Axion-Like Particle Search

The ALPS Project at DESY

DESY, Hamburger Sternwarte, Laser Zentrum Hannover

Outline

- Search for new physics at low energies
- Introducing ALPS
- Experimental considerations
- Outlook and summary

New Physics at low Energies?

Basic idea:

- there might be unknown light particles
  - QCD axion

The QCD Axion

The axion was invented to clean the CP problem of QCD:

- QCD prediction for electric dipole moment of the neutron:
  $d_n \approx 5 \cdot 10^{-16}\,\theta$
- Experiment: $\theta < 10^{-10}$
- Theory (1977):
  Peccei-Quinn symmetry which predicts a new particle, the axion (christened by Frank Wilczek).

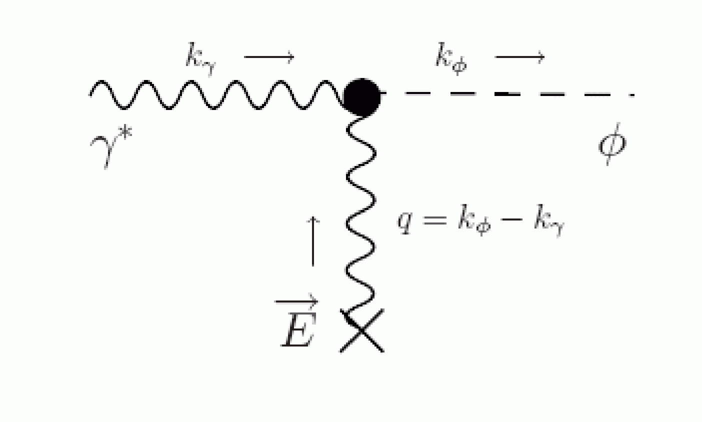
- Axion and cosmology:
  Candidate for cold dark matter with $m \approx 10^{-5}$ eV

New Physics at low Energies?

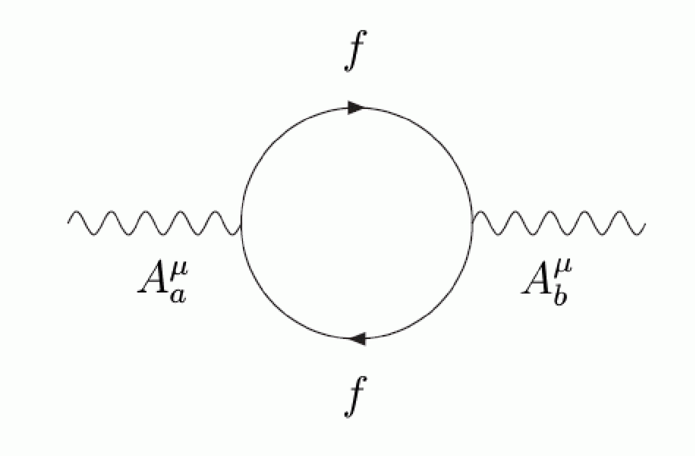
Basic idea:

- there might be unknown light particles
  - QCD axion
  - scalars or pseudoscalars related to Dark Matter or Dark Energy
  - predictions from string theory
- Search for effects in a very well known and calculable environment

Examples related to QED



- Primakoff effect
  – new neutral particles?



- virtual (or real) production of
  – new charged particles?
  may also involve external fields

What to expect from QED

Folgerungen aus der Diracschen Theorie des Positrons.

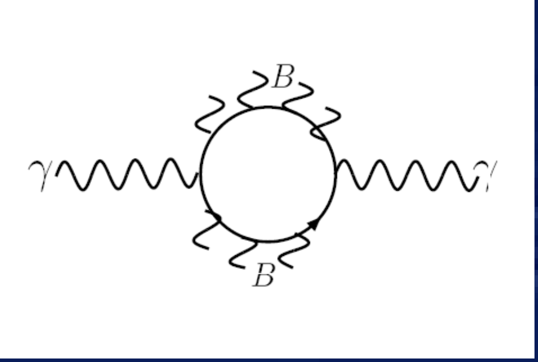
Von **W. Heisenberg** und **H. Euler** in Leipzig.

Mit 2 Abbildungen. (Eingegangen am 22. Dezember 1935.)

Aus der Diracschen Theorie des Positrons folgt, da jedes elektromagnetische Feld zur Paarerzeugung neigt, eine Abänderung der Maxwellschen Gleichungen des Vakuums. Diese Abänderungen werden für den speziellen Fall berechnet, in dem keine wirklichen Elektronen und Positronen vorhanden sind, und in dem sich das Feld auf Strecken der Compton-Wellenlänge nur wenig ändert. Es ergibt sich für das Feld eine Lagrange-Funktion:

http://www.physik.fu-berlin.de/~kleinert/

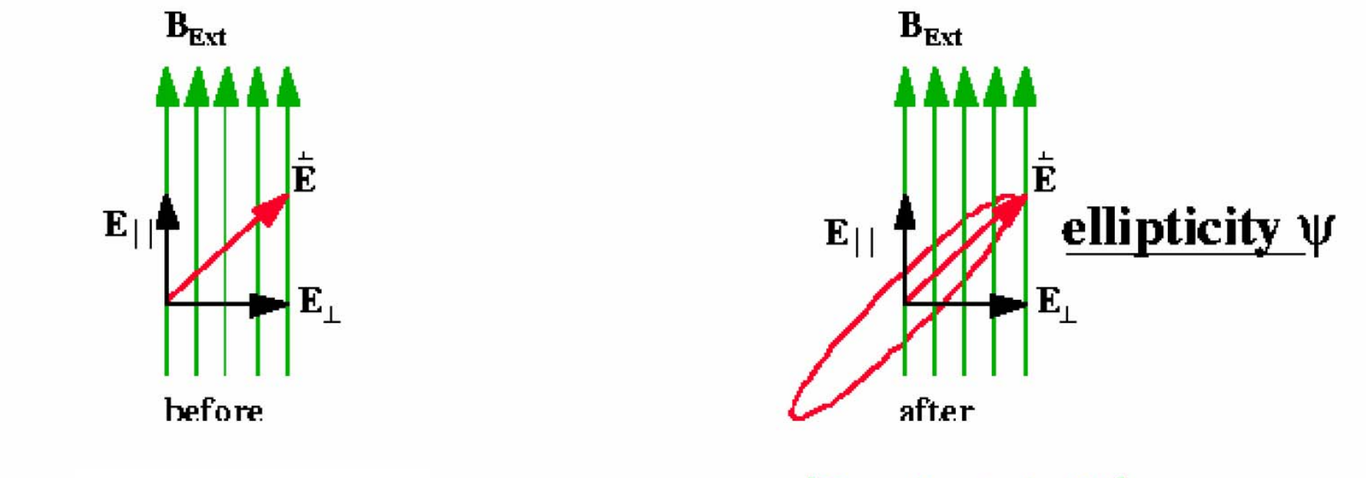
QED: Vacuum Magnetic Birefringence



Different coupling of polarization component parallel and perpendicular to the magnetic field

→ different indices of refraction /velocities

Linear polarization turns into elliptical polarization



Talk by A. Ringwald

[Brandi *et al.* '01]

QED: Vacuum Magnetic Birefringence

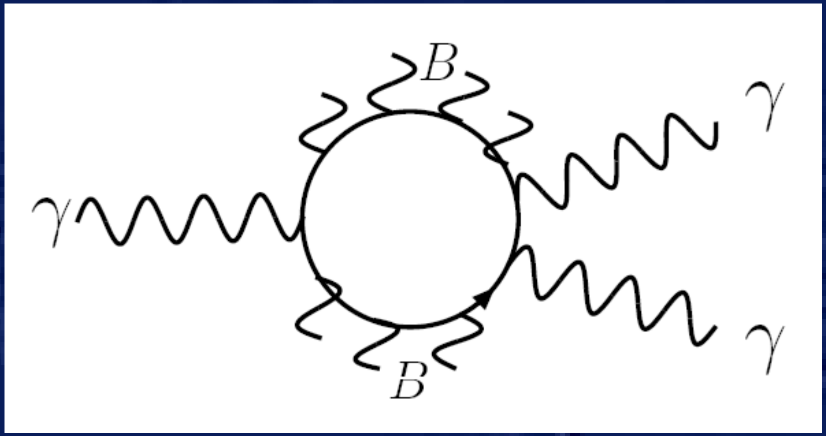
Very small effects:

$\Delta n (\perp - \parallel) = 3.6 \cdot 10^{-22}$ (9.5 T @ LHC dipole)

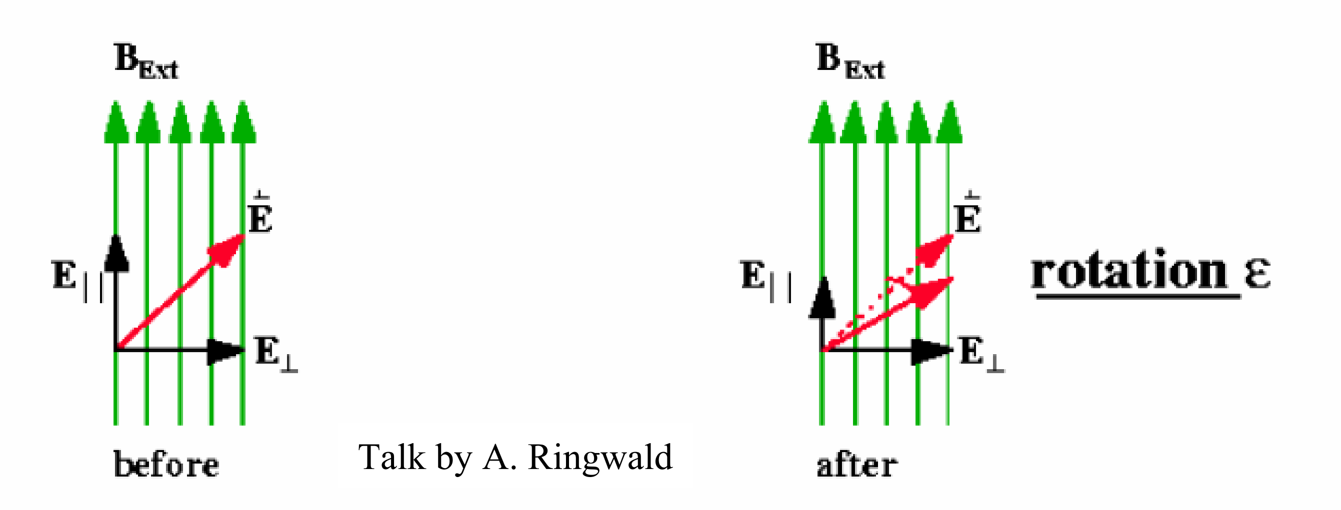
$\Psi = 2 \cdot 10^{-10}$ (250 km length, $\lambda = 1550$ nm)

(P. Pugnat, CERN)

QED: Vacuum Magnetic Dichroism

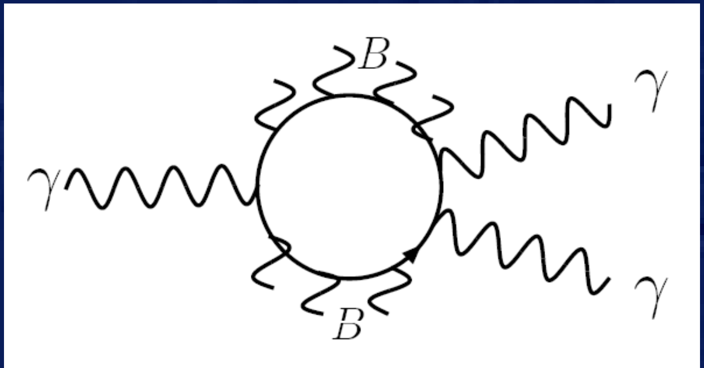


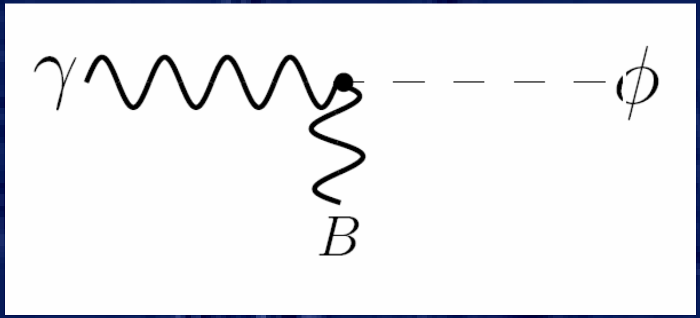
different absorption of light polarized ‖ and ⊥ to the magnetic field → rotation



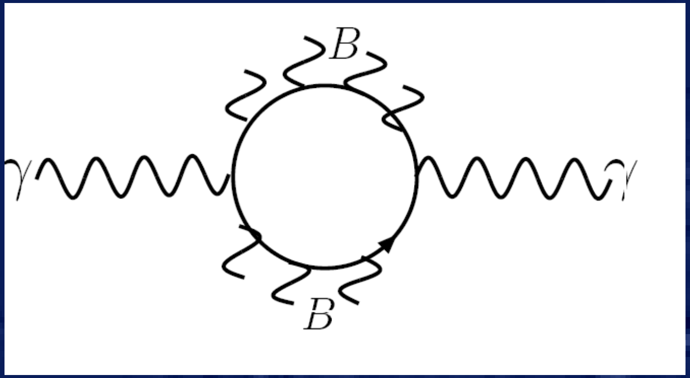
New Particles may interfere!

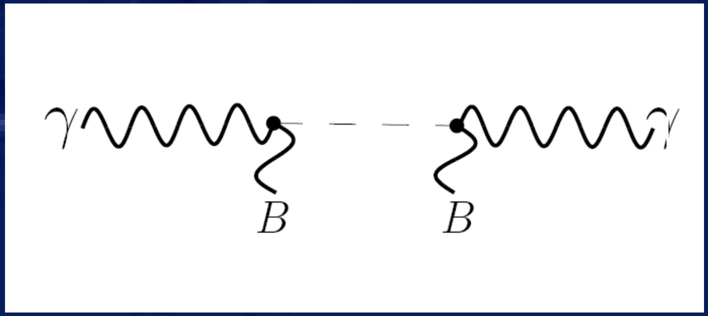
Rotation:



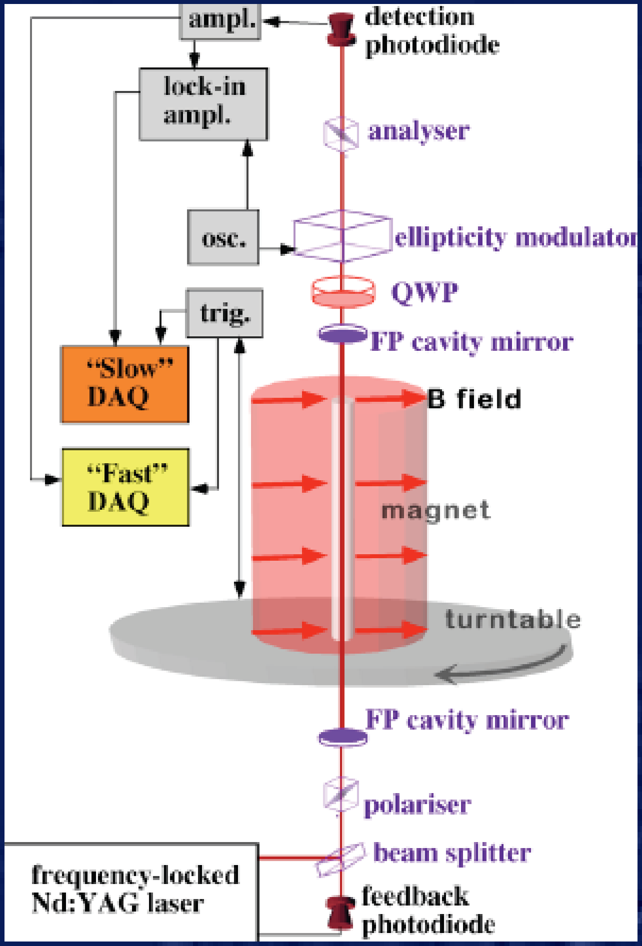


Ellipticity:





The PVLAS Experiment



- Located at INFN Legnaro (Padua)
- Capability to measure rotation and ellipticity with unprecedented precision
- If new particles exist: measure induced effects, no direct detection

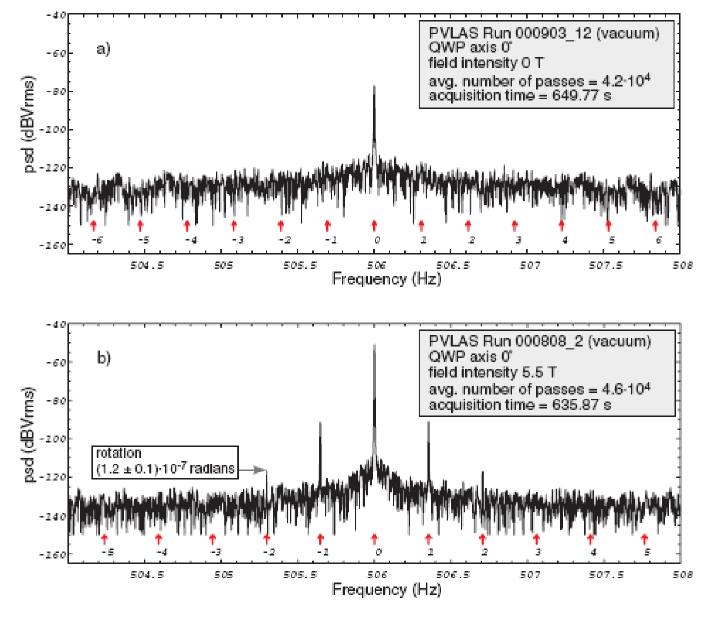
The published PVLAS Result

PRL 96, 110406 (2006) PHYSICAL REVIEW LETTERS week ending 24 MARCH 2006

Experimental Observation of Optical Rotation Generated in Vacuum by a Magnetic Field

E. Zavattini,[1] G. Zavattini,[2] G. Ruoso,[3] E. Polacco,[4] E. Milotti,[5] M. Karuza,[1] U. Gastaldi,[3] G. Di Domenico,[2] F. Della Valle,[1] R. Cimino,[6] S. Carusotto,[4] G. Cantatore,[1,*] and M. Bregant[1]

(PVLAS Collaboration)



$$\alpha = (3.9 \pm 0.5) \times 10^{-12} \ \text{rad/pass.}$$

Rotation measured:
in the magnetic field light is absorbed
$\approx 10^{28} \cdot$ (QED expectation)

BFRT Limits

PHYSICAL REVIEW D VOLUME 47, NUMBER 9 1 MAY 1993

ARTICLES

Search for nearly massless, weakly coupled particles by optical techniques

R. Cameron,* G. Cantatore,† A. C. Melissinos, G. Ruoso,‡ and Y. Semertzidis§
Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627

