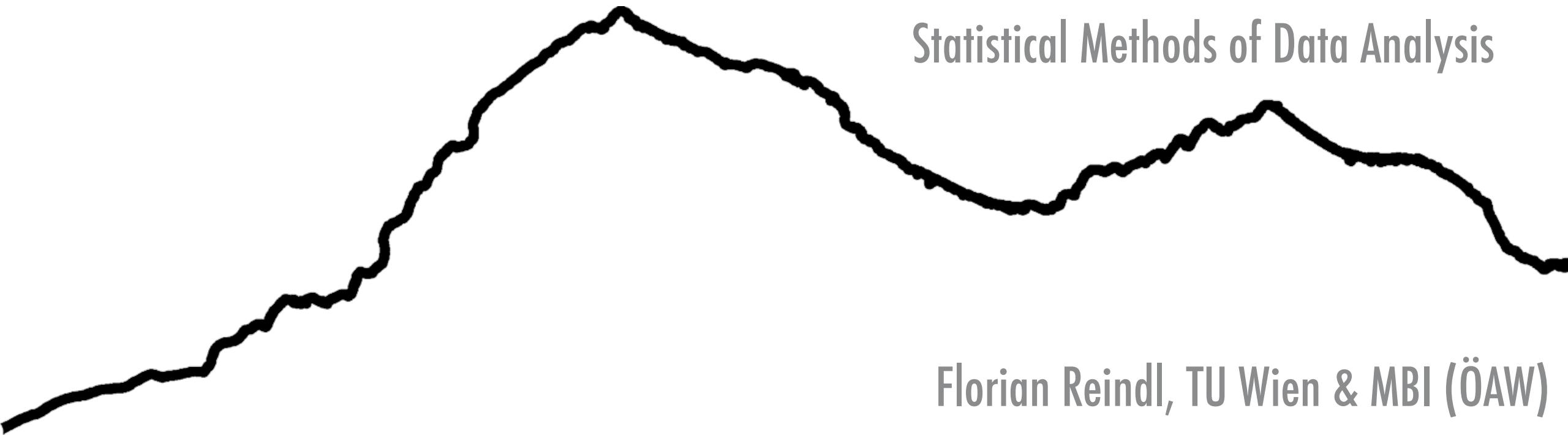


RARE EVENT SEARCHES

@MBI / TU WIEN

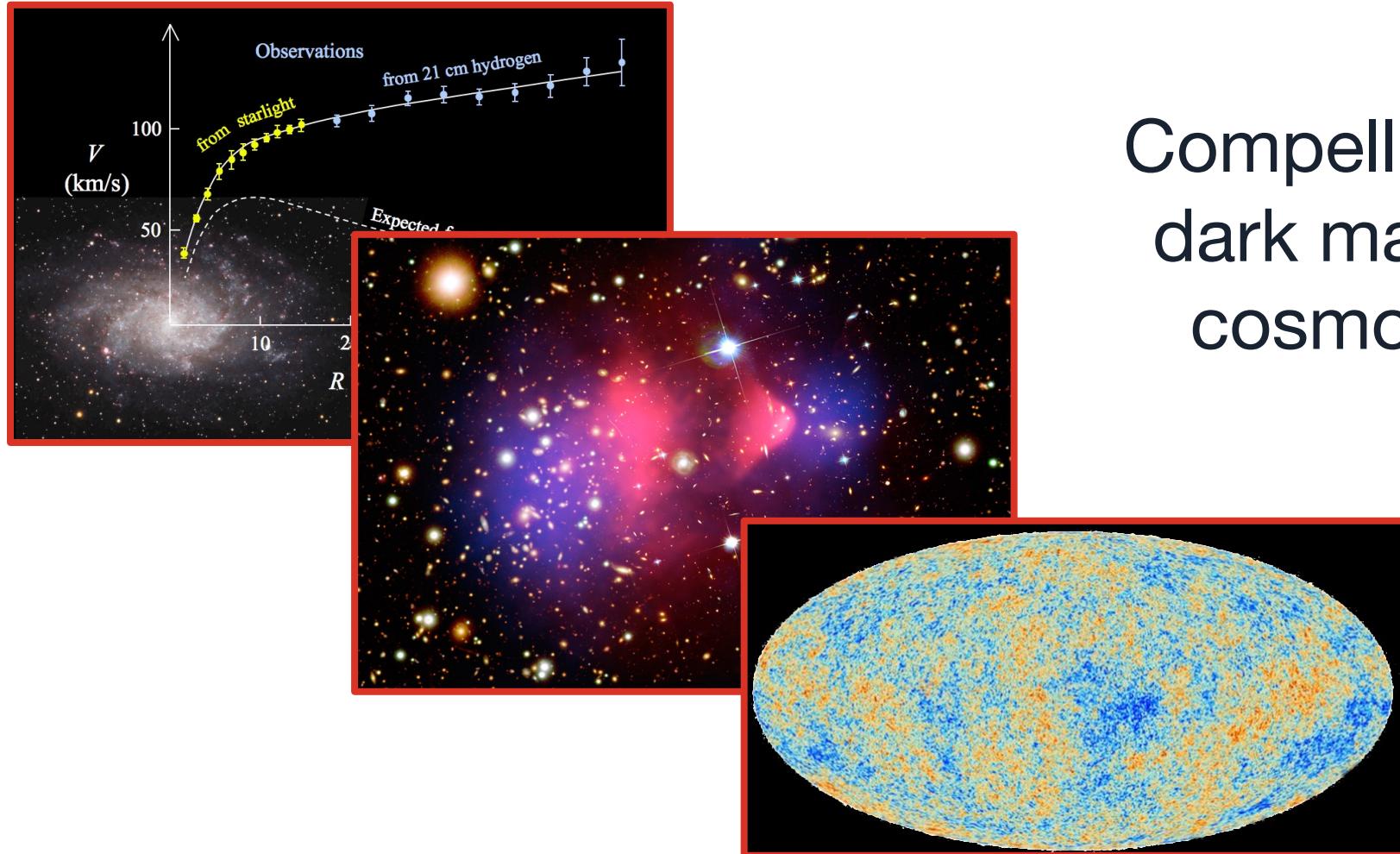
Dec. 2025

Statistical Methods of Data Analysis



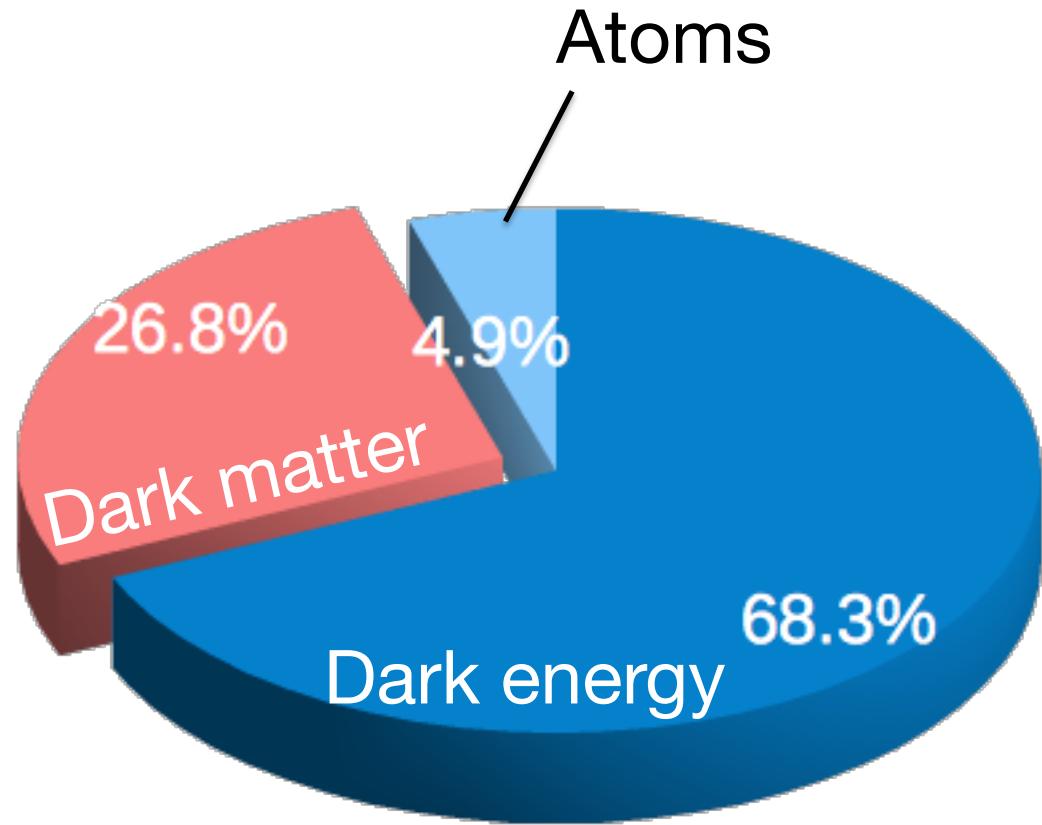
Florian Reindl, TU Wien & MBI (ÖAW)

EVIDENCE FOR DARK MATTER



Compelling evidence for
dark matter on various
cosmological scales

DARK MATTER



Astronomy

There is a lot of dark matter
in the Universe!

(Astro-) Particle Physics

What is it made of?

DARK MATTER = PHYSICS BEYOND THE STANDARD MODEL

Standard Model Plus Set



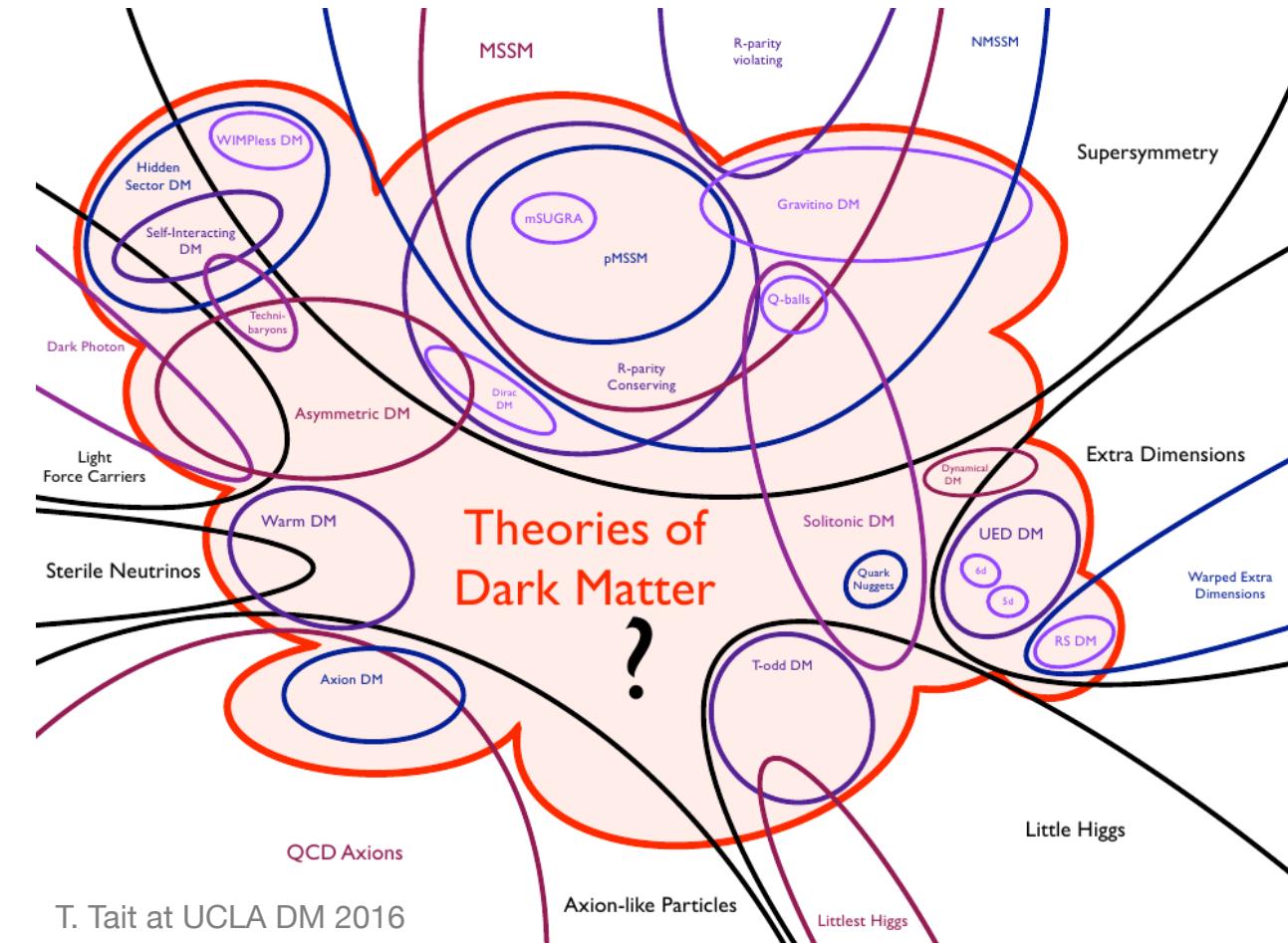
Available at <https://www.particlezoo.net/products/standard-model-plus> for €197,95

DARK MATTER = PHYSICS BEYOND THE STANDARD MODEL

Standard Model Plus Set



Available at <https://www.particlezoo.net/products/standard-model-plus> for €197,95

