Astroparticle and Neutrino
Research in Switzerland

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Bern, February 2025
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UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Ph.D.
R&D Neutrino Optical TPC

CHIPP
Swiss Institute of Particle Physics

Joined in 2020
Liaison officer from 2023

UNIVERSITY OF TORONTO

CERN

***Good* years ahead...**

DUNE

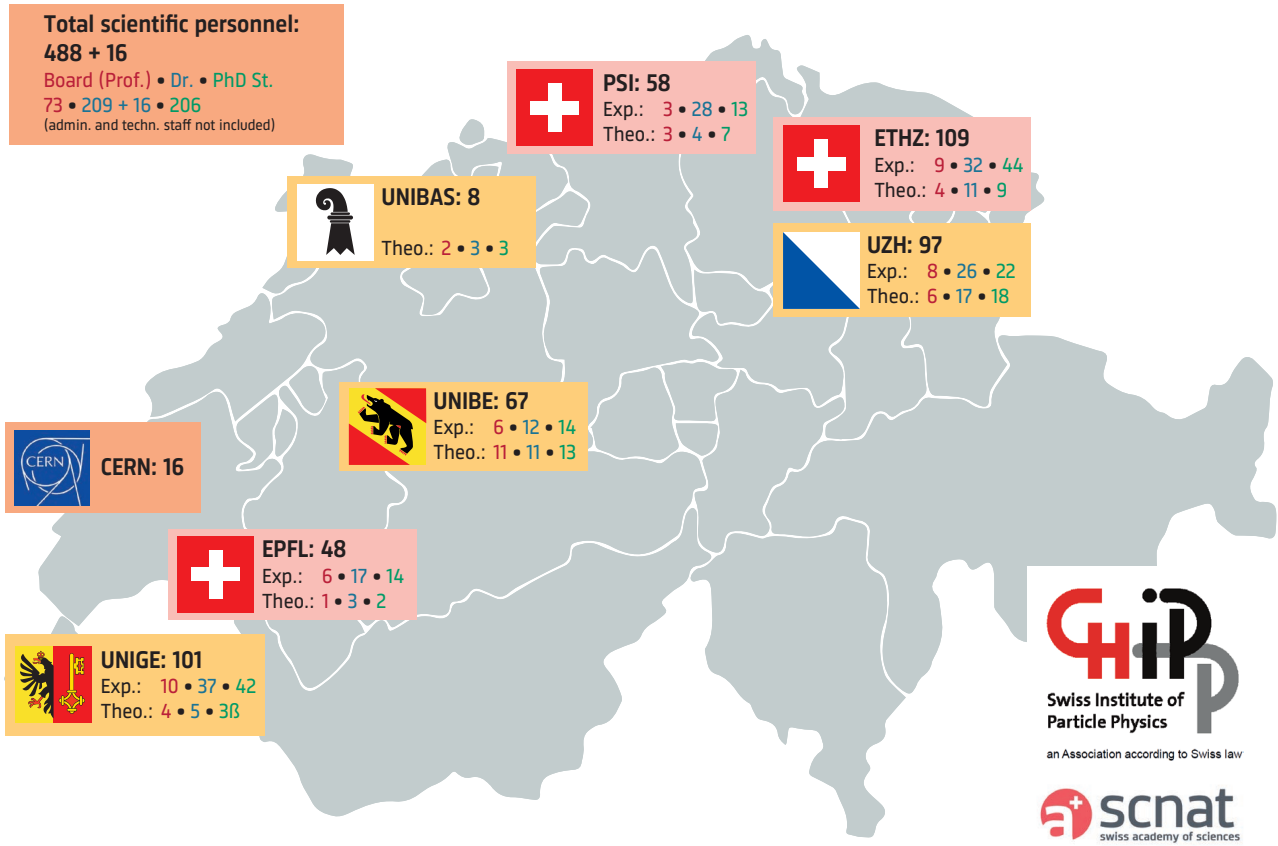
Pillar 2 and Pillar 3 of CHIPP

The focus of **CHIPP Pillar 2** focuses on **neutrino physics**.

- Measurement of PMNS matrix parameters
- CP violation
- Majorana/Dirac
- Mass ordering .

Pillar 3 relates to **astroparticle physics**, including searches for and measurements of particles from space.

- CR: ground/space based
- Multi-messenger physics (gamma, X-ray, DM, neutrinos, gravitational waves)
- Dark Matter (DM) searches.



Swiss Institute of Particle Physics
an Association according to Swiss law

scnat
swiss academy of sciences

Source: CHIPP Membership Database, October 2024

Neutrino and astroparticle experiments in CH

Unige:

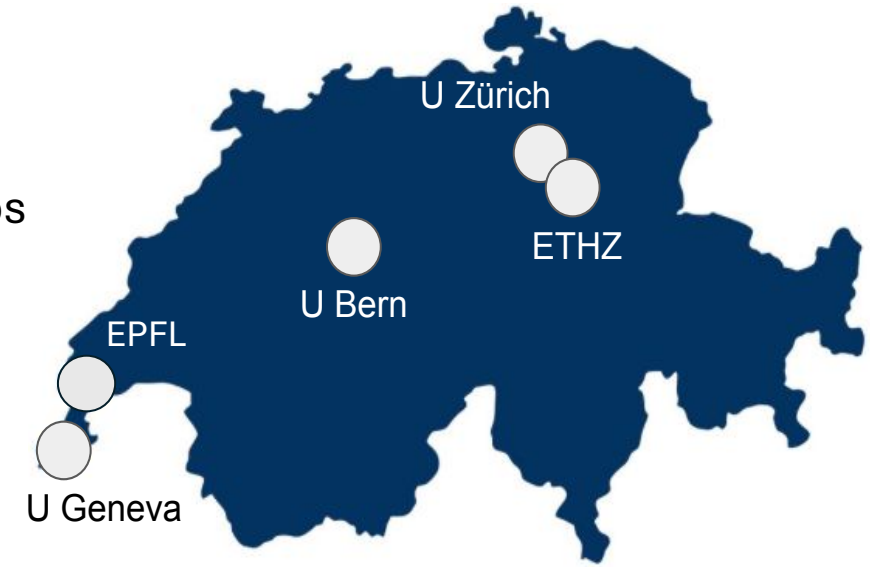
T2K, Hyper K (Sanchez)
IceCube, *CTA* (Montaruli, della Volpe)
DAMPE, HERD (Tykhonov, Wu)
AMS-02, Polar, PAN, eXTP (Wu)
Einstein Telescope (Schramm, Fragkos (astro), Maggiore (theory))

EPFL:

DAMPE, HERD (C. Perrina)
CTA (Kneib, Charbon, Nironov)

Bern:

DUNE, MicroBooNE, SBN (Weber)
CTA (Falanga through ISSI)



UniZ:

Gerda, Legend (Baudis)
XENONnT (Baudis), Tesseract (Penning)
Darwin, XLZD, Qrocodile (Baudis, Penning)
CTA (Saha, Serra)
DAMIC-M, OSCURA (Kilminster)
LIGO/LISA (Jetzter)

ETH:

T2K, Hyper K (Sgalaberna, Rubbia)
CTA, MAGIC, FACT (Biland)

Pillar 2 presentation (Prof. Weber, UniBe)

Pillar 3 presentation (Prof Baudis, UZH)

Neutrino Physics | Pillar 2

Pillar 2 CHIPP priorities:

- "The Precise measurement of the neutrino oscillation probability at long-baseline accelerator-based experiments is **the highest priority task of the neutrino pillar in Switzerland**."
- The search for **0$\nu\beta\beta$** is also recommended
- Success of extraterrestrial neutrinos continued: IceCube → IceCube Gen2
- Novel technologies developed at PSI (strong support from CERN Neutrino Platform)
- All experimental progress provides input for UNIBAS theoretical efforts.

