On a new light-particle candidate observed in high-energy nuclear transitions

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Searching for new particles created in nuclear transitions has a very long history…

- The axion particle was proposed by Weinberg and by Wilczek (1978) as one mechanism for preserving CP invariance of strong interactions.
- The search for axions in nuclear transitions culminated in 1982.

- It turned out that nuclear transitions provide a useful laboratory to search for light particles which couple to quarks and/or gluons. The spin and parity of a particle emitted in nuclear decay can be constrained by an appropriate choice of the nuclear transition.
- The atomic nucleus can be considered as a femto-laboratory including probably all of the interactions in Nature. A real discovery machine like LHC, but at low energy.

- A new impetus was given to this research by the observation of narrow peaks observed in the spectra of positrons emitted in heavy-ion collisions (J. Schweppe et al., Phys. Rev. Lett. 51, 2261 (1983)).
- Unfortunately, the new 1.7 MeV particle was ruled out very fast [M.J. Savage et al., PRL 57 178 (1986)].
- Fokke de Boer et al., published anomalous internal pair conversion in ^{8}Be caused by a new particle with mass of about 9 MeV still in 2001, but their experimental results were not very convincing.
- No experimental searches were performed above 10 MeV/c^2, and then gave up.

https://aps.altmetric.com/details/3886365

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

SUMMARY | News | Blogs | Twitter | Facebook

Title	Observation of Anomalous Internal Pair Creation in <span class
Published in	Physical Review Letters, January 2016
DOI	10.1103/physrevlett.116.042501
Pubmed ID	26871324
Authors	A. J. Krasznahorkay, M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi, T. J. Ket
Abstract	Electron-positron angular correlations were measured for the isovector magne (J^{... [show]

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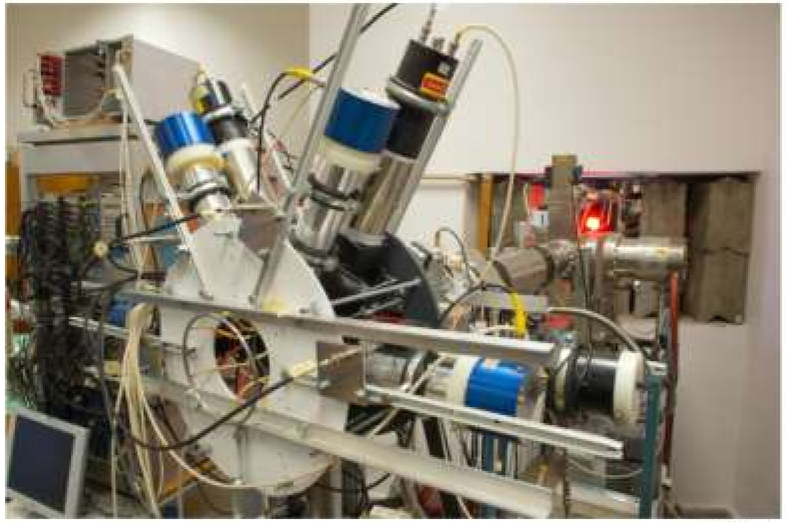
NATURE | NEWS

Has a Hungarian physics lab found a fifth force of nature?

Radioactive decay anomaly could imply a new fundamental force, theorists say.

Edwin Cartlidge

25 May 2016



MTA-Atomki

Physicists at the Institute for Nuclear Research in Debrecen, Hungary, say this apparatus — an electron-positron spectrometer — has found evidence for a new particle.

Print

A laboratory experiment in Hungary has spotted an anomaly in radioactive decay that could be the signature of a previously unknown fifth fundamental force of nature, physicists say – if the finding holds up.

Attila Krasznahorkay at the Hungarian Academy of Sciences's Institute for Nuclear Research in Debrecen, Hungary, and his colleagues reported their surprising result in 2015 on the arXiv preprint server, and this January in the journal *Physical Review Letters*[1]. But the report – which posited the existence of a new, light boson only 34 times heavier than the electron – was largely overlooked.

Then, on 25 April, a group of US theoretical physicists brought the finding to wider attention by publishing its own analysis of the result on arXiv[2]. The theorists showed that the data didn't conflict with any previous experiments – and concluded that it could be evidence for a fifth fundamental force. "We brought it out from relative obscurity," says Jonathan Feng, at the University of California, Irvine, the lead author of the arXiv report.

Four days later, two of Feng's colleagues discussed the finding at a workshop at the SLAC National Accelerator Laboratory in

Dark matter may feel a "dark force" that the ...st of the Universe ...es not

Evidence for a Protophobic Fifth Force from ^{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]

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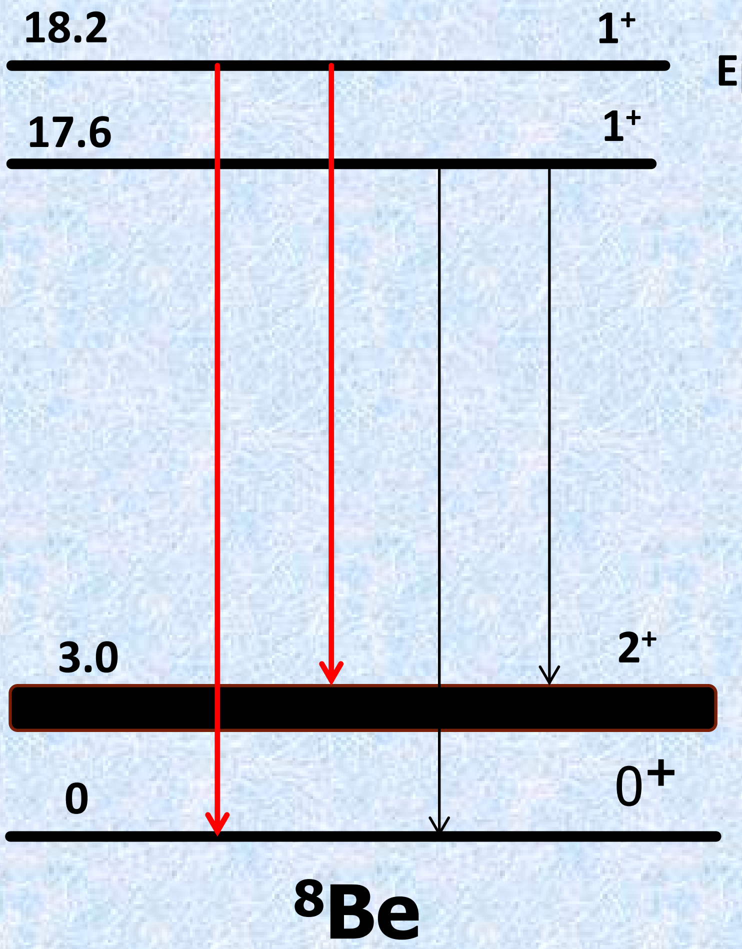
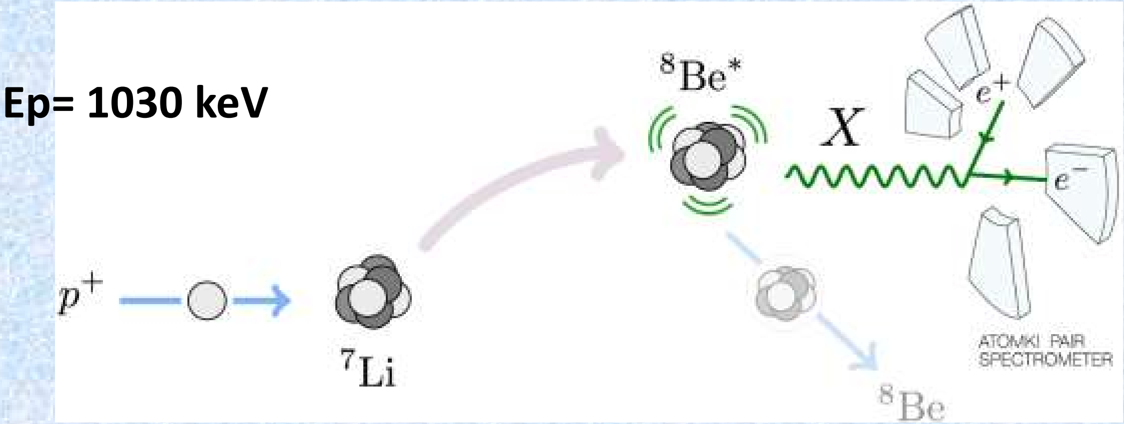
Department of Ph... ...cky 40506-0055 US

