Kinematical evidence for the X17 particle

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UNIVERSITY of DEBRECEN

atomki DEBRECEN

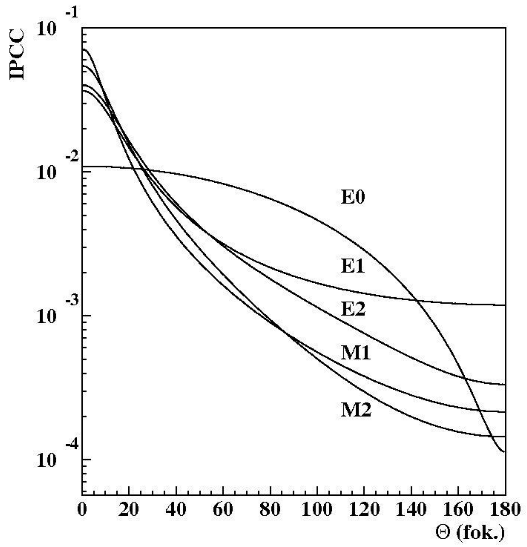
CERN

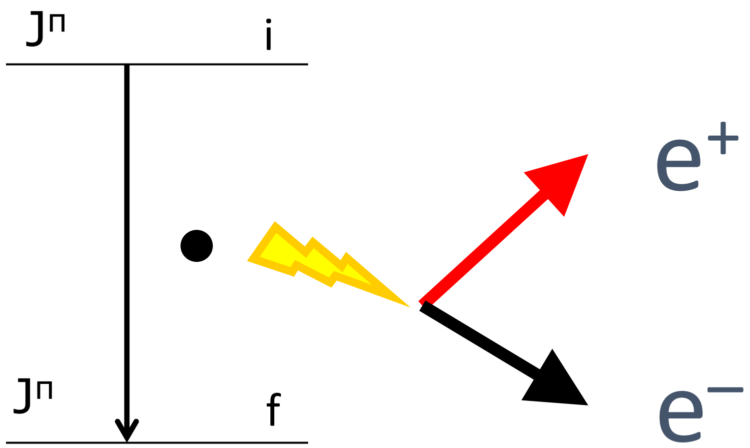
LDMA'25

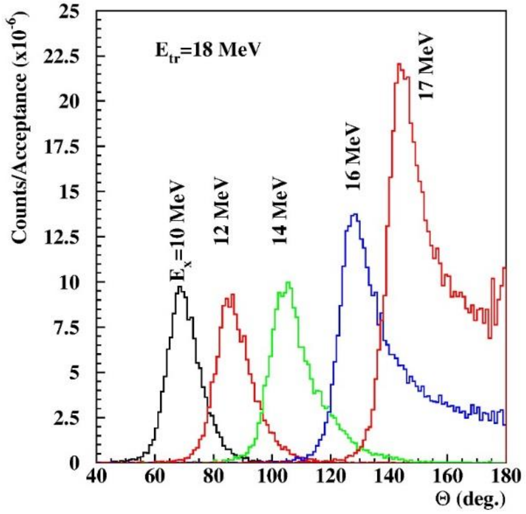
Searching for the e^+-e^- decay of a new particle (axion, dark photon) in nuclear transitions

e^+-e^- internal pair creation

Two body decay of a moving particle



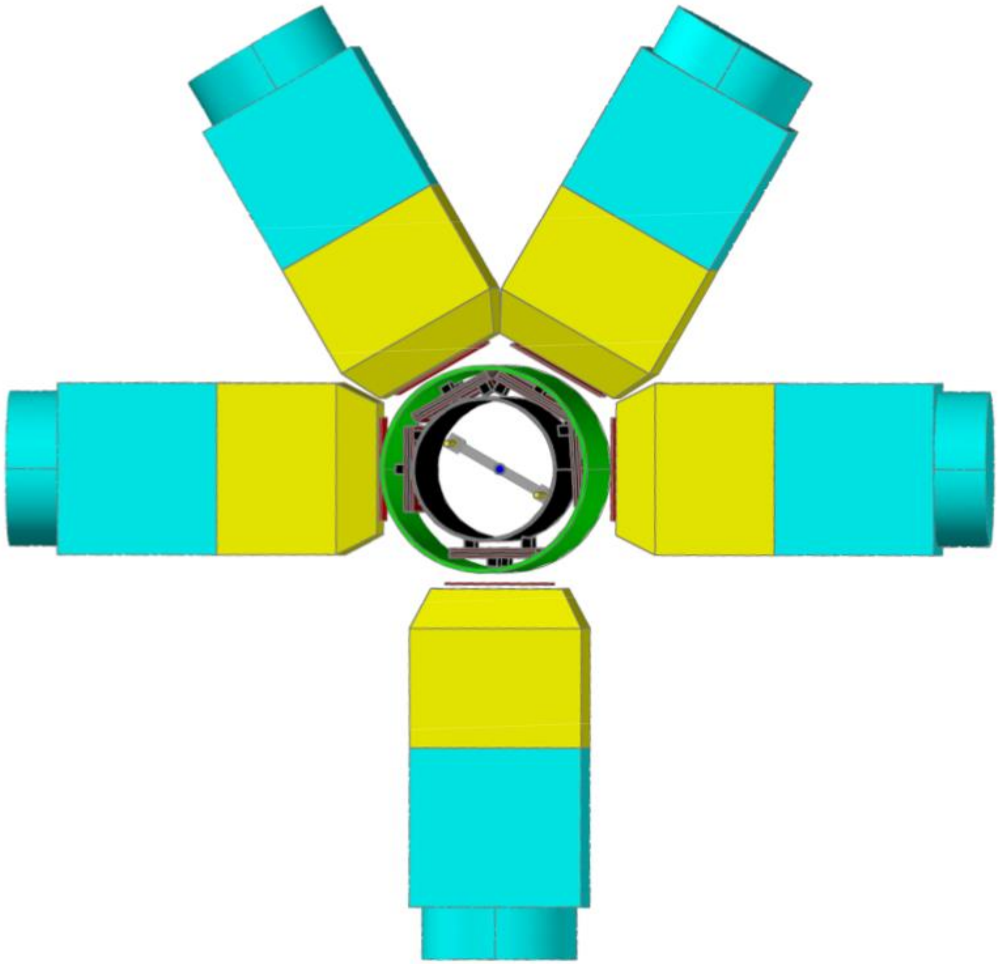




M.E. Rose Phys. Rev. 76 (1949) 678
E.K. Warburton Phys. Rev. B133 (1964) 1368.
P. Schlüter, G. Soff, W. Greiner, Phys. Rep. 75 (1981) 327.

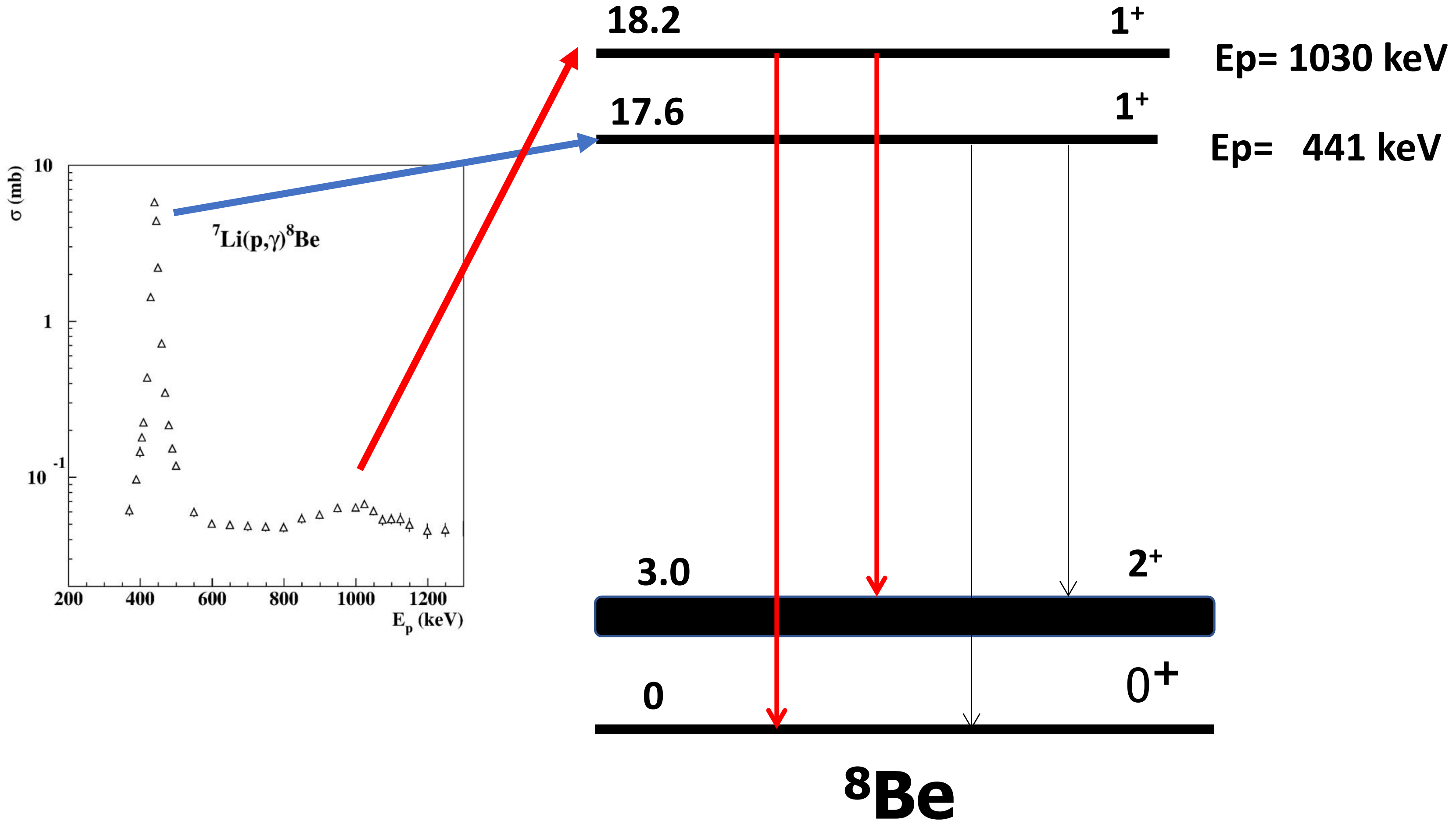
- S. Weinberg, A New Light Boson?, Phys. Rev. Lett. 40 (1978) 223
- Donelly, et al. , Phys. Rev. D 18 (1978) 1607

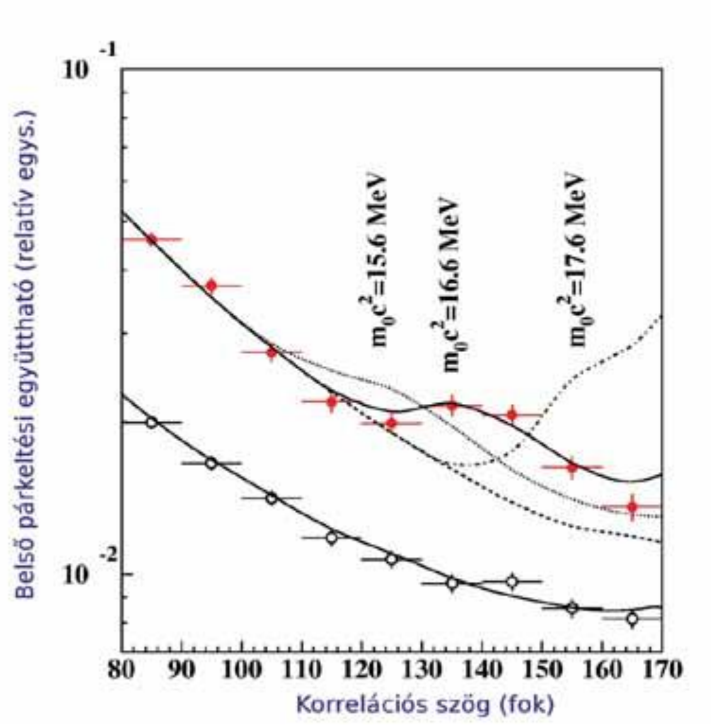
Geometrical arrangement of the scintillator telescopes (NIM, A808 (2016) 21)



Study of the ^{8}Be M1 transitions

Excitation with the ^{7}Li(p,γ)^{8}Be reaction





m_0c^2=16.7 ±0.35(stat)±0.5(syst.)