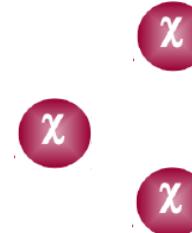


T. Tait at UCLA DM 2016

DIRECT DETECTION OF DARK MATTER

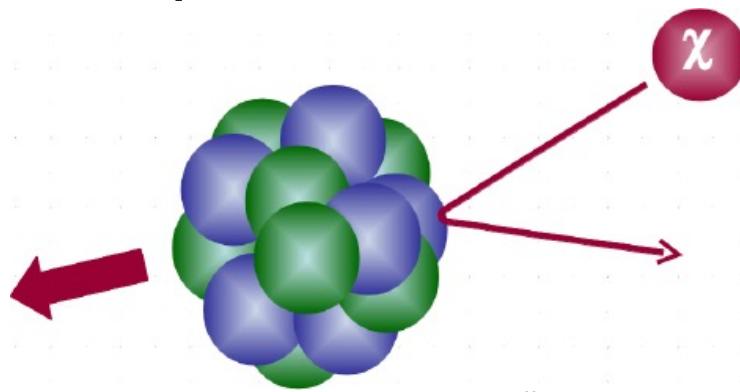
basic idea

dark matter is made of particles
which interact with Standard Model particles



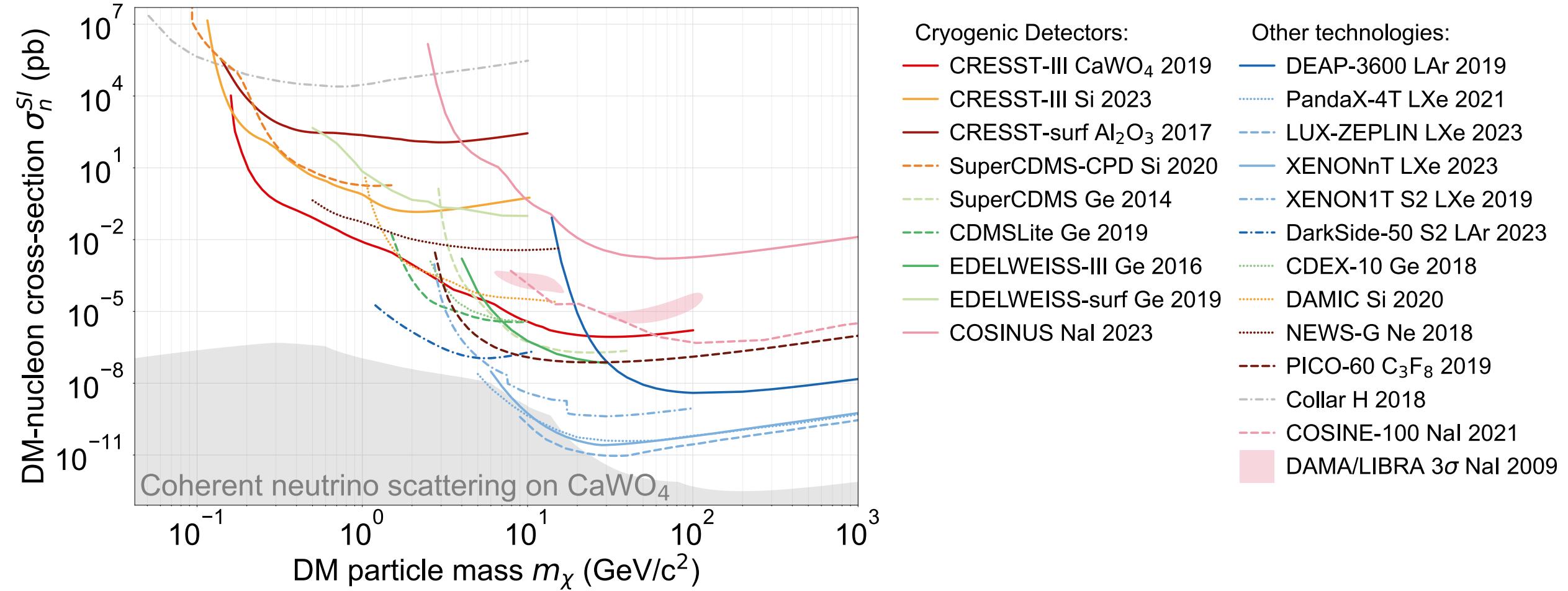
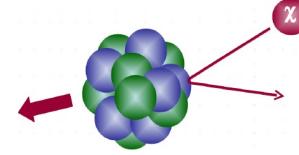
most common

dark matter particles induce nuclear recoils



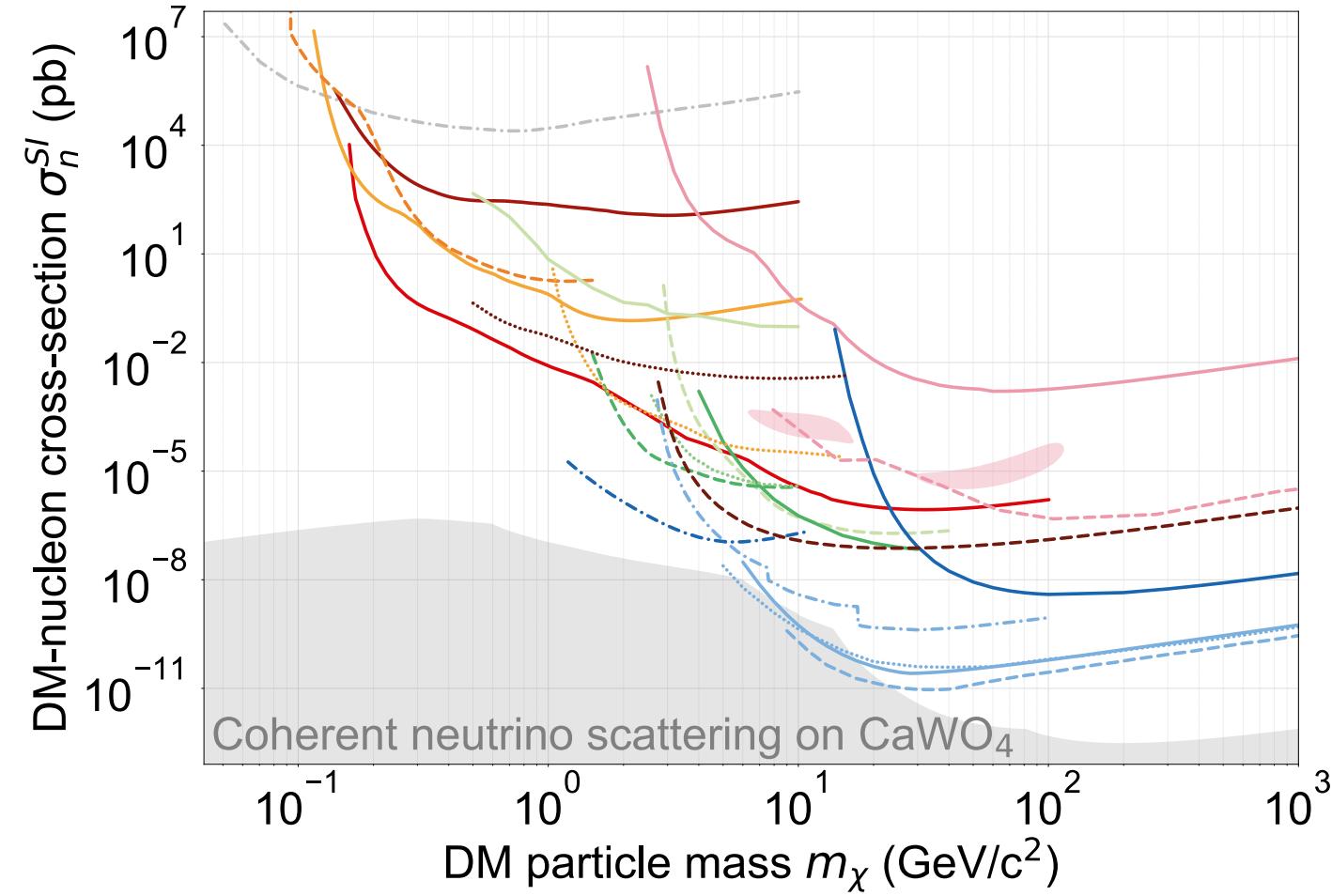
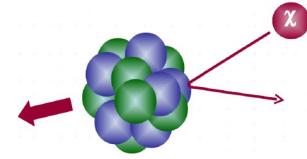
F. Reindl

STATUS DIRECT DARK MATTER DETECTION

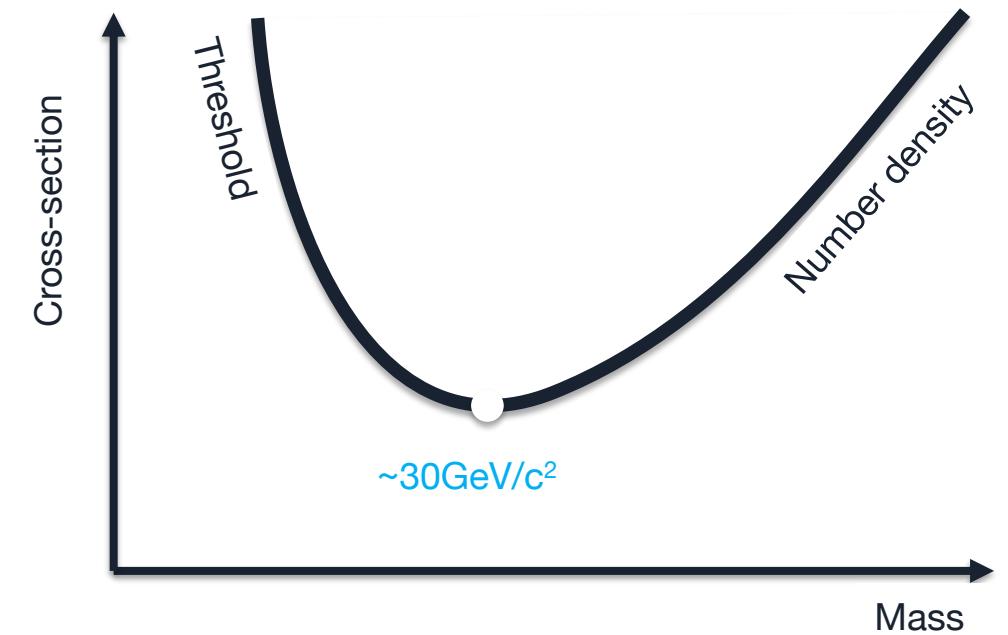


Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

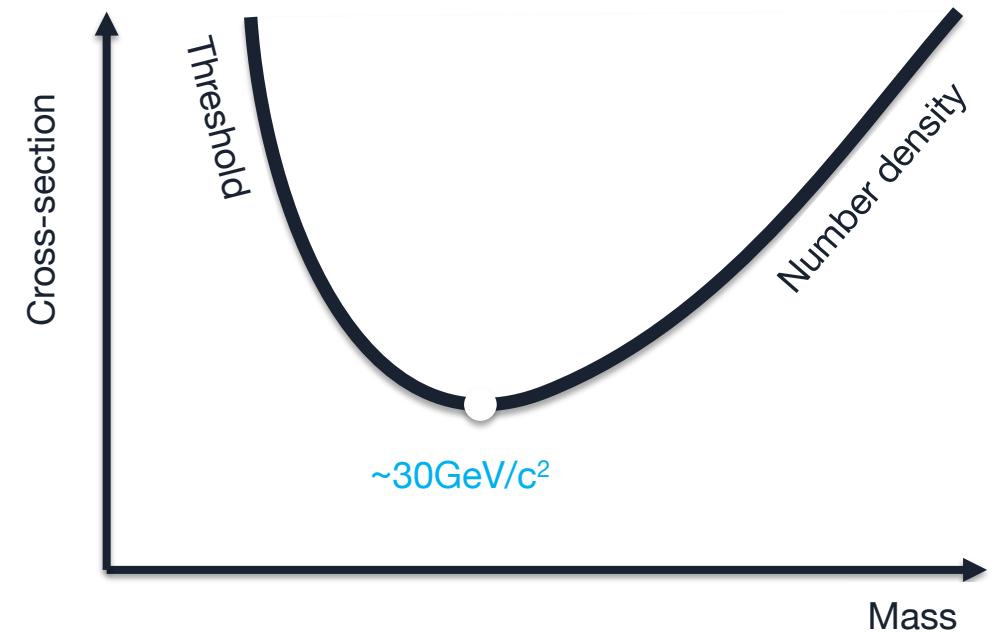
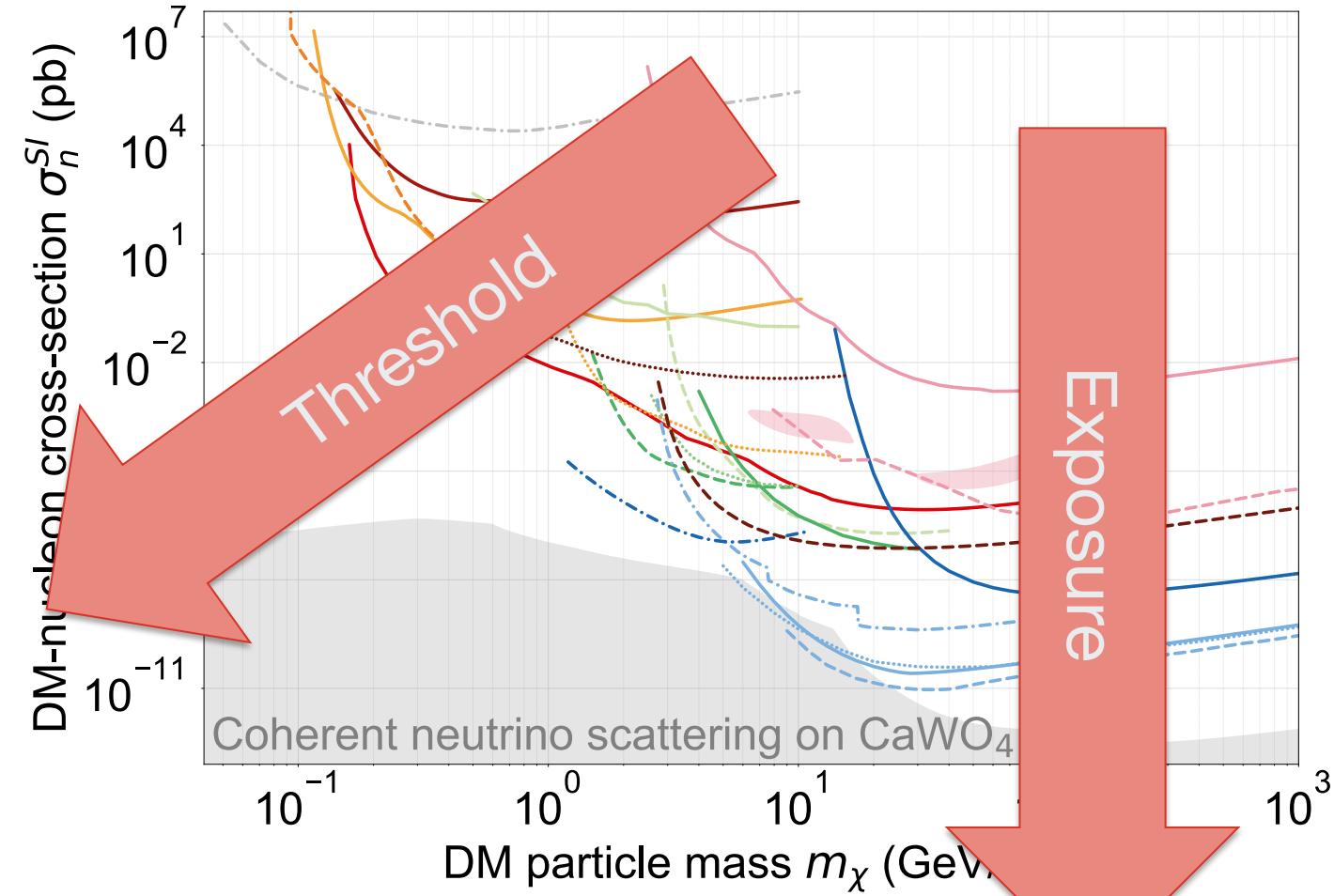
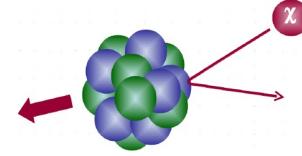
STATUS DIRECT DARK MATTER DETECTION



Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

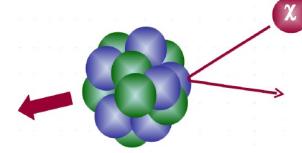


STATUS DIRECT DARK MATTER DETECTION

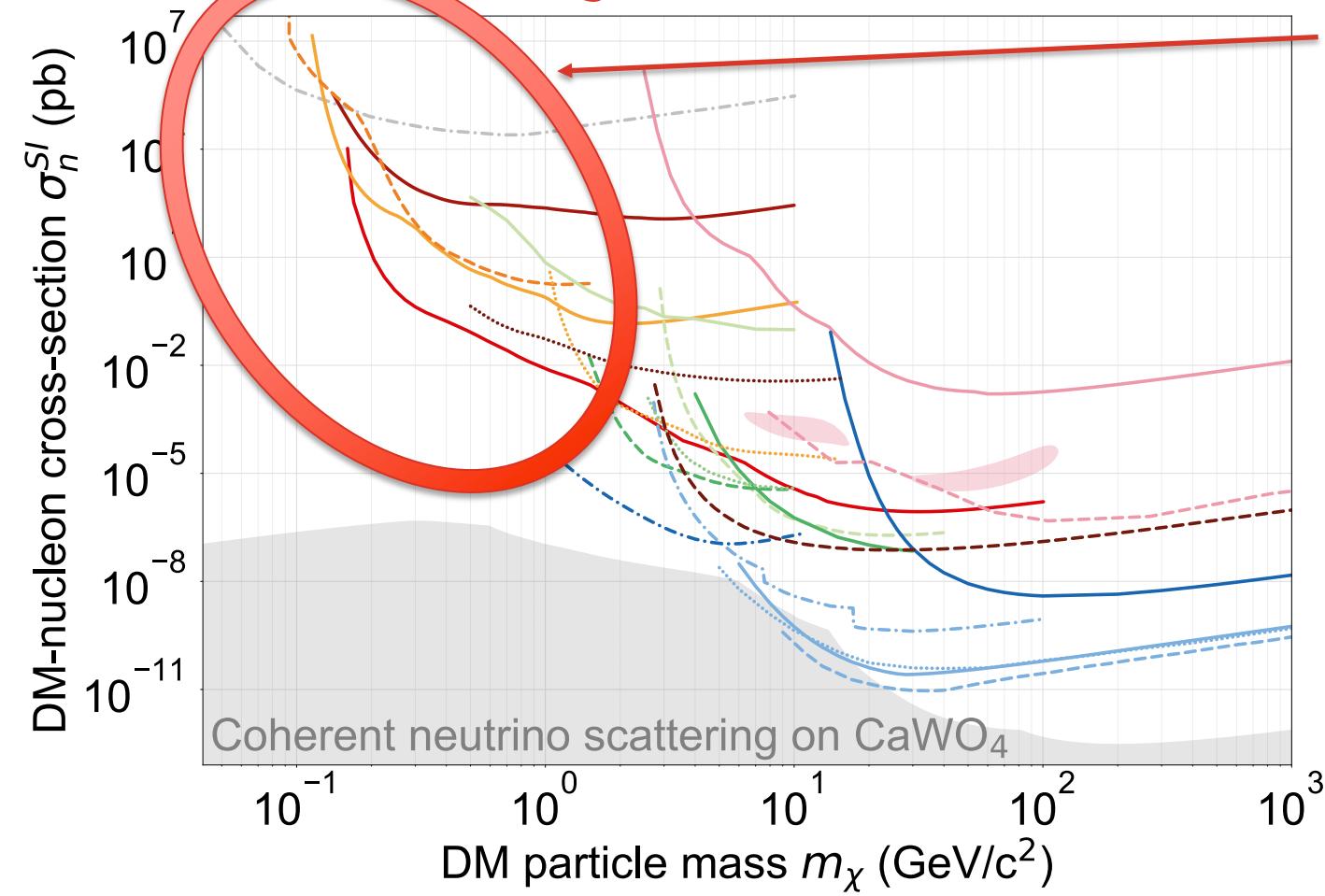


Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION



Cryogenics



Cryogenic Detectors:

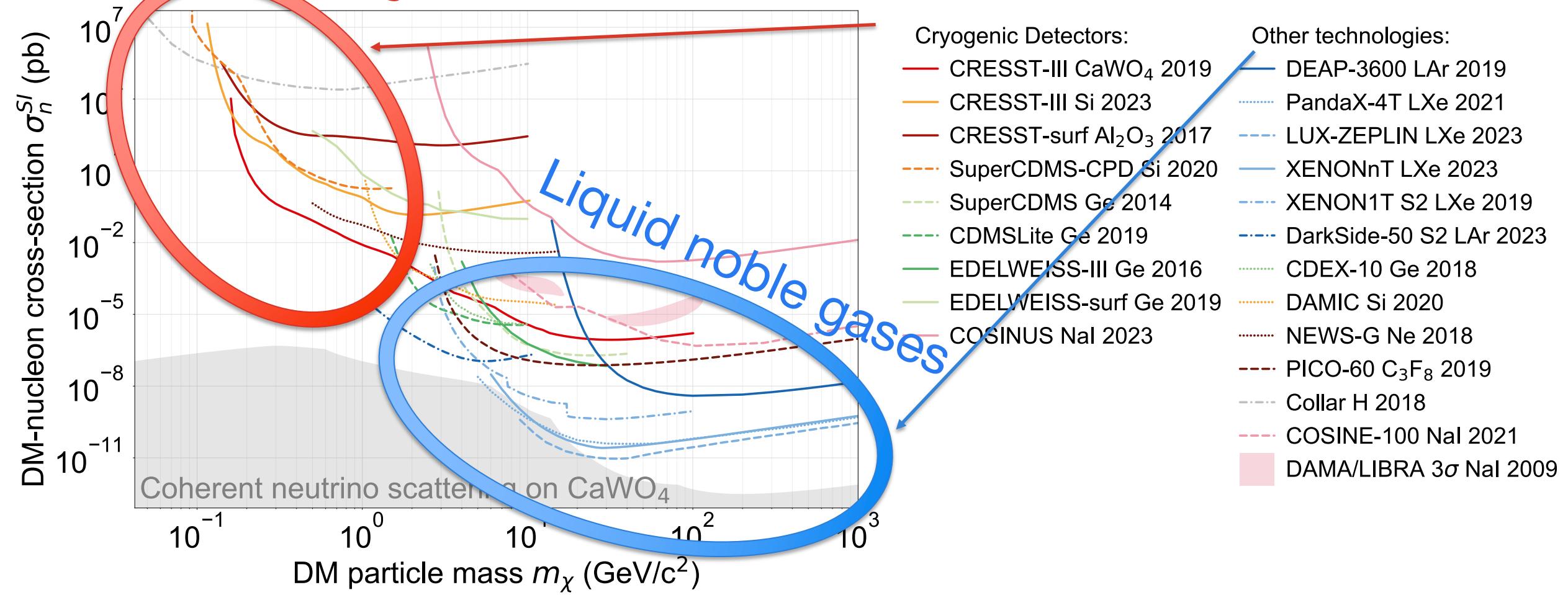
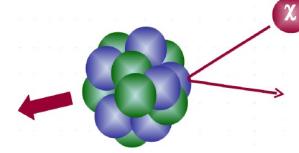
- CRESST-III CaWO₄ 2019
- CRESST-III Si 2023
- CRESST-surf Al₂O₃ 2017
- - SuperCDMS-CPD Si 2020
- - SuperCDMS Ge 2014
- - CDMSLite Ge 2019
- - EDELWEISS-III Ge 2016
- - EDELWEISS-surf Ge 2019
- - COSINUS NaI 2023

Other technologies:

- DEAP-3600 LAr 2019
- ... PandaX-4T LXe 2021
- - LUX-ZEPLIN LXe 2023
- XENONnT LXe 2023
- - XENON1T S2 LXe 2019
- - DarkSide-50 S2 LAr 2023
- - CDEX-10 Ge 2018
- - DAMIC Si 2020
- ... NEWS-G Ne 2018
- - PICO-60 C₃F₈ 2019
- - Collar H 2018
- - COSINE-100 NaI 2021
- DAMA/LIBRA 3 σ NaI 2009

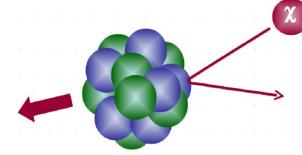
Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION

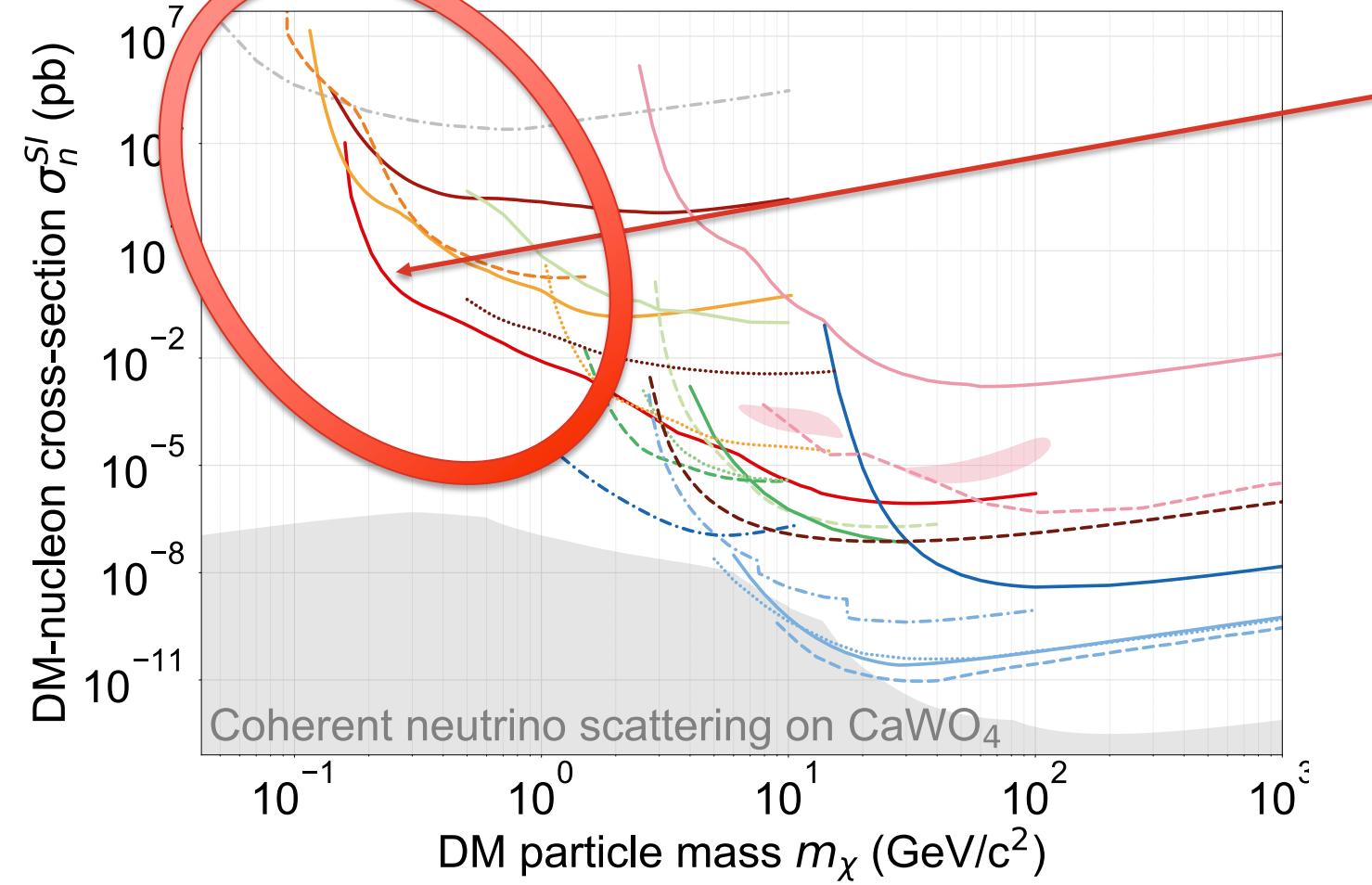


Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION



Cryogenics

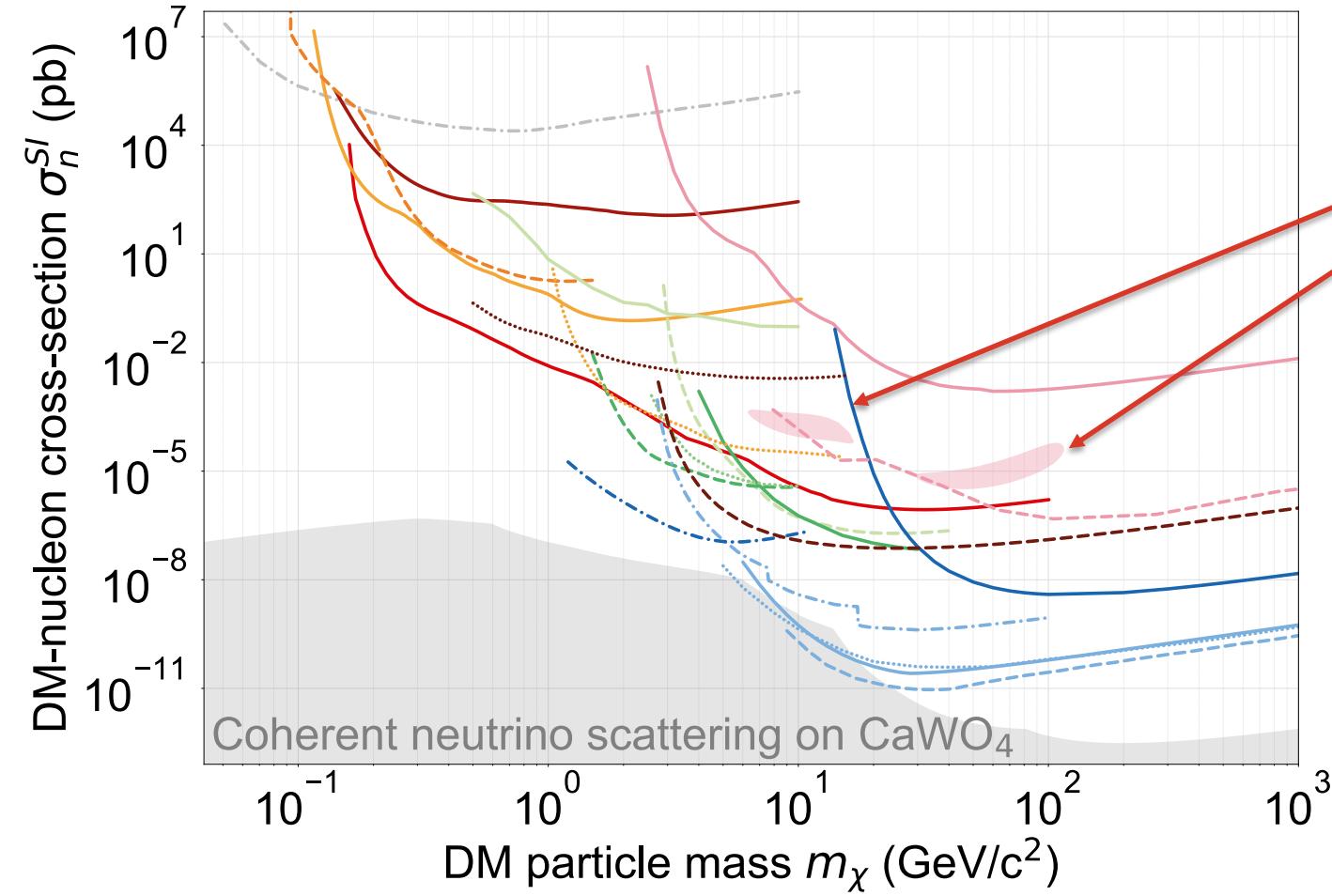
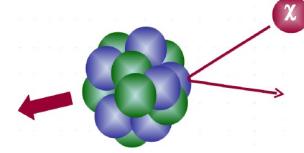


CRESST

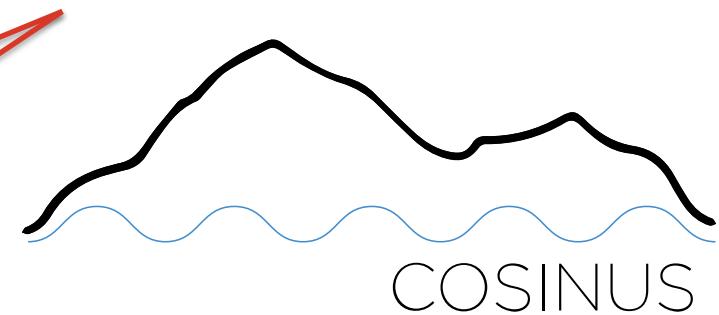
search for light dark
matter with low-
threshold cryogenic
detectors

Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION



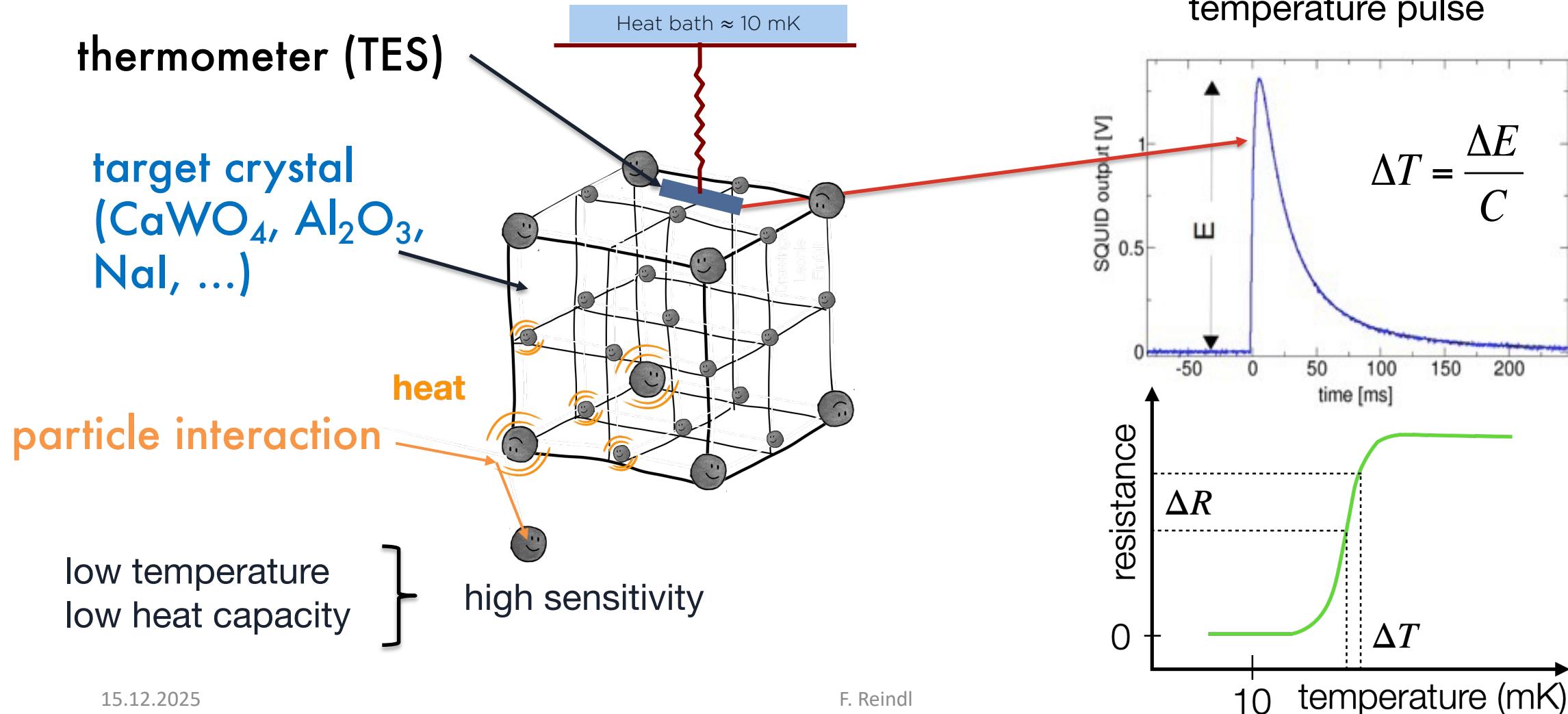
DAMA: strong DM claim (13.7σ)



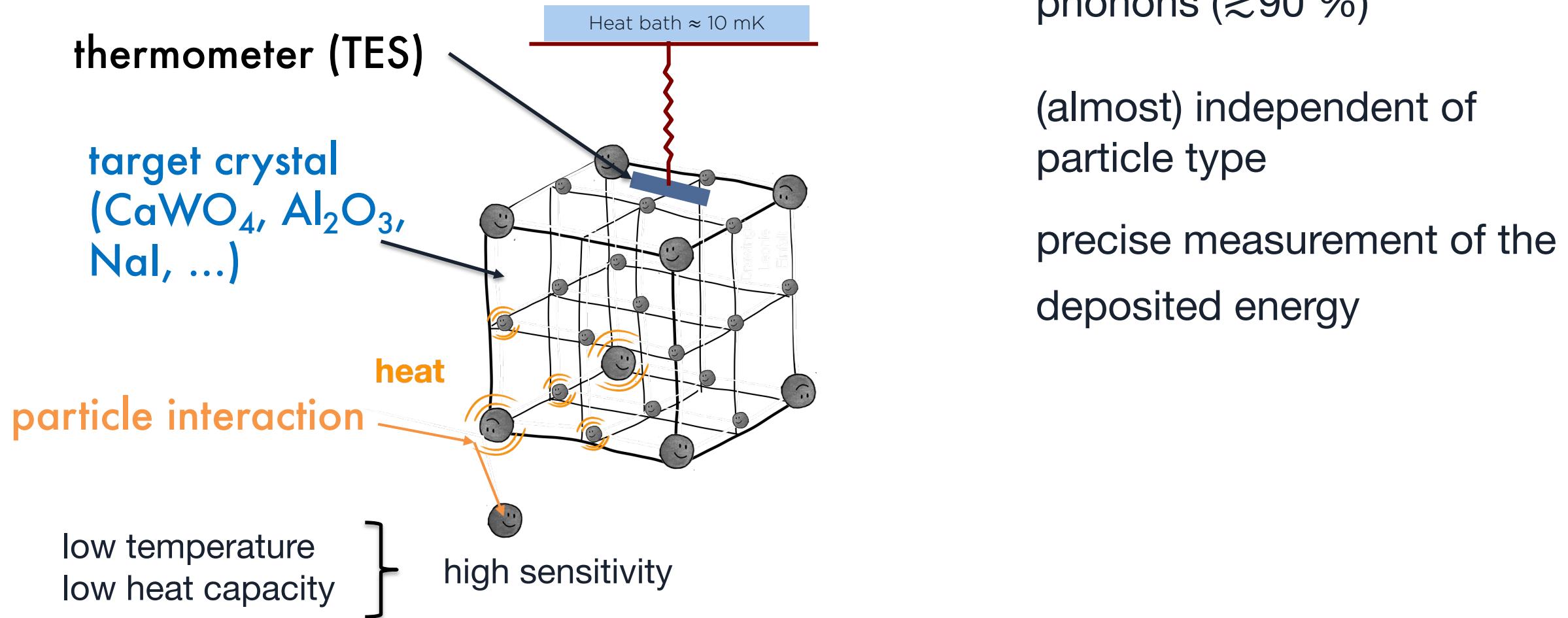
clarify the DAMA claim in a
model-independent way
using a same-material
(NaI) cryogenic detector

Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

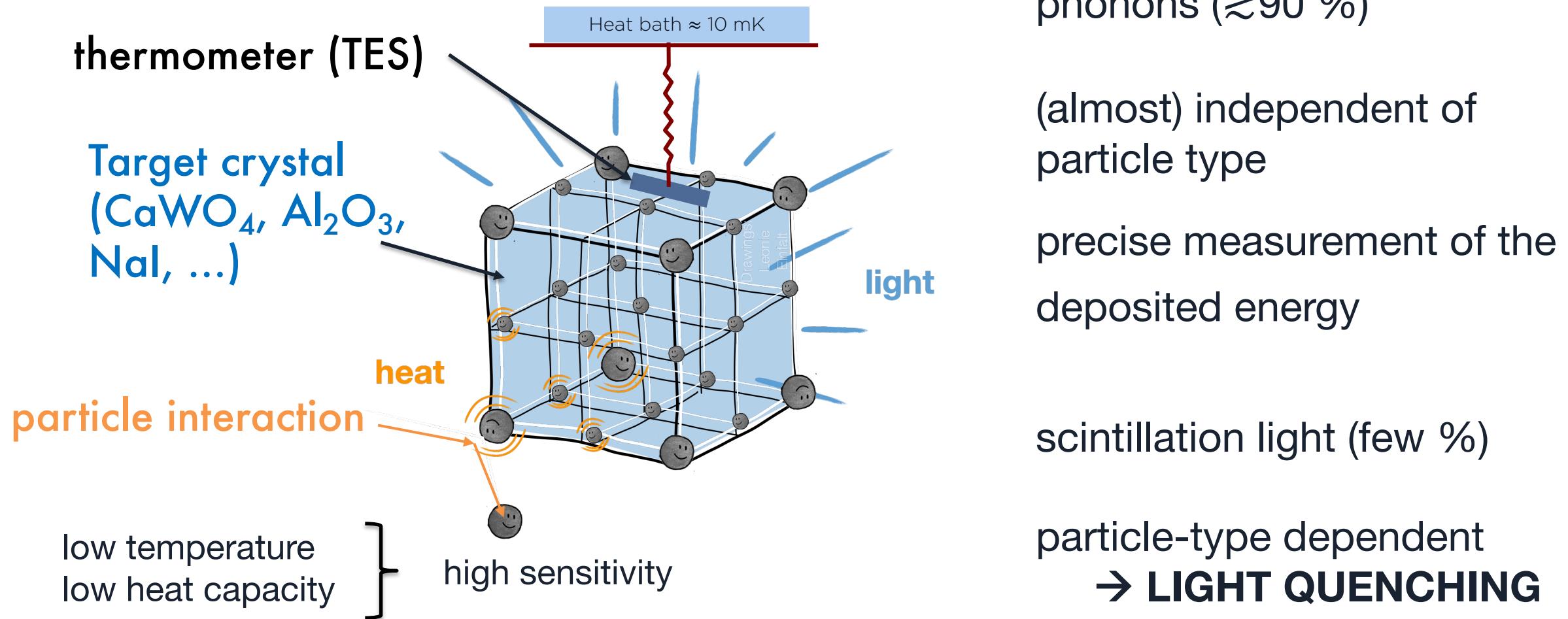
CRYOGENIC DETECTOR



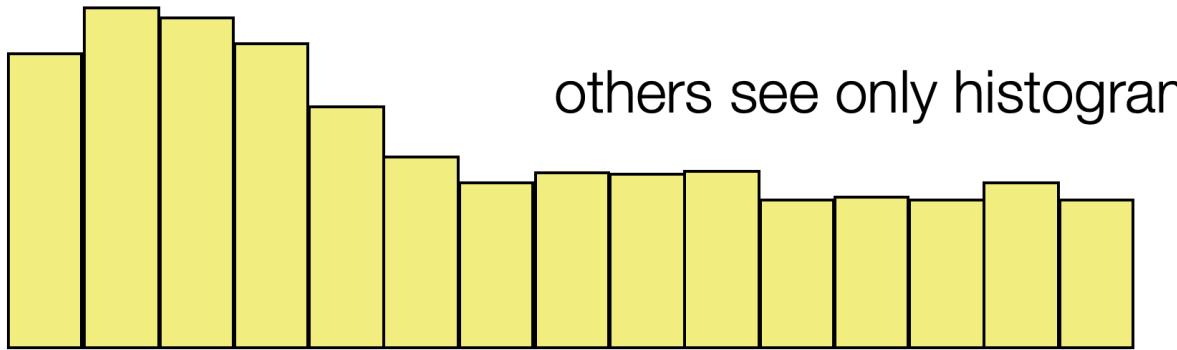
CRYOGENIC DETECTOR



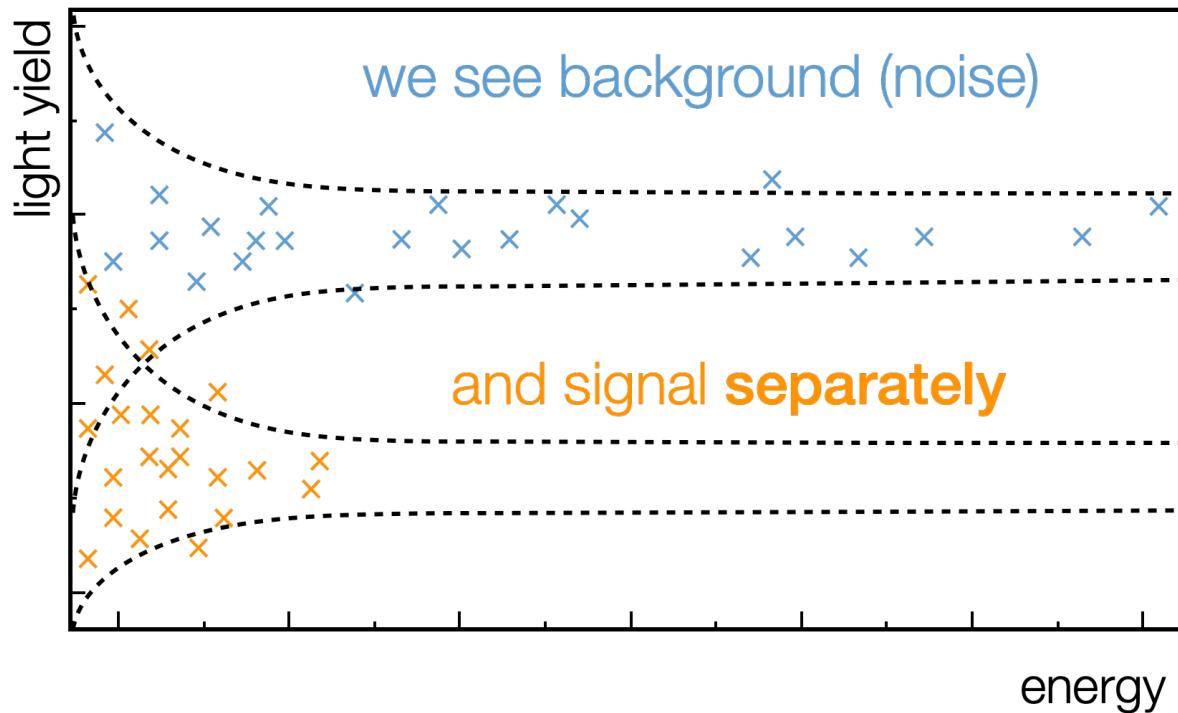
SCINTILLATING CALORIMETER



THE CRUCIAL DIFFERENCE

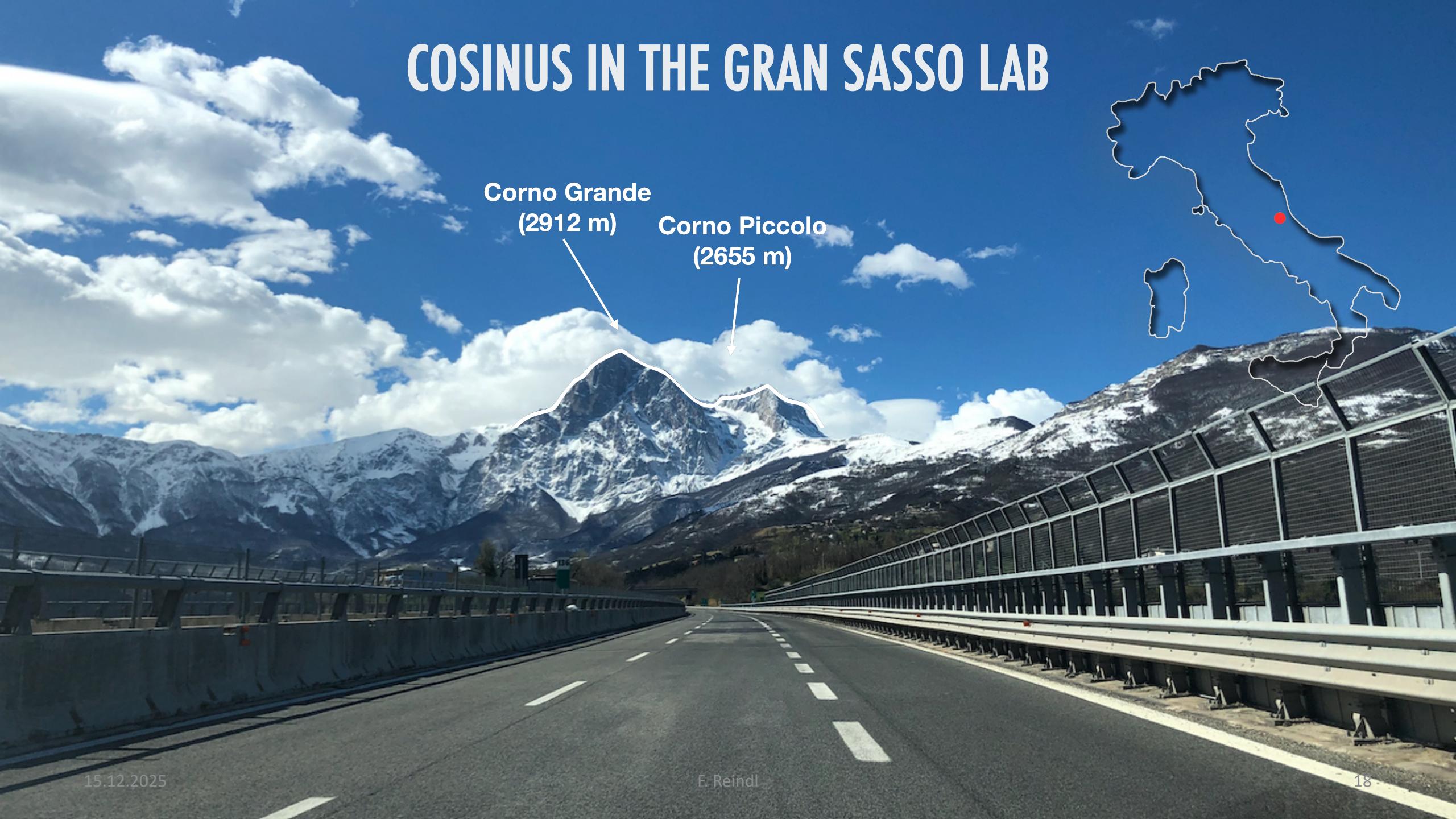


experiments (like DAMA/LIBRA)
which read only one channel



experiments (like COSINUS
and CRESST) who read two
channels

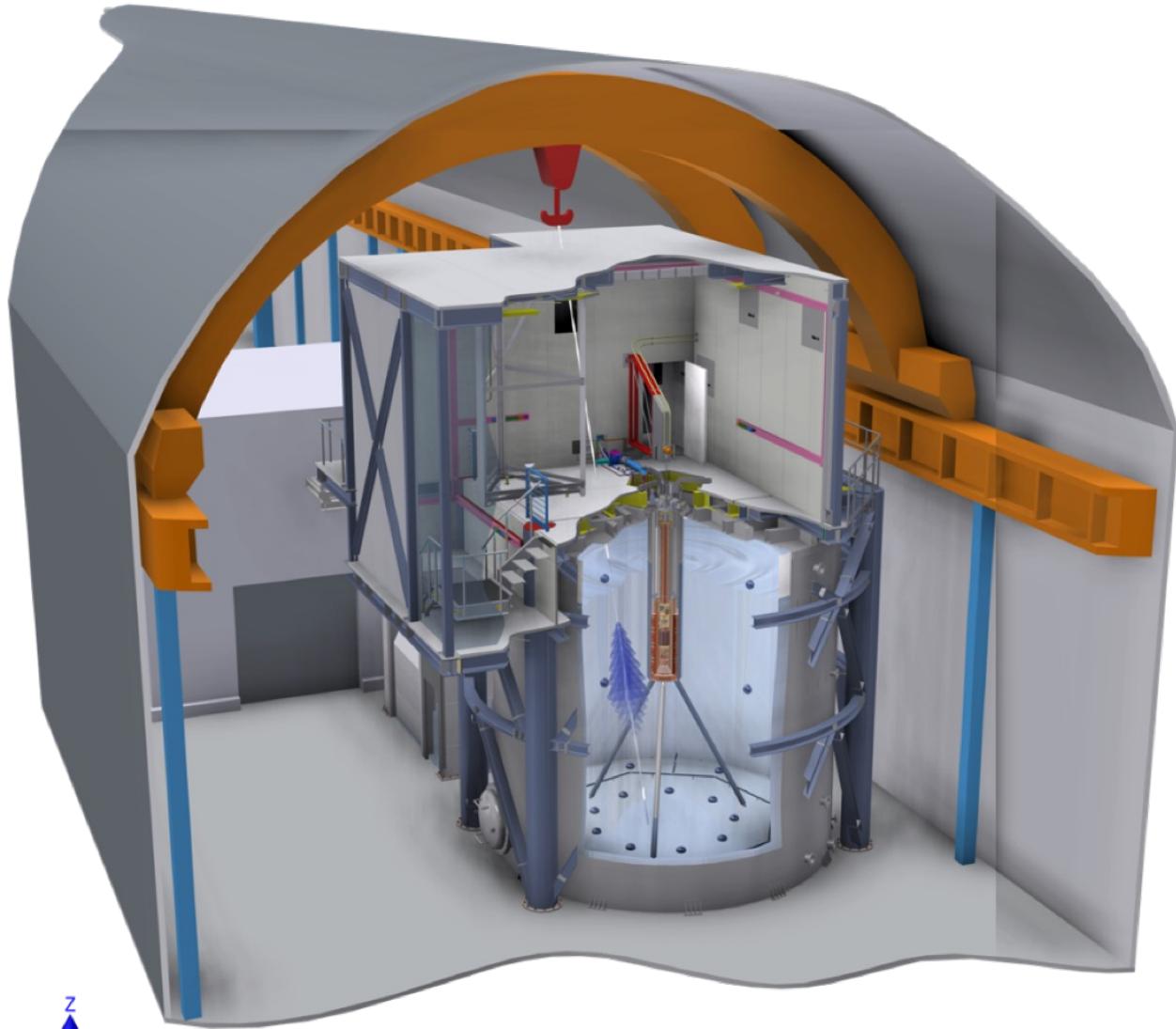
COSINUS IN THE GRAN SASSO LAB



COSINUS IN THE GRAN SASSO LAB

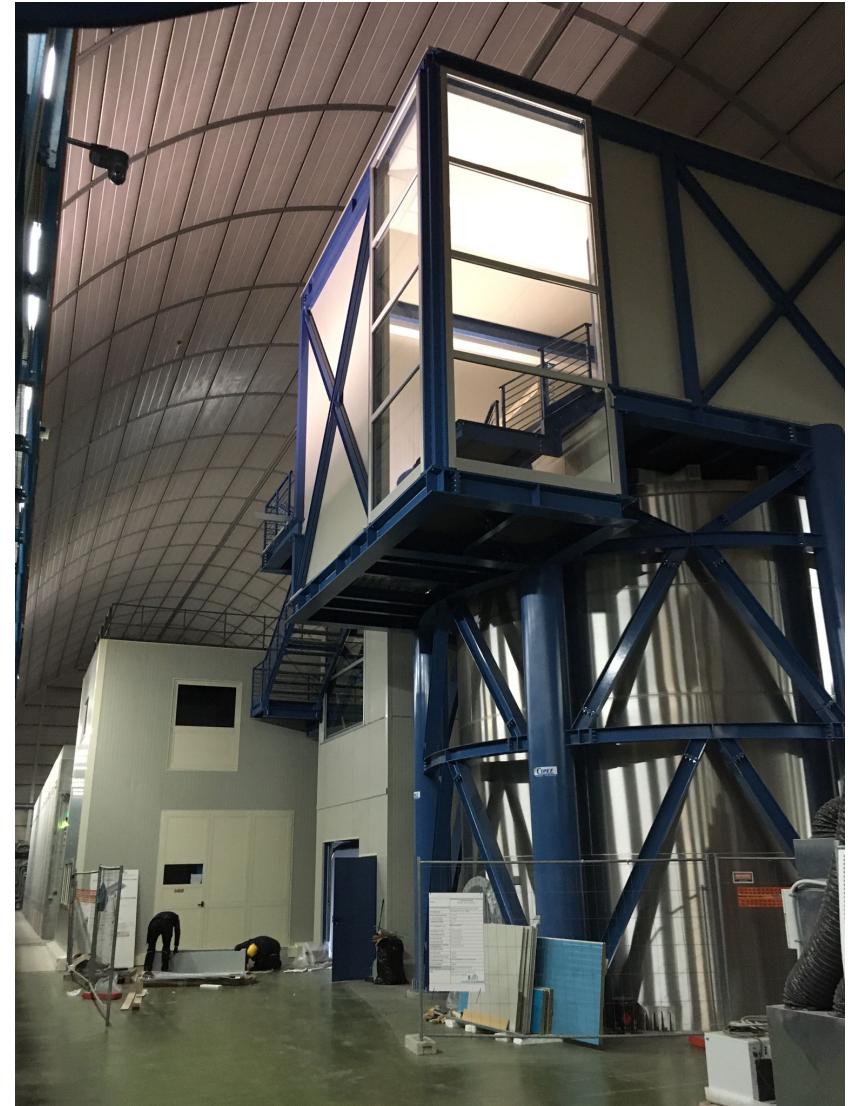


COSINUS EXPERIMENTAL SITE



15.12.2025

F. Reindl



20

INAUGURATION

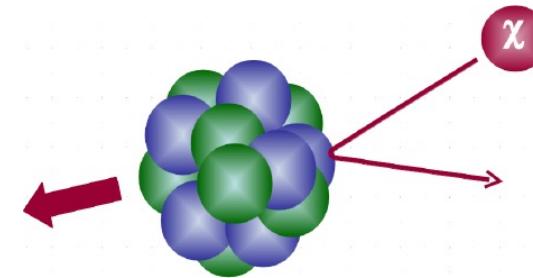
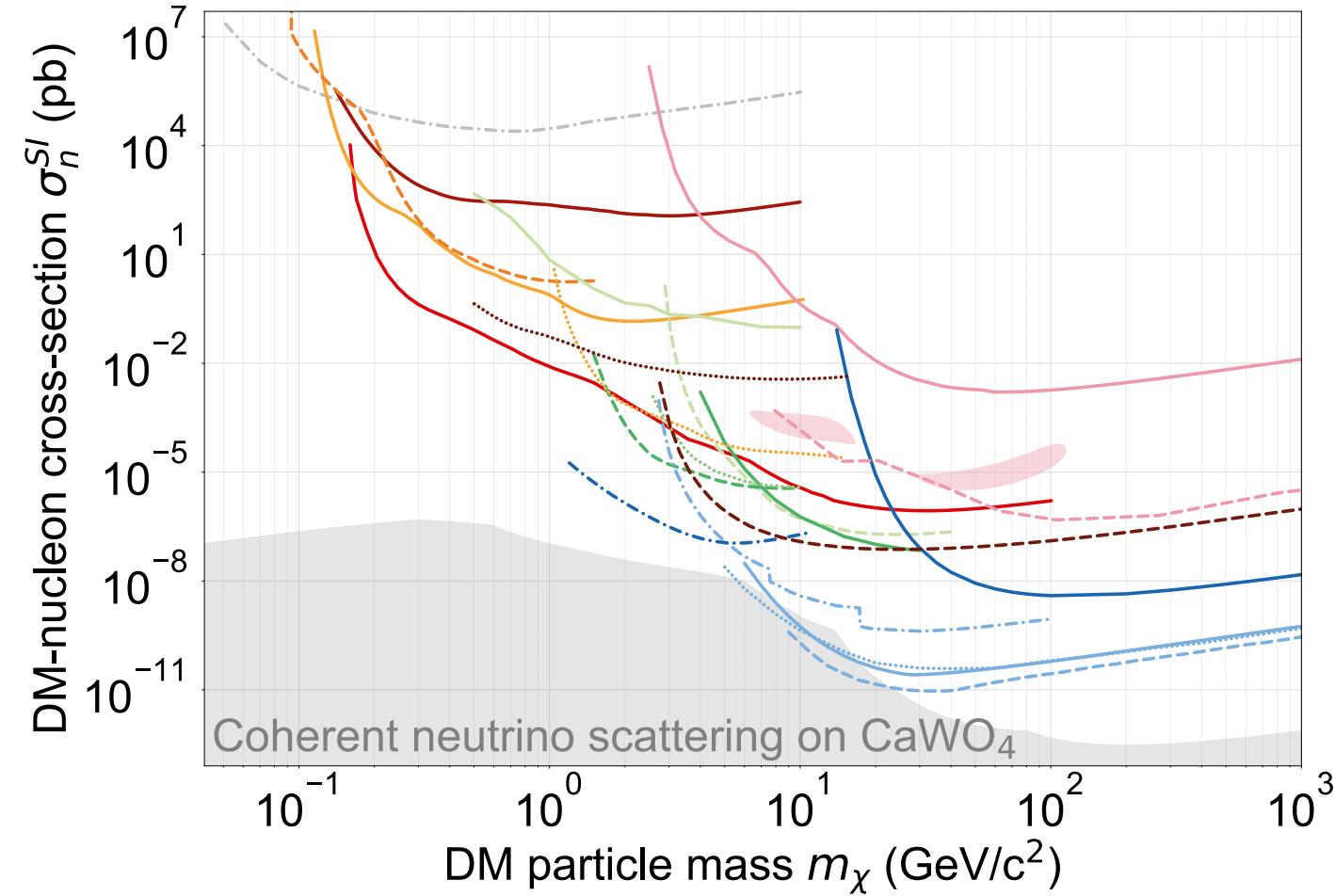


April 2024

The collage includes several news snippets and images:

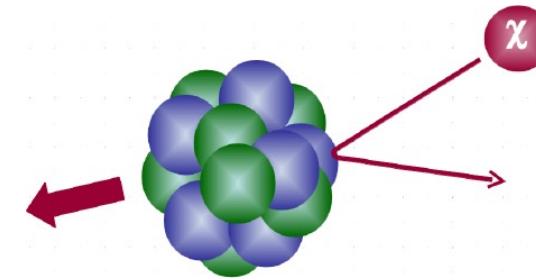
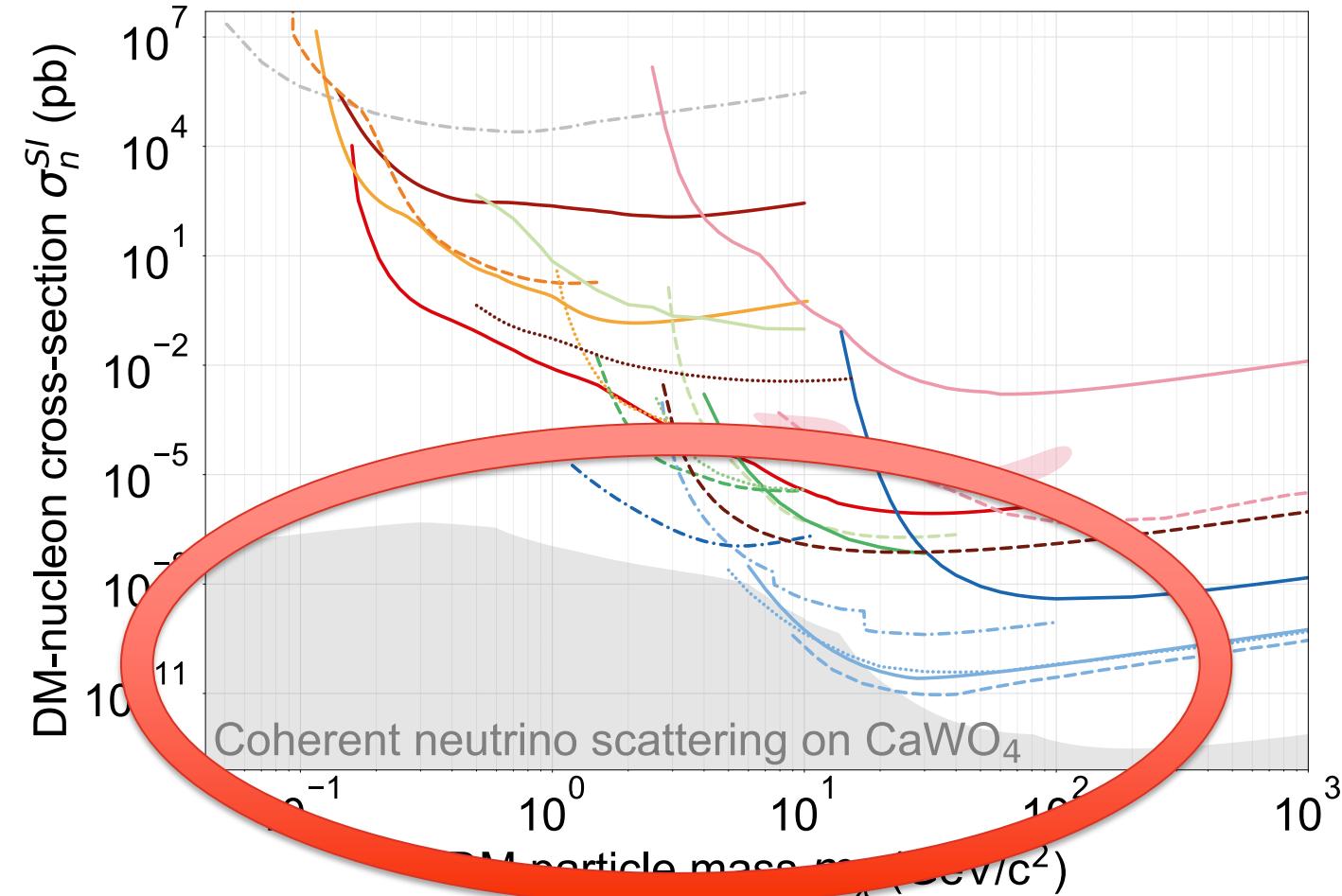
- A main article from "1400 METER UNTER DER ERDE" titled "Neues Experiment im weltgrößten Untergrundlabor soll Dunkle Materie finden". It discusses the CosmoS experiment at Gran Sasso.
- A smaller image of a nebula with the caption: "Aus Beobachtungen von Galaxien und Sternen ist evident, dass es Dunkle Materie gibt. Was sie genau ist, bleibt aber nach wie vor unklar. In der Konstellation Orion." (ESA/Hubble & NASA, B. Reipurth)
