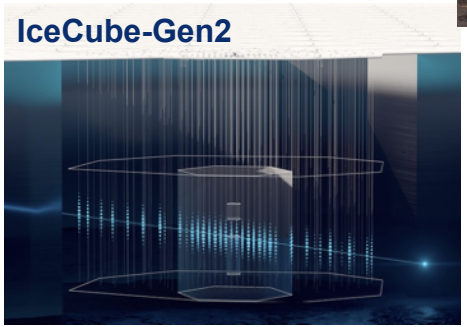
Topic Outlook:

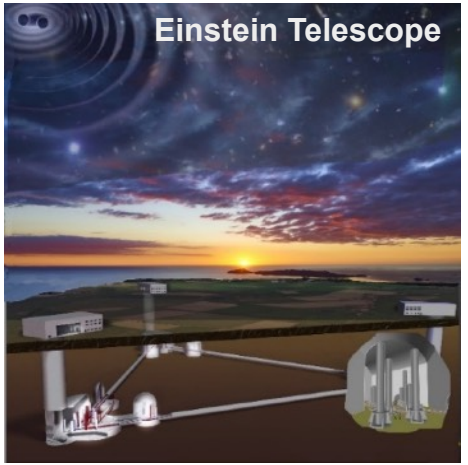
Matter and Radiation from the Universe

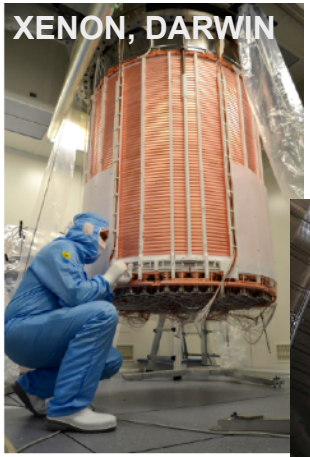
Kathrin Valerius & Christian Stegmann

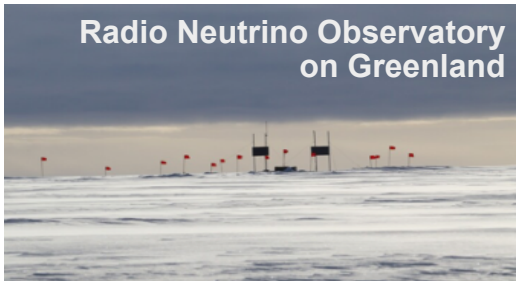
Virtual MU Days, Nov. 24-25, 2021

MRU landscape: developments in PoF IV and beyond

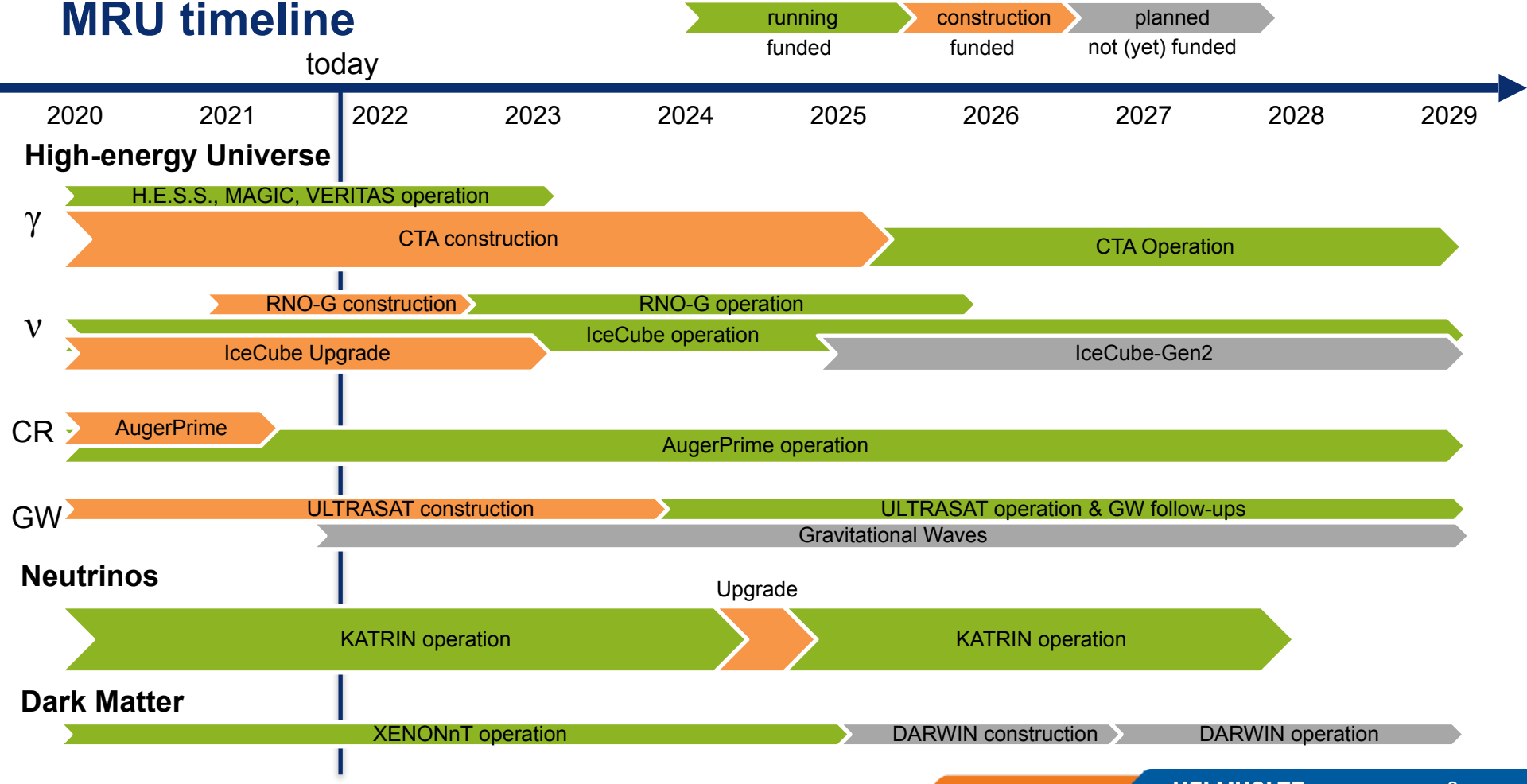






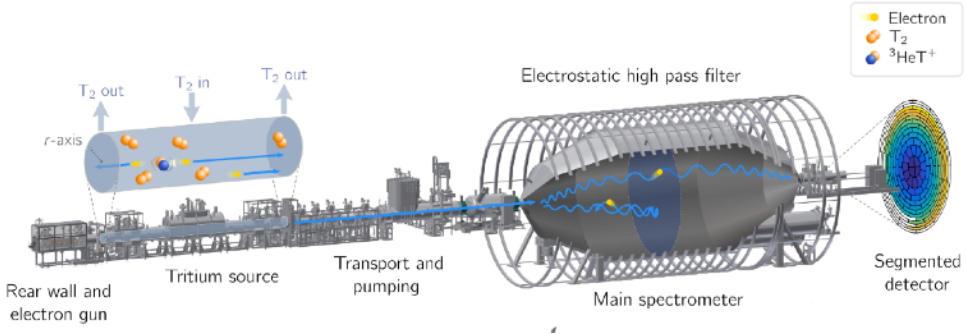


MRU timeline



Karlsruhe Tritium Neutrino Experiment (KATRIN)

Direct neutrino-mass measurement at endpoint of tritium β-spectrum



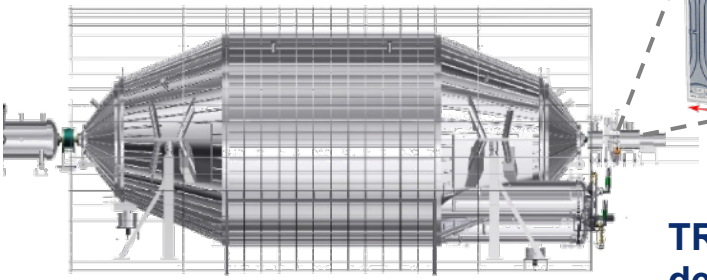
- Start of data-taking in 2019, achieved new sub-eV m_ν limit with 5% of total anticipated data
- Reliable operation of KATRIN beamline Tritium Laboratory > 200 days / year
- On the way towards goal of $m_\nu < 0.2$ eV (90% CL)

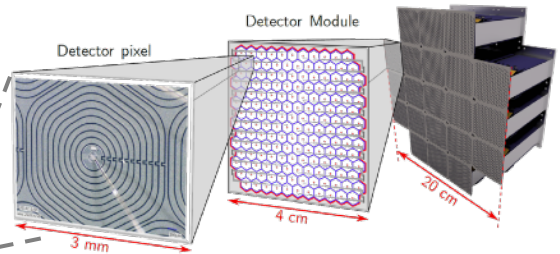
- Next data release (2022): ~ 20% of total KATRIN data
- Background reduction by optimized operating conditions
- Campaigns for improved understanding of systematics

KATRIN 2025-2027

Measurement of full tritium β-decay spectrum with differential readout

- keV-scale sterile ν as “warm” dark matter
- Right-handed current interactions
- Light extra bosons, ...

