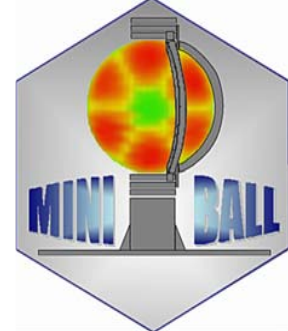


Coulomb excitation of n-rich $N=40$ and $N=50$ nuclei with REX-ISOLDE and Miniball



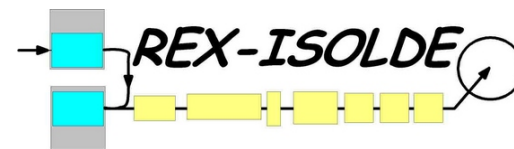
I. Stefanescu, P. Van Duppen, M. Huyse, O. Ivanov, J. Van de Walle

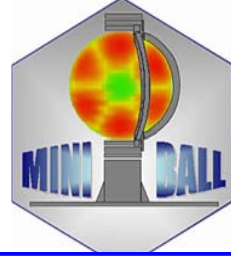
IKS, KU Leuven, Belgium

G. Georgiev

CSNSM Orsay, France

Miniball and REX-ISOLDE collaboration



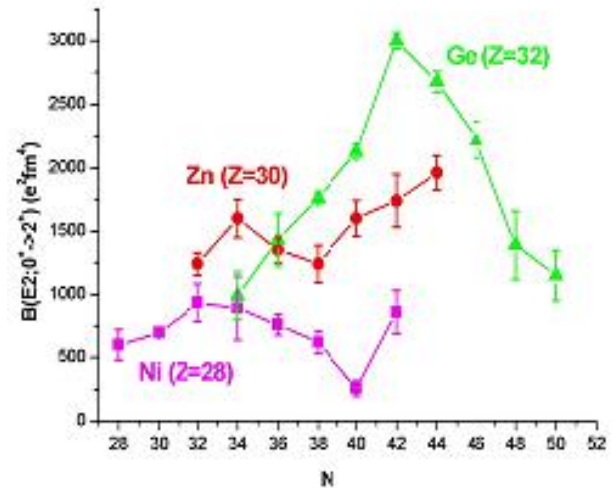
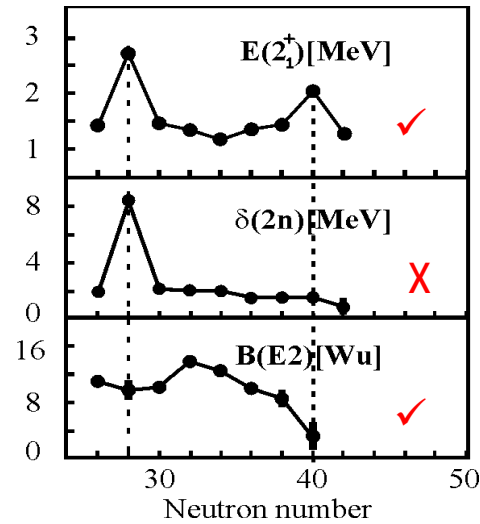


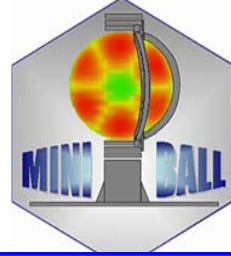
Nuclear structure around N=40

32
30
28

Ge70 0+ 21.23	Ge71 11.43 d 1/2- *	Ge72 0+ 27.66	Ge73 9/2+ *	Ge74 0+ 35.94	Ge75 82.78 m 1/2-	Ge76 0+ 7.44	Ge77 11.30 h 7/2+ *	Ge78 88.0 m 0+	Ge79 18.98 s (1/2)- *	Ge80 29.5 s 0+	Ge81 7.6 s (9/2+)	Ge82 4.60 s 0+	Ge83 1.85 s (5/2+)
Ga69 3/2- 60.108	Ga70 21.14 m 1+	Ga71 3/2- 39.892	Ga72 14.10 h 3-	Ga73 4.86 h 3/2-	Ga74 8.12 m (3-)	Ga75 126 s 3/2-	Ga76 32.6 s (2+,3+)	Ga77 13.2 s (3/2-)	Ga78 5.09 s (3+)	Ga79 2.847 s (3/2-)	Ga80 1.697 s (3)	Ga81 1.217 s (5/2-)	Ga82 0.599 s (1,2,3)
Zn68 0+ 18.8	Zn69 56.4 m 1/2-	Zn70 58+14 y 0+	Zn71 2.45 m 1/2-	Zn72 46.5 h 0+	Zn73 23.5 s (1/2-)	Zn74 95.6 s 0+	Zn75 10.2 s (7/2+)	Zn76 5.7 s 0+	Zn77 2.08 s (7/2+)	Zn78 1.47 s 0+	Zn79 995 ms (9/2+)	Zn80 0.545 s 0+	Zn81 0.29 s 0+
Cu66 61.83 h 3/2-	Cu68 31.1 s 1+	Cu69 2.85 m 3/2-	Cu70 4.5 s (1+)	Cu71 19.5 s (3/2-)	Cu72 6.6 s (1+)	Cu73 3.9 s 0+	Cu74 1.594 s (1+,3+)	Cu75 1.224 s 0+	Cu76 0.641 s 0+	Cu77 469 ms 0+	Cu78 342 ms 0+	Cu79 188 ms 0+	Cu80 0+
Ni66 54.6 h 0+	Ni67 21 s (1/2-)	Ni68 19 s 0+	Ni69 11.4 s 0+	Ni70 0+ 44	Ni71 1.86 s 0+	Ni72 2.1 s 0+	Ni73 0.90 s 0+	Ni74 1.1 s 0+	Ni75 0+	Ni76 0+	Ni77 0+	Ni78 0+	
Co65 1.20 s (7/2-)	Co66 0.23 s (3+)	Co67 0.22 s (7/2-)	Co68 0.18 s 0+	Co69 27 s 0+	Co70 0+	Co71 0+	Co72 0+						
Fe64 2.0 s 0+	Fe65 0.4 s 0+	Fe66 0+ 44	Fe67 0+	Fe68 0.10 s 0+	Fe69 0+								

