Dark Matter Searches: WISPs

Dark Matter and searches for WISPy extensions of the Standard Model

Axel Lindner
DESY

DESY Summer Student Lecture, 21 August 2013

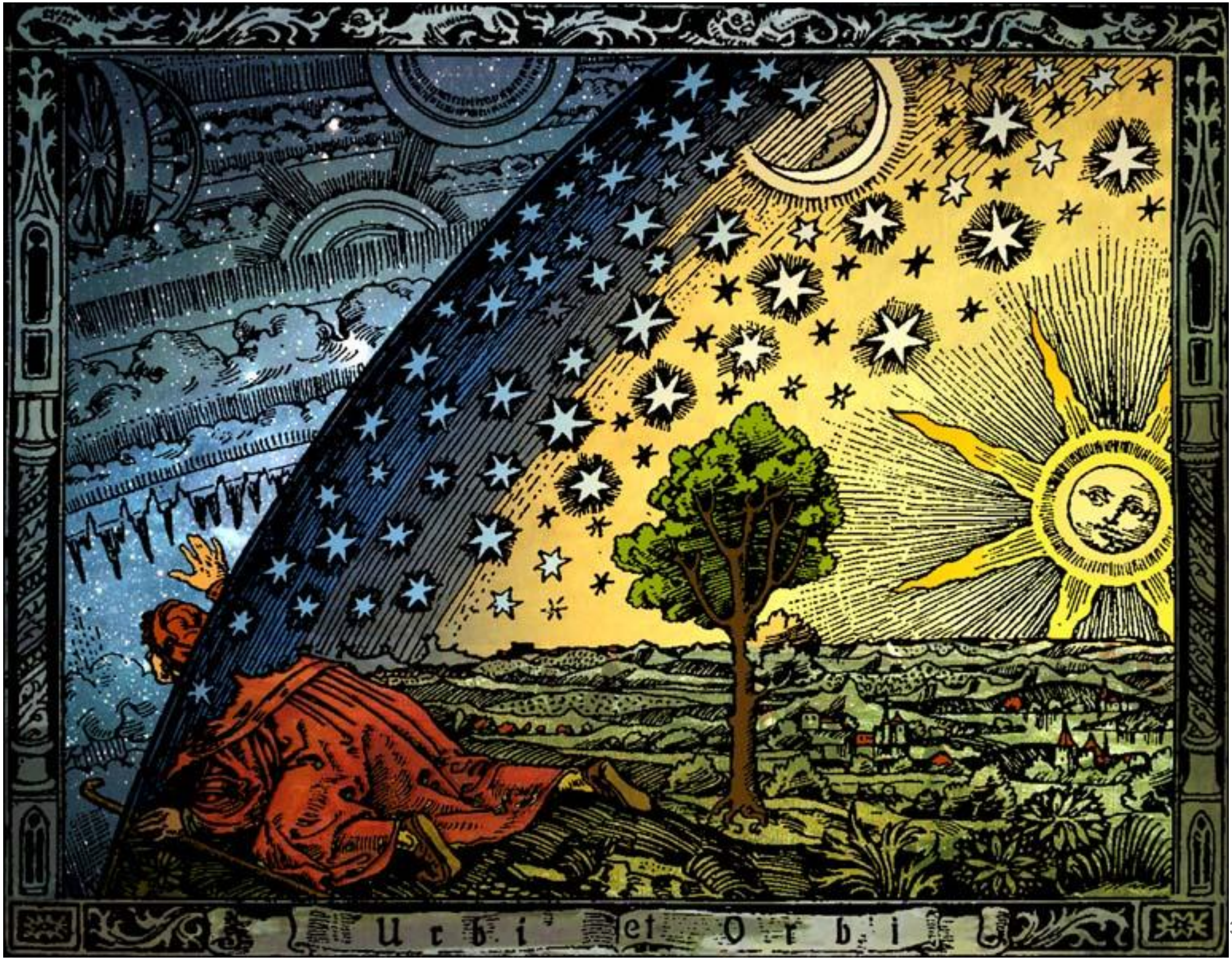
HELMHOLTZ ASSOCIATION

DESY

Dark matter searches

- Repetition
  - Dark matter
  - The Standard Model of particle physics
  - Dark matter candidates
- WISPy physics
  - Hints for WISPs
  - WISPs and the Standard Model
  - Basics of WISP experiments
- WISP experiments
  - Laboratory: ALPS-II @ DESY
  - Helioscopes
  - Dark matter searches
- Summary

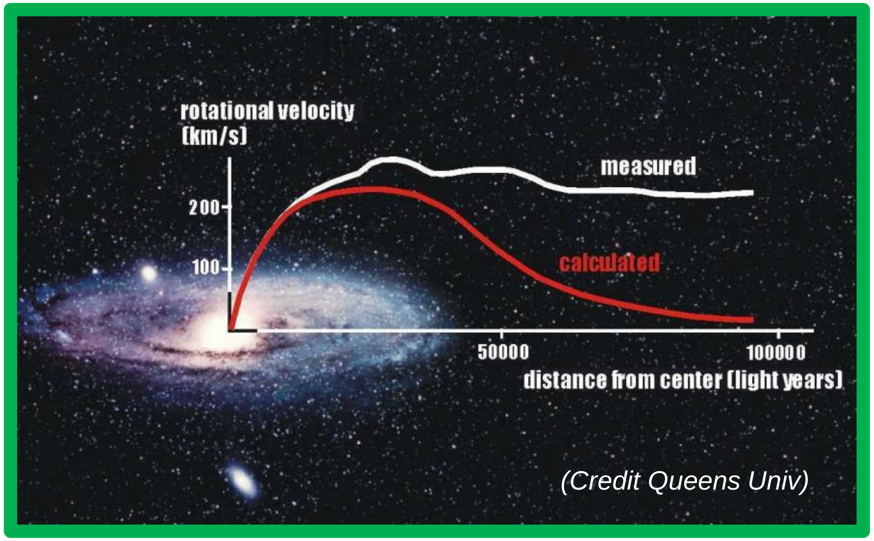
Physics beyond the standard model

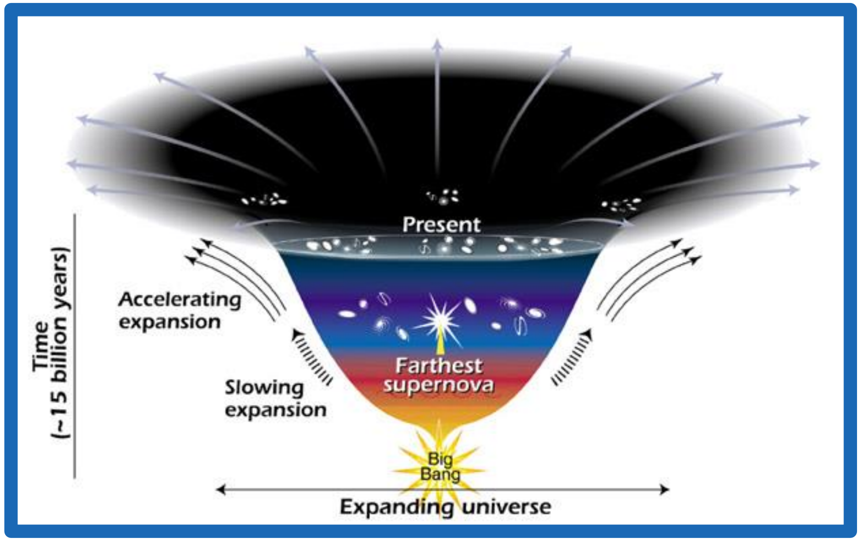


http://es.wikipedia.org/wiki/Archivo:Universum.jpg

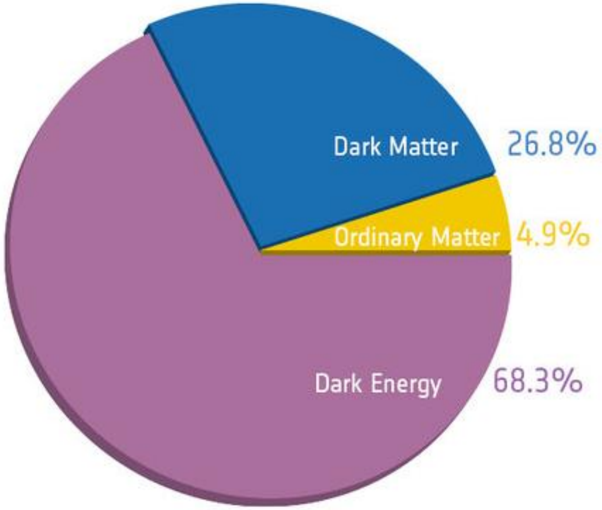
There is physics beyond the SM

- Dark matter and dark energy:





http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/

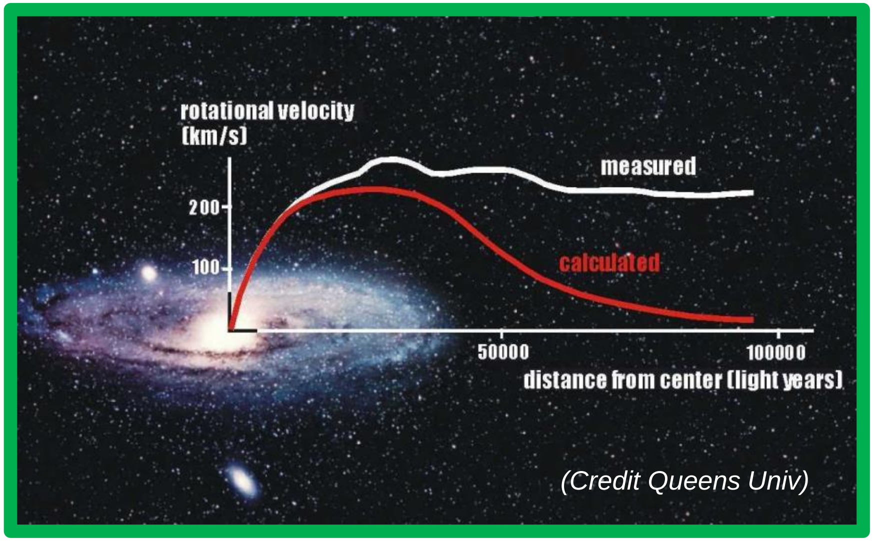


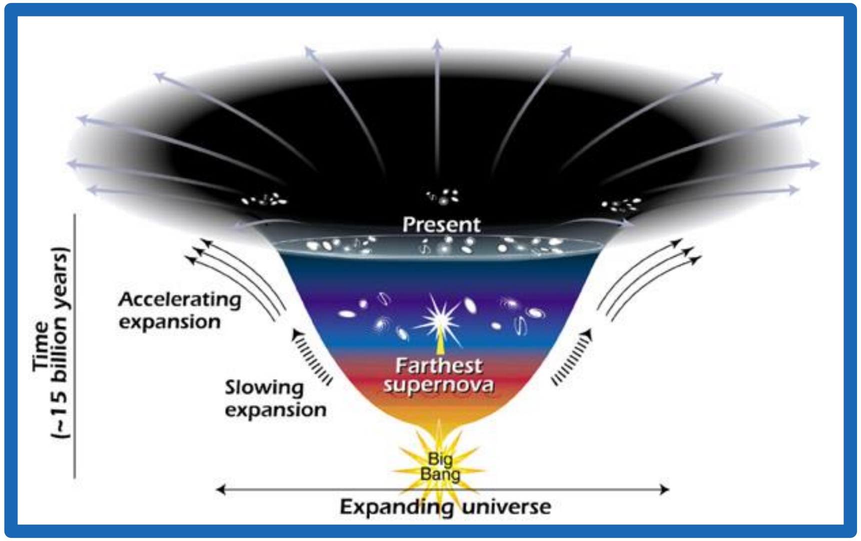
http://www.esa.int/For_Media/Photos/Highlights/Planck

Even if one neglects dark energy:
85% of the matter is of unknown constituents.

There is physics beyond the SM

- Dark matter and dark energy candidate constituents:





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- Very weak interaction with SM matter
- Very weak interaction among themselves
- Stable on cosmological times
- Non-relativistic

There is physics beyond the SM

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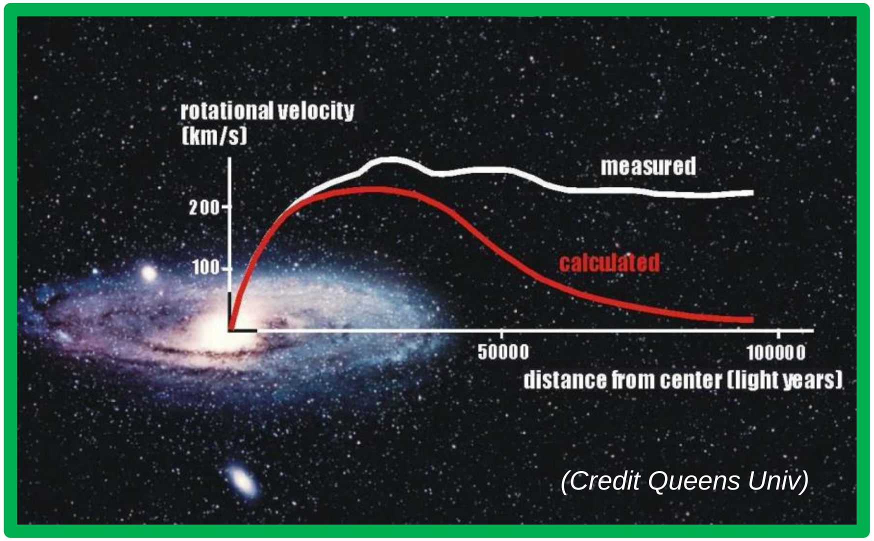

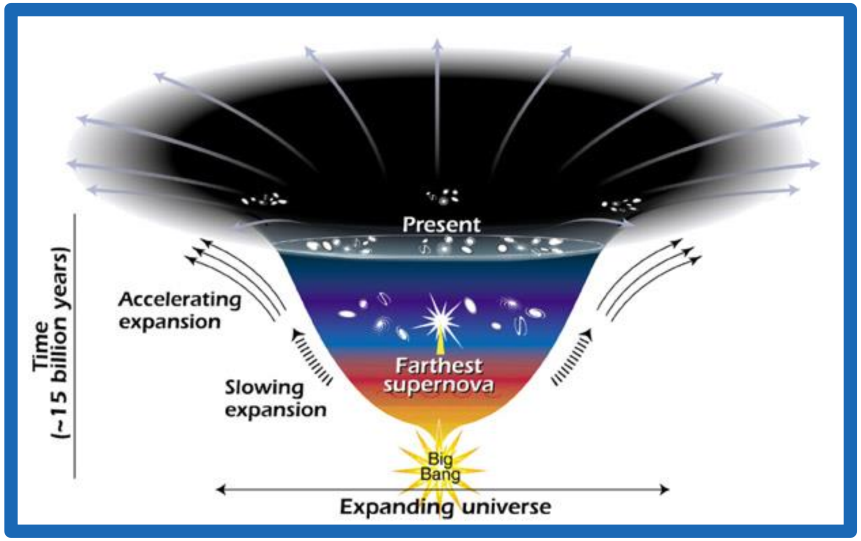

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- Stable on cosmological times
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NO HINT ON MASS OF DM CONSTITUENTS!

- Extremely lightweight scalar particle

Precision cosmology!

http://lambda.gsfc.nasa.gov/

- Geometry of the Universe: flat
- Age of the Universe: 13.796 ± 0.058 Gyr
- Hubble Constant: 67.9 ± 1.5 km s^{-1} Mpc^{-1}
- Fluctuations compatible with inflation

- Ω_b (baryons): 0.0481
- Ω_c (dark matter): 0.257
- Ω_Λ (dark energy): 0.693 ± 0.019
- Early star light (re-ionisation): $\Omega_v \ll \Omega_{dm}$

Very good agreement among very different data (CMBR, supernova search with HST, galaxy counting, Big Bang Nucleon-synthesis, ...)

Some caveats on our picture of a strange universe

- The Copernican principle is used to interpret the data.
  - The Universe in our neighborhood is not special.

    Homogeneity (similarity in all regions of space)
    Isotropy (similarity in all directions).

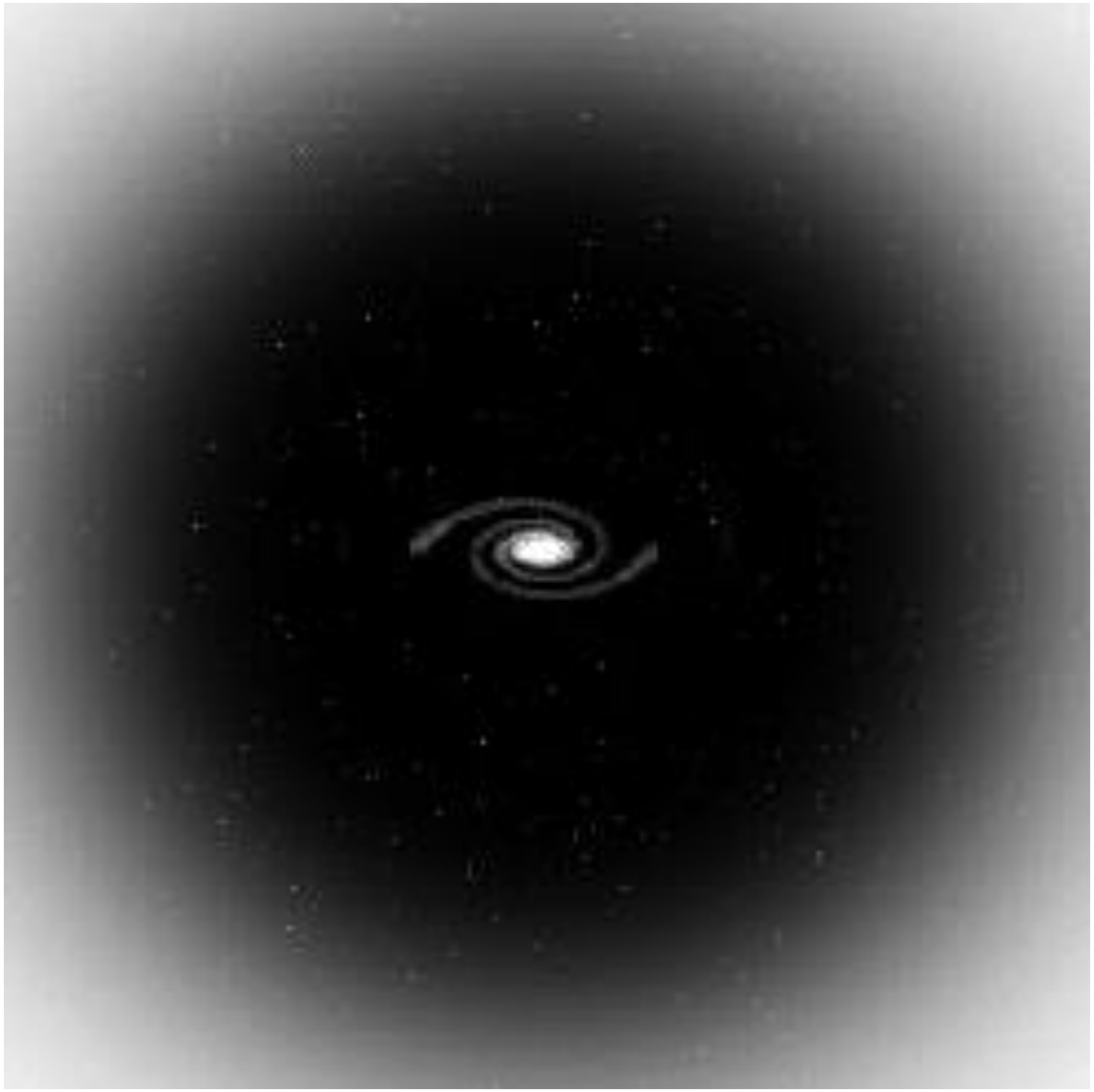
  This principle is

  - compatible with observations (if you accept “Dark Energy”!),
  - **but fundamentally untested!**

- Which is the relevant scale for homogeneity of the Universe?
  Does one have to take into account in-homogeneities when calculating cosmological parameters?

- Do we really understand gravity in the weak acceleration regime on cosmological scales?