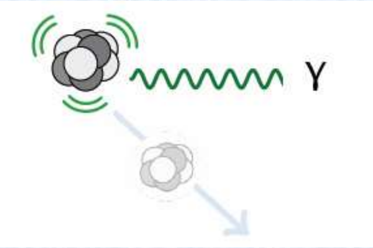
Phys. Rev. Lett. 117, 071803

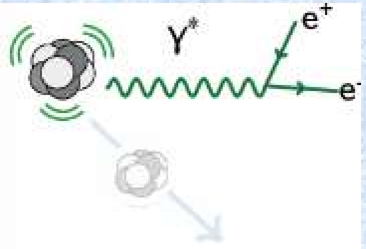
The Atomki anomaly → signals for a new 17 MeV boson → gauge boson of a new fundamental force of nature

The creation and decay of ^{8}Be*





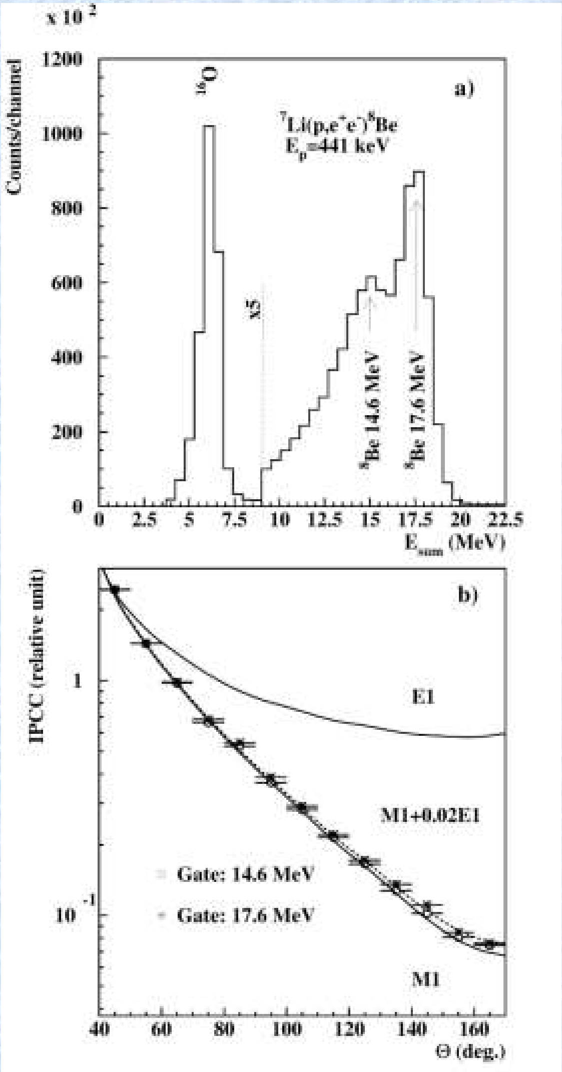


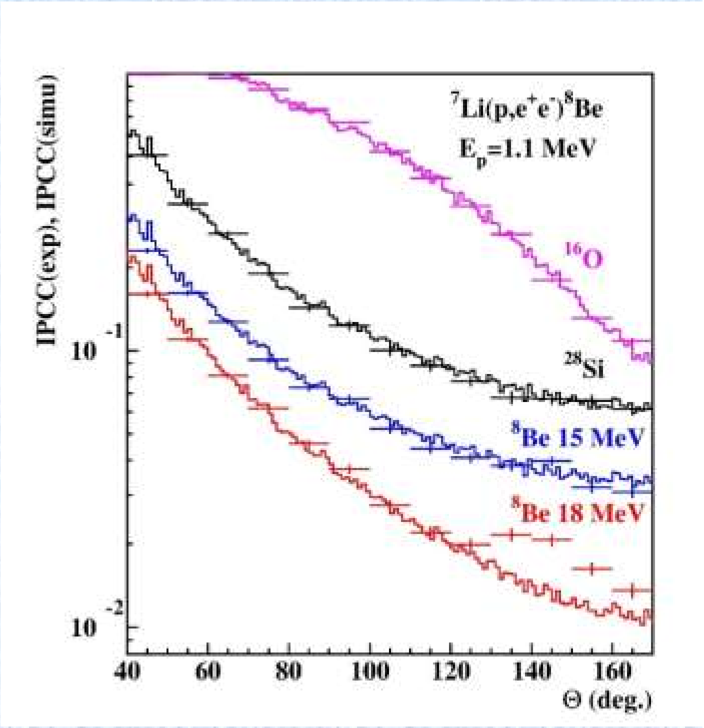


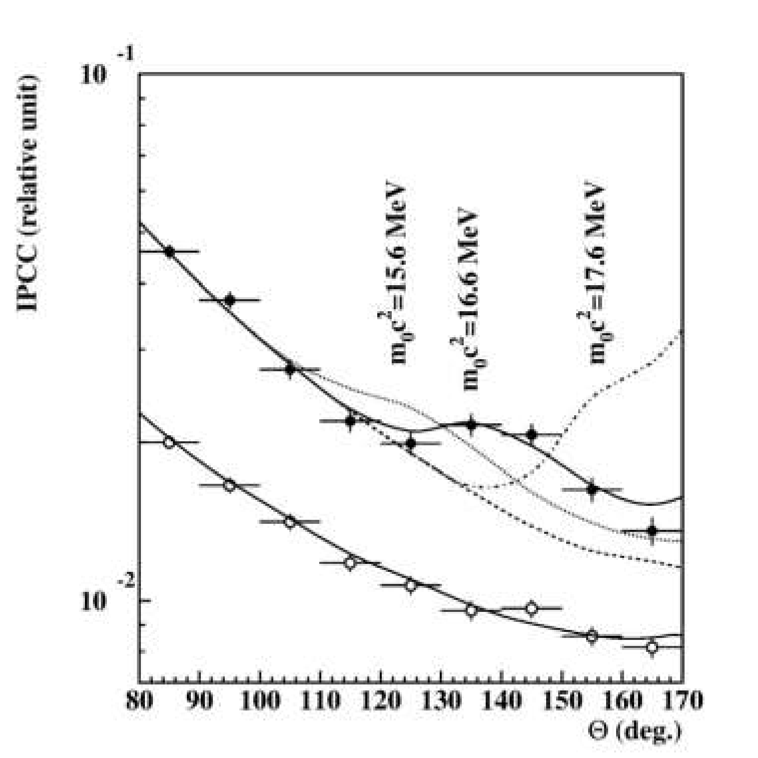
- Proton decay: B(p + ^{7}Li) ≈ 100%
- γ-decay: B(^{8}Be + γ) ≈ 1.5 x 10^{-5}
- Internal pair creation: B(^{8}Be + e^{+} e^{-}) ≈ 5.5 x 10^{-8}
- Ejection of a new particle: B(^{8}Be + X) ≈ 5.5 x 10^{-10}
- Building the most efficient $e^{+}e^{-}$ spectrometer in the world (NIM, A808 (2016) 21)

