First results of the CLARA – PRISMA setup installed at LNL

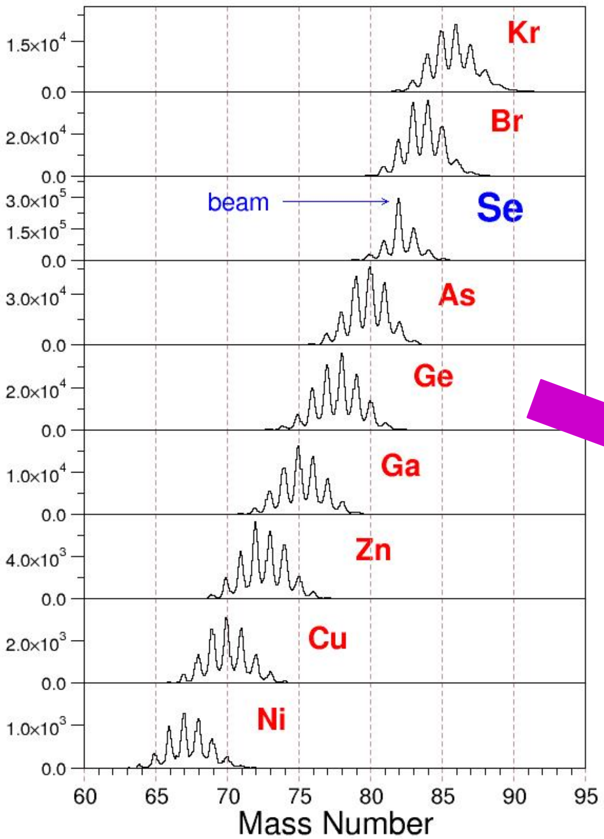
A.Gadea INFN-LNL Legnaro

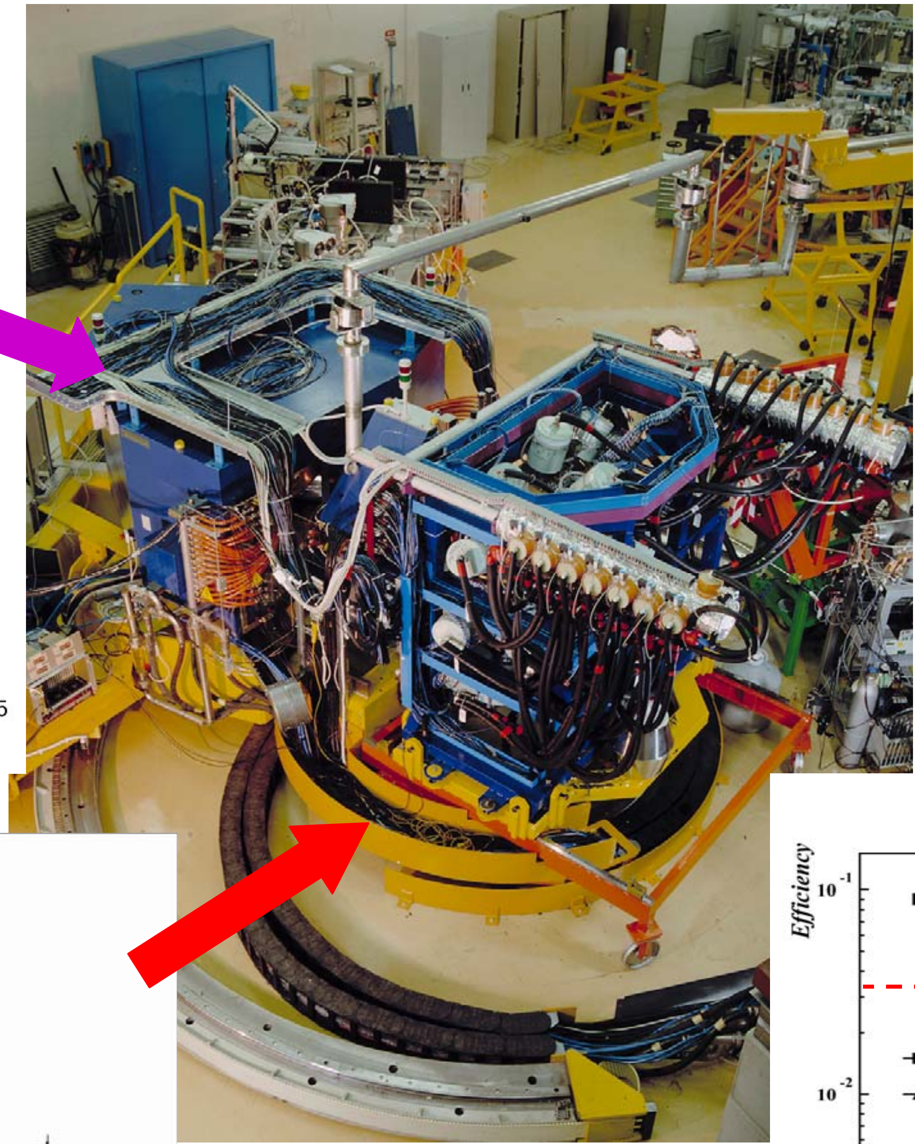
Gamma Spectroscopy in products of binary reactions with "intense" stable beams

