

US Participation in MADMAX

Stefan Knirck

Fermi National Accelerator Laboratory

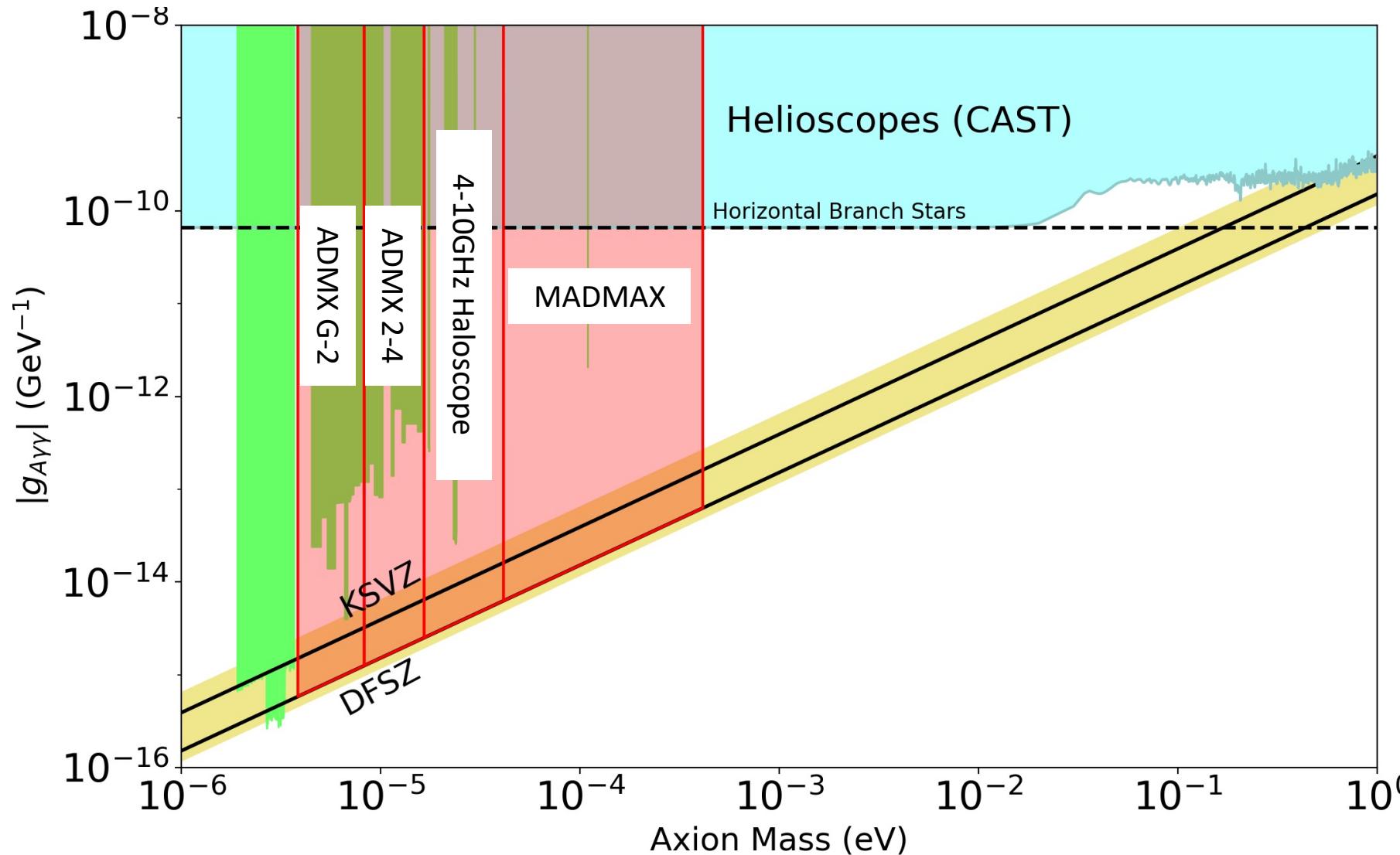


for the ADMX and MADMAX collaborations

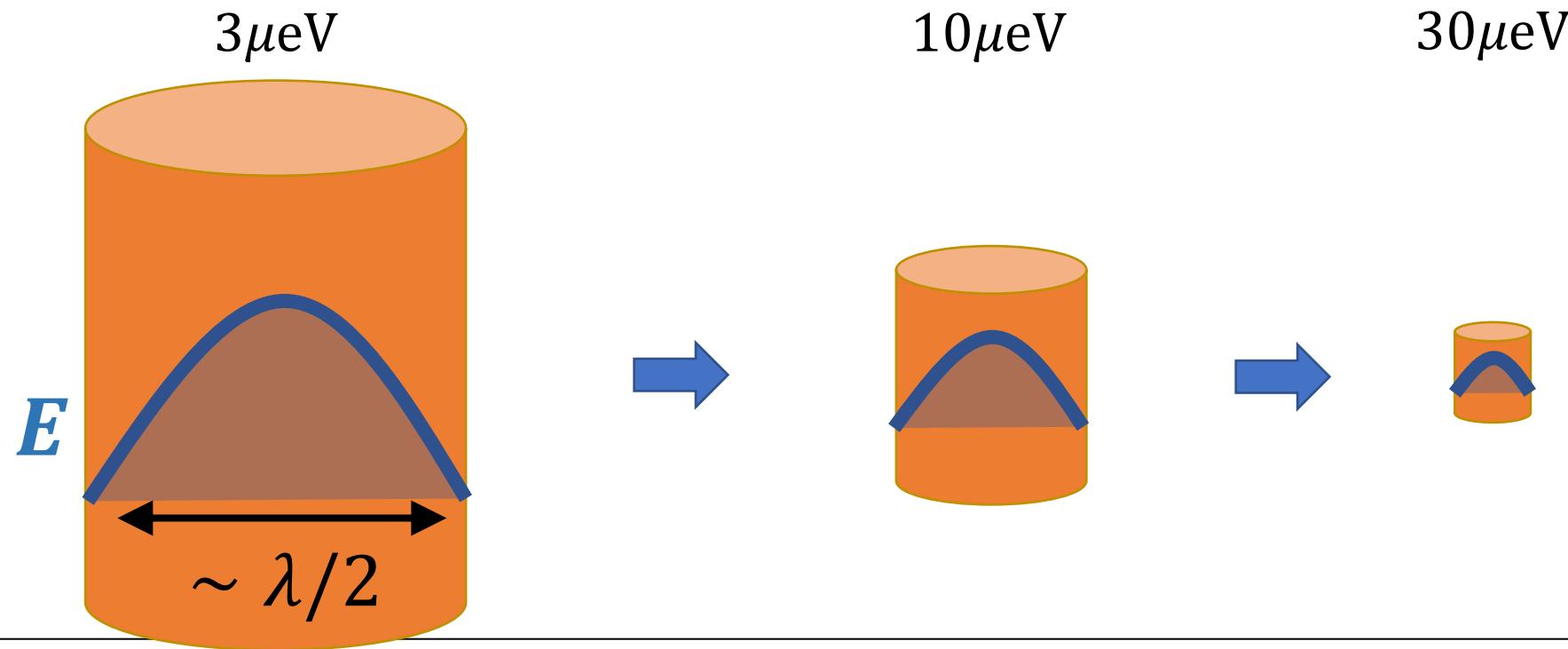


[LOI: https://www.snowmass21.org/docs/files/summaries/CF/SNOWMASS21-CF2_CF0_Gray_Rybka-160.pdf]