Results

e^+ - e^- sum energy spectra and angular correlations

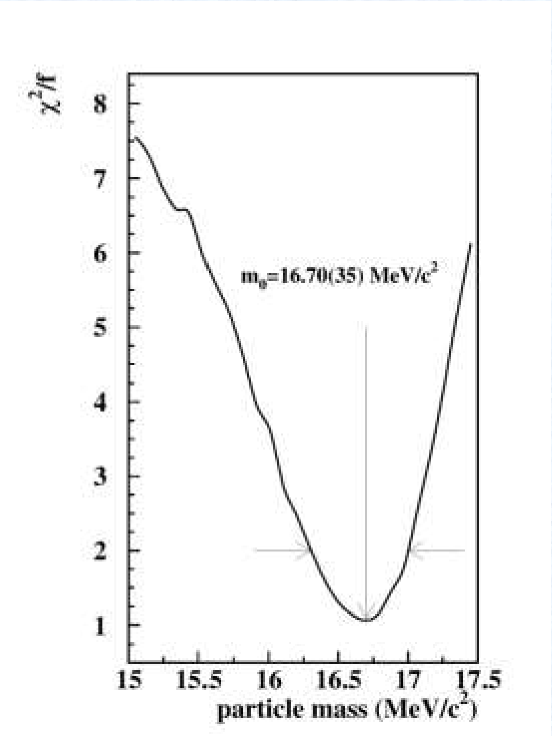






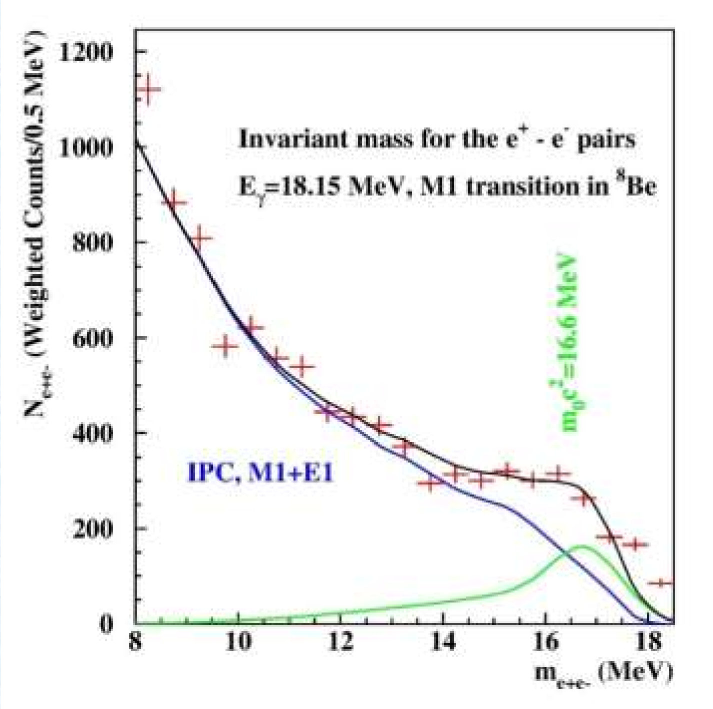
Experimental angular e^+e^- pair correlations measured in the ^{7}Li(p,e^+e^-) reaction at E_p=1.10 MeV with -0.5< y <0.5 (closed circles) and |y|>0.5 (open circles), where y=(E1-E2)/(E1+E2).