H. J. Halama, D. M. Lazarus, and A. G. Prodell
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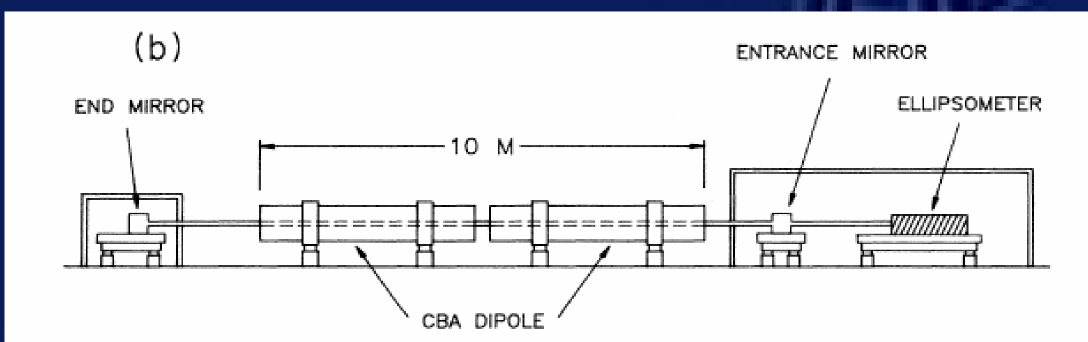
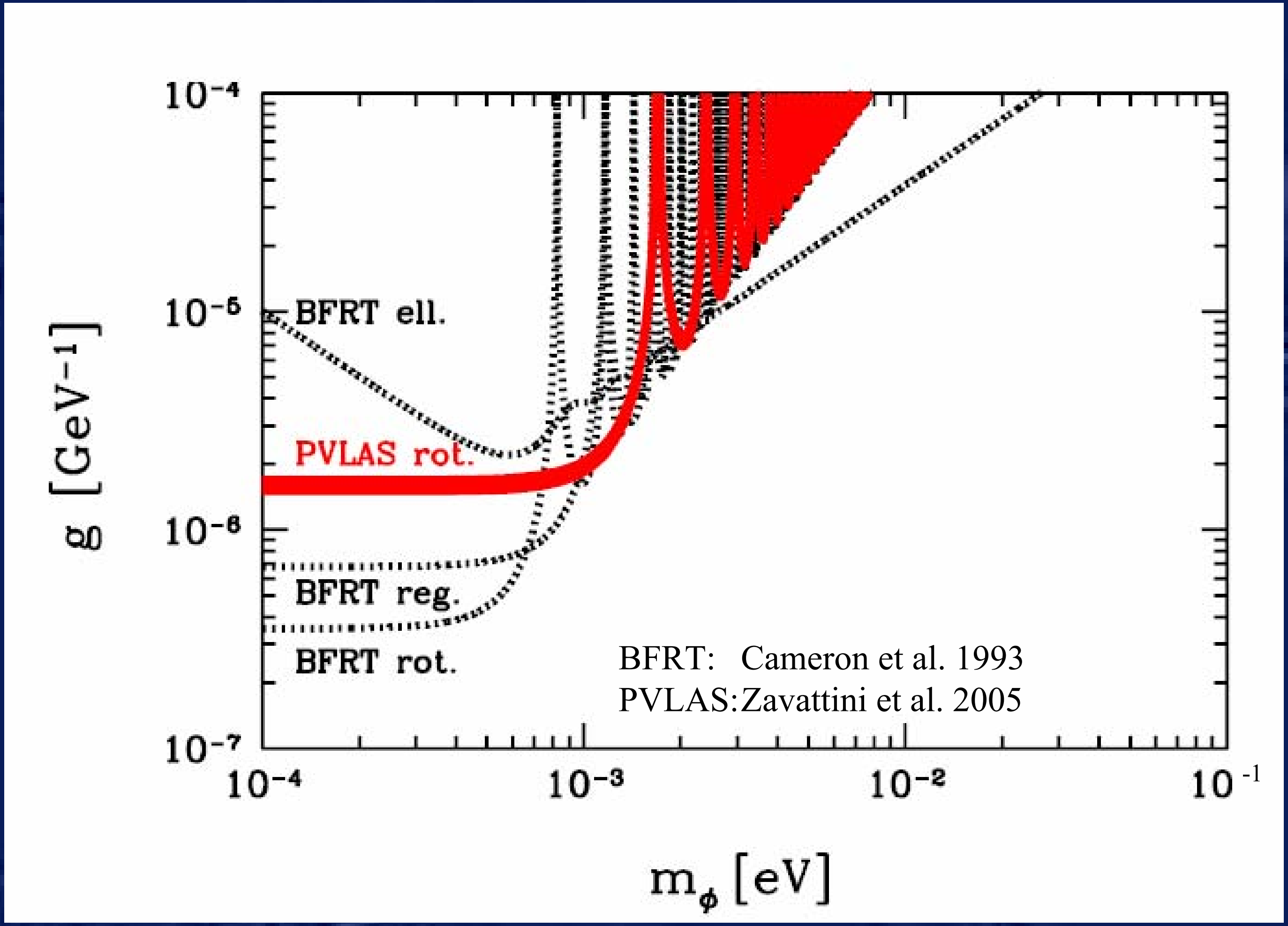
F. Nezrick
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

C. Rizzo and E. Zavattini
Dipartimento di Fisica, University of Trieste and Istituto Nazionale di Fisica Nucleare Sezione di Trieste, 34127 Trieste, Italy
(Received 5 October 1992)

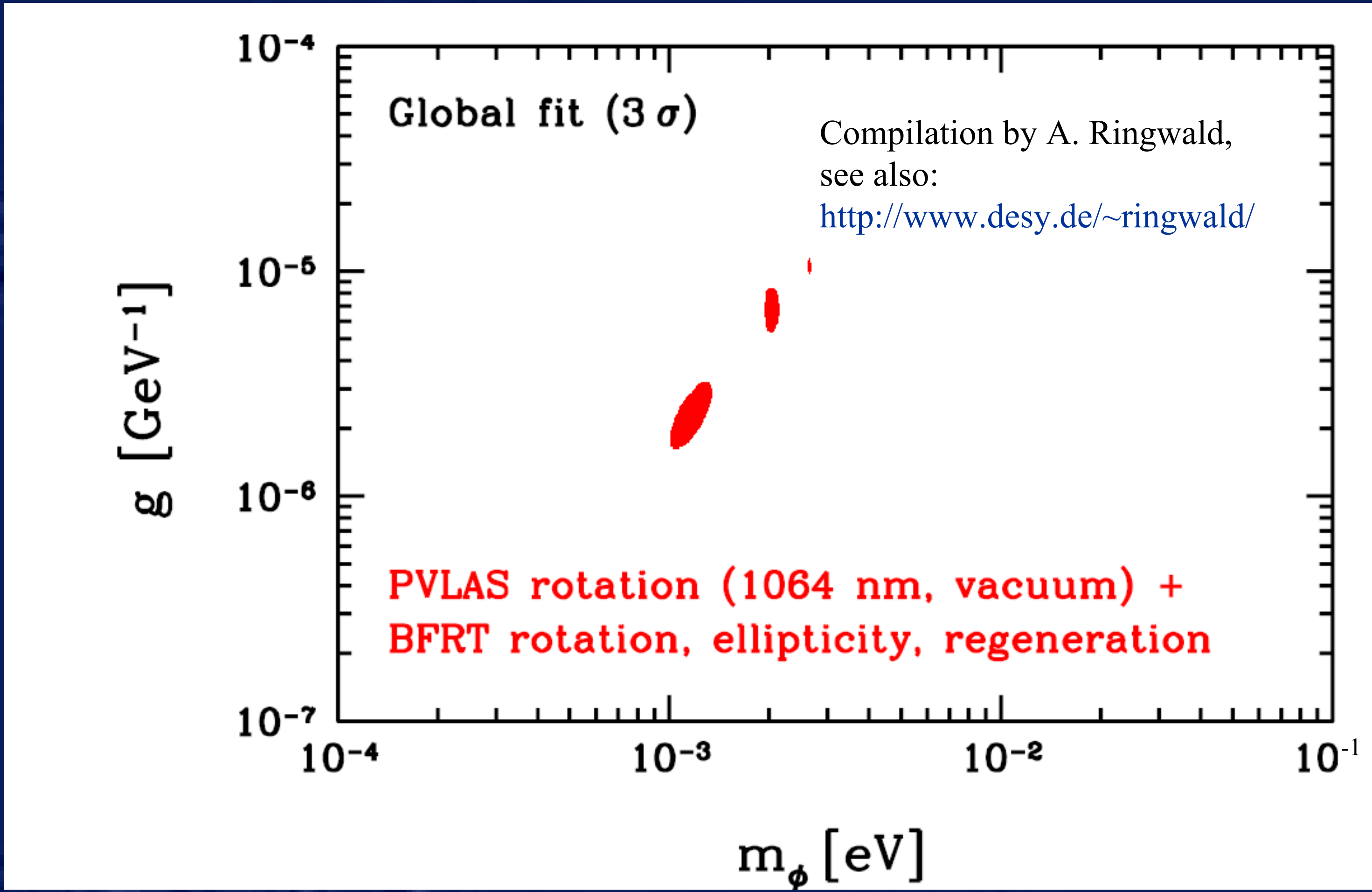


Best limits so far from measurements of rotation, ellipticity and regeneration.

PVLAS and BFRT

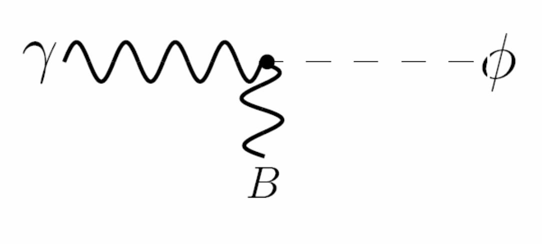


PVLAS and BFRT



One Interpretation

- A new neutral particle is produced by interaction of light with the magnetic field (so that the interacting photons are lost).



- Properties of such a particle:
  - scalar or pseudoscalar ("axion-like")
  - 1 meV < mass < 1.5 meV
  - coupling strength 1/M with $2 \cdot 10^5$ GeV < M < $6 \cdot 10^5$ GeV

Independent confirmation of this interpretation badly needed!

Limits from Astrophysics

Astrophysical Axion Bounds

hep-ph/0611350v1

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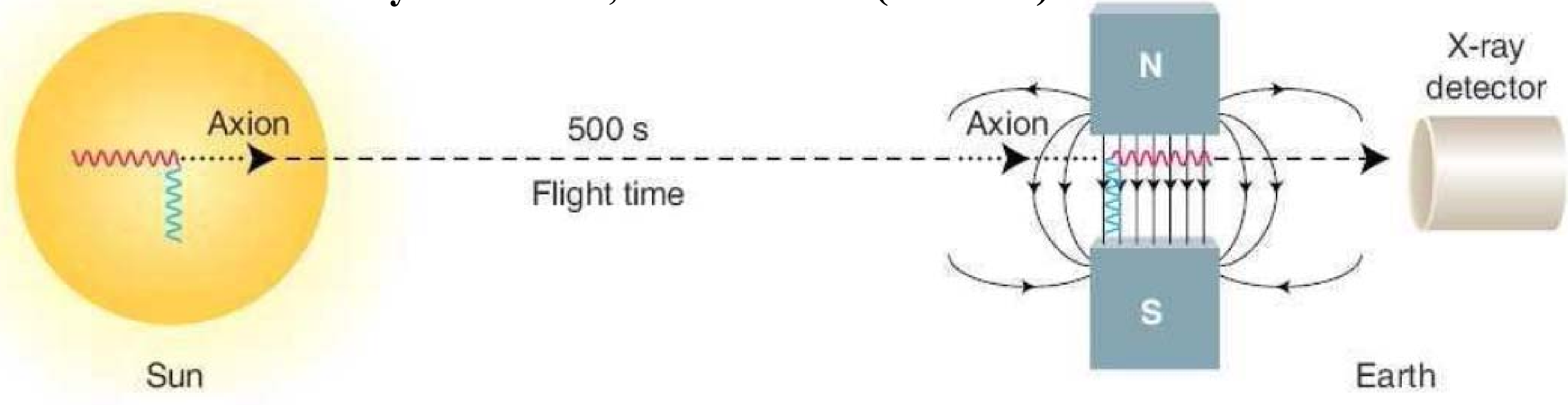
General approach:

production of axions or axion-like particles would open up new energy loss channels.

CAST at CERN

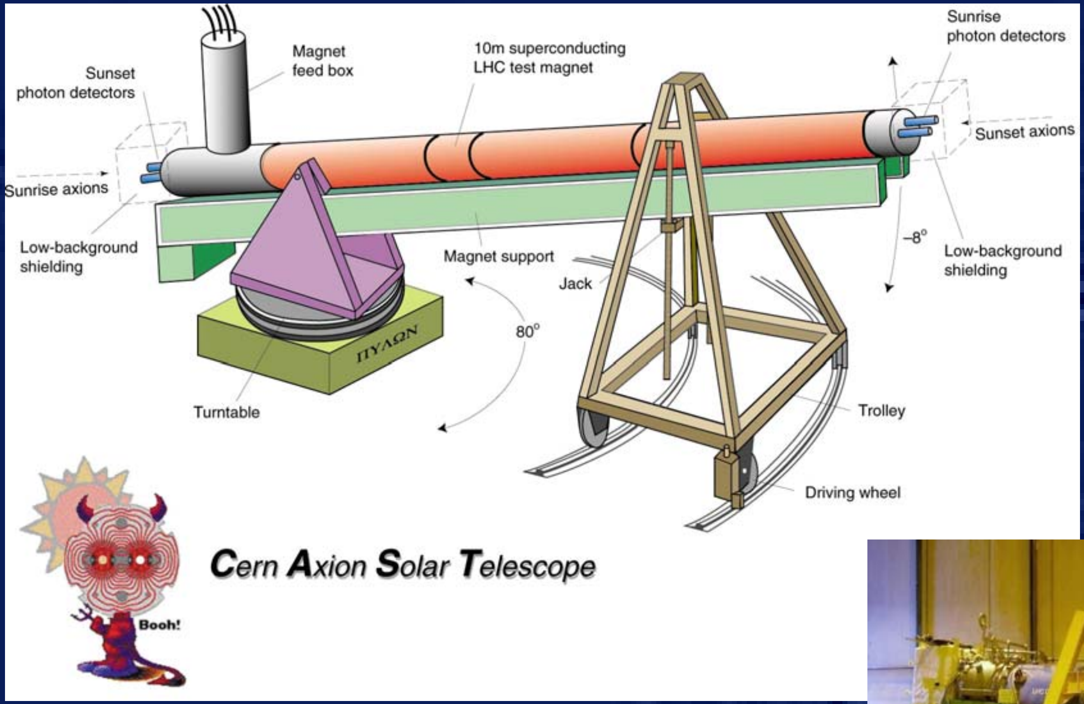
Looking for axions from the sun

Talk by M. Kuster, CERN SPSC (07.06.05)

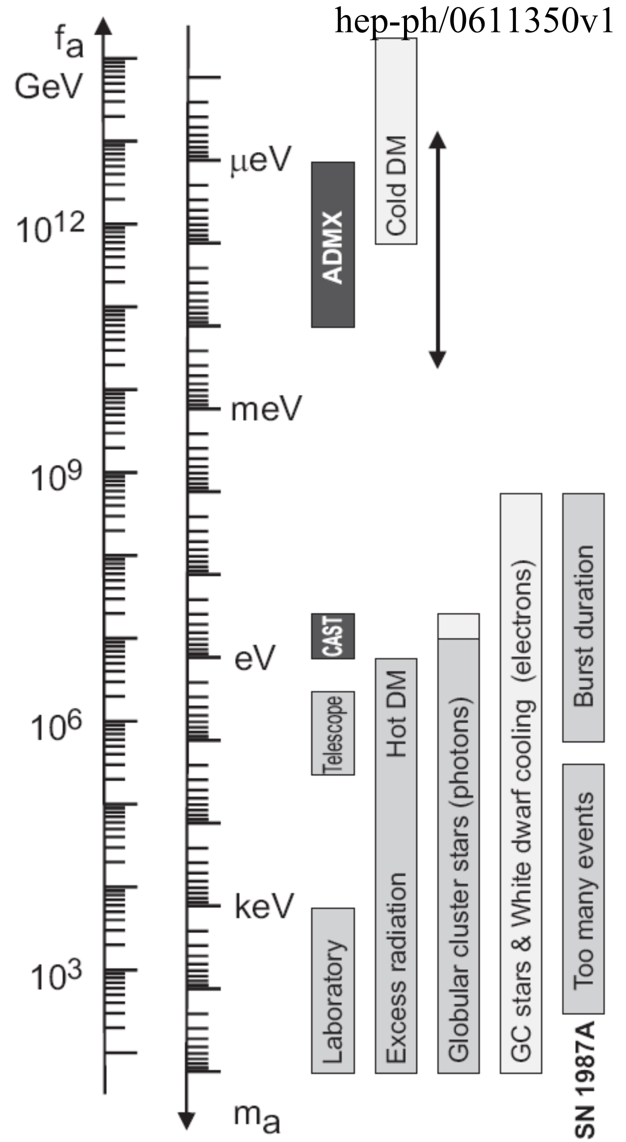


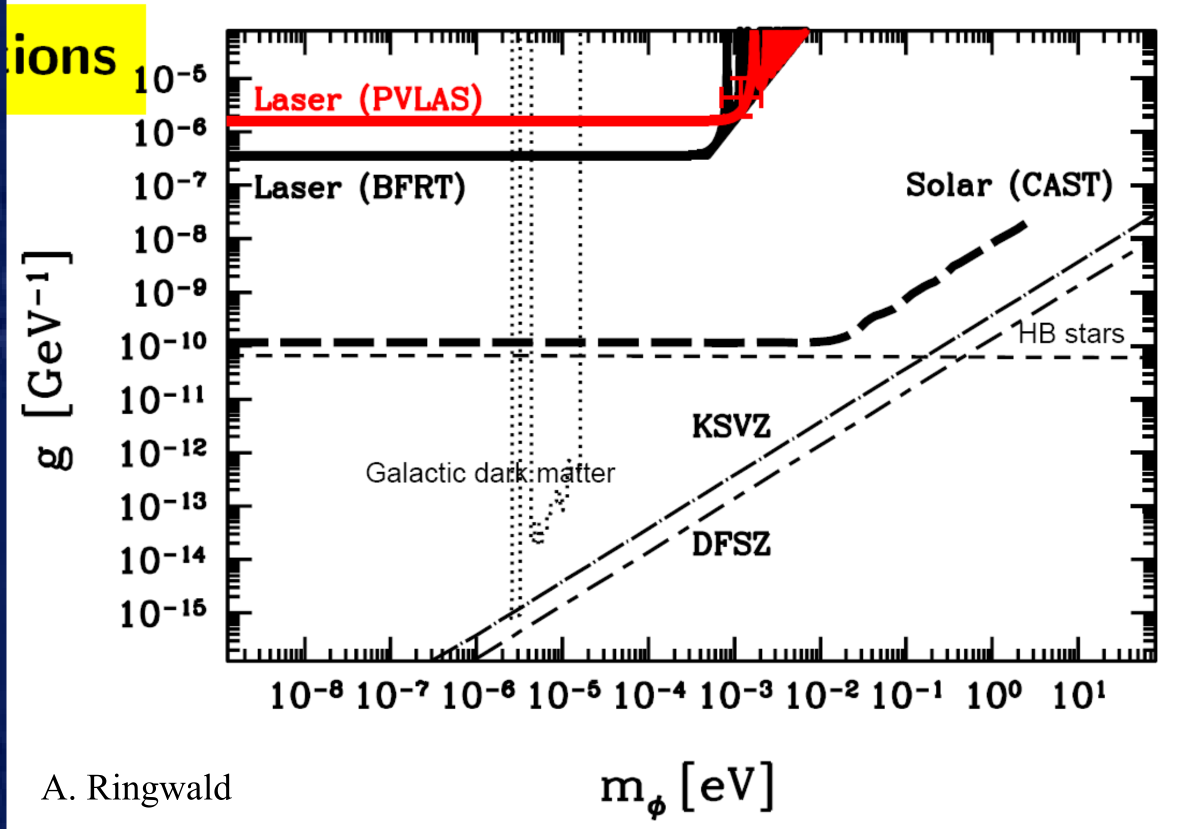
CAST at CERN

Looking for axions from the sun



Limits from Astrophysics





More laboratory experiments!

