Status of ALPS

"Any Light Particle Search" at DESY

A. Lindner for the
ALPS Collaboration

Outline

- Achievements and
- Results up to spring 2008.

- Upgrades

- Outlook

The Physics Case for a Low Energy Frontier of Fundamental Physics

-

A White Paper

Steven Abel[1], Markus Ahlers[2], Ignatios Antoniadis[3], Carsten van de Bruck[4], Wilfried Buchmüller[5], Joe Conlon[6], Claudio Coriano[7], Mark Goodsell[8], Marco Guzzi[7], Joerg Jaeckel[1,*], Valentin V. Khoze[1], Ralf Lehnert[9], Alessandro Mirizzi[10], Javier Redondo[1,†], Andreas Ringwald[5,‡], Guenter Sigl[11], Christoph Weniger[5]

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[3] *CERN*

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[8] *LPTHE Paris*

[9] *MIT or MPI*

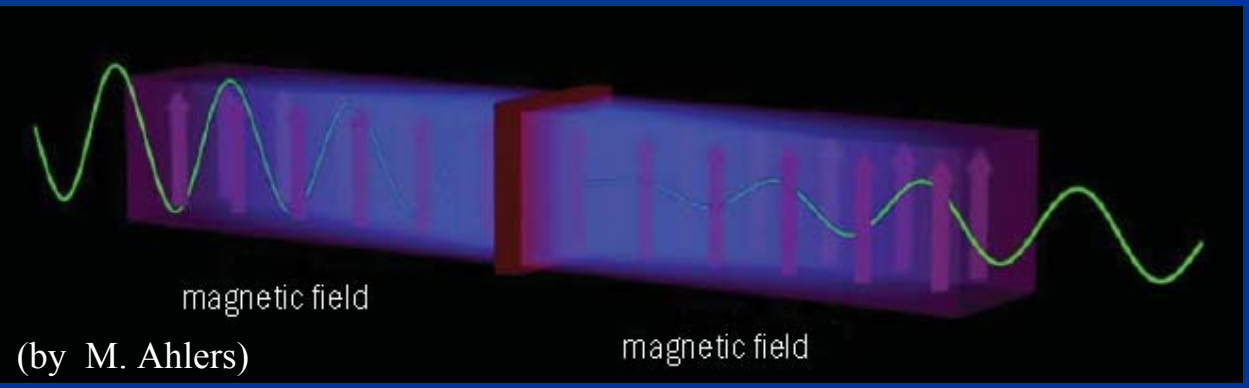
[10] *MPI Munich*

[11] *Hamburg*

under preparation

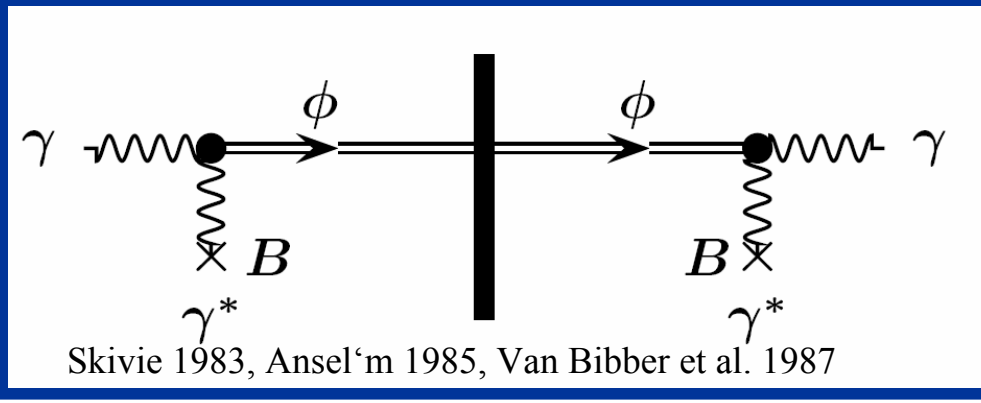
Direct WISP Search

Weakly Interacting Sub-eV Particles



(by M. Ahlers)

"Light shining through walls" (LSW) or "photon regeneration" experiments.



