CERN, 3rd December 2007

CERN-SPSC-2007-039
SPSC-M-762

M E M O R A N D U M

To: J. B. Dainton (Chairman of the CERN/SPSC), U. Wiedemann, M. Erdmann, and M. Mannelli

Cc: J. Engelen, Ph. Lebrun, S. Myers, J. J. Blaising, and L. Walckiers

From: R. Ballou, B. Barbara, L. Duvillaret, R. Jost, M. Finger, J. Hošek, K.A. Meissner, P. Pugnat, A. Siemko, M. Šulc, and J. Zicha*

Subject: **Summary of OSQAR First Achievements and Main Requests for 2008**

Abstract - In the first paragraph, OSQAR foremost achievements are summarised together with a brief reminder of its scientific context. In the second paragraph, activities planned for 2008 are briefly reviewed including the expected scientific results. The third paragraph is devoted to the requests addressed to CERN as the host laboratory and as a collaboration member of the OSQAR photon regeneration experiment.

1. Summary of OSQAR First Achievements

Recent intensive theoretical[1,2,3,4,5,6,7,8,9,10,11,12] and experimental[13,14,15,16] studies shed light on possible new physics beyond the standard model, which can be probed with sub-eV energy experiments. They were mainly triggered by the observation of the PVLAS collaboration[17], eventually disclaimed[18,19], of a rotation of polarization for light propagating in the vacuum permeated by a transverse magnetic field. The OSQAR project[20] proposed to investigate such possibilities at CERN by re-using superconducting dipole prototypes and related infrastructure developed for the LHC. The state-of-the-art superconducting magnets will be combined to innovative optical techniques to provide unique opportunities in the emerging field of laser-based particle physics.

1.1. OSQAR Photon Regeneration Experiment

As a short reminder, the OSQAR photon regeneration experiment is based on the following underlying mechanism. When submitted to a transverse magnetic field, properly polarized photons can couple to weakly interacting scalar or pseudo-scalar particles like axions to

---

* **On the behalf of the OSQAR collaboration** for Optical Search of QED vacuum magnetic birefringence, Axion and photon Regeneration :

Dr. R. Ballou, Dr. B. Barbara	Institut Néel, CNRS, Grenoble, France
Prof. L. Duvillaret, Dr. G. Vitrant	Minatec, INPG, Grenoble, France
Prof. R. Jost, Dr. D. Romanini	LSP, UJF/CNRS, Grenoble, France
Prof. M. Finger, Dr. M. Finger	Charles University, Prague, Czech Republic
Dr. Jan Hošek, Dr. M. Král, Dr. M. Virius, Prof. J. Zicha	Czech Technical University, Prague, Czech Republic
Prof. K.A. Meissner, A. Hryczuk	University of Warsaw, Poland
Dr. P. Pugnat, Dr. A. Siemko	CERN, Geneva, Switzerland
Dr. Miroslav Šulc	Technical University of Liberec, Czech Republic
Dr. A. Srnka	ISI, ASCR, Brno, Czech Republic

undergo quantum oscillations[21] in a similar way to neutrinos. If an optical barrier is introduced in the light path, only photons converted into scalars or pseudo-scalars will not be absorbed and can be regenerated on the other side of the barrier, allowing their detection as “a shining light through a wall”[22]. For this and as a first step, a LHC superconducting dipole providing a field up to 9.5 T over 14.3 m was equipped with an optical barrier at centre. As a new way to amplify the photon-axion conversions, the magnet aperture was filled with nitrogen gas at a pressure allowing resonant conversions compatible with the PVLAS results. At one magnet end, an 18 W Ar+ laser was installed and aligned with a CCD LN_2-cooled detector sitting on the opposite end. As a result, no regenerated photon was detected. New bounds for mass and coupling constant for purely laboratory experiments aiming to detect any hypothetical scalars and pseudo-scalars which can couple to photons are obtained at 95% confidence level (Fig.1). These results were presented during the 3rd Joint ILIAS-CERN-DESY Axion-WIMPs training-workshop, which was held at the University of Patras in Greece on 19-25 June 2007[23] and submitted recently for publication[24]. It should be emphasized that OSQAR was the only collaboration that presented during this workshop and before the PVLAS retraction[18] null results from a photon regeneration experiment sensitive to both scalar and pseudo-scalar particles i.e. with light polarization perpendicular and parallel to the magnetic field respectively.

