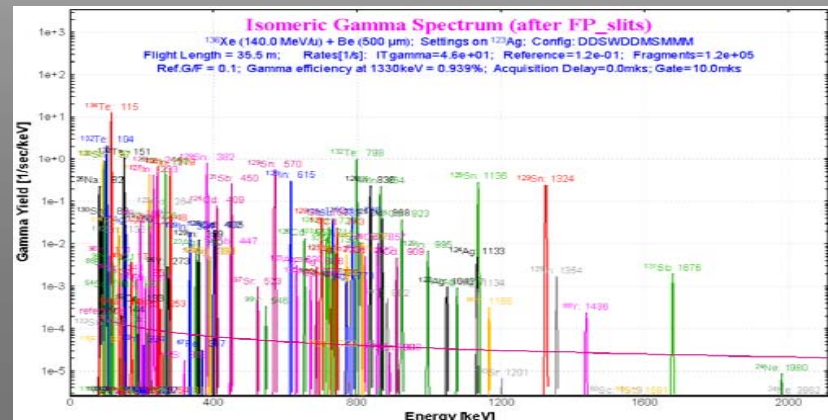


Isomers in LISE++

¹⁰⁹ Cd	¹¹⁰ Cd
¹⁰⁸ Ag	¹⁰⁹ Ag
¹⁰⁷ Pd	¹⁰⁸ Pd
¹⁰⁶ Rh	¹⁰⁷ Rh
¹⁰⁵ Ru	¹⁰⁶ Ru
¹⁰⁴ Tc	¹⁰⁵ Tc
¹⁰³ Mo	¹⁰⁴ Mo

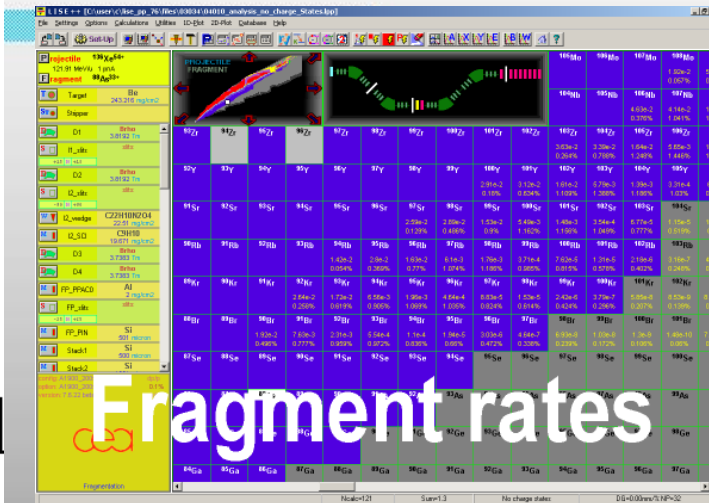
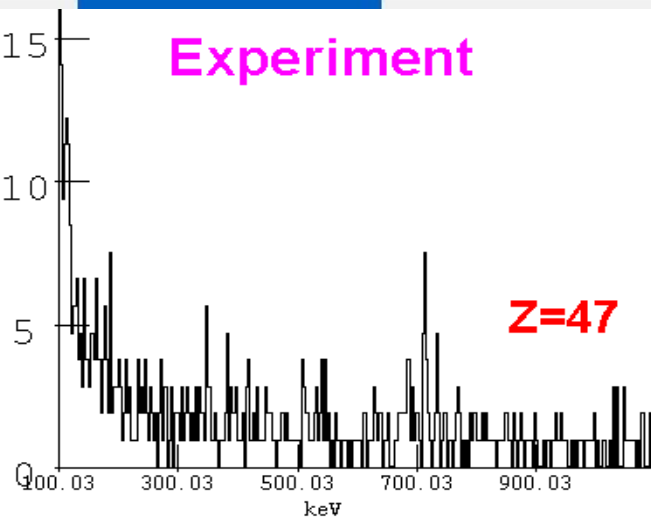
- * Introduction
- * GANIL isomer database in LISE++
- * LISE internal isomer database
- * γ -detector efficiency
- * Rate calculation of isomer γ -rays
- * Isomeric γ -spectrum
- * Identification 2D-plot in coincidence with γ -rays

Version 7.6.39 from
01/16/06 available
through LISE sites



Fragment identification using isomeric γ -rays

How do we work now?



Experiment	Isomers	Ex. Energy (keV)	γ -energies (keV)	Half-life (μ s)
03034a	59Co	503	193	96
	64Ni	135	?	>1000
	65Fe	364	?	0.430
	67Fe	367	?	648
	66Co	175	?	1.218
	66Co	648	?	>1000
	69Ni	2701	148	0.439
	70Ni	2860	183	0.232
	72Cu	2708	?	1.768
	78Zn	2673	?	0.319
88Er	273	111, 159	5.48	
93Fm	254	254 and 266 from 2nd level	578	
97Sr	308	141, 167	0.170	
97Sr	830	523	0.255	
99Y	171	50, 171	0.62	
98Y	496	50, 121, 170, 204	7.68	
98Y	1181	111, 119, 130, 158, 186, 476, 596	0.838	
99Y	2141	126, 159, 198, 223, 245, 269, 273, 283, 346, 882, 1166, 1433, 1529	8.68	
107Mo	668	668	0.470	
117Pb	?	1848	>58	
121Pd	?	1368	0.694	
123Ag	?	349, 384, 391, 630, 386, 714, 733, 769, 1049, 1077, 1133	0.214	
124Ag	?	156, 1132	1.98	
125Ag	?	670, 684, 715, 729	0.310	
125Cd	?	409, 720, 743, 786, 868, 922	>58	
126Cd	?	220, 248, 402, 405, 652, 807, 815, 856	0.270	
127Cd	?	739, 771, 821, 909	1.98	
129Xe	?	334, 359	2.98	
05028a	117Pb	?	1848	>58
	121Pd	?	1368	0.694
	123Ag	?	349, 384, 391, 630, 386, 714, 733, 769, 1049, 1077, 1133	0.214
	124Ag	?	156, 1132	1.98
	125Ag	?	670, 684, 715, 729	0.310
	126Cd	?	220, 248, 402, 405, 652, 807, 815, 856	0.270
	127Cd	?	739, 771, 821, 909	1.98
	129Xe	?	334, 359	2.98

Nuclear Levels and Gammas Search

Specify Nuclei :

Nucleus: Ex: 232Th or th232 or 232-Th or th-232 or

Z / Element: A: N:

20 $\leq Z \leq 54$ $\leq A \leq$ $\leq N \leq$

Any Z Any A Any N

E(level) condition: enabled disabled 100 $\leq E_{level}(keV) \leq$ 20000

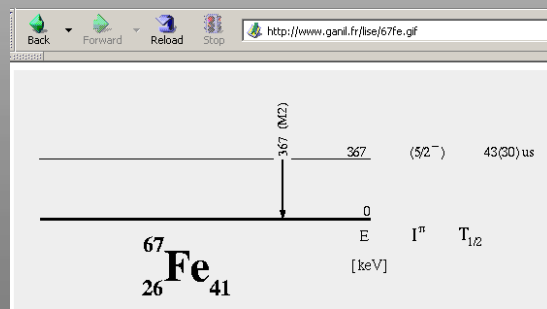
Decay Mode condition: enabled disabled **Decay Mode** ANY

Jn(level) condition: enabled disabled J = Order : ALL Parity : ANY

T_{1/2}(level) condition: enabled disabled 1 ns $\leq T_{1/2} \leq$ 100 us

γ condition #1: enabled disabled 100 $\leq E_{\gamma}(keV) \leq$ 3000 Multipolarity: ANY

γ condition #2: enabled disabled 0 $\leq E_{\gamma}(keV) \leq$ 40000 Multipolarity: ANY



Old GANIL database available through LISE

Private communications

Internet database (NNDC) region of stable isotopes

LISE isomer database

Nuclear Levels and Gammas Search
(Help)

Specify Nuclei : Nucleus: Ex: 232Th or th232 or 232.Th or th-232 or
 Z / Element: A: N:
 $20 \leq Z \leq 54$ $\leq A \leq$ $\leq N \leq$
 Any Z Any A Any N

