SUMMARY ON CHANGES MADE TO THE MANUSCRIPT

1. Summary

Thank you very much for taking the time to review this manuscript. Please find the detailed responses below and the corresponding revisions/corrections highlighted/in track changes in the re-submitted files

2. Point-by-point changed in the revised manuscript.

Revised 1: Correct name of third author name.

Attila J. Krasznahorky → Attila J. Krasznahorkay

Revised 2: Updated Abstract

[original] L1-7 → "[revised]" L1-7

Abstract:

We have repeated the experiment performed recently by Krasznahorkay et al., (Phys. Rev. Lett. 116, 042501 (2016)), which may indicate a new particle called X17 in the literature. In order to get a reliable, and independent result, we used a different structure of electron-positron pair spectrometer at the VNU University of Science. The spectrometer has two-arm and more simple acceptance/efficiency as a function of the correlation angle, but the other conditions of the experiment were very similar to the published ones. We could confirm the presence of the anomaly measured at Ep= 1225 keV, which is above the Ep=1040 keV resonance.

Revised 3: Added text

[original] L21 → "[revised]" L21-25

Zhang and Miller [4] studied the protophobic vector boson explanation in 8Be, by deriving an isospin relation between the coupling of photon and X17 to nucleons. They are expected to have contributions from M1 multipolarity transitions coming from the resonant proton capture (17.6 and 18.15 MeV Jπ = 1+ states) as well as from the E1 multipolarity transitions resulting from the direct proton-capture process.

Revised 4: Added references

[original] L29 → "[revised]" L34

…the $^{3}H(p,e^{+}e^{-})^{4}He$ [5] and $^{11}B(p,e^{+}e^{-})^{12}C$ [6] …

Revised 5: Added references

[original] L36-44 → "[revised]" L41-50

- *The anomaly has been observed in 8Be with experimental setups using different geometries, with 5 and 6 arms spectrometers [7].*
- *The anomaly has been observed using fundamentally different position sensitive 38 detectors: multi-wire chambers and silicon strip detectors [1,7].*
- *The anomaly has been observed in three different nuclei by now (^{9} Be, ^{4} He and ^{12} C), showing up at*

e^+e^- opening angles consistent with a single particle [1,5,6].

- *The anomaly has been observed at different proton beam energies at varying e^+e^- opening angles, also consistent with a single particle [1,5,6]*
- *All observed anomalies have a very high statistical significance with 6.8σ [1], 6.6—8.9σ [5], and 3—8 σ [6].*

Revised 6: Added references

[original] L48 → "[revised]" L54

Many of these experiments [8–11] already put constraints on the coupling of such a hypothetical particle with ordinary matter.

Revised 7: Updated text

[original] L53-55 → "[revised]" L59-65

At the University of Science, Hanoi National University (HUS), we have a 5SDH-2 Pelletron, a 1.7 MV tandem electrostatic type. It can provide a proton beam with energy from 0.35 to 3.4 MeV or 0.7-5.1 MeV for the alpha beam. The accelerator was installed and operated in 2011 [12], and some initial work for the research in nuclear reaction cross-sections has been done [13]. This article aims to look for the 8Be anomaly at the VNU University of Science (HUS) with a two-arm electron-positron spectrometer specifically designed and built for this purpose.

Revised 8: Updated text

[original] L79-80 → "[revised]" L89-91

Much better energy resolution could be achieved with the latter two types of detectors than with of a plastic scintillator. The FWHM at 17.6 MeV can be achieved below 20 keV for the Ge detector and 150 keV for the LaBr3 detector.

Revised 9: Updated text

[original] L82 → "[revised]" L93-95

… response function is greatly reduced compared to the integral of the response function. The ratio between full energy events and total recorded events is smaller than 1.5% at electron energy of 18 MeV for 3x3 inches LaBr3 detector.

Revised 10: Updated text

[original] L93-94 → "[revised]" L106-107

…Hamamatsu photomultiplier tube (PMT) type R594 assemblies.

Revised 11: Corected sentence

[original] L97 → "[revised]" L110

… found to be less than 1 ns, as shown in Fig 2.

