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MEMORANDUM

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Concerne/Subject: **OSQAR Revised Program**

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1. Introduction

OSQAR is the combination of two experiments for Optical Search of QED vacuum magnetic birefringence, Axion and photon Regeneration[1]. Thanks to the availability of spare LHC dipoles as well as related infrastructure, unique opportunities can be conducted at CERN to explore the low, *i.e.* sub-eV, energy frontier of particle/astroparticle physics. This Memorandum is a follow-up of the 2009 OSQAR Status Report[2] highlighting the revised program with an emphasis for the next two years. The years 2010-2011 can be considered as a transitory period supported financially by the OSQAR collaborating institutes. Hereafter the planning will depend mostly of the availability of additional resources for the personnel and the material, which are not yet secure.

2. Planned Activities for 2010-2011

The main objective for 2010-2011 is still to complete the test program addressed to the SPSC in December 2007[3].

2.1 OSQAR Photon Regeneration Experiment

Physics runs in 2007 for low mass axion and Axion Like Particles (ALP) searches were conducted using a single LHC dipole and an 18 W Ar+ laser. Results were obtained in gas[4] as well as in vacuum[5]. Significant improvements of the sensitivity of the photon regeneration experiment can be obtained by increasing the light pass in the magnetic field as well as the incoming optical power.

Two main activities will be conducted in 2010 for the OSQAR photon regeneration experiment. The first one will focus on the preparation, installation and running of the experiment with a 1st upgrade configuration based on the simultaneous use of 2 LHC dipoles. The results of the feasibility study assess the possibility of using two aligned LHC dipoles and related infrastructures to build a twice longer photon regeneration experiment[3]. This will allow exploring in 2010 a virgin territory in the Axion and ALP parameter space of purely laboratory experiments. Results from preliminary calculations are given in Fig.1 and show an improvement by a factor of about 3 of the present reference exclusion limit obtained with a photon regeneration experiments[6]. To compete with OSQAR will become a challenge for the other experiments in operation worldwide[6],[7],[8],[9].

The second activity planned for 2010 deals with dedicated R&D to prepare the 2nd upgrade of the OSQAR photon regeneration experiment, for which the sensitivity will be further improved by increasing the laser optical power. For this, an extended cavity for the Ar+ laser will be developed to cover the whole length of the dipole with its cryogenics connection box, *i.e.* a total length of 19.6 m. Preliminary results obtained within a 3 to 4 meter long extended cavity show that the optical power can be increased by a factor between 10 and 100.

In 2011, the 2nd upgrade of the OSQAR photon regeneration experiment will be implemented and the experiment will run with 2 LHC dipoles and the Ar+ laser in extended cavity.

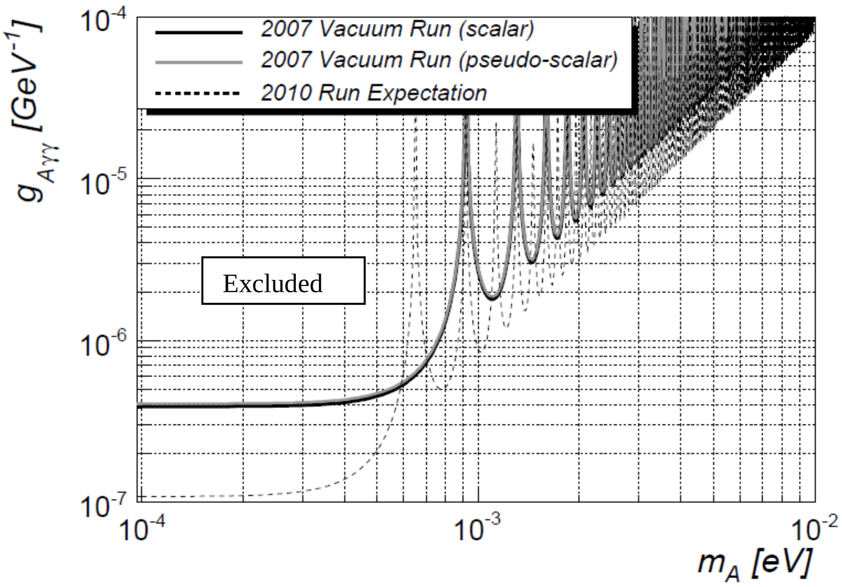

Fig. 1 *OSQAR photon regeneration experiment: a) Exclusion limits for scalar and pseudo-scalar ALPs obtained in vacuum for the 2007 run using one LHC dipole magnet b) Expected OSQAR photon regeneration exclusion limits using two LHC dipole magnets in 2010.*

