Search for X17 at n_TOF

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Sommario

Two striking anomalies have been observed recently in the emission of electron - positron pairs in $^7Li(p,e^-e^+)^8Be$ and $^3H(p,e^-e^+)^4He$ reactions. These anomalies have been interpreted as the signature of a new particle, the so-called X17 boson. We are going to perform an experiment to clarify the present scenario by searching for the X17 boson in the decay of excited levels of ^4He and ^8Be. In particular, X17 can be studied at n_TOF for the first time by a spallation neutron beam through the conjugated reactions $^3He(n,e^-e^+)^4He$ and $^7Be(n,e^-e^+)^8Be$, thus providing a complementary experimental approach with respect to the reported measures in the literature.

Introduction

Two significant anomalies have been recently observed in the emission of electron-positron pairs in the $^7Li(p,e^-e^+)^8Be$ and $^3H(p,e^-e^+)^4He$ [1] [2]. These anomalies have been interpreted as the signature of the existence of a boson (hereafter referred to as X17) of mass M_{X17} = 16.8 MeV (see Fig.1) that could be a mediator of a fifth force, characterised by a strong coupling suppression of protons compared to neutrons (protophobic force [3]). Beyond the importance of such a discovery - if confirmed -, this scenario could explain, at least partially, the long-standing (recent) anomaly on the muon (electron) magnetic moment. More in general, the possible existence of a new particle is of paramount importance in particle physics and in cosmology (dark matter). Therefore, the ATOMKY claim [1] [2], clearly calls for new experimental studies. Our proposal is to carry on an experiment at n_TOF, where the excited levels of ^4He, ^8Be can be populated via the conjugated $^3H(n,e^-e^+)^4He$ and $^7Be(n,e^-e^+)^8Be$ reactions. This approach has two relevant advantages:

- for the first time X17 existence is investigated through neutron induced reactions;
- the experimental setup is completely different with respect to the one used by the ATOMKY group.

More in detail, the ATOMKI experimental setup used for the $^3H(p,e^-e^+)^4He$ reaction (a very similar one was used for the other reactions published) consists of a tritium target adsorbed on Ti layer, bombarded with a 900 keV proton beam with a current of about 1 μA. In correspondence of the target the beam line is surrounded by a 1 mm thick carbon fiber tube. The detection of the ejectiles is performed with 6 telescopes mounted in a plane orthogonal to the beam line. Each telescope consists of a double-sided silicon strip detector coupled with a plastic scintillator. The scintillators provide the measurement of the energy of escaping particles. With this setup it was possible to measure the relative angle of the e^-e^+ pairs and their energies. As it can be seen in Fig.2, data show a clear excess of e^-e^+ pairs emitted at large relative angles (within $115° \div 140°$), allowing to derive the invariant mass M_{X17}.

Our approach aims to realise a suited detection setup for the determination of particle kinematics and able to discriminate particles, i.e. the reaction ejectiles (assumed to be e^-e^+ pairs) in a wide energy range. If the existence of X17 is confirmed, with the here- proposed experimental setup it will be possible to establish quantum numbers and mass of the X17 boson, and to shed light on the so-called protophobic nature of a fifth force, according to the study done by INFN Pisa Nuclear Theory Group, see [4]). In fact, state-of-the-art "ab-initio" calculations are in good agreement with present literature data (in particular for the "few body" ^4He nucleus) and would provide quantitative predictions to establish the X17 nature, e.g. if it is a scalar, pseudoscalar, vector or axial boson and to get information on the interaction of the X17 boson with quarks and gluons [4]. The study of the $^3H(n,e^-e^+)^4He$ and $^7Be(n,e^-e^+)^8Be$ can be performed at the EAR2 station of the n TOF facility at CERN. In fact, the facility provides a pulsed neutron beam in a wide energy range, which broadly covers the region of interest for this experiment, i.e. $10^3 \leq E_n\ (eV) \leq 10^7$. In addition, count-rate estimations have demonstrated that the neutron intensity at EAR2 is high enough to carry on a conclusive experiment within about 1 month of measurement.

