Recent results for the X17 particle

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UNIVERSITY of DEBRECEN

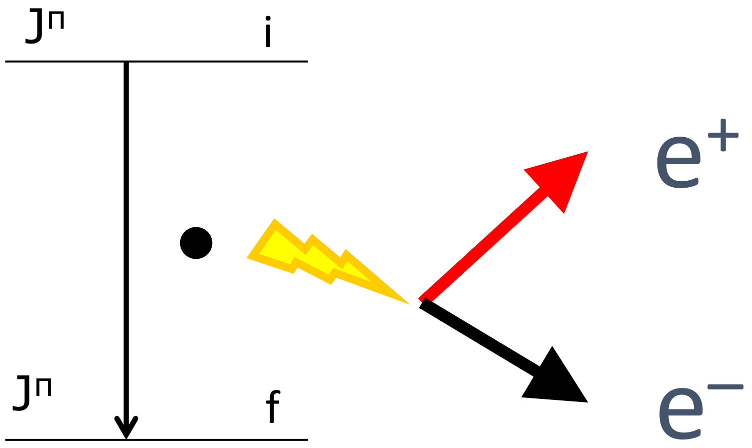
atomki DEBRECEN

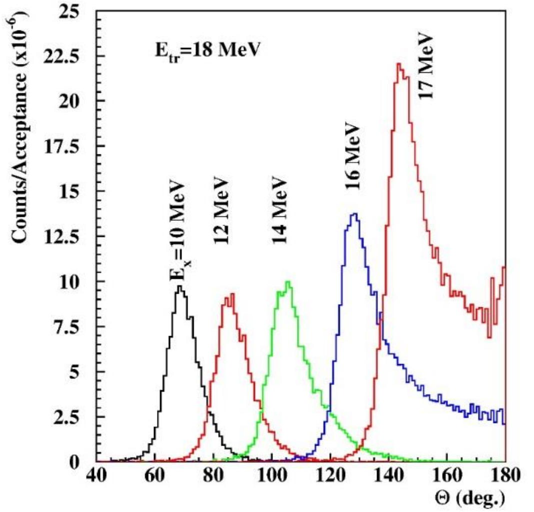
CERN

Lepton Interactions with Nucleons and Nuclei--Elba XVII

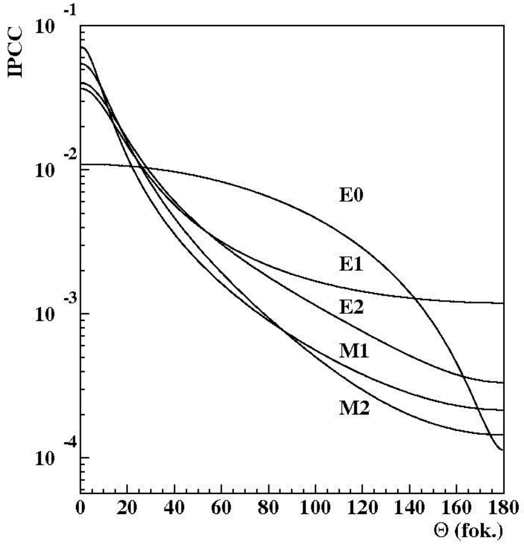
Searching for the e⁺-e⁻ decay of a new particle in nuclear transitions

Two body decay of a moving particle





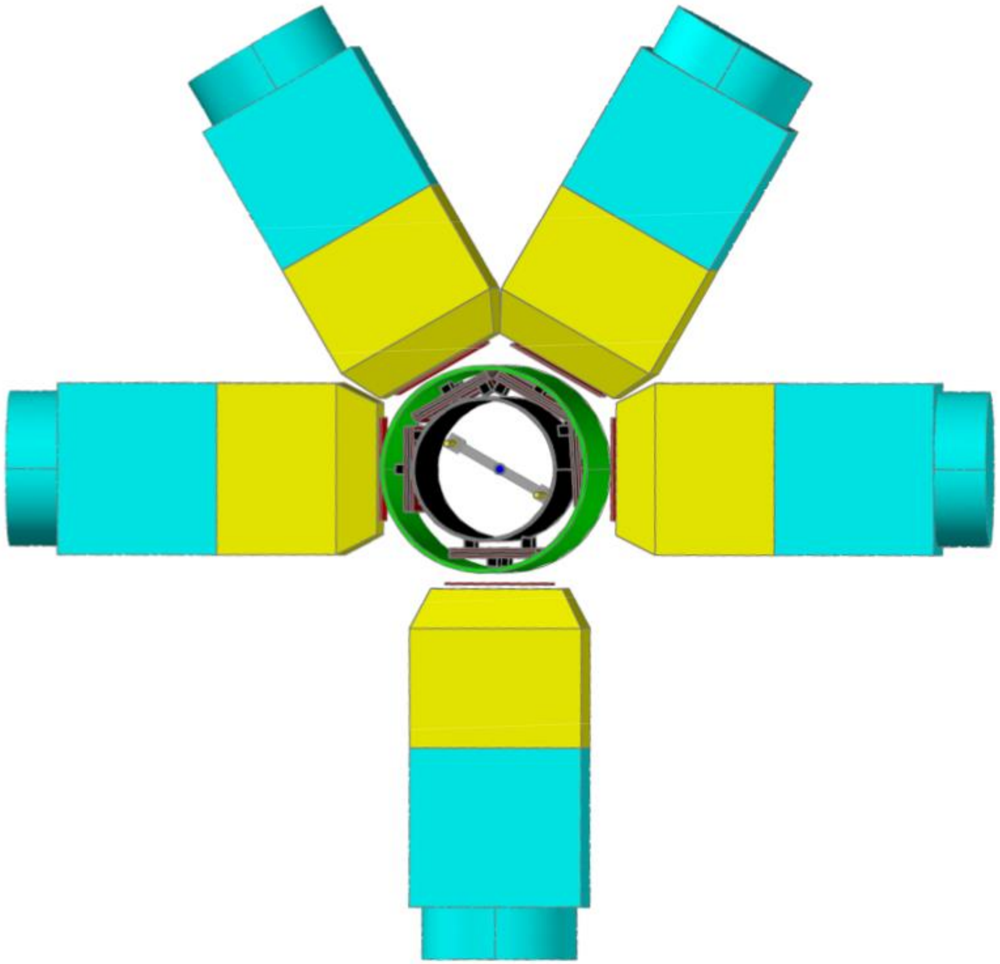
e⁺-e⁻ internal pair creation



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

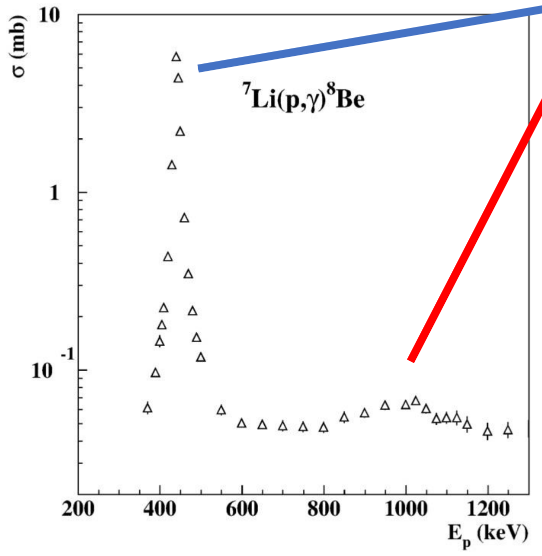
M.E. Rose Phys. Rev. 76 (1949) 678
E.K. Warburton Phys. Rev. B133 (1964) 1368.
P. Schlüter, G. Soff, W. Greiner, Phys. Rep. 75 (1981) 327.

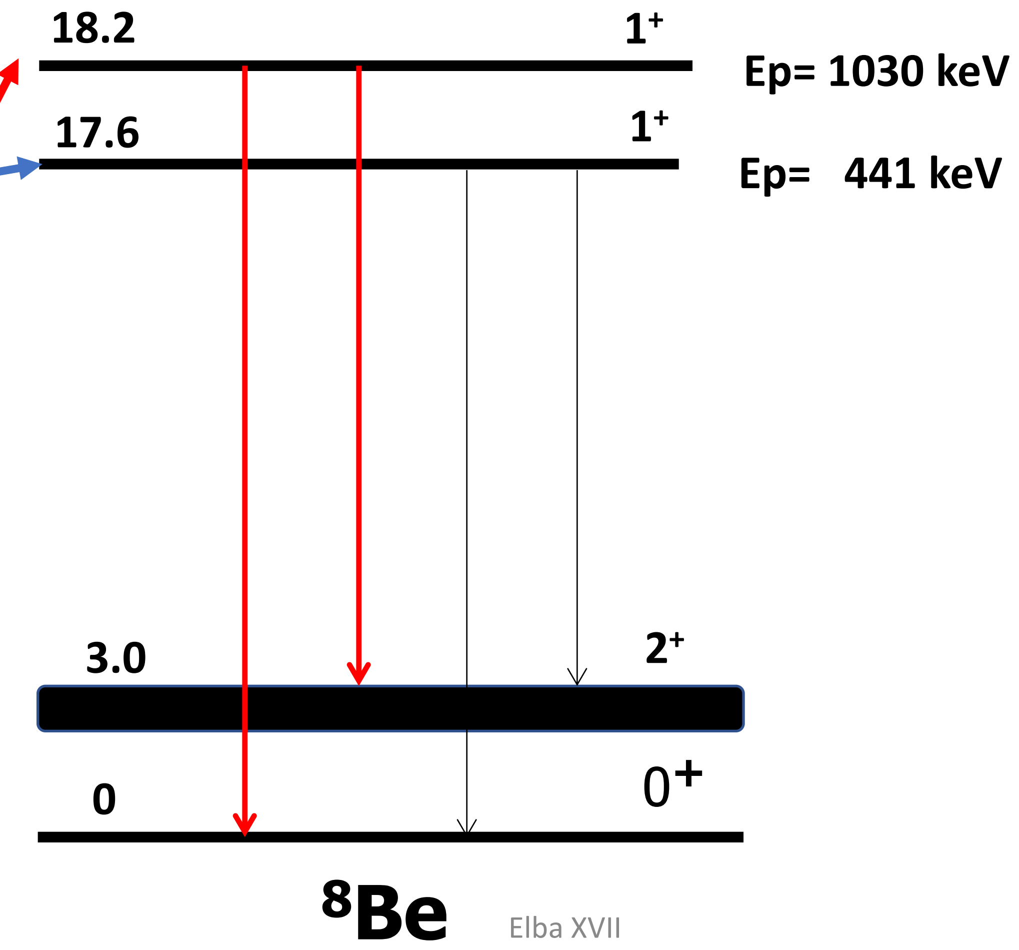
Geometrical arrangement of the scintillator telescopes (NIM, A808 (2016) 21)

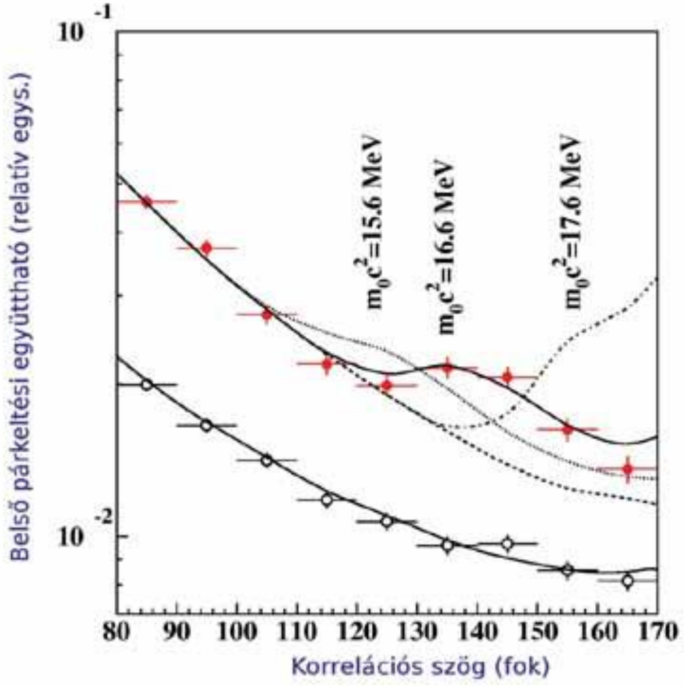


Study of the ^{8}Be M1 transitions

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







$m_0c^2=16.7 \pm 0.35(stat) \pm 0.5(syst.)$

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

A. J. Krasznahorkay,* M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi, I. Kuti, B. M. Nyakó, L. Stuhl, J. Timár, T. G. Tornyi, and Zs. Vajta
Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

