How to detect a QCD axion with MADMAX

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On behalf of the MADMAX collaboration

TAUP VIENNA 2023

Overview

Motivation for MADMAX

Latest news:

- Run at CERN and monitoring system
- New cryostat
- MADMAX new magnet update

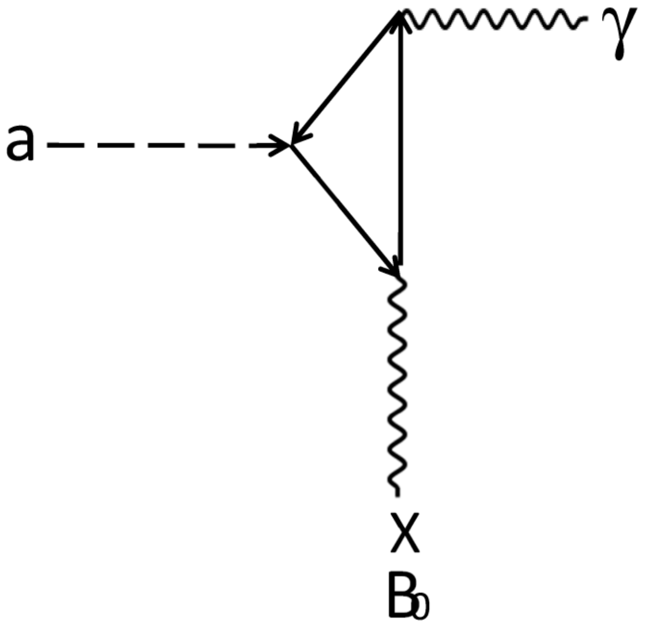
Next steps:

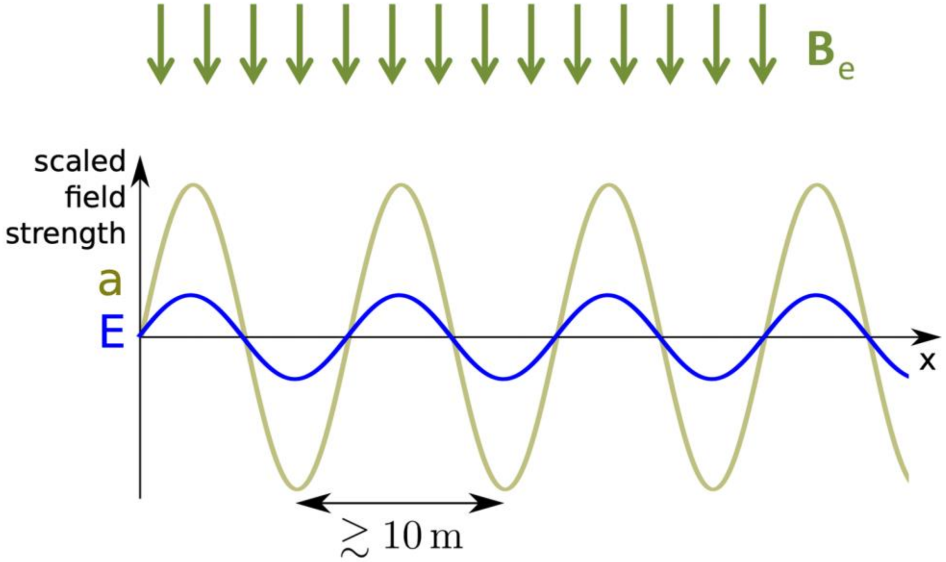
- Cold operation of CB-100
- The next prototype
- Main cryostat

The MADMAX experiment

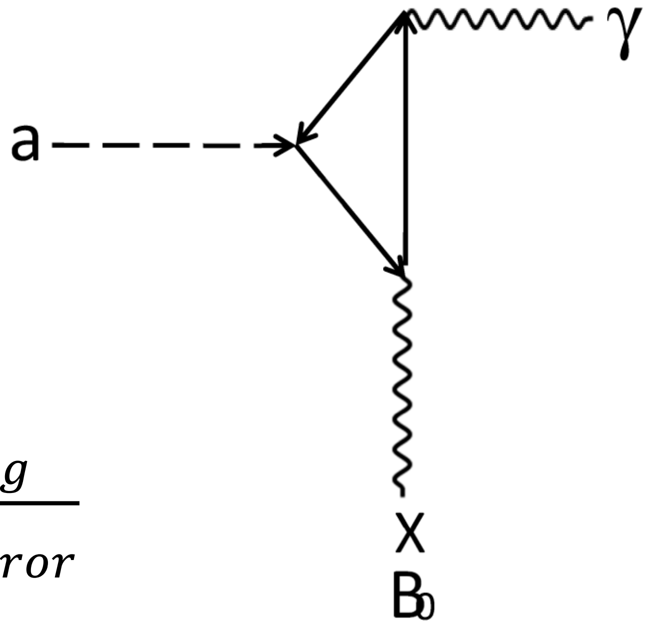
Idea:

1) Induce inverse Primakoff effect in a strong external B field





The MADMAX experiment

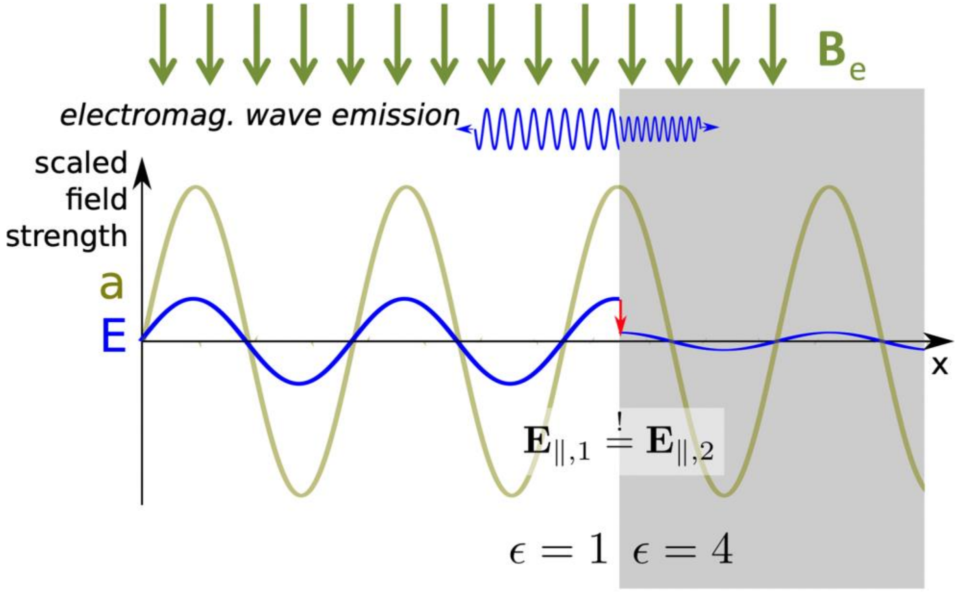


Idea:

