

**β -decay studies of neutron rich $^{61-70}\text{Mn}$ isotopes
with the new LISOL β -decay setup**

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S. Franchoo, IPN Orsay, France

G. Georgiev, CSNSM, IN2P3-CNRS, Orsay, France

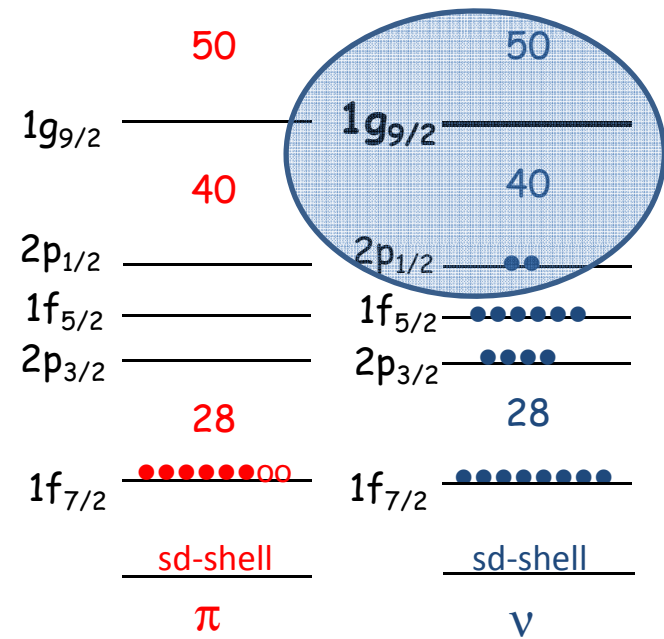
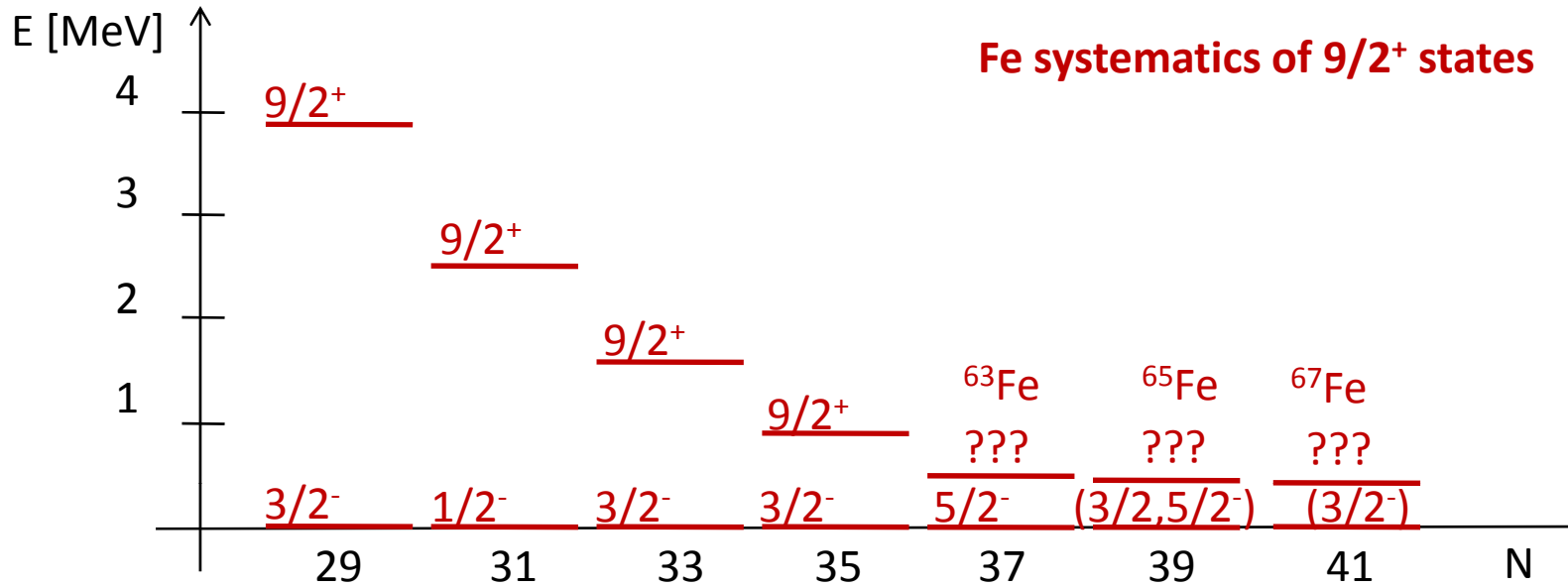
O. Sorlin, GANIL, Caen, France

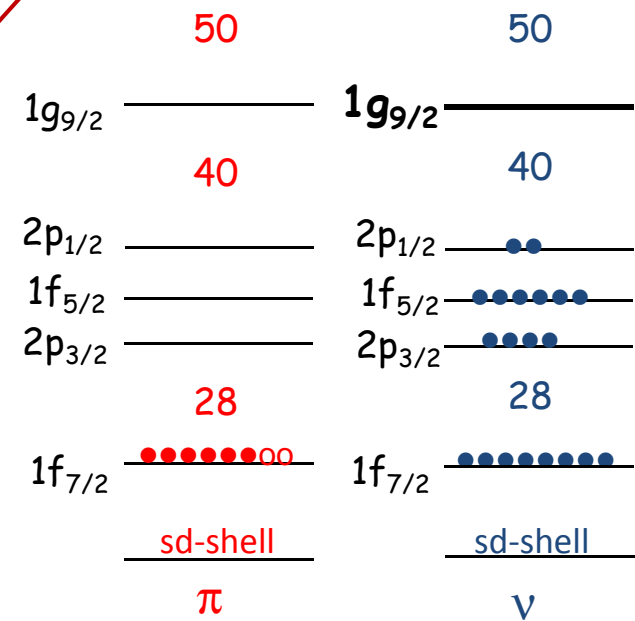
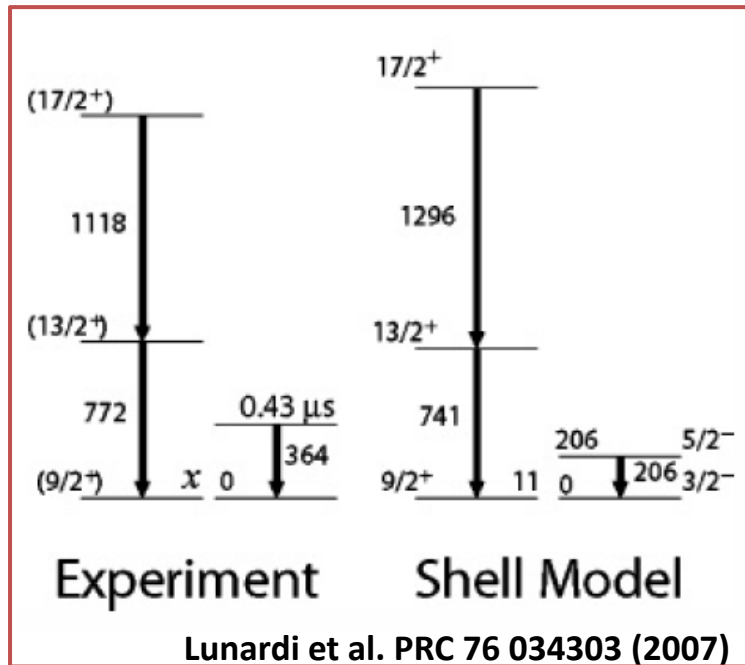
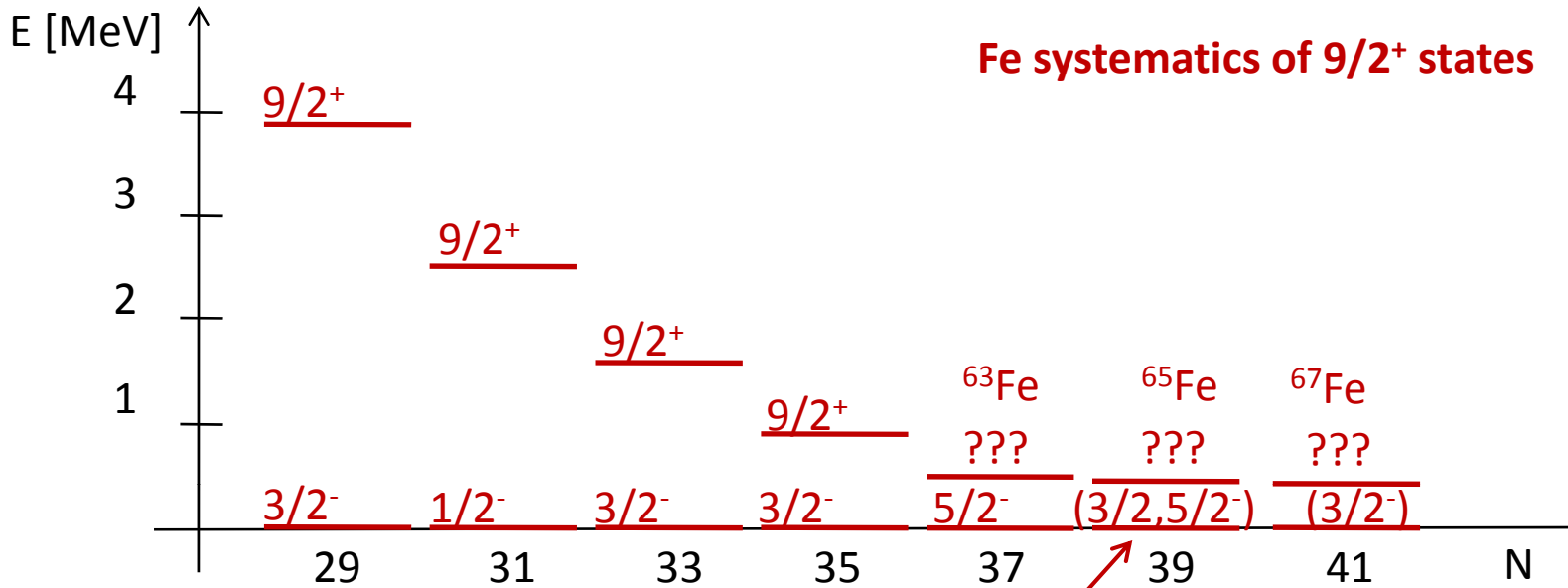
U. Koster, ILL, Grenoble, France

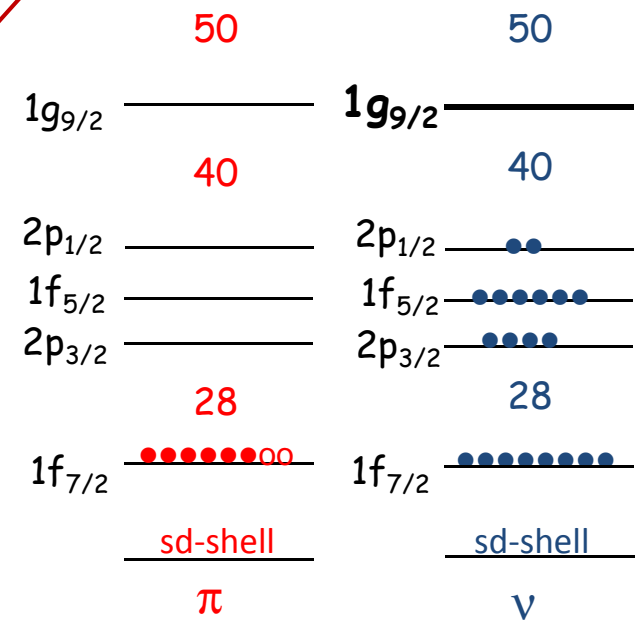
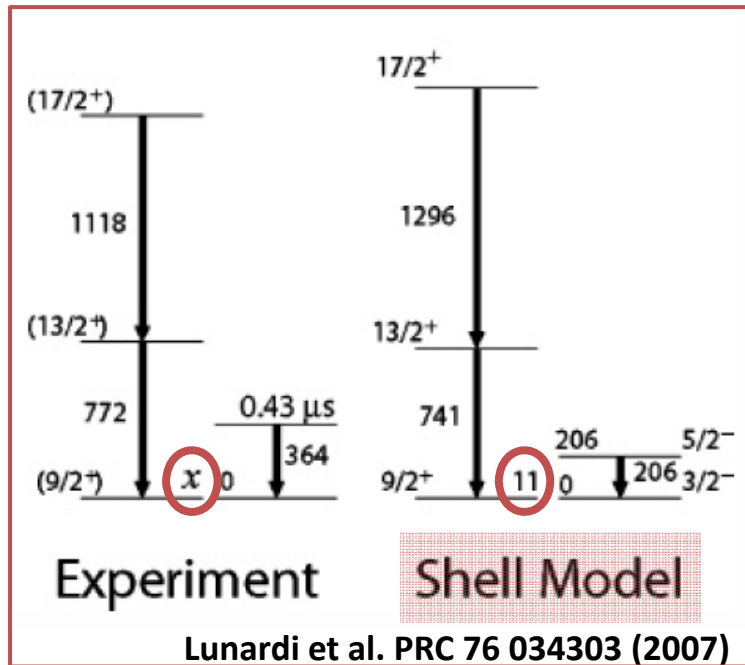
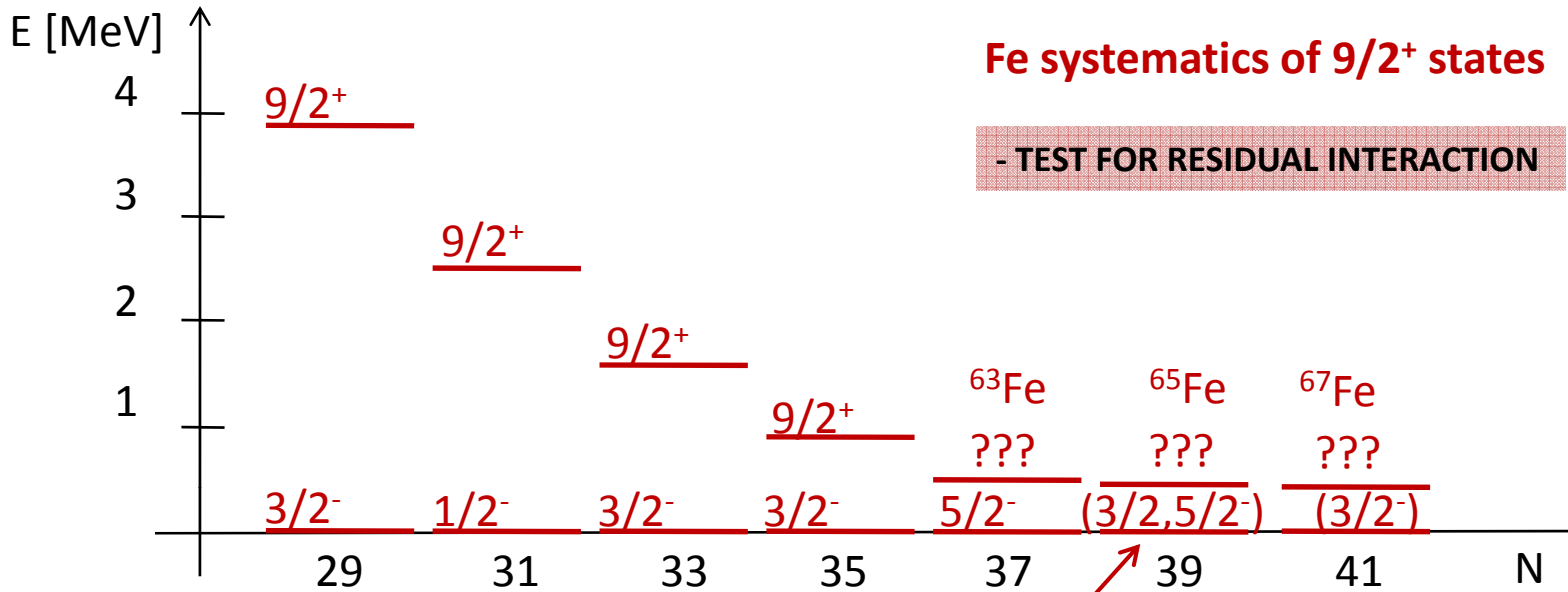
W.B. Walters, University of Maryland, USA

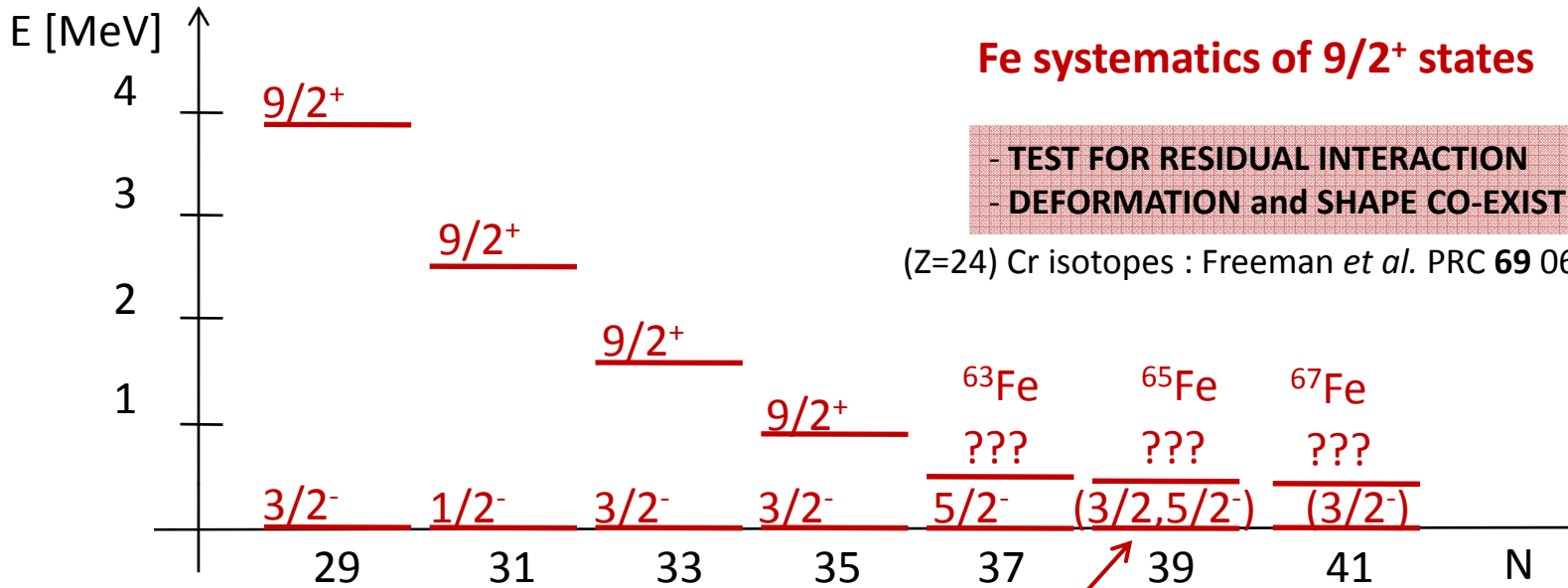
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- 4. Contamination and Yields**
- 5. Conclusions**





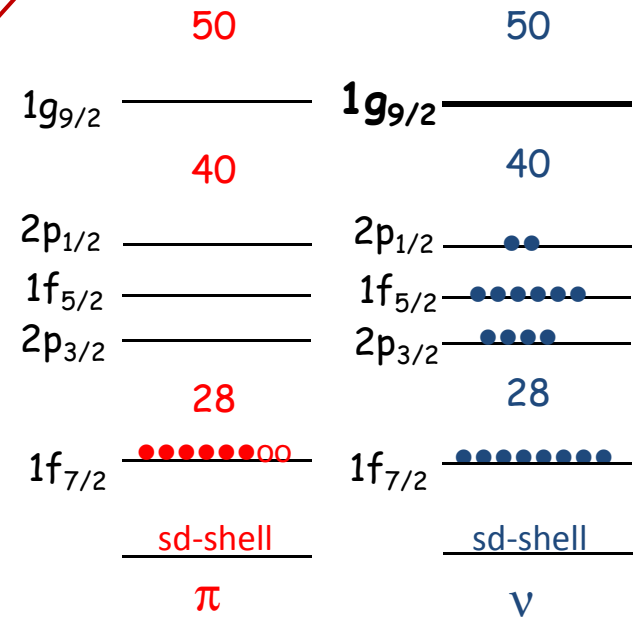
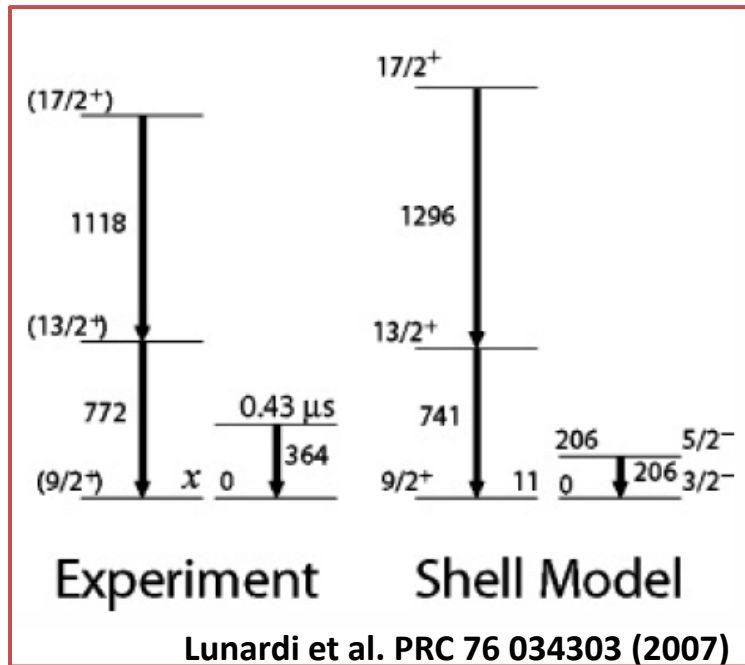


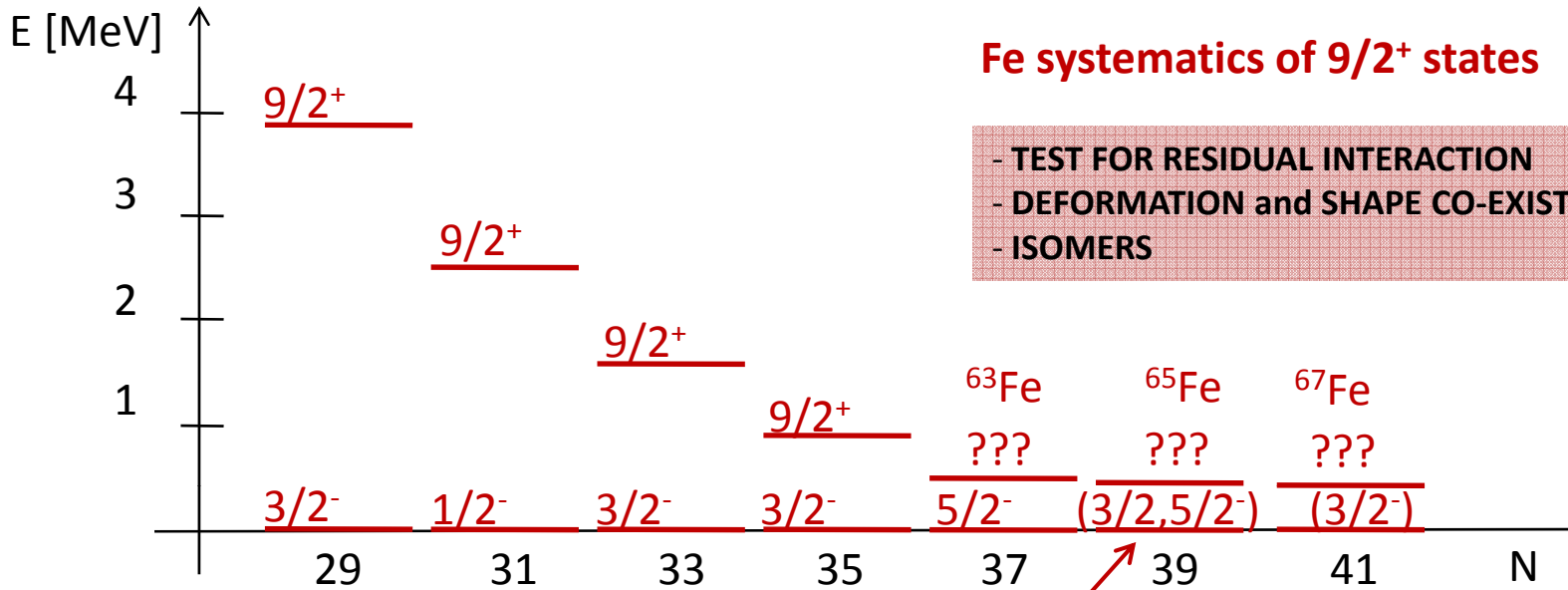


Fe systematics of $9/2^+$ states

- TEST FOR RESIDUAL INTERACTION
- DEFORMATION and SHAPE CO-EXISTENCE

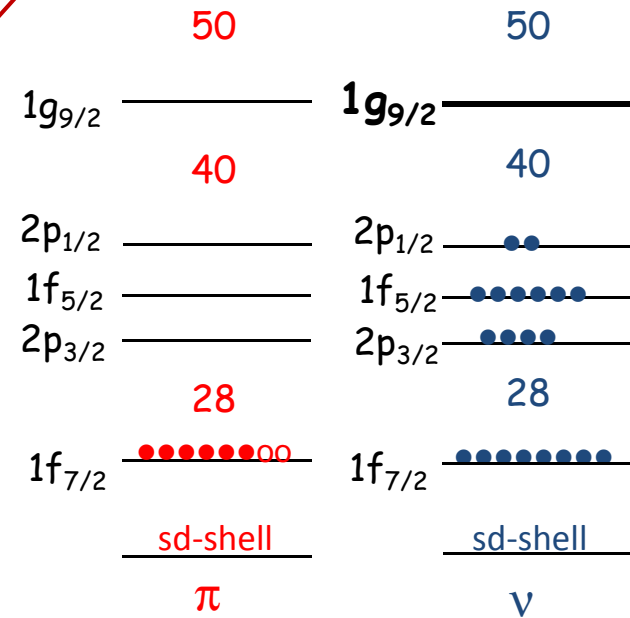
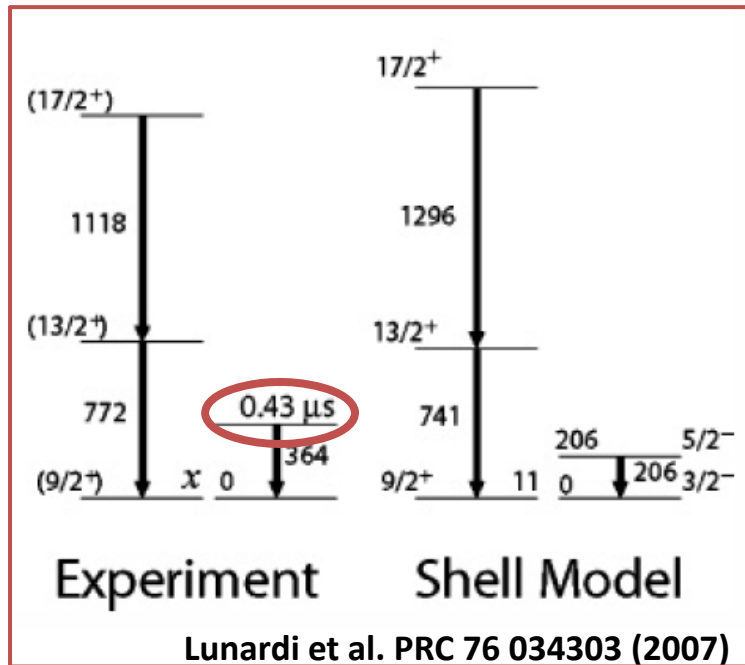
(Z=24) Cr isotopes : Freeman *et al.* PRC **69** 064301 (2004)