Coulomb excitation with RIB@REX-ISOLDE





Nuclear structure towards N=50

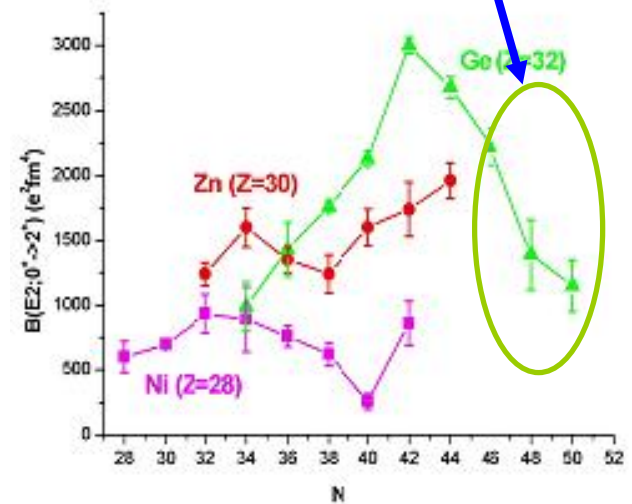
32

30

28

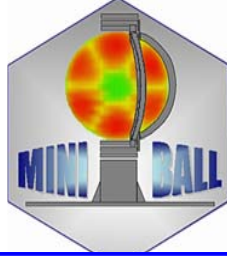
Ge70 0+ 21.23	Ge71 11.43 d 1/2- EC	Ge72 0+ 27.66	Ge73 9/2+ 7.73	Ge74 0+ 35.94	Ge75 82.78 m 1/2- β	Ge76 0+ 7.44	Ge77 71.30 h 7/2+ β	Ge78 88.0 m 0+ β	Ge79 18.98 s (1/2)- β	Ge80 29.5 s 0+ β	Ge81 7.6 s (9/2+) β	Ge82 4.60 s 0+ β	Ge83 1.85 s (5/2+) β
Ga69 3/2- 60.108	Ga70 21.14 m 1+ EC,β	Ga71 3/2- 39.892	Ga72 14.10 h 3- β	Ga73 4.86 h 3/2- β	Ga74 8.12 m (3)- β	Ga75 126 s 3/2- β	Ga76 32.6 s (2+,3+) β	Ga77 13.2 s (3/2)- β	Ga78 5.09 s (3+) β	Ga79 2.347 s (3/2)- β	Ga80 1.697 s (3) β	Ga81 1.217 s (5/2)- β	Ga82 0.599 s (1,2,3) β
Zn68 0+ 18.9	Zn69 56.4 m 1/2- β	Zn70 5E+14 y 0+ β	Zn71 2.45 m 1/2- β	Zn72 46.5 h 0+ β	Zn73 23.5 s (1/2)- β	Zn74 95.6 s 0+ β	Zn75 10.2 s (7/2+) β	Zn76 5.7 s 0+ β	Zn77 2.08 s (7/2+) β	Zn78 1.47 s 0+ β	Zn79 995 ms (9/2+) β	Zn80 0.545 s 0+ β	Zn81 0.29 s β
Cu67 61.83 h 3/2- β	Cu68 31.1 s 1+ β	Cu69 2.85 m 3/2- β	Cu70 4.5 s (1+) β	Cu71 19.5 s (3/2)- β	Cu72 6.6 s (1+) β	Cu73 3.9 s β	Cu74 1.594 s (1+,3+) β	Cu75 1.224 s β	Cu76 0.641 s β	Cu77 469 ms β	Cu78 342 ms β	Cu79 188 ms β	Cu80 β
Ni66 54.6 h 0+ β	Ni67 21 s (1/2)- β	Ni68 19 s 0+ β	Ni69 11.4 s β	Ni70 0+ β	Ni71 1.86 s β	Ni72 2.1 s 0+ β	Ni73 0.59 s β	Ni74 1.1 s 0+ β	Ni75 β	Ni76 0+ β	Ni77 β	Ni78 0+ β	
Co65 1.20 s (7/2)- β	Co66 0.23 s (3+) β	Co67 0.42 s (7/2)- β	Co68 0.18 s β	Co69 0.27 s β	Co70 β	Co71 β	Co72 β						
Fe64 2.0 s 0+ β	Fe65 0.4 s β	Fe66 0+ β	Fe67 β	Fe68 0.10 s 0+ β	Fe69 β								

E. Padilla-Rodal et al., PRL94, 122501(2005)



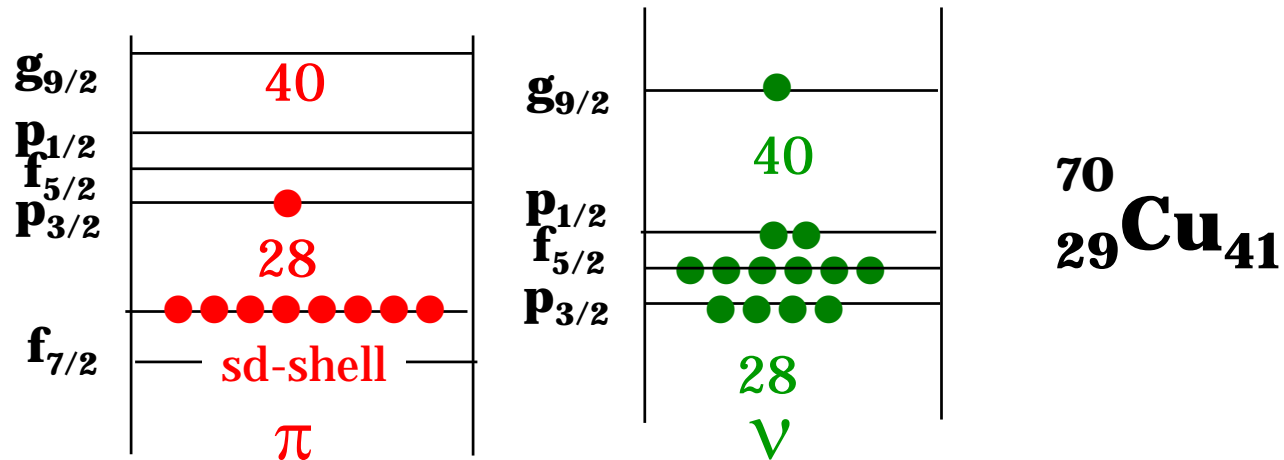
Coulomb excitation of ^{74,76,78}Zn @ REX-ISOLDE





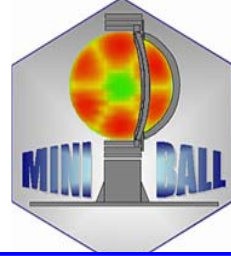
N=40: neutron-rich Cu isotopes

➤ odd-A and odd-odd nuclei around ^{68}Ni → nuclear wave function dominated by single-particle configurations

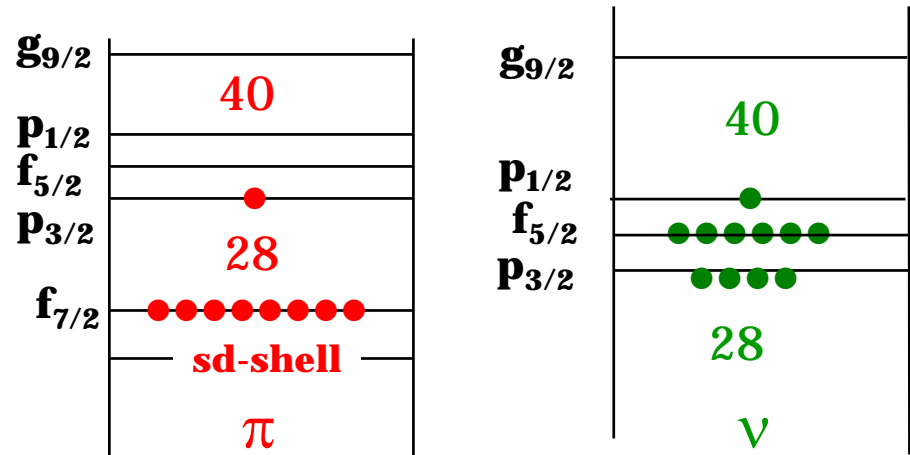


➤ Coulex of $^{67,68,69,70,71}\text{Cu}$: strength of the $N=40$ subshell closure, evolution of collectivity around ^{68}Ni , testing ground for shell model calculations

✓ July 2005: Coulex of $^{68,70}\text{Cu}$



N=40: coulex of $^{68,70}\text{Cu}$ isotopes



$$\pi p_{3/2} \otimes \nu p_{1/2} \quad (J^\pi = 1^+, 2^+)$$

$$\pi p_{3/2} \otimes \nu g_{9/2} \quad (J^\pi = 3^-, 4^-, 5^-, 6^-)$$

(3^-) ————— $0.7 < T_{1/2} < 4 \text{ ns}$
 6^- ————— $T_{1/2} = 3.7 \text{ min}$

(2^+) ————— $T_{1/2} = 7.84 \text{ ns}$
 1^+ ————— $T_{1/2} = 30 \text{ s}$

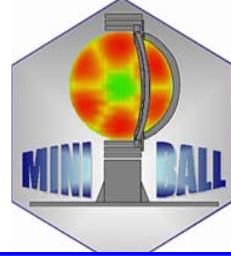
^{68}Cu

2^+ —————
 1^+ ————— $T_{1/2} = 6.6 \text{ s}$
 (3^-) ————— $T_{1/2} = 33 \text{ s}$
 (6^-) ————— $T_{1/2} = 44.5 \text{ s}$