Determination of the mass of the new particle



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

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

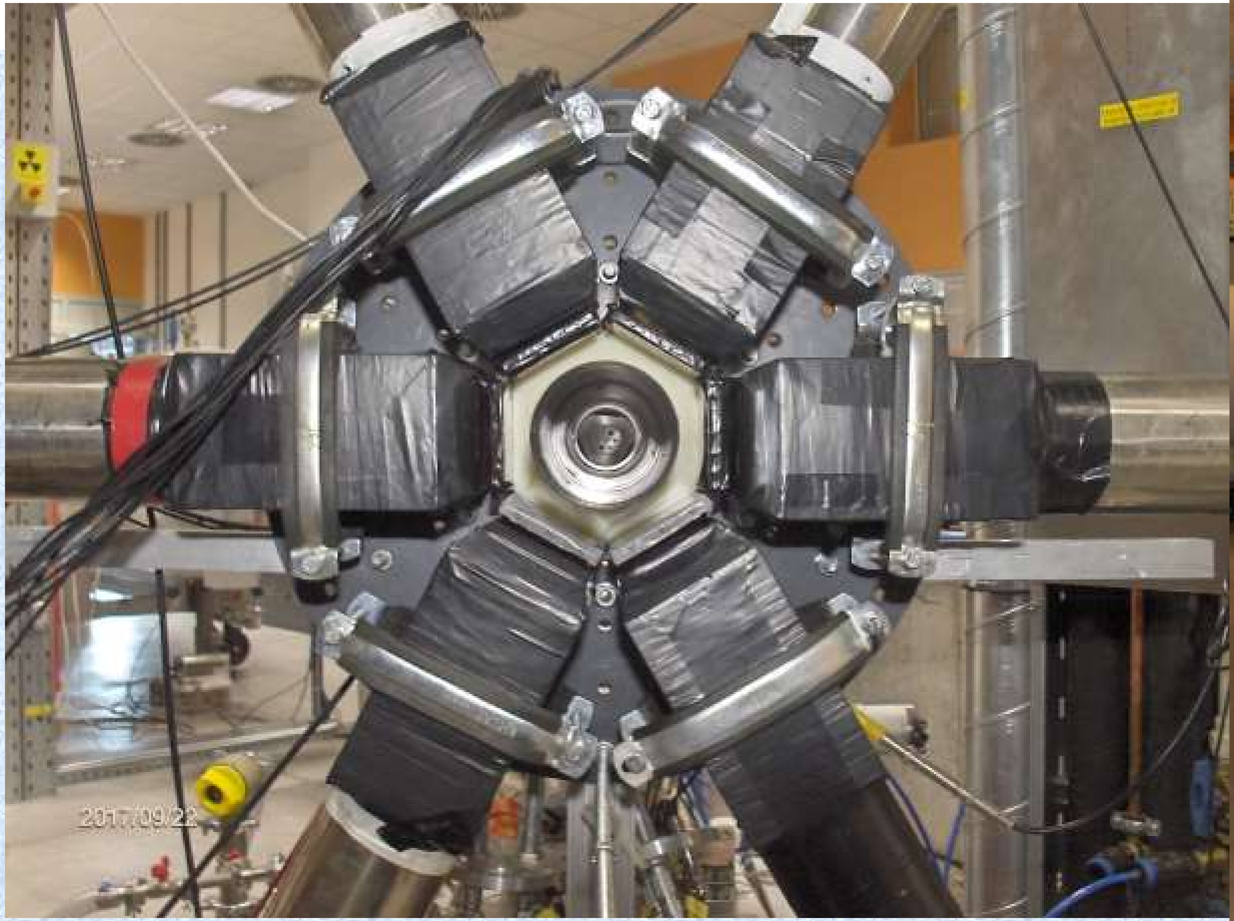


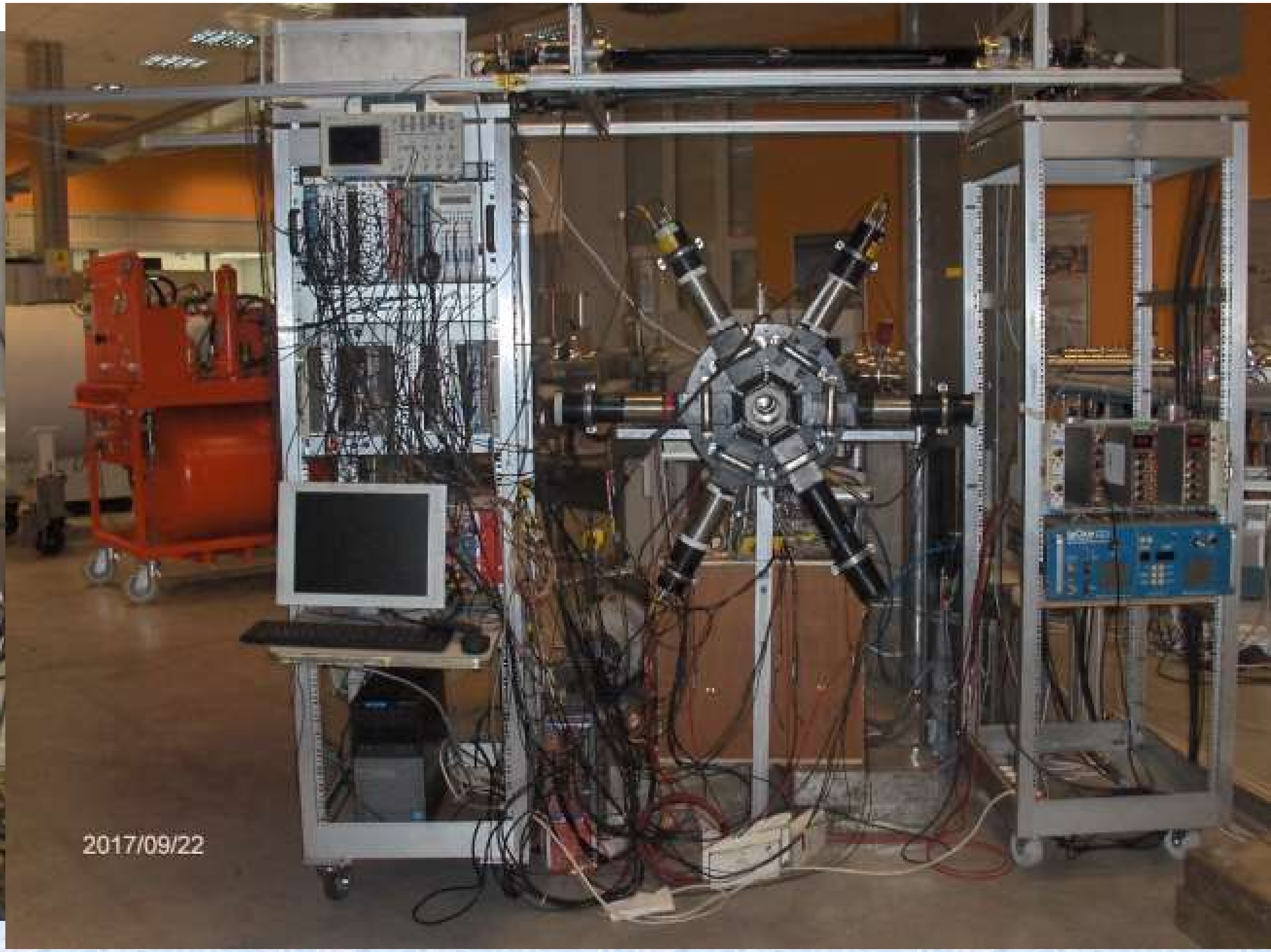
Fitting the angular correlations by the X^2/f method.

Invariant mass distribution plot for the electron-positron pairs

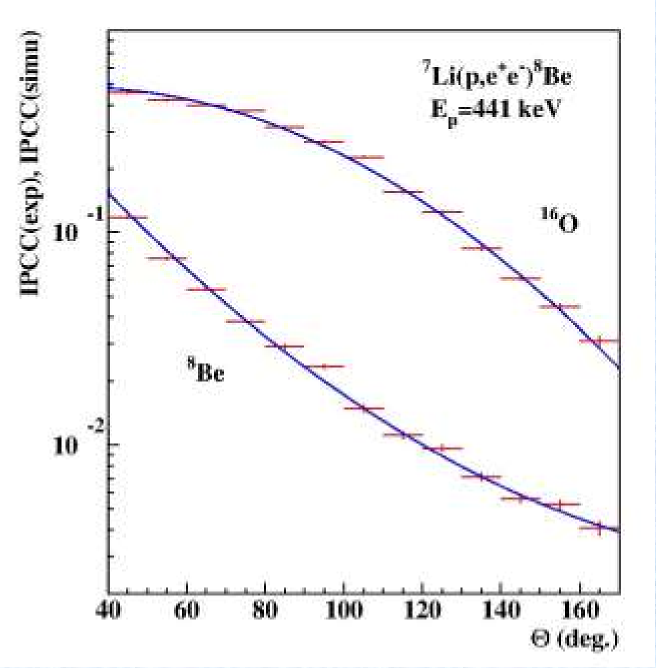
Repeating the experiments at a new Medium-Current Tandetron Accelerator System in Atomki Debrecen

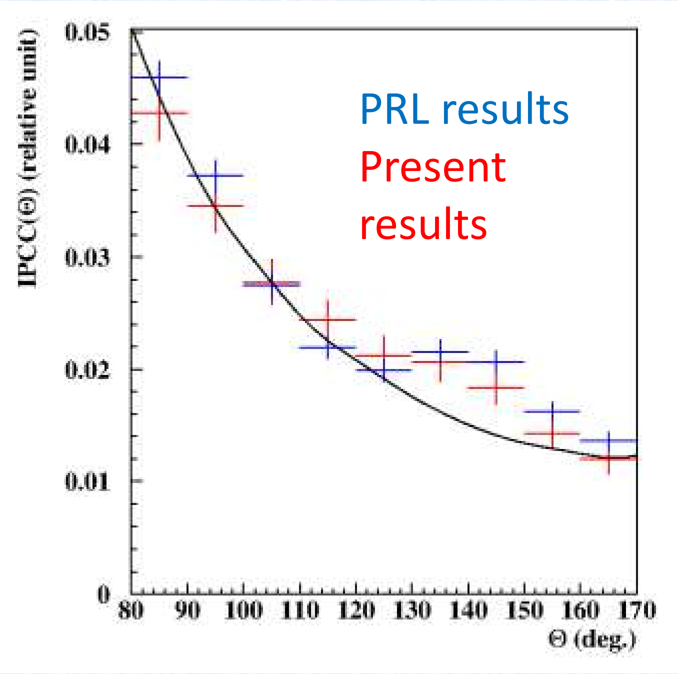
The new e^+e^- pair spectrometer with six telescopes equipped with Si DSSD's, new electronics and new VME data acquisition system.