E(level) condition: enabled disabled $100 \leq E_{level}(keV) \leq 20000$

Decay Mode condition: enabled disabled Decay Mode | ANY

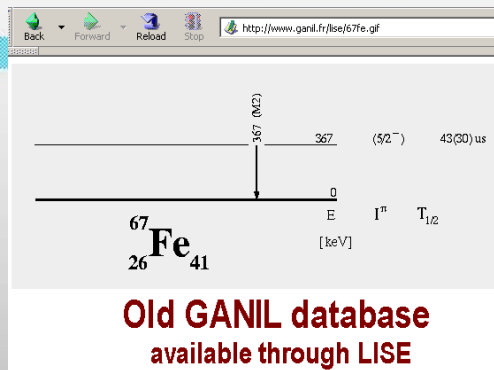
In(level) condition: enabled disabled $I =$ Order : ALL Parity : ANY

T_{1/2}(level) condition: enabled disabled $1 \leq T_{1/2} \leq 100$ us

γ condition #1: enabled disabled $100 \leq E_{\gamma}(keV) \leq 3000$ Multipolarity: ANY

γ condition #2: enabled disabled $0 \leq E_{\gamma}(keV) \leq 40000$ Multipolarity: ANY

**Internet database (NNDC)
region of stable isotopes**



Experiment	Isomers	Ex. Energy (keV)	γ -energies (keV)	Half-life (yr)
03034e	59Cr	502e	193e	96e
**	64Mn	135e	7e	>100e
**	65Fe	364e	7e	0.430e
**	67Fe	367e	7e	64e
**	66Co	175e	7e	1.21e
**	66Co	64e	7e	>100e
**	69Ni	2701e	148e	0.430e
**	70Ni	2669e	183e	0.232e
**	72Cu	270e	7e	1.76e
**	78Zn	2673e	7e	0.319e
**	88Zn	275e	111, 159e	5.4e
**	92Zn	254e	254 and 266 from 2nd level	57e
**	97Zn	308e	141, 167e	0.170e
**	97Zn	830e	52e	0.255e
**	98Y	171e	50, 171e	0.62e
**	98Y	496e	50, 121, 170, 204e	7.6e
**	98Y	1181e	111, 119, 130, 158, 186, 476, 596e	0.83e
**	99Y	2141e	83, 126, 159, 198, 223, 245, 269, 273, 283, 308, 382, 1166, 1438, 1529e	8.6e
**	107Mo	66e	66e	0.470e
**	117Ru	7e	184e	>5e
**	121Pd	7e	136e	0.694e
**	123Ag	7e	349, 384, 391, 630, 386, 714, 733, 769, 1049, 1077, 1133e	0.214e
**	124Ag	7e	156, 1132e	1.9e
**	125Ag	7e	670, 684, 715, 729e	0.310e
**	125Cd	7e	409, 720, 743, 786, 868, 923e	>5e
**	126Cd	7e	220, 248, 402, 405, 652, 807, 815, 856e	0.270e
**	127Cd	7e	739, 771, 821, 909e	1.9e
**	129In	7e	334, 359e	2.9e
**	129In	7e	7e	7e
0502e	117Ru	7e	184e	>5e
**	121Pd	7e	136e	0.694e
**	123Ag	7e	349, 384, 391, 630, 386, 714, 733, 769, 1049, 1077, 1133e	0.214e
**	124Ag	7e	156, 1132e	1.9e
**	125Ag	7e	670, 684, 715, 729e	0.310e
**	126Cd	7e	220, 248, 402, 405, 652, 807, 815, 856e	0.270e
**	127Cd	7e	739, 771, 821, 909e	1.9e
**	129In	7e	334, 359e	2.9e

LISE++ database (dbf-format)

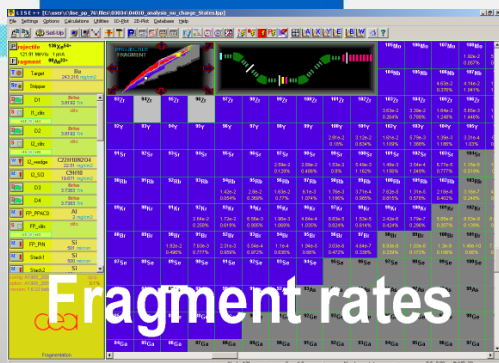
New experimental data

Private communications

It will be nice to simulate...

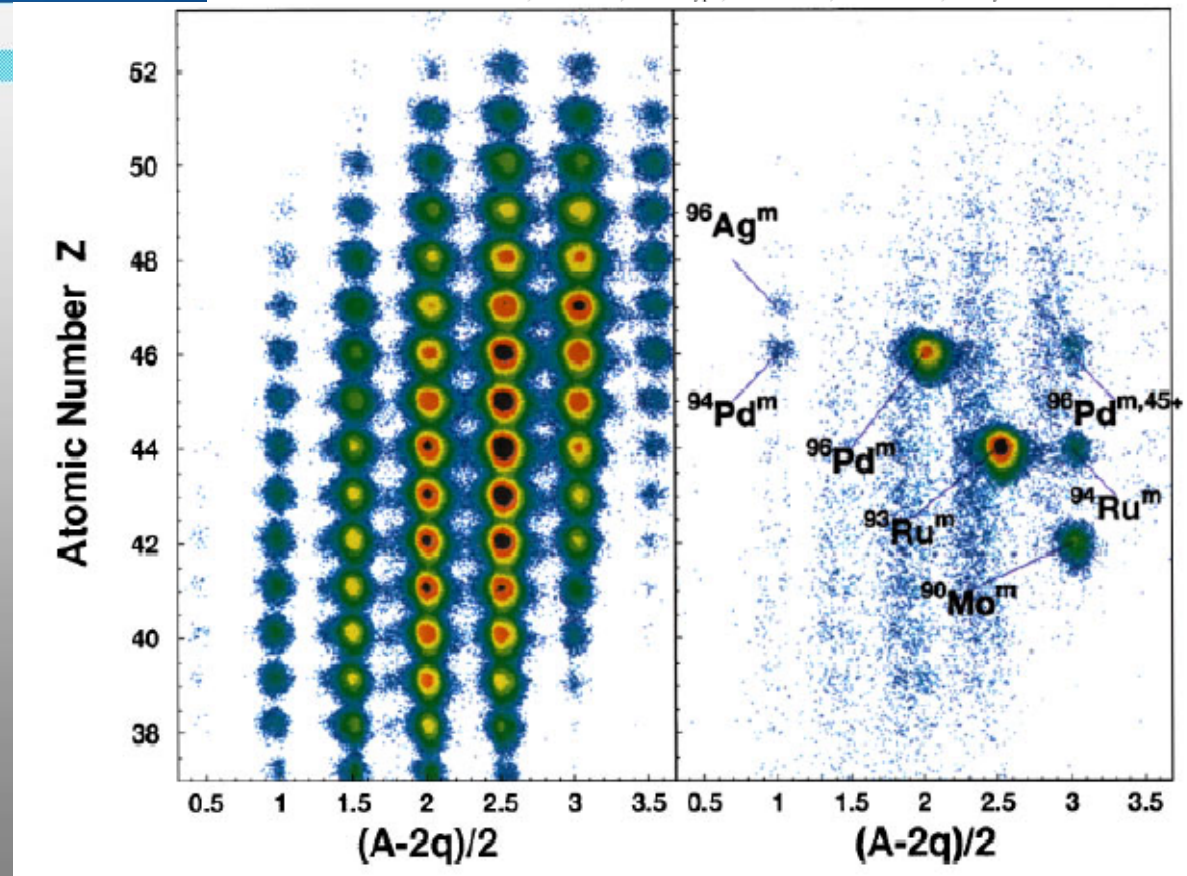
New μ s isomers in $T_z=1$ nuclei produced in the $^{112}\text{Sn}(63A \text{ MeV}) + ^{\text{nat}}\text{Ni}$ reaction

R. Grzywacz,^{1,2} R. Anne,² G. Auger,² C. Borcea,³ J. M. Corre,² T. Dörrler,⁴ A. Fomichev,⁵ S. Grevy,⁶ H. Grawe,⁷ D. Guillemaud-Mueller,⁶ M. Huyse,⁸ Z. Janas,⁷ H. Keller,⁷ M. Lewitowicz,² S. Lukyanov,^{5,2} A. C. Mueller,⁶ N. Orr,⁹ A. Ostrowski,² Yu. Penionzhkevich,⁵ A. Piechaczek,⁸ F. Pougheon,⁶ K. Rykaczewski,^{1,10} M.G. Saint-Laurent,² W. D. Schmidt-Ott,⁴ O. Sorlin,⁶ J. Szerypo,¹ O. Tarasov,^{5,2} J. Wauters,⁸ J. Zylicz¹



LISE++
 γ -database

γ -registration
settings



Color identification plot of all nuclei observed (left panel) and those in correlation with gamma radiation (right panel). The $(A-2q)/2$ variable is equal to the T_z of the nucleus for fully stripped ion ($q=Z$). A symbol “ $^{96m}\text{Pd}^{45+}$ ” denotes ^{96m}Pd nuclei transmitted and detected as a hydrogen like ions.

