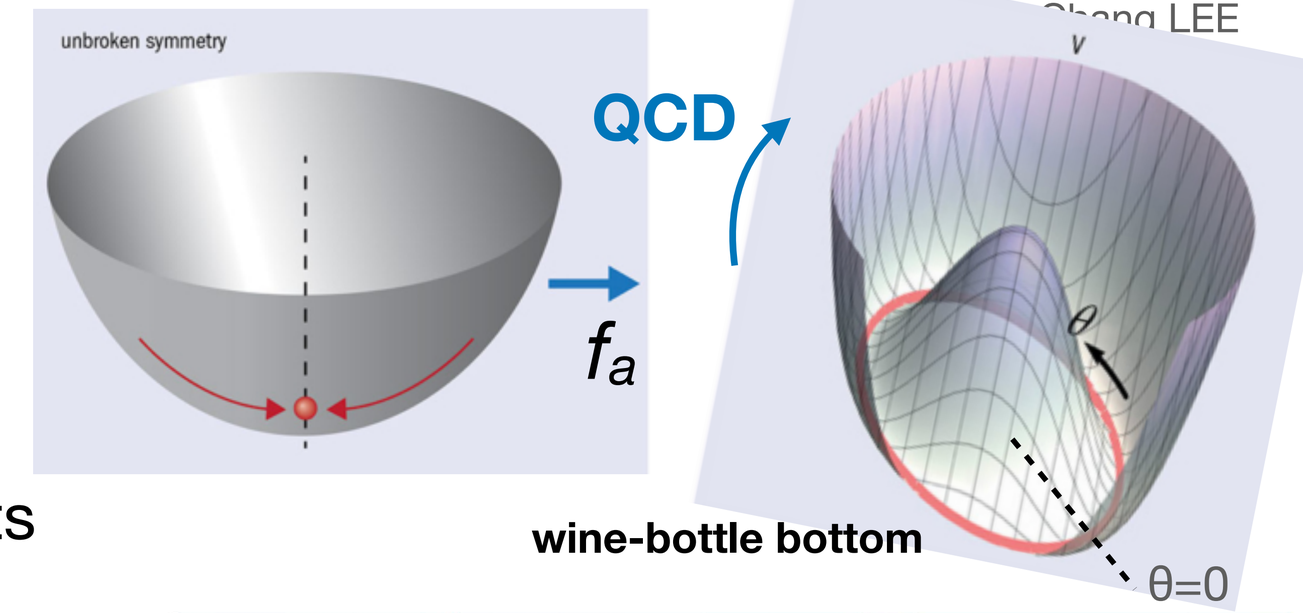
Hunt for Axion dark matter

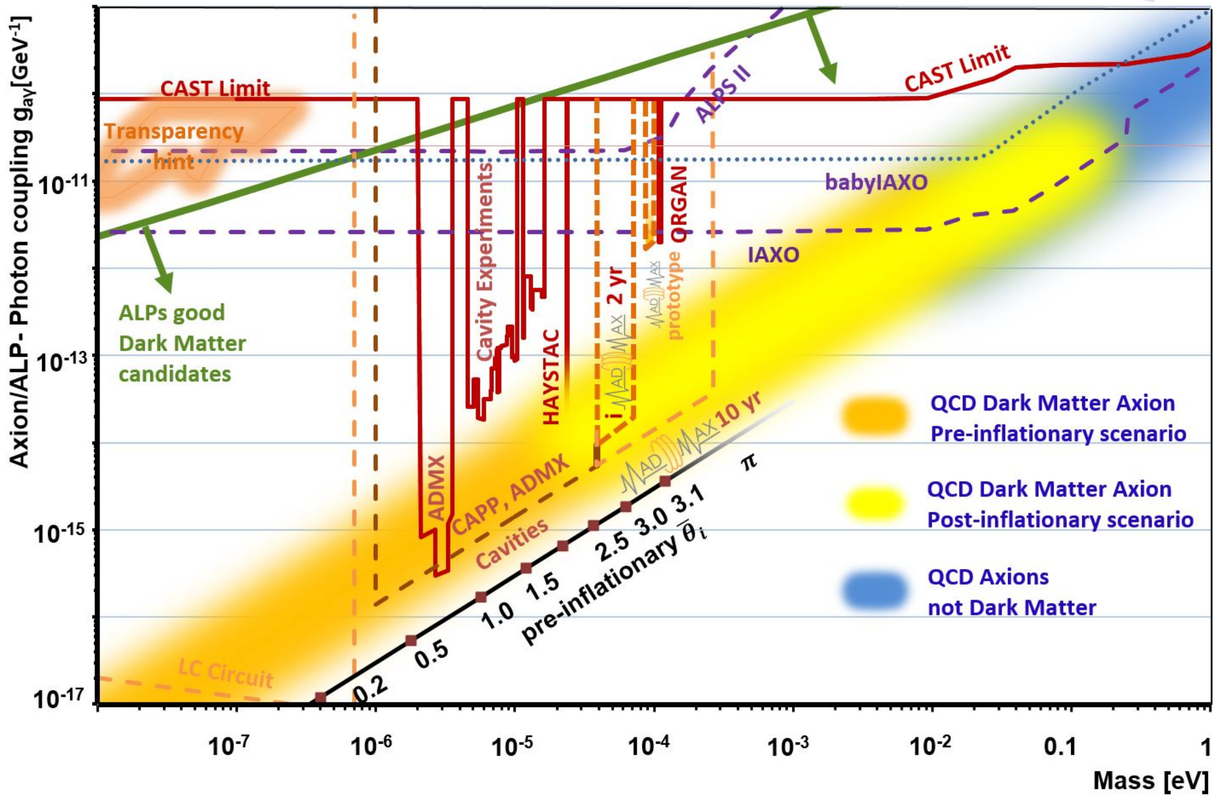
MPP Project review 2020

14 Dec 2020, Chang Lee on behalf of the Madmax group @ MPP

Axion dark matter



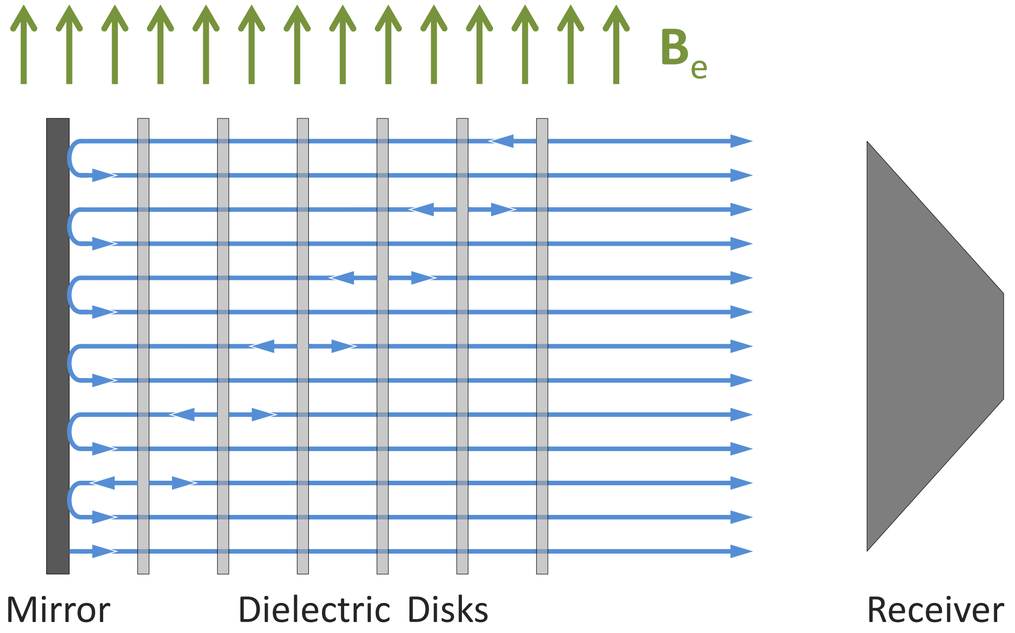
- Explicit symmetry breaking by QCD produces particle that weakly interacts with SM particles
- Axion solves the strong CP problem
- Post-inflationary scenario: **m_a ~100μeV**
  - Hard to reach by the existing resonant cavity searches.
- $\lambda_{\text{de Broglie}}$~1m, **"wave-like"**

