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Search for X17 by Neutron Induced Reactions: A New Physics Beyond the Standard Model?

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ABSTRACT
We present the state-of-art activity of n_TOF Collaboration Working Group dedicated to study how to solve the puzzle about the existence of the so called new particle X17, spotted for the first time few years ago by a team at ATOMKI in Hungary and since then never confirmed by other independent experimental collaborations but also never refuted. An "ad hoc" detection set-up is under realization for this goal, in order to reach an angular resolution of the two emerging trajectories from the X17 decay and an energy resolution for the invariant mass reconstruction enough to cast light in a definitive way about this puzzle. To design the present detection setup we work in close contact with the Pisa Nuclear Theory team, that has deeply studied the implication of X17 existence and extracted by the ATOMKI results its eventual nature, kinematics and general properties.

Keywords: X17, New boson, Physics beyond standard model

Introduction

Two significant anomalies have been recently observed in the emission of electron-positron pairs in the ^{7}Li(p,e$^-$ e$^+$)^{8}Be and ^{3}H(p,e$^-$ e$^+$)^4 He reactions[1,2]. These anomalies have been deciphered as the signature of the existence of a new boson called X17 of mass $M_{X17} \simeq 16.8$ MeV that could be a mediator, if it exists, of a fifth force, characterized by a strong coupling suppression of protons compared to neutrons (protophobic force) [3]. The evidence for such a particle was first reported in 2012 at a workshop in Italy by the group led by Attila Krasznahorkay at the Institute for Nuclear Research at Hungarian Academy of Sciences (ATOMKI, Debrecen, Hungary): they reported about unexpected results observed in their nuclear physics experiments. But this first evidence was weak as it was only around three sigma level: in nuclear physics it is required a sigma level of 5 or higher to have confidence in new results. In April 2015, the same group of ATOMKI confirmed the existence of the new light boson, giving an evaluation of its mass (nearly 17 MeV): this time the sigma levels were 6.8 excess. According to the team, this was the simplest way to explain the experimental results of anomalies in Beryllium transitions and such excess of sigma levels cannot be related to any statistical fluctuations [1]. For the 2015 measurement, a thin lithium foil of 15 µg/cm^2 thick LiF_2 and 700 μµg/cm^2 thick LiO_2 targets evaporated on 10 μm Al backings was used. The X17 decays through e$^-$ e$^+$ pairs that were detected by five telescopes. Each telescope is made of a double-sided silicon strip detectors coupled with a plastic scintillator. The scintillators provide the measurement of the energy of escaping particles. The telescopes are placed perpendicular to the beam direction at azimuthal angles of 0^o, 60^o, 120^o, 180^o and 270^o around the vacuum chamber made of a carbon fiber tube in order to minimize the leptons multiple scattering. 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 Figure. 1, data show a clear excess of e^-e^+ pairs emitted at large relative angles, allowing to derive the invariant mass M_{X17}. The target was irradiated by protons of energy around 1.03 MeV, thus exciting lithium nuclei up to the 18.15 MeV beryllium state. The excited beryllium nucleus is expected to reach its ground state through-out the transition 0^+ 0^- by internal pair conversion (IPC), the only possible way according to nuclear spectroscopy rules (angular momentum and parity conservation). The angular distribution between two emerging leptons from IPC has an apparent peak around 10^o -15^o, after this angular interval is going fast to zero, i.e. the probability to measure a relative angle for the $e^- e^+$ pairs over 30^o is negligible. What it has been observed instead is a clear peak (up to 6.8 excess from the e+e- background) in the angular range of 100^o- 130^o, with a maximum around 120^o (see Figure. 1). For the 2019 experiment, the team had similar setup. Instead of lithium targets, tritium targets adsorbed on Ti layer were used. The density of tritium atoms was 2.66×10^{20} atoms/cm^2.

