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**

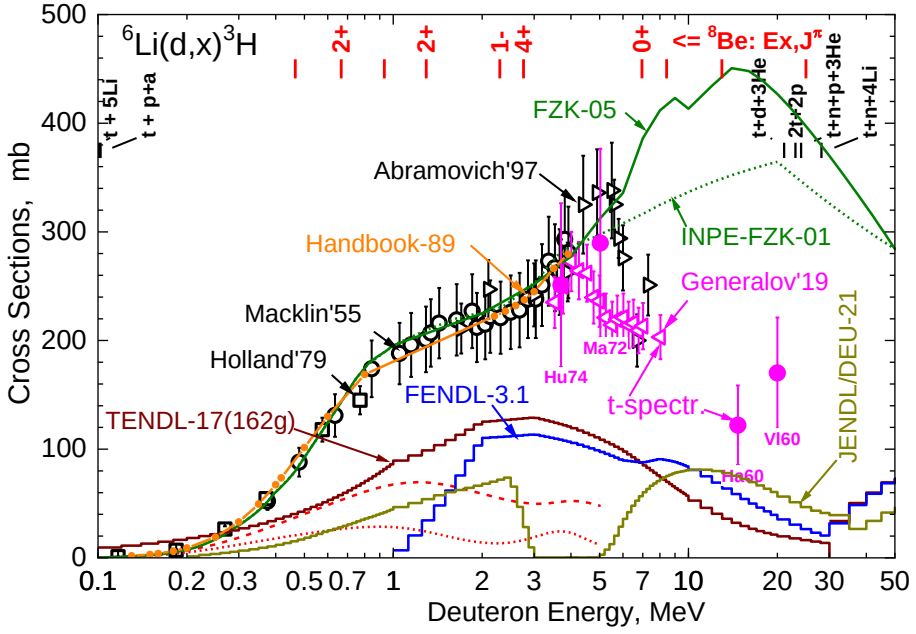
However since end of 2020, the JENDL/DEU-2020 was released in Feb 2021:

- **endf6 files are available here *https://wwwndc.jaea.go.jp/ftpnd/jendl/jendl-deu-2020.html***
- **reference: S. Nakayama et al. "JENDL/DEU-2020: deuteron nuclear data library for design studies of accelerator-based neutron sources" *J. Nucl. Sci. Technology (2021)***

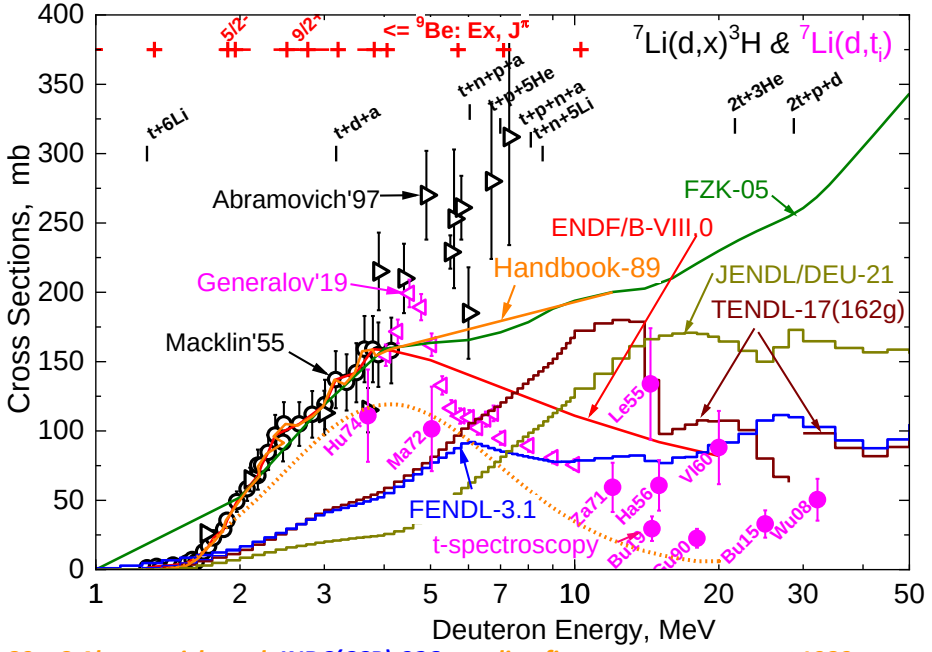
so the JENDL/DEU-2021 data were additionally included in this presentation

