what bothers me?

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[1]

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1. **All the calculations presented here were done with the TALYS code**

Inelastic cross section : actinides case

Actinides = deformed nuclei $\Longrightarrow$ CCC framework

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Coupled Channel Calculations $\Longrightarrow$ good OP + coupling scheme

Optical Model $\leftrightarrow \sigma_{tot}, \sigma_{SE}, \sigma_{DI}, \sigma_R$ et $T_{l,j}^{J\pi}$

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good Opt. Pot. $\equiv$ **good tank σ_R and also $T_{l,j}^{J\pi}$**

Optical Model $\leftrightarrow \sigma_{tot}, \sigma_{SE}, \sigma_{DI}, \sigma_R$ et $T_{l,j}^{J\pi}$

But !

Are we sure to use the "best" coupling scheme ?

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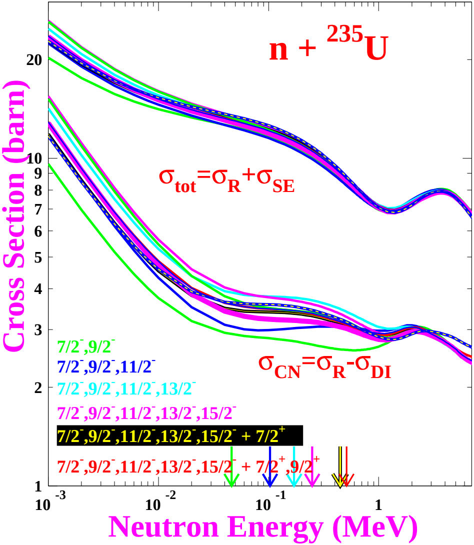
OMP - CCC ↔ which coupling scheme ?



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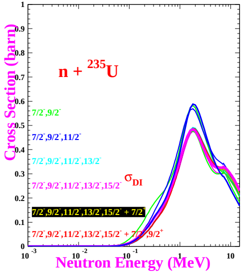

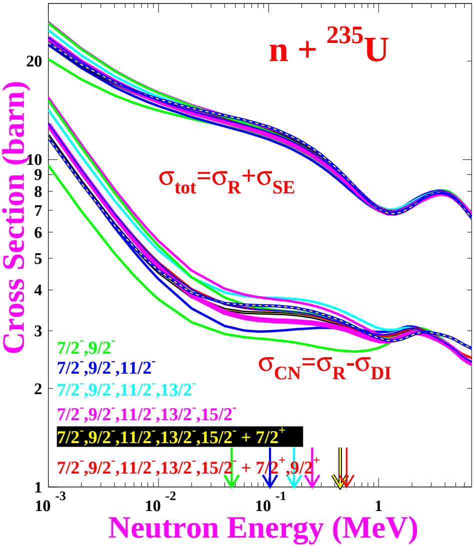

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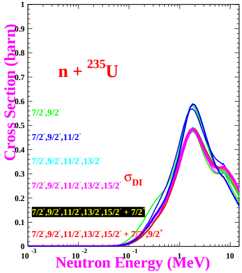

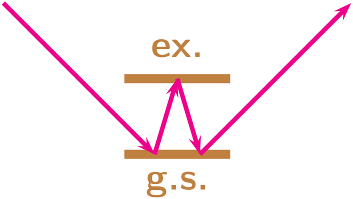

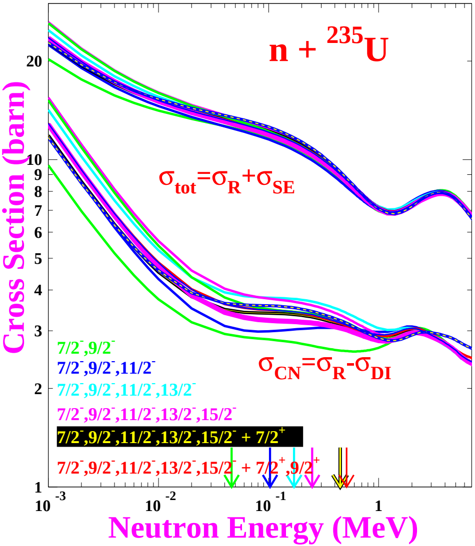

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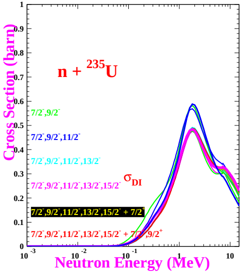
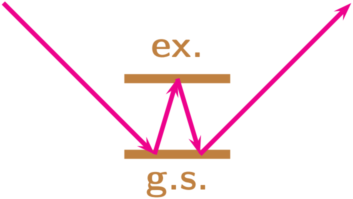
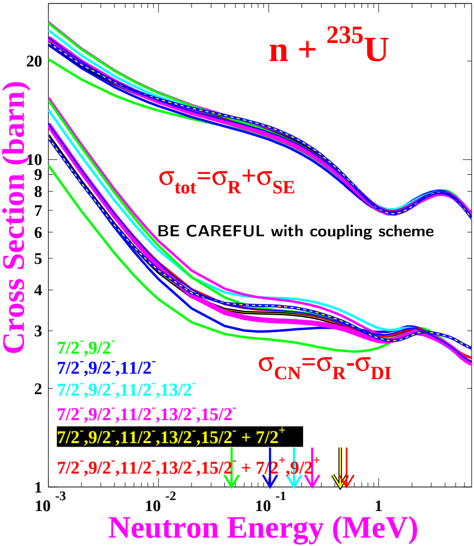
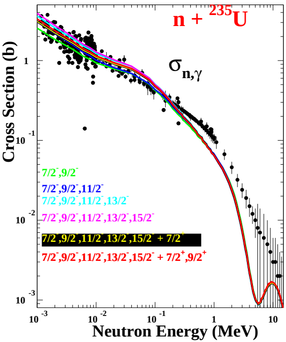


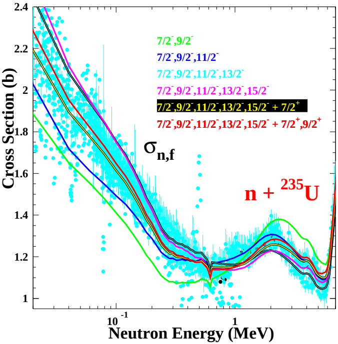


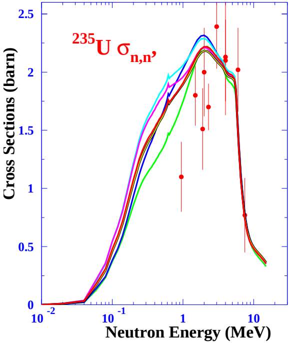


CCC : coupling scheme effects on statistical model caculations

Cross Sections behaviour

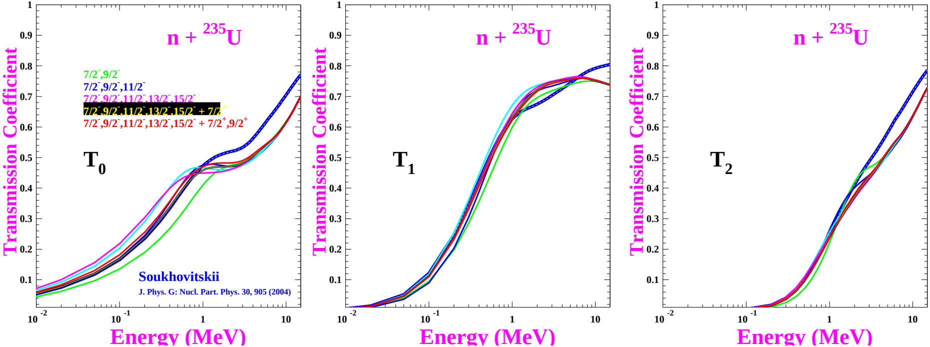






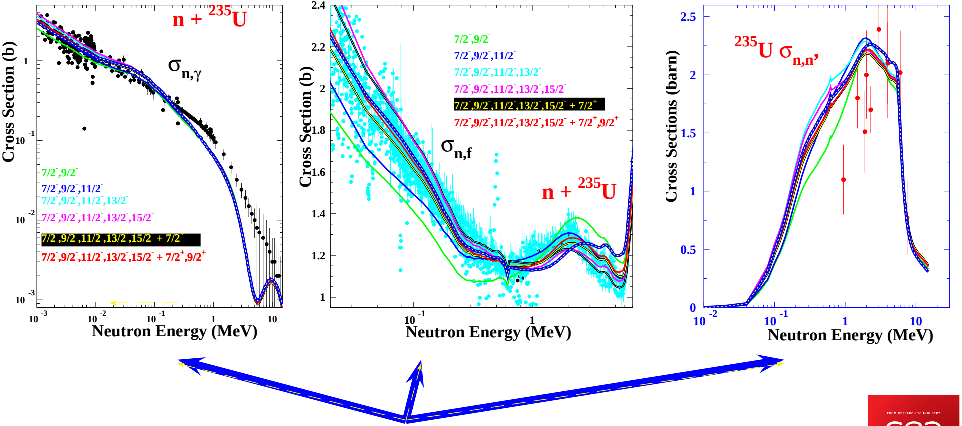
CCC : coupling scheme effects on statistical model caculations

Transmission Coefficients used



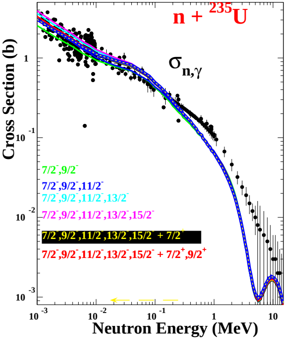
CCC : optical potentiel effects on statistical model caculations

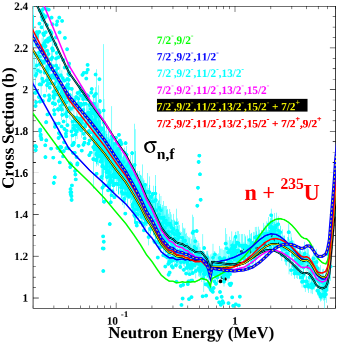
Cross Sections behaviour

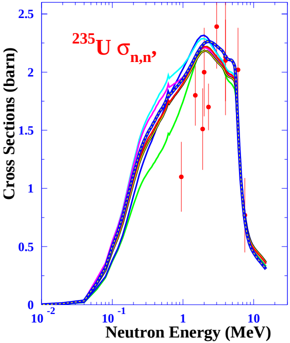


Soukhovitskii (non dispersive OP)

Cross Sections behaviour







$\neq T_l \implies \neq$ **Trans. States populated**

Soukhovitskii (non dispersive OP)

Barrier Heights strongly OP dependent

Once Optical Potentiel and coupling scheme adopted ...

Inelastics

we are now able to define many interesting quantities

compound emission probabilities

For energies $E < E^{seuil}_{(n,2n)}$ when considering **compound emission processes**, we get :

$$\sigma_{CN} = \sigma_R - \sigma_{DI} \quad = \sigma_{CE} + \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f}$$

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$$\begin{aligned} \sigma_{CN} &= \sigma_{n,n} + \sigma_{n,\gamma} + \sigma_{n,f} \\ \iff 1 &= \frac{\sigma_{n,n}}{\sigma_{CN}} + \frac{\sigma_{n,\gamma}}{\sigma_{CN}} + \frac{\sigma_{n,f}}{\sigma_{CN}} \end{aligned}$$

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Then defining GLOBAL compound emission probability for each processes occuring in this energy range :

$$1 \quad = P_{n,n} + P_{n,\gamma} + P_{n,f}$$

Now, for a surrogate reaction defined by an entrance channel EC, we have :

$$1 \quad = P_{EC,n} + P_{EC,\gamma} + P_{EC,f}$$

Use of Shannon theorem towards surrogate reactions

From another point of view, we can also define the lack of information on the compound emission processes for an emitting system (CN). When using the same notations as previously defined, according to the Shannon theorem [1], the lack of information (also called entropy) on the compound emission processes for an emitting CN is defined as :

$$H_{EC}(CN,E) = \begin{array}{l} -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) \\ -P_{EC,n}(E)\log_2 P_{EC,n}(E) \\ -P_{EC,f}(E)\log_2 P_{EC,f}(E). \end{array}$$

Instead of plotting each probabibality of all exit channels for each studied entrance channel versus energy, this representation is more compact, and so, more clearly to read.

In addition, using these functions, Bohr independence hypothesis implies that for two different entrance channels EC_1 and EC_2 leading to the same CN at the same excitation energies in the same spin-parity states, the lack of information on these compound nuclei emission processes or the uncertainties on their emission processes should be identical :

$$H_{EC_1}(CN,E) = H_{EC_2}(CN,E).$$

[1] C.E Shannon, Bell System Technical Journal, **27** , 379 and 623, (1948).

Shannon information and the surrogate reactions

we are now able to define many interesting quantities

in order to avoid the fission channel we can begin to study some rare earth nuclei which are also deformed nuclei (CCC).

