Direct measurements of neutron capture on radioactive isotopes

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Abstract

We simulated the response of a $4\pi$ calorimetric $\gamma$-detector array to decays of radioactive isotopes on the $s$-process path. The GEANT 3.21 simulation package was used. The main table contains estimates on the maximum sample size and required neutron flux based on the latest available neutron capture cross section at 30 keV. The results are intended to be used to estimate the feasibility of neutron capture measurements with $4\pi$ arrays using the time of flight technique.

Key words: keV neutron capture, spallation neutron source, calorimetric measurement, scintillator, nucleosynthesis

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1 Introduction

The scope of this work is to provide a tool for experimentalists to quickly estimate the feasibility of a direct neutron capture \((n,\gamma)\) measurement using a calorimeter to detect the emitted \(\gamma\)-rays. Such measurements are typically performed with the time-of-flight (TOF) technique, which allows the determination of the cross sections as a function of incident neutron energy. Particularly, the need for data in the keV neutron energy region where the competing elastic scattering channel is very strong drove the trend to detect the emitted prompt \(\gamma\)-rays after the capture event with \(4\pi\) calorimeters [Wisshak et al. (1990); Reifarth et al. (2004a); Cano-Ott et al. (2006)]. The Q-value for capture events is unique for each isotope, but typically ranges from 4-10 MeV. The decay multiplicity following capture typically ranges from three to six, though there are some nuclei where low multiplicity (one or two) decay is preferred. By exploiting knowledge of the capture signature, scattering as well as radioactive decay events can then very efficiently be discriminated from neutron capture events based on the total energy deposited in the detector and the observed multiplicity of the events. The TOF technique offers advantages over activation techniques in that it is not limited to isotopes with a long-lived product. Furthermore, as the data needs change over time, the cross-section for the desired neutron distribution can be determined whereas activation methods determine a cross-section for the specific distribution used in the experiment.

Calorimetric detectors have close to 100\% total detection efficiency for \(\gamma\)-rays with energies between \(\approx 100\) keV and a few MeV. The decay of the radioactive samples inside a calorimeter implies a certain count rate, which depends on the detection efficiency and the decay properties of the isotopes under investigation. Experimental techniques such as passive shielding and increased energy-thresholds on the individual detectors can be used to lower the rate from the intrinsic activity of the source.

The isotopes under investigation in this paper are of interest for the \(s\)-process nucleosynthesis. About 50\% of the element abundances beyond iron are produced via slow neutron capture nucleosynthesis \((s\) process). Starting at iron-peak seed, the \(s\)-process mass flow follows the neutron rich side of the valley of stability. The isotopes capture neutrons and become more neutron rich until the neutron capture lifetime exceeds the beta-decay lifetime, at which point the isotope will \(\beta^-\)-decay to a more stable neighbor which has a higher Z and is less neutron rich. This stair-step procedure allows the \(s\) process to work to higher and higher atomic and mass numbers. The reader is referred to Käppeler (1999) for a review on the \(s\) process. The position of this stair-step edge depends upon the actual neutron density in the stellar scenario. For particular nuclei, the beta-decay rate and the neutron capture rate are close
Fig. 1. Neutron capture life times (open circles) and terrestrial $\beta^-$ life times (filled circles) for unstable isotopes on the classical $s$-process path as a function of mass number. Shown are only isotopes where the neutron capture is faster than the stellar $\beta^-$ decay for a neutron density of $5 \times 10^8$ cm$^{-3}$ at a temperature of 30 keV. The neutron capture cross sections are taken from the references given in the table and the stellar decay rates from Takahashi and Yokoi (1987).

enough that there is a branching, allowing some of the material to capture an additional neutron while the rest of it decays before an additional capture can take place. These so-called “branch-point” isotopes are particularly interesting since they can provide the tools to constrain modern stellar $s$-process models. Experimental neutron capture cross-sections of all of the isotopes on the $s$-process paths are needed, but the cross-sections of the branch-point isotopes are particularly useful in constraining the temperatures and neutron densities at the nucleosynthesis site. Unfortunately, the radioactive nature of the branch-point isotopes has made them difficult to study in the laboratory.

In a recent estimate, the neutron density within the classical $s$-process model Käppeler et al. (1989) was calculated to be $n_n = (4.94^{+0.66}_{-0.50}) \times 10^8$ cm$^{-3}$ (Reifarth et al., 2003a). Figure 1 shows a summary of the neutron capture and $\beta^-$ decay times for radioactive isotopes on the neutron rich side of the valley of stability, under the condition that the classical neutron capture occurs faster than the terrestrial $\beta^-$ decay. The vast majority of isotopes where an experimental neutron capture cross section is desirable have $\beta^-$ half-lives of at least hundreds of days, though some isotopes of interest have half-lives of as little as tens of days.

The modern picture of the main $s$-process component refers to the He shell burning phase in AGB stars Lugaro et al. (2003). The $s$ process in these stars experiences episodes of low neutron densities of about $3 \cdot 10^7$ cm$^{-3}$, the $^{13}\text{C}(\alpha,n)$-phase, and very high neutron densities, the $^{22}\text{Ne}(\alpha,n)$ phase. The
Fig. 2. Neutron capture live times (open circles) and terrestrial $\beta^-$ live times (filled circles) for unstable isotopes on the classical $s$-process path as a function of mass number. Shown are only isotopes where the neutron capture is faster than the stellar $\beta^-$ decay for a neutron density of $3 \times 10^7$ cm$^{-3}$ at a temperature of 8 keV. The neutron capture cross sections are taken from the references given in the table and the stellar decay rates from Takahashi and Yokoi (1987).

Improved experimental techniques, especially as far as the neutron source and sample preparation are concerned, are necessary to perform direct neutron capture measurements on such isotopes Reifarth et al. (2004b); Walter et al. (2006). The Detector for Advanced Neutron Capture Experiments (DANCE) is currently one of the strongest combinations of $\gamma$-ray detector and neutron source Reifarth et al. (2004a). It is designed as a high efficiency, highly segmented $4\pi$ BaF$_2$ detector for calorimetrically detecting $\gamma$-rays following a neutron capture. DANCE is located on the 20 m neutron flight path 14 (FP14) at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE) Lisowski et al. (1990). Neutrons are produced via spallation reactions induced by 800 MeV protons hitting a tungsten target. The design of the detector is such that a full $4\pi$ array would consist of 162 crystals of four different shapes, each shape covering the same solid angle. The BaF$_2$ crystals form a spherical shell with an inner radius of $\approx$17 cm and a thickness of 15 cm. Two crystals are removed in order to allow the neutron beam to enter and exit, so that the array has 160 elements as used in a typical experiment. The neutron flux per energy decade available at the current posi-
Fig. 3. Neutron capture live times (open circles) and terrestrial $\beta^-$ live times (filled circles) for unstable isotopes on the classical s-process path as a function of mass number. Shown are only isotopes where the neutron capture is faster than the stellar $\beta^-$ decay for a neutron density of $10^{11}$ cm$^{-3}$ at a temperature of 25 keV. The neutron capture cross sections are taken from the references given in the table and the stellar decay rates from Takahashi and Yokoi (1987).

The Total Absorption Calorimeter (TAC) at CERN can perform $(n,\gamma)$ experiments with samples sizes of 10-100 mg. TAC is also a $4\pi$ BaF$_2$ detector array, but with 42 crystals to cover the entire solid angle (40 in use during the experiments). The BaF$_2$ crystals form a spherical shell with an inner radius of $\approx 10$ cm and a thickness of 15 cm. TAC is located at a 185 m flight path at nTOF. Neutrons are produced via spallation reactions induced by 20 GeV protons hitting a lead target (Borcea et al. (2003); Marrone et al. (2006)).

The newly established Frankfurt Neutron Source at the Stern-Gerlach-Zentrum (FRANZ) at the university of Frankfurt, Germany, will provide pulsed keV-neutron fluxes in the order of $10^6$ n/s/cm$^2$. A $4\pi$ BaF$_2$ array for detecting the $\gamma$-rays following a neutron capture is planned.

These arrays all use flash ADCs with sample rates of 500-1000MHz to directly digitize the response from the detectors. This offers great flexibility in event reconstruction in software offline.

This paper gives estimates of the maximum number of radioactive atoms which could be tolerated by the DANCE array as well as the number of neutrons at the sample required for a direct measurement using a DANCE-like detector. While similar calculations could be done for any geometry, the authors had
greatest access to the DANCE array, and thus, could most easily verify that
the decay simulation produced realistic events with this detector. The basic
assumption underlying all of the simulations and estimates is that the rate of
pile-up in the calorimeter and the individual detectors is sufficiently low as
to be negligible. While the pile-up effects could be calculated for a particular
instrument under very high rate conditions for a particular experiment, the
results would not be very portable as they would necessarily depend strongly
on the details of how the acquisition is accomplished as well as the number
and layout of the individual crystals for a particular detector at a particular
site. Since the goal of this work was to provide a reference that would allow a
quick check on what would be required for a measurement at a wide range of
facilities, the decision was made to give values for which pile-up effects should
not play a role.

It should be straightforward for the reader to scale the numbers given in the
table to the specific conditions of other experiments. Suggestions for how that
scaling may be done and which factors may be important can be found in the
detailed discussion of the simulations for $^{191}$Os. More details will be given in
the next sections. The radio-isotopes under investigation are isotopes heavier
than $^{56}$Fe and fulfill the condition that at least 10% of the expected reaction
flow is through neutron capture during the $^{22}$Ne phase.

### 1.1 Monte Carlo Simulations

The results presented in the table are based on Monte Carlo simulations of
the decay cascades and the DANCE detector array.

First, decay cascades according to the decay schemes of each isotope (Firestone
(1996)) were generated using a Monte Carlo method. The energy distribution
of the emitted electrons or positrons was calculated by means of the Fermi the-
ory of beta decay. Following Krane (1988), the internal conversion coefficients
were estimated according to

\[
\alpha_{\text{conversion}} = \frac{l}{l+1} \frac{\alpha}{4} Z^3 \left[ \frac{2m_e}{E_\gamma} \right]^{l+2.5}, \text{if } E_\gamma > E_k
\]

\[
\alpha_{\text{conversion}} = \frac{l}{l+1} \frac{\alpha}{4} Z^3 \left[ \frac{2m_e}{E_\gamma} \right]^{l+2.5}, \text{if } E_\gamma \leq E_k
\]

as a function of the multipolarity ($l$), the fine structure constant ($\alpha$), the
charge of the product nucleus ($Z$), the mass of the electron ($m_e$), the energy
of the transition ($E_\gamma$), and the ionization energy of the k-shell electron ($E_k$).
The probability for electron conversion is then:

\[
P_{\text{conversion}} = \frac{\alpha_{\text{conversion}}}{1 + \alpha_{\text{conversion}}}
\]
In order to simplify the simulations, an "average multipolarity" of $l = 1.7$ was assumed. Then these cascades were started inside the DANCE ball and the response of the array was simulated using the GEANT 3.21 detector simulation package \cite{Apostolakis1993}. Reference \cite{Reifarthetal2004a} can be consulted for more details on the simulated geometry.

Since a 6 cm $^6$LiH shell is usually used at DANCE to reduce the background from scattered neutrons, the array was simulated with and without the $^6$LiH shell. A similar sphere is in place inside TAC at n-TOF, but made of $C_{12}H_{20}O_4(^6Li)_2$ \cite{Cano-Ottetal2006}. In addition, simulations were also done with one, two, and five millimeters of lead serving as a passive shield around the sample to reduce the radio-decay background. All of the simulations with lead shielding included the $^6$LiH shell. A total of one million cascades were randomly created for each isotope. Each cascade was then simulated five times with randomly chosen angular distributions under each of the five geometric conditions. Individual detector thresholds were set in software in 100 keV intervals to investigate the additional reduction of the count rate from the decay of the source.

Absorbing material between sample and detectors does not only affect the radiation from the radioactive decay, but also $\gamma$-rays following a neutron capture. Since these are the desired signature for the capture event, better shielding or increased thresholds will always be a trade-off between decreased sensitivity to background and decreased efficiency for capture events. Figure 4 shows the effect of different thicknesses of lead around the sample on the energy spectrum of the $4\pi$ array following neutron captures on gold \cite{Becvar2000} for a single-detector threshold of 100 keV. Figure 5 shows the response of the array to gold captures for different absorbers and different thresholds.

In many cases, the radioactive decays populate daughters which either have metastable states or which are themselves radioactive. If the lifetime of the daughter state was shorter than the one hundred days, then the daughter and the parent were assumed to be in equilibrium. This condition was considered a reasonable determination on the ability to separate the decay products from the parent. The decay rate of the daughter was equal to the rate of the decay which populated the daughter since the two were in equilibrium. The final rate of observations in the array was the sum of the rate of observations from the parent and the observations from any daughters.

1.2 Neutron capture cross sections

The neutron capture cross-sections used for determining which isotopes were included in the compilation as well as estimating the necessary neutron flux...
Fig. 4. Sum energy spectrum for $^{197}$Au(n,γ) events for different absorbing materials and 100 keV single detector threshold. One million capture events were simulated.

for an improved measurement was based on the 30 keV Maxwellian averaged cross-section (MACS). The cross-sections were based on the most recent data available as of January 2006. For most isotopes, this meant that the values were taken from Bao et al. (2000). There were several isotopes where more recent measurements have been made, however. These were included when available. If values were not available from Bao et al. (2000) or a recent measurement, then the values were calculated from JEFF3.0 (2005).

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Fig. 5. Sum energy spectrum for \textsuperscript{197}Au(n,\gamma) events for different absorbing materials and variable single detector threshold. One million capture events were simulated for each setup.

2 Explanation of Tables

2.1 General Remarks

The first row of Table \( \text{2} \) gives the isotope and the Maxwellian Averaged Cross Section (MACS) at \( kT = 30 \) keV including the reference for the cross section.

The numbers in columns 2-5 and rows 4-8 provide the maximum number of atoms tolerable inside a \( 4\pi \) array (simulated for the example of DANCE) for each isotope under investigation (\( N_{\text{max}} \)). \( N_{\text{max}} \) depends on the following three variables:
• $R_{\text{max}}$, the maximum rate tolerable in the array. For the DANCE array, the primary limitation is the coincidence time window. $R_{\text{max}}$ was chosen to be $R_{\text{max}} = 10^7 \text{s}^{-1}$ for these calculations, consistent with the conditions mentioned in the Introduction regarding pile-up. With the 160 detectors in DANCE, this would correspond to a rate of $\approx 10^5$ in each detector for low multiplicity decays. For a less segmented detector, the primary limitation may come from the rate in the individual detectors rather than the rate in the array since the individual detector signals will have lengths of approximately 500 ns. More details can be found on determining this parameter for a particular setup in the detailed discussion of the $^{191}$Os case.

• $q$, the quality factor of the array for the decay cascade, given by the ratio of the number of observed cascades to the number of simulated cascades. The number of cascades observed is dependent on the condition that the energy deposition in a single detector is above a given threshold. This number comes from the Monte Carlo simulations and depends strongly on the decay properties of the isotope. A quality factor of $q=1.0$ would indicate that every cascade was observed while a quality factor of 0.01 would indicate that 99% of the cascades deposited no energy above threshold in any detector. A quality factor of $q > 1$ is possible and would indicate that on average multiple detectors were above threshold for each cascade.

• $\tau$, the life-time of the isotope versus radiodecay. The lifetime is related to the half-life by $\tau = t_{1/2}/\ln(2)$.

$$N_{\text{max}} = \frac{R_{\text{max}} \, \tau}{q}$$  \hspace{1cm} (1)

The columns refer to different single-detector thresholds in keV and the rows correspond to different absorbers between sample and detectors.

The last column gives the required neutron flux in (neutrons/cm$^2$/s/energy-decade) for each geometry and single-detector threshold of 100 keV for a desired capture rate of $0.1 \text{ s}^{-1}$/energy-decade. The unit (neutrons/cm$^2$/s/energy-decade) is especially useful for neutron spectra at spallation sources (LANSCE, n-TOF), since the resulting spallation neutron spectrum has typically a high-energy part following a $1/E$ dependence, hence the number of neutrons per energy decade will be constant. This would correspond to approximately 10,000 events/energy decade over the course of a two week experiment. This is a typical number of statistics needed in order to improve the status of the data. For comparison, the neutron flux available at the sample position of DANCE is approximately $3 \cdot 10^5$ neutrons/cm$^2$/s/energy-decade, at the sample position of TAC at n-TOF approximately $10^5$ neutrons/cm$^2$/s/energy-decade are available.
2.2 Detailed Example: $^{191}\text{Os}$

In order to further clarify the steps which were taken both in the simulations and in the determination of the maximum number of atoms tolerable, the calculation for $^{191}\text{Os}$ will be done explicitly. $^{191}\text{Os}$ beta-decays to a metastable state of $^{191}\text{Ir}$. The half-life of $^{191}\text{Os}$ is 15.4 days, while the lifetime of the metastable state of $^{191}\text{Ir}$ has a lifetime of 4.94 seconds [Firestone (1996)]. Since the lifetime of the daughter is so much shorter than the lifetime of the parent, the ratio of $^{191}\text{Os}:^{191}\text{mIr}$ will quickly come in to equilibrium and the decay rate of $^{191}\text{mIr}$ will be approximately the decay rate of $^{191}\text{Os}$, though the two will be asynchronous. The decay rate $\lambda$ is given by $\lambda = \ln(2)/t_{1/2}$, or $\lambda = 5.21 \times 10^{-7}$ decays/sec/atom.

The first step is then to generate decays for both the osmium and the iridium and determine the detector response to the decay. The osmium will be discussed first and then the iridium. One million decays were generated in a Monte Carlo method for the beta decay of $^{191}\text{Os}$. The simulated beta-decay spectrum can be seen in Fig. 6. Each cascade was then started five times, meaning a total of five million events were simulated using GEANT. Because of the low kinetic energy of the beta, even before placing cuts on the detectors, there is very little response from the detector array. Fig. 7 illustrates the array sum energy for a threshold of 0 keV and different thicknesses of $^6\text{LiH}$. All other simulated combinations of geometry and threshold resulted in no detected events. The detection probability was determined by calculating the ratio of events seen in the array to decays simulated. Table 1 follows this discussion and contains the information from all of the simulations.

The $^{191}\text{mIr}$ depopulates via a 2-3 (partly converted) gamma cascade with a total cascade energy of 171 keV. Five million gamma cascades were started inside the detector and the energy deposition was checked. Since gamma-rays are much more penetrating than electrons, the detector exhibited a much more pronounced response. Fig. 8 shows the response of the array to the gamma-cascade under various thresholds when only the $^6\text{LiH}$ shell was in place. In contrast, Fig. 9 shows the response of the array with no threshold condition on the individual crystal but with different passive shielding conditions. The detection probability is calculated as in the case of the osmium decay.

In order to determine the maximum number of atoms of the radioisotope which can be used in the array, the only thing which remains is to determine the maximum tolerable rate. Typical BaF$_2$ arrays of that size achieve time resolution of better than 1 ns. The Karlsruhe 4$\pi$ detector, which has an almost identical geometry as the TAC array at n-TOF reports 0.5 ns [Wissak et al. (1990)] and the time resolution measured with the DANCE array was as small as 0.7 ns (see Fig. 10). The total width of the coincidence window for
such a detector array can therefore be 5 ns, or even shorter. In order to be able to neglect pile-up effects, we assumed a maximum event rate of $10^7 \text{s}^{-1}$, which means on average 1 event every 100 ns. The probability for a random coincidence (or a 1-fold pile-up) would then be less than 5%. It should be noted that this is the pile-up rate for the array, not for an individual crystal. At this point, the reader has to decide what the maximum tolerable rate is under the specific conditions of the experiment and scale the numbers found in the table accordingly.

Then the maximum number of atoms is given by

$$N_{\text{max}} = \frac{10^7}{\lambda (q_{\text{Os}} + q_{\text{Ir}})} = 1.92 \times 10^{13} \frac{1}{q_{\text{Os}} + q_{\text{Ir}}}. \quad (2)$$

The average number of detectors firing due to a decay event varies strongly depending on the isotope. While it is between one and two for most isotopes, it can reach up to six. This is important for estimating the pile-up effect within a single detector. An event rate of $10^7 \text{s}^{-1}$ (or one event every 100 ns) would correspond to only $6.25 \times 10^4 \text{s}^{-1}$ (or one event every 16 µs) for multiplicity one events, which is easily manageable. However, it would correspond to a detection rate of $3.75 \times 10^5 \text{s}^{-1}$ (or one event every 2.7 µs) for multiplicity six events. This might require additional measures to avoid pile-up problems.
Fig. 7. Response of the $4\pi$ array to decays of $^{191}\text{Os}(\beta^-)$. A threshold of 100 keV discriminates almost all events. Five million decay events were simulated.

The information provided on the maximum sample size for zero threshold can give some indication as to whether individual detector pile-up will introduce significant problems.

The rate of capture events for a particular energy region ($dY/dt$) is given by

$$dY/dt = \sigma N_t \phi_n$$

where $\sigma$ is the capture cross-section over the energy range of interest, $N_t$ is the number of target atoms, and $\phi_n$ is the neutron flux per second over the same energy region. The determination of necessary neutron flux was based on the assumption that 0.1 event per second per energy decade would be necessary for a reasonable experiment, so

$$\phi_n = \frac{0.1}{\sigma N_{max}}. \quad (3)$$

The cross-section used was the MACS for 30 keV, since this would roughly correspond to the cross-section for the 10-100 keV decade.
Fig. 8. Response of the $4\pi$ array to decays of $^{191}\text{Ir}^m(\beta^-)$ with different thresholds. No lead, but 6 cm $^6\text{LiH}$ were assumed between sample and detector. Five million decay events were simulated.

