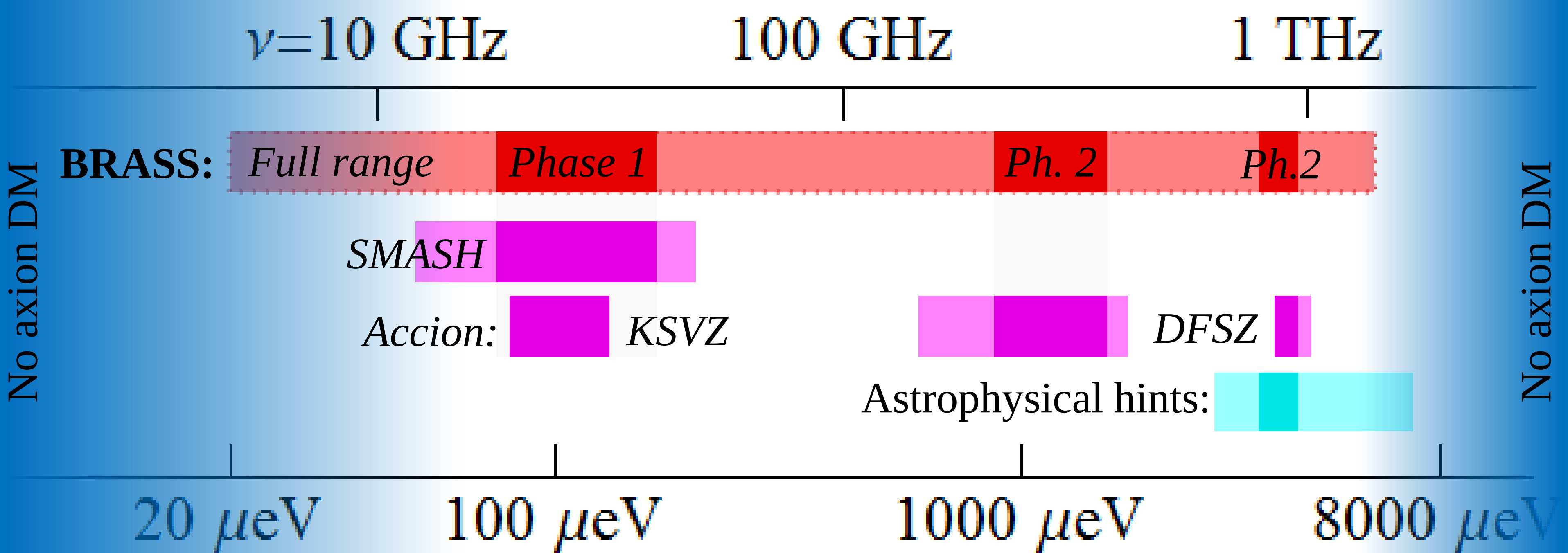
BRASS:
Broadband Radiometric Axion/ALP SearcheS



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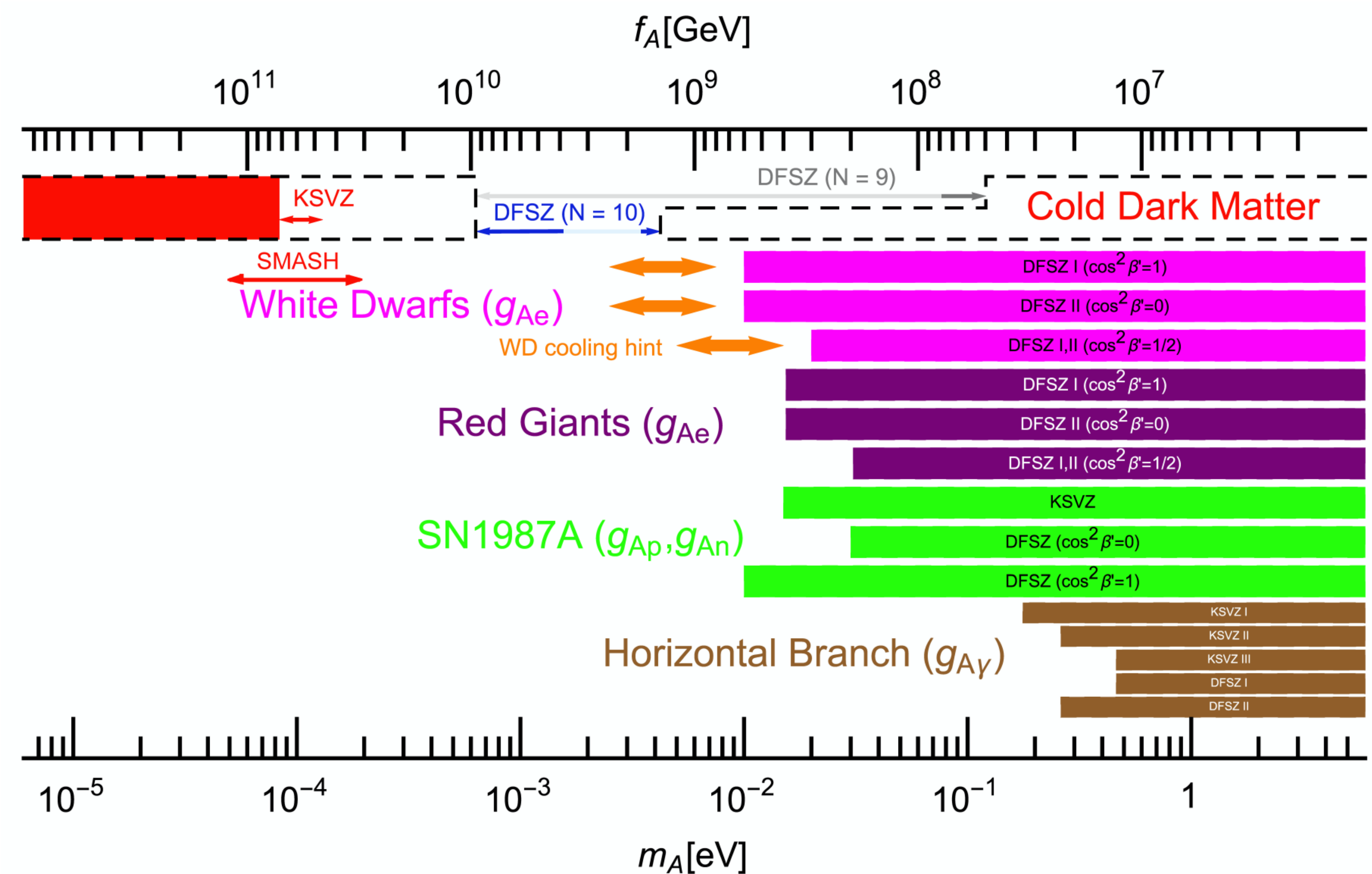
3 – Hamburg University of Technology. 4 – Deutsches Elektronen Synchrotron (DESY).

