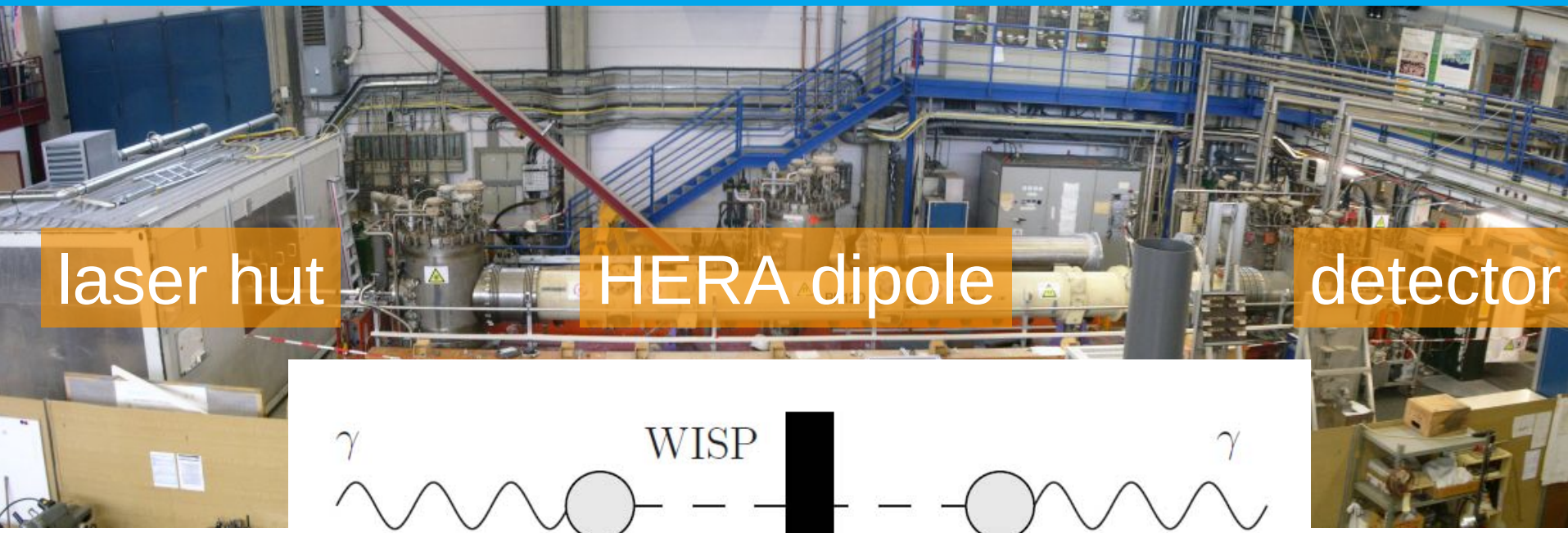
Axions, WIMPs and WISPs @ DESY

Status & Plans

J. Mnich

DESY

The ALPS Project: Any Light Particle Search @ DESY



A “light-shining-through-a-wall” experiment searching for yet very light and very weakly interacting particles (“WISPs”) suggested by theory and astrophysics.

ALPS is a joint effort of:

Universität Hamburg

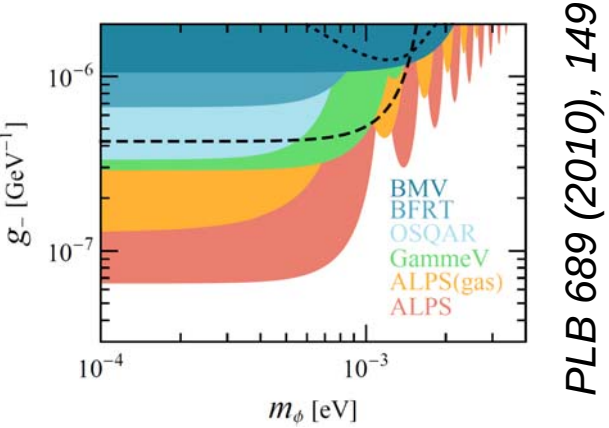
Leibniz Universität Hannover

LASER ZENTRUM HANNOVER e.V.

