The Discovery of the Nuclear Electron and its Mass Measurement

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The experimenting team

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* Examination of neutron-related experimental data

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Science history context

* 1932: Chadwick discovers the neutron

* 1930s: Heisenberg proposes that the neutron is a tightly bound e^--p^+ composite, Pauli proposes that the neutron is an elementary particle

* 1940s-1960s: most physicists model the neutron as an elementary particle

* 1970s: a decade of extraordinary claims. Gell-Mann, Weinberg, and others claim that the neutron comprises 3 fractionally charged quarks, + an unidentified number of "virtual quarks", and decays by emitting an 80 GeV mass particle.

* 1980s-2010s: most theorists embrace the Gell-Mann - Weinberg model, despite the absence of experimental support (e.g. 80 GeV mass particles are never observed in neutron decays).

    *1980s: the fractional quantum hall effect is discovered (but no quarks)

* 2021: the neutron is discovered to comprise a proton and a nuclear electron

* Science history context

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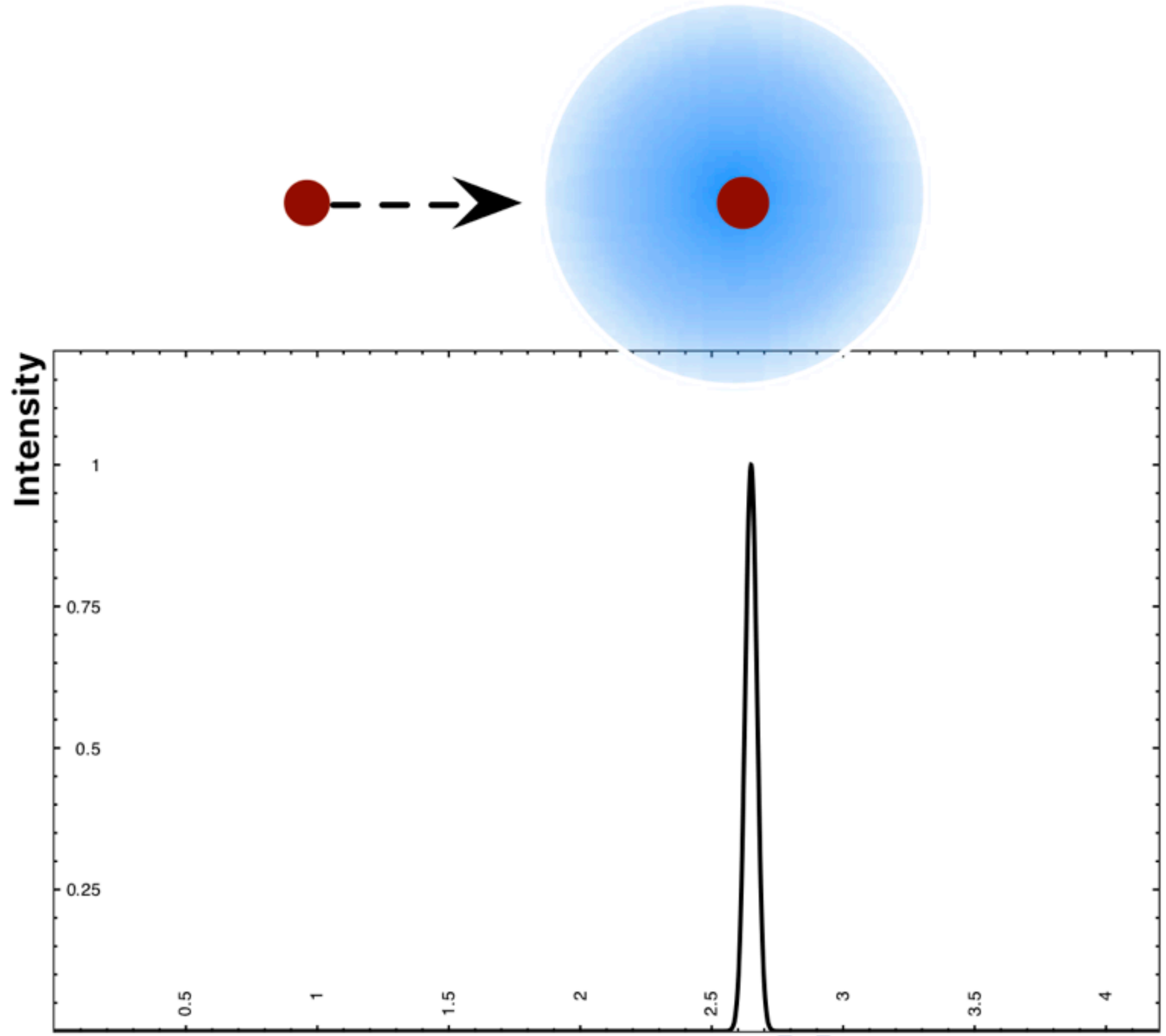
Hydrogen vs Neutron reaction with a proton

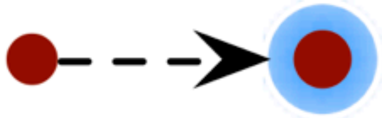


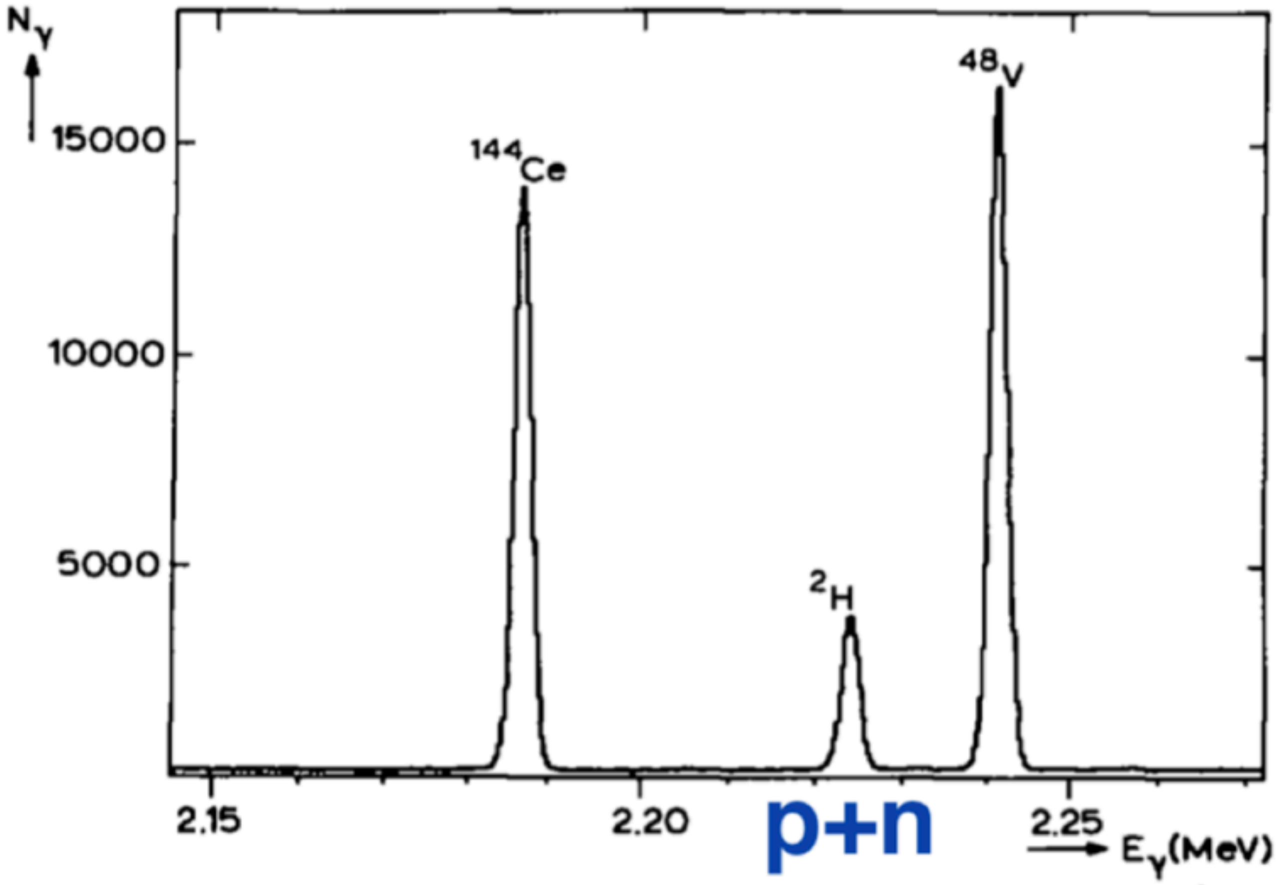
p+H

Proton interaction causes single-frequency radiation emission

↓

Understood to be emitted according to the electron’s QM state change





p+n

Proton interaction causes single-frequency radiation emission

↓

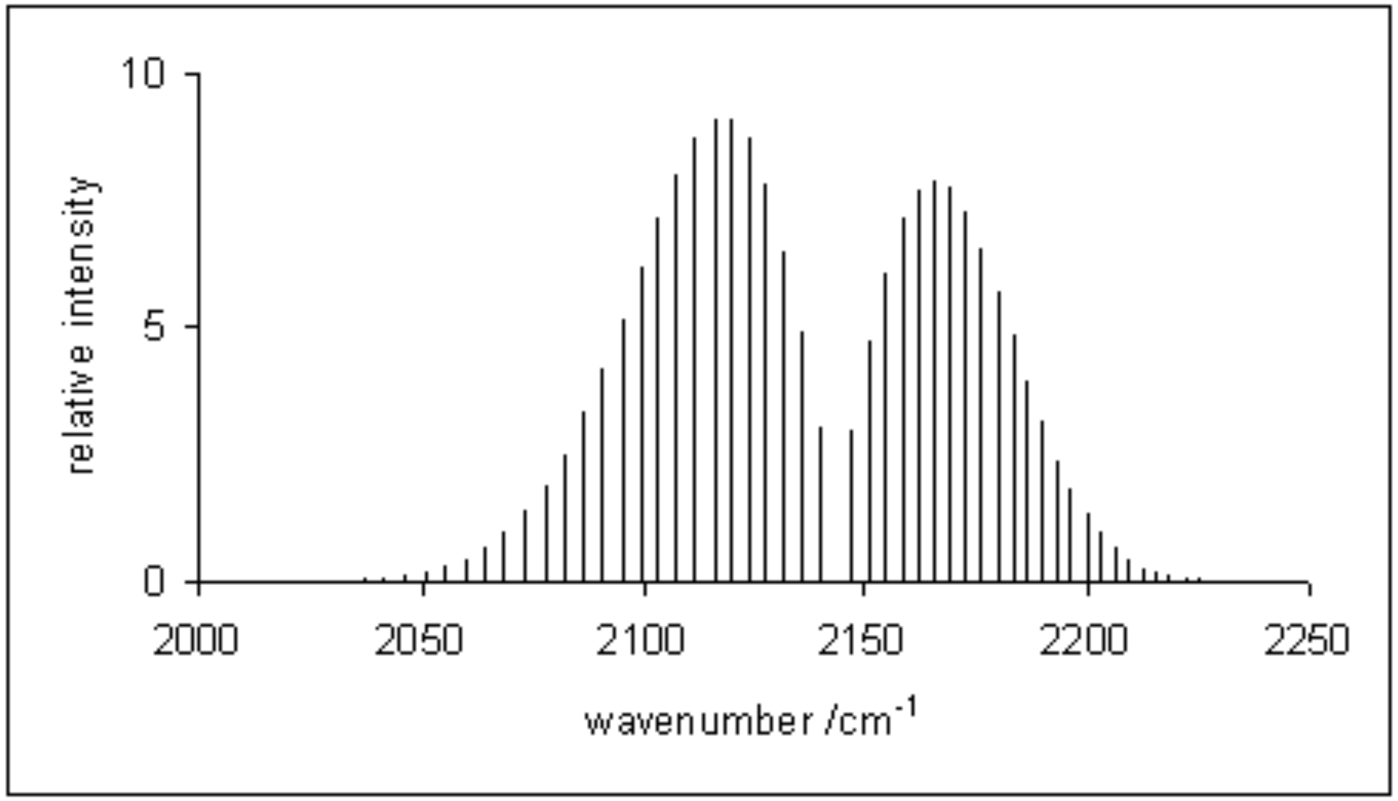
QM state change of a nuclear electron?

Electromagnetic interaction of 3+3 quarks

Quark-based model: the proton-neutron reaction is a gluon-mediated interaction among six valence quarks plus an unidentified amount of virtual quarks.

It is a complicated many-body problem: no reason for the emission of single-frequency radiation.

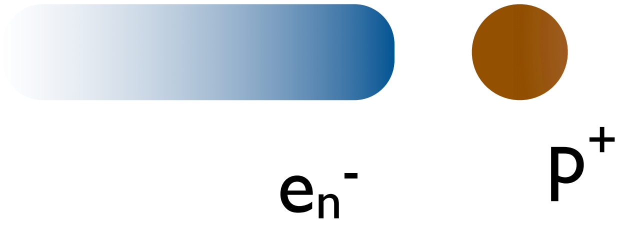
Experimental data from the past 100 years: quark-like interaction within molecules, which contain multiple charge centers, always produces a complex roto-vibrational emission spectrum.



Typical roto-vibrational spectrum

Those who claim that the interaction of 3+3 quarks + unknown number of virtual quarks produces single-frequency radiation are denying Maxwell's equation.

The capture of a Nuclear Electron



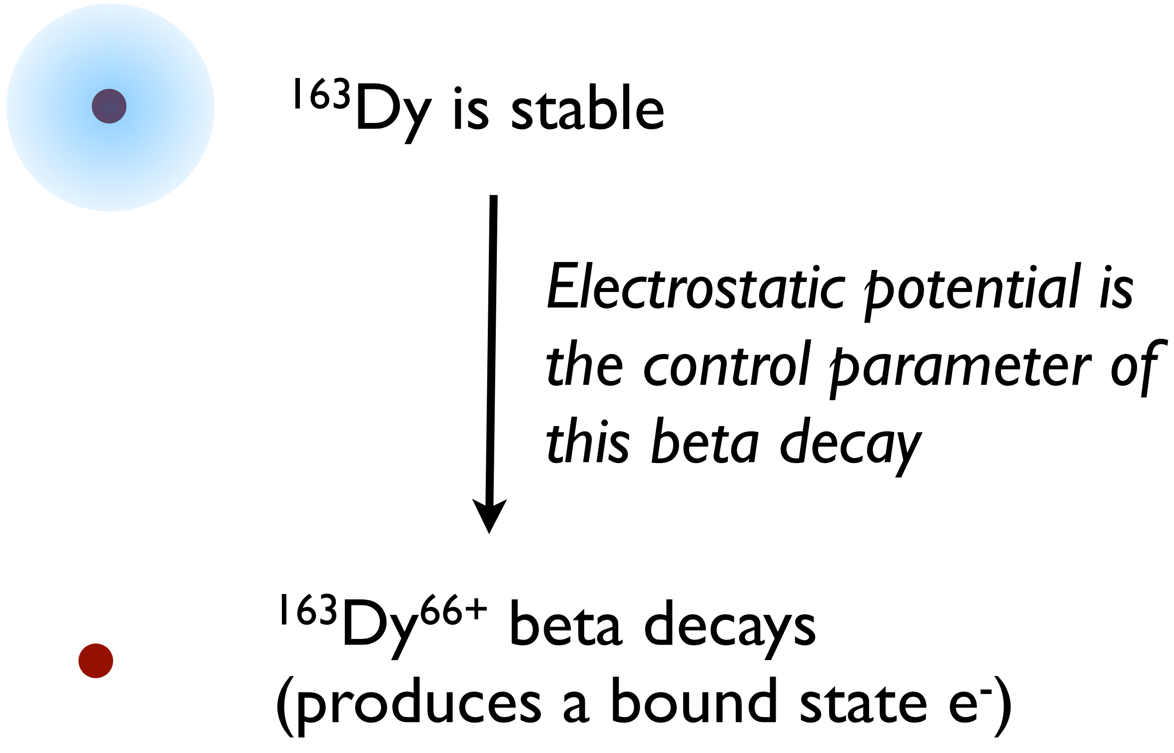
- We anticipate that a nuclear electron's QM state changes are always accompanied by the emission or absorption of single-frequency gamma radiation.