Revised 12: Updated text

[original] L101 → "[revised]" L114

Double-sided Silicon Strip Detectors (DSSD), W1(DS)-500, were used to measure…

Revised 13: Updated text

[original] L101 → "[revised]" L114

Double-sided Silicon Strip Detectors (DSSD), W1(DS)-500, were used to measure…

Revised 14: Updated text

[original] L105 → "[revised]" L118

printed circuit board (PCB)

Revised 15: Updated text

[original] L108-110 → "[revised]" L122-127

…The full width of the 5th-order shaped energy signals is 1.5 µs, and the full rate capability of the MUX32 unit is 800 kHz. The energy resolution of the channels is 5.5 keV Si + 0.064 keV/pF. The timing filter amplifier signals are shaped with 20 ns integration time and 100 ns differentiation time, followed by leading edge discriminators. It is a very fast multiplexed preamplifier, shaper, and discriminator combination with very good energy and timing resolutions.

Revised 16: Updated text

[original] L110-112 → "[revised]" L127-132

…The MUX-32 consists of two MUX-16s; each MUX-16 manages 16 inputs, up to two simultaneous responding channels are identified, and two amplitudes plus the two corresponding amplitude-coded addresses (position signals) are sent to the outputs. Therefore, it can manage the double-hit events with full energy and position information in the x and y directions. These modules are especially well-suited for DSSD detectors.

Revised 17: Corrected text

[original] L114 → "[revised]" L134

PCBs

Revised 18: Updated text

[original] L118-119 → "[revised]" L138-141

…. The experimental configuration was used in Geant4 simulation code[14]. All materials used to construct the experiment have been included in simulation geometry. Therefore, the energy loss in the Al foil and in the air (5 mm) were taken into account.

Revised 19: Updated text

[original] L121 → "[revised]" L143-1145

…Versa Module Eurocard (VME) Analog-to-Digital Converter (ADC), Time-to-Digital Converter (TDC), and Charge-to-Digital Converter (QDC) units,…

Revised 20: Updated text

[original] L124 → "[revised]" L148

Constant fraction discriminators (CFDs)

Revised 21: Updated text

[original] L130 → "[revised]" L154
The energy measured by the DSSD was calibrated…

Revised 22: Updated text
[original] L132-134 → "[revised]" L156-159
… . When creating the spectrum, we required real coincidence between the DSSD detector and the plastic scintillator located behind it by requiring the time different between two plastics is smaller than 40 ns. The two plastics measured the total energy of the e+e− particles. …

Revised 23: Updated text
[original] L140 → "[revised]" L165-166
…when both the e^+ and e^- created during the internal pair production…

Revised 24: Updated text
[original] L149 → "[revised]" L174-175
…, only around 3% of events had to be excluded due to missing information in either the x or y direction.

Revised 25: Updated text
[original] L156 → "[revised]" L181-183
…The energy spectrum measured by the scintillators for events selected by gating on double-hit..

Revised 26: added text
[original] L161 → "[revised]" L186-187
… The typical beam currents for this experiments were from 1 to 1.5 μA.

Revised 27: Updated text
[original] L162-164 → "[revised]" L188-196
LiF targets with thicknesses of ≈30 μg/cm2 evaporated onto 10 μm thick Al foil, as well as Li2O targets with thicknesses of ≈0.3 mg/cm2, were used on 1 μm thick Ni foils in order to maximize the yield of the e+e− pairs. The LiF is a more stable target, and it is easy to evaporate. That was the reason we used it at low bombarding energy (Ep=441 keV, 184 Ex=17.6 MeV) to calibrate the spectrometer. However, if we increase the beam energy from 441 keV (Ex= 17.6 MeV) to 1.04 MeV (Ex=18.15 MeV) the cross-section of the 19F(p,α)16O reaction increases very fast and the created e+e−-pairs coming from the decay of the 6.05 MeV E0 transition would overload our electronics and data acquisition, and observing e+e−-pairs from the 18.15 MeV transition would not be feasible.

Revised 28: Added text
[original] L173 → "[revised]" L205-209
The energy resolution of the plastic scintillator at 17.6 MeV was extremely good (5.2%), proving the very good light collection from the whole detector. The ''background" below the peak comes mostly from the wide (1.5 MeV) transition going to the first excited state of ^{8}Be and from the tail of the 17.6 MeV transition. The energy resolution of the 6.05 MeV (^{16}O) peak is also good.