1) Induce inverse Primakoff effect in a strong external B field

$$\beta^2 = \frac{P_{sig}}{P_{mirror}}$$

2) Boost the signal using spatially-periodic dielectric discontinuities



The MADMAX experiment

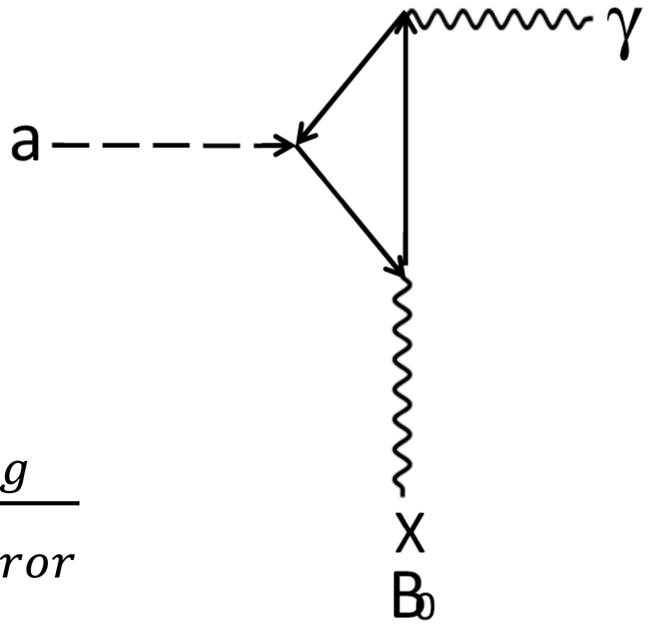
Idea:

1) Induce inverse Primakoff effect in a strong external B field

2) Boost the signal using spatially-periodic dielectric discontinuities

3) Reduce thermal background with cryogenics

4) Analyze boosted signal



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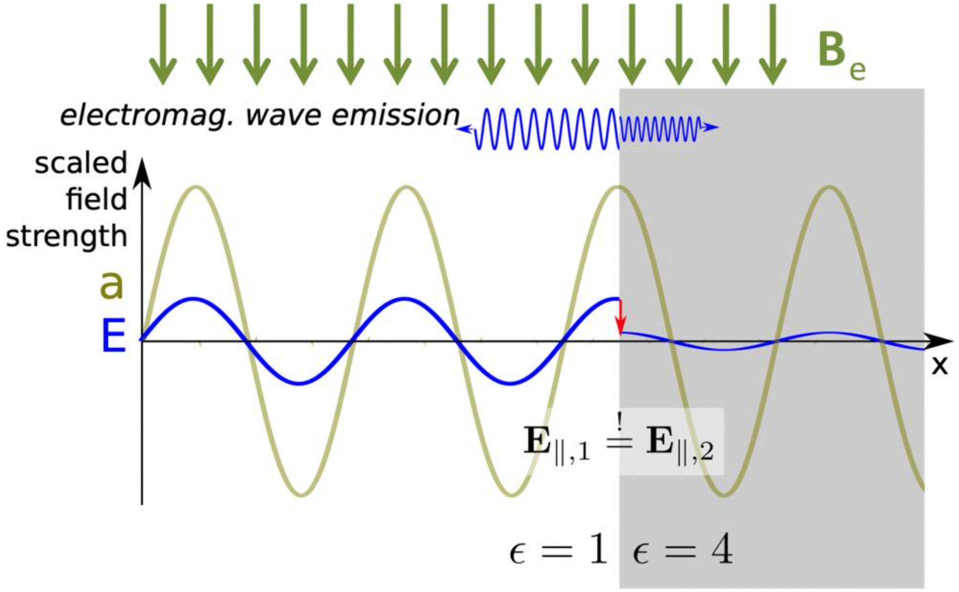
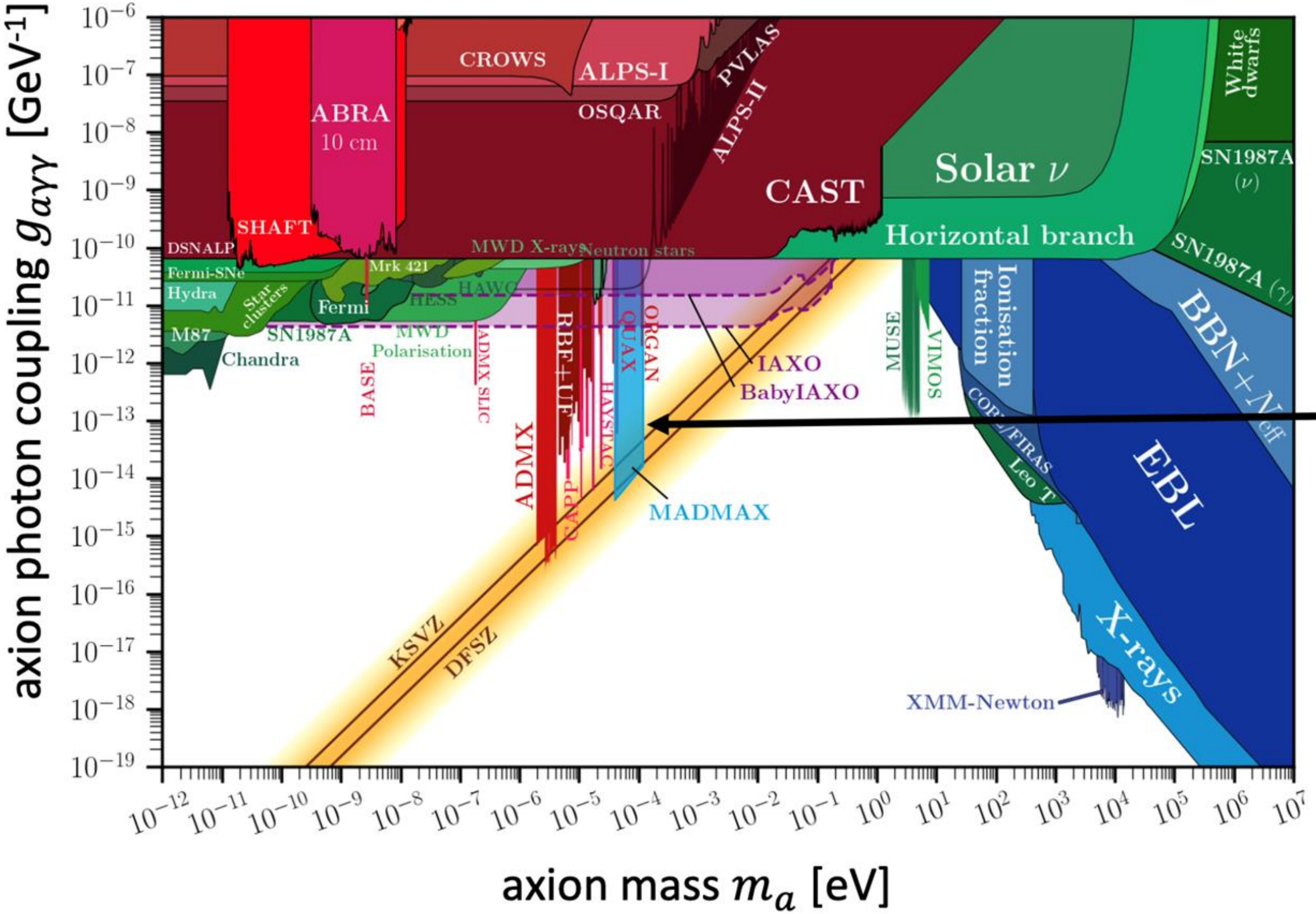