Shannon theorem - non fissile nuclei : 2 exit channels

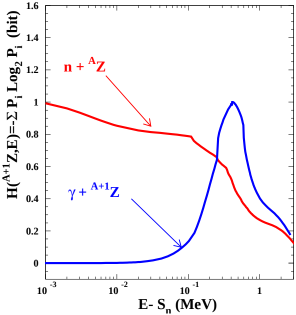


Figure : *Lack of information on the compound emission processes, $H_\gamma(^{A+1}Z, E)$ and $H_n(^{A+1}Z, E)$ related to a given entrance channel $EC = \gamma$ or $EC = n$, plotted versus $E - S_n$.*

$$
\begin{aligned}
H_{EC}(CN, E) = \quad & -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) \\
& -P_{EC,n}(E)\log_2 P_{EC,n}(E) \\
= \quad & -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) \\
& -(1 - P_{EC,\gamma}(E))\times \\
& \qquad \log_2(1 - P_{EC,\gamma}(E)).
\end{aligned}
$$

When, (for the $EC_1 = \gamma$), γ emission is the most important emission process then :

$$P_{EC_1,\gamma}(E) \approx 1, \quad P_{EC_1,n}(E) = 1 - P_{EC_1,\gamma}(E) \approx 0$$

and

$$H_{EC_1}(CN, E) = 0$$

For the $EC_1 = \gamma$ and $EC_2 = n$ entrance channels, the lack of information on the compound emission processes is maximum when :

$$P_{EC,\gamma}(E) = P_{EC,n}(E) = \frac{1}{2}$$

[since $h = -p\log_2 p - (1-p)\log_2(1-p)$ is maximum for $p = \frac{1}{2}$].

Shannon theorem - non fissile nuclei : 2 exit channels

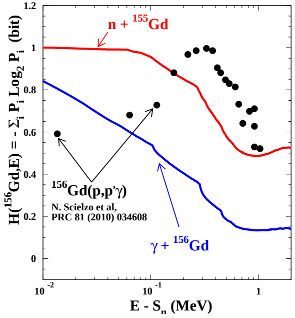


Figure : *Lack of information on the compound emission processes,* $H_\gamma(^{156}Gd, E)$ *and* $H_n(^{156}Gd, E)$ *and,* $H_{(p,p'\gamma)}(^{156}Gd, E)$ *related to a given entrance channel, plotted versus* $E - S_n$ *(*$S_n = 8.536$ *MeV).*

$$H_{EC}(CN, E) = -P_{EC,\gamma}(E) \log_2 P_{EC,\gamma}(E) - P_{EC,n}(E) \log_2 P_{EC,n}(E)$$

becomes here :

$$H_{EC}(CN, E) = -P_{EC,\gamma}(E) \log_2 P_{EC,\gamma}(E) - (1 - P_{EC,\gamma}(E)) \log_2 (1 - P_{EC,\gamma}(E))$$

Shannon Theorem translation of Bohr independence hypothesis :

$$H_{EC_1}(CN, E) = H_{EC_2}(CN, E).$$

BUT HERE :

$$H_n(^{156}Gd, E) \quad \neq \quad H_\gamma(^{156}Gd, E)$$

AND HERE ALSO FOR $SR = (p, p'\gamma)$ **:**

$$H_n(^{156}Gd, E) \quad \neq \quad H_{(p,p'\gamma)}(^{156}Gd, E)$$

$$\Updownarrow$$

$$J_n, \pi_n \quad \neq \quad J_{SR}, \pi_{SR}$$

or at least

Bohr independence hypothesis failed for $E \sim S_n$ with incident n since $W \neq 1$

$$H_{EC}(CN,E) = -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) - P_{EC,n}(E)\log_2 P_{EC,n}(E)$$

becomes here :

$$H_{EC}(CN,E) = -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) - (1-P_{EC,\gamma}(E))\log_2(1-P_{EC,\gamma}(E))$$

Shannon Theorem translation of Bohr independence hypothesis :

$$H_{EC_1}(CN,E) = H_{EC_2}(CN,E).$$

BUT HERE :

$$H_n(^{176}LU,E) \neq H_\gamma(^{176}Lu,E)$$

AND HERE ALSO FOR $SR = {}^{174}$Yb$({}^3$He$,p)^{176}$Lu :

$$H_n(^{176}Lu,E) \neq H_{SR}(^{176}Lu,E)$$
$$\Updownarrow$$
$$J_n,\pi_n \neq J_{SR},\pi_{SR}$$

or at least

Bohr independence hypothesis failed for $E \sim S_n$ with incident n since $W \neq 1$

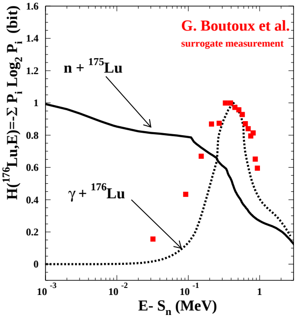


Figure : *Lack of information on the compound emission processes,* $H_\gamma(^{176}Lu,E)$ *and* $H_n(^{176}Lu,E)$ *and,* $H_{SR}(^{176}Lu,E)$ *related to a given entrance channel, plotted versus* $E - S_n$.

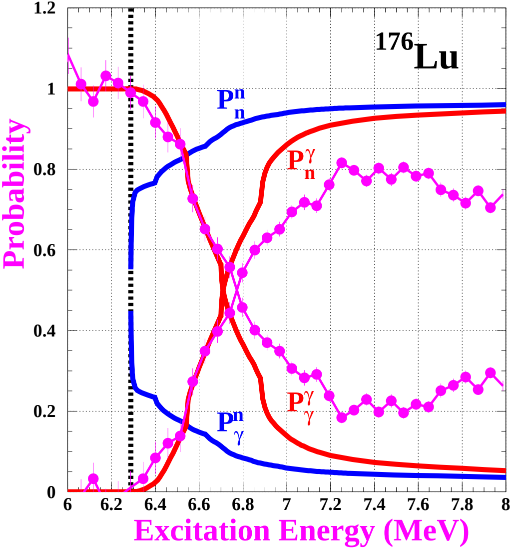
E.D.P.S : the only 2 exit channels case

$$P_{EC,\gamma} + P_{EC,n} = 1$$

$$\Updownarrow$$

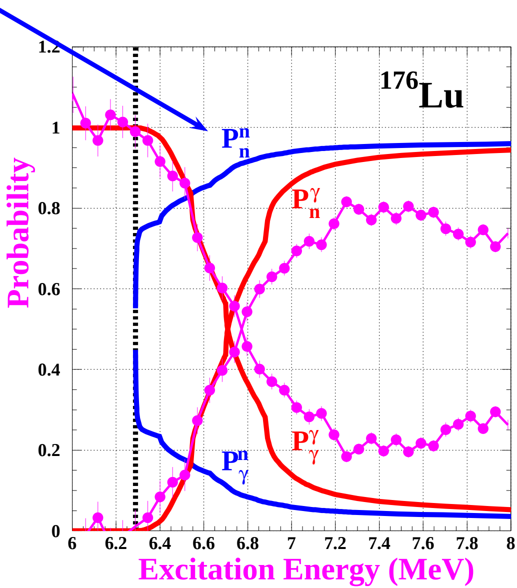
$$P_{EC,n} = 1 - P_{EC,\gamma}$$

E.D.P.S : the only 2 exit channels case



E.D.P.S : the only 2 exit channels case

calc. ^{175}**Lu**$(n,n)^{175}$**Lu**



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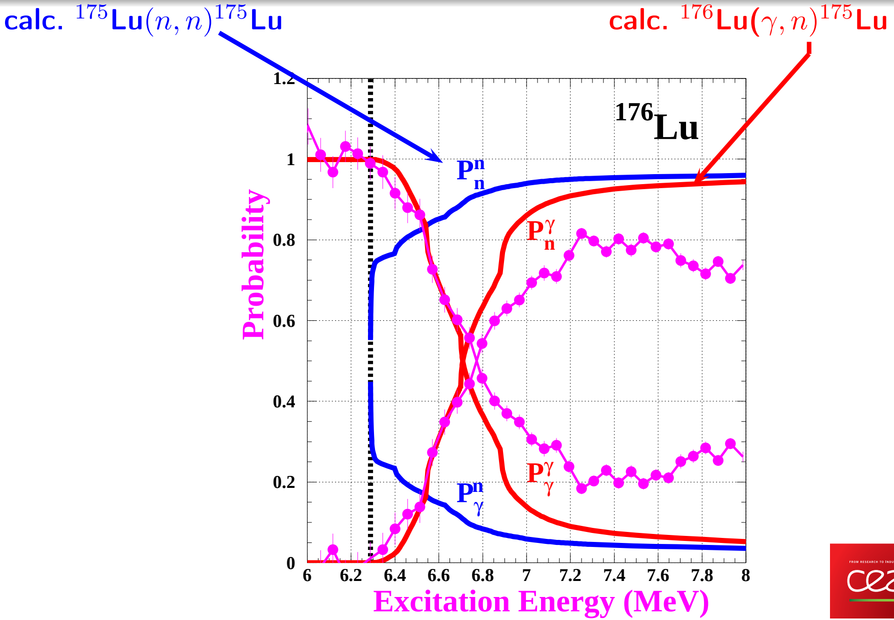

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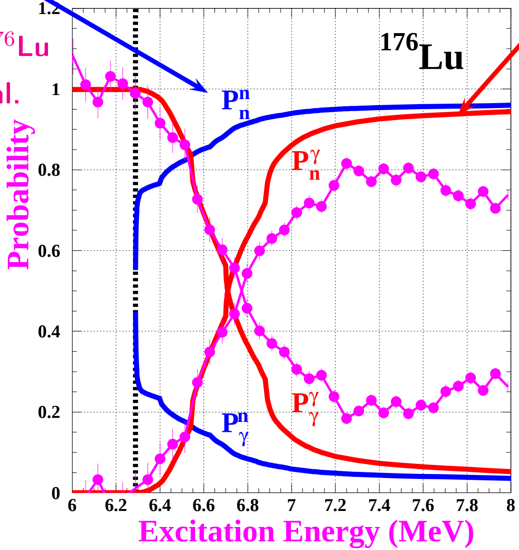
G. Boutoux et al.

CENBG



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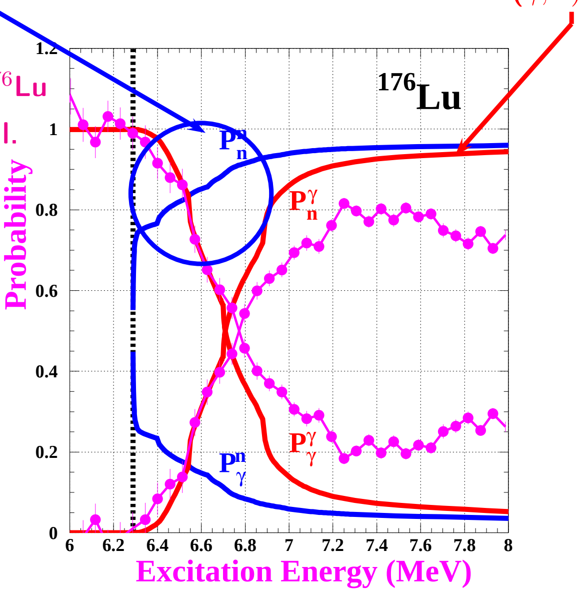

structures = opening channels

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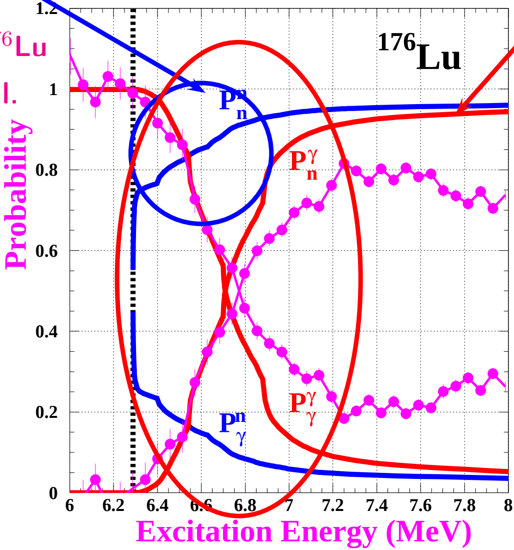


structures = opening channels

id. for P_n^γ et P_n^{SR}

E.D.P.S : the only 2 exit channels case

$$P_{EC,\gamma} + P_{EC,n} = 1$$

$$\Updownarrow$$

$$P_{EC,n} = 1 - P_{EC,\gamma}$$

But neutron emissions on discret states = threshold reactions

$\Longrightarrow$ interest of energy derivative study :

$$\frac{dP_{EC,n}}{dE} = -\frac{dP_{EC,\gamma}}{dE}$$

Inelastic neutron emission probability

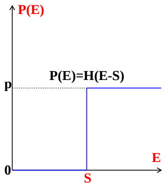


Figure : *Inelastic neutron emission probability for populating an $E = S$ energy state (Heaviside function)= threshold reaction.*

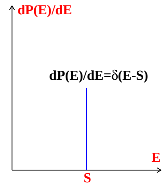


Figure : *Energy derivative of the inelastic neutron emission probability for populating an $E = S$ energy state (Dirac distribution =* energy distribution of populated states*).*

Energy distribution of populated states

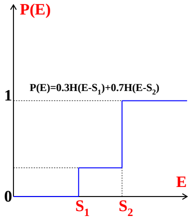


Figure : *Inelastic neutron emission probability for populating two energy states $E = S_1$ and $E = S_2$ (Heaviside functions)= threshold reactions.*

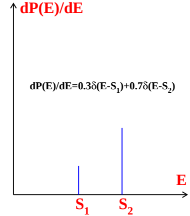
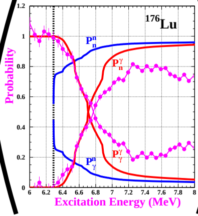


Figure : *Energy derivative of the Inelastic neutron emission probability for populating two energy states $E = S_1$ and $E = S_2$ (Dirac distributions =* **energy distribution of populated states)**.