Model: galaxies "swim" in a halo of dark matter

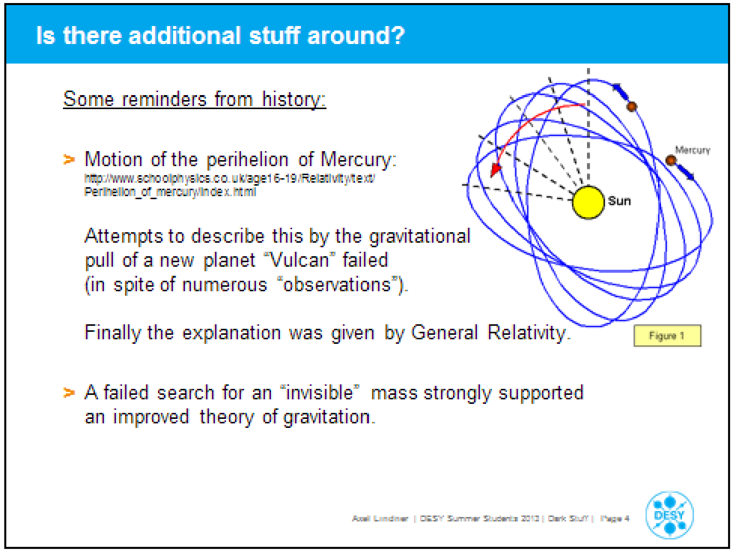


However, the detailed structure of such a halo is a matter of intense discussion!

Evidence for dark matter in the universe

Dark matter

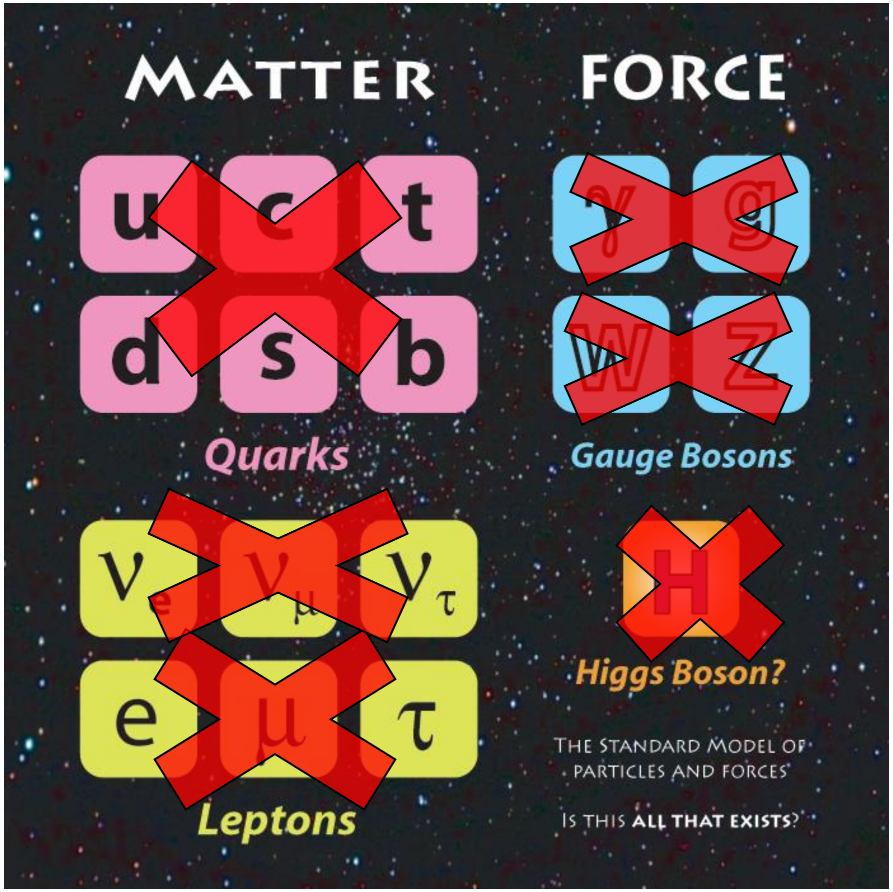
- shows up in gravitation only, which is the only interaction not embedded in the standard model.
- can not consist out of standard model constituents.
- only shows up in large systems much beyond the scale of the solar system!



What is dark matter?

Dark matter

- shows no strong or electromagnetic interaction (some weak interaction could have escaped detection by now).
- has not decayed during the evolution of the universe.
- should be "cold" to form the structures in the universe.
  Neutrinos are very lightweight so that cosmic neutrinos move at relativistic speeds. Hence neutrinos can not explain the structure formation.



http://www.gridpp.ac.uk/cubes/

What is dark matter?

Dark matter

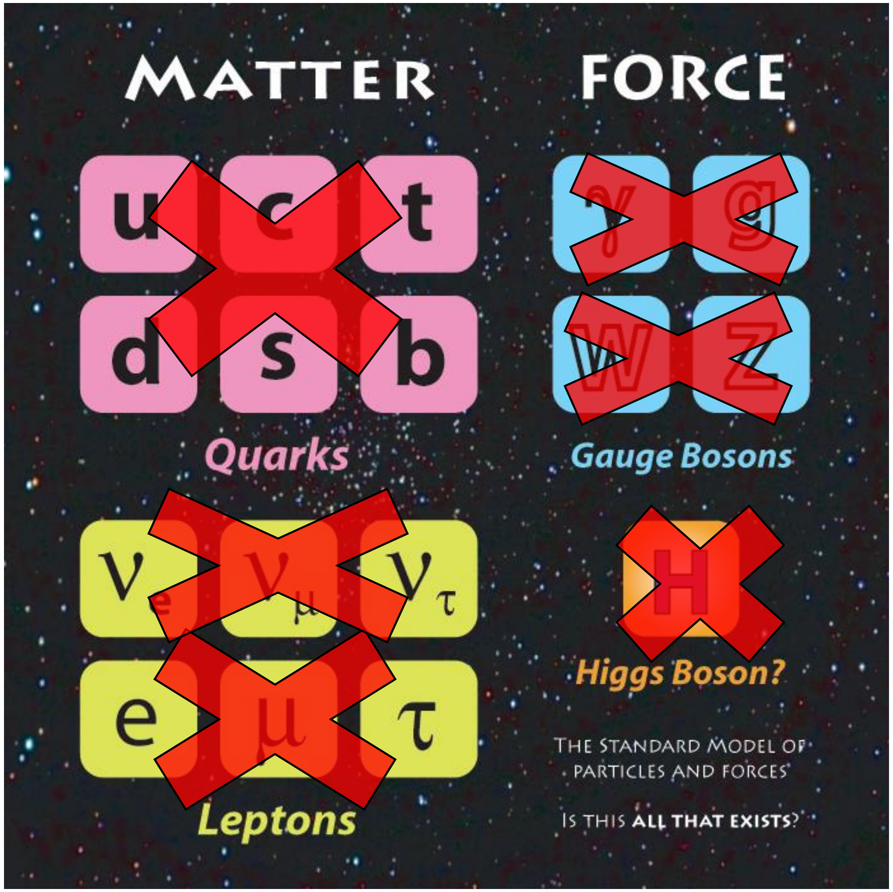
constituents are not

the particles of

the Standard Model !

At least the dominant

fraction of dark matter …



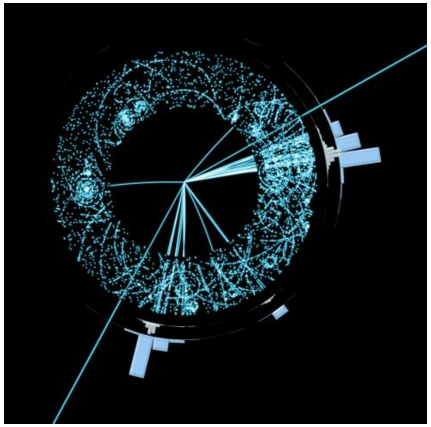
http://www.gridpp.ac.uk/cubes/

Dark matter candidates

Let's concentrate on candidates which could solve not only the dark matter problem!

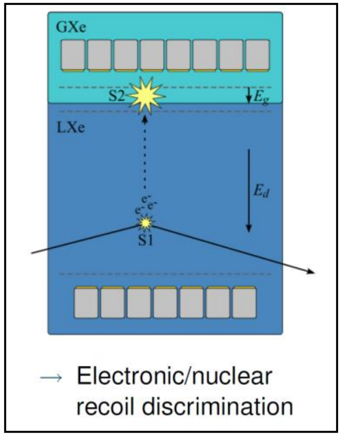
- The SUSY-WIMP scenario:
  SUSY might also explain some "fine-tuning" issues at the TeV scale.
  Very heavy (around 10^{11}eV).

WIMPs at LHC



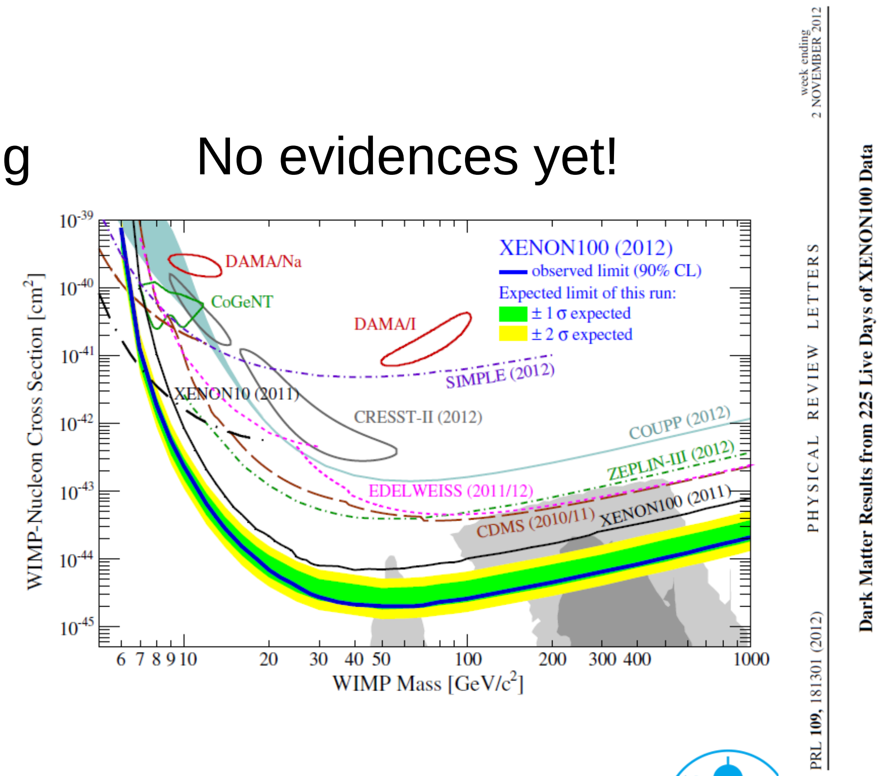
http://www.atlas.ch/photos/events-simulated-supersymmetry.html

DM WIMP scattering



T. Marrodán Undagoitia, PATRAS 2013, Mainz

No evidences yet!



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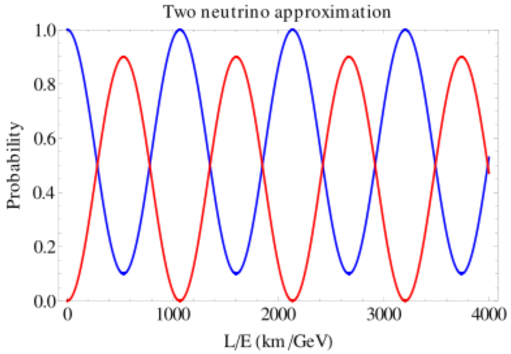
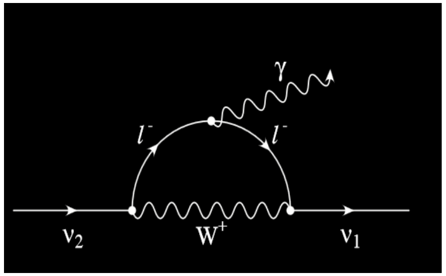
  might explain the small mass of neutrinos and also the matter-antimatter asymmetry in the universe.
  Medium (around 10^{3}eV).

Neutrino mixing



X-ray excess from decaying DM



http://www.sciencedirect.com/science/article/pii/S2212686412000131

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- Axions and similar Weakly Interacting Slim Particles (WISPs)
  might explain "fine-tuning" issues at the GeV scale and some strange phenomena observed in astrophysics.
  Very light (around 10^{-6}eV).

Dark matter candidates: hints from observations

Let's concentrate on candidates which could solve not only the dark matter problem!

- The SUSY-WIMP scenario:
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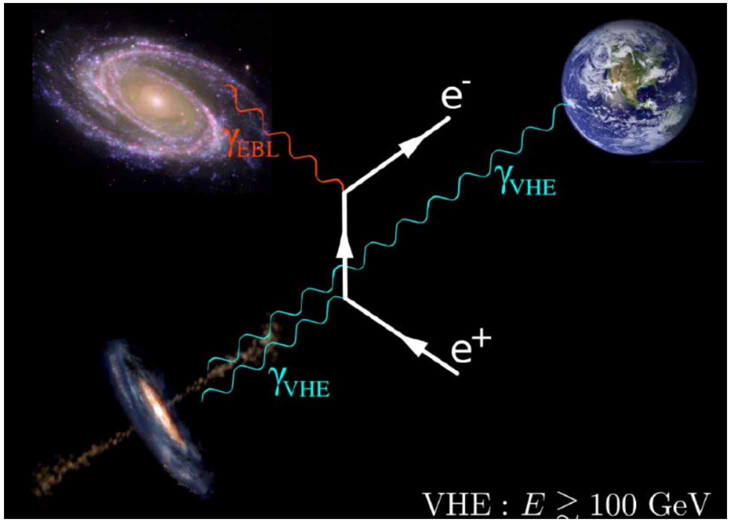
TeV photons in intergalactic space

> Puzzles from astrophysics:

Example: TeV photons should be absorbed in the intergalactic space, …



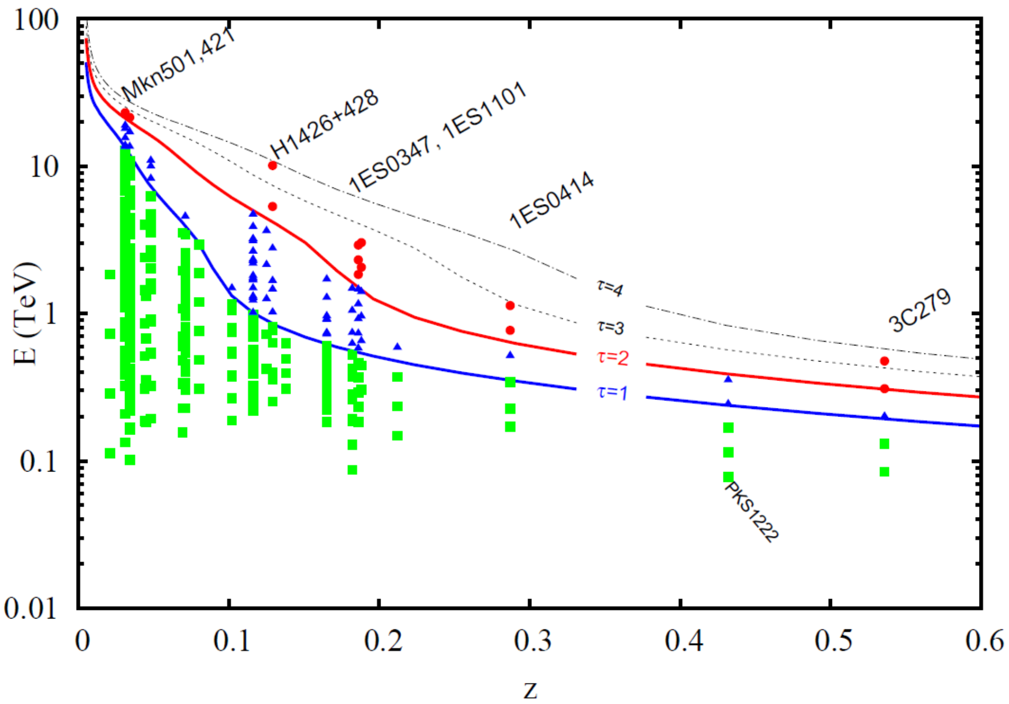
Center of mass energy about 1 MeV!

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

TeV photons in intergalactic space

> Puzzles from astrophysics:

… but this seems to be in conflict with observations.

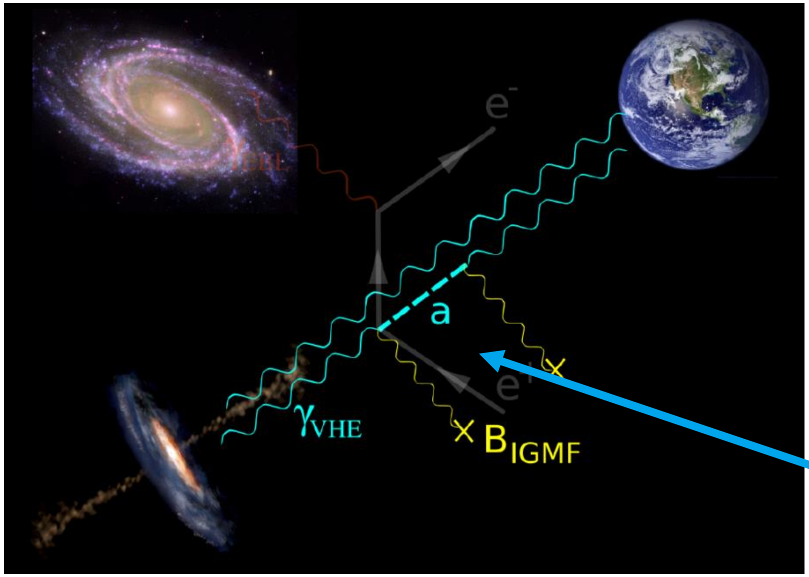


D. Horns, M. Meyer, JCAP 1202 (2012) 033

> If physics beyond the SM is involved, it happens below the MeV scale!

ALPs and cosmic TeV photons

- 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 ALPs:

ALPs and cosmic TeV photons

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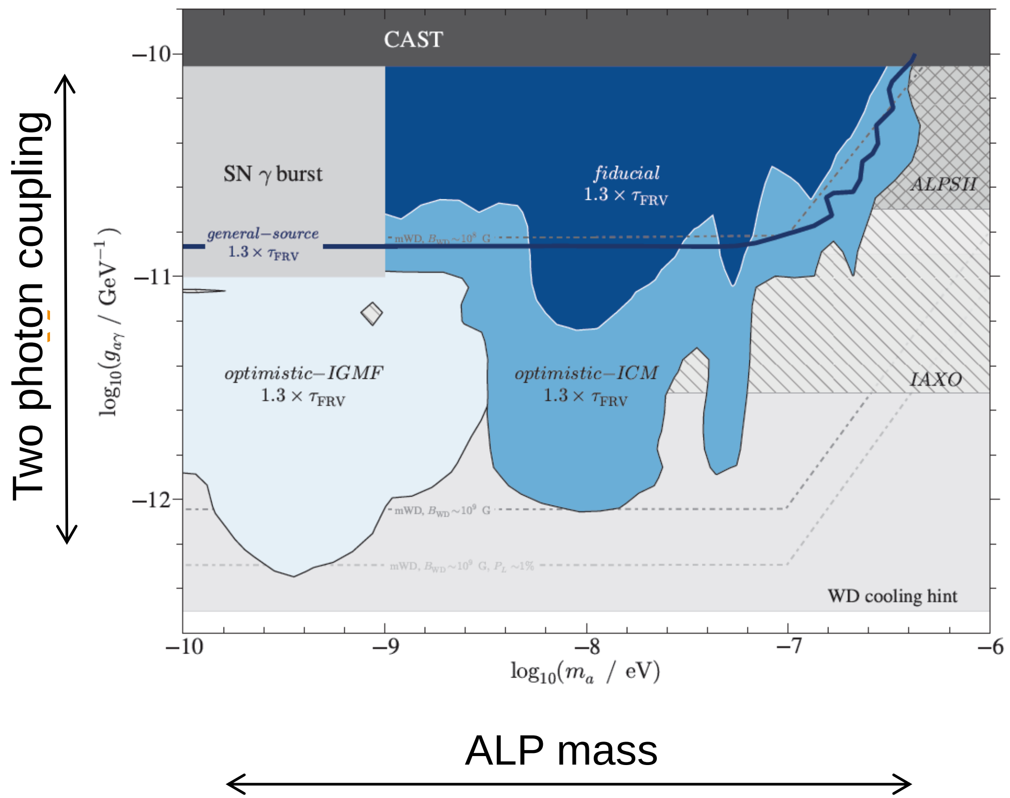


$g_{a\gamma} \approx 10^{-11}\mathrm{GeV}^{-1}$, $m_a < 10^{-7}\mathrm{eV}$ have to be probed!

M. Meyer, D. Horns, M. Raue,
arXiv:1302.1208 [astro-ph.HE], Phys. Rev. D 87, 035027 (2013)

Unexplained astrophysics phenomena

might hint at Weakly Interacting Slim Particles (WISPs).

