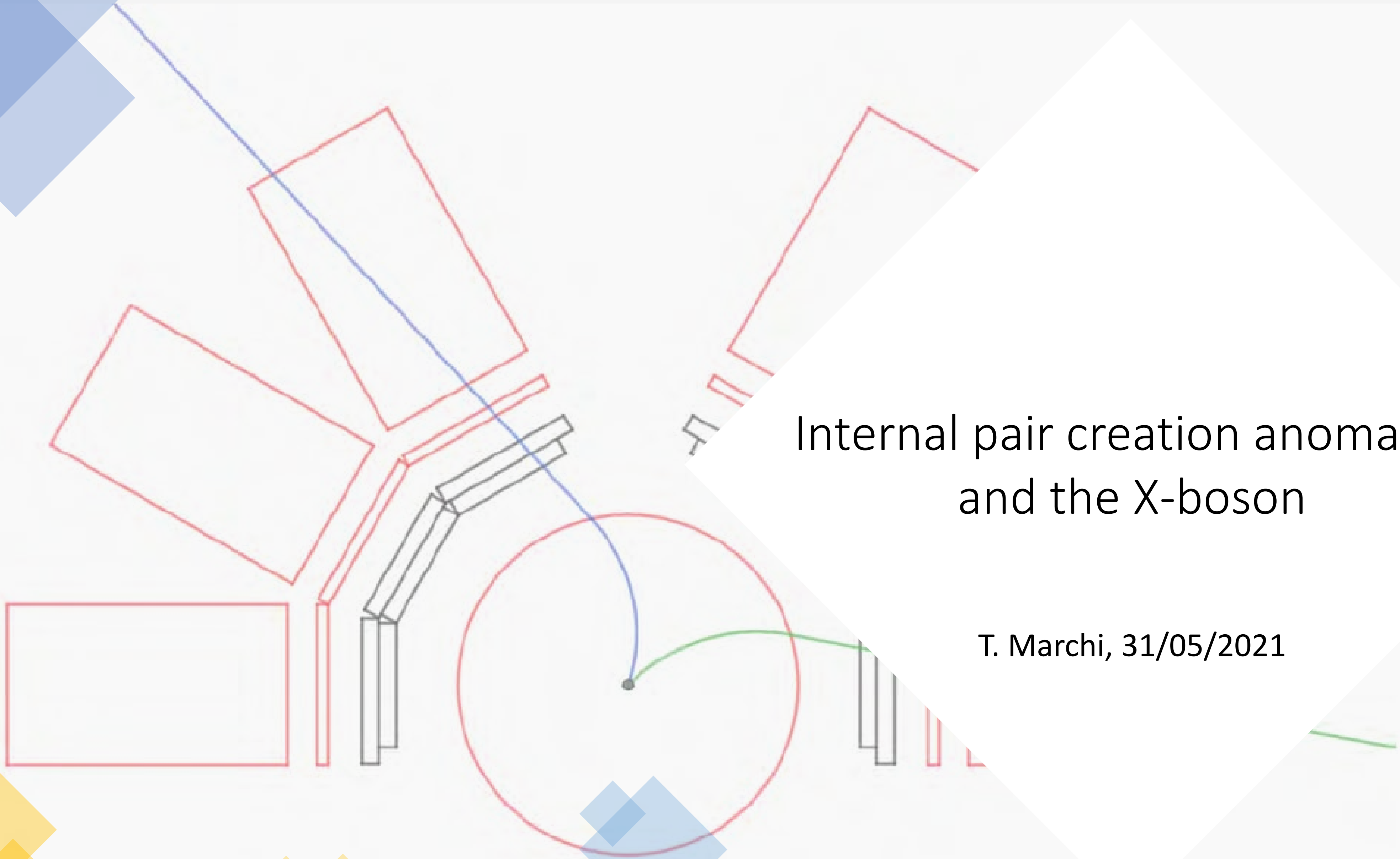


Internal pair creation anomalies and the X-boson

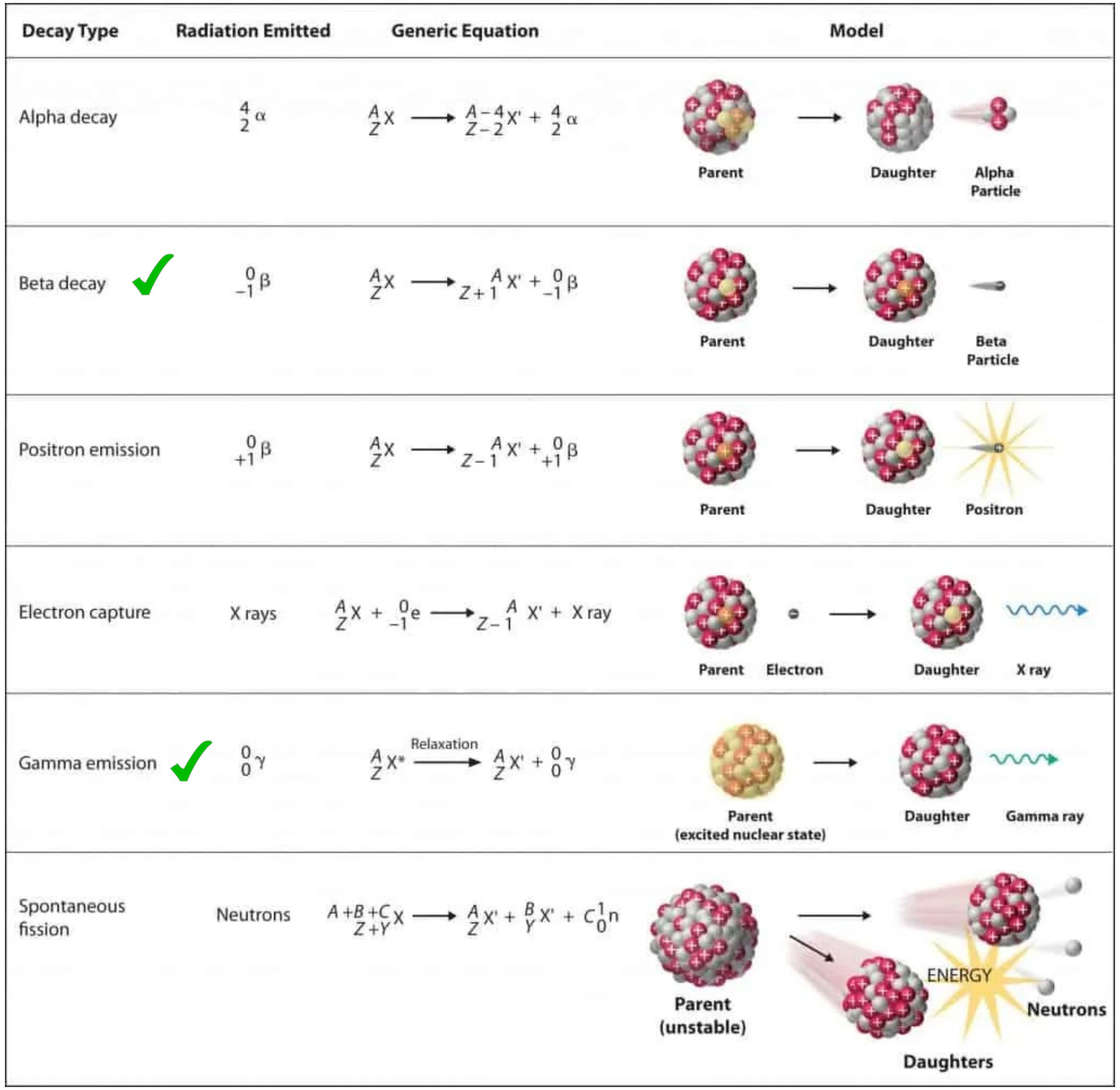
T. Marchi, 31/05/2021

Outline

- Internal pair creation in Nuclear decays.
- The Hungarian anomaly: experimental evidence and interpretations.
- Direct channels and complementary approaches.

- Aipac8Be: a new setup at LNL for an independent measurement.

Foreword: Nuclear Transitions and Internal Pair Creation



In a typical nuclear spectroscopy experiment:

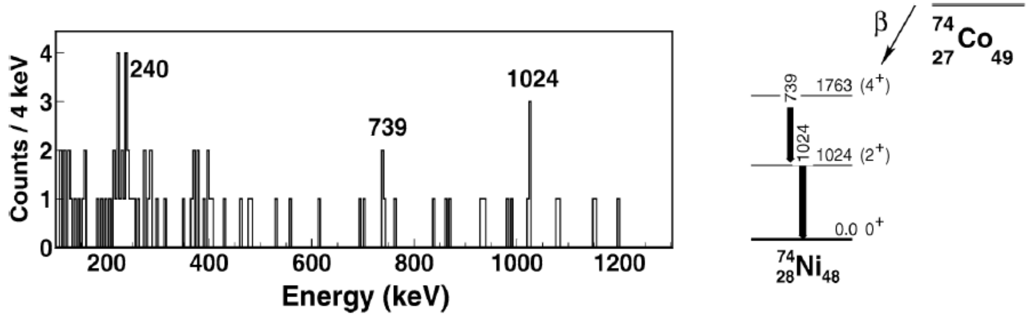
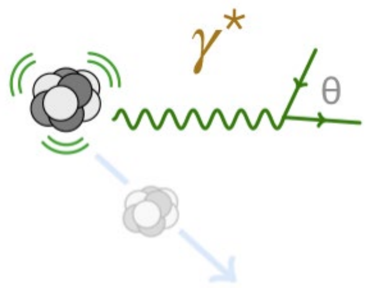


Figure 1.21: Experimental ^{74}Ni level scheme. On the left: the γ-ray spectrum as measured from the ^{74}Co β decay. On the right: level scheme as reconstructed from the systematics of even-even Ni isotopes. Adapted from [65]

Gamma-ray emission

Δl	transition name	$\pi_i \pi_f = +1$	$\pi_i \pi_f = -1$
0	*monopole*	*forbidden*	*forbidden*
1	*dipole*	M1	E1
2	*quadrupole*	E2	M2
3	*octupole*	M3	E3

Table 2.1: Electromagnetic transitions involving photon emission allowed by the selection rules. The list is limited to $\Delta l \leqslant 3$.



Emission of e^+e^- pairs coupled to the Nuclear Field.
It must be disentangled from pair production due to high energy gamma rays.

- Possible only for ΔE>1.022 MeV
- Competes with gamma emission (typical cross section ratio is 10^{-3})
- Allowed for monopole transitions

- Allows to directly probe transition properties

Theory is well established since Rose's work:

- M.E. Rose, Phys Rev 76, 678 (1949);
- E.K. Warburton, Phys Rev 133, 6B (1964)
- P. Schlüter et al, Phys Rep 75, 327 (1981)
- P. Schlüter et al, At Data and Nucl Data Tab 24, 509 (1979)

It is possible to compute:

Pair Conversion Coefficients (PCC)

Electron-positron angular correlations

Detecting "high energy" e^+e^- pairs (sharing 10-20 MeV of kinetic energy) emitted in an environment dominated by gamma-rays poses an experimental challenge.

Emission of Electron–Positron Pairs from Light Nuclei I: Monopole Transition in $^{16}O^*$

By S. DEVONS, G. GOLDRING† and G. R. LINDSEY‡
Department of Physics, Imperial College, London

MS. received 21st August 1953, and in amended form 30th October 1953

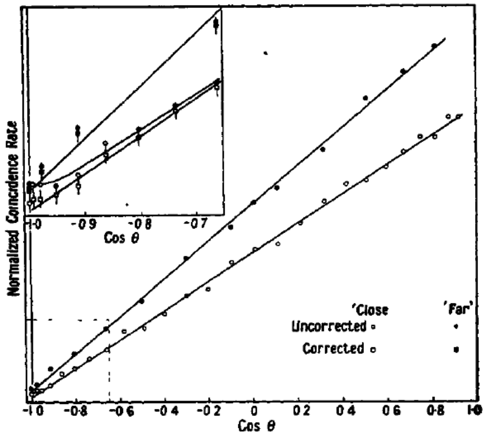
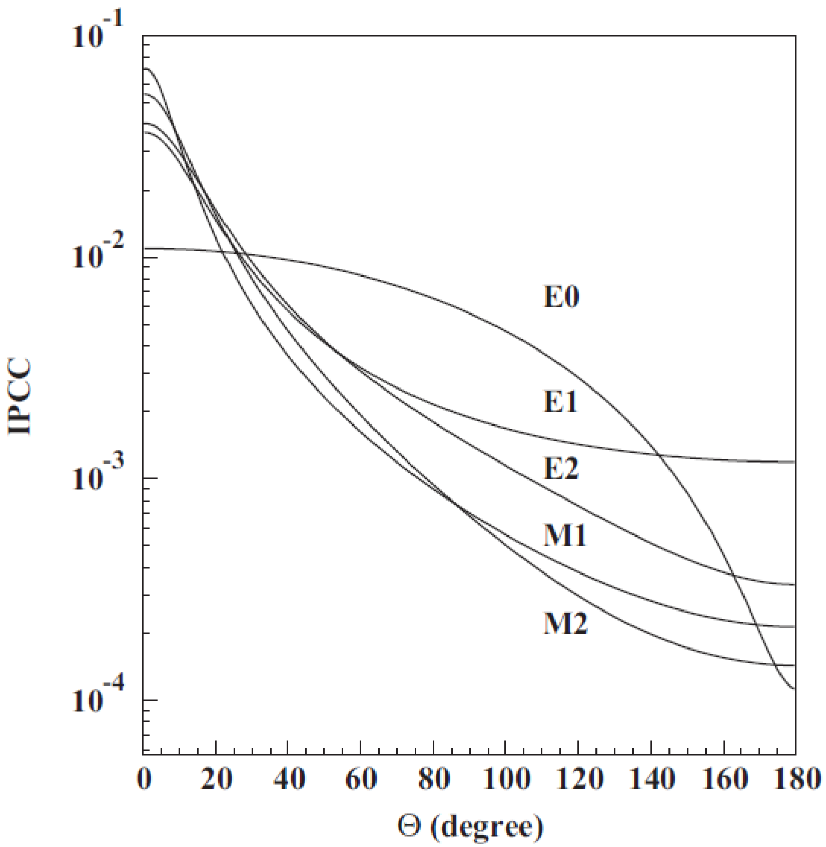


Figure 5. Electron–positron angular correlation.

The $^{19}F(p,\alpha)^{16}O^*$ reaction is the calibration standard for e^+e^- correlations since 1950's.
Beam energies: 0.5 – 1.5 MeV.
Transition of interest (**E0**): $^{16}O(6.06\ MeV;\ 0^+)$ -> g.s.

What to expect for a 17 MeV transition?

