New results supporting the existence of the X17 particle

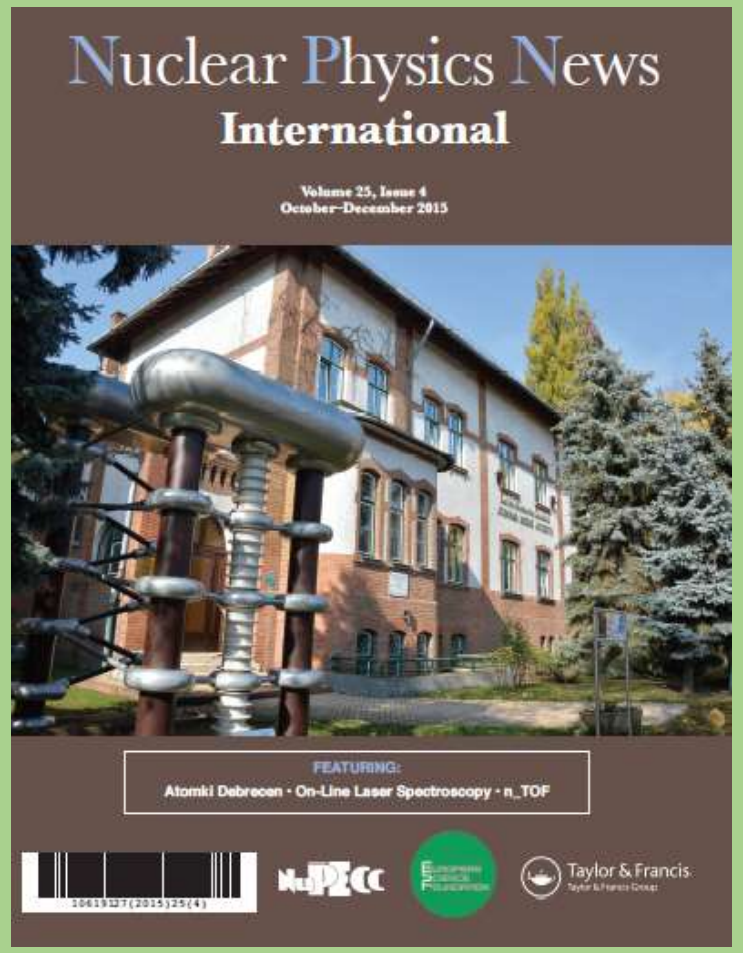
Attila J. Krasznahorkay

Inst. of Nucl. Res. (Atomki)

In the downtown of Debrecen.

www.atomki.hu

http://www.nupecc.org/npn/npn254.pdf



Accelerator	Energy (proton)	Particle	Start	Source
VdG-1	0.1 – 1.0 MeV	H, D, He	1970	homemade
VdG-5	0.6 – 5.0 MeV	H, D, He, C, N, O, Ne	1971	homemade
Cyclotron	5 – 20 MeV	H, D, He	1985	purchased
ECR ion source	50 eV - 30 KeV	H to Pb, molecules	1996	homemade
Isotope separator	50 eV – 50 KeV	He, Ne, Ar, N, S, Se	2009	homemade
AMS	*200 KeV (C^-)*	*C^-*	*2011*	*purchased*
Tandetron	0.2 - 4 MeV	H, C, O	2015	purchased

Leitmotif of my 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)

tric – Observation of Anomalous Internal Pair Creation in <span class - Mozilla Firefox

Phys. Rev. Lett. 116, 04 × | Altmetric – Observatio × | +

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

Observation of Anomalous Internal Pair Creation in

Overview of attention for article published in Physical Review Letters, January 2016

624

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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. Ketel, A...
Abstract	Electron-positron angular correlations were measured for the isovector magnetic dipo (J^{... [show]

TWITTER DEMOGRAPHICS | MENDELEY READERS

The data shown below were collected from the profiles of **89** tweeters who shared

about how the information was compiled.

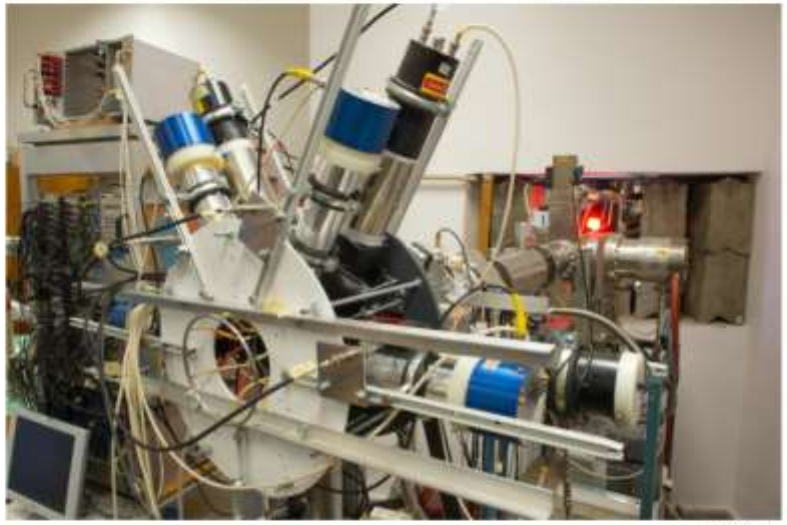
NATURE | NEWS

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

thinking about different ways to check it," he says. Groups in Europe and the United States say that they should be able to confirm or rebut the Hungarian experimental results within about a year.

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

Evidence for a Protophobic Fifth Force from ^{8}Be Nuclear Transitions

Jonathan L. Feng,[1] Bartosz Fornal,[1] Iftah Galon,[1] Su
Jordan Smolinsky,[1] Tim M. P. Tait,[1] and Phili
[1]*Department of Physics and Astronomy, University of California, Irvin*
[2]*Department of Physics and Astronomy, University of Kentucky, Lexing*

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

Phys. Rev. Lett. 117, 071803

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

SEARCHES FOR NEW PHYSICS | NEWS

Rekindled Atomki anomaly merits closer scrutiny

20 December 2019

Hunting down the X17 boson at the CERN SPS, NA64 collaboration (Submitted on 6 Sep 2020 to arXiv, last revised 8 Sep 2020)

Recently, the ATOMKI experiment has reported new evidence for the excess of $e+e-$ events with a mass ~17 MeV in the nuclear transitions of 4He, that they previously observed in measurements with 8Be. These observations could be explained by the existence of a new vector $X17$ boson. So far, the search for the decay $X17 \rightarrow e+e-$ with the NA64 experiment at the CERN SPS gave negative results. Here, we present a new technique that could be implemented in NA64 aiming to improve the sensitivity and to cover the remaining $X17$ parameter space. If a signal-like event is detected, an unambiguous observation is achieved by reconstructing the invariant mass of the $X17$ decay with the proposed method.

Is X17 a vector boson?

U Ellwanger, S Moretti - Journal of High Energy Physics, 2016

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

J Kozaczuk, DE Morrissey, SR Stroberg - Physical Review D, 2017

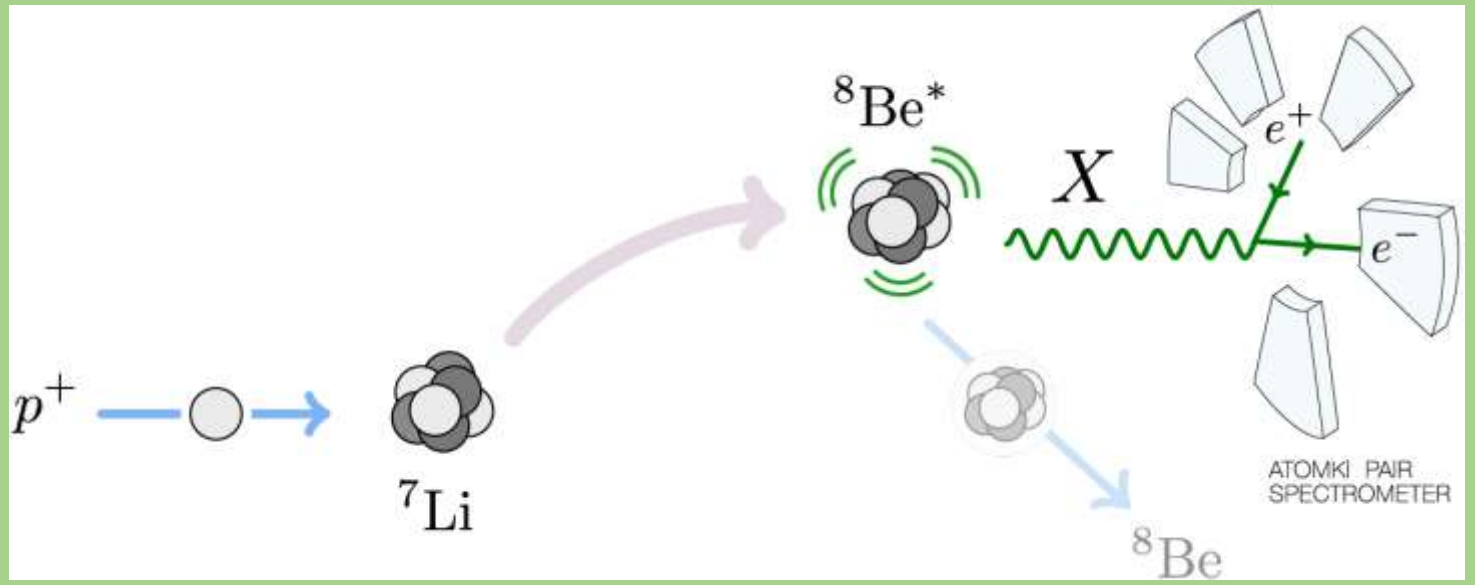
Light axial vector bosons, nuclear transitions, and the 8Be Anomaly

DSM Alves, N Weiner - Journal of High Energy Physics, 2018

A viable QCD axion in the MeV mass range

„We find a variant axion model that remains compatible with existing constraints."

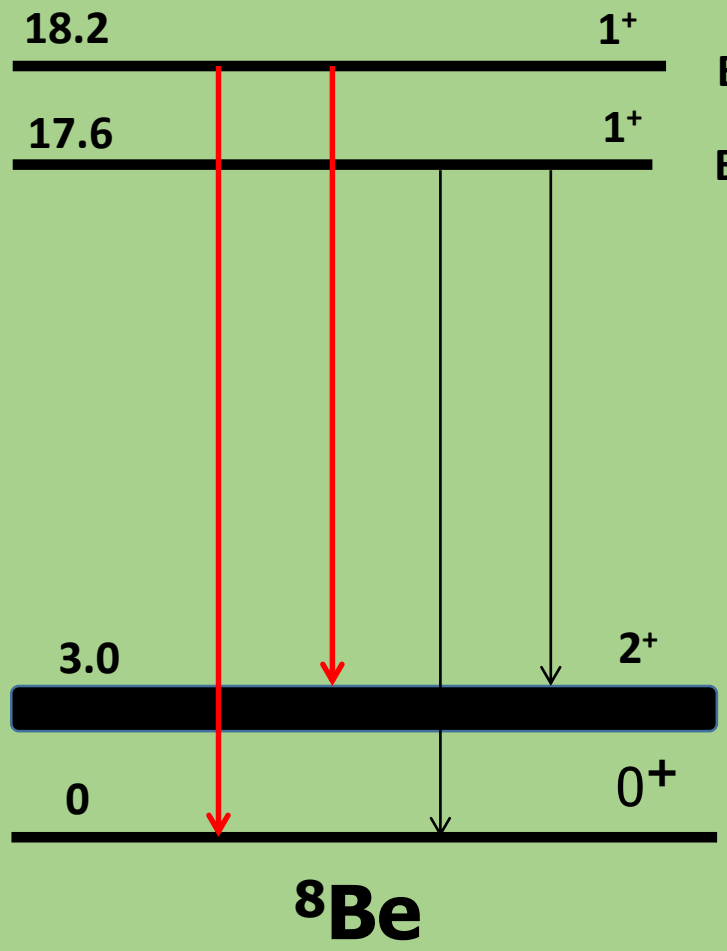
The creation and decay of $^8Be^*$



- $^8Be \rightarrow \alpha\alpha \approx 100\%$
- γ-decay: $B(^8Be + \gamma) \approx 1.5 \times 10^{-5}$
- Internal pair creation: $B(^8Be + e^+ e^-) \approx 5.5 \times 10^{-8}$
- Ejection of a new particle: $B(^8Be + X) \approx 5.5 \times 10^{-10}$

