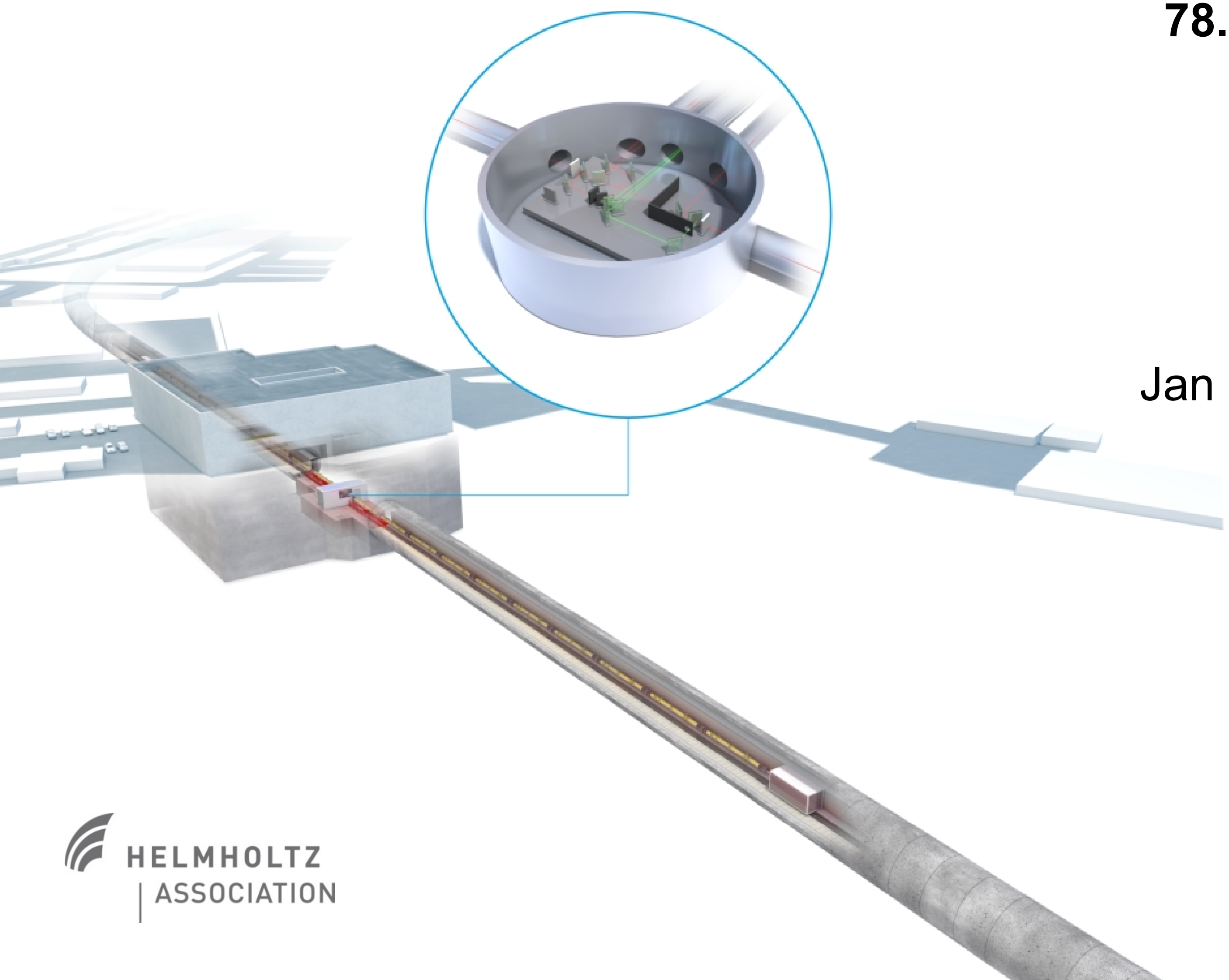
ALPS II status



78. Physics Research Committee (PRC) Open Session

16 October 2014
Zeuthen

Jan Dreyling-Eschweiler
(DESY)

Outline

- *Reminder:* WISPs and motivations
- **Update:** new astronomical motivations
- *Reminder:* ALPS experiment
- **Update:** experimental news on
  - optics
  - magnets
  - detector

→ Summary and Conclusion

WISP properties

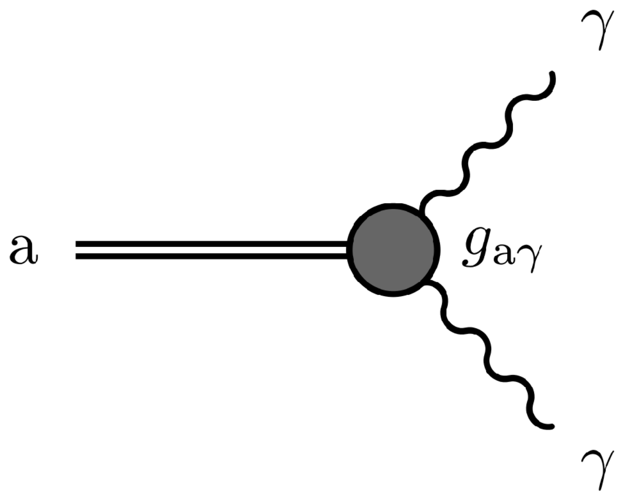
Any Light Particle Search (ALPS) ...

- ... searches for (hypothetical) **W**eakly **I**nteracting **S**ub-eV **P**articles (WISPs)

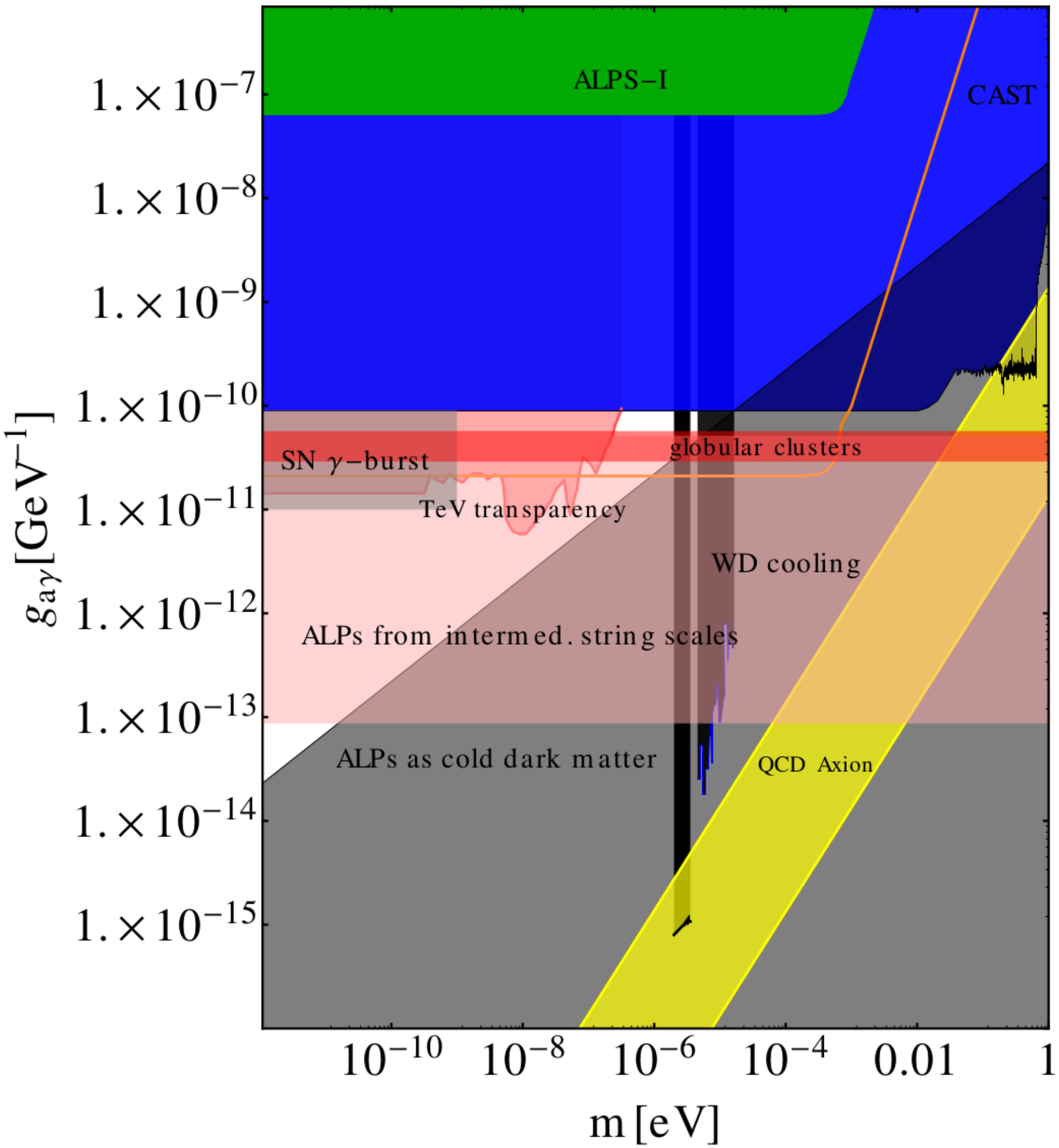
WISPs:
QCD axion, Axion-like particles (ALPs), Hidden photons (HP), ...