T. J. Ketel
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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.

CERN ABOUT NEWS

News › News › Topic: Physics

Voir en français

The plot thickens for a hypothetical "X17" particle

Additional evidence of an unknown particle from a Hungarian lab gives a new impetus to NA64 searches

27 NOVEMBER, 2019 | By Ana Lopes

CERNCOURIER Reporting on international high-energy physics

Physics ▾ Technology ▾ Community ▾ In focus Magazine

SEARCHES FOR NEW PHYSICS | NEWS

Rekindled Atomki anomaly merits closer scrutiny

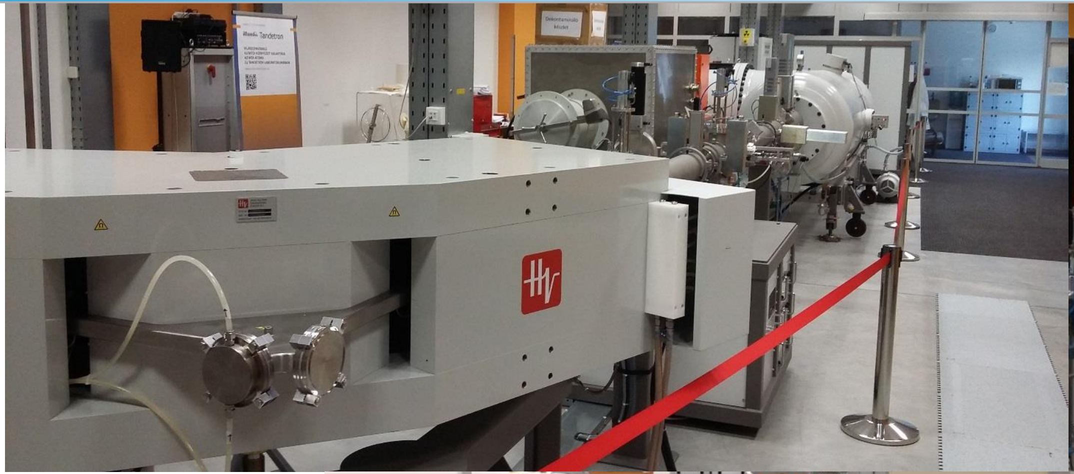
20 December 2019

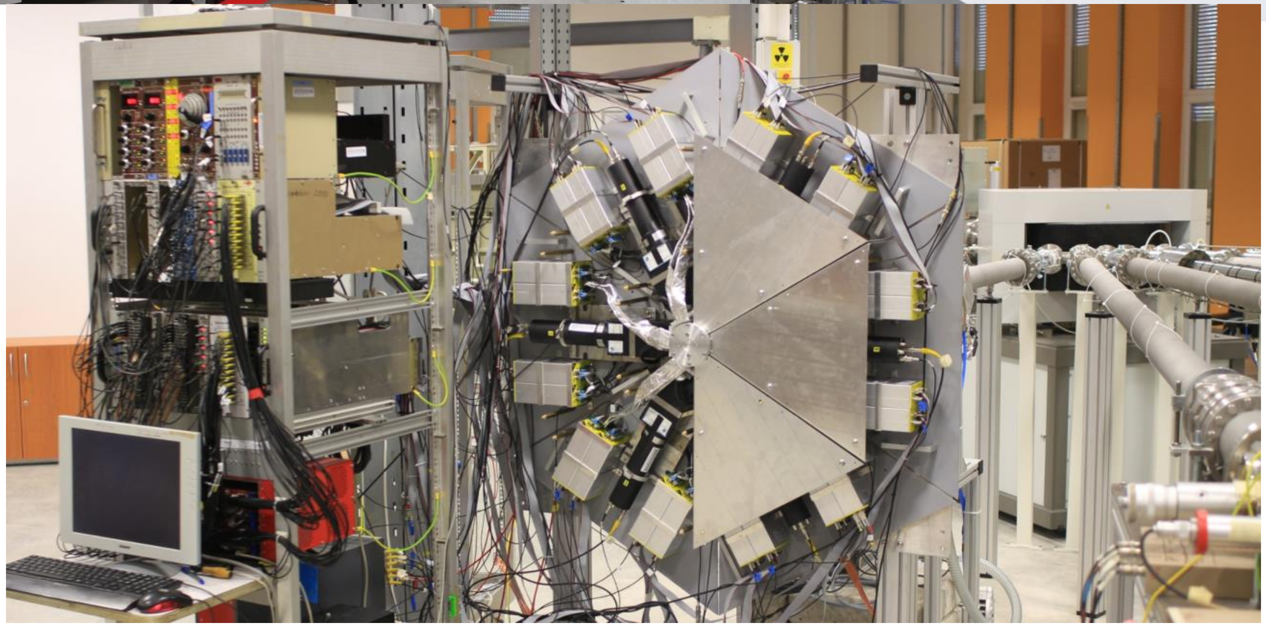
The ATOMKI anomaly → signals for a new 17 MeV/c² particle called later X17, which may be connected to dark matter

Should not have to defend this too much…

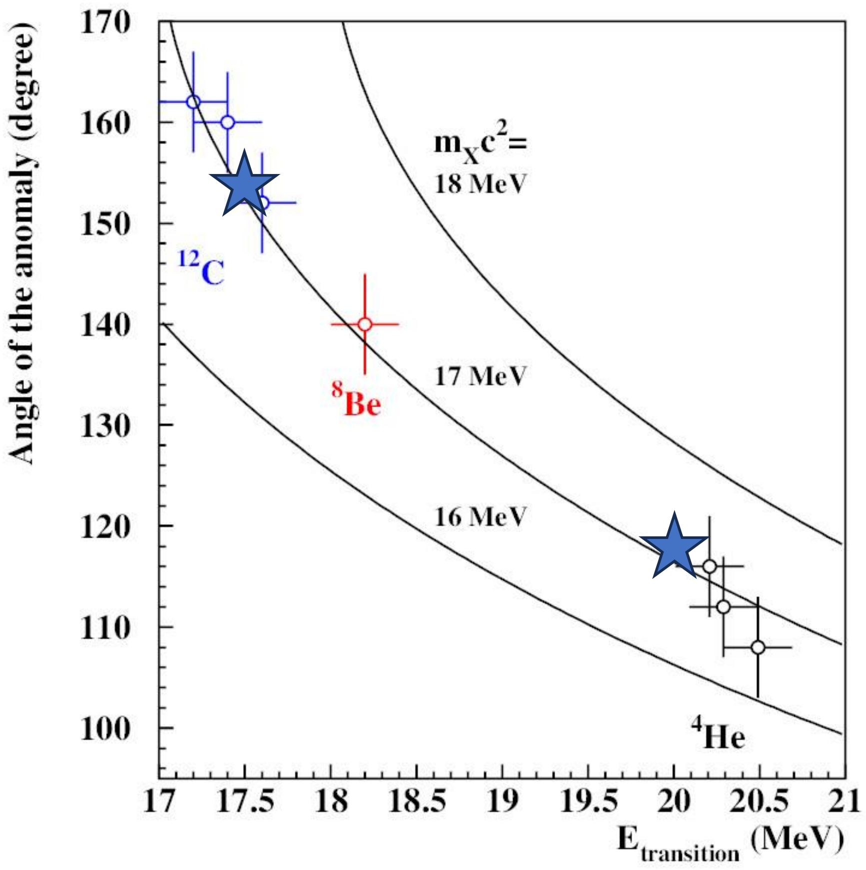
Article in Nature, CNN news, boom in the media

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





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.

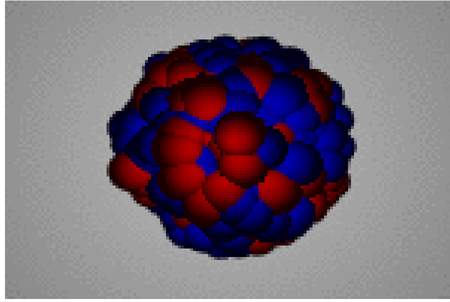
Frontiers of Fundamental Physics (FFP16), Conf. Proc. 2024

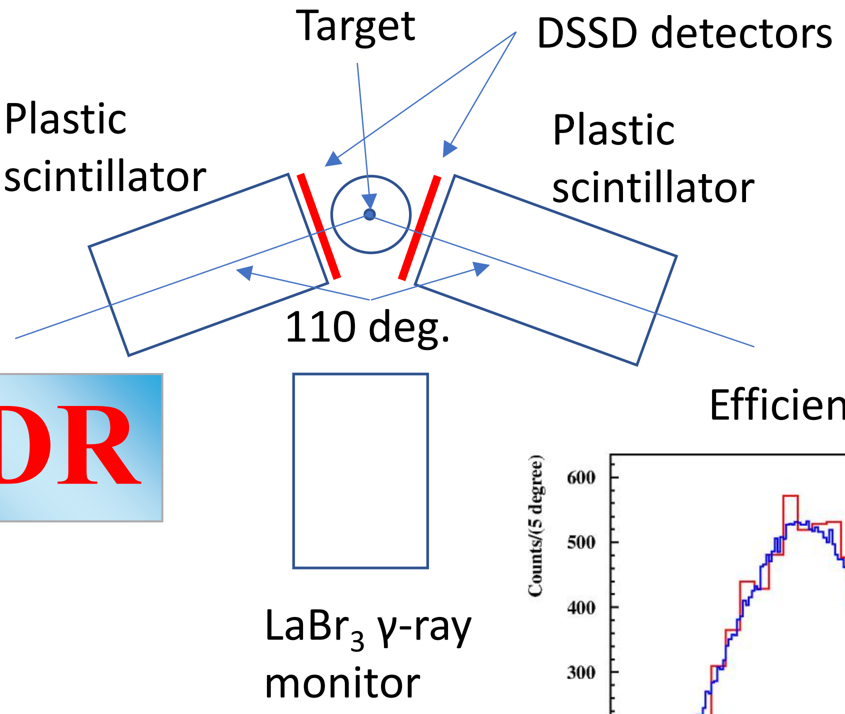
What is the spin and parity of X17?

