Experimental WISP searches

Dark matter and dark matter candidate searches for Axions, ALPs and other WISPs

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DESY

HAP Dark Matter 2015, Karlsruhe, 23 Sept. 2015

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Disclaimer

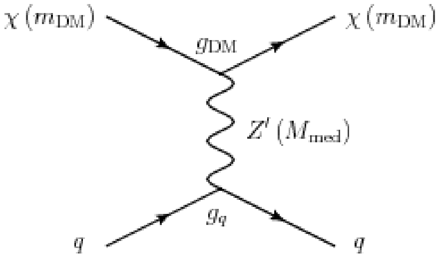
This presentation focuses mainly on hypothetical

very *Weakly Interacting and very lightweight Sub-eV Particles (WISPs),*

which are viable dark matter constituents.

Searches for hypothetical

dark mediators,



which care for self-interacting dark matter and/or dark matter couplings to SM constituents, are not covered here.

The WISP program of this session

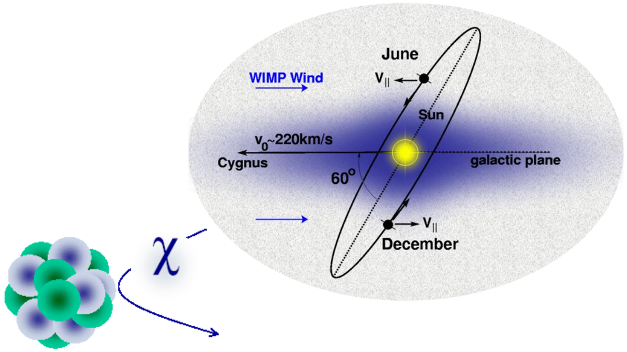
- Dark matter and dark matter candidate search strategies
- Some recollection: Weakly Interacting Sub-eV (Slim) Particles

- Direct dark matter searches
- Indirect dark matter searches

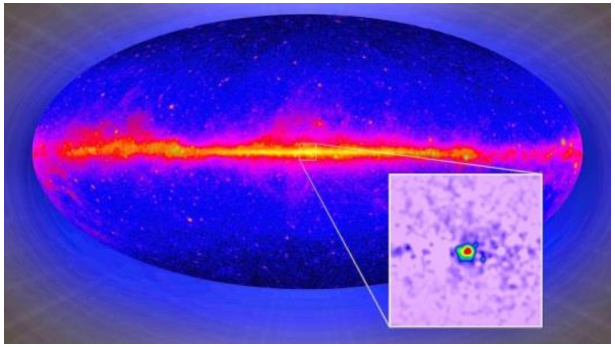
- Direct searches for WISPs as dark matter candidates
- Indirect searches for WISPs as dark matter candidates

Dark matter search strategies: WIMPs

- Direct:
  detecting particles of the DM halo



- Indirect:
  finding astrophysical signatures
  of the DM halo constituents.



Dark matter search strategies: WISPs

- Direct:
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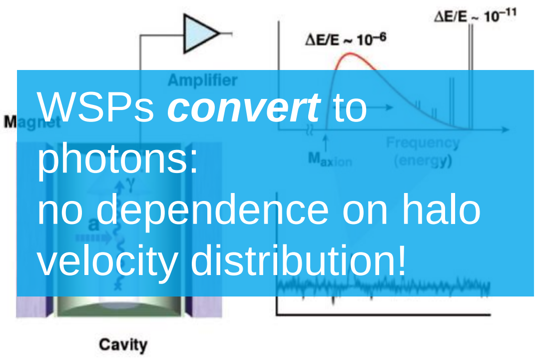
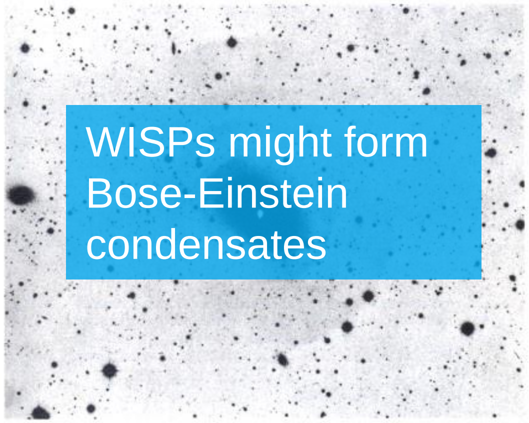


WSPs ***convert*** to photons:
no dependence on halo velocity distribution!

- Indirect:
  finding astrophysical signatures of the DM halo constituents.



WISPs might form Bose-Einstein condensates

Figure 7-22. The giant elliptical galaxy NGC 3923 is surrounded by faint ripples of brightness. Courtesy of D. F. Malin and the Anglo-Australian Telescope Board.

Dark matter candidate search strategies:

- Laboratory experiments:
  finding (possible) candidates

- Astrophysics:
  identifying phenomena hinting at new particles which could be the dark matter constituents

Dark matter candidate search strategies: WIMPs

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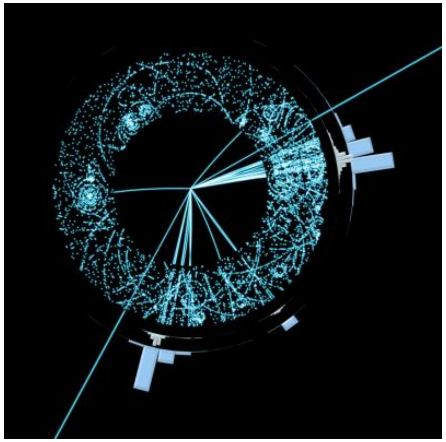

- Astrophysics:
  identifying phenomena hinting at new particles which could be the dark matter constituents

In general: the high WIMP mass prohibits significant influence in present day's astrophysics.

Dark matter candidate search strategies: WISPs

- Laboratory experiments:
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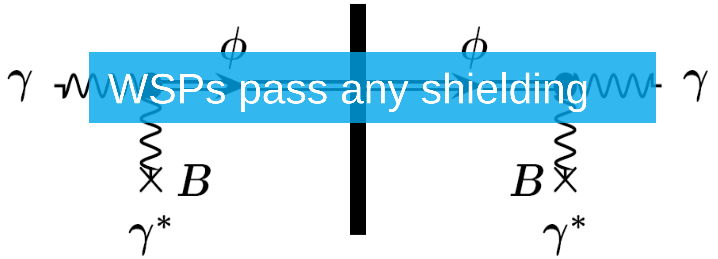

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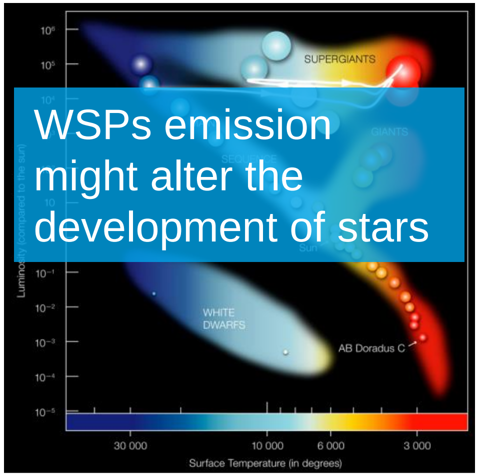
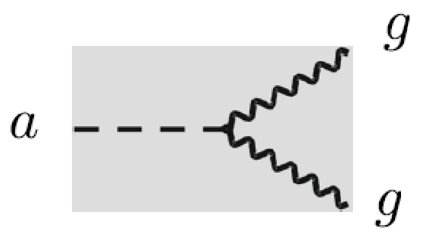


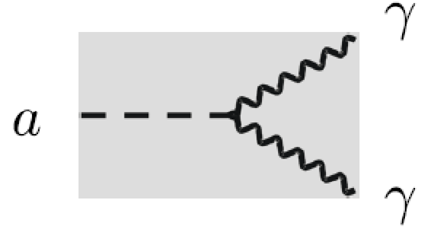
https://physics.aps.org/assets/d3e15240-0e17-4941-9195-f9fb739a1058/e14_1.png

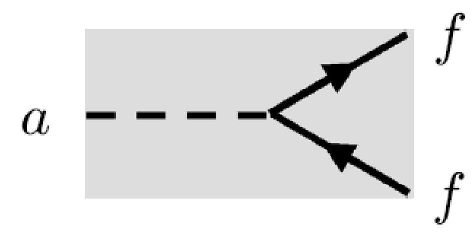
Recollection: axion and ALP couplings

- Axion and other Nambu-Goldstone bosons arising from spontaneous breakdown of global symmetries are theoretically well-motivated very weakly interacting slim (ultra-light) particles.
  The coefficients are determined by specific ultraviolet extension of SM.

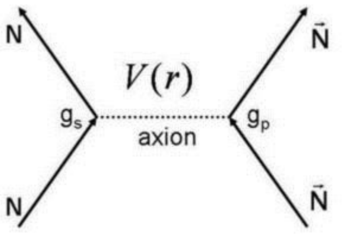
$$\mathcal{L} \supset -\frac{\alpha_s}{8\pi}\frac{C_{ag}}{f_a}\, a\, G^b_{\mu\nu}\tilde{G}^{b,\mu\nu} - \frac{\alpha}{8\pi}\frac{C_{a\gamma}}{f_a}\, a\, F_{\mu\nu}\tilde{F}^{\mu\nu} + \frac{1}{2}\frac{C_{af}}{f_a}\partial_\mu a\, \overline{\psi}_f\gamma^\mu\gamma_5\psi_f$$

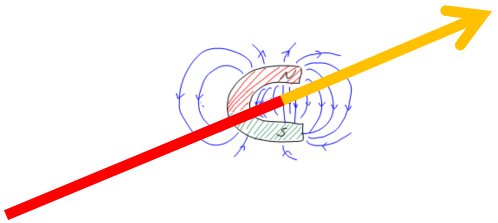


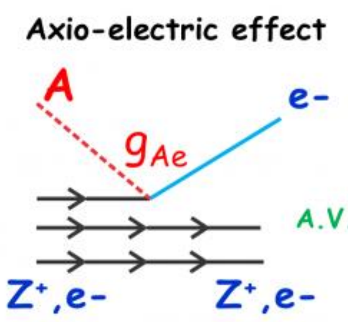




Courtesy A. Ringwald

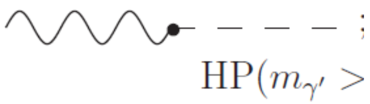




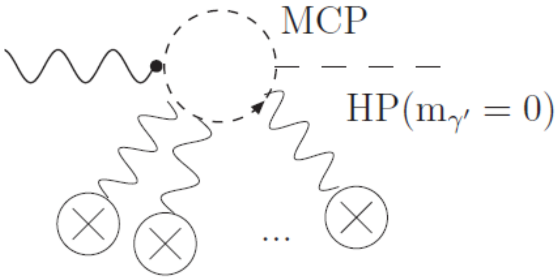


Recollection: hidden photons and other WISPs

- Hidden photons (neutral vector bosons):



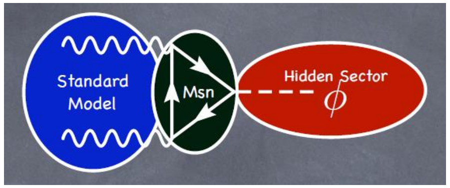
- Mini-charged particles:

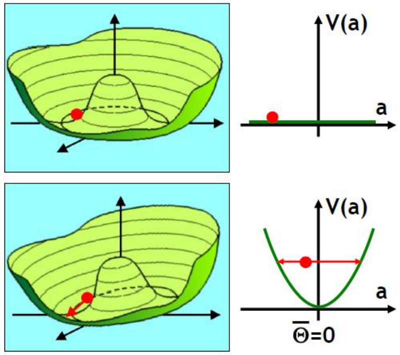


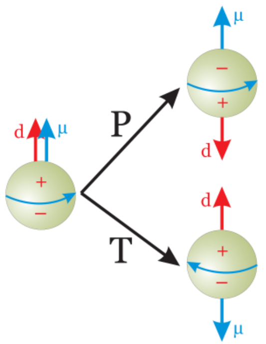
- Chameleons (self-shielding scalars), massive gravity scalars, might be related to dark energy.

Introducing this session's dark matter candidates: WISPs

- Weakly Interacting Slim Particles (WISPs)
  - Theory: WISPs might arise as (pseudo) Goldstone bosons related to extra dimensions in theoretical extensions (like string theory) of the standard model.
  - Dark matter: in the early universe WISPs are produced in phase transitions and would compose very cold dark matter in spite of their low mass.
  - Additional benefit: with axions (the longest known WISP) the CP conservation of QCD could be explained, axion-like particles could explain different astrophysical phenomena.







- Prediction:
  Dark matter is composed out of elementary particles with masses below 1 meV. Its number density is larger than 10^{12} 1/cm^3.

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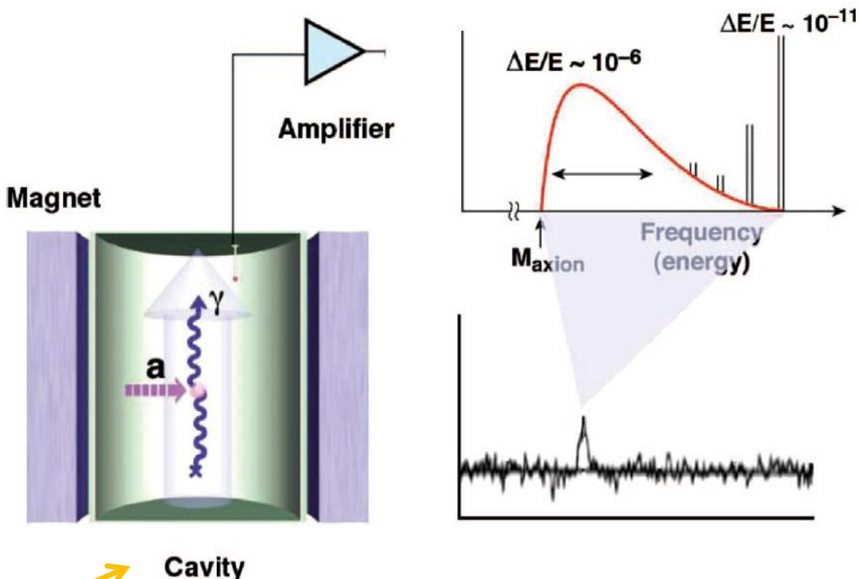
http://thisdarkmatter.com/reviews/lockwood-co-just-dark-enough/

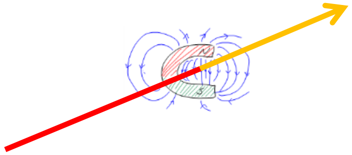
WISP experiments (a personal selection)

- Direct dark matter searches
  - ADMX (US), WISPDMX (Hamburg) — Axion, ALP, HP
  - FUNK (KIT) — HP
  - CASPEr (Mainz) — Axion, ALP
- Indirect dark matter searches
  - Just a comment on BECs — Axion, ALP, HP

WISPy dark matter: option I

- Make dark matter WISPs convert to photons in an otherwise dark environment.
  P. Sikivie, Experimental Tests of the "Invisible" Axion, Phys. Rev. Lett. 51, 1415 (1983):
- When converting to photons, the photon energy is given by the WISP rest mass + an O(10^{-6}) correction (WISPs move non-relativistic).





$$P_{a\rightarrow\gamma} \propto \left(B_0^2 V Q\right)\left(g_\gamma^2 \frac{\rho_a}{m_a}\right)$$

Cavity volume

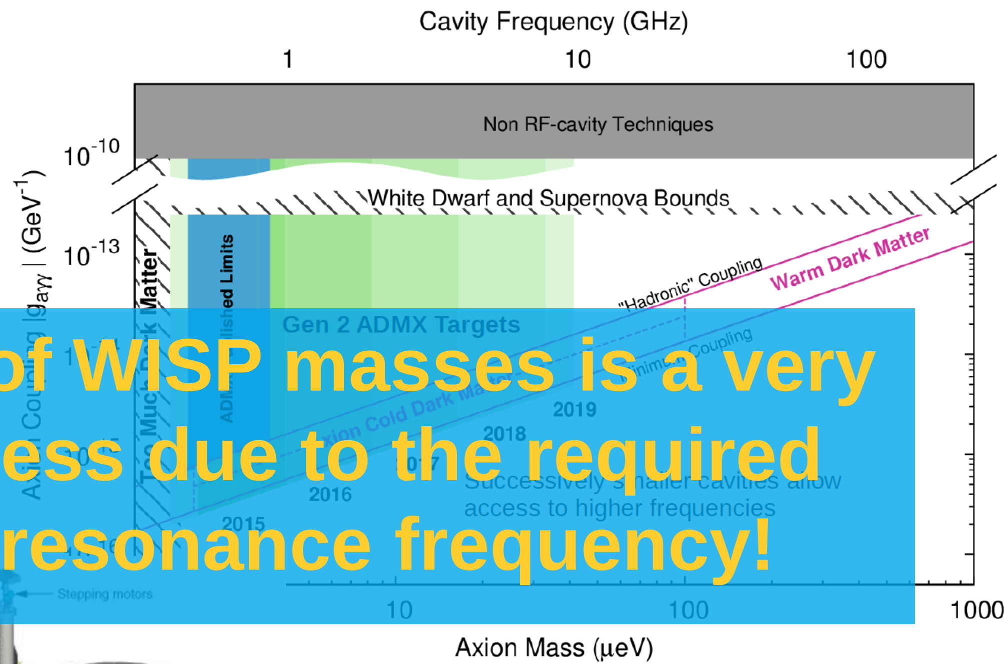
Cavity power build-up: the cavity frequency has to match m_a!

