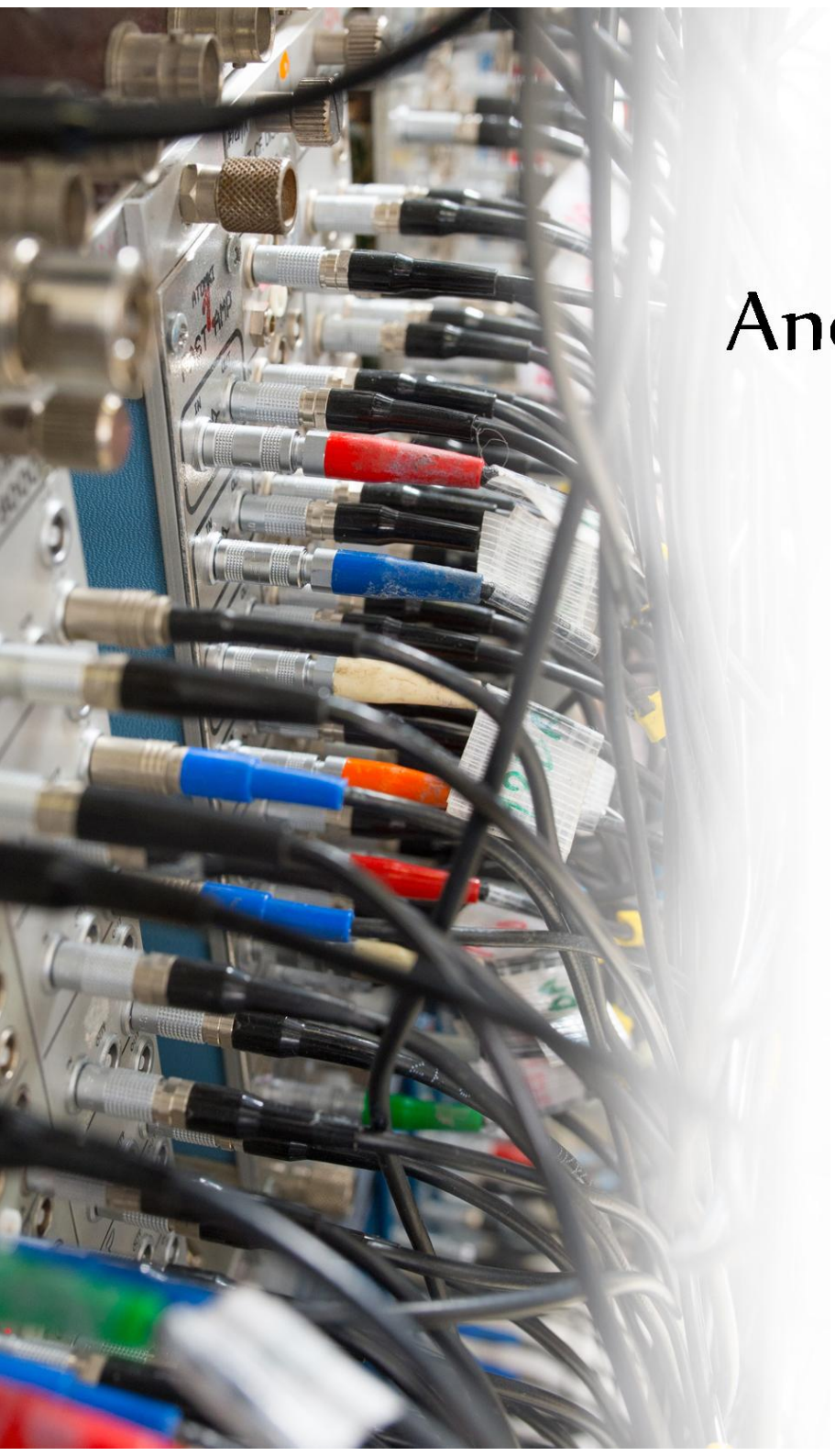


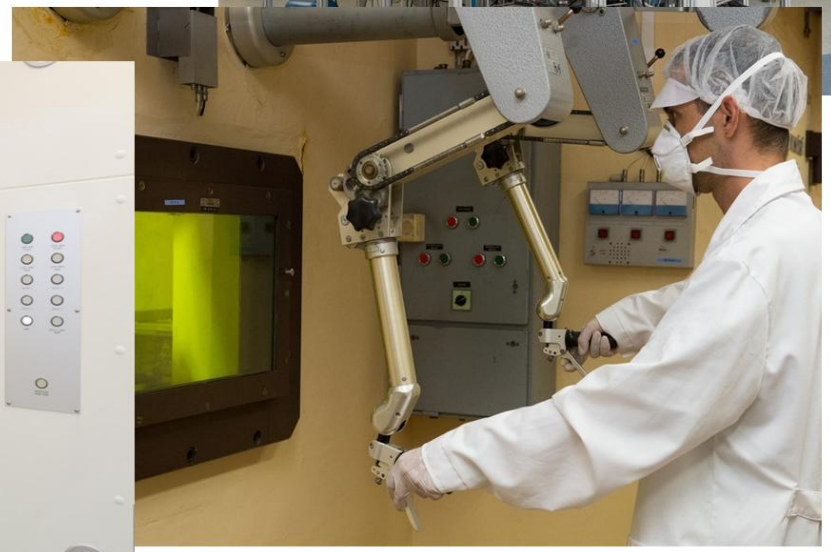
Anomalous e^+e^--production in ^{8}Be (On the track of dark force?)

MTA Atomki

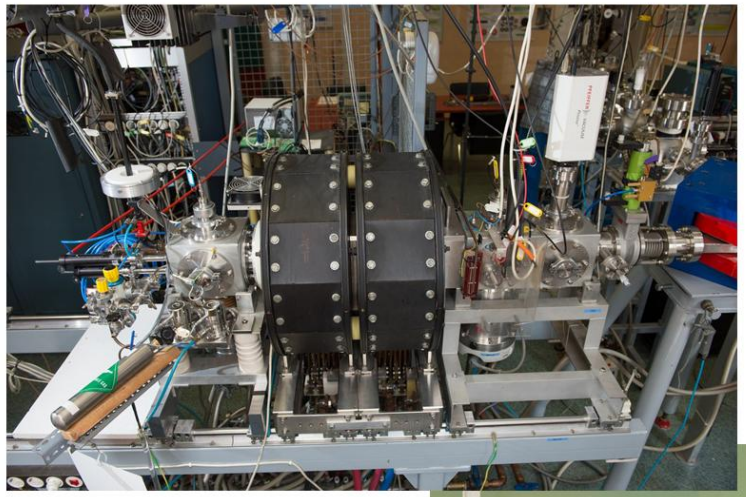
ATOMKI
Institute for Nuclear Research
Hungarian Academy of Sciences
Debrecen