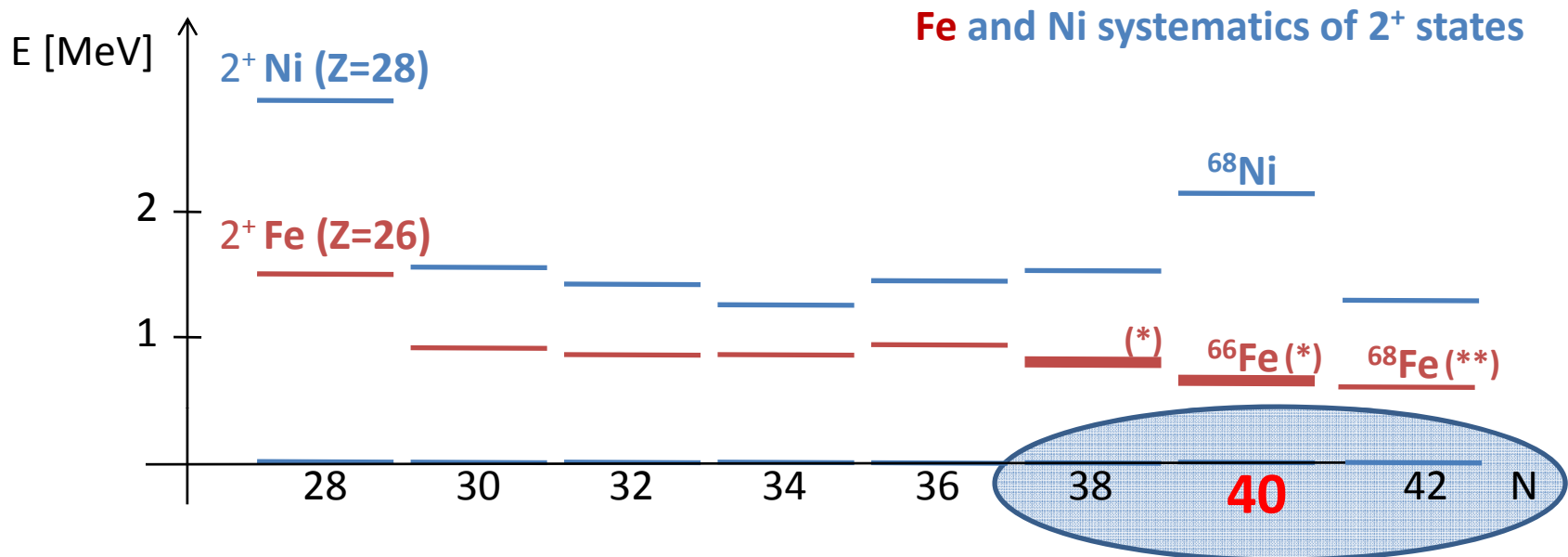




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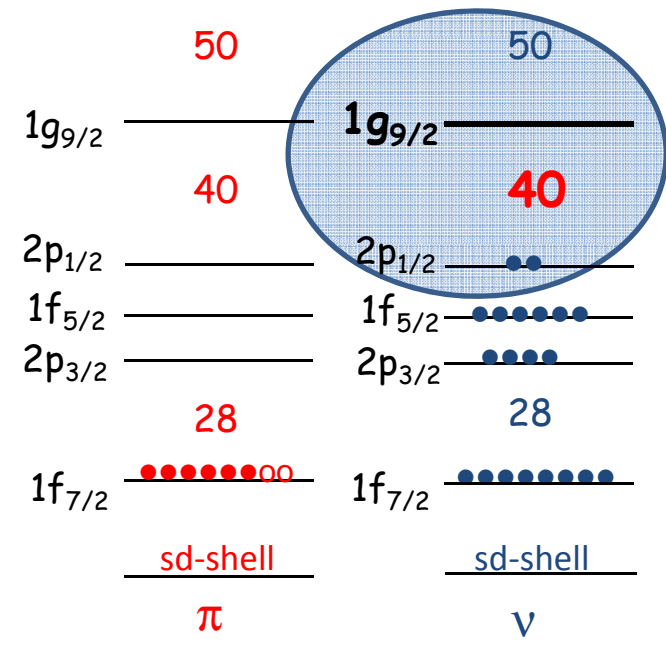
- TEST FOR RESIDUAL INTERACTION
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- ISOMERS





(**) β -decay study ⁶⁸Mn at GANIL (2006)
 J.M. Daugas et al., AIP Conf Proc 831 p 427-429

(*) β -decay study ^{64,66}Mn at ISOLDE (1998)
 Hannawald et al. PRL 82 1391 (1999)



1998 : "EXTENDED TARGET TEST" ...

yielding surprisingly interesting physics !!!

β -decay study at ISOLDE of ^{64,66}Mn
 M. Hannawald, PhD dissertation Mainz universitat 1999

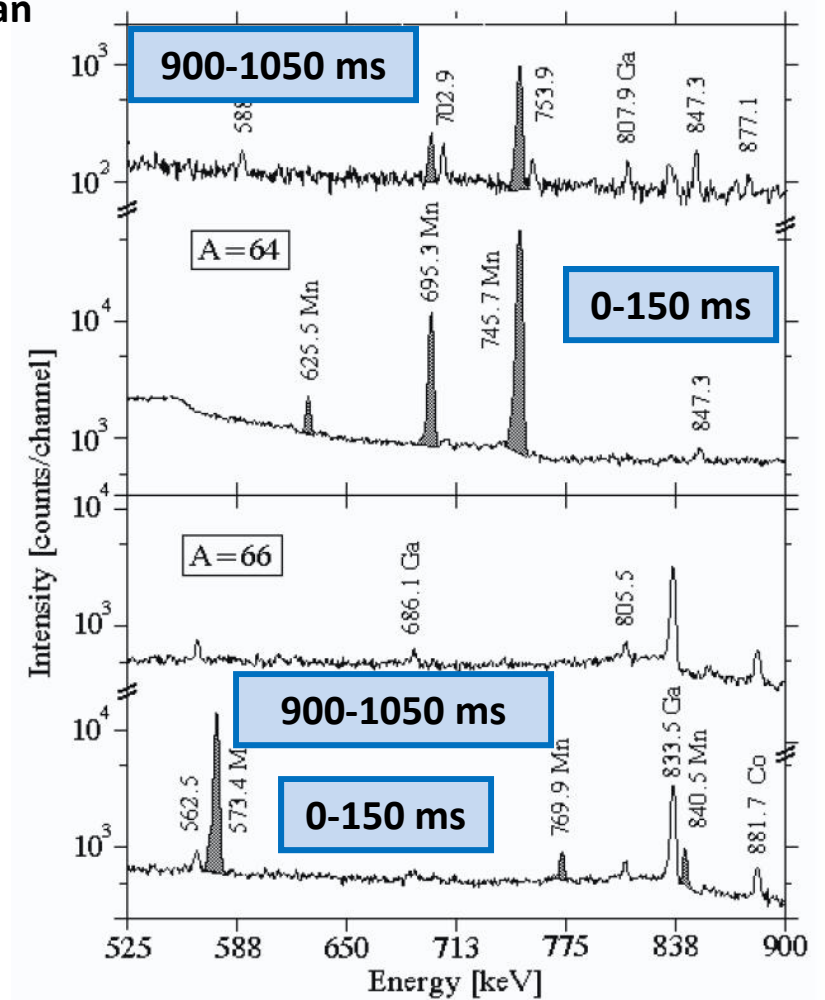
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- Only Single γ 's in time slices of 150 ms after proton impact
- No β -gated γ -ray spectra
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PROPOSAL 2008 : extended β -decay study at ISOLDE of $^{61-70}\text{Mn}$

- Singles AND β -gated γ -ray spectra
- NEW TECHNOLOGY :
 - Two segmented MINIBALL cluster detectors
 - Digital electronics : TOTAL DATA READOUT
- Use the unique Mn beams at ISOLDE again :
 - one of the highest laser ionization efficiencies
 - "standard" beam with UC_x target since 1998
- Physics :
 - Search for isomeric states ;
 - Spin and parity assignments in $^{61-70}\text{Fe}$;
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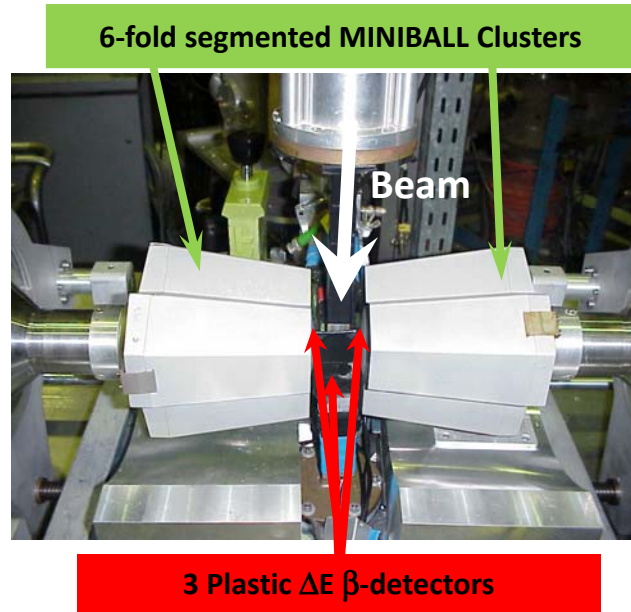
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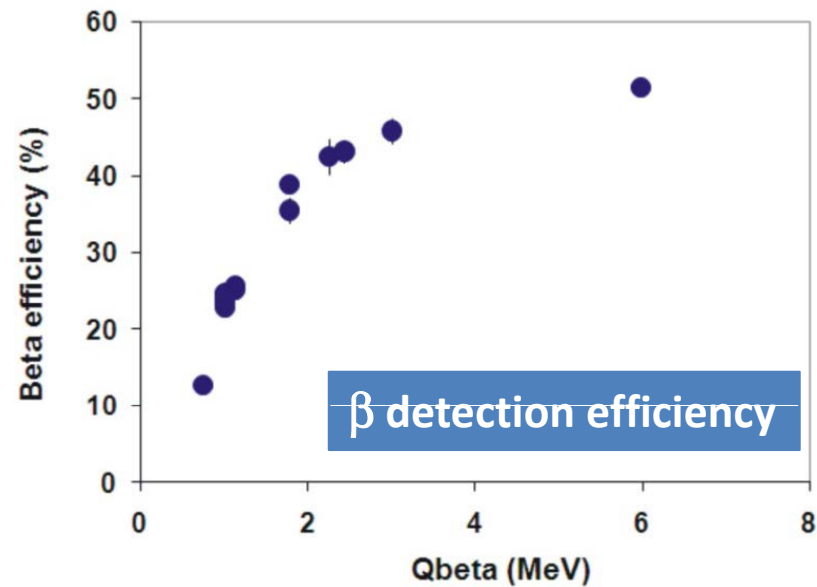
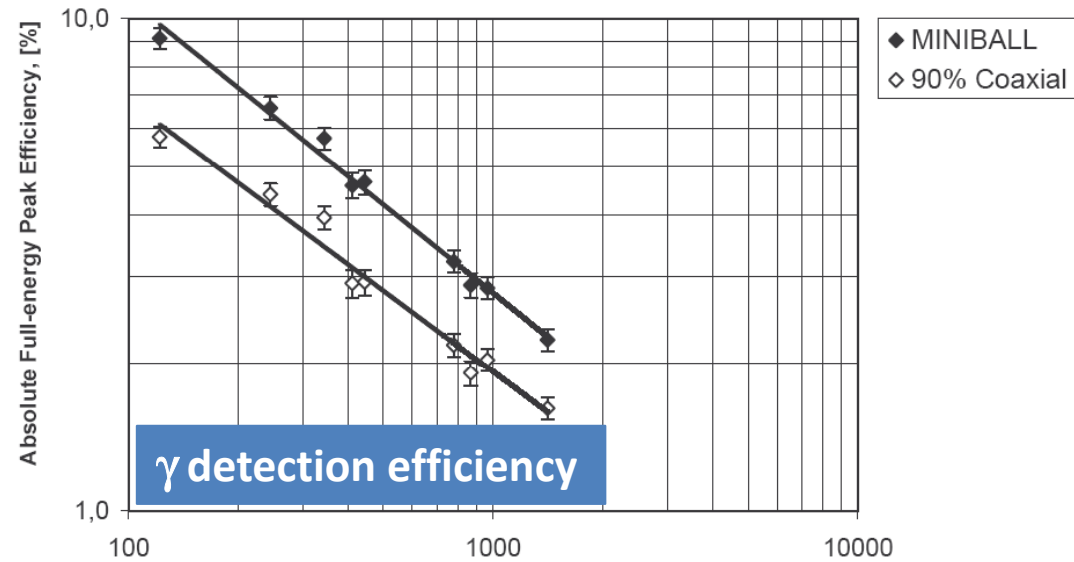
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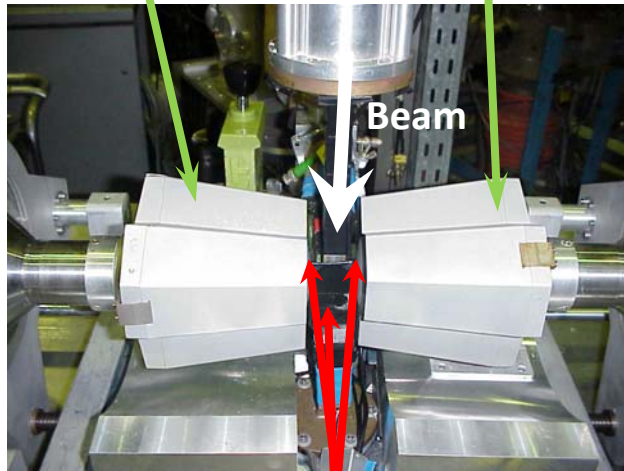


- ✓ shielding (polyethylene-borax-Cu-Lead)
- ✓ digital electronics readout
- ✓ high segmentation (6 cores, 36 segments) reduces “true coincidence summing effects”

Efficiency Curves
for the MINIBALL Cluster and 90% Coaxial Detector



6-fold segmented MINIBALL Clusters



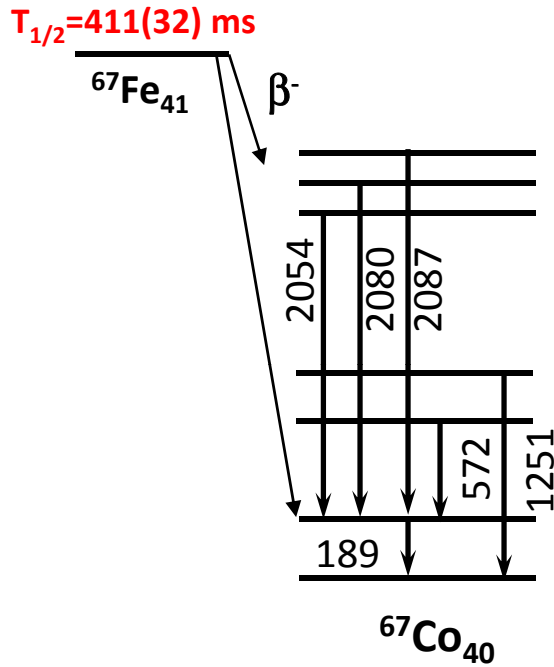
3 Plastic ΔE β -detectors

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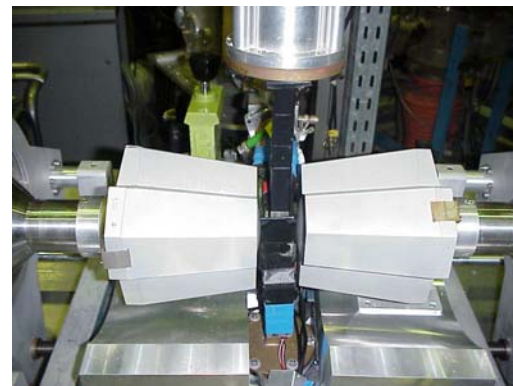
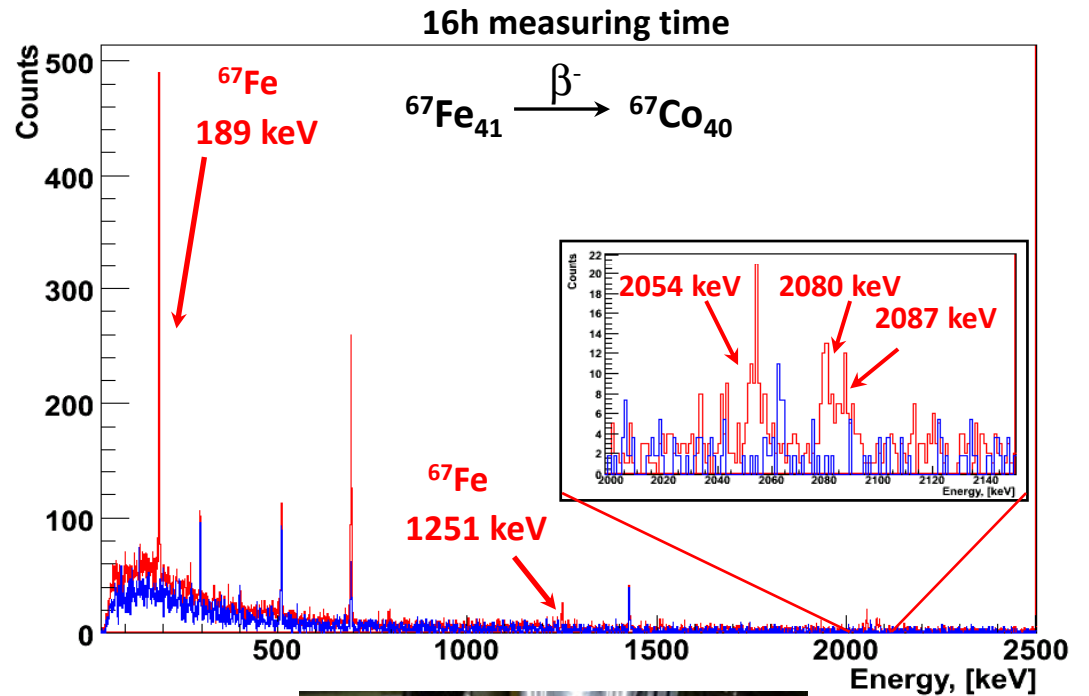
⇒ Coincidences and Correlations (γ - γ , $\beta\gamma$ - γ , ...) are performed OFFLINE

⇒ **TOTAL DATA READOUT**

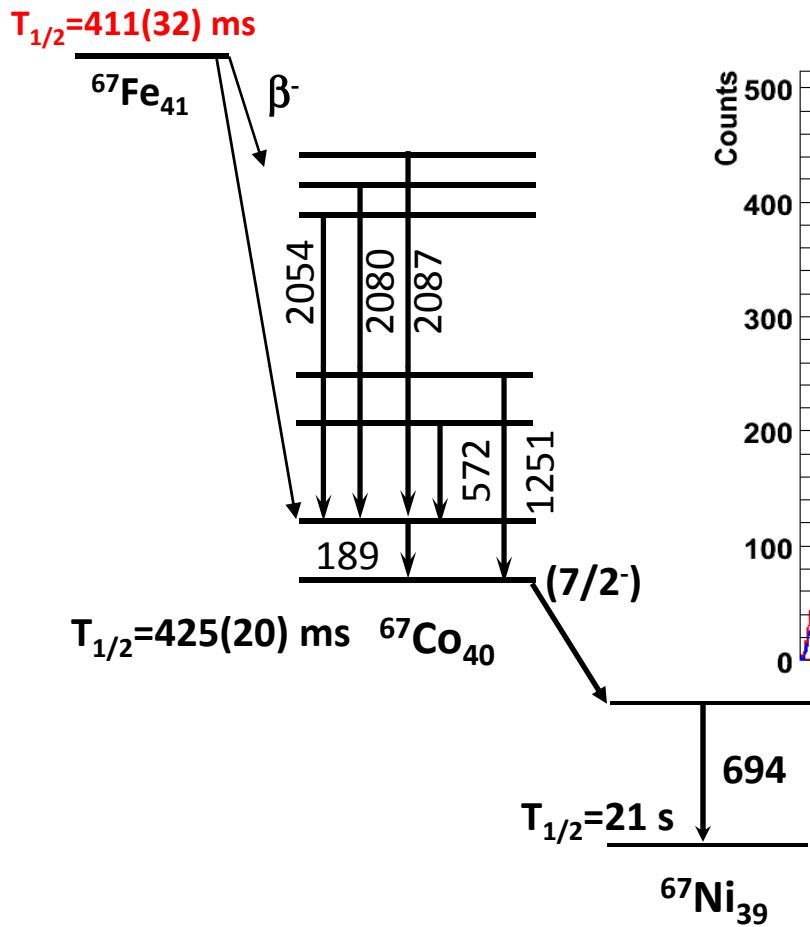
^{67}Fe - ^{67}Co - ^{67}Ni decay chain
 D. Pauwels, NIM B, to be published 2008



β -gated γ -spectra: Red: Laser ON Blue: Laser OFF

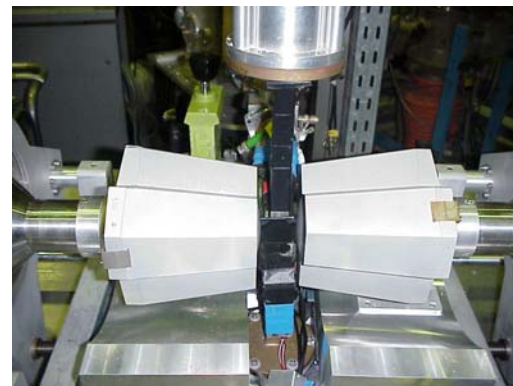
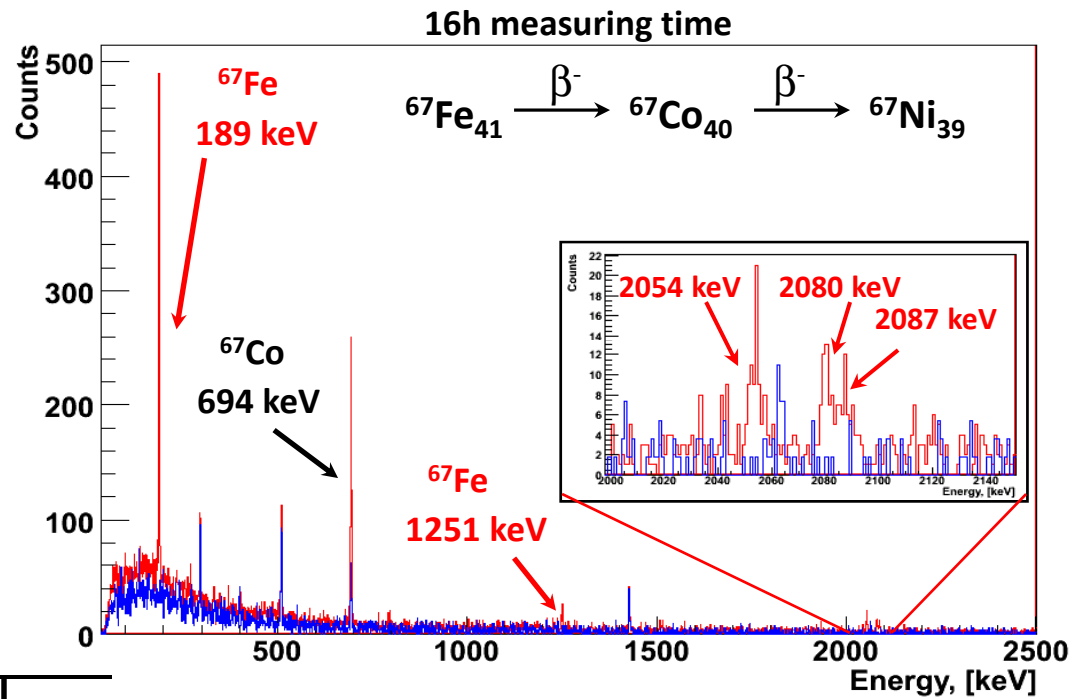


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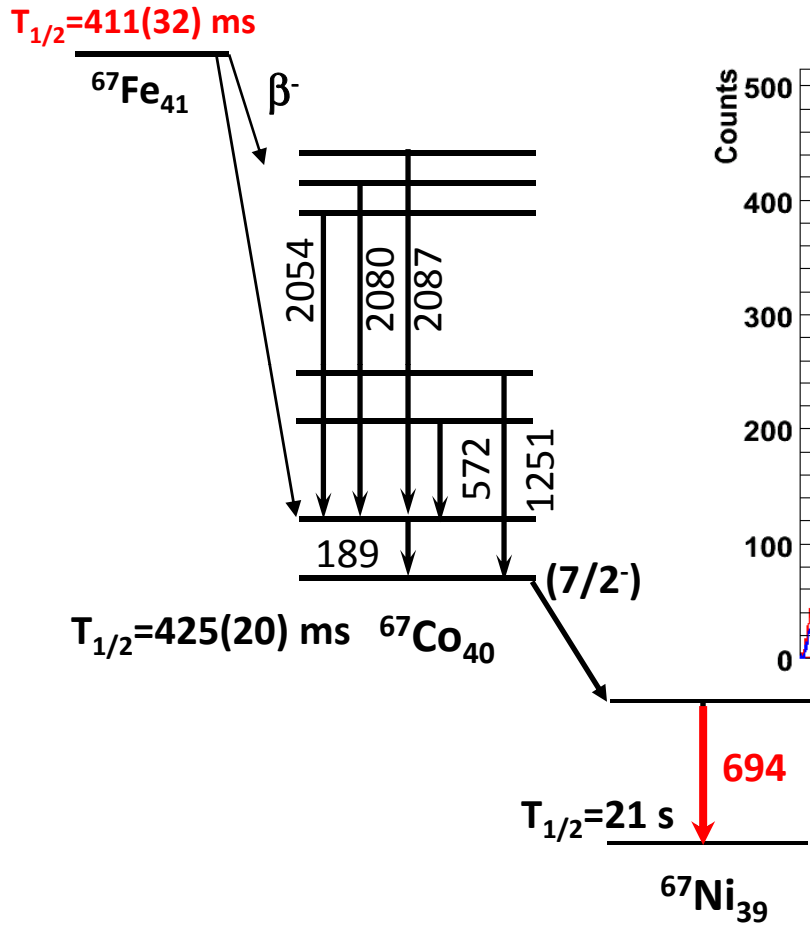