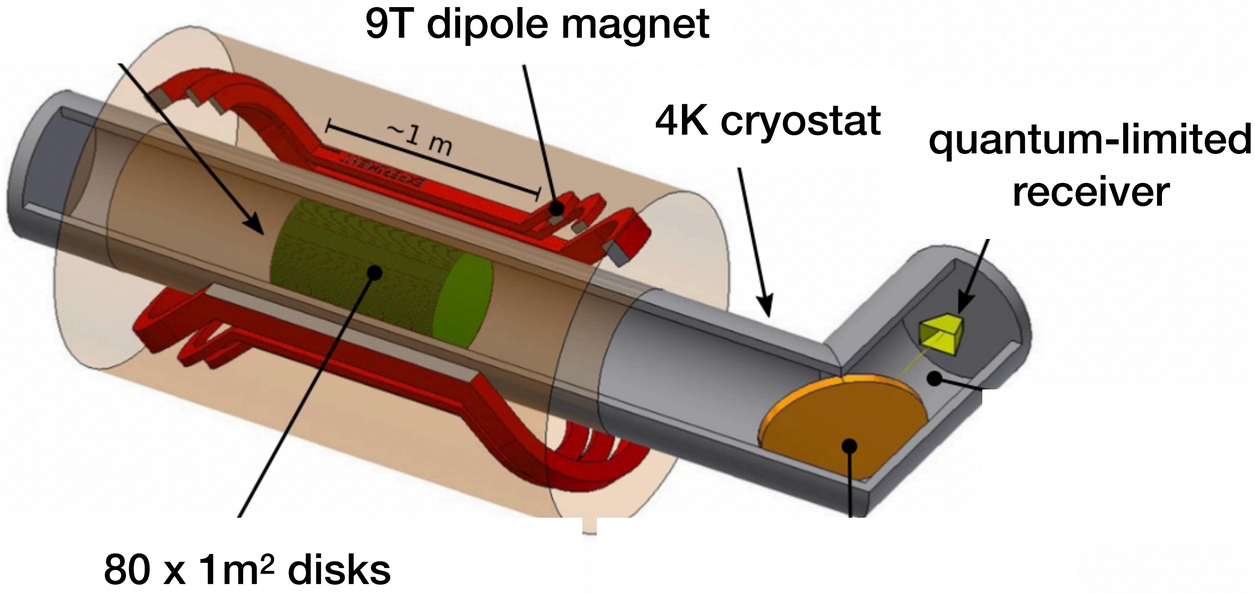


MADMAX

Dielectric haloscope

- Axions convert to **photons** at boundary of different materials in magnetic field.
- More & wider boundaries → stronger signal
- Constructively interfering signal:
  - tuning by changing the disk spacings
- 1D structure can be easily scaled up.
- Full MADMAX: sensitivity to QCD axions





MADMAX collaboration

RWTH AACHEN UNIVERSITY

Max-Planck-Institut für Radioastronomie

NÉEL institut

DESY

UHH

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)

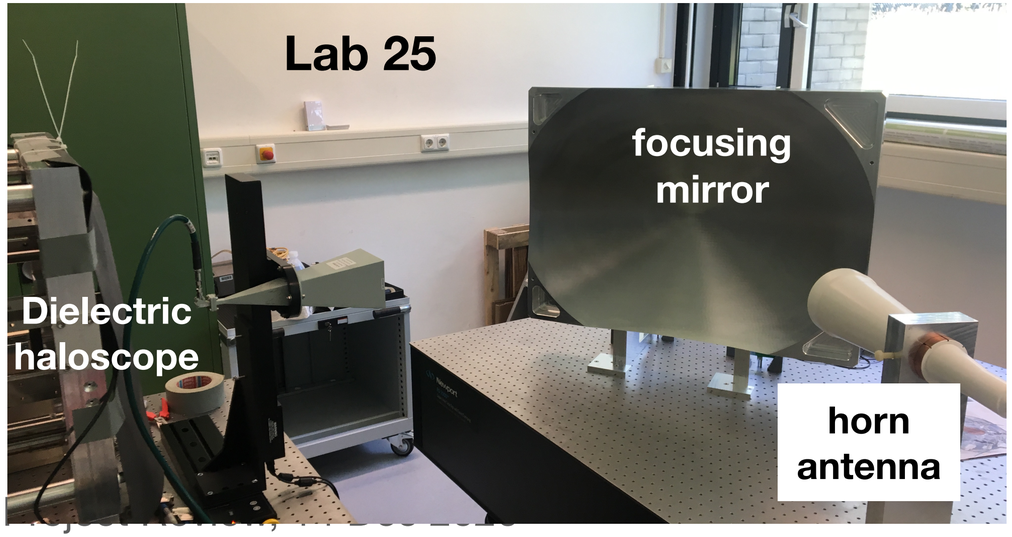
cea

Universidad Zaragoza 1542

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

MADMAX group @ MPP

- Tasks: rf understanding, proof-of-principle setups, prototype design and magnet design.
- S. Knirck to join the ADMX group @ Fermilab



Director	A. Caldwell	Exp
Project leader	B. Majorovits	Spokesperson
	O. Reimann	Exp
Scientists	G. Raffelt	Theory
	F. Steffen	Theory
Postdocs	C. Lee	Exp
	X. Li	Exp
Ph. D. students	S. Knirck*	Exp
	L.Shtembari	Exp
	J. Diehl	Theory
Engineering	D. Strom	
	A. Hambardzumjan	
	C. Gooch	
	D. Kittlinger	
	A. Sedlak	

and special thanks to the **workshop**!!