Axion number density

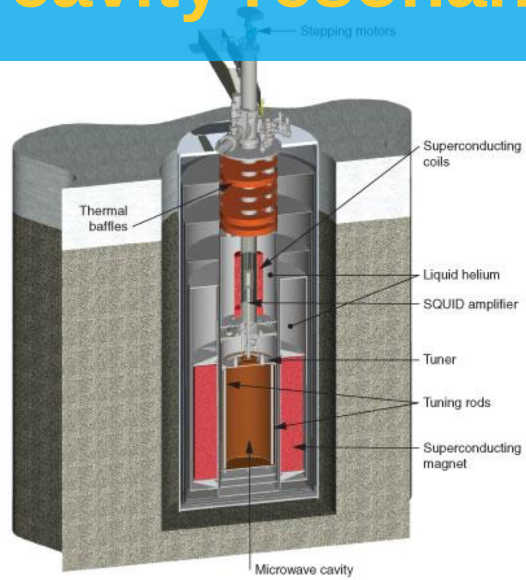
The Axion Dark Matter eXperiment

- ADMX at Washington Univ., Seattle.
- Sufficient sensitivity to detect DM axions,
  - if axions happen to have the right mass.

Probing a large range of WISP masses is a very time consuming process due to the required tuning of the cavity resonance frequency!



G. Rybka, PATRAS 2015



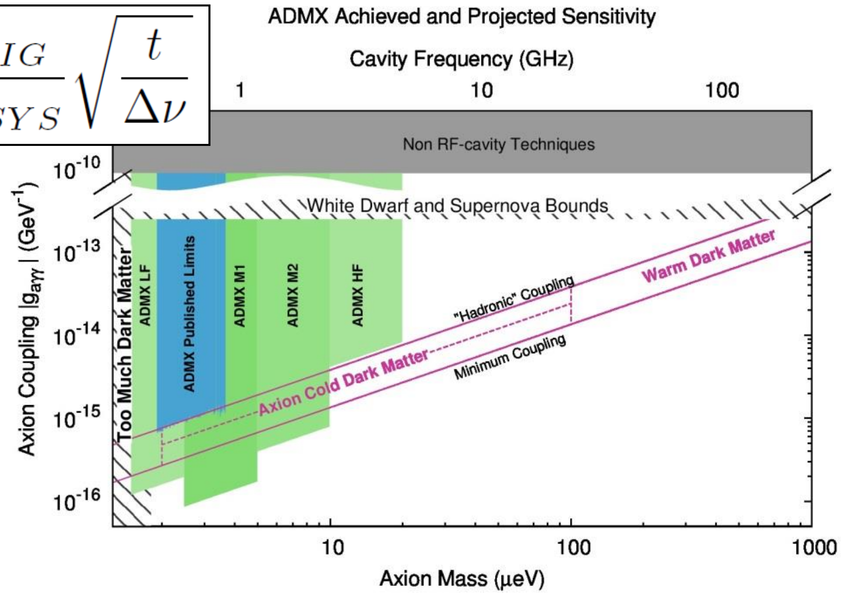
The Search for Axions, Carosi, van Bibber, Pivovaroff, Contemp. Phys. 49, No. 4, 2008

Extending the DM search mass range

> Improve on cavity experiments

- ADMX will be upgraded with a new SQUID amplifier and dilution refrigerator to cover a mass region up to 10 µeV.
- ADMX-HF will be a pathfinder for higher masses and test-bed for hybrid superconducting cavities (to be placed in a 10 T field). Up to a few 10 µeV?
- For searches above 10 GHz photonic-band-gap cavities are evaluated.

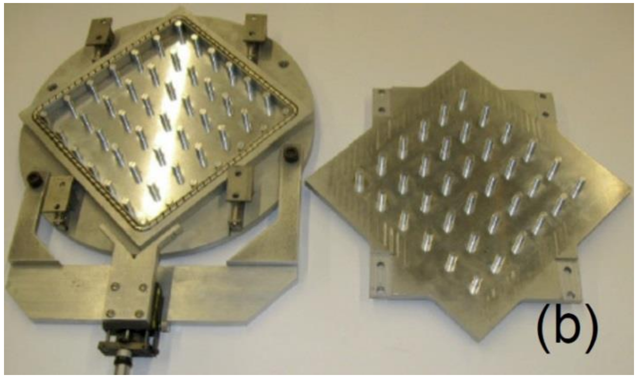
$$\frac{S}{N} = \frac{P_{SIG}}{kT_{SYS}}\sqrt{\frac{t}{\Delta\nu}}$$



http://www.phys.washington.edu/groups/admx/home.html

Get smaller! → $\frac{\rho_a}{m_a}$, V

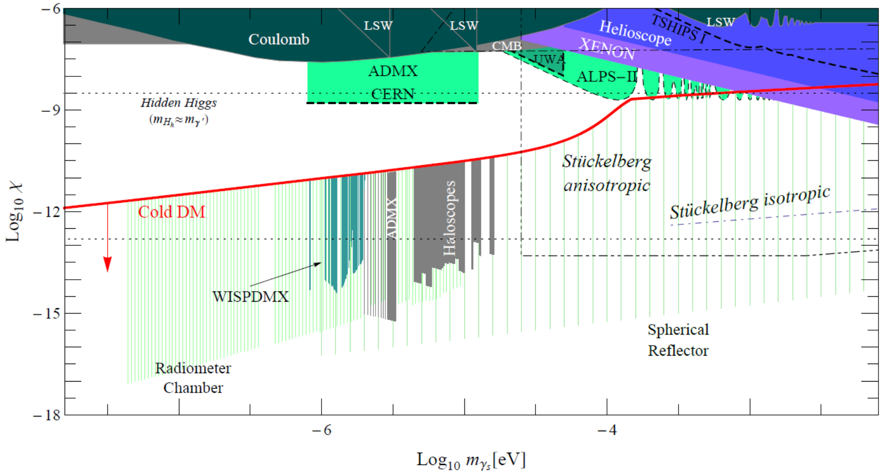
$$P_{a\to\gamma} \propto \left(B_0^2 V Q\right)\left(g_\gamma^2 \frac{\rho_a}{m_a}\right)$$

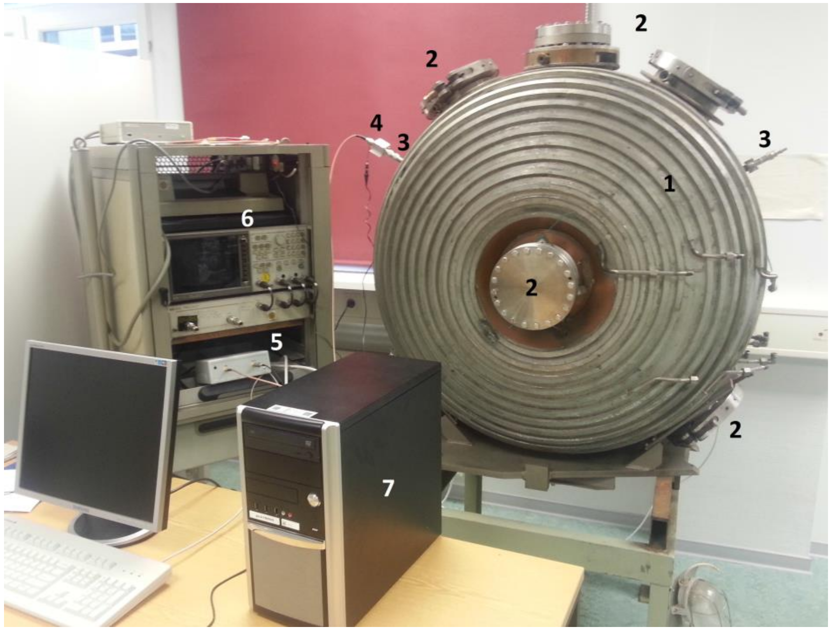


arXiv:1405.3685 [physics.ins-det]

WISPDMX in Hamburg

- A 208 MHz cavity from the HERA accelerator is used to search for hidden photons below the ADMX mass range.



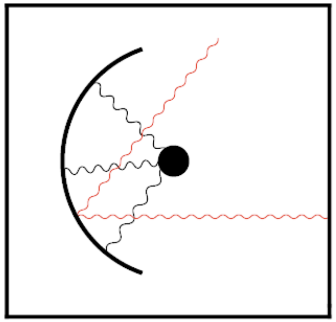


http://arxiv.org/abs/1410.6302

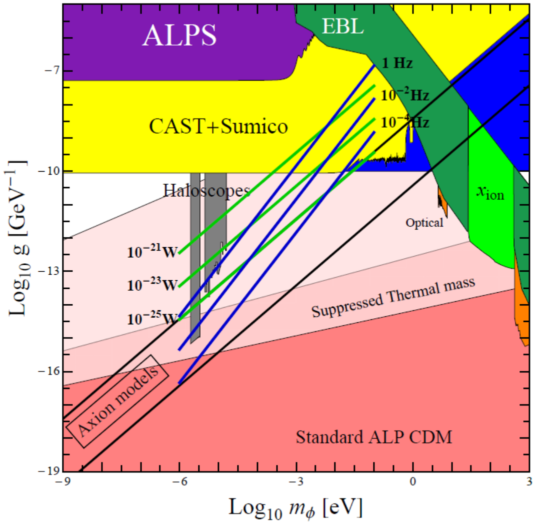
- If a suitable magnet is found, axions and ALPs can be searched for.

WISPy dark matter: option II

- Convert dark matter to photons, but do not exploit resonance effects to achieve a broad acceptance in mass.
  - If the WISP wave function encounters a sharp reflecting surface a (tiny) electromagnetic wave is reflected.
  - This wave is emitted perpendicular to a reflecting surface (assuming cold dark matter).
  - This emission can be concentrated onto a photon detector.
  - Axions/ALPs: with dish sizes of 1m^2 in a 5T field competitive sensitivities can be reached.



$$g_{\phi\gamma\gamma,\,\mathrm{sens}} = \frac{4.6\times10^{-6}}{\mathrm{GeV}}\left(\frac{5\,\mathrm{T}}{\sqrt{\langle|\mathbf{B}_{||}|^2\rangle}}\right)\left(\frac{R_{\gamma,\mathrm{det}}}{1\,\mathrm{Hz}}\right)^{\frac{1}{2}}\left(\frac{m_\phi}{\mathrm{eV}}\right)^{\frac{3}{2}}\left(\frac{0.3\,\mathrm{GeV/cm^3}}{\rho_{\mathrm{DM,halo}}}\right)^{\frac{1}{2}}\left(\frac{1\,\mathrm{m}^2}{A_{\mathrm{dish}}}\right)^{\frac{1}{2}}$$

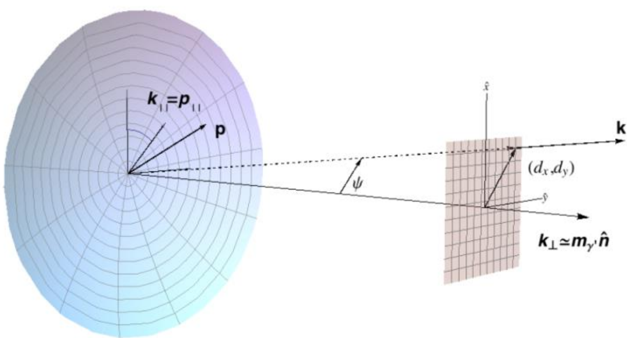


D. Horns et al., JCAP04 (2013) 016

Seeing the dark matter halo!

- This "dish antenna" approach even allows to measure the DM velocity distribution with respect to the dish!

J. Jaeckel, J. Redondo, JCAP11 (2013) 016



For some theory:

PHYSICAL REVIEW D 88, 115002 (2013)

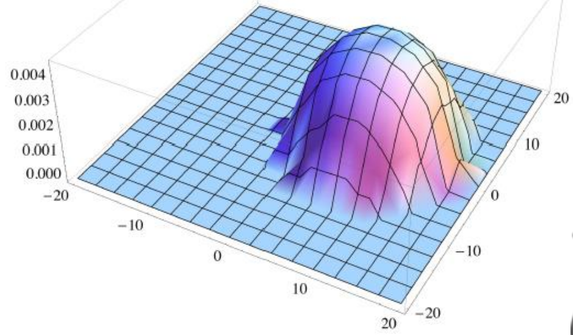
Resonant to broadband searches for cold dark matter consisting of weakly interacting slim particles

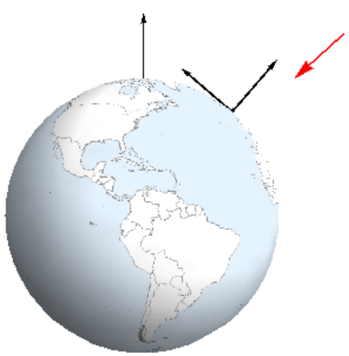
Joerg Jaeckel[1] and Javier Redondo[2,3]

[1]*Institut für theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany*
[2]*Arnold Sommerfeld Center, Ludwig-Maximilians-Universität, Theresienstrasse 37, 80333 Munich, Germany*
[3]*Max-Planck-Institut für Physik, Fohringer Ring 6, 80805 Munich, Germany*

(Received 6 September 2013; published 2 December 2013)

Image on a CCD





Thanks to J. Redondo

FUNK: a KIT- DESY study

- Pilot “dish” experiment searching for hidden photons: **F**inding **U**(1)s of a **N**ovel **K**ind.

