# Cosmogenic activation of materials

I. G. Irastorza, S. Cebrián, *(University of Zaragoza, Spain)* for the IDEA/ILIAS working group on Cosmogenics

The problem of cosmogenic activation produced at sea level in materials typically used in underground experiments looking for rare events like the double beta decay is being studied by one of the working groups of the IDEA (Integrated Double-beta decay European Activities) project inside the ILIAS (Integrated Large Infrastructures for Astropaticle Science) activity funded by the European Union.

Several nuclear data libraries have been screened looking for relevant isotope production cross-sections, mainly in Te and Ge.

| | EXFOR / CSISRS | MENDL-2, MENDL-2P | Isotope Production Cross-Section Libraries for Neutrons and Protons to 1.7 GeV |
|---|---|---|---|
| *Type of data* | ***experimental*** nuclear reaction data | excitation functions ***calculated*** (ALICE), ***checked*** against some experimental data | excitation functions including available ***experimental data*** and ***calculated results*** (HMS-ALICE, CEM, LAHET) |
| *Reference* | http://www.nndc.bnl.gov/nndc/exfor/, http://www-nds.iaea.or.at | ftp://iaeand.iaea.or.at/ http://www.nea.fr/html/dbdata/data/mendl2.html | *S. G. Mashnik et al, [arXiv:nucl-th/9812071].* *K. A. Van Riper et al, LA-UR-98-5379.* http://t2.lanl.gov/publications/publications.html |
| *Useful data* | Cross-sections for $^{nat}Ge(p,X)^{60}Co$ at 660 MeV $^{nat}Ge(p,X)^{68}Ge$ at 24-64 and 660 MeV $^{nat}Te(p,X)^{A}Sb$ at 1.7 GeV | excitation functions with a very wide range of targets and products, for n (up to 100 MeV) and p (up to 200 MeV) as projectiles | excitation functions up to 1.7 GeV for $^{A}Ge(n,X)^{68}Ge$ $^{A}Ge(p,X)^{68}Ge$ |
| | not enough to make a complete activation study but essential to check calculated results | very valuable for activation studies, even if with a limited energy range for cosmogenics | useful specially for Ge DBD experiments |

+ individual references:

**Ge**: ***Calculated*** neutron-induced excitation functions on Ge isotopes for **$^{68}$Ge** and others *(F. T. Avignone et al., NPB (PS) 28A (1992) 280, H. Miley et al., ibid p.212)* and for **$^{68}$Ge** using ISABEL *(Majorana Collaboration, [arXiv.org:nucl-ex/0311013])*

**Ge:** ***Measured*** production cross section of **$^{60}$Co** by p at 800 MeV *(E. Norman, Poster at Neutrino 2004, Paris. To appear in NPB (PS))*

**Te:** ***Measured*** production cross sections (including $^{60}$Co) at Berkeley with p at 0.8, 1.85 and 5 GeV *(D. W. Bardayan et al, PRC 55 (1997) 820. E. Norman, Poster at Neutrino 2004)*

Different codes which can be applied to activation studies have been reviewed.

### Semiempirical codes

Based on Silberberg&Tsao equations for cross-sections of different processes producing residual nuclei (spallation, fission, …)

*AJS 25 (1973) 315, AJS 25 (1973) 335, AJS 35 (1977) 129, AJS 58 (1985) 873, Phys. Rep. 191 (1990) 351, AJ 501 (1998) 911.*

**COSMO, Σ, YIELDX**

+ wide coverage of targets and products
+ short calculation time and simplicity of use
- only proton-induced reactions

### Hadronic Monte Carlo codes

Many families of codes based on the MC simulation of the hadronic interactions between nucleons and nuclei

**HETC, CEM, LAHET, ISABEL, INUCL, CASCADE, ALICE, SHIELD, MARS, GEM, LAQGSM, …**

+ neutron activation studies possible
- very time-consuming (specially for some products)