PRL **116,** 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Indication of a Light, Neutral Boson

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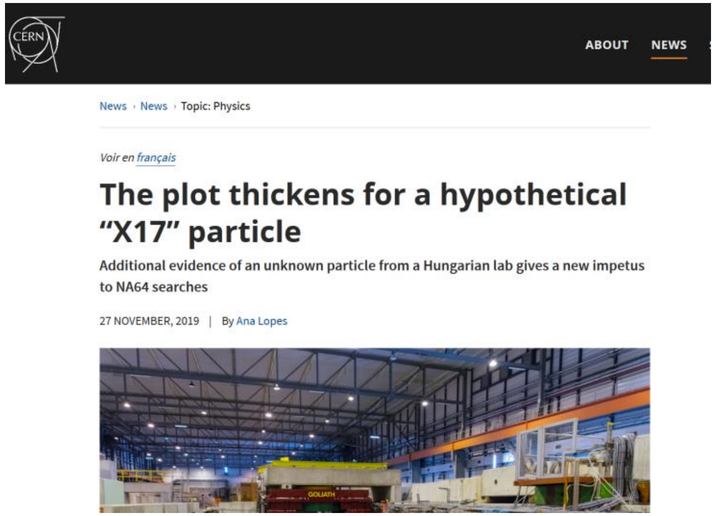
(Received 7 April 2015; published 26 January 2016)

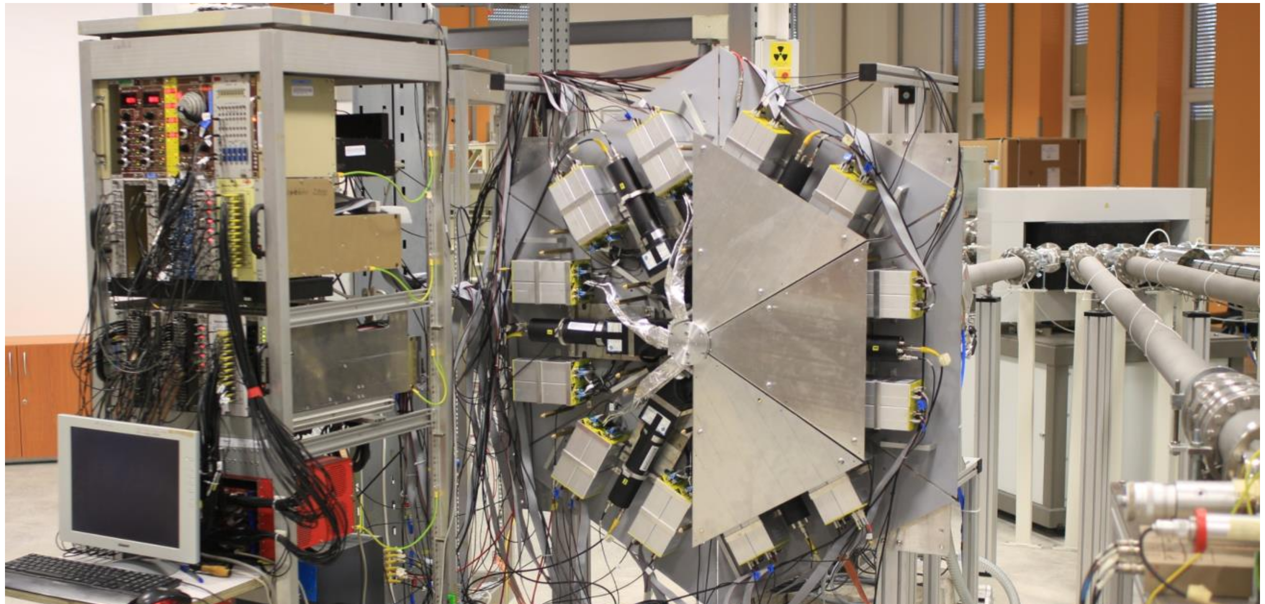
Electron-positron angular correlations were measured for the isovector magnetic dipole 17.6 MeV ($J^\pi = 1^+$, $T = 1$) state → ground state ($J^\pi = 0^+$, $T = 0$) and the isoscalar magnetic dipole 18.15 MeV ($J^\pi = 1^+$, $T = 0$) state → ground state transitions in ^{8}Be. Significant enhancement relative to the internal pair creation was observed at large angles in the angular correlation for the isoscalar transition with a confidence level of $> 5\sigma$. This observation could possibly be due to nuclear reaction interference effects or might indicate that, in an intermediate step, a neutral isoscalar particle with a mass of $16.70 \pm 0.35(\text{stat}) \pm 0.5(\text{syst})$ MeV$/c^2$ and $J^\pi = 1^+$ was created.

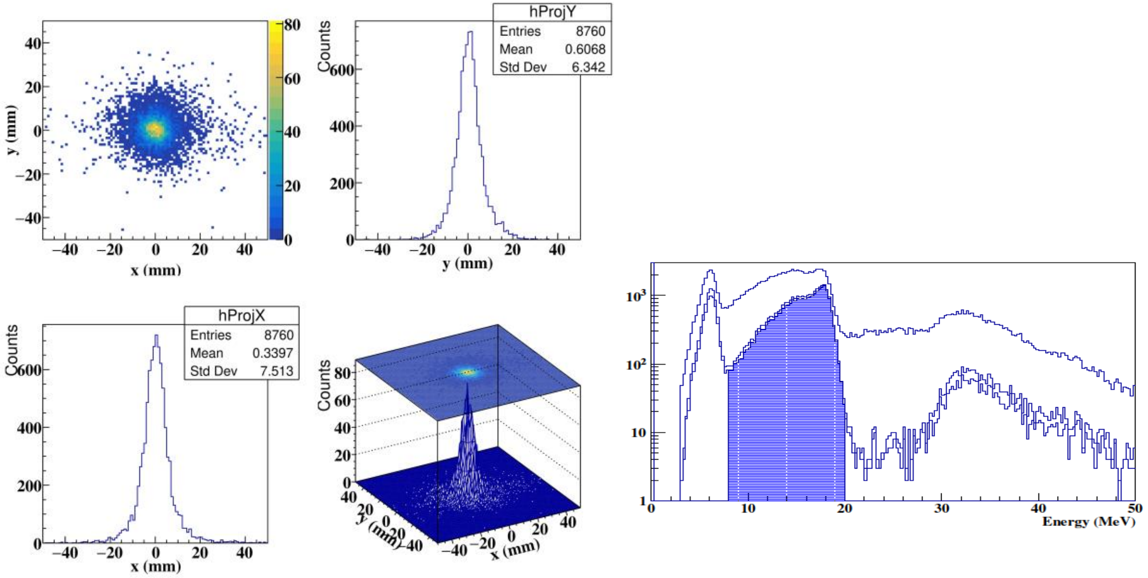


The ATOMKI anomaly → signals for a new 17 MeV/c² particle called later X17

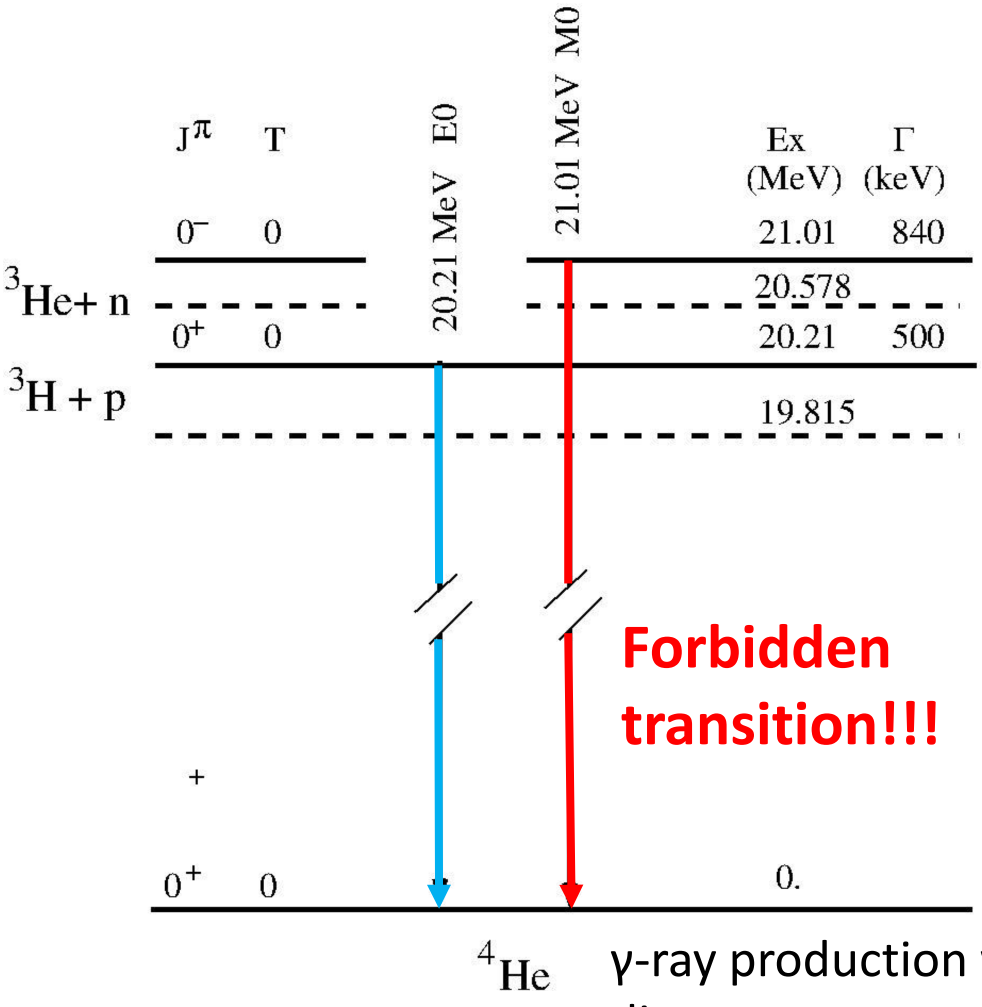
Article in Nature, CNN news, boom in the media

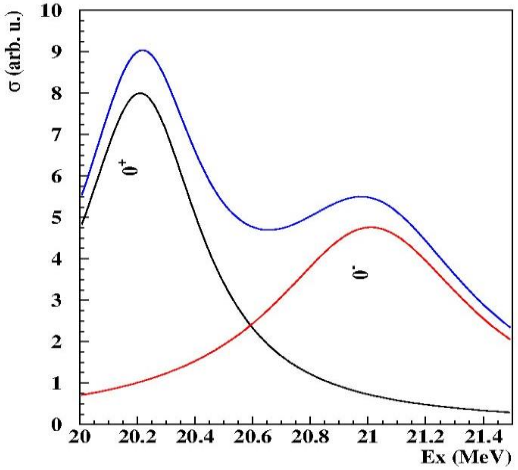
The newly built tandetron lab. in ATOMKI and the newest version of the e^+e^- spectrometer

