First MADMAX Campaign and next steps

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On behalf of the MADMAX collaboration

Overview

Physical principles of MADMAX

How to calibrate the experiment

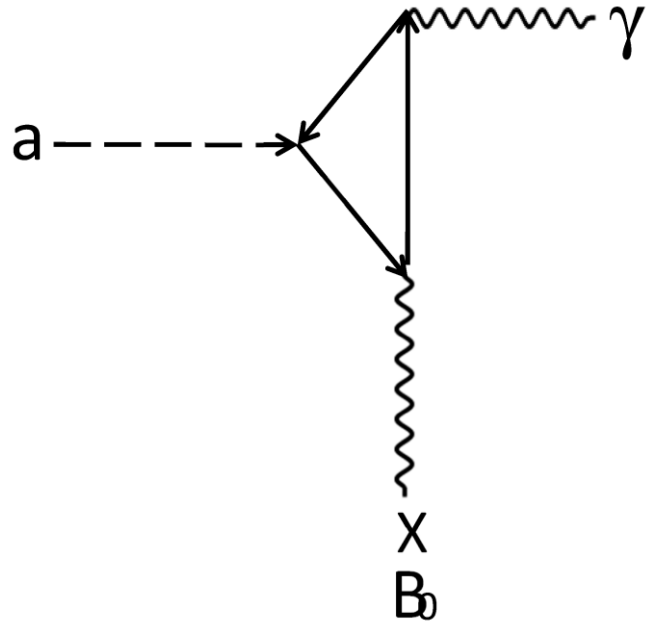
CERN runs and monitoring system

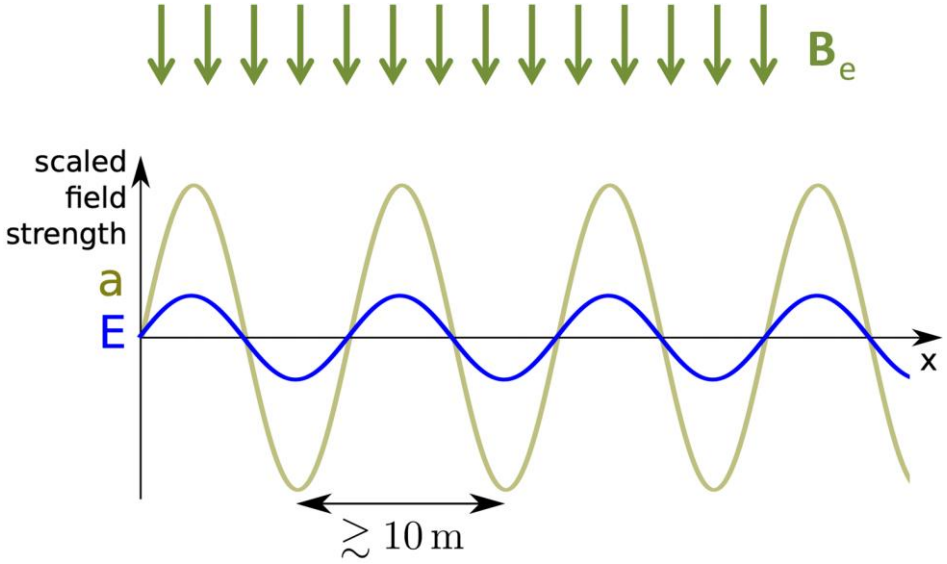
Cold calibration challenges and idea

The experiment

Idea:

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



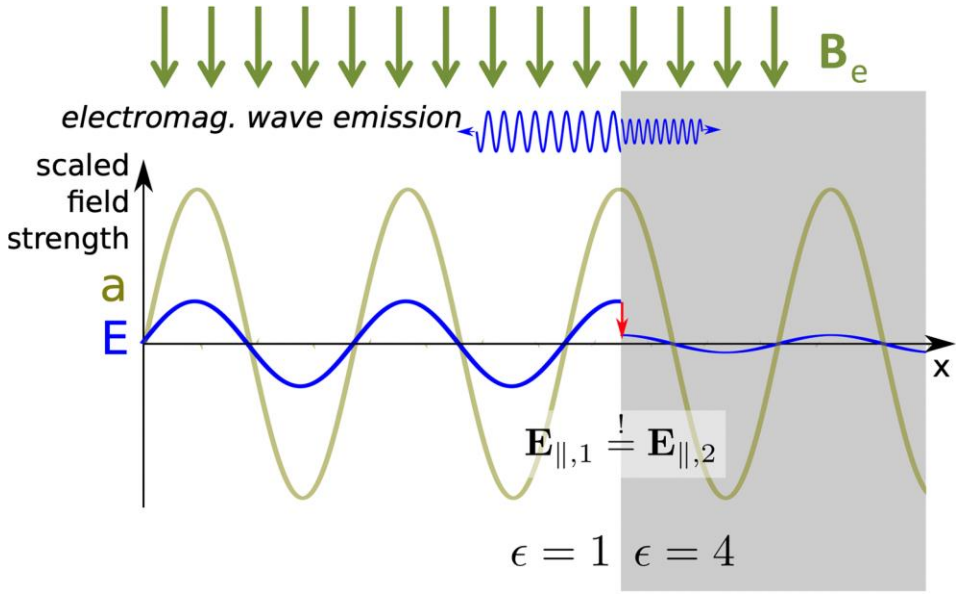


The experiment

Idea:

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

2) Boost the signal using spatially-periodic dielectric discontinuities



The experiment

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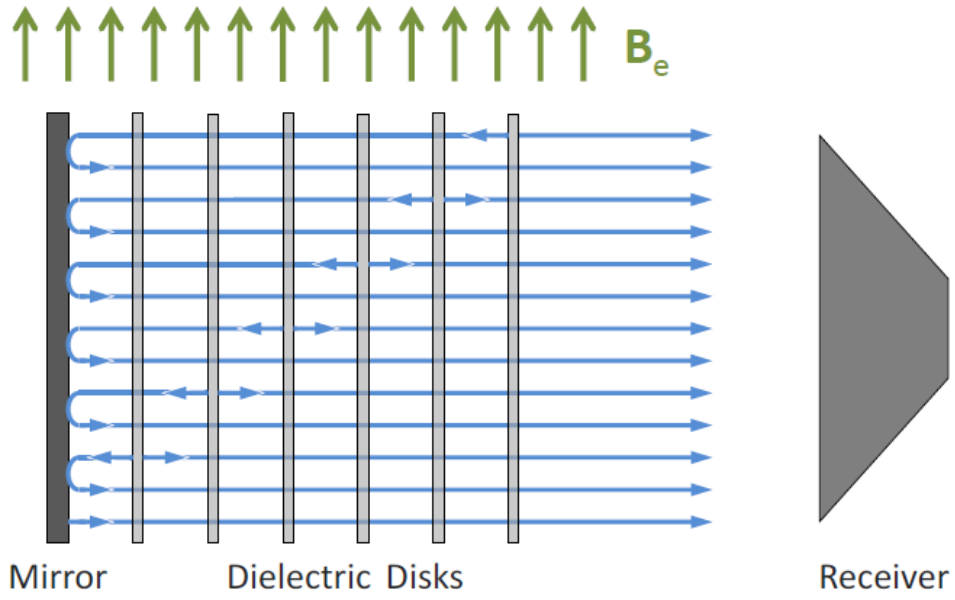
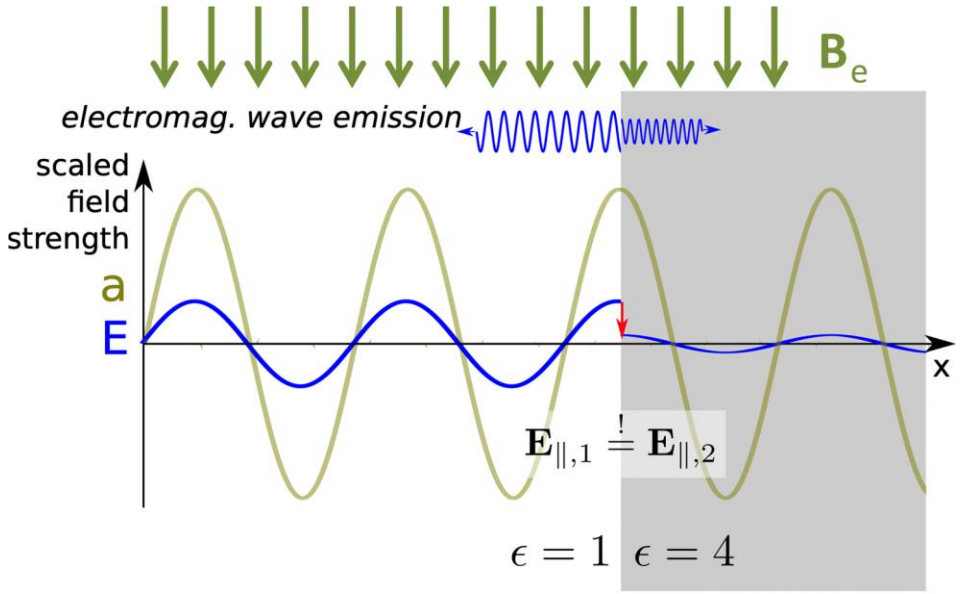
$$\beta^2 = \frac{P_{sig}}{P_{mirror}}$$





