Decay of ^{61}Cu in oxide and metallic environment

Aleksandra Cvetinović
Department of Low and Medium Energy Physics (F-2)
Jožef Stefan Institute, Slovenia

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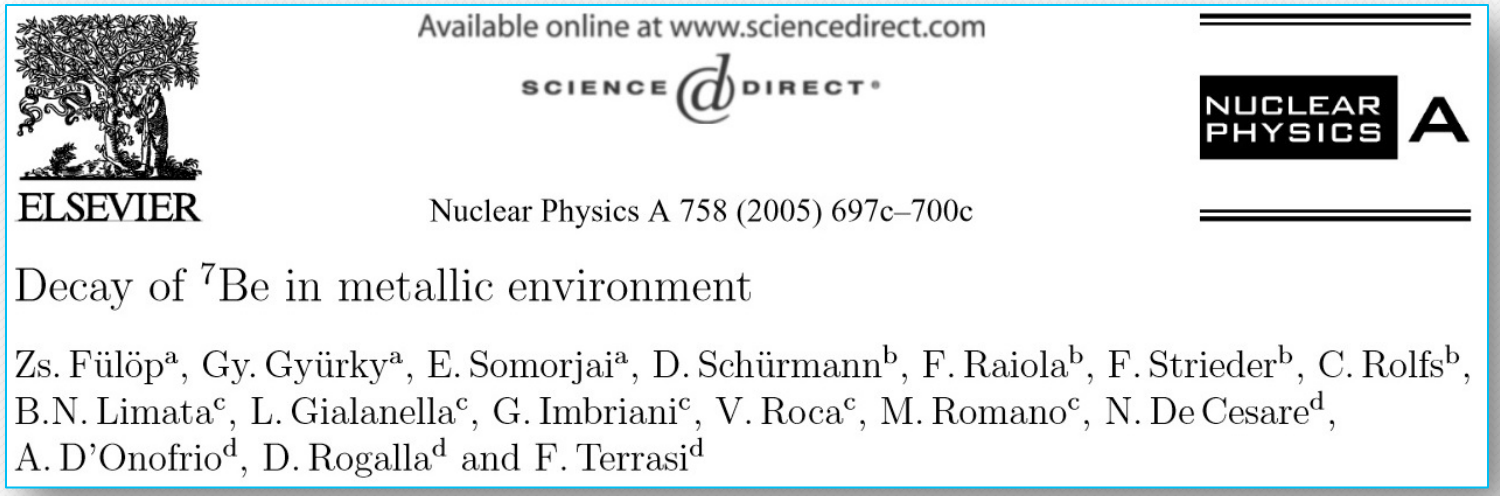
Motivations and previous results

- For the most radionuclides that decay by electron capture or internal conversion, the probability for these processes is usually insensitive to the nuclear environment
- The decay rate depends only very weakly on the electron wave functions
- Be-7 decays only by electron capture



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Nuclear Physics A 758 (2005) 697c–700c

Decay of ^{7}Be in metallic environment

Zs. Fülöp[a], Gy. Gyürky[a], E. Somorjai[a], D. Schürmann[b], F. Raiola[b], F. Strieder[b], C. Rolfs[b], B.N. Limata[c], L. Gialanella[c], G. Imbriani[c], V. Roca[c], M. Romano[c], N. De Cesare[d], A. D'Onofrio[d], D. Rogalla[d] and F. Terrasi[d]

- Kettner et al. predicted a possibility to observe:
  - shorter half-life for α and β^+-decay
  - longer half-life for β^--decay and electron capture

Journal of Physics G: Nuclear and Particle Physics

High-*Z* electron screening: the cases $^{50}V(p,n)^{50}Cr$ and $^{176}Lu(p,n)^{176}Hf$

K U Kettner[1], H W Becker[2], F Strieder[2] and C Rolfs[2]

[1] Fachhochschule Bielefeld, Bielefeld, Germany
[2] Institut für Physik mit Ionenstrahlen, Ruhr-Universität Bochum, Bochum, Germany

K U Kettner *et al* 2006 *J. Phys. G: Nucl. Part. Phys.* **32** 489. doi:10.1088/0954-3899/32/4/007

CPC(HEP & NP), 2011, **35**(5): 449–452 Chinese Physics C Vol. 35, No. 5, May, 2011

Environmental effects on nuclear decay rates*

ZHOU Shu-Hua(周书华)[1)]