L. Weissman et al., PRC 59, 2004(1999).

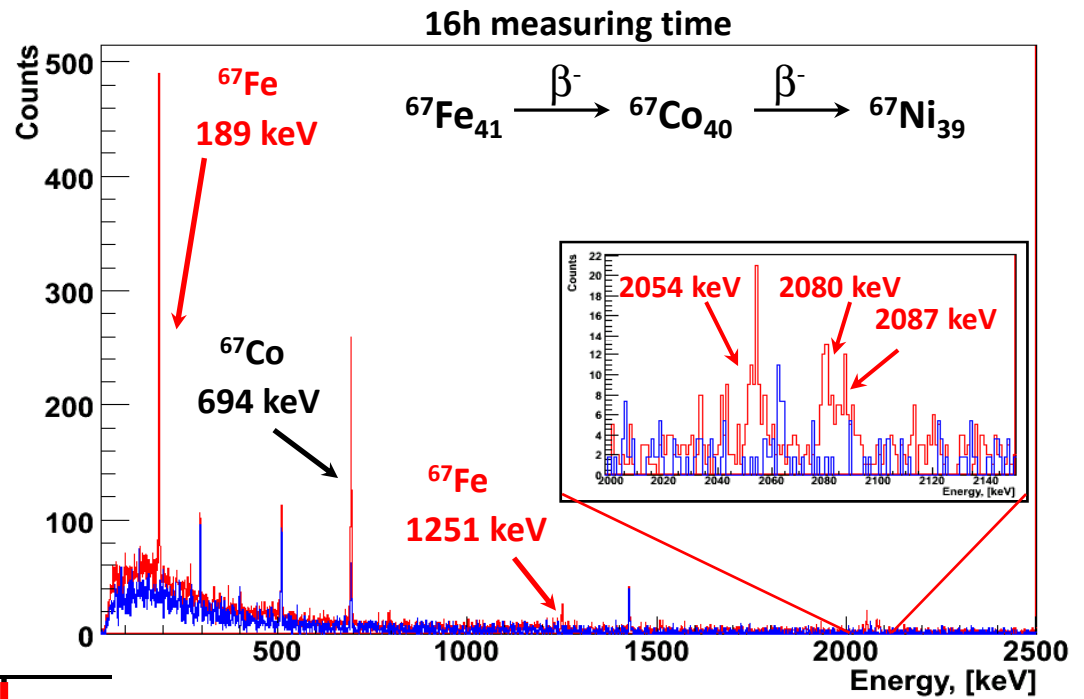
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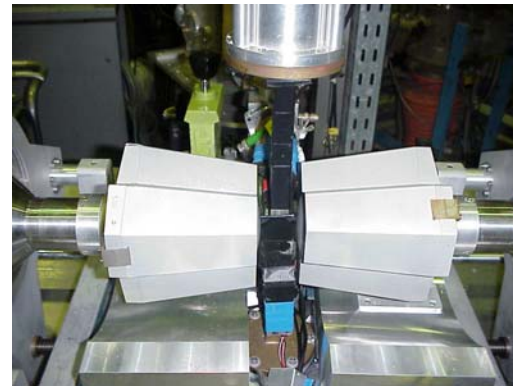
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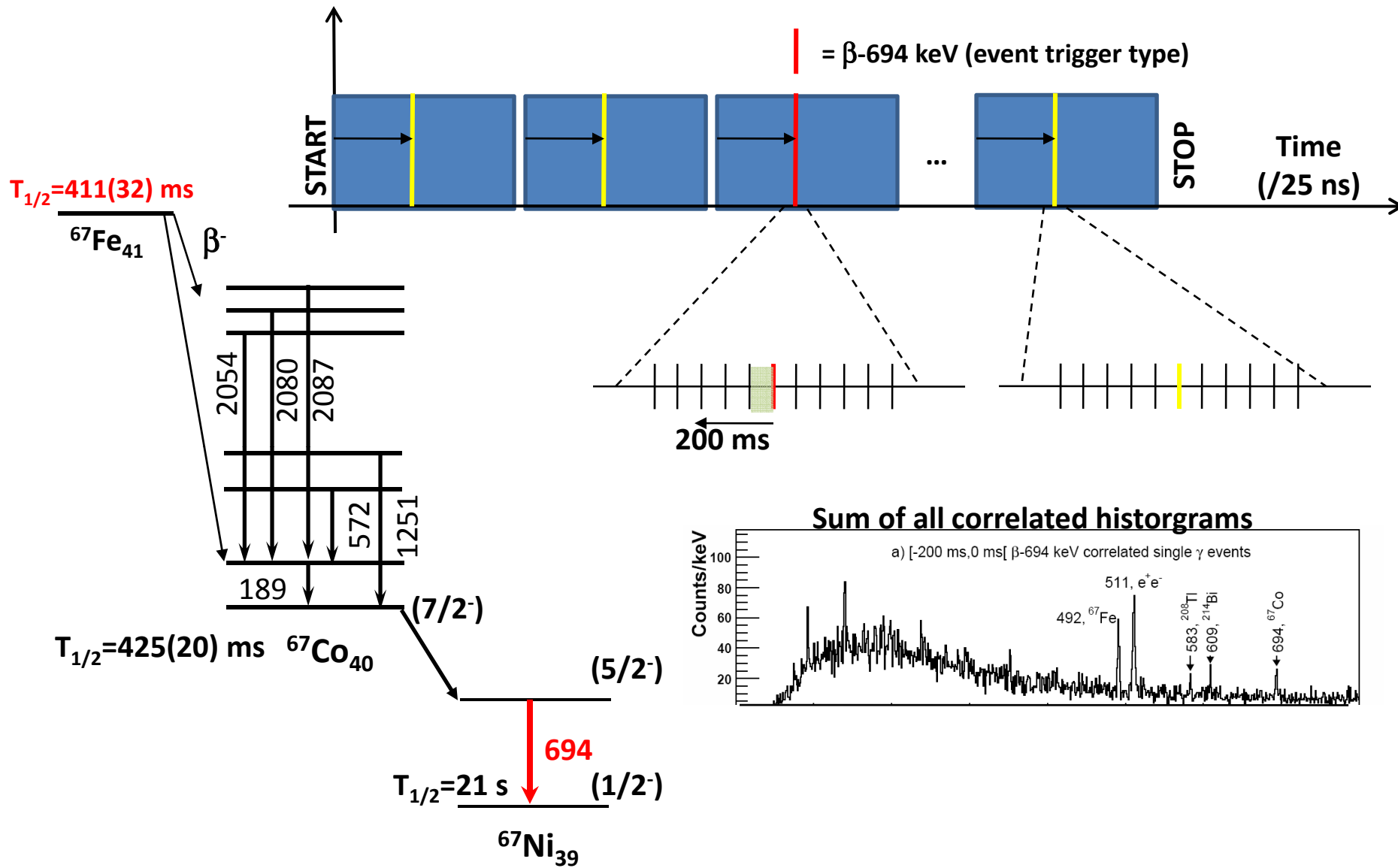


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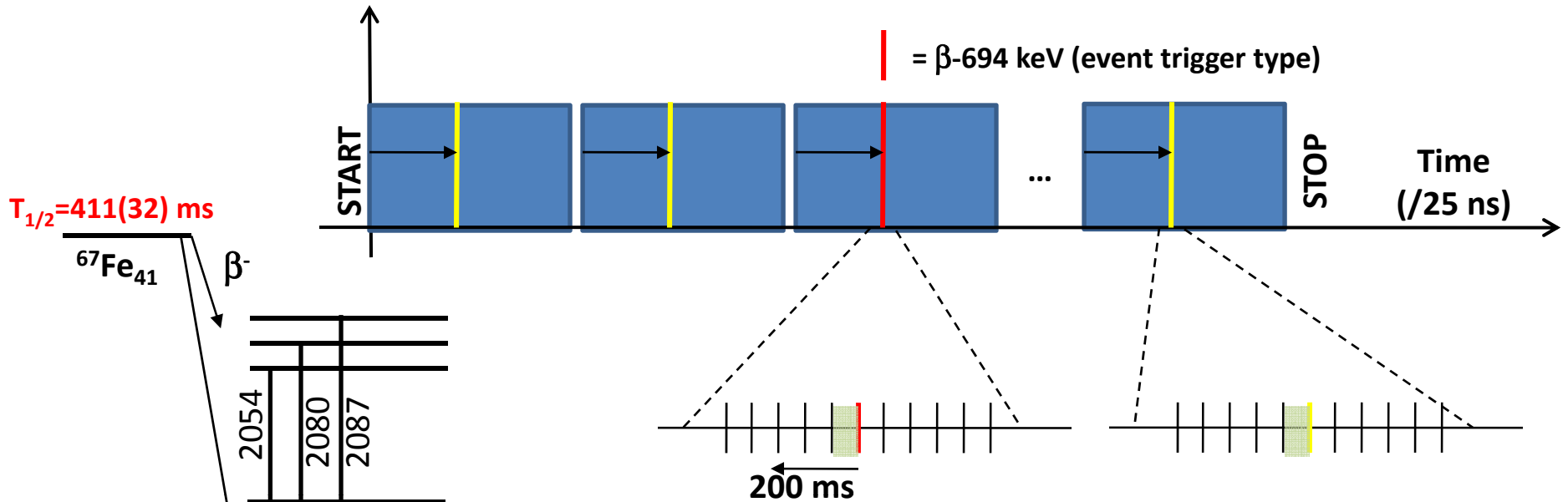


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$T_{1/2} = 411(32)$ ms $^{67}\text{Fe}_{41}$

β^-

2054 2080 2087

572 1251

189

$(7/2^-)$

$T_{1/2} = 425(20)$ ms $^{67}\text{Co}_{40}$

$(5/2^-)$

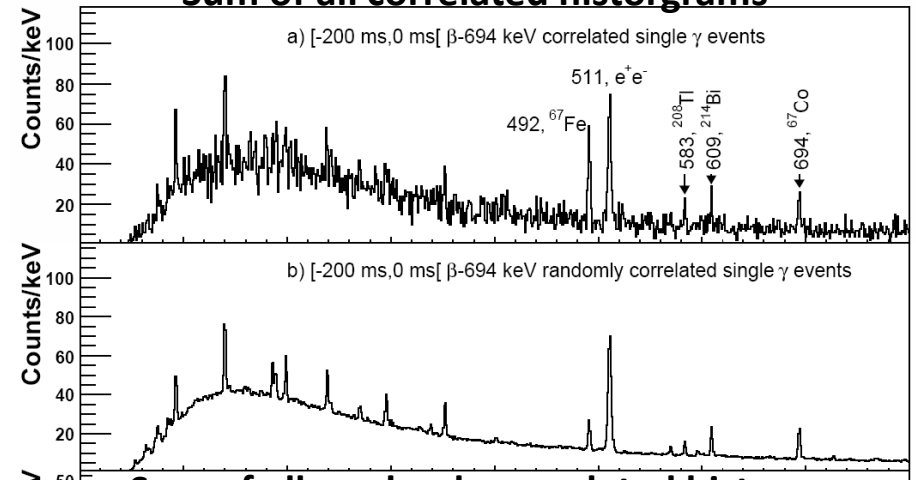
694

$T_{1/2} = 21$ s $(1/2^-)$

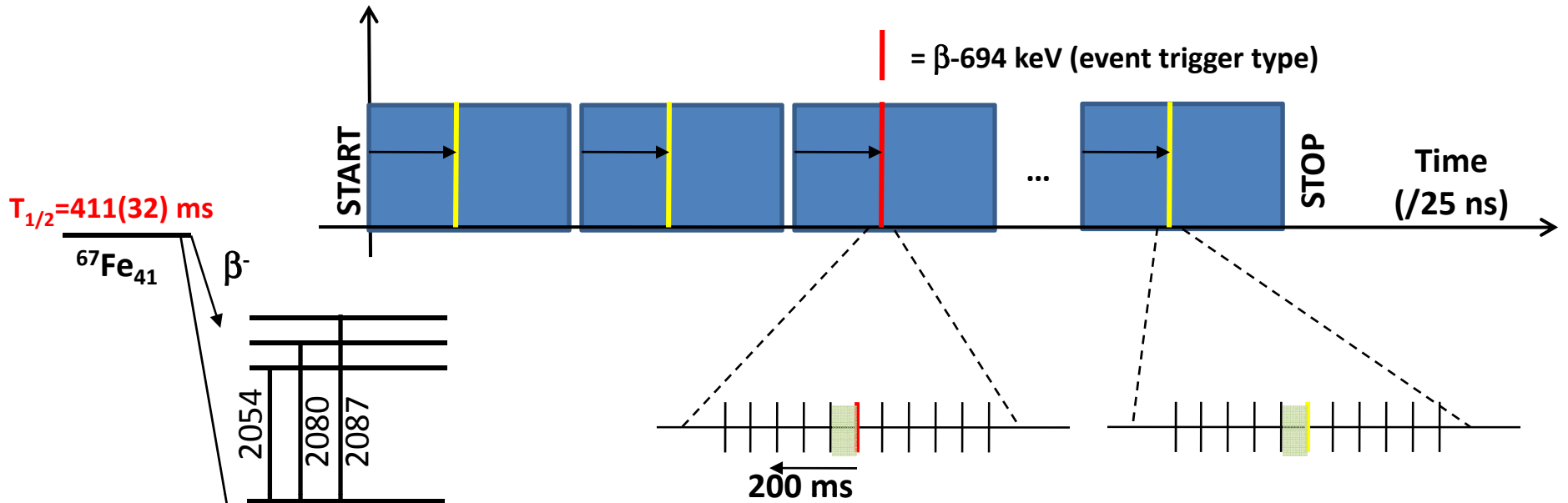
$^{67}\text{Ni}_{39}$

L. Weissman et al., PRC 59, 2004(1999).

Sum of all correlated histograms



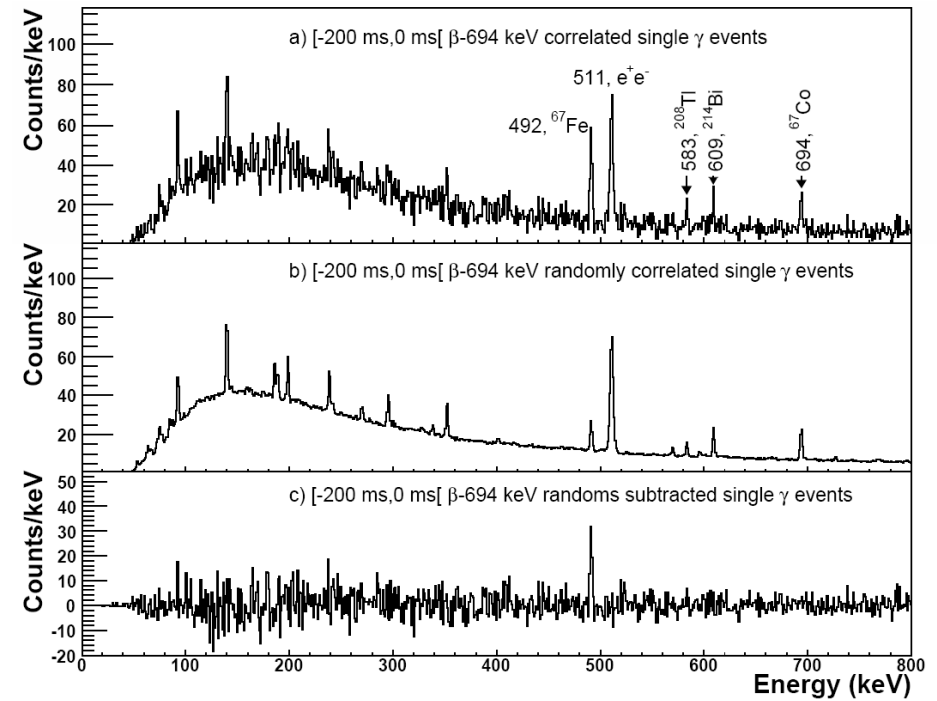
Sum of all randomly correlated histograms

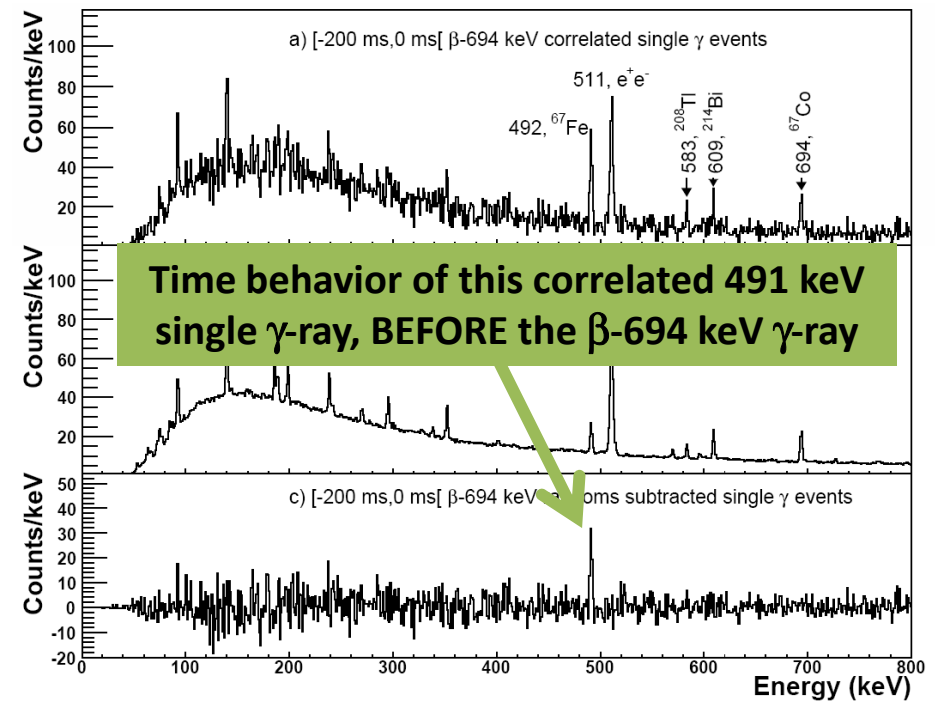
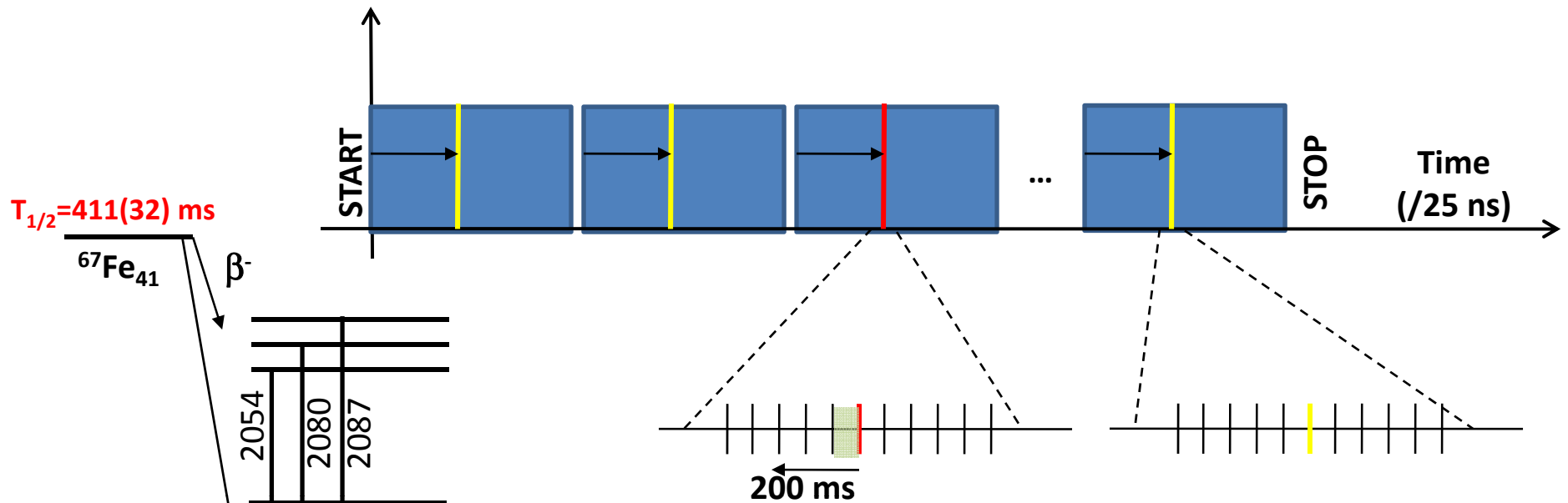


$T_{1/2} = 425(20)$ ms $^{67}\text{Co}_{40}$ $(7/2^-)$

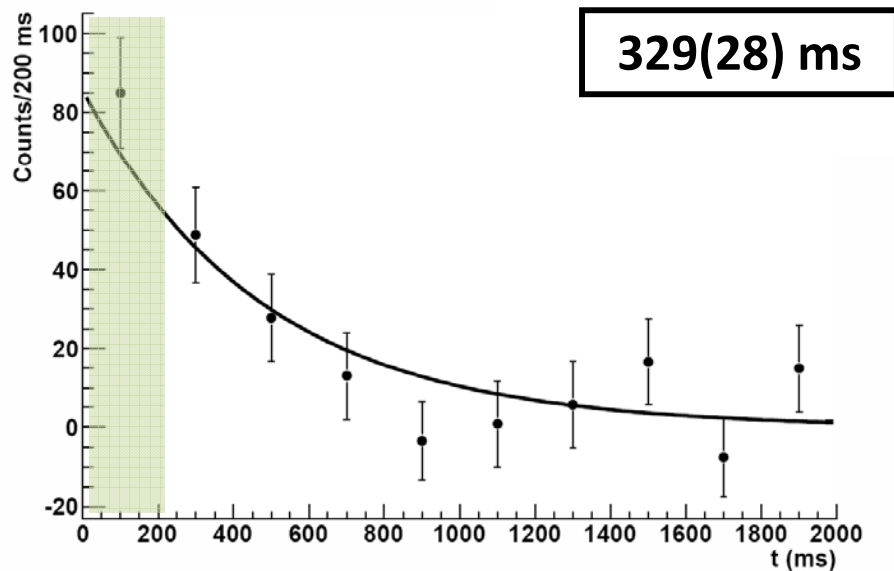
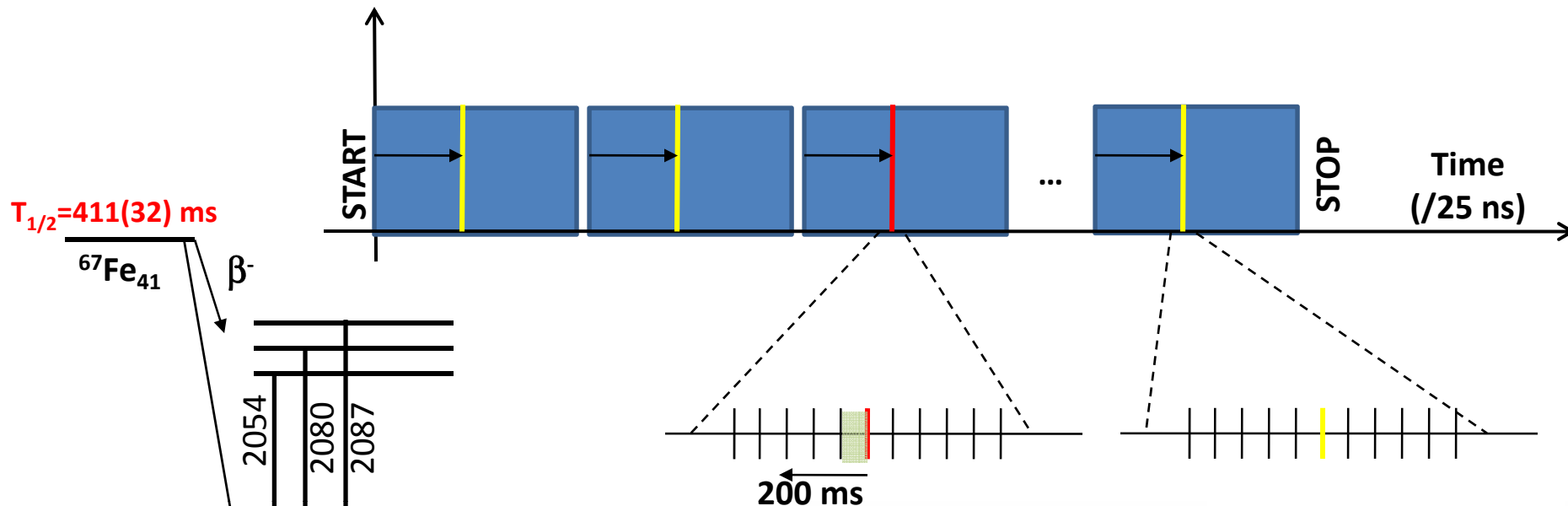
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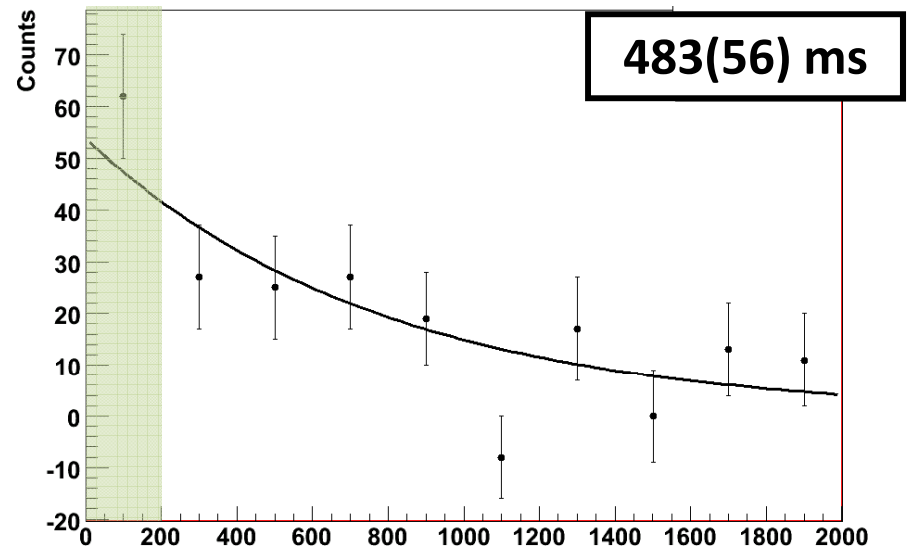
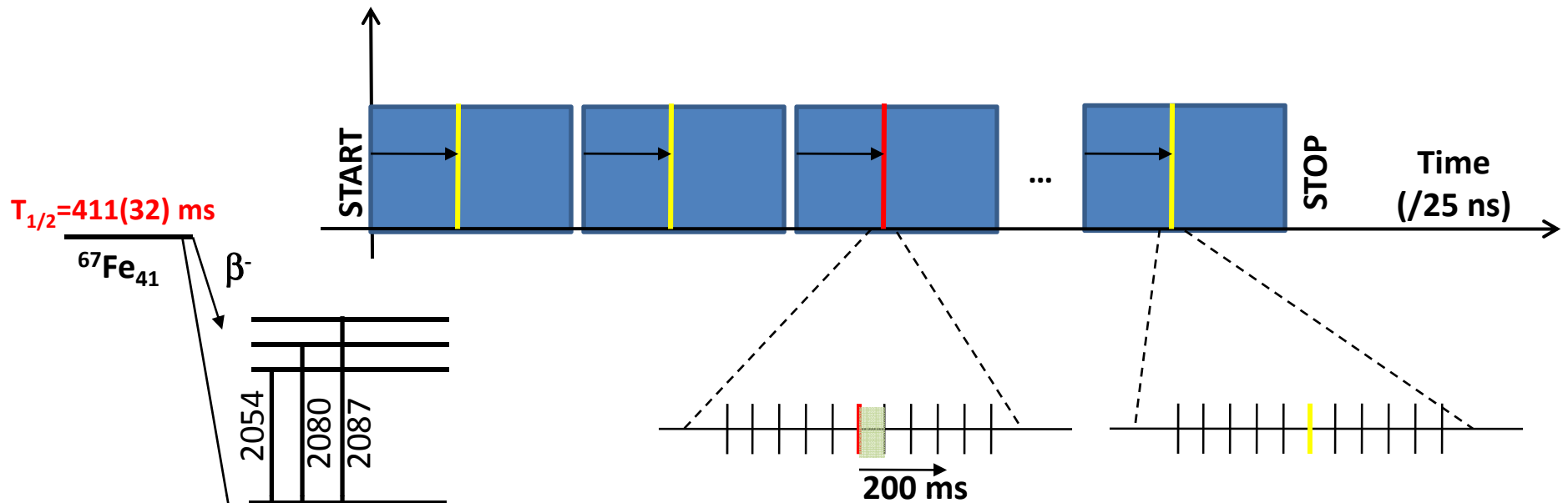