DESY

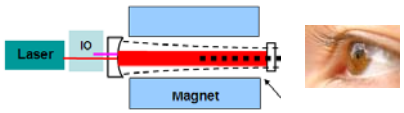
ALPS results (see talk by K. Ehret)

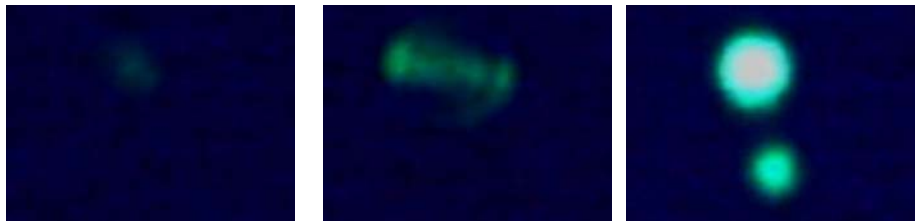
> ALPS is the most sensitive experiment for WISP searches in the laboratory.



PLB 689 (2010), 149

> Crucial is the set-up of an optical resonator in the HERA dipole magnet.





Resonator detuned.

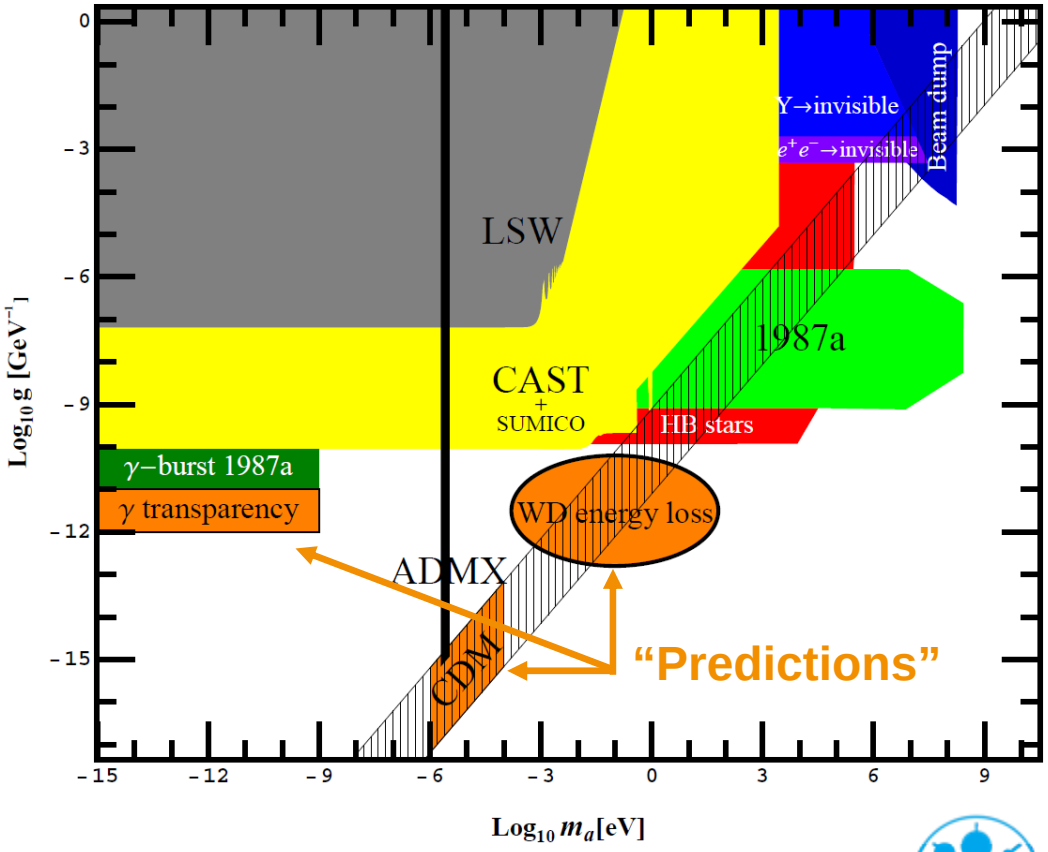
tuned, but not "locked".

Locked!