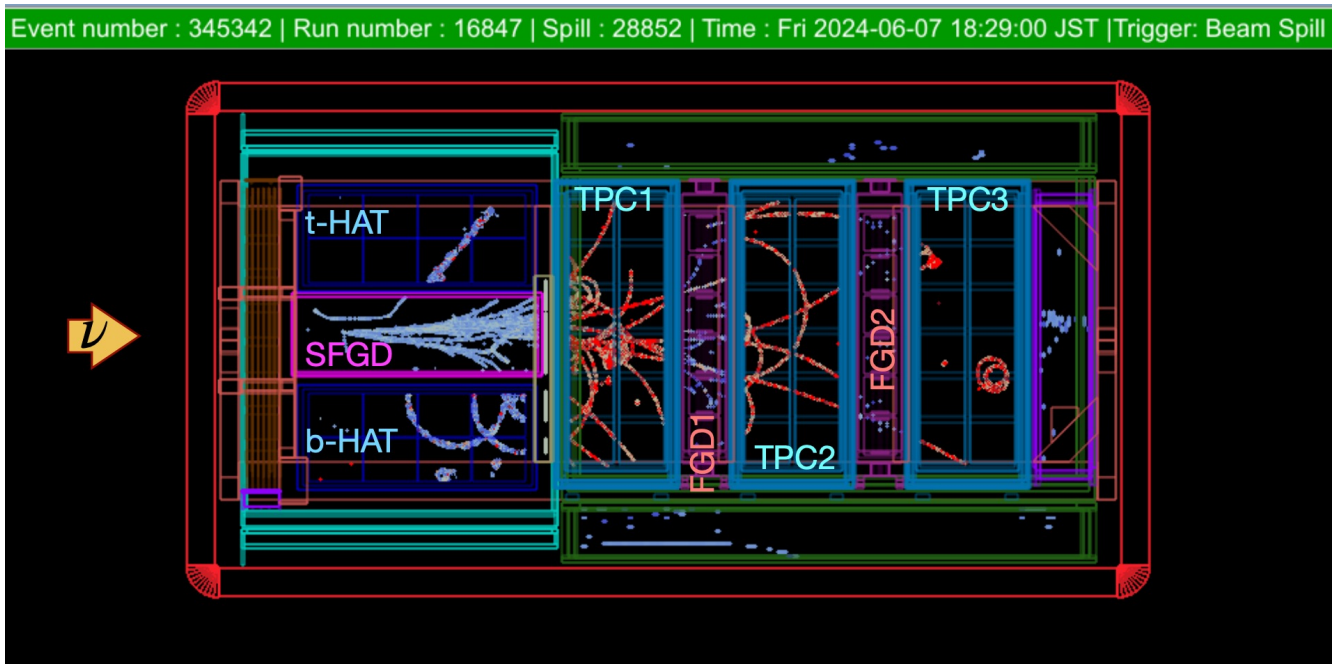
Institution	Main involvements
UNIBE	Long-baseline experiment: DUNE Short-baseline experiments: MicroBooNE, SBN
UNIGE	Long-baseline experiment: T2K/Hyper-K Ground-based astroparticle experiment: IceCube
UZH	Neutrinoless double-beta decay experiments: GERDA, LEGEND
ETHZ	Long-baseline experiment: T2K/Hyper-K

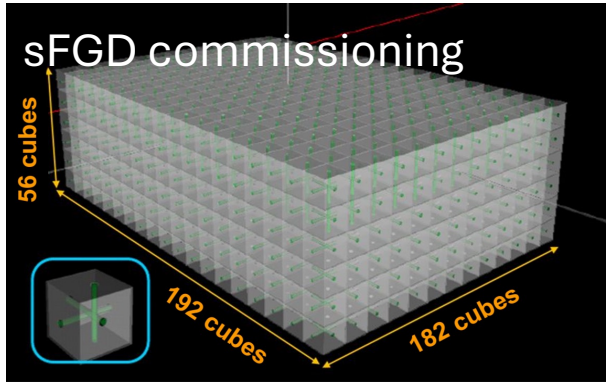
The Japanese Neutrino Program

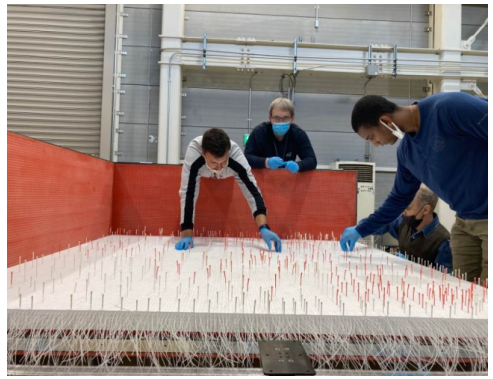
T2K (running) and Hyper-K (future)

T2K is a currently running long-baseline experiment in Japan:

- Strong contributions from UniGe, ETH, and UNIBE.
- UniGe and ETH fully committed to the future







T2K Leadership Positions:

Prof. F. Sanchez Nieto (UniGe):
Previously two-times spokesperson, ND280 magnet convener

Stefania Bordoni (UniGe):
ToF detector convener, previously Scintillation detector convener.

Davide Sgalaberna (ETH):
Near detector physics convener

The Japanese Neutrino Program

T2K (running) and **Hyper-K (future)**

Hyper Kamiokande is a future long baseline experiment:

- Measurement of Θ_{13} and δ_{cp}.
- Strong commitment from UniGe and ETH
- ***Flagship*** CHIPP experiment!

Hyper K Leadership Positions:

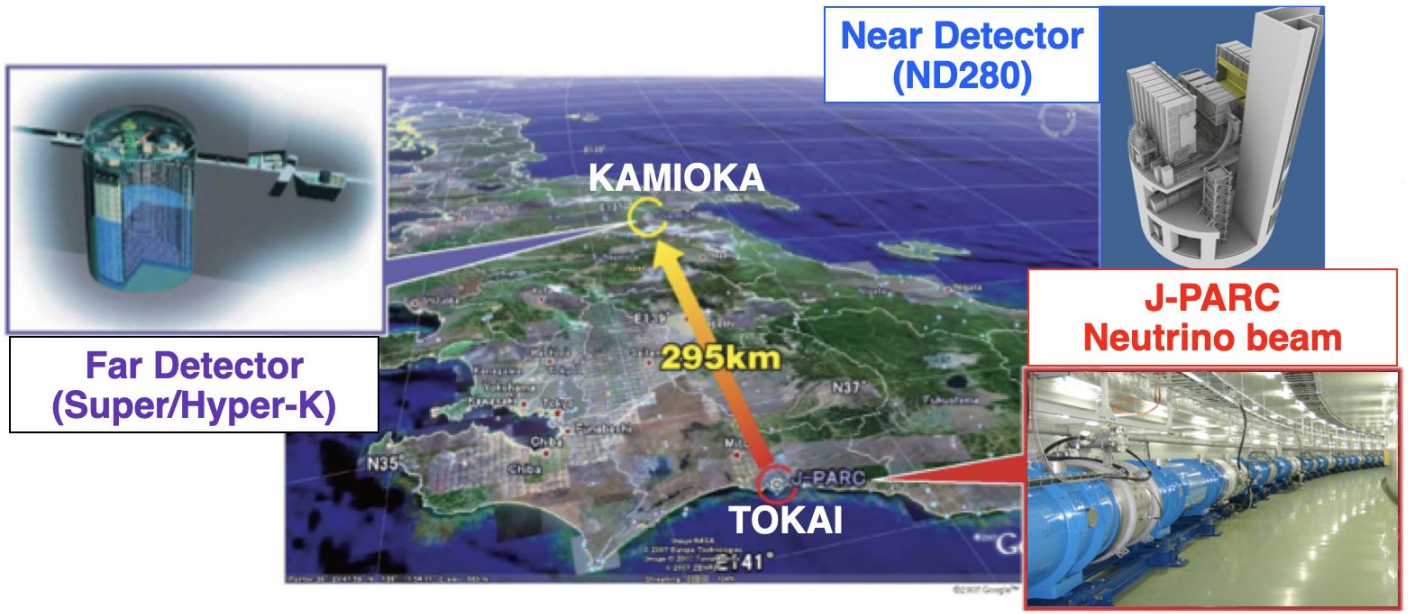
Federico Sanchez (UniGe), ND280 convener

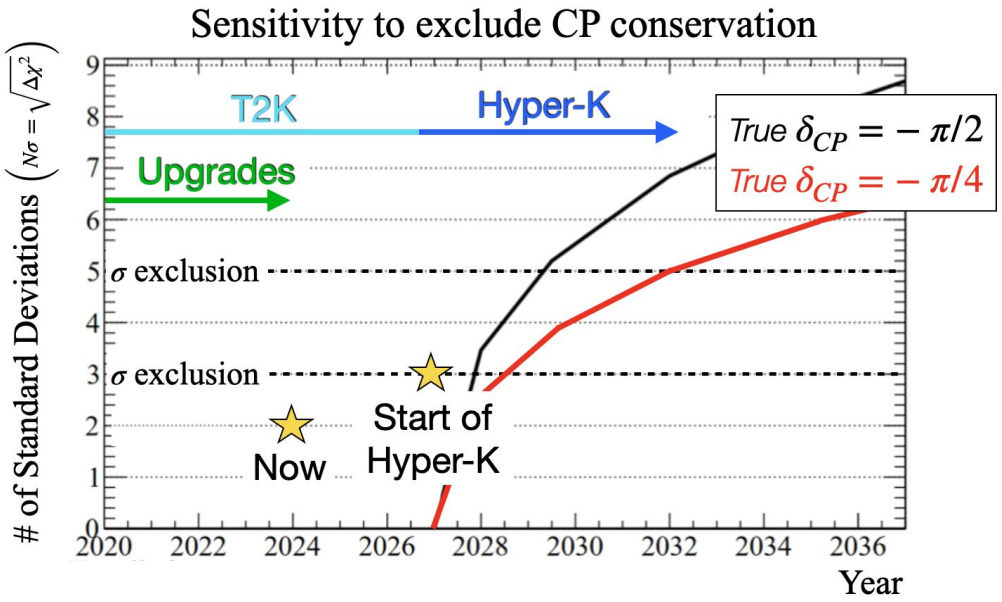
Davide Sgalaberna (ETHZ) far detector electronics assembly project

Umut Kose (ETHZ) far detector electronics assembly project technical coordinator and HV/LV convener

Adamo Gendotti (ETHZ), far detector electronics mechanics convener

D. Bordoni, WCTE safety responsible





The U.S. Neutrino Program

SBN (running) and **DUNE (future)**

SBN Leadership Positions:

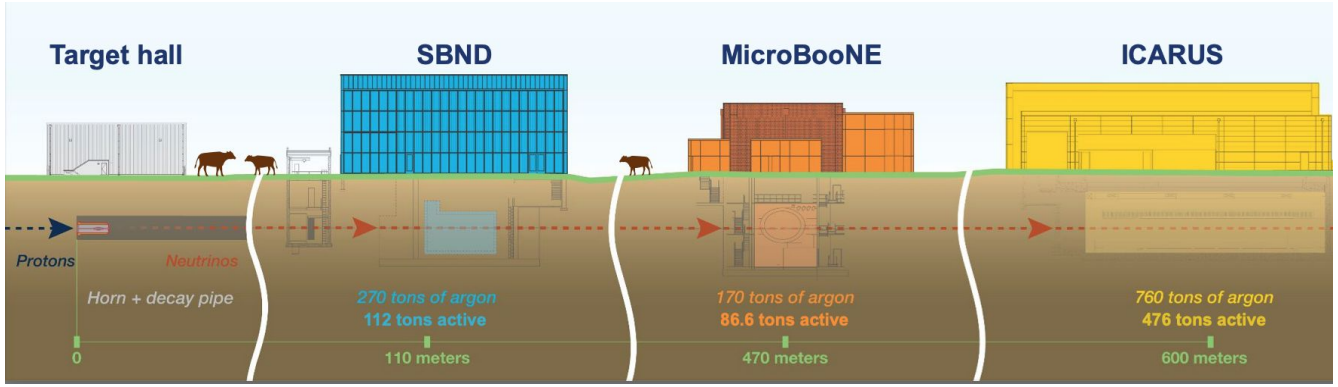
M. Weber, Physics coordinator MicroBooNE (until 2022) UV-laser manager

R. Diurba, MicroBooNE detector systematics convener

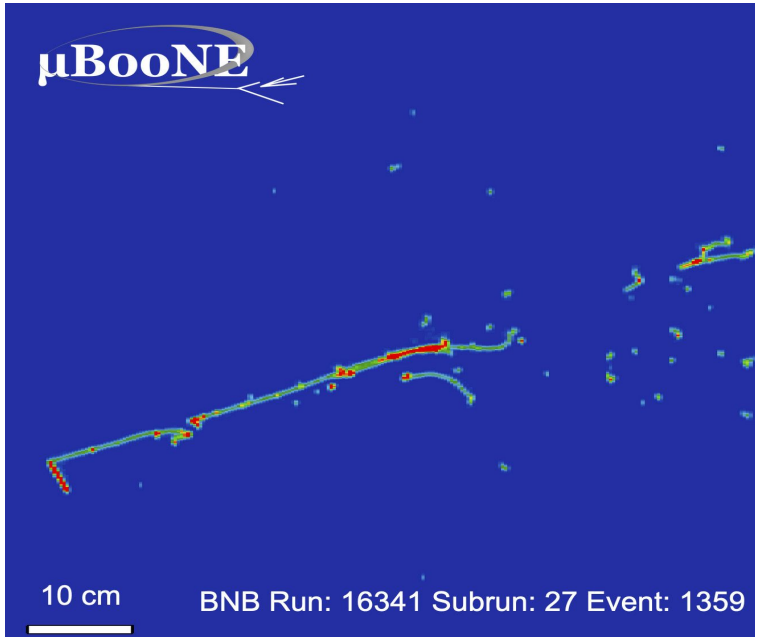
I. Kreslo, CRT manager (until 2023)