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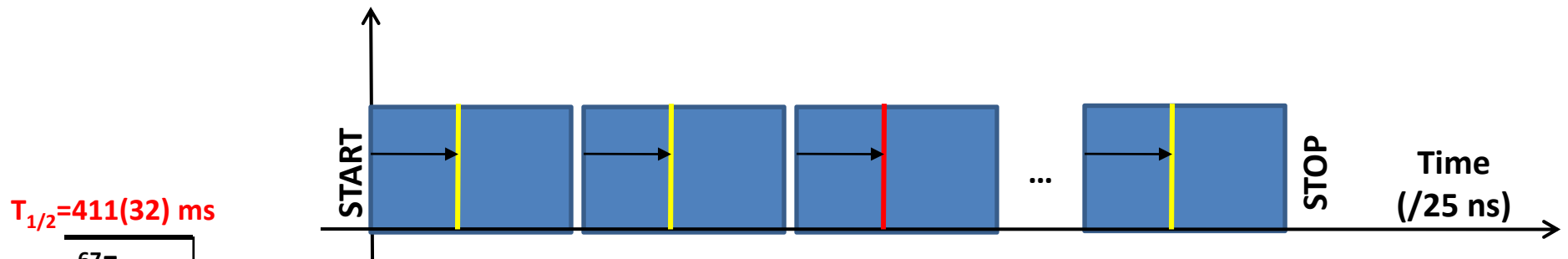
Time behavior of this correlated 491 keV single γ -ray, BEFORE the β -694 keV γ -ray

L. Weissman et al., PRC 59, 2004(1999).

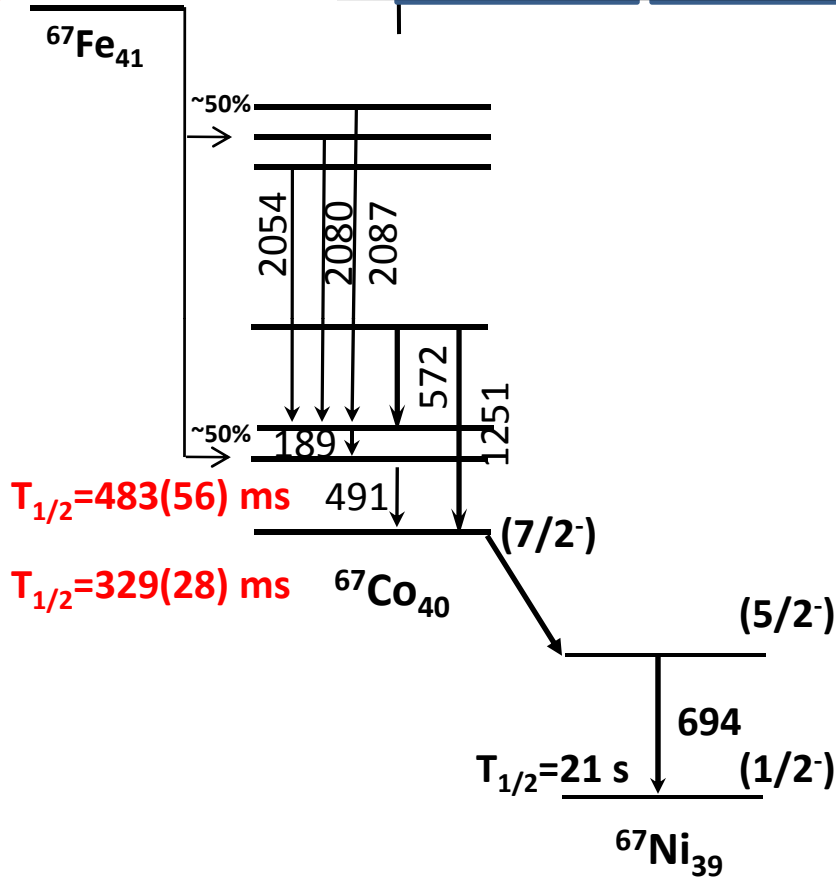


Time behavior of this correlated 491 keV single γ -ray, AFTER the β -189 keV γ -ray

L. Weissman et al., PRC 59, 2004(1999).



$T_{1/2} = 411(32) \text{ ms}$



$T_{1/2} = 483(56) \text{ ms}$

$T_{1/2} = 329(28) \text{ ms}$

$T_{1/2} = 21 \text{ s}$

An isomeric state was discovered thanks to the possibility to correlate events offline with digital electronics readout.

L. Weissman et al., PRC 59, 2004(1999).

Conditions for applicability :

- pure sources of radioactive ions
- element selectivity
- low background
- efficient detection system
- low count rate

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**Laser ON and laser OFF
measurements with RILIS**

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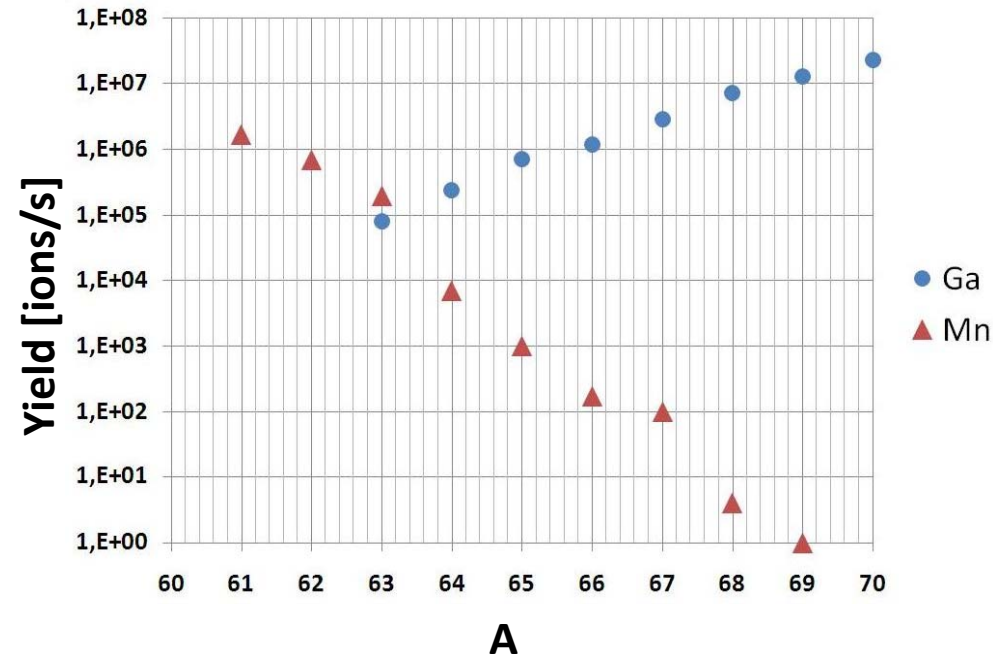
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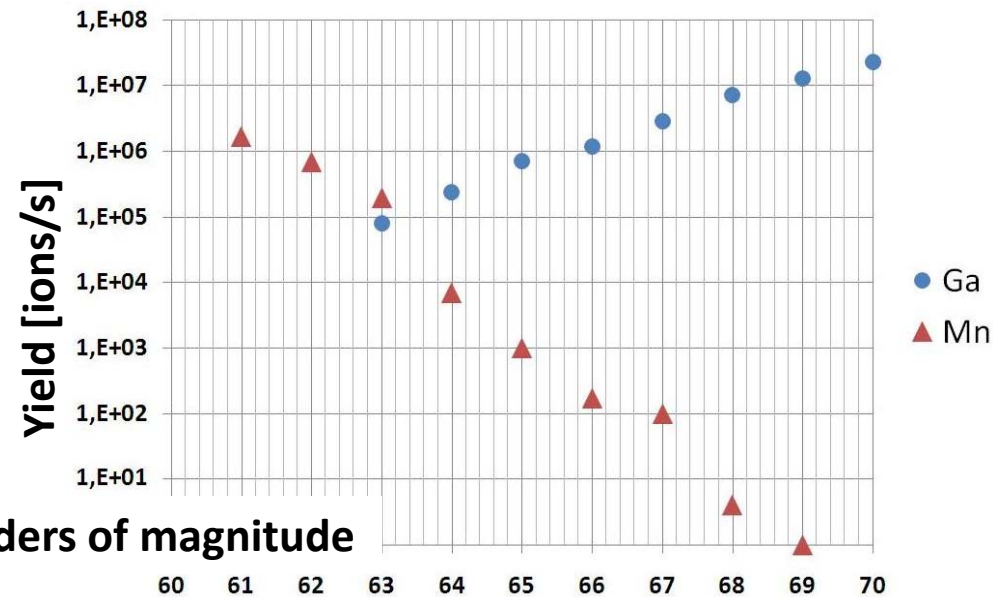
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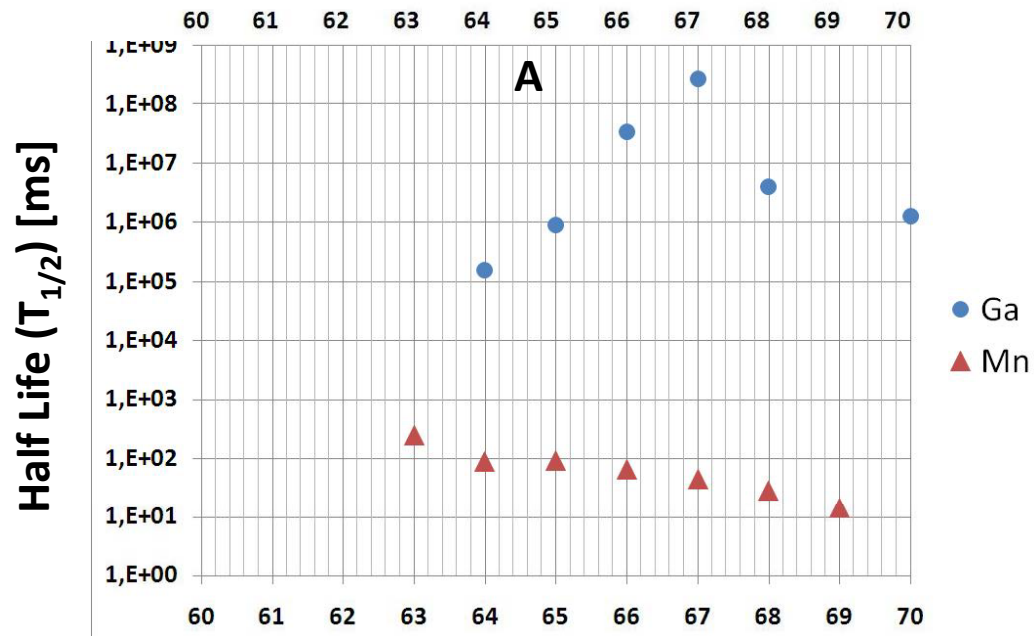
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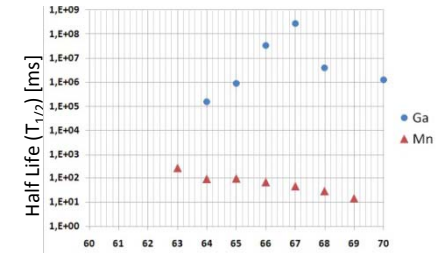
Ga production yields from fission cross section measurements of ^{238}U with 1 GeV protons
<http://www-w2k.gsi.de/charms/data-arb04.htm> or
M. Bernas *et al.* Nucl. Phys. A 725 213 (2003) + 1% ionization efficiency
Mn yields from ISOLDE Yield database





1/ **Half Lives** differ orders of magnitude



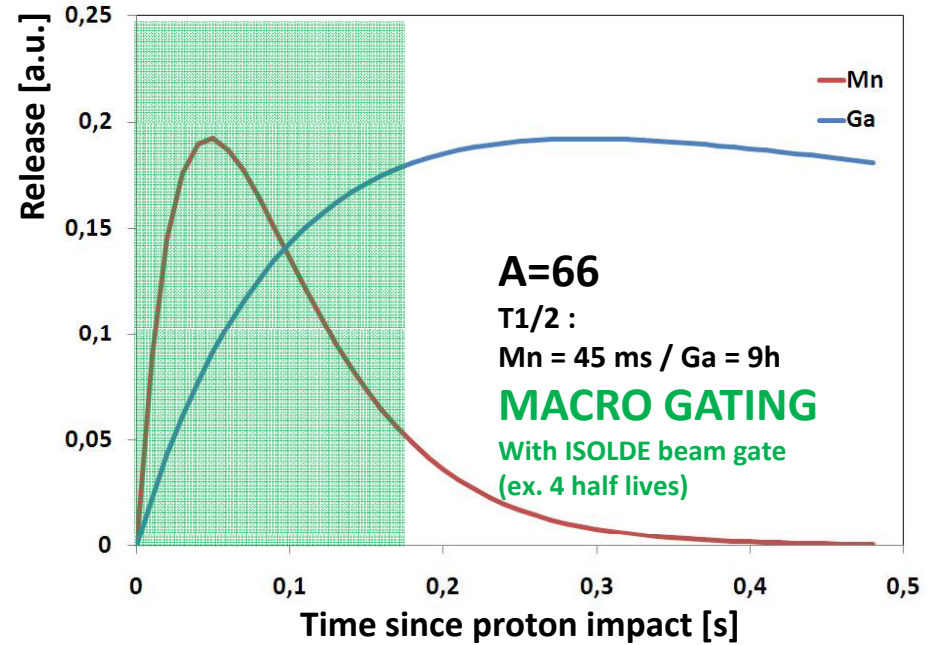


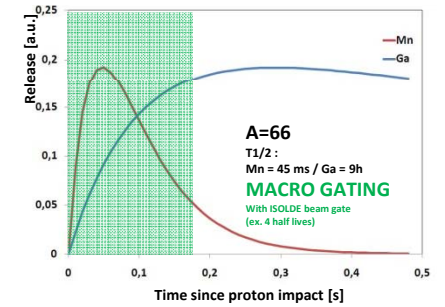
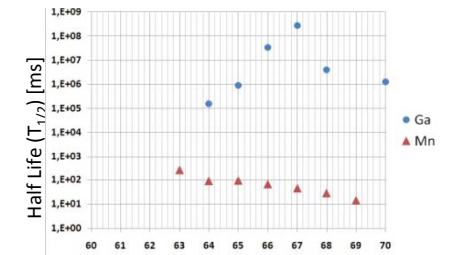
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- 2/ Different release times (**macro gating**) ;

Release Curves : $C(1-e^{-t/\tau}).[\alpha e^{-t/\tau_f} + (1-\alpha)e^{-t/\tau_s}].e^{-t/\tau}$

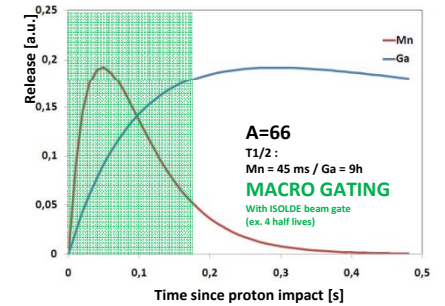
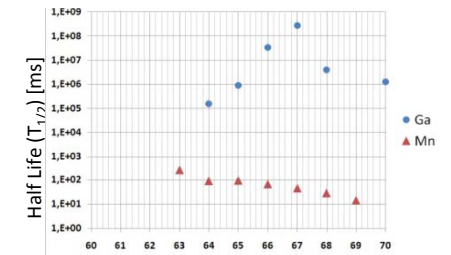
T=2000°C

Parameters taken from U. Koester, These 1999, TU Munchen
+ additional life time factor





- 1/ **Half Lives** differ orders of magnitude ;
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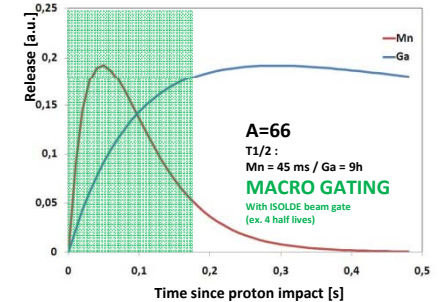
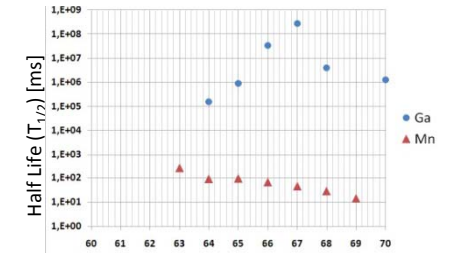


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- 4/ **Tape transport** after each measuring cycle ;
- 5/ Good **beam steering**



CONCLUSION

ISOLDE provides the **UNIQUE** possibility to combine

- 1/ the new technology utilized with the LISOL β -decay setup
- 2/ the laser ionized neutron rich Mn beams at ISOLDE

- 1/ search for isomeric states in Iron and Manganese isotopes ;
- 2/ complement the knowledge of the nuclear structure below (neutron rich) Nickel isotopes (Co, Fe and Mn)

Nr of Shifts

Example ^{67}Fe LISOL

1.25 ions/s on tape

58h (or 7 shifts) measurement

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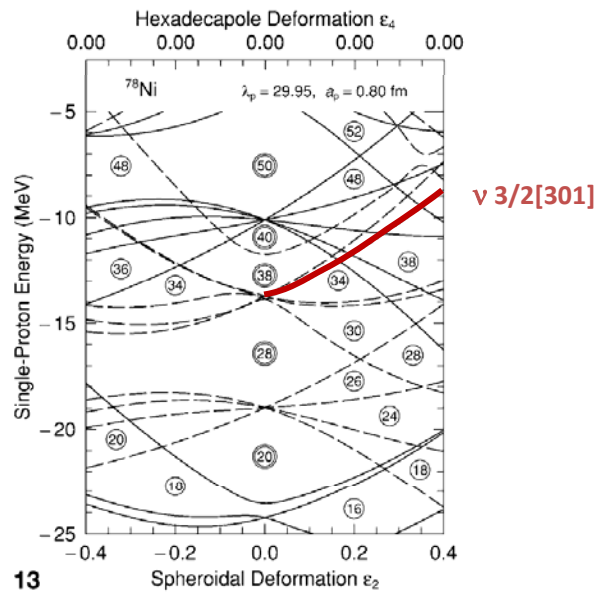
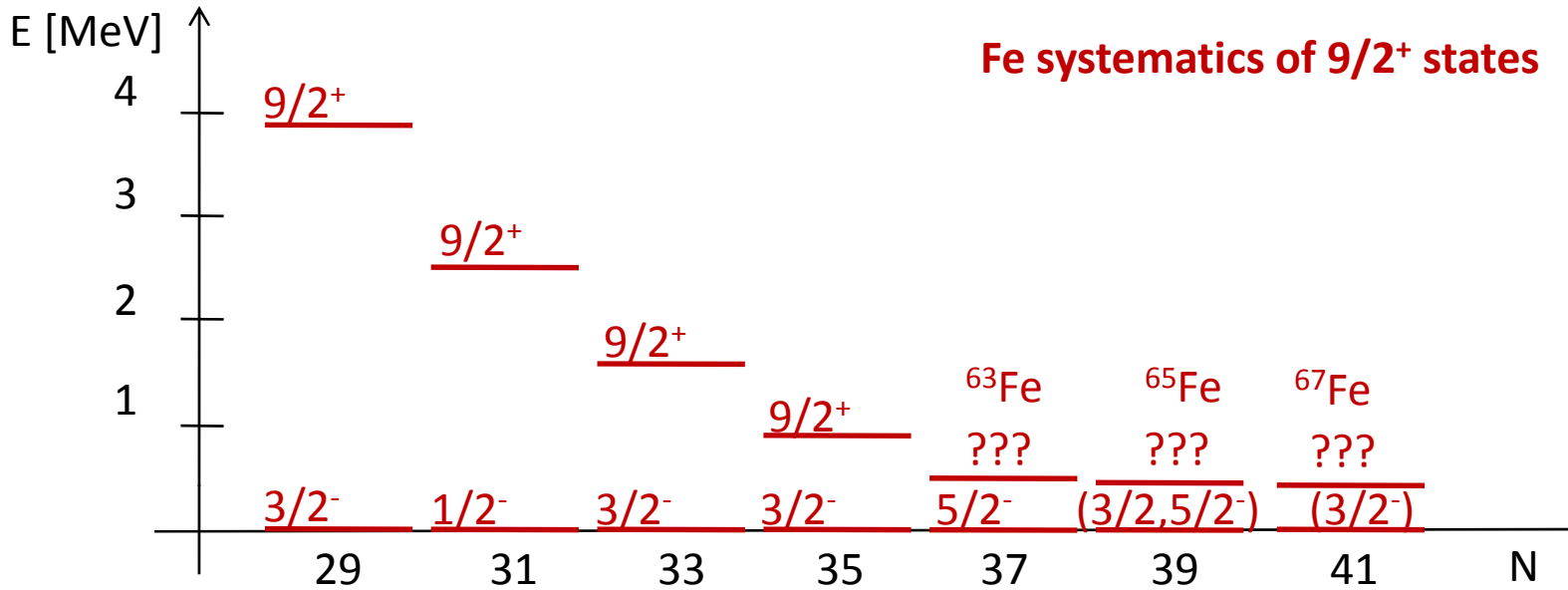
58h (or 7 shifts) measurement

Similar for $^{68,69}\text{Mn}$: 7 shifts / isotope
(6 laser on, 1 laser off)

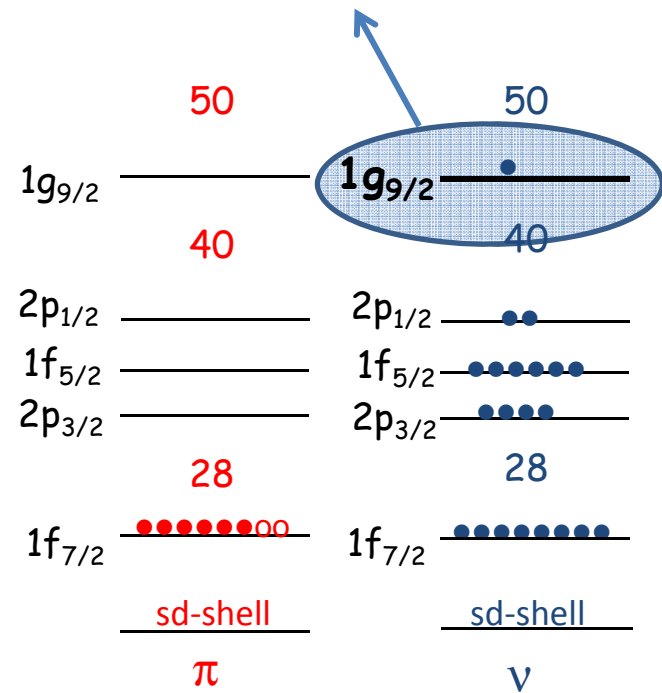
$^{61-67}\text{Mn}$: average 1 shift / isotope

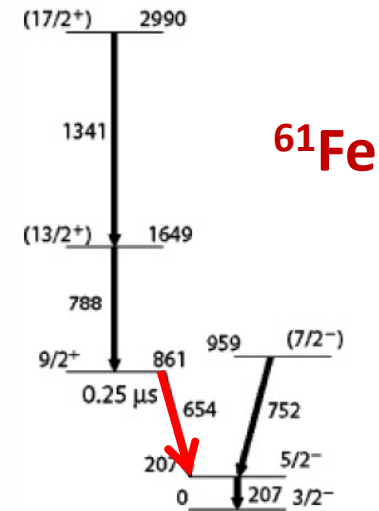
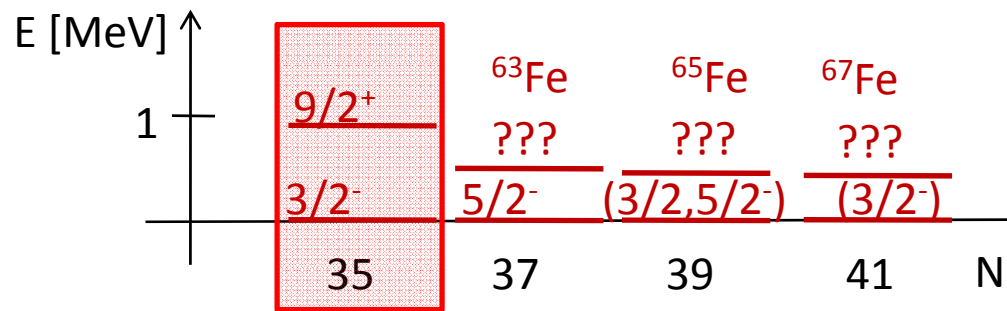
^{70}Mn : 2 shifts

24 SHIFTS



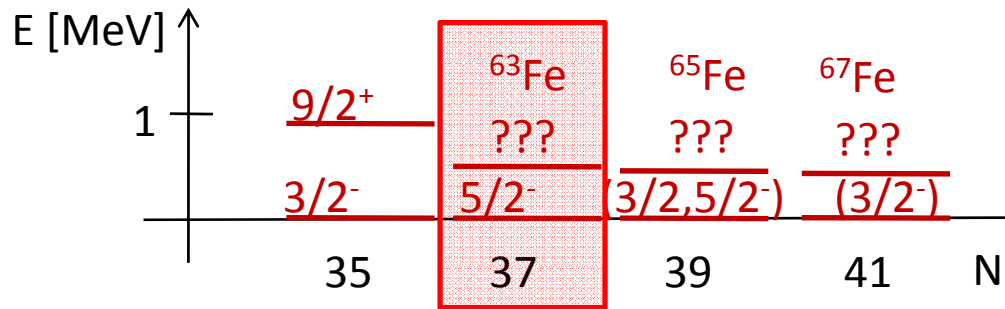
g.s. = $3/2^-$ state from β -decay feeding to ^{67}Co
 D. Pauwels et al., to be published