2.2 Preparatory phase of the OSQAR "n-1" experiment to measure the VMB

For 2010-2011, activities related to Vacuum Magnetic Birefringence (VMB) measurements will be mostly carried out in the collaborating institutes. In particular, recent results have validated a novel method to measure ultra-low birefringence[2]. The integration within the OSQAR experimental environment requires a dedicated study. This concerns in particular the realization of a 19.6 m long **rotating** Fabry-Perot cavity. Two different approaches will be conducted simultaneously. One will investigate the possibility to build a rigid monobloc cavity based on the design of long magnetic shafts used to characterize LHC magnets whereas the other will study the mean to synchronize the rotation of two separated mirrors.

2.3 OSQAR requests to CERN

In the SM18 test hall, both selected test benches and dipoles[2] are requested to be fully operational with the required cryogenic cooling capacity and the dedicated personnel resources. **The minimum request for 2010 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.

3. Strategy and preliminary schedule

For the next 5 years, this project can be split in different phases for both experiments (Table 1), each of them being characterized by an upgraded configuration and a clear objective. Two LHC dipoles are required for the photon regeneration experiment and only one for the VMB measurement, the later being performed within the second aperture of one of the dipoles dedicated to OSQAR.

The photon regeneration experiment is built first, also to gain experience before launching the construction of the most challenging part of the OSQAR project dedicated to the VMB and linear dichroism measurements. For example, the development of the 19.6 m long Fabry-Perot cavity during the phase-1 of the photon regeneration experiment will contribute to the realization of the rotating cavity to measure the VMB.

The phase-1 of the fine optical measurement system for the VMB is characterized by the developments of the highly linearly polarized laser source, the electro-optical polarization modulator and the rotating Fabry-Perot cavity. The realization of the ultra-fine detection system based on the Fabry-Perot rejection filter[10] is expected to be implemented during the phase-2 as one of the possible solutions to further optimize the signal over noise ratio. It requires beforehand a deeper analysis, which is now ongoing, to assess its proof of principle.

For the photon regeneration experiment, long experimental runs are planned. They can be split in two slots of nearly the same duration, one requiring the magnetic field switched-on whereas the other not, to probe the coupling of photons with spin-0 (axions/ALPs) and spin-1 (paraphotons) particles respectively. The different phases of the OSQAR photon regeneration experiment were defined to allow the monitoring of progress and the main objective at the end of the phase-2 is to achieve the resonantly-enhanced axion-photon regeneration[11].

	Photon Regeneration Experiment	**VMB Measurement**
Phase 0 *or Preliminary Phase*	***Objective : Cross check of the PVLAS result*** . 1 LHC dipole . 18 W CW Ar+ laser ► **Done in 2007 - Results published** [3],[4]	***Objective : Proof of Principle*** . Measurement of the Cotton-Mouton effect of air at ambient pressure within 1 LHC dipole ► **Done in 2005**[12] . R&D to optimize the sensitivity of birefringence measurements: state-of-the-art reached in 2009 and validated by measuring the Kerr effect of some gases (He, Ne, Ar, N_2, O_2, CO_2) with a table top experiment[2]
Phase 1	***Objective : Optimization of the Axion/ALP source*** . 2 LHC dipoles . Axion source made of Ar+ laser beam of 18 W (CW) within the aperture of one LHC dipole ► **1st milestone - end of 2010** . Axion source made of Ar+ laser in extended cavity of 19.6 m long, i.e. the length of one LHC dipole, for an expected laser intracavity power of 0.1-1 kW ► **2nd milestone - end of 2011**	***Objective : Measurement of the 1st order VMB*** . 1 LHC dipole . Low RIN Laser coupled to a *rotating* Fabry-Perot (FP) cavity of 19.6 m long . Measurement of the Cotton-Mouton effect of Gases as a function of the residual pressure down to 10^{-9} torr to have access to the VMB signal . Analysis in term of Axion/ALP searches & comparison with final results of the phase-2 of the Photon Regeneration Experiment ► **3rd milestone - end of 2012 at the earliest**
Phase 2	***Objective : Optimization of the photon regeneration part*** . 2 LHC dipoles . Intracavity laser power of 0.1-1 kW (CW) coupled to a 2nd FP cavity of 19.6 m long for the photon regeneration according to the proposal of P. Sikivie *et al.* [10] . Sensitivity approaching cosmological constraints ► **4th milestone - end of 2013 at the earliest**	***Objective : Toward the measurement of the 2nd order VMB*** . 1 LHC dipole . Low RIN Laser coupled to a *rotating* FP cavity of 19.6 m long + further optimization of the signal over noise ratio . **Measurement of the 2nd order VMB** ► **5th milestone – date to be defined;** *in metrology, 1 order of magnitude is gained typically each ~5 years, once a new measurement method is established…*