The experiment

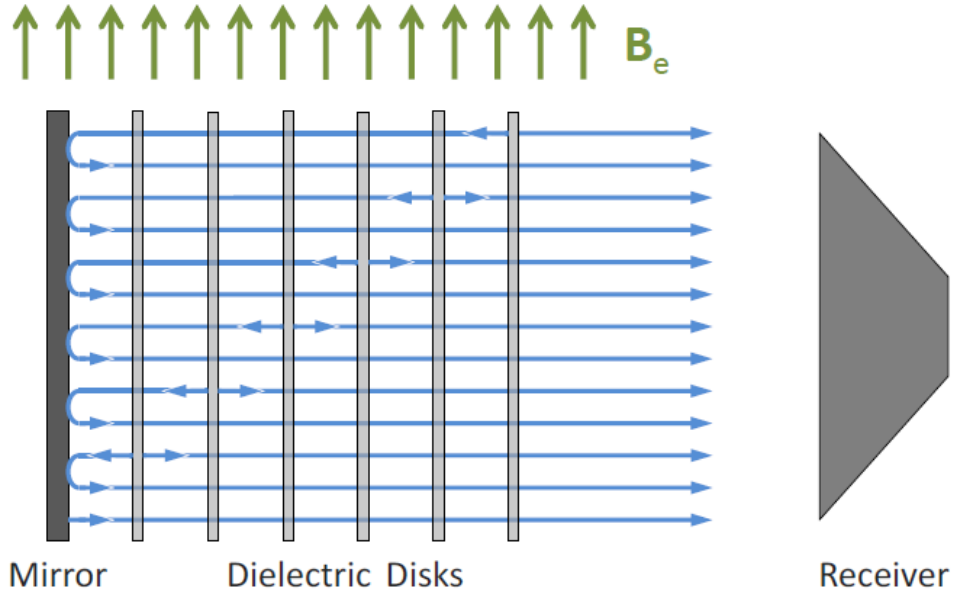
Idea:

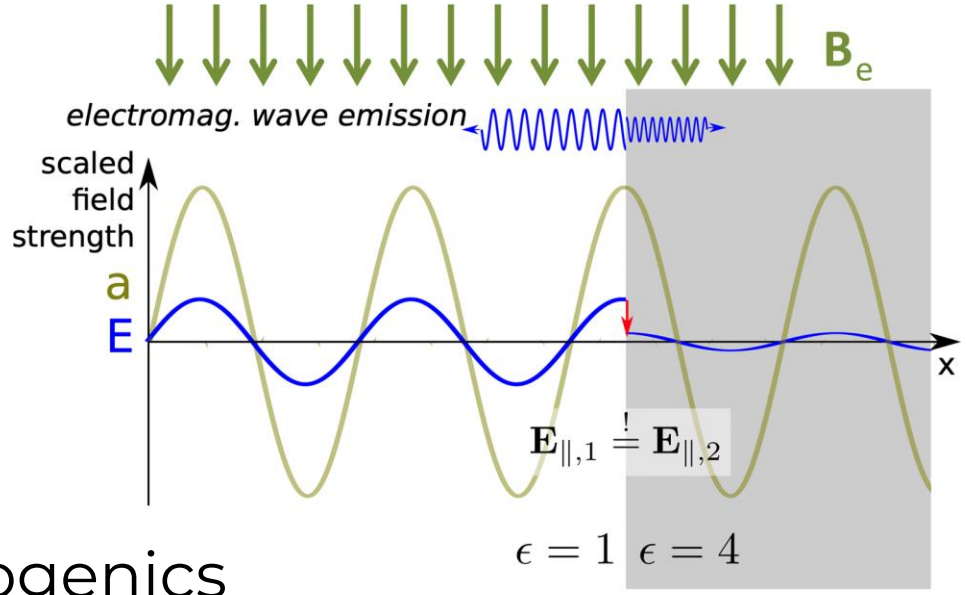
1) Induce inverse Primakoff effect in a strong external B field

