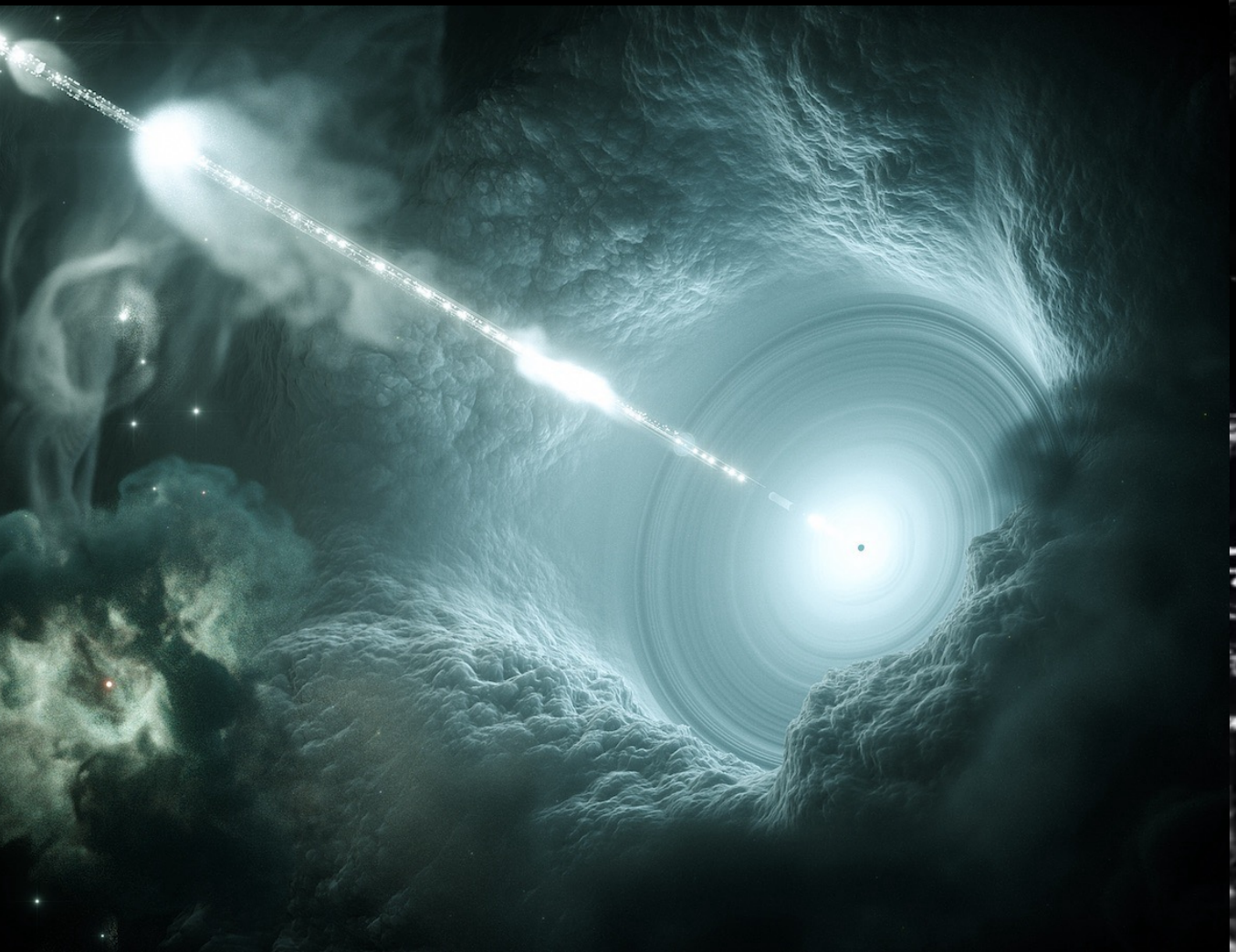
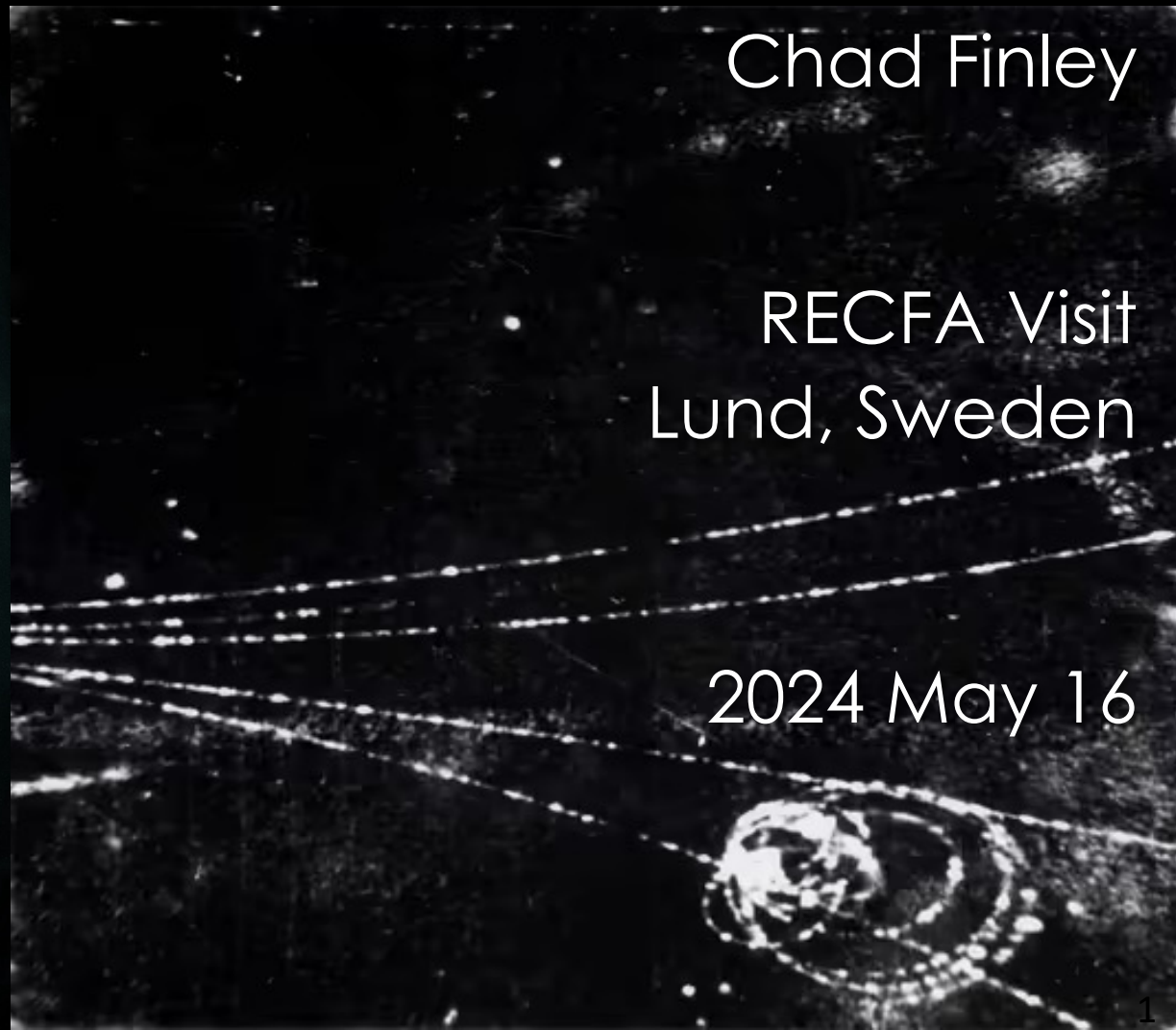
Experimental Astroparticle Physics in Sweden

Stockholm University





Chad Finley

RECFA Visit
Lund, Sweden

2024 May 16

Experimental Astroparticle Physics in Sweden

KTH Royal Institute of Technology
Lund University
Stockholm University
Uppsala University

12 faculty, 13 researchers & postdocs, 15 PhD students

Active participation in world-class projects that lead their fields
Strong engagement in large international collaborations

Member of Astroparticle Physics European Consortium
- C. Finley member of Science Advisory Committee
(See R. Catena's talk for Astroparticle theory Commissions)

