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Status of $^{39}K(n,p)^{39}Ar$ and $^{39}K(n,np)^{38}Ar$ Cross Sections and Impact on IFMIF or DONES Design

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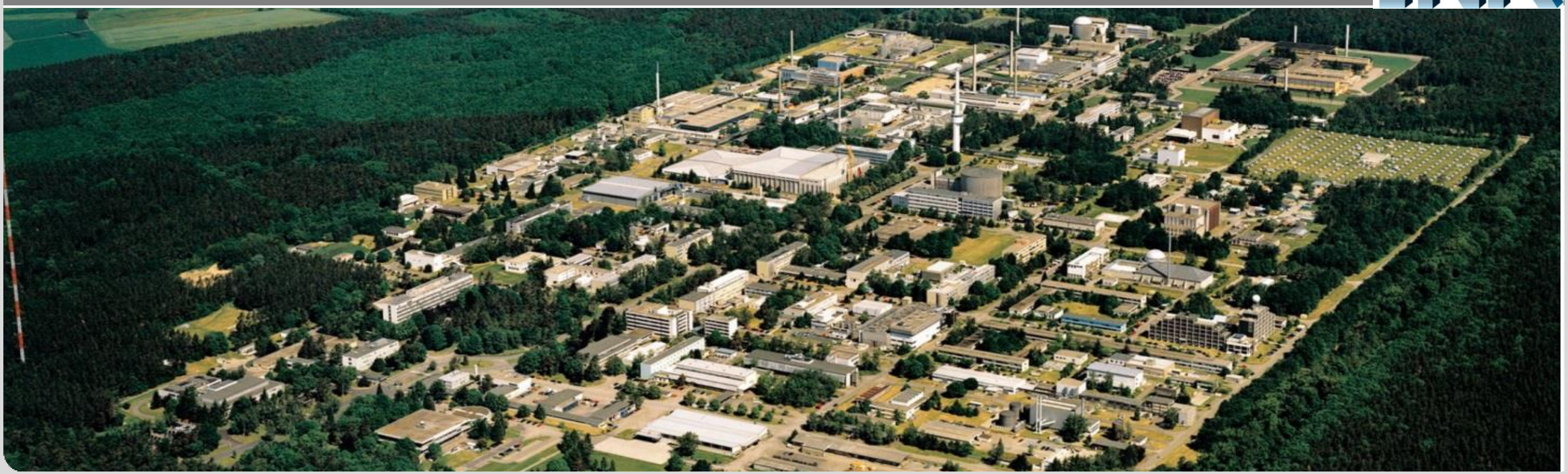

Motivations:

in IFMIF or DONES projects, the HFTM rigs with test specimens were supposed to be filled by eutectic NaK to take out a heat due to its favourable properties:

- *low melting temperature = -12.6°C,*
- *low mass density = 0.86 g/cc,*
- *high thermal conductivity = 0.22 W/cm/°C*

under the intensive neutron irradiation the constituent elements/isotopes of NaK (^{23}Na - 100%, **^{39}K - 93.26%**, ^{41}K - 6.73%) will be transmuted in other stable or radioactive isotopes

neutronics analysis shown that **^{39}Ar ($T_{1/2}$ = 269 y)** makes dominant contribution **to long-lived radioactive inventories produced in NaK,**
i.e. via reaction ^{39}K(n,p)^{39}Ar

for design it is crucial to know the **total amount of Ar gas** transmuted from K,
i.e. via reaction ^{39}K(n,np)^{38}Ar (*stable*)

Goals of this presentation:

- Status/Uncertainties of Experimental/Evaluated cross sections for these reactions
- if they differ, then to assess an impact on IFMIF/DONES neutronics results

Experimental and Evaluated Cross Sections for reactions $^{39}K(n,p)^{39}Ar$ and $^{39}K(n,np)^{38}Ar$