Motivation



The Resonant Cavity – High Masses

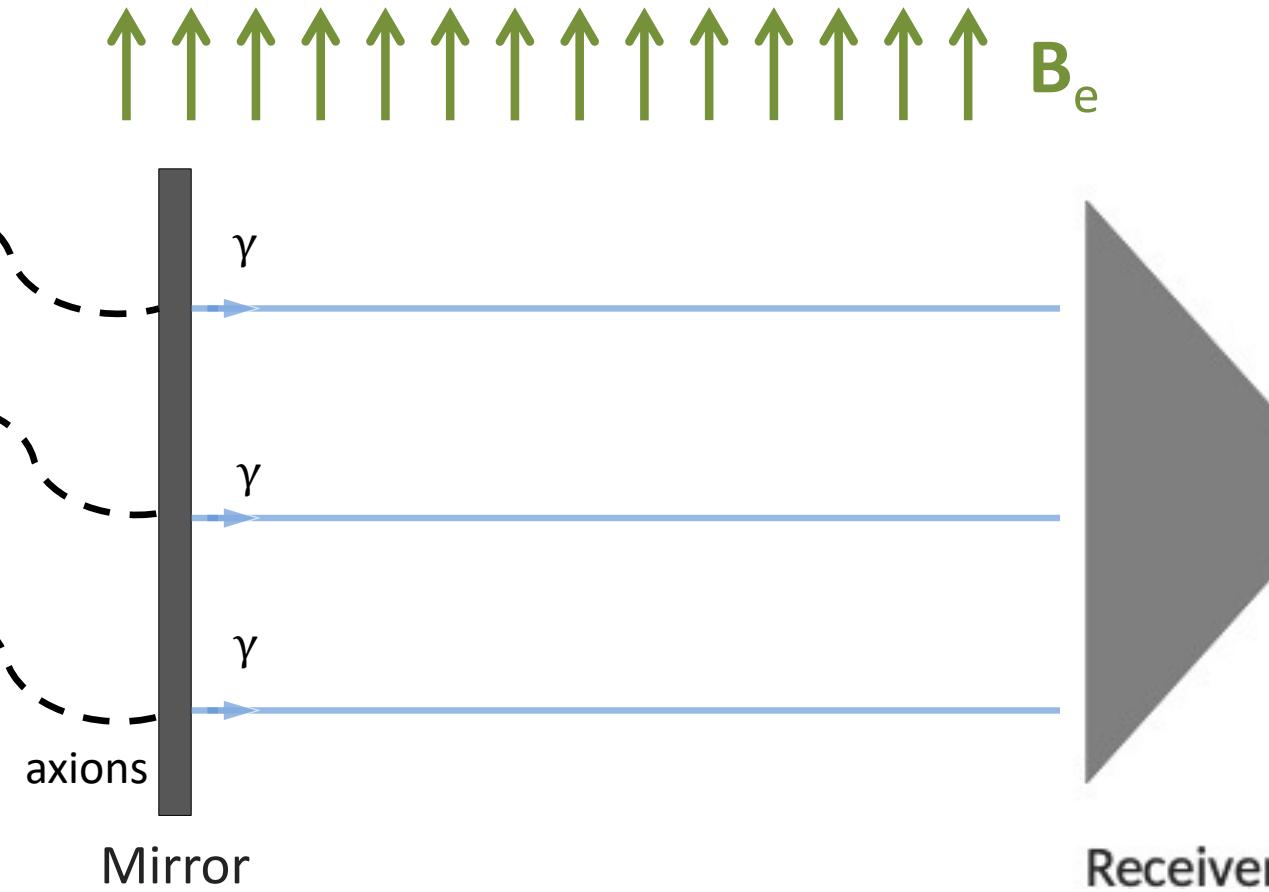


V	$100L$	$3L$	$0.1L$
$Q \propto V/\delta V$	30,000	10,000	3,000

$$P_{\text{sig}} = 2 \cdot 10^{-23} \text{ W} \cdot \left(\frac{B}{7.6 \text{ T}} \right)^2 \left(\frac{V}{136 L} \right) \left(\frac{C}{0.4} \right) \left(\frac{Q}{30,000} \right) \left(\frac{g_\gamma}{0.36} \right)^2 \left(\frac{m_a}{3 \mu\text{eV}} \right) \left(\frac{\rho_{\text{DM}}}{0.45 \text{ GeV cm}^{-3}} \right)$$

Dish Antenna

[Horns *et al.*,
JCAP 04 (2013) 016]



$$P/A = 2.2 \cdot 10^{-27} \frac{W}{m^2} \left(\frac{B}{10 \text{ T}} \right)^2 |C_{a\gamma}|$$

FUNK
[A. Andrianavalomahefana *et al.*,
PRD 102 (2020)]

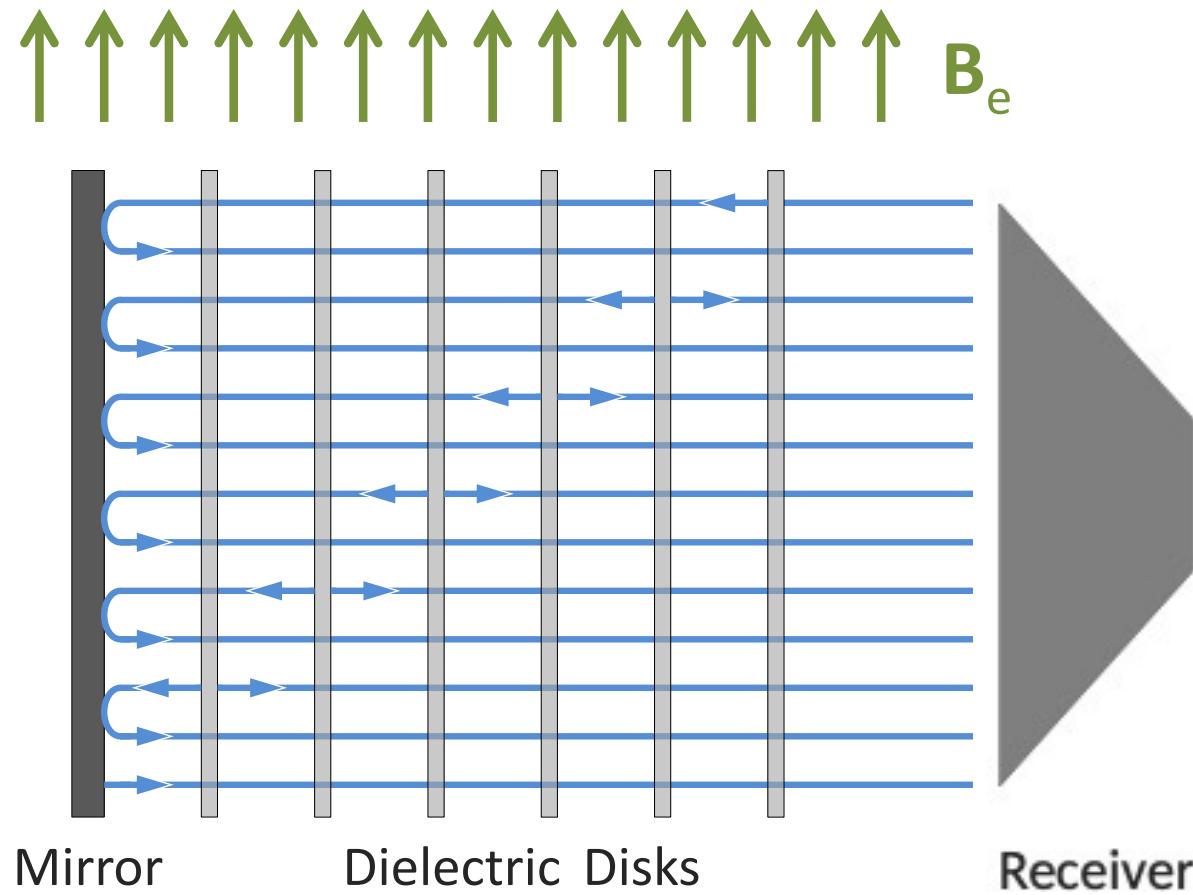
Tokyo
e.g., [J. Suzuki *et al.*,
JCAP 09 (2015) 042]

SHUKET
[P. Brun *et al.*,
PRL 122 (2019) 20]

BRASS
[<http://wwwiexp.desy.de/groups/astroparticle/brass/brassweb.htm>]