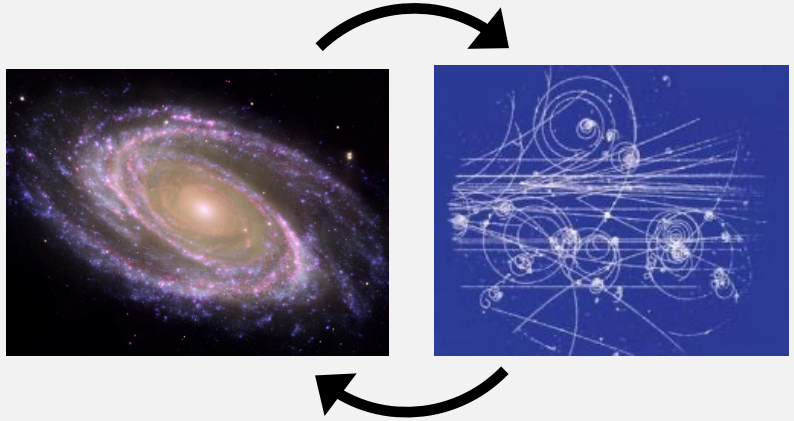
Externally Financed by:

Swedish Research Council (VR)
European Research Council (ERC)
Swedish National Space Agency (SNSA)

And private foundations:

Knut & Alice Wallenberg (KAW)
Crafoord Foundation

Astrophysics ⟷ Particle Physics



Discoveries leading to Nobel Prizes include:

1912 Discovery of Cosmic Radiation (CR)
1932 Discovery of positron in CRs (also muon 1936, kaon 1947)
1968 Detection of solar neutrinos
1987 Detection of neutrinos from Supernova 1987A
1998 Discovery of neutrino oscillations using CR air showers

Today in Sweden, two areas of activity at the center of Astroparticle physics research

Multi-Messenger Astronomy

- New Observatories for neutrinos, gravitational waves reveal a hidden Universe

- Together with photons and cosmic-rays, explore physics of extreme environments

Dark Matter

- Existence inferred from astro. observations
- Leading assumption: new kind of particle

Therefore may be detected via:
- Creation (in a lab)
- Interaction (from space or in a lab)
- Annihilation (in space)

IceCube Neutrino Observatory

South Pole, Antarctica

VR: Research Infrastructure of National Interest

Stockholm and **Uppsala** Universities

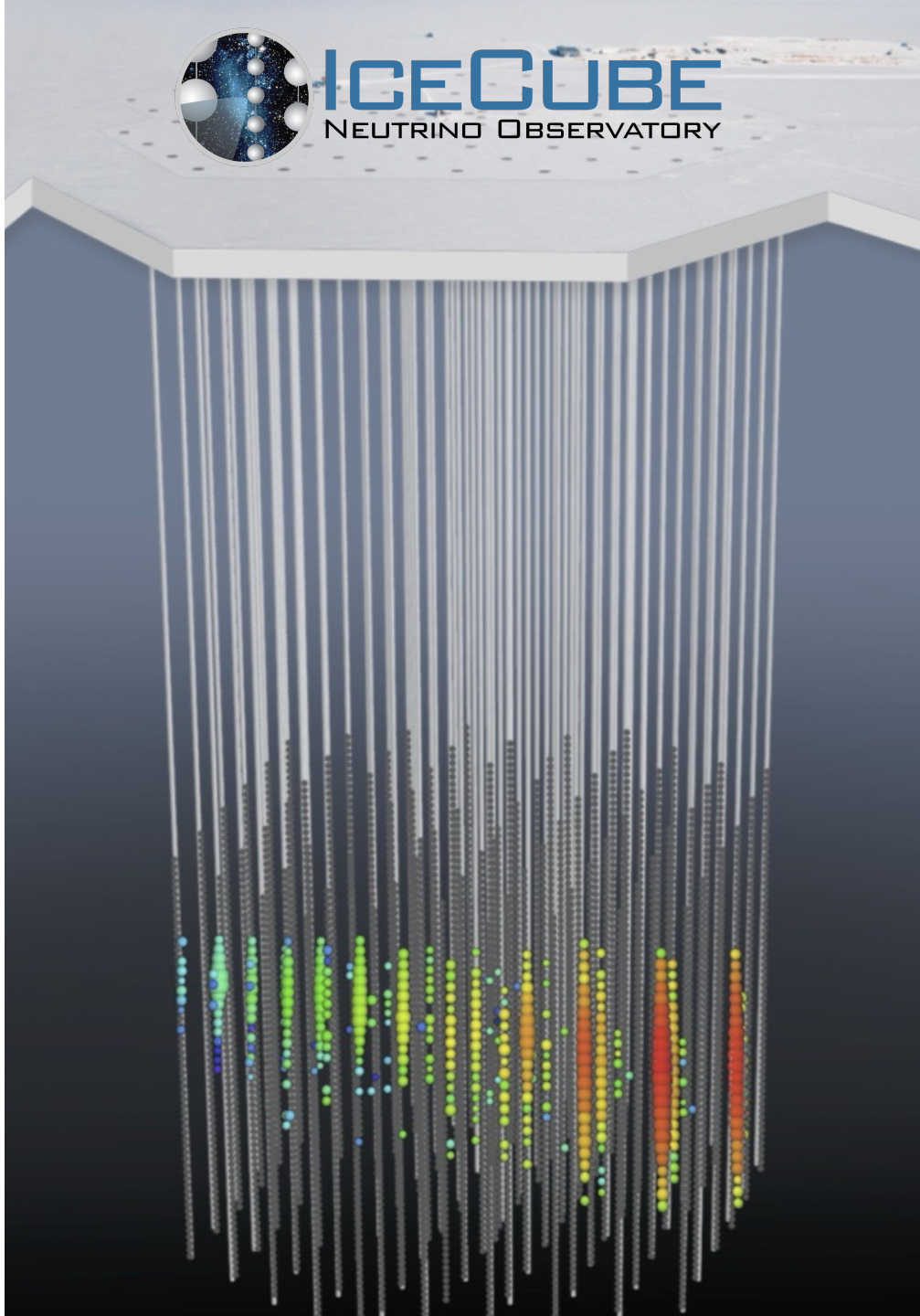
History: Started ice-based neutrino astronomy

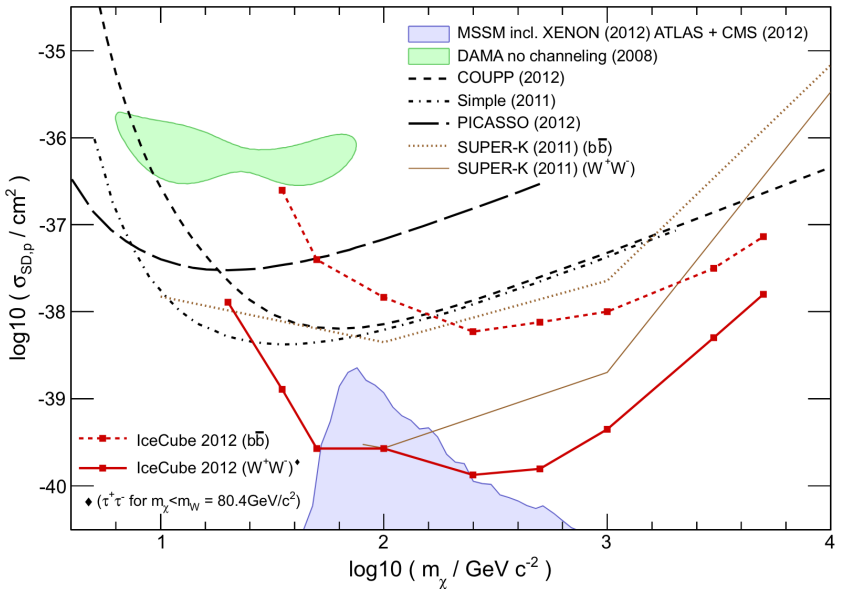
1992: 5 institutions (3 U.S. + Stockholm, Uppsala)

Today: 58 institutions in 14 countries

Key Swedish contributions since prototype stage:

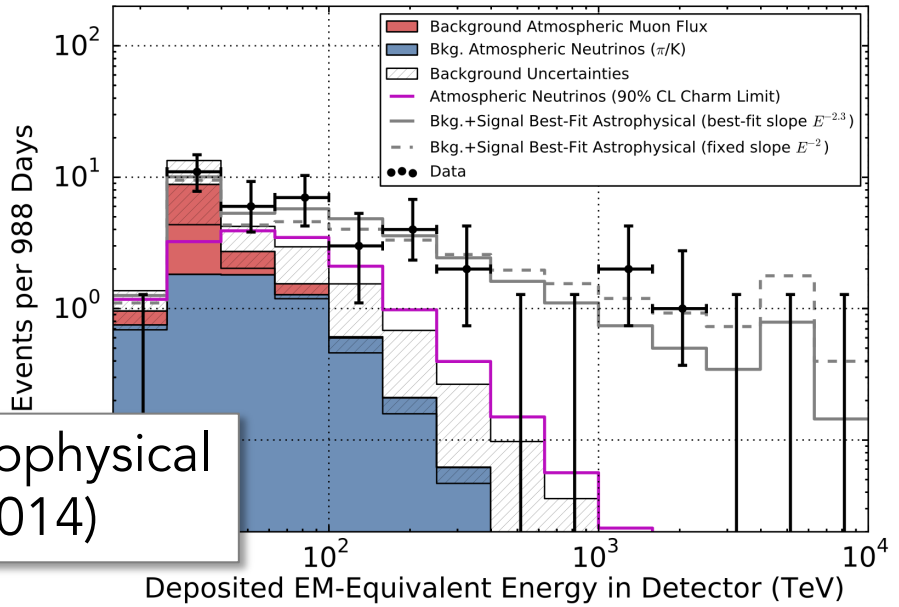
- Construction (20% of IceCube modules built in Sweden)
- DeepCore inner detector (KAW)
- Leadership roles in collaboration:
  - 2 out of 7 spokespersons ; 2 pub. comm. chairs
  - Convenorships of most working groups multiple times (e.g. BSM, astro sources, diffuse flux, supernova)
  - corresponding author for 2 of 10 most-cited result papers



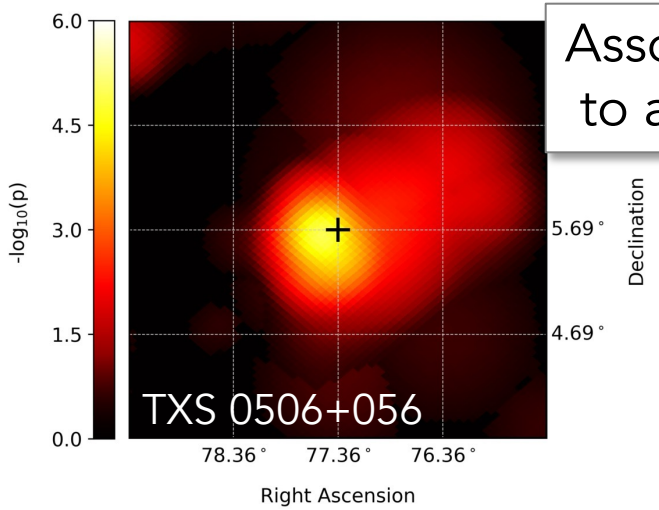


Spin-dependent DM limits (PRL, 2013)

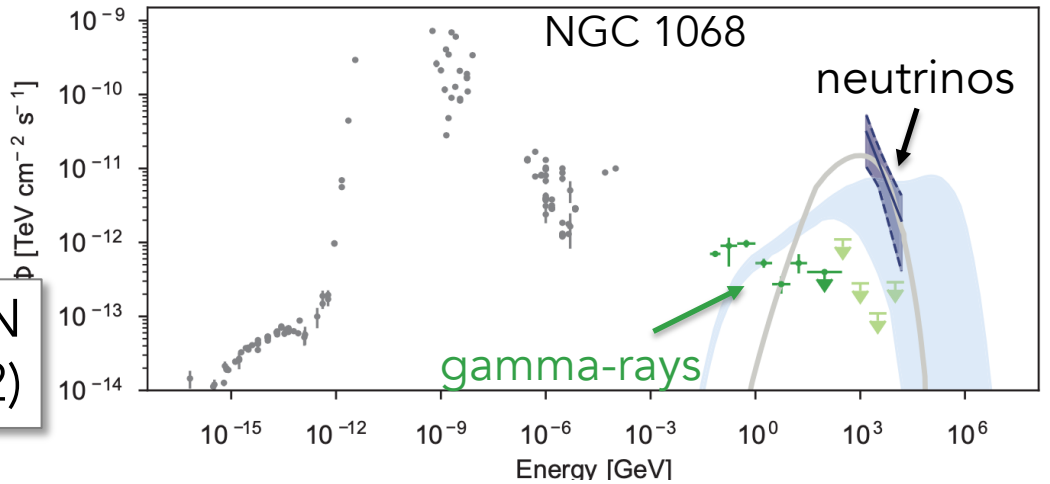
IceCube Neutrino Observatory



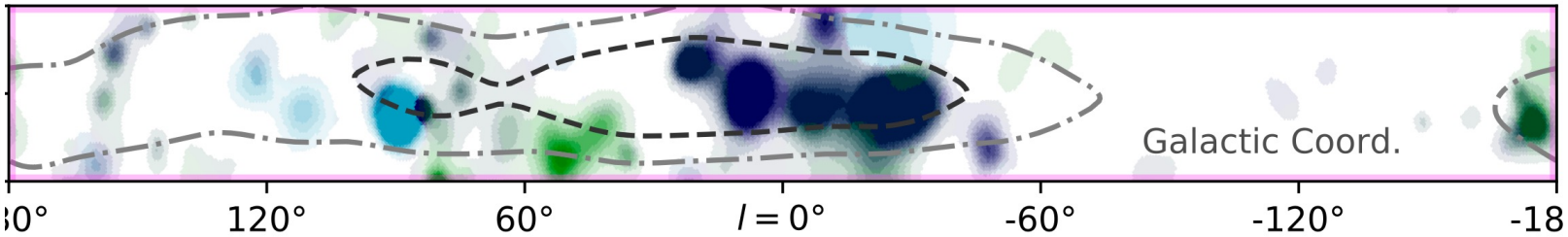
Discovery of the astrophysical neutrino flux (PRL, 2014)



Association of neutrino emission to a blazar (Science, 2018)



… and to a Seyfert AGN (Science, 2022)



Discovery of the Galactic neutrino flux (Science, 2023)