The X17 can be emitted with L=0, L=1 …

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

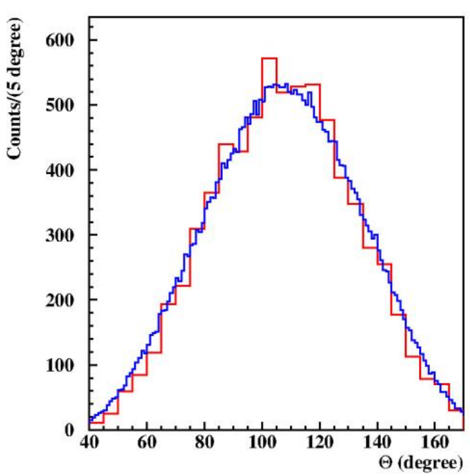
Searching for the X17 particle in the decay of the Giant Dipole Resonance (GDR)

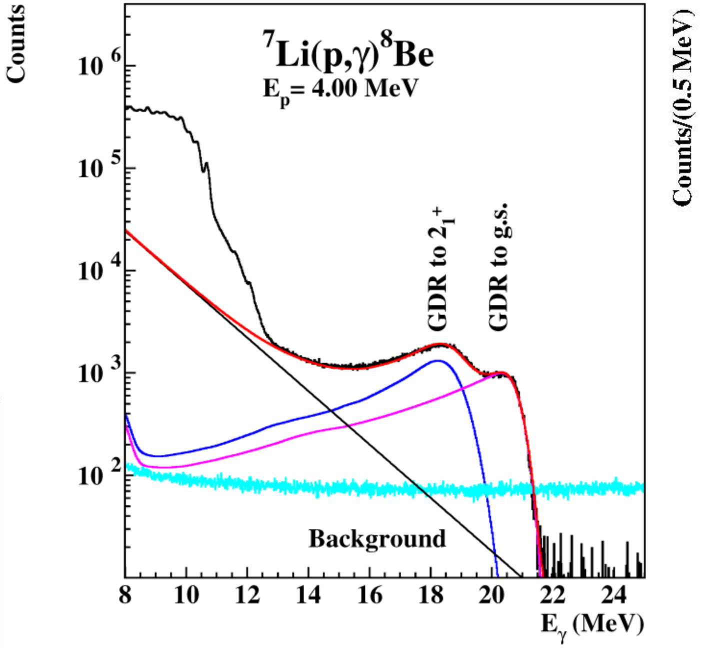


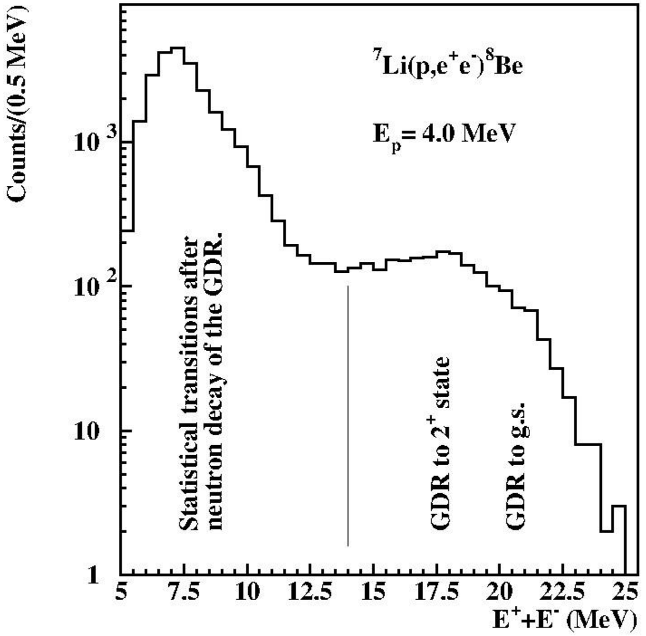


GDR

Efficiency

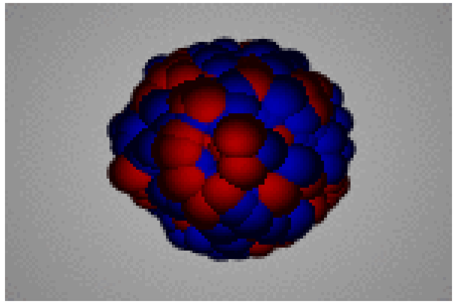




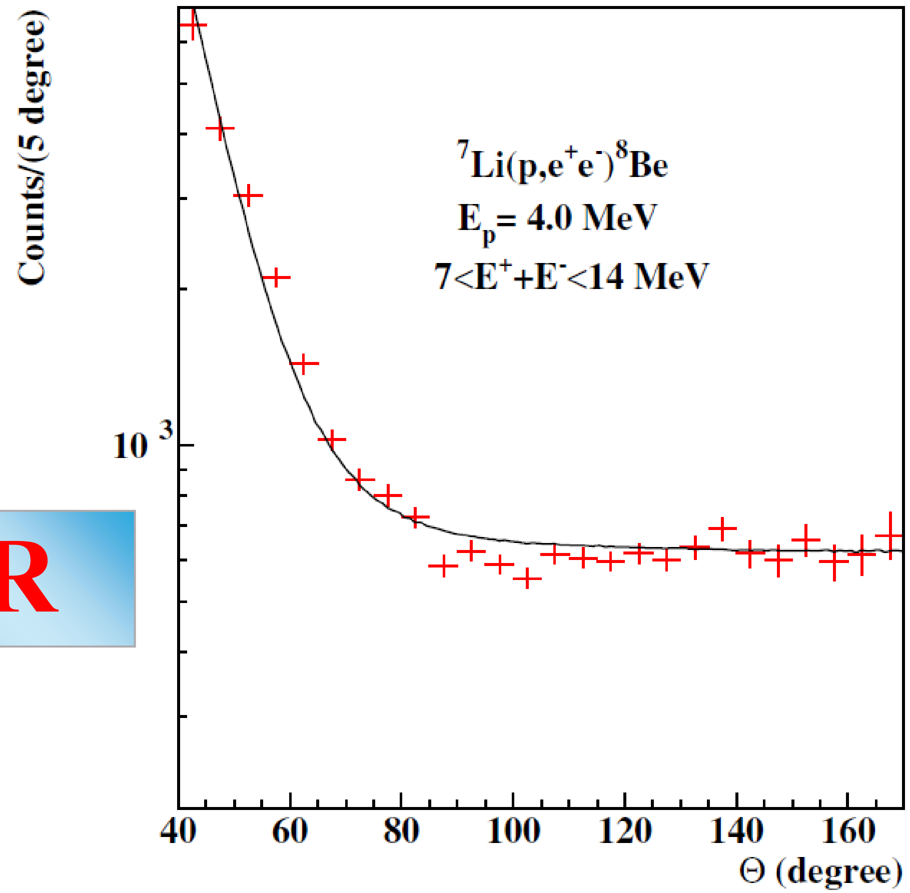


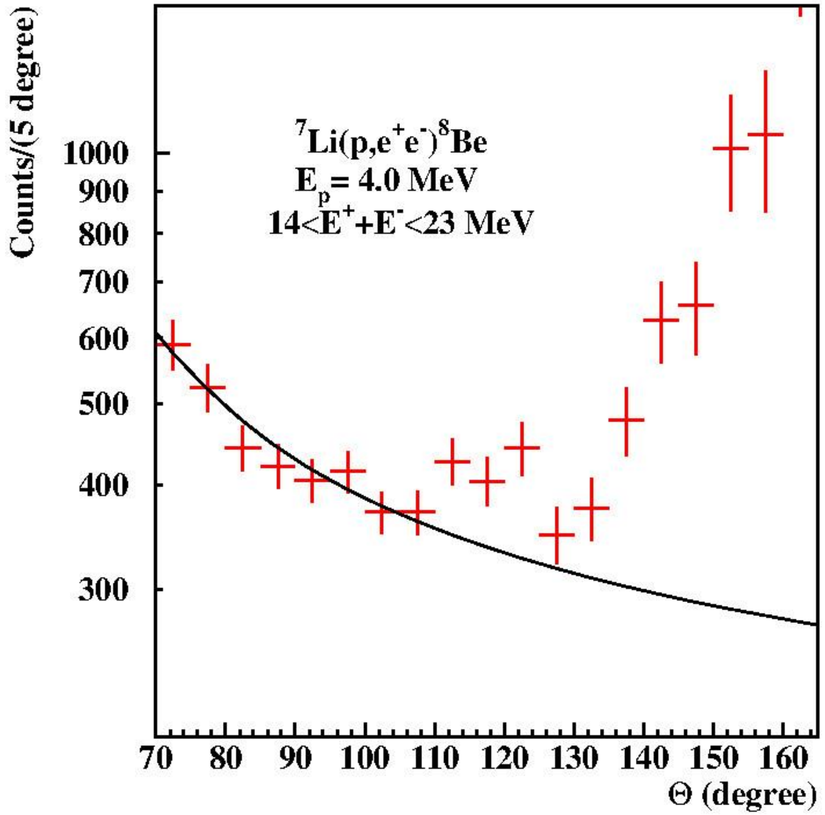
Energy-sum spectrum

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

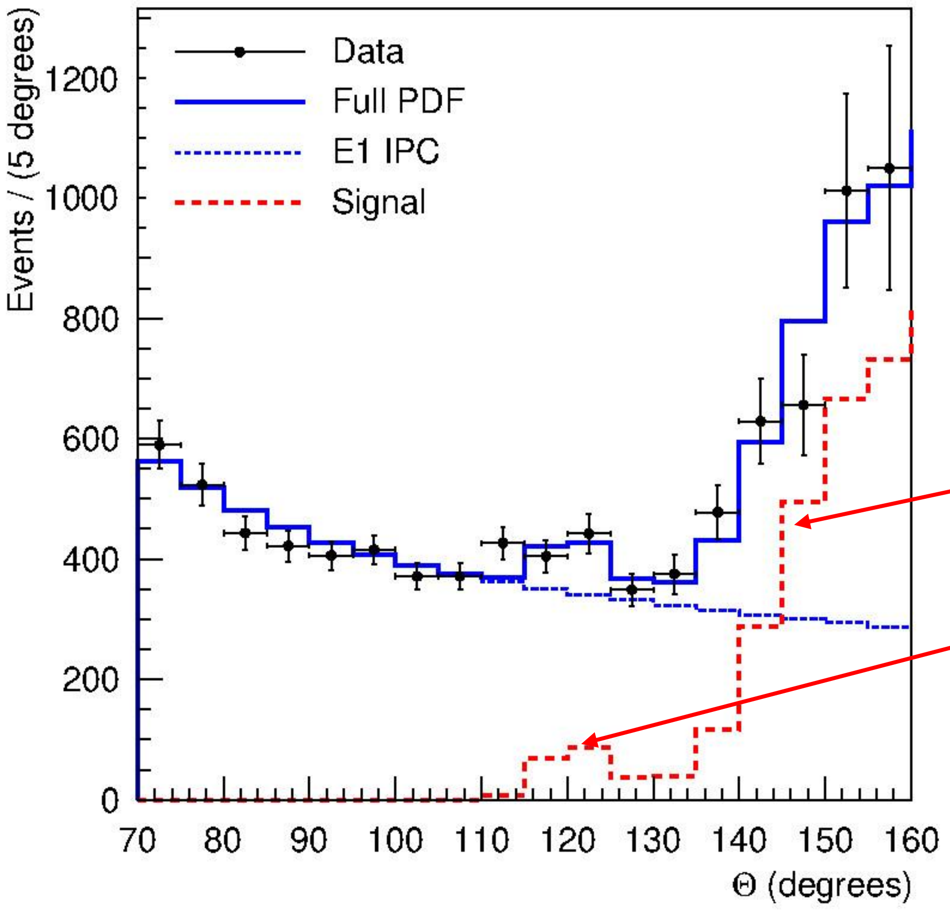


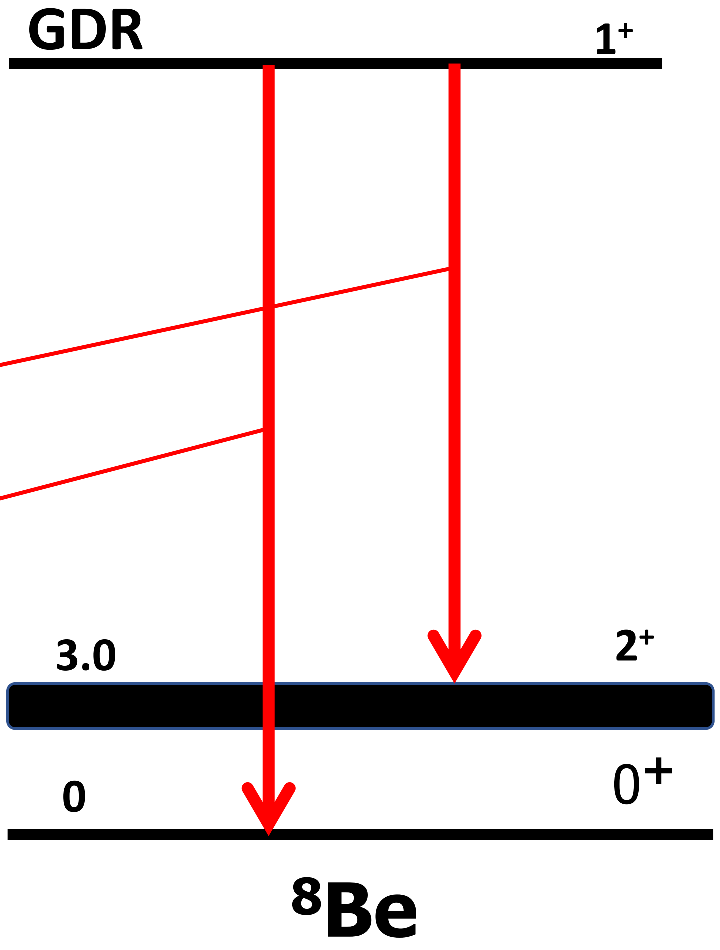
GDR





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





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

m_0c^2=16.94 ±0.47(stat)±0.35(syst.)