- A very relevant QM state change is the nuclear capture of a nuclear electron (from free-particle state), which must also be accompanied by the emission of single-frequency radiation.

- Neutrino emission happens only upon the nuclear electron's decay.

^{163}Dy disproves the theory of 80 GeV mediating particles

Experiment:

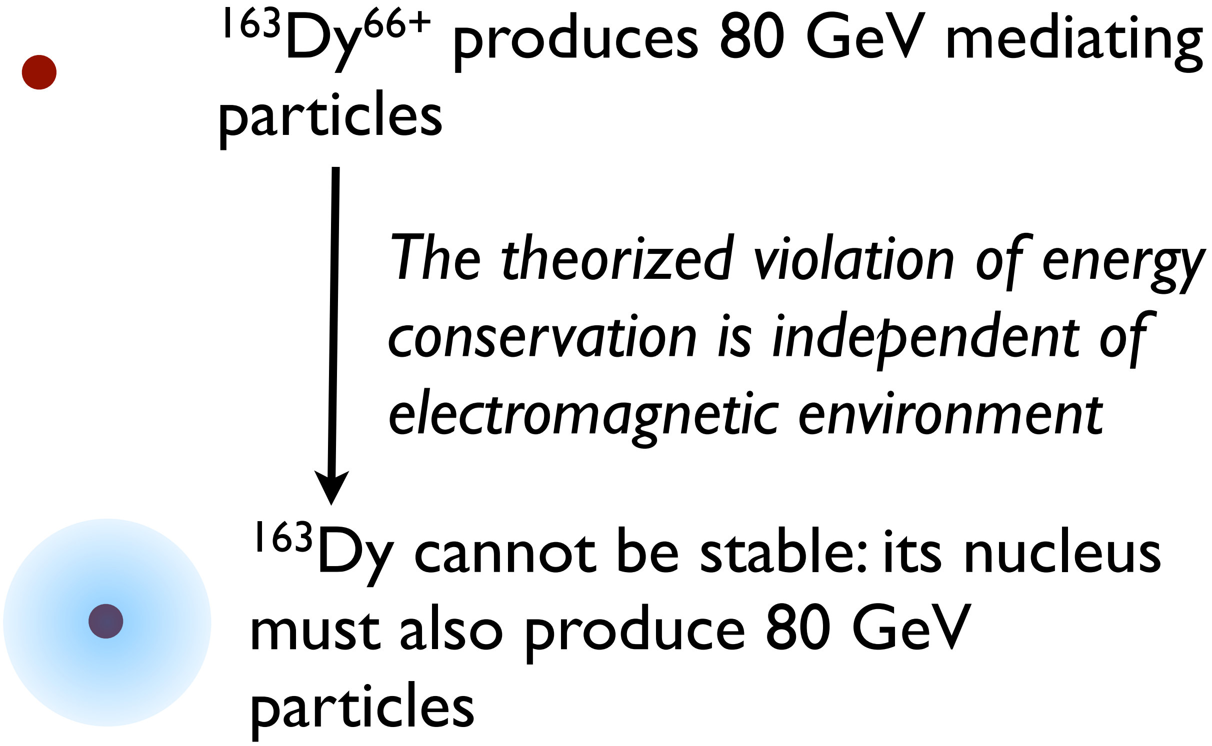


^{163}Dy is stable

Electrostatic potential is the control parameter of this beta decay

^{163}Dy^{66+} beta decays (produces a bound state e$^-$)

Theory of 80 GeV mediating particles:



^{163}Dy^{66+} produces 80 GeV mediating particles

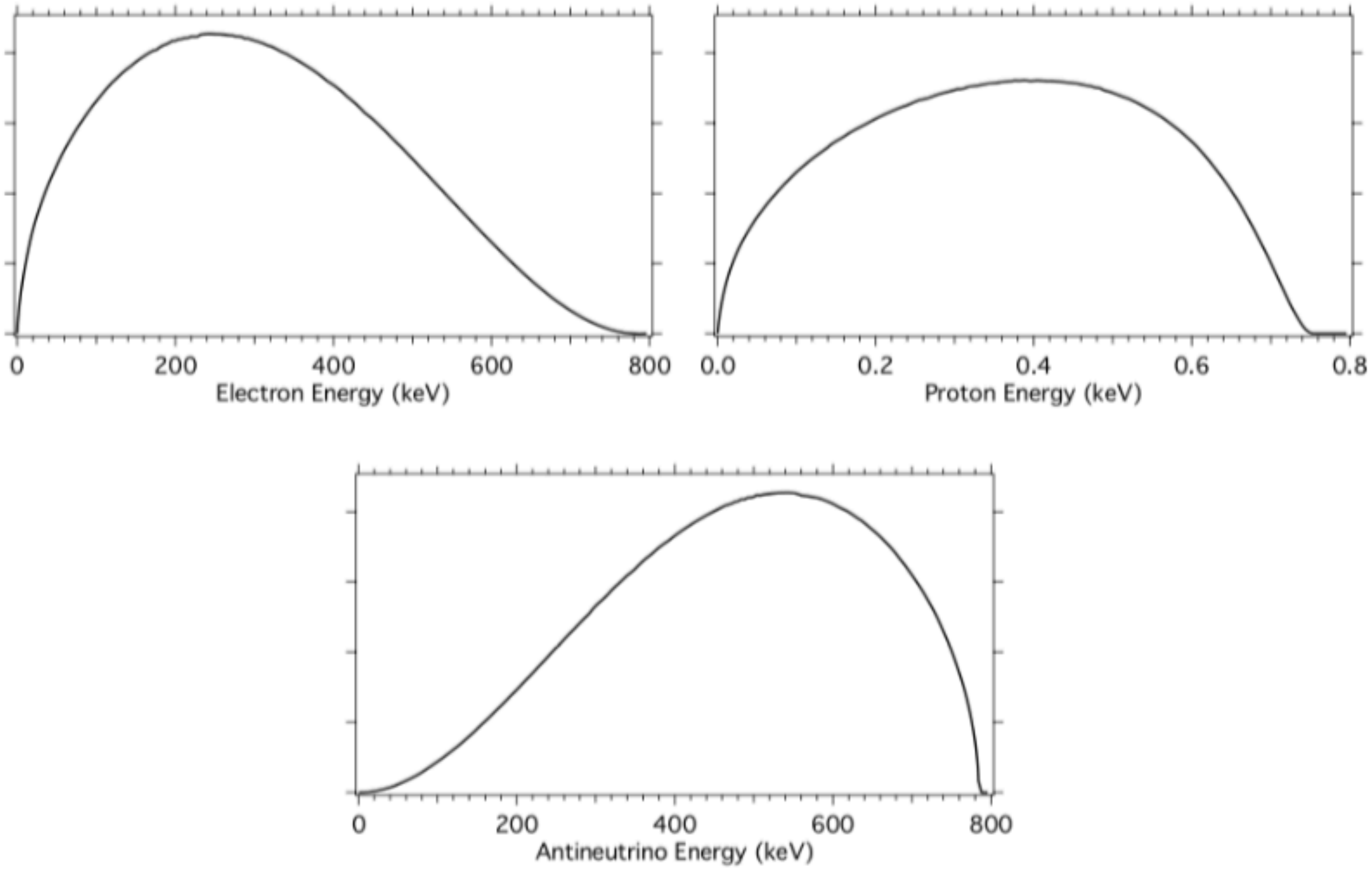
The theorized violation of energy conservation is independent of electromagnetic environment

^{163}Dy cannot be stable: its nucleus must also produce 80 GeV particles

- It is clear that the electric potential is the controlling parameter of this beta decay process
- The contradiction between experiment and "theory" demonstrates that the 80 GeV mass W bosons have nothing to do with nuclear beta decay.

Neutron decay

$$p^+ + e_n^- \rightarrow p^+ + e^- + \text{antineutrino}$$



Kinetic energy spectra for the electron, proton and antineutrino products of neutron decay

By momentum conservation:

$$m_p v_p = m_{en} v_{en} \longrightarrow m_p m_p v_p^2 = m_{en} m_{en} v_{en}^2 \longrightarrow m_p / m_{en} = (m_{en} v_{en}^2/2)/(m_p v_p^2/2)$$

As estimation, we take the ratio of distribution peaks:

$$\frac{250\ keV}{0.4\ keV} = 625 \approx \frac{1836.15}{3} = \frac{m_{p^+}}{3m_{e^-}} \longrightarrow m_{en} \approx 3m_e$$

* Science history context

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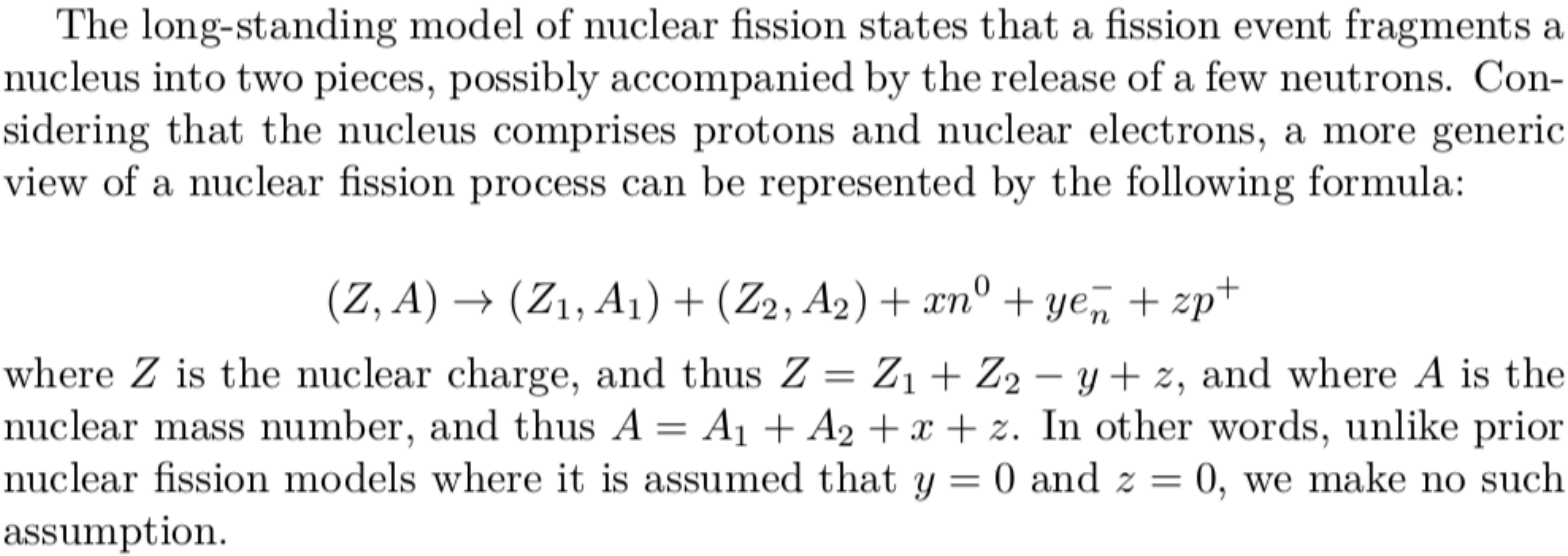
What particle are released during nuclear fission?



The long-standing model of nuclear fission states that a fission event fragments a nucleus into two pieces, possibly accompanied by the release of a few neutrons. Considering that the nucleus comprises protons and nuclear electrons, a more generic view of a nuclear fission process can be represented by the following formula:

$$(Z, A) \rightarrow (Z_1, A_1) + (Z_2, A_2) + xn^0 + ye_n^- + zp^+$$

where Z is the nuclear charge, and thus $Z = Z_1 + Z_2 - y + z$, and where A is the nuclear mass number, and thus $A = A_1 + A_2 + x + z$. In other words, unlike prior nuclear fission models where it is assumed that $y = 0$ and $z = 0$, we make no such assumption.

Uranium fission

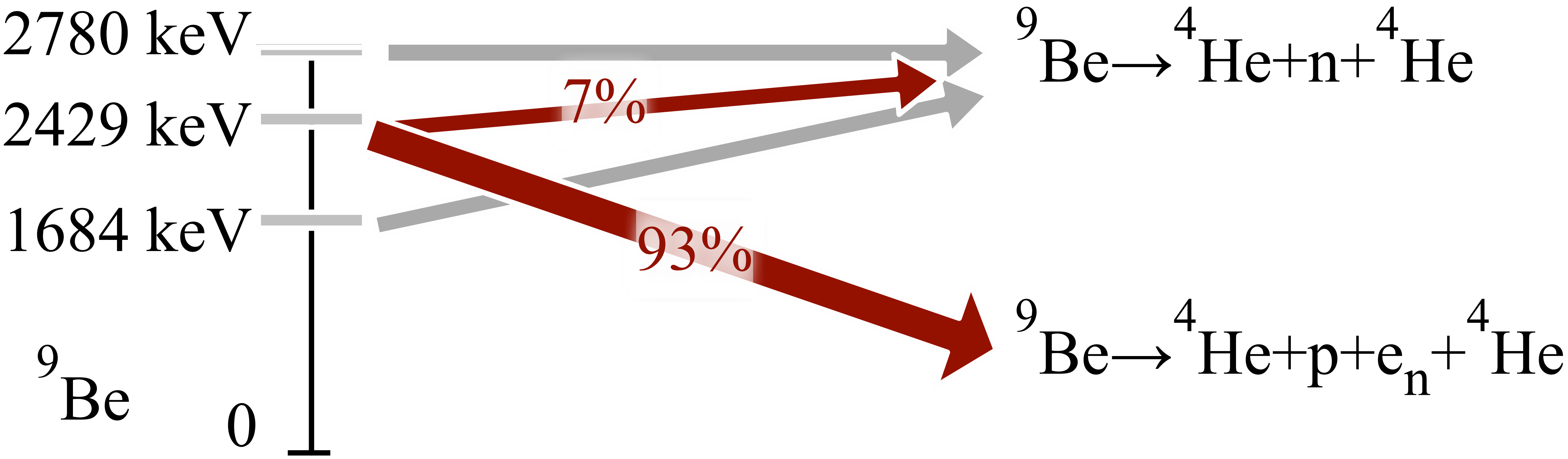
- In the well-studied case of uranium fission, about 8 MeV of its fission energy is released in the form of prompt anti-neutrino radiation. What could be the source of these immediately released anti-neutrinos?