Table 1: Extended version of Table 2 for the example of a $^{191}\text{Os}$

| $^{191}\text{Os}$ Calculation Table |
|-----------------|-----------------|-----------------|
| $t_{1/2} = 15.4$ days | $\lambda = 5.21 \times 10^{-7}$ decays/sec/atom | $\sigma = 1290$ mb |

| Observed Events | Quality factor |
|-----------------|----------------|
| $^{191}\text{Os}$ | $T=0$ | $T=100$ | $T=200$ |
| $T=0$ | $T=100$ | $T=200$ |
| Shielding                          | T=0  | T=100 | T=200 | T=0  | T=100 | T=200 |
|-----------------------------------|------|-------|-------|------|-------|-------|
| No Shielding                      | 356  | 0     | 0     | 7.1·10⁻⁵ | 0.0  | 0.0   |
| LiH Shell                         | 285  | 1     | 0     | 5.7·10⁻⁵ | 2·10⁻⁷ | 0.0   |
| LiH+1mm Pb                        | 0    | 0     | 0     | 0.0  | 0.0  | 0.0   |
| LiH+2mm Pb                        | 0    | 0     | 0     | 0.0  | 0.0  | 0.0   |
| LiH+5mm Pb                        | 0    | 0     | 0     | 0.0  | 0.0  | 0.0   |

| ^{191m}Ir                         | T=0  | T=100 | T=200 | T=0  | T=100 | T=200 |
|-----------------------------------|------|-------|-------|------|-------|-------|
| No Shielding                      | 4580573 | 236879 | 23 | 0.916115 | 0.047376 | 4·10⁻⁶ |
| LiH Shell                         | 4569545 | 157837 | 16 | 0.913909 | 0.031567 | 3·10⁻⁶ |
| LiH+1mm Pb                        | 293388  | 8941  | 0   | 0.058678 | 0.001788 | 0.0   |
| LiH+2mm Pb                        | 20397   | 499   | 1   | 0.004079 | 1·10⁻⁴  | 2·10⁻⁷ |
| LiH+5mm Pb                        | 4      | 0     | 0   | 8·10⁻⁷  | 0.0    | 0.0   |

| Totals                            | T=0  | T=100 | T=200 | T=0  | T=100 | T=200 |
|-----------------------------------|------|-------|-------|------|-------|-------|
| No Shielding                      | 4580929 | 236879 | 23 | 0.916186 | 0.047376 | 4·10⁻⁶ |
| LiH Shell                         | 4569830 | 157838 | 16 | 0.913966 | 0.031568 | 3·10⁻⁶ |
| LiH+1mm Pb                        | 293388  | 8941  | 0   | 0.058678 | 0.001788 | 0.0   |
| LiH+2mm Pb                        | 20397   | 499   | 0   | 0.004079 | 1·10⁻⁴  | 2·10⁻⁷ |
| LiH+5mm Pb                        | 4      | 0     | 0   | 8·10⁻⁷  | 0.0    | 0.0   |

Maximum Atoms

\[ N_{\text{atoms}} = \frac{10^7}{\lambda \cdot q_{\text{tot}}} \]

Required Neutron Flux

\[ \phi_n = \frac{0.1}{\sigma \cdot N_{\text{atoms}}} \]

| T=0  | T=100 | T=200 | T=0  | T=100 | T=200 |
|------|-------|-------|------|-------|-------|
|      |       |       |      |       |       |
|                  | 2.09·10^{13} | 4.05·10^{14} | 4.17·10^{18} | 3.70·10^9  | 1.91·10^8  | 1.86·10^4  |
|------------------|---------------|---------------|---------------|-------------|-------------|-------------|
| No Shielding     | 2.10·10^{13}  | 6.08·10^{14}  | 6.00·10^{18}  | 3.69·10^9  | 1.27·10^8  | 1.29·10^4  |
| LiH Shell        | 3.27·10^{14}  | 1.07·10^{16}  | ∞             | 2.37·10^8  | 7.22·10^6  | 0.0         |
| LiH+1mm Pb       | 4.71·10^{15}  | 1.92·10^{17}  | 9.60·10^{19}  | 1.65·10^7  | 4.03·10^5  | 8.08·10^2  |
| LiH+5mm Pb       | 2.40·10^{19}  | ∞             | ∞             | 3.23·10^3  | 0.0         | 0.0         |
Fig. 9. Response of the $4\pi$ array to decays of $^{191}$Ir$^{m}(\beta^-)$. A threshold of 0 keV and different geometries are shown. The case without $^6$LiH is very similar to the one with $^6$LiH, no Pb, and therefore not shown (see Fig. 7). Five million decay events were simulated for each setup.

There are several issues to note in Table I. First, for brevity, the results for thresholds with 400 and 600 keV were excluded. Second, the bottom section differs slightly from what will be found in the full tables. In the full tables, if events were observed in the simulation but the maximum number of atoms which the system could handle was greater than $10^{20}$, then no value was listed as the limitation on the maximum sample size would most likely not come from the radioactivity of the sample. Correspondingly, no neutron flux was listed as the neutron flux depends on the number of target atoms. These cases are indicated by at “∗” in the final table. If no events were observed in the simulation, then there is no limitation on the sample size from the radioactivity. Similarly, the necessary neutron flux cannot be calculated. These cases are indicated by “—” in the final table.

2.2.1 Scaling Results to Different Instruments

Before proceeding to present the estimate for sample sizes, it is appropriate to make a few comments about how one might estimate the result for a different instrument. The first matter to consider is the maximum tolerable instrument
Fig. 10. Time distribution of events between two neighboring crystals at DANCE on the same digitizer card (Wouters et al. (2006)). The histogram shows actual data, while the solid line represents a least square fit of a Gaussian curve and a constant background. The full width at half maximum (FWHM) of the Gaussian curve is 2.35 ns, which means each detector has a time resolution of $\pm 0.7$ ns.

As was mentioned before, a rate of $10^7$ s$^{-1}$ was assumed for these calculations. This was based on the excellent time resolution of BaF$_2$ detectors and an observed time coincidence for the DANCE array of better than 5 ns. The second consideration is the rate in individual crystals. Because of the high segmentation of the DANCE array, the primary limitation came from the array rate, not the detector rate. Even in the case of a $\sim 40$ element detector, this is likely to be the case. High segmentation can alter the observed multiplicity due to increased cross-talk. This effect which is highly geometry dependent. In the case of a very low segmentation instrument ($\sim 10$ elements), the primarily limitation may well come from the individual detector rate. Inspection of the decay scheme and benchmarking to a similar decay would be highly advisable.
### Table 2: Master table

|                  | 59Fe | 60Fe |
|------------------|------|------|
|                  | 18 mb | 29 mb |
|                  | JEFF30 (2005) | JEFF30 (2005) |
|                  |       |       |
| Max. No. of Atoms|       |       |
| $\phi_n$         |       |       |
| $\phi_n$         |       |       |
| $\phi_n$         |       |       |
| $\phi_n$         |       |       |
| $\phi_n$         |       |       |
| $\phi_n$         |       |       |

|                  | No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|------------------|--------------|-----------|------------|------------|------------|
| $T=0$            | 6.35·10^{13} | 6.20·10^{13} | 6.32·10^{13} | 6.52·10^{13} | 7.27·10^{13} |
| $T=100$          | 6.42·10^{13} | 6.36·10^{13} | 6.50·10^{13} | 6.70·10^{13} | 7.48·10^{13} |
| $T=200$          | 6.57·10^{13} | 6.76·10^{13} | 6.93·10^{13} | 7.15·10^{13} | 8.01·10^{13} |
| $T=400$          | 7.00·10^{13} | 7.70·10^{13} | 7.99·10^{13} | 8.31·10^{13} | 9.42·10^{13} |
| $T=600$          | 7.75·10^{13} | 8.97·10^{13} | 9.41·10^{13} | 9.87·10^{13} | 1.15·10^{14} |
| $T=100$          | 8.80·10^{10} | 8.89·10^{10} | 8.70·10^{10} | 8.43·10^{10} | 7.55·10^{10} |

|                  | No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|------------------|--------------|-----------|------------|------------|------------|
| $T=0$            | *            | *         | *          | *          | *          |
| $T=100$          | *            | *         | *          | *          | *          |
| $T=200$          | *            | *         | *          | *          | *          |
| $T=400$          | *            | *         | *          | *          | *          |
| $T=600$          | *            | *         | *          | *          | *          |
| $T=100$          | *            | *         | *          | *          | *          |
| 60Co          | 17 mb \textit{JEFF30} (2005) | Max. No. of Atoms | \( \phi_n \) |
|--------------|-------------------------------|------------------|--------------|
|              |                               | \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding |                               | 2.43\( \cdot 10^{15} \) | 2.44\( \cdot 10^{15} \) | 2.45\( \cdot 10^{15} \) | 2.49\( \cdot 10^{15} \) | 2.56\( \cdot 10^{15} \) | 2.49\( \cdot 10^{9} \) |
| LiH Shell    |                               | 2.42\( \cdot 10^{15} \) | 2.43\( \cdot 10^{15} \) | 2.47\( \cdot 10^{15} \) | 2.57\( \cdot 10^{15} \) | 2.73\( \cdot 10^{15} \) | 2.49\( \cdot 10^{9} \) |
| LiH+1mm Pb   |                               | 2.43\( \cdot 10^{15} \) | 2.44\( \cdot 10^{15} \) | 2.48\( \cdot 10^{15} \) | 2.61\( \cdot 10^{15} \) | 2.80\( \cdot 10^{15} \) | 2.48\( \cdot 10^{9} \) |
| LiH+2mm Pb   |                               | 2.44\( \cdot 10^{15} \) | 2.46\( \cdot 10^{15} \) | 2.51\( \cdot 10^{15} \) | 2.65\( \cdot 10^{15} \) | 2.87\( \cdot 10^{15} \) | 2.47\( \cdot 10^{9} \) |
| LiH+5mm Pb   |                               | 2.52\( \cdot 10^{15} \) | 2.54\( \cdot 10^{15} \) | 2.61\( \cdot 10^{15} \) | 2.82\( \cdot 10^{15} \) | 3.12\( \cdot 10^{15} \) | 2.39\( \cdot 10^{9} \) |

| 63Ni          | 26.1 mb \textit{Nassar et al.} (2005) | Max. No. of Atoms | \( \phi_n \) |
|--------------|------------------------------------------|------------------|--------------|
|              |                                           | \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding |                                           | *                | —         | —         | —         | —         | —         |
| LiH Shell    |                                           | *                | —         | —         | —         | —         | —         |
| LiH+1mm Pb   |                                           | —                | —         | —         | —         | —         | —         |
| LiH+2mm Pb   |                                           | —                | —         | —         | —         | —         | —         |
| LiH+5mm Pb   |                                           | —                | —         | —         | —         | —         | —         |
### 64Cu

| Max. No. of Atoms | \( \phi_n \) |
|------------------|-------------|
|                  | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 1.22\cdot10^{14} | 1.51\cdot10^{14} | 1.62\cdot10^{14} | 1.72\cdot10^{14} | 1.84\cdot10^{14} | 2.75\cdot10^9 |
| LiH Shell        | 1.21\cdot10^{14} | 1.51\cdot10^{14} | 1.67\cdot10^{14} | 1.87\cdot10^{14} | 2.09\cdot10^{14} | 2.74\cdot10^9 |
| LiH+1mm Pb       | 1.42\cdot10^{14} | 1.50\cdot10^{14} | 1.66\cdot10^{14} | 1.93\cdot10^{14} | 2.18\cdot10^{14} | 2.76\cdot10^9 |
| LiH+2mm Pb       | 1.55\cdot10^{14} | 1.60\cdot10^{14} | 1.72\cdot10^{14} | 2.00\cdot10^{14} | 2.28\cdot10^{14} | 2.59\cdot10^9 |
| LiH+5mm Pb       | 1.75\cdot10^{14} | 1.79\cdot10^{14} | 1.91\cdot10^{14} | 2.21\cdot10^{14} | 2.56\cdot10^{14} | 2.31\cdot10^9 |

### 65Zn

| Max. No. of Atoms | \( \phi_n \) |
|------------------|-------------|
|                  | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 6.80\cdot10^{14} | 6.88\cdot10^{14} | 7.01\cdot10^{14} | 7.48\cdot10^{14} | 8.42\cdot10^{14} | 8.98\cdot10^8 |
| LiH Shell        | 6.64\cdot10^{14} | 6.81\cdot10^{14} | 7.24\cdot10^{14} | 8.28\cdot10^{14} | 9.82\cdot10^{14} | 9.07\cdot10^8 |
| LiH+1mm Pb       | 6.76\cdot10^{14} | 6.96\cdot10^{14} | 7.44\cdot10^{14} | 8.63\cdot10^{14} | 1.04\cdot10^{15} | 8.87\cdot10^8 |
| LiH+2mm Pb       | 6.98\cdot10^{14} | 7.18\cdot10^{14} | 7.69\cdot10^{14} | 9.00\cdot10^{14} | 1.09\cdot10^{15} | 8.59\cdot10^8 |
| LiH+5mm Pb       | 7.85\cdot10^{14} | 8.08\cdot10^{14} | 8.68\cdot10^{14} | 1.03\cdot10^{15} | 1.28\cdot10^{15} | 7.64\cdot10^8 |
### 71Ge

**150 mb JEFF30 (2005)**

| Max. No. of Atoms | \( \phi_n \) |
|------------------|----------------|
| \( T=0 \)       | \( T=100 \)   |
| \( T=200 \)     | \( T=400 \)   |
| \( T=600 \)     | \( T=100 \)   |
| No Shielding    | \( 9.98 \cdot 10^{18} \) | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) |
| LiH Shell       | \( 3.49 \cdot 10^{18} \) | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) |
| LiH+1mm Pb      | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) |
| LiH+2mm Pb      | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) |
| LiH+5mm Pb      | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) | \( \ldots \) |

### 76As

**540 mb JEFF30 (2005)**

| Max. No. of Atoms | \( \phi_n \) |
|------------------|----------------|
| \( T=0 \)       | \( T=100 \)   |
| \( T=200 \)     | \( T=400 \)   |
| \( T=600 \)     | \( T=100 \)   |
| No Shielding    | \( 2.78 \cdot 10^{12} \) | \( 2.90 \cdot 10^{12} \) | \( 3.04 \cdot 10^{12} \) | \( 3.85 \cdot 10^{12} \) | \( 1.13 \cdot 10^{13} \) | \( 6.43 \cdot 10^{10} \) |
| LiH Shell       | \( 2.76 \cdot 10^{12} \) | \( 2.95 \cdot 10^{12} \) | \( 3.30 \cdot 10^{12} \) | \( 4.60 \cdot 10^{12} \) | \( 1.41 \cdot 10^{13} \) | \( 6.31 \cdot 10^{10} \) |
| LiH+1mm Pb      | \( 2.77 \cdot 10^{12} \) | \( 2.89 \cdot 10^{12} \) | \( 3.26 \cdot 10^{12} \) | \( 4.73 \cdot 10^{12} \) | \( 1.38 \cdot 10^{13} \) | \( 6.44 \cdot 10^{10} \) |
| LiH+2mm Pb      | \( 3.08 \cdot 10^{12} \) | \( 3.19 \cdot 10^{12} \) | \( 3.56 \cdot 10^{12} \) | \( 5.17 \cdot 10^{12} \) | \( 1.48 \cdot 10^{13} \) | \( 5.83 \cdot 10^{10} \) |
| LiH+5mm Pb      | \( 4.06 \cdot 10^{12} \) | \( 4.21 \cdot 10^{12} \) | \( 4.68 \cdot 10^{12} \) | \( 6.79 \cdot 10^{12} \) | \( 1.84 \cdot 10^{13} \) | \( 4.43 \cdot 10^{10} \) |
### 77As

| Max. No. of Atoms | $\phi_n$ |
|-------------------|---------|
| $T = 0$ | $T = 100$ | $T = 200$ | $T = 400$ | $T = 600$ |
| No Shielding | $5.11 \cdot 10^{13}$ | $6.04 \cdot 10^{13}$ | $1.13 \cdot 10^{14}$ | $5.79 \cdot 10^{14}$ | $4.38 \cdot 10^{16}$ | $6.28 \cdot 10^9$ |
| LiH Shell | $5.04 \cdot 10^{13}$ | $6.73 \cdot 10^{13}$ | $1.45 \cdot 10^{14}$ | $7.25 \cdot 10^{14}$ | $6.15 \cdot 10^{16}$ | $5.63 \cdot 10^9$ |
| LiH+1mm Pb | $1.12 \cdot 10^{14}$ | $1.30 \cdot 10^{14}$ | $2.15 \cdot 10^{14}$ | $8.29 \cdot 10^{14}$ | $6.22 \cdot 10^{16}$ | $2.90 \cdot 10^9$ |
| LiH+2mm Pb | $2.01 \cdot 10^{14}$ | $2.23 \cdot 10^{14}$ | $3.18 \cdot 10^{14}$ | $9.60 \cdot 10^{14}$ | $8.54 \cdot 10^{16}$ | $1.70 \cdot 10^9$ |
| LiH+5mm Pb | $5.46 \cdot 10^{14}$ | $5.81 \cdot 10^{14}$ | $7.14 \cdot 10^{14}$ | $1.45 \cdot 10^{15}$ | $1.29 \cdot 10^{17}$ | $6.51 \cdot 10^8$ |

### 79Se

| Max. No. of Atoms | $\phi_n$ |
|-------------------|---------|
| $T = 0$ | $T = 100$ | $T = 200$ | $T = 400$ | $T = 600$ |
| No Shielding | * | * | — | — | — | — | * |
| LiH Shell | * | * | — | — | — | — | * |
| LiH+1mm Pb | — | — | — | — | — | — | — |
| LiH+2mm Pb | — | — | — | — | — | — | — |
| LiH+5mm Pb | — | — | — | — | — | — | — |

260 mb JEFF30 (2005)

263 mb Bao et al. (2000)
### $^{81}\text{Kr}$

607 mb Bao et al. (2000)

Max. No. of Atoms

| $\phi_n$  | T=0  | T=100 | T=200 | T=400 | T=600 | T=100 |
|-----------|------|-------|-------|-------|-------|-------|
| No Shielding | *    | *     | *     | _     | _     | _     | *
| LiH Shell   | *    | *     | *     | _     | _     | _     | *
| LiH+1mm Pb  | *    | *     | *     | _     | _     | _     | *
| LiH+2mm Pb  | *    | *     | *     | _     | _     | _     | *
| LiH+5mm Pb  | *    | *     | *     | _     | _     | _     | *

### $^{85}\text{Kr}$

55 mb Bao et al. (2000)

Max. No. of Atoms

| $\phi_n$  | T=0  | T=100 | T=200 | T=400 | T=600 | T=100 |
|-----------|------|-------|-------|-------|-------|-------|
| No Shielding | 1.16·10^{18} | 4.42·10^{18} | 2.64·10^{19} | * | _ | 4.12·10^5 |
| LiH Shell   | 1.21·10^{18} | 5.90·10^{18} | 3.88·10^{19} | * | _ | 3.08·10^5 |
| LiH+1mm Pb  | 2.48·10^{18} | 3.49·10^{18} | 8.09·10^{18} | * | _ | 5.21·10^5 |
| LiH+2mm Pb  | 6.82·10^{18} | 7.93·10^{18} | 1.41·10^{19} | * | _ | 2.29·10^5 |
| LiH+5mm Pb  | 3.18·10^{19} | 3.46·10^{19} | 4.84·10^{19} | * | * | 5.26·10^4 |
|       | 202 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|-------|--------------------------|-------------------|---------|
| $^{86}$Rb |                          |                  | T=100   |
| No Shielding | 2.30·$10^{14}$ | 2.71·$10^{14}$ | 3.01·$10^{14}$ | 3.36·$10^{14}$ | 3.90·$10^{14}$ | 1.83·$10^9$ |
| LiH Shell | 2.30·$10^{14}$ | 2.77·$10^{14}$ | 3.16·$10^{14}$ | 3.76·$10^{14}$ | 4.60·$10^{14}$ | 1.79·$10^9$ |
| LiH+1mm Pb | 2.17·$10^{14}$ | 2.32·$10^{14}$ | 2.70·$10^{14}$ | 3.62·$10^{14}$ | 4.68·$10^{14}$ | 2.13·$10^9$ |
| LiH+2mm Pb | 2.52·$10^{14}$ | 2.62·$10^{14}$ | 2.93·$10^{14}$ | 3.82·$10^{14}$ | 4.95·$10^{14}$ | 1.89·$10^9$ |
| LiH+5mm Pb | 3.16·$10^{14}$ | 3.27·$10^{14}$ | 3.56·$10^{14}$ | 4.46·$10^{14}$ | 5.86·$10^{14}$ | 1.51·$10^9$ |

|       | 19 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|-------|--------------------------|-------------------|---------|
| $^{89}$Sr |                          |                  | T=100   |
| No Shielding | 2.95·$10^{15}$ | 7.08·$10^{15}$ | 1.98·$10^{16}$ | 8.88·$10^{16}$ | 2.76·$10^{17}$ | 7.44·$10^8$ |
| LiH Shell | 3.15·$10^{15}$ | 9.18·$10^{15}$ | 2.99·$10^{16}$ | 1.70·$10^{17}$ | 5.60·$10^{17}$ | 5.73·$10^8$ |
| LiH+1mm Pb | 2.75·$10^{15}$ | 3.30·$10^{15}$ | 5.32·$10^{15}$ | 2.13·$10^{16}$ | 8.24·$10^{16}$ | 1.59·$10^9$ |
| LiH+2mm Pb | 4.79·$10^{15}$ | 5.25·$10^{15}$ | 7.24·$10^{15}$ | 2.40·$10^{16}$ | 9.03·$10^{16}$ | 1.00·$10^9$ |
| LiH+5mm Pb | 1.14·$10^{16}$ | 1.22·$10^{16}$ | 1.49·$10^{16}$ | 3.52·$10^{16}$ | 1.15·$10^{17}$ | 4.32·$10^8$ |
| 90Sr | 20 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|------|---------------------|-------------------|---------|
|      | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 2.76·10^{17} | 5.71·10^{17} | 1.28·10^{18} | 3.83·10^{18} | 8.86·10^{18} | 8.76·10^6 |
| LiH Shell | 2.94·10^{17} | 7.21·10^{17} | 1.75·10^{18} | 6.06·10^{18} | 1.55·10^{19} | 6.93·10^6 |
| LiH+1mm Pb | 2.02·10^{17} | 2.33·10^{17} | 3.35·10^{17} | 8.71·10^{17} | 2.07·10^{18} | 2.14·10^7 |
| LiH+2mm Pb | 3.08·10^{17} | 3.32·10^{17} | 4.25·10^{17} | 9.65·10^{17} | 2.23·10^{18} | 1.51·10^7 |
| LiH+5mm Pb | 5.91·10^{17} | 6.23·10^{17} | 7.31·10^{17} | 1.32·10^{18} | 2.84·10^{18} | 8.03·10^6 |

| 90Y | 190 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|-----|---------------------|-------------------|---------|
|      | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 7.54·10^{13} | 1.52·10^{14} | 3.35·10^{14} | 1.03·10^{15} | 2.41·10^{15} | 3.45·10^9 |
| LiH Shell | 7.98·10^{13} | 1.87·10^{14} | 4.51·10^{14} | 1.59·10^{15} | 4.08·10^{15} | 2.79·10^9 |
| LiH+1mm Pb | 5.22·10^{13} | 6.00·10^{13} | 8.59·10^{13} | 2.21·10^{14} | 5.29·10^{14} | 8.72·10^9 |
| LiH+2mm Pb | 7.93·10^{13} | 8.55·10^{13} | 1.09·10^{14} | 2.48·10^{14} | 5.72·10^{14} | 6.12·10^9 |
| LiH+5mm Pb | 1.50·10^{14} | 1.58·10^{14} | 1.86·10^{14} | 3.37·10^{14} | 7.22·10^{14} | 3.31·10^9 |
|  | 91Y |  | 48 mb JEFF30 (2005) |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 2.94·10^{14} | 6.09·10^{14} | 1.24·10^{15} | 2.34·10^{15} | 3.02·10^{15} | 3.45·10^{9} |
| LiH Shell | 3.10·10^{14} | 7.41·10^{14} | 1.53·10^{15} | 2.82·10^{15} | 3.61·10^{15} | 2.84·10^{9} |
| LiH+1mm Pb | 2.67·10^{14} | 3.15·10^{14} | 4.73·10^{14} | 1.33·10^{15} | 2.66·10^{15} | 6.69·10^{9} |
| LiH+2mm Pb | 4.34·10^{14} | 4.71·10^{14} | 6.18·10^{14} | 1.48·10^{15} | 2.87·10^{15} | 4.47·10^{9} |
| LiH+5mm Pb | 8.75·10^{14} | 9.22·10^{14} | 1.08·10^{15} | 1.93·10^{15} | 3.43·10^{15} | 2.28·10^{9} |