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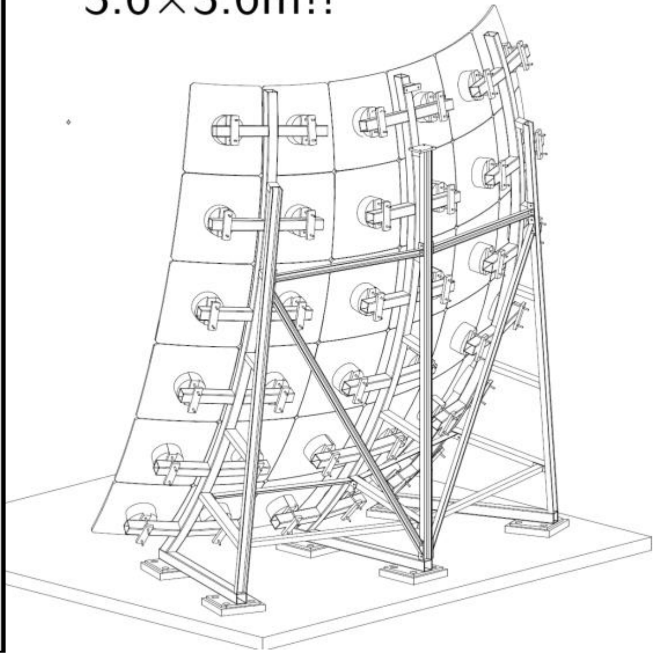
Alliance for Astroparticle Physics

Thanks to HAP for the PMT $!

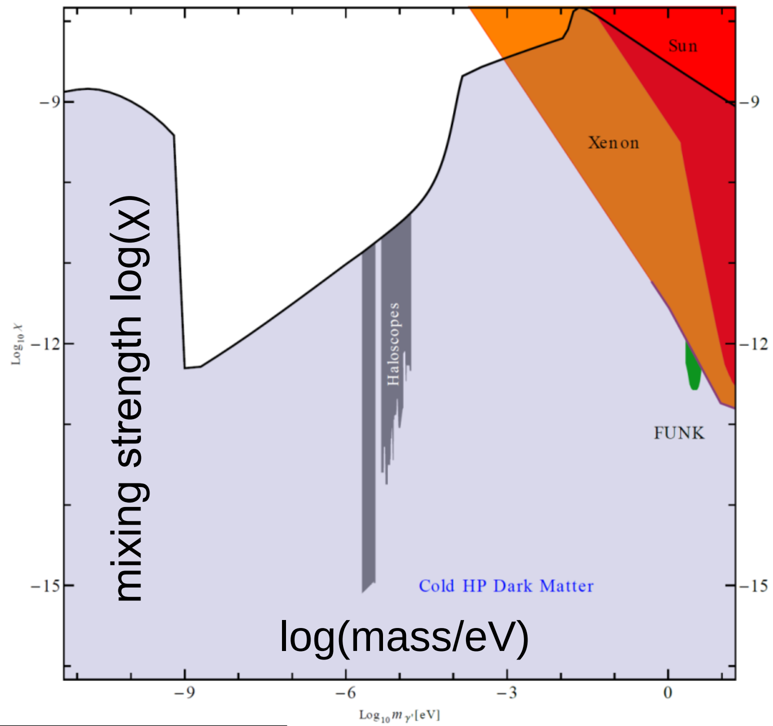
3.6×3.6m!!



Hidden photons convert to light at a spare mirror system of the AUGER fluorescence telescopes, which is focused onto a photomultiplier.

FUNK: a KIT- DESY study

- However, to find dark matter soon a little luck is required.
- Most important:
  getting started with a new experimental approach!
- More info at:
  arXiv:1501.03274



Hidden Photon Dark Matter Search with a Large Metallic Mirror

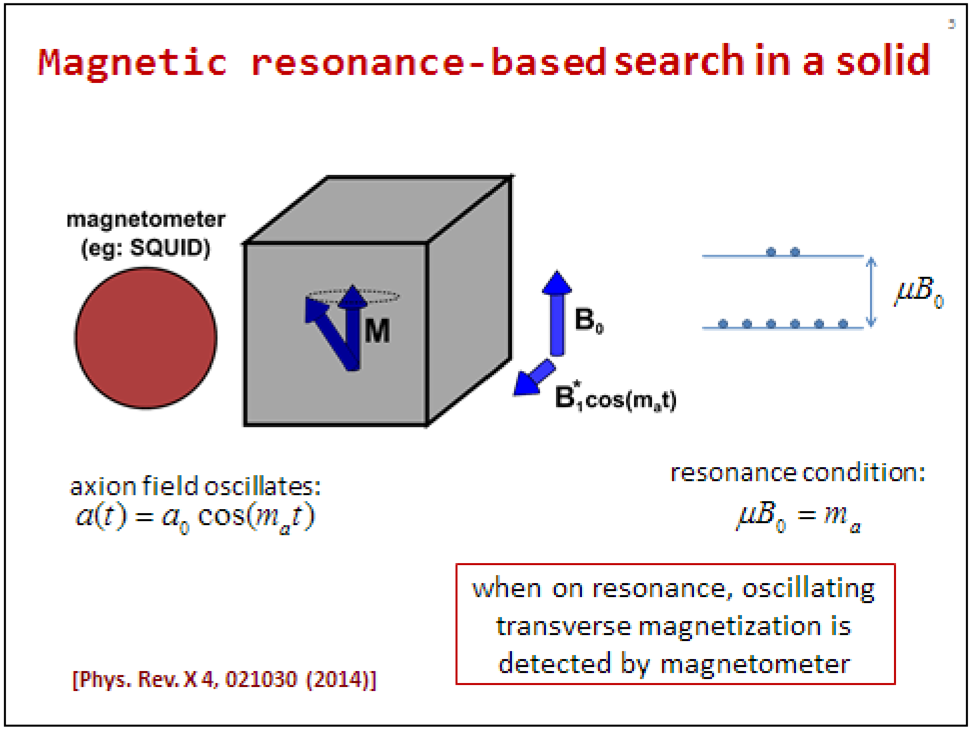
Babette Döbrich[1], Kai Daumiller[2], Ralph Engel[2], Marek Kowalski[1,3], Axel Lindner[1], Javier Redondo[4], Markus Roth[2]

[1]Deutsches Elektronen-Synchrotron (DESY), 22607 Hamburg and 15738 Zeuthen, Germany
[2]Karlsruher Institut für Technologie (KIT), IKP, 76021 Karlsruhe, Germany
[2]Humboldt Universität, Institut für Physik, 12489 Berlin, Germany
[4]Zaragoza University, Pedro Cerbuna 12, E-50009 Zaragoza, Spain

WISPy dark matter: option III

Exploit time-dependent effects:

- Axions (and other dark matter WISPs) are the quanta of an oscillating field in the universe: $a(t) = a_0 \cdot \cos(ma \cdot t)$
- This oscillating field induces an oscillating electric dipole moment:
  $d \approx 3\times10^{-16}(a/f_a)\,e\cdot cm$
- This can be searched for in NMR-like experiments.



A. Sushkov, PATRAS 2015

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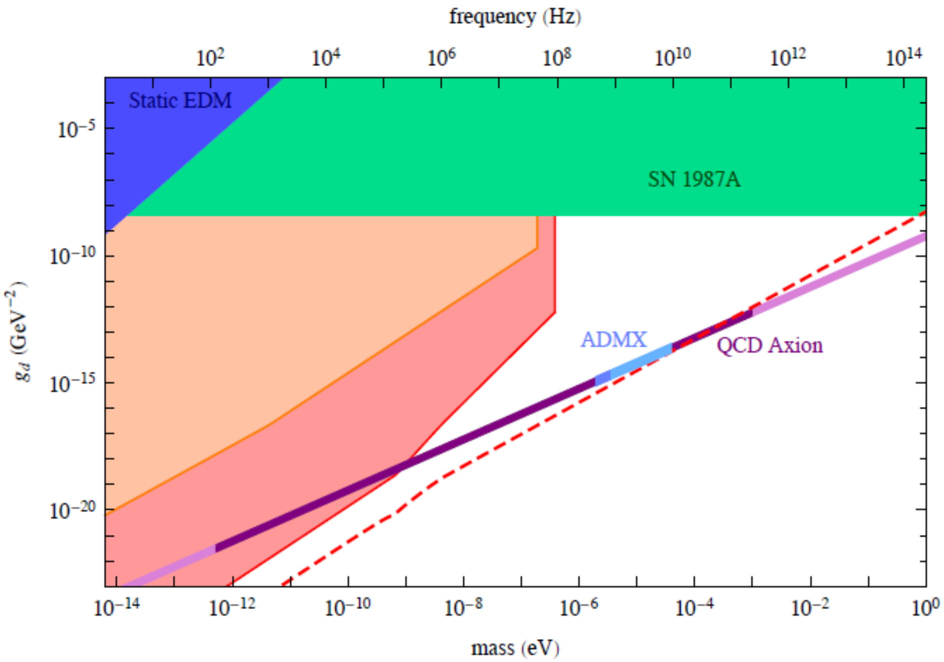
- This can be searched for in NMR-like experiments.
- NMR experiments would concentrate on very low mass DM candidates.



DESY

WISPy dark matter: option III

PHYSICAL REVIEW X **4**, 021030 (2014)

Proposal for a Cosmic Axion Spin Precession Experiment (CASPEr)

Dmitry Budker,[1,5] Peter W. Graham,[2] Micah Ledbetter,[3] Surjeet Rajendran,[2] and Alexander O. Sushkov[4]

[1]*Department of Physics, University of California, Berkeley, California 94720, USA*
and Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
[2]*Department of Physics, Stanford Institute for Theoretical Physics, Stanford University, Stanford, California 94305, USA*
[3]*AOSense, 767 North Mary Avenue, Sunnyvale, California 94085-2909, USA*
[4]*Department of Physics and Department of Chemistry and Chemical Biology, Harvard University, Cambridge, Massachusetts 02138, USA*
[5]*Helmholtz Institute Mainz, Johannes Gutenberg University, 55099 Mainz, Germany*

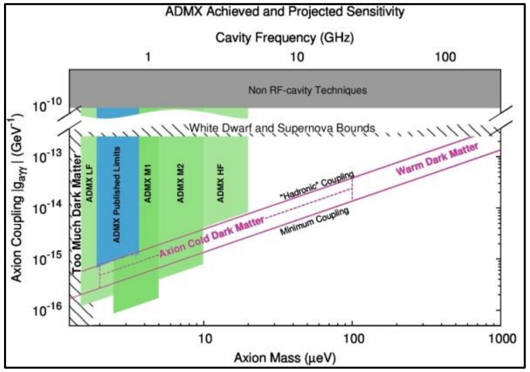
(Received 9 July 2013; published 19 May 2014)

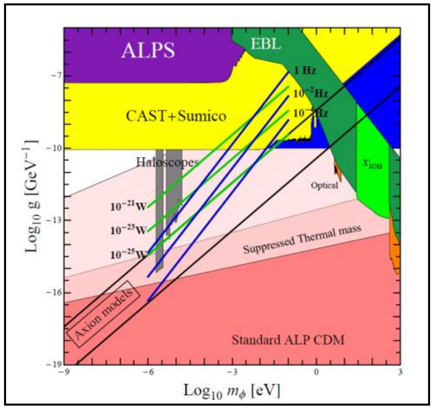
Summary on direct WISPy dark matter searches

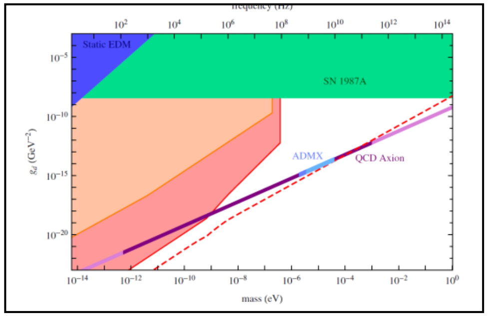
- **>** Option I:
  resonating cavity experiments
  can probe the most promising
  dark matter axion parameter space.

- **>** Option II:
  proposals for dish experiments which
  allow for quick axion / ALP searches
  and measurements of the DM halo
  velocity distribution.

- **>** Option III:
  proposals for NMR-like experiments
  which allow for axion / ALP searches
  at very low masses.







Indirect WISPy dark matter searches

- Dark matter WISPs, which do not originate from a thermal freeze-out process, but have been produced by a phase transition, are extremely cold and might even form Bose-Einstein condensates (BECs).
- Ultralight WISPy ($m<10^{-20}$ eV, $\lambda_c>10^{13}$ m) dark matter would suppress small scale structure formation.
- Very lightweight WISPs might mimic dark energy.

PHYSICAL REVIEW D **78,** 063508 (2008)

Caustic ring model of the Milky Way halo

L. D. Duffy[1,*] and P. Sikivie[2,+]
[1]*Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[2]*University of Florida, Gainesville, Florida 32611, USA*
(Received 30 May 2008; published 5 September 2008)

A search for ultralight axions using precision cosmological data

Renée Hlozek,[1] Daniel Grin,[2] David J. E. Marsh,[3,*] and Pedro G. Ferreira[4]
[1]*Department of Astronomy, Princeton University, Princeton, NJ 08544, USA*
[2]*Kavli Institute for Cosmological Physics, Department of Astronomy and Astrophysics, University of Chicago, Chicago, Illinois, 60637, U.S.A.*
[3]*Perimeter Institute, 31 Caroline Street N, Waterloo, ON, N2L 6B9, Canada*
[4]*Astrophysics, University of Oxford, DWB, Keble Road, Oxford, OX1 3RH, UK*
(Dated: May 22, 2015)

Phys. Rev. D 91, 103512 (2015)

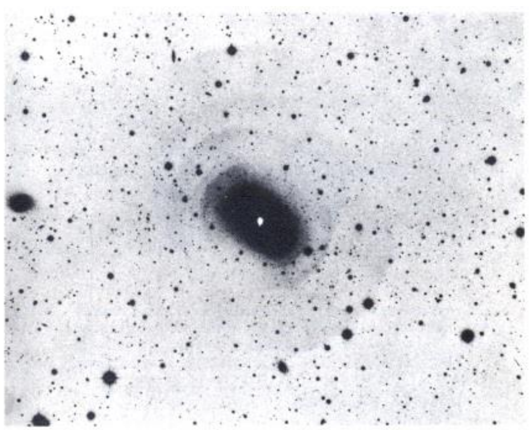


Figure 7-22. The giant elliptical galaxy NGC 3923 is surrounded by faint ripples of brightness. Courtesy of D. F. Malin and the Anglo-Australian Telescope Board.

Cosmological implications of WISPy dark matter: work in progress, very interesting!