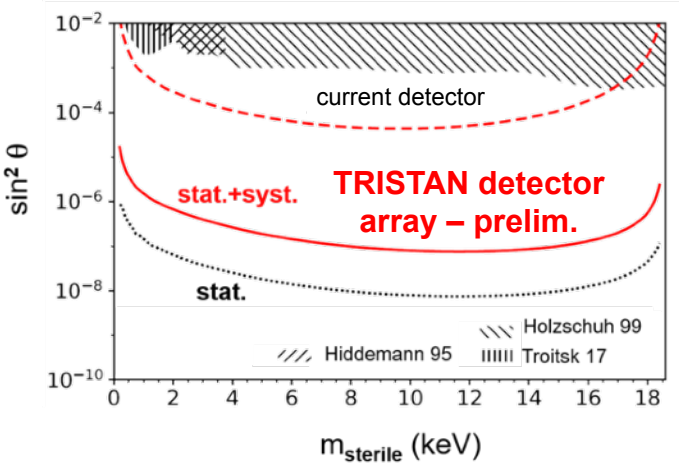




148 → 1500 channels
10^5 → 10^8 cps

TRISTAN: array of silicon drift detectors → *Cross-cutting activity with MT*

Mertens++, J. Phys. G 46 (2019) 065203



Further activities:

- Exploration of technologies towards $m_\nu < 0.2$ eV/c²
- Transfer of KATRIN expertise to other projects (e.g. direct dark matter search)

Direct dark matter search

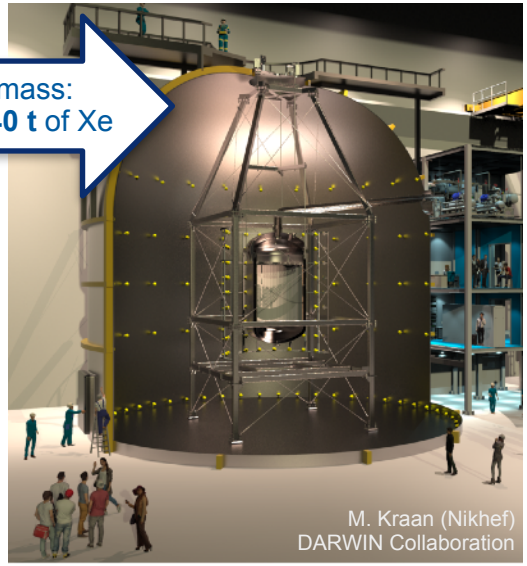
Xenon based two-phase time projection chambers

XENONnT at LNGS

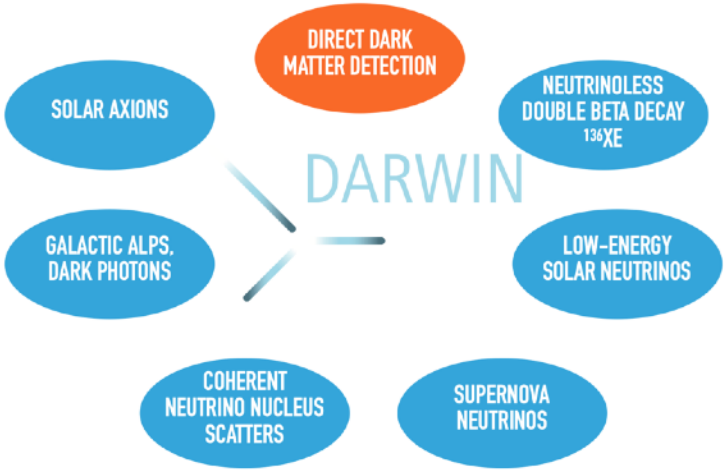
TPC active mass:
from **6 t** to **40 t** of Xe

Timeline: Construction completed in 2020, start of science data in 2021 (5+ yrs)

