

Towards the ALPS-II Experiment

Status Report to the DESY PRC

A. Lindner, for the ALPS Collaboration

DESY, 28 April 2011

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- > Motivations for further WISP searches
- > Challenges and activities worldwide
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- > ALPS-II timeline and potential
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ALPS @ DESY in Hamburg



PETRA III

coming: OLYMPUS

FLASH

European XFEL

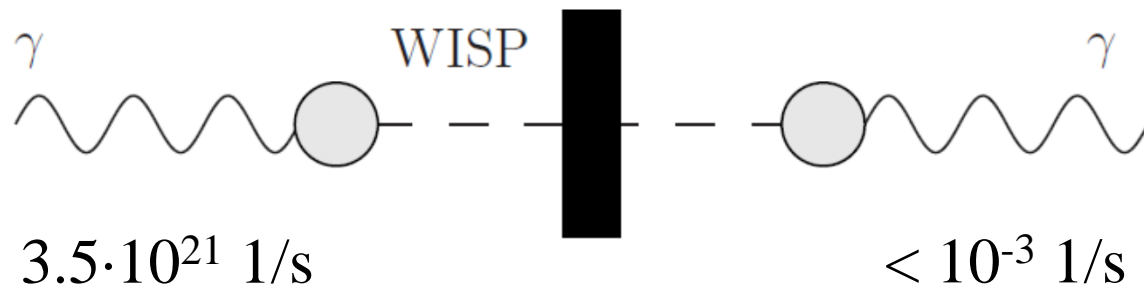
aimed at: ALPS-II

ALPS
(was the only particle physics experiment on site)
> Approved January 2007
> Final data run Dec. 2009 (end of first phase)

Reminder: ALPS-I Results

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

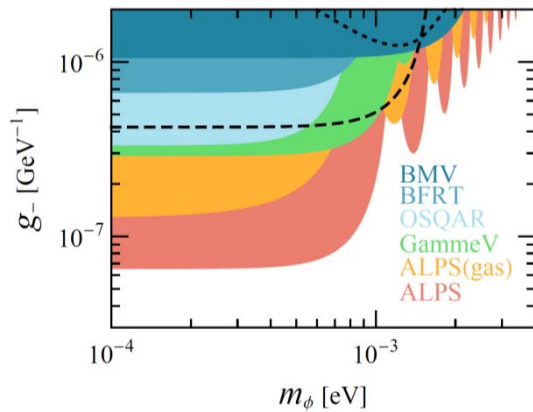
> Unfortunately, no light was shining through the wall!



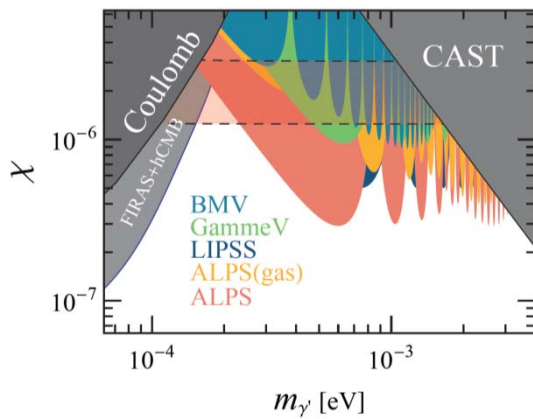
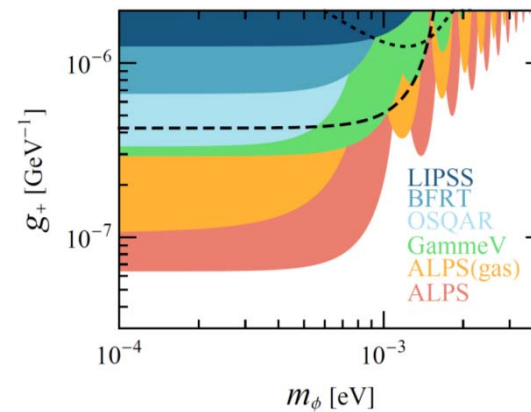
Reminder: ALPS-I Results

still

> ALPS is the most sensitive experiment for WISP searches in the laboratory.

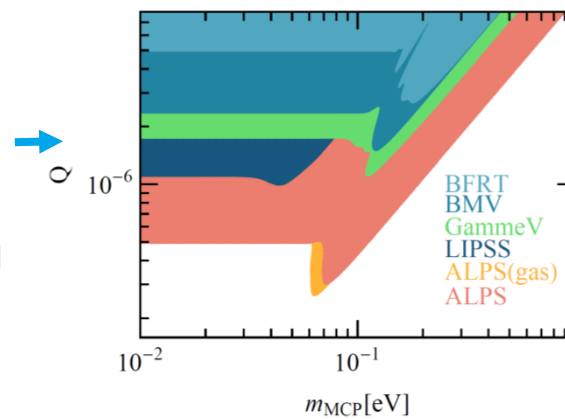


← pseudoscalar
and
scalar →
axion-like particles



← hidden sector photons
and
minicharged particles

← Filling a gap remaining
from astrophysics and
other experiments!



PLB 689 (2010), 149



Outreach (see also <http://alps.desy.de>)

Large interest in media, many invited talks, mentioned in *Nature*.

The screenshot shows a web browser window with the URL <http://alps.desy.de/e163/>. The page is titled "ALPS in the Media" and lists various media mentions of the ALPS experiment. The browser's address bar shows "http://alps.desy.de/e163/" and the page title is "Deutsches Elektronen-Synchrotron D...".

ALPS in the Media

- » **Physics: Not a WISP of evidence**
Nature 465, page 271 (20 May 2010), doi:10.1038/465271c
- » **As you can see, there is nothing to see!**
symmetriemagazin (Volume 7 Issue 2 April 2010)
- » **Wie Sie sehen, sehen Sie nichts!**
DESYinForm May 2010 (in German, also available in English)
- » **LASER PHYSICS: 'Light shining through walls' experiment gets a boost**
Laser Focus World (Volume 45 Issue 8 August, 2009, in English)
- » **Licht am Ende des Magneten**
DESYinForm August 2009 (in German, also available in English)
- » **Nachwuchs für den Teilchenzoo**
Weser Kurier, 01.04.2009 (in German)
- » **Gesucht: axionartige Teilchen**
Siegener Zeitung, 07.03.2009 (in German)
- » **Dark matters: when light walks through a wall**
Hamburg News, 03/2009
- » **Licht ins Dunkel: Hamburg will dunkle Materie nachweisen**
Hamburg News, 03/2009 (in German)
- » **Physiker fahnden nach Axionen**
Dresdner Neueste Nachrichten, 27.01.2009 (german)
- » **Nachwuchs im Teilchenzoo?**
Landeszeitung Lüneburg, 24.01.2009 (german)
- » **Bald Nachwuchs im Teilchenzoo?**
Wiesbadener Kurier, 20.01.2009 (german)
- » **Nachwuchs im Teilchenzoo?**
Kieler Nachrichten, 15.01.2009 (german)
- » **Auf der Suche nach ultraleichten Axionen**
Fuldaer Zeitung, 14.01.2009 (german)
- » **Experiment schickt "Licht durch die Wand"**

The screenshot shows the Nature journal website. The article title is "Physics: Not a WISP of evidence". The journal is "Nature", International weekly journal of science. The article is from Nature 465, 271 (20 May 2010), doi:10.1038/465271c. The article is published online 19 May 2010. The article is cited in Phys. Lett. B doi:10.1016/j.physletb.2010.04.066 (2010). The article is available in full text access provided to DESY by Library. The article is available in English. The article is available in German. The article is available in French. The article is available in Italian. The article is available in Japanese. The article is available in Korean. The article is available in Spanish. The article is available in Chinese. The article is available in Russian. The article is available in Arabic. The article is available in Hindi. The article is available in Bengali. The article is available in Telugu. The article is available in Malayalam. The article is available in Kannada. The article is available in Marathi. The article is available in Gujarati. The article is available in Odia. The article is available in Assamese. The article is available in Punjabi. The article is available in Sindhi. The article is available in Urdu. The article is available in Pashto. The article is available in Persian. The article is available in Farsi. The article is available in Dari. The article is available in Tajik. The article is available in Uzbek. The article is available in Kazakh. The article is available in Kyrgyz. The article is available in Turkmen. The article is available in Azerbaijani. The article is available in Georgian. The article is available in Armenian. The article is available in Azerbaijani. The article is available in Georgian. The article is available in Armenian. The article is available in Azerbaijani. The article is available in Georgian. The article is available in Armenian.

nature International weekly journal of science

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» previous article next article »

Physics: Not a WISP of evidence

Nature 465, 271 (20 May 2010) | doi:10.1038/465271c
Published online 19 May 2010

Cited research: *Phys. Lett. B* doi:10.1016/j.physletb.2010.04.066 (2010)

In extensions to the standard model, which describes the fundamental particles and forces of physics, some theorists have proposed the existence of very light subatomic particles called WISPs. These could be dark matter, which keeps a spinning galaxy from flying apart.