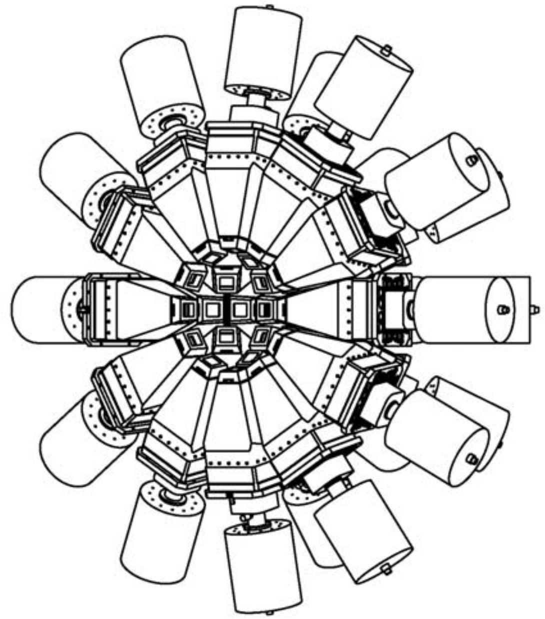
- Moderately neutron rich nuclei produced by Multi-nucleon transfer or deep inelastic collisions
- Non-Yrast states populated in quasielastic reactions