- The fast decay of nuclear electrons into ordinary electrons produces anti-neutrino radiation.

- The fast release of anti-neutrinos indicates the short half-life of nuclear electrons.

- The release of a few nuclear electrons therefore probably accompanies uranium fission reactions, but they have remained unnoticed up to now.

^{9}Be fission



2780 keV

2429 keV

1684 keV

^{9}Be

0

7%

93%

$^9\mathrm{Be} \rightarrow {}^4\mathrm{He} + n + {}^4\mathrm{He}$

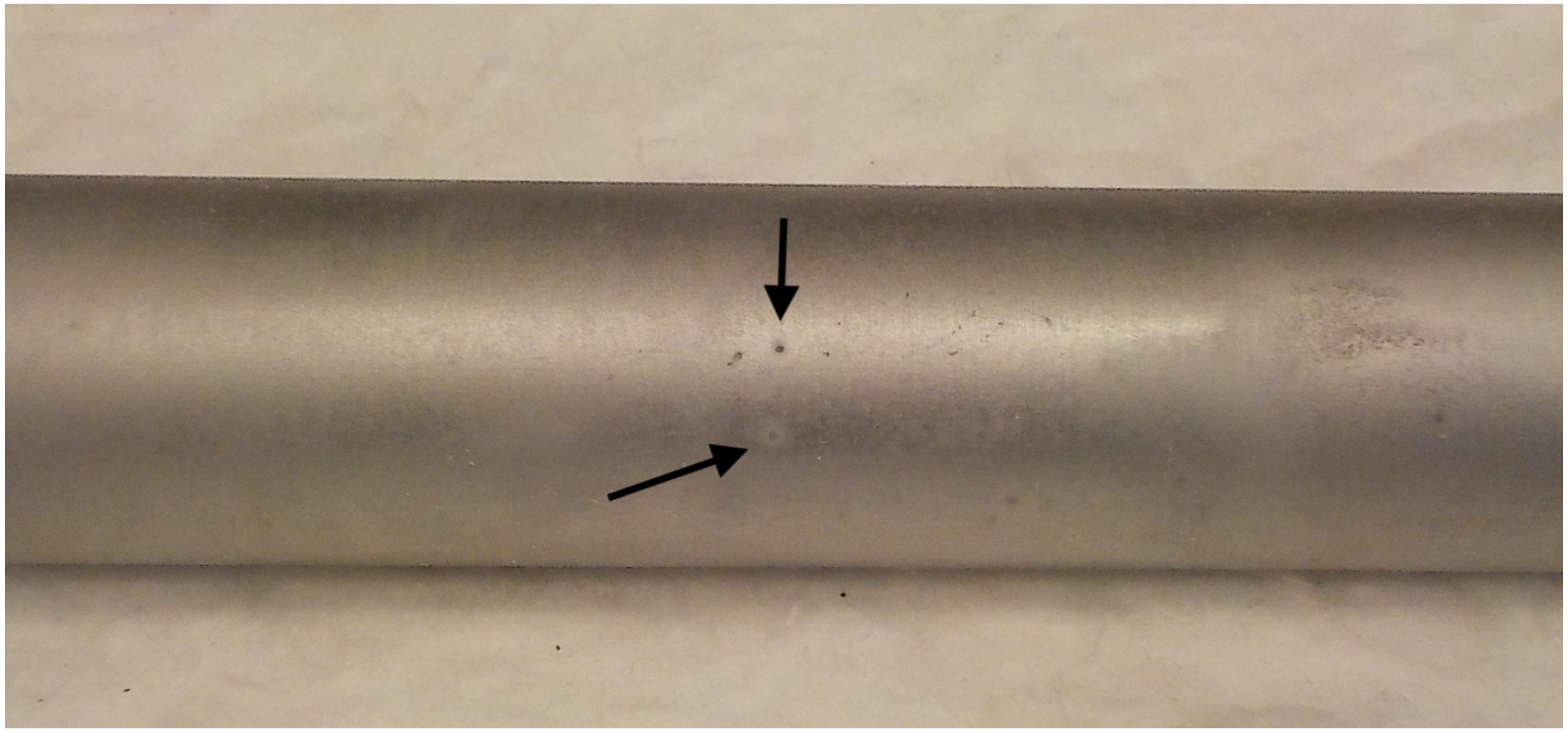
$^9\mathrm{Be} \rightarrow {}^4\mathrm{He} + p + e_n + {}^4\mathrm{He}$

- Note: I) ^{5}He and ^{5}Li do not exist, and 2) a proton separation into ^{5}Li+p requires >16 MeV Therefore the above shown two outcomes are the only possible break-up pathways.

- The 2429 keV excitation decays by neutron emission in only 7% of cases. Thus the 2429 keV excitation decays mainly by emitting a proton and an electron.

- Such a prompt release of an electron upon nuclear break-up demonstrates that there must be nuclear electrons in the ^{9}Be nucleus.
  (“prompt” means much faster than neutron half-life)

Molybdenum fission -1/5



- We enclosed Li+CuNi alloy into two containers. The outer container is made of TZM alloy, whose specified composition is 99.5% Mo, 0.4% Ti, 0.1% Zr, 0.01% Si, 0.01% Fe. We verified by elemental analysis of container samples that the Ti concentration is indeed 0.4%.

- The experiment was conducted using the Uppsala University reactor: under Ar atmosphere, the temperature was cycled in the 1240℃ - 1300℃ range

- After a two-days run, the above shown **spots appeared on the container**. The fresh container did not have these spots. **No such spots appeared on the "calibration" TZM tube**, which contained an iron bar, and underwent same thermal treatment for about half-day duration.

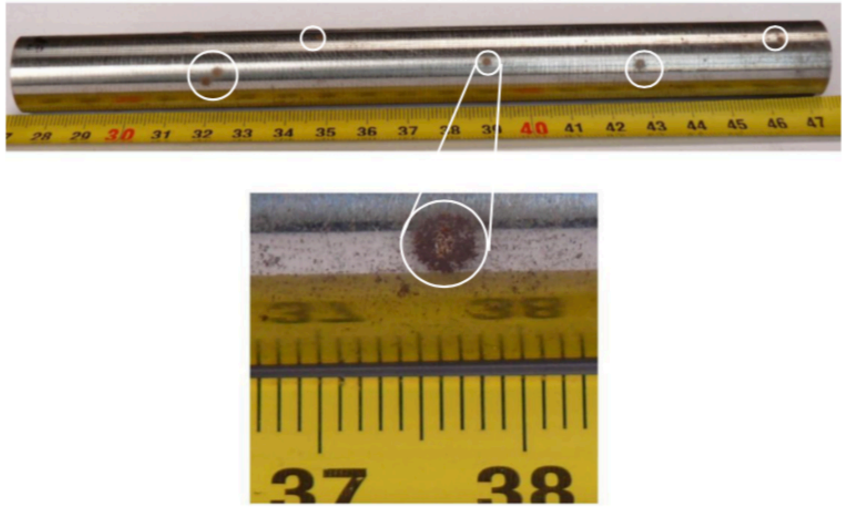
- TZM's melting point is 2620℃, titanium's melting point is 1670℃.

Molybdenum fission -2/5

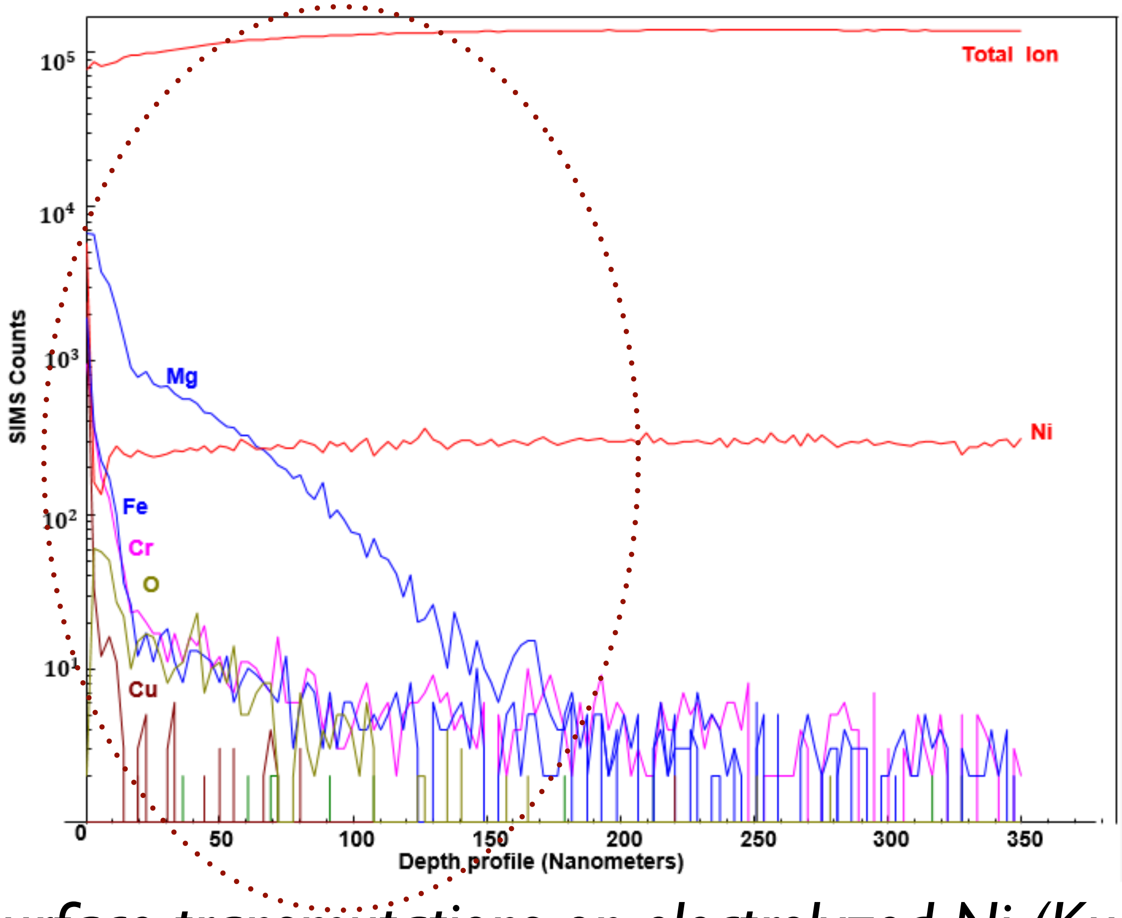
Nuclear reaction signatures of such experimental setup were reported in our past publication* .

The observed spots on the container are a surface phenomenon: there is normal metal under them.

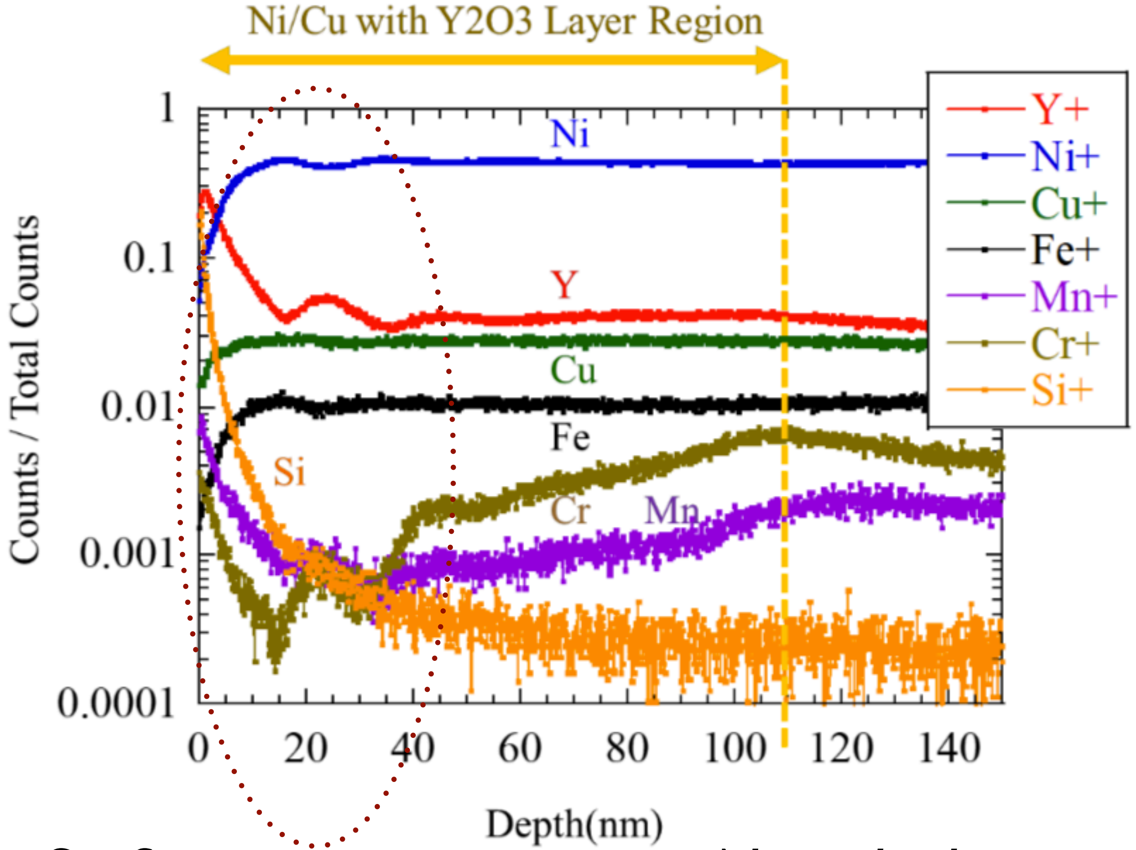
They fit into the pattern of well-documented **nuclear transmutations on metallic surfaces**.



Transmutation spots on the surface of utrasonicated iron bar (Cardone)



Surface transmutations on electrolyzed Ni (Kumar)

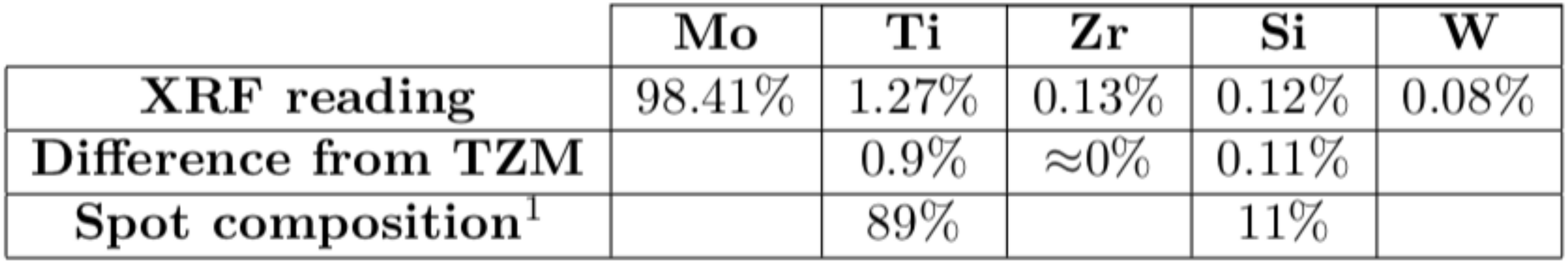


Surface transmutations on Ni, as hydrogen diffuses through Ni-Y_2O_3 layers (Iwamura)

* *A. Kovacs et al "Exothermic Reactions in the Partially Molten Li–Ni–Cu Alloy", Journal of Condensed Matter Nuclear Science, Volume 25 (2017), Pages 159–180*

Molybdenum fission -3/5

- We measured the spot composition by XRF instrument, which measures the average composition over a 1 cm^2 area.
- Considering that the spot is 1 mm^2 sized, we interpret this XRF data as a near complete transmutation of Mo within the spot, with little or no transmutation on other surface areas.
- We assume that the 0.08% tungsten is a contamination in our TZM material, and note that its producer also makes tungsten cylinders.