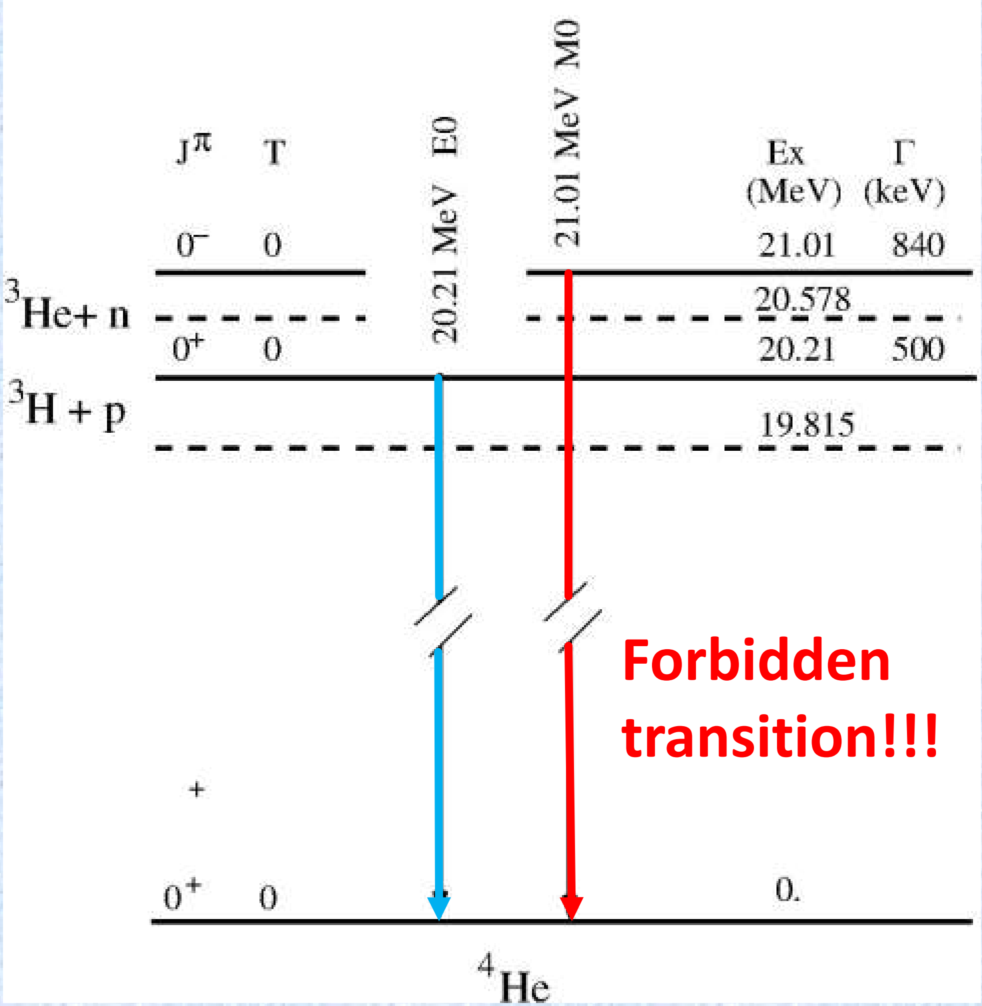
Recent results for the 17.6 and 18.15 MeV transitions in ^8Be

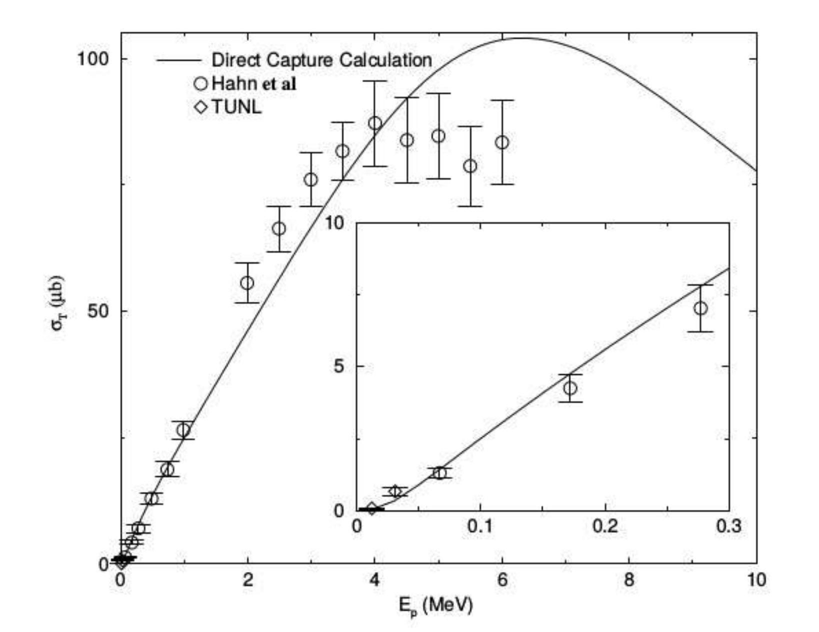




	Exp1	Exp2	Average
$m_0c^2(MeV)$	16.86(6)	17.17(7)	17.01(16)
B_x	$6.8(10) \times 10^{-6}$	$4.7(21) \times 10^{-6}$	$6(1) \times 10^{-6}$
Significance	7.37σ	4.90σ	

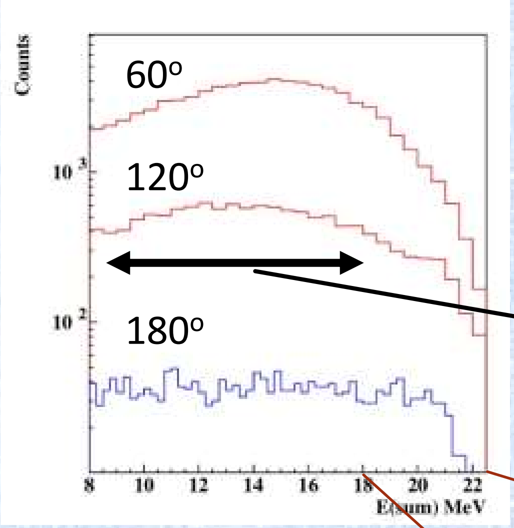
Study of the 21 MeV M0 transition in ^{4}He excited by ^{3}H+p, and ^{3}He+n reactions