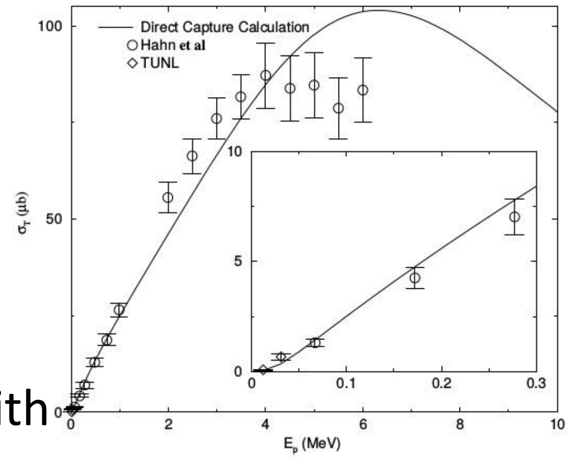




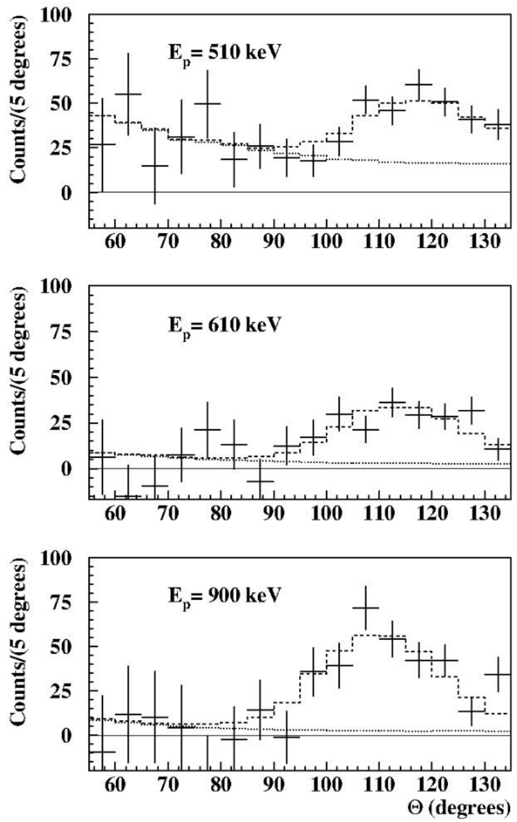
Study of the 21 MeV M0 transition in ^{4}He excited by ^{3}H+p, and ^{3}He+n reactions







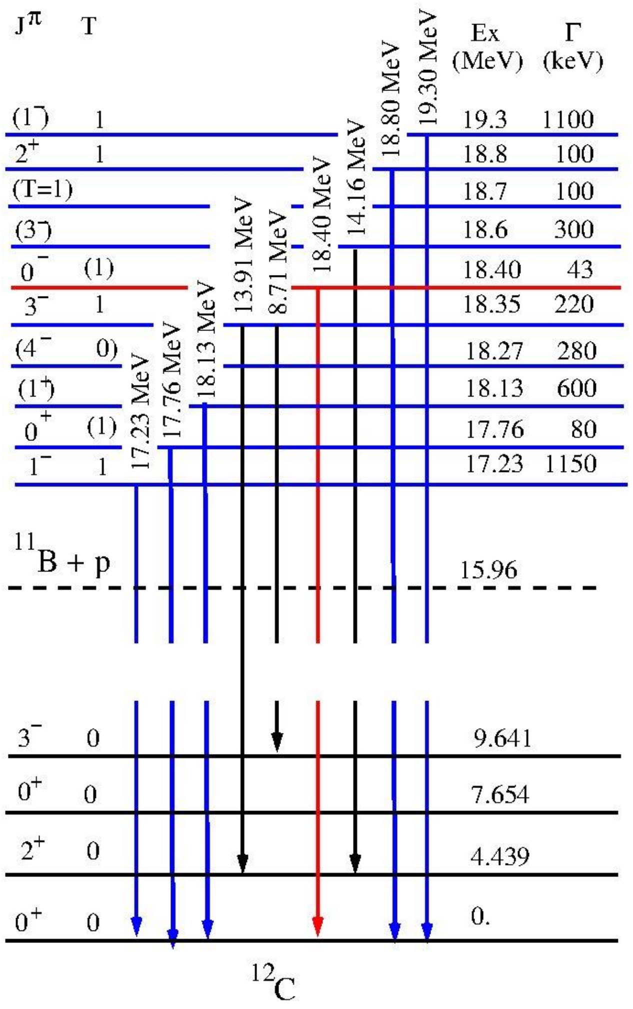
γ-ray production with direct proton capture.

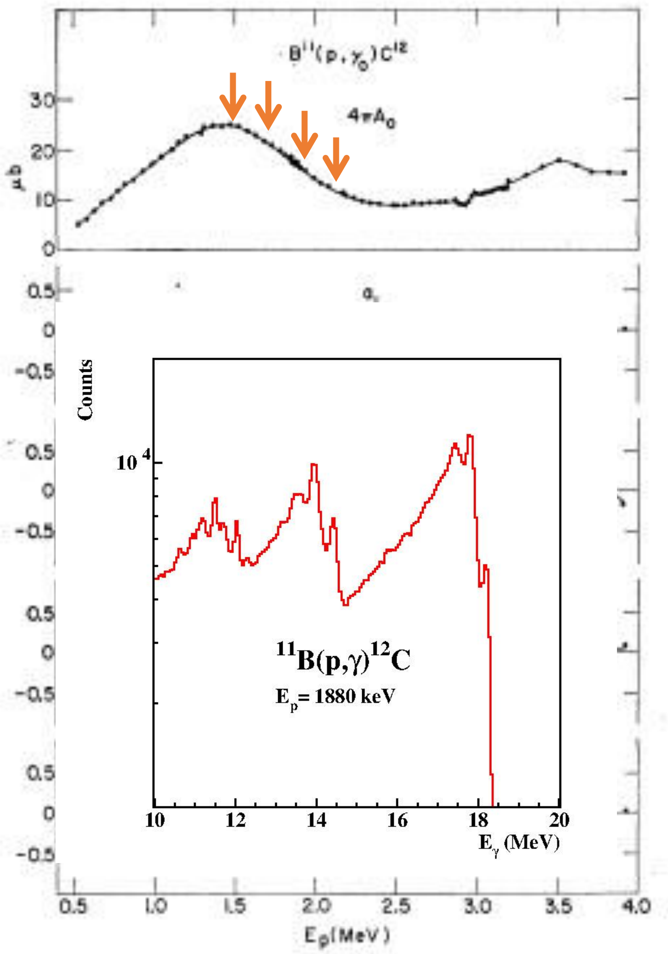


Phys. Rev. C 104, 044003 (2021)

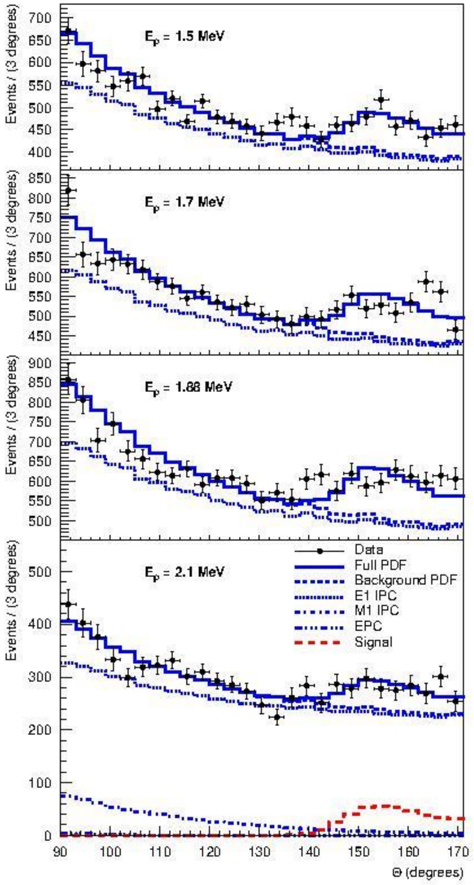
$m_0c^2 = 16.94 \pm 0.12(\mathrm{stat}) \pm 0.21(\mathrm{syst.})$

Results for $^{11}B(p,e^+e^-)^{12}C$ reaction





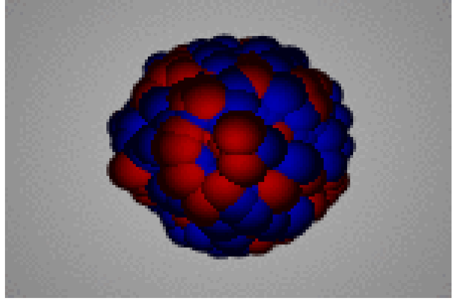
γ-ray spectrum taken with a 3”x3” $LaBr_3$ detector.



Phys. Rev. C 106, L061601 (2022)

$m_0c^2 = 17.03 \pm 0.11(\text{stat}) \pm 0.20(\text{syst.})$

Observation of the X17 anomaly in the decay of the Giant Dipole Resonance



GDR

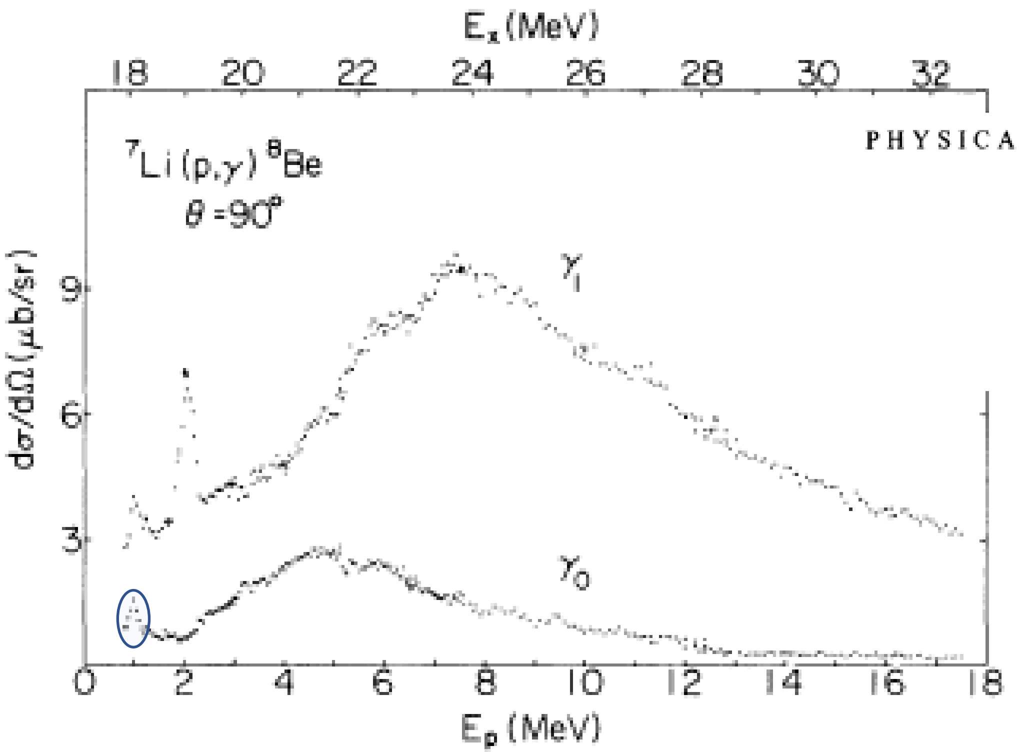


FIG. 3. The yield functions for the γ_0 and γ_1 transitions obtained at 90°, which show the broad giant resonances built on the ground state and the first excited state of ^8Be.