GANIL isomer database by J.M.Daugas

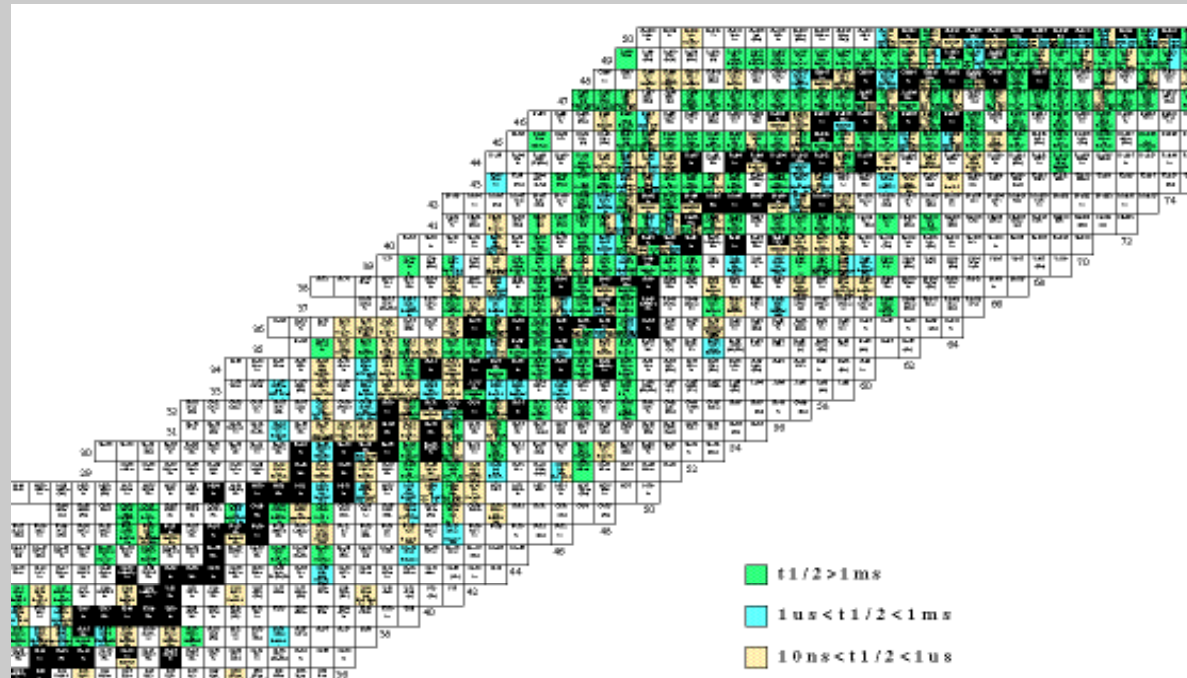
Nuclei from **Z=1 -50**. About 400 isomers.



Isomers which are referenced on this chart have a half-life greater than **10 ns**.

Three different codes of colors have been used in order to have information about the half-life of the isomeric states:

- for isomeric states with half life over 1 millisecond.
- for isomeric state with half life between 1 microsecond and 1 millisecond.
- for isomeric state with half life between 10 nanosecond and 1 microsecond.

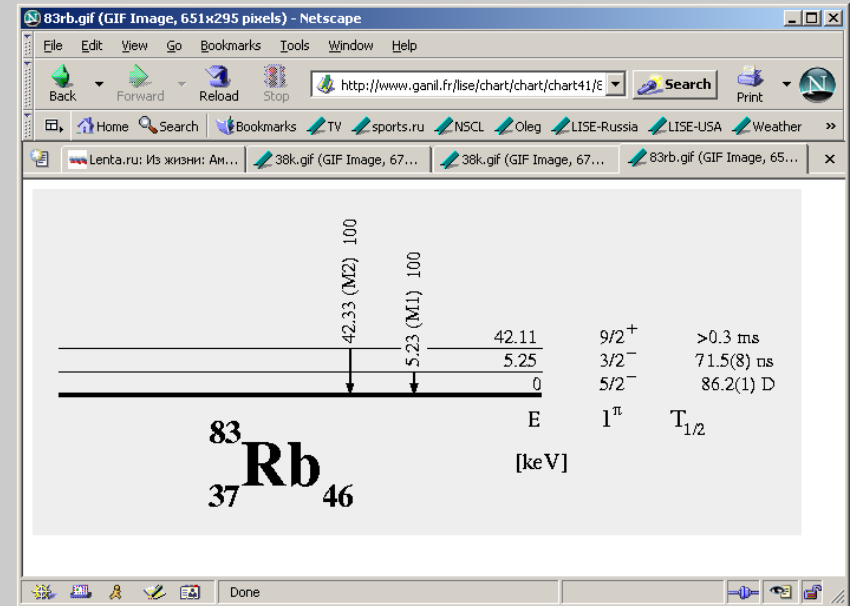
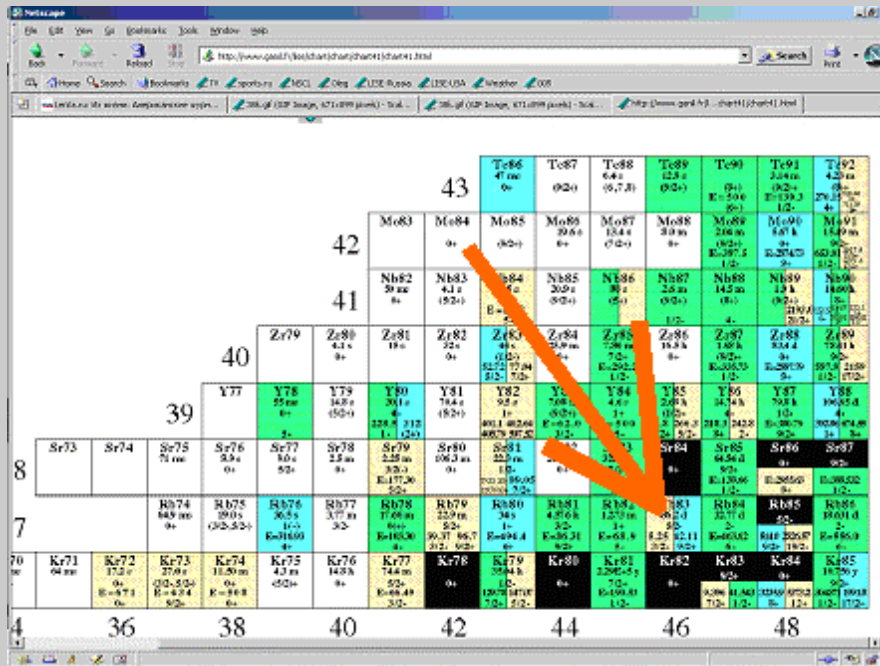


Isomer Database in Internet

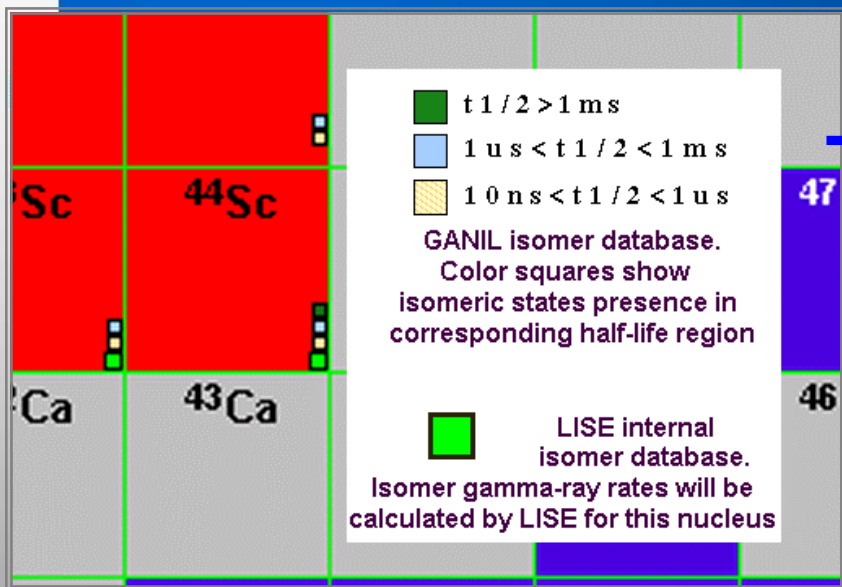
It is interactive!