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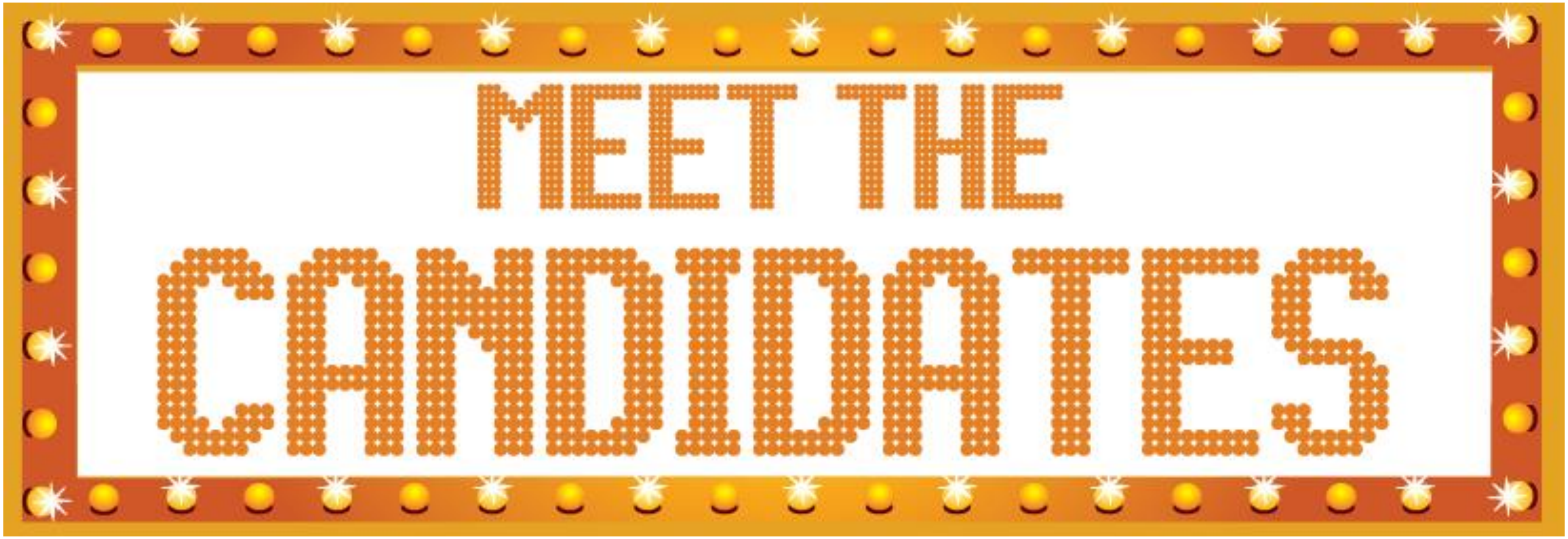
- Indirect searches for WISPs as dark matter candidates

WISPy dark matter candidates



WISP experiments (a personal selection)

> Direct searches for WISPs as dark matter candidates

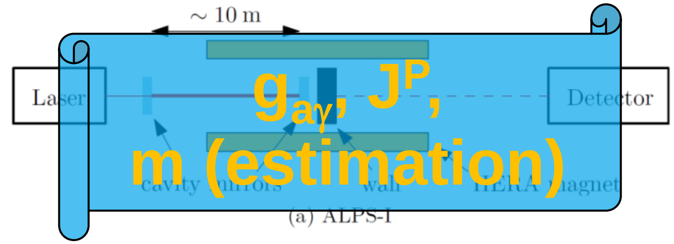
- Laboratory: ALPS (DESY) — ALP, HP
- Helioscopes: SHIPS, CAST (CERN)+IAXO, EDELWEISS — Axion, ALP, HP

> Indirect searches for WISPs as dark matter candidates

- TeV transparency of the universe — ALP
- Development of stars — Axion, ALP, (HP)

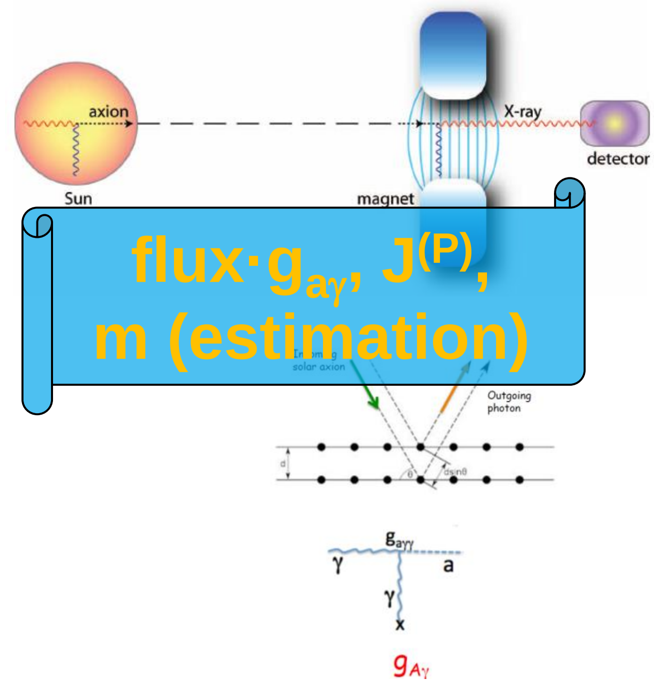
Direct searches for WISPs as dark matter candidates

- Experiments in the laboratory



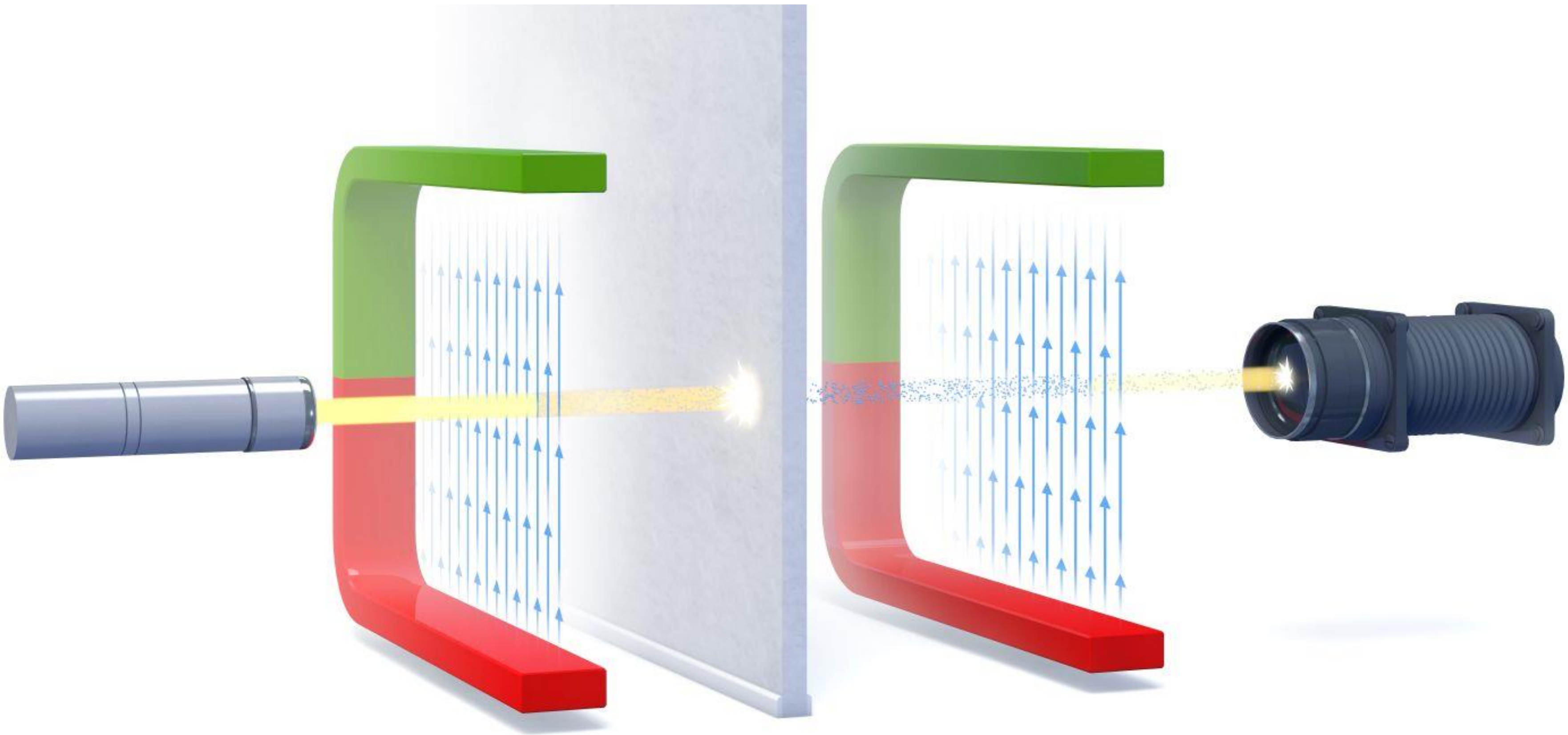
$g_{a\gamma}$, J^P,
m (estimation)

- Helioscopes



flux·$g_{a\gamma}$, $J^{(P)}$,
m (estimation)

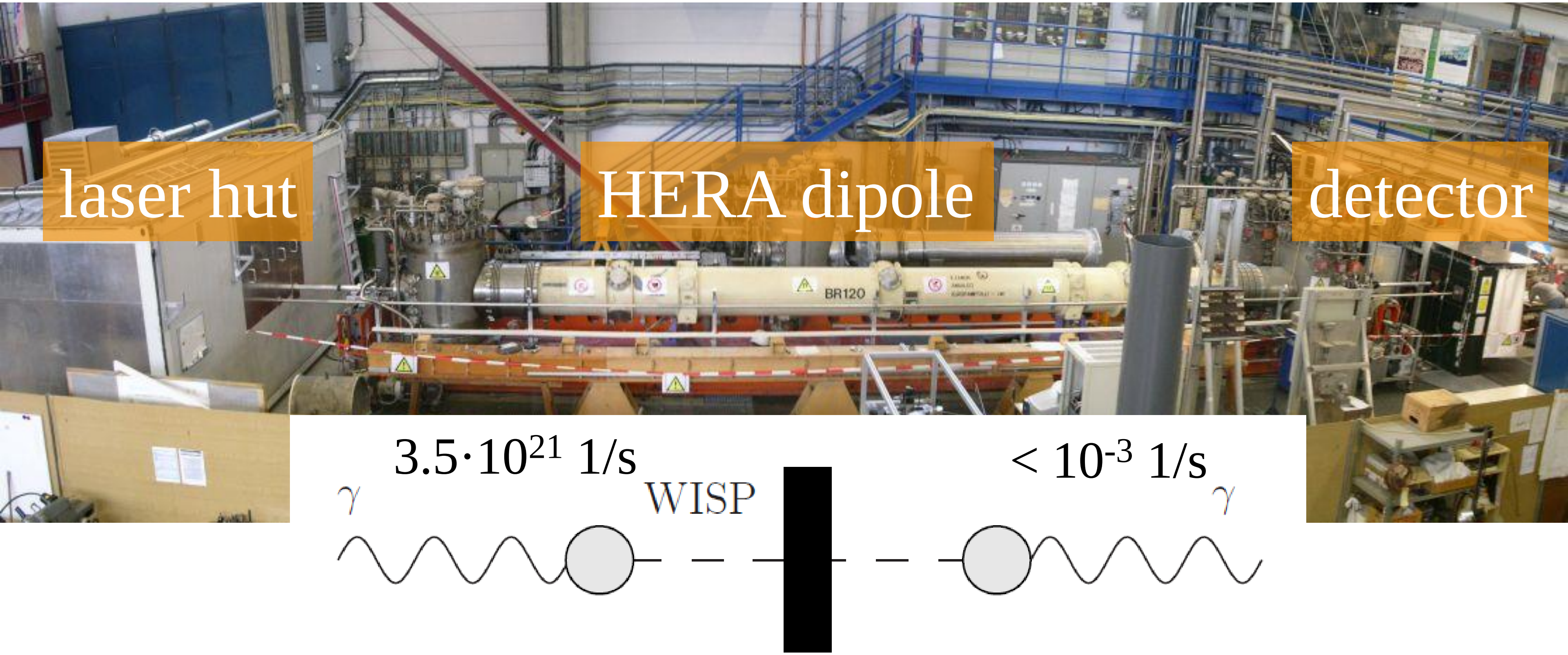
Laboratory experiments



ALPS I 2007-2010

(PLB Vol. 689 (2010), 149, or http://arxiv.org/abs/1004.1313)

> Unfortunately, no light was shining through the wall!



> The most sensitive WISP search experiment in the laboratory (nearly).

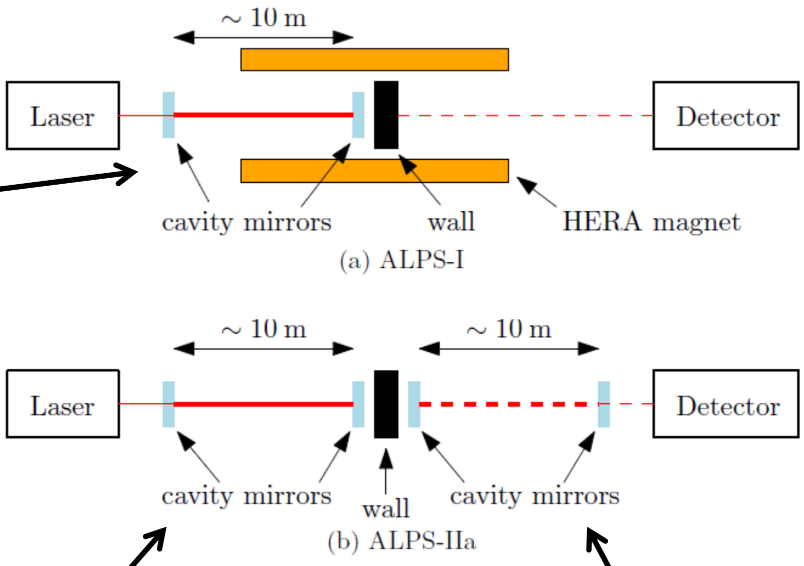
Prospects for ALPS II @ DESY

- Laser with optical cavity to recycle laser power, switch from 532 nm to 1064 nm, increase effective power from 1 to 150 kW.
- Magnet: upgrade to 10+10 straightened HERA dipoles instead of ½+½ used for ALPS I.
- Regeneration cavity to increase WISP-photon conversions, single photon counter (superconducting transition edge sensor).

All set up in a clean environment!

ALPS II essentials: laser & optics

ALPS I:
basis of success was the optical resonator in front of the wall.



> **ALPS IIa**

Optical resonator to increase effective light flux by recycling the laser power

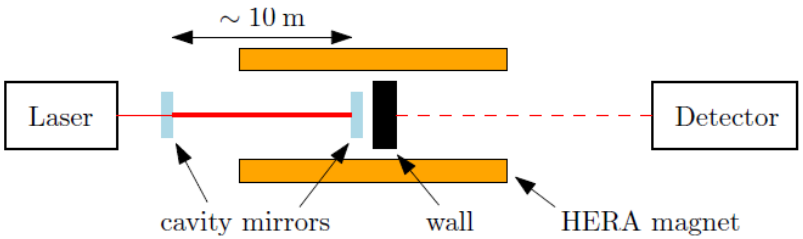
Optical resonator to increase the conversion probability

WISP→γ

First realization of a 23 year old proposal!