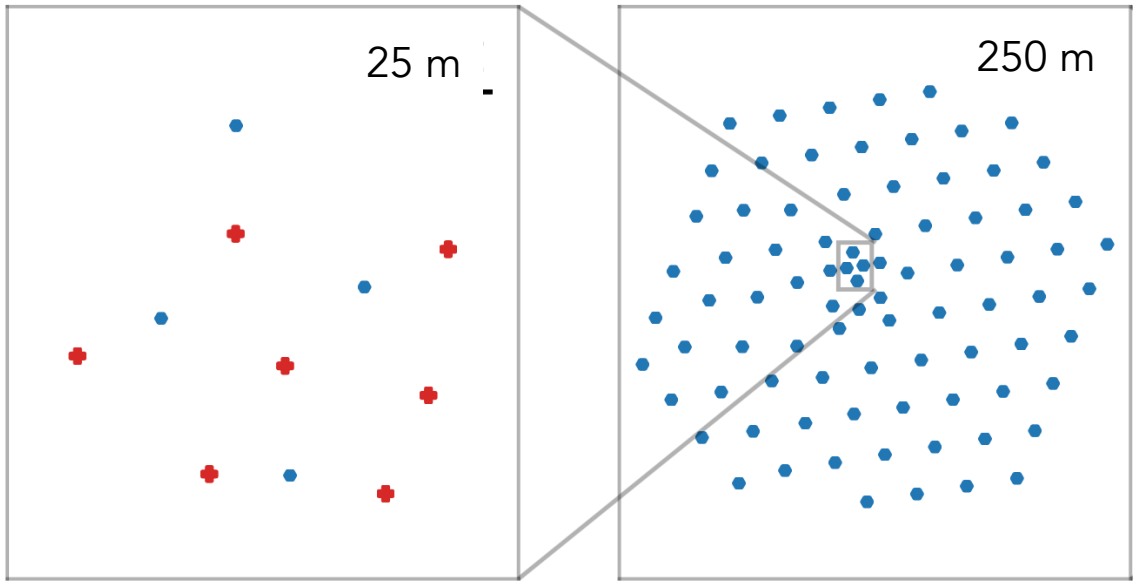
2025-26 – IceCube Upgrade

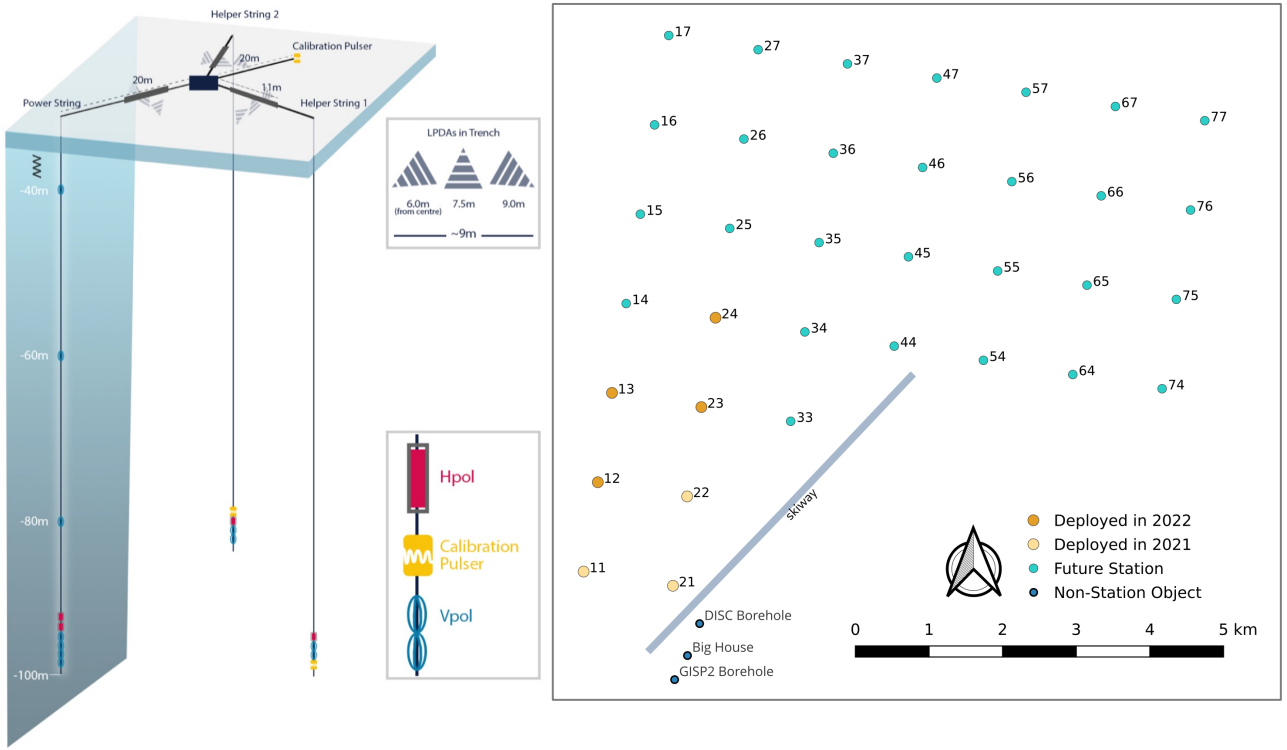
7 new strings of instruments in detector center for:

- Precision neutrino oscillation measurements
- Calibration of ice properties (largest sys. unc.)

Main Swedish HW contribution:

Camera calibration system





Radio Neutrino Observatory – Greenland

- Discovery instrument for EeV neutrinos
- Test Site for IceCube-Gen2

2024-26 completion of RNO-G 35

2027-28 deploy shallow infill array

RNO-G
Radio Neutrino Observatory - Greenland

Main Swedish HW contributions:

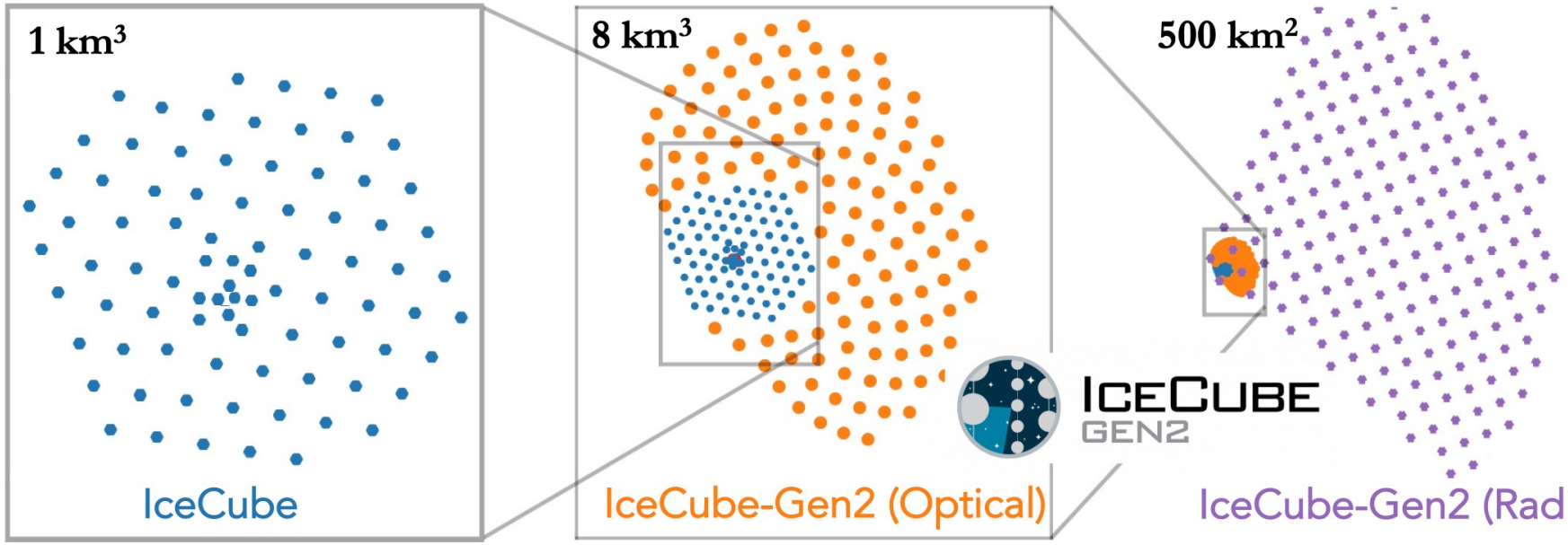
- Develop & construct shallow ice radio stations
- DAQ development to support AI trigger
- Wind power for polar conditions

Next Generation Neutrino Observatory: IceCube-Gen2

- Characterize the astrophysical neutrino energy spectrum: Features? Extension to EeV energies? Relation to underlying source populations and propagation of cosmic rays?

- Identification and characterization of extragalactic neutrino sources, and the neutrino flux from the Milky Way

- Searches for BSM physics; Precision measurements of neutrino properties



IceCube-Gen2 – 8x larger than IceCube for TeV-PeV energies ; 10x larger than RNO-G for EeV energies.

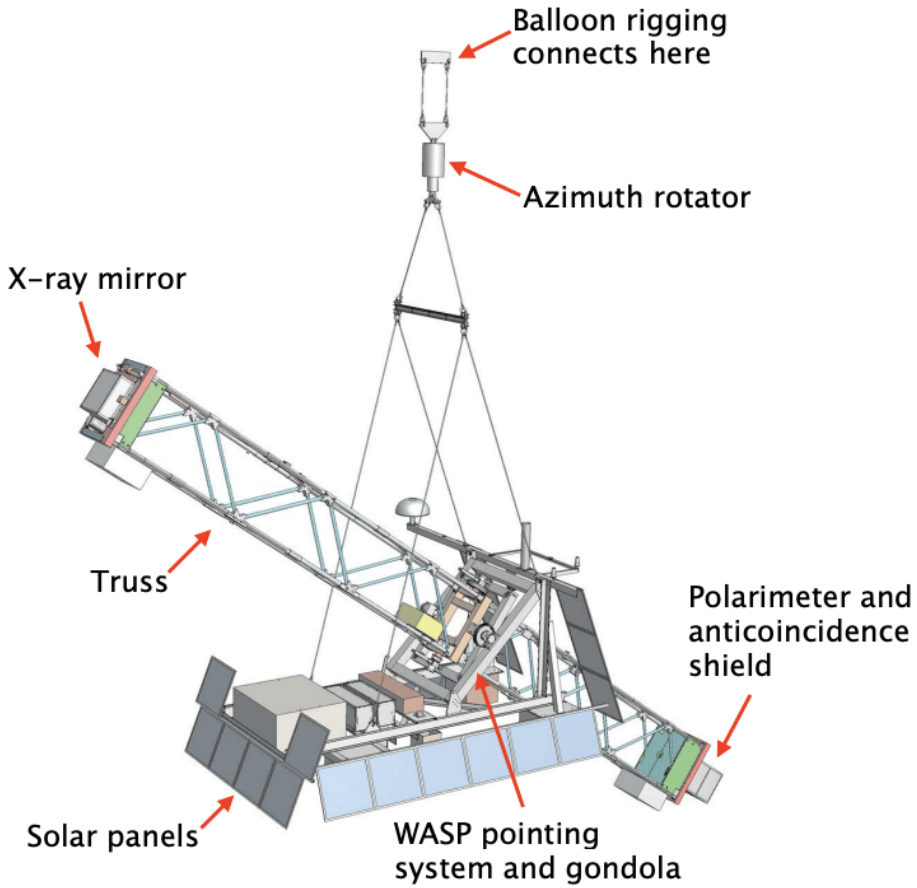
Swedish contributions to Upgrade & RNO-G pave the way for IceCube-Gen2