The photon regeneration experiment was also performed within vacuum and preliminary analysis confirms, only partially at present, the null results obtained within gas (Fig.1). Problems mostly related to the cryogenics operation of the SM18 test hall, which will be briefly reviewed in a dedicated paragraph, prevented the accomplishment of this study in summer 2007. Additional experimental runs planned for the end of 2007 could allow further increase of the present exclusion region in the axion mass versus di-photon coupling constant parameters space.

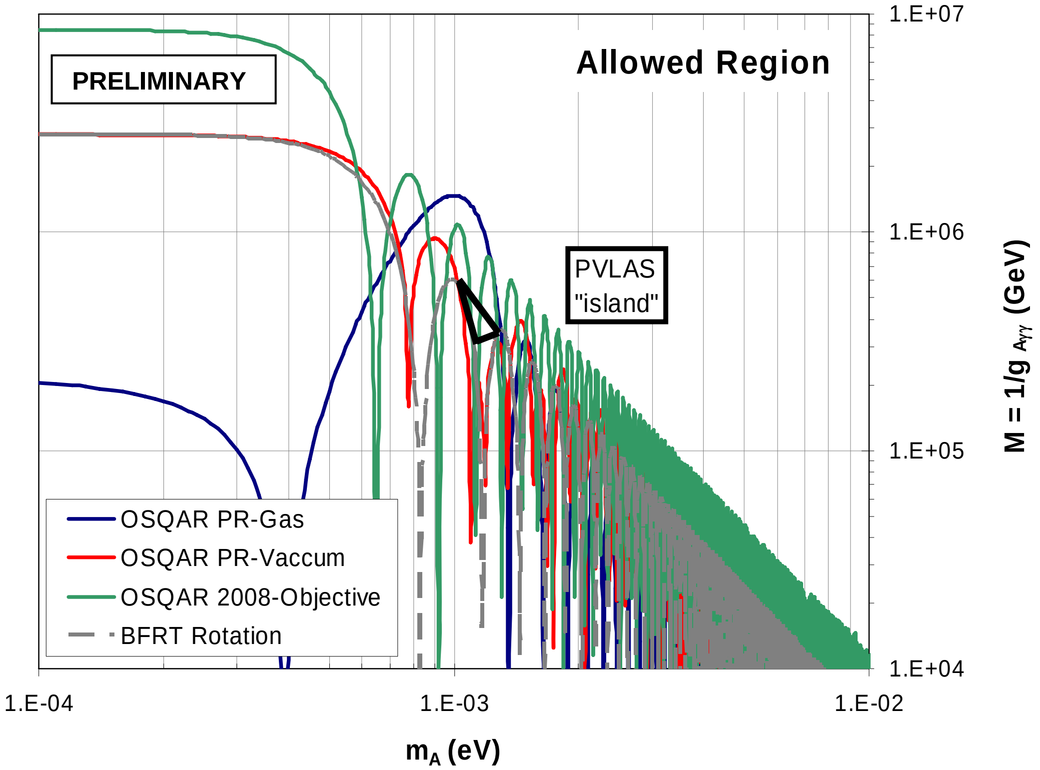

Fig. 1. *OSQAR photon regeneration results in gas, in vacuum and expected for 2008 with 2 LHC dipoles. The PVLAS “island” is unambiguously located inside the exclusion region obtained with the OSQAR photon regeneration experiment using N_2 gas as an amplifier medium. The present reference results from the BFRT collaboration[25] is also shown as a baseline. From a preliminary analysis, rather conservative, results obtained in vacuum are comparable with the BFRT ones and a deeper analysis is on-going.*

1.2. OSQAR "n-1" Experiment

Concerning the part of OSQAR related to the measurements of the Vacuum Magnetic Birefringence (VMB) and dichroism, M. Král from the Czech Technical University of Prague has succefully defended his Ph-D[26] the September 18th. The feasibility study of the VMB measurements and the prototyping phase are both conclusive. The next phase is the realization of the mirror supports with the tuning mechanism and this will be pursued by Czech and French teams of the collaboration.

2. Planned Activities for 2008

2.1. OSQAR Photon Regeneration Experiment

Two main activities are intended to be conducted at CERN in 2008 for the OSQAR photon regeneration experiment.