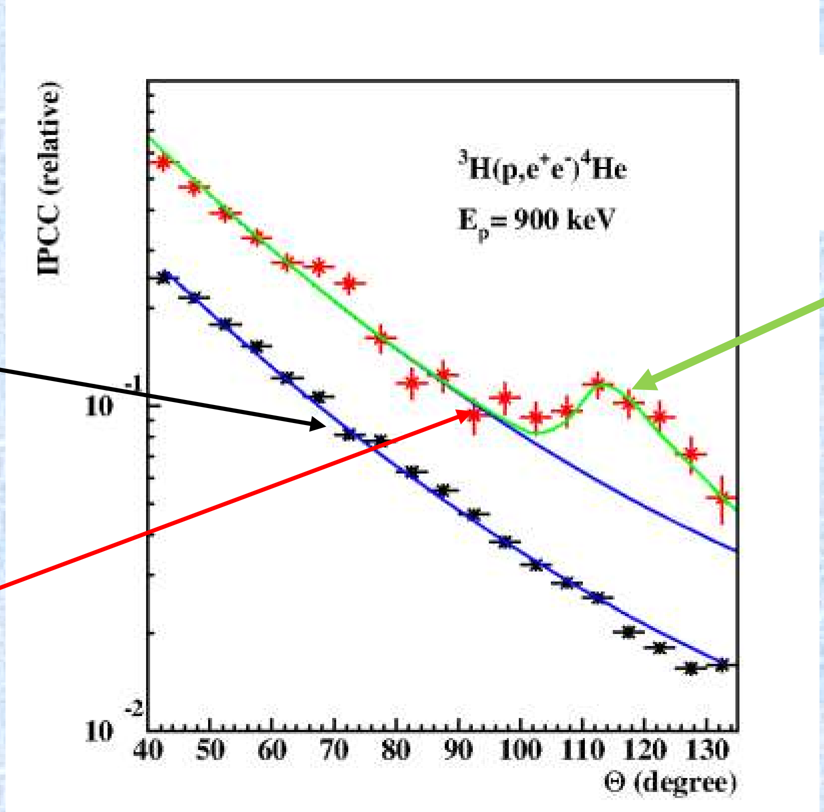


γ-ray production with direct proton capture. The main source of background produced by external pair creation on the backing of the target and on the other surrounding materials. **GEANT simulations.**

Results for the e^+e^- decay measured in Debrecen



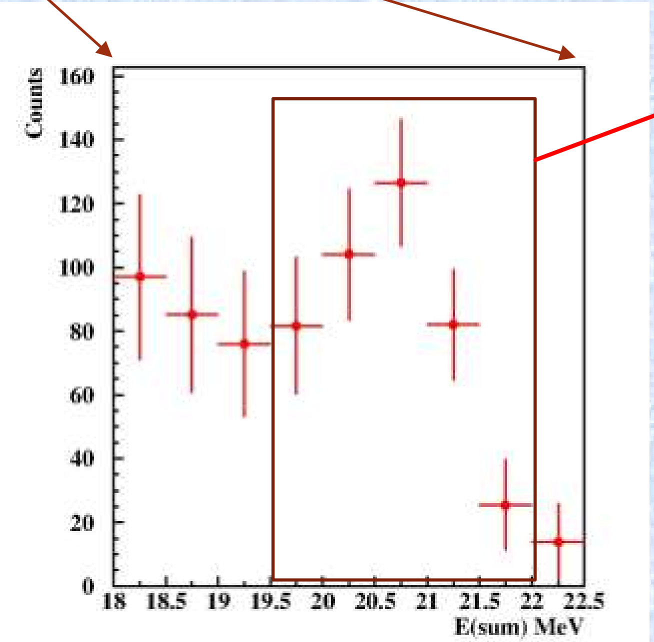
Measured e^+e^- sum-energy spectra for different detector combinations.



