HPRL proposal: deuteron induced Tritium and Beryllium-7 production cross sections and TTY in Lithium

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The Goal of this presentation:

- to show Status of experimental and evaluated data for the deuteron induced Tritium and Beryllium-7 production Cross Sections (XS) and Thick Target Yield (TTY) in elemental Lithium or its isotopes
- to present the Draft of Request

Relevant documents with very detailed information on Status of XS and TTY:

- KIT Scientific Working Papers 147, KIT, Jun 2020
- EFFDOC-1438, JEFF Meetings, OECD/NEA, Nov 2020

However since end of 2020, the JENDL/DEU-2020 was released in Feb 2021:

- endf6 files are available here https://wwwndc.jaea.go.jp/ftpnd/jendl/jendl-deu-2020.html

so the JENDL/DEU-2021 data were additionally included in this presentation
Experimental data: There are no reliable $^6,^7\text{Li}(d,xt)$ experimental data for $E_d$ above 5 - 7 MeV since:
- Tritium counting (i.e. activation) measurements stop at $\approx 7$ MeV
- Tritium spectrometry measurements exist up to 15 MeV but they are $(d,t_i,t \neq i)$, i.e. only part of total $(d,xt)$
  moreover only $t$-discrete forward angular $d\sigma (d,t_i)/d\Omega$ were indeed measured - I fit Legendre polynomials and obtained $\sigma (d,t_i)$

Evaluated data:
- FZK-05 [P.Pereslavtsev et al. NIM B266(2008)3501] looks better than all others, but is it correct above 5 - 7 MeV ?
- ENDF/B-VIII.0 = ENDF/B-VII.1 have no Tritium production
- TENDL-17(162g), FENDL-3.1 and JENDL/DEU-2021 underestimate experiment by factor 2 – 3 or more

$^6\text{Li}(d,x)^3\text{H}$ production XS for $d + ^6\text{Li}$:
- $^3\text{H}$ production XS for $d + ^6\text{Li}$:
- $^3\text{H}$ production XS for $d + ^7\text{Li}$:

$^7\text{Li}(d,x)^3\text{H} \& ^7\text{Li}(d,t)$
(1) Cross Section (XS): Beryllium-7 production in the d + Li-6 and d + Li-7 reactions

Be-7 production XS for d + Li-6:

Be-7 production XS for d + Li-7:

Experimental data: there are no Li-6(d,xt)Be7 measurements at Ed ≥ 15 MeV and no Li-7(d,xt)Be7 measurements at Ed ≥ 12 MeV

Evaluated data: - FZK-05 has no data (eye-guide was drawn via measurements in 2004 to estimate 3H production in IFMIF, see JNM 329(2004)213)
- ENDF/VII.0 cuts off at 20 MeV and gives only Li-6(d,n0,1)Be-7(g.s.)
- TENDL-17(162g), FENDL-3.1 and JENDL/DEU-2021 look to be out of experimental trend

Handbook-89 = S. Abramovich et al. INDC(CCP)-326 = spline fit to measurements ≤ 1989
(2) Thick Target Yield (TTY): Tritium and Beryllium-7 production in thick Li-nat by deuterons

**H-3 production TTY by deuterons in natLi:**

TTY: $^{7}\text{Li}(d,x)^{3}\text{H}$

- Mollendorff'02
- McDeLicious: FZK-05
- d-Activ: ENDF/B-VIII.0
- d-Activ: TENDL-17(162g)
- d-Activ: FENDL-3.1

**Be-7 production TTY by deuterons in natLi:**

TTY: $^{7}\text{Li}(d,x)^{7}\text{Be}$

- McDeLicious: FZK-05
- FISPACT-II: TENDL-17(162g)
- d-Activ: TENDL-17(162g)
- d-Activ: ENDF/B-VIII.0
- d-Activ: FENDL-3.1

TTY Measured data:
- H-3 production: there is only one measurement and only at single energy 40 MeV !!!
- Be-7 production: several measurements covering $E_d$ from 4 to 40 MeV do exist

TTY computed employing Evaluated data *(with a help of various codes d-Activ, McDeLicious, FISPACT-II):*
- H-3 production: FZK-05 agrees, ENDF/B-VIII.0, TENDL-17(162g), FENDL-3.1 and JENDL/DEU-2021 underestimate single experiment 2 – 3 times
- Be-7 production: FZK-05 agrees, ENDF/B-VIII.0 agrees but up to 20 MeV; TENDL-17(162g), FENDL-3.1, ENDL/DEU-2021 disagree with experiment
Questions from Request Template and Answers:

Target (Z,A): (3,6) or (3,7) or (3,000)
Reaction/Process: (d,x)H-3 and (d,x)Be-7 and (d,x)H-3
Quantity: Cross Section and Thick Target Yield
Incident Energy range: 5 - 40 MeV and 10 - 40 MeV ≤ 40 MeV
Secondary energy/angle: No (however the emitting Tritium DDX will be desirable)
Covariance information: Uncertainties ≤ 10%
Type of request: High Priority / General / Special Purpose Quantity
Application areas: Fusion: DONES (ENS), IFMIF and Accelerator driven neutron sources, e.g. SARAF-II

Besides the experimental data the upgrade of the most evaluated libraries suffering from very poor agreement with existing measurements are requested

Simplified Safety impact analysis (case of Tritium inventory):
- DONES room for Tritium Yttrium traps will accept [2] ≈ 3.9 g/fpy of T
- Calculation of H generation with FZK-05 in IFMIF [3] = 7.5 g/fpy = (6.0 g/fpy due to Li(d,x)t in Li-jet + 1.5 g/fpy due to Li(n,x)t in whole Li-loop)
  hence in DONES (ENS) = 1/2 IFMIF = 3.75 g/fpy
  thus at the moment we are ≈ near the safety limit
- The same calculation but with 6,7Li(d,x)3H data from all other considered evaluations results to Tritium production rate ≈ several times lesser than safety limit