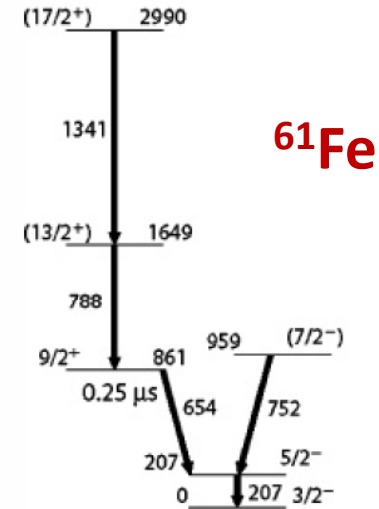
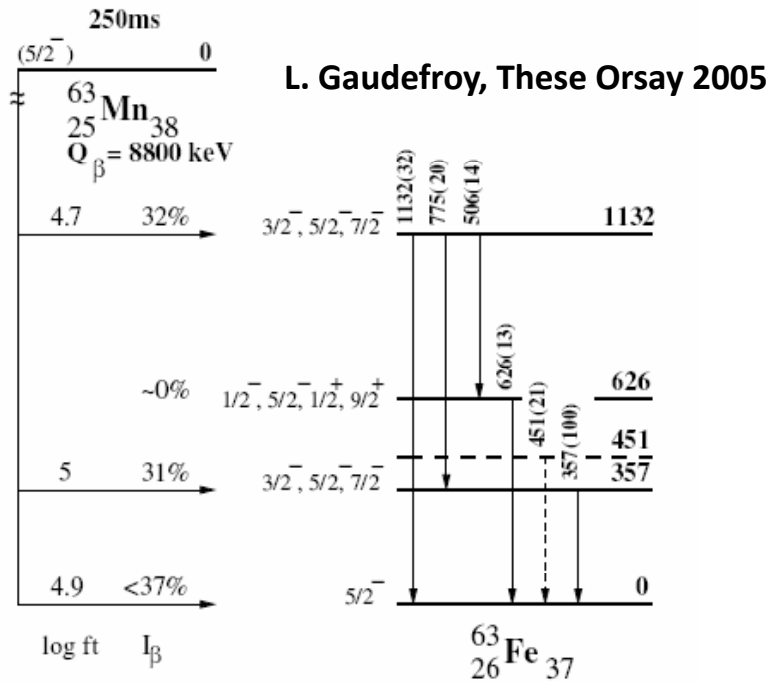


Lunardi et al. PRC 76 034303 (2007)

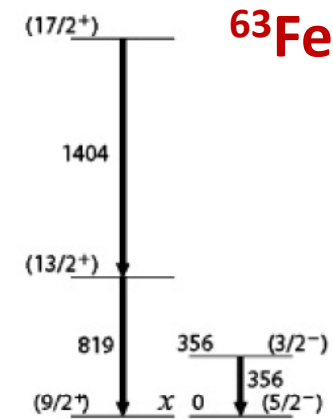
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns



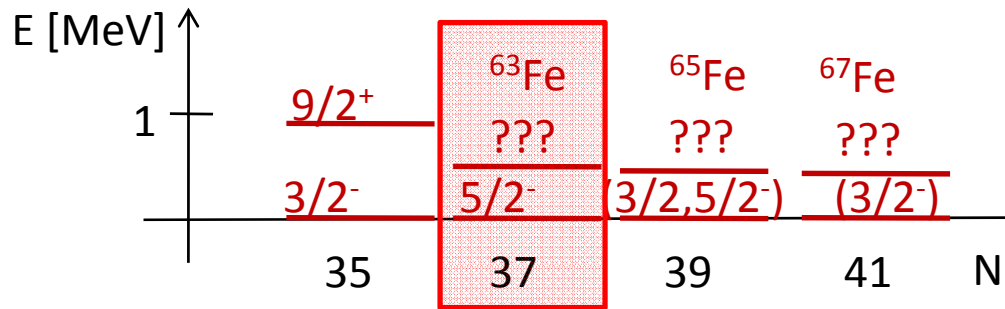
1st forbidden GT transition $5/2^- \rightarrow 9/2^+$



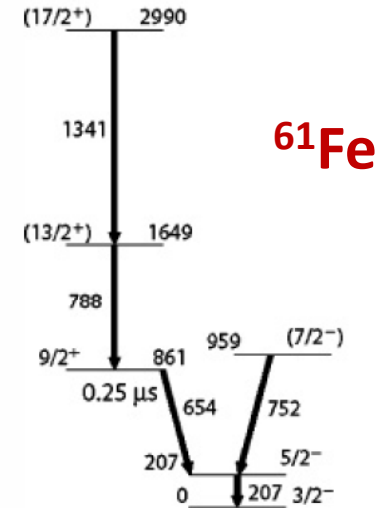
Lunardi et al. PRC 76 034303 (2007)
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns



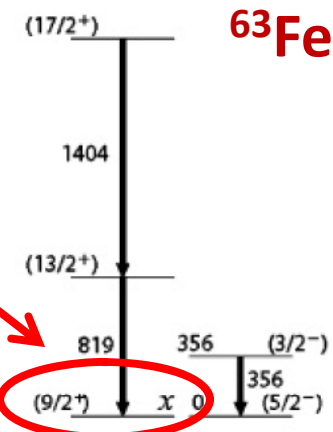
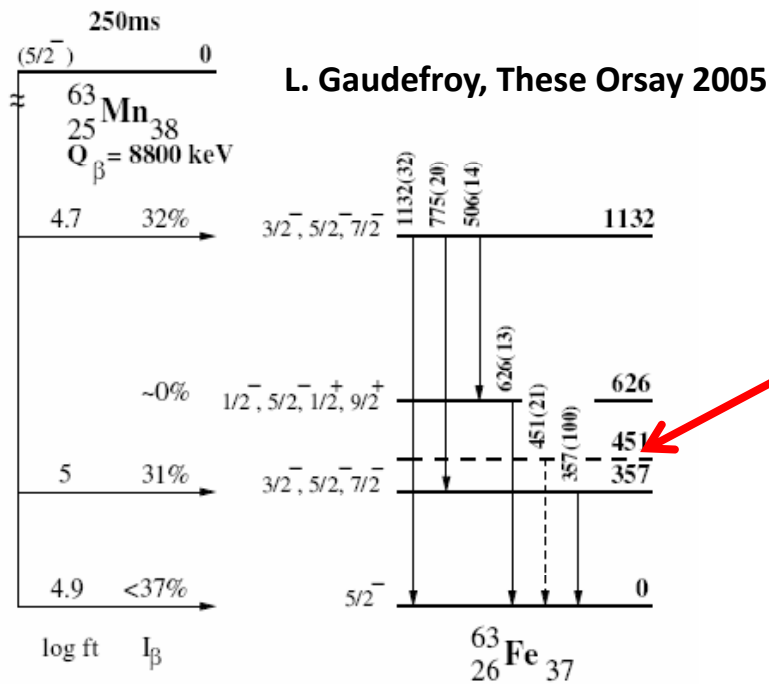
Lunardi et al. PRC 76 034303 (2007)



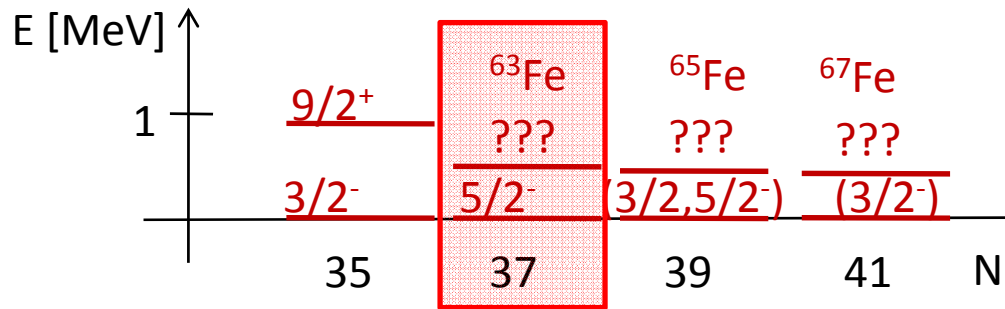
1st forbidden GT transition $5/2^- \rightarrow 9/2^+$



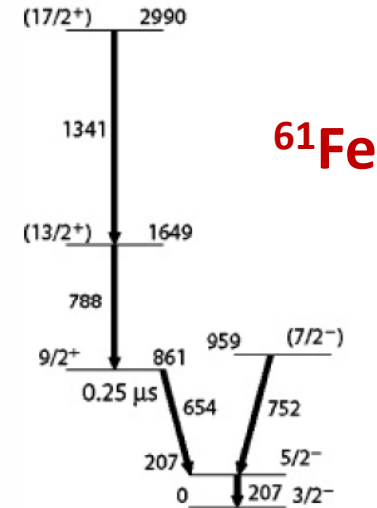
Lunardi et al. PRC 76 034303 (2007)
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns



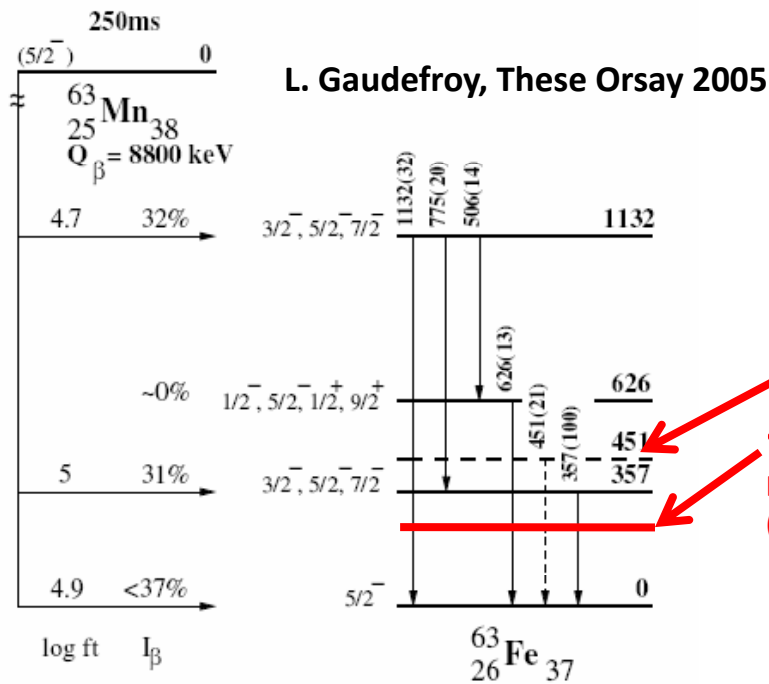
Lunardi et al. PRC 76 034303 (2007)



1st forbidden GT transition $5/2^- \rightarrow 9/2^+$



Lunardi et al. PRC 76 034303 (2007)
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns

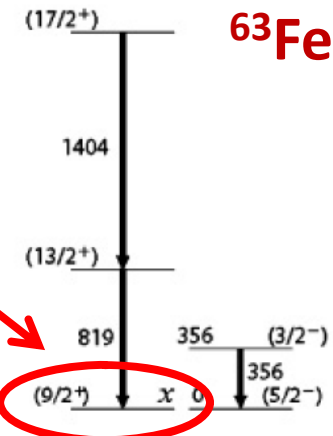


L. Gaudfroy, These Orsay 2005

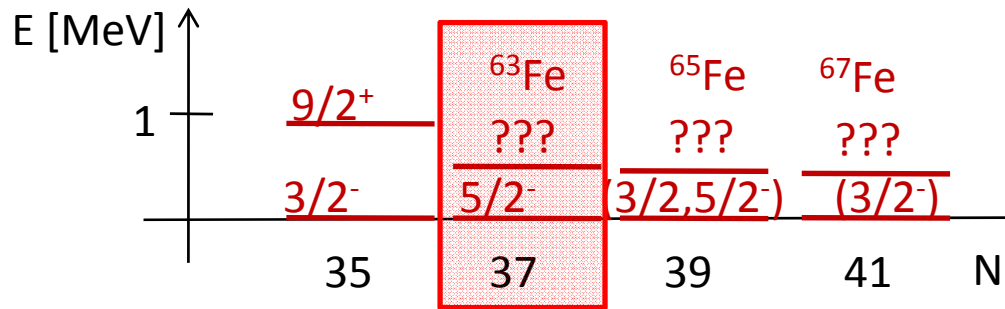
???

< 350 keV ???

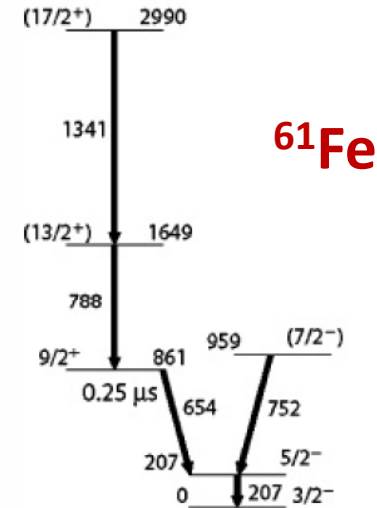
From deep-inelastic data
(W.B. Walters, priv. comm.)



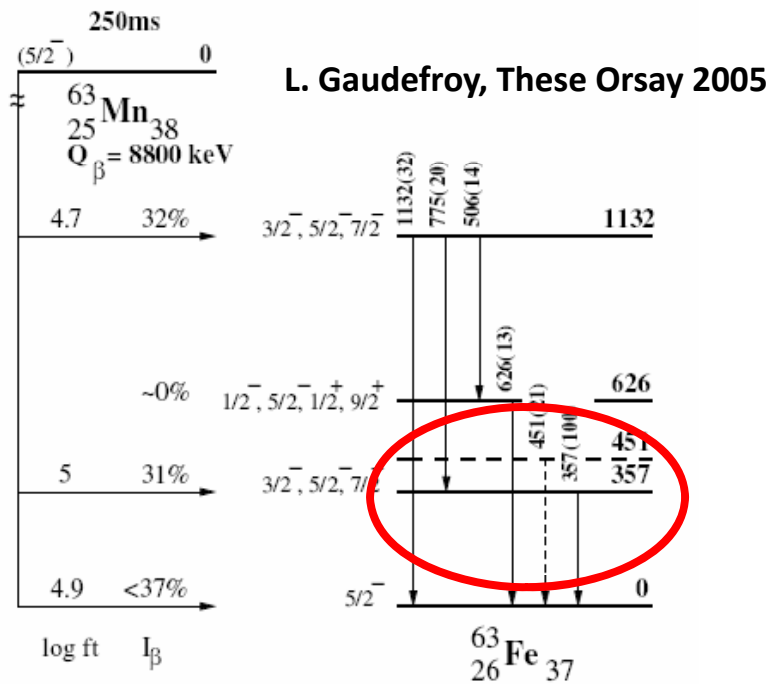
Lunardi et al. PRC 76 034303 (2007)



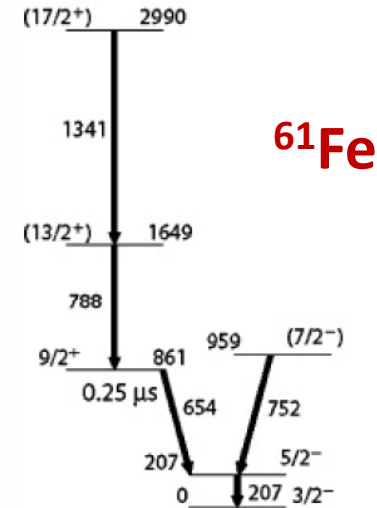
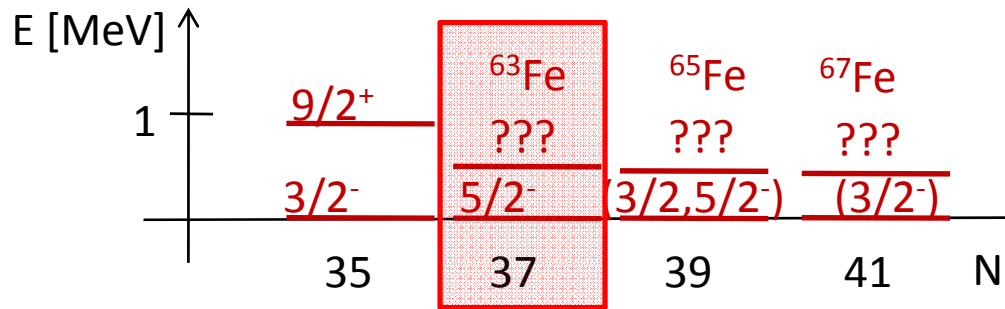
1st forbidden GT transition $5/2^- \rightarrow 9/2^+$



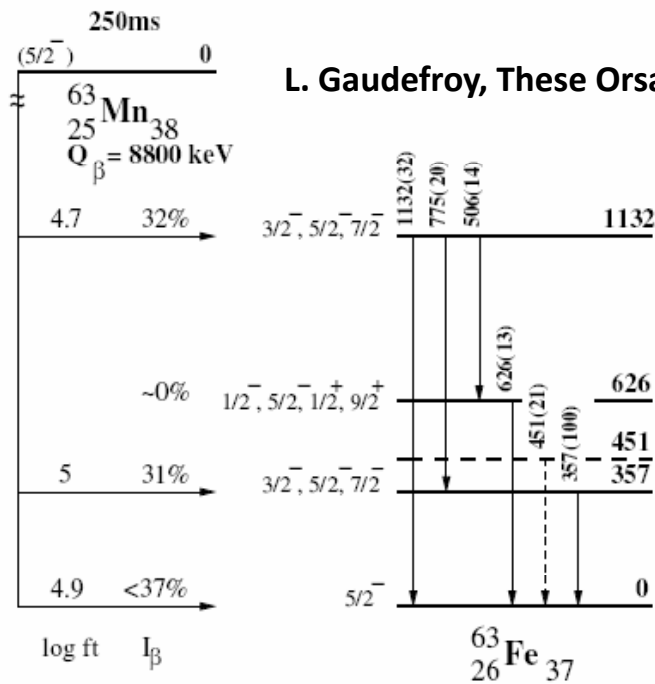
Lunardi et al. PRC 76 034303 (2007)
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns



$9/2^+ \rightarrow 5/2^- = \mu\text{s}$ isomer ...
lost in prompt β - γ coincidences,
re-gained with the digital readout !

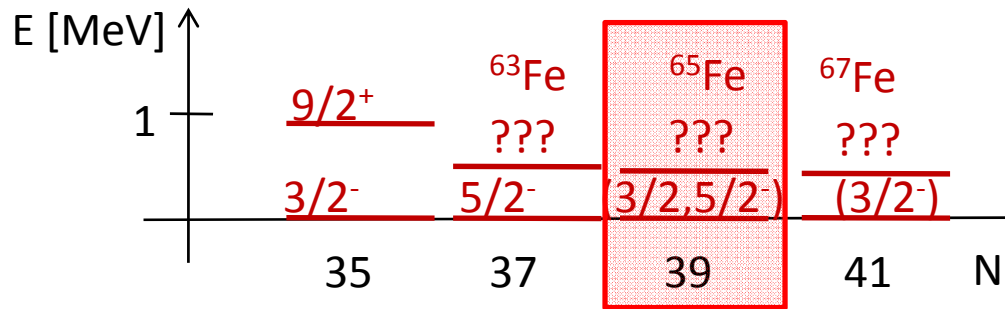


Lunardi et al. PRC 76 034303 (2007)
M2 654 keV $9/2^+ \rightarrow 5/2^-$: 239(5) ns

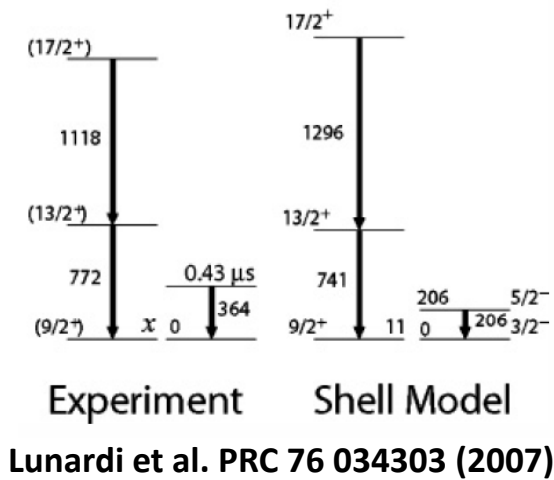
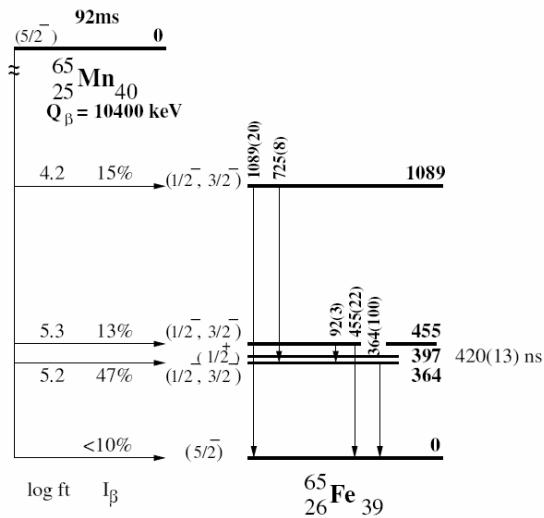


L. Gaudfroy, These Orsay 2005

^{64}Mn decay :
33(2)% β -delayed neutron branch
 \Rightarrow Feeding of low-spin states in ^{63}Mn !!!

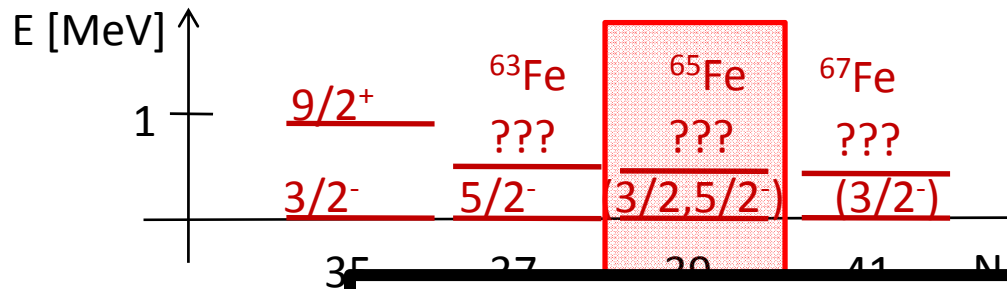


L. Gaudefroy, These Orsay 2005

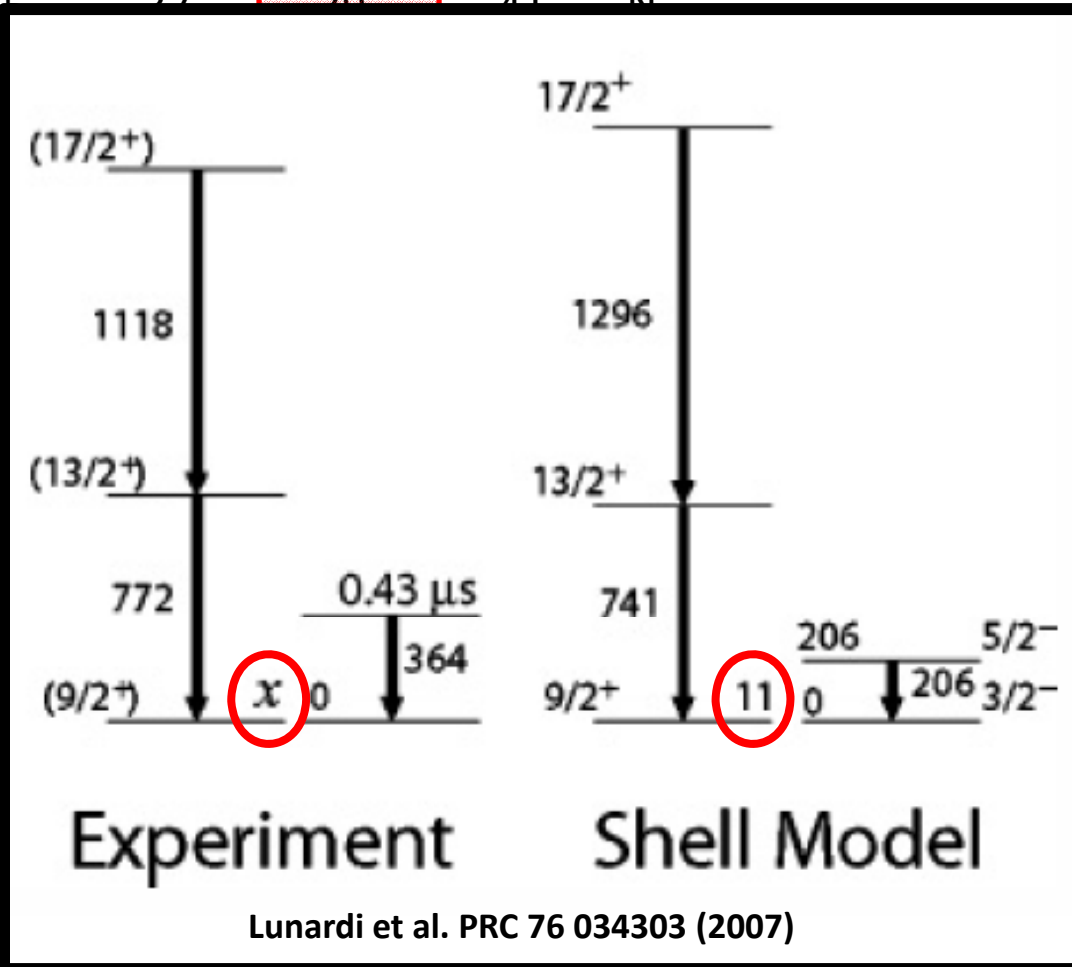
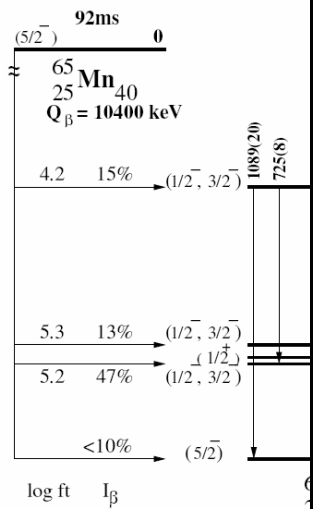


+ MSU mass measurements :
isomer around 400 keV
Block *et al.* (MSU)

+ LISOL β -decay ^{65}Fe
Indication for β -decaying isomer
D. Pauwels *et al.* (KU Leuven)



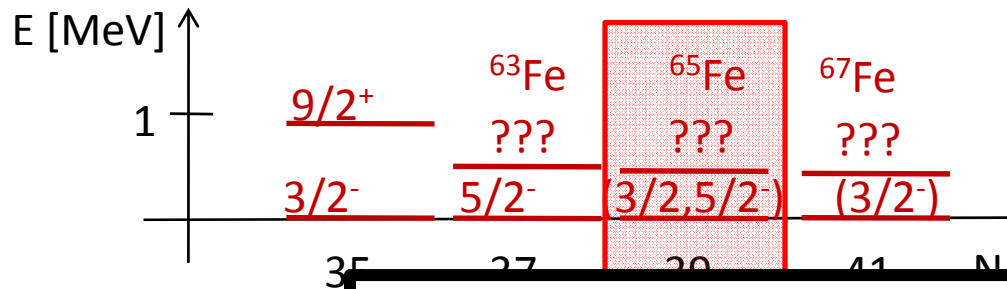
L. Gaodefroy, These



Mass measurements :
around 400 keV
et al. (MSU)

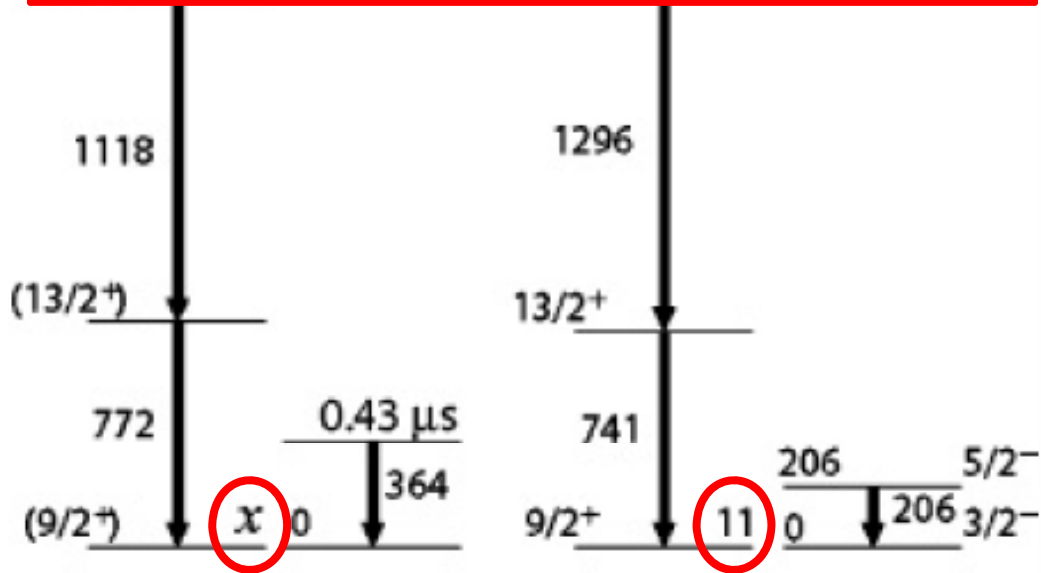
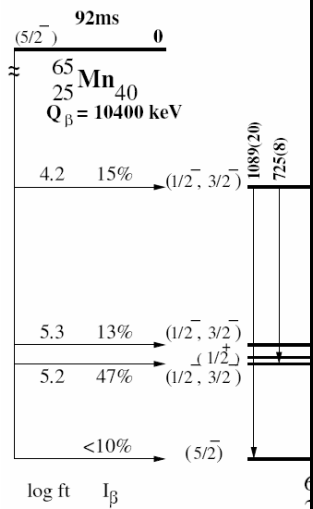
β -decay ^{65}Fe
for β -decaying isomer
et al. (KU Leuven)

Lunardi et al. PRC 76 034303 (2007)



Experimental information to test SHELL MODEL calculations !!!