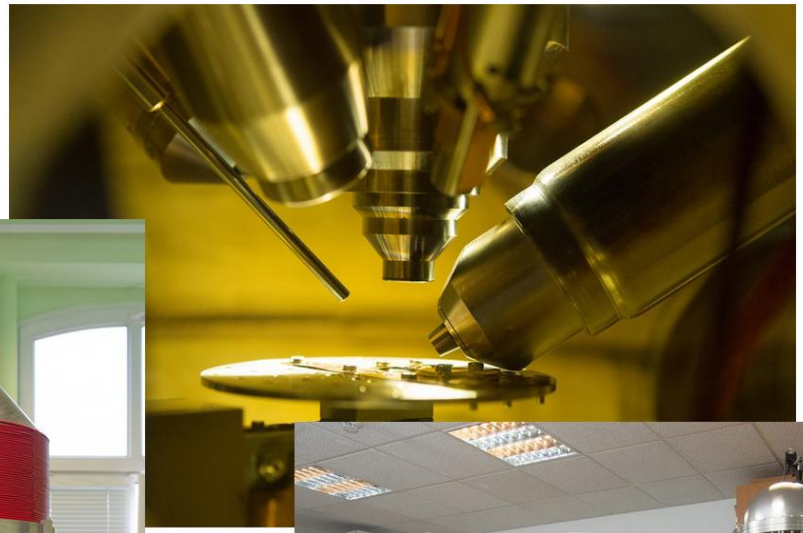
Accelerators for low-energy nuclear physics

Accelerators for radioisotopes

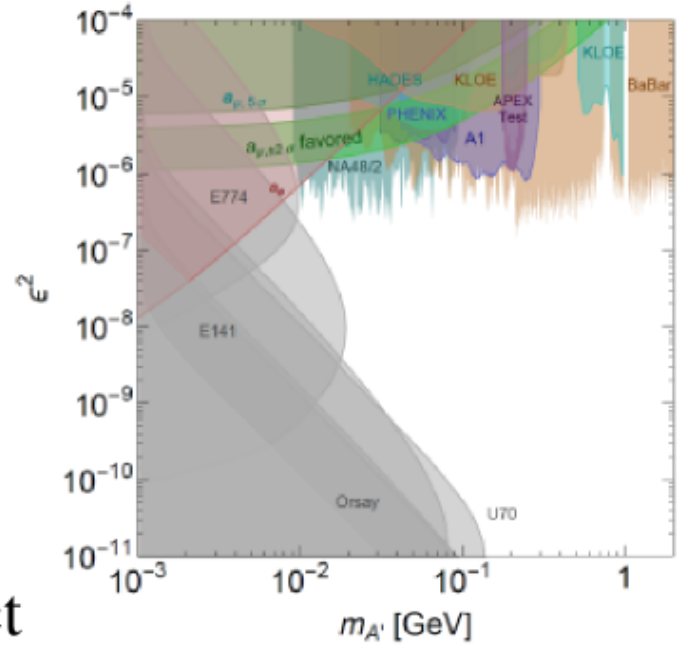


Atomic physics and Materials Science



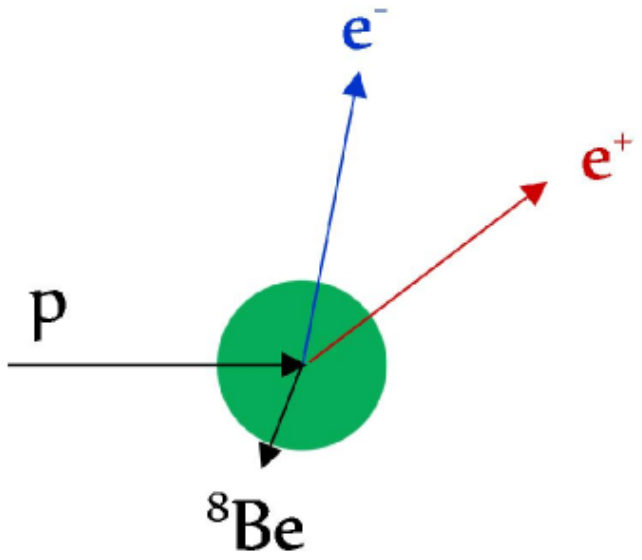


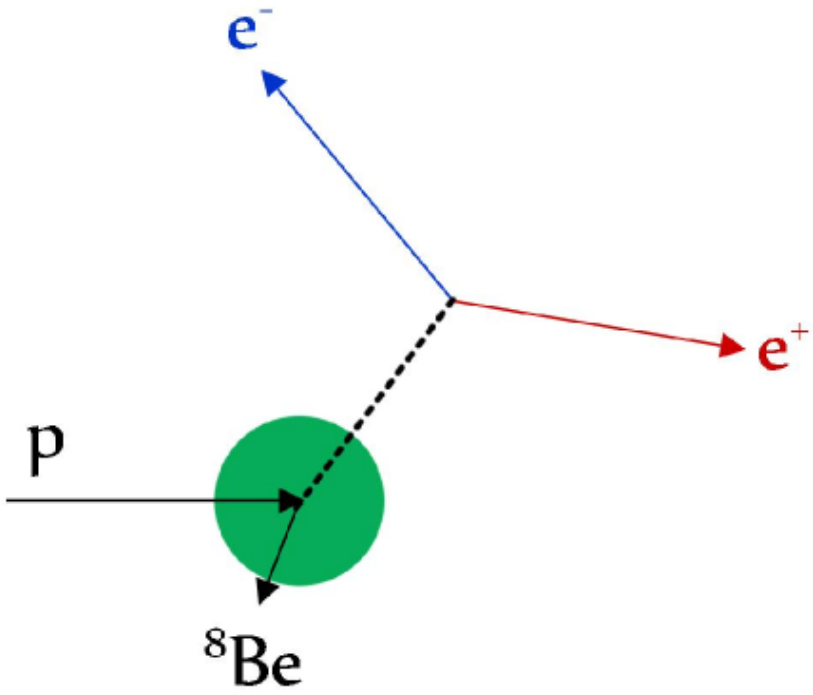
Light dark particles in nuclear transitions



