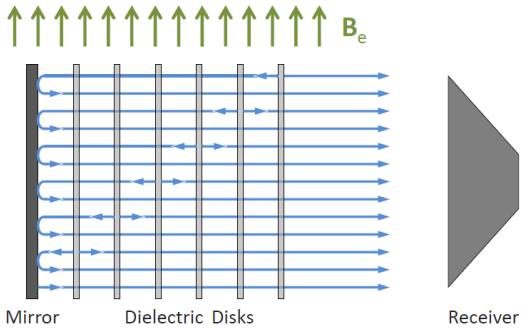
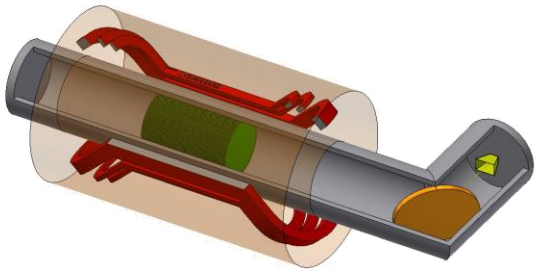
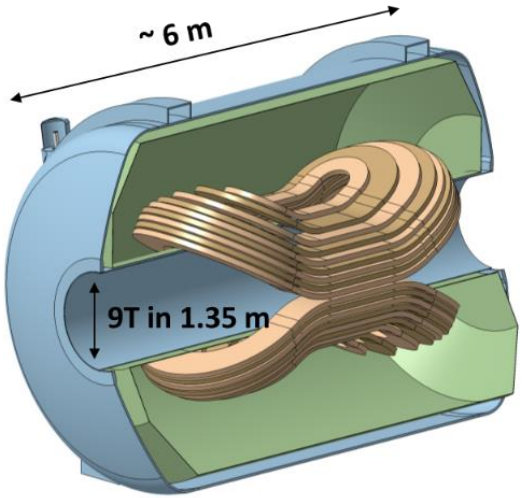
MADMAX update and plans

Béla Majorovits on behalf of the MADMAX collaboration

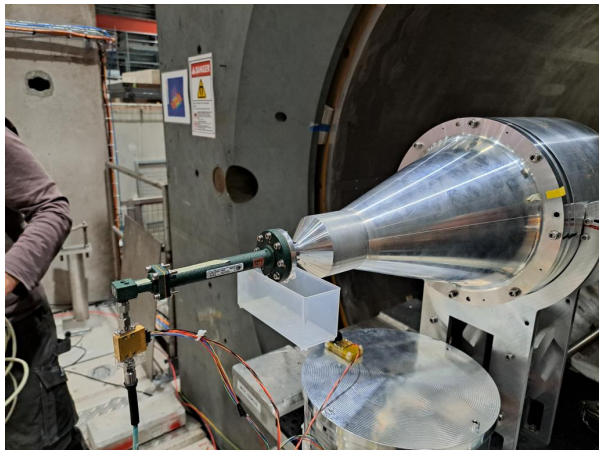
MAX-PLANCK-INSTITUT FÜR PHYSIK



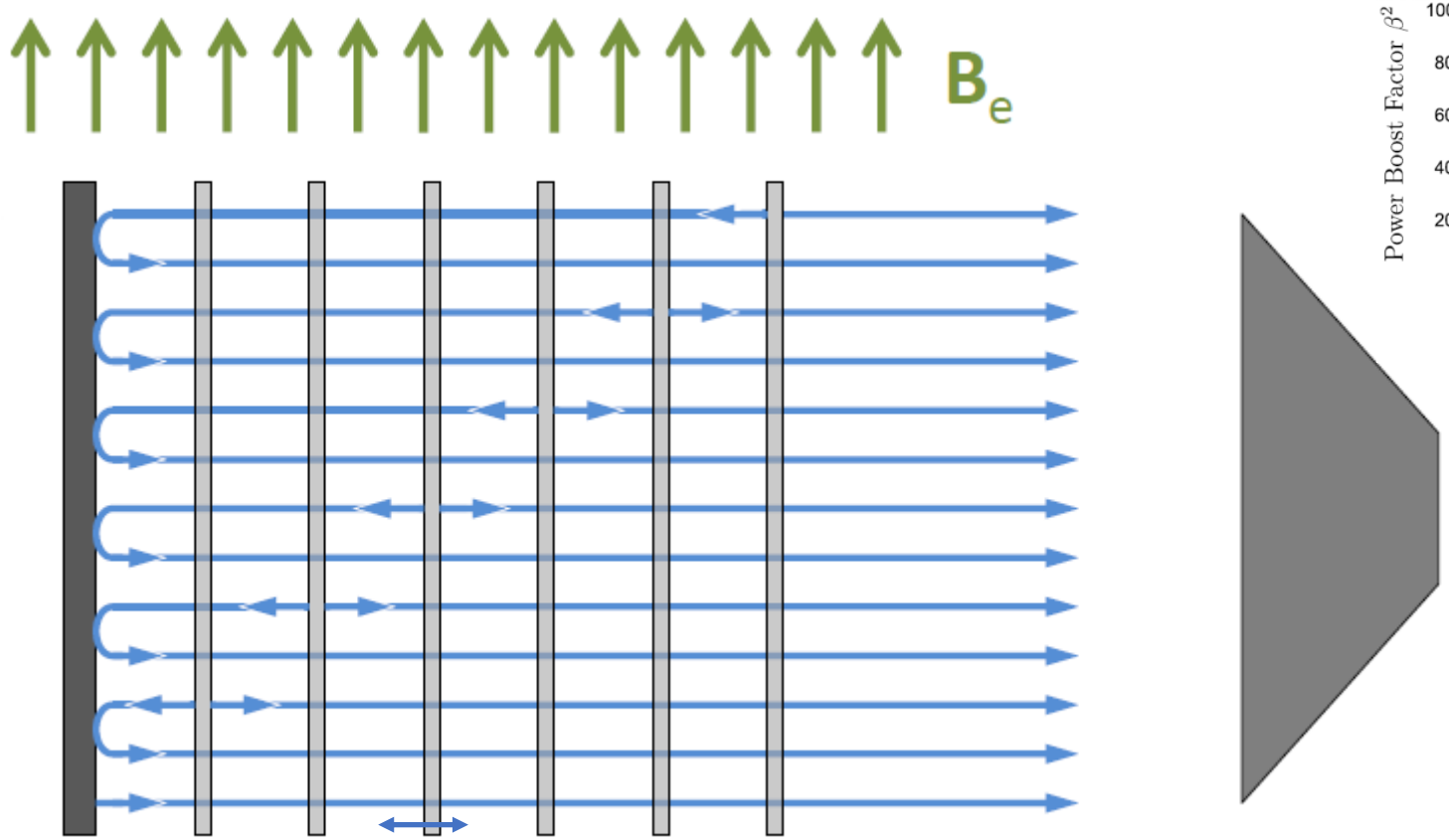


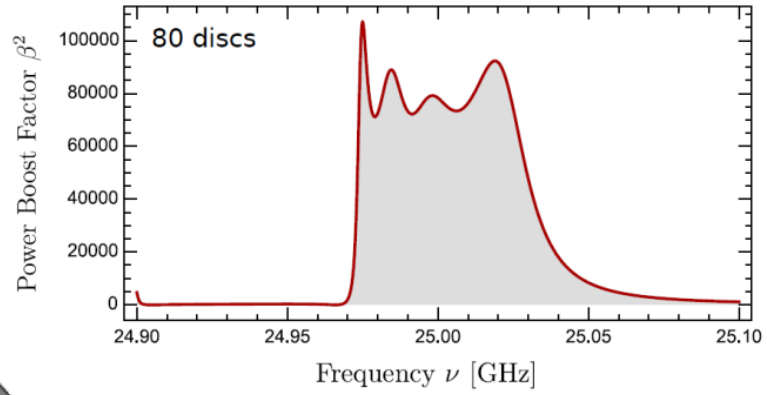


- **MADMAX: a dielectric haloscope for discovering dark matter axions**
- **Magnet status**
- **Closed and open booster Prototypes**
- **Latest measurement campaigns**
- **MADMAX FNAL solenoid**