DESY Physics Review Committee review

November review

Key comments and recommendations for MADMAX

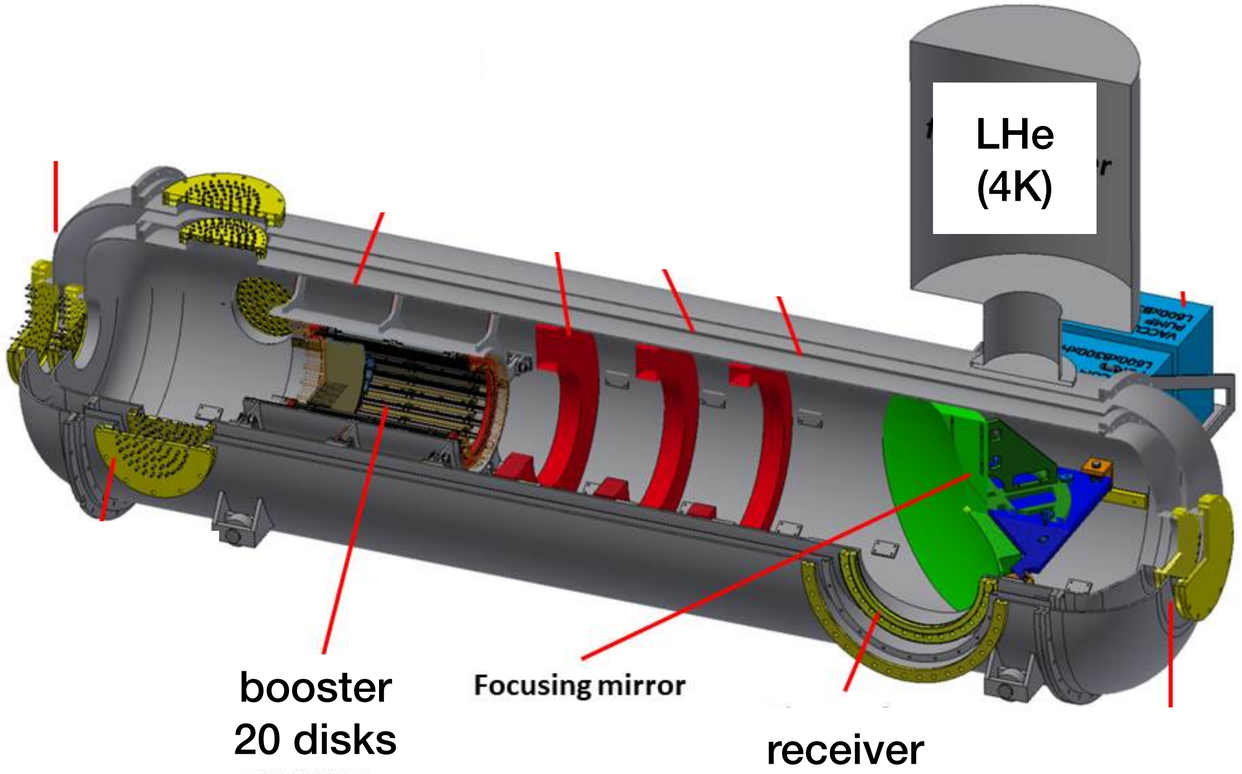
We strongly encourage the collaboration and DESY to come up with a viable plan to keep MADMAX with a strong physics programme even with the prototype magnet.

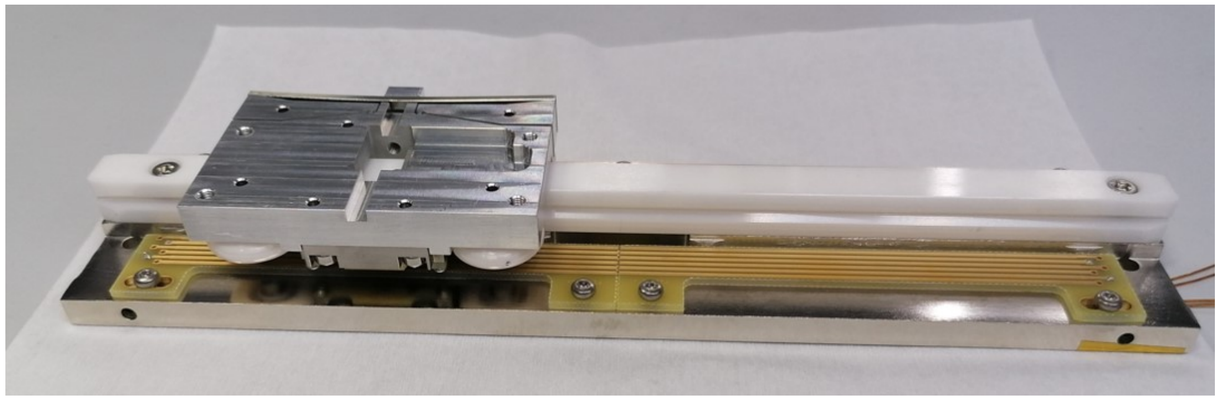
MADMAX will dominate the axion dark matter field for more than a decade, but it needs support to keep post-docs and graduate students interested now.

The prototype MADMAX setup coupled with the prototype magnet can make all the difference, and DESY should provide a strong support to keep the momentum and the interest of the community. There is a need for a small investment for the long term, which it's critical to its final success. The investment should be geared towards materializing the prototype magnet for a reasonable physics program in the interim.

Prototype

- R&D platform
  - 20 x 30cm ϕ sapphire disks
  - 4K operation
- Cryostat design fixed
- First cryogenic piezo positioner & laser interferometer assembly delivered
  - to be tested in the MPP LHe cryostat





Morpurgo magnet @ CERN

- 1.6 T dipole field
  - Test of the booster in B-field
- Usage during the SPSS shut down
  - CERN SPSC approved the usage
  - LHe provided by CERN
- ALP search after successful commissioning