Features of an **A**xion-**L**ike **P**article (ALP)

- **sub**-eV mass
- **weakly** interacting with SM-particles
- an effective **coupling** to two photons



ALPs parameter space



Some motivations

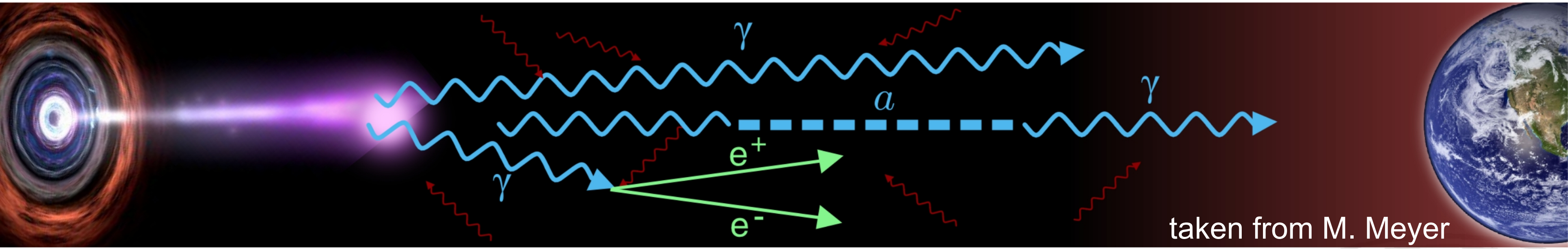
from theory:

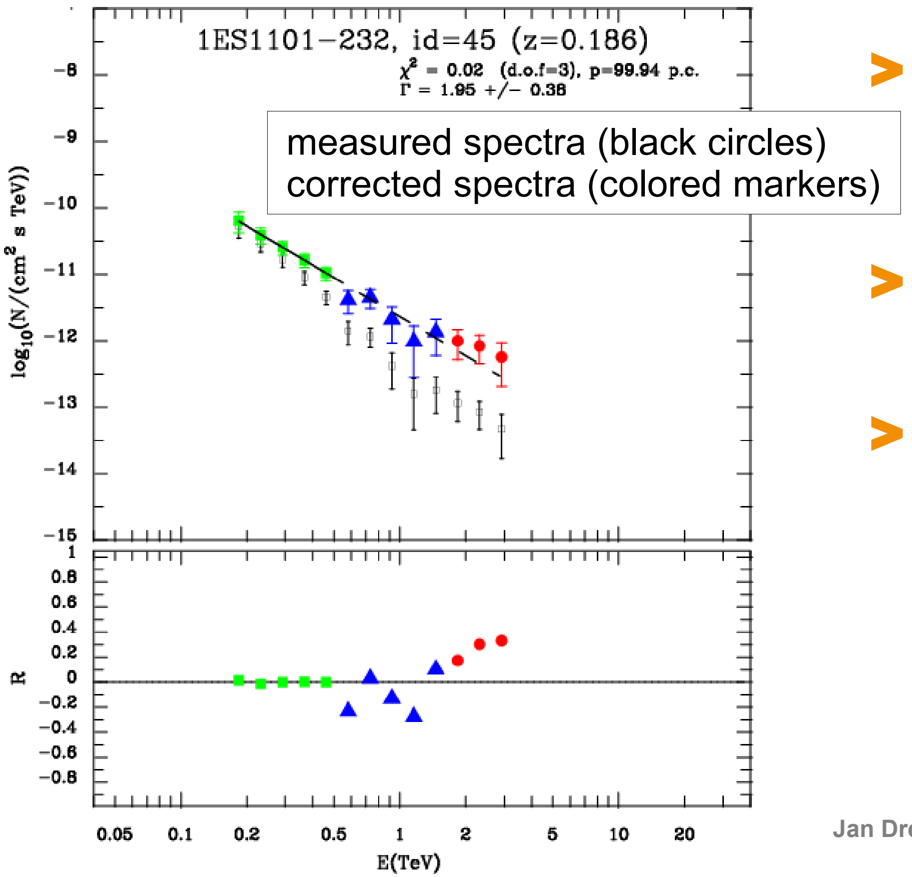
- QCD axion for strong CP problem
- string theory
- …

from observations:

- **TeV transparency**
- star cooling
  - white dwarfs
  - **He-burning stars**
- dark matter
- cosmic ALP background
- ...

TeV transparency





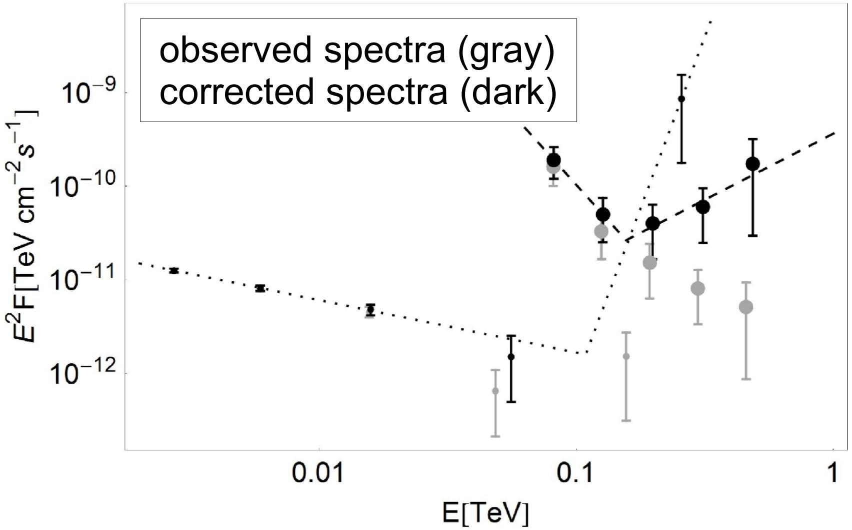
- TeV photons **should** interact with extragalactic background light: → attenuated spectrum.
- but predicted absorption is **not** seen for high-energetic photons
- analysis with blazars (IACT data)
  → **4.2 sigma** (e-e+)-anomaly
  → also **hint** for an ALPs mixing

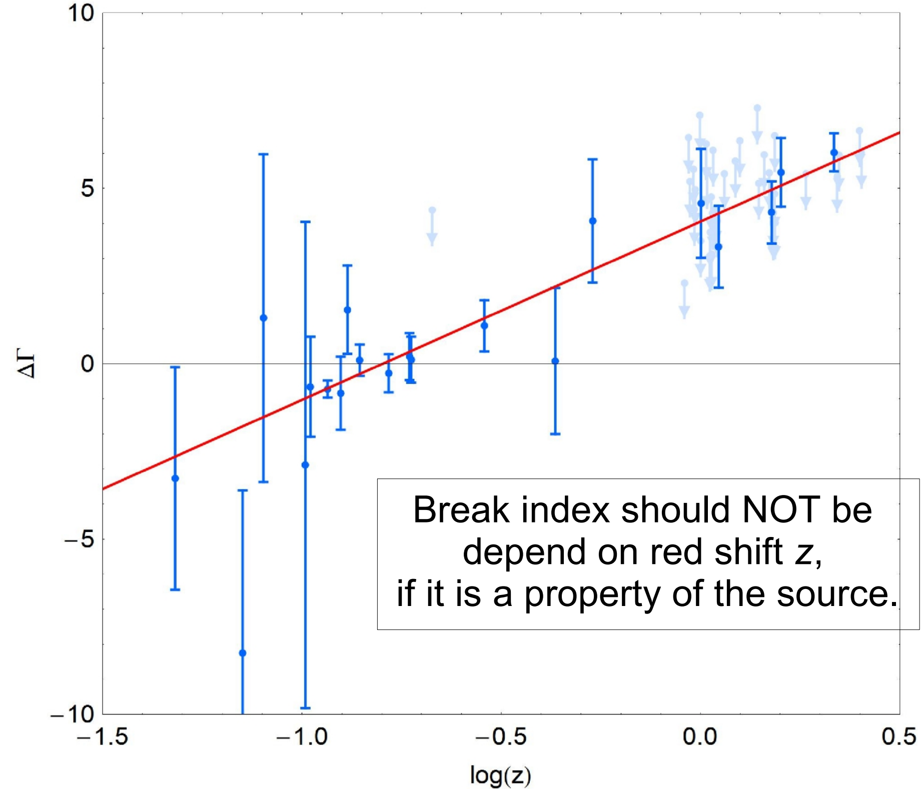
D. Horns and M. Meyer (JCAP 1202 (2012) 033)

TeV transparency (update)

- analysis including more spectra (also FERMI-data)
- different statistical method: break index