The first one will focus on the preparation, installation and running of the experiment with a first upgrade configuration based on the simultaneous use of 2 LHC dipoles. Physics runs in 2007 for low mass axion and Axion Like Particle (ALP) searches were conducted using a single LHC dipole. A significant improvement of the sensitivity of the experiment, i.e. by a factor of 2^4, can be obtained by doubling the light pass in the magnetic field[20]. This will allow to explore in 2008 a virgin territory in the Axion and ALP parameter space of purely laboratory experiments. To further increase the experiment sensitivity, the time integration of the photon counting will be increased and dedicated shielding on the top of the CCD detector will be installed to reduce the number of spurious signals coming from cosmic rays. Results from preliminary calculations are shown in Fig.1. **None of the other photon regeneration experiments running around the world[13,14,15,16] is competitive with OSQAR for axion mass below ~10^{-3}eV**. The results of the feasibility study assess the possibility of using two LHC dipoles and related infrastructures for a twice longer photon regeneration experiment. This will be briefly presented in the next paragraph together with our main requests.

The second activity planned for 2008 will deal with dedicated R&D to prepare the 2nd upgrade of the OSQAR photon regeneration experiment. The sensitivity of the experiment will be further improved by increasing the laser optical power. The solution that will be developed consists in building an extended cavity for the Ar+ laser to cover the whole length of the dipole with its cryogenics connection box *i.e. a total length of 19.6 m*. With such a configuration preliminary results[23] show that the optical power can be increase by a factor between 10 and 100. The alignment of the lasing output beam of the extended cavity with the second LHC dipole is difficult to realize and this work will be conducted for most of its duration with both dipoles at room temperature.

2.2. OSQAR "n-1" Experiment

Activities related to VMB measurements will be carry on in the Institutes of the OSQAR collaboration. In particular a Ph-D student supervised by Prof. L. Duvillaret has just started his work at MINATEC to develop the foreseen optical fine measurement system.

3. Requests for 2008 and Afterwards

3.1. Cryogenics issues at SM18

For the series tests of all LHC superconducting magnets, the 18 kW cryogenic plant foreseen for the sector 1-2 of the LHC was connected to the circuit of the SM18 test hall to provide the required cooling capacity. Once series tests were ended, this cryoplant was connected to the LHC and the old 6 kW one was re-put in operation. As there is no long term experience with this cryoplant connected to the overall test facility, problems arose mainly due to impurities contamination. The cold box was stopped several times preventing the cooling of the magnet dedicated to OSQAR. The installation was completely warmed-up one time for an extended duration and the problems seem now to have been solved.

With the 6 kW cryoplant, it is possible to furnish the cooling capacity for 3 LHC dipoles at 1.9 K in stable regime or one LHC dipole at 1.9 K plus one stand for the RF cavities, this later case needing confirmation. As a consequence, activities in the SM18 hall should be carefully planed and prioritized to share the cryogenics resources.

As an information which might be addressed to the CERN management, the team of Aleš Srnka, from the Institute of Scientific Instruments of the Academy of Science of the Czech Republic, recently joined the OSQAR collaboration and is willing to help the cryogenics operation in SM18 if needed.

3.2. Slot allocation at SM18 and dipoles selection

Two test benches fully equipped with LHC type superconducting dipoles are requested to be dedicated to the OSQAR project in the SM18 hall. As a result of the feasibility study, the unique possibility concerns the benches B1 and E1 (Fig.2) for which it was carefully checked that a laser beam can propagate within the curved apertures of two aligned dipoles. Two of the very first pre-series magnets with numbers 1001, 1002 or 3001 will be chosen for the running of the OSQAR photon regeneration experiment in 2008 in agreement with the AT/MCS Group Leader. Note that all these three dipoles are not qualified to be used in the LHC.