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

ALPS @ DESY in Hamburg

The ALPS Project

Axion-Like Particle Search @ DESY

A photon regeneration experiment

The ALPS Project

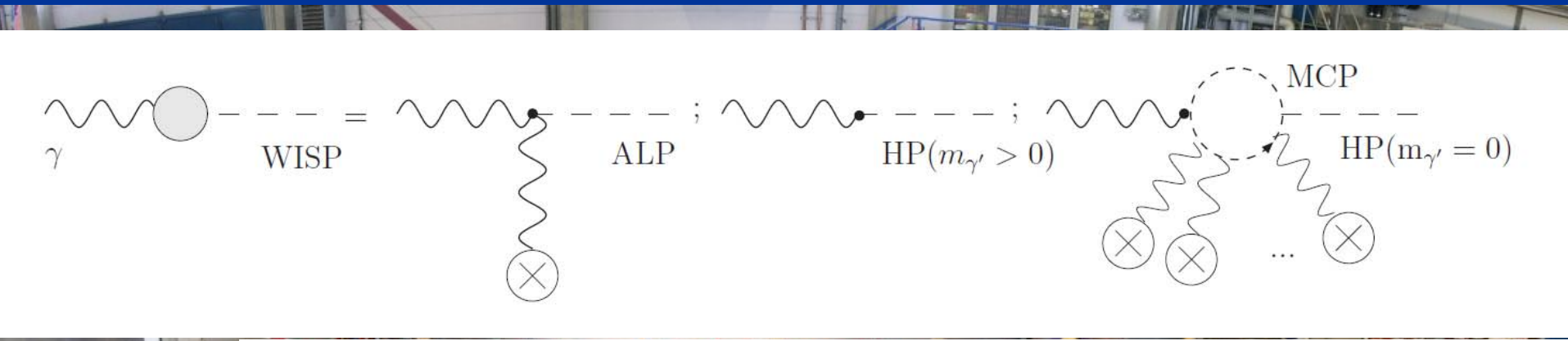
Axion-Like Particle Search @ DESY

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

A photon regeneration

The ALPS Project

Any-Light-Particle-Search @ DESY



Axion-Like Particles, Hidden Photons, MiniCharged Particles

A photon regeneration experiment

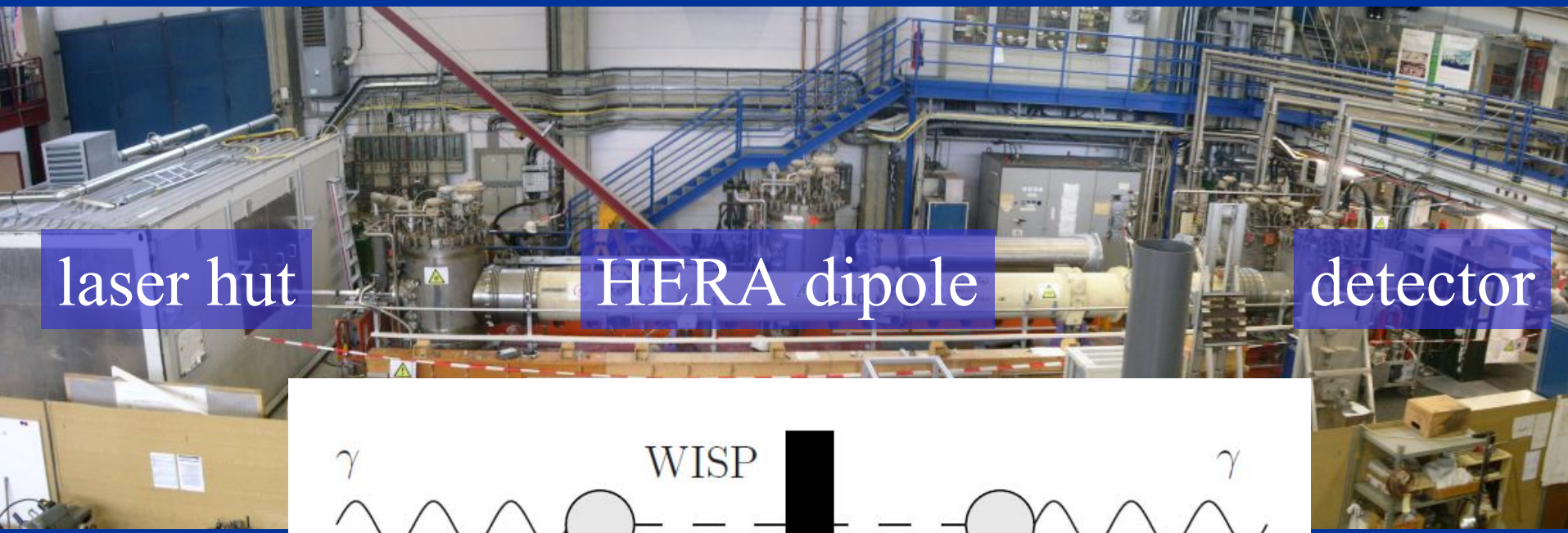
The ALPS Project

Any-Light-Particle-Search @ DESY

A photon regeneration experiment

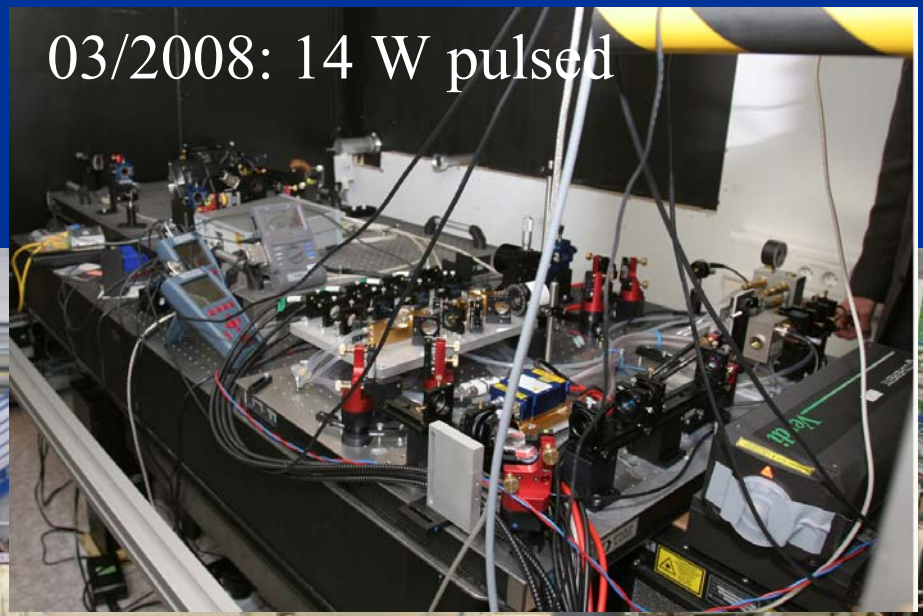
The ALPS Project

Any-Light-Particle-Search @ DESY



The ALPS 532 nm Lasers

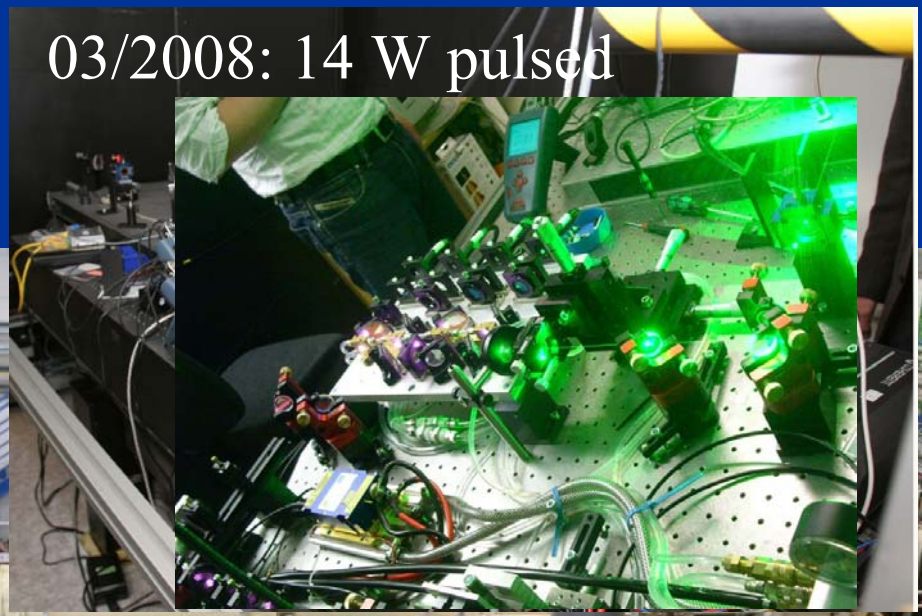
The ALPS 532 nm Lasers



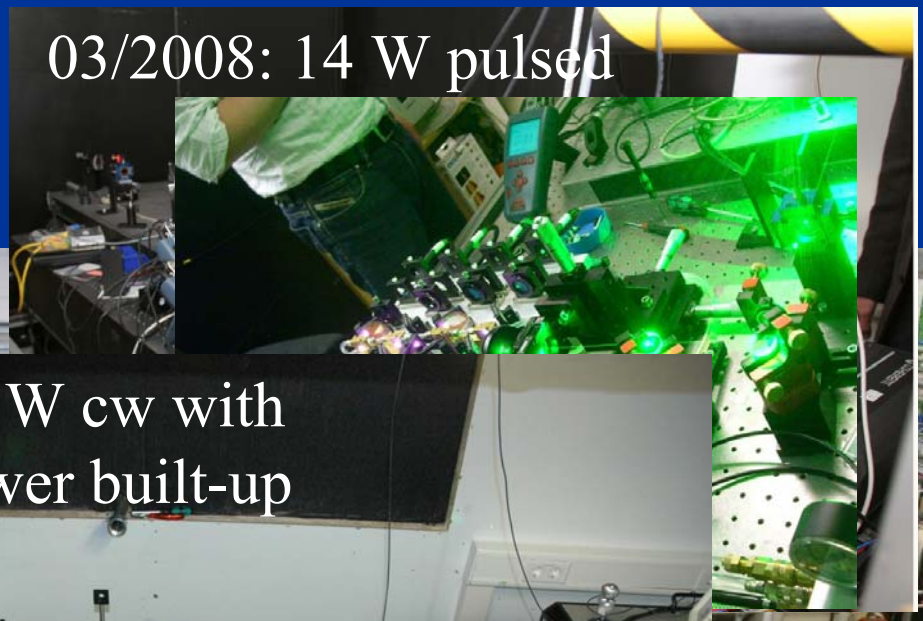
The ALPS 532 nm Lasers

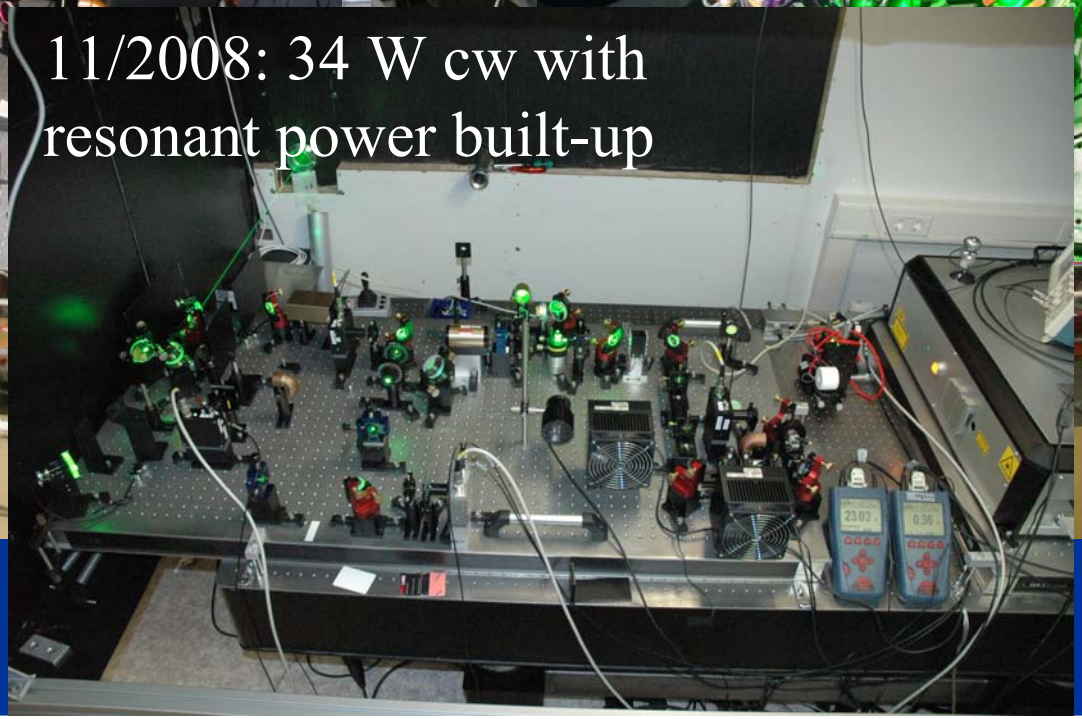
09/2007: 3 W cw

03/2008: 14 W pulsed



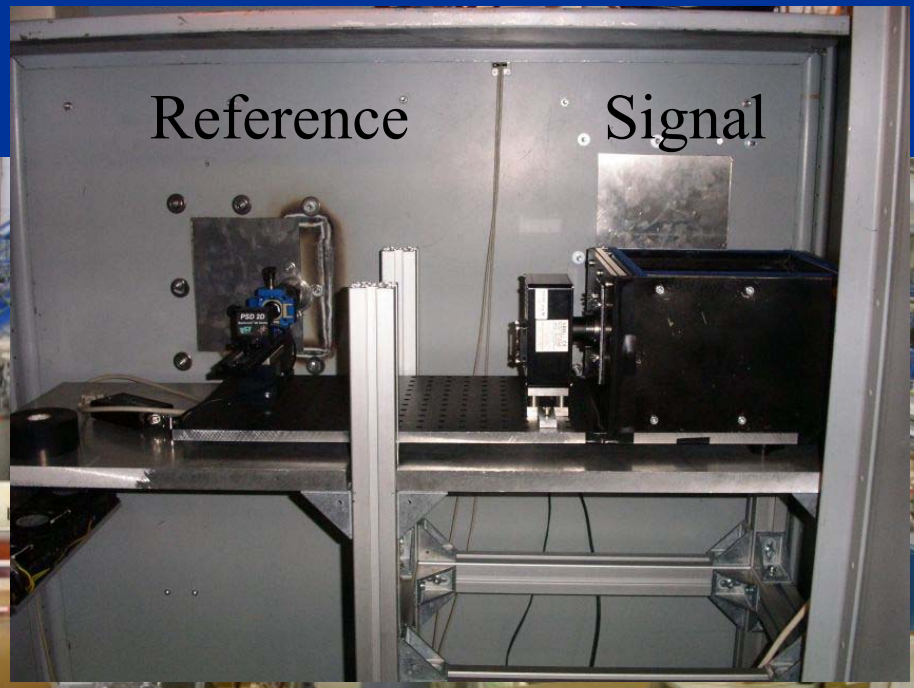
The ALPS 532 nm Lasers





The ALPS Project

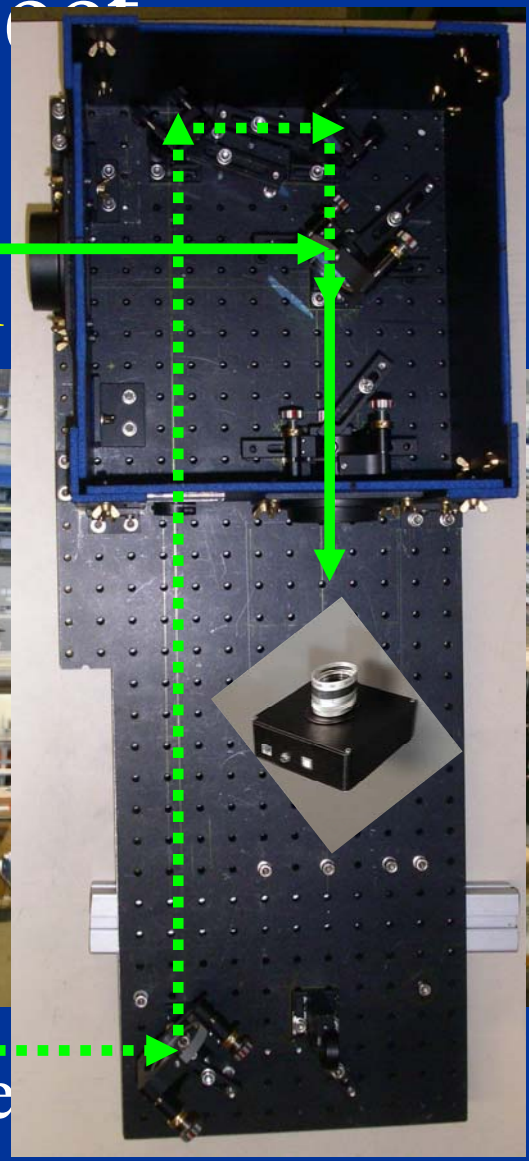
Axion-Like Particle