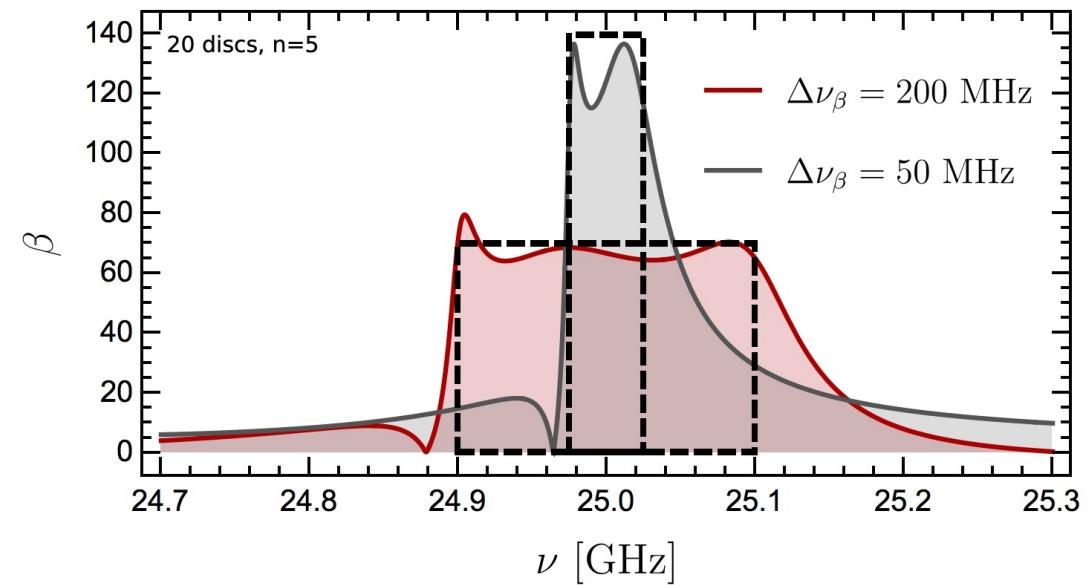
BREAD
[talk at PATRAS2021]
[next talk]

The MADMAX Idea



[A. Caldwell *et al.*, PRL 118, 091801 (2017)]
 [A. J. Millar *et al.*, JCAP, 061 (2017)]

Power \propto Boost Factor β^2
 tunable via disk positions



$$P/A = 2.2 \cdot 10^{-27} \frac{W}{m^2} \left(\frac{B}{10 T} \right)^2 |C_{a\gamma}| \times \beta^2$$

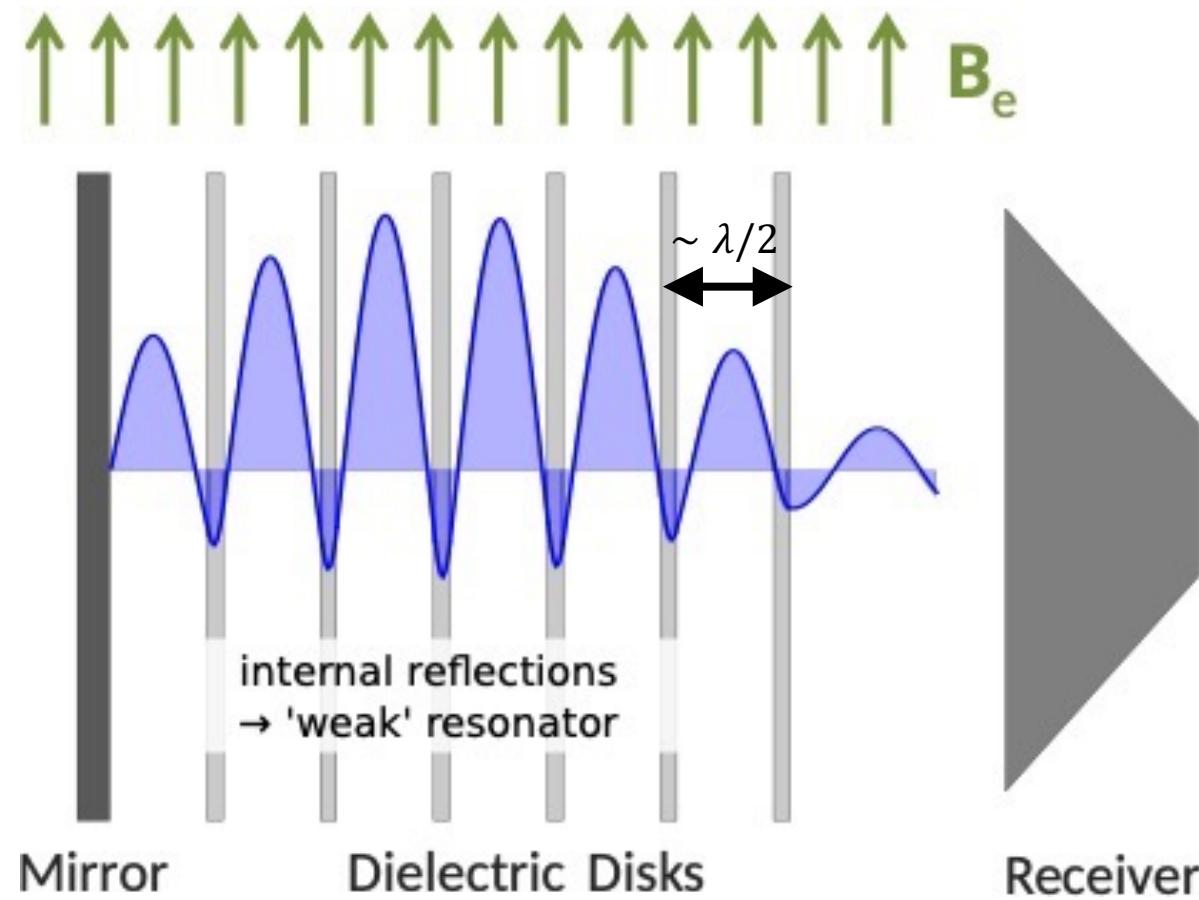
ORPHEUS (15-18GHz)
 [Cervantes *et al.*, Springer Proc.Phys.
 245 (2020) 169-175]

MADMAX (10-100GHz)
 [P. Brun *et al.*,
 Eur. Phys. J. C (2019) 79: 186]

DALI (6-60GHz)
 [J. De Miguel,
 JCAP 04(2021)075]

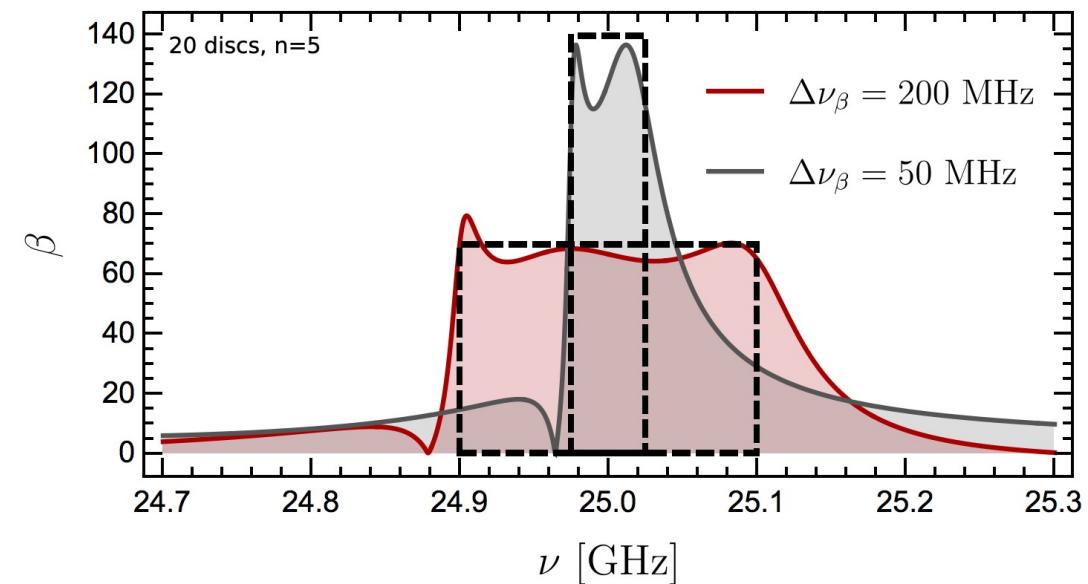
LAMPOST (optical)
 [J. Chiles *et al.*,
 arXiv:2110.01582]

