# ALPS-II

## Goals, Status and Tools (including instrumentation...)

Babette Döbrich (for ALPS)
Instrumentation Seminar
DESY Hamburg, April 26th 2013

HELMHOLTZ GEMEINSCHAFT

DESY

# Outline

- ALPS-II: Motivation, Goals and Tools Overview
- Laser and optics
- Magnet system
- Detection system
- Closing words

# Theory and Motivation in a Nutshell

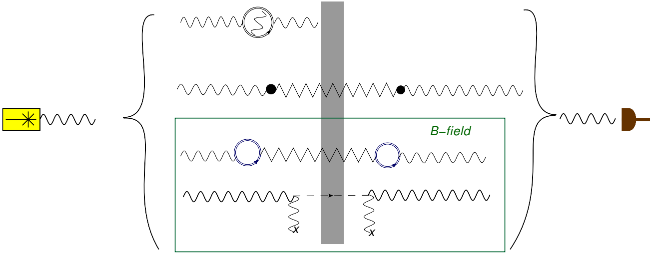
**Light particles ($\sim$ sub-eV) can have evaded detection if very weakly coupled to known particles**

## Motivation comes from..

- fine-tuning issues in the Standard Model (Axion)
- astrophysical hints (Dark Matter & astro-phenomena)
- Standard Model Extensions (e.g. String Theory)

$\Rightarrow$ search the most promising mass-coupling parameter space for such particles (axion-like particles, hidden photons, minicharged particles...) with appropriate/available means

# The LSW principle and technical upgrades



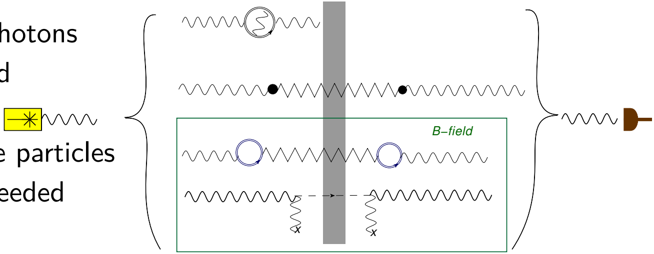
# The LSW principle and technical upgrades

hidden photons

no B-field

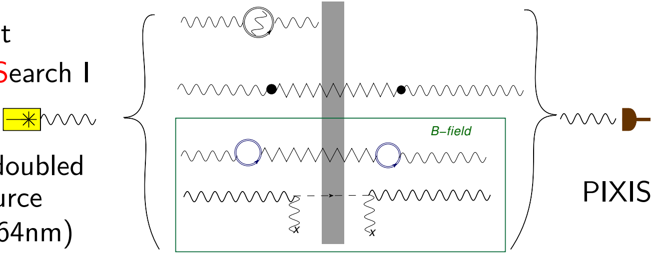
axion-like particles

B-field needed



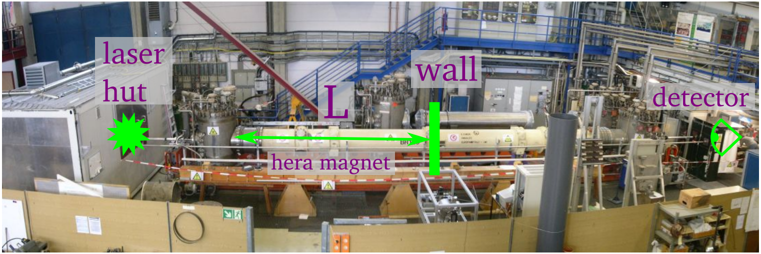
# The LSW principle and technical upgrades

Any Light Particle Search I




frequency doubled infrared source ('35W', 1064nm)

PIXIS CCD



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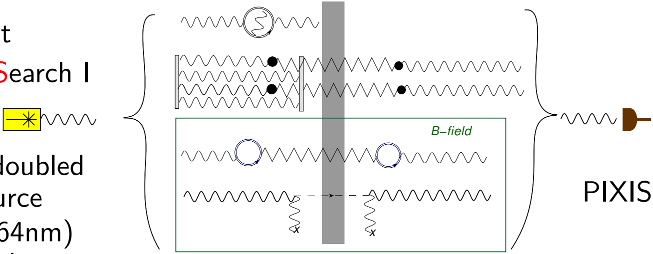


frequency doubled infrared source ('35W', 1064nm) +Resonator!

