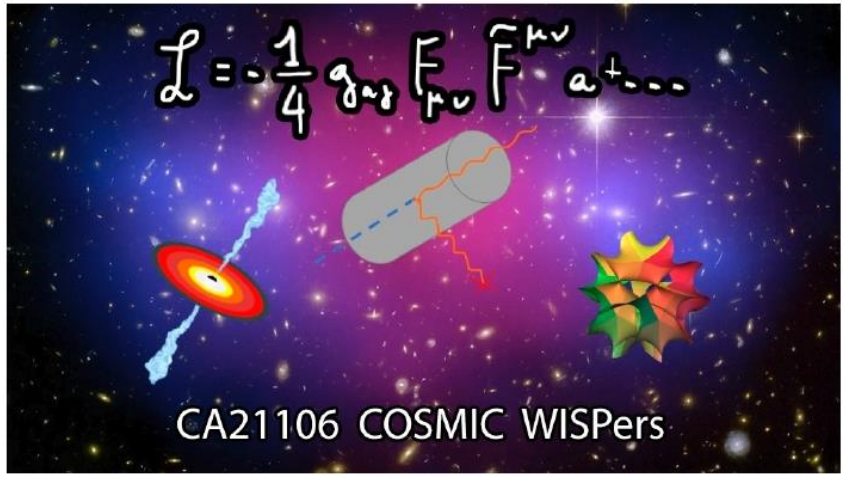
Eavesdropping @ DESY

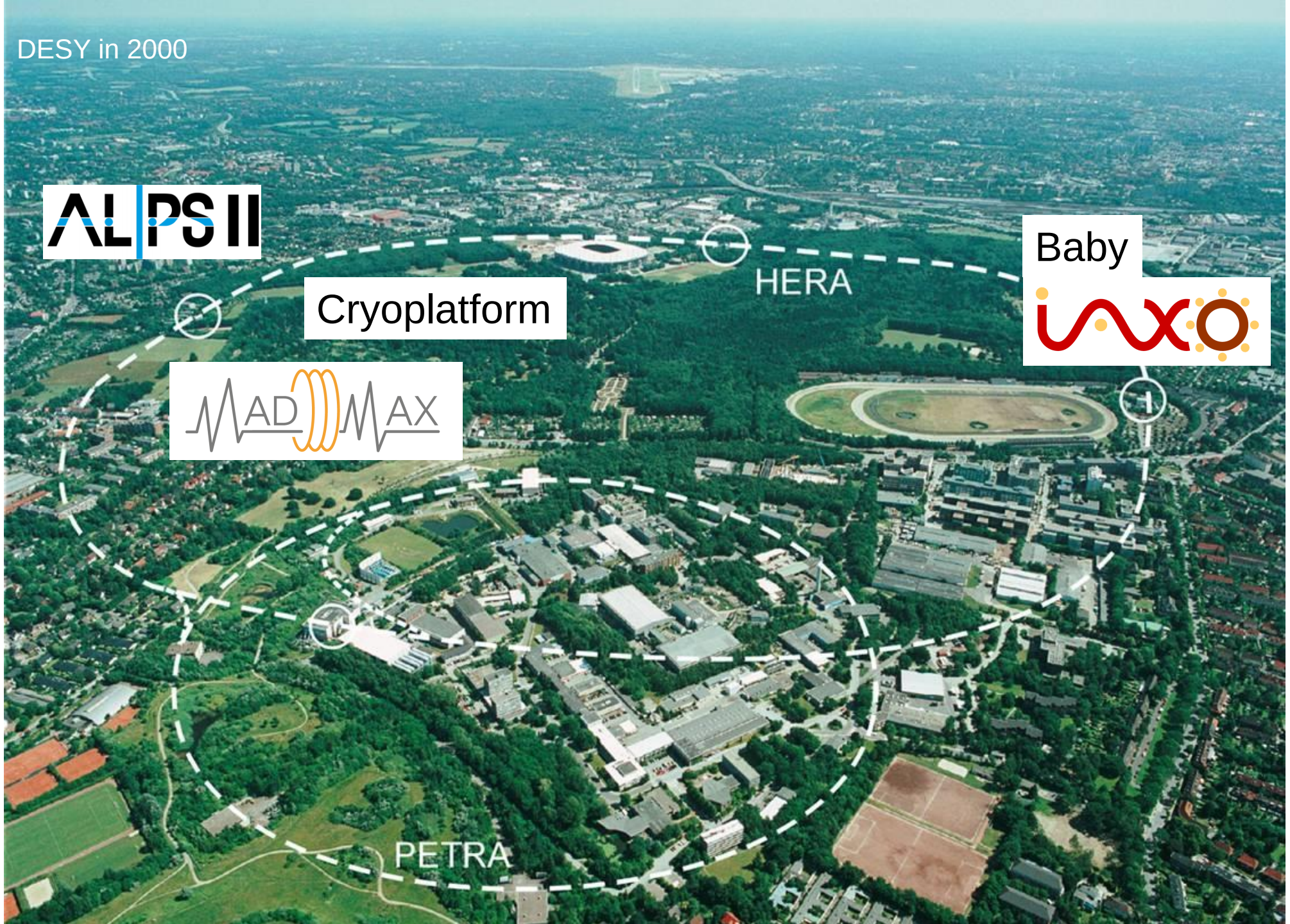


Funded by the European Union

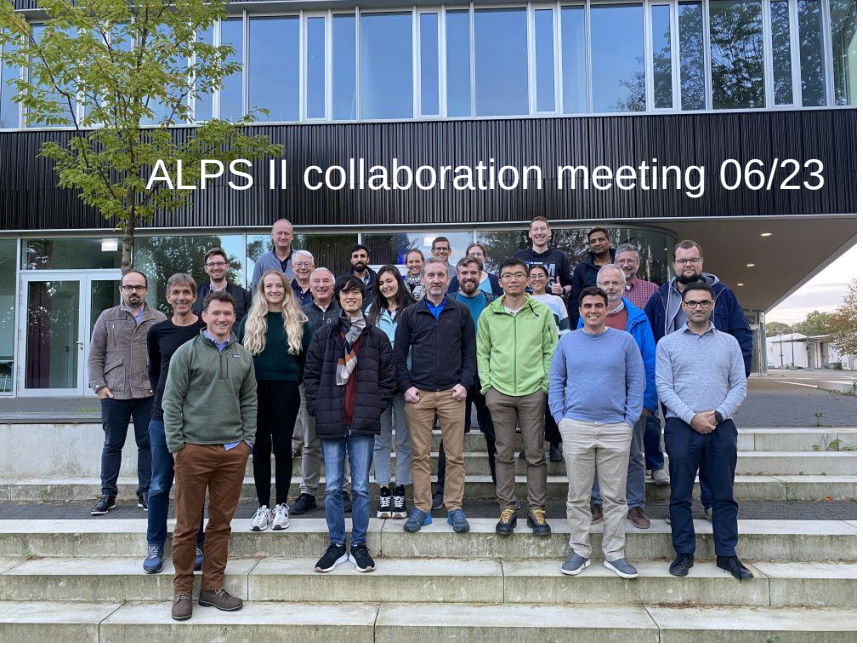
2 February 2024

Axel Lindner, DESY

Cryoplatform


DESY in 2000
ALPS II
Cryoplatform
MADMAX
Baby
IAXO
HERA
PETRA


ALPS II



Collaboration members

ALPS II

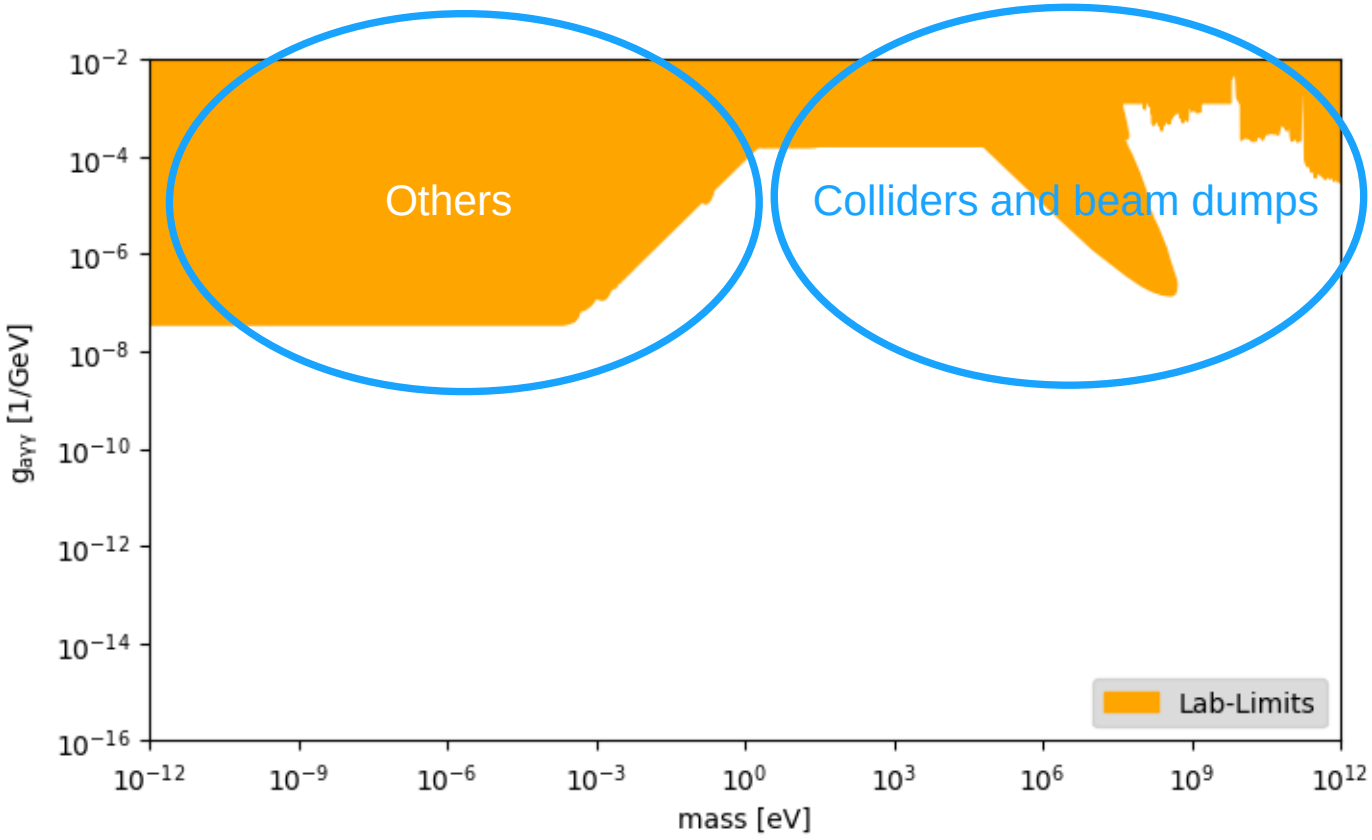
Supported by

The axion landscape

Axion-photon coupling vs. axion mass

Data by Ciaran O'Hare
https://cajohare.github.io/AxionLimits/

Purely laboratory based searches: model-independent results.



ALPS II

The axion landscape

Data by Ciaran O'Hare
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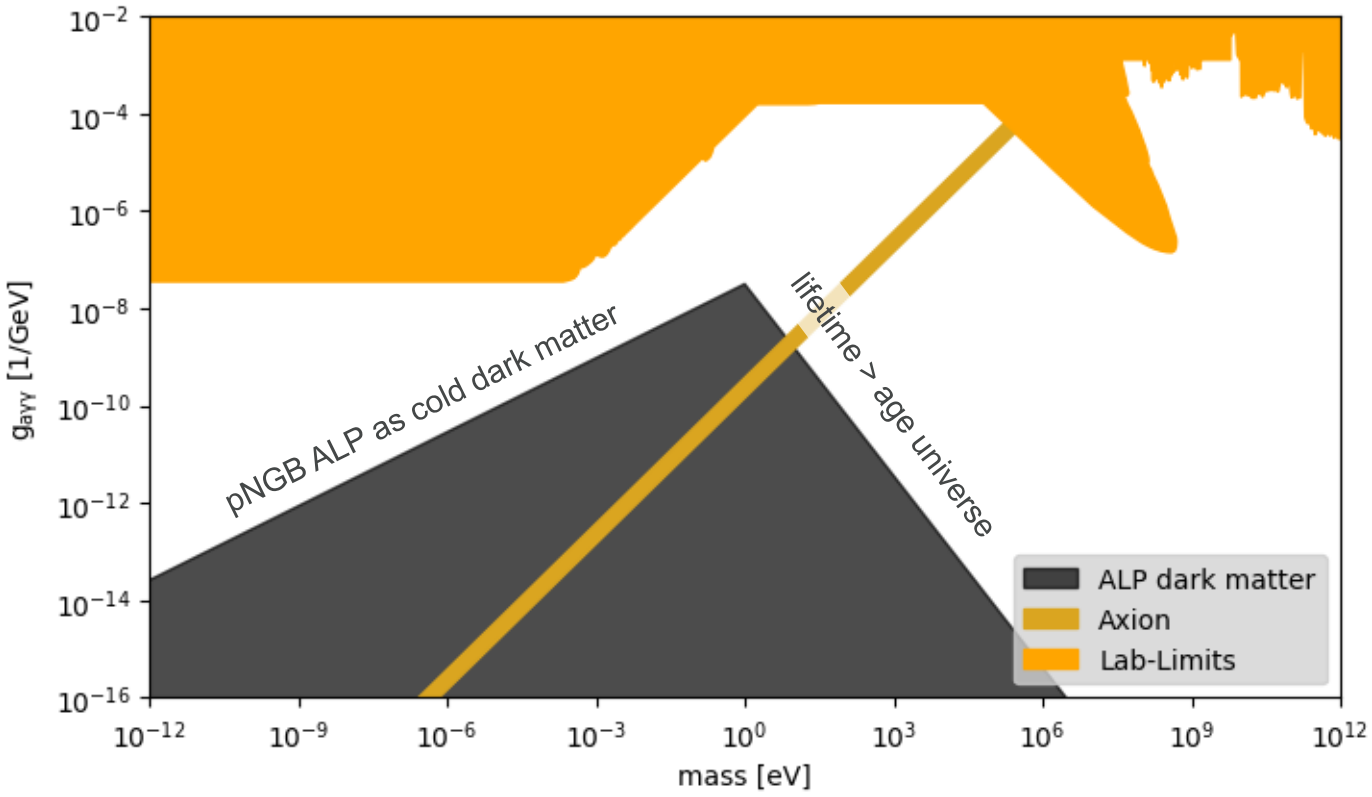

The dark matter region
is far away from the reach of present accelerator-based experiments.