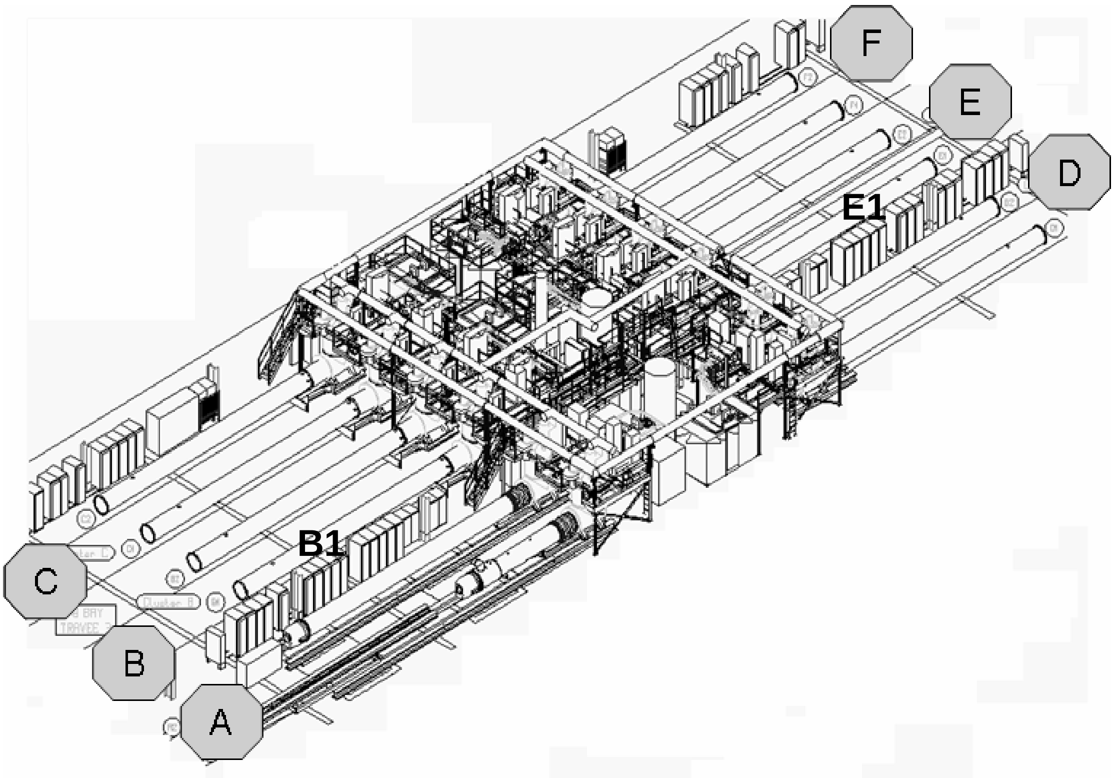

Fig. 2. *Layout of the LHC superconducting magnet test plant consisting of 12 test benches grouped in 6 clusters (A to F) in the SM18 hall. The benches B1 and E1 foreseen for OSQAR are labeled.*

3.3. OSQAR requests to CERN

Activities related to OSQAR experiments are growing up rapidly and this will continue in 2008 and afterwards. Concerning personnel resources, there are essentially three requests to CERN. The first two ones concern the host laboratory and the third one the member of the OSQAR collaboration.

i) In the SM18 test hall, both selected test benches and dipoles are requested to be fully operational with the required cryogenic cooling capacity and the dedicated personnel resources. **The minimum request for 2008 allowing the targeted results shown in Fig.1 is to have the 2 selected LHC dipoles at 1.9 K for 1 period of 2 weeks and 4 periods of 1 week each**. It should be emphasized that more time would allow further increase of the explored region in the axion and ALP parameters space as the later grows with the integration time of the photon counting[20].

ii) **The second important request concerns the conditional engagement of CERN in the approval of the OSQAR experiments for the coming 4 years period. This is typically the duration of applications that OSQAR collaboration members are addressing to national funding agencies.**

iii) **One FTE with relevant experience in magneto-optics and superconducting magnets is needed, ideally from the second half of 2008.** This person will be dedicated to the coordination of various OSQAR activities in the SM-18 test hall including preparation, installation and running of the experiment as well as the R&D phase for the next upgrades. She/he will also contribute to the preparation of the approval by CERN of the overall OSQAR project, which is on long term basis, with an ambitious and tough scientific program[20]. **A possibility within the European FP-7 framework is under consideration and was discussed with the Head of the PH department.**

REFERENCES

[1] Masso, E., and Redondo, J. Evading Astrophysical Constraints on Axion-Like Particles. *Phys. Rev. Lett.* **97**, 151802 (2006); http://arxiv.org/abs/hep-ph/0504202.

[2] Antoniadis, I., Boyarsky, A., and Ruchayskiy, O. Axion alternatives. Preprint at (http://arxiv.org/PS_cache/hep-ph/pdf/0606/0606306v1.pdf).

[3] Gies, H., Jaeckel, J., Ringwald, A., Polarized Light Propagating in a Magnetic Field as a Probe of Millicharged Fermions. *Phys. Rev. Lett.* **97**, 140402 (2006); http://arxiv.org/abs/hep-ph/0607118.

[4] Abel, S. A., Jaeckel, J., Khoze, V. V., Ringwald, A. Illuminating the Hidden Sector of String Theory by Shining Light through a Magnetic Field. Preprint at (http://arxiv.org/PS_cache/hep-ph/pdf/0608/0608248v1.pdf).

