The CERN Resonant WISP search (CROWS)

M. Betz, F. Caspers, M. Gasior

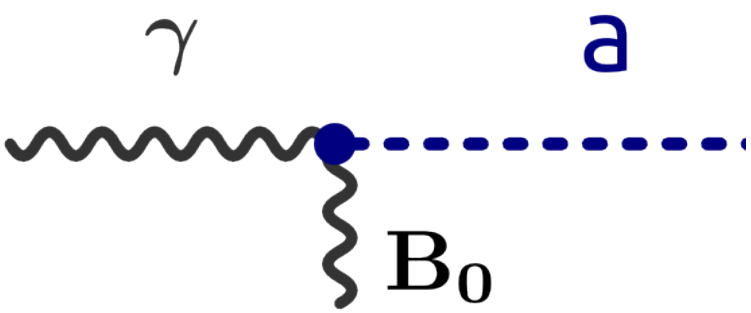
"Shining microwaves through walls"

DESY Physics Seminar, Forum on New Results from WISP Searches
Hamburg (Germany), 12/2013

Outline

- Light Shining through the wall (LSW) experiments
- A LSW setup with microwaves
  - Microwave cavities
  - Shielding of Electromagnetic Interference (EMI)
  - Narrowband signal detection
- The latest measurement run and its results

A quick recap



ALP = Axion Like Particle

HP = Hidden Photon

The ALP and the HP are **hidden** – but **not** completely **invisible** (if they exist):

ALPs (**a**) couple to photons (**γ**) in a strong magnetic field ($\mathbf{B_0}$)
→ **"Primakoff effect"**

Hidden photons (**HP**s) couple to photons (**γ**)
→ **"Kinetic mixing"**

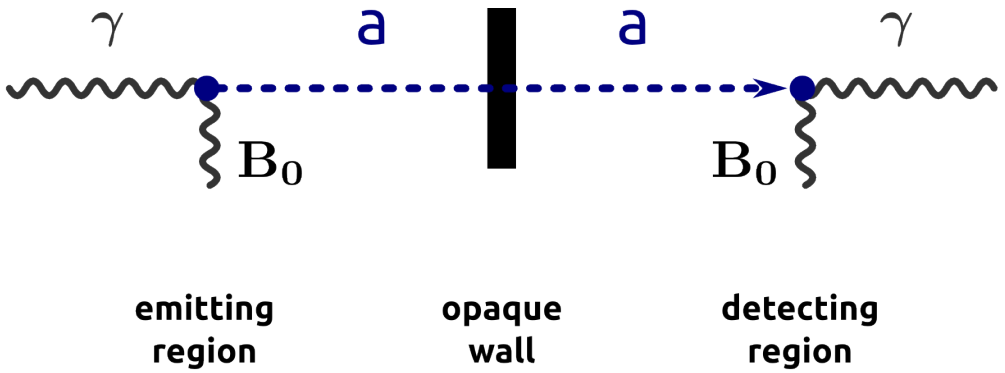
Light shining through the Wall (LSW) experiments

Exploit the fact that ALPs or HPs …

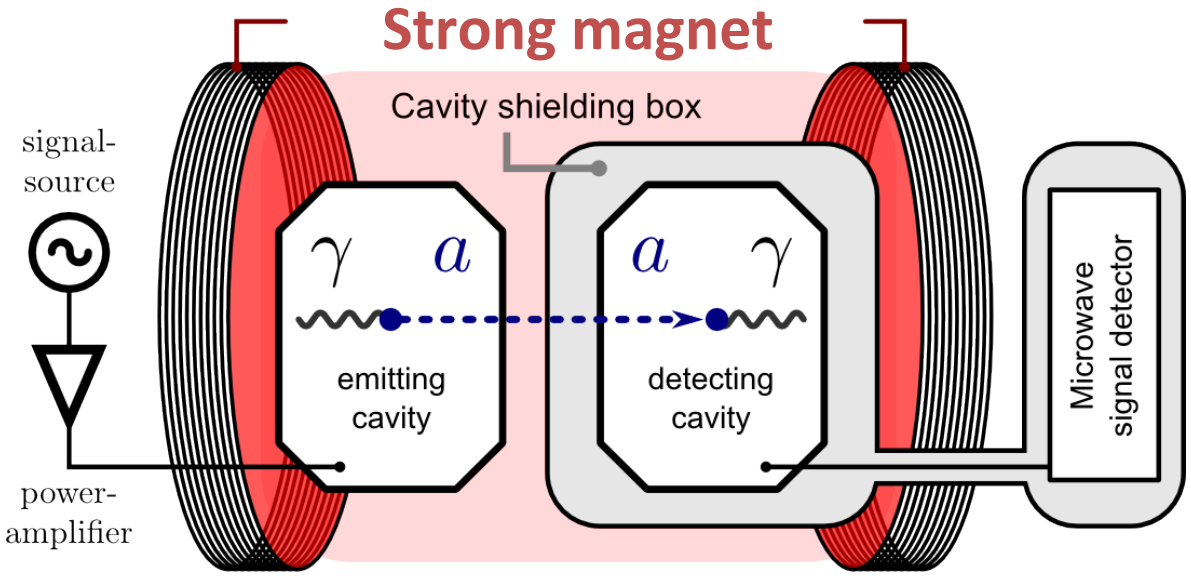
- … can **convert** to **photons** and vice versa
- … can **penetrate** "**walls**"

γ = Photon
a = Axion Like Particle / Hidden Photon
B_0 = Static Magn. field

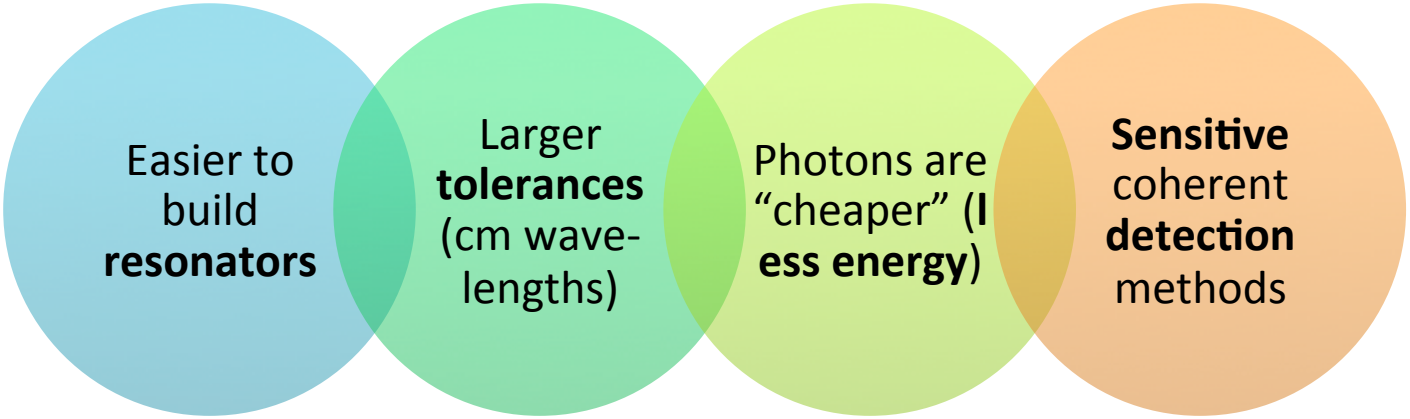
The energy of the photon can be between **μeV** (microwave photon) up to **keV** and beyond (gamma quantum)