One way to detect WISPs would be to look for the rare conversion of light particles to WISPs, and later back to photons. In between these conversions, a WISP could zip through any barrier. So Axel Lindner at DESY, the German electron synchrotron in Hamburg, and his colleagues shone green laser light at a "wall", a thick piece of light-absorbing material, hoping that a few photons might pop out the other side. They increased the chances of a WISP conversion by using optical resonators to boost the power of the laser light and by applying a strong magnetic field. But the researchers did not detect any emerging photons, limiting the chance of a WISP conversion to nearly 1 in 10^{25} — the most sensitive limit yet. E.H.

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Open innovation challenges

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Deadline: Jul 11 2010
Reward: \$0 USD
The Seeker is looking for an individual, laboratory or other organization that would be able to prov...

Identification of Substrates that Mimic Human Skin
Deadline: Jul 03 2010
Reward: \$10,000 USD



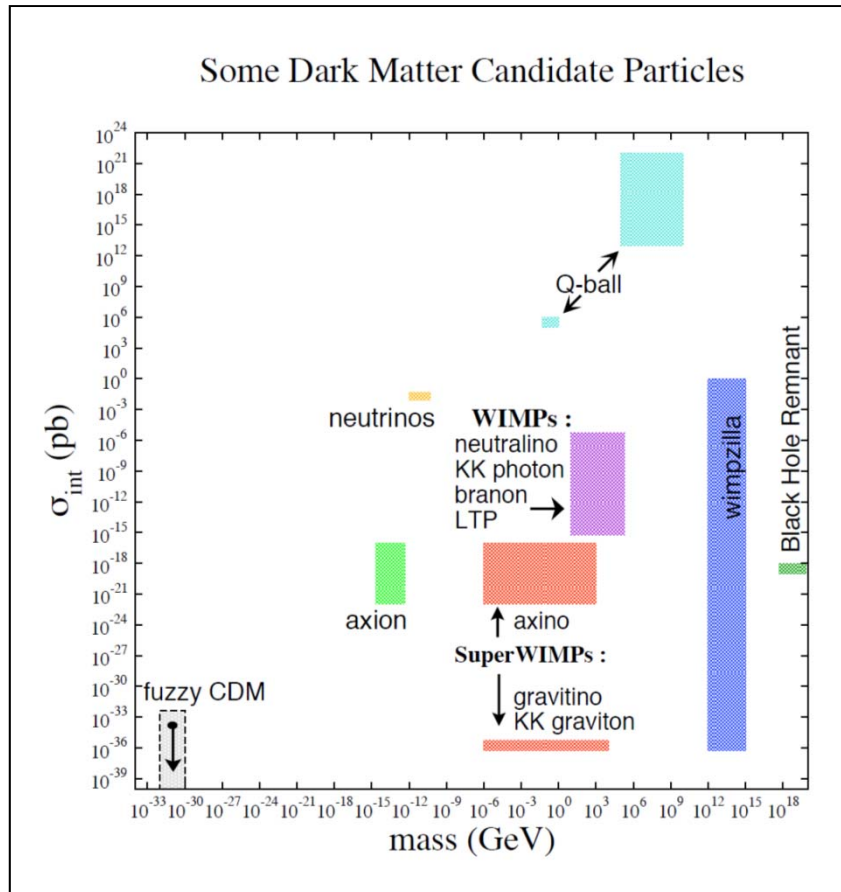
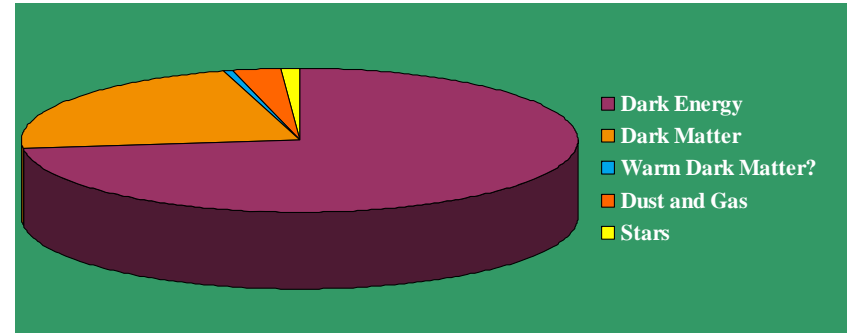
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Motivation for further WISP Searches: the Universe

The Universe is essentially dark:



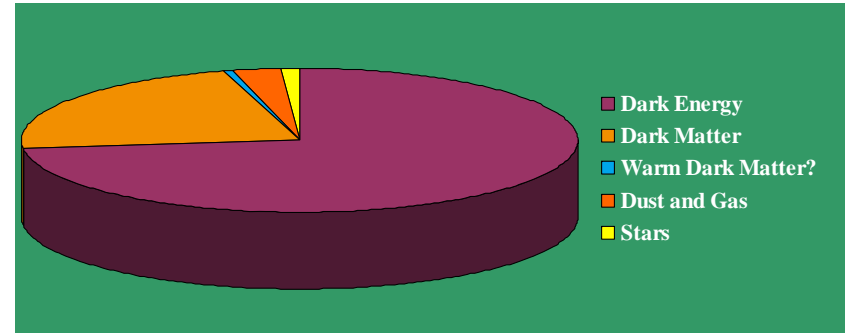
Dark Matter could be WISPy!

H. Baer, presentation at 5th Patras Workshop on Axions, WIMPs and WISPs, 2009



Motivation for further WISP Searches: the Universe

The Universe is essentially dark:



The cosmological constant problem,
S. Weinberg,
Rev. Mod. Phys.
61, 1–23 (1989)

ute to the effective cosmological constant. In order to keep $\rho_V < 10^{-48} \text{ GeV}^4$, we need the scalar field adjustment to cancel the effect of gravitational and electromagnetic field fluctuations down to frequencies 10^{-12} GeV ; for this purpose we must have $m_\phi < 10^{-12} \text{ GeV}$. A field this light will have a macroscopic range: $\hbar/m_\phi c \gtrsim 0.01 \text{ cm}$.

Laboratory constraints on chameleon dark energy and power-law fields

J. H. Steffen¹, A. Upadhye², A. Baumbaugh¹, A. S. Chou¹, P. O. Mazur¹, R. Tomlin¹, A. Weltman³, and W. Wester¹

¹*Fermi National Accelerator Laboratory, PO Box 500, Batavia, IL 60510*

²*Kavli Institute for Cosmological Physics, University of Chicago, IL 60637*

³*Astrophysics, Cosmology and Gravity Centre, University of Cape Town, Rondebosch, Private Bag, 7700, South Africa*

(Dated: October 6, 2010)

arXiv:1010.0988v1 [astro-ph.CO]

Dark Energy could be WISPy!