Experimental setup

We would realize an experimental setup in order to measure without any ambiguities wheter or not X17 does exists. Two are the main parameters: the relative angle between the couple electron-positron emerging from the target and the total energy of the two particles, that must be around $\tilde{1}7$ MeV, with an energy distribution between the two leptons ranging within 2 $\div$ 15 MeV. The lepton tracks will be detect by five detection plains on each side of the target. On each side there will be two μR-Well plain, around 1 cm thck each, 50 X 50 cm^2 (see Fig.3) with a tracking of around 1$\div$2 mm space resolution. Each μR-Well garantees a small multiple scattering by the emerging leptons and are almost insensitive to protons from beam induced background. After there will be two plain of EJ-200 slabs, 1 cm large, 50 cm long and 0.5 cm thick, read by SiPM on both side of each slab. By TOF technique between the SiPM placed at the opposite sides of the slab, we could have an extra information about the striking point on the longitudinal coordinate of the slab with a space resolution around 0.5 cm. The expected final angle resolution would better than 4°. We plain to fix an upper and lower energy threshold too on EJ-200 slabs, in order to get a better efficency on X17 lepton discrimination (with respect to pair production outside X17). The two slab plains will cover the X and Y coordinate, in order to follow the incident trajectory of the leptons. After the EJ-200 slabs there will be scintillator blocks again of EJ-200 of 10 x 10 x 10 cm^3, read by fast PMT. The EJ-200 blocks must totally absorbe the lepton energy, the expected overall X_{17} energy resolution is around 10%. The setup will be placed at around 3 cm from the target, 3 cm diameter and 4 cm long, made of carbon fiber of 0.6 mm thick, full by 250 $\div$ 300 atm of ^3He: the very small thickness of inert material on the leptons path has been chosen in order to minimize the multiple scattering (*the X17 leptons have low energy!* The coincidence between μR-Well gas detector, the EJ-200 slabs and blocks will garantee, according with GEANT4 simulation a good signal to background ratio, enough for our purpose. With this experimental setup we think it will be possible to solve the question about the existence of X17 and in case of positive answer, to to measure enough kinematic information establish whether X17 boson is a scalar, pseudoscalar, vector of pseudovector, according with the calculation published in [4]