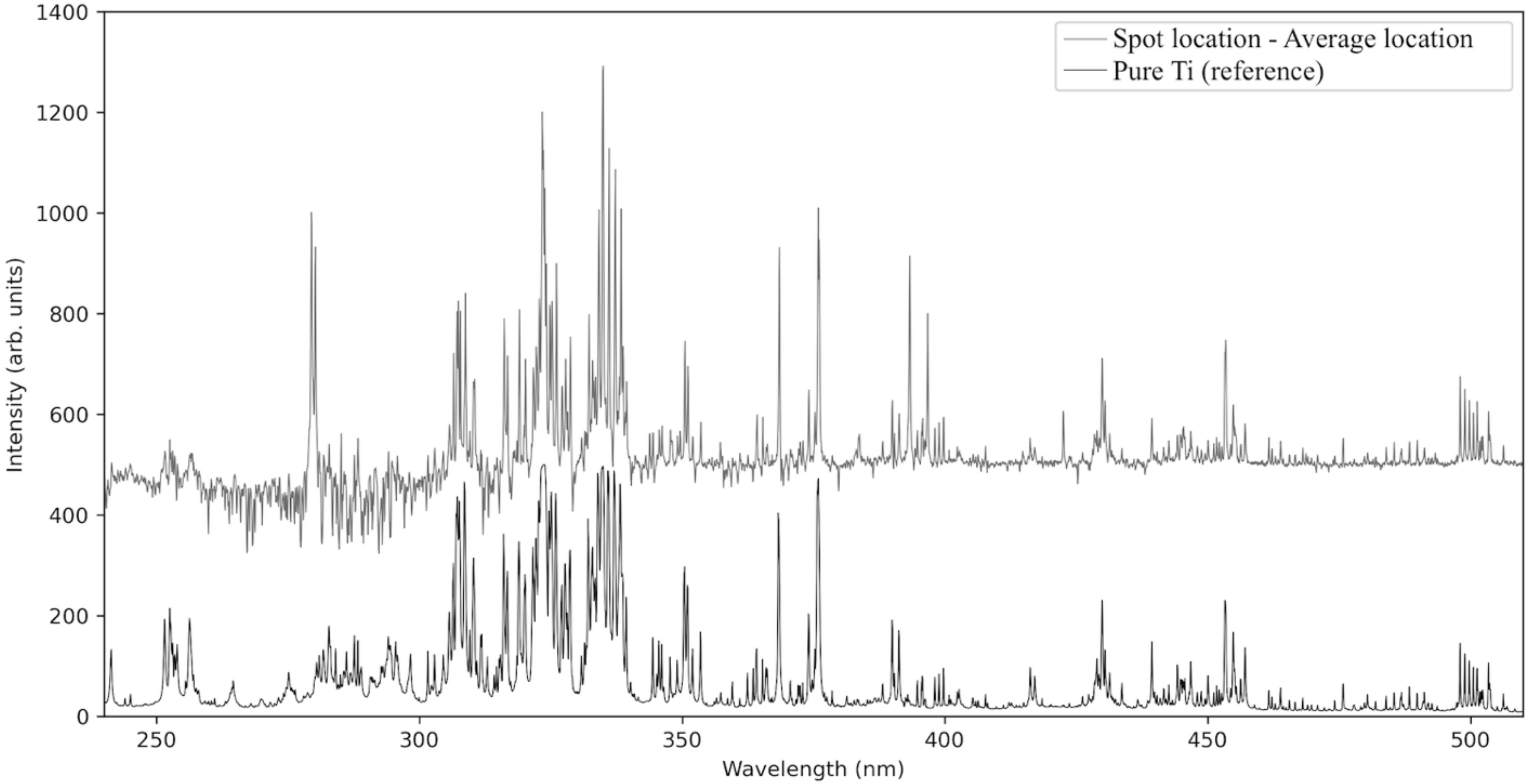


	Mo	Ti	Zr	Si	W
XRF reading	98.41%	1.27%	0.13%	0.12%	0.08%
Difference from TZM		0.9%	≈0%	0.11%	
Spot composition[1]		89%		11%	

[1] other elements than Mo

Molybdenum fission -4/5

- We used LIBS as a second method to analyze the spot composition.
- In order to have a clear signal of the newly created elements, we looked at the difference between the spectrum at the spot and the spectrum at an average location.
- The LIBS measurement confirms that the newly created elements are mainly titanium atoms.



Molybdenum fission -5/5

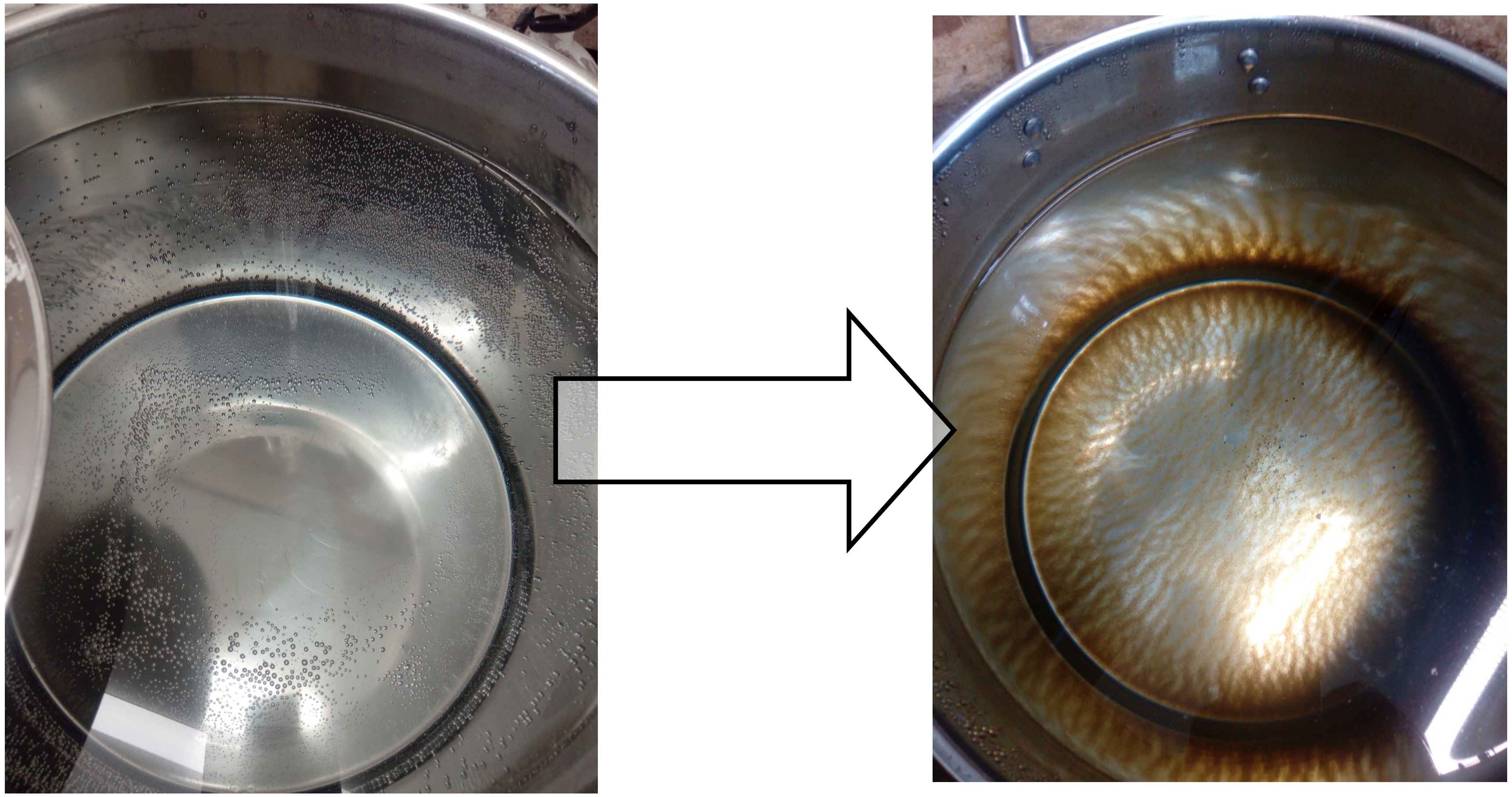
- The Mo to Ti fission reaction may be written as follows:

$$^{96}Mo \quad \rightarrow \quad 2 \times {}^{48}Ti + 2 \times e^-$$

- The fission of other molybdenum isotopes proceeds analogously.
- The release of nuclear electrons is required by charge conservation! If molybdenum nuclei were to fission without the release of nuclear electrons, the fission product would have been scandium, or a mixture of titanium and calcium.

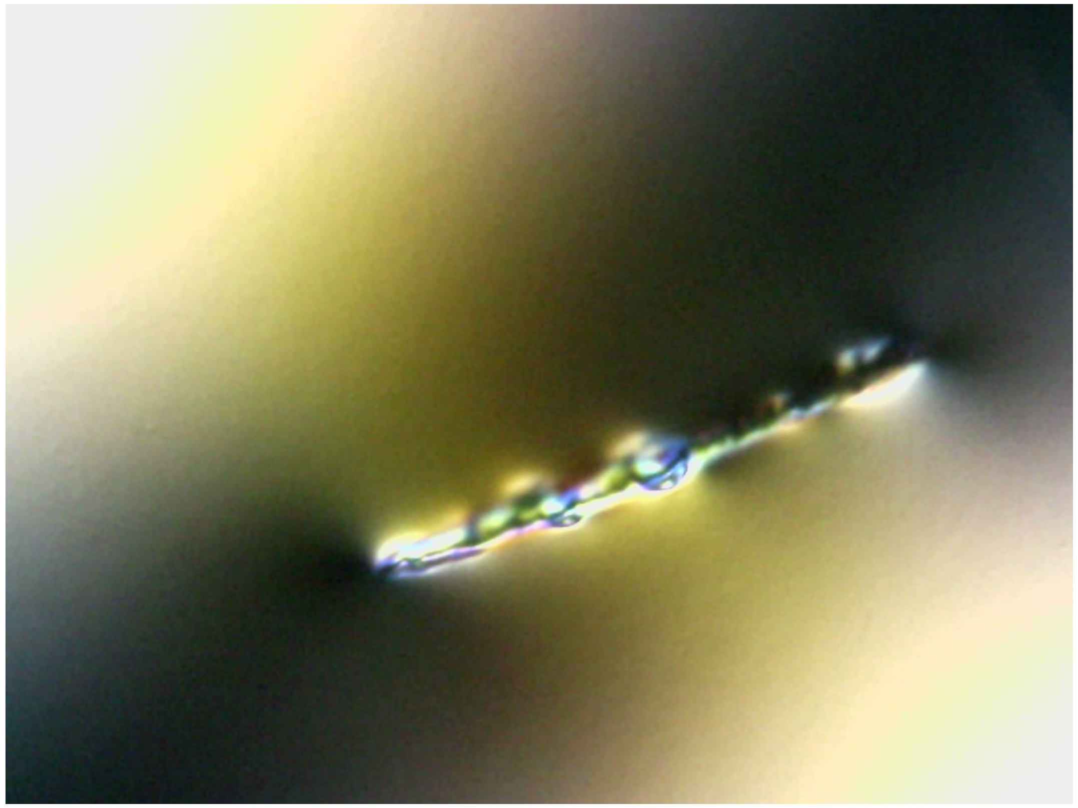
Copper fission -1/4

- We performed 230 V arc discharge, using copper electrode immersed into an aqueous solution of 10% KNO_3
- After the 15 minute experiment run, the solution became slightly copper-colored, which later sedimented.

