On the track of the dark forces

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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 $16.70 \pm 0.35(\mathrm{stat}) \pm 0.5(\mathrm{syst})\ \mathrm{MeV}/c^2$ and $J^{\pi} = 1^{+}$ was created.

UCI-TR-2016-09

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

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Recently a 6.8σ anomaly has been reported in the opening angle and invariant mass distributions of e^+e^- pairs produced in ^{8}Be nuclear transitions. The data are explained by a 17 MeV vector gauge boson X that is produced in the decay of an excited state to the ground state, $^8\text{Be}^* \to {}^8\text{Be}\,X$, and then decays through $X \to e^+e^-$. The X boson mediates a fifth force with a characteristic range of 12 fm and has milli-charged couplings to up and down quarks and electrons, and a proton coupling that is suppressed relative to neutrons. The protophobic X boson may also alleviate the current 3.6σ discrepancy between the predicted and measured values of the muon's anomalous magnetic moment.

PACS numbers: 14.70.Pw, 27.20.+n, 21.30.-x, 12.60.Cn, 13.60.-r

Introduction. The four known forces of nature, the electromagnetic, weak, strong, and gravitational interactions, are mediated by the photon, the W and Z bosons, the gluon, and the graviton, respectively. The possibility of a fifth force, similarly mediated by an as-yet-unknown gauge boson, has been discussed [1] since shortly after the introduction of Yang-Mills gauge theories, and has a rich, if checkered, history [2]. If such a force exists, it must either be weak, or short-ranged, or both to be consistent with the wealth of experimental data. In recent years, interest in this possibility has been heightened by the obvious need for dark matter, which has motivated new particles and forces in a dark or hidden sector that may mix with the visible sector and naturally induce a weak fifth force between the known particles.

Recently, studies of decays of an excited state of ^{8}Be to its ground state have found a 6.8σ anomaly in the opening angle and invariant mass distribution of e^+e^- pairs produced in these transitions [3]. The discrepancy from expectations may be explained by as-yet-unidentified nuclear reactions or experimental effects, but the observed distribution is beautifully fit by assuming the production of a new boson. In this work, we advance the new particle interpretation, carefully considering the putative signal and the many competing constraints on its properties, and present a viable proposal for the new boson and the fifth force it induces.

The ^{8}Be Decay Anomaly. The ^{8}Be nuclear excitation spectrum is precisely known [4]. For this discussion, the most relevant ^{8}Be nuclear states and their properties are given in Table I. To simplify our notation, we use the given symbols to denote specific states. The ground state atomic mass is 8.005305 u $\simeq$ 7456.89 MeV; the ground state nuclear mass listed in Table I is about $4m_e$ below this. There are also several unlisted broad resonance excited states both above and below $^8\text{Be}^*$ and $^8\text{Be}^{*\prime}$ with widths as large as several MeV.

In the experiment of Krasznahorkay *et al.* [3], an intense proton beam impinges on thin ^{7}Li targets. Given

TABLE I. Relevant ^{8}Be states and their masses, decay widths, and spin-parity and isospin quantum numbers.

State	Mass (MeV)	Width (keV)	J^P	Isospin
$^8\text{Be}^*$ (18.15)	7473.00	138	1^+	0
$^8\text{Be}^{*\prime}$ (17.64)	7472.49	10.7	1^+	1
^{8}Be (g.s.)	7454.85	—	0^+	0

the ^{7}Li nucleus mass of 6533.83 MeV, the $^8\text{Be}^*$ and $^8\text{Be}^{*\prime}$ states are resonantly produced by tuning the proton kinetic energies to 1.025 and 0.441 MeV, respectively. The resulting excited states then decay promptly, dominantly back to $p\,^7$Li, but also through rare electromagnetic processes. For $^8\text{Be}^*$, radiative decay to the ground state has branching ratio $B(^8\text{Be}^* \to {}^8\text{Be}\,\gamma) \approx 1.4 \times 10^{-5}$, and there are also decays via internal pair conversion (IPC) with branching ratio $B(^8\text{Be}^* \to {}^8\text{Be}\,e^+e^-) \approx 3.9 \times 10^{-3} B(^8\text{Be}^* \to {}^8\text{Be}\,\gamma) \approx 5.5 \times 10^{-8}$ [5].

For the IPC decays, one can measure the opening angle Θ between the e^+ and e^- and also the invariant mass $m_{e^+e^-}$. One expects these distributions to be sharply peaked at low values of Θ and $m_{e^+e^-}$ and fall smoothly and monotonically for increasing values. This is not what is seen in the $^8\text{Be}^*$ decays. Instead, there are pronounced bumps at $\Theta \approx 140°$ and at $m_{e^+e^-} \approx 17$ MeV [3]. The experimental analysis fits the contributions from nearby broad resonances, but these cannot reproduce the shape of the observed excesses. The deviation has a significance of 6.8σ, corresponding to a background fluctuation probability of 5.6×10^{-12} [3]. The excess is maximal on the $^8\text{Be}^*$ resonance and disappears as the proton beam energy is moved off resonance. No such effect is seen in $^8\text{Be}^{*\prime}$ IPC decays.

The fit may be improved by postulating a new boson X that is produced on-shell in $^8\text{Be}^* \to {}^8\text{Be}\,X$ and decays promptly via $X \to e^+e^-$. The authors of Ref. [3] have simulated this process, including the detector energy resolution, which broadens the $m_{e^+e^-}$ peak significantly [6]. They find that the observed excess's shape and

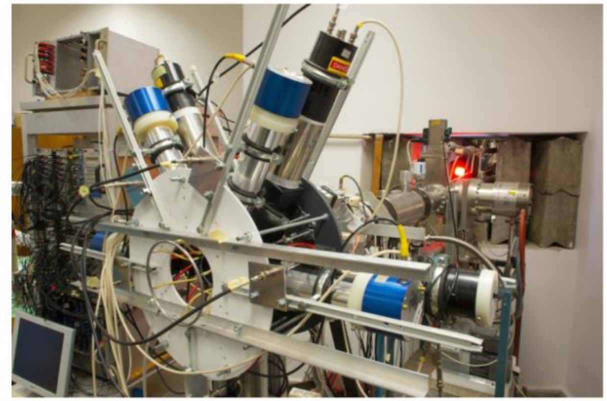
NATURE | NEWS

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.

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

Four days later, two of Feng's colleagues discussed the finding at a workshop at the SLAC National Accelerator Laboratory in Menlo Park, California. Researchers there were sceptical but excited about the idea, says Bogdan Wojtsekhowski, a physicist at the Thomas Jefferson National Accelerator Facility in Newport News, Virginia. "Many participants in the workshop are 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.

Search for new forces

Gravity, electromagnetism and the strong and weak nuclear forces are the four fundamental forces known to physics — but researchers have made many as-yet unsubstantiated claims of a fifth. Over the past decade, the search for new forces has ramped up because of the inability of the standard model of particle physics to explain dark matter — an invisible substance thought to make up more than 80% of the Universe's mass. Theorists have proposed various exotic-matter particles and force-carriers, including "dark photons", by analogy to conventional photons that carry the electromagnetic force.

Freefall space cubes are test for gravitational wave spotter

Krasznahorkay says his group was searching for evidence of just such a dark photon – but Feng's team think they found something different. The Hungarian team fired protons at thin targets of lithium-7, which created unstable beryllium-8 nuclei that then decayed and spat out pairs of electrons and positrons. According to the standard model, physicists should see that the number of observed pairs drops as the angle separating the trajectory of the electron and positron increases. But the team reported that at about 140º, the number of such emissions jumps — creating a 'bump' when the number of pairs are plotted against the angle — before dropping off again at higher angles.

Outline

- Introduction: the light dark matter
- Previous results and new plans
- The internal pair creation process
- Electron-positron decay of an assumed new particle
- Our electron-positron spectrometer
- Monte-Carlo simulations
- Experimental results
- On the possible interference effects
- Conclusion

The light, the Sun and our visible world

Ra/Re is the ancient Egyptian god of the sun. By the Fifth Dynasty in the 25th and 24th centuries BC, he had become a major god in ancient Egyptian religion, identified primarily with the noon sun.

Question:

Is the mass in the universe all observable through emmission or absorbsion of electromagnetic radiation ?

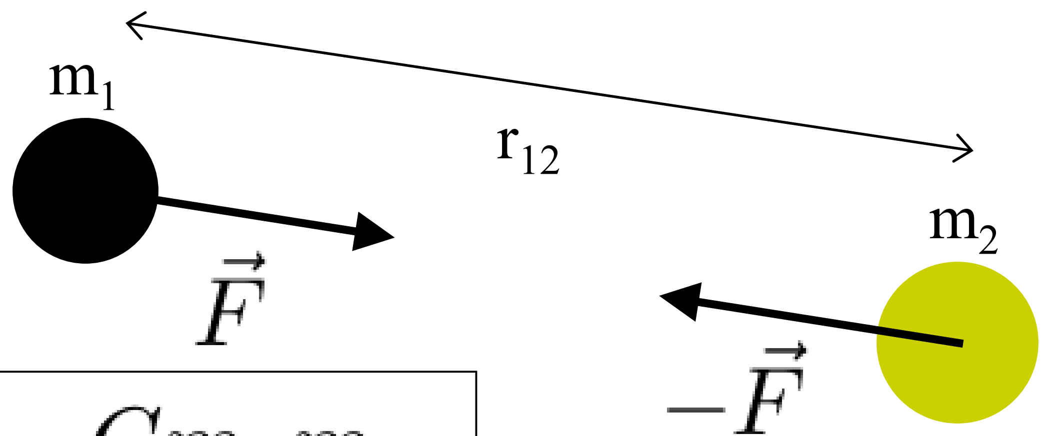
Dark Matter

...is matter that does not shine or absorb light, and has therefore escaped direct detection by electromagnetic transducers like telescopes, radio antennas, x-ray satellites...

It turns out that there is strong experimental evidence that there is more than 4 times as much dark matter as luminous matter in the observable universe

Evidence for Dark Matter

Use the fact that massive objects, even if they emit no light, exert gravitational forces on other massive objects.



$$\left|\vec{F}\right| = \frac{G m_1 m_2}{r_{12}^2}$$

Study the motions (dynamics) of visible objects like stars in galaxies, and look for effects that are not explicable by the mass of the other light emmitting or absorbing objects around them.

Rotation of Stars around Galactic Centres

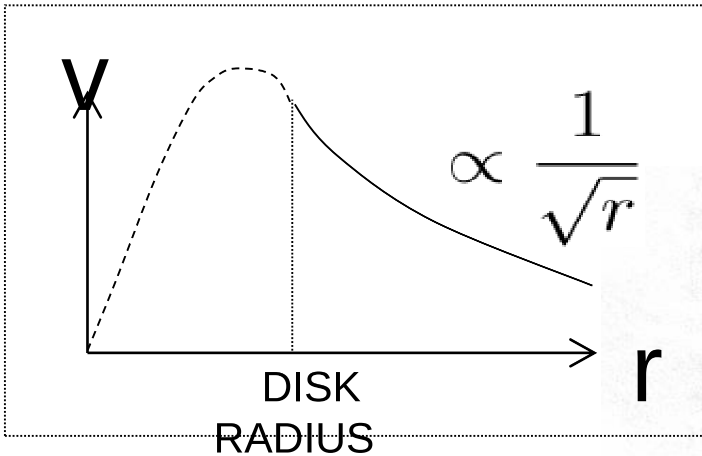
We can measure how fast stars rotate around galactic centres by looking at the frequency shift of known spectral lines originating in the stars due to the Doppler effect.

Star’s motion towards you, relative to the galactic centre alters wavelength of light

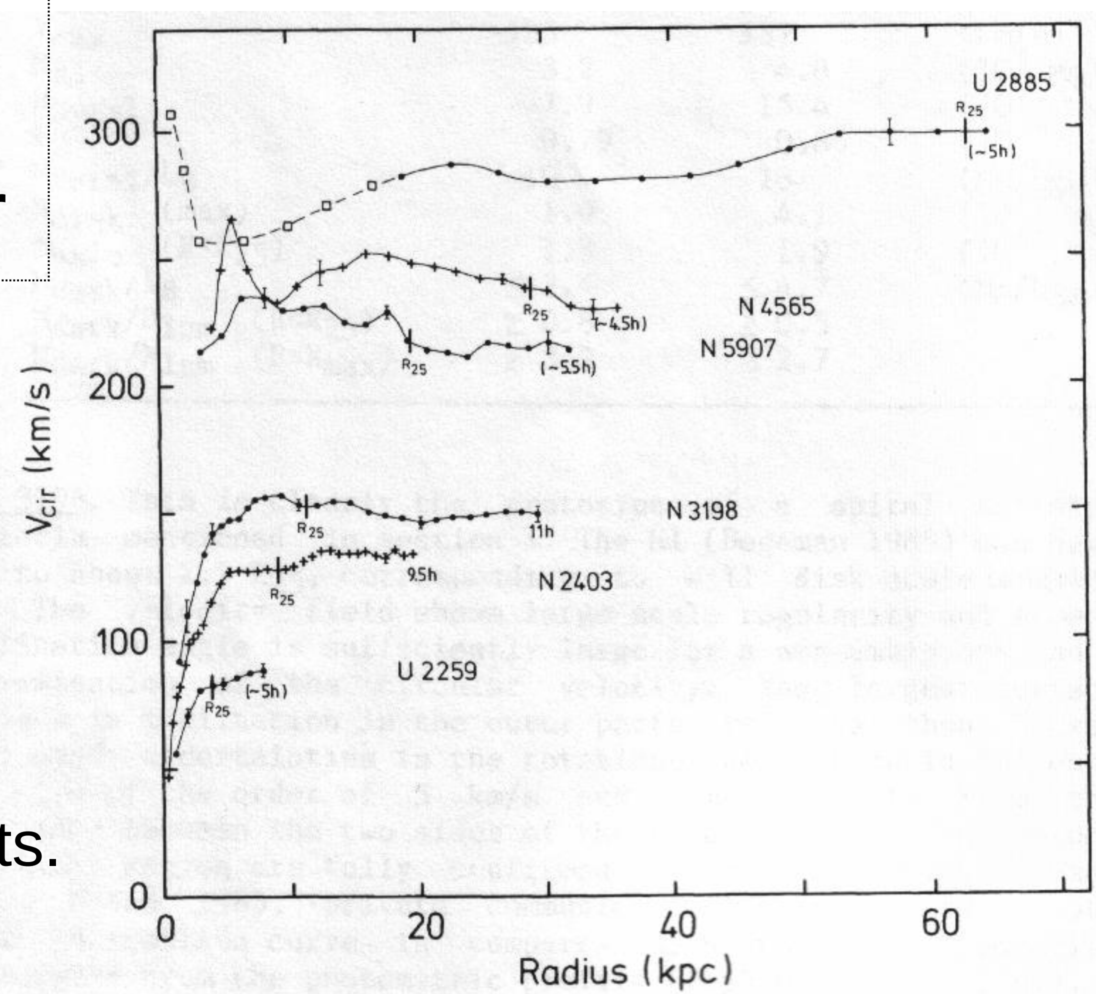
$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

Some Results

This is what we expect....