SBND:

- Short Baseline Neutrino facility at Fermilab
- Strong implication from UniBe
  - UV-laser calibration system
  - Cosmic Ray Tagger for MicroBooNE and SBND.
  - Led the MicroBooNE physics program (M. Weber, 2014–2022) → **LArTPC expertise** and > 50 publications, including on sterile neutrino.



data taking:	2024– (filled 5.3.2024)	2015–2021	2021–

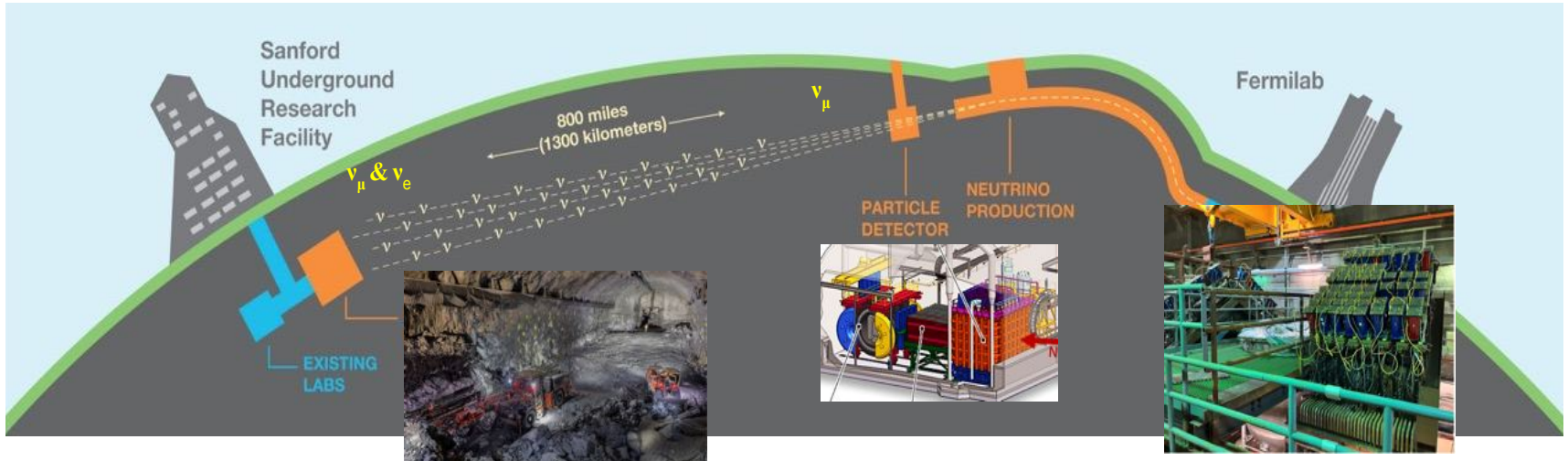


The U.S. Neutrino Program

SBN (running) and **DUNE (future)**

DUNE:

- Long Baseline Neutrino: Fermilab → South Dakota (~1000 km)
- **CHIPP flagship** together with Hyper-K (equal priority)
- Swiss Innovation (UniBe):
  - ArgonCube chosen as the DUNE Near Detector (ND)
  - R&D and Prototyping finalized in Bern (2023)
  - Pre-production module tests in Bern (2024)
  - Beam tests with neutrinos at Fermilab
  - Production 2025 - 2027



DUNE Leadership Positions:

Kreslo: DUNE ND-LAr detector systems lead

M. Weber, DUNE ND-LAr consortium lead (spokesperson equivalent) and DUNE Executive Board member

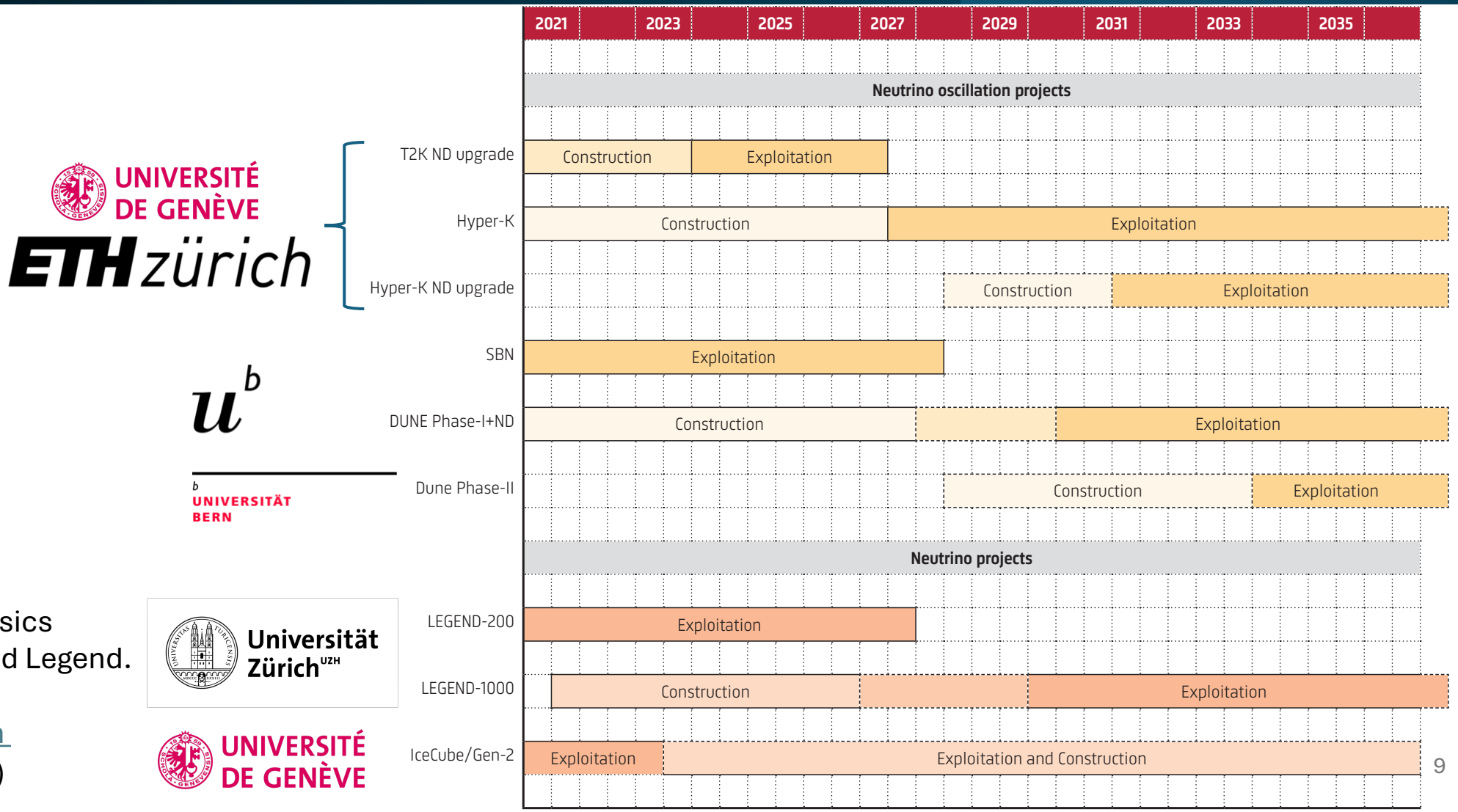
S. Parsa, DUNE ND first physics analyses convener, and ND-LAr HV convener

S. Bosco, DUNE ND-LAr module structure engineering lead

R. Diurba, ProtoDUNE hadron analysis convener

L. Meier, DUNE ND-LAr full-size demonstrator facility lead

Timeline for neutrino physics in CH



UNIVERSITÉ DE GENÈVE

ETH zürich

UNIVERSITÄT BERN

Universität Zürich[UZH]

UNIVERSITÉ DE GENÈVE

Strong neutrino physics through IceCube and Legend.