A photon regeneration experiment

The ALPS Project

Axion-Like Particle Search

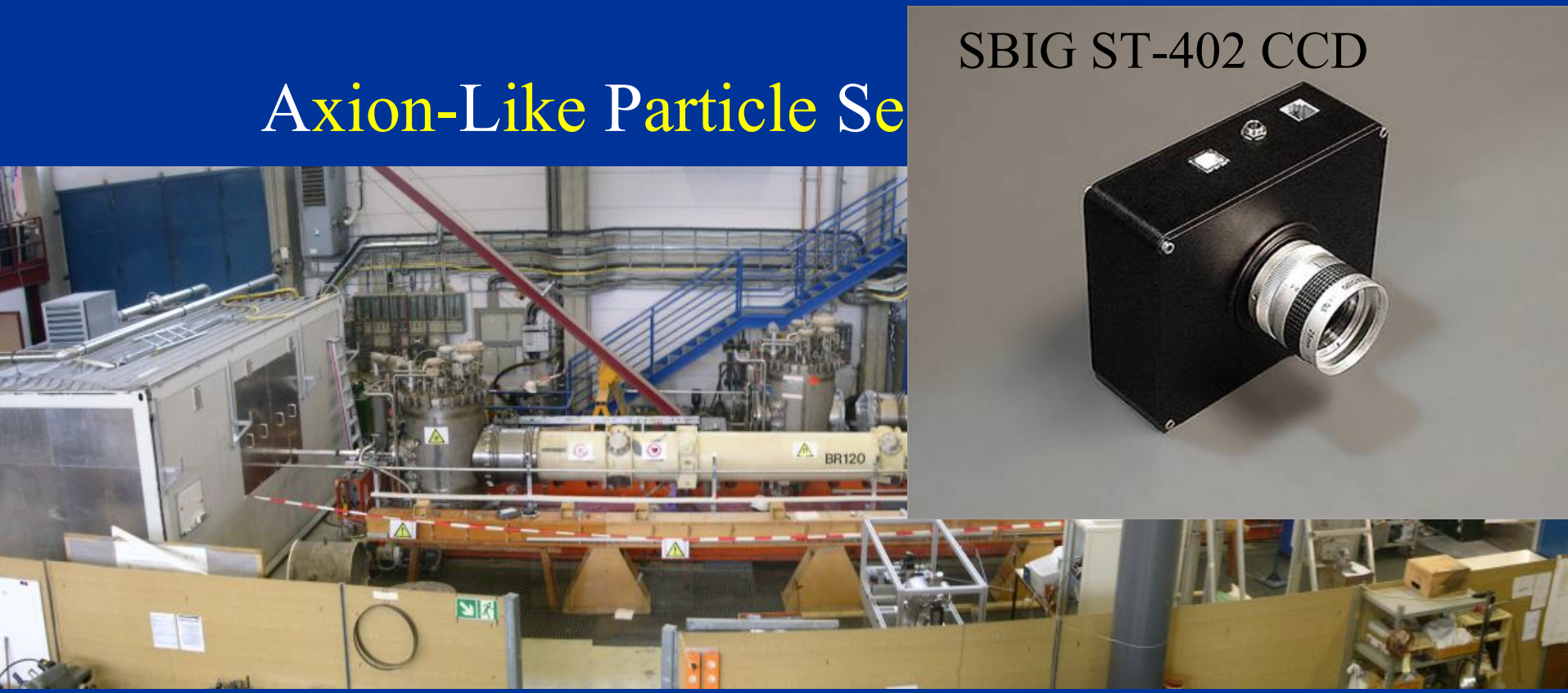


A photon regeneration expe

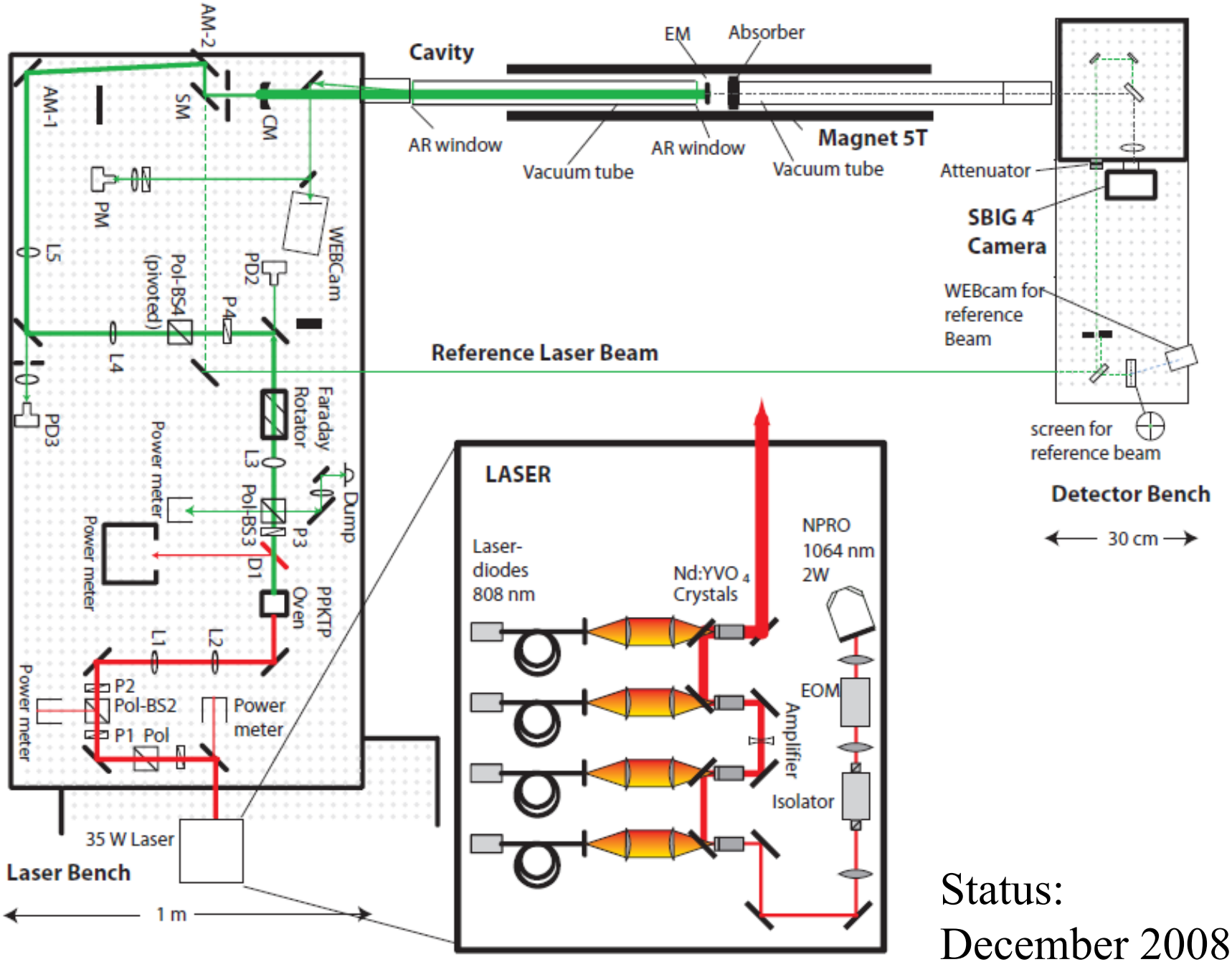
The ALPS Project

Axion-Like Particle Se

SBIG ST-402 CCD



A photon regeneration experiment



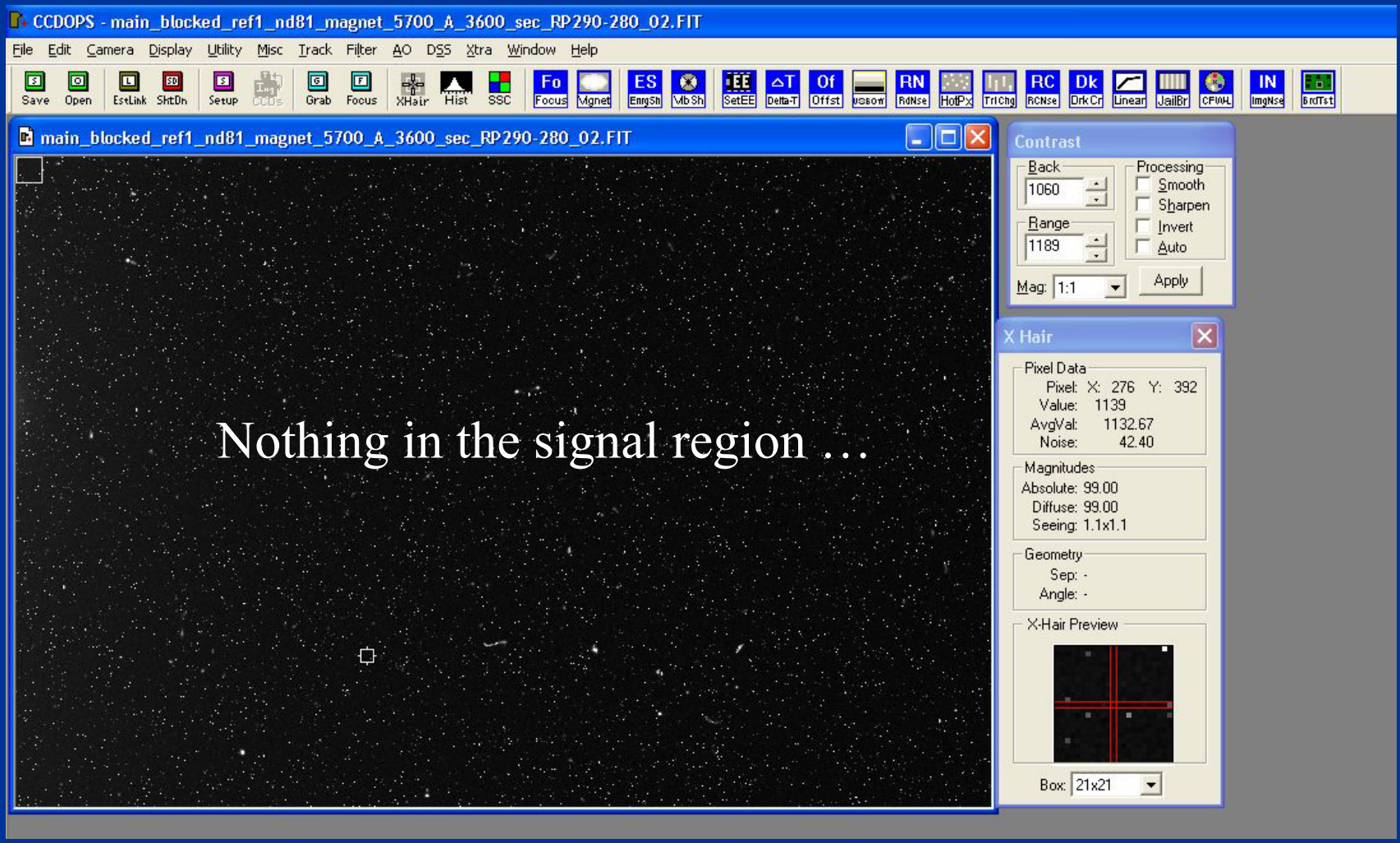
Status:
December 2008

ALPS at Work

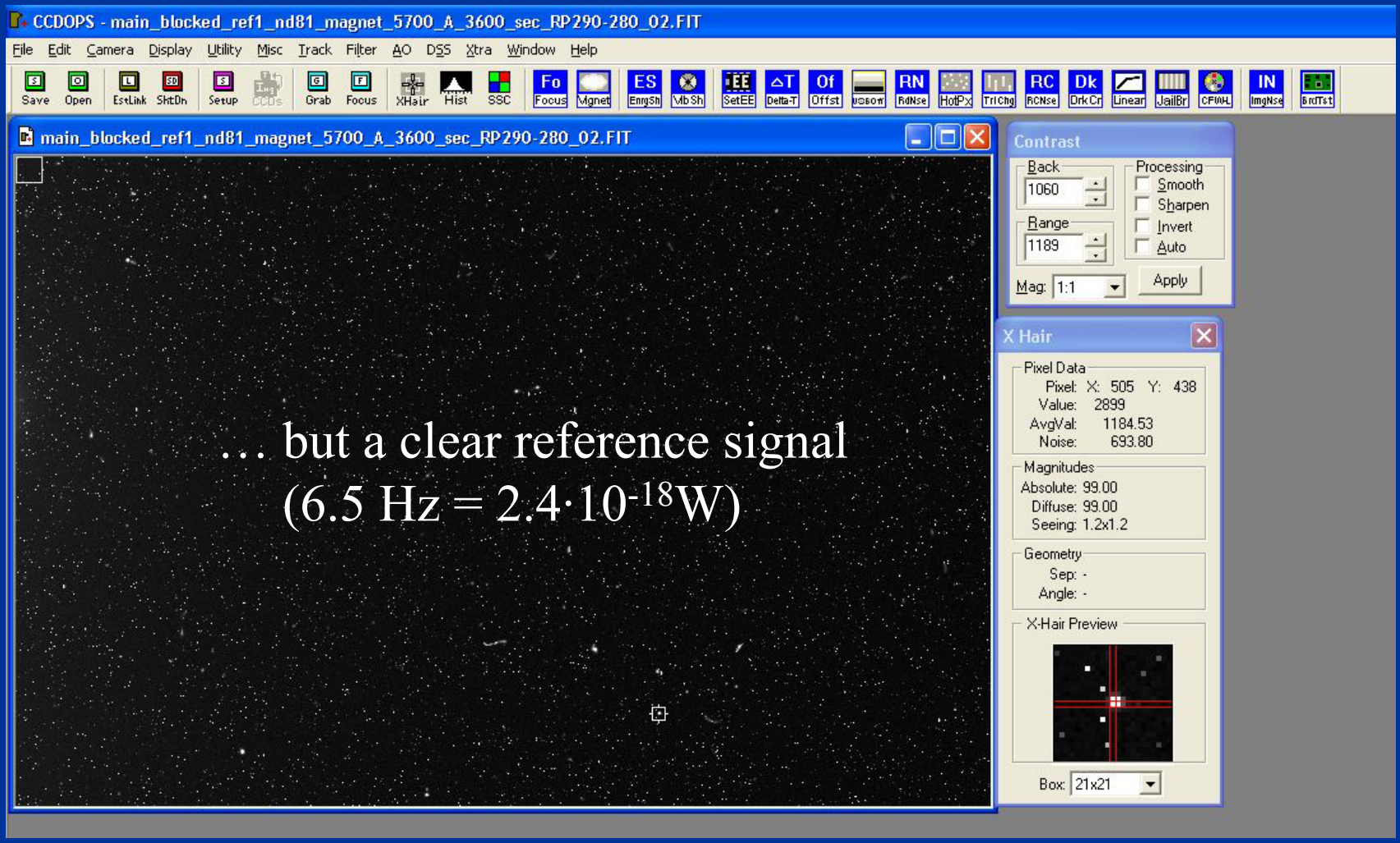
Steps of data taking:

1. Test alignment with open detector tube and fraction of laser light passing the mirror (10^{-4}).
2. Demount detector and detector tube, close tube and reinstall all.
3. Take data
4. Demount detector and detector tube, open tube and reinstall all.
5. Test alignment like in step 1.

One Data Frame



One Data Frame



Paper submitted to NIM A

arXiv:0905.4159v1

DESY 09-058

Resonant laser power build-up in ALPS
– a "light-shining-through-walls" experiment –

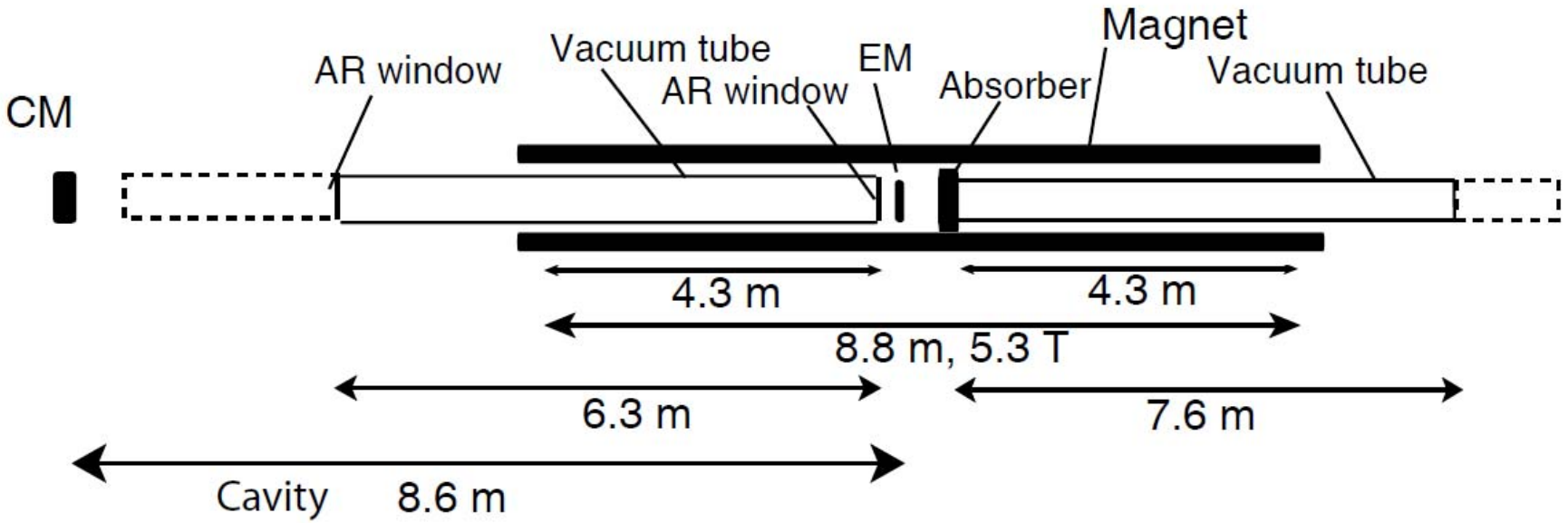
Klaus Ehret[a], Maik Frede[b], Samvel Ghazaryan[a], Matthias Hildebrandt[b], Ernst-Axel Knabbe[a], Dietmar Kracht[b], Axel Lindner[a], Jenny List[a], Tobias Meier[c], Niels Meyer[a], Dieter Notz[a], Javier Redondo[a], Andreas Ringwald[a], Günter Wiedemann[d], Benno Willke[c]