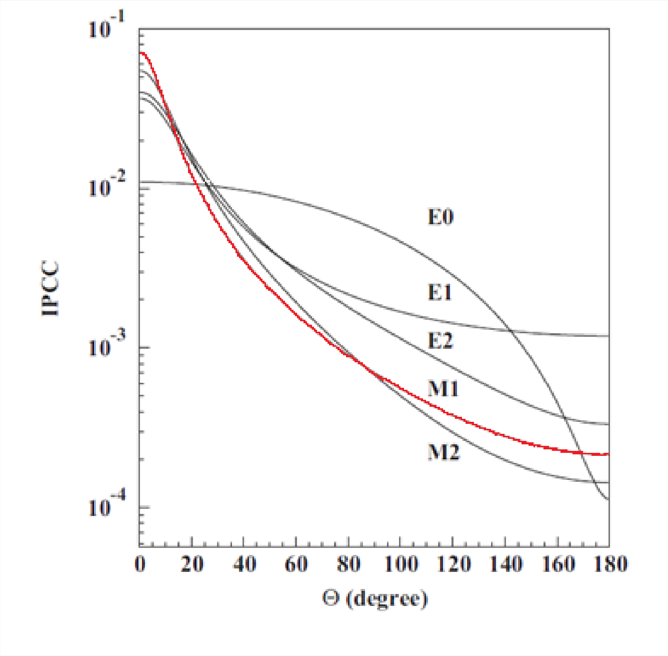


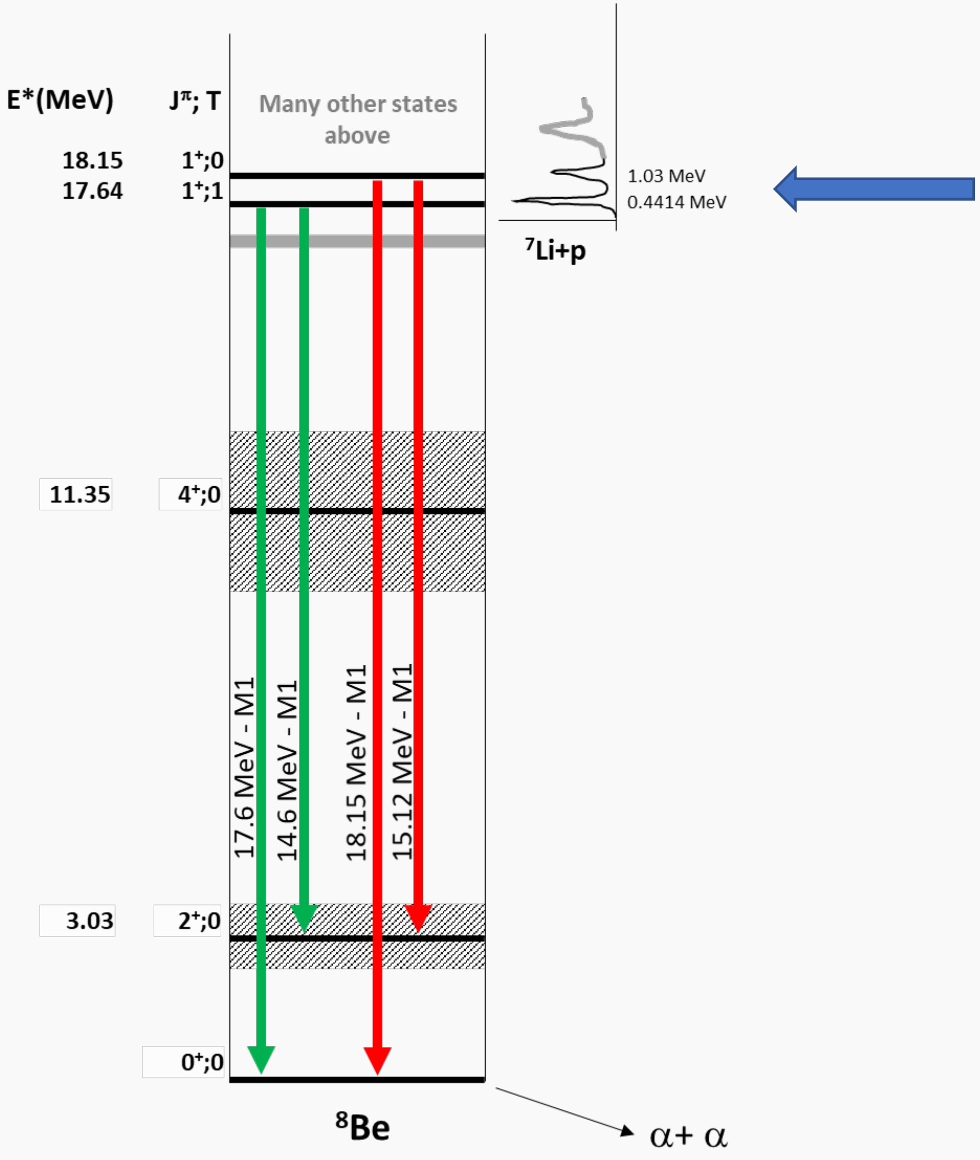
Computed using Rose's model

[J. Gulyás et al, Nucl Instr and Meth in Phys Res A 808, 21 (2016)]

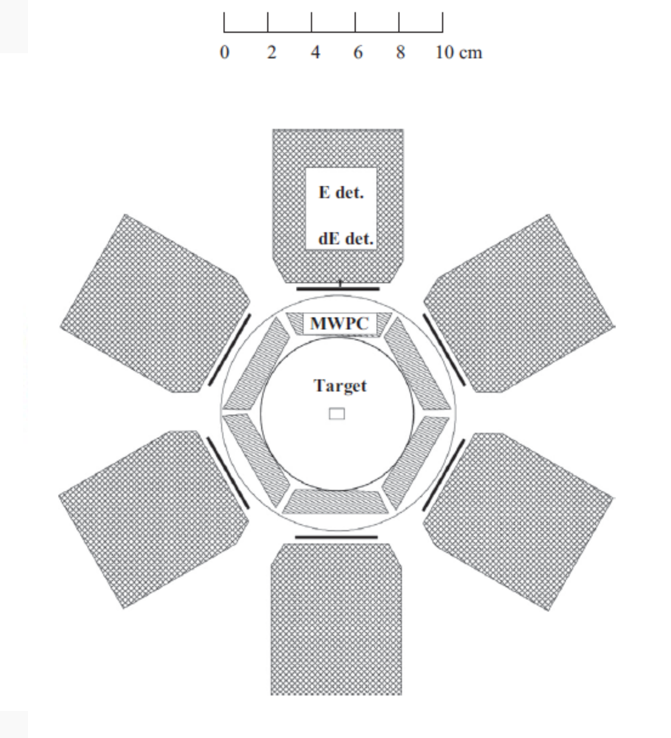
Transitions in excited ^{8}Be

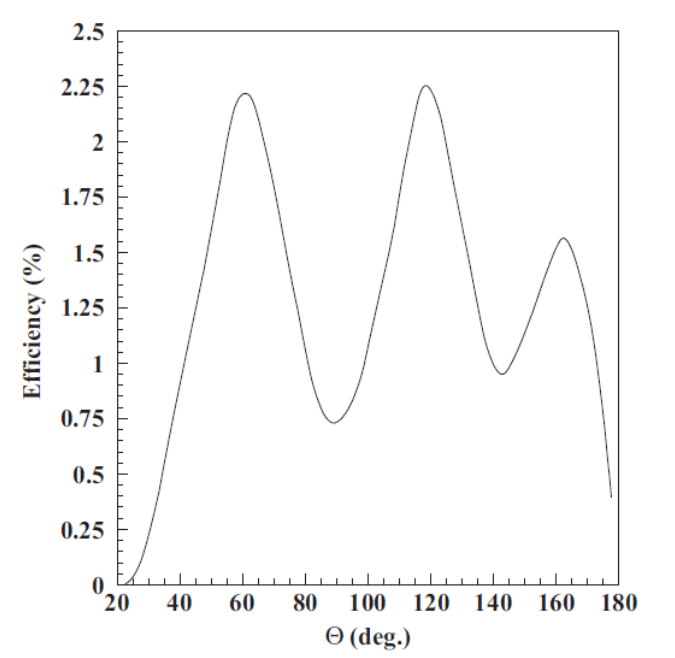
The reaction: ^{7}Li(p,e^{+}e^{-})^{8}Be allows to selectively populate the 17.64 MeV and 18.15 MeV resonances.
The considered transitions are M1 type.
Isospin is assigned in analogy to isobaric nuclei -> two iso-scalar and two iso-vector transitions.

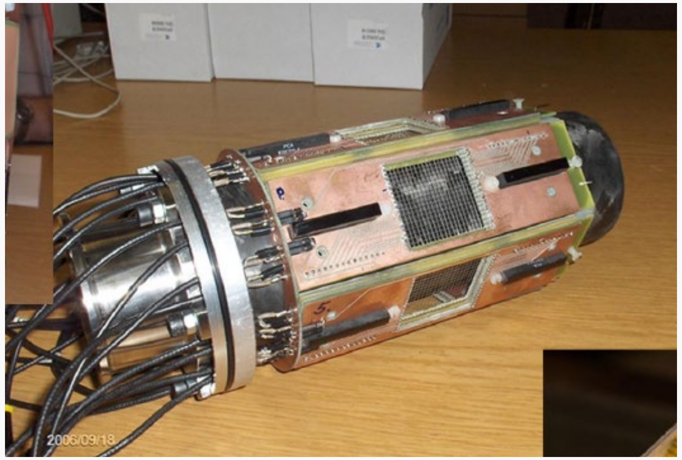




The Hungarian setup for pair spectrosocpy.





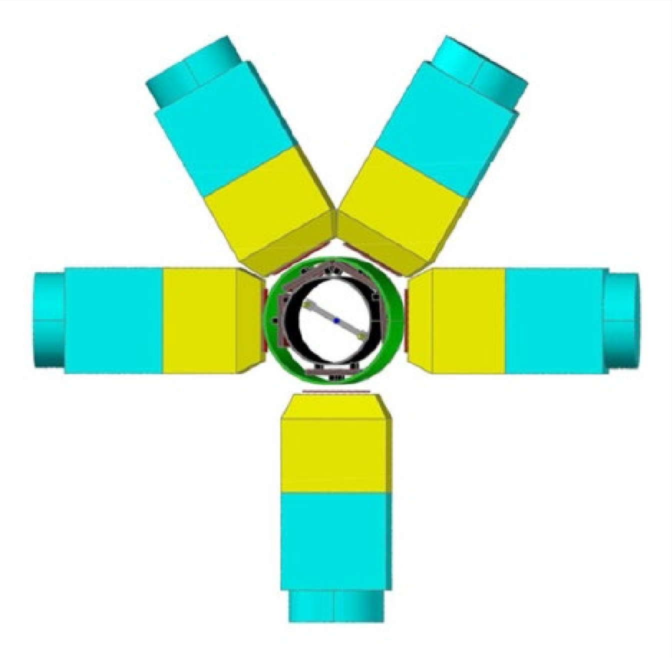


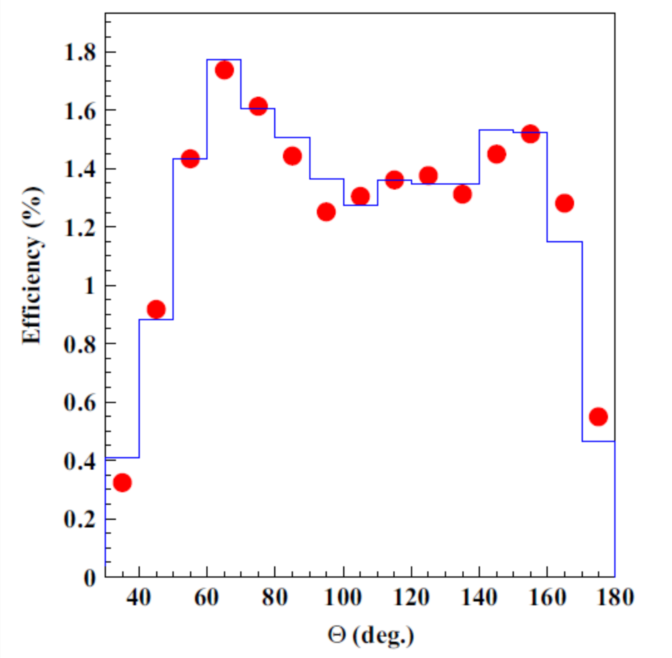
$\Delta\theta \sim 2°$, but:

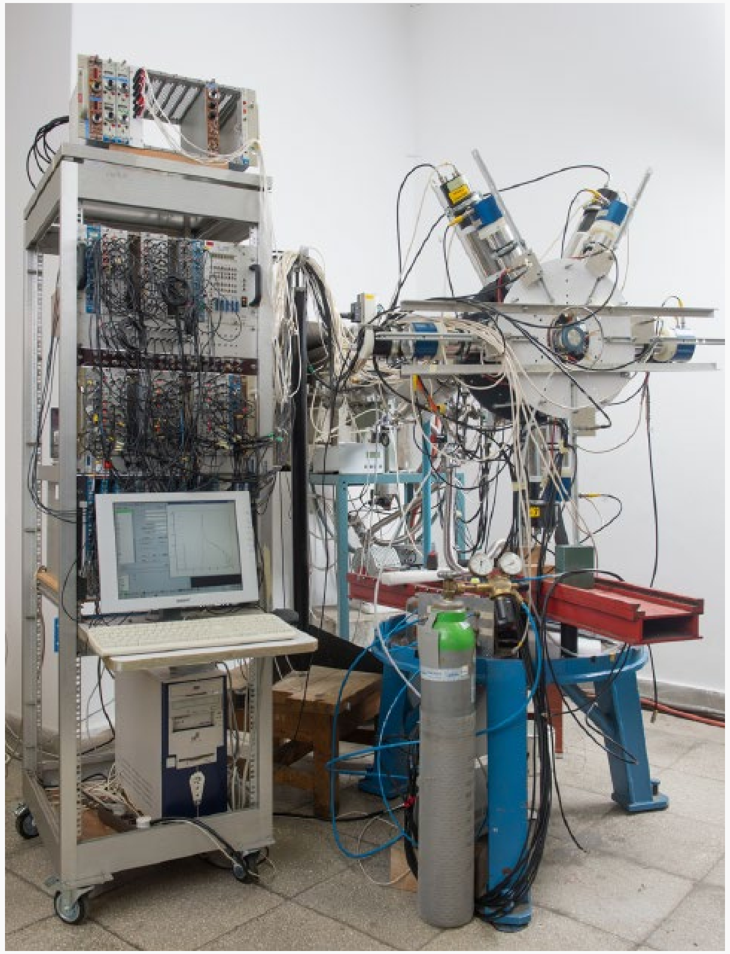
The simulated angular resolution corresponds to FWHM $\approx 7°$. We use bins of $10°$ in the correlation spectra.

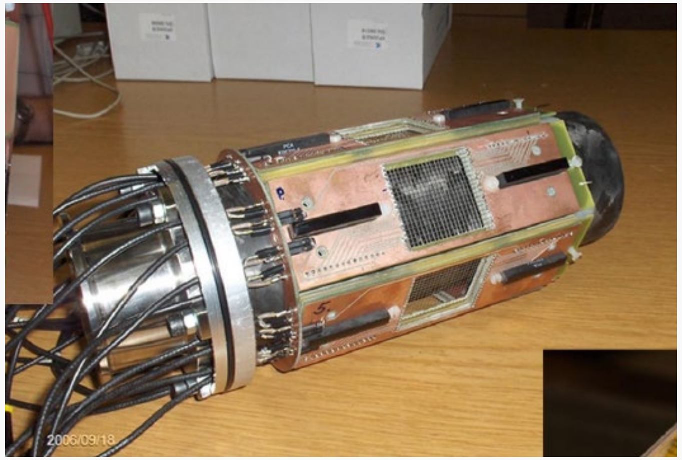
[J. Gulyás et al, Nucl Instr and Meth in Phys Res A 808, 21 (2016)]

The Hungarian setup.









Δθ ~ 2°, but:

The simulated angular resolution corresponds to FWHM ≈ 7°. We use bins of 10° in the correlation spectra.

[J. Gulyás et al, Nucl Instr and Meth in Phys Res A 808, 21 (2016)]

The updated Hungarian setup.

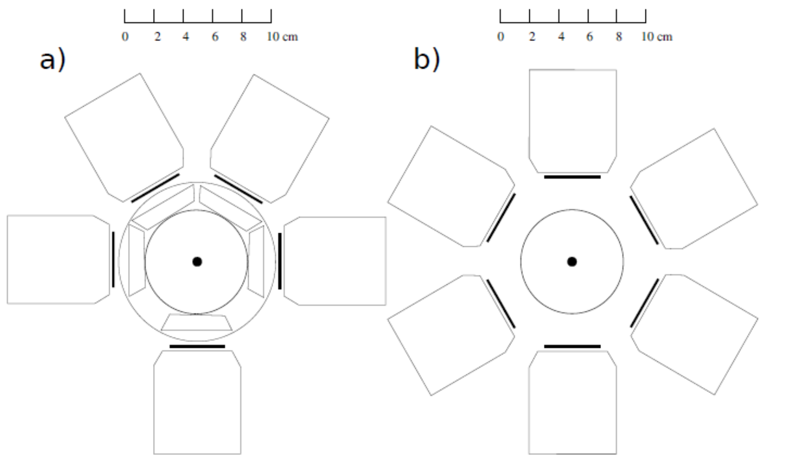


Figure 1. Comparison between the old and new setups. The previous setup (a) used 5 telescopes, each with a MWPC to gather the position of the particles and a thin scintillator in front of the main one to differentiate electrons and positrons from gammas. The new setup (b) consisted of 6 telescopes, and the MWPCs was replaced by DSSDs, which can be used for the particle identification, removing the need for the thin scintillators.