Experiments/Institutes connected to the X17 particle

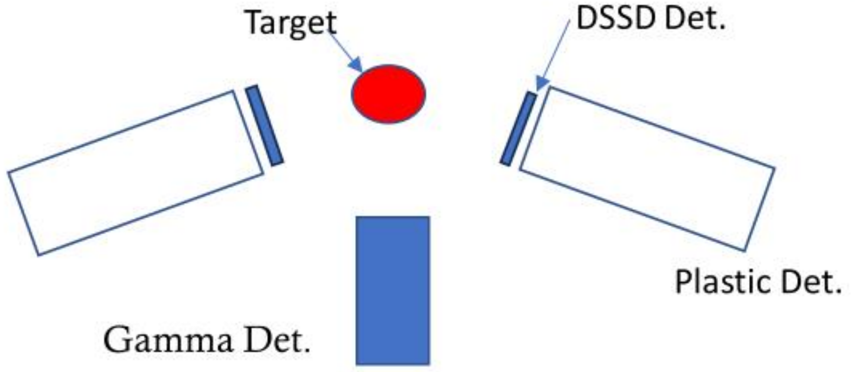
1. HUS, Hanoi, Vietnam
2. JINR, Dubna, Russia
3. MEG II, PSI, Willigen, Switzerland
4. PADME, Rome, Italy
5. New JEDI project , GANIL, France
6. INFN, Legnaro, Italy
7. DAFNE, Montral, Canada
9. CTU, Prague, Czechia
10. nTOF, CERN, Switzerland
11. NA64, CERN, Switzerland
12. NA62, CERN, Switzerland
13. 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

ACTA PHYSICA POLONICA B PROCEEDINGS SUPPLEMENT 18 : 4 Paper: 4-A1 (2025

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

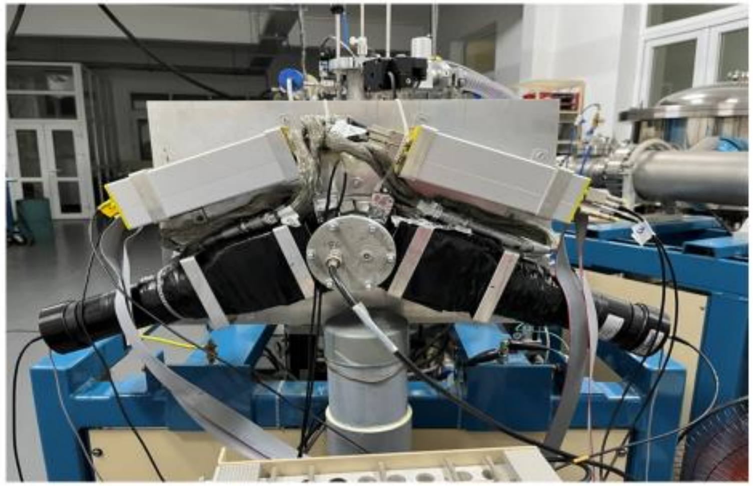
We used p-beam with different energies to bombard the Li-target to populate 18.15 and 17.6 MeV ^{8}Be excited states with resonant proton capture.

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



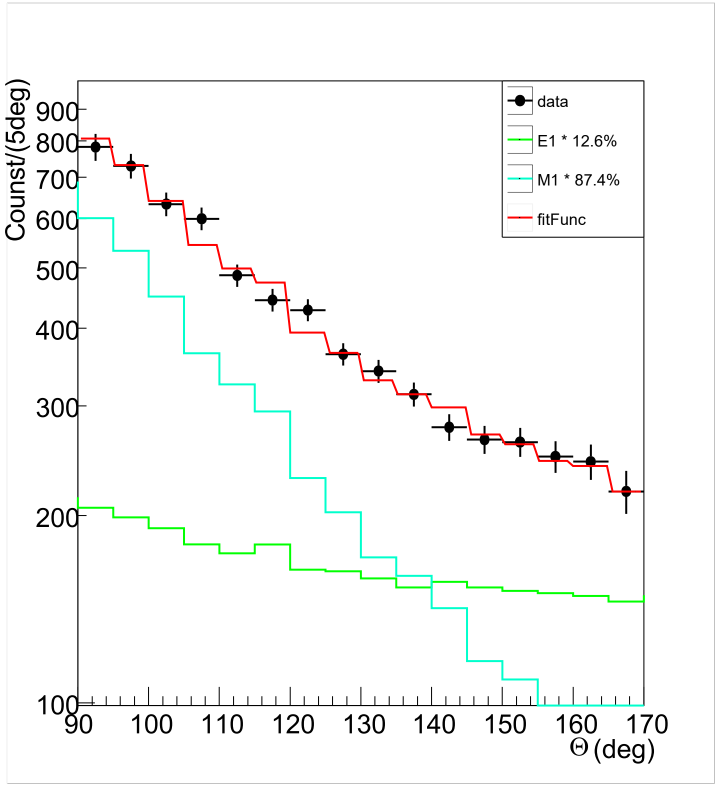
Detector setup to measure the energies and the angle between the $e^{+}e^{-}$ particles.

Why did we arrange the Det-system like this?

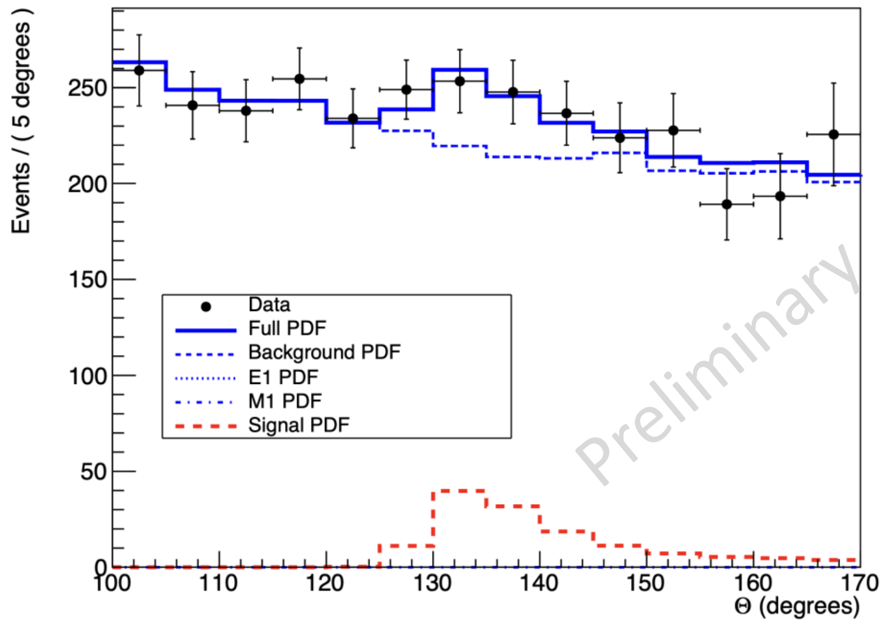


Picture in lab of the detector system and the DAQ connected to Pelletron

Aceptance corrected angular correlations



E_p=441 keV
No anomaly



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

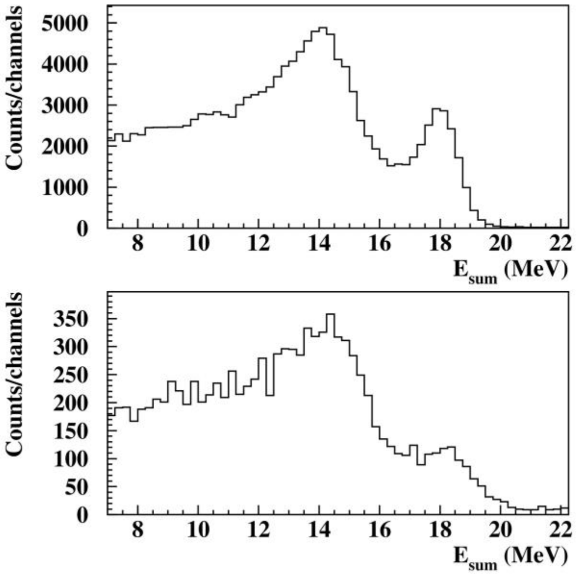
m_{boson}=16.7 ± 0.47 (MeV)
Significance: 4-5σ

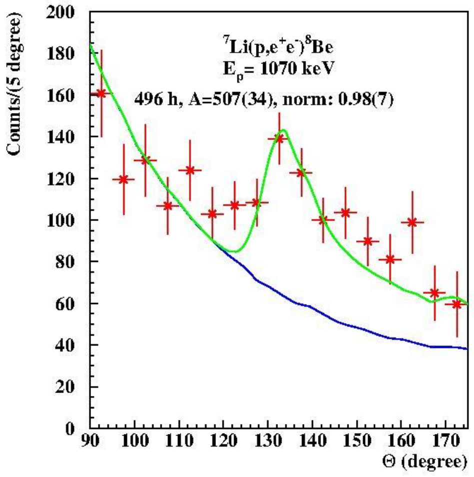
Tran The Anh et al., Universe 2024, 10(4) 168.