[a] *Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany*
[b] *Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover, Germany*
[c] *Max-Planck-Institute for Gravitational Physics, Albert-Einstein-Institute, and Institut für Gravitationsphysik, Leibniz Universität, Hannover, Callinstraße 38, D-30167 Hannover, Germany*
[d] *Hamburger Sternwarte, Gojenbergsweg 112, D-21029 Hamburg, Germany*

- Overview on WISPs.
- Characterization of the resonant power built-up.
- Results from an exemplary data run.

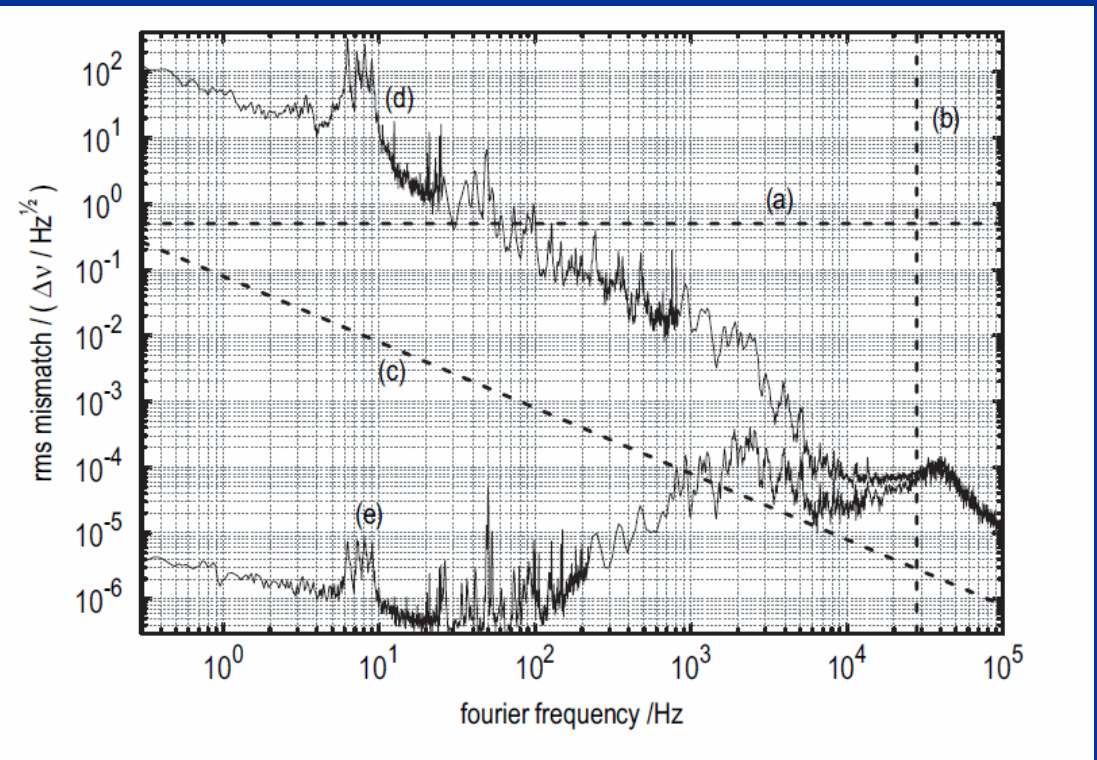
The Optical Resonator

Challenge: 8.6 m long optical resonator
in the "noisy" HERA dipole (workshops near by)



The Optical Resonator

Characteristics:

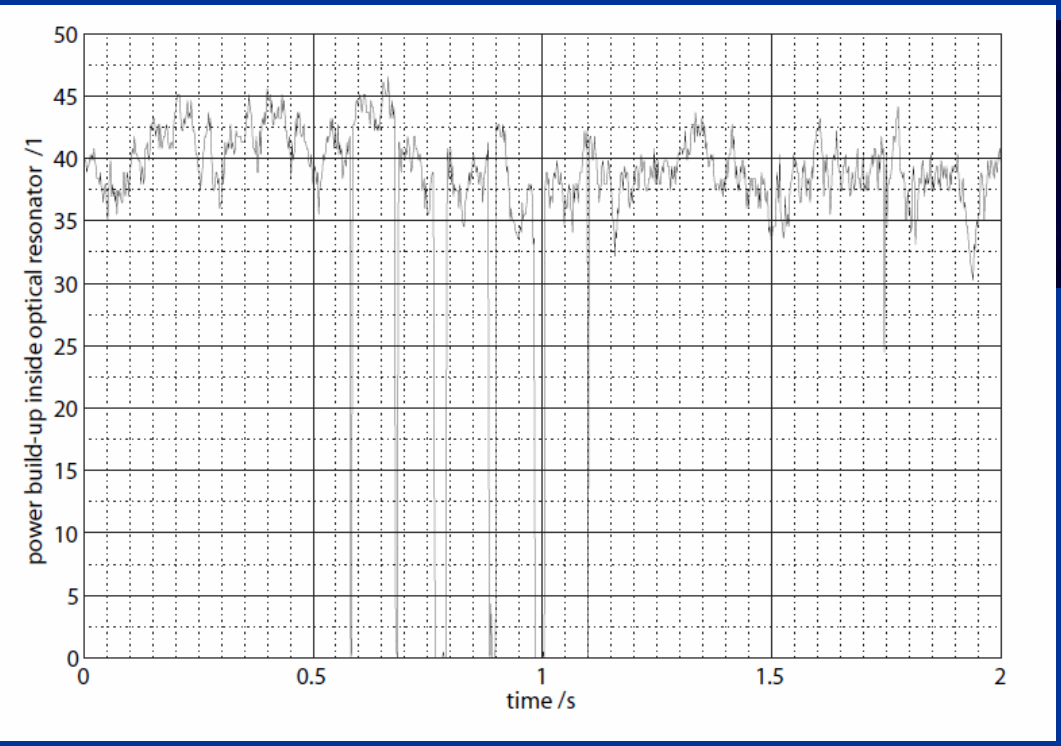


Free spectral range: 17.4 MHz
FWHM: 127±12 kHz
Power built-up:
PB_{TEM00} = 55±3
Missmodematching: ≈ 20%

All characteristics very well compatible with losses at the anti-reflective coated surfaces of the two windows of (0.22±0.01)% per pass.