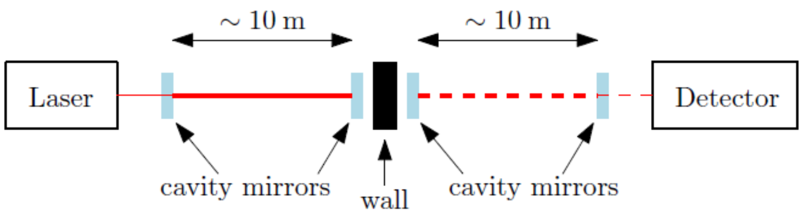
ALPS II is realized in stages

ALPS I



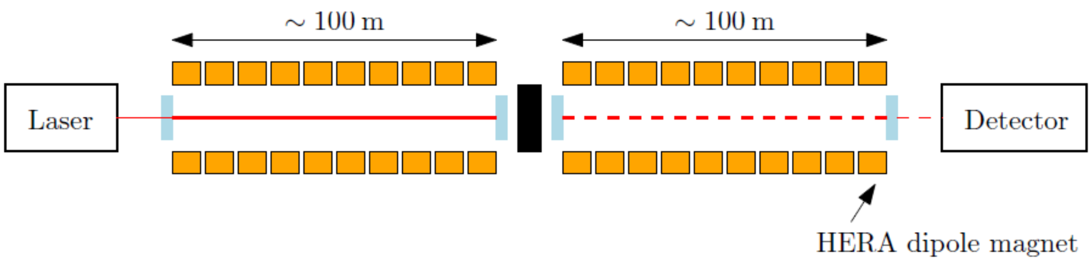
(a) ALPS-I

> **ALPS IIa**



(b) ALPS-IIa

> **ALPS IIc**



(d) ALPS-IIc

The ALPS II challenge

> Photon regeneration probability:

$$P_{\gamma\to\phi\to\gamma} = \frac{1}{16} \cdot \mathcal{F}_{PC}\mathcal{F}_{RC} \cdot (g_{a\gamma\gamma} B l)^4 = 6 \cdot 10^{-38} \cdot \mathcal{F}_{PC}\mathcal{F}_{RC} \cdot \left(\frac{g_{a\gamma\gamma}}{10^{-10} GeV^{-1}} \frac{B}{1\,T} \frac{l}{10 m} \right)^4$$

> ALPS II:

- F_{PC} = 5000, F_{RC} = 40000 (power build-up in the optical resonators)
- B = 5.3 T, l = 88 m

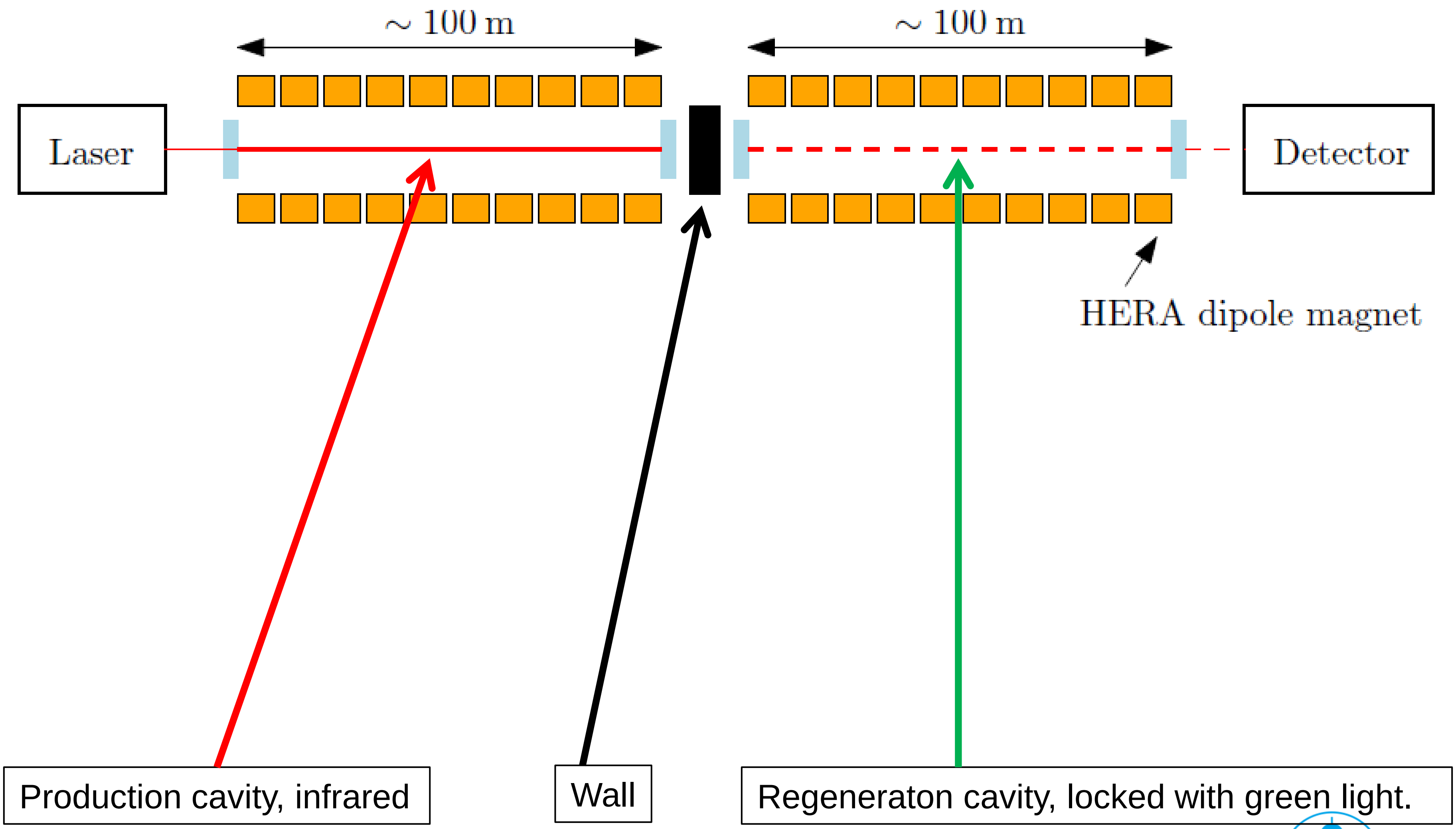
$P_{\gamma\to\phi\to\gamma}$ = $6 \cdot 10^{-23}$ for g=10^{-10}GeV^{-1} resp. $6 \cdot 10^{-27}$ for g=10^{-11}GeV^{-1}

- With a laser power of 35 W (1064 nm):

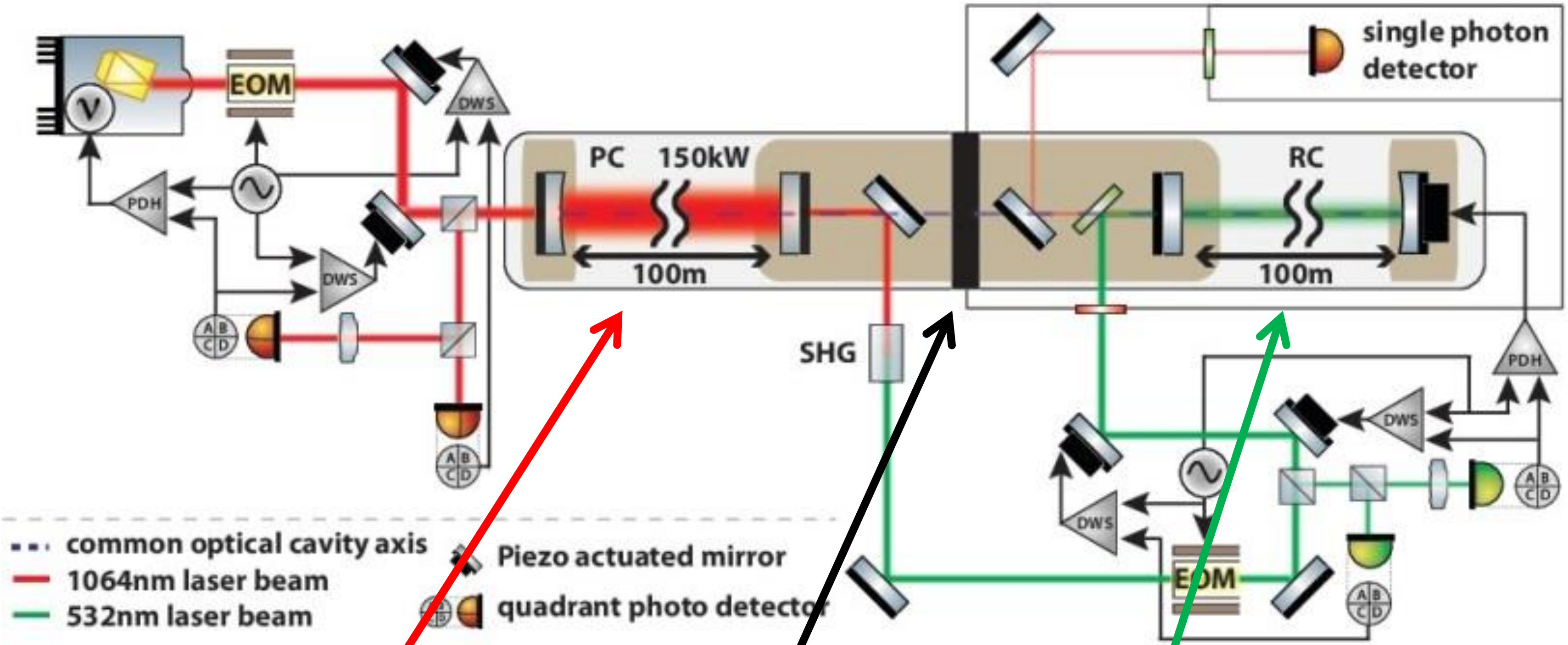
expected photon rates:
dn/dt = 30 h^{-1} for g=10^{-10}GeV^{-1} resp. 3 month^{-1} for g=10^{-11}GeV^{-1}

> ALPS II will probe the ALP region indicated by astrophysics phenomena (see later).

ALPS II optics



ALPS II optics

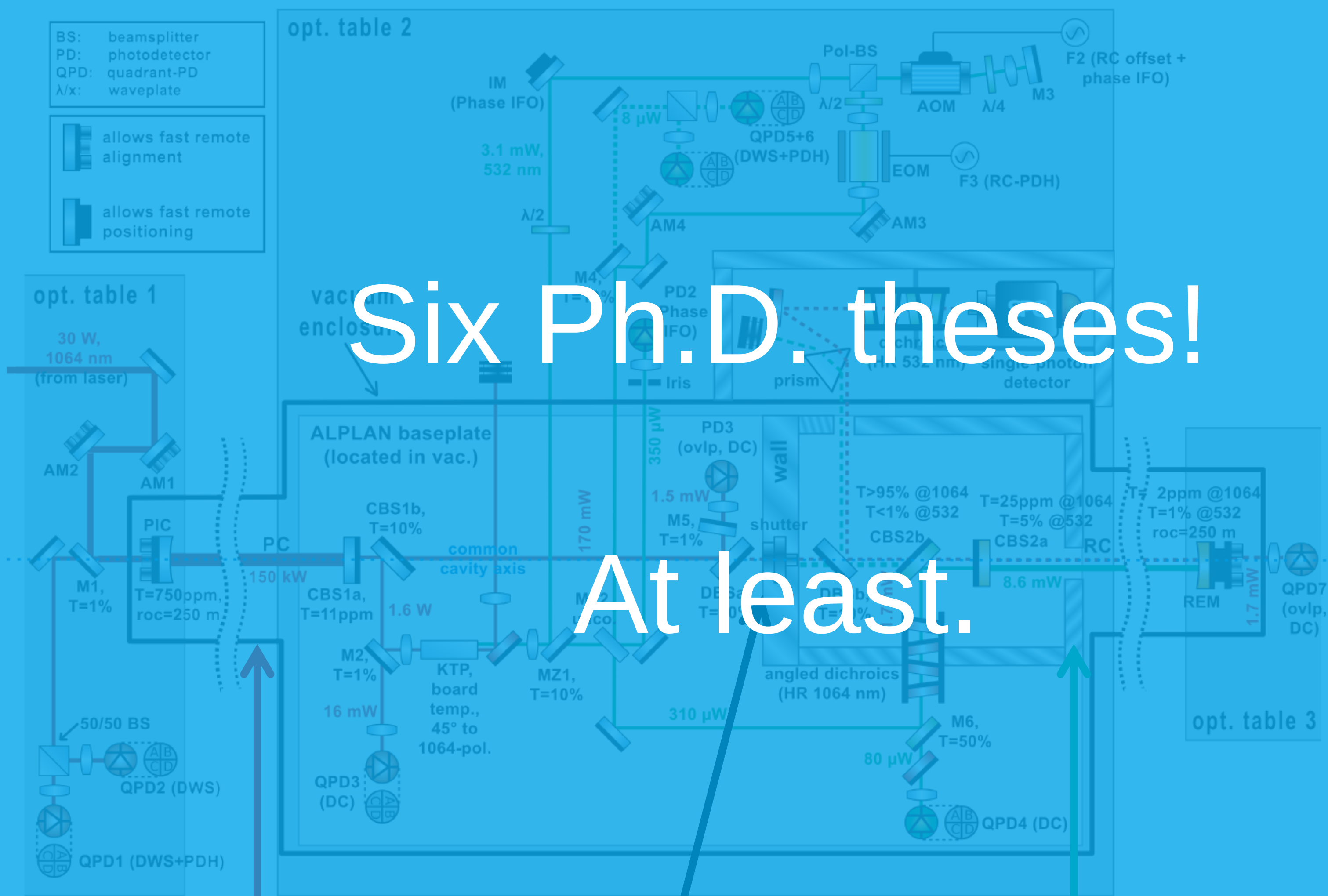


Production cavity, infrared

Wall

Regeneraton cavity, locked with green light.

ALPS II optics



Six Ph.D. theses!

At least.

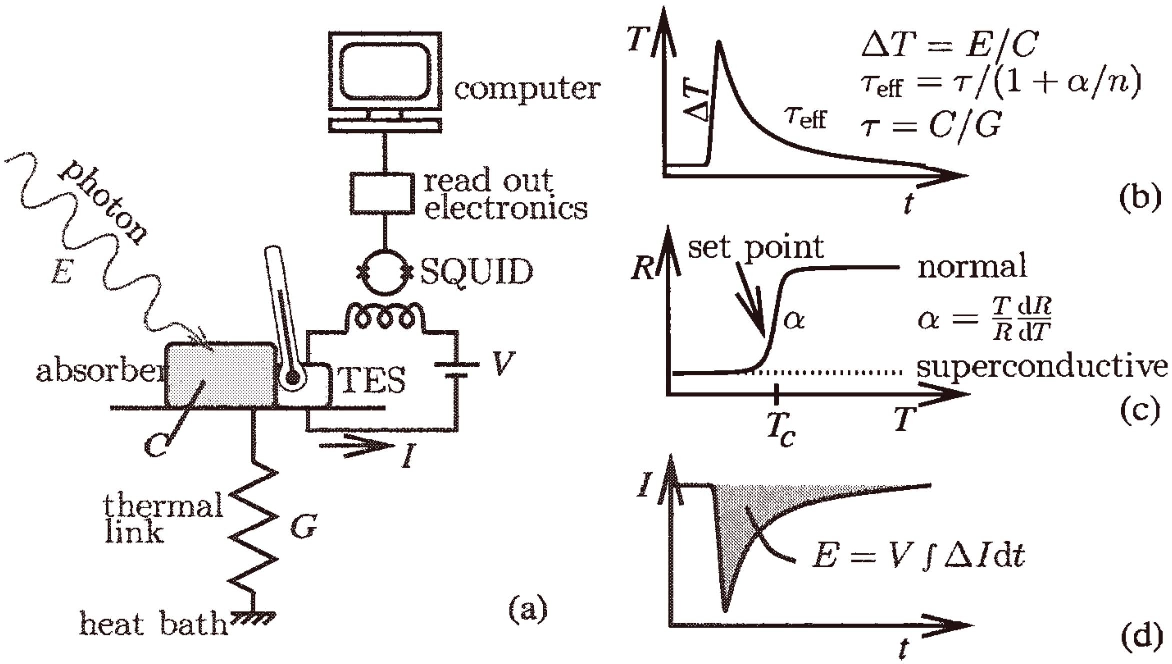
Production cavity, infrared

Wall

Regeneraton cavity, locked with green light.