The QCD axion in the dark matter region is far away from model-independent searches.

ALPS II

The axion landscape

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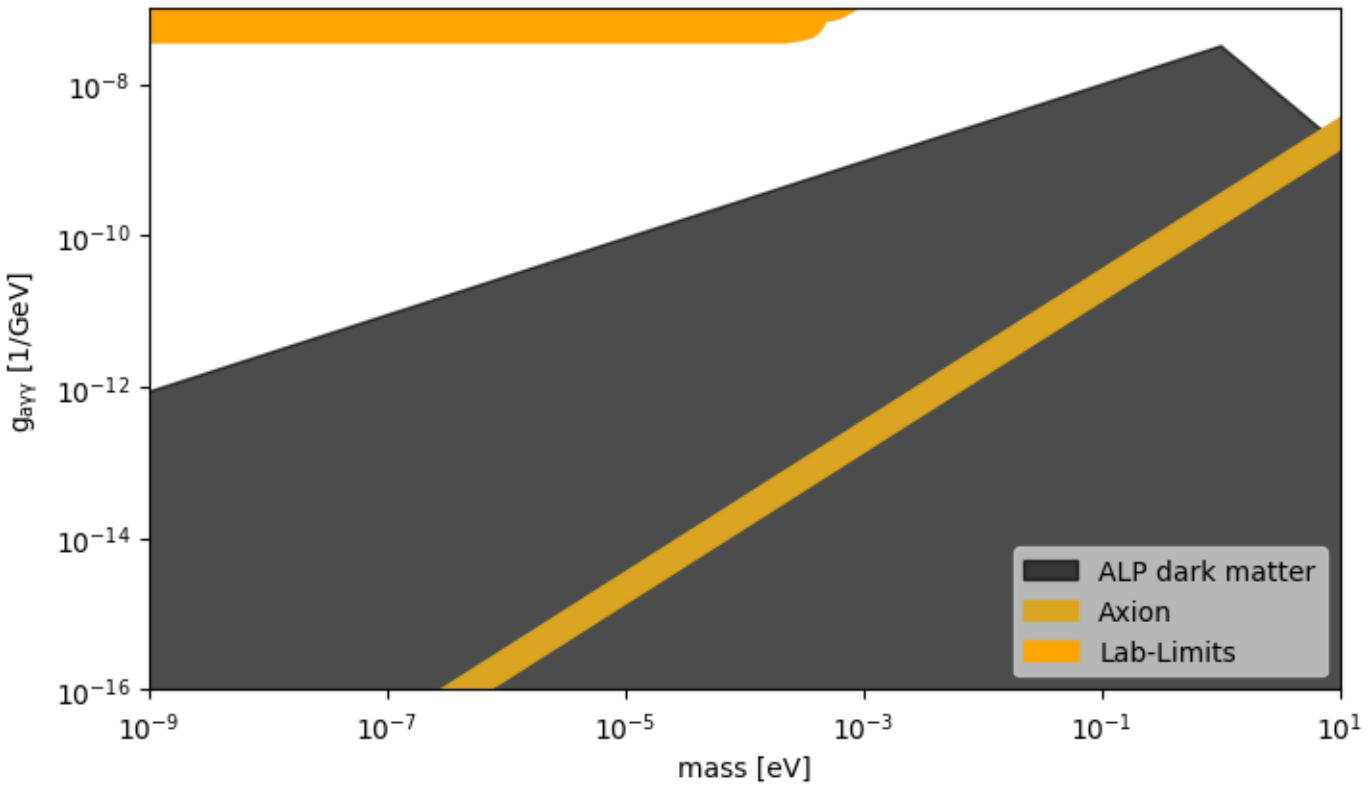

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ALPS II

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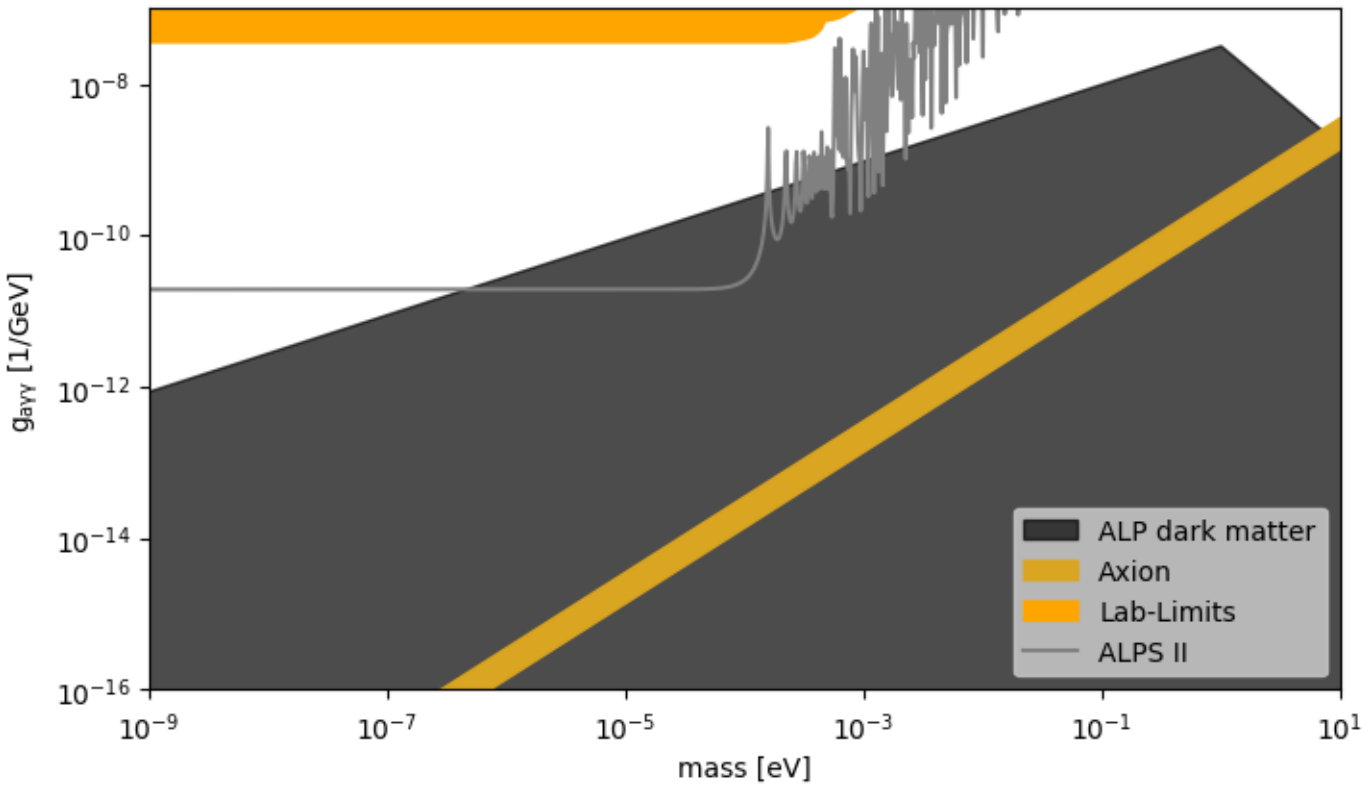
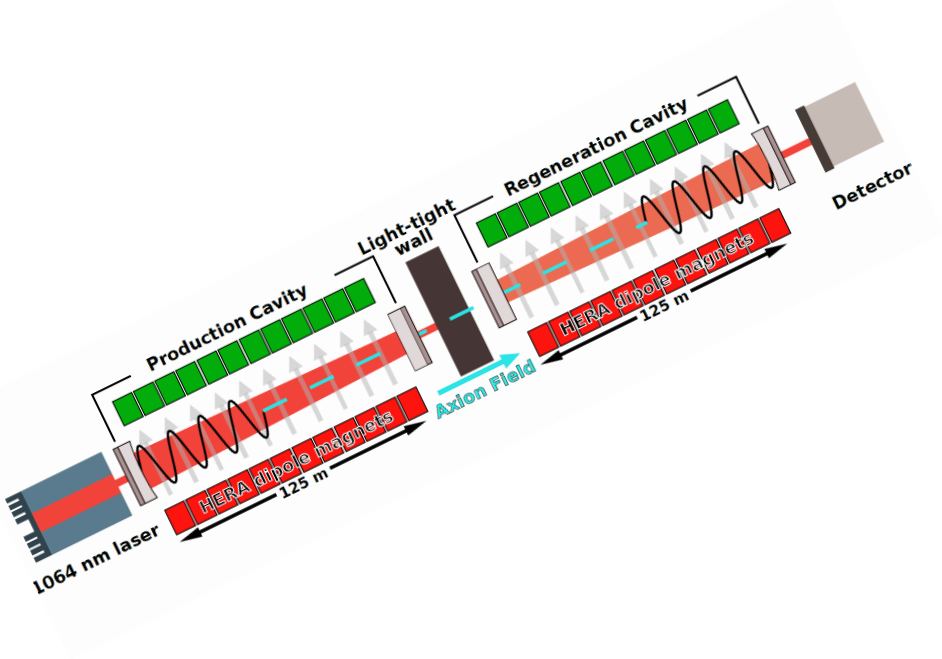


Bridging the gap with **ALPS II**:

Improve the sensitivity by O(10^3)!

ALPS II in the HERA tunnel

Light-shining-through-a-wall with resonant amplification



ALPS II in the HERA tunnel

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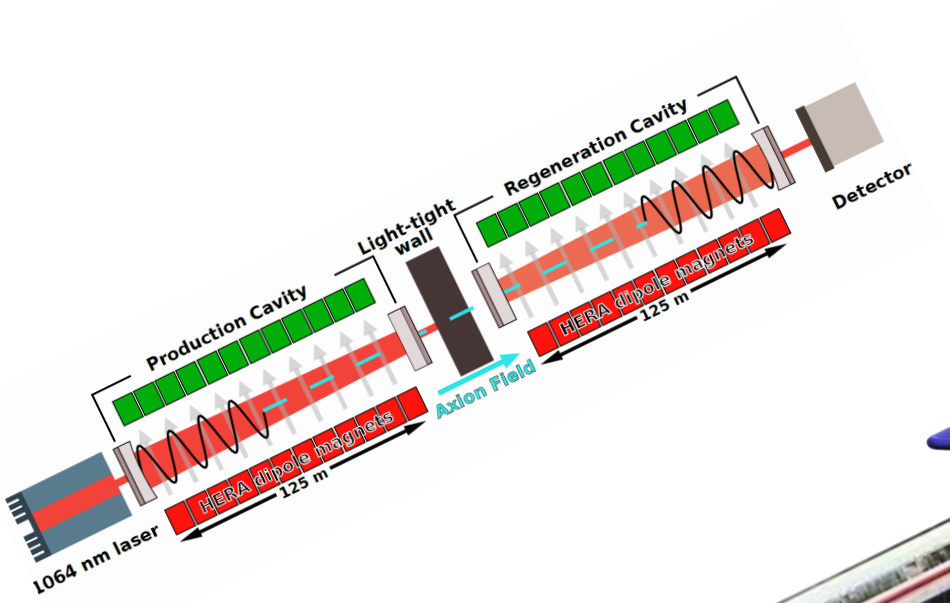


Clean-room,
high power laser

12 HERA dipole magnets

Cryogenics

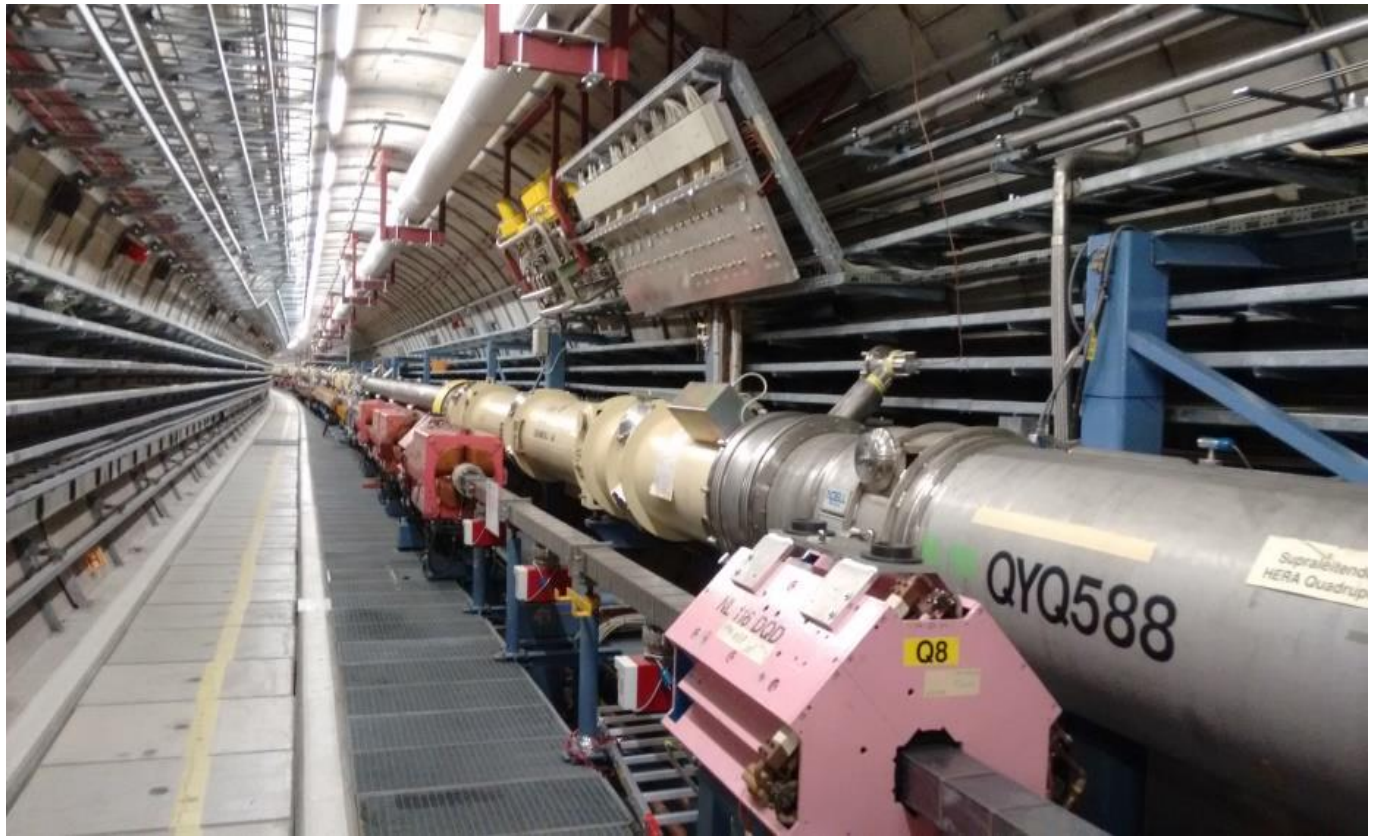
Clean-room,
„wall“

12 HERA dipole magnets

Clean-room,
detector

ALPS II

Construction 2019-2023



Dismantling the HERA accelerator around HERA North.