DARWIN: future observatory for rare-event searches



Timeline: Construction/commissioning end of PoF IV, operation through PoF V
Goal: 200 t yr exposure



from L. Baudis

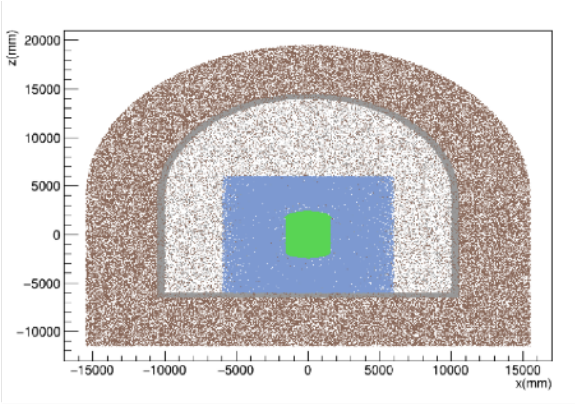
- DARWIN science program: JCAP 11 (2016) 017, EPJ C80 (2020) 808, EPJ C80 (2020) 1133
- APPEC Committee Report, arXiv:2104.07634
- Community White Paper (3G xenon detector) under way

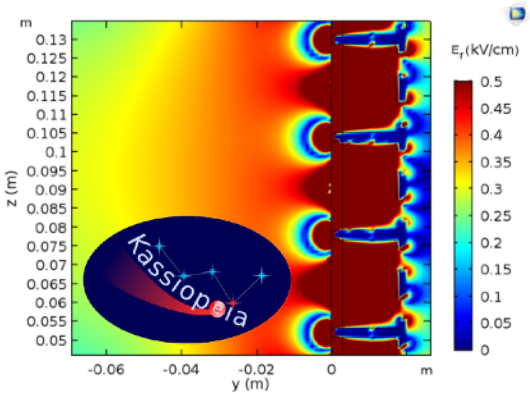
Direct dark matter search

Current activities towards DARWIN in Helmholtz

Helmholtz Roadmap: First-stage proposal for FIS commission in preparation for 2022

- Background studies (muons, neutrons, activation)
- Detector development: TPC aspect ratio, field cage design, concepts for large electrodes



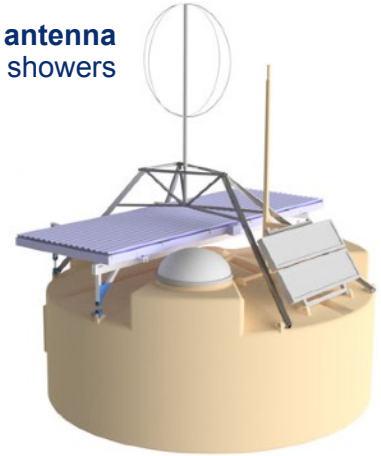


- Physics studies (e.g. constraining sterile neutrinos through precision solar neutrino flux, Th. Schwetz, 2109.14898; supernova neutrino detection, trigger and DAQ optimization)
- Further overlap with KATRIN expertise: cryogenics, screening & purification, …

Exploring the origins of cosmic rays with AugerPrime

radio antenna
for inclined showers

plastic scintillator to disentangle muon + electromagn. components

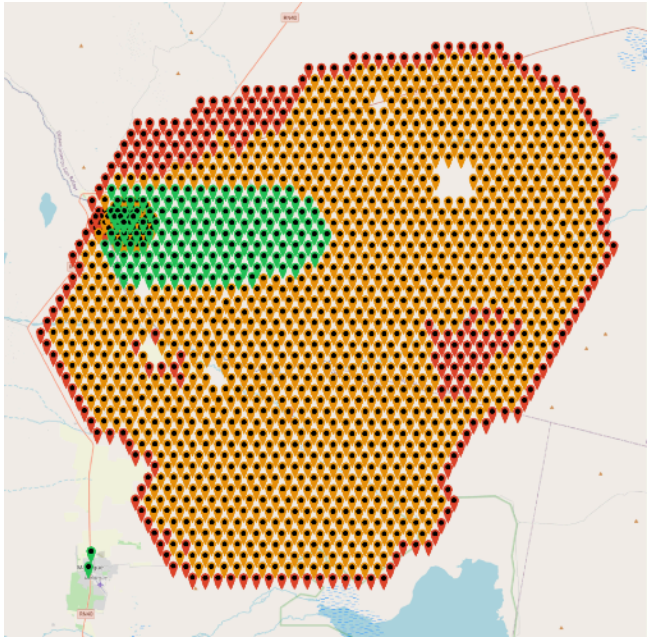


Key goal: Composition measurement up to 10^{20} eV
- Composition-enhanced anisotropy studies
- Improved test of hadronic interactions