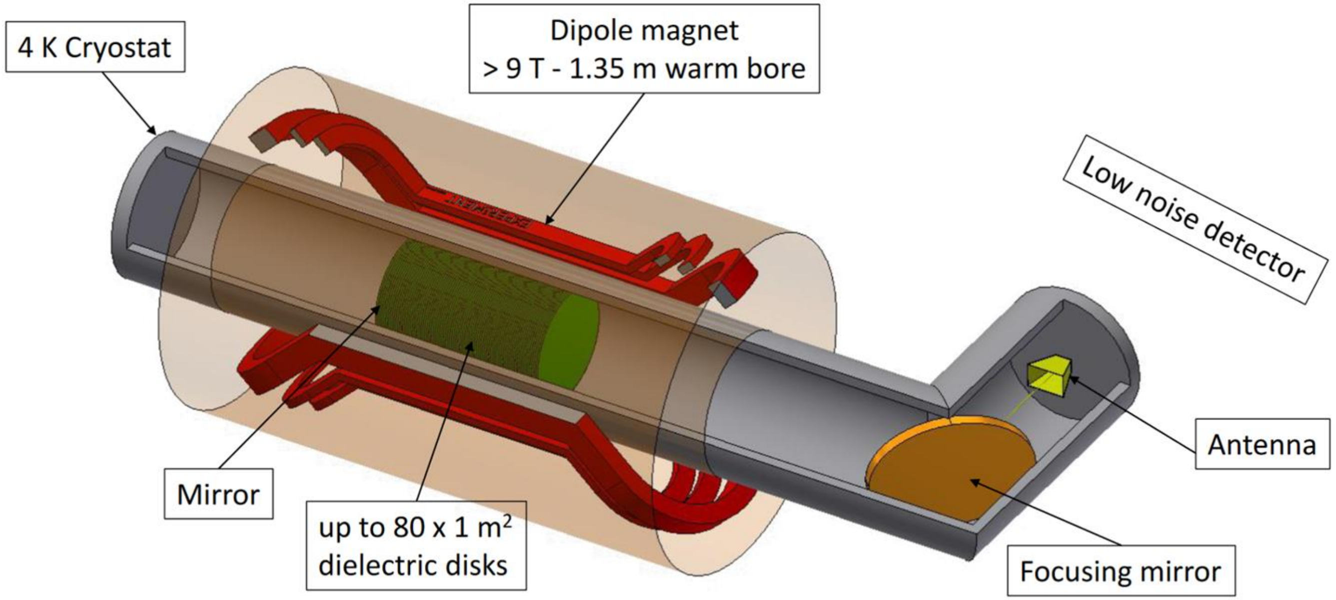
Status of axion experiments



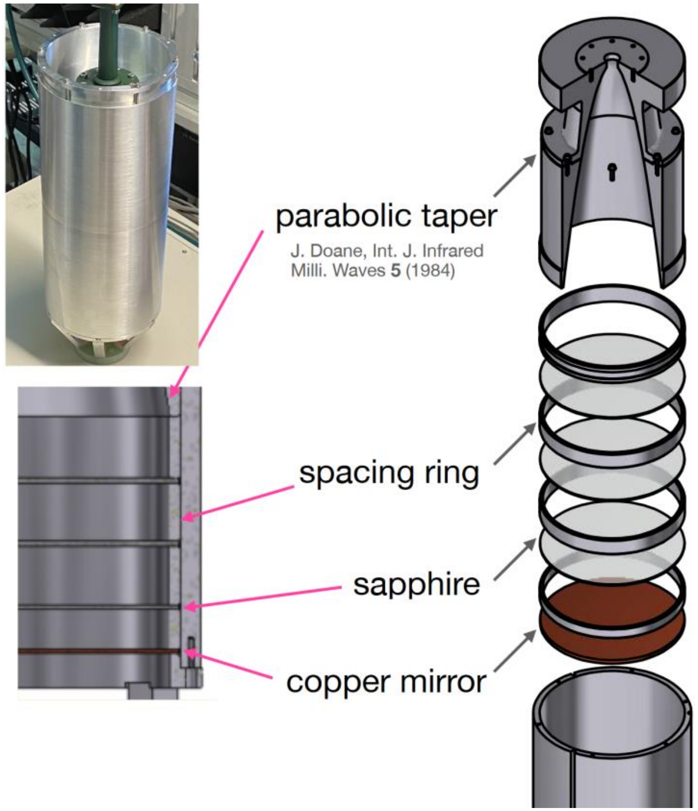
Aspirational setup

Probing the QCD axion between 40-400 μeV

The MADMAX experiment



Aspirational setup

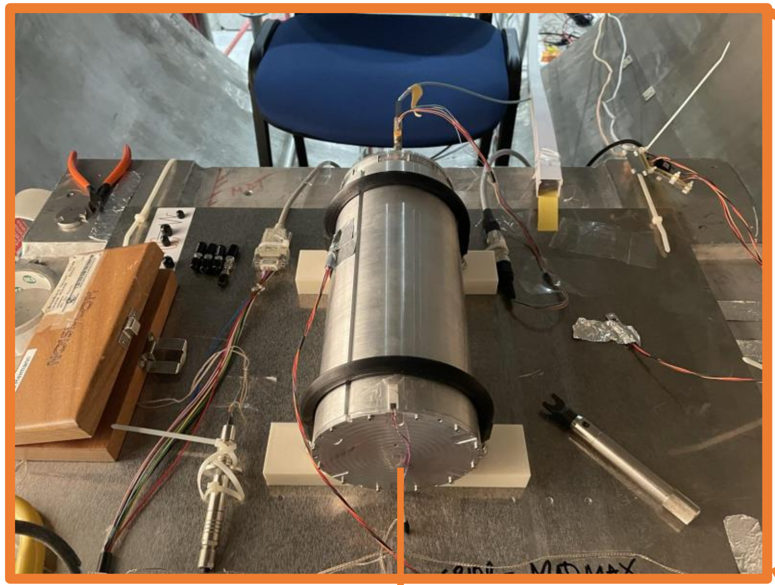


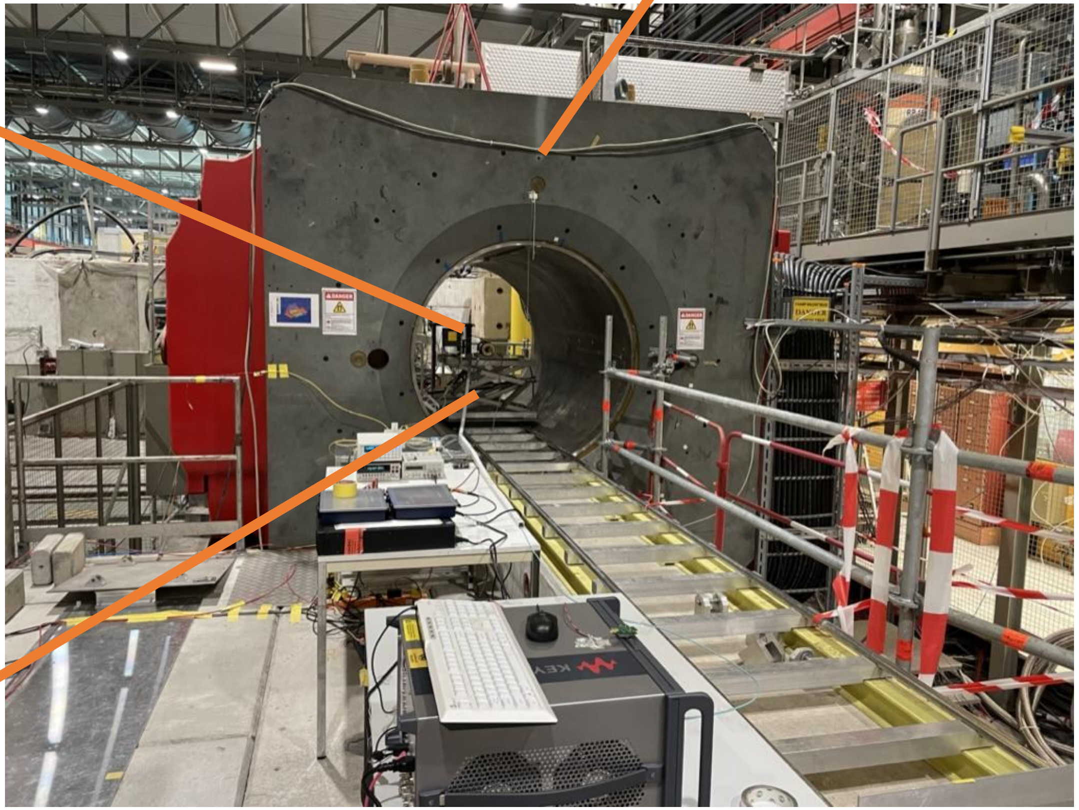
Prototype: CB-100

$$g_{a\gamma} = 0.2 m_a \left(\frac{50000}{\beta^2}\right)^{\frac{1}{2}} \left(\frac{10\mathrm{T}}{B_e}\right) \left(\frac{1\mathrm{m}^2}{A}\right)^{\frac{1}{2}} \left(\frac{SNR}{5}\right)^{\frac{1}{2}} \left(\frac{T_{sys}}{4\mathrm{K}}\right) \left(\frac{1.8\ \mathrm{days}}{\tau}\right)^{\frac{1}{4}} \left(\frac{\Delta\nu}{20\ \mathrm{kHz}}\right) \left(\frac{300\ \mathrm{MeV\ cm^{-3}}}{\rho}\right)^{\frac{1}{2}}$$