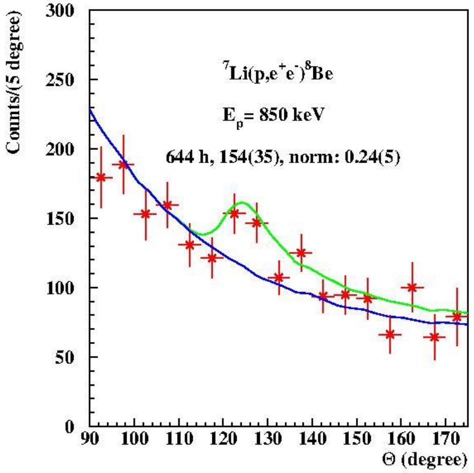
Recent (2025) experimental Results from Hanoi

(Li metallic target on 5 μm thick Ni backing)

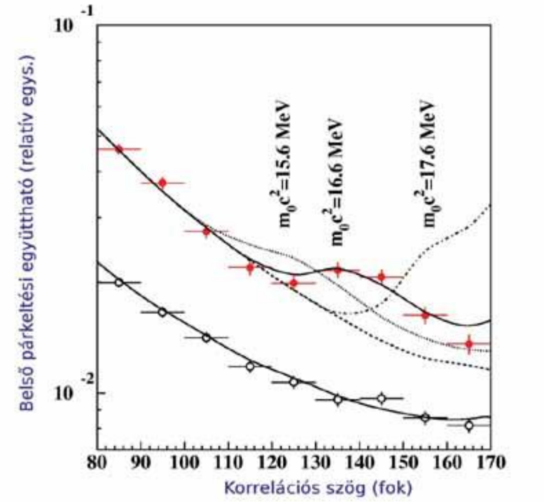
Hanoi
2025

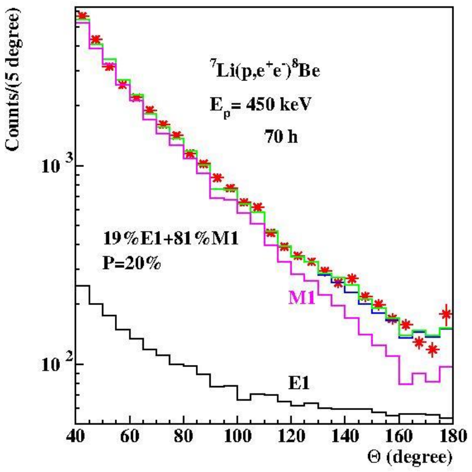


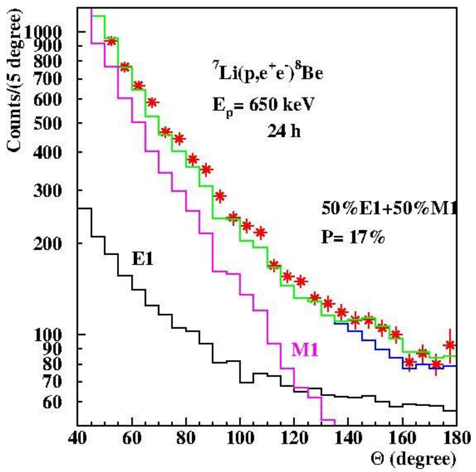


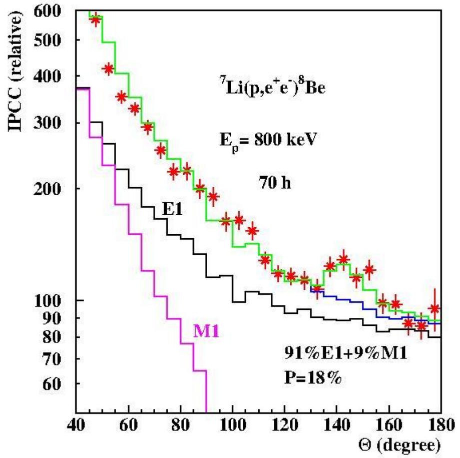


ATOMKI

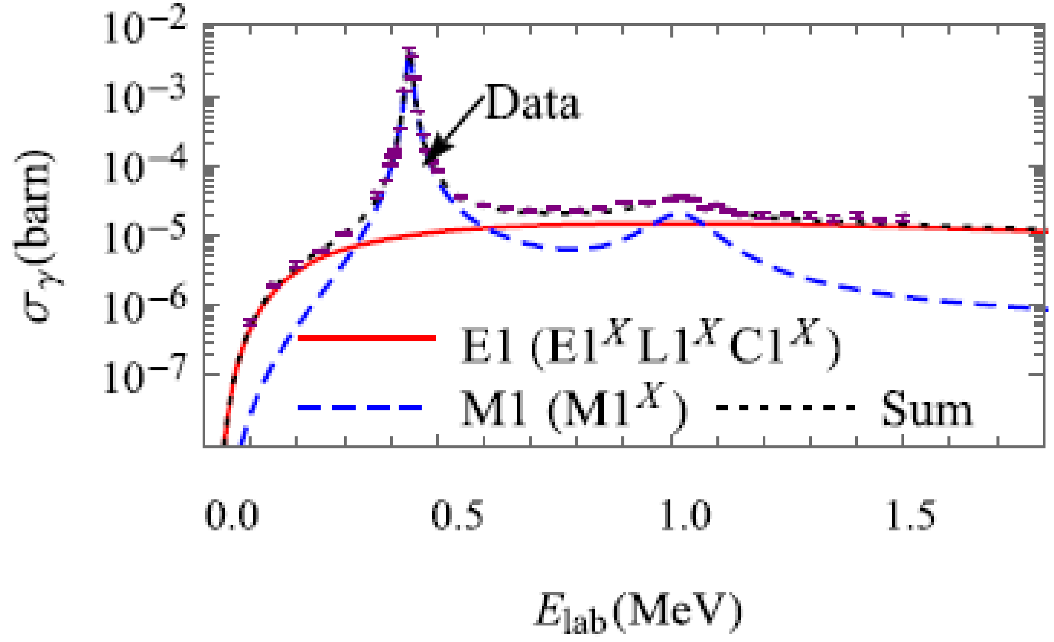




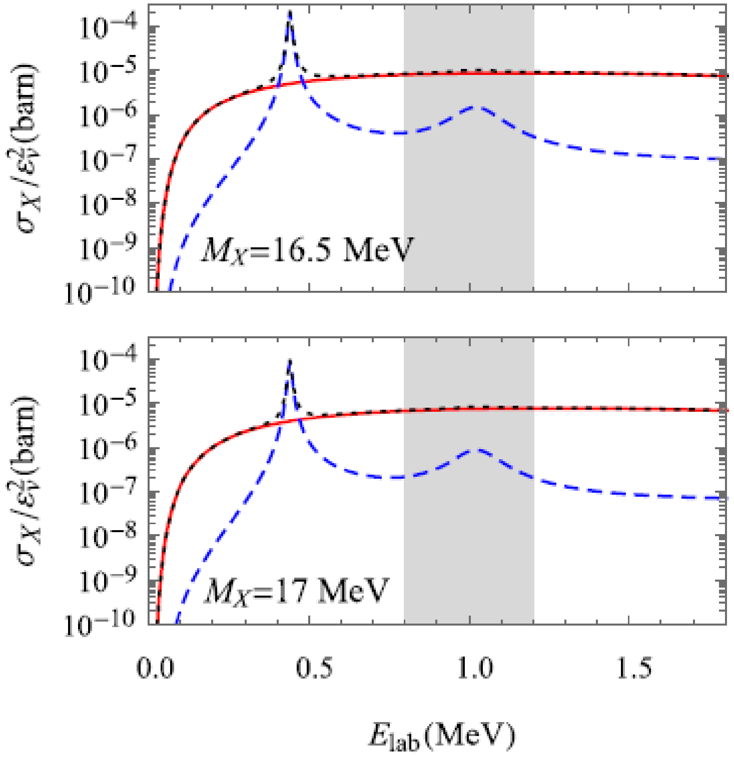




Xilin Zhang, Gerald Miller: Can a protophobic vector boson explain the ATOMKI anomaly? Physics Letters B 813 (2021) 136061



The theoretical results can reproduce very accurately the previous experimental results regarding the excitation function of the nuclear reaction.



However, according to the theoretical prediction, the X17 emission should have a maximum at the 441 keV resonance, and then it should occur dominantly in the E1 radiation generated in direct capture.

PHYSICAL REVIEW D **95**, 115024 (2017)

Light axial vector bosons, nuclear transitions, and the ^{8}Be anomaly

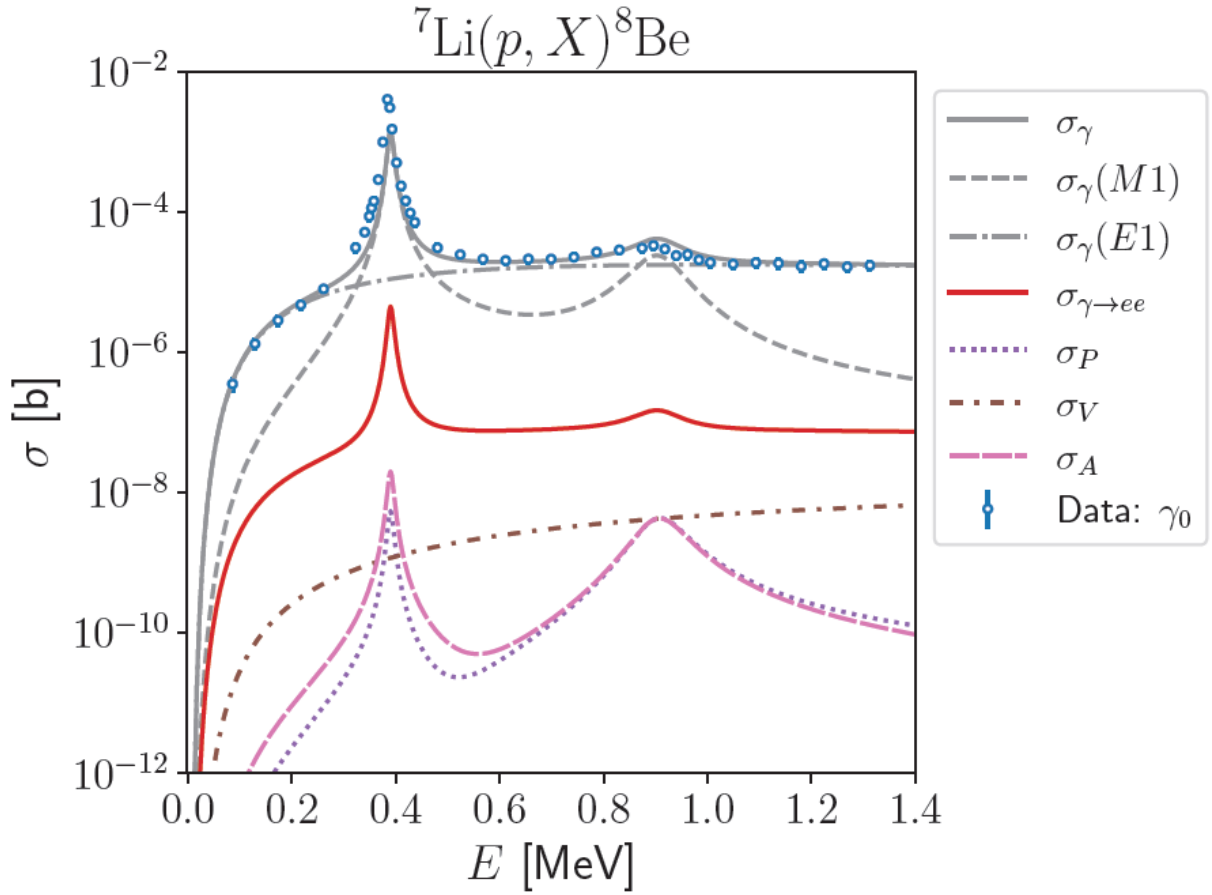
Jonathan Kozaczuk,[1,2,*] David E. Morrissey,[2,†] and S. R. Stroberg[2,3,‡]

The relevant matrix elements for ^{8}Be(1^+) → ^{8}Be(0^+) transitions are calculated using ab initio methods with inter-nucleon forces derived from chiral effective field theory.

We find that the emission of a light axial vector with mass Mx =17 MeV can account for the anomaly seen in the 1+ → 0+ isoscalar transition together with the absence of a significant anomaly in the corresponding isovector transition.