CLARA-PRISMA setup

A & Z identification







25 Euroball Clover detectors

for Eγ= 1.3MeV

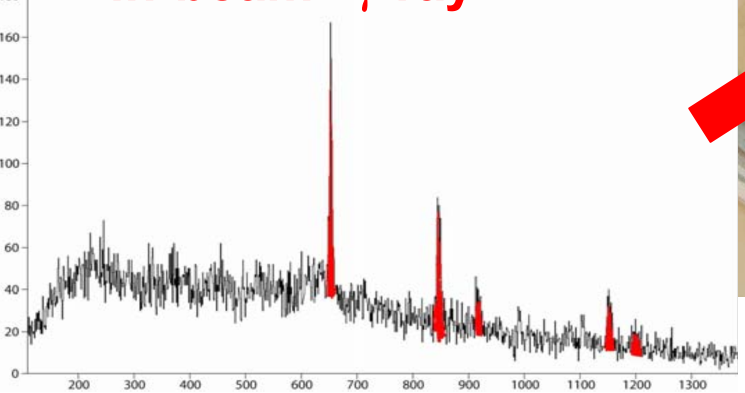
Efficiency ~ 3 %

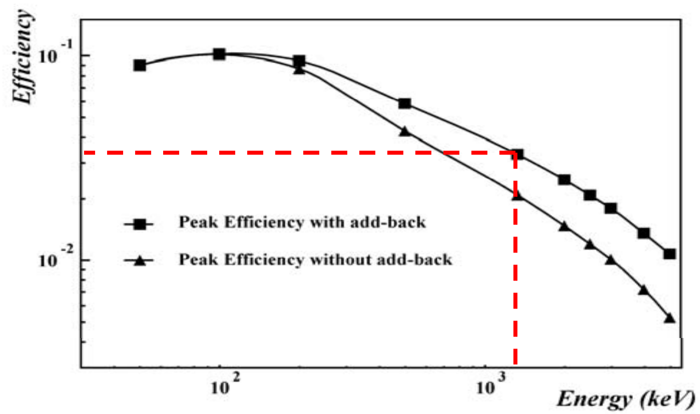
Peak/Total ~ 45 %

FWHM ~ 10 keV

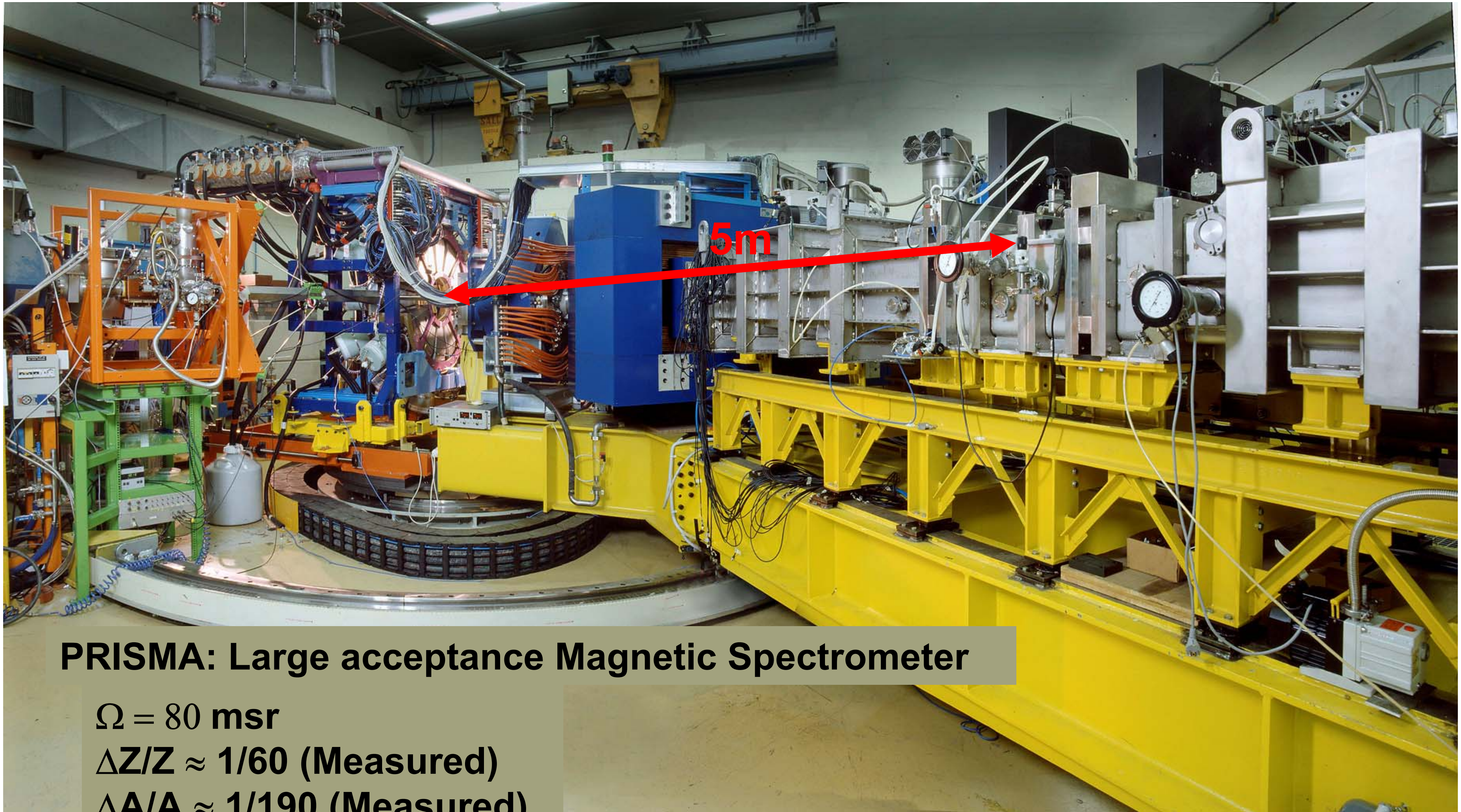
(at v/c = 10 %)