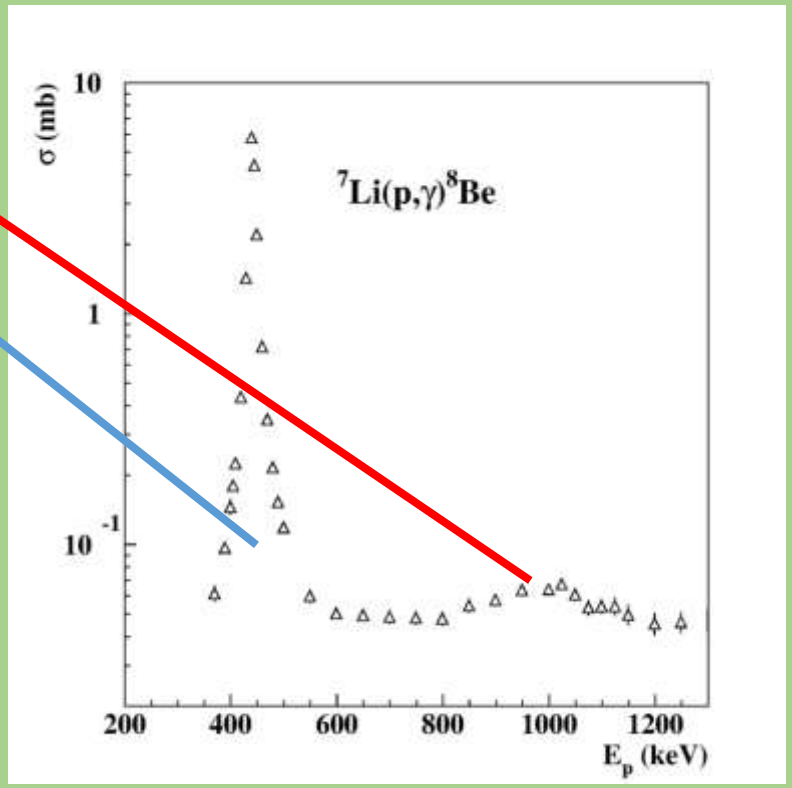
Study the ^{8}Be M1 transitions

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

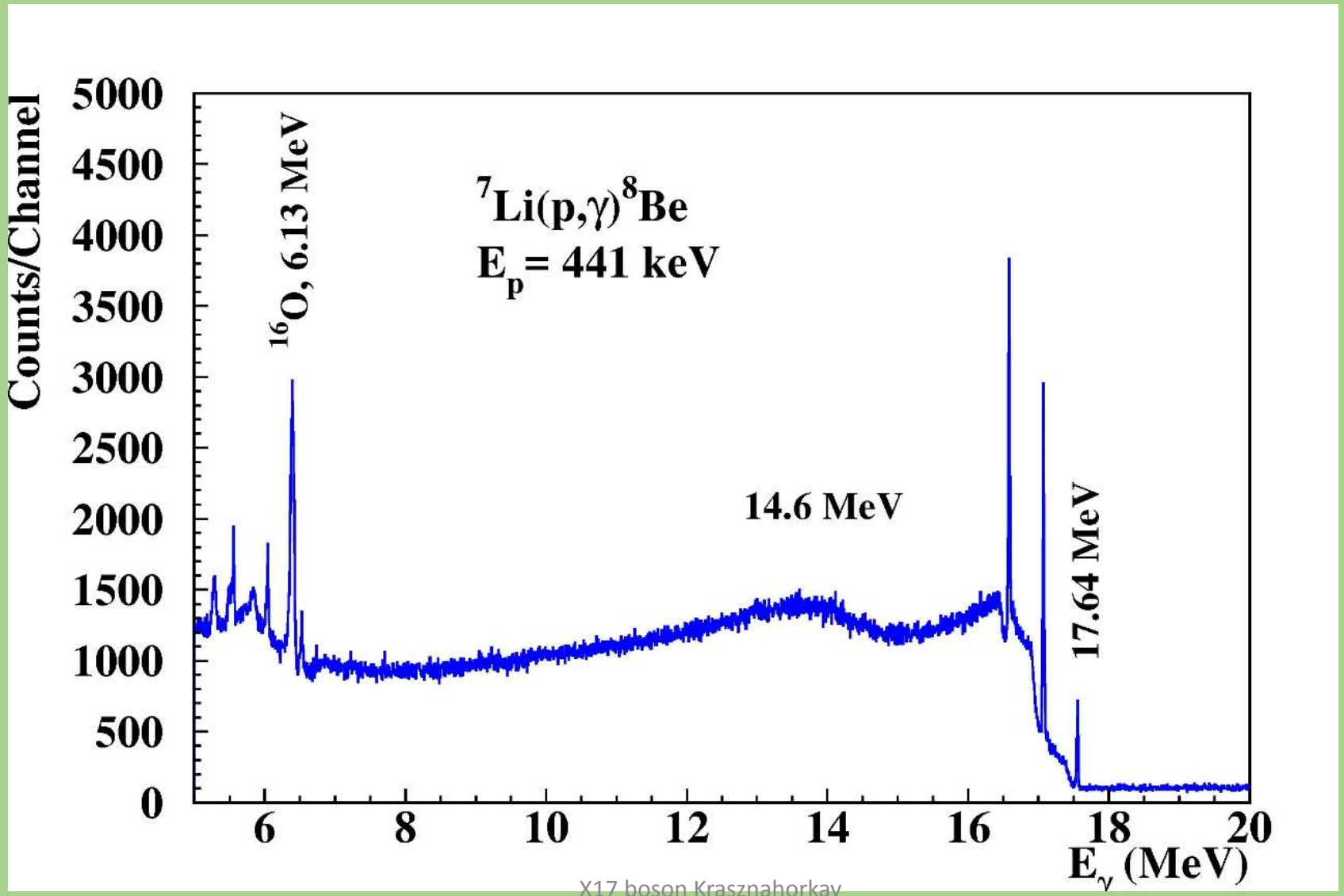


Ep= 1030 keV

Ep= 441 keV

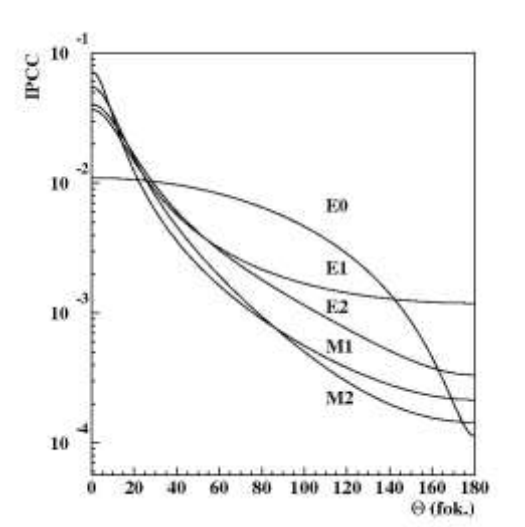


γ-ray spectrum measured with a 100% HpGe detector

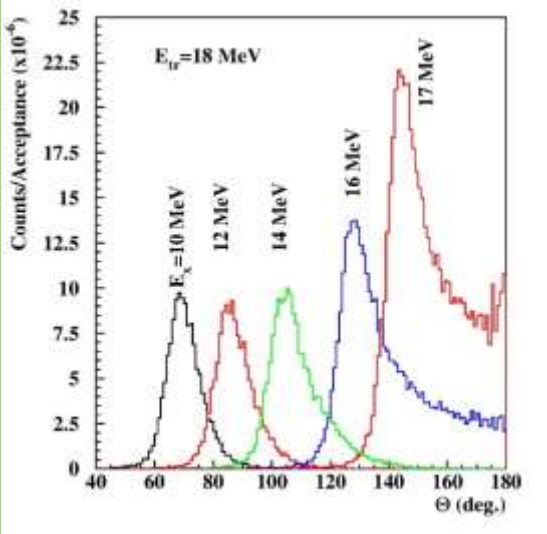


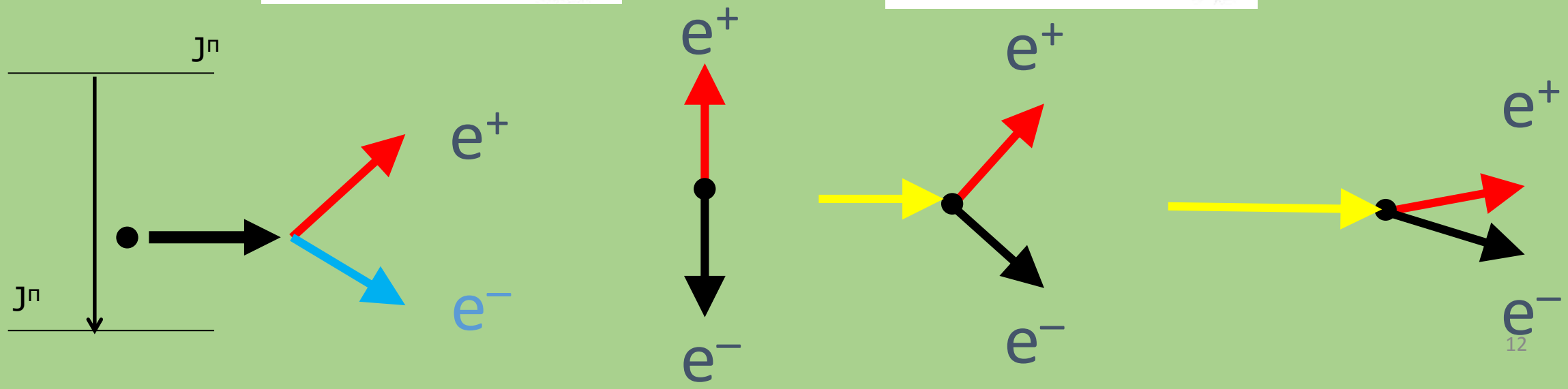
Study the ^{8}Be M1 transitions

Background

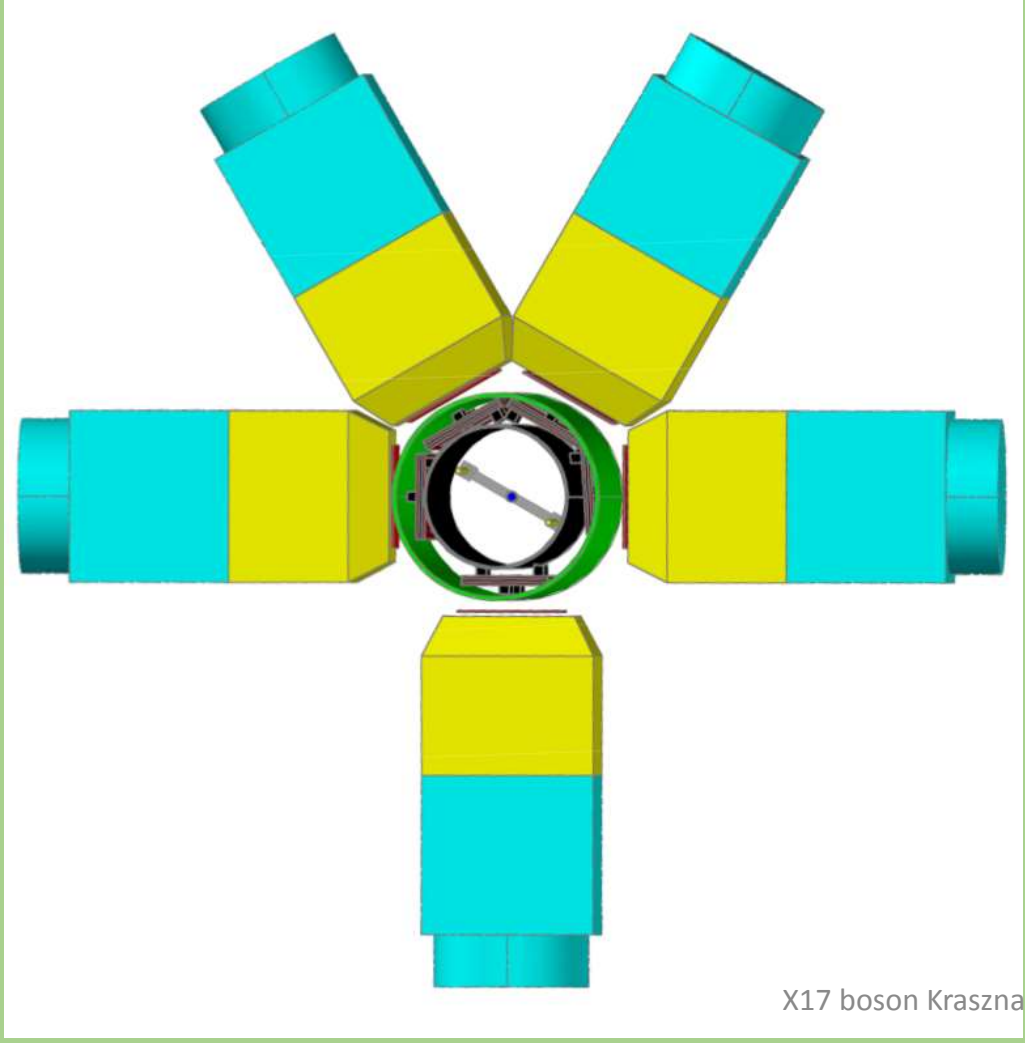


Signal



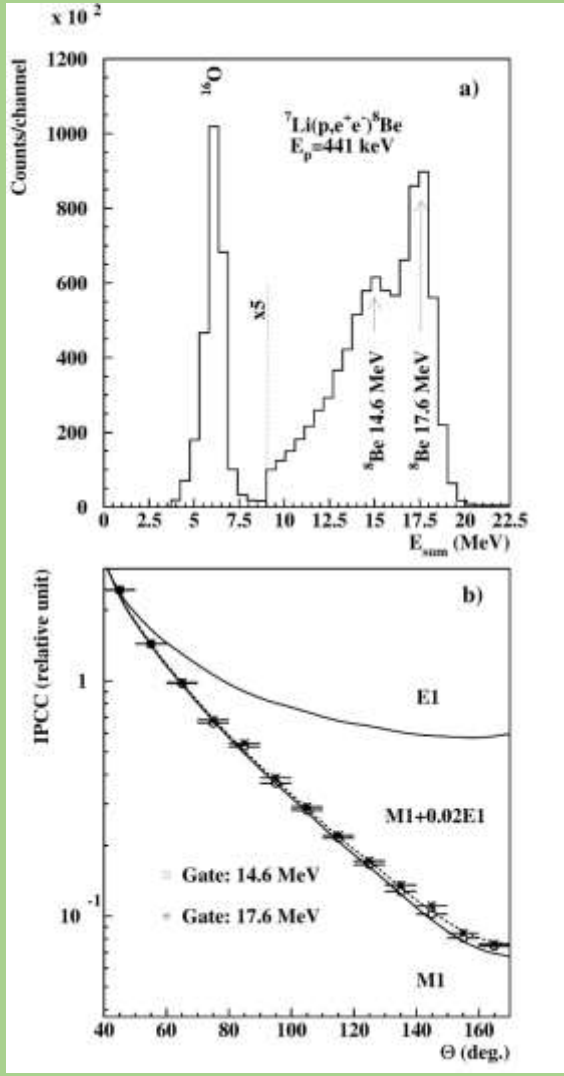


Geometrical arrangement of the scintillator telescopes (NIM, A808 (2016) 21)



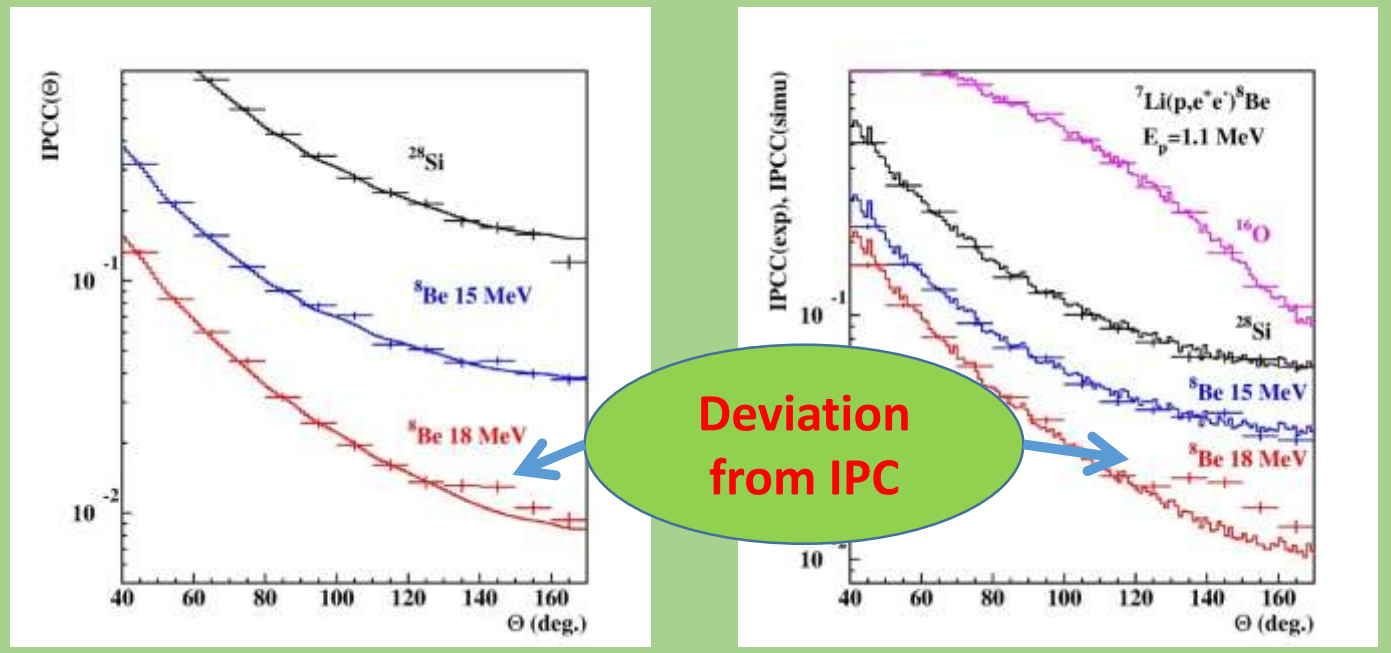
Results

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



Ep=1.04 MeV

Ep=1.10 MeV



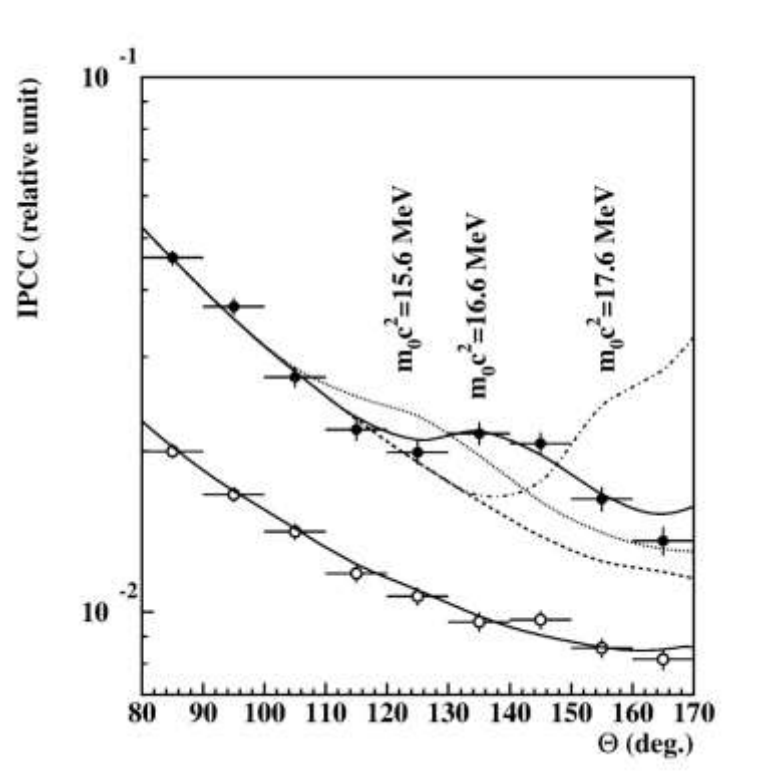
- **Can it be some artificial effect caused by γ-rays?**
- **Can it be some nuclear physics effect?**
- **…**

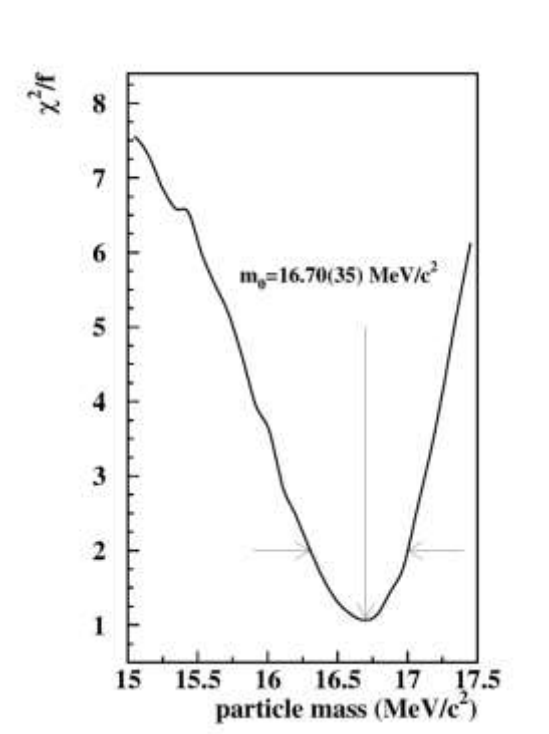
X Zhang, GA Miller - Physics Letters B, 2017

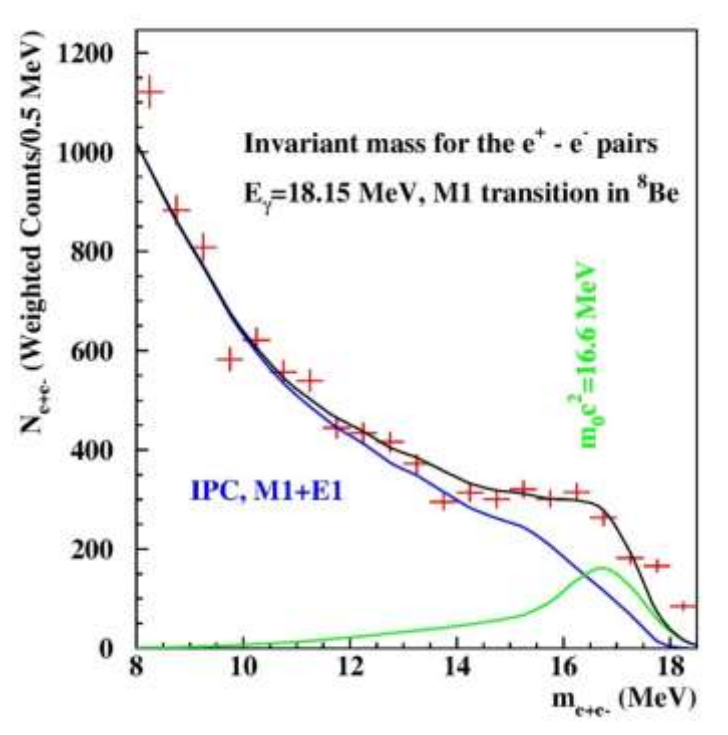
Can nuclear physics explain the anomaly observed in the internal pair production in the Beryllium-8 nucleus?

No. It is fine.