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|  | 93Zr |  | 95 mb Bao et al. (2000) |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | * | — | — | — | — | — |
| LiH Shell | * | — | — | — | — | — |
| LiH+1mm Pb | — | — | — | — | — | — |
| LiH+2mm Pb | — | — | — | — | — | — |
| LiH+5mm Pb | — | — | — | — | — | — |
|         | Max. No. of Atoms |          |          |          |          |          |
|---------|-------------------|----------|----------|----------|----------|----------|
|         | \( \phi_n \)      | \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) |
| \( ^{95} \text{Zr} \) |
| No Shielding | \(9.99\cdot 10^{13} \) | \(9.09\cdot 10^{13} \) | \(9.35\cdot 10^{13} \) | \(1.08\cdot 10^{14} \) | \(1.52\cdot 10^{14} \) | \(1.39\cdot 10^{10} \) |
| LiH Shell | \(8.76\cdot 10^{13} \) | \(9.06\cdot 10^{13} \) | \(9.92\cdot 10^{13} \) | \(1.26\cdot 10^{14} \) | \(1.93\cdot 10^{14} \) | \(1.40\cdot 10^{10} \) |
| LiH+1mm Pb | \(9.20\cdot 10^{13} \) | \(9.53\cdot 10^{13} \) | \(1.05\cdot 10^{14} \) | \(1.36\cdot 10^{14} \) | \(2.11\cdot 10^{14} \) | \(1.33\cdot 10^{10} \) |
| LiH+2mm Pb | \(9.79\cdot 10^{13} \) | \(1.01\cdot 10^{14} \) | \(1.12\cdot 10^{14} \) | \(1.47\cdot 10^{14} \) | \(2.30\cdot 10^{14} \) | \(1.25\cdot 10^{10} \) |
| LiH+5mm Pb | \(1.21\cdot 10^{14} \) | \(1.26\cdot 10^{14} \) | \(1.39\cdot 10^{14} \) | \(1.86\cdot 10^{14} \) | \(3.02\cdot 10^{14} \) | \(1.01\cdot 10^{10} \) |
| \( ^{94} \text{Nb} \) |
| No Shielding | \(9.18\cdot 10^{18} \) | \(9.20\cdot 10^{18} \) | \(9.26\cdot 10^{18} \) | \(9.63\cdot 10^{18} \) | \(1.12\cdot 10^{19} \) | \(2.25\cdot 10^{4} \) |
| LiH Shell | \(9.15\cdot 10^{18} \) | \(9.20\cdot 10^{18} \) | \(9.40\cdot 10^{18} \) | \(1.03\cdot 10^{19} \) | \(1.31\cdot 10^{19} \) | \(2.26\cdot 10^{4} \) |
| LiH+1mm Pb | \(9.22\cdot 10^{18} \) | \(9.29\cdot 10^{18} \) | \(9.57\cdot 10^{18} \) | \(1.07\cdot 10^{19} \) | \(1.39\cdot 10^{19} \) | \(2.23\cdot 10^{4} \) |
| LiH+2mm Pb | \(9.35\cdot 10^{18} \) | \(9.45\cdot 10^{18} \) | \(9.79\cdot 10^{18} \) | \(1.11\cdot 10^{19} \) | \(1.47\cdot 10^{19} \) | \(2.20\cdot 10^{4} \) |
| LiH+5mm Pb | \(1.01\cdot 10^{19} \) | \(1.03\cdot 10^{19} \) | \(1.08\cdot 10^{19} \) | \(1.28\cdot 10^{19} \) | \(1.79\cdot 10^{19} \) | \(2.02\cdot 10^{4} \) |
| $^{95}$Nb | 310 mb $^{\text{Bao et al. (2000)}}$ | Max. No. of Atoms | $\phi_n$ |
|---|---|---|---|
| | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 4.86·10^{13} | 4.91·10^{13} | 5.05·10^{13} | 5.72·10^{13} | 8.10·10^{13} | 6.57·10^{9} |
| LiH Shell | 4.74·10^{13} | 4.89·10^{13} | 5.35·10^{13} | 6.69·10^{13} | 1.02·10^{14} | 6.59·10^{9} |
| LiH+1mm Pb | 4.96·10^{13} | 5.14·10^{13} | 5.64·10^{13} | 7.19·10^{13} | 1.11·10^{14} | 6.28·10^{9} |
| LiH+2mm Pb | 5.26·10^{13} | 5.45·10^{13} | 6.00·10^{13} | 7.72·10^{13} | 1.21·10^{14} | 5.92·10^{9} |
| LiH+5mm Pb | 6.45·10^{13} | 6.68·10^{13} | 7.37·10^{13} | 9.67·10^{13} | 1.56·10^{14} | 4.83·10^{9} |

| $^{96}$Nb | 430 mb $^{\text{JEFF3.0 (2005)}}$ | Max. No. of Atoms | $\phi_n$ |
|---|---|---|---|
| | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 1.22·10^{12} | 1.22·10^{12} | 1.22·10^{12} | 1.24·10^{12} | 1.43·10^{12} | 1.91·10^{11} |
| LiH Shell | 1.22·10^{12} | 1.22·10^{12} | 1.22·10^{12} | 1.28·10^{12} | 1.61·10^{12} | 1.91·10^{11} |
| LiH+1mm Pb | 1.22·10^{12} | 1.22·10^{12} | 1.23·10^{12} | 1.31·10^{12} | 1.69·10^{12} | 1.91·10^{11} |
| LiH+2mm Pb | 1.22·10^{12} | 1.23·10^{12} | 1.24·10^{12} | 1.35·10^{12} | 1.78·10^{12} | 1.90·10^{11} |
| LiH+5mm Pb | 1.26·10^{12} | 1.28·10^{12} | 1.32·10^{12} | 1.50·10^{12} | 2.10·10^{12} | 1.82·10^{11} |
|          | $^{99}$Mo 240 mb Bao et al. (2000) | $^{99}$Tc 781 mb Bao et al. (2000) |
|----------|-----------------------------------|-----------------------------------|
|          | Max. No. of Atoms | Max. No. of Atoms |
| T=0      | T=100 | T=200 | T=400 | T=600 | T=100 | T=100 |
| No Shielding |   |     |     |     |     |     |     |
| LiH Shell |     |     |     |     |     |     |     |
| LiH+1mm Pb |     |     |     |     |     |     |     |
| LiH+2mm Pb |     |     |     |     |     |     |     |
| LiH+5mm Pb |     |     |     |     |     |     |     |

No Shielding

LiH Shell

LiH+1mm Pb

LiH+2mm Pb

LiH+5mm Pb

| No Shielding | * | * | * | — | — | — |
| LiH Shell    | * | * | * | — | — | * |
| LiH+1mm Pb   | * | * | — | — | — | — |
| LiH+2mm Pb   | * | * | — | — | — | * |
| LiH+5mm Pb   | — | — | — | — | — | — |
### 103Ru

343 mb  [Bao et al. (2000)]

Max. No. of Atoms \( \phi_n \)

|            | \( T=0 \)    | \( T=100 \)   | \( T=200 \)   | \( T=400 \)   | \( T=600 \)   | \( T=100 \)   |
|------------|--------------|---------------|---------------|---------------|---------------|---------------|
| No Shielding | 5.45\cdot10^{13} | 5.52\cdot10^{13} | 5.79\cdot10^{13} | 8.01\cdot10^{13} | 2.46\cdot10^{15} | 5.28\cdot10^{9} |
| LiH Shell   | 3.60\cdot10^{13} | 5.58\cdot10^{13} | 6.44\cdot10^{13} | 1.04\cdot10^{14} | 3.42\cdot10^{15} | 5.22\cdot10^{9} |
| LiH+1mm Pb  | 5.97\cdot10^{13} | 6.26\cdot10^{13} | 7.28\cdot10^{13} | 1.21\cdot10^{14} | 3.90\cdot10^{15} | 4.65\cdot10^{9} |
| LiH+2mm Pb  | 6.80\cdot10^{13} | 7.14\cdot10^{13} | 8.31\cdot10^{13} | 1.40\cdot10^{14} | 4.40\cdot10^{15} | 4.09\cdot10^{9} |
| LiH+5mm Pb  | 1.03\cdot10^{14} | 1.09\cdot10^{14} | 1.27\cdot10^{14} | 2.20\cdot10^{14} | 6.51\cdot10^{15} | 2.68\cdot10^{9} |

### 106Ru

88 mb  [JEFF3.0 (2005)]

Max. No. of Atoms \( \phi_n \)

|            | \( T=0 \)    | \( T=100 \)   | \( T=200 \)   | \( T=400 \)   | \( T=600 \)   | \( T=100 \)   |
|------------|--------------|---------------|---------------|---------------|---------------|---------------|
| No Shielding | 1.56\cdot10^{15} | 1.75\cdot10^{15} | 1.94\cdot10^{15} | 2.59\cdot10^{15} | 9.67\cdot10^{15} | 6.48\cdot10^{8} |
| LiH Shell   | 1.70\cdot10^{15} | 2.01\cdot10^{15} | 2.41\cdot10^{15} | 3.71\cdot10^{15} | 1.93\cdot10^{16} | 5.65\cdot10^{8} |
| LiH+1mm Pb  | 1.48\cdot10^{15} | 1.59\cdot10^{15} | 1.89\cdot10^{15} | 3.11\cdot10^{15} | 1.07\cdot10^{16} | 7.16\cdot10^{8} |
| LiH+2mm Pb  | 1.78\cdot10^{15} | 1.87\cdot10^{15} | 2.16\cdot10^{15} | 3.47\cdot10^{15} | 1.14\cdot10^{16} | 6.09\cdot10^{8} |
| LiH+5mm Pb  | 2.60\cdot10^{15} | 2.71\cdot10^{15} | 3.07\cdot10^{15} | 4.74\cdot10^{15} | 1.37\cdot10^{16} | 4.20\cdot10^{8} |
| \( {^{105}}\text{Rh} \) | \( \text{Max. No. of Atoms} \) for various temperatures and shielding configurations. | \( \phi_n \) |
|---|---|---|
| \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding | \( 2.78 \cdot 10^{13} \) | \( 3.81 \cdot 10^{13} \) | \( 4.47 \cdot 10^{13} \) | \( 7.51 \cdot 10^{15} \) | — | \( 3.06 \cdot 10^9 \) |
| LiH Shell | \( 2.82 \cdot 10^{13} \) | \( 3.99 \cdot 10^{13} \) | \( 5.44 \cdot 10^{13} \) | \( 1.05 \cdot 10^{16} \) | — | \( 2.92 \cdot 10^9 \) |
| LiH+1mm Pb | \( 5.10 \cdot 10^{13} \) | \( 5.62 \cdot 10^{13} \) | \( 7.78 \cdot 10^{13} \) | \( 1.28 \cdot 10^{16} \) | — | \( 2.07 \cdot 10^9 \) |
| LiH+2mm Pb | \( 7.51 \cdot 10^{13} \) | \( 8.21 \cdot 10^{13} \) | \( 1.13 \cdot 10^{14} \) | \( 1.52 \cdot 10^{16} \) | — | \( 1.42 \cdot 10^9 \) |
| LiH+5mm Pb | \( 2.34 \cdot 10^{14} \) | \( 2.55 \cdot 10^{14} \) | \( 3.49 \cdot 10^{14} \) | \( 2.66 \cdot 10^{16} \) | — | \( 4.56 \cdot 10^8 \) |

| \( {^{107}}\text{Pd} \) | \( \text{Max. No. of Atoms} \) for various temperatures and shielding configurations. | \( \phi_n \) |
|---|---|---|
| \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding | — | — | — | — | — | — |
| LiH Shell | — | — | — | — | — | — |
| LiH+1mm Pb | — | — | — | — | — | — |
| LiH+2mm Pb | — | — | — | — | — | — |
| LiH+5mm Pb | — | — | — | — | — | — |

107Pd 1340 mb Bao et al. (2000)
### $^{109}$Pd

Max. No. of Atoms $\phi_n$

|            | T=0             | T=100            | T=200            | T=400            | T=600            |
|------------|-----------------|------------------|------------------|------------------|------------------|
| No Shielding | $3.08\cdot10^{12}$ | $2.59\cdot10^{13}$ | $3.99\cdot10^{14}$ | $1.27\cdot10^{15}$ | $2.70\cdot10^{15}$ |
| LiH Shell  | $3.22\cdot10^{12}$ | $3.90\cdot10^{13}$ | $5.21\cdot10^{14}$ | $1.64\cdot10^{15}$ | $3.52\cdot10^{15}$ |
| LiH+1mm Pb | $4.82\cdot10^{13}$ | $9.09\cdot10^{13}$ | $1.69\cdot10^{14}$ | $8.57\cdot10^{14}$ | $3.23\cdot10^{15}$ |
| LiH+2mm Pb | $1.42\cdot10^{14}$ | $1.65\cdot10^{14}$ | $2.39\cdot10^{14}$ | $9.64\cdot10^{14}$ | $3.55\cdot10^{15}$ |
| LiH+5mm Pb | $4.17\cdot10^{14}$ | $4.46\cdot10^{14}$ | $5.52\cdot10^{14}$ | $1.50\cdot10^{15}$ | $5.17\cdot10^{15}$ |

### $^{108m}$Ag

Max. No. of Atoms $\phi_n$

|            | T=0             | T=100            | T=200            | T=400            | T=600            |
|------------|-----------------|------------------|------------------|------------------|------------------|
| No Shielding | $2.29\cdot10^{17}$ | $2.44\cdot10^{17}$ | $2.48\cdot10^{17}$ | $2.58\cdot10^{17}$ | $2.68\cdot10^{17}$ |
| LiH Shell  | $2.25\cdot10^{17}$ | $2.41\cdot10^{17}$ | $2.51\cdot10^{17}$ | $2.74\cdot10^{17}$ | $2.95\cdot10^{17}$ |
| LiH+1mm Pb | $2.38\cdot10^{17}$ | $2.43\cdot10^{17}$ | $2.54\cdot10^{17}$ | $2.80\cdot10^{17}$ | $3.04\cdot10^{17}$ |
| LiH+2mm Pb | $2.41\cdot10^{17}$ | $2.46\cdot10^{17}$ | $2.58\cdot10^{17}$ | $2.86\cdot10^{17}$ | $3.13\cdot10^{17}$ |
| LiH+5mm Pb | $2.57\cdot10^{17}$ | $2.62\cdot10^{17}$ | $2.75\cdot10^{17}$ | $3.09\cdot10^{17}$ | $3.44\cdot10^{17}$ |
### $^{110m}{\text{Ag}}$

|                  | $\phi_n$ | No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|------------------|----------|--------------|-----------|------------|------------|------------|
|                  | $T=0$    | $T=100$      | $T=200$   | $T=400$    | $T=600$    | $T=100$    |
|                  | $T=0$    | $T=100$      | $T=200$   | $T=400$    | $T=600$    | $T=100$    |
| No Shielding     | $3.12\cdot10^{14}$ | $3.13\cdot10^{14}$ | $3.16\cdot10^{14}$ | $3.19\cdot10^{14}$ | $3.35\cdot10^{14}$ | $2.51\cdot10^{8}$ |
| LiH Shell        | $3.12\cdot10^{14}$ | $3.14\cdot10^{14}$ | $3.17\cdot10^{14}$ | $3.26\cdot10^{14}$ | $3.61\cdot10^{14}$ | $2.51\cdot10^{8}$ |
| LiH+1mm Pb       | $3.16\cdot10^{14}$ | $3.17\cdot10^{14}$ | $3.18\cdot10^{14}$ | $3.30\cdot10^{14}$ | $3.73\cdot10^{14}$ | $2.49\cdot10^{8}$ |
| LiH+2mm Pb       | $3.17\cdot10^{14}$ | $3.18\cdot10^{14}$ | $3.20\cdot10^{14}$ | $3.36\cdot10^{14}$ | $3.86\cdot10^{14}$ | $2.48\cdot10^{8}$ |
| LiH+5mm Pb       | $3.23\cdot10^{14}$ | $3.25\cdot10^{14}$ | $3.32\cdot10^{14}$ | $3.60\cdot10^{14}$ | $4.37\cdot10^{14}$ | $2.42\cdot10^{8}$ |

### $^{111}{\text{Ag}}$

|                  | $\phi_n$ | No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|------------------|----------|--------------|-----------|------------|------------|------------|
|                  | $T=0$    | $T=100$      | $T=200$   | $T=400$    | $T=600$    | $T=100$    |
|                  | $T=0$    | $T=100$      | $T=200$   | $T=400$    | $T=600$    | $T=100$    |
| No Shielding     | $2.87\cdot10^{14}$ | $5.46\cdot10^{14}$ | $7.52\cdot10^{14}$ | $1.64\cdot10^{16}$ | $7.14\cdot10^{16}$ | $3.02\cdot10^{8}$ |
| LiH Shell        | $2.98\cdot10^{14}$ | $5.99\cdot10^{14}$ | $9.04\cdot10^{14}$ | $2.48\cdot10^{16}$ | $9.79\cdot10^{16}$ | $2.75\cdot10^{8}$ |
| LiH+1mm Pb       | $5.10\cdot10^{14}$ | $5.89\cdot10^{14}$ | $8.69\cdot10^{14}$ | $1.27\cdot10^{16}$ | $7.48\cdot10^{16}$ | $2.80\cdot10^{8}$ |
| LiH+2mm Pb       | $8.05\cdot10^{14}$ | $8.78\cdot10^{14}$ | $1.19\cdot10^{15}$ | $1.50\cdot10^{16}$ | $8.18\cdot10^{16}$ | $1.88\cdot10^{8}$ |
| LiH+5mm Pb       | $2.10\cdot10^{15}$ | $2.27\cdot10^{15}$ | $2.94\cdot10^{15}$ | $2.52\cdot10^{16}$ | $1.19\cdot10^{17}$ | $7.28\cdot10^{7}$ |
### $^{109}\text{Cd}$

560 mb [JEFF30 (2005)]

|                  | $\phi_n$ |
|------------------|----------|
|                  | T=0      | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | $1.66 \times 10^{15}$ | $2.63 \times 10^{16}$ | —      | —      | —      | $6.81 \times 10^6$ |
| LiH Shell        | $1.77 \times 10^{15}$ | $4.12 \times 10^{16}$ | —      | —      | —      | $4.35 \times 10^6$ |
| LiH+1mm Pb       | $1.06 \times 10^{17}$ | $9.77 \times 10^{17}$ | —      | —      | —      | $1.83 \times 10^5$ |
| LiH+2mm Pb       | $2.59 \times 10^{18}$ | $2.28 \times 10^{19}$ | —      | —      | —      | $7.85 \times 10^3$ |
| LiH+5mm Pb       | —        | —      | —      | —      | —      | —      |

