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Status and perspectives of the PADME experiment

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Summary. — One of the most striking problems of modern physics concerns the explanation of cosmological phenomena, whose behaviour cannot be explained taking into account only visible matter. We can postulate the existence of some kind of matter which does not produce radiation, but gives a gravitational contribution to the Universe: the *dark matter*. The PADME experiment, that will take place in the Laboratori Nazionali di Frascati, will study the coupling between ordinary matter and dark matter.

1. – Introduction

The study of cosmological phenomena, like galaxies rotation or cosmic microwave background, does not find a validation from gravitational laws. On the other hand, we can suppose that visible matter is not the only one affected by (and responsible for) gravitation. We can then assume the existence of a new kind of matter, which does not produce radiation, and interacts with standard matter only gravitationally: we call it *dark matter* (DM).

In the last decades, many experiments were devoted to the detection of DM. The difficulty which these experiments run into finding evidences of DM gives a hint that the coupling between DM and ordinary matter is quite weak. We can explain this struggle if we suppose that DM lives in a different world with respect to the one where Standard Model (SM) particles live. DM and SM particles could then interact through a new interaction, associated to a mediator which can have different nature. In the next section we shall take into consideration a possible candidate of the mediator, and we shall explain the strategy PADME will use to search for it.

2. – Dark photon and its detection in PADME

2˙1. *A simple theory of dark photon.* – One of the most simple models describing the theory of a new interaction introduces a $U(1)$ symmetry between SM particles and DM

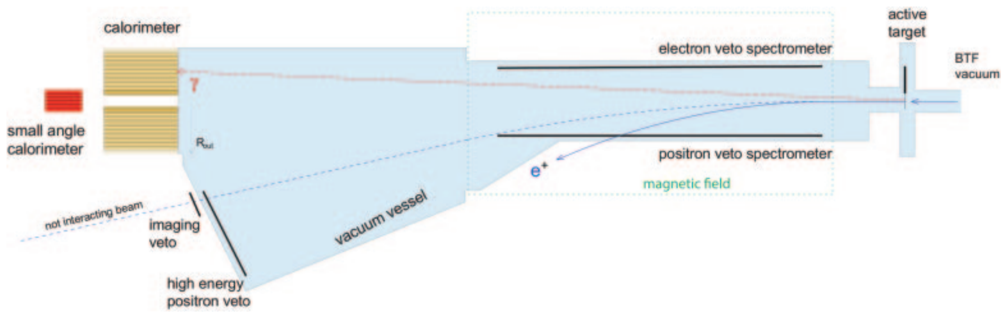

Fig. 1. – Description of the experiment.

particles. We will consider a possible candidate for the mediator, called *dark photon* (DP), in analogy with the standard photon. DP can be produced in many ways, in this work we focus only on production modes that involve electron/positron couples. As a standard photon, a DP can be produced in the final state of i) annihilation processes ($e^+e^- \to A'\gamma$), ii) the emission of *bremsstrahlung* radiation ($e^-N \to e^-NA'$). DP decay depends on its mass: if DM particles with $m_{DM} \leq m_{A'}/2$ exist, DP dominantly decays in SM particles, and an *invisible* decay occurs. Otherwise, if there are not such DM particles, DP can only decay in SM particles, giving rise to a *visible* decay.

2˙2. *Description of the PADME experiment.* – The PADME experiment [1,2], which will be hosted by Laboratori Nazionali di Frascati (LNF), will look for DP produced from positron/electron annihilation, decaying into DM particles. PADME will search for DP using the annihilation of a positron beam on the atomic electrons of a fixed target: the detection of DP is not possible, so the experiment will search for the standard photon in the electromagnetic calorimeter. Since the beam properties are user-determined and the target is fixed, the kinematic of the process is closed if we detect the photon emitted with DP. It is then possible to reconstruct the missing mass spectrum of the annihilation, and look for the peak associated to the mass of DP.

The experiment (described in fig. 1) will use positrons from the LNF's LINAC [3]: a beam of 550 MeV (5000 e^+/bunch, frequency ~ 50 Hz) will collide on an active diamond target, able to give information about the beam position. A magnetic field (0.5 T) will deflect charged particles towards vetoes, while neutral particles will move forward to the Electromagnetic Calorimeter (ECAL) [4]. The calorimeter is made of 616 $2.1 \times 2.1 \times 23\,\text{cm}^3$ BGO crystals, and has a cylindrical shape with a central hole, which allows the passage of *bremsstrahlung* radiation. A fast Small Angle Calorimeter (SAC), made of 25 $3 \times 3 \times 14\,\text{cm}^3$ PbF_2 crystals, is placed in front of the hole.

2˙3. *Main background contribution.* – As previously mentioned, the experiment signal is given from a single photon in the calorimeter. Other processes can mimic this signature, for example a SM annihilation or a *bremsstrahlung* process. Background studies and cuts were performed to give a framework of the running condition of the experiment. Pile-up contribution to the background is quite relevant, but a good cut strategy has been implemented.

2˙4. *Experiment sensitivities.* – A Monte Carlo simulation of the experiment has been created, using the GEANT4 software. $2.5 \cdot 10^{10}$ 550 MeV e^+ on target events were extrapolated to 10^{13}, to evaluate the sensitivity reached by the experiment. With a 550 MeV beam energy, PADME can explore in a model-independent way a mass region up to $m^2_{A'} = 2m_e E^+_e$.

3. – Conclusions

The PADME experiment will study the interaction between ordinary matter and dark matter searching for the dark photon, as a possible mediator of the interaction. PADME will explore the invisible decay of DP, by means of the annihilation process $e^+e^- \to A'\gamma$. With a 550 MeV beam energy, the experiment will search for a DP with mass up to 23.7 MeV/c^2 (beam energy = 550 MeV). The data taking will start in September 2018 at LNF. The Collaboration expects to collect $\sim 1 \times 10^{13}$ positrons on target by the end of 2018. The main components of the experiment are ready.

The Collaboration expects a second physics run in 2019 at LNF.

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