The Optical Resonator

Characteristics:



resonator detuned

free running

locked

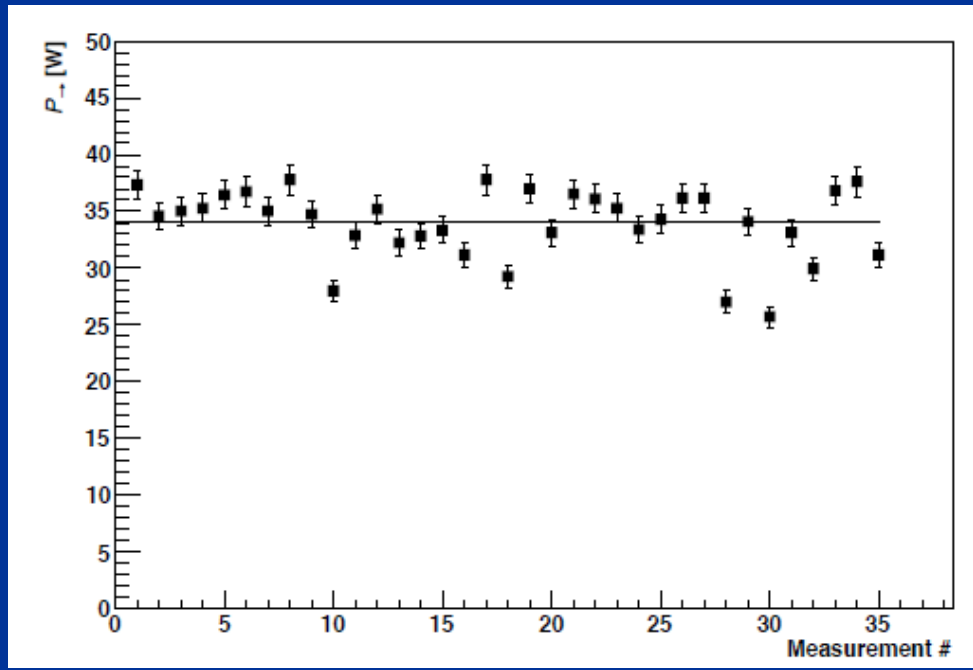
Lock very robust, power enhancement of 44±2

Results

from the 31 h long exemplary data run:

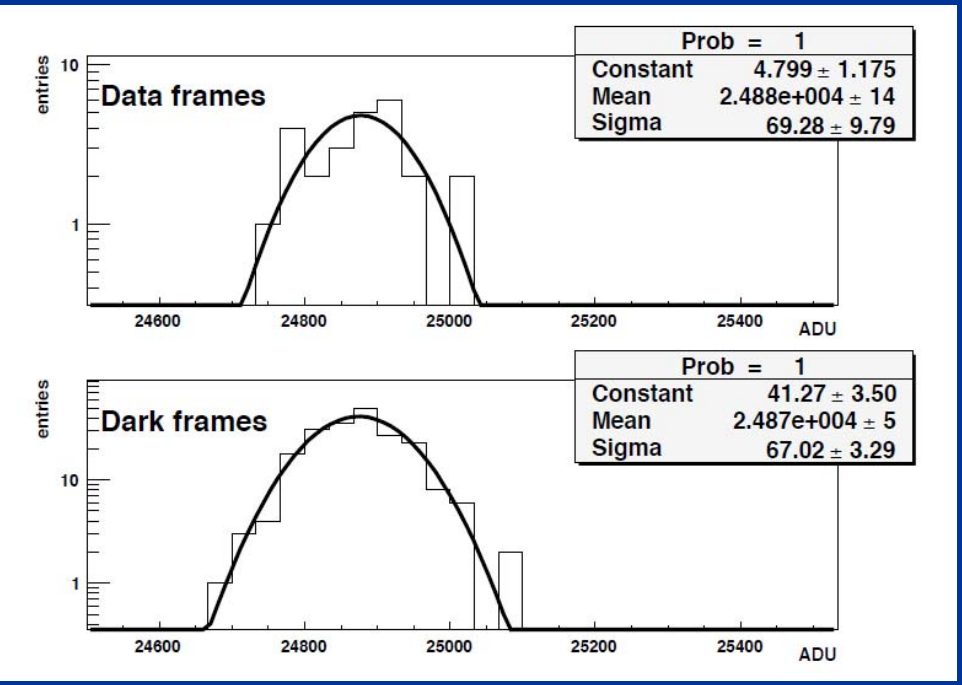
- 25 exposures of 1 h length selected;
  6 rejected due to cosmics and magnet quenches.
- Effective laser power:
  34±4 W
  (0.8 W · 44)

- Field strength:
  B = 5.3 T

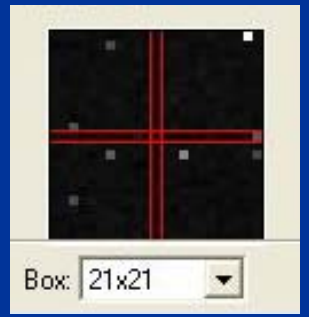


ALPS Sensitivity

Data analysis of 25 h run in November 2008:



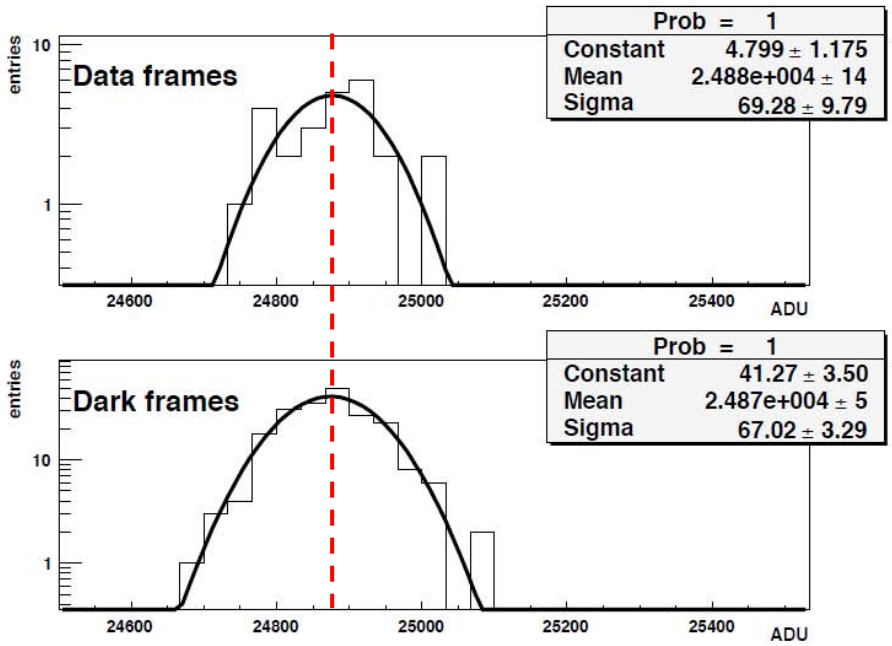
1. Plot sum of ADUs of 5x5 pixels in signal region for all 1h exposures.