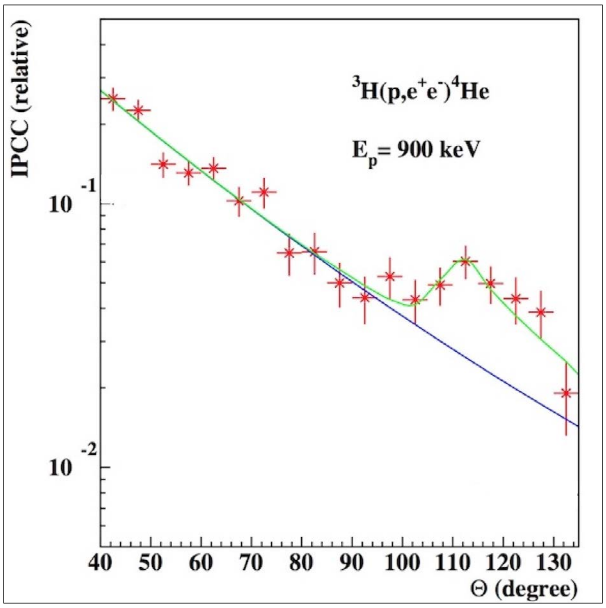

Figure 1: Angular correlations for the e^-e^+ pairs measured in the $^3H(p,e^- e^+)^4$ He reaction at E_p=900 keV. The red points are the experimental data showing the $e^- e^+$ pairs excess around 115^o. The blue is the expected angular distribution of e^-e^+ pairs based on standard IPC physics, while the green line is the best data fit assuming M_{X17}=16.87 MeV

The detection apparatus was upgraded in order to include six arms instead of the previous five, the new arm was placed at an azimuthal angle of 300^o. All of them were again perpendicular to the proton beam direction. In Octo- ber 2019, and in Winter 2020 similar anomalies were announced, this time using the helium transitions from the reaction $^3H(p, e^- e^+)^4$ He with an incident proton beam with a current of about 1 μA and of 0.9 MeV, enough to reach the second excited state of 4He that de-excite with an energy of 20.49 MeV [2,4]. Again important deviation from the expected angular correlation (based on IPC effect) was observed, this time with a peak at around 115^o, strengthening the claim for the existence of X17 boson: with the last measurements the sigma levels reached the impressive value of 7.2 sigma excess. The importance of such a discovery - if confirmed {is beyond nuclear physics. Every new particles, specially bosons, could be associated with a new force or at least with a new, unknown and unexpected aspect of one of the known forces. X17 could be related to the role of quarks, trapped in the hadronic bag and to the nucleon binding energy inside nucleus. Preliminary theoretical studies [3] has pointed out the hypothesis of different behaviour for up and down quarks unveiled by a much stronger cross section when neutron transitions are observed with respect to the ones of protons (protophobic scenario). This innovative scenario could provide new ideas to explain, at least partially, the long-standing anomaly on the muon 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 clearly calls for new experimental studies [1,2,4].

Presently we are engaged to carry on a first series of measures at n_TOF, where the excited levels of ^{4}He, ^{8}Be can be populated via the conjugated $^3He(n,e^- e^+)$ ^{4}He and $^7Be(n,e^- e^+)^8Be$ reactions using the spallation neutron beam EAR2 at CERN. This approach has two relevant advantages: (i) for the first time X17 existence is investigated through neutron induced reactions exploiting the world unique properties of EAR2 beam and (ii) the experimental setup is completely different with respect to the one used by the ATOMKY group [5]. The main limitations of the ATOMKI measurement setup are: (i) a monochromatic beam (of 900 keV for lithium experiment, 1.03 MeV for tritium), i.e. no information about the X17 production at different energies is available; (ii) no tracking and vertex recognition, (iii) only particles produced (almost) orthogonally to the beam line are detected; (iv) no charge and particle identication, i.e. the ejectiles are only deduced to be $e^- e^+$ pairs. Our efforts aim to realize a suited detection setup for the determination of particle kinematics with a strong capability to discriminate particles, i.e. the reaction ejectiles (assumed to be $e^- e^+$ pairs) in a wide energy range. We would study the reactions induced by both neutron and proton beams. If the existence of X17 is confirmed, we would be able to establish quantum numbers and mass of the X17 boson, and to shed light on the so-called protophobic nature of a fifth force. In fact, state-of-the-art "ab-initio" calculations are in good agreement with present literature data (in particular for the "few body" ^{4}He 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 [3,6]. EAR2 station of the n TOF facility at CERN provides a pulsed neutron beam in a wide energy range, which broadly covers the region of interest for this experiment, i.e. 10^3 eV < E_n < 10^7 eV. Count-rate estimations show that the neutron intensity at EAR2 is high enough to carry on a conclusive experiment within approximately one measurement month. Working at a spallation neutron beam line means to have to tackle the problem of beam induced background. It is well-known that the dominant outgoing channel in the neutron-induced reaction is the proton final state, in the case of $^3He(n,p)$ ^3H with a reaction Q-value = 764 keV. The sub-dominant process $^3He(n, \gamma)$ ^{4}He produces single photons with E_γ > 20 MeV. Finally, virtual photons can produce $e^- e^+$ pairs through the internal pair conversion (IPC) channel $^3He(n,e^- e^+)^4He$.