Axion DM Searches: Motivation

- Axion DM: the 10^{-5}–10^{-1} eV (2.4 GHz – 24 THz) range is best motivated.
- Effective approaches needed to cover this range. BRASS could be one.



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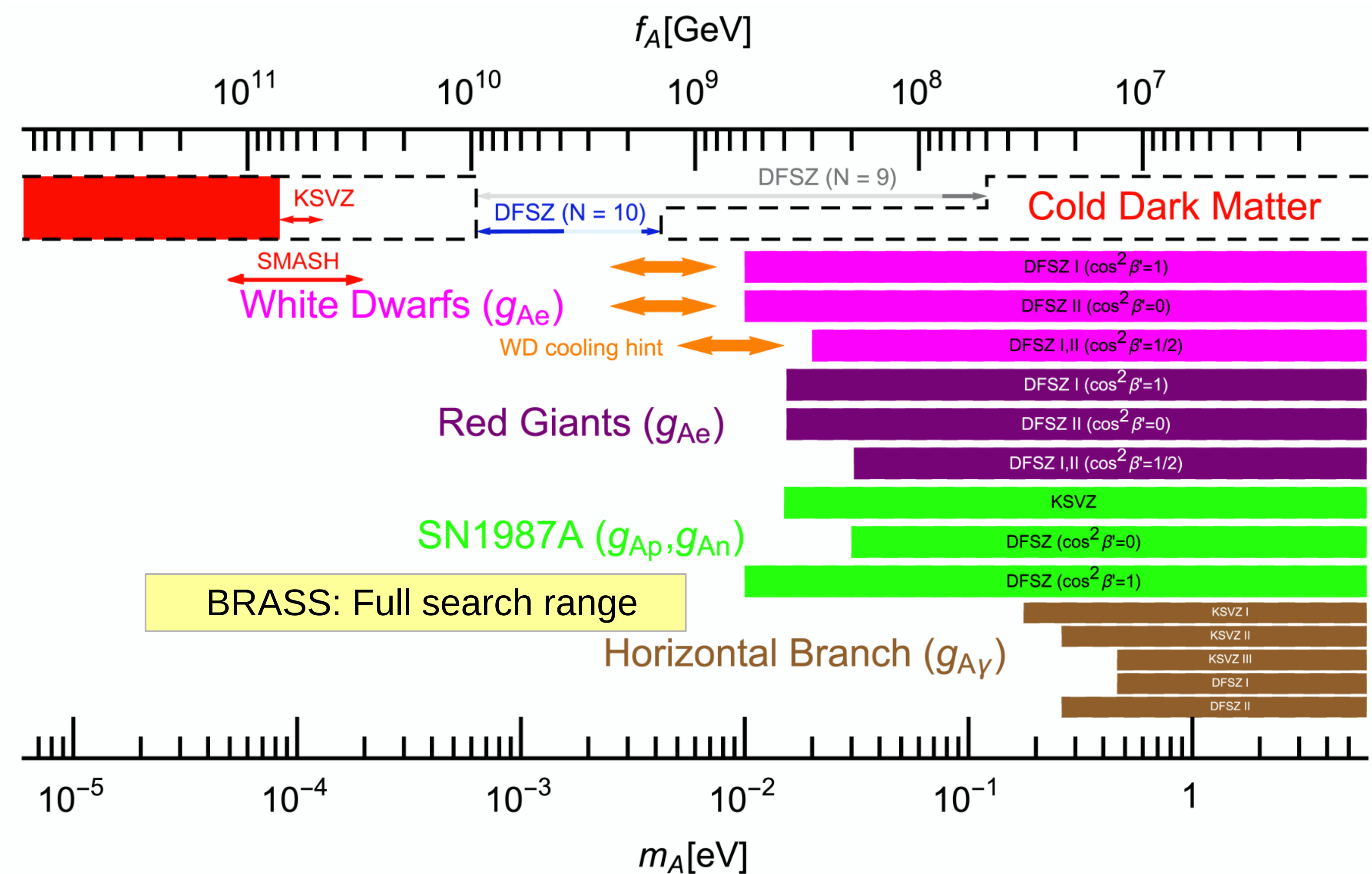
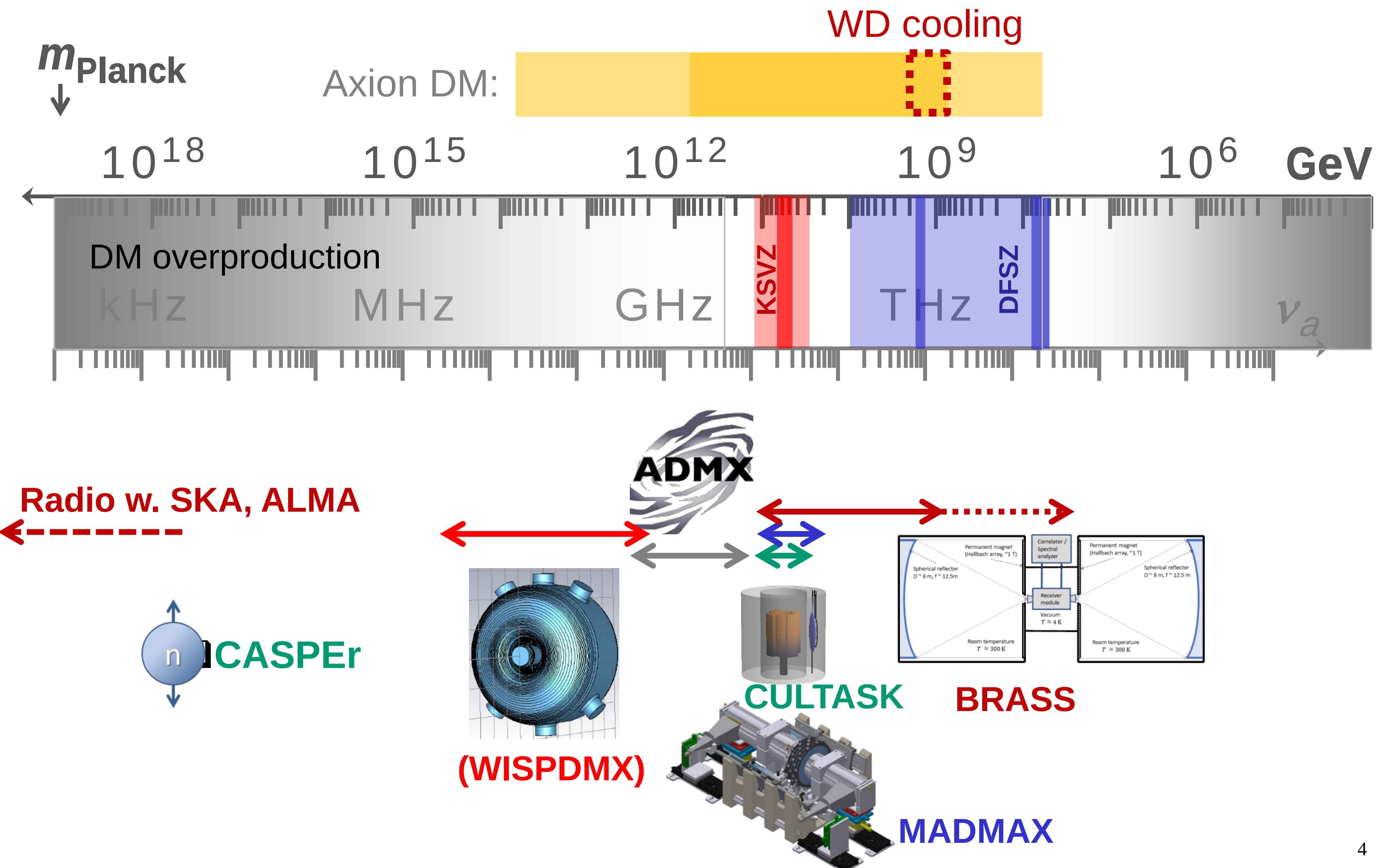