Click on the chart to have the level scheme of the request isomer

Unfortunately there are not data tables which could be transformed in a database. Just level scheme pictures.



Using GANIL isomer database in LISE++

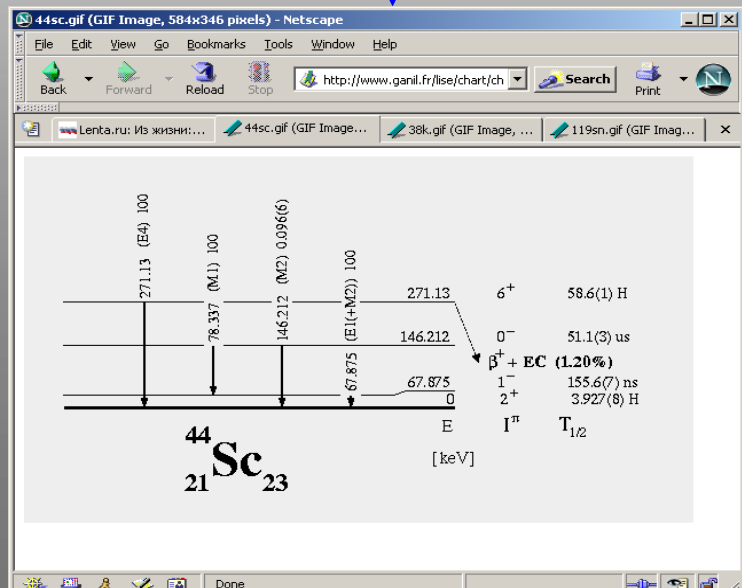


statistics 44Sc

44Sc Beta+ decay (Z=21, N=23)

Q1 (D1)	21
Q2 (D2)	21
Q3 (D3)	21
Q4 (D4)	21
Production Rate (pps)	2.9e-5
Reaction	Fragmentn
Sum of reactions (pps)	2.9e-5
CS in the target (mb)	7.1e-8
Total transmission (%)	1.058
Target (%)	99.07
X space transmission (%)	100
Y space transmission (%)	100
Unreacted in mater. (%)	99.07
Unstopped in mater. (%)	100
D1 (%)	72.4

Buttons: Analysis, Print, WWW TOI, Chemistry - Sc, File Save, **Isomer(GANIL)**, Isomer(LISE)



Information about the GANIL isomer database is kept in the "bin/isomers.txt" file. Fields are separated by comma. One Line per one nucleus. There are 3 fields to get a level scheme.

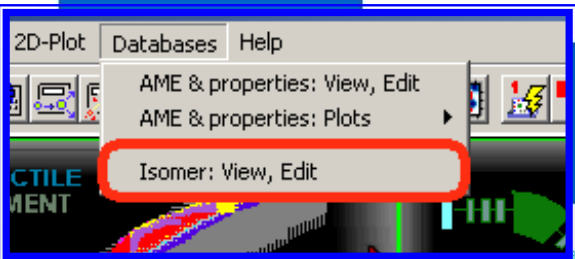
Example: 38cl, 21, 4

Web address: <http://www.ganil.fr/lise/chart/chart/chart21/38cl.gif>

First field: $^A \text{El}$; Second field: Chart index (11-54)

Third field: half-life (4*Green + 2*Blue + 1*Yellow)

LISE++ isomer database



Obligatory fields

Z, A, E_γ
IT ratio, I_γ, T_{1/2},
User Name

Selection from NNDC

- Z,A: no conditions
- 100 < E_{level} (keV) < 10000
- 100 < E_{gamma} (keV) < 4000
- 1 ns < T_{1/2} < 100 μs

NNDC	1752
Bryan Tomlin's thesis	44
Caamano, EPJA23 (2005) 201	40
GANIL JM-database	13
Daugas, PLB476(2000)213	4
Robison, PRC53(1996)1465	1
Grand Total (gamma-rays)	1854

Isomer Database

A: 38, Element: K, Z: 19, N: 19

Beta+ decay

Current isomeric gamma ray: 1 of 8

Database Index: 38190037

	Value	Error	
Gamma energy	37.8	AP	keV
Isomeric ratio (level population)	10	AP	%
T 1/2	2.198E+1	1.10E+1	micro-second
Level energy	3458.	2.	keV
J pi	7+.(5+)		
I gamma	100.	11.	%
M gamma	E1(+M2)		
M ratio	0.	13.	
Conversion Coef.	0.4	0.6	
Data source	NNDC		

User Name: DT

LISE isomer database base (dBASE3 format) is kept initially in the "bin/isomers.dbf" file. All fields in "char" format.

Automatic record sorting in the database after "Add", "Delete" and "Save" commands. Index is recalculated automatically basing on A,Z,E_γ.

Database file size is about 360 kB. (in the LISE package)

Only users with administrative privileges can modify the database in the "Program files" directory.

There is the possibility of a net database version.

Use arrow buttons in the right bottom corner to change current isomeric gamma ray.

LISE++ isomer database location (v.7.6.39)

Production Mechanism

Reactions / Energy Loss, Straggling / Charge state / **Databases: Masses, Isomers**

40Ar(140.0 MeV/u) + Be -> 32S

New tabulation field

Masses

Database + Calculations DataBase: 0 - AME2003 (A&W)

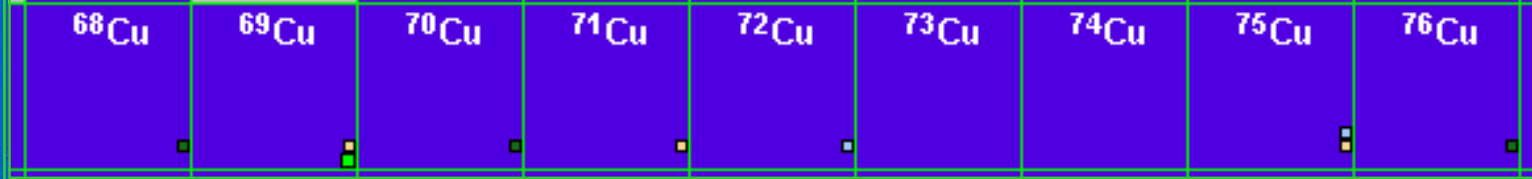
only Calculations Formula: 2 - LDM#1 + shell corrections (D.T.)