CERN runs

Morpurgo magnet:
1.6 T dipole field



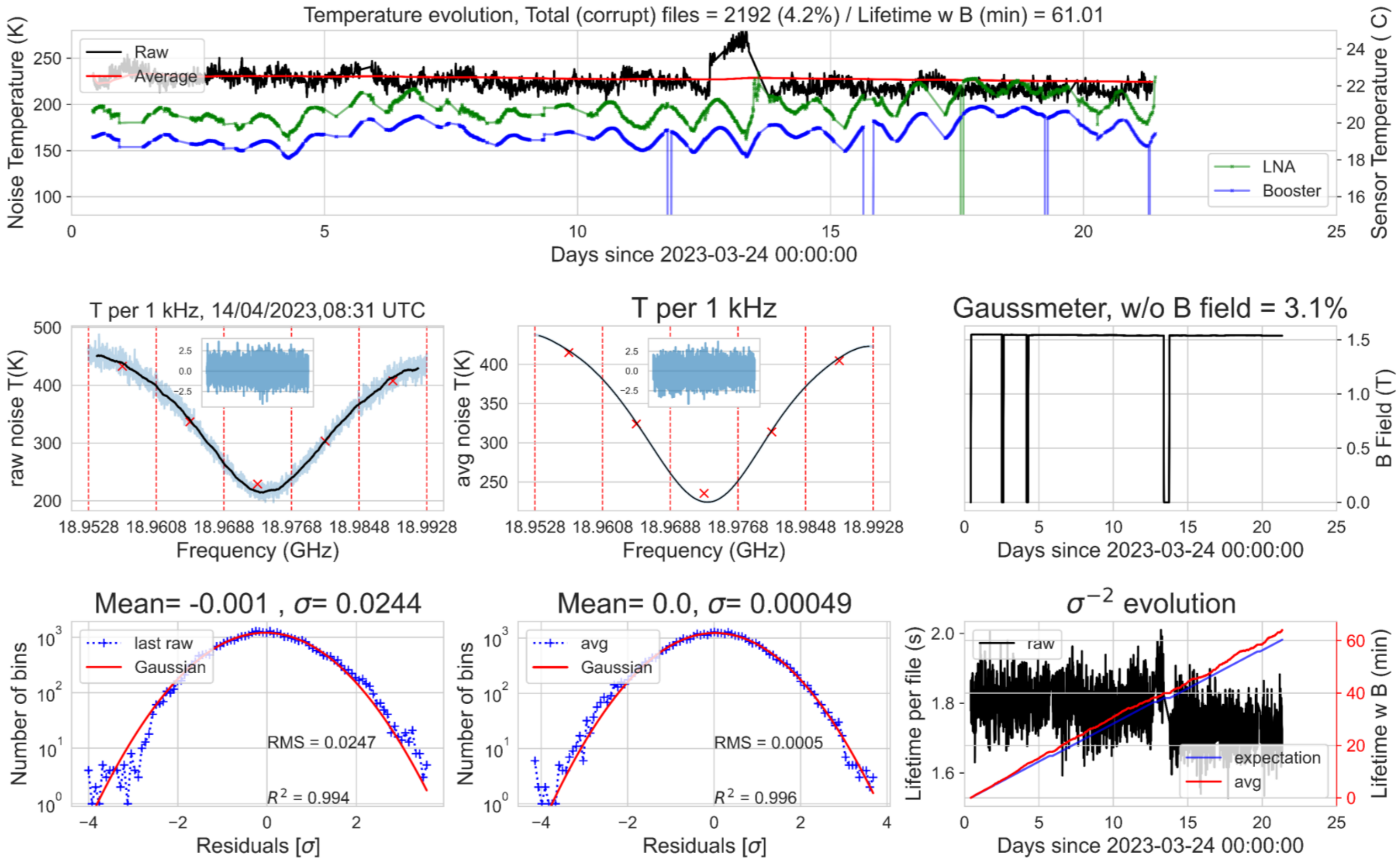


- CB-100 at room temperature
- ~10 hours integration time

Data analysis ongoing

Successful test: booster in magnet running continuously

Monitoring system

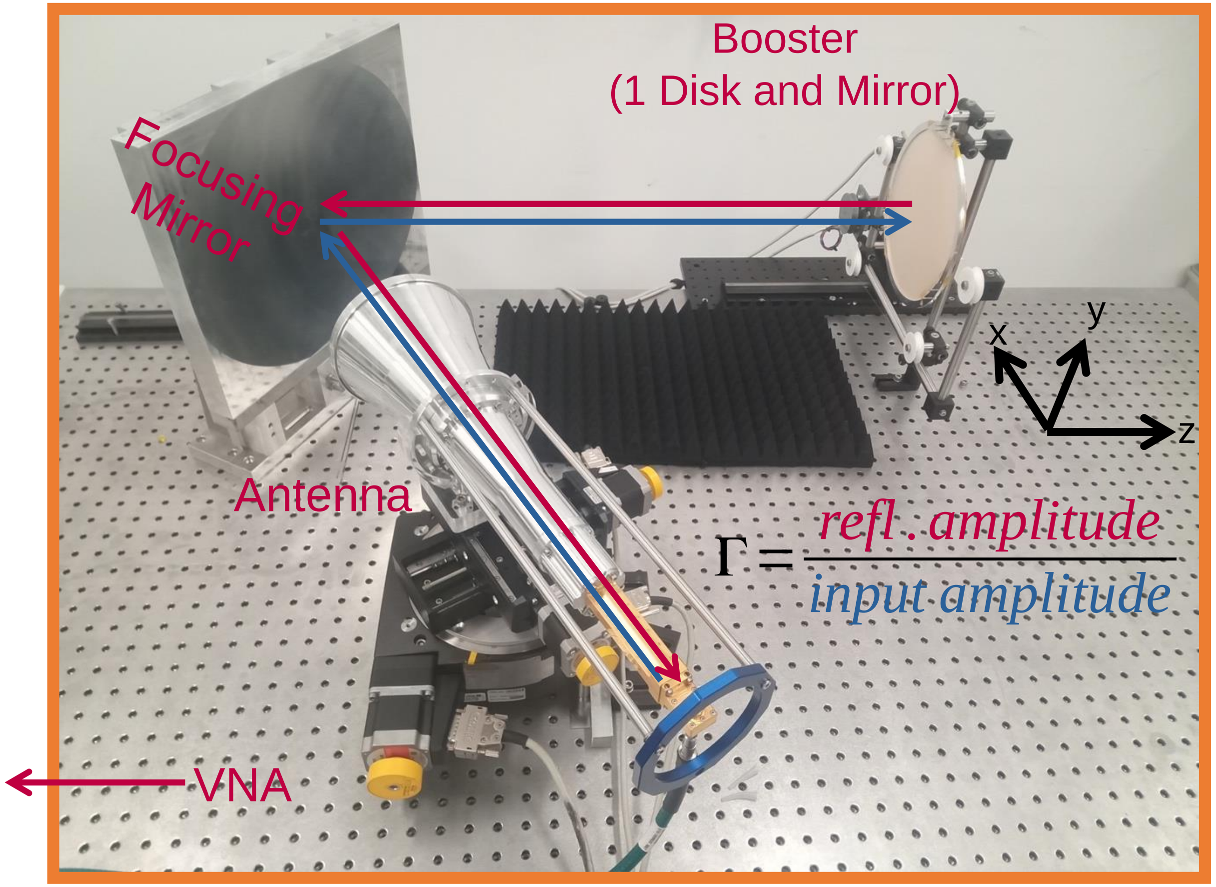


24/7 experiment monitoring

- Noise gaussianity
- Frequency dependent linearity
- Magnetic field
- Overheating
- Allan variance and total integration time
- Shifters incorporated
- E-mail alarms for urgent action (B field off, DAQ frozen, etc.)