MADMAX: a dielectric haloscope



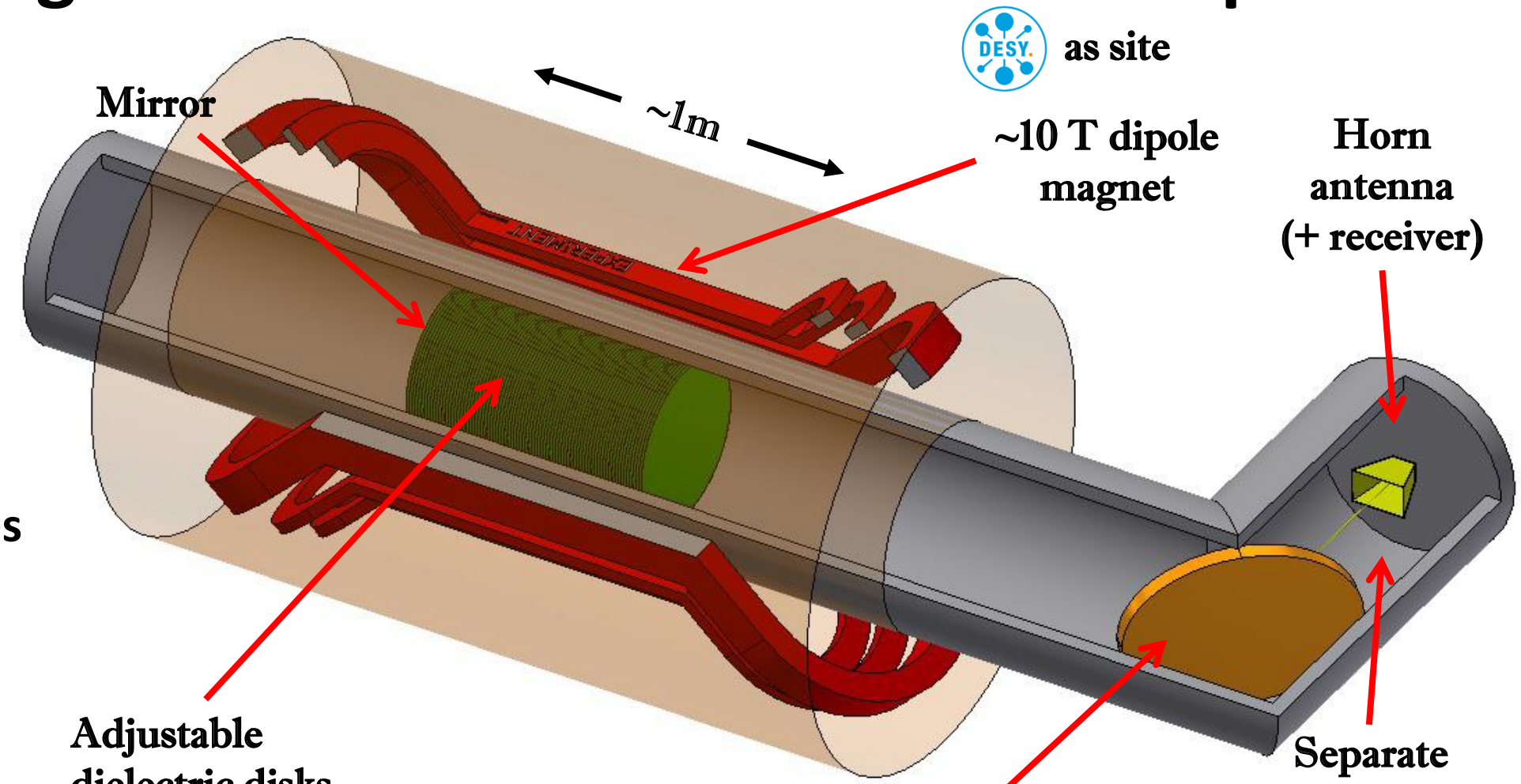


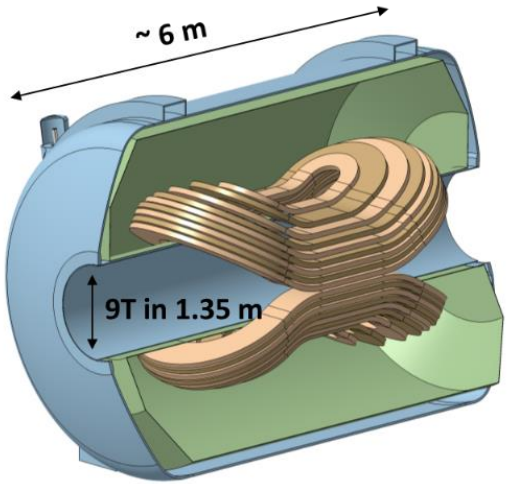
$$\beta^2 = \frac{P_{booster}}{P_{mirror}}$$

$$\left(\frac{P}{A}\right)_{booster} \sim 2 \cdot 10^{-27} \frac{\mathrm{W}}{\mathrm{m}^2} \left(\frac{B_{||}}{10\ T}\right)^2 (g_{a\gamma\gamma} m_a)^2 \beta^2$$

MADMAX: MAgnetized disk and Mirror Axion eXperiment

MADMAX goal:
DFSZ sensitivity at
10 – 100 GHz
Magnet: 100 T^2m^2
Boost factor > 10.000
T_{sys} ~ 10 K
Tunable disc distances