- Axions and axion-like particles (ALPs, pseudoscalar or scalar bosons)
- Hidden photons (neutral vector bosons)
- Mini-charged particles
- Chameleons (self-shielding scalars)

Phenomenon	WISPy explanation	WIMPy explanation
White dwarf cooling ★	Axion, ALP	
TeV transparency ★	ALP	
Dark matter ★	Axion, ALP, HP	LSP
Dark energy ★	Chameleon	

★ to be confirmed!

A phenomenon pointing at BSM physics?

- CP-conservation in QCD:

F. Wilczek at "Vistas in Axion Physics", Seattle, 26 April 2012
(see http://www.int.washington.edu/talks/WorkShops/int_12_50W/People/Wilczek_F/Wilczek.pdf)

The overall phase of the quark mass matrix is physically meaningful.
In the minimal standard model, this phase is a free parameter, theoretically.
Experimentally it is very small.
This is the most striking unnaturality of the standard model, aside from the cosmological term.
It does not seem susceptible of anthropic "explanation".

In QCD a free parameter Θ could have any value between 0 and 2π.

Experimentally, $\Theta < 10^{-9}$.

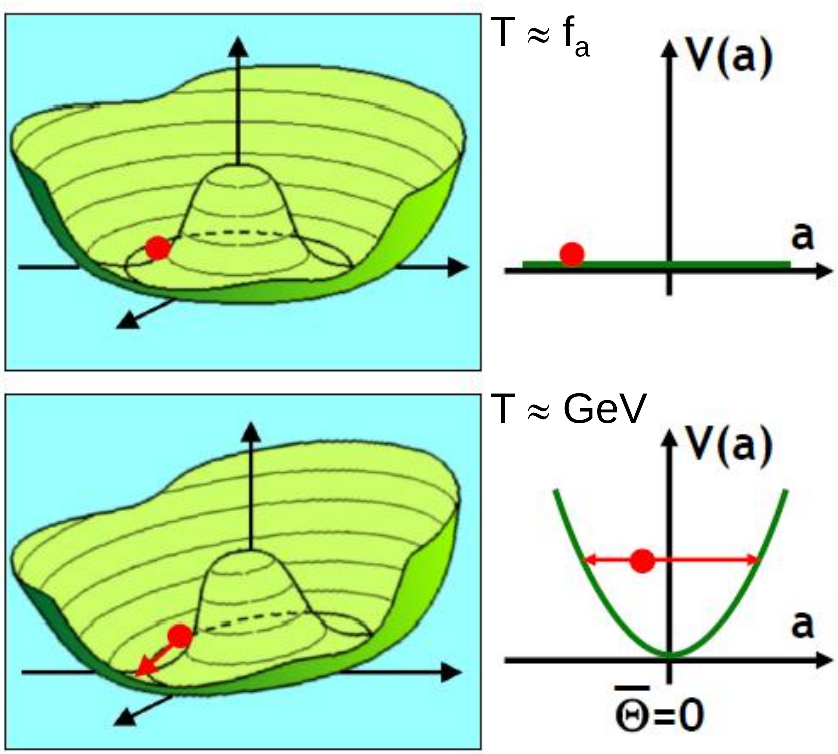
- A "fine-tuning" problem?

Introducing the axion

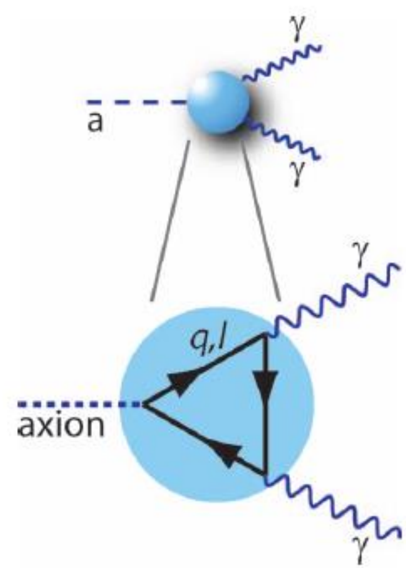
> CP-conservation in QCD:

A dynamic explanation for $\Theta < 10^{-9}$ predicts the axion, which couples very weakly to two photons.

Peccei-Quinn 1977



Wilczek and Weinberg 1978



S. Hannestaad, presentation at 5th Patras Workshop on Axions, WIMPs and WISPs, 2009

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

Introducing the axion

> CP-conservation in QCD:

A dynamic explanation for $\Theta < 10^{-9}$ predicts the axion, which couples very weakly to two photons.

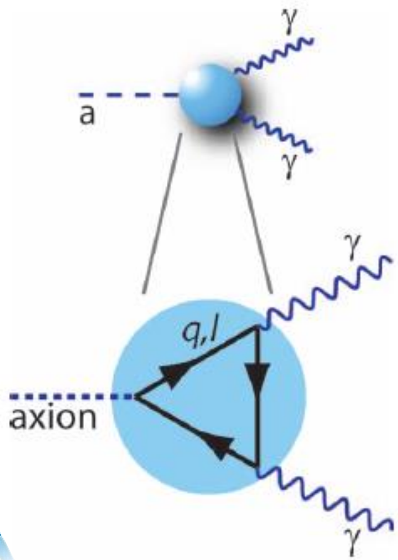
The axion "wipes out" the CP-conservation problem in QCD.

Properties of the axion

- The QCD axion: light, neutral pseudoscalar boson.
- The QCD axion: the light cousin of the π^0.
  - Mass and the symmetry breaking scale f_a are related:
    $m_a = 0.6eV \cdot (10^7 GeV / f_a)$
  - The coupling strength to photons is
    $g_{a\gamma\gamma} = \alpha \cdot g_\gamma / (\pi \cdot f_a)$,
    where g_γ is model dependent and O(1).
    Note: $g_{a\gamma\gamma} = \alpha \cdot g_\gamma / (\pi \cdot 6 \cdot 10^6 GeV) \cdot m_a$
  - The axion abundance in the universe is
    $\Omega_a / \Omega_c \sim (f_a / 10^{12} GeV)^{7/6}$.

    $f_a < 10^{12}$GeV
    $m_a > \mu$eV

NON-THERMAL ORIGIN
FROM VACUUM RE-ALIGNMENT



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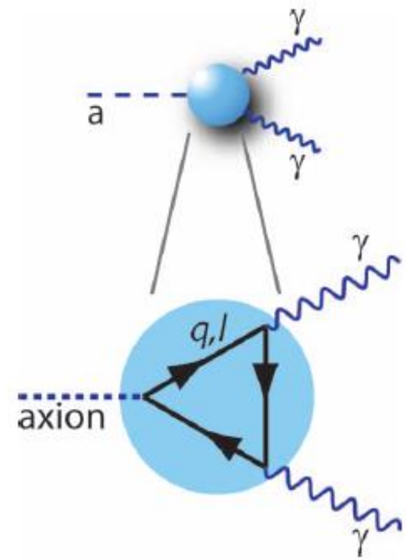
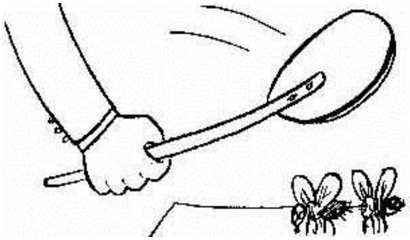
VERY LIGHTWEIGHT COLD DARK MATTER!



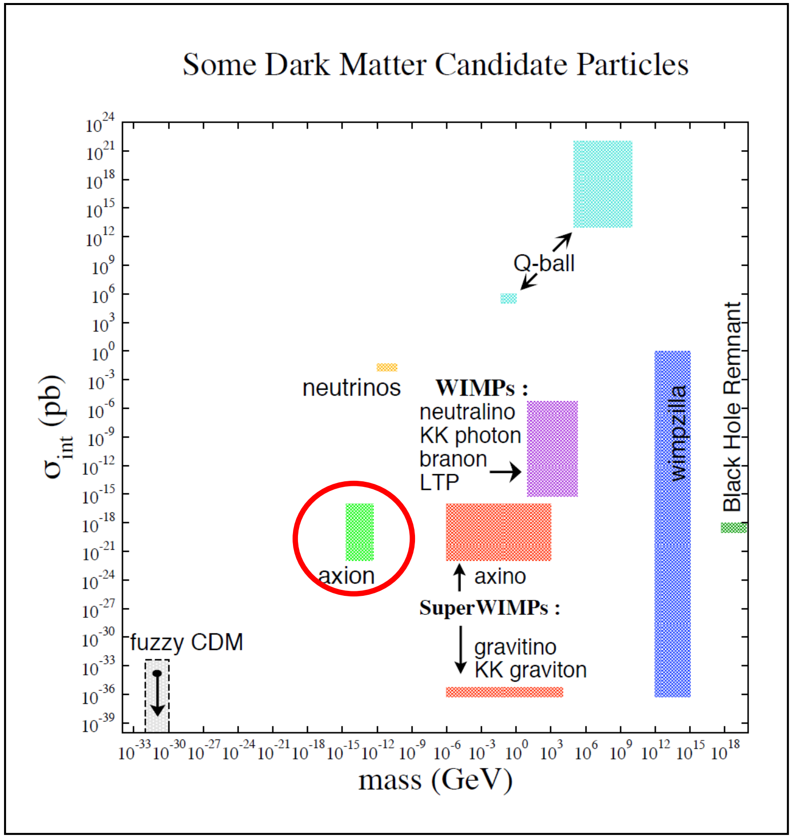
The Search for Axions, Carosi, van Bibber, Pivovaroff, Contemp. Phys. 49, No. 4, 2008

Axions are perfect cold DM candidates

- Axions with μeV mass are perfect cold dark matter candidates.
- They would interact extremely weakly with SM constituents.
- Similar to SUSY-WIMPs axions would solve two puzzles in one go:
  - Dark matter
  - CP conservation in QCD.



52 orders of magnitude

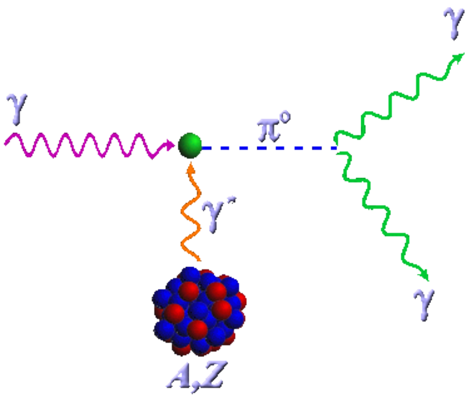


52 orders of magnitude

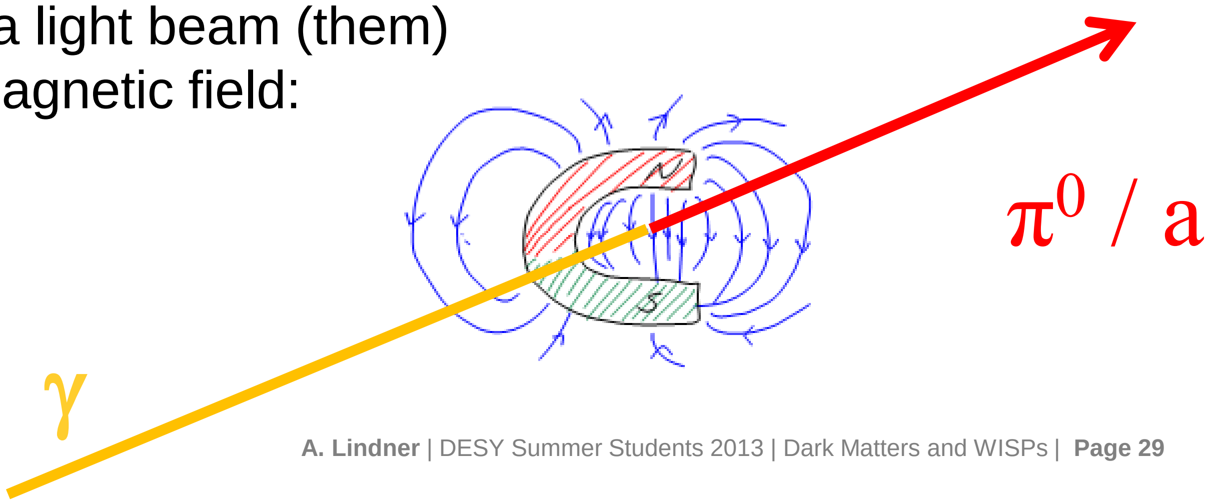
H. Baer, presentation at 5th Patras Workshop on Axions, WIMPs and WISPs, 2009

Properties of the axion

- The QCD axion: the light cousin of the π^0.
- It couples to two photons.
- Therefore the Primakoff effect will also work for the axion!

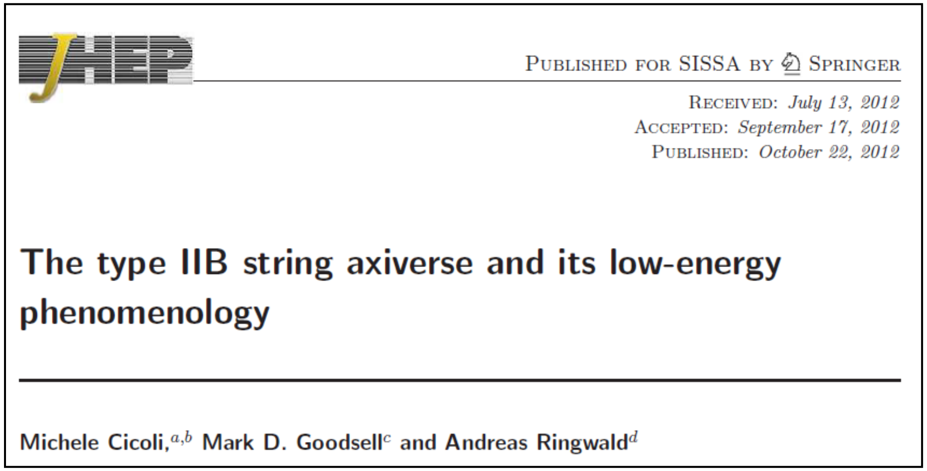


- Axions could be produced (detected) by sending a light beam (them) through a magnetic field:



More general: WISPy particles

- Axions and other Weakly Interacting Slim Particles (WISPs) occur naturally in string theory inspired extensions of the standard model as components of a “hidden sector”.



JHEP

Published for SISSA by Springer

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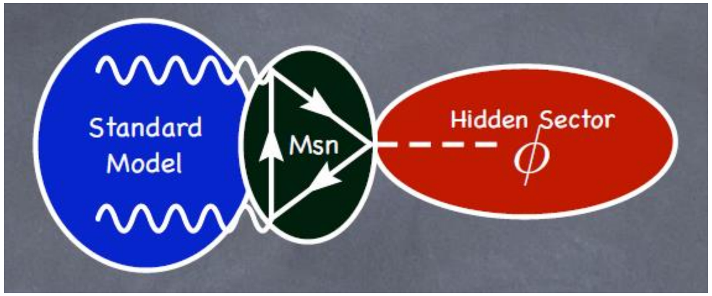
The type IIB string axiverse and its low-energy phenomenology

Michele Cicoli,[a,b] Mark D. Goodsell[c] and Andreas Ringwald[d]

DOI: 10.1007/JHEP10(2012)146
http://www.arxiv.org/abs/1206.0819v1

- Their weak interaction might be related to very heavy messenger particles.
Thus WISPs may open up a window to particle physics at highest energies.



More general: WISPy particles

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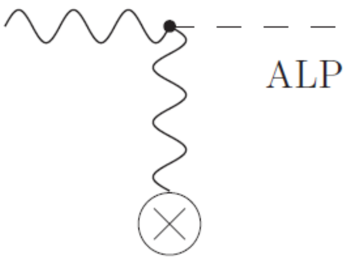
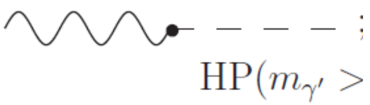
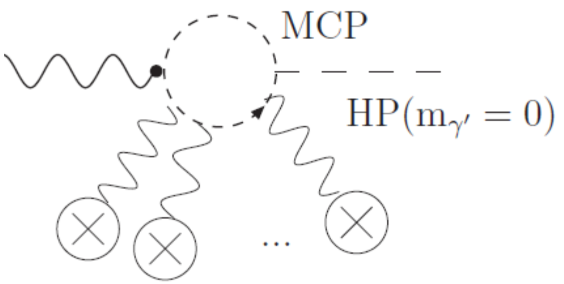


- Hidden photons (neutral vector bosons)



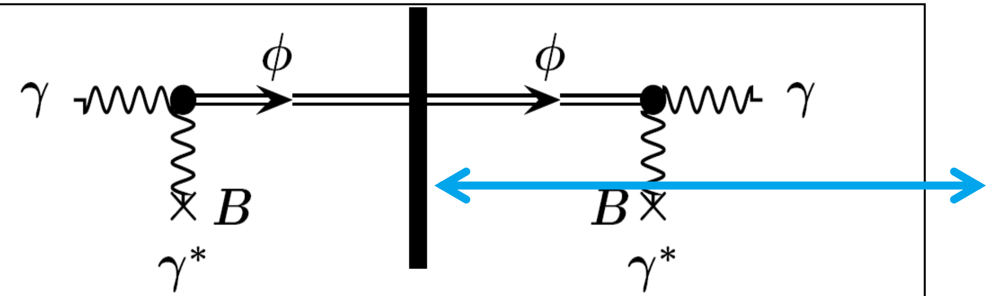
- Mini-charged particles



- Chameleons (self-shielding scalars), massive gravity scalars

Basics of WISP experiments (I)

- Basic idea: due to their very weak interaction WISPs may traverse any wall opaque to Standard Model constituents (except ν and gravitons).
  - WISP could transfer energy out of a shielded environment
  - WISP could convert back into detectable photons behind a shielding.
- "Shining-through-a-wall"



Okun 1982, Skivie 1983, Ansel'm 1985, Van Bibber et al. 1987

steel wall, cryostat,
earth's atmosphere,
stellar body,
intergalactic background light,
….

Basics of WISP experiments (II)

- Basic idea: due to their very weak interaction WISPs may traverse any wall opaque to Standard Model constituents (except ν and gravitons).
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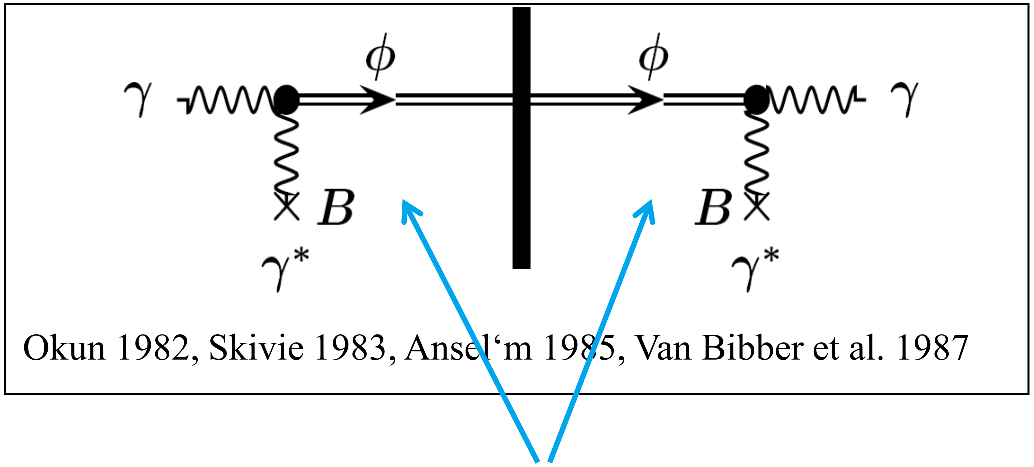

Real WISPs are produced!