L. Gaodefroy, These



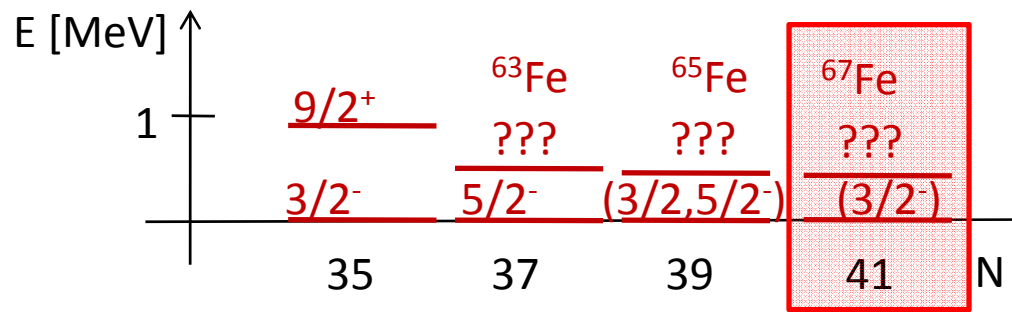
Experiment

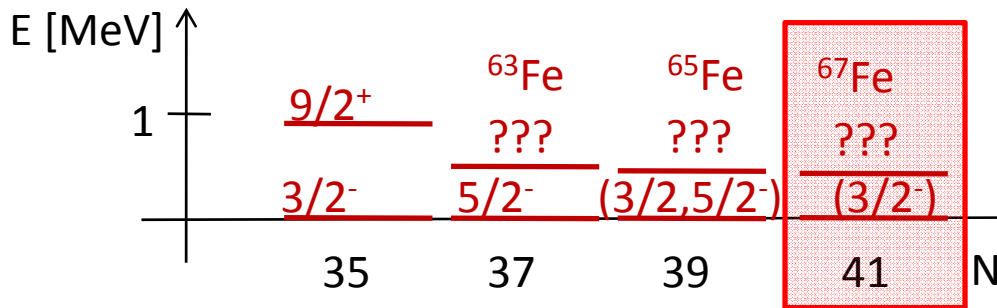
Shell Model

Lunardi et al. PRC 76 034303 (2007)

Mass measurements :
around 400 keV
et al. (MSU)

β -decay ^{65}Fe
for β -decaying isomer
et al. (KU Leuven)

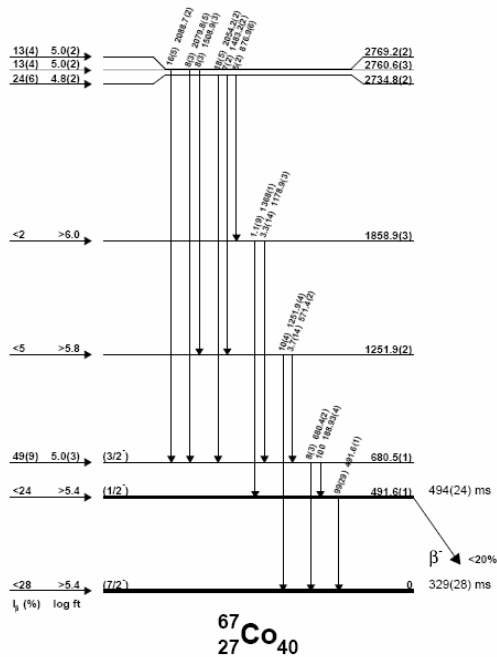
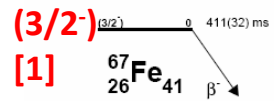


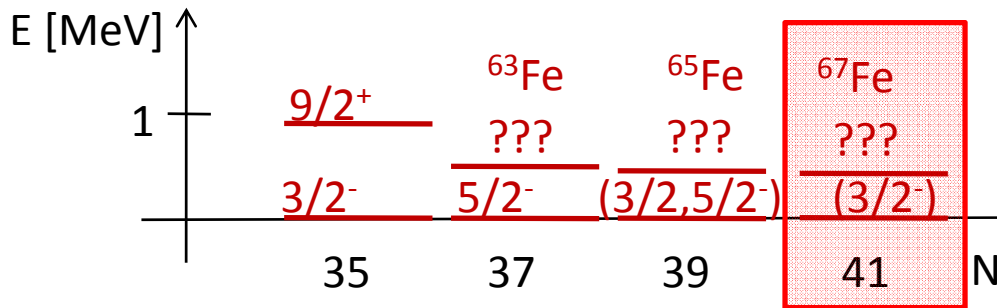


β -decay study of ^{67}Fe at LISOL (2007)

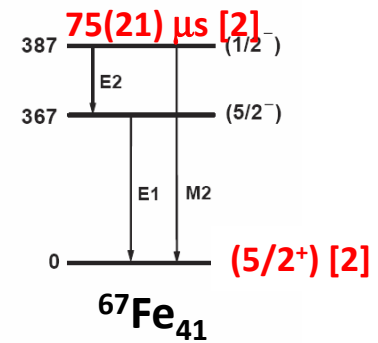
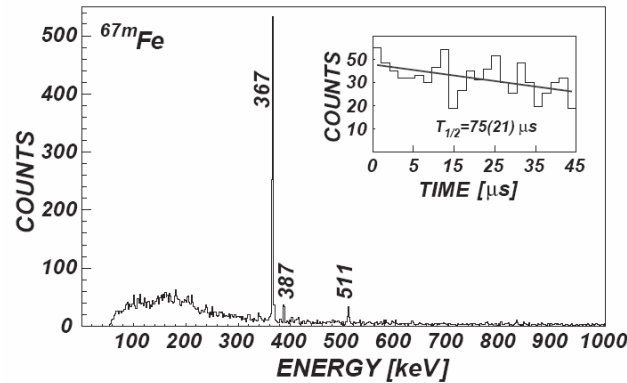
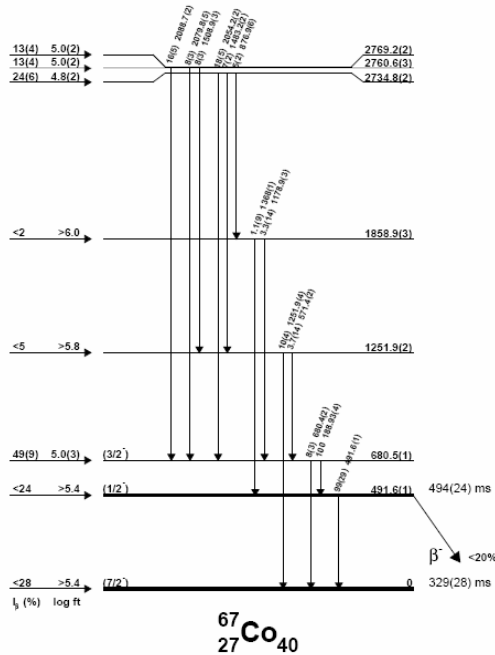
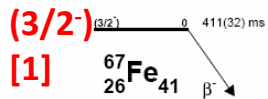
D. Pauwels et al., These KU Leuven 2008

(to be published) [1]

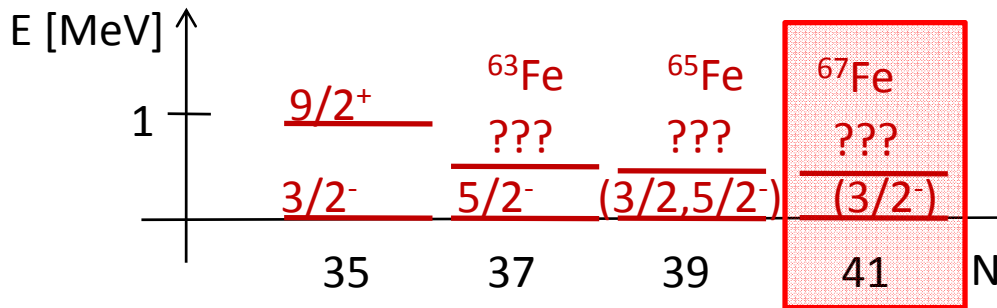




β -decay study of ^{67}Fe at LISOL (2007)
 D. Pauwels et al., These KU Leuven 2008
 (to be published) [1]

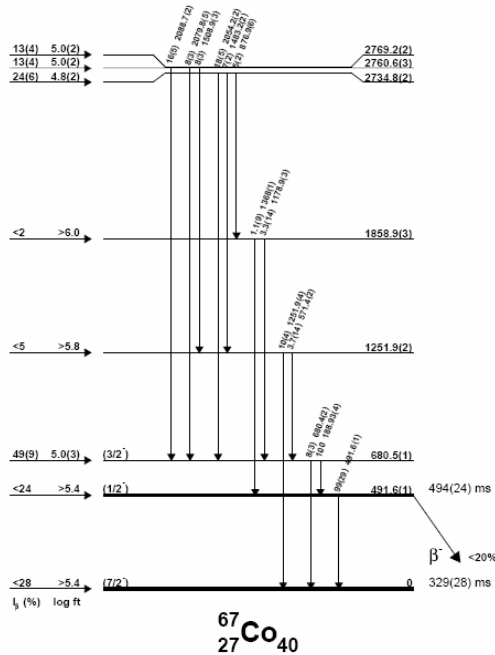


In-flight separation and isomeric decay study at GANIL
 M. Sawicka et al. EPJA 16 51-54 (2003) [2]



β -decay study of ^{67}Fe at LISOL (2007)
 D. Pauwels et al., These KU Leuven 2008
 (to be published) [1]

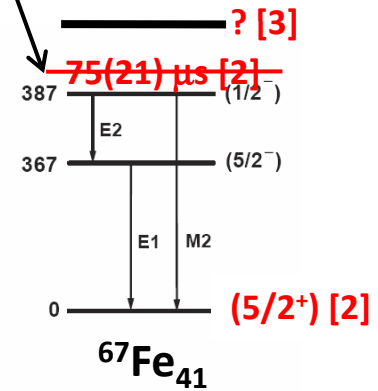
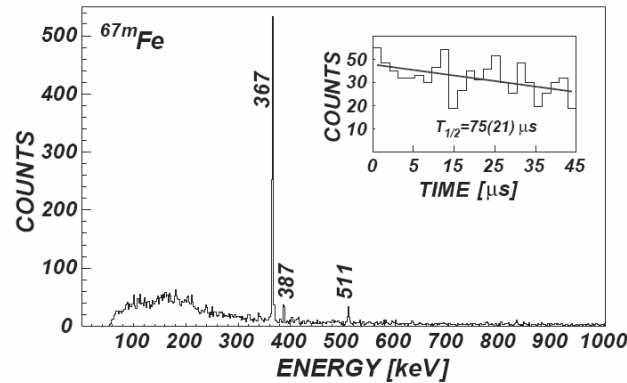
$(3/2^-)$ [1]
 $^{67}_{26}\text{Fe}_{41} \beta^-$



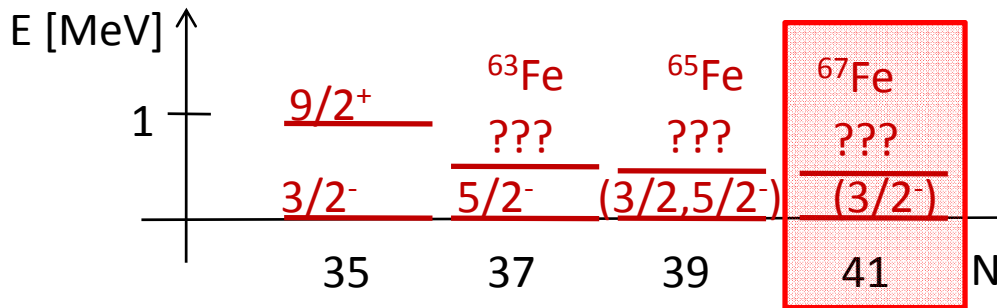
[3] = β -decay study of ^{67}Mn at GANIL
 J.M. Daugas et al., AIP Conf Proc 831 p 427
 No spin assignments (!)

$^{67}\text{Mn} (5/2^-)$

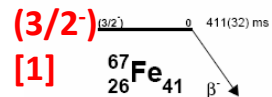
β^-



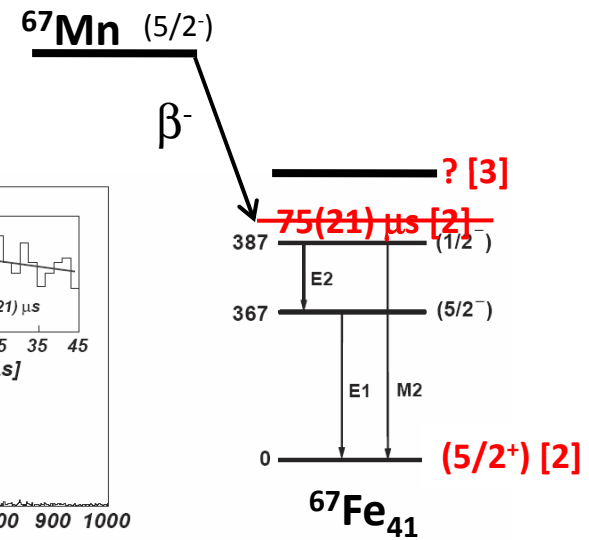
In-flight separation and isomeric decay study at GANIL
 M. Sawicka et al. EPJA 16 51-54 (2003) [2]



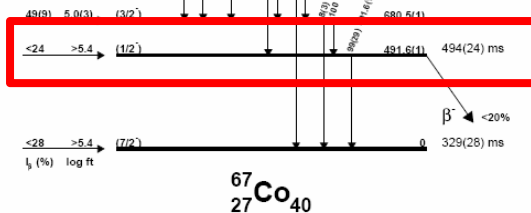
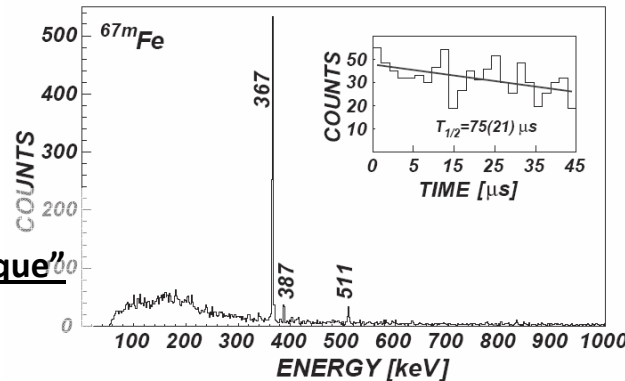
β^- -decay study of ^{67}Fe at LISOL (2007)
 D. Pauwels et al., These KU Leuven 2008
 (to be published) [1]



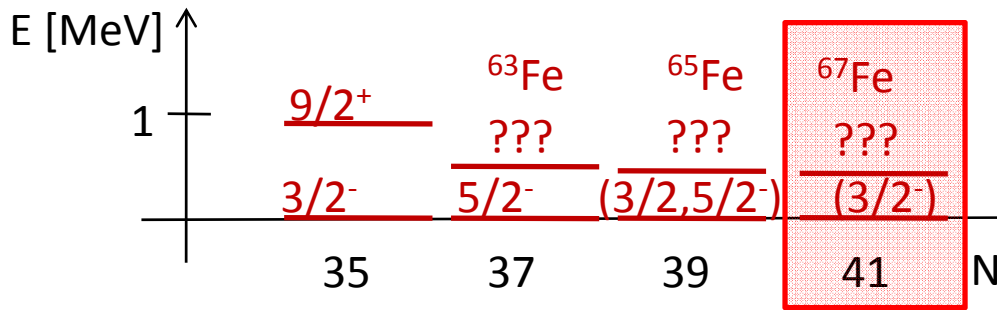
[3] = β^- -decay study of ^{67}Mn at GANIL
 J.M. Daugas et al., AIP Conf Proc 831 p 427
 No spin assignments (!)



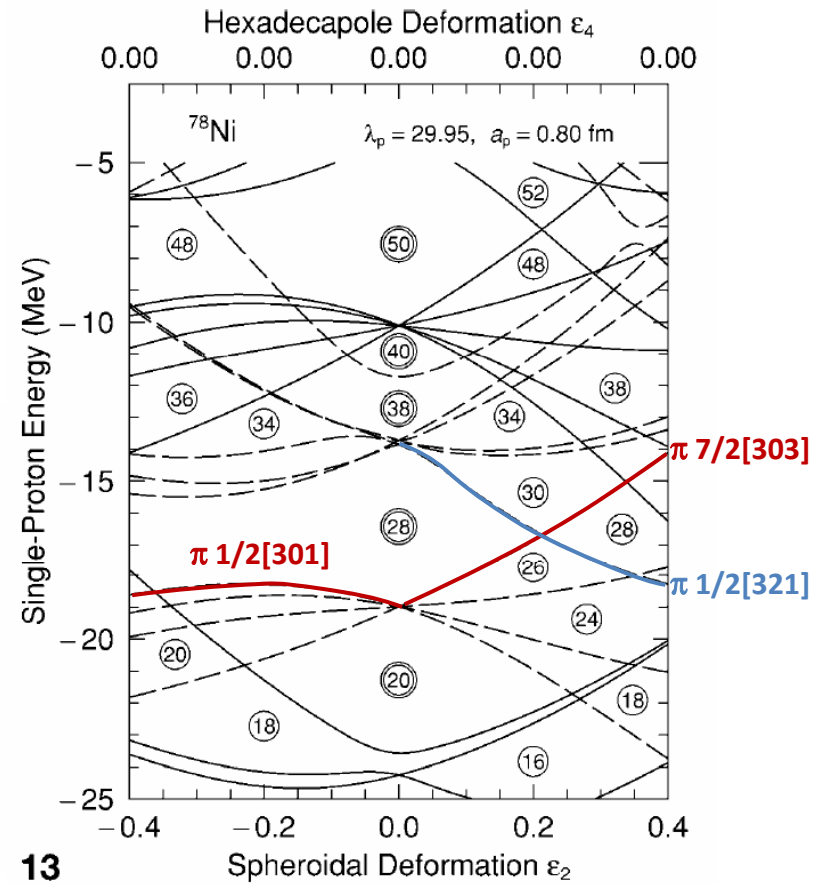
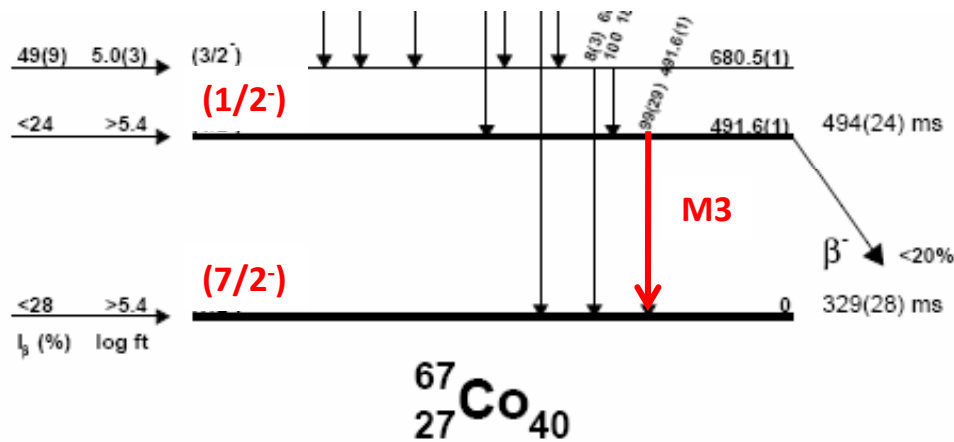
[1] = new isomeric state at 492 keV
 Discovered with the "slow correlation technique"
 D. Pauwels et al. NIMB to be published



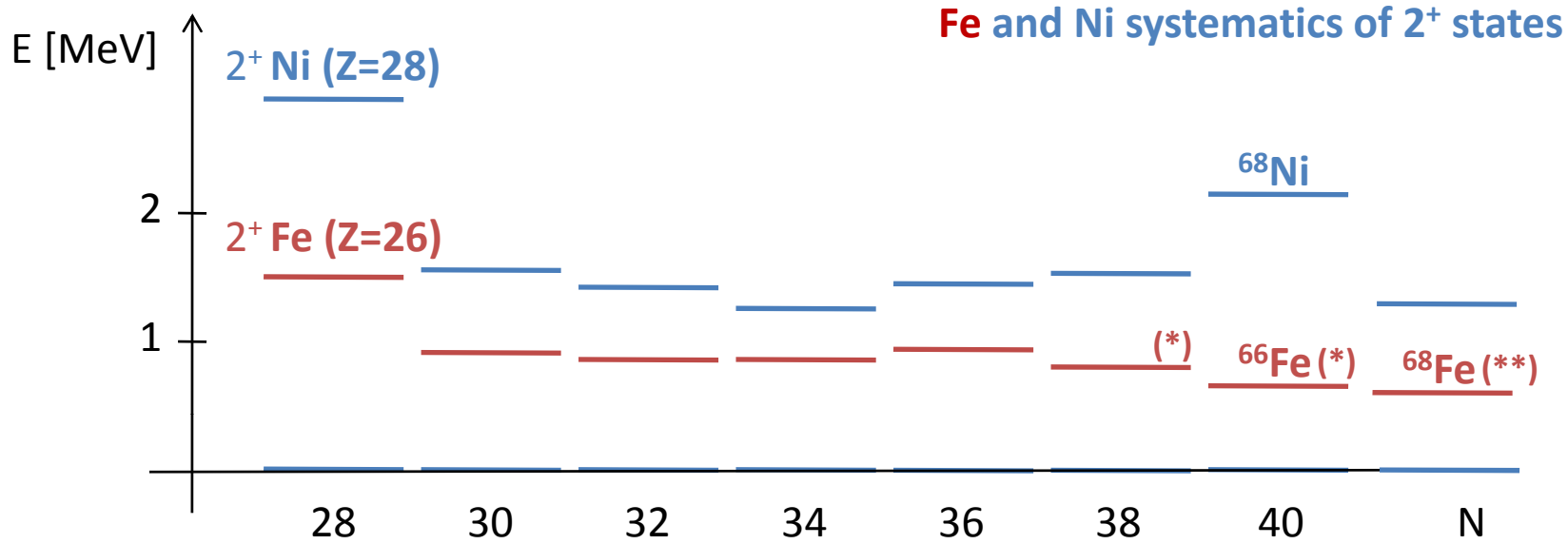
In-flight separation and isomeric decay study at GANIL
 M. Sawicka et al. EPJA 16 51-54 (2003) [2]



Preliminary interpretation, related to shape coexistence and deformation
 D. Pauwels et al., These KU Leuven 2008
 (to be published) [1]