(1) Cross Section (XS): Tritium production in the d + Li-6 and d + Li-7 reactions

H-3 production XS for d + Li-6:



H-3 production XS for d + Li-7:



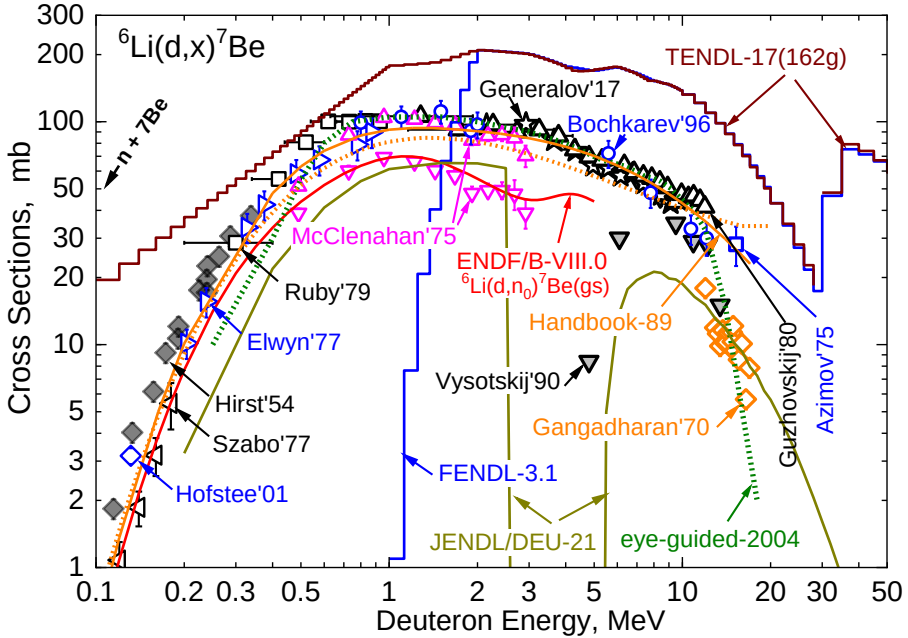
Handbook-89 = S.Abramovich et al. INDC(CCP)-326 = spline fit to measurements ≤ 1989

Experimental data: **There are no reliable ^{6,7}Li(d,xt) experimental data for Ed above 5 - 7 MeV since:**
- **Tritium counting (i.e. activation) measurements stop at ≈ 7 MeV**
- **Tritium spectrometry measurements exist up to 15 MeV but they are (d,t$_{0,1,2}$), i.e. only part of total (d,xt)**
  moreover only t-discrete forward angular dσ(d,t$_i$)/dΩ were indeed measured - I fit Legendre polynomials and obtained σ(d,t$_i$)

