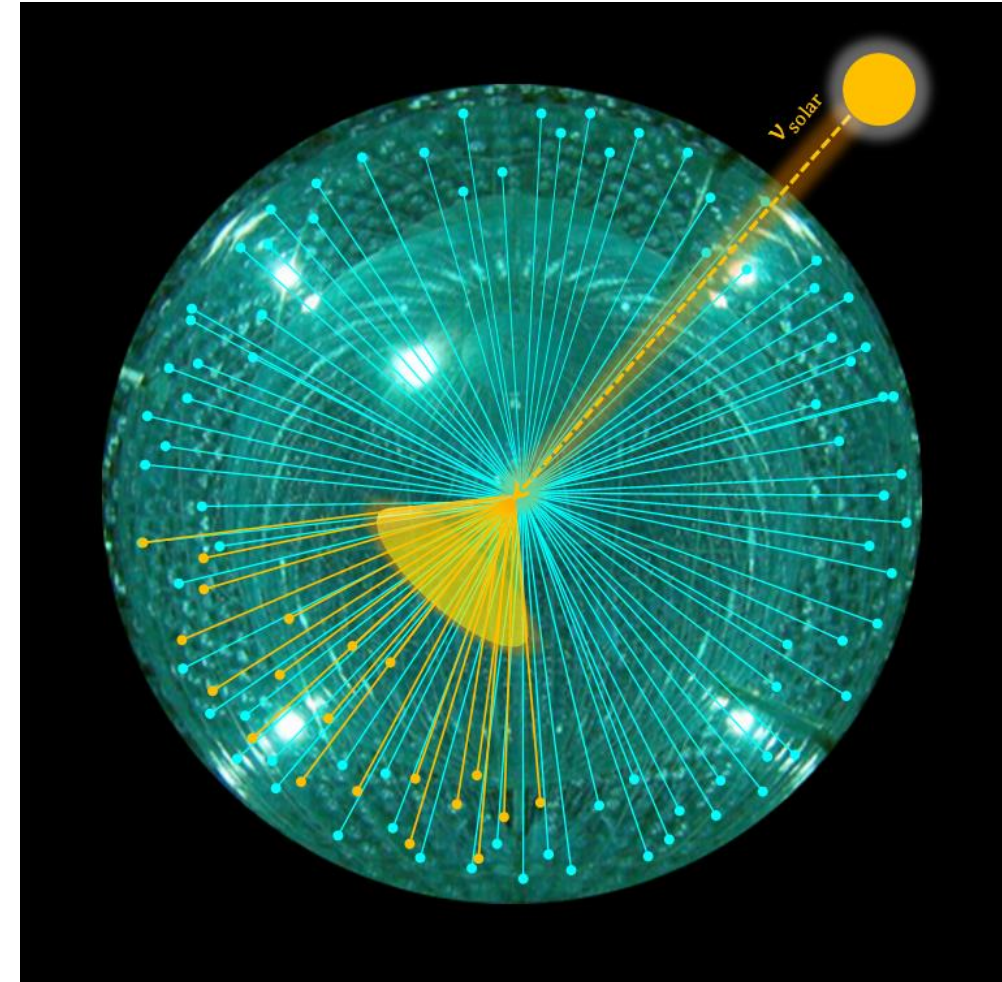
- **Borexino**: spectroscopy of solar  $\nu$ 's
- **JUNO**: reactor neutrino oscillations and observatory for astrophysical sources (currently under construction)

## Major results of Borexino

- First direct measurement of solar CNO  $\nu$ 's
- First directional measurement of sub-MeV solar  $\nu$ 's in a liquid-scintillator detector

## Future plans

- Determination of neutrino mass ordering and first observation of diffuse supernova  $\nu$  background in JUNO
- R&D on hybrid Cherenkov-scintillation detectors (**THEIA**)