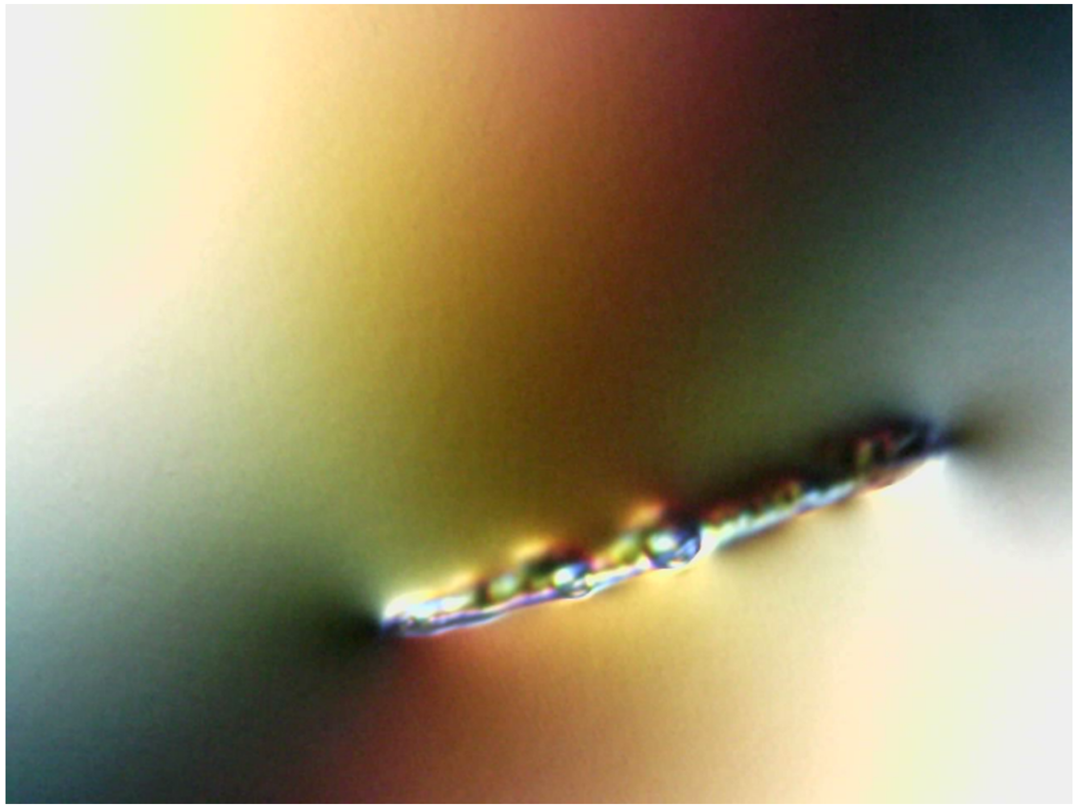


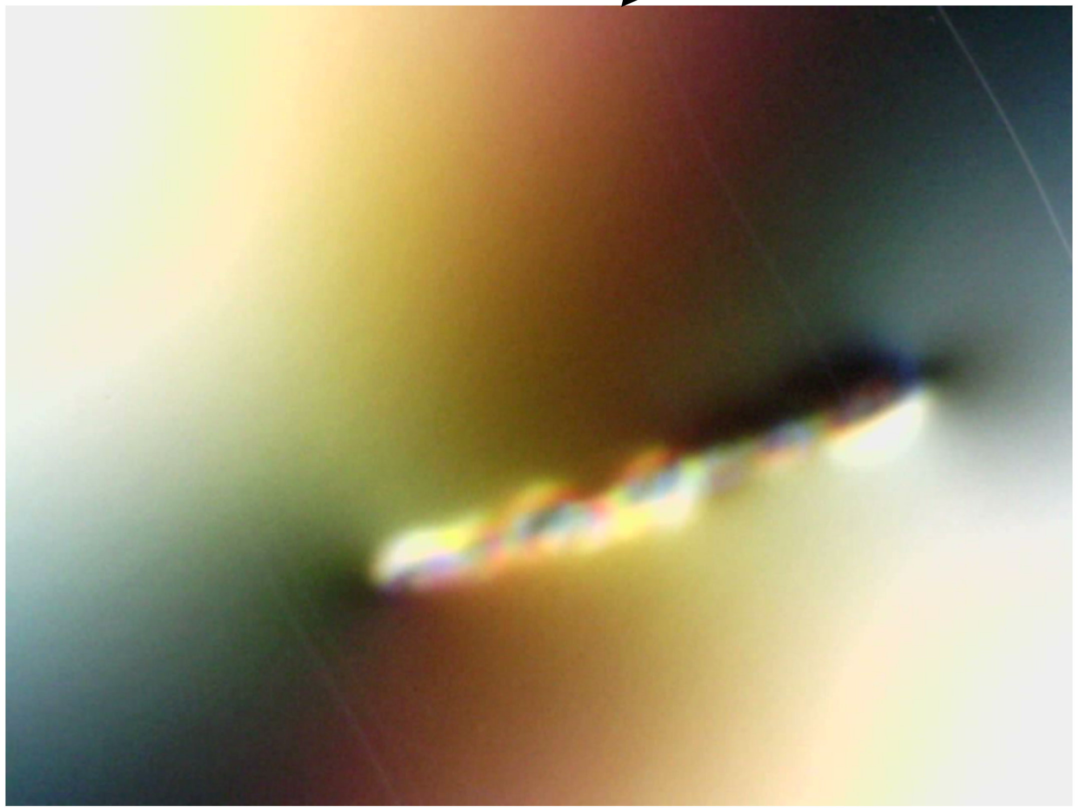
Copper fission -2/4

Several **non-chemical reaction signatures** were observed. For example, tracks appeared in the polycarbonate material, which was placed at the outer surface of the reaction container:



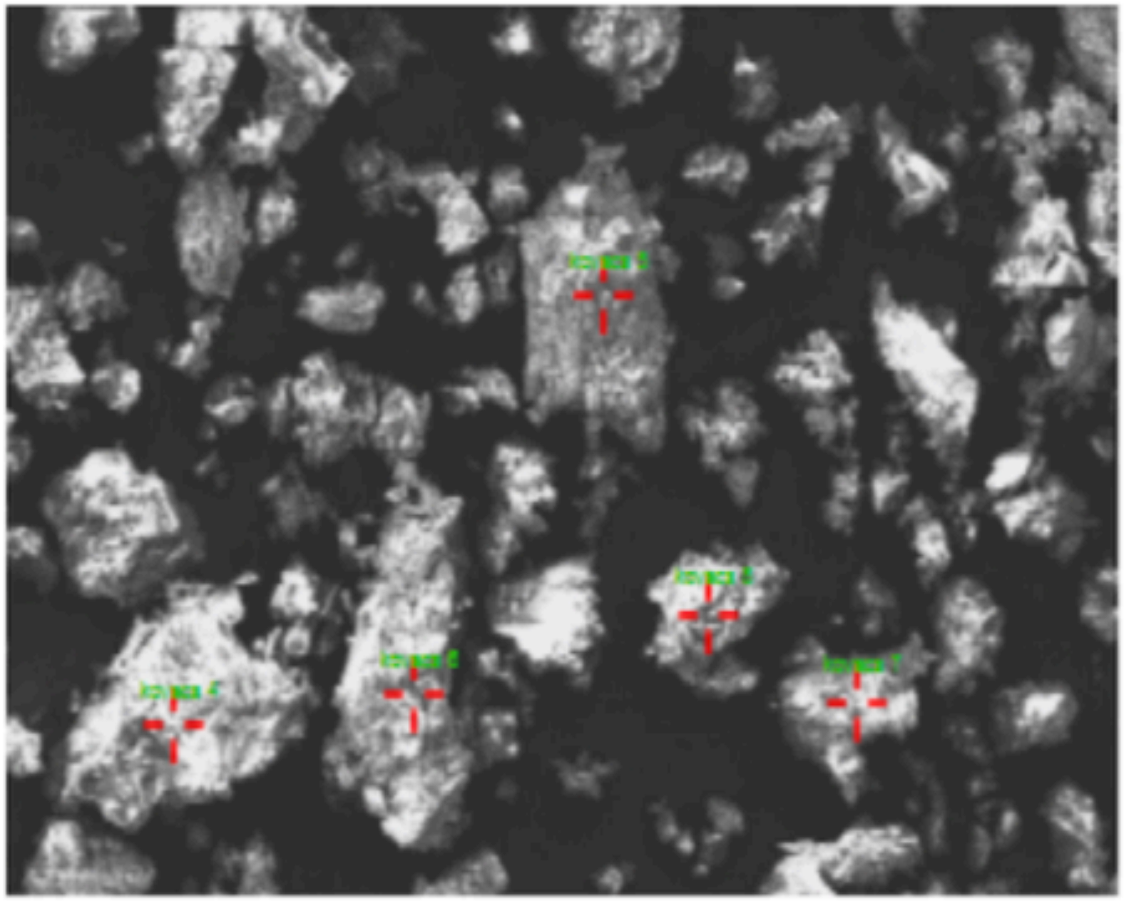
Focus is below the surface





Focus is on the surface (see scratch)

Copper fission -3/4



Si	P	S	Cu
0.1%	0.2%	0.2%	2.8%
0.1%	0.15%	0.15%	3%
0.1%	0.4%	0.1%	3.3%
0.4%	1.2%	1.3%	13.7%
1%	1.8%	1.7%	15.2%

Left: the copper-derived sediment appearing after an arc discharge. Right: the concentration of Si, P, S, and Cu at five locations (atomic percentages). The red crosses show the measurement locations, where the surface elemental composition was evaluated.

- The presence of Cu is anticipated, but the presence of Si, P, and S is unexpected. Their total amount is below 100% mainly because of the KNO_3 salt that crystalized after drying

- Across all measurements, the concentrations of Si, P, and S are correlated to the Cu concentrations. If Si, P, and S were contaminations, there would be no reason for such correlations, and there would be no reason for the very similar quantities of P and S.

Copper fission -4/4

- While the masses of stable P and S isotopes match the masses of Cu isotopes, the release of nuclear electrons is required by charge conservation.
- The main nuclear reaction pathway is:

$$^{63}Cu \quad \rightarrow \quad ^{31}P + ^{32}S + 2 \times e^-$$

$$^{65}Cu \quad \rightarrow \quad ^{31}P + ^{34}S + 2 \times e^-$$

Argon fission -1/3

- Electric discharges are made in water-argon plasma*
- The spectrum of the resulting plasma is analyzed:

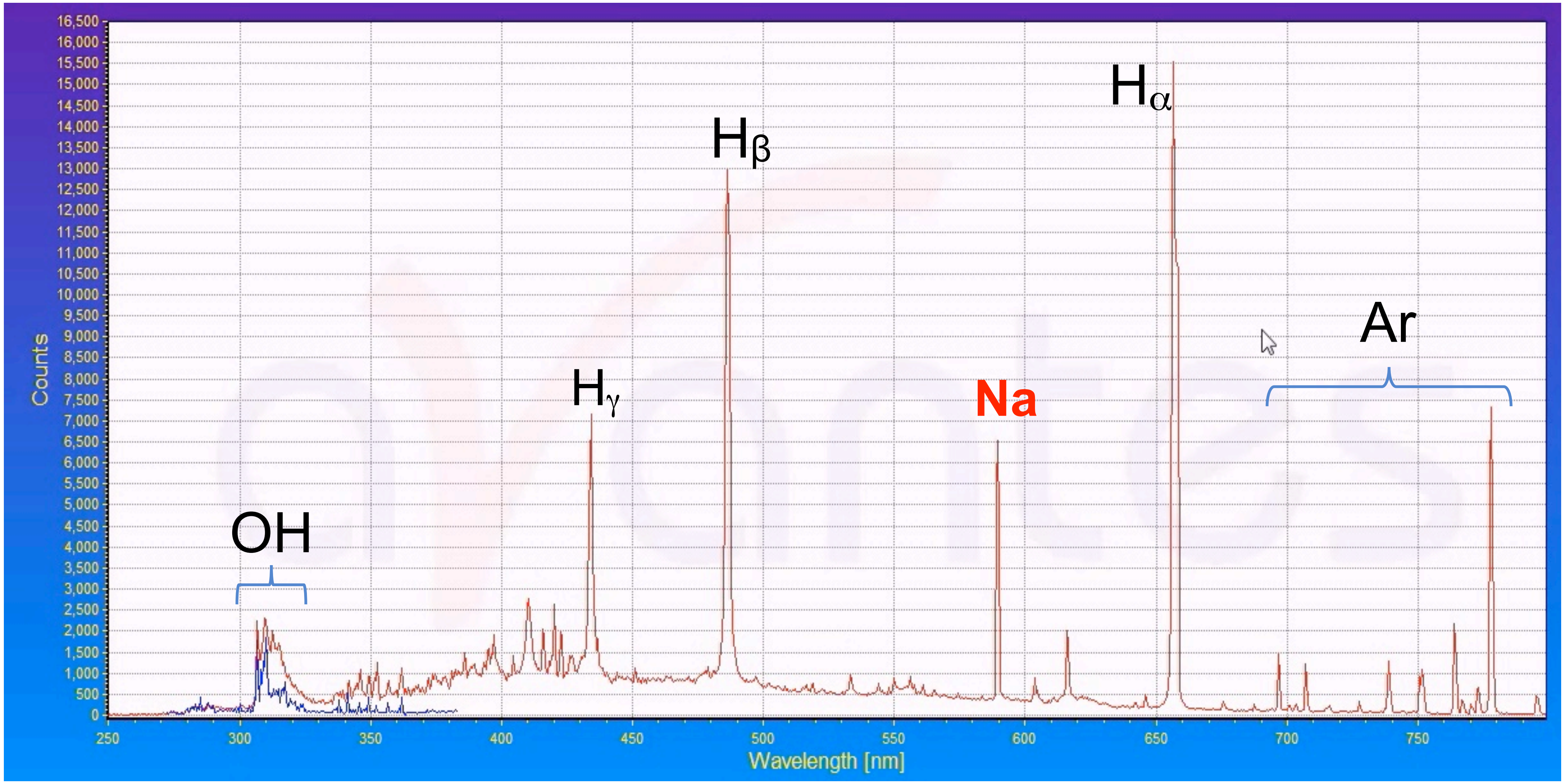
Ar:H2O = 2:1

Operation time T = 15 s

** A. Klimov "Decay-Instability of Transmutated Chemical Elements Obtained in LENR Experiment", presentation at the ICCF-23 Conference, Xiamen, China (2021)*

Argon fission -2/3

The H, OH, and Ar excitation lines are anticipated. The only new element is Na.



Possible Ar fission reactions, which involve only Na and O:

$$^{40}Ar \quad \rightarrow \quad ^{23}Na + {}^{17}O + e^-$$

$$^{40}Ar \quad \rightarrow \quad ^{23}Na + {}^{16}O + e^- + n^0$$

$$^{40}Ar \quad \rightarrow \quad ^{23}Na + {}^{16}O + 2 \times e^- + p^+$$

Each reaction involves electron release.

Nuclear fission observations summary

- ✓The observed prompt release of electrons during fission reactions demonstrates the existence of nuclear electrons.

- ✓The release of neutrons and nuclear electrons are concurrent processes. The presence of neutrons generally indicates the presence of nuclear electrons and vice versa.

- ✓The released nuclear electrons will exist as a free particle for short time.

- * Science history context

- * Examination of neutron-related experimental data

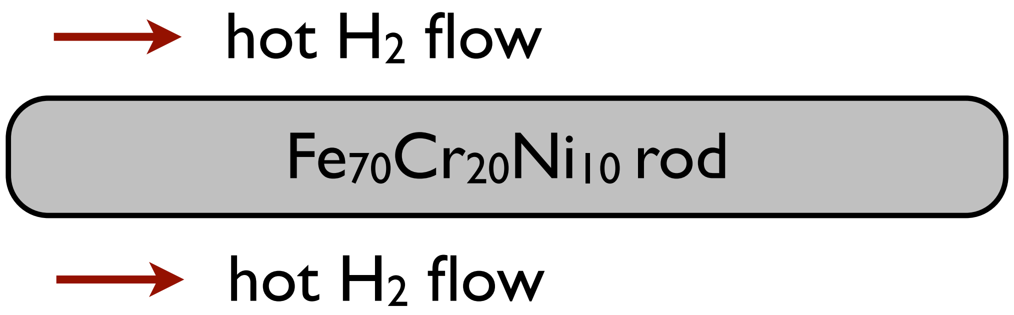
- * Experimental proofs for the nuclear electron’s existence

- * Measurement of the nuclear electron mass

Nuclear electron capture by ^{58}Ni - 1/3

Focardi's group observed a surface transmutation along an $Fe_{70}Cr_{20}Ni_{10}$ alloy rod, under H_2 flow, which appears to be Fe → Cr + He fission* .