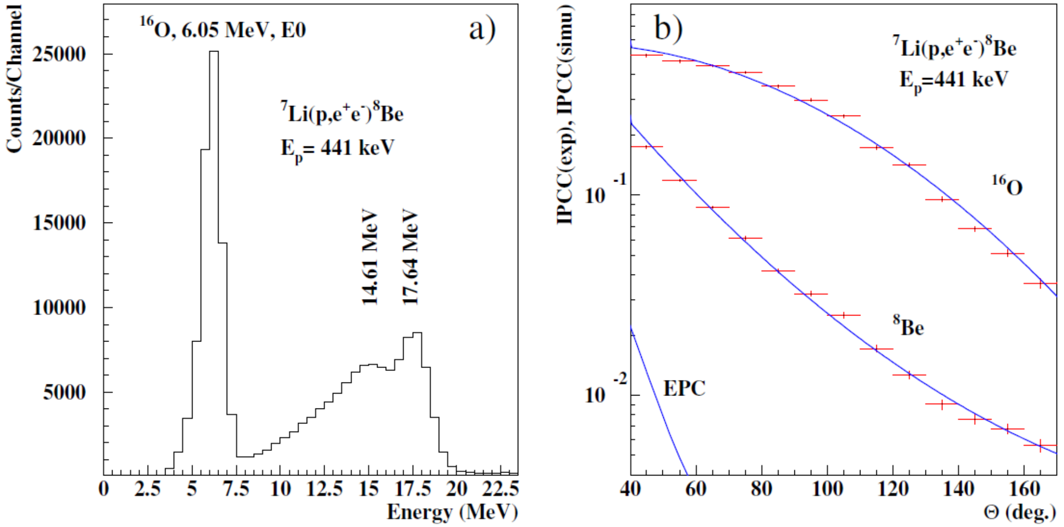


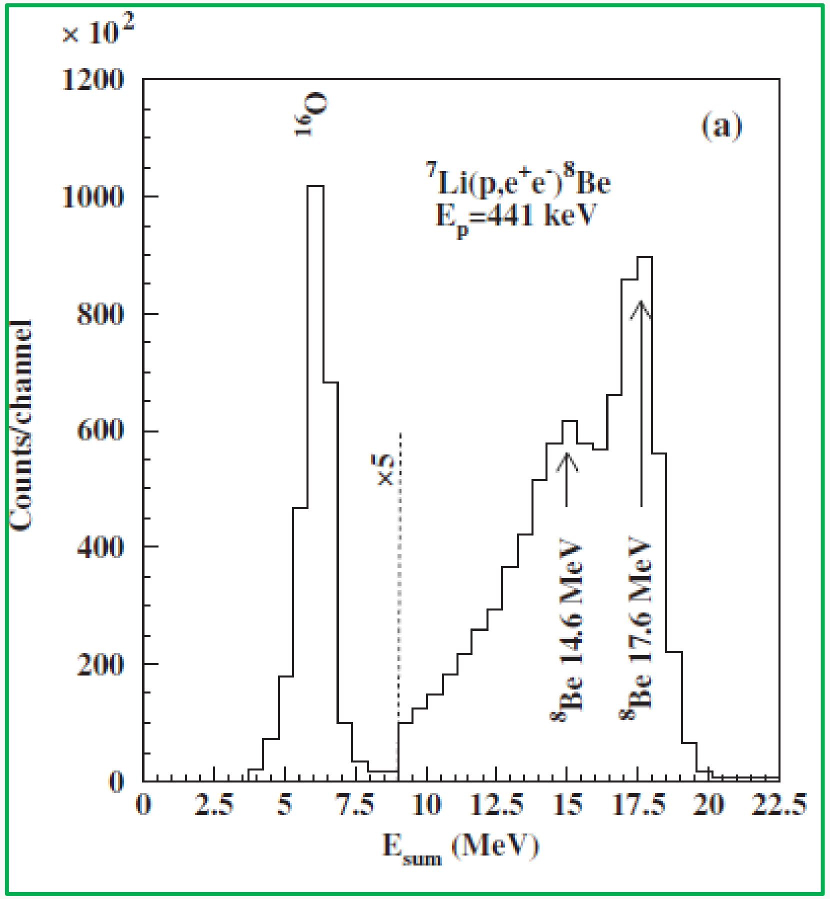
Figure 2. Energy sum spectrum (a) and angular correlation (b) of the e^+e^-pairs from the 17.6 MeV transition. Full blue curve shows the simulated results, and red points with error bars shows the experimental results

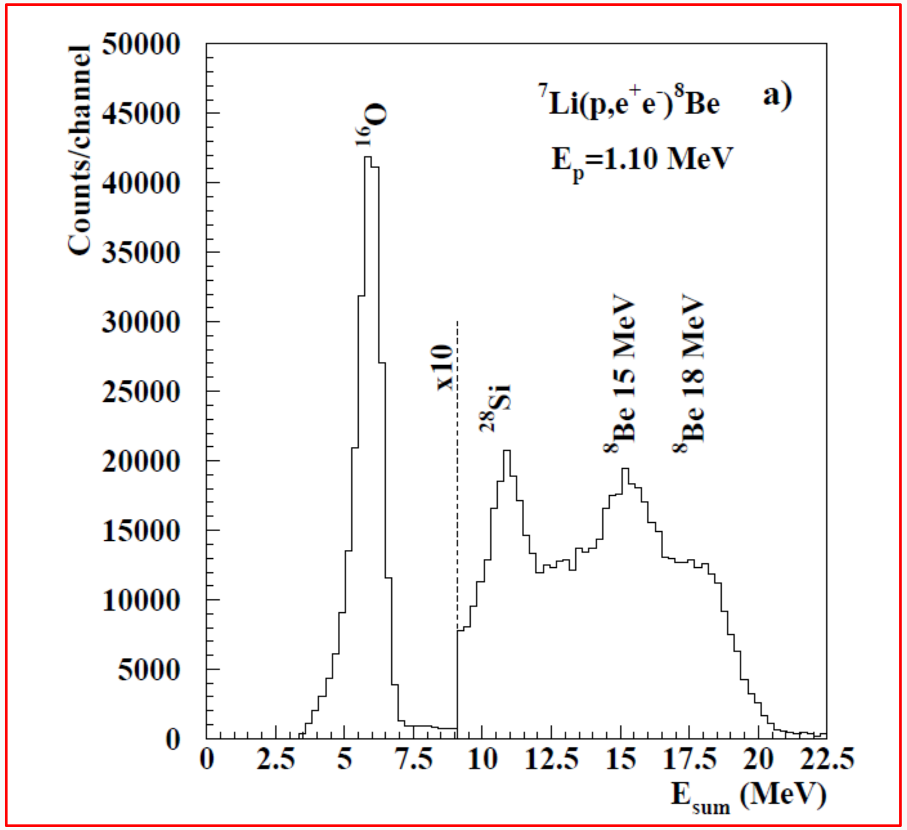
[D. S. Firak et al, EPJ Web of Conferences 232, 04005 (2020)]

Krasznahorkay et al. (2016)

Beam: protons in the 0.5 -1.2 MeV range

Targets: LiF_2, LiO_2.

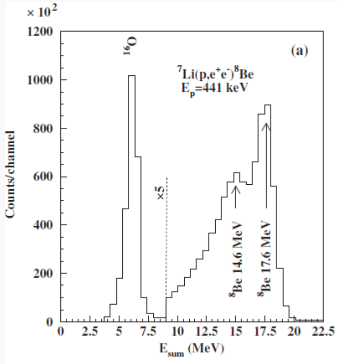




[A. J. Krasznahorkay et al, Phys Rev Lett 116, 042501 (2016)]

[A. J. Krasznahorkay et al, arXiv:1504.01527]

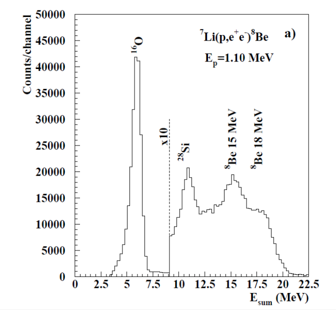
The Hungarian anomaly

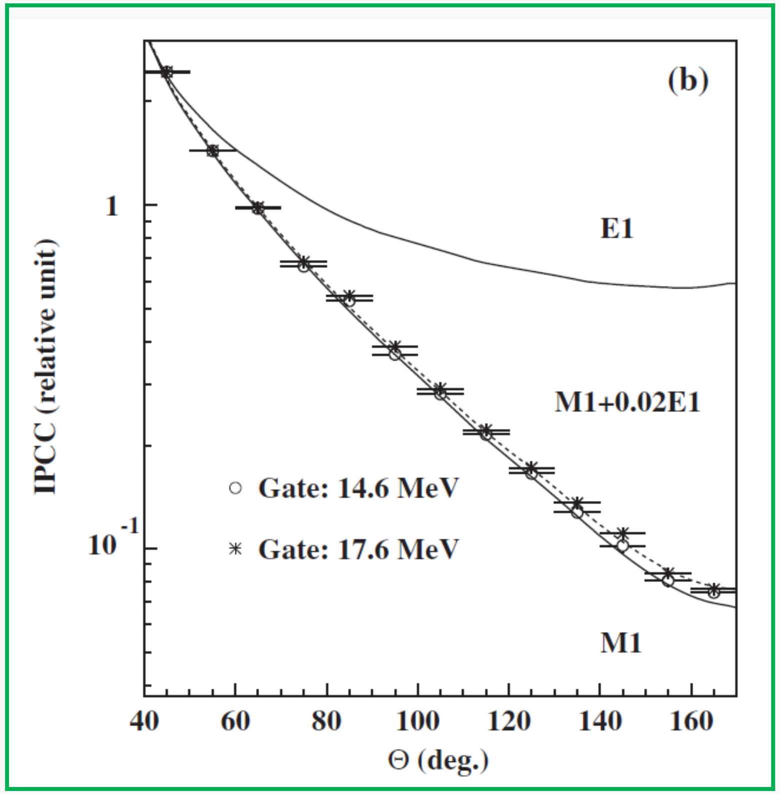


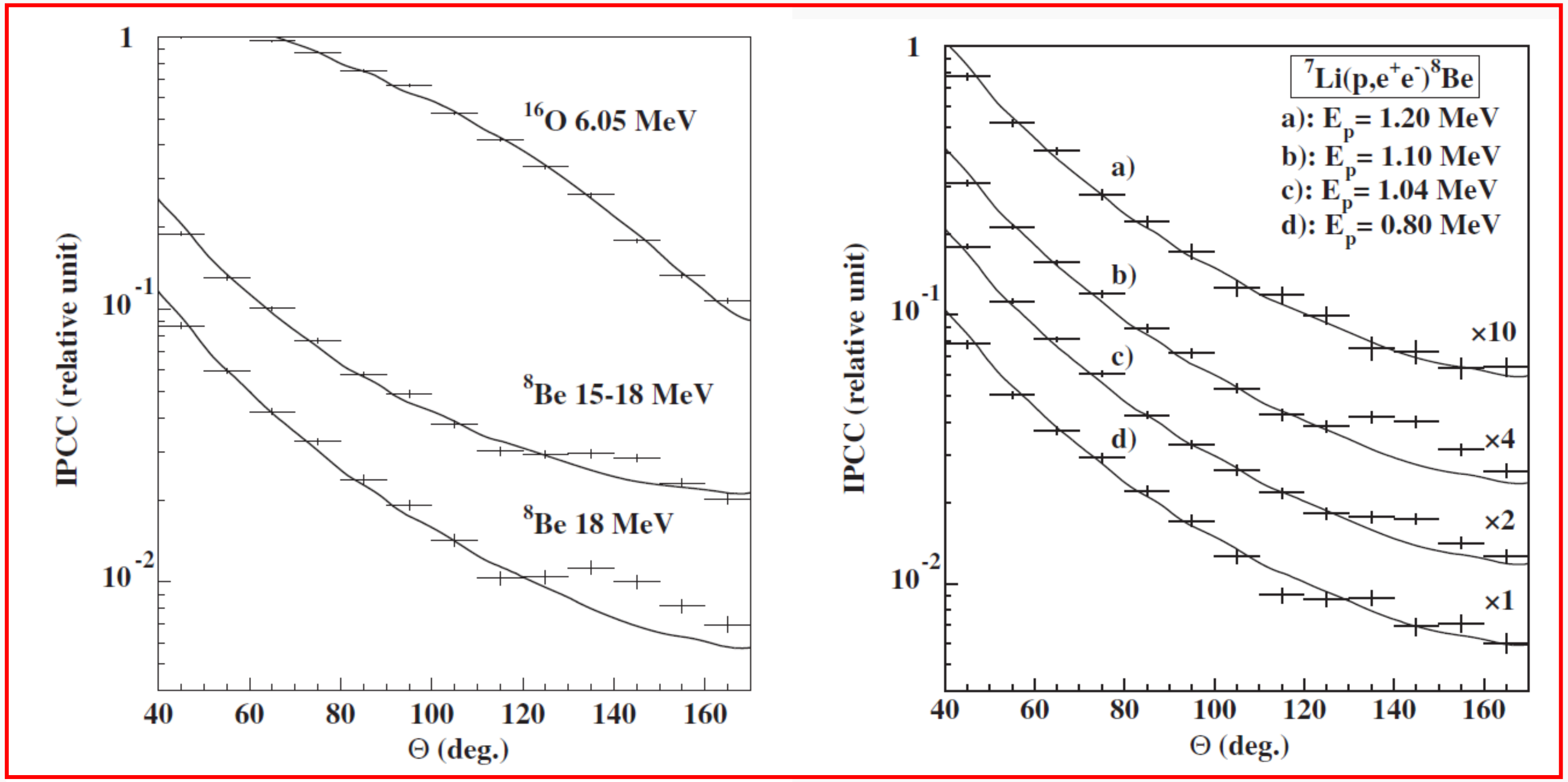
Krasznahorkay et al. (2016)

Beam: protons in the 0.5 -1.2 MeV range

Targets: LiF_2, LiO_2.







[A. J. Krasznahorkay et al, Phys Rev Lett 116, 042501 (2016)]

The Hungarian anomaly

PRL **116,** 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

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

A. J. Krasznahorkay,* M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi, I. Kuti, B. M. Nyakó, L. Stuhl, J. Timár,

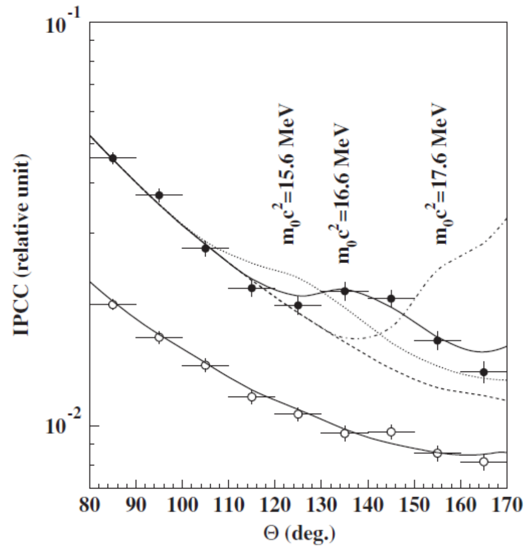


FIG. 4. Experimental angular e^+e^- pair correlations measured in the $^7\mathrm{Li}(p, e^+e^-)$ reaction at $E_p = 1.10$ MeV with $-0.5 \leq y \leq 0.5$ (closed circles) and $|y| \geq 0.5$ (open circles). The results of simulations of boson decay pairs added to those of IPC pairs are shown for different boson masses as described in the text.

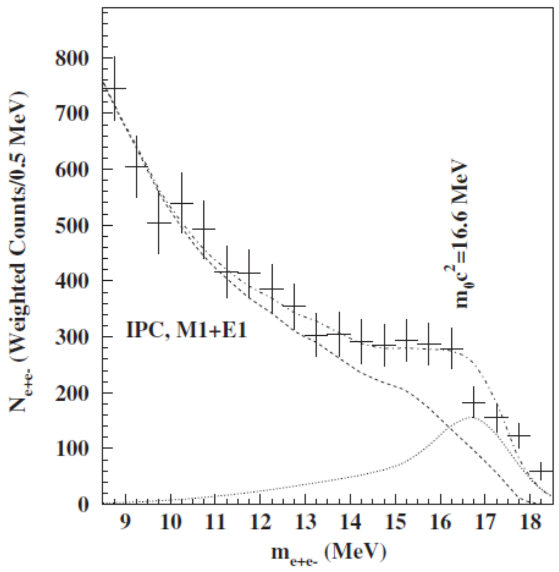


FIG. 5. Invariant mass distribution derived for the 18.15 MeV transition in ^{8}Be.