The IPC pairs and the $e^- e^+$ pairs generated by the interaction of real photons with the material surrounding the ^{3}He target represent a relevant background for the process of interest. However, the amount of $e^- e^+$ pairs produced by (virtual or real) photons rapidly decreases while increasing their emission relative angle. Instead, the $^4He^* \rightarrow {}^4He + X17$ process and successive $X17 \rightarrow e^- e^+$ decay produces pairs with a large relative angle, determined by the X17 mass and energy. As a consequence, the excess of pairs at large relative angles (see Fig. 1) represents a clear signature of new physics. It is worth pointing out that a possible existence of a vector X17 boson would alleviate the present tension between data and calculations concerning the muon magnetic moment. The prediction for the value of the (electron) muon anomalous magnetic moment includes three parts:

$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{hadron} = 0.001\ 165\ 918\ 04(51)$$

Of the first two components, represents the photon and lepton loops, and the W boson, Higgs boson and Z boson loops; both can be calculated precisely. The third term represents hadron loops and it cannot be calculated accurately from theory alone. It is estimated from experimental measurements of the ratio of hadronic to muonic cross sections in electron-positron ($e^+ e^-$) colli- sions. As of July 2020, the measurement disagrees with the Standard Model by about 3.5 standard deviations, suggesting physics beyond the Standard Model may be having an effect (or that the theoretical/ experimental uncertainties are not completely under control). This is one of the long-standing discrepancies between the Standard Model and experiments. If X17 exists and has a hadron nature, the hadronic term of the anomalous magnetic moment must be increased taking into account this new contribution that it could be evaluated around from 10^{-6} up to 10^{-5}.

International scenario about X17 hunting

The present scenario is summarized in Figure. 2, where the grey colour shows the areas determined by the mixing parameter εe and the possible dark photon mass M_x already excluded by recent measures (between these measures we remind the recent results of NA64 Collaboration at CERN)[7]. Quite a good number of international collaborations foresee to study X17 problem, but as by product of data taking done with detectors designed for different purposes, the main ones are reported in Figure.2. The results on ^8Be from ATOMKI are shown in Figure.2 by the red vertical line: they fall in a region where at the moment no constraints have been proved. Considering the future projects specifically dedicated to X17 hunting, we have rumors about two new projects, one from the Institute of Experimental and Applied Physics (UTEF) of Czech Technical University of Praha, where it is foreseen to develop an almost 4 detector following the line-guide of what has been done up to now at ATOMKI, increasing the granularity and the energy resolution of the emerging leptons and using protons on ^7Be as main reaction under investigation. The second one, more ambitious, is the collaboration from University of Utah, University of California at San Diego and Los Alamos National Laboratories: they plan to have measures using both protons and neutrons exploiting the Los Alamos proton beam and the Los Alamos Cold Neutron Facility (UCN), with the theoretical support of the Theory Group of Los Alamos. Both projects together with our one, have been presented at the workshop "Shedding light on X17", Rome, September 6-8, 2021, organized by University of Rome "La Sapienza".