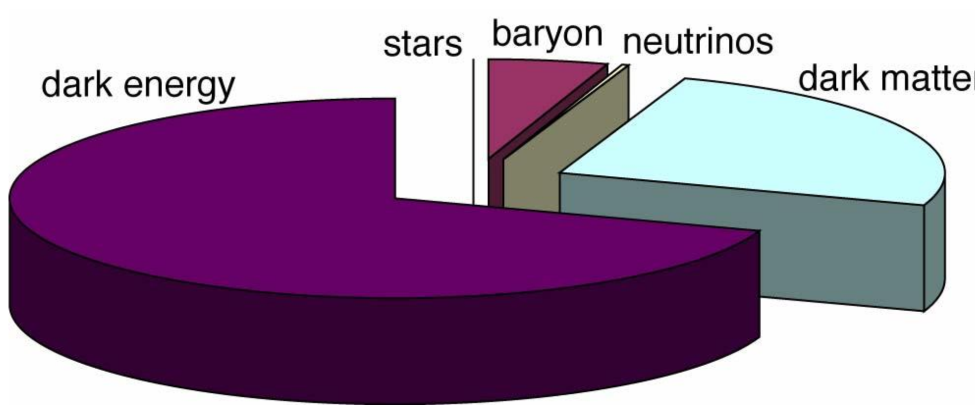
...but here are some typical results



Wavelength shifts are about a part in 10^6. These are hard measurements.

Energy budget of Universe

- Stars and galaxies are only ~0.5%
- Neutrinos are ~0.3–10%
- Rest of ordinary matter (electrons and protons) are ~5%
- Dark Matter ~30%
- Dark Energy ~65%
- Anti-Matter 0%



Dark Forces at Accelerators

16^{th} - 19^{th}, 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.

Kinetic mixing from the vector portal

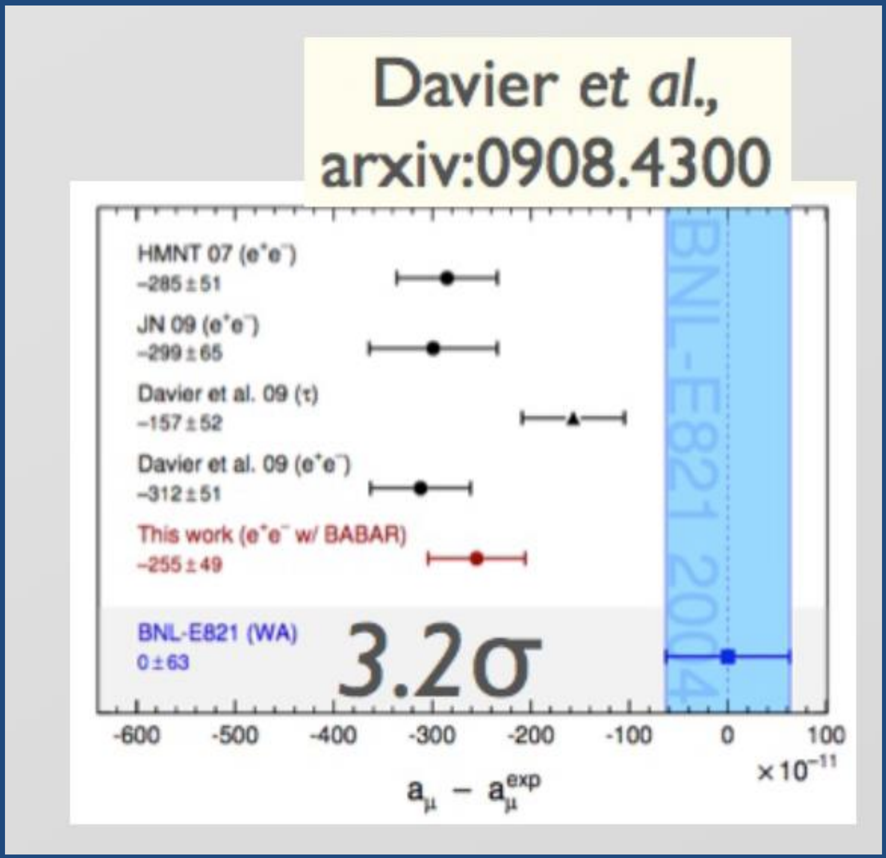
- *an old idea: if there is an additional U(1) symmetry in nature, there will be mixing between the photon and the new gauge boson (Holdom, Phys. Lett B166, 1986)*
- extremely general conclusion...even arises from broken symmetries gives coupling of normal charged matter to the new "dark photon" $q=\varepsilon_e$

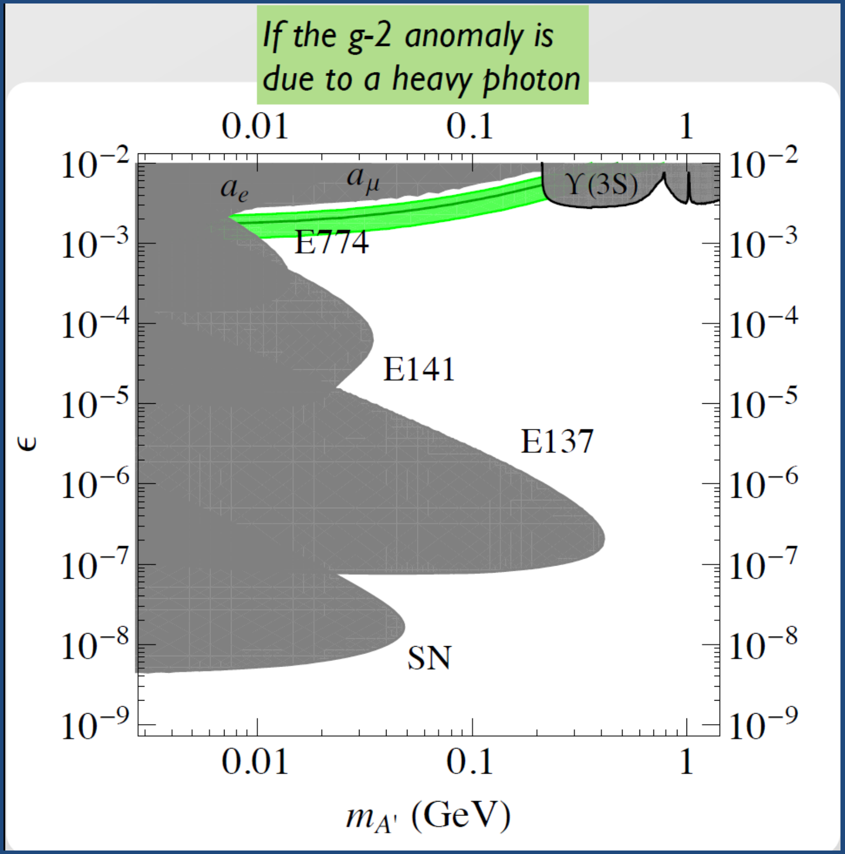
- *Jaeckel and Ringwald,* The Low-Energy Frontier of Particle Physics, *hep-ph/1002.0329 (2010)*

Ok, what about the mass?

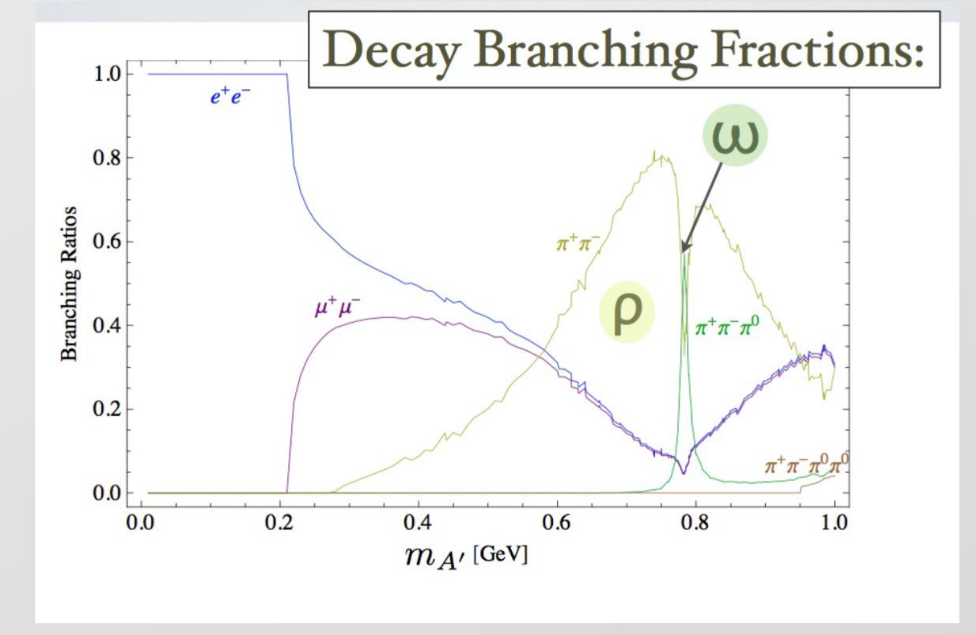
- Could be massless ⇒ millicharges!
- Non-perturbative ⇒ chaos!
- Same origin as weak scale ⇒ $O(M_Z)$
- → Depending on model, mass scales like:
- $M(A')/M(W) \sim \varepsilon^1 - \varepsilon^{1/2}$
- leading to $M(A') \sim$ MeV-GeV

Dark photons and the g-2 anomaly

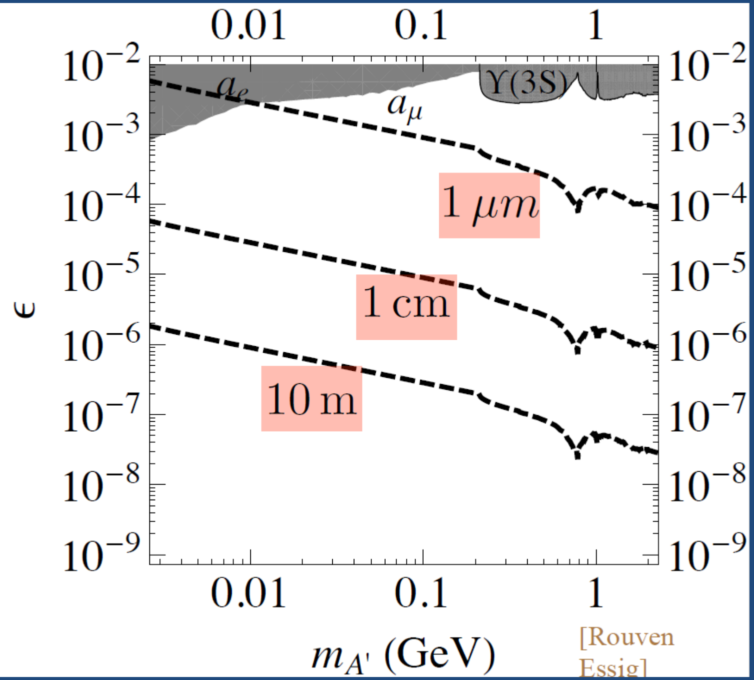




Decay modes and lifetime

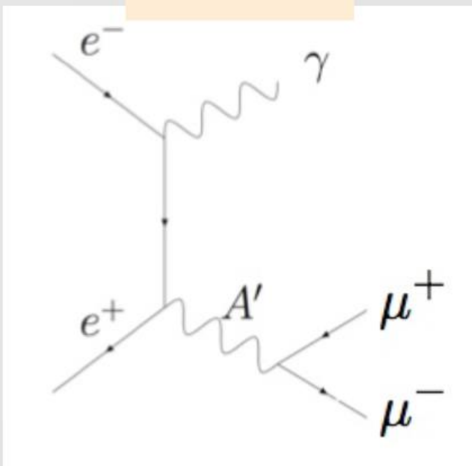


$$\gamma c\tau \propto \left(\frac{10^{-4}}{\epsilon}\right)^2 \left(\frac{100\ \mathrm{MeV}}{m_{A'}}\right)^2$$



Wherever there is a photon there is a dark photon...

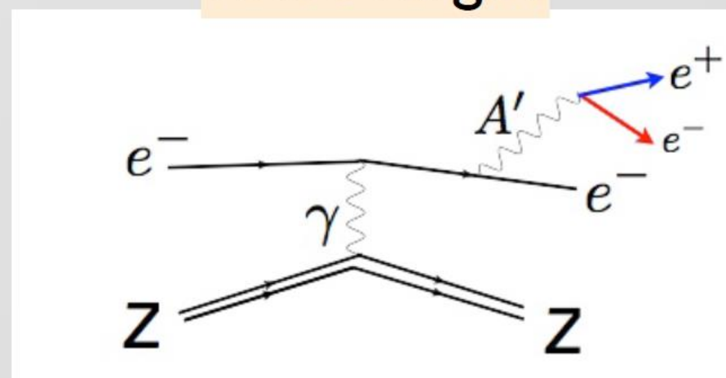
Collider



$$\sigma \sim \frac{\alpha^2 \epsilon^2}{E^2} \sim O(10\ fb)$$

$O\ ab^{-1}$ per ~~decade~~ month

Fixed Target



$$\sigma \sim \frac{\alpha^3 Z^2 \epsilon^2}{m^2} \sim O(10\ pb)$$

$O\ ab^{-1}$ per day

...much higher backgrounds

Dark Force searches in the Labs

https://sites.google.com/site/zprimeguide/ Hye-Sung Lee (JLAB)

Many searches for Dark Force in the Labs around the world (ongoing/proposed).

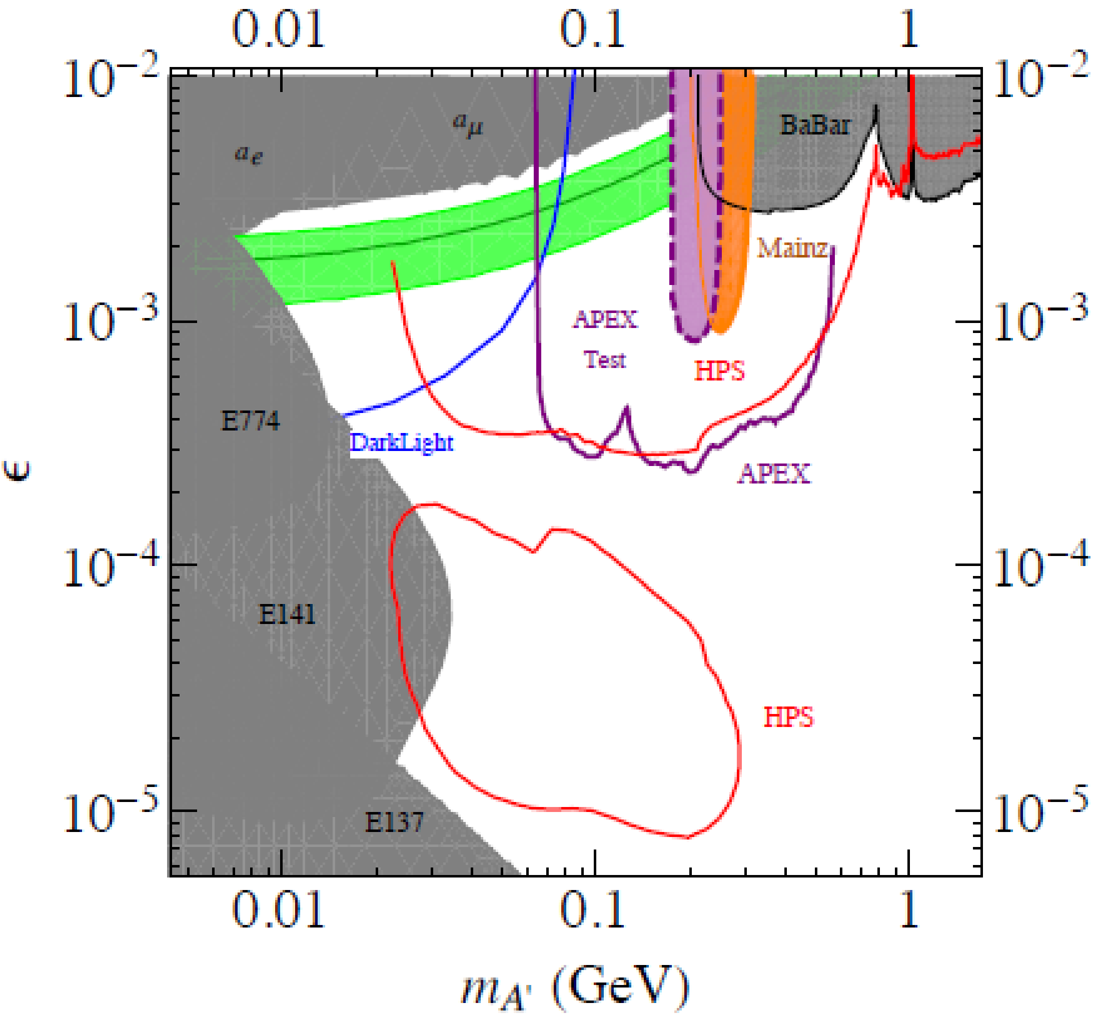
Typical searches for Dark Force exploit the small Z' coupling to the SM particles (rather than using the DM particles).