E.D.P.S : the only 2 exit channels case

$$\frac{d}{dE}\left(\quad \right)$$



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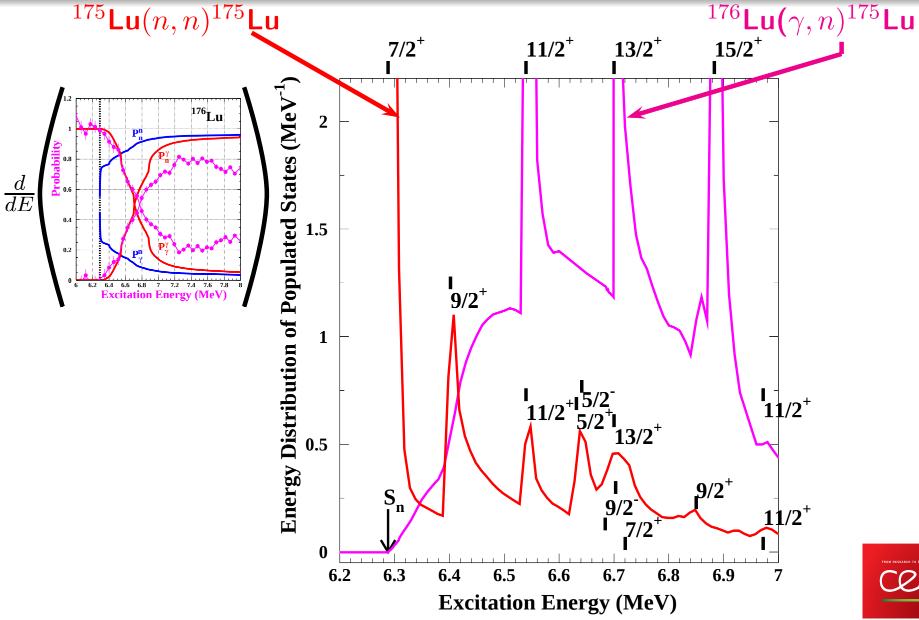
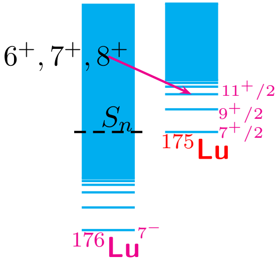


Spin/Parity states reached

absorption :	composition :	states :	states pop. after n-emission :
$\gamma +^{176} Lu$:	$1(-) + 7^-$	$6^+, 7^+, 8^+$	$\frac{11}{2}^+, \frac{13}{2}^+$ $\frac{15}{2}^+, \frac{17}{2}^+$



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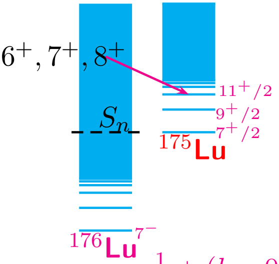
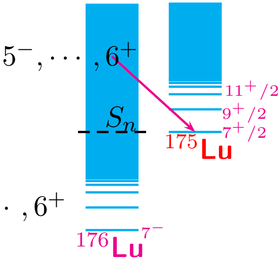




$(l = 0, 2) : 1^+, \cdots, 6^+$

$\frac{1}{2} + (l = 0) + \frac{7}{2}^+$

$n + ^{175}Lu$: $\frac{1}{2} + (l = 1) + \frac{7}{2}^+$ $\frac{1}{2}^+, \cdots, \frac{13}{2}^+$

$\frac{1}{2} + (l = 2) + \frac{7}{2}^+$ $\frac{1}{2}^-, \cdots, \frac{13}{2}^-$

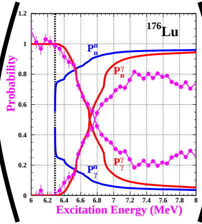
$(l = 1) : 2^-, \cdots, 5^-$

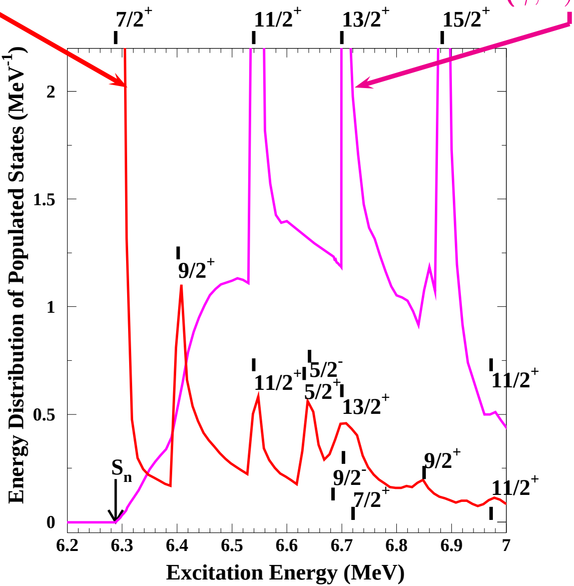
E.D.P.S : the only 2 exit channels case

$^{175}\mathbf{Lu}(n,n)^{175}\mathbf{Lu}$

$^{176}\mathbf{Lu}(\gamma,n)^{175}\mathbf{Lu}$

$$\frac{d}{dE}\left(\right)$$





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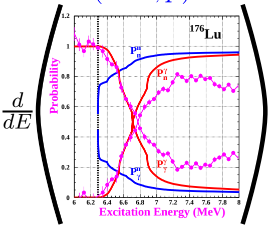
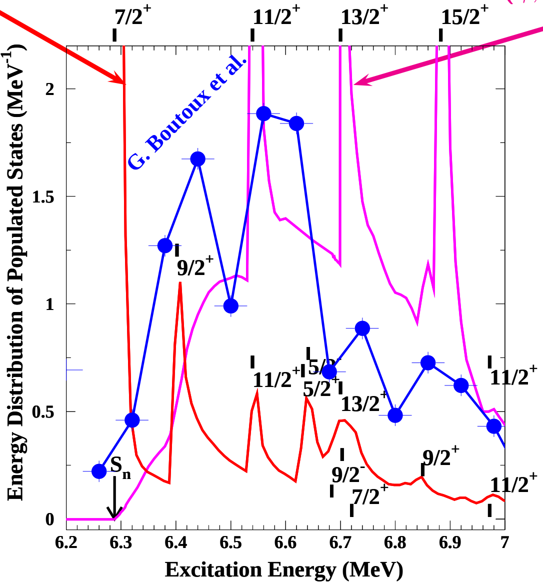
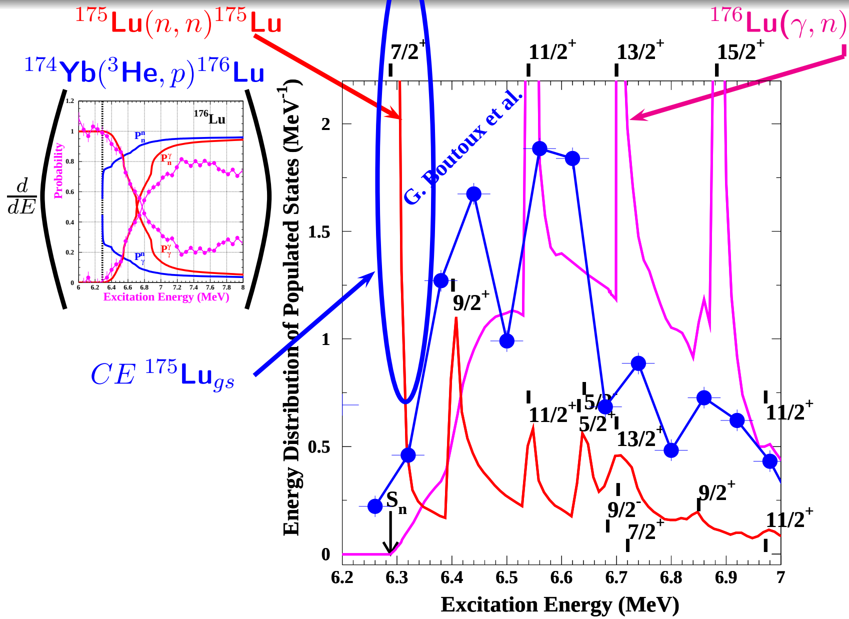
$^{176}\mathbf{Lu}(\gamma,n)^{175}\mathbf{Lu}$

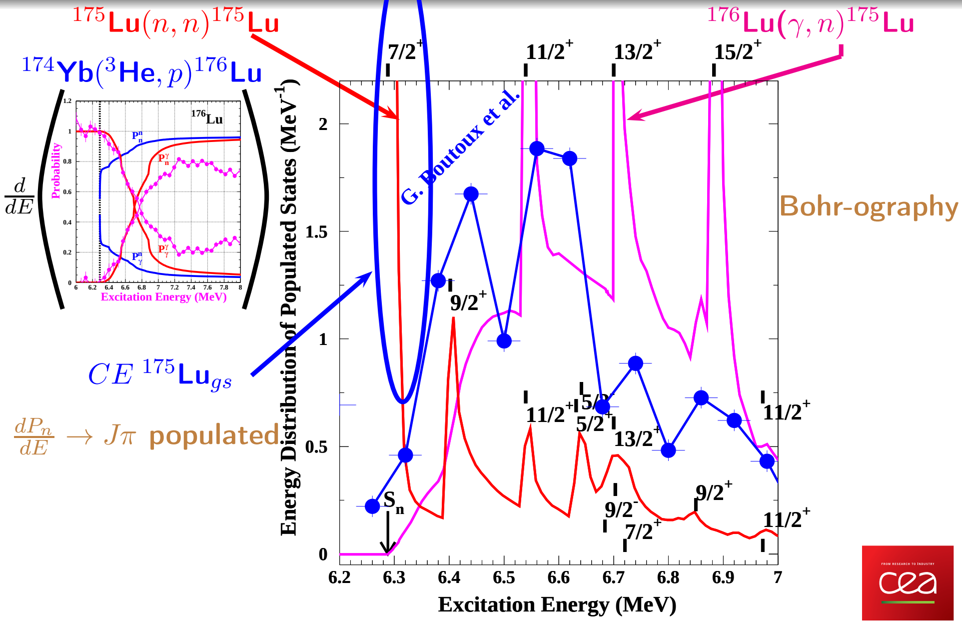
$^{174}\mathbf{Yb}(^{3}\mathbf{He},p)^{176}\mathbf{Lu}$





E.D.P.S : the only 2 exit channels case




^{175}Lu$(n,n)^{175}$Lu
^{176}Lu$(\gamma,n)^{175}$Lu
^{174}Yb$(^3$He$,p)^{176}$Lu
$\frac{d}{dE}$
^{176}Lu
Probability
Excitation Energy (MeV)
G. Boutoux et al.
7/2+
11/2+
13/2+
15/2+
9/2+
11/2+
5/2
5/2+
13/2+
9/2-
7/2+
9/2+
11/2+
11/2+
S_n
Energy Distribution of Populated States (MeV^{-1})
Excitation Energy (MeV)
Bohr-ography
$CE\ ^{175}$Lu$_{gs}$
$\frac{dP_n}{dE} \to J\pi$ populated

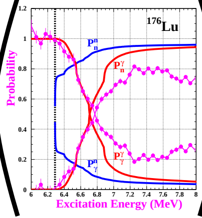
E.D.P.S : the only 2 exit channels case

^{175}**Lu**$(n,n)^{175}$**Lu**

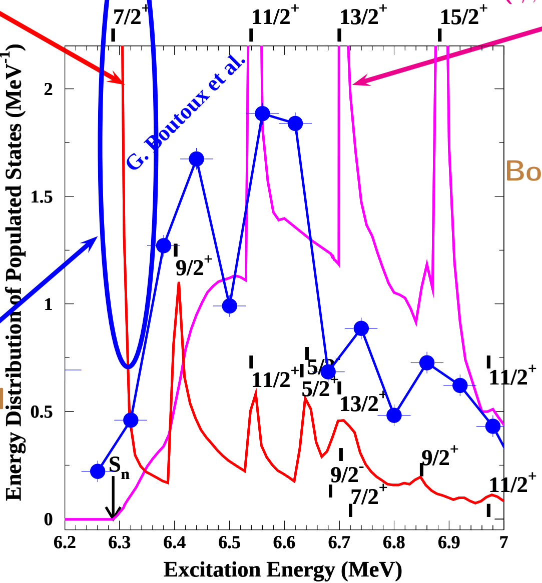
^{176}**Lu**$(\gamma,n)^{175}$**Lu**

^{174}**Yb**$(^{3}$**He**$,p)^{176}$**Lu**

$\frac{d}{dE}$ (



)



Bohr-ography

$CE\ ^{175}$**Lu**$_{gs}$

$\frac{dP_n}{dE} \rightarrow J\pi$ **populated**

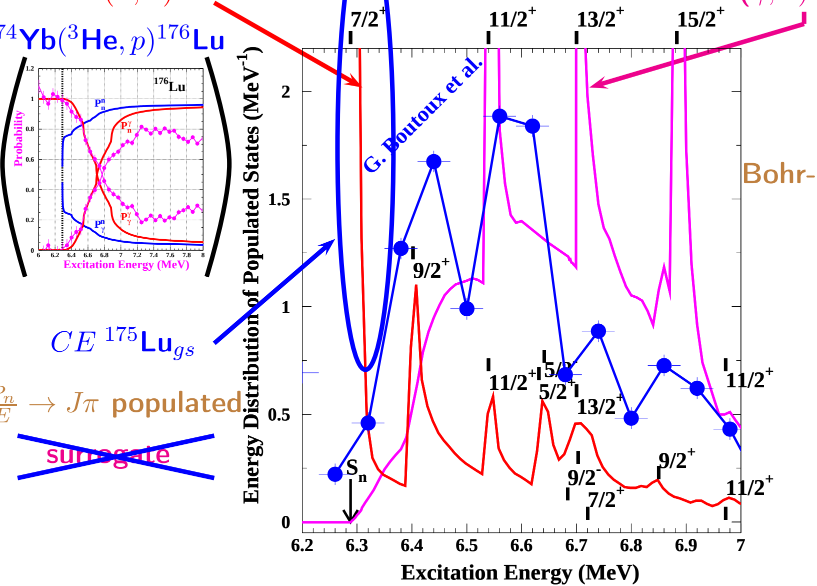
surrogate

^{175}Lu$(n,n)^{175}$Lu

^{176}Lu$(\gamma,n)^{175}$Lu

^{174}Yb$(^3$He$,p)^{176}$Lu

$\frac{d}{dE}\left(\right)$



Bohr-ography

$CE\ ^{175}$Lu$_{gs}$

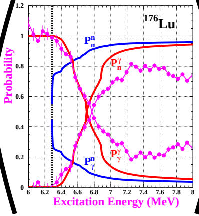
$\frac{dP_n}{dE} \to J\pi$ populated

~~surrogate~~

E.D.P.S : the only 2 exit channels case

^{175}Lu$(n,n)^{175}$Lu

^{174}Yb$(^3$He$,p)^{176}$Lu

$\frac{d}{dE}$ ()

