New results on a 10 year old particle candidate (X17) observed in nuclear transitions

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Leitmotif of the present talk:

In an age of giant accelerators, of complex experiments and of mystifying theories it is a pleasure to report on some simple experiments, made with simple equipment and having a simple interpretation

Robert Hofstadter (Nobel, 1961)

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.

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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

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Rekindled Atomki anomaly merits closer scrutiny

20 December 2019

The ATOMKI anomaly → signals for a new 17 MeV boson → gauge boson of a new fundamental force of nature

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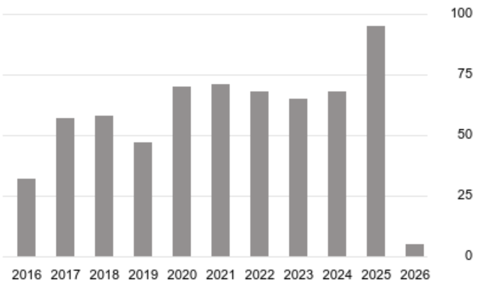


Article in Nature, CNN news, boom in the media

How can we identify the X17 particle? (AI answers)

The identification of the **X17 particle** is primarily achieved by detecting a specific "bump" or anomaly in the angular distribution of electron-positron (e^+e^-) pairs produced during certain nuclear transitions.

As of January 2026, researchers use the following methods and experimental signatures to identify this hypothetical particle:

1. Angular Correlation Anomaly (The "Bump")

The most distinct signature of the X17 is an excess of e^+e^- pairs at a specific wide angle:

Beryllium-8 Decay: When an excited 8Be nucleus de-excites, it can emit an e^+e^- pair. In standard models, these pairs should mostly appear at small angles. Identifying X17 involves finding a peak at approximately **140°.**

Helium-4 Decay: In transitions of ^{4}He, the anomaly appears as a peak at approximately **115°.**

Invariant Mass: By measuring the energies and angles of these pairs, physicists calculate an invariant mass of roughly **17 MeV/c2**, which is the namesake of the particle.

2. Experimental Setup and Detection

To identify these signals, sophisticated spectrometers are used in several key experiments:

ATOMKI Spectrometer: The original detection method at the Hungarian Institute for Nuclear Research (ATOMKI) uses five to six telescopes to measure the energy sum and angular correlation of the pairs.

PADME Experiment: Located at INFN Frascati, this experiment seeks to identify X17 by bombarding a diamond target with positrons and looking for "missing mass" in the collisions. In April 2025, PADME reported a modest 2σ **excess** at the 17 MeV mass range.

MEG II: At the Paul Scherrer Institute, researchers use a superconducting solenoid spectrometer to verify the Beryllium-8 anomaly. While results reported in late 2025 were mixed, a dedicated "Physics Run 2025" aimed to provide a definitive check.

3. Determining Quantum Numbers

Identifying *what* the particle is (its spin and parity) is an ongoing task:

Spin/Parity ($J\pi$) : Currently debated as either a **vector boson** (1^-) or a **pseudoscalar** (0^-).

Protophobic Nature: Theoretical identification suggests it is a "protophobic" force carrier, meaning it interacts with neutrons but has very suppressed or no interaction with protons

Direct Mass Measurement

The particle is identified mathematically by solving for a new force-carrying boson that fits the **Internal Pair Creation (IPC)** coefficients. If the experimental "bump" consistently aligns with a mass of ≈17 MeV across different nuclei (Beryllium, Helium, and Carbon-12), it supports the identification of a single new particle rather than a nuclear physics error.

AI responses may include mistakes.

Theoretical prediction for a new light particle

- The CP problem of the Standard Model
- Peccei, Quinn, Weinberg, Wilczek (1977-1978) – almost 50 years ago -
- PQ symmetry → light Nabu-Goldstone boson, axion
- S. Weinberg, A New Light Boson?, Phys. Rev. Lett. 40 (1978) 223
- Donelly, et al. Nuclear deexcitations via axions, Phys. Rev. D 18 (1978) 1607

$$m_a = 25N\left(X + \frac{1}{X}\right)$$ keV

X: ratio of the Higgs-fields

$$\tau_{a\to e^+e^-} = \frac{8\pi X^2 f_\Phi^2}{m_a^2\left(m_a^2 - 4m_e^2\right)^{1/2}}$$

$$f_\Phi = \sqrt{\lambda_1^2 + \lambda_2^2} = \sqrt{G\sqrt{2}} \approx 250GeV$$

Magnetic photon !

$$\Delta J^\pi = 0^-, 1^+, 2^-, \ldots$$

Experimental search for the axion

- Anomalous narrow peaks have been observed in the spectra of positrons emitted in heavy-ion collisions in several experiments at Gesellschaft für Schwerionenforschung Darmstadt (GSI) between 1983-1986.
- Their superconducting solenoid transporter electron-positron spectrometer, EPoS, also used the most modern techniques.

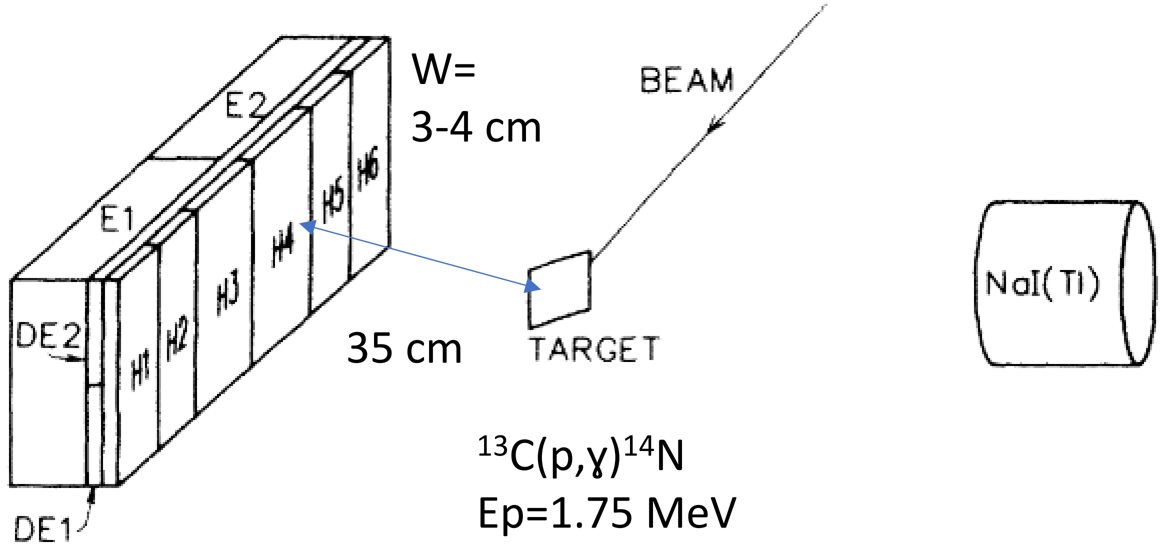
The UNILAC accelerator, whose control room, with its many huge monitors, looked like a space launch center

One explanation for these peaks is the production and subsequent decay of a previously unobserved neutral particle of mass ~1.7 MeV.

The new 1.7 MeV particle was ruled out very fast

- **Search for a Short-Lived Neutral Particle Produced in Nuclear Decay**

M. J. Savage, et al., Phys. Rev. Lett. 57 (1986) 178.



$^{13}C(p,\gamma)^{14}N$

Ep=1.75 MeV

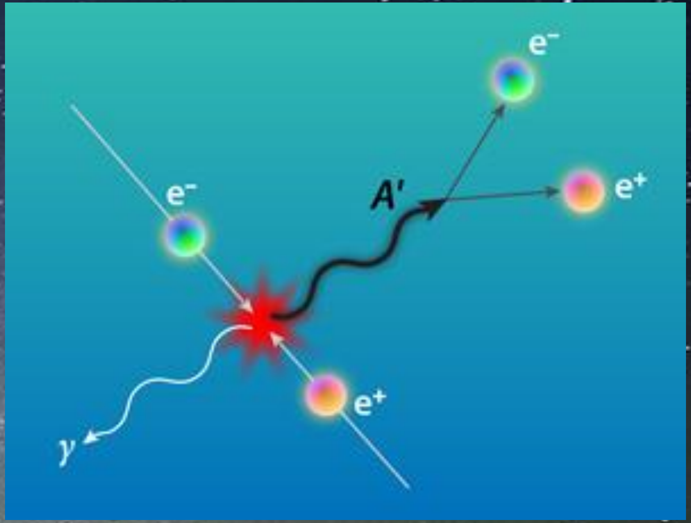
Eɣ = 9.17 MeV

M1

The angular resolution of the hodoscope was approximately 7 degrees and the maximum detectable angle between two charged particles was 29 degrees.