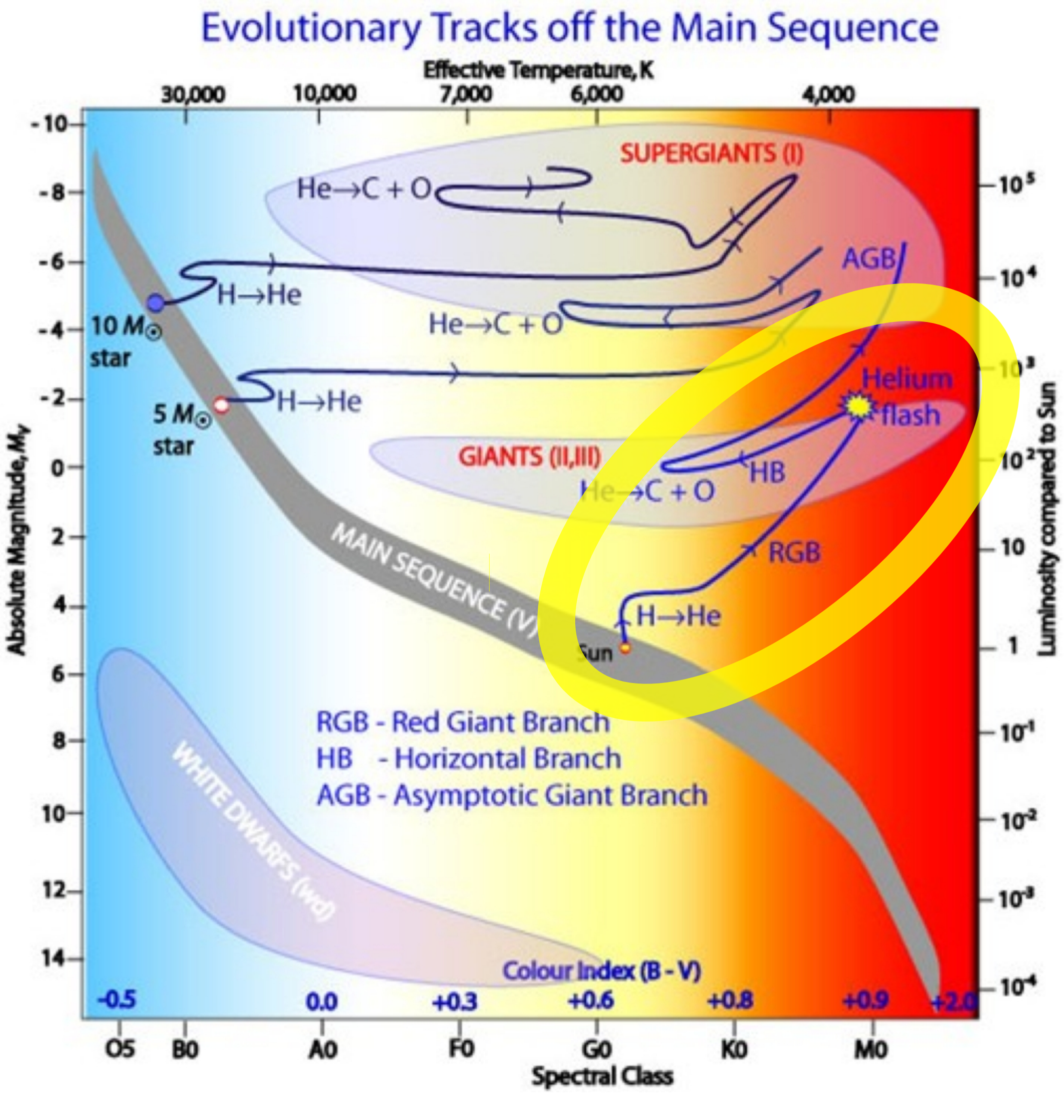
→ **12 sigma** (e-e+)-anomaly



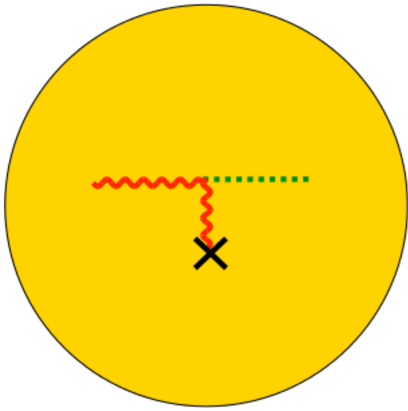


G. I. Rubtsov and S. V. Troitsky, "Breaks in gamma-ray spectra of distant blazars and transparency of the Universe," JETP Lett. 100 (2014) 397 [arXiv:1406.0239]

Stellar Clusters (update)



- star **cooling channel** through photon-ALP conversion

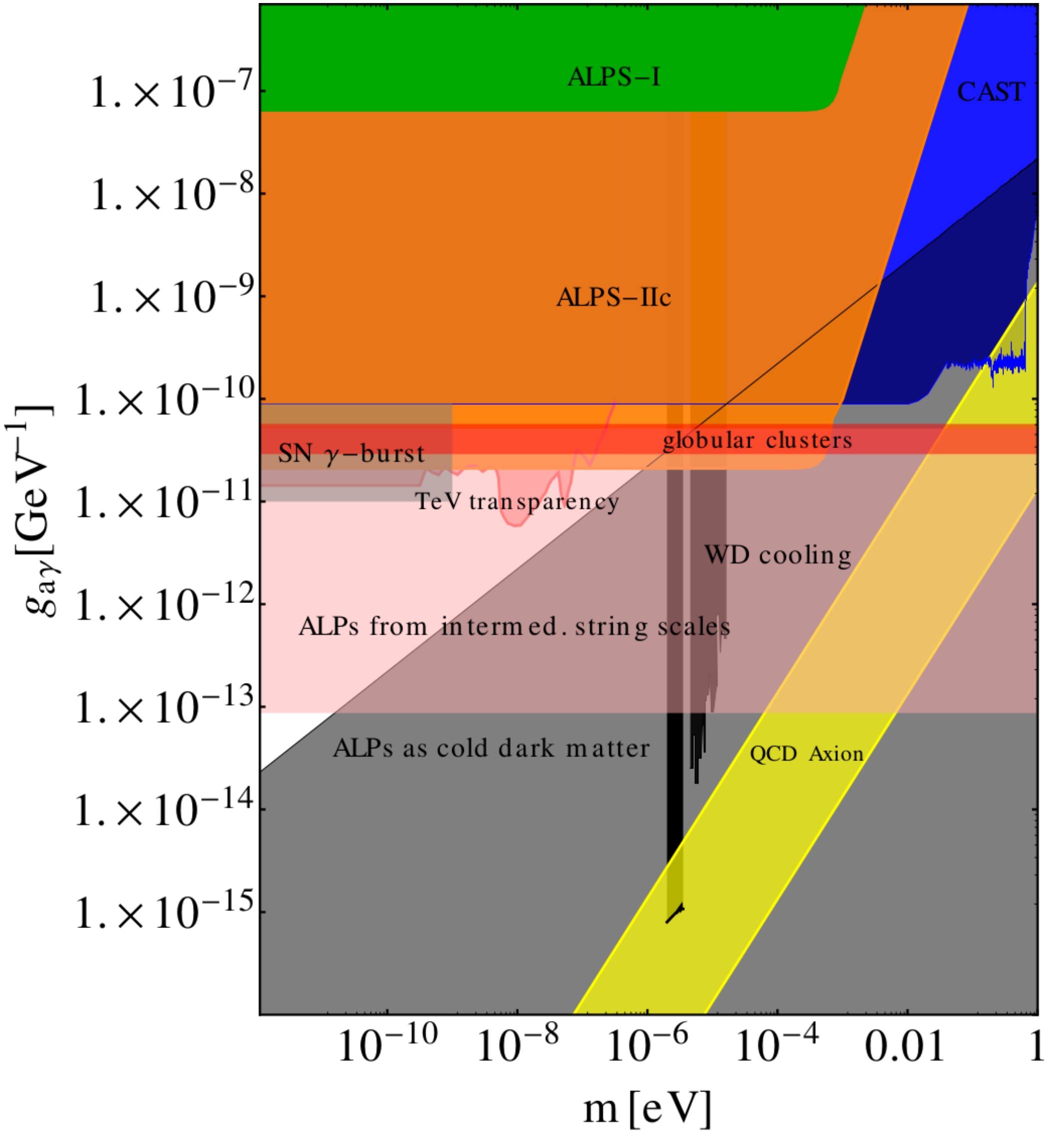


- new analysis of 39 Galactic Global clusters comparing the branches (HB and RGB)

→ **hint** for photon-ALP coupling

A. Ayala, I. Dominguez, M. Giannotti, A. Mirizzi and O. Straniero, "An improved bound on axion-photon coupling from Globular Clusters," arXiv:1406.6053

ALPS IIc can reach this!