The deviation between the experimental and theoretical angular correlations is significant and can be described by assuming the creation and subsequent decay of a $J^\pi=1^+$ boson with $m_0c^2=16.70\pm0.35(stat)\pm0.5(syst)$ MeV/c^2. 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 was found to be 5.8×10^{-6} for the best fit.

Such a boson might be a good candidate for the relatively light $U(1)_d$ gauge boson [4], or the light mediator of the secluded WIMP dark matter scenario [5] or the dark Z (Zd) suggested for explaining the muon anomalous magnetic moment [7].

<u>Zhang and Miller extend Rose's theory:</u>

- Halo-Effective field theory framework considering polarization.
- Naturally includes different multipoles interference.
- Includes constraints on pair productions coming from gamma-ray spectroscopy.
- Ad-hoc form factors are considered.

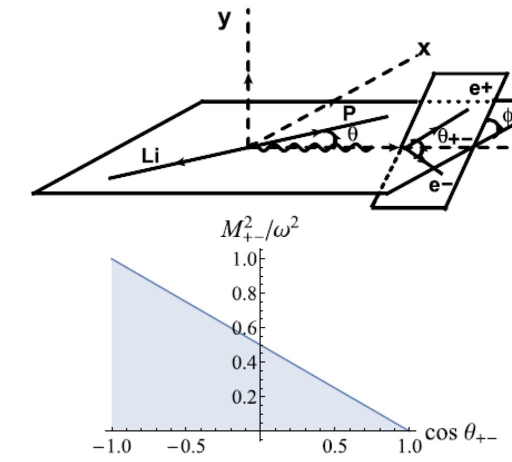


Fig. 1. The top shows the kinematics for the e^+–e^- pair production as well as the photon production (without the lepton line). The bottom plots the allowed phase space (shaded area) in terms of M_{+-} and $\cos\theta_{+-}$ assuming $m_e = 0$.

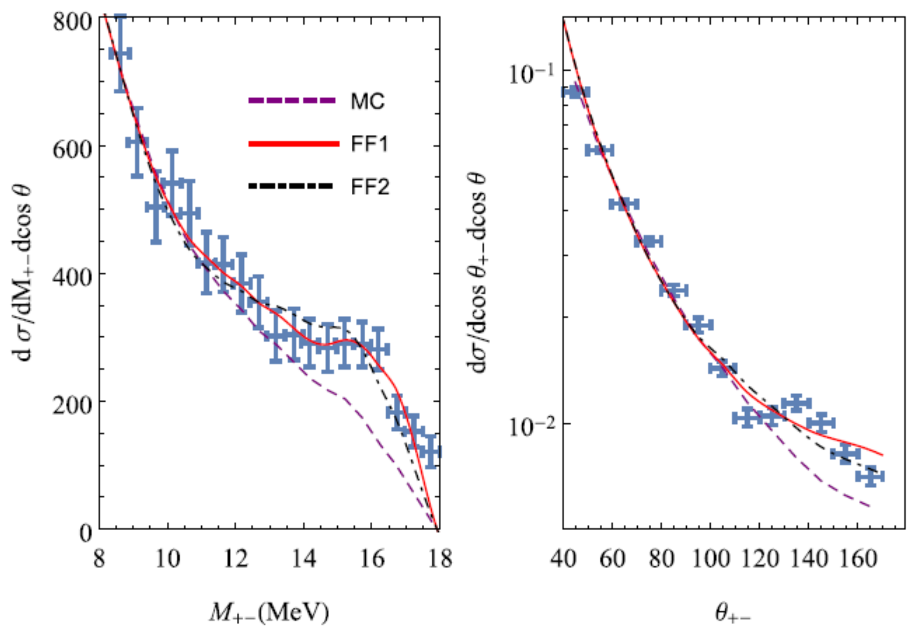


Fig. 7. The differential cross sections vs M_{+-} and θ_{+-} with $\theta = 90°$. Again "MC" is the MC simulation. The other curves are explained in the text.

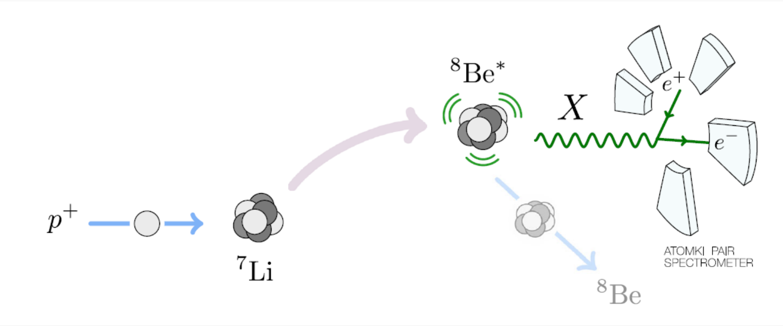
The improvements **can not explain the anomaly.**

[X. Zhang et al, Phys Lett B 773, 159 (2017)]

Interpretations II: the protophobic force

Here we focus on the vector case. We consider a massive spin-1 Abelian gauge boson X that couples nonchirally to standard model (SM) fermions with charges ε_f in units of e. The new Lagrangian terms are

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



Coupling's constraints:

$$\frac{\Gamma(^8\text{Be}^* \to {}^8\text{Be}\,X)}{\Gamma(^8\text{Be}^* \to {}^8\text{Be}\,\gamma)} = (\varepsilon_p + \varepsilon_n)^2 \frac{|\mathbf{p}_X|^3}{|\mathbf{p}_\gamma|^3} \approx 5.8 \times 10^{-6}\,, \qquad (4)$$

which implies

$$|\varepsilon_u + \varepsilon_d| \approx 3.7 \times 10^{-3}\,. \qquad (5)$$

Therefore, the strength of the Atomki signal provides a constraint only on the sum of the X couplings to the up and down quarks, and does not depend on the couplings to leptons.

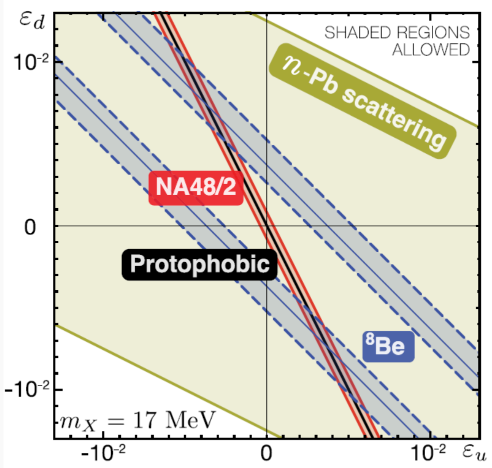
Not a Dark Photon because ε~ 0.01 is excluded by NA48/2

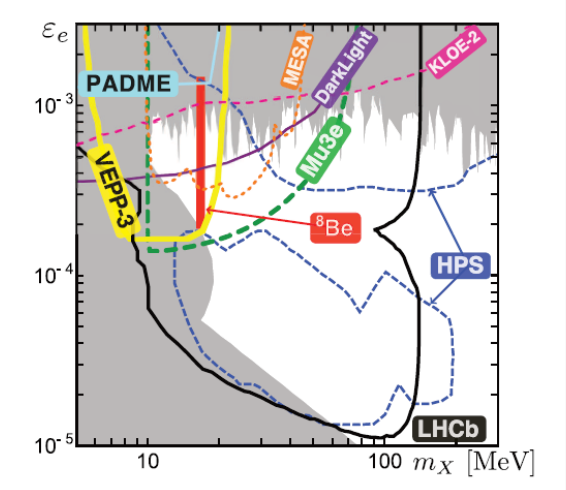
NA48/2 also imposes $|2\varepsilon_u + \varepsilon_d| < 8 \times 10^{-4}\,.$

$$-0.067 < \frac{\varepsilon_p}{\varepsilon_n} < 0.078\,.$$

"protophobic"

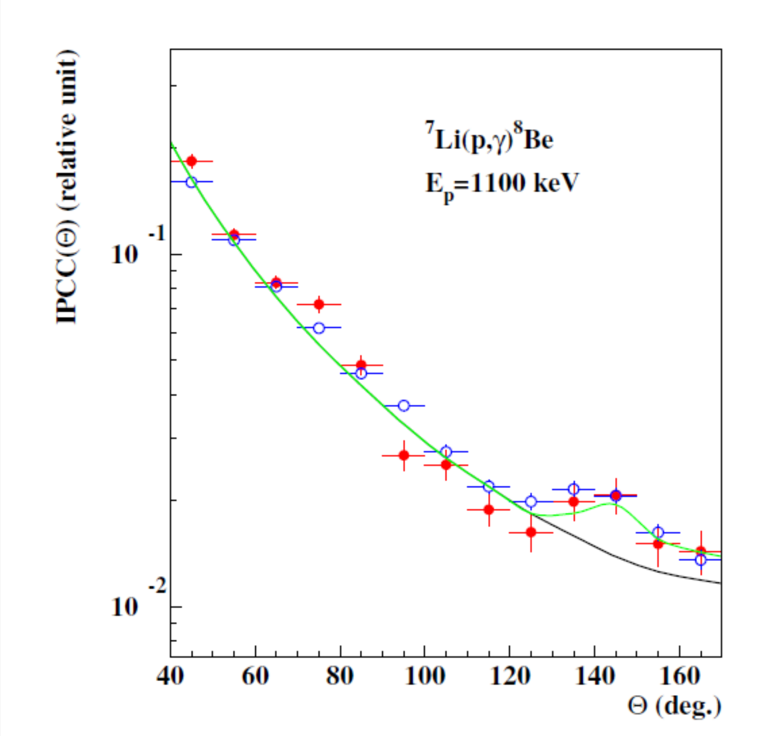
The theory introduces a new vector boson: the X17 particle.

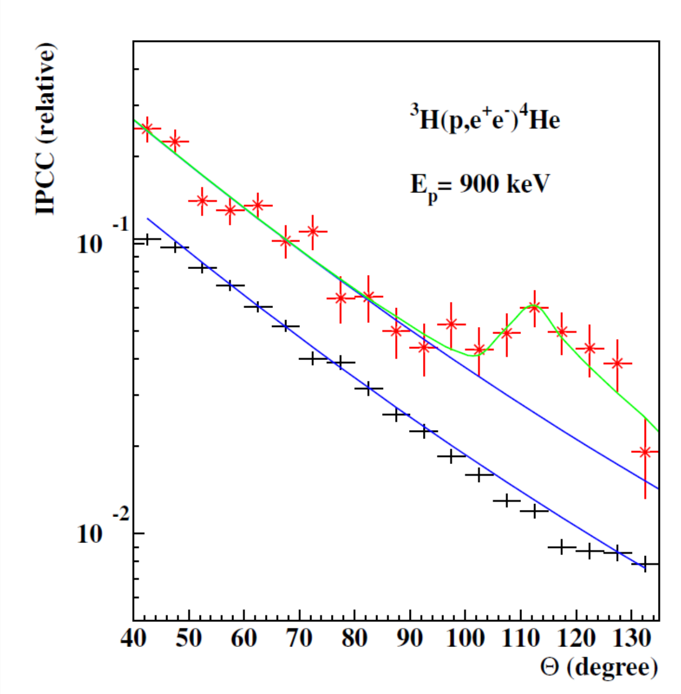


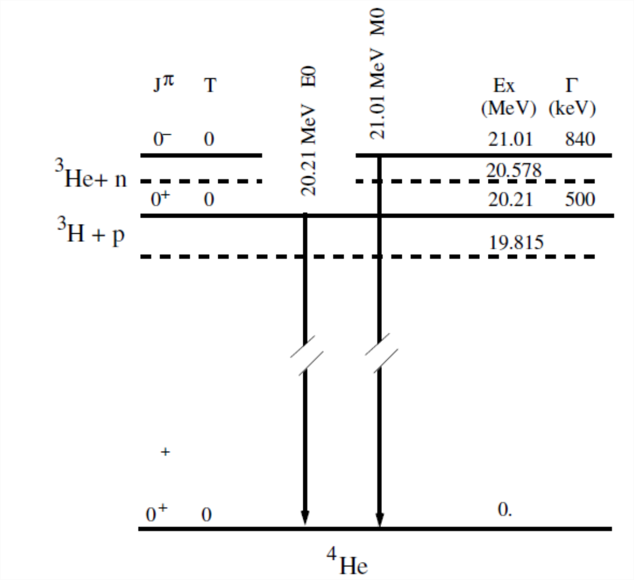


J. L. Feng et al, Phys Rev Lett 117 (2016)
B. Fornal, Int Journ of Mod Phys A 32, 1730020 (2017) 25
J. L. Feng et al, Phys Rev D 95, 035017 (2017)
J. L. Feng et al, Phys Rev D 102, 036016 (2020)

The Hungarian anomaly, updated







Further data with improved setup

A different reaction

A.J. Krasznahorkay et al, EPJ Web of Conferences 137, 08010 (2017)
A.J. Krasznahorkay et al, EPJ Web of Conferences 142, 01019 (2017)
A. J. Krasznahorkay et al, J Phys: Conf Ser 1056, 012028 (2018)
A.J. Krasznahorkay et al, Act Phys Pol B 50, 675 (2019)
A. J. Krasznahorkay et al, J Phys: Conf Ser 1643, 012001 (2020)
D. S. Firak et al, EPJ Web of Conferences 232, 04005 (2020)

Direct Channels, two examples.

Eur. Phys. J. C (2020) 80:1159
https://doi.org/10.1140/epjc/s10052-020-08725-x
THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

Hunting down the X17 boson at the CERN SPS

NA64 Collaboration

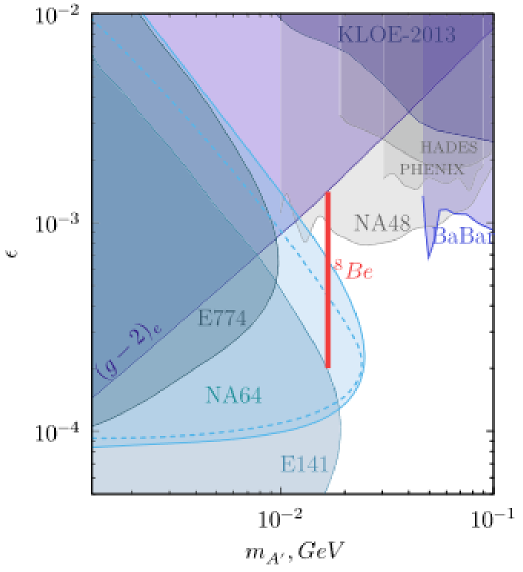


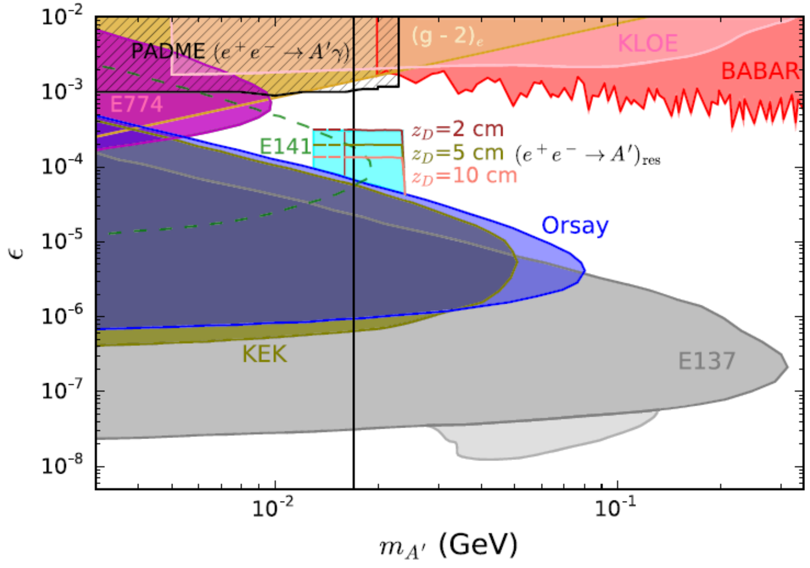
Fig. 1 The blue area shows the NA64 experiment exclusion areas at 90% CL in the $(m_{A'}/m_X; \epsilon)$ plane (s). For the mass of 16.7 MeV, the $X - e^-$ coupling region excluded by NA64 is $1.2 \times 10^{-4} < \epsilon_e < 6.8 \times 10^{-4}$. The vertical red bar shows the full allowed range of ϵ_e explaining the ^{8}Be* anomaly, $2.0 \times 10^{-4} \lesssim \epsilon_e \lesssim 1.4 \times 10^{-3}$ from [1]

No evidence in the available data,
new setup proposed.