Experimental set-up:

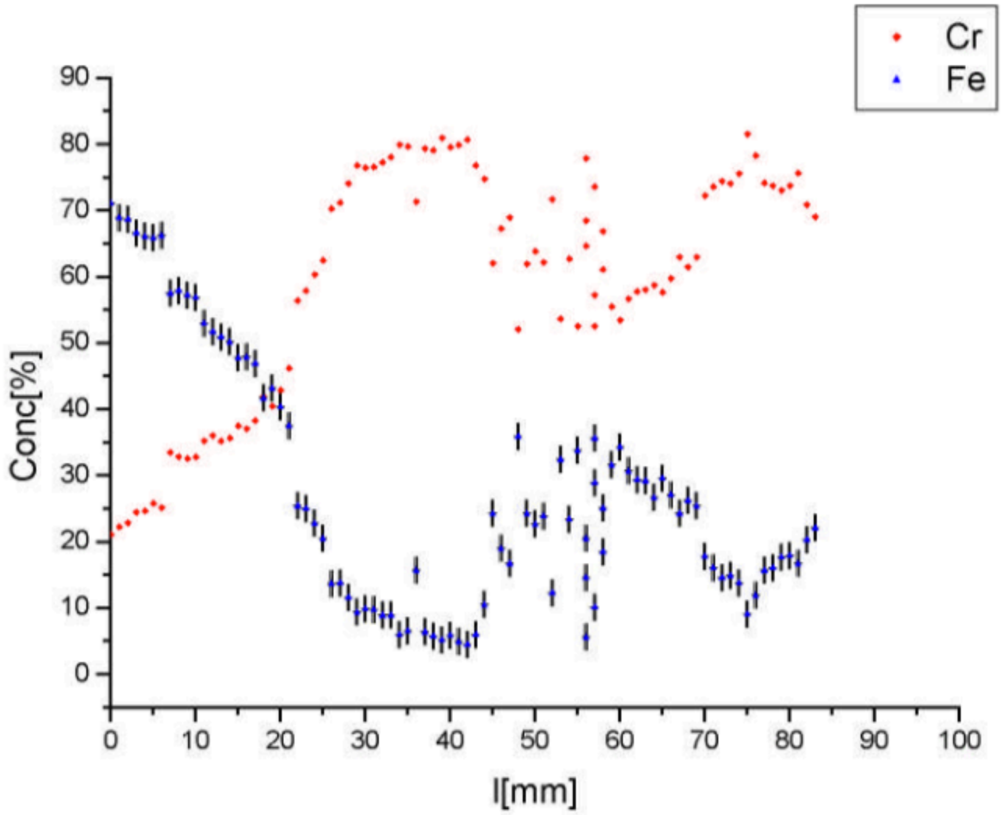


hot H_2 flow

$Fe_{70}Cr_{20}Ni_{10}$ rod

hot H_2 flow

Surface transmutation along the rod axis:



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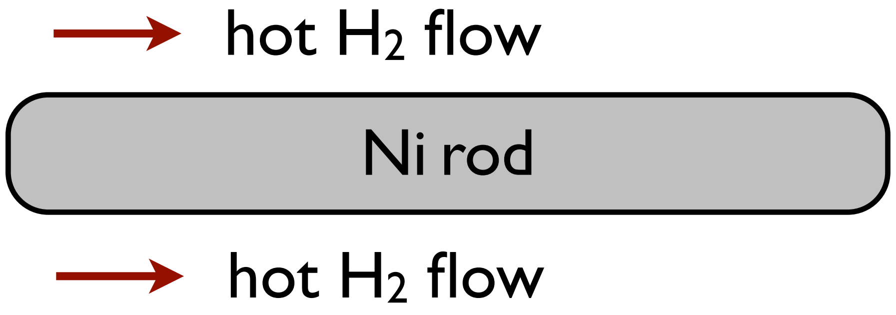
* *E. Campari et al "Surface Analysis of hydrogen loaded nickel alloys", proceedings of the ICCF-12 (2006)*

Nuclear electron capture by ^{58}Ni -2/3

Using a Ni rod under H_2 flow, interesting nuclear phenomena appeared*:

- Detection of neutrons
- The appearance of a 661.5 keV gamma peak (diminishes with time), which the authors could not explain.

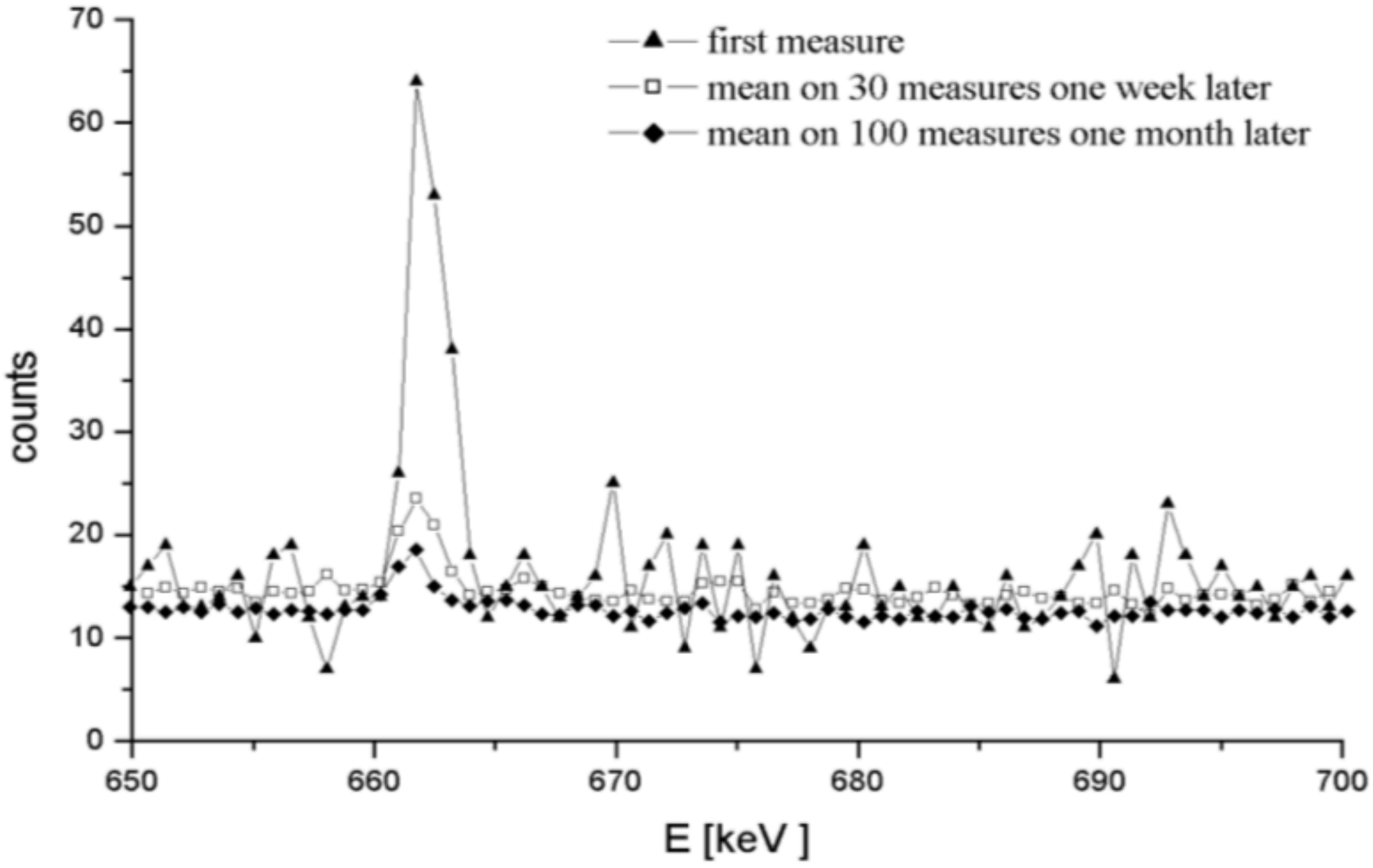
Experimental set-up:


hot H_2 flow

Ni rod

hot H_2 flow

Gamma radiation measurement:



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* S. Focardi et al "Evidence of electromagnetic radiation from Ni-H Systems", proceedings of the ICCF-11 (2004)

Nuclear electron capture by ^{58}Ni -3/3

The observed fission and neutrons indicate the presence of nuclear electrons.

There are two possibilities for ^{58}Ni to ^{58}Co transmutation:

- Capture of an ordinary electron, yielding electron capture energy E_{ec}
  $m_e c^2 + m_{58Ni} c^2 = m_{58Co} c^2 + E_{ec}$
- Capture of a nuclear electron, yielding binding energy E_b
  $m_{en} c^2 + m_{58Ni} c^2 = m_{58Co} c^2 + E_b$

By subtracting the above two equations, we may write:

$$m_{en}c^2 - m_e c^2 = E_b - E_{ec}$$

Identifying E_b with the 661.5 keV peak, we have:

$m_e c^2$=511 keV, E_b=661.5 keV, E_{ec}=-381.6 keV

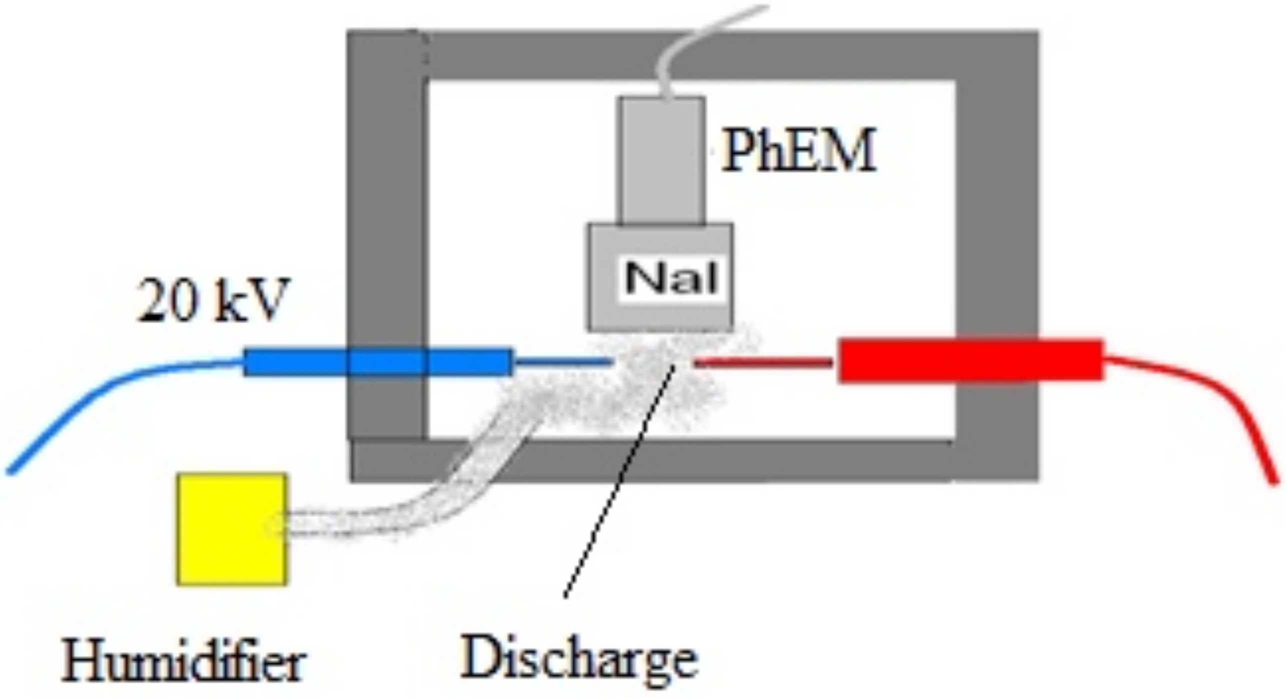
The above numbers yield: $m_{en}c^2$=1554 keV

Nuclear electron capture by ^{1}H -1/5

The phenomenon of neutron production by lightning was studied in many works*.

It was determined that such neutrons originate from the $^{14}N \rightarrow {}^{13}N + n$ fission reaction.

We produced lab-made lightning strikes:



** A.V. Gurevich et al "Strong Flux of Low-Energy Neutrons Produced by Thunderstorms", Physical Review Letters, Volume 108 (2012)*

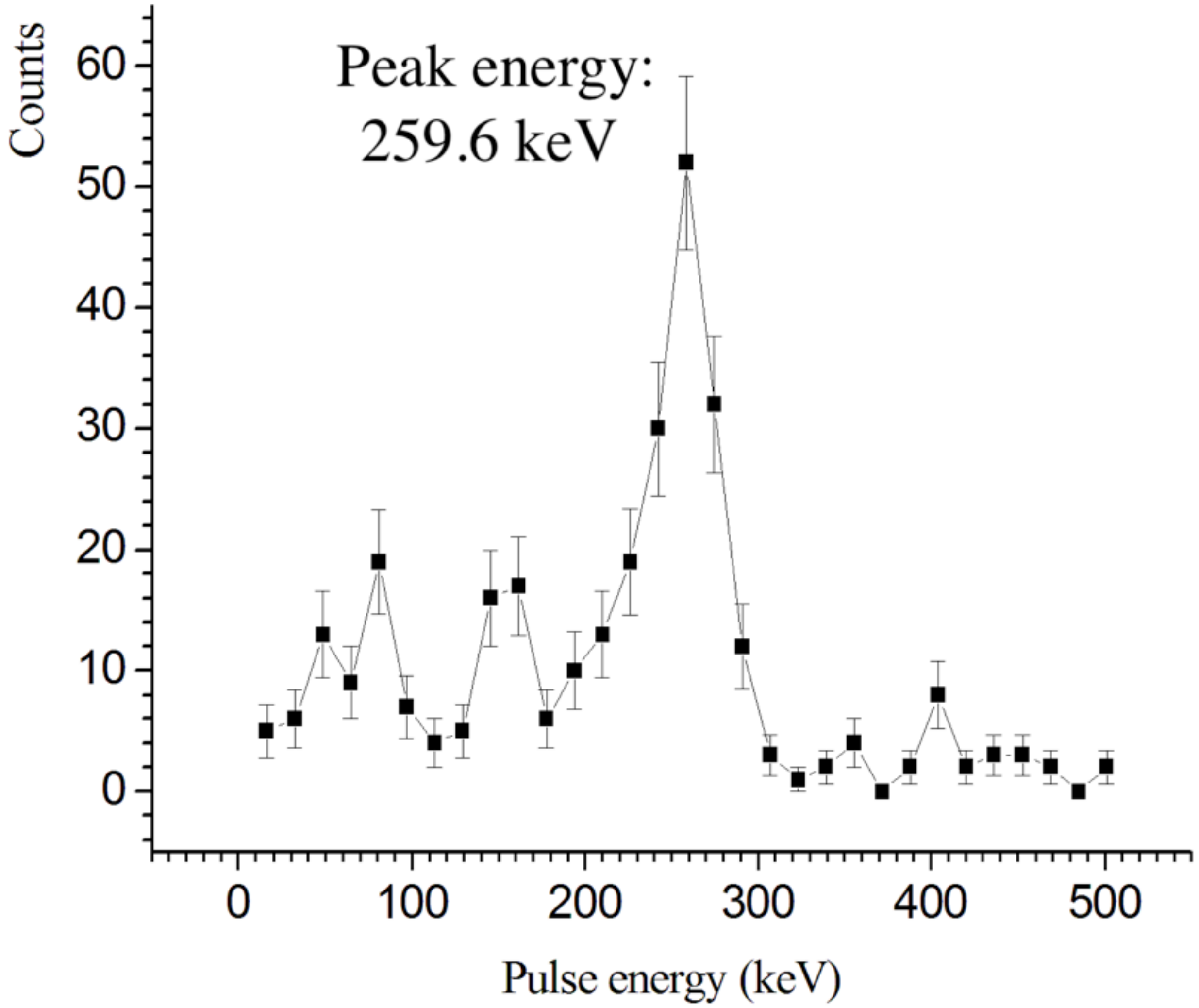
L. P. Babich "Thunderstorm neutrons", Physics-Uspekhi, Volume 62.10 (2019)