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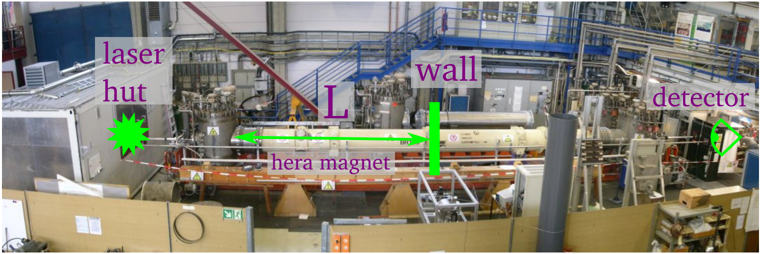

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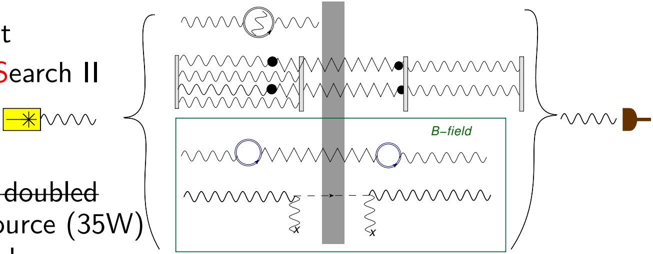


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## Possible upgrades

- (Even) More photons $\rightarrow$ enhanced probability

## Technical realization

- *coupled* cavities on both sides of the wall

# The LSW principle and technical upgrades

Any Light

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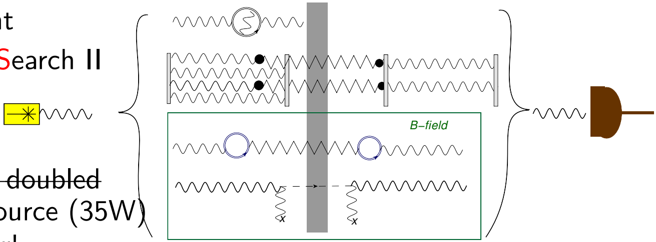


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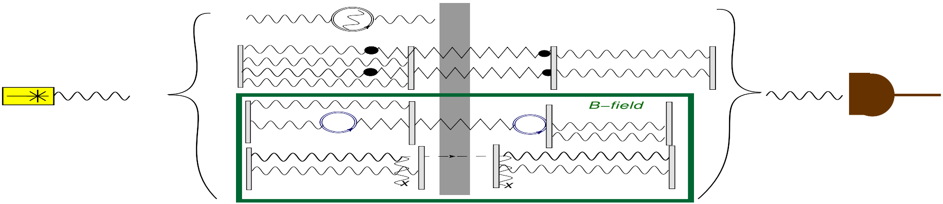


## Possible upgrades

- (Even) More photons $\rightarrow$ enhanced probability
- better single photon detection
- More (magnetic) length

## Technical realization

- *coupled* cavities on both sides of the wall
- Transition edge sensor (CCD low Q.E. for inrared)
- enhance length $\rightarrow$ tunnel, more HERA dipoles

# Upgrade benefits and ALPS-II stages

| Parameter | Scaling | ALPS-I | ALPS-IIc | Sens. gain |
|---|---|---|---|---|
| Effective laser power $P_{\mathrm{laser}}$ | $g_{a\gamma} \propto P_{\mathrm{laser}}^{-1/4}$ | 1 kW | 150 kW | 3.5 |
| Rel. photon number flux $n_\gamma$ | $g_{a\gamma} \propto n_\gamma^{-1/4}$ | 1 (532 nm) | 2 (1064 nm) | 1.2 |
| Power built up in RC $P_{\mathrm{RC}}$ | $g_{a\gamma} \propto P_{reg}^{-1/4}$ | 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 |

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  - (magnetic) length $\sim 21$'
  - optics‘$\sim 59$'
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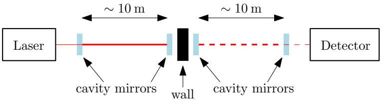