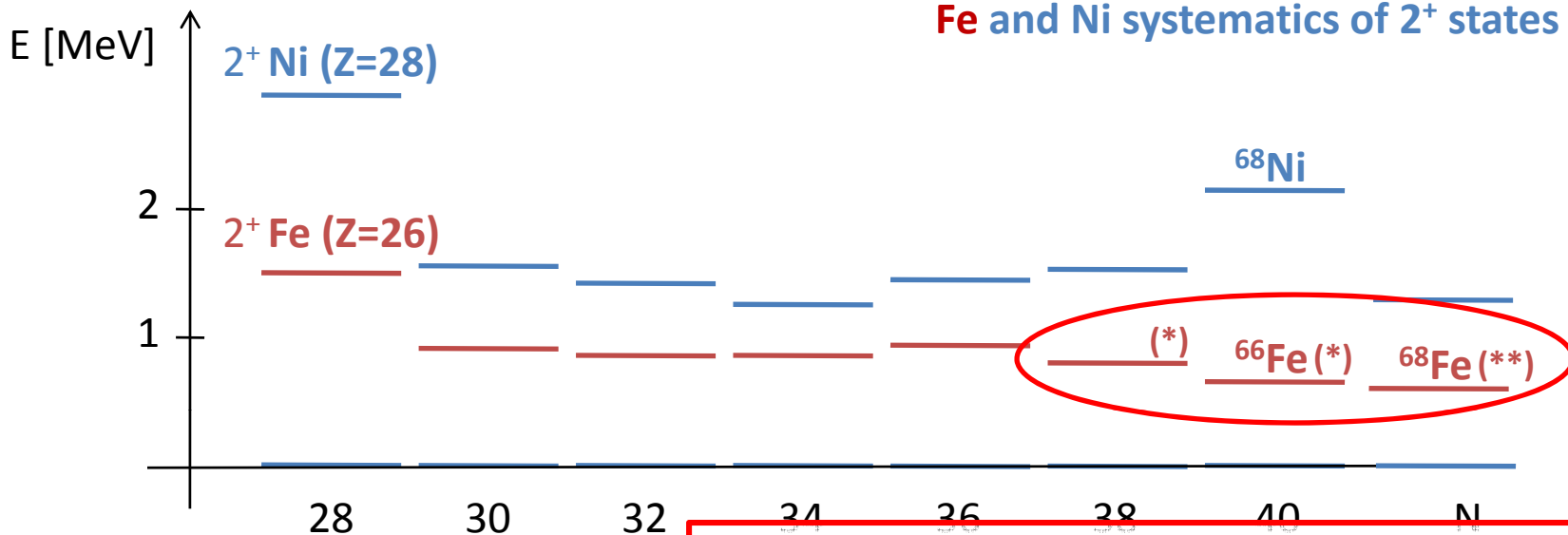
1. General Physics Motivation



(**) β -decay study ⁶⁸Mn at GANIL (2006) ↗
 J.M. Daugas et al., AIP Conf Proc 831 p 427-429
 (*) β -decay study ^{64,66}Mn at ISOLDE (1998) ↖
 Hannawald et al. PRL 82 1391 (1999)

Z=28	Ni 61 1.1399 <small>σ 2.5 $\sigma_{n,\alpha}$ 0.00003</small>	Ni 62 3.6345 <small>σ 15</small>	Ni 63 100 a <small>β^- 0.07 no γ σ 20</small>	Ni 64 0.9256 <small>σ 1.6</small>	Ni 65 2.52 h <small>β^- 2.1... γ 1482; 1115; 366... σ 22</small>	Ni 66 54.6 h <small>β^- 0.2 no γ</small>	Ni 67 21 s <small>β^- 3.8... γ (1937; 1115; 822...)</small>	Ni 68 29 s <small>β^- γ 758; 84 g</small>	Ni 69 11.4 s <small>β^- γ 1871; 690; 1213; 1483...</small>	Ni 70 6.0 s <small>β^- 3.3... m_2 γ 1036; 79...</small>	Ni 71 2.56 s <small>β^- γ 534; 2016</small>	Ni 72 1.57 s <small>β^- γ 378; 94</small>	
	Co 60 10.5 m <small>β^- 5.272 a γ 59 e^- 3.5... β^- γ 1332; γ (1332; 1173)</small>	Co 61 1.65 h <small>β^- 1.2...</small>	Co 62 14.0 m <small>β^- 2.8... γ 1173; γ 1173; 1163; 2302</small>	Co 63 1.5 m <small>β^- 3.6...</small>	Co 64 27.5 s <small>β^- 7.0...</small>	Co 65 0.3 s <small>β^- 6.0... γ 1142; 311;</small>	Co 66 1.14 s <small>β^- 7.2; 8.5... γ 1426; 1246;</small>	Co 67 0.18 s <small>β^- 8.0...</small>	Co 68 425 ms <small>β^- γ 2033; 476; β^- γ 2033;</small>	Co 69 227 ms <small>β^- γ 1260; 698; 1858</small>	Co 70 0.50 s <small>β^- γ 1260; 870</small>	Co 71 119 ms <small>β^- γ 566; 774; 253; 281 (β)</small>	Co 72 79 ms <small>β^- γ 378; 94</small>
Z=26	Fe 59 44,503 d <small>β^- 0.5; 1.6... γ 1099; 1292... σ 13</small>	Fe 60 1.5 · 10 ⁶ a <small>β^- 0.1 m</small>	Fe 61 6.0 m <small>β^- 2.6; 2.8... γ 1205; 1027; 298</small>	Fe 62 68 s <small>β^- 2.5 g</small>	Fe 63 6.1 s <small>β^- 6.7... γ 995; 1427; 1296... γ 311</small>	Fe 64 2.0 s <small>β^- γ 311</small>	Fe 65 0.45 s <small>β^- γ 311</small>	Fe 66 0.44 s <small>β^- γ 311</small>	Fe 67 0.47 s <small>β^- γ 311</small>	Fe 68 0.1 s <small>β^- γ 311</small>	Fe 69 0.17 s <small>β^- γ 311</small>	Fe 70 94 ms <small>β^- γ 311</small>	
	Mn 58 65.3 s <small>β^- 3.9... γ 811; β^- 6.1... 152... γ 1447; 172; e^- 3433...</small>	Mn 59 3.0 s <small>β^- 4.4; 4.8... γ 720; 473; 571...</small>	Mn 60 0.28 s <small>β^- 5.7... γ 625; β^- 8.2... 169... γ 803; 1150; 1932</small>	Mn 61 0.71 s <small>β^- 6.4... γ 629; 207...</small>	Mn 62 92 ms <small>β^- 6.7... γ 877; 942; 1099... γ 356</small>	Mn 63 0.25 s <small>β^- γ 356</small>	Mn 64 8.8 ms <small>β^- γ 746...</small>	Mn 65 92 ms <small>β^- γ 366</small>	Mn 66 64.4 ms <small>β^- γ 573...</small>	Mn 67 45 ms <small>β^- β n</small>	Mn 68 2.9 ms <small>β^- β n</small>	Mn 69 14 ms <small>β^- β n</small>	
Z=24	Cr 57 21.1 s <small>β^- 5.1... γ 83; 850; 1752; 1535...</small>	Cr 58 7.0 s <small>β^- γ 883; 126; 290; 520... m</small>	Cr 59 1.05 s <small>β^- γ 1238; 1900; 112; 663...</small>	Cr 60 0.49 s <small>β^- 6.7... γ 349; 410; 758</small>	Cr 61 0.27 s <small>β^- γ 285; 355; 640... m</small>	Cr 62 209 ms <small>β^- γ 250 - 3454</small>	Cr 63 129 ms <small>β^- γ 188</small>	Cr 64 43 ms <small>β^- γ 272; 1368 β n ?</small>	Cr 65 27 ms <small>β^- γ 272; 1368 β n ?</small>	Cr 66 10 ms <small>β^- γ 272; 1368 β n ?</small>	Cr 67 >300 ns <small>β^- ?</small>	Cr 68 <small>2.60E-7 3.51E-6</small>	
	35						40					43	

1. General Physics Motivation



ONSET TO DEFORMATION IN NEUTRON RICH Fe ISOTOPES (N>36)

Hannawald et al. PRL 82 1391 (1999)

Z=28

26

24

Ni 61 1.139		Co 60		Co 61		Co 62		Co 63		Co 64		Co 65		Co 66		Co 67		Co 68		Co 69		Co 70		Co 71	
σ 2.5	σ _{n, n} 0.00003	σ 15	no γ	σ 20	σ 1.6	σ 22	β ⁻ 0.2	γ (1937, 1115, 822...)	γ 758; 84	γ 1871; 680; 1213, 1483...	γ 1036; 78...	β ⁻ γ 534; 2016	β ⁻ γ 376; 94												
10.5 m	5.272 a	1.65 h	14.0 m	1.5 m	27.5 s	0.3 s	1.14 s	0.18 s	425 ms	1.6 s	0.23 s	227 ms	0.50 s	119 ms	79 ms										
β ⁻ 3.9...	β ⁻ 6.1...	β ⁻ 4.4; 4.8...	β ⁻ 2.8...	β ⁻ 2.5...	β ⁻ 6.7...	β ⁻ 7.0...	β ⁻ 6.0...	β ⁻ 7.2; 8.5...	β ⁻ 8.0...	β ⁻ 1260; 698; 1368	β ⁻ 1260; 698; 1368	β ⁻ 566; 774; 253; 281													
γ 811; 1523...	γ 1447; 2433...	γ 720; 473; 571...	γ 625; 803; 1150; 1532...	γ 629; 207...	γ 87; 982	γ 1346; 931	γ 1142; 311	γ 426; 1246; 1405	γ 694	γ 476; 1260; 2744...	γ 594														
β ⁻ 3.9...	β ⁻ 6.1...	β ⁻ 4.4; 4.8...	β ⁻ 2.8...	β ⁻ 2.5...	β ⁻ 6.7...	β ⁻ 7.0...	β ⁻ 6.0...	β ⁻ 7.2; 8.5...	β ⁻ 8.0...	β ⁻ 1260; 698; 1368	β ⁻ 1260; 698; 1368	β ⁻ 566; 774; 253; 281													
65.3 s	3.0 s	4.6 s	1.77 s	0.28 s	92 ms	625 ms	0.25 s	8.8 ms	92 ms	64.4 ms	45 ms	2.9 ms	14 ms												
β ⁻ 5.1...	β ⁻ 6.1...	β ⁻ 4.4; 4.8...	β ⁻ 2.8...	β ⁻ 2.5...	β ⁻ 6.7...	β ⁻ 7.0...	β ⁻ 6.0...	β ⁻ 7.2; 8.5...	β ⁻ 8.0...	β ⁻ 1260; 698; 1368	β ⁻ 1260; 698; 1368	β ⁻ 566; 774; 253; 281													
γ 83; 850; 1752; 1535...	γ 883; 126; 290; 520...	γ 720; 473; 571...	γ 1238; 1900; 112; 663...	γ 349; 410; 758	γ 87; 982	γ 1346; 931	γ 1142; 311	γ 426; 1246; 1405	γ 694	γ 476; 1260; 2744...	γ 594														
Cr 57	Cr 58	Cr 59	Cr 60	Cr 61	Cr 62	Cr 63	Cr 64	Cr 65	Cr 66	Cr 67															
21.1 s	7.0 s	1.05 s	0.49 s	0.27 s	209 ms	129 ms	43 ms	27 ms	10 ms	>300 ns															
β ⁻ 5.1...	β ⁻ 6.1...	β ⁻ 4.4; 4.8...	β ⁻ 2.8...	β ⁻ 2.5...	β ⁻ 6.7...	β ⁻ 7.0...	β ⁻ 6.0...	β ⁻ 7.2; 8.5...	β ⁻ 8.0...	β ⁻ 1260; 698; 1368															
γ 83; 850; 1752; 1535...	γ 883; 126; 290; 520...	γ 720; 473; 571...	γ 1238; 1900; 112; 663...	γ 349; 410; 758	γ 87; 982	γ 1346; 931	γ 1142; 311	γ 426; 1246; 1405	γ 694	γ 476; 1260; 2744...															

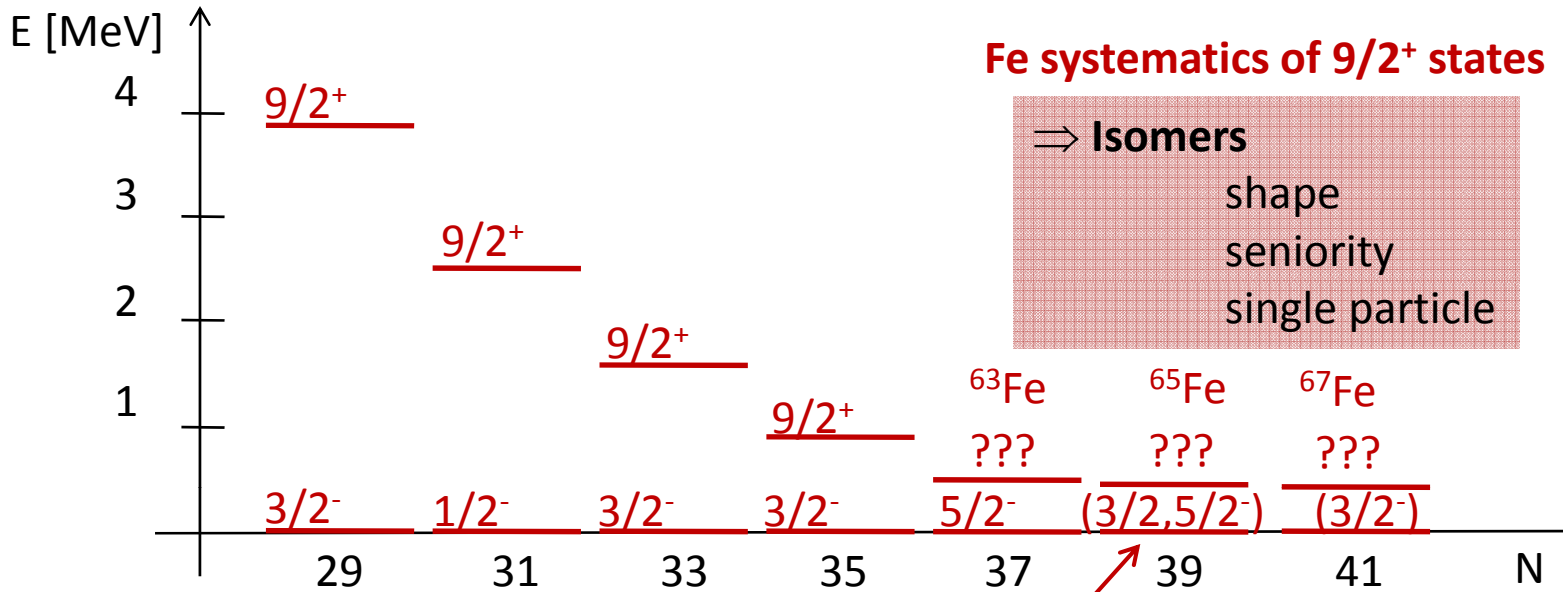
- (**) β-decay study ⁶⁸Mn at GANIL (2006) → J.M. Daugas et al., AIP Conf Proc 831 p 427-429
- (*) β-decay study ^{64,66}Mn at ISOLDE (1998) → Hannawald et al. PRL 82 1391 (1999) →

35

40

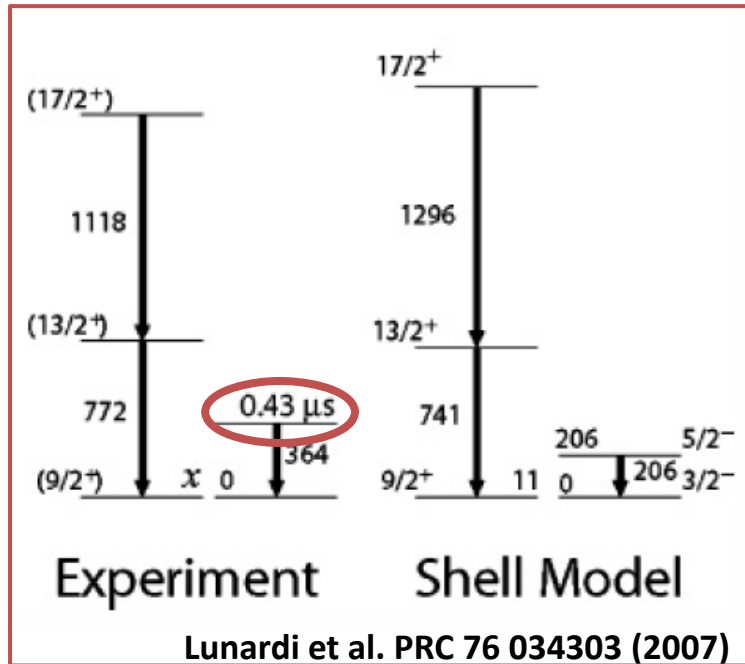
43

1. General Physics Motivation



Fe systematics of $9/2^+$ states

⇒ **Isomers**
 shape
 seniority
 single particle

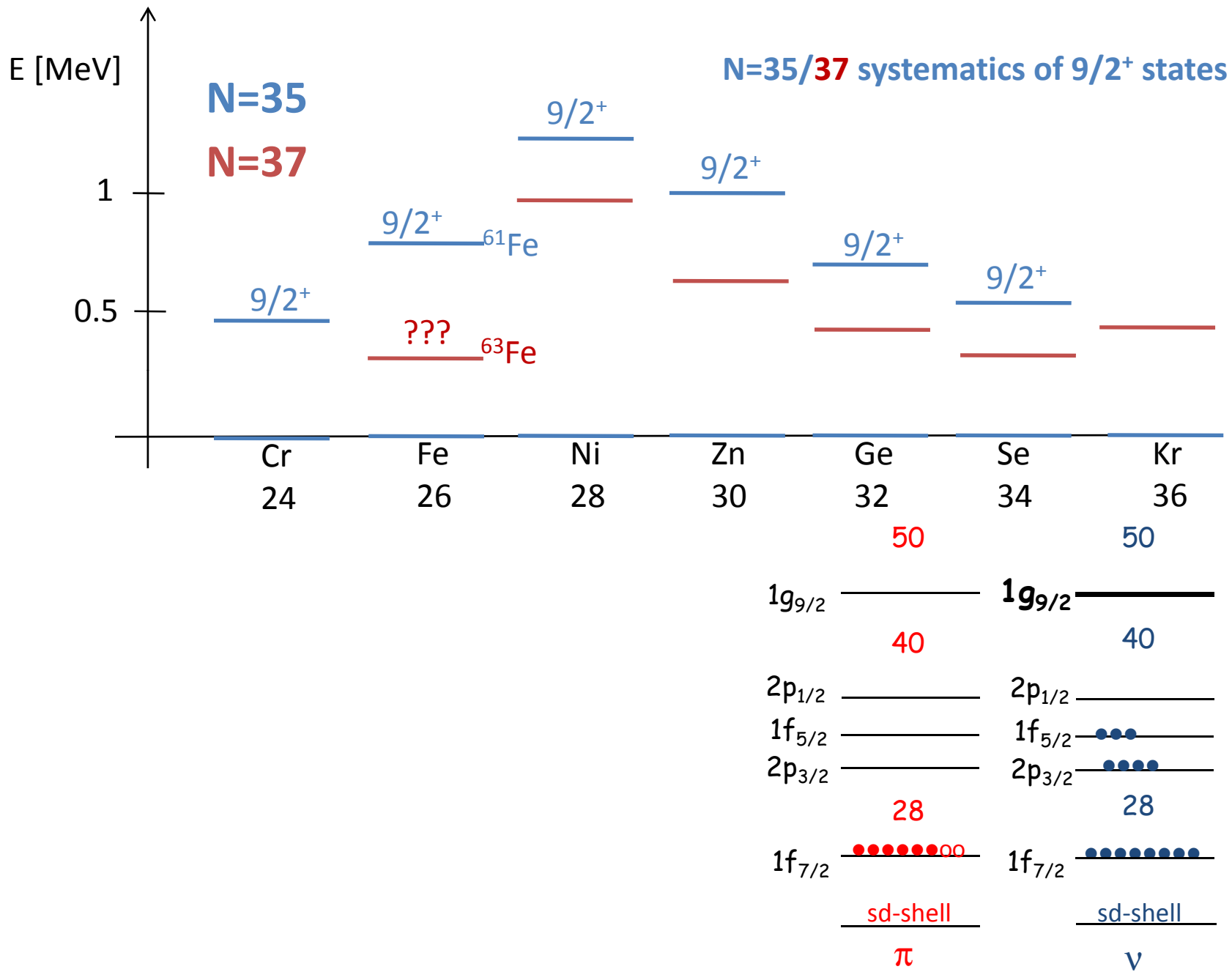


+ MSU mass measurements :
 isomer around 400 keV
 Block *et al.* (MSU)

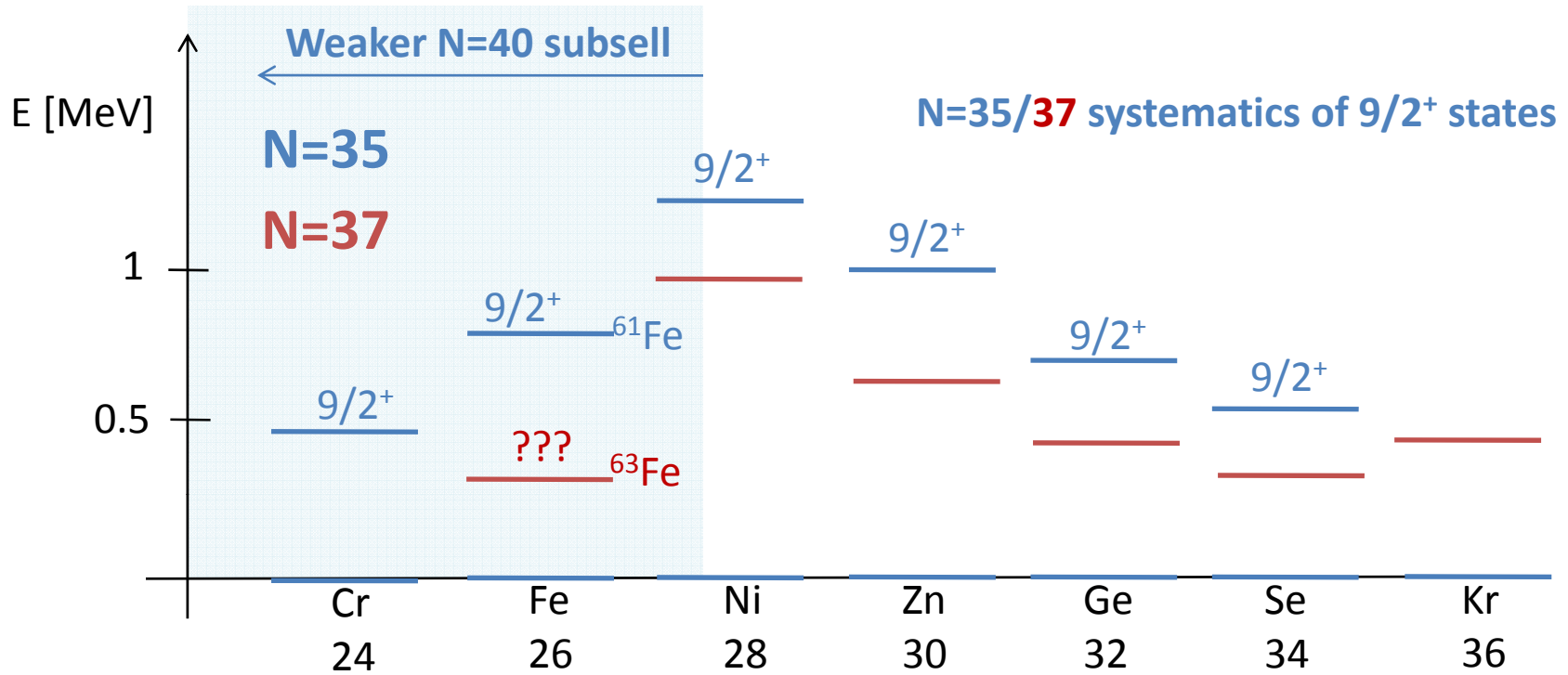
+ LISOL β -decay ^{65}Fe
 Indication for β -decaying isomer
 D. Pauwels *et al.* (KU Leuven)

+ GANIL : 397 keV 420(13) ns

1. General Physics Motivation



1. General Physics Motivation



$9/2^+$ excitation energy drops to low energy region dominated by pf orbitals

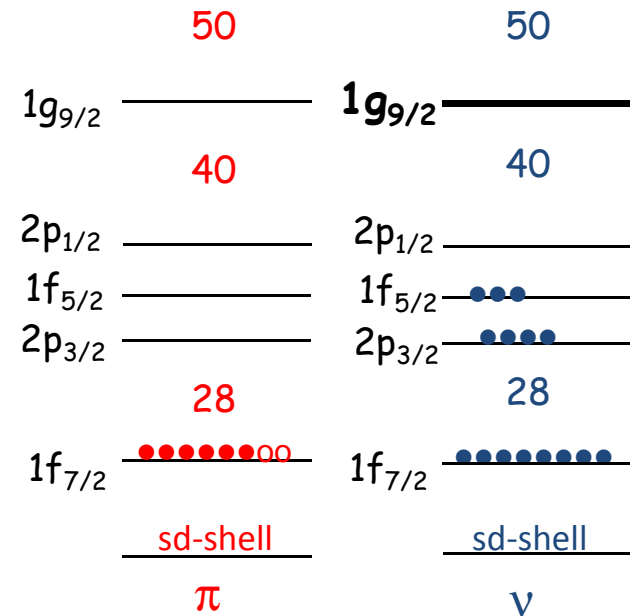
⇒ **Deformation**

⇒ **Shape co-existence**

Ex. High spin study $^{59}\text{Cr}_{35}$

Freeman *et al* PRC **69** 064301 (2004)

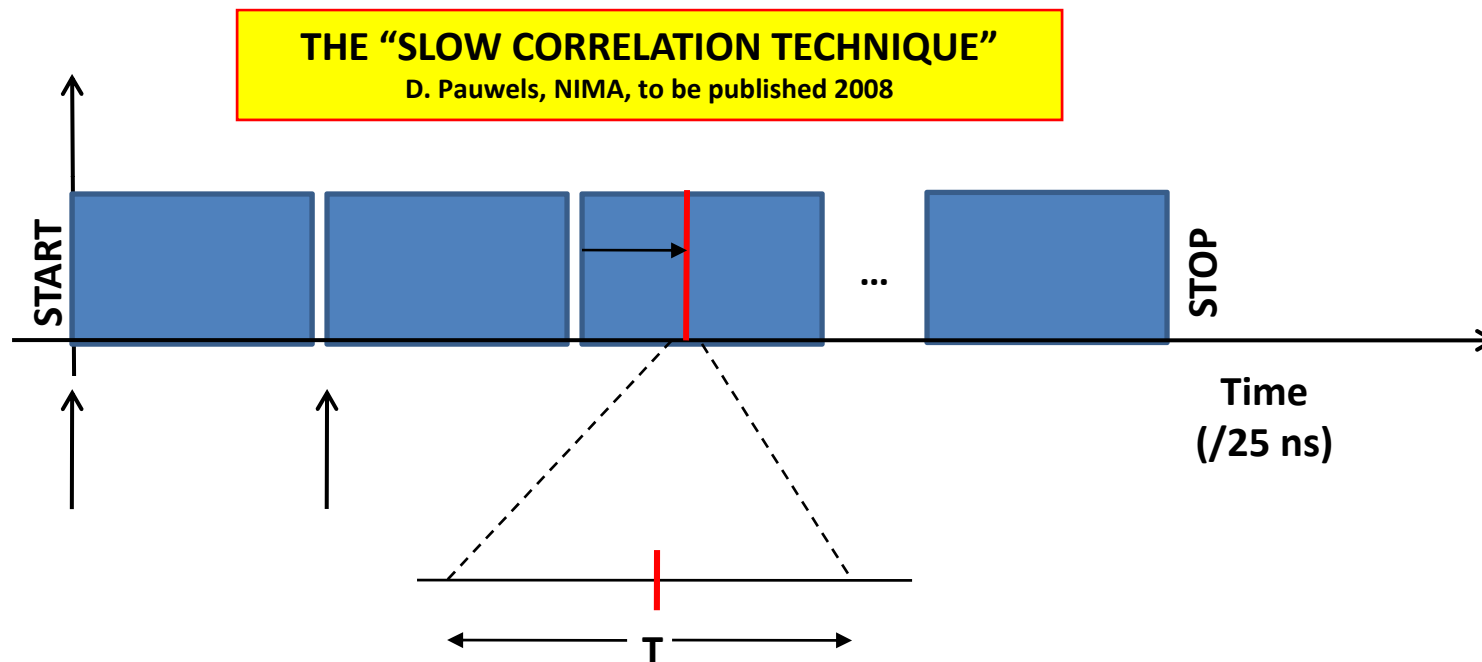
Sorlin *et al* NPA **669** 351-367 (2000)



3. The LISOL β -decay setup

- Single γ -rays and β 's are individually “timestamped”
- Only the energy of the γ -ray is registered
- No hardware conditions are implied on the raw data !