^{70}Cu

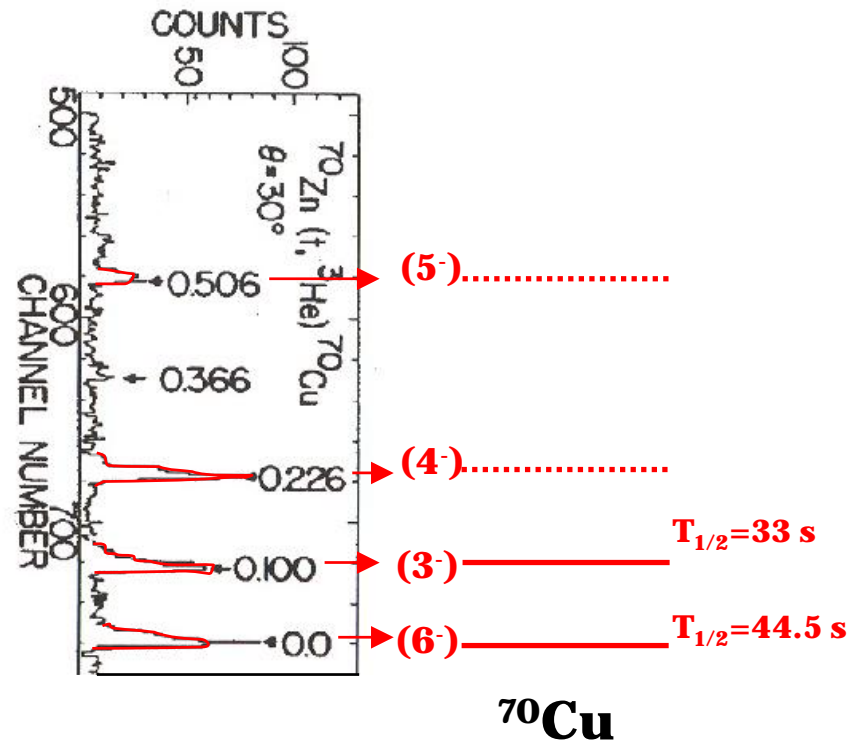
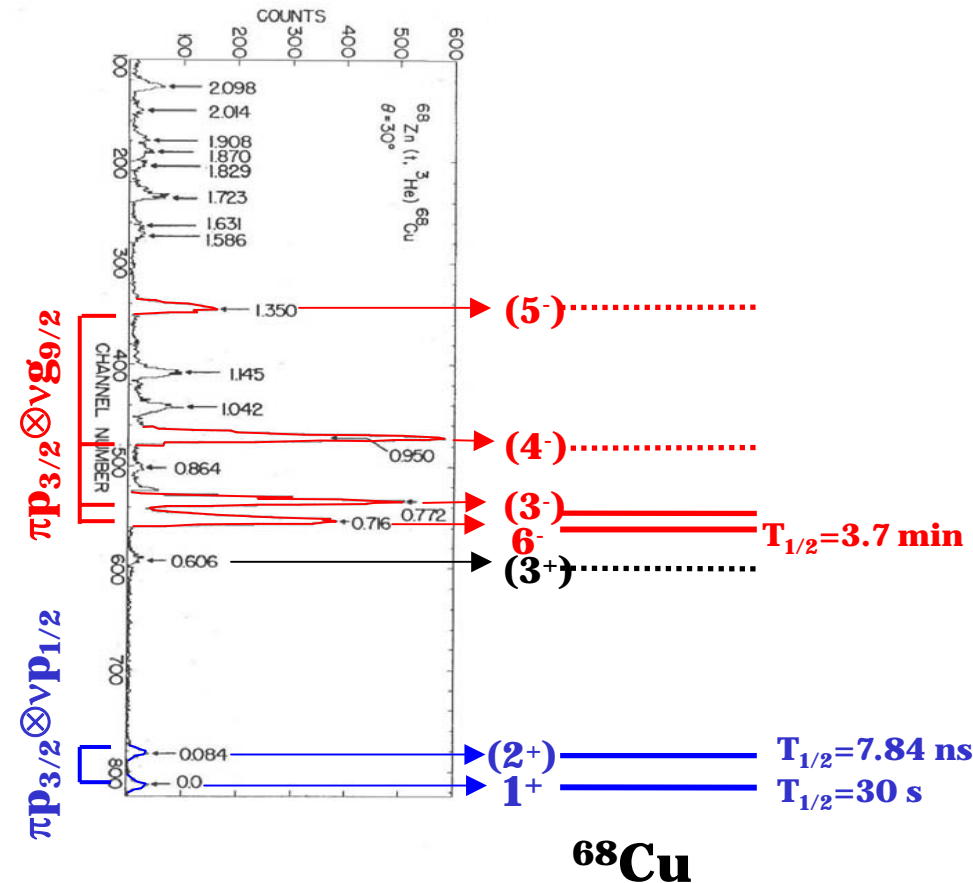
T. E. Ward et al., PR88, 1802(1969)
L. Hou et al., PRC68, 054306(2003)

J. Van Roosbroeck et al., PRL92(2004)112501
J. Van Roosbroeck et al., PRC69(034313).



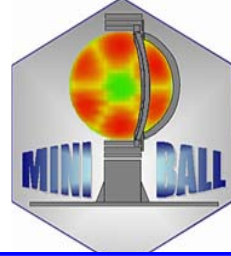
Neutron-rich even-A Cu isotopes

- $^{68,70}\text{Cu}$ -

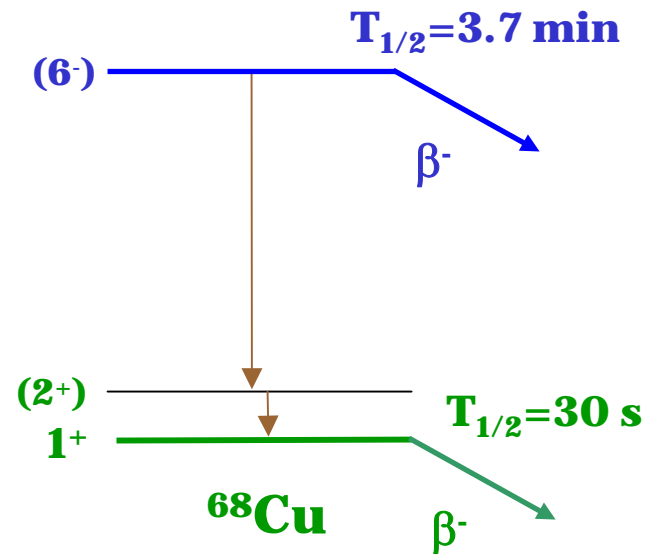
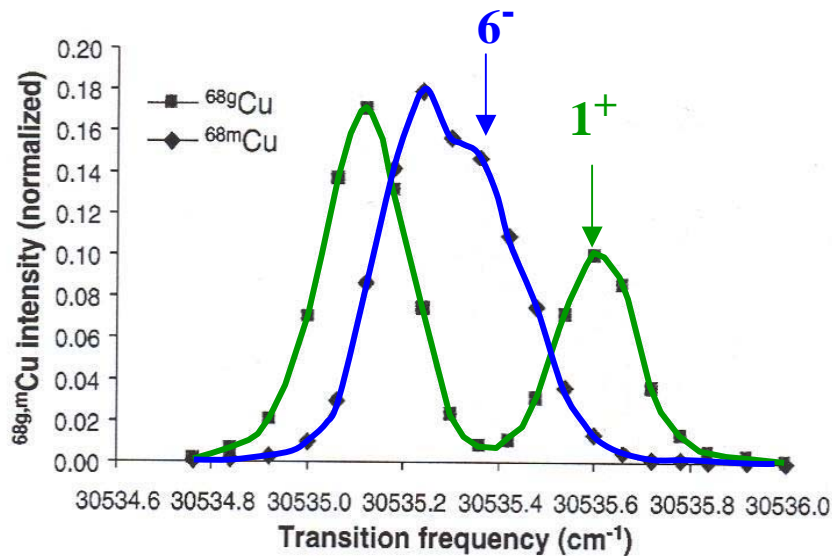
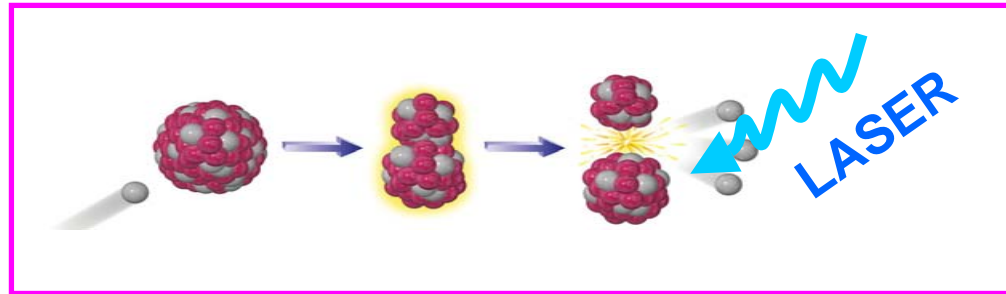