2) Boost the signal using spatially-periodic dielectric discontinuities

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

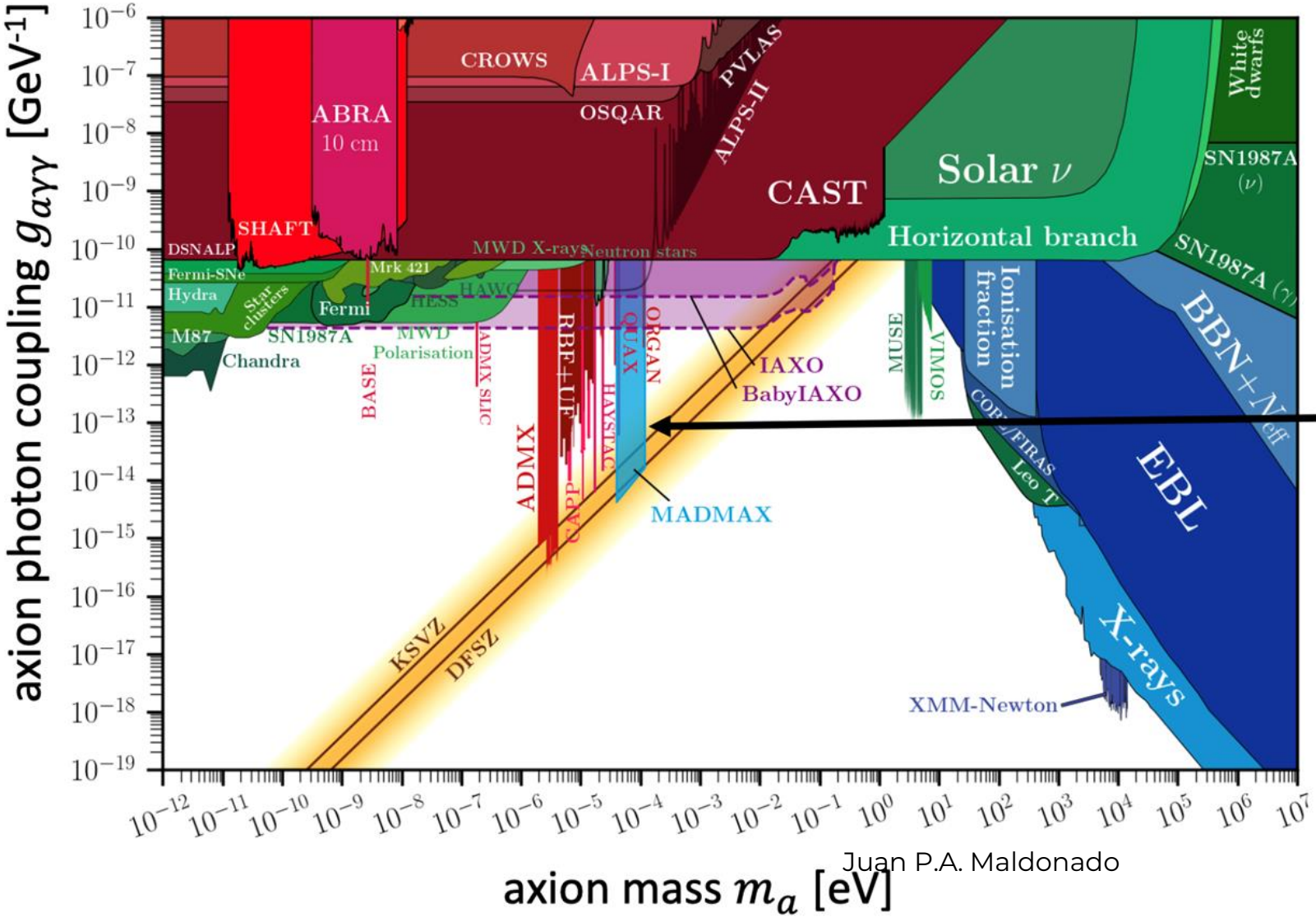
3) Move discs to change resonant frequency