Searching for new physics and Dark Matter (Should not have to defend this too much…)

Searching from the basement to the attic already for 40 years, every corner with tremendous strength, but didn't find anything significant so far …



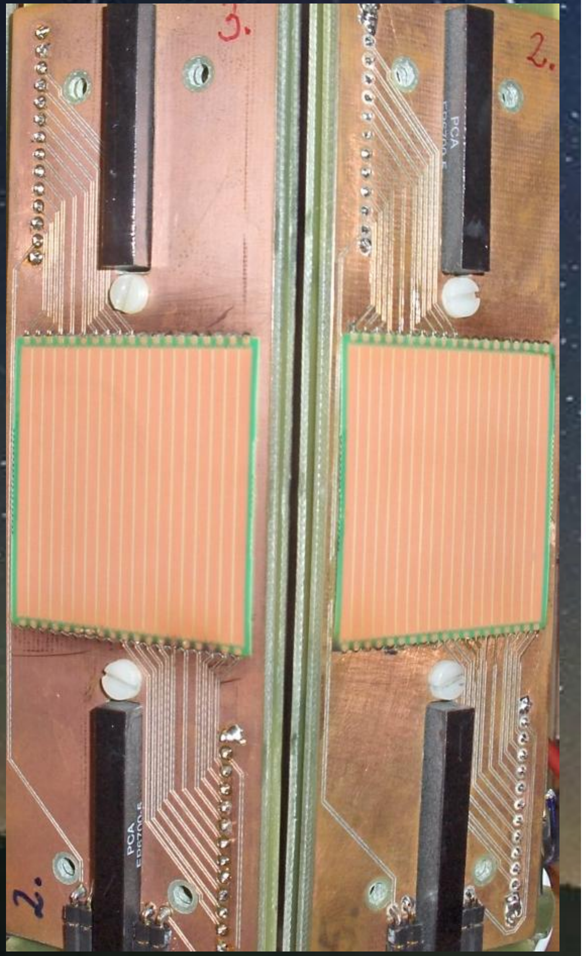
Fertile ground:

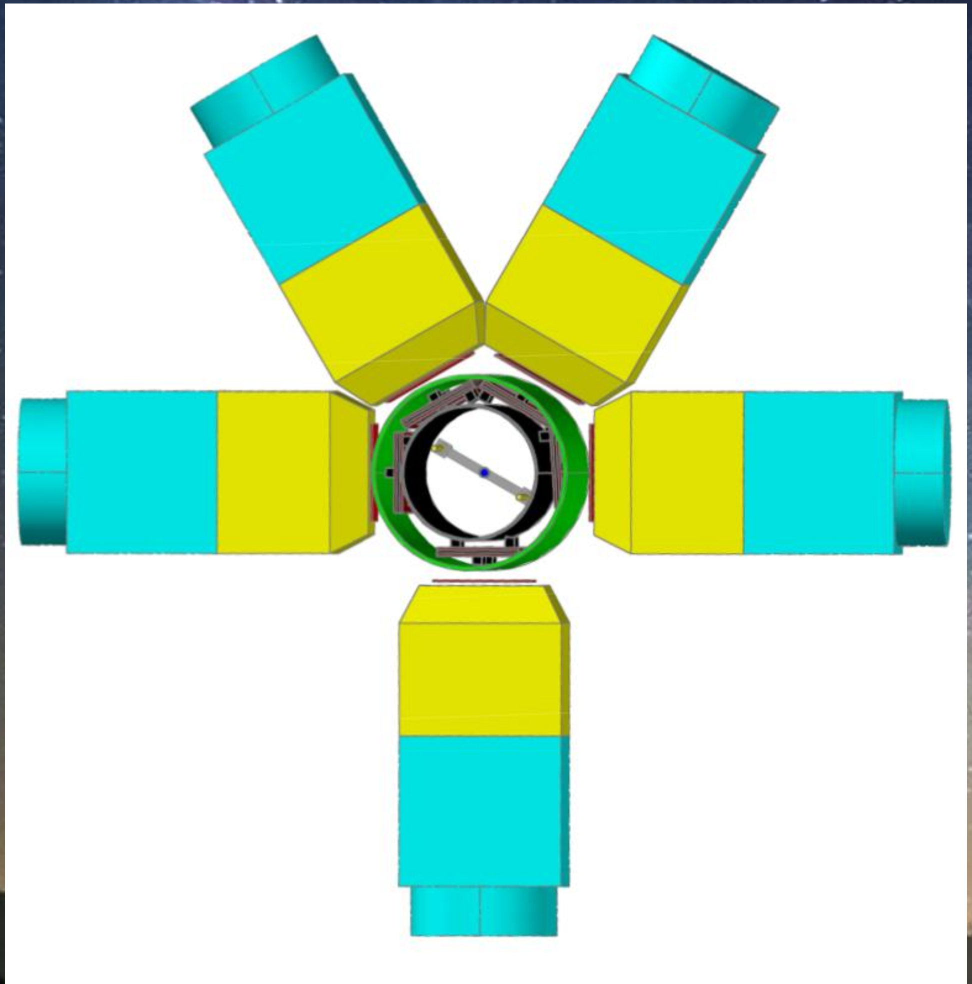
- Light, Weakly Interacting DM, the dark photon concept (γ-like vector particles)
- Pseudoscalar, Axion Like Particles (ALP) (axion search in nuclear transitions 1978 →)
- Z^0-like particles

M. Pospelov and A. Ritz, "Astrophysical Signatures of Secluded Dark Matter," Phys. Lett. B **671**, 391 (2009)


Dark Forces at Accelerators
16th - 19th, October 2012
Laboratori Nazionali di Frascati, INFN
Frascati (Rome), Italy
INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Frascati
The workshop will focus on experimental searches of new gauge bosons with masses in the MeV to GeV range. The connection of these studies to the search for dark matter will also be addressed.

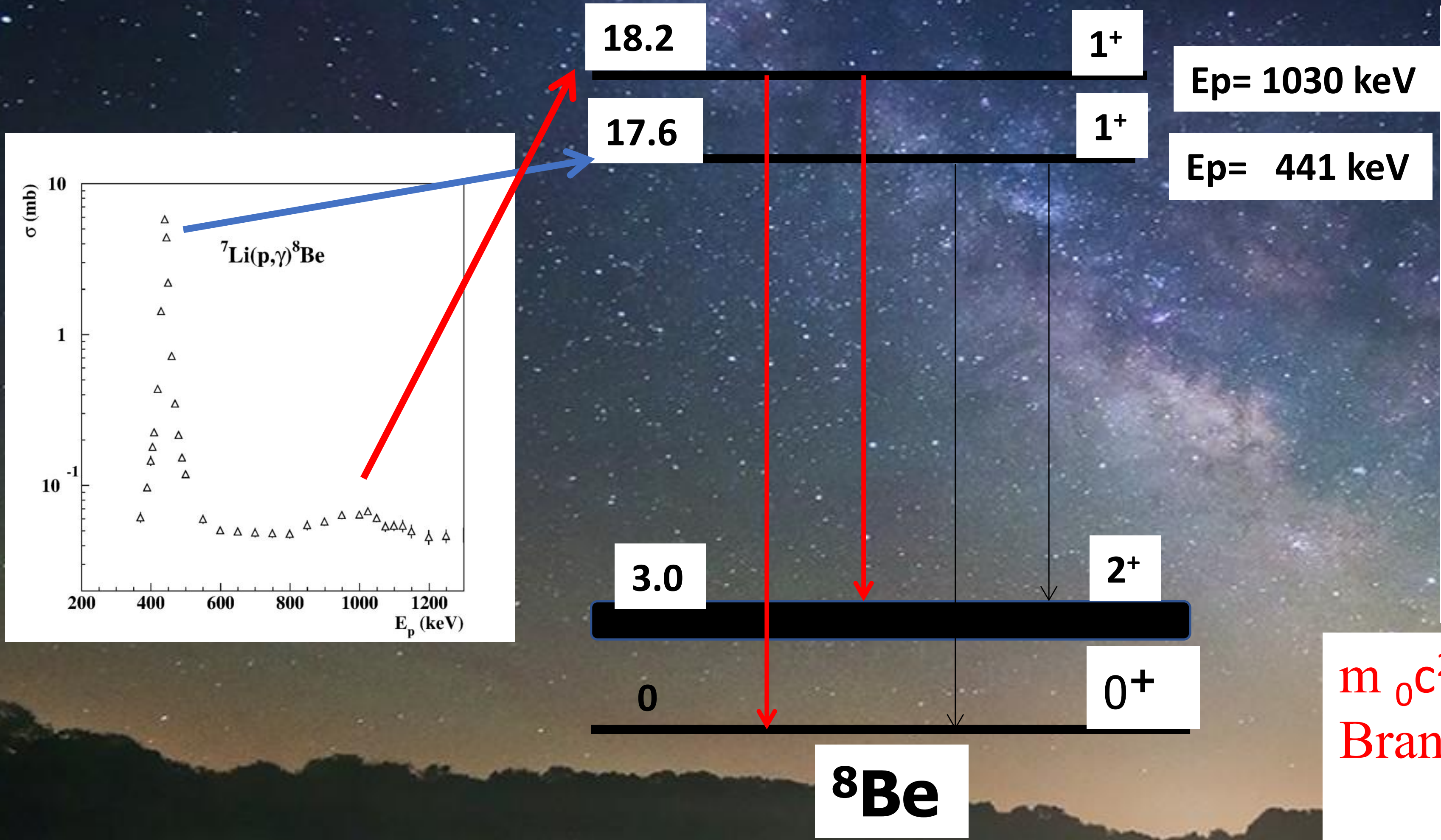
An e^+ - e^- spectrometer constructed by Multi Wire Proportional Counters and plastic scintillator telescopes