Simulation for m_0c^2= 17.0 MeV

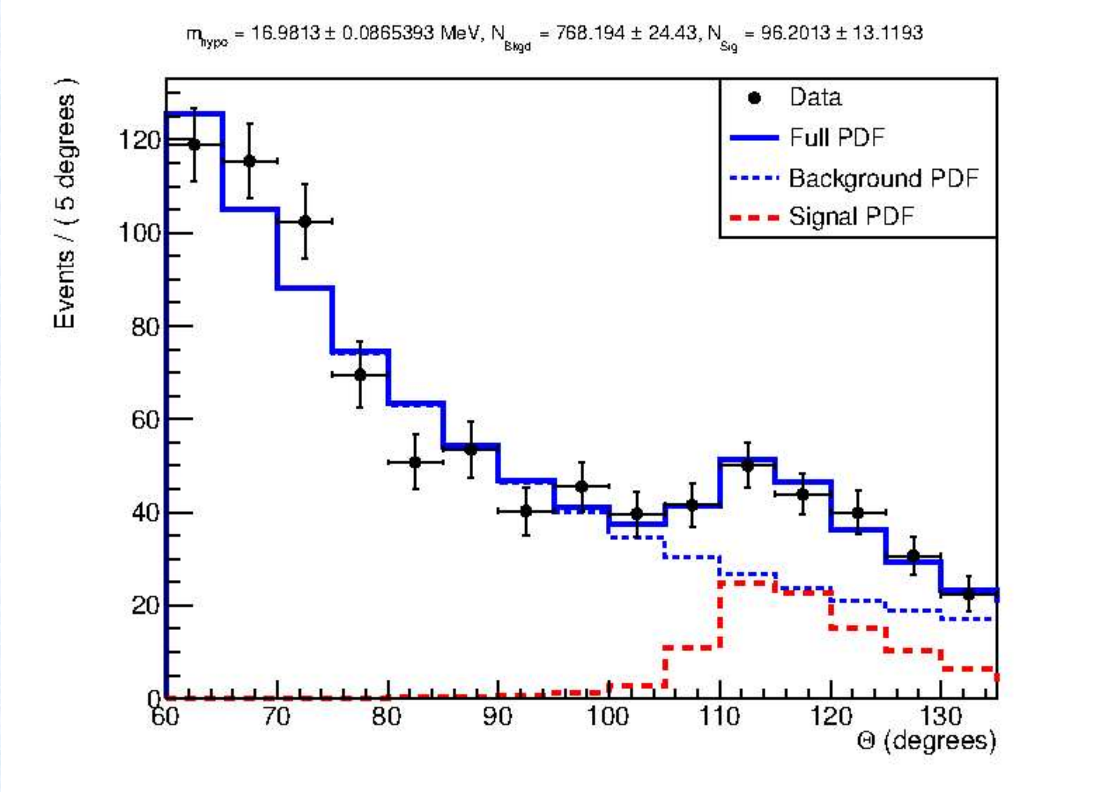
Significance: 7.6 σ

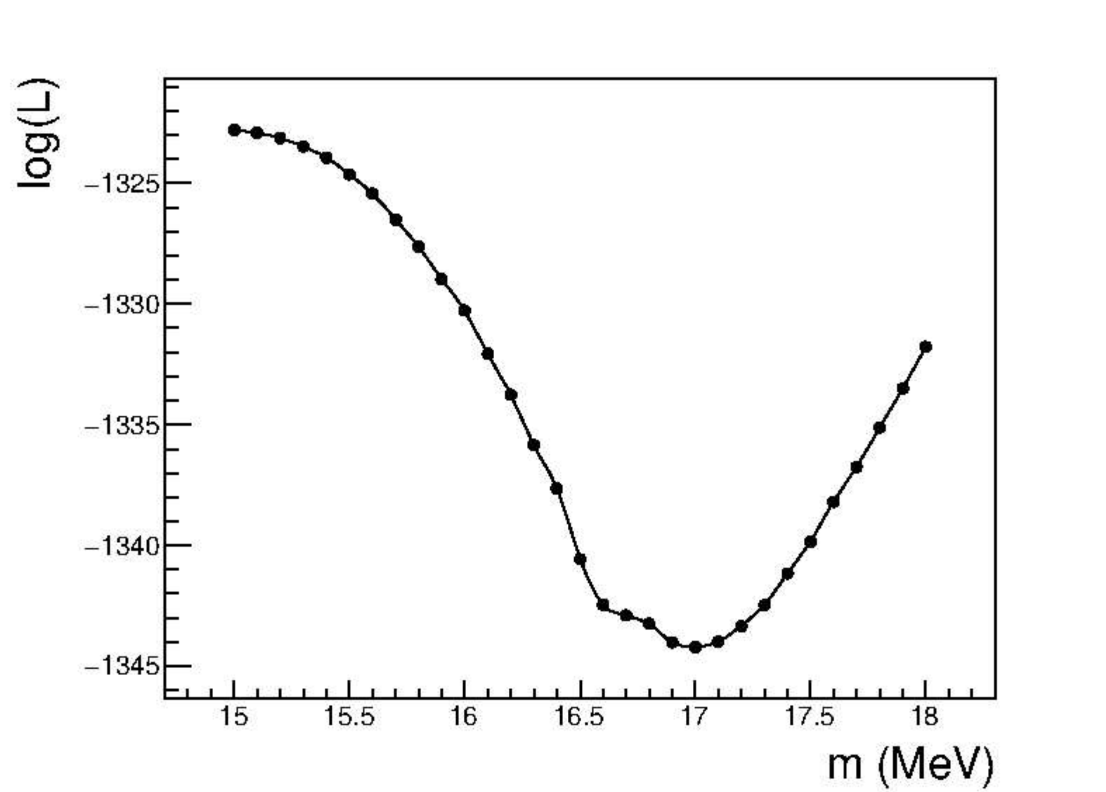
Difference between spectra measured at 120° and 60°.



Measured (gated) e^+e^- pair correlation for the full energy pairs.

Details of the fit performed by RooFit

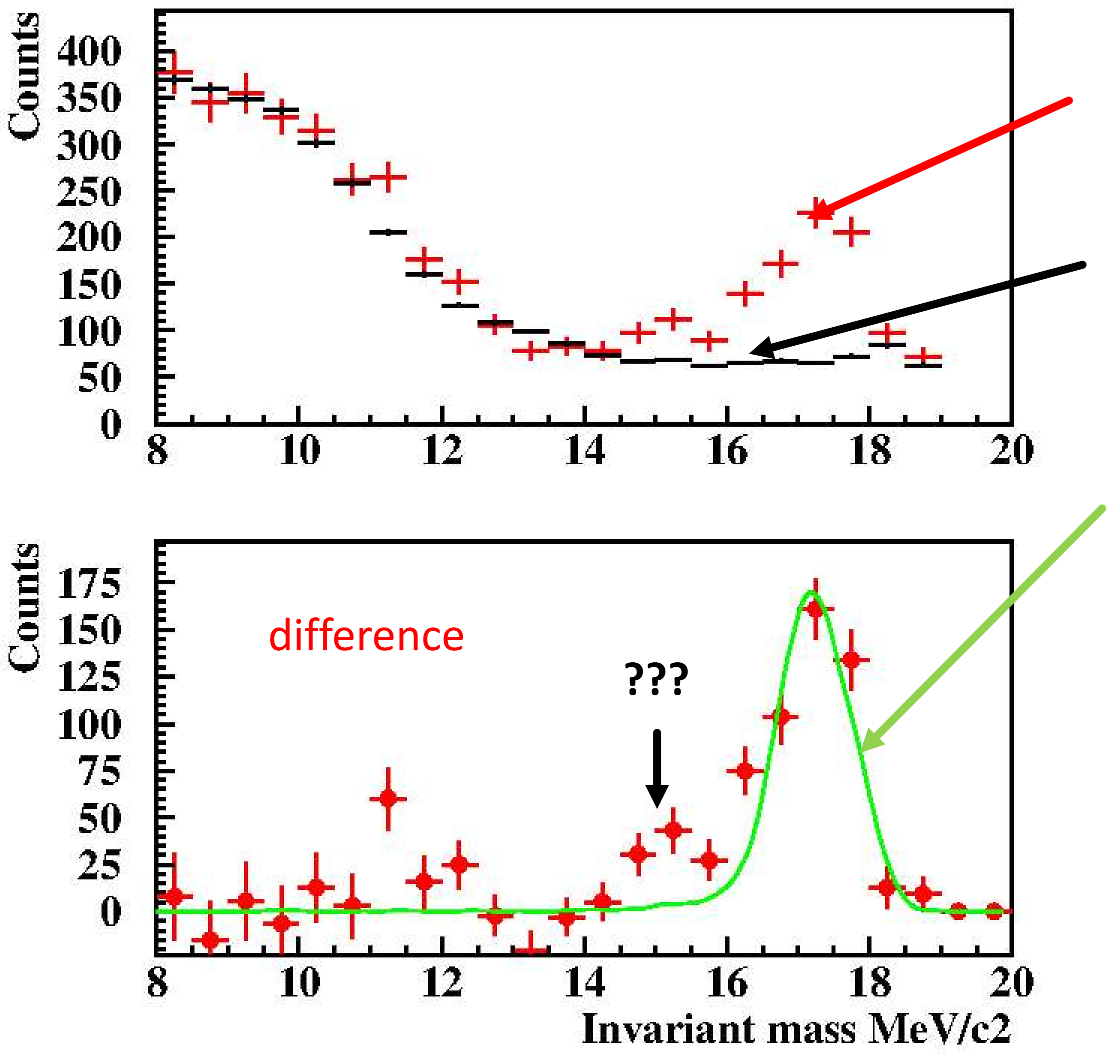




Invariant mass distribution

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

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



Gated invariant mass distr. for full energy pairs.

Gated invariant mass distr. for external pairs.