Motivation for further WISP Searches: Astrophysics

- > *Axions and the cooling of white dwarf stars.*
J. Isern et al., arXiv:0806.2807v2 [astro-ph], Astrophys.J.L. 682 (2008) L109
- > *Evidence for a New Light Boson from Cosmological Gamma-Ray Propagation?*
M. Roncadelli et al., arXiv:0902.0895v1 [astro-ph.CO]
- > Does the X-ray spectrum of the sun points at a 10 meV axion?
K. Zioutas et al., arXiv:0903.1807v4 [astro-ph.SR]
- > Large-Scale Alignments of Quasar Polarization Vectors: Evidence at Cosmological Scales for Very Light Pseudoscalar Particles Mixing with Photons?
D. Hutsemekers et al., arXiv:0809.3088v1 [astro-ph]
- > Signatures of a hidden cosmic microwave background
J.Jaeckel, J. Redondo, A. Ringwald, Phys.Rev.Lett.101:131801,2008



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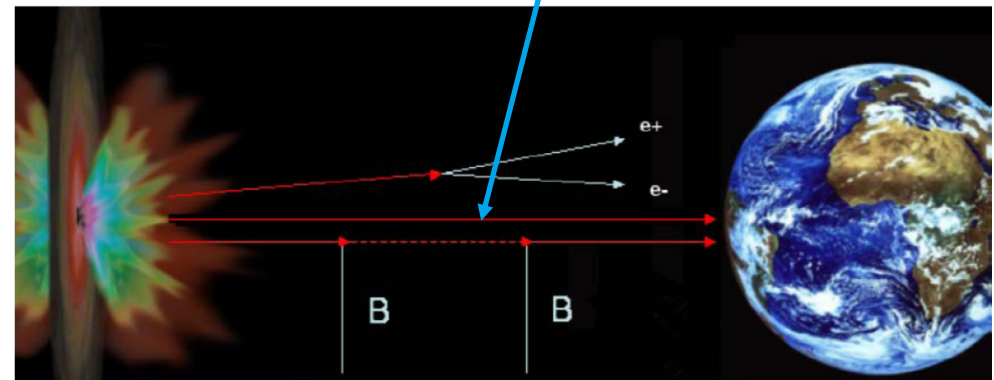
TeV photons should be absorbed by e^+e^- pair production due to interaction with the extragalactic background light (EBL):

$$\gamma_{\text{TeV}} + \gamma_{\text{eV}} \rightarrow e^+ + e^-$$

However, the TeV spectra of distant galaxies do hardly show any absorption.

TeV photons may “hide” as ALPs!

M. Roncadelli, presentation at the 4th Patras Workshop on Axions, WIMPs and WISPs, 2008



Motivation for further WISP Searches: Theory

- > The CP conservation in QCD is best explained by an axion.
- > A QCD axion in the mass region of 10^{-5} to 10^{-4} eV would be a “perfect” cold Dark Matter candidate.
- > **String Axiverse**
A. Arvanitaki, S. Dimopoulos, S. Dubovsky, N. Kaloper, and J. March-Russell, arXiv:0905.4720 [hep-th]
String theory suggests the simultaneous presence of many ultralight axions, possibly populating each decade of mass down to the Hubble scale 10^{-33} eV. Conversely the presence of such a plenitude of axions (an “axiverse”) would be evidence for string theory, ...

- > **Naturally Light Hidden Photons in LARGE Volume String Compactifications**
M. Goodsell, J. Jaeckel, J. Redondo and A. Ringwald, arXiv:0909.0515 [hep-ph], JHEP 0911:027,2009
Extra “hidden” U(1) gauge factors are a generic feature of string theory that is of particular phenomenological interest. They can kinetically mix with the Standard Model photon and are thereby accessible to a wide variety of astrophysical and cosmological observations and laboratory experiments.

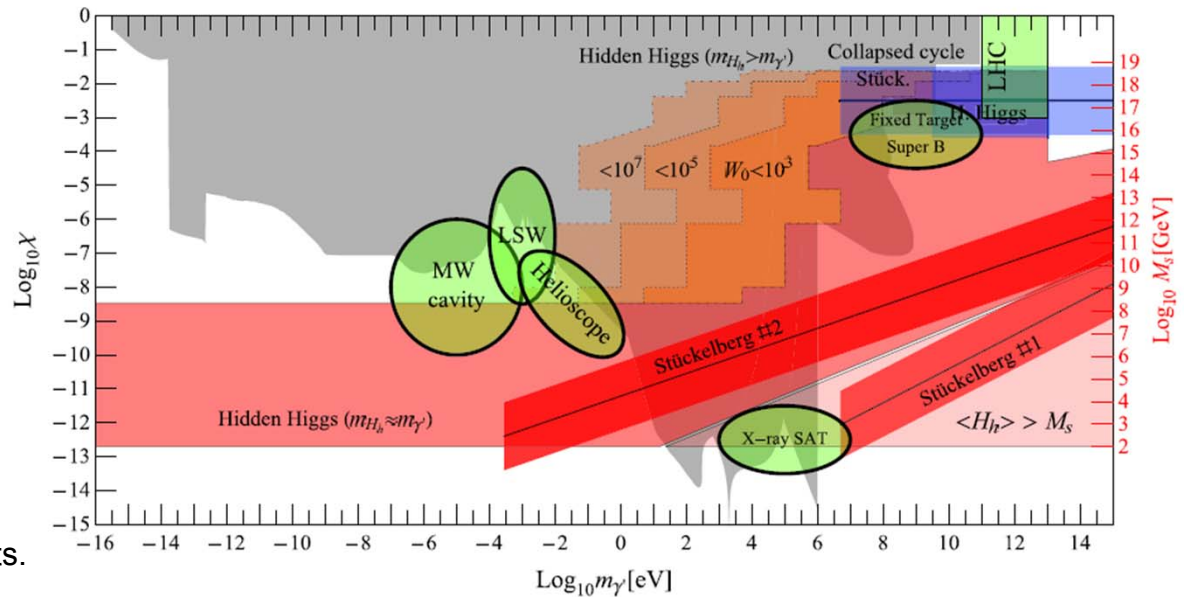


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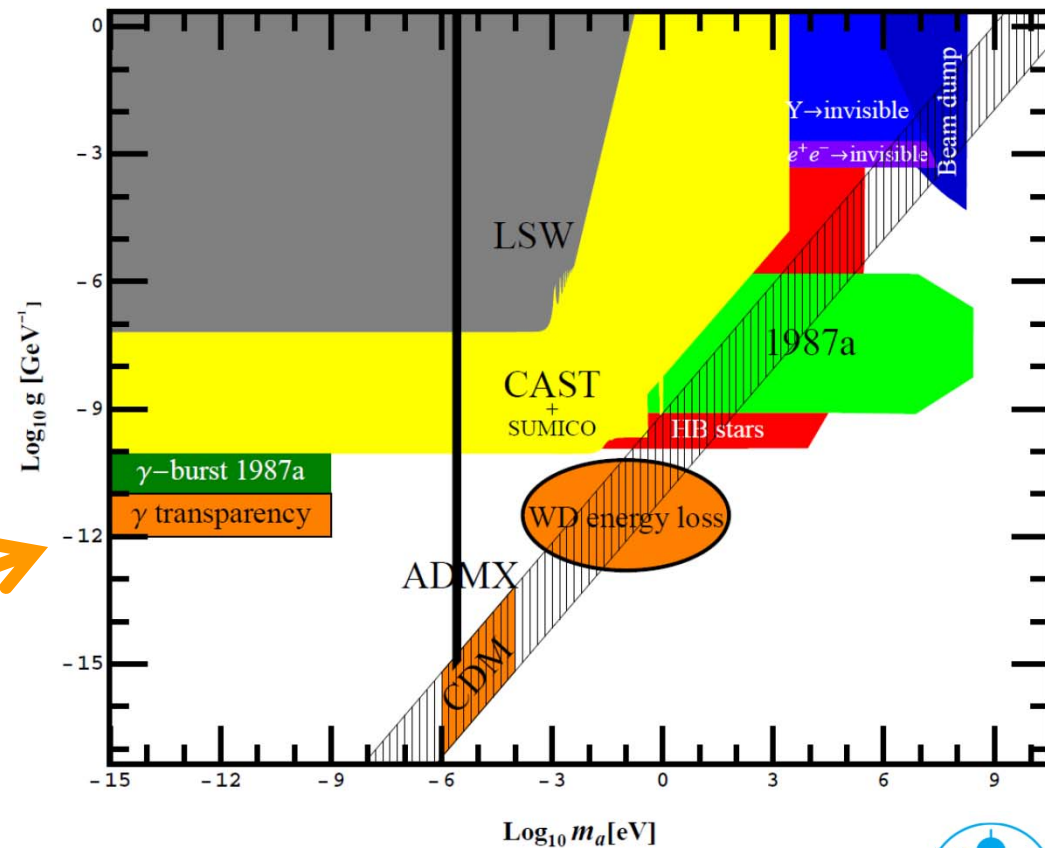
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ALPS-I Summary and the ALPs / Axion Challenge