PHYSICAL REVIEW C VOLUME 14, NUMBER 1

Giant $E1$ resonances in ^8Be from the reaction $^7Li(p,\gamma)^8Be$ †

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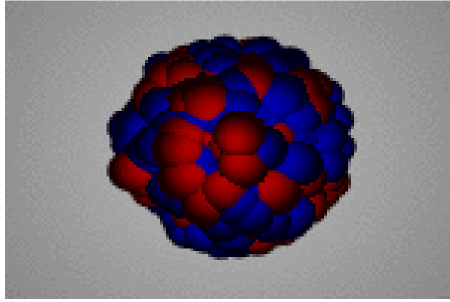
Department of Physics, Stanford University, Stanford, California 94305

(Received 21 January 1976)

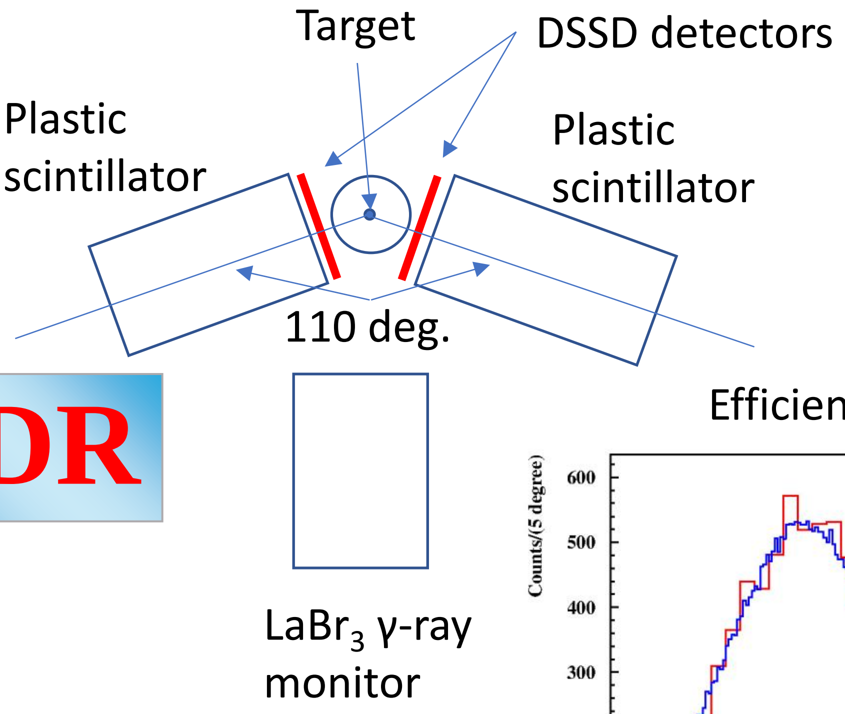
TRK sum rule

$$\int_{18}^{33} \sigma(E)\,dE = 60\,\frac{NZ}{A}\ \mathrm{MeV\ mb}$$

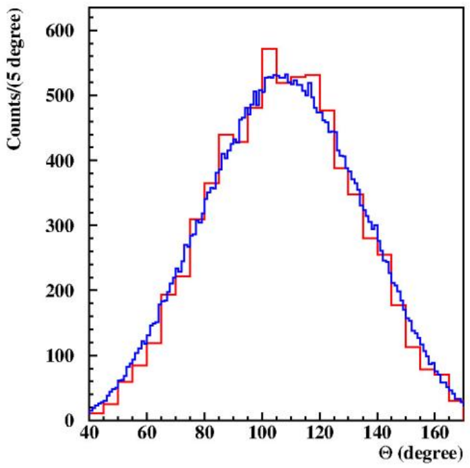
A new e^+e^- spectrometer, their acceptance, γ-ray and energy-sum specta