J.D. Sherman *et al.* PLB67 (77) 257
T. Ishii *et al.*, Jaeri-Review, 2002-029, 25

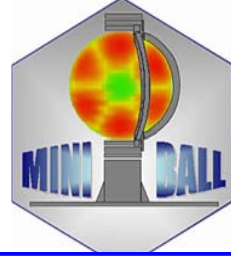
68,70,m,gCu: production of isomeric beams



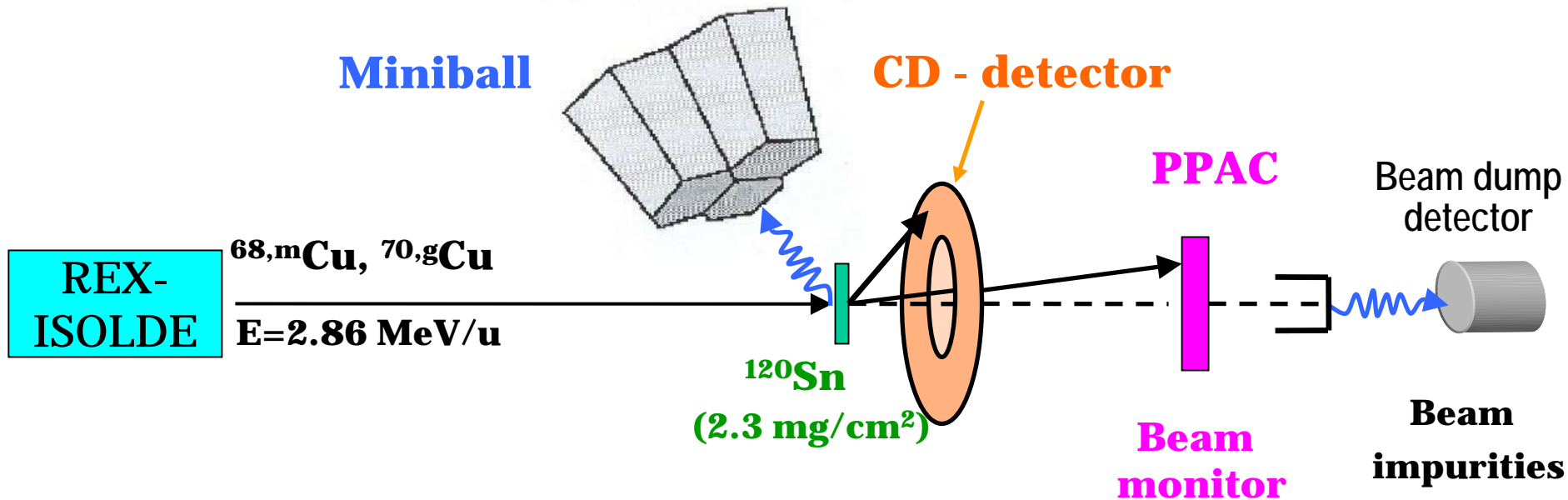
Example: ⁶⁸Cu



U. Koester et al., NIMB167(2000)528
⁷⁰Cu: J. Van Roosbroeck et al., PRL92(2004)112501

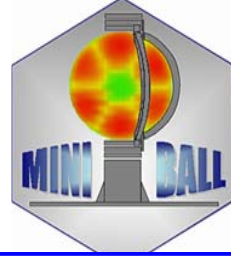


Experimental setup for coulex @ Isolde



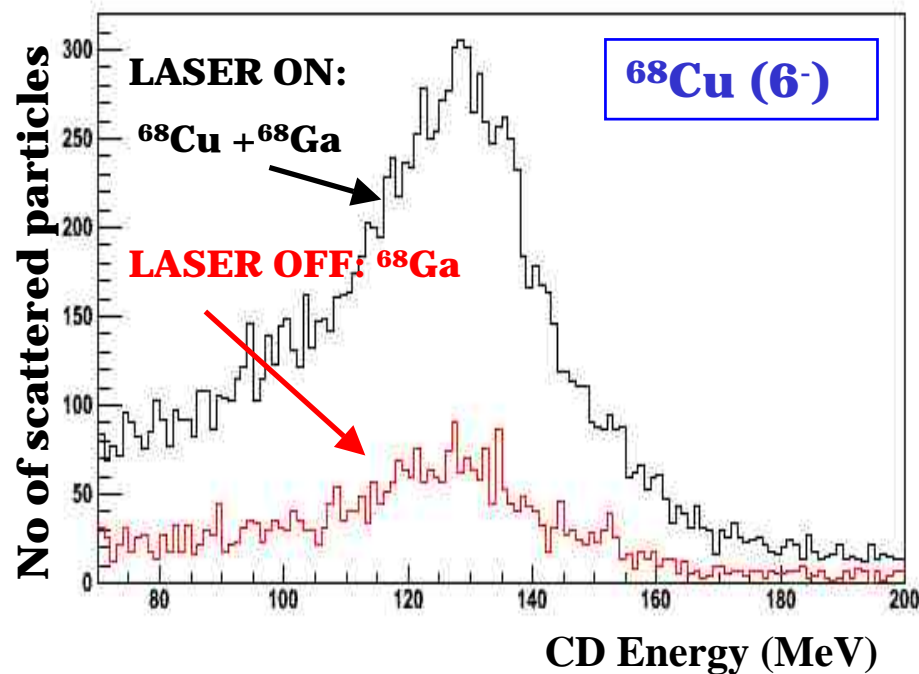
$$Y_{\text{MB}}(^{68,m}\text{Cu}) \sim 3 \cdot 10^5 \text{ pps}$$

$$Y_{\text{MB}}(^{70,g}\text{Cu}) \sim 5 \cdot 10^4 \text{ pps}$$

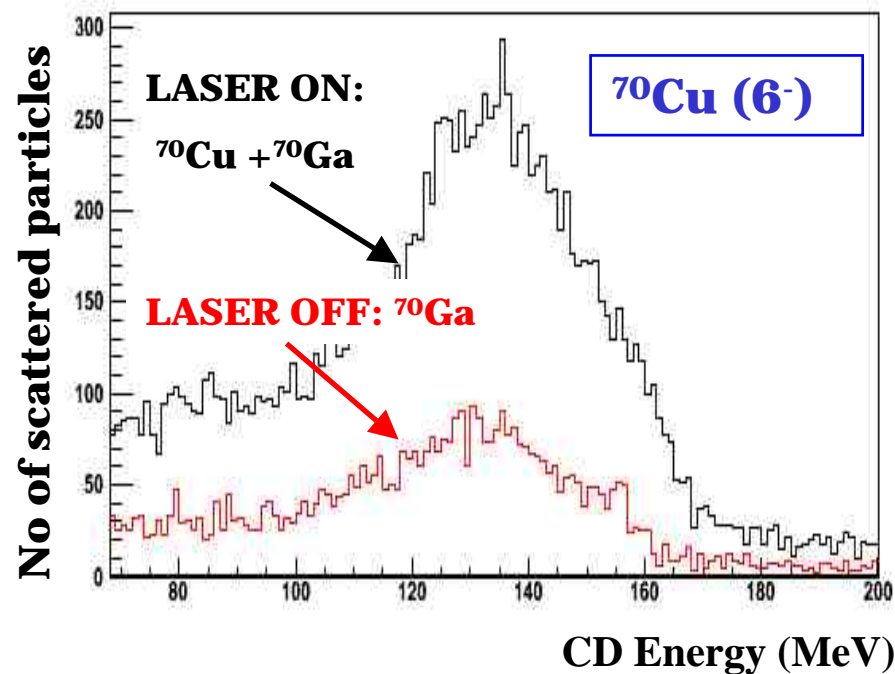


Coulex of $^{68,70,m,g}\text{Cu}$

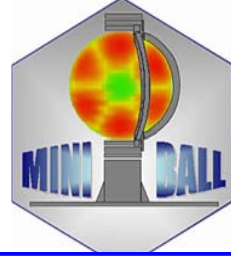
➤ Laser ON/OFF runs for determining isobaric contaminants (Ga)