Detour: a low Energy Frontier?

- Neutrinos
  - sub eV masses from mixing?
- Dark Energy
  - could be explained by 1 meV axion-like particles
    (see for example H. J. de Vega, N. G. Sanchez, astro-ph/0701212)
- PVLAS / BFRT:
  indication of a 1 meV axion-like particle

Detour: Hint at String Theory?

hep-ph/0608248

Illuminating the Hidden Sector of String Theory by Shining Light through a Magnetic Field

Steven A. Abel,[1] Joerg Jaeckel,[2] Valentin V. Khoze,[1] and Andreas Ringwald[2]

[1] *Centre for Particle Theory, Durham University, Durham, DH1 3LE, UK*

[2] *Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany*

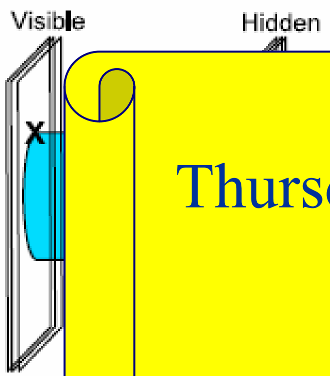


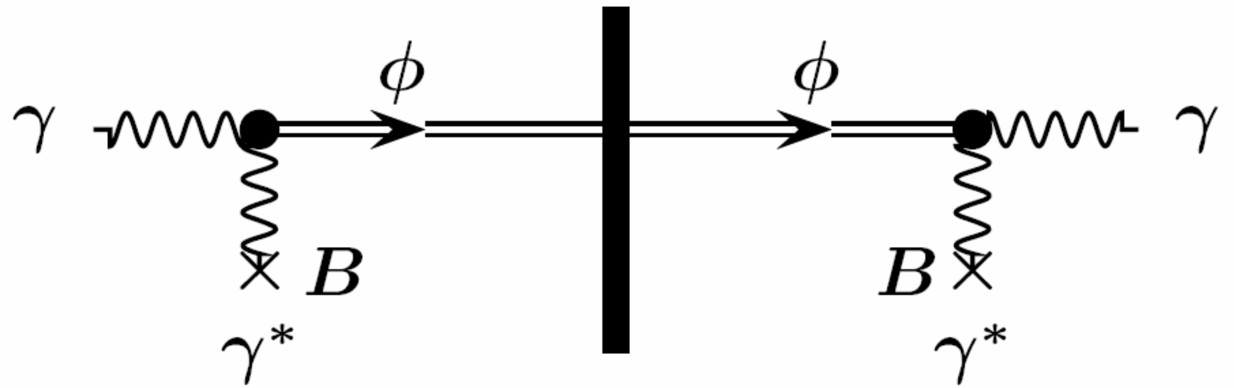
FIG. 2: Kinetic-mixing ... breaking on "hidden" b... a phenomenologically w... etermined supersymmetric configuration of D3-branes ... ixed point in the 6 dimensional compact manifold, possibly with D7-branes passing through to cancel local tadpoles. Global absence of tadpoles is assumed to require additional branes and/or anti-branes in the bulk. Closed string interactions are mediated from hidden to visible sector by cylinder diagrams, and are equivalent to Fig. 1(b).

Thursday 8:30 and Saturday 8:30:
Talks by A. Ringwald

... can provide the ... n of the PVLAS ... iate string scales ... e of millicharged ... with near future laboratory experiments.

Brief Introduction to Photon Regeneration Experiments

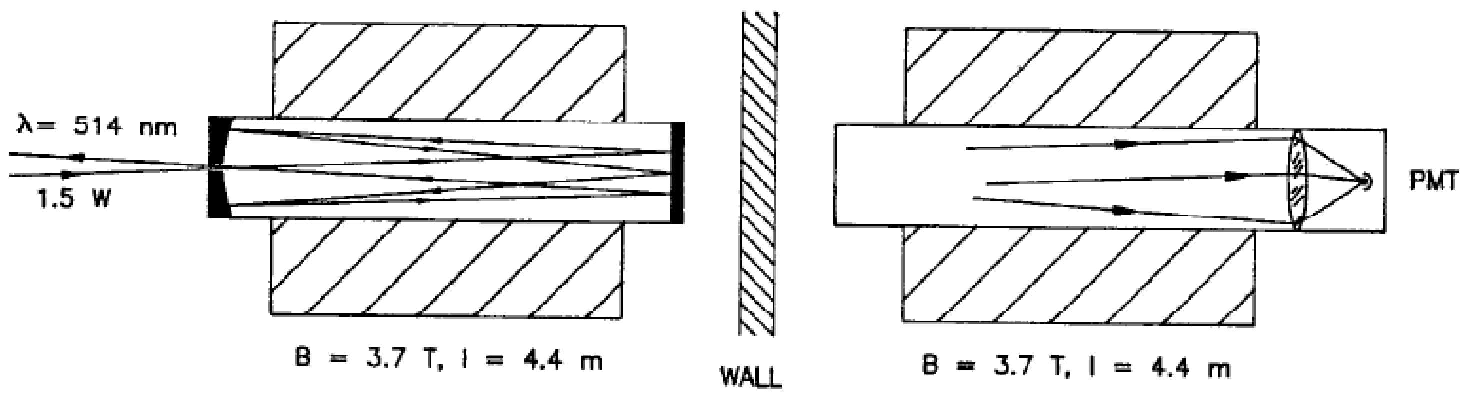
Light shining through a wall



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

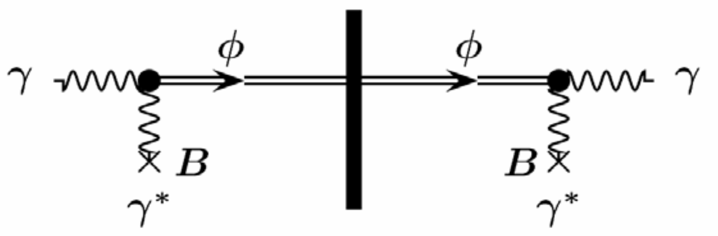
Brief Introduction to Photon Regeneration Experiments

1992: Brookhaven-Fermilab-Rochester-Trieste



Cameron et al. 1993

Theoretical Basics



$\gamma - \phi$ and $\phi - \gamma$ conversion probability are equivalent

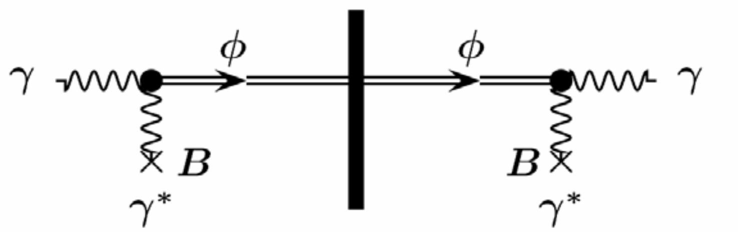
$$P_{1/2} = \frac{g^2}{4} \left| \int_L e^{iq(z)z} \; B(z) \; \cos\theta(z) \; dz \right|^2$$

For homogeneous conditions $B(z) = B \quad q(z) = q \quad \cos\theta(z) = 1$

$$P_{1/2} = \frac{g^2}{4} B^2 L^2 \frac{\sin^2(qL/2)}{(qL/2)^2} \qquad q = \frac{m_\phi^2}{2E_\gamma}$$

Scalar instead of pseudo-scalar ALP: $\cos\theta \rightarrow \sin\theta$

Theoretical Basics



$$P_{\gamma\to\phi\to\gamma} = P_{\gamma\to\phi}(B_1,\ell_1,q_1)\,P_{\phi\to\gamma}(B_2,\ell_2,q_2)$$

$$P_{\gamma\to\phi} \equiv P_{\phi\to\gamma}$$

$$P_{\gamma\to\phi}(B,\ell,q) = \frac{1}{4}\,(g\,B\,\ell)^2\;F(q\ell)$$

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

$$q = p_\gamma - p_\Phi$$

Secondary and primary photons have same properties!

Experimental parameters:

- Strength of magnetic field: B
- Length of magnets: l
- Momentum of photons: p_γ
- Polarization to discriminate between 0^+ and 0^- axion-like particles (ALPs)

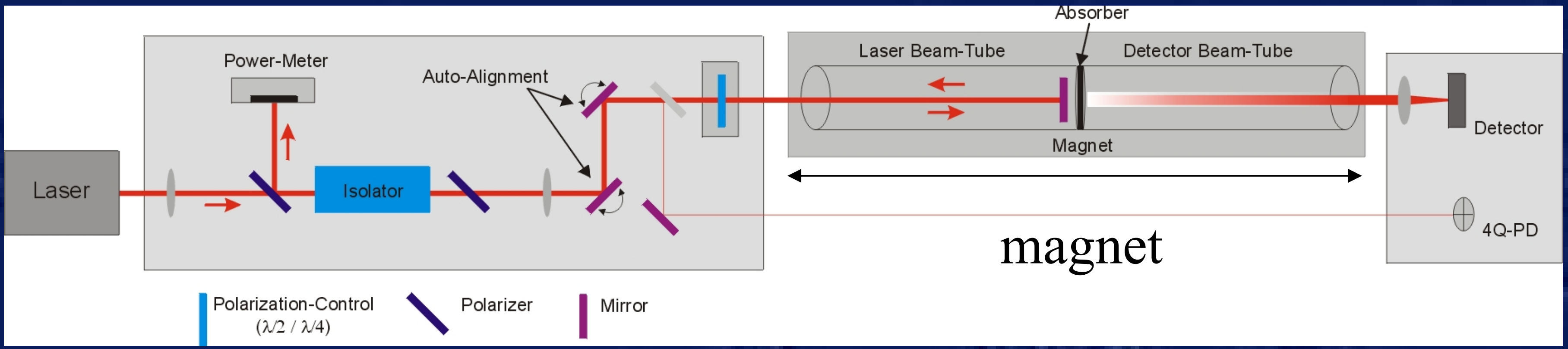
The ALPS Project

Axion-like Particle Search

following a proposal by A. Ringwald

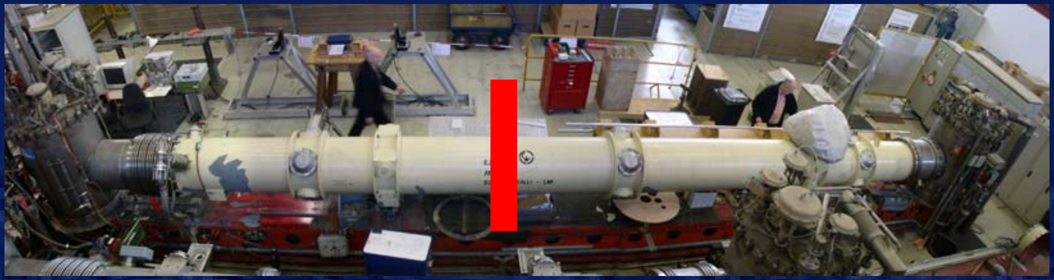
Can we help to clarify the situation with magnets available at DESY?

Experimental Setup



Challenge: only one magnet can be used,
mirror and absorber in the middle of the magnet,
no direct access possible.

ALPS Parameter



$$P_{\gamma\to\phi\to\gamma} = P_{\gamma\to\phi}(B_1, \ell_1, q_1)\, P_{\phi\to\gamma}(B_2, \ell_2, q_2)$$

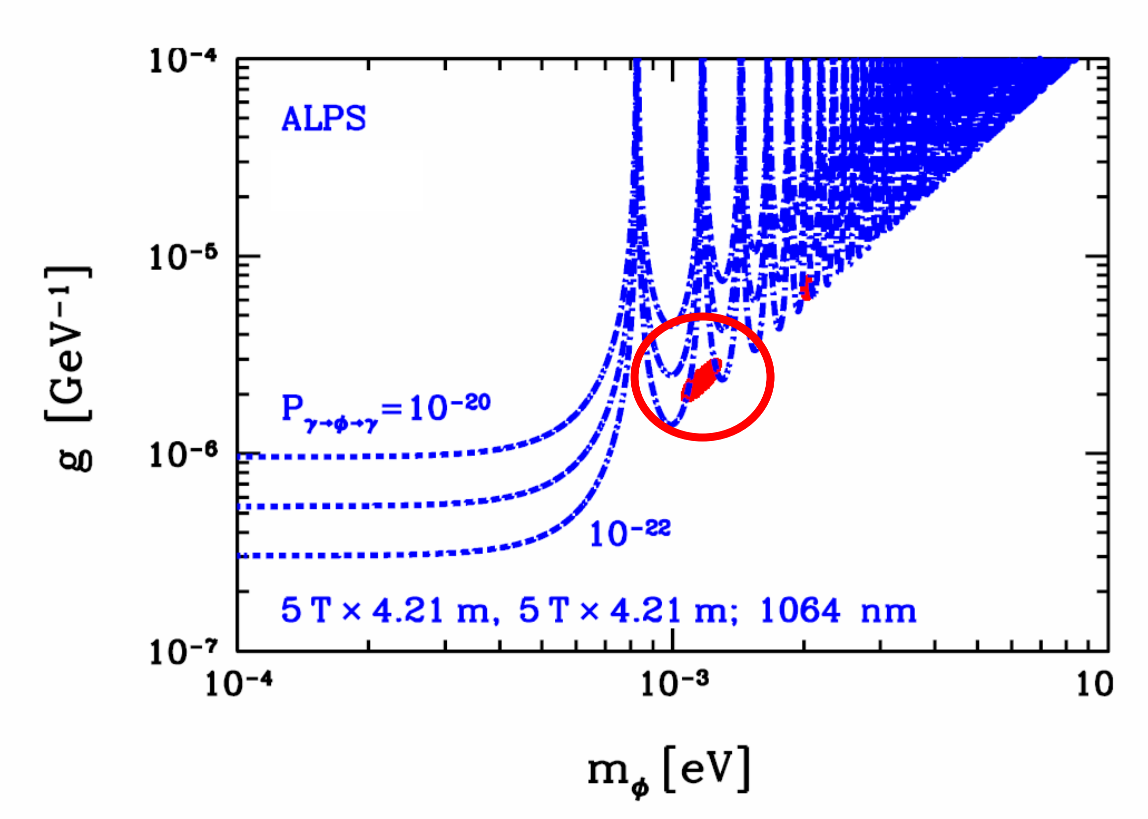
$$P_{\gamma\to\phi}(B, \ell, q) = \frac{1}{4}\,(g\, B\, \ell)^2\; F(q\ell)$$

Rate of re-converted photons ~ $(B \cdot l)^4$

- HERA-dipole: $B_1 = B_2 = 5$ T ; $l_1 = l_2 = 4.21$ m
- Initial photon flux ≈ 10^{21} (200 W @ 1064 nm)

Sensitivity ≈ [2.8 (magnet length) · 1.4 (laser)] · BFRT

ALPS Challenges



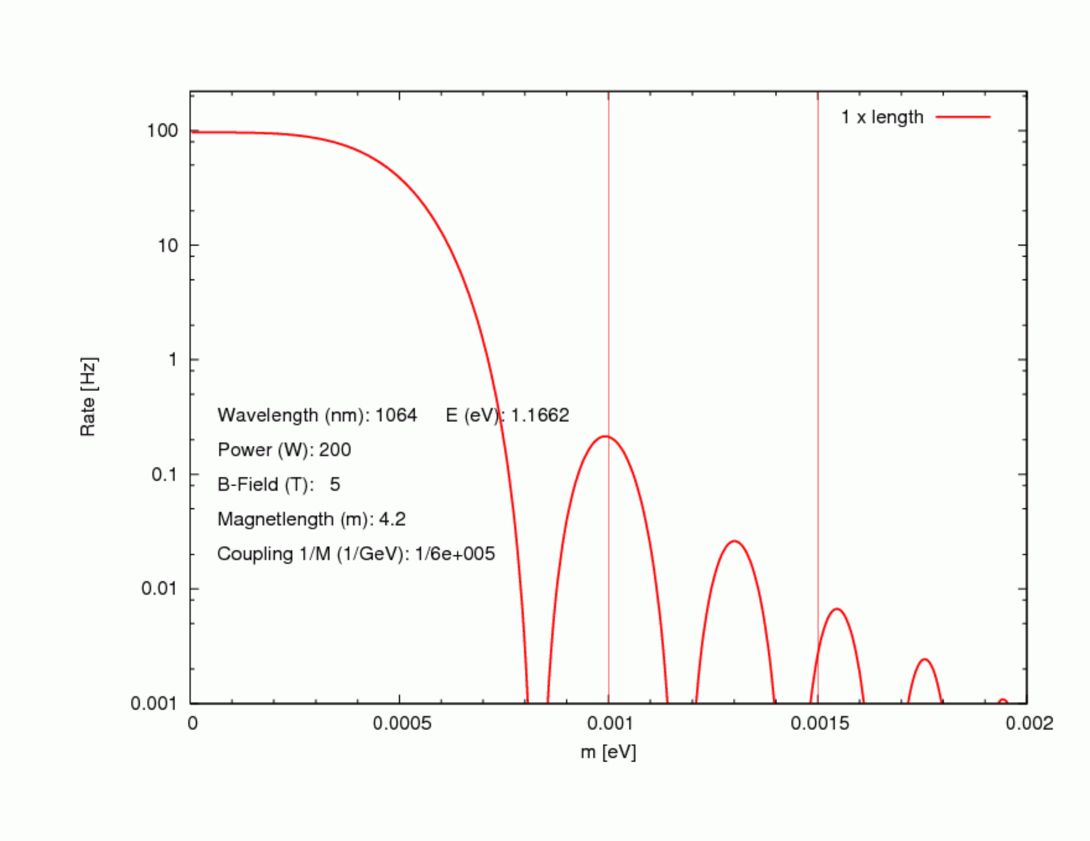
- initial photon flux $10^{21\text{-}22}$/s (200-400 W @ 1064 nm)
- avoid "gaps" in sensitivity to test "PVLAS islands"

A closer Examination

$$P_{\gamma\to\phi} \equiv P_{\phi\to\gamma}$$

$$P_{\gamma\to\phi}(B,\ell,q) = \frac{1}{4}\,(g\,B\,\ell)^2\;F(q\ell)$$

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

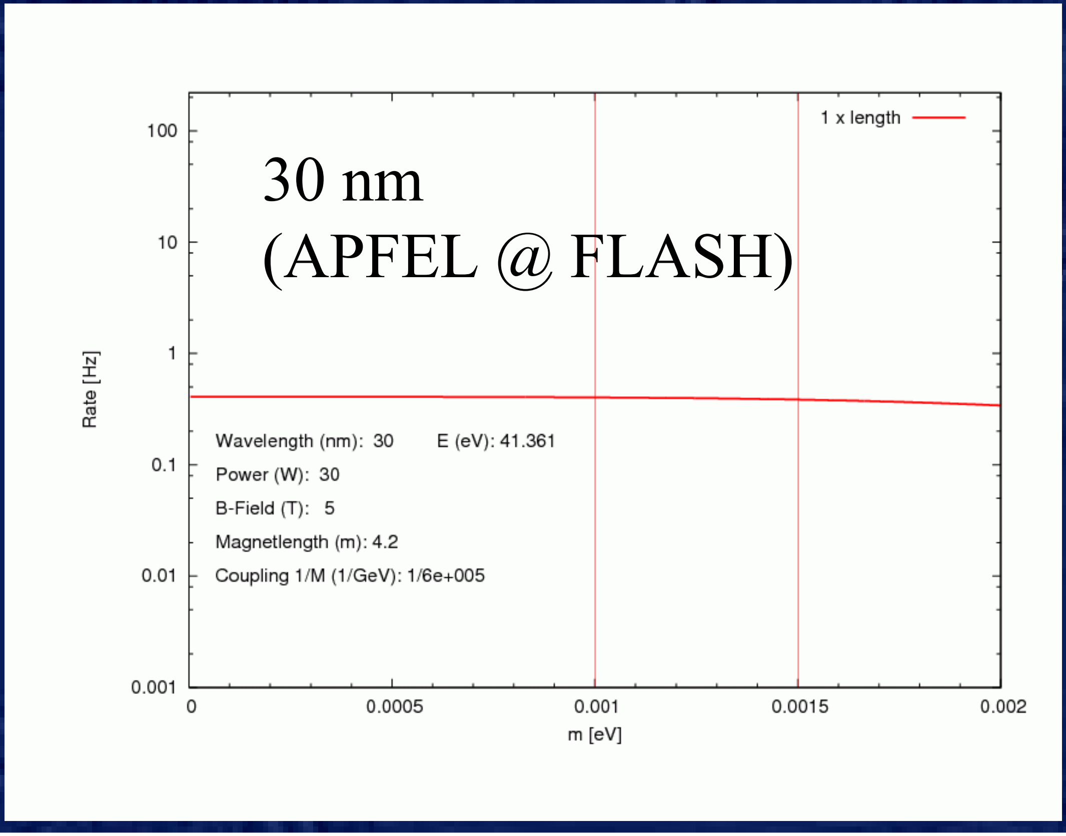


- Sensitivity decreases rapidly for „higher“ ALP masses
- High rate only for ql << 1: F(ql) = 1
- Oscillation similar to υ mixing

How to recover?