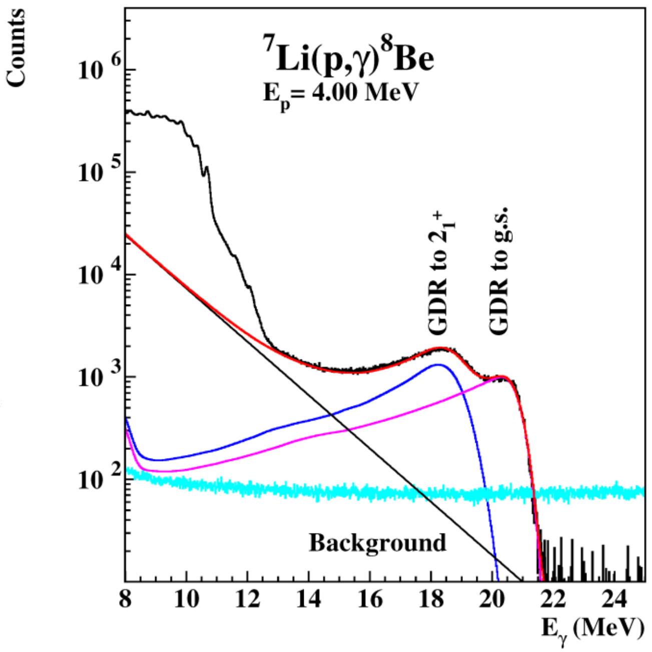


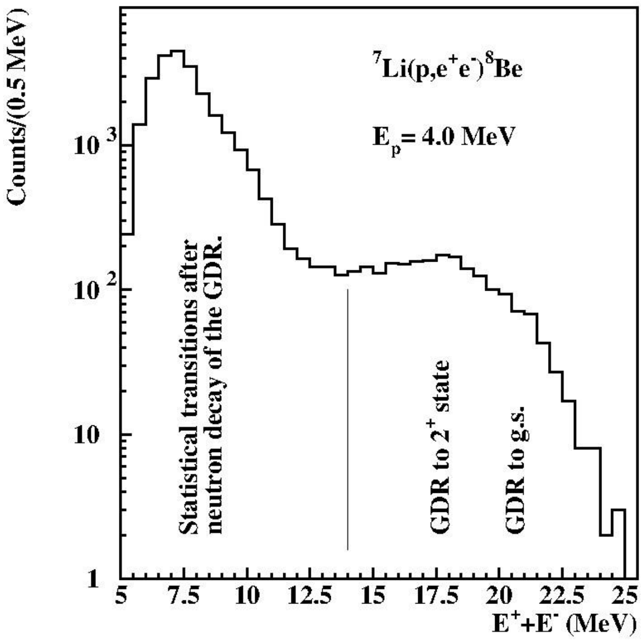
GDR



Efficiency

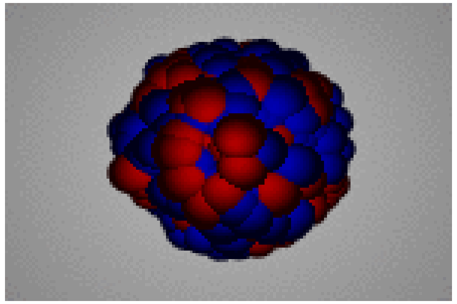


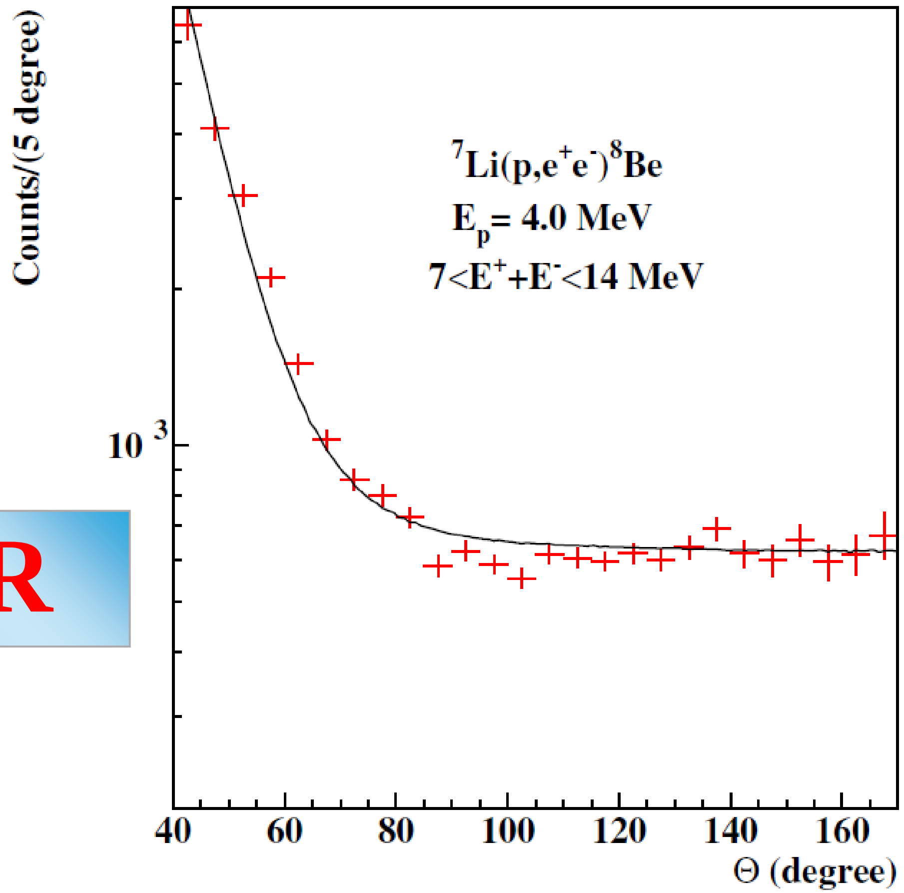


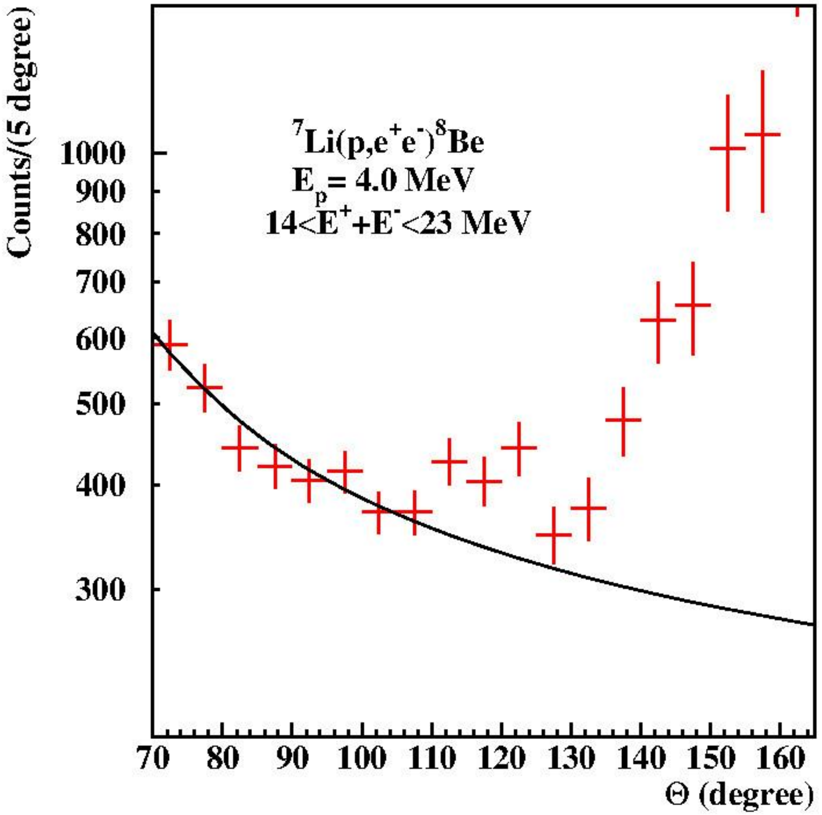


Energy-sum spectrum

e^+e^- angular correlations for the low-enegy region, and for the GDR one

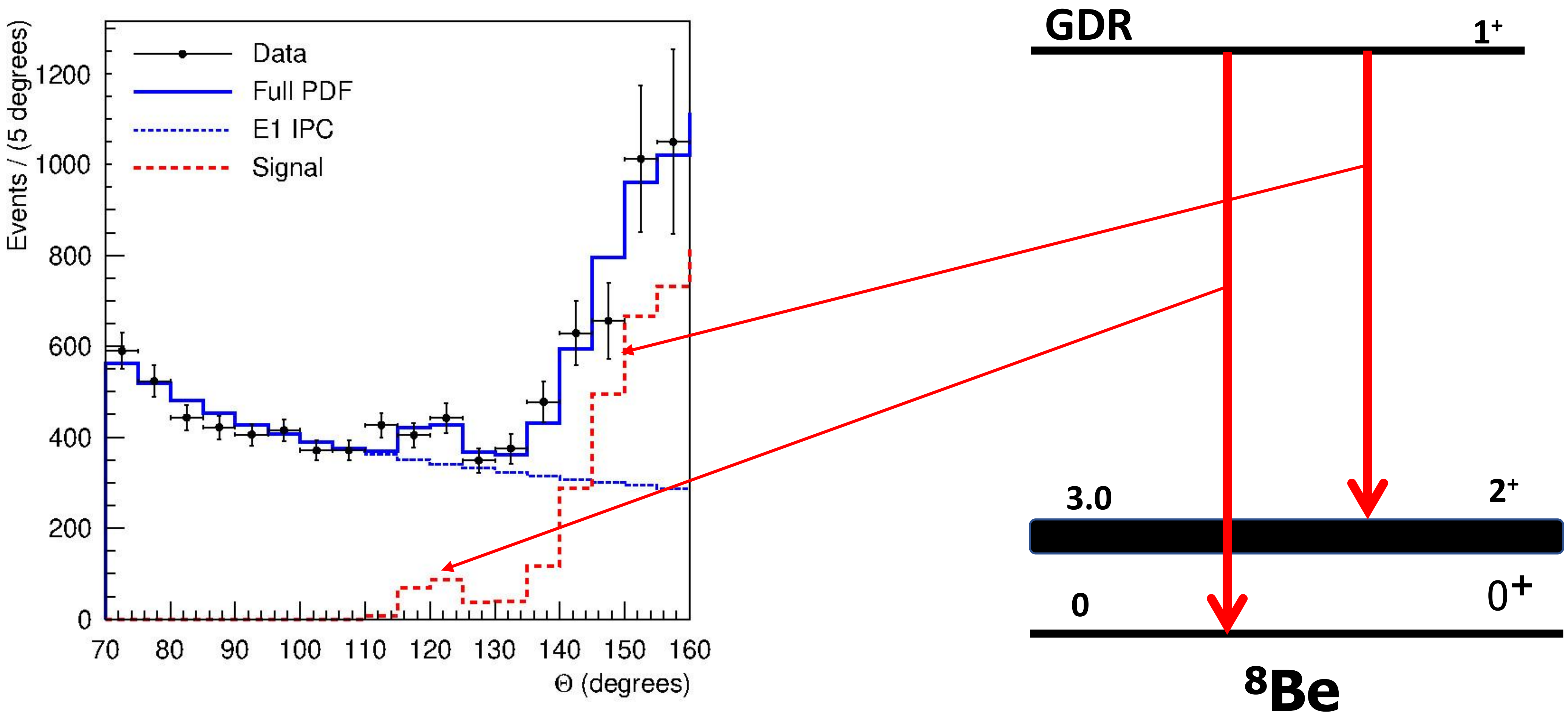






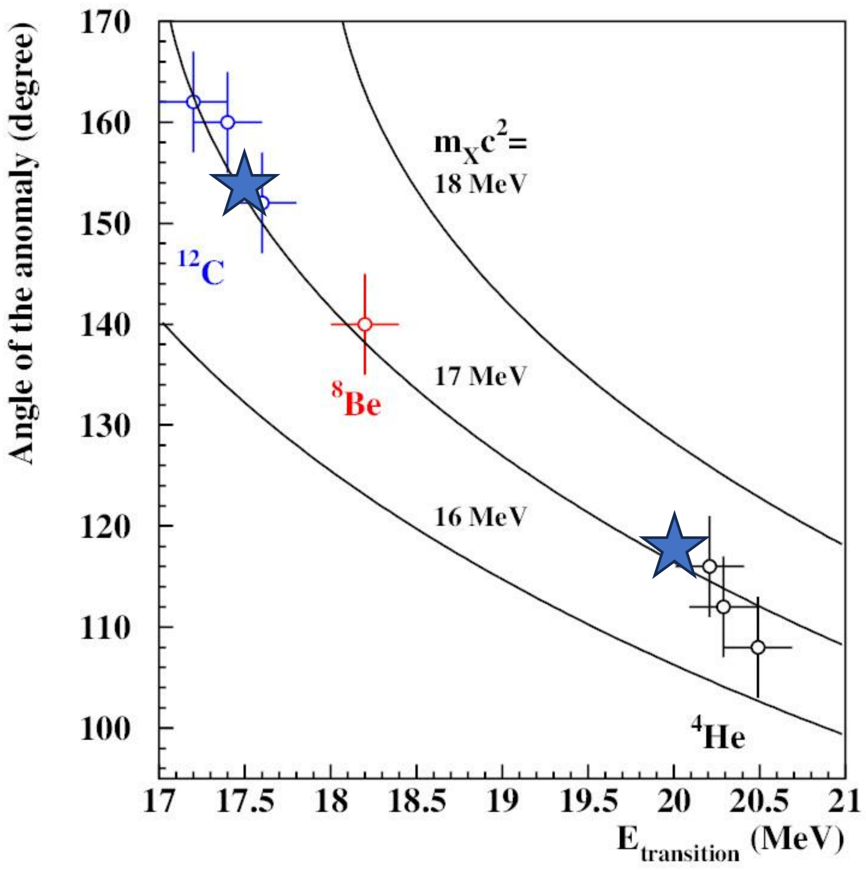
GDR

Fitting the e^+e^- angular correlation for the GDR region



$m_0c^2 = 16.94 \pm 0.47(\text{stat}) \pm 0.35(\text{syst.})$

Kinematical evidence for the X17 particle



A.J. Krasznahorkay et al. : An Update of the Hypothetical X17 Particle
Universe **2024**, *10*(11),409;
https://doi.org/10.3390/universe10110409

Nucl. Phys. News.

Frontiers of Fundamental Physics (FFP16), Conf. Proc. 2024

What is the spin and parity of X17?

The X17 can be emitted wth L=0, L=1 …

Can we measure the angular distribution of X17 to dtermine L?
We need a new spectrometer with larger angular coverage.

Experiments/Institutes connected to the X17 particle

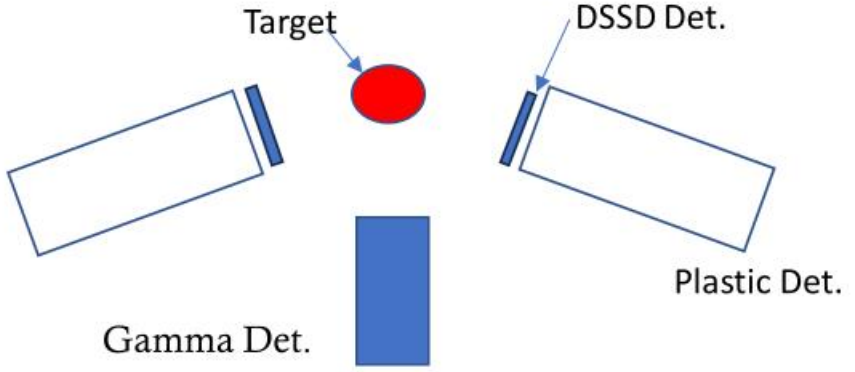
Leitmotiv: Since Galileo, we have known that one of the most effective ways to learn about the world around us is to conduct experiments. If we don't know something, let's ask nature itself. That's what experiments are for.

1. HUS, Hanoi, Vietnam
2. JINR, Dubna, Russia
3. MEG II, PSI, Willigen, Switzerland
4. PADME, Rome, Italy
5. New JEDI projekt , GANIL, France
6. INFN, Legnaro, Italy
7. DAFNE, Montral, Canada
9. CTU, Prague, Czechia
10. nTOF, CERN, Switzerland
11. NA64, CERN, Switzerland
12. NA62, CERN, Switzerland
13. BES-III, Beijing, China
14. FASER, CERN, Switzerland
15. SUPER-X, ANU, Canberra, Australia
16. DARKLIGHT, GLAB, USA
17. PRad, GLAB, USA
18. REDTOP, USA, Purdue, USA
19. Belle-II, SuperKEKB, Japan
20. NA48, CERN, Switzerland
21. MAGIX, Dark MESA, Mainz, Germany
22. VEPP-3, Vladivostok, Russia

Experimental setup built at the Hanoi University of Science, Vietnam in collaboration with ATOMKI, Debrecen, Hungary

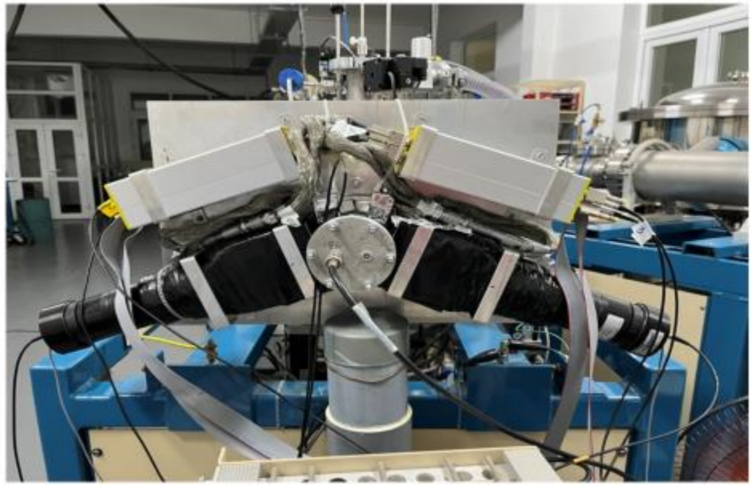
We used p-beam with different energies to bombard the Li-target to populate 18.15 and 17.6 MeV ^{8}Be excited states with resonant proton capture.

^{7}Li(p,e e)^{8}Be



Detector setup to measure the energies and the angle between the $e^{+}e^{-}$ particles.