XL-Calibur

9 institutions from
US, Japan, Sweden, KTH joined in 2018

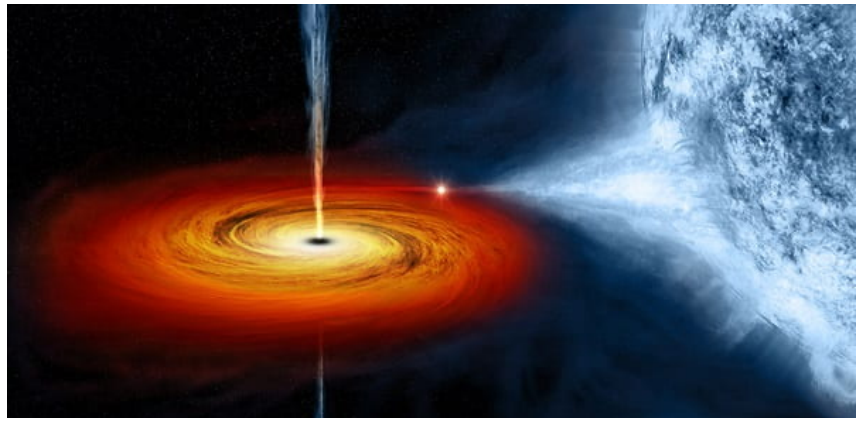
KTH
- Long experience in balloon-borne astroparticle physics, x-ray polarimetry
- Built, operated PoGO+ (Polarized Gamma-ray Observer)

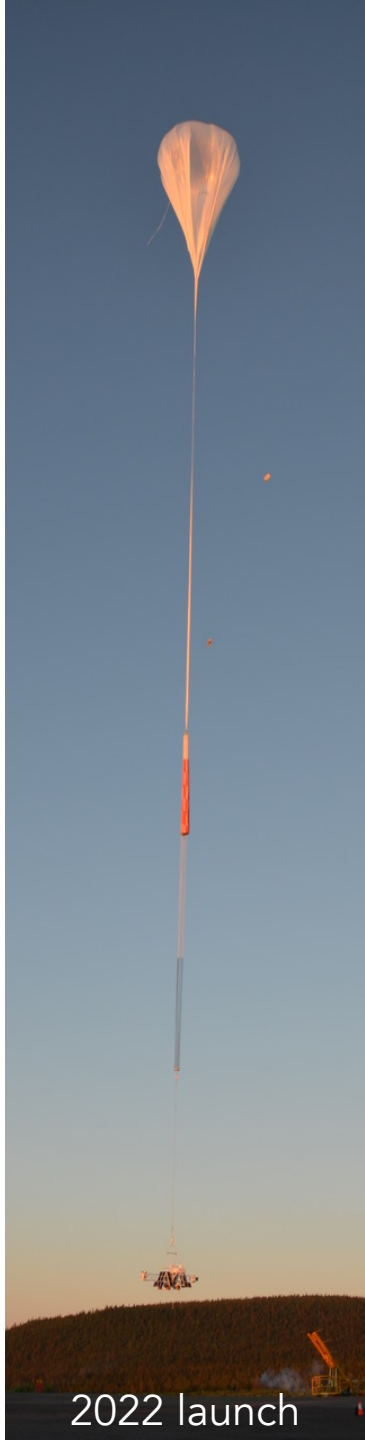
XL-Calibur
- order of magnitude more sensitive than PoGO+
- KTH has designed and built the anti-coincidence shield



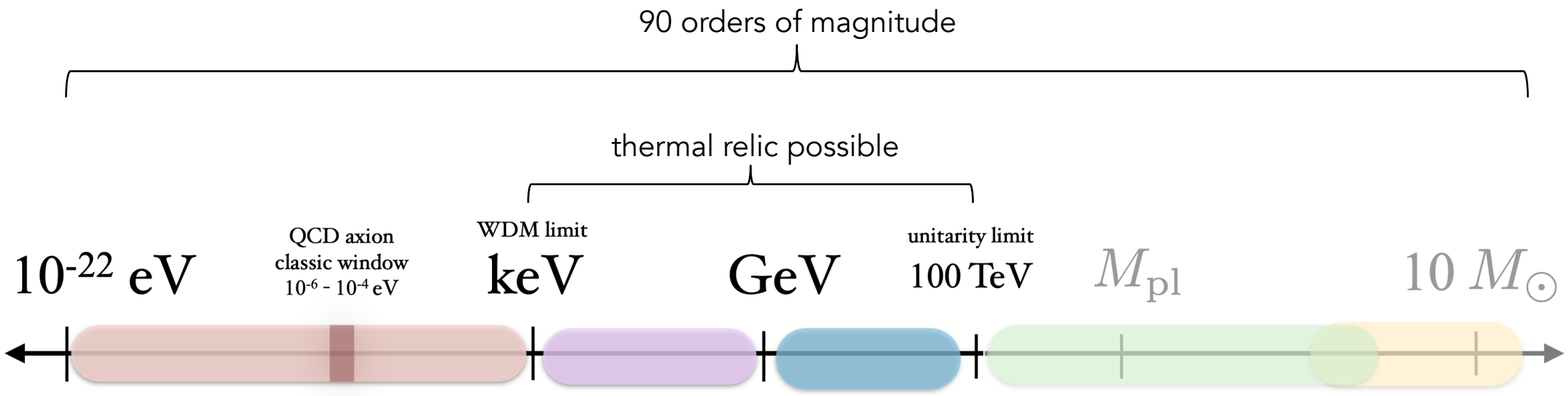
Launch from Esrange (northern Sweden) May 2024 (waiting for stratospheric winds)

Plan to observe the black-hole binary Cygnus X-1 and the Crab pulsar during week-long flight to Canada





Dark Matter Experiments



T. Lin,
1904.07915

alpha

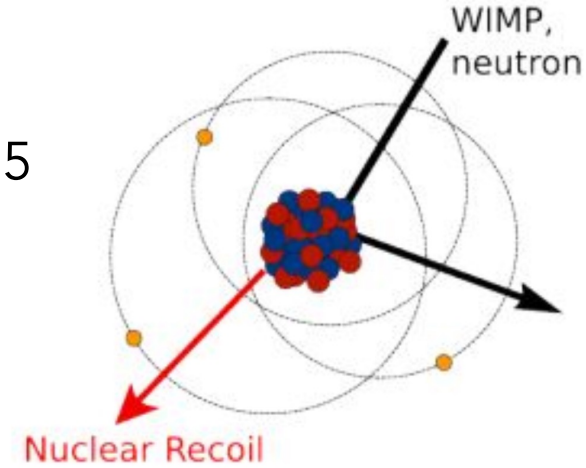
LDMX

XENON

DM Experiments with
Major Swedish Involvement

XENON Dark Matter Project

Located in Gran Sasso, Italy
29 institutions, 12 countries
Stockholm University member since 2015

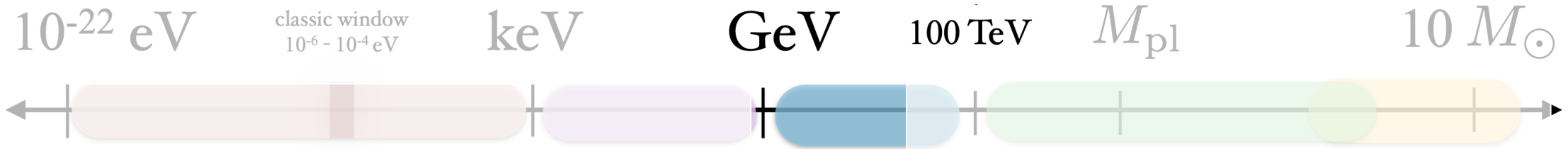


VR, K&A Wallenberg Project funding

SU contributes to physics analysis and to hardware

XENONnT uses 494 Photomultiplier tubes (PMTs)
- PMTs were tested in liquid xenon at SU
- Assembly of the XENONnT arrays in 2019 led by SU