- A snippet from "16 | Österreich" featuring Philipp Schreiner.
- A news item from "COSINUS-EXPERIMENT AM START" by Manfred Lindinger, dated 18.04.2024, 17:22.
- A large image of a star field with the caption: "Bislang scheint die Dunkle Materie sich jeglichem Nachweis zu entziehen. Mit dem Cosinus-Experiment wollen Physiker nun endlich Klarheit schaffen und inspizieren dazu verstärkt die Milchstraße."
- A small image of a person in a yellow hard hat in a lab.
- A snippet from "Experimente" featuring RZJ / NORBERT SWOBODA (OÖ APA).
- A large headline: "Der eiskalte Griff nach der Dunklen Materie" with the subtext: "Österreichische Physiker starten Experiment in den Abruzzen, mit dem Teilchen der Dunklen Materie gefunden werden sollen."

STATUS DIRECT DARK MATTER DETECTION



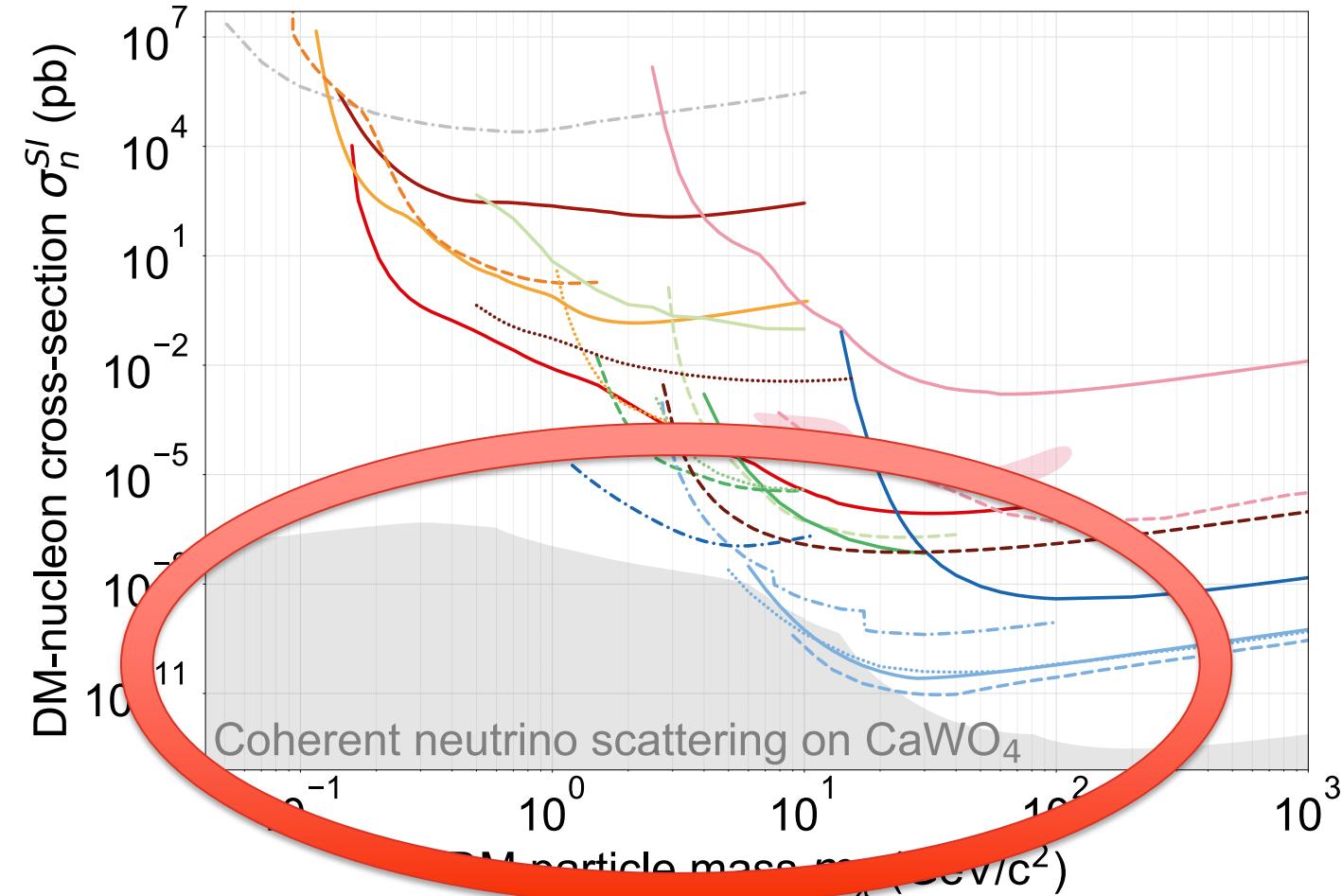
Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION

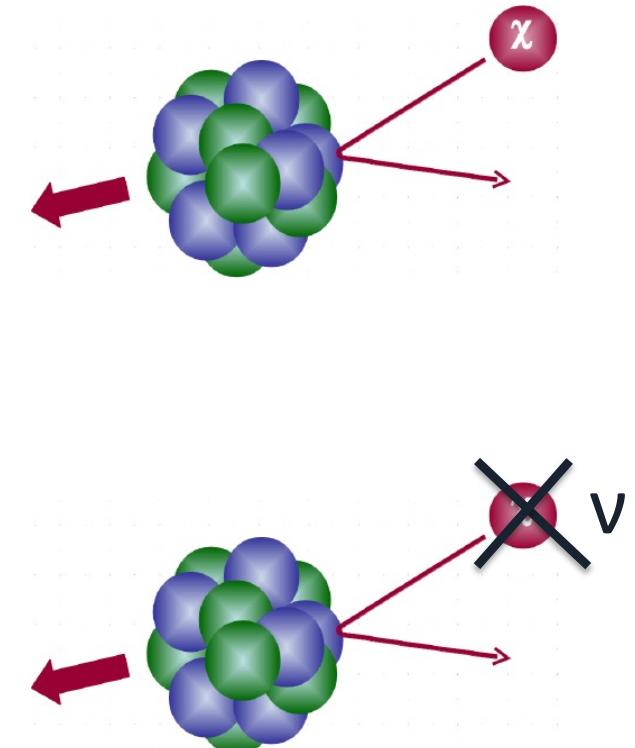


Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search

STATUS DIRECT DARK MATTER DETECTION



Plot: M. Kaznacheeva, K. Schäffner, Scintillating low-temperature calorimeters for direct dark matter search



