Searching for two γ-decay of X(17)

European Nuclear Physics Conference
September 2^{nd}-7^{th}, 2018, Bologna, Italy

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.

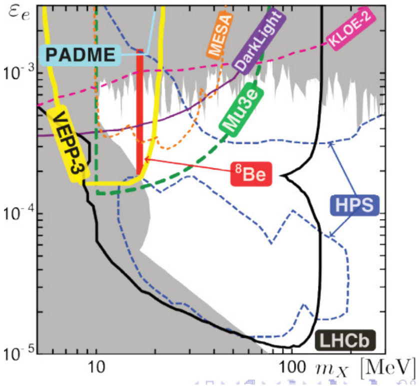

Figure: Many experiments search for dark matter candidates.

Motivations

- $^7Li(p, e^-e^+)^8Be$ reaction was used for creating excited state of ^8Be.
- 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.

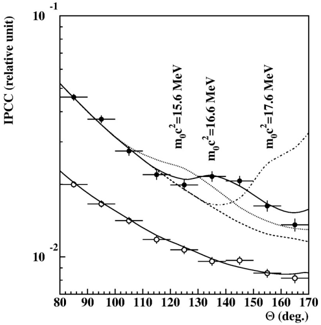

Figure: Bump at $\Theta \simeq 145^\circ$ in the angular correlation. Smooth curve shows the theoretical angular e^-e^+ pair correlations. Points shows the experimental result.

Motivations

- The detected bump can be a signature of $X17 \to e^- e^+$.

  (A. J. Krasznahorkay et al.; Phys. Rev. Lett. 116, 042501, (2016).)

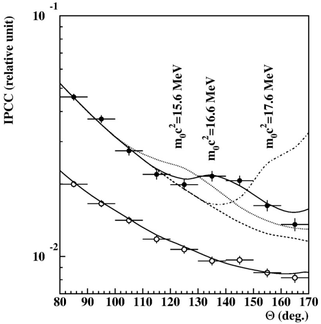

Figure: Bump at $\Theta \simeq 145°$ in the angular correlation. Smooth curve shows the theoretical angular $e^- e^+$ pair correlations. Points shows the experimental result.

Motivations

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

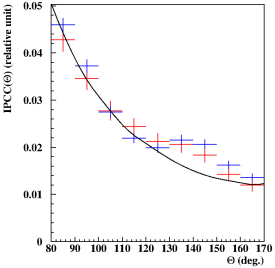

Figure: Bump at $\Theta \simeq 145°$ in the angular correlation. Smooth curve shows the theoretical angular pair correlation. Blue points show the "PRL result". Red points show the "present result ".

Theoretical interpretations of $^7Li(p, e^-e^+)^8Be$

- This result got an great international interest.
- The experimental result doesn't explained by nuclear reactions.
  (X. Zhang, G. A. Miller; Phys. Lett. B773, 159, (2017).)
- The experimental result explained by new particle ($m_0c^2 = 16.7$ MeV), with $J^\pi = 1^+$.
  (J. L. Feng et al.; Phys. Rev. Lett. 117, 071803, (2016).)
- There is an *other* other interpretation: we observed an particle with $J^\pi = 0^-$.
  (U. Ellwanger, S. Moretti; arXiv: 1609.01669v2.)

Theoretical interpretations of $^{7}Li(p, e^{-}e^{+})^{8}Be$

PRL **117,** 071803 (2016) PHYSICAL REVIEW LETTERS week ending 12 AUGUST 2016

Protophobic Fifth-Force Interpretation of the Observed Anomaly in ^{8}Be Nuclear Transitions

Jonathan L. Feng,[1] Bartosz Fornal,[1] Iftah Galon,[1] Susan Gardner,[1,2] Jordan Smolinsky,[1] Tim M. P. Tait,[1] and Philip Tanedo[1]
[1]*Department of Physics and Astronomy, University of California, Irvine, California 92697-4575, USA*
[2]*Department of Physics and Astronomy, University of Kentucky, Lexington, Kentucky 40506-0055, USA*
(Received 3 May 2016; published 11 August 2016)

Which theoretical model gives the right features?