P. Gysbers et al.,: Ab initio investigation of the ^{7}Li(p, $e^{+}e^{-}$)^{8}Be process and the X17 boson arXiv:2308.13751 (2024)

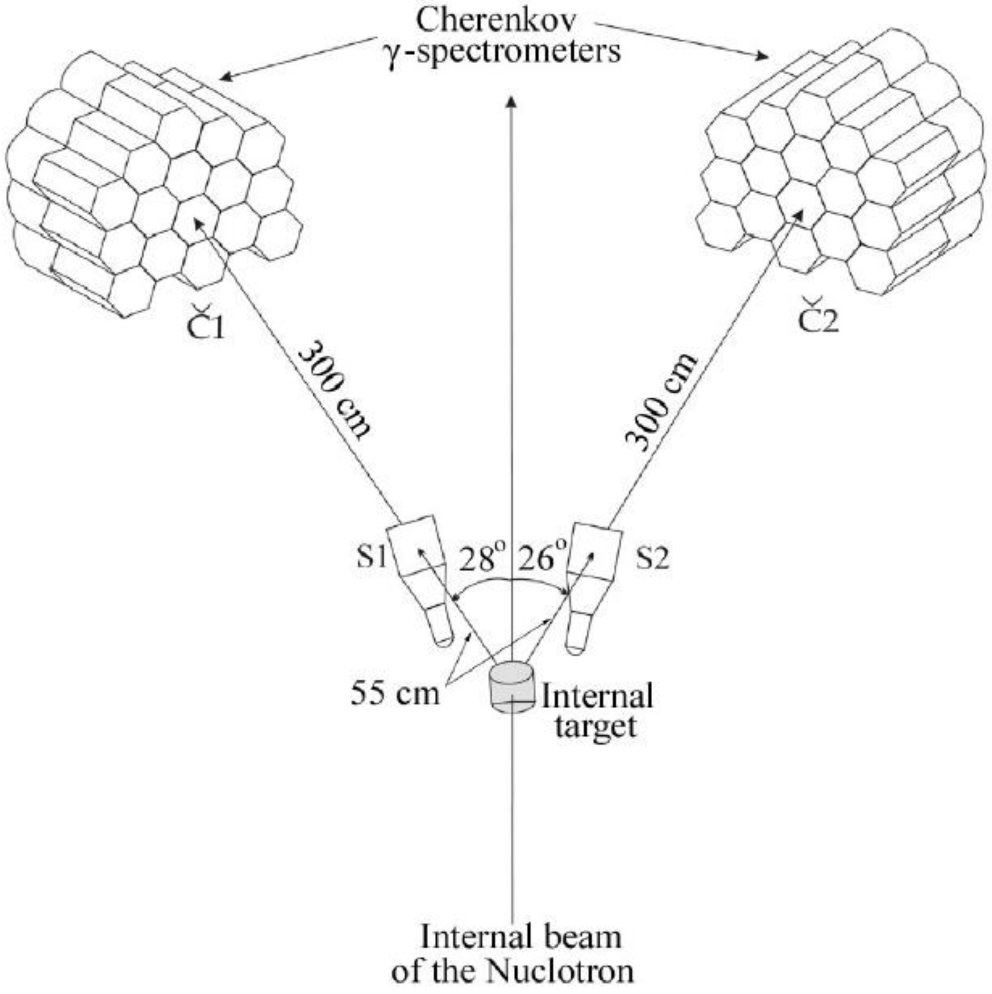
We showed that the effect of the hypothetical boson could be expected at 18.15 MeV 1^{+} resonance in the case of a pseudoscalar, axial vector, or vector character while a signal at the 17.64 MeV 1^{+} resonance would likely be overwhelmed by the isovector M1 Standard Model e^{+} e^{-} background.

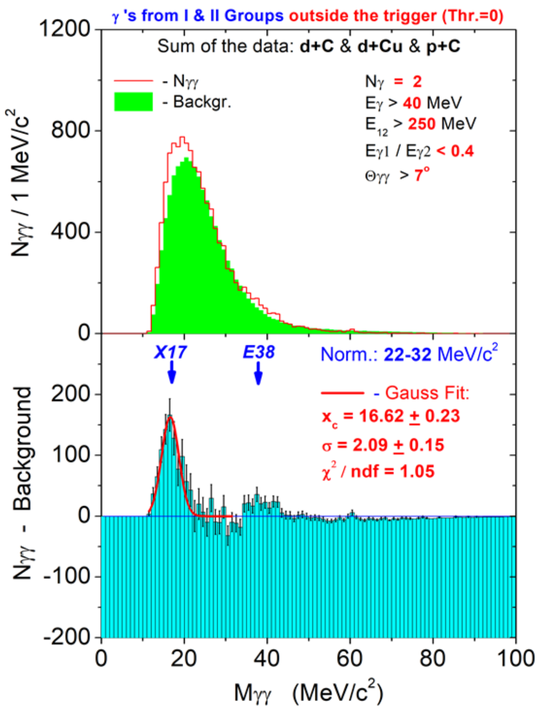


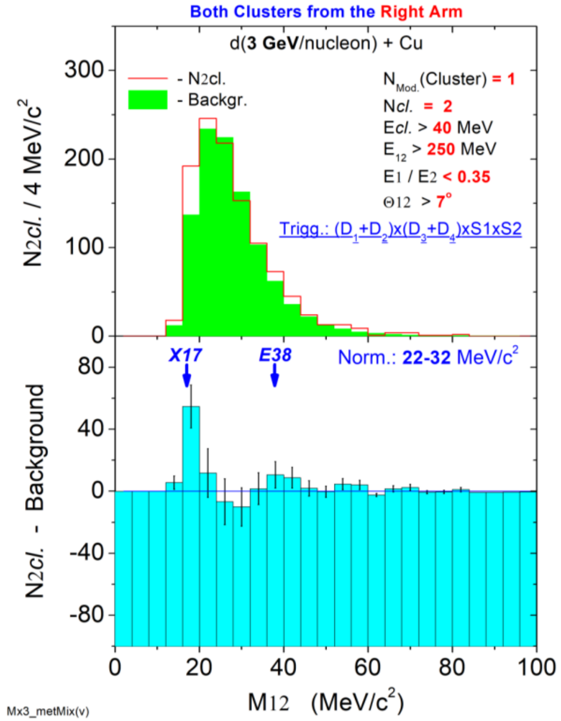
On the spin, parity and isospin of the X17 boson

- The X17 emission in the E1 radiation is also supported by our experimental data, but in our case the X17 emission shows a maximum at the 1040 keV resonance, while its effect at the 441 keV resonance is negligibly weak. The isospin of the particle obviously plays an important role in the processes, but it seems that the isospin of the X17 particle was assumed to be inappropriate for the calculations of Zhang and Miller.
- Recent discussion with theorists… → X17 is a $J^{\pi} = 1^{\pm}$, vector boson with isoscalar couplings to nucleons.

Results of the Dubna experiment





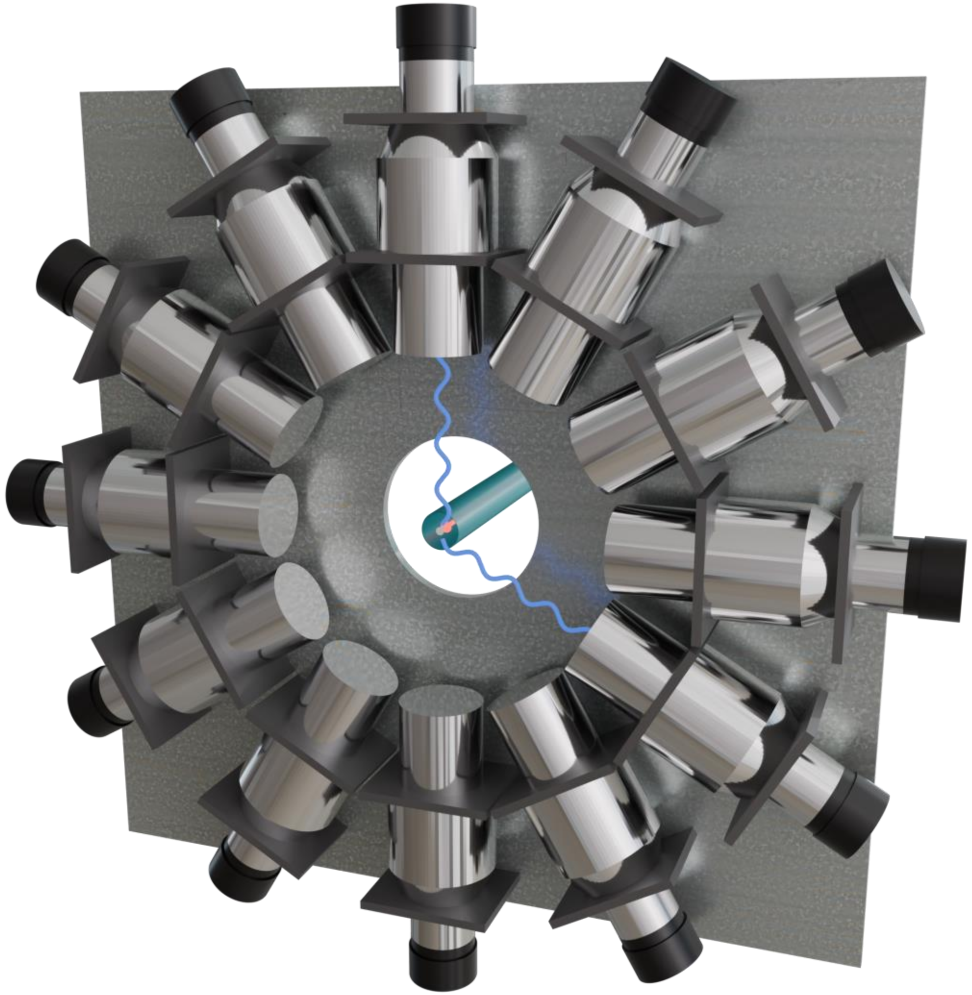


Confirms our results on the $\gamma\gamma^-$ -decay of X17

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

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

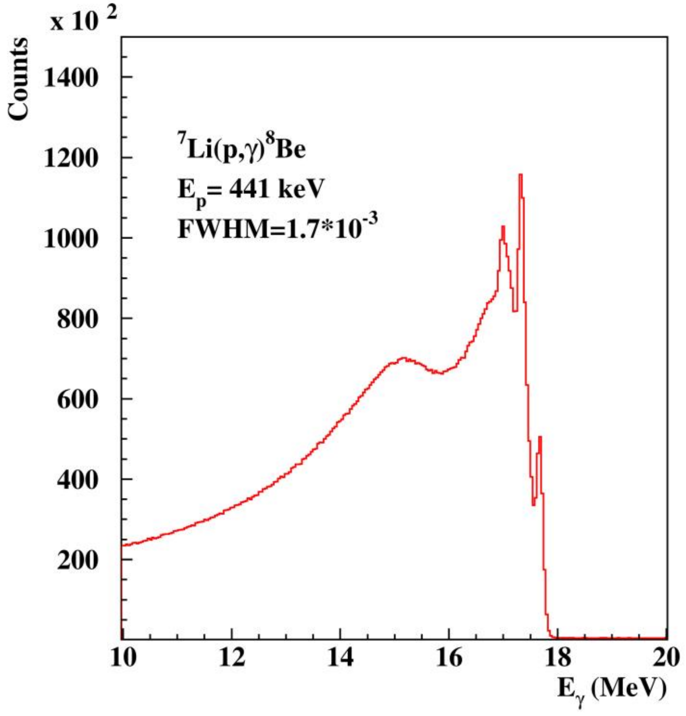
New experiments in HUN-REN ATOMKI
Study the γγ-decay of the X17 particle