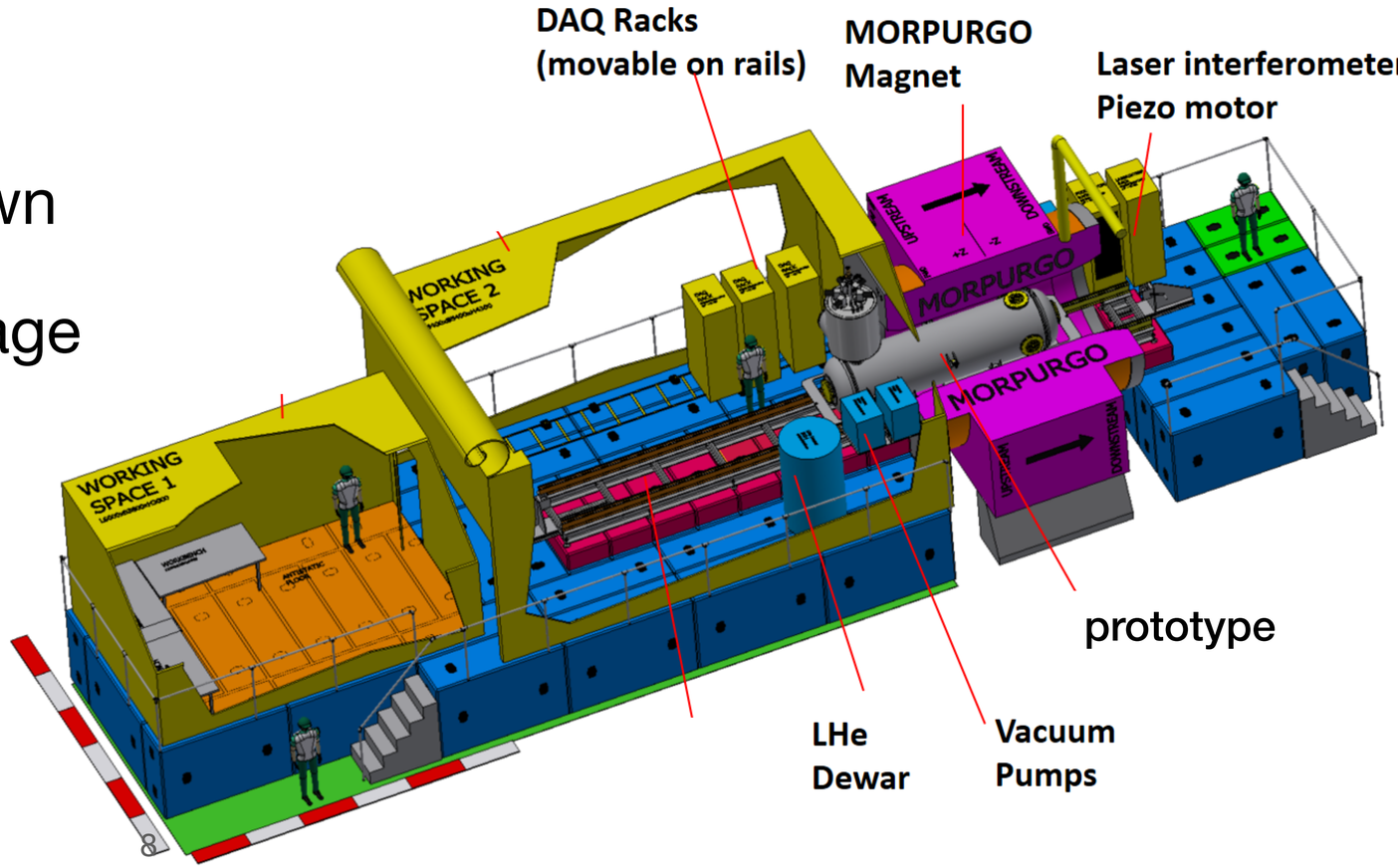
Voir en français

MADMAX and CERN's Morpurgo magnet

A new collaboration, MADMAX, will seize the chance to use a CERN magnet named Morpurgo to test their dark-matter prototype

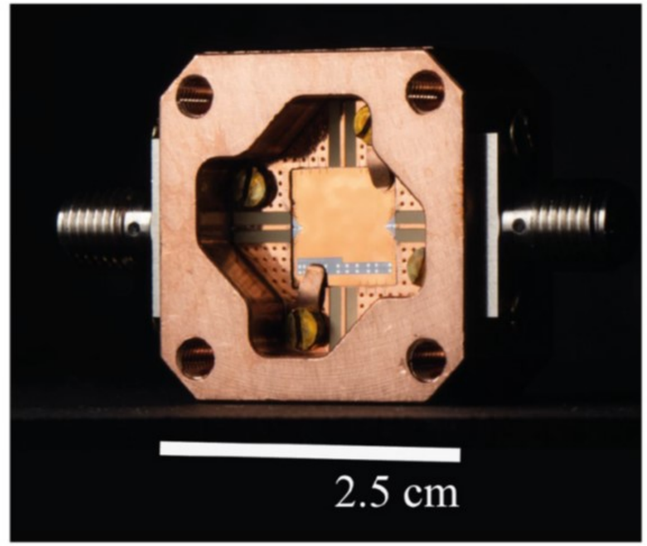
10 NOVEMBER, 2020 | By Thomas Hortala

CERN Bulletin
https://home.cern/news/news/experiments/madmax-and-cerns-morpurgo-magnet

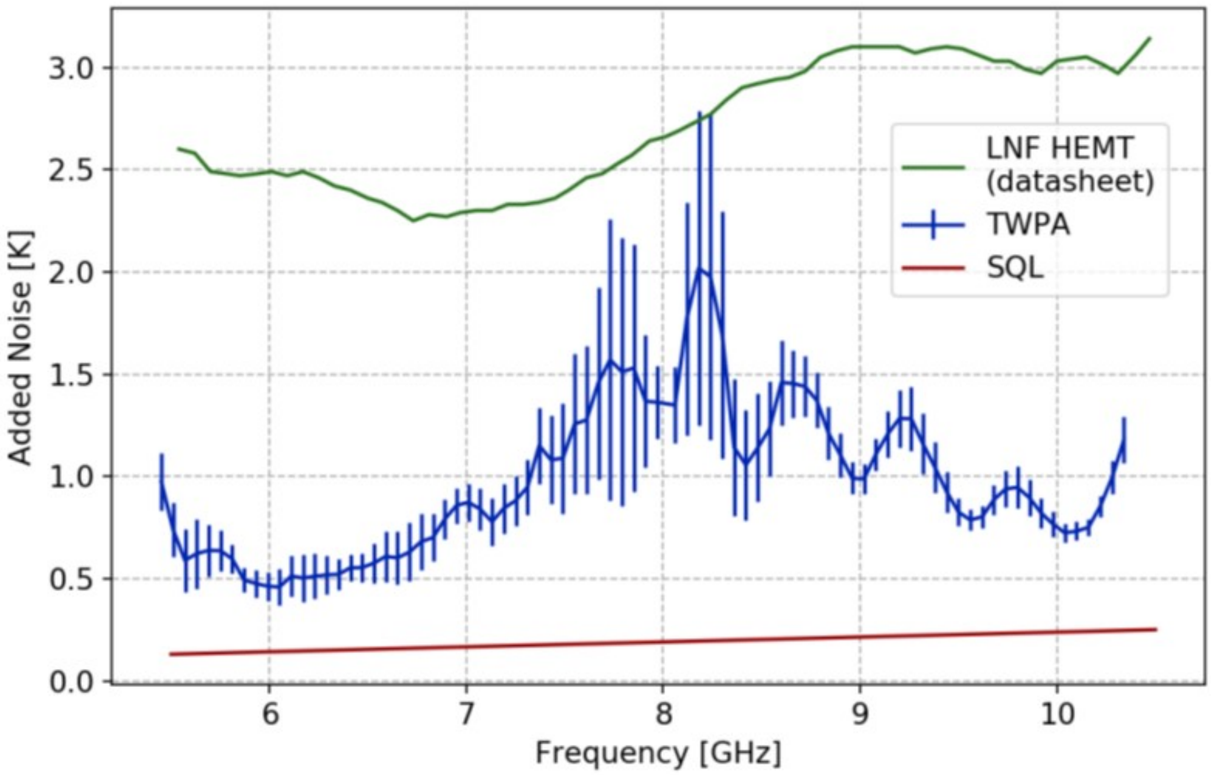


Quantum-limited amplifier

Traveling wave parametric amplifier (TWPA)



