CNNP, Catania, 2017

New results on the Be-8 anomaly

Attila Krasznahorkay

Inst. for Nucl. Res., Hung. Acad. of Sci. (MTA-Atomki)

4 main divisions:

- Nuclear Physics Division
- Atomic Physics Division
- Applied Physics Division

Size: 100 scientists, 100 other staff

www.atomki.mta.hu

Observation of Anomalous Internal Pair Creation in

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

SUMMARY | News | Blogs | Twitter | Facebook | Goo

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 dipol (J^{... [show]

About this Attention Score

In the top 5% of all research outputs scored by Altmetric

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Mentioned by

- **55** news outlets
- **19** blogs
- **89** tweeters
- **6** Facebook pages

TWITTER DEMOGRAPHICS | MENDELEY READERS

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

about how the information was compiled.

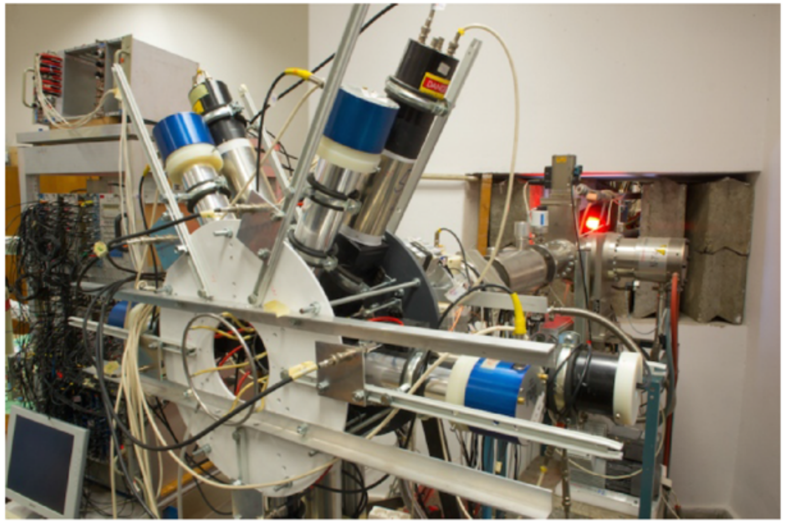
NATURE | NEWS

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 ... known fifth fundamental force of nature, physicists ...

Attila Krasznahorkay at the ... lleagues reported their surprising result in 2015 o... which posited the existence of a new, light bo...

Then, on 25 April, a group ... the result on arXiv[2]. The th... could be evidence for a fift... University of California, Irvi...

Four days later, two of Fen... Menlo Park, California. Res... at the Thomas Jefferson N... thinking about different way... confirm or rebut the Hunga...

Dark matter may feel a "dark force" that the rest of the Universe does not

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] Susan Gardner,[1,2] Jordan Smolinsky,[1] Tim M. P. Tait,[1] and Philip Tanedo[1]

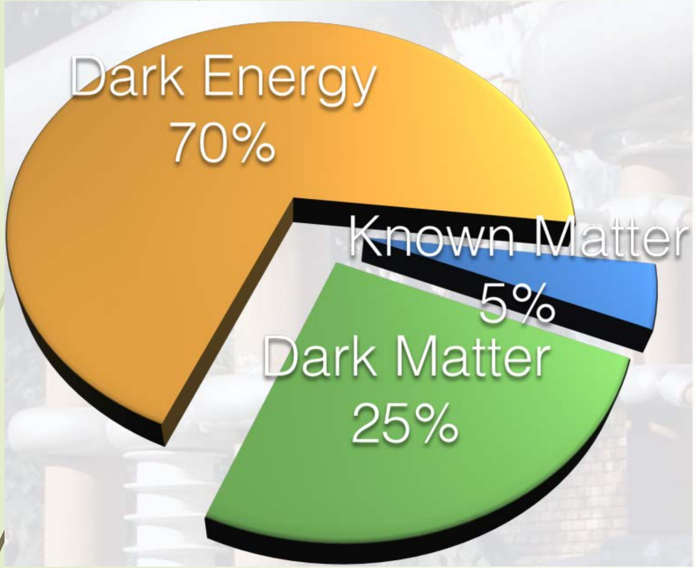
[1] *Department of Physics and Astronomy, University of California, Irvine, California 92697-4575 USA*

[2] *Department of Physics and Astronomy, University of Kentucky, Lexington, Kentucky 40506-0055 USA*

Phys. Rev. Lett. 117, 071803

Searching for Dark Matter

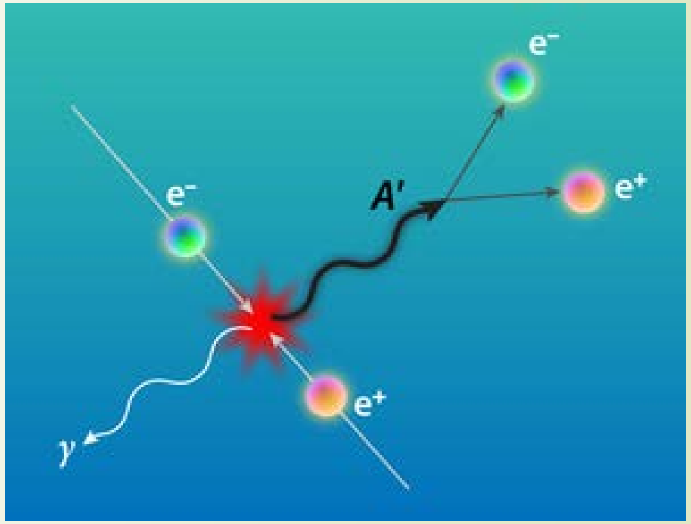
- Should not have to defend this too much…



DM searches at the LHC didn't find anything significant so far

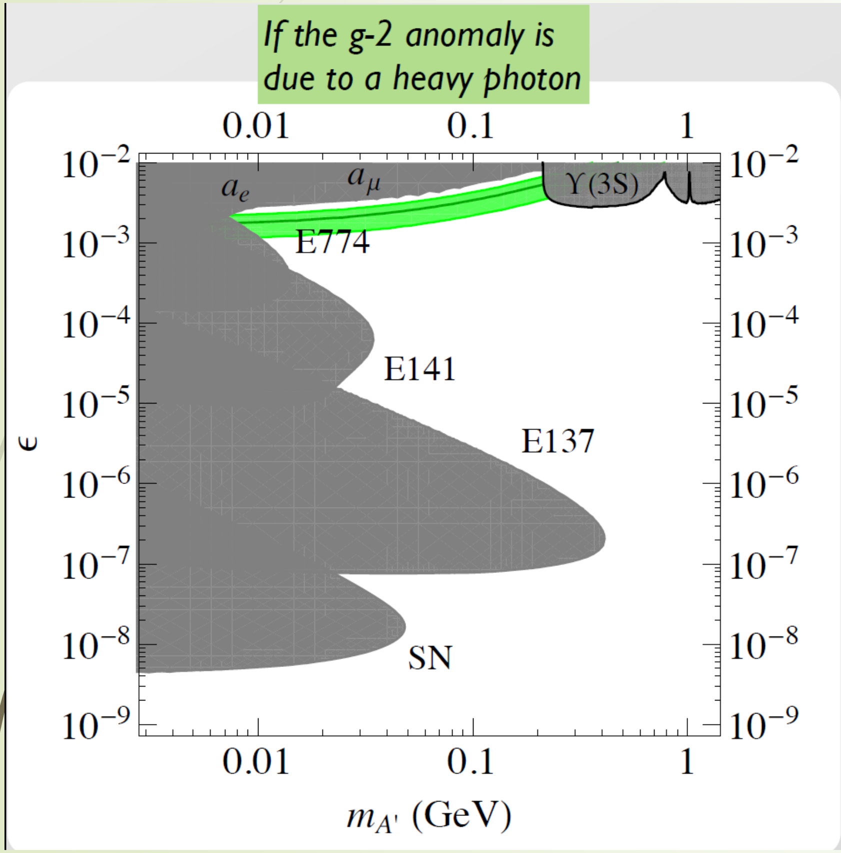
Light, Weakly Interacting DM, the dark photon concept

It is speculated that within dark matter there might be a family of particles and forces—a so-called "dark sector"—that has thus far escaped detection. In analogy with electromagnetism, for which the massless photon is the force carrier between charged particles, there could be a dark electromagnetism with a possibly massive dark photon that transmits the forces between dark particles

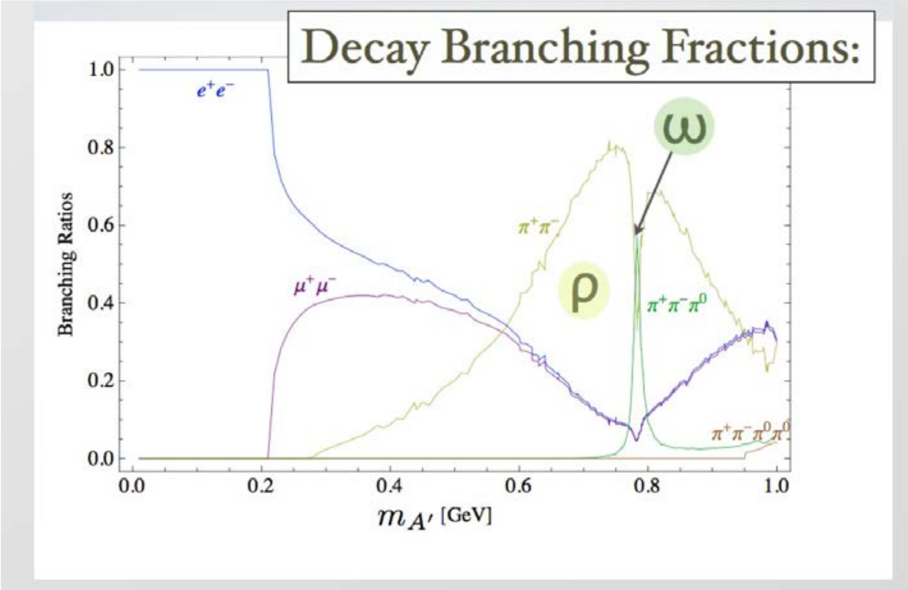


M. Pospelov and A. Ritz, "Astrophysical Signatures of Secluded Dark Matter," Phys. Lett. B **671**, 391 (2009)

Theoretical predictions for the dark photon



Branching ratio



Lifetime

$$\gamma c\tau \propto \left(\frac{10^{-4}}{\epsilon}\right)^2 \left(\frac{100\ \mathrm{MeV}}{m_{A'}}\right)^2$$