- > Experience gathered with ALPS is a firm foundation for continuing to probe the hints for WISPs, now on larger scales.
- > The essential strength of ALPS is the collaboration of particle physicists (theory and experiment) and laser physicists from the gravitational wave detector community.
- > Infrastructure and large magnets provided by a lab like DESY are essential to accomplish experiments like ALPS.
- > Significant efforts required to check indirect limits from and to compete with astrophysics!

We have to aim for this sensitivity! →

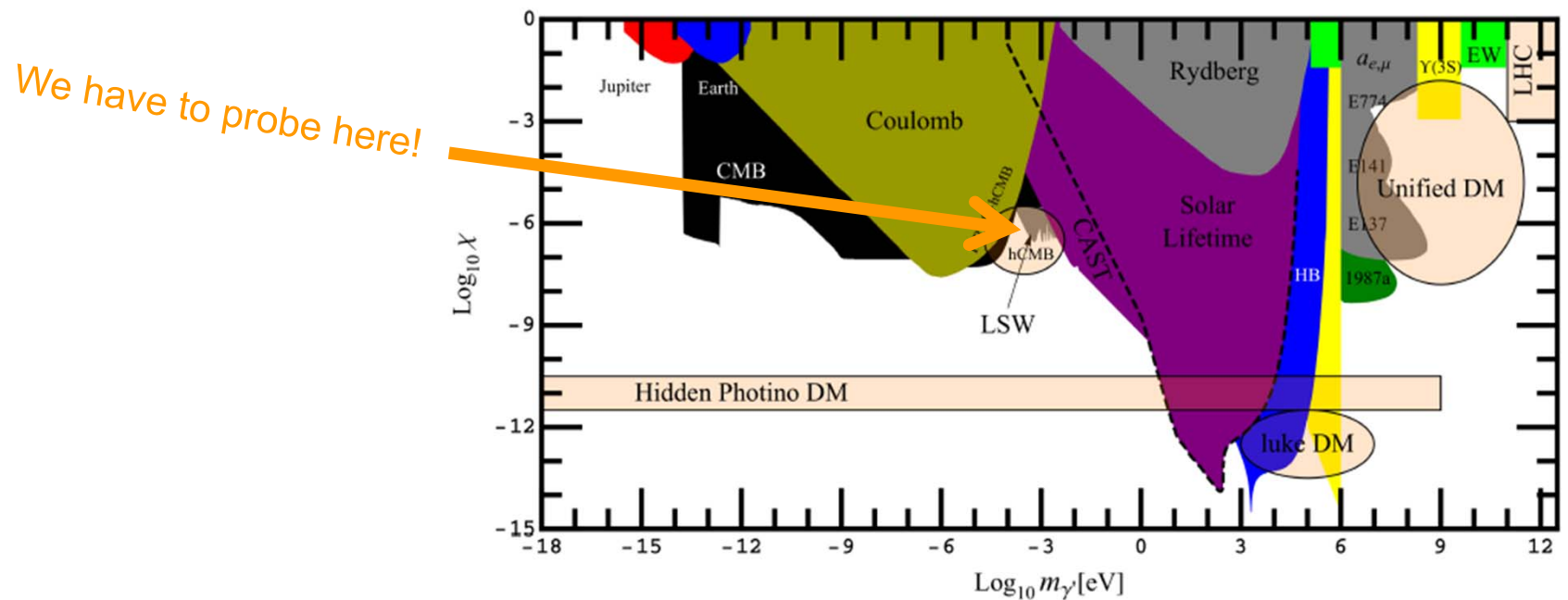


compiled by J. Jäckel and A. Ringwald



ALPS-I Summary and the “hidden Photon” Challenge

- > In the near term experiment should strive for probing the “hidden CMB” interpretation of the neutrino number excess derived from CMB data.
- > A drastic increase in sensitivity is required to probe for hidden photino Dark Matter. This will not be possible in the near term future.



compiled by J. Jäckel and A. Ringwald



WISPs Searches in the Lab worldwide I

> The world-wide activities in this research field are strengthening.

Light shining through walls 17

Experiment	ω	P_g	β_g	Magnets
ALPS (DESY) [61, 62]	2.33 eV	4 W	300	$B_g = B_r = 5$ T $L_g = L_r = 4.21$ m
BFRT (Brookhaven) [64, 65]	2.47 eV	3 W	100	$B_g = B_r = 3.7$ T $L_g = L_r = 4.4$ m
BMV (LULI) [66, 67]	1.17 eV	$8 \times 10^{21} \frac{\gamma}{\text{pulse}}$ (14 pulses)	1	$B_g = B_r = 12.3$ T $L_g = L_r = 0.4$ m
GammeV (Fermilab) [68]	2.33 eV	$4 \times 10^{17} \frac{\gamma}{\text{pulse}}$ (3600 pulses)	1	$B_g = B_r = 5$ T $L_g = L_r = 3$ m
LIPSS (JLab) [69, 70]	1.03 eV	180 W	1	$B_g = B_r = 1.7$ T $L_g = L_r = 1$ m
OSQAR (CERN) [71, 72]	2.5 eV	15 W	1	$B_g = B_r = 9$ T $L_g = L_r = 7$ m
BMV (ESRF) [73]	50/90 keV	10/0.5 mW	1	$B_g = B_r = 3$ T $L_g = 1.5, L_r \sim 1$ m

Table 1. Some experimental parameters of the past and current generation of LSW experiments.

Light shining through walls,
 Javier Redondo, Andreas Ringwald,
 arXiv:1011.3741v1 [hep-ph]



WISPs Searches in the Lab worldwide II

> CERN: OSQAR

- Results announced for the end of 2010, but nothing communicated yet.
 $B \cdot L(\text{OSQAR}) = 4 \times B \cdot L(\text{ALPS})$; factor 4 in $B \cdot L \Leftrightarrow$ factor 256 in laser power!

> FNAL: GammeV, CHASE

- At present concentrating on holographic noise,
strong push with planned shutdown of TEVATRON?

> KEK: plans for different experiments exploiting high power lasers

- In the planning phase, likely to be delayed.

> Korea: plans for a dedicated “axion search laboratory”

- Details of the activities are not fixed yet.