User's MassExcess File: user_mass_excess_2003.lme

Isomer database

Isomer File: \\projects\proj4\temp\lise\bin\isomer.dbf

Make default



LISE database limitation

Examples

- Cu neutron-rich isotopes
- ^{38}K isomer gamma rays

Isomer Database

A: 38, Element: K, Z: 19, N: 19

Beta+ decay

Find

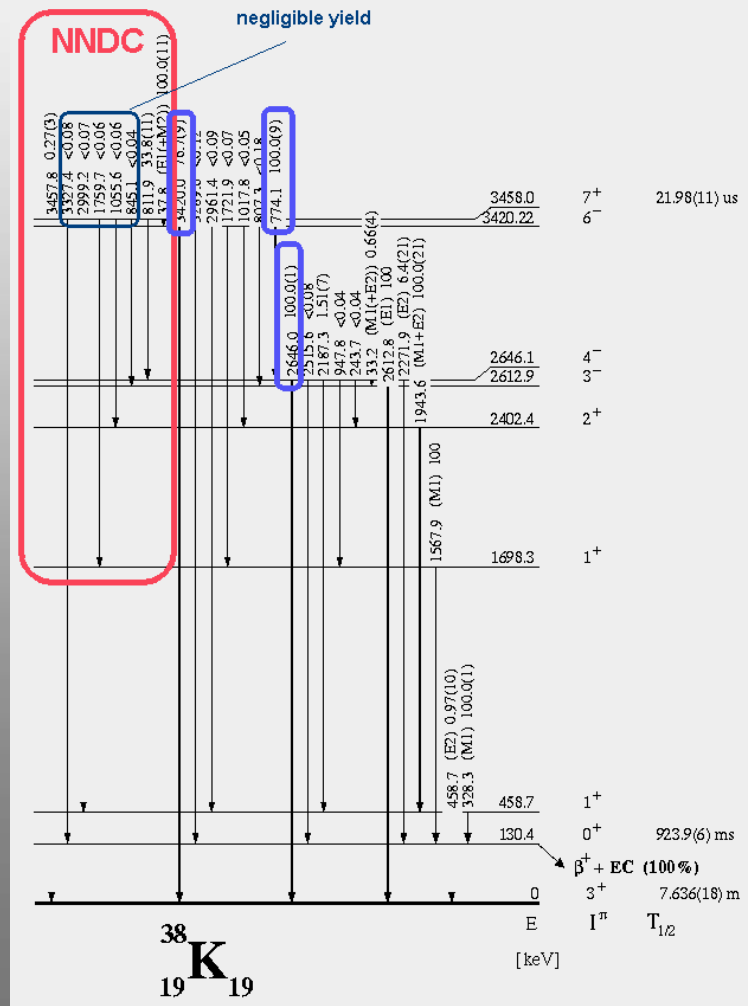
Current isomeric gamma ray: 1 (circled in red), Total number of isomer gamma rays: 8

Database Index: 38190037

Property	Value	Error	Unit
Gamma energy	37.8	AP	keV
Isomeric ratio (level population)	10	AP	%
T 1/2	2.198E+1	1.10E+1	micro-second
Level energy	3458.	2.	keV
J pi	7+, [5+]		
I gamma	100.	11.	%
M gamma	E1(+M2)		
M ratio	0.	13.	
Conversion Coef.	0.4	0.6	
Data source	NNDC		

User Name: OT

Buttons: Save, Quit, Help, Add Record, Delete Record, Show Structure



- Settings
- Options
- Calculations
- Utilities
- 1D
- Projectile
- Target
- Stripper after Target
- Spectrometer Designing
- Gamma registration**
- Setting Fragment
- Tune spectrometer for the primary beam

γ -detector efficiency

Reference line

Gamma-ray yield is proportional to a number of implanted fragments in the telescope at the final focal plane.
 Reference gamma-rays are randomly distributed on time and on energy in region 0 – 4 MeV

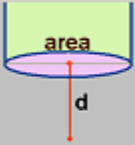
If G is the number of gamma rays per implanted fragment then
 $R = G * Gate / 4000 [1 / keV / sec]$

Gamma detection

[A] - Geometrical efficiency

Use [A] to calculate the total efficiency

One gamma-detector



Detector surface area: 38.81 cm²
 Distance to detector: 20.4 cm
 Geometrical efficiency: 0.726 %

Acquisition for Gamma

Delay = 0 microsec
Gate = 10 microsec

Delay is assumed after arrival of fragment stopped in detectors at the end of spectrometer

Reference line is based on 0.1 gamma per implanted fragment

[B] - Energy efficiency

eff(x) = a*exp(-b*log(x-c+d*exp(-e*x)))

Use [B] to calculate the total efficiency

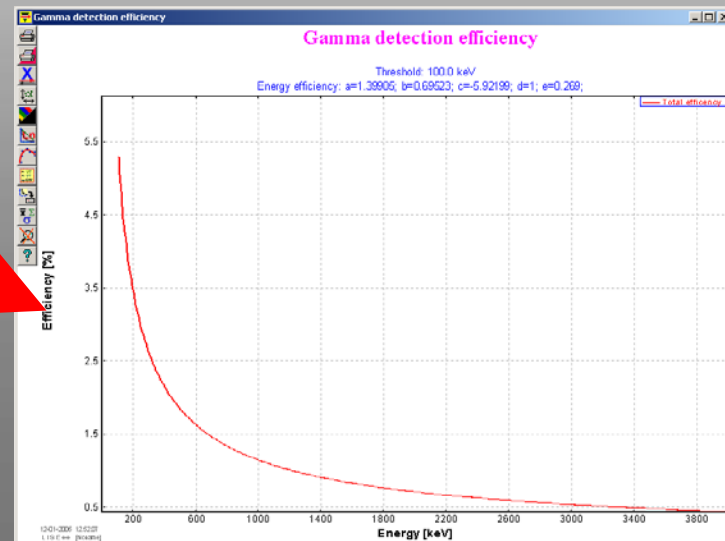
a = 1.39905 [x]=keV
 b = 0.69523 d = 1
 c = -5.92199 e = 0.269
 Threshold = 100 keV

Total Efficiency = 0.939 %
at Energy = 1330 keV

Make default

Efficiency Plot

Ok Cancel



Calculation of γ -rays yield

Only for isomer states from the LISE internal isomer database

- $Y_{\gamma \text{ isomer}} = I_{\text{ratio}}^m \times I_{\gamma} \times Y_{\text{fragment}} \times \epsilon_{\text{AcqGate}} \times \epsilon_{\text{detect}}$
- $\epsilon_{\text{AcqGate}}$: probability to be in the γ - acquisition gate
 $T_{1/2}$, Length of flight, Fragment Energy,
Gamma-acquisition delay and gate
- ϵ_{detect} : detector efficiency
geometrical efficiency or/and $f(E_{\gamma})$
- A survival of fully stripped ions in flight is not taken into account for fully stripped ions

γ -rays yield calculation result

statistics 38K

38K Beta+ decay (Z=19, N=19)

Q1 (D1)		19
Q2 (D2)		19
Q3 (D3)		19
Q4 (D4)		19

Production Rate	(pps)	6.4e+2
Reaction		Fragmentn
Sum of reactions	(pps)	6.4e+2
CS in the target	(mb)	6.71e-2
Total transmission	(%)	24.66

Target	(%)	99.1
X space transmission	(%)	100
Y space transmission	(%)	100
Unreacted in mater.	(%)	99.1

fast access to
LISE isomer database

Isomeric states: gamma/frag=3.51e-07 IT=2.24e-04/s

E_gamma	T12 [mks]	ITrt&Ig	Efficien	g-AcqGate	Result
37.8	2.198e+01	1.0e-01	0.00e+00	2.68e-01	0.00e+00
811.9	2.198e+01	3.4e-02	1.32e-02	2.68e-01	1.20e-04
845.1	2.198e+01	4.0e-05	1.28e-02	2.68e-01	1.38e-07
1055.6	2.198e+01	6.0e-05	1.10e-02	2.68e-01	1.77e-07
1759.7	2.198e+01	6.0e-05	7.74e-03	2.68e-01	1.25e-07
2999.2	2.198e+01	7.0e-05	5.34e-03	2.68e-01	1.00e-07
3327.4	2.198e+01	8.0e-05	4.97e-03	2.68e-01	1.07e-07
3457.8	2.198e+01	2.7e-04	4.84e-03	2.68e-01	3.51e-07