Pillar 2 presentation (Prof. Weber, UniBe)

Astroparticle Physics | Pillar 3

CHIPP Recommends:

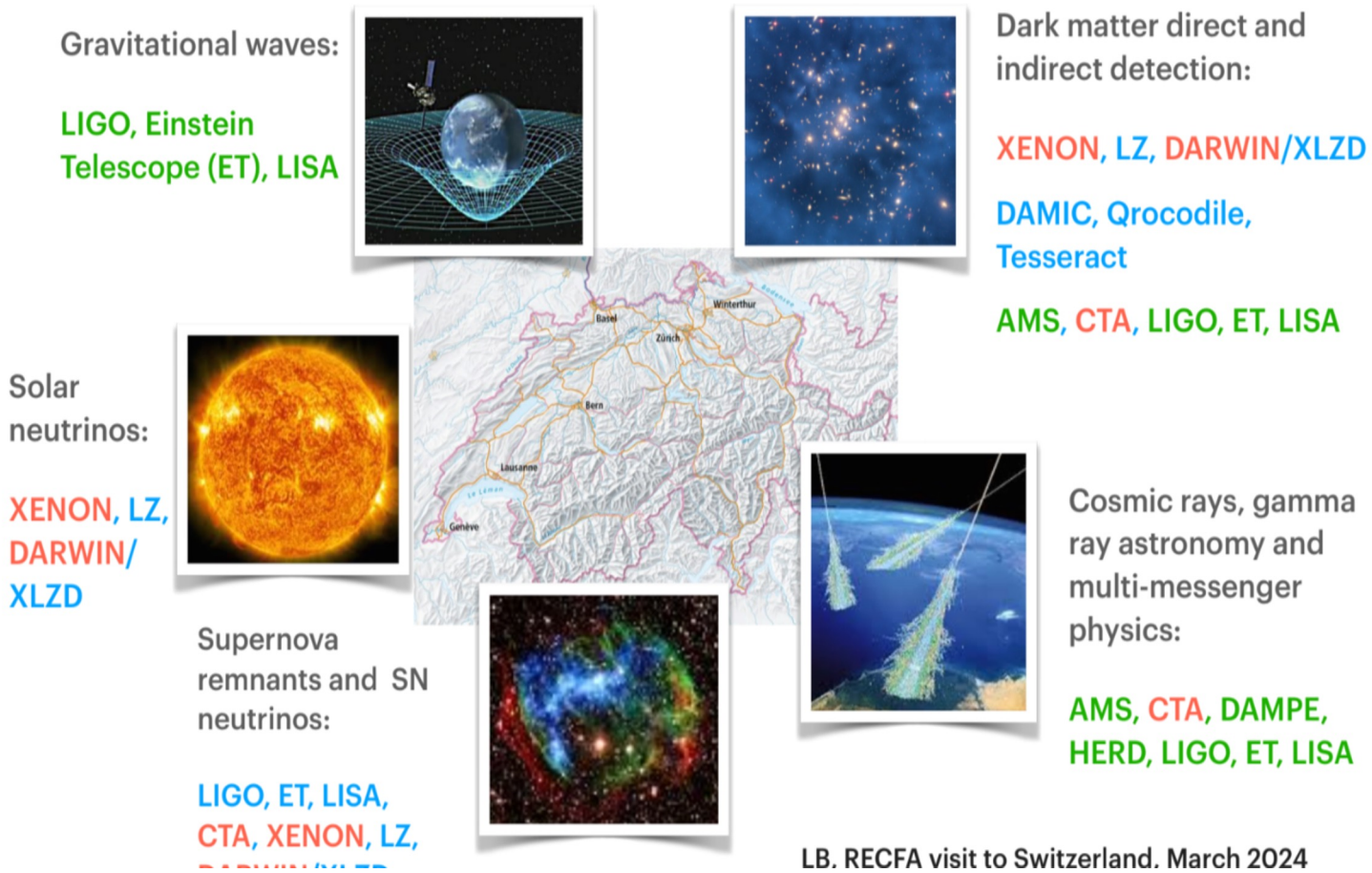
Rec 6: IceCube has a strong neutrino oscillation scientific case. Upgrades not planned for CH institutes, but physics yes.

Rec 8: Become full member of CTAO.

Rec 7/9: Call for collaboration between particle physics, cosmology, and astronomers (CHAPS). Both CHIPP and CHAPS interested in the Einstein telescope.

Rec 10: Continue leadership in large and small DM experiments, and establish leadership for future experiments, such as DARWIN/XLZD.

Taken from CHIPP 2024 Roadmap



LB. RECFA visit to Switzerland. March 2024

Image credit Prof. Baudis

Red: Flagship projects on SWISS Roadmap
Green: Overlap with Astrophysics Community

Space Based Experiments

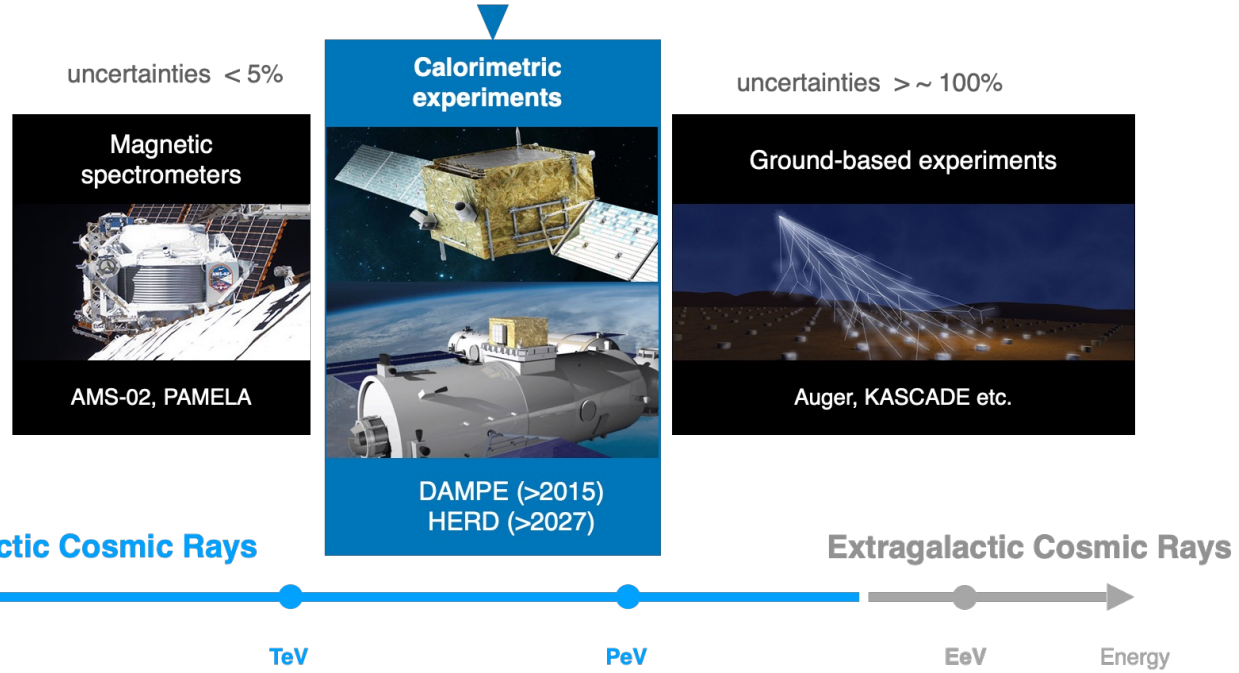
Cosmic-Ray Physics: DAMPE (running) and HERD (future)