Ancillary proton reaction studies

Given that the $^3H(p, \gamma)^4He$ and $^3H(p,e^+ e^-)^4He$ reactions are conjugated to the $^3He(n, \gamma)^4$ He and $^3He(n, e^+e^-)^4$ He, they represent the natural counterpart for an exhaustive program [6]. The proton reaction induced on tritium could be studied by a proton beam up to hundreds of mA striking upon a thin tritium target on an inert backing. High statistics measurements could be performed at LNL or at LUNA-MV [10]. In fact, the LUNA-MV accelerator at LNGS has some very suitable characteristics for these measurements: excellent beam energy determination, high proton beam luminosity (a factor 2 higher than the ATOMKI) and a unique shielding against cosmic rays. With respect to the ATOMKI measurement, performed at fixed beam energy, this study requires to be carried out in a wide energy range. As shown in Fig. 3, the energy range 0.2 MeV < E_p < few MeV's is adequate to scan the $Jp = 0^+$ resonance in ^4He and the other excited states with $J_p = 0^-, 1^-$. We would investigate all the resonances with the n_TOF neutron beam (First stage) and after with a suitable proton beam (second stage): we plan to overlap our experimental results with the ATOMKI ones. All the measurement can be carried out by using the same setup described in the following and designed to be moveable to far laboratories. Considering only the first state, and therefore with respect to the n_TOF and ATOMKI measurements, we have several advantages: i) it is possible to place the setup inside the reaction chamber, because the pro- posed detection apparatus can operate in the beam line vacuum, ii) for tritium measures it would be possible to use a quasi-point like target, with a thin ^3H layer on an inert backing. In this way we benefit from the use of a bare tar- get (at least in one surface), in which the ejectiles are almost unaffected by multiple scattering and energy degradation thus high energy photons do not convert in the material surrounding the target, iii) the beam luminosity is tunable up to more than 2 orders of magnitude higher than with respect to the ATOMKI accelerator (this enable collections of large statistics also at proton low energies, in spite of the exponential decrease of the cross section due to the Coulomb barrier between interacting nuclei), iv) if the LUNA-MV proton beam would be exploited, the underground site makes negligible the cosmic ray induced background. We note that a muon can be misidentied as a pair of ejectiles at large relative angles if no tracking is performed. At LNGS the flux of cosmic muons is suppressed by six orders of magnitude and cannot hamper at all the experimental program even in the most difficult conditions. The achievement of the tritium study is connected to a R&D program to realize a target that must be robust enough and stable against the heating due to the intense proton beam, exploiting the LUNA galvanic cell already used to prepare solid targets for nuclear astrophysics measurements [8]. We conclude remarking for reactions with A=4 in the final state the following: i) the energy range covered by n TOF (neutron beam) and eventually LUNA-MV (proton beam) allows us to study the ^4He excited levels. In particular the e+e- channel has never been studied to our knowledge (apart from the measurement in ATOMKI), providing a unique source of experimental data to be compared with ab-initio calculations, ii) the setup requires particle identification of ejec- tiles, with the aim to constrain theoretical interpretation of the data, iii) the possibility of changing the projectile energy make the investigation of different Jp levels possible, iv) the use of a setup different from the ATOMKI one rein- forces, if successful, the hypothesis for the X17 existence by an independent research team, v) the use of parallel measurements in which ^4He is produced either with neutrons or protons could clearly enlight the protophobic nature of the hypothetical fifth force, vi) if confirmed, the measurement and characterization of the X17 particle would represent an important step forward to the understanding of the dark matter nature. Finally, we would like to stress that this project could be considered the starting point for a more extended research program. In fact, n TOF can also be used to study for the first time the $^7Be(n,e^+e^-)^8$ Be reaction, in order to verify by a complementary reaction the claim of the ATOMKI team relative to the $^7Li(p,e^+e^-)^8Be$ process. In this concern, ^7Be target has been already successfully used by the n_TOF Collab- oration to study the n+^{7}Be → ^{4}He+^{4}He reaction [9]. Finally, with a suitable proton beam (LUNA-MV or LNL) it would also be possible to study for the first time the ^{11}B(p,e^{+}e^{-})^{12}C process.

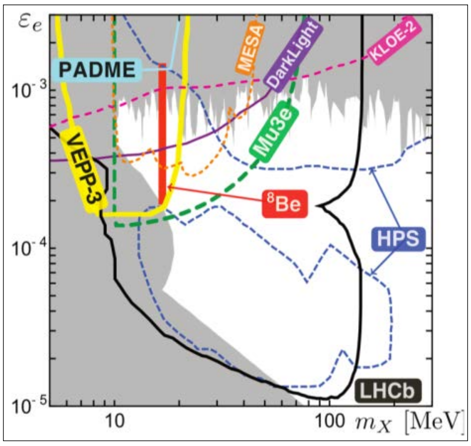

Figure 2: Projected sensitivities of future experiments on the kinetic mixing parameter and a possible dark photon mass mX, taken from [3]. Current experimental constraints (grey) and constraint from 8Be (red), established from, are also reminded [1,3].

