Gamma production following quasi-metastable state production
Memo CP-D/1057

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Subject: **Gamma production following quasi-metastable state production**

Dictionary 33 (particles) defines the following two codes:

`G` Gammas (Use DG for decay gammas)

`DG` Decay gammas – Used for gammas emitted from *metastable states* and for gammas following a particle-emitting decay (e.g., beta decay)

Obviously "metastable state" in the explanation of `DG` does not include quasi-metastable states (Otherwise all cascade gammas eventually belong to `DG` since we do not have the lower boundary of the half-life for quasi-metastable states.). Then there are probably following three cases for the datasets currently coded with `PAR,$SF6,G`:

Isomeric States:

Metastable state: An excited state having a half-life of the order of $T_{1/2} \geq 0.1$ seconds.

Quasi metastable state: States that have measured half-lives $T_{1/2} < 0.1$ seconds. We do not have the lower boundary of the half-life for quasi-metastable states.

Three possibility for the gamma production following quasi-metastable state production are:

- all gammas of the transition
- gammas from cascades going through quasi-metastable state
- gammas from cascades bypassing quasi-metastable state

The dataset presently has three cases coded with PAR,$ SF6,G:

1. All cascade gammas (usual gamma production cross section)

Examples:

`(82-PB-206(N,INL)82-PB-206,PAR,DA,G)`

for the full portion of the 803 keV gamma production

`(13-AL-27(N,INL)13-AL-27,PAR,DA,G)`

for the full portion of the 1014 keV gamma production excluding decay gamma originating from ^{27}Al(n,p)^{27}Mg (9.5 min)→^{27}Al.

2. Cascade gammas not following quasi-metastable state ($T_{1/2}$<0.1 sec) production

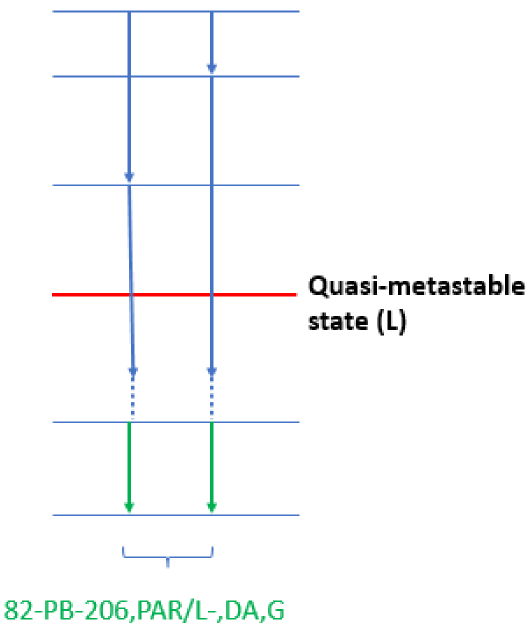
This could be coded with a new modifier (say `L-`) indicating "excluding formation via quasi-metastable state production".

Example (<u>proposal</u>):

`82-PB-206(N,INL)82-PB-206,PAR/L-,DA,G`

for the 803 keV gamma production from a cascade bypassing the 125 μsec quasi-metastable state production (e.g., 31492.006.1)

L- Excluding formation via quasi-metastable state production.



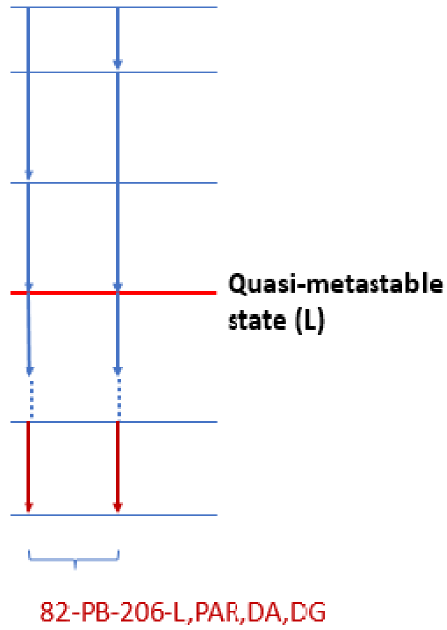
3. Cascade gammas following quasi-metastable state ($T_{1/2}$<0.1 sec) production

This could be coded with a quasi-metastable state flag in SF4:

Example (<u>proposal</u>):

`82-PB-206(N,INL)82-PB-206`**`-L`**`,PAR,DA,DG`

for the 803 keV gamma production following the 125 μsec quasi-metastable state production (e.g., 31492.006.2).