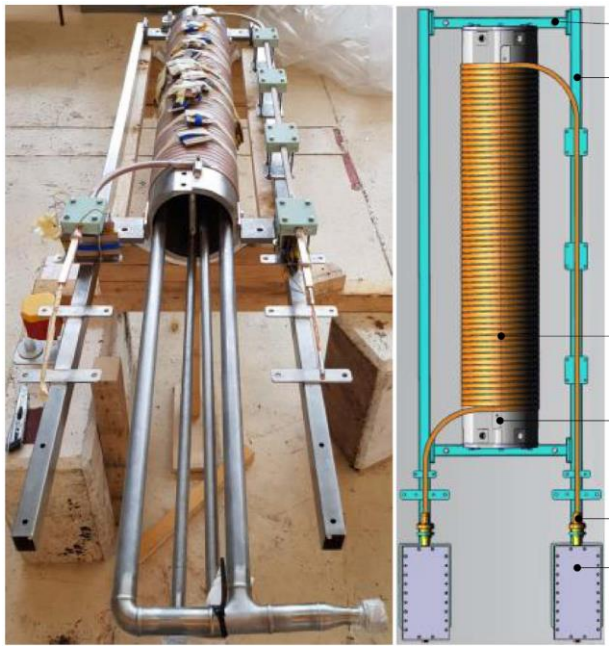


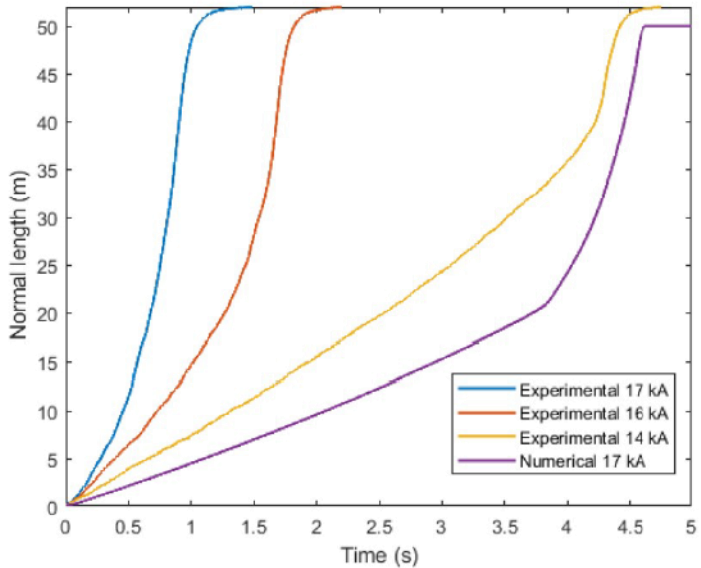
MADMAX magnet status

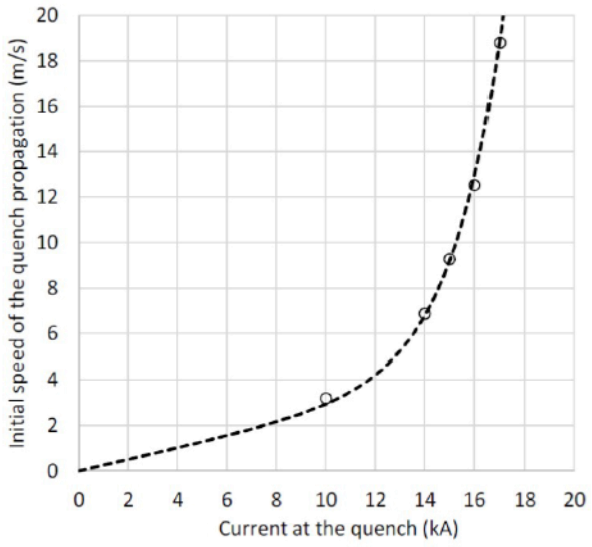
- **Design study within innovation partnership finished:**
  → 9.1 T dipole with 1.35 m warm bore feasible
- **First important R&D results**
  - Conductor based on CICC can be produced:
  Suppliers for conductor available
  - Copper yield strength ok after compaction
  - Quench protection feasible (propagation velocity)
  - Cooling concept of conductor

All results in special MADMAX issue IEEE Transactions on Applied Superconductivity, 33(7):1–11, 2023.

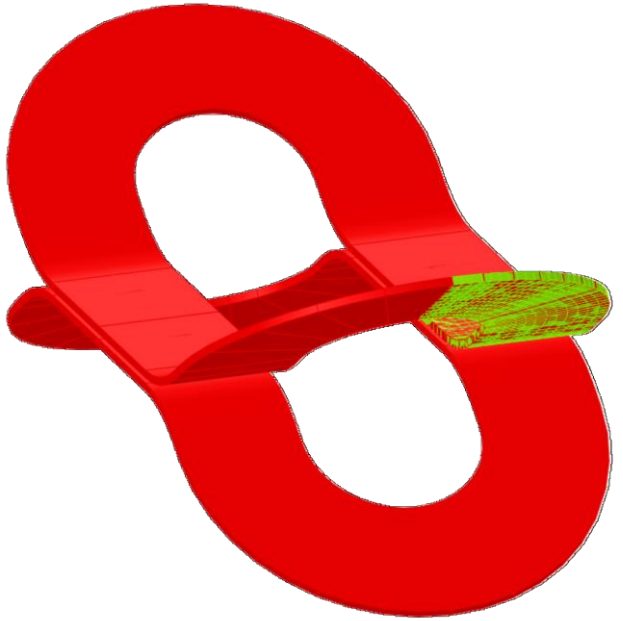
MACQU test solenoid







MADMAX path forward



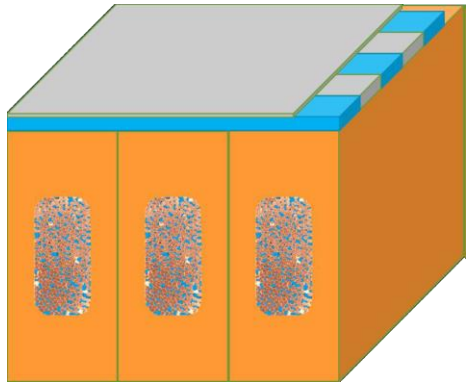
Path forward: Design, build and test demonstrator coils

- Stick slip heat deposition

- Extraction of heat after stick slip

- Develop conductor termination

→ Mitigate underperformance risk



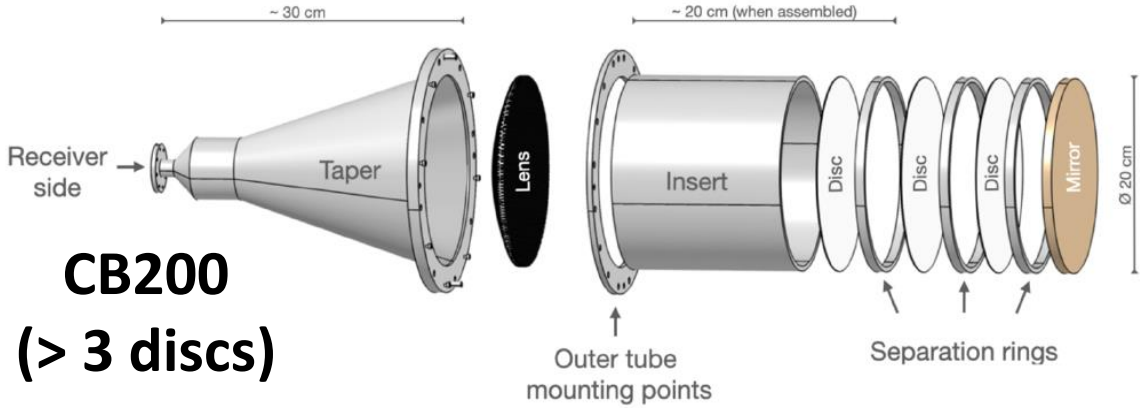
Test and understand conductor production, bending, impregnation…

→ Verify production sequence

closed and open prototypes

Closed Booster with 100mm and 200mm diameter
Well defined boundary conditions
Not tunable by motors
Understand boost factor determination using reflectivity: **CB100 & CB200**

Both used inside MORPURGO magnet at CERN

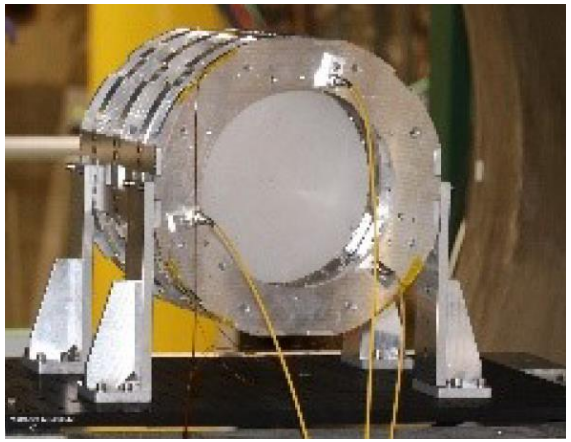


CB200
(> 3 discs)