> DESY: ALPS-II



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The ALPS Collaboration

Any Light Particle Search @ DESY

- DESY
- Max Planck Institute for Gravitational Physics (Albert Einstein Institute), and Institute for Gravitational Physics, Leibniz University Hannover
- Laserzentrum Hannover /neoLASE
- Hamburger Sternwarte and Hamburg University (new)



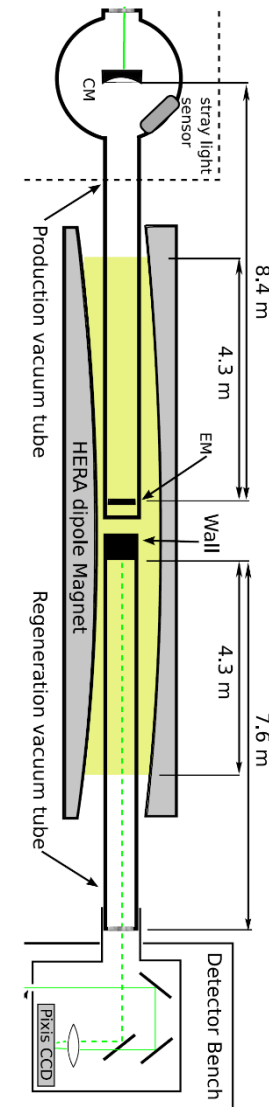
Four PhD students fully committed to ALPS started in autumn 2010!



Three main ALPS-I Components



- > Powerful laser:
optical cavity to recycle laser power
(high quality laser beam)
- > Strong magnet:
One HERA dipole: 5 T, superconducting
- > Sensitive detector:
CCD



Tubes:

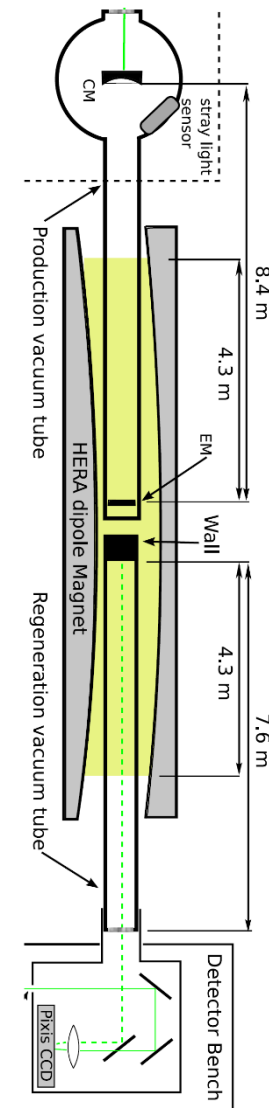
- diameter:
34 mm
- clear aperture:
14 mm



An ALPS-II Scenario



- > Powerful laser:
optical cavity to recycle laser power
(high quality laser beam)
ALPS-II: improve power!
- > Strong magnet:
One HERA dipole: 5 T, superconducting
ALPS-II: switch to magnet strings!
- > Sensitive detector:
CCD
ALPS-II: regeneration cavity and
TES detector!



Tubes:

- diameter:
34 mm
- clear aperture:
14 mm

ALPS-II:
Straighten
magnets!



ALPS-II in Numbers (realistic, but wishful ...)

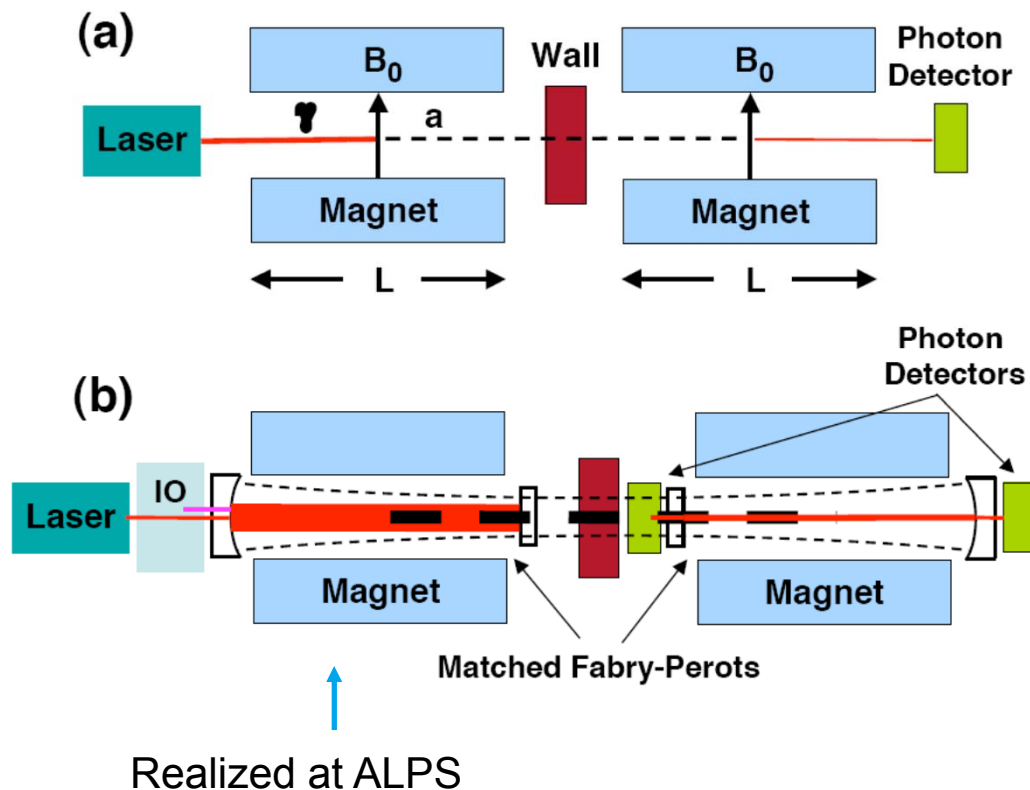
Parameter	Achieved at ALPS-I	Aimed for at ALPS-II	Sensitivity to ALP coupling g	Sensitivity compared to ALPS-I	Gain to
Effective Laser power LP	1 kW	150 kW	$g \sim LP^{-1/4}$	3.5	
Magnetic length BL	0.5+0.5 Hera Dipole	12+12 HERA Dipoles	$g \sim 1/BL$	24.0	
Detector Efficiency QE	0.9	0.9	$g \sim QE^{-1/4}$	1.0	
Detector Noise DC	0.01 1/s	0.0001 1/s	$g \sim DC^{-1/8}$	1.8	
Power built-up in a regeneration cavity PB	1	40,000	$g \sim PB^{-1/4}$	14.1	
Total					2,100



ALPS-II: Regeneration Cavity

Essential:

- > Implementation of a second cavity in the regeneration part of the experiment to enhance the conversion probability $WISP \rightarrow$ photon.



“Resonantly enhanced Axion-Photon Regeneration”

[P. Sikivie](#), [D.B. Tanner](#), [Karl van Bibber](#). *Phys.Rev.Lett.*98:172002,2007.

(also [F. Hoogeveen](#), [T. Ziegenhagen](#), DESY-90-165, *Nucl.Phys.B*358)