> Plans are being worked out to significantly enhance the sensitivity.

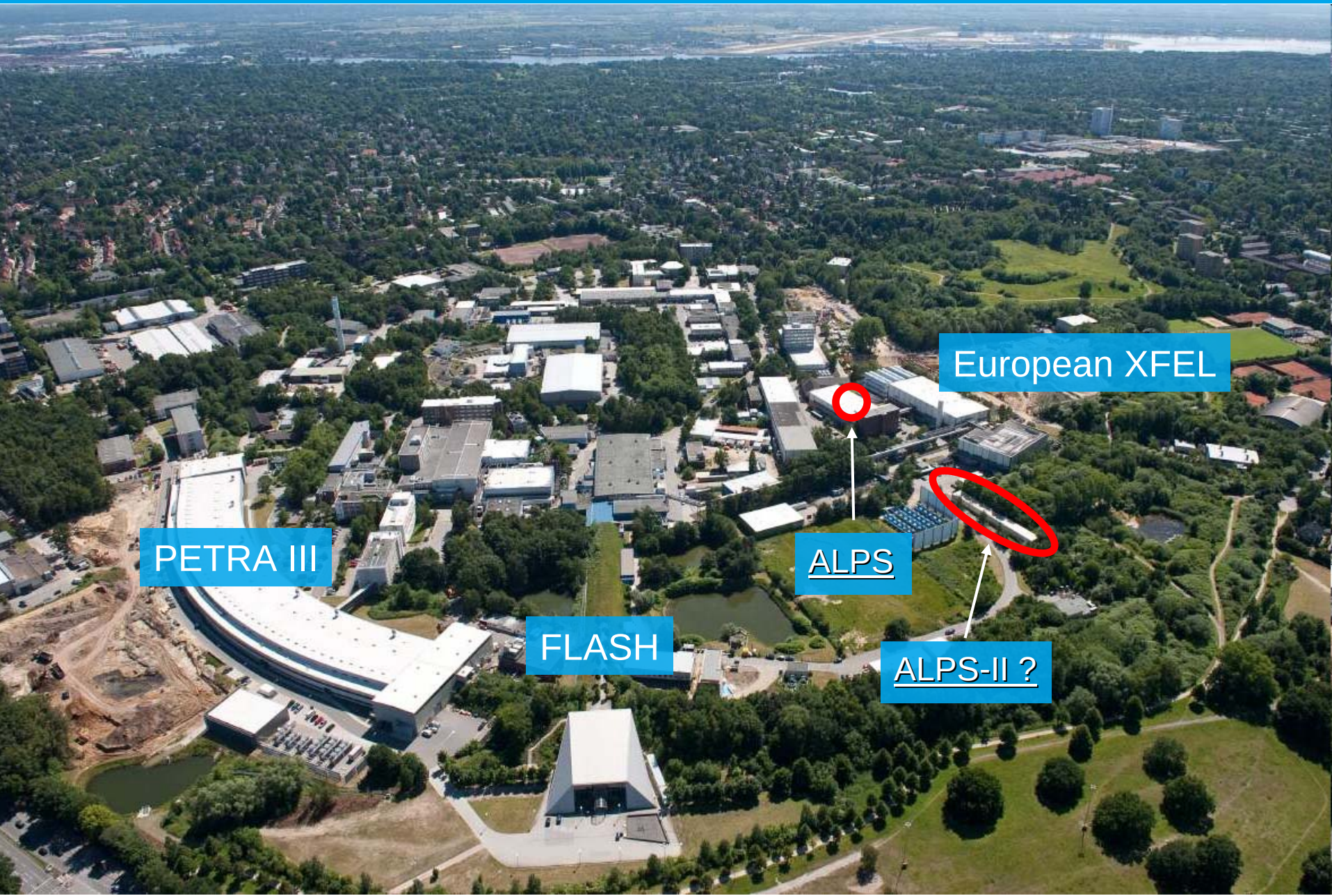
Lessons learned from ALPS

- 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 is essential to accomplish experiments like ALPS.
- Significant efforts required to compete with astrophysics!



compiled by J. Jäckel and A. Ringwald

ALPS II @ DESY in Hamburg?