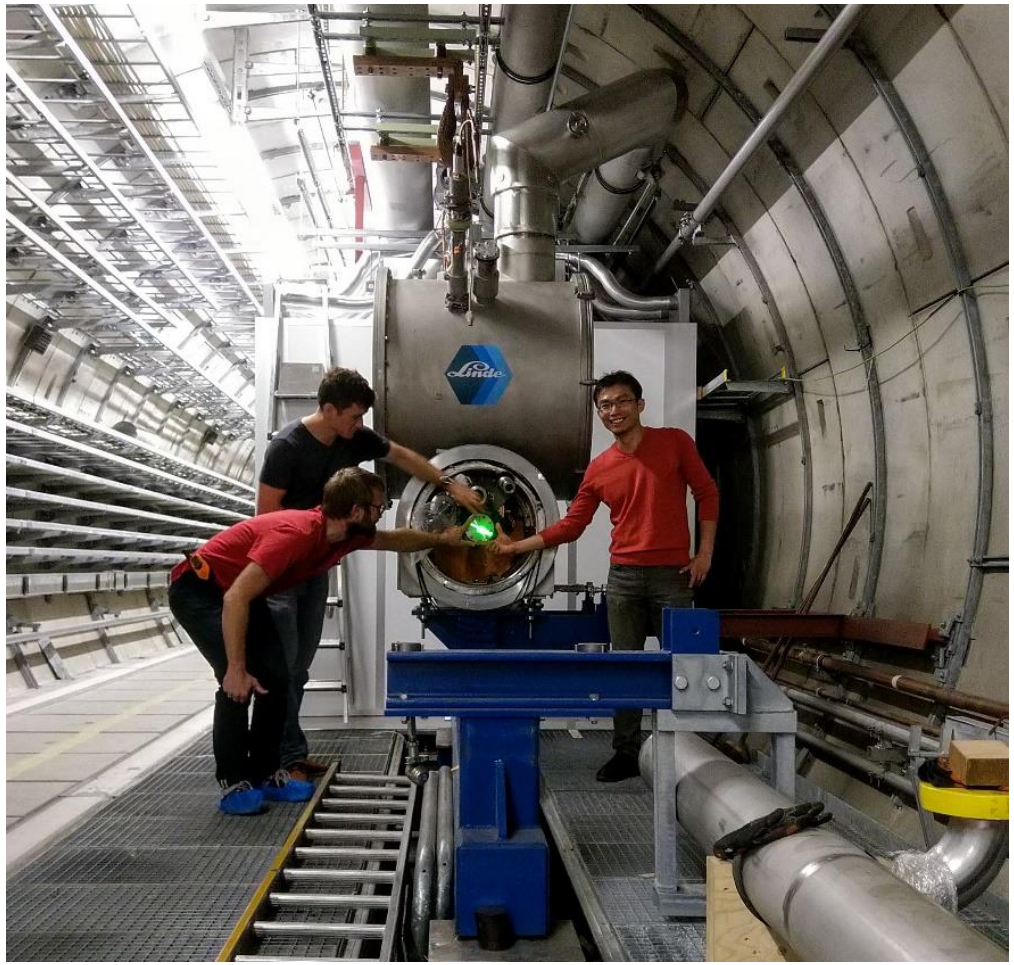
ALPS II

Construction 2019-2023

The straightened dipoles are coming.

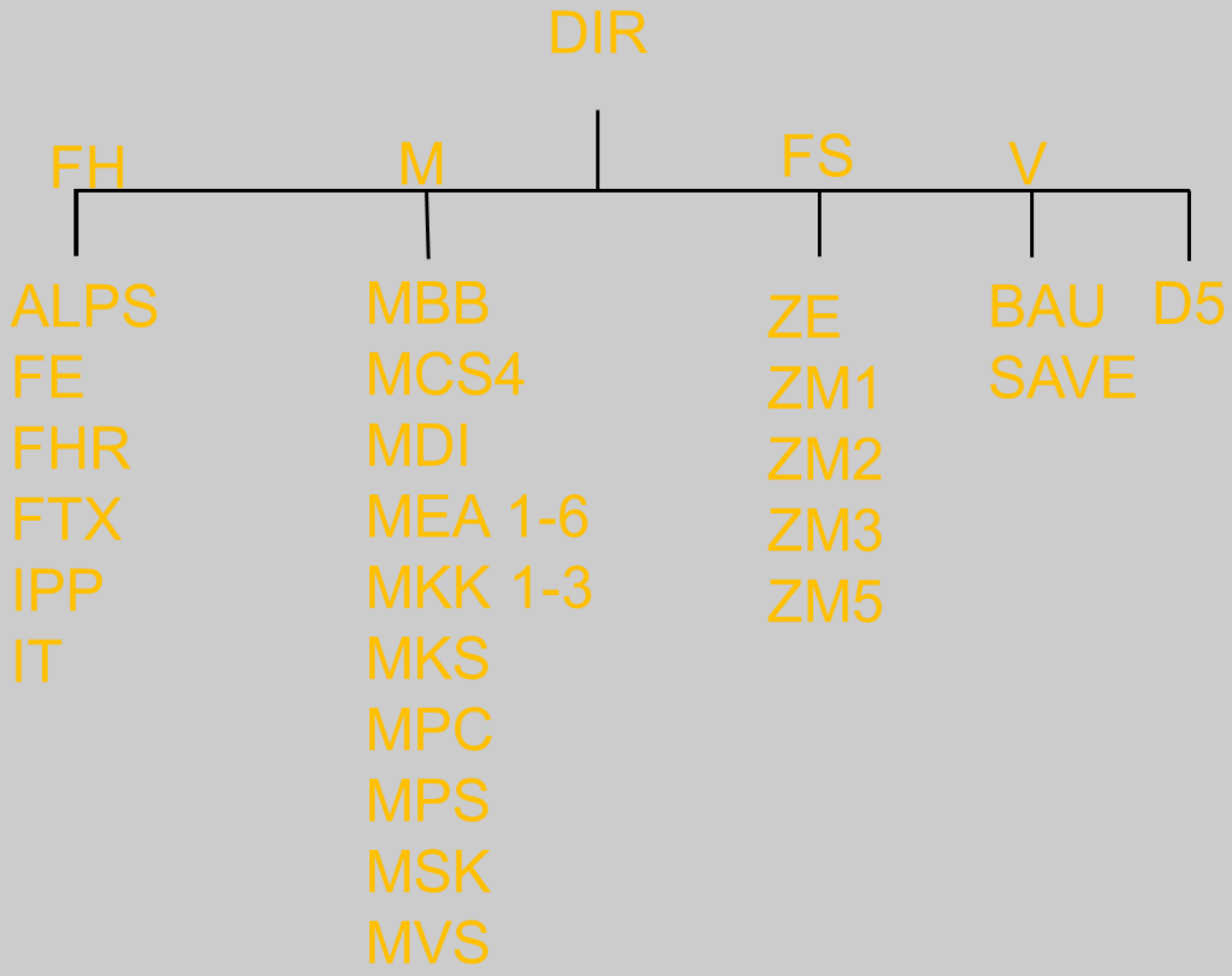
ALPS II

Construction 2019-2023



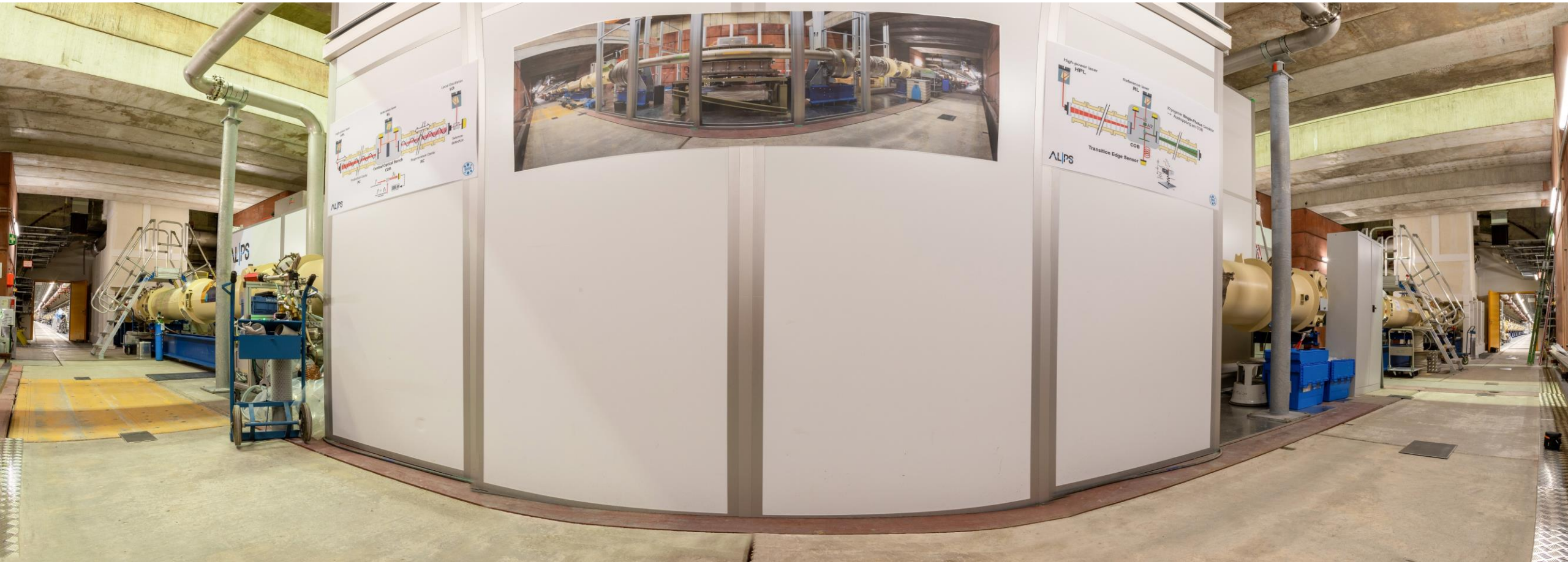
Light-through-first-magnets.

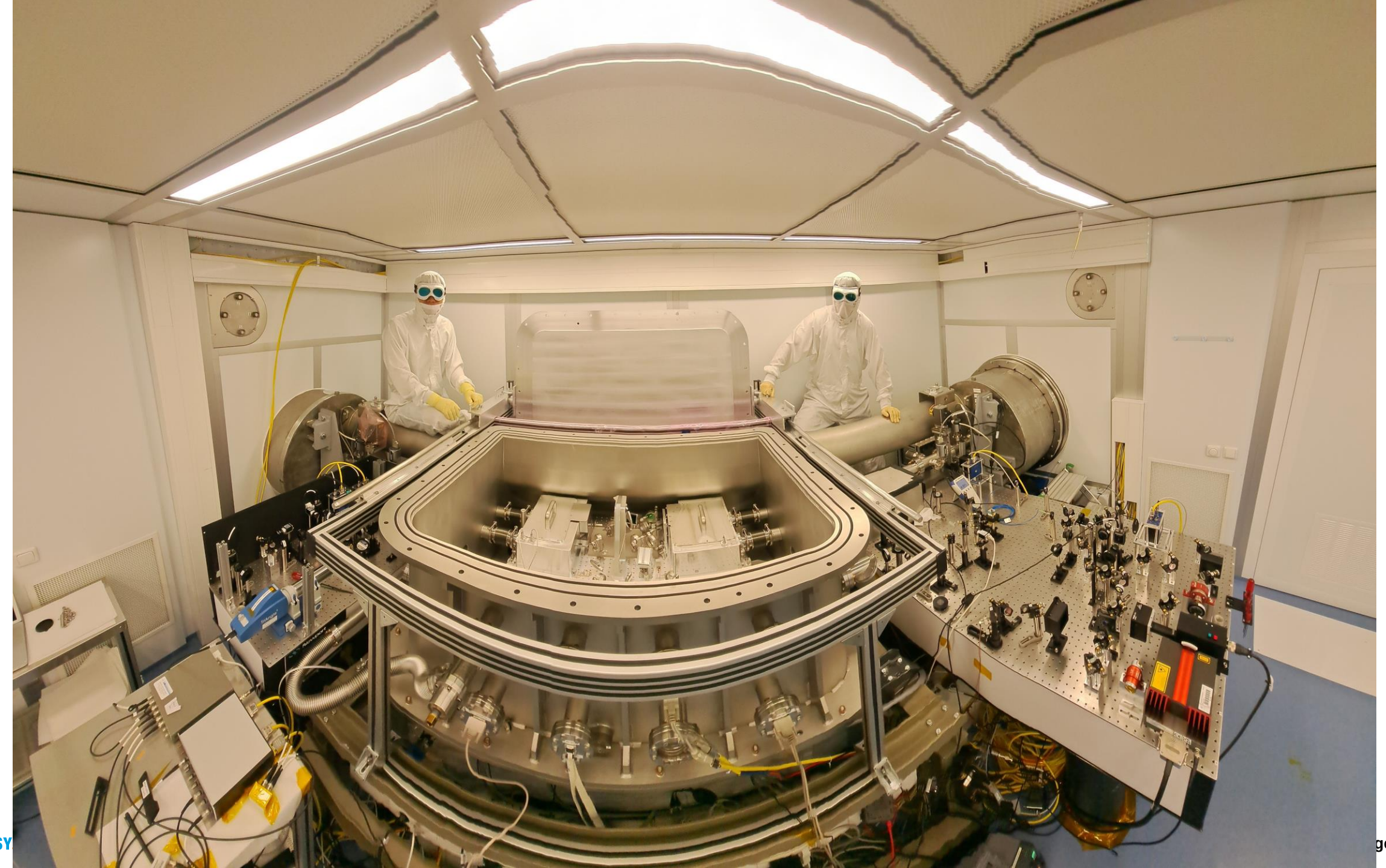
ALPS II: coordination of DESY groups and companies