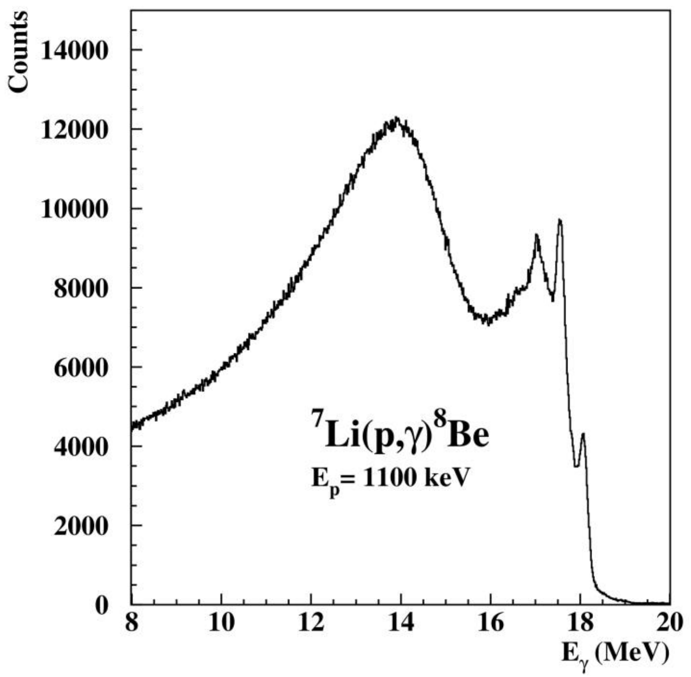


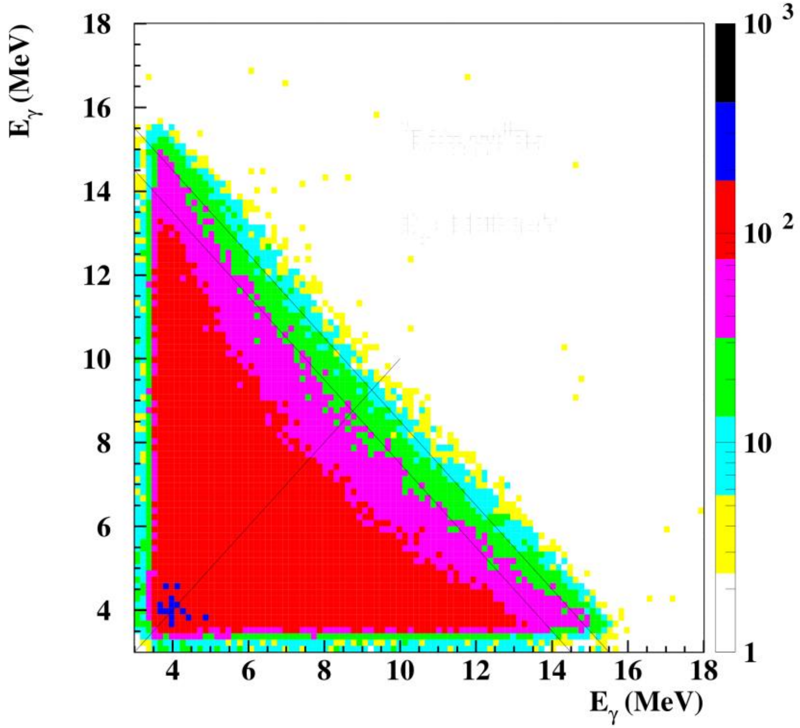
The Dubna results for 2γ decay …
X17 is a QED meson ???
Cheuk-Yin Wong, MDPI, Universe, 2024, 10, 173

According to the Landau-Yang theorem, the decay of a vector boson is forbidden by double γ-emission, however a pseudoscalar one is allowed.

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

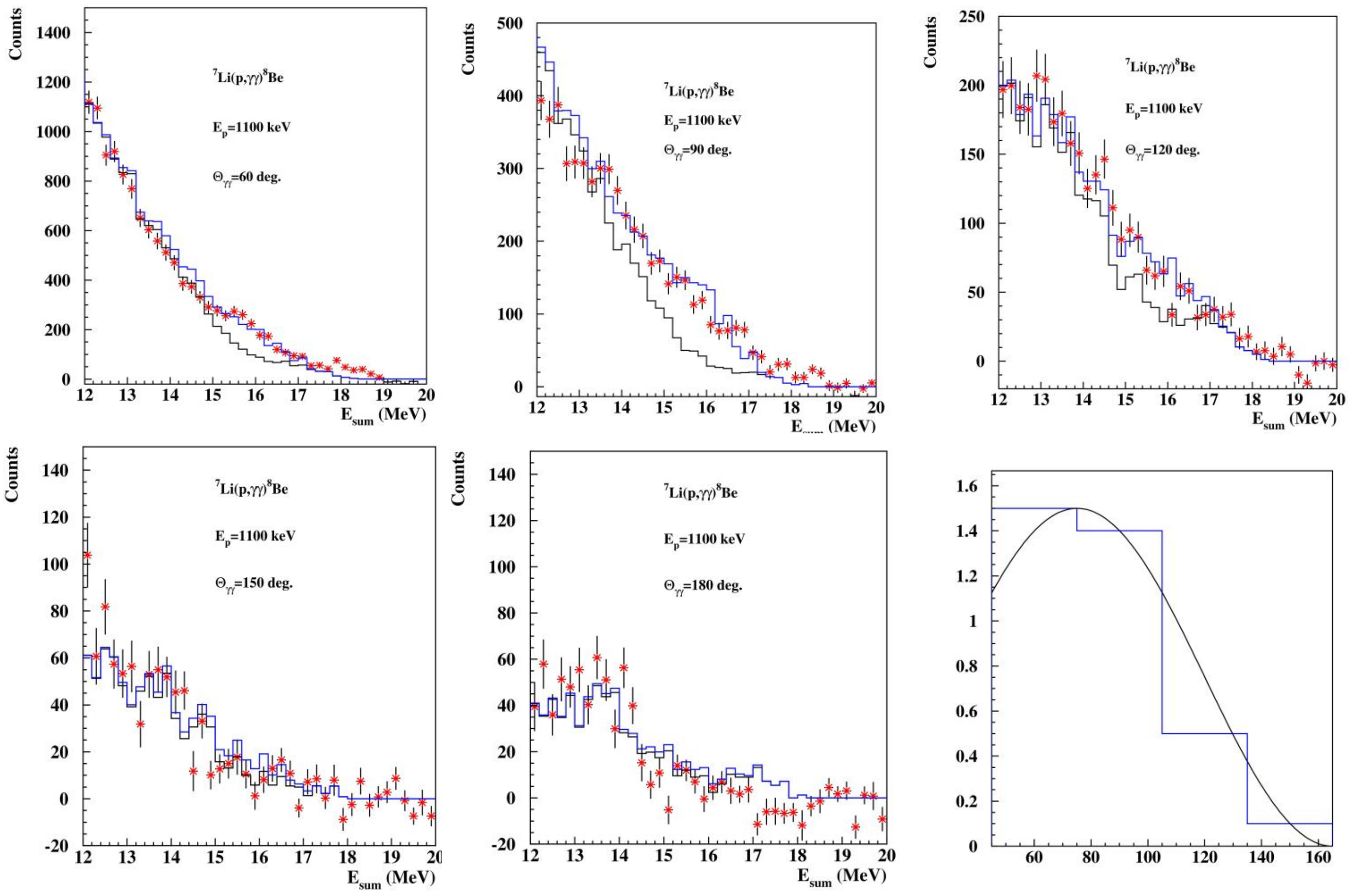






γγ-coincidence measurements, with high statistics (10^{10}) and good energy resolution

Preliminary results of the γγ-decay measurements

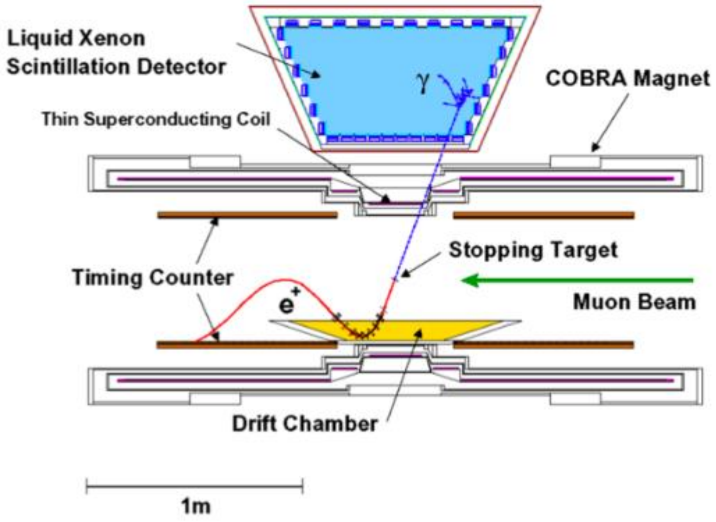


Dexcitation of atomic nuclei by double emission of γ-rays

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.

Search for the X(17) particle in the $^7Li(p,e^+e^-)^8Be$ reaction with the MEG II detector (PSI, Willigen, Switzerland)



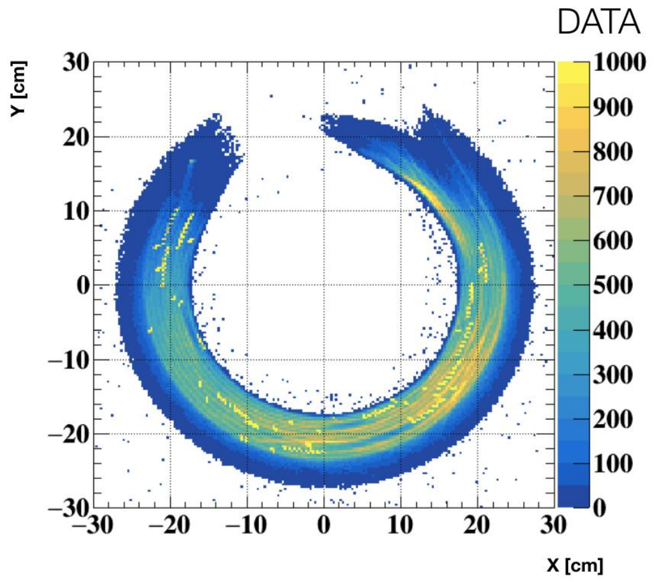
Collected data sample

- **Pivotal** run **2022**: Proton beam tuning, Mechanical/integration test of the new parts, LiF and LiPON target test, Different trigger settings, Optimised Data Taking and Reconstruction Algorithms

- **Physics** run **2023**: 4 weeks producing mainly the 17.6 MeV gamma-line
  - Proton energy at 1080 keV
  - Beam composition: H+ (~75%) and H2+(~25%)
  - Thick LiPON (~7 um)
  - Both 440 keV and 1030 keV excited simultaneously

- Statistics:
  - ~75 M Events
  - ~**300 K** Events Reconstructed pairs

- On full range of the Esum and Angular Opening angle observables:
  - ~60% EPC (14.6 + 17.6 MeV)
    - Dominant at low angle, negligible in the signal region
  - ~40% IPC (14.6 + 17.6 MeV)
    - Dominant in the signal region



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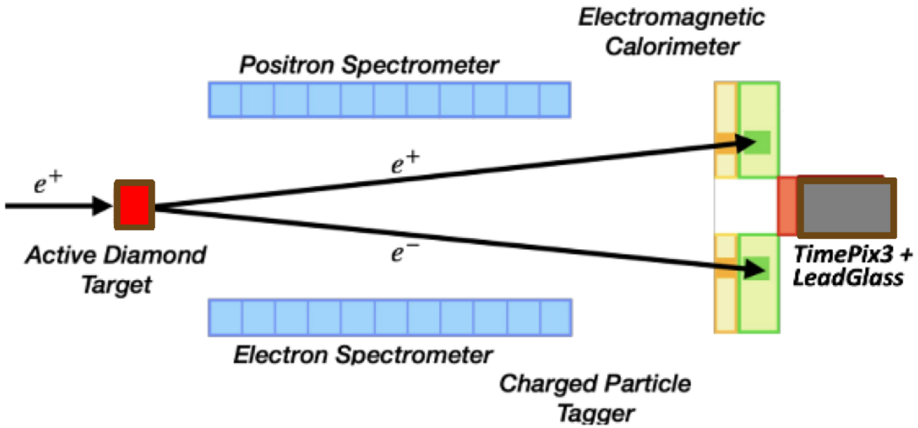
A X17 data collection fully exploiting the 1030 keV is foreseen during the first part of 2025.

