

β^- and γ -ray emission probabilities in decay of ^{67}Cu

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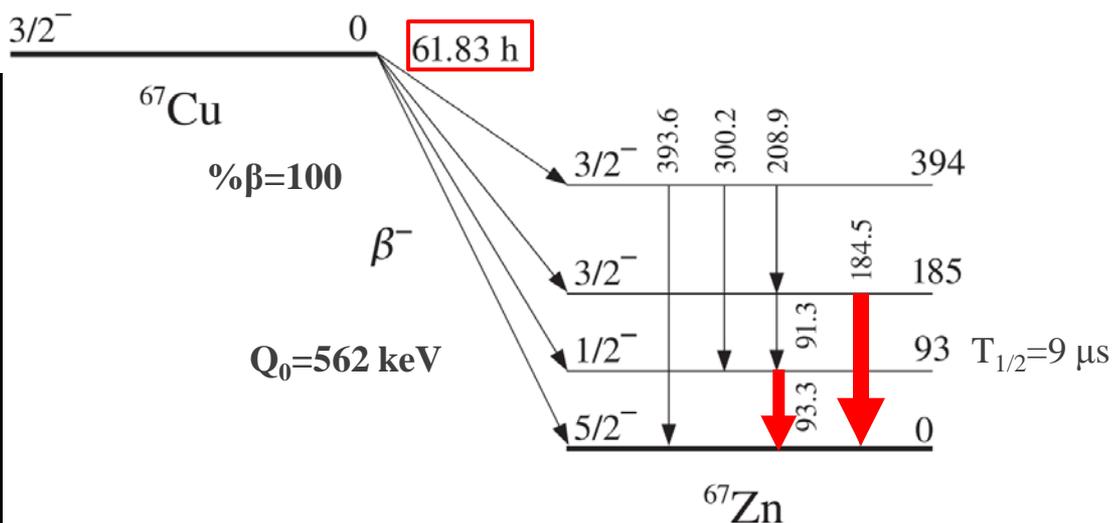
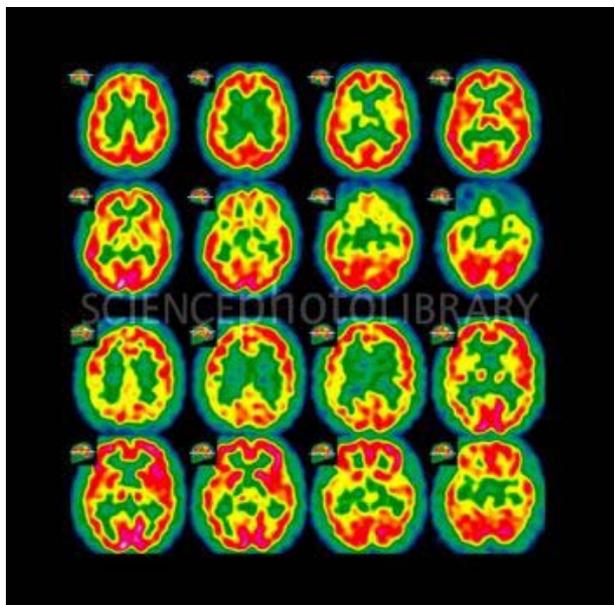
Argonne National Laboratory

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Motivation

^{67}Cu radionuclide has a potential for wide use in SPECT imaging and cancer therapy because of its desirable physical and biologic characteristics.

An example of SPECT imaging



~0.6 MeV β^- particles & $T_{1/2}$ ~62 h --- ideal for cancer therapy
93 and 185 keV γ -rays --- suitable for SPECT imaging

^{67}Cu production:

(p,2p), (p, α), (n,p), (γ ,p) @BNL, LANL, TRIUMF and FRIB (future)

But it's expensive (~\$295/mCi (DOE-NIDC)) and its availability is limited.