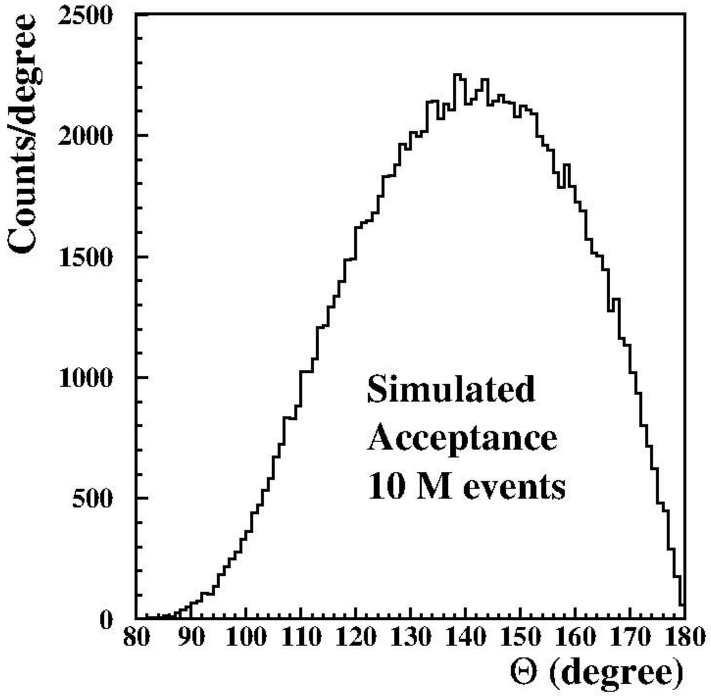
Why did we arrange the Det-system like this?



Picture in lab of the detector system and the DAQ connected to Pelletron

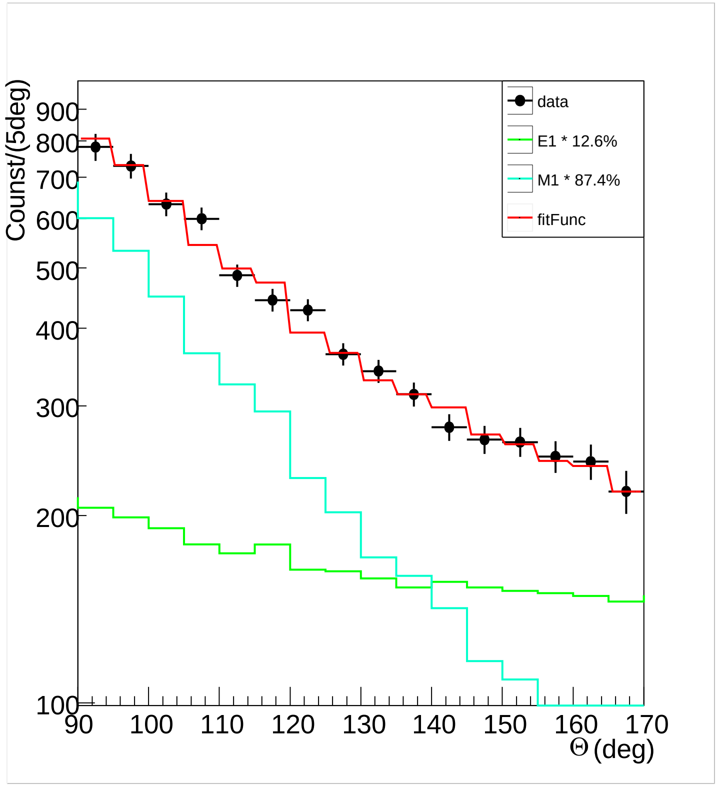
The idea of the new e^+e^- spectrometer with two arms

- Concentrate on the 140 degree region.
- Put the detectors closer to the target 30 mm than they were used in Debrecen (60 mm).
- We can have similar acceptance at 140 degree in this way for the two cases.

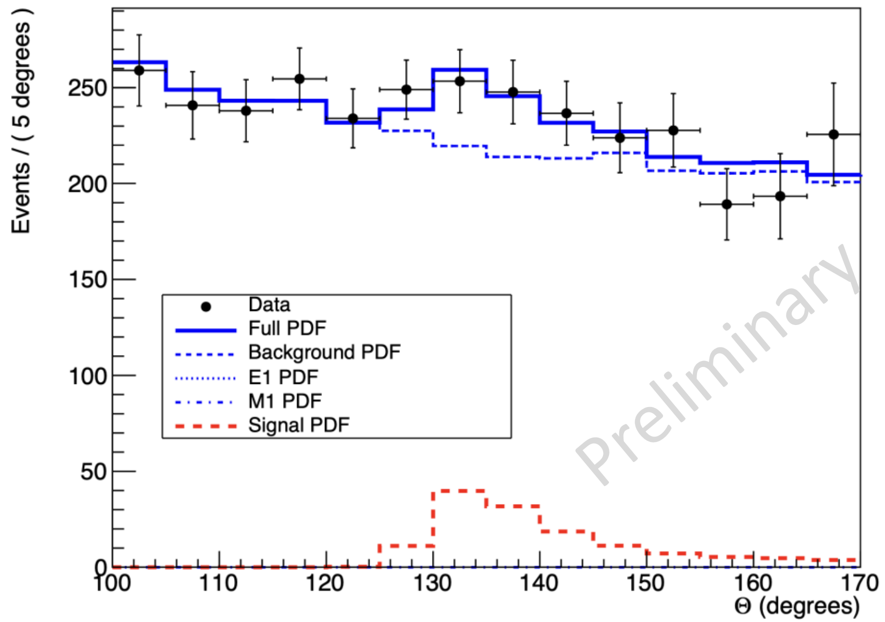


The simulation curve of acceptation before making setup

Aceptance corrected angular correlations



E_p=441 keV
No anomaly

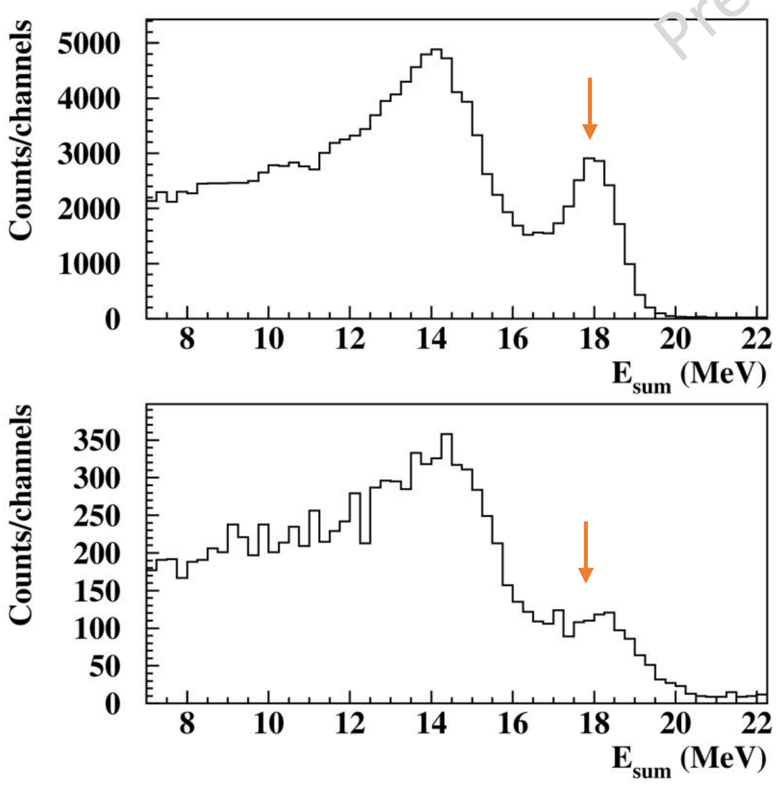


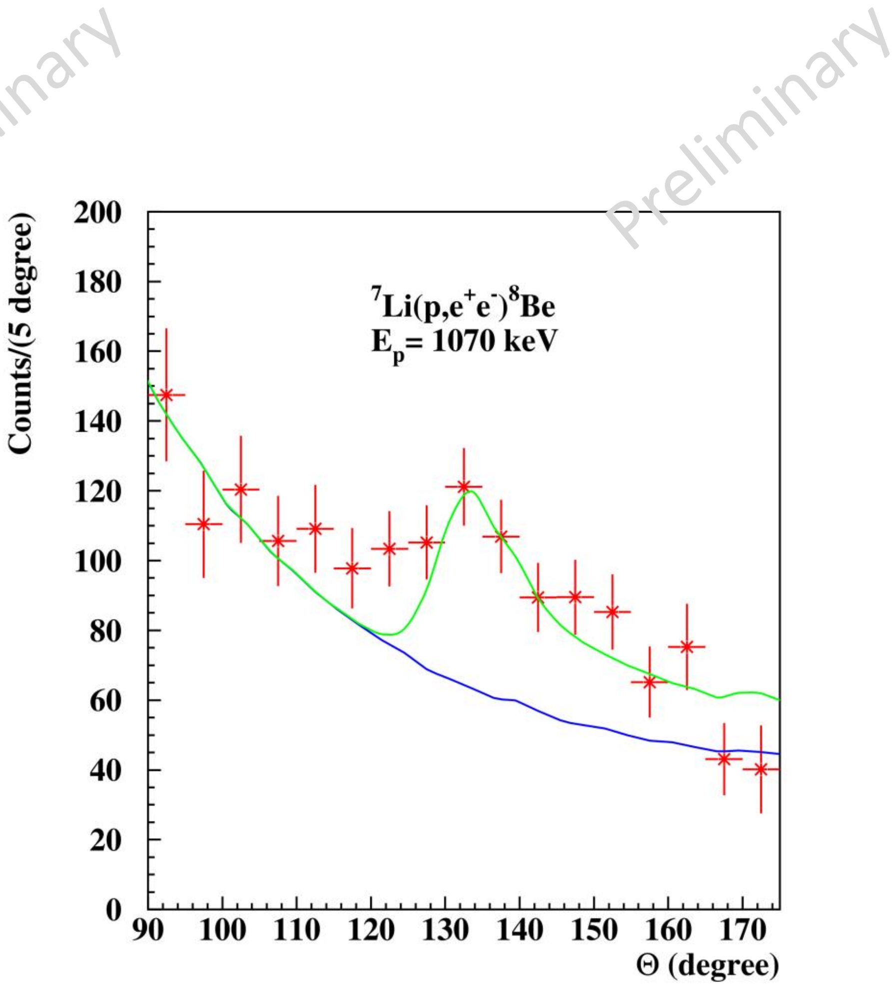
E_p=1.04 MeV. Background: M1+E1
The anomaly appears at angle around 140° (*)

m_{boson}=16.7 ± 0.47 (MeV)
Significance: 4-5σ

Tran The Anh et al., Universe 2024, 10(4) 168.