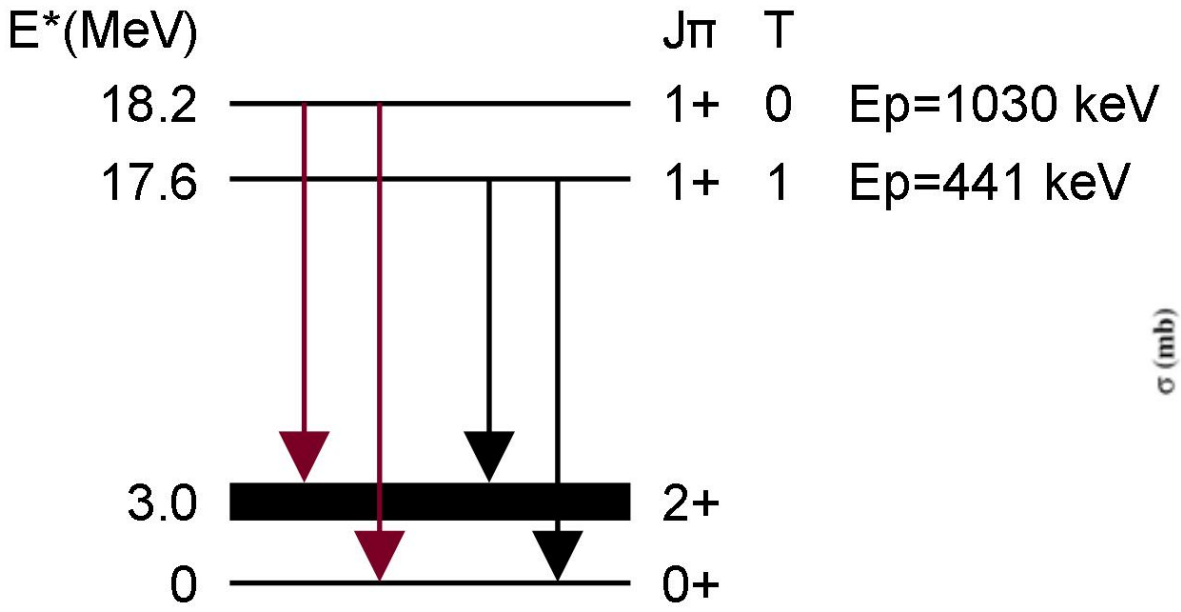
Excited states are requested:
- to be located above the **threshold** of the dark particle rest mass
- to have **structural contrast** with respect to the specific decay channel
- with minimized multipole **mixing** and **interference** effect between the incoming and outgoing channels