^{67}Cu β^- decays: previous studies

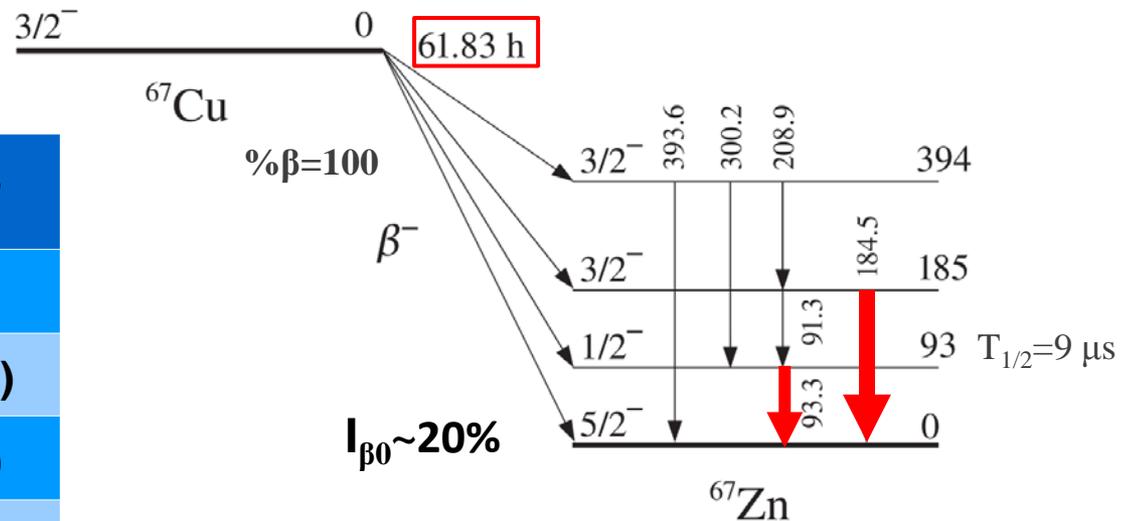
^{67}Cu production yield and radiation doses are determined using the absolute β^- and γ -ray emission probabilities.

Values adopted in ENSDF and MIRD

Level (keV)	$I_\beta(\%)$	E_γ (keV)	$I_\gamma(\%)^b$
0	$\sim 20^a$	---	---
93	~ 22	93	16.1(2)
185	~ 57	91	7.0(1)
		185	48.7(3)
394	~ 1.1	209	0.115(5)
		300	0.797(11)
		394	0.220(8)

a. H. T. Easterday, Phys. Rev. 91, 653 (1953).

b. R. A. Meyer et al., Phys. Rev. C 17, 1822 (1978).



Problems:

- Values are deduced from relative γ -ray intensities [Meyer78] and ground-state to ground-state β -feeding estimate of $\sim 20\%$, measured 60 years ago [Easterday53].
- Key requirement: one needs to know accurately the ground-state to ground-state β -feeding, which is expected to be significant.

Experiment details

- ^{67}Cu production: $^{68}\text{Zn}(\gamma, p)$ reaction; 60 MeV bremsstrahlung at RPI LINAC
- Chemical purification: at ANL-CSE; N. Smith et al. ARI 70 (2012) 2392
- Source preparation: ANL-PHY; thin sources $\sim 1\mu\text{Ci}$

Two independent series of measurements:

- ❑ γ - and β -singles measurements with an analog DAQ

$$I_{\gamma} (\%) = (S_{\gamma}/S_{\beta}) \times (\epsilon_{\beta}/\epsilon_{\gamma})$$