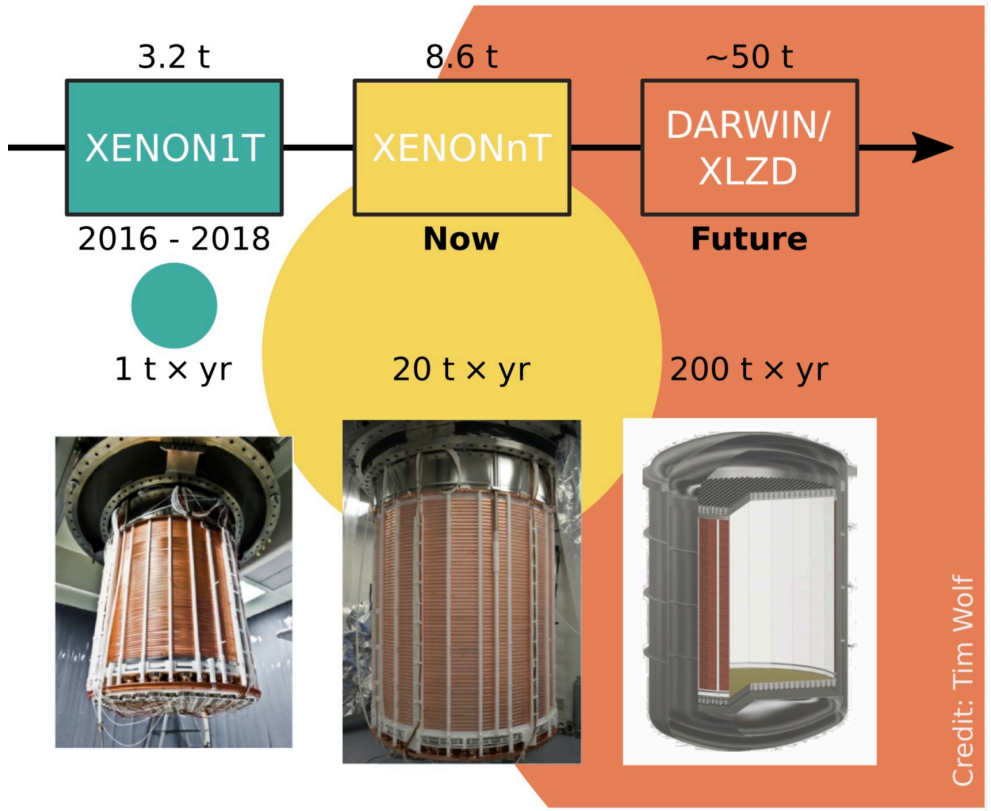
Taking science data since 2021

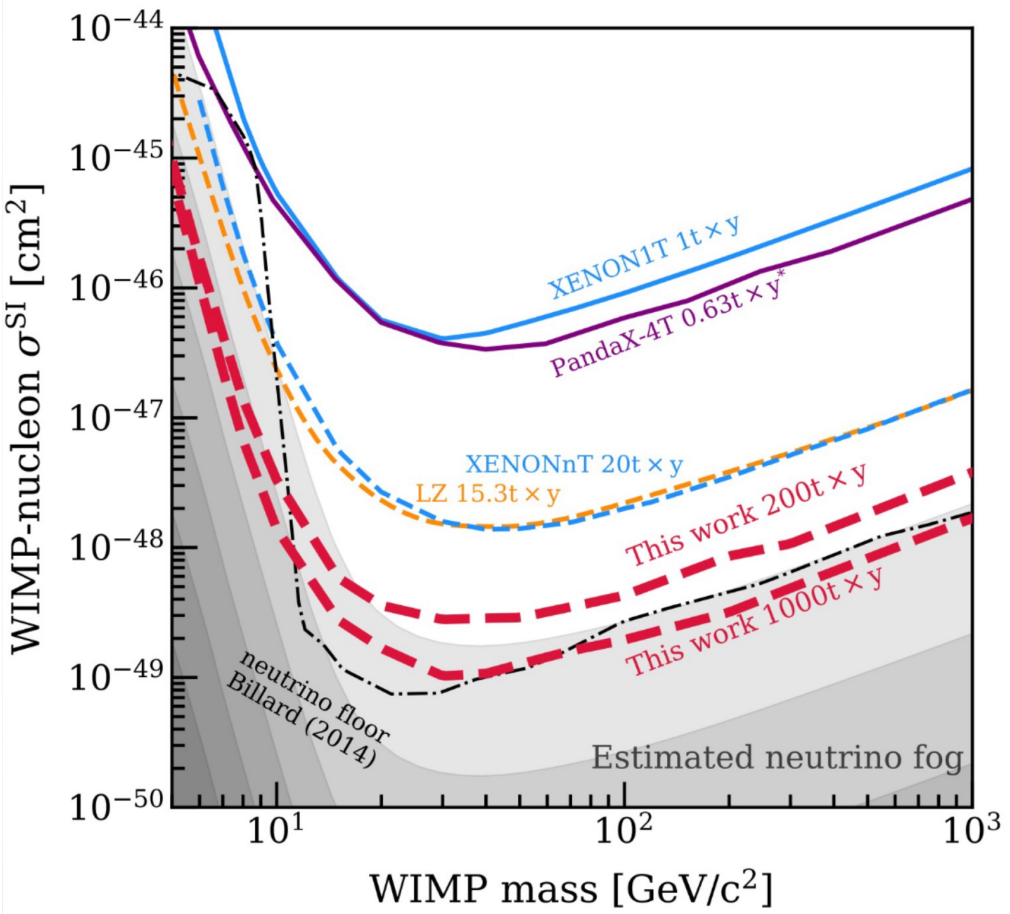


Future: XENON + LUX-ZEPLIN + DARWIN = XLZD

www.xlzd.org

SU - R&D on novel photosensors
- Co-lead of detector design and R&D working group