$^{68}\text{Cu}/\text{total} = 74 \pm 2 \%$

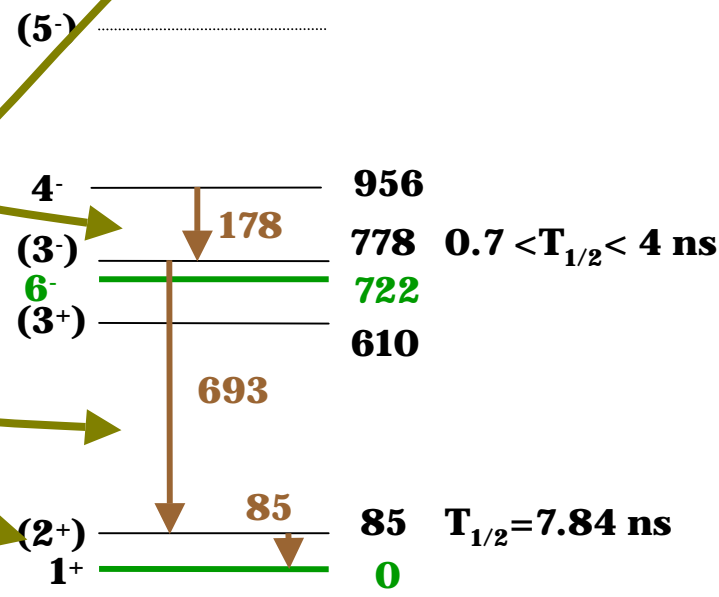
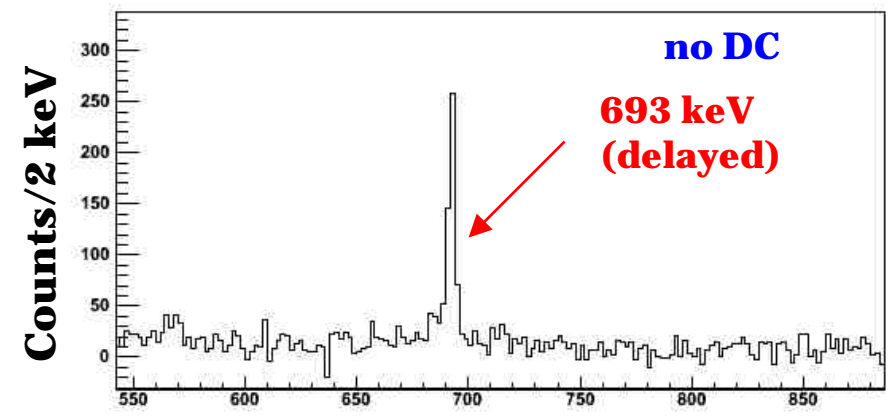
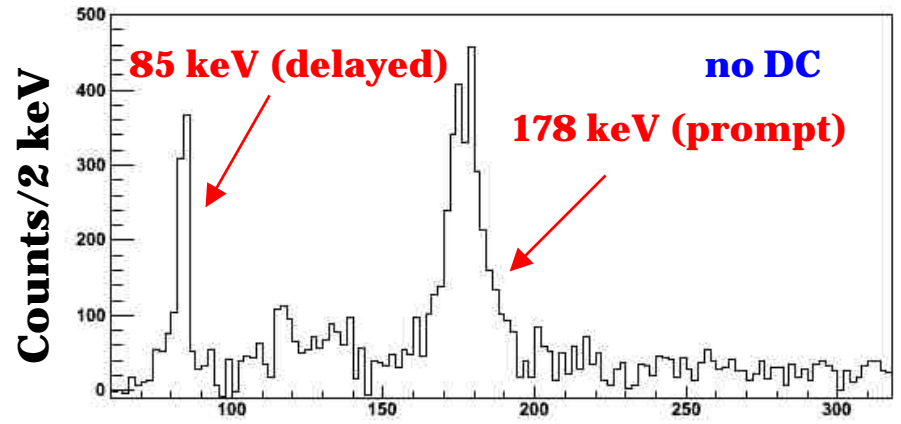
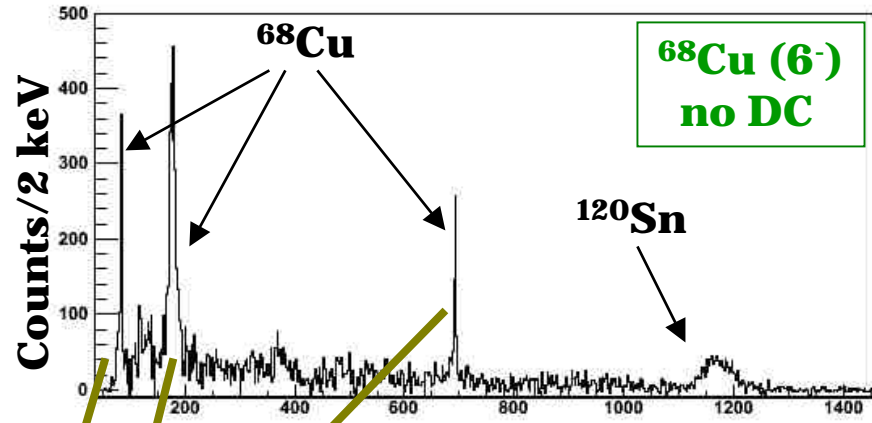


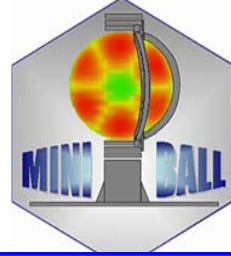
$^{70}\text{Cu}/\text{total} = 70 \pm 3 \%$



Coulex of $^{68,m}\text{Cu}$

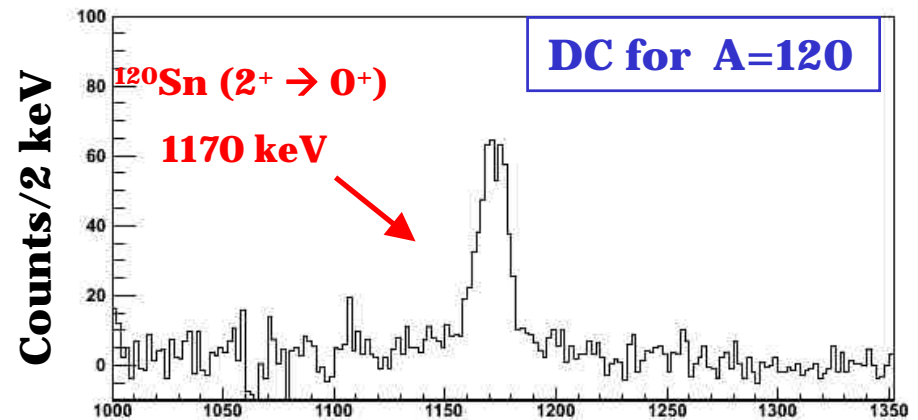
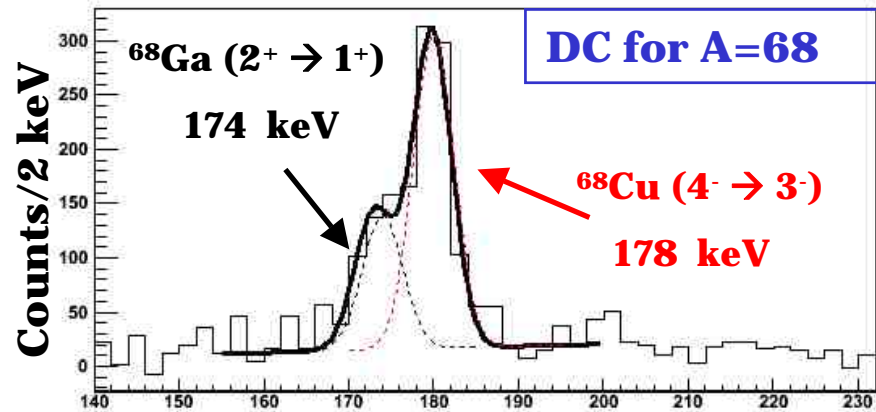
➤ $^{68,m}\text{Cu}$ (2.86 MeV/u) @ ^{120}Sn (2.3 mg/cm²)