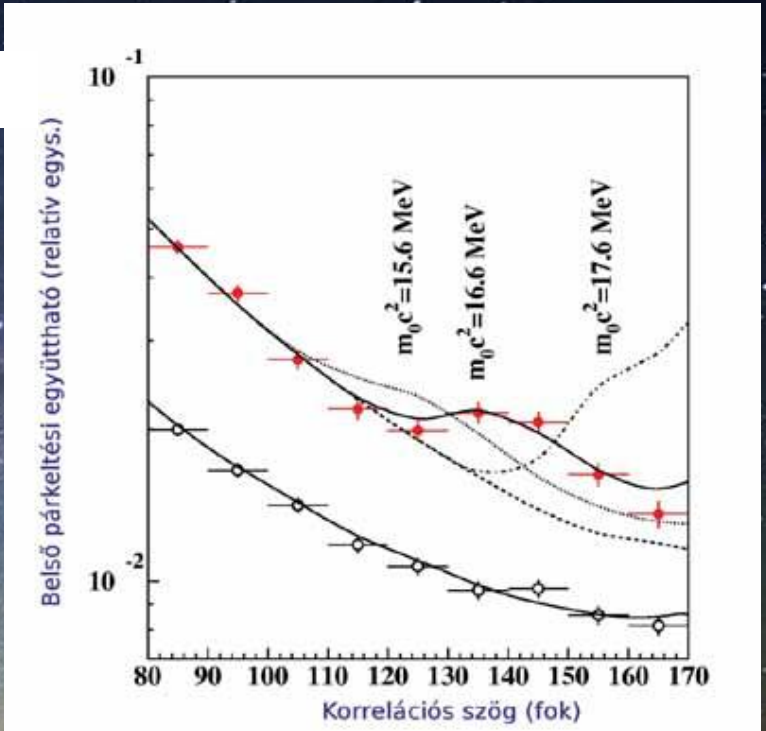




Study of the ^{8}Be M1 transitions

Excitation with the $^{7}Li(p,\gamma)^{8}Be$ reaction

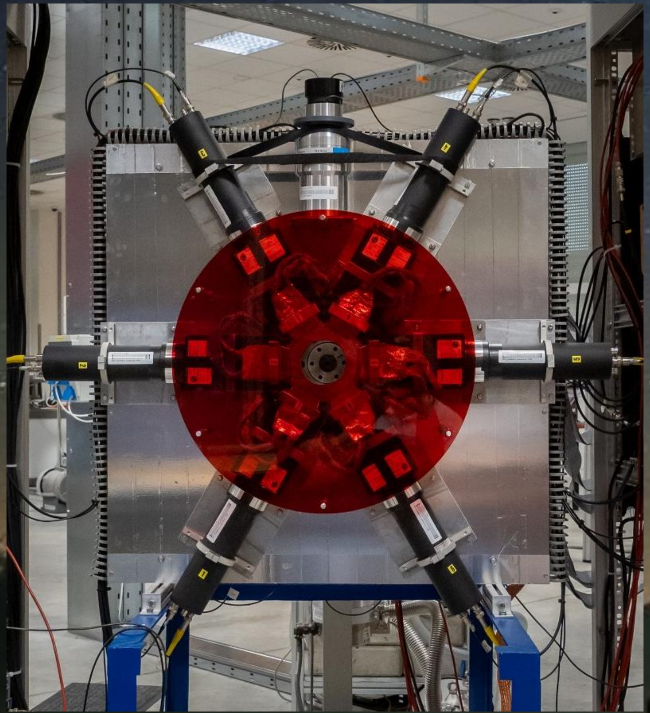




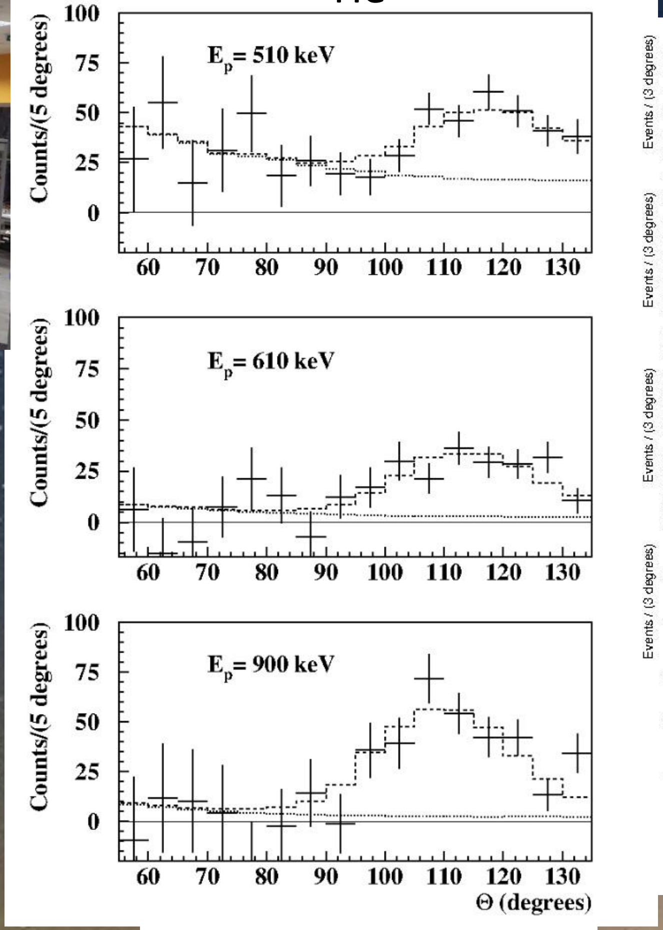
m_0c^2=16.7 ±0.35(stat)±0.5(syst.)

Branching ratio: $6x10^{-6}$

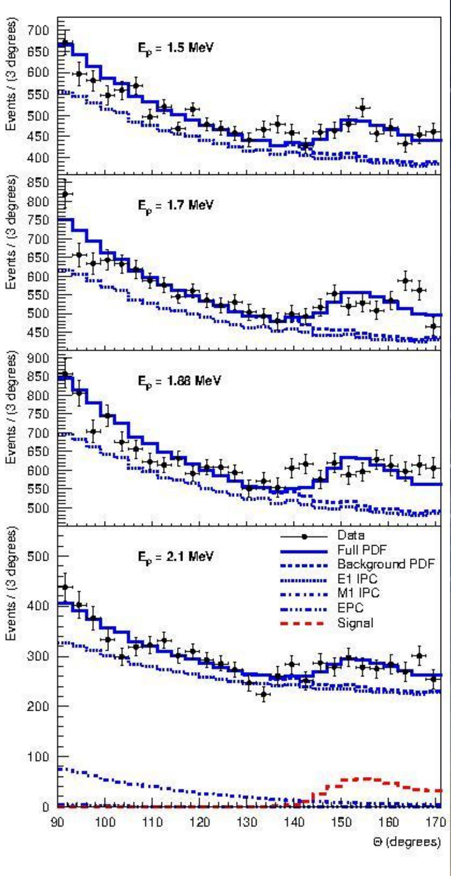
Experimental results obtained at the Tandetron



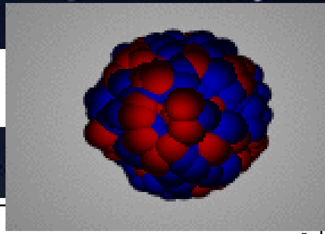
^{4}He

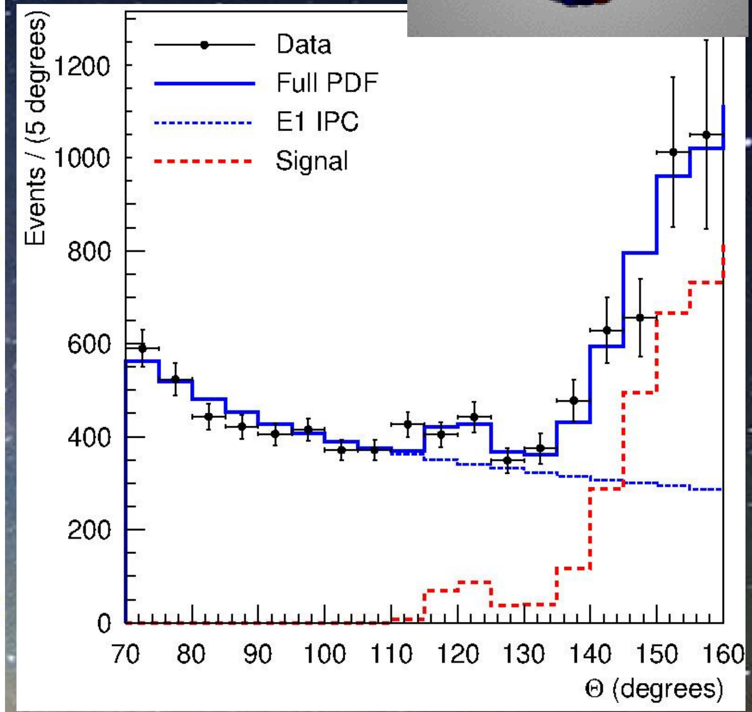


^{12}C



^{4}He, GDR





Phys. Rev. C 104, 044003 (2021)

Phys. Rev. C 106, L061601 (2022)

Universe 210 (11), 409, (2024)

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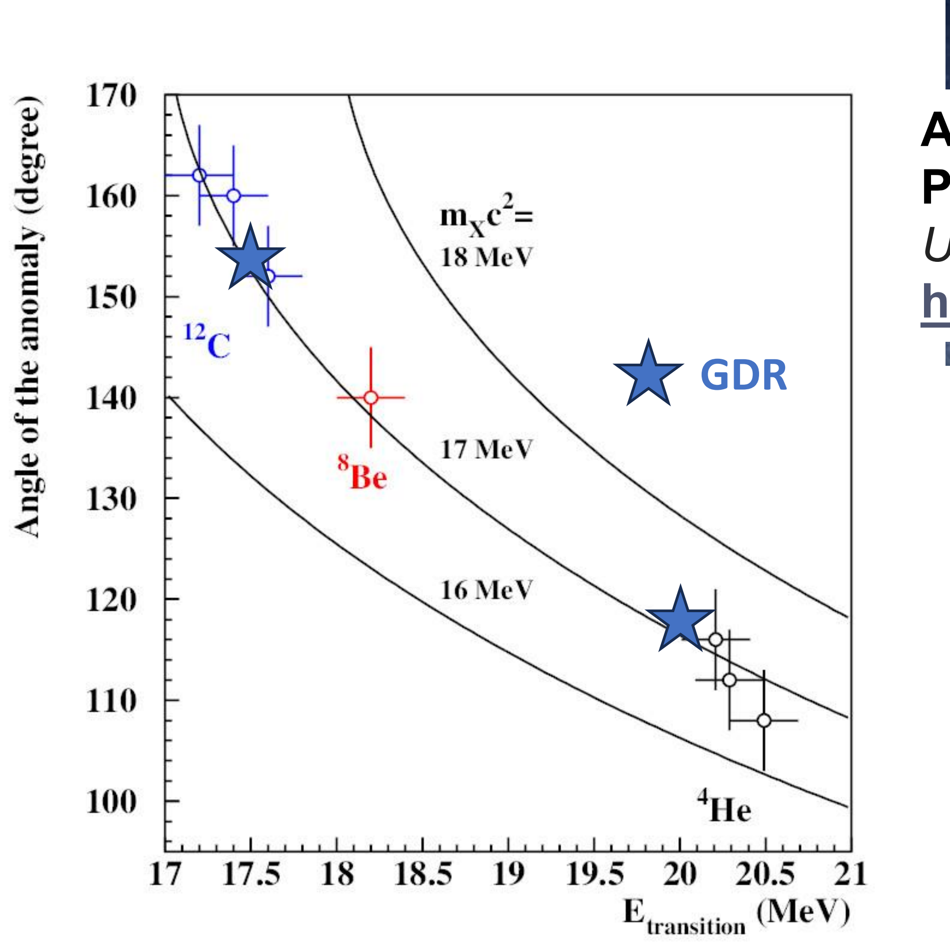
Kinematical evidence for the X17 particle