Basics of WISP experiments (III)

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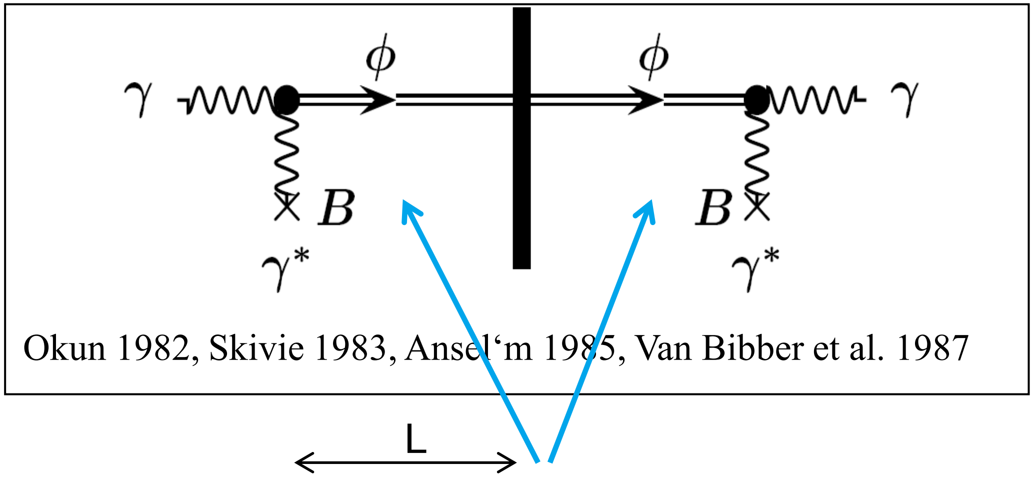

Coherent production and regeneration: $P_{\gamma\to\Phi} \propto (B\cdot L)^2$

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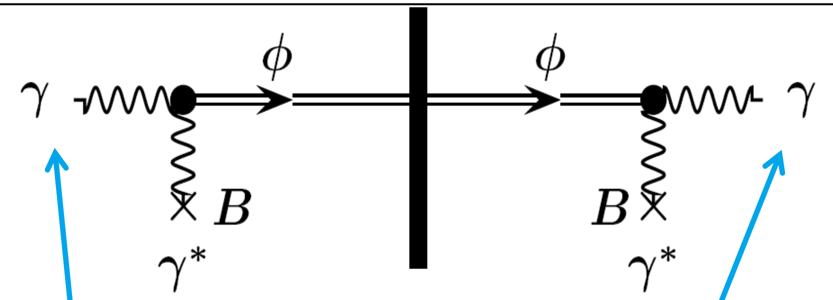


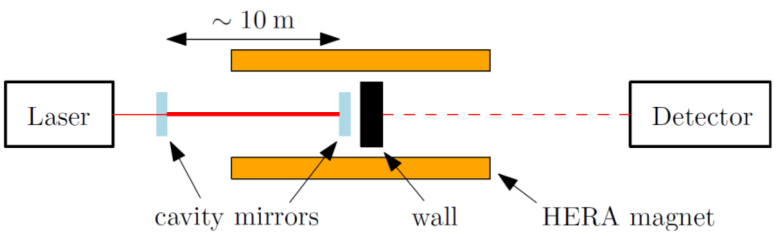
Okun 1982, Skivie 1983, Ansel'm 1985, Van Bibber et al. 1987

The primary and the regenerated photons have exactly the same properties (energy, polarization).

Three kinds of WISP searches

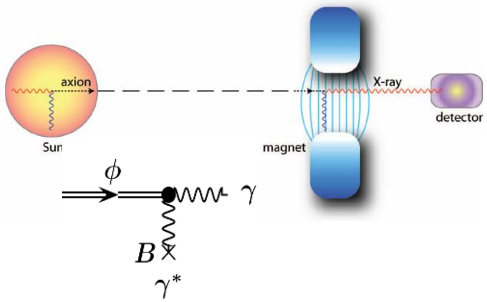
Weakly Interacting Slim Particles (WISPs) are searched for by

- Purely laboratory experiments ("light-shining-through-walls") optical photons,

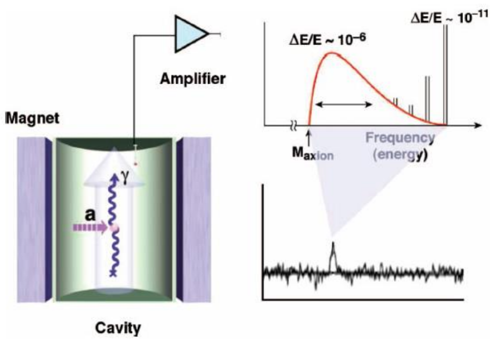


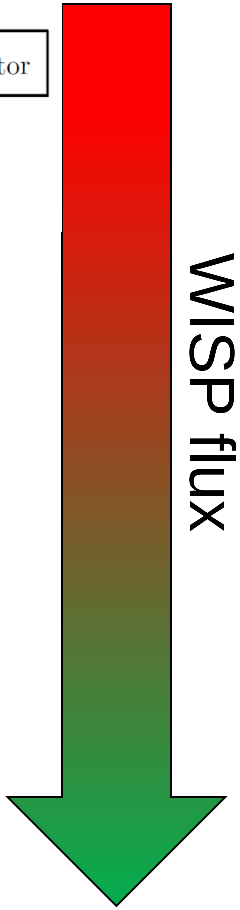
(a) ALPS-I

- Helioscopes (WISPs emitted by the sun), X-rays,



- Haloscopes (looking for dark matter constituents), microwaves.





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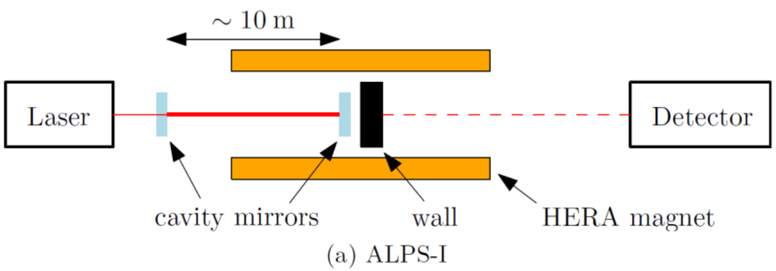

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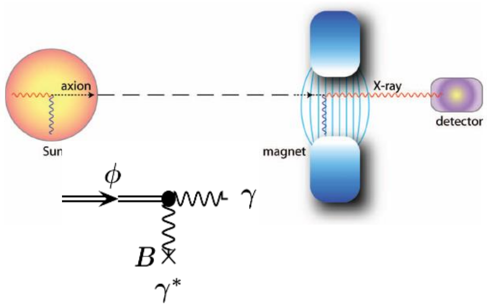

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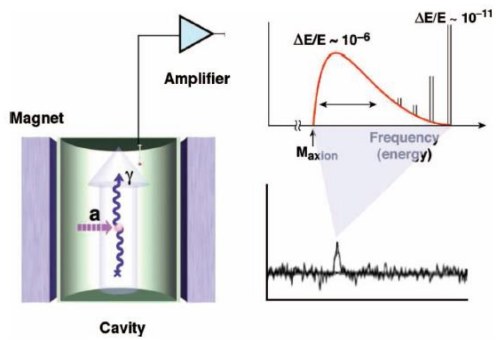

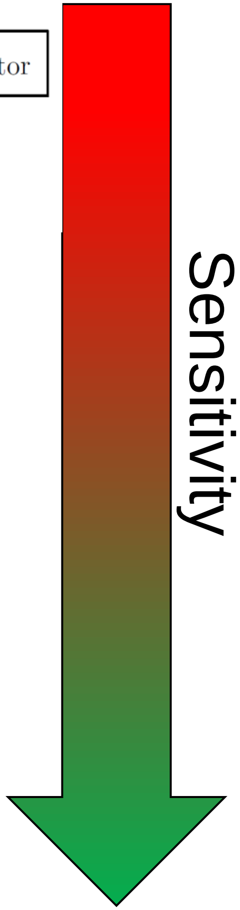

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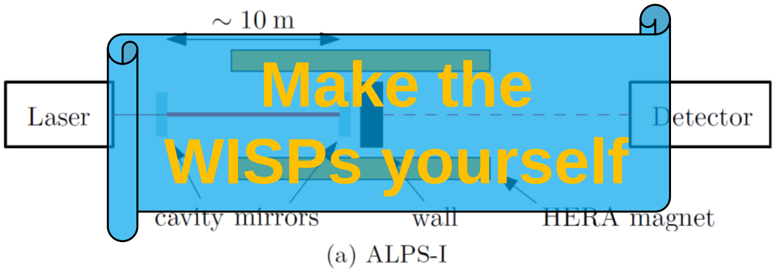

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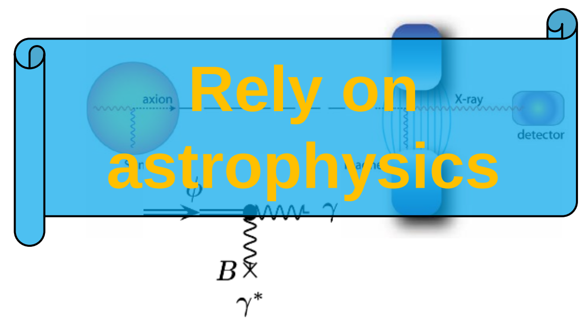

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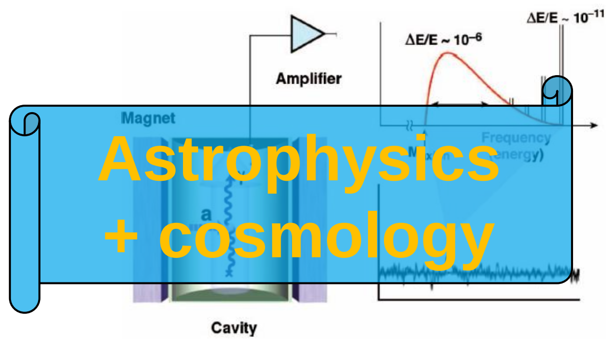

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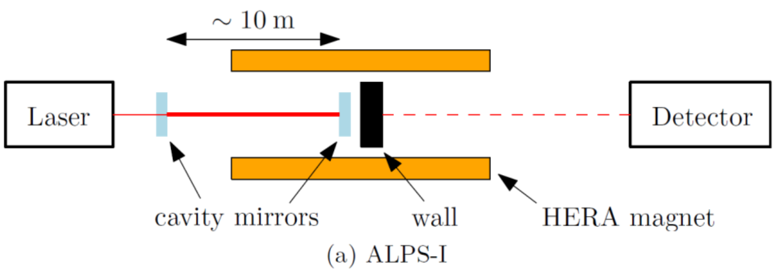

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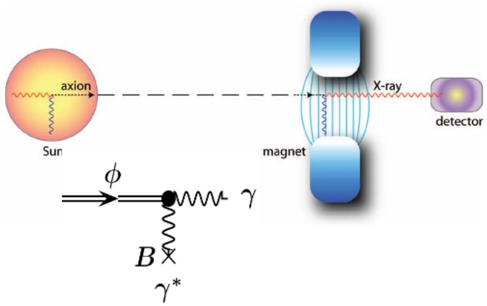

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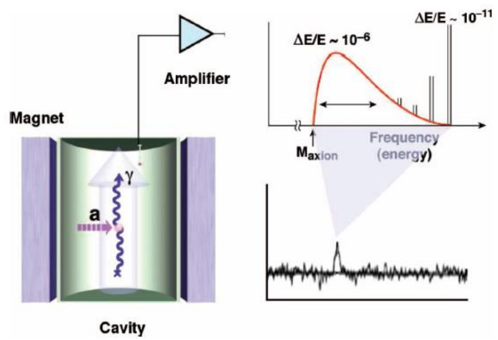

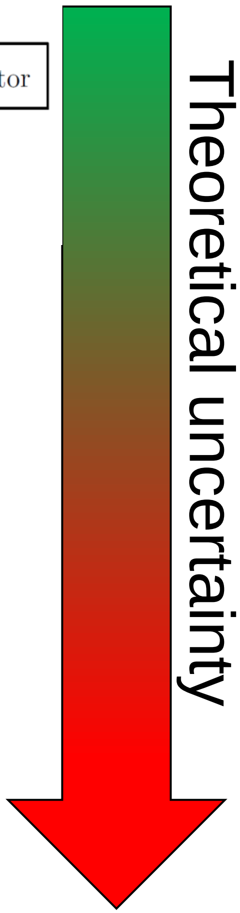

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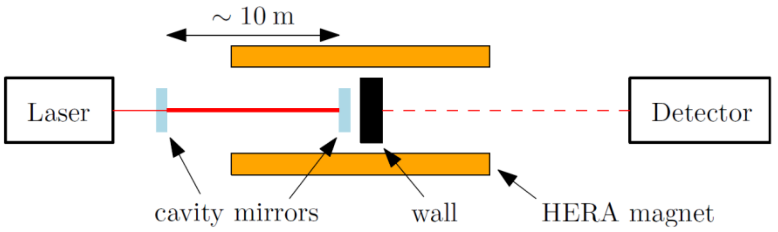

(a) ALPS-I

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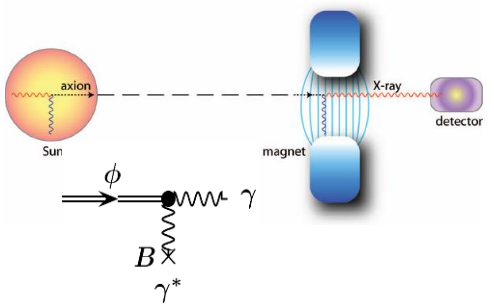

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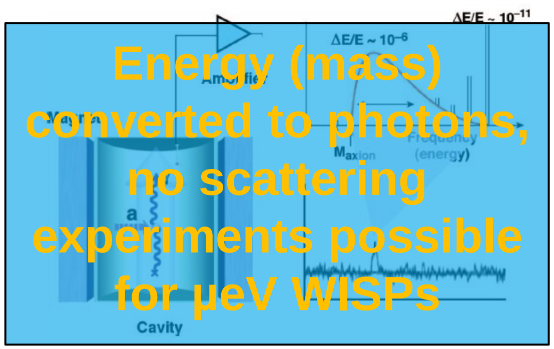

Energy (mass) converted to photons, no scattering experiments possible for μeV WISPs

Three kinds of WISP searches

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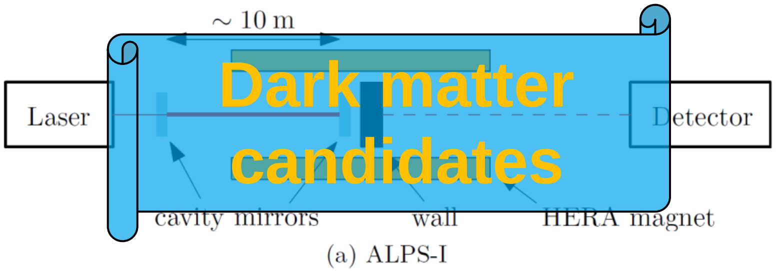

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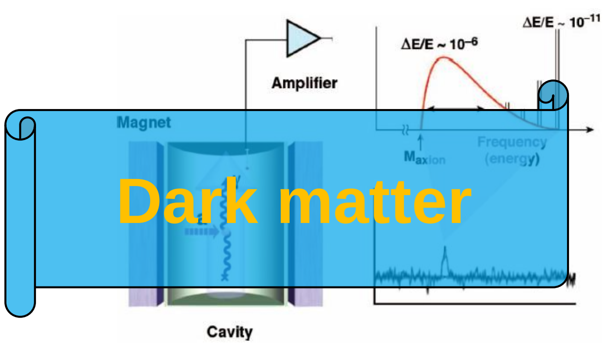


Dark matter searches

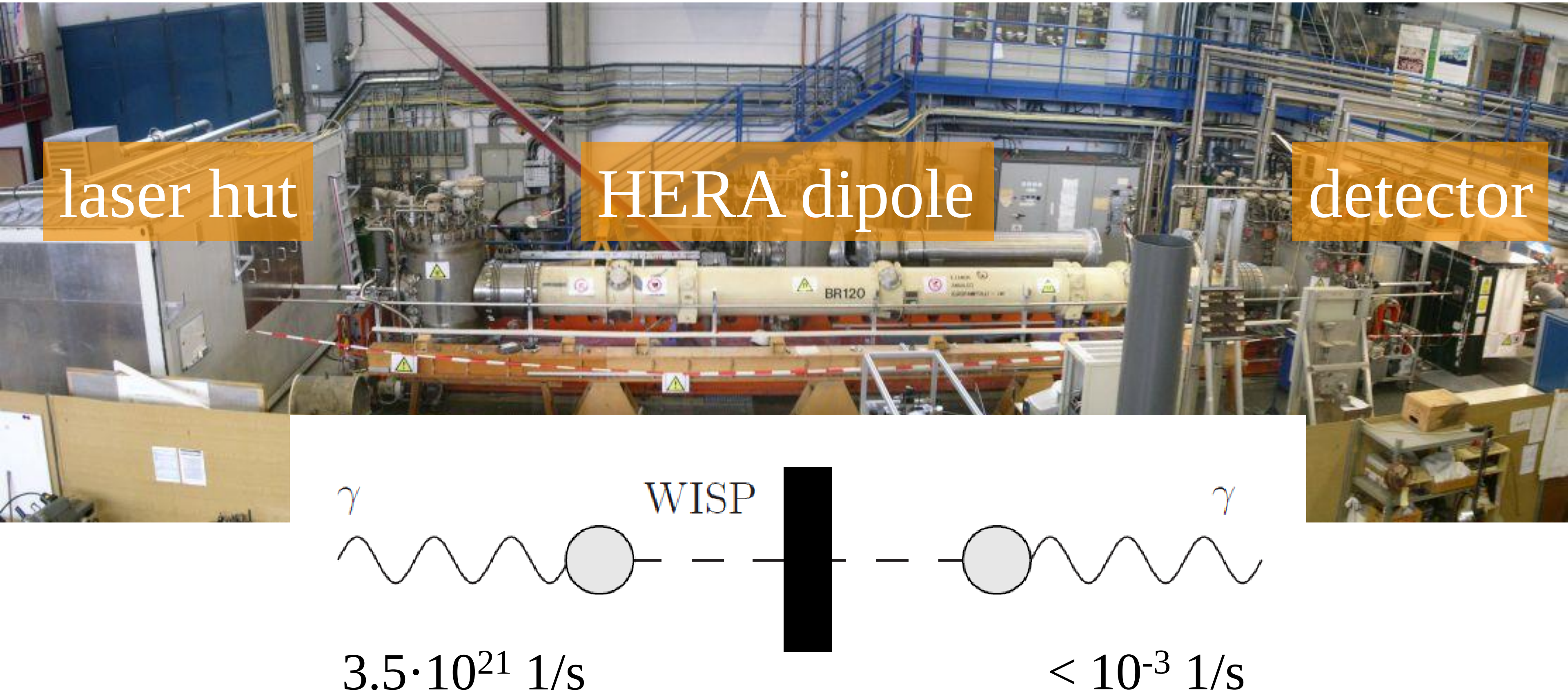
- Repetition
  - Dark matter
  - The Standard Model of particle physics
  - Dark matter candidates
- WISPy physics
  - Hints for WISPs
  - WISPs and the Standard Model
  - Basics of WISP experiments
- WISP experiments
  - Laboratory: ALPS-II @ DESY
  - Helioscopes
  - Dark matter searches
- Summary

ALPS @ DESY in Hamburg

ALPS-I results

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

- The most sensitive WISP search experiment in the laboratory (still).
- Unfortunately, no light was shining through the wall!



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!

Sensitivity of a LSW experiment

The number of detected photons behind the wall is proportional to

- the number of photons shining against the wall N_γ
- the efficiency of the detector ε
- the fourth power of the WISP-photon coupling strength $g_{a\gamma}{}^4$
- the fourth power of the magnetic length. $(B \cdot L)^4$

$$N_{LSW} \propto N_\gamma \cdot \varepsilon \cdot g_{a\gamma}{}^4 \cdot (B \cdot L)^4$$

The ALPS-II reach

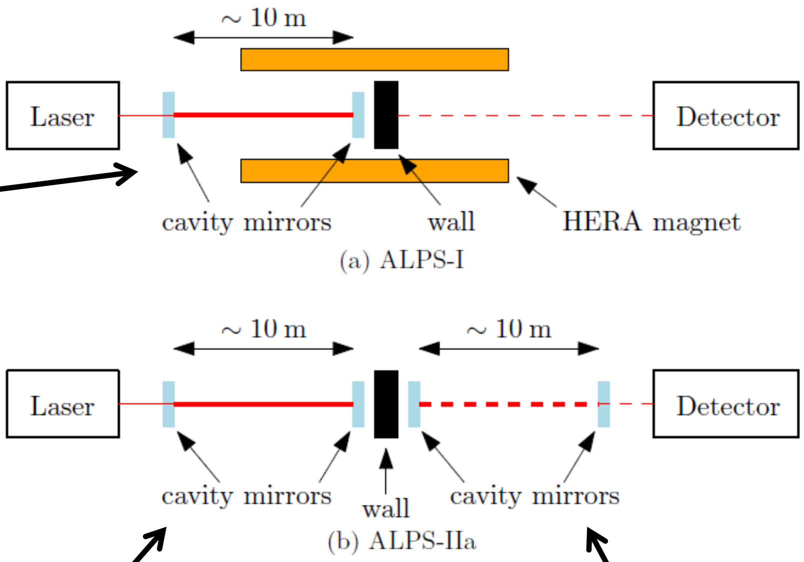
Parameter	Scaling	ALPS-I	ALPS-IIc	Sens. gain
Effective laser power P_{laser}	$g_{a\gamma} \propto P_{\text{laser}}^{-1/4}$	$1\,\text{kW}$	$150\,\text{kW}$	3.5
Rel. photon number flux n_γ	$g_{a\gamma} \propto n_\gamma^{-1/4}$	1 (532 nm)	2 (1064 nm)	1.2
Power built up in RC P_{RC}	$g_{a\gamma} \propto P_{reg}^{-1/4}$	1	40,000	14
BL (before& after the wall)	$g_{a\gamma} \propto (BL)^{-1}$	$22\,\text{Tm}$	$468\,\text{Tm}$	21
Detector efficiency QE	$g_{a\gamma} \propto QE^{-1/4}$	0.9	0.75	0.96
Detector noise DC	$g_{a\gamma} \propto DC^{1/8}$	$0.0018\,\text{s}^{-1}$	$0.000001\,\text{s}^{-1}$	2.6
Combined improvements				3082

Three orders of magnitude gain in ALP coupling and two orders of magnitude in HP mixing!