Microwave LSW (CROWS)

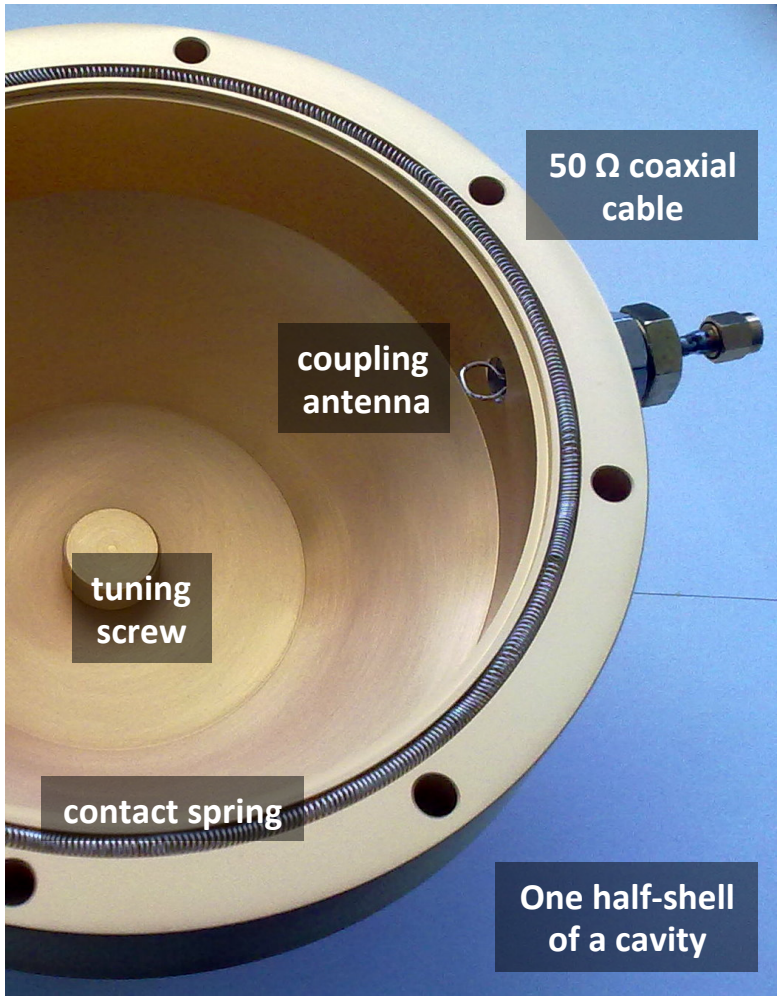


Why micro-waves?

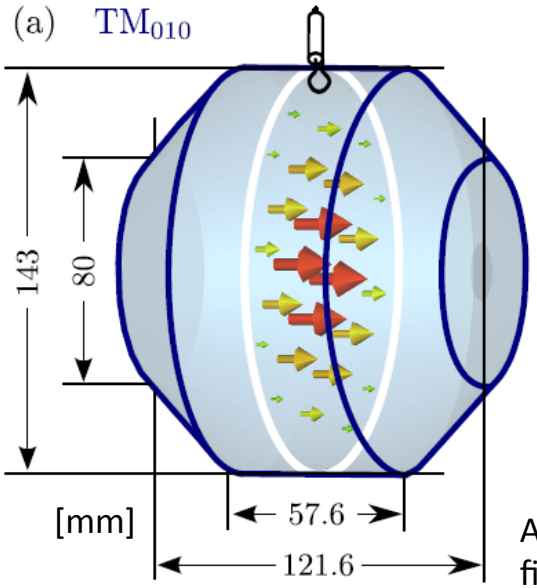


M. Betz, 2013

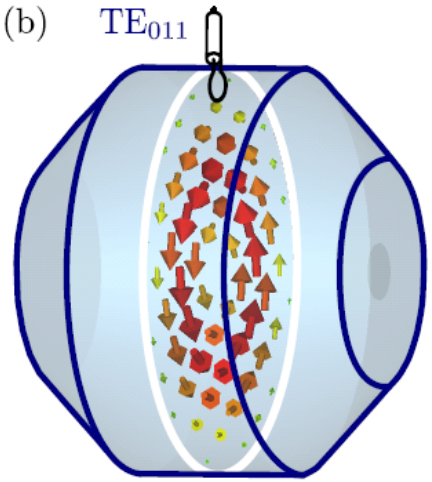
Cavities: the WISP "antennas"



ALP search (1.7 GHz)



HP search (2.9 GHz)



Arrows show oscillating electric field in the cavity

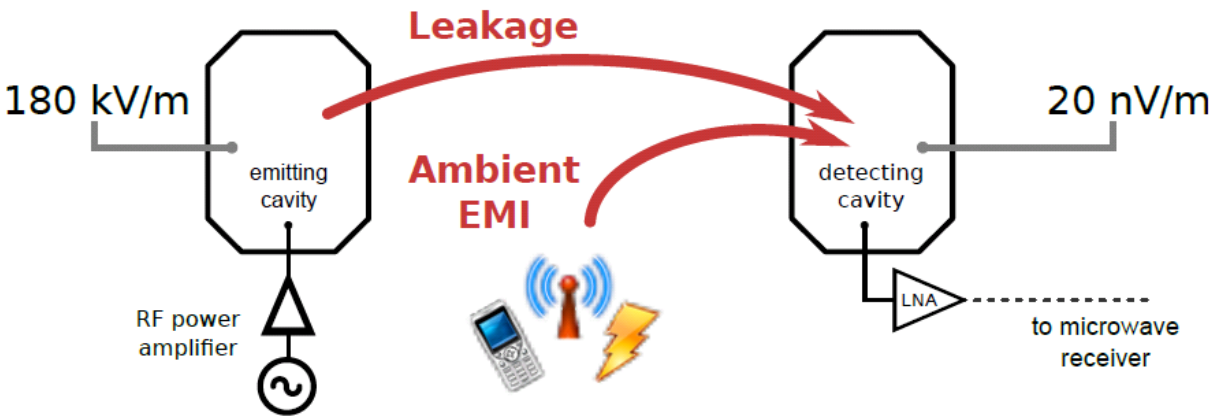
Emitting cavity:

- RF input power = 50 W
- Equivalent to **1 MW** due to resonant enhancement

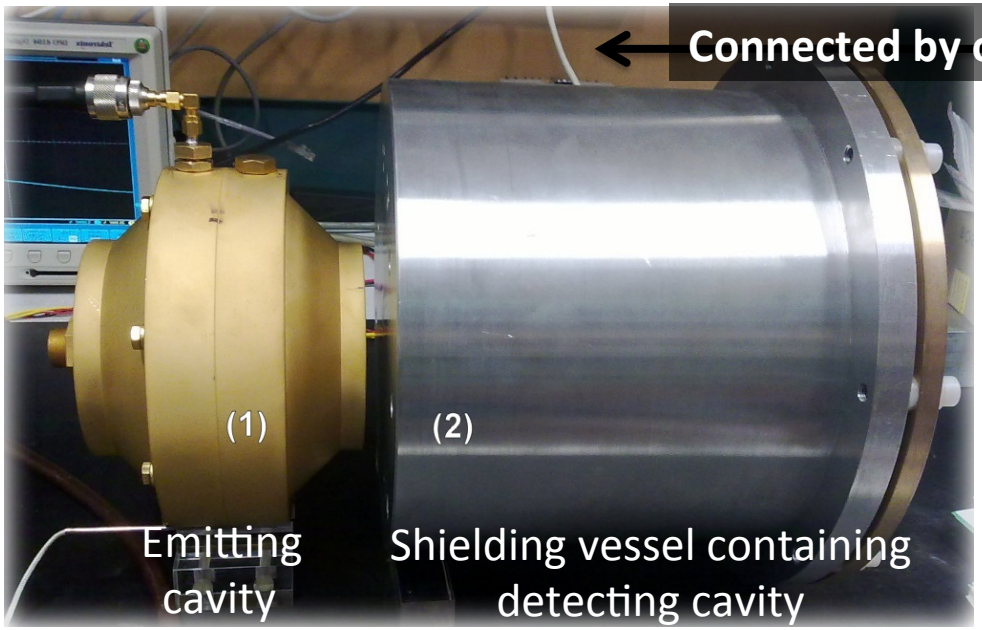
Detecting cavity:

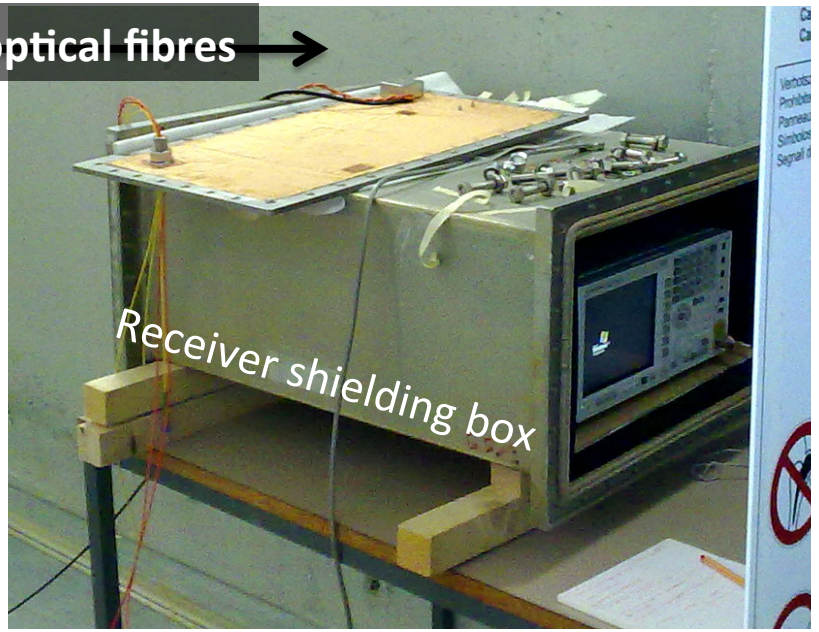
- No input power (passive)
- Connected to a sensitive low noise amplifier
- Placed in a EM. Shielding enclosure

Electromagnetic (EM) shielding

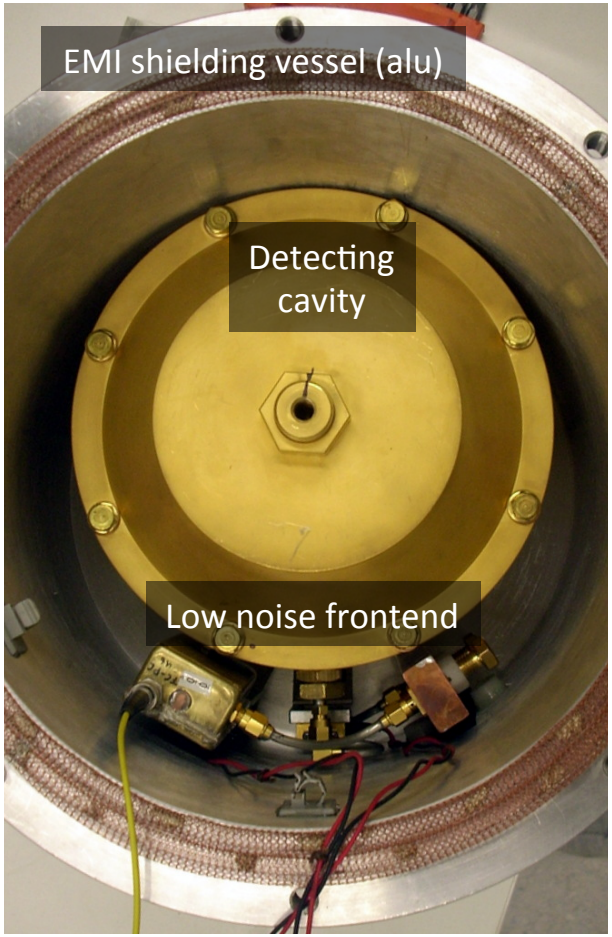


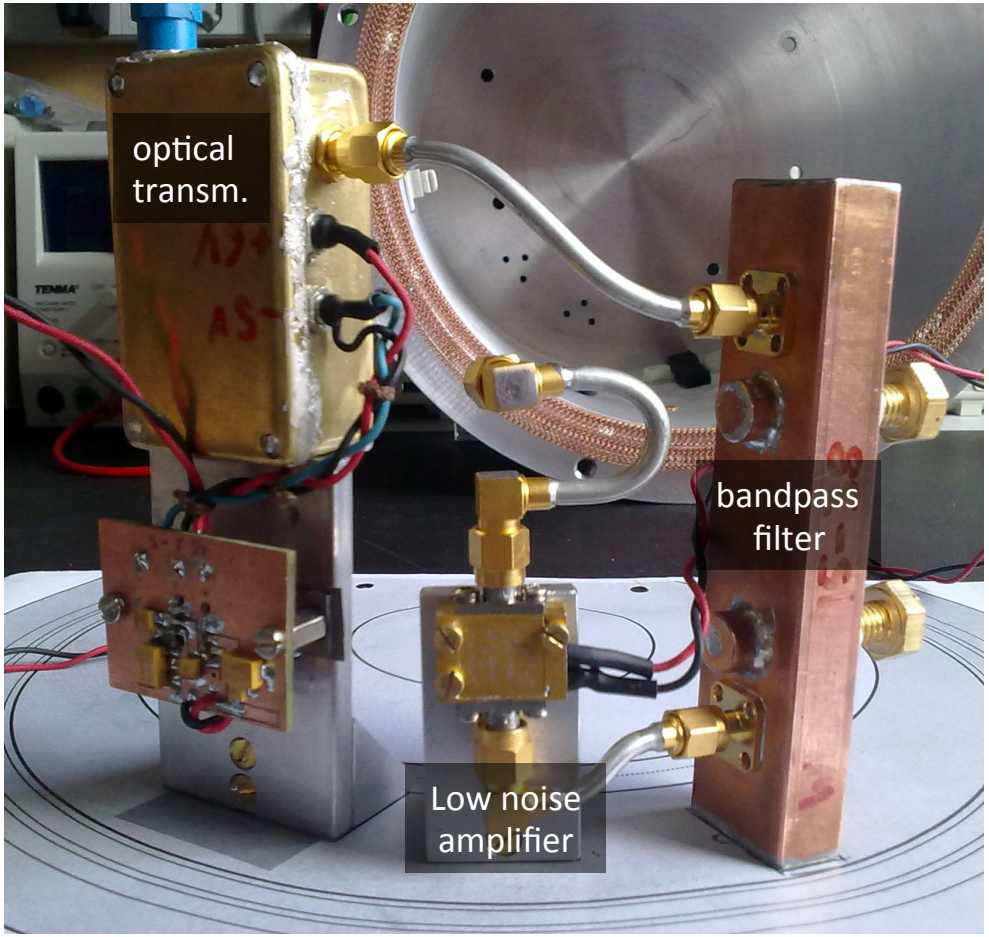
≈ **300 dB** of EM shielding is needed to attenuate **Leakage** and **Ambient EMI** below the detection threshold