ALPS II detector

Transition Edge Sensor (TES)



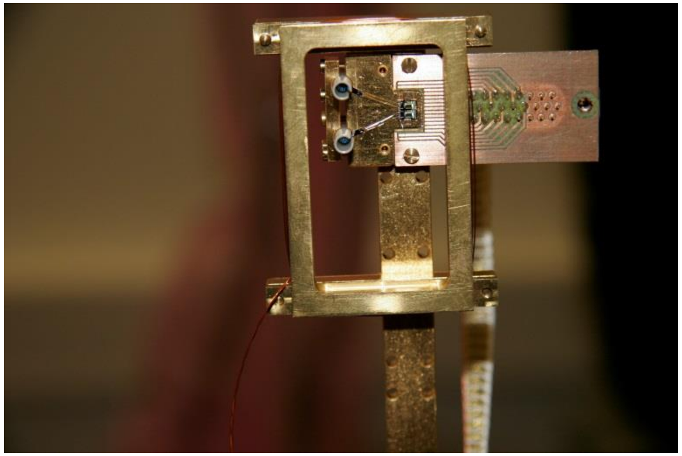
$\Delta T \approx 100\ \mu K$

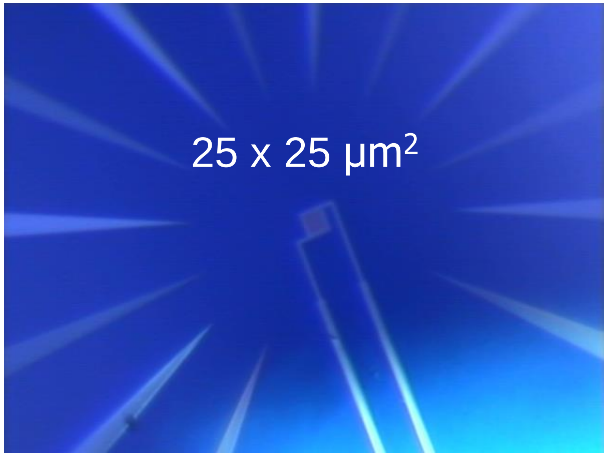
$\Delta R \approx 1\ \Omega$

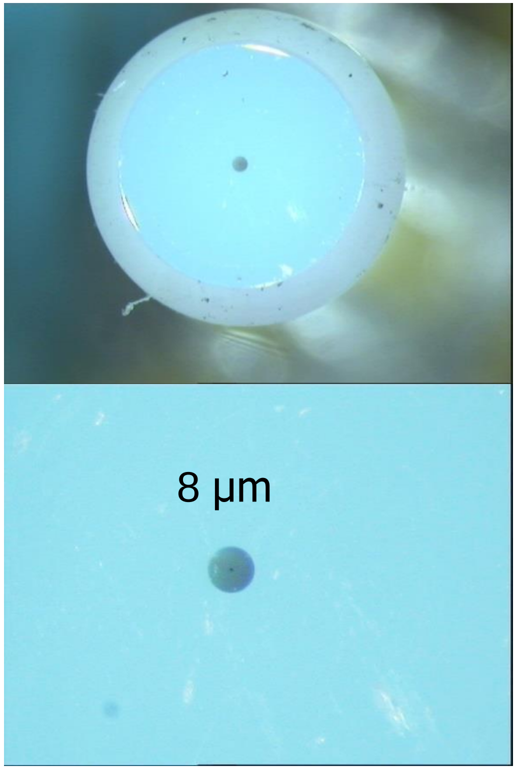
$\Delta I \approx 70$ nA

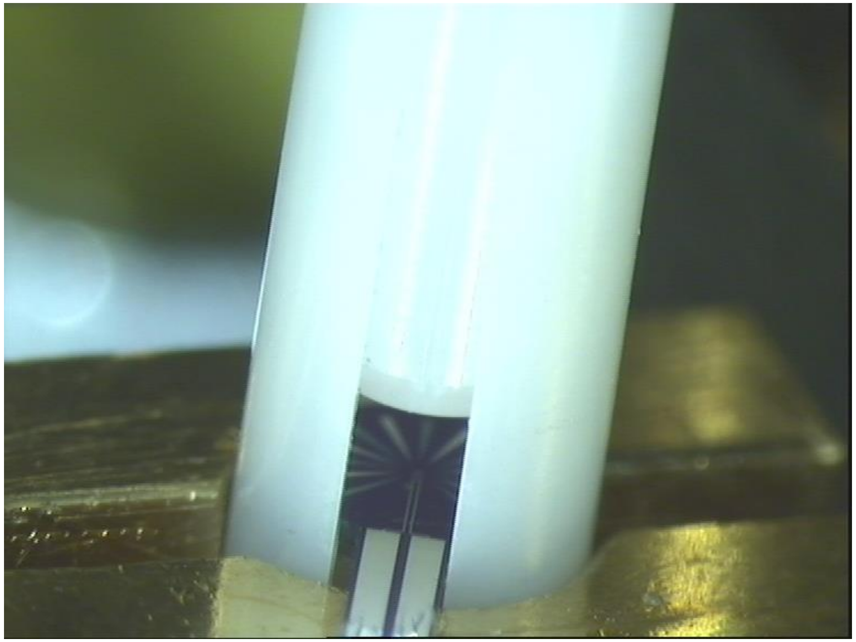
> Expectation:
very high quantum efficiency, also at 1064 nm,
very low noise.

ALPS II: Transition Edge Sensor (TES)



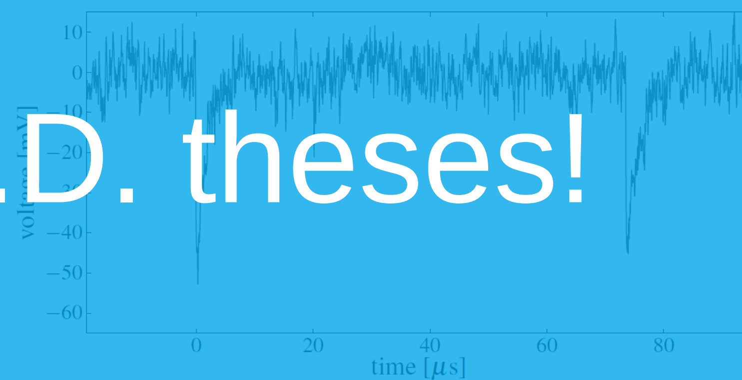






ALPS II: Transition Edge Sensor (TES)

- Tungsten film kept at the transition to superconductivity at 80 mK.
- Sensor size 25µm x 25µm x 20nm.



Four Ph.D. theses!

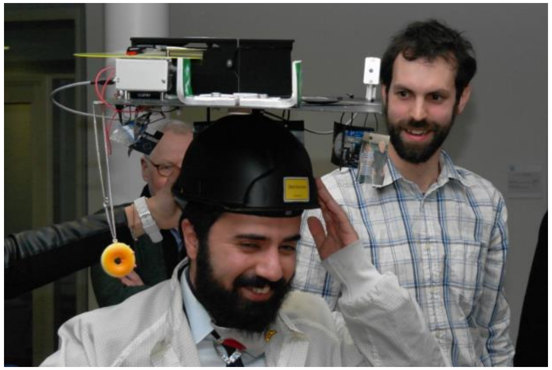
At least.

- Single 1066 nm photon pulses!
- Energy resolution ≈8%.
- Dark background 10^{-4} counts/second.
- Ongoing: background studies, optimize fibers, minimize background from ambient thermal photons.

module with two channels
(scale ~ 3cm x 3cm)

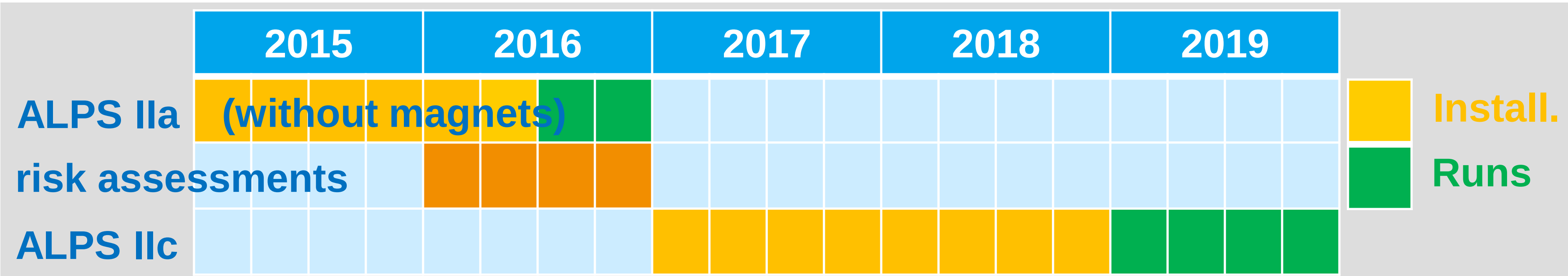
First ALPS II results

- WISP measurements: none
- But starting careers with ALPS seems to work:
  The three (male) DESY PhD students have finished 2014 and 2015.

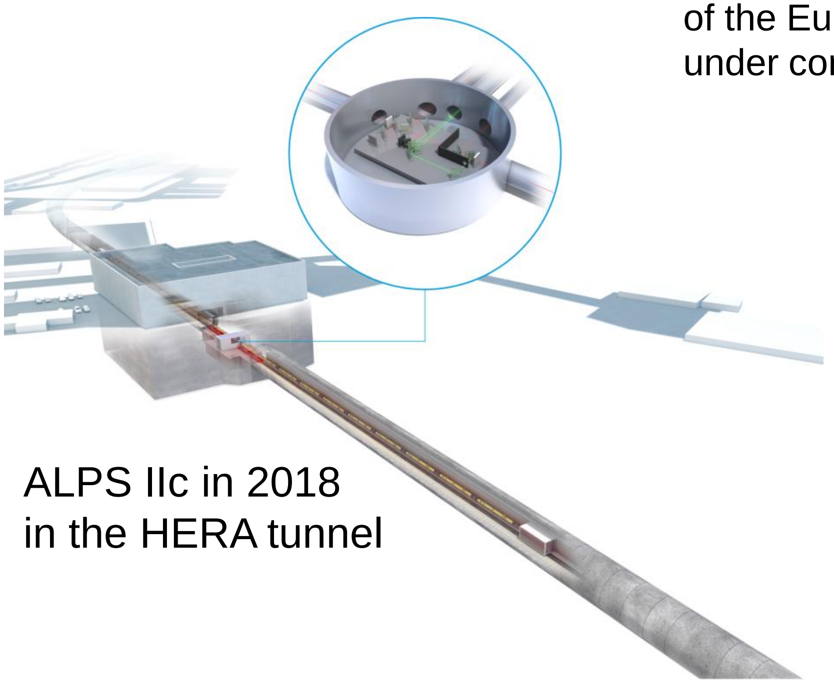


- The two (female) postdocs got nice positions:
  - Tenure track at XFEL (much too early from the ALPS point of view),
  - CERN fellowship.

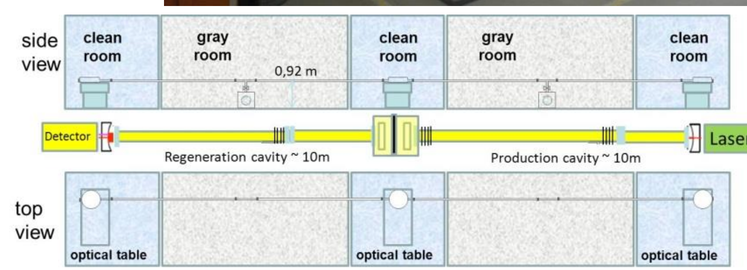
ALPS II schedule (rough)



Closure of the LINAC tunnel
of the European XFEL
under construction at DESY.



ALPS IIc in 2018
in the HERA tunnel



DESY

The ALPS collaboration

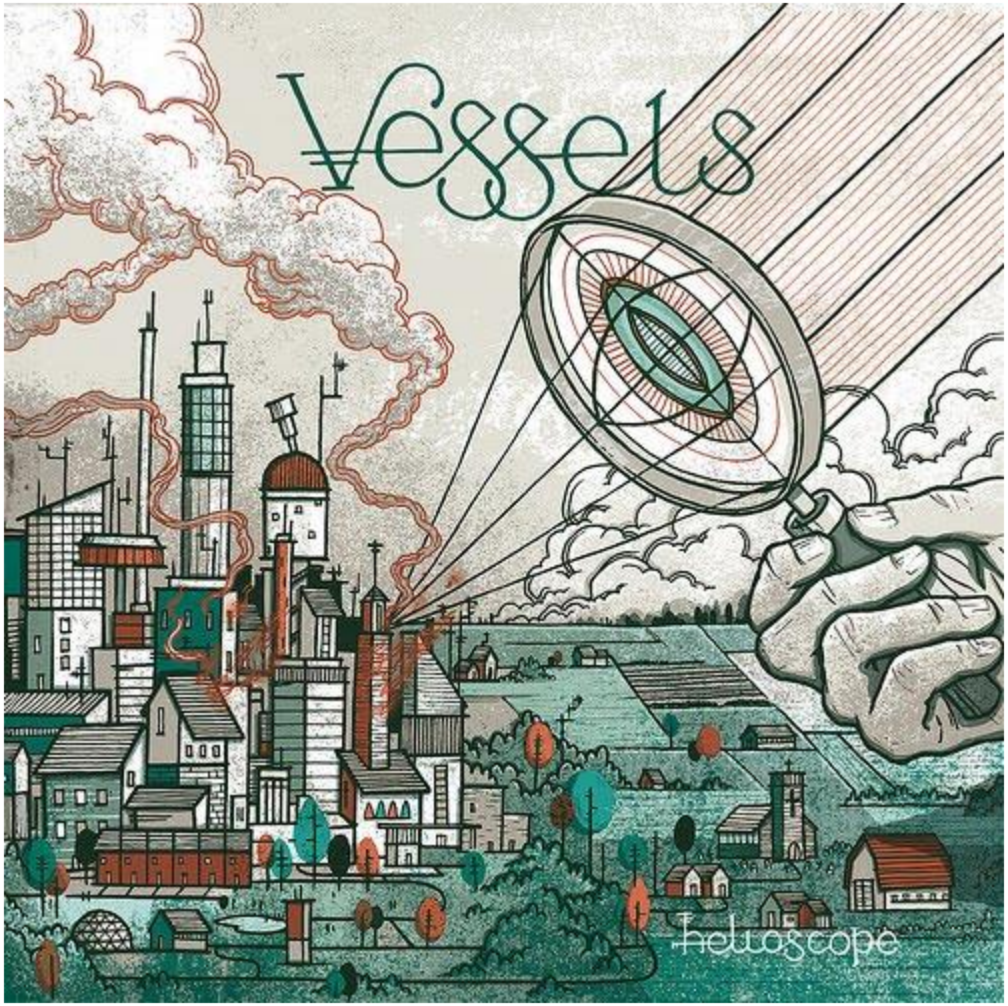
ALPS II is a joint effort of

- DESY,
- Hamburg University,
- AEI Hannover
  (MPG & Hannover Uni.),
- Mainz University,
- University of Florida
  (Gainesville)

with strong support from

- neoLASE, PTB Berlin, NIST (Boulder).