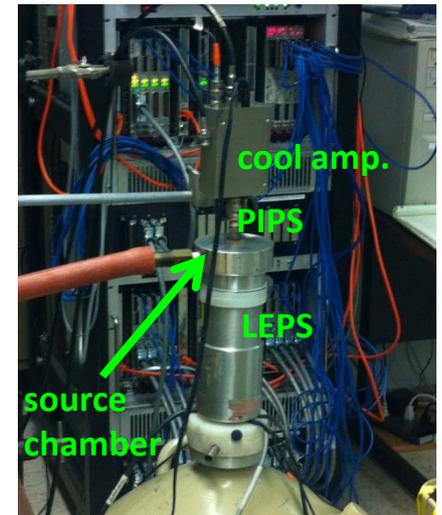
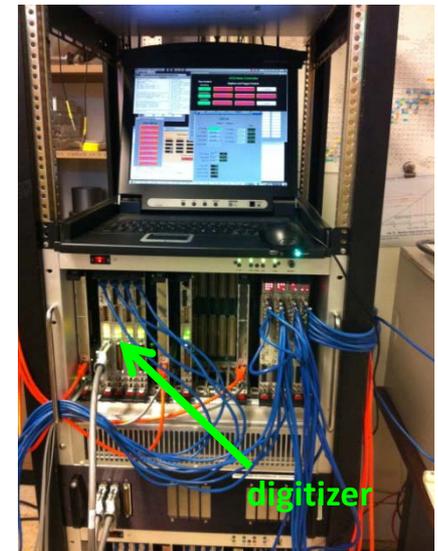
measure separately absolute γ and β -decays

- ❑ β - γ coincidence measurement with a digital DAQ

$$I_{\beta}(\text{gs to gs}) \sim 100 - \sum N_{\beta\gamma\text{-coin}}/N_{\text{singles}}$$

- ✓ LEPS : FWHM=0.5 keV at 122.06 keV