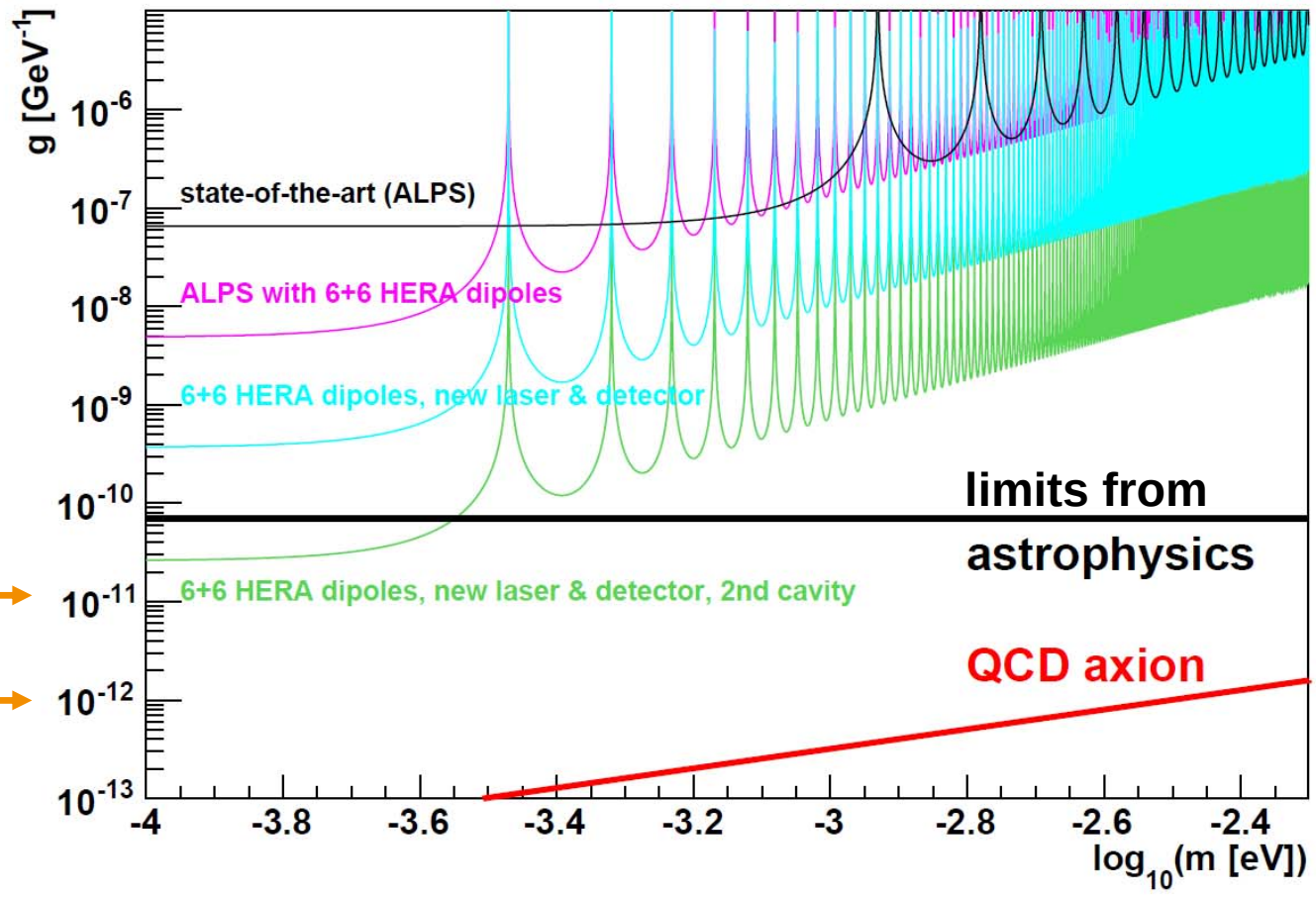


Prospects for ALPS-II components

- Laser with optical cavity to recycle laser power (like in ALPS, but 150 kW instead of 1 kW).
- Magnet:
  upgrade to 6+6 (?) HERA dipoles instead of ½+½ (260 Tm on each side equivalent to 2 LHC dipoles, see talk by P. Arias Reyes).
- Regeneration Cavity
- Superconducting Transition Edge Sensor? (see talk by G. Cantatore)

All set up in a clean environment!