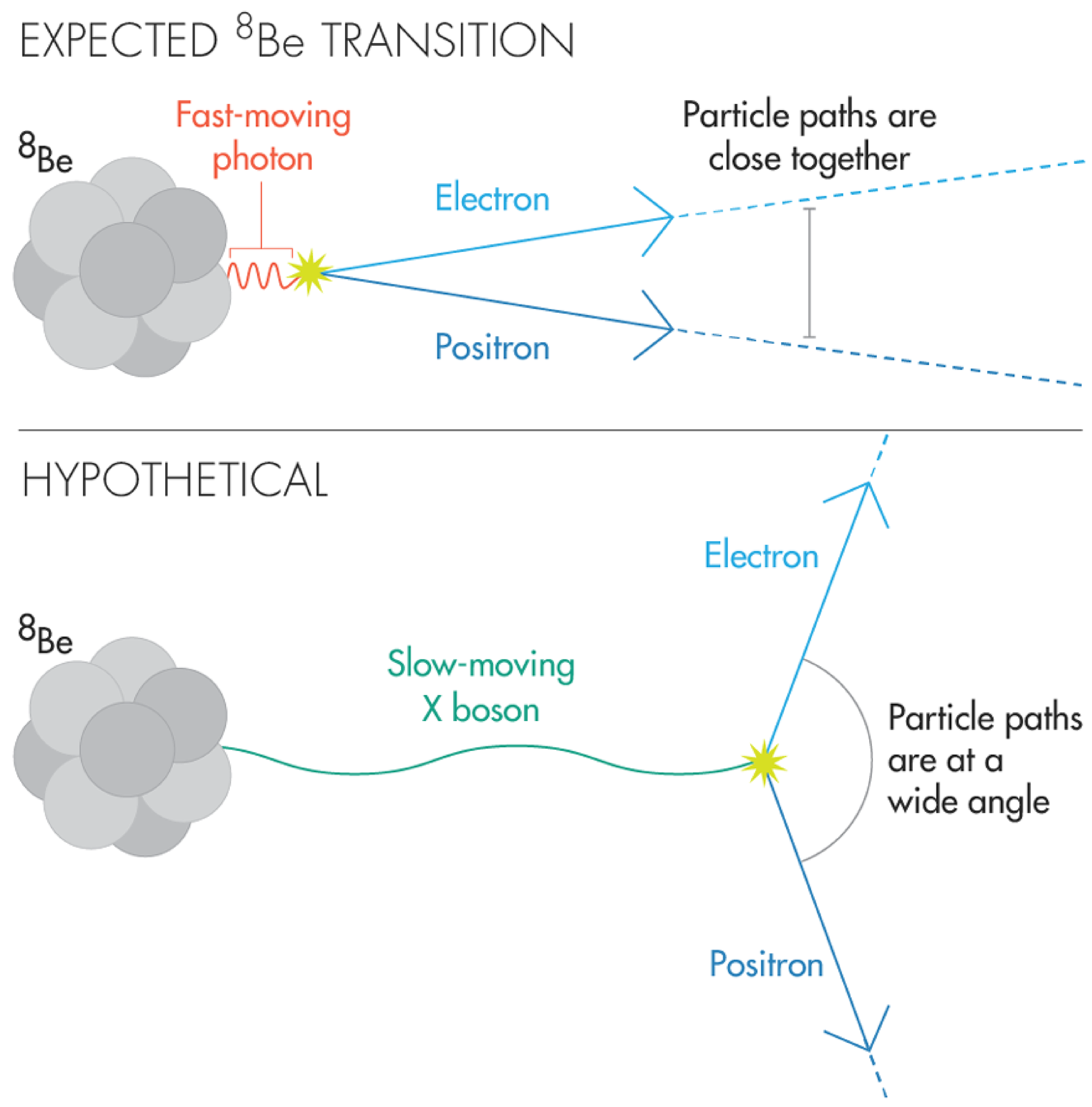

Figura 1: Internal pair conversion from ^8Be transition in the usual case (upper) and in the case of X17(bottom)