- ✓ Ge : FWHM=1.8 keV at 1332.49 keV
- ✓ PIPS : FWHM=4 keV, 500 μm thick (singles)
FWHM=4 keV, 1 mm thick (coincidence)

digital DAQ

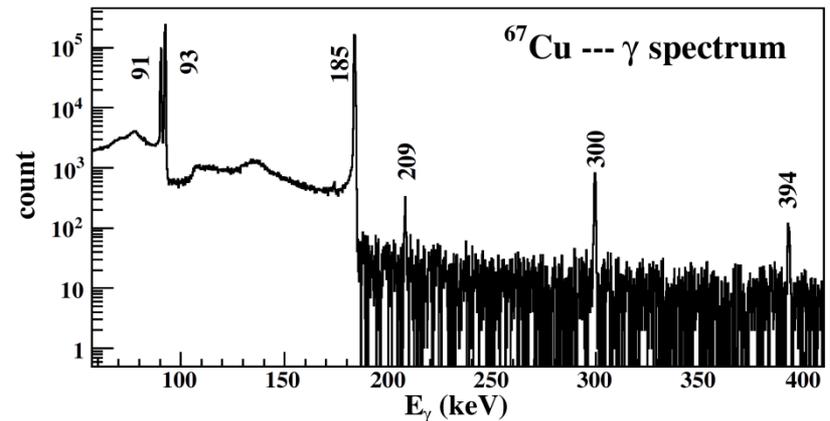
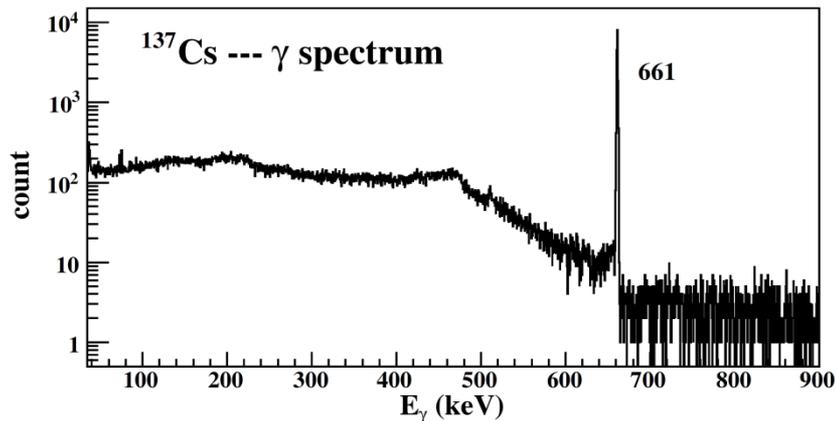
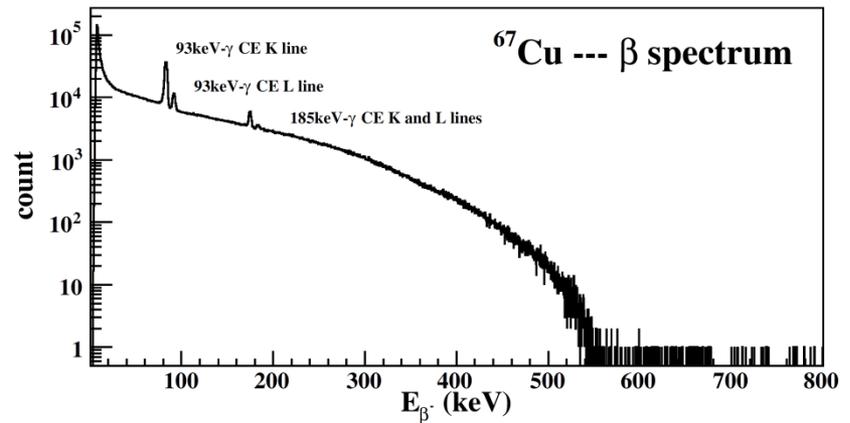
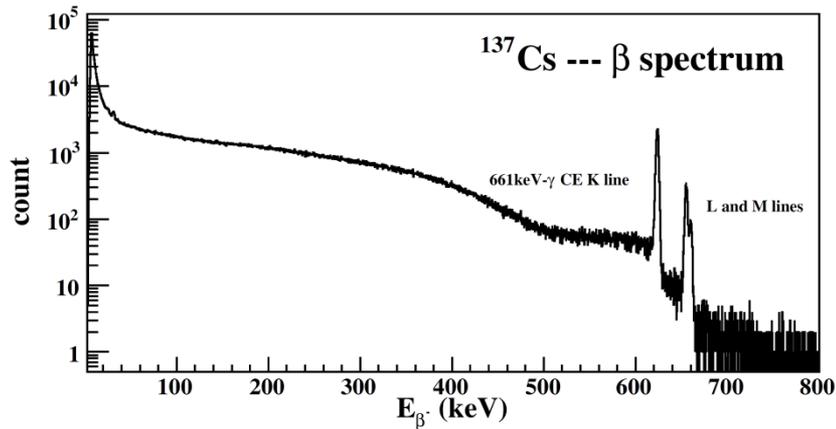