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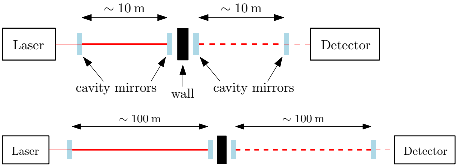


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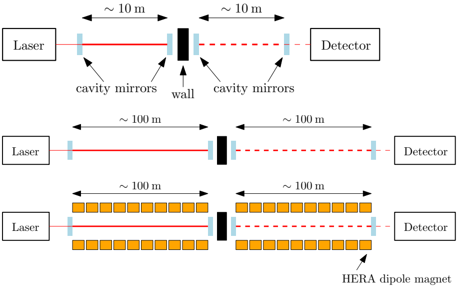


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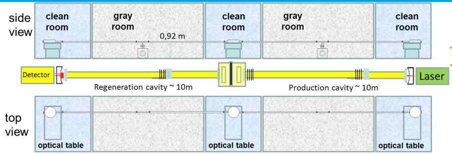
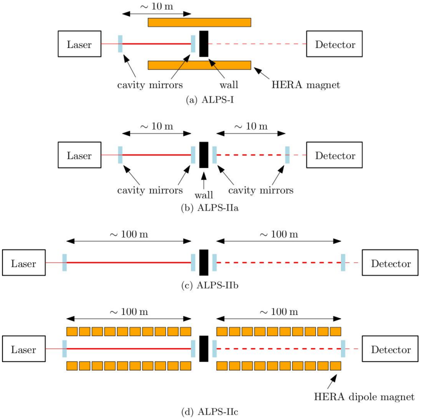
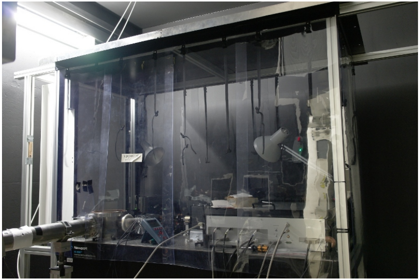
# Status & Organizational matters




> Towards ALPS-IIa data in 50/607



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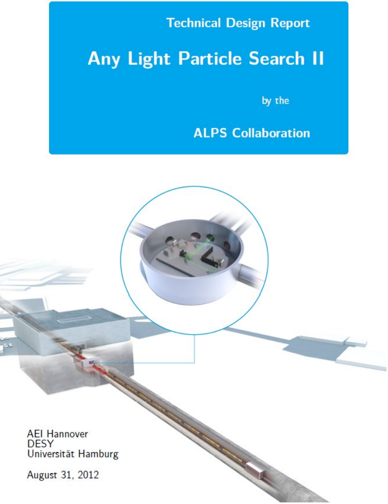


- Towards ALPS-IIa data in 50/607
- Technical design report submitted to DESY PRC in August 2012
- ALPS-II review at PRC in Zeuthen in November 2012
- approval for ALPS-IIa and b in Feb. 2013 and TDR on arXiv:1302.5647
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- ALPS group in DESY FH division, headed by Andreas Ringwald
- People and collaborators
  - 3 institutions (DESY, UHH, AEI)
  - 4 (part-time) scientists, 3 retired, 2 postdocs, 4 PhD students
  - tentative expansion!

DESY

Albert-Einstein-Institut Hannover

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- **Laser and optics**
- Magnet system
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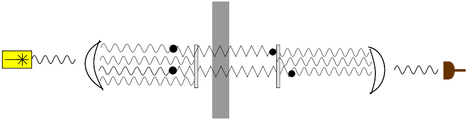
# Resonant regeneration



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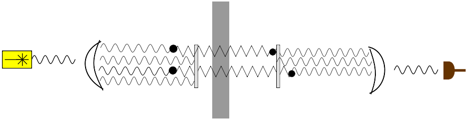
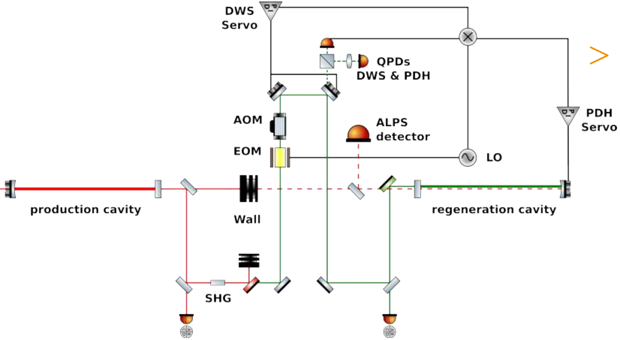
  - momentum conservation → frequency-lock (PDH) the two cavities