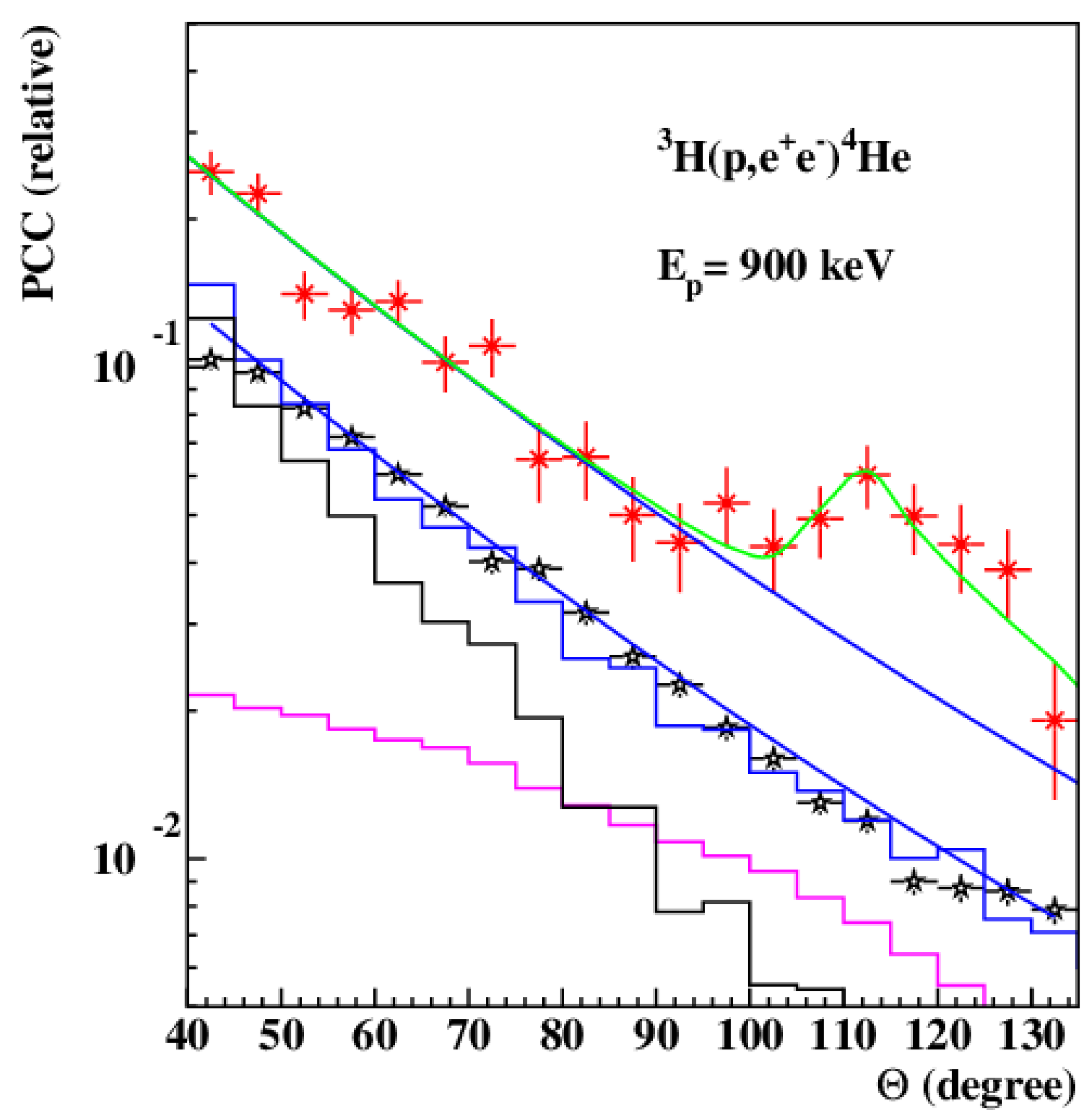

Figura 2: The big anomaly claimed by [1] [2] in the pair production on $^3H(p,e^-e^+)$ reaction between $115° \div 140°$. The red crosses are the experimental data, the blue line the total background and under is the background disintangle in its components

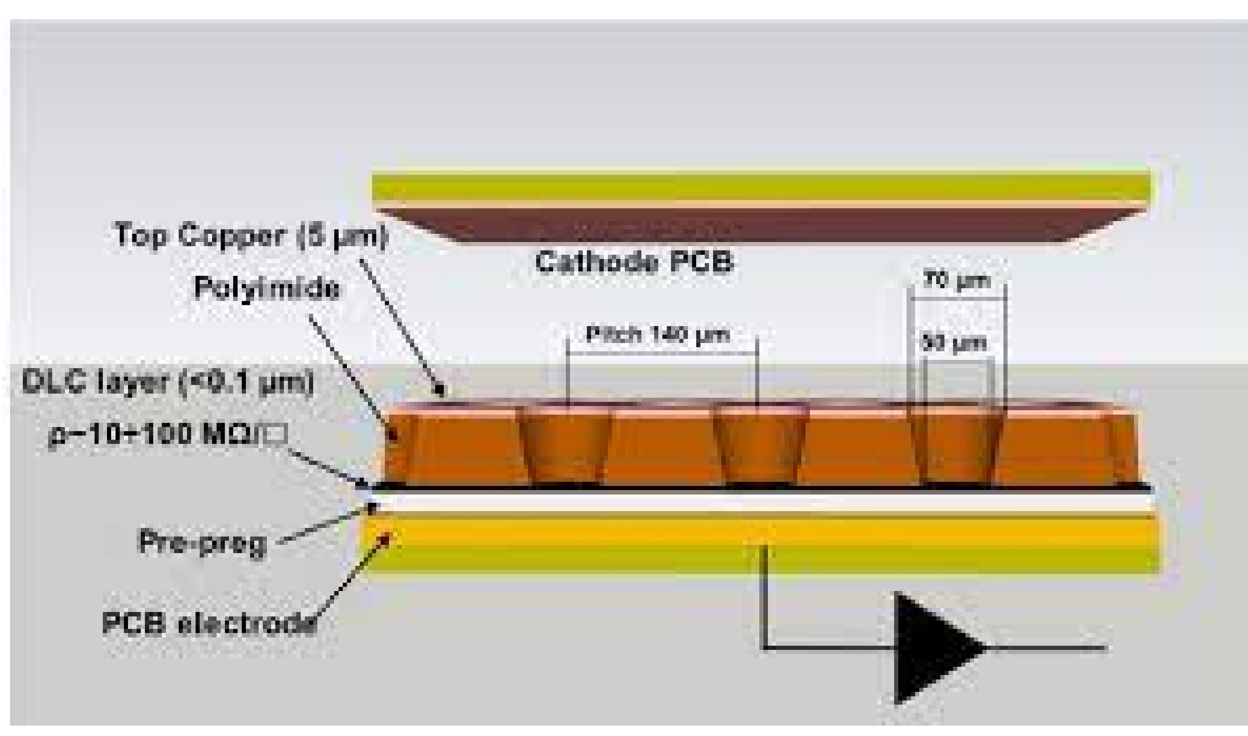

Figura 3: The lepton gas tracker working principle (μR-Well built at LNF by G. Bencivenni [5]): there will be two plains of gas tracker like this one for each side of the target. After the μR-Well there will be two plains (X and Y) of EJ-200 slabs and at finally a EJ-200 calorimeter able to absorbe completely the X17 leptons energy)

Riferimenti bibliografici

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