Low noise frontend





Needs to function **in the magnet** at 3 Tesla! Several design iterations were necessary!

Narrowband signal detection

- **We search for a sinusoidal WISP signal at a known frequency**

- **Best method:**
  Discreet Fourier Transf.
  → Power spectrum

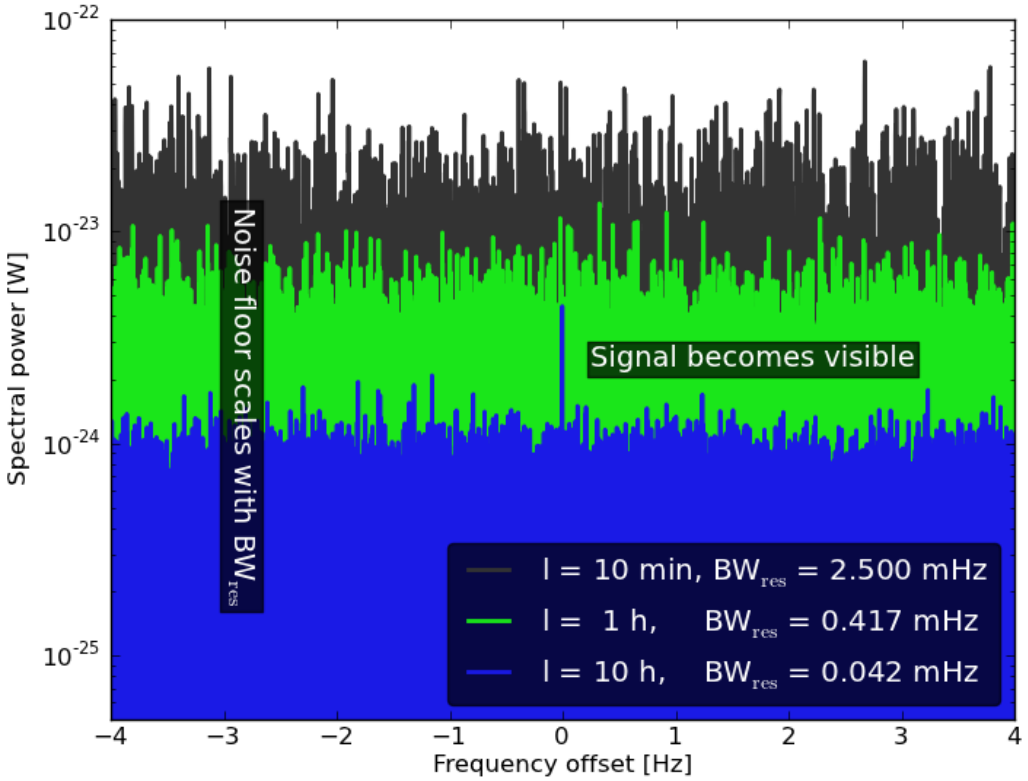
- **Dominating background:**
  thermal noise from the cavity
  - Scales with **1/l**
  - Power of WISP signal stays constant with **l**

Linear increase of signal to noise ratio with measurement time

Average spectral noise power:

$$P_n = k_B T_n / l$$

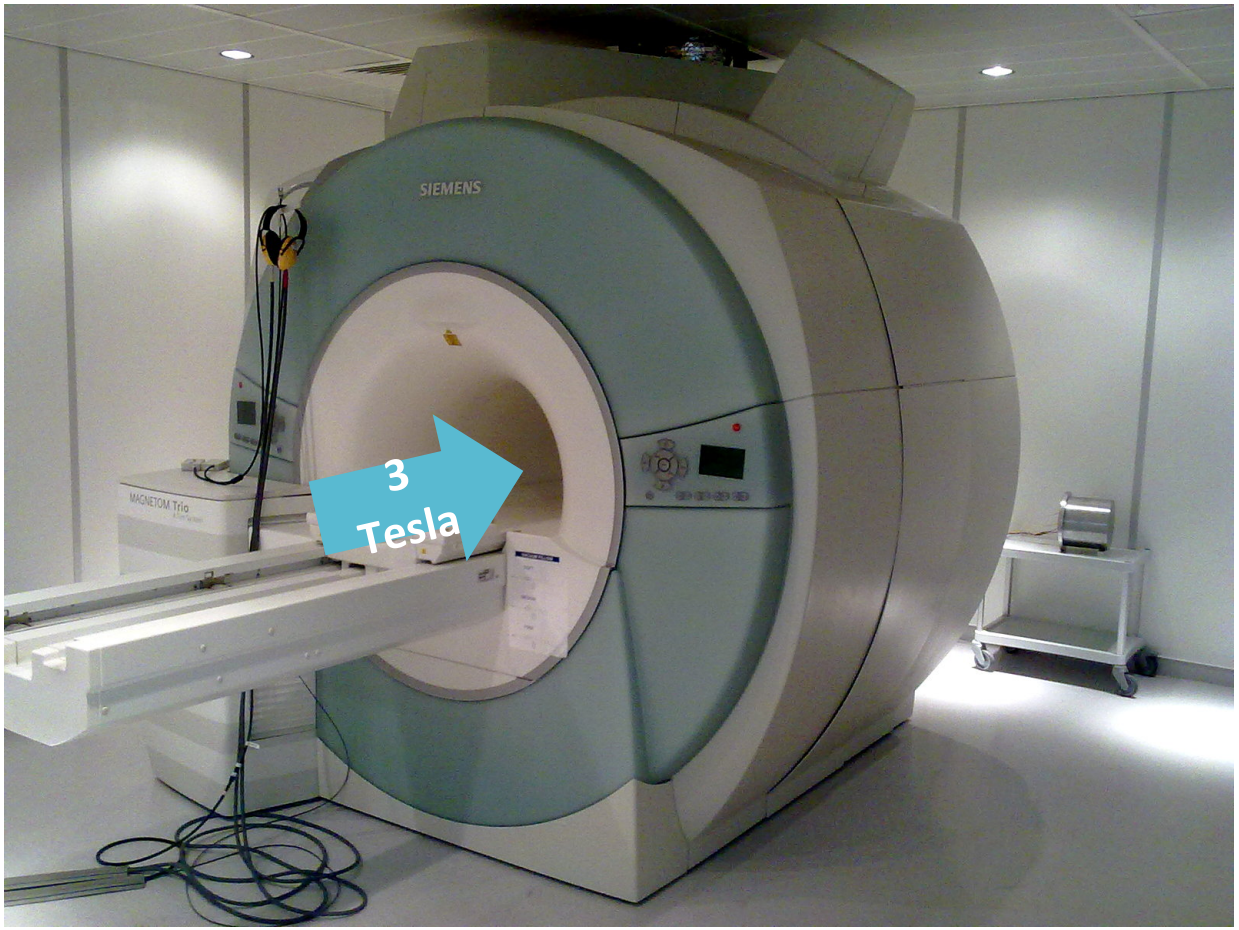
k_B = Boltzmann const.
l = length of the recorded time trace
T_n = cav. noise temp. (≈ 300 K)