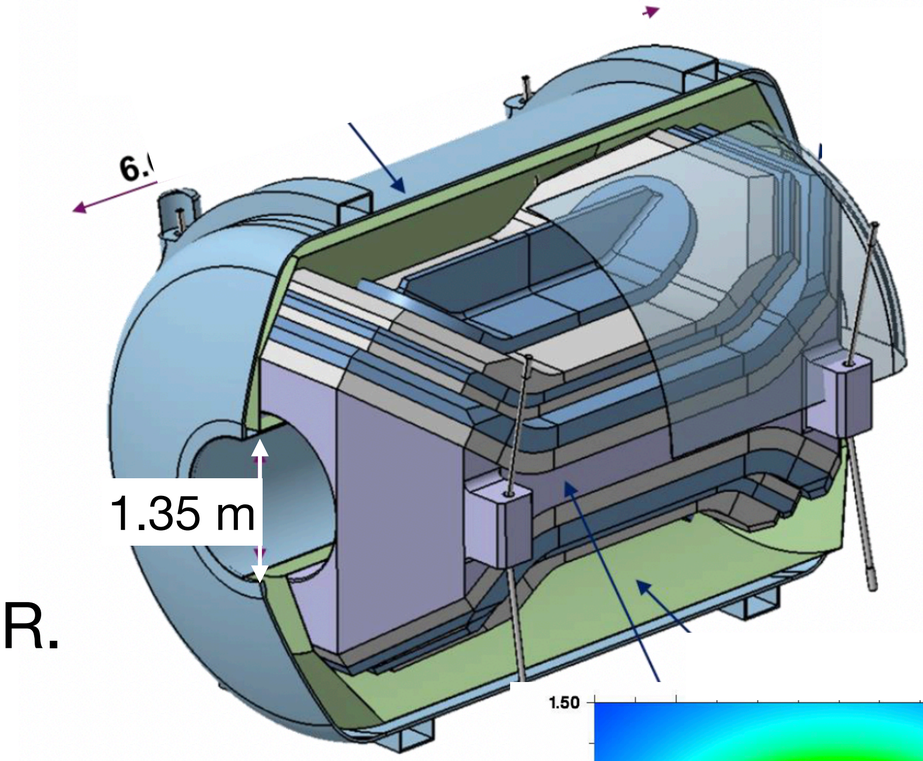
- Amplifier is a major source of thermal noise.
- **First 10 GHz TWPA**
  produced and characterized:
  Phys. Rev. X **10**, 021021
- Noise temperature ~ 1K!
  - Remaining source is the substrate.
- Future development to 30 GHz.

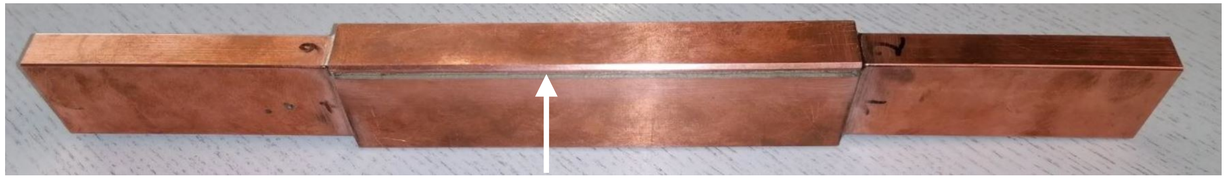


Magnet development

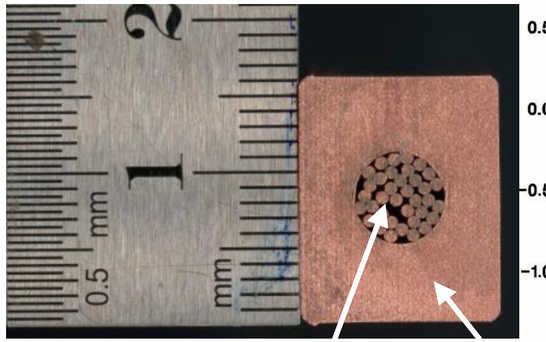
Full scale MADMAX magnet

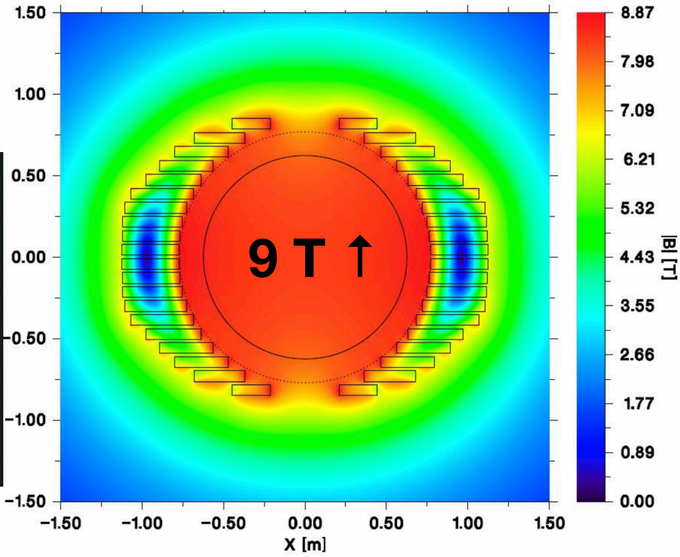
- 9T, 1.35-m warm bore **dipole** magnet
- Superconducting CICC conductor
  - experience and infrastructure from ITER.
  - Quench test: 1/2 size mockup coil