# Cosmic rays

## Main projects

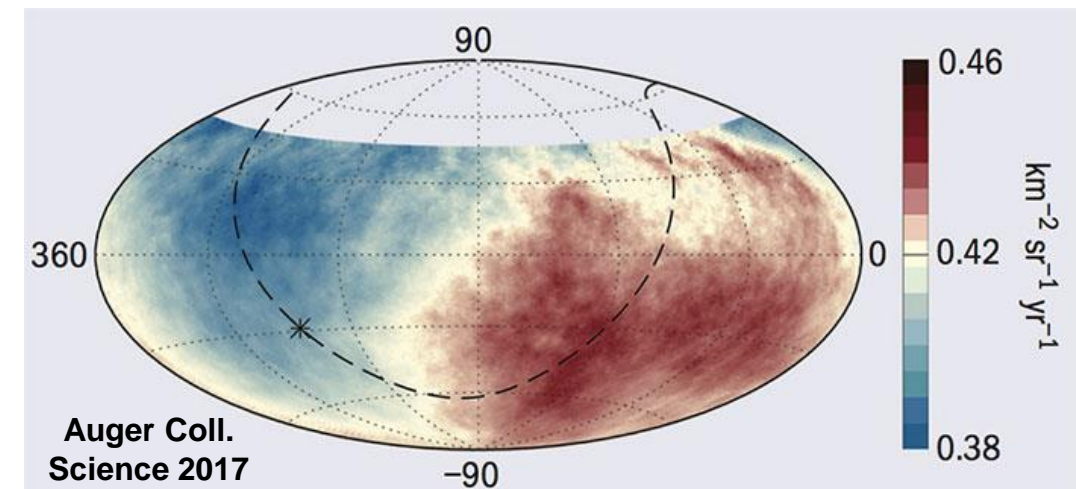
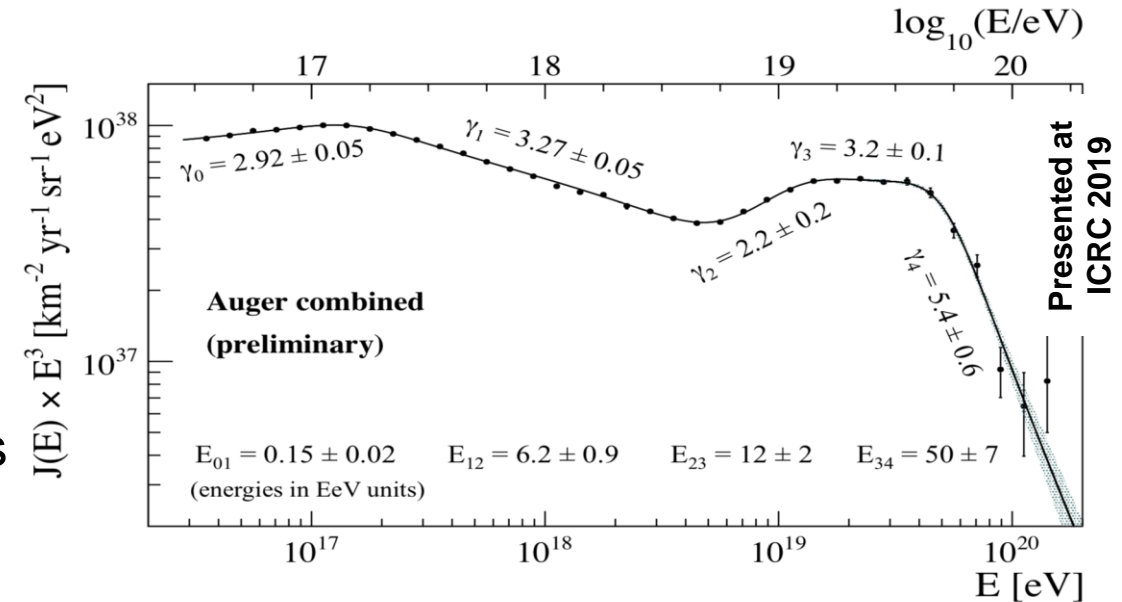
- [Pierre Auger Observatory](#) (Argentina): 3000 km<sup>2</sup>, largest cosmic ray experiment
- [AugerPrime](#): Add scintillators and radio antennas (by 2024)

## Major results

- Cosmic ray spectrum 10<sup>16</sup>–10<sup>20</sup> eV, new features
- Arrival direction distribution shows anisotropy
- p-p and p-Air cross sections at EeV
- Heavy composition at highest energies

## Future plans

- Calibration/operation of AugerPrime until 2030+
- R&D for next generation observatory ([GCOS](#))
- Community effort for CORSIKA8 (significant overlap with LHC forward physics)