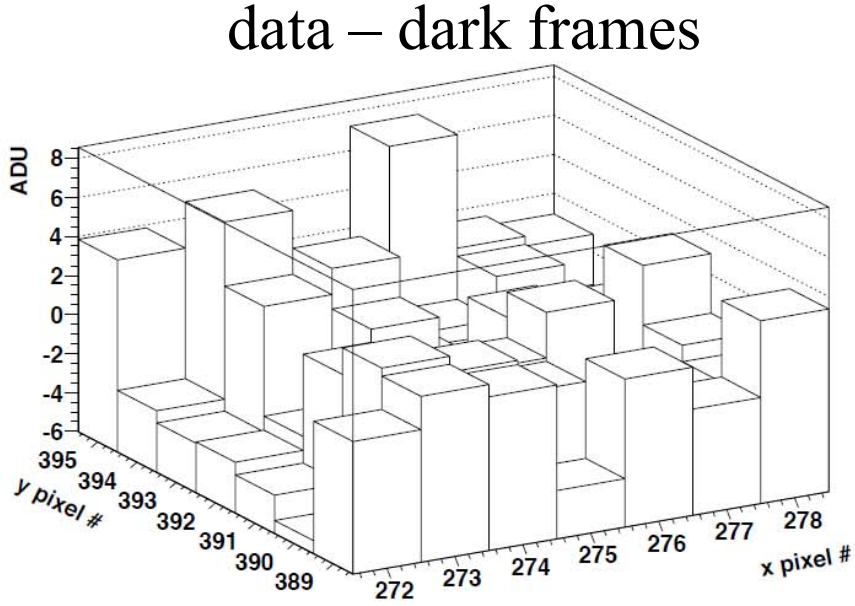


2. Compare mean of "signal" and dark frames.

Results

Data analysis of 25 h run in November 2008: no evidence for WISP production ☹





Sensitivity reached (95% CL): flux(2.3eV γ) < 28 mHz

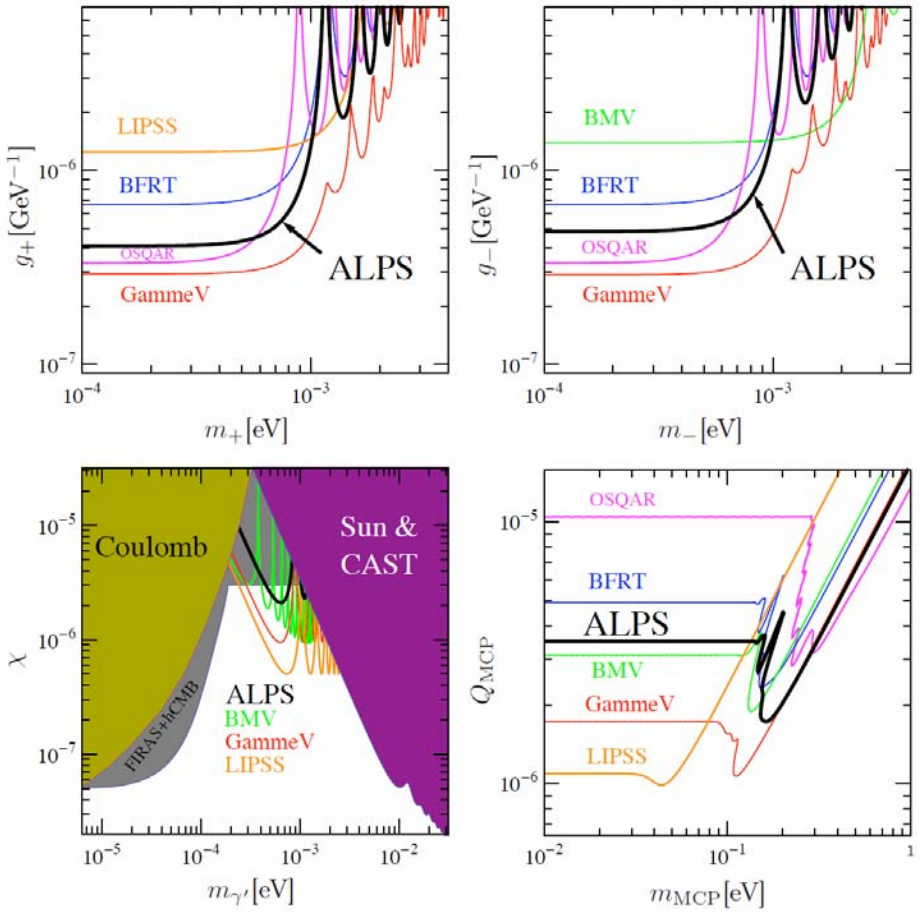
Results

Polarization	Prob.$\times 10^{22}$	95% C.L.	99% C.L.
Parallel	0.8 ± 4.4	9.4	12
Perpendicular	0.4 ± 2.2	4.5	5.8
Independent	0.3 ± 1.4	3.0	3.9

Remark:

laser polarization at 55° with respect to the B-field.

The angle is determined by the angle of incidence of the laser beam on the windows (placed inside the resonator!).



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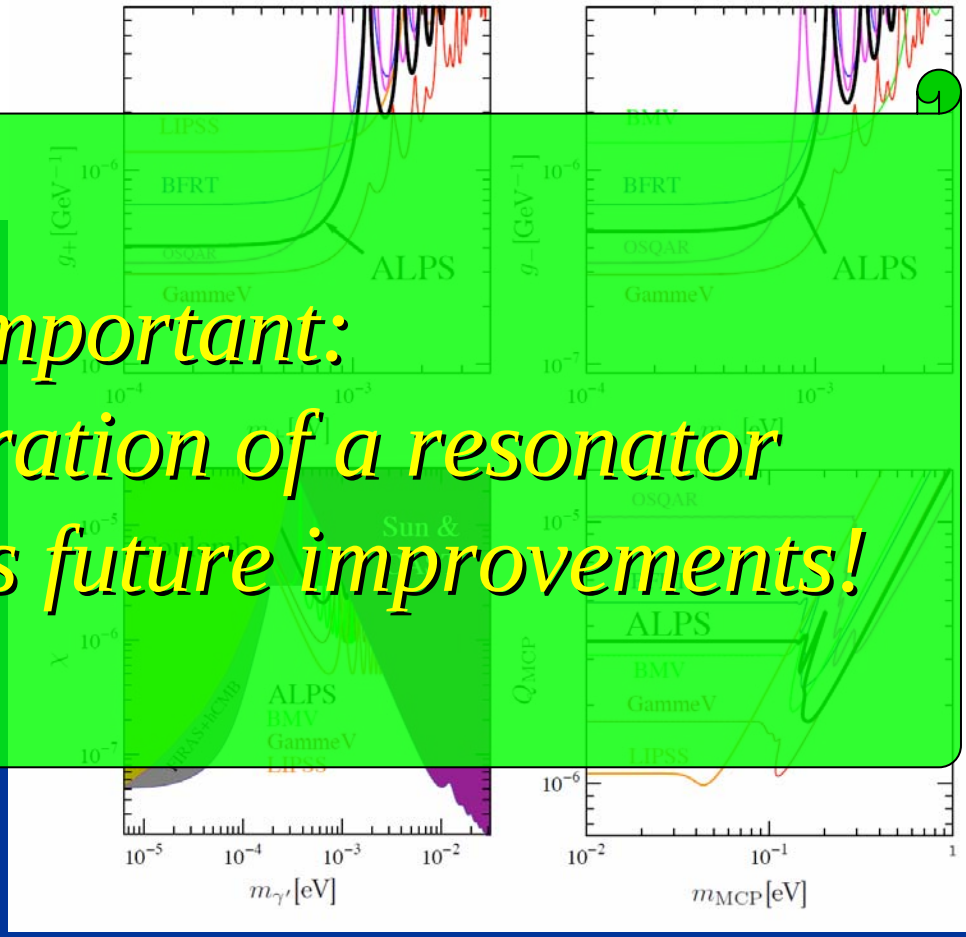
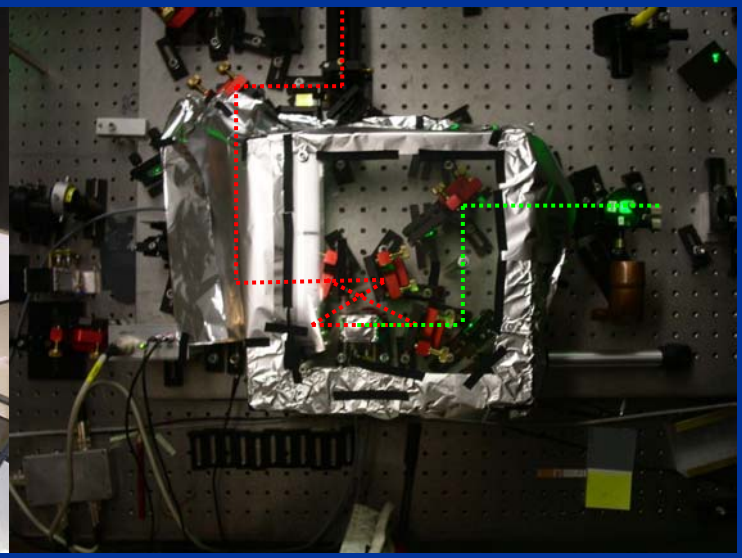


More important:
the successful operation of a resonator
opens a path towards future improvements!