Different set of separation rings
→ Different frequencies: 18 – 21 GHz

Open Booster with 200mm and 300mm diameter:
Ideally "absorbing" boundary conditions
Tunable in frequency by motors
Determination of boost factor by „**bead pull**" method & mechanical test

OB200 used for **mechanical qualification** in B-field & cryo
Used „static" open booster to perform **hidden photon meas**
OB300 to be used in special cryostat at CERN - MORPURGO



OB200
(1 disc)

closed and open prototypes

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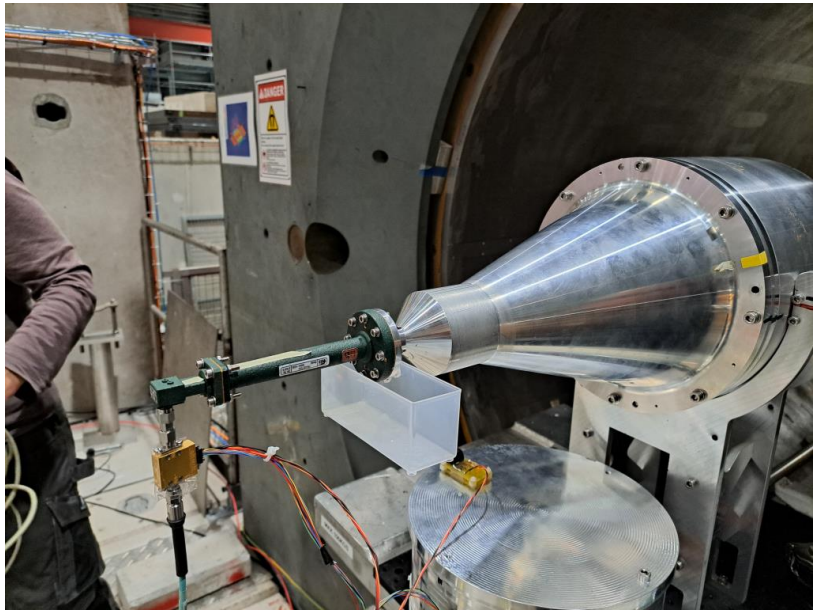

CB200
At CERN
(3 discs)

Open Booster with 200mm and 300mm diameter:
Ideally "absorbing" boundary conditions
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Determination of boost factor by „**bead pull**" method & mechanical test

OB200 used for **mechanical qualification** in B-field & cryo
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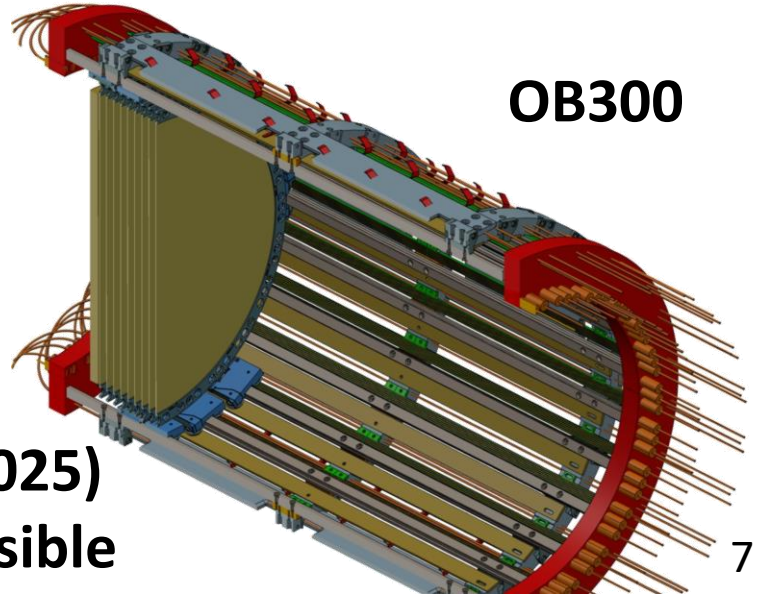
OB300 to be used in special cryostat at CERN - MORPURGO