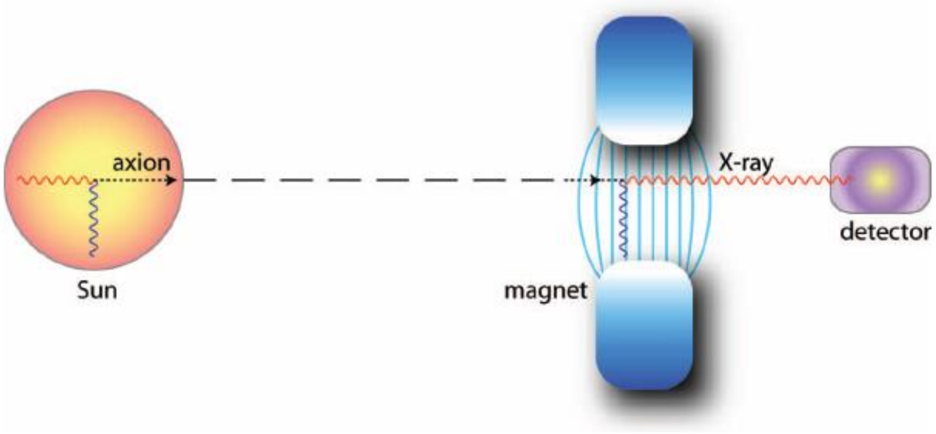
Helioscopes

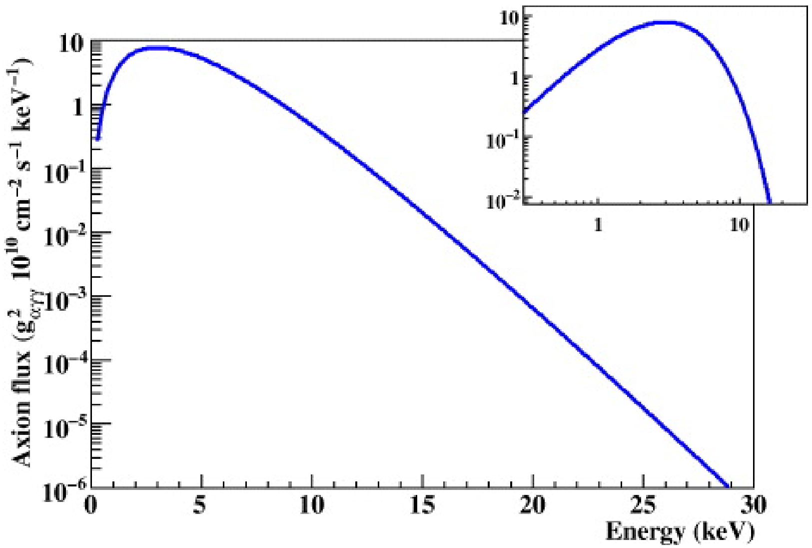


http://middleboop.blogspot.de/2011/02/vessels-helioscope.html

CAST: the dominating helioscope

- LHC prototype magnet pointing to the sun.



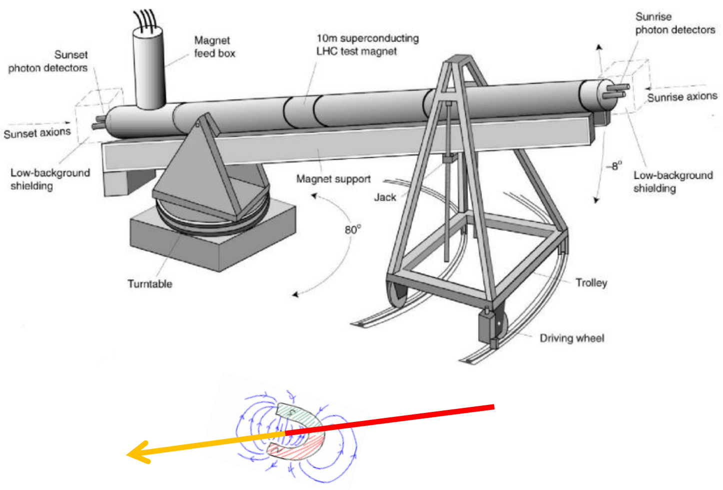


Axions or ALPs from the center of the sun would come with X-ray energies.

New J. Phys. **11** (2009) 105020

CAST: the dominating helioscope

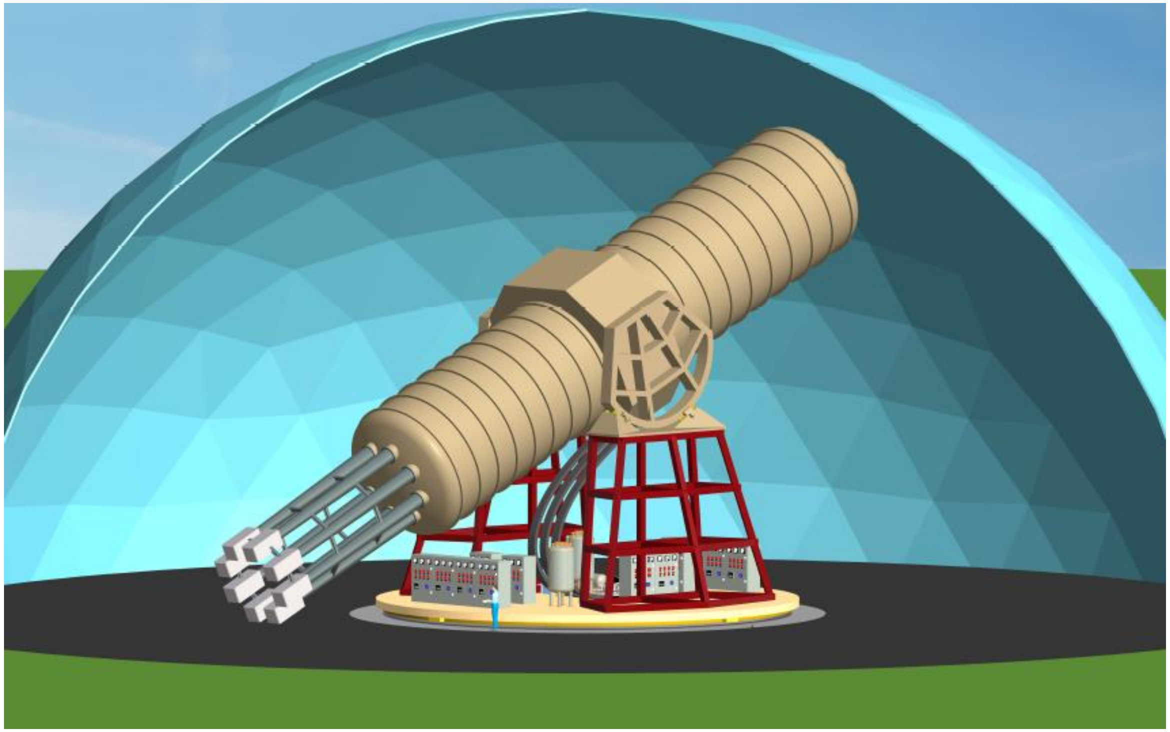
- LHC prototype magnet pointing to the sun.



- Most sensitive experiment searching for axion-like particles.
  - Unfortunately no hints for WISPs yet.
  - If a WISP is found, it would be compatible with known solar physics!

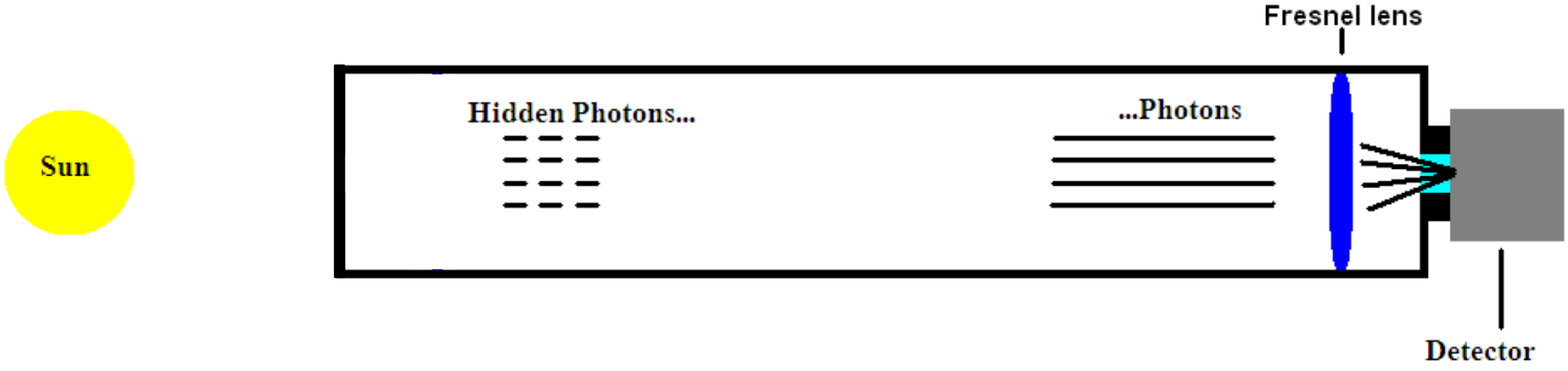
IAXO proposal

- The International Axion Observatory
  - CAST principle with dramatically enlarging the aperture
  - Use of toroid magnet similar to ATLAS @ LHC
  - X-ray optics similar to satellite experiments.



A nice Ph.D. thesis: TSHIPS, observatory Bergedorf

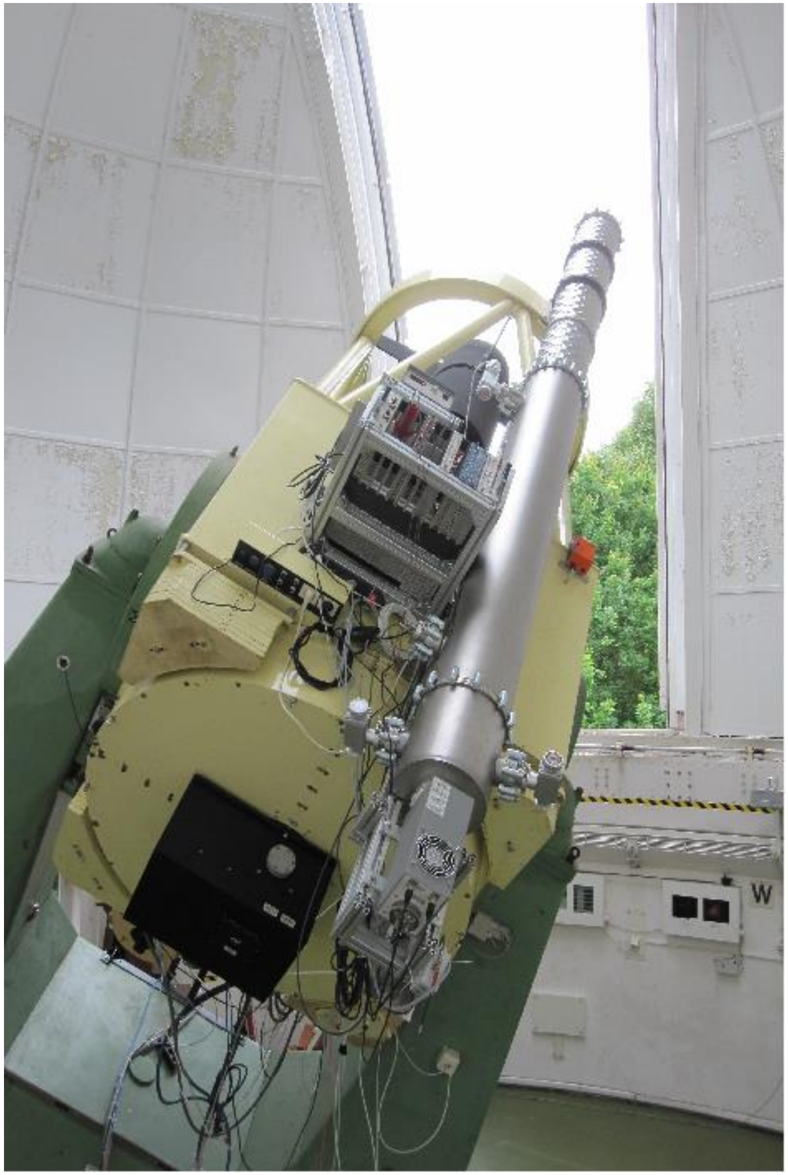
Telescope for Solar Hidden Photon Search



- DESY
- Hamburger University (observatory Bergedorf)

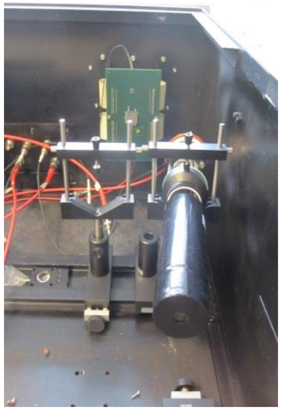
Universität Hamburg

TSHIPS results



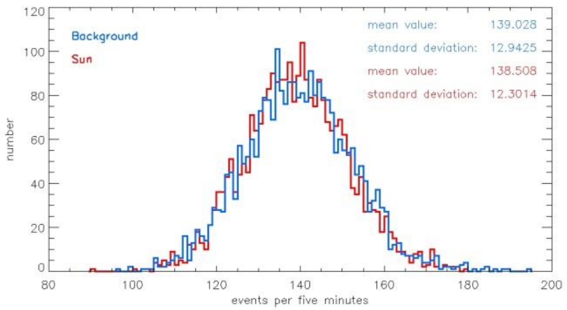
- Light collected via a 20 cm Fresnel lens:

- Low noise PM:
  (ET Enterprises 9893/350B)



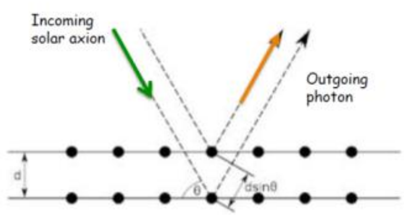
- Data taking in March 2013: 300 h of sun + background data each,

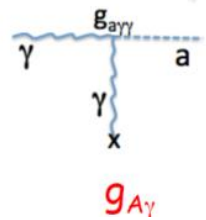
  but no hint for an excess.