ALPS-II essentials: laser & optics

ALPS-I:

basis of success was the optical resonator in front of the wall.



> **ALPS-IIa**

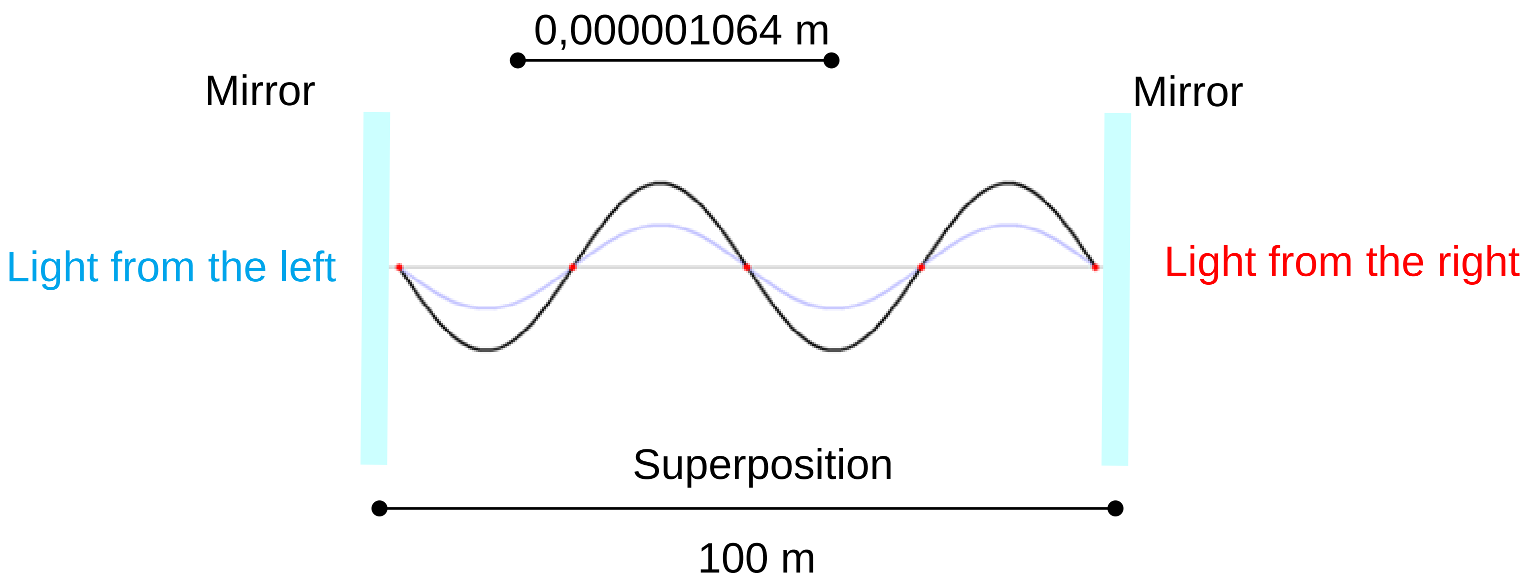
Optical resonator to increase effective light flux by recycling the laser power

Optical resonator to increase the conversion probability

WISP→γ

Optical resonator

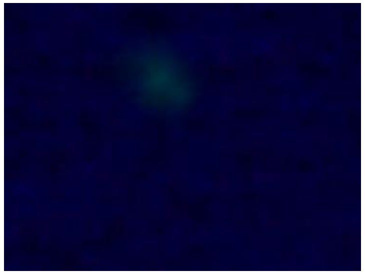
- Trick:
  Light is reflected back and forth and recycled,
  a photon has multiple chances to convert into a WISP.



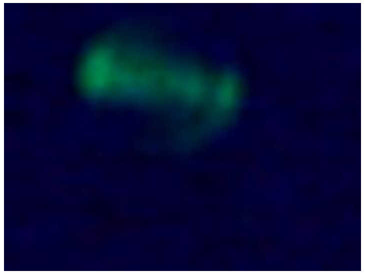
Light is stored between the mirrors:
the effective power is amplified!

Optical resonator

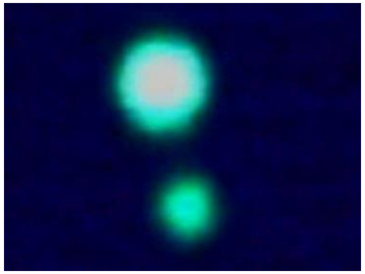
- Challenge:
  - The distance between the mirrors and the wavelength of the light have to agree within a few nanometers.
    A dedicated control system is needed.
  - The light is to be reflected back in exactly the same path on which iit arrived.



Resonator detuned.



Tuned,, but not locked



Locked!

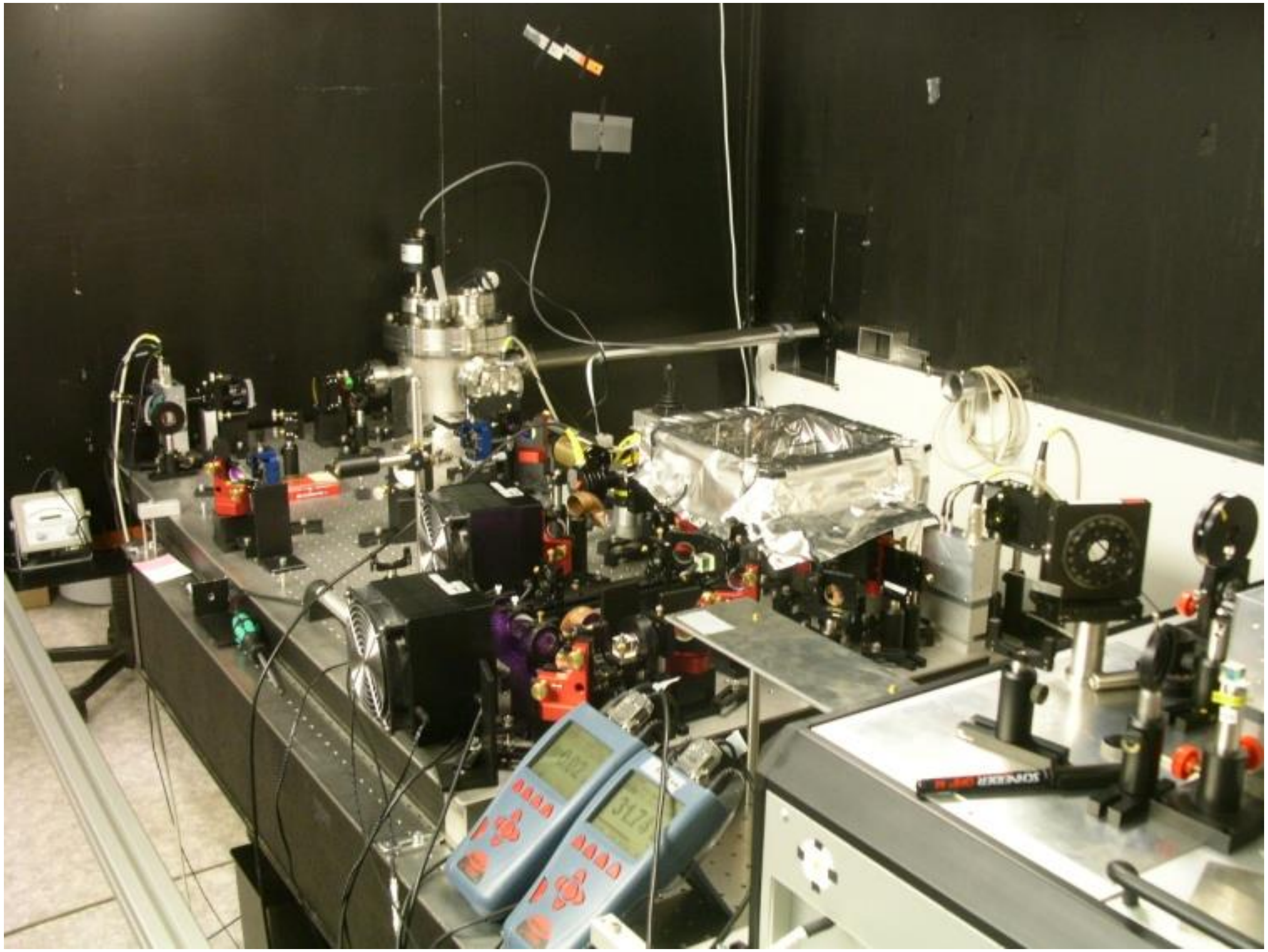
- ALPS-I was the first LSW experiment suceeding here.

  ALPS-I: Q = 300 turnarounds in the resonator

  ALPS-II: Q = 40.000 turnarounds planned.

The optical setup in ALPS-I

- Basically a PhD thesis!