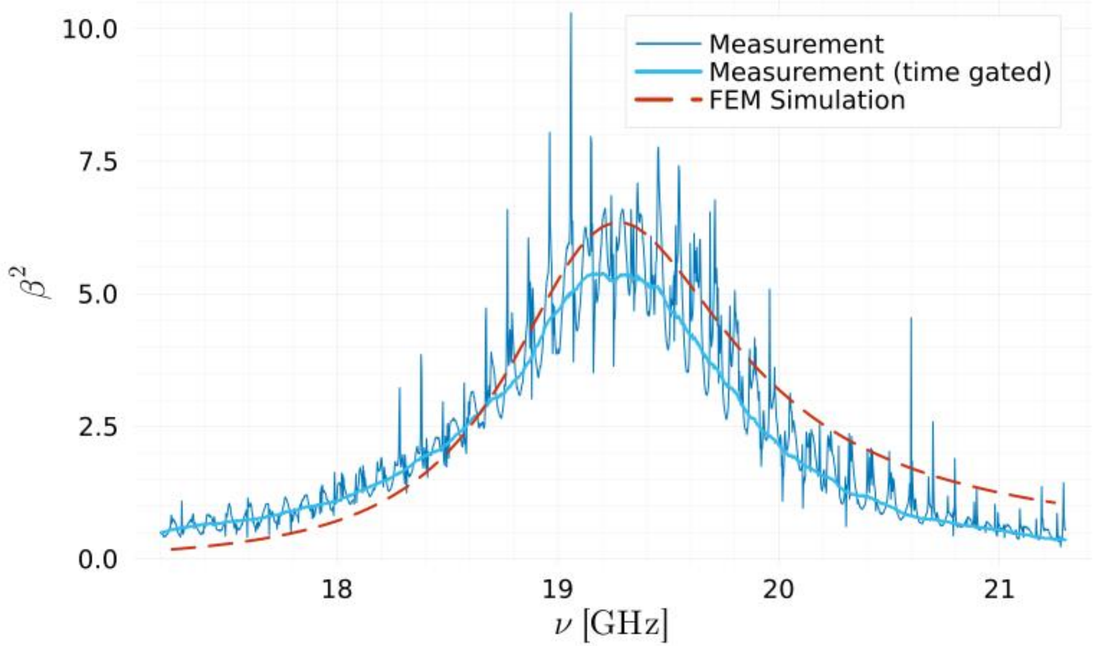
Boost factor determination

Additional setup to determine β^2 by direct measurement of the field



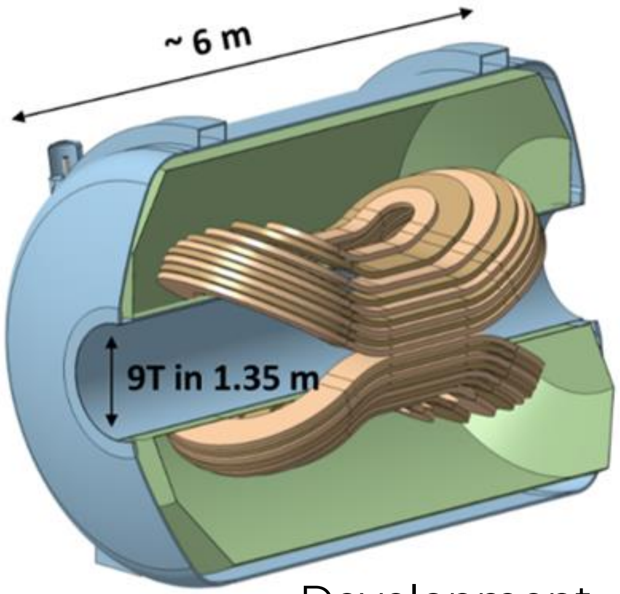
Before: Only data-tuned simulations

Now: measurement also possible via bead-pull method



J. Egge (MADMAX): "Reciprocity approach" https://iopscience.iop.org/article/10.1088/1475-7516/2023/04/064

MADMAX magnet update



Development in innovation partnership

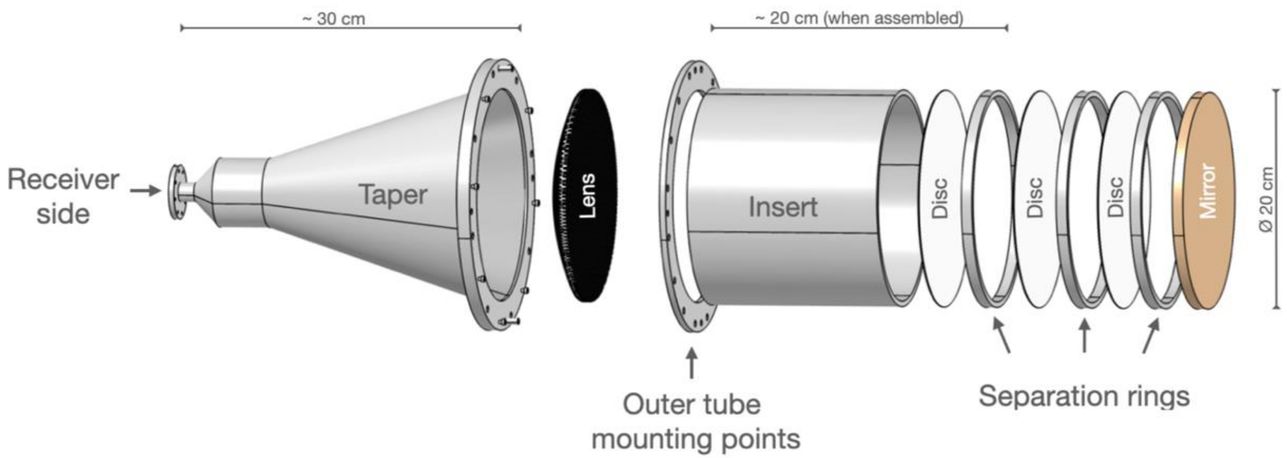
- Dipole Magnet most critical item for full-size MADMAX

- **Cable in conduit conductor (CICC) with a copper matrix**
  ➔ production is feasible

- Quench propagation velocity was measured in dedicated setup
  ➔ **Main project risk mitigated**: Quench propagation according to requirements for safe operation