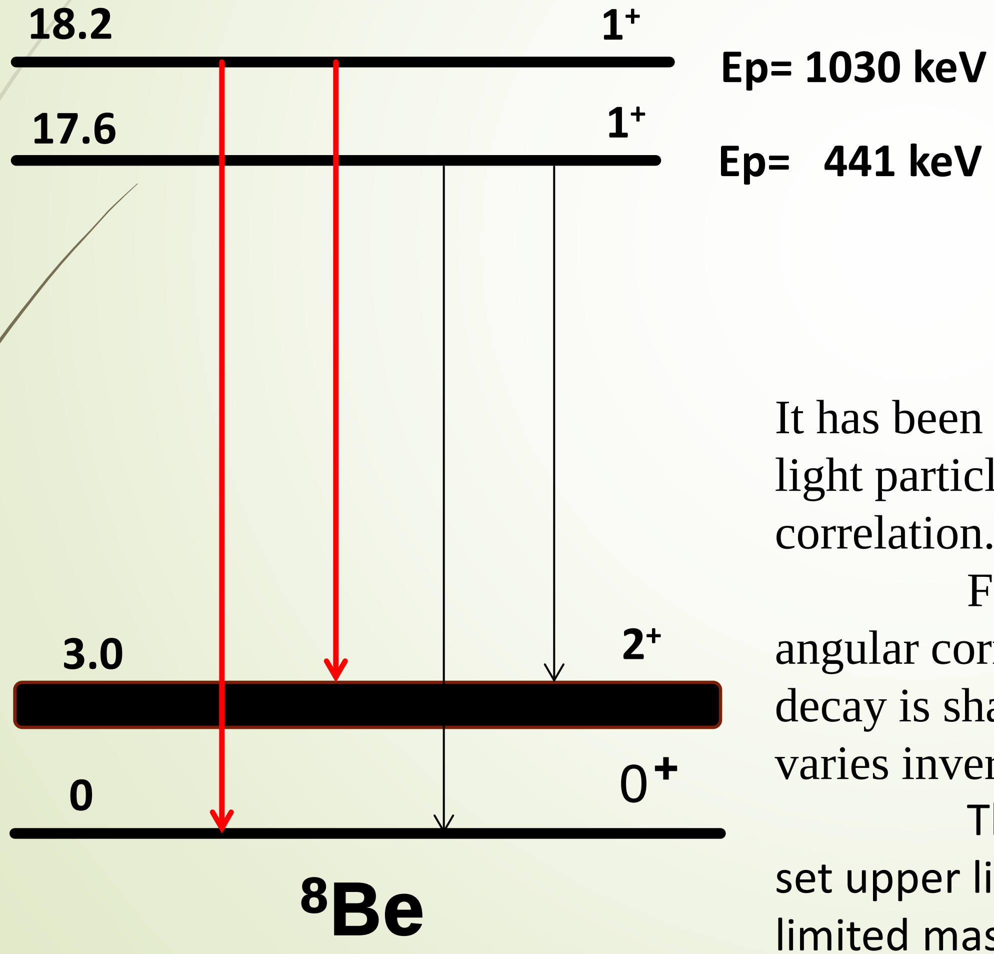
Searching for new particles created in nuclear transitions has a very long history…

(The first activities of Mount Etna started around 600.000 years ago in the inferior Pleistocene.)

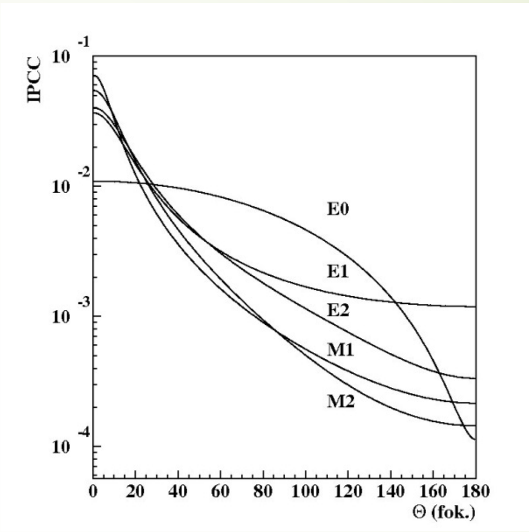
- The axion particle was proposed by Weinberg and by Wilczek as one mechanism for preserving CP invariance of strong interactions in the presence of instantons almost 40 years ago.
- The search for axions in nuclear transitions culminated in 1982.
- It turned out that nuclear transitions provide a useful 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.

Study the ^{8}Be M1 transitions

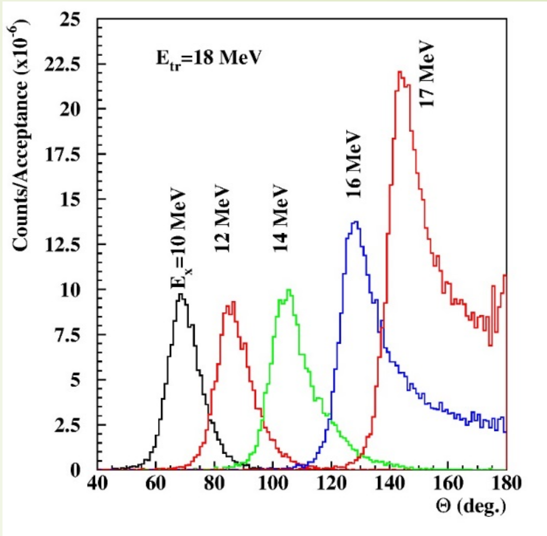
Excitation with the
^{7}Li(p,γ)^{8}Be reaction



Background



Signature

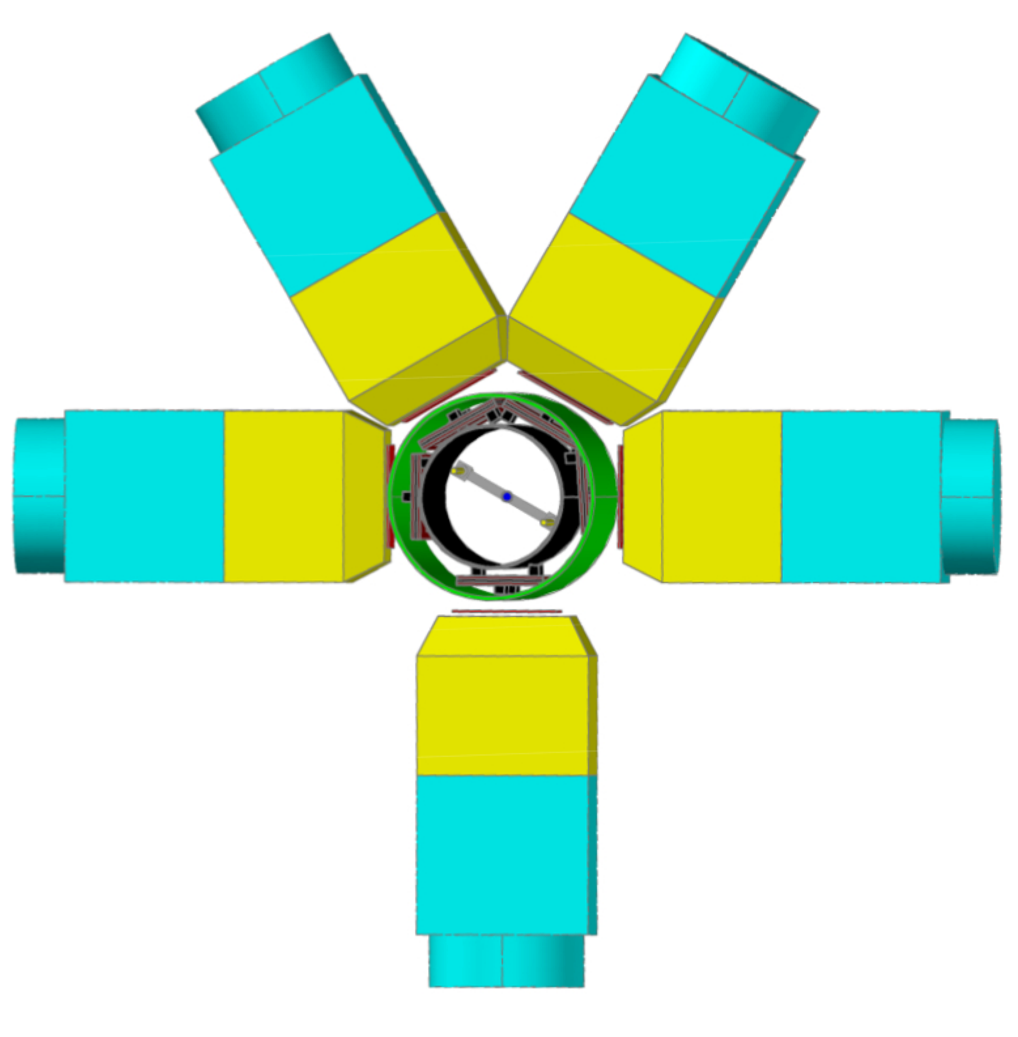


It has been suggested previously that pairs produced from the decay of a light particle can be distinguished from internal pairs by their angular correlation.

For a transition energy significantly larger than M_x, the angular correlation between the electron and positron produced in the X decay is sharply peaked in the laboratory frame at a nonzero angle that varies inversely with the transition energy.