Revised 29: Added text

[original] L174 → "[revised]" L210

Li_2O

Revised 30: Updated text

[original] L176 → "[revised]" L212-213

…in the plastic scintillator larger than…

Revised 31: Updated text

[original] L177 → "[revised]" L214

Two resonance peaks were…

Revised 32: Added text

[original] L179 → "[revised]" L215-217

For the 441 keV resonance, it was found to be approx. 150 keV, which means about 0.44 mg/cm^2 target thickness, since the energy loss of the protons is 340 keV/mg/cm^2.

Revised 33: Updated text

[original] L188-190 → "[revised]" L226-230

Coincidence events, with both arms of the spectrometer detecting e+/e− particles, were also recorded. The opening angle distribution of e+e− pairs from such events is shown in Fig. 8 (right). The cosmic background data had been collected and analyzed similar to the experiment data and subtracted. Total time collection of both data had been normalized.

Revised 34: Added text

[original] L201 → "[revised]" L241-246

The dominant M1 part (87.4%) is clearly understood since it is a 1^+ --> 0^+ transition. The 12.8% E1 mixing can also be understood since the energy loss in the target was about 150 keV, which is about 14 times larger than the width of the resonance Γ=10.7 keV [16], and we integrated a reasonable amount from the proton direct capture part of the excitation function [17] as well, which has a multipolarity of E1.

Revised 35: Added text

[original] L206 → "[revised]" L251-257

As can be seen in the insert of Fig 10, the background could be described well with 48.9% E1 and 51.1% M1 components. The E1 component comes from the direct proton capture, while the 51.1% from the tails of the Ep=441 keV and 1040 keV resonances. We did not observe any contribution from the X17 decay like N.J. Sas, et al. [18] observed before. Since during this experiment the target was burned out (punctured) many times, the effective energy of the protons was changing and may washed out the anomaly caused by the X17 e^+e^- decay.

Revised 36: Updated text

[original] L207 → "[revised]" L258-259

Finally, we changed the proton beam energy to 1225 keV, above to the 1040 keV resonance to check the off resonance region.

Revised 37: Updated text

[original] L213-214 → "[revised]" 264-265

…, we can calculate a mass of $mxc^2 = 16.66 \pm 0.47$ (stat.) MeV for this particle with a confidence above 4σ.

Revised 38: Added text

[original] L214 → "[revised]" L265-267

As can be seen in the insert of Fig 11, we could describe the background with pure E1 distribution, which show that we are indeed in the off resonance region.

Revised 39: Updated text

[original] L215-220 → "[revised]" L268-270

The systematic uncertainty on the calculated particle mass from the beam spot's position was estimated using a series of simulations using different beam spot positions. This resulted in a $\Delta m_X c^2$ (systematic)= ±0.35 MeV uncertainty.

Revised 40: Updated text

[original] L215-220 → "[revised]" L271-278

Based on the best fit results shown in Fig. 11, it can be concluded that X17-boson particles were created simultaneously with the IPC due to the E1 transition in this experiment. The branching ratio of the e^+e^- decay of such boson to IPC and γ decay of the 18.15 MeV 253 level is found to be 2.8×10^{-3} and 1.1×10^{-5}, respectively. It seems that the X17 particle is created in the E1 transition and not in the M1 one. In Ref. [1], they obtained a branching ratio of 5.8×10^{-6}, which is about half of the value we obtained here. They did the experiment on the 1040 keV resonance, in this way the M1 contribution of the resonance may not produced any X17 particle.

Revised 41:

[original] L225-229 → "[revised]" L283-287

…. The angular correlation of the e^+e^- pairs measured for the 17.6 MeV transition (Ep=~~441~~keV) agrees well with the simulated one for the M1 transition. No anomaly was observed for this, or the Ep = 800 keV transition either. However, a significant anomaly (> 4σ) was observed for the 18.15 MeV transition (Ep=1040keV) at around 135° …

Revised 42: Updated the caption of Fig. 1
Revised 43: Updated the caption of Fig. 2
Revised 44: Updated Fig. 3
Revised 45: Update Fig. 5
Revised 46: Updated Fig. 6 and its caption
Revised 47: Updated Fig. 7 and its caption
Revised 48: Updated Fig. 8 and its caption
Revised 49: Updated Fig. 9 and its caption
Revised 50: Updated Fig.10 and its caption
Revised 51: Updated Fig. 11 and its caption