Components:
Water Cherenkov Detectors enhanced by
- Surface Scintillation Detector (3.8 m^2)
- Radio antenna (for inclined air showers)
- Small PMT (increased dynamic range)
- Electronics upgrade

+ Underground muon-counting array
+ Increased duty cycle of Fluorescence Detectors

Exploring the origins of cosmic rays with AugerPrime



Scintillator deployed + acquiring data

- Deployment of scintillator modules and electronics progressing well, radio antennas to follow
- Upgrade to be completed in 2023
- Renewal of international agreement foreseen to extend operations until 2030

- Community building to prepare for next generation experiment GCOS (beyond 2030), e.g. GCOS workshops and Snowmass process

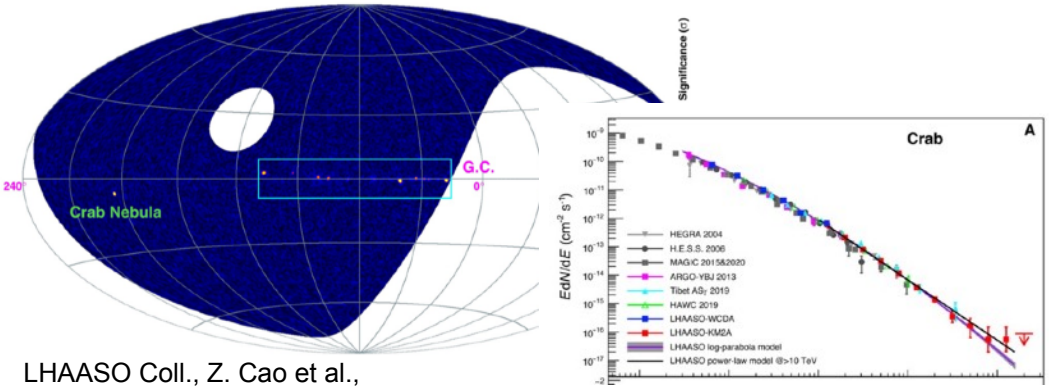
CTA: The future of gamma-ray astronomy

First open observatory in ground-based gamma-ray astronomy

Key aspects of CTA science:

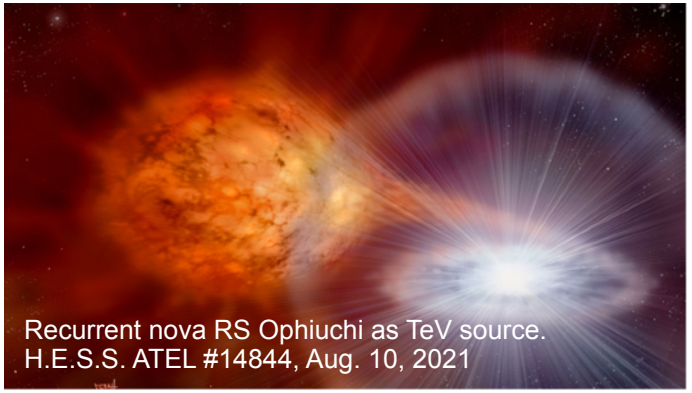
- **excellent sensitivity** and
- **good angular resolution**

for deep surveys and transient follow-up.



LHAASO Coll., Z. Cao et al., Nature, 17 May 2021

Z. Cao et al., Science, 8 July 2021



Recurrent nova RS Ophiuchi as TeV source. H.E.S.S. ATEL #14844, Aug. 10, 2021

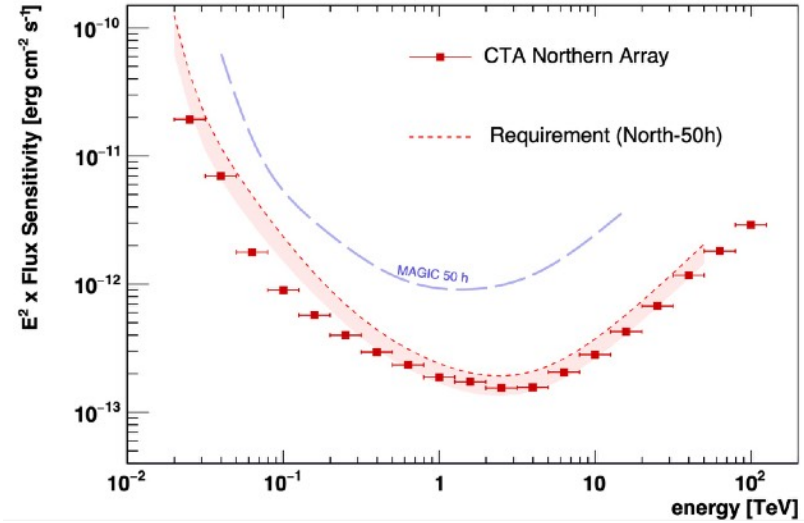
A tidal disruption event coincident with a high-energy neutrino. R. Stein et al., Nature Astronomy 5 (2021)