### $^{115}\text{Cd}$

290 mb [JEFF30 (2005)]

|                  | $\phi_n$ |
|------------------|----------|
|                  | T=0      | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | $2.30 \times 10^{12}$ | $2.37 \times 10^{12}$ | $2.64 \times 10^{12}$ | $1.23 \times 10^{13}$ | $6.24 \times 10^{14}$ | $1.45 \times 10^{11}$ |
| LiH Shell        | $2.24 \times 10^{12}$ | $2.44 \times 10^{12}$ | $3.09 \times 10^{12}$ | $1.58 \times 10^{13}$ | $8.96 \times 10^{14}$ | $1.41 \times 10^{11}$ |
| LiH+1mm Pb       | $2.86 \times 10^{12}$ | $3.07 \times 10^{12}$ | $3.89 \times 10^{12}$ | $1.82 \times 10^{13}$ | $1.02 \times 10^{15}$ | $1.12 \times 10^{11}$ |
| LiH+2mm Pb       | $3.66 \times 10^{12}$ | $3.91 \times 10^{12}$ | $4.93 \times 10^{12}$ | $2.09 \times 10^{13}$ | $1.19 \times 10^{15}$ | $8.82 \times 10^{10}$ |
| LiH+5mm Pb       | $7.44 \times 10^{12}$ | $7.93 \times 10^{12}$ | $9.82 \times 10^{12}$ | $3.20 \times 10^{13}$ | $1.93 \times 10^{15}$ | $4.35 \times 10^{10}$ |
### 115mCd

|          | T=0     | T=100   | T=200   | T=400   | T=600   | T=100   |
|----------|---------|---------|---------|---------|---------|---------|
| No Shielding | 1.41·10^{15} | 2.40·10^{15} | 3.41·10^{15} | 4.59·10^{15} | 6.32·10^{15} | 6.92·10^7 |
| LiH Shell  | 1.47·10^{15} | 2.66·10^{15} | 3.81·10^{15} | 5.34·10^{15} | 7.50·10^{15} | 6.25·10^7 |
| LiH+1mm Pb | 1.38·10^{15} | 1.57·10^{15} | 2.12·10^{15} | 4.13·10^{15} | 6.87·10^{15} | 1.06·10^8 |
| LiH+2mm Pb | 1.96·10^{15} | 2.09·10^{15} | 2.55·10^{15} | 4.45·10^{15} | 7.32·10^{15} | 7.96·10^7 |
| LiH+5mm Pb | 3.17·10^{15} | 3.31·10^{15} | 3.75·10^{15} | 5.52·10^{15} | 8.65·10^{15} | 5.02·10^7 |

### 114mIn

|          | T=0     | T=100   | T=200   | T=400   | T=600   | T=100   |
|----------|---------|---------|---------|---------|---------|---------|
| No Shielding | 8.27·10^{13} | 8.59·10^{13} | 2.75·10^{14} | 1.54·10^{15} | 2.47·10^{15} | 4.49·10^8 |
| LiH Shell  | 8.08·10^{13} | 9.68·10^{13} | 3.85·10^{14} | 1.71·10^{15} | 3.13·10^{15} | 3.98·10^8 |
| LiH+1mm Pb | 2.27·10^{14} | 2.67·10^{14} | 7.98·10^{14} | 1.81·10^{15} | 3.44·10^{15} | 1.44·10^8 |
| LiH+2mm Pb | 5.42·10^{14} | 6.13·10^{14} | 1.21·10^{15} | 1.93·10^{15} | 3.76·10^{15} | 6.28·10^7 |
| LiH+5mm Pb | 1.57·10^{15} | 1.62·10^{15} | 1.81·10^{15} | 2.39·10^{15} | 5.00·10^{15} | 2.38·10^7 |
| Table 1 | \(^{121}\text{Sn}\) | \(^{167}\text{mb}\) Bao et al. (2000) | Max. No. of Atoms | \(\phi_n\) |
|---------|-------------------|-------------------------------|------------------|--------|
| T=0     | T=100             | T=200                         | T=400            | T=600  |
| No Shielding | 1.12 \(\cdot\) 10\(^{15}\) | 7.76 \(\cdot\) 10\(^{15}\) | 1.47 \(\cdot\) 10\(^{17}\) | —     | —     | 7.72 \(\cdot\) 10\(^{7}\) |
| LiH Shell          | 1.22 \(\cdot\) 10\(^{15}\) | 1.03 \(\cdot\) 10\(^{16}\) | 2.13 \(\cdot\) 10\(^{17}\) | —     | —     | 5.80 \(\cdot\) 10\(^{7}\) |
| LiH+1mm Pb         | 7.29 \(\cdot\) 10\(^{15}\) | 1.68 \(\cdot\) 10\(^{16}\) | 9.92 \(\cdot\) 10\(^{16}\) | —     | —     | 3.55 \(\cdot\) 10\(^{7}\) |
| LiH+2mm Pb         | 4.54 \(\cdot\) 10\(^{16}\) | 6.77 \(\cdot\) 10\(^{16}\) | 2.27 \(\cdot\) 10\(^{17}\) | —     | —     | 8.84 \(\cdot\) 10\(^{6}\) |
| LiH+5mm Pb         | 1.01 \(\cdot\) 10\(^{18}\) | 1.01 \(\cdot\) 10\(^{18}\) | 2.35 \(\cdot\) 10\(^{18}\) | —     | —     | 5.95 \(\cdot\) 10\(^{5}\) |

| Table 2 | \(^{121}\text{Sn}\) | \(^{200}\text{mb}\) JEFF3.0 (2005) | Max. No. of Atoms | \(\phi_n\) |
|---------|-------------------|-------------------------------|------------------|--------|
| T=0     | T=100             | T=200                         | T=400            | T=600  | T=100 |
| No Shielding | 2.00 \(\cdot\) 10\(^{17}\) | *                  | *                | —     | —     | *     |
| LiH Shell          | 2.19 \(\cdot\) 10\(^{17}\) | *                  | *                | —     | —     | *     |
| LiH+1mm Pb         | *                  | *                  | *                | —     | —     | *     |
| LiH+2mm Pb         | *                  | *                  | *                | —     | —     | *     |
| LiH+5mm Pb         | *                  | *                  | *                | —     | —     | *     |
### $^{123}\text{Sn}$

|                  | $\phi_n$ |
|------------------|----------|
|                  | T=0     | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 6.76·10^{15} | 1.25·10^{16} | 2.04·10^{16} | 2.91·10^{16} | 3.55·10^{16} | 6.09·10^{7} |
| LiH Shell        | 7.04·10^{15} | 1.44·10^{16} | 2.34·10^{16} | 3.36·10^{16} | 4.24·10^{16} | 5.30·10^{7} |
| LiH+1mm Pb       | 6.66·10^{15} | 7.75·10^{15} | 1.12·10^{16} | 2.49·10^{16} | 3.96·10^{16} | 9.85·10^{7} |
| LiH+2mm Pb       | 1.02·10^{16} | 1.10·10^{16} | 1.39·10^{16} | 2.70·10^{16} | 4.22·10^{16} | 6.94·10^{7} |
| LiH+5mm Pb       | 1.81·10^{16} | 1.89·10^{16} | 2.16·10^{16} | 3.31·10^{16} | 5.03·10^{16} | 4.04·10^{7} |

### $^{125}\text{Sn}$

|                  | $\phi_n$ |
|------------------|----------|
|                  | T=0     | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 5.58·10^{13} | 6.14·10^{13} | 6.53·10^{13} | 7.01·10^{13} | 7.85·10^{13} | 2.76·10^{10} |
| LiH Shell        | 5.59·10^{13} | 6.23·10^{13} | 6.72·10^{13} | 7.51·10^{13} | 8.81·10^{13} | 2.72·10^{10} |
| LiH+1mm Pb       | 5.16·10^{13} | 5.37·10^{13} | 5.90·10^{13} | 7.19·10^{13} | 8.85·10^{13} | 3.15·10^{10} |
| LiH+2mm Pb       | 5.67·10^{13} | 5.81·10^{13} | 6.22·10^{13} | 7.46·10^{13} | 9.24·10^{13} | 2.92·10^{10} |
| LiH+5mm Pb       | 6.56·10^{13} | 6.70·10^{13} | 7.10·10^{13} | 8.39·10^{13} | 1.06·10^{14} | 2.53·10^{10} |
| \( ^{126}\text{Sn} \) | 10 mb Bao et al. (2000) | Max. No. of Atoms | \( \phi_n \) |
|---|---|---|---|
| T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 1.72\cdot10^{19} | 2.30\cdot10^{19} | 2.45\cdot10^{19} | 2.52\cdot10^{19} | 2.92\cdot10^{19} | 4.35\cdot10^{5} |
| LiH Shell | 1.72\cdot10^{19} | 2.35\cdot10^{19} | 2.46\cdot10^{19} | 2.63\cdot10^{19} | 3.37\cdot10^{19} | 4.26\cdot10^{5} |
| LiH+1mm Pb | 2.40\cdot10^{19} | 2.45\cdot10^{19} | 2.48\cdot10^{19} | 2.72\cdot10^{19} | 3.58\cdot10^{19} | 4.08\cdot10^{5} |
| LiH+2mm Pb | 2.46\cdot10^{19} | 2.47\cdot10^{19} | 2.51\cdot10^{19} | 2.82\cdot10^{19} | 3.83\cdot10^{19} | 4.05\cdot10^{5} |
| LiH+5mm Pb | 2.58\cdot10^{19} | 2.61\cdot10^{19} | 2.71\cdot10^{19} | 3.25\cdot10^{19} | 4.74\cdot10^{19} | 3.83\cdot10^{5} |

| \( ^{125}\text{Sb} \) | 260 mb Bao et al. (2000) | Max. No. of Atoms | \( \phi_n \) |
|---|---|---|---|
| T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 1.42\cdot10^{15} | 1.81\cdot10^{15} | 2.34\cdot10^{15} | 3.61\cdot10^{15} | 1.29\cdot10^{16} | 2.13\cdot10^{8} |
| LiH Shell | 1.41\cdot10^{15} | 1.91\cdot10^{15} | 2.61\cdot10^{15} | 4.66\cdot10^{15} | 1.77\cdot10^{16} | 2.02\cdot10^{8} |
| LiH+1mm Pb | 2.35\cdot10^{15} | 2.49\cdot10^{15} | 2.99\cdot10^{15} | 5.37\cdot10^{15} | 2.00\cdot10^{16} | 1.55\cdot10^{8} |
| LiH+2mm Pb | 2.77\cdot10^{15} | 2.92\cdot10^{15} | 3.43\cdot10^{15} | 6.18\cdot10^{15} | 2.25\cdot10^{16} | 1.32\cdot10^{8} |
| LiH+5mm Pb | 4.27\cdot10^{15} | 4.48\cdot10^{15} | 5.21\cdot10^{15} | 9.33\cdot10^{15} | 3.27\cdot10^{16} | 8.58\cdot10^{7} |
### 126Sb

|                | T=0     | T=100   | T=200   | T=400   | T=600   | T=100  |
|----------------|---------|---------|---------|---------|---------|--------|
| No Shielding   | 1.55·10^{13} | 1.55·10^{13} | 1.55·10^{13} | 1.57·10^{13} | 1.72·10^{13} | 1.21·10^{10} |
| LiH Shell      | 1.55·10^{13} | 1.55·10^{13} | 1.55·10^{13} | 1.61·10^{13} | 1.93·10^{13} | 1.21·10^{10} |
| LiH+1mm Pb     | 1.55·10^{13} | 1.55·10^{13} | 1.56·10^{13} | 1.65·10^{13} | 2.03·10^{13} | 1.21·10^{10} |
| LiH+2mm Pb     | 1.55·10^{13} | 1.55·10^{13} | 1.57·10^{13} | 1.69·10^{13} | 2.15·10^{13} | 1.20·10^{10} |
| LiH+5mm Pb     | 1.59·10^{13} | 1.60·10^{13} | 1.65·10^{13} | 1.88·10^{13} | 2.59·10^{13} | 1.17·10^{10} |

### 127Sb

|                | T=0     | T=100   | T=200   | T=400   | T=600   | T=100  |
|----------------|---------|---------|---------|---------|---------|--------|
| No Shielding   | 5.35·10^{12} | 5.47·10^{12} | 5.71·10^{12} | 7.64·10^{12} | 2.07·10^{13} | 4.70·10^{10} |
| LiH Shell      | 5.25·10^{12} | 5.51·10^{12} | 6.21·10^{12} | 9.40·10^{12} | 2.63·10^{13} | 4.66·10^{10} |
| LiH+1mm Pb     | 5.83·10^{12} | 6.07·10^{12} | 6.88·10^{12} | 1.05·10^{13} | 2.88·10^{13} | 4.24·10^{10} |
| LiH+2mm Pb     | 6.49·10^{12} | 6.76·10^{12} | 7.67·10^{12} | 1.17·10^{13} | 3.14·10^{13} | 3.80·10^{10} |
| LiH+5mm Pb     | 9.05·10^{12} | 9.43·10^{12} | 1.07·10^{13} | 1.63·10^{13} | 4.09·10^{13} | 2.72·10^{10} |
### 127\text{Te} 440 mb JEFF30 (2005)

|                  | T=0     | T=100   | T=200   | T=400   | T=600   | T=100 |
|------------------|---------|---------|---------|---------|---------|-------|
| No Shielding     | 3.28·10^{13} | 4.51·10^{13} | 5.45·10^{13} | 1.27·10^{14} | —       | 5.08·10^{9} |
| LiH Shell        | 3.29·10^{13} | 4.74·10^{13} | 6.30·10^{13} | 1.76·10^{14} | —       | 4.83·10^{9} |
| LiH+1mm Pb       | 4.67·10^{13} | 5.25·10^{13} | 7.07·10^{13} | 2.20·10^{14} | —       | 4.36·10^{9} |
| LiH+2mm Pb       | 6.55·10^{13} | 7.02·10^{13} | 8.92·10^{13} | 2.70·10^{14} | —       | 3.26·10^{9} |
| LiH+5mm Pb       | 1.32·10^{14} | 1.40·10^{14} | 1.73·10^{14} | 5.28·10^{14} | 2.43·10^{18} | 1.63·10^{9} |

### 127\text{mTe} 910 mb JEFF30 (2005)

|                  | T=0     | T=100   | T=200   | T=400   | T=600   | T=100 |
|------------------|---------|---------|---------|---------|---------|-------|
| No Shielding     | 1.17·10^{15} | 4.84·10^{15} | 1.54·10^{16} | 3.56·10^{16} | 2.60·10^{18} | 2.28·10^{7} |
| LiH Shell        | 1.17·10^{15} | 6.38·10^{15} | 1.78·10^{16} | 4.93·10^{16} | 3.75·10^{18} | 1.73·10^{7} |
| LiH+1mm Pb       | 9.41·10^{15} | 1.42·10^{16} | 2.00·10^{16} | 6.13·10^{16} | 3.84·10^{18} | 7.78·10^{6} |
| LiH+2mm Pb       | 1.81·10^{16} | 1.98·10^{16} | 2.52·10^{16} | 7.51·10^{16} | 3.95·10^{18} | 5.57·10^{6} |
| LiH+5mm Pb       | 3.71·10^{16} | 3.95·10^{16} | 4.85·10^{16} | 1.45·10^{17} | 5.96·10^{18} | 2.79·10^{6} |
### 129mTe

| Max. No. of Atoms | $\phi_n$ |
|------------------|---------|
|                  | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 1.48·10^{14} | 2.42·10^{14} | 2.65·10^{14} | 3.51·10^{14} | 6.94·10^{14} | 3.02·10^{14} |
| LiH Shell        | 1.51·10^{14} | 2.48·10^{14} | 2.91·10^{14} | 4.31·10^{14} | 9.00·10^{14} | 2.95·10^{14} |
| LiH+1mm Pb       | 2.24·10^{14} | 2.40·10^{14} | 2.86·10^{14} | 4.54·10^{14} | 9.60·10^{14} | 3.05·10^{14} |
| LiH+2mm Pb       | 2.66·10^{14} | 2.79·10^{14} | 3.23·10^{14} | 5.04·10^{14} | 1.05·10^{15} | 2.62·10^{14} |
| LiH+5mm Pb       | 3.83·10^{14} | 4.00·10^{14} | 4.54·10^{14} | 6.85·10^{14} | 1.40·10^{15} | 1.83·10^{14} |

### 131mTe

| Max. No. of Atoms | $\phi_n$ |
|------------------|---------|
|                  | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 1.48·10^{12} | 1.57·10^{12} | 1.97·10^{12} | 2.23·10^{12} | 2.74·10^{12} | 4.26·10^{11} |
| LiH Shell        | 1.47·10^{12} | 1.63·10^{12} | 2.05·10^{12} | 2.43·10^{12} | 3.16·10^{12} | 4.12·10^{11} |
| LiH+1mm Pb       | 1.87·10^{12} | 1.92·10^{12} | 2.12·10^{12} | 2.51·10^{12} | 3.32·10^{12} | 3.49·10^{11} |
| LiH+2mm Pb       | 2.03·10^{12} | 2.07·10^{12} | 2.21·10^{12} | 2.63·10^{12} | 3.50·10^{12} | 3.23·10^{11} |
| LiH+5mm Pb       | 2.33·10^{12} | 2.37·10^{12} | 2.52·10^{12} | 3.03·10^{12} | 4.15·10^{12} | 2.83·10^{11} |
| 129I          | 441 mb Bao et al. (2000) | Max. No. of Atoms | \( \phi_n \) |
|--------------|--------------------------|-------------------|-------------|
| T=0   | T=100  | T=200 | T=400 | T=600 | T=100 |
| No Shielding | *       | *     | —     | —     | —     | —     | *     |
| LiH Shell    | *       |       |       | —     | —     | —     | —     |
| LiH+1mm Pb   | —       |       | —     | —     | —     | —     | —     |
| LiH+2mm Pb   | —       |       | —     | —     | —     | —     | —     |
| LiH+5mm Pb   | —       |       | —     | —     | —     | —     | —     |

| 130I          | 480 mb JEFF30 (2005) | Max. No. of Atoms | \( \phi_n \) |
|--------------|----------------------|-------------------|-------------|
| T=0   | T=100  | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 6.41\times10^{11} | 6.42\times10^{11} | 6.42\times10^{11} | 6.55\times10^{11} | 8.17\times10^{11} | 3.26\times10^{11} |
| LiH Shell    | 6.41\times10^{11} | 6.42\times10^{11} | 6.45\times10^{11} | 6.84\times10^{11} | 9.69\times10^{11} | 3.26\times10^{11} |
| LiH+1mm Pb   | 6.62\times10^{11} | 6.43\times10^{11} | 6.49\times10^{11} | 7.05\times10^{11} | 1.04\times10^{12} | 3.25\times10^{11} |
| LiH+2mm Pb   | 6.45\times10^{11} | 6.47\times10^{11} | 6.57\times10^{11} | 7.31\times10^{11} | 1.12\times10^{12} | 3.23\times10^{11} |
| LiH+5mm Pb   | 6.74\times10^{11} | 6.82\times10^{11} | 7.08\times10^{11} | 8.44\times10^{11} | 1.41\times10^{12} | 3.07\times10^{11} |
|        | $^{131}\text{I}$ | Max. No. of Atoms | $\phi_n$ | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
|--------|-------------------|-------------------|---------|-----|-------|-------|-------|-------|-------|
| No Shielding | 1.15·10^{13} | 1.20·10^{13} | 1.34·10^{13} | 9.14·10^{13} | 3.45·10^{14} | 6.87·10^{10} |
| LiH Shell | 1.12·10^{13} | 1.24·10^{13} | 1.56·10^{13} | 1.24·10^{14} | 4.69·10^{14} | 6.68·10^{10} |
| LiH+1mm Pb | 1.45·10^{13} | 1.55·10^{13} | 1.97·10^{13} | 1.49·10^{14} | 5.27·10^{14} | 5.32·10^{10} |
| LiH+2mm Pb | 1.85·10^{13} | 1.98·10^{13} | 2.51·10^{13} | 1.78·10^{14} | 5.89·10^{14} | 4.18·10^{10} |
| LiH+5mm Pb | 3.85·10^{13} | 4.11·10^{13} | 5.15·10^{13} | 2.91·10^{14} | 8.30·10^{14} | 2.01·10^{10} |

|        | $^{131}\text{mXe}$ | Max. No. of Atoms | $\phi_n$ | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
|--------|----------------------|-------------------|---------|-----|-------|-------|-------|-------|-------|
| No Shielding | 2.61·10^{13} | 2.80·10^{13} | 8.45·10^{14} | —   | —     | —     | —     | 4.07·10^{10} |
| LiH Shell | 2.56·10^{13} | 3.32·10^{13} | 1.36·10^{15} | —   | —     | —     | —     | 3.43·10^{10} |
| LiH+1mm Pb | 1.38·10^{14} | 1.80·10^{14} | 7.58·10^{15} | —   | —     | —     | —     | 6.33·10^{9} |
| LiH+2mm Pb | 7.54·10^{14} | 9.78·10^{14} | 4.30·10^{16} | —   | —     | —     | —     | 1.16·10^{9} |
| LiH+5mm Pb | 1.21·10^{17} | 1.57·10^{17} | 9.27·10^{18} | —   | —     | —     | —     | 7.23·10^{6} |
|          | $^{133}$Xe                       | 130 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|----------|---------------------------------|----------------------|-------------------|---------|
|          | T=0                             | T=100                | T=200             | T=400   | T=600   | T=100 |
| No Shielding | 7.76·10^{12}       | 1.02·10^{14}       | 7.55·10^{16}   | 1.13·10^{18} | — | 7.71·10^{9} |
| LiH Shell   | 7.71·10^{12}       | 1.63·10^{14}       | 1.03·10^{17}   | 1.92·10^{18} | — | 4.82·10^{9} |
| LiH+1mm Pb  | 9.35·10^{13}       | 1.96·10^{15}       | 1.54·10^{17}   | 2.18·10^{18} | — | 4.02·10^{8} |
| LiH+2mm Pb  | 1.15·10^{15}       | 2.08·10^{16}       | 2.19·10^{17}   | 2.04·10^{18} | — | 3.79·10^{7} |
| LiH+5mm Pb  | 3.40·10^{17}       | 4.14·10^{17}       | 6.17·10^{17}   | 4.08·10^{18} | — | 1.90·10^{6} |