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. 32, 10 (2022)

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

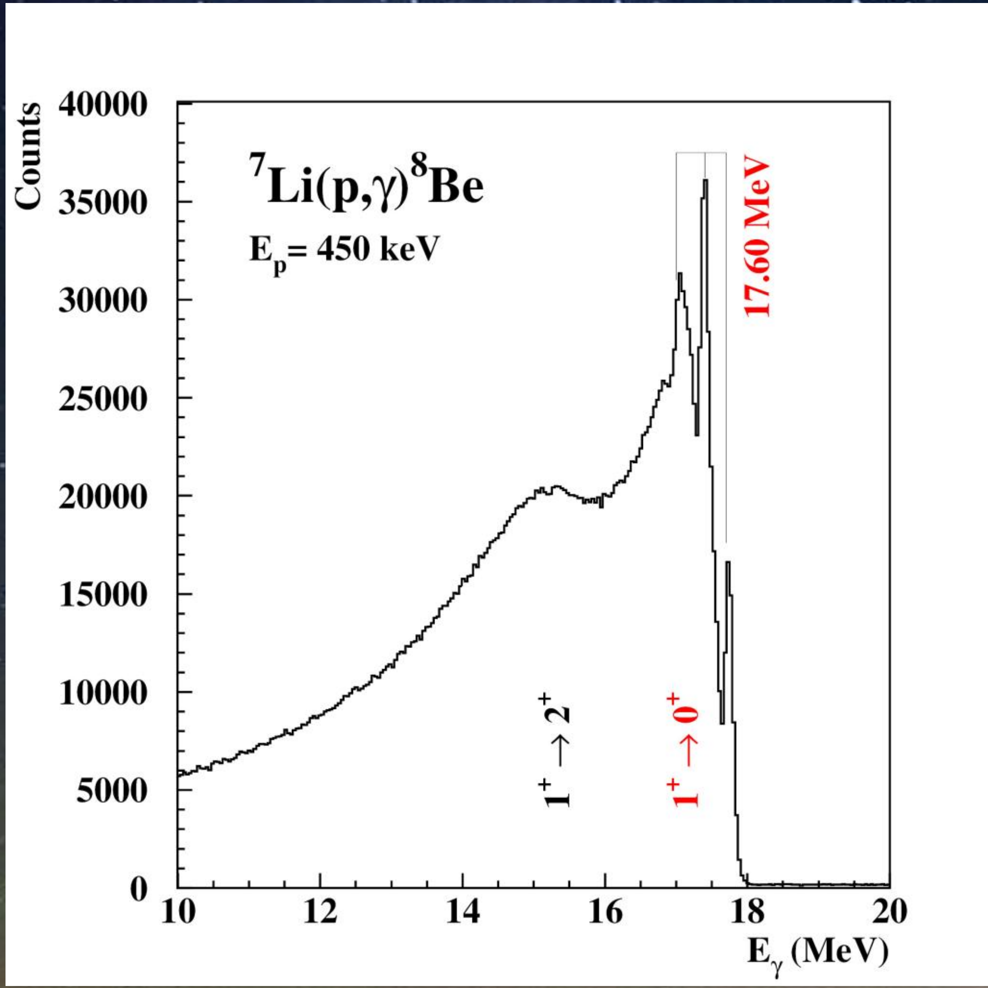
Better precision for the mass of X17

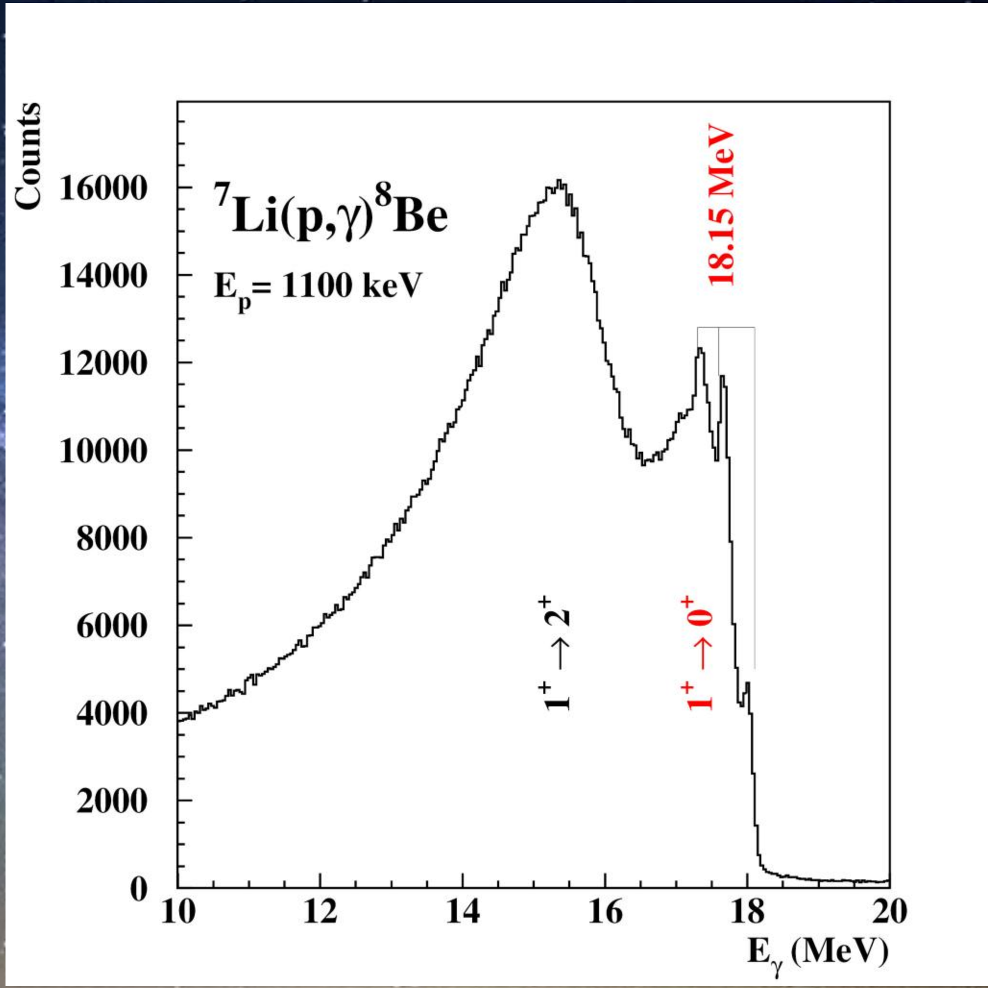
What is the spin and parity of X17?

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.