Note: Reduce thermal background with cryogenics

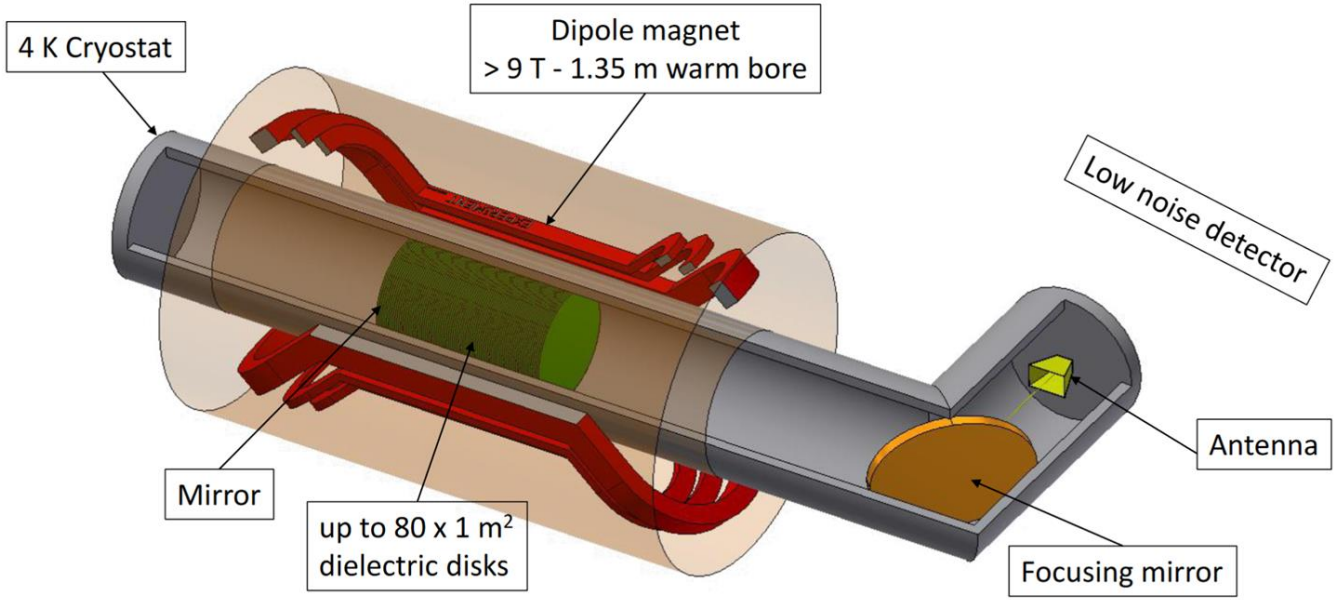
Status of axion experiments



Aspirational setup

Probing the QCD axion between 40-400 μeV

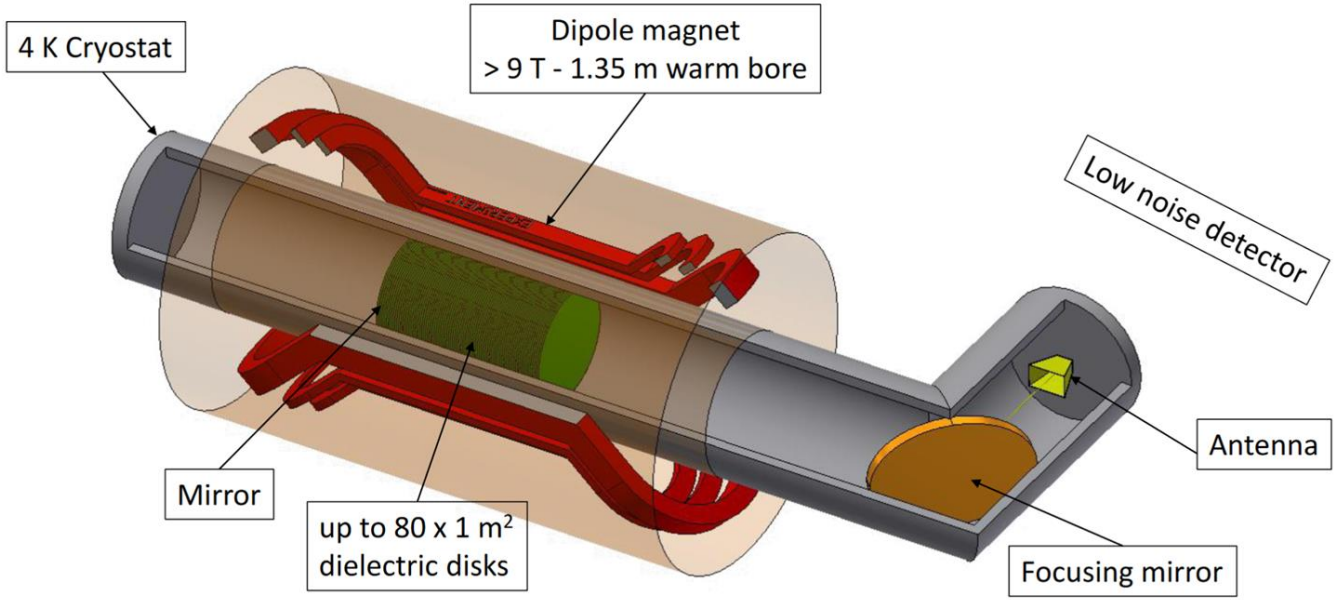
The experiment



Aspirational setup

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

The experiment



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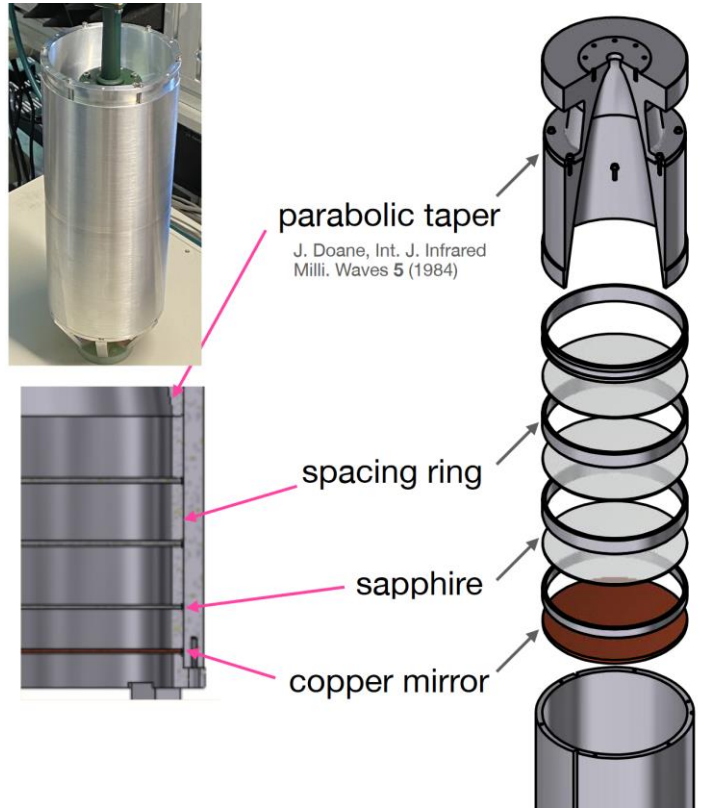
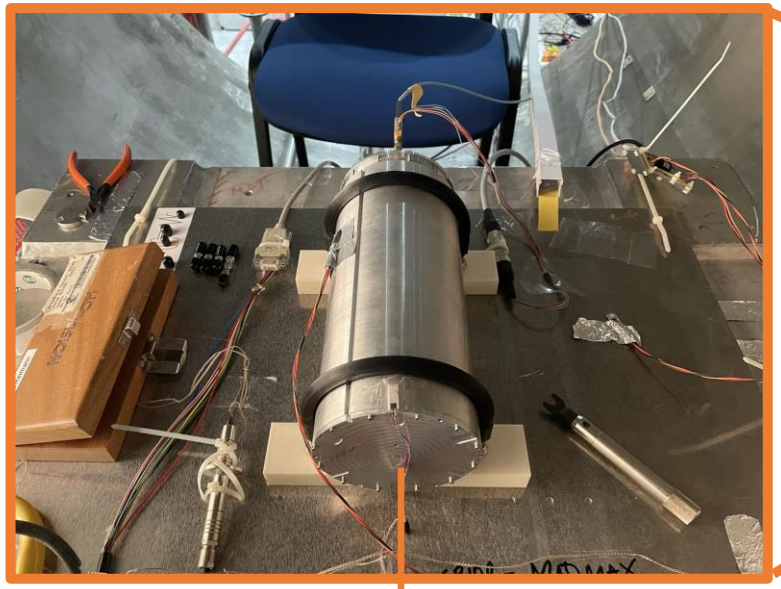