laser welding



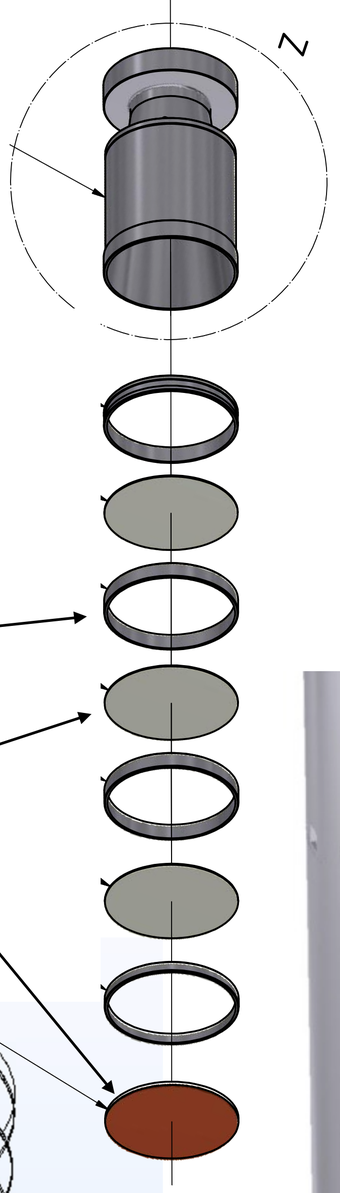


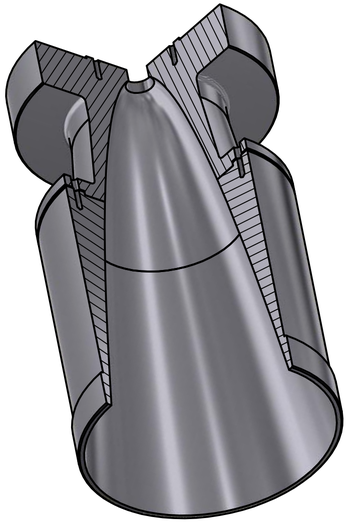
Meanwhile in Lab 39

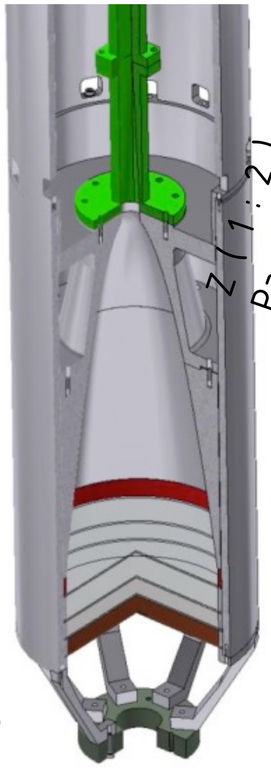
Proof-of-principle setup

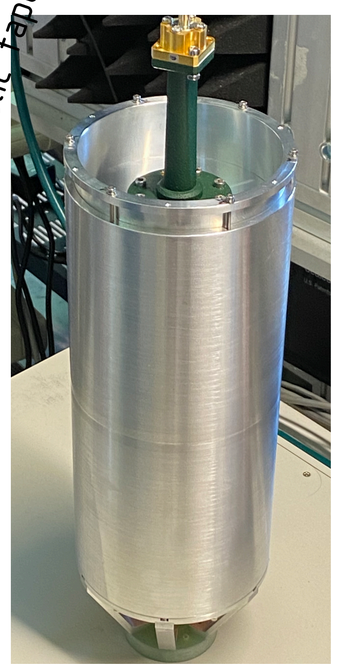
3x 100mm disks in LHe

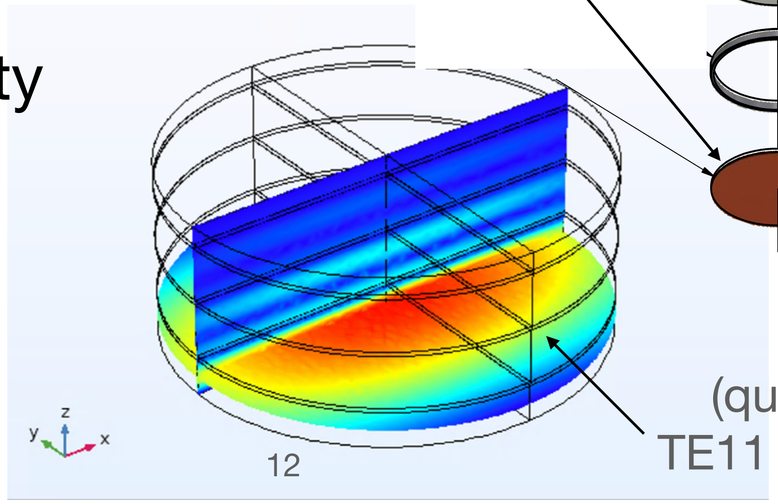
- Simple and robust dielectric haloscope
  - Easy comparison with simulation
  - easier calibration & understanding
- Thermal noise measurement in LHe
  - comparison with reflectivity
- ALP / hidden photon search