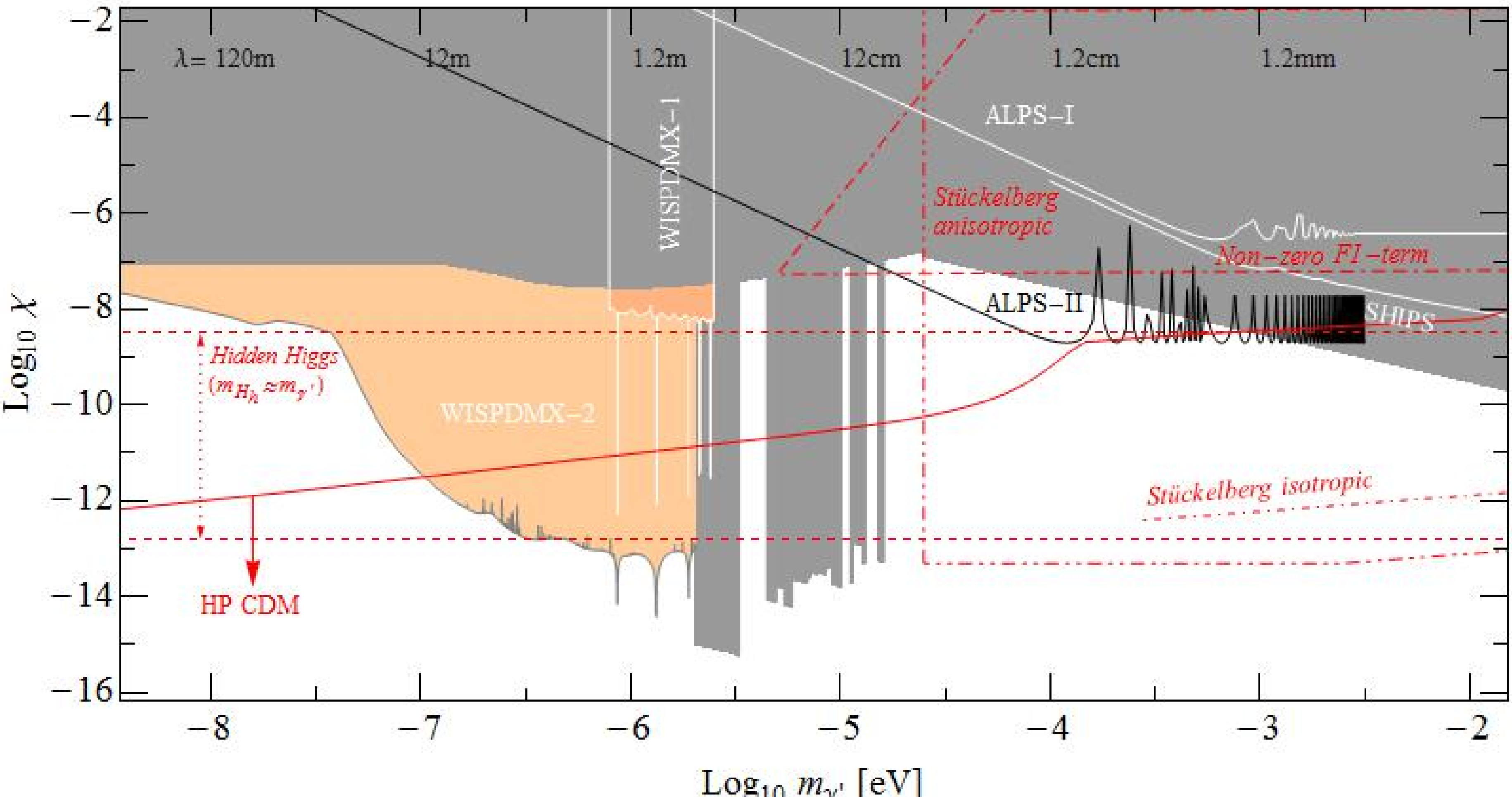
Axion DM Searches: Experiments



WISPDMX on Hidden Photon DM

- WISPDMX: resonant and broadband search in the 0.01-500 MHz range.

(see poster presentation on Thursday by Le Hoang Nguyen)



To Boost or Not To Boost?

- Scanning a mass range (m_1,m_2=αm_1).
- A broad band measurement is more efficient than a narrow band one if

$$t_{broad} < t_{narrow}\, N_{mes}$$

- If a narrow band measurement has “boost” factor Q, this implies

$$1 + Q\ \log\alpha > \left(\frac{T_b}{T_n}\right)^2 \left(\frac{B_b}{B_n}\right)^{-4} \left(\frac{V_b}{V_n}\right)^{-2} \left(\frac{G_b}{G_n}\right)^{-2}$$

- For typical $T_b = 100T_n$, $B_b = 1.0\ B_n$, $V_b = 100V_n$, and $G_b = 0.01G_n$, to scan as efficiently over a decade in mass, a narrow band experiment must have Q<10000.
- Hence, boosting is very good to have when you know where to search.
- “Boosted” searches: ADMX, CULTASK, MADMAX: 1 – 100 GHz.
- Broadband searches: BRASS: 20 – 1000 GHz.
- Broadband searches: sensitivity is an issue.

Broadband Conversion Methods

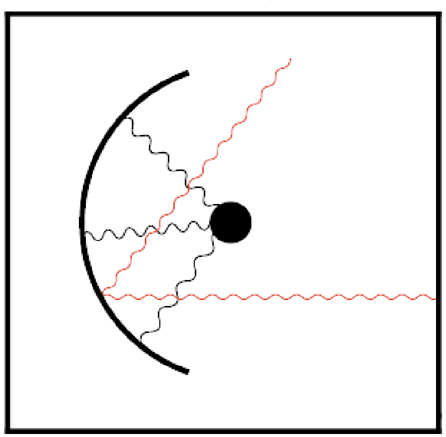
- Employing spherical reflectors enhance (focus) the near field EM signal from the reflector surface which arises due to its interaction with WISP dark matter (Horns et al. 2013). Promising for masses above 10 μeV.