Particularly attractive: One of the New physics scenarios that can be tested with Low-energy experimental facilities (Nuclear/Hadronic physics labs).

[Dark force carrier Z' scale (GeV) $\approx$ 1/1000 × Typical new physics scale (TeV)]

"various Low-E Labs" "LHC"

Planned Experiments worldwide

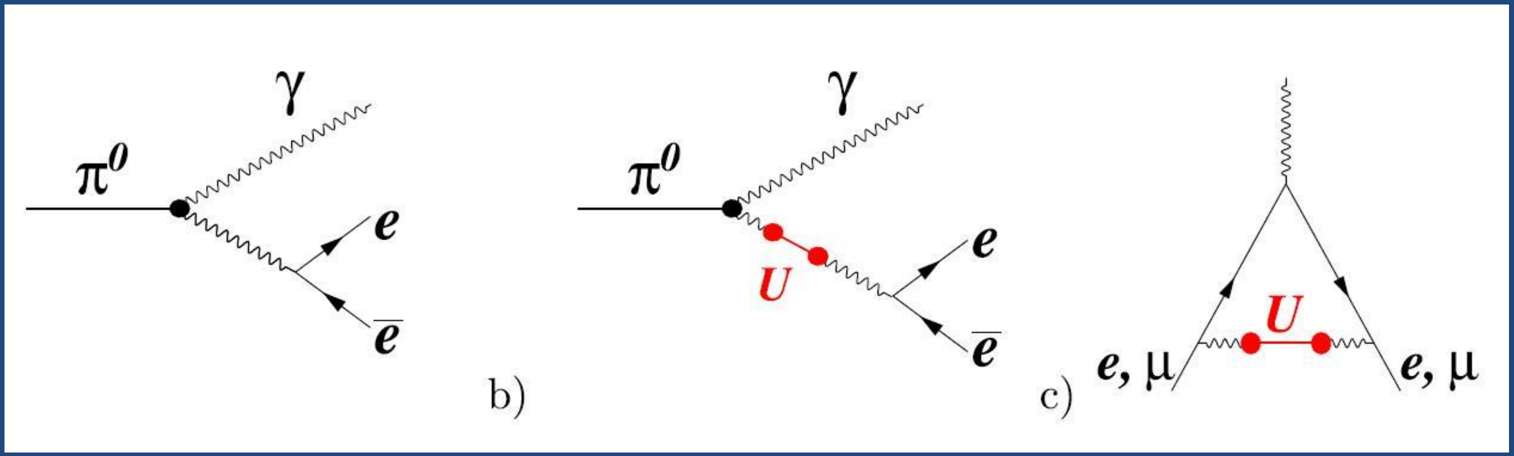


Many experiments in the works to look for Dark Forces:

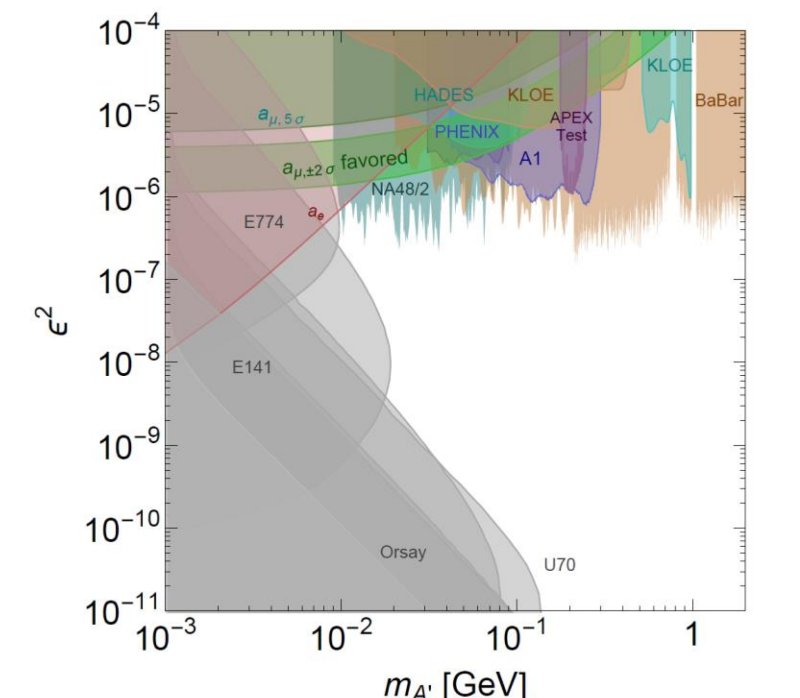
Mainz and APEX (JLab) ~ forward spectrometers
HPS (JLab) ~ compact Si-based vertex-tracker
DarkLight (JLab FEL) ~ high acceptance, H_2 gas target
HIPS(DESY)~ beam dump (not shown)

Search for a dark photon in the $\pi^0 \to e^+e^- \gamma$ decay,

NA48/2 Collaboration, Phys. Lett. B 746, 178 (2015).

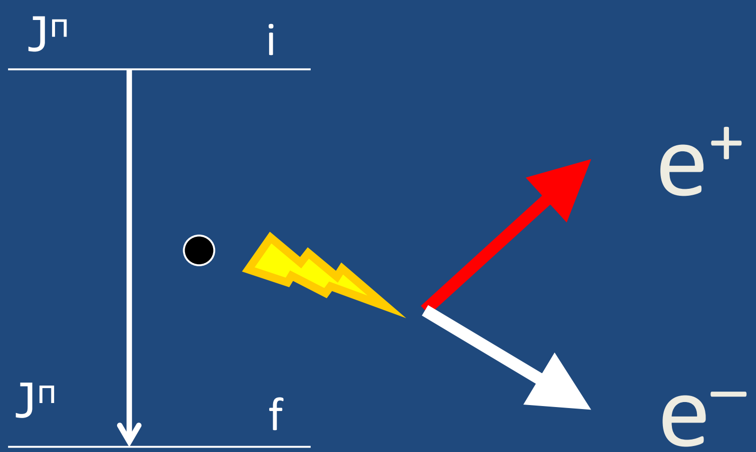


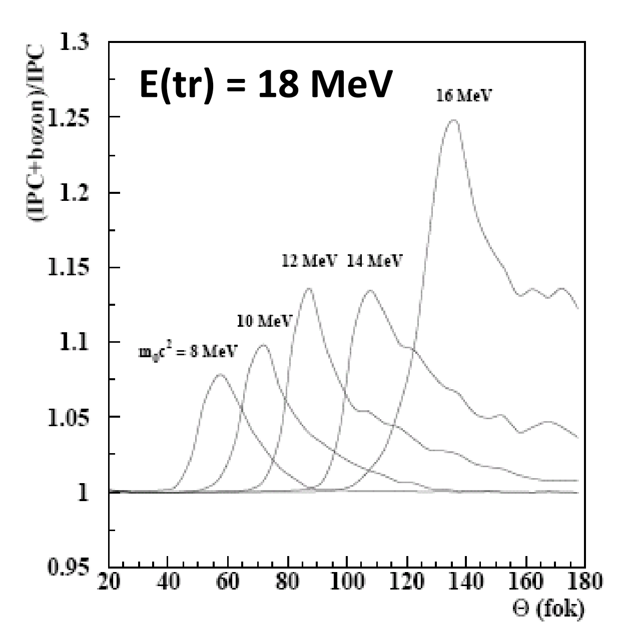
$$\mathcal{B}(\pi^0 \to \gamma A') = 2\varepsilon^2 \left(1 - \frac{m_{A'}^2}{m_{\pi^0}^2}\right)^3 \mathcal{B}(\pi^0 \to \gamma\gamma),$$



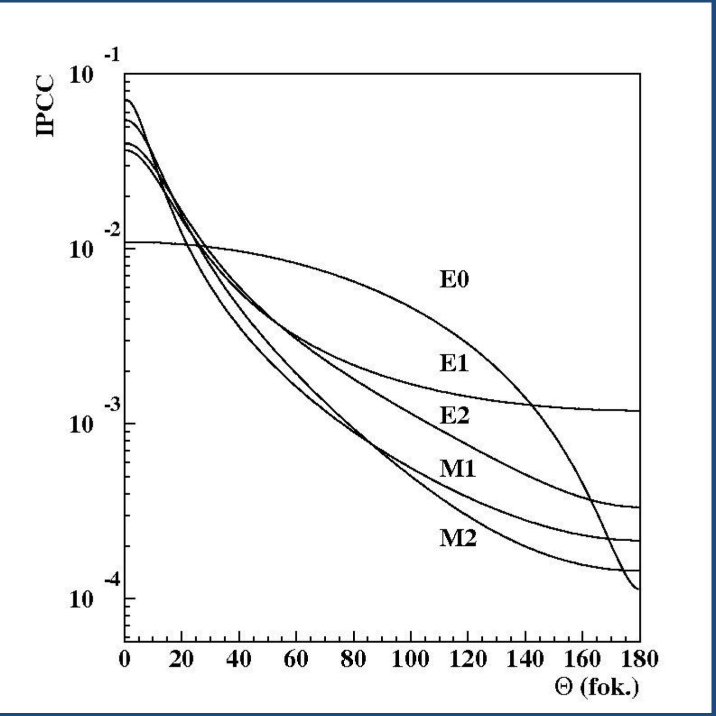
Search for the e^+-e^- decay of the dark photon in nuclear transitions

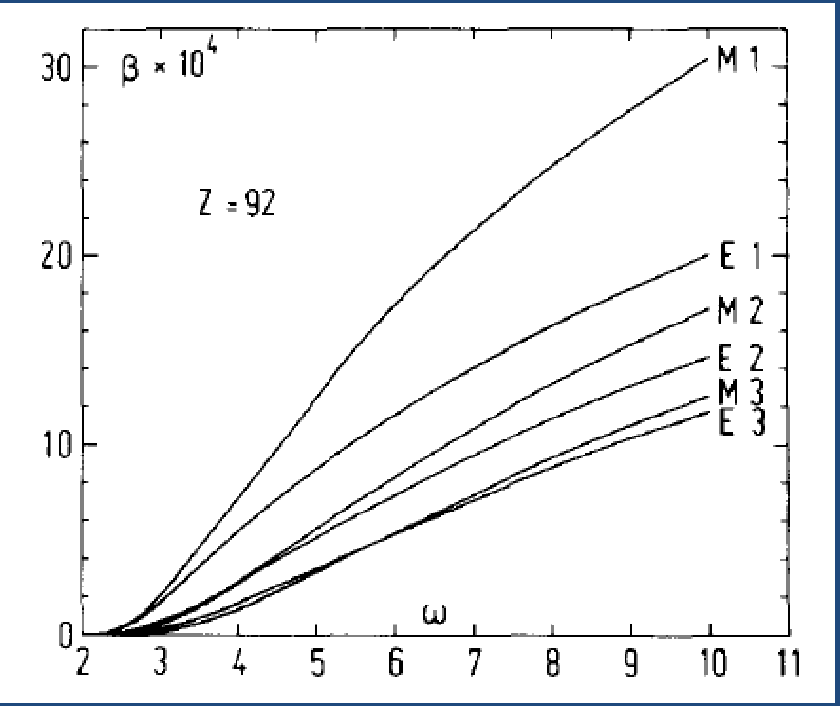
The atomic nucleus is a femto-laboratory including all of the interactions in Nature. A real discovery machine like LHC, but at low energy.





e^+-e^- internal pair creation



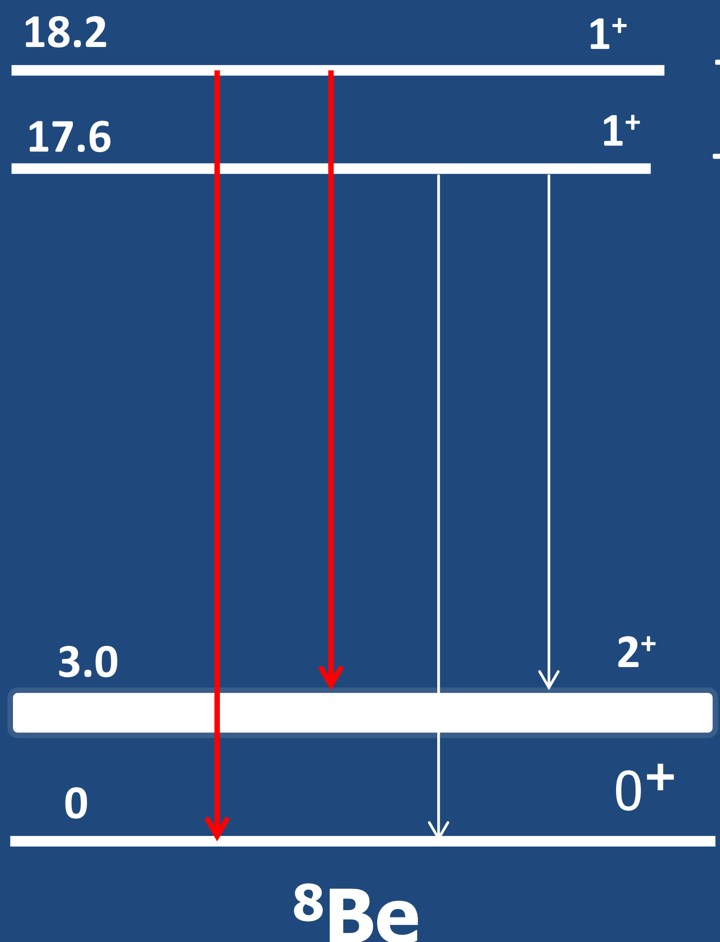


M.E. Rose Phys. Rev. 76 (1949) 678

E.K. Warburton Phys. Rev. B133 (1964) 1368.