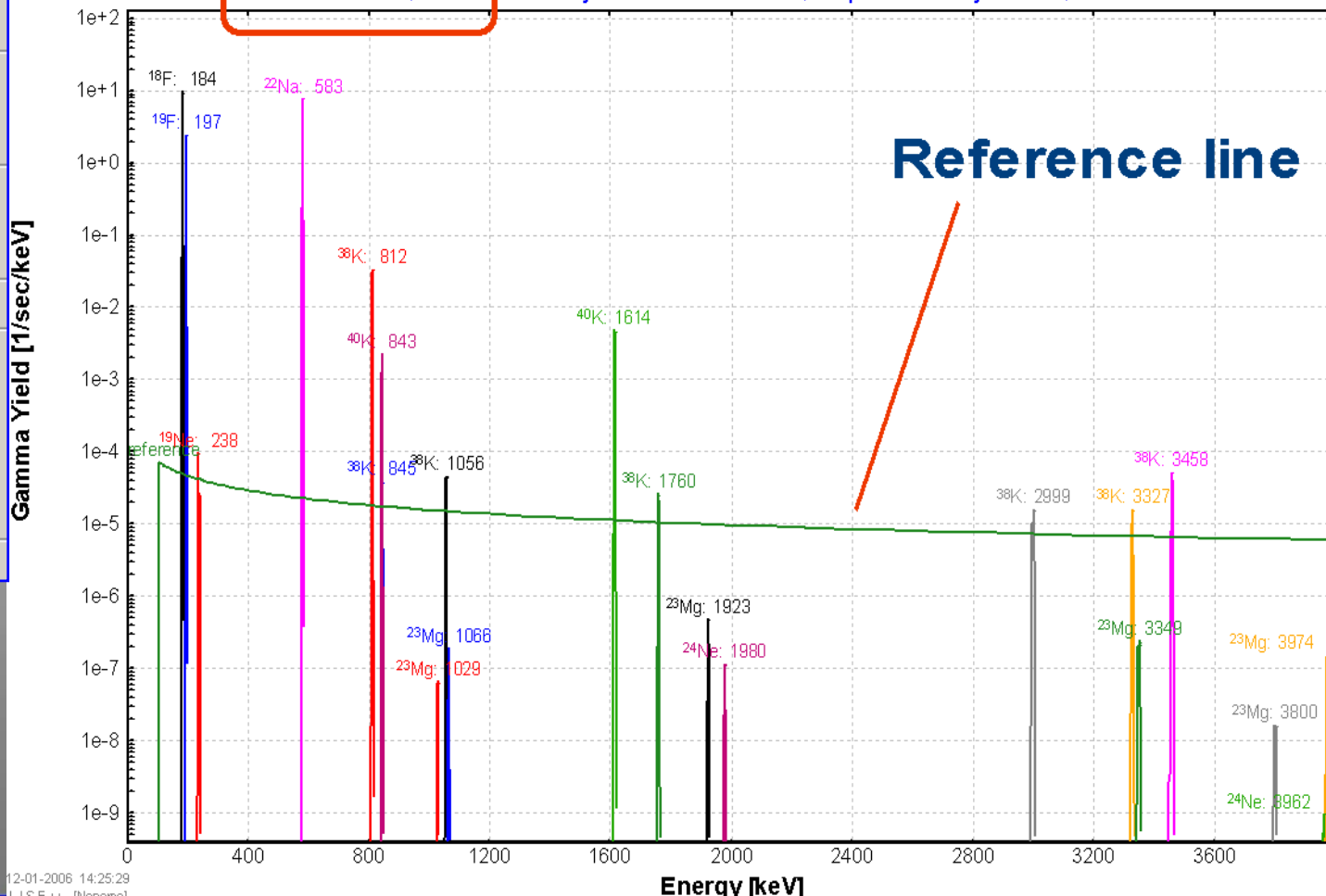
information about isomer
gamma yield of given isotope
in the Statistics window

Isomeric γ -spectrum

Isomeric Gamma Spectrum (after FP_slits)

^{40}Ar (140.0 MeV/u) + Be (500 μm); Settings on ^{32}S ; Config: DDSWDDMSMMM

Flight Length = 35.5 m; Rates[1/s]: ITgamma=3.8e+01; Reference=5.2e-02; Fragments=5.4e+05
 Ref.G/F = 0.01; Gamma efficiency at 1330keV = 0.939%; Acquisition Delay=0.0mks; Gate=10.0mks

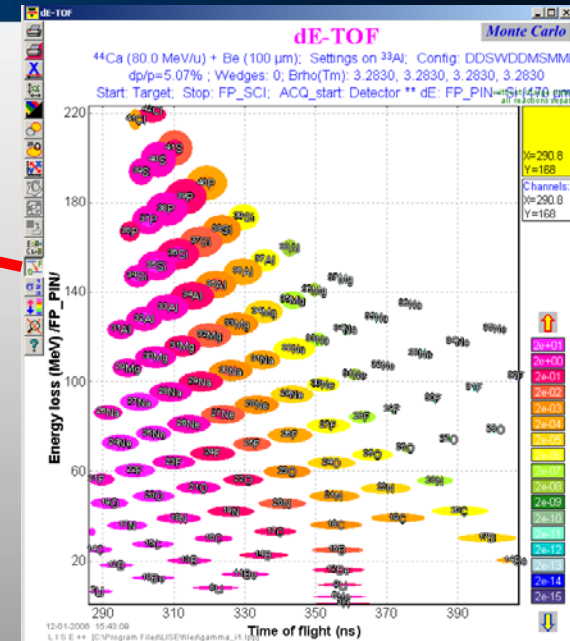
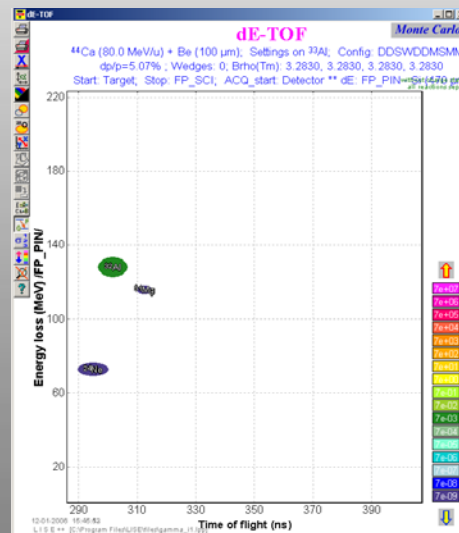


Identification 2D-plot in coincidence with γ -rays

Fragment/Isomer

Fragments
 Fragments in coincidence with Isomeric Gamma
 Fragments in coincidence with Any Gamma