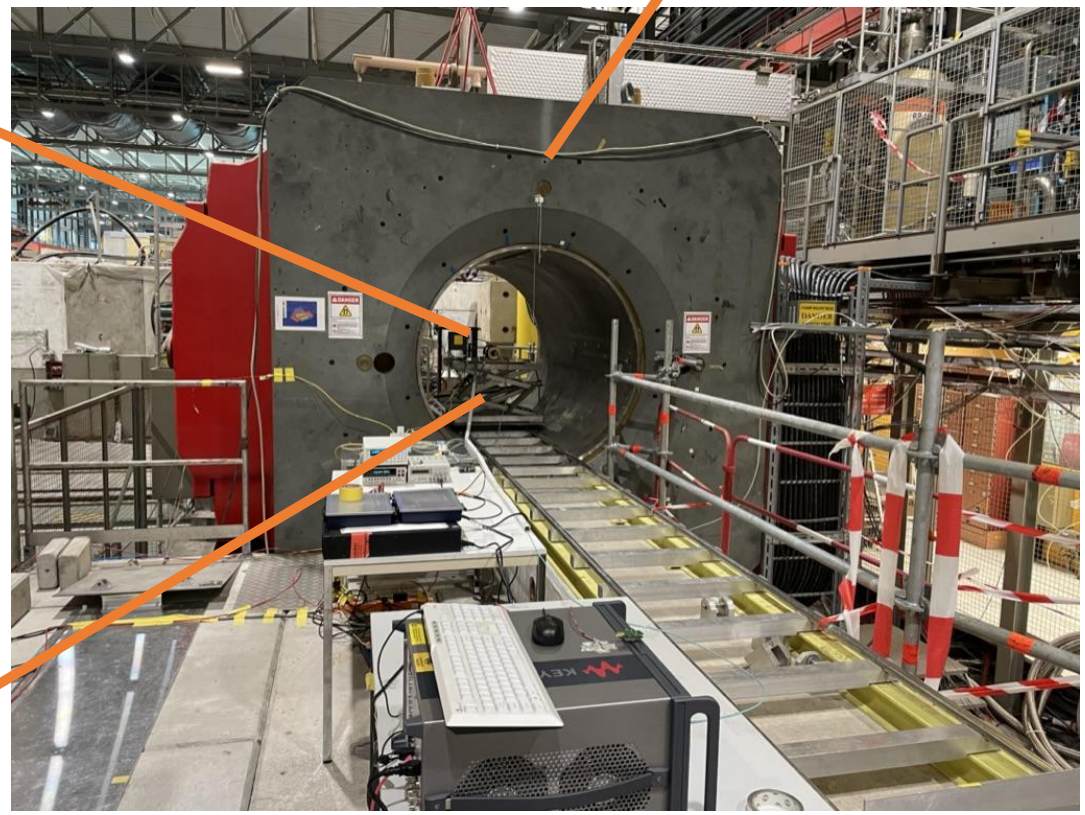
Prototype: CB-100

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

CERN runs

Morpurgo magnet:
1.6 T dipole field



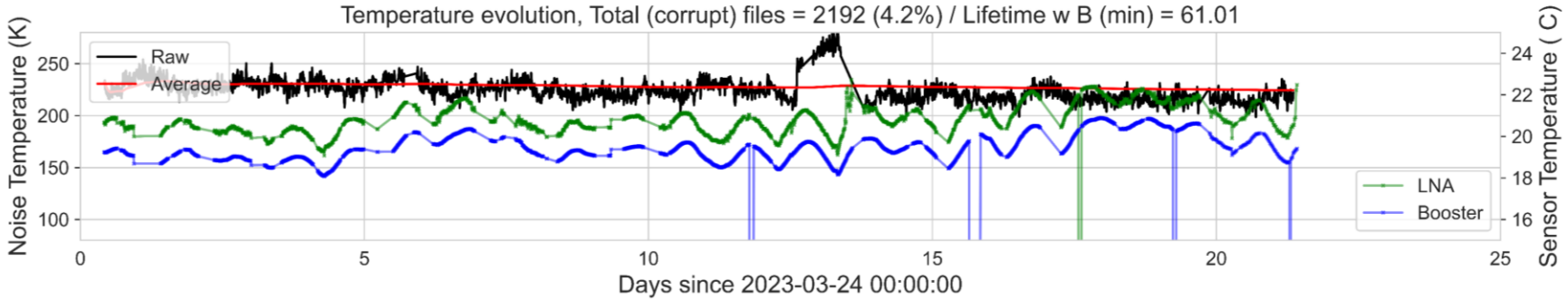


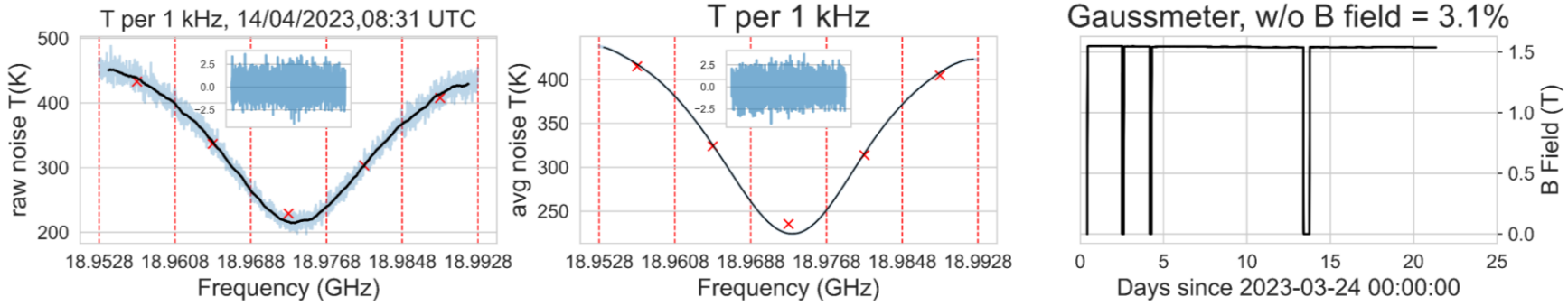
- CB-100 at room temperature
- ~10 hours integration time

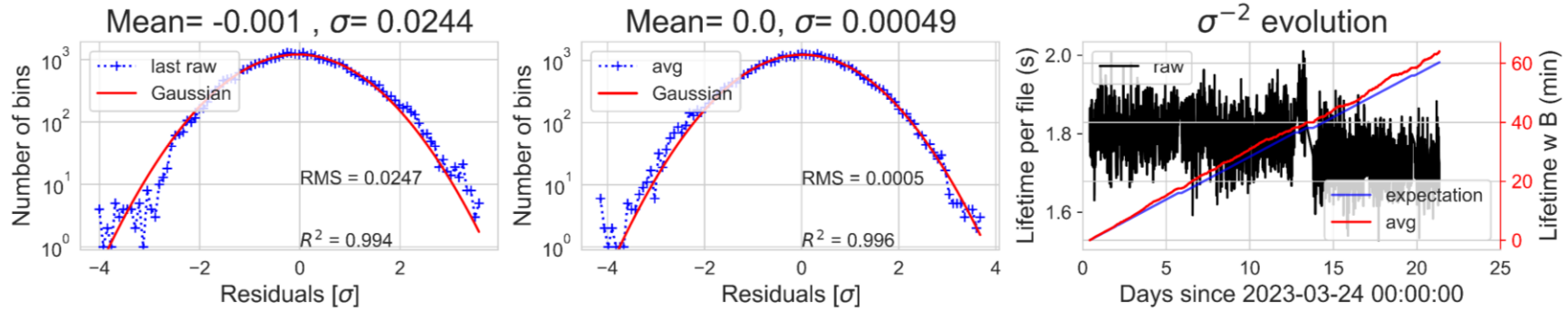
Data analysis ongoing

Successful test: booster in magnet running continuously

Monitoring system







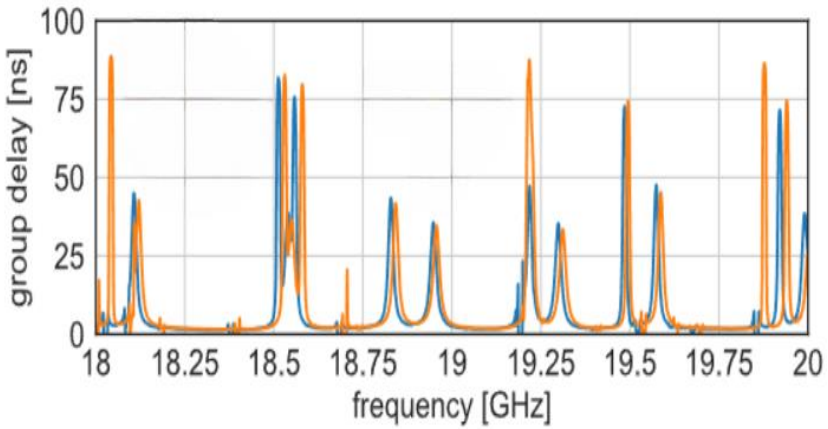
24/7 experiment monitoring

- 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.)

How to calibrate?

Reflectivity calibration

Goal: Understand the resonance of the booster (closely related to β^2)

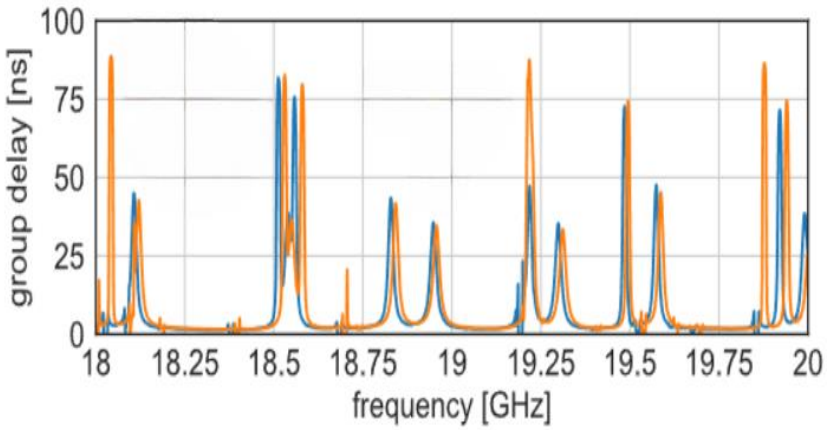


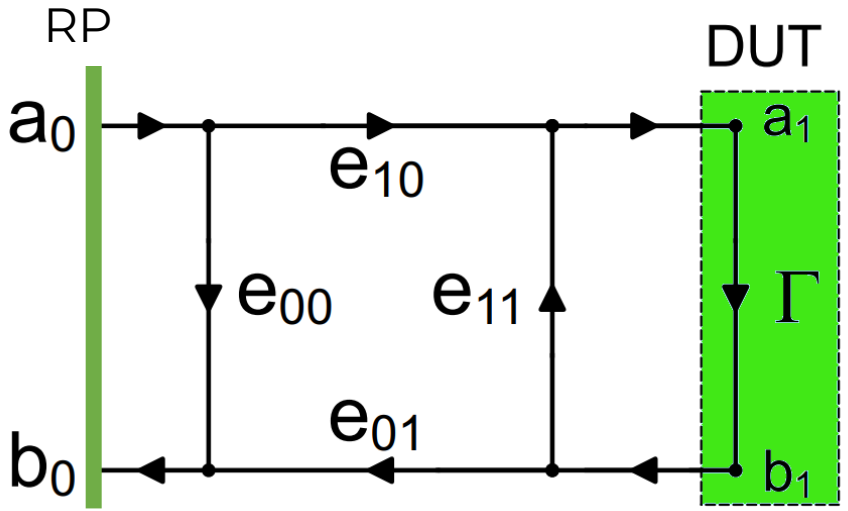
How to calibrate?