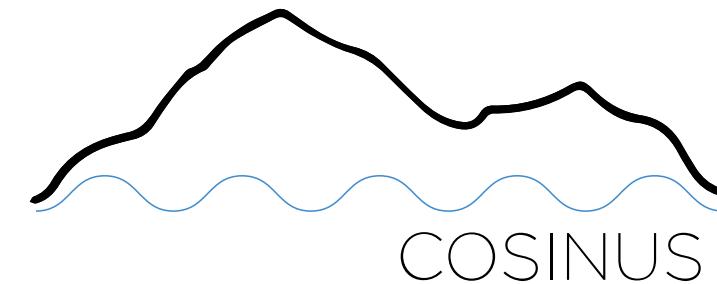
CRESST AND COSINUS



search for light dark matter with
low-threshold detectors

currently taking data

~45 scientists

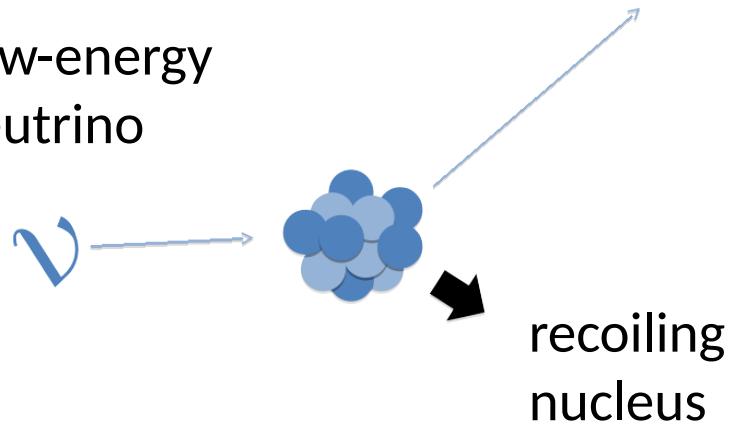


clarification of the DAMA dark
matter claim

start of data taking in 2026

~30 scientists

Low-energy
neutrino



PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†

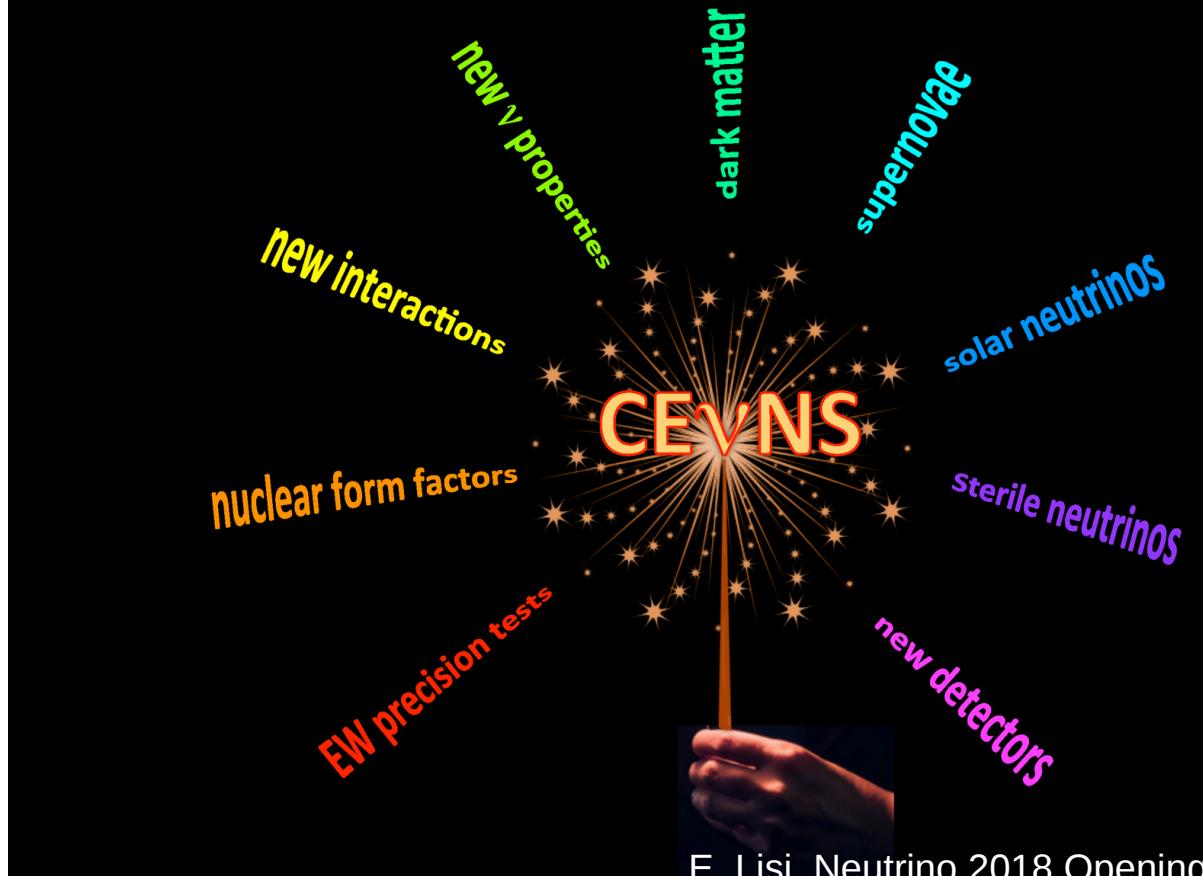
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 October 1973; revised manuscript received 19 November 1973)

Our suggestion may be an act of hubris, because the inevitable constraints of interaction rate, resolution, and background pose grave experimental difficulties for elastic neutrino-nucleus scattering.

Predicted: 1974; Detected: 2017

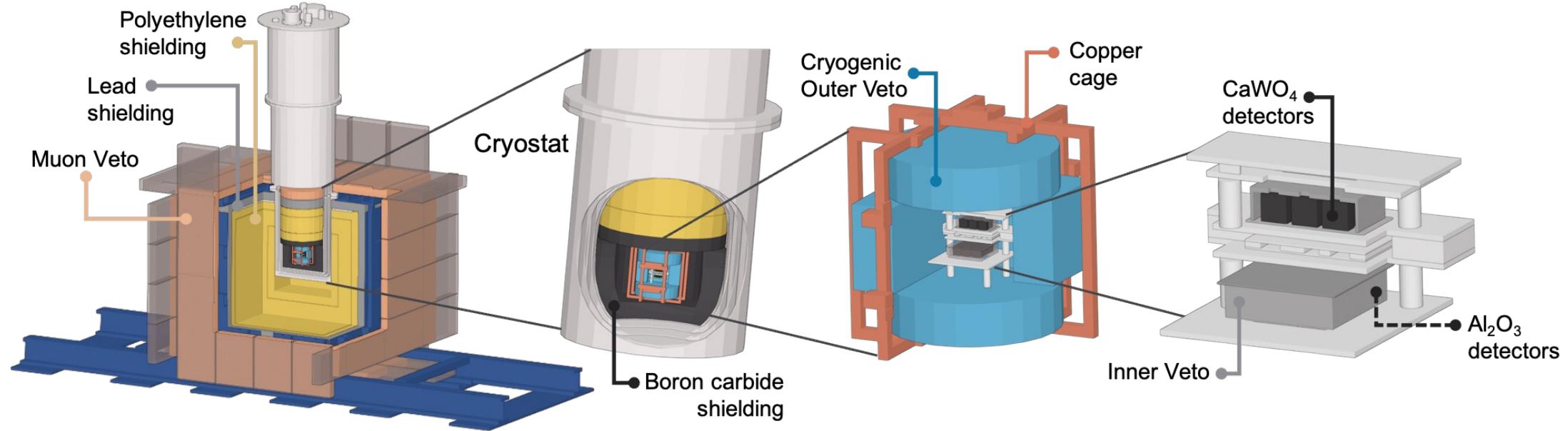
CEvNS

A new portal to (non)standard particle and nuclear physics
... small but **multicolor** !



E. Lisi, Neutrino 2018 Opening Talk

LOW BACKGROUND DESPITE ABOVE-GROUND LOCATION

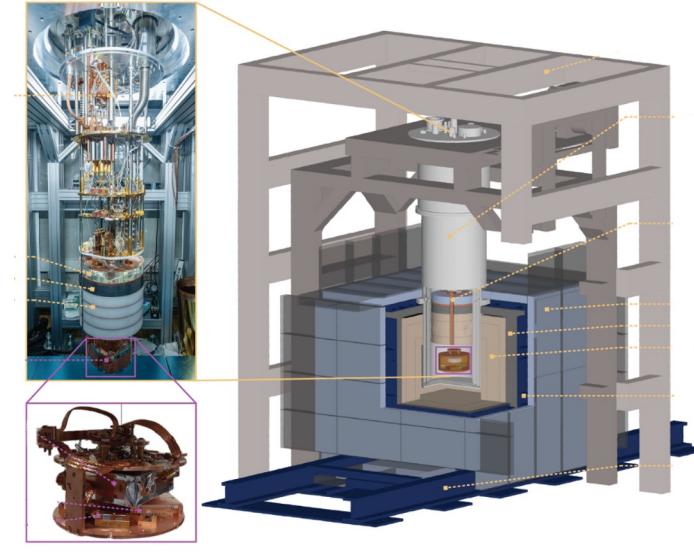
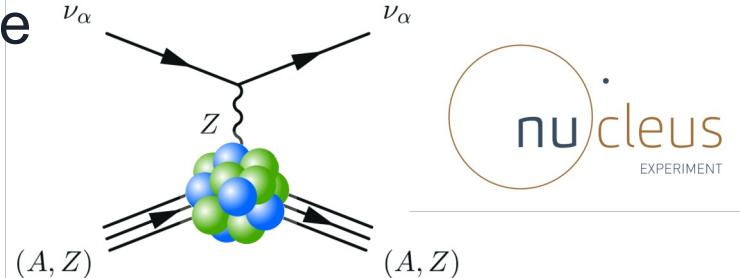


Combination of active and passive (both cryogenic and at room temperature) layers of shielding

MASTER THESIS IN THE NUCLEUS EXPERIMENT



Coherent elastic neutrino nucleus scattering (CEvNS) detection with cryogenic calorimeters at the Chooz nuclear power plant, France



Master thesis 1: Low energy event extraction with Machine Learning

- more CEvNS signals with a lower threshold
- extract tens of eV signals from noise induced by electronics and environmental factors
- combine recurrent neural networks (RNNs) with clustering techniques

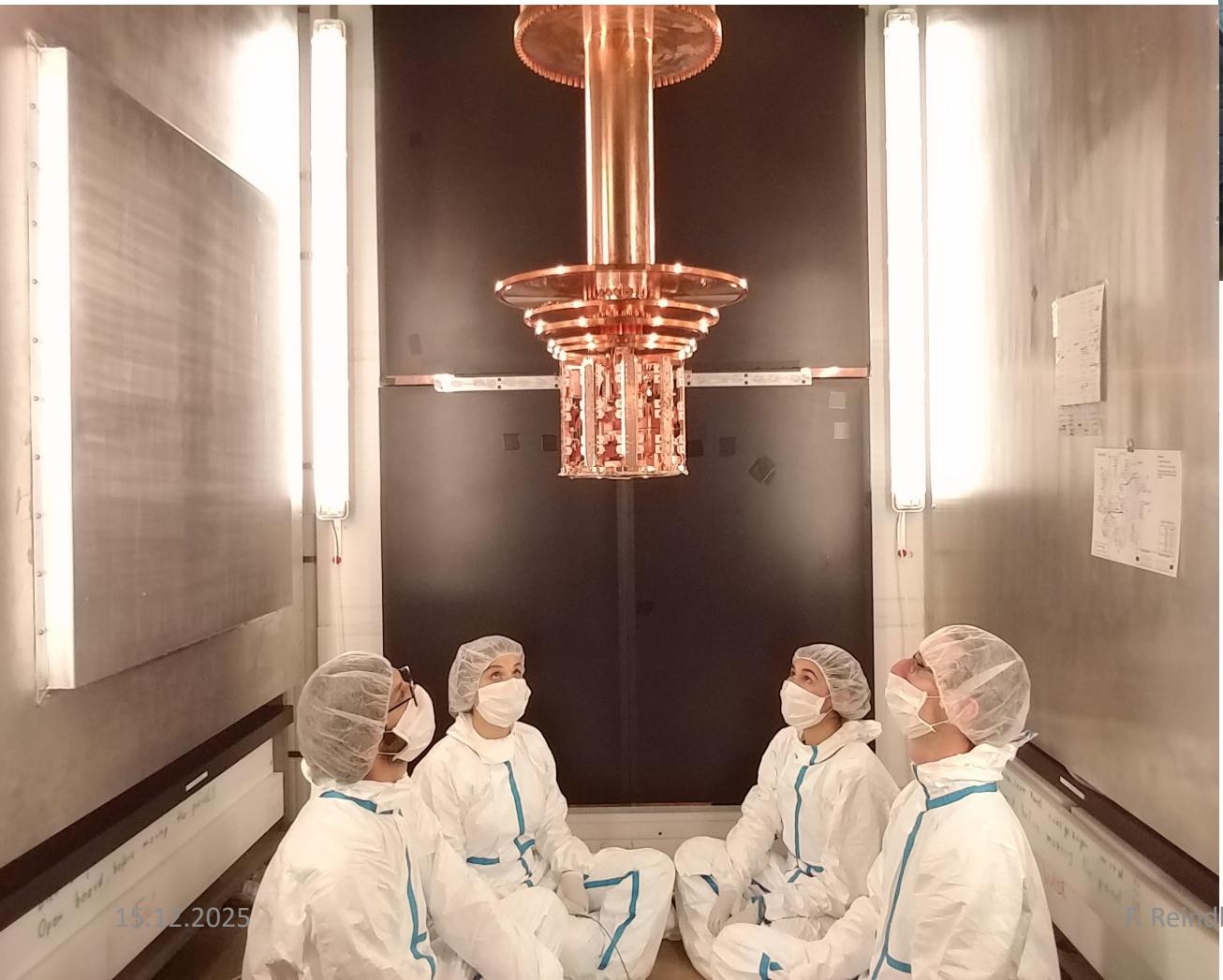
Master thesis 2: Reactor neutrino spectrum studies with CEvNS

- explore how much can be learned about reactor neutrinos with CEvNS
- derive what requirements need to be met to discriminate between the latest theoretical and experimental reactor neutrino models

SUMMARY

- NUCLEUS is on its way to measure CEvNS at a reactor
- Successful commissioning run done!
- Move to Chooz nuclear power plant in 2026
- Simulations on background budget finalized