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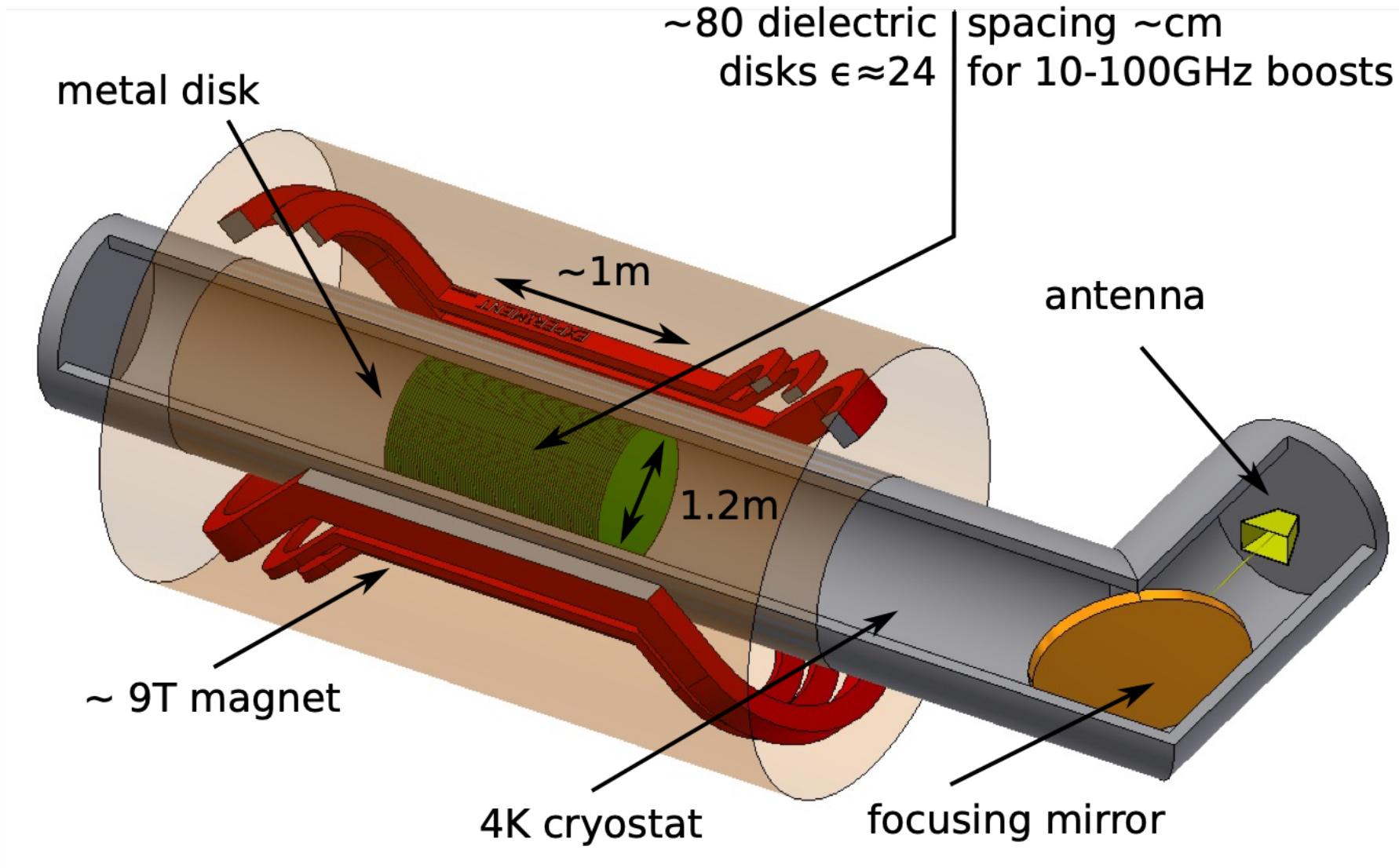
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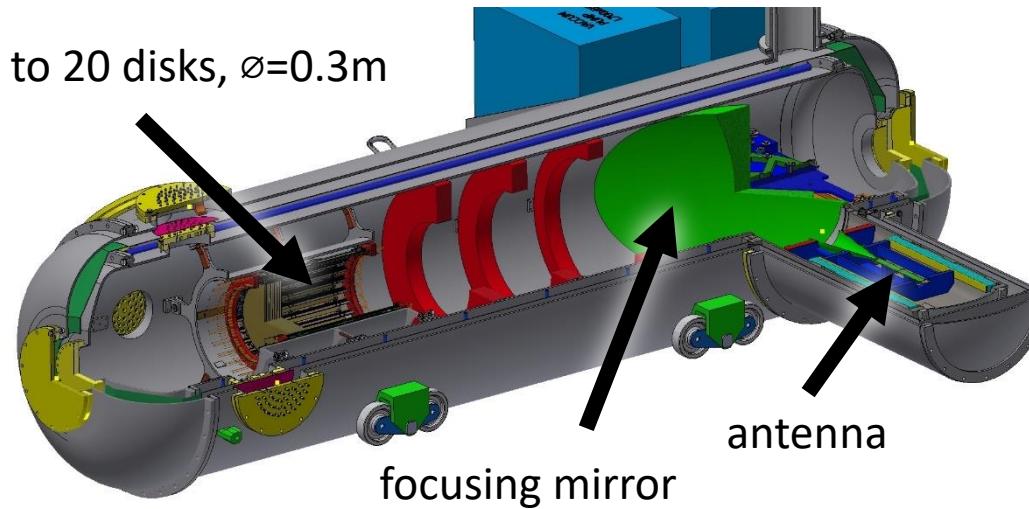
Full-Scale MADMAX Setup



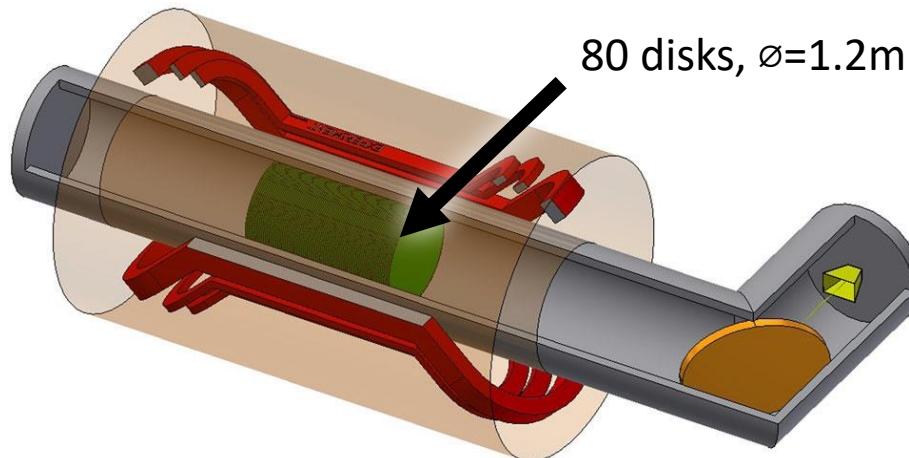
Timeline & Sensitivity

2024: Prototype @ CERN MORPURGO (1.6T)