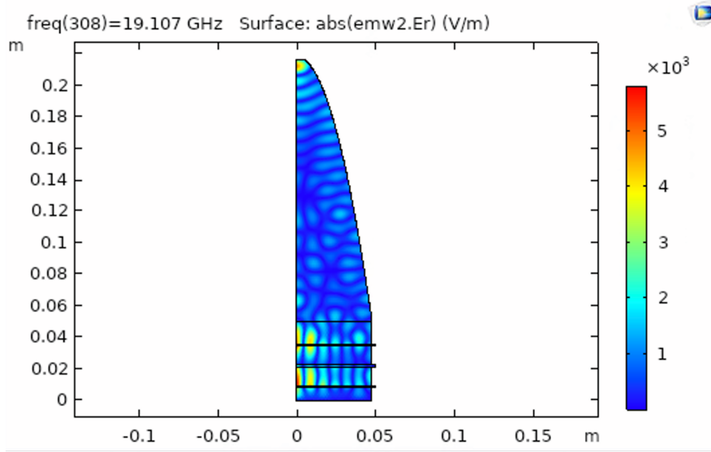






Proof-of-principle setup

Room temperature reflectivity measurement

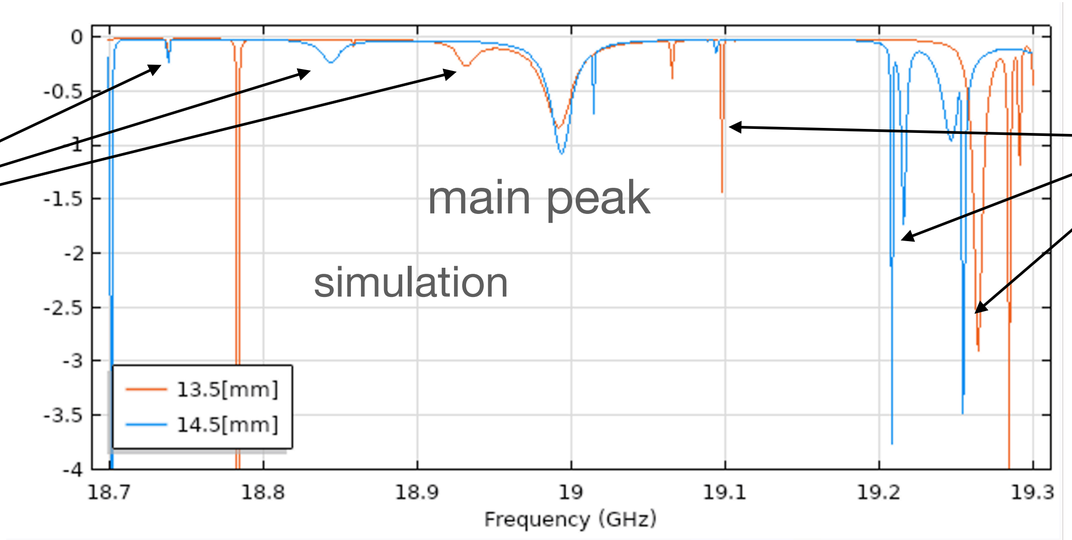


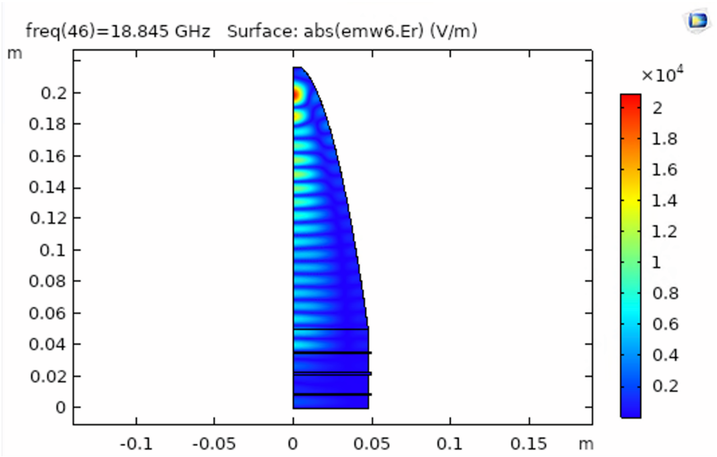
whispering gallery modes

Taper modes

main peak

simulation





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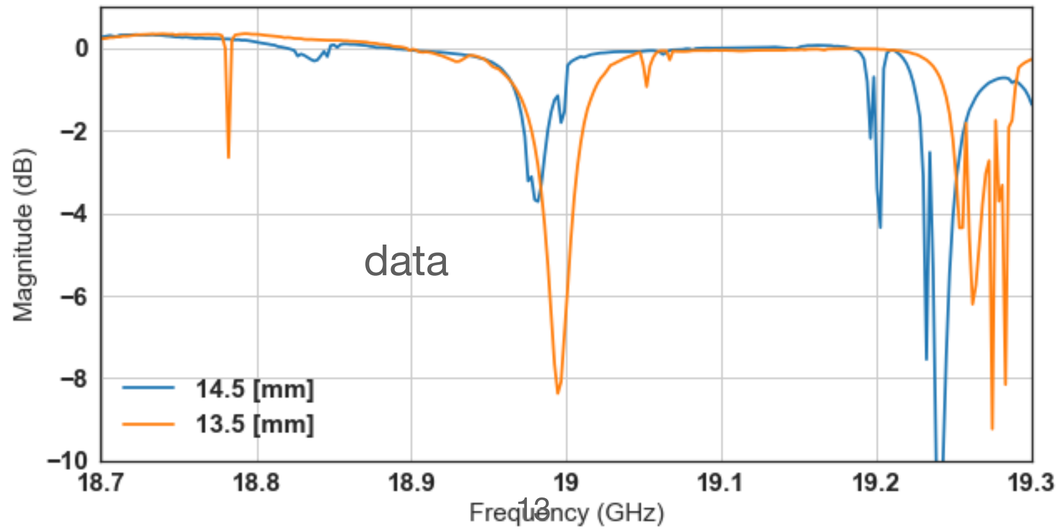
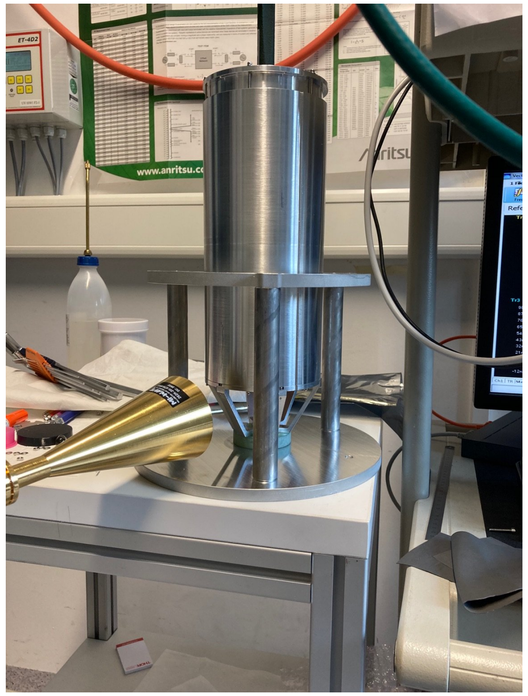