|          | $^{133m}$Xe                    | 88 mb JEFF30 (2005)  | Max. No. of Atoms | $\phi_n$ |
|----------|--------------------------------|---------------------|-------------------|---------|
|          | T=0                             | T=100                | T=200             | T=400   | T=600   | T=100 |
| No Shielding | 3.39·10^{12}       | 3.48·10^{12}       | 4.63·10^{12}   | —       | —       | 3.28·10^{11} |
| LiH Shell   | 3.31·10^{12}       | 3.78·10^{12}       | 6.44·10^{12}   | —       | —       | 3.01·10^{11} |
| LiH+1mm Pb  | 6.54·10^{12}       | 7.48·10^{12}       | 1.30·10^{13}   | —       | —       | 1.52·10^{11} |
| LiH+2mm Pb  | 1.31·10^{13}       | 1.50·10^{13}       | 2.63·10^{13}   | —       | —       | 7.57·10^{10} |
| LiH+5mm Pb  | 1.11·10^{14}       | 1.27·10^{14}       | 2.22·10^{14}   | —       | —       | 8.96·10^{9} |
|          | 134Cs | 664 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|----------|-------|--------------------------|-------------------|---------|
| T=0      | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 3.08·10^{15} | * | — | — | — | * |
| LiH Shell | 9.57·10^{14} | 9.61·10^{14} | 9.81·10^{14} | 1.09·10^{15} | 1.65·10^{15} | 1.57·10^{8} |
| LiH+1mm Pb | 9.65·10^{14} | 9.72·10^{14} | 1.00·10^{15} | 1.14·10^{15} | 1.78·10^{15} | 1.55·10^{8} |
| LiH+2mm Pb | 9.80·10^{14} | 9.91·10^{14} | 1.03·10^{15} | 1.20·10^{15} | 1.92·10^{15} | 1.52·10^{8} |
| LiH+5mm Pb | 1.07·10^{15} | 1.09·10^{15} | 1.15·10^{15} | 1.42·10^{15} | 2.43·10^{15} | 1.38·10^{8} |

|          | 135Cs | 160 mb Patronis et al. (2004) | Max. No. of Atoms | $\phi_n$ |
|----------|-------|--------------------------|-------------------|---------|
| T=0      | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | * | * | * | — | — | — | * |
| LiH Shell | * | * | — | — | — | — | * |
| LiH+1mm Pb | * | * | — | — | — | — | * |
| LiH+2mm Pb | * | * | — | — | — | — | * |
| LiH+5mm Pb | — | — | — | — | — | — | — |
|                | 136Cs | 280 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|----------------|-------|-----------------------|-------------------|----------|
|                |       |                       |                   |          |
|                | T=0   | T=100                 | T=200             | T=400    | T=600    | T=100    |
| No Shielding  | 1.51·10^{13} | 1.52·10^{13} | 1.66·10^{13} | 1.73·10^{13} | 1.91·10^{13} | 2.39·10^{10} |
| LiH Shell      | 1.50·10^{13} | 1.53·10^{13} | 1.68·10^{13} | 1.82·10^{13} | 2.12·10^{13} | 2.36·10^{10} |
| LiH+1mm Pb     | 1.63·10^{13} | 1.64·10^{13} | 1.71·10^{13} | 1.87·10^{13} | 2.21·10^{13} | 2.20·10^{10} |
| LiH+2mm Pb     | 1.67·10^{13} | 1.69·10^{13} | 1.74·10^{13} | 1.92·10^{13} | 2.31·10^{13} | 2.15·10^{10} |
| LiH+5mm Pb     | 1.77·10^{13} | 1.79·10^{13} | 1.86·10^{13} | 2.12·10^{13} | 2.66·10^{13} | 2.02·10^{10} |
|                |       |                       |                   |          |
|                | 137Cs | 280 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|                |       |                       |                   |          |
|                | T=0   | T=100                 | T=200             | T=400    | T=600    | T=100    |
| No Shielding  | 7.82·10^{15} | 7.91·10^{15} | 8.16·10^{15} | 1.01·10^{16} | 1.44·10^{16} | 4.48·10^{7}  |
| LiH Shell      | 7.62·10^{15} | 7.91·10^{15} | 8.77·10^{15} | 1.20·10^{16} | 1.92·10^{16} | 4.48·10^{7}  |
| LiH+1mm Pb     | 8.12·10^{15} | 8.43·10^{15} | 9.41·10^{15} | 1.32·10^{16} | 2.15·10^{16} | 4.20·10^{7}  |
| LiH+2mm Pb     | 8.76·10^{15} | 9.10·10^{15} | 1.02·10^{16} | 1.44·10^{16} | 2.39·10^{16} | 3.90·10^{7}  |
| LiH+5mm Pb     | 1.13·10^{16} | 1.18·10^{16} | 1.32·10^{16} | 1.90·10^{16} | 3.32·10^{16} | 3.01·10^{7}  |
### 140La

**220 mb**, JEFF30 (2005)

| No Shielding | T=0    | T=100  | T=200  | T=400  | T=600  | T=100  |
|--------------|--------|--------|--------|--------|--------|--------|
|              | 2.14·10^{12} | 2.15·10^{12} | 2.16·10^{12} | 2.25·10^{12} | 2.52·10^{12} | 2.14·10^{11} |
| LiH Shell    | 2.13·10^{12} | 2.14·10^{12} | 2.18·10^{12} | 2.37·10^{12} | 2.75·10^{12} | 2.14·10^{11} |
| LiH+1mm Pb   | 2.14·10^{12} | 2.16·10^{12} | 2.21·10^{12} | 2.43·10^{12} | 2.83·10^{12} | 2.12·10^{11} |
| LiH+2mm Pb   | 2.17·10^{12} | 2.19·10^{12} | 2.25·10^{12} | 2.49·10^{12} | 2.92·10^{12} | 2.09·10^{11} |
| LiH+5mm Pb   | 2.29·10^{12} | 2.32·10^{12} | 2.41·10^{12} | 2.72·10^{12} | 3.23·10^{12} | 1.98·10^{11} |

### 141Ce

**76 mb**, Bao et al. (2000)

| No Shielding | T=0    | T=100  | T=200  | T=400  | T=600  | T=100  |
|--------------|--------|--------|--------|--------|--------|--------|
|              | 6.56·10^{13} | 1.35·10^{14} | 6.82·10^{16} | *     | —      | 9.73·10^{9} |
| LiH Shell    | 6.47·10^{13} | 1.73·10^{14} | 1.15·10^{17} | 6.75·10^{19} | —      | 7.58·10^{9} |
| LiH+1mm Pb   | 8.27·10^{14} | 1.77·10^{15} | 2.97·10^{17} | 5.06·10^{19} | —      | 7.44·10^{8} |
| LiH+2mm Pb   | 9.50·10^{15} | 1.70·10^{16} | 7.18·10^{17} | 2.02·10^{19} | —      | 7.74·10^{7} |
| LiH+5mm Pb   | 1.73·10^{18} | 2.09·10^{18} | 3.37·10^{18} | *     | —      | 6.31·10^{5} |
### 143\(^{\text{Ce}}\)

|                | \(\phi_n\) |
|----------------|-------------|
| Max. No. of Atoms |             |
| \(T=0\)         | 1.95\(\times10^{12}\) |
| \(T=100\)       | 3.04\(\times10^{12}\) |
| \(T=200\)       | 3.45\(\times10^{12}\) |
| \(T=400\)       | 1.51\(\times10^{13}\) |
| \(T=600\)       | 2.42\(\times10^{13}\) |
| \(T=100\)       | 3.51\(\times10^{11}\) |

| Shielding       | \(\phi_n\) |
|-----------------|-------------|
| No Shielding    |             |
| LiH Shell       |             |
| LiH+1mm Pb      |             |
| LiH+2mm Pb      |             |
| LiH+5mm Pb      |             |

### 142\(^{\text{Pr}}\)

|                | \(\phi_n\) |
|----------------|-------------|
| Max. No. of Atoms |             |
| \(T=0\)         | 1.43\(\times10^{13}\) |
| \(T=100\)       | 1.99\(\times10^{13}\) |
| \(T=200\)       | 2.53\(\times10^{13}\) |
| \(T=400\)       | 3.06\(\times10^{13}\) |
| \(T=600\)       | 3.36\(\times10^{13}\) |
| \(T=100\)       | 1.21\(\times10^{10}\) |

| Shielding       | \(\phi_n\) |
|-----------------|-------------|
| No Shielding    |             |
| LiH Shell       |             |
| LiH+1mm Pb      |             |
| LiH+2mm Pb      |             |
| LiH+5mm Pb      |             |
| 143Pr | 350 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|-------|--------------------------|-------------------|---------|
|       | $T=0$ | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding | 2.04·10^{15} | 6.23·10^{15} | 2.51·10^{16} | 2.78·10^{17} | 4.23·10^{18} | 4.59·10^{7} |
| LiH Shell | 2.15·10^{15} | 8.34·10^{15} | 4.04·10^{16} | 6.51·10^{17} | 2.82·10^{19} | 3.43·10^{7} |
| LiH+1mm Pb | 2.92·10^{15} | 3.80·10^{15} | 7.29·10^{15} | 6.69·10^{16} | 1.11·10^{18} | 7.52·10^{7} |
| LiH+2mm Pb | 6.28·10^{15} | 7.09·10^{15} | 1.10·10^{16} | 7.68·10^{16} | 1.02·10^{18} | 4.03·10^{7} |
| LiH+5mm Pb | 2.15·10^{16} | 2.32·10^{16} | 3.06·10^{16} | 1.34·10^{17} | 1.60·10^{18} | 1.23·10^{7} |

| 147Nd | 544 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|-------|--------------------------|-------------------|---------|
|       | $T=0$ | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding | 2.32·10^{13} | 2.13·10^{14} | 3.04·10^{14} | 5.75·10^{14} | 4.77·10^{15} | 8.62·10^{8} |
| LiH Shell | 2.38·10^{13} | 2.37·10^{14} | 3.42·10^{14} | 7.73·10^{14} | 6.52·10^{15} | 7.77·10^{8} |
| LiH+1mm Pb | 2.81·10^{14} | 3.13·10^{14} | 3.86·10^{14} | 9.21·10^{14} | 7.19·10^{15} | 5.88·10^{8} |
| LiH+2mm Pb | 3.60·10^{14} | 3.82·10^{14} | 4.62·10^{14} | 1.09·10^{15} | 7.93·10^{15} | 4.81·10^{8} |
| LiH+5mm Pb | 6.31·10^{14} | 6.67·10^{14} | 7.99·10^{14} | 1.80·10^{15} | 1.11·10^{16} | 2.75·10^{8} |
### 147Pm

| No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|--------------|-----------|------------|------------|------------|
| T=0 | T=100 | T=200 | T=400 | T=600 |
| 709 mb Reifarth et al. (2003a) | Max. No. of Atoms | \( \phi_n \) | \( \phi_n \) |
|\( 4.02\times10^{18} \) | \( 5.15\times10^{19} \) | * | * | * |
|\( 4.20\times10^{18} \) | \( 8.53\times10^{19} \) | * | * | * |

### 148Pm

| No Shielding | LiH Shell | LiH+1mm Pb | LiH+2mm Pb | LiH+5mm Pb |
|--------------|-----------|------------|------------|------------|
| T=0 | T=100 | T=200 | T=400 | T=600 |
| 2970 mb Bao et al. (2000) | Max. No. of Atoms | \( \phi_n \) | \( \phi_n \) |
|\( 1.55\times10^{13} \) | \( 1.64\times10^{13} \) | \( 1.70\times10^{13} \) | \( 1.90\times10^{13} \) | \( 2.67\times10^{13} \) |
|\( 1.53\times10^{13} \) | \( 1.65\times10^{13} \) | \( 1.77\times10^{13} \) | \( 2.11\times10^{13} \) | \( 3.08\times10^{13} \) |
|\( 1.54\times10^{13} \) | \( 1.59\times10^{13} \) | \( 1.73\times10^{13} \) | \( 2.14\times10^{13} \) | \( 3.17\times10^{13} \) |
|\( 1.65\times10^{13} \) | \( 1.69\times10^{13} \) | \( 1.82\times10^{13} \) | \( 2.25\times10^{13} \) | \( 3.32\times10^{13} \) |
|\( 1.93\times10^{13} \) | \( 1.98\times10^{13} \) | \( 2.13\times10^{13} \) | \( 2.63\times10^{13} \) | \( 3.85\times10^{13} \) |

\( 147Pm \)  
\( 148Pm \)
### 148mPm

- **4000 mb JEFF3.0 (2005)**

|          | $T=0$     | $T=100$    | $T=200$    | $T=400$    | $T=600$    | $T=100$ |
|----------|-----------|------------|------------|------------|------------|---------|
| No Shielding | 5.18·10^{13} | 5.43·10^{13} | 5.44·10^{13} | 5.58·10^{13} | 7.64·10^{13} | 4.60·10^{8} |
| LiH Shell   | 5.18·10^{13} | 5.43·10^{13} | 5.46·10^{13} | 5.85·10^{13} | 9.21·10^{13} | 4.60·10^{8} |
| LiH+1mm Pb  | 5.43·10^{13} | 5.44·10^{13} | 5.50·10^{13} | 6.06·10^{13} | 9.94·10^{13} | 4.59·10^{8} |
| LiH+2mm Pb  | 5.46·10^{13} | 5.48·10^{13} | 5.58·10^{13} | 6.32·10^{13} | 1.07·10^{14} | 4.56·10^{8} |
| LiH+5mm Pb  | 5.75·10^{13} | 5.82·10^{13} | 6.06·10^{13} | 7.39·10^{13} | 1.37·10^{14} | 4.30·10^{8} |

### 149Pm

- **2510 mb Bao et al. (2000)**

|          | $T=0$     | $T=100$    | $T=200$    | $T=400$    | $T=600$    | $T=100$ |
|----------|-----------|------------|------------|------------|------------|---------|
| No Shielding | 6.11·10^{13} | 7.68·10^{13} | 9.61·10^{13} | 9.67·10^{14} | 1.72·10^{15} | 5.19·10^{8} |
| LiH Shell   | 6.08·10^{13} | 8.23·10^{13} | 1.19·10^{14} | 1.18·10^{15} | 2.21·10^{15} | 4.84·10^{8} |
| LiH+1mm Pb  | 8.71·10^{13} | 9.88·10^{13} | 1.43·10^{14} | 1.03·10^{15} | 2.25·10^{15} | 4.03·10^{8} |
| LiH+2mm Pb  | 1.37·10^{14} | 1.51·10^{14} | 2.06·10^{14} | 1.14·10^{15} | 2.45·10^{15} | 2.64·10^{8} |
| LiH+5mm Pb  | 3.81·10^{14} | 4.10·10^{14} | 5.19·10^{14} | 1.50·10^{15} | 3.16·10^{15} | 9.71·10^{7} |
|          | 151\text{Sm} | 3080 mb Marrone et al. (2006) |
|----------|---------------|-------------------------------|
|          | Max. No. of Atoms | $\phi_n$                      |
|          | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | * | — | — | — | — | — |
| LiH Shell | * | — | — | — | — | — |
| LiH+1mm Pb | — | — | — | — | — | — |
| LiH+2mm Pb | — | — | — | — | — | — |
| LiH+5mm Pb | — | — | — | — | — | — |

|          | 153\text{Sm} | 1095 mb Bao et al. (2000) |
|----------|---------------|----------------------------|
|          | Max. No. of Atoms | $\phi_n$                      |
|          | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 3.37$\times$10^{12} | 1.88$\times$10^{13} | 1.14$\times$10^{15} | 1.96$\times$10^{15} | 1.85$\times$10^{16} | 4.86$\times$10^{9} |
| LiH Shell | 3.36$\times$10^{12} | 2.83$\times$10^{13} | 1.32$\times$10^{15} | 2.47$\times$10^{15} | 2.48$\times$10^{16} | 3.22$\times$10^{9} |
| LiH+1mm Pb | 5.04$\times$10^{13} | 3.70$\times$10^{14} | 1.13$\times$10^{15} | 2.77$\times$10^{15} | 3.05$\times$10^{16} | 2.47$\times$10^{8} |
| LiH+2mm Pb | 5.10$\times$10^{14} | 9.95$\times$10^{14} | 1.45$\times$10^{15} | 3.19$\times$10^{15} | 3.17$\times$10^{16} | 9.18$\times$10^{7} |
| LiH+5mm Pb | 2.00$\times$10^{15} | 2.11$\times$10^{15} | 2.52$\times$10^{15} | 4.77$\times$10^{15} | 5.11$\times$10^{16} | 4.33$\times$10^{7} |
| \(^{152}\)Eu   | 7600 mb Bao et al. (2000) | Max. No. of Atoms | \(\phi_n\) |
|-----------------|--------------------------|------------------|----------|
|                 | T=0  | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding    | 2.23\(\cdot10^{16}\) | 2.41\(\cdot10^{16}\) | 2.55\(\cdot10^{16}\) | 3.07\(\cdot10^{16}\) | 3.69\(\cdot10^{16}\) | 5.47\(\cdot10^{5}\) |
| LiH Shell       | 2.22\(\cdot10^{16}\) | 2.42\(\cdot10^{16}\) | 2.65\(\cdot10^{16}\) | 3.43\(\cdot10^{16}\) | 4.33\(\cdot10^{16}\) | 5.45\(\cdot10^{5}\) |
| LiH+1mm Pb      | 2.51\(\cdot10^{16}\) | 2.58\(\cdot10^{16}\) | 2.78\(\cdot10^{16}\) | 3.59\(\cdot10^{16}\) | 4.58\(\cdot10^{16}\) | 5.11\(\cdot10^{5}\) |
| LiH+2mm Pb      | 2.64\(\cdot10^{16}\) | 2.71\(\cdot10^{16}\) | 2.94\(\cdot10^{16}\) | 3.77\(\cdot10^{16}\) | 4.82\(\cdot10^{16}\) | 4.85\(\cdot10^{5}\) |
| LiH+5mm Pb      | 3.11\(\cdot10^{16}\) | 3.21\(\cdot10^{16}\) | 3.47\(\cdot10^{16}\) | 4.38\(\cdot10^{16}\) | 5.68\(\cdot10^{16}\) | 4.10\(\cdot10^{5}\) |

| \(^{154}\)Eu   | 4420 mb Bao et al. (2000) | Max. No. of Atoms | \(\phi_n\) |
|-----------------|--------------------------|------------------|----------|
|                 | T=0  | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding    | 4.23\(\cdot10^{15}\) | 4.69\(\cdot10^{15}\) | 4.94\(\cdot10^{15}\) | 5.29\(\cdot10^{15}\) | 6.10\(\cdot10^{15}\) | 4.82\(\cdot10^{6}\) |
| LiH Shell       | 4.22\(\cdot10^{15}\) | 4.71\(\cdot10^{15}\) | 5.07\(\cdot10^{15}\) | 5.79\(\cdot10^{15}\) | 7.09\(\cdot10^{15}\) | 4.80\(\cdot10^{6}\) |
| LiH+1mm Pb      | 4.81\(\cdot10^{15}\) | 4.92\(\cdot10^{15}\) | 5.20\(\cdot10^{15}\) | 6.02\(\cdot10^{15}\) | 7.47\(\cdot10^{15}\) | 4.60\(\cdot10^{6}\) |
| LiH+2mm Pb      | 4.96\(\cdot10^{15}\) | 5.07\(\cdot10^{15}\) | 5.38\(\cdot10^{15}\) | 6.27\(\cdot10^{15}\) | 7.87\(\cdot10^{15}\) | 4.46\(\cdot10^{6}\) |
| LiH+5mm Pb      | 5.53\(\cdot10^{15}\) | 5.67\(\cdot10^{15}\) | 6.05\(\cdot10^{15}\) | 7.18\(\cdot10^{15}\) | 9.27\(\cdot10^{15}\) | 3.99\(\cdot10^{6}\) |
### 155\text{Eu}

Max. No. of Atoms

|            | $T=0$     | $T=100$   | $T=200$   | $T=400$   | $T=600$   | $T=100$ |
|------------|-----------|-----------|-----------|-----------|-----------|---------|
| No Shielding | $4.26 \times 10^{15}$ | $3.13 \times 10^{18}$ | * | — | — | 2.42 \times 10^4 |
| LiH Shell   | $4.37 \times 10^{15}$ | $4.75 \times 10^{18}$ | * | — | — | 1.59 \times 10^4 |
| LiH+1mm Pb  | $9.47 \times 10^{18}$ | * | — | — | — | — |
| LiH+2mm Pb  | *           | *           | — | — | — | — |
| LiH+5mm Pb  | —           | —           | — | — | — | — |