JHEP Published for SISSA by Springer
Received: *September 23, 2016*
Revised: *October 24, 2016*
Accepted: *October 28, 2016*
Published: *November 8, 2016*

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

Ulrich Ellwanger[a,b] and Stefano Moretti[b]

Motivation of $X17 \to \gamma\gamma$ experiments

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

- We have $X17$:
  - If $J^\pi = 1^+ \to$ double γ–decay of $X17$ is forbidden.
  - If $J^\pi = 0^- \to$ double γ–decay of $X17$ 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%.

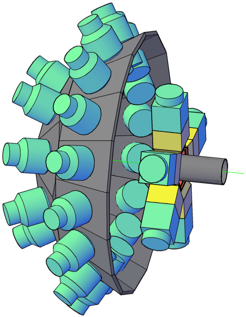

Figure: Experimental setup for searching $X17 \rightarrow \gamma\gamma$. Moreover, the figure shows the e^-e^+–spectrometer, which was used for measuring the angular e^-e^+ pair correlations.

The $^3H(p,\gamma\gamma)^4He$ experiment in Debrecen

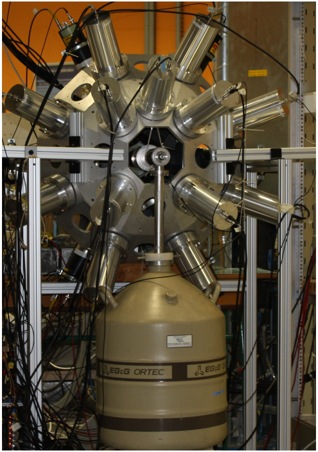

Figure: Experimental setup for searching $X \rightarrow \gamma\gamma$.
(A photo about the $\gamma\gamma$– coincidence spectrometer.)

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.

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.

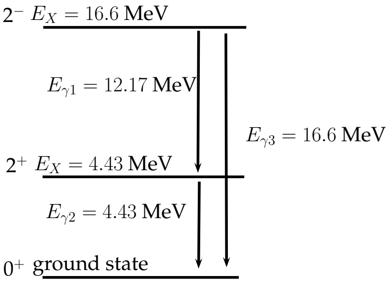

Figure: Level scheme of ^{12}C.

The $^3H(p,\gamma\gamma)^4He$ experiment in Debrecen

Calibration measurement

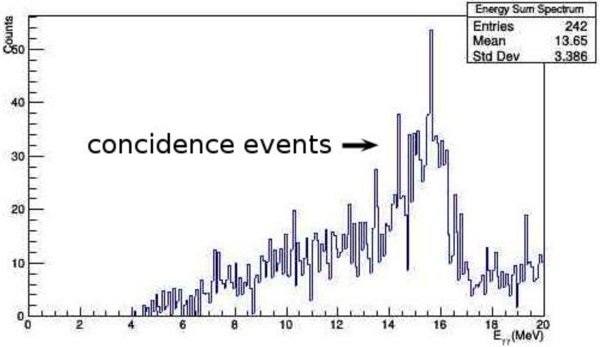

Figure: Energy sum spectrum of γ-ray, which are in coincidence. There is an 1 MeV difference between $E_X = 16.6$ MeV and $E = 15.6$ MeV. $\leftrightarrow$ We detected the second escape peak.

The $^3H(p,\gamma\gamma)^4He$ experiment in Debrecen

$X17 \rightarrow \gamma\gamma$ measurement

Aim:

- Search for coincidence events which are supporting the $X17 \rightarrow \gamma\gamma$.

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.

$X17 \to \gamma\gamma$ 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 γ–energies:

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

- Correction by subtracting
  - the random events,
  - the cosmic events.

$X17 \to \gamma\gamma$ measurement

Data analysis:

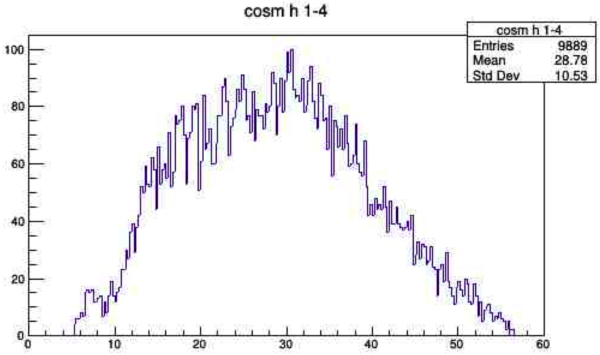

Figure: Energy sum spectrum of cosmic ray. The histogram consists of those events which are in coincidence.