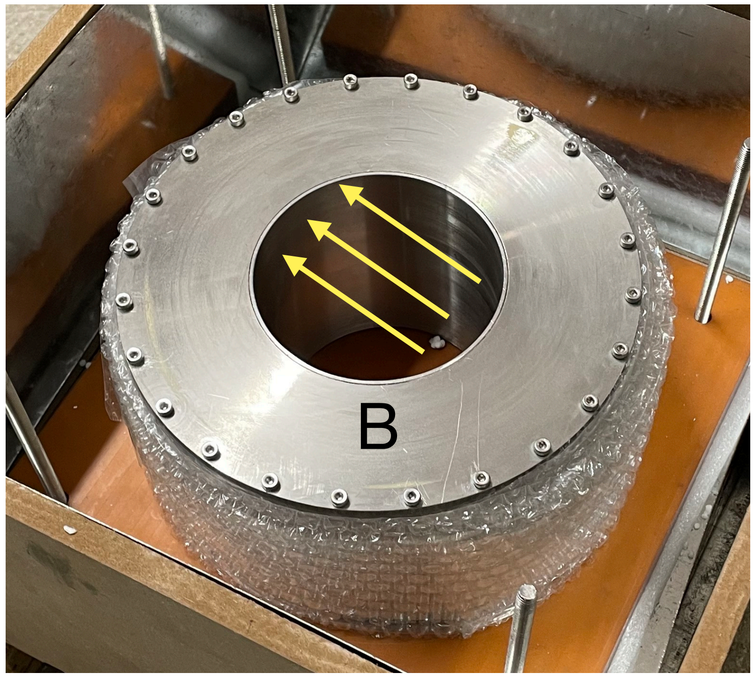
“leakage” to the external

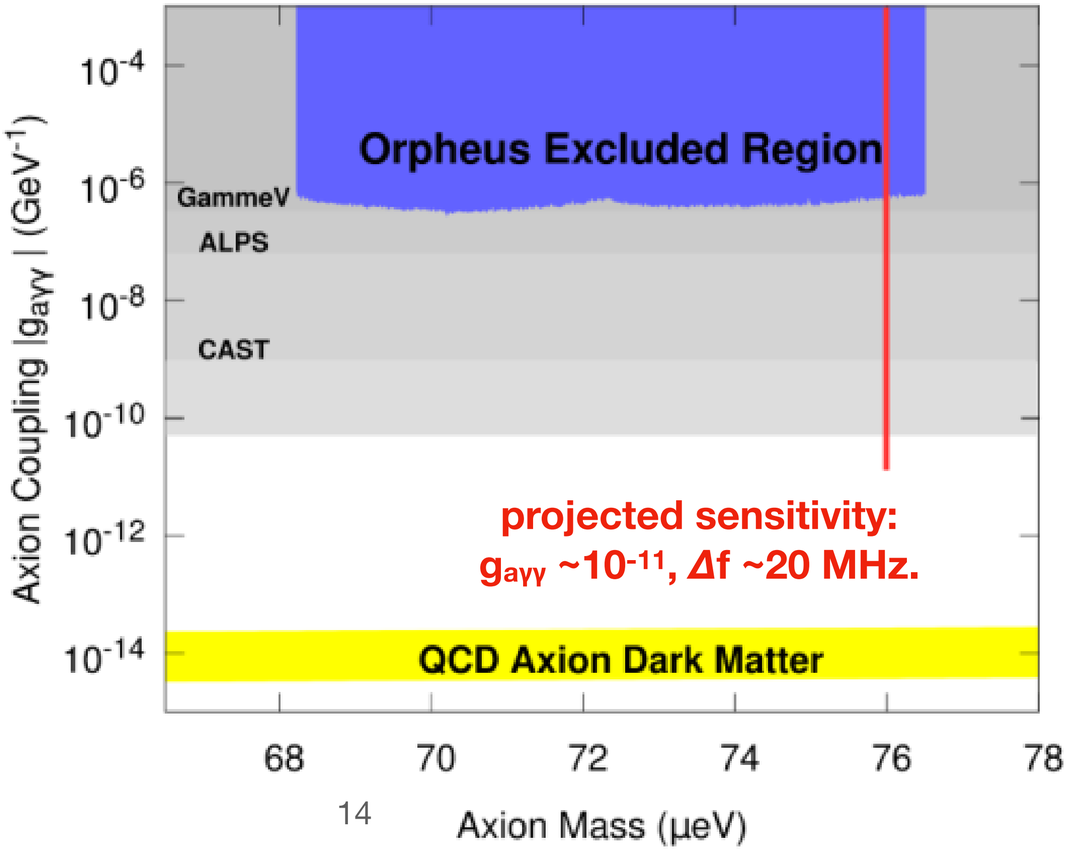
Proof-of-principle setup

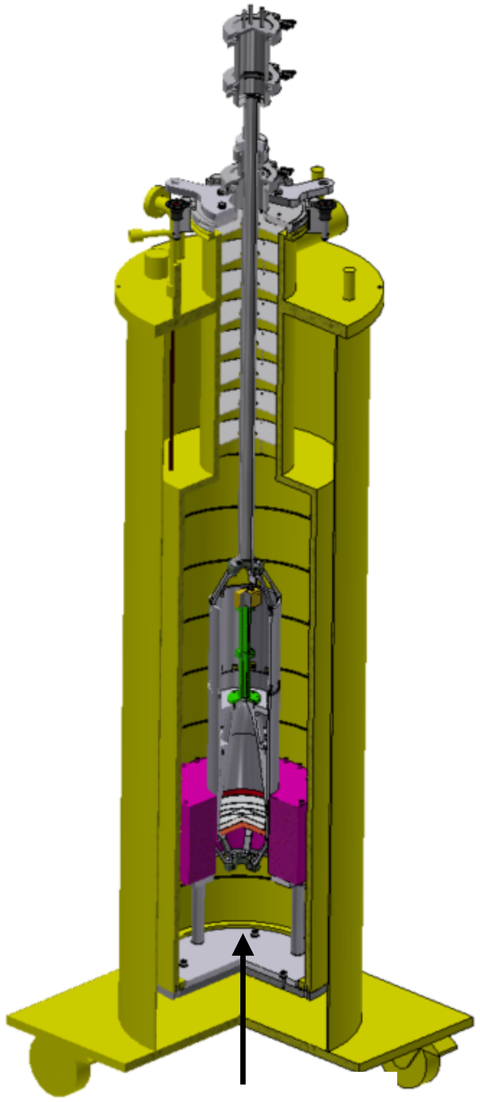
ALP / hidden photon search

- LHe cryostat & dipole magnet procured & operational.

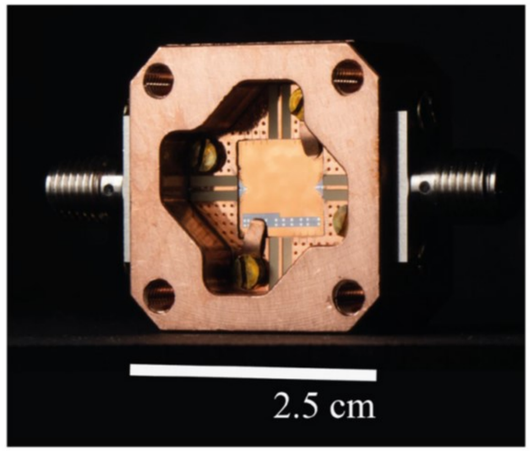
0.45 T dipole Halbach array



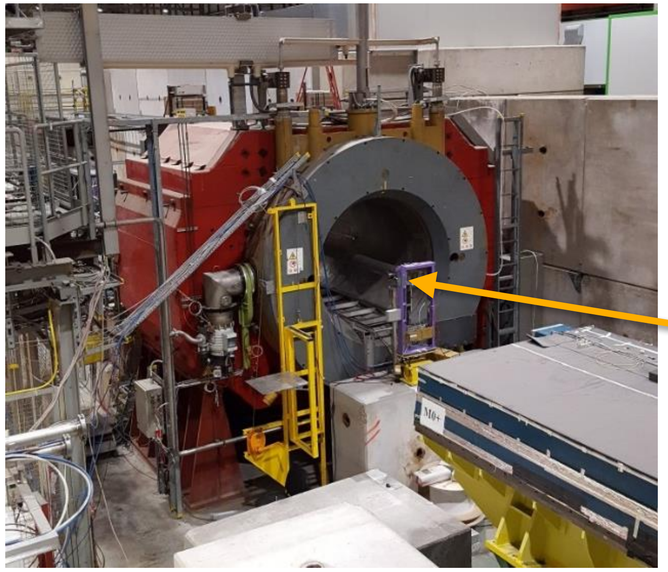


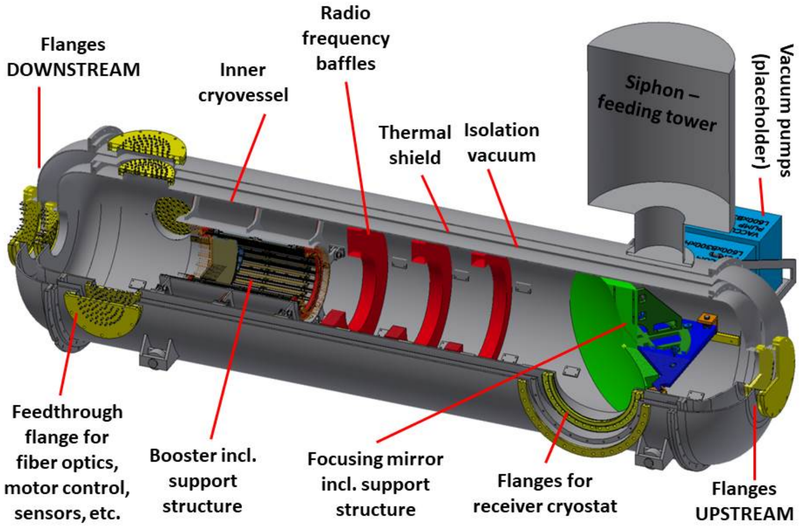


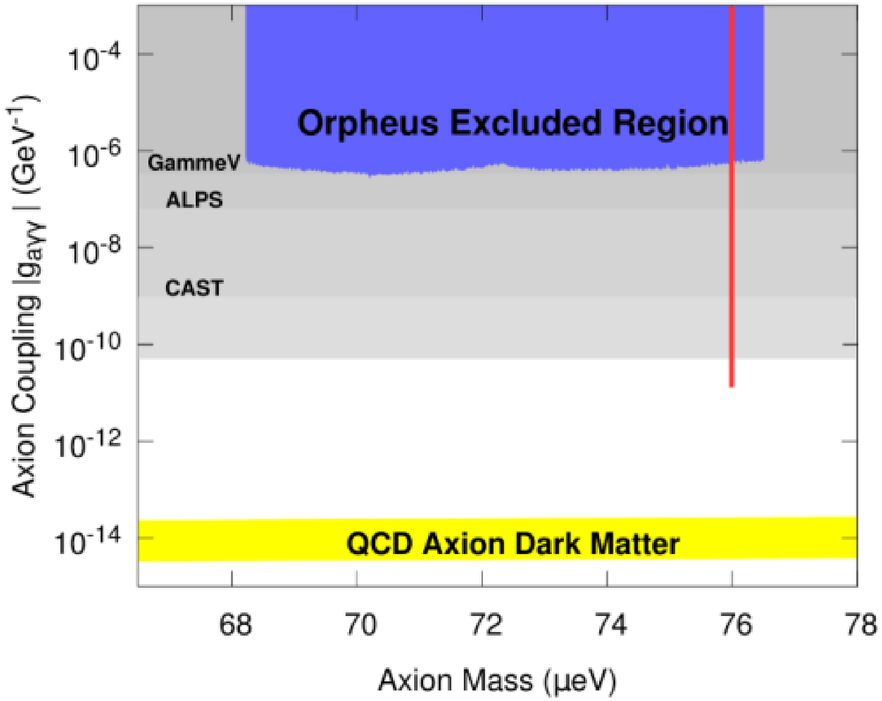
Conclusion



- Important milestones in 2020 for MADMAX
- 2021 will be another exciting year!







Thank you

Stay tuned!