Solar axions in EDELWEISS

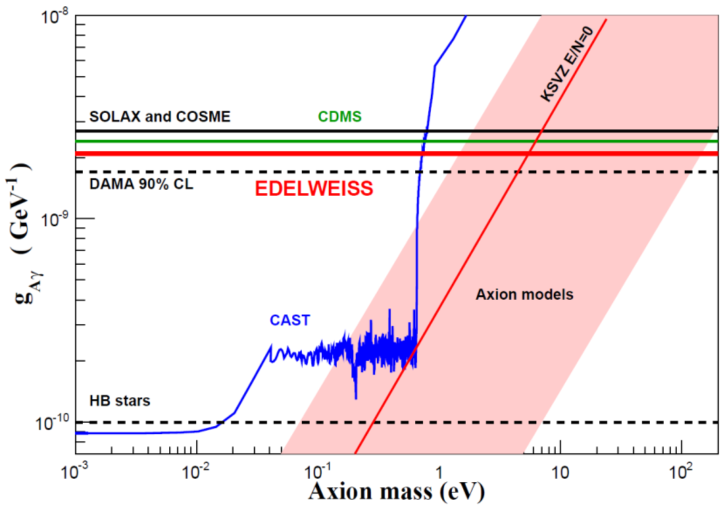
- Axions /ALPs produced in the sun might convert into photons via coherent Bragg diffraction in the crystals of EDELWEISS.





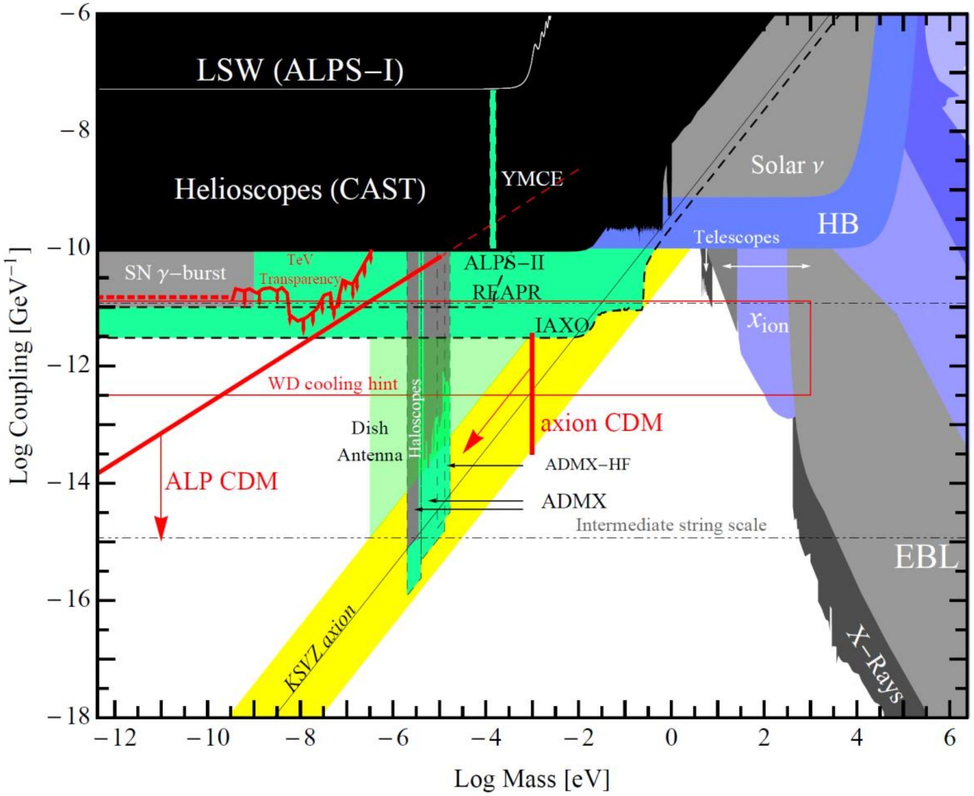
- Such experiments probe parameter region higher masses not accessible in other experiments.
- Nice opportunities to search for WISPs in experiments designed for WIMPs!

JCAP 1311 (2013) 067



Summary on WISPy dark matter candidate searches

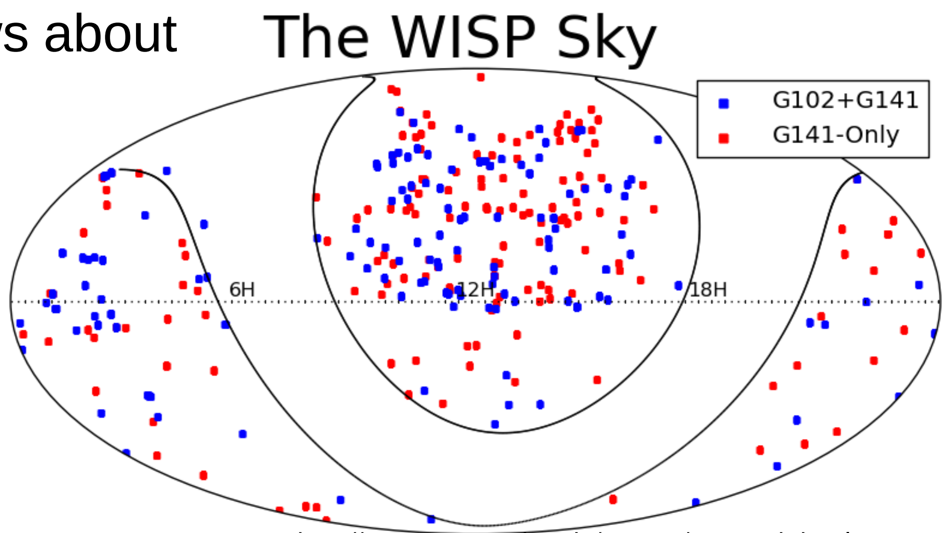
- Laboratory experiments look for ALPs, but cannot reach the QCD axion. However, they probe the parameter region indicated by astrophysics (see later) due to an increase in sensitivity by ≈ 3,000.
- Helioscopes might reach their final incarnation soon. Part of the axion parameter space can be probed.



Indirect searches for WISPs as dark matter candidates

WISPy effects could show up in astrophysics due to the low WISP masses.

Google knows about



http://www.astro.ucla.edu/~nross/research.html

Unfortunately this is the WFC3 Infrared Spectroscopic Parallel survey …

Indirect searches for WISPs as dark matter candidates

WISPy effects could show up in astrophysics due to the low WISP masses.

> WISP could change the propagation of TeV photons in the universe.

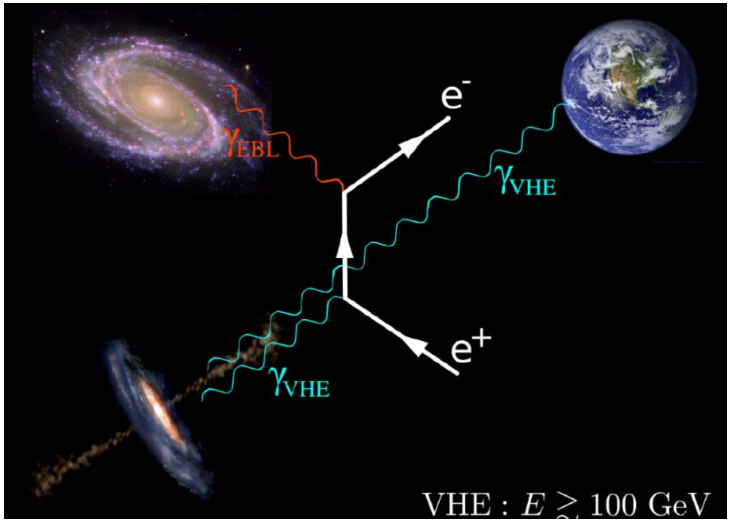
> WISP could change the development of stars.

> There could be a Cosmic Axion Background (CAB).

Indications for unexplained effects?

Probe the transparency of the universe!

- GeV photons have a mean free path-length comparable to the size of the universe.
- 100 GeV to TeV photons **should** travel just about 100 Mpc, because they **should** interact with extragalactic background light.



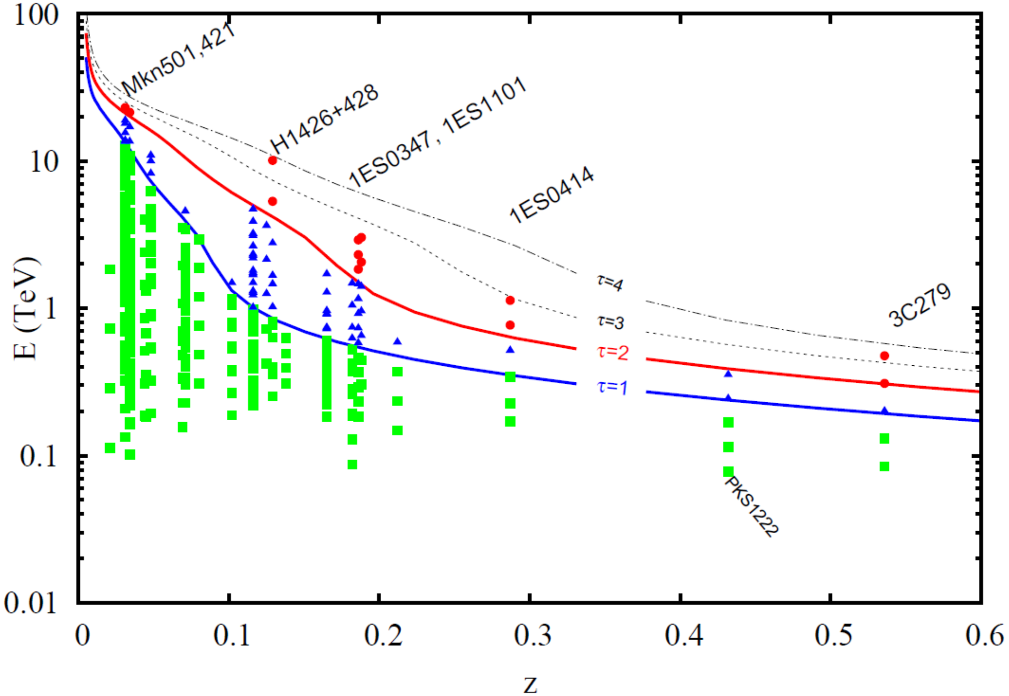
Center of mass energy about 1 MeV (0.0000001· LHC)!

M. Meyer, 7th Patras Workshop on Axions, WIMPs and WISPs, 2011

Indications for unexplained effects?

However:

- The expected propagation of TeV photons seems to be in conflict with observations:

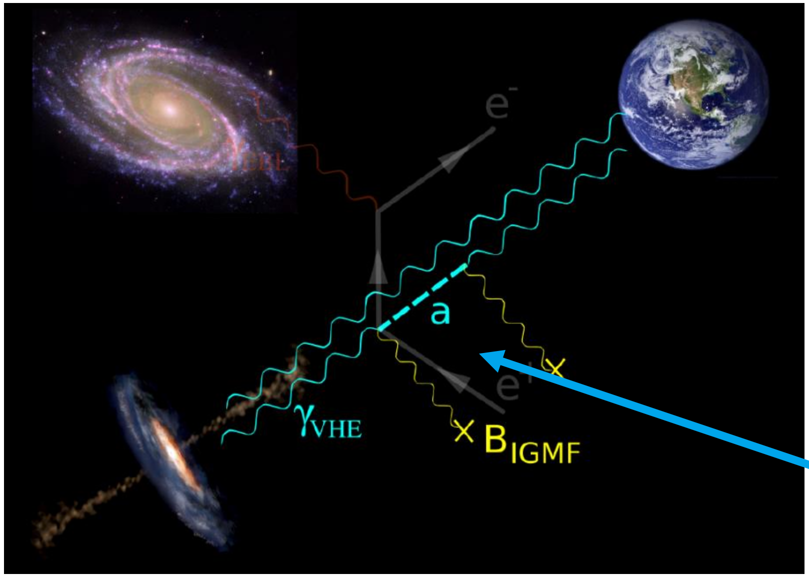


D. Horns, M. Meyer, JCAP 1202 (2012) 033

- If physics beyond the SM is involved, it shows up around the MeV scale!

Indications for unexplained effects?

- Axion-like particles might explain the apparent transparency of the universe for TeV photons:



M. Meyer, 7th Patras Workshop on Axions, WIMPs and WISPs, 2011

TeV photons may "hide" as axions.

A very nice offer to you …

PhD thesis on the search for axion-like particles with gamma-ray telescopes

PhD thesis on the search for axion-like particles with gamma-ray telescopes. DESY is one of the world-wide leading institutions in astroparticle physics with gamma rays. Experimental groups at DESY are participating in all major gamma-ray observatories (HESS/MAGIC/ VERITAS/Fermi-LAT). The DESY theory groups are modeling astrophysical particle accelerators and studying physics beyond the standard model.

The DESY gamma-ray group offers a PhD position starting at the next possible date, with a project connecting the experimental groups and theory groups in Zeuthen and Hamburg. The project comprises the search for evidences for a new fundamental type of ultra-light elementary particle, so-called axion-like particles, through observations of distant active galactic nuclei with gamma-ray telescopes.

Requirements: Recent university degree in physics: M.Sc. or German diploma (candidates about to obtain such a degree are welcome to apply) and a solid background in physics and astrophysics

Contact:
G.Maier (gernot.maier@desy.de)
R.Buehler (rolf.buehler@desy.de)
A.Lindner (axel.lindner@desy.de)
A.Ringwald (andreas.ringwald@desy.de)

(Vague) hints for unexpected phenomena?

- TeV transparency of the universe?
- Cooling of stars?
- Indications for a Cosmic Axion-like-particle (ALP) Background (CAB)?

Phenomenon	ALP mass [eV]	ALP-γ coupl. [GeV^{-1}]	Reference
TeV transparency	$< 10^{-7}$	$> 10^{-11}$	arXiv:1302.1208 [astro-ph.HE]
Globular cluster stars (HB)	$< 10^{4}$	$\approx 5 \cdot 10^{-11}$	arXiv:1406.6053 [astro-ph.SR]
CAB (Coma Cluster)	$< 10^{-13}$	10^{-12} to 10^{-13}	arXiv:1406.5188 [hep-ph]
White dwarfs	$< 10^{-2}$	$(g_{ae} \approx 5 \cdot 10^{-13})$	arXiv:1304.7652 [astro-ph.SR]

- There are allowed regions in parameter space where an ALP can simultaneously explain the gamma ray transparency, the cooling of HB stars, and the soft X-ray excess from Coma and be a subdominant contribution to CDM.

Maturity of selected WISP searches

A very coarse and very subjective classification scheme:

WISP search	Quick experiment just with stuff sitting around	Do the best with available equipment	Dedicated tools for dedicated experiments
Direct DM search	FUNK		ADMX
Indirect DM search	Analysis of archive data		
Candidates in the laboratory	ALPS I	ALPS II	
Candidates in astrophysics		CAST	IAXO
	Analysis of archive data		

WISP experiments: success with new expertise only!

- Direct dark matter searches
  - ADMX (US), WISPDMX (Hamburg) — radio techniques
  - FUNK (KIT) — optics, radio
  - CASPEr (Mainz) — NMR
- Indirect dark matter searches
  - Just a comment on BECs
- Direct searches for WISPs as dark matter candidates
  - Laboratory: ALPS I and ALPS II (DESY) — optics, detectors
  - Helioscopes: SHIPS, CAST (CERN)+IAXO, EDELWEISS — X-rays
- Indirect searches for WISPs as dark matter candidates
  - TeV transparency of the universe — astroparticle physics
  - Development of stars — astrophysics

To-take-home

- WISPs are wonderful dark matter candidates and fit nicely into theoretical extensions of the standard model.
- Perhaps we already start seeing WISPy phenomena in astrophysics.
- WISPy experiments are not always mature yet, so new parameter regions might be probed quickly with modest resources.
- There are plenty new ideas and concepts waiting for realization.
- Although it all started with the “invisible axion”, WISPy experiment might detect dark matter or dark matter candidates already “tomorrow”.