set-up for β - γ coin.



^{67}Cu decay: beta and gamma spectra

From beta and gamma single measurement

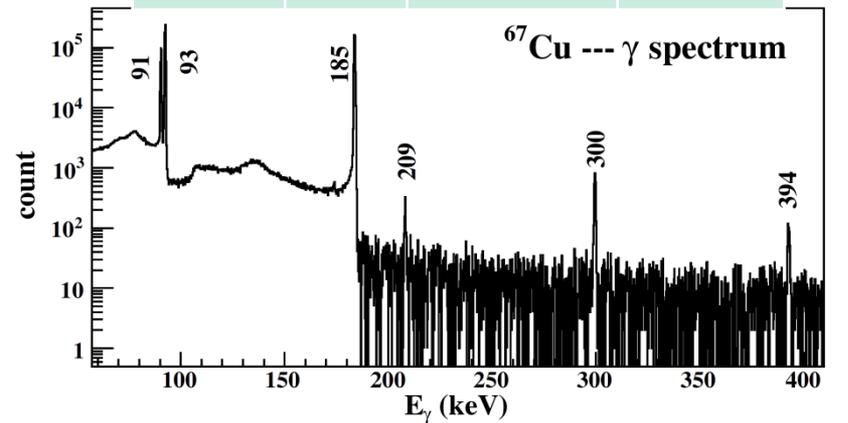
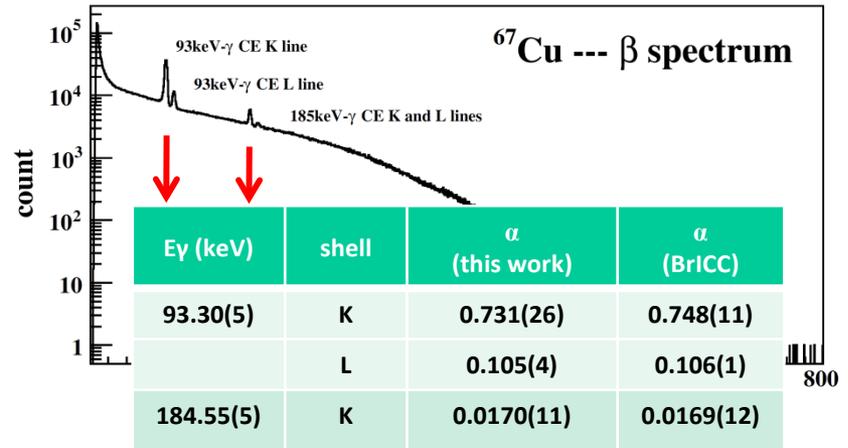
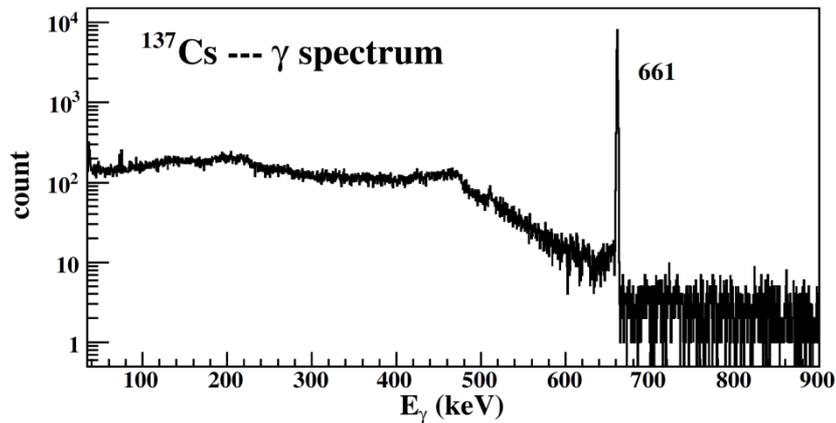
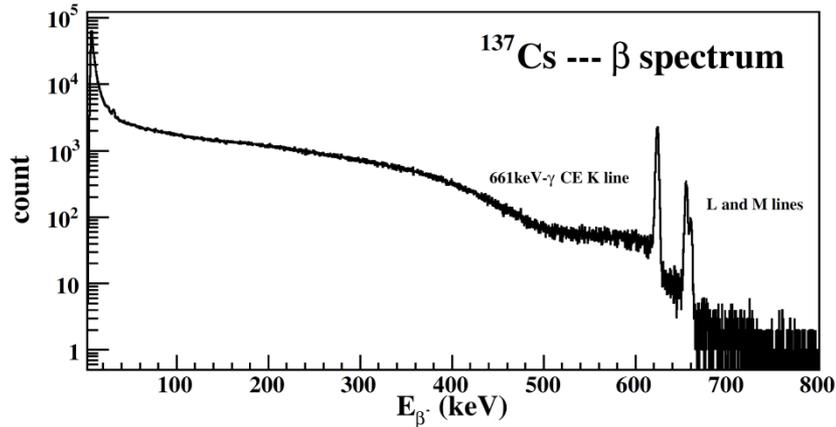


Our preliminary g.s. feeding $I_{\beta 0}$ is different from previous measurement by more than 50%