Kinematic separation: decay length

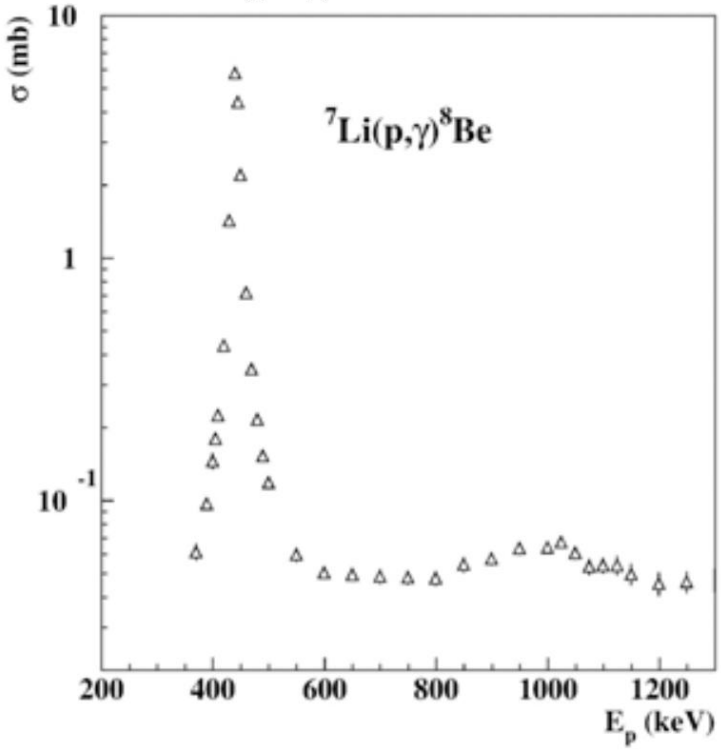




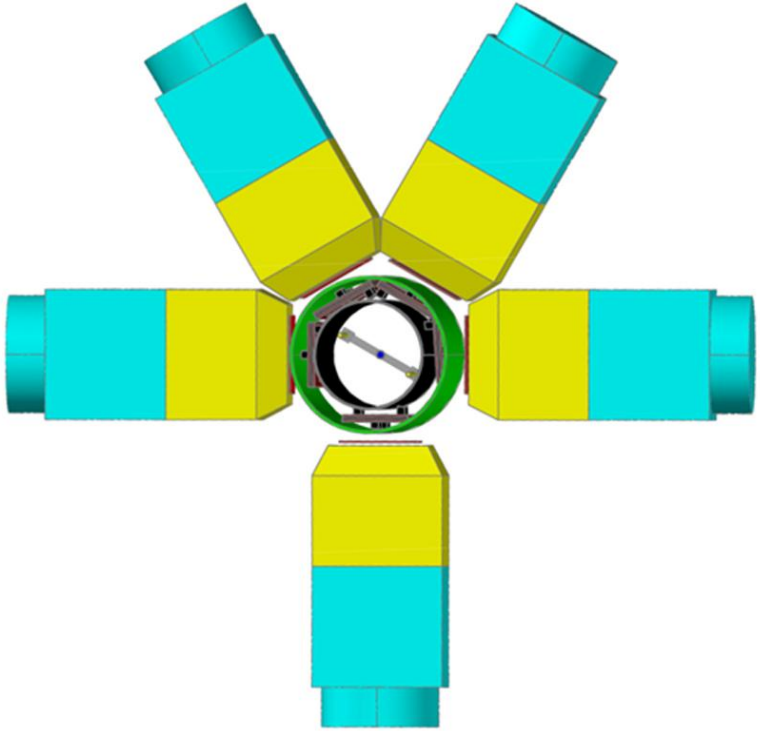
M1 transitions in ^{8}Be

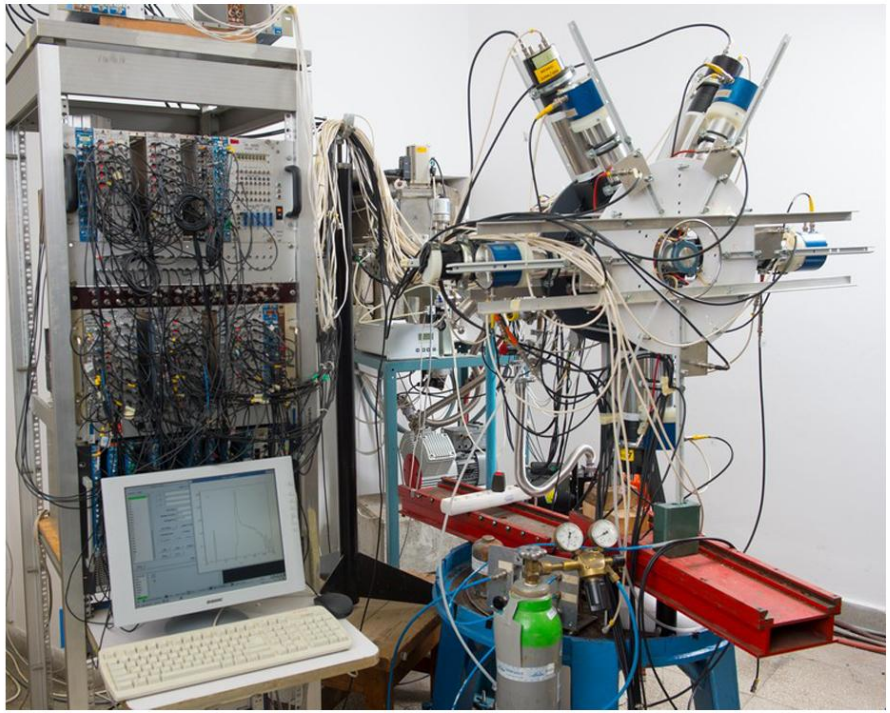


Excitation with the
^{7}Li(p,γ)^{8}Be reaction

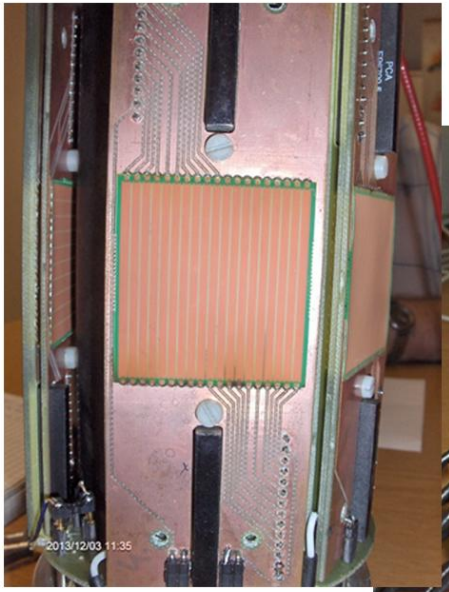


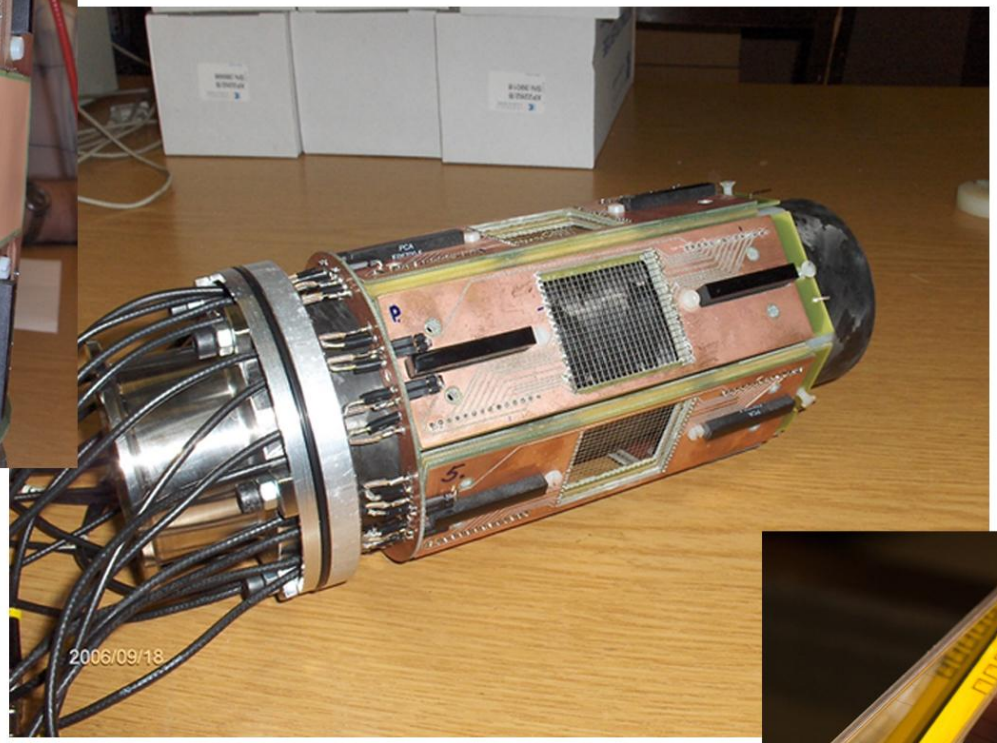
The scintillator array

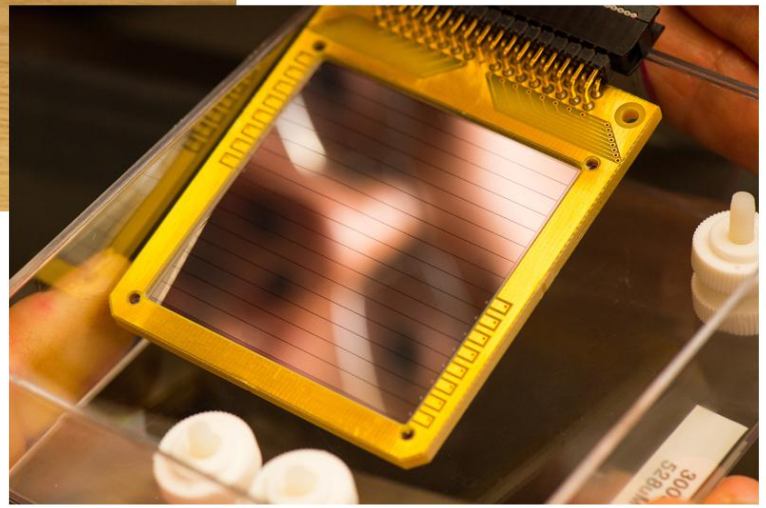