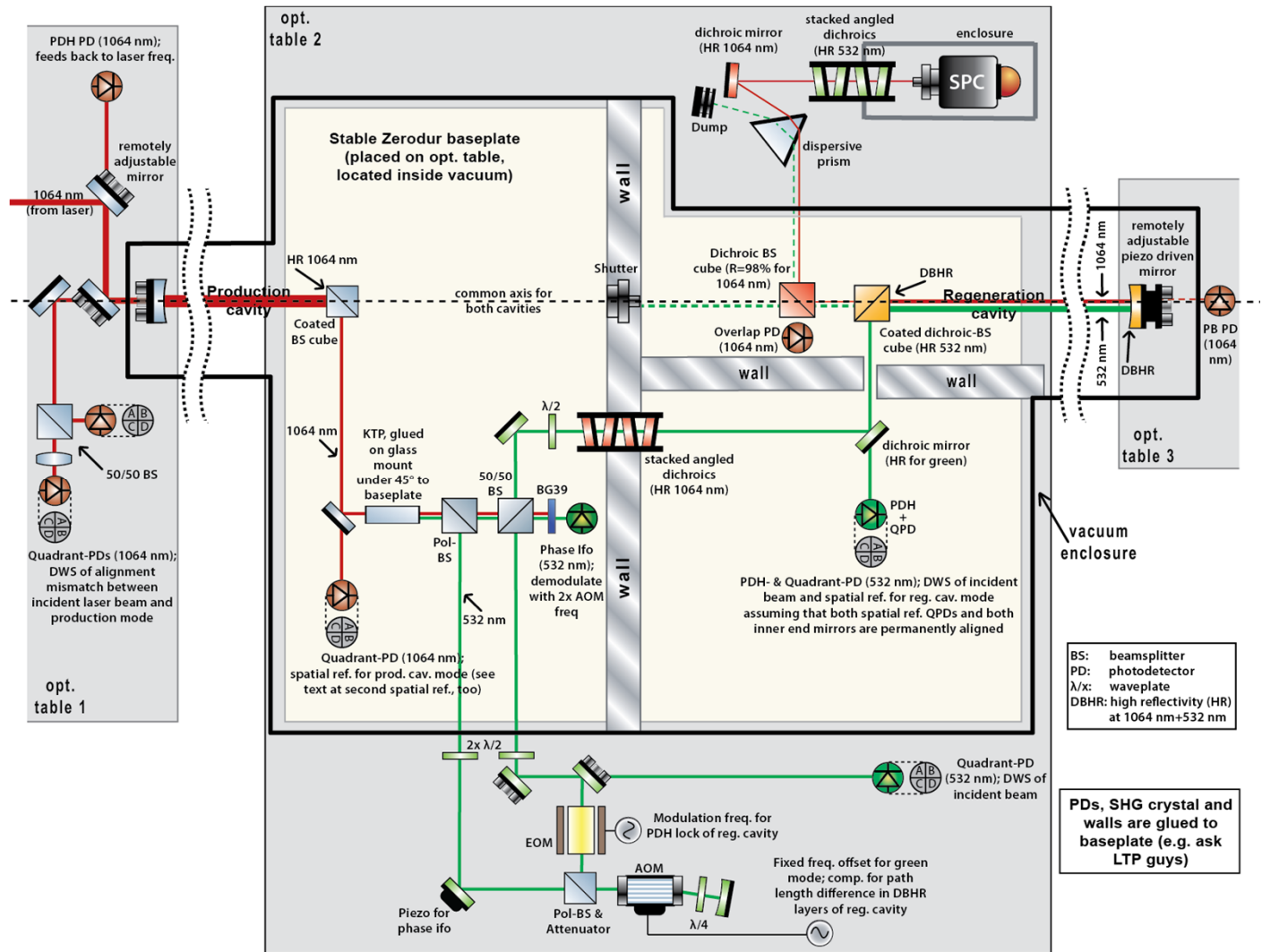


ALPS-II: optical System

Sketch of the optical system:

On paper a working scenario exists. Alternatives have been worked out also.

Crucial to decide on the next steps is the measurement of the amount of down-converted light from the green light used to lock the regeneration cavity.

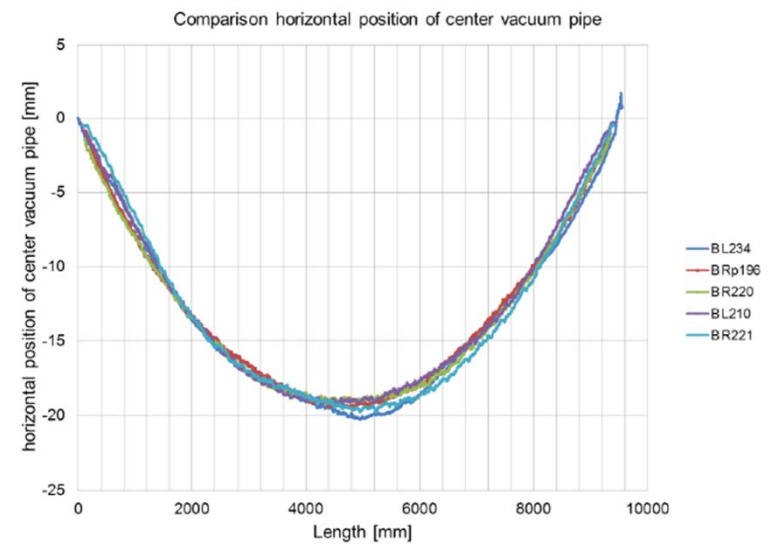
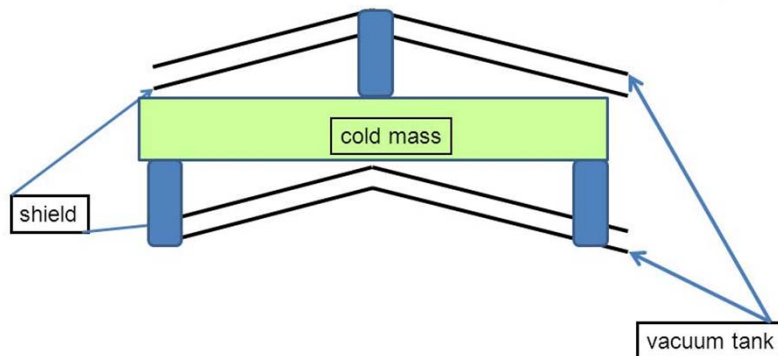


ALPS-II: HERA Dipoles

- > Prepare for attempt to straighten a dipole to increase the aperture.

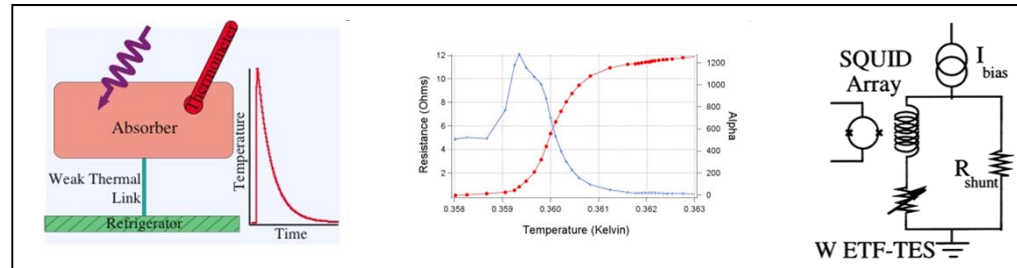


Third step: force ends of cold mass towards the center by ~8 mm and fix it by appropriate structures



ALPS-II: Transition Edge Sensor to count 1064 nm Photons

> Principle:



> Aims:

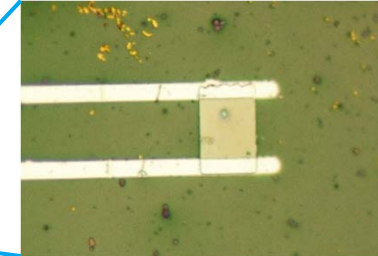
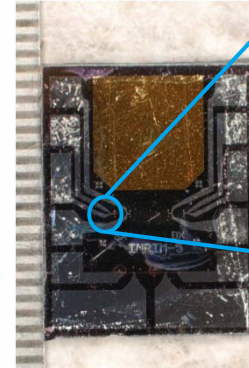
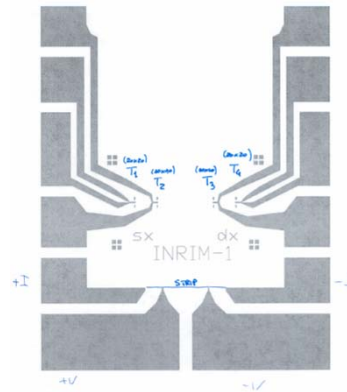
- Determination of background counts (only an upper limits of 10^{-3} 1/s are published)
- Energy resolution for single photons
- Efficient guiding of light onto the TES

> A dedicated international team:



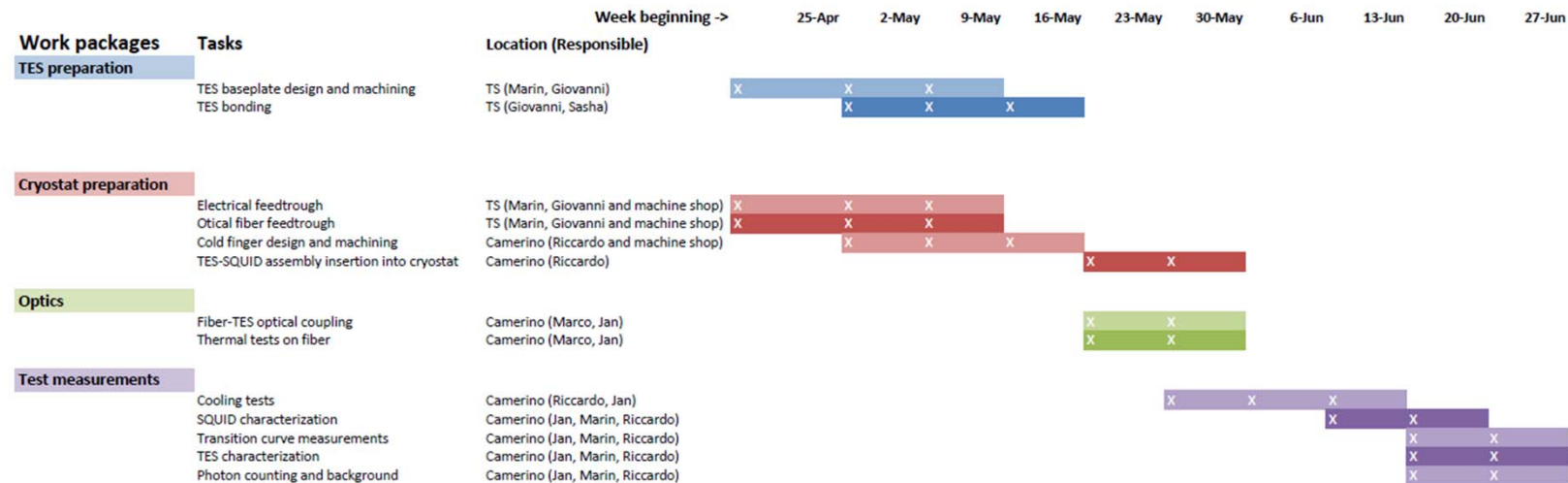
ALPS-II: Transition Edge Sensor to count 1064 nm Photons

> Our first TES from INRIM:

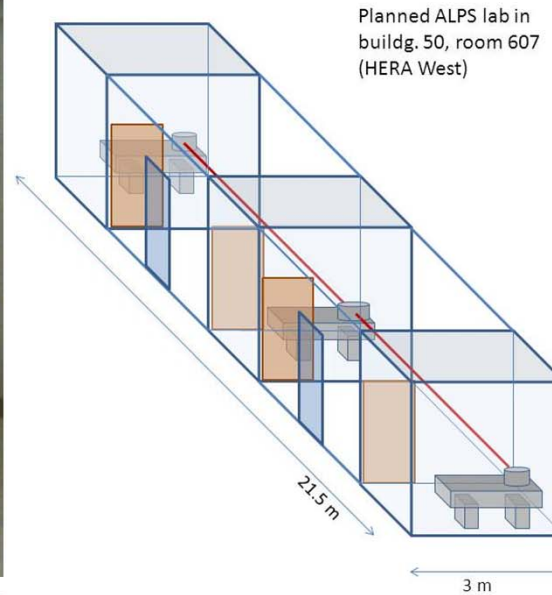


sensor area: 20µm x 20µm

> We hope for first experience and results in summer this year:



ALPS-II: a new Laser Laboratory in HERA-Hall West



Former klystron hall in
HERA-West, area
cleaned and prepared.



Test of different supports for optical tables with
seismic measurements.

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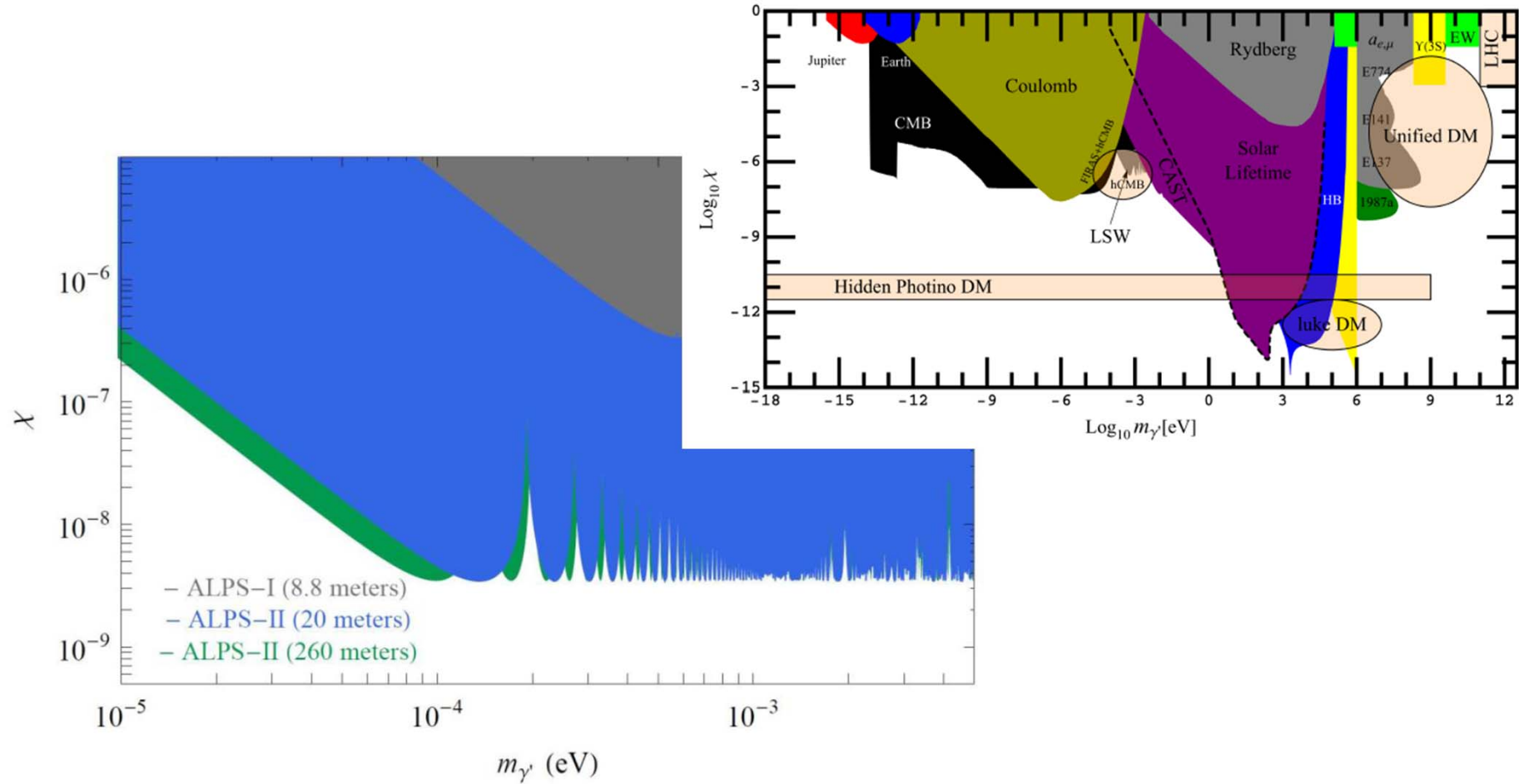
ALPS-II: Timeline