ALP measurement runs in June 2013:

a strong magnet is needed …

MRI magnet at UNIVERSITÉ DE GENÈVE

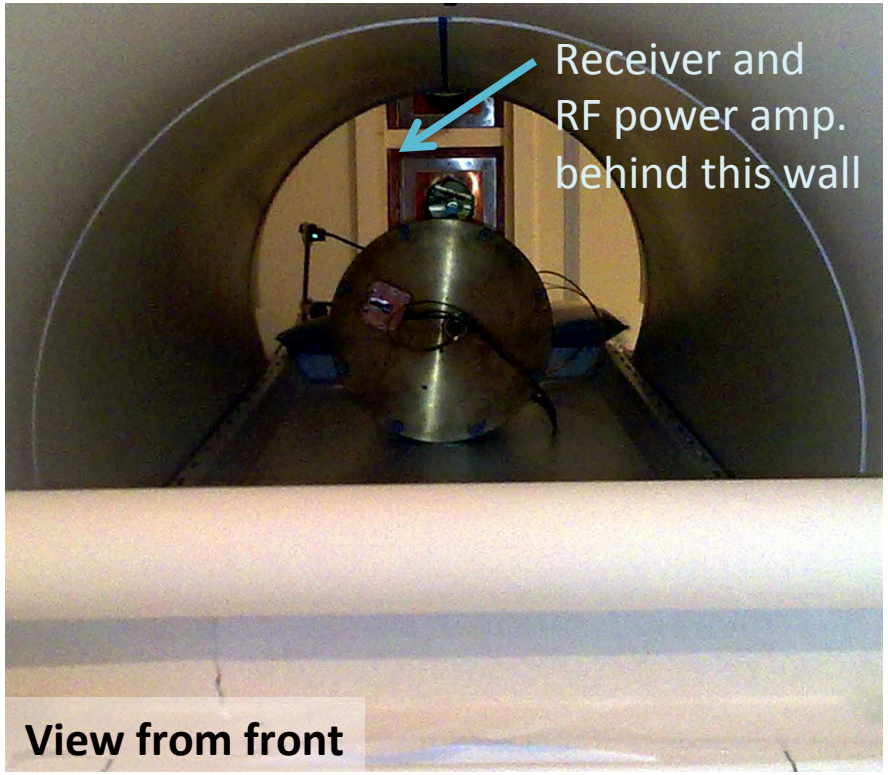


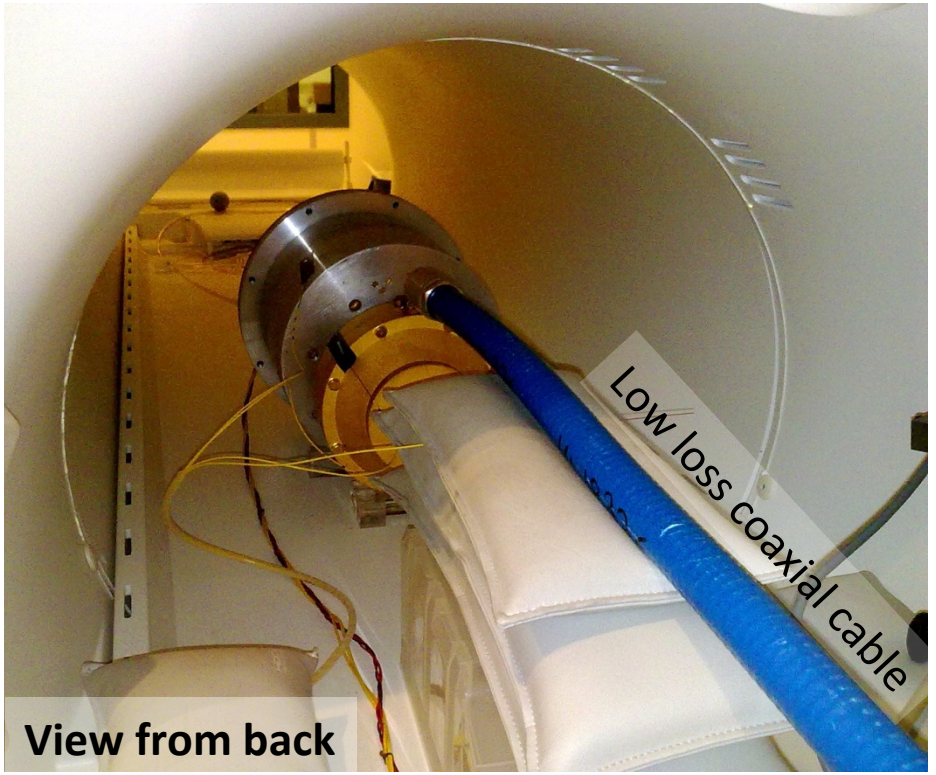
University of Geneva, Brain & Behaviour Laboratory