P. Schlüter, G. Soff, W. Greiner, Phys. Rep. 75 (1981) 327.

Study the ^{8}Be M1 transitions

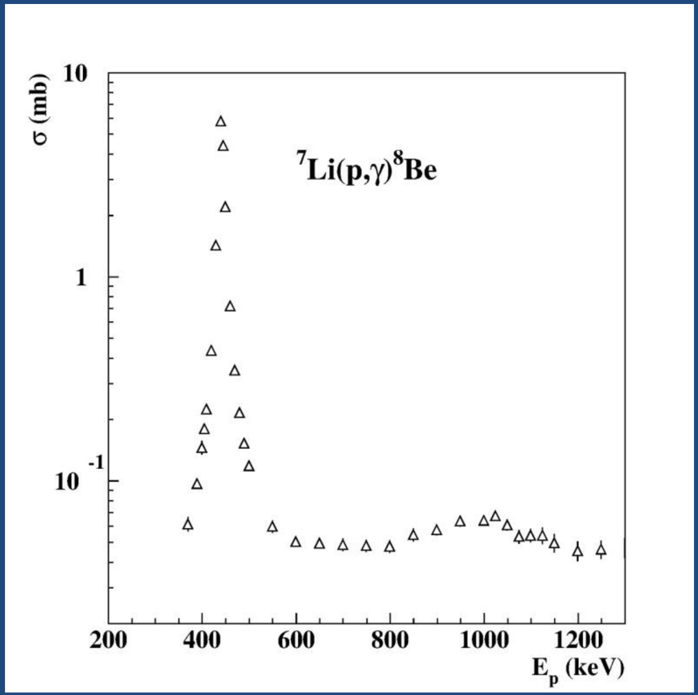


T=0 Ep= 1030 keV

T=1   Ep= 441 keV

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

^{7}Li, p3/2^{-} + p



Who else investigated it?

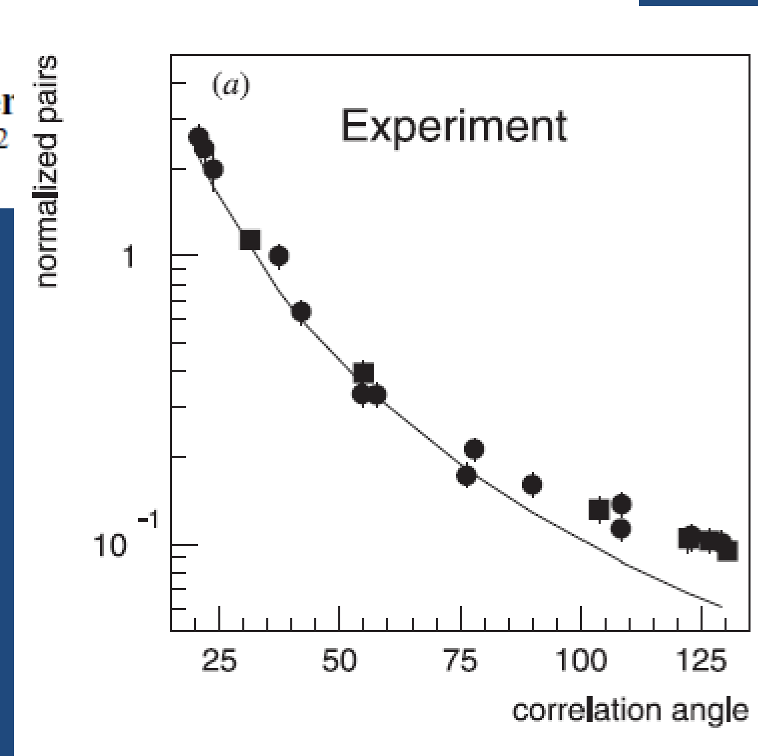
INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS

J. Phys. G: Nucl. Part. Phys. **27** (2001) L29–L40 www.iop.org/Journals/jg PII: S0954-3899(01)21791-5

LETTER TO THE EDITOR

Further search for a neutral boson with a mass around 9 MeV/c^2

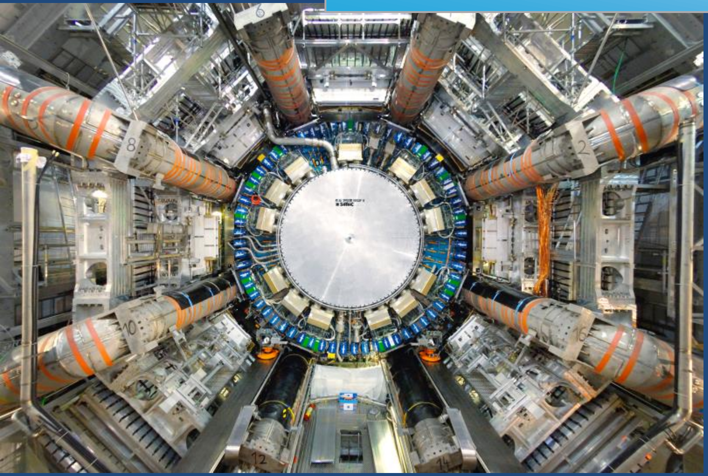
F W N de Boer[1], K Bethge[2], H Bokemeyer
J van Klinken[4], V Mironov[5], K A Müller[2]



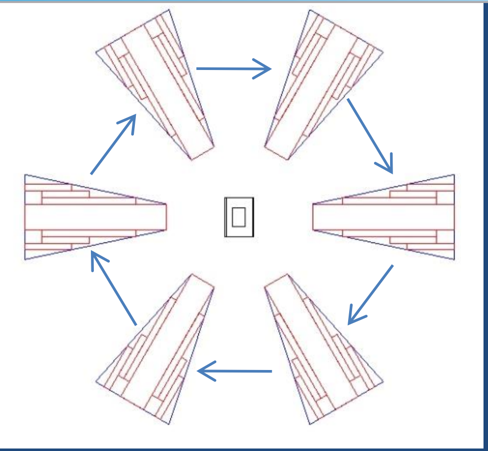
IPCC of the 18 MeV ^{8}Be transition.

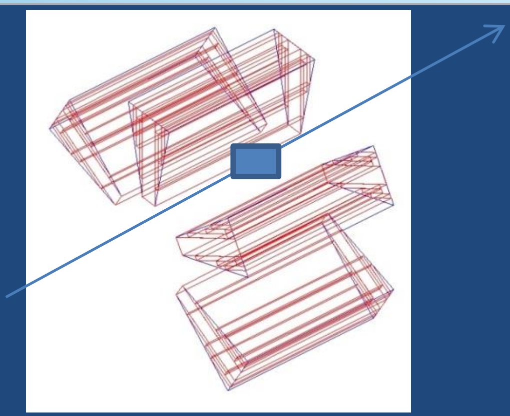
- Their maximal correlation angle was 131 degree only.

A Compact Positron Electron spectrometer (COPE) for internal pair creation studies (ENSAR, FP7 support)

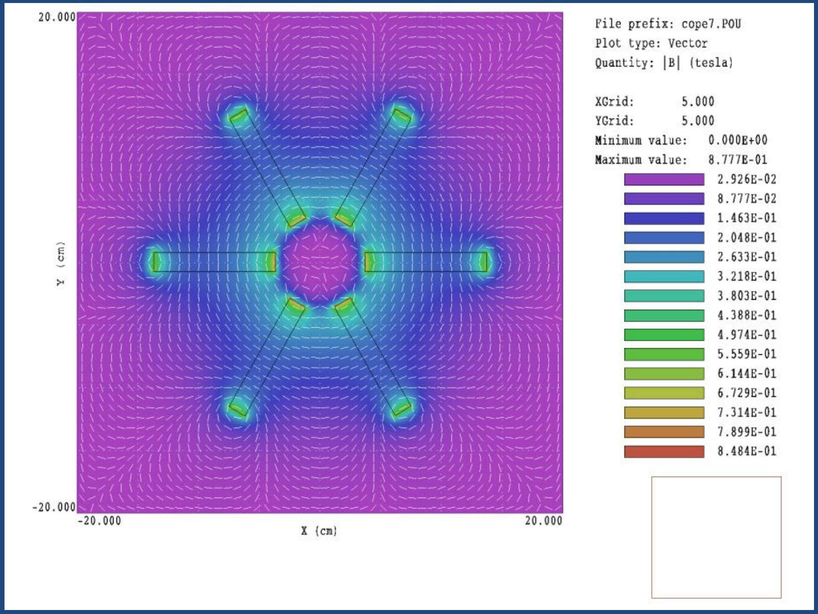


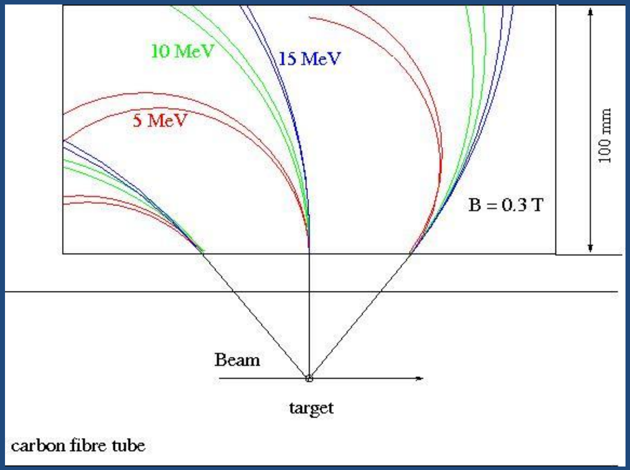
ATLAS





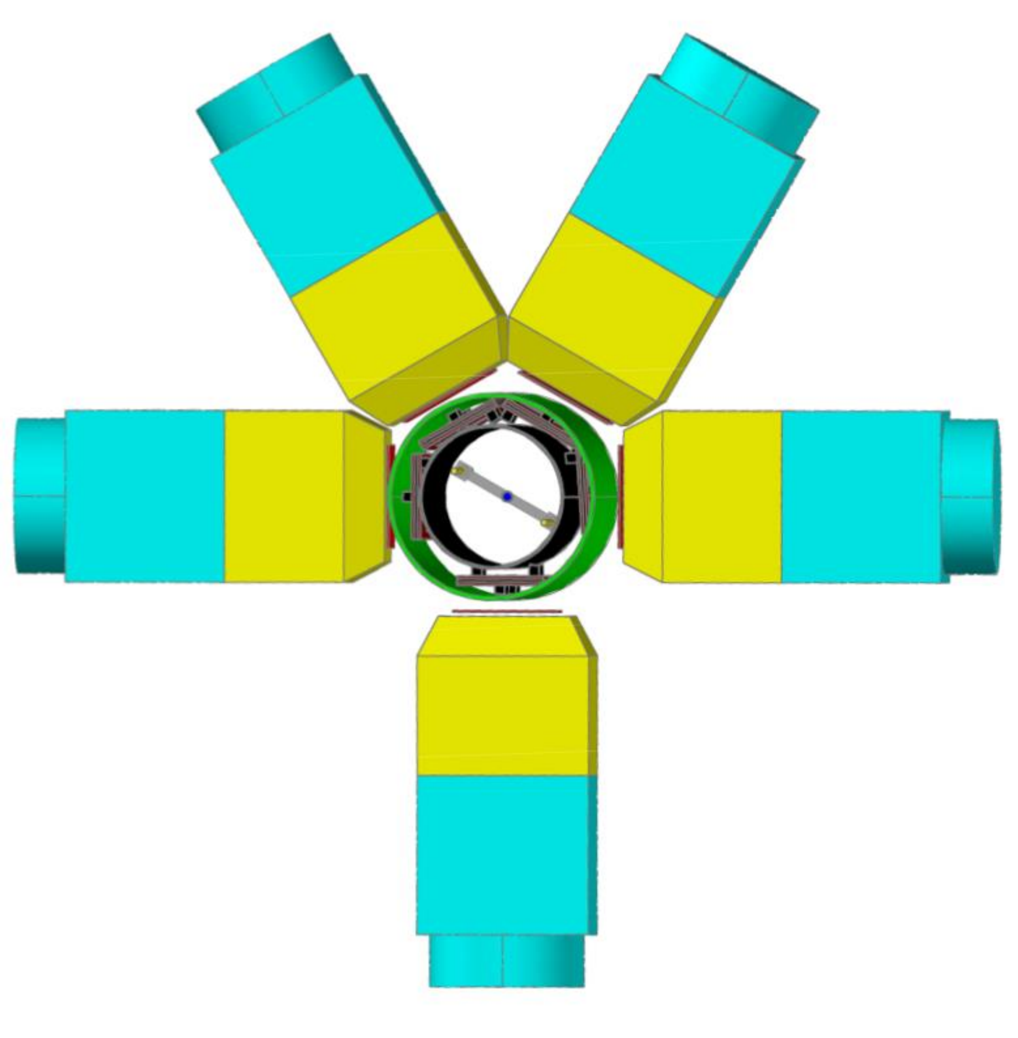
COPE 100:1





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

Geometrical arrangement of the scintillator telescopes



The completed spectrometer

Nuclear Instruments and Methods in Physics Research A 808 (2016) 21–28

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journal homepage: www.elsevier.com/locate/nima

A pair spectrometer for measuring multipolarities of energetic nuclear transitions

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Internal pair conversion
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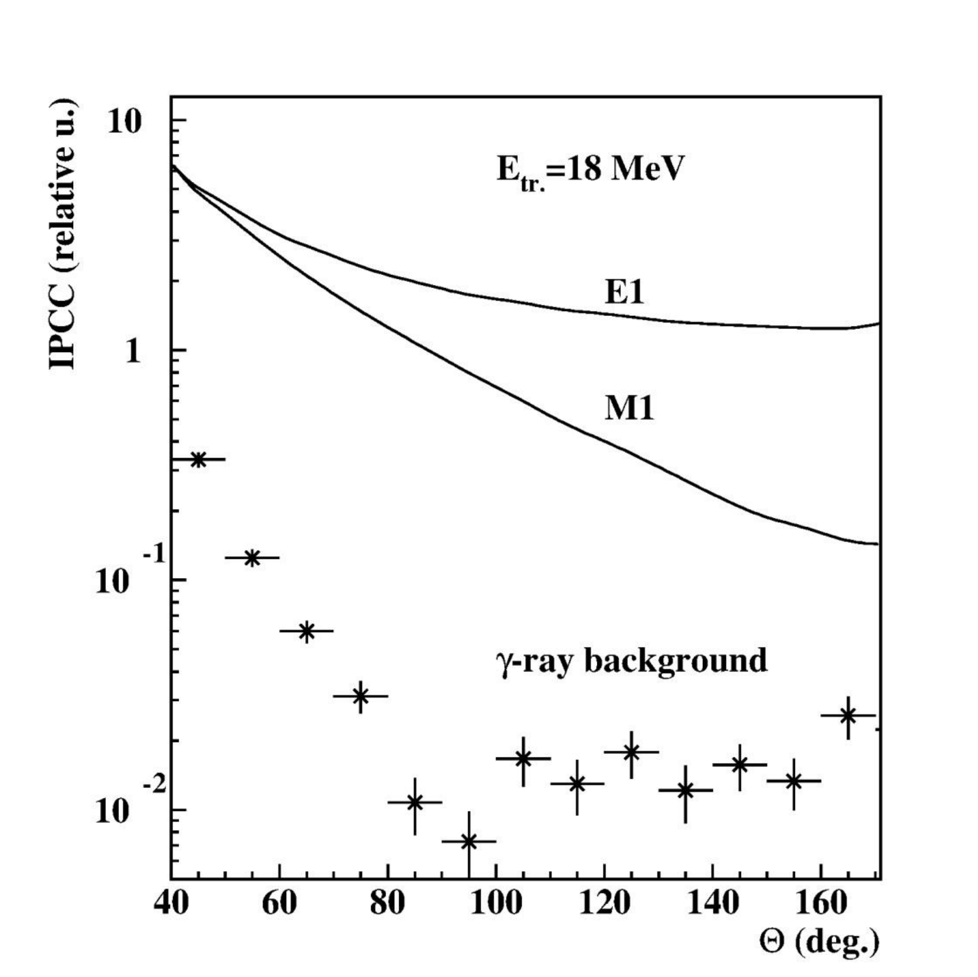
Anomalous angular correlation in ^{8}Be

ABSTRACT

An electron–positron pair spectrometer has been designed and constructed for the simultaneous measurement of energy- and angular correlations of e^+e^- pairs. Experimental results are obtained over a wide angular range for high-energy transitions in ^{16}O, ^{12}C and ^{8}Be. The results showed that the angular correlations between 50 and 180° of the e^+e^- pairs in the energy range between 6 and 18 MeV can be determined with sufficient resolution and efficiency in good agreement with the GEANT simulations.