The Dream: come close to g = 10^{-11} GeV^{-1}

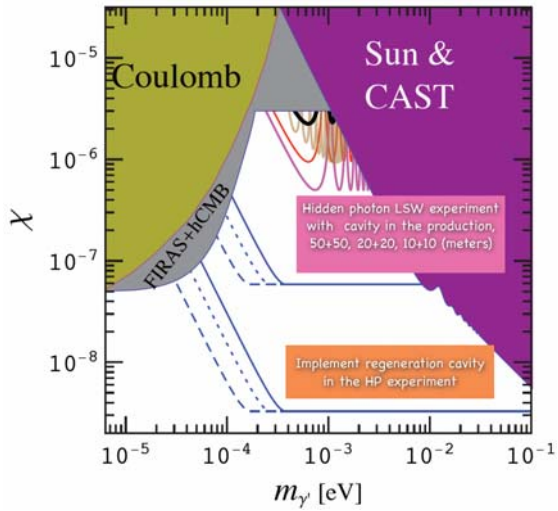


"Predictions" from astrophysics →

A very preliminary sketch of a possible schedule

- 2010: design of laser system, decision on detector baseline (CCD, TES?)
  purchase detector to measure “down conversion” of 532 to 1064nm light.
  costing of “clean room” infrastructure
  decision on baseline magnet configuration, coarse costing.
- late 2011: TDR for system without magnets
  “go ahead” for hidden photon search
- 2012: start of construction for hidden photon search
  completion of magnet TDR
- 2014: final data run on hidden photon search
  construction of magnet set-up
- 2016: data run with magnets