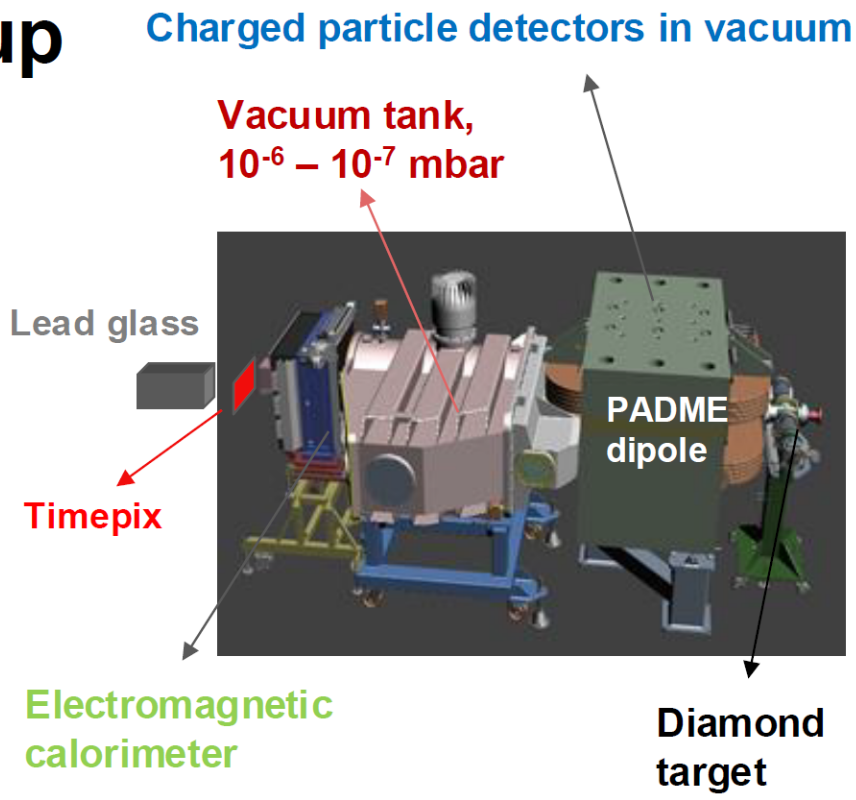
PADME Run-III preliminary results

Run-III setup

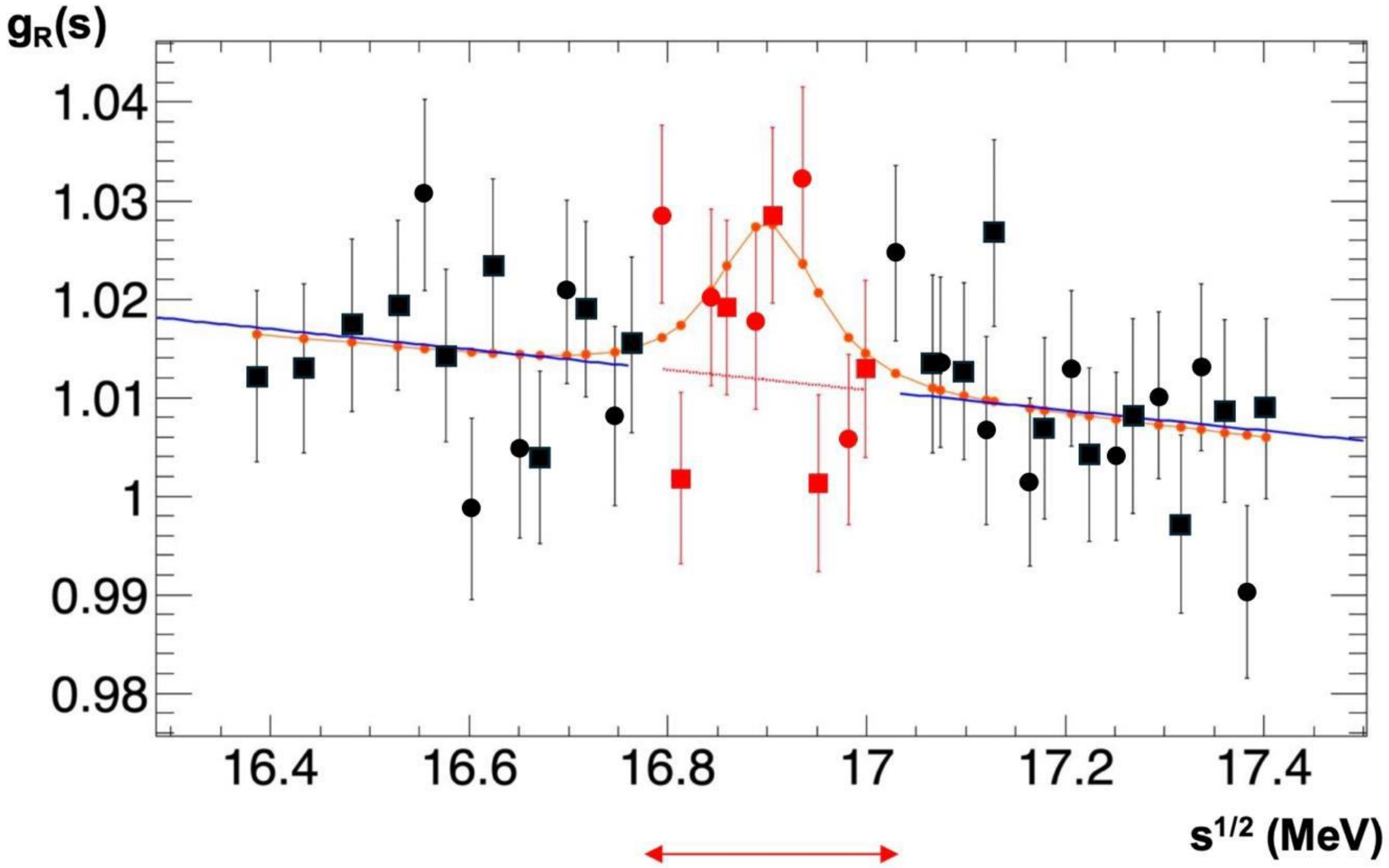
2022 Run-III setup adapted for the X17 search:

- Active target, polycrystalline diamond
- No magnetic field
- Charged-veto detectors <u>not used</u>
- Newly built hodoscope in front of Ecal for e/γ
- Timepix silicon-based detector for beam spot
- Lead-glass beam catcher (NA62 LAV spare block)





PADME preliminary results



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.

What is that good for?

Most importantly, finding these particles could open the door to making dark matter detectable and tangible. If we indeed finally find a force that interacts with dark matter (other than gravity), we might be able to use it to somehow design new types of experiments in laboratories here on Earth. Basically, we could leverage it to grab hold of dark matter for the first time.

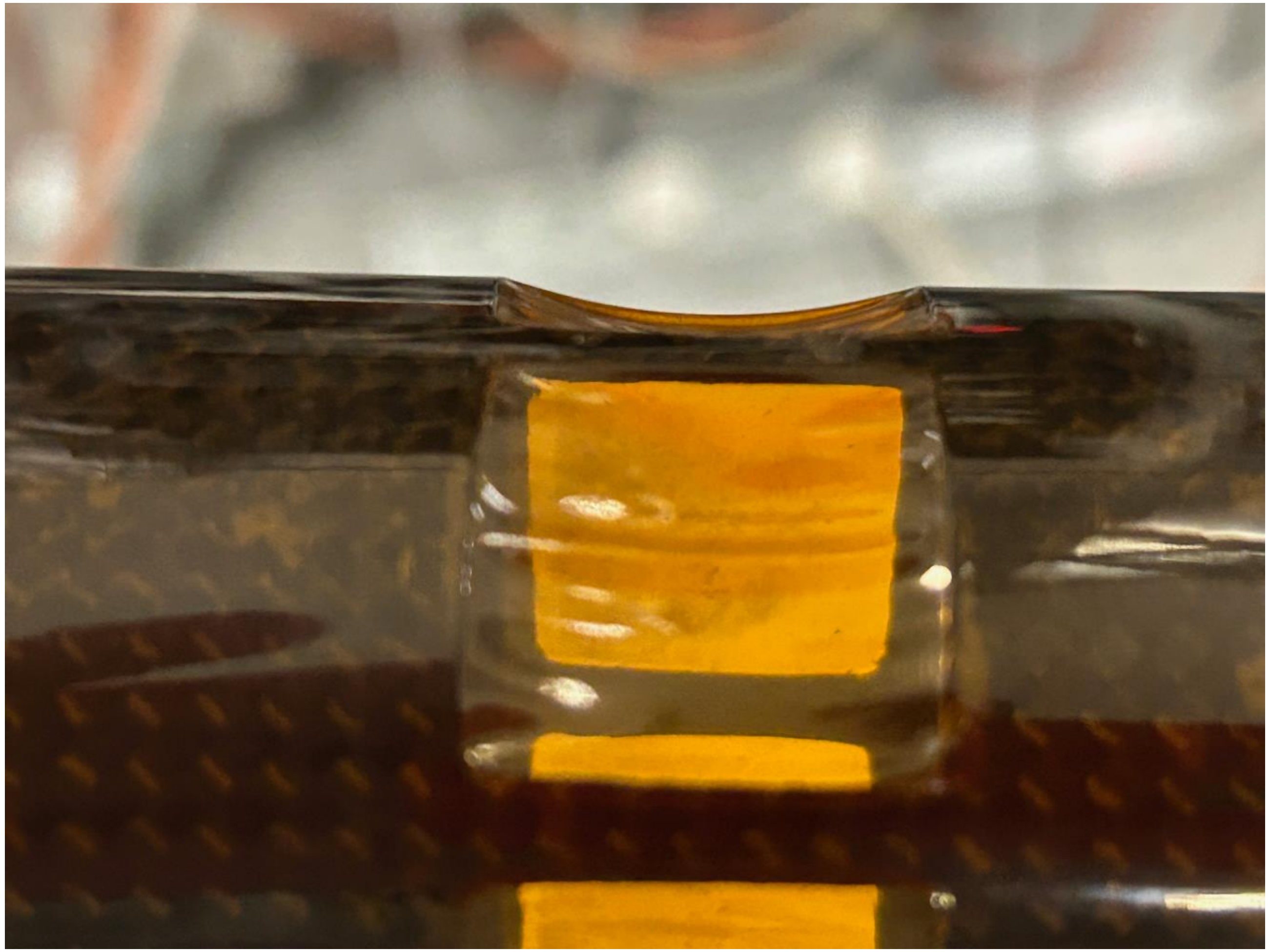
Thank you very much for your kind attention.

A viable QCD axion in the MeV mass range

Daniele S.M. Alves and Neal Weiner, JHEP07 (2018) 092

Visible axions with decay constants at or below the electroweak scale are believed to have been long excluded by laboratory searches. Considering the significance of the axion solution to the strong CP problem, we revisit experimental constraints on QCD axions in the O(10 MeV) mass window. In particular, we find a variant axion model that remains compatible with existing constraints. This model predicts new states at the GeV scale coupled hadronically, and a variety of low-energy axion signatures, such as rare meson decays, nuclear de-excitations via axion emission, and production in e +e − annihilation and fixed target experiments. This reopens the possibility of solving the strong CP problem at the GeV scale.

The new beam-pipe with capton windows



- TABLE I. Internal Pair Creation Coefficients (IPCC), X17
- Boson branching ratios (Bx), masses of the X17 particle, and
- confidences derived from the fits.
- E p IPCC B x Bx(renorm) Mass
- (keV) $\times 10^{-4}$ $\times 10^{-6}$ $\times 10^{-4}$ (MeV/c 2)
- 510 2.5(3) 6.2(7) 1.6 17.01(12)
- 610 1.0(7) 4.1(6) 1.1 16.88(16)
- 900 1.1(11) 6.5(20) 1.7 16.68(30)
- Averages 1.5(10) 5.1(13) 1.3 16.94(12)