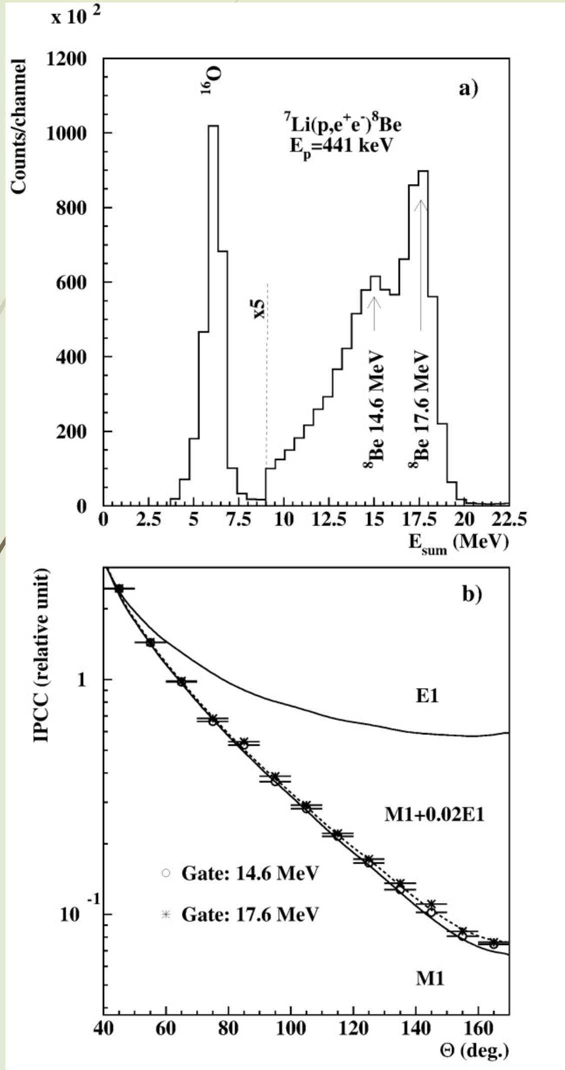
This method has been used previously by several groups to set upper limits on the branching ratio to such particles within certain limited mass and lifetime regions.

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

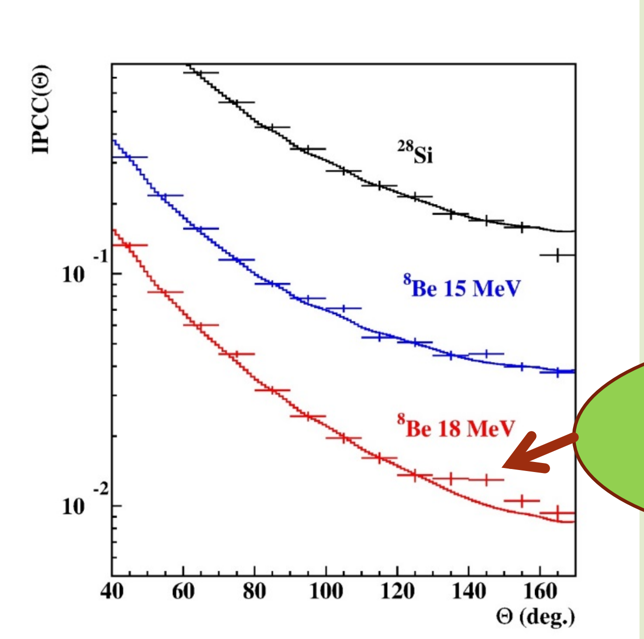


Results

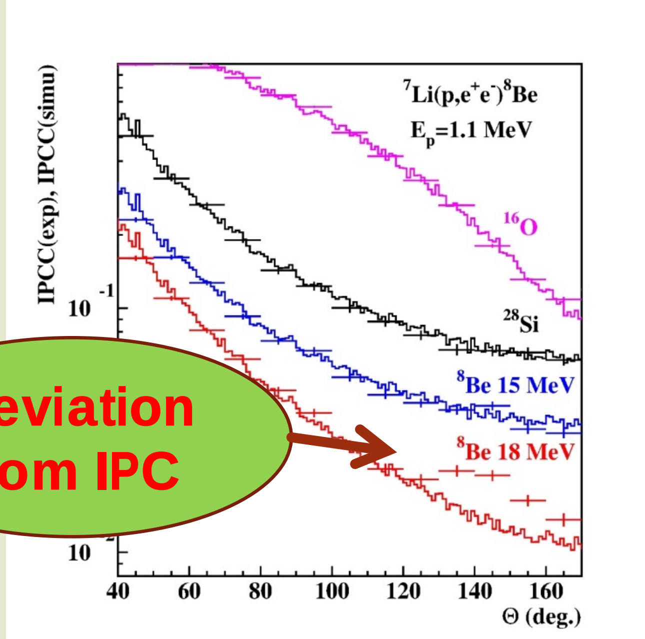
e^+ - e^- sum energy spectra and angular correlations



Ep=1.04 MeV



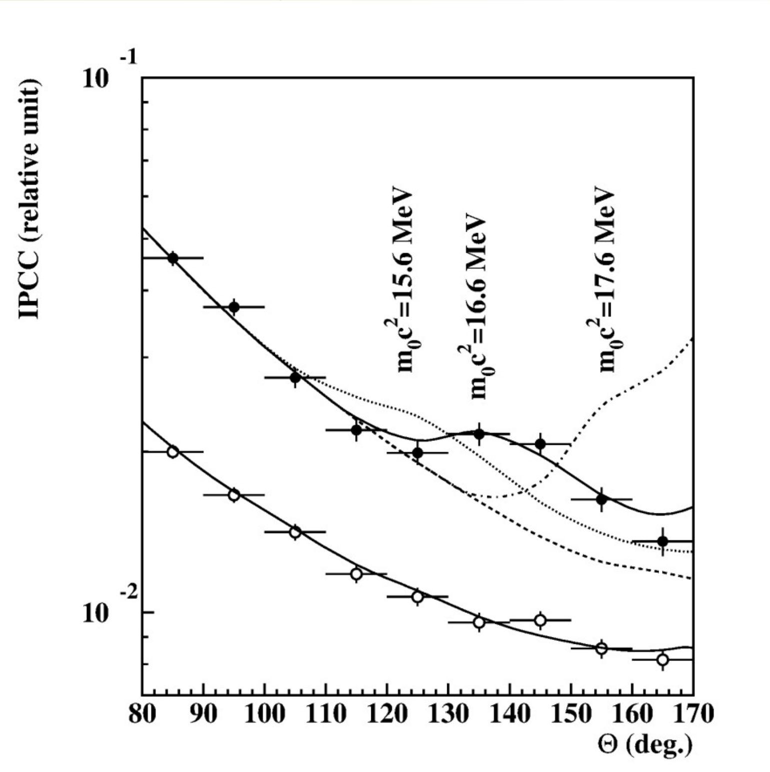
Ep=1.10 MeV

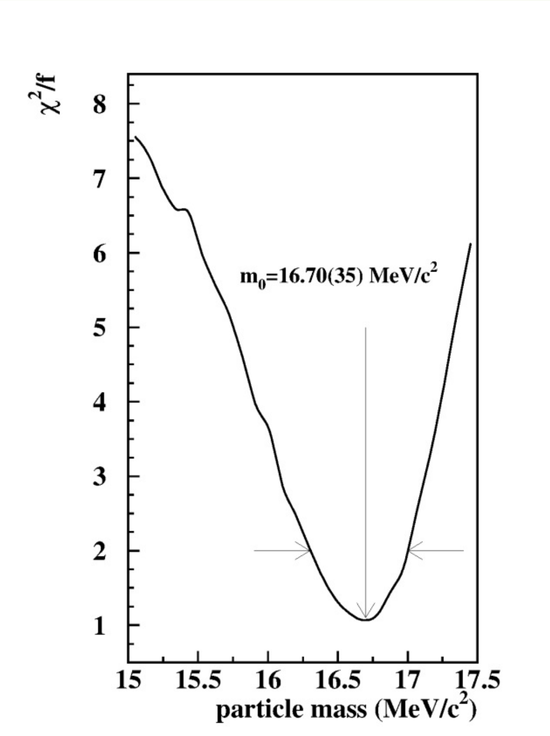


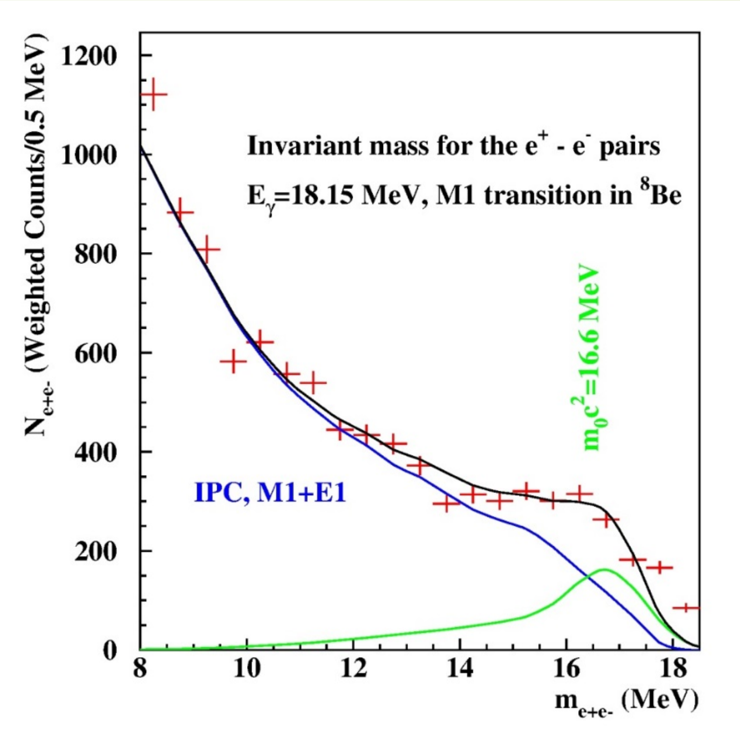
Deviation from IPC

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

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







Experimental angular e^+e^- pair correlations measured in the ^{7}Li(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

Invariant mass distribution plot for the electron-positron pairs

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

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

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

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

$$|\varepsilon_p + \varepsilon_n| \approx 0.011 \qquad |\varepsilon_u + \varepsilon_d| \approx 3.7 \times 10^{-3}$$

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

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

Promising Outlook

IPC:

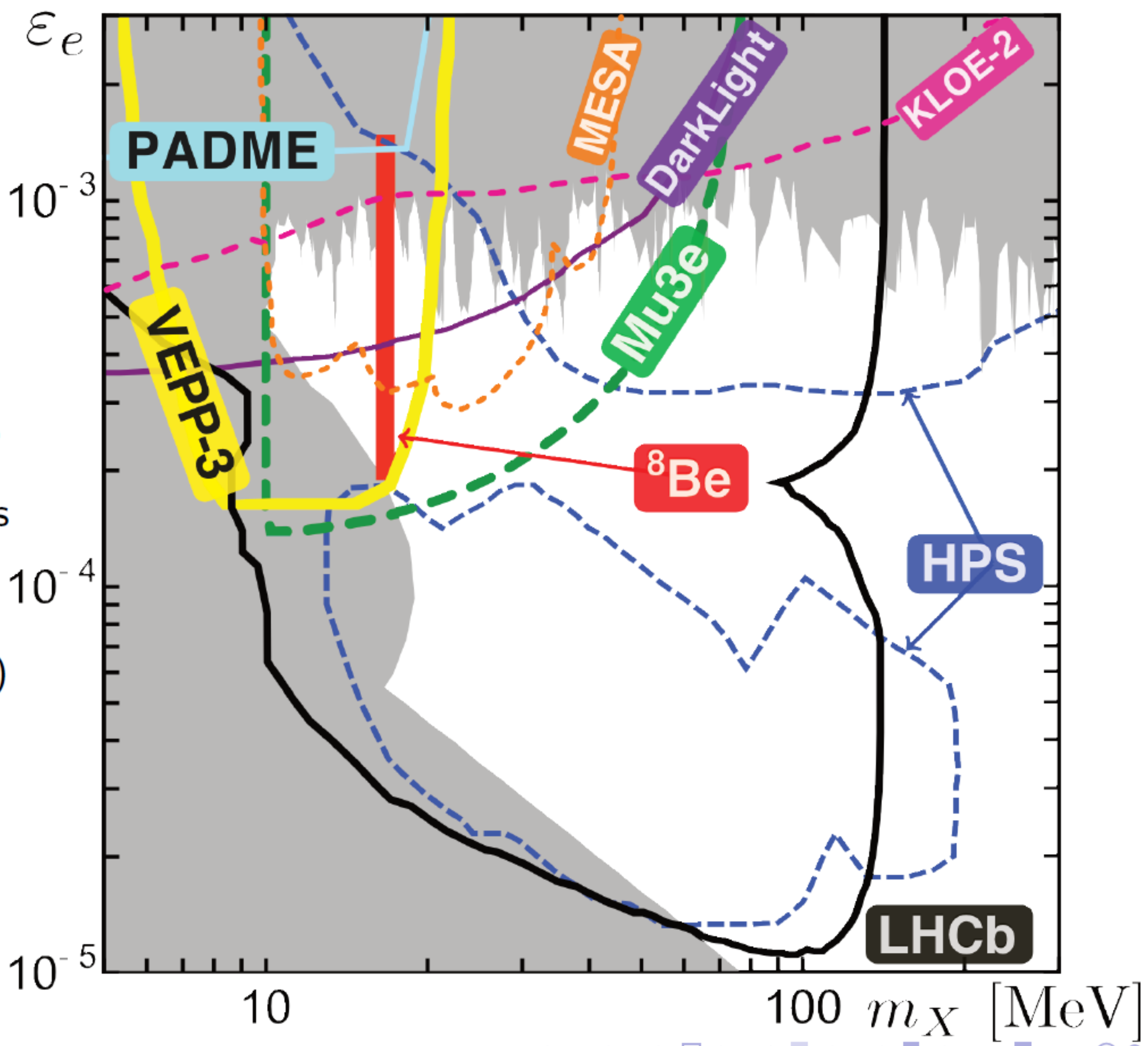
- verify $^{8}\mathrm{Be}$
- $^{10}\mathrm{B}$: 19.3 MeV
- $^{10}\mathrm{Be}$: 17.79 MeV

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

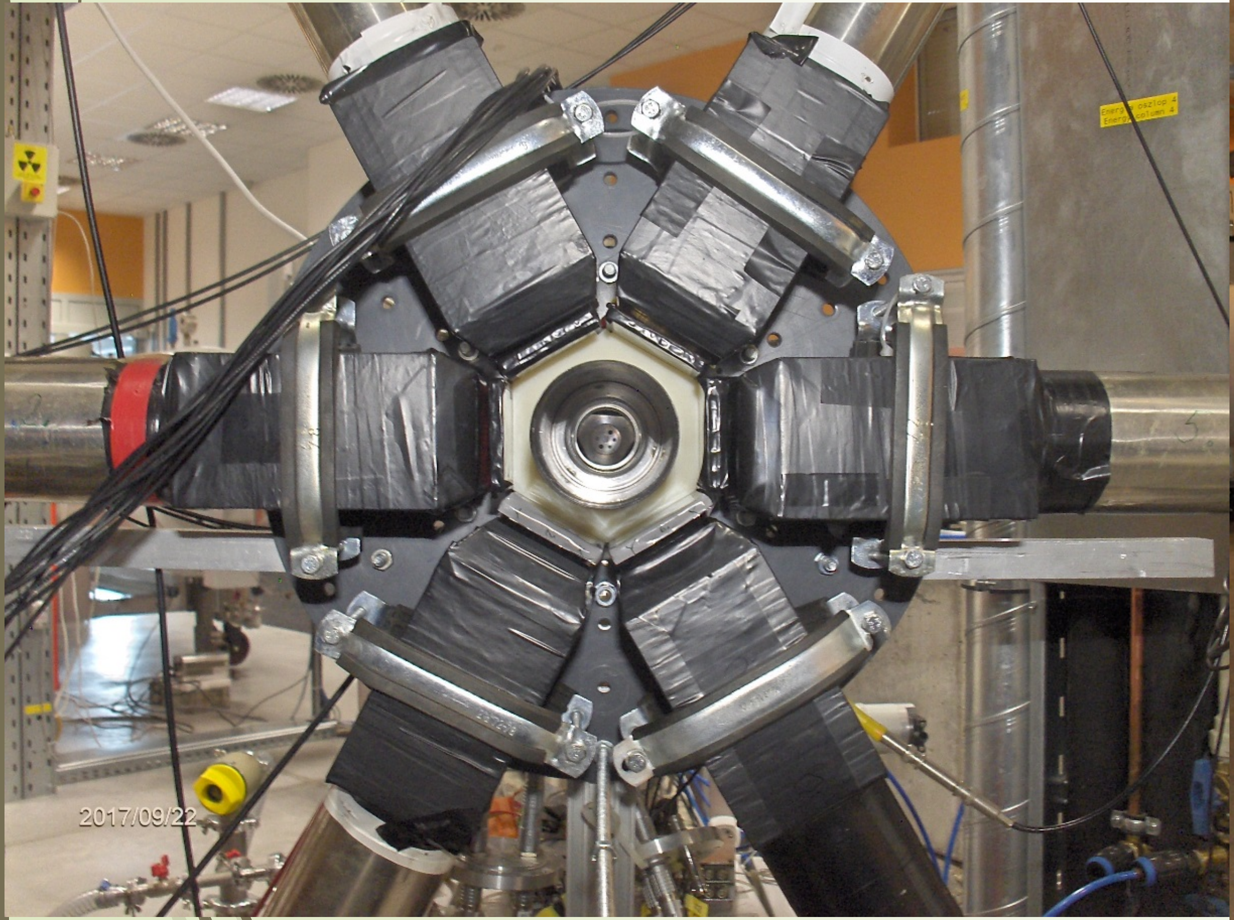


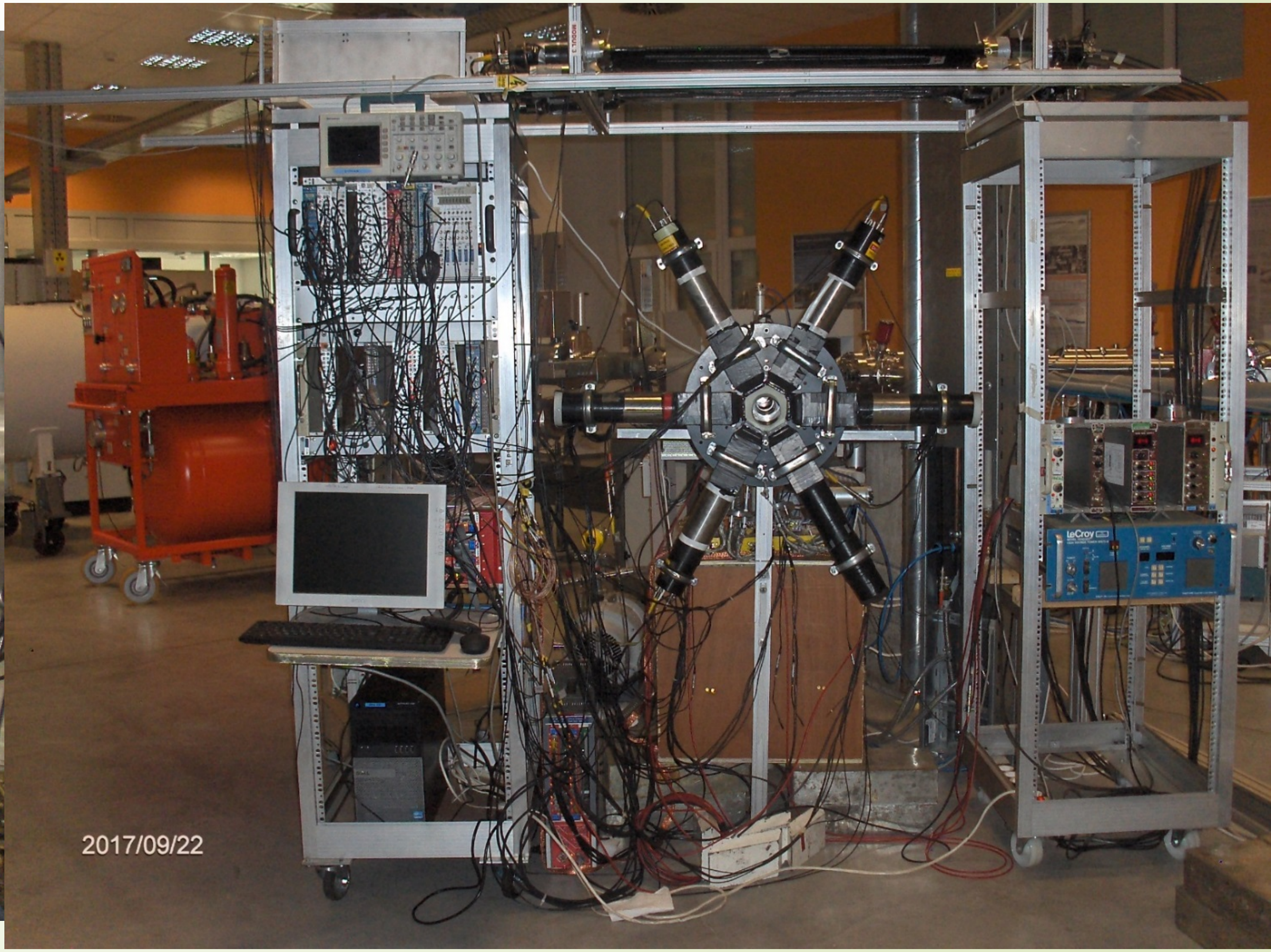
Repeating the experiments at a new Medium-Current Tandetron Accelerator System