China Institute of Atomic Energy, P. O. Box 275(18), Beijing 102413, China

If the half-life of radioactive nuclei depends on the electron density at the nucleus due to the physical or the chemical state of the atoms

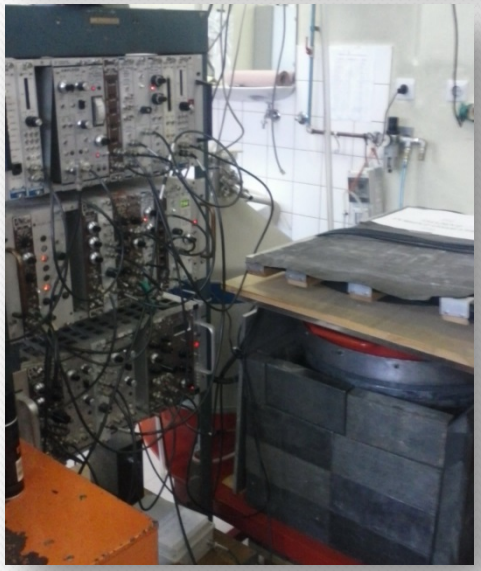
Different half-life in stellar plasma than in the laboratory

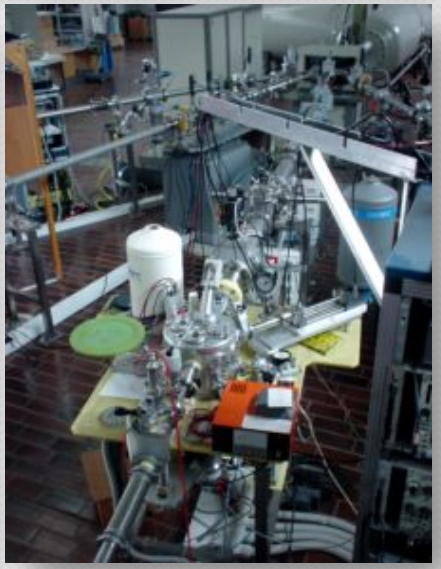
Different probability for nucleosynthesis in stars