$CE\ ^{175}$Lu$_{gs}$

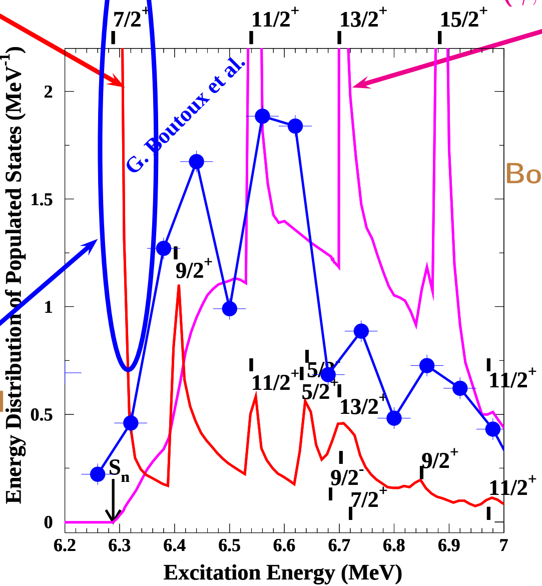
$\frac{dP_n}{dE} \rightarrow J\pi$ populated

~~surrogate~~

forget it

even for fission !

^{176}Lu$(\gamma,n)^{175}$Lu



Bohr-ography

Fission barriers distributions

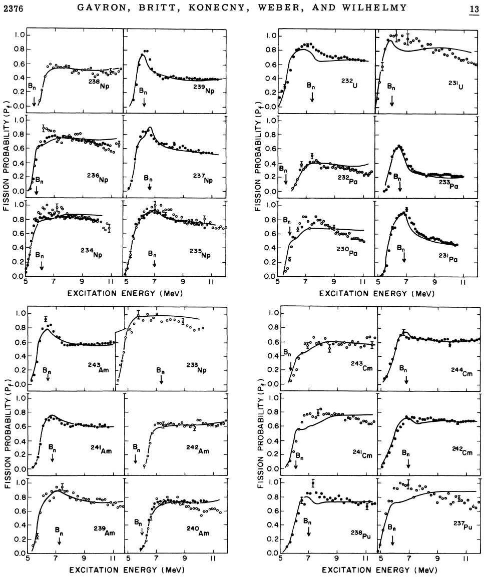


FIG. 2. Measured fission probabilities: open circles, from (^{3}He,tf) reactions; closed circles, from (^{3}He,df) reactions; full lines, model fits as discussed in the text.

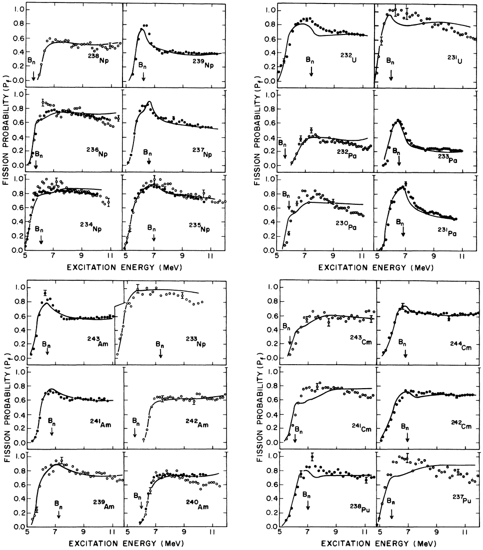
fission Probabilities from

Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

Fission barriers distributions

$P_f \to 1$!!!

2376 GAVRON, BRITT, KONECNY, WEBER, AND WILHELMY 13



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fission Probabilities from

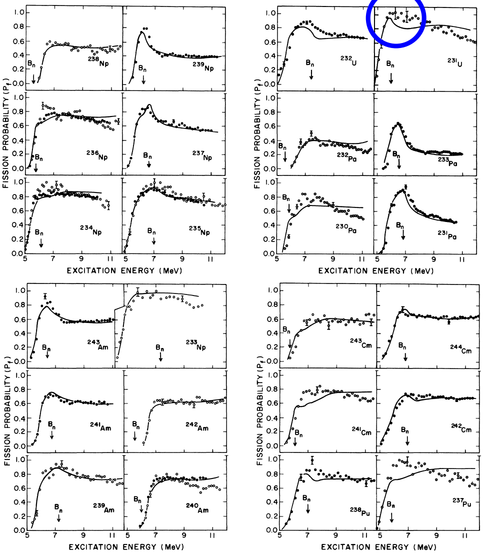
Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

Fission barriers distributions

$P_f \to 1$! ! !

^{231}U

2376 GAVRON, BRITT, KONECNY, WEBER, AND WILHELMY 13



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fission Probabilities from

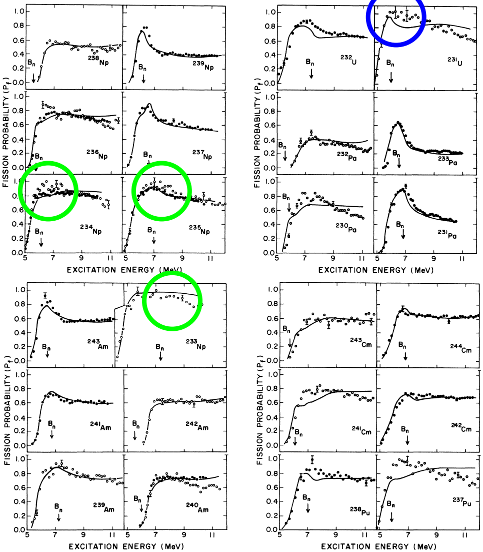
Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

Fission barriers distributions

$P_f \to 1$! ! !

^{231}U

^{233,234,235}Np



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fission Probabilities from

Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

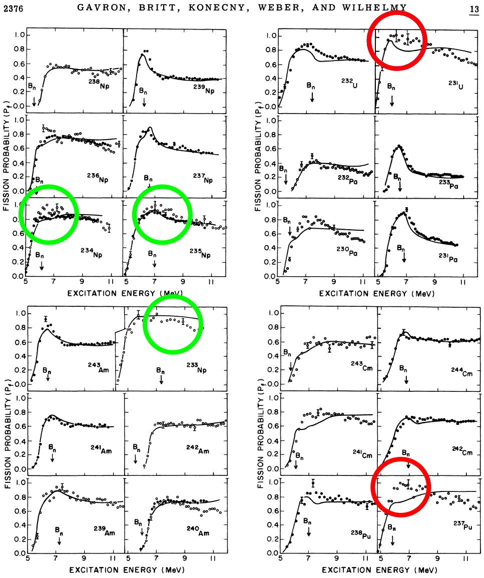
Fission barriers distributions

$P_f \to 1\,!!!$

^{231}U

^{233,234,235}Np

^{237}Pu



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fission Probabilities from

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Fission barriers distributions

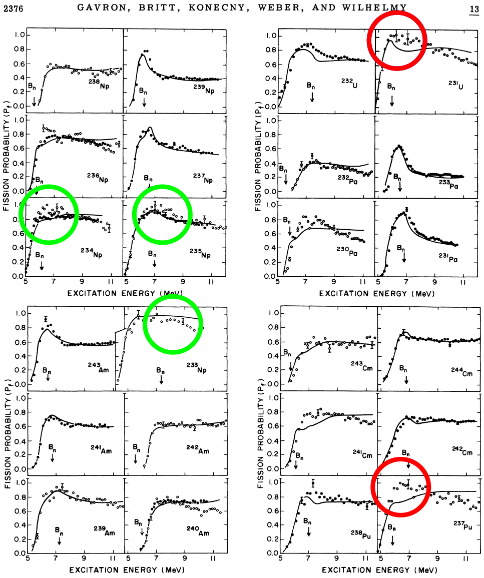
$P_f \rightarrow 1$!!!

^{231}**U**

^{233,234,235}**Np**

^{237}**Pu**

$\Longrightarrow \neq J_{SR}\pi_{SR}$ **populated**



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Fission barriers distributions

$P_f \to 1$! ! !

^{231}U

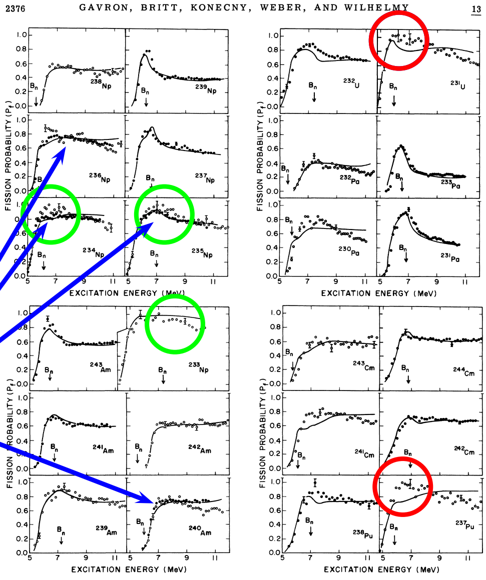
^{233,234,235}Np

^{237}Pu

$\Longrightarrow \neq J_{SR}\pi_{SR}$ **populated**

additionnally

(^{3}He,t) $\neq$(^{3}He,d)



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fission Probabilities from

Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

Fission barriers distributions

$P_f \to 1$! ! !

^{231}U

^{233,234,235}Np

^{237}Pu

$\Longrightarrow \neq J_{SR}\pi_{SR}$ populated

additionnally

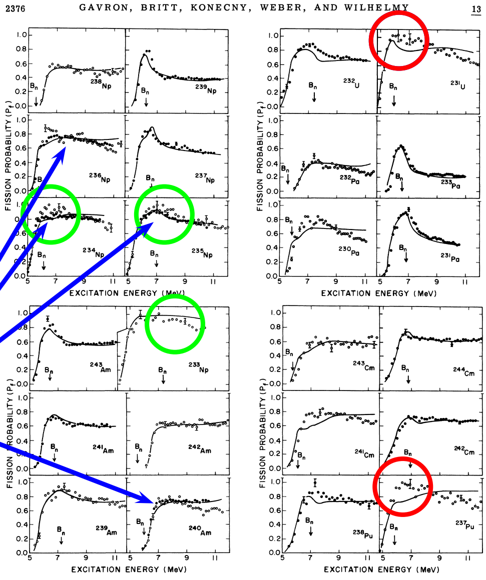
(^{3}He,t) $\neq$(^{3}He,d)

$P_f \to 1 \Longrightarrow P_n \to 0$

no neutron emissions ! ! !

fission Probabilities from

Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)



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Fission barriers distributions

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^{233,234,235}Np

^{237}Pu

$\Longrightarrow \neq J_{SR}\pi_{SR}$ **populated**

additionnally

(^{3}He,t) $\neq$(^{3}He,d)

BUT

fission Probabilities from

Gavron et al. : Phys. Rev. C 13 p. 2374 (1976)

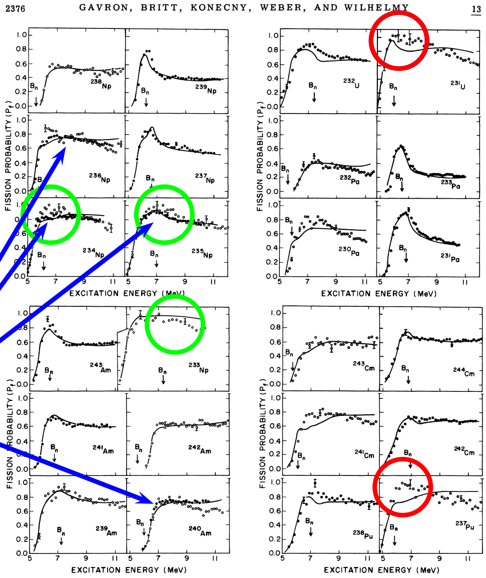


FIG. 2. Measured fission probabilities: open circles, from (^{3}He,tf) reactions; closed circles, from (^{3}He,df) reactions; full lines, model fits as discussed in the text.