Try to retain ql << 1 in the interesting mass region:

- increase q: higher photon energies



However:

- hard to get beam-time at FLASH
- time-consuming, costly to install large magnets at FLASH

How to recover?

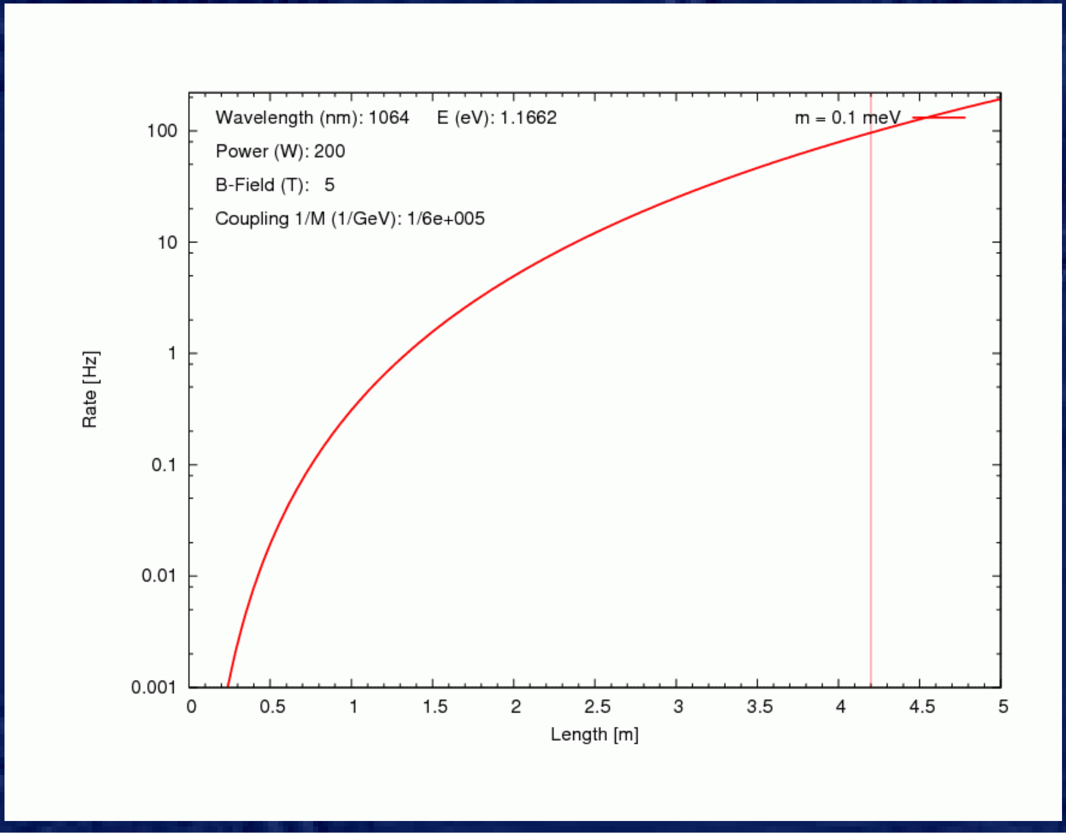
Try to retain ql << 1 in the interesting mass region:

- increase q: higher photon energies → not possible

How to recover?

Try to retain ql << 1 in the interesting mass region:

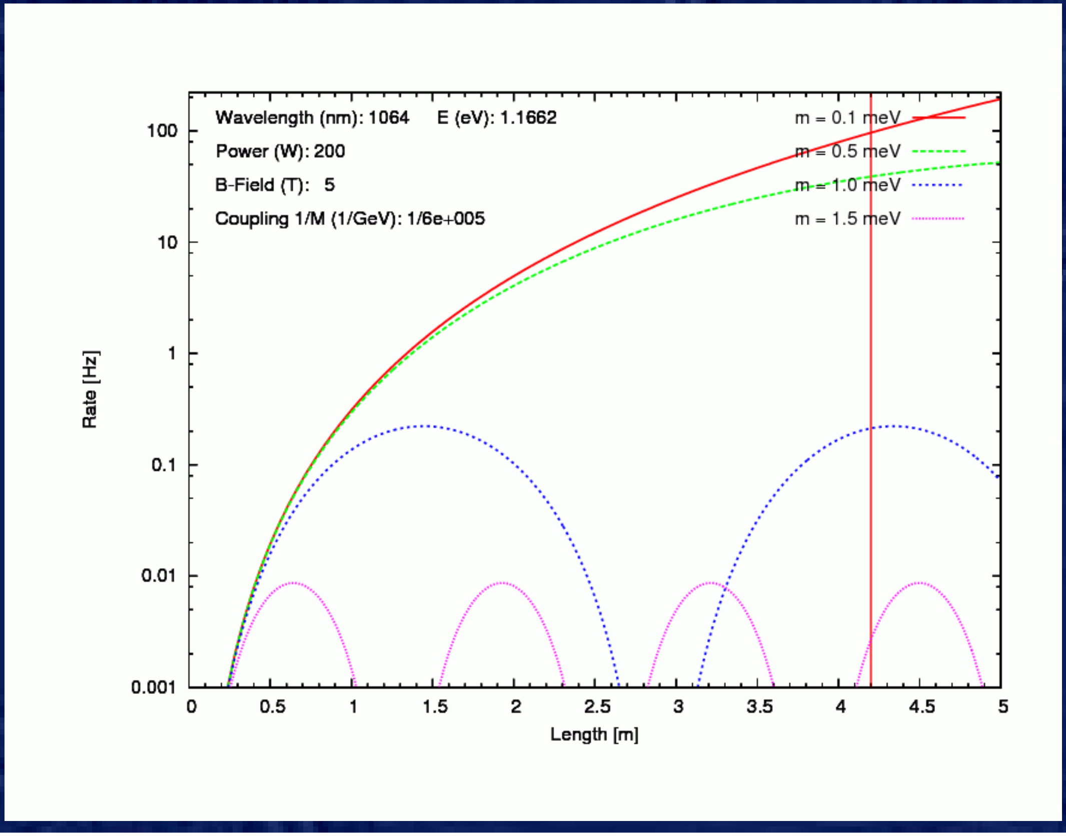
- decrease length of magnet



How to recover?

Try to retain ql << 1 in the interesting mass region:

- decrease length of magnet



Optimal length:

- 0.6 to 1.4 m
- but very low rate!
- no profit of length of HERA dipole!

How to recover?

Try to retain ql << 1 in the interesting mass region:

- decrease length of magnet → strong rate losses

How to recover?

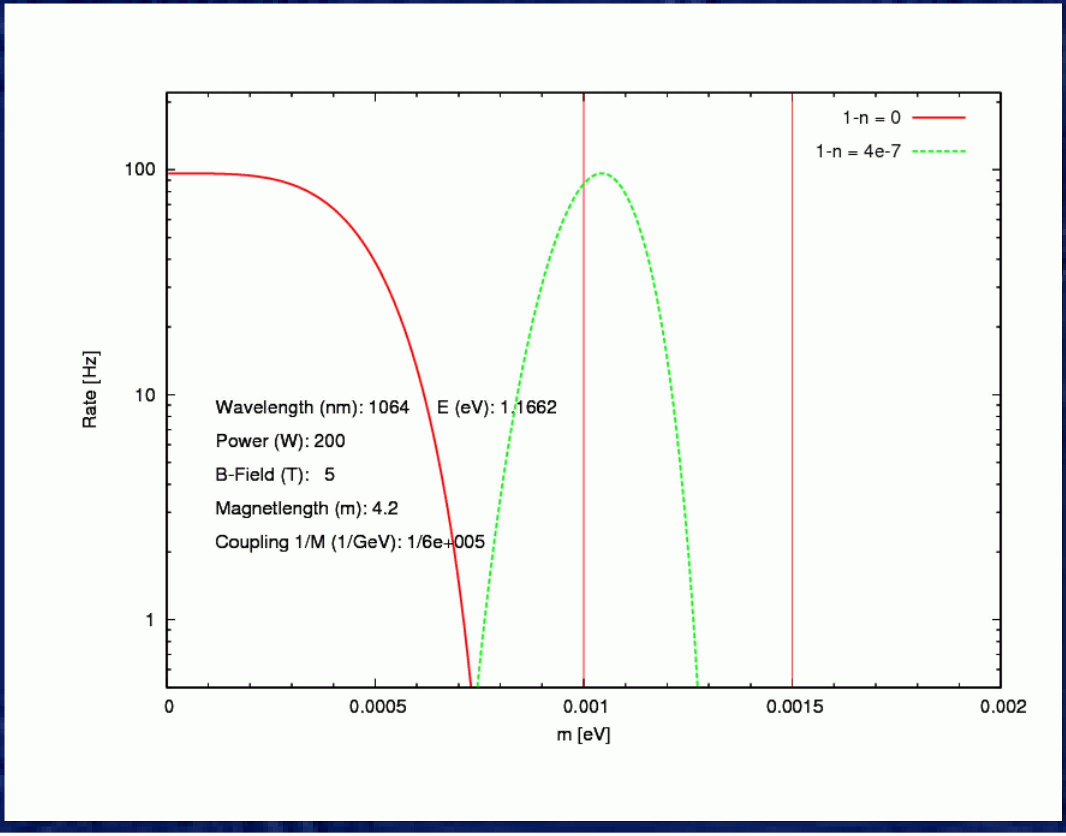
Try to retain ql << 1 in the interesting mass region:

- adopt photon momentum to ALP momentum
  - p (ALP) = $\sqrt{E^2(\text{photon}) - m^2(\text{ALP})}$
  - in medium with refraction index n:
    p (photon) → p (photon) · n

How to recover?

Try to retain ql << 1 in the interesting mass region:

- adopt photon momentum to ALP momentum



However:

- n < 1
- works only with plasma (or with X-rays)!

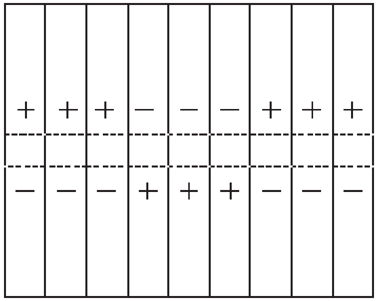
How to recover?

Try to retain ql << 1 in the interesting mass region:

- adopt photon momentum to ALP momentum
  → not possible

Unfortunately the ALPS Letter of Intent (as well as other proposals) had a sign-error pretending ALP-photon coherence could be retained with n>1.

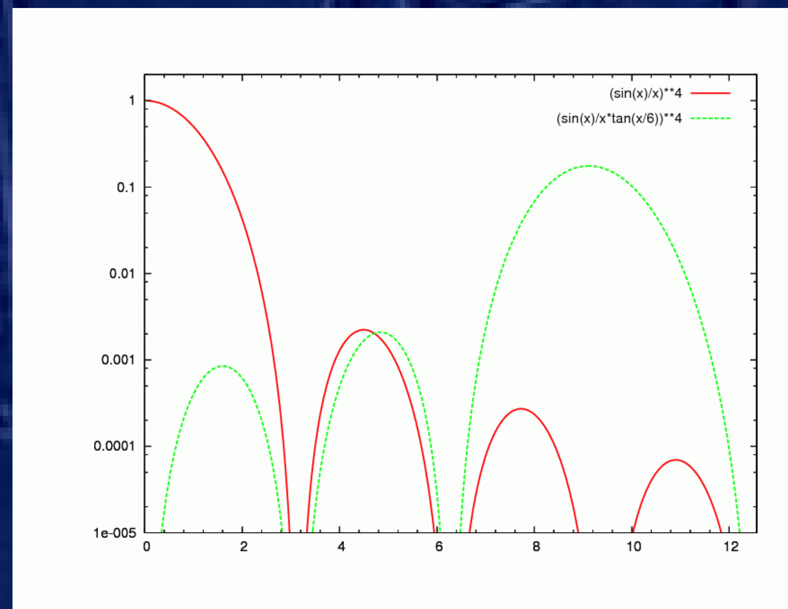
A “Wiggler“ Configuration



$$F(q) = [(\sin \tfrac{1}{2} ql)/\tfrac{1}{2} ql] \tan(qNL/2n)$$

A. V. Afanasev et al., arXiv: hep-ph/0605250, 2006
van Bibber et al., Phys. Rev Letter 59 (7), 750 (1987)

- *N* magnets of length L in *n* alternating orientations
- $NL = l$



A “Wiggler” with one Dipole

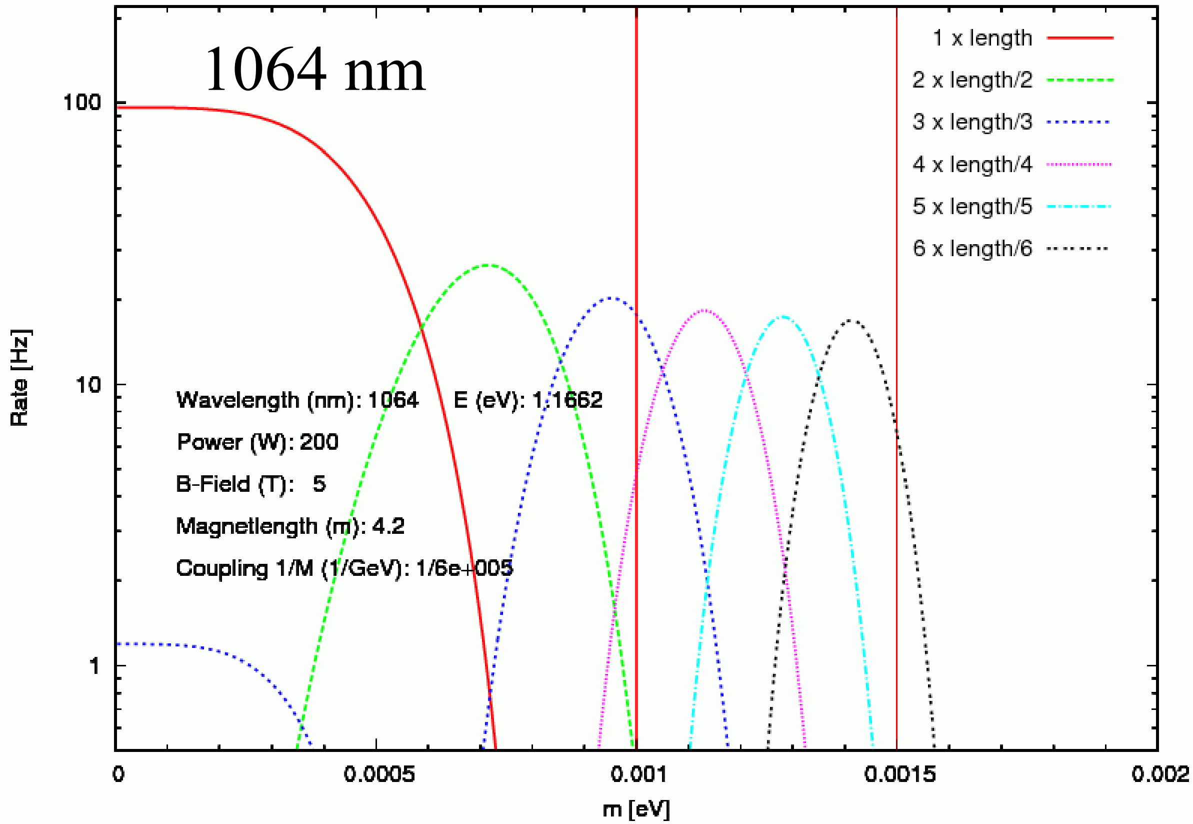
- from theoretical point of view:
  alternate magnetic field ≡ shift phase of light by 180°

phase shift (λ/2) plates

Possibility to profit from the length of the HERA dipole!