Main specifications:

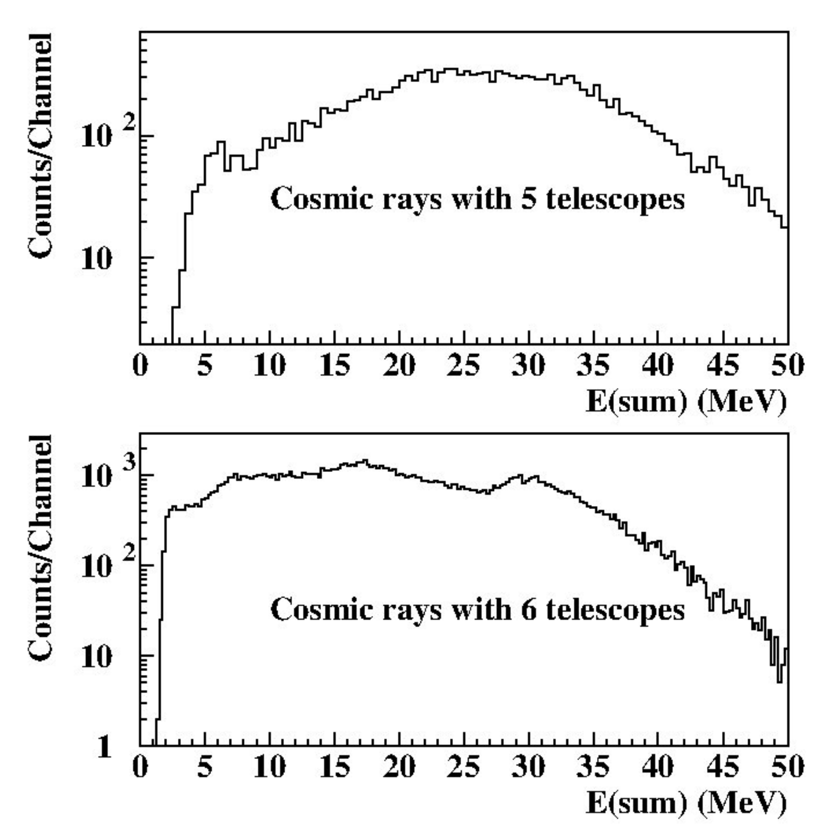
- TV ripple: 25 V_{RMS}, TV stability: 200 V (GVM), 30 V (SLITS)
- Beam current capability at 2 MV: 200 µA proton, 40 µA He

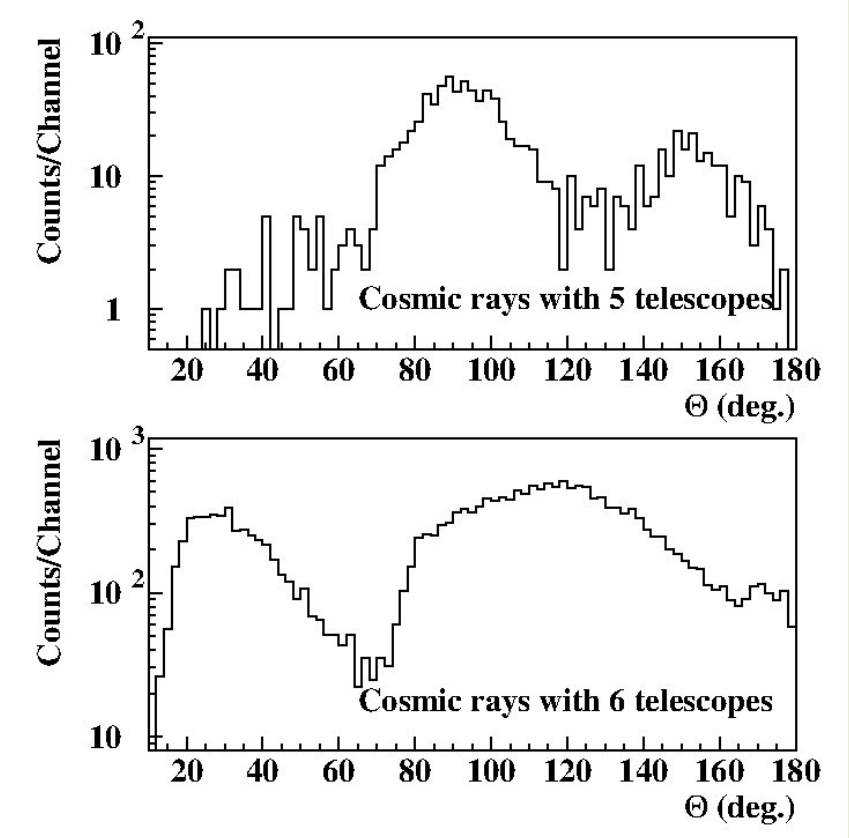
The new e^+e^- pair spectrometer with six telescopes equipped with Si DSSD's



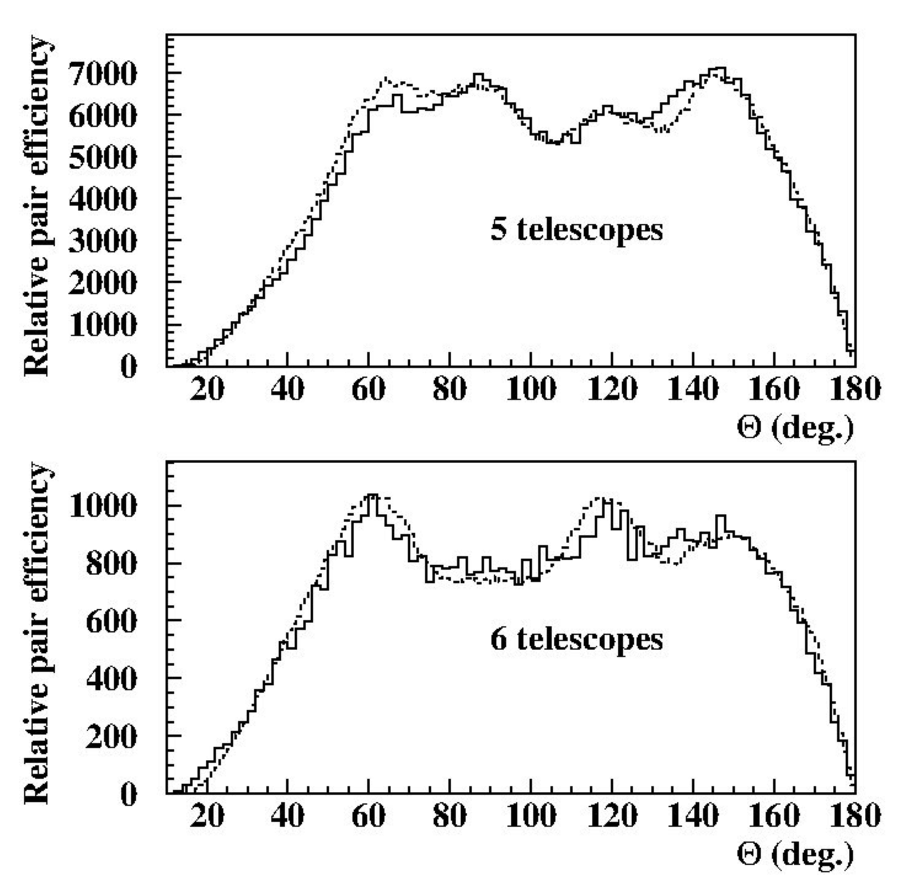


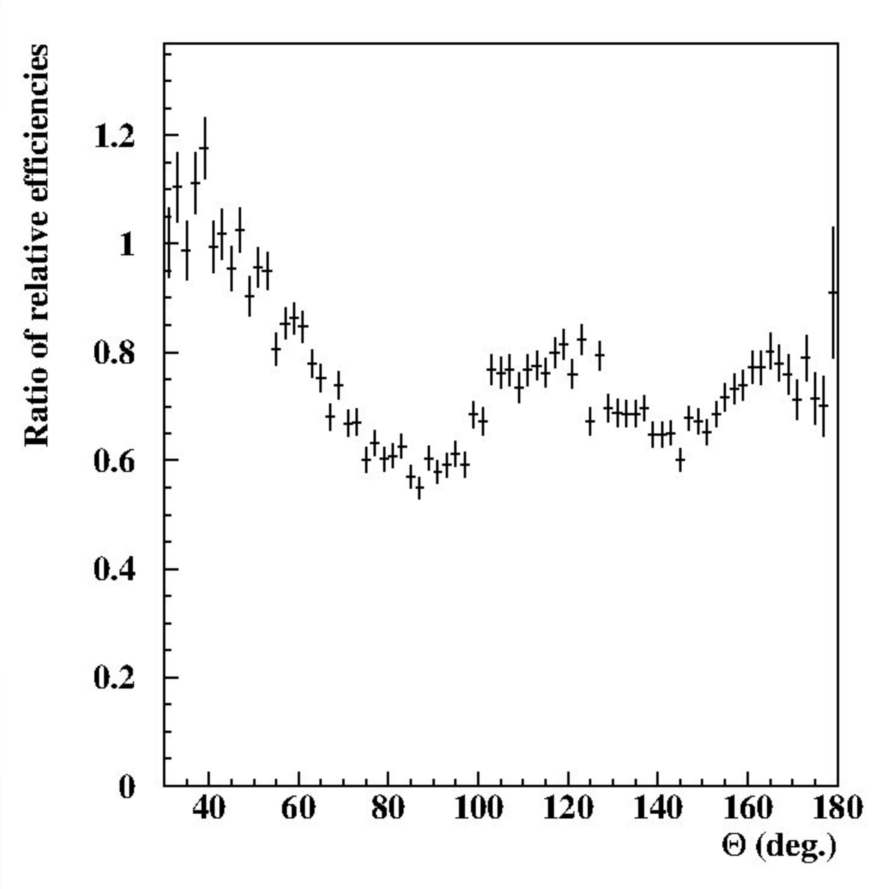
Background from cosmic rays in the setups with 5 and 6 telescopes