$X17 \rightarrow \gamma\gamma$ measurement

Data analysis: Result

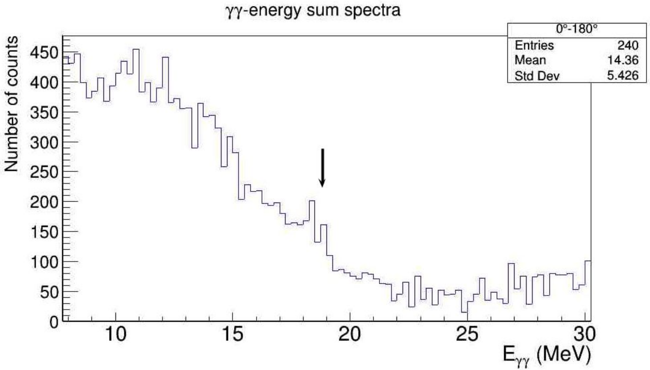

Figure: Energy sum ($E_{\gamma 1} + E_{\gamma 2}$) spectrum which shows coincidence events in $0^\circ - 180^\circ$ interval. (tiny peak around 18 MeV, which comes from the 2γ decay of 21.1 MeV state)

The $^3He(n,\gamma\gamma)^4He$ 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 ^4He
  - $E_X = 20.21$ MeV, $\Gamma = 0.50$ MeV;
  - $E_X = 21.01$ MeV, $\Gamma = 0.84$ MeV.
- We used the $^3He(n,\gamma)^4He$ at $E_n = 1$ meV.
- Target: a gas target with the pressure is $P = 2$ bar.
- Advantages of $^3He(n,\gamma)^4He$ reaction:
  - hight cross section of the neutron capture
  - $\sigma(n,\gamma)$ is low $\rightarrow$ $\sigma(n,\gamma)$ and $\sigma(n,\gamma\gamma)$ are comparable.

The $^3He(n,\gamma\gamma)^4He$ experiment in Munchen

Photos about the experimental setup:

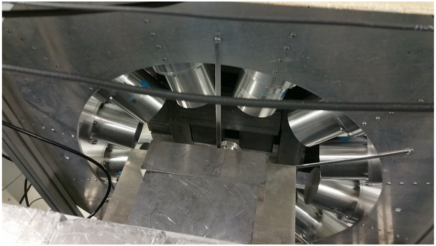

Figure: γ-spectrometer which was used in the experiment. The setup consists of 12 $LaBr_3$ detectors. The relative angle is 30° between the detectors.

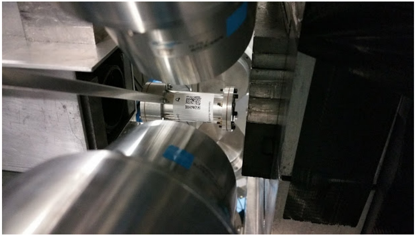

Figure: ^3He gas target. Pressure is $P = 2$ bar.

The $^3He(n,\gamma\gamma)^4He$ experiment in Munchen

Results of the experiment:

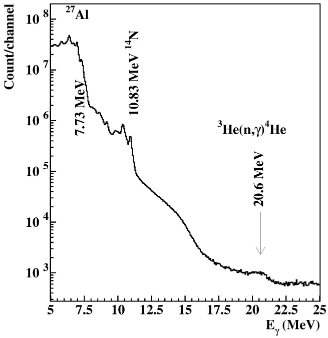

Figure: This histogram shows the detected energy spectrum of single gamma events.

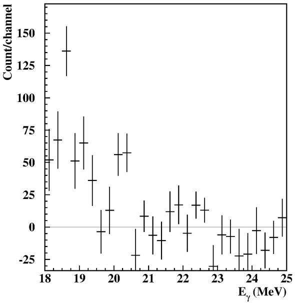

Figure: Energy sum spectrum of detected γ-energies. The histogram consists of coincidence events after random event and cosmic subtraction.

Conclusion

- The ^8Be 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 $X17$.
- The $\gamma\gamma$-decay of $X17$ was studied, but could not be cleanly observed. We are planning further studies.

Thank you for your attention