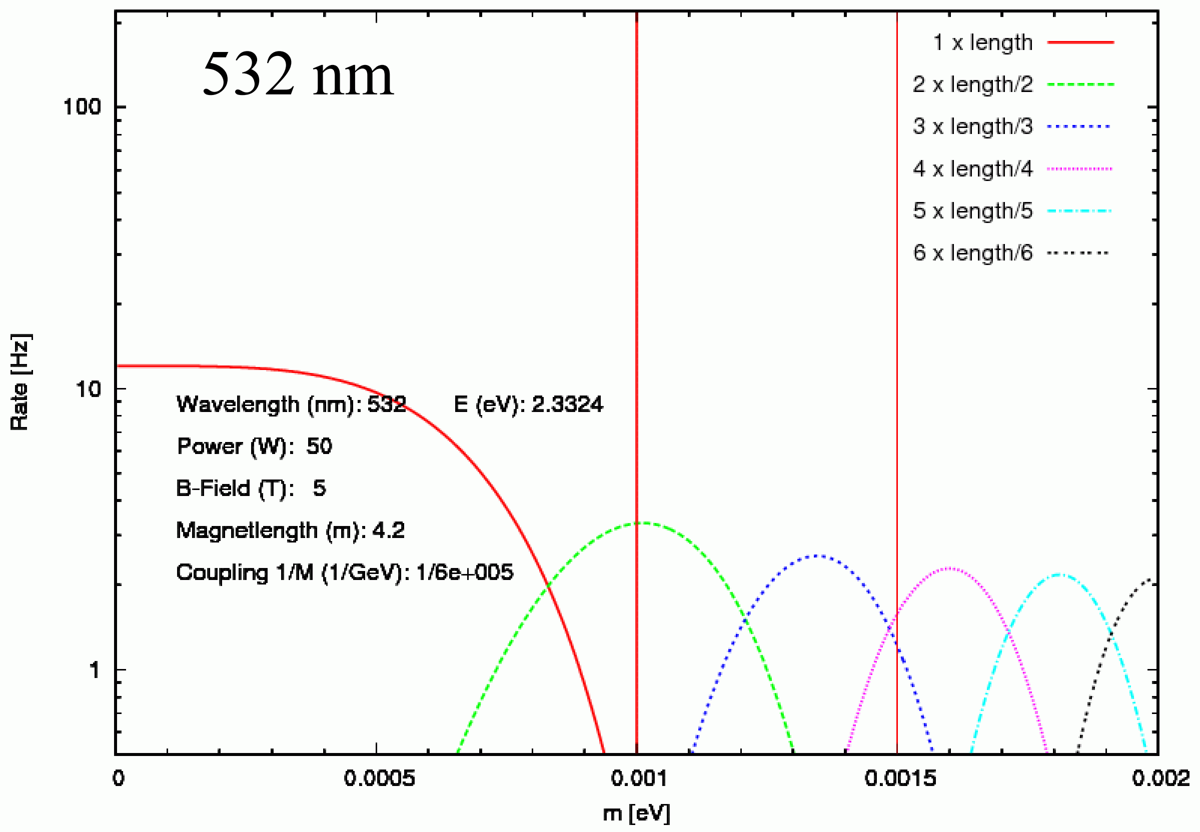
ALPS as a “Wiggler”

Same configuration on laser and detector side

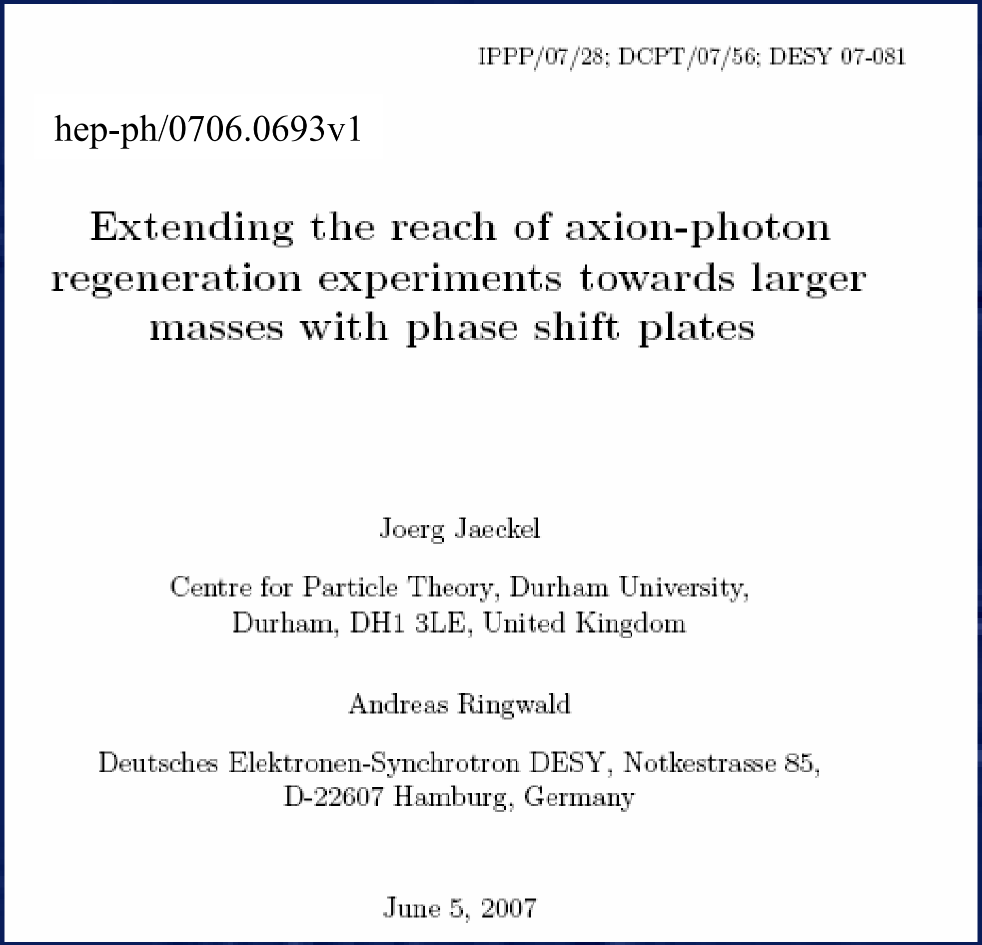


ALPS as a "Wiggler"

Same configuration on laser and detector side



All about Phase Shift Plates


IPPP/07/28; DCPT/07/56; DESY 07-081

hep-ph/0706.0693v1

Extending the reach of axion-photon regeneration experiments towards larger masses with phase shift plates

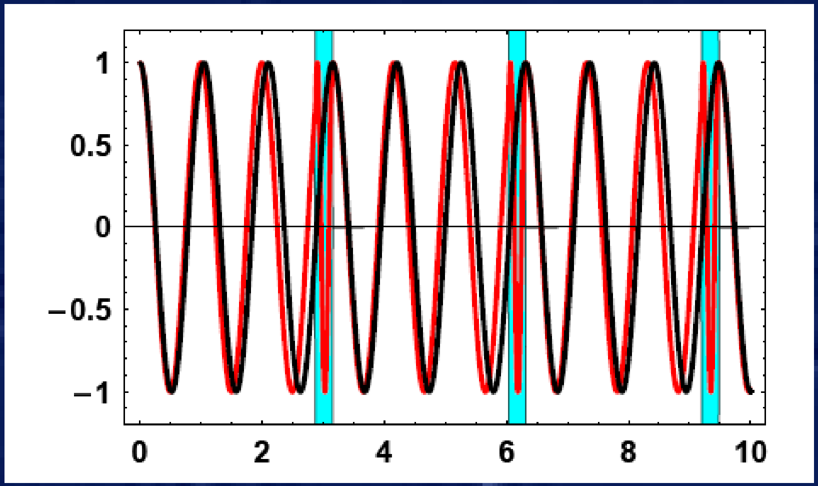
Joerg Jaeckel

Centre for Particle Theory, Durham University, Durham, DH1 3LE, United Kingdom

Andreas Ringwald

Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, D-22607 Hamburg, Germany

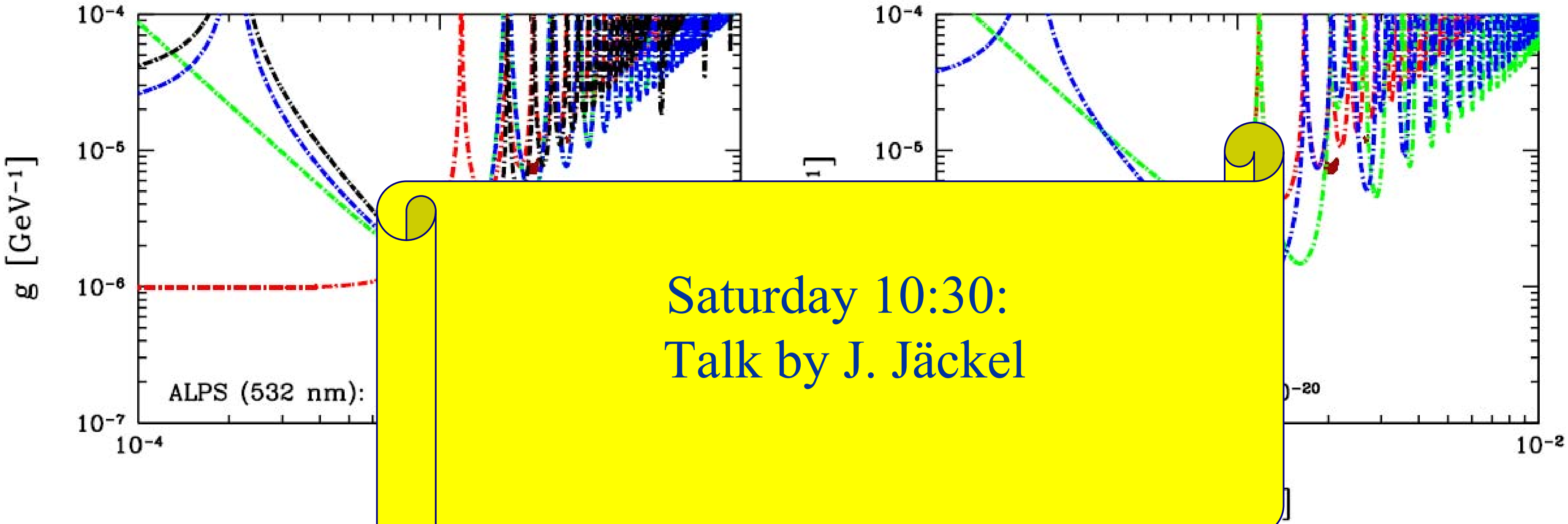
June 5, 2007



Plates correct for phase shift between photons and ALPs

Phase Shift Plates at ALPS

hep-ph/0706.0693v1



Saturday 10:30:
Talk by J. Jäckel

Figure 6: Iso-contours of the regeneration probability, as in Fig. 2. In the left figure, we have used no phase correction (red), one plate with $\kappa = \pi$ (green), and one plate with the optimal choice of κ according to Eq. (16) for $m_\phi = 1.2\,\text{meV}$ (blue). The black curve is for 20 plates with the optimal choice of κ. In the right figure, we have the same but with 3 plates for the green and blue curves.

Summary: general Considerations

Compared to previous “light shining through a wall“ exp.:

- with only one HERA dipole improved sensitivity
- implementation of phase shift plates in magnet insert allows to avoid “gaps” in sensitivity

ALPS: possibility for a fast check for axion-like particles

Summary: main Requirements

- Initial photon flux ≈ 10^{21} photons/second
  - Laser: some 100 W @ 1064 nm
  - Remark:
    set-up of optical delay lines or cavities too ambitious within our timeframe due to constraints given by the magnet (next section)
- Laser beam linear polarized
- Detector: sensitive to few photons / second

Experimental Considerations

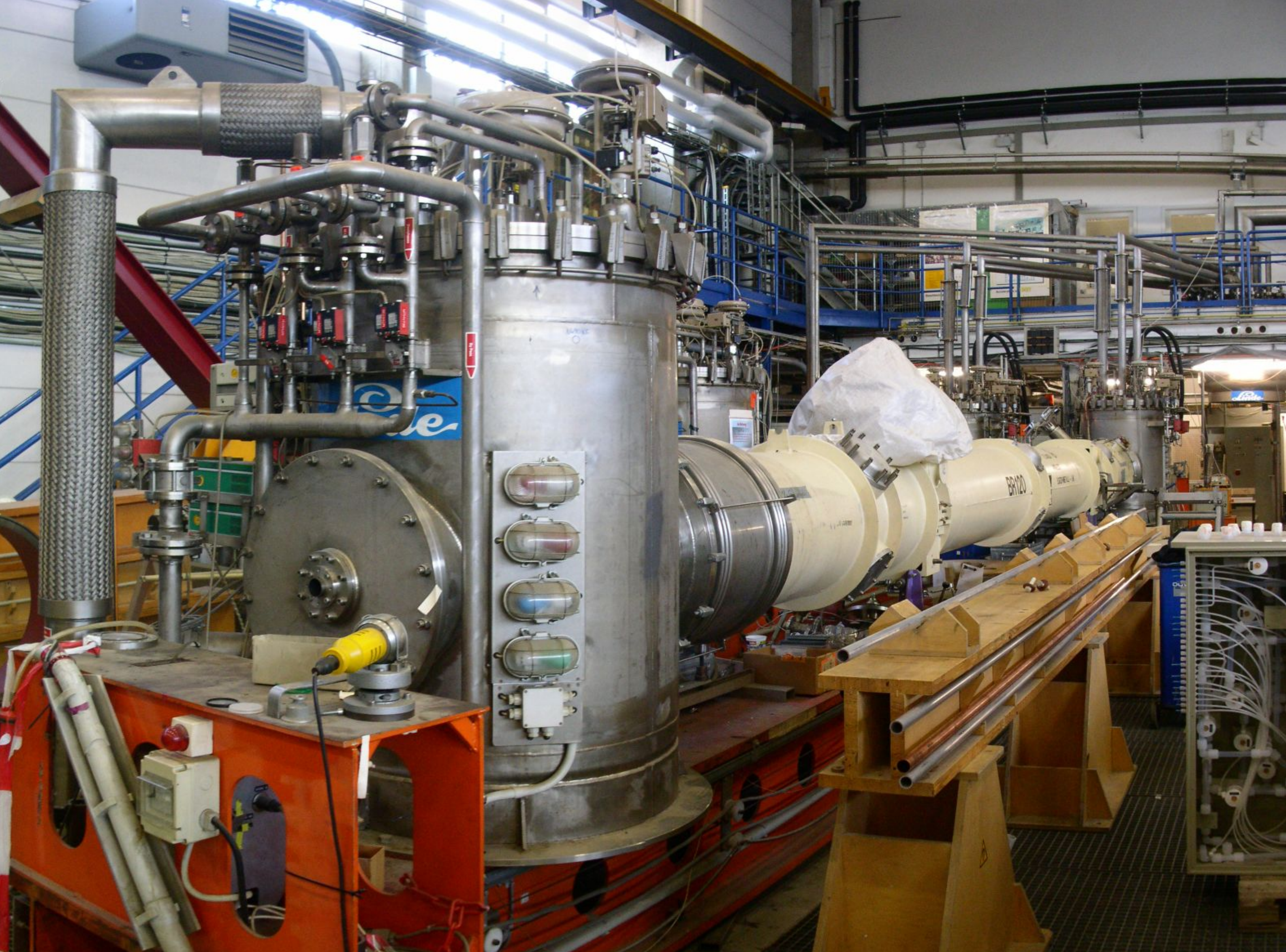
- Magnet
- Magnet insert
- Laser system
- Detector system

Location of ALPS

Magnet: HERA Dipole

- Designed and constructed in the late 1980'ties to keep 920 GeV protons on track
- superconducting
- $B_{max} = 5.6$ T
- magnetic length: 8.4 m

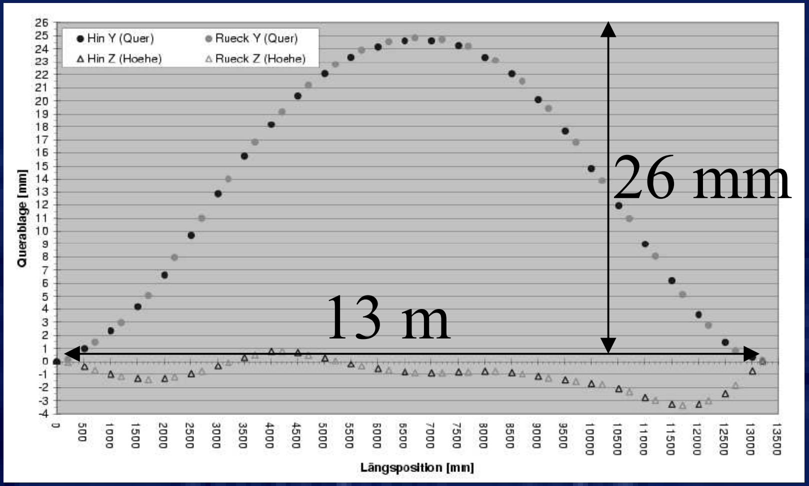
Installed and ready for operation!


BR120

Magnet: HERA Dipole

Magnet: HERA Dipole

- Challenging:
  - the magnet beam pipe is bent and hence the clear aperture is only 18 mm
  - no access to mirror in the middle of the magnet



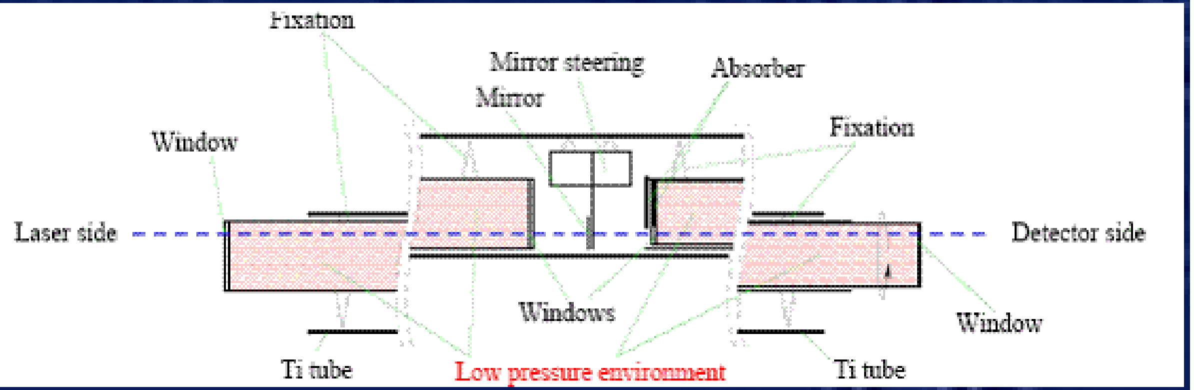
- Important constrain on beam quality of laser

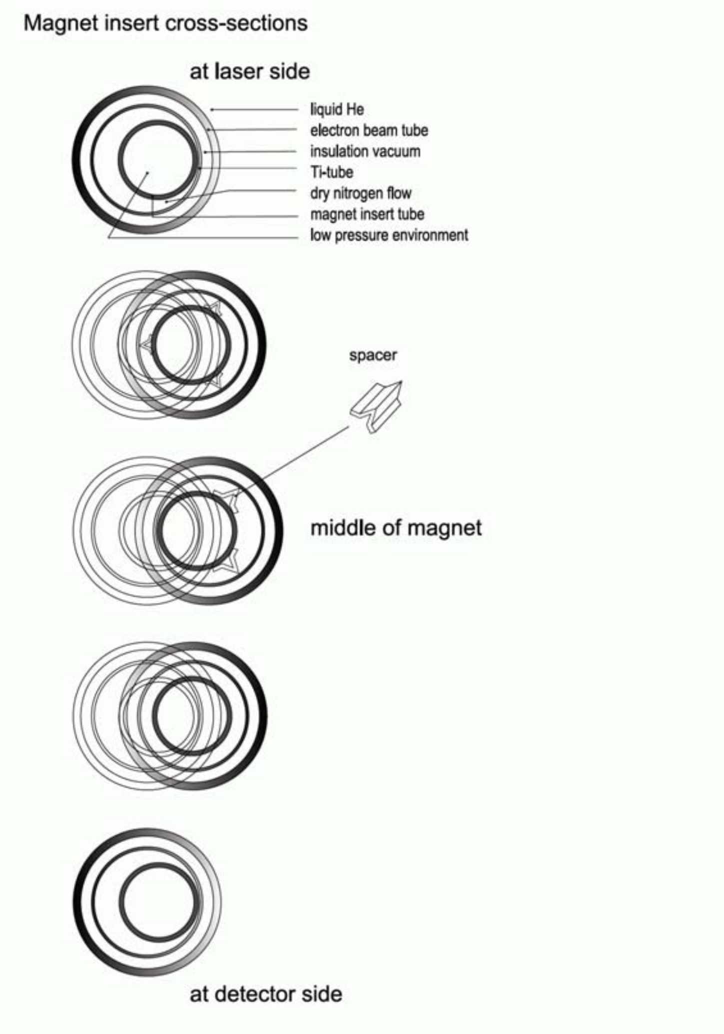
- beam pipe insulated against cold part, can be kept at room temperature