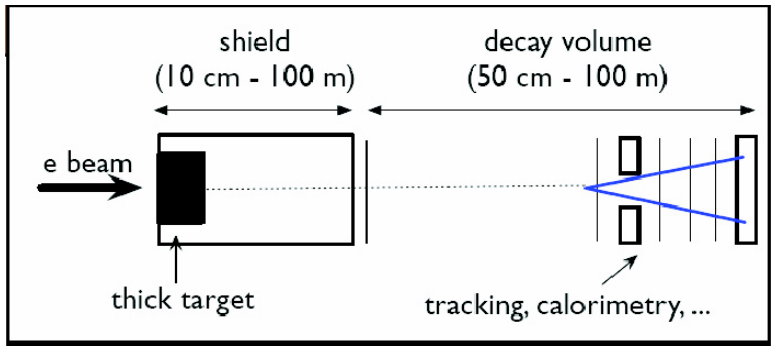
Hidden photon search

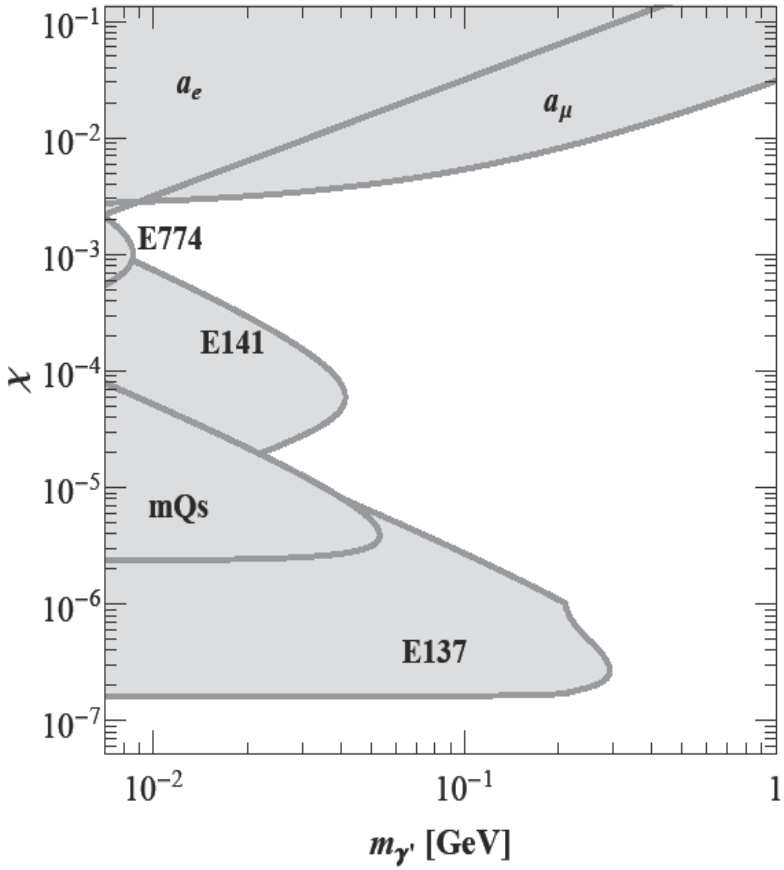


(compiled by J. Redondo)

Sub-GeV scale hidden U(1) gauge boson

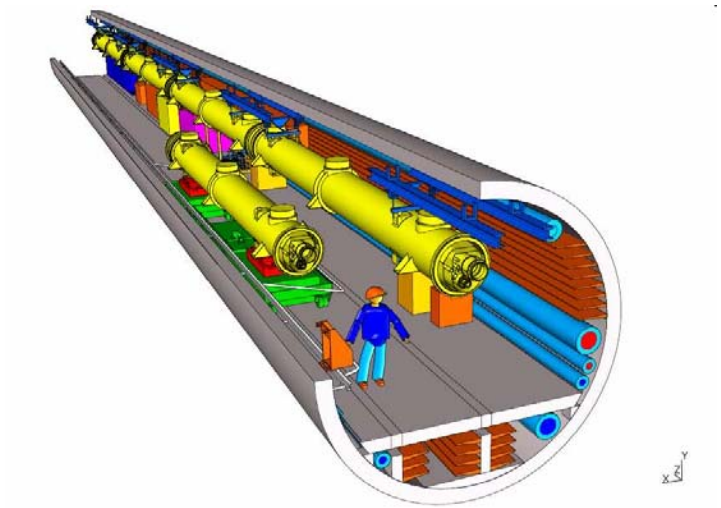
- Strong physics case for sub-GeV scale hidden photon (see talk S. Andreas)
  - may explain Dark Matter features/anomalies
  - many hidden U(1)s from uniifcation/strings
- Current bounds quite loose
  - tightest bounds presently from beam dumps





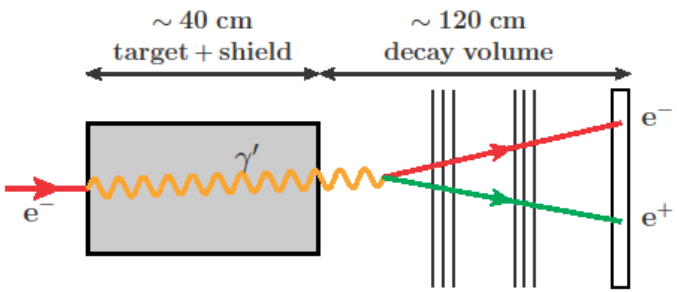
New beam dump/fixed target experiments at DESY?

- Suited electron (or positron) beams at DESY:
  - DESY II: 10 nA, 450 MeV – 6 GeV
  - FLASH: 30 μA, 1.2 GeV
  - XFEL: 30 μA, 14 GeV