PHYSICAL REVIEW D **97**, 095004 (2018)

Resonant production of dark photons in positron beam dump experiments

Enrico Nardi,[1,*] Cristian D. R. Carvajal,[2] Anish Ghoshal,[1,3] Davide Meloni,[3,4] and Mauro Raggi[5]



PADME at LNF.
Positron beam dump experiment for Dark Photon searches

NATALIE WOLCHOVER 06.17.16 04:44 PM

The Mysterious X Boson Could Upend the Standard Model. If It Actually Exists

[https://www.wired.com/2016/06/mysterious-x-boson-upend-standard-model-actually-exists/]

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News & Comment > News > 2019 > May > Article

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 | Updated: 17 August 2016

CERNCOURIER

SEARCHES FOR NEW PHYSICS | NEWS

Rekindled Atomki anomaly merits closer scrutiny

20 December 2019

NUCLEAR PHYSICS

Evidence of a 'Fifth Force' Faces Scrutiny

By NATALIE WOLCHOVER

June 7, 2016

A lab in Hungary has reported an anomaly that could lead to a physics revolution. But even as excitement builds, closer scrutiny has unearthed a troubling backstory.

EDITORS' PICK | Nov 26, 2019, 02:00am EST | 63,504 views

This Is Why The 'X17' Particle And A New, Fifth Force Probably Don't Exist

Ethan Siegel Senior Contributor
Starts With A Bang Contributor Group
Science
The Universe is out there, waiting for you to discover it.

Next steps: Feng's outlook

$$\text{Protophobic vector boson: } \Gamma(^4\text{He}(20.21) \to {}^4\text{He}\, X) = (0.3 - 3.6) \times 10^{-5} \text{ eV} \quad (126)$$

$$\text{ATOMKI Experiment [26, 27]: } \Gamma(^4\text{He}(20.21) \to {}^4\text{He}\, X) = (2.8 - 5.2) \times 10^{-5} \text{ eV}. \quad (127)$$

The reported 7σ anomalies reported in ^{8}Be and ^{4}He nuclear decays are both kinematically and dynamically consistent with the production of a 17 MeV protophobic gauge boson.

What is the path forward? Clearly, now is the time for other collaborations to perform the same nuclear measurements to check the ATOMKI results. But in this work, we also propose simple modifications of the ATOMKI setup that could provide incisive tests of the new particle interpretation. The comparison between theory and experiment will be sharpened considerably by including the E1 background in the experimental analysis and running on the ^{4}He(20.21) 0^+ resonance. In addition, scanning through the ^{4}He(20.21) 0^+ resonance can provide important information to disentangle vector and axial vector X bosons and quantify the properties of particles with mixed couplings. Last, we find that the protophobic vector boson could also be observable in the decays of the ^{12}C(17.23) 1^- excited state, and we have provided precise predictions for this rate.

1 Jun 2020: J. L. Feng et al, Dynamical Evidence For a Fifth Force Explanation of the ATOMKI Nuclear Anomalies

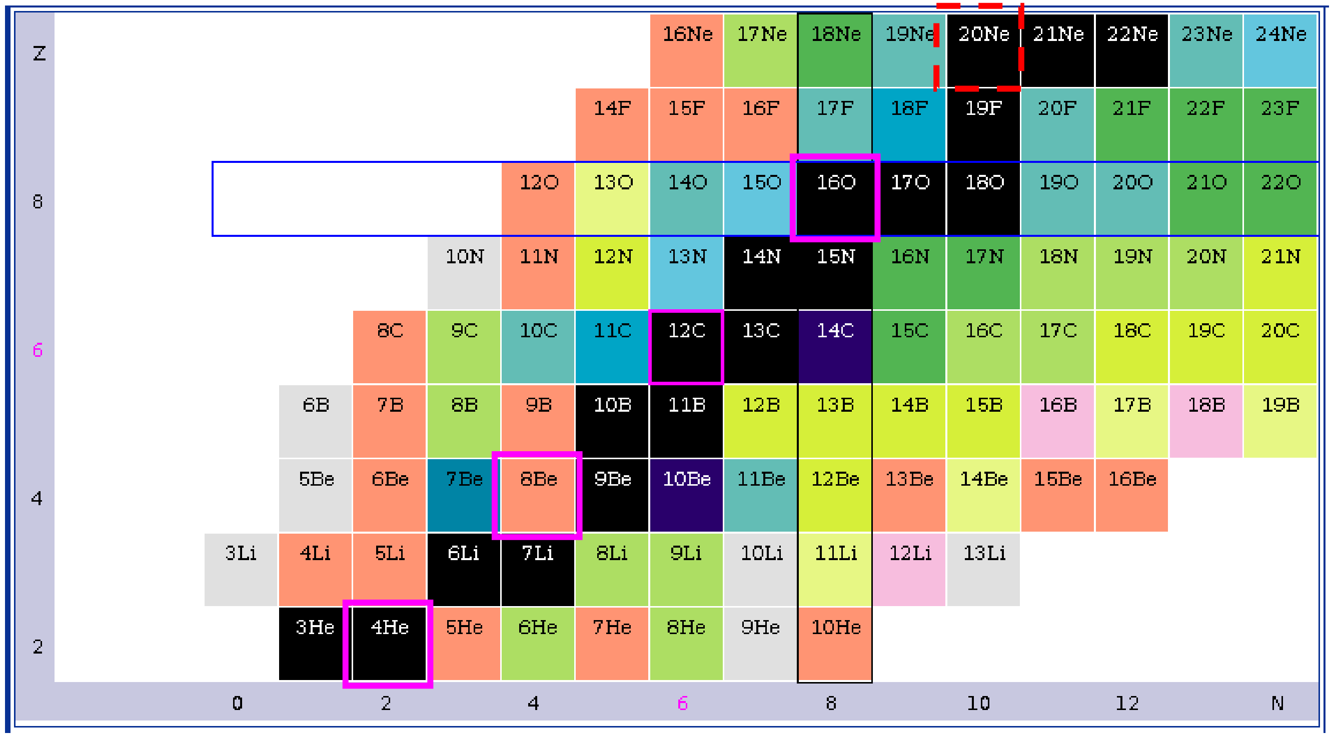
Next steps: Feng's outlook

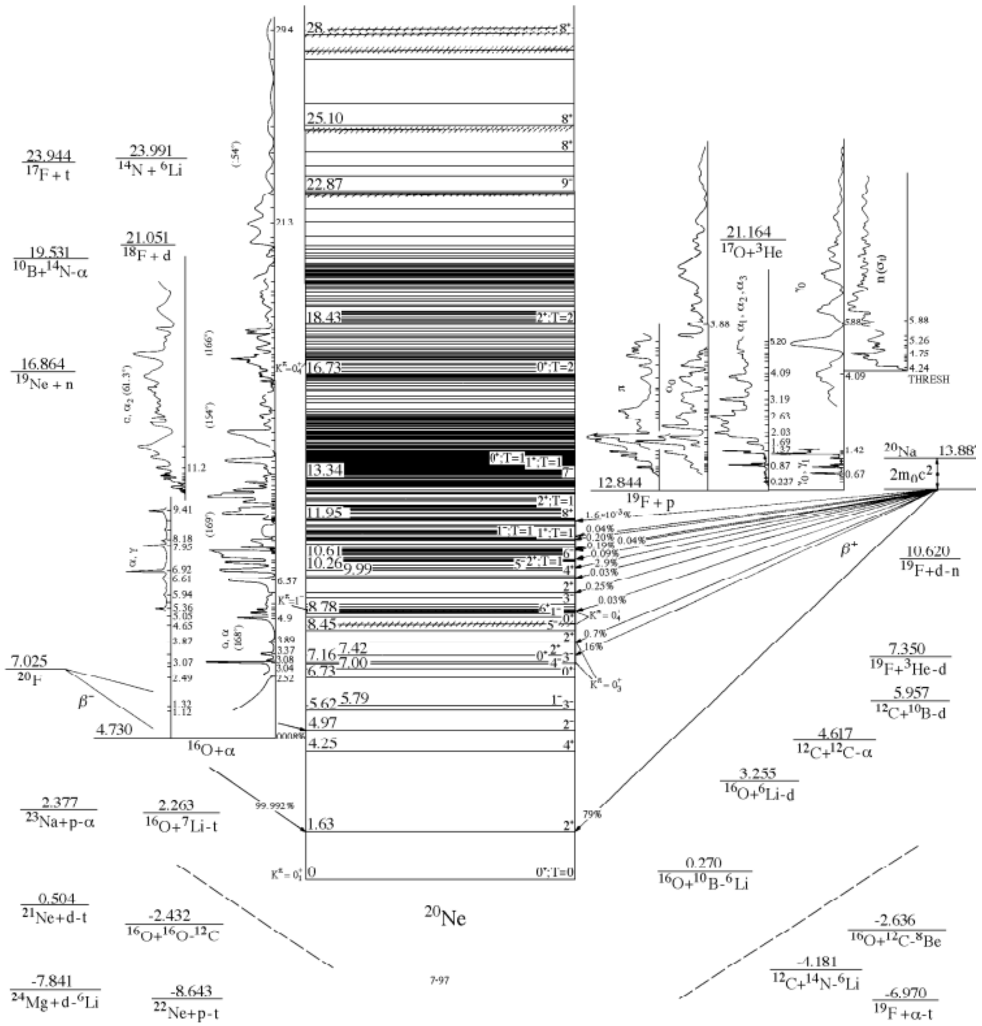
TABLE I. Production and decay kinematic parameters. Beams of protons with kinetic energy E_{beam} collide with nuclei A at rest to form excited nuclei N_*, which then decay to the ground state nucleus N_0 through $N_* \to N_0 X$. We fix $m_X = 17$ MeV, and for each of the relevant processes, we give the values of E_{beam}, m_A, m_{N_*}, v_{N_*} (the N_* velocity in the lab frame), v_X (the X velocity in the N_* rest frame), and $\theta_{e^+e^-}^{\text{min}}$ (the minimum e^+e^- opening angle). ^{4}He(20.49) indicates the resonance energy probed in Ref. [33], which sits between the ^{4}He(21.01) and ^{4}He(20.21) states.

$p + A \to$	N_*	E_{beam} [MeV]	m_A [MeV]	m_{N_*} [MeV]	v_{N_*}/c	v_X/c	$\theta_{e^+e^-}^{\text{min}}$
$p + {}^7\text{Li} \to$	^{8}Be(18.15)	1.03	6533.83	7473.01	0.0059	0.350	139°
$p + {}^7\text{Li} \to$	^{8}Be(17.64)	0.45	6533.83	7472.50	0.0039	0.267	149°
$p + {}^{11}\text{B} \to$	^{12}C(17.23)	1.40	10252.54	11192.09	0.0046	0.163	161°
$p + {}^3\text{H} \to$	^{4}He(21.01)	1.59	2808.92	3748.39	0.0146	0.587	108°
$p + {}^3\text{H} \to$	^{4}He(20.49)	0.90	2808.92	3747.87	0.0110	0.557	112°
$p + {}^3\text{H} \to$	^{4}He(20.21)	0.52	2808.92	3747.59	0.0084	0.540	115°

1 Jun 2020: J. L. Feng et al, Dynamical Evidence For a Fifth Force Explanation of the ATOMKI Nuclear Anomalies

Is alpha-clustering hiding behind the scene?





Let’s have a look back in time

F.W. N. de Boer et al, Phys Lett B 388, 235 (1996)
F.W. N. de Boer et al, J. Phys G: Nucl Part Phys 23, L85 (1997)
F.W. N. de Boer et al, J Phys G: Nucl Part Phys 27, L29 (2001)
And several others.

Results of two dedicated experiments are reported yielding further indications for an anomaly at 9 MeV/c2 in the angular correlation of IPC. The first experiment (8Be) shows a deviation from IPC at large correlation angles presumably due to the same anomaly in the transition to the first excited state. The second experiment (12C) shows a relatively large anomaly at 9 MeV/c2, albeit with limited statistics. Both results are compatible with an X-boson scenario where the boson–nucleon coupling strength is proportional to the isoscalar strength in the M1 transition. Exploiting isospin structure as a guideline, further high statistics experiments are needed to establish the nature of the anomaly.

A “pandemonium” of X-bosons

Table 1. Experimental results relevant for the search of anomalous e^+e^- production in nuclear transitions with respect to IPC, in the invariant mass range from 5 to 15 MeV/c^2. Listed are the nucleus, the quantum numbers, the energy (E) and character (E1, M1) of the transition, the derived boson emission branching ratio (B_X) with respect to γ emission, the boson decay width (Γ_X), the isospin dependent effective coupling strength (α_X), relative to $\tilde{\alpha} = 1.7 \times 10^{-6}$ (the axion–nucleon coupling strength), the invariant mass m_X and the literature references. Values for B_X and Γ_X have been derived at 95% CL.

^AZ	I^π	T	E MeV	B_X	Γ_X meV	α_X 1.7×10^{-6}	m_X MeV/c^2	Reference
^{20}Ne	1^-	1	17.8 E1	$\leqslant 1.3\times10^{-4}$	$\leqslant 3$	$\leqslant 1.8$		[20]
			16.2 E1					
^{12}C	1^-	1	17.2 E1	$\leqslant 2.3\times10^{-5}$	$\leqslant 1$	$\leqslant 0.3$		[1]
	2^-	1	12.3 E1					
^{12}C	1^+	0	12.7 M1	$(1.6\pm0.7)\times10^{-3}$	0.55 ± 0.24	38 ± 17	9.2 ± 1.0	[6]
^{12}C	1^+	1	15.1 M1	$\leqslant 4.6\times10^{-5}$	$\leqslant 1.7$	$\leqslant 0.9$		[6]
^{12}C			114 M1	$\leqslant 9.8\times10^{-5}$	$\leqslant 8$	$\leqslant 0.8$		[8, 23]
^{8}Be	1^+	1, 0	17.6 M1	$(11.4\pm3.4)\times10^{-5}$	1.9 ± 0.4	1.5 ± 0.4	9 ± 1	[1]
			14.6 M1					
^{4}He	0^-	0	21.0 e^+e^-		74 ± 30	32 ± 12	8 ± 2	[15, 5]

Table 1. Experimental results for anomalous e^+e^--emission interpreted in the light of a short-lived 9 MeV/c^2 X-boson in six M1 transitions and an M0 transition. Listed are the nucleus, the energy and the width of the resonance E_R and Γ_R, the (iso)spin-parity quantum numbers, the transition energy E_γ, the X-branching ratio B_X with respect to γ-emission, the X-decay width Γ_X, the coupling strength α_X relative to $\tilde{\alpha} = 1.7\times10^{-6}$ (the axion–nucleon coupling strength), the invariant mass m_X, and the references. Values for B_X and m_X have been derived at 95% CL.