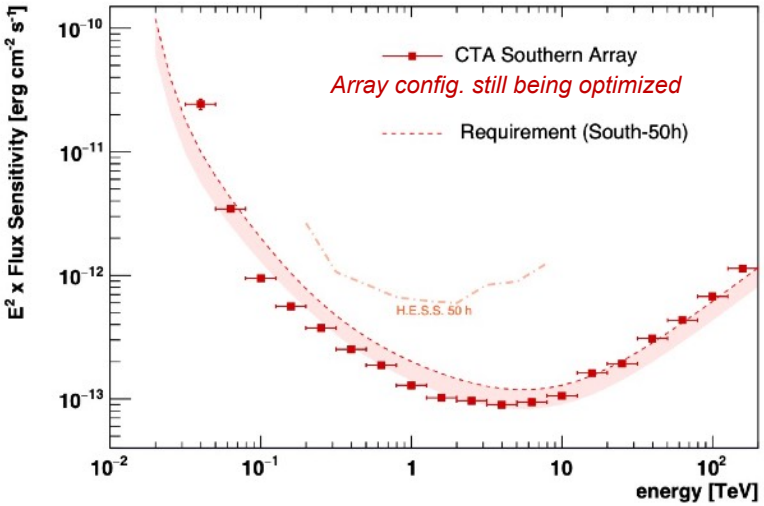
CTA: The future of gamma-ray astronomy

CTA alpha configuration meets many of the original CTA requirements

- North: 4 LST, 9 MST (Baseline 4 LST, 15 MST)
- South: 14 MST, 37 SST (Baseline 4 LST, 25 MST, 70 SST)

Main deficit: reduction in sky coverage below 50 GeV





CTA: The future of gamma-ray astronomy

Preparations are in full swing:

The necessary part

- The foundation of a legal entity to construct and operate the CTA-Observatory expected in 2022

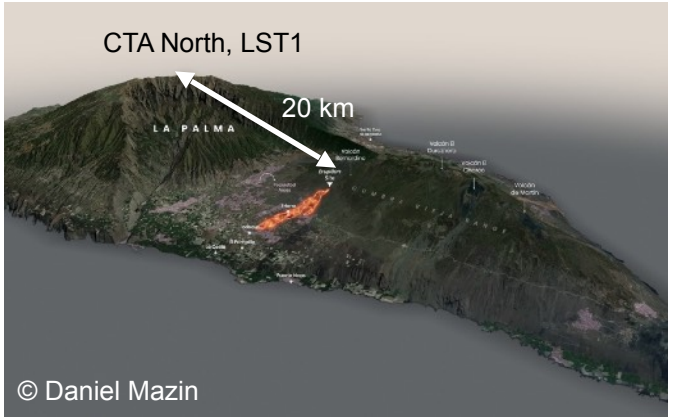
The exciting part

- Preparations for the construction of the telescopes are underway

The worries

- Costs and a volcano…


MST construction hall near DESY Zeuthen



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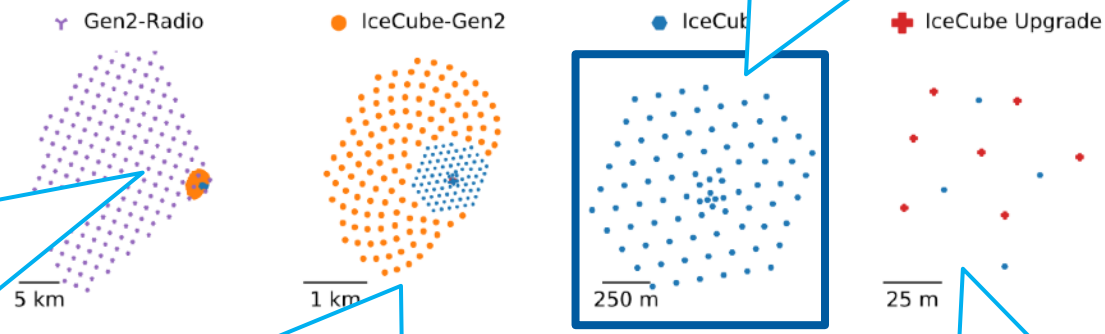
IceCube → IceCube Upgrade → IceCube-Gen2