Experimental Considerations

- Magnet ✓
- Magnet insert
- Laser system
- Detector system

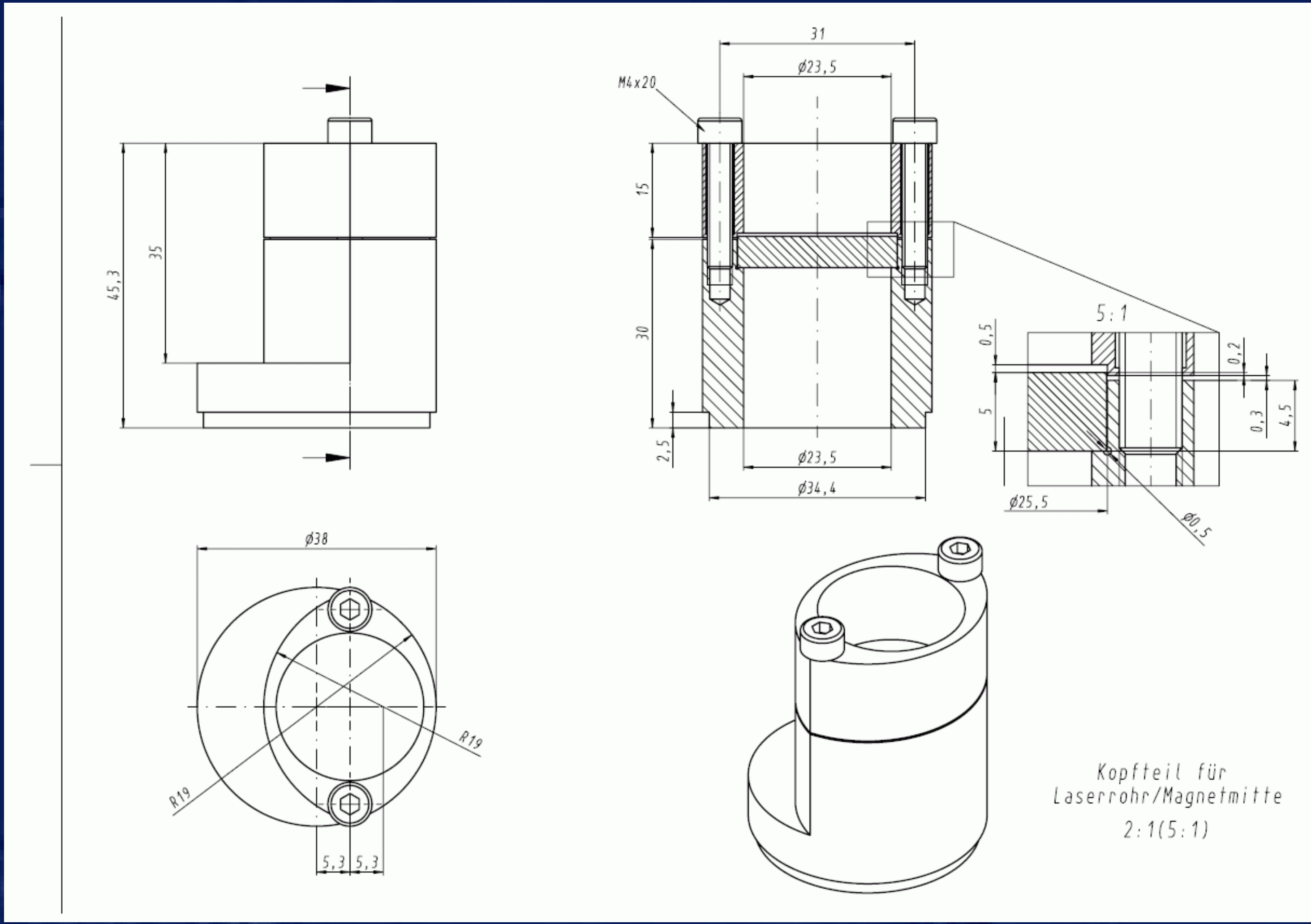
Sketch of Insert



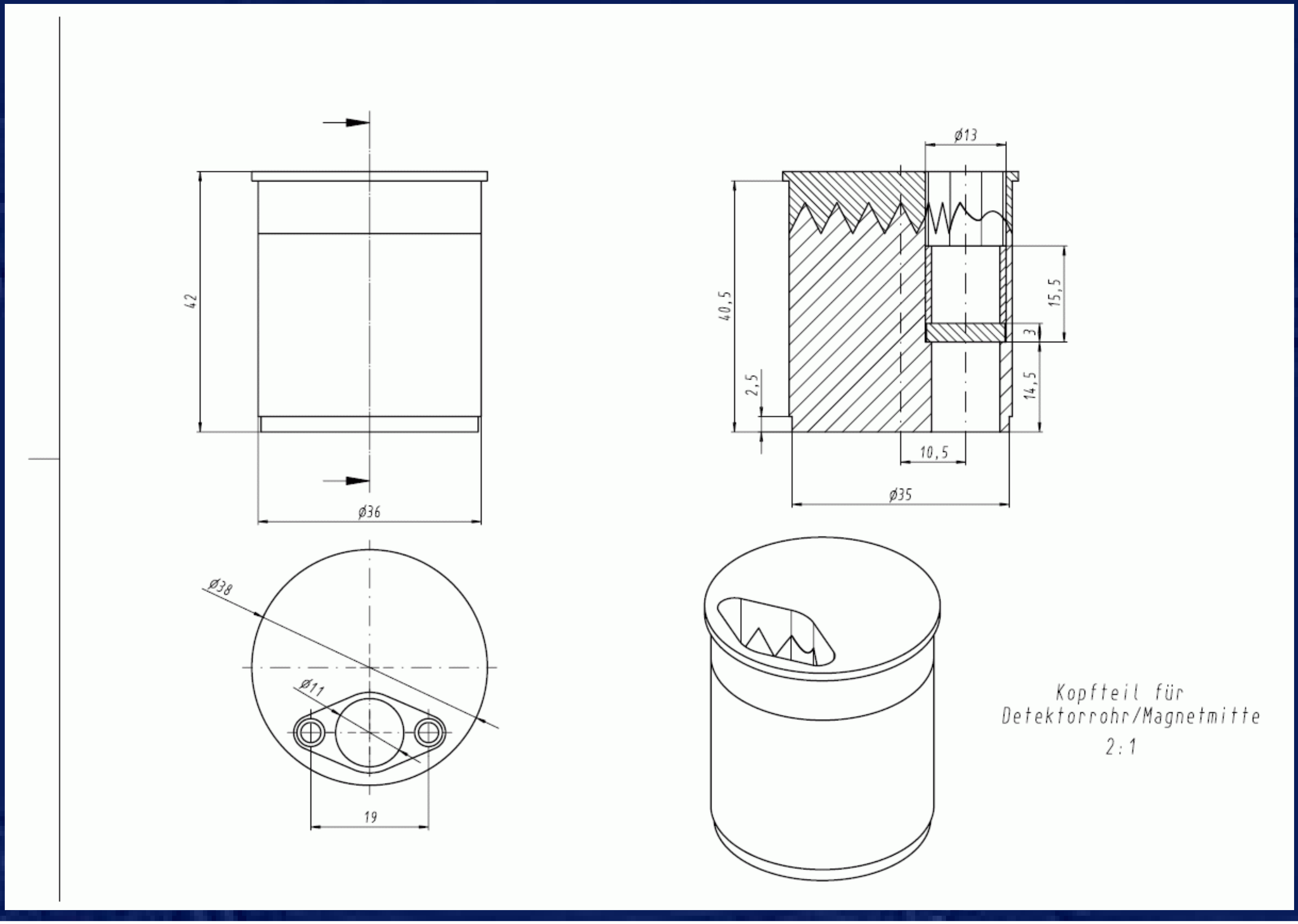


Turning the detector-side tube for alignment with approx. 0.1% fraction of beam intensity passing the mirror

Fix Windows to the Tube

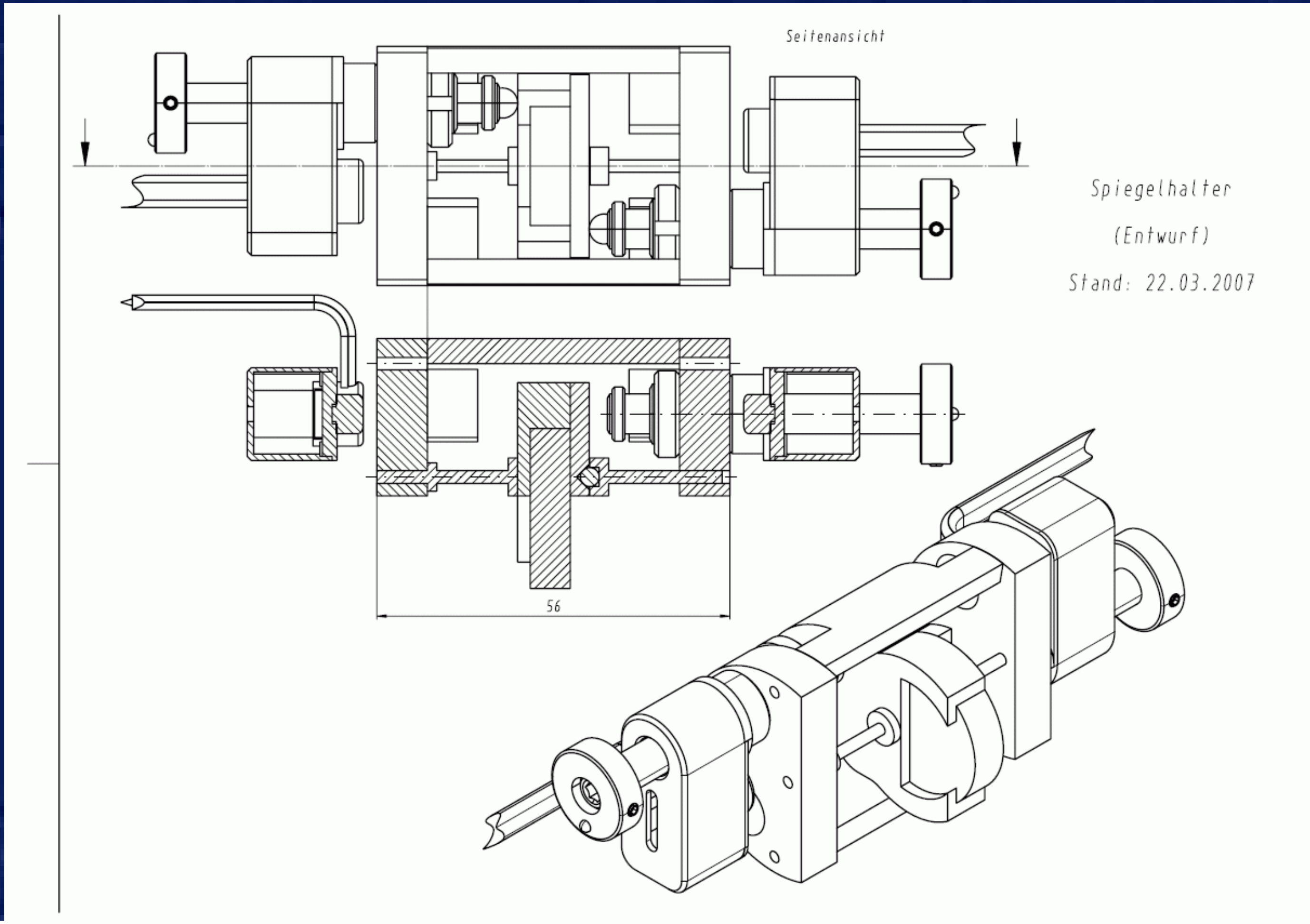


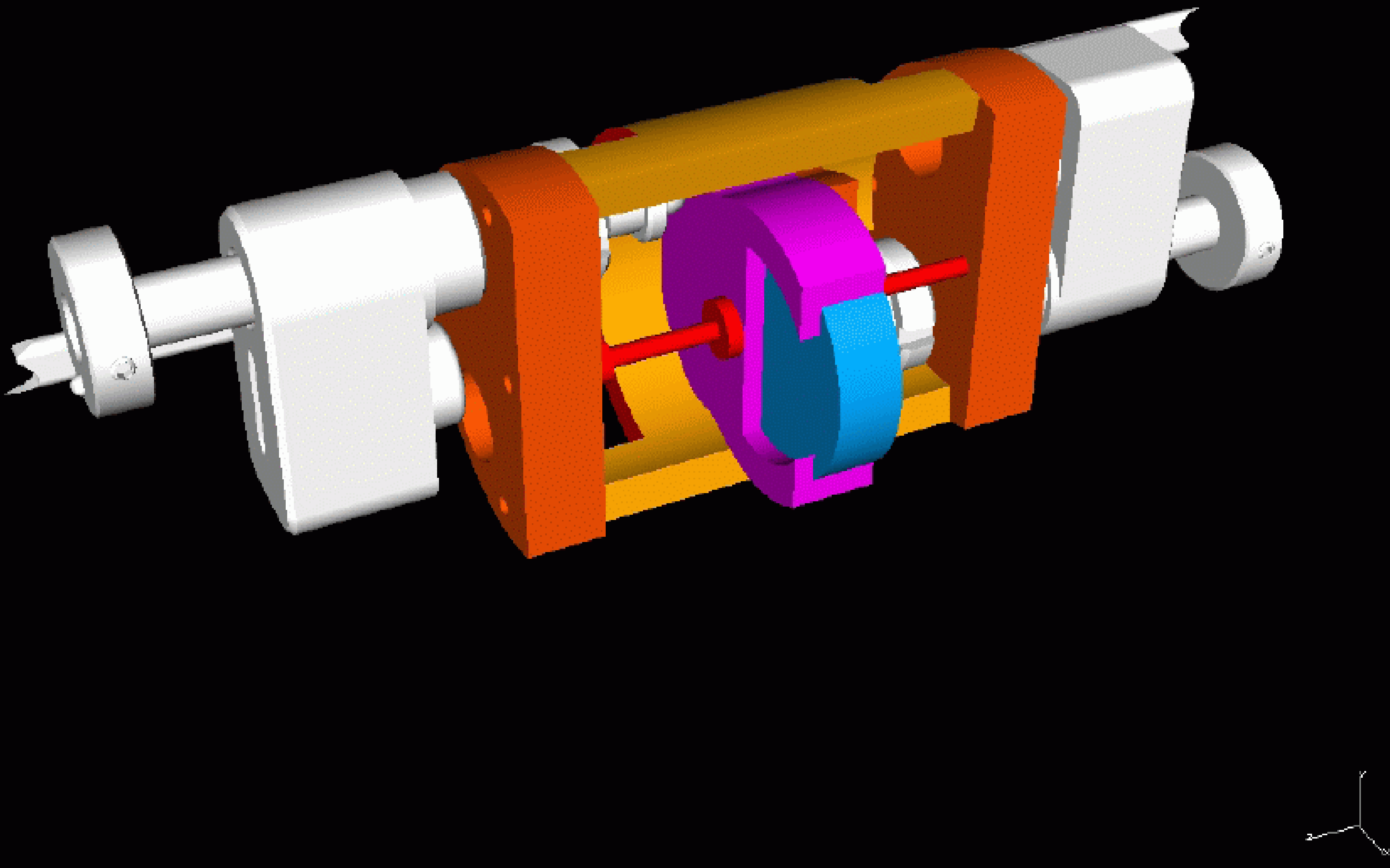
Tube at Detector Side



Mirror Support

(centre of HERA dipole!)

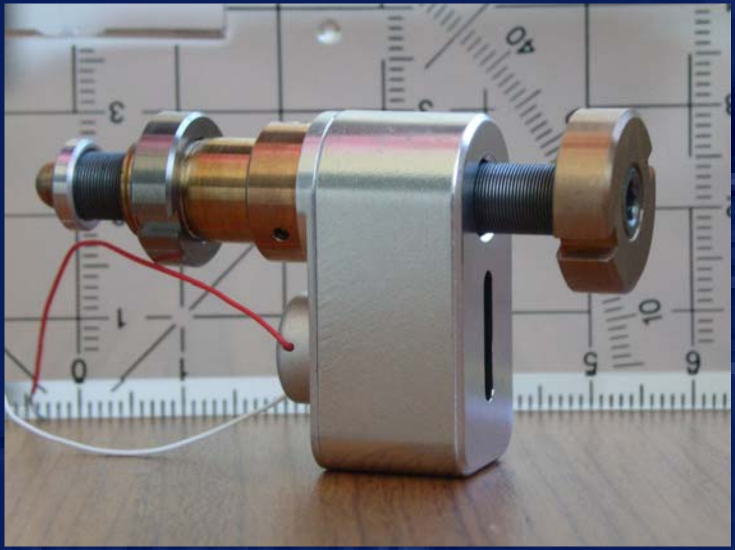




How to move the Mirror?

Movement necessary for alignment

- How to align a mirror deep inside a 5 T magnet?
- dedicated picomotor actuators developed by *New Focus* (molybdenum, copper)



Tested successfully in 5 T field!

Experimental Considerations

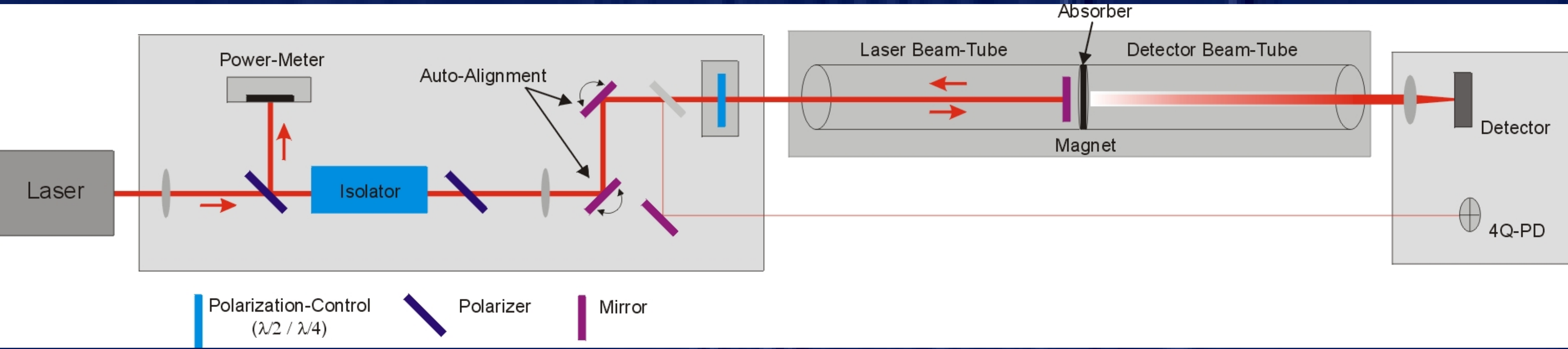
- Magnet ✓
- Magnet insert ✓
- Laser system
- Detector system

Laser System

General considerations:

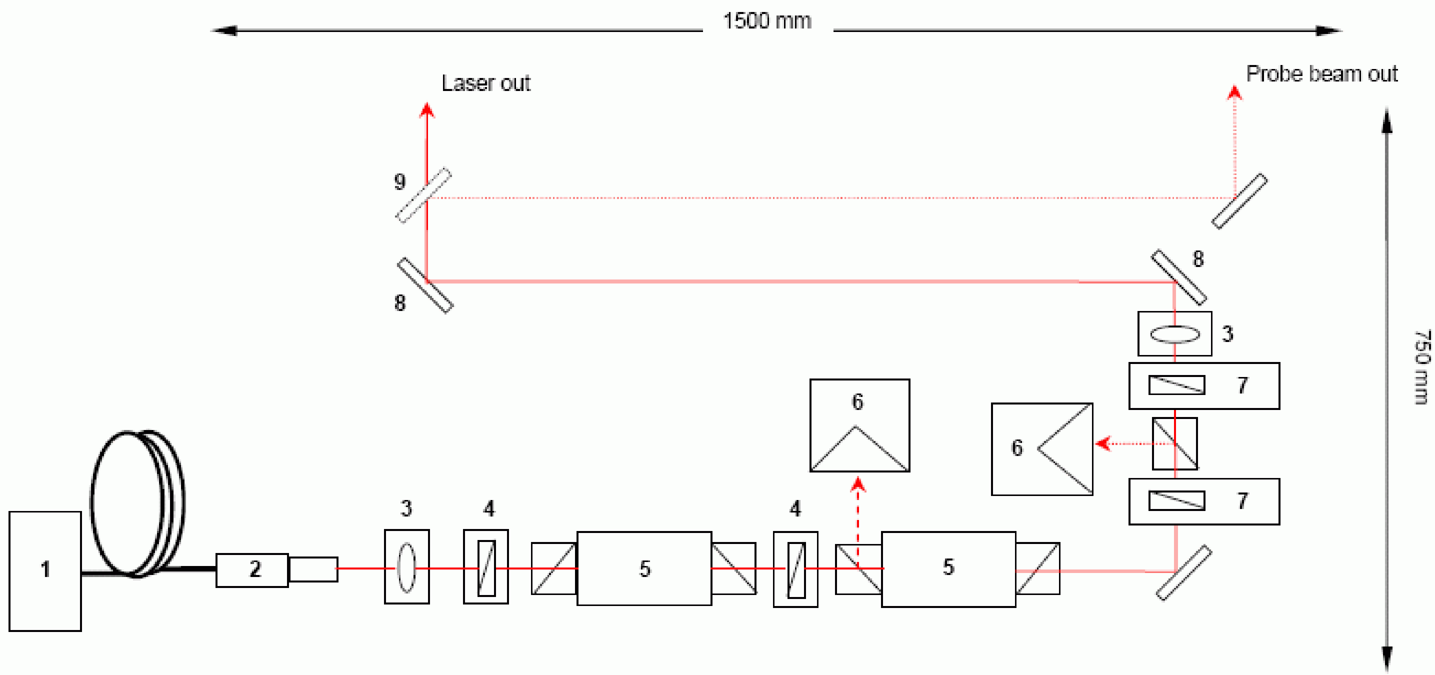
- high photon flux
- linear polarization
- beam quality sufficient to
  - match magnet geometry
  - allow for focusing on small detector element

Setup



Absorber
Power-Meter
Auto-Alignment
Laser Beam-Tube
Detector Beam-Tube
Detector
Magnet
Laser
Isolator
4Q-PD
Polarization-Control
(λ/2 / λ/4)
Polarizer
Mirror

Schematic Laser Setup – LZH



1 IPG laser – 19"-rack
2 IPG fiber connector (QBH compatible)
3 Lens holder
4 λ/2 - waveplate holder
5 Faraday isolator
6 1.5 kW power meter
7 Motorized λ/2 - waveplate holder
8 Piezo-electric transducer mirror
9 AR-coated substrate – probe beam

M. Hildebrandt 10.01.07

Laser System: Beam Quality

- Avoid diffraction losses at laser entrance window:
  beam diameter σ < 2/π d (entrance window) ⇨ σ < 12 mm

- Propagation of a Gaussian beam inside the laser beam tube:

$$\sigma(z) = \sigma_0 \cdot \sqrt{\frac{z^2 \cdot \lambda \cdot M^2}{\pi \cdot \sigma_0{}^2 / 4}}$$

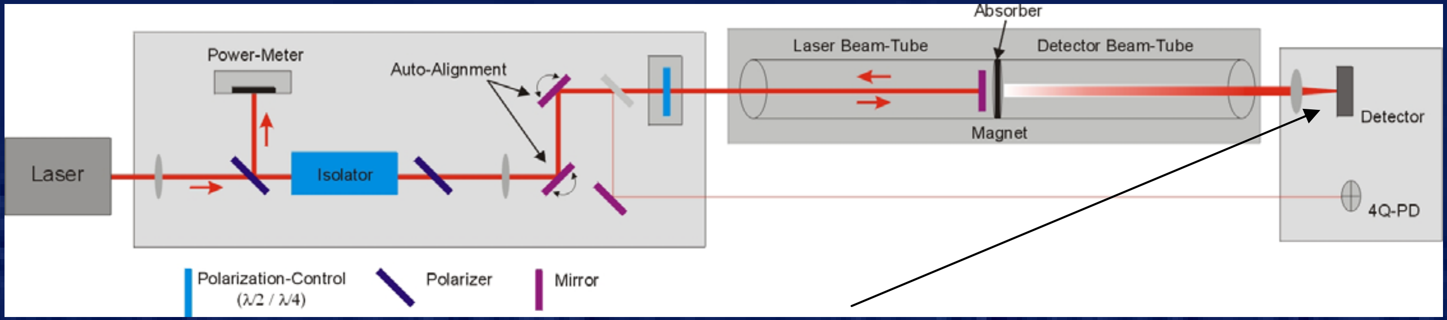
z = coord. along beam

M^2 = beam quality

$$M^2 = \sigma_0 \cdot \Theta \cdot \frac{\pi}{\lambda}$$

Θ = divergence angle

Focus Spot Size



The secondary photons should be focused on a small spot size to allow for a small detector (element) with low noise.

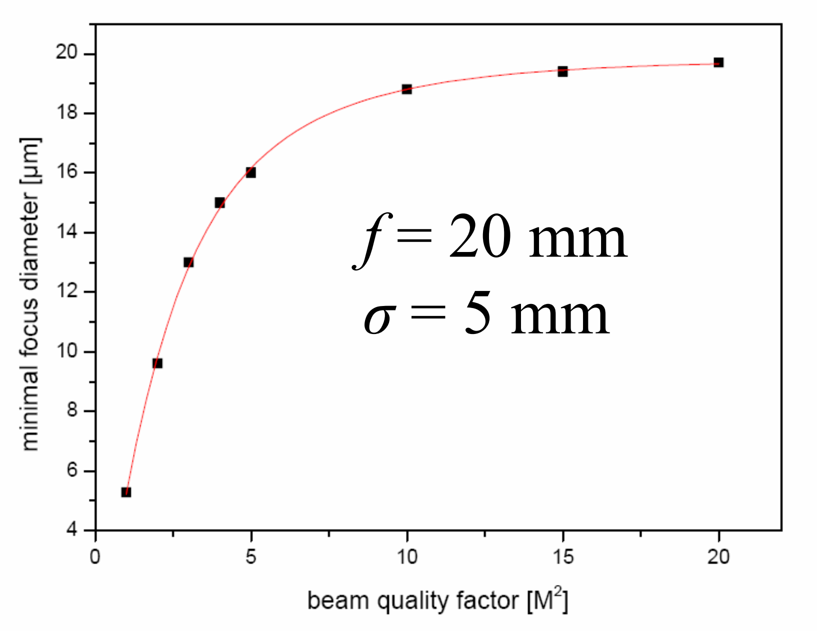
The beam of secondary photons has the same properties as the laser beam. Therefore the possible focus spot size of the laser beam is discussed.

focus spot size: $$\sigma_{\min} = \frac{\lambda \cdot f \cdot M^2}{\pi \cdot \sigma}$$

f = focal length

σ = spot size on lens

Focus Spot Size



Spot sizes in the range of 15 µm possible for beams with qualities $M^2 < 5$

Focus spot size comparable to pixel size of digital cameras!

How to choose λ

- Signal proportional to photon number flux provided by the laser: S [Hz]
- To be optimized:
  Time to measure a significant signal taking into account a detector background rate B [Hz]

$$\frac{S \cdot t}{\sqrt{2 \cdot B \cdot t}} > 5 \iff t > 25 \cdot \frac{2 \cdot B}{S^2}$$

S [Hz]	B [Hz]	t [s]
5	1	2
5	10	20
0.5	0.1	20

Optimize system of camera (“B”) and laser (“S”)!

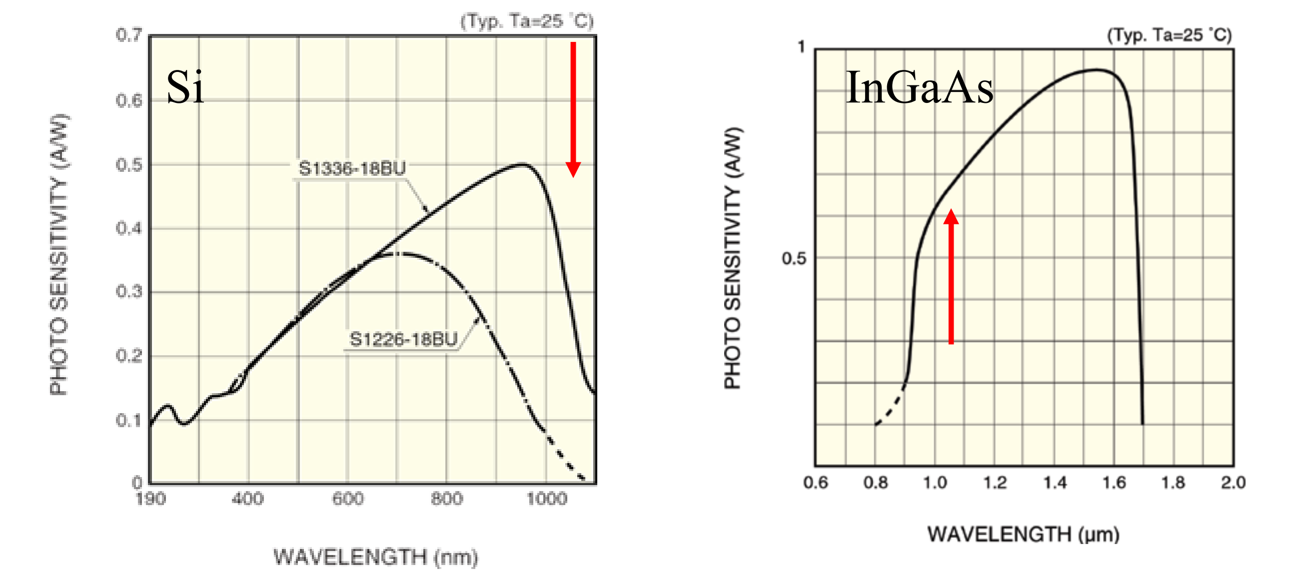
Possible Laser

High power lasers with sufficient beam quality:
fiber laser (Nd:YAG) at 1064 nm (http://www.ipgphotonics.com).

- multi 100W fiber laser @ ≈1064 nm
- "industry standard": easy to operate, reliable
- $M^2 < 1.15$
- linear polarized
- Critical issues:
  - maximize output power *(500 W not demonstrated yet)*

Possible Detectors

Low background detectors for 1064 nm

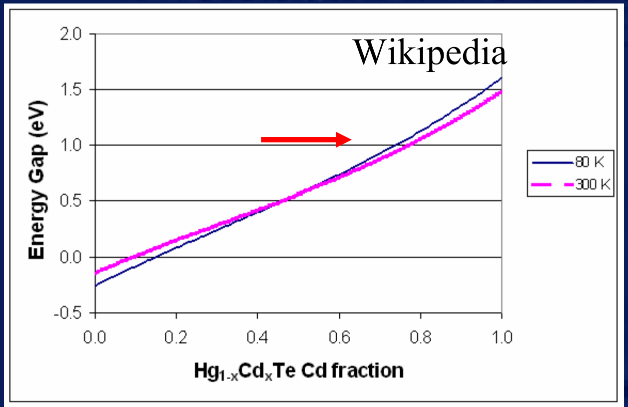


http://www.hamamatsu.com

Si: very low QE at 1064 nm

Possible Detectors

"dream detector" option for 1064 nm:
mercury-cadmium-telluride used in infrared astronomy



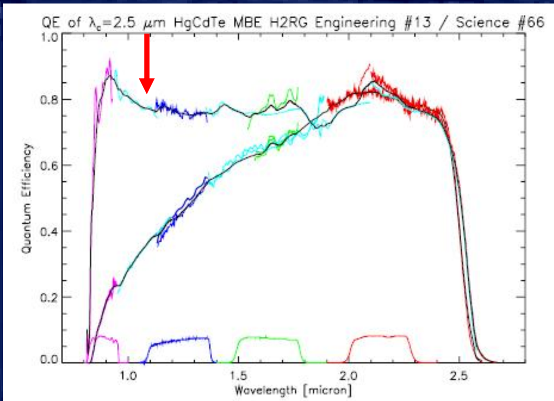


Figure 6 Quantum efficiency of λc=2.5 μm Hawaii-2RG engineering grade and science grade arrays. Transmission of band-pass filters is indicated at the bottom.

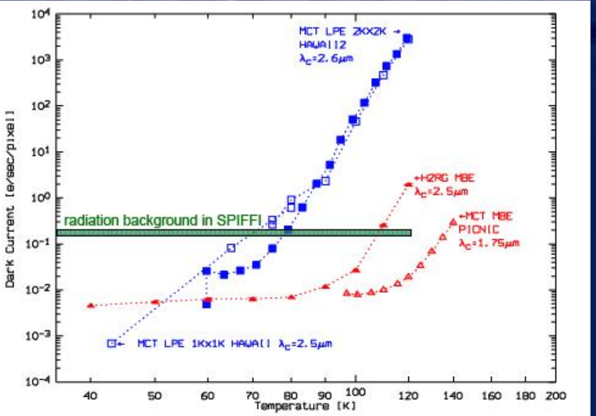


Figure 3 Dark of HgCdTe arrays current versus temperature. Squares: LPE material. (empty squares is Hawaii1 1Xx1K and filled squares is Hawaii2 2Kx2K). Triangles: MBE on CdZnTe substrate. (filled triangles is λ_c=2.5 μm Hawaii-2RG array and empty triangles is λ_c=1.7 μm PICNIC array).

G. Finger et al., NIM A (2005)

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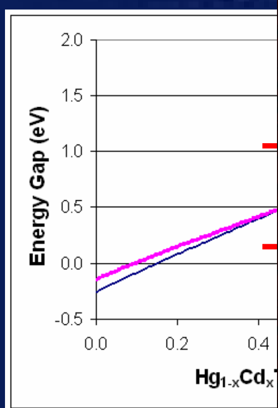
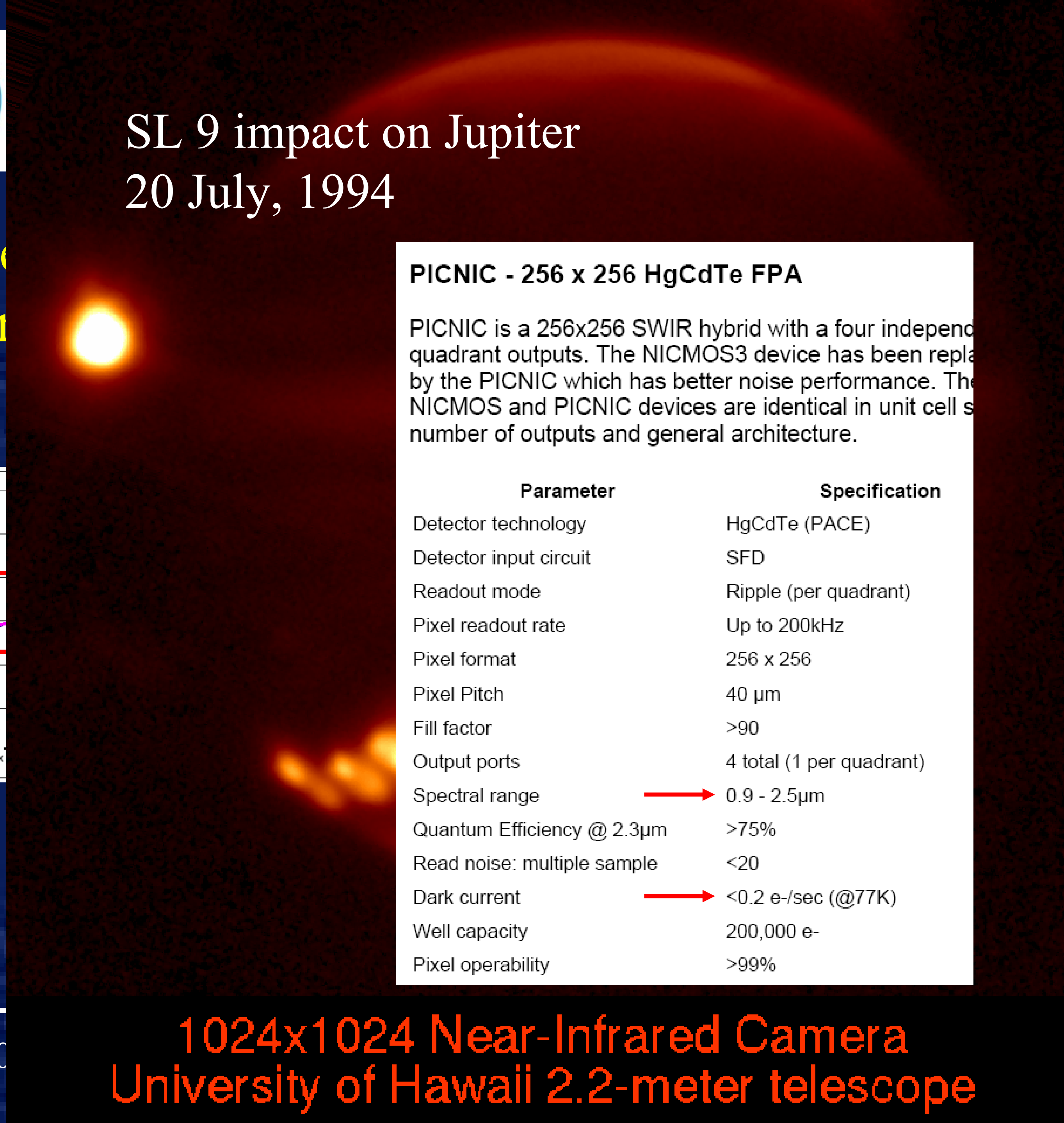
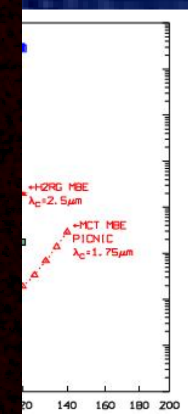




PICNIC - 256 x 256 HgCdTe FPA

PICNIC is a 256x256 SWIR hybrid with a four independ
quadrant outputs. The NICMOS3 device has been repla
by the PICNIC which has better noise performance. The
NICMOS and PICNIC devices are identical in unit cell s
number of outputs and general architecture.