Reflectivity calibration

Goal: Understand the resonance of the booster (closely related to β^2)

Method: Send a signal to the booster and measure its reflection





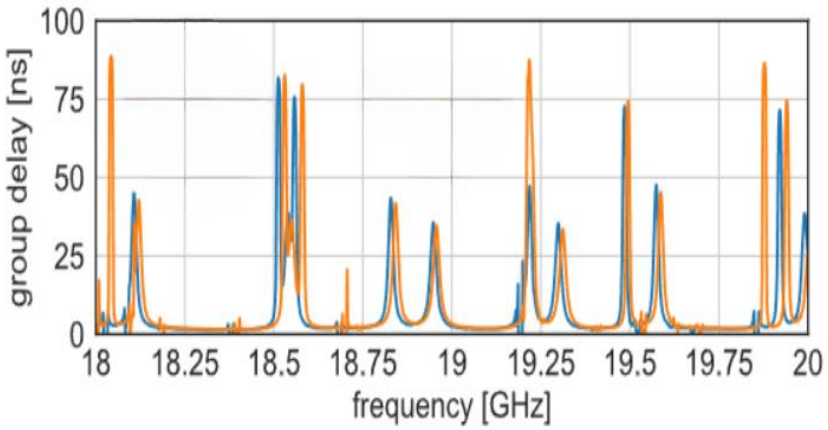
How to calibrate?

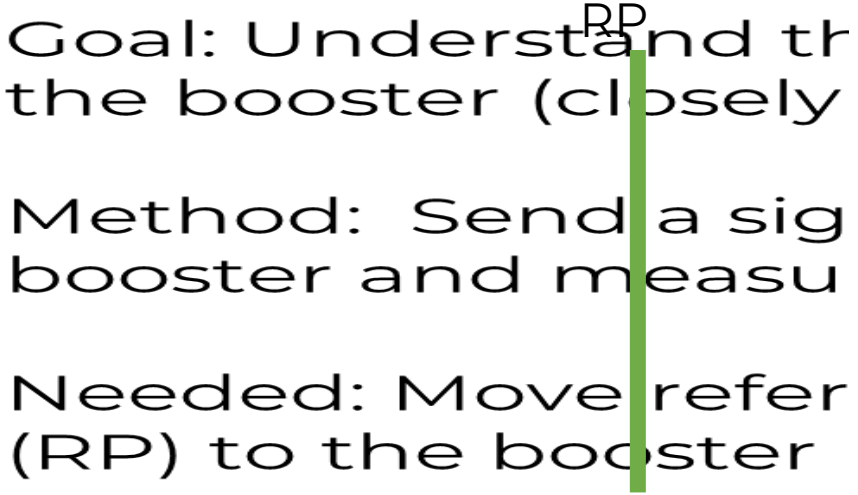
Reflectivity calibration

Goal: Understand the resonance of the booster (closely related to β^2)

Method: Send a signal to the booster and measure its reflection

Needed: Move reference plane (RP) to the booster





How to calibrate?

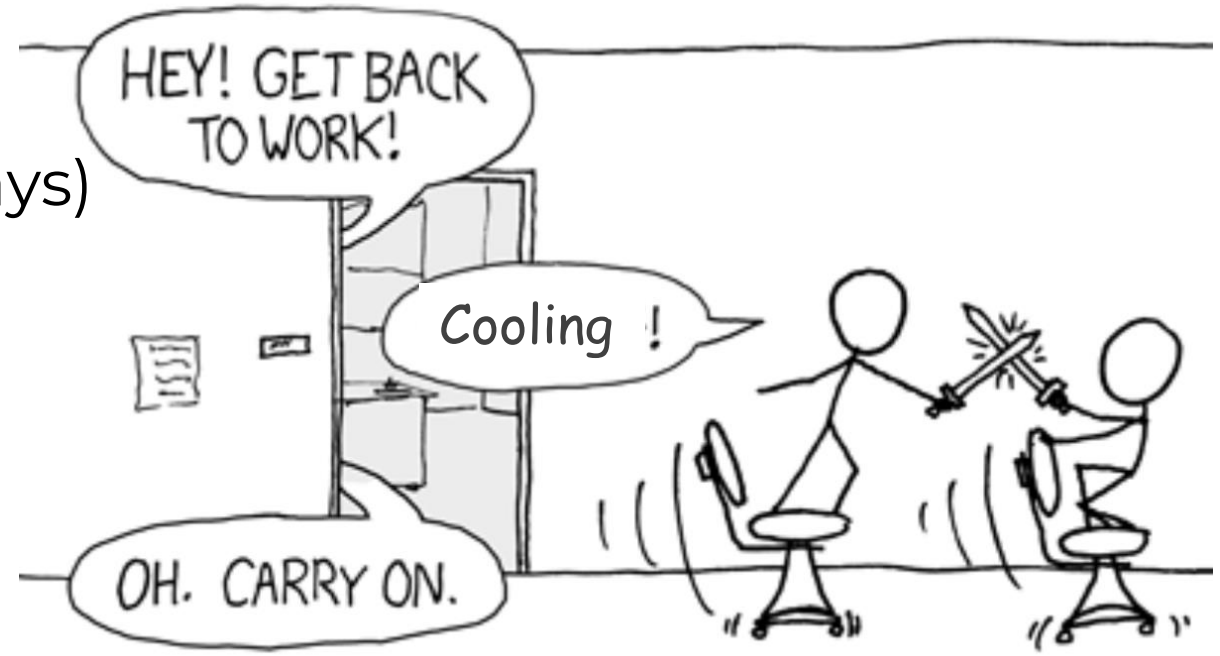
Manually perform ~10 different measurements to understand the receiver chain and the reflectivity of the booster