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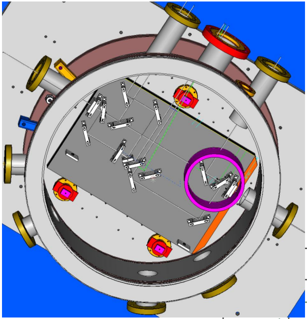

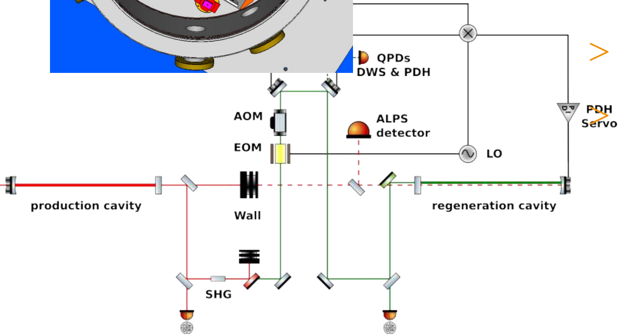


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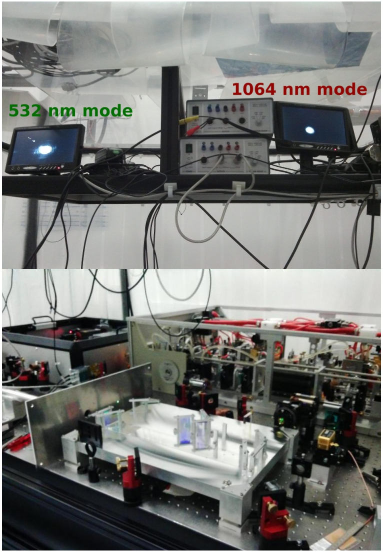


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  - 1m test-proof-of-principle in Hannover

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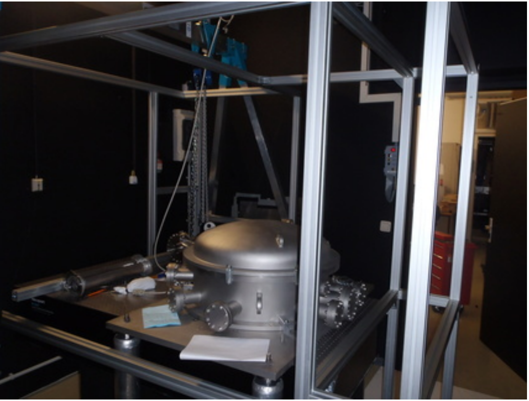

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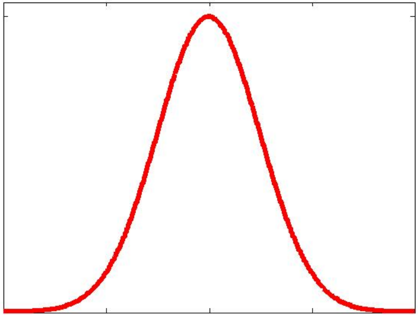
  - towards implementation at DESY

# Aperture constraints



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  $PB_{PC} = 5000$,
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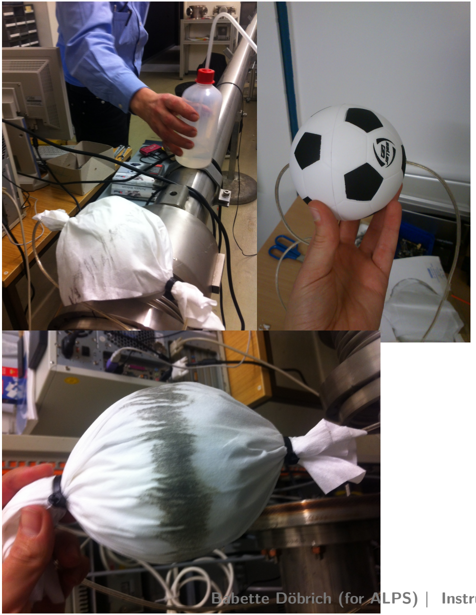