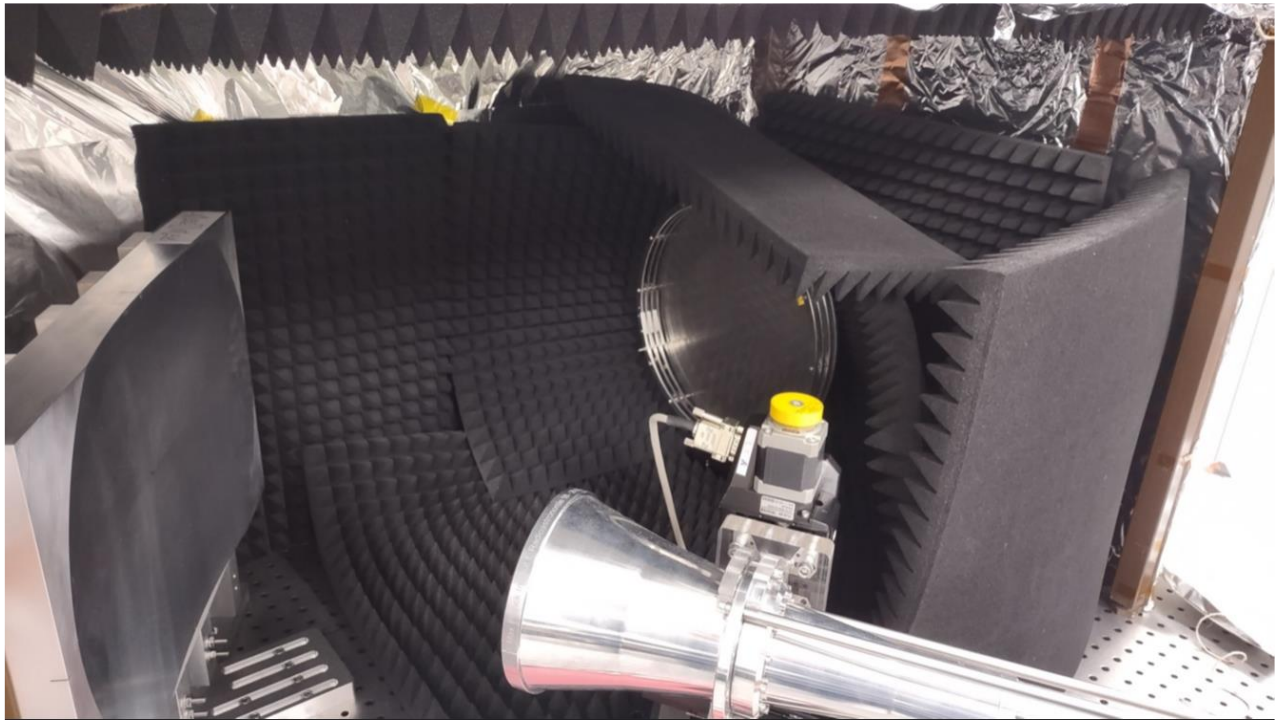
OB300

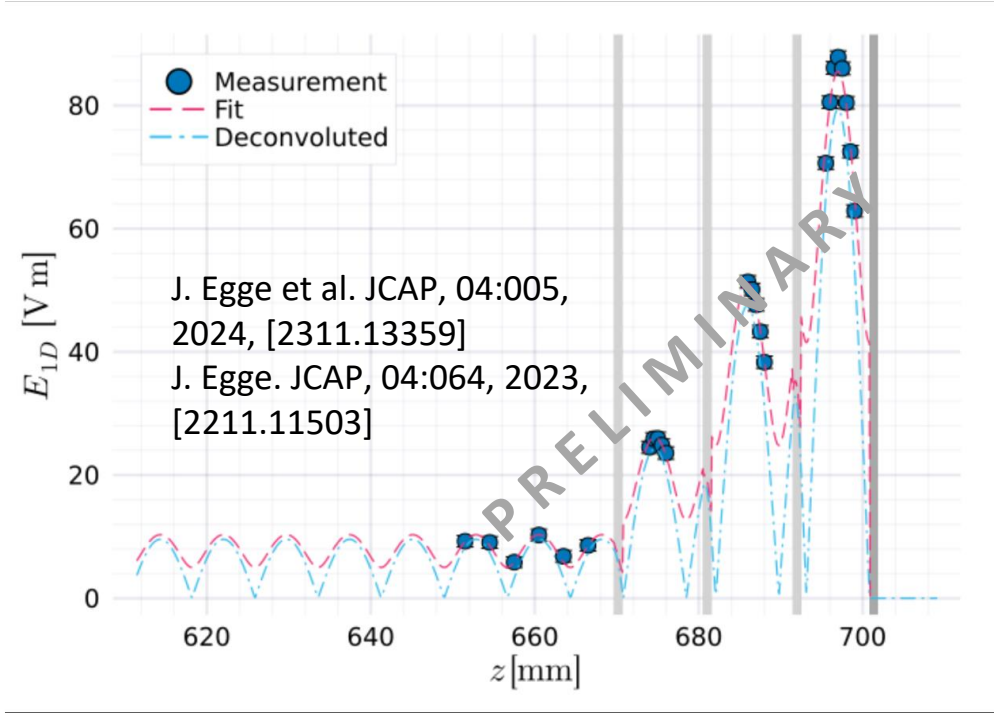


Initially 3 discs (2025)
Up to 20 discs possible

MADMAX open booster measurement

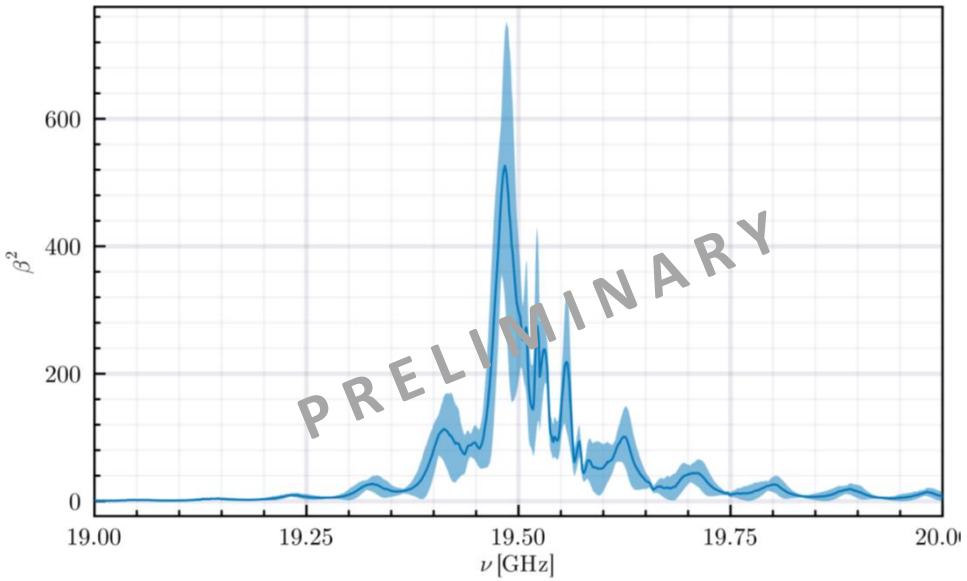
3 disc „static“ open booster system

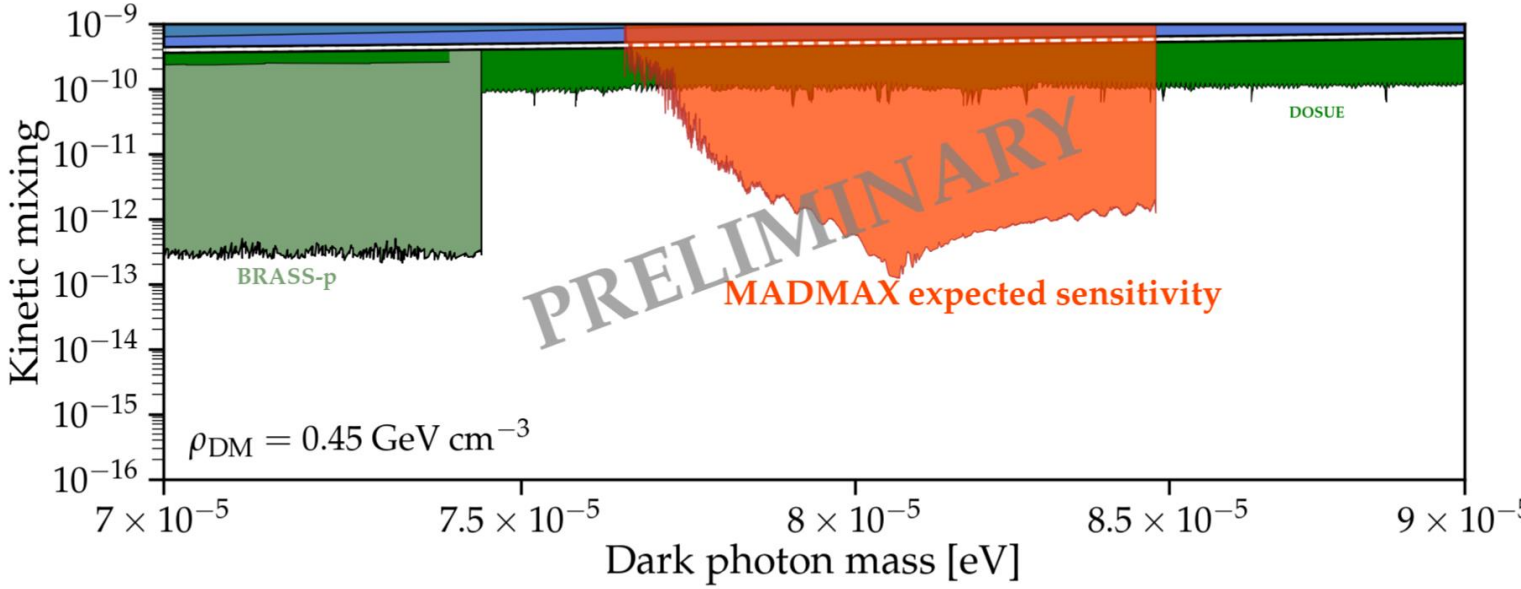




Determination of boost factor by bead pull
adaptation of BREAD DAQ for MADMAX
~ 10 days data taking inside SHELL laboratory