How can we understand the peak like deviation? Fitting the angular correlations







Experimental angular e^+e^- pair correlations measured in the $^7Li(p,e^+e^-)$ reaction at Ep=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 by the X^2/f method

$$m^2 \approx (1-y^2)E^2 \sin(\Theta/2)$$

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

Introduction of the protophobic fifth force (J. Feng et al.PRL 117, 071803, (2016))

$$\mathcal{L} = -\frac{1}{4}X_{\mu\nu}X^{\mu\nu} + \frac{1}{2}m_X^2 X_\mu X^\mu - X^\mu J_\mu,$$

$$\varepsilon_p = 2\varepsilon_u + \varepsilon_d$$

$$\varepsilon_n = \varepsilon_u + 2\varepsilon_d$$

Branching ratio:

$$\frac{B(^8\mathrm{Be}^* \to {}^8\mathrm{Be}\, X)}{B(^8\mathrm{Be}^* \to {}^8\mathrm{Be}\,\gamma)} = (\varepsilon_p + \varepsilon_n)^2 \frac{|\vec{p}_X|^3}{|\vec{p}_\gamma|^3} \approx 5.6 \times 10^{-6}$$

$$|\varepsilon_p + \varepsilon_n| \approx 0.011$$

$$|\varepsilon_u + \varepsilon_d| \approx 3.7 \times 10^{-3}$$

Pion decay constrain:

$$|2\varepsilon_u + \varepsilon_d| < \varepsilon_{\max} = 8 \times 10^{-4}$$

$$-2.3 < \frac{\varepsilon_d}{\varepsilon_u} < -1.8\,, \quad -0.067 < \frac{\varepsilon_p}{\varepsilon_n} < 0.078$$

Promising Outlook

IPC:

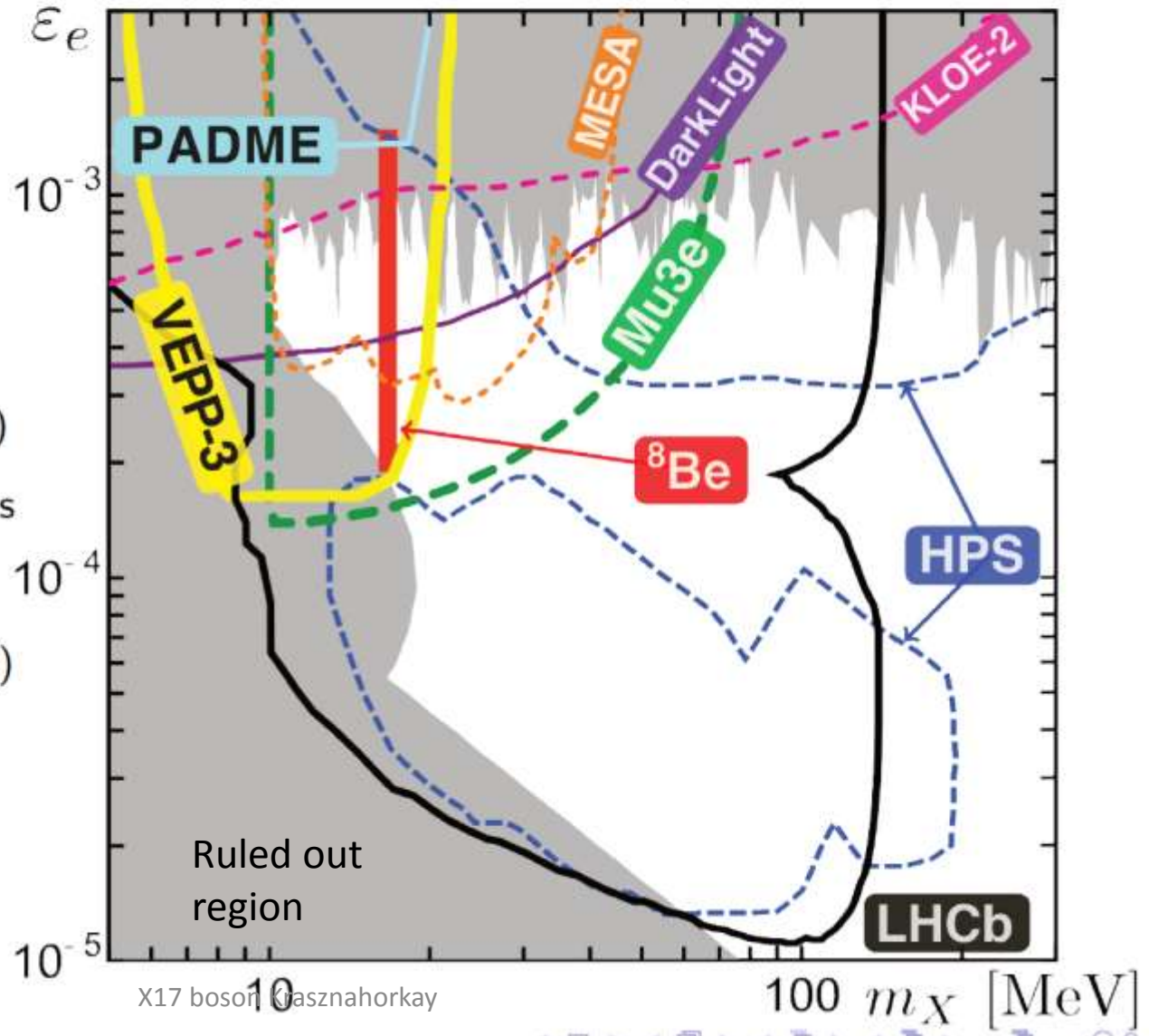
- verify ^{8}Be
- ^{10}B : 19.3 MeV
- ^{10}Be : 17.79 MeV

More Exp:

- TUNL (HIGS facility γ *Nuc*)
- TREK@JPARC: K^{+} Decays
- SHIP
- SeaQuest (Gardner & Holt)
- VdG UK
- BESIII (arXiv:1607.03970)

Prob UV

- ATLAS, CMS



Xilin Zhang, Gerald A. Miller arXiv: 25 Aug 2020

Can a protophobic vector boson explain the ATOMKI anomaly?

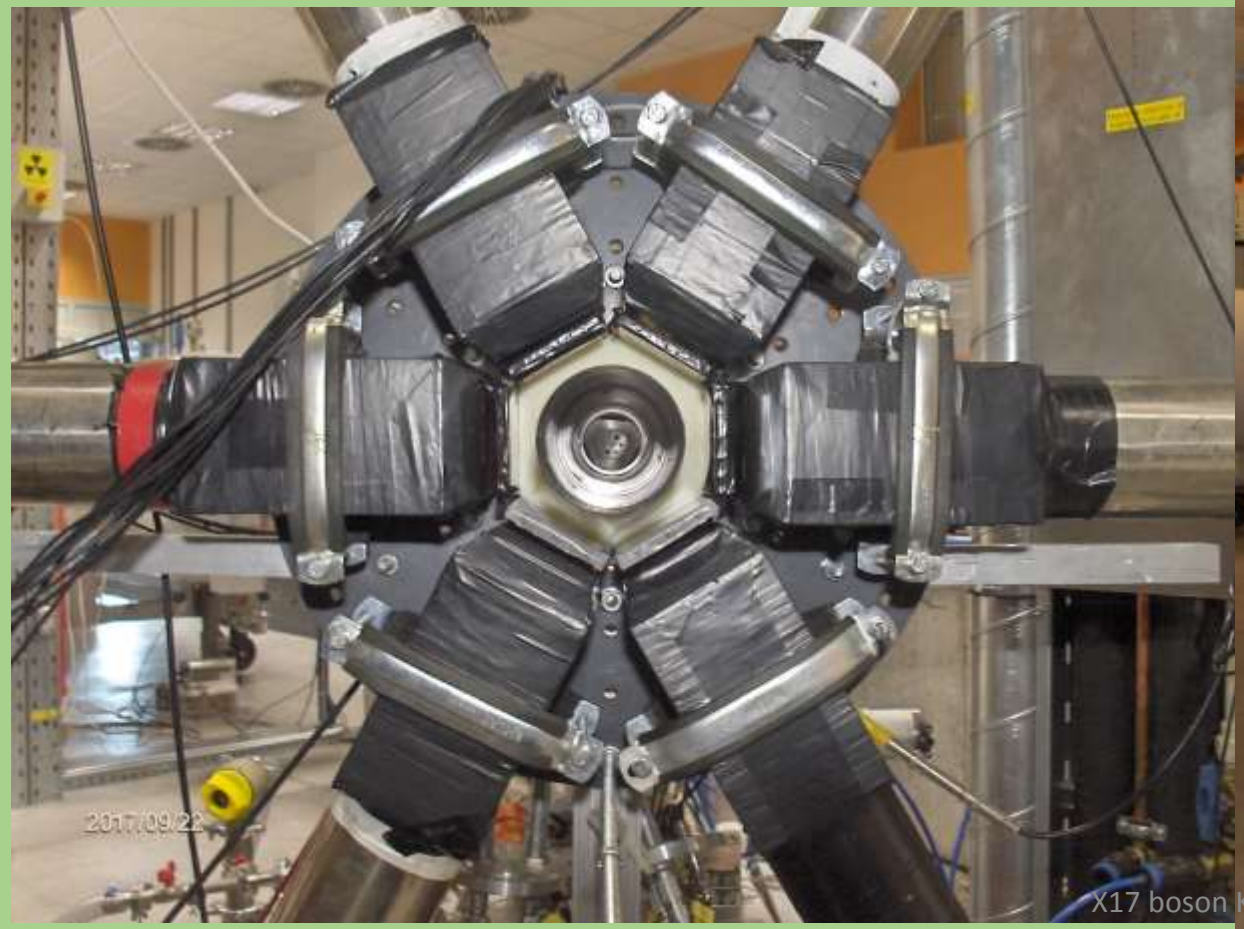
No. → X17 must be pseoudoscalar or axialvector

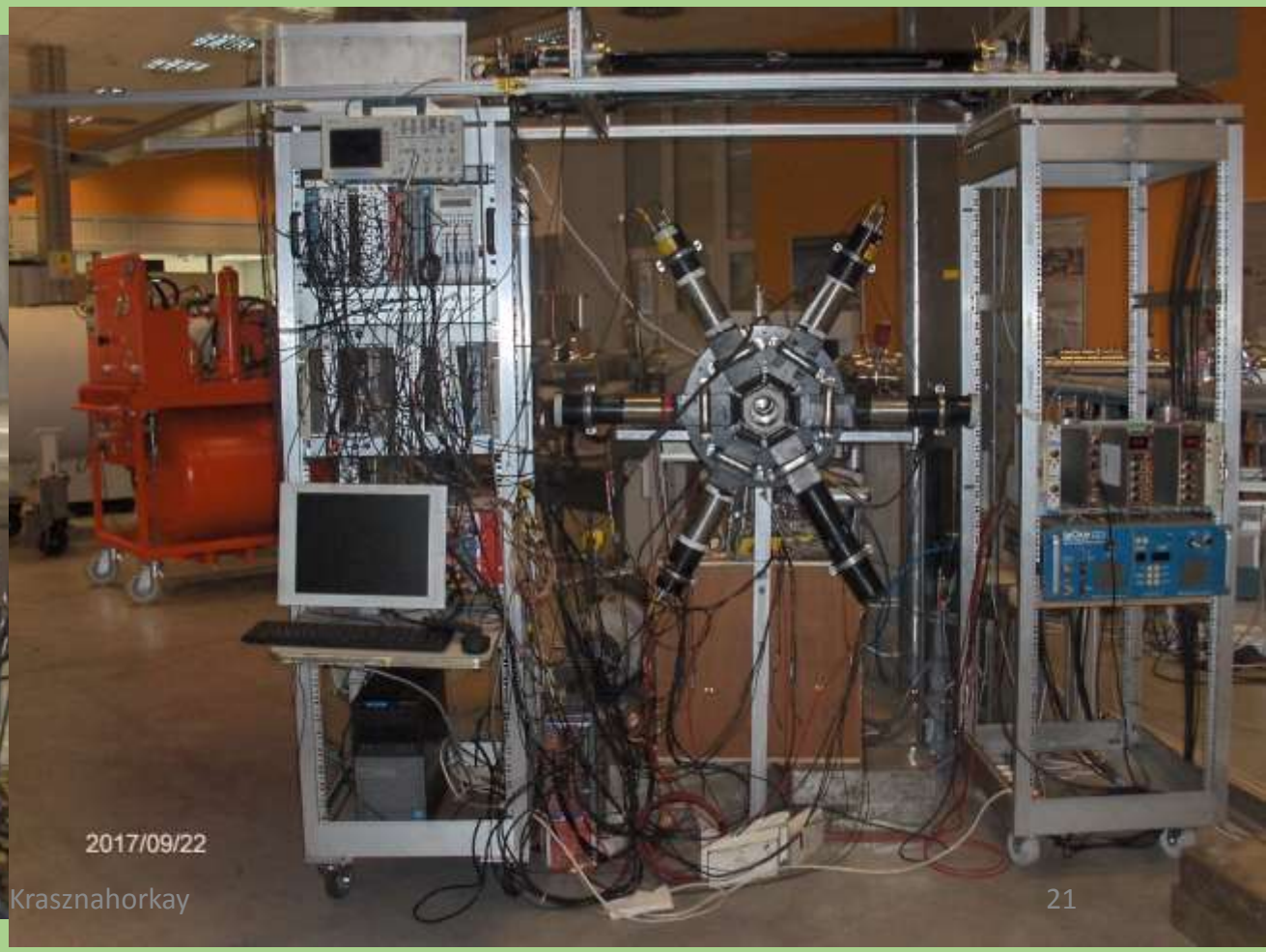
Repeating the experiments at a new Medium-Current Tandetron Accelerator in Atomki

Main specifications:

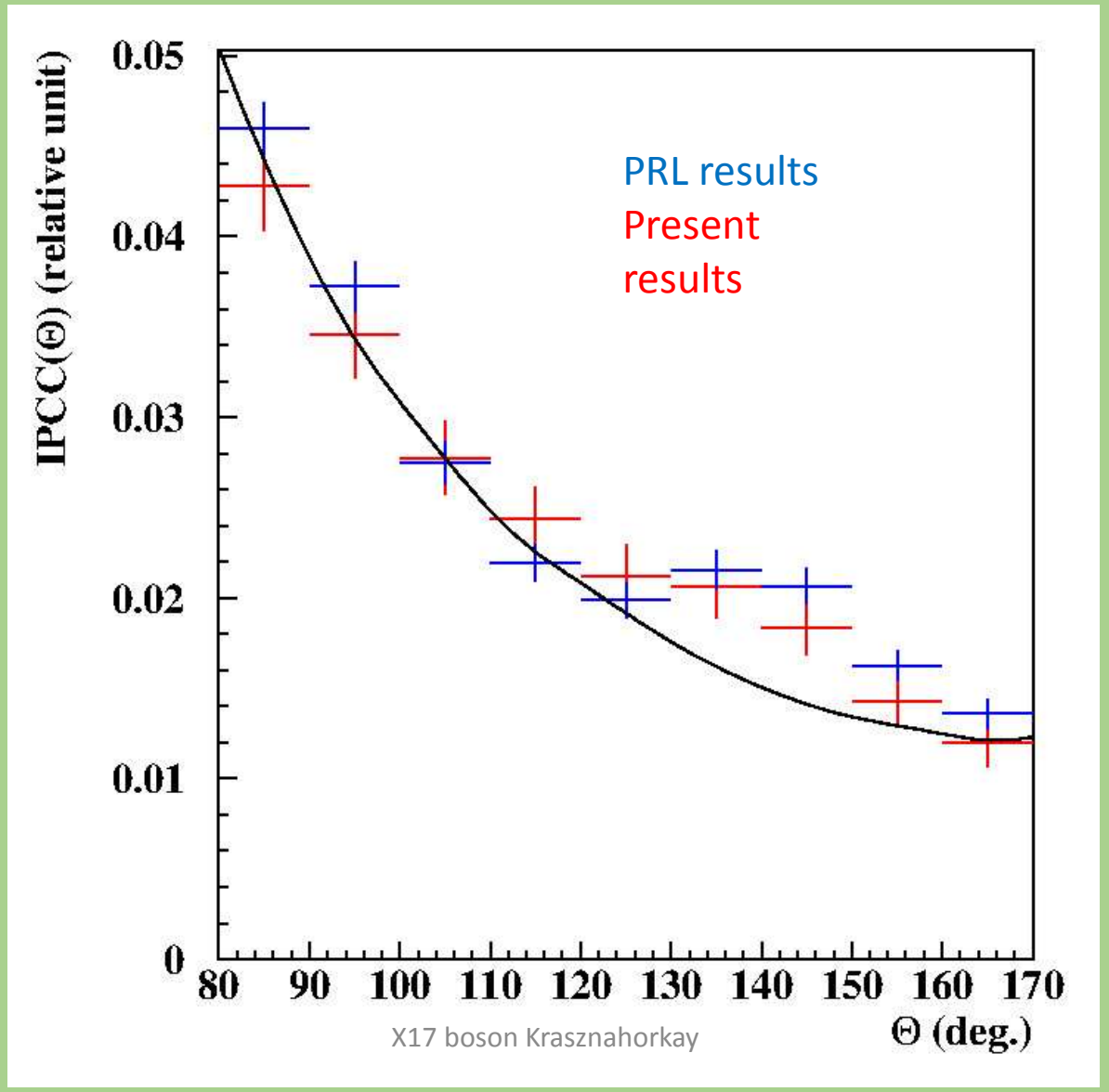
- TV ripple: 25 $V_{RMS,}$ TV stability: 200 V (GVM), 30 V (SLITS)
- Beam current capability at 2 MV: 200 μA proton, 40 μA He

The new e^+e^- pair spectrometer with six telescopes equipped with Si DSSD's

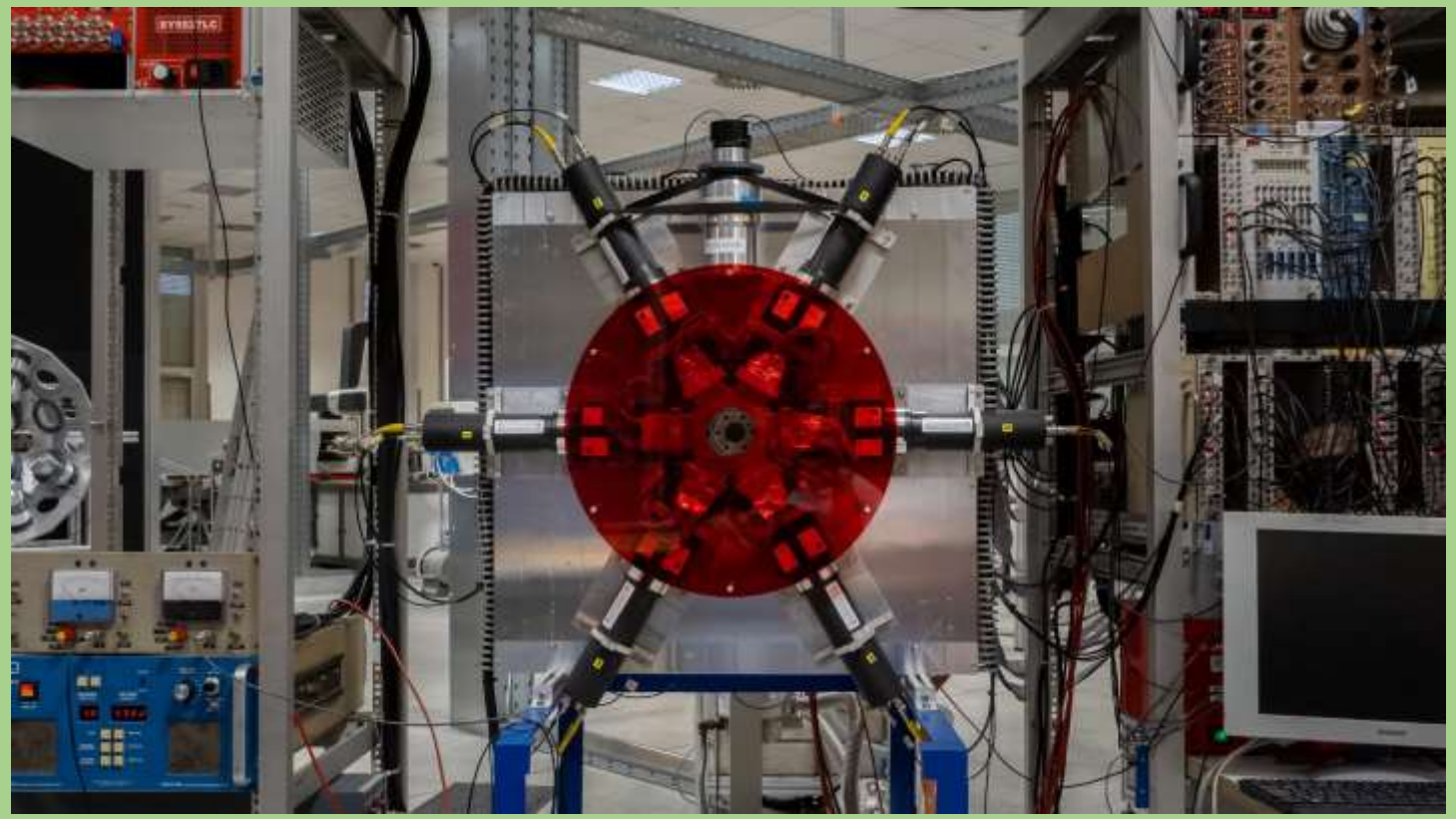




Recent results for the 18.15 MeV transition



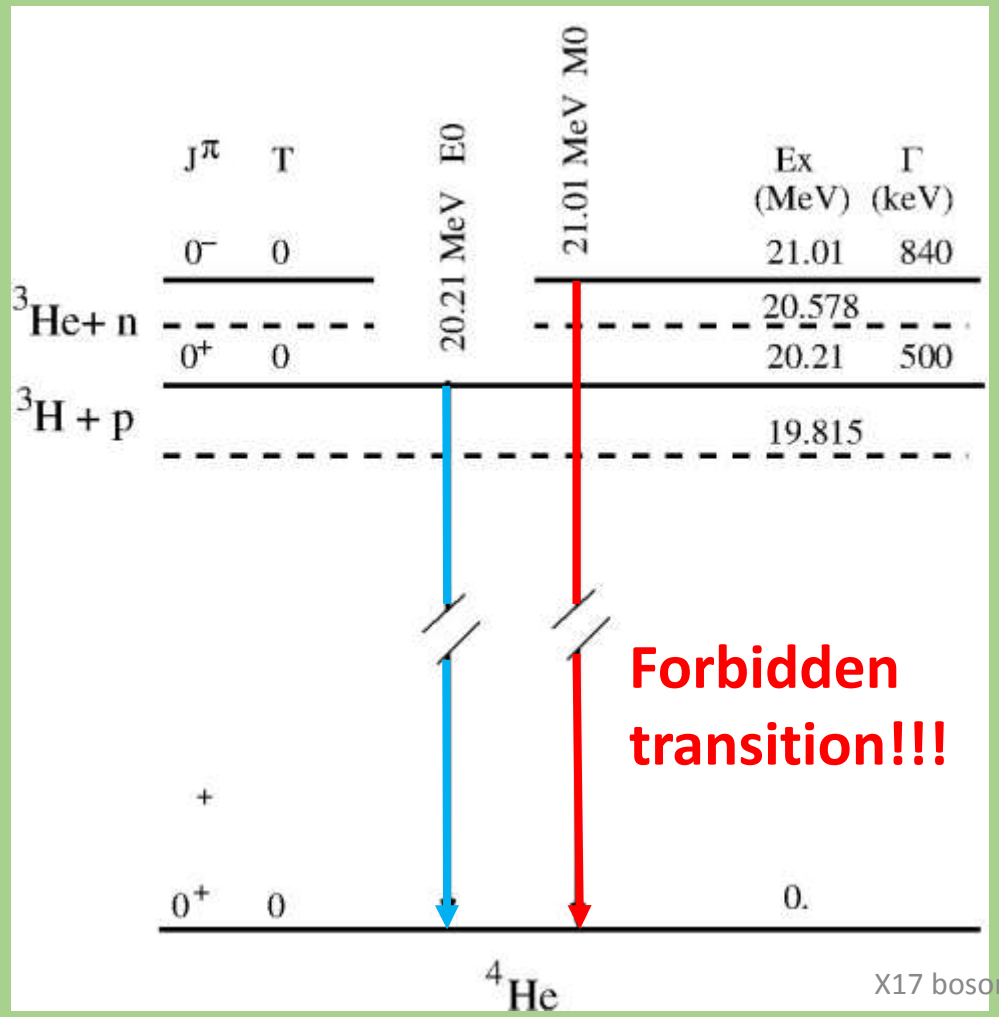
The present version of the spectrometer

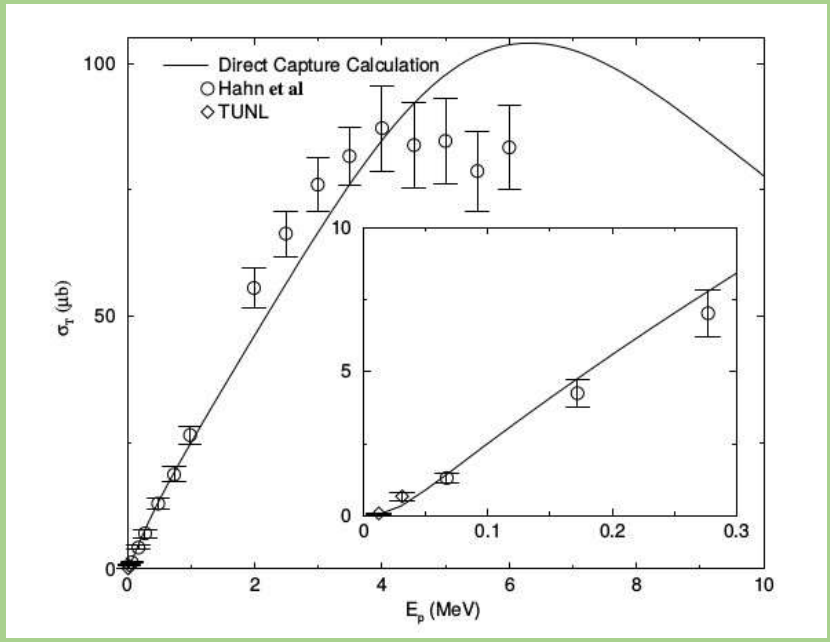


New scintillation and DSSD detectors, new DAQ.