^{67}Cu decay: beta and gamma spectra

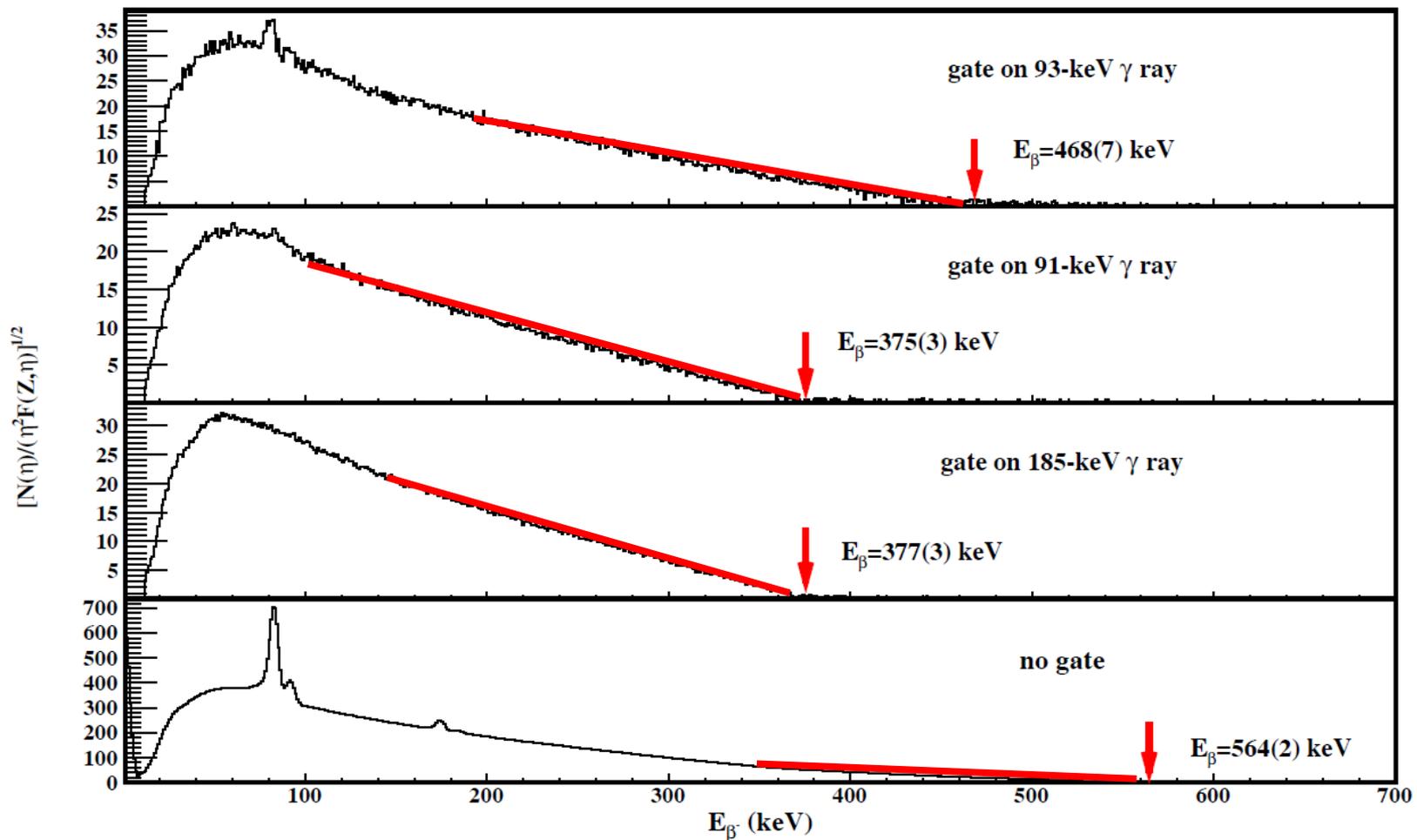
From beta and gamma single measurement



Our preliminary g.s. feeding $I_{\beta 0}$ is different from previous measurement by more than 50%