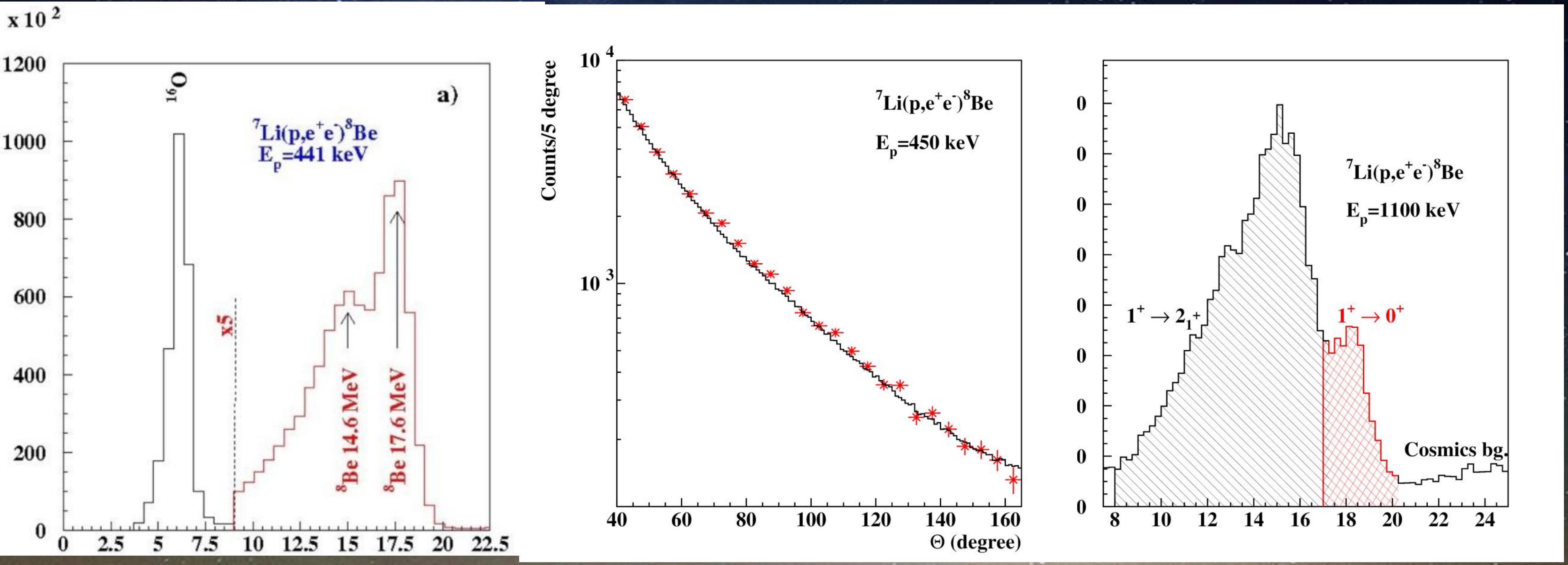
New results for ^8Be





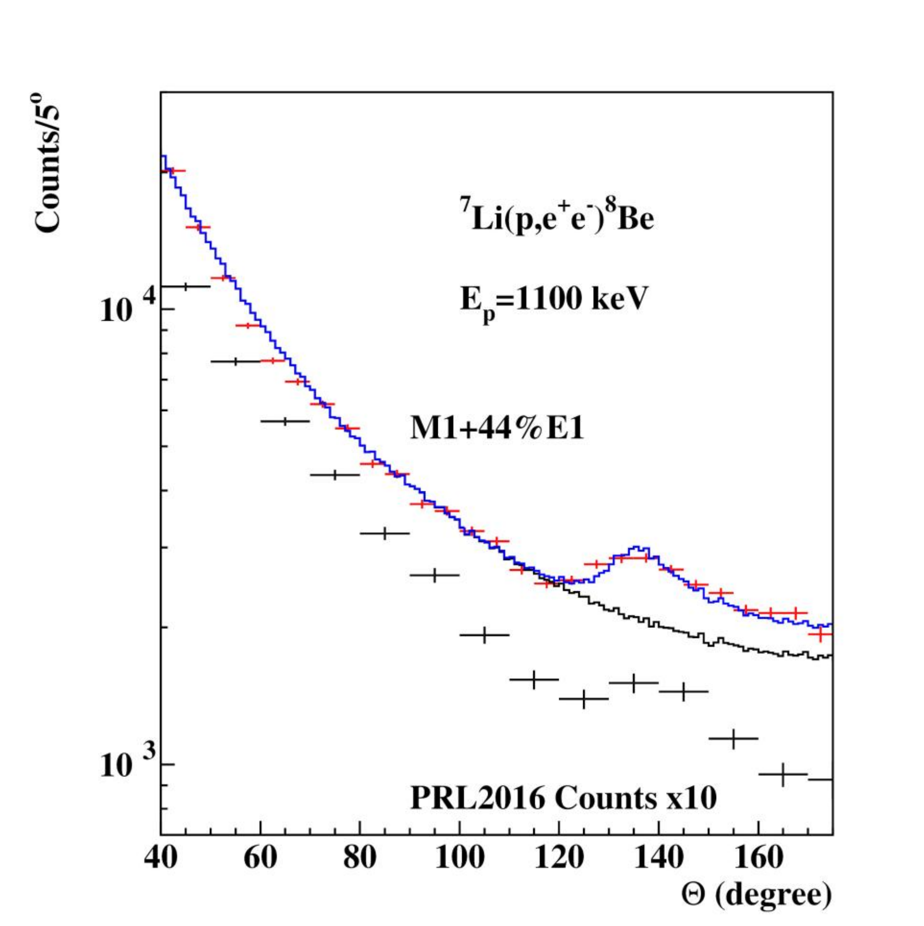
γ-ray spectra measured for the two resonances in ^8Be

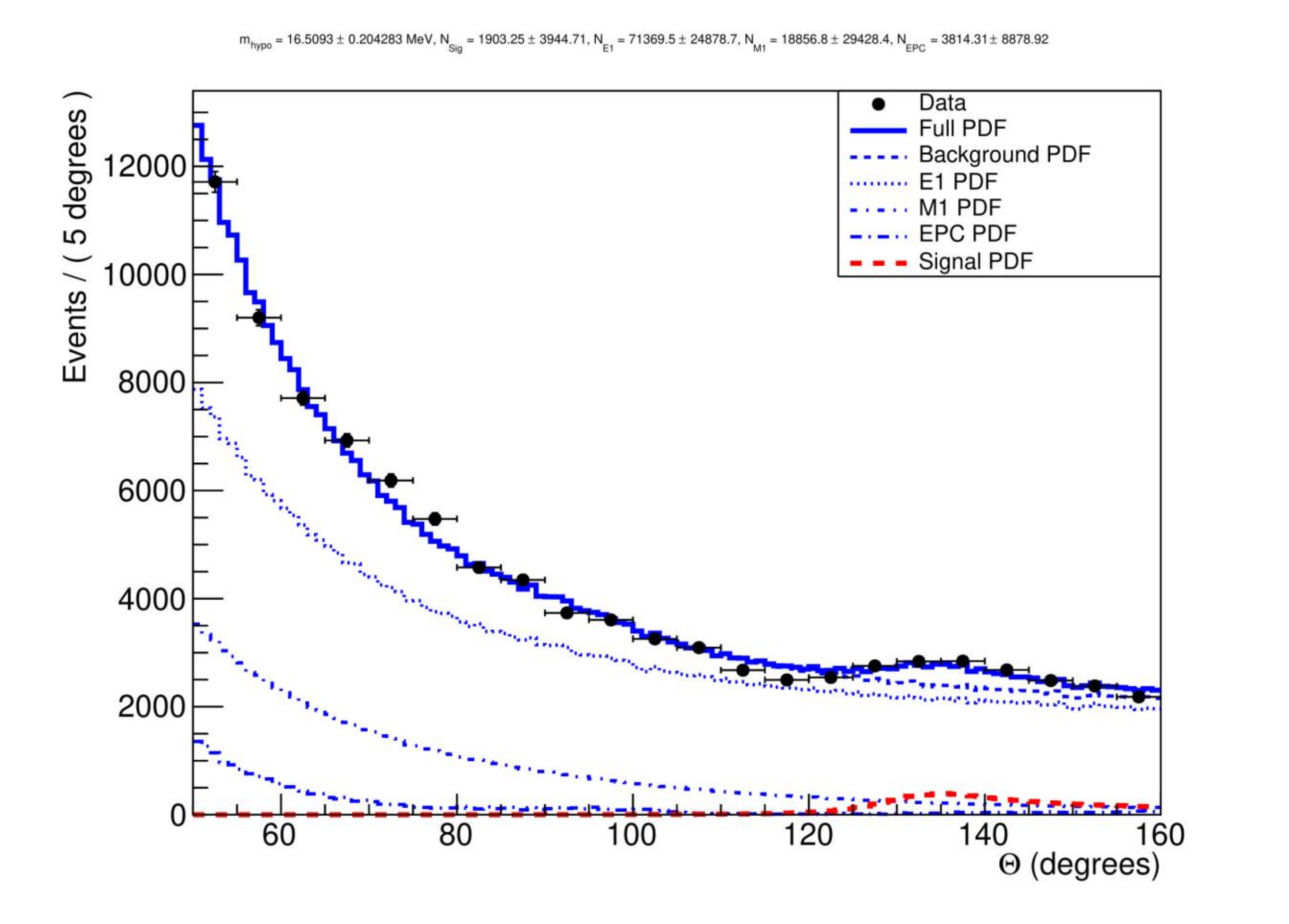
New results for ^8Be



e^+e^- sum spectra,and angular correlations measured for the two resonances in ^8Be

New results for ^{8}Be





Angular correlation of the e$^+$e$^-$ pairs measured for the 18.15 MeV transition in ^{8}Be

m_0c^2=16.5±0.20(stat)±0.3(syst.)

Future plans: determination of the mass of the X17 particle ten times more precisely

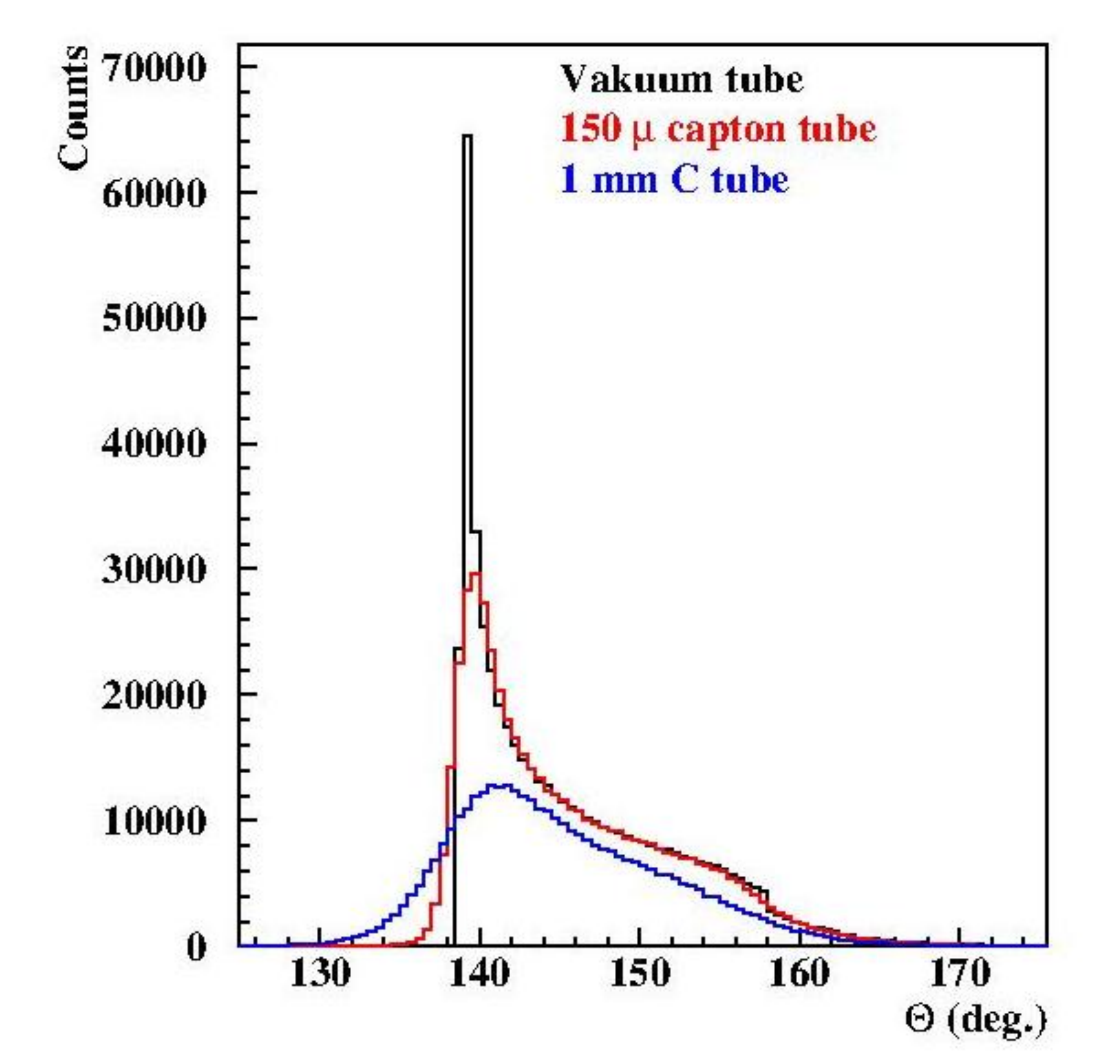
The invariant mass of the particle can be determined from the data we measure using the following expression:

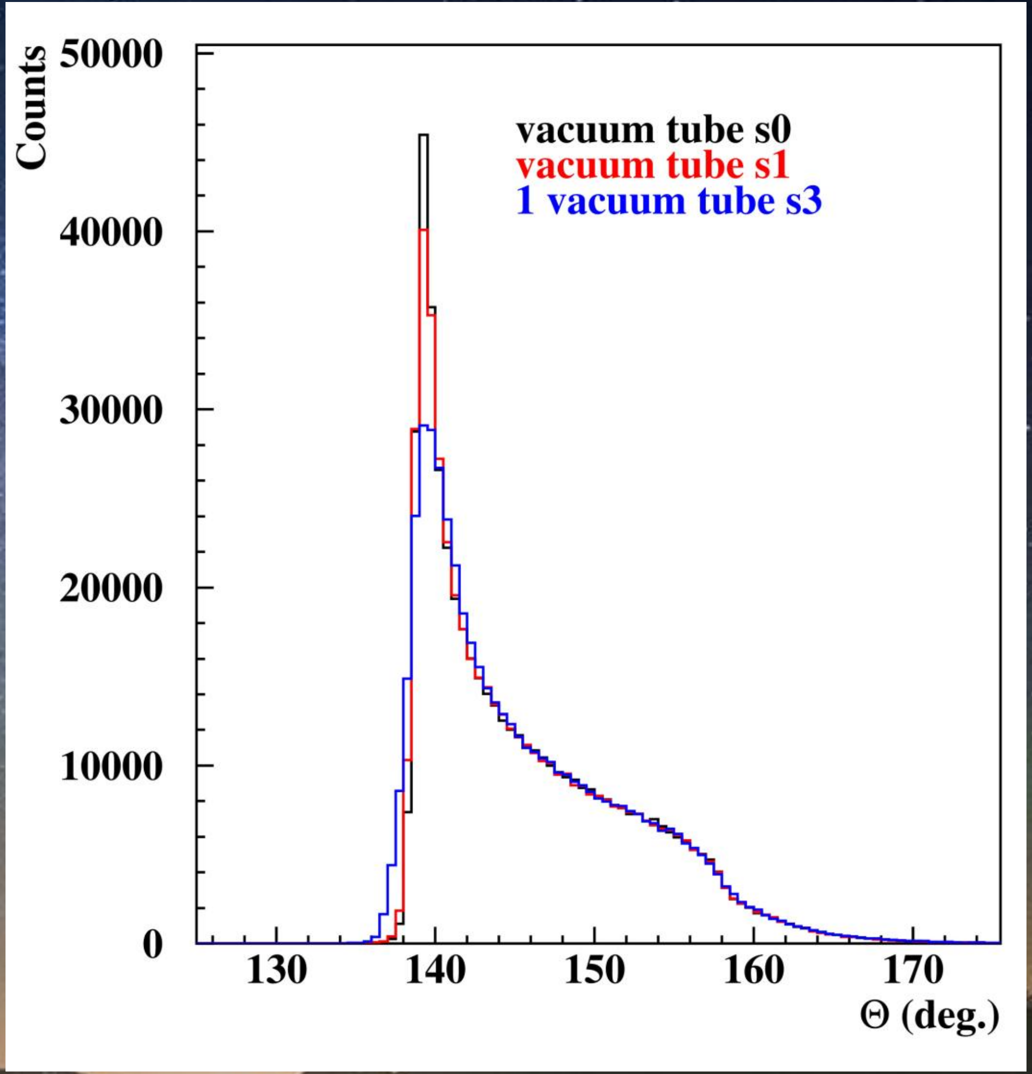
$$mc^2=\sqrt{(1-y^2)}E\sin(\Theta/2)$$

$$y=\frac{E_+ - E_-}{E_+ + E_-}$$

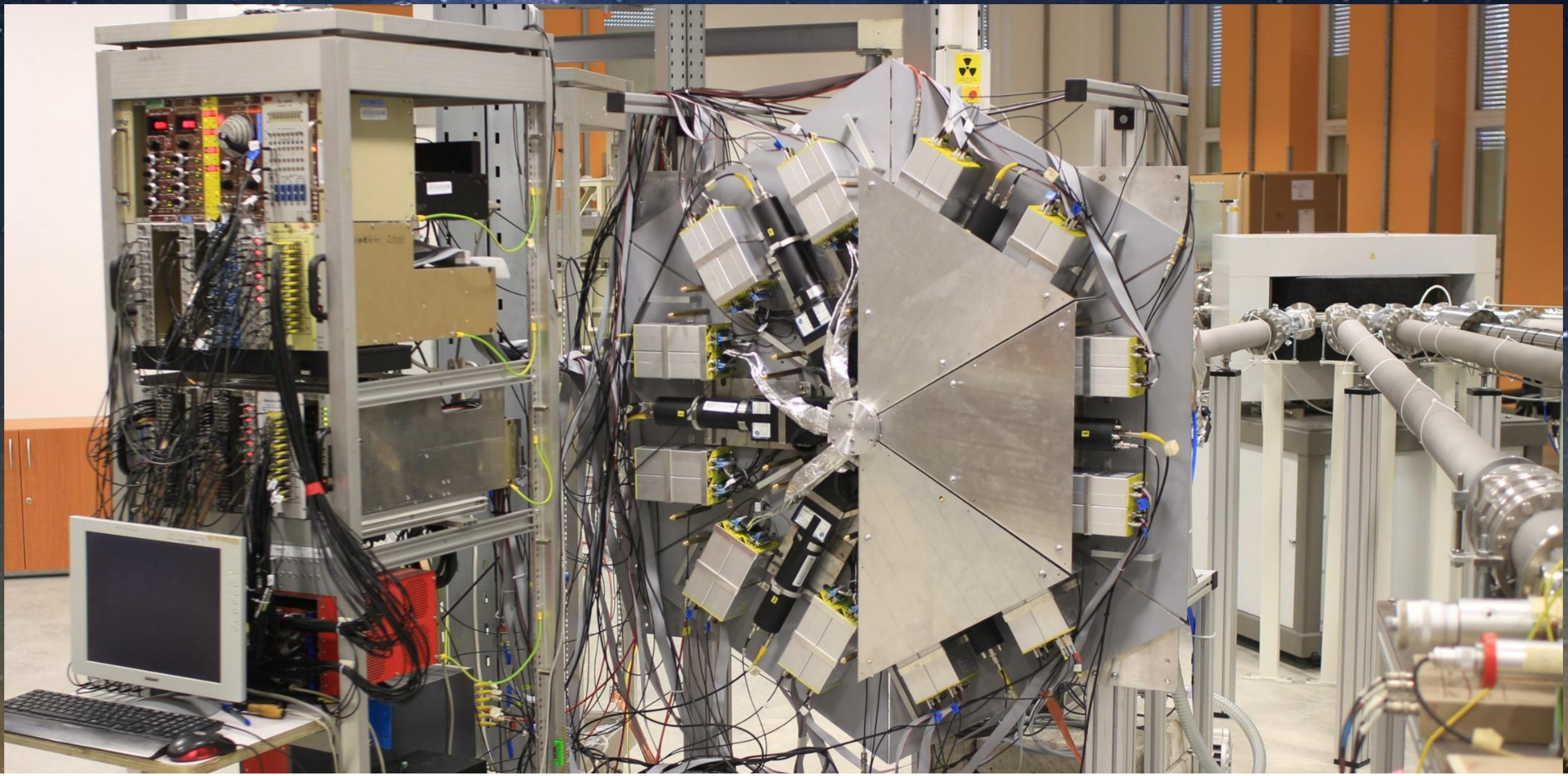
Since the sum of the kinetic energies (E), in our case the energy of the nuclear transition, is precisely known, the accuracy of the mass determination primarily depends on the accuracy of the angle measurement. Using state-of-the-art Double-sided Silicon Strip Detectors (DSSDs), allowing us to better track the particles and to increase the angular resolution of the spectrometer.