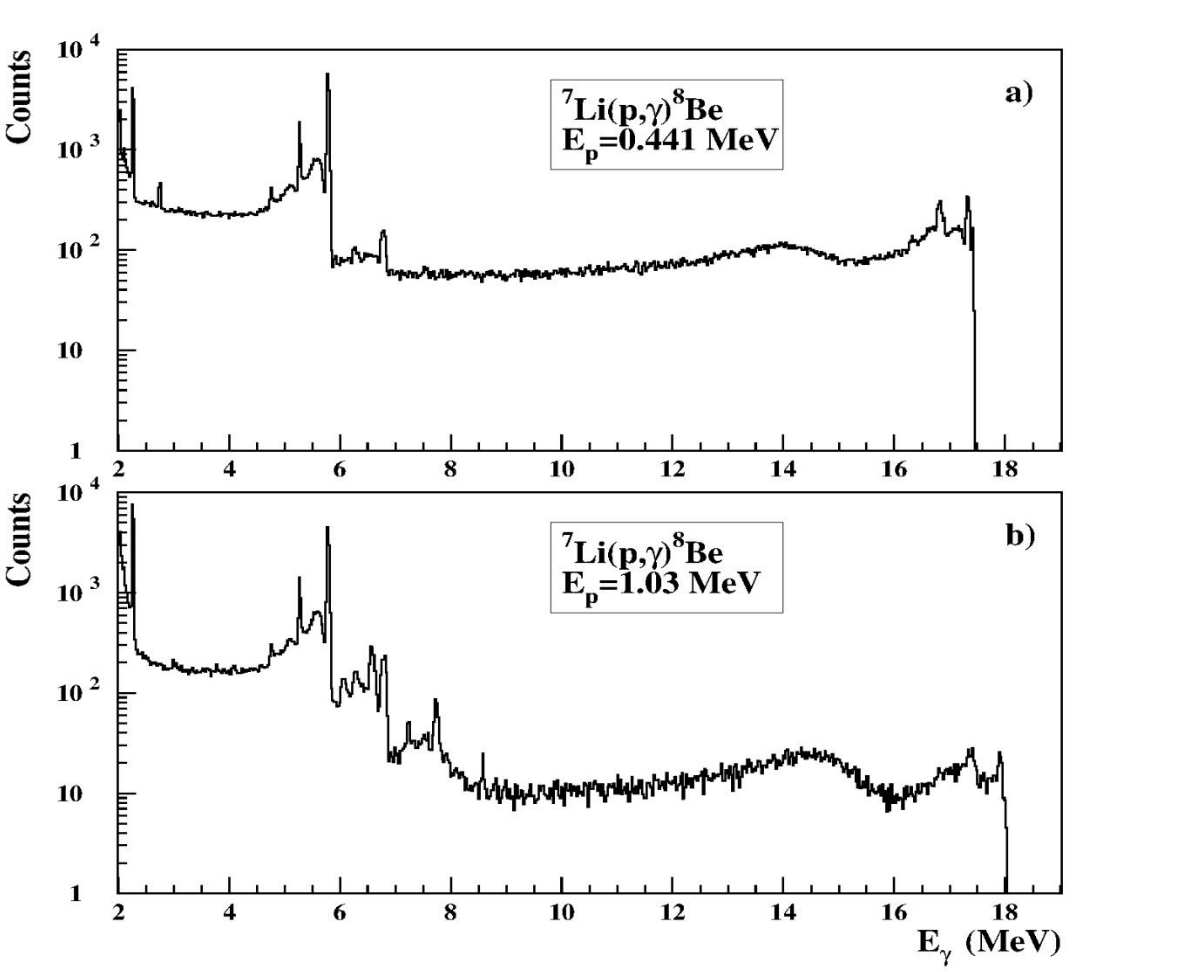
Advantages of the spectrometer

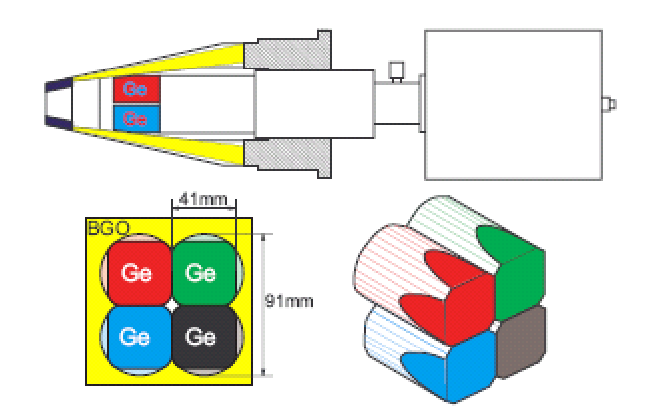
- 1000 times bigger efficiency
- Online efficiency calibration
- Better angular resolution
- Better γ-ray suppression
- Large angular range <170^o

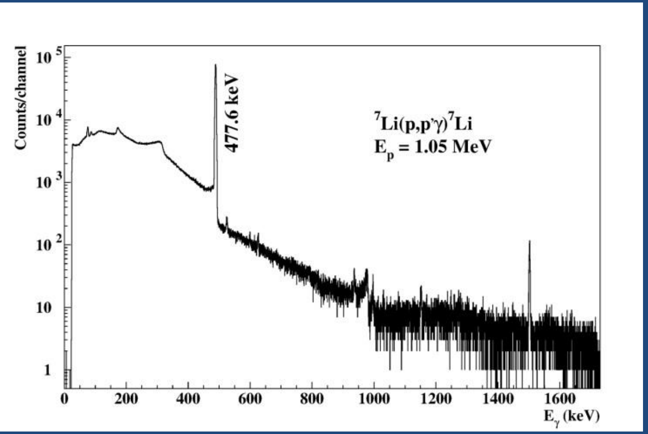


γ-background of the spectrometer

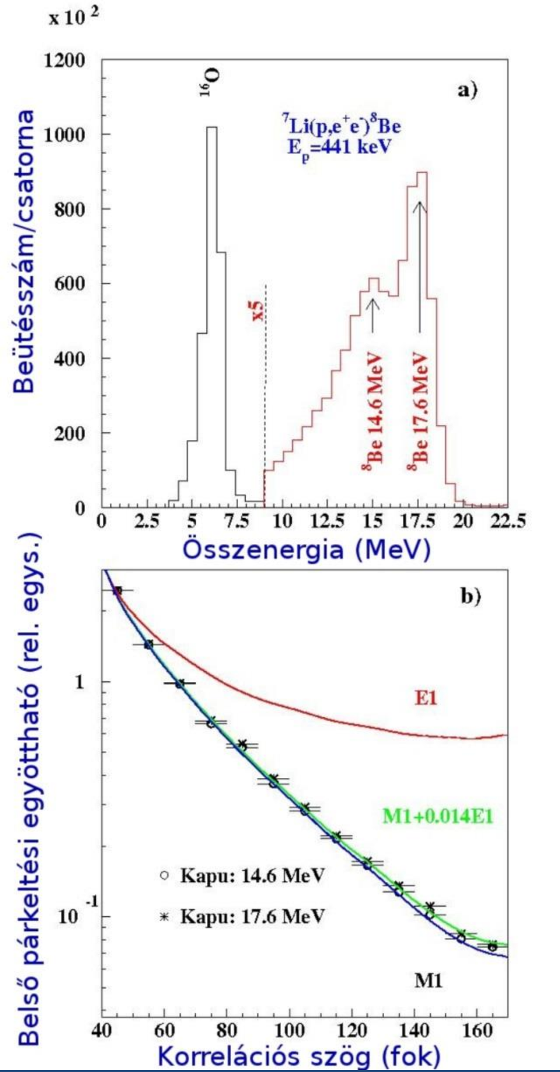
γ-ray spectra measured on the two resonances and from (p,p')

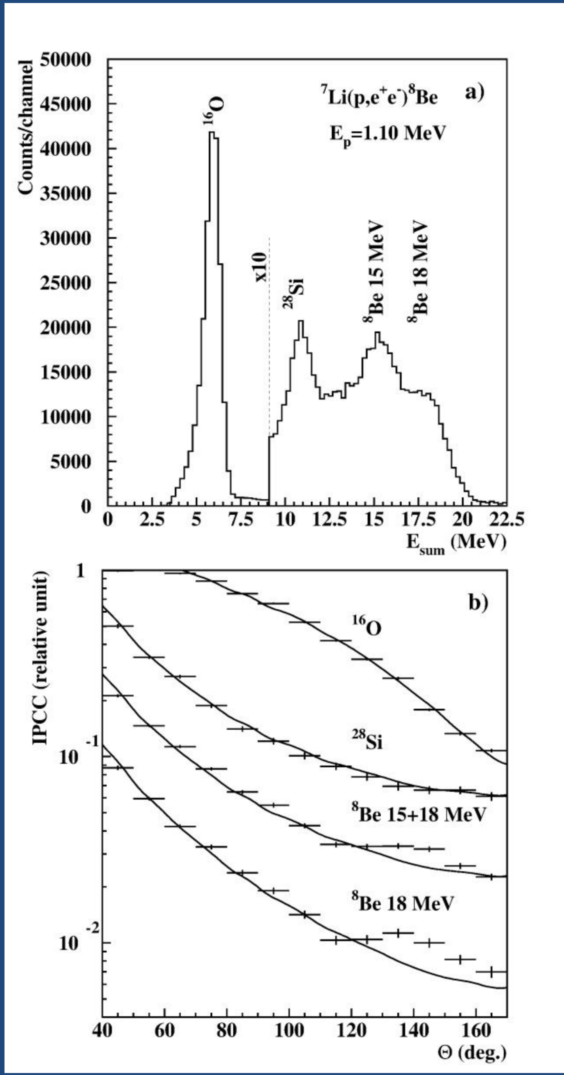






$E_{e+} + E_{e-}$ sum energy spectra and angular correlations





Can it be some artificial effect caused by γ-rays?

No, since we observed it at Ep= 1.1 MeV but not at 0.441 MeV.

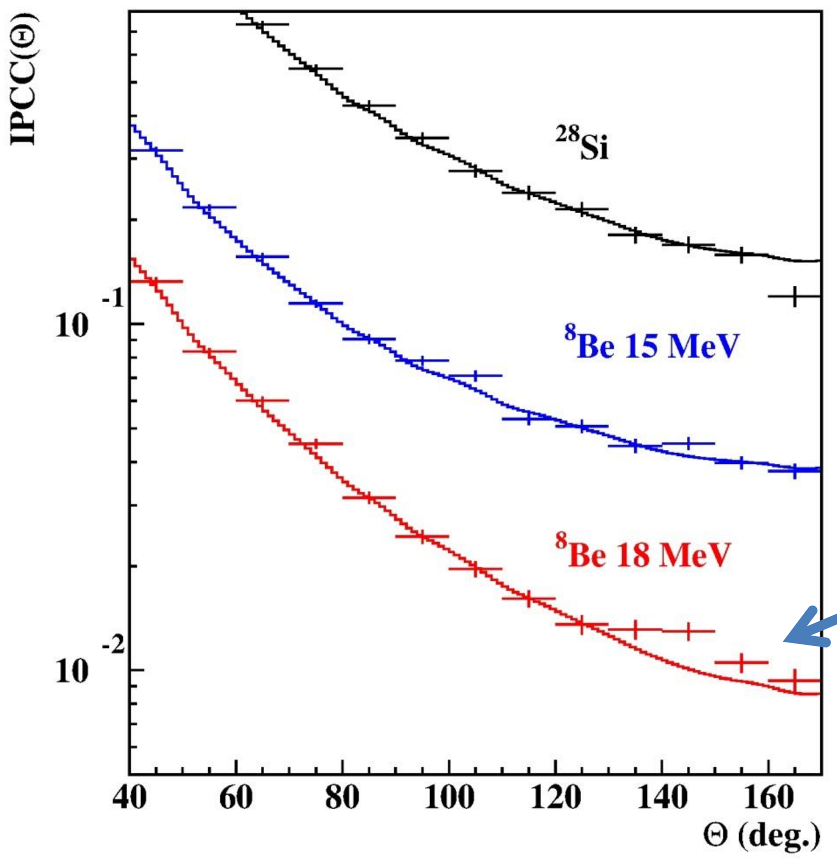
Can it be some nuclear physics effect?

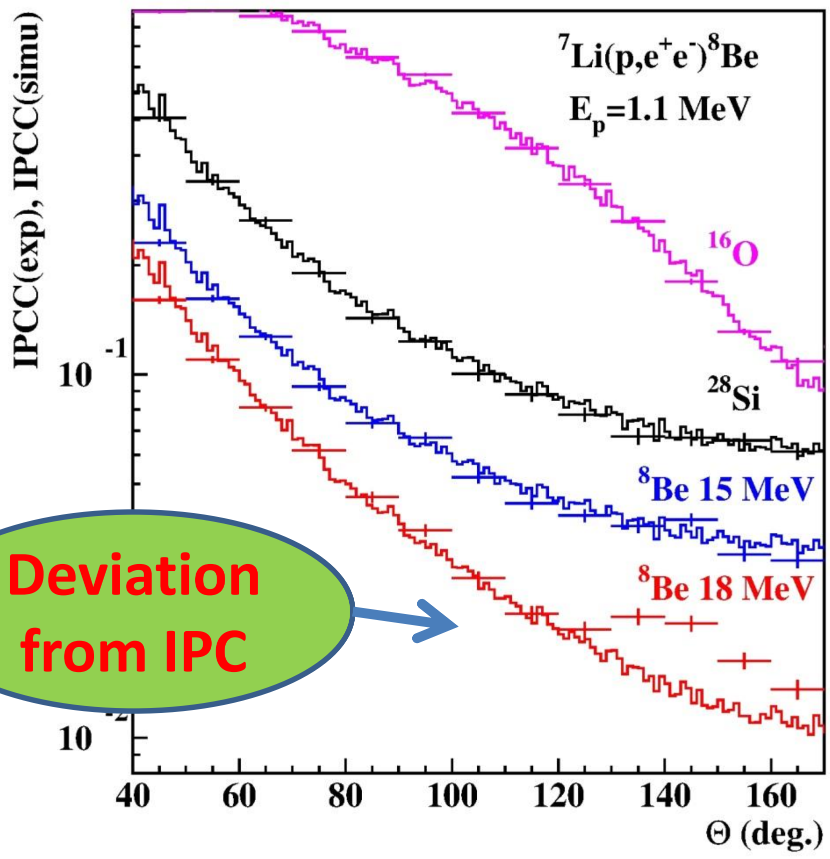
Let's investigate that at different bombarding energies!