ALPS IIc will test ALP-photon explanations for:

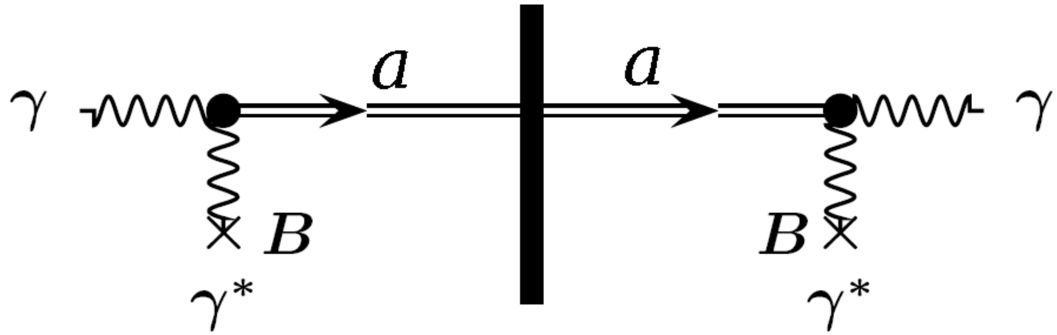
- TeV transparency
- stellar cluster cooling
- White Dwarf cooling
- X-ray excess of Coma cluster

Reminder: ALPS scheme

Any Light Particle Search (ALPS) ...

- … is a “Light-Shining-through-a-Wall” experiment

Experimental ingredients:
Laser, optical cavity, magnets, SM opaque wall, single photon detection



- … increases the experimental sensitivity in **ALPS II**

$$g_{a\gamma} \propto \frac{1}{BL} \times \left(\frac{1}{\dot{\gamma}_{\text{prod}}\, \beta_{\text{cavities}}} \right)^{1/4} \times \left(\frac{\sqrt{DC}}{DE} \right)^{1/4}$$

magnetic length ***optics (laser + cavities)*** ***detector***

DESY

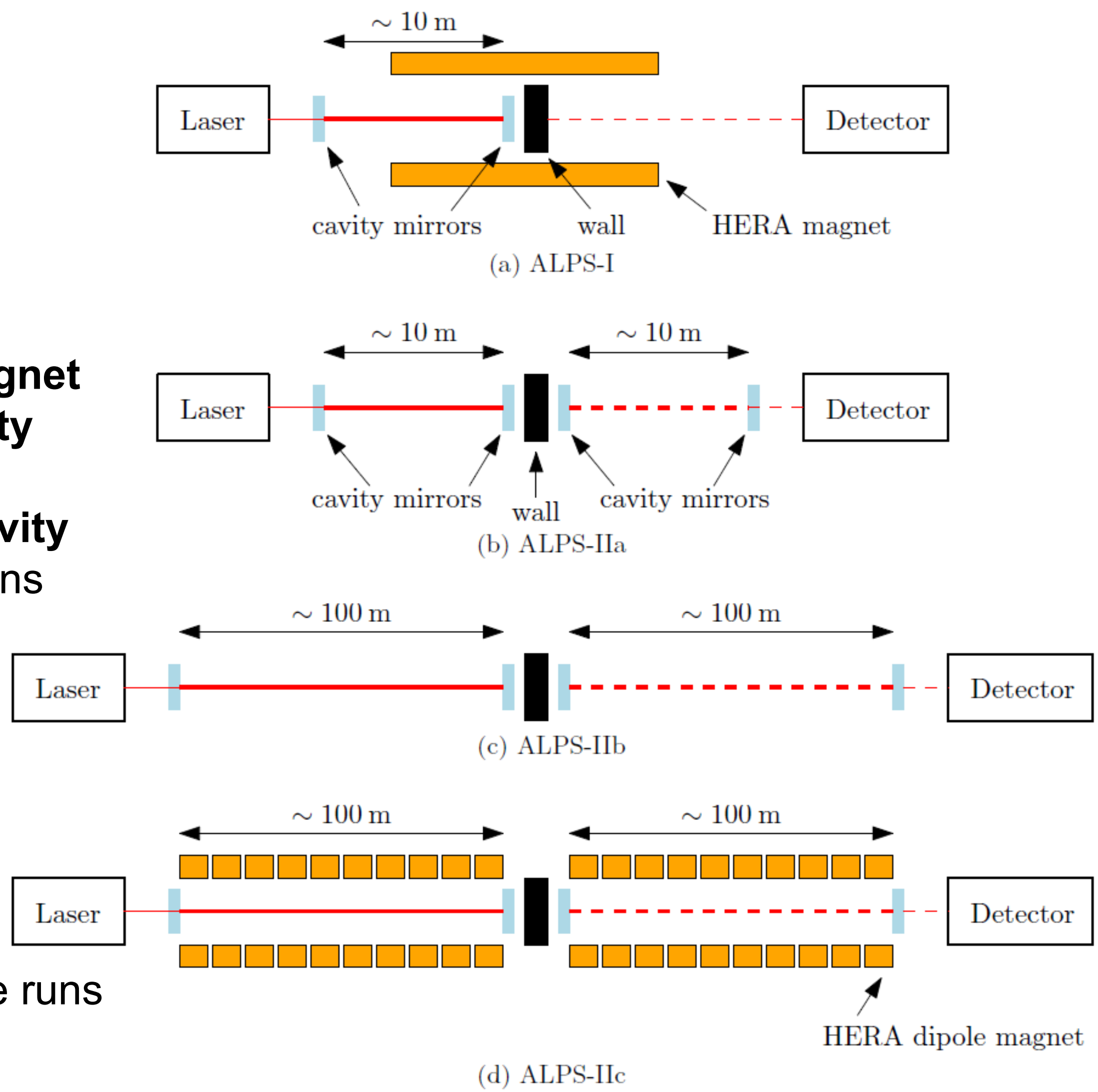
On the road to ALPS IIc

ALPS I
- 2x4 m
- 1 HERA dipole
- production cavity
- 532 nm

> ALPS IIa
- **2x10 m, w/o magnet**
- **production cavity with 1064 nm**
- **regeneration cavity**
- hidden photon runs

> (ALPS IIb)

> ALPS IIc
- 2x100 m
- axion-like particle runs



2010

(Bld. 50, 607)

2014

2018

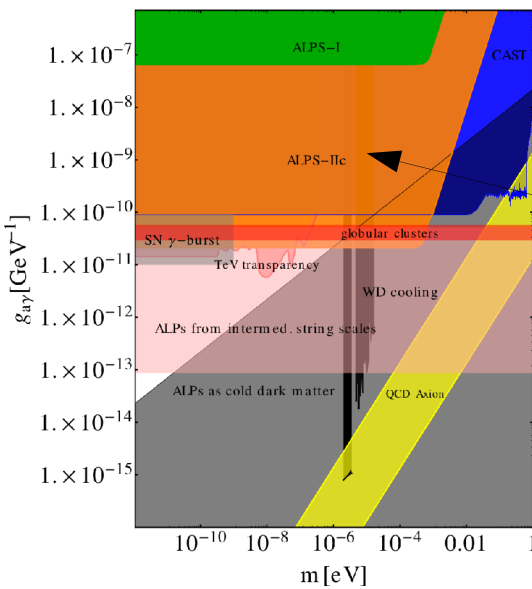
DESY

Increase the experimental sensitivity

$$g_{a\gamma} \propto \frac{1}{BL} \times \left(\frac{1}{\dot{\gamma}_{\mathrm{prod}}\,\beta_{\mathrm{cavities}}}\right)^{1/4} \times \left(\frac{\sqrt{DC}}{DE}\right)^{1/4}$$

magnetic length — ***optics (laser + cavities)*** — ***detector***

Parameter	Scaling	ALPS-I	ALPS-IIc	Sens. gain
Effective laser power P_{laser}	$g_{a\gamma} \propto P_{\mathrm{laser}}^{-1/4}$	1 kW	150 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 Tm	468 Tm	21
Detector efficiency QE	$g_{a\gamma} \propto QE^{-1/4}$	0.9	0.75	0.96
Detector noise DC	$g_{a\gamma} \propto DC^{1/8}$	$0.0018\,\mathrm{s}^{-1}$	$0.000001\,\mathrm{s}^{-1}$	2.6
Combined improvements				3082