- Modifications of the original concept:
  -- MADMAX: boost by multiple conversion surfaces (Caldwell+ 2016) for ~10-80 GHz range
  -- BRASS: magnetized conversion surface for 20 – 1000 GHz range.

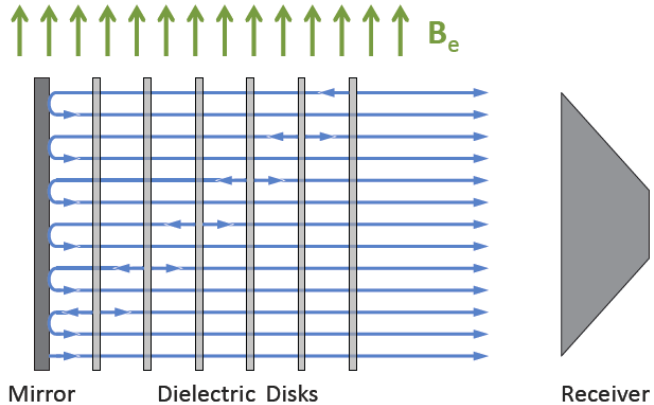
  Great potentials for synergies with mm, sub-mm detection technology

Sensitivity $\propto B^2 A \; T_n^{1/2}$

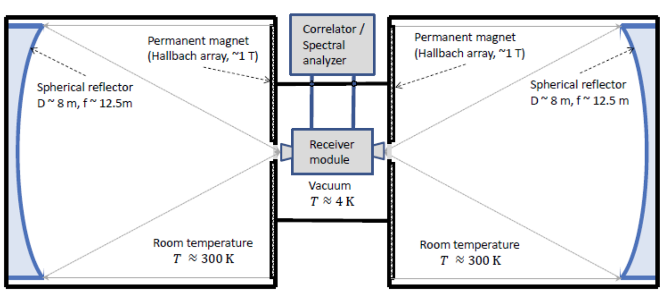
DISH: Original



MADMAX

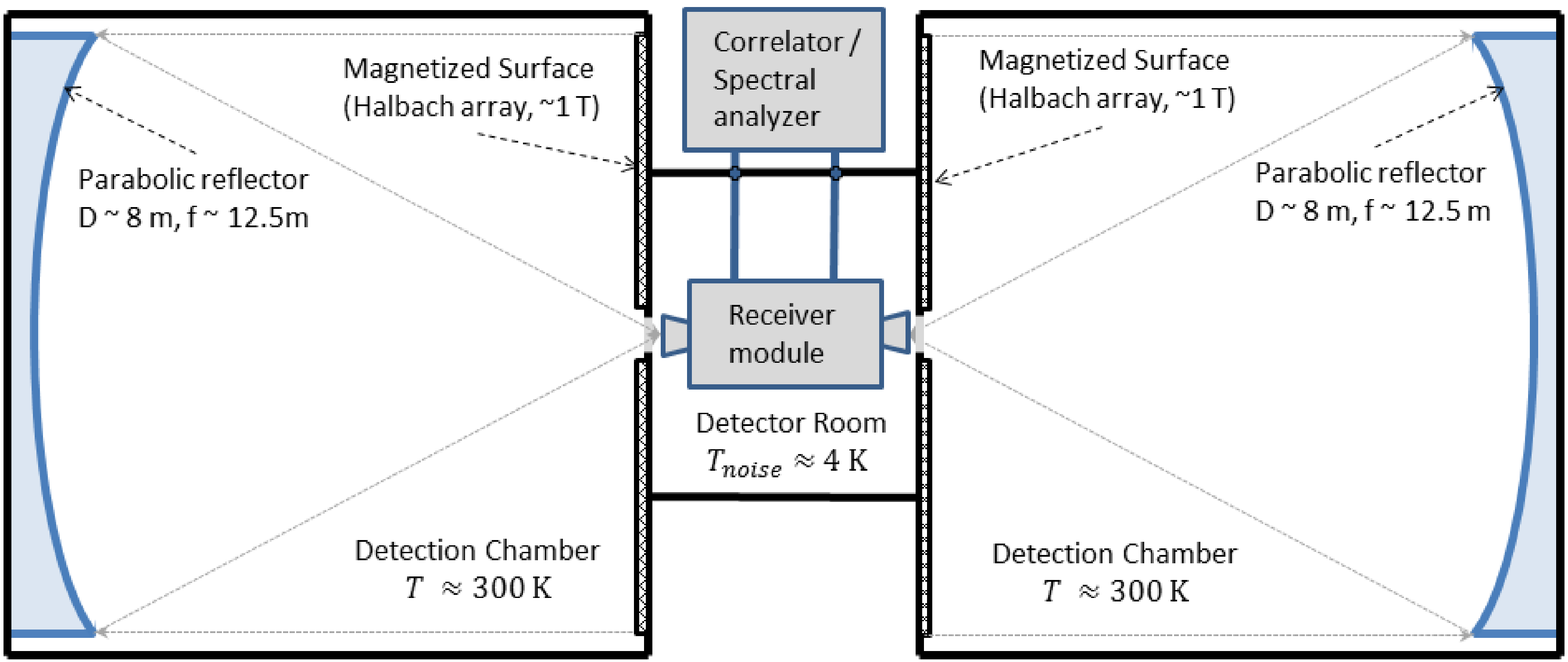


BRASS



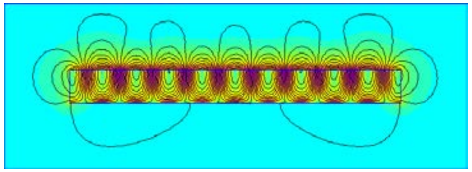
Conceptual Design for BRASS

- Broadband Radiometric Axion/ALP SearcheS:
  - -- Flat, permanently magnetized surface (Halbach array; 100 m^2, B~1T)
  - -- Focusing the signal with a parabolic reflector
  - -- Broadband recording (16+ GHz bandwidth, spectral resolution of 10^{-7}).
  - -- Correlating signals from multiple modules
  - -- Natural synergy with VLBI and ALMA/APEX developments at MPIfR