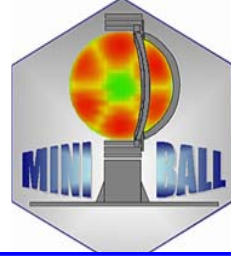


Coulex of $^{68,m}\text{Cu}$

➤ $^{68,m}\text{Cu}$ (2.86 MeV/u) @ ^{120}Sn (2.3 mg/cm²)



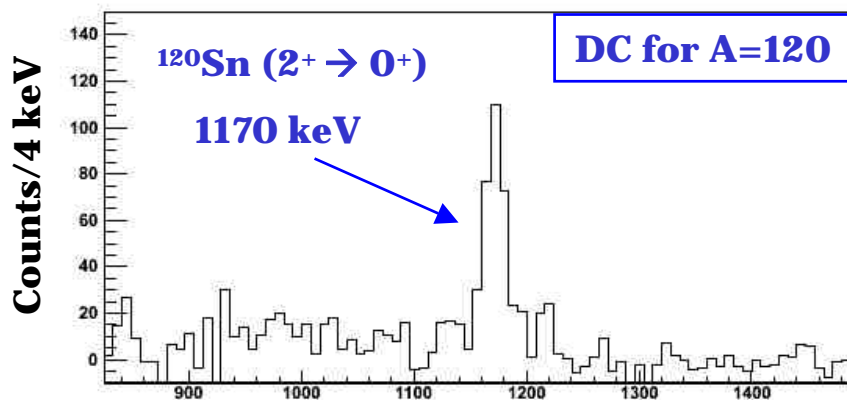
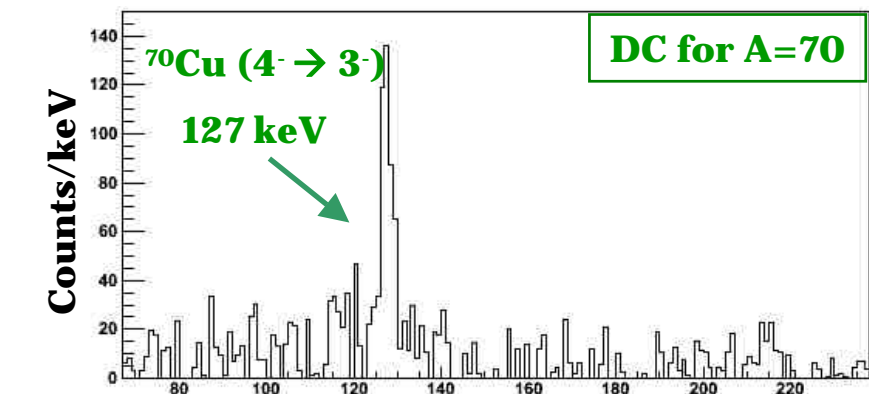
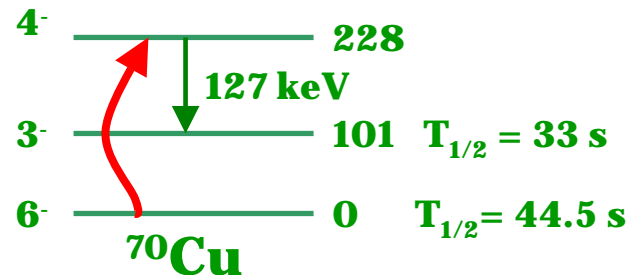
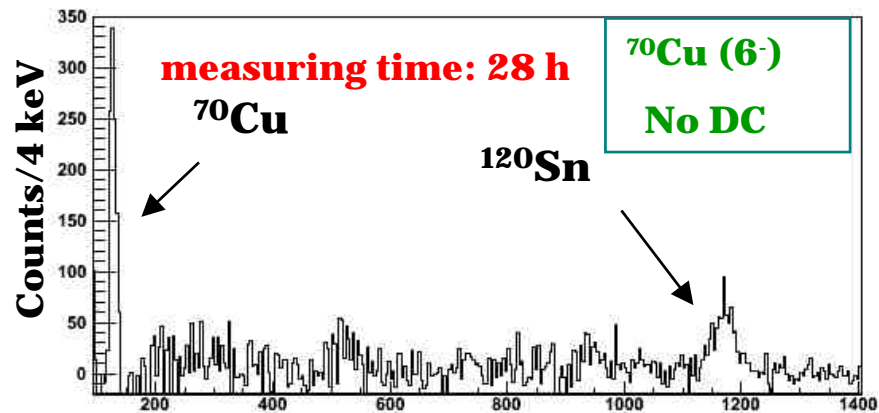
^{68}Cu (preliminary): $B(E2; 4^- \rightarrow 6^-) = 6.7 \pm 0.6 \text{ W.u.}$



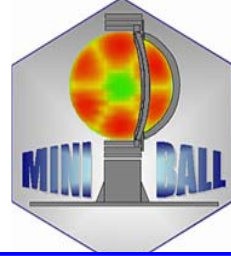
Coulex of $^{70,g}\text{Cu}$

➤ $^{70,g}\text{Cu}$ (2.86 MeV/u) @ ^{120}Sn (2.3 mg/cm²)

(5-) _____ 506



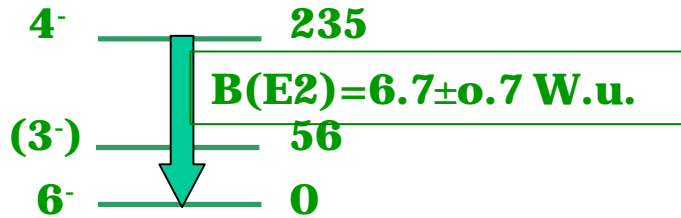
^{70}Cu (preliminary): $B(E2; 4^- \rightarrow 6^-) = 7.2 \pm 0.9 \text{ W.u.}$



Coulex of $^{68,m}\text{Cu}$, $^{70,g}\text{Cu}$

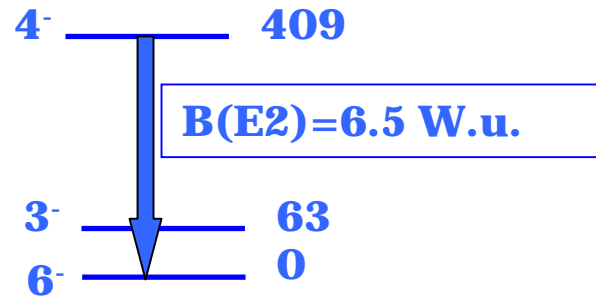
EXP.