The MWPC detectors

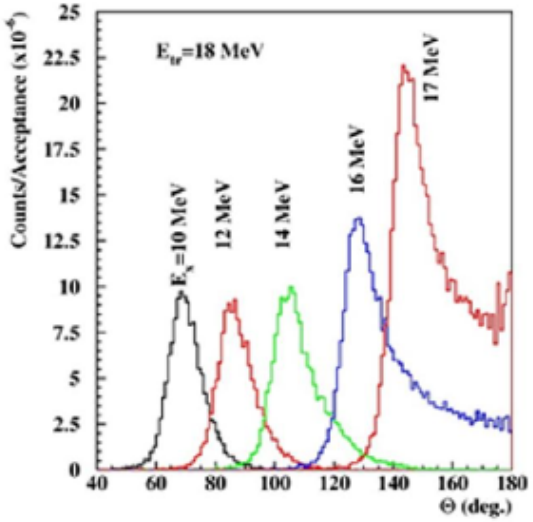


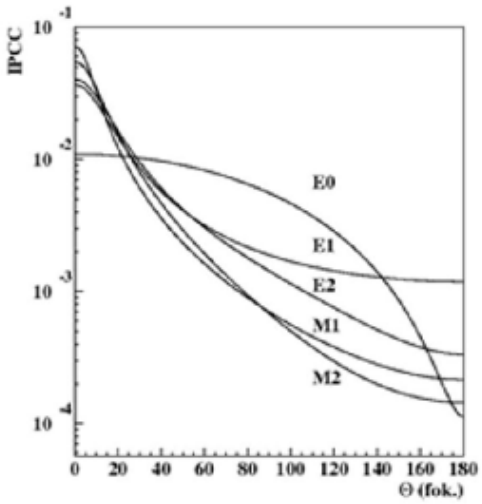


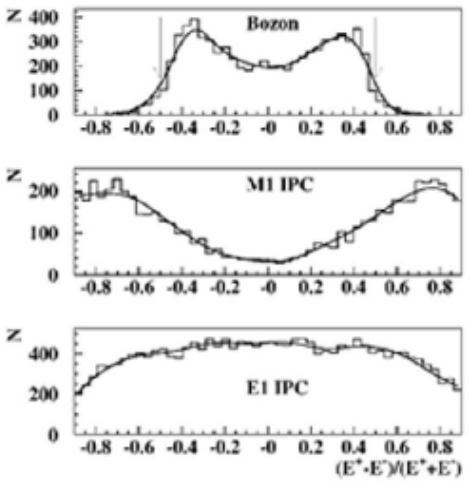


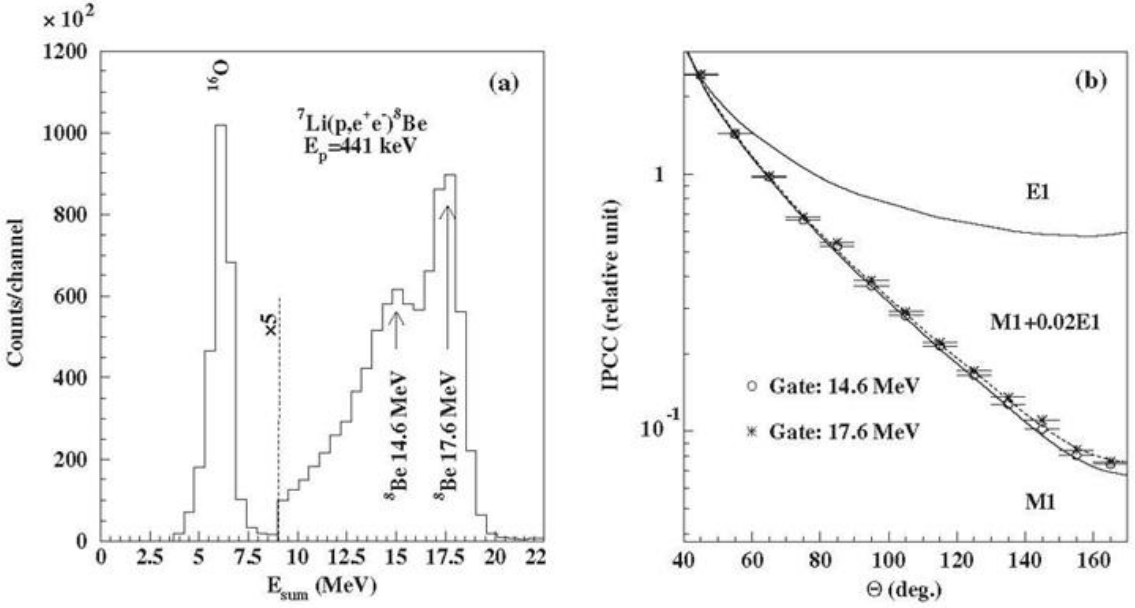
Characteristics of the decay channel

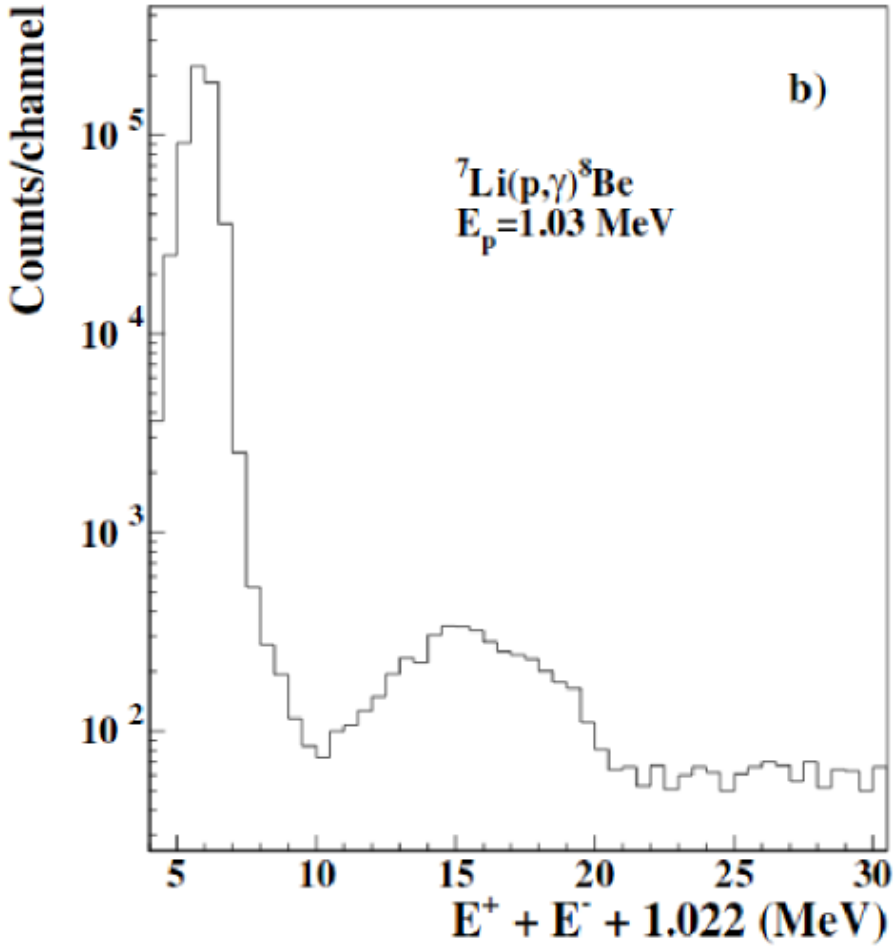
- MC simulations of the particle mass
- possible multipole components
- symmetry energy term