OK
 Cancel



a. $Y_{frag}(A, Z)$

b. $Y_{\gamma isomer}(A, Z) = Y_{frag}(A, Z) \sum P_{\gamma}(A, Z)$

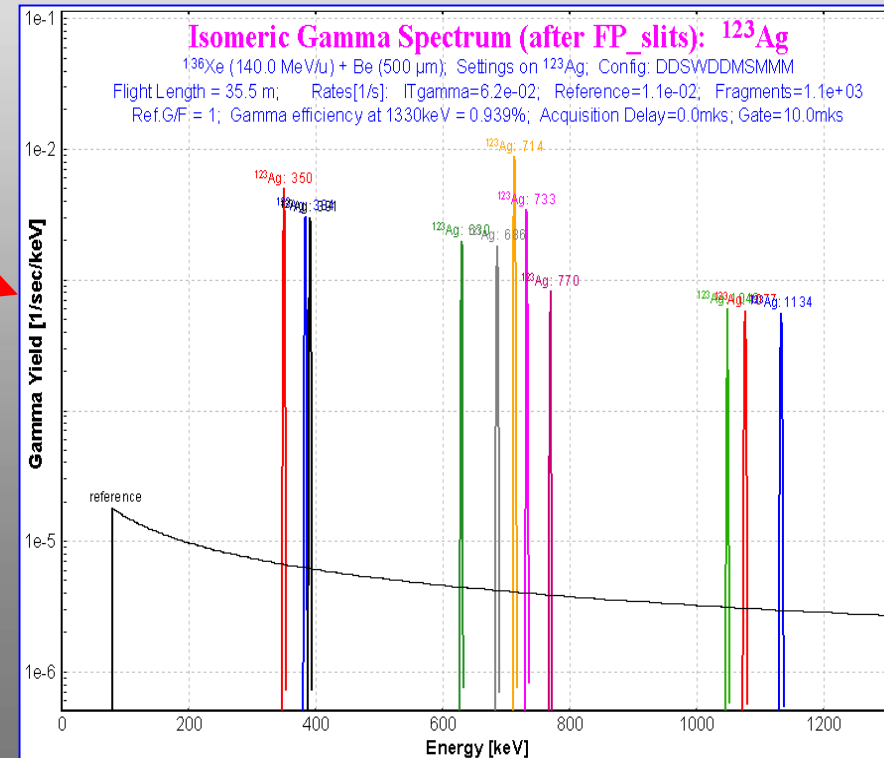
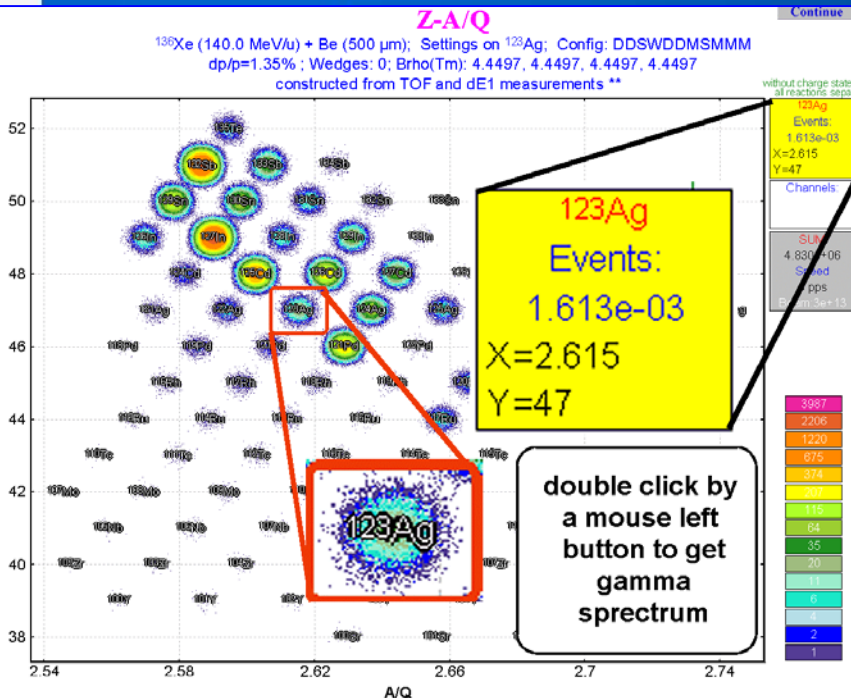
where $P_{\gamma} = \xi_{surviv} \cdot \xi_{ITratio} \cdot \xi_{I\gamma} \cdot \xi_{detector}$

c. $Y_{\gamma}(A, Z) = Y_{frag}(A, Z) \cdot RefDens + Y_{\gamma isomer}(A, Z)$

It was done for both methods:

- Monte Carlo
- “ellipse” mode

Isomer γ -spectrum (for one isotope) from the identification 2D-plot

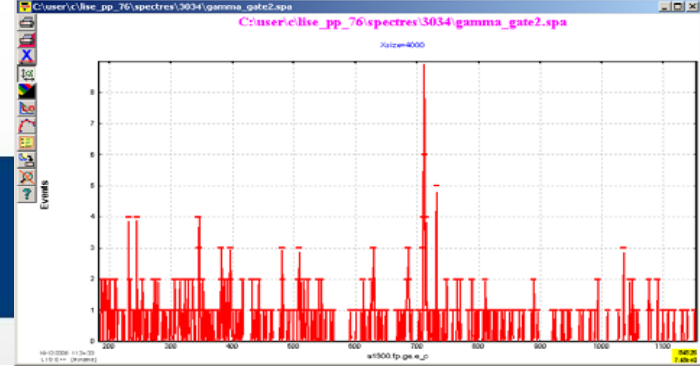
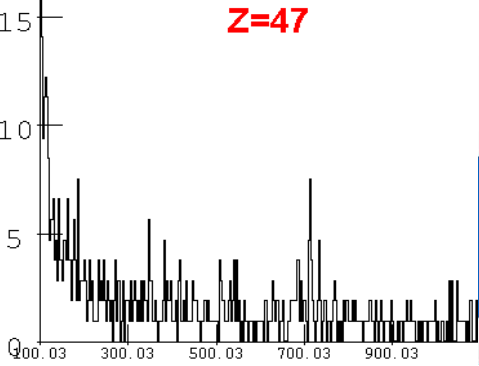