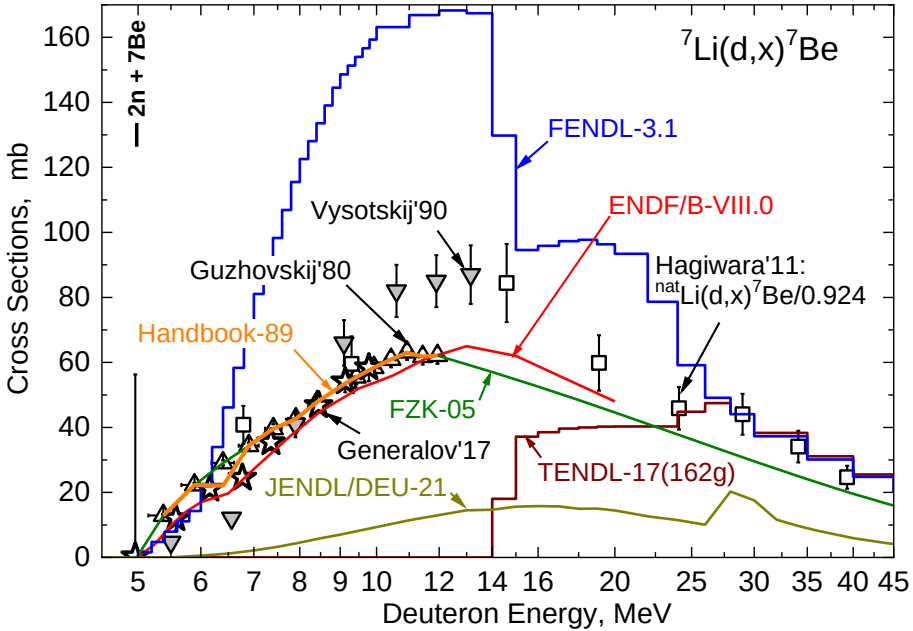
Evaluated data:
- **FZK-05** *[P.Pereslavtsev et al. NIM B266(2008)3501]* **looks better than all others, but is it correct above 5 - 7 MeV ?**
- **ENDF/B-VIII.0 = ENDF/B-VII.1 have no Tritium production**
- **TENDL-17(162g), FENDL-3.1 and JENDL/DEU-2021 underestimate experiment by factor 2 – 3 or more**

(1) Cross Section (XS): Berylium-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:



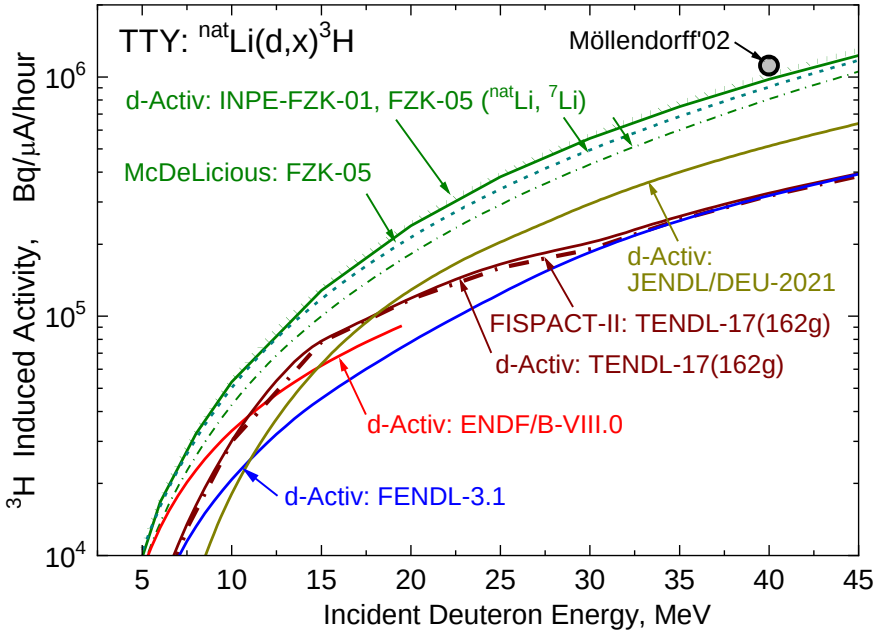
Handbook-89 = S.Abramovich et al. INDC(CCP)-326 = spline fit to measurements ≤ 1989