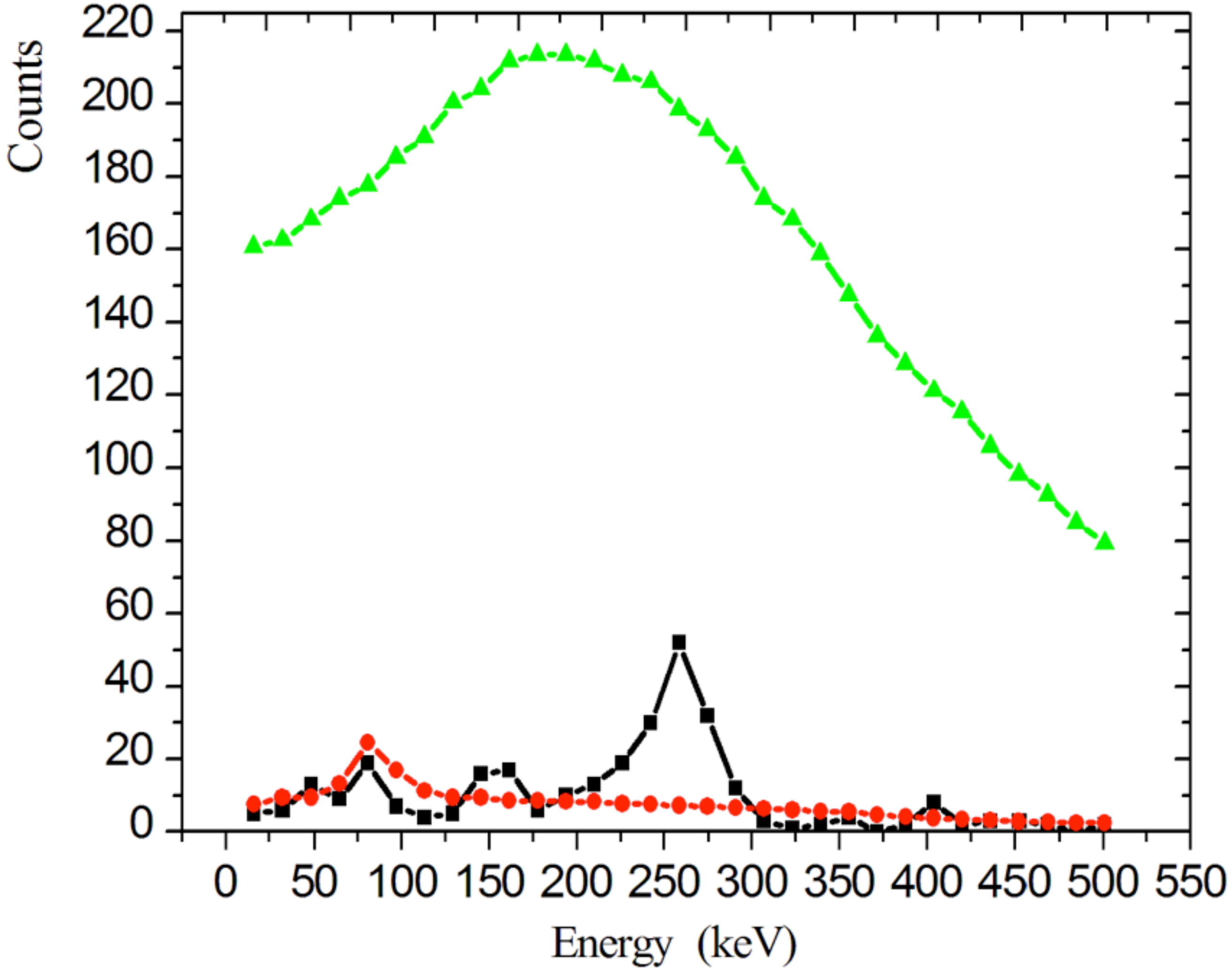
T. Enoto et al "Photonuclear reactions triggered by lightning discharge", Nature, Volume 551 (2017)

Nuclear electron capture by ^{1}H -2/5

We detected a gamma peak at 260 keV:

(the small peak at 150 keV is the Compton shoulder of the 260 keV signal peak)





The use of lead shielded chamber was essential.

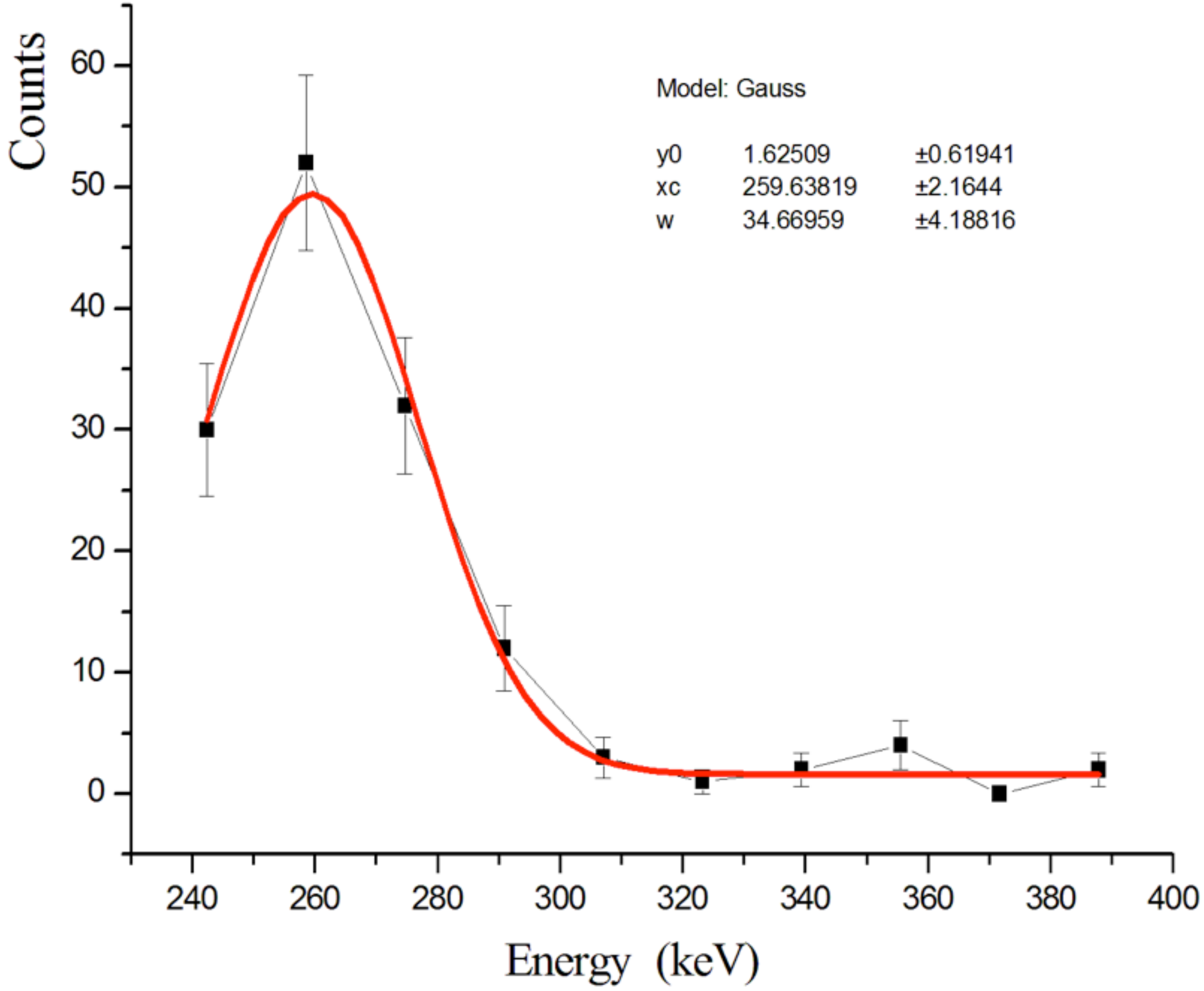
Green: unshielded background

Red: shielded background

Black: shielded signal

Nuclear electron capture by ^{1}H -3/5

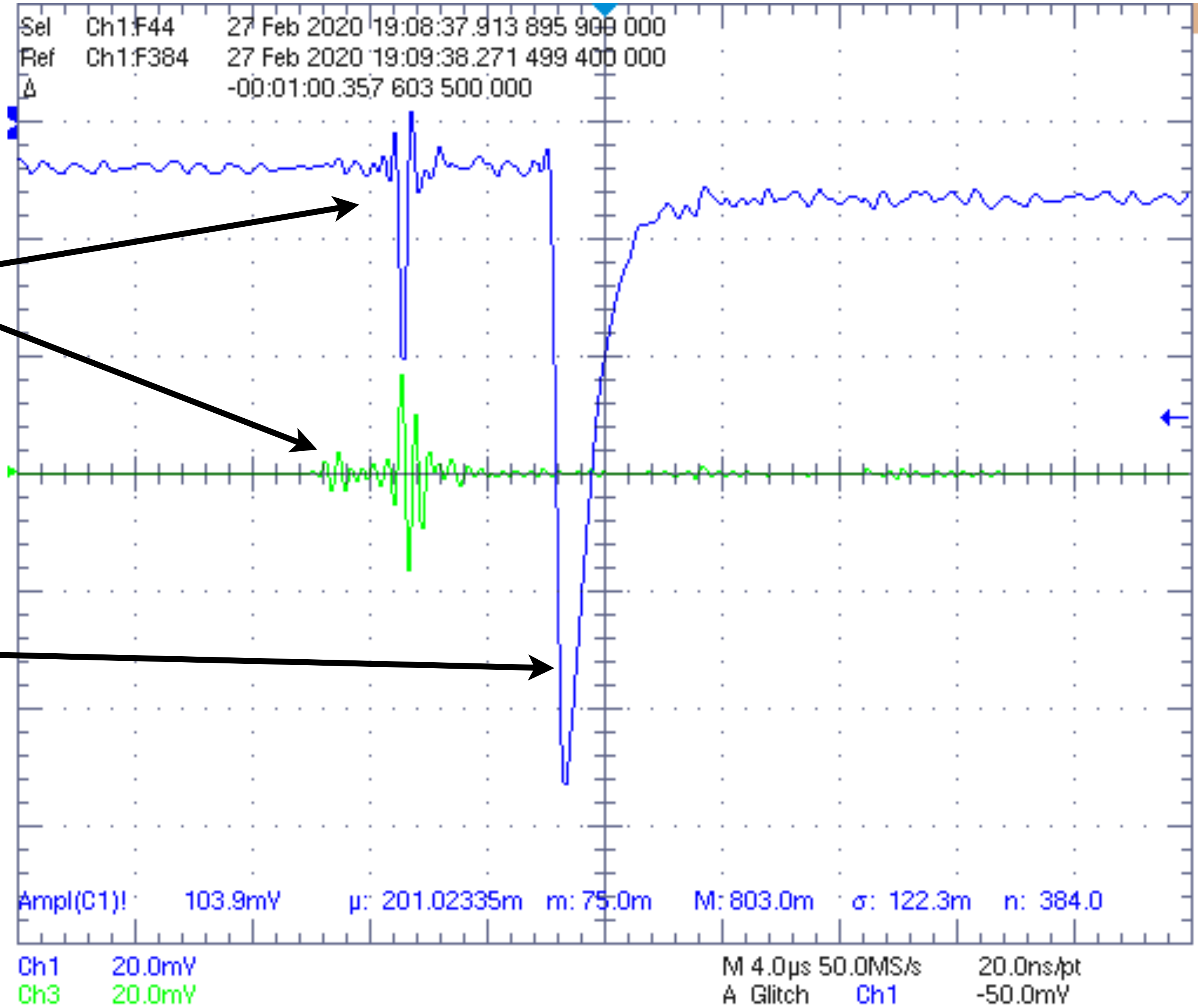
Using Gauss curve fitting, the peak center-point is determined to be at 259.6 keV:



Nuclear electron capture by ^{1}H -4/5

To investigate the time correlation between the gamma ray signals and the electric discharge sparks, we use an oscilloscope to register gamma ray and RF signals.

The oscillogram recording was triggered when two conditions were met by the gamma signal: i) the duration of the signal is more than 1.5 microseconds, and ii) the signal amplitude is more than 50 mV (corresponds to >200 keV gamma photon energy)

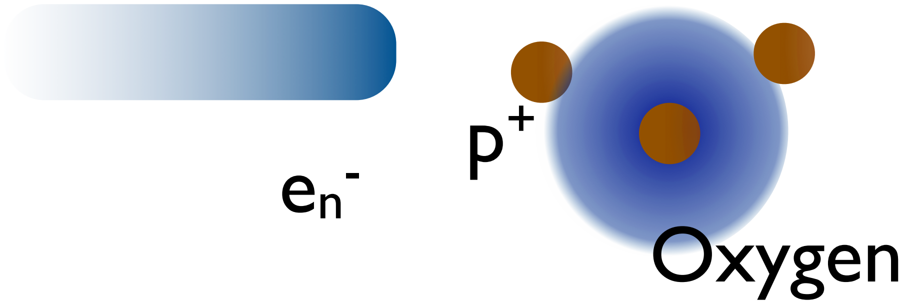


RF signal of the spark discharge

>200 keV gamma pulse

Nuclear electron capture by ^{1}H -5/5

The observed gamma peak is time-correlated with the spark discharges, and we interpret it as the capture signal of nuclear electrons. The electron capture capable nucleus in this environment is ^{1}H.



There are two possibilities for ^{1}H to neutron transmutation:

- Capture of an ordinary electron, yielding electron capture energy E_{ec}
- Capture of a nuclear electron, yielding binding energy E_b

As before, the mass-energy balance equation yields:

$$m_{en}c^2 - m_ec^2 = E_b - E_{ec}$$

Identifying E_b with the 259.6 keV peak, we have:

$m_ec^2=511$ keV, $E_b=259.6$ keV, $E_{ec}=-782.4$ keV

The above numbers yield: $m_{en}c^2=1553$ keV

Nuclear electron mass result

We have two measurements of the nuclear electron mass:

- ^{58}Ni capture measurement yields 1554 keV
- ^{1}H capture measurement yields 1553 keV

Our final estimate is the average of the above numbers: 1553.5 keV

Nuclear electron capture by ^{63}Cu -1/5

We further validate our nuclear electron mass measurement via experiments involving the ^{63}Cu nucleus.