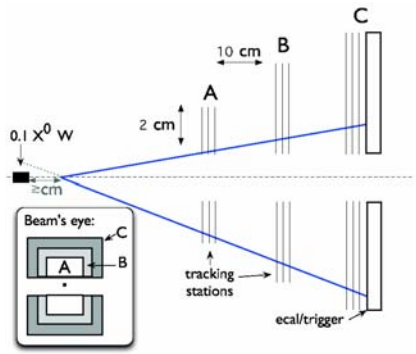


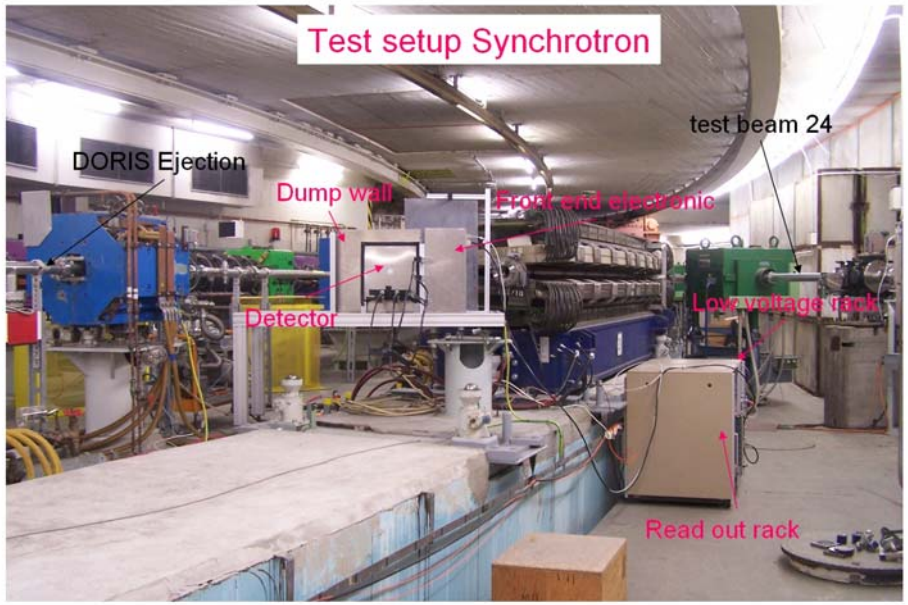
HIdden Particle Search HIPS

- Test experiment at DESY II
  - beam dump of 10 nA at 450 MeV



  - thin target with 10 nA at 6 GeV





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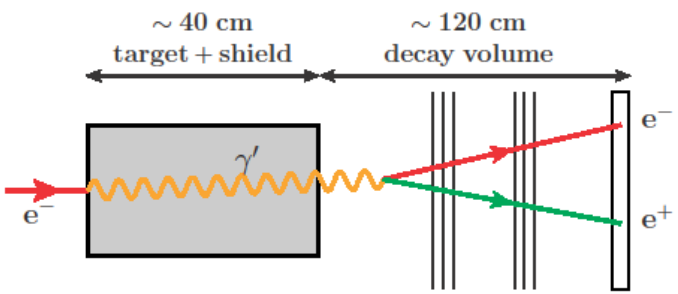

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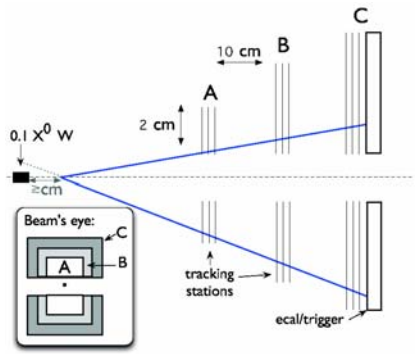