Covering all the remaining WIMP space until reaching the neutrino floor -> fog

The Light Dark Matter Experiment: LDMX

Located at SLAC, California

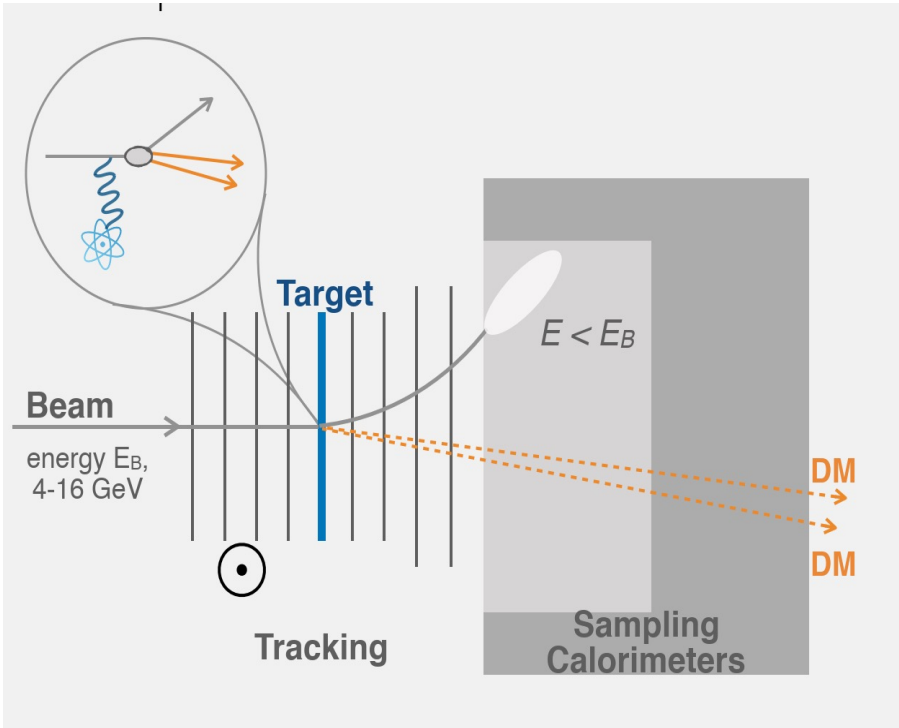
9 US institutions + **Lund University**

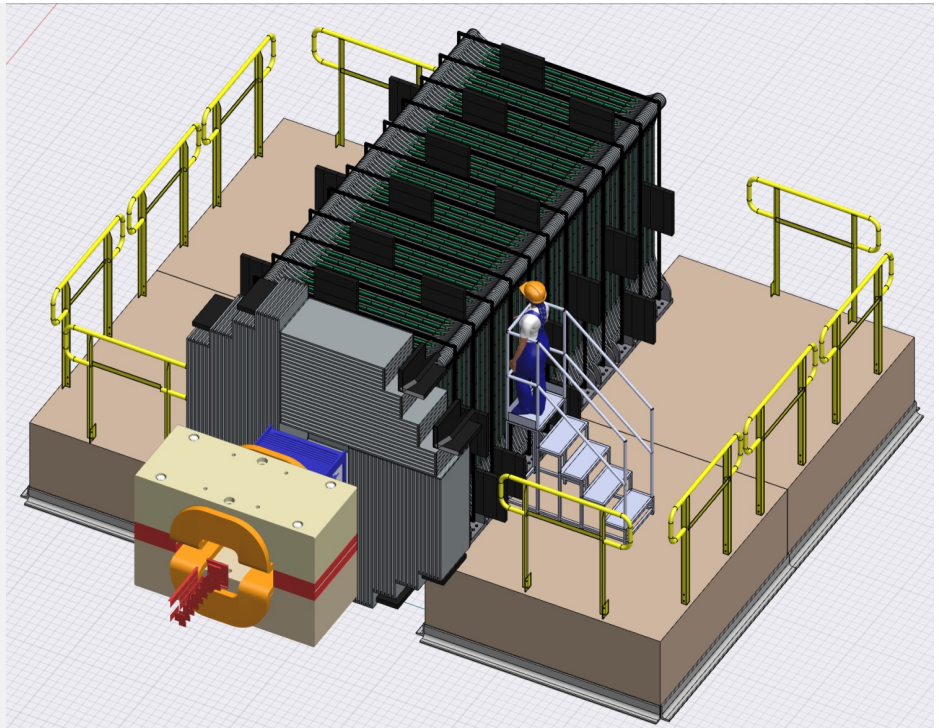
funded by VR; Crafoord; KAW project "Light Dark Matter" (also with Chalmers, Stockholm U.)

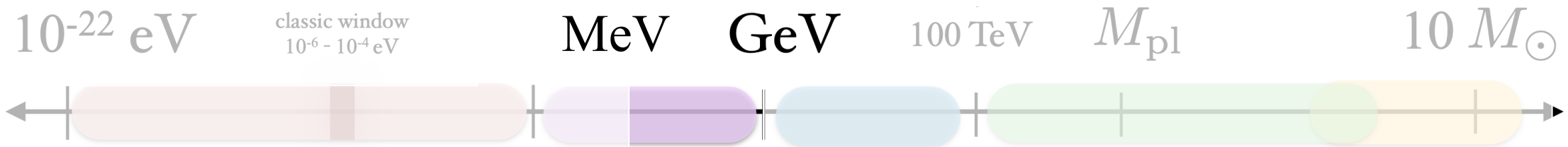
4 & 8 GeV electron beam

10^{16} electrons
=> Produce sub-GeV DM if thermal relic

Look for deflection and missing *E*







The Light Dark Matter Experiment: LDMX

Dedicated Beamline under construction

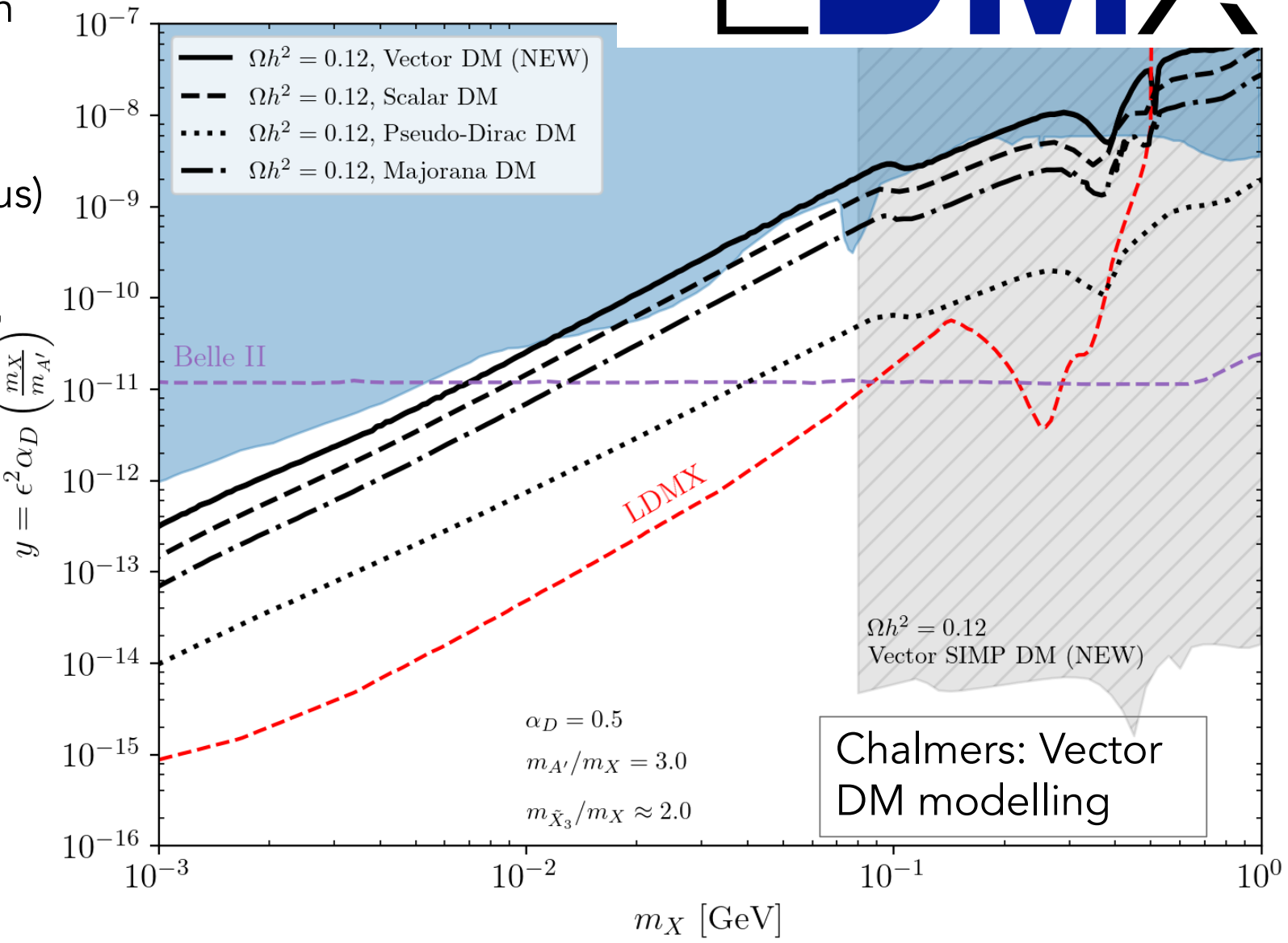
2026 – Start full LDMX construction

2029 – Data taking with 8 GeV beam

(Could start earlier with partial apparatus)

Major Lund contributions:

- HCal design and performance
- Joined Geant4, strengthening its low-energy modelling
- initiated the grid computing system (LDCS) for LDMX
- Multi-electron triggering and analysis
- Leadership from Lund:
  - Co-Spokesperson
  - Physics co-coordinator
  - Computing co-coordinator



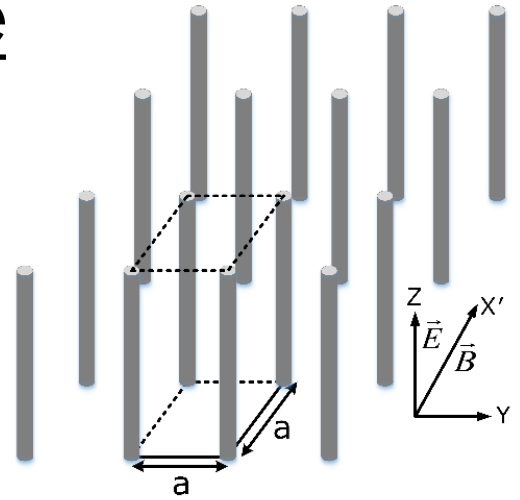
Chalmers: Vector DM modelling

ALPHA: Axion Longitudinal Plasma HAloscope

14 institutes in 6 countries

Spokesperson Stockholm U.