The DSSD detectors in the heart of the spectrometer

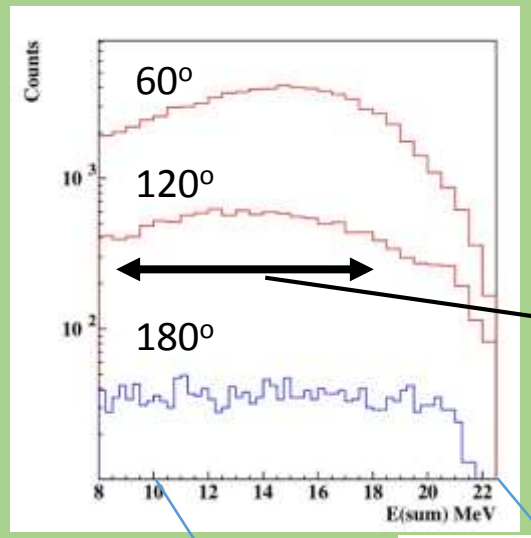
Study of the 21 MeV M0 transition in ^{4}He excited by ^{3}H+p, and ^{3}He+n reactions



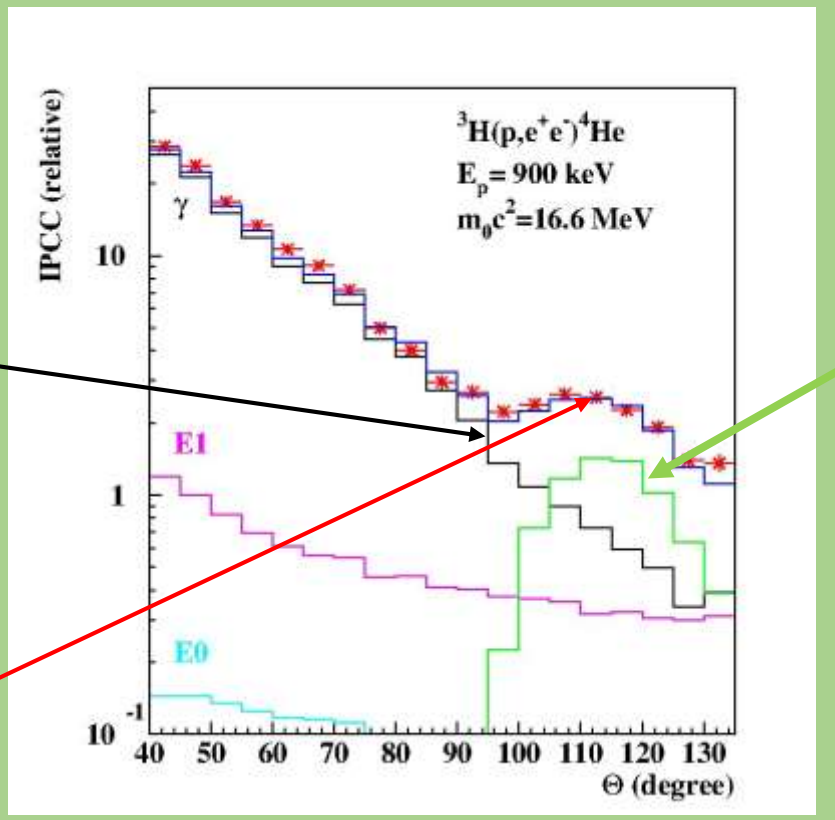


γ-ray production with direct proton capture. The main source of background produced by external pair creation on the backing of the target and on the other surrounding materials. **GEANT simulations.**

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



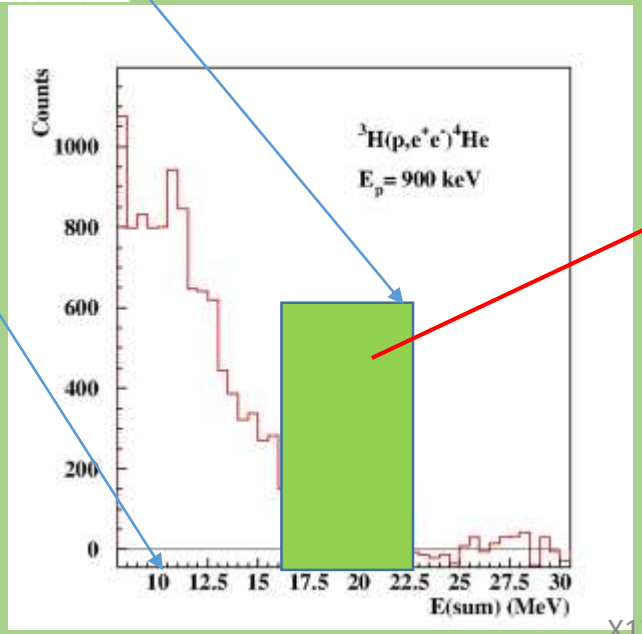
Measured e^+e^- sum-energy spectra for different detector combinations.



Simulation for m_0c^2= 16.6 MeV

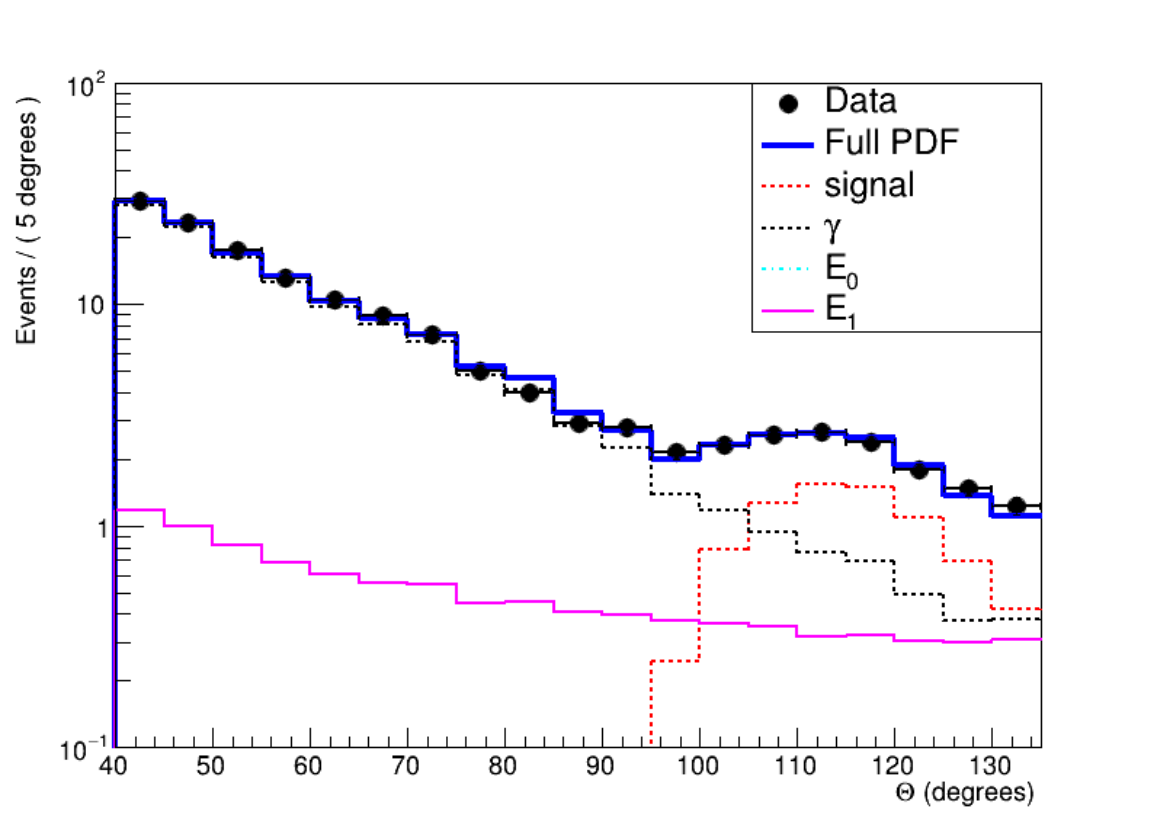
Significance: gt. 7.6 σ

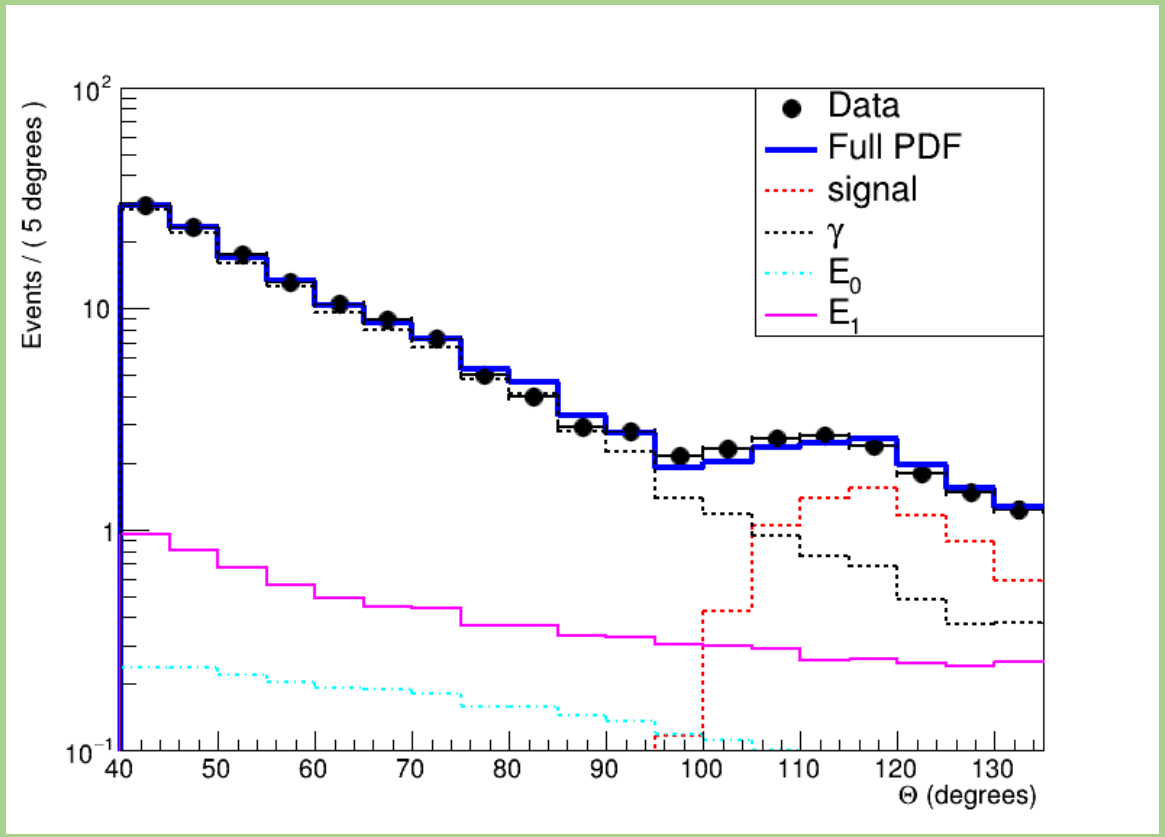
Difference between spectra measured at 120° and 60°.