IceCube operates smoothly

Radio

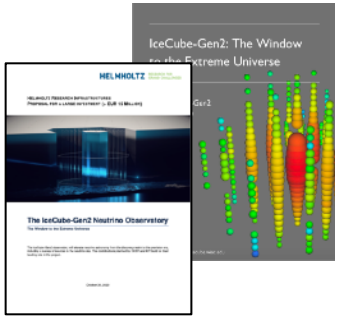
- Build radio array in Greenland as a precursor for Gen2-Radio
- First successful installation in Greenland this summer

Surface enhancement



IceCube-Gen2

- Comprehensive **science White Paper** published in Journal of Physics G
- Endorsed by **Astro2020** Decadal Survey
- Helmholtz Roadmap: recommendation by **FIS commission** to proceed with full proposal



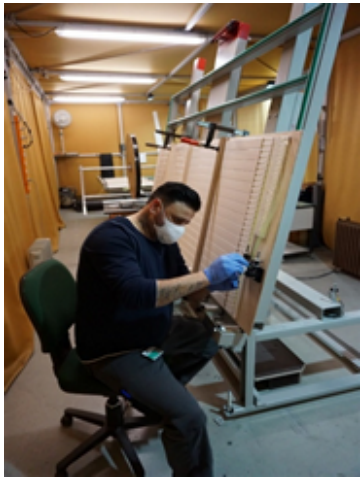
IceCube Upgrade (in progress)

- 7 additional strings for increased low energy sensitivity and improved detector calibration
- R&D for IceCube-Gen2
- Delay due to COVID-19

IceCube Surface Array Enhancement

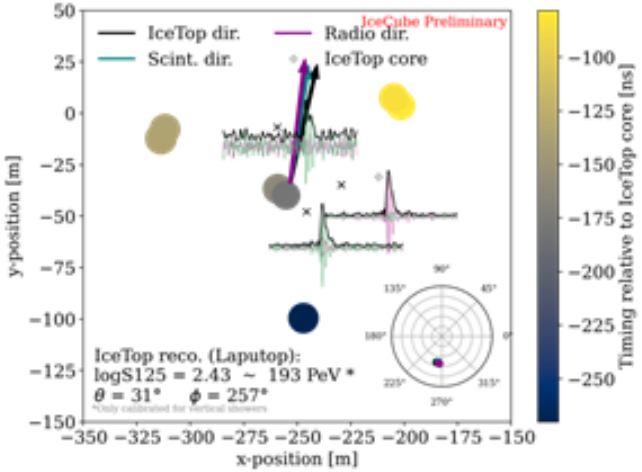
Improving veto & calibration capabilities as well as cosmic-ray & air-shower measurements in the PeV primary energy range

- First hybrid prototype station is in operation at the South Pole
- Hybrid air-showers in coincidence with IceTop measured and analyzed



Detector production at KIT

Prototype station at the South Pole (sunrise in 2019)



High-energy Cosmic Ray measured with the surface array enhancement prototype station

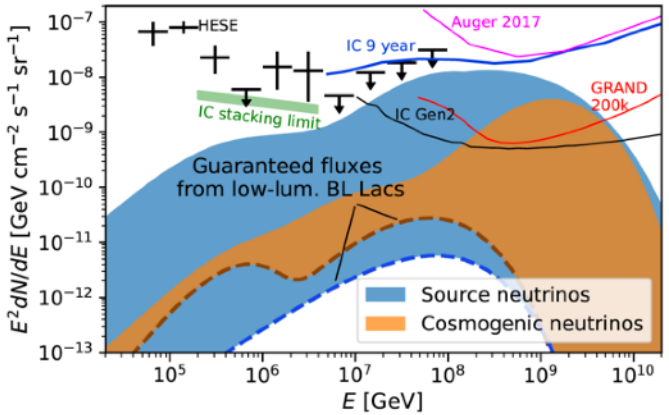
Radio Neutrino Observatory on Greenland (RNO-G)

The search for the highest energy neutrinos

Theory: Which neutrino flux dominates at the highest energies? Is it sources or the cosmogenic neutrino flux? Important prediction for future radio neutrino telescopes.