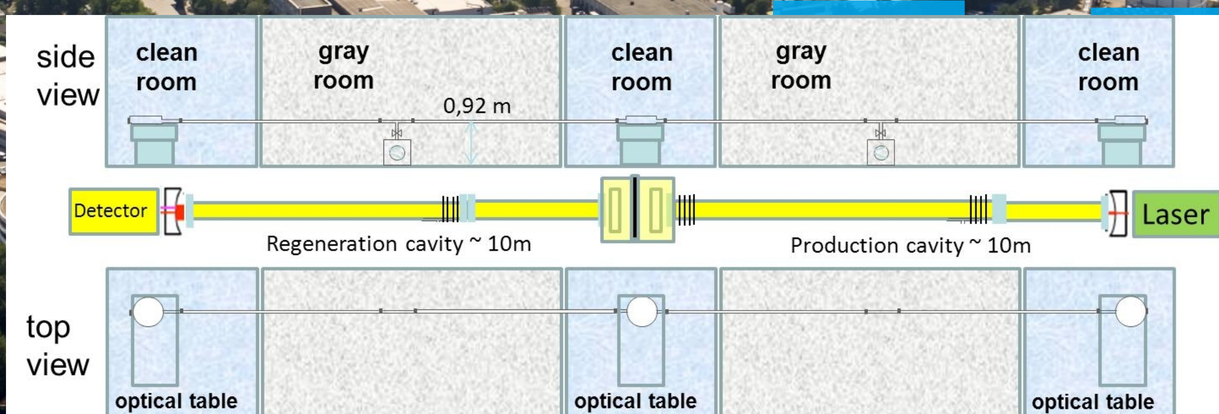


3 orders of magnitudes improvement with ALPS IIc

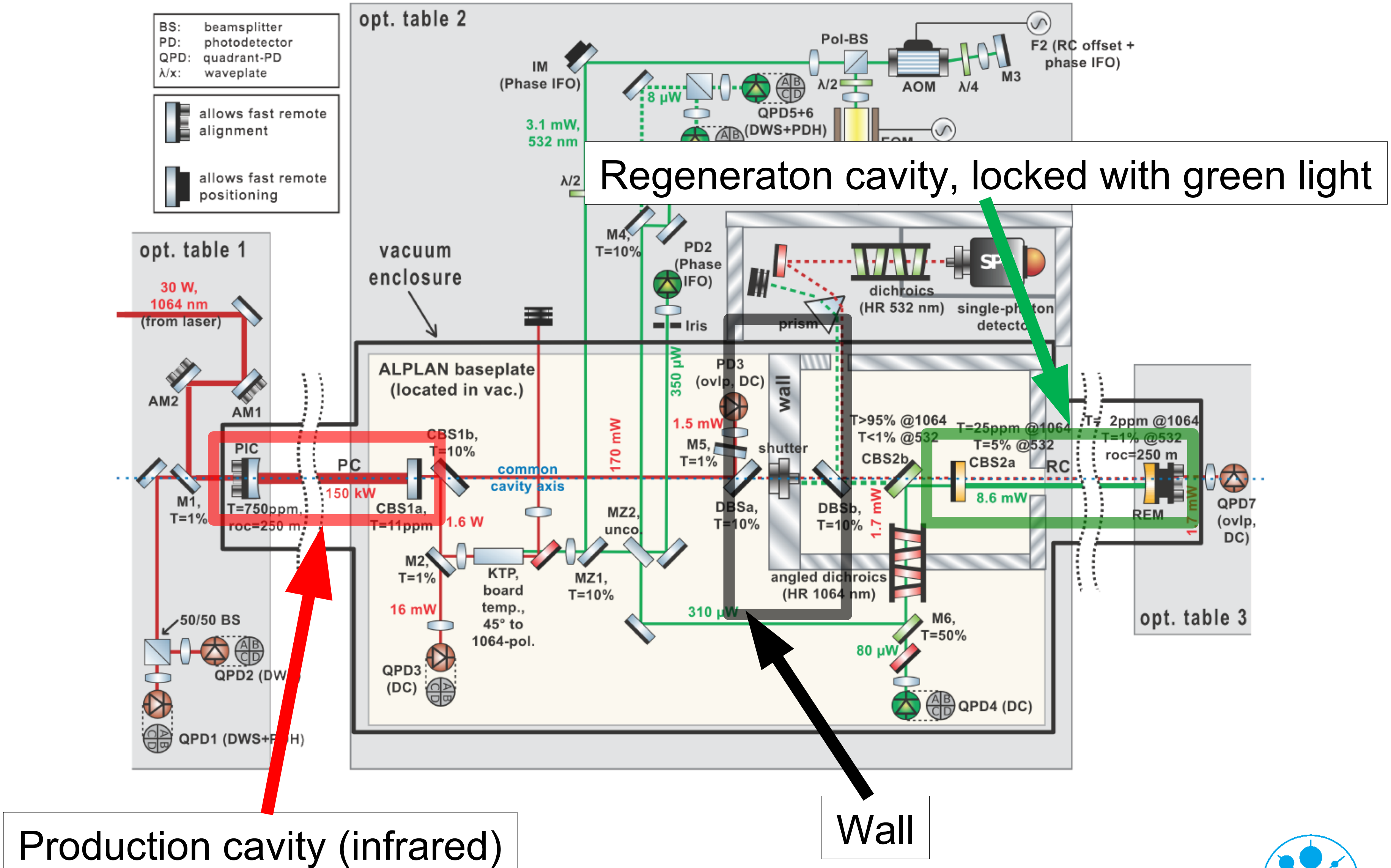
ALPS at DESY in Hamburg

ALPS IIa in HERA-WEST

Since 2012: the ALPS IIa laboratory in HERA-West

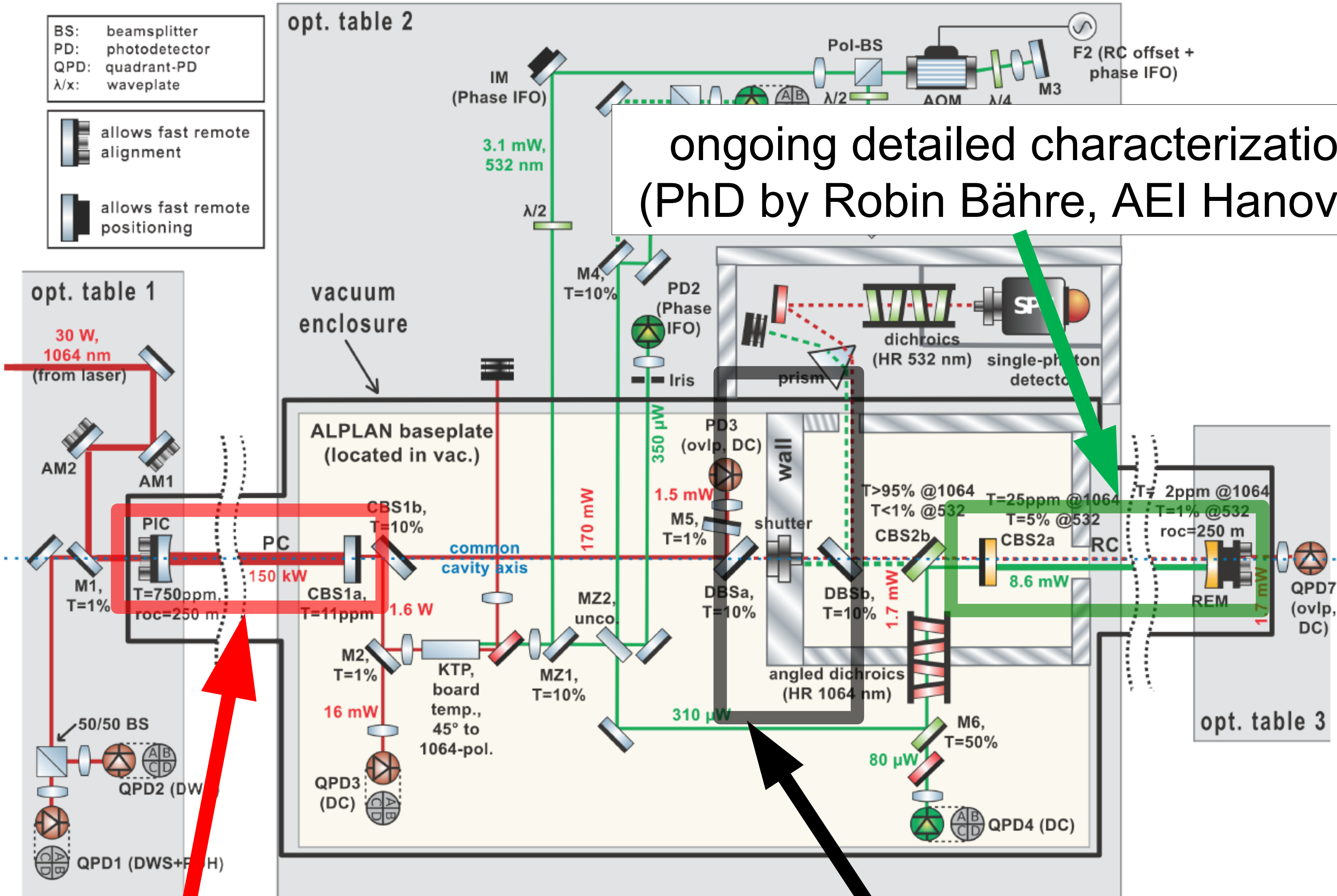


Optics: laser & cavities



DESY

Optics: laser & cavities (update)



ongoing detailed characterization (PhD by Robin Bähre, AEI Hanover)

detailed characterization (PhD by Reza Hodajerdi, DESY)