MADMAX open booster measurement



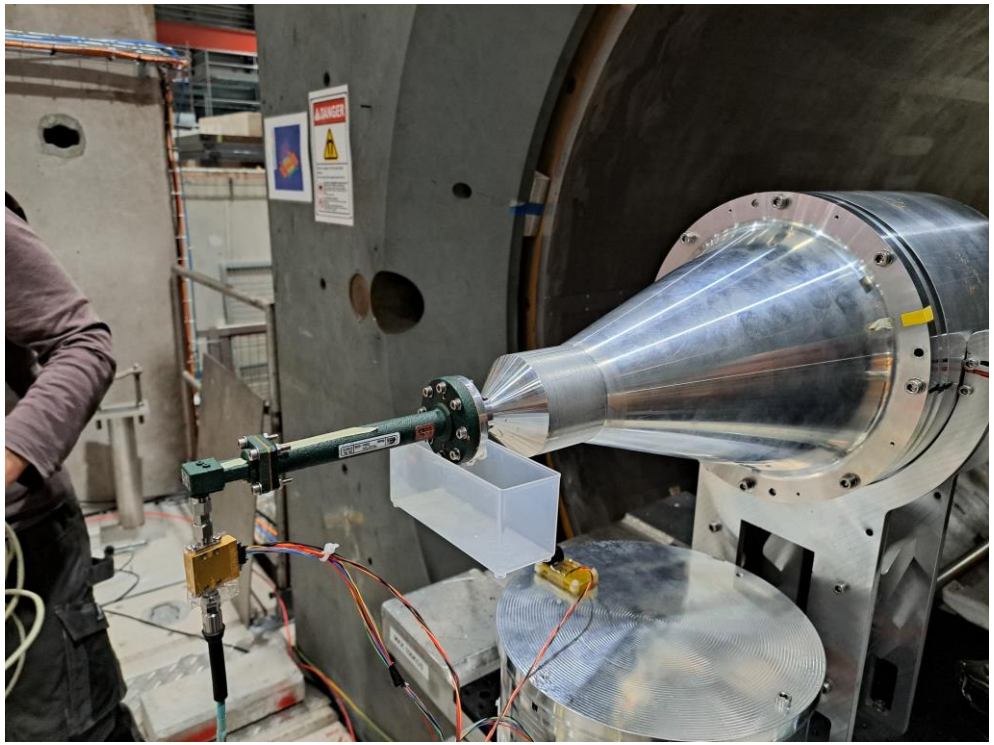


Determination of boost factor by bead pull

→ Competitive hidden photon limits

2024 measurements at CERN

CB200 at CERN at 1.0 – 1.6 T



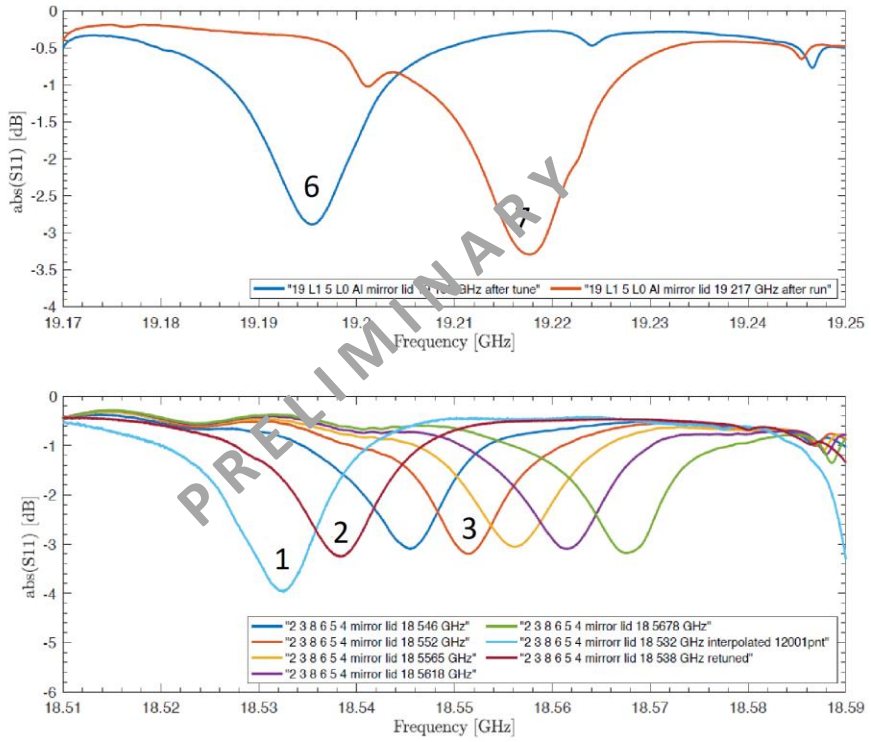
At room temperature
Different frequencies

CB100 inside MORPURGO at 1.6 T

Inside cryostat at < 10K
→ Cold calibration!

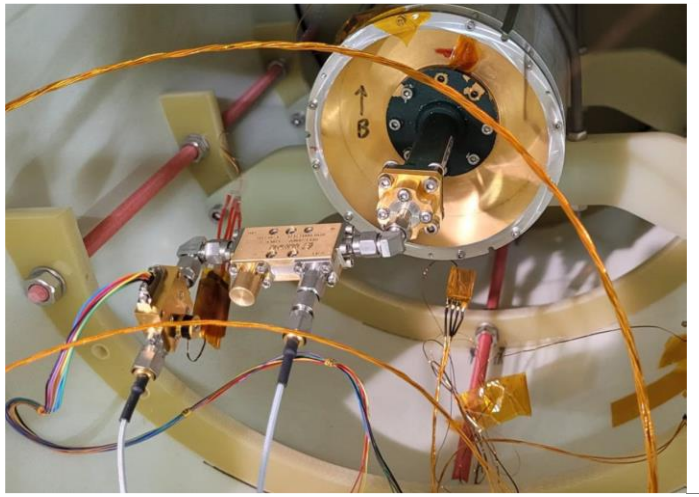
2024 measurements at CERN

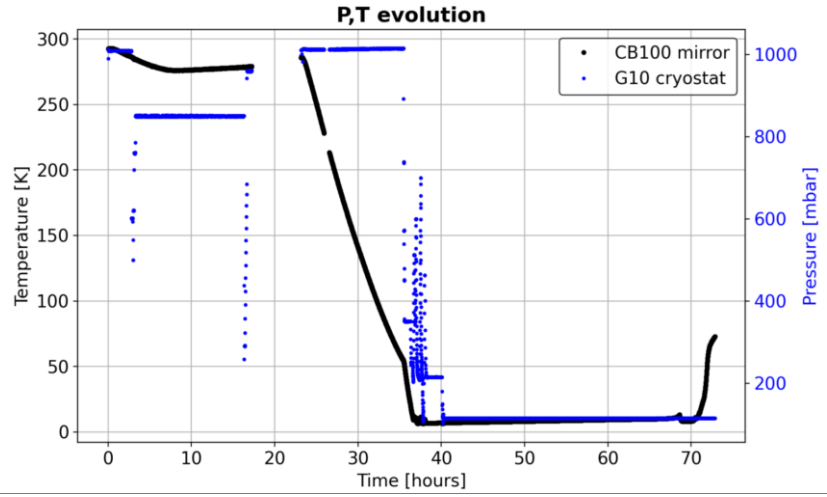
CB200 at CERN



Room temperature,
Different frequencies

CB100 inside MORPURGO





Data analysis ongoing.
Expect DM ALP limits at 7 10 MHz frequency intervals at $3\text{-}6*10^{-11}\text{GeV}^{-1}$