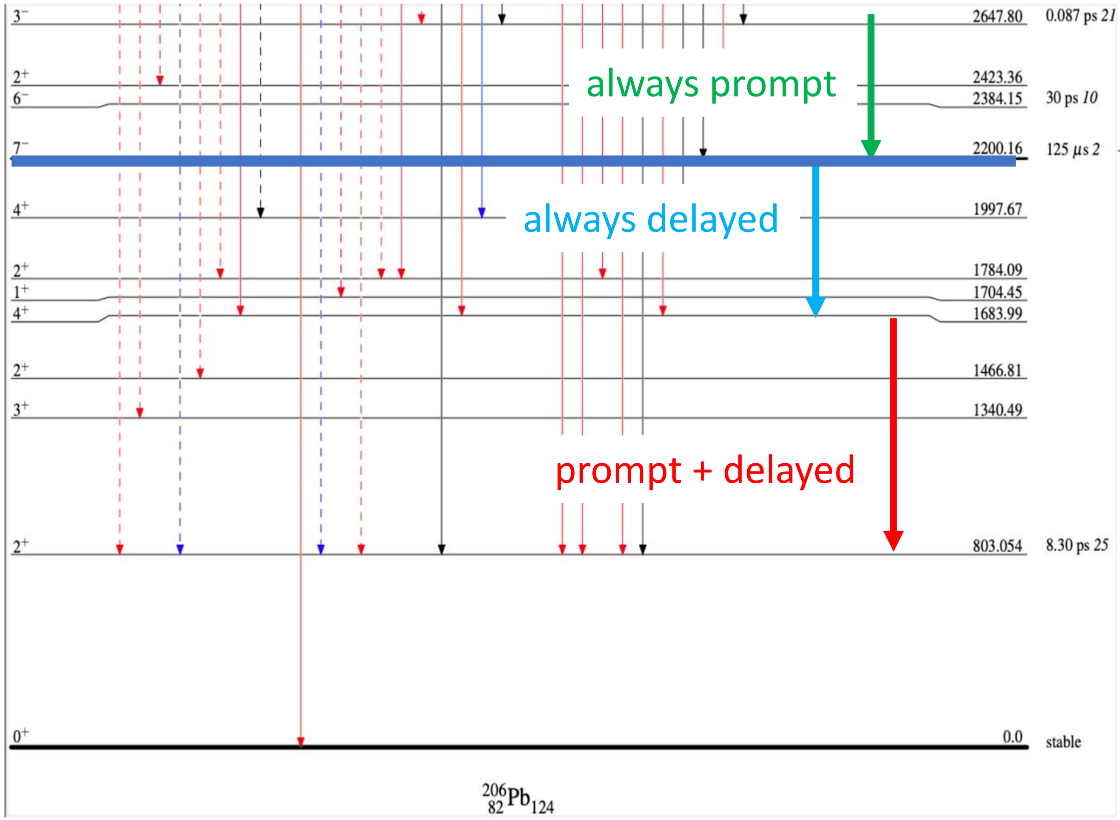
- DG Used for gammas emitted from *metastable states* and for gammas following a particle-emitting decay (e.g., beta decay)

Hongyu Zhou+, J,NSE,134,106,2000, (EXFOR 31492)

The table below shows the gamma production cross sections from irradiation of natural Pb by 14.9 MeV neutrons at Beijing Normal University.

The authors report two components (“prompt” and “124 μsec”) for several ^{206}Pb gamma lines (*e.g.*, 803 keV $2^+ \rightarrow 0^+$ γ line).

- The “delayed” component is originated from gamma cascades through the 125 μsec quasi-metastable state at 2200 keV.
- The gamma cascades above 2200 keV always originate the “prompt” component “as no effect of the 125 μsec quasi-metastable state .



Quasi-metastable state

E_γ (keV)	Final Nucleus	Transition (keV)	$t_{1/2}$	Elemental Cross Secti…		
				Present Work		
				55 deg	90 deg	140 deg
343.3	^{206}Pb	1648.1 to 1340.6	Prompt	1.27 ± 0.38	1.47 ± 0.34	1.11 ± 0.33
343.3	^{206}Pb	1648.1 to 1340.6	124 μs	5.63 ± 1.13	3.94 ± 1.58	4.10 ± 1.64
458.1	^{206}Pb	2658.5 to 2200.2	Prompt	2.86 ± 0.28	2.45 ± 0.34	2.74 ± 0.21
516.4	^{206}Pb	2200.2 to 1684.1	124 μs	20.5 ± 1.0	21.0 ± 1.0	19.9 ± 1.5
537.3	^{206}Pb	1340.6 to 803.1	Prompt	10.2 ± 0.5	9.82 ± 0.40	10.2 ± 0.6
537.3	^{206}Pb	1340.6 to 803.1	124 μs	6.24 ± 0.50	5.70 ± 0.54	6.29 ± 0.60

A.Negret+,J,PR/C,91,064618,2015 (EXFOR 23292)

The Pb+n γ production cross section measurement at GELINA. According to this article:

> "The second limitation concerns an isomer at 2200.2 keV with a lifetime of 180(3) μs. The γ rays from the decay of this isomer (516.2 and 202.4 keV) are delayed and almost all of the decay occurs outside of the 24-μs time span of the present measurement. Therefore the **γ rays emitted following the decay of the isomer are hard to observ**e and…"

> The fast timing measurement might only capture the "prompt" part of the gamma production cross section.