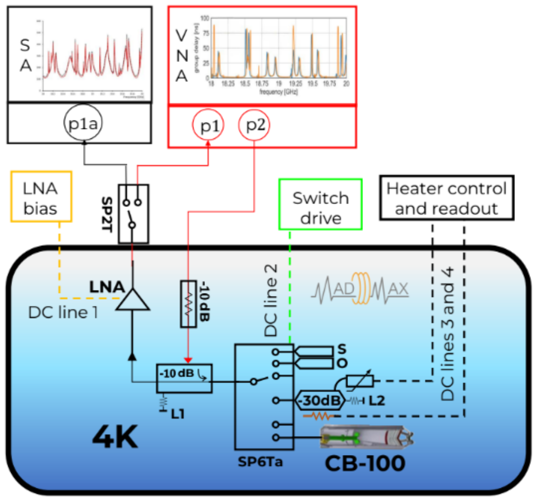
C. Lorin et. al
IEEE Transactions on Applied Superconductivity vol. 33 Issue 7 (2023) 1-11

Next steps



Next prototype: CB-200

Gain in sensitivity of ~40%



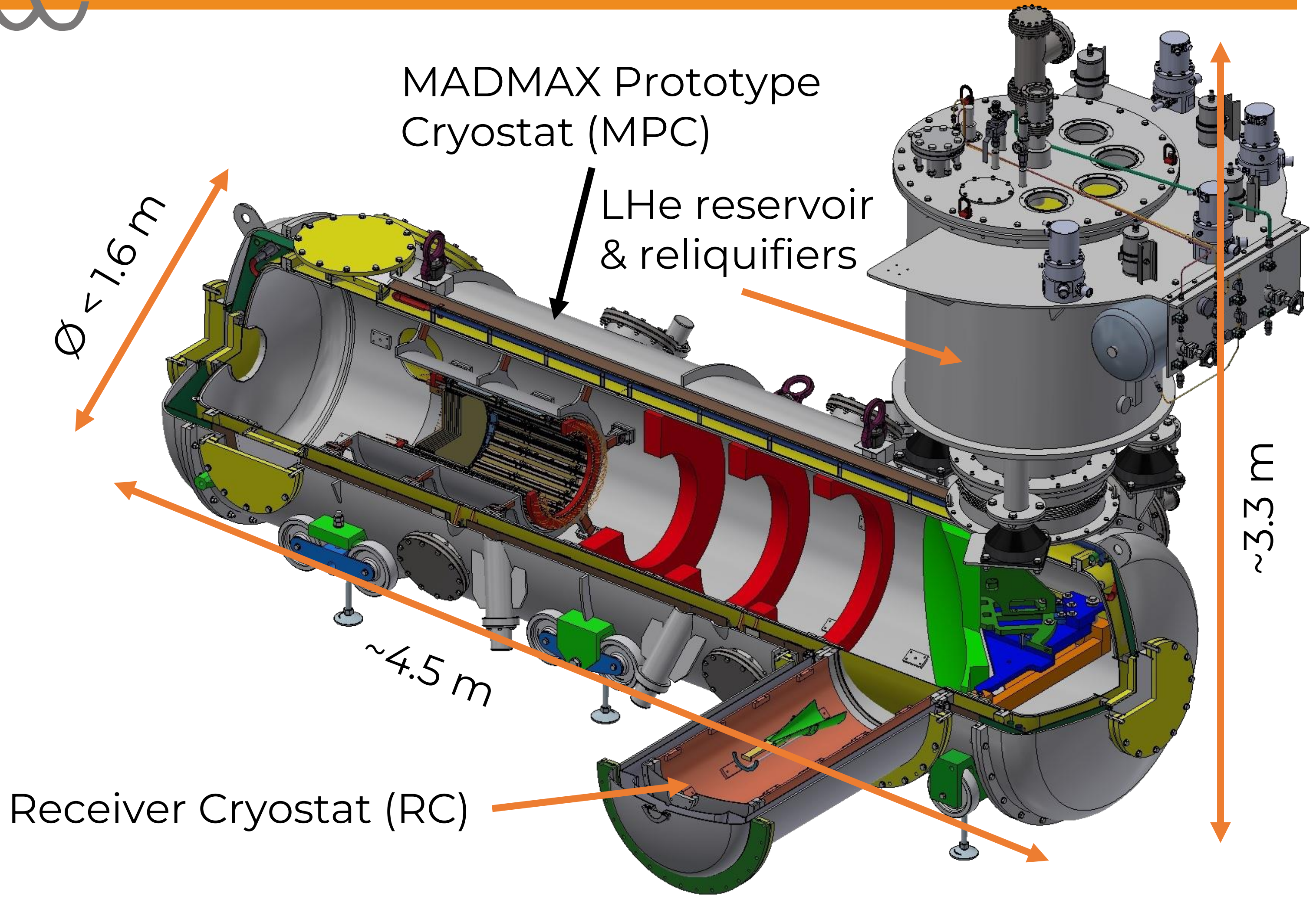
Cold (4K) run with CB-100

Gain in sensitivity of ~1 order of magnitude

For more information see poster

"Towards a cryogenic calibration of a dielectric haloscope for direct dark matter detection" – Juan PA M.