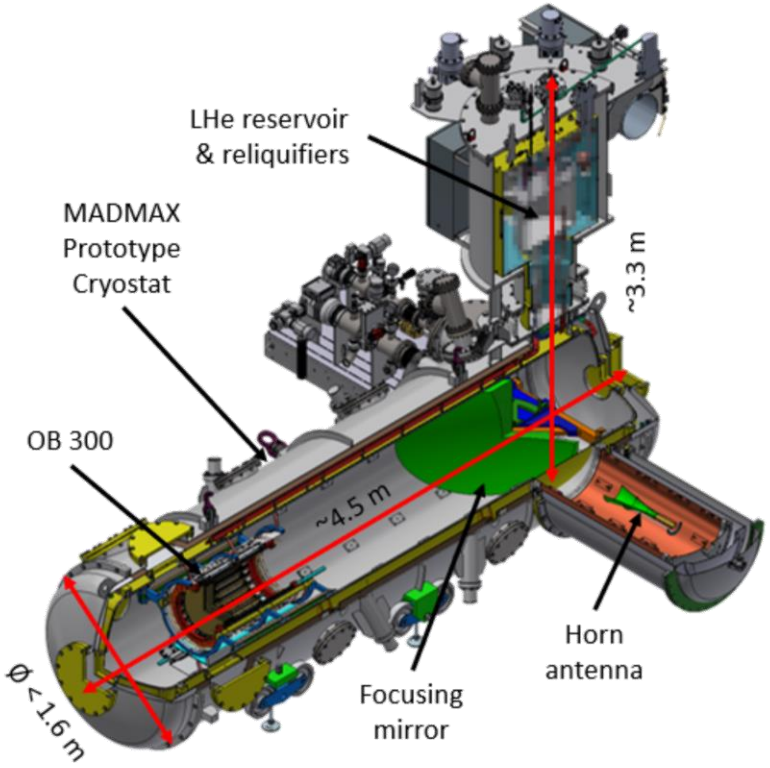
in cryostat at < 10K
→ Cold calibration!

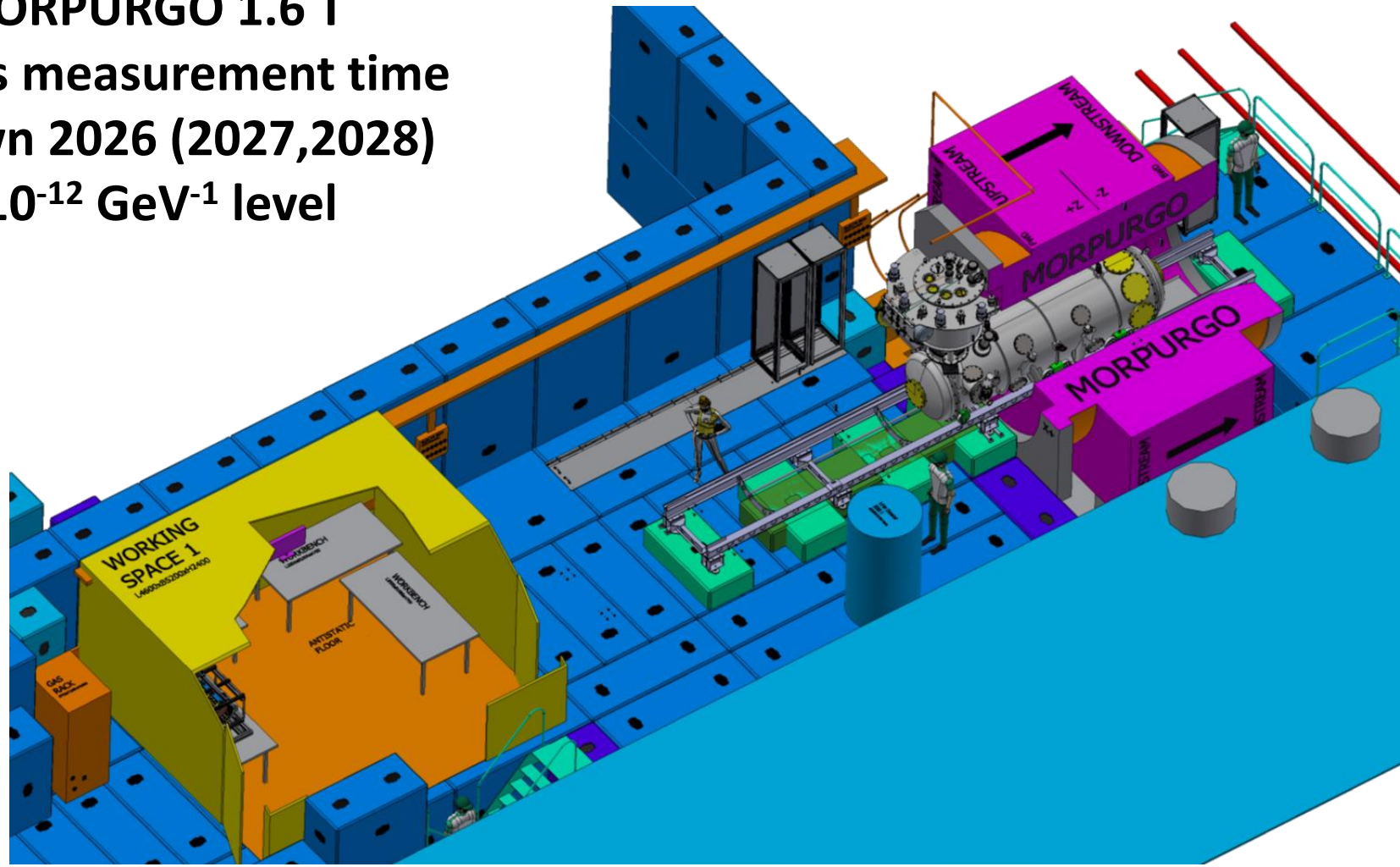
MADMAX future plans at CERN with OB300

OB300 in MPC in MORPURGO 1.6 T

→ Applying for 9 months measurement time during long shut-down 2026 (2027,2028)

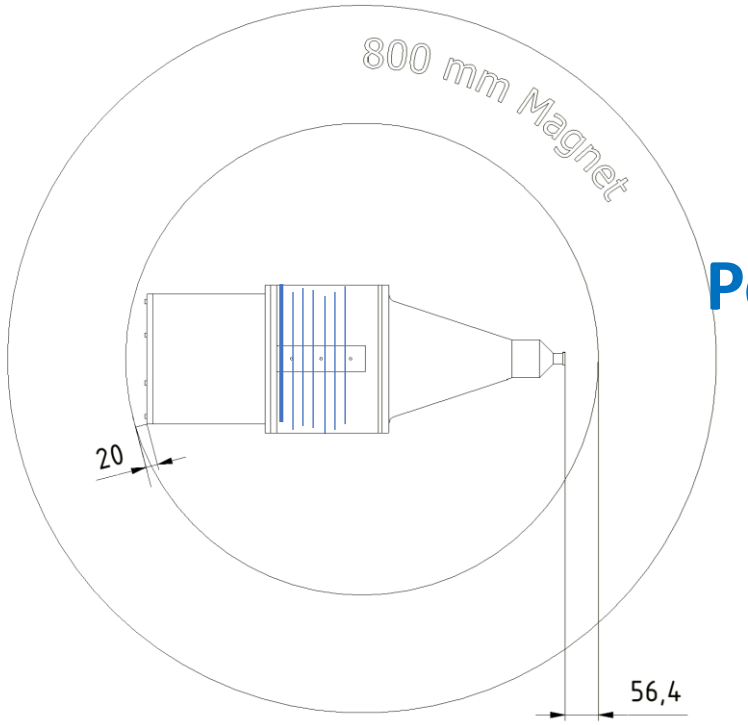
→ Scan 1.5 GHz at 10^{-12} GeV^{-1} level