Companies

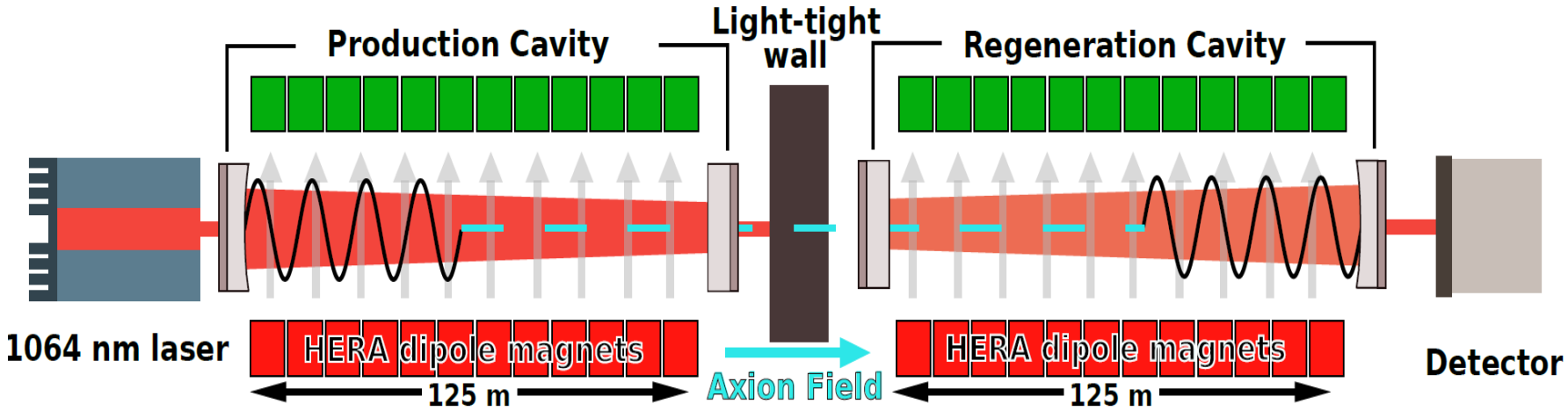
A&S
DeMaCo
Elektro-Wille
IMD
Isolier-Technik Held
Judtka Metallbau
Kliewe Metallbau
Loemat
Milz Klimatechnik
Pfeiffer


ALPS
High-power laser
HPL
Reference laser
RL
COB
Transition Edge Sensor
ALPS



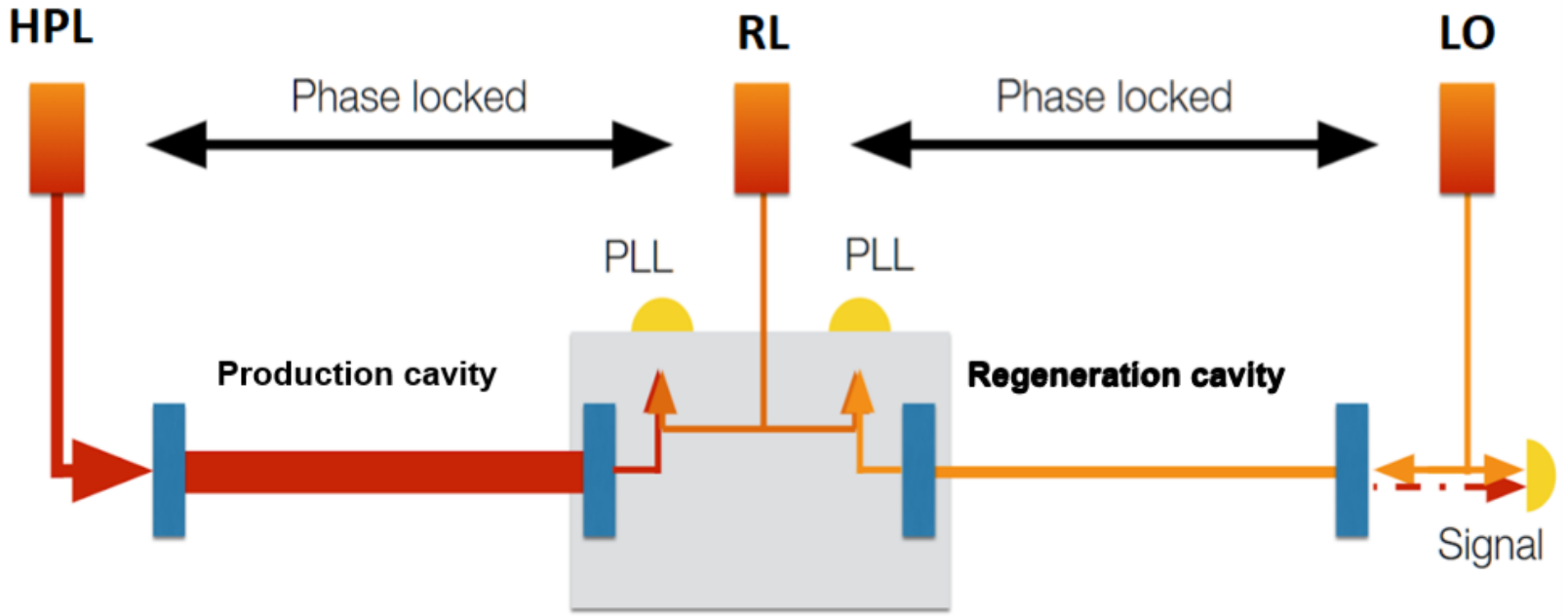
ALPS II: a glimpse on the challenges

Cavities and Heterodyne Sensing



ALPS II: a glimpse on the challenges

Cavities and Heterodyne Sensing



Problem:
Light in regeneration cavity required to sense seismic mirror motions to maintain resonance condition for light from axion reconversion.

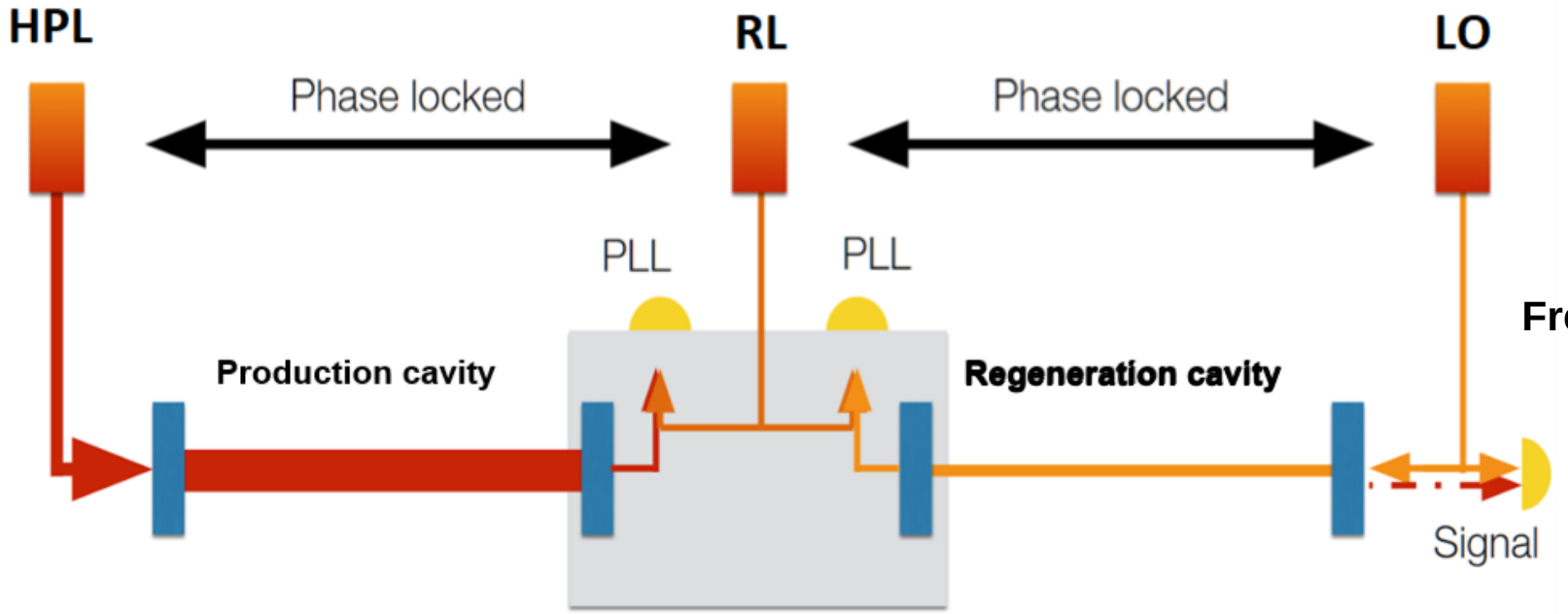
From a problem to a benefit:
Maintain a constant

- frequency difference and
- phase difference

between sensing light and "axion-light".
Superpose both light fields and look for the beat-signal (heterodyne sensing).

ALPS II: a glimpse on the challenges

Cavities and Heterodyne Sensing



Frequencies involved:

281.759.828.947.368,0 Hz
(variable to compensate seismic noise)

Difference to above: 58.659.993,2 Hz

Down-mixing for signal detection:

58.659.993,2 + 2,4 Hz
Stability requirement: 0.1 µHz

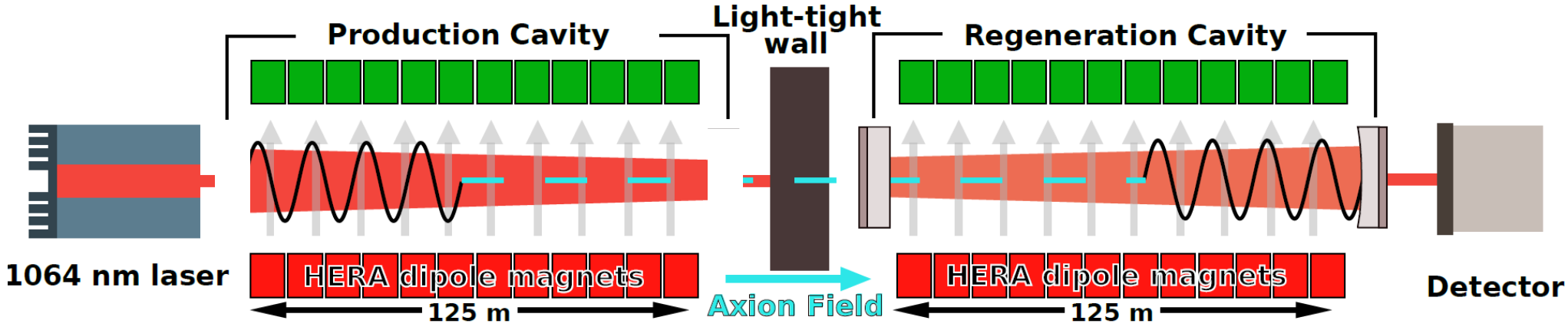
ALPS II: data taking has started!

23 May 2023

After more than 10 years of R&D and construction…

ALPS II initial science run

No optical cavity in front of the wall



Prime motivations:

- Characterize and mitigate stray-light reaching the detector:
  50-fold enhancement without the production cavity.
- Demonstrate stable data taking.