Time needed: ~5 hours

Now at 4K

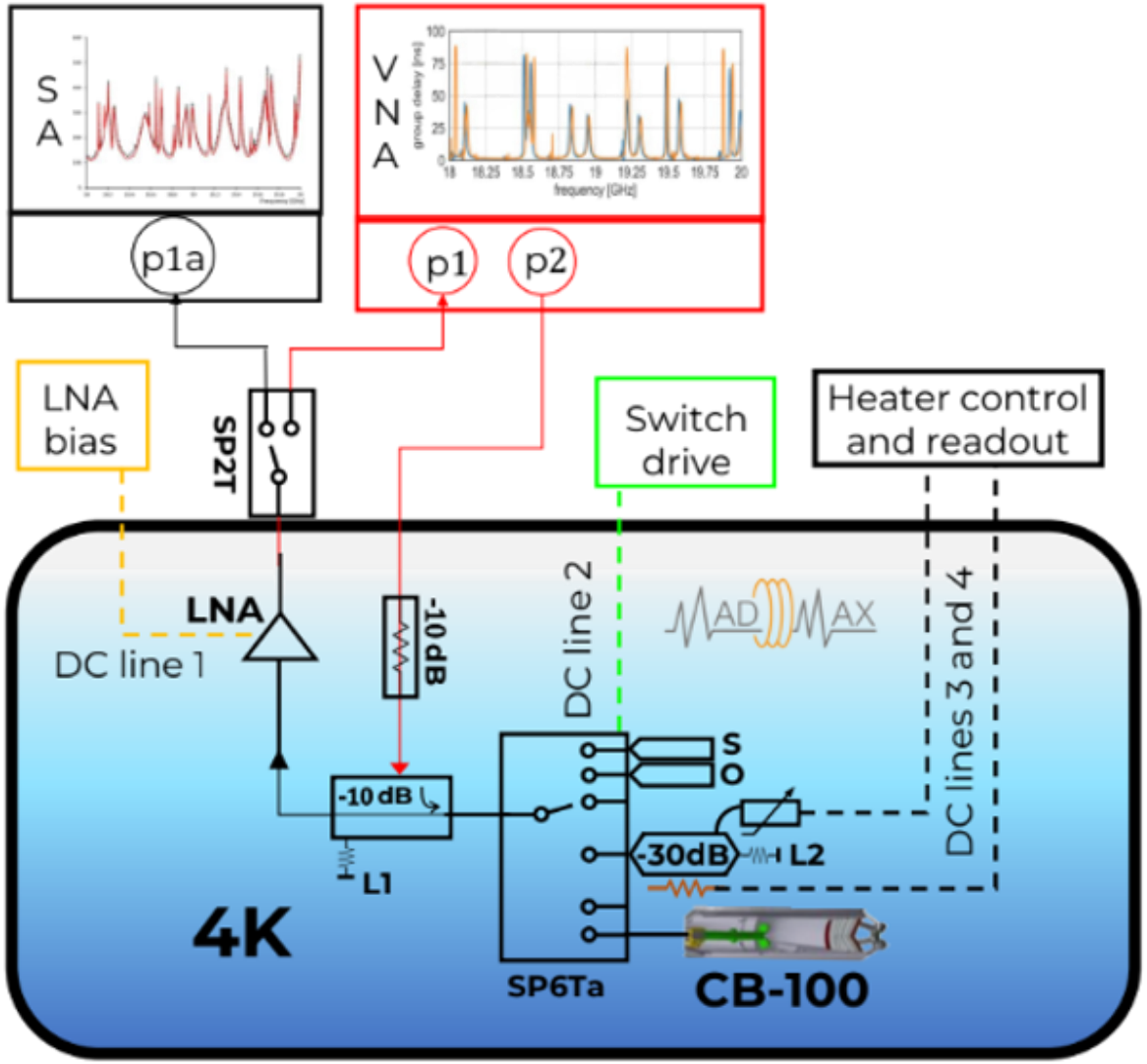
1. Insert the device in a liquid Helium cryostat (couple of days)
2. Measure (15 minutes)
3. Extract the device (couple of days)
4. Repeat N times

Total time required ~ 1 month



…. and if something went wrong?

Cold operation idea



Single thermal cycle semi-automatic calibration.

Goal: Maximize stability and reproducibility of our measurements

Main new additions with respect to room temperature: Cryostat, coupler, switch,

Summary

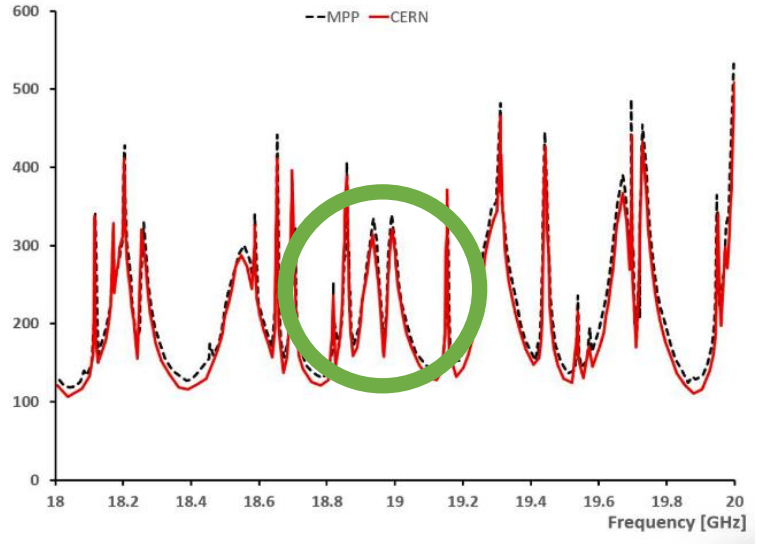
MADMAX will search for axions between 40-400 μeV

First runs with CB-100 at 300K done; data analysis ongoing

First monitoring system implemented

Semi-automatic cryogenic calibration needed. Tests ongoing

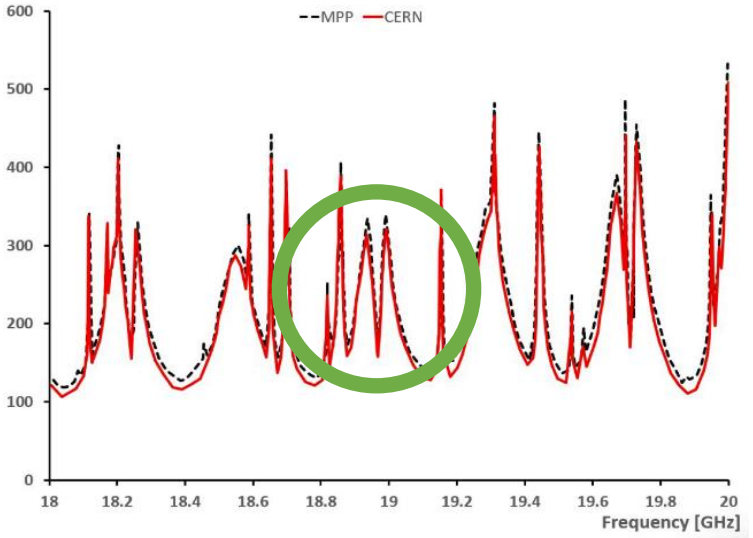
How to calibrate?