(5⁻) 628



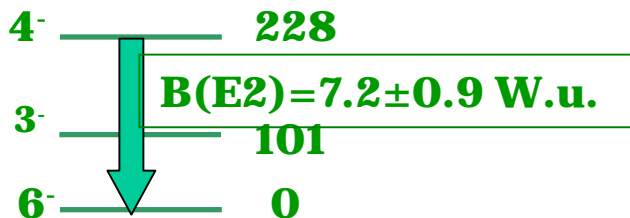
Shell-model ($e_p=1.9$; $e_n=0.9$; ^{56}Ni core)

5⁻ 768

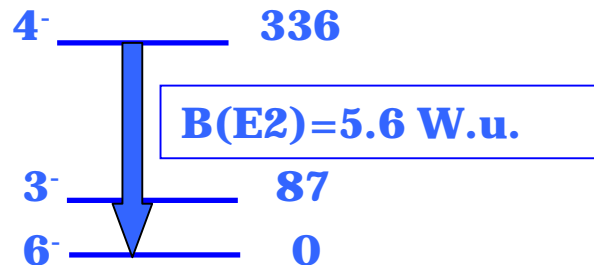


^{68}Cu

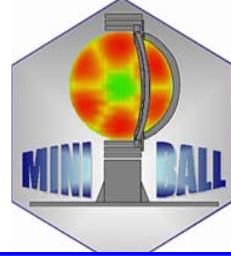
(5⁻) 506



5⁻ 582



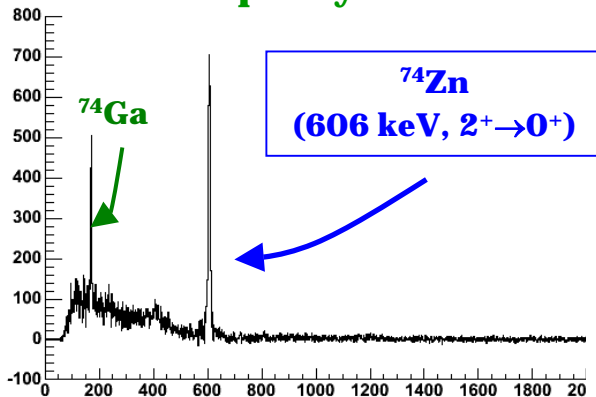
^{70}Cu



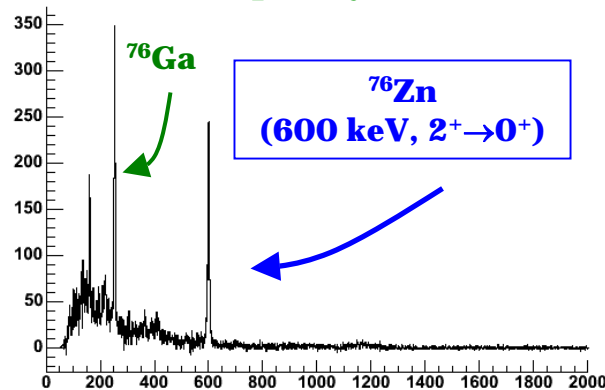
Towards the doubly magic ^{78}Ni

- evolution of collectivity in $^{74,76,78}\text{Zn}$ -

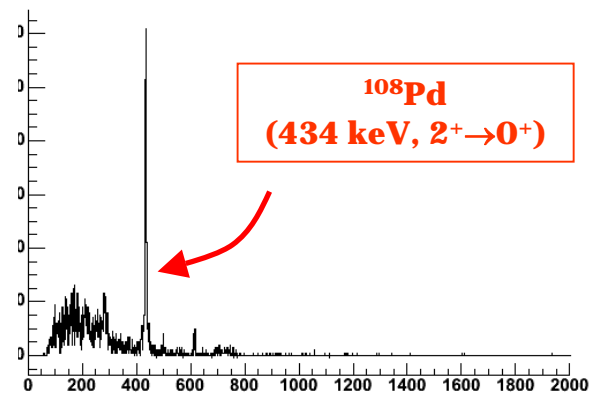
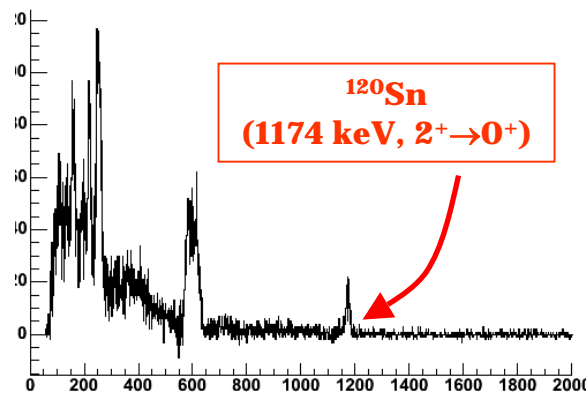
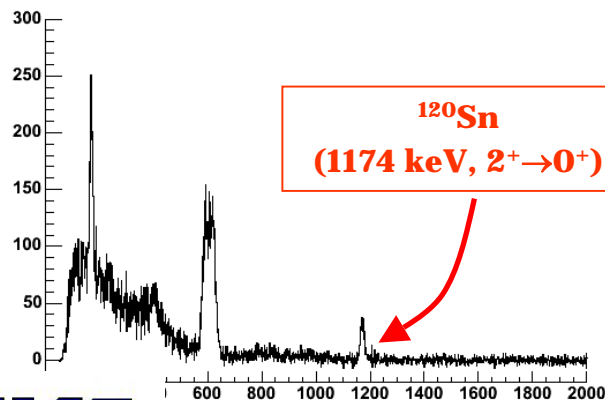
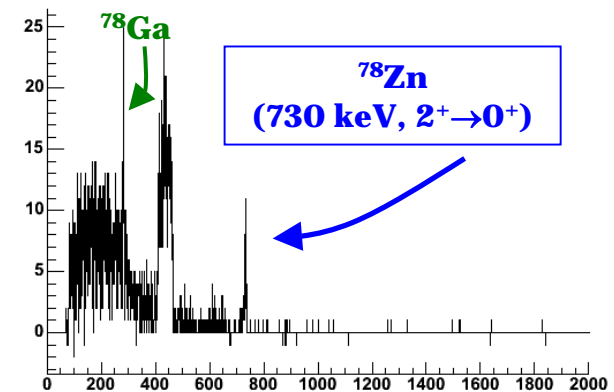
- ~12.5 h beam
- ~ $7 \cdot 10^5$ $^{74}\text{Zn}/\text{s}$
- ^{120}Sn target (2.3 mg/cm²)
- ~80% purity

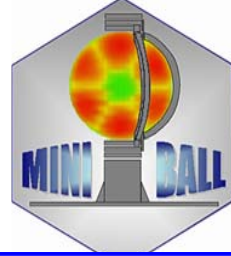


- ~14.5 h beam
- ~ $3 \cdot 10^5$ $^{76}\text{Zn}/\text{s}$
- ^{120}Sn target (2.3 mg/cm²)
- ~68% purity



- ~23.5 h beam
- ~ $8 \cdot 10^3$ $^{78}\text{Zn}/\text{s}$
- ^{108}Pd target (2 mg/cm²)
- ~59% purity