Recent experimental Results from Hanoi
(Li metallic target on 2 μm thick Ni backing)

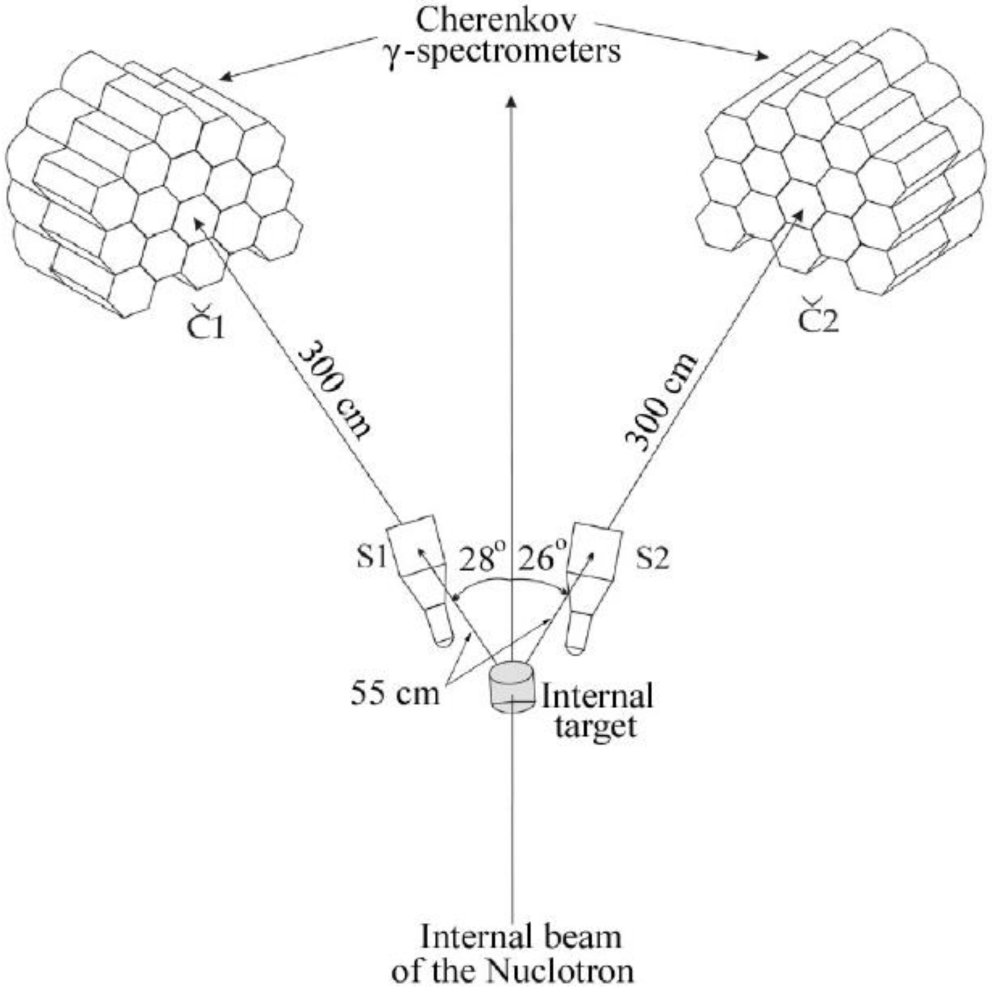


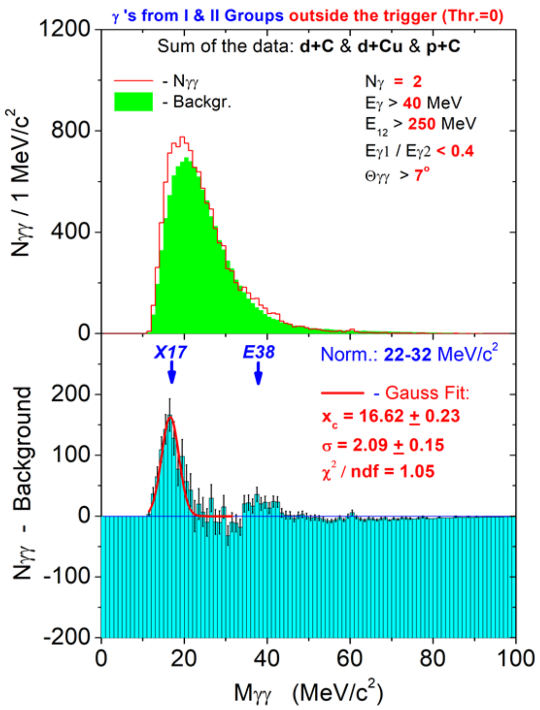


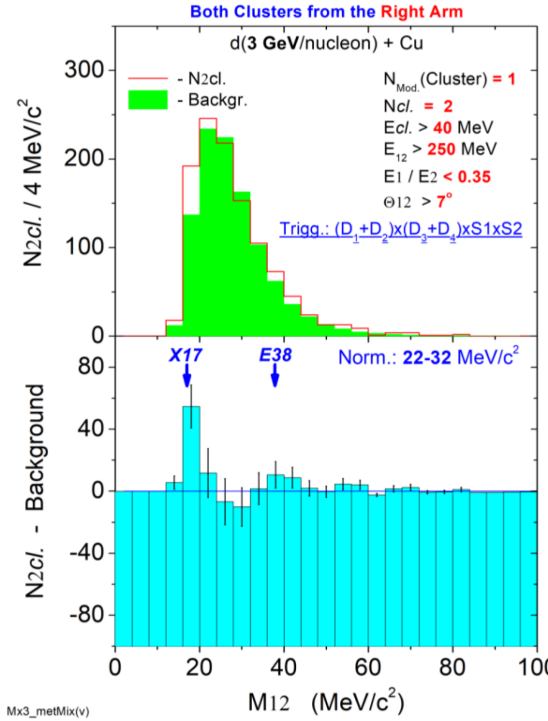
Joint Institute for Nuclear Research

SCIENCE BRINGS NATIONS TOGETHER

Confirmation of the X17 particle in the Dubna experiment





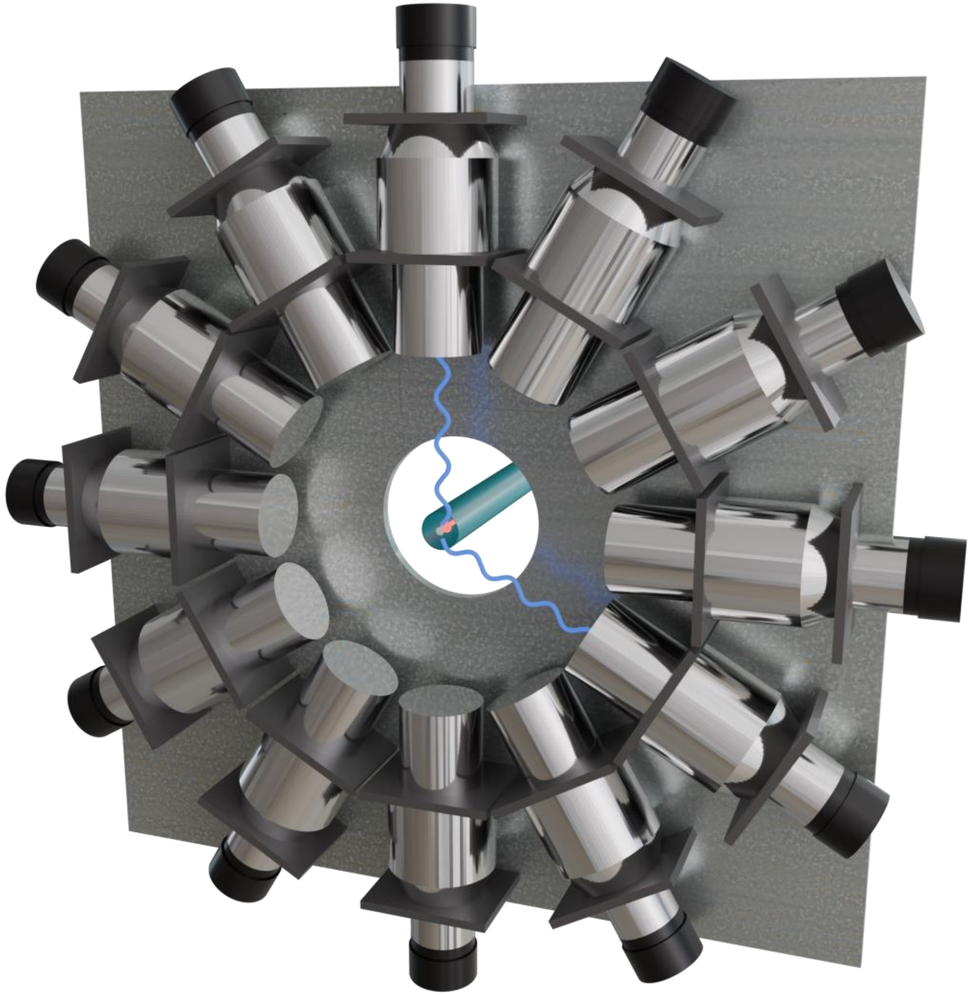


Confirms our results on the $\gamma\gamma^{-}$ -decay of X17

Confirms our results on the $e^{+}e^{-}$ -decay of X17

Abraamyan et al., Phys. Part. and Nuclei, 2024, **55**, 4.

New experiments in HUN-REN ATOMKI
Study the γγ-decay of the X17 particle



The Dubna results for 2γ decay …
X17 is a QED meson ???
Cheuk-Yin Wong, MDPI, Universe, 2024, 10, 173