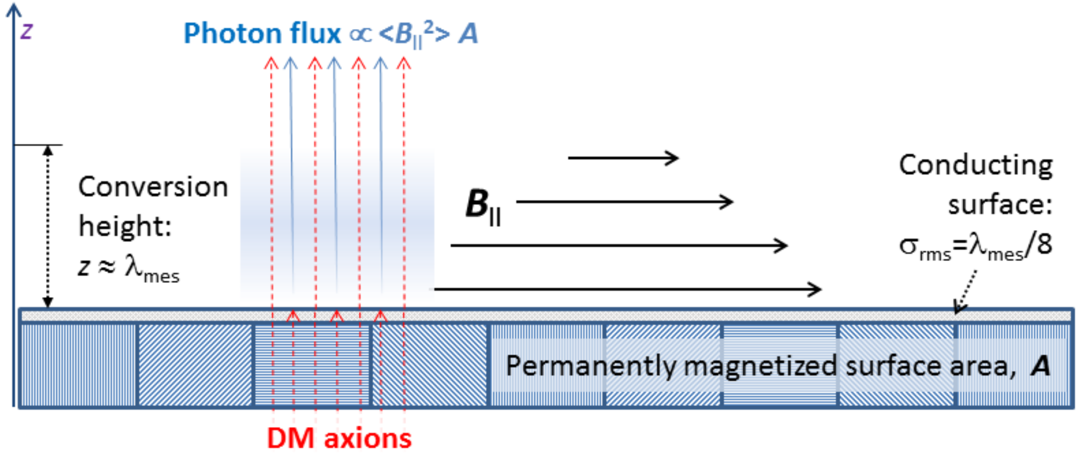


Magnetized Conversion Surface

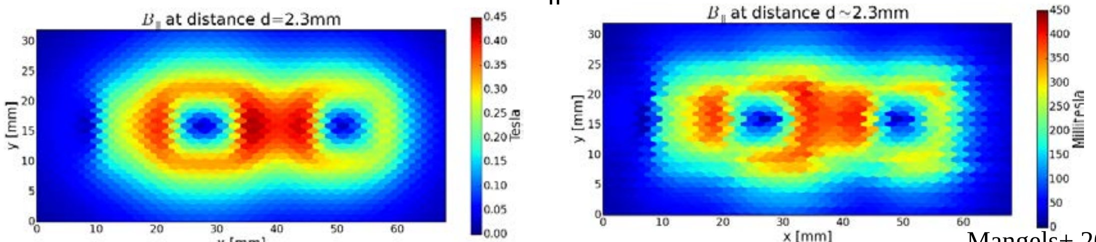
- ❑ Halbach array configuration to optimize the parallel B-field component.



- ❑ $Nd_2Fe_{14}B$ magnets: B_{max} ~ 1.2T, for room temperature operation.
- ❑ RE-Ba-Cu-O magnets: B_{max} ~ 10T at T~30K (Tomita &Murakami 2003)
- ❑ Potential use of thin dielectric layers to boost a specific band.

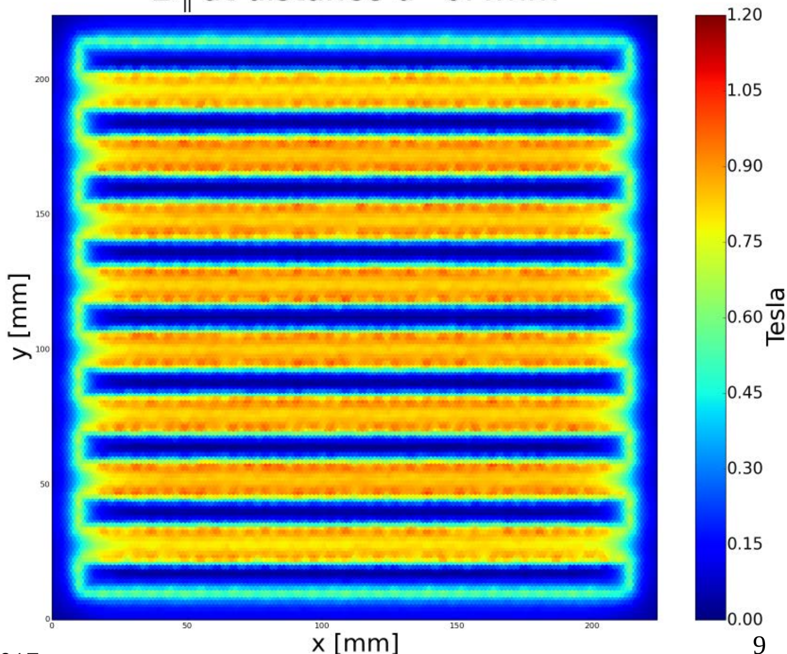


Simulated and measured $B_{||}$ in a 4x1 Halbach stripe



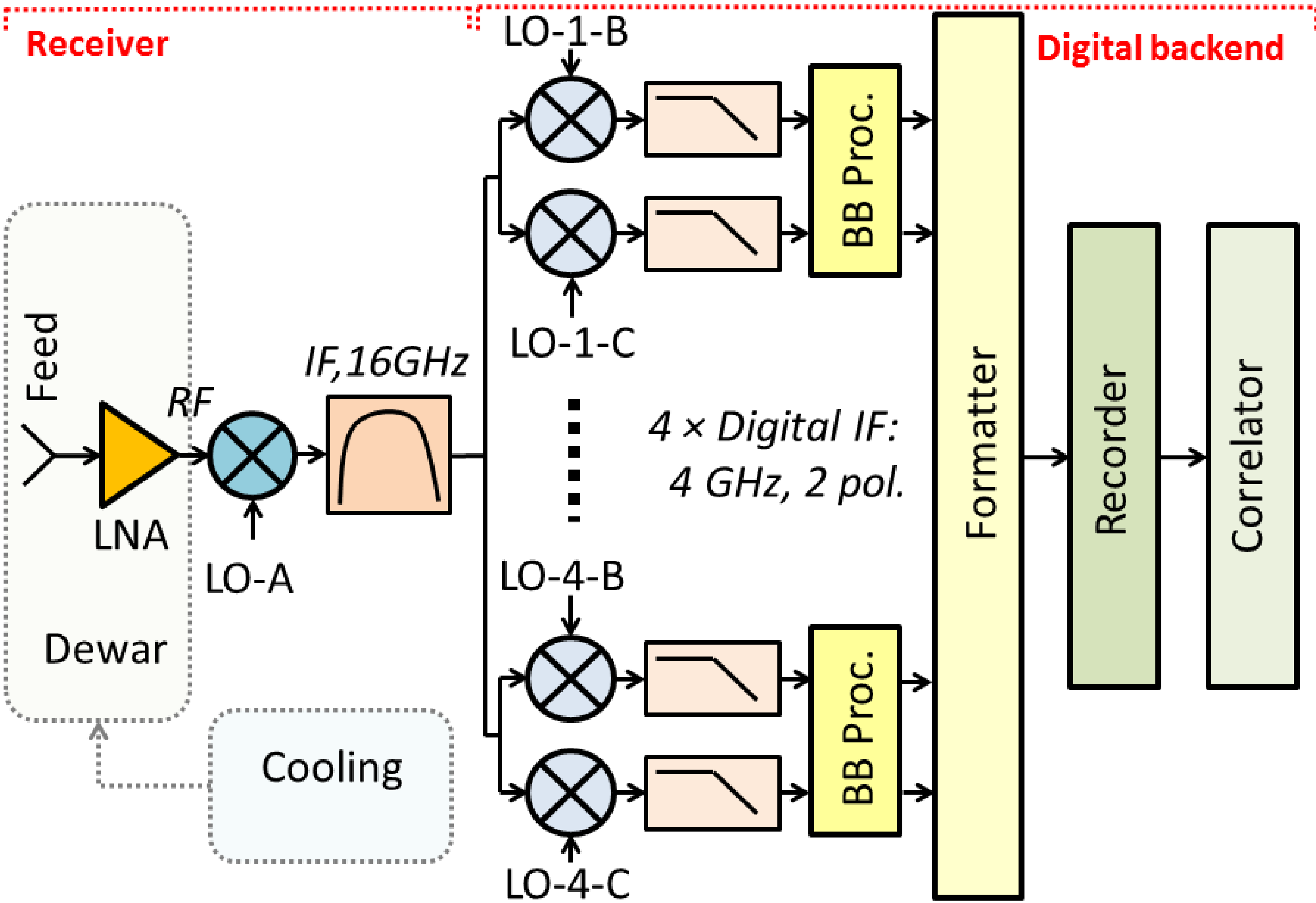
Simulated17x17 Halbach array:

$B_{||}$ at distance d=0.4mm

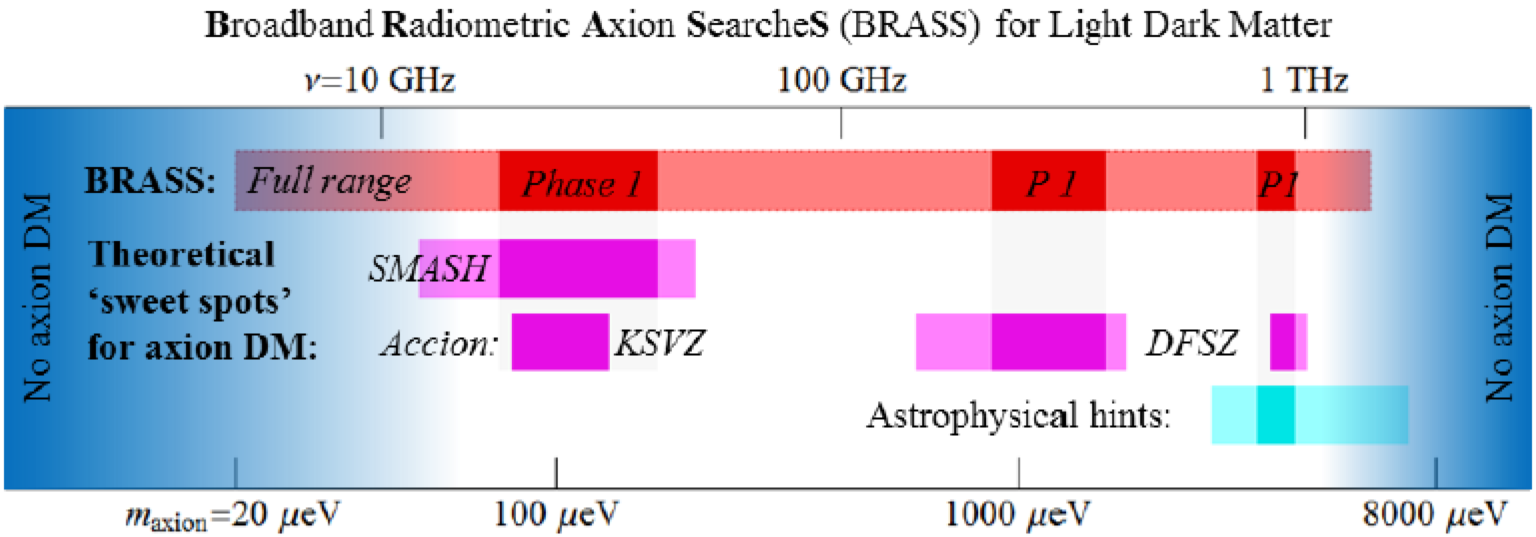


Mangels+ 2017

Detector Frontend & Backend



Prioritized Search Bands

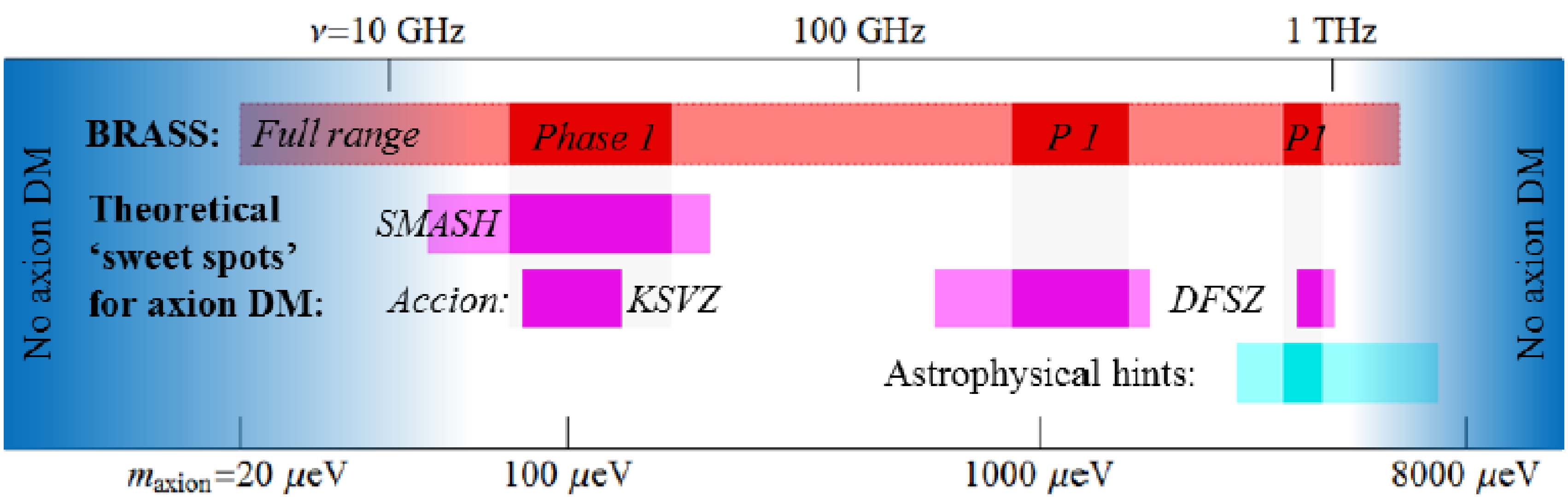


Axion Model		m_{axion} [meV]	ν [GHz]	P_{DM} [10^{-26} W]	W_{DM} [kHz]	Bands
SMASH		0.05–0.20	12.0–48.1	7.1	0.6–2.6	U,K,Q
Accion:	KSVZ	0.08–0.13	19.2–31.3	7.1	1.0–1.7	K
	DFSZ I	0.60–1.70	144–409	2.6	7.7–21.9	APEX 1-3
	DFSZ II	3.50–4.20	842–1010	4.6	45.0–54.0	ALMA 9,10