### General-purpose MC codes

Some hadronic MC codes are included in the these packages

**GEANT4, FLUKA, MCNPX**

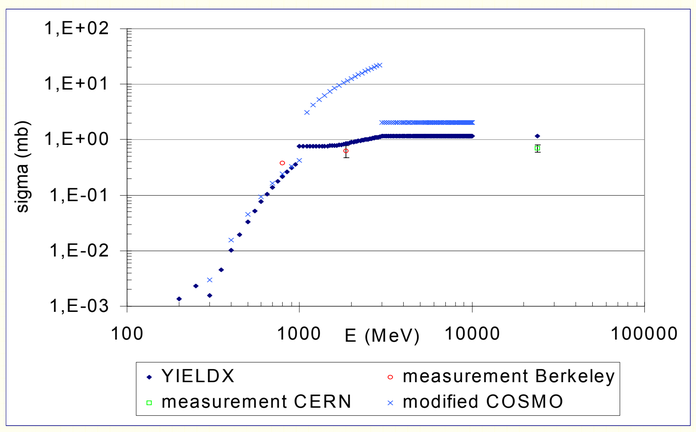
+ neutron activation studies possible
+ wide coverage of projectiles, targets and energies
+ easy availability and support
+ different models can be used for the hadronic physics
- very time-consuming (specially for some products)
- not many comparisons with measurements of activation yields available

The excitation functions and corresponding activation yields for some problems of interest have been derived, taking into account all the available sources.

$$R \propto \int dE\, \sigma(E)\, \phi_n(E)$$

$$A = R(1 - e^{-\lambda t_{exp}})e^{-\lambda t_{dec}}$$

**Cosmic neutron spectrum** from parameterization in *J. F. Ziegler, IBM J. of R&D 42 (1998) 1.*



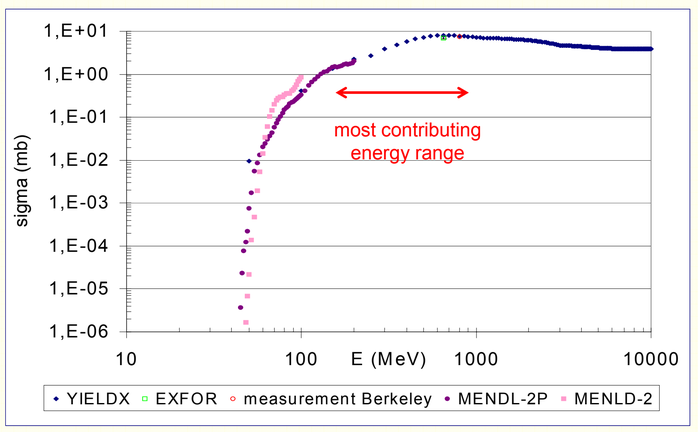

**$^{60}$Co** in $^{nat}$Te

For **$TeO_2$** crystals using YIELDX estimate:

**R=0.06 kg$^{-1}$day$^{-1}$**

$t_{exp}$=4 months, $t_{dec}$=2 years

**A=0.02 μBq/kg**



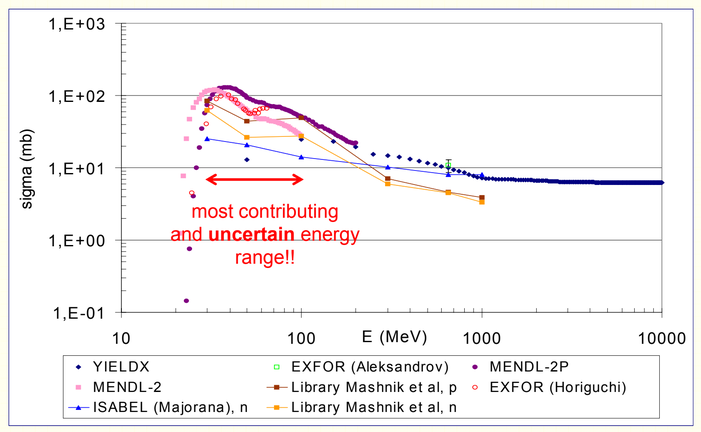

**$^{60}$Co** in $^{nat}$Ge

For **$^{nat}$Ge** using MENDL-2 (-100 MeV), MENDL-2P (100-200 MeV) and YIELDX (>200 MeV):

**R=5.1 kg$^{-1}$day$^{-1}$** in good agreement with estimate in Miley'92!

$t_{exp}$=10 days

**A=0.21 μBq/kg**




**$^{68}$Ge** in $^{nat}$Ge

Important discrepancies in production σ at low energies and by isotope

***Maximal*** activation rate using MENDL-2P (-200 MeV) and YIELDX (>200 MeV) in **$^{nat}$Ge** could be R=147 kg$^{-1}$day$^{-1}$ versus R~30 kg$^{-1}$day$^{-1}$ in Avignone'92 !!