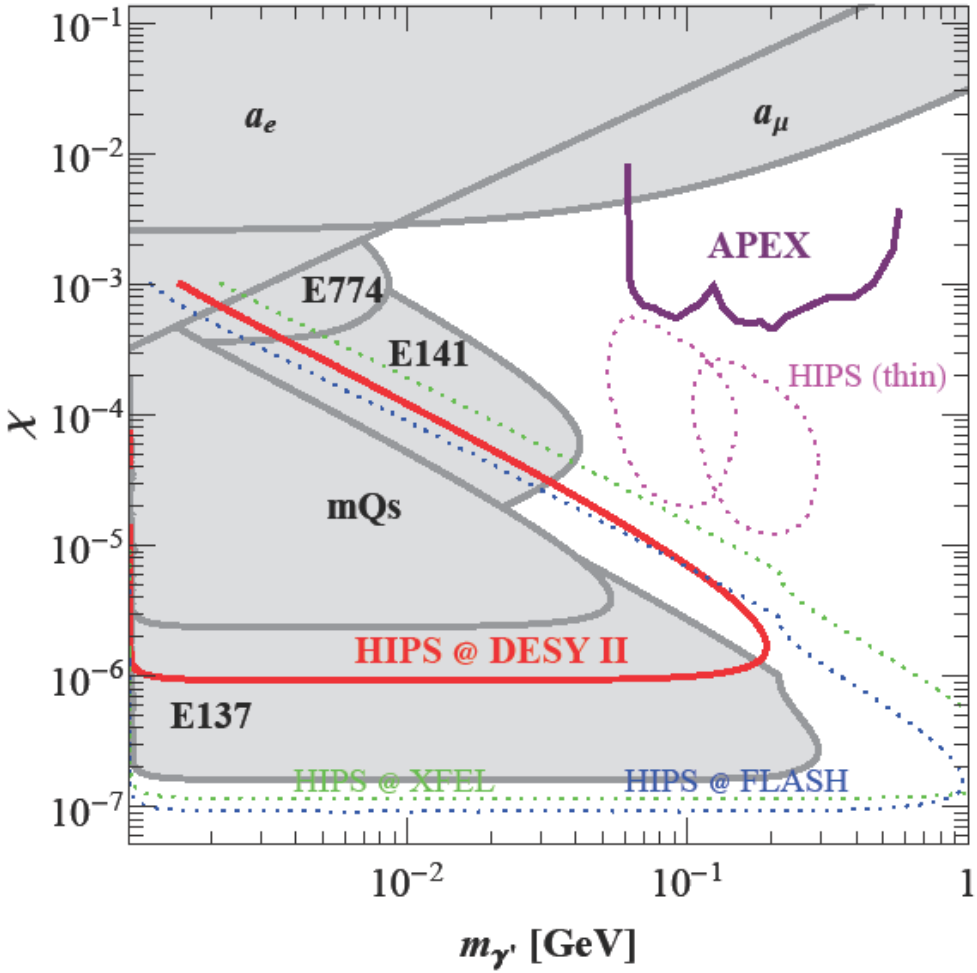

Backup Slides

Hints for WISP Physics (see also Talks at this Workshop)

Theory:

- A QCD axion in the mass region of 10^{-5} to 10^{-4} eV would be a “perfect” cold Dark Matter candidate.
- A zoo of WISPs is expected from string theory inspired extensions of the Standard Model
  A. Arvanitaki, S. Dimopoulos, S. Dubovsky, N. Kaloper, and J. March-Russell, arXiv:0905.4720 [hep-th]
  M. Goodsell, J. Jaeckel, J. Redondo and A. Ringwald, arXiv:0909.0515 [hep-ph], JHEP 0911:027,2009

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]
- *AGN X/γ-ray luminosity relations: hints for axion-like particles*
  C. Burrage et al., arXiv:0902.2320v1 [astro-ph.CO], Phys.Rev.Lett.102:201101,2009
- 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

DESY

Numbers

- We‘ve reached $g = 7 \cdot 10^{-8}$ GeV^{-1}
  - B·L: 6 HERA dipoles instead of ½ — factor of 12.0
  - B: full field strength — factor of (5.6/5.0) = 1.1
  - Laser power: 150 kW instead of 1 kW, now IR: — factor of (2·150)^0.25 = 4.1
  - Regeneration cavity: — factor of (40,000)^0.25 = 14.1
  - Detector: improve mHz sensitivity by 100: (about a photon per day!) — factor of (100)^0.25 = 3.2
- This would result in an improvement factor of about 2500!
- In addition: more beam time, assume 10 days instead of 10 hours.
  - if background limited: — (24)^0.125 = 1.5
  - for a “background-free” detector: — (24)^0.25 = 2.2
- Conclusion: if everything works out, a few 10^{-11} GeV^{-1} are within reach!
  - Personally I would like to add another order of magnitude as motivated by astrophysics.

ALPS-II Sharing of Responsibilities

- Laser and Cavities: partners from Hannover + DESY
- Magnets: DESY
  - use cold magnet bore instead of anti-cryostat in ALPS
  - design optics suited for HERA and LHC dipoles.
- Detector:
  - DESY
  - Hamburg University
  - INFN / Trieste University.

Jointly with the SHIPS project?
(Hamburg Observatory, DESY)