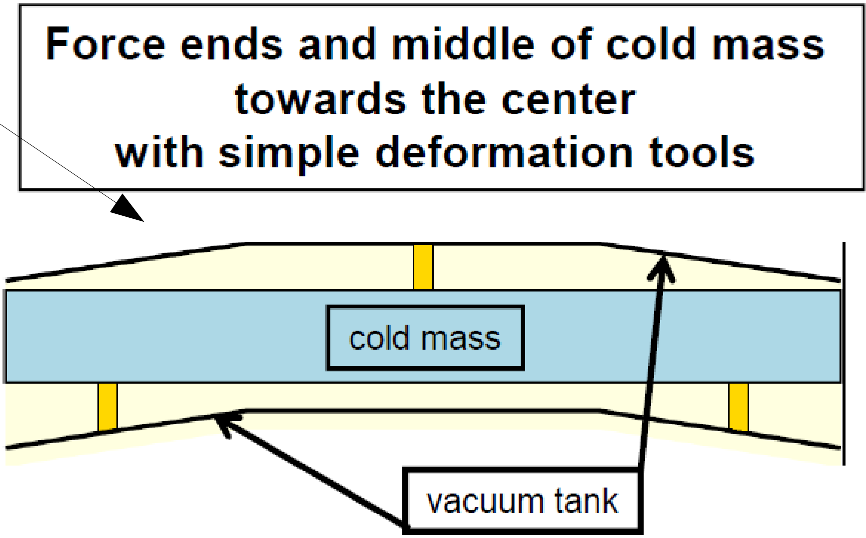
realization and lighttight-tests

Magnets

- **straighten** 20 HERA dipoles
- one HERA dipole was straightened by brutal-**force**-method and operated (5.3 T)

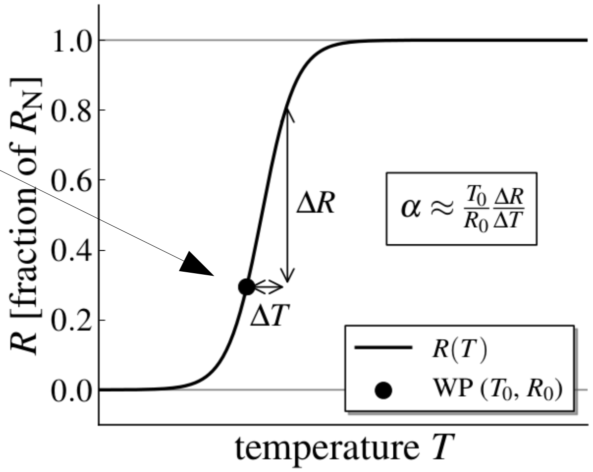
Update:

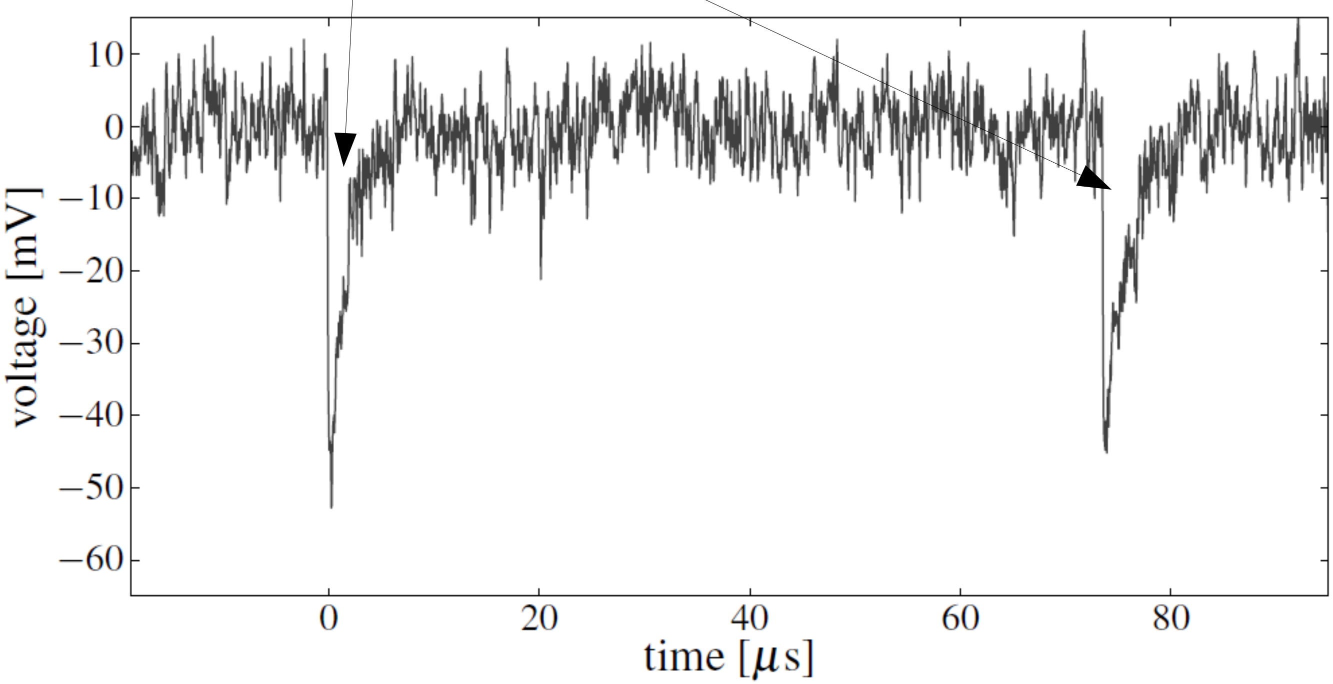
- **second** magnet straightening
- refined straightening method with customized tools



TES Detector

- **T**ransition-**E**dge **S**ensor (TES):
  set point at the superconducting transition
- microcalorimeter (25µm x 25µm x 20nm tungsten film), operated at 80 **mK**
- resolves **single** 1064 nm photons
  (time constant 1.5 µs, energy res. ≈ 6-8%)

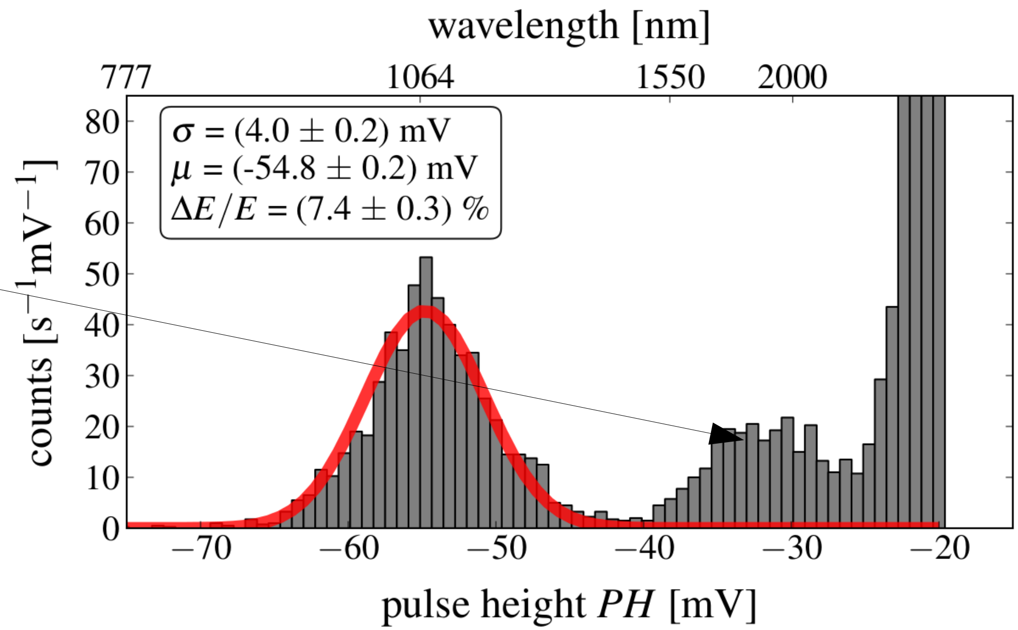




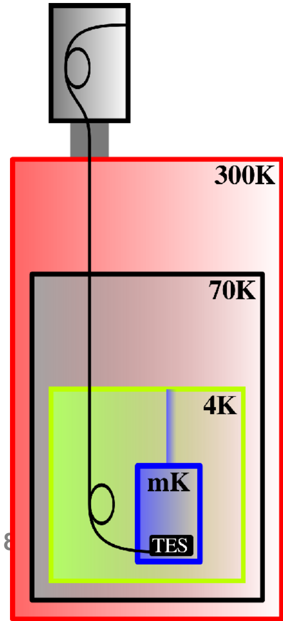
TES detector (update)

- extensive background analysis
  - **1064 nm signal** region
  - fiber-coupled TES is pile-up dominated by **thermal photons** (300 K blackbody)
  - dark count rate for TES: *DC* ~ $\mathbf{10^{-2}\ s^{-1}}$ (at *DE* ~ 20%)
  - sensitivity **gain** compared to using the ALPS I detector (CCD)!