Parameter	Specification
Detector technology	HgCdTe (PACE)
Detector input circuit	SFD
Readout mode	Ripple (per quadrant)
Pixel readout rate	Up to 200kHz
Pixel format	256 x 256
Pixel Pitch	40 µm
Fill factor	>90
Output ports	4 total (1 per quadrant)
Spectral range →	0.9 - 2.5µm
Quantum Efficiency @ 2.3µm	>75%
Read noise: multiple sample	<20
Dark current →	<0.2 e-/sec (@77K)
Well capacity	200,000 e-
Pixel operability	>99%



erature. Squares:
filled squares is
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triangles is λ_c=1.7

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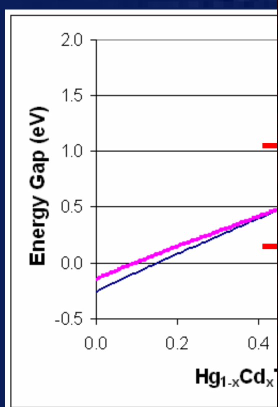
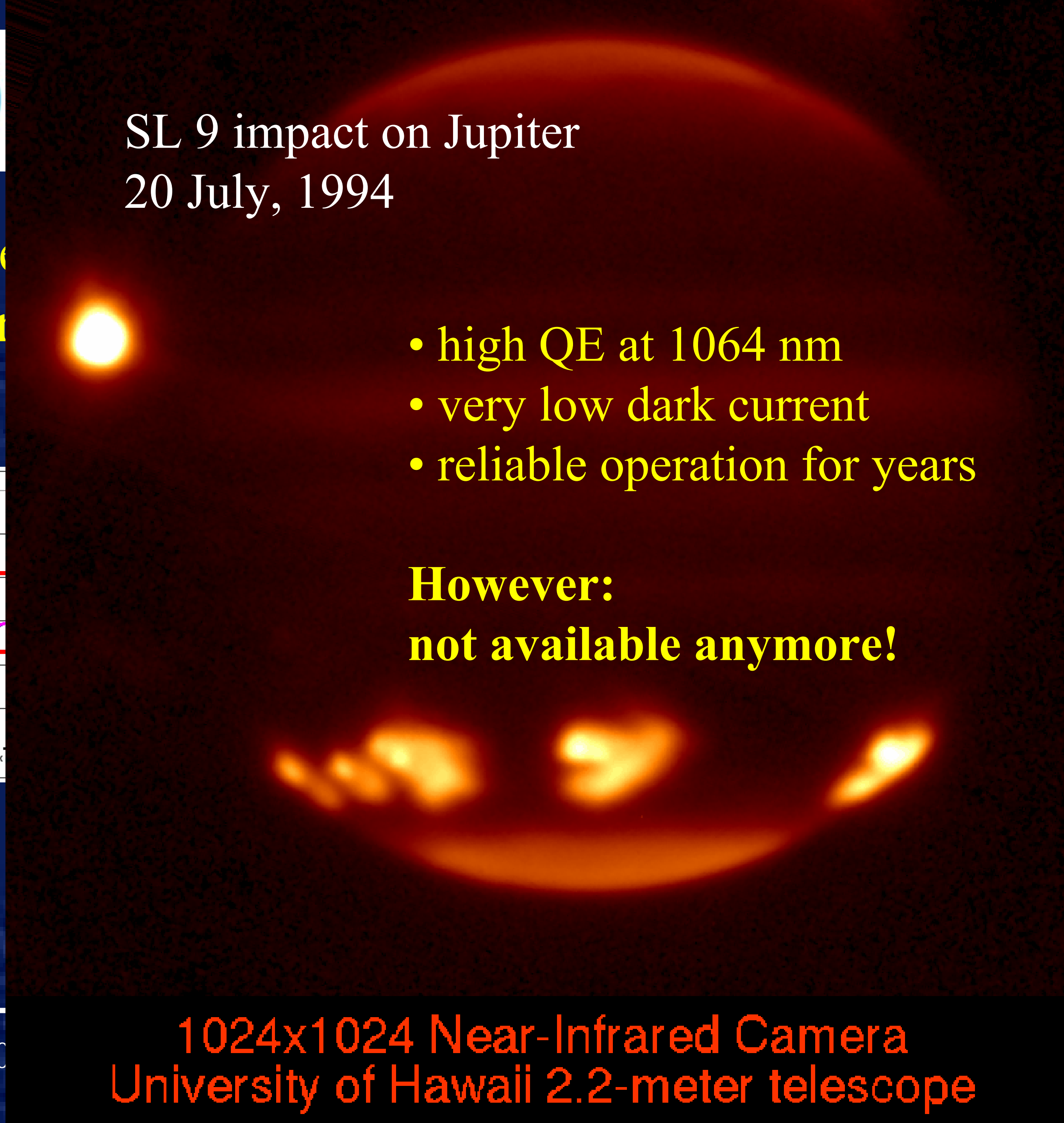
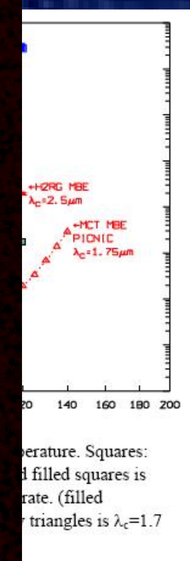


2.0
1.5
1.0
0.5
0.0
-0.5
Energy Gap (eV)
0.0
0.2
0.4
Hg1-xCdx



SL 9 impact on Jupiter
20 July, 1994
• high QE at 1064 nm
• very low dark current
• reliable operation for years
However:
not available anymore!
1024x1024 Near-Infrared Camera
University of Hawaii 2.2-meter telescope



140
160
180
200
erature. Squares:
l filled squares is
rate. (filled
triangles is λc=1.7

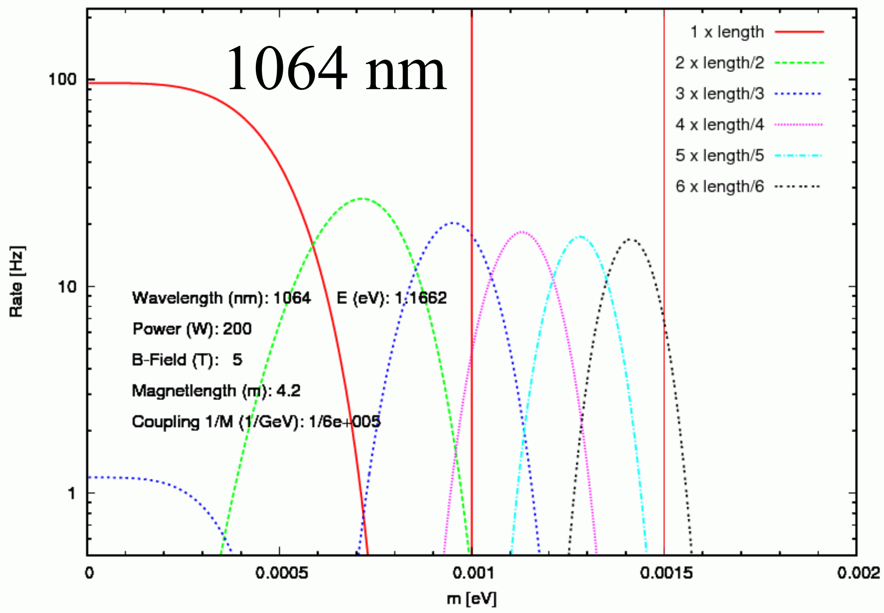
Available infrared Detector

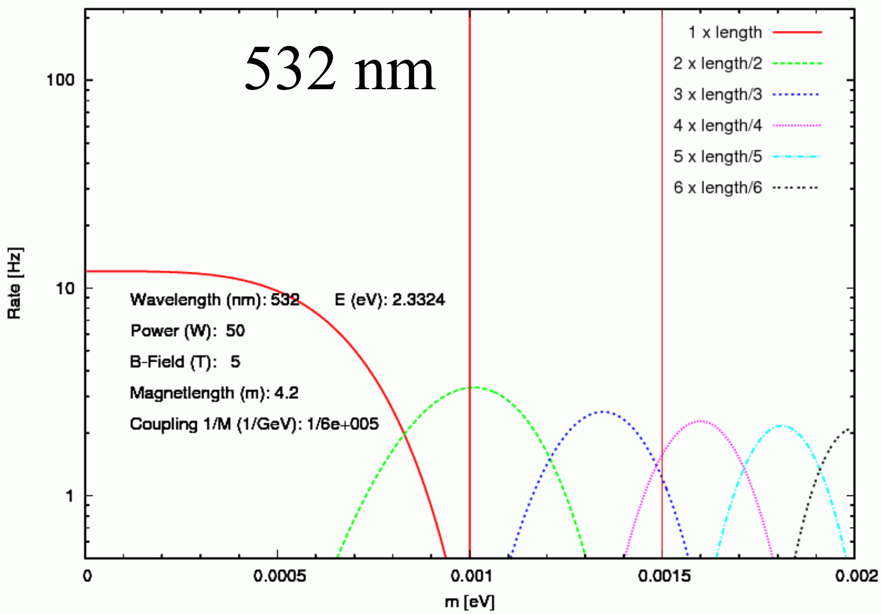
SWIR InGaAs MicroCam (Teledyne)

- dark current < 8e-/sec (40 · HgCdTe!)
- long delivery time
- necessity of R&D (by Teledyne)?

Therefore: switch to another wavelength?

532 vs. 1064 nm





50 W laser at 532 nm sufficient to clarify PVLAS/BFRT

532 vs. 1064 nm

Advantages and disadvantages of 532 nm compared to 1064 nm:

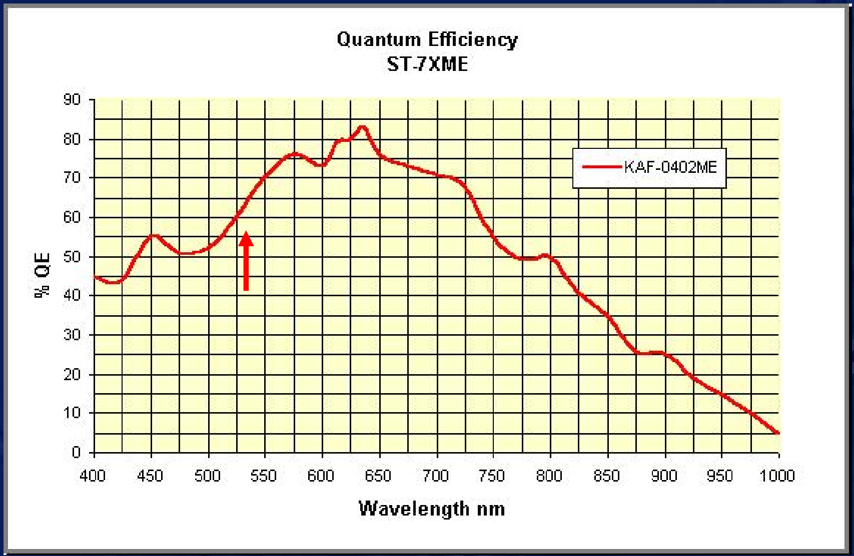
- Laser power about 50 instead of 200 W:
  Rate factor ≈ 8 smaller
- Only 3 instead of 6 retardation plates
- 1064nm: cw operation   532nm: pulsed 15-25 kHz
  at 532 nm background suppression by triggering possible
- 532 nm: detector systems with very low noise available:
  overcompensation of rate loss
- 532 nm: light is visible!
  simplified operation

Decision: first stage 532 nm

preliminary time schedule

- Laser Zentrum Hannover will develop a laser system by end of July 2007
- System at DESY in August 2007
- Detector at hand:

SBIG ST-407



- **CCDCCD** Kodak KAF-0402ME
- **Pixel Array** 765 x 510 pixels
- **CCD Size** 6.9 x 4.3 mm
- **Total Pixels** 390,000
- **Pixel Size** 9 x 9 microns
- **Full Well Capacity** ~100,000 e-
- **Dark Current** 1e-/pixel/sec at 0° C

Many others (superior) commercial systems available!

Status and next Steps

- Mainly due to problems with detector purchase some delay of ALPS schedule
- Now decided to start with 532 nm instead of 1064 nm
- July 2007:
  decision on configuration of 532 nm option
- August 2007: 532 nm laser system at DESY
- End of August 2007: start data taking at 532 nm
- September 2007:
  decision on 1064 nm option as 2nd step of ALPS

Infrastructure is being set up

Infrastructure is being set up

Infrastructure is being set up

If we see a Signal …

… there are several ways to prove its ALP origin:

1. dependence on polarization orientation: distinguish $J^P = 0^+$ and 0^-

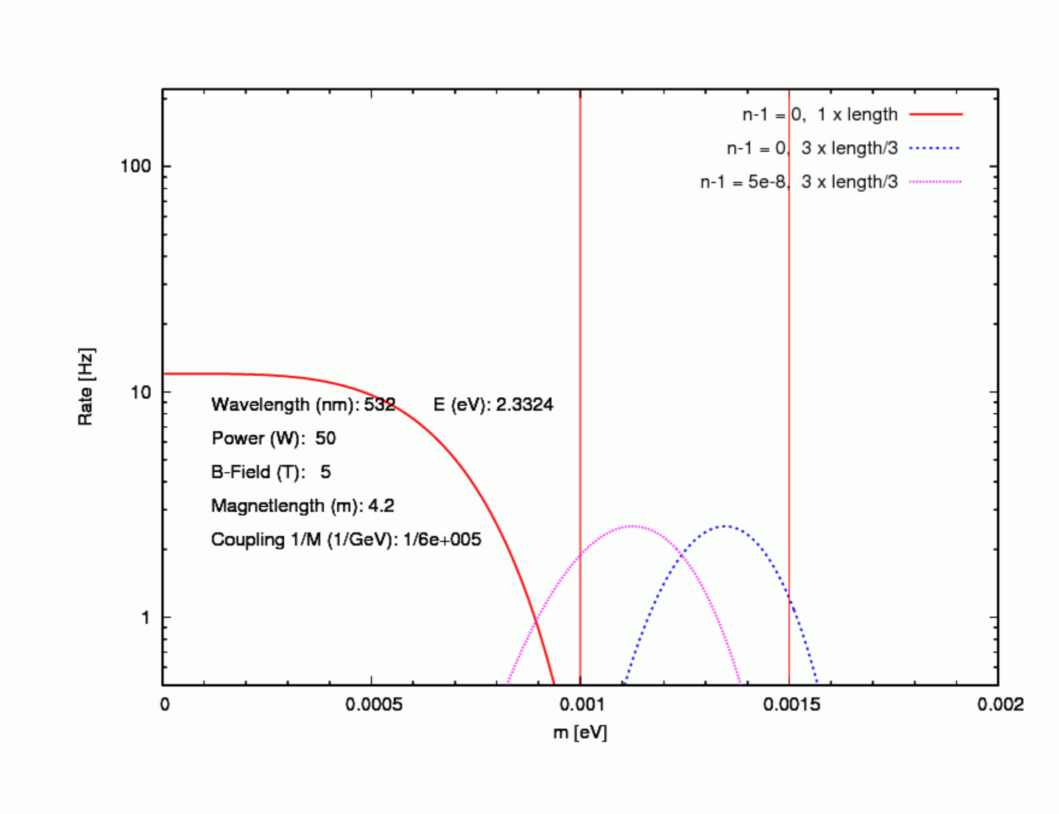
2. dependence on magnetic field strength:

$$\dot{N} = f(B^4)$$

If we see a Signal …

… there are several ways to prove its ALP origin:

3. dependence on refraction index (gas pressure):



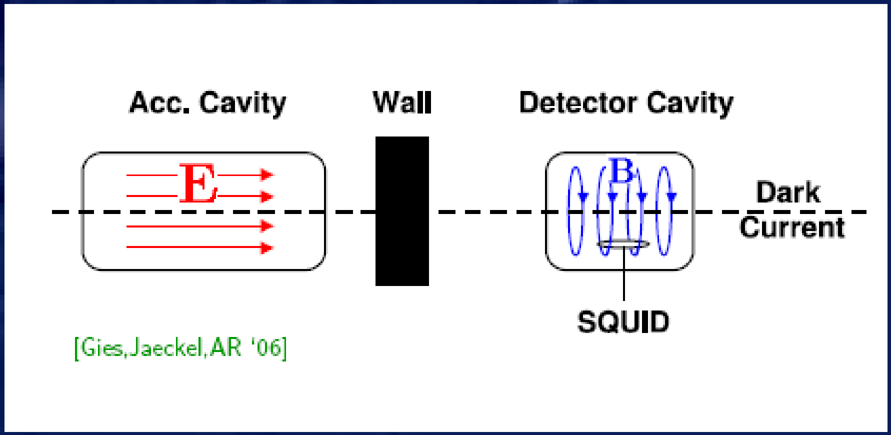
Possibility to determine mass of ALP!

If we do not see a Signal …

… there are several ways for future experiments:

1. Has ALPS the sensitivity to look for paraphotons?
   M. Ahlers, H. Gies, J. Jäckel, J. Redondo, A. Ringwald
   on the preprint archive today: hep-ph 0706.2836

2. PVLAS anomaly may be explained by millicharged particles: could be probed by dark current of accelerator cavities



Regeneration Plans worldwide

Table 1

name	place	magnet (field length)	laser wavelength power	P_{PVLAS}	photon flux at detector
ALPS	DESY	5 T 4.21 m	1064 nm 200 W cw	$= 10^{-19}$	10/s
BMV	LULI	11 T 0.25 m	1053 nm 500 W 4 pulses/day	$= 10^{-21}$	10/pulse
LIPSS	Jefferson Laboratory	1.7 T 1.0 m	900 nm 10 kW cw	$= 10^{-23.5}$	0.1/s
OSQAR (preliminary phase)	CERN	9.5 T 1.0 m 9.5 T 3.3 m	540 nm 1 kW cw	$= 10^{-20}$	10/s
PVLAS (regeneration)	INFN Legnaro	5 T 1 m 2.2 T 0.5 m	1064 nm 0.8 W cw Npass $= 5 \times 10^5$	$= 10^{-23}$	10/s

A. Lindner, K. Zioutas, *CERN Courier* March 2007

Now also GammeV at Fermilab

LHC ILC

meV scale

neutrinos, DE, PVLAS

"Spin-off"

hep-ph 0704.0490

Long Distance Signaling Using Axion-like Particles

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Abstract

The possible existence of axions or axion-like particles could lead to a new type of long distance communication. In this letter, basic antenna concepts are defined and a Friis-like equation is derived to facilitate long-distance link calculations. An example calculation is presented showing that world-wide signaling may be possible if the axion interpretation of the recent PVLAS experiment is confirmed.

Summary

- The "low energy frontier" is exciting.
  - A lot of interest also by the press and media
- "Table top" experiments might contribute significantly to particle physics (and cosmology).
- ALPS could be one of the first experiments to clarify the axion-like particle interpretation of the PVLAS anomaly.

Summary (cont.)

- Independent of ALPS result:

  many fascinating physics ideas for the years to come in the “new” (?) field of “table top” particle physics.

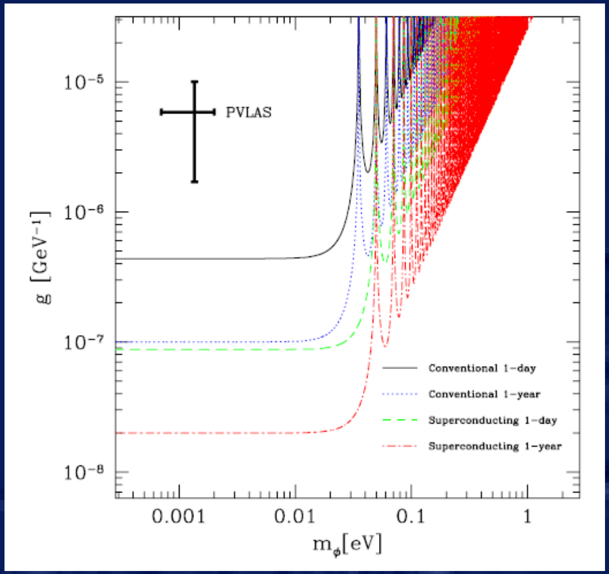
- New light sources will be available!

Future Dreams …

PRL 96, 110407 (2006) PHYSICAL REVIEW LETTERS week ending 24 MARCH 2006

Photon Regeneration from Pseudoscalars at X-Ray Laser Facilities

Raúl Rabadán,[1,*] Andreas Ringwald,[2,†] and Kris Sigurdson[1,‡]
[1]*Institute for Advanced Study, Einstein Drive, Princeton, New Jersey 08540, USA*
[2]*Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany*
(Received 5 December 2005; published 24 March 2006)



Fundamental physics at a new generation of light sources:

X-ray Free Electron Lasers

Thanks to the ALPS Team!

K. Ehret, E.-A. Knabbe, (U. Kötz), AL, N. Meyer,
D. Notz, A. Ringwald
DESY

G. Wiedemann
Hamburger Sternwarte

M. Frede, M. Hildebrandt, D. Kracht
Laser Zentrum Hannover