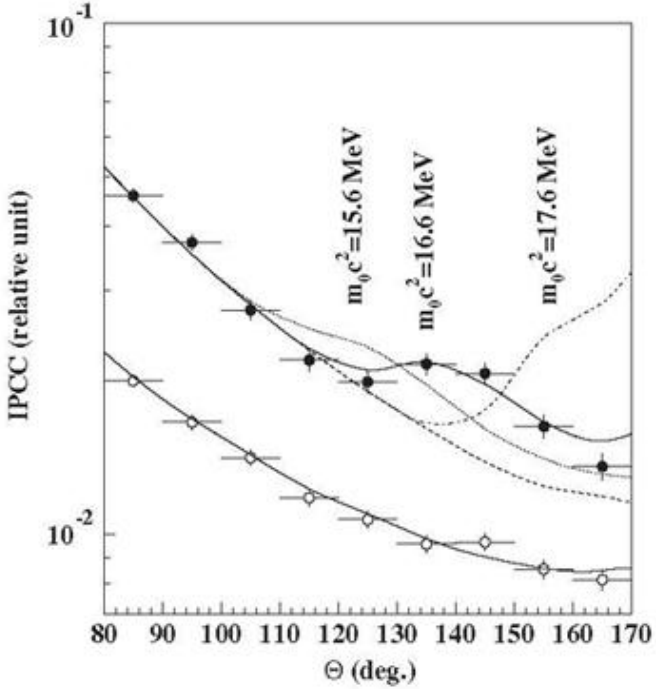


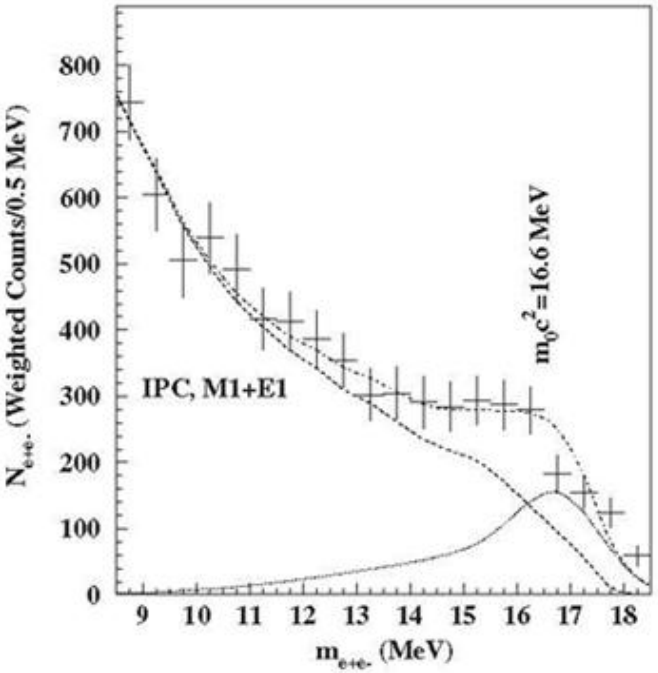


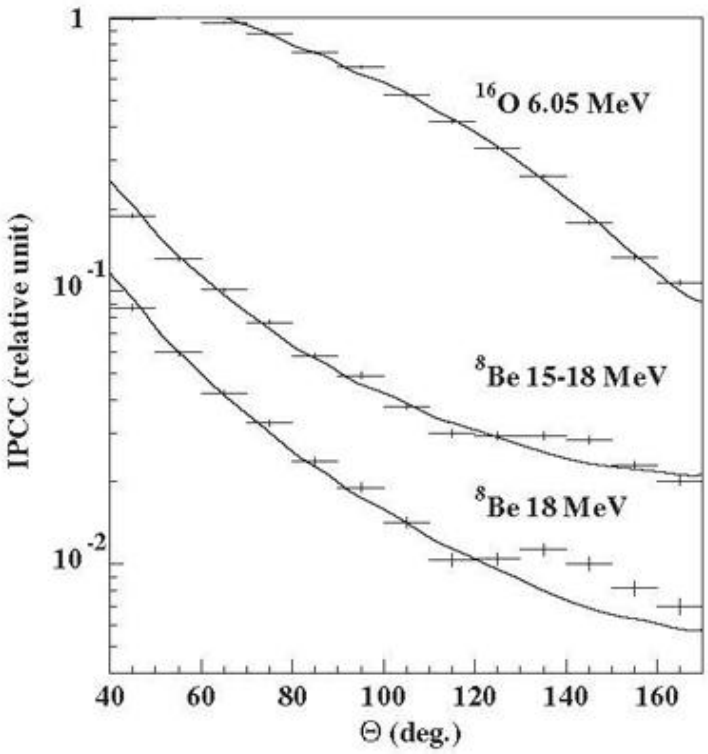


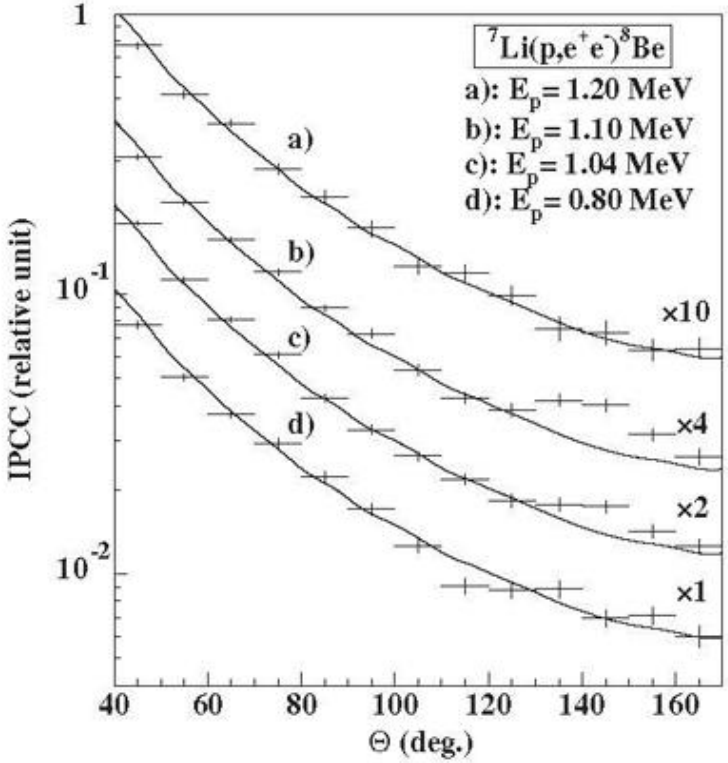

× 10^2
1200
1000
800
600
400
200
0
Counts/channel
(a)
16O
7Li(p,e+e-)8Be
Ep=441 keV
×5
8Be 14.6 MeV
8Be 17.6 MeV
0
2.5
5
7.5
10
12.5
15
17.5
20
22
Esum (MeV)
(b)
IPCC (relative unit)
1
10-1
E1
M1+0.02E1
Gate: 14.6 MeV
Gate: 17.6 MeV
M1
40
60
80
100
120
140
160
Θ (deg.)


b)
^{7}Li(p,γ)^{8}Be
E_p=1.03 MeV
Counts/channel
10 5
10 4
10 3
10 2
5
10
15
20
25
30
E+ + E- + 1.022 (MeV)


IPCC (relative unit)
10^{-1}
10^{-2}
m_0c^2=15.6 MeV
m_0c^2=16.6 MeV
m_0c^2=17.6 MeV
80 90 100 110 120 130 140 150 160 170
Θ (deg.)