Funded by VR and KAW grants



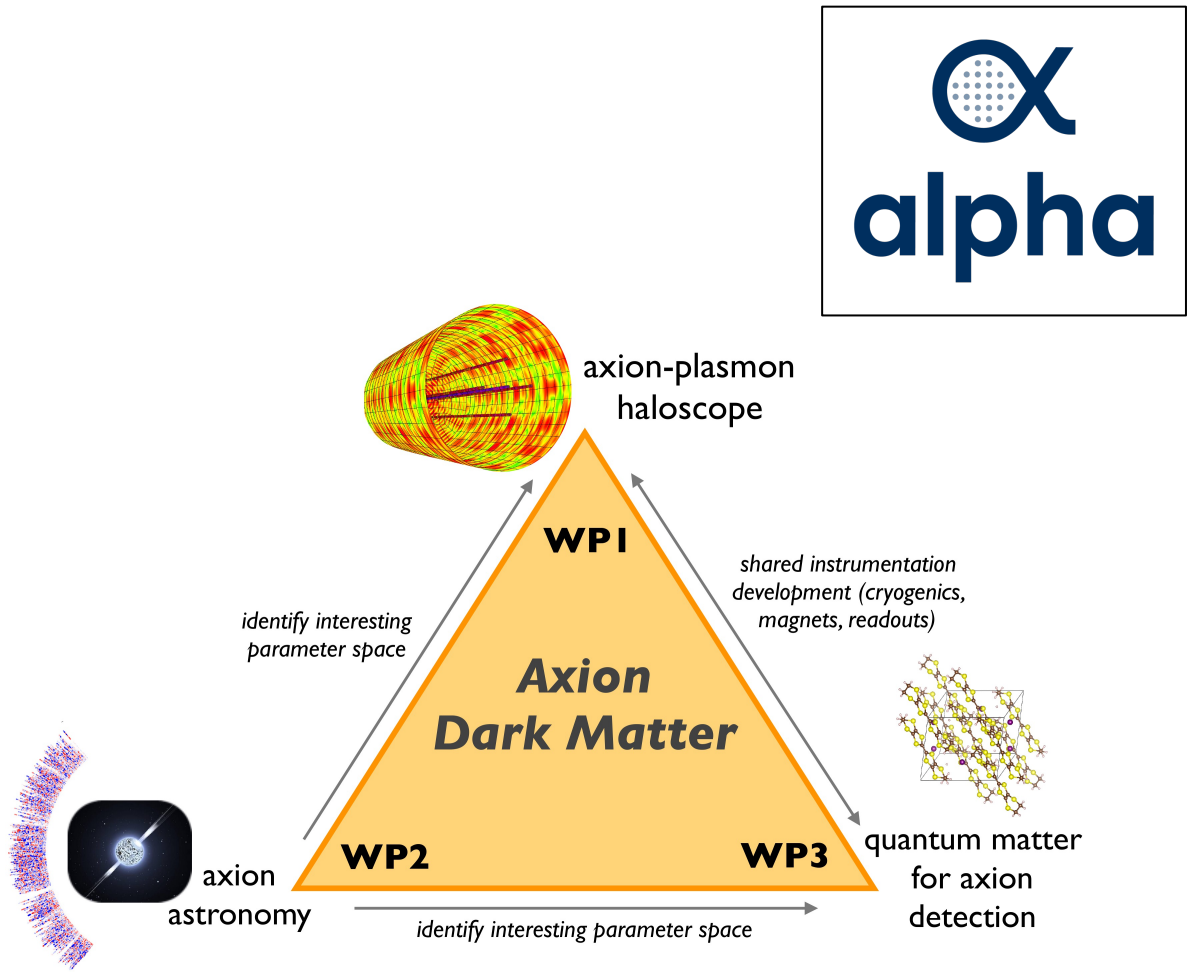
Construction of detector at Stockholm U.

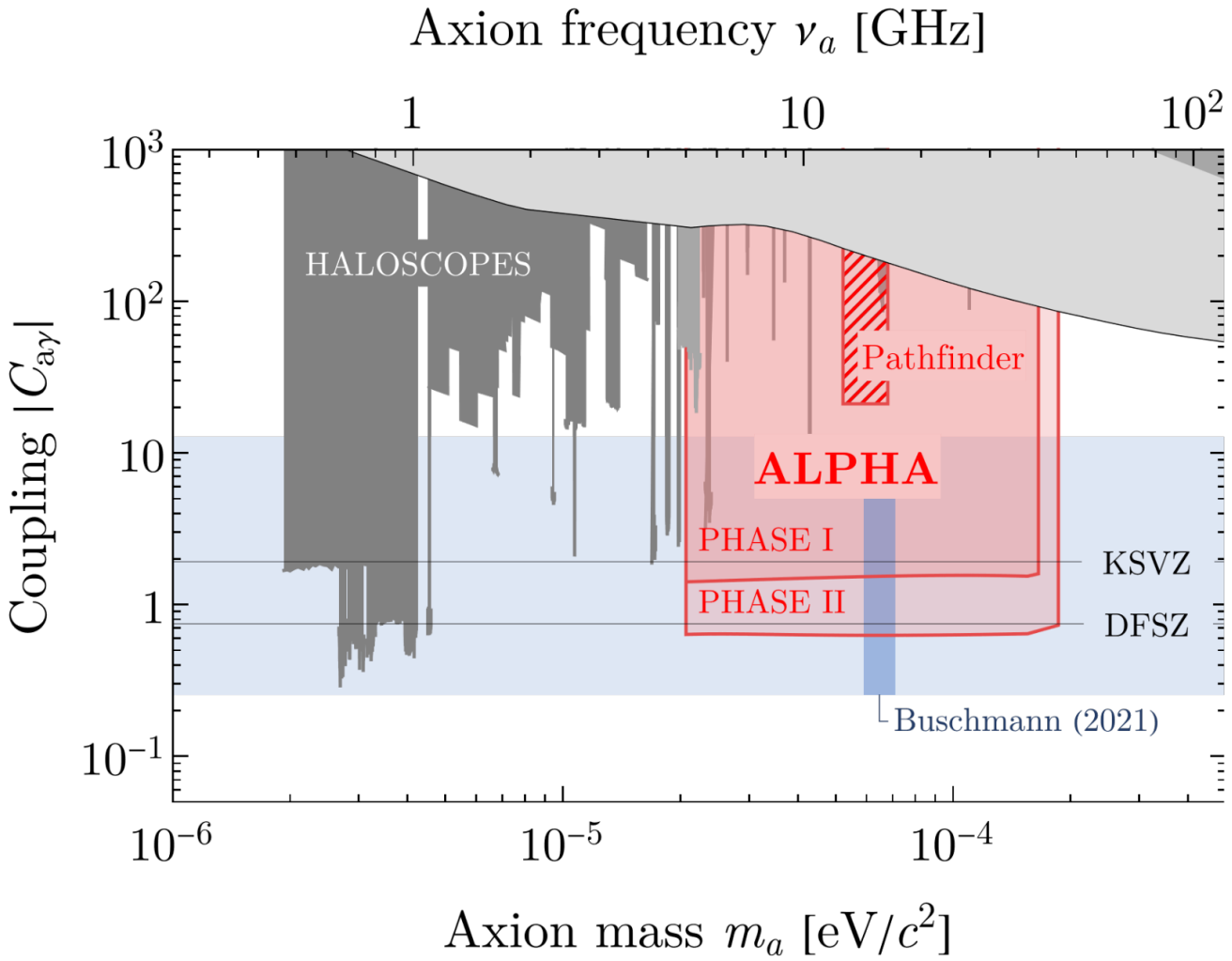
Perform experiment (in high B field) in US at Yale

Metamaterial: Artificial plasma
- Effective medium with tunable plasma frequency
- frequency depends on lattice geometry
- Tunability based on wire spacing
- Operate at cryogenic temps and high B fields

ALPHA: Axion Longitudinal Plasma HAloscope

First data run expected 2026





ALPHA is one part of VR-funded Research Environment: AxionDM — theorists and experimentalists

Summary

Sweden hosts vibrant astroparticle physics activity

Participates in world class international projects

Achieves international visibility

Program focused towards
- Dark matter searches
- Multimessenger astronomy

Future plans aligned with those of the international community

photo: David Björken