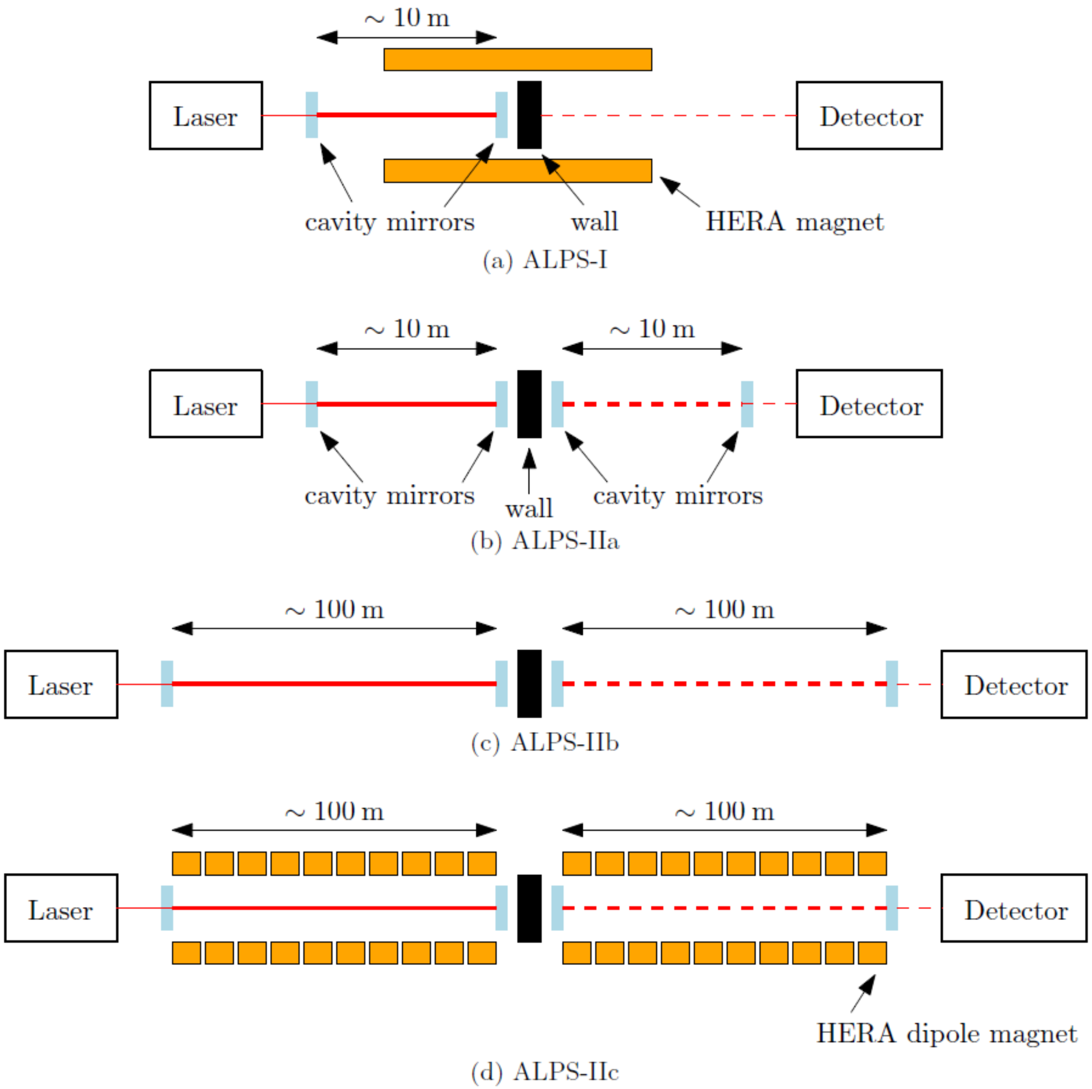
ALPS-II will be realized in stages

ALPS-I

> **ALPS-IIa**

> **ALPS-IIb**

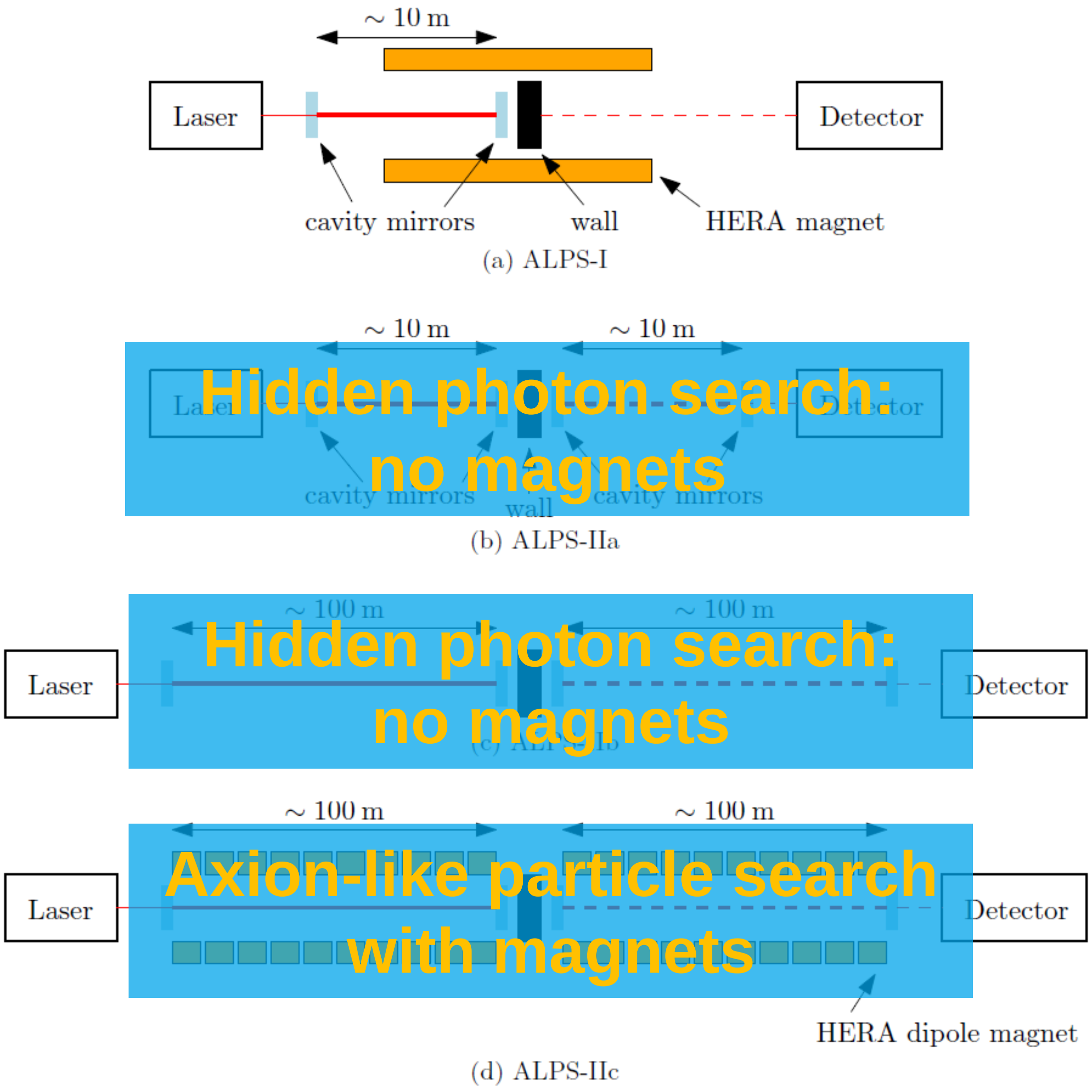
> **ALPS-IIc**



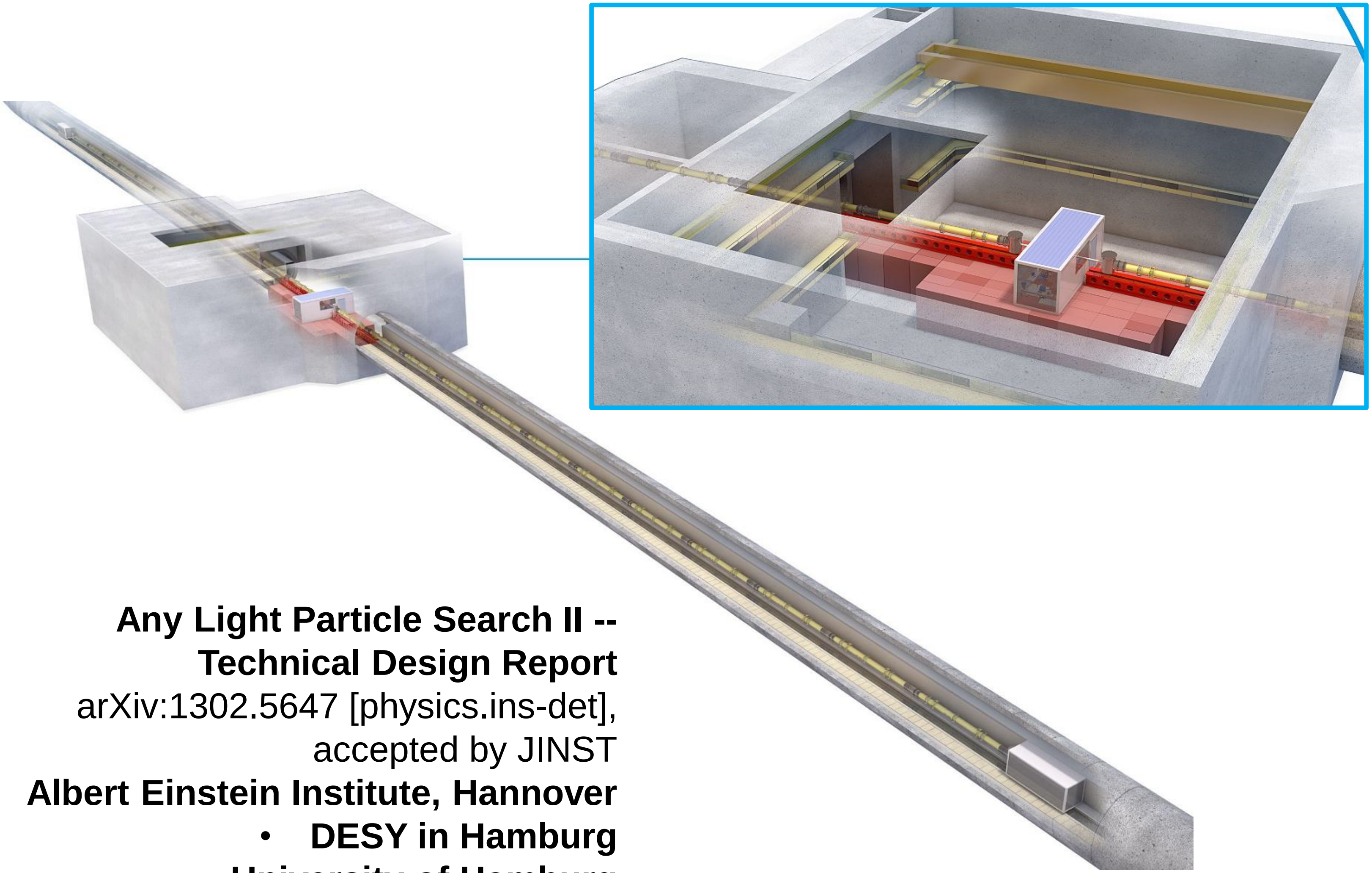
ALPS-II will be realized in stages

ALPS-I

- ALPS-IIa
- ALPS-IIb
- ALPS-IIc



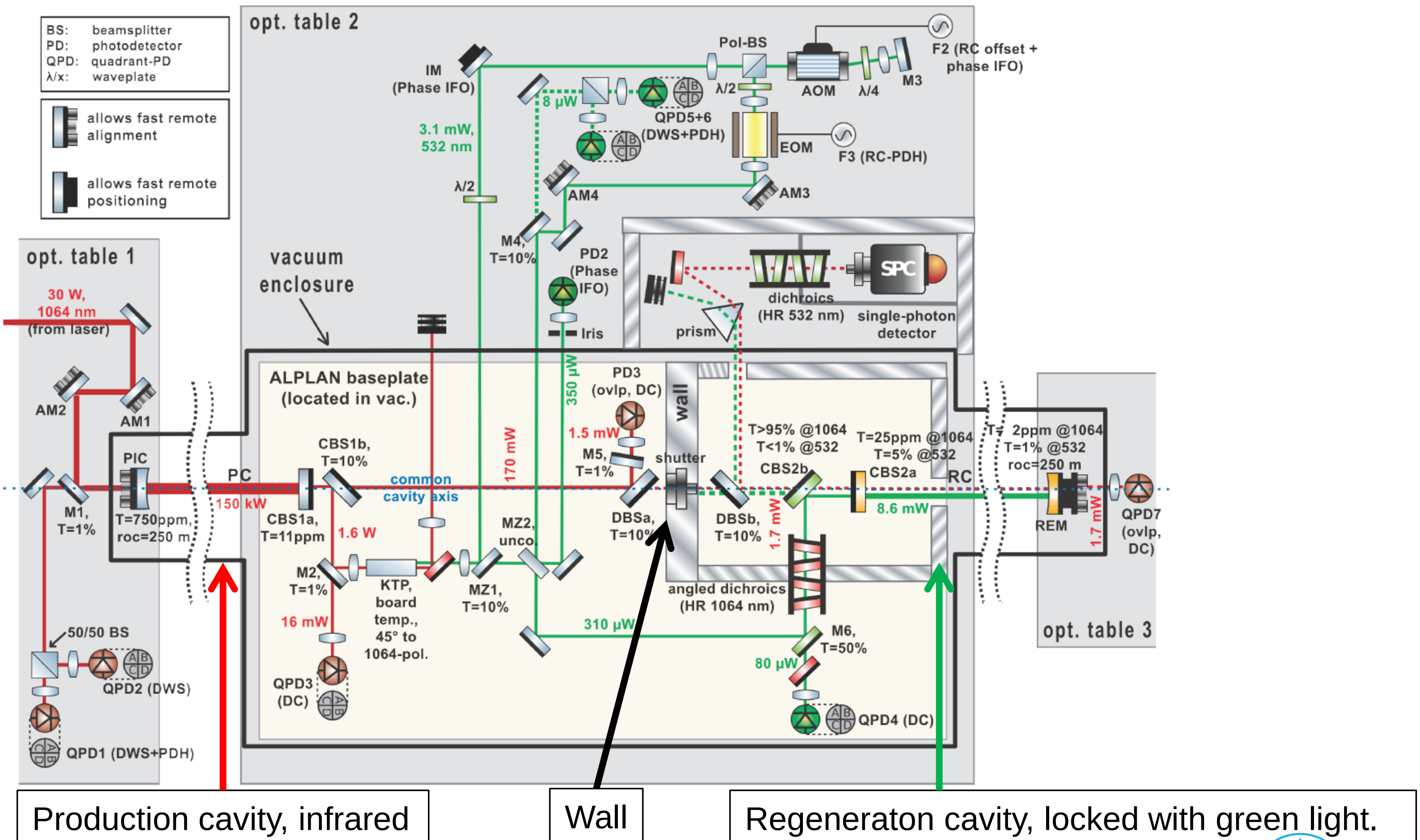
ALPS-II in 2017 in the HERA tunnel



Any Light Particle Search II -- Technical Design Report
arXiv:1302.5647 [physics.ins-det], accepted by JINST

- **Albert Einstein Institute, Hannover**
- **DESY in Hamburg**
- **University of Hamburg**

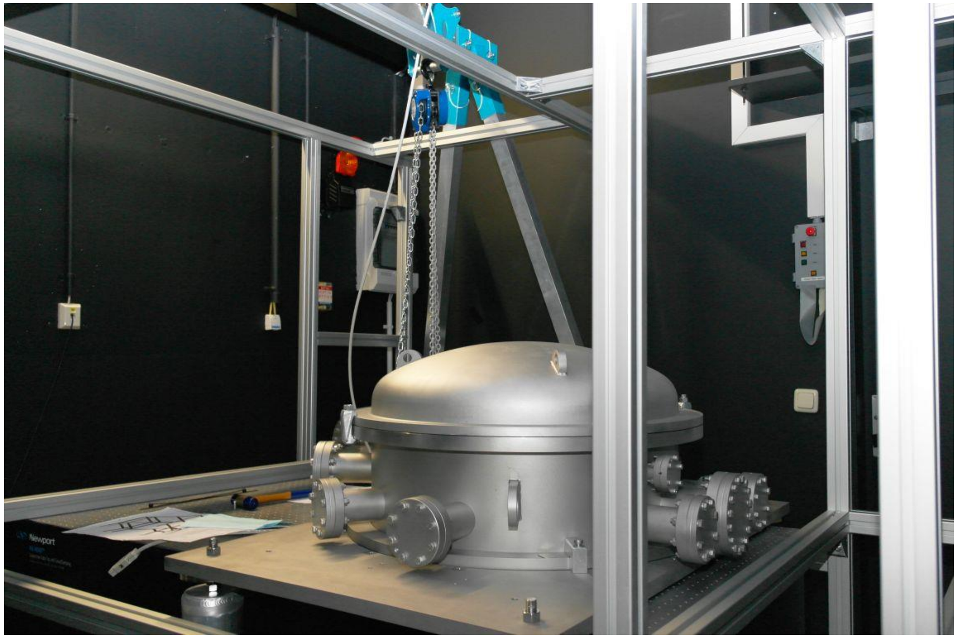
ALPS-II optics

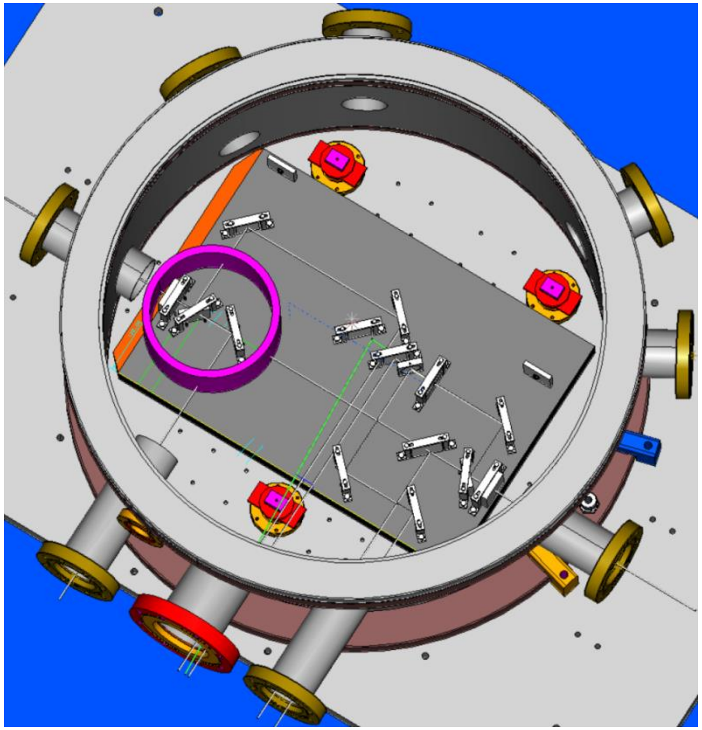


ALPS-II optics

- The mirrors for the production and regeneration cavities have been specified in detail and finally ordered on April 9. They should be available in July.

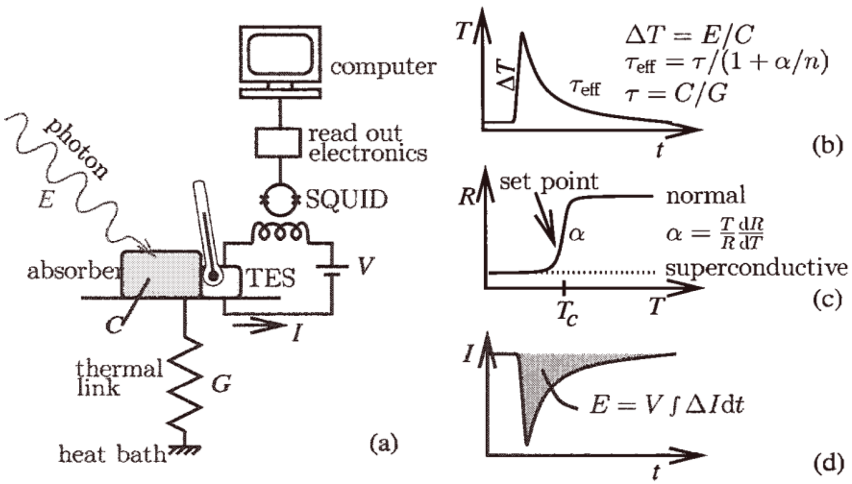
- The design of the central breadboard housed in a big vacuum chamber is (nearly) finished.



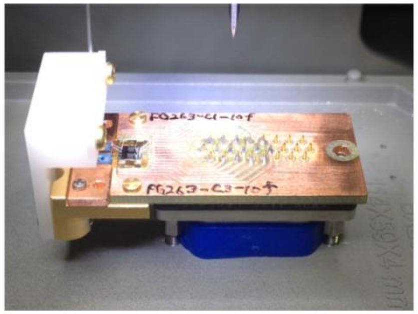


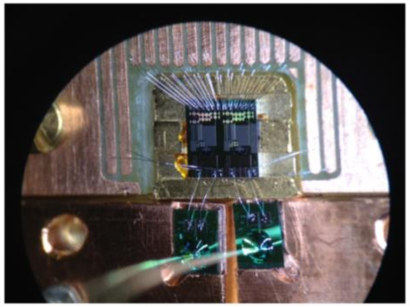
ALPS-II detector: Transition Edge Sensor (TES)

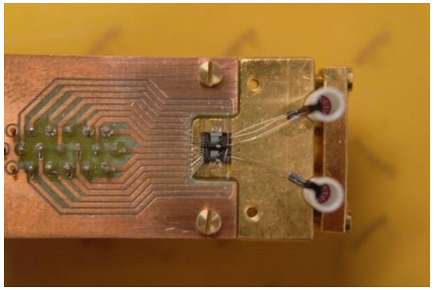
- A thin and small film (25µm x 25µm) is kept at the transition between super- and normal conductivity.
  The energy of a single absorbed photon warms up the film which induces a large change in resistance and a corresponding change in a bias current flowing through the TES.
  The changing current is detected by its changing magnetic field sensed by a SQUID.



- To get a TES into operation is a typical PhD work:
  - Built-up contacts to experts outside DESY.
  - Learn to work at 100 mK temperatures.
  - Learn to work with SQUIDs.
  - Understand superconductivity.
  - Learn to guide light onto a TES
  - Set up a stable and easy-to-operate detector system.







- Other transition edge sensors are used for WIMP searches (e.g. CRESST)

ALPS-II magnets

The aperture of the magnets determines the lenghts of the optical cavities:

- The laser beam diverges and clipping is to be avoided to not spoil the power built-up in the cavities.

Eff. dipole aperture		Max. # of dipoles		B·L (Tm)	
		HERA	LHC	HERA	LHC
35 mm	(HERA)	2·4		187	
40 mm	(LHC)	2·6	2·4	281	514
50 mm	(HERA almost straight)	2·10		468	
55 mm	(HERA straight)	2·12		562	

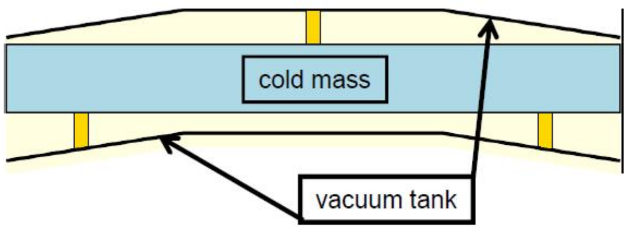
HERA dipoles are competitive with LHC dipoles, if one could get them straight!

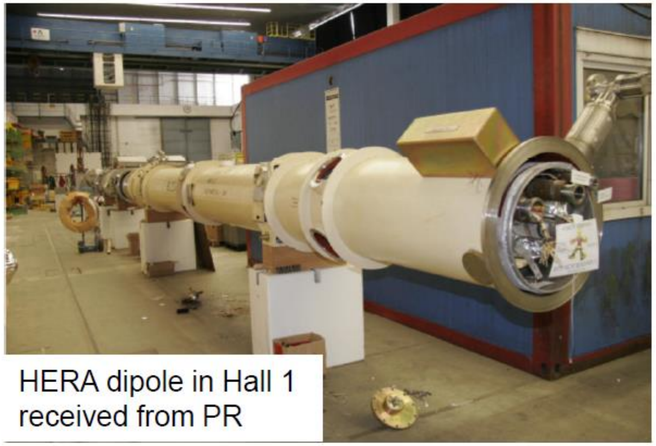
- Challenge:
  develop (cheap) straigthening procedure for HERA dipole magnets!

ALPS-II magnets

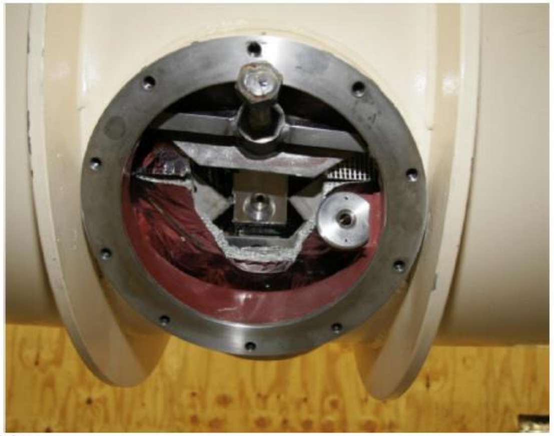
Inexpensive method to increase the aperture of the vacuum pipe in the HERA dipole

Force ends and middle of cold mass towards the center with simple deformation tools





HERA dipole in Hall 1
received from PR



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PRC Review Nov 7th 2012

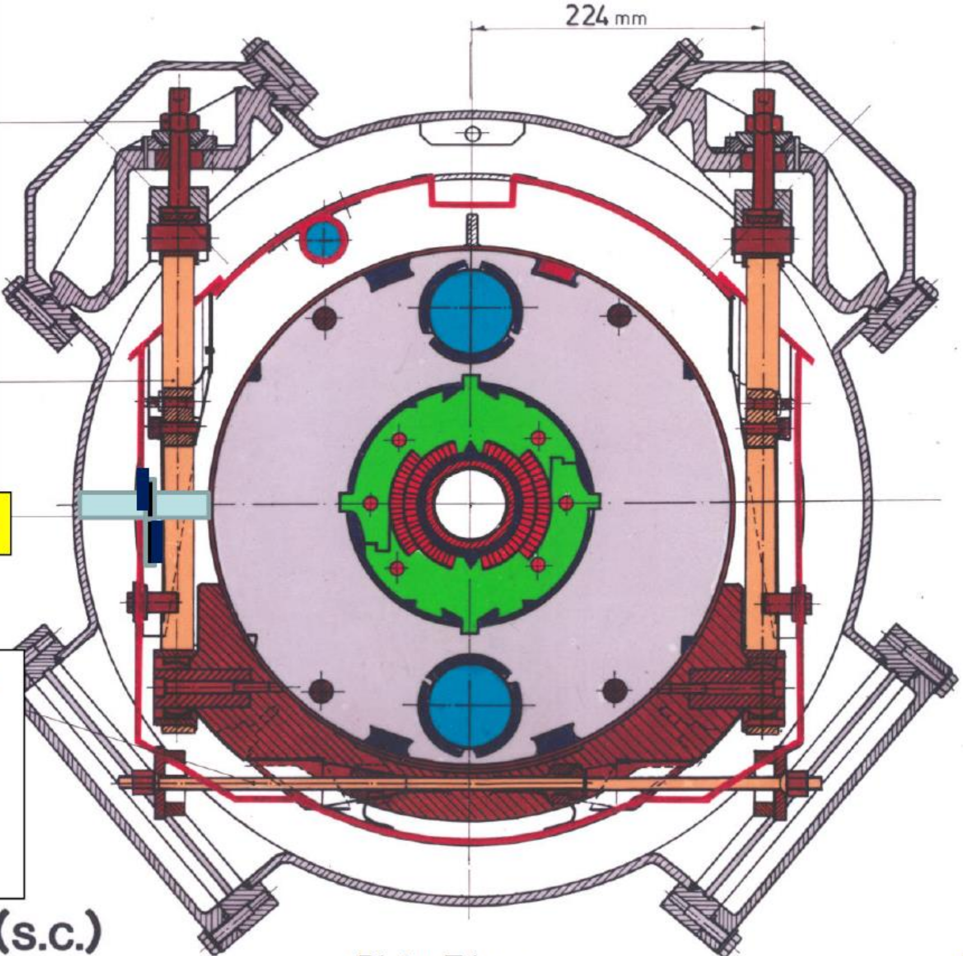
5

ALPS-II magnets

The deformation of the yoke is elastic. Therefore the force must be maintained also during cryogenic operation of the dipole.
So, the deformation tools are replaced by **pressure props with a sufficiently low heat flow to the 4K helium vessel**.

pressure prop

The outer pressure props have to follow the length change of the helium vessel during cool down and warm-up.



Dipole Magnet (s.c.)

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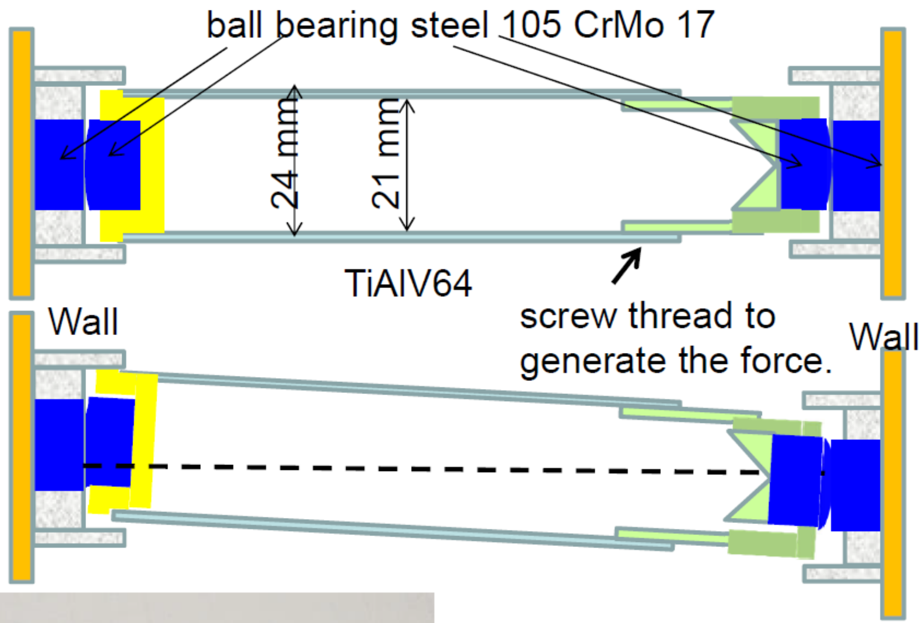
ALPS-II magnets

The problem to follow the shrinkage of the cold mass was solved by using the section of a sphere, which rolls with the motion of the cold mass.