^{67}Cu decay: Fermi-Kurie plots and Q_{β} -value

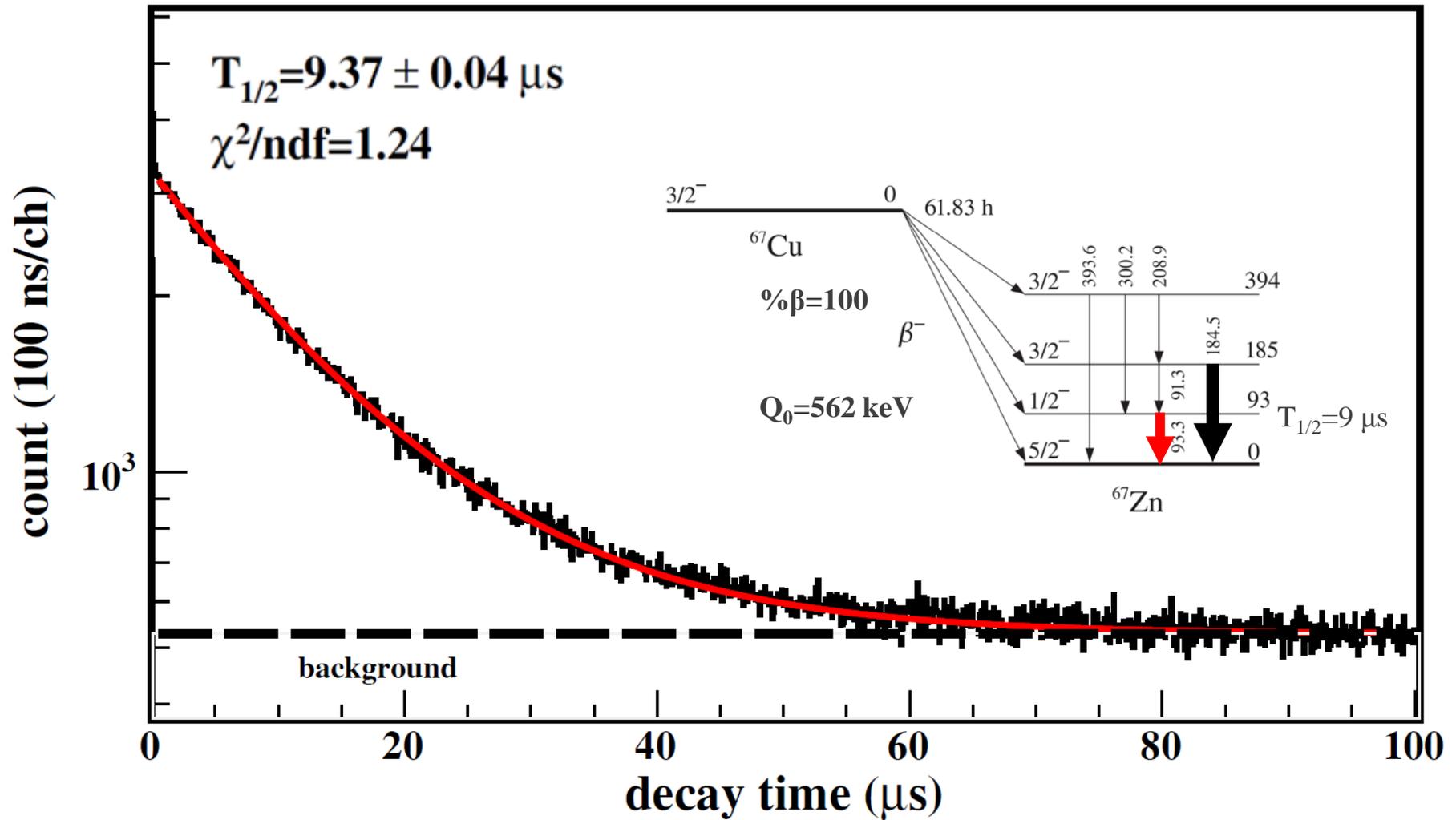


$Q(\text{g.s.}) = 562(2)$ keV (this work), $577(8)^*$ (previously measured), $561.3(15)$ (AME2012)

* H. T. Easterday, Phys. Rev. 91, 653 (1953).