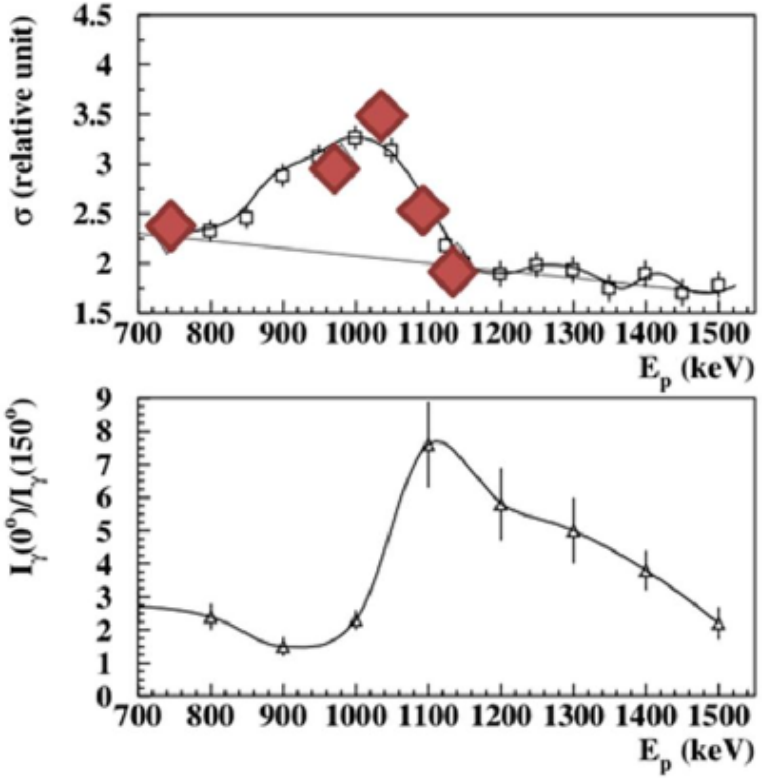

N_{e+e-} (Weighted Counts/0.5 MeV)
0 100 200 300 400 500 600 700 800
IPC, M1+E1
m_0c^2=16.6 MeV
9 10 11 12 13 14 15 16 17 18
m_{e+e-} (MeV)


1
10^{-1}
10^{-2}
IPCC (relative unit)
^{16}O 6.05 MeV
^{8}Be 15-18 MeV
^{8}Be 18 MeV
40
60
80
100
120
140
160
Θ (deg.)


1
10^{-1}
10^{-2}
IPCC (relative unit)
^{7}Li(p,e^{+}e^{-})^{8}Be
a): E_p= 1.20 MeV
b): E_p= 1.10 MeV
c): E_p= 1.04 MeV
d): E_p= 0.80 MeV
a)
b)
c)
d)
×10
×4
×2
×1
40
60
80
100
120
140
160
Θ (deg.)

Interference effect?

Mapping the resonance shape
to compare forward-backward symmetry
of the gamma channel



UCI-TR-2016-09

Protophobic Fifth Force Interpretation of the Observed Anomaly in ^{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*

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, $^8\mathrm{Be}^* \to {}^8\mathrm{Be}\,X$, 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 protophobic

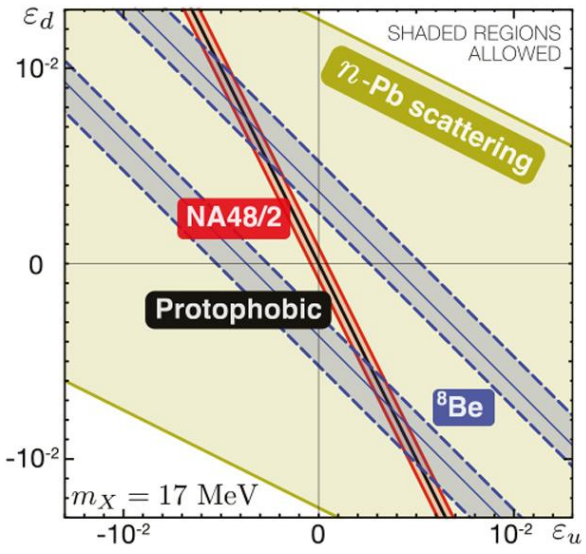
TABLE I. Relevant ^{8}Be states and their masses, decay widths, and spin-parity and isospin quantum numbers.

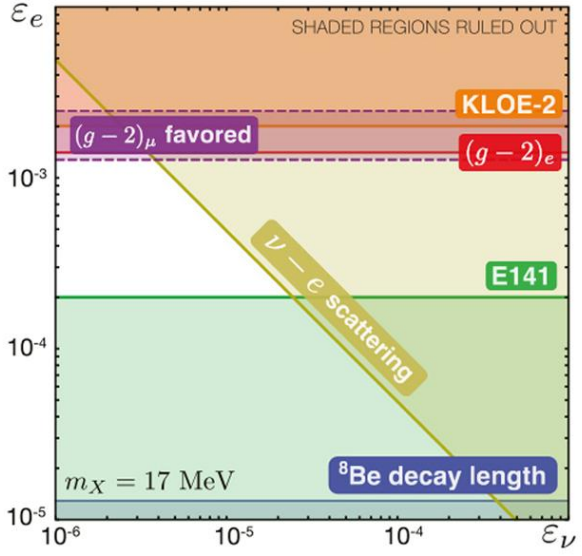
State	Mass (MeV)	Width (keV)	J^P	Isospin
$^8\mathrm{Be}^*$ (18.15)	7473.00	138	1^+	0
$^8\mathrm{Be}^{*\prime}$ (17.64)	7472.49	10.7	1^+	1
^{8}Be (g.s.)	7454.85	—	0^+	0

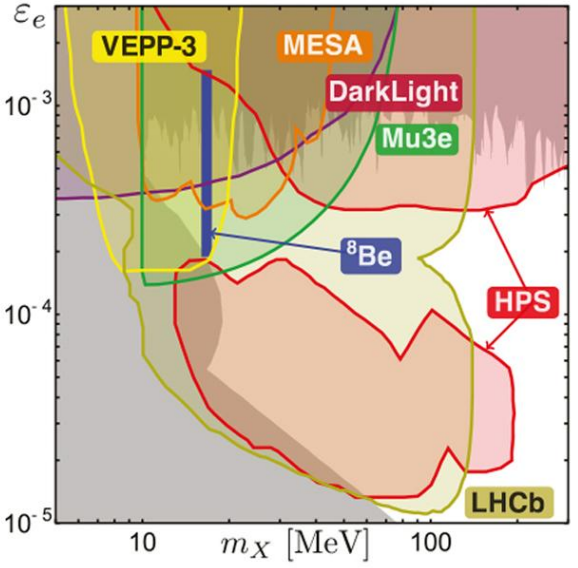
tense proton beam impinges on thin ^{7}Li targets. Given the ^{7}Li nucleus mass of 6533.83 MeV, the $^8\mathrm{Be}^*$ and $^8\mathrm{Be}^{*\prime}$ states are resonantly produced by tuning the proton kinetic energies to 1.025 and 0.441 MeV, respectively. The resulting excited states then decay promptly,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