On-resonance measurements

Ep=1.04 MeV

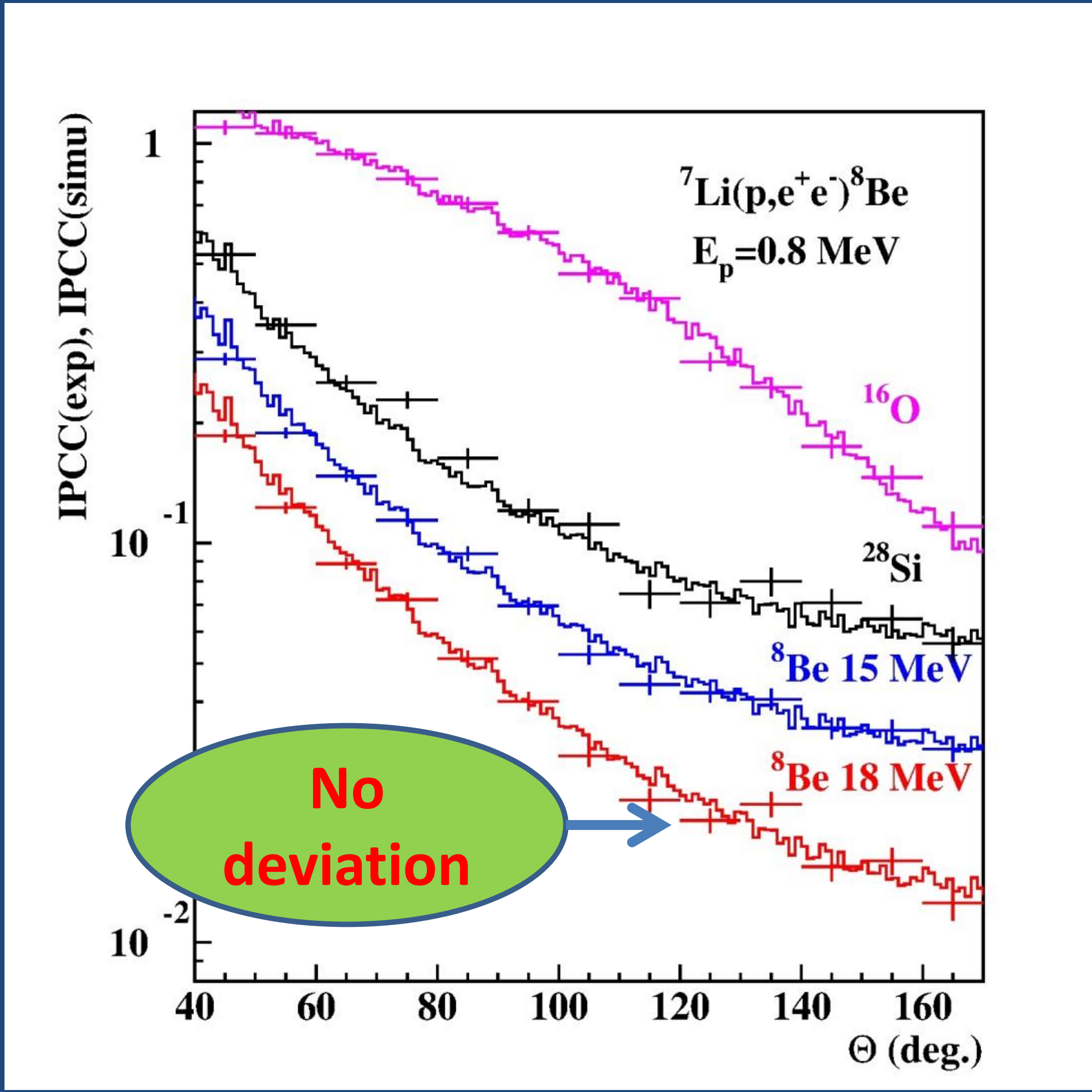
Ep=1.10 MeV



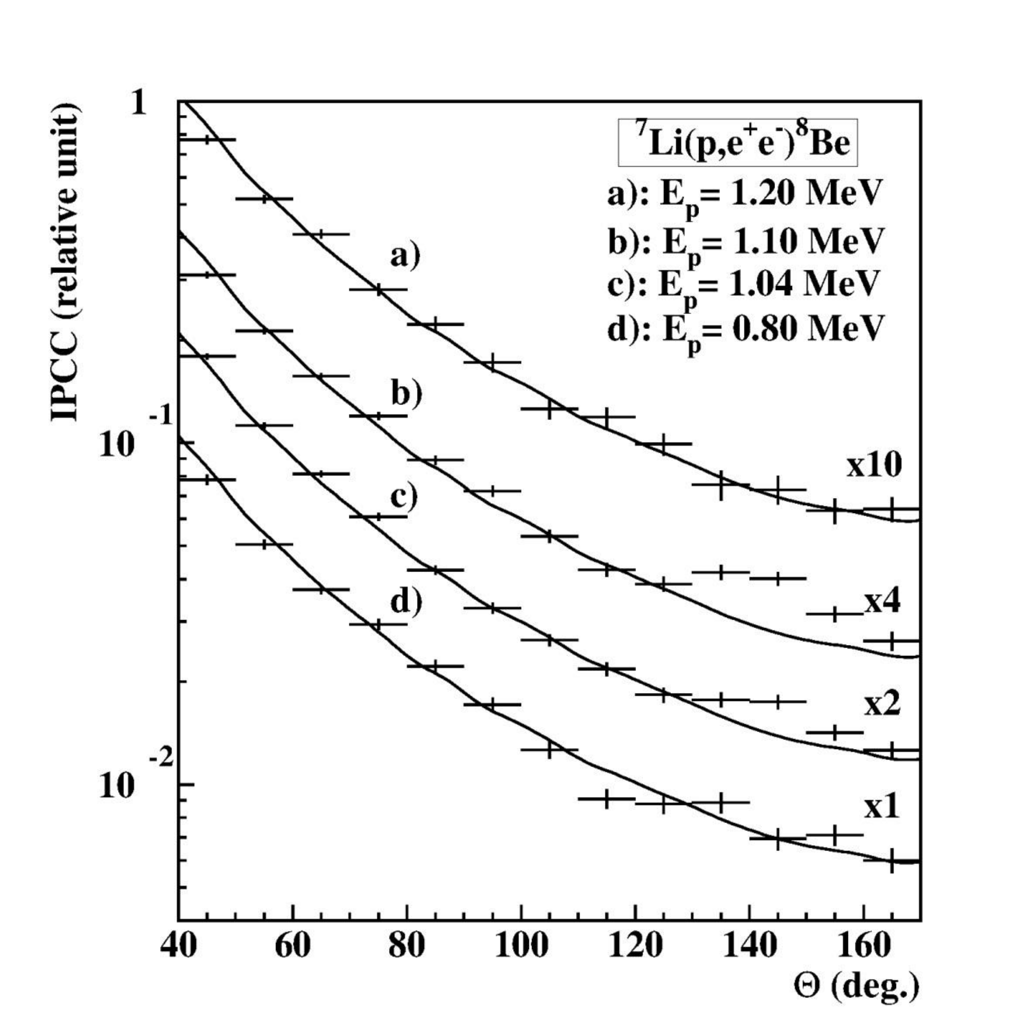


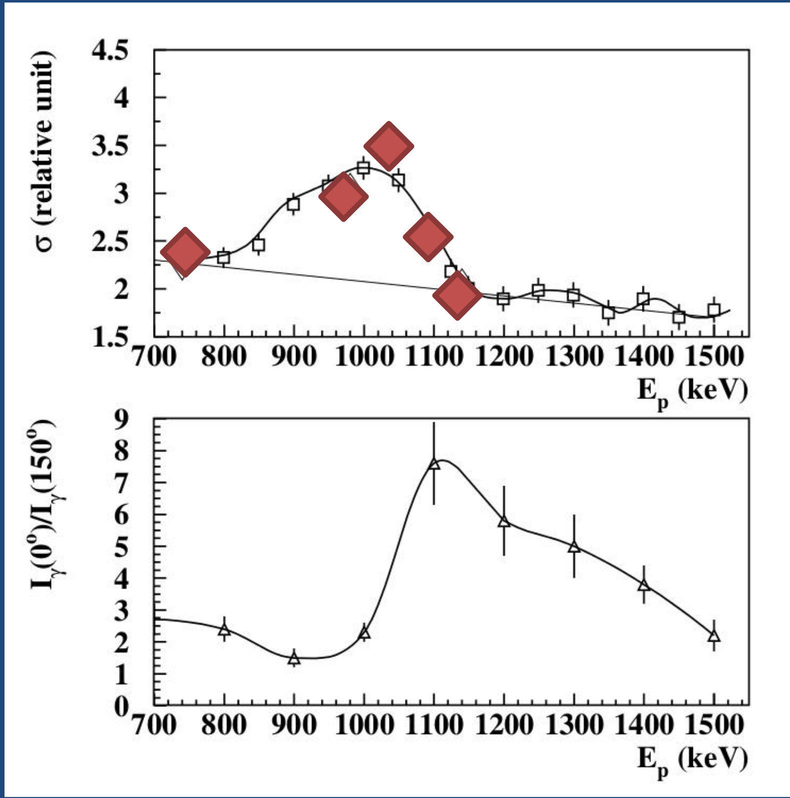
Deviation from IPC

Off-resonance measurement



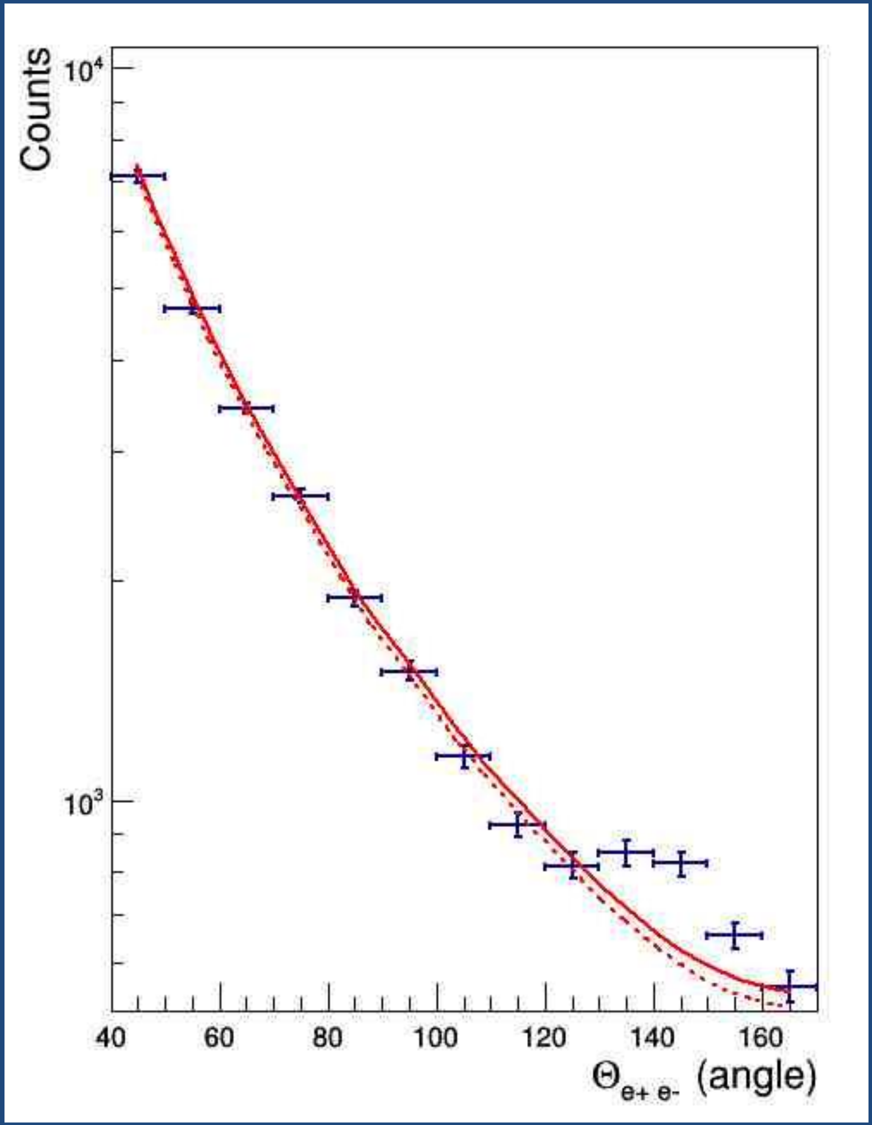
Can it be some kind of interference effect between transitions with different multipolarities?





Most probably not. In case of any interference the peak should behave differently.

What is the significance of the peak?



- E1+M1 simulated **background**: fitted with Minuit minimization (red line) between 60˚ - 130˚

- Integrals in 130˚ - 160˚:
  - Background: 2009 counts
  - Signal+Background: 2320 counts

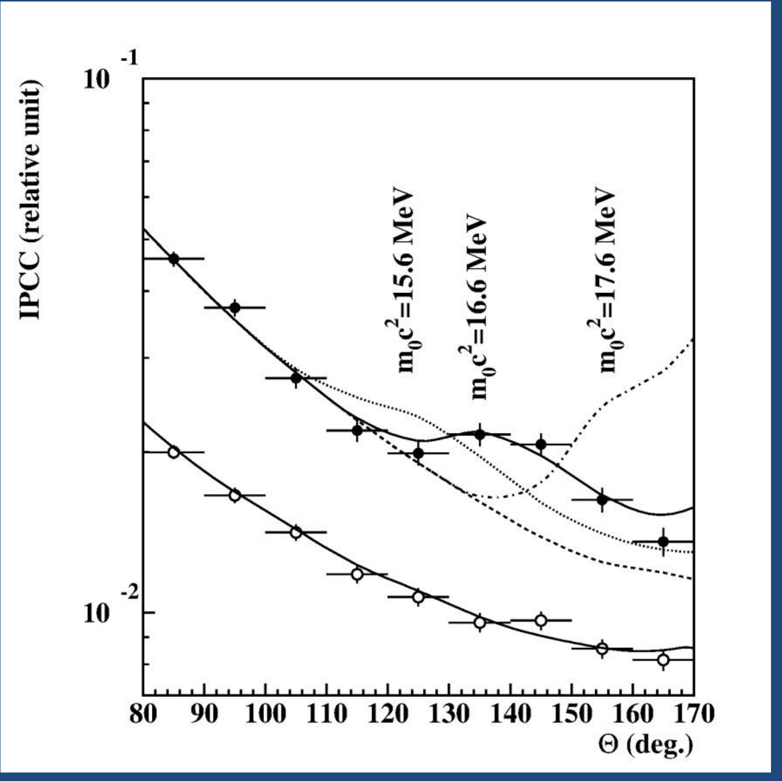
→ peak significance: 6.8 σ

(p-value: $5.6\text{x}10^{-12}$)

(Glen Cowan: Statistical Data Analysis, 1998, Oxford Press)