MAD MAX @ Fermilab

How to use MRI magnet: existing prototypes: CB100 – CB200



CB200 easily fits 80cm bore at room temperature

Increase #discs

Power boost factor ~10.000

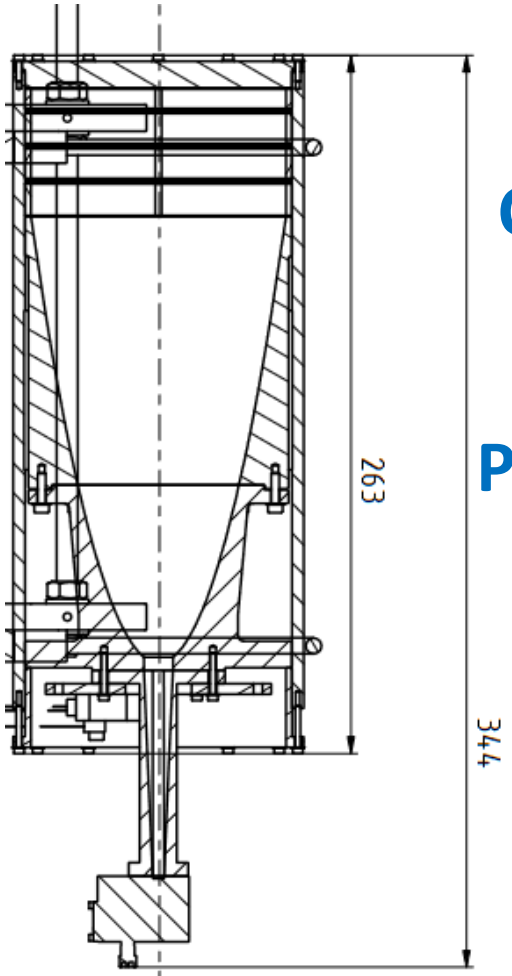
Sensitivity around: 10^{-12} GeV^{-1}

Some tuning possible

Remember: B-field parallel to discs!

MADMAX @ Fermilab

How to use MRI magnet: existing prototypes: CB100 – CB200



CB100 should fit cryostat

Increase #discs

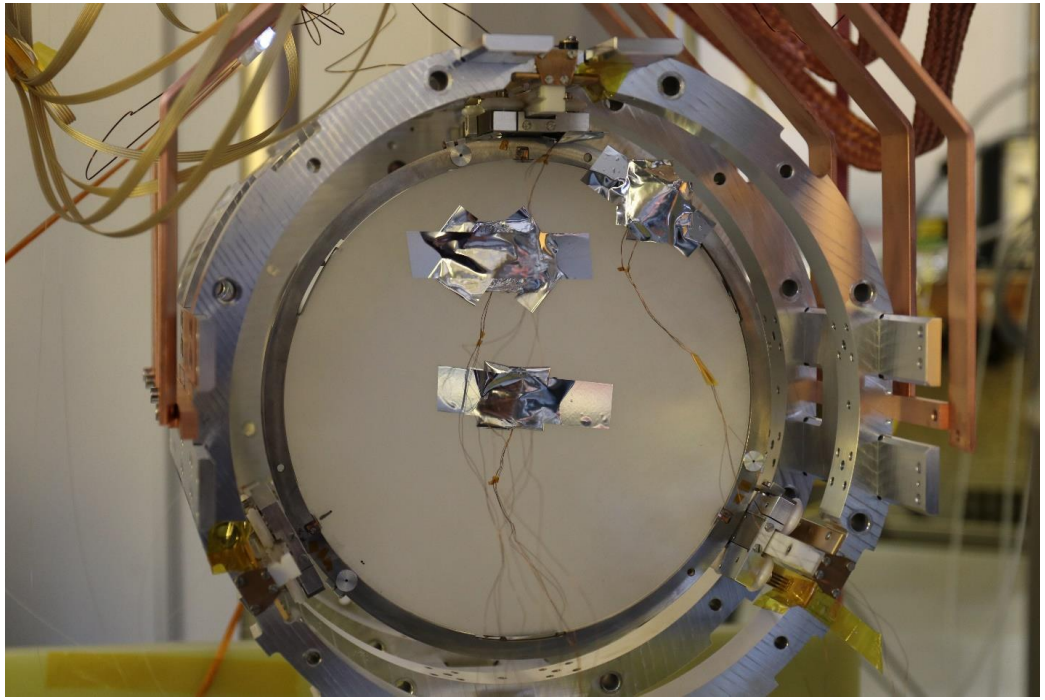
Power boost factor ~5.000

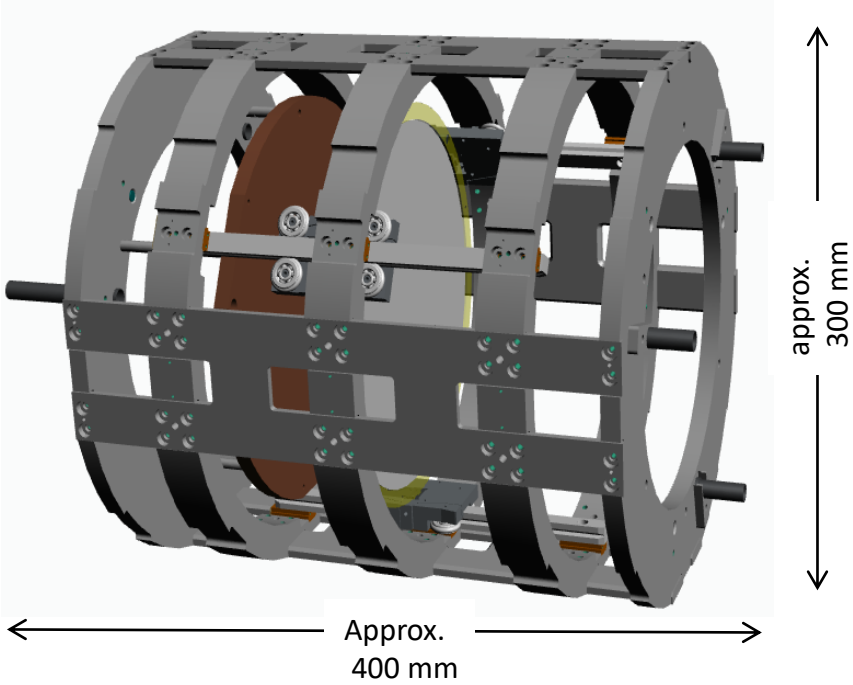
Sensitivity around:
10^{-12} GeV^{-1} after 1 week

MAD MAX @ Fermilab

How to use MRI magnet: existing prototypes: CB100 – CB200

Potentially test baseline design technology at nominal B-field & temperature





CONCLUSIONS:

Lots of MADMAX progress:

- **Magnet R&D ongoing**
- **Boost factor determination via measurement & simulation**
- **Performed ALPs measurement at CERN**
- **Tunable open booster in cryostat to come**
- **9.4 T MRI magnet at FNAL is opportunity for MADMAX**