### 156\text{Eu}

Max. No. of Atoms

|            | $T=0$     | $T=100$   | $T=200$   | $T=400$   | $T=600$   | $T=100$ |
|------------|-----------|-----------|-----------|-----------|-----------|---------|
| No Shielding | $2.84 \times 10^{13}$ | $2.99 \times 10^{13}$ | $3.05 \times 10^{13}$ | $3.19 \times 10^{13}$ | $3.47 \times 10^{13}$ | $3.06 \times 10^9$ |
| LiH Shell   | $2.83 \times 10^{13}$ | $2.98 \times 10^{13}$ | $3.10 \times 10^{13}$ | $3.41 \times 10^{13}$ | $3.87 \times 10^{13}$ | $3.07 \times 10^9$ |
| LiH+1mm Pb  | $2.89 \times 10^{13}$ | $2.95 \times 10^{13}$ | $3.09 \times 10^{13}$ | $3.47 \times 10^{13}$ | $4.01 \times 10^{13}$ | $3.10 \times 10^9$ |
| LiH+2mm Pb  | $2.97 \times 10^{13}$ | $3.03 \times 10^{13}$ | $3.17 \times 10^{13}$ | $3.57 \times 10^{13}$ | $4.17 \times 10^{13}$ | $3.02 \times 10^9$ |
| LiH+5mm Pb  | $3.22 \times 10^{13}$ | $3.29 \times 10^{13}$ | $3.45 \times 10^{13}$ | $3.95 \times 10^{13}$ | $4.72 \times 10^{13}$ | $2.78 \times 10^9$ |
| $^{153}\text{Gd}$ | 4550 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|-----------------|--------------------------|------------------|--------|
|                 | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding    | 3.33·10^{14} | 6.03·10^{16} | 6.52·10^{19} | —     | —     | 3.64·10^{5} |
| LiH Shell       | 3.36·10^{14} | 9.24·10^{16} | *     | —     | —     | 2.38·10^{5} |
| LiH+1mm Pb      | 6.13·10^{16} | 2.67·10^{18} | *     | —     | —     | 8.23·10^{3} |
| LiH+2mm Pb      | 1.44·10^{18} | 2.94·10^{19} | *     | —     | —     | 7.47·10^{2} |
| LiH+5mm Pb      | —     | —     | —     | —     | —     | —     |

| $^{159}\text{Gd}$ | 520 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|-----------------|--------------------------|------------------|--------|
|                 | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding    | 3.13·10^{12} | 8.70·10^{12} | 9.93·10^{12} | 1.07·10^{14} | 1.07·10^{14} | 1.07·10^{14} | 2.19·10^{10} |
| LiH Shell       | 3.13·10^{12} | 9.02·10^{12} | 1.17·10^{13} | 1.17·10^{13} | 1.57·10^{14} | 6.64·10^{15} | 2.12·10^{10} |
| LiH+1mm Pb      | 1.02·10^{13} | 1.11·10^{13} | 1.45·10^{13} | 1.45·10^{13} | 1.97·10^{14} | 6.51·10^{15} | 1.72·10^{10} |
| LiH+2mm Pb      | 1.36·10^{13} | 1.46·10^{13} | 1.88·10^{13} | 1.88·10^{13} | 2.51·10^{14} | 7.82·10^{15} | 1.31·10^{10} |
| LiH+5mm Pb      | 3.01·10^{13} | 3.24·10^{13} | 4.14·10^{13} | 4.14·10^{13} | 5.40·10^{14} | 1.06·10^{16} | 5.90·10^{9} |
|                  | 2700 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|------------------|-----------------------|-------------------|----------|
|                  | T=0       | T=100  | T=200  | T=400  | T=600  | T=100  |
| No Shielding     | $8.01 \cdot 10^{16}$ | $6.11 \cdot 10^{17}$ | —       | —       | —       | $5.97 \cdot 10^{4}$ |
| LiH Shell        | $7.95 \cdot 10^{16}$ | $9.67 \cdot 10^{17}$ | —       | —       | —       | $3.77 \cdot 10^{4}$ |
| LiH+1mm Pb       | $1.44 \cdot 10^{18}$ | $1.79 \cdot 10^{19}$ | —       | —       | —       | $2.04 \cdot 10^{3}$ |
| LiH+2mm Pb       | $2.57 \cdot 10^{19}$ | *       | —       | —       | —       | *      |
| LiH+5mm Pb       | *          | —       | —       | —       | —       | —      |
|                  | 3600 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |
|                  | T=0       | T=100  | T=200  | T=400  | T=600  | T=100  |
| No Shielding     | $3.88 \cdot 10^{17}$ | $4.90 \cdot 10^{17}$ | $5.53 \cdot 10^{17}$ | $6.13 \cdot 10^{17}$ | $7.67 \cdot 10^{17}$ | $5.73 \cdot 10^{4}$ |
| LiH Shell        | $3.88 \cdot 10^{17}$ | $4.99 \cdot 10^{17}$ | $5.80 \cdot 10^{17}$ | $6.94 \cdot 10^{17}$ | $9.22 \cdot 10^{17}$ | $5.62 \cdot 10^{4}$ |
| LiH+1mm Pb       | $5.19 \cdot 10^{17}$ | $5.52 \cdot 10^{17}$ | $6.08 \cdot 10^{17}$ | $7.32 \cdot 10^{17}$ | $9.83 \cdot 10^{17}$ | $5.08 \cdot 10^{4}$ |
| LiH+2mm Pb       | $5.66 \cdot 10^{17}$ | $5.86 \cdot 10^{17}$ | $6.38 \cdot 10^{17}$ | $7.72 \cdot 10^{17}$ | $1.05 \cdot 10^{18}$ | $4.79 \cdot 10^{4}$ |
| LiH+5mm Pb       | $6.66 \cdot 10^{17}$ | $6.87 \cdot 10^{17}$ | $7.46 \cdot 10^{17}$ | $9.15 \cdot 10^{17}$ | $1.27 \cdot 10^{18}$ | $4.09 \cdot 10^{4}$ |
### 160\(^{\text{Tb}}\)

3240 mb [Bao et al. (2000)]

| Max. No. of Atoms | \(\phi_n\) |
|-------------------|------------|
| \(T=0\)          | \(T=100\)  | \(T=200\) | \(T=400\) | \(T=600\) | \(T=100\) |
| No Shielding      | 9.48\(\times\)10\(^{13}\) | 1.00\(\times\)10\(^{14}\) | 1.03\(\times\)10\(^{14}\) | 1.16\(\times\)10\(^{14}\) | 1.41\(\times\)10\(^{14}\) | 3.08\(\times\)10\(^{8}\) |
| LiH Shell         | 9.41\(\times\)10\(^{13}\) | 9.99\(\times\)10\(^{13}\) | 1.07\(\times\)10\(^{14}\) | 1.30\(\times\)10\(^{14}\) | 1.67\(\times\)10\(^{14}\) | 3.09\(\times\)10\(^{8}\) |
| LiH+1mm Pb        | 1.01\(\times\)10\(^{14}\) | 1.04\(\times\)10\(^{14}\) | 1.12\(\times\)10\(^{14}\) | 1.37\(\times\)10\(^{14}\) | 1.77\(\times\)10\(^{14}\) | 2.98\(\times\)10\(^{8}\) |
| LiH+2mm Pb        | 1.06\(\times\)10\(^{14}\) | 1.09\(\times\)10\(^{14}\) | 1.17\(\times\)10\(^{14}\) | 1.44\(\times\)10\(^{14}\) | 1.88\(\times\)10\(^{14}\) | 2.84\(\times\)10\(^{8}\) |
| LiH+5mm Pb        | 1.23\(\times\)10\(^{14}\) | 1.27\(\times\)10\(^{14}\) | 1.37\(\times\)10\(^{14}\) | 1.68\(\times\)10\(^{14}\) | 2.25\(\times\)10\(^{14}\) | 2.44\(\times\)10\(^{8}\) |

### 161\(^{\text{Tb}}\)

1400 mb [JEFF30 (2005)]

| Max. No. of Atoms | \(\phi_n\) |
|-------------------|------------|
| \(T=0\)          | \(T=100\)  | \(T=200\) | \(T=400\) | \(T=600\) | \(T=100\) |
| No Shielding      | 1.11\(\times\)10\(^{13}\) | 5.69\(\times\)10\(^{14}\) | 5.79\(\times\)10\(^{15}\) | 2.01\(\times\)10\(^{16}\) | 6.07\(\times\)10\(^{17}\) | 1.26\(\times\)10\(^{8}\) |
| LiH Shell         | 1.12\(\times\)10\(^{13}\) | 8.57\(\times\)10\(^{14}\) | 6.80\(\times\)10\(^{15}\) | 2.60\(\times\)10\(^{16}\) | 6.16\(\times\)10\(^{17}\) | 8.36\(\times\)10\(^{7}\) |
| LiH+1mm Pb        | 3.79\(\times\)10\(^{14}\) | 4.41\(\times\)10\(^{15}\) | 8.20\(\times\)10\(^{15}\) | 3.16\(\times\)10\(^{16}\) | 7.84\(\times\)10\(^{17}\) | 1.62\(\times\)10\(^{7}\) |
| LiH+2mm Pb        | 3.57\(\times\)10\(^{15}\) | 7.92\(\times\)10\(^{15}\) | 1.08\(\times\)10\(^{16}\) | 3.44\(\times\)10\(^{16}\) | 8.45\(\times\)10\(^{17}\) | 9.05\(\times\)10\(^{6}\) |
| LiH+5mm Pb        | 1.69\(\times\)10\(^{16}\) | 1.81\(\times\)10\(^{16}\) | 2.21\(\times\)10\(^{16}\) | 5.28\(\times\)10\(^{16}\) | 1.35\(\times\)10\(^{18}\) | 3.96\(\times\)10\(^{6}\) |
|          | $^{159}$Dy | 1500 mb JEFF30, (2005) | Max. No. of Atoms | $\phi_n$ |
|----------|------------|-------------------------|------------------|--------|
|          |            |                         |                  |        |
| T=0      | T=100      | T=200                   | T=400            | T=600  |
| No Shielding | 2.04·10^{14} | 1.59·10^{15} | 2.90·10^{19} | —     | —     | 4.11·10^{7} |
| LiH Shell | 2.03·10^{14} | 2.50·10^{15} | 3.10·10^{19} | —     | —     | 2.61·10^{7} |
| LiH+1mm Pb | 3.70·10^{15} | 4.70·10^{16} | 6.92·10^{19} | —     | —     | 1.39·10^{6} |
| LiH+2mm Pb | 6.88·10^{16} | 8.56·10^{17} | 8.99·10^{19} | *     | —     | 7.63·10^{4} |
| LiH+5mm Pb | 6.00·10^{19} | 8.18·10^{19} | 8.18·10^{19} | —     | —     | 7.99·10^{2} |

|          | $^{163}$Ho | 2125 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|----------|------------|---------------------------|------------------|--------|
|          |            |                           |                  |        |
| T=0      | T=100      | T=200                     | T=400            | T=600  |
| No Shielding | 2.95·10^{18} | *                        | —                | —     | —     | *          |
| LiH Shell | 2.99·10^{18} | *                        | —                | —     | —     | *          |
| LiH+1mm Pb | *          | *                        | —                | —     | —     | *          |
| LiH+2mm Pb | *          | —                        | —                | —     | —     | —          |
| LiH+5mm Pb | —          | —                        | —                | —     | —     | —          |
### 166Ho 1400 mb JEFF30 (2005)

|          | T=0     | T=100   | T=200   | T=400   | T=600   | T=100 |
|----------|---------|---------|---------|---------|---------|-------|
| No Shielding | 3.17·10^{12} | 2.67·10^{13} | 8.72·10^{13} | 1.18·10^{14} | 1.34·10^{14} | 2.65·10^{9} |
| LiH Shell | 3.17·10^{12} | 3.59·10^{13} | 9.78·10^{13} | 1.33·10^{14} | 1.55·10^{14} | 1.97·10^{9} |
| LiH+1mm Pb | 1.76·10^{13} | 3.35·10^{13} | 4.69·10^{13} | 9.07·10^{13} | 1.34·10^{14} | 2.11·10^{9} |
| LiH+2mm Pb | 3.99·10^{13} | 4.60·10^{13} | 5.62·10^{13} | 9.65·10^{13} | 1.40·10^{14} | 1.54·10^{9} |
| LiH+5mm Pb | 6.95·10^{13} | 7.24·10^{13} | 8.12·10^{13} | 1.16·10^{14} | 1.61·10^{14} | 9.77·10^{8} |

### 166mHo 1400 mb JEFF30 (2005)

|          | T=0     | T=100   | T=200   | T=400   | T=600   | T=100 |
|----------|---------|---------|---------|---------|---------|-------|
| No Shielding | 5.47·10^{17} | 5.49·10^{17} | 5.56·10^{17} | 5.92·10^{17} | 8.18·10^{17} | 1.29·10^{5} |
| LiH Shell | 5.47·10^{17} | 5.50·10^{17} | 5.66·10^{17} | 6.44·10^{17} | 9.76·10^{17} | 1.29·10^{5} |
| LiH+1mm Pb | 5.55·10^{17} | 5.60·10^{17} | 5.80·10^{17} | 6.76·10^{17} | 1.05·10^{18} | 1.27·10^{5} |
| LiH+2mm Pb | 5.67·10^{17} | 5.74·10^{17} | 5.99·10^{17} | 7.13·10^{17} | 1.12·10^{18} | 1.24·10^{5} |
| LiH+5mm Pb | 6.29·10^{17} | 6.42·10^{17} | 6.83·10^{17} | 8.54·10^{17} | 1.40·10^{18} | 1.10·10^{5} |
### $^{169}\text{Er}$  
653 mb  \cite{Bao2000}  
Max. No. of Atoms $\phi_n$

|                | T=0       | T=100     | T=200     | T=400     | T=600     | T=100 |
|----------------|-----------|-----------|-----------|-----------|-----------|-------|
| No Shielding   | 1.27·10^{16} | 1.06·10^{17} | 3.09·10^{18} | —         | —         | 1.45·10^6 |
| LiH Shell      | 1.40·10^{16} | 1.51·10^{17} | 4.19·10^{18} | —         | —         | 1.01·10^6 |
| LiH+1mm Pb     | 1.21·10^{17} | 3.69·10^{17} | 3.91·10^{18} | —         | —         | 4.15·10^5 |
| LiH+2mm Pb     | 7.92·10^{17} | 1.22·10^{18} | 5.86·10^{18} | —         | —         | 1.25·10^5 |
| LiH+5mm Pb     | 2.93·10^{19} | 2.93·10^{19} | 5.86·10^{19} | —         | —         | 5.23·10^3 |

### $^{170}\text{Tm}$  
1870 mb  \cite{Bao2000}  
Max. No. of Atoms $\phi_n$

|                | T=0       | T=100     | T=200     | T=400     | T=600     | T=100 |
|----------------|-----------|-----------|-----------|-----------|-----------|-------|
| No Shielding   | 8.62·10^{14} | 4.19·10^{16} | 2.38·10^{17} | 2.36·10^{18} | 4.71·10^{19} | 1.28·10^6 |
| LiH Shell      | 8.73·10^{14} | 5.88·10^{16} | 3.90·10^{17} | 6.85·10^{18} | *         | 9.09·10^5 |
| LiH+1mm Pb     | 2.18·10^{16} | 3.50·10^{16} | 6.72·10^{16} | 5.73·10^{17} | 9.77·10^{18} | 1.53·10^6 |
| LiH+2mm Pb     | 5.82·10^{16} | 6.64·10^{16} | 1.02·10^{17} | 6.96·10^{17} | 1.01·10^{19} | 8.05·10^5 |
| LiH+5mm Pb     | 1.98·10^{17} | 2.14·10^{17} | 2.77·10^{17} | 1.20·10^{18} | 1.38·10^{19} | 2.50·10^5 |
### $^{171}$Tm

|                  | Max. No. of Atoms | $\phi_n$ |
|------------------|-------------------|---------|
|                  | T=0   | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 5.90·10^{16} | *     | —     | —     | —     | —     |
| LiH Shell        | 5.96·10^{16} | *     | —     | —     | —     | —     |
| LiH+1mm Pb       | 9.33·10^{18} | —     | —     | —     | —     | —     |
| LiH+2mm Pb       | *     | —     | —     | —     | —     | —     |
| LiH+5mm Pb       | —     | —     | —     | —     | —     | —     |

**350 mb** Reifarth et al. (2003b)

### $^{172}$Tm

|                  | Max. No. of Atoms | $\phi_n$ |
|------------------|-------------------|---------|
|                  | T=0   | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 5.14·10^{12} | 1.01·10^{13} | 1.16·10^{13} | 1.25·10^{13} | 1.36·10^{13} | 9.14·10^9 |
| LiH Shell        | 5.11·10^{12} | 1.04·10^{13} | 1.19·10^{13} | 1.36·10^{13} | 1.55·10^{13} | 8.94·10^9 |
| LiH+1mm Pb       | 9.55·10^{12} | 1.08·10^{13} | 1.18·10^{13} | 1.38·10^{13} | 1.60·10^{13} | 8.61·10^9 |
| LiH+2mm Pb       | 1.10·10^{13} | 1.14·10^{13} | 1.22·10^{13} | 1.43·10^{13} | 1.67·10^{13} | 8.14·10^9 |
| LiH+5mm Pb       | 1.25·10^{13} | 1.29·10^{13} | 1.37·10^{13} | 1.60·10^{13} | 1.90·10^{13} | 7.22·10^9 |

**1100 mb** JEFF30 (2005)
|                | Max. No. of Atoms | $\phi_n$ |
|----------------|------------------|--------|
|                | T=0              | T=100  | T=200  | T=400  | T=600  | T=100 |
| No Shielding   | 4.56·10^{13}     | 1.05·10^{14} | 1.37·10^{14} | 9.23·10^{14} | —     | 1.70·10^{9} |
| LiH Shell      | 4.55·10^{13}     | 1.12·10^{14} | 1.65·10^{14} | 1.36·10^{15} | —     | 1.60·10^{9} |
| LiH+1mm Pb     | 1.52·10^{14}     | 1.69·10^{14} | 2.29·10^{14} | 1.71·10^{15} | —     | 1.06·10^{9} |
| LiH+2mm Pb     | 2.20·10^{14}     | 2.38·10^{14} | 3.15·10^{14} | 2.18·10^{15} | —     | 7.52·10^{8} |
| LiH+5mm Pb     | 5.58·10^{14}     | 6.02·10^{14} | 7.76·10^{14} | 4.61·10^{15} | —     | 2.98·10^{8} |

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|                | Max. No. of Atoms | $\phi_n$ |
|----------------|------------------|--------|
|                | T=0              | T=100  | T=200  | T=400  | T=600  | T=100 |
| No Shielding   | 4.17·10^{13}     | 5.58·10^{13} | 6.87·10^{13} | 2.86·10^{14} | —     | 3.21·10^{9} |
| LiH Shell      | 4.11·10^{13}     | 5.92·10^{13} | 8.13·10^{13} | 4.14·10^{14} | —     | 3.03·10^{9} |
| LiH+1mm Pb     | 7.38·10^{13}     | 8.23·10^{13} | 1.06·10^{14} | 5.26·10^{14} | —     | 2.18·10^{9} |
| LiH+2mm Pb     | 9.99·10^{13}     | 1.07·10^{14} | 1.37·10^{14} | 6.79·10^{14} | —     | 1.67·10^{9} |
| LiH+5mm Pb     | 2.19·10^{14}     | 2.34·10^{14} | 2.95·10^{14} | 1.38·10^{15} | —     | 7.65·10^{8} |
### $^{177}\text{Lu}$

**890 mb JEFF30 (2005)**

Max. No. of Atoms $\phi_n$

|             | T=0   | T=100 | T=200 | T=400 | T=600 | T=100 |
|-------------|-------|-------|-------|-------|-------|-------|
| No Shielding| 4.37$\cdot$10$^{13}$ | 1.03$\cdot$10$^{14}$ | 2.29$\cdot$10$^{14}$ | 1.39$\cdot$10$^{19}$ | —     | 1.09$\cdot$10$^{9}$ |
| LiH Shell   | 4.37$\cdot$10$^{13}$ | 1.17$\cdot$10$^{14}$ | 3.36$\cdot$10$^{14}$ | —     | —     | 9.58$\cdot$10$^{8}$ |
| LiH+1mm Pb  | 2.57$\cdot$10$^{14}$ | 3.26$\cdot$10$^{14}$ | 8.52$\cdot$10$^{14}$ | 2.08$\cdot$10$^{19}$ | —     | 3.44$\cdot$10$^{8}$ |
| LiH+2mm Pb  | 6.93$\cdot$10$^{14}$ | 8.21$\cdot$10$^{14}$ | 2.14$\cdot$10$^{15}$ | 4.17$\cdot$10$^{19}$ | —     | 1.36$\cdot$10$^{8}$ |
| LiH+5mm Pb  | 1.14$\cdot$10$^{16}$ | 1.35$\cdot$10$^{16}$ | 3.46$\cdot$10$^{16}$ | —     | —     | 8.31$\cdot$10$^{6}$ |

### $^{177m}\text{Lu}$

**1.6 mb JEFF30 (2005)**

Max. No. of Atoms $\phi_n$

|             | T=0   | T=100 | T=200 | T=400 | T=600 | T=100 |
|-------------|-------|-------|-------|-------|-------|-------|
| No Shielding| 1.64$\cdot$10$^{14}$ | 1.65$\cdot$10$^{14}$ | 1.70$\cdot$10$^{14}$ | 7.49$\cdot$10$^{14}$ | 4.32$\cdot$10$^{16}$ | 3.92$\cdot$10$^{11}$ |
| LiH Shell   | 1.64$\cdot$10$^{14}$ | 1.65$\cdot$10$^{14}$ | 1.82$\cdot$10$^{14}$ | 1.07$\cdot$10$^{15}$ | 7.66$\cdot$10$^{16}$ | 3.92$\cdot$10$^{11}$ |
| LiH+1mm Pb  | 1.76$\cdot$10$^{14}$ | 1.82$\cdot$10$^{14}$ | 2.23$\cdot$10$^{14}$ | 1.43$\cdot$10$^{15}$ | 1.70$\cdot$10$^{17}$ | 3.54$\cdot$10$^{11}$ |
| LiH+2mm Pb  | 2.14$\cdot$10$^{14}$ | 2.26$\cdot$10$^{14}$ | 2.86$\cdot$10$^{14}$ | 1.83$\cdot$10$^{15}$ | 3.38$\cdot$10$^{17}$ | 2.85$\cdot$10$^{11}$ |
| LiH+5mm Pb  | 4.68$\cdot$10$^{14}$ | 5.01$\cdot$10$^{14}$ | 6.37$\cdot$10$^{14}$ | 3.65$\cdot$10$^{15}$ | 2.22$\cdot$10$^{18}$ | 1.29$\cdot$10$^{11}$ |
### $^{181}\text{Hf}$

| Shielding | $T=0$    | $T=100$   | $T=200$   | $T=400$   | $T=600$   | $T=100$ |
|-----------|----------|-----------|-----------|-----------|-----------|---------|
| No Shielding  | $5.33 \cdot 10^{13}$ | $5.49 \cdot 10^{13}$ | $6.61 \cdot 10^{13}$ | $1.08 \cdot 10^{14}$ | $2.53 \cdot 10^{16}$ | $9.39 \cdot 10^9$ |
| LiH Shell  | $5.31 \cdot 10^{13}$ | $5.67 \cdot 10^{13}$ | $7.45 \cdot 10^{13}$ | $1.43 \cdot 10^{14}$ | $4.23 \cdot 10^{16}$ | $9.10 \cdot 10^9$ |
| LiH+1mm Pb  | $6.78 \cdot 10^{13}$ | $7.20 \cdot 10^{13}$ | $8.67 \cdot 10^{13}$ | $1.68 \cdot 10^{14}$ | $1.29 \cdot 10^{17}$ | $7.16 \cdot 10^9$ |
| LiH+2mm Pb  | $8.09 \cdot 10^{13}$ | $8.54 \cdot 10^{13}$ | $1.02 \cdot 10^{14}$ | $1.98 \cdot 10^{14}$ | $1.70 \cdot 10^{17}$ | $6.04 \cdot 10^9$ |
| LiH+5mm Pb  | $1.33 \cdot 10^{14}$ | $1.40 \cdot 10^{14}$ | $1.66 \cdot 10^{14}$ | $3.22 \cdot 10^{14}$ | $2.67 \cdot 10^{17}$ | $3.68 \cdot 10^9$ |