Prof. Andrii Tykhonov
Prof. Xin Wu

Chiara Perrina – SNSF Starting Grant

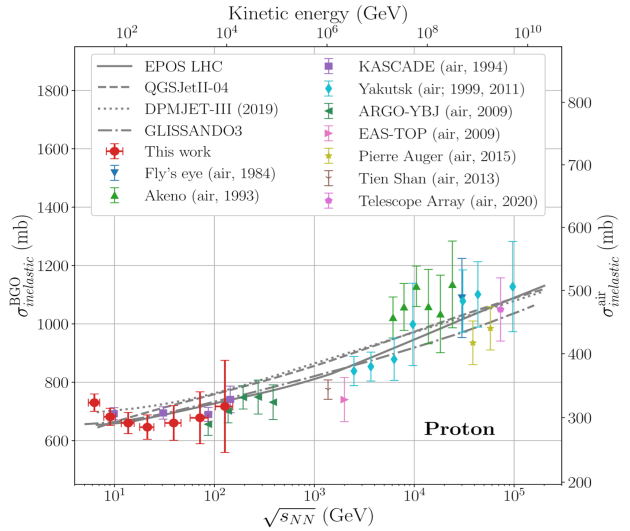
Direct (calorimetric) detection of TeV-PeV Galactic Cosmic Rays in Space:

- Understand their origin → holy grail in astroparticle physics
- **Direct measurements** of cosmic ray spectra at PeV regime
- Calorimetric experiments → only *quick* solution for PeV CRs.
- Unique DM channels.



Highlights from **DAMPE**:

- AI for PeV CR analysis…
- Hadronic x-section measurements (**bridge between space → accelerators**)
- CR (p+He) spectral measurement reaching 0.5 PeV! (bridge between space → ground).



Space Based Experiments

Cosmic-Ray Physics: DAMPE (running) and HERD (future)

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- **nts from DAMPE:**
- **eV CR analysis…**
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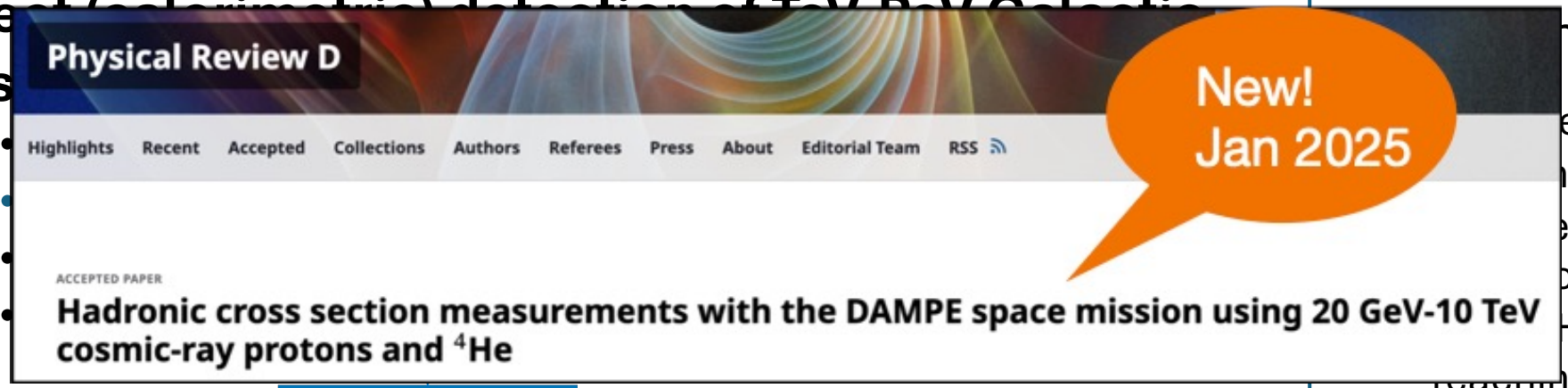
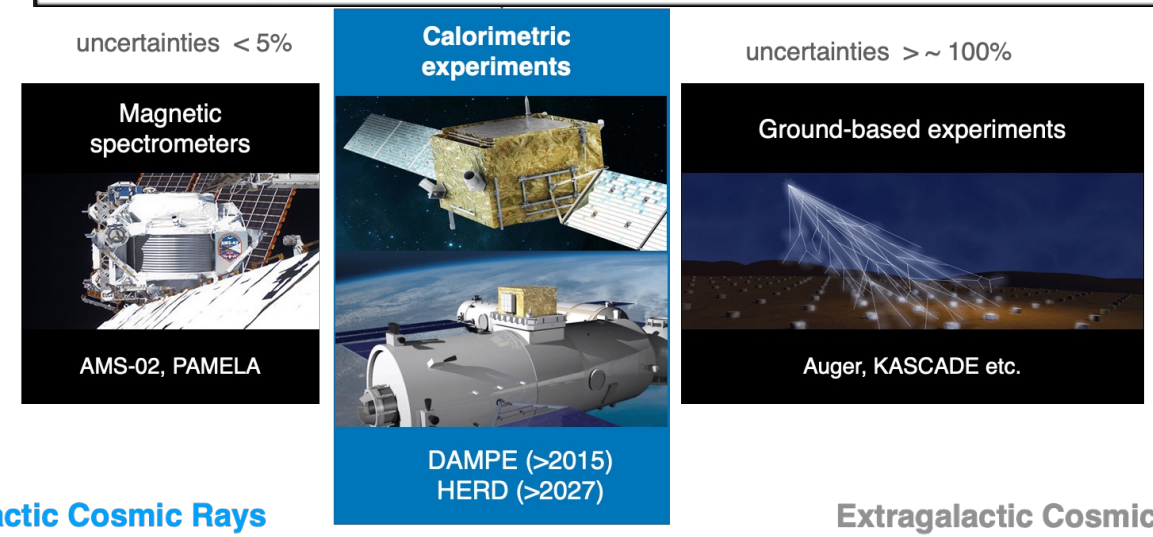
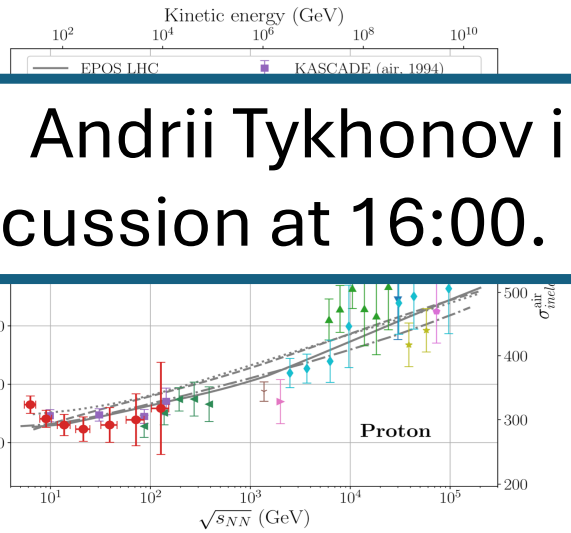
- **ors)**
- **He) spectral measurement**
- **ng 0.5 PeV! (bridge between space → ground).**