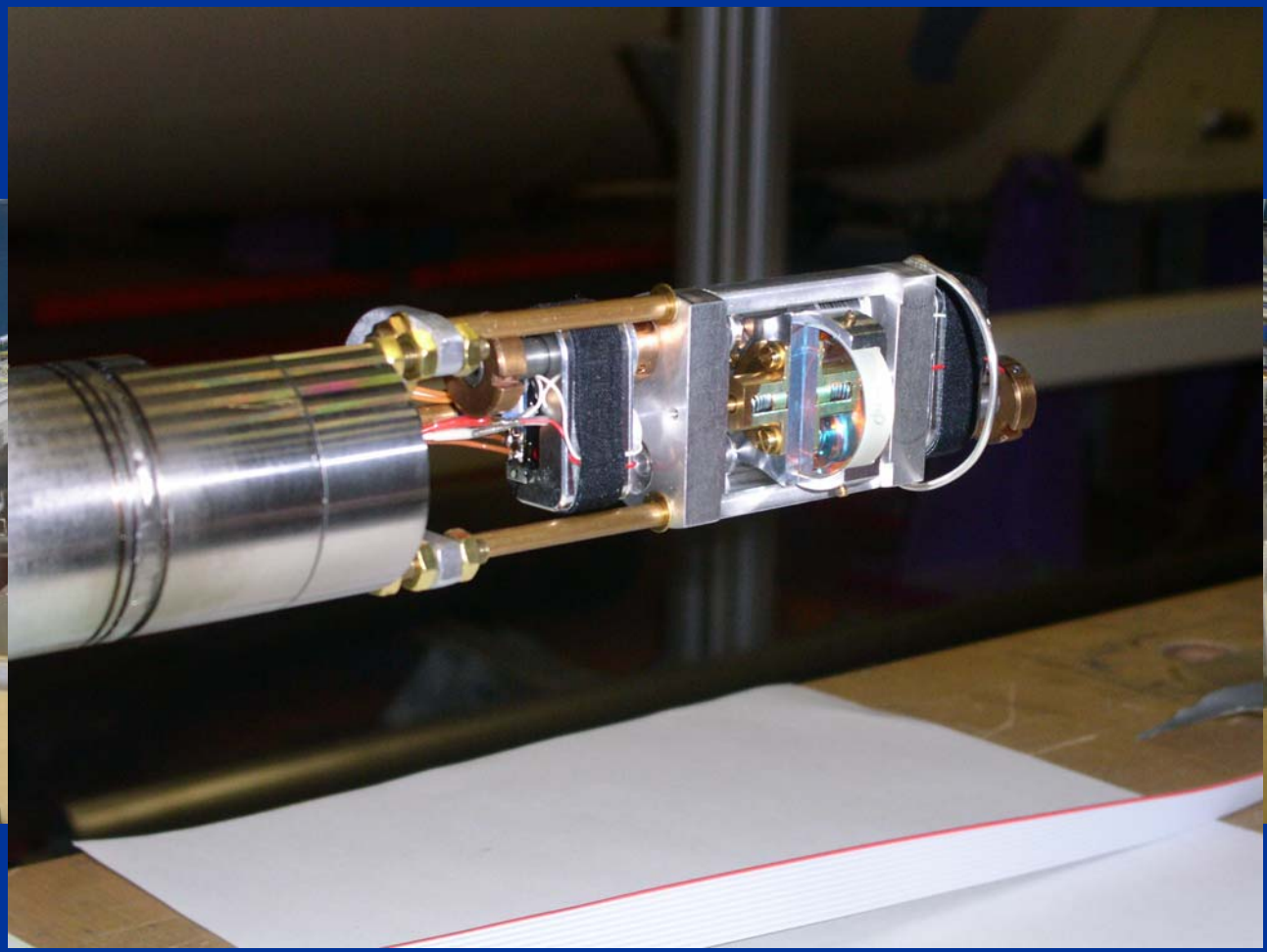
Laser Upgrade I

- Resonant Second Harmonic Generation (SHG) to increase conversion efficiency



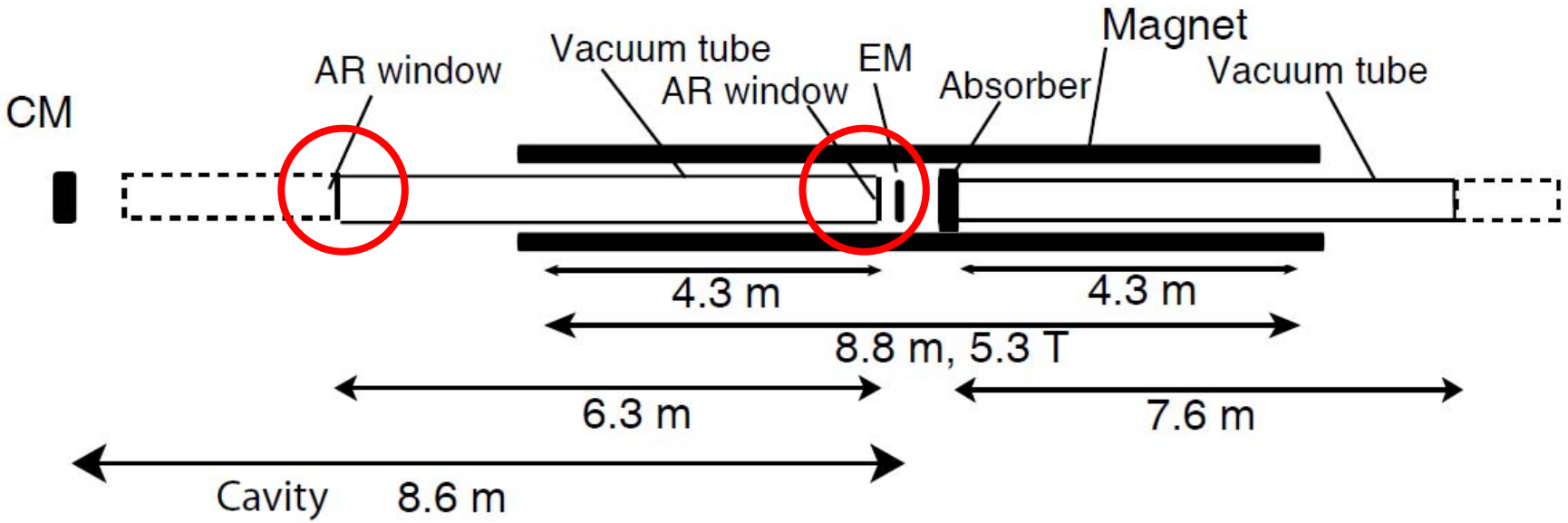
since 18 Feb. 2009:
Simultaneous lock of both cavities works!
5 W @ 532nm from
14 W @ 1064 nm
(instead of 0.8 from 34 W)

The ALPS Project



Laser Upgrade II

- Include mirrors of cavity in magnet into the vacuum
  - no windows necessary, much stronger power built-up expected.



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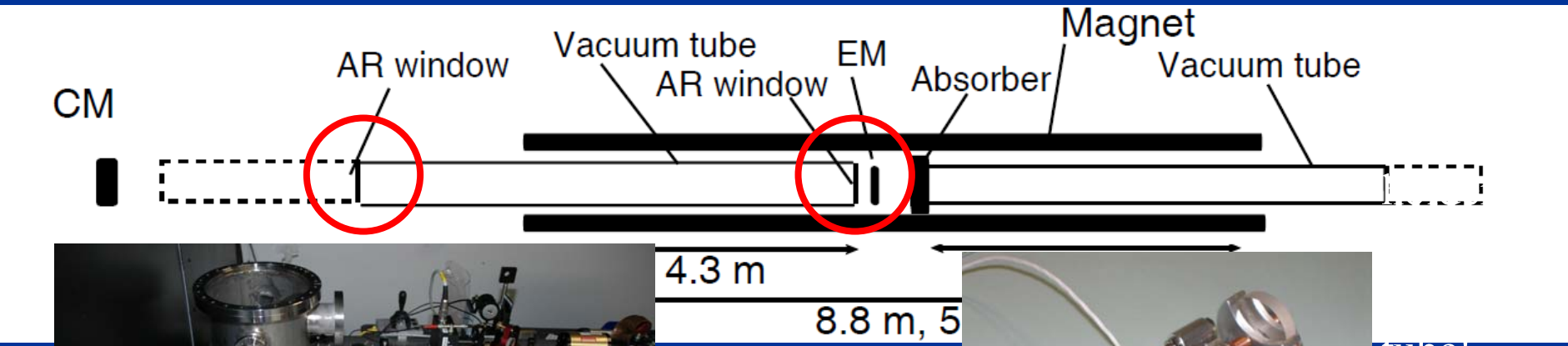
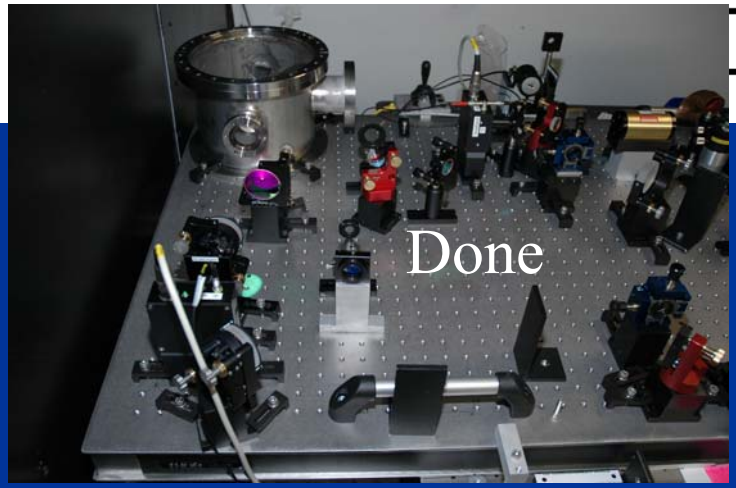
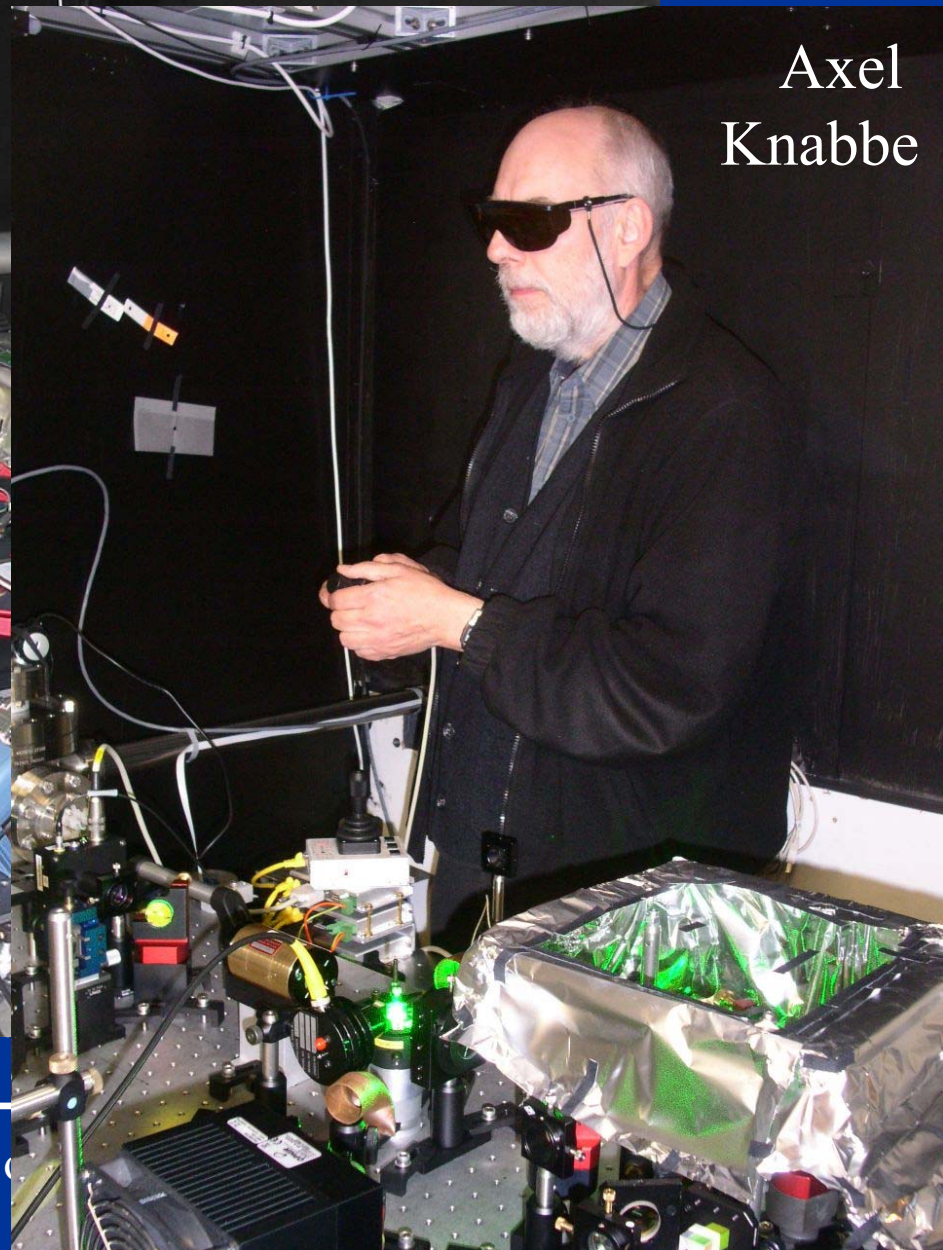




Vacuum tank mounted on laser breadboard

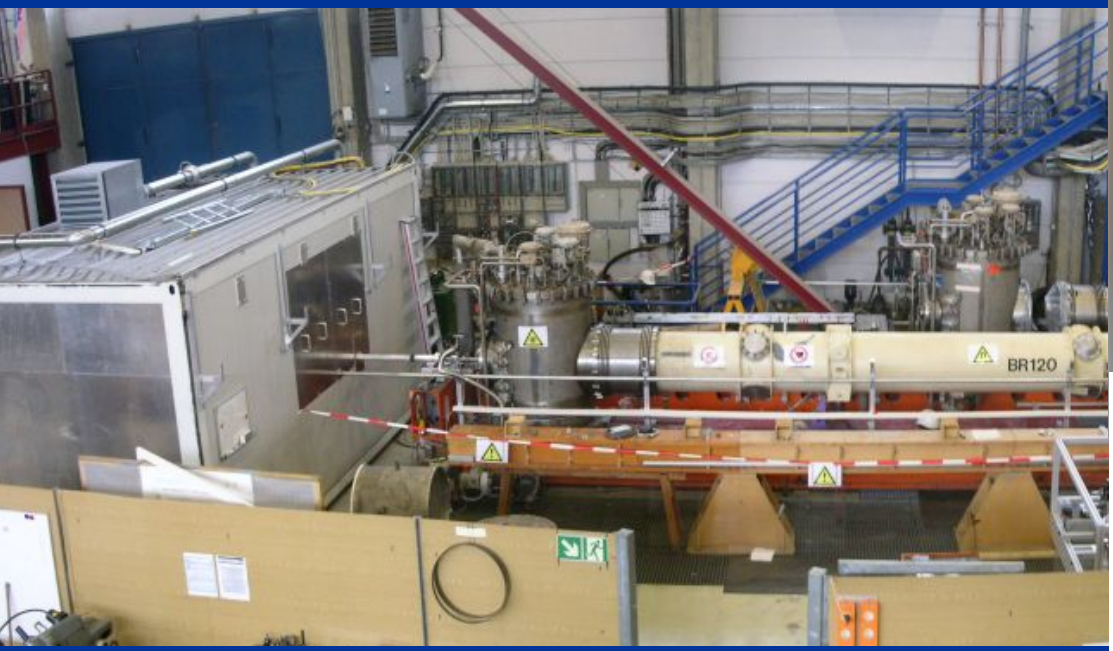
- Diameter 38 mm.
- Vacuum compatible.
- Operational in 5 T field.