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**

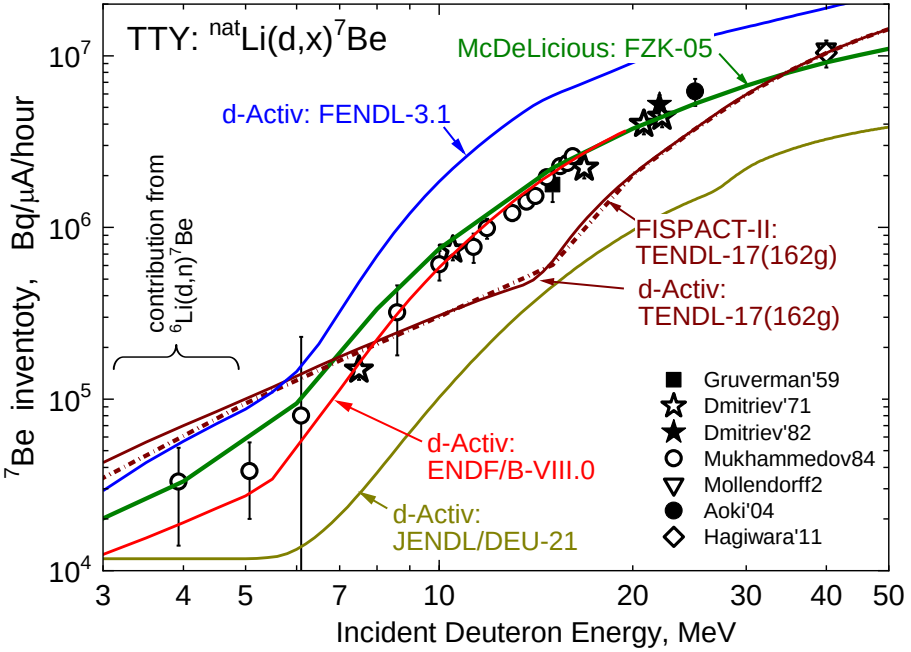
Evaluated data:
- **FZK-05 has no data *(eye-guide was drawn via measurements in 2004 to estimate ^{3}H production in IFMIF,* see JNM 329(2004)213)**
- **ENDF/VIII.0 cuts off at 20 MeV and gives only Li-6(d,n$_0$,)Be-7(g.s.)**
- **TENDL-17(162g), FENDL-3.1 and JENDL/DEU-2021 look to be out of experimental trend**

(2) Thick Target Yield (TTY): Tritium and Berylium-7 production in thick Li-nat by deuterons

H-3 production TTY by deuterons in ^{nat}Li:



Be-7 production TTY by deutrons in ^{nat}Li:



TTY Measured data:

- **H-3 production: there is only one measurement and only at single energy 40 MeV !!!**
- **Be-7 production: several measurements covering Ed from 4 to 40 MeV do exist**

TTY computed employing Evaluated data *(with a help of various codes d-Active, 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:

Draft of Request for HPRL

Target (Z,A):	(3,6) or (3,7)	(3,000)
Reaction/Process:	(d,x)H-3 and (d,x)Be-7	(d,x)H-3
Quantity:	Cross Section	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	
Impact documentation:	[1] A.Ibarra et al. "The European approach to the fusion-like neutron source: the IFMIF-DONES project", Nucl. Fusion 59(2019)065002 ; [2] F.Martín-Fuertes et al. "Integration of Safety in IFMIF-DONES Design", Safety 5(2019)74; [3] S.Simakov et al. "Assessment of the ^{3}H and ^{7}Be generation in the IFMIF lithium loop", JNM 329(2004)213	
Justification documentation:	S.Simakov et al. KIT Scientific Working Papers 147, KIT, Jun 2020; EFFDOC-1438, JEFF Meetings, NEA, Nov 2020. JEFF EUROFusion Group Action: "*A8. Need for measurements of Li(d,xt), entry to HPRL suggested …*"	

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

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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 ^{6,7}Li(d,x)^{3}H data from all other considered evaluations results to Tritium production rate ≈ several times lesser than safety limit