"in-beam" γ-ray





CLARA-PRISMA setup

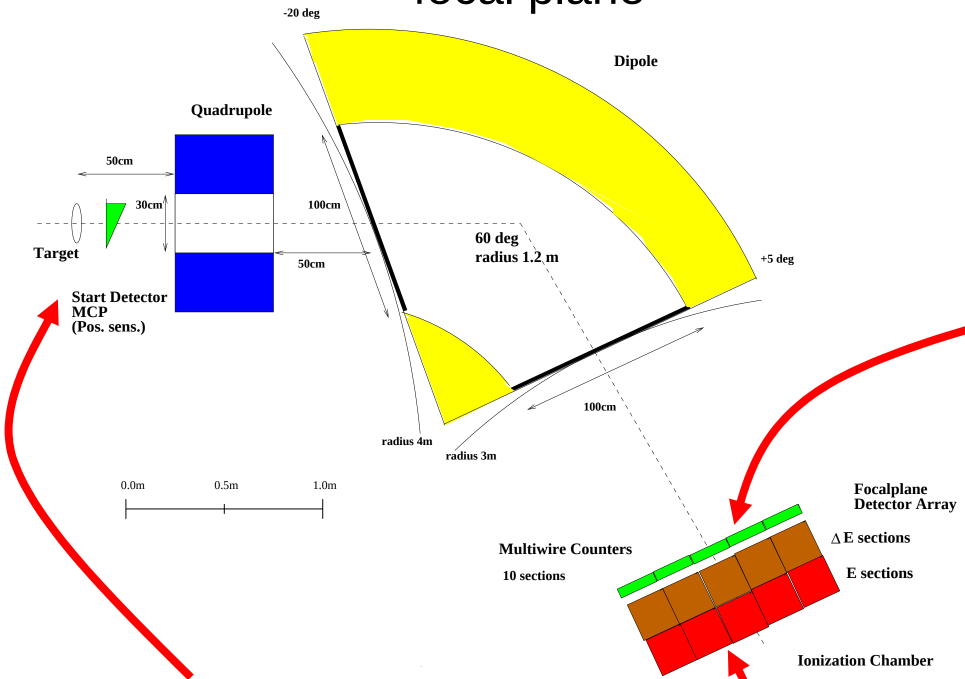


PRISMA: Large acceptance Magnetic Spectrometer

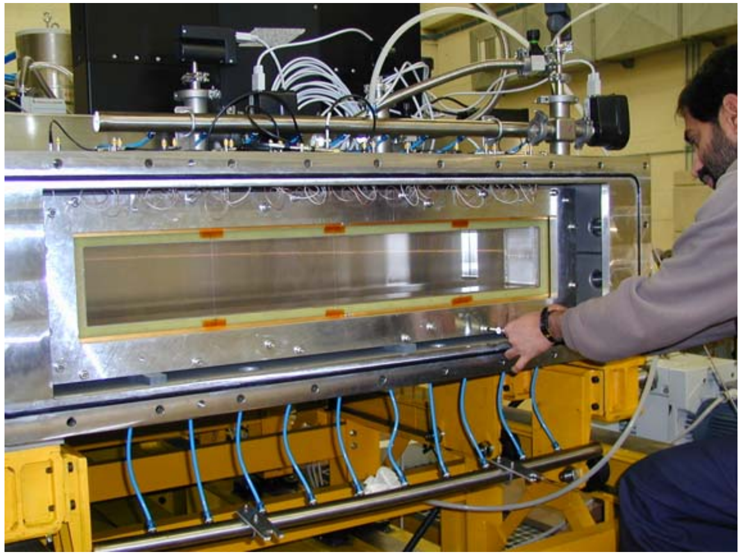
$\Omega = 80$ msr
$\Delta Z/Z \approx 1/60$ (Measured)
$\Delta A/A \approx 1/190$ (Measured)
Energy acceptance ±20%
$B\rho$ = 1.2 T.m