Made accessible for us on weekends

many thanks to
S. Rieger & **C. Burrage**

The setup in the magnet

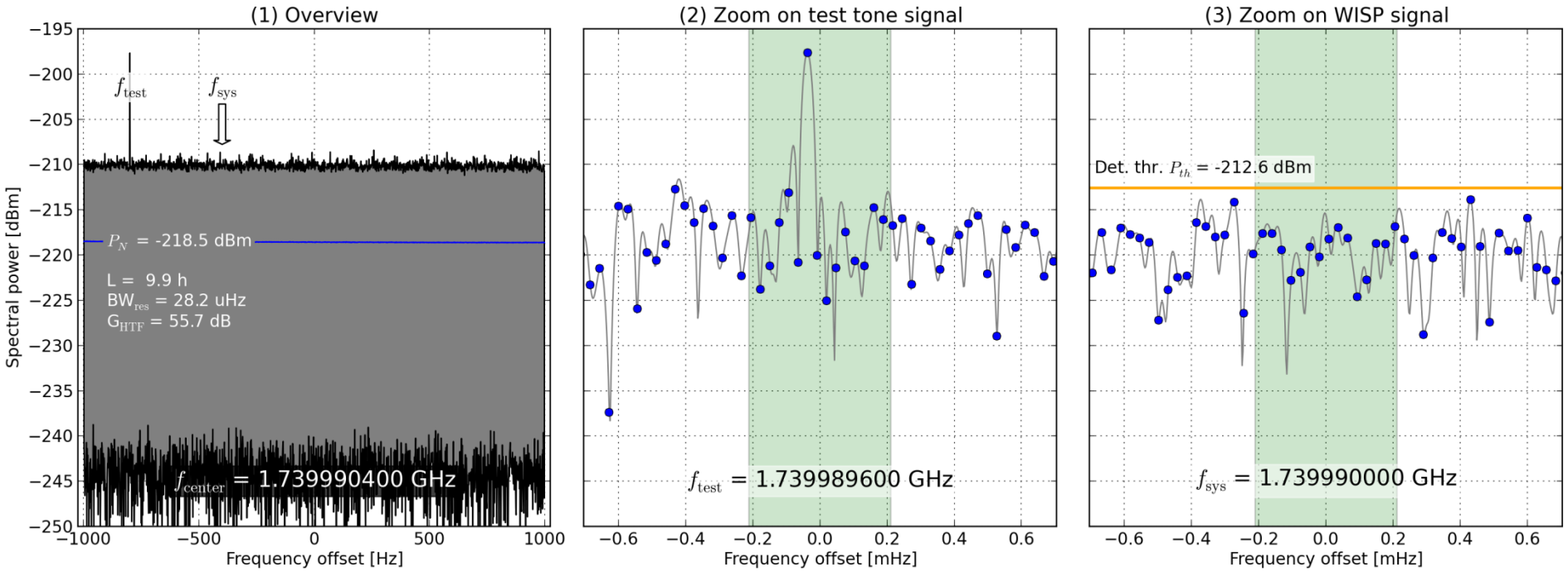




Magnet could not be ramped down!

We had to be very careful during commissioning to avoid the "**Missile effect**"
→ Only non-magnetic tools and components allowed

The results (ALPs, June 2013)



- **Test tone** signal is visible as narrow line → Receiving chain was operational
- **No ALP candidate visible**

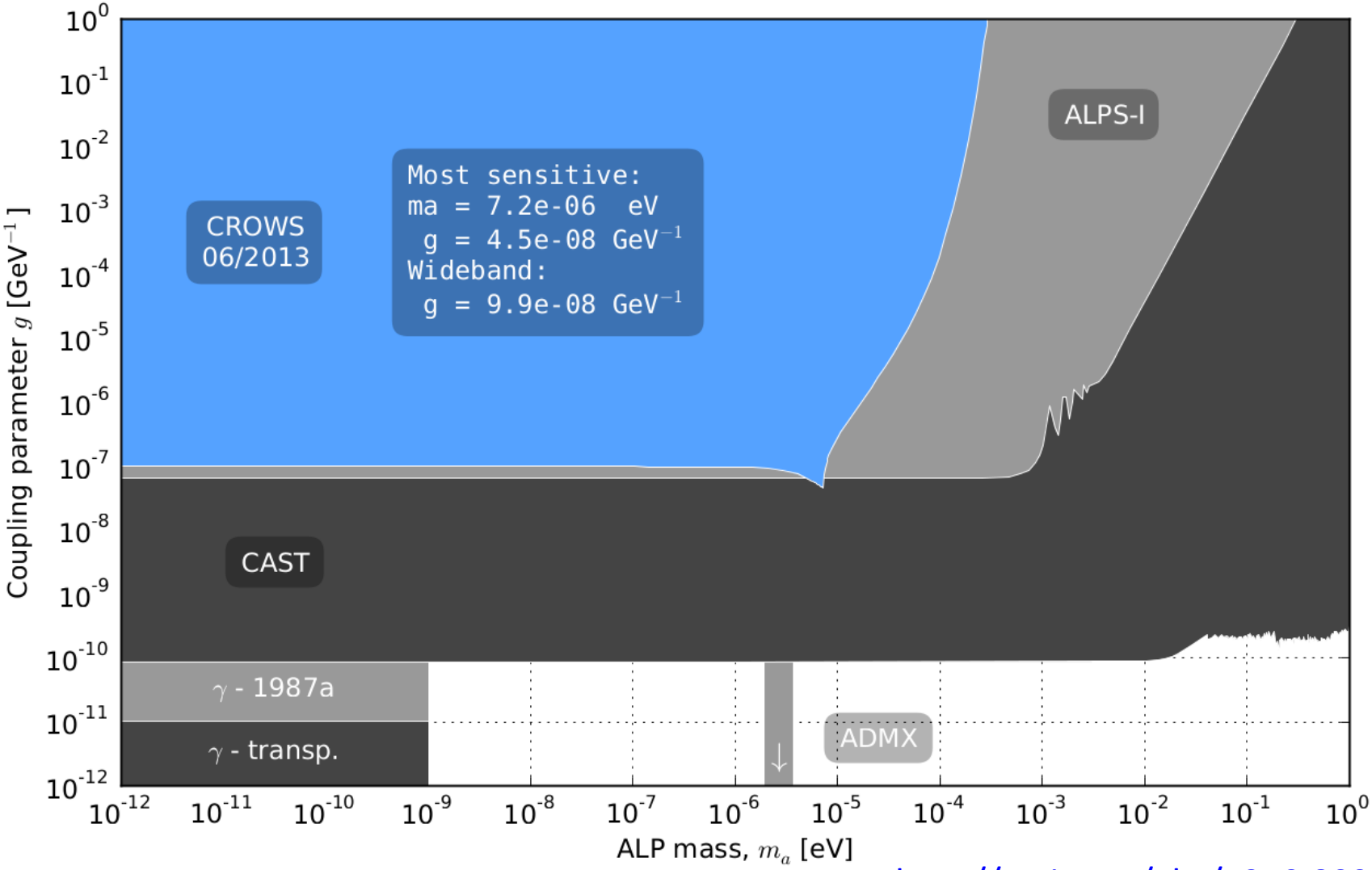
detection threshold
-212.6 dBm = 5 · **10^{-25} W**
≈ 1 photon every 2 seconds