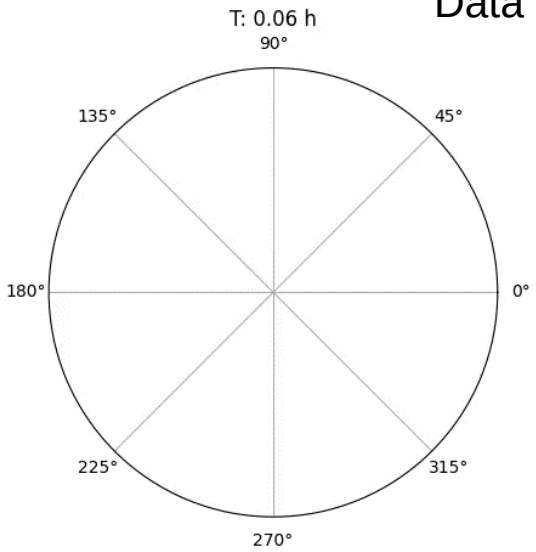
ALPS II status

Initial science run 23 to 31 May 2023

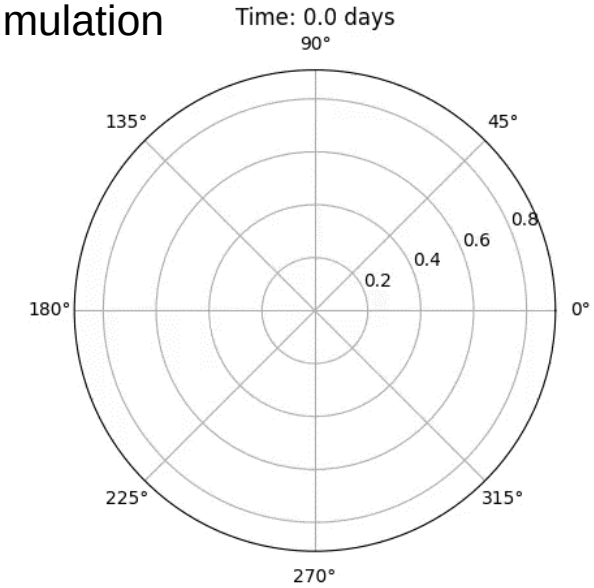
Radial:
integrated number of photons

Circular:
integrated phase difference

Data



Simulation



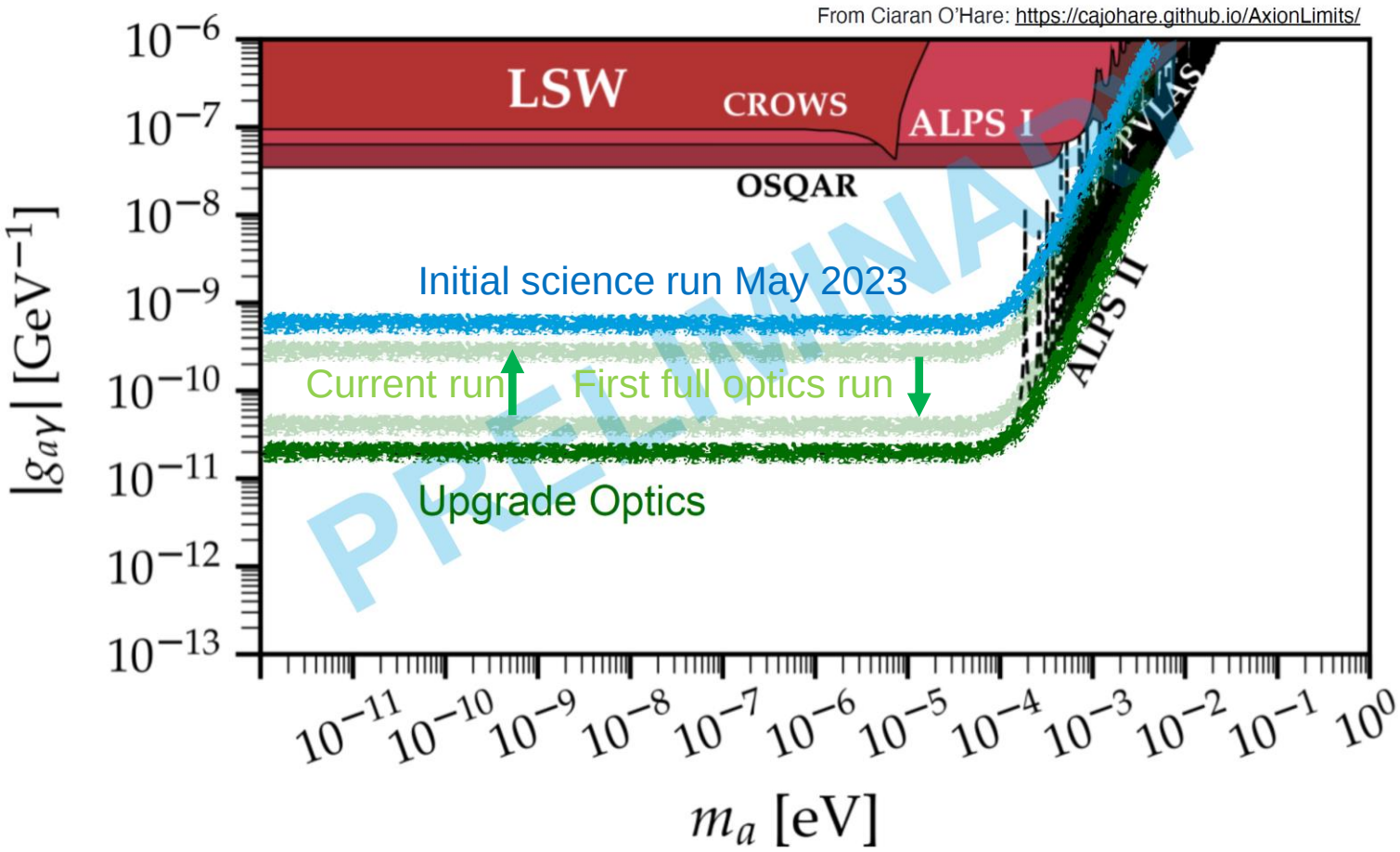
Very preliminary results:

- No light shining through the wall.
- Stray-light level < 10^{-22} W after 10,000 seconds.

- At present:
  start of a 1,000,000 second run for further tests.

ALPS II sensitivities (projections)

Very preliminary !



Next steps:

- Full optics in 2024.
- Design sensitivity in 2025.

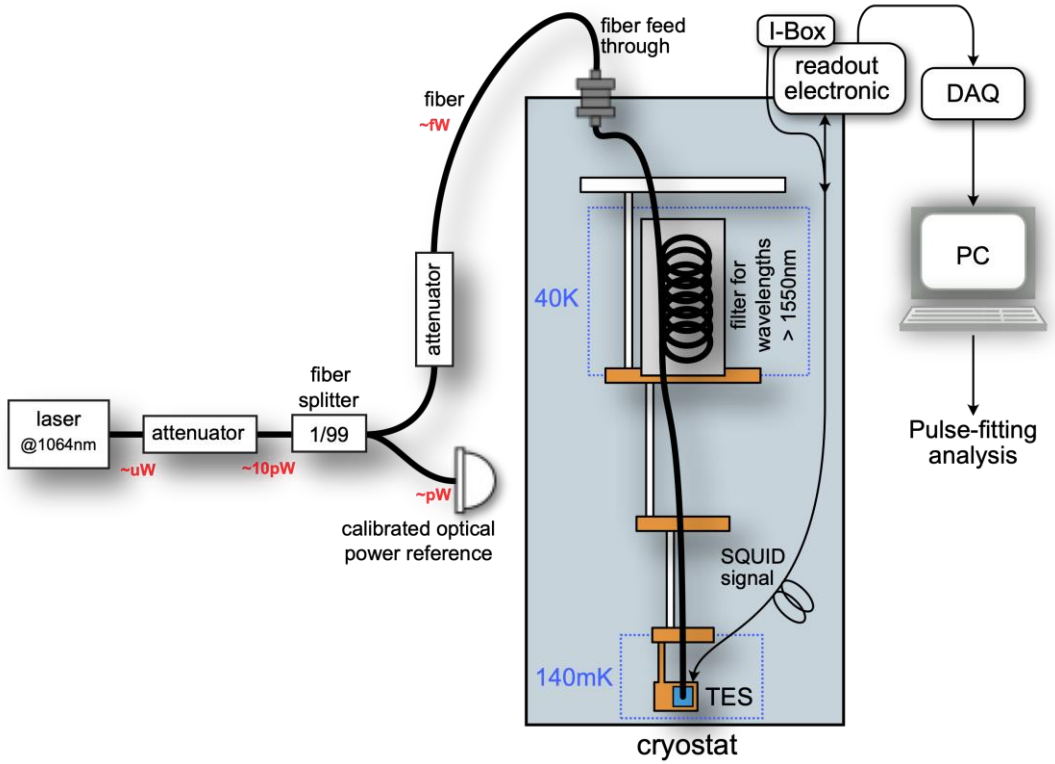
Beyond (depending on results):

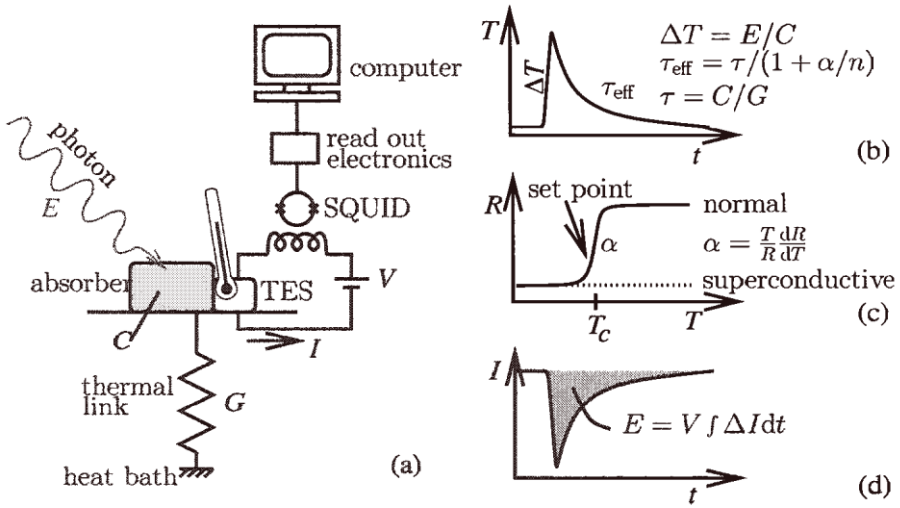
- Further axion searches (TES-based?).
- Vacuum magnetic birefringence.
- High frequency gravitational waves.

ALPS II: TES detectors

Counting photons with $5 \cdot 10^{-24}$ W @ 1064 nm and <10% single photon energy resolution

- Using a superconducting transition edge sensor operated at about 100 mK.



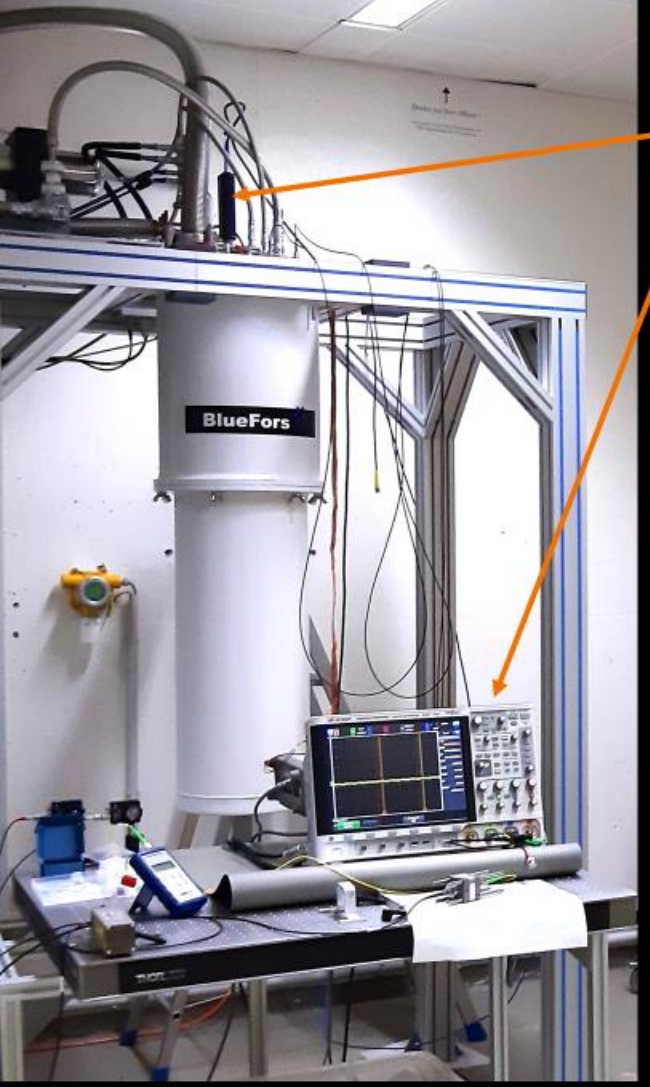


ΔT ≈ 300 µK

ΔR ≈ 1 Ω

ΔI ≈ 70 nA

- Two dilution refrigerators available.
- TES for direct dark matter searches?
- TES for squeezed light photon statistics?

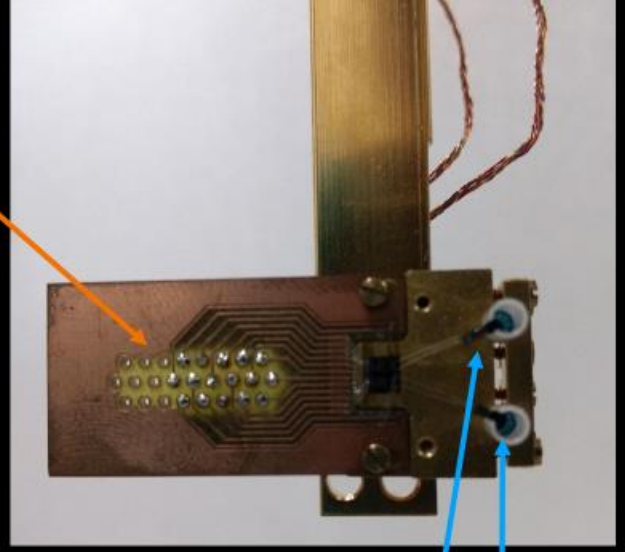


Cryostat

- Bluefors Dilution refrigerator (mixing He3/4) achieving 21mK
- Control from Bluefors (manually and remote software)
- Remote control (Windows PC)
- DOOCS Panel for remote view

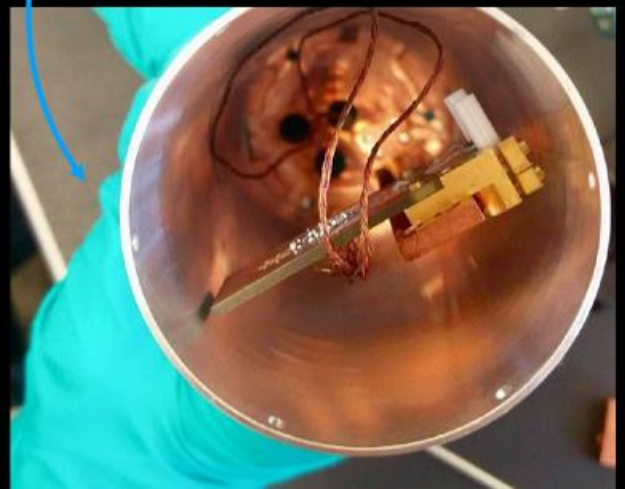
SQUID (PTB, Magnicon)

- I-Box
- Electronics from Magnicon
- IV curve measurement via Oscilloscope



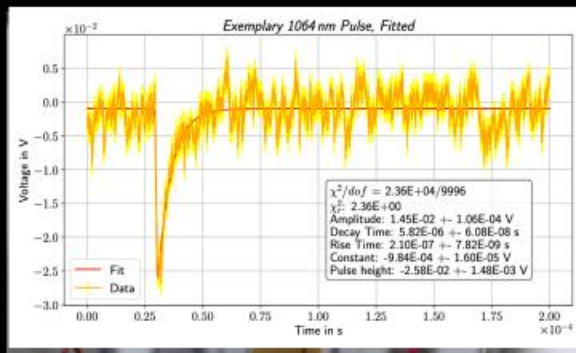
TES

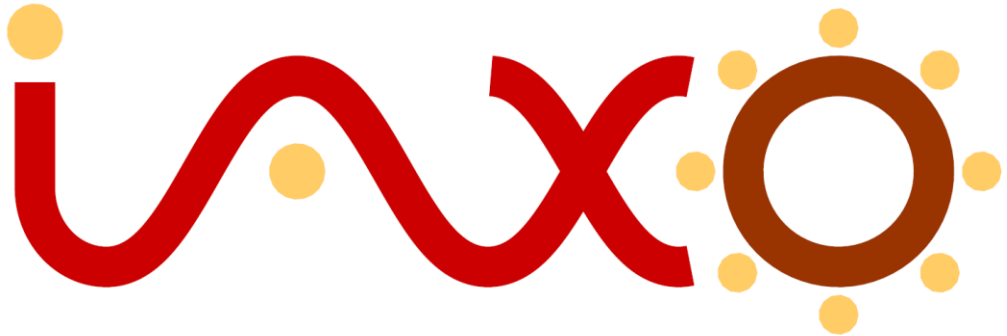
- 2 Tungsten sensors (NIST)
- High-efficient layers (>99% transmission for 1064 nm)
- Fiber coupled
- Coupled to the bath via copper
- aluminium can for shielding against magnetic, EM, BB… ?