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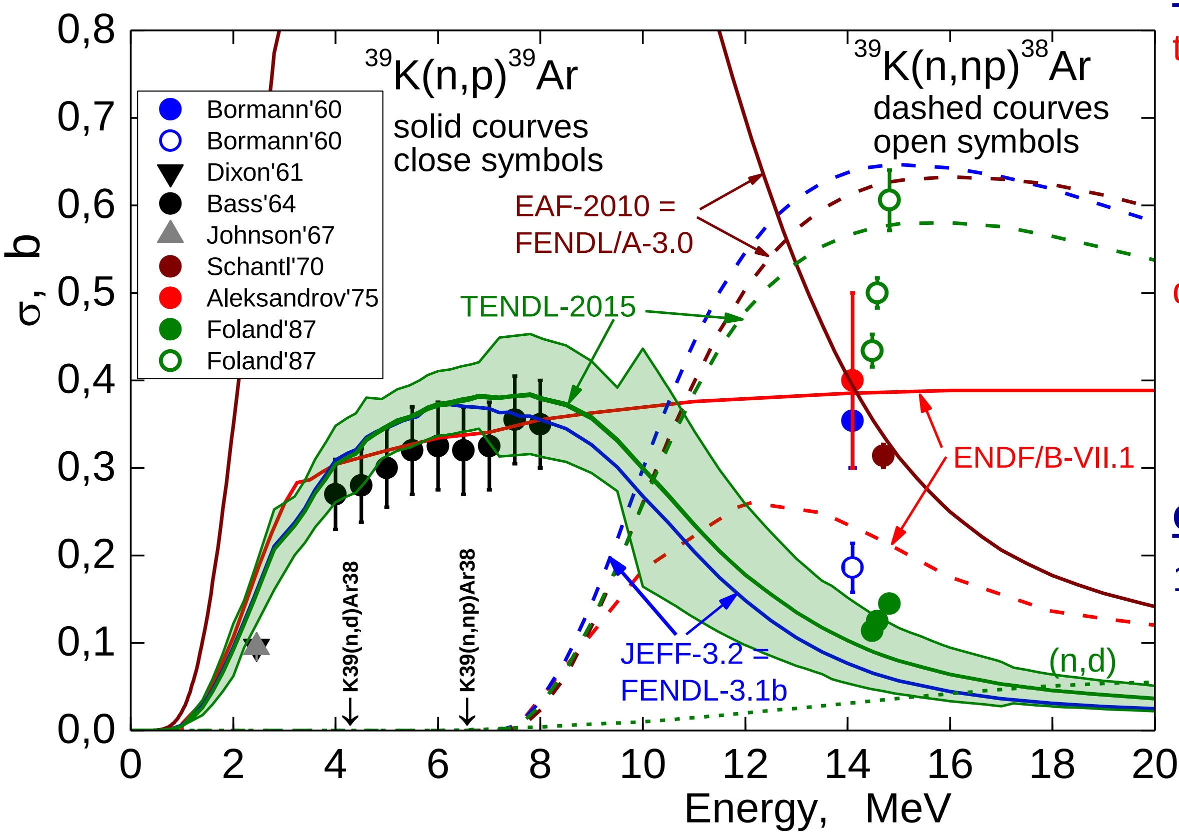


Observations for Measurements

this group of 3 Experiments at 14 MeV

Bormann'60 – p-spectroscopy

Aleksandrov'75 - p-spectroscopy

Schantl'70 – Activation

delivers 3 times higher $^{39}K(n,p)$ but

3 times lower $^{39}K(n,np)$ than

Foland'87 - AMS

Observations for Evaluations

1. $^{39}K(n,p)$ reaction:

   ENDF/B-VII.1, FENDL/A-3.0=EAF-2010
   seem to be wrong

   JEFF-3.2 and FENDL-3.1b
   are physically more reasonable

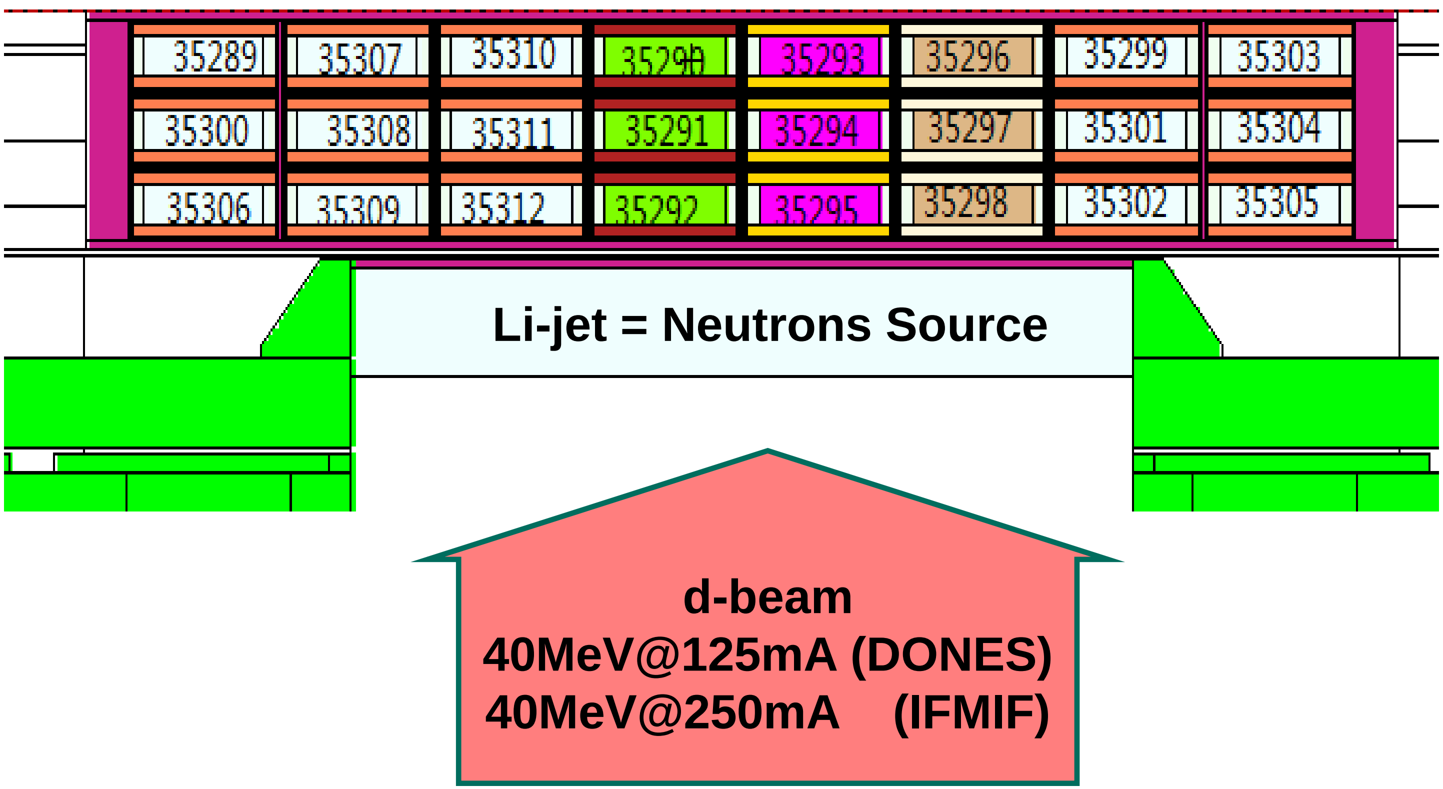
   TENDL-2015 is likely the best

2. $^{39}K(n,p)+^{39}K(n,np)=^{39}Ar+^{38}Ar$ production:

   all, except FENDL/A-3.0=EAF-2010,
   predict comparable XS

Impact on IFMIF and DONES Design

Layout of HFTM with 24 sealed Rigs containing the Testing Specimens (Steel) and NaK which conducts the Nuclear Heat to He gas flowing between Rigs



Impact on IFMIF and DONES Design (*cont.*): Neutronics

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Inventory of ^{39}Ar produced by $^{39}K(n,p)^{39}Ar$ in HFTM/DONES (40MeV@125mA)

Central Rig (MCNP cell 35291)	JEFF-3.2 or FENDL-3.1b	TENDL-2015	ENDF/B-VII.1	EAF-2010 or FENDL/A-3.0
^{39}Ar generation, atom/cc/fpy	2.743 E+19	2.942 E+19	5.026 E+19	10.97 E+19
^{39}Ar activity, Bq/cc	2.239 E+9	2.401 E+9	4.103 E+9	8.955 E+9
Ratio to TENDL 2015	**0.93**	**1.00**	**1.71**	**3.73**

Total Argon ($^{38}Ar+^{39}Ar$) generation in central rig of HFTM/DONES(40MeV@125mA)

24 rigs of HFTM	JEFF-3.2 or FENDL-3.1b	TENDL-2015	ENDF/B-VII.1	EAF-2010 or FENDL/A-3.0
Ar generation, atoms/fpy	2.134 E+22	2.442 E+22	2.356 E+22	5.644 E+22
Ratio to TENDL 2015	**0.87**	**1.00**	**0.96**	**2.31**

Inventory of radioactive ^{39}Ar (relying on TENDL-2015 as seems to be the most reasonable):
= $(2.9 \pm 10\%)10^{19}$ atoms/cc/fpy or $(2.4 \pm 10\%)10^{9}$ Bq/cc/fpy in central rig of DONES

Total Ar gas generation from K (practically library independent, except EAF-2010=FENDL/A-3.0, but still relying on TENDL-2015):
= $(2.4 \pm 15\%)10^{22}$ Ar atoms/fpy in 24 rigs = 0.040 moles = 0.90 litres at normal T and P
(this rate is considered to be too large for the sealed rigs !!! – as designers tell us …)

Summary

I. Nuclear Data

Existing Measured XS for $^{39}K(n,p)^{39}Ar$ and $^{39}K(n,np)^{38}Ar$ reactions are controversy:

- 3 measurements performed at 14 MeV so far by p-spectroscopy and activation differ 3 times from 1 measurement which used AMS
- no experimental data do exist at higher energies

Thus we recommend additional measurements to solve contradiction at 14 MeV and to obtain data at higher energies

Current Evaluations for these reactions:

- TENDL-2015 looks as most physical (JEFF-3.2 = FENDL-3.1b are similar)
- ENDF/B-VII.1, EAF-2010 and FENDL/A-3.0 are out of trend (since EAF-2010 is underlying library for FISPACT and FENDL/A-3.0 is a reference activation library for fusion, they have to be cautiously used for Ar inventory calculations)

II. Argon radioactive and total inventories due to neutron reactions with K

- long term (≈ 300 y) radioactive inventory in NaK are due to **^{39}Ar** which comes from **$^{39}K(n,p)$**
- total Argon inventory in NaK is determined by **$^{39}K(n,p)^{39}Ar$ and $^{39}K(n,np)^{38}Ar$**
- relying on TENDL-2015 we estimate nuclear production rates now with uncertainty ≈ 10-15% (by comparing with JEFF-3.2 = FENDL-3.1b)
- Argon gas production rate in the sealed Rigs turns out to be critically high for engineering design of IFMIF/DONES