# High-energy neutrino astrophysics

## Main projects

Neutrino astronomy and neutrino physics with

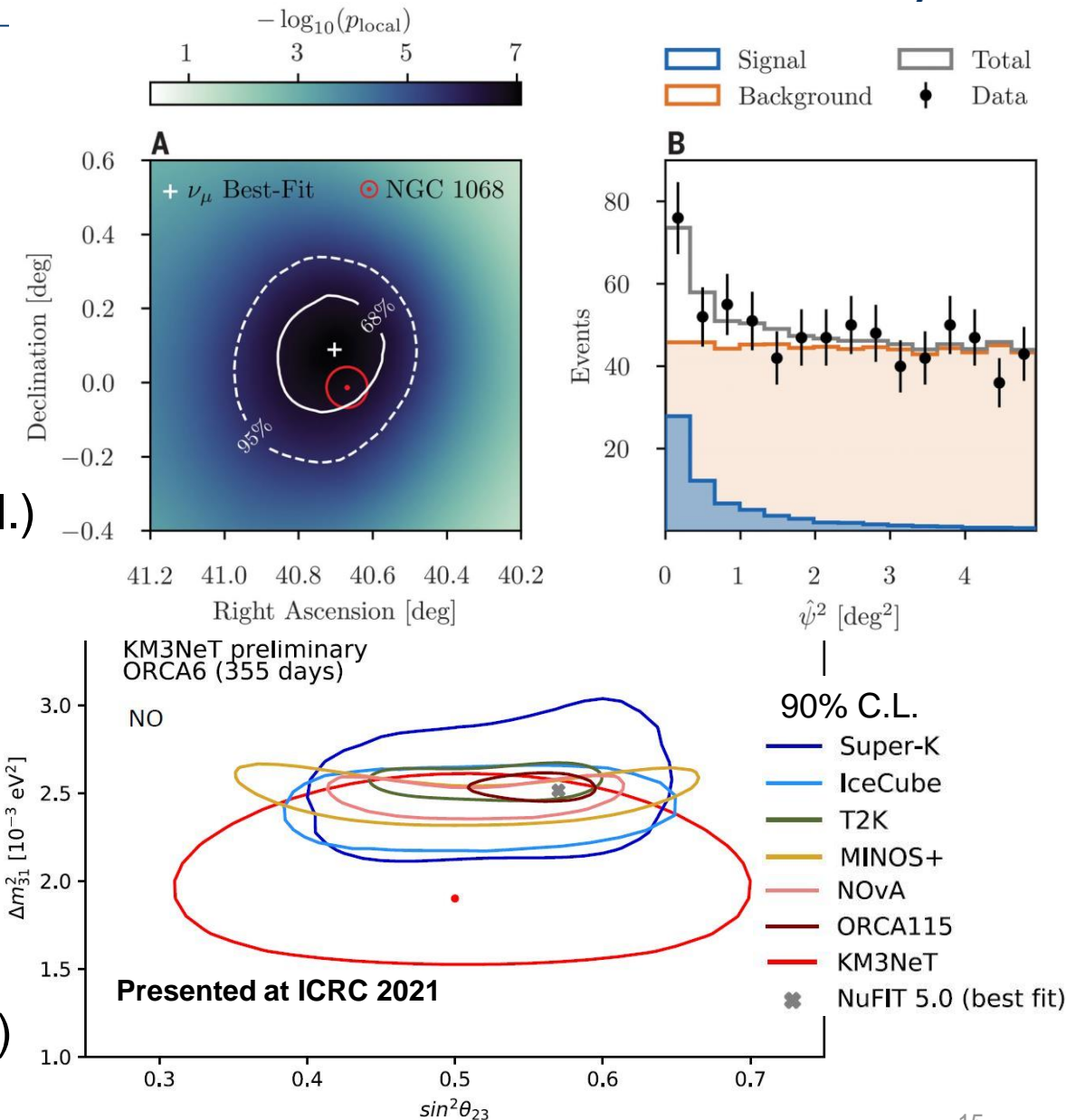
- IceCube (South Pole)
- KM3NeT (Mediterranean Sea)

## Major results

- Discovery of cosmic  $\nu$  flux (10 TeV ... 10 PeV)
- First evidence for source association(s):  
TXS 0506+056 (blazar), NGC 1068 (Seyfert gal.)
- Competitive  $\nu$  oscillation measurements

## Future plans

- IceCube Upgrade (constr. 2025/26)  $\rightarrow \nu$  oscil.
- IceCube-Gen2: Extended detector + surface array + radio detector (constr. 2026-33)  $\rightarrow \nu$  astronomy
- KM3NeT: Complete construction of ARCA (2027,  $\rightarrow \nu$  astronomy) and ORCA (2026,  $\rightarrow \nu$  oscillation,  $\nu$  mass hierarchy)