### $^{182}\text{Hf}$

| Shielding | $T=0$    | $T=100$   | $T=200$   | $T=400$   | $T=600$   | $T=100$ |
|-----------|----------|-----------|-----------|-----------|-----------|---------|
| No Shielding  | *        | *         | *         | *         | *         | *       |
| LiH Shell  | *        | *         | *         | *         | *         | *       |
| LiH+1mm Pb  | *        | *         | *         | *         | *         | *       |
| LiH+2mm Pb  | *        | *         | *         | *         | *         | *       |
| LiH+5mm Pb  | *        | *         | *         | *         | *         | *       |
|                      | 1334 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|----------------------|----------------------------|-------------------|----------|
|                      |                            | $T=0$  | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding         | 9.81·10^{14}               | 1.85·10^{17}      | —       | —       | —       |         | 4.06·10^{5} |
| LiH Shell            | 9.84·10^{14}               | 3.09·10^{17}      | —       | —       | —       |         | 2.42·10^{5} |
| LiH+1mm Pb           | 3.70·10^{16}               | 1.29·10^{19}      | —       | —       | —       |         | 5.82·10^{3} |
| LiH+2mm Pb           | 1.40·10^{18}               | *                  | —       | —       | —       |         | *     |
| LiH+5mm Pb           | —                           | —                  | —       | —       | —       |         | —     |

|                      | 1120 mb Bao et al. (2000) | Max. No. of Atoms | $\phi_n$ |
|----------------------|----------------------------|-------------------|----------|
|                      |                            | $T=0$  | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding         | 1.46·10^{14}               | 1.79·10^{14}      | 1.96·10^{14} | 2.22·10^{14} | 2.45·10^{14} |         | 4.98·10^{8} |
| LiH Shell            | 1.46·10^{14}               | 1.81·10^{14}      | 2.04·10^{14} | 2.44·10^{14} | 2.84·10^{14} |         | 4.93·10^{8} |
| LiH+1mm Pb           | 1.86·10^{14}               | 1.94·10^{14}      | 2.11·10^{14} | 2.52·10^{14} | 2.97·10^{14} |         | 4.60·10^{8} |
| LiH+2mm Pb           | 1.99·10^{14}               | 2.05·10^{14}      | 2.21·10^{14} | 2.62·10^{14} | 3.12·10^{14} |         | 4.35·10^{8} |
| LiH+5mm Pb           | 2.28·10^{14}               | 2.35·10^{14}      | 2.52·10^{14} | 2.98·10^{14} | 3.63·10^{14} |         | 3.80·10^{8} |
| 183Ta    | 700 mb JEFF30 (2005) | Max. No. of Atoms | $\phi_n$ |  |
|----------|----------------------|------------------|---------|---|
|          | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 3.21·10^{12} | 4.28·10^{12} | 1.19·10^{13} | 6.86·10^{14} | — | 3.32·10^{10} |
| LiH Shell    | 3.20·10^{12} | 5.08·10^{12} | 1.53·10^{13} | 1.01·10^{15} | 3.18·10^{19} | 2.80·10^{10} |
| LiH+1mm Pb   | 1.27·10^{13} | 1.60·10^{13} | 2.49·10^{13} | 1.43·10^{15} | 3.18·10^{19} | 8.87·10^{9} |
| LiH+2mm Pb   | 2.39·10^{13} | 2.67·10^{13} | 3.91·10^{13} | 1.89·10^{15} | 3.18·10^{19} | 5.32·10^{9} |
| LiH+5mm Pb   | 8.76·10^{13} | 9.58·10^{13} | 1.32·10^{14} | 4.19·10^{15} | 3.18·10^{19} | 1.49·10^{9} |

| 185W     | 687 mb Sonnabend et al. (2003) | Max. No. of Atoms | $\phi_n$ |  |
|----------|----------------------|------------------|---------|---|
|          | T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | 4.29·10^{16} | 2.49·10^{17} | 5.08·10^{18} | — | — | 5.85·10^{5} |
| LiH Shell    | 4.51·10^{16} | 3.55·10^{17} | 8.06·10^{18} | — | — | 4.10·10^{5} |
| LiH+1mm Pb   | 2.90·10^{17} | 6.48·10^{17} | 2.77·10^{18} | * | — | 2.25·10^{5} |
| LiH+2mm Pb   | 1.60·10^{18} | 2.16·10^{18} | 5.92·10^{18} | — | — | 6.73·10^{4} |
| LiH+5mm Pb   | 1.80·10^{19} | 1.95·10^{19} | 2.92·10^{19} | — | — | 7.48·10^{3} |
### 187\(^{\text{W}}\)  

| Max. No. of Atoms | \(\phi_{n}\) |
|------------------|-------------|
| T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | \(1.88 \cdot 10^{12}\) | \(1.98 \cdot 10^{12}\) | \(2.09 \cdot 10^{12}\) | \(2.67 \cdot 10^{12}\) | \(6.07 \cdot 10^{12}\) | \(3.26 \cdot 10^{11}\) |
| LiH Shell | \(1.85 \cdot 10^{12}\) | \(1.99 \cdot 10^{12}\) | \(2.28 \cdot 10^{12}\) | \(3.29 \cdot 10^{12}\) | \(8.00 \cdot 10^{12}\) | \(3.24 \cdot 10^{11}\) |
| LiH+1mm Pb | \(2.08 \cdot 10^{12}\) | \(2.18 \cdot 10^{12}\) | \(2.48 \cdot 10^{12}\) | \(3.66 \cdot 10^{12}\) | \(8.85 \cdot 10^{12}\) | \(2.95 \cdot 10^{11}\) |
| LiH+2mm Pb | \(2.31 \cdot 10^{12}\) | \(2.42 \cdot 10^{12}\) | \(2.74 \cdot 10^{12}\) | \(4.09 \cdot 10^{12}\) | \(9.84 \cdot 10^{12}\) | \(2.67 \cdot 10^{11}\) |
| LiH+5mm Pb | \(3.16 \cdot 10^{12}\) | \(3.30 \cdot 10^{12}\) | \(3.74 \cdot 10^{12}\) | \(5.64 \cdot 10^{12}\) | \(1.33 \cdot 10^{13}\) | \(1.95 \cdot 10^{11}\) |

### 186\(^{\text{Re}}\)  

| Max. No. of Atoms | \(\phi_{n}\) |
|------------------|-------------|
| T=0 | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding | \(2.28 \cdot 10^{13}\) | \(1.24 \cdot 10^{14}\) | \(4.00 \cdot 10^{15}\) | \(1.15 \cdot 10^{16}\) | \(2.11 \cdot 10^{16}\) | \(5.20 \cdot 10^{8}\) |
| LiH Shell | \(2.28 \cdot 10^{13}\) | \(1.61 \cdot 10^{14}\) | \(5.49 \cdot 10^{15}\) | \(1.51 \cdot 10^{16}\) | \(2.78 \cdot 10^{16}\) | \(4.02 \cdot 10^{8}\) |
| LiH+1mm Pb | \(2.69 \cdot 10^{14}\) | \(6.41 \cdot 10^{14}\) | \(1.49 \cdot 10^{15}\) | \(7.28 \cdot 10^{15}\) | \(2.44 \cdot 10^{16}\) | \(1.01 \cdot 10^{8}\) |
| LiH+2mm Pb | \(1.14 \cdot 10^{15}\) | \(1.42 \cdot 10^{15}\) | \(2.14 \cdot 10^{15}\) | \(8.42 \cdot 10^{15}\) | \(2.72 \cdot 10^{16}\) | \(4.53 \cdot 10^{7}\) |
| LiH+5mm Pb | \(3.59 \cdot 10^{15}\) | \(3.85 \cdot 10^{15}\) | \(4.78 \cdot 10^{15}\) | \(1.27 \cdot 10^{16}\) | \(3.94 \cdot 10^{16}\) | \(1.68 \cdot 10^{7}\) |
### 186mRe

|       | T=0      | T=100    | T=200    | T=400    | T=600    | T=100    |
|-------|----------|----------|----------|----------|----------|----------|
| No Shielding | 6.33×10^{19} | * | * | * | * | * | *
| LiH Shell     | 6.38×10^{19} | * | * | * | * | * | *
| LiH+1mm Pb    | *          | * | * | * | * | * | *
| LiH+2mm Pb    | *          | * | * | * | * | * | *
| LiH+5mm Pb    | *          | * | * | * | * | * | *

### 188Re

|       | T=0      | T=100    | T=200    | T=400    | T=600    | T=100    |
|-------|----------|----------|----------|----------|----------|----------|
| No Shielding | 3.07×10^{12} | 6.43×10^{12} | 2.37×10^{13} | 3.26×10^{13} | 5.62×10^{13} | 2.44×10^{10} |
| LiH Shell     | 3.05×10^{12} | 7.70×10^{12} | 2.64×10^{13} | 3.87×10^{13} | 6.99×10^{13} | 2.04×10^{10} |
| LiH+1mm Pb    | 9.36×10^{12} | 1.15×10^{13} | 1.67×10^{13} | 3.01×10^{13} | 5.91×10^{13} | 1.36×10^{10} |
| LiH+2mm Pb    | 1.50×10^{13} | 1.61×10^{13} | 1.96×10^{13} | 3.29×10^{13} | 6.40×10^{13} | 9.74×10^{9} |
| LiH+5mm Pb    | 2.41×10^{13} | 2.51×10^{13} | 2.84×10^{13} | 4.29×10^{13} | 8.04×10^{13} | 6.24×10^{9} |
### 189Re

| Max. No. of Atoms | $\phi_n$ |
|------------------|---------|
|                  | T=0     | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 4.12·10^{12} | 6.94·10^{12} | 1.16·10^{13} | 1.01·10^{14} | 9.17·10^{14} | 3.02·10^{10} |
| LiH Shell        | 4.08·10^{12} | 7.74·10^{12} | 1.56·10^{13} | 1.30·10^{14} | 1.32·10^{15} | 2.70·10^{10} |
| LiH+1mm Pb       | 1.26·10^{13} | 1.54·10^{13} | 2.67·10^{13} | 1.46·10^{14} | 1.46·10^{15} | 1.36·10^{10} |
| LiH+2mm Pb       | 2.47·10^{13} | 2.78·10^{13} | 4.36·10^{13} | 1.70·10^{14} | 1.68·10^{15} | 7.53·10^{9} |
| LiH+5mm Pb       | 8.47·10^{13} | 9.09·10^{13} | 1.16·10^{14} | 2.59·10^{14} | 2.50·10^{15} | 2.30·10^{9} |

#### 191Os

| Max. No. of Atoms | $\phi_n$ |
|------------------|---------|
|                  | T=0     | T=100 | T=200 | T=400 | T=600 | T=100 |
| No Shielding     | 2.09·10^{13} | 4.05·10^{14} | 4.17·10^{18} | — | — | 1.91·10^{8} |
| LiH Shell        | 2.10·10^{13} | 6.08·10^{14} | 6.00·10^{18} | — | — | 1.27·10^{8} |
| LiH+1mm Pb       | 3.27·10^{14} | 1.07·10^{16} | — | — | — | 7.22·10^{6} |
| LiH+2mm Pb       | 4.71·10^{15} | 1.92·10^{17} | 9.60·10^{19} | — | — | 4.03·10^{5} |
| LiH+5mm Pb       | 2.40·10^{19} | — | — | — | — | — |
### 193\(^{ }\)Os

| Max. No. of Atoms | \( \phi_n \) | 110 mb JEFF30 (2005) |
|------------------|----------------|----------------------|
| \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding | \( 3.96 \cdot 10^{12} \) | \( 1.06 \cdot 10^{13} \) | \( 1.70 \cdot 10^{13} \) | \( 3.26 \cdot 10^{13} \) | \( 7.28 \cdot 10^{14} \) | \( 8.43 \cdot 10^{10} \) |
| LiH Shell | \( 3.94 \cdot 10^{12} \) | \( 1.18 \cdot 10^{13} \) | \( 1.93 \cdot 10^{13} \) | \( 4.32 \cdot 10^{13} \) | \( 1.01 \cdot 10^{15} \) | \( 7.57 \cdot 10^{10} \) |
| LiH+1mm Pb | \( 1.39 \cdot 10^{13} \) | \( 1.73 \cdot 10^{13} \) | \( 2.21 \cdot 10^{13} \) | \( 5.01 \cdot 10^{13} \) | \( 1.10 \cdot 10^{15} \) | \( 5.14 \cdot 10^{10} \) |
| LiH+2mm Pb | \( 2.03 \cdot 10^{13} \) | \( 2.18 \cdot 10^{13} \) | \( 2.66 \cdot 10^{13} \) | \( 5.87 \cdot 10^{13} \) | \( 1.29 \cdot 10^{15} \) | \( 4.09 \cdot 10^{10} \) |
| LiH+5mm Pb | \( 3.58 \cdot 10^{13} \) | \( 3.78 \cdot 10^{13} \) | \( 4.50 \cdot 10^{13} \) | \( 9.35 \cdot 10^{13} \) | \( 1.86 \cdot 10^{15} \) | \( 2.36 \cdot 10^{10} \) |

### 194\(^{ }\)Os

| Max. No. of Atoms | \( \phi_n \) | 38 mb JEFF30 (2005) |
|------------------|----------------|----------------------|
| \( T=0 \) | \( T=100 \) | \( T=200 \) | \( T=400 \) | \( T=600 \) | \( T=100 \) |
| No Shielding | \( 6.70 \cdot 10^{15} \) | — | — | — | — | — |
| LiH Shell | \( 6.95 \cdot 10^{15} \) | — | — | — | — | — |
| LiH+1mm Pb | * | — | — | — | — | — |
| LiH+2mm Pb | — | — | — | — | — | — |
| LiH+5mm Pb | — | — | — | — | — | — |
### 192Ir

**2080 mb Bao et al. (2000)**

| Max. No. of Atoms | $\phi_n$ |
|-------------------|---------|
|                   | $T=0$  | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding      | 9.77$\cdot10^{13}$ | 1.00$\cdot10^{14}$ | 1.04$\cdot10^{14}$ | 2.21$\cdot10^{14}$ | 1.70$\cdot10^{15}$ | 4.81$\cdot10^{8}$ |
| LiH Shell         | 9.74$\cdot10^{13}$ | 1.01$\cdot10^{14}$ | 1.12$\cdot10^{14}$ | 2.86$\cdot10^{14}$ | 2.34$\cdot10^{15}$ | 4.76$\cdot10^{8}$ |
| LiH+1mm Pb        | 1.08$\cdot10^{14}$ | 1.12$\cdot10^{14}$ | 1.29$\cdot10^{14}$ | 3.33$\cdot10^{14}$ | 2.70$\cdot10^{15}$ | 4.28$\cdot10^{8}$ |
| LiH+2mm Pb        | 1.24$\cdot10^{14}$ | 1.30$\cdot10^{14}$ | 1.52$\cdot10^{14}$ | 3.88$\cdot10^{14}$ | 3.09$\cdot10^{15}$ | 3.70$\cdot10^{8}$ |
| LiH+5mm Pb        | 2.09$\cdot10^{14}$ | 2.21$\cdot10^{14}$ | 2.63$\cdot10^{14}$ | 6.04$\cdot10^{14}$ | 4.54$\cdot10^{15}$ | 2.18$\cdot10^{8}$ |

### 192mIr

**3800 mb JEFF3.0 (2005)**

| Max. No. of Atoms | $\phi_n$ |
|-------------------|---------|
|                   | $T=0$  | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
| No Shielding      | 1.26$\cdot10^{17}$ | 3.25$\cdot10^{17}$ | 3.98$\cdot10^{19}$ | —     | —     | 8.09$\cdot10^{4}$ |
| LiH Shell         | 1.24$\cdot10^{17}$ | 4.16$\cdot10^{17}$ | 6.67$\cdot10^{19}$ | —     | —     | 6.32$\cdot10^{4}$ |
| LiH+1mm Pb        | 1.49$\cdot10^{18}$ | 3.33$\cdot10^{18}$ | *             | —     | —     | 7.89$\cdot10^{3}$ |
| LiH+2mm Pb        | 1.44$\cdot10^{19}$ | 2.47$\cdot10^{19}$ | *             | —     | —     | 1.06$\cdot10^{3}$ |
| LiH+5mm Pb        | *     | *     | —     | —     | —     | *     |
|          | $^{193\text{m}}\text{Ir}$ | $1.0 \text{ mb JEFF30 (2005)}$ | $\phi_n$ | $T=0$ | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
|----------|---------------------------|---------------------------------|---------|-------|--------|--------|--------|--------|--------|
| No Shielding |                          |                                 |         | 1.56·10^{13} | 2.33·10^{14} | —       | —       | —       | 4.25·10^{11} |
| LiH Shell    |                          |                                 |         | 1.56·10^{13} | 3.78·10^{14} | —       | —       | —       | 2.62·10^{11} |
| LiH+1mm Pb   |                          |                                 |         | 1.80·10^{14} | 4.41·10^{15} | —       | —       | —       | 2.25·10^{10} |
| LiH+2mm Pb   |                          |                                 |         | 2.12·10^{15} | 5.41·10^{16} | —       | —       | —       | 1.84·10^{9} |
| LiH+5mm Pb   |                          |                                 |         | 3.13·10^{17} | 6.56·10^{19} | —       | —       | —       | 1.51·10^{6} |

|          | $^{194}\text{Ir}$ | $450 \text{ mb JEFF30 (2005)}$ | $\phi_n$ | $T=0$ | $T=100$ | $T=200$ | $T=400$ | $T=600$ | $T=100$ |
|----------|-------------------|---------------------------------|---------|-------|--------|--------|--------|--------|--------|
| No Shielding |                      |                                 |         | 5.87·10^{12} | 6.88·10^{12} | 8.02·10^{12} | 2.86·10^{13} | 3.90·10^{13} | 3.21·10^{10} |
| LiH Shell    |                      |                                 |         | 5.86·10^{12} | 7.20·10^{12} | 9.14·10^{12} | 3.32·10^{13} | 4.80·10^{13} | 3.06·10^{10} |
| LiH+1mm Pb   |                      |                                 |         | 6.34·10^{12} | 6.88·10^{12} | 8.70·10^{12} | 2.62·10^{13} | 4.24·10^{13} | 3.20·10^{10} |
| LiH+2mm Pb   |                      |                                 |         | 8.25·10^{12} | 8.74·10^{12} | 1.07·10^{13} | 2.84·10^{13} | 4.56·10^{13} | 2.52·10^{10} |
| LiH+5mm Pb   |                      |                                 |         | 1.47·10^{13} | 1.54·10^{13} | 1.80·10^{13} | 3.53·10^{13} | 5.60·10^{13} | 1.43·10^{10} |
### 194mIr

|                | Max. No. of Atoms |      |      |      |      | T=100 |
|----------------|-------------------|------|------|------|------|-------|
| No Shielding   | 2.13\times10^{14} | 2.13\times10^{14} | 2.13\times10^{14} | 2.21\times10^{14} | 4.28\times10^{14} | 1.03\times10^{9} |
| LiH Shell      | 2.13\times10^{14} | 2.13\times10^{14} | 2.13\times10^{14} | 2.35\times10^{14} | 5.43\times10^{14} | 1.03\times10^{9} |
| LiH+1mm Pb     | 2.13\times10^{14} | 2.13\times10^{14} | 2.14\times10^{14} | 2.47\times10^{14} | 6.08\times10^{14} | 1.03\times10^{9} |
| LiH+2mm Pb     | 2.14\times10^{14} | 2.14\times10^{14} | 2.17\times10^{14} | 2.62\times10^{14} | 6.76\times10^{14} | 1.02\times10^{9} |
| LiH+5mm Pb     | 2.26\times10^{14} | 2.29\times10^{14} | 2.40\times10^{14} | 3.25\times10^{14} | 9.31\times10^{14} | 9.59\times10^{8} |