- > **Step 0** (spring 2012):
Preparation of an ALPS-II TDR
- > **Step 1** (end of 2012):
Set-up of hidden photon search with two 10m long vacuum tubes in the new laser laboratory in HERA-West.
Magnets are not required here!
- > **Step 2** (end of 2014):
Search for hidden photons with two 100m long vacuum tubes in the HERA tunnel (using the proton vacuum tube).
- > **Step 3** (2017):
Search for axion-like particles in the HERA tunnel with two strings of HERA dipole magnets.
 - 4x4 dipoles
 - 12x12 straightened dipoles



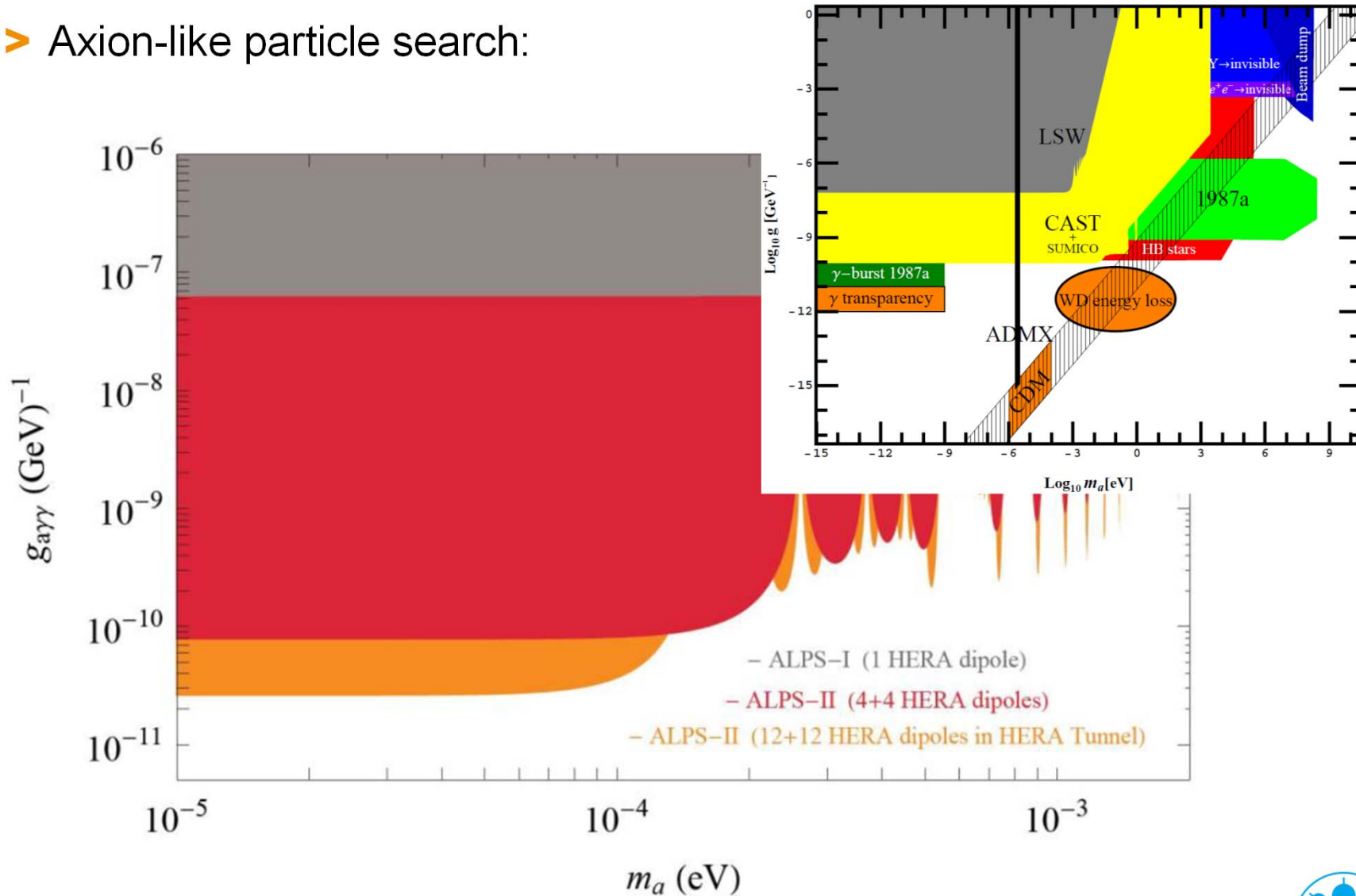
The ALPS-II Potential

> Hidden photon search (no magnets required):



The ALPS-II Potential

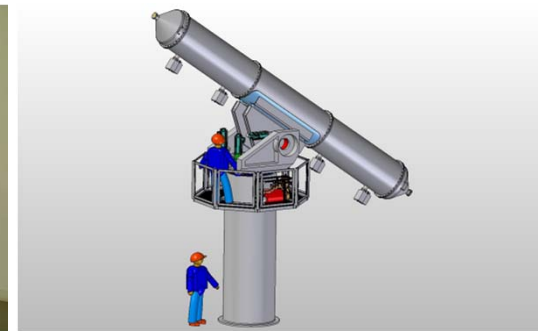
> Axion-like particle search:



Summary

- > ALPS-II has the potential to reach new horizons in WISP searches
 - Hidden photons: probe the hCMB prediction.
 - Axion-like particles: check indirect limits from astrophysics in the laboratory, touch regions of interest given by astrophysics.
- > ALPS-II could be a nucleus at DESY for more WISP searches

- SHIPS at Bergedorf / DESY



- Discussions with other groups (CERN, Italy, Yale) on common projects.
- > The ALPS activities trigger contacts to new scientific communities
 - (laser, gravitational waves, astronomy, optical detectors, quantum optics ...)

ALPS-II @ DESY

... standing on the shoulders of a giant ...



> ALPS-II (would like to) profit from

- the treasury of HERA magnets,
- the knowledge in cryogenics,
- the expertise in vacuum technology,
- the unique infrastructure (like long straight sections in the HERA tunnel),
- the know-how in detector technology,
- the world-leading position in theory,

> and could give

- new background-free optical photon detectors,
- 10-100 mK cryogenics,
- laser expertise,
- **break-through physics results!**



Invitation to the 7th Patras Workshop

4th Patras Workshop on Axions, WIMPs and WISPs
Physics of Axions, Weakly Interacting Massive Particles and Weakly Interacting Sub-eV Particles in Universe and Laboratory



Organizing committee:
Laura Baudis (Zürich University)
Josef Jochum (Universität Tübingen)
Axel Lindner (DESY)
Javier Redondo (DESY)
Andreas Ringwald (DESY)
Konstantin Zioutas (DESY/University of Patras)

5th Patras Workshop on Axions, WIMPs and WISPs
13-15 June 2010
University of Patras
<http://axion-wimp.desy.de/>



Organizing committee:
Laura Baudis (University of Zurich)
Joerg Jaeckel (IPPP/Durham University)
Axel Lindner (DESY)
Andreas Ringwald (DESY)
Konstantin Zioutas (University of Patras)

6th Patras Workshop on Axions, WIMPs and WISPs
13-15 June 2011
University of Patras
<http://axion-wimp.desy.de/>



7th Patras Workshop on Axions, WIMPs and WISPs
26 June - 1 July 2011
Mykonos (GR)



Programme

- The physics case for WIMPs, Axions, WISPs
- Review of collider experiments
- Signals from astrophysical sources
- Direct searches for Dark Matter
- Indirect laboratory searches for Axions, WISPs
- Direct laboratory searches for Axions, WISPs
- New theoretical developments

Organizing committee:
Vassilis Anastassopoulos (University of Patras)
Laura Baudis (University of Zurich)
Joerg Jaeckel (IPPP/Durham University)
Axel Lindner (DESY)
Andreas Ringwald (DESY)
Marc Schumann (University of Zurich)
Konstantin Zioutas (University of Patras) (chairman)

<http://axion-wimp.desy.de>

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