^AZ	E_R (MeV)	Γ_R (eV)	I^π, T	E_γ (MeV)	B_X	Γ_X (meV)	α_X 1.7×10^{-6}	m_X (MeV/c^2)	Refs
^{12}C	12.71	18.1	$1^+, 0$	12.71	$(7\pm3)\times10^{-4}$	0.24 ± 0.11	18 ± 7	9.0 ± 1.0	Present
				12.71	$(1.6\pm0.7)\times10^{-3}$	0.56 ± 0.25	38 ± 17	9.2 ± 1.0	[5–7]
	15.11	43.6	$1^+, 1$	15.11	$\leqslant 4.6\times10^{-5}$	$\leqslant 1.8$	$\leqslant 0.9$	—	[5–7]
^{8}Be	17.64	10.7×10^3	$1^+, 1$	17.64	$(1.1\pm0.3)\times10^{-4}$	1.9 ± 0.4	1.5 ± 0.4	9 ± 1	[2–4]
				14.64	$(8.5\pm2.6)\times10^{-5}$	0.7 ± 0.2	1.5 ± 0.4	9 ± 1	[2–4]
	18.15	138×10^3	$1^+, 0$	18.15	$\leqslant 4.1\times10^{-4}$	$\leqslant 1.2$	$\leqslant 5.7$	—	Present
				15.15	$(5.8\pm2.2)\times10^{-4}$	2.2 ± 0.8	10.5 ± 4.5	9.5 ± 1.2	Present
^{4}He	21.0	850×10^3	$0^-, 0$	M0	$0^- \to 0^+, e^+e^-$	74 ± 30	32 ± 12	8 ± 2	[5–7]

The ATOMKI group has been studying e+e- pairs for decades

Again ^{16}O

Vol. 37 (2006) *ACTA PHYSICA POLONICA B* No 1

LEPTON PAIRS FROM A FORBIDDEN M0 TRANSITION: SIGNALING AN ELUSIVE LIGHT NEUTRAL BOSON?*

A. Krasznahorkay[a], F.W.N. de Boer[b], M. Csatlós[a], L. Csige[a]
Z. Gácsi[a], J. Gulyás[a], M. Hunyadi[a], T.J. Ketel[c], J. van Klinken[d]
A. Krasznahorkay Jr[a], A. Vitéz[a]

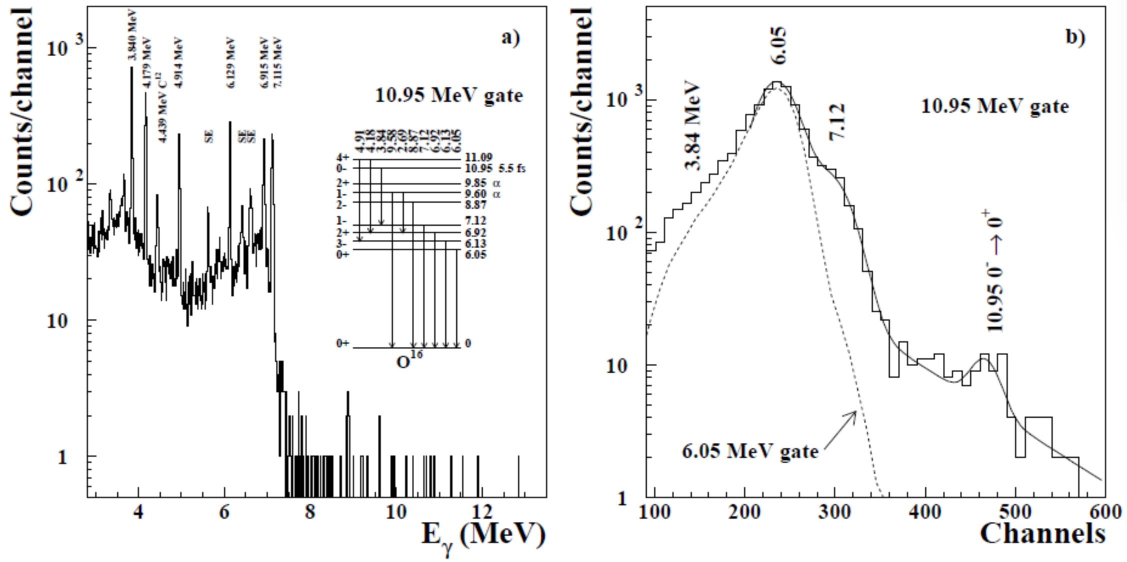


Fig. 1. γ-ray (a) and internal pair creation (b) spectra obtained from the $^{14}N(^{3}He,p)^{16}O$ reaction. See text for details.

4. Conclusion

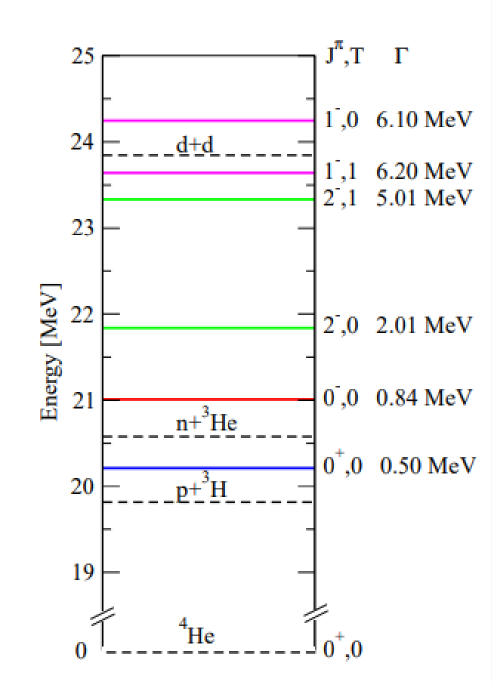
We observed for the first time the 10.95 MeV $0^- \to 0^+$ decay in ^{16}O by measuring e^+e^- pairs. The energy sum of the pairs corresponds to the energy of the transition (10.95 MeV), and the branching ratio $B = (20 \pm 5) \times 10^{-5}$ agrees with that of the expected boson. The angular correlation of the pairs might be described by assuming the decay of a boson with a mass of $m_u \approx$ 9–10 MeV$/c^2$. New experiments with better statistics are needed to settle the question and to determine the mass of the boson more precisely.

Recent theoretical efforts by Italian groups.

The X17 boson and the ^{3}H$(p, e^+e^-)^4$He and ^{3}He$(n, e^+e^-)^4$He processes: a theoretical analysis

M. Viviani[1], E. Filandri[2,3], L. Girlanda[4,5], C. Gustavino[6], A. Kievsky[1], L.E. Marcucci[1,7], and R. Schiavilla[8,9]

arXiv:2104.07808v1 [nucl-th] 15 Apr 2021



The chiral-effective-field-theory (χEFT) framework is used to describe nuclear dynamics and to model the interactions of nucleons with the hypothetical boson.

Ab initio calculations for the differential cross sections of the 3H(p, e+e −) 4He and 3He(n, e+e −) 4He reactions.

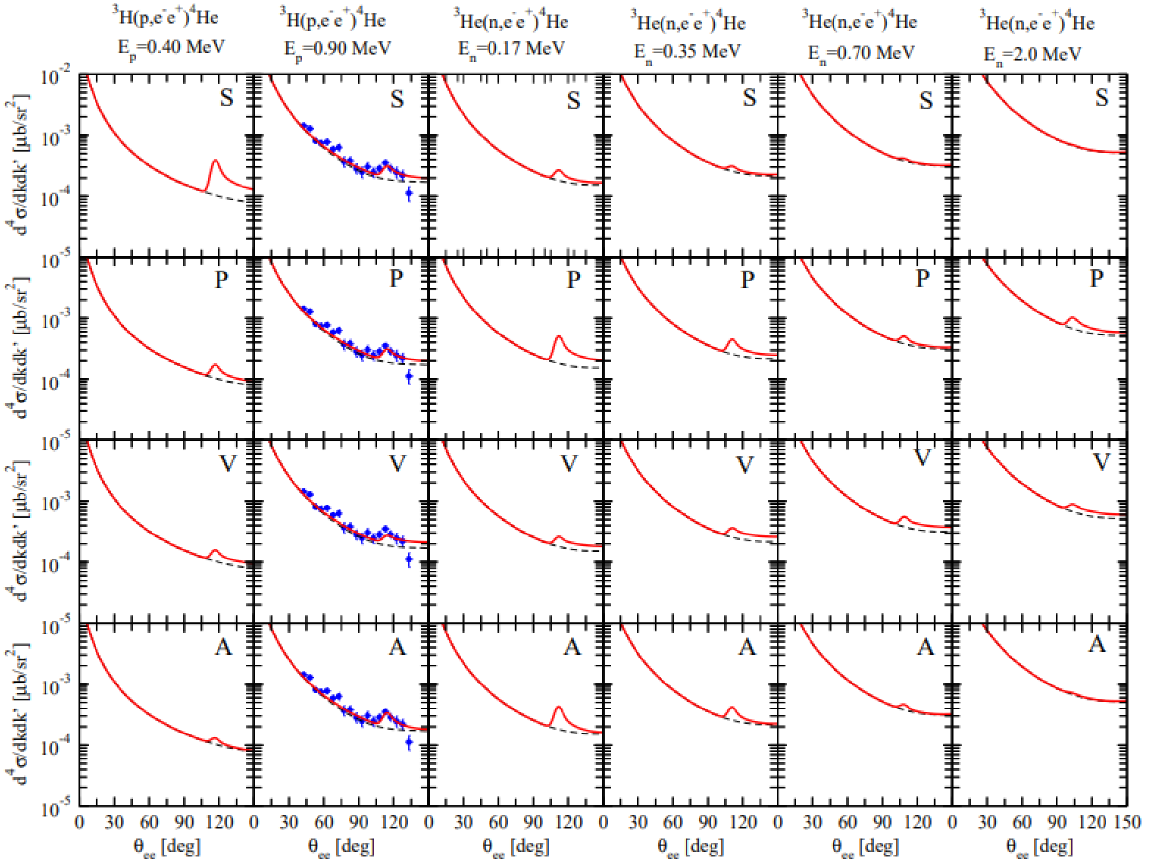


FIG. 5. The four-fold differential cross section for the ^{3}H$(p, e^-e^+)^4$He and ^{3}He$(n, e^-e^+)^4$He processes at six different incident nucleon energies for the configuration in which the e^+ and e^- momenta are in the plane orthogonal to the incident nucleon momentum and as function of the angle θ_{ee} between them. The panels labeled S, P, V, and A show the results obtained by including the exchange of a scalar, pseudoscalar, vector, and axial X17, respectively. In all cases, we have taken $M_X = 17$ MeV and Γ_X as given from the X17 decay in e^-e^+, see text for further explanations. The dashed (black) and solid (red) curves show the results obtained by including the electromagnetic only or both the electromagnetic and X17 amplitudes. The coupling constants have been adjusted so as to reproduce the ATOMKI ^{3}H$(p, e^-e^+)^4$He cross section data at the incident proton energy of 0.90 MeV, rescaled as discussed in the main text. The calculations are based on the N3LO500/N2LO500 interactions and accompanying electromagnetic currents.

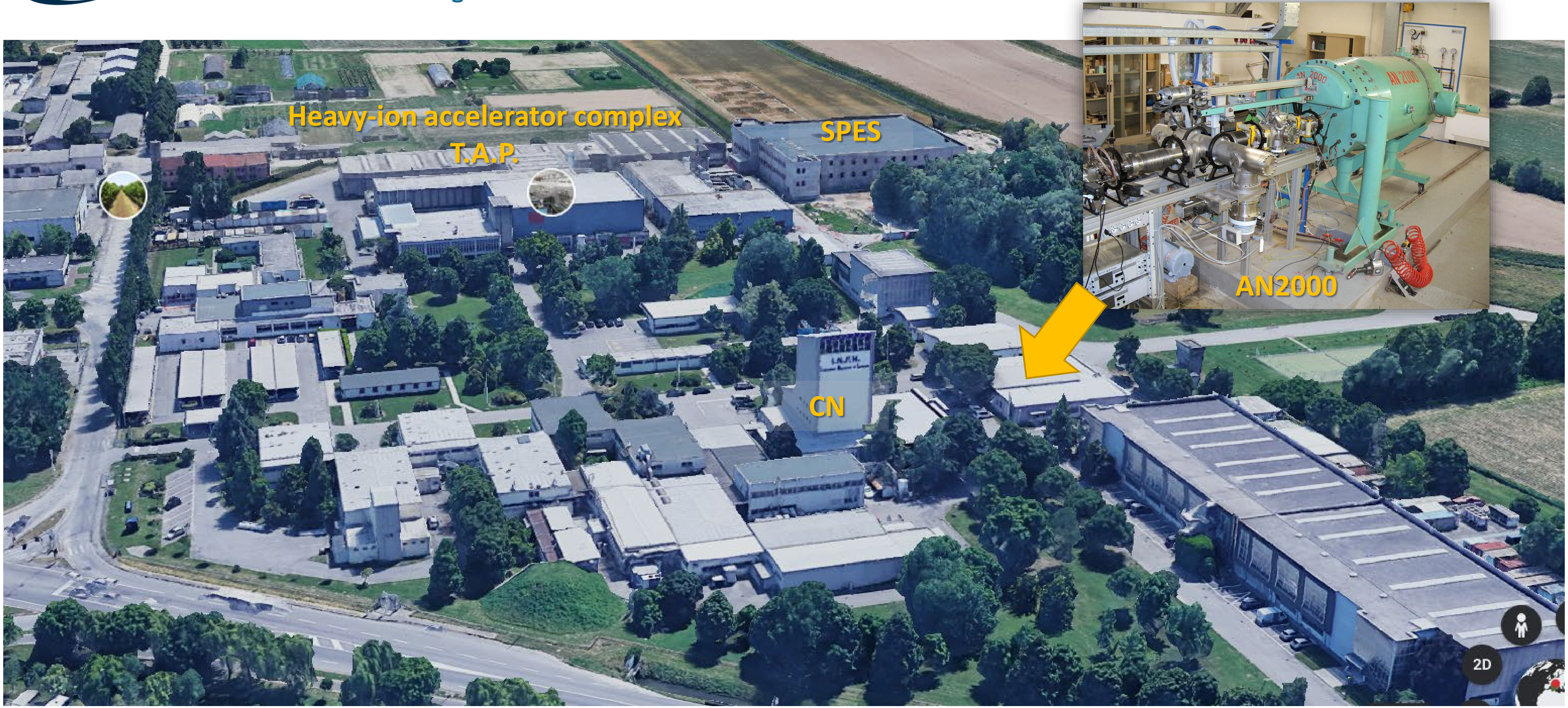
Two open questions:

1. Experimental confirmation of the anomaly

2. Contradicting interpretations

call for new experimental efforts

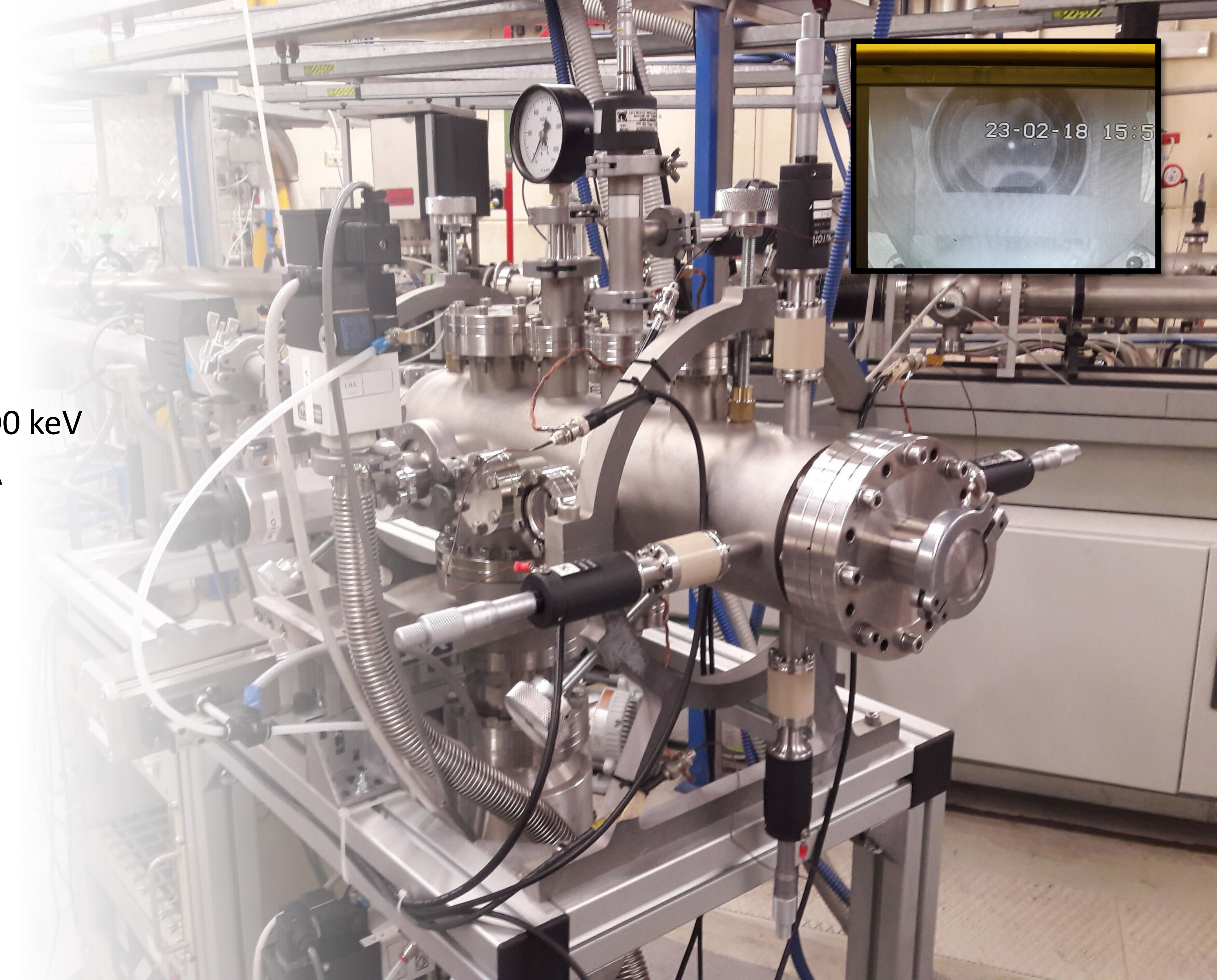
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro