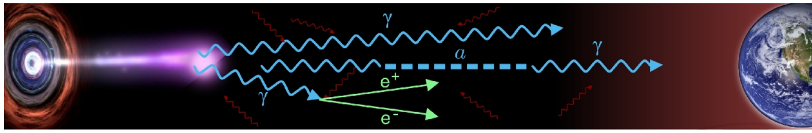
  → PhD by JDE



- instrumentation **paper** in progress (Journal of Modern Optics)
- first **detection efficiency measurements**
  → high systematic uncertainties, "> 50 %", improved setup
- mK-cryostat: precooling problems due to cold **water** supply
  → new (advanced) heat exchanger is designed

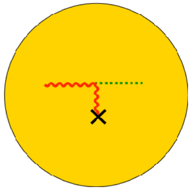


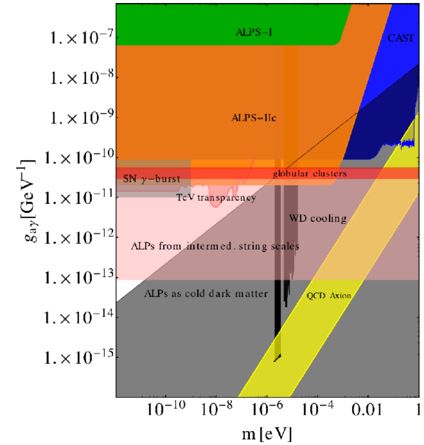
Summary and Conclusion



WISPs and ALPS

- Physics case has **again strengthened**: TeV transparency, stellar cooling, …
- ALPS IIa will explore this region

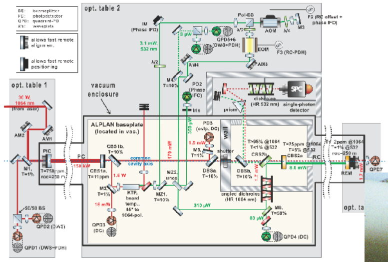


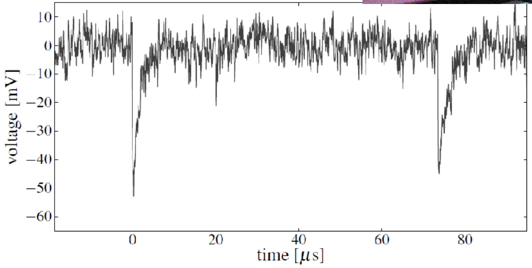


Experimental status

- **Optics:** new (quantitative) insights
  → detailed challenges to solve
- **Magnets:** second bending ongoing
  → infrastructure support needed
- **Detector:** first sensitivity limits
  → improvements are underway

→ **no show stopper at all**





ALPS collaboration and outreach

ALPS II is a joint effort of

- **DESY**
  Babette Döbrich, Jan Dreyling-Eschweiler, Samvel Ghazaryan, Reza Hodajerdi, Friederike Januschek, Ernst-Axel Knabbe, Natali Kuzkova, Axel Lindner, Andreas Ringwald, Jan Pöld, Jan Eike von Seggern, Richard Stromhagen, Dieter Trines
- **Hamburg University**
  Noemie Bastidon, Dieter Horns
- **AEI Hannover**
  (MPG & Hannover Uni.):
  Robin Bähre, Benno Willke
- **Mainz University**
  Matthias Schott, Christoph Weinsheimer

with strong support from

- neoLASE, PTB-Berlin, NIST (Boulder)

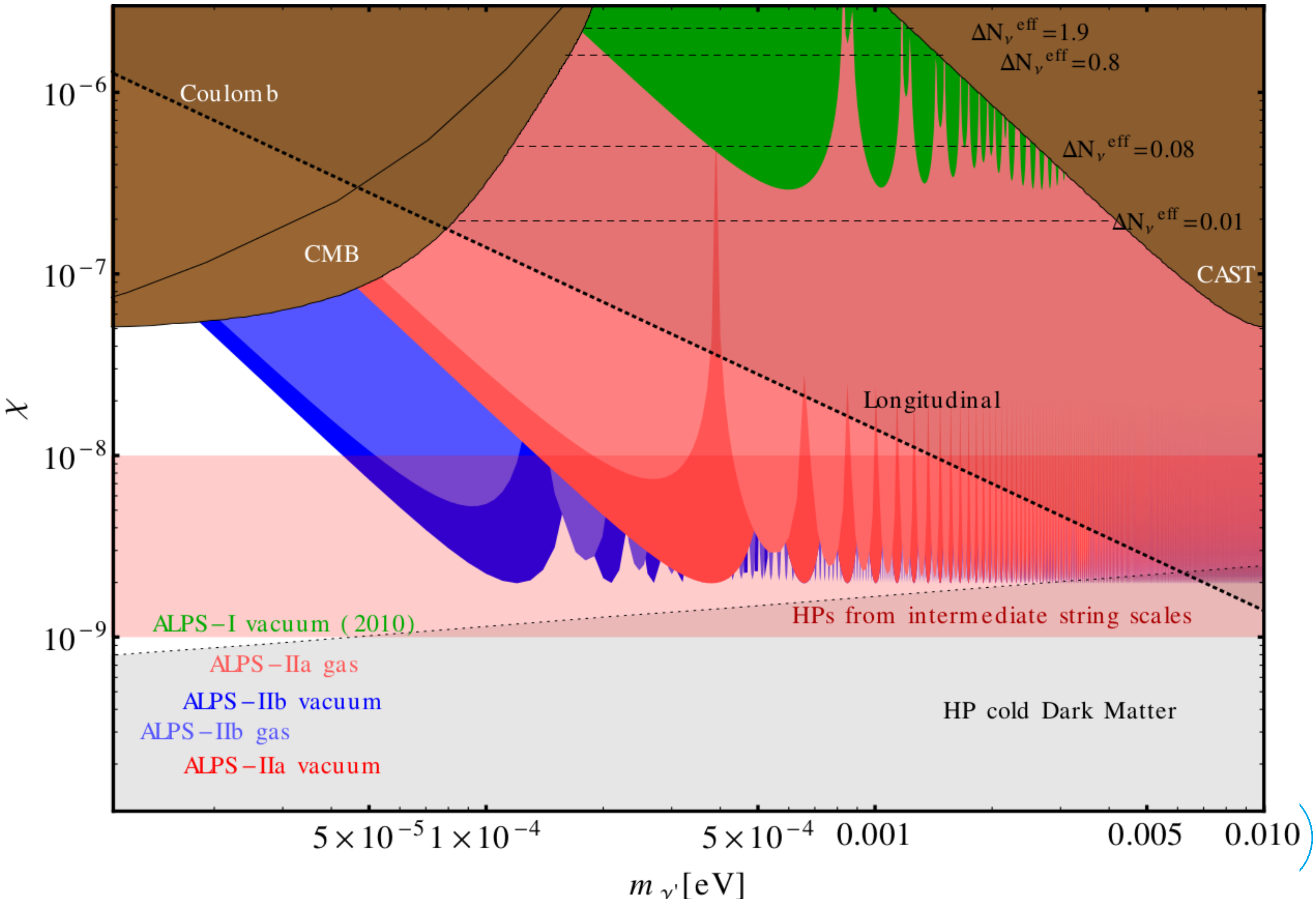
DIE AUTOREN

Joerg Jaeckel (links) ist Professor am Institut für Theoretische Physik der Universität Heidelberg und forscht über Physik jenseits des Standardmodells. Er beschäftigt sich mit ultraleichten Teilchen, aber auch mit LHC-Physik. **Axel Lindner** (Mitte) ist experimenteller Teilchenphysiker am Deutschen Elektronen-Synchrotron (DESY) in Hamburg und Sprecher des ALPS-Projekts. **Andreas Ringwald** ist ebenfalls Physiker am DESY. Er konzentriert sich auf theoretische Vorhersagen der Eigenschaften ultraleichter Teilchen sowie auf ihre Überprüfung in Laborexperimenten und hat in diesem Rahmen das ALPS-Projekt angestoßen.