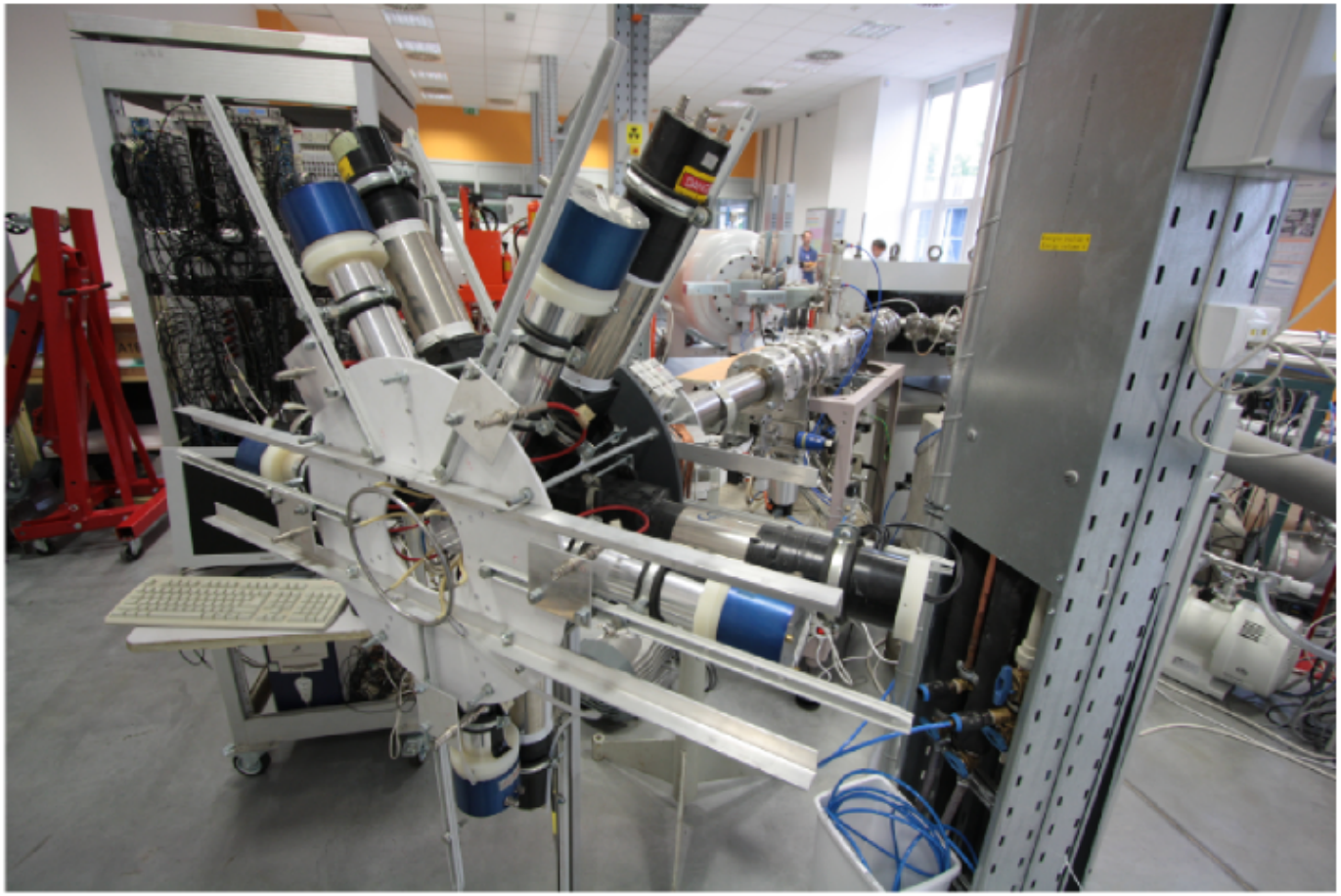
Search for the dark particle that interacts with the SM particles



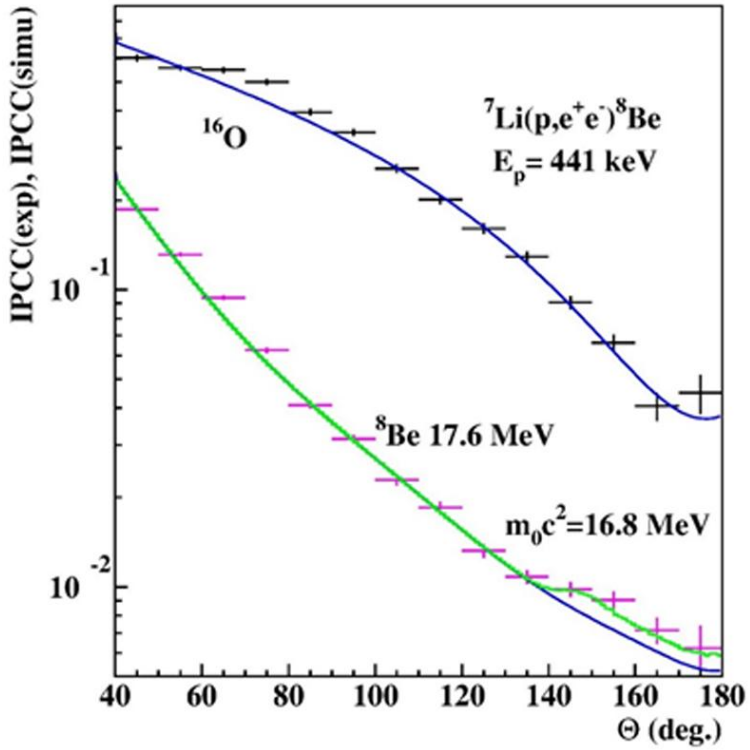


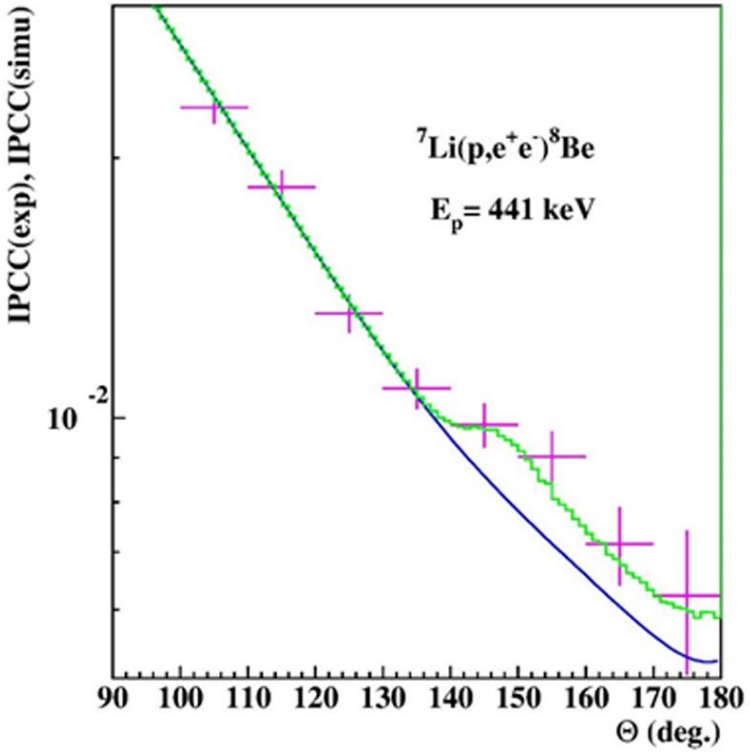


Pair spectrometer at the new Tandetron accelerator beamline (2016)



New results on the decay of the isovector state





Future perspectives

- new model systems for nuclear spectroscopy studies at low-energy accelerators
- electron-positron collisions (PADME project)
- more precise and more high-statistic revision of ^{8}Be measurement
- ...

Thank you for your attention!