# Theory

**Rich landscape in astroparticle theory,**  
~30 PIs all over Germany

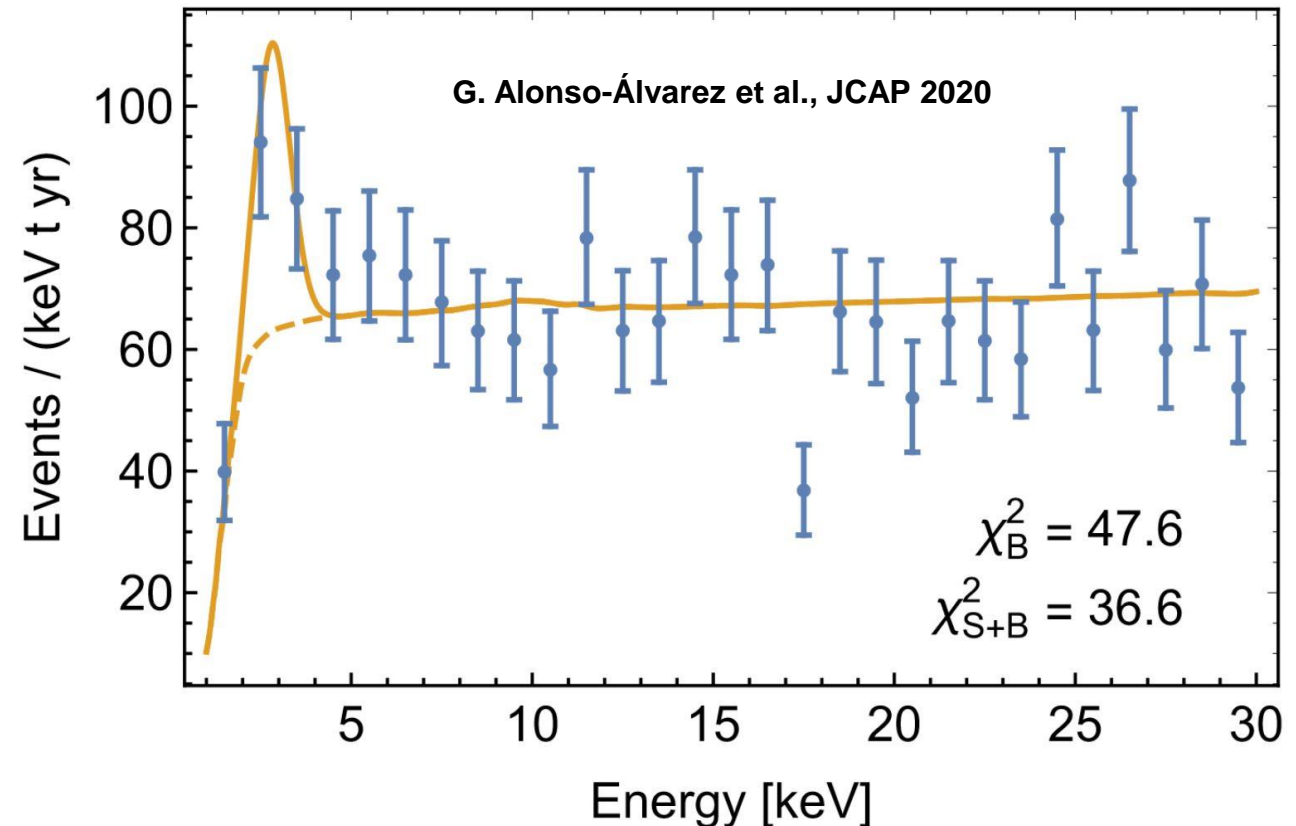
## Topics

- Multi-messenger astronomy
- UHE cosmic rays and cosmogenic  $\nu$  (simulations and predictions)
- Gravitational wave signatures
- Dark matter, axion, ALP theory and phenomenology
- Neutrino physics

## Links to particle physics

- BSM searches at colliders
- Top-down model building
- Use of HEP tools and methods (e.g. Monte Carlo codes & tuning)
- ...