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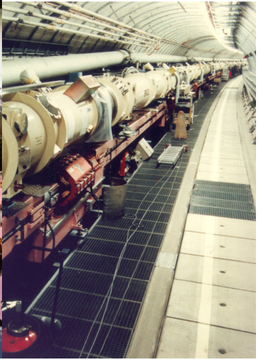

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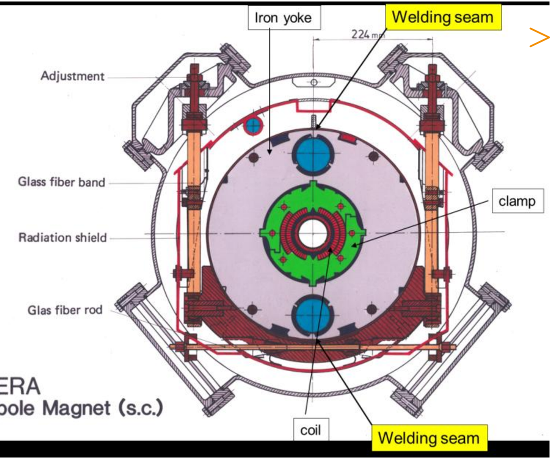
- ALPS-IIc $\rightarrow$ effective aperture 35mm limits to 4+4 dipoles (not enough) at proposed PB but “true” aperture larger (55mm)
- reestablish “true aperture”?

# Outline

# Magnet straightening in a (very small) nutshell




- howto
  - force on cold mass

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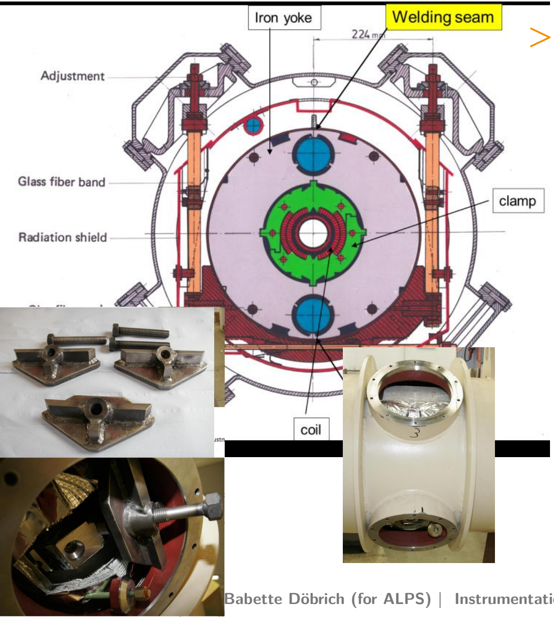


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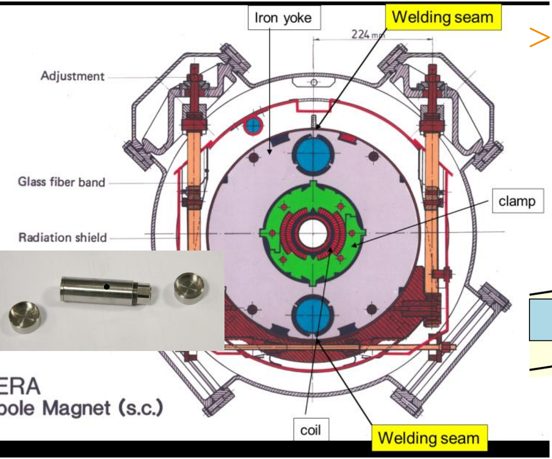


- howto
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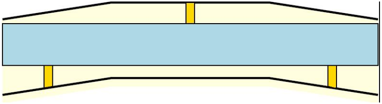
  - pressure prop at middle and ends



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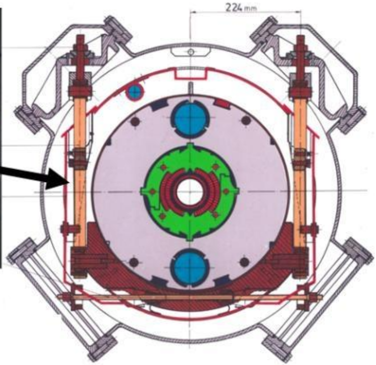