The PRISMA Spectrometer Detectors

Large dispersion dipole: 4cm / % at the focal plane

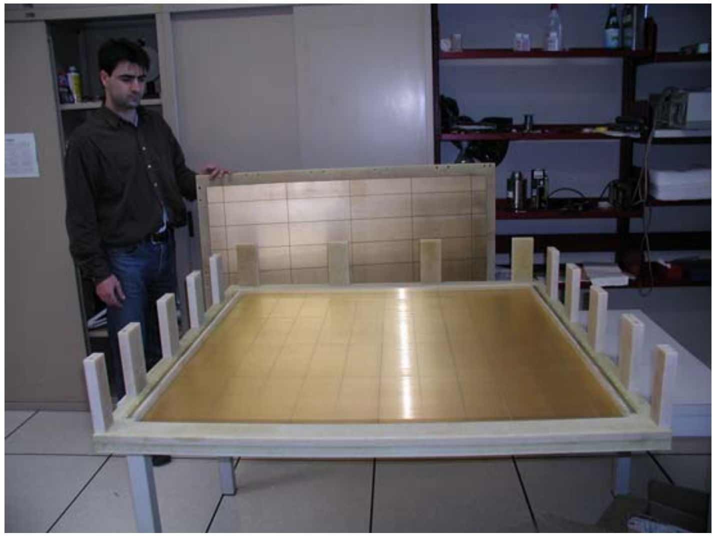


10 sections Multiwire PPAC



S.Beghini et al. LNL annual Report 2000 pg.163

10 x 4 sections Ionization Chamber



Position sensitive MCP

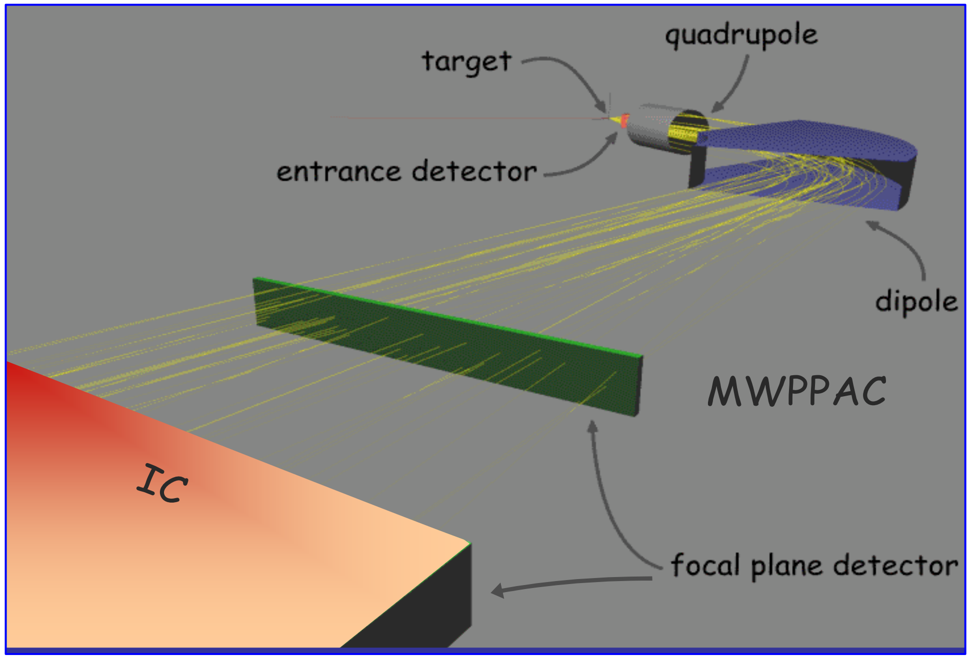
G.Montagnoli et al. LNL annual Report 2000 pg.165

Analysis of PRISMA (CLARA) data

A complete tracking algorithm for PRISMA was developed

Ingredients

- Entrance detector position (MCP)
- TOF Entrance detector- MWPPAC (~5m)
- Focal Plane position MWPPAC + IC
- Total Energy and Z ($\Delta E/E$) from IC



Doppler correction
- precise position on entrance detector
- true recoil velocity