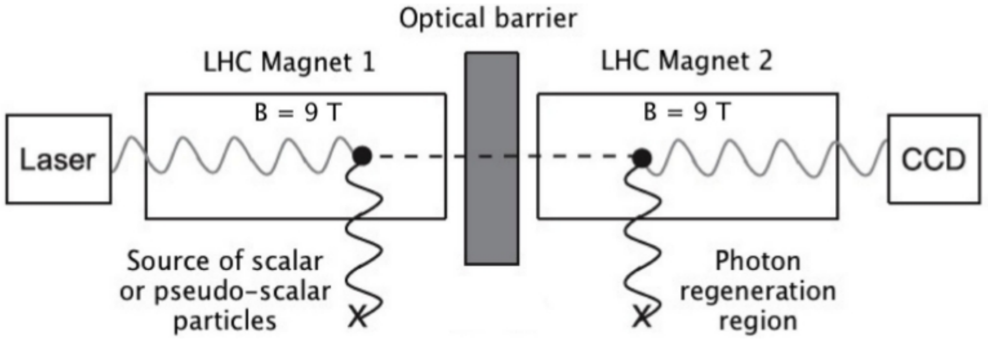
Backup

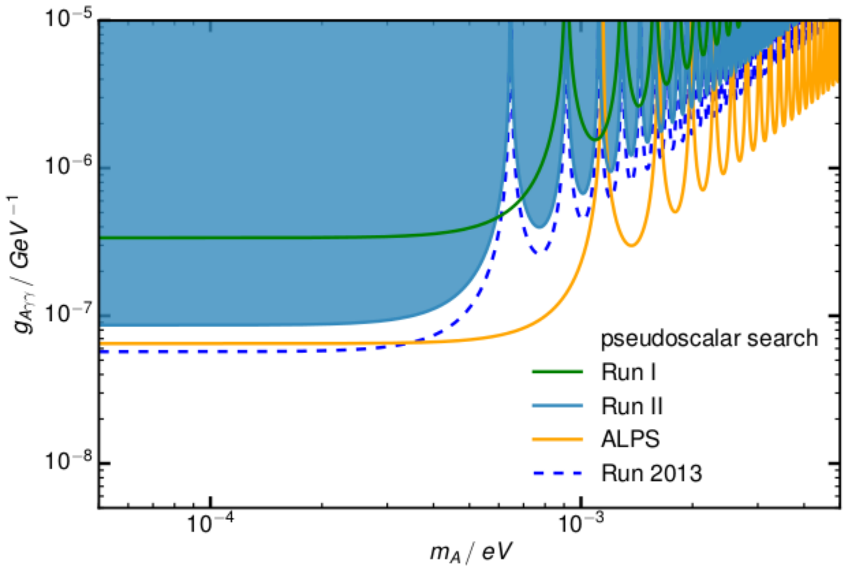
ALPS IIa physics

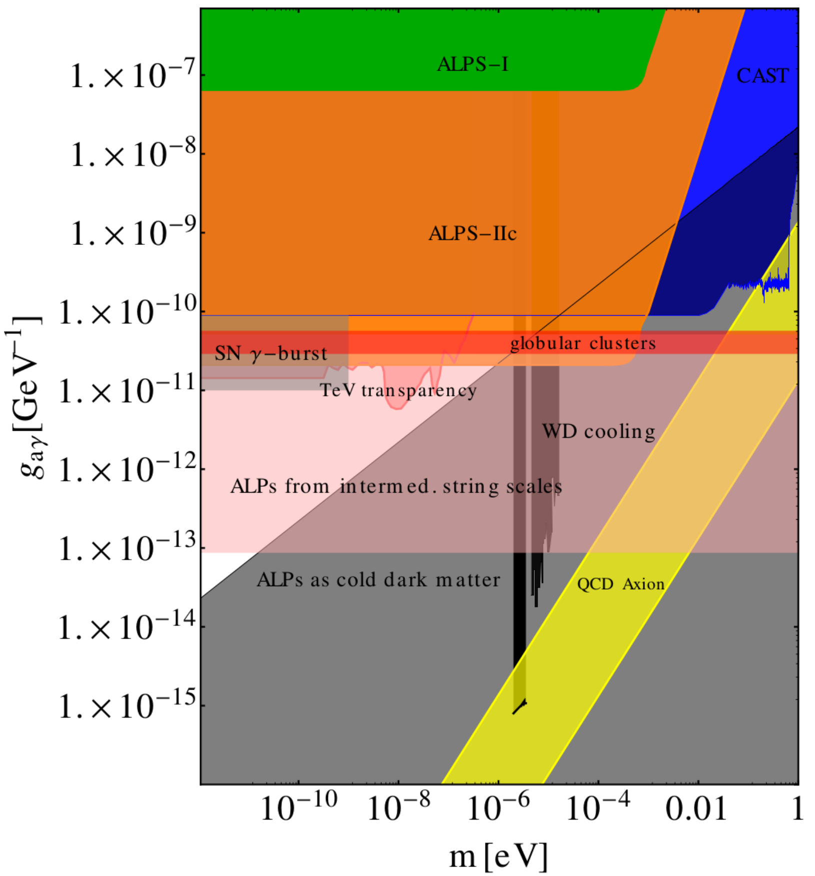
- Hidden photon search at 2x10 m without magnets



OSQAR



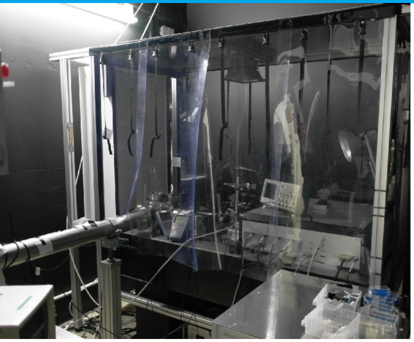


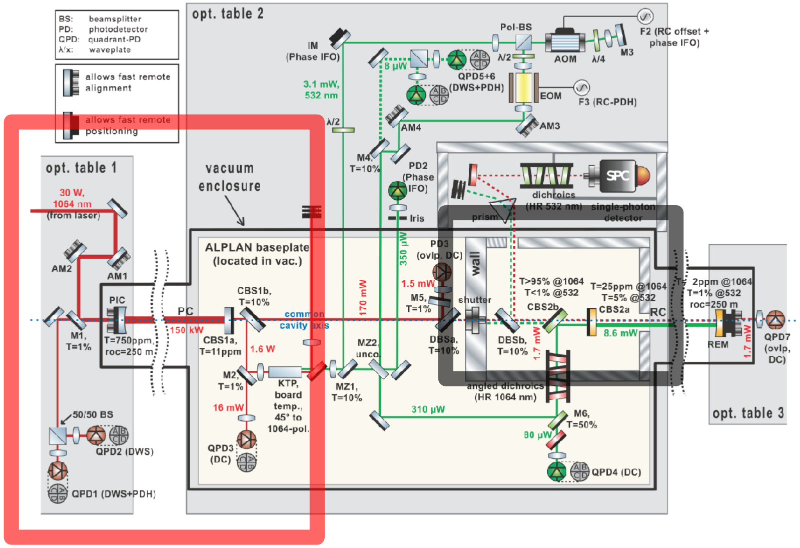


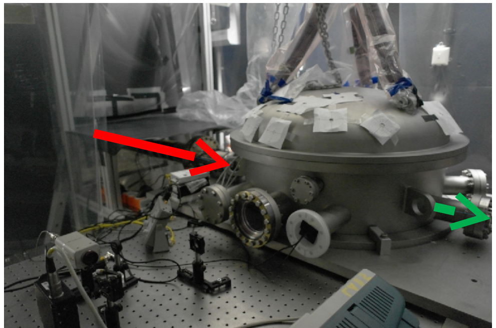
OSQAR collaboration: Latest Results of the OSQAR Photon Regeneration Experiment for Axion-Like Particle Search

arXiv: 1410.2566, 9. Oct 2014

Optics (update)







Production cavity

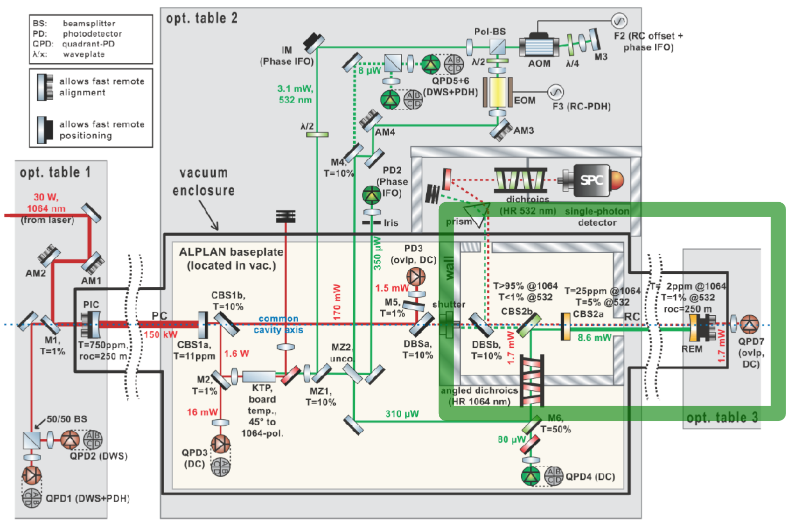
- **detailed** characterization of production cavity in vacuum
  - robust lock (> 4 h)
  - (length) noise of cavity is in strong coherence with seismic noise
    → faster feedback electronics or additional damping is needed

  → PhD thesis by Reza Hodajerdi (DESY)
- envisaged plane **mirrors** arrived (from Laseroptics)

"Wall" = breadboard & shutter:

- non-vacuum tests with CCD camera
- current design is not **lighttight**
  → improved design is underway

Optics (update)



Regeneration cavity

- Hamburg (ALPS IIa)
  - Infrastructure: first **vacuum** tests are underway
- Hanover (1 m table-top experiment)
  - detailed characterization for the stabilization of the regeneration cavity
  - lower power fluctuations inside the production cavity are required
  - developing a **automatic** alignment system

→ PhD thesis by Robin Bähre