It was done for both methods:
 • Monte Carlo
 • “ellipse” mode

Z=47

from 12/16/2005

γ -analysis: ^{123}Ag from the experiment #3034

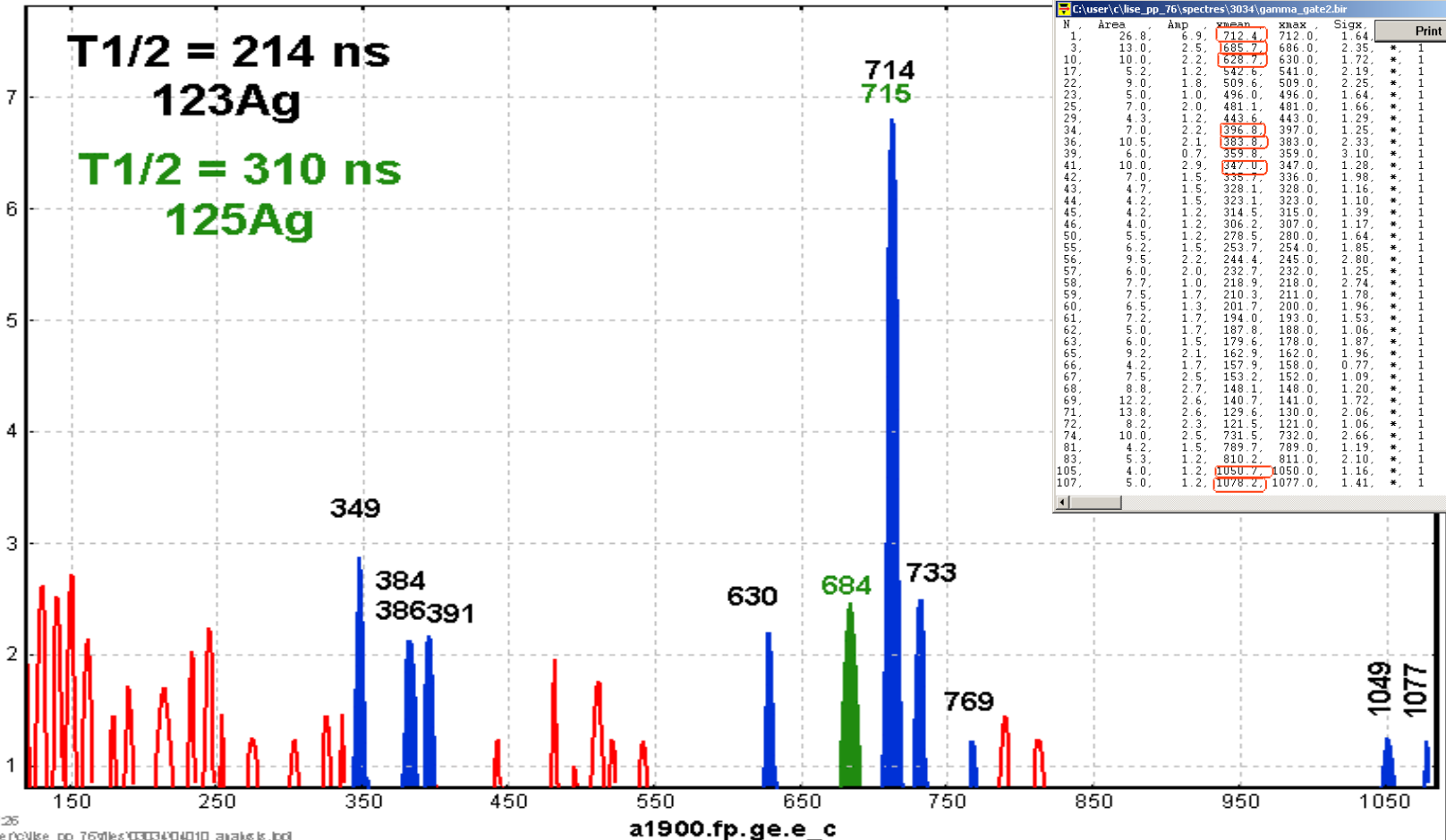


C:\user\c\lise_pp_76\spectres\3034\gamma_gate2.sp

Result file: C:\user\c\lise_pp_76\spectres\3034\gamma_gate2.bir

Xsize=4000 Global: Sum=1.10e+04; Xsigma=1.33

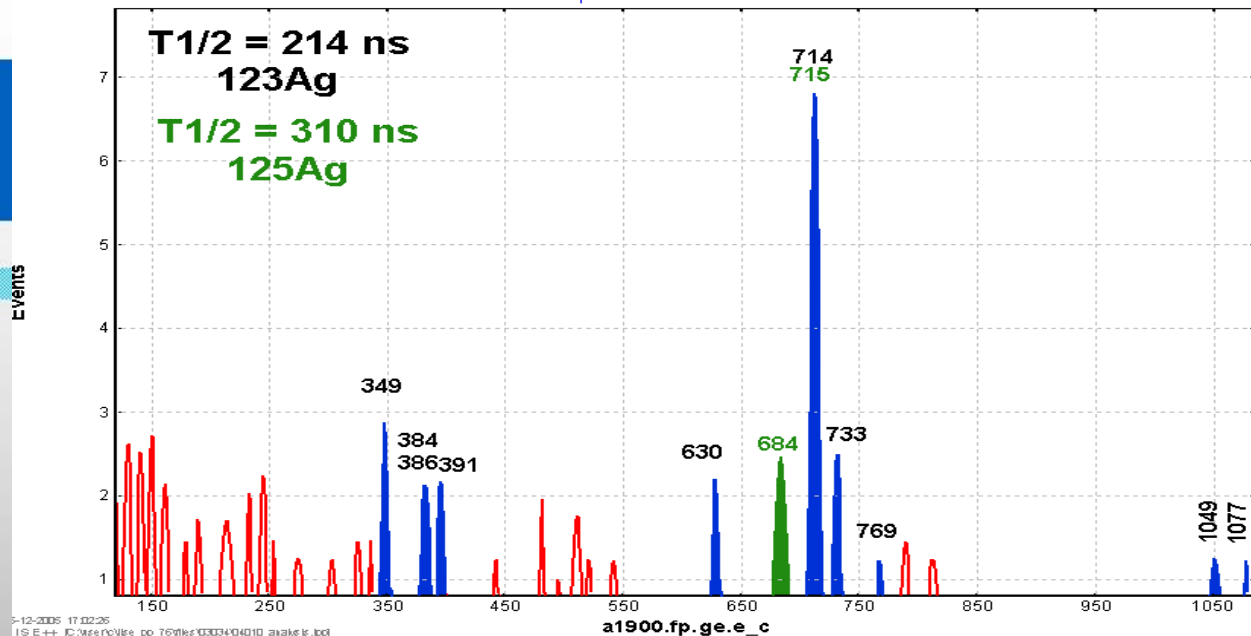
Input: Sx=2.0 4.9 0.8 0.01



Events

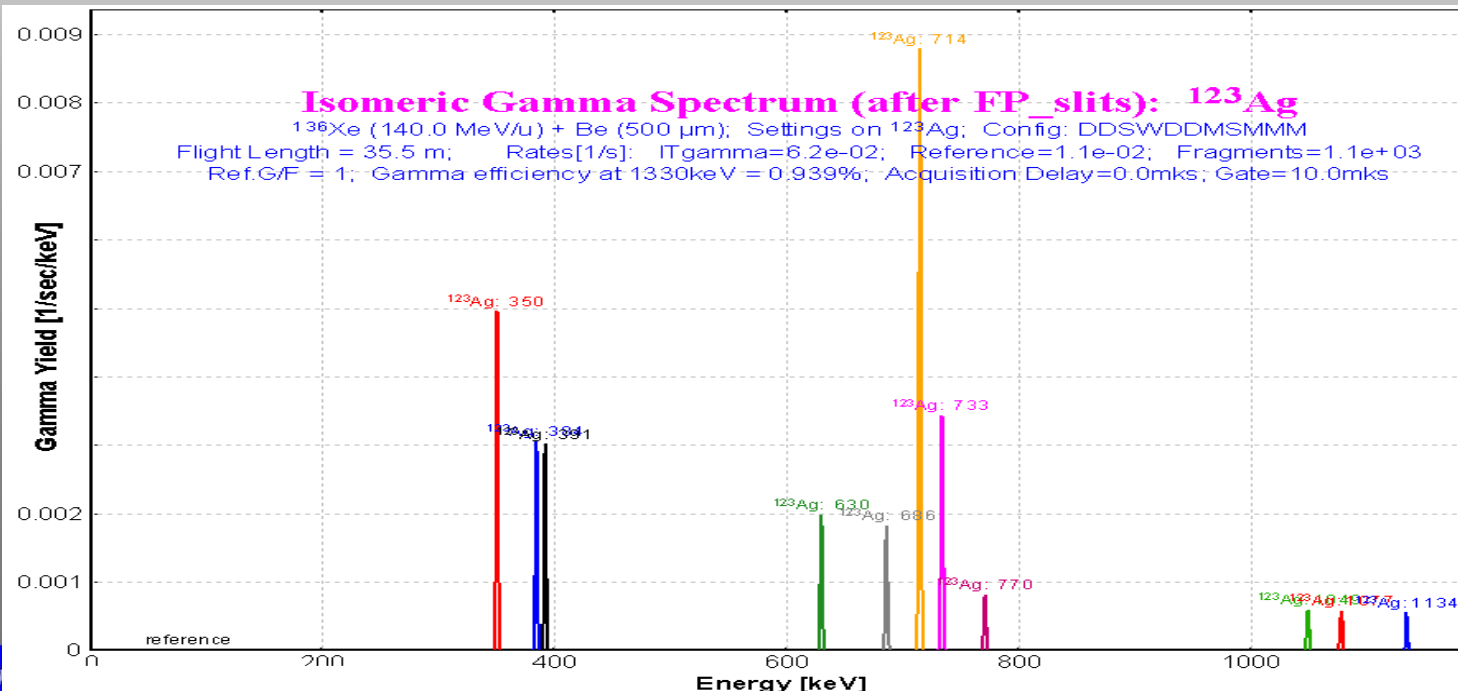


^{123}Ag
 γ -spectrum:
 from the
 experiment #3034
 &
 LISE simulation



Temporary.
 Waiting for
 final version of
 B.Tomlin's thesis

Egamma	Igamma
350.	30.
384.	20.
391.	20.
630.	20.
686.	20.
714.	100.
733.	40.
770.	10.
1049.	10.
1077.	10.
1134.	10.



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Projectile fragmentation: new option for momentum distribution

Projectile fragmentation

Fragment velocity / Momentum distribution / Cross section, Excitation energy and etc

136Xe(140.0 MeV/u) + Ta -> 123Ag

Fragment velocity

Constant V fragment / V beam Terminal relation Vf/Vb been used in the program

Calculation - A [V.Borrel et al., Z.Pyhs.A314(1983)191]

Calculation - B [F.Rami et al., NPA 444(1985)349]

Calculation - C [D.Tarasov, NPA 734(2004)536]

Calculation - D [from two-body reaction]

Calculation - E [D.Morrissey, PRC 39(1989)460]

Assume symmetric velocity distribution around $A_{\text{projectile}} / 2$
 It is important for light fragments.

Velocity after reaction can not exceed fragment velocity from two-body reaction kinematics (0 degrees)
 It is important for light fragments.

dE/dA = MeV/A [default 8]

for all models

A - V.Borrel et al., Z.Pyhs. A314(1983)191

$$\frac{v_F}{v_P} = s + \sqrt{1 - \frac{B_n(A_P - A_F)}{A_F E_P}}$$

Shift of Vf/Vb relation velocity (s) (default 0) Vf / Vb

Energy necessary to ablate one nucleon (Br) MeV (default 8)

B - F.Rami et al., NPA 444 (1985)349

$$\frac{v_F}{v_P} = \sqrt{1 - \frac{2S}{A_F E_P}}$$

Vf / Vb

g (MeV/fm²)

S(MeV)

Prefragment Mass

use prefragment option

Information (only for simple target)

Vfrag /Vbeam from two-body reaction

Angle (deg)

V of C.M. / Vbeam

C - convolution

Vf / Vb

Make default