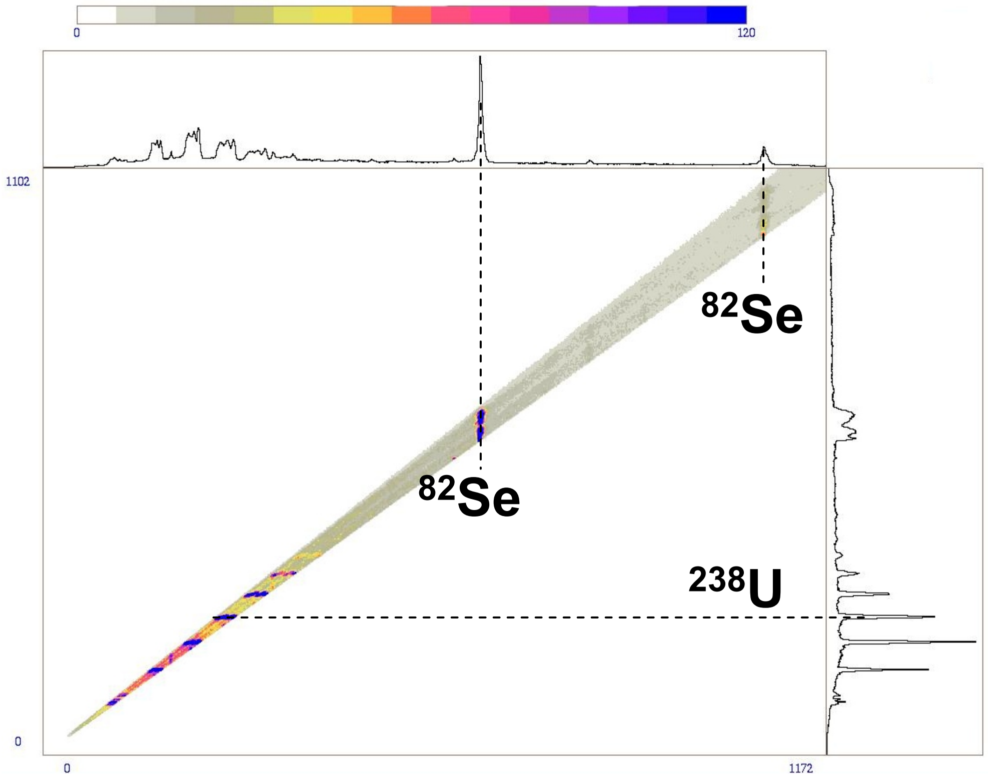
A/q

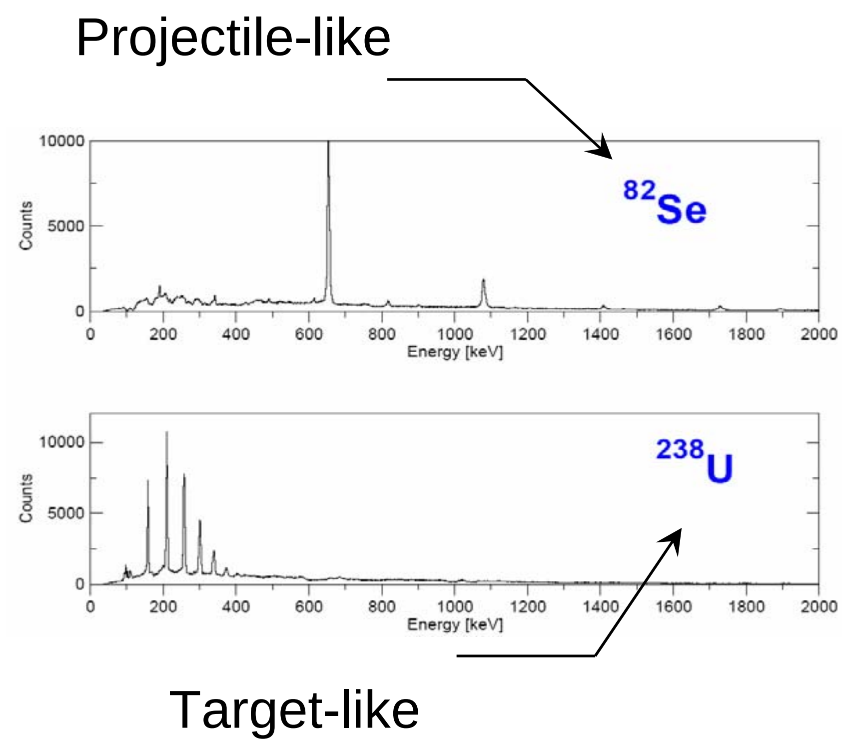
Charge state
- trajectory in dipole
- total energy