M. Betz, 2013

http://arxiv.org/abs/1310.8098

Exclusion result for ALPs

no ALP detected

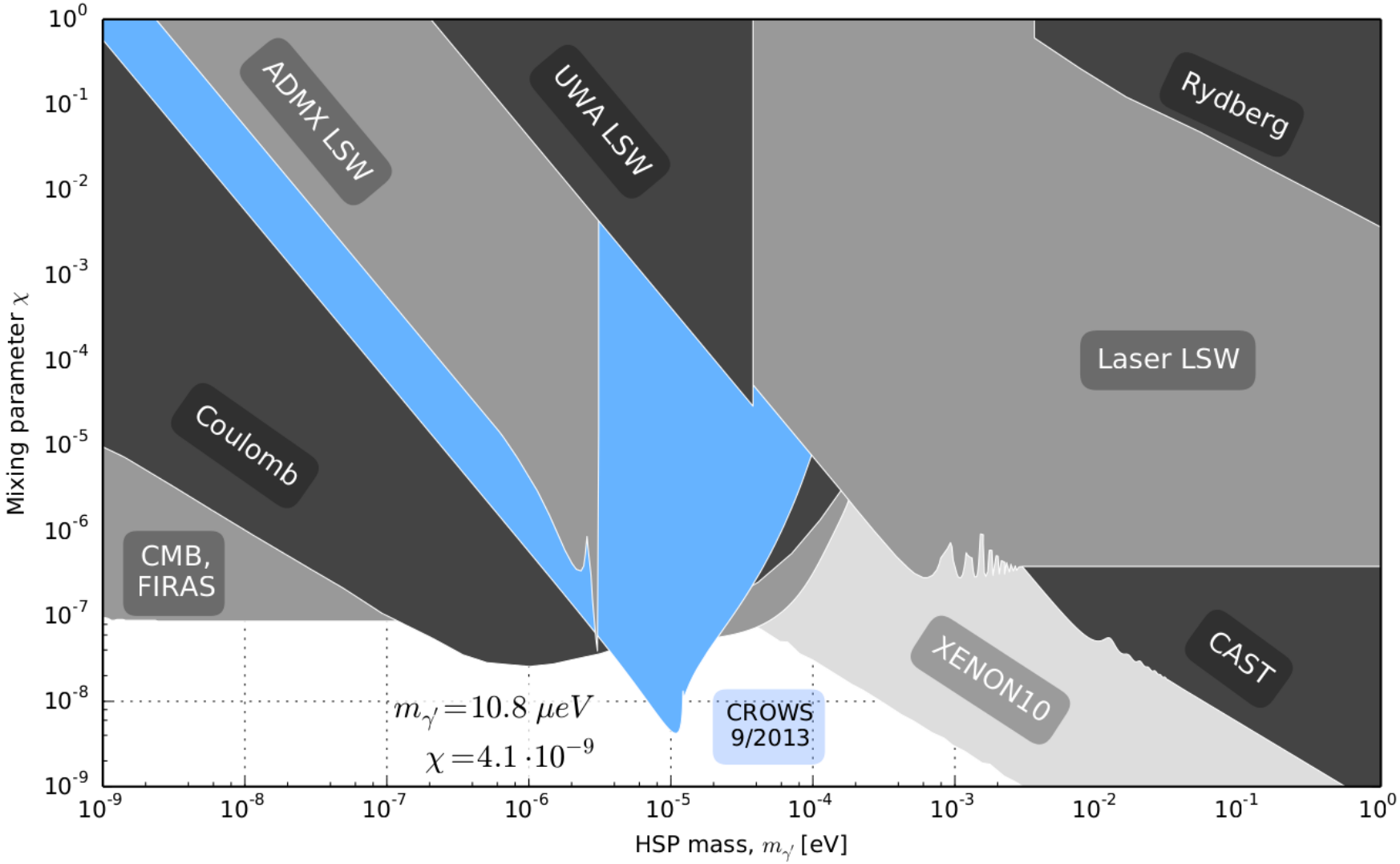


M. Betz, 2013

http://arxiv.org/abs/1310.8098

Exclusion result for HSPs

same setup – but no magnet



M. Betz, 2013

http://arxiv.org/abs/1310.8098

Conclusion

- The CERN Resonant WISP search (CROWS)
  - Competitive with the currently most sensitive optical LSW experiment for ALPs (ALPS-I)
  - New exclusion limits for HPs (!)
  - Purely Lab based. **Most certain** exclusion limits
  - Not competitive with “non – terrestrial” experiments (but complementary)
- Achieved with a minimum of manpower

Outlook

- Better sensitivity to **ALPs** with:
  - Stronger magnets (free 7 T MRI scanner?)
  - Larger cavities (lower frequency)
  - More RF power (we are only limited by cooling)

- Better sensitivity to **HSPs** with:
  - Superconducting cavities (very challenging to keep them on the same resonant frequency)

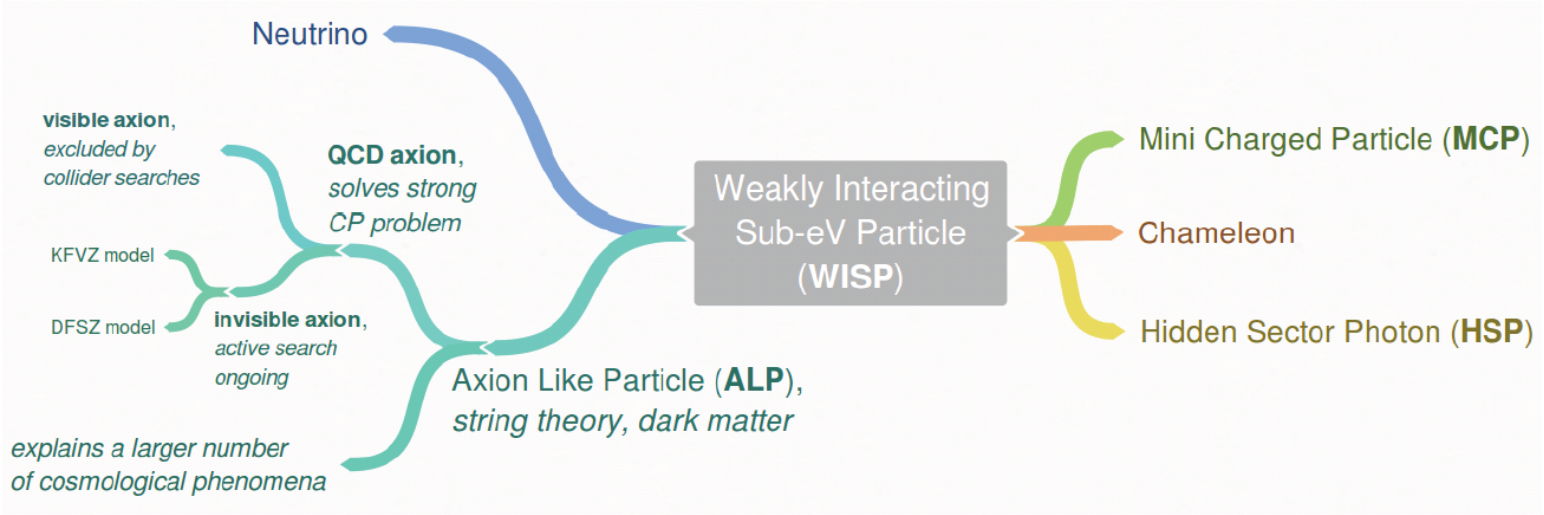
Acknowledgements

- Thanks to S. Rieger and the Brain & Behaviour Laboratory at the University of Geneva for making the ALPs measurement in the MRI magnet possible

- We are grateful for support from R. Jones, E. Jensen and the BE department management at CERN