Experimental

To measure the particle kinematics observables, to reach a high level of particle identification in a wide energy range and to optimize the signal-to-noise ratio, thus disentangling the different contributions eventually leading to e^{+}e^{-} pairs, we have studied a detection setup based upon two trackers of rectangular shape placed at the side of the target at around 5 cm, one in front of the other. Back to each tracker it is placed an outer electromagnetic calorimeter made of two planes of EJ-200 slabs, 50 cm long, 1 cm wide and 0.6 cm thick. The two EJ-200 slab planes are mounted in a perpendicular way, one along x-axis and the other along y in order to strength the incident particle trajectory reconstruction that starts into the tracker. Back to the EJ-200 slabs the volume is fulfilled by 16 cube of EJ-200 scientillators, 10 cm side, able to stop and to absorbe all the incident leptons energy. The detection setup is the same on both side of the target. In the following all the items that jointly cooperate to build up the experimental apparatus are discussed and analyzed.

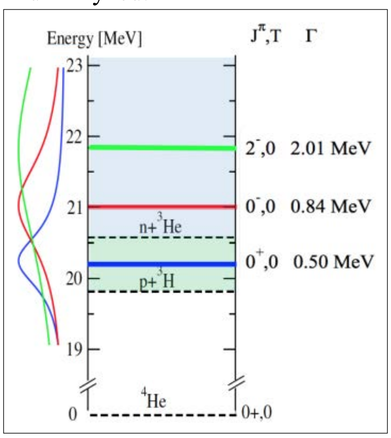

Figure 3: Level scheme of ^{4}He nucleus, with indicated the rest mass of the ^{3}He+n and ^{3}H+p systems. The Breit-Wigner resonance curves of the first excited states above the ^{4}He ground level are also shown. The horizontal black line corresponds to the proton beam energy used in [1],[2] (Ep = 0.9 MeV). The green area shows the energy range that can be explored with the LUNA-MV accelerator. The light blue area shows the energy range that it is possible to study with the n TOF facility.

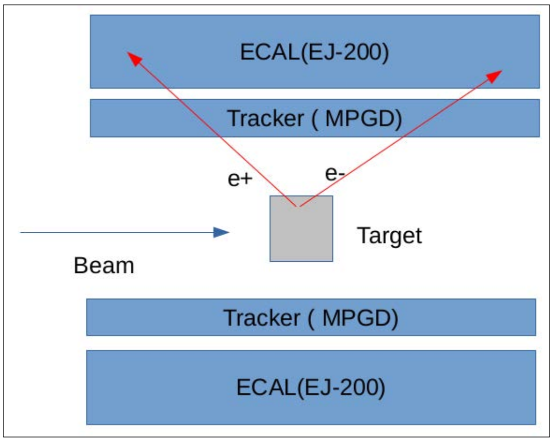

Figure 4: Conceptual design of the ^{3}He(n,e^{-}e^{+})4He at EAR2. The neutron beam strikes on a ^{3}He target, done in special carbon fiber, 0.6 mm thick, 300 - 350 atm. The tracks direction are measured for the first 3 cm with the inner detector (TPC) then by the EJ- 200 slab planes, the energy of each particle is measured with a e.m. calorimeter with adequate granularity (EJ-200).

Tracker

In order to dissolve all the doubts about the existence or not of X17, the most of kinematic observables of the induced reactions must be measured at low uncertainties. Then the core of the detection set-up must be a tracker, in Figure. 4 (see caption) a block diagram is shown. The outer blue sector represents an electromagnetic calorimeter dedicated to the total energy of the emerging leptons and then allowing a precise measure of X17 mass.