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

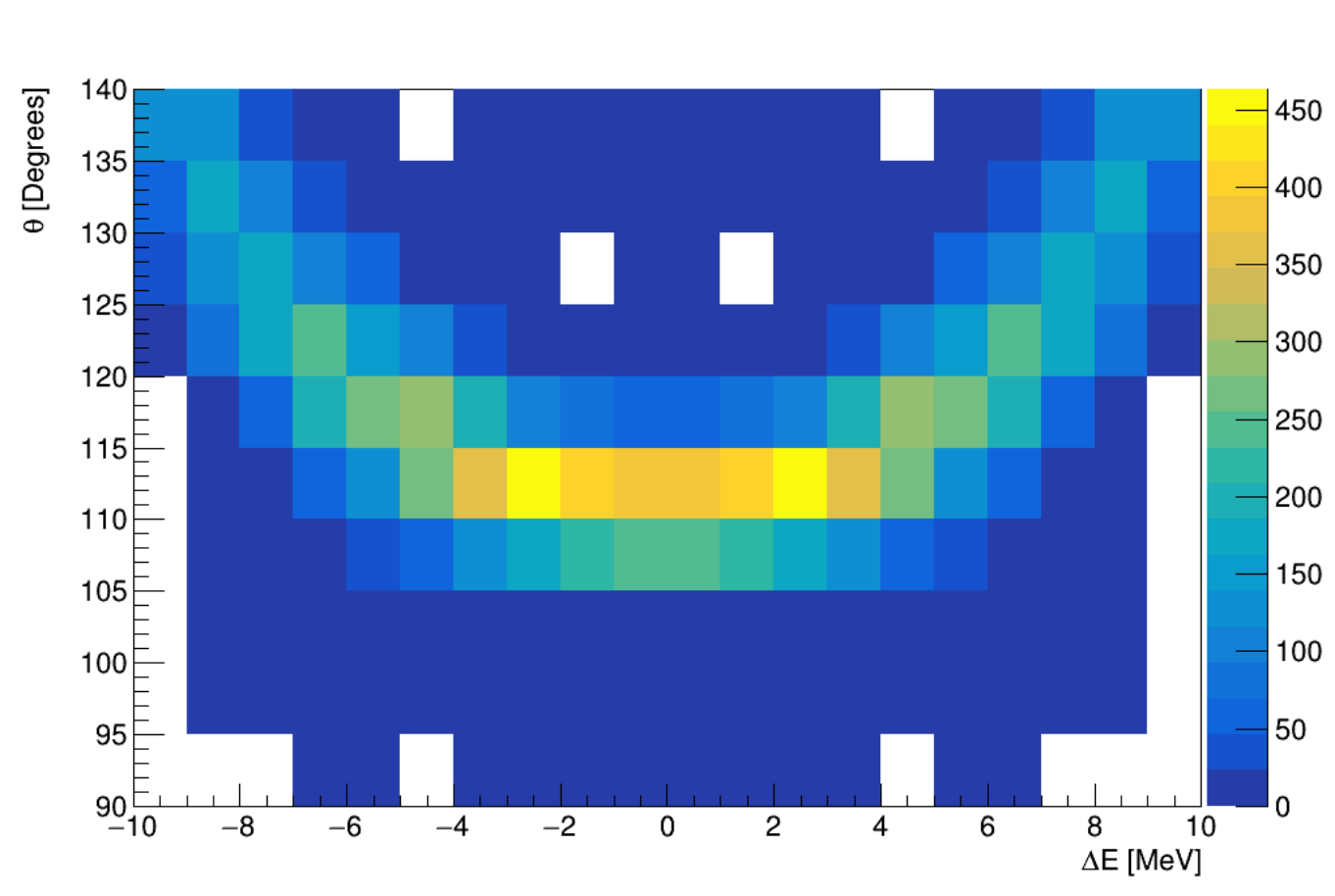
Details of the fit performed by RooFit





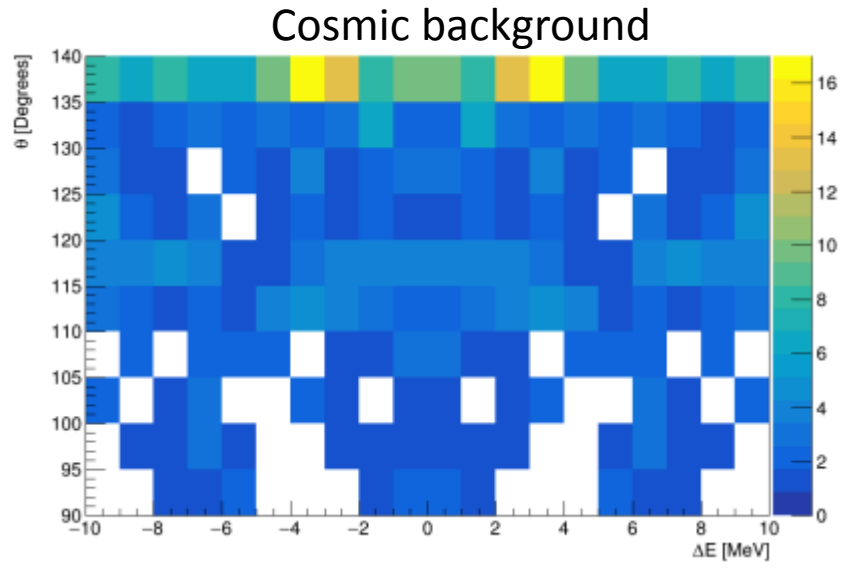
On the kinematics of the e^+,e^- decay of X17

Results of the GEANT simulation:
Ex=20.5 MeV
m_0c^2= 17 MeV
N= 1 M

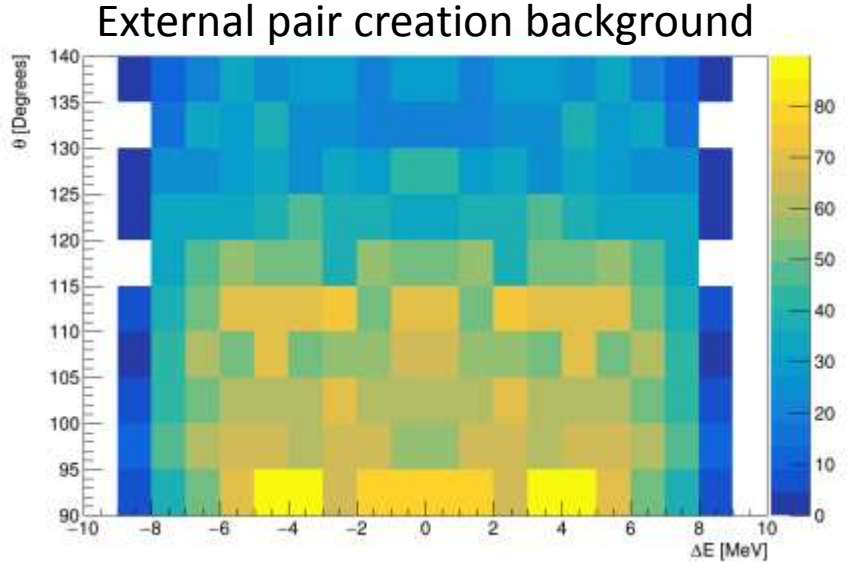


Experimental results after one week running

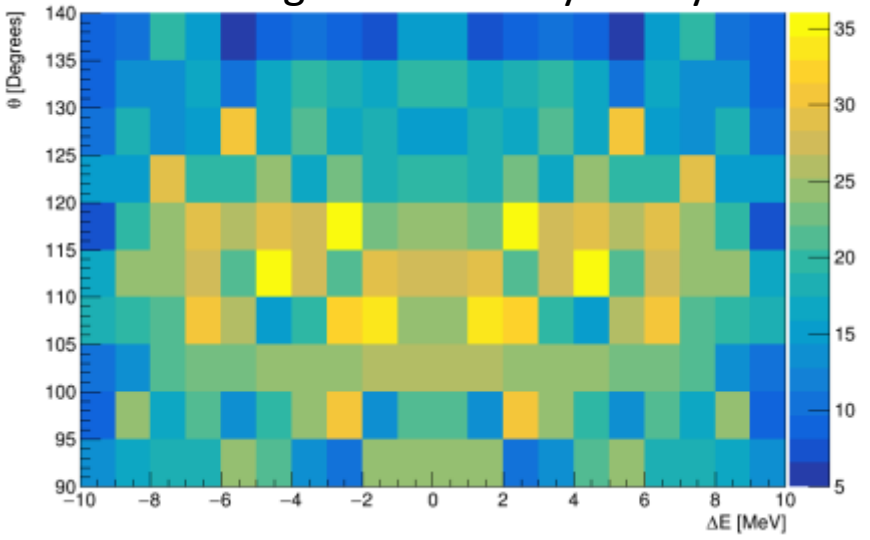
Cosmic background



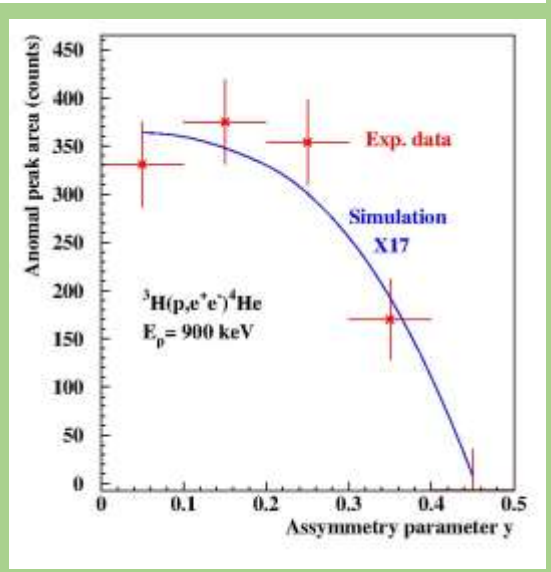
External pair creation background



Events showing the two-body Decay of X17



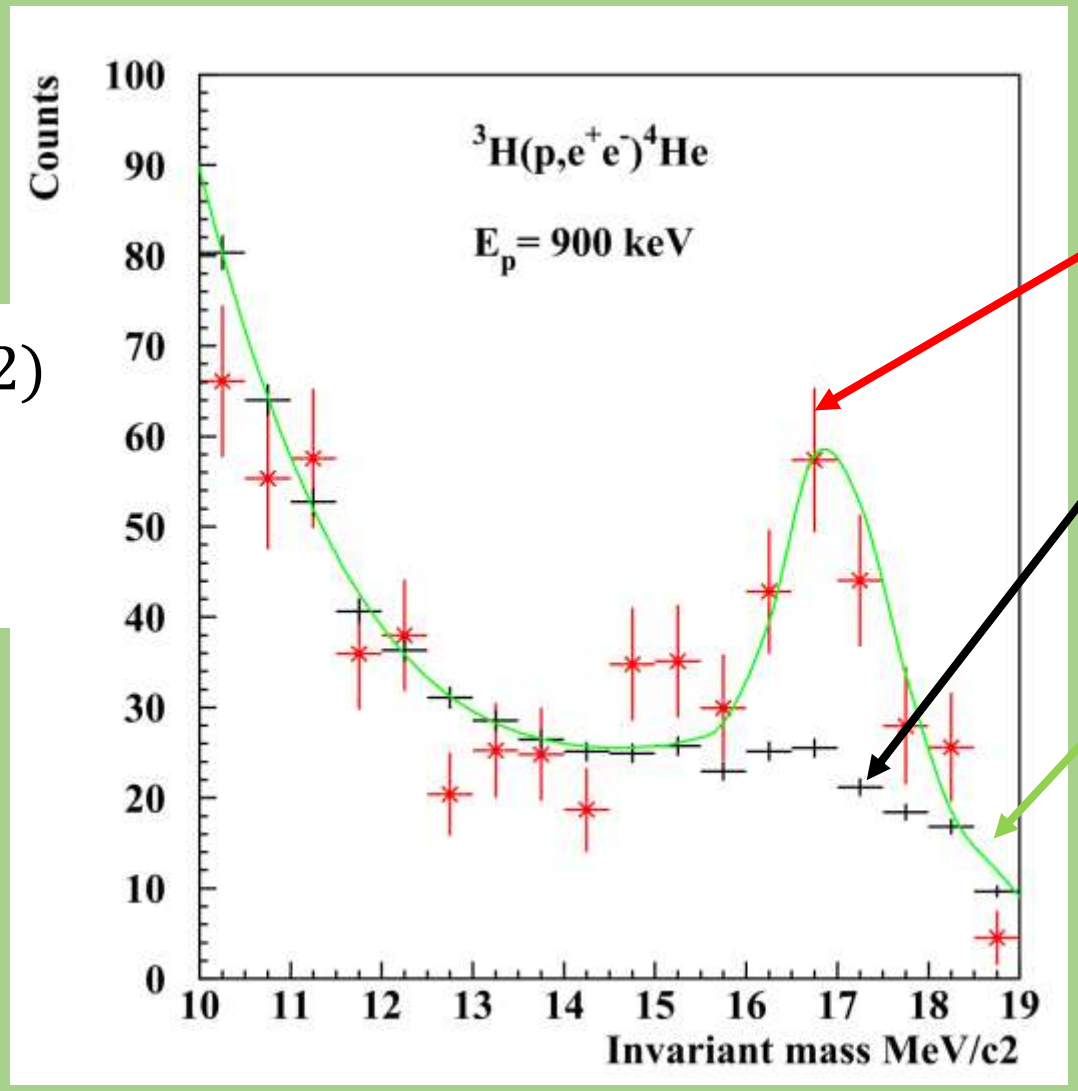
$$y=\frac{E_+-E_-}{E_++E_-}$$



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 $\gamma\gamma$-decay of X17 in ^{4}He

Vector particle (1+) or axialvector (0-)?

According to the Landau-Yang theorem the $\gamma\gamma$ decay of a vector boson is forbidden, while for axialvector it is allowed.

Suffert and Bertholet used two 10”x12” NaI(Tl) detectors placed at a relative angle of 90ºat backward angles with respect to the beam direction.

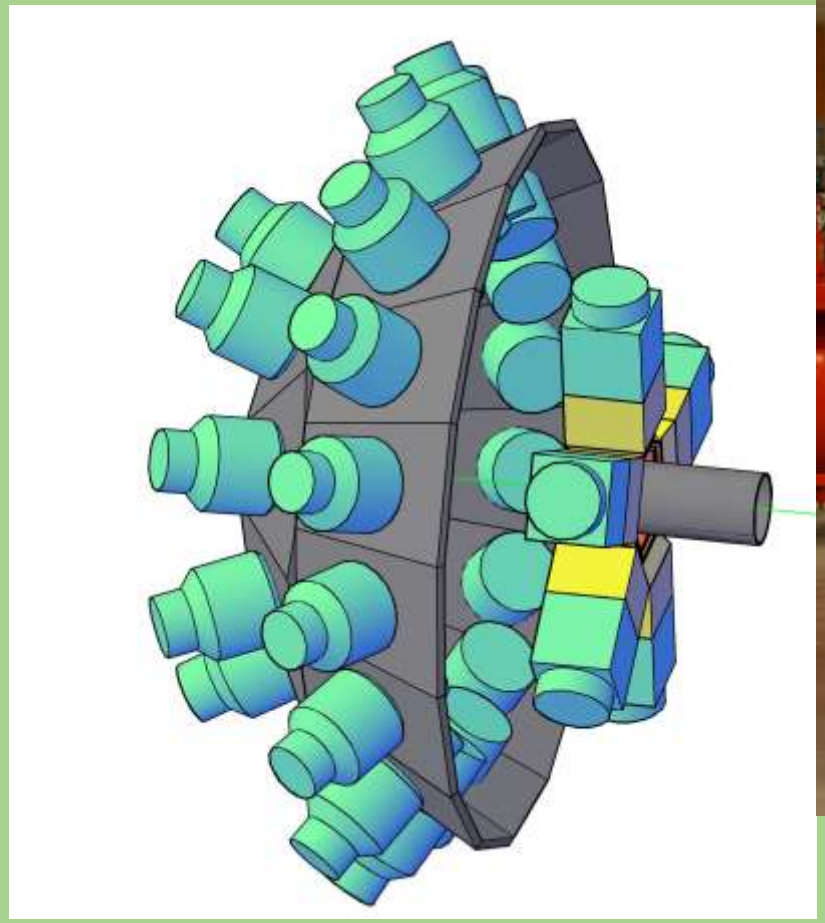
Coincident γ-rays were observed from the simultaneous two-γ decay of the 0+state. The branching ratio σ(2γ)/σ(1γ) was measured to be 0.28±0.07. This value was about ten times larger than the theoretical result indicating some unknown contribution to the two-photon decay.