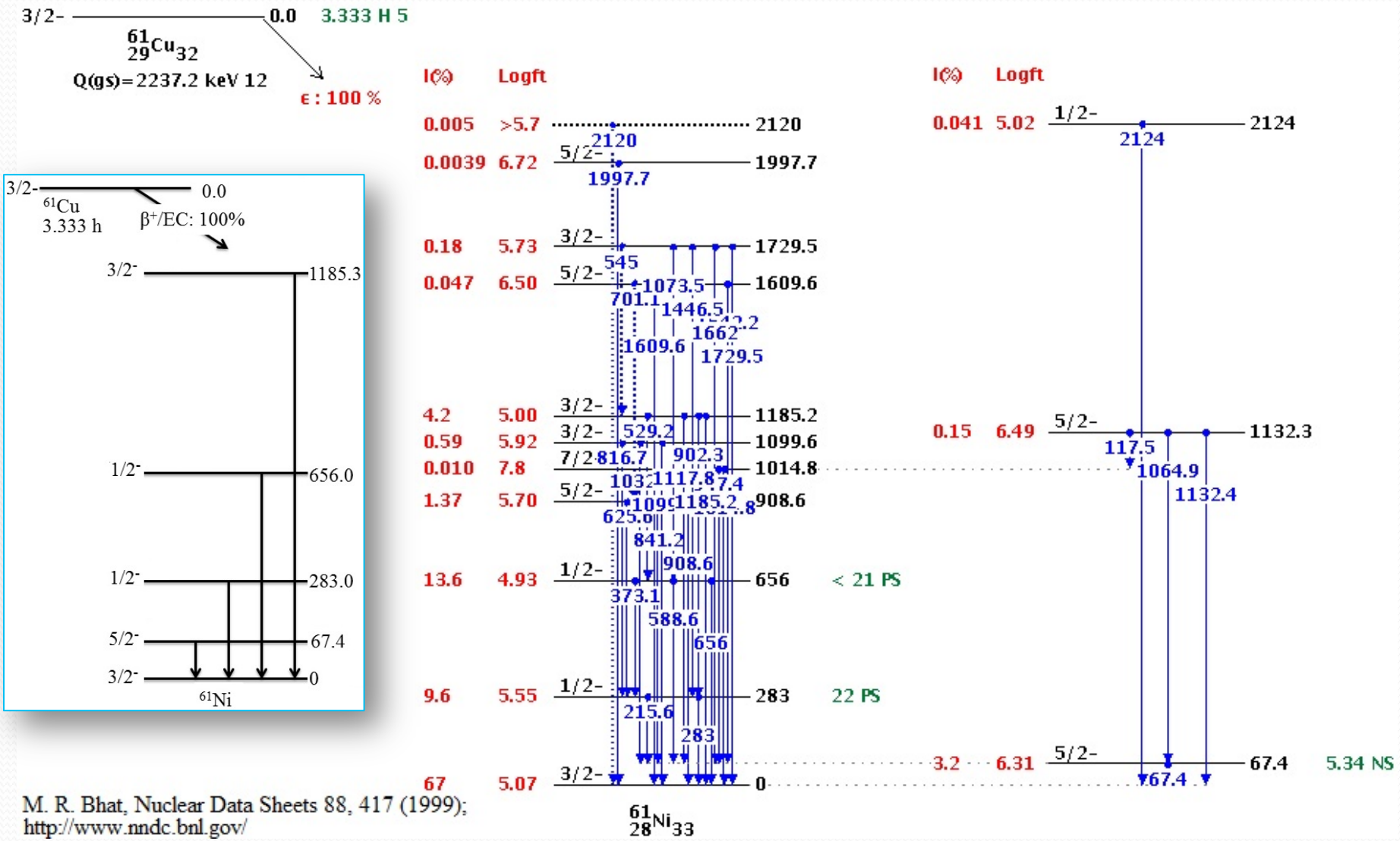
Experiment

^↑61↓🅰🅰→🅰↑+ /🅰🅰⊥^↑61↓🅰🅰 produced in the reaction: $^{60}Ni(p,\gamma)^{61}Cu$

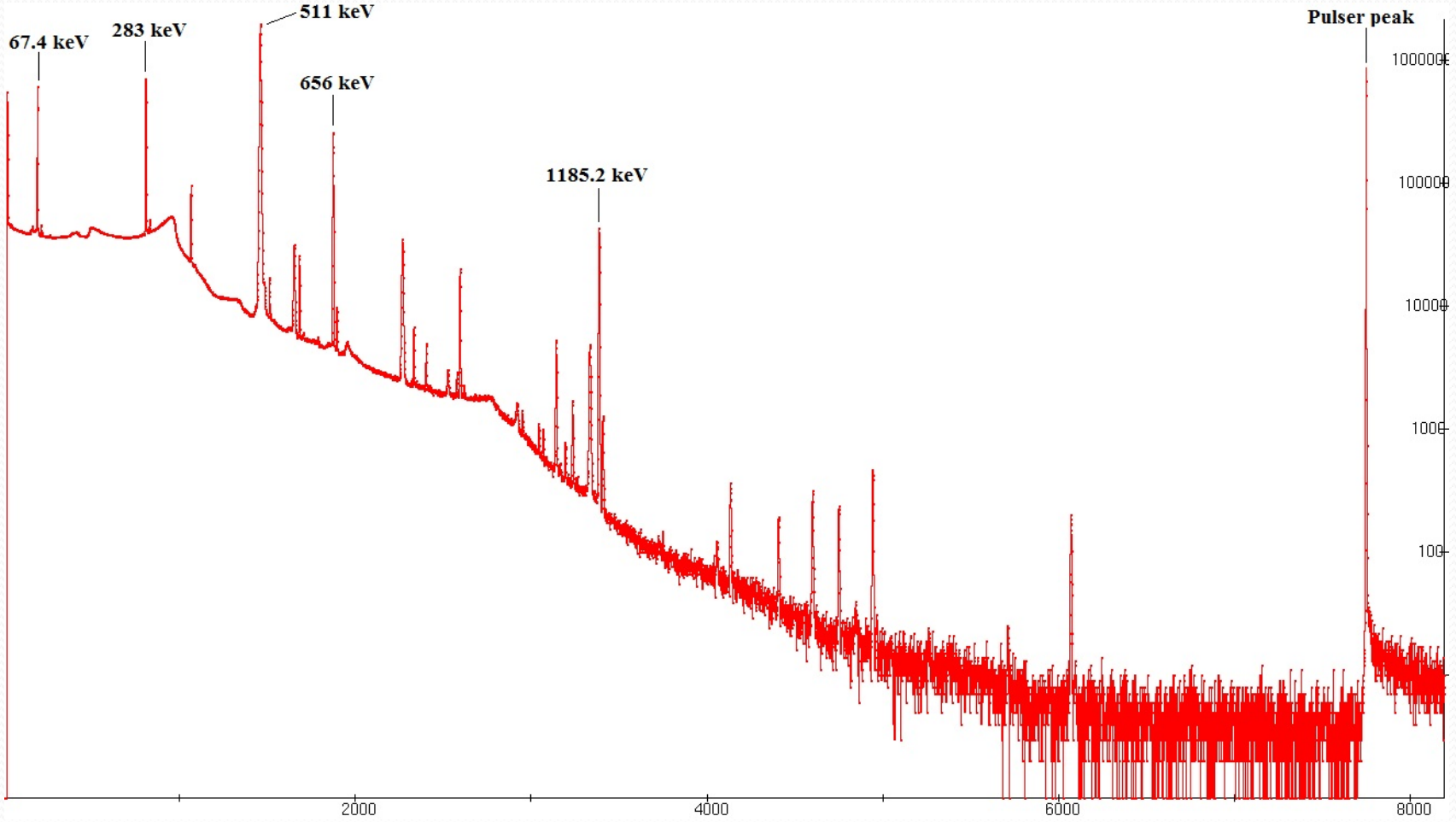
- Oxide and metallic nickel targets were activated for 12 hours by proton beam
- Beam energy: 2.48 MeV
- p accelerated by the 2 MV Tandetron accelerator at Jožef Stefan Institute
- Decays were recorded in low-background laboratory every half hour for three days