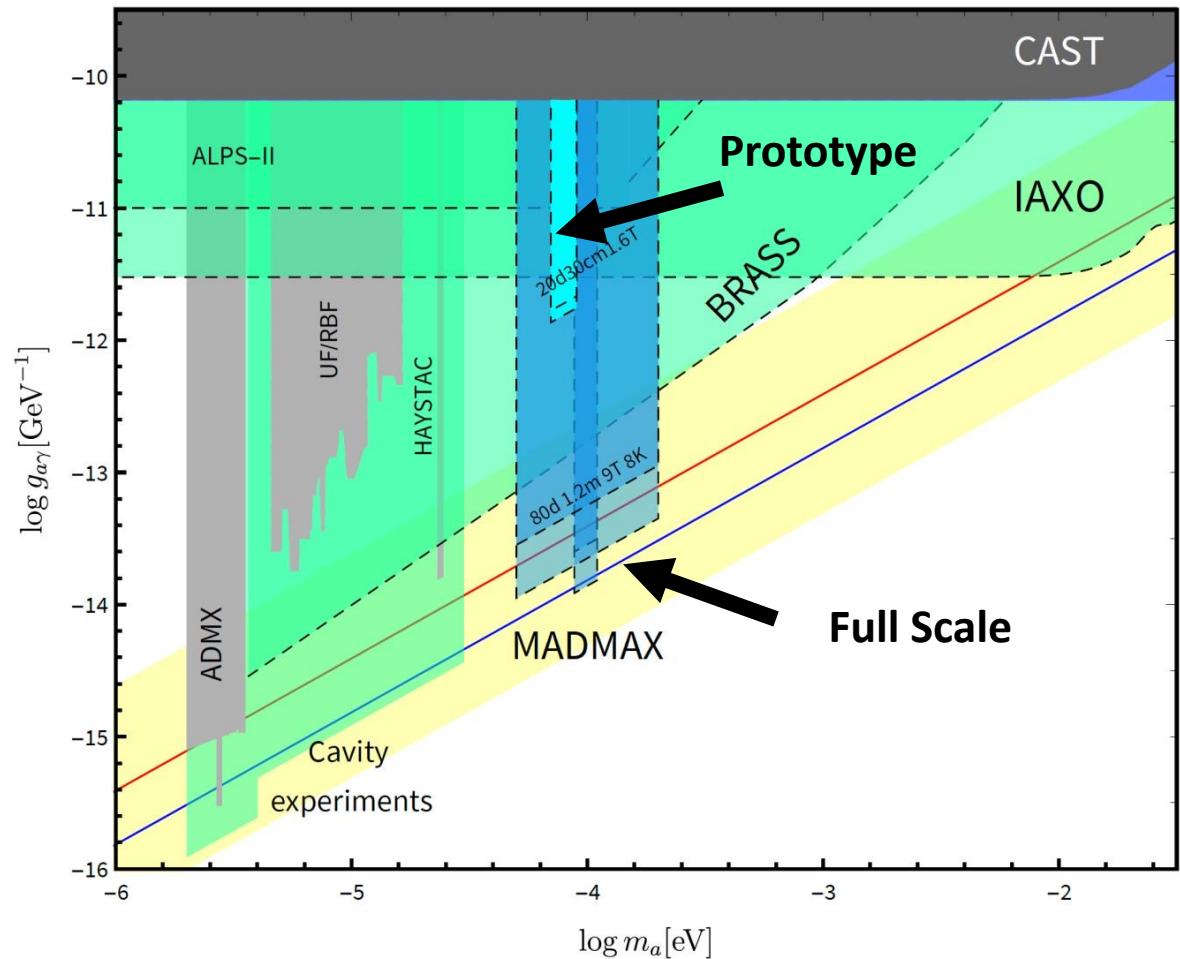
up to 20 disks, $\varnothing=0.3\text{m}$



≥ 2028 : Full Scale @DESY, custom 9T magnet



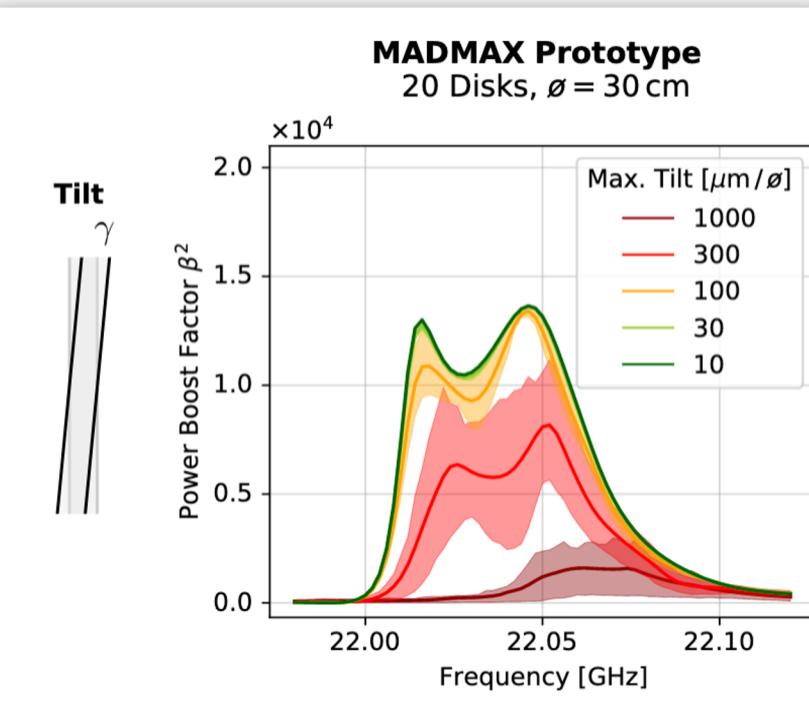
Projected Sensitivities



[S. Beurthey *et al.*, arXiv:2003.10894]

Booster R&D (Examples)

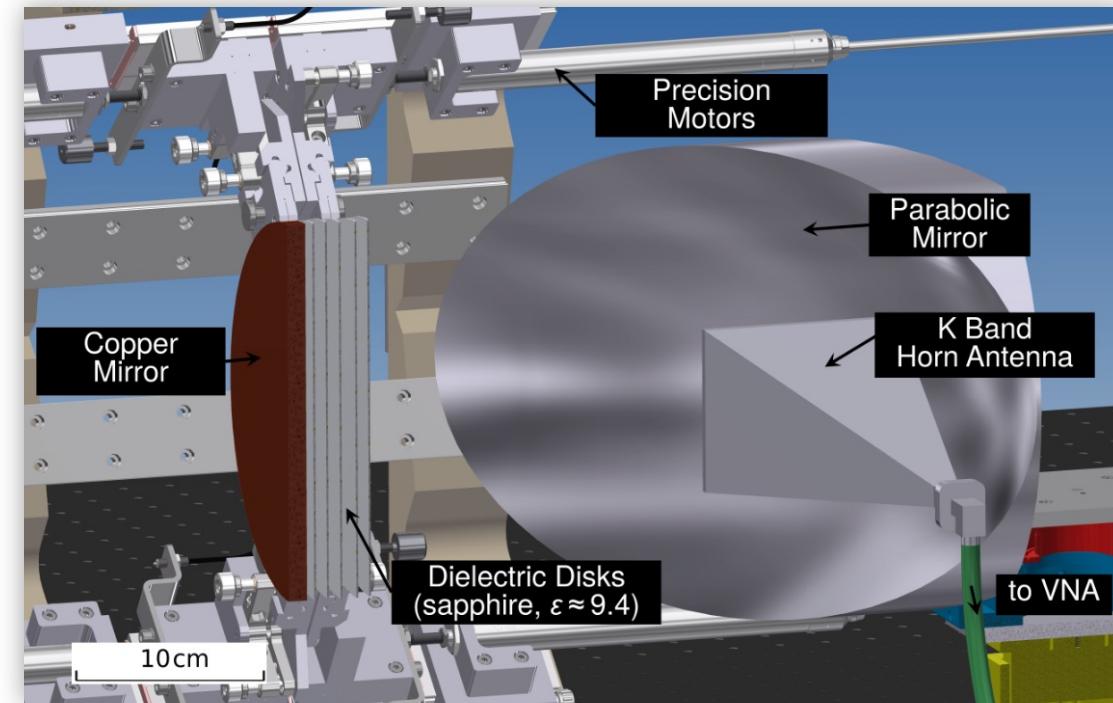
Simulation



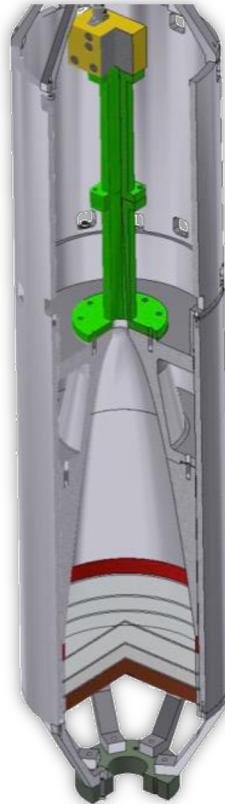
RF understanding
requirements

[SK *et al.* (MADMAX collab.), JCAP (2021, accepted)]
[SK *et al.*, JCAP 08 (2019) 026]

Open Booster Setup



Closed Booster Setup



5 disks, $\varnothing=20\text{cm}$
room temp.