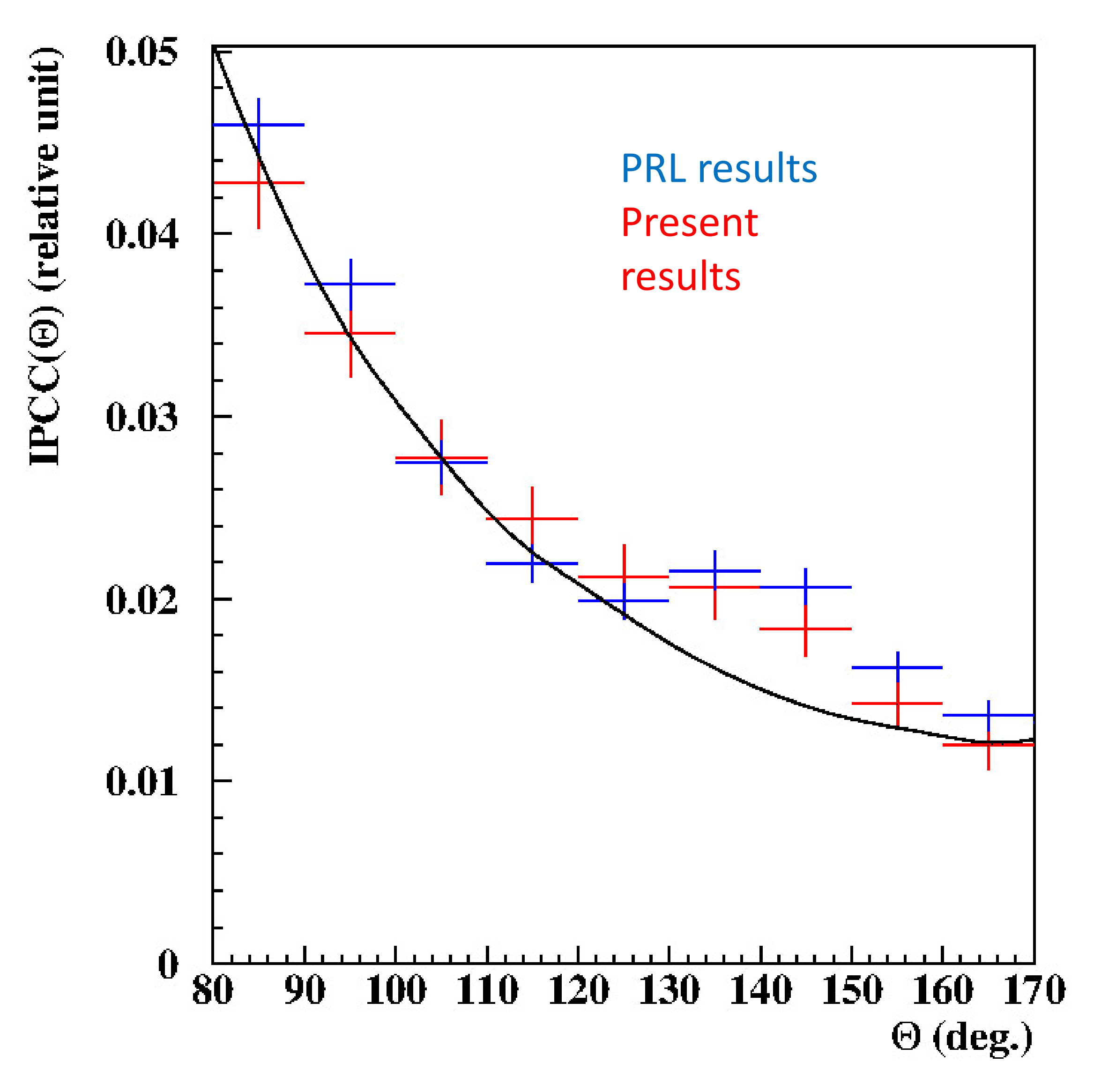
Efficiency curves for the setups with 5 and 6 telescopes



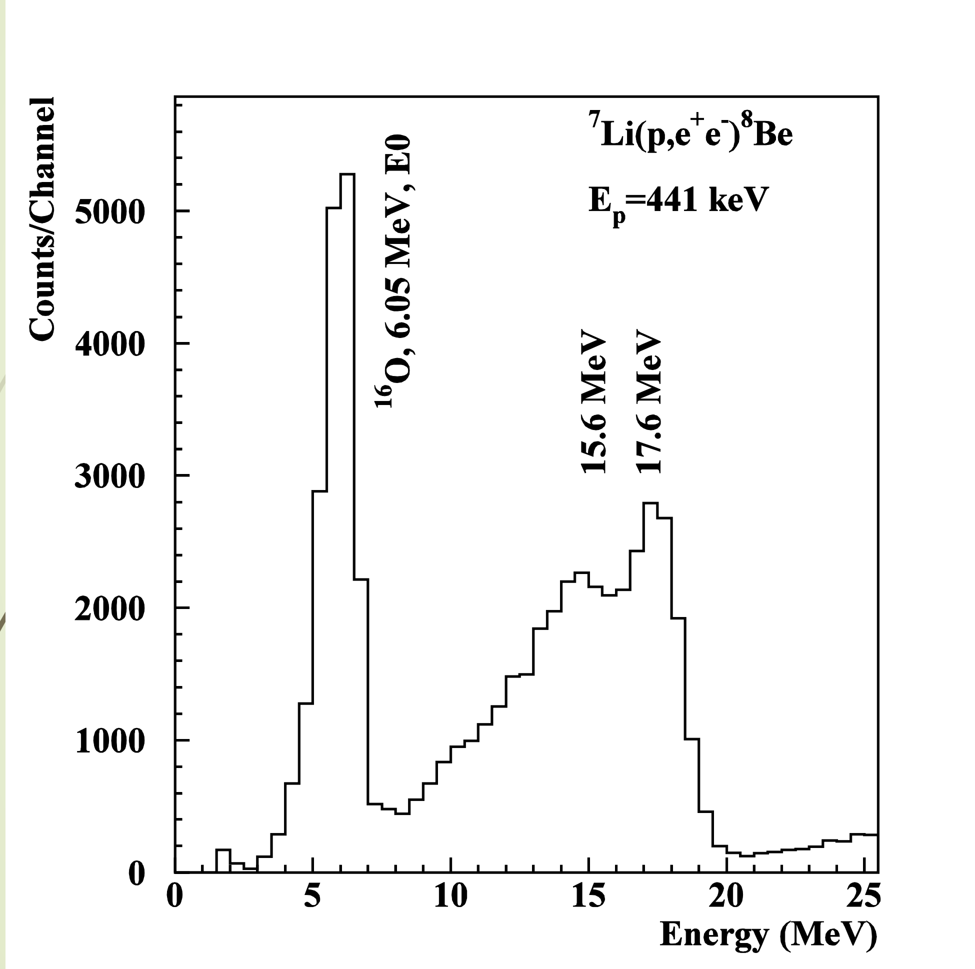


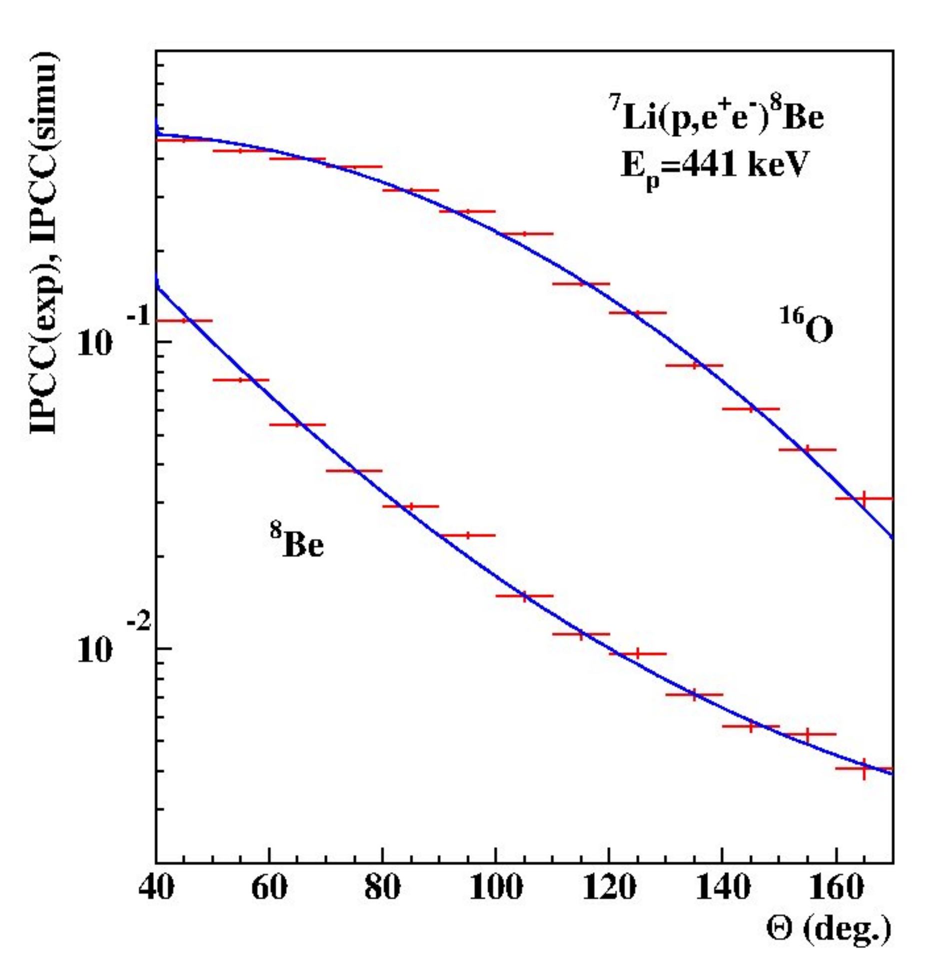
The results of the present experiment can be cosidered independent from the one we published in PRL in 2016.

Recent (preliminary) results for the 18.15 MeV transition



Recent (preliminary) results for the 17.6 MeV transition





Physics Letters B 773 (2017) 159–165

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www.elsevier.com/locate/physletb

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

Xilin Zhang *, Gerald A. Miller

Department of Physics, University of Washington, Seattle, WA 98195, USA

ARTICLE INFO

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ABSTRACT

Recently the experimentalists in Krasznahorkay (2016) [1] announced observing an unexpected enhancement of the e^+–e^- pair production signal in one of the ^{8}Be nuclear transitions. The subsequent studies have been focused on possible explanations based on introducing new types of particle. In this work, we improve the nuclear physics modeling of the reaction by studying the pair emission anisotropy and the interferences between different multipoles in an effective field theory inspired framework, and examine their possible relevance to the anomaly. The connection between the previously measured on-shell photon production and the pair production in the same nuclear transitions is established. These improvements, absent in the original experimental analysis, should be included in extracting new particle's properties from the experiment of this type. However, the improvements can not explain the anomaly. We then explore the nuclear transition form factor as a possible origin of the anomaly, and find the required form factor to be unrealistic for the ^{8}Be nucleus. The reduction of the anomaly's significance by simply rescaling our predicted event count is also investigated.