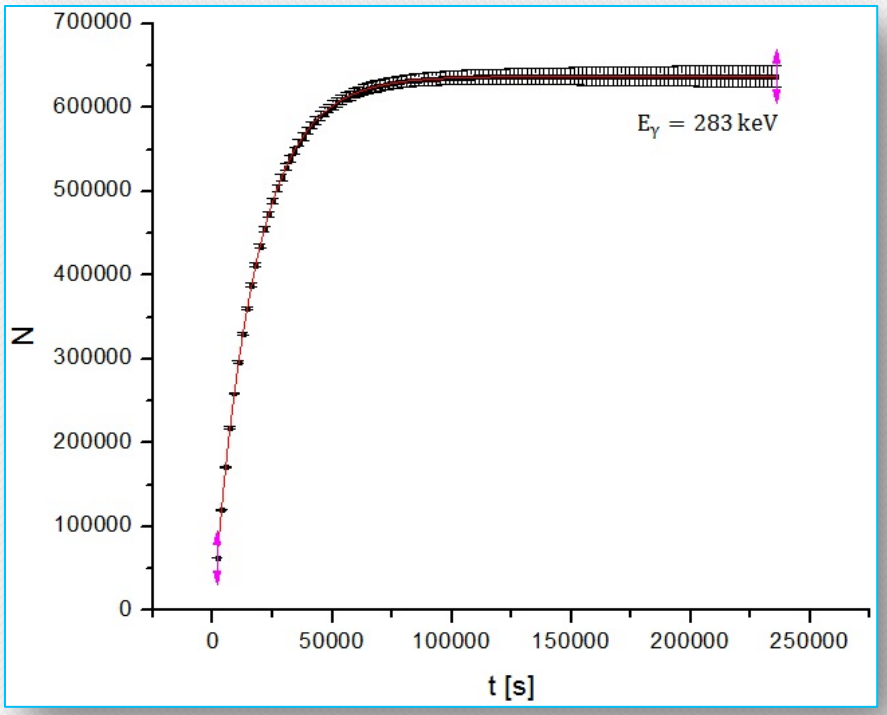
M. R. Bhat, Nuclear Data Sheets 88, 417 (1999);
http://www.nndc.bnl.gov/


67.4 keV
283 keV
511 keV
656 keV
1185.2 keV
Pulser peak
1000000
100000
10000
1000
100
2000
4000
6000
8000