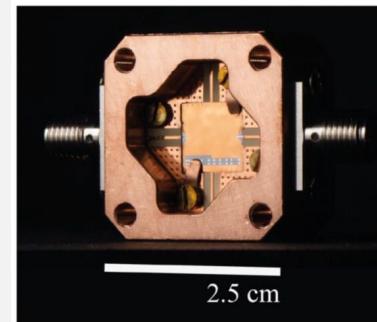
demonstrate
basic tuning

Synergies with ADMX

Electronics / Detection Methods



Current MADMAX baseline:
HEMT amp. $T_{\text{sys}} = (5-6)\text{K}$

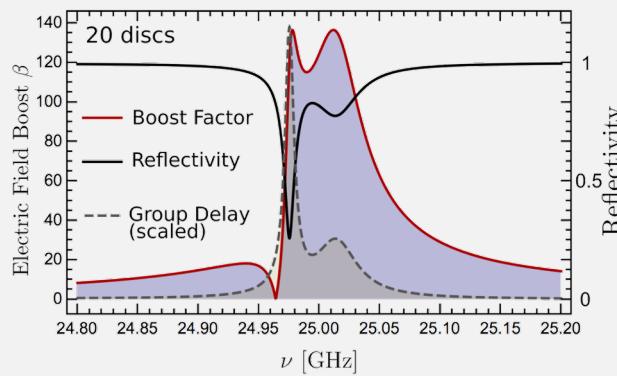


10GHz TWPA from NEEL, i.a. for MADMAX
[Ranadive *et al.*, arXiv:2101.05815]

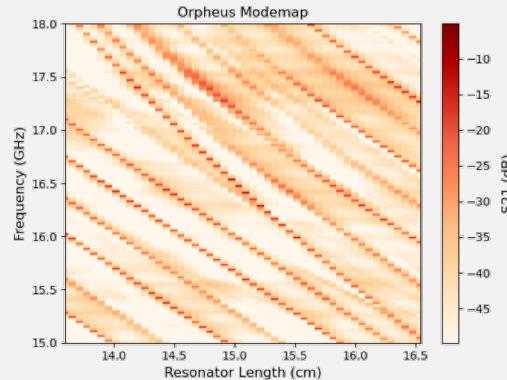


ADMX-Sidecar already uses TWPA
[C. Bartram *et al.* (ADMX collab.), in prep.]

RF Behavior, Calibration



MADMAX Reflectivity-Boost Factor Correlation



ADMX-ORPHEUS Mode Map [R. Cervantes]

Dielectric Material Characterization



University of Western Australia [M. Tobar]
LLNL [G. Carosi]
Dielectric Material Metrology

Operation & Data Analysis

...

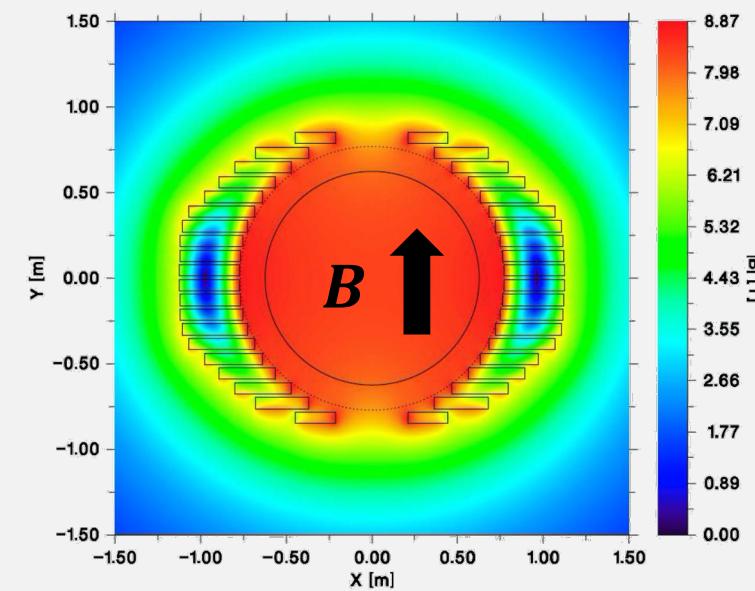
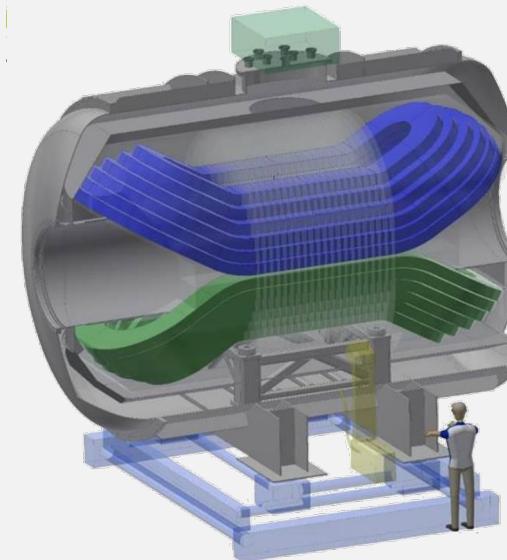
Synergies with ADMX

Magnets & Cryogenics

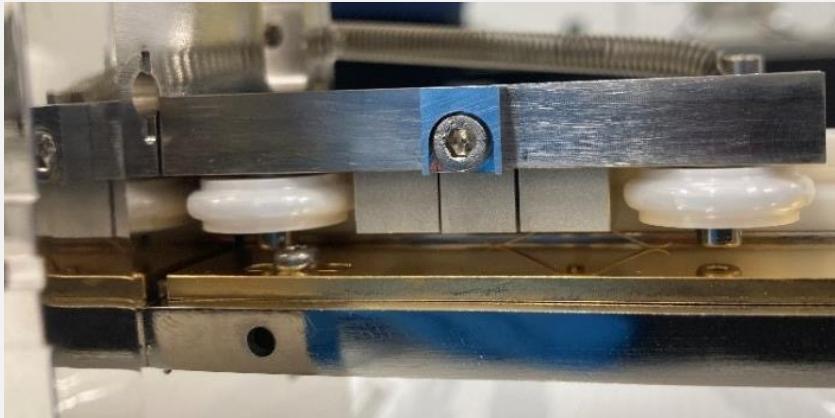
$$B^2 A = 100 \text{ T}^2 \text{m}^2$$



first of a kind dipole magnet!