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,‡]

[1]*Amherst Center for Fundamental Interactions, Department of Physics, University of Massachusetts, Amherst, Massachusetts 01003, USA*

[2]*TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia V6T 2A3, Canada*

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(Received 18 January 2017; published 22 June 2017)

New hidden particles could potentially be emitted and discovered in rare nuclear transitions. In this work, we investigate the production of hidden vector bosons with primarily axial couplings to light quarks in nuclear transitions, and we apply our results to the recent anomaly seen in ^{8}Be decays. The relevant matrix elements for $^{8}\mathrm{Be}^{*}(1^{+}) \to {}^{8}\mathrm{Be}(0^{+})$ transitions are calculated using *ab initio* methods with internucleon forces derived from chiral effective field theory and the in-medium similarity renormalization group. We find that the emission of a light axial vector with mass $m_X \simeq 17$ MeV can account for the anomaly seen in the $1^{+} \to 0^{+}$ isoscalar transition together with the absence of a significant anomaly in the corresponding isovector transition. We also show that such an axial vector can be derived from an anomaly-free ultraviolet-complete theory that is consistent with current experimental data.

More generally, we also find that the Atomki measurements of the ^{8}Be system can provide the most sensitive model-independent probe of the interactions of a light vector with quarks. This motivates future searches for light vector bosons and other particles in rare nuclear transitions.

A viable QCD axion in the MeV mass range

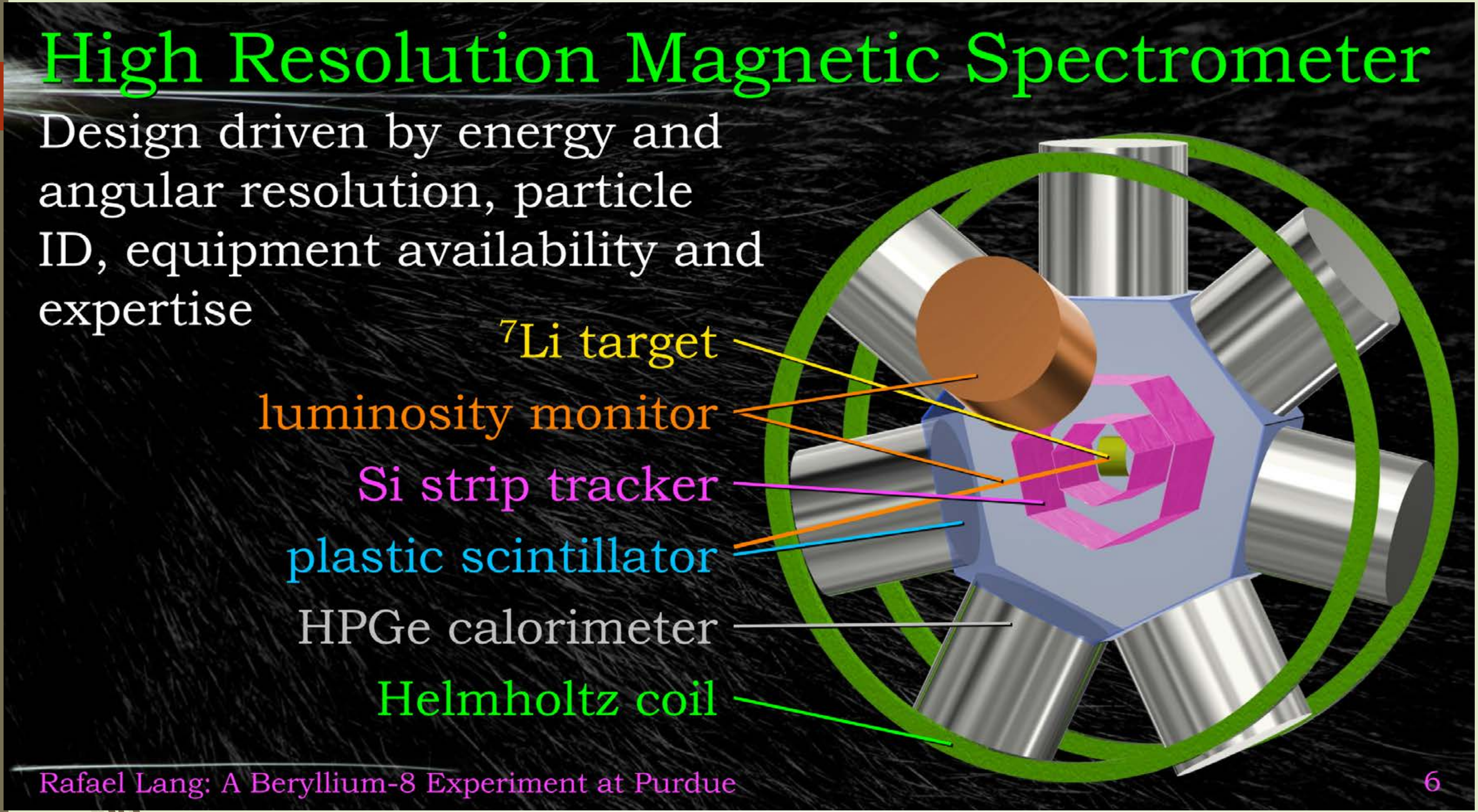
Daniele S. M. Alves[1,2,3,*] and Neal Weiner[1,†]

[1]*Center for Cosmology and Particle Physics,*
Department of Physics, New York University, New York, NY 10003
[2]*Department of Physics, Princeton University, Princeton, NJ 08544*
[3]*Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA*

(Dated: October 12, 2017)

X. DISCUSSION

A short-lived, *pion-phobic* QCD axion with mass of several MeV might still offer a viable solution to the strong CP problem. Constraints that have excluded generic MeV axions can be evaded by coupling the axion exclusively to the first generation of SM fermions. Bounds from $K^+ \to \pi^+ a$, previously believed to be severe, in fact suffer from large hadronic uncertainties and are currently sufficiently ambiguous to experimentally allow portions of the axion parameter space.


High Resolution Magnetic Spectrometer
Design driven by energy and angular resolution, particle ID, equipment availability and expertise
7Li target
luminosity monitor
Si strip tracker
plastic scintillator
HPGe calorimeter
Helmholtz coil
Rafael Lang: A Beryllium-8 Experiment at Purdue
6

Experimental searches for the X(17) boson

- **The ATLAS Collaboration** (ATLAS NOTE ATLAS-CONF-2016-042) presented results of a search for long-lived neutral particles decaying into collimated jets of light leptons and mesons, so-called “lepton-jets”, using a sample of 3.4 fb^{-1} of proton-proton collisions data at a center-of-mass energy of $\sqrt{s}$=13 TeV collected during 2015 with the ATLAS detector at the LHC. Assuming conventional production cross section σ·BR to the dark sector of 5.0 pb for a 800 GeV heavy scalar boson, dark photon cτ is excluded in the range 0.6 mm <cτ< 63 mm for the Higgs → $2\gamma_d$+ X model and in the range 0.8 mm <cτ< 186 mm for the Higgs → $4\gamma_d$+ X model.

$$c\tau_{A' \to e^+e^-} \simeq 0.8\,\mathrm{mm} \left(\frac{10^{-4}}{\epsilon}\right)^2 \frac{10\,\mathrm{MeV}}{m_{A'}}$$

- $2\times10^{-4} < \varepsilon_e < 1{,}4\times10^{-3}$ esetén → 2.5 μm <cτ< 120 μm
- Our results are not affected.

The **DarkLight** experiment at JLAB

- The DarkLight experiment proposes to search for dark photon through complete reconstruction of the final states of electron–proton collisions. In order to accomplish this, the experiment requires a moderate-density target and a very high intensity, low energy electron beam.
- Projected reaches in mass and coupling for upcoming experiments near the Beryllium-8 anomaly. Note that these are taken in the fully protophobic limit, so the sensitivities of experiments that search for the dark photon through hadronic probes are heavily suppressed. The DarkLight projection marks the region where an anomaly yields a 5σ with 1 ab^{-1} of data, which is readily achievable with anticipated luminosities.

Searching for the X(17) in particle decays

- Araki et al, (Phys. Rev. D 95, 055006 (2017)) discussed the feasibility of detecting the gauge boson of the U(1) symmetry, which possesses a mass in the range between MeV and GeV, at the **Belle-II experiment**. They have found that the Belle-II experiment with the design luminosity can examine a part of the parameter region that evades the current experimental constraints and, at the same time, is favored by the observation of the muon anomalous magnetic moment.
- Rare leptonic kaon and pion decays $K^+(\pi^+) \rightarrow \mu^+ \nu_\mu e^+ e^-$ can also be used to probe a dark photon of mass O(10)MeV. Cheng-Wei Chiang (Physics Letters B 767 (2017) 289) evaluated the reach of future experiments for the dark photon with vectorial couplings to the standard model fermions except for the neutrinos, and show that a great portion of the preferred 16.7-MeV dark photon parameter space can be decisively probed.

Data mining and new projects

- Long-Bin Chen et al., (arXiv:1607.03970v2) discussed, the production of this yet-not-verified new boson in electron-positron collision, using BaBar, and the results are encouraging. The data collected at **BESIII and BaBar** turn out to be enough to perform a decisive analysis and hence give a definite answer to the existence of X(16.7).
- Marin Benito et al., (IOP Conf. Series: Journal of Physics: Conf. Series **800** (2017) 012031) discussed the prospects for the search of $K_S^0 \rightarrow \pi^+\pi^- e^+ e^-$ at LHCb. **LHCb has proved to be very competitive in the search for such rare strange decays.** The feasibility of observing such K0 decay at LHCb is studied using simulated and real data. During the Run I of LHC (2012), the yield of events expected per fb^{-1} of pp collisions at $\sqrt{s}$= 8 TeV is found to be N_{Run1} =120+280-100. A dedicated trigger selection has been developed for the 2016 data-taking. A large signal yield, $N_{Upgrade}$= $(5\pm0.3)\cdot10^4$ per fb^{-1}, is expected in the LHC upgrade phase. Pseudo experiments have been run to assess the feasibility of discovering evidence for the observation of the signal already in the Run I data-set.