^{67}Cu beta decay: half-life of the 93-keV isomer



Summary

- ❑ Absolute β^- and γ -ray emission probabilities in decay of ^{67}Cu were measured using both singles and coincidence techniques.
- ❑ Preliminary results indicate that the β^- feeding to the ^{67}Zn ground state is significantly different compared to the previously adopted values that are based on a single measurement carried out 60 years ago.
- ❑ Due to the importance and limited availability of the ^{67}Cu radionuclide, the impact of the new results on the reaction production cross section and on the therapeutic application of this radioisotope will be imminent
- ❑ Q-value of 562(2) keV was measured and it is 4σ more precise than the previously measured one of 577(8) keV.
- ❑ Precise value of half-life of 9.37(4) μs was measured for the isomer.



collaborators



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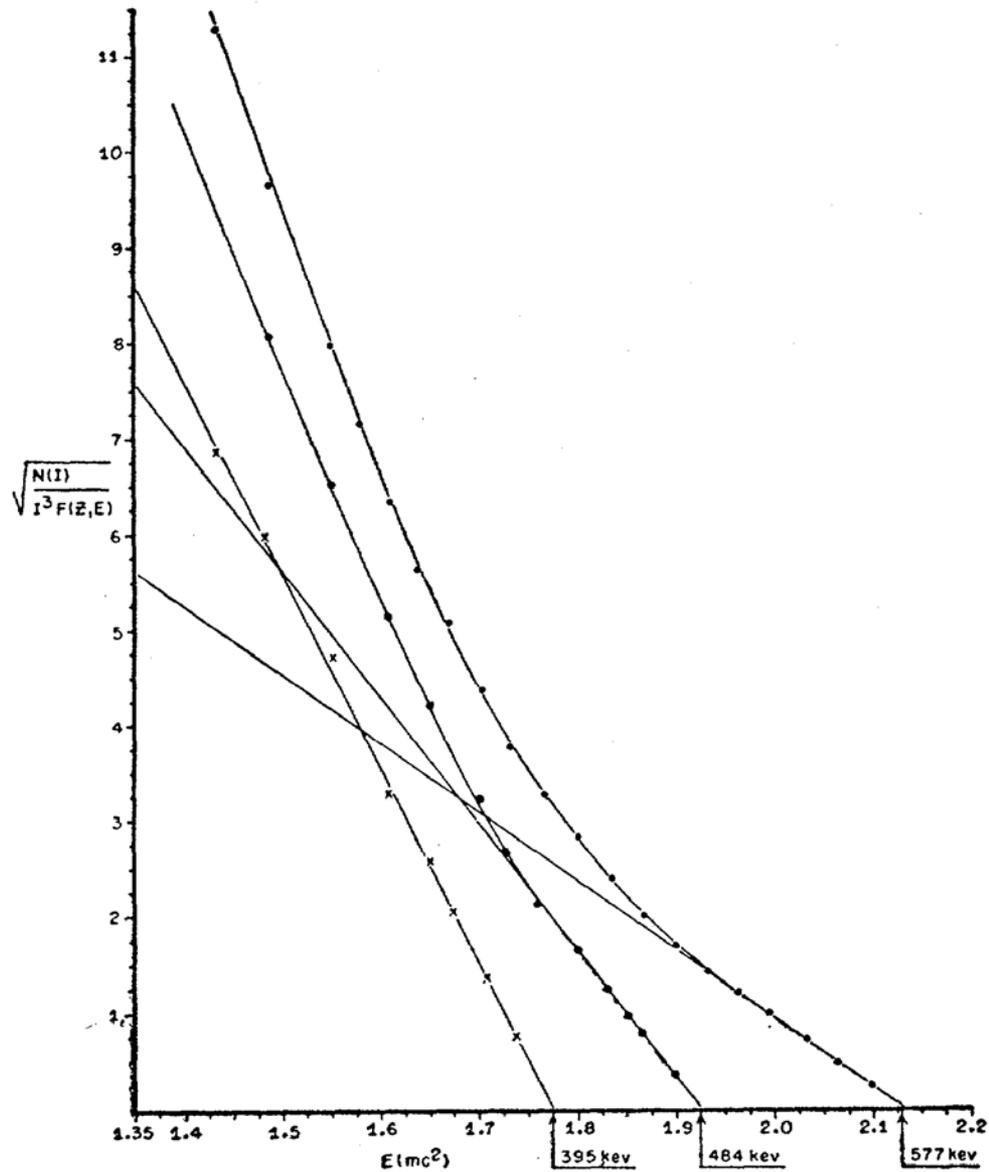


FIG. 3. Cu^{67} Fermi analysis of β spectrum.