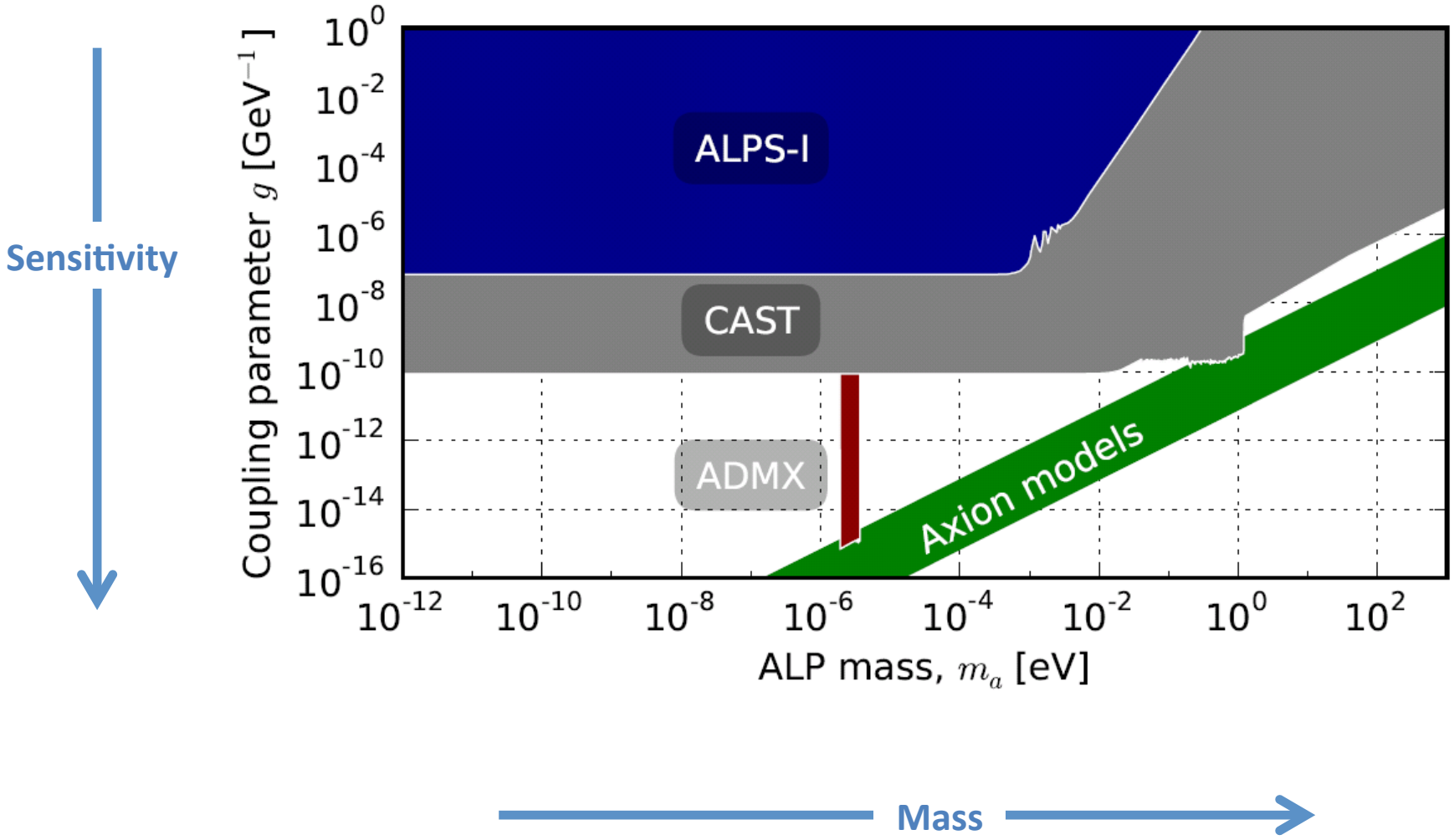
Thank you!

Axions? Hidden Photons? WISPs?



- **QCD axion**:
  - Postulated in 1977 as solution to the "**strong CP-problem**" in the Standard Model (SM)
  - Later generalized to **Axion Like Particles (ALPs)**
- **Hidden Sector Photon (HSP):**
  - Common feature in many SM extensions (String theory, etc.)
- Both turned out to be excellent **dark matter** candidates and can explain many astrophysical phenomena

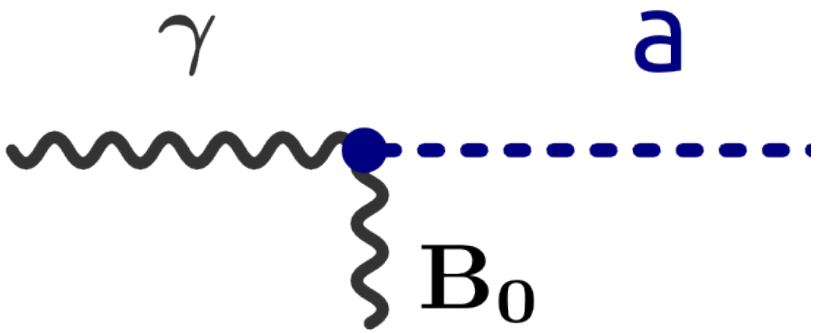
Where we hunt for Axion Like Particles (ALPs)



Detecting WISPs

- WISPs **couple to photons** (and vice versa)
  - **ALPs** by the "Primakoff effect", requires an external magnetic field
  - **HSPs** by kinetic mixing, identical to neutrino oscillations, no magnet needed

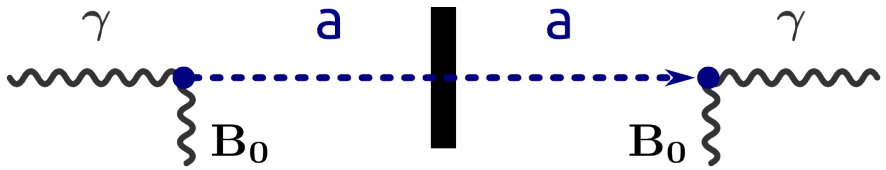
Likelihood of producing a WISP: **Typically < 1 / 10^{24}**



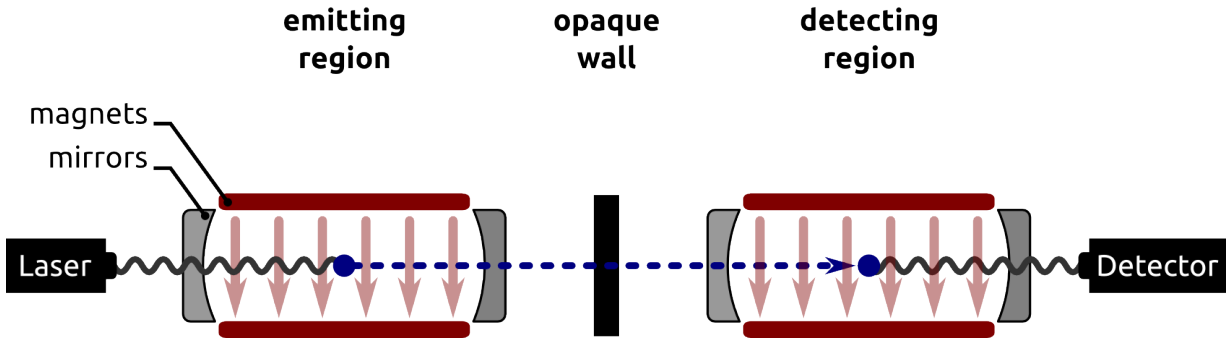
γ = Photon
a = Axion like particle (ALP)
B_0 = Backg. Magn. field

Light shining through the Wall experiments

γ = Photon
a = Axion like particle
$\mathbf{B_0}$ = Backg. Magn. field



The energy of the photon can be between **μeV** (microwave photon) up to **keV** and beyond (gamma quantum)



Optical LSW:

For example "Any Light Particle Search" (**ALPS-I**) at DESY.