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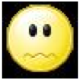

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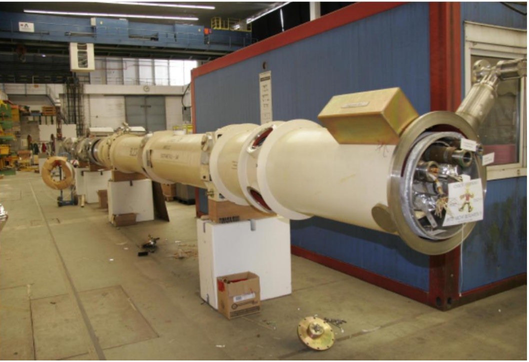

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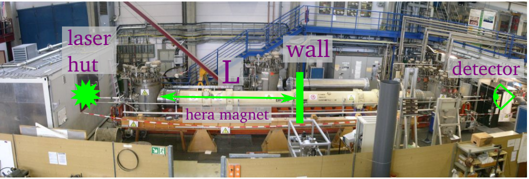


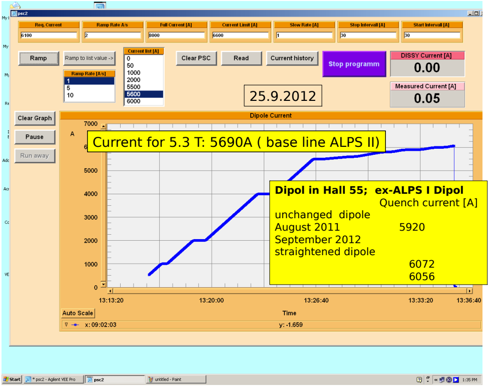


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  - pressure screws at lower flanches
  - pressure prop at middle and ends
  - requires modified suspensions
- good to know
  - first tests with “PR” magnet (non-functional)
  - real-life tests with ALPS-I magnet (hall 55)
  - ultimate setup: 24 spare magnets at Reemtsma
  - even reversible

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- > **Detection system**
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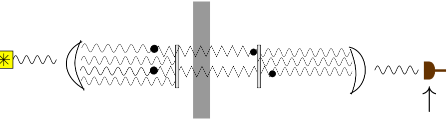
# Detector requirements and TES working principle



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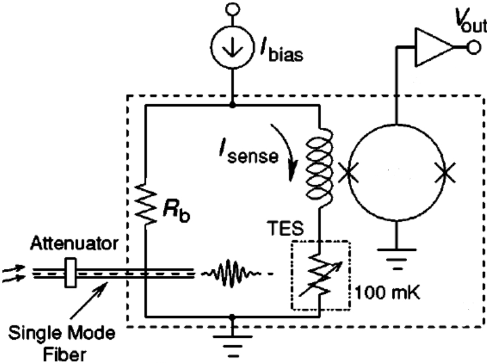
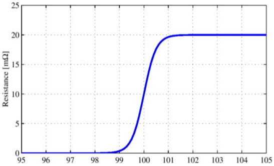
pic ad.: Miller Appl.Phys.Lett. 83/4

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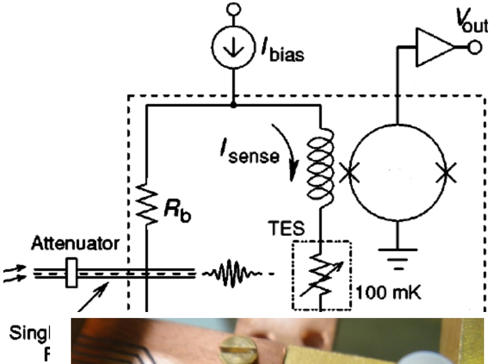
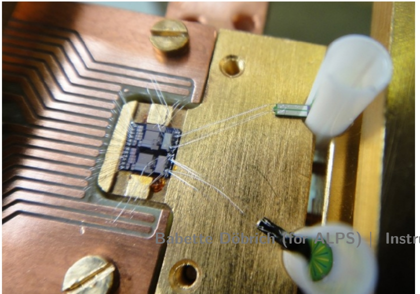
  - low rates of single infrared photons (<1/h)
  - high quantum efficiency (PIXIS: 1.2%)
  - low background
- TES working principle
  - TES = superconducting absorber at transition $T$
  - fiber → guide light there
  - Photon absorption → current change → pick up by SQUID