The angle of the expected peak in the angular correlation is:

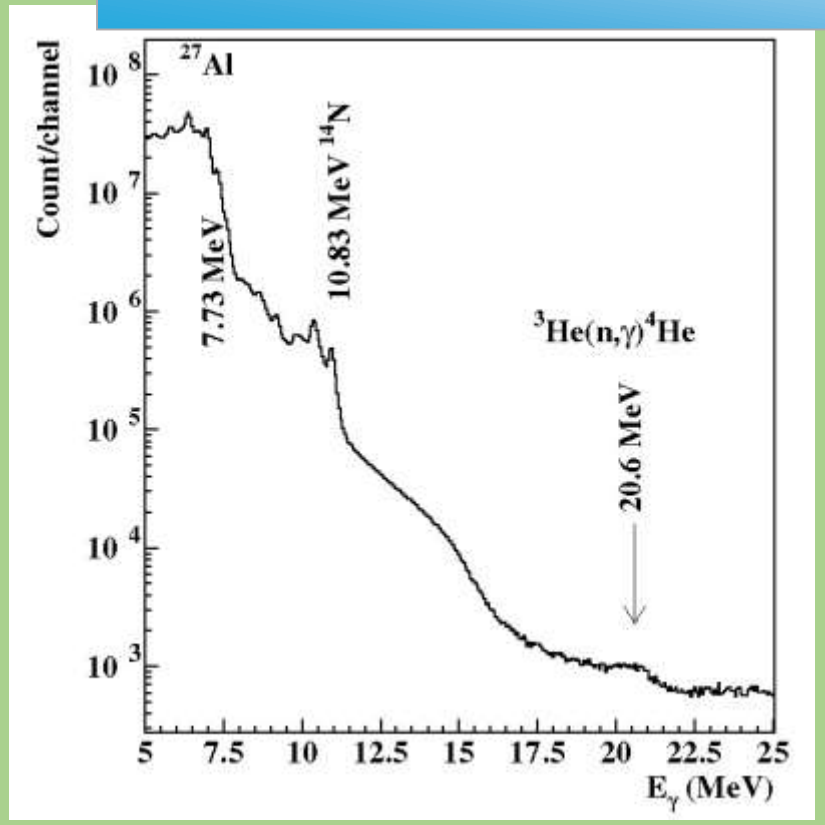
$$\cos(\Theta) = 1 - \frac{m_x^2}{2E_1E_2}$$

Study the angular correlation with state of the art 3”x3” $LaBr_3$ detectors!

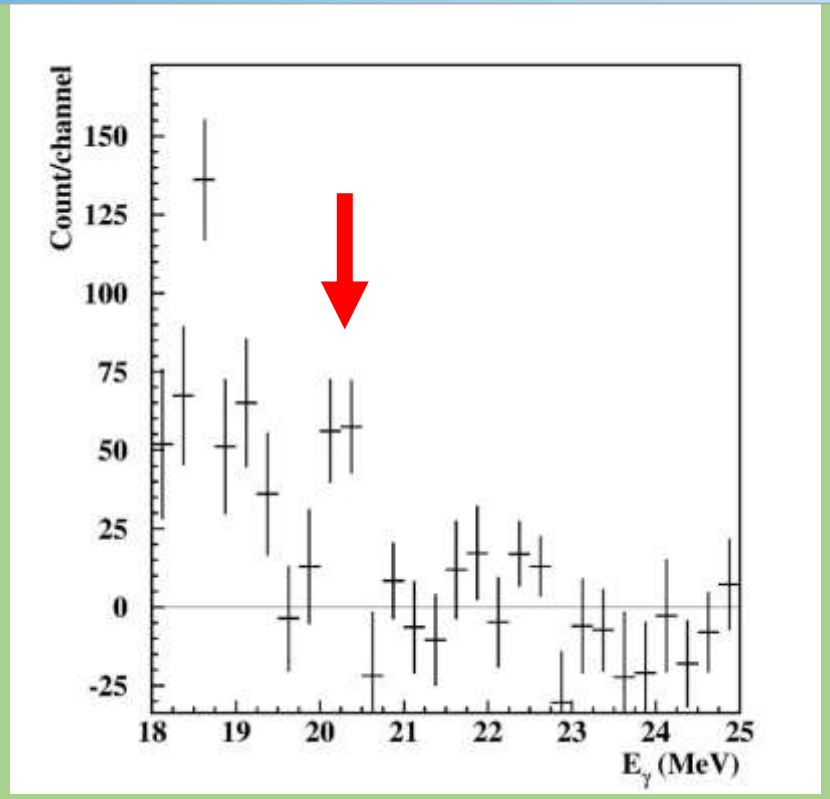
The experimental setup in Debrecen including both the e^+e^- and the γ-ray spectrometers



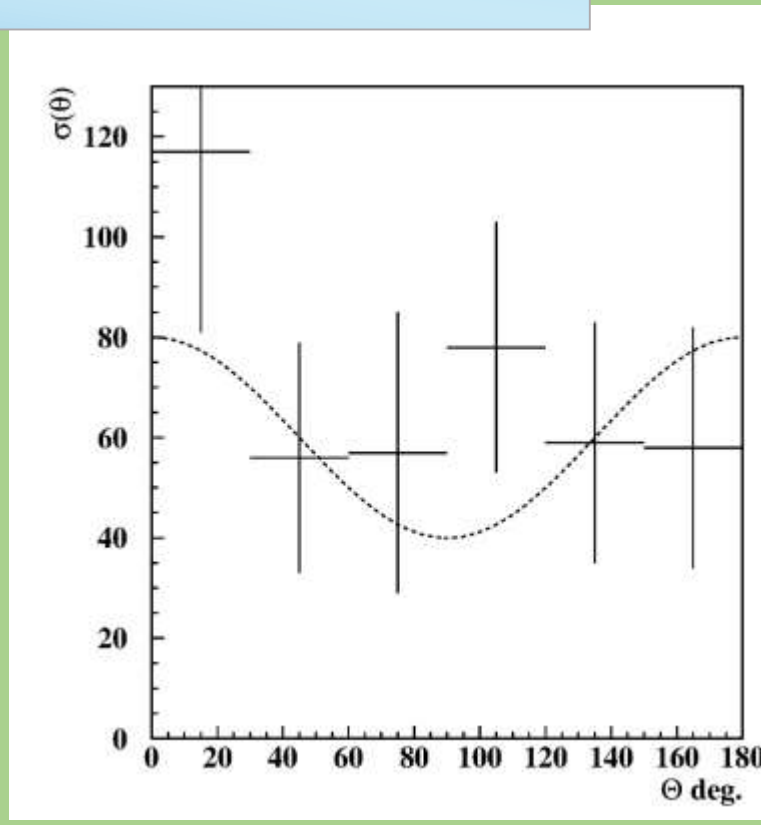
The first (very preliminary) results obtained in Garching



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 upgraded spectrometer.
- The anomaly can be successfully described by a new particle called X17.
- The effect of X17 was observed also in ^{4}He at a correspondingly smaller angle. The significance of the peak is 7.2 σ.
- The existence of the particle was demonstrated by checking the kinematics of their two-body decay
- We are planning to study the γγ-decay of X17 to determine their spin.
- Promising outlook.

Acknowledgement

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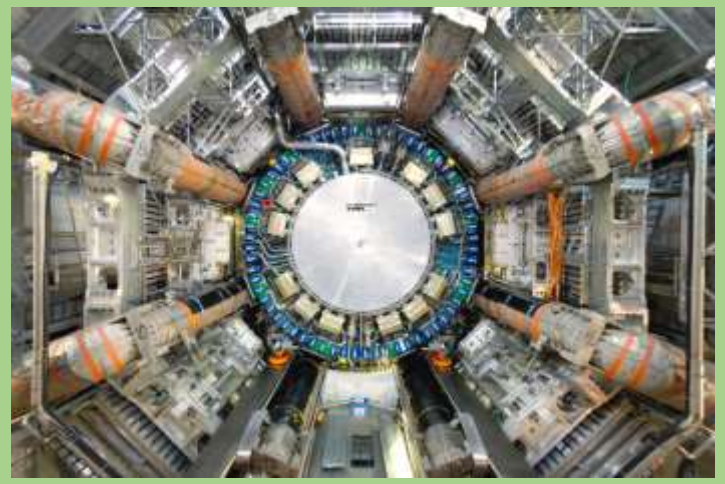
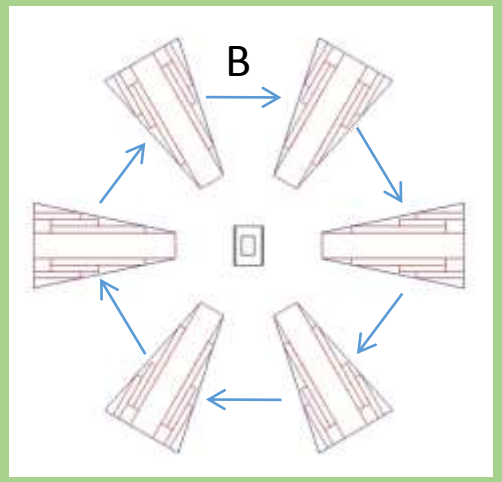
To ^{8}Be continued…

Thank you very much for your attention

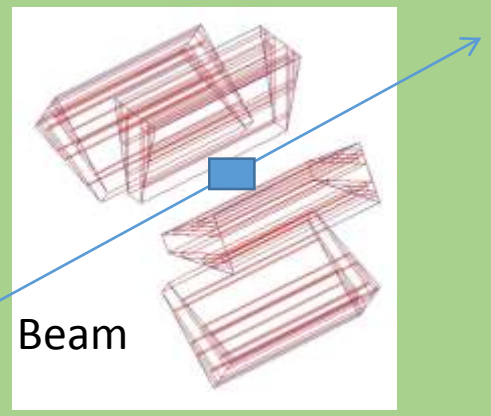
A Compact Positron Electron spectrometer (COPE) for internal pair creation studies (ENSAR support)

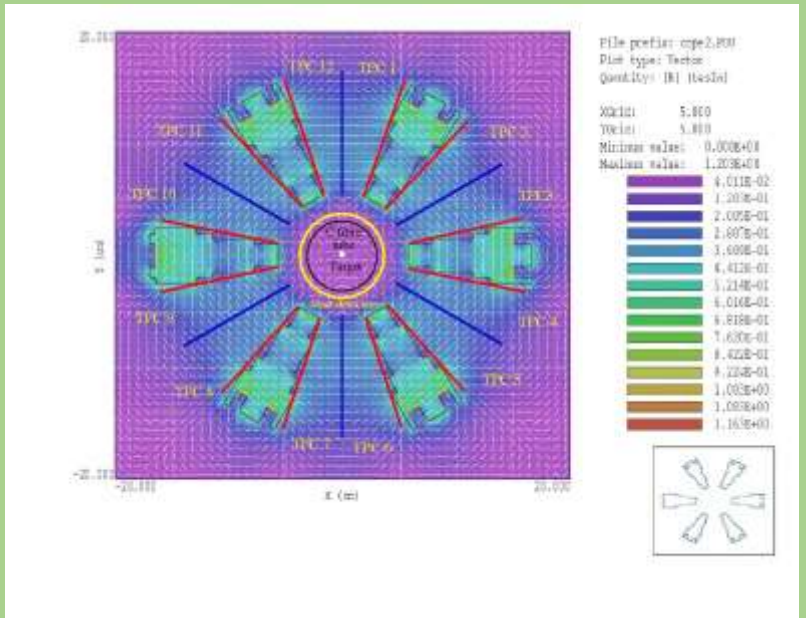


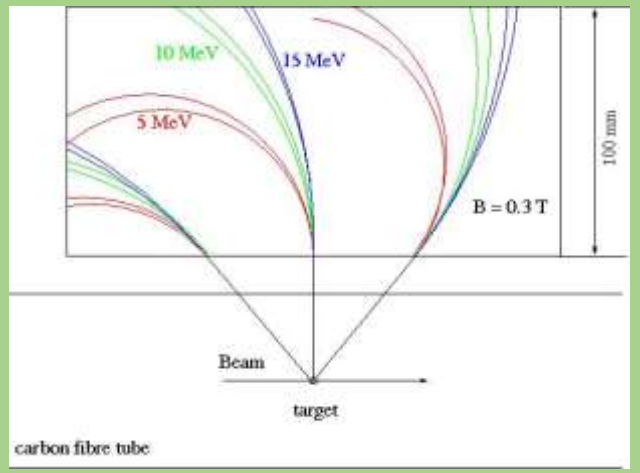
ATLAS



COPE 100:1







GEM detectors,
μ-TPC technology for particle tracking,
DSP cards for readout.