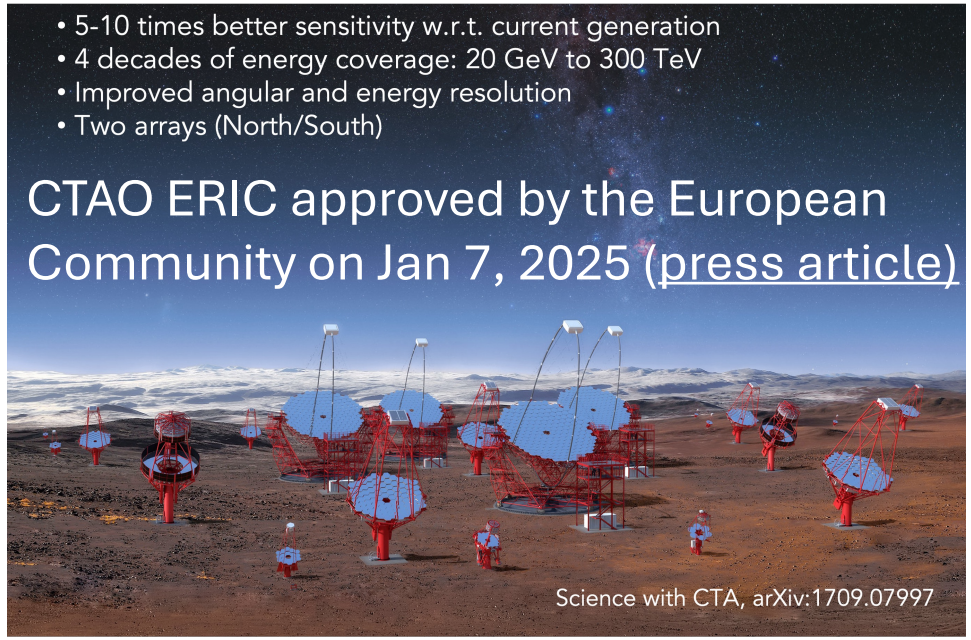




Questions to Andrii Tykhonov in the panel discussion at 16:00.

Ground Based Experiments

The Cherenkov Telescope Array Observatory



CTAO **Science:**

- Study of Cosmic accelerators
- Dark Matter searches (WIMPs, axions)
- Hubble constant, cosmological magnetic fields
- Lorentz invariance

Financed configuration:

- North → 4 Large-Sized Telescopes (LSTs) of 23 m diameter + 9 Middle-Sized telescopes of 12 m diameter;
- South → 2 LSTs + 37 Small-Sized Telescopes
- Headquarter in Bologna, Science Data Management Centre in DESY Zeuthen
- 4 off-site data centres of which one at CSCS, Lugano

CTAO-CH Collaboration is regulated by a collaboration agreement

CH-CTAO Whitepaper

Ground Based Experiments

The Cherenkov Telescope Array Observatory

The CTAO-CH collaboration contribution:

calibration of the array, the quality pipeline, bulk archive, array control, data handler, CNN data analysis of images, system engineering, data analysis.

CTAO Leadership Positions:

Prof. Montaruli (UniGe) lead of CTAO-CH and in the council of the ERIC and in the LST steering board.

Prof. della Volpe (UniGe) Member in the CTAO executive board.

MA Vitalii Sliusar (UniGe) is the software control lead.

Mykhailo Dalchenko (UniGe) leads the CalibPipe

Matthieu Heller (UniGe) leads the Work Package on Adv Camera and in executive board

CTAO-CH Collaboration is regulated by a collaboration agreement

CH-CTAO Whitepaper

Dark Matter Experiments

University of Zurich (UZH)

Main aim: Identify the nature of dark matter, via the search for scatters of galactic dark matter particles in LXe detectors operated deep underground

LXe experiments:

- XENONnT (Baudis, co-founder/ previously co-spokesperson)
- LZ (Penning)
- XLZD/DARWIN (Baudis/Penning)

Low mass DM via quasiparticle sensing:

- Tesseract (Penning)
- QROCODILE (Baudis, Penning)

Low mass DM via ionisation:

- DAMIC-M, OSCURA (Kilminster)

Vast expertise in Liquid Xenon TPCs, low background PMT/SiPM development, physics analyses, cryogenic detectors…

Two phase TPCs

Dark Matter Experiments

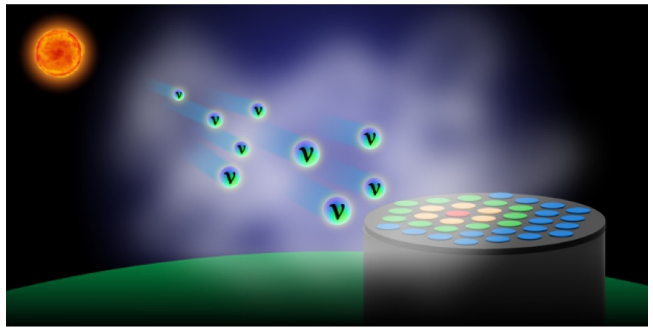
Ongoing at University of Zurich (UZH)

Highlights of the Year

December 16, 2024 • *Physics* 17, 181

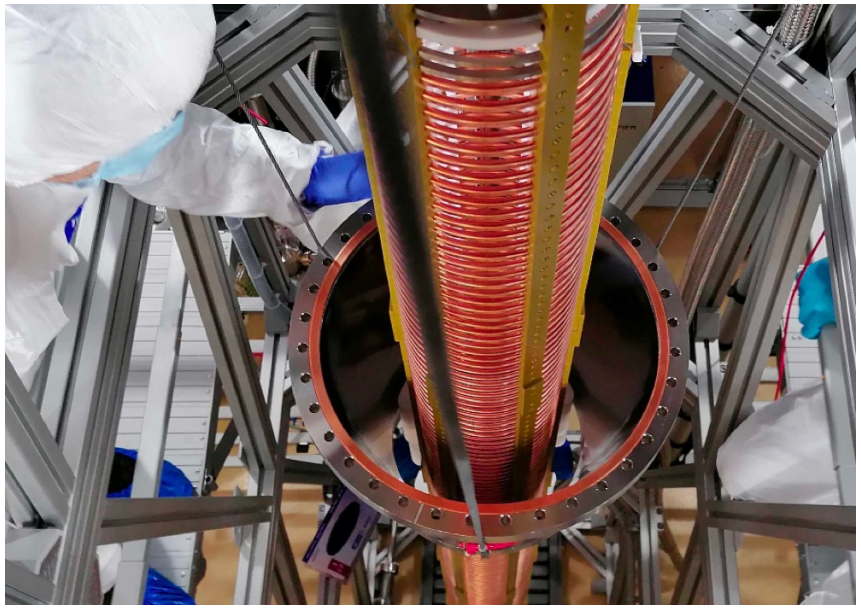
Physics Magazine **Editors pick their favorite stories from 2024.**