[5] Mohapatra, R. N., and Nasri, S., Reconciling the CAST and PVLAS Results. *Phys. Rev. Lett.* **98**, 050402 (2007); http://arxiv.org/abs/hep-ph/0610068.

[6] Abel, S. A, Jaeckel, J., Khoze, V. V., Ringwald, A. Vacuum Birefringence as a Probe of Planck Scale Noncommutativity. *J. High Energy Phys.* 09 (2006) 074.

[7] Brax, P., van de Bruck, C., Davis, A. C., Mota, D. F., Shaw, D. J. Testing Chameleon Theories with Light Propagating through a Magnetic Field. *Phys. Rev. D* **76**, 085010 (2007); http://arxiv.org/PS_cache/arxiv/pdf/0707/0707.2801v2.pdf.

[8] Jaeckel, J., Massó, E., Redondo, J., Ringwald, A., Takahashi, F. The Need for Purely Laboratory-Based Axion-Like Particle Searches. *Phys. Rev. D* 75 (2007) 013004

[9] Brax, Ph., van de Bruck, C., Davis, A. C. A Chameleon Primer. Preprint at (http://uk.arxiv.org/PS_cache/arxiv/pdf/0706/0706.1024v2.pdf).

[10] Antoniadis, I., Boyarsky, A., Ruchayskiy, O. Anomaly induced effects in a magnetic field. Preprint at (http://arxiv.org/PS_cache/arxiv/pdf/0708/0708.3001v1.pdf)

[11] Gies, H., Mota, David, F., Shaw, D. J. Hidden in the Light: Magnetically Induced Afterglow from Trapped Chameleon Fields. http://arxiv.org/PS_cache/arxiv/pdf/0710/0710.1556v1.pdf

[12] Ahlers, M., Lindner, A., Ringwald, A., Schrempp, L., Weniger, C. Alpenglow - A Signature for Chameleons in Axion-Like Particle Search Experiments. DESY-07-162, Oct 2007. Preprint at (http://uk.arxiv.org/PS_cache/arxiv/pdf/0710/0710.1555v1.pdf).

[13] ALPs : Axion-Like Particule Search project at DESY.

[14] Robbilliard, C. et al. [BMV collaboration] No light shining through a wall: new results from a photoregeneration experiment. Preprint at (http://arxiv.org/PS_cache/arxiv/pdf/0707/0707.1296v3.pdf).

[15] LIPPS : LIght Pseudo Scalar Search project at Jefferson Laboratory.
[16] GammeV Particle Search Experiment at FermiLab.
[17] Zavattini, E. et al. Experimental observation of optical rotation generated in vacuum by a magnetic field. *Phys. Rev. Lett.* **96**, 110406 (2006).
[18] Zavattini, E. et al., New PVLAS results and limits on magnetically induced optical rotation and ellipticity in vacuum. Preprint at (http://xxx.arxiv.org/abs/0706.3419).
[19] Pugnat, P. Comment on "Experimental Observation of Optical Rotation Generated in Vacuum by a Magnetic Field". Preprint at (http://arxiv.org/ftp/arxiv/papers/0706/0706.2149.pdf)
[20] Pugnat, P. et al., Optical Search for QED vacuum magnetic birefringence, Axions and photon Regeneration (OSQAR). CERN-SPSC-2006-035 Proposal, 9 November 2006. Preprint at (http://doc.cern.ch//archive/electronic/cern/preprints/spsc/public/spsc-2006-035.pdf)
[21] Sikivie, P. Experimental Tests of the "Invisible" Axion. *Phys. Rev. Lett.* **51** 1415-1417 (1983).
[22] van Bibber, K. et al. Proposed experiment to produce and detect light pseudoscalars. *Phys. Rev. Lett.* **59** 759-762 (1987).
[23] Transparencies at (http://axion-wimp.desy.de/e30/index_eng.html).
[24] P. Pugnat et al., First results from the OSQAR photon regeneration experiment: No light shining through a wall. Submitted for publication, 15 November 2007.
[25] Cameron, R. et al. [BFRT collaboration] Search for nearly massless, weakly coupled particles by means of optical techniques. Phys. Rev. D **47**, 3707-3725 (2007)
[26] Král, M. Feasibility Study of an Experiment to Measure Vacuum Magnetic Birefringence, Doctoral Thesis, Czech Technical University in Prague, 2007.