BRASS 1.	*SMASH/KSVZ:*	0.07–0.14 meV:	18–32 GHz	– K/Ka band
BRASS 2.	*DFSZ I a:*	0.88–1.14 meV:	213–275 GHz	– APEX 1 band
BRASS 3.	*DFSZ I b:*	1.14–1.54 meV:	267–370 GHz	– APEX 2 band
BRASS 4.	*DFSZ II:*	3.27–3.95 meV:	787–950 GHz	– ALMA 10 band

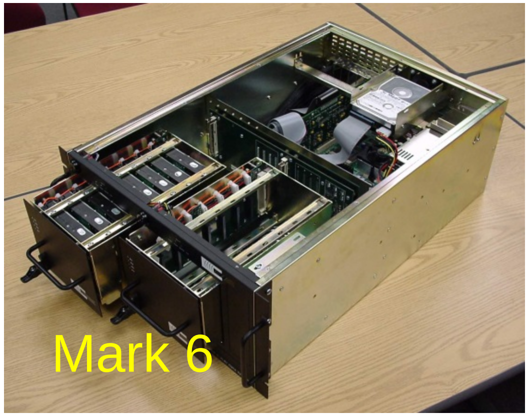
BRASS Status and Plans

- 2018: University of Hamburg funding (500 k€) for the first prototype, with a 2-m reflector, a 12 – 18 GHz receiver, and a 4GHz DBBC.
- 2018: Proposal for a DFG Research Unit, seeking funding for BRASS-6
  2018-21: A double chamber BRASS-6 setup for Band 1 (~900 k€)
  2021-24: Detector extensions to Bands 2-4 (~800 k€)
- 2021: Seek funds for BRASS-100 (~8M€), through Large Instrumentation Programs of the DFG and MPG.



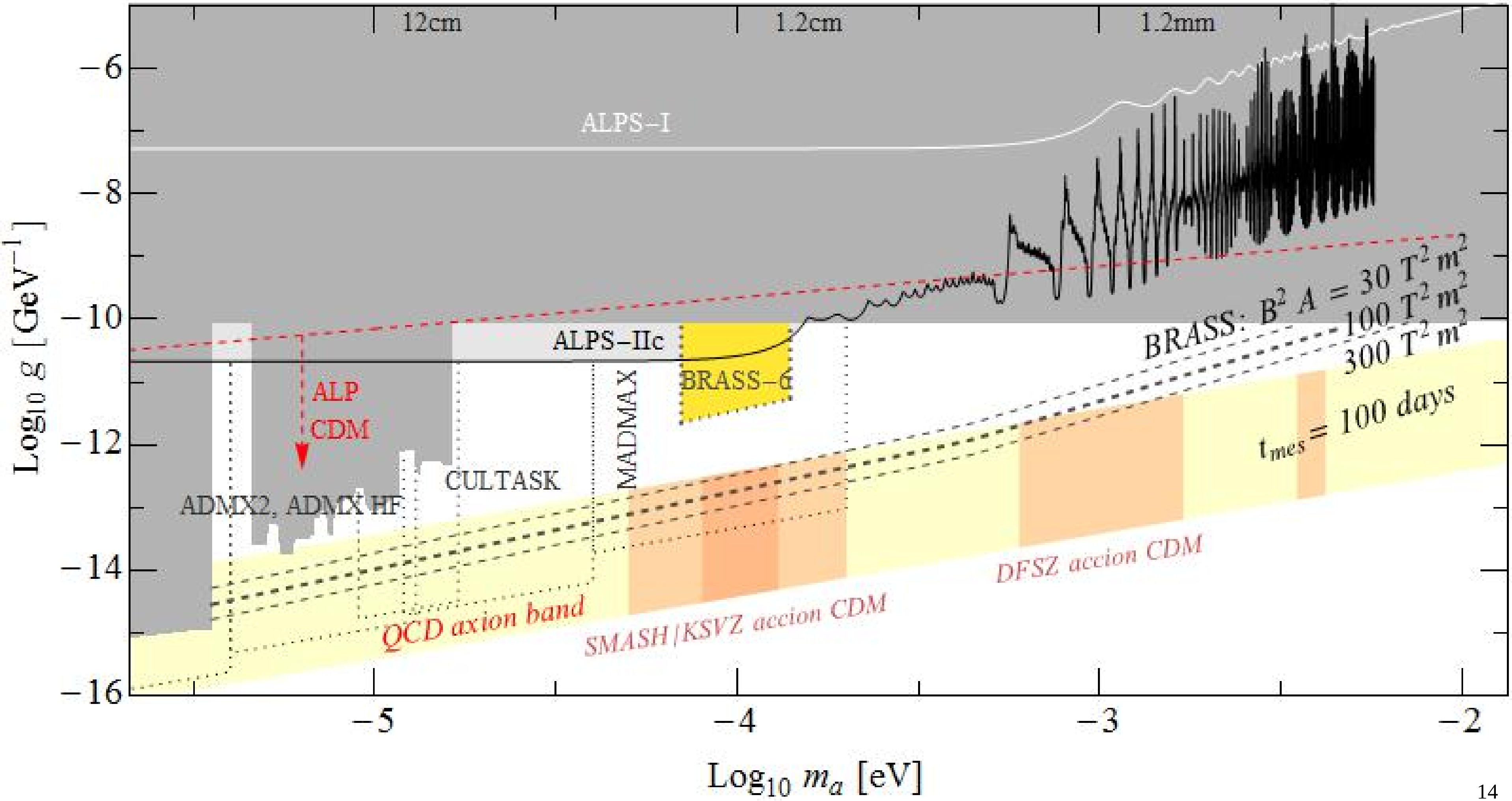
BRASS-6: 2018-2021

- A two-chamber, 6m^2 setup, with two 2-m reflectors.
- Operating at 18 – 32 GHz band, with 4 GHz bandwidth (DBBC/Mark 6).
- Tsys = 40 K.
- B ~ 0.7 T.
- A single chamber prototype is planned to be constructed in 2018-19, operating only for hidden photon DM searches.



BRASS on Axion/ALP Dark Matter

- BRASS: Assuming 4K and 5$h\nu$ detection sensitivity.
  BRASS-6: T_{sys} = 40 K, Band 1: 18 – 32 GHz.