### 193Pt

|                | Max. No. of Atoms |      |      |      |      | T=100 |
|----------------|-------------------|------|------|------|------|-------|
| No Shielding   | 2.73\times10^{16} | 5.37\times10^{17} | —     | —     | —     | 1.66\times10^{5} |
| LiH Shell      | 2.72\times10^{16} | 8.72\times10^{17} | —     | —     | —     | 1.02\times10^{5} |
| LiH+1mm Pb     | 3.21\times10^{17} | 1.06\times10^{19} | —     | —     | —     | 8.41\times10^{3} |
| LiH+2mm Pb     | 3.86\times10^{18} | *     | —     | —     | —     | *     |
| LiH+5mm Pb     | *                 | —     | —     | —     | —     | —     |
### 197⁠ₚₜ

|                | φₙ       |
|----------------|----------|
| No Shielding   | 8.14·10¹⁰ |
| LiH Shell      | 6.19·10¹⁰ |
| LiH+1mm Pb     | 1.62·10¹⁰ |
| LiH+2mm Pb     | 5.43·10⁹  |
| LiH+5mm Pb     | 5.08·10⁸  |

### 195⁠ₐₕ

|                | φₙ       |
|----------------|----------|
| No Shielding   | 1.59·10⁸  |
| LiH Shell      | 1.06·10⁸  |
| LiH+1mm Pb     | 5.37·10⁶  |
| LiH+2mm Pb     | 2.84·10⁵  |
| LiH+5mm Pb     |          |
### 196\text{Au}

|                  | T=0      | T=100    | T=200    | T=400     | T=600     | T=100    |
|------------------|----------|----------|----------|-----------|-----------|----------|
| No Shielding     | 7.81\cdot10^{12} | 8.60\cdot10^{12} | 9.59\cdot10^{12} | 9.39\cdot10^{13} | 3.46\cdot10^{15} | 1.59\cdot10^{10} |
| LiH Shell        | 7.78\cdot10^{12} | 8.85\cdot10^{12} | 1.10\cdot10^{13} | 1.35\cdot10^{14} | 4.51\cdot10^{15} | 1.55\cdot10^{10} |
| LiH+1mm Pb       | 1.02\cdot10^{13} | 1.10\cdot10^{13} | 1.37\cdot10^{13} | 1.80\cdot10^{14} | 5.29\cdot10^{15} | 1.25\cdot10^{10} |
| LiH+2mm Pb       | 1.29\cdot10^{13} | 1.38\cdot10^{13} | 1.74\cdot10^{13} | 2.30\cdot10^{14} | 6.05\cdot10^{15} | 9.92\cdot10^{9}   |
| LiH+5mm Pb       | 2.75\cdot10^{13} | 2.95\cdot10^{13} | 3.76\cdot10^{13} | 4.69\cdot10^{14} | 7.94\cdot10^{15} | 4.65\cdot10^{9}   |

### 198\text{Au}

|                  | T=0      | T=100    | T=200    | T=400     | T=600     | T=100    |
|------------------|----------|----------|----------|-----------|-----------|----------|
| No Shielding     | 3.68\cdot10^{12} | 3.84\cdot10^{12} | 4.14\cdot10^{12} | 8.71\cdot10^{12} | 6.15\cdot10^{14} | 1.39\cdot10^{10} |
| LiH Shell        | 3.59\cdot10^{12} | 3.92\cdot10^{12} | 4.75\cdot10^{12} | 1.24\cdot10^{13} | 7.96\cdot10^{14} | 1.36\cdot10^{10} |
| LiH+1mm Pb       | 4.40\cdot10^{12} | 4.68\cdot10^{12} | 5.69\cdot10^{12} | 1.54\cdot10^{13} | 8.54\cdot10^{14} | 1.14\cdot10^{10} |
| LiH+2mm Pb       | 5.33\cdot10^{12} | 5.66\cdot10^{12} | 6.90\cdot10^{12} | 1.91\cdot10^{13} | 9.46\cdot10^{14} | 9.42\cdot10^{9}   |
| LiH+5mm Pb       | 9.74\cdot10^{12} | 1.03\cdot10^{13} | 1.26\cdot10^{13} | 3.66\cdot10^{13} | 1.24\cdot10^{15} | 5.16\cdot10^{9}   |
| 199Au            | 370 mb JEFF30 (2005) | \( \phi_n \) |
|-----------------|----------------------|--------------|
| No Shielding    | T=0                  | T=100        |
|                 | T=200                | T=400        |
|                 | T=600                | T=100        |
|                 | 4.78 \times 10^{12}  | 1.07 \times 10^{13} | 6.66 \times 10^{13} | — | — | 2.49 \times 10^{10} |
| LiH Shell       | 4.72 \times 10^{12}  | 1.32 \times 10^{13} | 9.87 \times 10^{13} | — | — | 2.03 \times 10^{10} |
| LiH+1mm Pb      | 3.69 \times 10^{13}  | 5.99 \times 10^{13} | 2.61 \times 10^{14} | — | — | 4.46 \times 10^{9} |
| LiH+2mm Pb      | 1.59 \times 10^{14}  | 2.04 \times 10^{14} | 6.71 \times 10^{14} | — | — | 1.31 \times 10^{9} |
| LiH+5mm Pb      | 3.53 \times 10^{15}  | 4.15 \times 10^{15} | 1.13 \times 10^{16} | — | — | 6.44 \times 10^{7} |

| 203Hg            | 98 mb Bao et al. (2000) | \( \phi_n \) |
|-----------------|-------------------------|--------------|
| No Shielding    | T=0                     | T=100        |
|                 | T=200                   | T=400        |
|                 | T=600                   | T=100        |
|                 | 6.47 \times 10^{13}     | 7.72 \times 10^{13} | 9.26 \times 10^{13} | 2.66 \times 10^{19} | — | 1.32 \times 10^{10} |
| LiH Shell       | 6.32 \times 10^{13}     | 8.21 \times 10^{13} | 1.17 \times 10^{14} | 3.65 \times 10^{19} | — | 1.24 \times 10^{10} |
| LiH+1mm Pb      | 1.14 \times 10^{14}     | 1.28 \times 10^{14} | 1.84 \times 10^{14} | 4.87 \times 10^{19} | — | 7.94 \times 10^{9} |
| LiH+2mm Pb      | 1.83 \times 10^{14}     | 2.02 \times 10^{14} | 2.90 \times 10^{14} | 9.75 \times 10^{19} | — | 5.04 \times 10^{9} |
| LiH+5mm Pb      | 7.37 \times 10^{14}     | 8.15 \times 10^{14} | 1.17 \times 10^{15} | * | — | 1.25 \times 10^{9} |
### 204Tl

|       | T=0    | T=100  | T=200  | T=400  | T=600  | T=100 |
|-------|--------|--------|--------|--------|--------|-------|
| No Shielding | 5.88·10^{16} | 3.76·10^{17} | 6.29·10^{18} | *      | —      | 1.24·10^{6} |
| LiH Shell   | 5.93·10^{16} | 5.65·10^{17} | 9.26·10^{18} | *      | —      | 8.23·10^{5} |
| LiH+1mm Pb | 4.28·10^{17} | 8.48·10^{17} | 1.92·10^{18} | 3.21·10^{19} | * | 5.49·10^{5} |
| LiH+2mm Pb | 1.48·10^{18} | 1.82·10^{18} | 3.14·10^{18} | 4.25·10^{19} | * | 2.56·10^{5} |
| LiH+5mm Pb | 6.90·10^{18} | 7.49·10^{18} | 1.03·10^{19} | 6.96·10^{19} | * | 6.21·10^{4} |

### 205Pb

|       | T=0    | T=100  | T=200  | T=400  | T=600  | T=100 |
|-------|--------|--------|--------|--------|--------|-------|
| No Shielding | *      | *      | —      | —      | —      | —     |
| LiH Shell   | *      | *      | —      | —      | —      | —     |
| LiH+1mm Pb | *      | *      | —      | —      | —      | —     |
| LiH+2mm Pb | *      | *      | —      | —      | —      | —     |
| LiH+5mm Pb | —      | —      | —      | —      | —      | —     |
### $^{210}$Bi

|                | $\phi_n$ | $T=0$     | $T=100$    | $T=200$    | $T=400$    | $T=600$    | $T=100$    |
|----------------|----------|-----------|------------|------------|------------|------------|------------|
| No Shielding   |          | $5.25\cdot10^{14}$ | $1.46\cdot10^{15}$ | $5.12\cdot10^{15}$ | $3.89\cdot10^{16}$ | $3.03\cdot10^{17}$ | $1.14\cdot10^{10}$ |
| LiH Shell      |          | $5.60\cdot10^{14}$ | $1.92\cdot10^{15}$ | $7.93\cdot10^{15}$ | $9.06\cdot10^{16}$ | $9.77\cdot10^{17}$ | $8.67\cdot10^{9}$ |
| LiH+1mm Pb     |          | $6.19\cdot10^{14}$ | $7.73\cdot10^{14}$ | $1.37\cdot10^{15}$ | $8.28\cdot10^{15}$ | $6.33\cdot10^{16}$ | $2.16\cdot10^{10}$ |
| LiH+2mm Pb     |          | $1.21\cdot10^{15}$ | $1.35\cdot10^{15}$ | $1.97\cdot10^{15}$ | $9.74\cdot10^{15}$ | $7.55\cdot10^{16}$ | $1.23\cdot10^{10}$ |
| LiH+5mm Pb     |          | $3.54\cdot10^{15}$ | $3.81\cdot10^{15}$ | $4.85\cdot10^{15}$ | $1.57\cdot10^{16}$ | $1.05\cdot10^{17}$ | $4.38\cdot10^{9}$ |

### $^{210m}$Bi

|                | $\phi_n$ | $T=0$     | $T=100$    | $T=200$    | $T=400$    | $T=600$    | $T=100$    |
|----------------|----------|-----------|------------|------------|------------|------------|------------|
| No Shielding   | *        | *         | *          | *          | *          | *          | *          |
| LiH Shell      | *        | *         | *          | *          | *          | *          | *          |
| LiH+1mm Pb     | *        | *         | *          | *          | *          | *          | *          |
| LiH+2mm Pb     | *        | *         | *          | *          | *          | *          | *          |
| LiH+5mm Pb     | *        | *         | *          | *          | *          | *          | *          |
|                | T=0      | T=100    | T=200    | T=400    | T=600    | T=100    |
|----------------|----------|----------|----------|----------|----------|----------|
| No Shielding   | 8.65·10^{15} | 2.08·10^{16} | 5.90·10^{16} | 2.62·10^{17} | 8.52·10^{17} | 1.46·10^{9} |
| LiH Shell      | 9.29·10^{15} | 2.73·10^{16} | 8.83·10^{16} | 4.99·10^{17} | 1.88·10^{18} | 1.11·10^{9} |
| LiH+1mm Pb     | 8.12·10^{15} | 9.79·10^{15} | 1.57·10^{16} | 6.20·10^{16} | 2.46·10^{17} | 3.10·10^{9} |
| LiH+2mm Pb     | 1.42·10^{16} | 1.56·10^{16} | 2.15·10^{16} | 7.11·10^{16} | 2.68·10^{17} | 1.94·10^{9} |
| LiH+5mm Pb     | 3.41·10^{16} | 3.62·10^{16} | 4.45·10^{16} | 1.05·10^{17} | 3.40·10^{17} | 8.38·10^{8} |

210Po 3.3 mb Bao et al. (2000)

Max. No. of Atoms

φₙ
References

Apostolakis, J., 1993. Cern program library long writeup, w5013. Tech. rep., CERN, GEANT library, [http://wwwinfo.cern.ch/asd/geant/].

Bao, Z. Y., Beer, H., Käppeler, F., Voss, F., Wisshak, K., Rauscher, T., 2000. Neutron cross sections for nucleosynthesis studies. Atomic Data Nucl. Data Tables 76, 70.

Bečvář, F., 2000. Statistical γ cascades following thermal and kev neutron capture in heavy nuclei. In: Wender, S. (Ed.), Gamma-Ray Spectroscopy and Related Topics. American Institute of Physics, New York, p. 504.

Borcea, C., Cennini, P., Dahlfors, M., Ferrari, A., García-Munoz, G., Haefner, P., Herrera-Martinez, A., Kadi, Y., Lacoste, V., Radermacher, E., Saldana, F., Vlachoudis, V., Zanini, P., Rubbia, C., Buono, S., Dangendorf, V., Nolte, R., Weierganz, M., Nov 2003. Results from the commissioning of the n-tof spallation neutron source at cern. NIM A 513 (3), 524.

Cano-Ott, D., Abbondanno, U., Aerts, G., Alvarez, H., Alvarez-Velarde, F., Andriamanjery, S., Andrzejewski, J., Assimakopoulos, P., Audouin, L., Badurek, G., Baumann, P., Becvar, F., Benlliure, J., Berlhoumieux, E., Calvino, F., Capote, R., Albornoz, A. C., Cennini, P., Chepel, V., Chiaveri, E., Colonna, N., Cortes, G., Cortina, D., Couture, A., Cox, J., David, S., Dolfini, R., Domingo-Pardo, C., Dridi, W., Duran, I., Embid-Segura, M., Ferrant, L., Ferrari, A., Fitzpatrick, L., Ferreira-Marques, R., Frais-Koebbl, H., Fujii, K., Furman, W., Goncalves, I., Gallino, R., Gonzalez-Romero, E., Goverdovski, A., Graneag, F., Griesmayer, E., Guerrero, C., Gunning, F., Haas, B., Haight, R., Heil, M., Herrera-Martinez, A., Igashira, M., Isaev, S., Jericha, E., Kadi, Y., Käppeler, F., Karamanis, D., Karadimos, D., Kerveno, M., Ketlerov, V., Koehter, P., Konovalov, V., Kossionides, E., Kräicka, M., Lamboudis, C., Leeb, H., Lindote, A., Lopes, I., Lozano, M., Lukic, S., Marganiec, J., Marques, L., Marrone, S., Mastinu, P., Mengoni, A., Milazzo, P. M., Moreau, C., Mosconi, M., Neves, F., Oberhummer, H., O’Brien, S., Oshima, M., Pancin, J., Papachristodouliou, C., Papadopoulos, C., Papaevangelou, T., Paradela, C., Patronis, N., Pavlik, A., Pavlopoulos, P., Perdikaki, G., Perrot, L., Plag, R., Plompen, A., Plukis, A., Poch, A., Pretel, C., Quesada, J., Rauscher, T., Reifarth, R., Rosetti, M., Rubbia, C., Rudolf, G., Rullhusen, P., Salgado, J., Sarchiapone, L., Stephan, C., Tagliente, G., Tain, J. L., Tassan-Got, L., Tavola, L., Terlizzi, R., Vannini, G., Vaz, P., Ventura, A., Villamarín, D., Vincente, M. C., Vlachoudis, V., Vlastou, R., Voss, F., Wendler, H., Wiescher, M., Wisshak, K., 2006. Neutron capture cross section measurements at n-tof of 237np, 240pu and 243am for the transmutation of nuclear waste. AIP Conference Proceedings 819, 318.

Firestone, R. B., 1996. Table of Isotopes. Wiley, New York.

JEFF30, 2005. The jeff-3.0 nuclear data library. Tech. rep., JEFF Report 19, OECD Nuclear Energy Agency, [www.nea.fr/html/dbdata/nds_jeffreports/jeffreport-19/jeffreport-19.pdf].
Käppeler, F., 1999. The origin of the heavy elements: the $s$ process. Prog. Nucl. Part. Phys. 43, 419 – 483.

Käppeler, F., Beer, H., Wisshak, K., 1989. $s$-process nucleosynthesis – nuclear physics and the classical model. Rep. Prog. Phys. 52, 945.

Krane, K. S., 1988. Introductory Nuclear Physics. Wiley.

Lisowski, P. W., Bowman, C. D., Russell, G. J., Wender, S. A., 1990. The los alamos national laboratory spallation neutron sources. Nucl. Sci. Engineering 106, 208.

Lugaro, M., Herwig, F., Lattanzio, J. C., Gallino, R., Straniero, O., 2003. $s$-process nucleosynthesis in asymptotic giant branch stars: A test for stellar evolution. Ap.J. 586, 1305.

Marrone, S., Abbondanno, U., Aerts, G., Alvarez-Velarde, F., Alvarez-Pol, H., Andriamonje, S., Andrzejsk, J., Badurek, G., Baumann, P., Becvar, F., Benlliure, J., Berthomieux, E., Calvino, F., Cano-Ott, D., Capote, R., Cennini, P., Chepel, V., Chiaveri, E., Colonna, N., Cortes, G., Cortina, D., Couture, A., Cox, J., Dababneh, S., Dahlfors, M., David, S., Dolfi, R., Domingo-Pardo, C., Duran-Escribano, I., Embid-Segura, M., Ferrant, L., Ferrari, A., Ferreira-Marques, R., Frais-Koelbl, H., Fujii, K., Furman, W. I., Gallino, R., Goncalves, I. F., Gonzalez-Romero, E., Goverdovski, A., Gramegna, F., Griesmayer, E., Gunsing, F., Haas, B., Haight, R., Heil, M., Herrera-Martinez, A., Isaev, S., Jericha, E., Kappeler, F., Kadi, Y., Karadimos, D., Kerveno, M., Kelterov, V., Koehler, P. E., Konovalov, V., Kritcka, M., Lamboudis, C., Leeb, H., Lindote, A., Lopes, M. I., Lozano, M., Lukic, S., Marganiec, J., Martinez-Val, J., Mastinu, P. F., Mengoni, A., Milazzo, P. M., Molina-Coballes, A., Moreau, C., Mosconi, M., Neves, F., Oberhummer, H., O’Brien, S., Pancin, J., Papavangelou, T., Paradela, C., Pavlik, A., Pavlopoulos, P., Perlado, J. M., Perrot, L., Pignatari, M., Pigni, M. T., Plag, R., Plompen, A., Plukis, A., Poch, A., Policarpo, A., Pretel, C., Quesada, J. M., Raman, S., Rapp, W., Rauscher, T., Reifarth, R., Rosetti, M., Rubbia, C., Rudolf, G., Rubsfusen, P., Salgado, J., Soares, J. C., Stephan, C., Tagliente, G., Tain, J. L., Tassan-Got, L., Tavora, L. M. N., Terlizzi, R., Vannini, G., Vaz, P., Ventura, A., Villamarin-Fernandez, D., Vincente-Vincente, M., Vlachoudis, V., Voss, F., Wendler, H., Wiescher, M., Wisshak, K., n TOF Collaborat, 2006. Measurement of the sm-151($n,\gamma$) cross section from 0.6 ev to 1 mev via the neutron time-of-flight technique at the cern n-tof facility. Phys. Rev. C 73, 034604.

Nassar, H., Paul, M., Ahmad, I., Berkovits, D., Bettan, M., Collon, P., Dababneh, S., Ghelberg, S., Greene, J. P., Heger, A., Heil, M., Henderson, D. J., Jiang, C. L., Käppeler, F., Koivist, H., O’Brien, S., Pardo, R. C., Patronis, N., Pennington, T., Plag, R., Rehm, K. E., Reifarth, R., Scott, R., Sinha, S., Tang, X., Vondrask, R., 2005. Stellar ($n,\gamma$) cross section of ni-62. Phys. Rev. Let. 94, 092504.

Patronis, N., Dababneh, S., Assimakopoulos, P. A., Gallino, R., Heil, M., Käppeler, F., Karamanis, D., Koehler, P. E., Mengoni, A., Plag, R., 2004. Neutron capture studies on unstable cs-135 for nucleosynthesis and trans-
mutation. Phys. Rev. C 69, 025803.
Rauscher, T., Thielemann, F.-K., 2001. reaction rates. Atomic Data Nucl. Data Tables 79, 47.
Reifarth, R., Arlandini, C., Heil, M., Käppeler, F., Sedychev, P., Mengoni, A., Herman, M., Rauscher, T., Gallino, R., Travaglio, C., 2003a. Stellar neutron capture on promethium - implications for the s-process neutron density. Ap. J. 582, 1251.
Reifarth, R., Bredeweg, T. A., Alpizar-Vicente, A., Browne, J. C., Esch, E.-I., Greife, U., Haight, R. C., Hatarik, R., Kronenberg, A., O’Donnell, J. M., Rundberg, R. S., Ullmann, J. L., Vieira, D. J., Wilhelmy, J. B., Wouters, J. M., 2004a. Background identification and suppression for the measurement of (n,γ) reactions with the dance array at lansce. Nucl. Instr. Meth. A 531, 528.
Reifarth, R., Haight, R. C., Heil, M., Fowler, M. M., Käppeler, F., Miller, G. G., Rundberg, R. S., Ullmann, J. L., Wilhelmy, J. B., 2003b. Neutron capture measurements on tm-171. Nucl. Phys. A 718, 478C – 480C.
Reifarth, R., Haight, R. C., Heil, M., Käppeler, F., Vieira, D. J., 2004b. Neutron capture measurements at a ria-type facility. Nucl. Instr. Meth. A 524, 215.
Sonnabend, K., Mohr, P., Vogt, K., Zilges, A., Mengoni, A., Rauscher, T., Beer, H., Käppeler, F., Gallino, R., 2003. The s-process branching at w-185. Ap. J. 583, 506.
Takahashi, K., Yokoi, K., 1987. Beta-decay rates of highly ionized heavy atoms in stellar interiors. Atomic Data Nucl. Data Tables 36, 375.
Walter, S., Heil, M., Käppeler, F., Plag, R., Reifarth, R., 2006. Method for (n,g) cross section measurements on unstable isotopes. AIP Conference Proceedings 819, 307.
Wissak, K., Guber, K., Käppeler, F., Krisch, J., Müller, H., Rupp, G., Voss, F., 1990. The karlsruhe 4π barium fluoride detector. Nucl. Instr. Meth. A 292, 595 – 618.
Wouters, J. M., Vicente, A. A., Bredeweg, T. A., Esch, E., Haight, R. C., Hatarik, R., O’Donnell, J. M., Reifarth, R., Rundberg, R. S., Schwantes, J. M., Sheets, S. A., Ullmann, J. L., Vieira, D. J., Wilhelmy, J. B., June 2006. Acquisition-analysis system for the DANCE (detector for advanced neutron capture experiments) BaF₂ γ-ray calorimeter. IEEE Transactions on Nuclear Science 53 (3), 880.