AN2000:

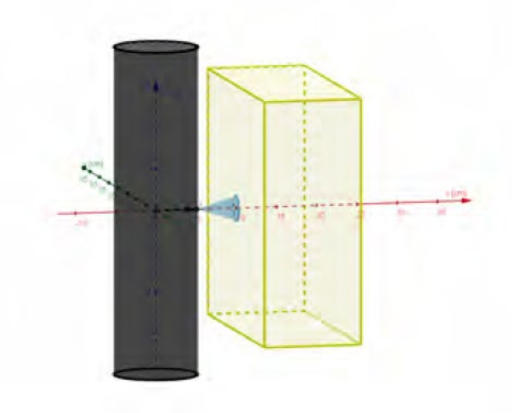
- Proton energy 200 – 2000 keV
- Beam current up to 1 μA

- One dedicated beamline



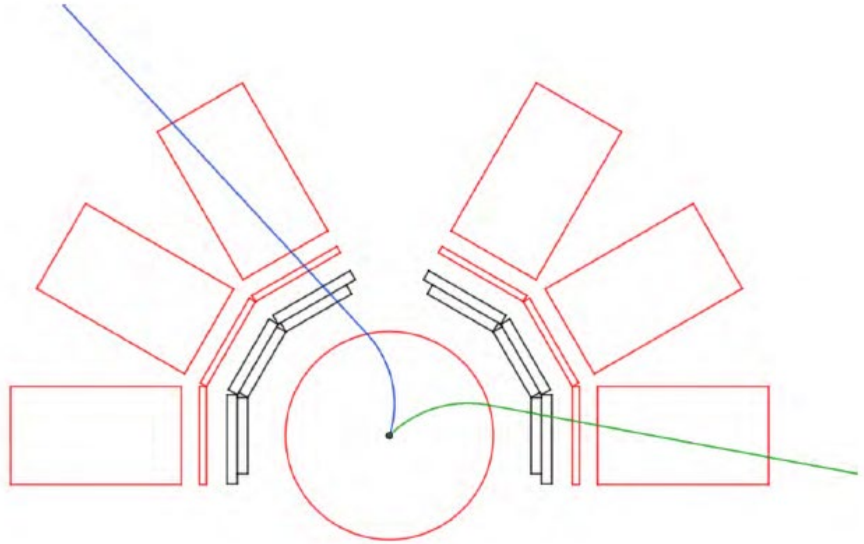
A new setup: criticalities and solutions

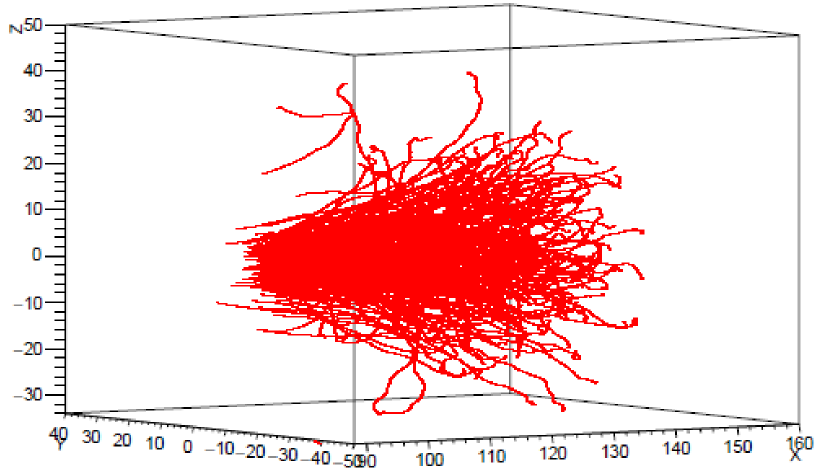
- Positrons are not discriminated from electrons.
- Target composition and stability are critical.
- Solid angle coverage is limited to theta=90°.
- Angular resolution is limited by straggling:



Spessore [mm]	Energie [MeV]		
	10	15	20
0.7	8°	5.5°	3.5°
1	9°	6.8°	4.5°
1.5	11°	8°	5.5°

[R. Bolzonella, Preparazione di un esperimento per la misura di coppie e+e- nel decadimento del 8Be*, Università di Padova (2019)]



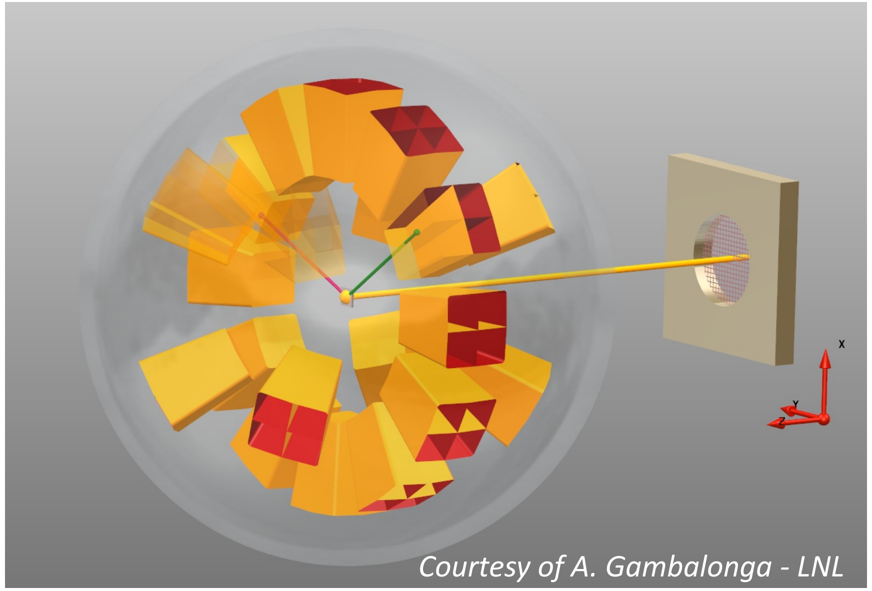


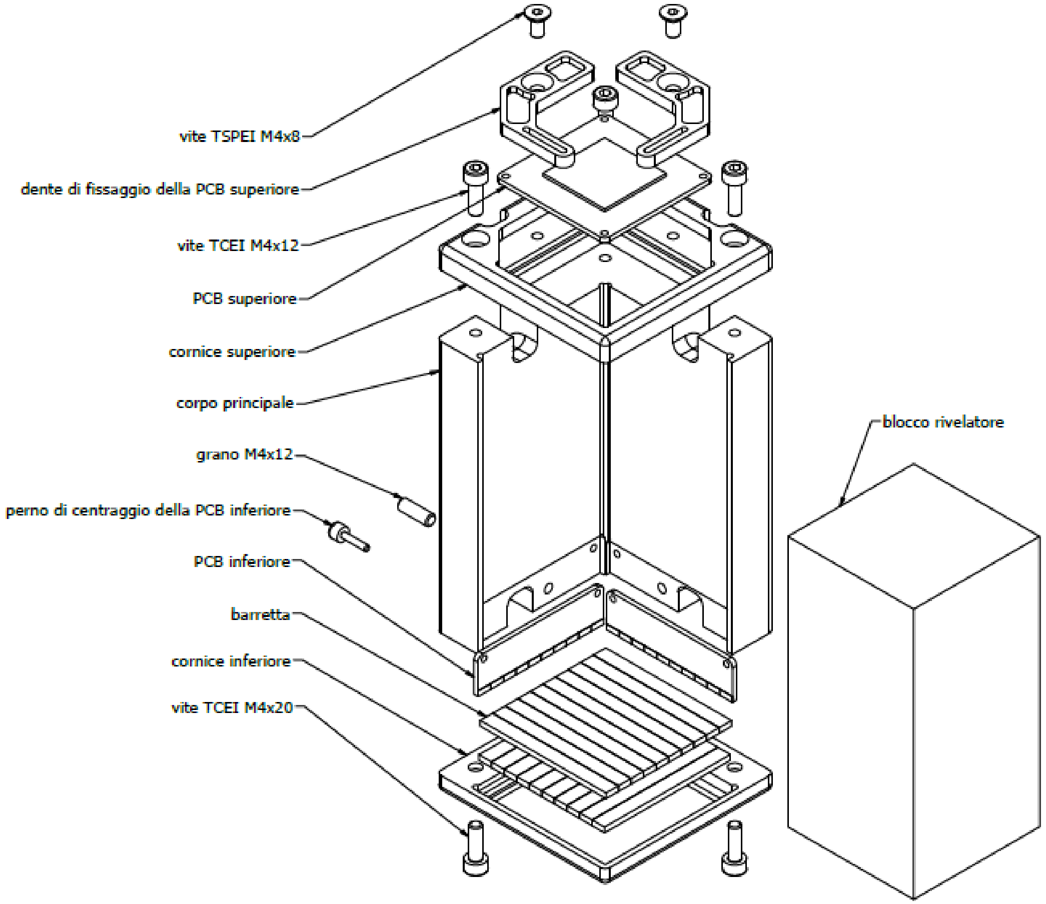
A new setup: criticalities and solutions

- Improve angular resolution by reducing material budget.
- Improve angular coverage and measure out-of-plane correlations
- Improve confidence on target composition.

- Allow future coupling with a magnetic field.

- Focus on ^{8}Be and, possibly, ^{12}C cases.





A new setup: simulations

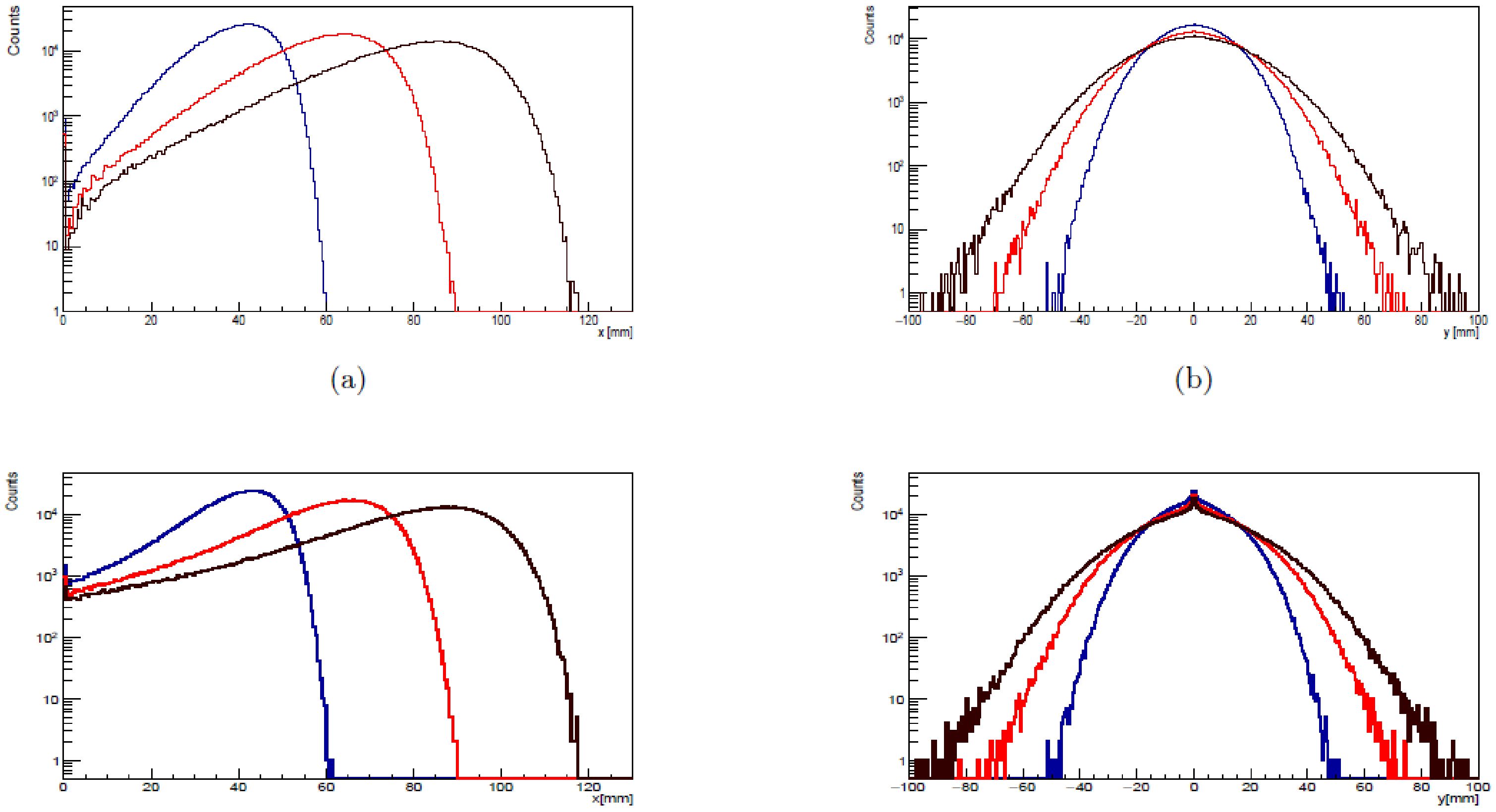
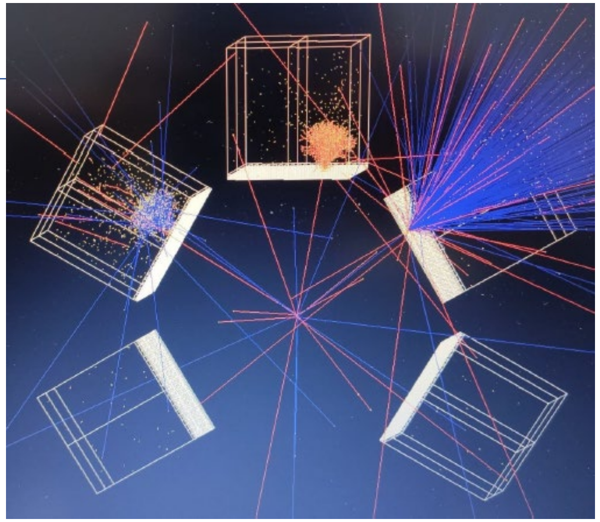
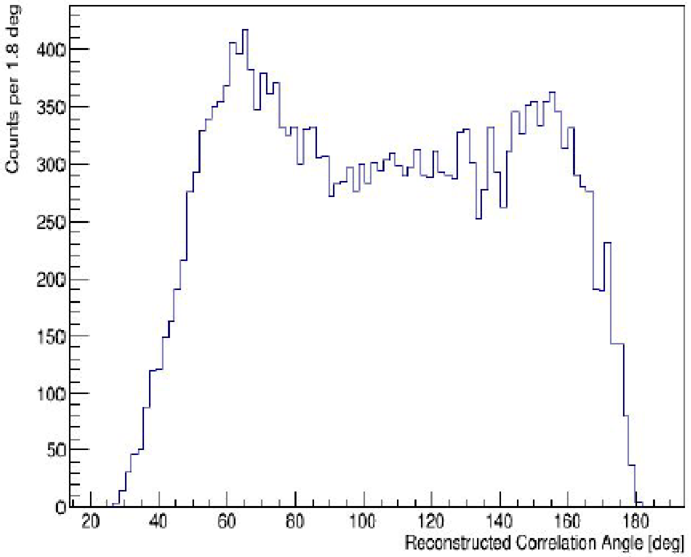
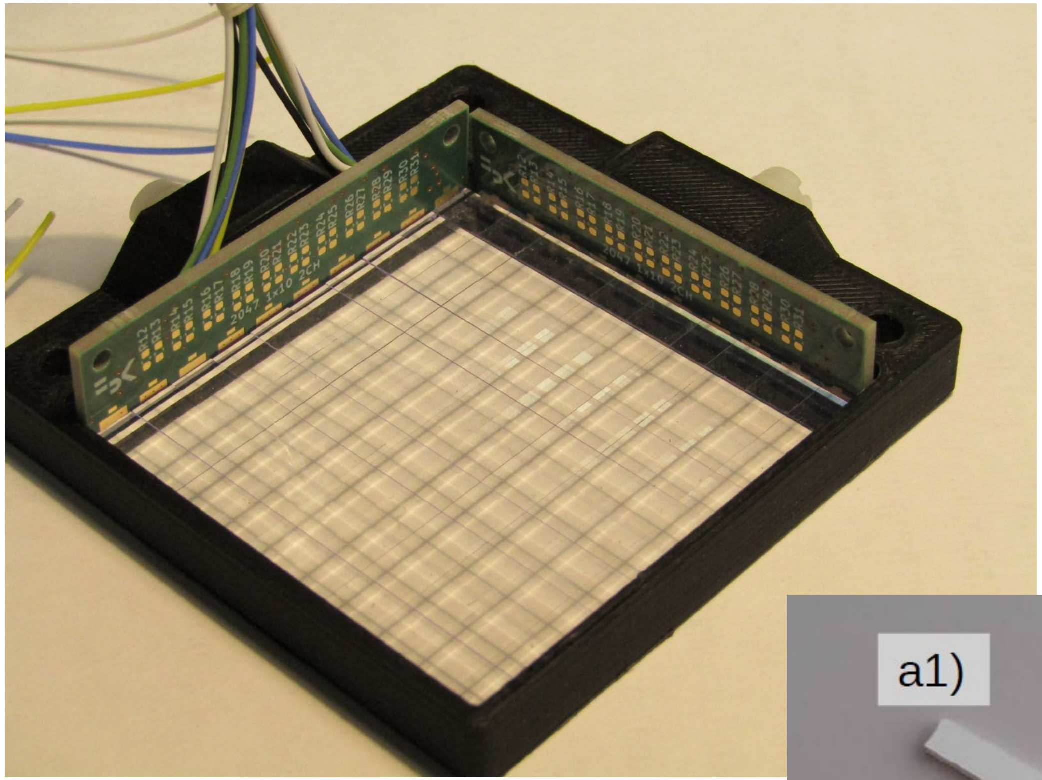