CLARA Doppler correction

Energy resolution of 1% at recoil velocity v/c = 10%

^{82}Se+^{238}U with ^{82}Se selected in PRISMA





Experiments performed: March-July 2004

- *Search for excited states in neutron rich ^{37}P and ^{39}P using deep inelastic processes.* X.Liang, Paisley ($^{36}S + ^{208}Pb$)
  Medium spin −spectroscopy of Ne, Mg, and Si neutron rich isotopes using the CLOVER ARRAY with PRISMA: the appearance and evolution of the intruder configurations. F.Azaiez, Orsay, Zs.Dombradi, Debrecen

- *Nuclear spectroscopy of neutron rich nuclei in the N=50 region*
  G.Duchene, Strasbourg, G.de Angelis, Legnaro ($^{82}Se + ^{238}U$)

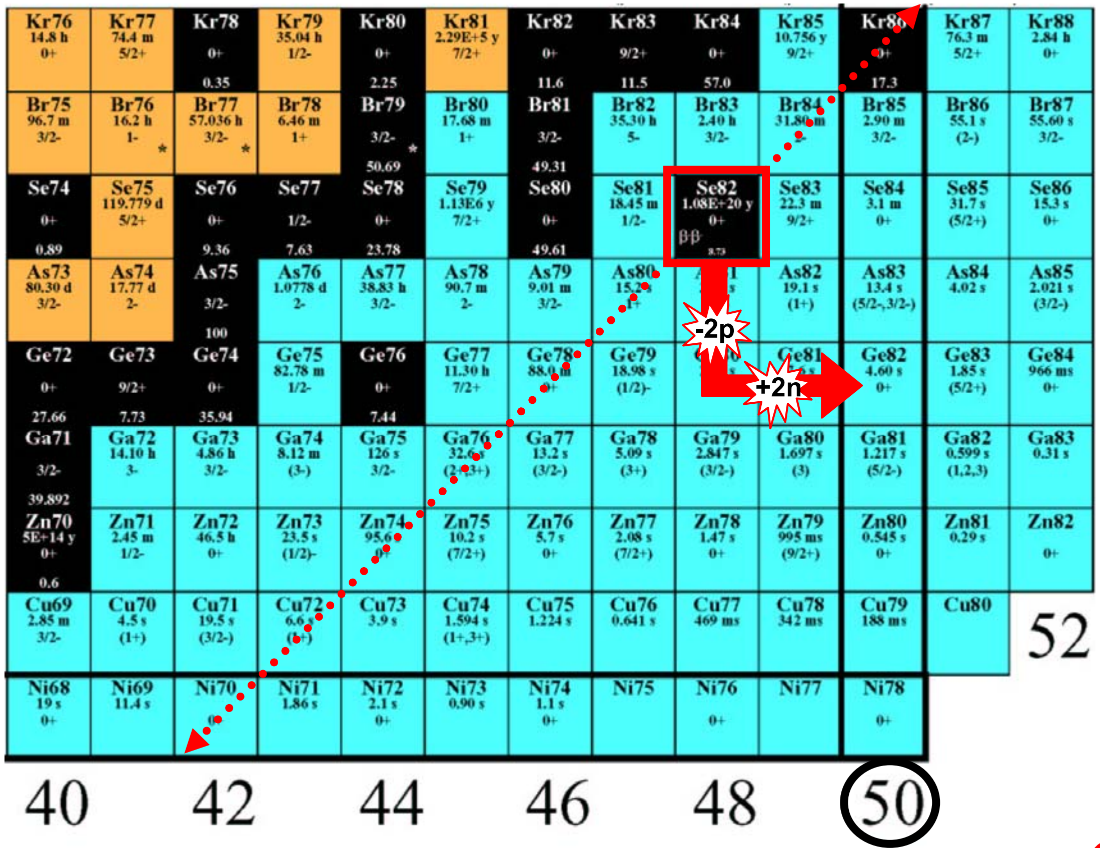
- *Spectroscopy of deformed neutron rich A ~ 60 nuclei*
  S.M.Lenzi, Padova, S.J.Freeman, Manchester ($^{64}Ni + ^{238}U$)