Plans for 2024-2025

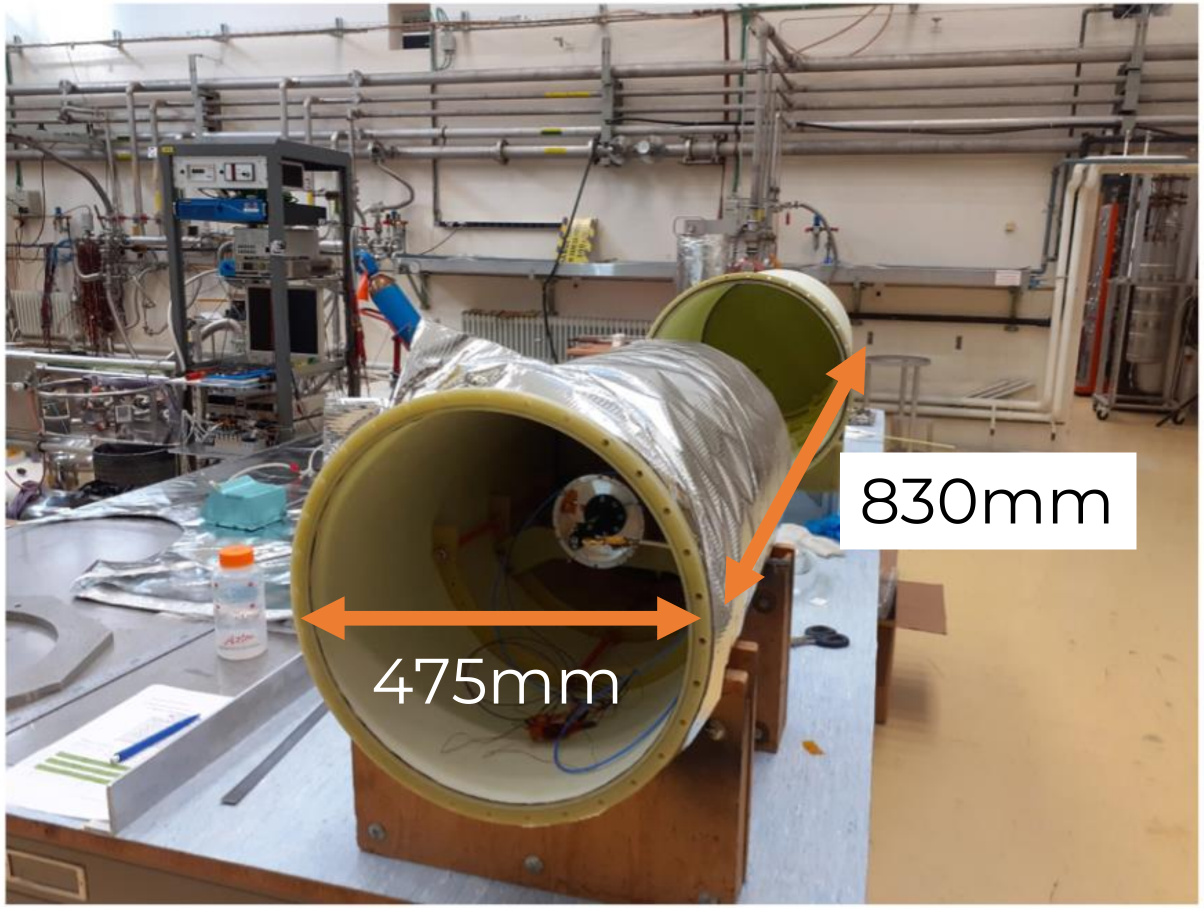


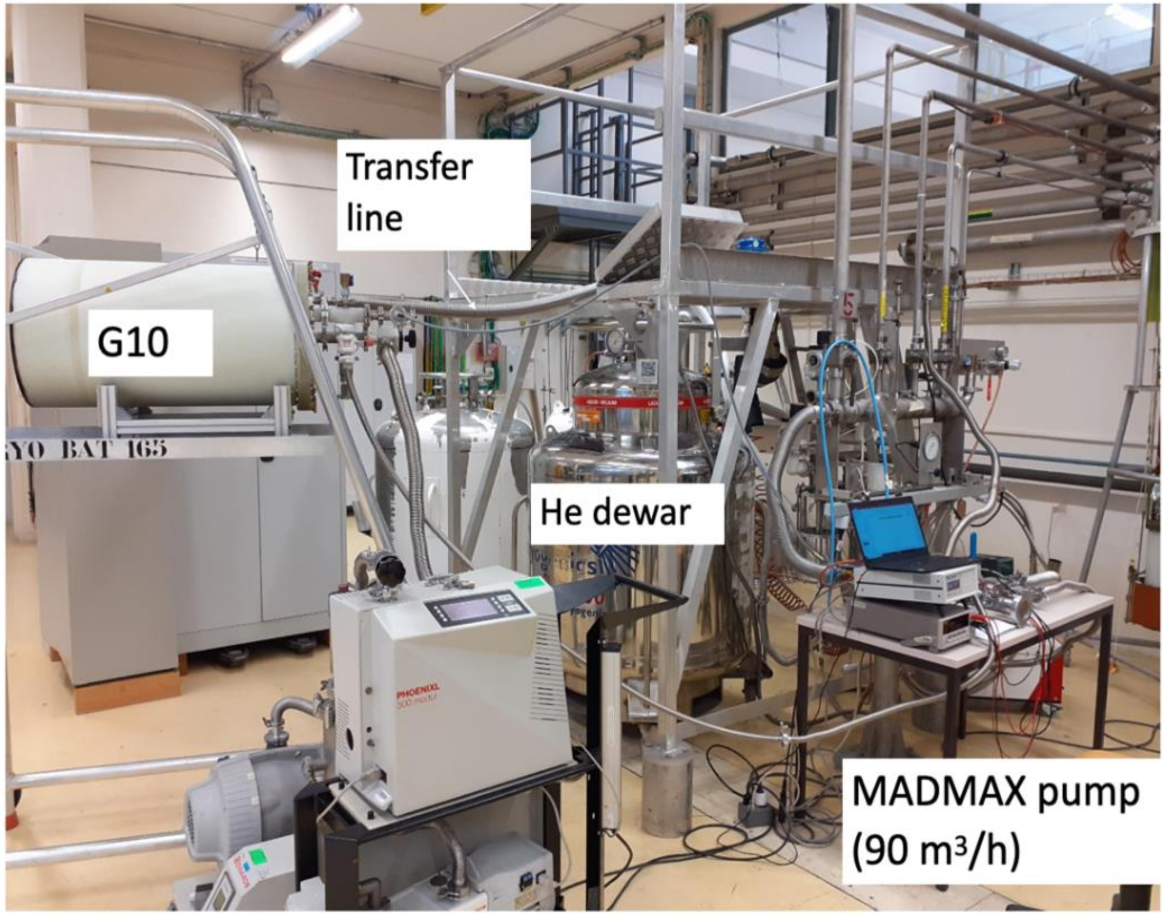
Main cryostat

- Delivery expected beginning of 2024
- Commissioning site: Hamburg
- Planned ALP search at CERN in 2025

G10 cryostat

Tested at
CERN cryolab





Stability reached: 24 hours at 10K

Summary

- MADMAX will search for axions between 40-400 μeV
- First runs with CB-100 at 300K done; data analysis ongoing
- Magnet feasibility confirmed
- Prototype cryostat soon to be available
- G10 cryostat tested and ready to use inside magnet
- First cryogenic operation intended for 2024 at CERN.

  Upgrade of the prototype also planned for 2024