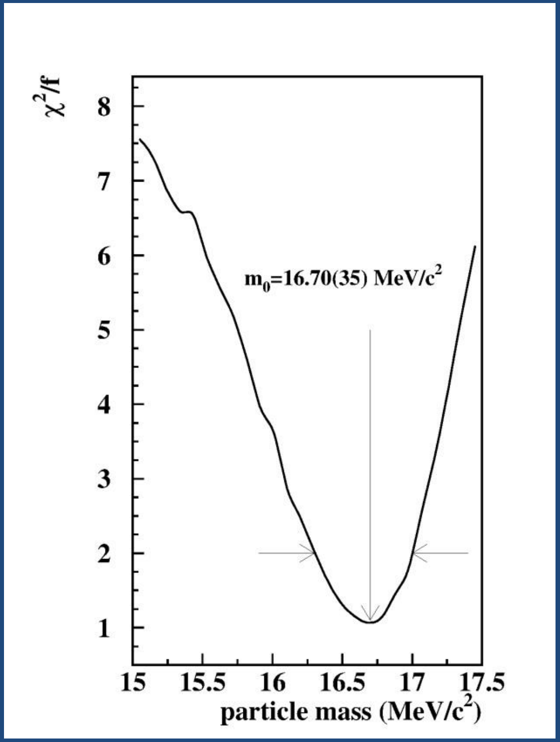
How can we understand the peak like deviation? Fitting the angular correlations

$$y=\frac{E^{+}-E^{-}}{E^{+}+E^{-}}$$

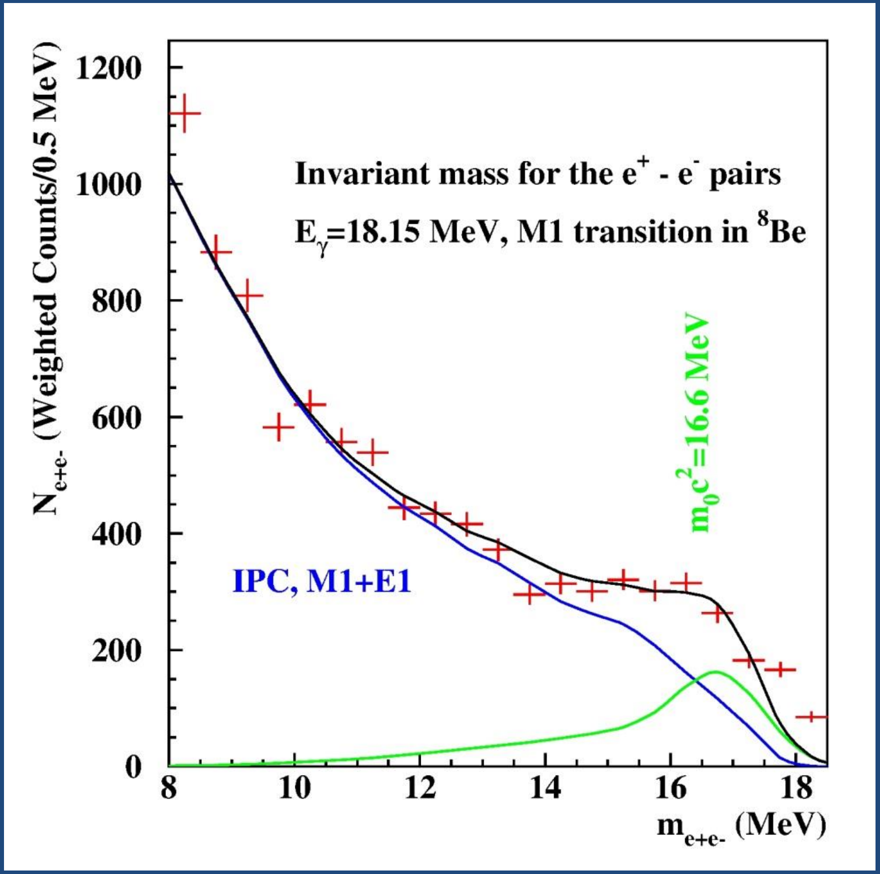


Experimental angular e^+e^- pair correlations measured in the $^7Li(p,e^+e^-)$ reaction at Ep=1.10 MeV with -0.5< y <0.5 (closed circles) and |y|>0.5 (open circles). The results of simulations of boson decay pairs added to those of IPC pairs are shown for different boson masses.

Determination of the mass of the new particle

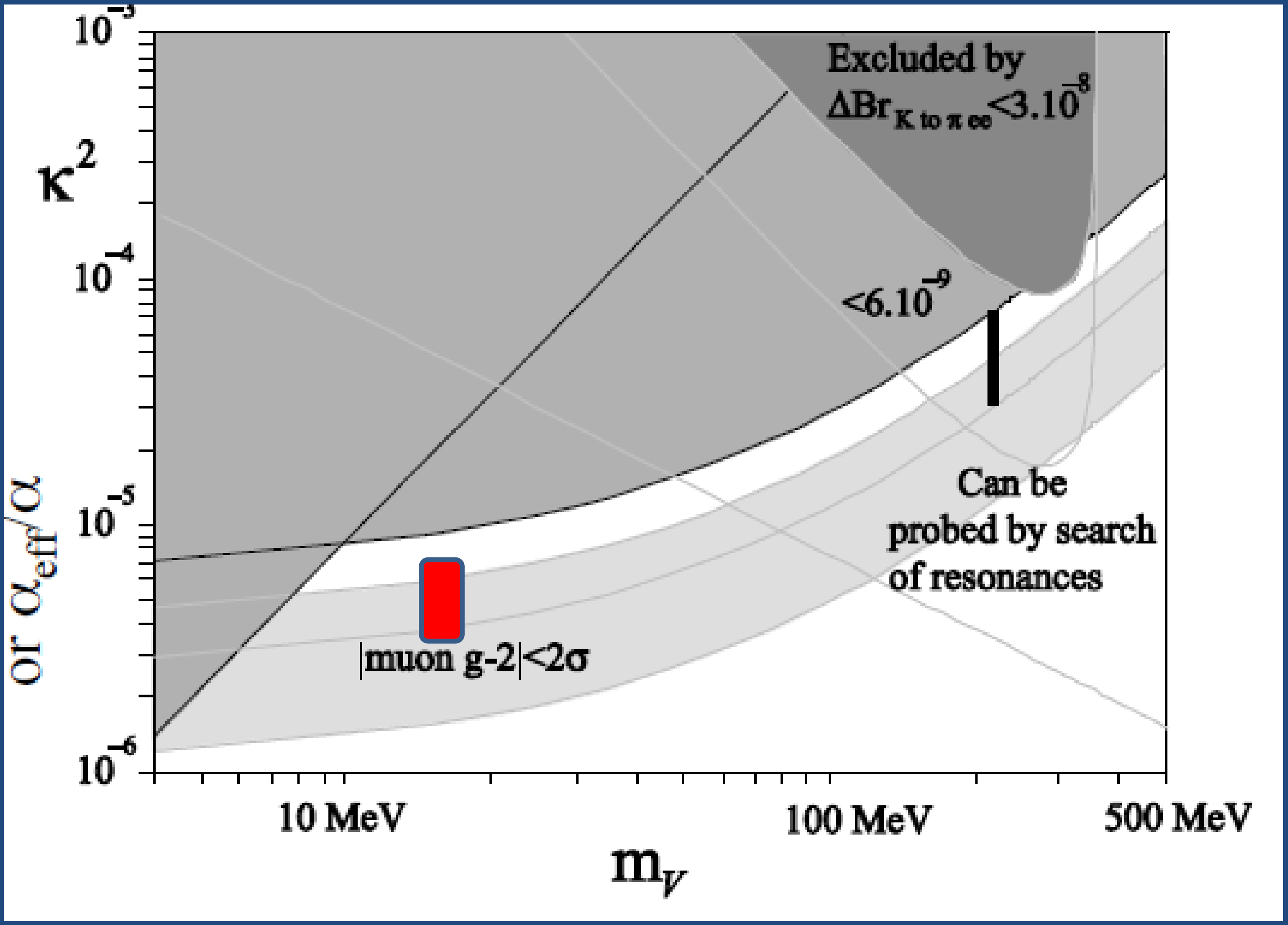


Determination of the mass of the new particle by the X^2/f method, by comparing the experimental data with the results of the simulations obtained for different particle masses.



Invariant mass distribution plot for the electron-positron pairs

The coupling constant



Our results is within the predicted band calculated from the muon g-2.

How can we calculate the coupling constant properly?

Nuclear deexcitations via Z’ emission

- Nuclear deexciations via axions (T.W. Donnelly et al., Phys. Rev. D18 (1978) 1607.)

$$\omega_a^{(J=1,\,T=0)} = \frac{1}{2}\frac{\tilde{\alpha}}{\alpha}\left(\frac{k_a}{k}\right)^3\left(\frac{\rho^{(0)}}{\mu^{(0)}-1/2}\right)^2 \omega_\gamma^{(M1,\,T=0)} . \tag{22a}$$

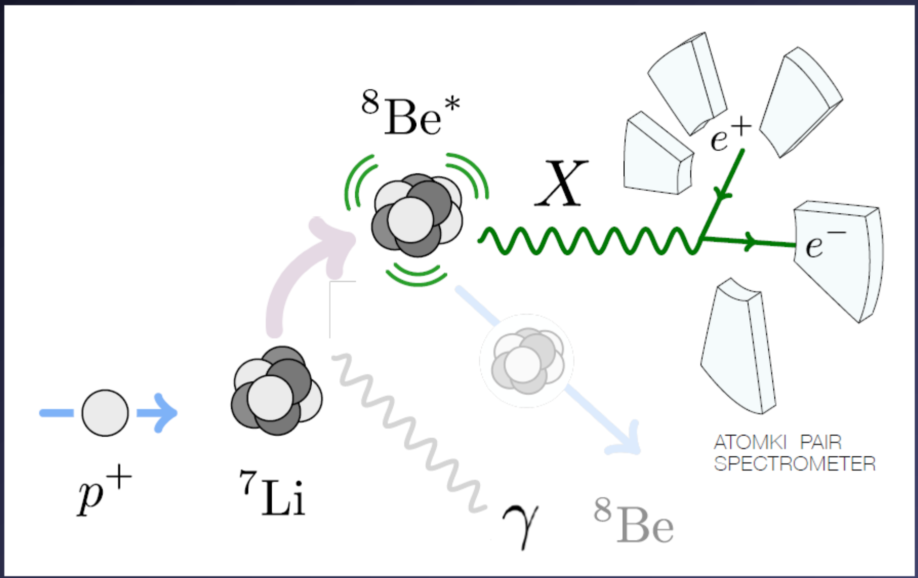
- → the coupling constant can be 10-30 times smaller then the branching ratio
- **→ it is not ruled out!**

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

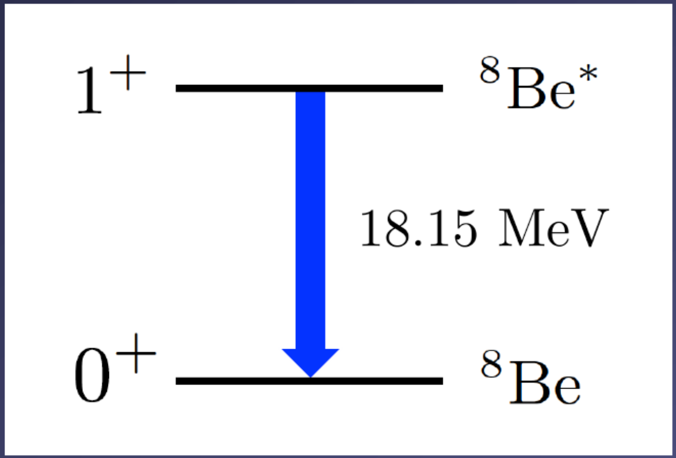
Jonathan L. Feng, Bartosz Fornal, Iftah Galon, Susan Gardner,
Jordan Smolinsky, Tim. M. P. Tait, and Philip Tanedo

Experimental design

(Krasznahorkay et al., PRL 116 (2016) 042501)



^{8}Be electromagnetic transition



$$Br(^{8}\mathrm{Be}^{*} \to {}^{8}\mathrm{Be}\,\gamma) \approx 1.4 \times 10^{-5}$$

$$Br(^{8}\mathrm{Be}^{*} \to {}^{8}\mathrm{Be}\; e^{+}e^{-}) \approx 5.5 \times 10^{-8}$$

Introduction of the protophobic fifth force
J. Feng et al.

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

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

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

$$\Gamma({}^8\mathrm{Be}^* \to {}^8\mathrm{Be}\, X) = \frac{(e/2)^2 (\varepsilon_p + \varepsilon_n)^2}{3\pi\Lambda^2} |\mathcal{M}|^2 |\vec{p}_X|^3$$

Prediction of the branching ratio

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

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

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

Derivation of the coupling strength to electrons

$$\Gamma(X \to e^+e^-) = \varepsilon_e^2 \alpha \frac{m_X^2 + 2m_e^2}{3m_X} \sqrt{1 - 4m_e^2/m_X^2}$$

$$v \approx 0.35c$$

$$L \approx \varepsilon_e^{-2}\, 1.8 \times 10^{-12}$$

$$L \lesssim 1 \text{ cm}$$

$$|\varepsilon_e| \gtrsim 1.3 \times 10^{-5}$$

Coupling strength to quarks

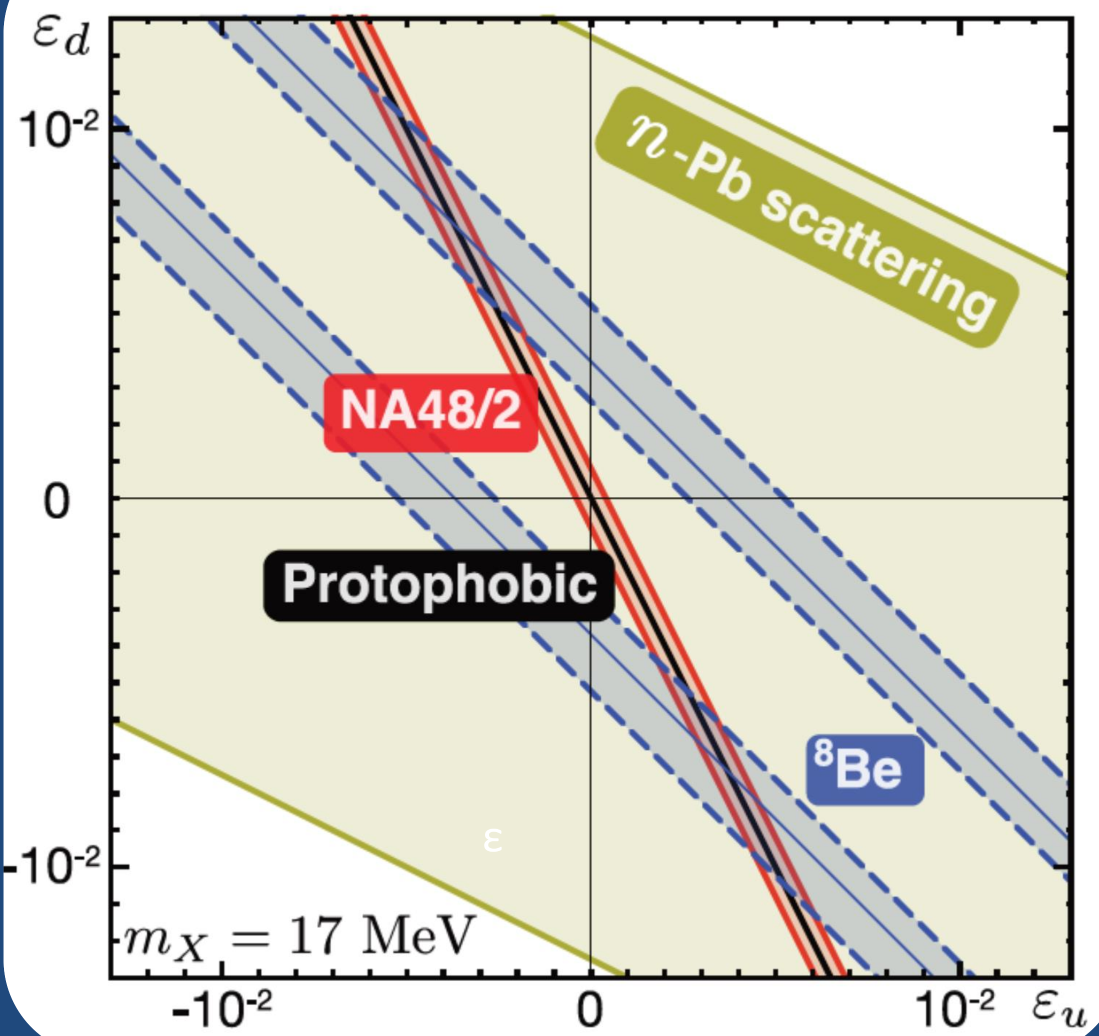
$$N_\pi \equiv (\varepsilon_u q_u - \varepsilon_d q_d)^2$$

$$N_\pi < \varepsilon_{\max}^2/9$$

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

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

The required charges to explain the ^{8}Be anomaly in the (ε_u; ε_d) planes, along with the leading constraints. The n-Pb and NA48/2 constraints are satisfied in the shaded regions. On the protophobic contour, $\varepsilon_d/\varepsilon_u = -2$. The width of the ^{8}Be bands corresponds to requiring the signal strength to be within a factor of 2 of the best.