With the help of our mass-energy balance equation, we calculate the E_b parameter for ^{63}Cu:

$$m_{en}c^2 - m_ec^2 = E_b - E_{ec}$$

where $m_{en}c^2$=1553.5 keV, m_ec^2=511 keV, E_{ec}=-67 keV

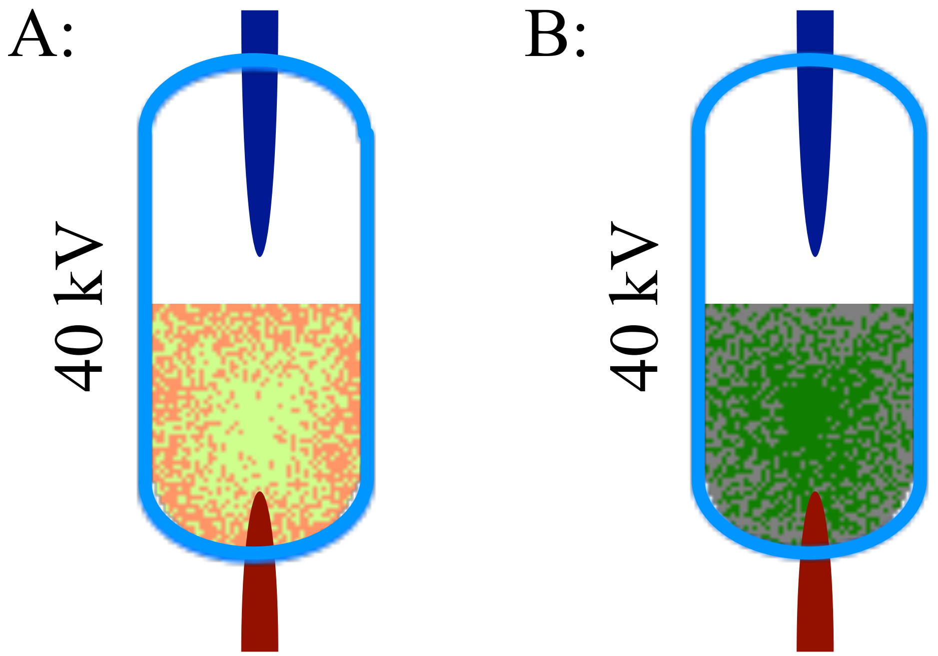
The above numbers yield E_b=976 keV.

This 976 keV energy is the anticipated gamma peak energy. Such high energy is in the low-noise region of our shielded chamber.

Nuclear electron capture by ^{63}Cu -2/5

We use a small plastic container which contains our target material. One electrode is immersed into the target, while the other one is a few millimeters above it.

There is 40 kV voltage between the electrodes, and the setup is enclosed in the same lead-shielded chamber that was used previously.



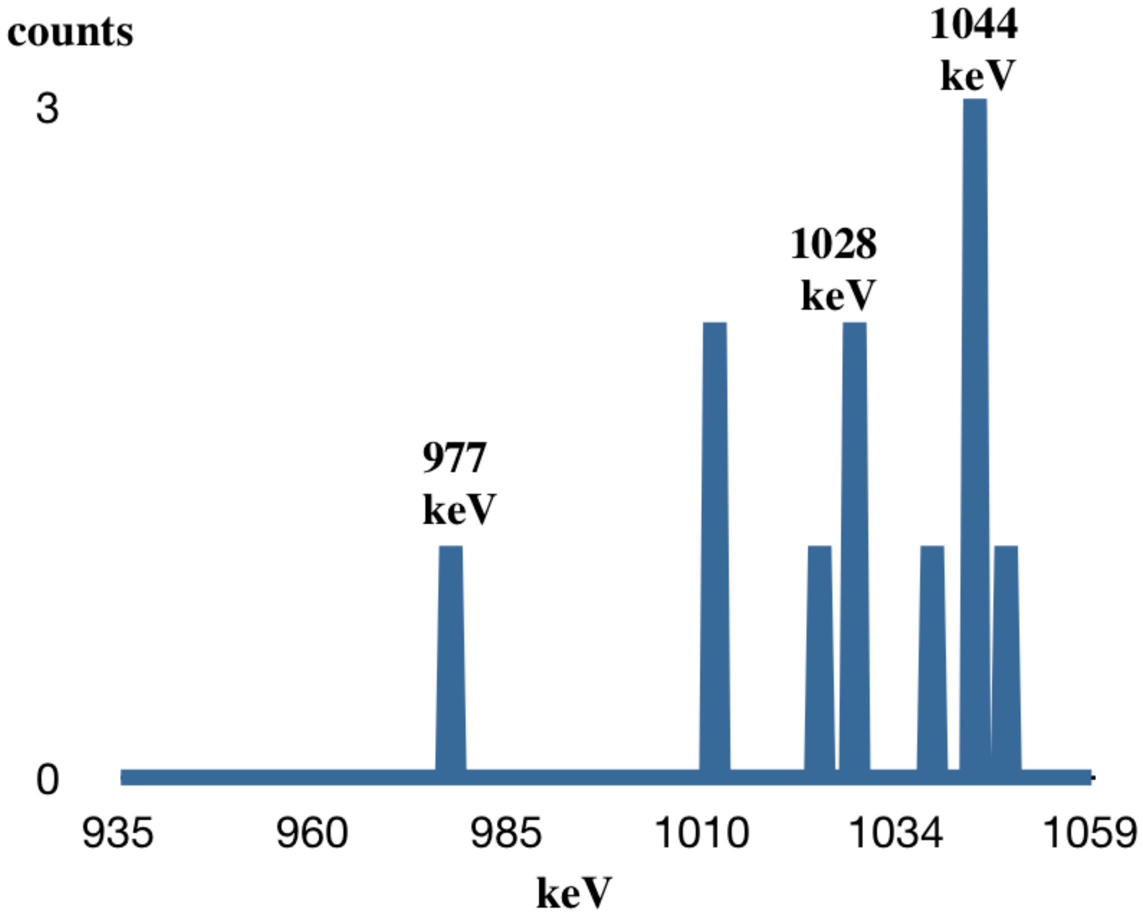
The target material comprises cotton wool, soaked with:

A. Dispersion of Cu and $Al_{95}Cu_5$ powders in water

B. Dispersion of Ni powder in aqueous $CuCl_2$ solution

Nuclear electron capture by ^{63}Cu -3/5

With setup A, we observe the following signals in the 1 MeV range * :



We interpret 977 keV signals as:

$^{63}\mathrm{Cu}+e_n \rightarrow {}^{63}\mathrm{Ni} \dashrightarrow$ *976 keV*

Potential interpretation of the 1044 keV signal:

$^{65}\mathrm{Cu}+n \rightarrow {}^{66}\mathrm{Cu} \dashrightarrow$ *1039 keV*

However, there is only one count of the 977 keV signal. We need to make sure it is not noise.

** 2.5 minutes experiment run-time*

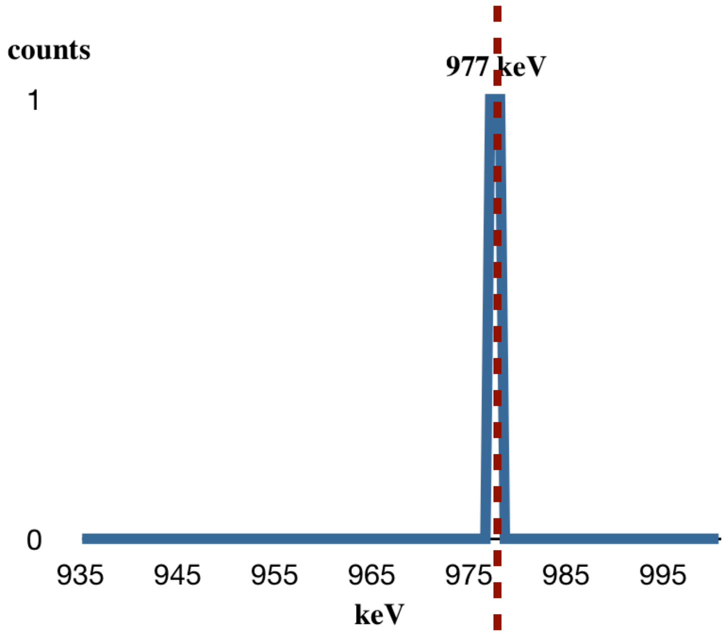
Nuclear electron capture by ^{63}Cu -4/5

In three different measurements, we persistently observe the gamma peak at 977-976 keV. Therefore, it is a real signal and not noise.

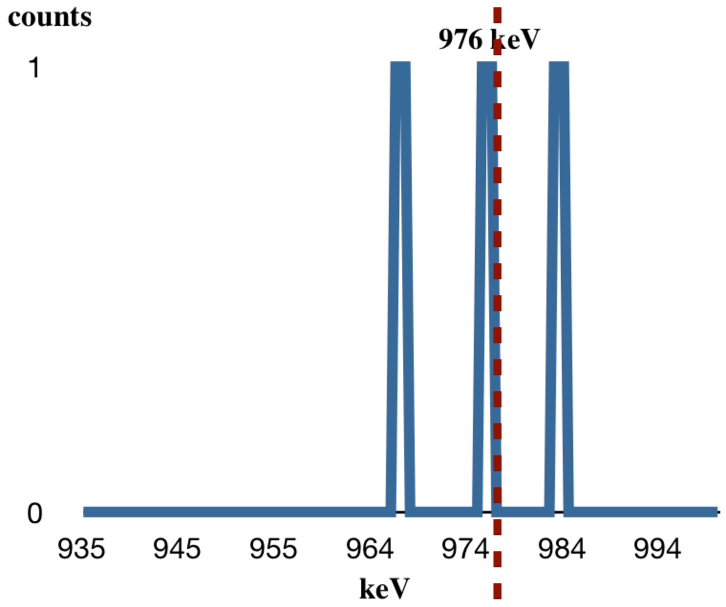
We thus observe the predicted 976 keV gamma signal.

Note: “setup A” and “setup B” refer to measurements during spark discharges, while “setup B*” refers to measurement after spark discharges. Apparently, some kind of delayed reaction occurs. In particular, a very strong gamma peak is observed under “setup B*” at 1320 keV.

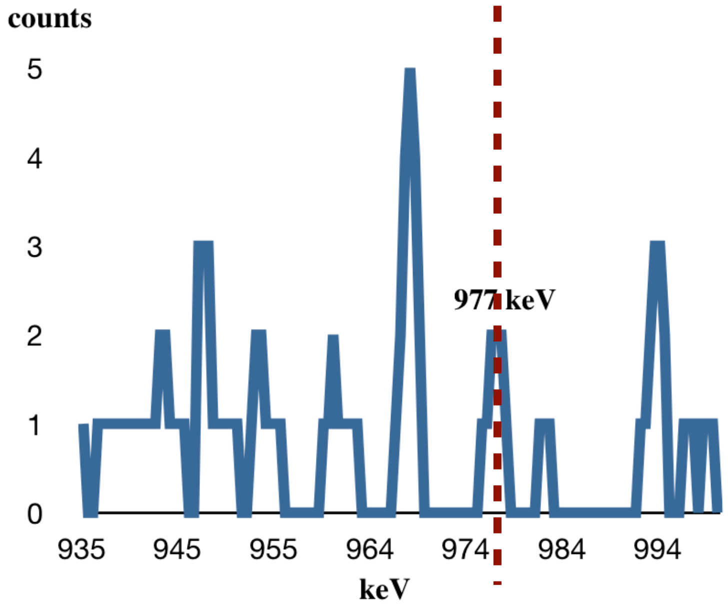
setup A:



setup B:



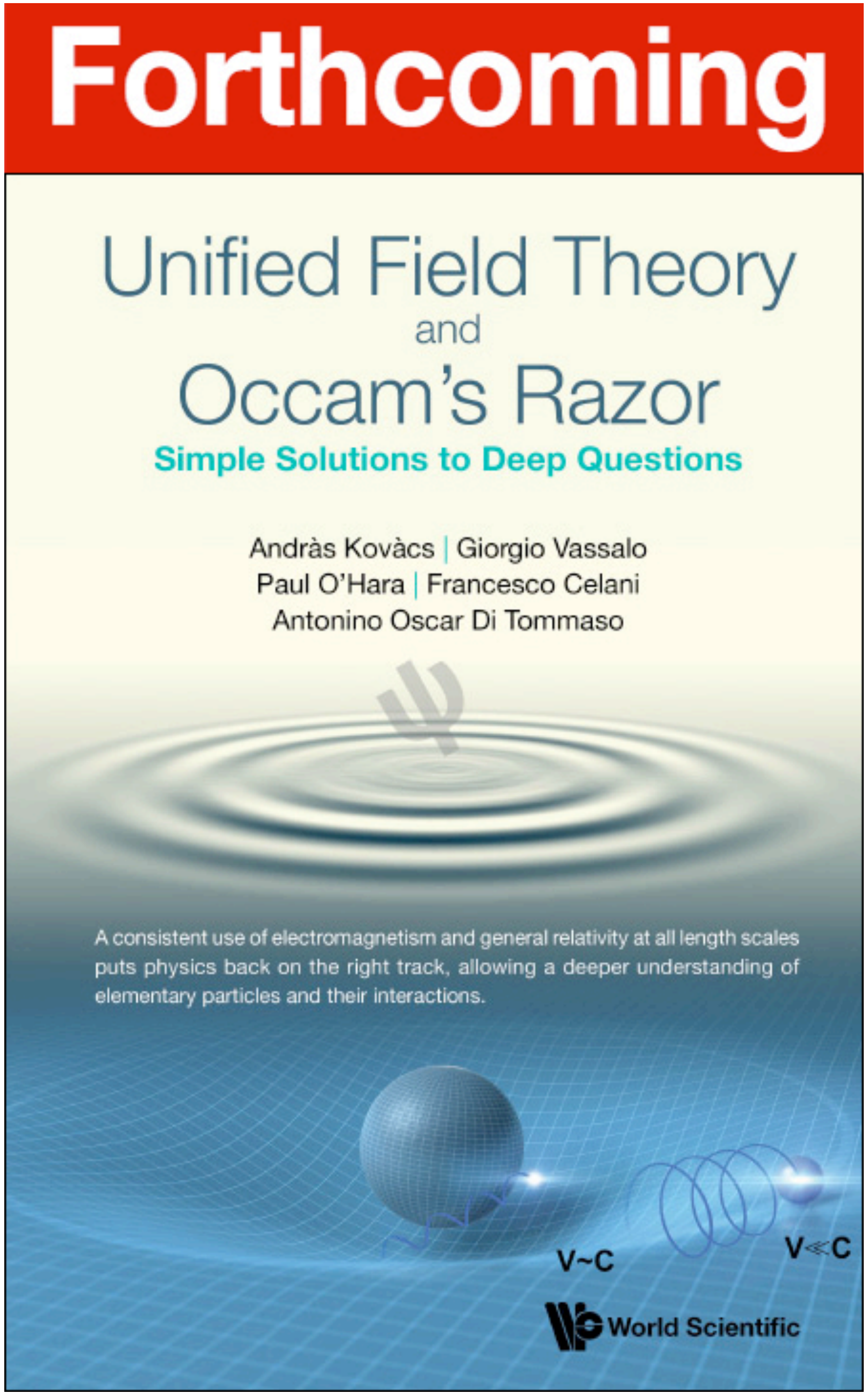
setup B*:



Nuclear electron capture by ^{63}Cu -5/5

In summary our Copper-based experiments comprise a third measurement of the nuclear electron mass, confirming its 1553.5 keV value.

Further details will be in our forthcoming book



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Conclusions

*** A neutron comprises a proton and a nuclear electron**

*** The nuclear electron mass is 1553.5 keV**

*** As a free particle, the nuclear electron has a short but non-zero half-life**

*** The nuclear electron is stabilized by binding with one or more protons. The binding energy between a proton and a nuclear electron is 260 keV.**

Thank you for your attention!