Searching for two $\gamma$-decay of $X(17)$

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Ádám Nagy
University of Debrecen;
Institute for Nuclear Research, Hungarian Academy of Sciences
Motivations

- Searching for dark matter is hot topics of physics.
- Many experiment performed to search for dark particles.
- Many theoretical models predict particles in the 10 MeV – 1 GeV range.
- Searching for light particles in nuclear transitions.

Figure: Many experiments search for dark matter candidates.
Motivations

- $^7\text{Li}(p, e^- e^+) ^8\text{Be}$ reaction was used for creating excited state of $^8\text{Be}$.
- Examined two excited state. The $e^-e^+$-pair correlation was measured:
  - $E_X = 17.5$ MeV $\rightarrow$ no bump.
  - $E_X = 18.15$ MeV $\rightarrow$ bump.

**Figure:** Bump at $\Theta \simeq 145^\circ$ in the angular correlation. Smooth curve shows the theoretical angular $e^-e^+$ pair correlations. Points shows the experimental result.
The detected bump can be a signature of $X_{17} \rightarrow e^- e^+$. 


**Figure**: Bump at $\Theta \simeq 145^\circ$ in the angular correlation. Smooth curve shows the theoretical angular $e^- e^+$ pair correlations. Points shows the experimental result.
Motivations

- We re-investigated $^7Li(p, e^-e^+)^8Be$ experiment.
- We used a different $e^-e^+$-pair spectrometer (with 6 telescopes).
- Experimental result $\rightarrow$ there is a bump at $\Theta \simeq 145^\circ$.

**Figure:** Bump at $\Theta \simeq 145^\circ$ in the angular correlation. Smooth curve shows the theoretical angular pair correlation. Blue points show the "PRL result". Red points show the "present result".
Theoretical interpretations of $^7Li(p, e^- e^+) ^8Be$

- This result got an great international interest.
- The experimental result doesn’t explained by nuclear reactions.  

- The experimental result explained by new particle  
  ($m_0c^2 = 16.7$ MeV), with $J^\pi = 1^+$.  

- There is an other other interpretation: we observed an particle  
  with $J^\pi = 0^-$.  
  ( U. Ellwanger, S. Moretti; arXiv: 1609.01669v2. )
Theoretical interpretations of $^7\text{Li}(p, e^- e^+)^8\text{Be}$

Which theoretical model gives the right features?

Possible explanation of the electron positron anomaly at 17 MeV in $^8\text{Be}$ transitions through a light pseudoscalar

Ulrich Ellwanger$^{a,b}$ and Stefano Moretti$^b$

Ádám Nagy

Searching for two $\gamma$-decay of $X(17)$
Motivation of $X_{17} \rightarrow \gamma\gamma$ experiments

- Landau-Young theorem:
  Considering a particle with spin 1 and mass $> 0$. Two $\gamma$-decay is forbidden.

- We have $X_{17}$:
  - If $J^\pi = 1^+$ → double $\gamma$-decay of $X_{17}$ is forbidden.
  - If $J^\pi = 0^-$ → double $\gamma$-decay of $X_{17}$ is allowed.
The $^3H(p, \gamma \gamma)^4He$ experiment in Debrecen

- Experiment at Tandetron Accelerator of the Institute for Nuclear Research.
- 14 $LaBr_3$ detectors in one detector-ball. (12 detectors are 3" $\times$ 3" and 2 detectors are 6.5" $\times$ 3.5".)
- Energy resolution of $LaBr_3$ detectors at $E \simeq 17$ MeV $\rightarrow$ 0.5%.

**Figure:** Experimental setup for searching $X17 \rightarrow \gamma \gamma$. Moreover, the figure shows the $e^-e^+$-spectrometer, which was used for measuring the angular $e^-e^+$ pair correlations.
The $^3H(p,\gamma\gamma)^4He$ experiment in Debrecen

**Figure:** Experimental setup for searching $X \rightarrow \gamma\gamma$. (A photo about the $\gamma\gamma$ coincidence spectrometer.)
The $^3H(p, \gamma \gamma)^4He$ experiment in Debrecen

Calibration measurement

Aim:
- Checking the $\gamma \gamma$-spectrometer.
- The $\gamma \gamma$–spectrometer records the coincidence events.

Features of the experiment:
- We used a $^{11}B$ target.
- We used a proton beam, at $E_p = 685$ keV.
The $^3H(p, \gamma\gamma)^4He$ experiment in Debrecen

Calibration measurement

- The energy of excited state is $E_X = 16.6$ MeV.
- Decay of this state $\rightarrow$ Emitting two gamma-ray with $E_{\gamma 1} = 12.7$ MeV, $E_{\gamma 2} = 4.43$ MeV.
- We measure cascade transmission.
- If the experimental setup is well calibrated for recording coincidence events. $\rightarrow$ A peak at $E = 15.6$ MeV in the energy sum spectrum.