Low heat flow pressure prop

The distance between warm and cold wall does not change during roll except for a thermal shrinkage of the pressure prop



The prototype was tested at liquid nitrogen temperature in vacuum

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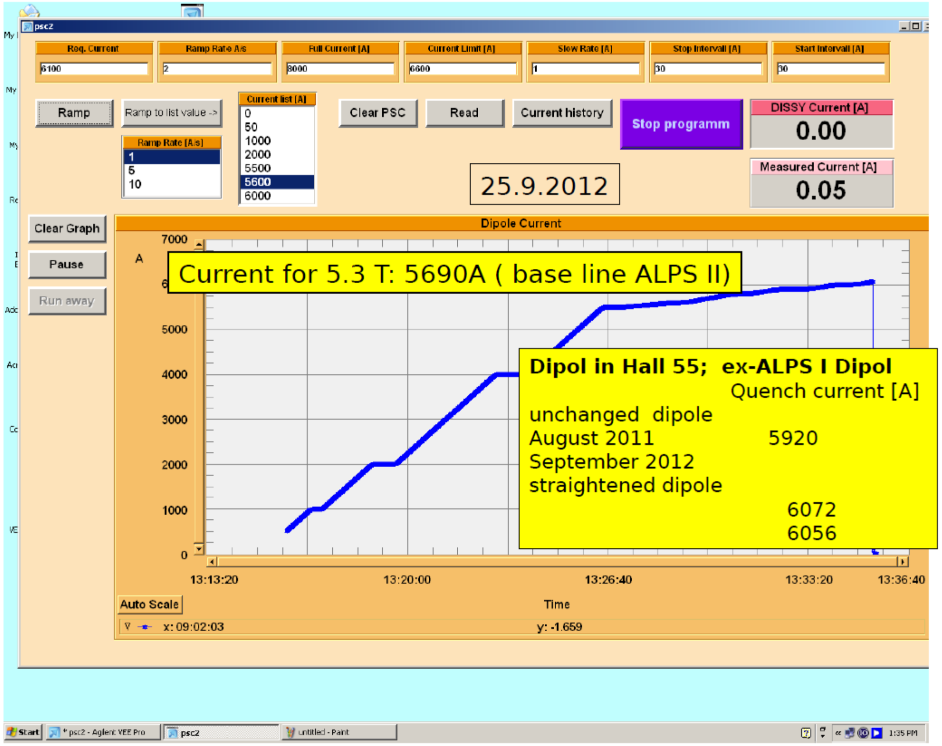
ALPS-II magnets

- Already the first test of the straightening procedure in September 2012 was very successful!

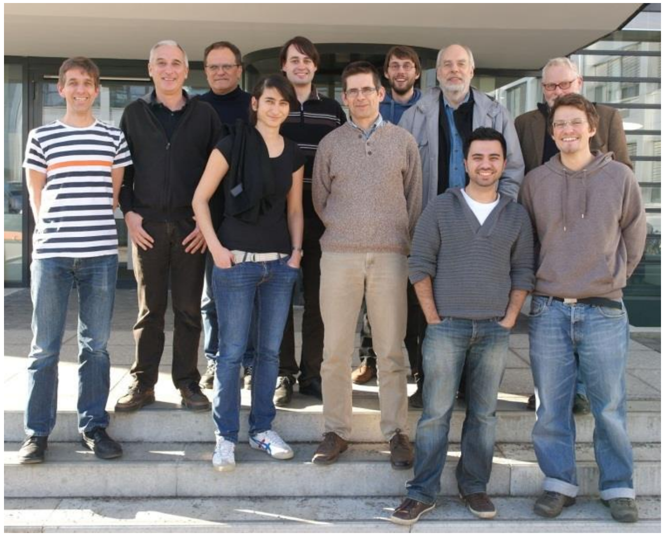


- The straightening procedure for the HERA dipoles has been revised. A simpler and more robust method will be tested soon.

The ALPS-II people

ALPS-II is a joint effort of

- DESY:
  Babette Döbrich, Jan Dreyling-Eschweiler, Samvel Ghazaryan, Reza Hodajerdi, Friederike Januschek, Ernst-Axel Knabbe, Axel Lindner, Dieter Notz, Andreas Ringwald, Jan Eike von Seggern, Richard Stromhagen, Dieter Trines
- Hamburg university:
  Dieter Horns
- AEI Hannover:
  Robin Bähre, Benno Willke



with strong support from

- LZH Hannover / neoLASE:
  Maik Frede, Bastian Schulz

ALPS-II

Theory **Exp. Particle physics** **Accelerator physics** **Surface physics**

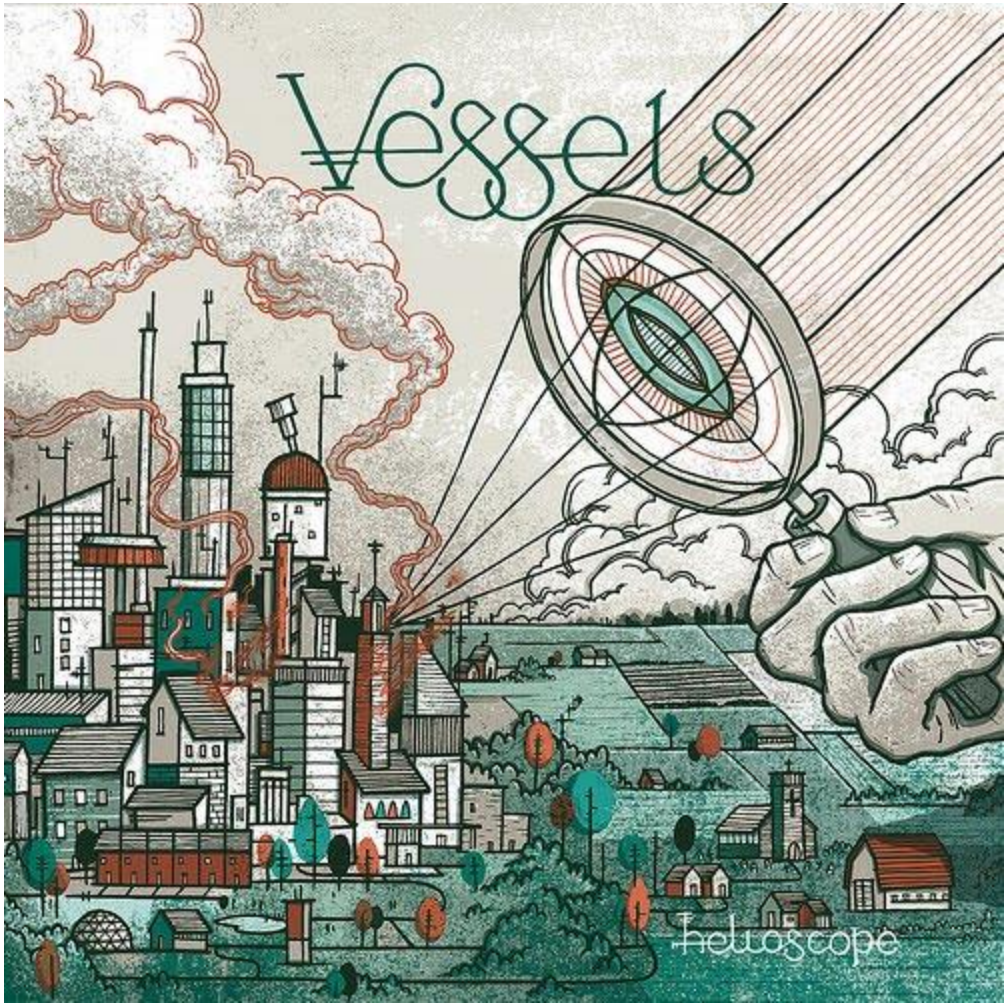
Astronomy **Astroparticle physics** **Laser physics** **Engineer**

Beyond ALPS-II

- Rough estimation with some crucial parameters:

Exp.	Photon flux (1/s)	Photon E (eV)	B (T)	L (m)	B·L (Tm)	PB reg.cav.	Sens. (rel.)	Mass reach (eV)
ALPS-I	$3.5 \cdot 10^{21}$	2.3	5.0	4.4	22	1	0.0003	0.001
ALPS-II	$1 \cdot 10^{24}$	1.2	5.3	106	468	40,000	1	0.0002
"ALPS-III"	$3 \cdot 10^{25}$	1.2	13	400	5200	100,000	27	0.0001
European XFEL	$< 10^{18}$	$1 \cdot 10^{4}$	5.3	106	562	1	0.001	0.01
PW laser	10^{20} 1/pulse	2.3	10^{6}	10^{-5}	10	1	0.0003	0.5

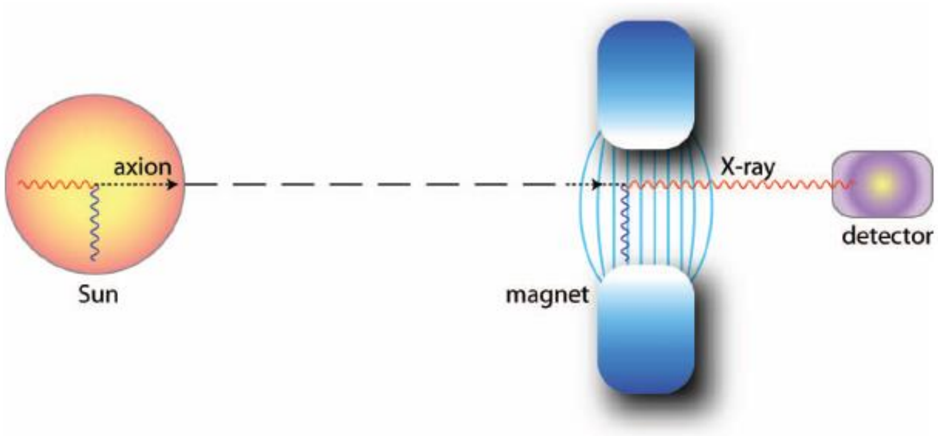
Helioscopes

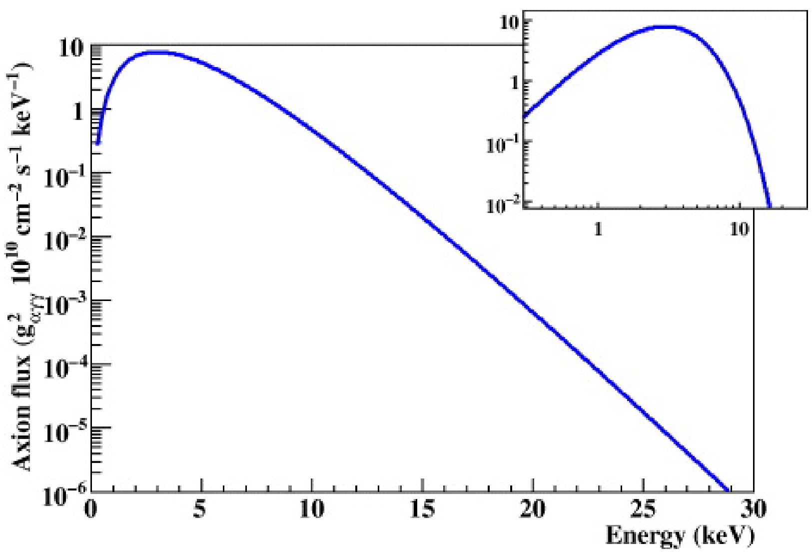


http://middleboop.blogspot.de/2011/02/vessels-helioscope.html

CernAxionSolarTelescope (CAST)

- LHC prototype magnet pointing to the sun.





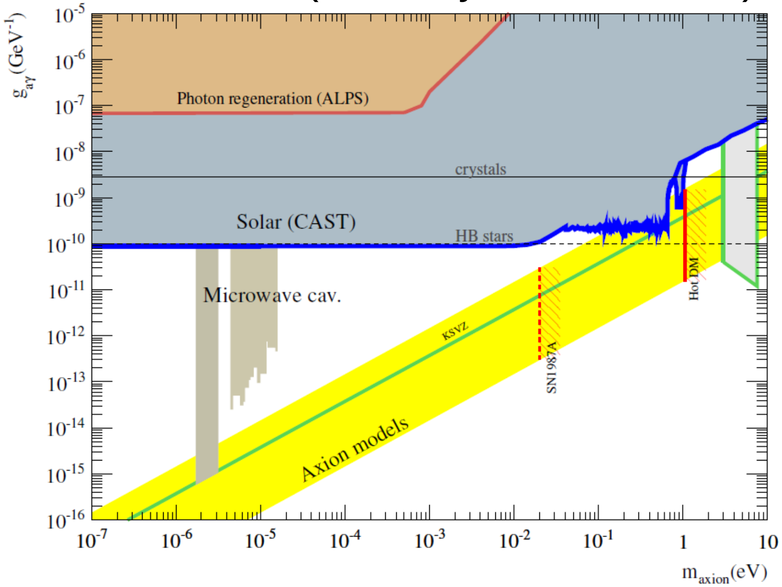
Axions or ALPs from the center of the sun would come with X-ray energies.

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

CernAxionSolarTelescope (CAST)

> LHC prototype magnet pointing to the sun.

(courtesy of I. Irastorza)



> Most sensitive experiment searching for axion-like particles.

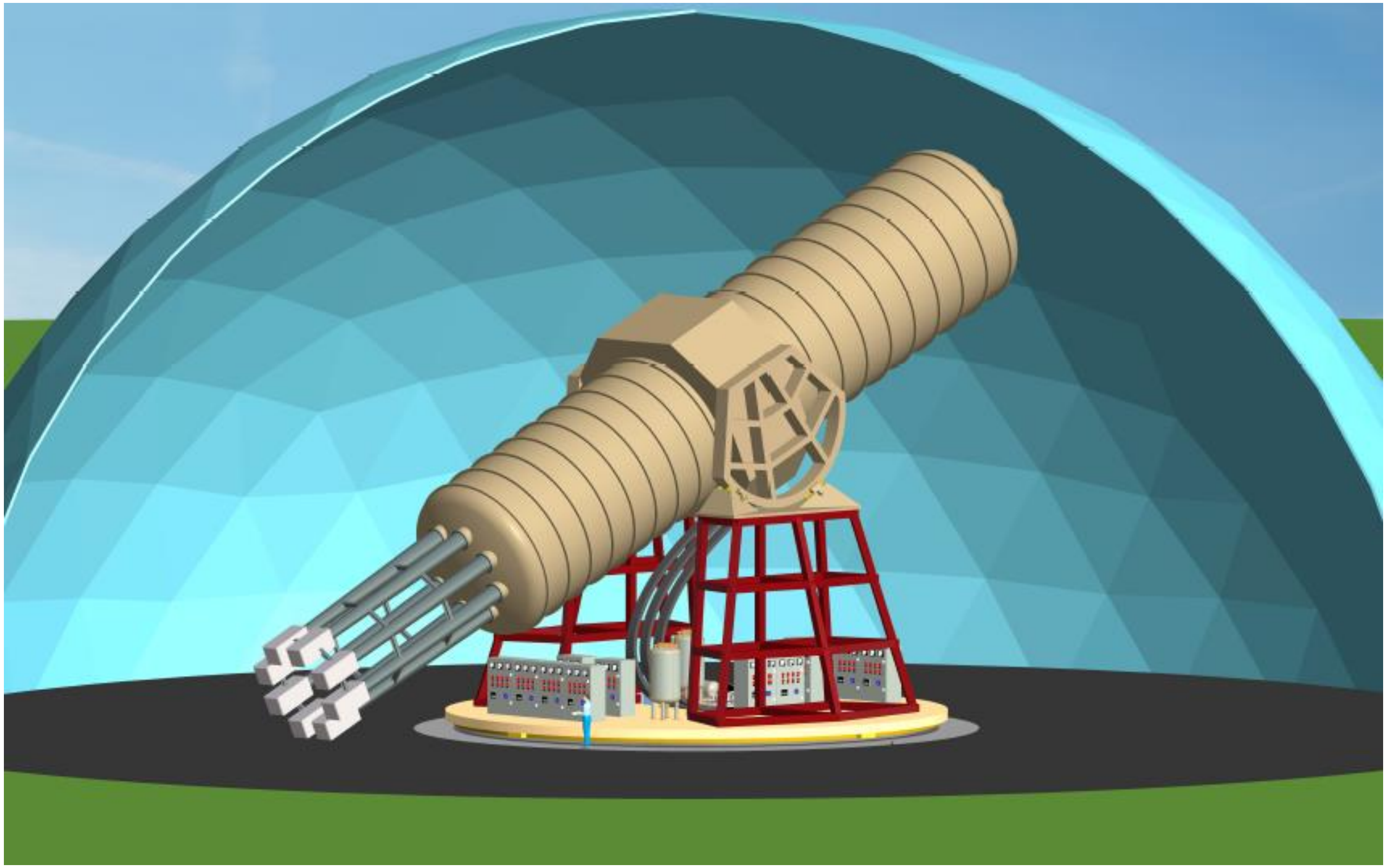
- Unfortunately no hint for WISPs yet.
- If an ALP is found, it would be compatible with known solar physics!

> However, CAST does not strictly meet the “no excuse theorem“.

- CAST has to assume ALP production in the sun.

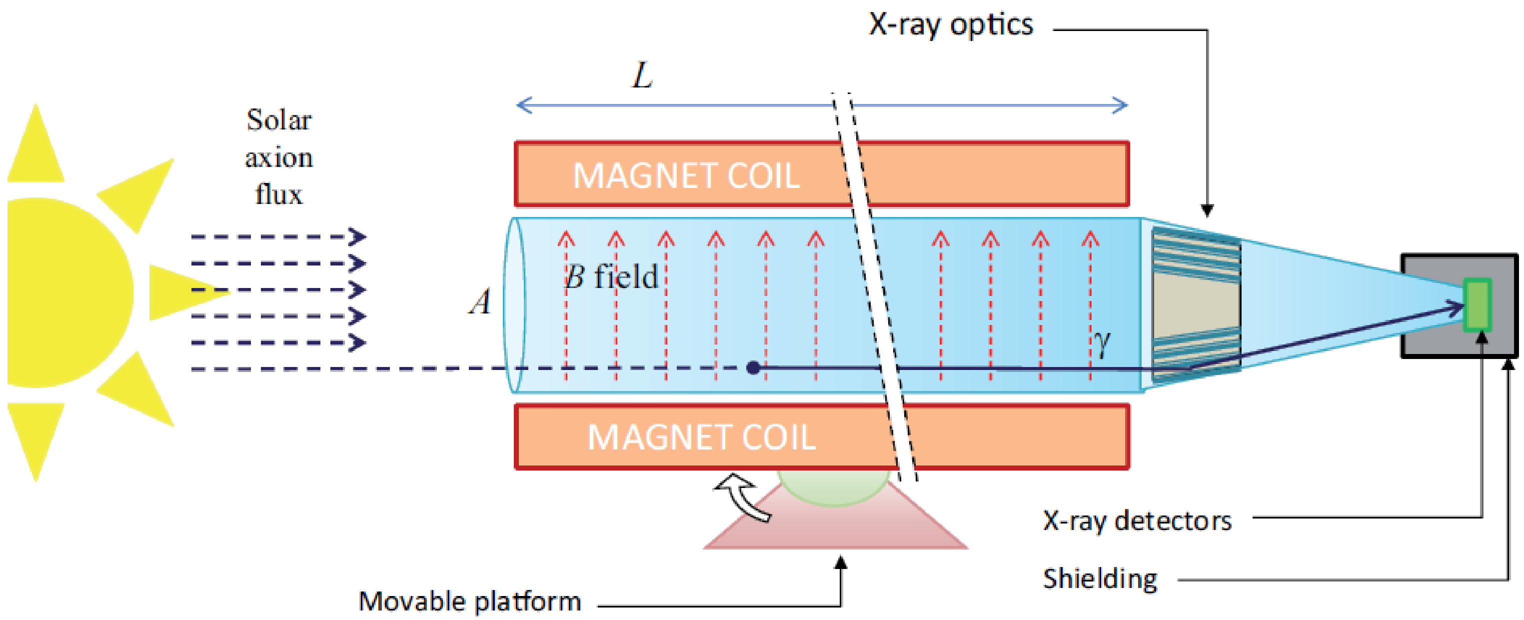
IAXO proposal

- The International Axion Observatory
  - CAST principle with dramatically enlarged aperture



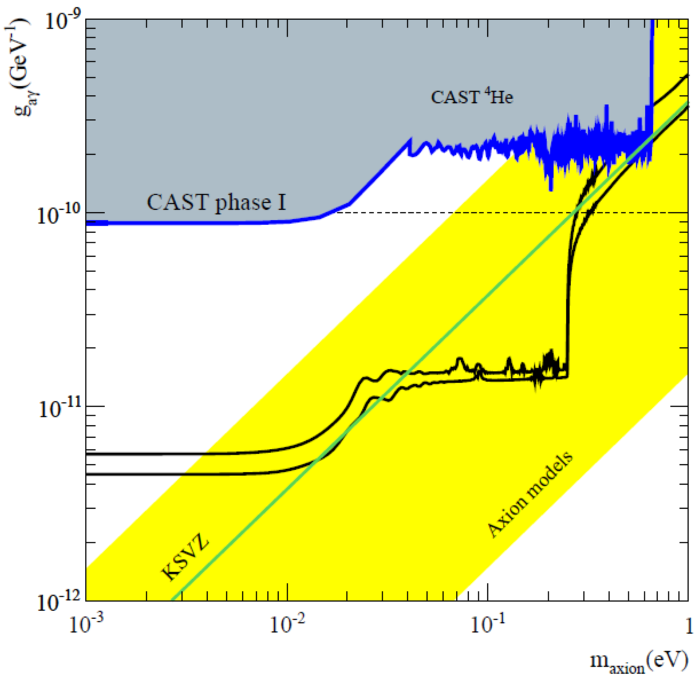
IAXO proposal

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



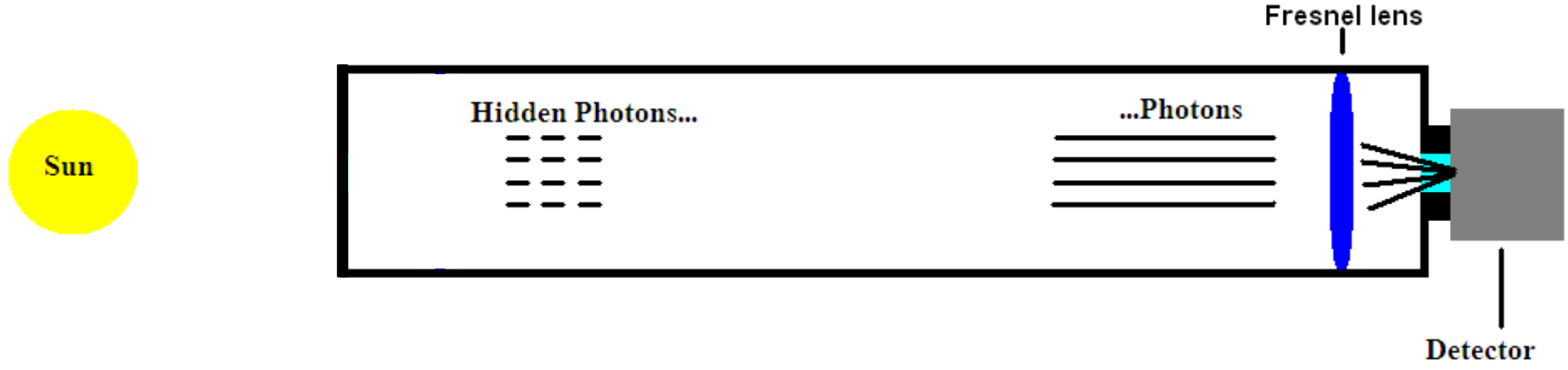
IAXO proposal

- The International Axion Observatory
  - Could be constructed within about six years.
- IAXO could reach deep into the region where astrophysical phenomena might indicate the existence of ALPs.