## Hidden Photon Dark Matter in the Light of XENON1T data and stellar cooling



# Theory

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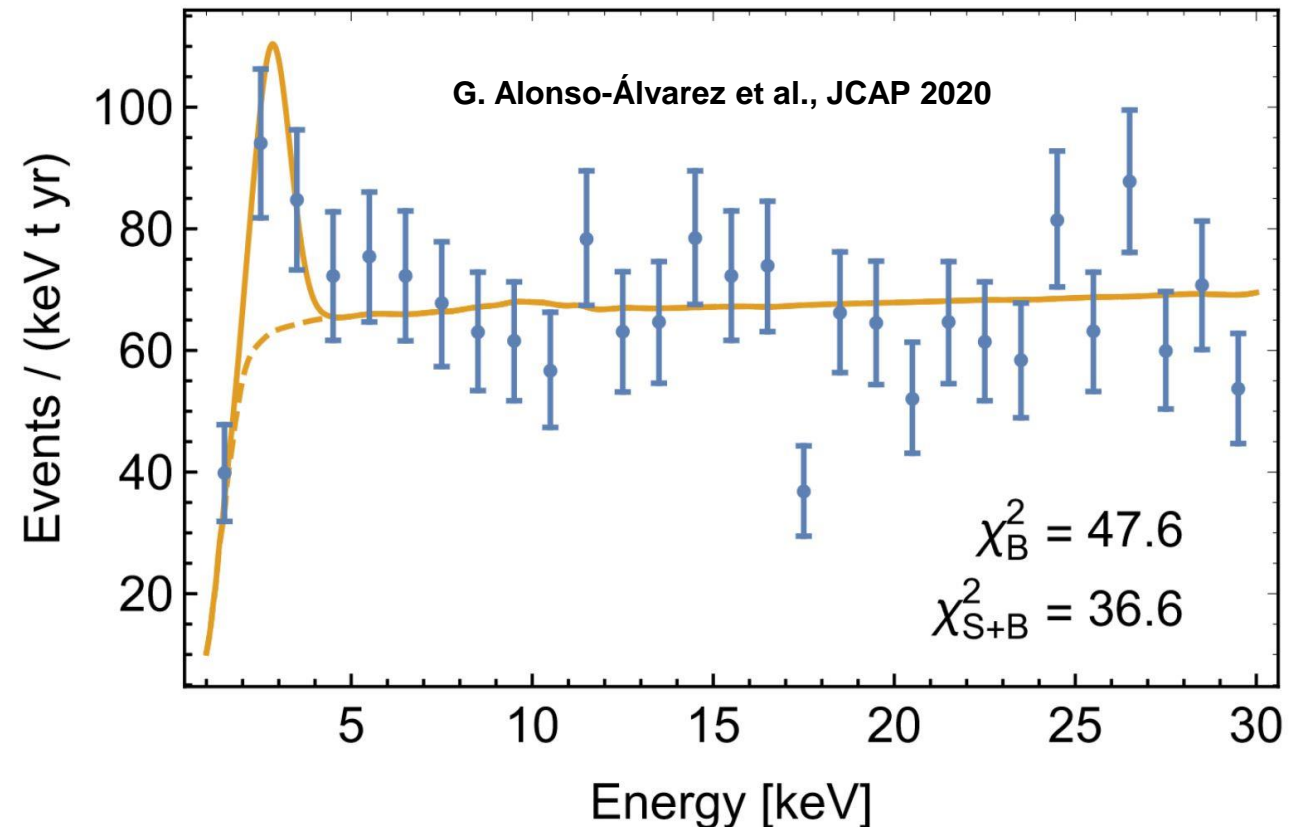
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**Meanwhile: XENONnT has shown that anomaly has been caused by tritium background**