⇒ Coincidences and Correlations (γ - γ , β γ - γ , ...) are performed OFFLINE

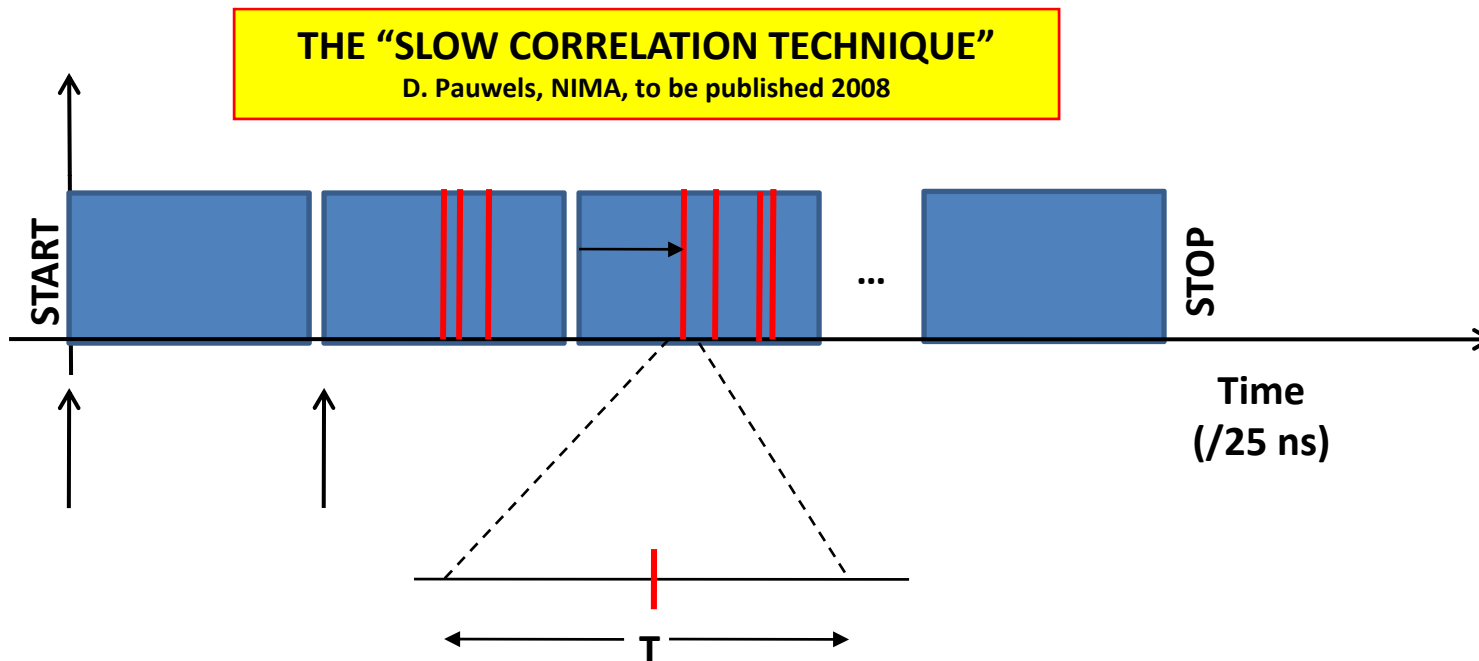


1- **Event type** definition : β - γ / single γ / ... + time window definition (T)

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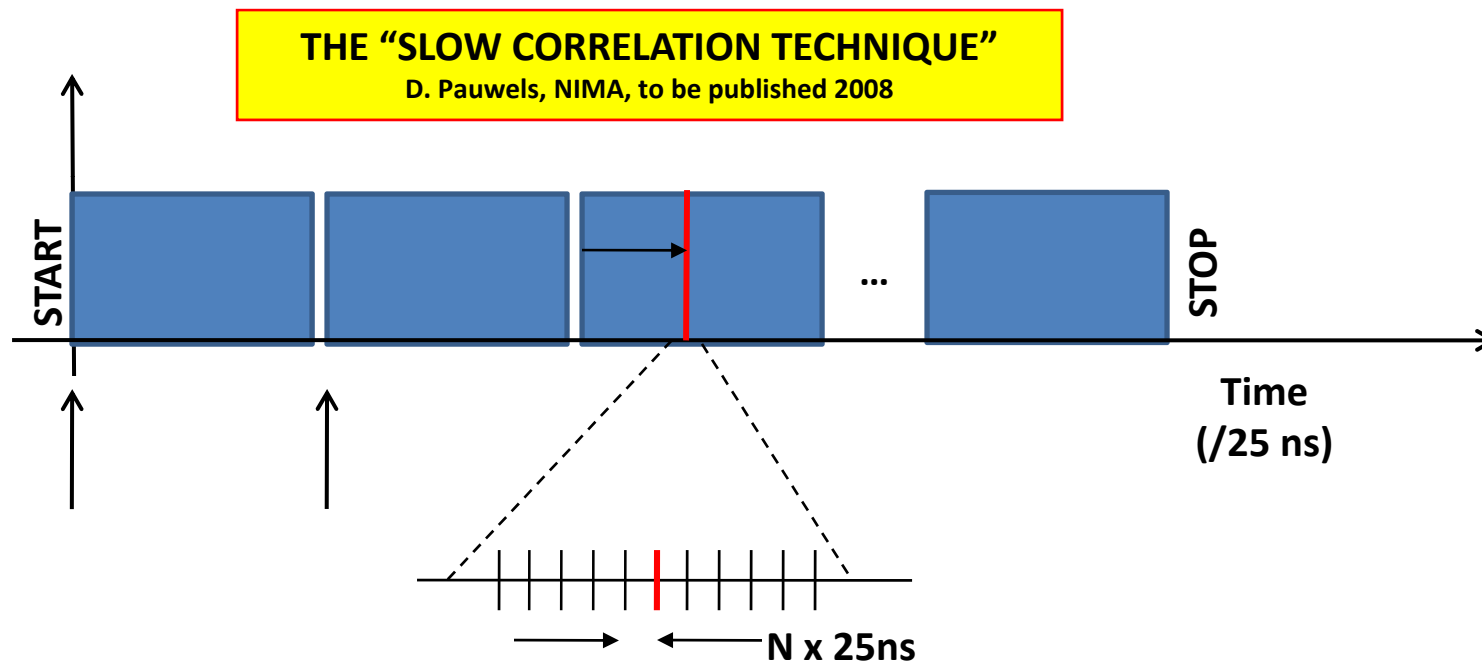
1- **Event type** definition : β - γ / single γ / ... + time window definition (T)

(scan over full data set for these event types)

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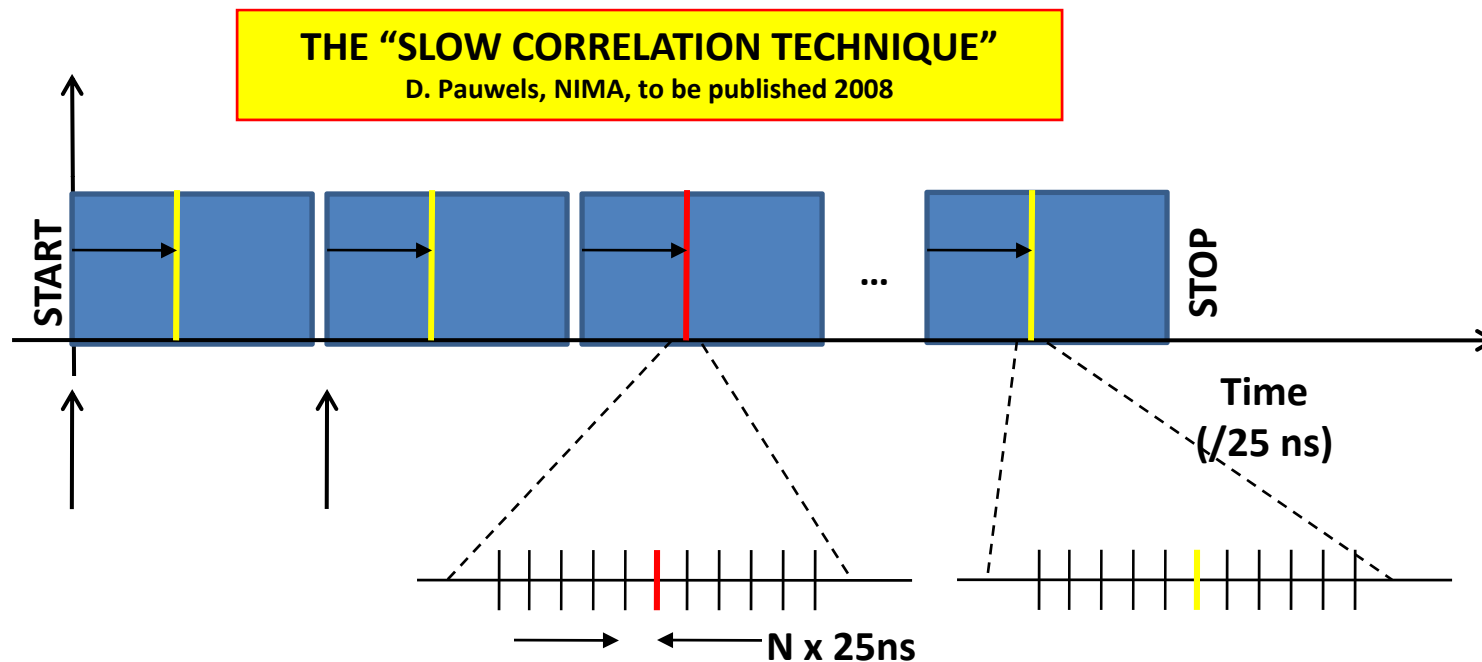


- 1- **Event type** definition : β - γ / single γ / ... + time window definition (T)
- 2- Single γ -ray histograms in time slices ($N \times 25\text{ns}$) before and after the detected "**event type**" = *CORRELATED HISTOGRAMS*

3. The LISOL β -decay setup

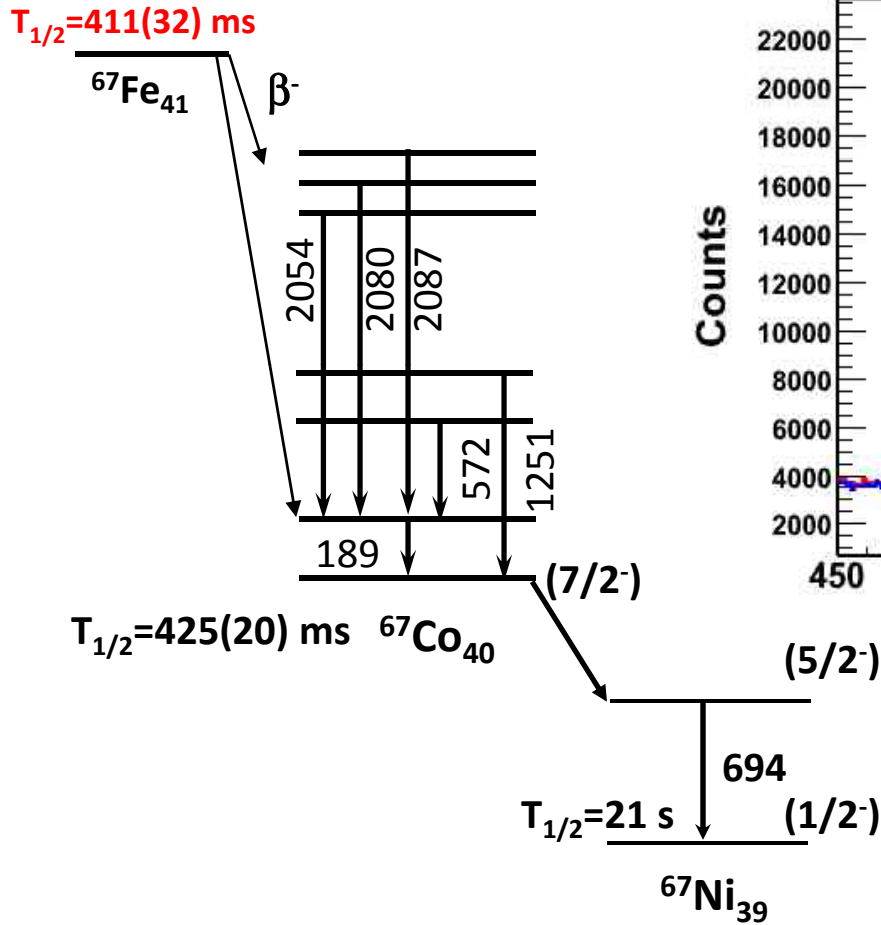
- Single γ -rays and β 's are individually “timestamped”
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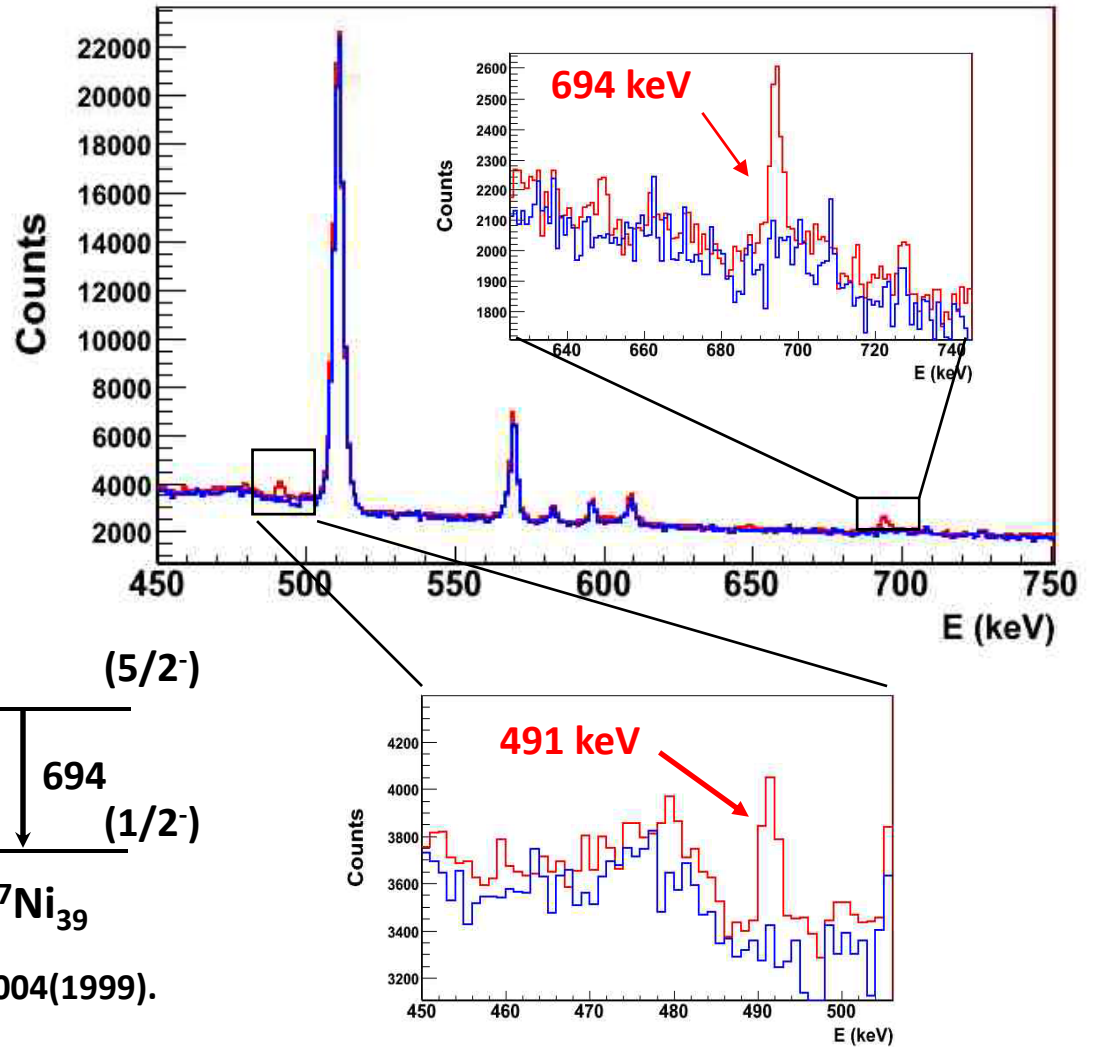
- 1- **Event type** definition : β - γ / single γ / ...
- 2- Single γ -ray histograms in time slices ($N \times 25\text{ns}$) before and after **the detected “event type” = CORRELATED HISTOGRAMS**
- 3- Single γ -ray histograms in the same time windows relative to the start of each cycle = **RANDOMLY CORRELATED HISTOGRAMS**

3. The LISOL β -decay setup



L. Weissman et al., PRC 59, 2004(1999).

Singles γ -spectra : Red: Laser ON Blue: Laser OFF



4. Contamination and Yields

2. Conditions for applicability :

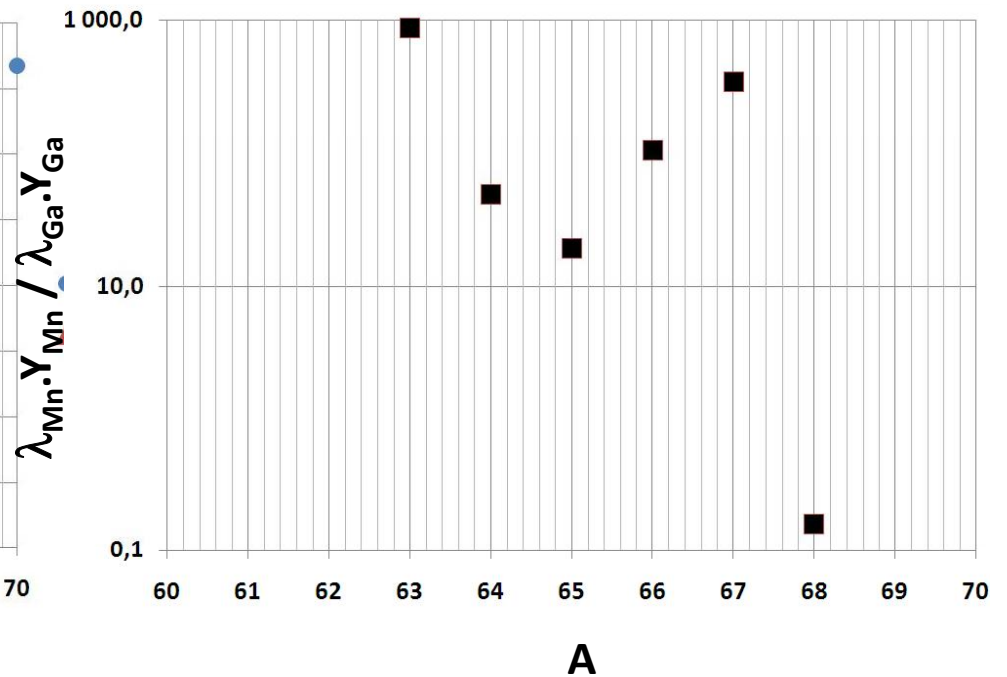
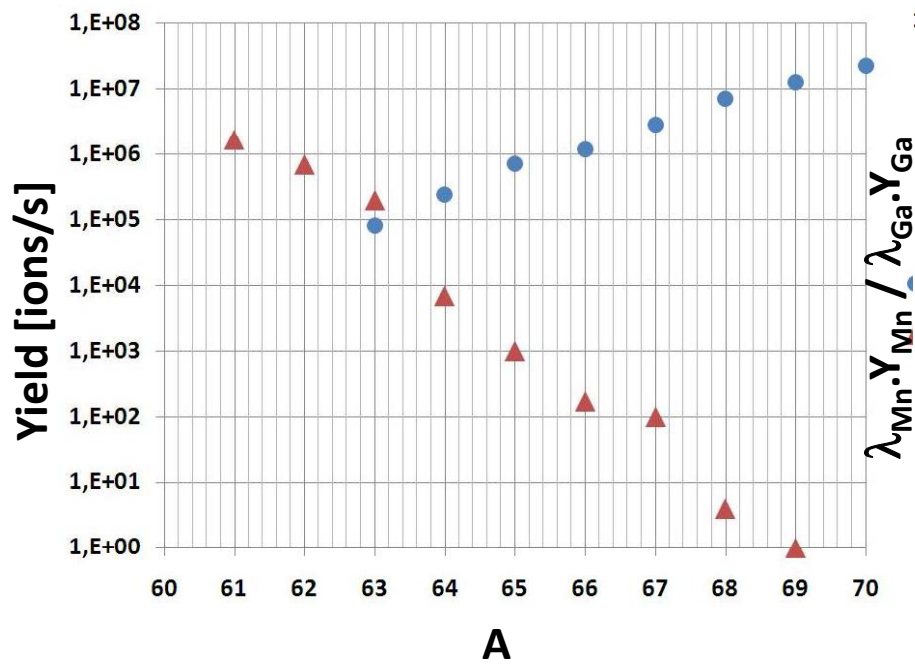
? pure sources of radioactive ions

✓ element selectivity

✓ low background

✓ efficient detection system

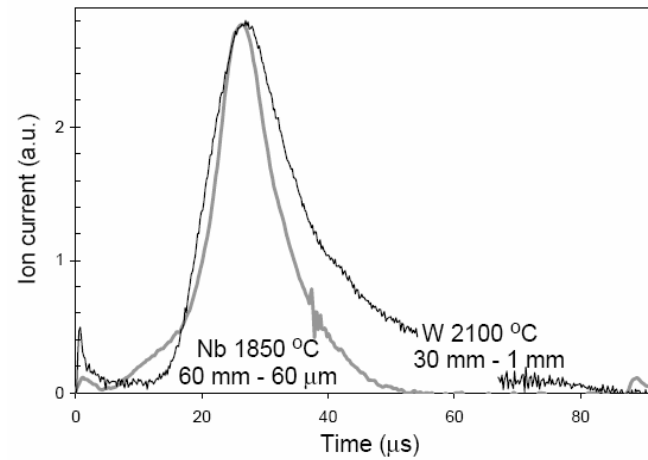
? low count rate



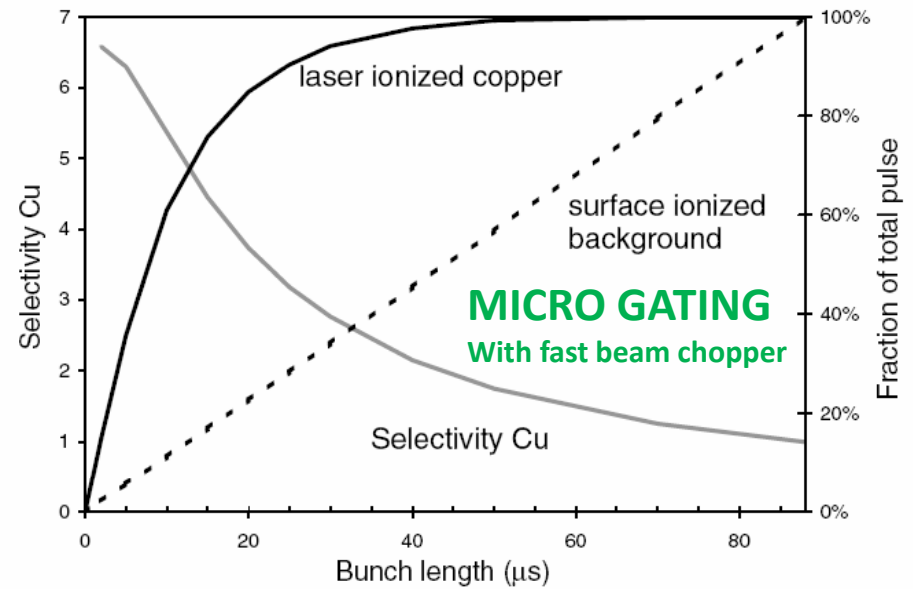
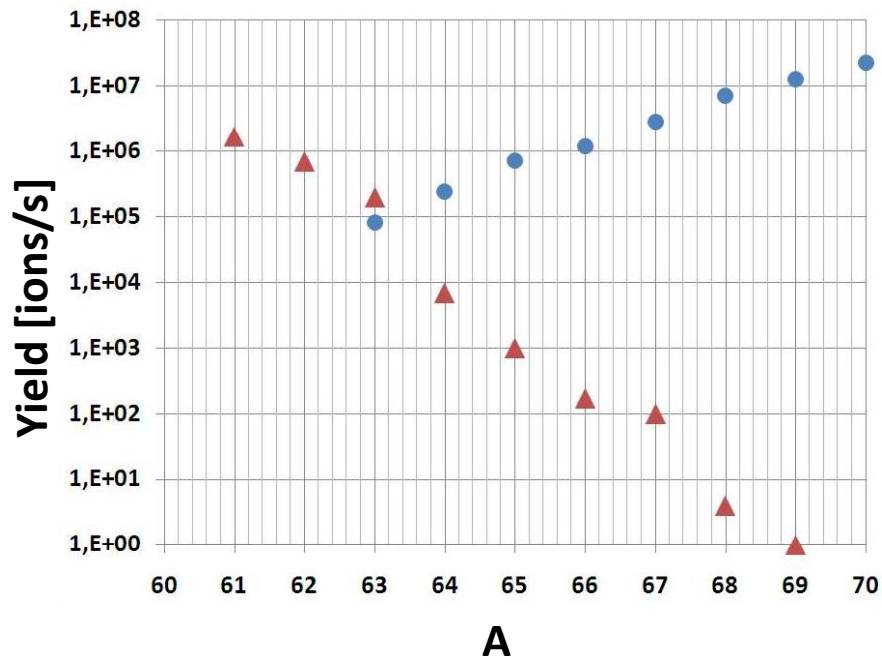
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2. Conditions for applicability :

- ? pure sources of radioactive ions
- ✓ element selectivity
- ✓ low background
- ✓ efficient detection system
- ? low count rate



Pictures taken from U. Koester, These 1999, TU Munchen
Method is exemplified for ^{67}Co isotopes



2. Previous experiment (1998) and Proposed experiment (2008)

1998 : β -decay study at ISOLDE of $^{64,66}\text{Mn}$

M. Hannawald, PhD dissertation Mainz universitat 1999

- Only Single γ 's in time slices of 150 ms after proton impact
- No β -gated γ -ray spectra
- Two coaxial Germanium detectors
- Only γ 's from $^{64,66}\text{Mn}$ were measured (experiment was an "extended target test")