Simulated result for m_0c^2= 17.0 MeV

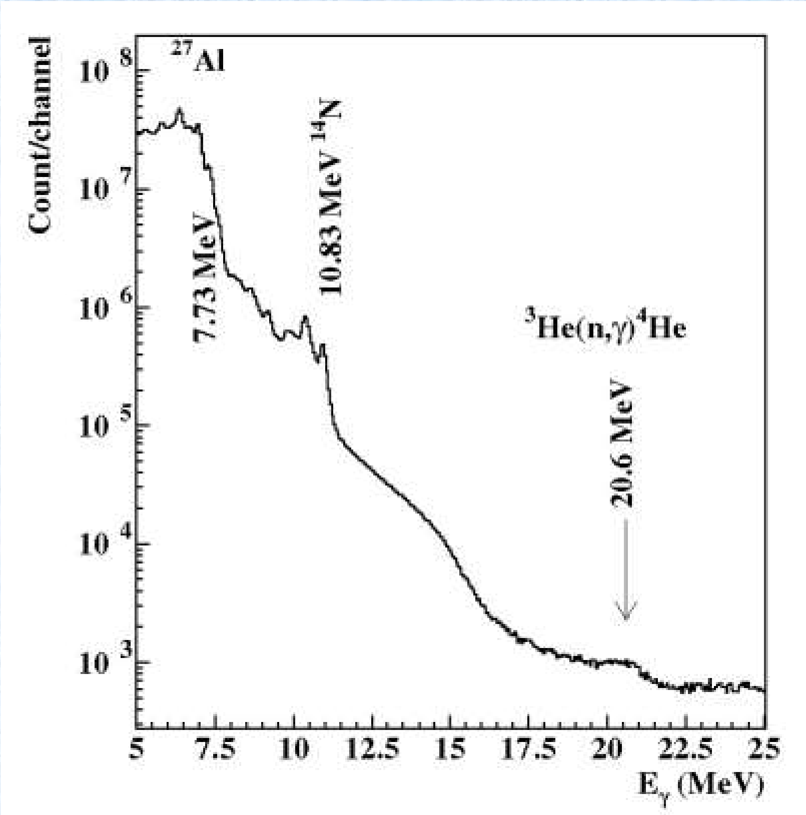
Study the γγ-decay of X(17) in ^{4}He

- Vector particle (1^{+}) or axialvector (0^{-})?
- If vector particle then γγ emission is forbidden (Landau-Yang theorem).
- If axialvector then it can decay by γγ emission.
- γγ-decay only known in a special case: $0^{+} \rightarrow 0^{+}$ (^{90}Zr, ^{40}Ca, ^{16}O) ^{4}He
- J. Schirmer et al., PRL 53, 1897 (1984)
- J. Kramp et al., NPA 474, 412 (1987)
- Walz, N. Pietrala et al., Competitive Double-Gamma' (γγ/γ) Decay *Nature* **526**, 406 (2015)

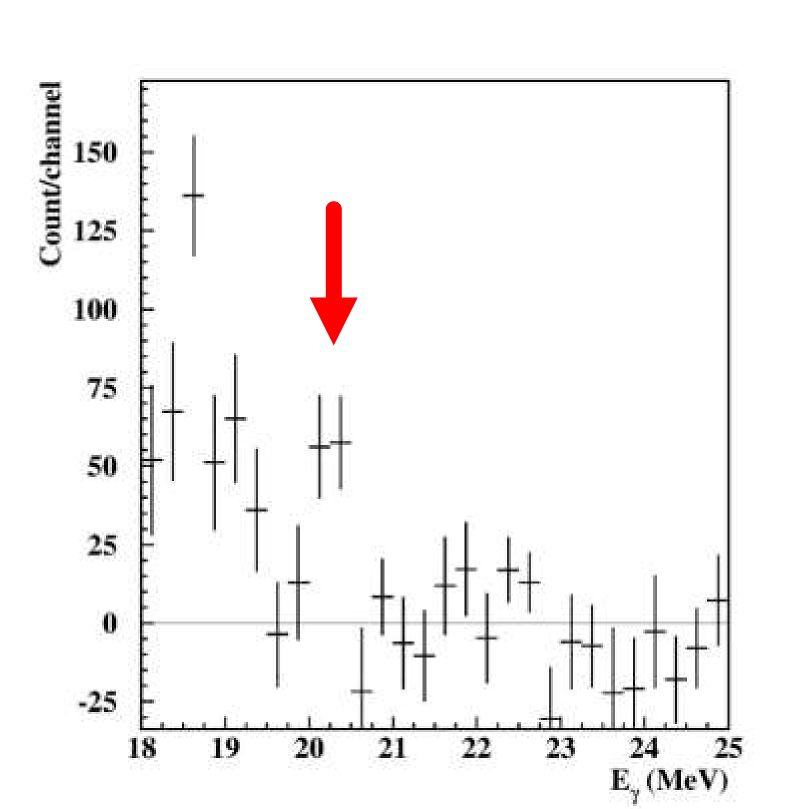
$$\cos(\Theta) = 1 - \frac{m_x^2}{2E_1E_2}$$

Study the angular correlation with big, state of the art $LaBr_3$ detectors.

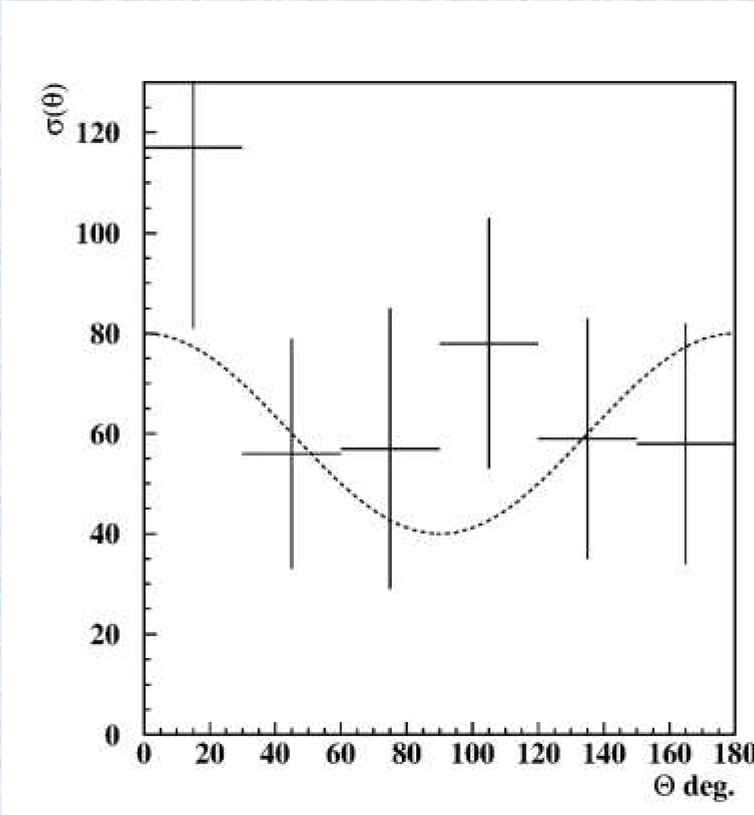
The first results obtained in Garching



A typical singles γ-ray spectrum



Typical sum-energy spectra for coincident detectors



Preliminary γγ-angular correlation

Conclusion

- The ^{8}Be anomaly has been 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 effect of X(17) was observed also in ^{4}He in a 20.6 MeV $0^- \rightarrow 0^+$ transition at a correspondingly smaller angle. The significance of the peak was 7.6 σ.
- The $\gamma\gamma$-decay of X17 was also studied. The expected branching ratio is about 100 times less compared to the e+e- decay. We are planning further experiments with much higher beam current.

Thank you very much for your attention