Each tracker is realized by TPC that could deliver direct 3D track information for pattern recognition even in high multiplicity events and particle identification over a wide momentum range. It is even suited to work, if needed, inside a magnetic field that deflects the tracks enabling the measure of the particle momentum. The drift time of each track segment could be measured to provide the vertical coordinate Z. The position in the XY projection is obtained by recording the induced charge profiles on the segmented read-out plane after amplification, the recorded charge provides $dE/d\varkappa$ useful for particle identification (PID). The TPCs have rectangular shape, 50 cm long 30 cm wide, with a radial electric field, read out by Micro Pattern Gaseous Detectors (MPGD) like μRwell. The very low material budget of a TPC with a helium-based gas mixture and an anode of 3 mm Cu minimizes the multiple scattering experienced by the ejectiles, while the radial field, compared to a more traditional longitudinal configuration, reduce the diffuusion experienced by the ionization electrons drifting toward the anode, so improving the space resolution of the detector. These features are expected to produce a substantial improvement in the measurement of the e^{+}e^{-} relative angle. The active path available for tracking is of 3 cm. For the segmented readout the use of bulk- µRwell technology (a well-known technology with limited ion feedback) shows the following advantages:

- All-in-one detector: blind areas minimized (including edges and corners);
- Simple design, cheap & robust;
- Good uniformity of performances;

In Figure. 5 (left side) the conceptual design of TPC is shown. The TPC would be divided in four quadrants, each quadrant would

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be read by 128 r-strips (0.78 mm pitch) and by 640 m-strips with a pitch of o.580 mm. Each TPC quadrant will have 768 analog readout channels, the total TPC would have 3072 channels. In Figure. 5 (right side) it is shown the TPC prototype. A block diagram of the TPC electronic read-out is shown in Figure. 6.

The performances of the prototype have been investigated with and without the target on the beam. The results of the test provide us with information on the response to the γ-flash and helps to evaluate the highest neutron energy that can be reached (around few MeV), together with a first measure of the background rate induced by the neutron beam in the target.

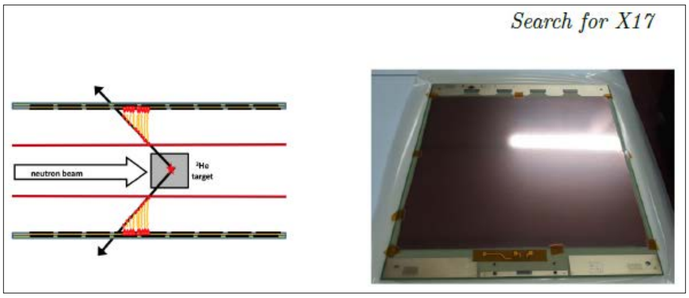

Figure 5: (Left side), conceptual design of the radial TPC detector equipped with MPGD planes. The e^-e^+ pairs provides prompt signals, whose duration is proportional to the drift length; (Right side), photograph of the TPC prototype, PCB characteristics: 512 1D strips, with 600 mm pitch. Gas gap=30 mm

Electromagnetic Calorimeter

The use of a dedicated segmented calorimeter composed by two arrays of scintillating slabs placed perpendicular to each other and back to the two slab planes, in the outer position, 16 cubic tiles 10x10x10 cm^3 of EJ-200 (equal situation on both target sides), together with the action of the tracker, allows a trajectories reconstruction of $\Delta\Theta = \Delta\phi = 5$ deg. or better. The cubic tiles are thick enough to fully absorb all the electron energy and stop them. According to theoretical model [6] the leptons emerging from X17 share an energy fraction between 2 (minimum) and 15 (maximum) MeV. By GEANT4 simulation, electrons of up of 20 MeV energy, that could be considered a safe upper limit for our measures, will have a range slightly over 11 cm in EJ-200 scintillator and each electron has to get across two slabs of 0.6 cm thick and a cube of 10 cm side, in the minimum path when they are emitted perpendicular to the electromagnetic calorimeter (without considering the tracker). The slab readout is provided by SiPM array placed at each ends and related electronics. The EJ-200 cubes will be read by fast PMTs with active divider in order to ensure constant gain up to the maximum allowable current: this is necessary because of the impact of ash on the detection system, the main source of beam induced background. All the electron energy would be fully contained inside the calorimeter and the energy loss inside the slabs and the cubes will be summed up: we expect to reach an energy resolution for X17 around 10%. The electromagnetic calorimeter provides complementary measurements with respect to the tracker detector. It is worth mentioning that the electromagnetic calorimeter would make possible to study in detail the two nuclear reactions $^3He(n,\gamma)^4He$ and $^3He(n,e^+e^-)^4He$ dierential cross section: these measurements are very important to firmly establish the structure of excited levels of ^4He, providing a robust experimental footing for the ab-initio calculations. Moreover, in case it is confirmed the scenario in which X17 decays into two unknown particles (and with unknown charge), it is possible to observe the different response of the calorimeter with respect to pairs at low relative angle, uniquely due to e^+e^- pairs from IPC, providing an independent check Concerning particle identification. Of course, the scintillator is also sensitive to the protons produced by the $^3He(n,p)^3H$ channel, that have approximately the same energy of the interacting neutrons (Q=764 keV), but we are confident to identify the protons with the joint action of tracker, electromagnetic calorimeter and TOF measure of the pulsed neutron beam. In fact, neutrons with $E_n > 15$ MeV reach the EAR2 experimental area not later than 350 ns after the spill time, while events generated by neutrons with $E_n < 10$ MeV are detected not before 400 ns in the EAR2 experimental hall. Therefore, events due to the residual protons with $E_p > 15$ MeV can be easily rejected using the TOF technique.