Fission barriers distributions = interest of surrogate reactions

Like in heavy ions fusion reactions

it is very interesting to study the energy derivative :

$$\Downarrow$$

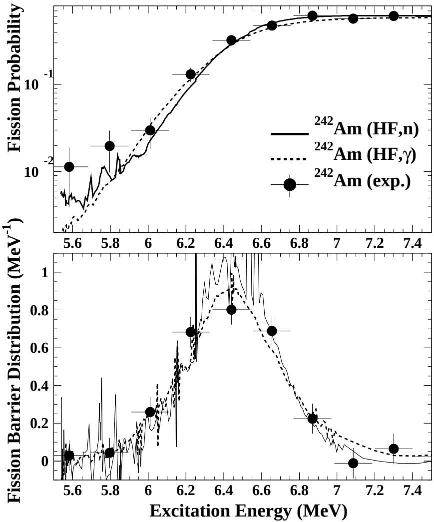
$$\frac{dP_{EC,f}}{dE} = D_f(E)$$

$$\Downarrow$$

$D_f(E)$ defines fission barriers distributions

Fission barriers distributions

$$D_f(E) = \frac{dP_f(E)}{dE}$$



$$SR = (^3\text{He}, \alpha f)$$

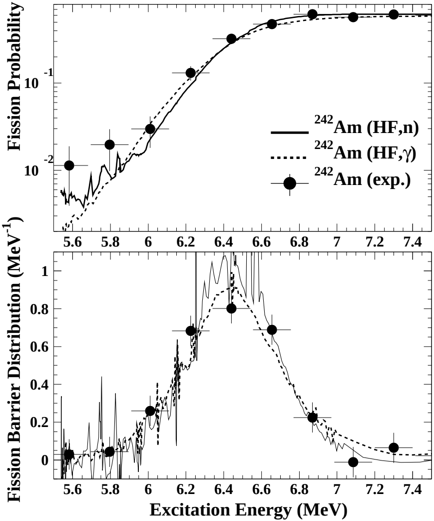
(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

Fission barriers distributions

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B >= \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$



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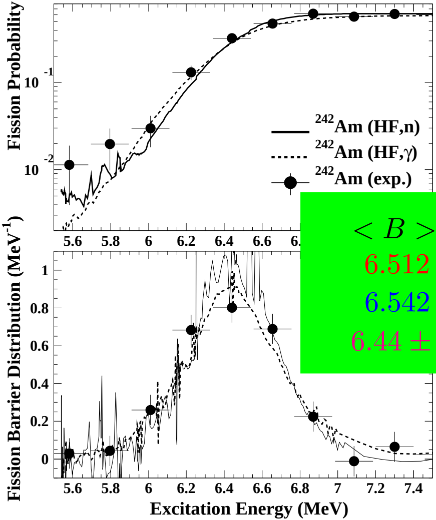


$SR = (^3\text{He}, \alpha f)$

$< B >$	reaction
6.512	n, f
6.542	γ, f
6.44 ± 0.11	SR

(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B > = \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

consistency

between EC

HOPE

surrogate for

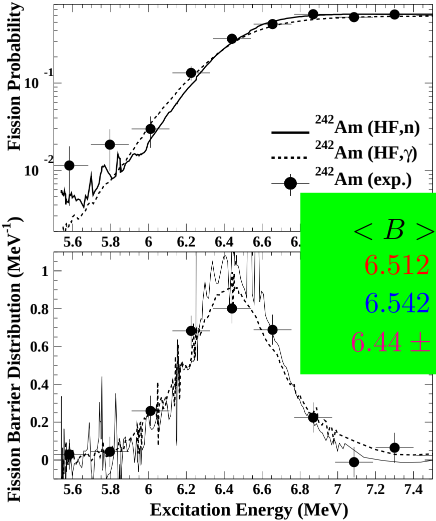
fission

$$\Downarrow$$

$$< B^{exp} >$$

completly exp.

using no model



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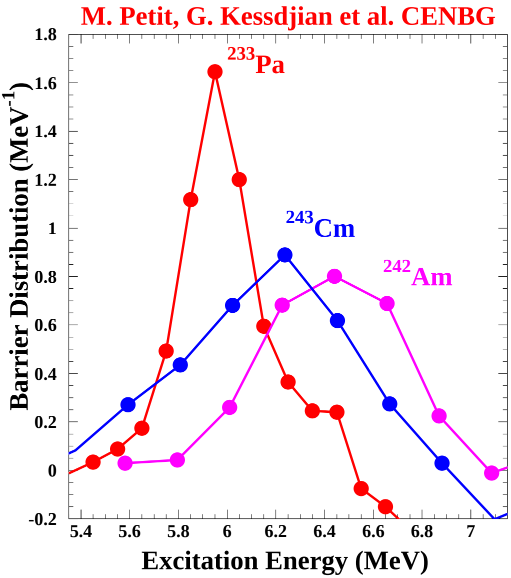
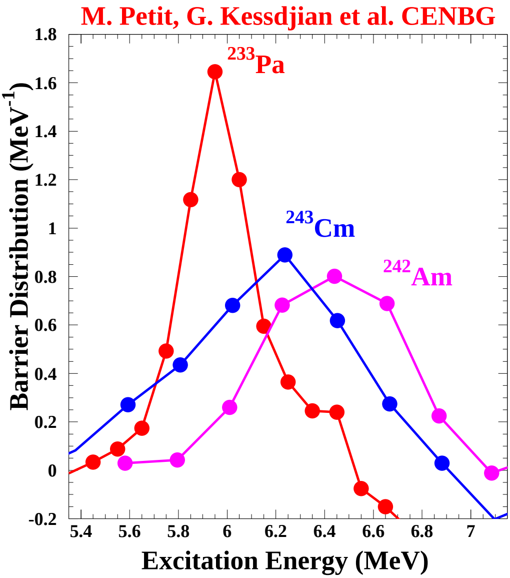


Fission barriers distributions

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B >= \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$



$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

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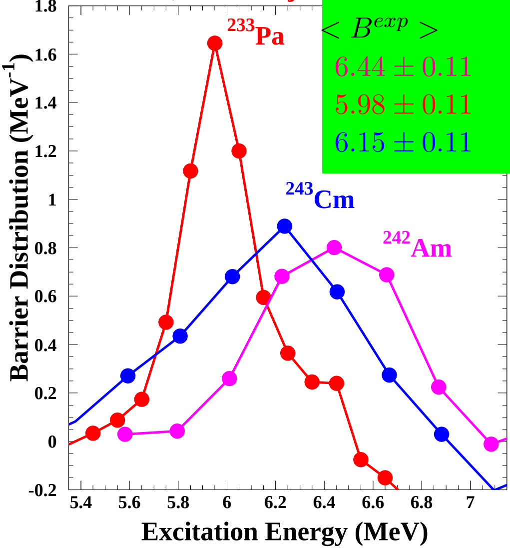
M. Petit, G. Kessdjian et al. CENBG



$< B^{exp} >$	Bjorn-Lynn
6.44 ± 0.11	6.5 ± 0.2
5.98 ± 0.11	6.1 ± 0.3
6.15 ± 0.11	6.4 ± 0.3

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B > = \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

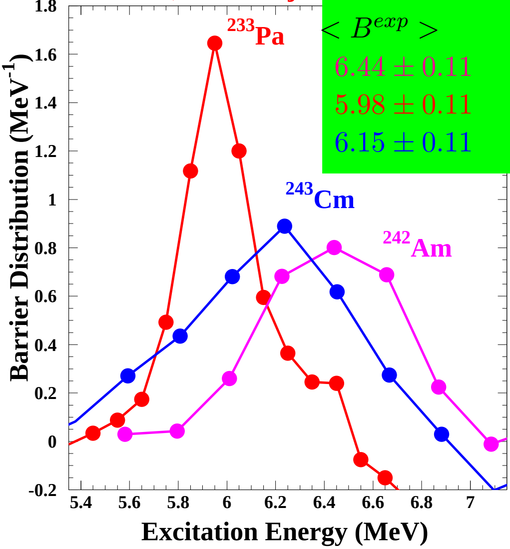
HOPE
surrogate for
fission

$$\Downarrow$$

$$< B^{exp} >$$

completly exp.
using no model

M. Petit, G. Kessdjian et al. CENBG



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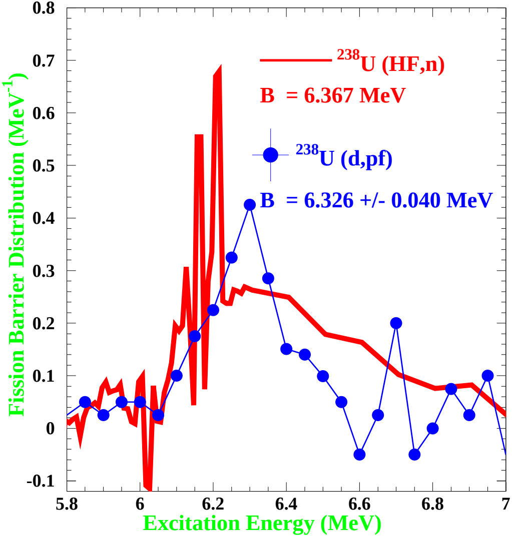
$$D_f(E) = \frac{dP_f(E)}{dE}$$

$P_f(E)$ = Q. Ducasse et al. CENBG ND2013



$SR = (d, pf)$

(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

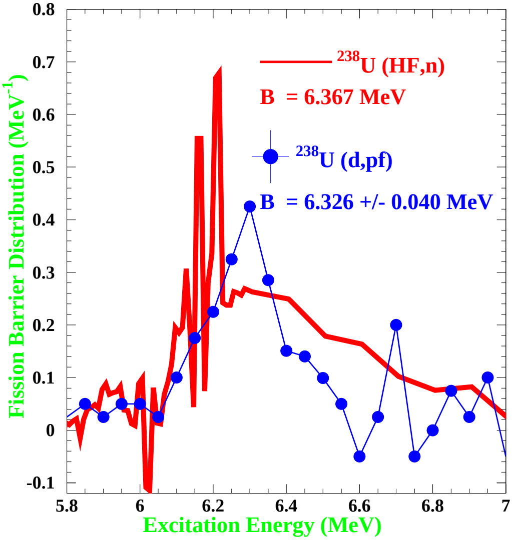
Fission barriers distributions

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B > = \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

$P_f(E)$ = Q. Ducasse et al. CENBG ND2013



$SR = (d, pf)$

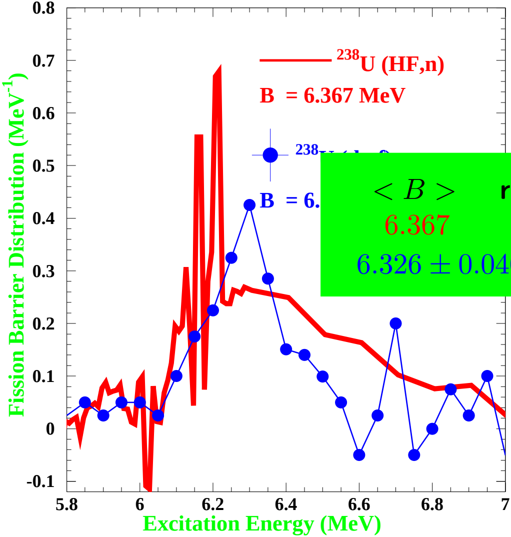
(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$$\Downarrow$$

$$< B >= \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

$P_f(E)$ = Q. Ducasse et al. CENBG ND2013



$SR = (d, pf)$

$< B >$	reaction
6.367	n, f
6.326 ± 0.040	SR

(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

$$D_f(E) = \frac{dP_f(E)}{dE}$$

$\Downarrow$

$$< B >= \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

consistency

between EC

HOPE

surrogate for

fission

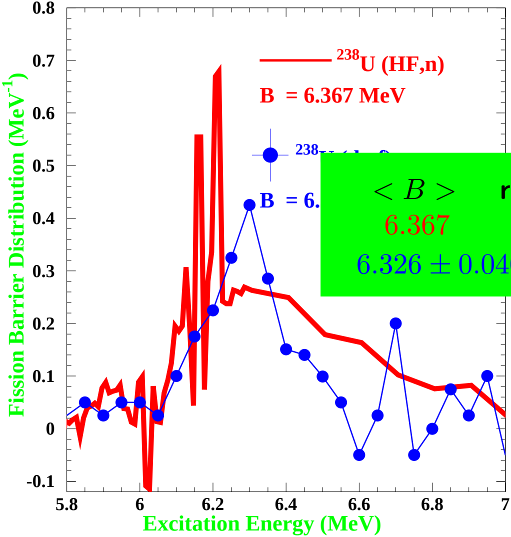
$\Downarrow$

$< B^{exp} >$

completly exp.

using no model

$P_f(E)$ = Q. Ducasse et al. CENBG ND2013



$SR = (d, pf)$

$< B >$	reaction
6.367	n, f
6.326 ± 0.040	SR

(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

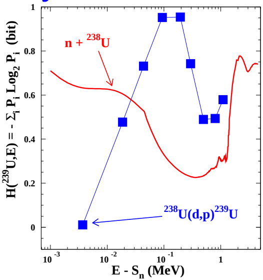
Fission barriers distributions (interest of surrogate)

$$D_f(E) = \frac{dP_f(E)}{dE}$$

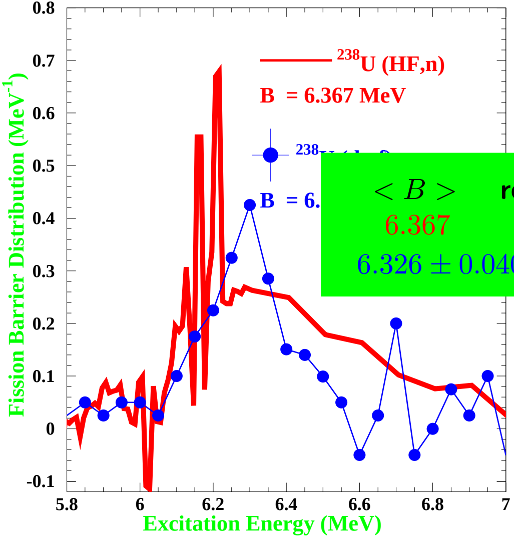
$$\Downarrow$$

$$< B > = \frac{\int E D_f(E) dE}{\int D_f(E) dE}$$

Since P_f and P_γ simul. measured by Ducasse et al.