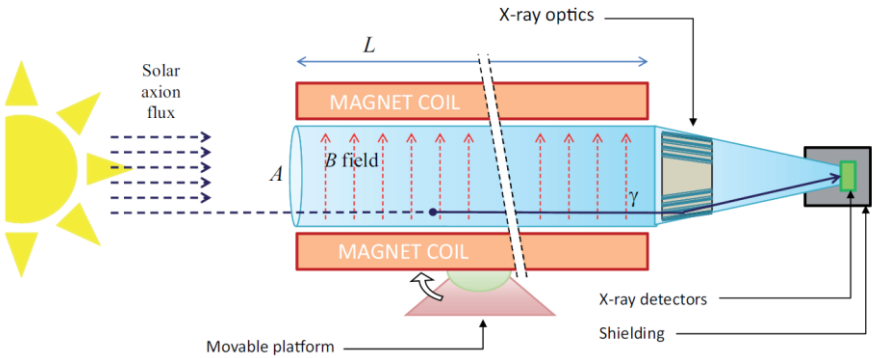
DAQ

- Alazar ATS9626 250Ms/s via PCI on a Linux system
- GUI programmed in-house
- Triggering for different working points of TES resistance
- Different analysis lines





Annual Review of Nuclear and Particle Science, Vol. 65: 485-514 (2015)

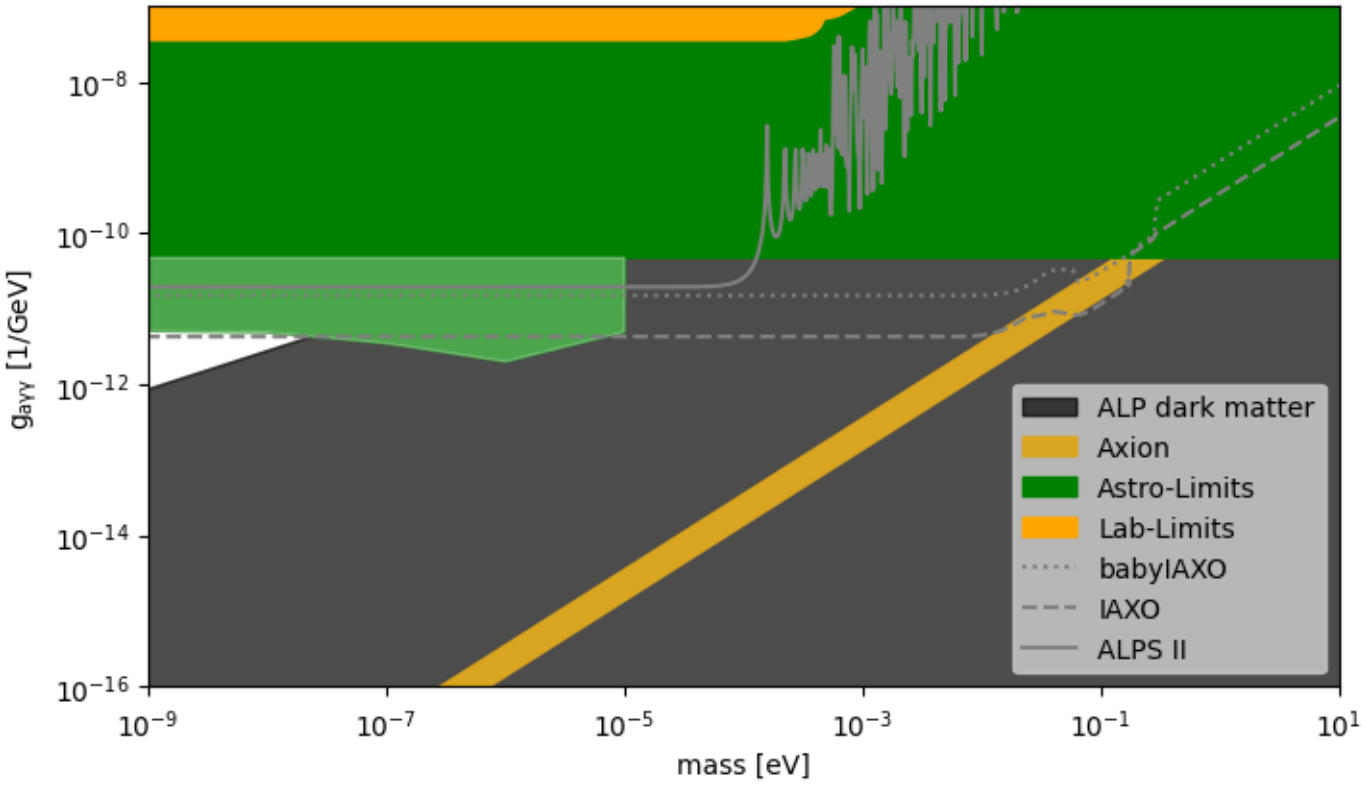


Full members: Kirchhoff Institute for Physics, Heidelberg U. (Germany) | Siegen University (Germany) | University of Bonn (Germany) | DESY (Germany) | University of Mainz (Germany) | Technical University Munich (TUM) (Germany) | University of Hamburg (Germany) | MPE/PANTER (Germany) | MPP Munich (Germany) | IRFU-CEA (France) | CAPA-UNIZAR (Spain) | INAF-Brera (Italy) | CERN (Switzerland) | ICCUB-Barcelona (Spain) | Barry University (USA) | MIT (USA) | LLNL (USA) | University of Cape Town (S. Africa) | CEFCA-Teruel (Spain) | U. Polytechnical of Cartagena (Spain)

Associate members: DTU (Denmark) | U. Columbia (USA) | SOLEIL (France) | IJCLab (France) | LIST-CEA (France)

Looking for solar axions

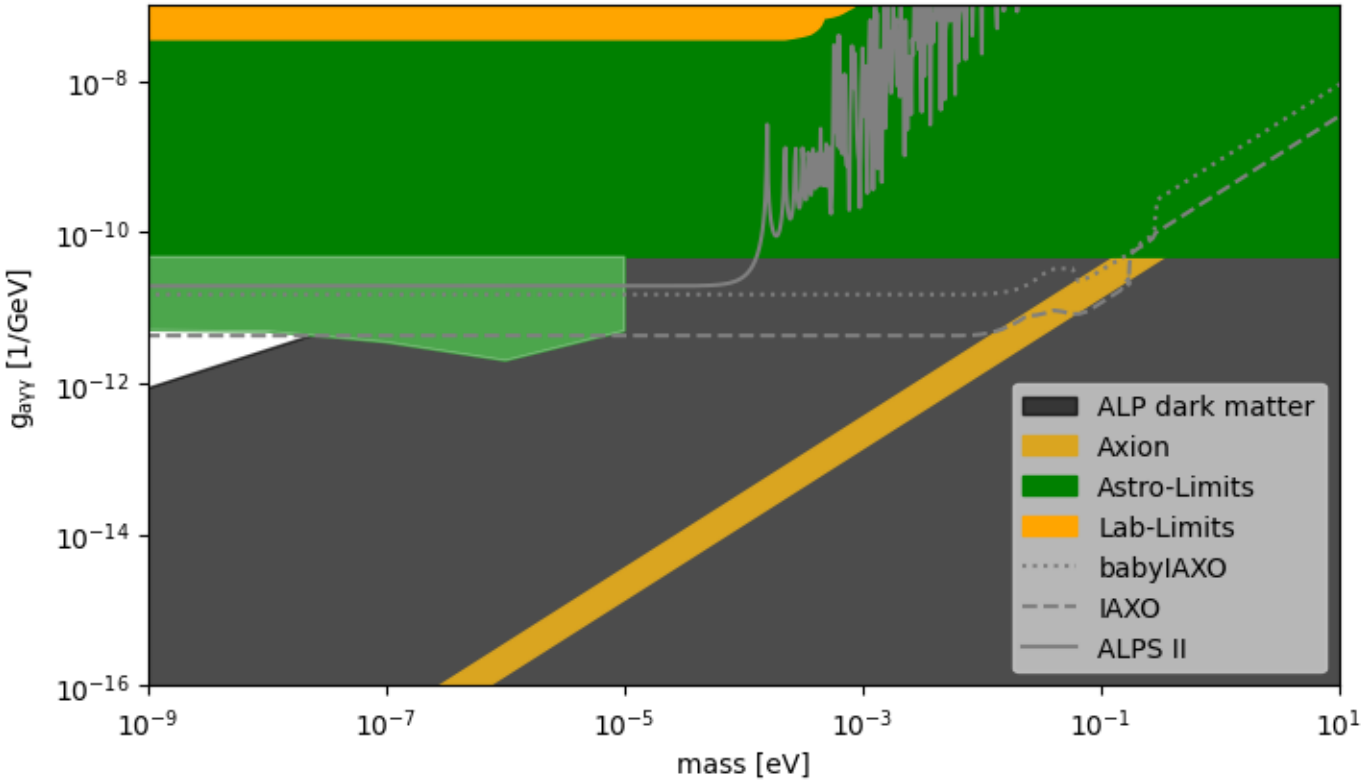
Axions from astrophysics

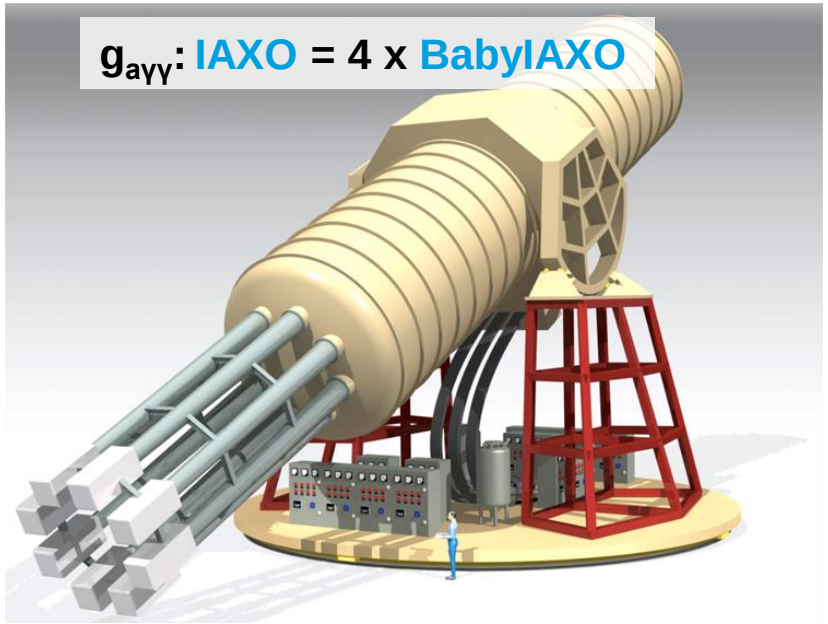


IAXO and BabyIAXO

Looking for solar axions

BabyIAXO as a full-fledged IAXO prototype
with own discovery potential.

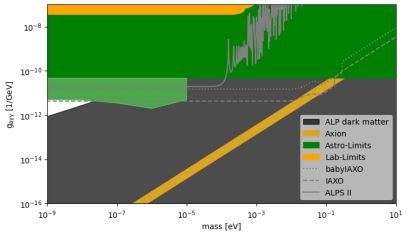




and Baby

Physics potential

Unique axion discovery potential,
overlapping with ALPS II and going beyond.



and Baby

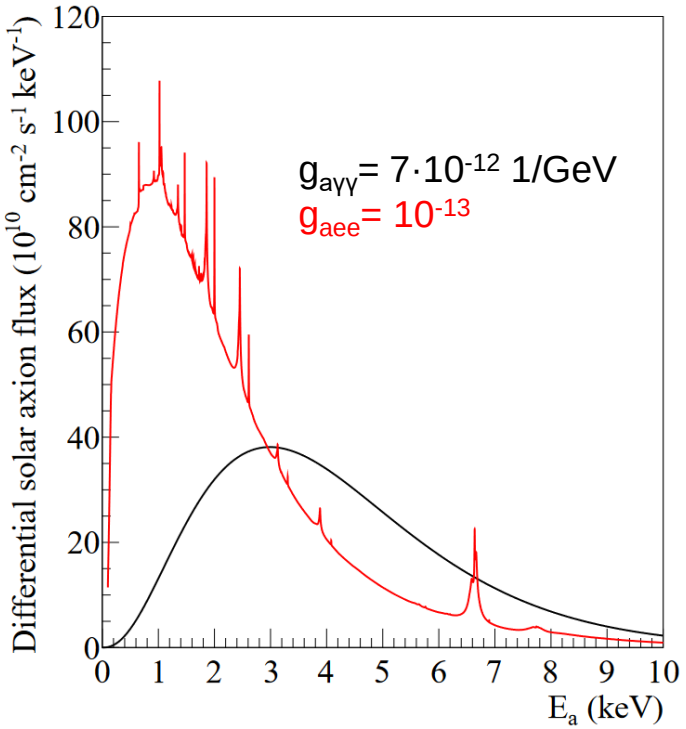
Physics potential

Unique axion discovery potential, overlapping with ALPS II and going beyond.

If axions are found:

Test axion models:

- Compare different couplings: Axion-photon, -electron, -nucleon.



Axions from ^{57}Fe at 14.4 keV

IAXO and Baby IAXO

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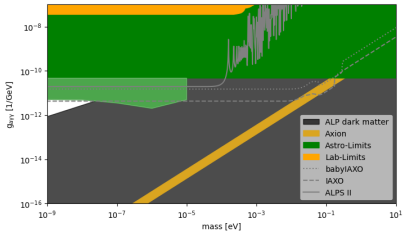
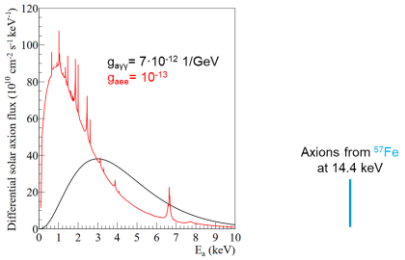
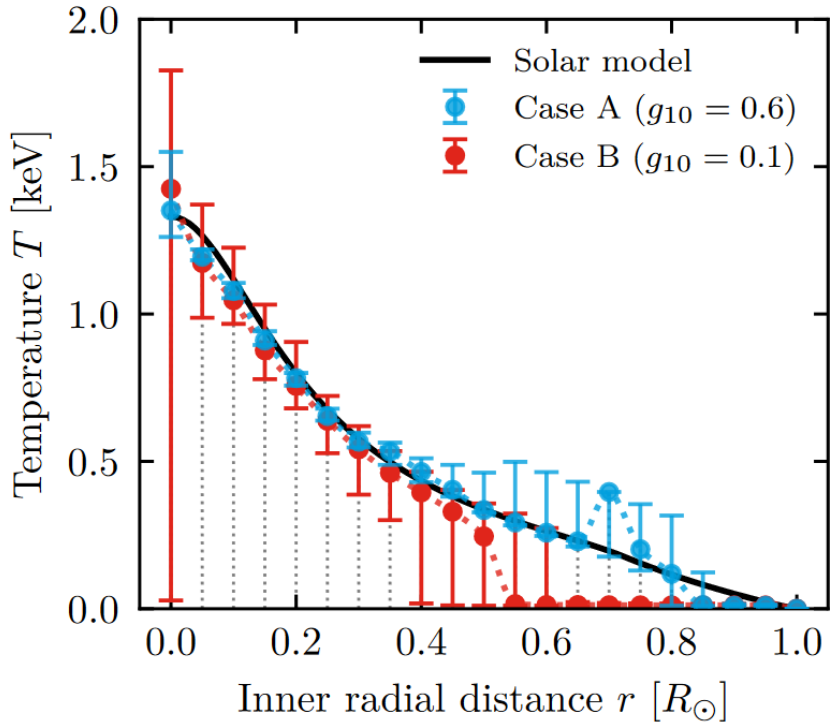
Solar physics:

- Map magnetic fields, temperature, chemical composition





Axions from ^{57}Fe at 14.4 keV



JCAP 10 (2023) 024

IAXO and Baby IAXO

Physics potential

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If axions are found:

Test axion models:

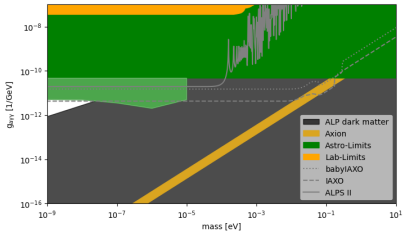
- Compare different couplings: Axion-photon, -electron, -nucleon.