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

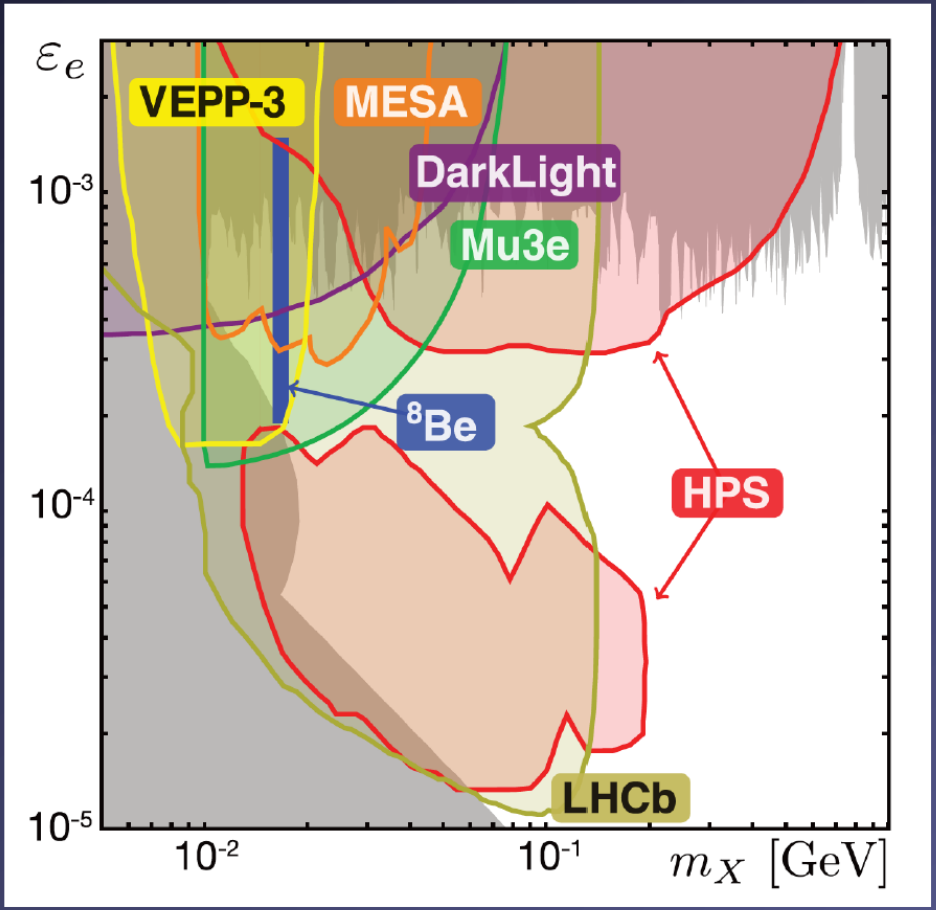
Feng et al., arXiv:1604.07411 [hep-ph]

- dark photon ✗
- scalar ✗
- axion ✗
- protophobic gauge boson ✓

$$\mathcal{L} \supset -X^\mu \sum_f e\,\varepsilon_f\,\bar{f}\gamma_\mu f$$

$$\varepsilon_u = -\frac{1}{3}\varepsilon_n \approx \pm 3.7\times 10^{-3}$$
$$\varepsilon_d = \frac{2}{3}\varepsilon_n \approx \mp 7.4\times 10^{-3}$$
$$2\times 10^{-4} \lesssim |\varepsilon_e| \lesssim 1.4\times 10^{-3}$$
$$|\varepsilon_\nu \varepsilon_e|^{1/2} \lesssim 7\times 10^{-5}$$

Future discovery prospects



Conclusions

- The search for new gauge bosons has a long history over a huge range of mass scales
- Something like a ***dark photon*** is very well theoretically motivated
- The observed deviation between the experimental and theoretical angular correlations is significant and can be described by assuming the creation and subsequent decay of a boson with mass $m_0c^2 = 16.70 \pm 0.35(\text{stat}) \pm 0.5(\text{sys})$ MeV.
- The branching ratio of the e^+e^- decay of such a boson to the γ decay of the 18.15 MeV level of ^{8}Be is found to be 5.8×10^{-6} for the best fit.
- The lifetime of the boson with the observed coupling strength is expected to be in the order of 10^{-14} s. This gives a flight distance of about 30 μm in the present experiment, and would imply a very sharp resonance ($\Gamma \sim 0.07$ eV) in the future e^+e^- scattering experiments.

Conclusions 2.

It’s very cool to think that there might be very complicated, very different physics going on all around us which we can’t examine but through this weak, tenuous connection.

Thank you very much for your attention

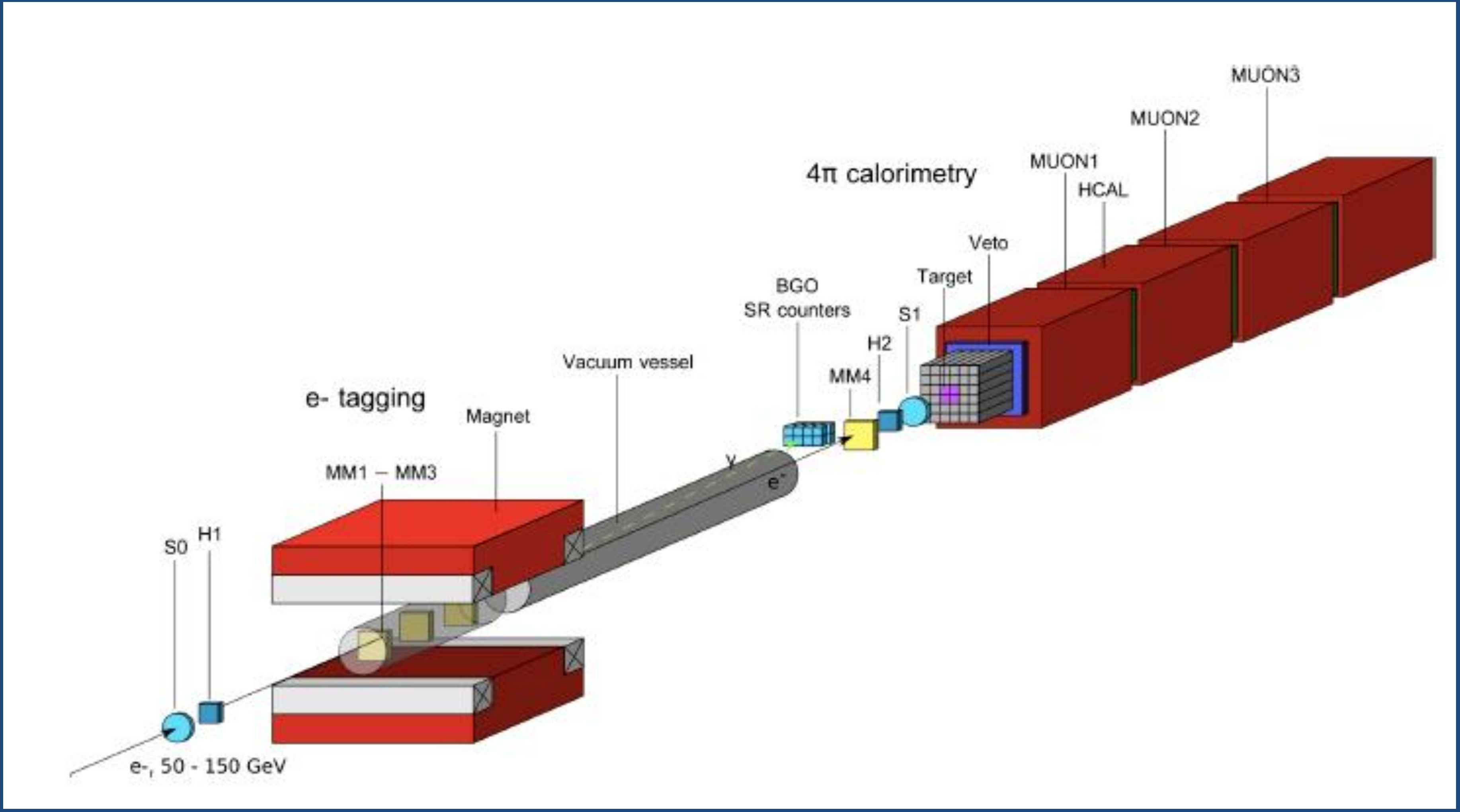
Getting close …

Missing energy signature from invisible decays of dark photons at the CERN SPS

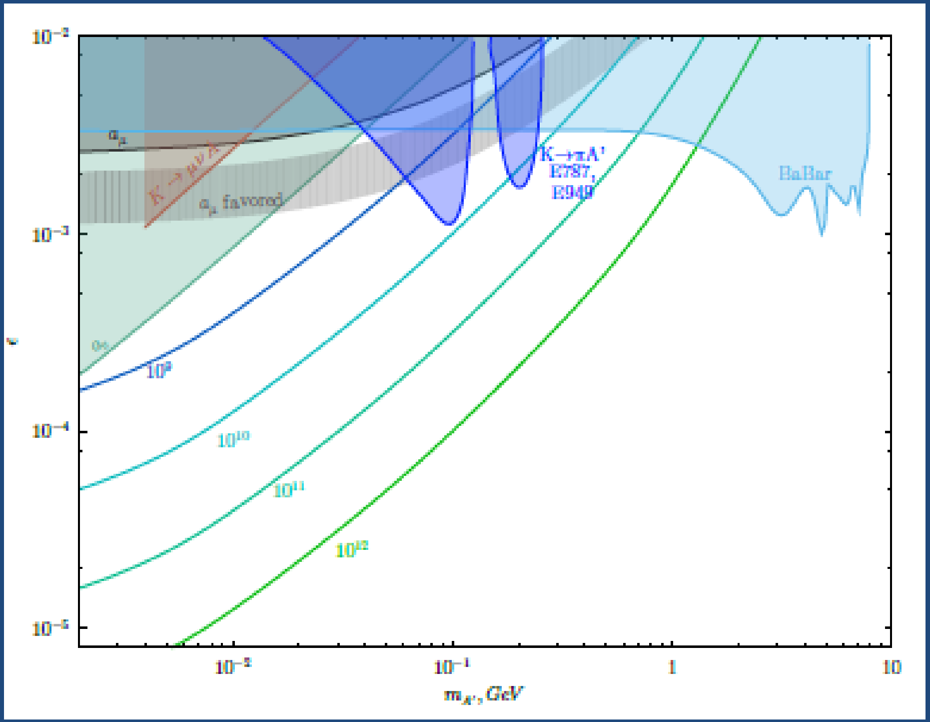
S.N. Gninenko[1], N.V. Krasnikov[1,2], M.M. Kirsanov[1], and D.V. Kirpichnikov[1]
[1] *Institute for Nuclear Research of the Russian Academy of Sciences, 117312 Moscow, Russia*
[2] *Joint Institute for Nuclear Research, 141980 Dubna, Russia*
(Dated: April 29, 2016)

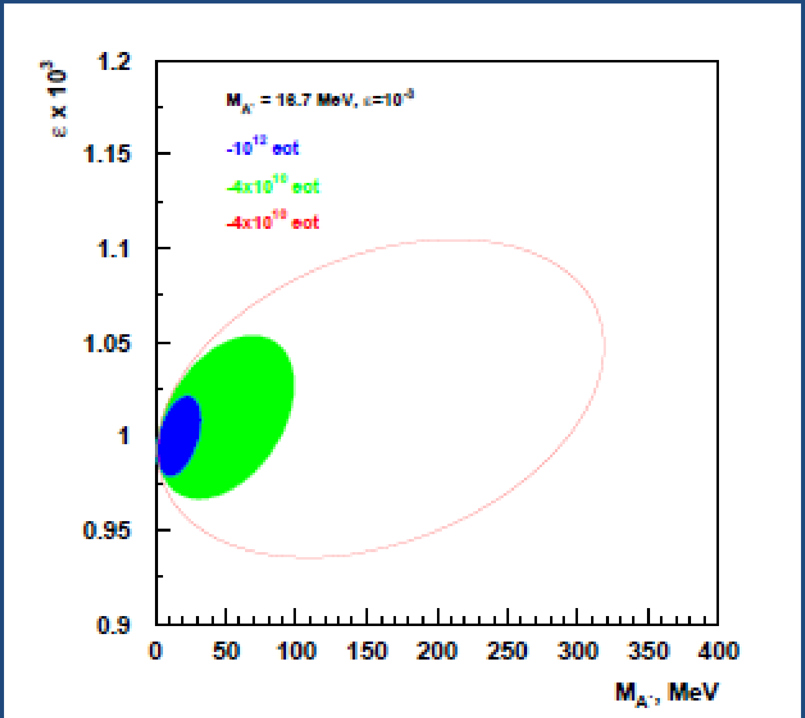
The dark photon (A') production through the mixing with the bremsstrahlung photon from the electron scattering off nuclei can be accompanied by the dominant invisible A' decay into dark-sector particles. In this work we discuss the missing energy signature of this process in the experiment NA64 aiming at the search for $A' \to$ *invisible* decays with a high-energy electron beam at the CERN SPS. We show the distinctive distributions of variables that can be used to distinguish the $A' \to$ *invisible* signal from background. The results of the detailed simulation of the detector response for the events with and without A' emission are presented. The efficiency of the signal event selection is estimated. It is used to evaluate the sensitivity of the experiment and show that it allows to probe the still unexplored area of the mixing strength $10^{-6} \lesssim \epsilon \lesssim 10^{-2}$ and masses up to $M_{A'} \lesssim 1$ GeV. The results obtained are compared with the results from other calculations. In the case of the signal observation, a possibility of extraction of the parameters $M_{A'}$ and ϵ by using the missing energy spectrum shape is discussed. We consider as an example the A' with the mass 16.7 MeV and mixing $\epsilon \lesssim 10^{-3}$, which can explain an excess of events recently observed in nuclear transitions of an excited state of ^{8}Be. We show that if such A' exists its invisible decay can be observed in NA64 within a month of running, while data accumulated during a few months would allow also to determine the ϵ and $M_{A'}$ parameters.

Experimental setup for the NA64 experiment at CERN SPS



Expected results





Exclusion regions for the mentioned number of beam particles

Discovery potential of the experiment for different number of beam particles.