$P_f(E)$ = Q. Ducasse et al. CENBG ND2013



$SR = (d, pf)$

$< B >$	reaction
6.367	n, f
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(P. Romain, H. Duarte, B. Morillon, PRC 85 044603)

Use of Shannon theorem for : $n+^{235}$U $\leftrightarrow$ $\gamma+^{236}$U

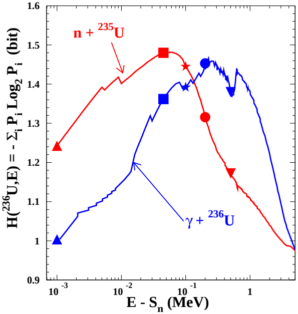


Figure : *Lack of information $H_\gamma(^{236}U, E)$ et $H_n(^{236}U, E)$ on compound emissions processes, related to a given entrance channel EC, (plotted versus $E - S_n$).*

$$H_{EC}(CN,E) = -P_{EC,\gamma}(E)\log_2 P_{EC,\gamma}(E) - P_{EC,n}(E)\log_2 P_{EC,n}(E) - P_{EC,f}(E)\log_2 P_{EC,f}(E).$$

Bohr independence hypothesis in term of Shannon theorem re-writes :

$$H_{EC_1}(CN,E) = H_{EC_2}(CN,E).$$

BUT HERE :

$$H_n(^{236}U,E) \neq H_\gamma(^{236}U,E)$$
$$\Updownarrow$$
$$J_n, \pi_n \neq J_\gamma, \pi_\gamma$$

or at least

Bohr independence hypothesis failed for $E \sim S_n$ with incident n since $W > 1$

Do not use Weisskopf-Ewing approximation !

Use of Shannon theorem for : $n+^{235}\mathrm{U} \leftrightarrow \gamma+^{236}\mathrm{U}$

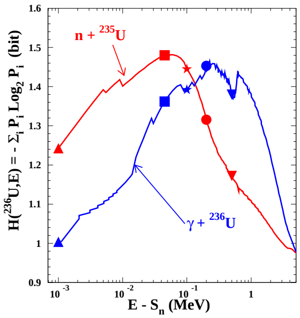


Figure : *Lack of information $H_\gamma(^{236}$U$, E)$ et $H_n(^{236}$U$, E)$ on compound emissions processes, related to a given entrance channel EC, (**plotted versus** $E - S_n$).*

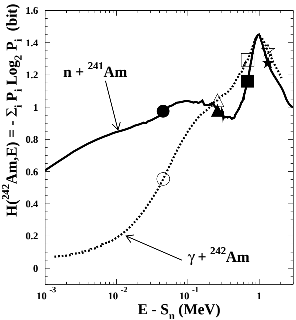


Figure : *Lack of information $H_\gamma(^{242}$Am$, E)$ et $H_n(^{242}$Am$, E)$ on compound emissions processes, related to a given entrance channel EC, (**plotted versus** $E - S_n$).*

Use of Shannon theorem for : $n+^{235}$U $\leftrightarrow$ $\gamma+^{236}$U

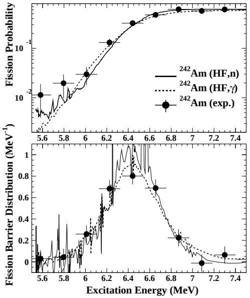


Figure : *(top) Fission probabilities of ^{242}Am CN formed by different EC : (n, f), (γ, f) and SR $(^3He, \alpha f)$,plotted versus excitation energy. (bottom) fission barriers distributions.*

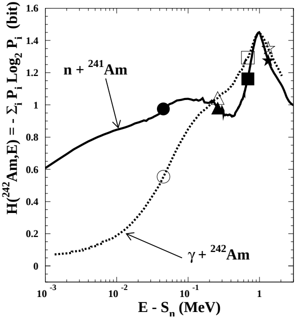
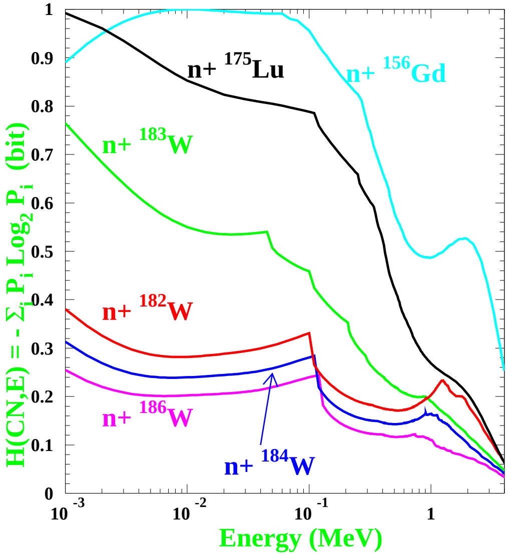


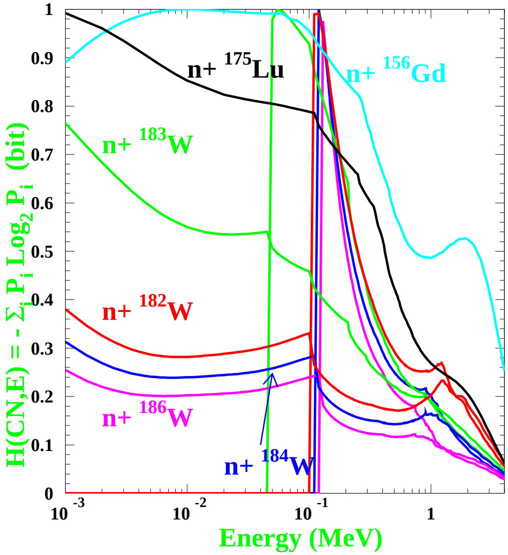
Figure : *Lack of information $H_\gamma(^{242}Am, E)$ et $H_n(^{242}Am, E)$ on compound emissions processes, related to a given entrance channel EC, (**plotted versus** $E - S_n$).*

Lack of information on compound emission processes

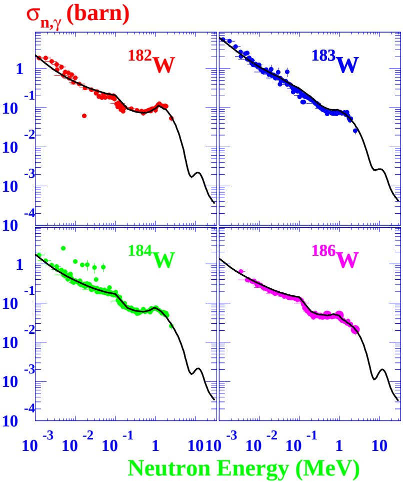
back to rare earth nuclei : the W isotopes



Lack of information on comp./non-elas. emission processes



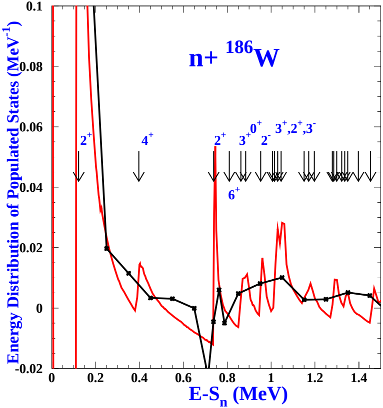
capture the way to inelastic scattering



energy derivative of calculated capture probability

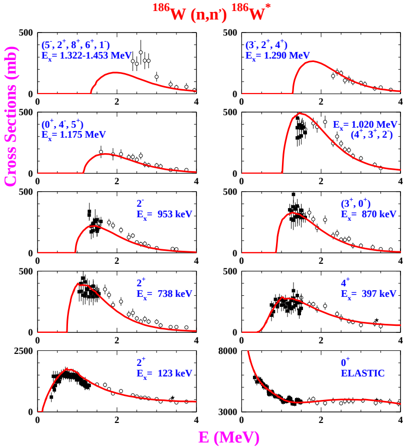
energy derivative of measured capture probability

$$P_\gamma = \frac{\sigma_{n,\gamma}}{\sigma_{CN}} \text{ with } \sigma_{CN} = 3 \text{ b}$$



inelastic scattering xs on a level / production xs of a level

D.Lister et al., P.T. Guenther et al. (ANL)



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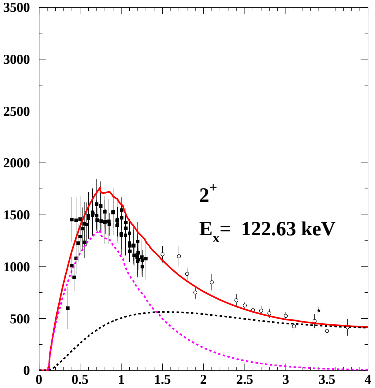

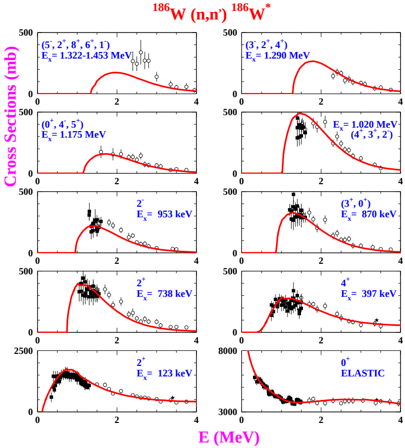

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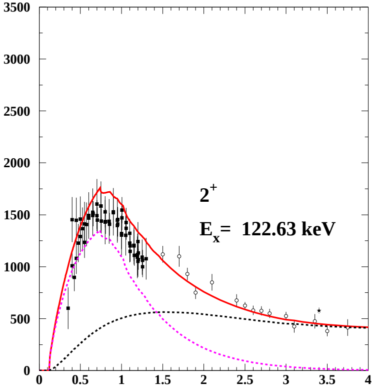

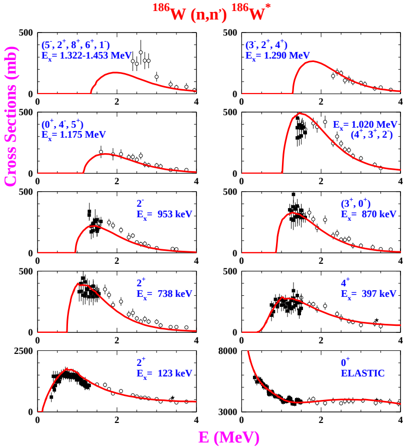

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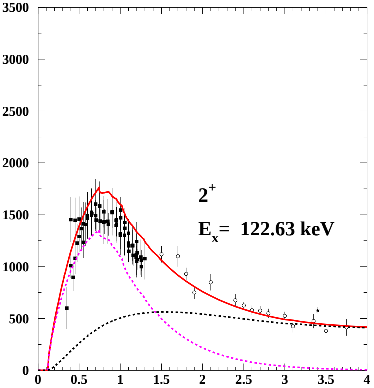

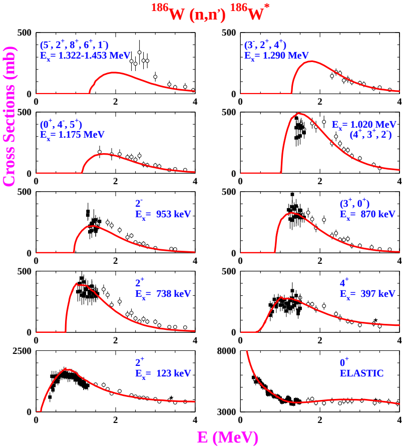

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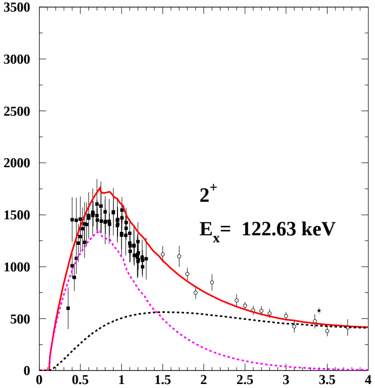

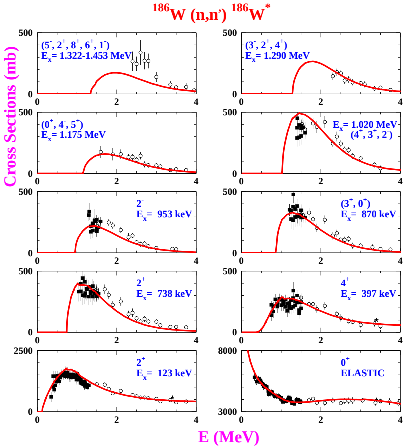

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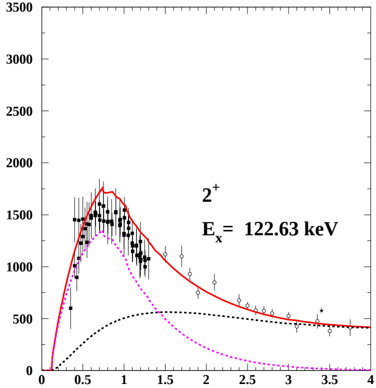
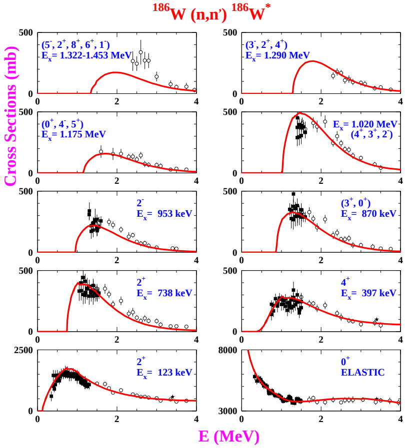
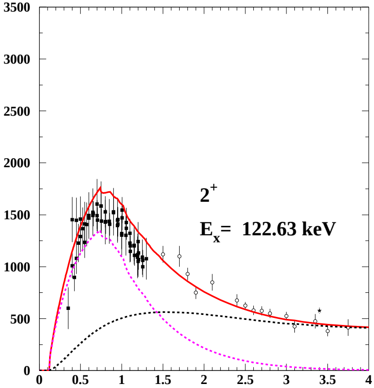
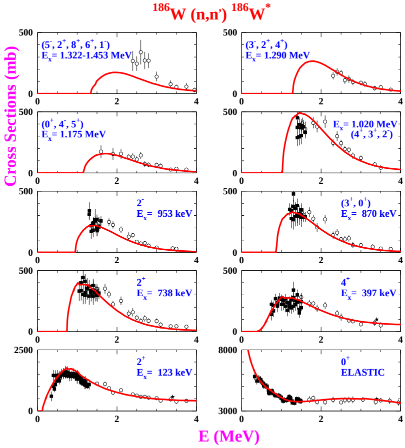
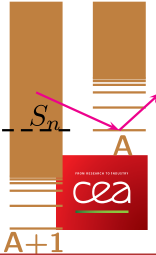