TALYS improves agreement by exclusion of the delayed component. So its indication in REACTION is important.

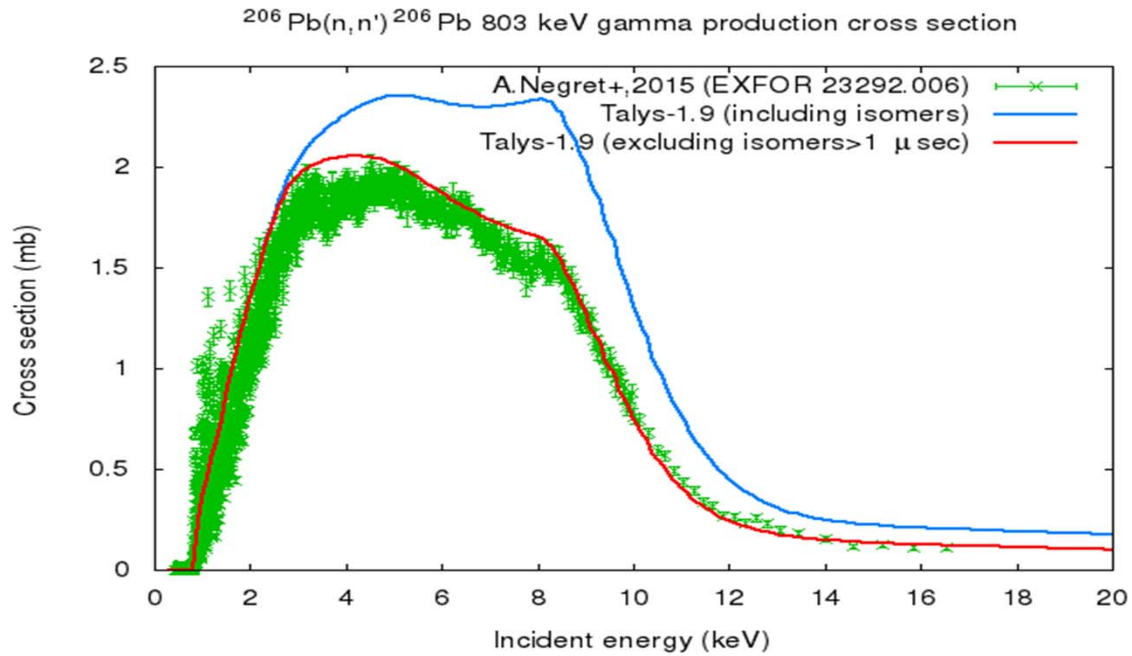


Table collects the 803 keV γ-ray production cross sections.

- "prompt" and "delayed" are in terms of the half-life of 125 μsec quasi-metastable state, and only the 31492 article gives two components separately.

- The aggregate production cross section for both the delayed and prompt components in 31492 is around 44 mb , which is almost equal to that of 20164 (42 mb) and 13034 (47 mb) without TOF.
- For 23341 the production cross section is 24.7 mb, which might include only prompt component.

Pb(n,γ+x) 803 keV (IT decay of 125 μsec ^{206}Pb may contribute to the delayed portion)

EXFOR #	Year	θ (deg)	En (MeV)	dσ/dΩ (mb/sr)	Remark
20164.057	1969	80	14.7	42(2)	GeLi
23341.026	1991	90	13.0	24.7(35)	NaI+TOF
13034.009	1972	90	14.4	47(8)	NaI
31492.006.1	2000	90	14.9	19.3(8)	GeLi+TOF, delayed
31492.006.2	2000	90	14.9	24.7(8)	GeLi+TOF, prompt
31492.006.1	2000	140	14.9	19.1(8)	GeLi+TOF, delayed
31492.006.2	2000	140	14.9	25.5(10)	GeLi+TOF, prompt

Summary of proposal

Approval for the following new codes:

Dictionary 236 (Quantities)

PAR/L-,DA,G Angular distribution of prompt discrete gamma ray transition, excluding formation via quasi-metastable state.

Dictionary 31 (Branches)

L- Excluding formation via quasi-metastable state production.

Thanks for your attention