Piezo Alignment Technology



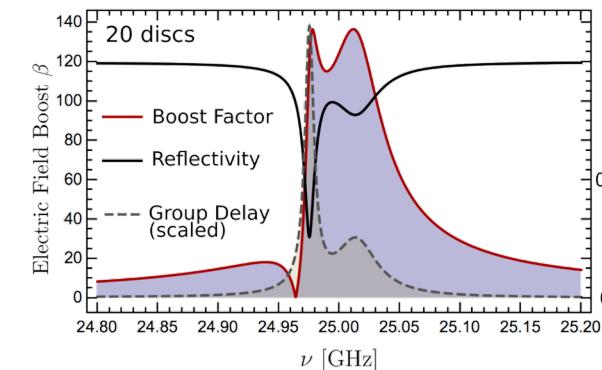
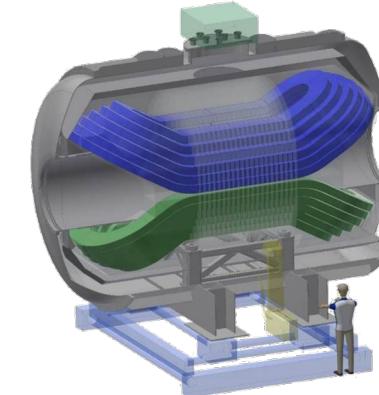
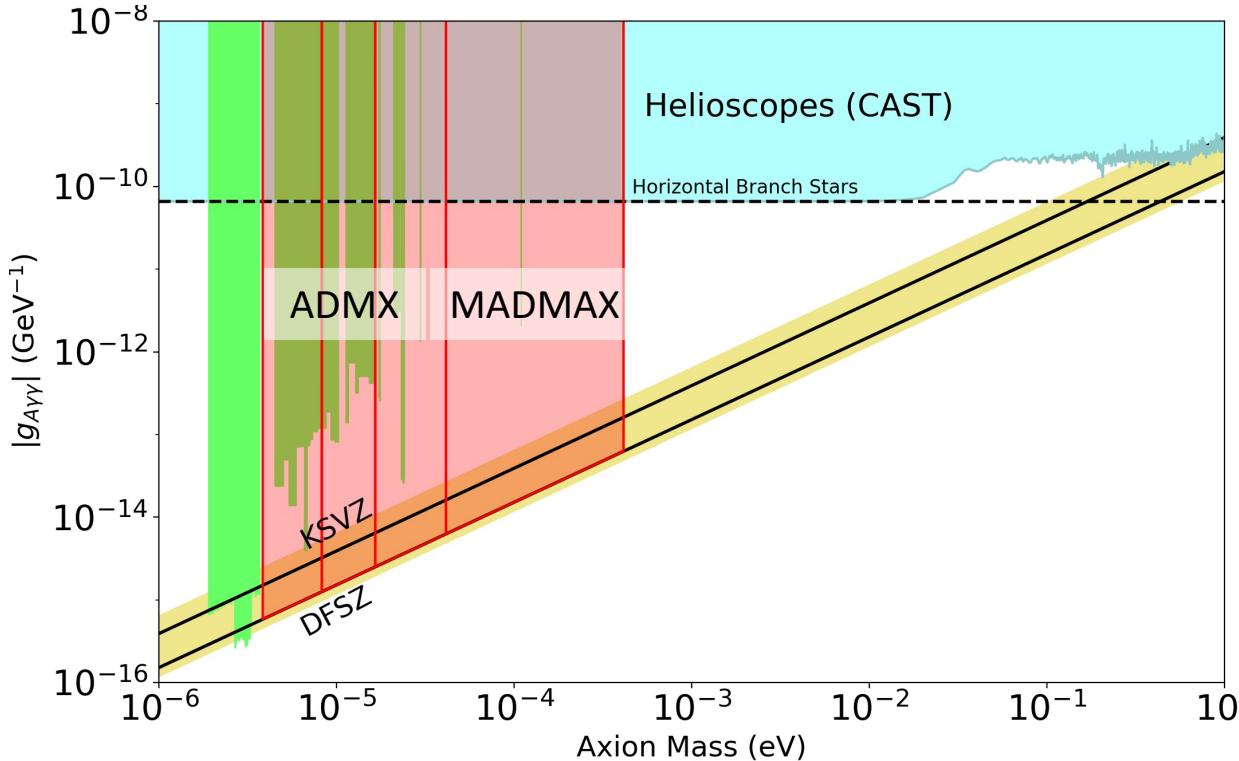
← JPE design for MADMAX

Attocube motors
for ADMX-G2 →



Thank you very much!

Complimentary searches,

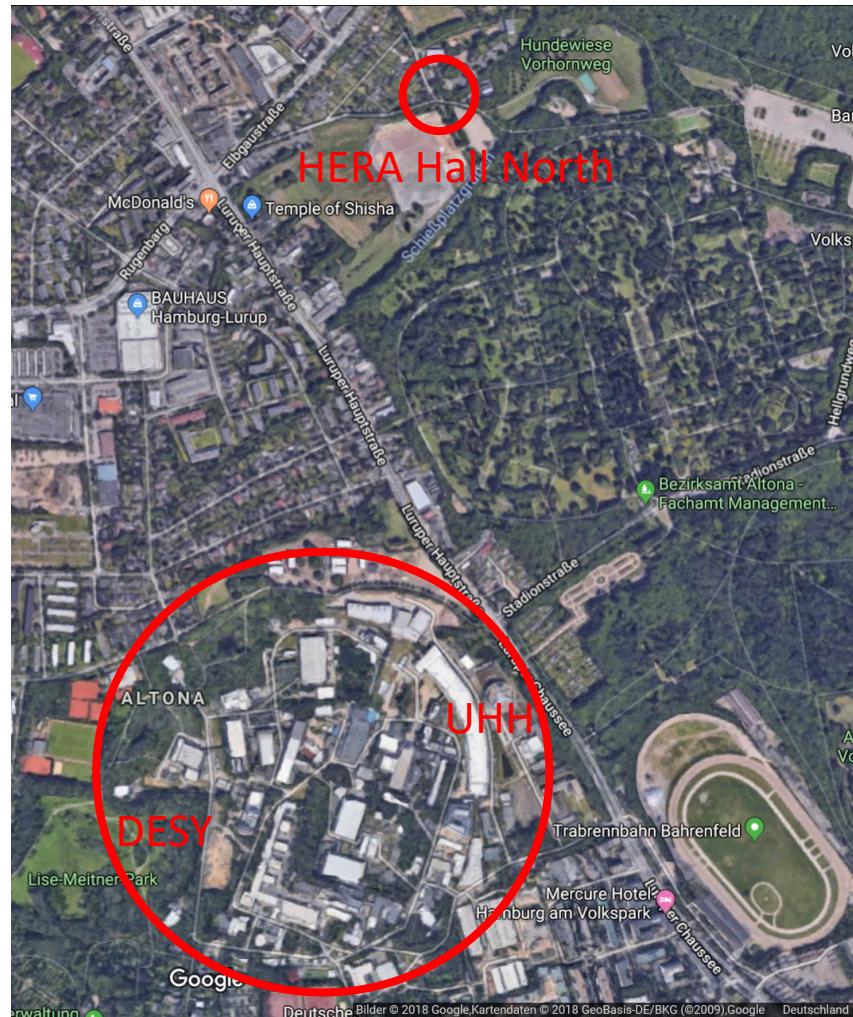


many synergies.

[LOI: https://www.snowmass21.org/docs/files/summaries/CF/SNOWMASS21-CF2_CF0_Gray_Rybka-160.pdf]