D.Lister et al., P.T. Guenther et al. (ANL)







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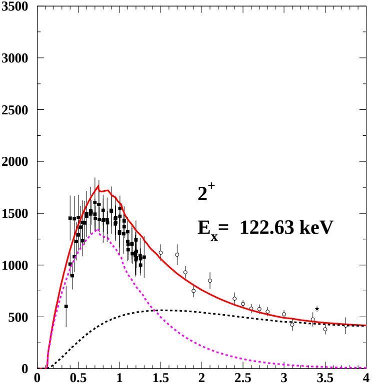
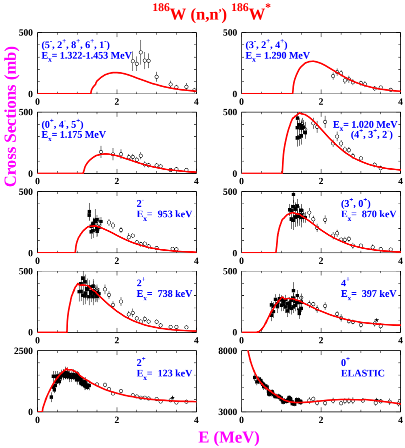
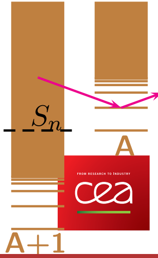
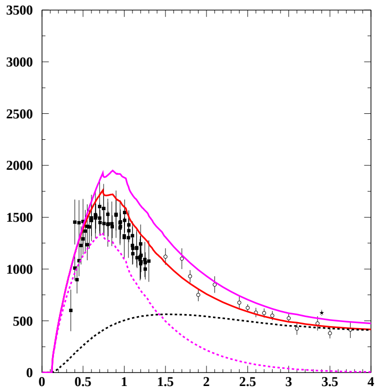
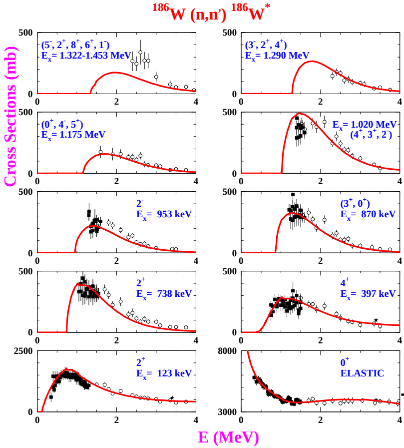


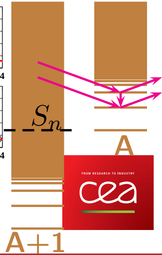




D.Lister et al., P.T. Guenther et al. (ANL)

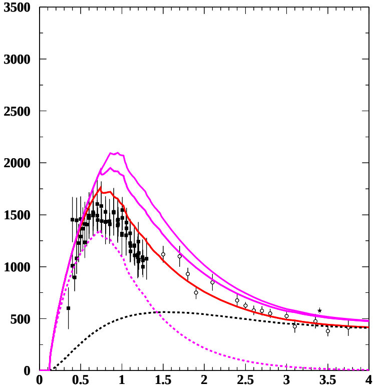


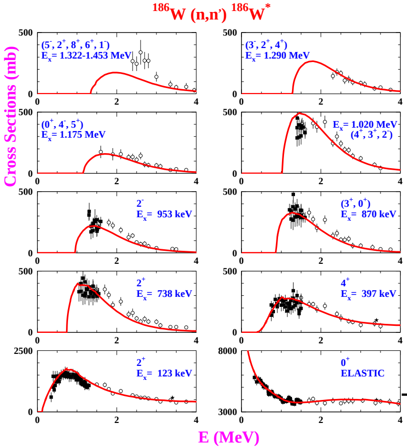


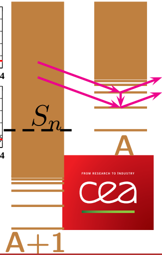


Weighted by right branching ratio

D.Lister et al., P.T. Guenther et al. (ANL)

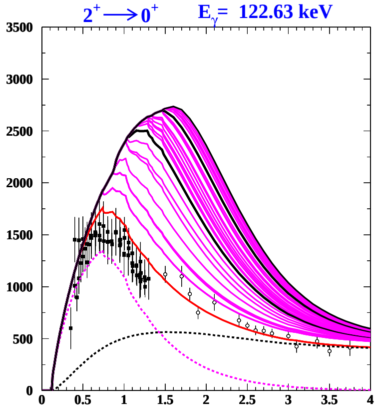


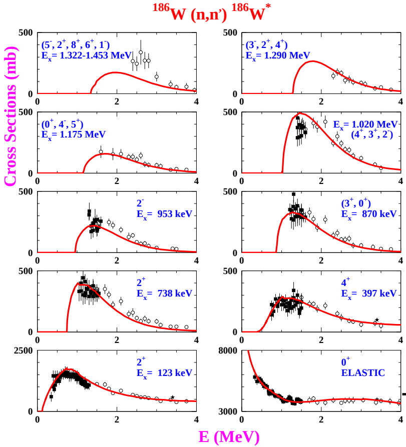


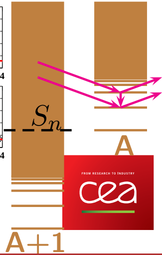


Weighted by right branching ratio

D.Lister et al., P.T. Guenther et al. (ANL)



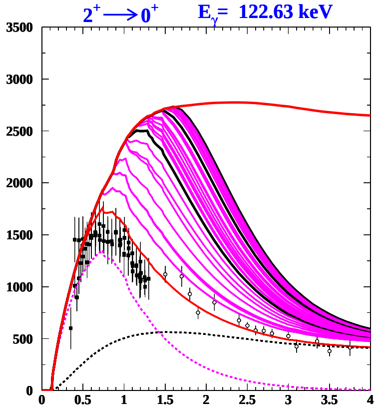


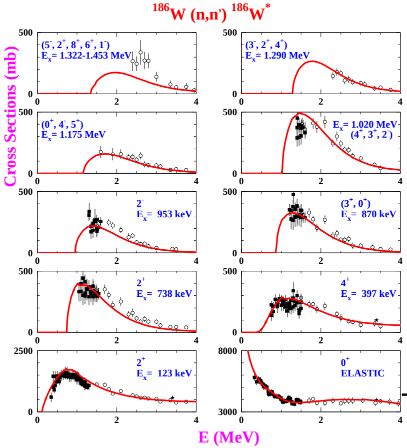


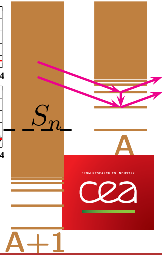
Weighted by right branching ratio

inelastic scattering xs on a level / production xs of a level

D.Lister et al., P.T. Guenther et al. (ANL)



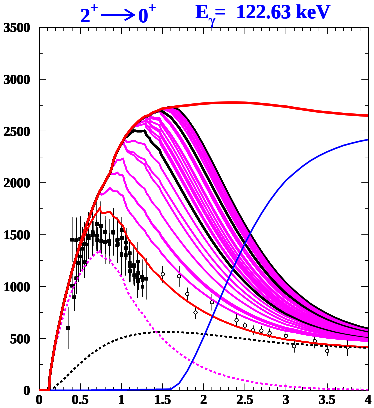


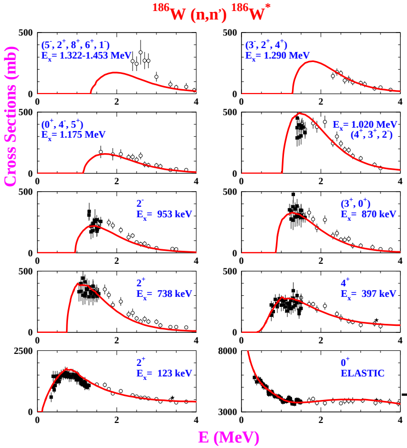


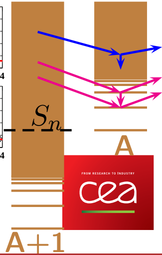
Weighted by right branching ratio

inelastic scattering xs on a level / production xs of a level

D.Lister et al., P.T. Guenther et al. (ANL)

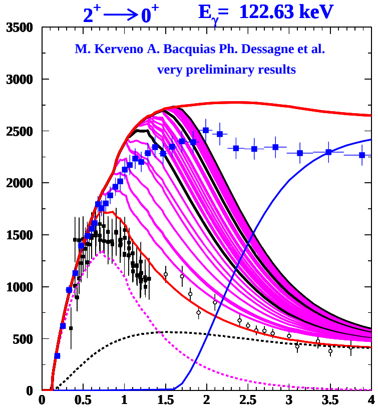


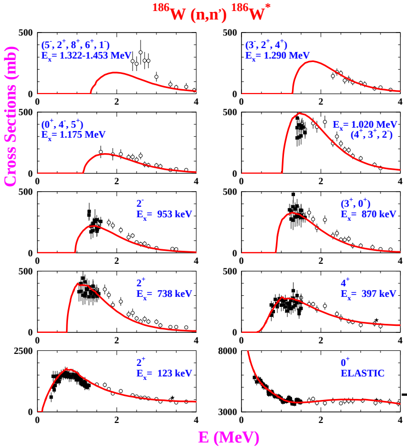


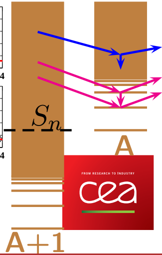


Weighted by right branching ratio

Branching ratios ? ? D.Lister et al., P.T. Guenther et al. (ANL)

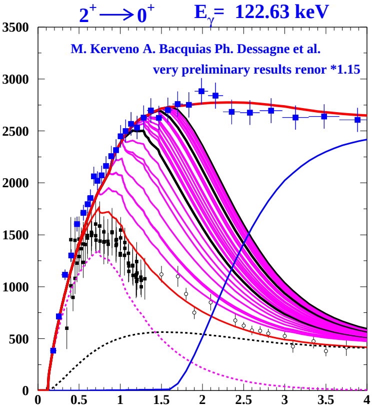


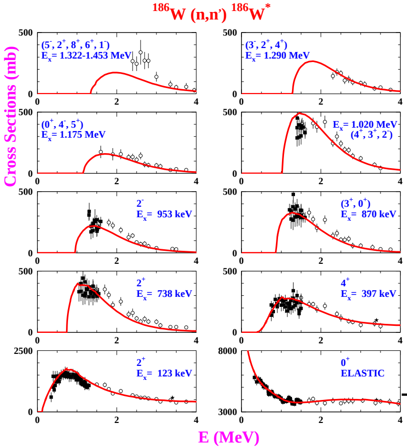


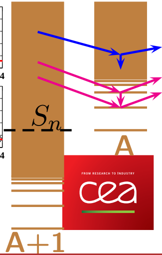


Weighted by right branching ratio

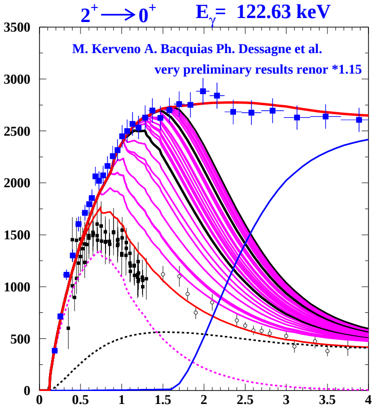
Branching ratios ? ? **D.Lister et al., P.T. Guenther et al. (ANL)**

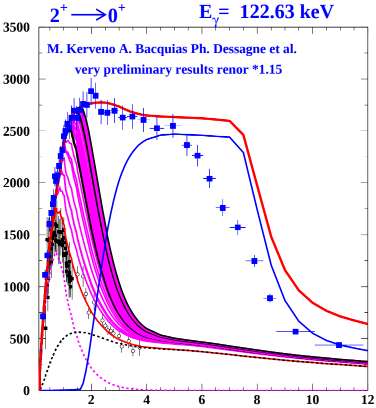






Branching ratios ? ? Spin distributions of PE models ? ?





Back to actinides inelastic cross section :

Back to actinides inelastic cross section

Back to actinides inelastic cross section : the special ^{238}U case ! ! ! ! !

Back to actinides inelastic cross section

Back to actinides inelastic cross section : the special ^{238}U case ! ! ! ! !