RARE EVENT SEARCHES @MBI / TU WIEN



- We do rare event searches with cryogenic detectors
- Our focus is on (arbitrary order):
 - Monte Carlo simulations
 - Data analysis from raw data to final physics result
 - Data acquisition electronics and software
- If you are interested in working with us (e.g. for a project or a master thesis): contact Prof. Jochen Schieck or Prof. Florian Reindl



“A world-leading experiment requires world-leading understanding of the background via high performance simulations” (Us, 16.12.2024)

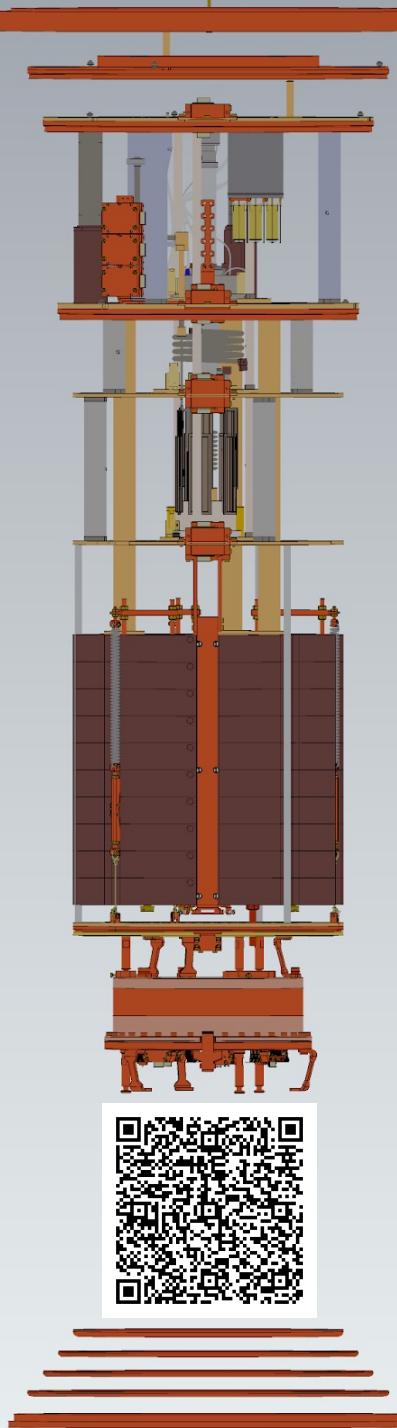
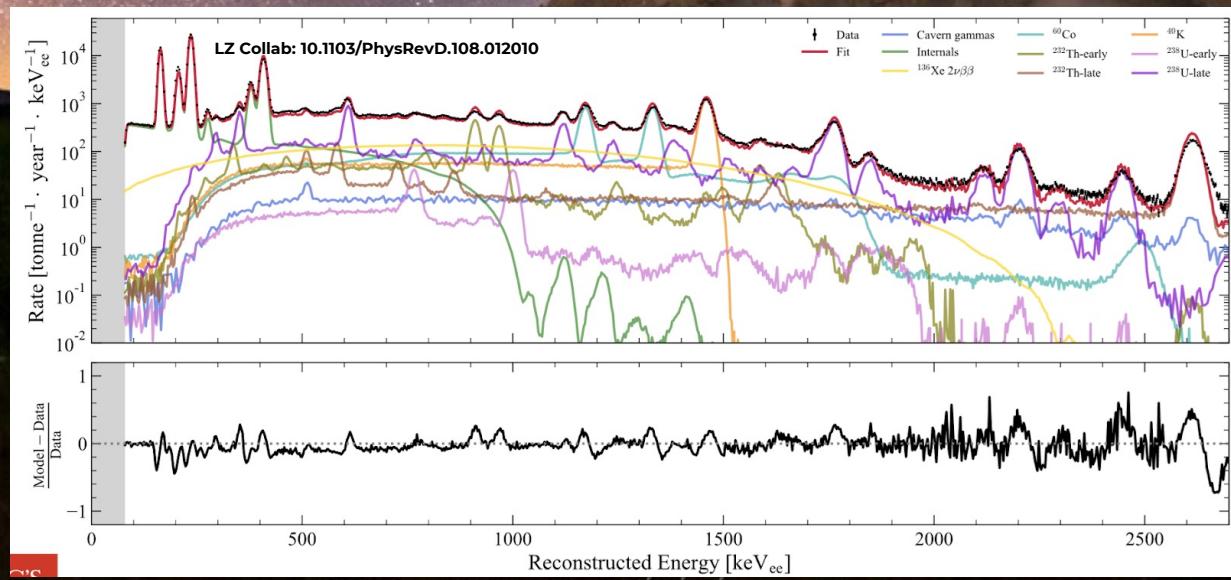
- ⇒ ImpCRESST (Geant4-based in-house made soft) allows us to characterize in detail possible backgrounds that could be highly detrimental to COSINUS goals and ***new particles discovery potential***
- ⇒ Radiogenic backgrounds (nuclear decays), cosmogenic backgrounds (muons and cosmic rays), among others
- ⇒ Simulations are instrumental to the development of new ***cutting-edge*** cryogenic-based experiments in **Austria** and **Worldwide**

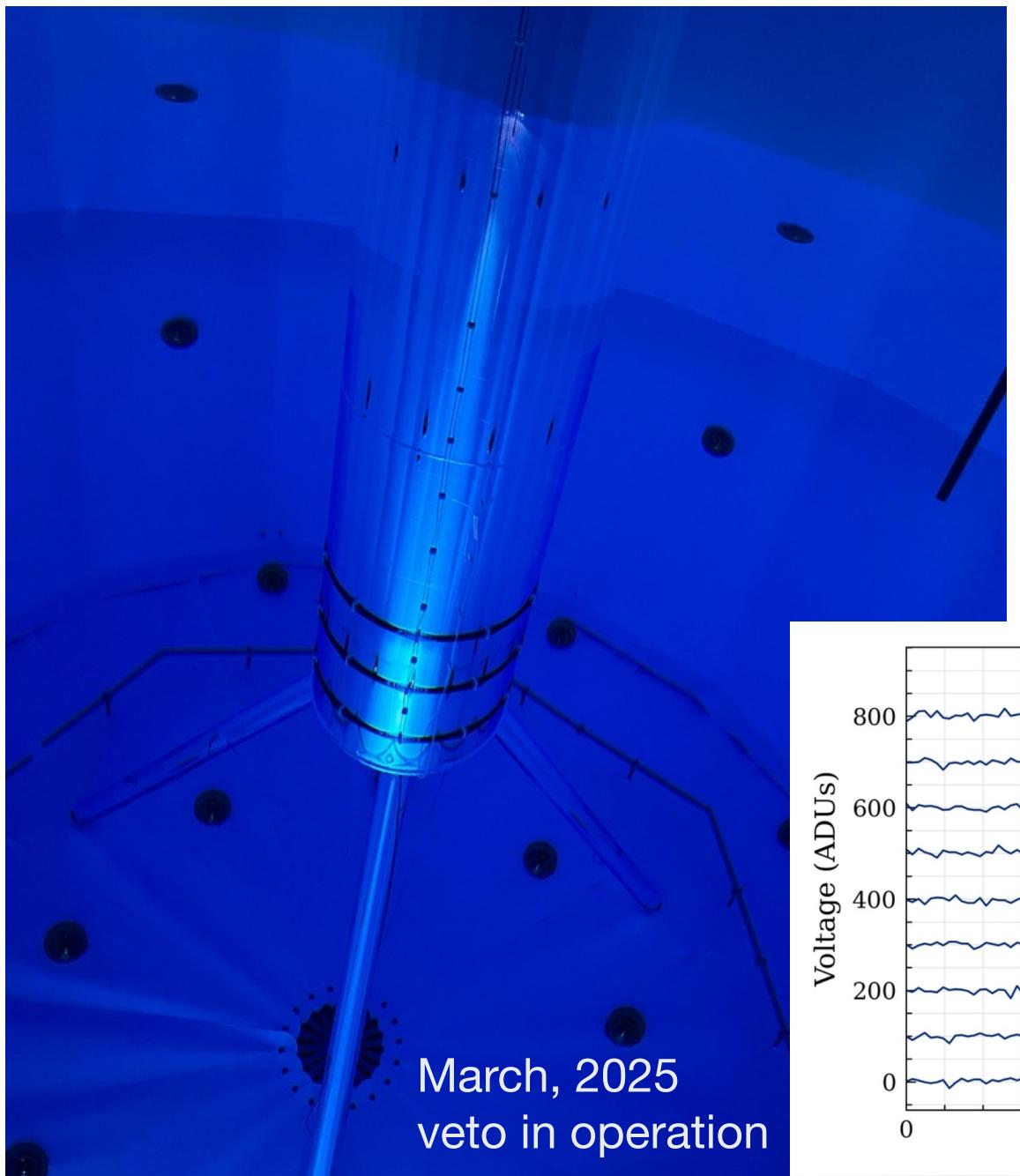
Projects availability:

- 👑 Background model (see Fig)
- 🏰 Non-proportionality in NaI
- 🕯 Phonon propagation
- 🐴 Supernovae neutrino directionality capabilities

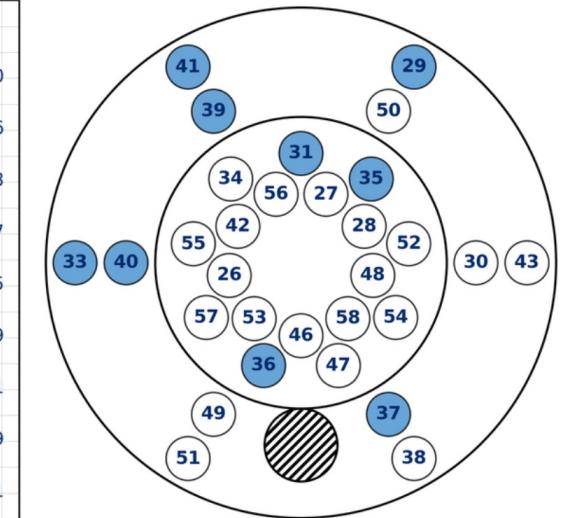
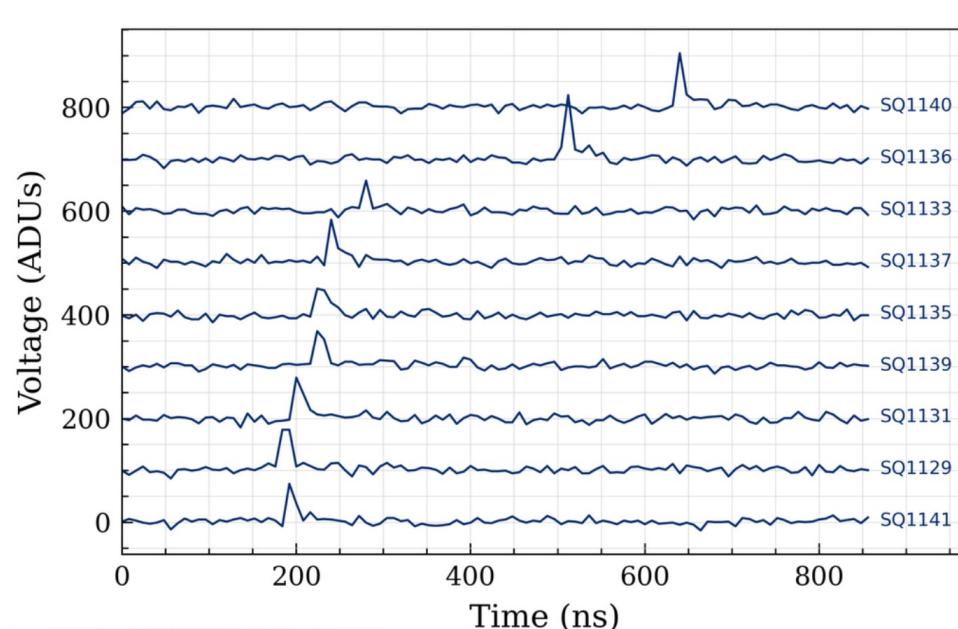
mailto: mariano.cababie@tuwien.ac.at

15.12.2025



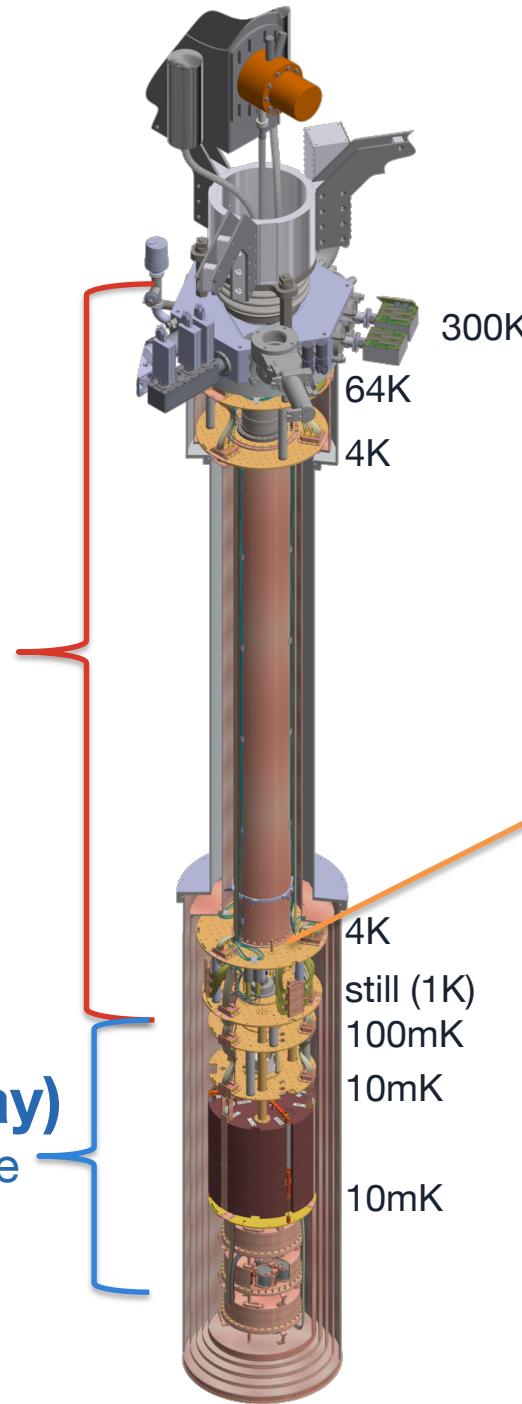


Tank filled
in Jan 2025



CABLING INSTALLATION

Step 1 (ongoing)
Cabling down to the 1K Stage (still)



Step 2 (starting today)
Cabling from still down to the detector stage (mK)