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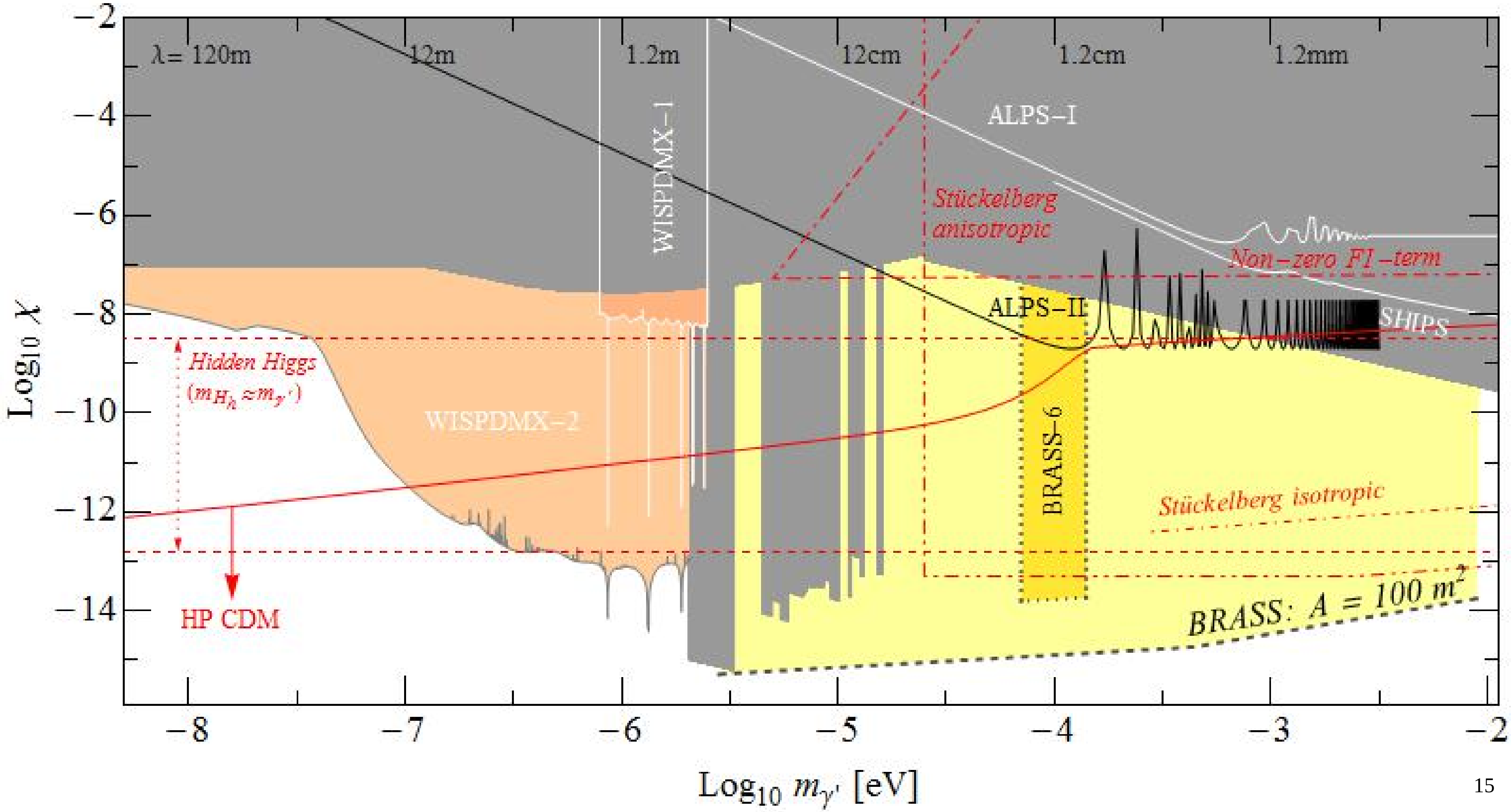
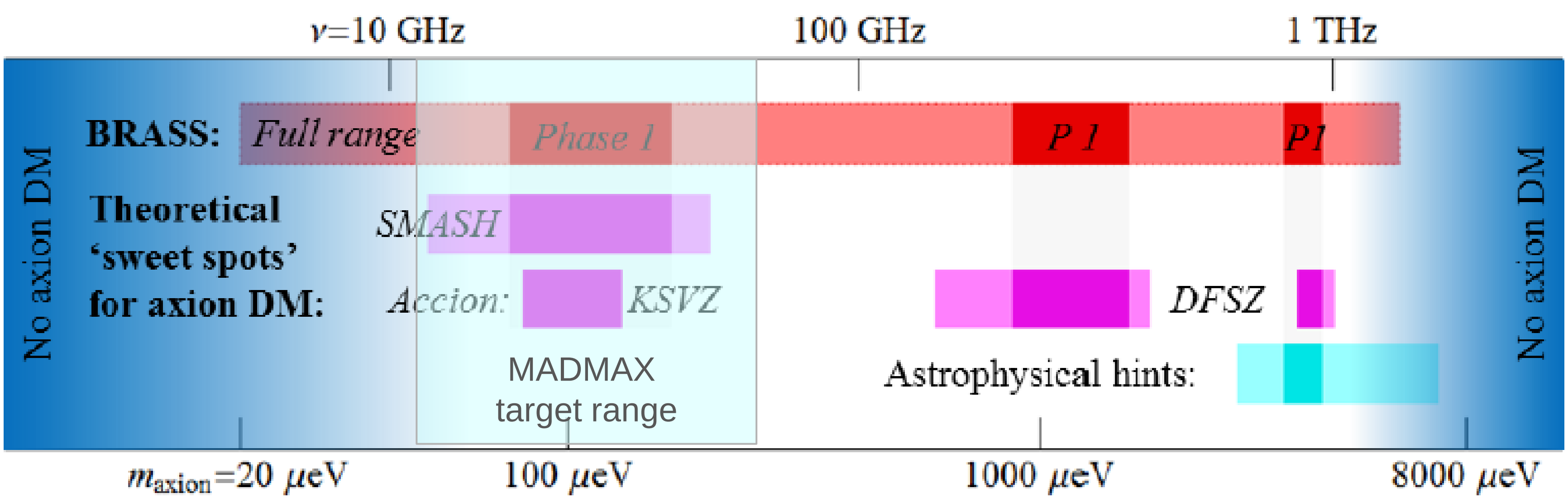


Potential Synergies

- BRASS is primarily an ultra broadband facility enabling ALP searches in the 70–4000+ μeV range, and potentially reaching axion sensitivity only at the latest stages of its operation.
- Detector frontends for BRASS and for MADMAX will be made at the MPIfR, avoiding whenever possible the duplication of effort.
- Overlap with MADMAX in backend technology for the Band 1.
- Overlaps in signal processing (to some extent) and analysis with any experiment using heterodyne detection.



Summary

- BRASS provides an affordable and scalable setup for extended searches for hidden photon and axion/ALP dark matter in the 20 – 1000 GHz range.

  The highest frequency is constrained only by the surface accuracy.

- In this capacity, BRASS will establish a long-term *facility* for WISP dark matter searches.

- Sensitivity will be an issue for QCD axion searches over the entire range. Will have to be addressed by employing a better tehcnology for permanent magnets or with multiple chambers.