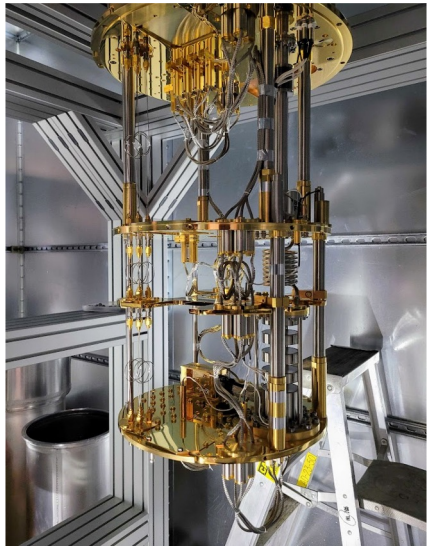
APS/Alan Stonebraker



"Neutrino fog rolling into sight" | First ever detection of 8B neutrinos with XENONnT.

Tests of full length **XLZD** TPC
arXiv:2105.13829

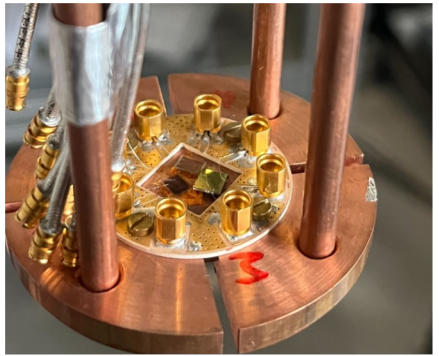




Tesseract brought @ UZH by Penning. **Fully funded low mass DM experiment!**

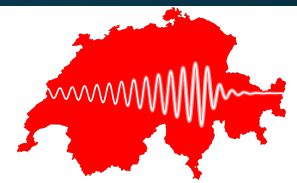
Estimated start 2028.

Qrocodile



Qrocodile. Low mass DM detection via complementary method to Tesseract. First publication 2412.16279!

Gravitational Waves



Switzerland: significant player in the field of GW.

Einstein Telescope:

- Communities come together for ET (CHIPP + CHAPS + theory)
- UniGe: Maggiore, Riotto, Schramm.

LISA (+LISA pathfinder launched in 2015):

- One of the early proponents: Giardini + Jetzter 2003
- UniGe: Bonvin, Caprini, Maggiore, Riotto
- UZH: Jetzter, Mayer, Soares-Santos
- ETHz: Giardini

LIGO: CH joined in 2017

- UZH: Jetzter

Einstein Telescope Leadership Positions:

Anastasios Fragos: task leader in ET Oraganisation (ETO) for computing models and requirements

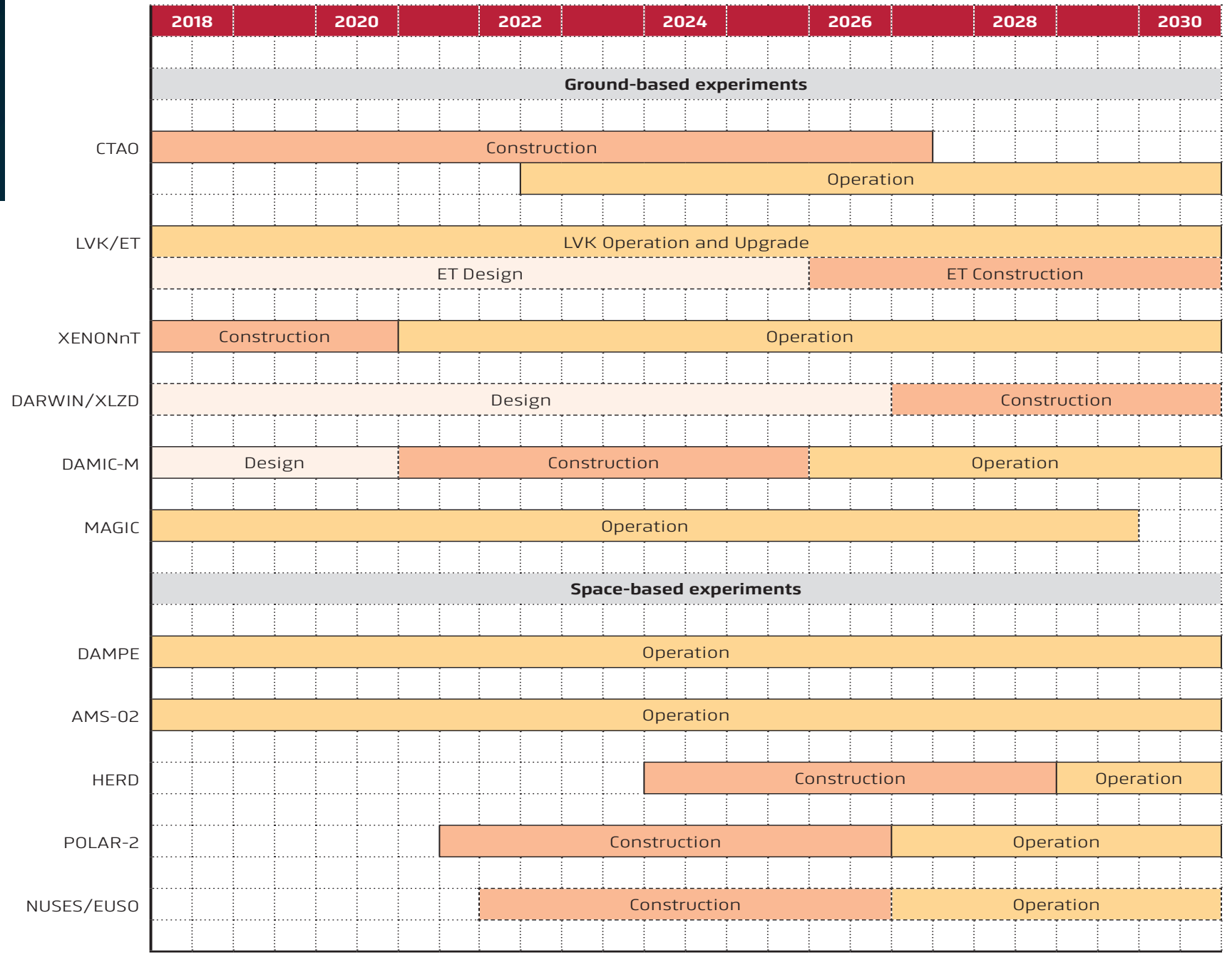
Michele Maggiore: Founder and Chair of the Observational Science Board (OSB), ET executive board member, science case leader for ET ESFRI proposal

Antonio Riotto: OSB Division Chair for Population Studies

Steven Schramm: Division Chair of ET E-infrastructure board (EIB) for Multimessenger Alert Infrastructure

See M. Maggiore et al, 1912.02622 for detailed view of ET Science Case.

Timeline for astroparticle



Thank you for your contribution to the slides!

F. Sanchez, S. Bordoni, A. Tykhonov, L. Baudis,
B. Penning, C. Perrina, M. Weber.

Swiss Institute of Particle Physics

ETH zürich

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UNIVERSITÄT BERN

EPFL

Universität Basel