From bump to saw-tooth





The newest version of our COmpact Positron Electron (COPE) spectrometer with two DSSD layers at each telescopes (NIM 1084, 171232 (2026))

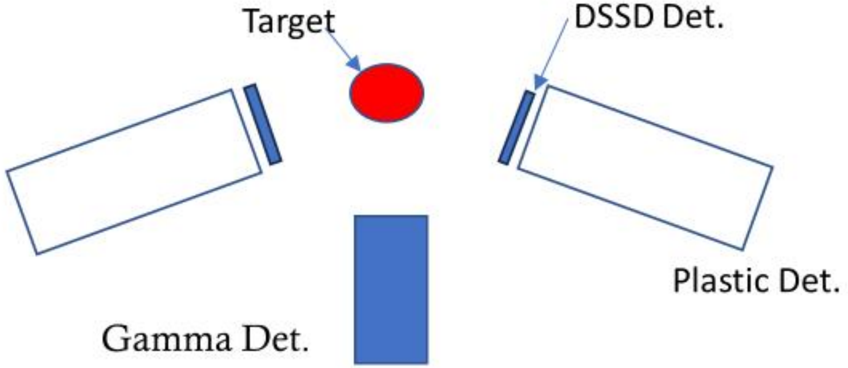


Using such a spectrometer we want to cope with the questions connected to the X17 particle

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

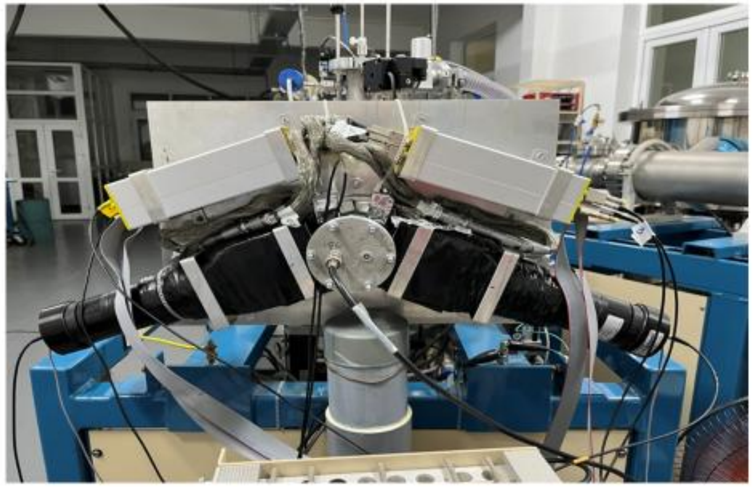
We used p-beam with different energies to bombard the Li-target to populate 18.15 and 17.6 MeV ^{8}Be excited states with resonant proton capture.

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



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

Why did we arrange the Det-system like this?

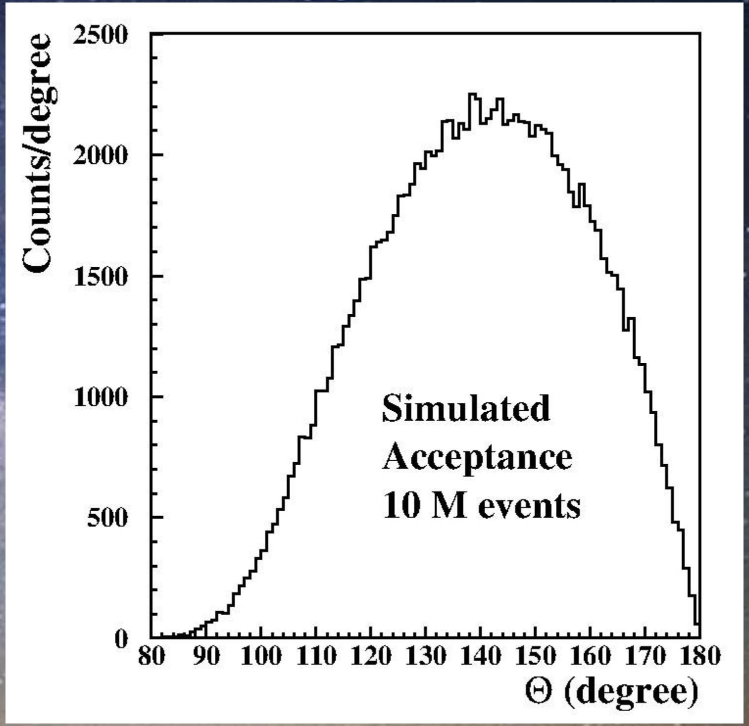


Picture in lab of the detector system and the DAQ connected to Pelletron

Experiment Setup

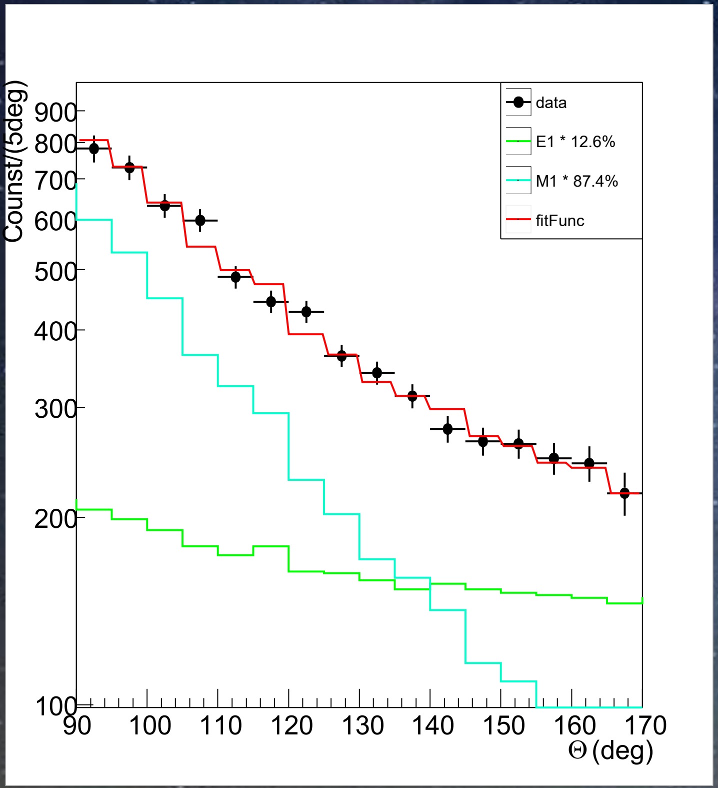
The idea of the new e^+e^- spectrometer with two arms

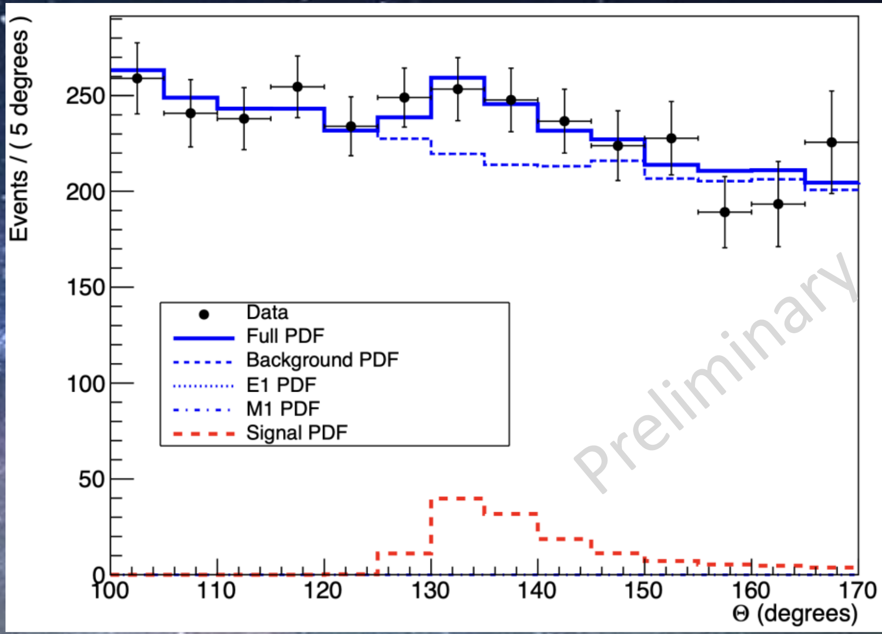
- Concentrate on the 140 degree region.
- Put the detectors closer to the target 30 mm than they were used in Debrecen (60 mm).
- We can have similar acceptance at 140 degree in this way for the two cases.



The simulation curve of acceptation before making setup

Aceptance corrected angular correlations





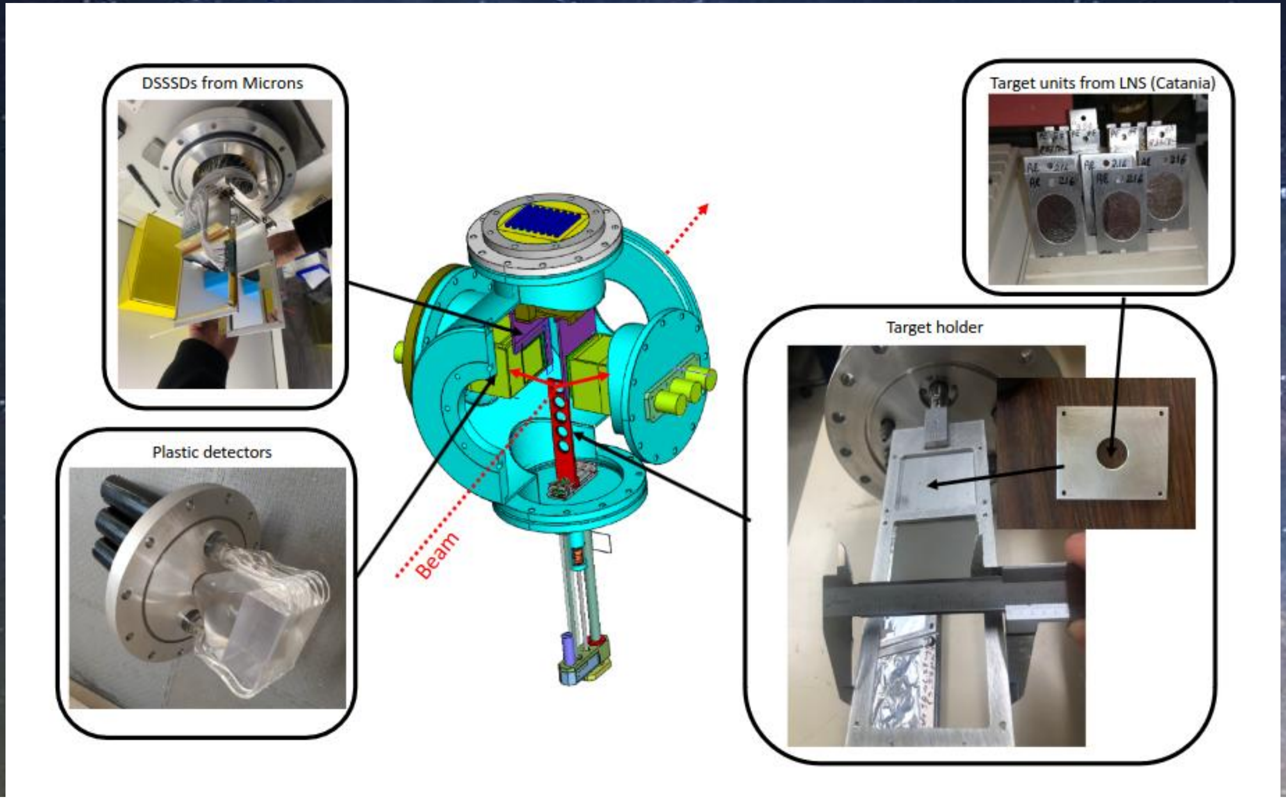
E_p=1.04 MeV. Background: M1+E1
The anomaly appears at angle around 140º (*)