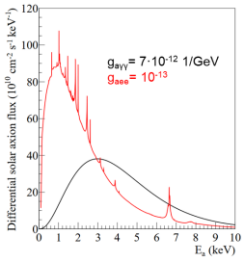
Solar physics:

- Map magnetic fields, temperature, chemical composition.

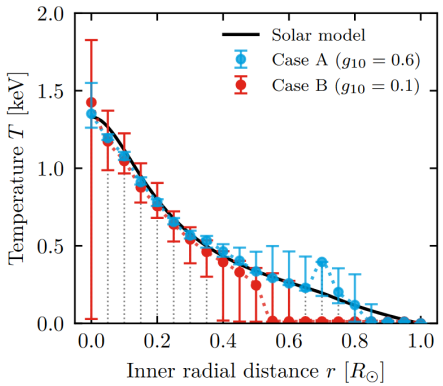
More astrophysics:

- Axions from supernovae?
- High frequency gravitational waves?

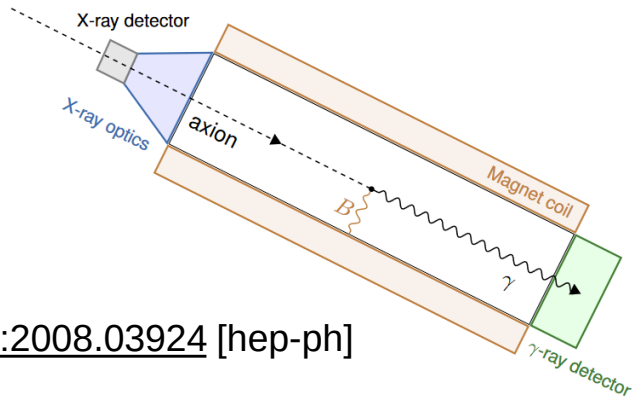




Axions from ^{57}Fe at 14.4 keV



SN



arXiv:2008.03924 [hep-ph]

Status of Baby IAXO

Ready to start construction in 2024?

In 2022 BabyIAXO was basically ready to start construction, but experienced a serious setback after the Russian invasion into the Ukraine and the subsequent discontinuation of collaborations with Russian partner institutes.

This mainly affected the BabyIAXO magnet.

Thanks to the collaboration and engagement by CERN and DESY, the magnet seems to be in reach again!

Component / Status	Technical	Funding
Structure & Drive system	(✓)	(✓)
Vacuum & Gas System	✓	✓
Magnet	(✓)	(?)
X-ray Telescopes	✓	✓
Detectors	✓	✓

DarkQuantum

ERC-Synergy Grant DarkQuantum obtained !

- Develop quantum tech for axions
- Quantum-enhanced haloscope in BabyIAXO
- Connection with experts (cryo, quantum,…)
- Contribution to magnet

I. Irastorza (U. Zaragoza), T. Kontos (École Normale Supérieure de Paris), S. Paraoanu (Aalto University), W. Wernsdorfer (KIT)


MADMAX

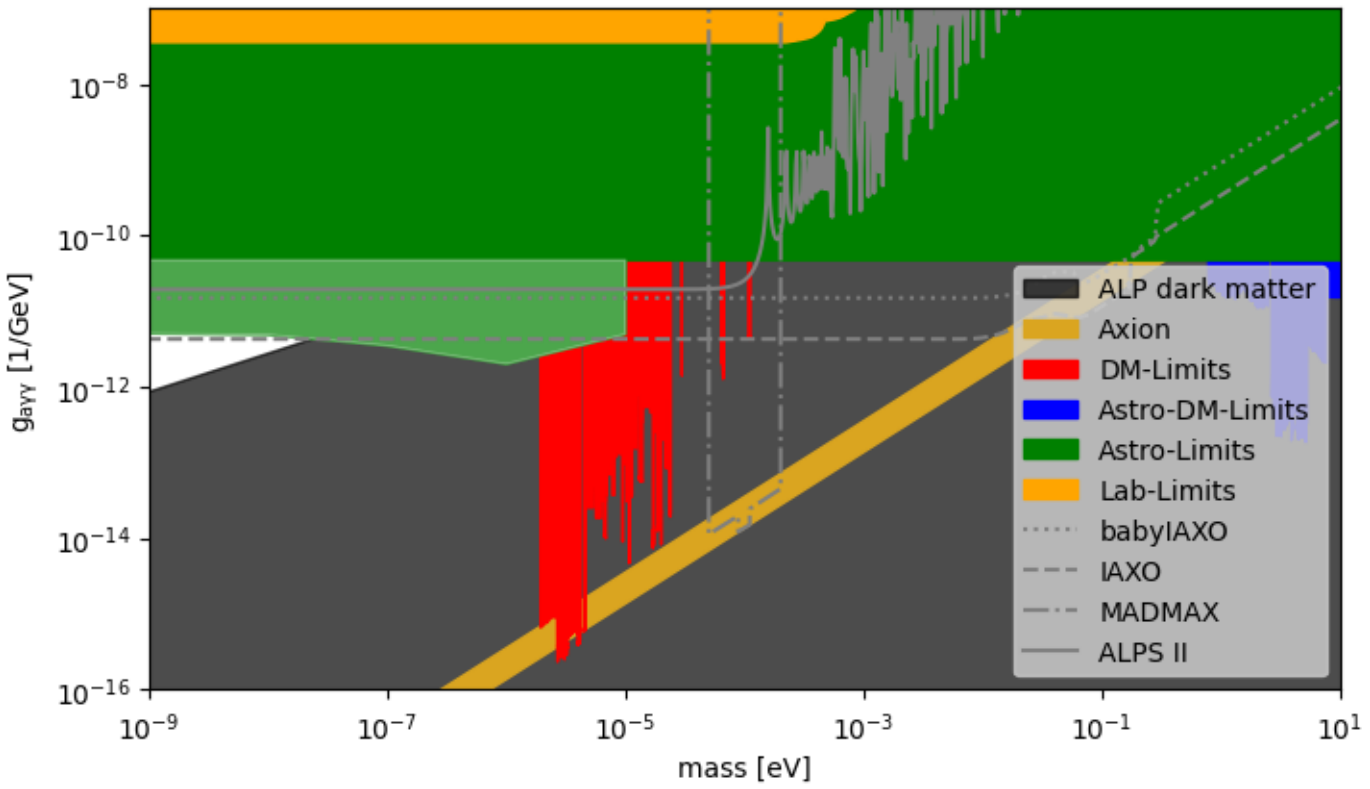
MAgnetized Disc and Mirror Axion eXperiment

https://madmax.mpp.mpg.de/

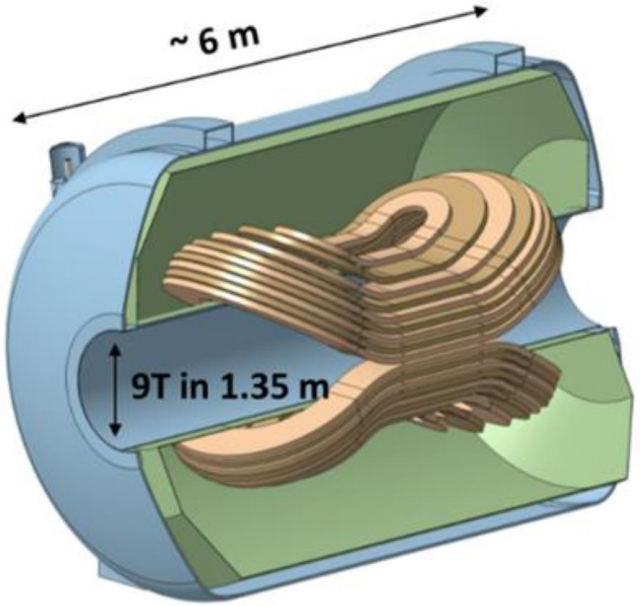
- CPPM, France
- DESY Hamburg, Germany
- Néel Institute, Grenoble, France
- **MPI für Physik, Munich, Germany**
- MPI für Radioastronomie, Bonn, Germany
- RWTH Aachen, Germany
- University of Hamburg, Germany
- University of Tübingen, Germany
- University of Zaragoza, Spain

Looking for dark matter axions

Axions from cosmology



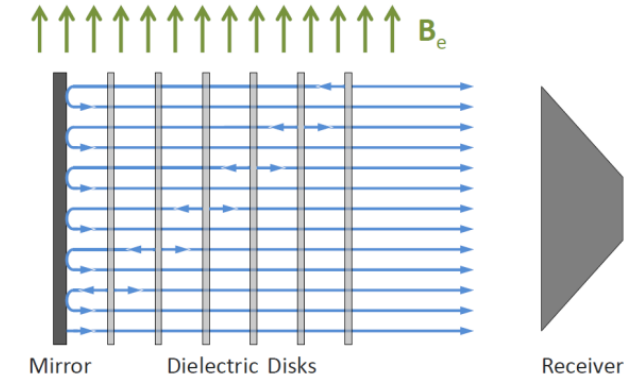
Dark matter axions @ DESY



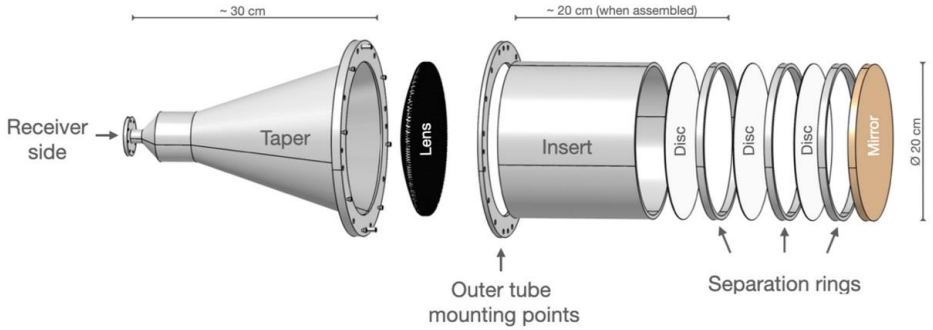
How

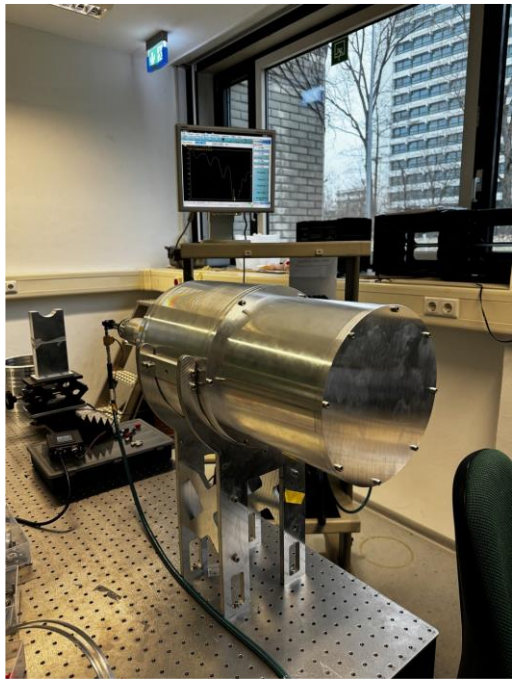
Approach: resonantly enhance axion-photon conversion

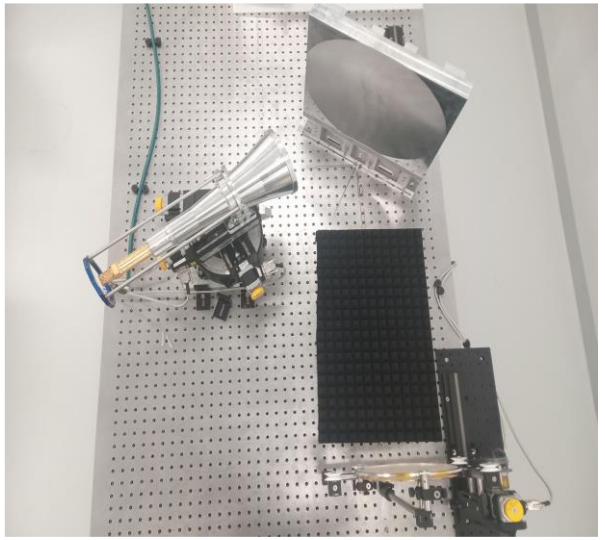
- Booster: a stack of dielectric plates inside a strong magnetic dipole field is tuned to the radiofrequencies corresponding to axion in the 100 µeV mass range.
  - The measured power can be enhanced by several 10^4.
  - Tradeoff between bandwidth and “boost factor”.
- Place the booster inside a huge dipole magnet of 10 T with an aperture of > 1 m.