The ALPS laser with resonant power built-up (June 2009).



Detector Upgrade

Any-Light Particle Sea

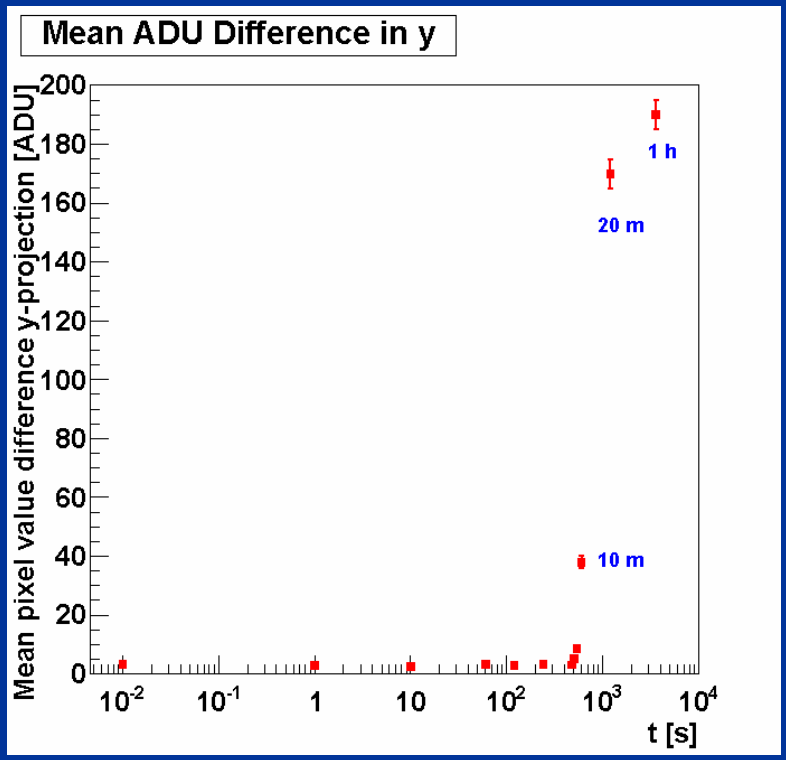


Princeton Instruments PIXIS:1024B: better QE, lower dark current, smaller read-out noise + improved optics: increase in sensitivity by a factor of ≈ 10.

A photon regeneration experiment

The new ALPS Camera

Liquid cooled PIXIS:1024B from Princeton Instruments

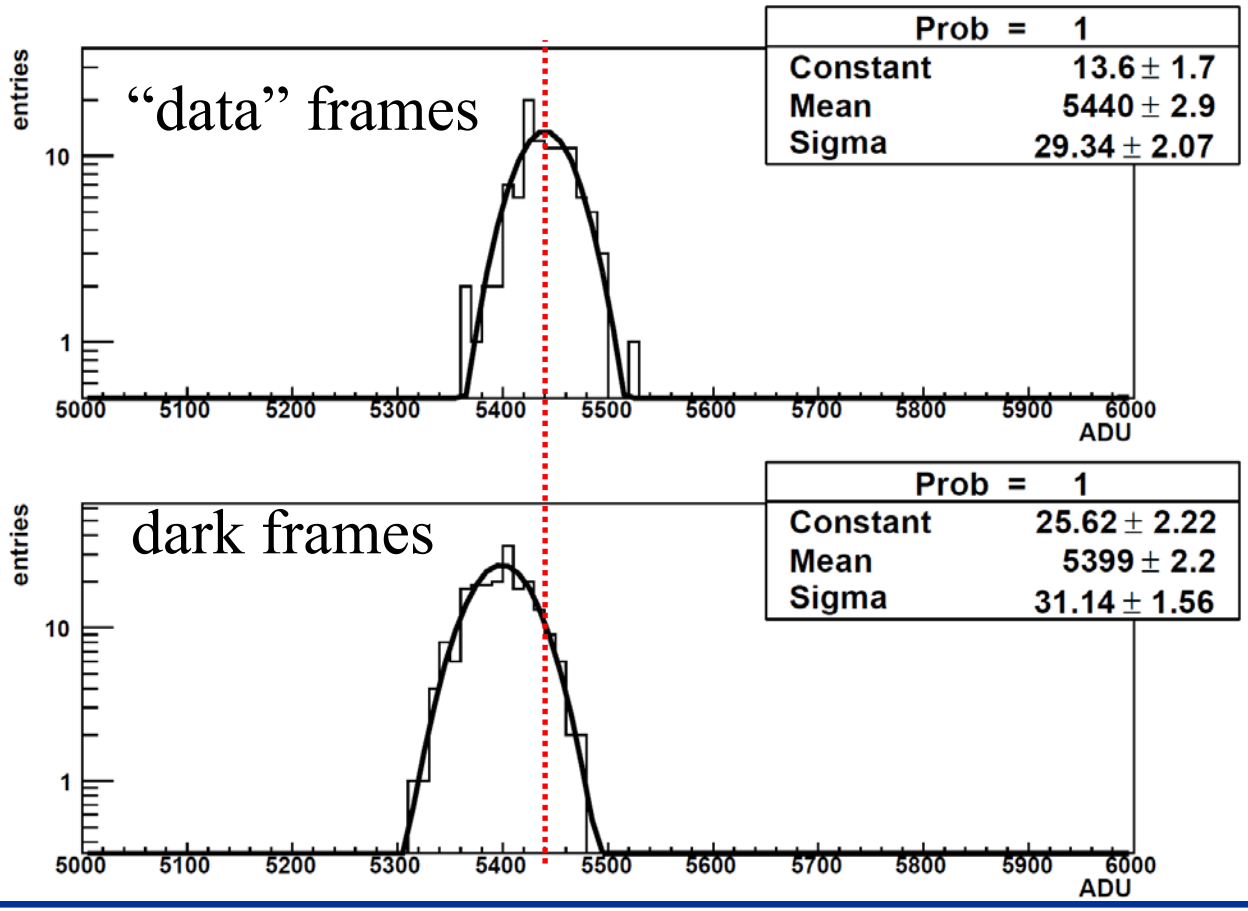


Problem concerning stability of pedestal and/or gain for exposure times larger than about 500 s (2^9!) found.
Reason still not identified
by the Company (nor by us).

Parameterization recovers sensitivity, but clearly unsatisfying!

Testing the Camera

Test with strongly attenuated laser beam: ≈ 45 γ per frame



The widths of both distributions agree nicely, but the mean value in the data frames is shifted to higher values showing an excess of 41.1±3.6 ADU (would be 11 mHz in 1h frames).

ALPS Prospects

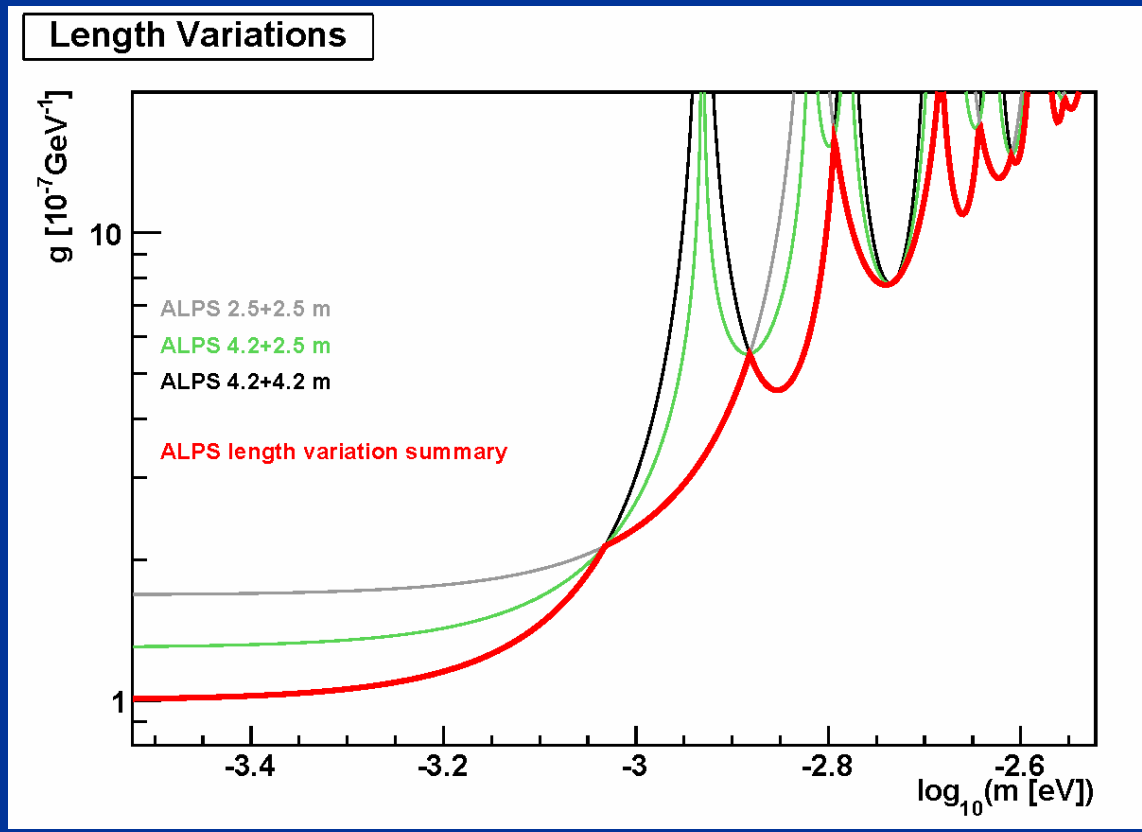
- PIXIS:1024B instead of SBIG ST-402:
  increase flux sensitivity by a factor of ≈ 10.
- Upgrade to a resonant SHG (1064 to 532 nm):
  increase 532 nm laser power by a factor of ≈ 6.
- Upgrade optical resonator: include mirrors into the vacuum to get rid of the windows.
  Increase power built-up by a by factor of ≈ 5
  (currently coping with power densities on mirror surfaces under vacuum conditions).

Increase sensitivity in g(ALPs) by $(10 \cdot 6 \cdot 5)^{1/4} = 4$

Extending the Mass Range

Combine measurements with different vacuum tube lengths to "beat" the form-factor:

$$F(q\ell) = \left[\frac{\sin\left(\frac{1}{2}q\ell\right)}{\frac{1}{2}q\ell}\right]^2$$



Outlook

- For the first time an optical resonator was successful operated in a LSW experiment.
- A clear path towards significant improvements in sensitivity has been opened.
- We aim for finishing ALPS in October 2009. (the cryogenics at DESY will be shut down for refurbishment and upgrades).
- It‘s fun to probe new territory!