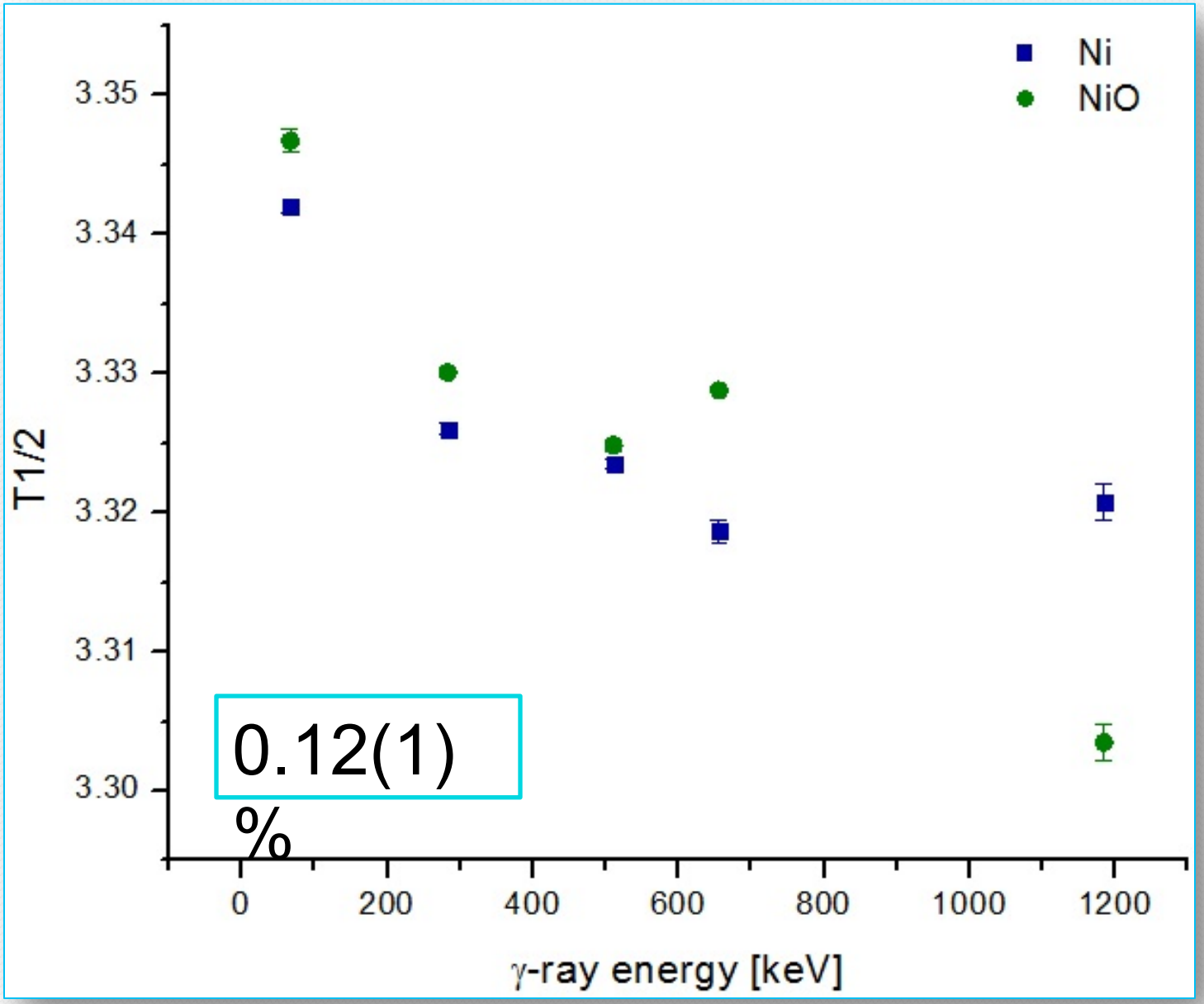
- Half-life is determined from decay law:

$$N(t) = N_0\,(1 - e^{-\lambda t}), \qquad \lambda = \ln 2 / T_{1/2}$$

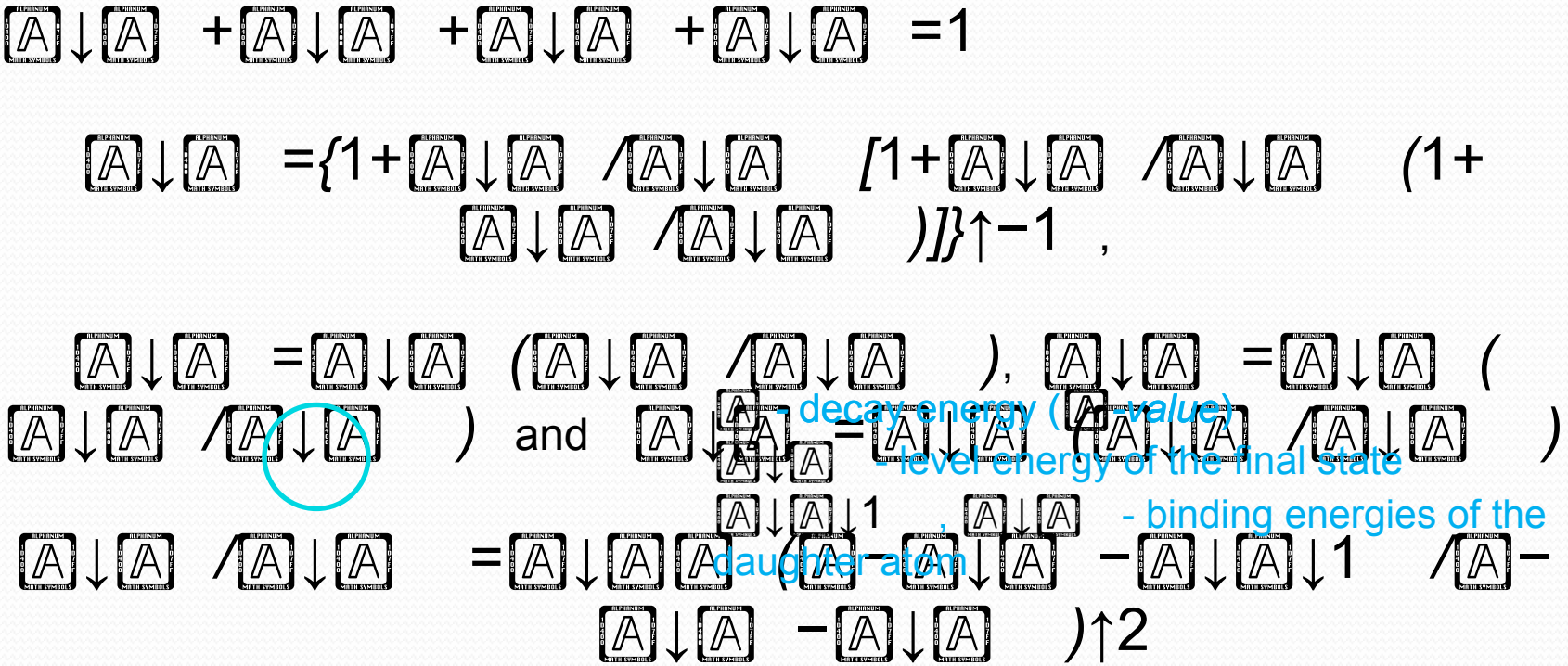
  - $N(t)$ is the number of decays occurred at time *t*



- Table value $T_{1/2}$ of ^{61}Cu: 3.333 (5) h
- Half-life in nickel-oxide: 3.3280 (2) h
- Half-life in nickel: 3.3238 (2) h


Ni
NiO
T1/2
3.35
3.34
3.33
3.32
3.31
3.30
0.12(1)
%
0
200
400
600
800
1000
1200
γ-ray energy [keV]

- Electronic configuration of nickel in the ground state is: [Ar] $3d^8\,4s^2$
  - The weakest bound electrons are from shell 4s and over them nickel can build chemical bond with an oxygen atom
  - In NiO this electrons cannot contribute to the electron capture, but in Ni they can
  - If we take into account the electron capture from N shell, for the fractional capture probabilities holds:



□↓□□ =□↓□↓1 ↑2 /□↓□↑2 ·□(□↓1)/□(□) ·[1+(□↓□↓2 /□↓□↓1)],

□↓□□ =□↓□↓1 ↑2 /□↓□↓1 ↑2 ·□(□↓1)/□(□↓1) ·[1+(□↓□↓2 /□↓□↓1)/1+(□↓□↓2 /□↓□↓1)] and □↓□□ =□↓□↓1 ↑2 /□↓□↓1 ↑2 ·□(□↓1)/□(□↓1) ·[1+(□↓□↓2 /□↓□↓1)/1+(□↓□↓2 /□↓□↓1)]

- □↓□↓1 ↑2 /□↓□↑2 , etc. – the ratios of the radial wave functions
- □(□↓1)/□(□) , etc. - the ratios of the correction factors for overlap and exchange
- □↓□↓2 /□↓□↓1 , etc. are the subshell ratios

Conclusions

- For difference in half-live time in metallic compared to oxide targets from the experiment we got 0.12(1) %
- For the variations in electron densities from the theoretical model we got 0.035(3) %

- We are not sure what is the electronic configuration of copper in the nickel lattice

- In atomic beryllium decay rate is much more sensitive to chemical state of the atoms than in copper

Thank you for your attention!