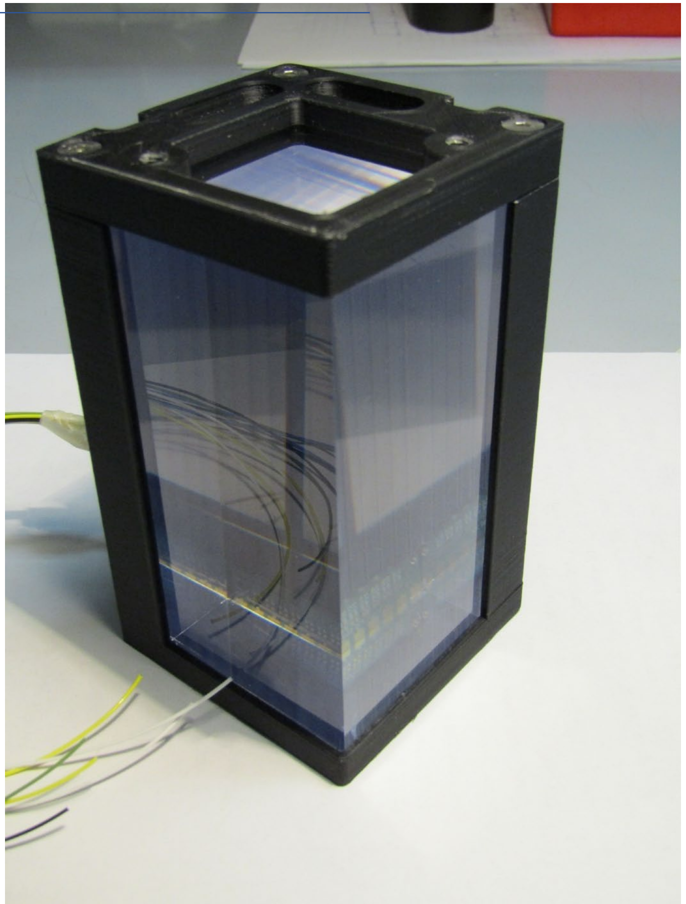
Figure 3.1: Absorption position of electrons (**a**, **b**) and positrons (**c**, **d**), with a logarithmic scale on the counts, at different emission energies: 10 MeV (blue), 15 MeV (red), 20 MeV (brown).

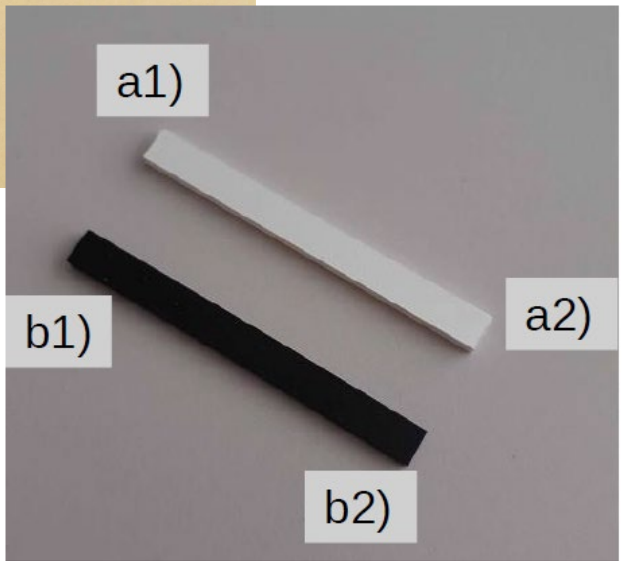




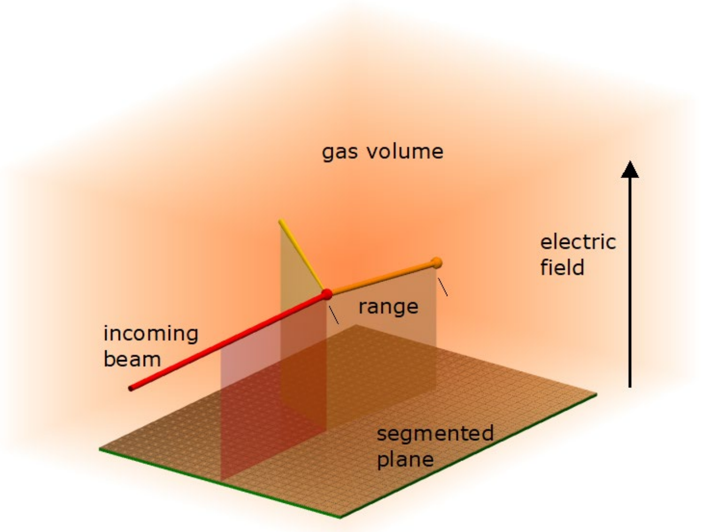
A new setup: prototypes

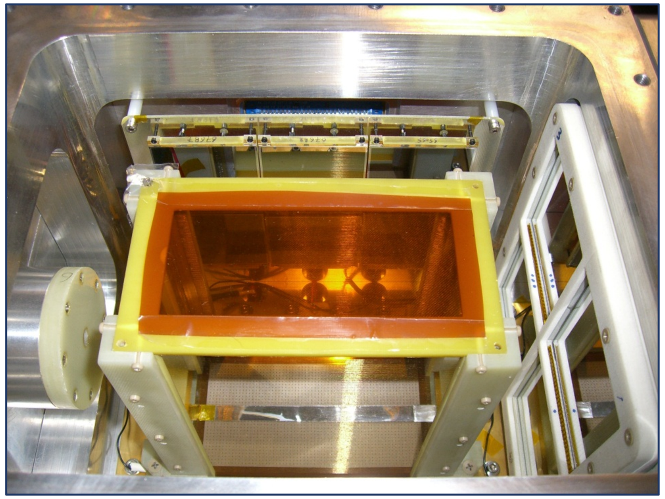


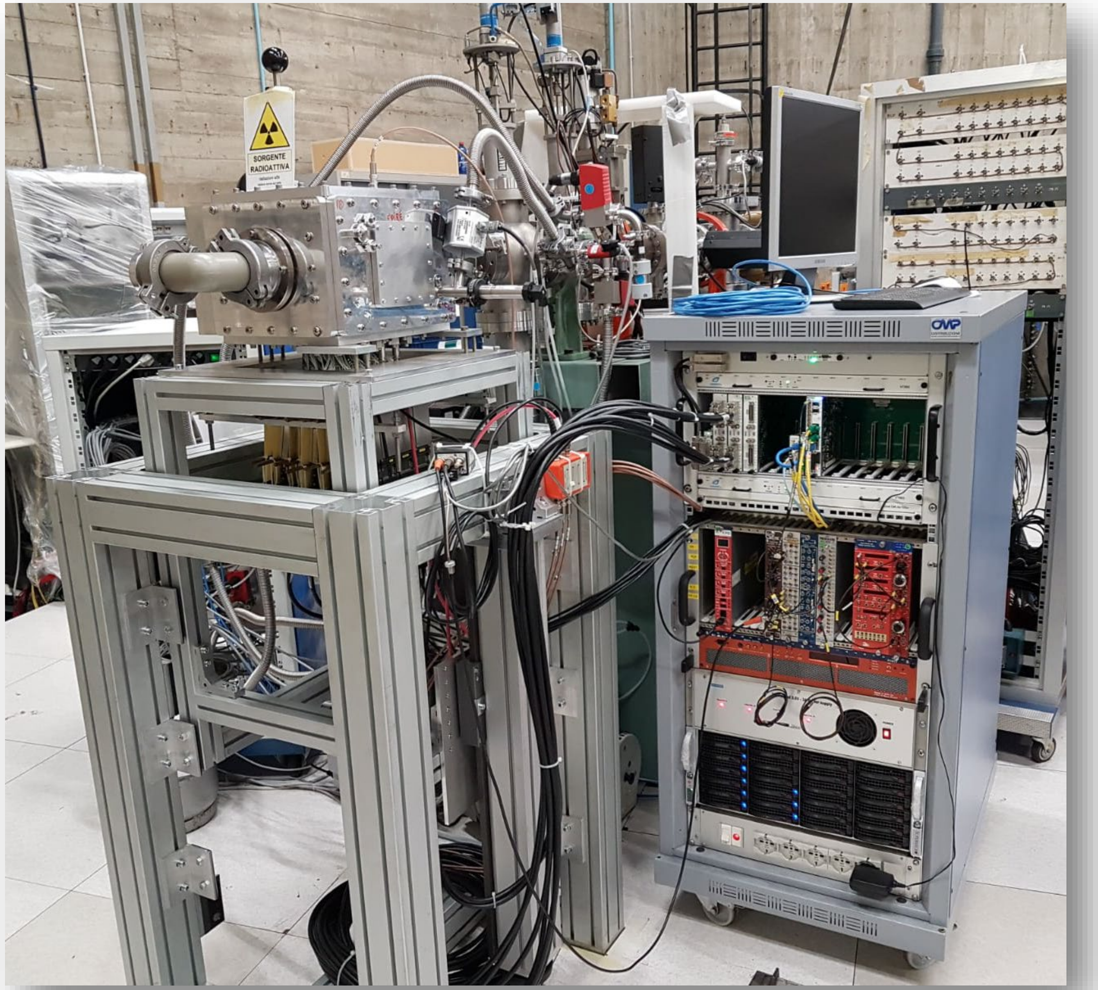




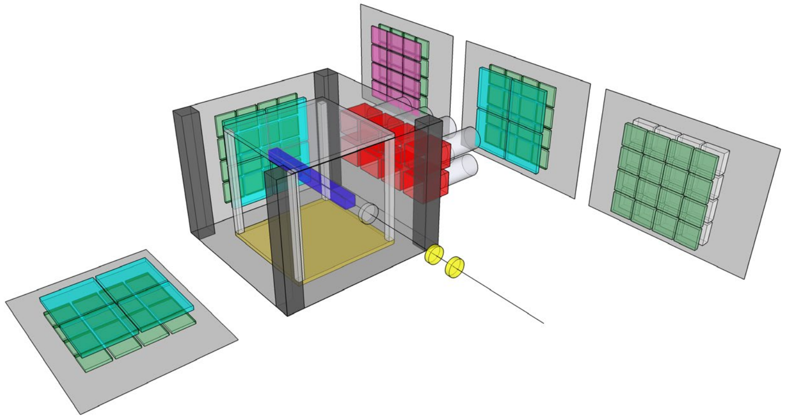
Outlook

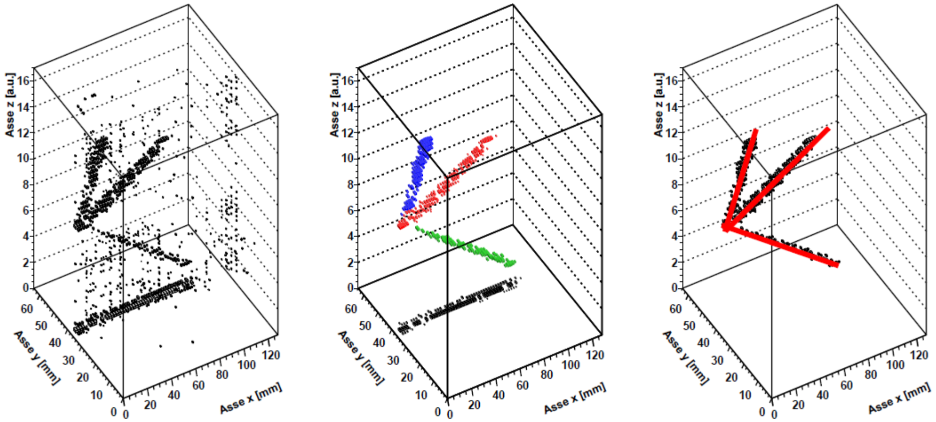

gas volume
electric field
range
incoming beam
segmented plane

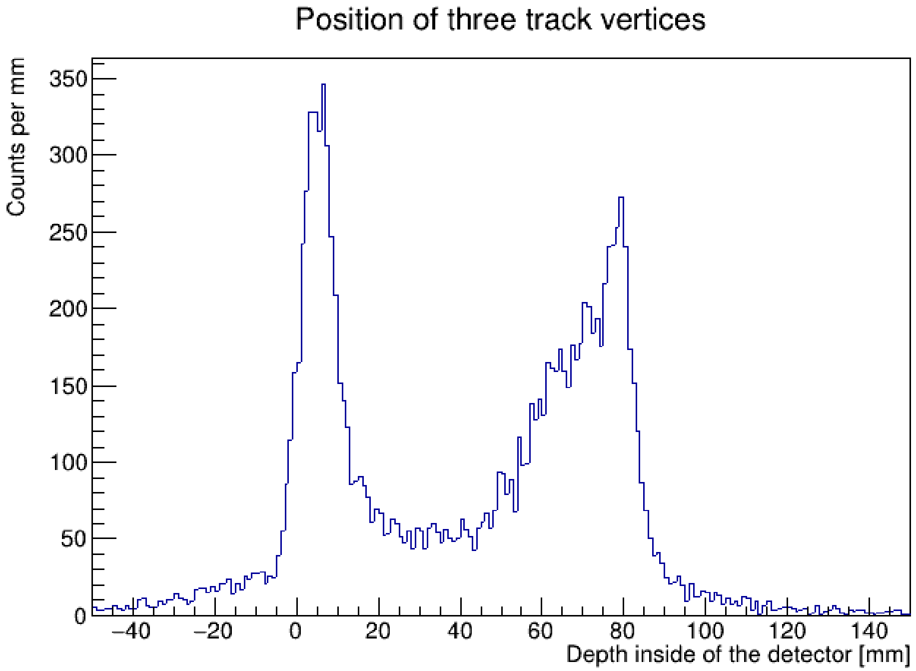




Outlook: inverse kinematics and tracking. Nuclear decay tagging!







$^{11}B + iC_4H_{10}$ at 32 MeV

3 stopped particles in the output channel

Summary

- Internal pair creation is an exotic and challenging process in Nuclear Physics, typically used to study gamma-forbidden transitions (such as E0).
- Anomalies in the e+e- angular correlation distributions have been reported for specific transitions in $^{8}Be^{*}$ and $^{4}He^{*}$ excited by resonant reactions.
- Several interpretations claim the existence of a previously unknown vector boson with mass of about 17 MeV/c2, possible mediator of a new force
- The direct observation via e+ + e- scattering is being studied but not yet reported

- Several experimental studies are being proposed and prepared worldwide.
  At LNL a dedicated setup is being developed by a cross-experiment collaboration.

…stay tuned *and thanks for listening*!

Collaboration

The experimental work is funded by INFN-CSN3 through the NUCLEX collaboration.

Other groups with complementary expertise are involved:
-INFN and University of Padova
-INFN Genova
-LNF
-INFN Roma 1
-INFN Roma 3 (Antonio and Diego)
-INFN Catania