An "inelasti-genic" nucleus

For energies $E < E_{(n,2n)}^{threshold}$, we can write :

$$\sigma_R = \sigma_{CE} + \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f}$$

For energies $E < E^{threshold}_{(n,2n)}$, we can write :

$$\sigma_R = \sigma_{CE} + \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f}$$

and finally :

$$\sigma_R - \sigma_{CE} = \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f} = \sigma_{non-elas}$$

$$1 = \frac{\sigma_{n,n'}}{\sigma_{non-elas}} + \frac{\sigma_{n,\gamma}}{\sigma_{non-elas}} + \frac{\sigma_{n,f}}{\sigma_{non-elas}}$$

For energies $E < E^{threshold}_{(n,2n)}$, we can write :

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For each non-elastic process GLOBAL probabilities can be defined :

$$1 = P^{non-elas}_{n,n'} + P^{non-elas}_{n,\gamma} + P^{non-elas}_{n,f}$$

non-elastic processes probabilities

For energies $E < E_{(n,2n)}^{threshold}$, we can write :

$$\sigma_R = \sigma_{CE} + \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f}$$

and finally :

$$\sigma_R - \sigma_{CE} = \sigma_{n,n'} + \sigma_{n,\gamma} + \sigma_{n,f} = \sigma_{non-elas}$$

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For each non-elastic process GLOBAL probabilities can be defined :

$$1 = P_{n,n'}^{non-elas} + P_{n,\gamma}^{non-elas} + P_{n,f}^{non-elas}$$

These probabilities are also directly deduced from evaluated files :

$$\sigma_{non-elas} = MF_3MT_4 + MF_3MT_{102} + MF_3MT_{18}$$

$$1 = \frac{MF_3MT_4}{\sigma_{non-elas}} + \frac{MF_3MT_{102}}{\sigma_{non-elas}} + \frac{MF_3MT_{18}}{\sigma_{non-elas}}$$

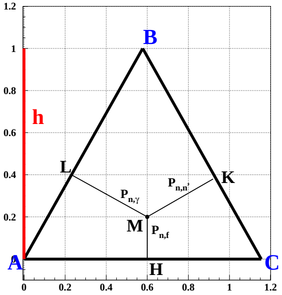


Figure : *Dalitz representation of non-elastic processes in the energy range* 1 *keV* $< E < E^{threshold}_{(n,2n)}$

For these three open channels a Dalitz representation can be used. Indeed for an equilateral triangle ABC $(AB = AC = BC)$ with height h, each point M inside this triangle satisfies the following property :

$$MH + MK + ML = h$$

where H, K, L are the M orthogonal projections on each side $[AC]$, $[BC]$ et $[AB]$ respectivly. When assuming :

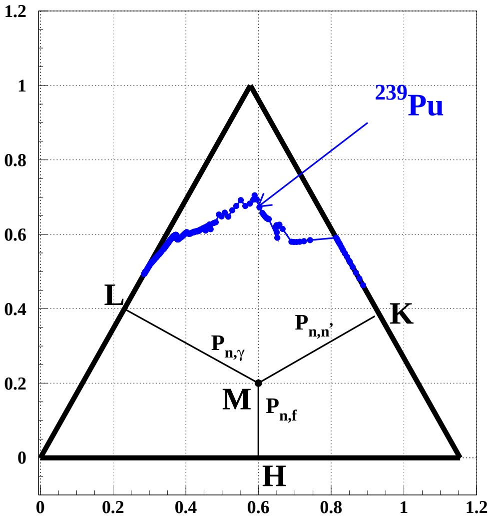
$$MH = P^{non-elas}_{n,f}, ML = P^{non-elas}_{n,\gamma},$$
$$MK = P^{non-elas}_{n,n'} \text{ with } h = 1$$
$$MH + MK + ML =$$
$$P^{non-elas}_{n,n'} + P^{non-elas}_{n,\gamma} + P^{non-elas}_{n,f} = 1$$

Then each set

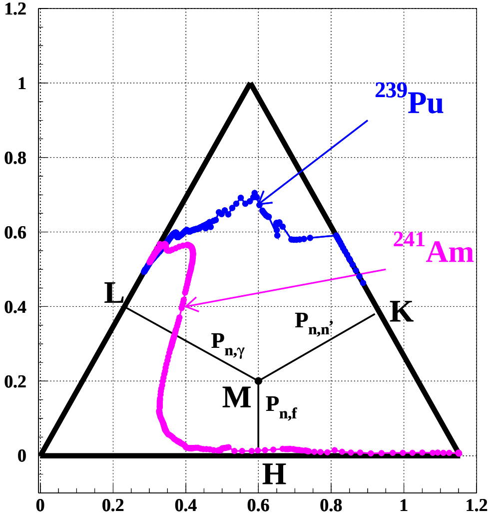
$$(E, \sigma_{n,n'}, \sigma_{n,\gamma}, \sigma_{n,f}) =$$
$$(E, MF_3MT_4, MF_3MT_{102}, MF_3MT_{18})$$

of an evaluated file can be represented by a corresponding point M inside an equilateral triangle ABC with unitary height $(h = 1)$. And finally an evaluated file will display a path inside this equilateral triangle.

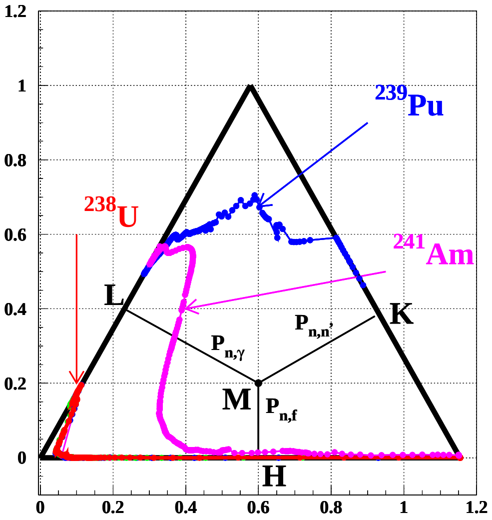
Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range



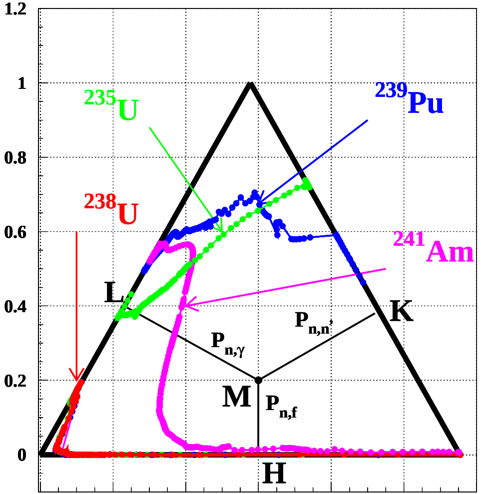
Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range



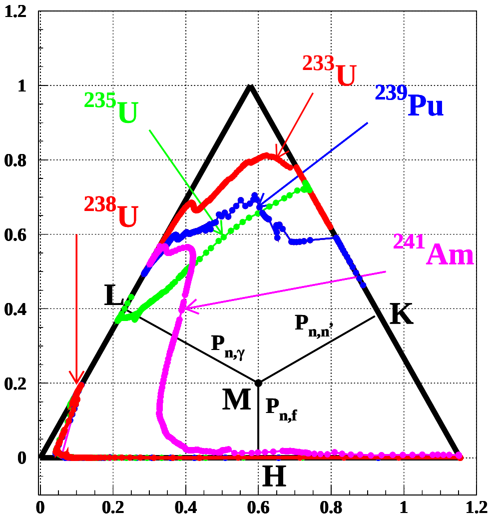
Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range



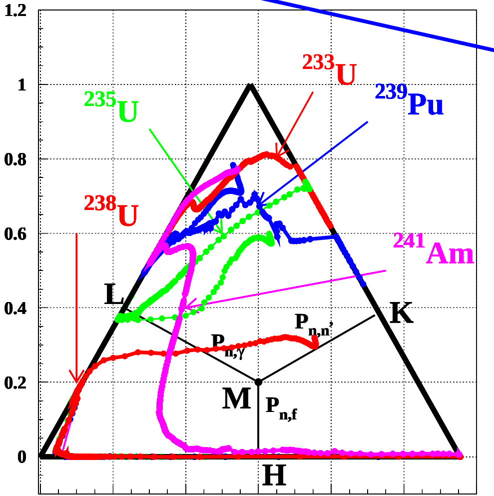
Dalitz Representation of non-elastic processes on 1 keV $< E < E_{(n,2n)}^{threshold}$ energy range



Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range



Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range

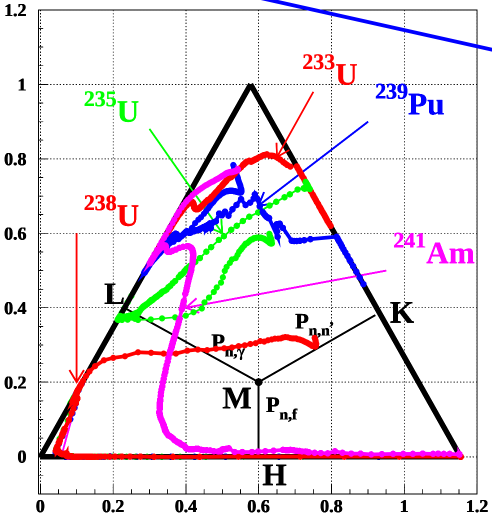


$E^{threshold}_{(n,3n)}$

$P^{non-elas}_{n,\gamma} \approx 0$

$P^{non-elas}_{n,\gamma} \leftrightarrow P^{non-elas}_{n,2n}$

Dalitz Representation of non-elastic processes on 1 keV $< E < E^{threshold}_{(n,2n)}$ energy range



$E^{threshold}_{(n,3n)}$

$P^{non-elas}_{n,\gamma} \approx 0$

$P^{non-elas}_{n,\gamma} \leftrightarrow P^{non-elas}_{n,2n}$

For ^{238}U always

$P^{non-elas}_{n,n'} > P^{non-elas}_{n,f}$

and mostly

$P^{non-elas}_{n,2n} > P^{non-elas}_{n,f}$

$\Longrightarrow$ ^{238}U prefers n-emissions as $fission$

Dalitz Representation - ^{238}U (BRC - ENDF-B/VII)

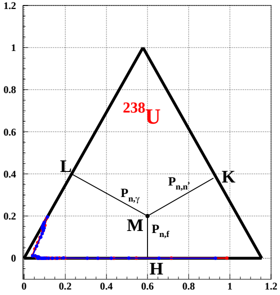


Figure : *Dalitz representation of non-elastic processes in the energy range* 50 *keV* $< E < E^{threshold}_{(n,2n)}$. *Here were considered the same energy points (between BRC and ENDF-B/VII) joined by black straight lines.*

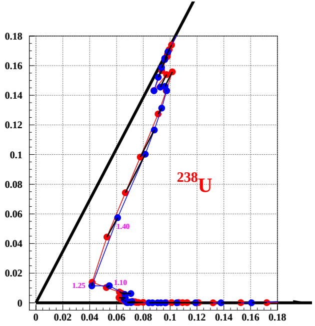


Figure : *Dalitz representation of non-elastic processes for energies* $0.2 < E < 1.3$ *MeV. Here were considered the same energy points (between BRC and ENDF-B/VII) joined by black straight lines.*

Dalitz Representation - ^{238}U (BRC - ENDF-B/VII)

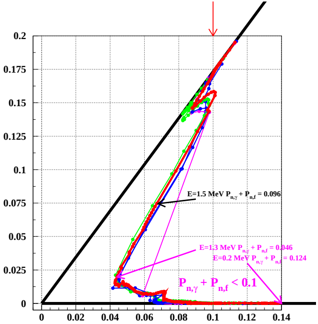


Figure : *Dalitz representation of non-elastic processes for energies* $0.2 < E < 1.3$ *MeV and for different evaluations : BRC - ENDF-B/VII - JENDL4.0 - JEFF3.1.* All Eval. are nearly the same

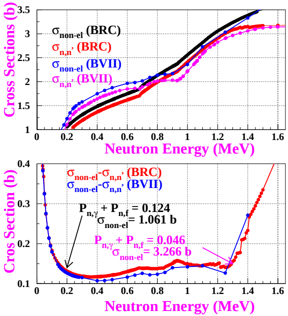
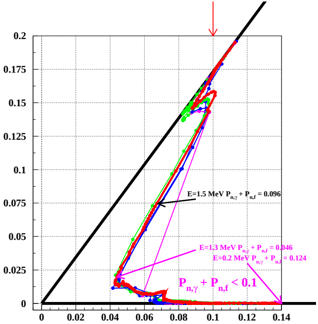


Figure : *Top : evaluated (BRC - ENDF-B/VII) inelastic cross sections compared to the BRC non-elastic cross section for energies* $0.2 < E < 1.3$ *MeV. Bottom : sum of capture and fission cross sections for energies* $0.2 < E < 1.3$ *MeV.*

$\sigma_{BRC} \neq \sigma_{ENDF-B/VII}$ but identical prob. (=ratio).



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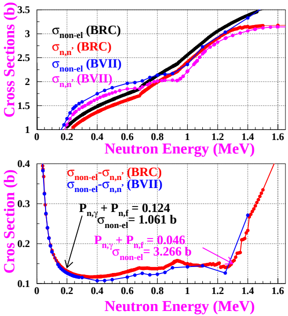

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^{238}U surprising effect

In the energy range $0.2 < E < 1.3$ MeV :

$$\sigma_{n,n'} \approx \sigma_{non-elas}$$

or more precisely

$$\sigma_{non-elas} \times 90\% < \sigma_{n,n'} < \sigma_{non-elas} \times 95\%$$

OK, but in this energy range $\sigma_{non-elas}$ depends on **OMP choices : coupling scheme effects and deformation parameters of course.**

Conclusion or what should be done...

OMP : Dispersive OP
Choice of Coupling Scheme

(n,xnγ) : What about Branching ratios
(n,xnγ) : What about Spin Distributions in the PE models
Inelastic XS (waste XS ?)

Measurements of this XS would be of great interest But effectivly experimental limits (to separate Inel. scat. to the low-lying states from the elast. scat.)

^{238}U : an "inelasti-genic" nucleus

Surrogate Reactions : Forget it, but nevertheless interesting to deduce fission barriers height