A NEW EXPERIMENT SEARCHING FOR DARK MATTER AT CERN ...

The Dark Sector Experiment

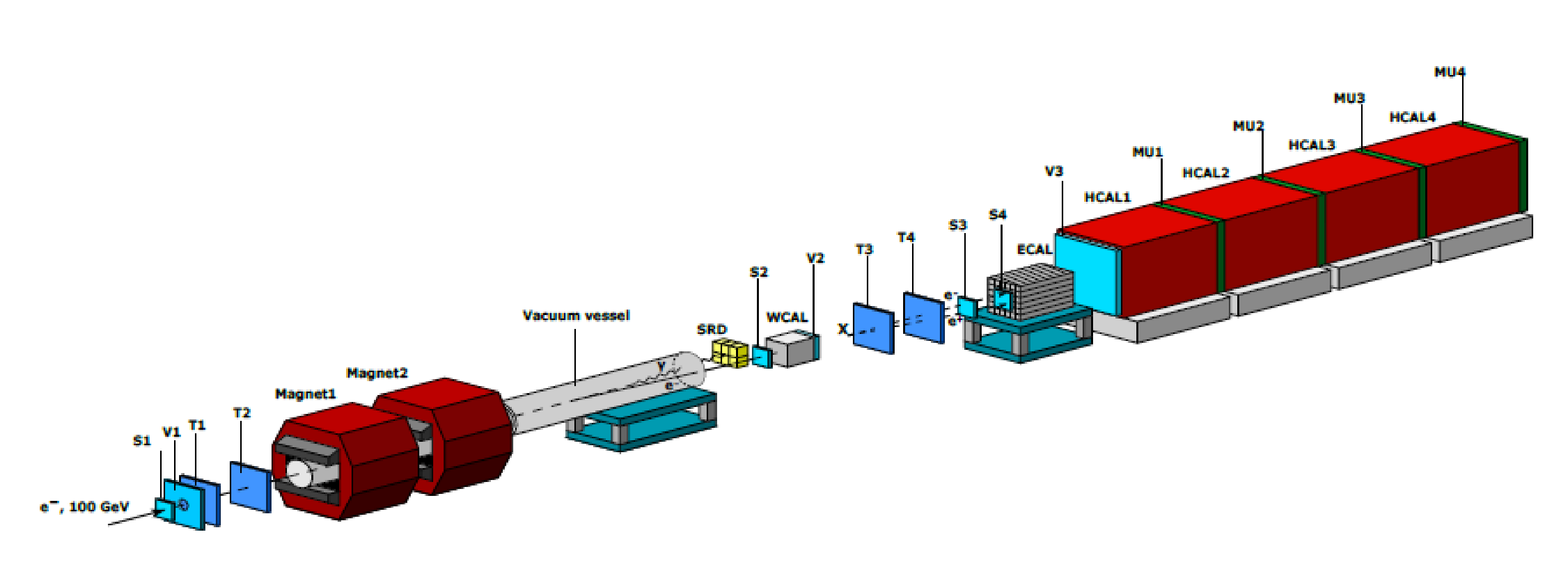
NA64 Analysis Note

CERN

NA64-17-02-v2
March 20, 2017

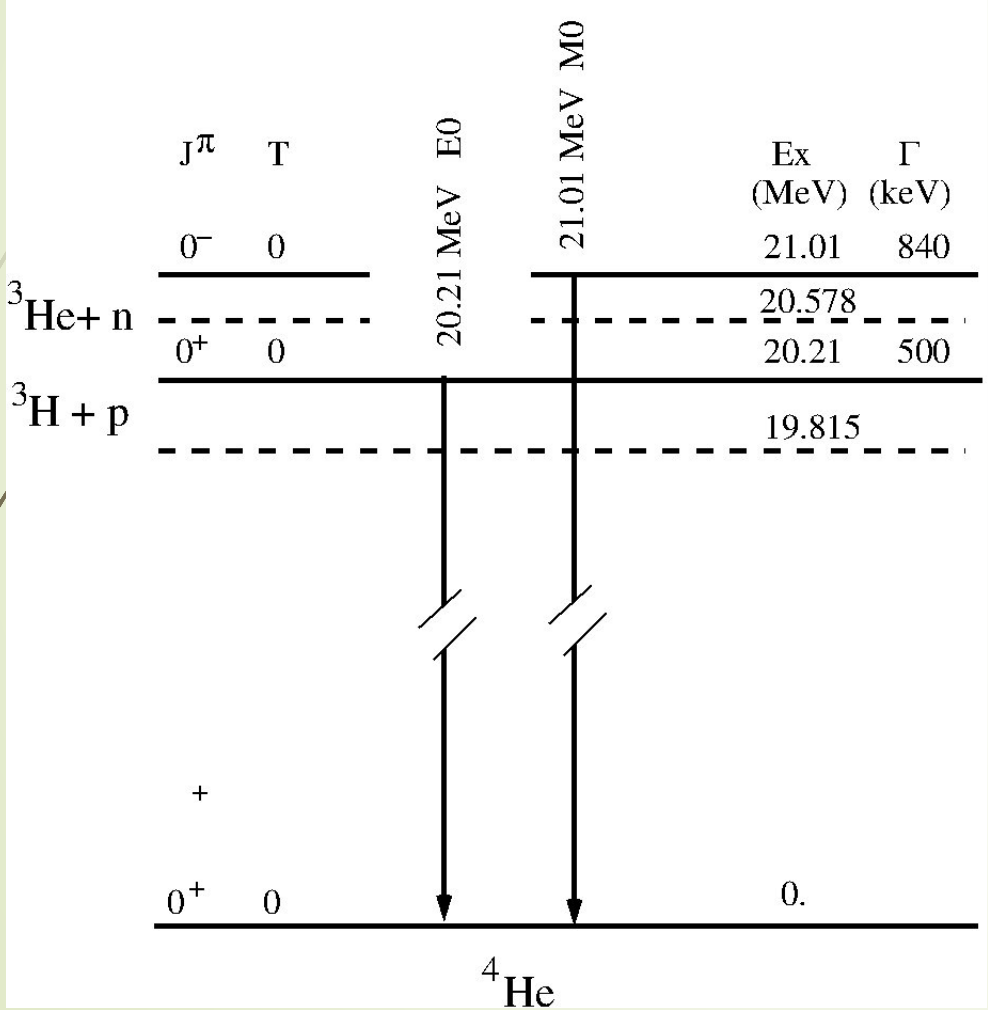
The ^{8}Be excess and search for the $X \to e^+e^-$ decay of a new light boson with NA64

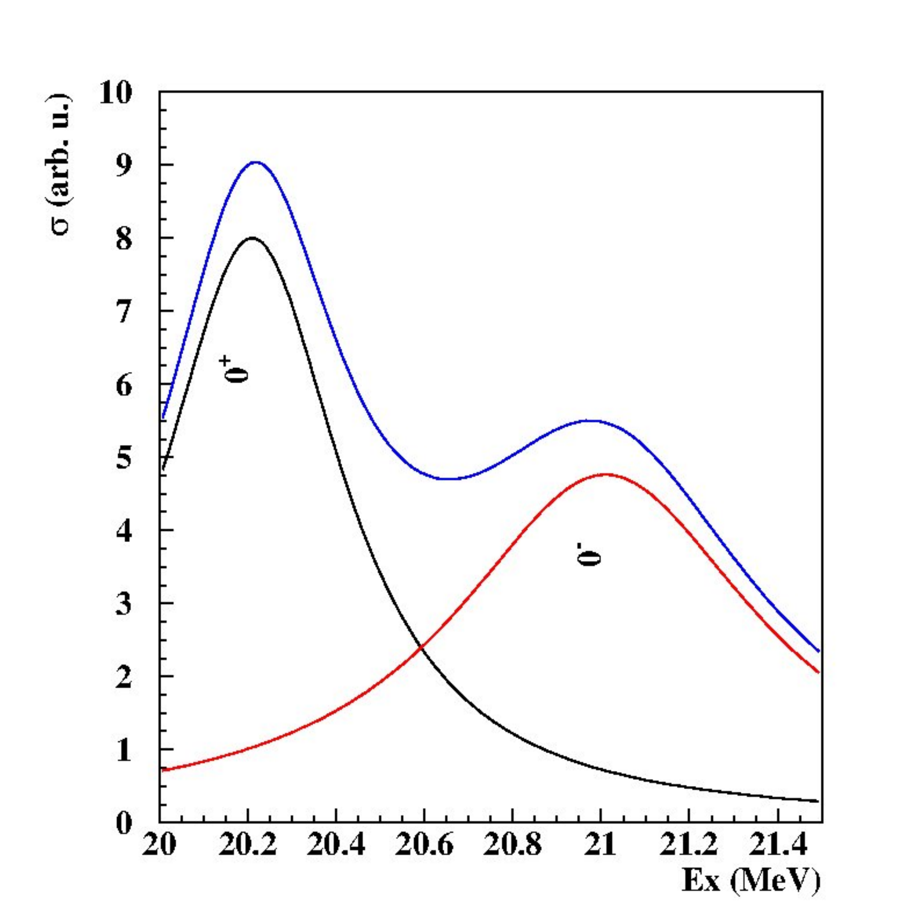
S.V. Donskov, S.N. Gninenko, M.M. Kirsanov, D.V. Kirpichnkov



https://www.youtube.com/watch?v=J1P5r3IvVrM

Our next experiment: Study of the 21.01 MeV M0 transition in ^4He excited by ^3He+n, and t+p reactions





Study the $\gamma\gamma$-decay of X(17) in ^4He

- Vector particle (1+) or axialvector (0-)? If axialvector than it can decay by $\gamma\gamma$ emission.

- $\gamma\gamma$-decay only known in a special case: $0^+ \rightarrow 0^+$ (^{90}Zr, ^{40}Ca, ^{16}O) ^4He
  - *J. Schirmer et al., PRL 53, 1897 (1984)*
  - *J. Kramp et al., NPA 474, 412 (1987)*
- Walz, N. Pietrala et al., Competitive Double-Gamma' ($\gamma\gamma/\gamma$) Decay *Nature* **526**, 406 (2015)

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

Study the angular correlation with $LaBr_3$ detectors.

To ^{8}Be continued...

Thank you very much for your attention