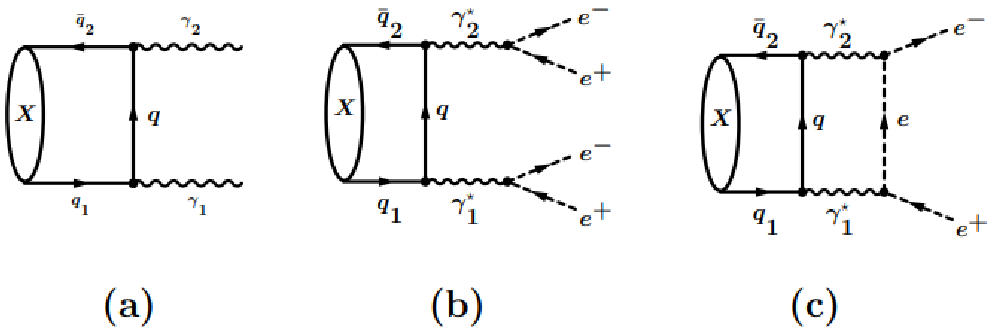
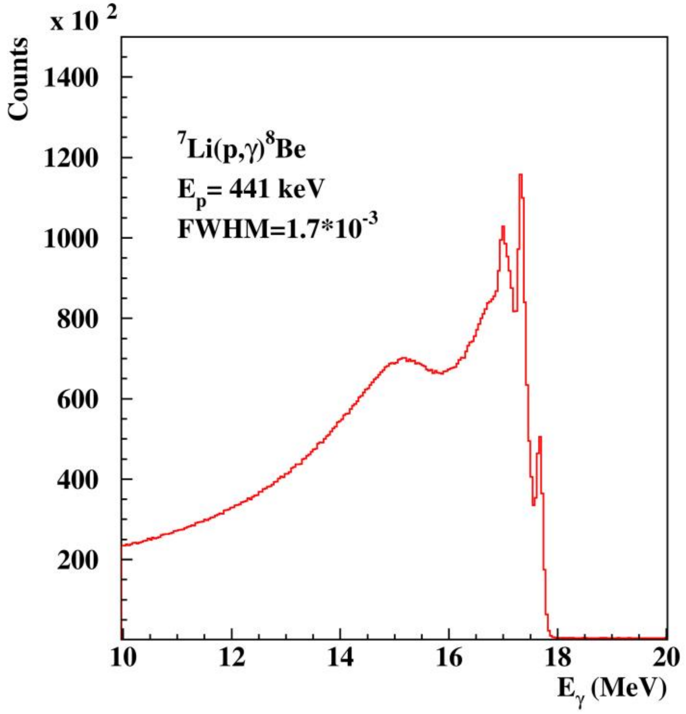
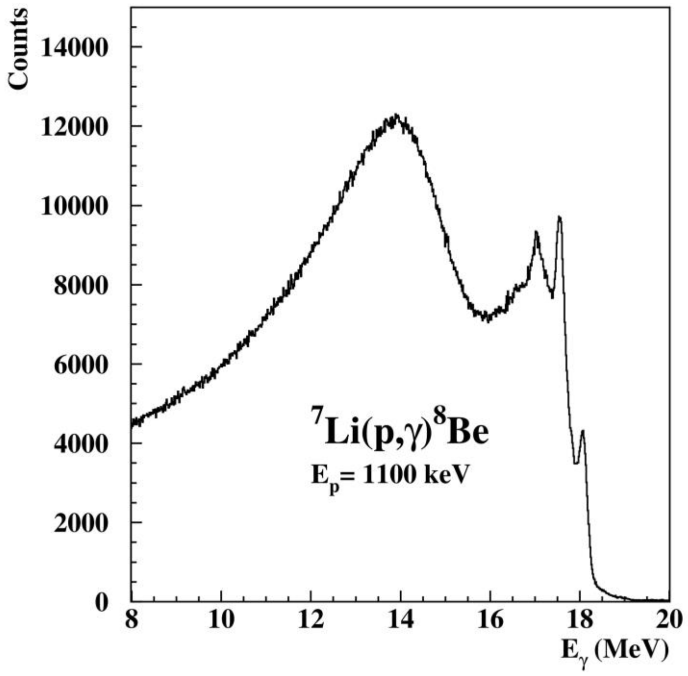
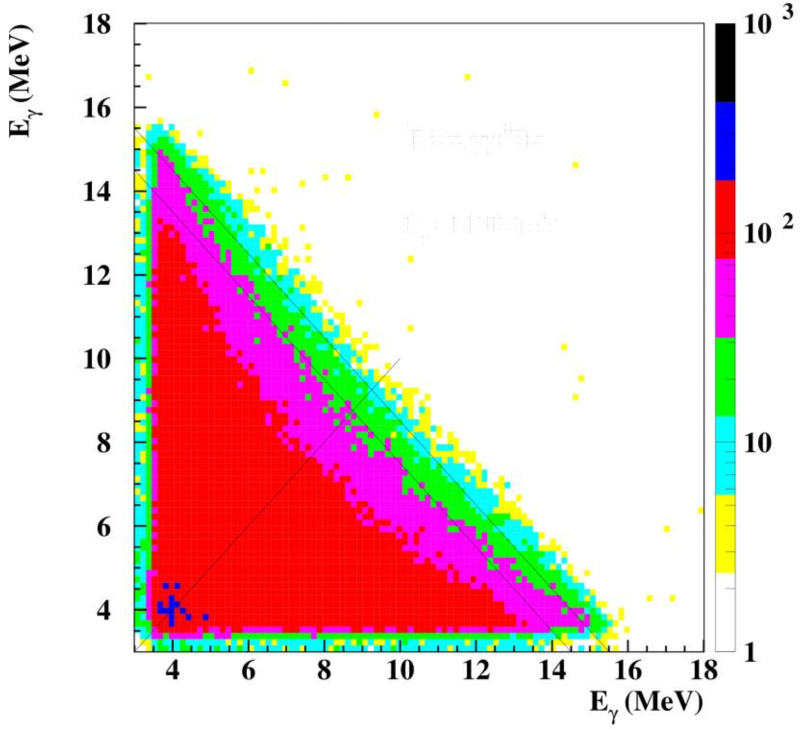


Figure 2. (**a**) A QED meson X can decay into two real photons $X \to \gamma_1 + \gamma_2$. (**b**) It can decay into two virtual photons, each of which subsequently decays into a (e^+e^-) pair, $X \to \gamma_1^* + \gamma_2^* \to (e^+e^-) + (e^+e^-)$, and (**c**) it can decay into a single (e^+e^-) pair, $X \to \gamma_1^* + \gamma_2^* \to e^+e^-$.

Investigation of the 2γ decay of the 17.6 and 18.15 MeV resonances of the ^{8}Be nucleus

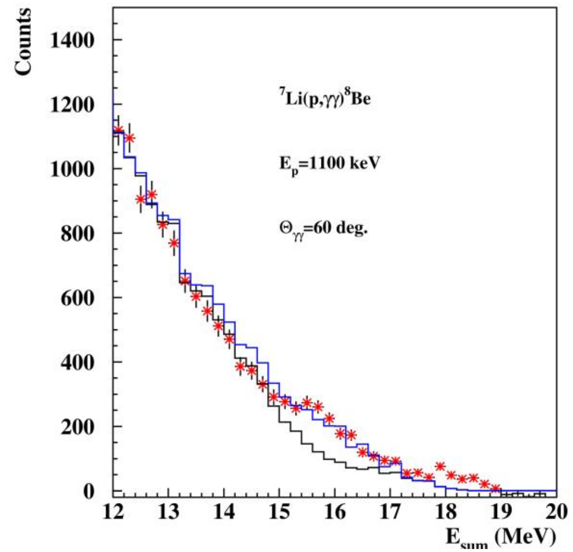


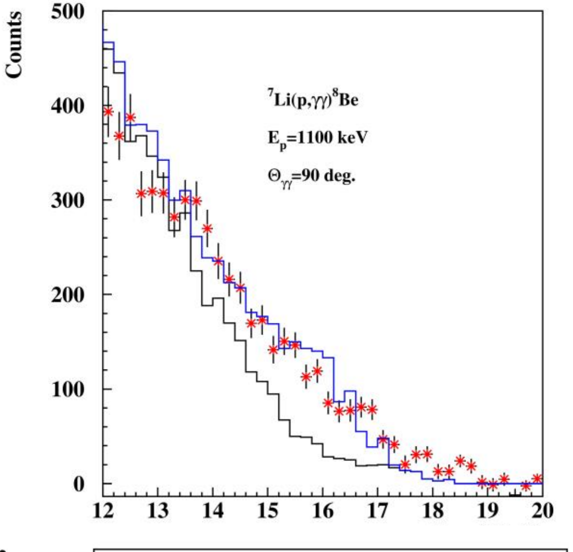


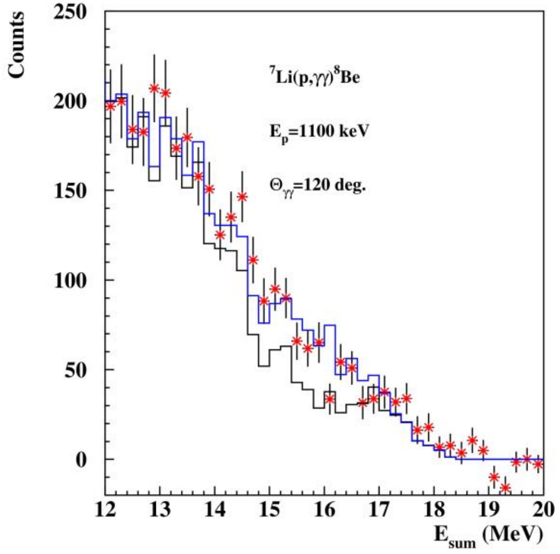


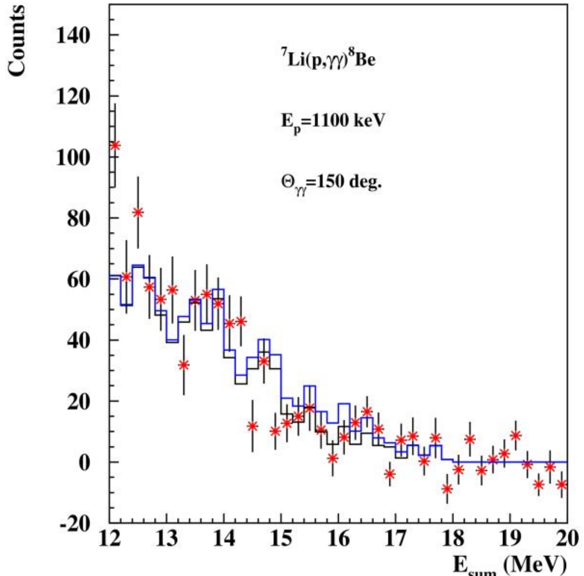
γγ-coincidence measurements, with high statistics (10^{10}) and good energy resolution

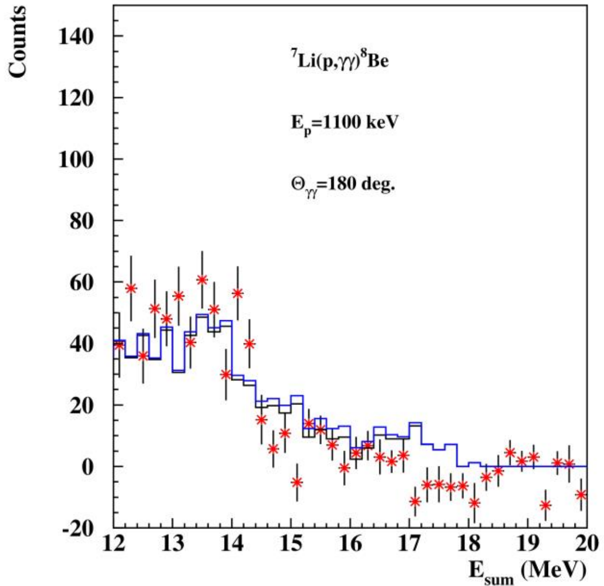
Preliminary results of our γγ-decay measurement

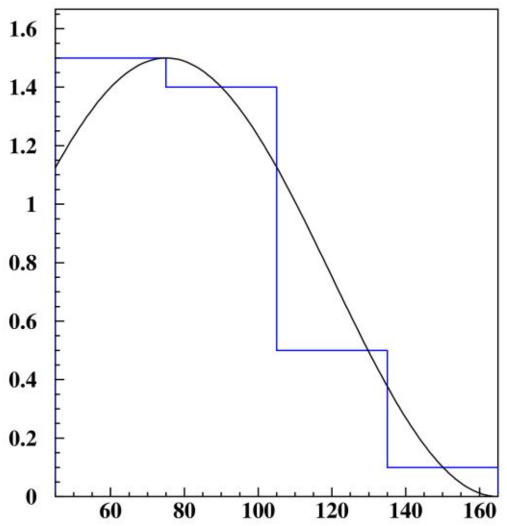












Dexcitation of atomic nuclei by double emission of γ-rays

A rare form of electromagnetic excitation of excited states of atomic nuclei, when the excitation occurs with the simultaneous emission of 2γ-rays. This process has only been observed in the excitation of the 0^+ state of a few atomic nuclei so far.

This is a second-order process that can be created using the electric and magnetic strength distributions above the given levels. The transition probability depends very strongly on the transition energy ($E\gamma^7$), therefore it was first detected in high-energy transitions (e.g. ^{16}O 6.05 MeV).

By measuring the transition probability of the process, we can determine important parameters that are necessary for the refinement of the nuclear equation of state, the neutron skin thickness of atomic nuclei and the interpretation of neutrino-free double beta decay.

Conclusion

- We are very happy that there are now many nuclear and particle physics laboratories where physicists are checking the existence of the X17 particle and trying to understand its properties.
- In two cases, the existence of the X17 particle has already been confirmed.
- In the coming years, we expect further results on the spin and parity of the particle.
- The 2γ decay of the X17 particle has not been confirmed. Limits will be published soon for the branching ratios.
- We have obtained data on the 2γ decay produced by a quantum mechanical second-order process.

Thank you very much for your kind attention.

Construction of a large, two-arm e^+e^- spectrometer for GDR measurements, where neutrons are also produced in large numbers