For details see:
- JCAP 10 (2021) 034
- Eur.Phys.J.C 79 (2019) 3, 186



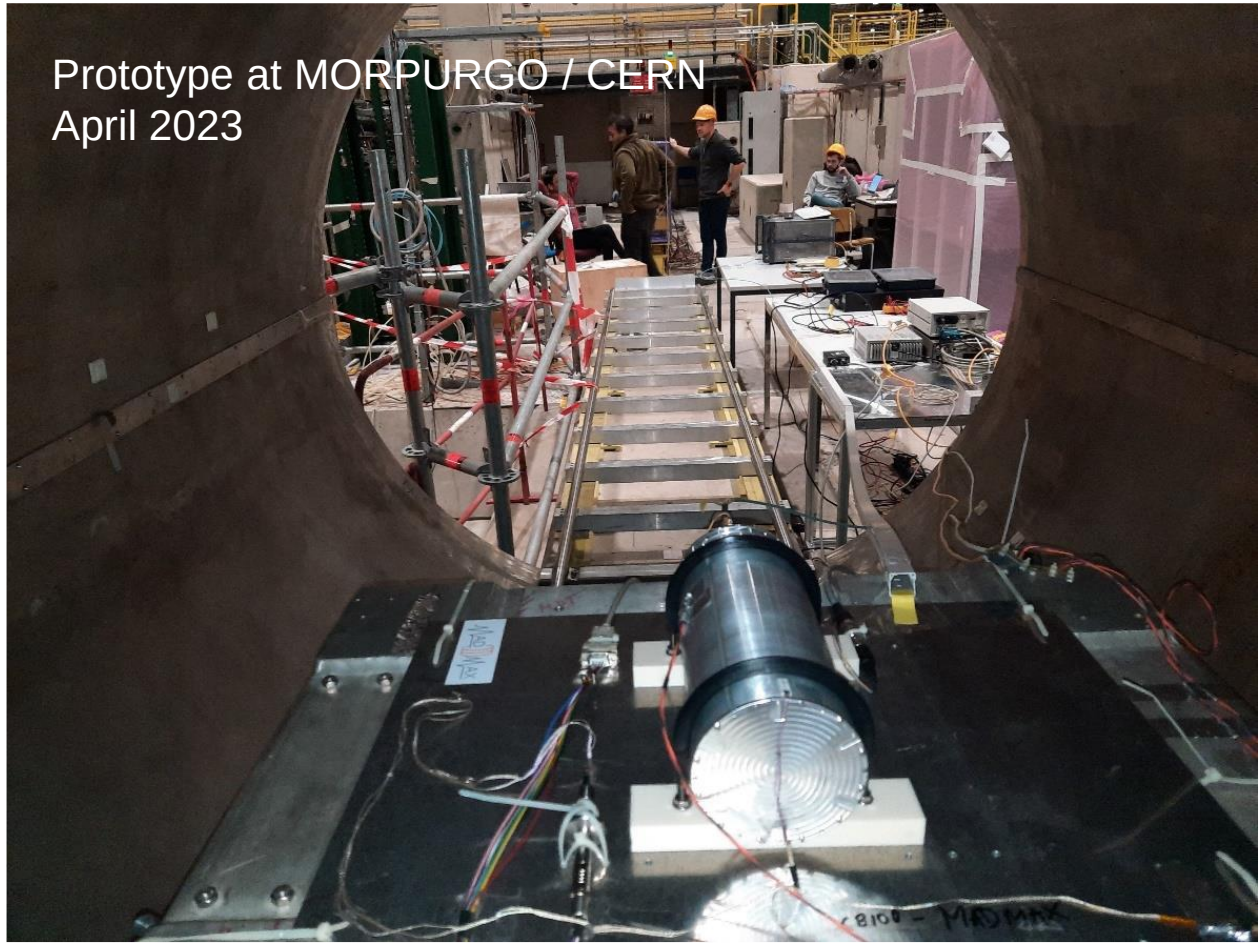




Status

Very substantial progress in the prototyping phase:

- Magnet:
  - Conceptual design.
  - Very successful conductor test at CEA / Saclay.
- Enabling technologies:
  - Dielectric disk handling and mounting.
  - Piezo motor tests (vacuum, cryogenics, magnetic field)
- Booster understanding:
  - Series of prototype tests started.
  - **Complex booster calibration method developed at MPP Munich and Hamburg University.**
  - **First physics results soon!**



Further schedule beyond using MORPURGO depends on availability of funds.

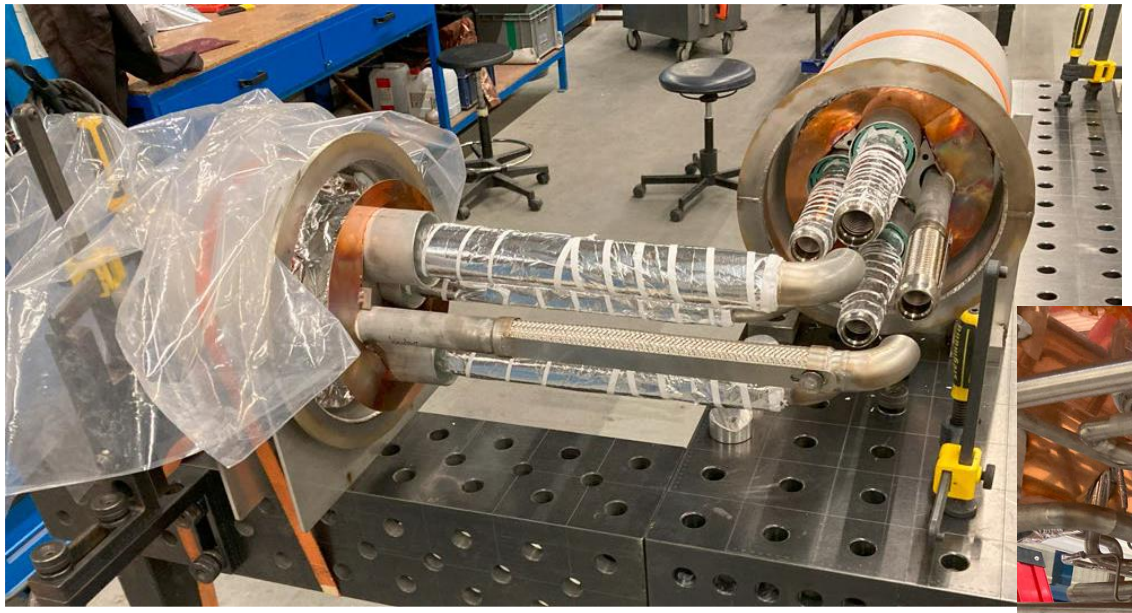
Cryoplatform

Cryoplatform

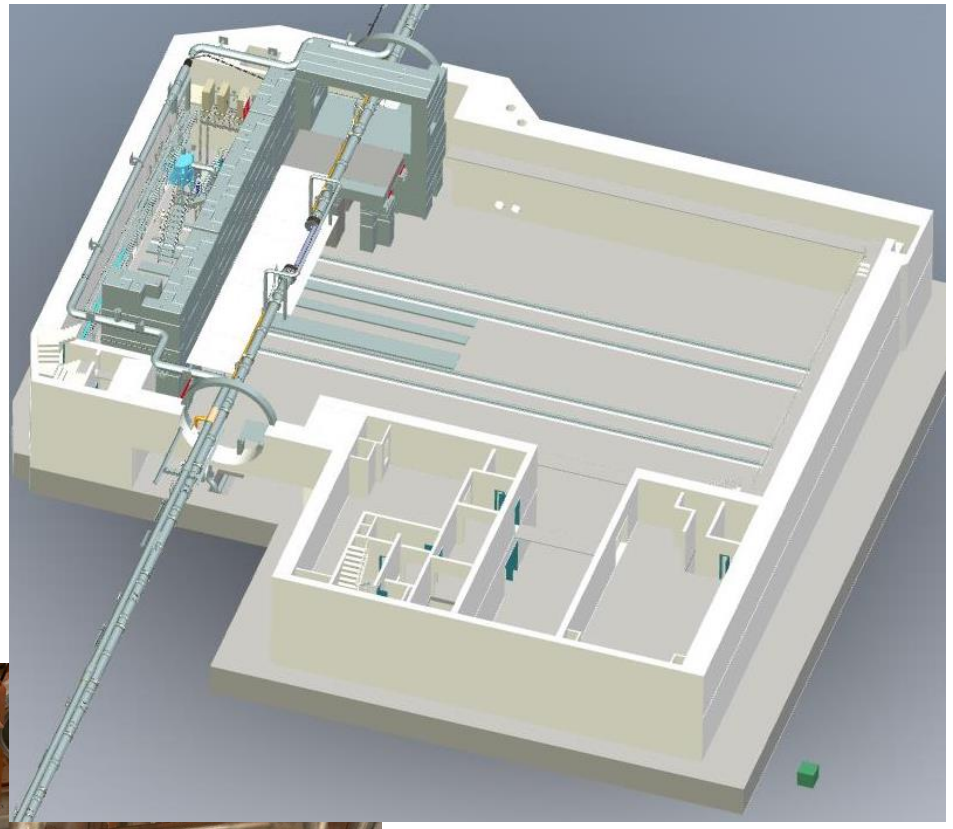
An infrastructure for larger scale “cold” experiments

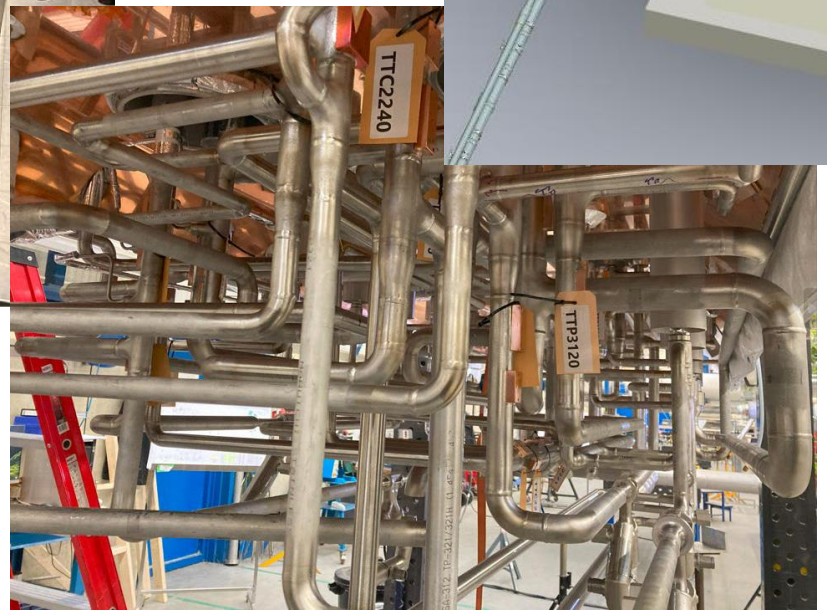
Provide 4 K helium to up to three experiments.

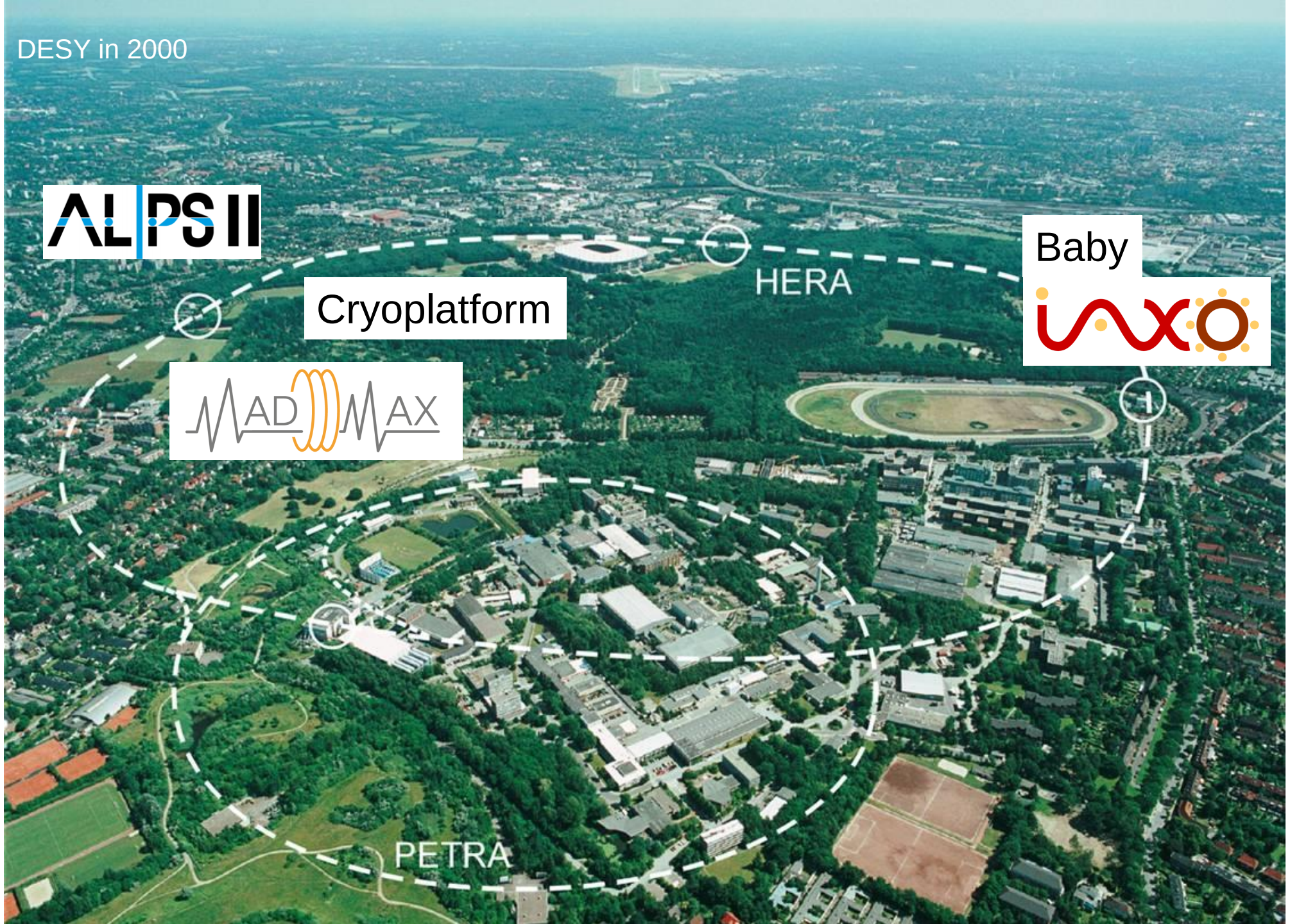
- Main first “customer”: MADMAX



The new cryobox for He distribution.






DESY in 2000
ALPS II
Cryoplatform
MADMAX
HERA
Baby
IAXO
PETRA

Summary

DESY: towards a center also for larger scale WISP searches

Four major activities:

Model independent WISP searches with ALPS II:

- Data taking has started!

Solar WISP searches with IAXO:

- Ready to start BabyIAXO construction in 2024?

Dark matter WISP searches with MADMAX:

- First physics results with prototypes in 2024.

Cryoplatform:

- New research infrastructure for the world-wide community.

Eavesdropping @ DESY: getting ready to catch Nature's WISP whispering.