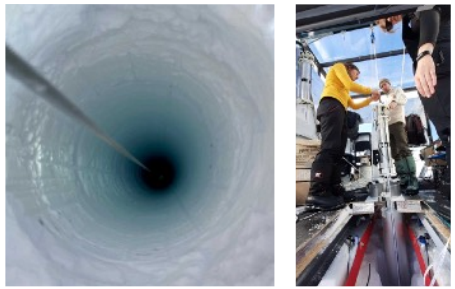
Experiment: Successful installation of the first RNO-G radio detectors on Greenland in the summer of 2021.

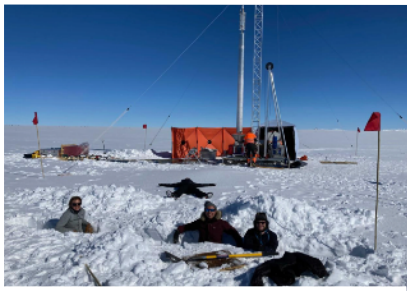
Rodrigues, Heinze, Palladino, van Vliet, Winter, PRL 126 (2021) 191101




The team


Drilling, installation of antennas at a depth of over 100 m

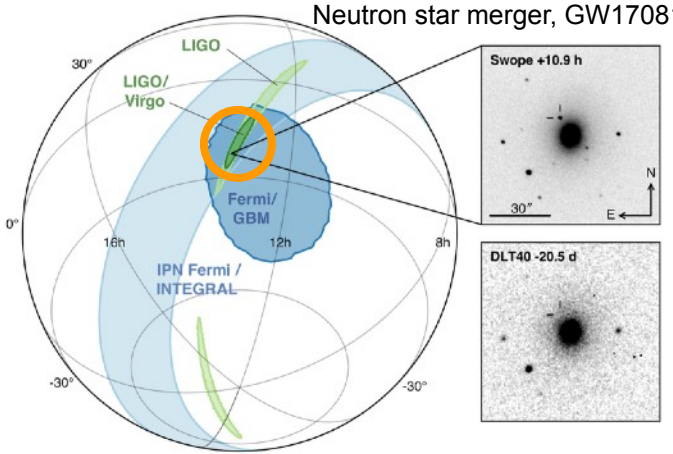



Digging for the surface antennas

ULTRASAT: Ultraviolet Transient Astronomy Satellite

Exploring the dynamic ultraviolet sky

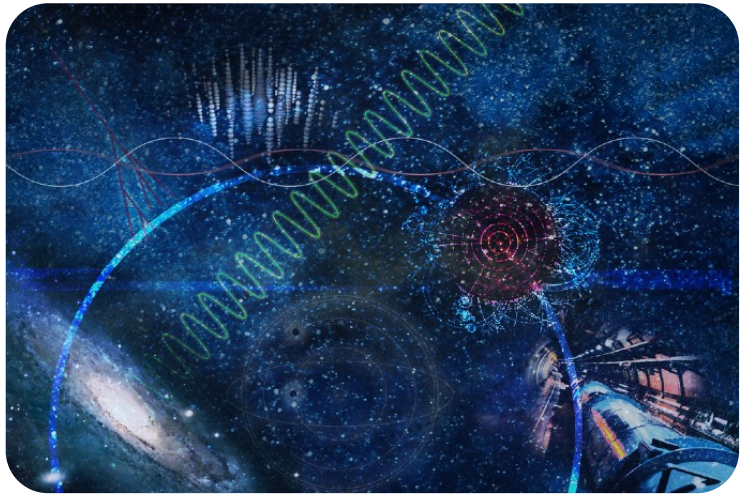
Neutron star merger, GW170817



- Large field of view (200 deg^2) allows rapid transient follow-up (<3 min) and alerts (<30 min) of the astrophysics community
- Wide-field camera built by DESY passed Critical Design Review in 10/2021
- Launch scheduled for 2024

Summary note

- Implementation of the MRU research plan for PoF IV is well under way, despite some impact of the pandemic.
- Major efforts are ongoing to upgrade existing experiments/observatories. Further plans for new large research infrastructures are in place.
- Recent research highlights show us that there is an exciting future ahead!



Thank You!

MU MRU
MATTER AND THE UNIVERSE

This presentation was built with input from

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based on the work of a dynamic team of motivated people

DESY.

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