E_p=441 keV
No anomaly

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

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

The New JEDI (Judicious Experiments for Dark sectors Investigations) project (GANIL, France)



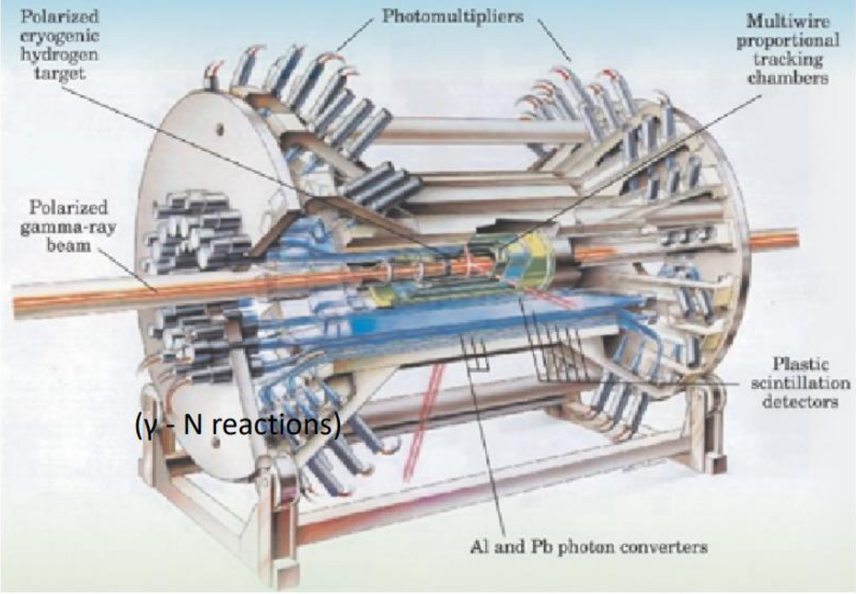
The two set of Double-Sided Silicon Strips Detectors (DSSSDs) of the New JEDI setup provides energy losses and angles of the detected electrons and positrons. In addition, the sets of plastic detectors with SiPM readout is used to measure the residual energy of electrons and positrons.

We plan to develop a long-term research program in the MeV terra incognita mass range at the new SPIRAL2 facility, that will deliver unique high-intensity beams of light, heavy-ions and neutrons in Europe.

In practice, three experiments using the New JEDI setup concerning the existence of the X17 Dark Boson are envisaged…

The Montreal X-17 Project

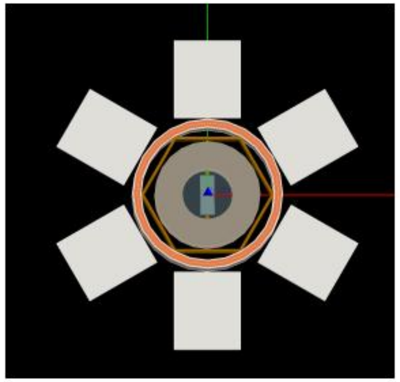
- Use parts of the DAPHNE experiment (Saclay/Mainz*)
- Tracking MWPC chamber & 16 scintillators (NE102A)
- Scints & MWPC from U. Mainz → now @ Montreal
- Phototubes and some ADC/TDC's borrowed from TRIUMF

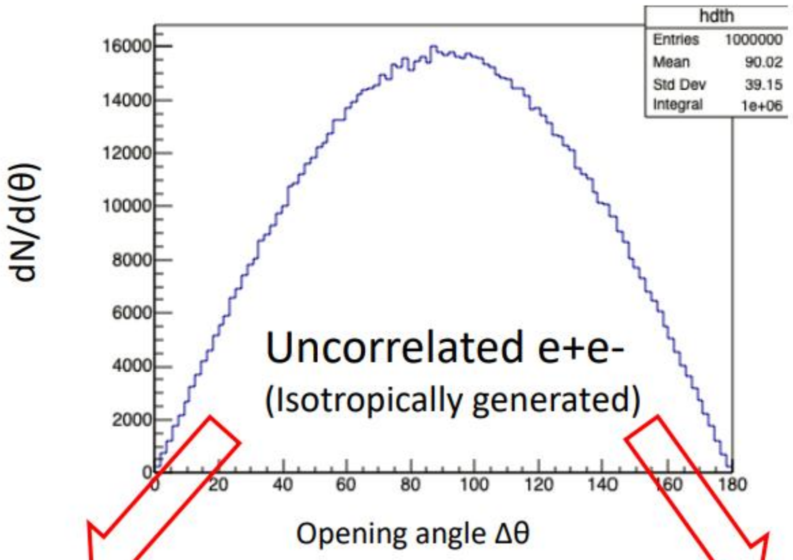


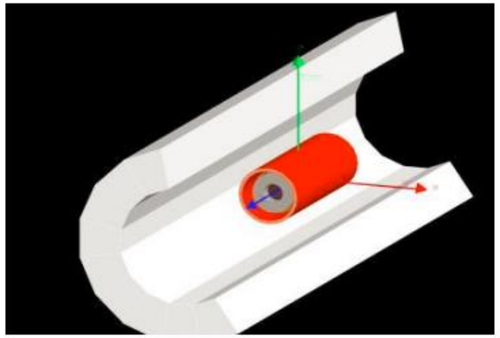
Large solid angle coverage → 0.95 x 4π

*Many thanks to L. Doria & U. Mainz!

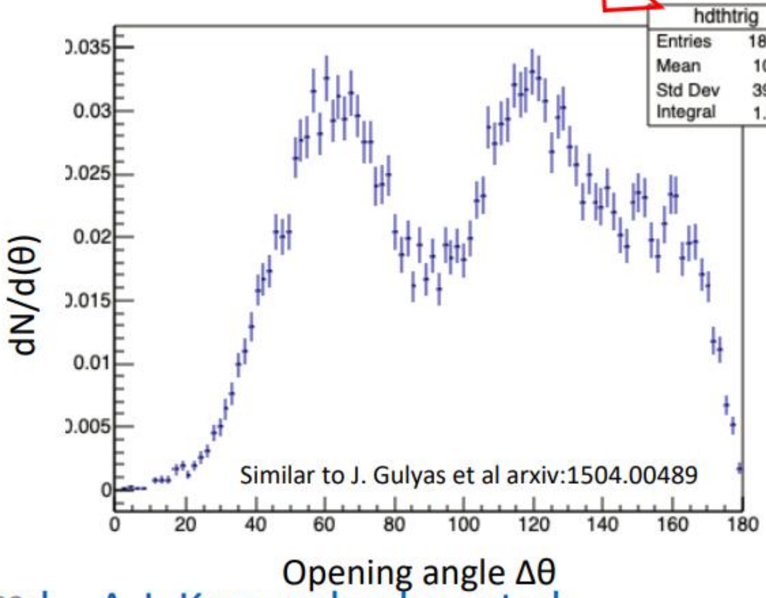
Geant4 Simulation: Acceptances



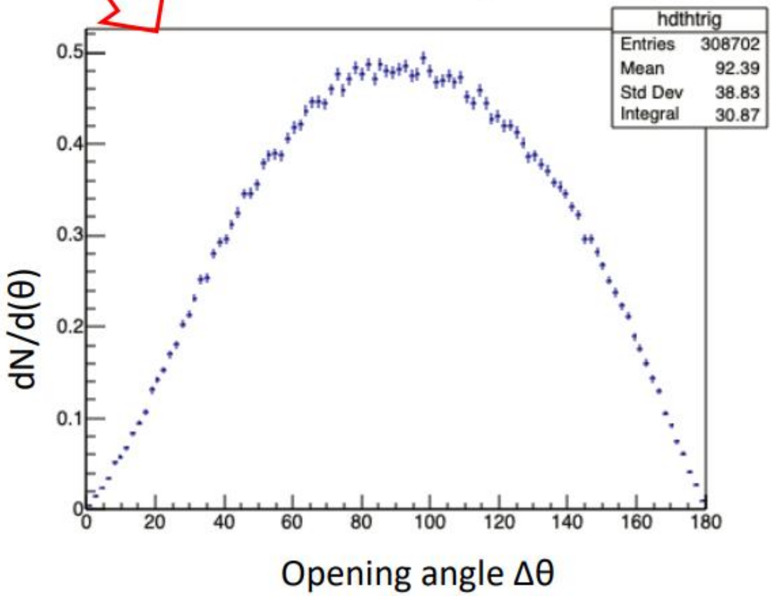




ATOMKI geometry



Montreal geometry



Gulyás J, et al. , A.J. Krasznahorkay et al.

To ^{8}Be continued...
Thank you very much for your attention!

Acknowledgements: M. Begala, S. Czellár, M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi, T.J. Ketel, A. Krakó, A. Krasznahorkay, I. Kuti, J. Molnár, B.M. Nyakó, N. Sas, L. Stuhl, J. Timár, T. Tornyi, Zs. Vajta, Z. Pitye