# Gravitational waves

## Main projects

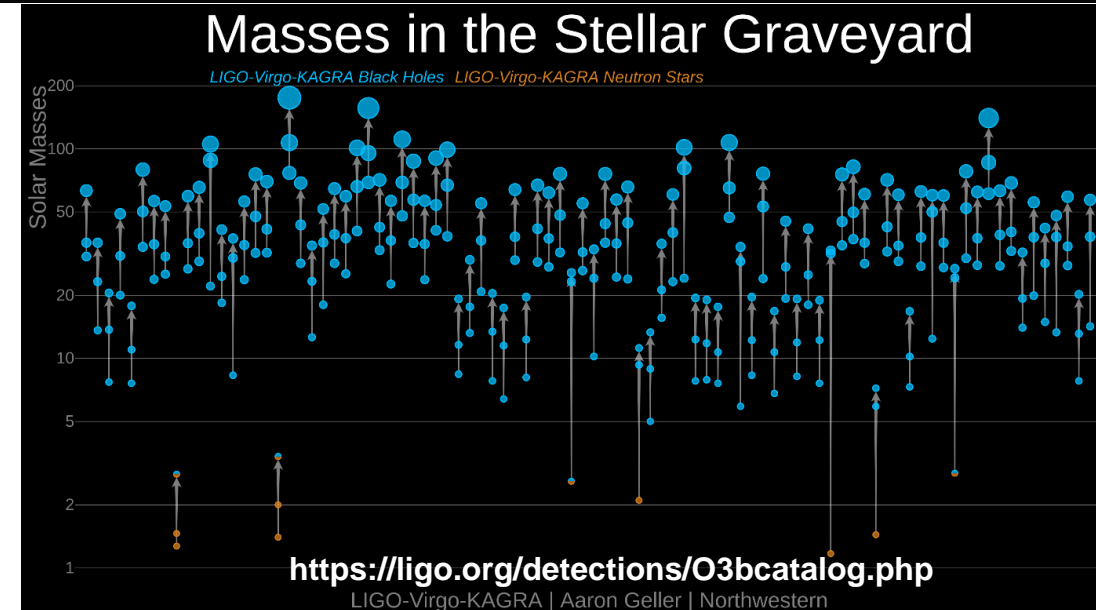
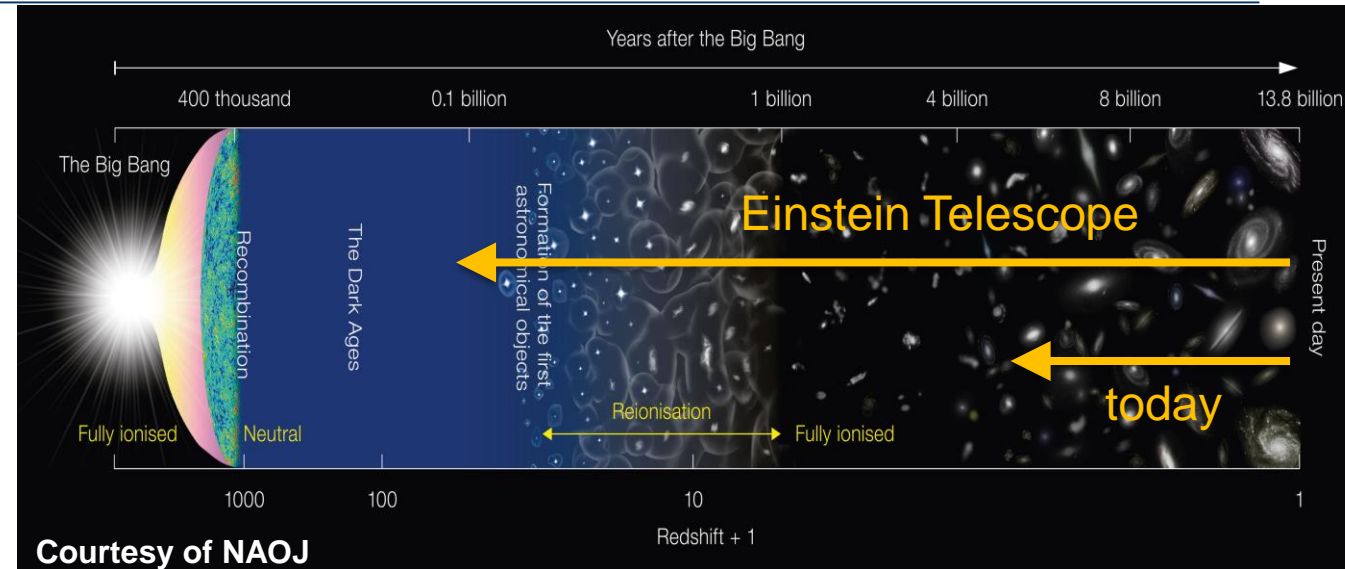
- Running: **Advanced LIGO + VIRGO, KAGRA, GEO600**
- Preparatory work towards **Einstein Telescope (ET), LISA** (space)

## Major results

- 90 validated GW detections so far (mostly BH-BH-mergers, some BH-NS, two binary NS (BNS))
- First multi-messenger observation: GW and electromagnetic emission of BNS

## Future plans

- Upgrade existing GW Detectors
- O4 run (1 year) starting late spring 2023
- ET and LISA data mid-late 2030s





# The Einstein Telescope

## Large project (> 1G€)

- A possible significant German contribution is beyond the capabilities of astroparticle physics alone (regular funding, HR)
- Included in ESFRI Roadmap since 2021

## Relation to DZA

- Technology development
- Investigation of granite stock in Lusatia as a possible ET site

## Ongoing:

- Sites qualification → site selection
- Cost evaluation
- Pre-engineering studies
- Formal collaboration founded in June 2022, governance building ongoing