Table 1: *Summary of the revised program of both OSQAR experiments.*

REFERENCES

[1] P. Pugnat, *et al.* (OSQAR collaboration), *"Optical Search for QED vacuum magnetic birefringence, Axions and photon Regeneration (OSQAR)"*, CERN-SPSC-2006-035 Proposal, 9 Nov. 2006,
http://doc.cern.ch//archive/electronic/cern/preprints/spsc/public/spsc-2006-035.pdf
http://indico.cern.ch/conferenceDisplay.py?confId=10912

[2] P. Pugnat, *et al.* (OSQAR collaboration), *"OSQAR Status Report: Progress in Ultra-fine Birefringence Measurements",* CERN-SPSC-2009-036, SPSC-SR-053-2009, 24 Nov. 2009,
http://cdsweb.cern.ch/record/1225479/files/SPSC-SR-053.pdf;
http://indico.cern.ch/conferenceDisplay.py?confId=73796

[3] P. Pugnat, *et al.* (OSQAR collaboration), "*Summary of OSQAR First Achievements and Main Requests for 2008"*, CERN-SPSC-2007-039, SPSC-M-762, 3 Dec. 2007, http://cdsweb.cern.ch/record/1072483/files/spsc-2007-039.pdf;
http://indico.cern.ch/conferenceDisplay.py?confId=24362

[4] P. Pugnat, *et al.* (OSQAR collaboration), "*Results from the OSQAR photon-regeneration experiment: No light shining through a wall"*, *Phys. Rev. D* ***78*** (2008) 092003

[5] M. Schott, *et al.* (OSQAR collaboration), *"Last results and Perspectives of the OSQAR Photon Regeneration Experiment"*, submitted to European Physical Journal Special Topics Series (EJP ST)

[6] A.S. Chou, *et al.* (GammeV collaboration), *"Search for Axionlike Particles Using a Variable-Baseline Photon-Regeneration Technique", Phys. Rev. Lett.* ***100*** (2008) 080402

[7] C. Robilliard, *et al.* (BMV collaboration), *"No Light Shining through a Wall: Results from a Photon Regeneration Experiment*", *Phys. Rev. Lett.* ***99*** (2007) 190403

[8] A. Afanasev, *et al.* (LIPPS collaboration), *"Experimental Limit on Optical-Photon Coupling to Light Neutral Scalar Bosons*", *Phys. Rev. Lett.* ***101*** (2008) 120401

[9] K. Ehret, *et al.* (ALPS collaboration), *"Resonant laser power build-up in ALPS - a light-shining-through-walls experiment -", Nucl. Instrum. Meth.* ***A612*** (2009) 83-96

[10] Lionel Duvillaret, *et al.* (OSQAR collaboration), Report to the 89th Meeting of the SPSC, 5 Nov. 2008
http://indico.cern.ch/conferenceDisplay.py?confId=42876

[11] P. Sikivie, D.B. Tanner, K. van Bibber, *"Resonantly Enhanced Axion-Photon Regeneration", Phys. Rev. Lett.* ***98*** (2007) 172002

[12] L. Duvillaret, M. Král, and P. Pugnat, *"On the Cotton-Mouton effect and its possible application to characterise Accelerator Magnets",* CERN-AT-MTM Internal Note 71, October 2005, CERN EDMS-Id-672179; P. Pugnat, L. Duvillaret, M. Král, CARE-HHH-AMT Workshop on Pulsed Accelerator Magnets, Frascati, 26-28 October 2005,
http://ecomag-05.web.cern.ch/ecomag-05/