Figure: Level scheme of $^{12}C$. 

\[
\begin{align*}
2^- & \quad E_X = 16.6 \text{ MeV} \\
& \quad E_{\gamma 1} = 12.17 \text{ MeV} \\
& \quad E_{\gamma 2} = 4.43 \text{ MeV} \\
0^+ & \quad \text{ground state} \\
& \quad E_{\gamma 3} = 16.6 \text{ MeV}
\end{align*}
\]
The $^3H(p, \gamma\gamma)^4He$ experiment in Debrecen

Calibration measurement

**Figure:** Energy sum spectrum of $\gamma$-ray, which are in coincidence. There is an 1 MeV difference between $E_X = 16.6$ MeV and $E = 15.6$ MeV. ↔ We detected the second escape peak.
The $^3H(p, \gamma\gamma)^4He$ experiment in Debrecen

$X_{17} \rightarrow \gamma\gamma$ measurement

Aim:
- Search for coincidence events which are supporting the $X_{17} \rightarrow \gamma\gamma$.

Features of the experiment:
- created the second excited state of $^4He$
- used reaction: $^3H(p, \gamma)^4He$, at $E_p = 1.000$ MeV
- $(p, n)$ channel is open at $E = 1.084$ MeV.
- The target was tritiated titanium foil on a 4 mm thick $Mo$ disk. The thickness of the target was 3 $mg/cm^2$.
- we must use cold target $\rightarrow$ we applied liquid nitrogen.
The $^3H(p, \gamma\gamma)^4He$ experiment in Debrecen

**X17 $\rightarrow \gamma\gamma$ measurement**

Data analysis:

- A general condition for energy variables and trigger time variables.
- If we detected a real coincidence event $\leftrightarrow$ time coincidence and multiplicity $= 2$.
- Energy symmetry for detected $\gamma$-energies:

  $$0.1 < \frac{E_1 - E_2}{E_1 + E_2} < 0.1$$

- Correction by subtracting
  - the random events,
  - the cosmic events.
The $^3H(p, \gamma \gamma)^4He$ experiment in Debrecen

$X_{17} \rightarrow \gamma \gamma$ measurement

Data analysis:

Figure: Energy sum spectrum of cosmic ray. The histogram consists of those events which are in coincidence.
The $^3H(p, \gamma \gamma)^4He$ experiment in Debrecen

$X_{17} \rightarrow \gamma \gamma$ measurement

Data analysis: Result

Figure: Energy sum ($E_{\gamma_1} + E_{\gamma_2}$) spectrum which shows coincidence events in $0^\circ - 180^\circ$ interval. (tiny peak around 18 MeV, which comes from the $2\gamma$ decay of 21.1 MeV state)
The $^3\text{He}(n,\gamma\gamma)^4\text{He}$ experiment in Munchen

Features of the experiment:

- We performed an experiment to investigate the $X \rightarrow \gamma\gamma$, respected Research Neutron Source Heinz Maier-Leibnitz in Munchen.
- We excited the following states of $^4\text{He}$
  - $E_X = 20.21$ MeV, $\Gamma = 0.50$ MeV;
  - $E_X = 21.01$ MeV, $\Gamma = 0.84$ MeV.
- We used the $^3\text{He}(n,\gamma)^4\text{He}$ at $E_n = 1$ meV.
- Target: a gas target with the pressure is $P = 2$ bar.
- Advantages of $^3\text{He}(n,\gamma)^4\text{He}$ reaction:
  - High cross section of the neutron capture
  - $\sigma(n,\gamma)$ is low $\rightarrow \sigma(n,\gamma)$ and $\sigma(n,\gamma\gamma)$ are comparable.
The $^3\text{He}(n,\gamma\gamma)^4\text{He}$ experiment in Munchen

Photos about the experimental setup:

Figure: $\gamma$-spectrometer which was used in the experiment. The setup consists of 12 $\text{LaBr}_3$ detectors. The relative angle is $30^\circ$ between the detectors.

Figure: $^3\text{He}$ gas target. Pressure is $P = 2$ bar.
The $^3\text{He}(n, \gamma\gamma)^4\text{He}$ experiment in Munchen

Results of the experiment:

**Figure:** This histogram shows the detected energy spectrum of single gamma events.

**Figure:** Energy sum spectrum of detected $\gamma$-energies. The histogram consists of coincidence events after random event and cosmic subtraction.
The $^8$Be anomaly could be reproduced with an independent spectrometer.

The effect can not be explained within nuclear physics.

The anomaly can be successfully described by a new particle called $X_{17}$.

The $\gamma\gamma$-decay of $X_{17}$ was studied, but could not be cleanly observed. We are planning further studies.
Thank you for your attention