# Detector requirements and TES working principle

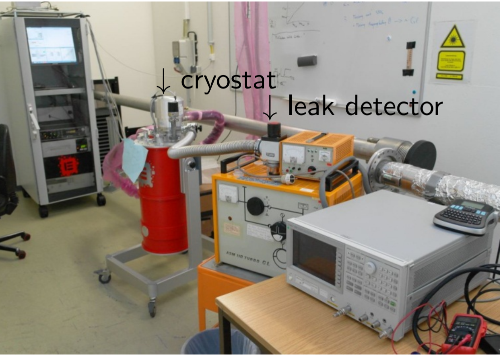


- Experimental needs
  - low rates of single infrared photons (<1/h)
  - high quantum efficiency (PIXIS: 1.2%)
  - low background
- TES working principle
  - TES = superconducting absorber at transition $T$
  - fiber → guide light there
  - Photon absorption → current change → pick up by SQUID
  - TES from NIST (and AIST) coated e.g. Tungsten ($\sim$ 100mK) or Ti/Au ($\sim$ 200mK)

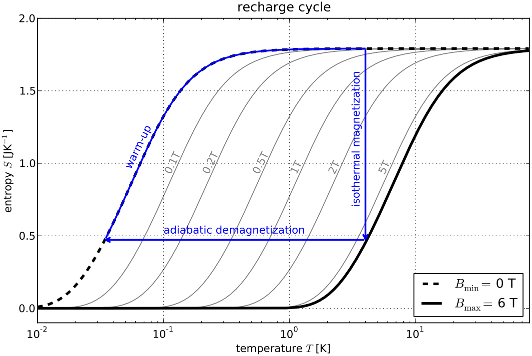
# Milli-Kelvin environment

↓ control rack



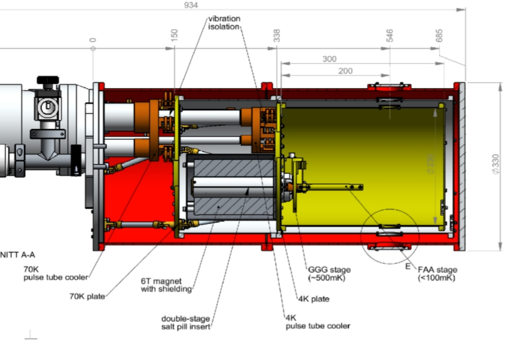

- ‘Entropy’ mK environment
  - dry (helium confined) & compact (only water & electricity)
  - time at <100mk: 48h
  - recharge time 1h

# Milli-Kelvin environment




- ‘Entropy’ mK environment
  - dry (helium confined) & compact (only water & electricity)
  - time at <100mk: 48h
  - recharge time 1h
- working principle
  - 4K pulse-tube stage
  - isothermal magnetization, adiabatic demagnetization

# Milli-Kelvin environment




- ‘Entropy’ mK environment
  - dry (helium confined) & compact (only water & electricity)
  - time at <100mk: 48h
  - recharge time 1h
- working principle
  - 4K pulse-tube stage
  - isothermal magnetization, adiabatic demagnetization

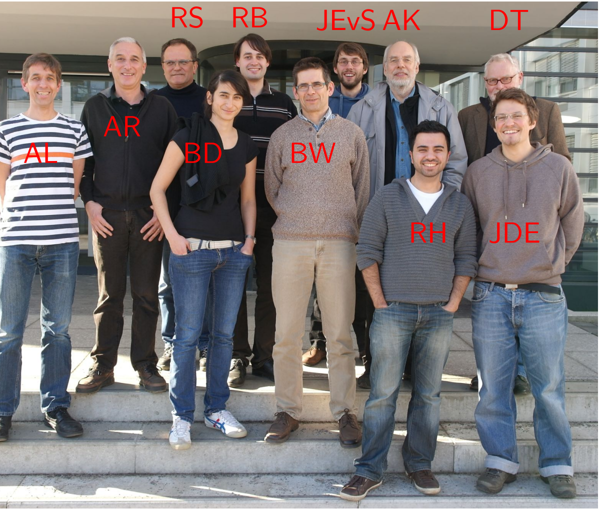
# Outline

# Take-home messages

## ALPS-II...

- looks for light beyond-Standard-Model particles with the 'light-shining-through-a-wall' principle
- combines a variety of techiques and methods (single photon detection, high-finesse cavities, accelerator infrastructure..)
- strives towards discovery (or exclusion) of new particles in 3 stages in the following 4-5 years