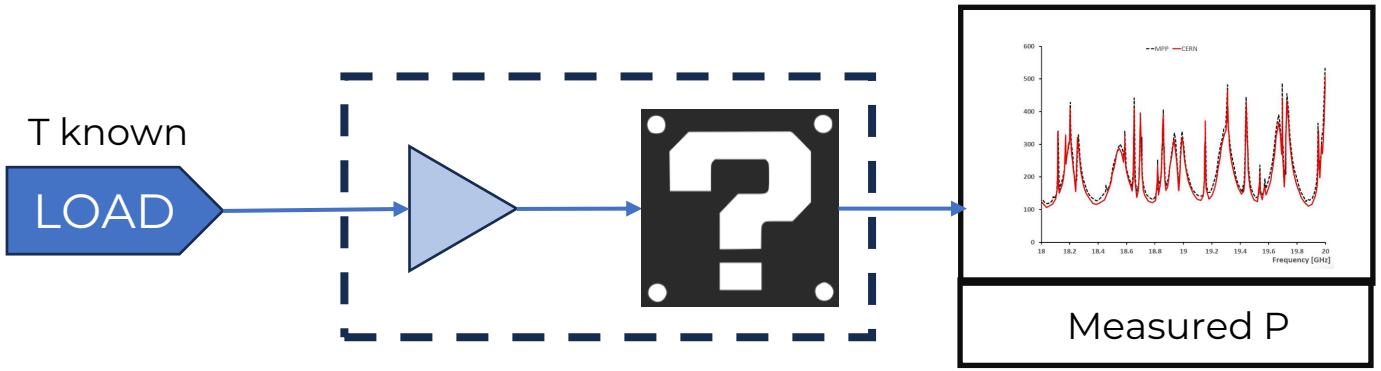


Receiver calibration

Goal: Measure the system temperature of the setup (determine T_{sys}^2)

How to calibrate?





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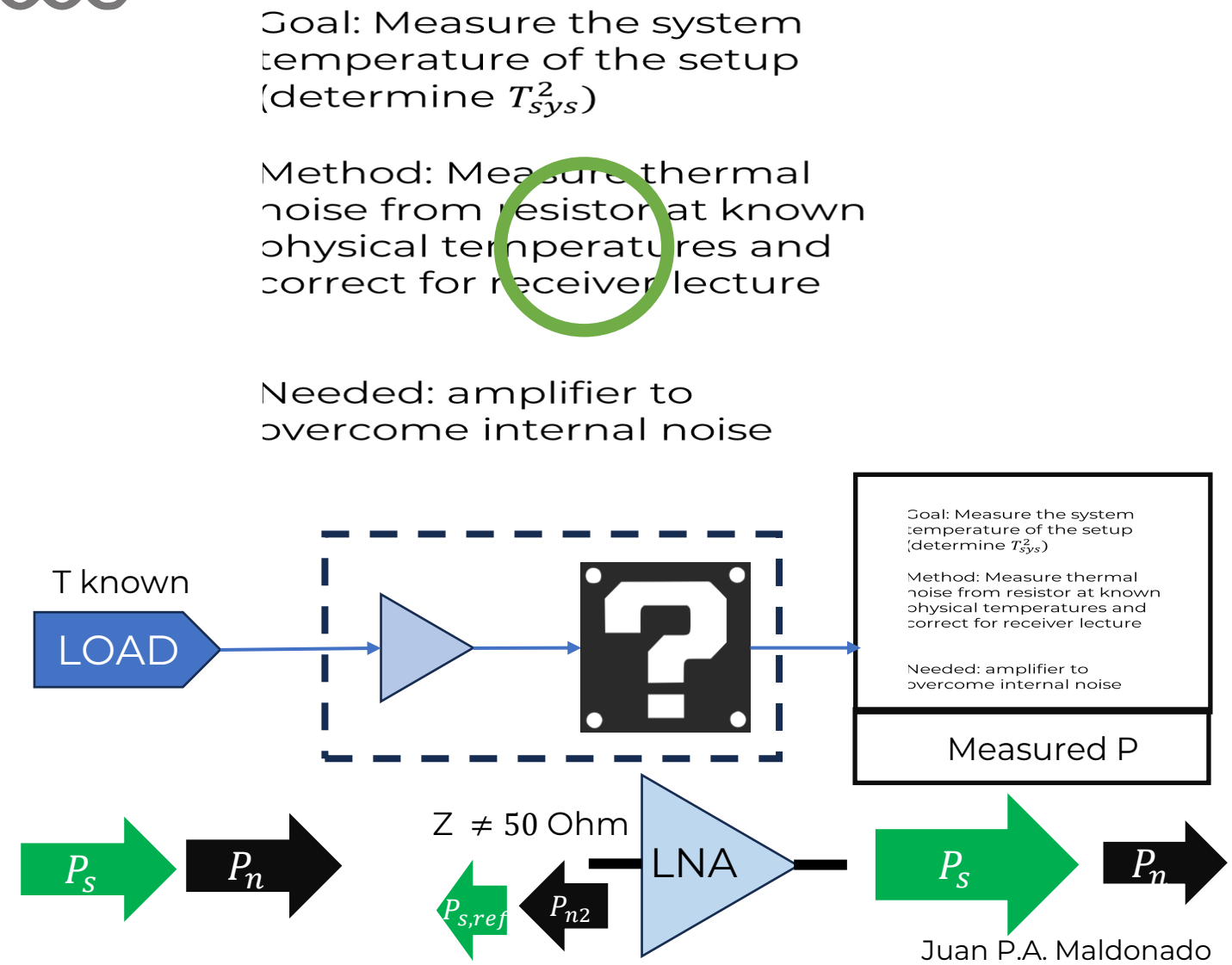

Receiver calibration

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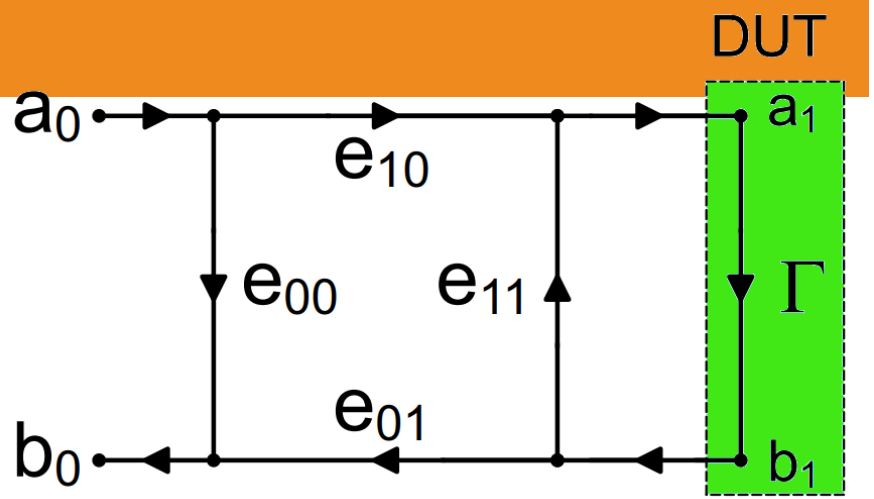
Needed: amplifier to overcome internal noise

1-port error model



$\mathbf{e_{00}}$: directivity
$\mathbf{e_{10}}$: transmission tracking
$\mathbf{e_{01}}$: reflection tracking
$\mathbf{e_{11}}$: port-match

1. *Measure 3 standards to find the error parameters from*

$$\begin{bmatrix} 1 & \Gamma_{M1}\Gamma_1 & -\Gamma_1 \\ 1 & \Gamma_{M2}\Gamma_2 & -\Gamma_2 \\ 1 & \Gamma_{M3}\Gamma_3 & -\Gamma_3 \end{bmatrix} \begin{bmatrix} e_{00} \\ e_{11} \\ \Delta_e \end{bmatrix} = \begin{bmatrix} \Gamma_{M1} \\ \Gamma_{M2} \\ \Gamma_{M3} \end{bmatrix}$$

2. *Measure the DUT and apply*

$$\Gamma_{DUT} = \frac{\Gamma_{M,DUT} - e_{00}}{\Gamma_{M,DUT} e_{11} - \Delta_e}$$