Appendix

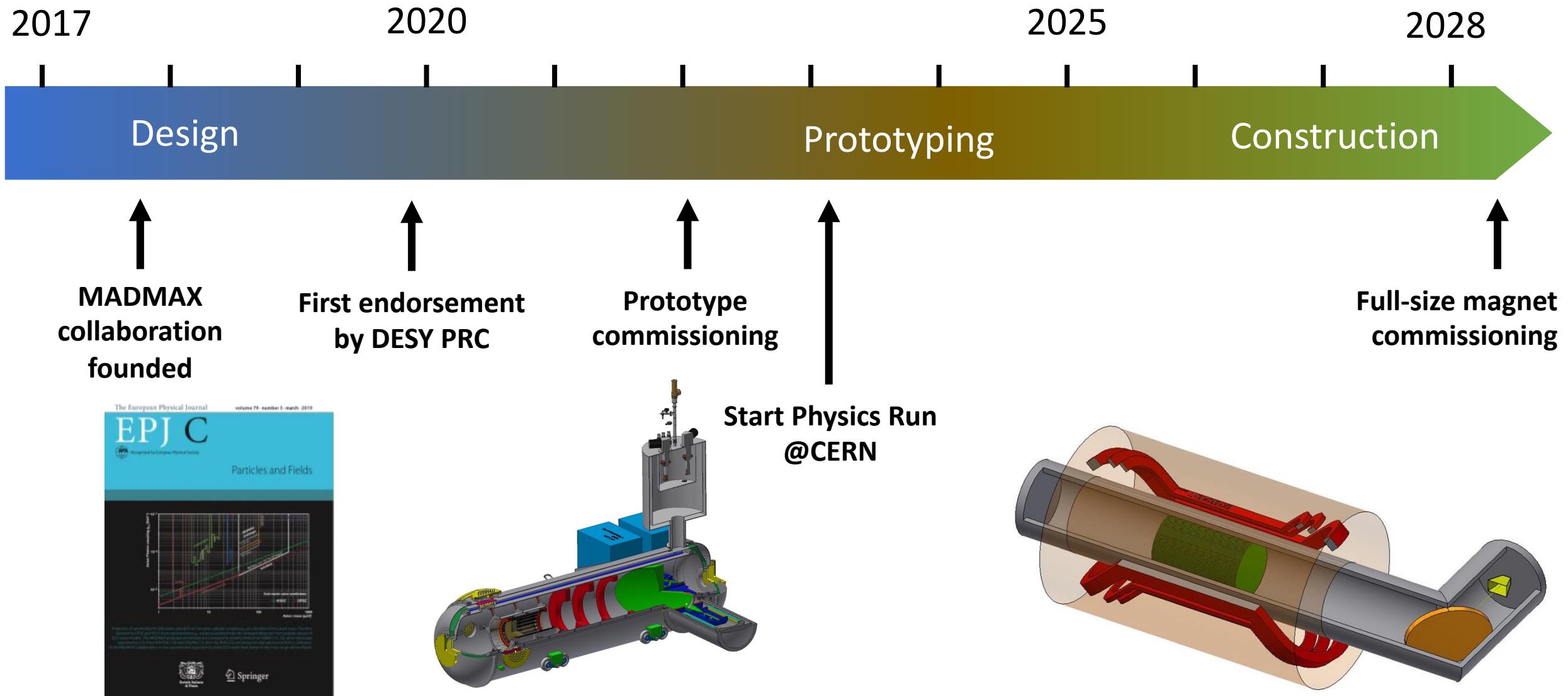
Experimental Site



- MADMAX to be built at Hera Hall North
- Make use of DESY infrastructure
- Benefit: re-use H1 yoke as magnetic shielding to reduce fringe field



Timeline



MADMAX Collaboration



Founded 18.10.2017
@ DESY/UHH



Max-Planck-Institut
für Radioastronomie



Universidad
de Zaragoza



RWTH AACHEN
UNIVERSITY

ADMX Collaboration



Berkeley
UNIVERSITY OF CALIFORNIA



GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN



UF UNIVERSITY of
FLORIDA

Lawrence Livermore
National Laboratory



Pacific
Northwest
NATIONAL LABORATORY



HEISING - SIMONS
FOUNDATION

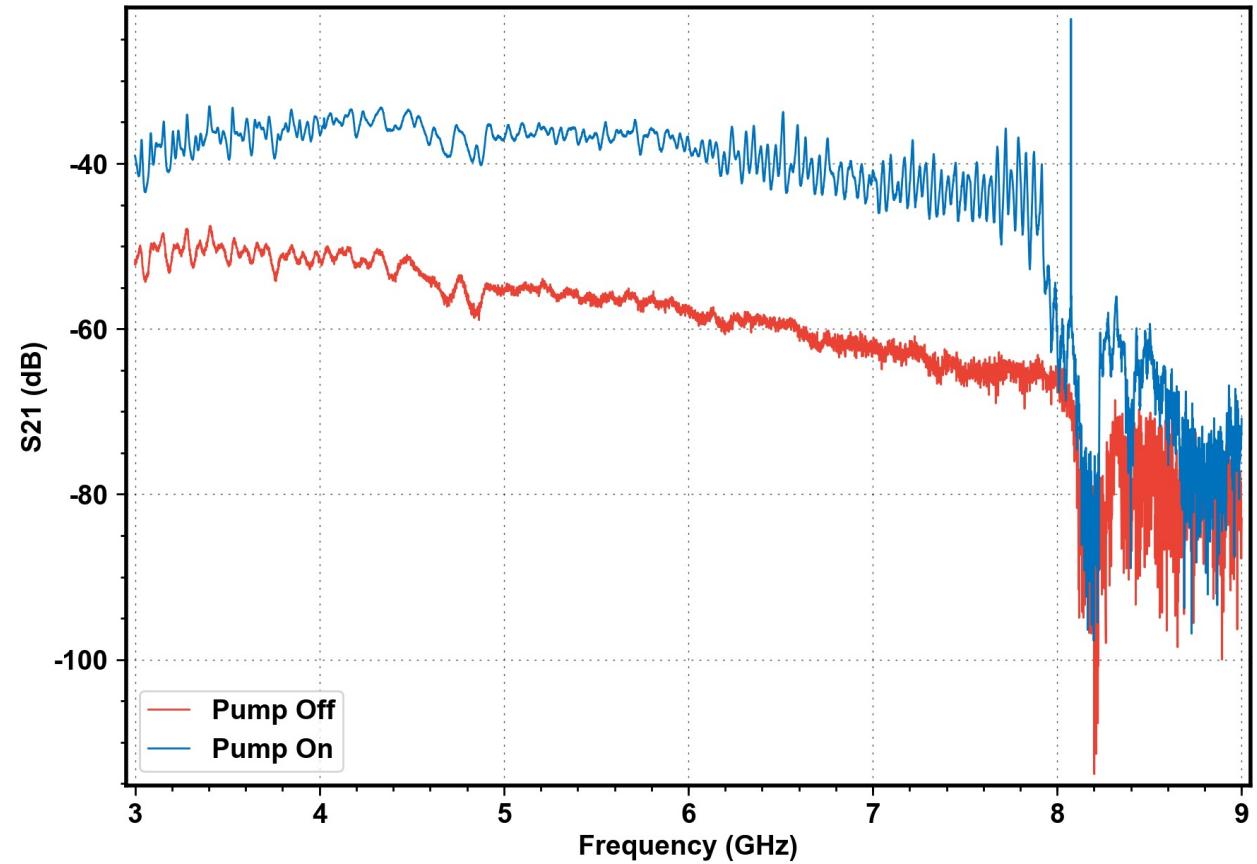
This work was supported by the U.S. Department of Energy through Grants No DE-SC0009800, No. DE-SC0009723, No. DE-SC0010296, No. DE-SC0010280, No. DE-SC0011665, No. DEFG02-97ER41029, No. DE-FG02-96ER40956, No. DEAC52-07NA27344, No. DE-C03-76SF00098 and No. DE-SC0017987. Fermilab is a U.S. Department of Energy, Office of Science, HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359. Additional support was provided by the Heising-Simons Foundation and by the Lawrence Livermore National Laboratory and Pacific Northwest National Laboratory LDRD offices.

Cavity: Testbed for High-Frequency Searches



Cavity: Clamshell Design,
Piezo Tuning, ...

TWPA: Broadband Amplification



Demonstrate TWPA operation in B-field

Solenoid Magnets

$B_0^2 V$ (T ² m ³)	Magnet	Application/ Technology	Location	Field (T)	Bore (m)	Len (m)	Energy (MJ)	Cost (\$M)
12000	ITER CS	Fusion/Sn CICC	Cadarache	13	2.6	13	6400	>500
5300	CMS	Detector/Ti SRC	CERN	3.8	6	13	2660	>458 ¹
650	Tore Supra	Fusion/Ti Mono Ventilated	Cadarache	9	1.8	3	600	
430	Iseult	MRI/Ti SRC	CEA	11.75	1	4	338	
320	ITER CSMC	Fusion/Sn CICC	JAEA	13	1.1	2	640	>50 ²
290	60 T out	HF/HTS CICC	MagLab	42	0.4	1.5	1100	
250	Magnex	MRI/Mono	Minnesota	10.5	0.88	3	286	7.8
190	Magnex	MRI/Mono	Juelich	9.4	0.9	3	190	
70	45 T out	HF/Nb ₃ Sn CICC	MagLab	14	0.7	1	100	14
12	ADMX	Axion/NbTi mono	U Wash	7	0.5	1.1	14	0.4
5	900 MHz	NMR/Sn mono	MagLab	21.1	0.11	0.6	40	15

Compilation by Mark Bird, NHMFL