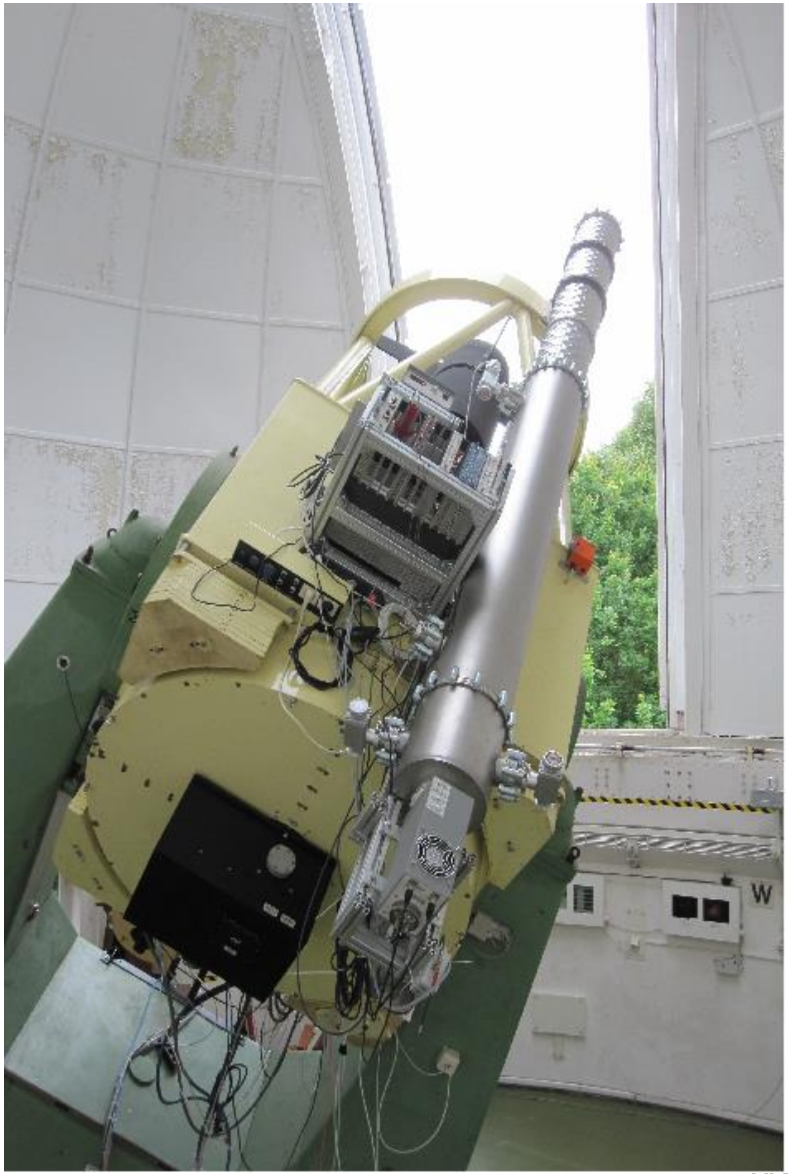
TSHIPS at the observatory Bergedorf

Telescope for Solar Hidden Photon Search



- DESY
- Hamburger University (observatory Bergedorf)

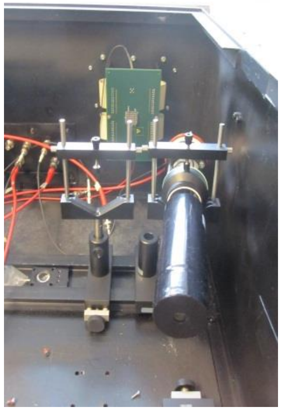
TSHIPS-I status

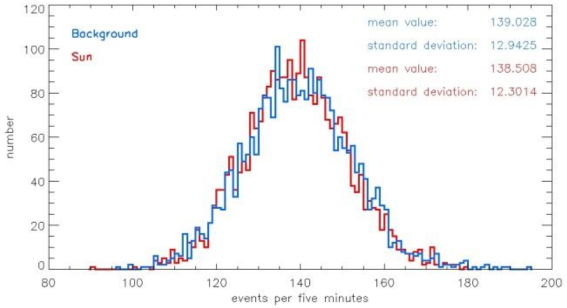


- Light collected via a 20 cm Fresnel lens:
- Low noise PM: (ET Enterprises 9893/350B)

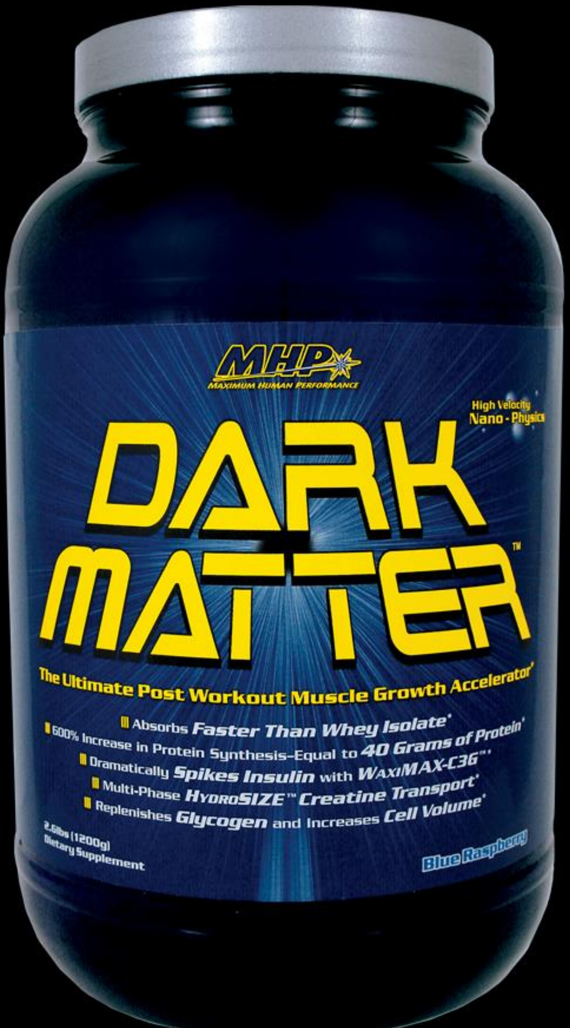
- Data taking since March 2013: 250 h of sun + background data each,

  but no hint for an excess (yet).



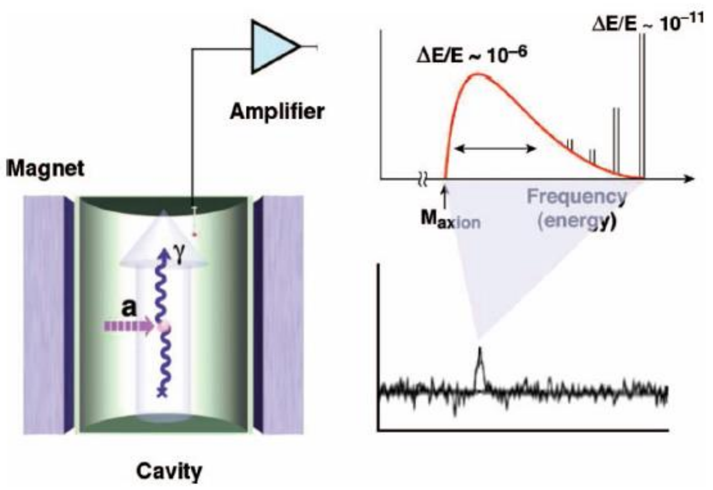


Haloscopes


MHP
MAXIMUM HUMAN PERFORMANCE
High Velocity
Nano - Physics
DARK MATTER™
The Ultimate Post Workout Muscle Growth Accelerator*
Absorbs Faster Than Whey Isolate*
600% Increase in Protein Synthesis–Equal to 40 Grams of Protein*
Dramatically Spikes Insulin with WaxiMAX-C36™*
Multi-Phase HydroSIZE™ Creatine Transport*
Replenishes Glycogen and Increases Cell Volume*
2.6lbs (1200g)
Dietary Supplement
Blue Raspberry

Searches for WISPy cold dark matter

- Due to their low mass WISPy cold dark matter can not be detected by recoil techniques.
- WISPy dark matter particles have to convert into photons in a thoroughly shielded environment.
- The mass of the dark matter particle determines the energy to be detected. For axions it is in the microwave range.
- The resonance frequency of the cavity is to be tuned to the WISP mass to be probed.
  This is a time consuming process!

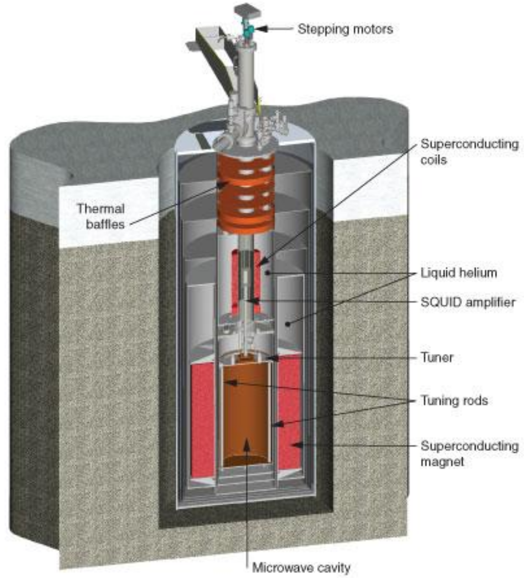


The Search for Axions, Carosi, van Bibber, Pivovaroff, Contemp. Phys. 49, No. 4, 2008

ADMX (Axion Dark Matter eXperiment)

- Existing experiment at Washington university.

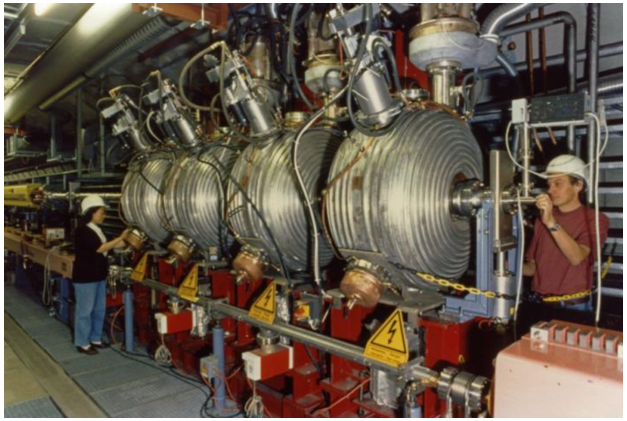
The Search for Axions, Carosi, van Bibber, Pivovaroff,
Contemp. Phys. 49, No. 4, 2008

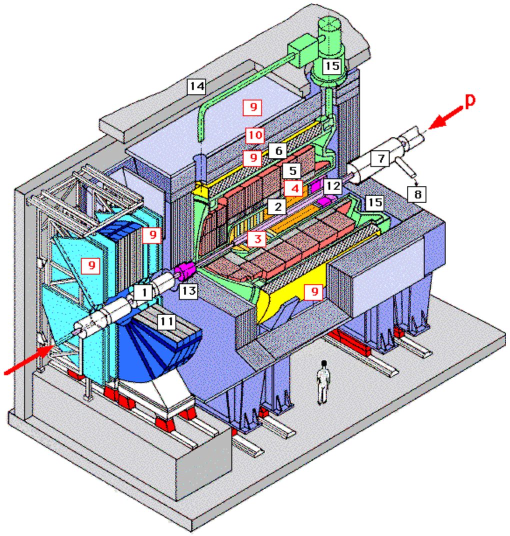


- ADMX-HF in preparation at Yale.
- Both experiments could probe a large part of the parameter space for dark matter axions!
- This is the only experiment of its kind!

New possibilities by combining forces

- Dark matter searched for by particle physicists and radio astronomers
  - MPIfR (A. Lobanov, R. Keller, M. Kramer)
  - DESY (A.L.,A. Lobanov, W.-D. Möller, A. Ringwald, J. Sekutowicz,D, Trines, A. Westphal)
  - ITP Heidelberg (J. Jaeckel)
- Combine accelerator cavities, detector magnets with receivers from radio astronomy?





http://www.mpifr.de/div/electronic/content/receivers/21cm/fig_4.jpg

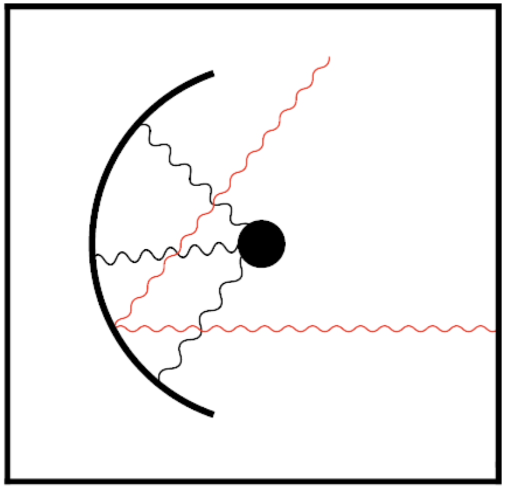
A new way of broadband DM seaches?

Searching for WISPy Cold Dark Matter with a Dish Antenna

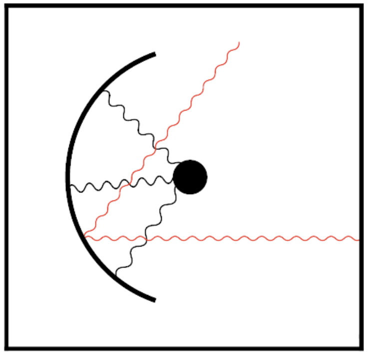
Dieter Horns[1], Joerg Jaeckel[2,3], Axel Lindner[4], Andrei Lobanov[5,⋆], Javier Redondo[6,7], Andreas Ringwald[4]

DESY-12-227, MPP-2012-158, arXiv:1212.2970 [hep-ph]

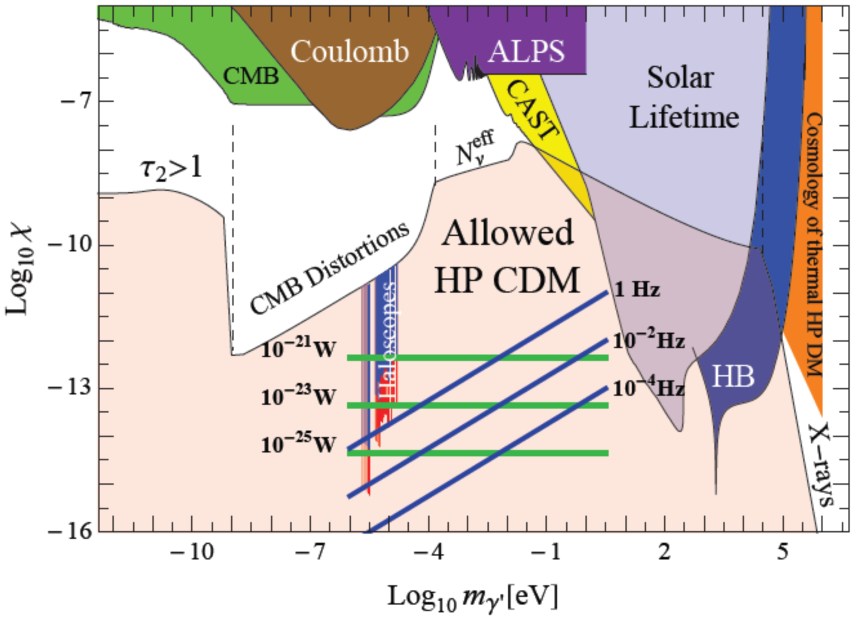
- The photonic component of a WISP excites electromagnetic radiation emitted by a conducting surface.
- This radiation is emitted perpendicular to the surface and can be focused onto a detector. This works for a broad range of WISP masses, given by the mirror reflectivity.

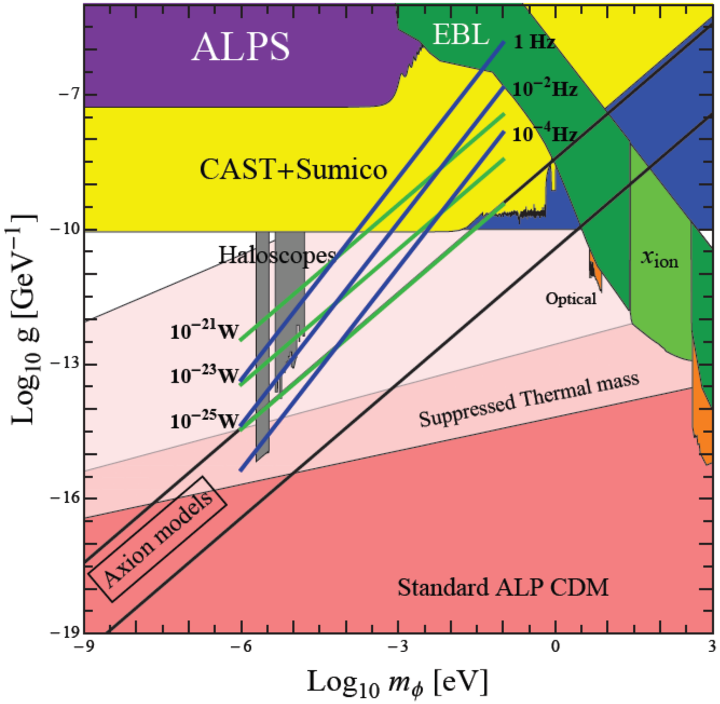


A new way of broadband DM seaches?



- The cold DM WISP em. radiation is focused in the center of a spherical mirror.
- Already a 1 m^2 dish could allow to reach high sensitivities





Keys to beyond SM physics

WISPs

Symmetry magazin, August 2006

Summary

- Weakly Interacting Slim Particles might explain puzzles from cosmology, astrophysics and particle physics.
- With the recent developments in theory and astrophysics phenomena we know where to go
  - for axion-like particles and hidden photons.
- Next generation experiments are being constructed or prepared with sensitivities allowing to probe these predictions.
- One should exploit carefully new options provided by high power pulsed laser systems, large existing magnets or new approaches for dark matter searches for example.
- Small scale and short term WISP experiments offer a fascinating complement to accelerator based “big science”.
- **There is plenty of room for new ideas and quick experiments having the potential to change the (particle physicist’s) world!**

BSM physics might hide anywhere!