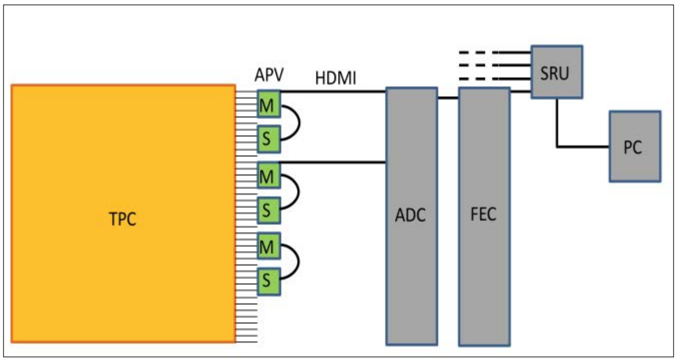

Figure 6: Block diagram of the electronic for the TPC

Conclusion

X17 is offering an exciting challenge for experimental nuclear physicists, with the unique opportunity of a real fundamental discovery or at least to contribute to cast light in a promising new physics field. Even if the existence of X17 would be not confirmed by the new experimental efforts, the data taken in the efforts to solve the puzzle would be useful to investigate effects that for too long have been neglected, like the IPC phenomenon on light nuclei, the light nuclei behaviour and testing experimentally the validity of the ab-initio nuclear theories, thanks to a new enthusiastic collaboration from nuclear theorists and experimentalists. In the optimistic side we could claim that these efforts triggered by X17 hunting, independent from the success or not of the chase, would start a new era for the study of strong interaction and nuclear structure.

References

1. AJ Krasznahorkay, M Csatlós, L Csige, Z Gácsi, J Gulyás, et al. (2016) Observation of Anomalous Internal Pair Creation in 8Be: A Possible Signature of a Light, Neutral Boson Phys. Rev. Lett 116: 042501.
2. AJ Krasznahorkay (2019) A new light particle is being born Phys. Rev. C 104: 044003
3. JL Feng (2016) Phys. Rev. Lett 117: 071803.
4. AJ Krasznahorkay (2020) Journal of Physics G: Conf. Series 1643: 012001
5. M Sabat_e-Gilarte (2017) First beams at Neutrons For Science Eur. Phys. J A53: 210.
6. M Viviani (2022) X17 boson and the $^3H(p,e^+e^-)^4He$ and $^3He(n,e^+e^-)^4He$ Phys. Rev C 105: 014001.
7. E Depero, Yu M Andreev, D Banerjee, J Bernhard, VE Burtsev et al. (2020) Eur. Phys. J.C 80:1159.
8. A Caciolli (2012) Nuclear Astrophysics in underground laboratories: the LUNA experiment Eur. Phys. A 48:144.
9. M. Barbagallo (2016) 7Be(n,α)4He Reaction and the Cosmological Lithium Problem: Measurement of the Cross

Section in a Wide Energy Range at n_TOF at CERN Phys. Rev. Lett. 117: 152701.

10. A Guglielmetti, Proc. XVII International Workshop on Neutrino Telescopes (NEUTEL2017) - Session DOI:https://doi.org/10.22323/1.307.0025