PVLAS experiment:
Measurement of optical properties of quantum vacuum

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Short introduction to PVLAS

- goal of the PVLAS experiment
- experimental technique

- Recent results
  - IR laser (1064 nm ~ 1 eV photon energy)

- Future
  - photon regeneration
PVLAS Theme and goal

**Theme:**
Vacuum as a “target”: low energy photon-photon collider
- QED interactions
- other interactions?

**Goal:**
Measure the *magnetically induced linear birefringence and optical rotation* of the Vacuum element (in practice a gas in the zero-pressure limit)

*Possible contributions to macroscopic properties*
- photon-photon scattering
- production of: neutral bosons, ?
PVLAS Experimental apparatus
- high sensitivity heterodyne ellipsometer

- measures changes in light polarization due to magneto-optical properties of the sample

- by inserting/removing QWP we can measure rotations/ellipticities

- signal dependence: - magnetic field
  - optical path length in the magnetic field region
PVLAS Experimental apparatus
- high sensitivity heterodyne ellipsometer, main parameters

- magnet
  • dipole, 6 T, temp. 4.2 K, 1 m field zone

- cryostat
  • rotation frequency ~300 mHz, sliding contacts, warm bore to allow light propagation in the interaction zone

- laser
  • 1064 nm, 100 mW, frequency-locked to the F.-P. cavity

- Fabry-Perot optical cavity
  • 6.4 m length, finesse ~100000, optical path in the interaction region ~ 60 km

- heterodyne ellipsometer
  • ellipticity modulator (SOM) and high extinction ($\sim 10^{-7}$) crossed polarisers
  • time-modulation of the effect

- detection chain
  • photodiode with low-noise amplifier

- DAQ
  • demodulated at low frequency and phase-locked to the magnetic field instantaneous direction
  • high sampling frequency direct acquisition
PVLAS Test measurements
- Cotton – Mouton in gas, birefringence

PVLAS Test measurements
- Cotton – Mouton in gas, phase and amplitude information

- Points represent 100 s long data records, various gas pressures, B=5.5 T
- Phase and amplitude information
- All points lie on the physical axis

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PVLAS IR results
- rotation in vacuum, spectra comparison

magnet off

magnet on
PVLAS IR results

- points represent 100 s long data records
- data taken at 5 T, with 44000 passes in the FP cavity

Note the sign change of the distribution under a QWP axis exchange
$\rho_0 = (3.9 \pm 0.5) \cdot 10^{-12}$ rad/pass

[E. Zavattini et al., hep-ex/0507107, PRL accepted]
PVLAS Discussion on IR results

Diagnostic tests made

- excluded
  - electrical pick-up
  - residual gas pressure
  - mirror coating birefringence
  - polarizer movement (Faraday?)
  - diffusion from magnetised surfaces

- open questions
  - beam pointing instability?
  - presence of a true physical signal?
PVLAS Possible interpretation
- light scalar/pseudoscalar boson production

\[ \rho_\phi = g_{\phi\gamma}^2 \frac{2FB_0^2 \omega^2}{\pi m_\phi^4} \sin^2 \left( \frac{m_\phi^2 L}{4\omega} \right) \sin(2\theta) = g_{\phi\gamma}^2 \frac{FB_0^2 L^2}{8\pi} \]

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**PVLAS Possible interpretation**
- comparison with previous measurements

\[1.7 \times 10^5 \, \text{GeV} < M_b < 5.6 \times 10^5 \, \text{GeV}\]
\[1 \, \text{meV} < m_b < 1.5 \, \text{meV}\]

BFRT see [R. Cameron et al., Phys. Rev. D 47, 3707 (1993)]

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PVLAS Mixing
- rotation in gas

\[ f_{\text{mix}}(p,M,m) = \frac{1}{4} \left( \frac{BL}{2M} \right)^2 \sin \left( \frac{2p_{\text{gas}}(n_{\text{gas}} - 1)\omega^2}{p_{\text{am}} + m^2} \right) L \]
PVLAS Mixing?
- rotation in gas, IR Data

- subjected to further investigation
- systematic effects subtracted – linear and under control

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PVLAS Recent developments

- incident photon energy changed
  1064 nm (~1 eV) infrared > 532 nm (~2 eV) green

- 2 runs (60 hours of data acquisition)
  - sensitivity worse than IR

- analysis in progress, effect present

- up to now results are compatible with IR measurements
PVLAS Physical tests

Photon regeneration

- already done at BNL

- to be done with PVLAS apparatus

- ongoing project
  - DESY
PVLAS Photon regeneration scheme

PVLAS parameters

production
1 m
5.5 T
$10^{22}$ photons in cavity

regeneration
0.5 m
2.5 T

counting rate
1 photon/s

magnet, photon regeneration region
detector
PVLAS Conclusions

- we have an unexpected rotation signal whose physical origin has yet to be determined

- up to now, compatibility between results with two different wavelengths (analysis in progress)

- now, IR run:  - more photons in cavity
  - different photon source
  - confirmation of previous results?

- near future:  - new amagnetic access structure

- not so distant future:  - powerful physics test
  (photon regeneration at PVLAS)
PVLAS The End