# Questions? Please ask also:

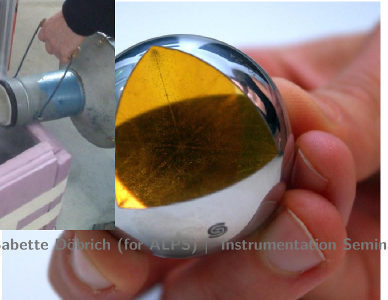



- *Optics:* Benno Willke (staff AEI) Robin Bähre (PhD, AEI), Reza Hodajerdi (PhD, DESY), Samvel Ghazaryan (staff)
- *Magnet/Site:* Dieter Trines + team
- *Detector:* Dieter Horns (staff HH), Friederike Januschek (Postdoc), Jan Dreyling-Eschweiler, Jan-Eike von Seggern (PhD)
- *Safety/Eng.:* Richard Stromhagen
- *Howto:* Ernst-Axel Knabbe (staff)
- *Science case & miscellanea:* Axel Lindner, Andreas Ringwald (staff), Babette Döbrich (Postdoc)

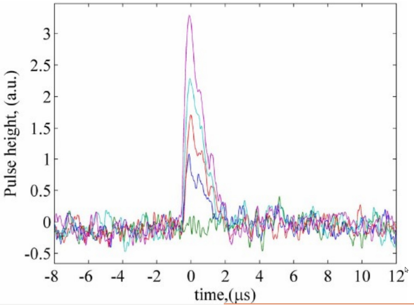
# More?

Bonus material

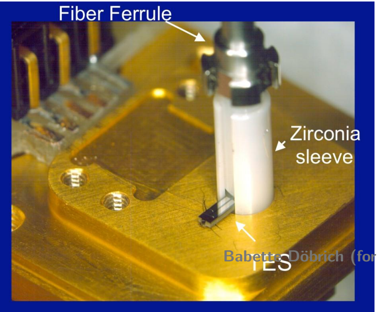
# How straight are the magnets?

- measurement so far only cooled down, achieved ∼50mm, Measurement at cold forseen

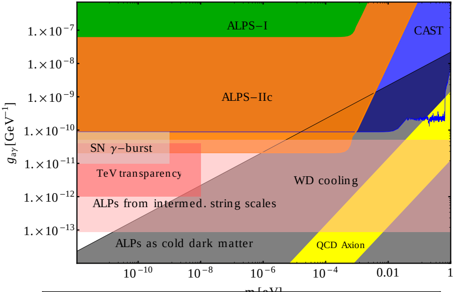


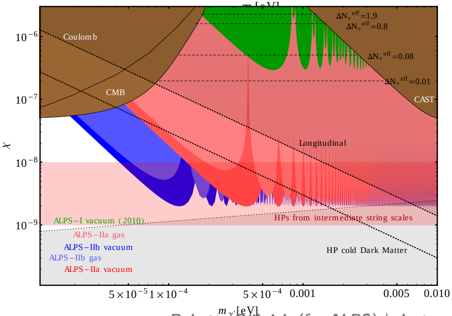

*Lita et al., Opt. Express, Vol. 16, 5 (2008)*




- single photon signals
- time/ energy resolution $\sim 1\mu s / \sim 0.1$eV, quantum efficiency up to 99% Lita et al., Proc. SPIE 681, 76810D (2010)
- not very fast, but almost background free
- good timing resolution valueable in case of unstable lock
- SQUID array acts as transimpedance element

# Discovery potential in mass-coupling




- Axion-like particles $\mathcal{L}_{\text{int,PS}} \sim g\phi F_{\mu\nu}\tilde{F}^{\mu\nu}$
- hidden (dark/heavy) photons from string & field-theory extensions

$$\mathcal{L} \sim \chi F_{\mu\nu} X^{\mu\nu} + m_{\tilde{\gamma}}^2 / 2 X_\mu X^\mu$$

- minicharged particles
- scalar fields of massive gravity theories [1206.1809]