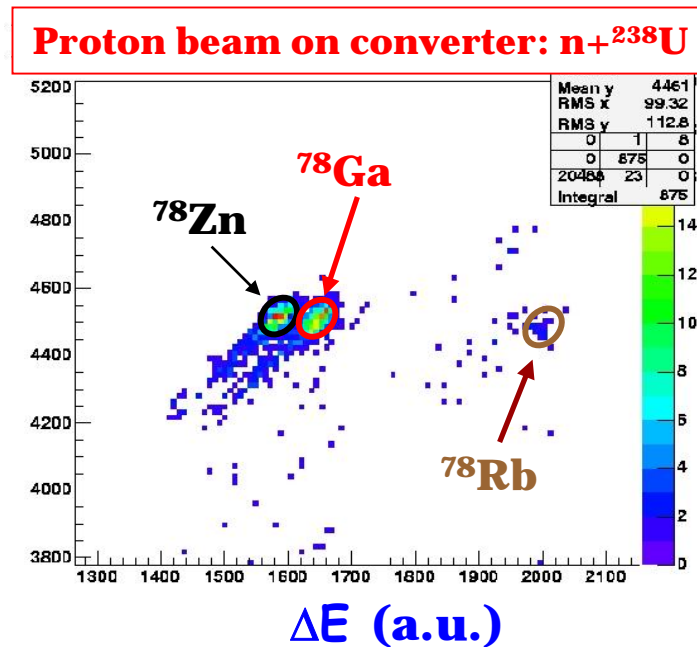
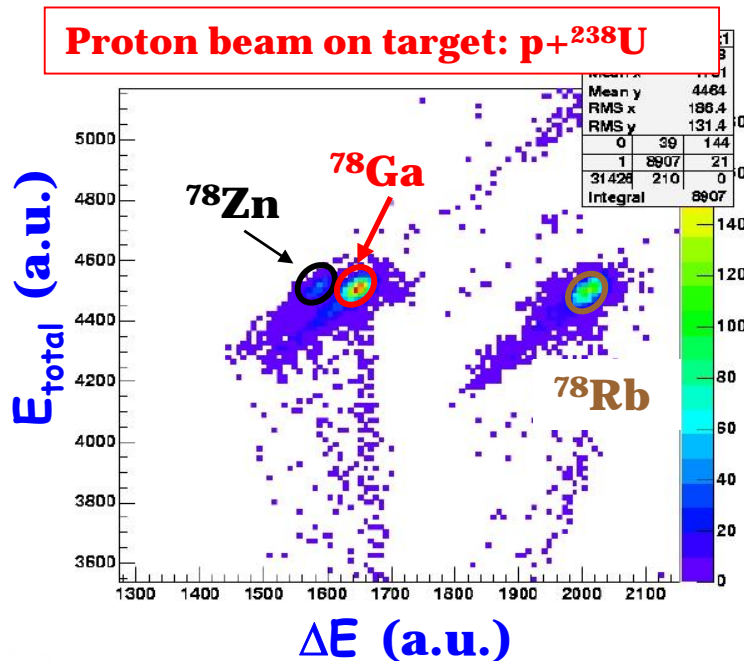
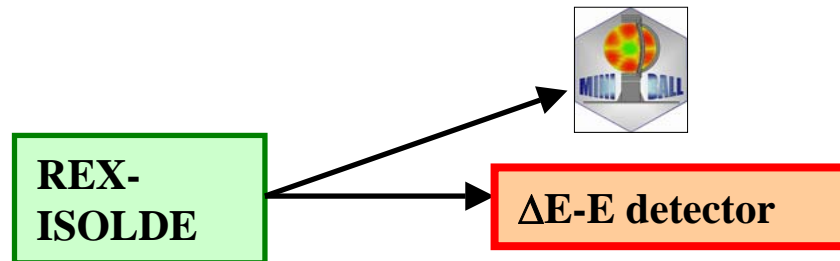


Towards the doubly magic ^{78}Ni

- evolution of collectivity in $^{74,76,78}\text{Zn}$ -

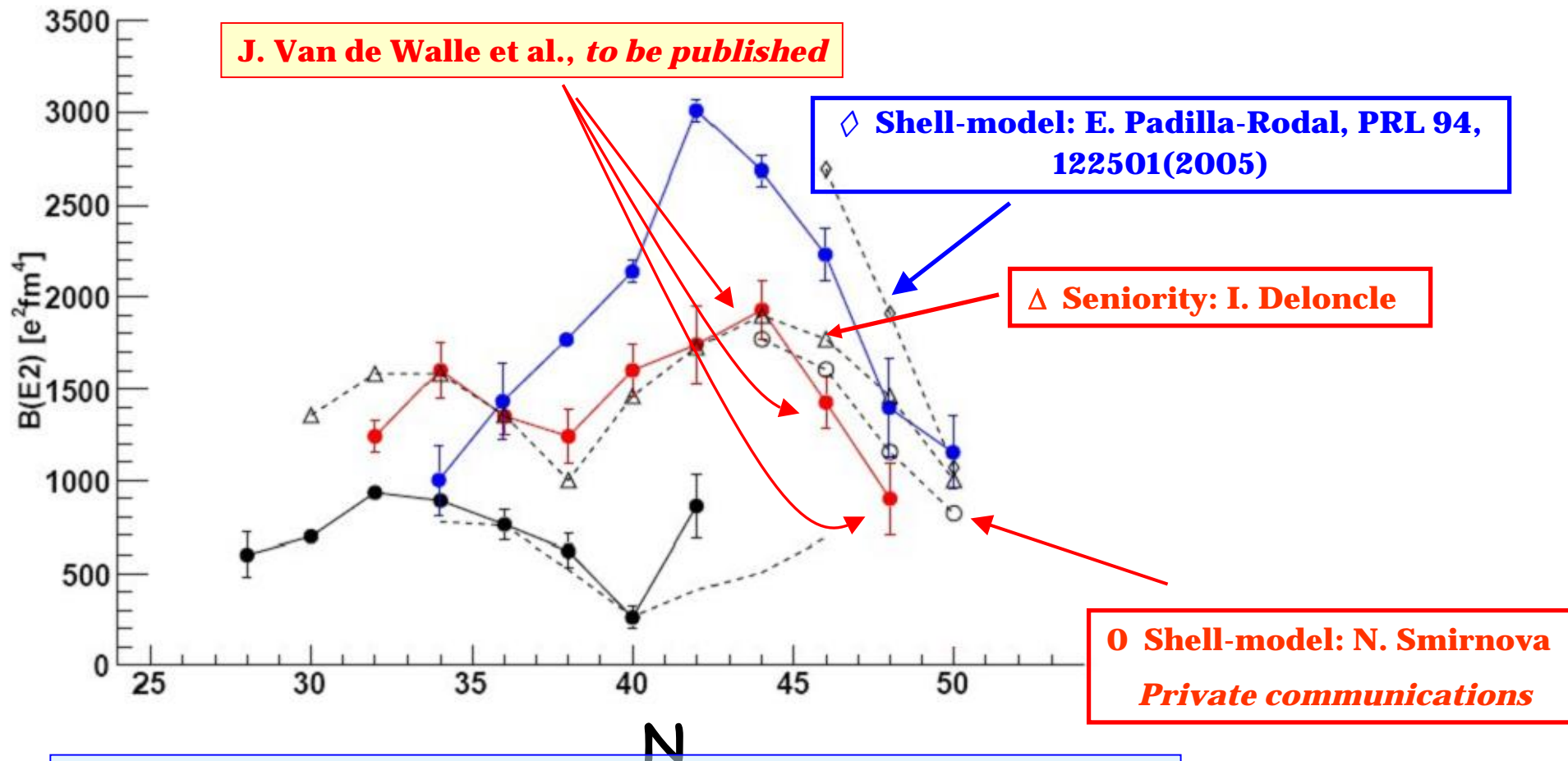
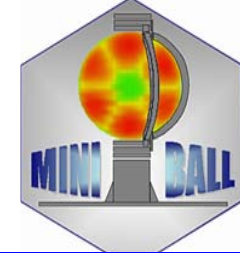
Beam composition for $^{74,76,78}\text{Zn}$:

- ✓ laser ON/OFF measurements;
- ✓ Ionization chamber – Si detector;
- ✓ proton-to-neutron detector;



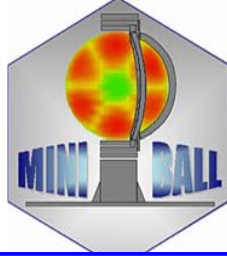
Towards the doubly magic ^{78}Ni

- evolution of collectivity in $^{74,76,78}\text{Zn}$ -



- ^{74}Zn : agreement with intermediate energy Coulex (Ganil)
- Steep drop in $B(E2)$ towards $N=50$





Conclusions and outlook

✓ **July 2004: coulex of $^{74,76,78}\text{Zn}$; $B(E2; 2^+ \rightarrow 0^+)$ measured;**

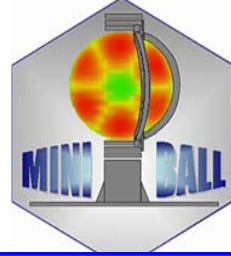
✓ **July 2005: first isomeric beams post-accelerated by REX-ISOLDE;**

✓ **Coulex of $^{68,70}\text{Cu}$, $\pi p_{3/2} \otimes \nu g_{9/2}$ multiplet : $B(E2; 4^- \rightarrow 6^-)$ measured, energy and spin of the 4^- state fixed; experimental results in good agreement with the preliminary shell model-calculations.**

Upcoming runs:

➤ **July 2006: coulex of ^{80}Zn ;**

➤ **August 2006: coulex of $^{67,69,71}\text{Cu}$.**



The Collaboration

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