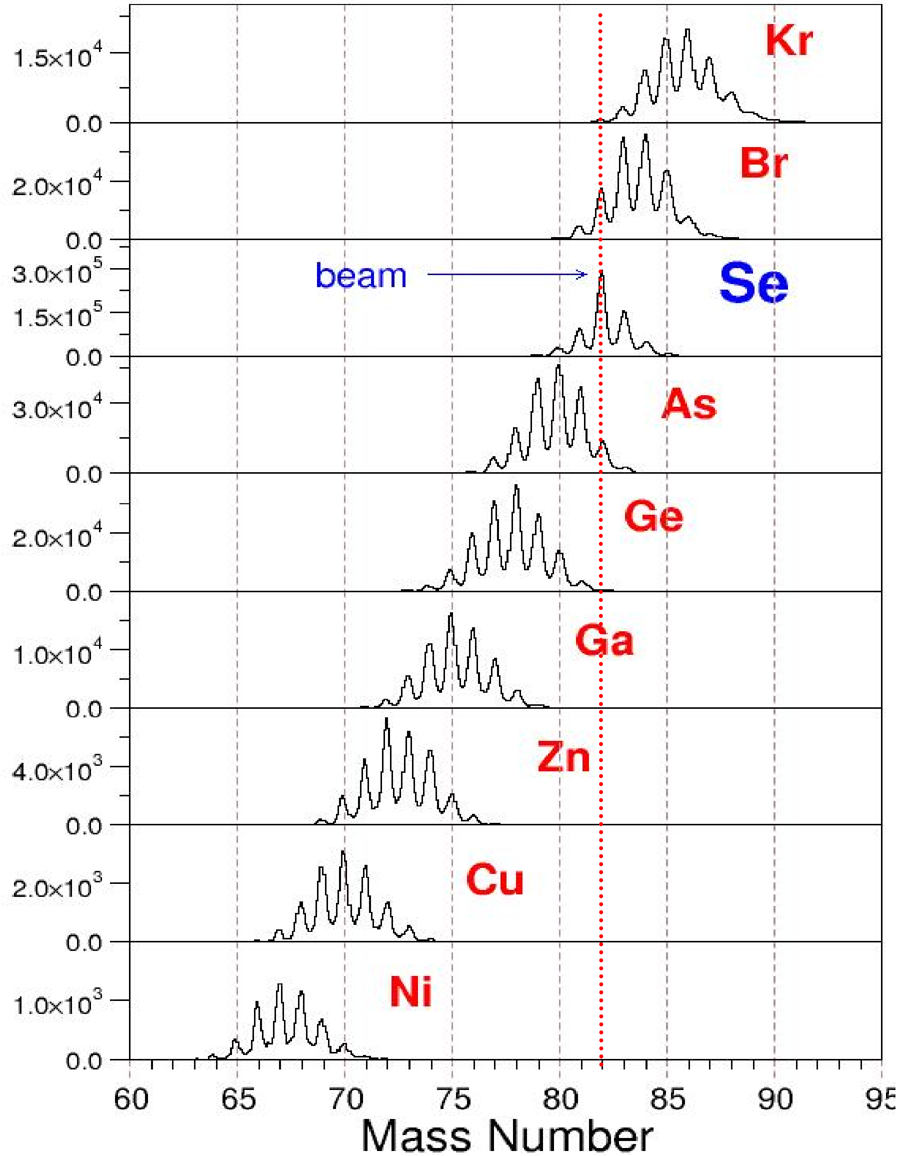
- *Pair transfer effects in $^{90}Zr+^{208}Pb$*
  L.Corradi, Legnaro ($^{90}Zr + ^{208}Pb$) *(see L.Corradi poster)*

- *Isotensor MED across the f7/2 shell: identification of the missing 6+ state in the odd-odd nucleus of the A=54 triplet*
  A.Gadea, Legnaro ($^{54}Fe + ^{58}Ni$)

^{82}Se + ^{238}U E=505 MeV
4 days, PRISMA at θ_G=64°

G.deAngelis, G.Duchêne
Analysis: N.Marginean

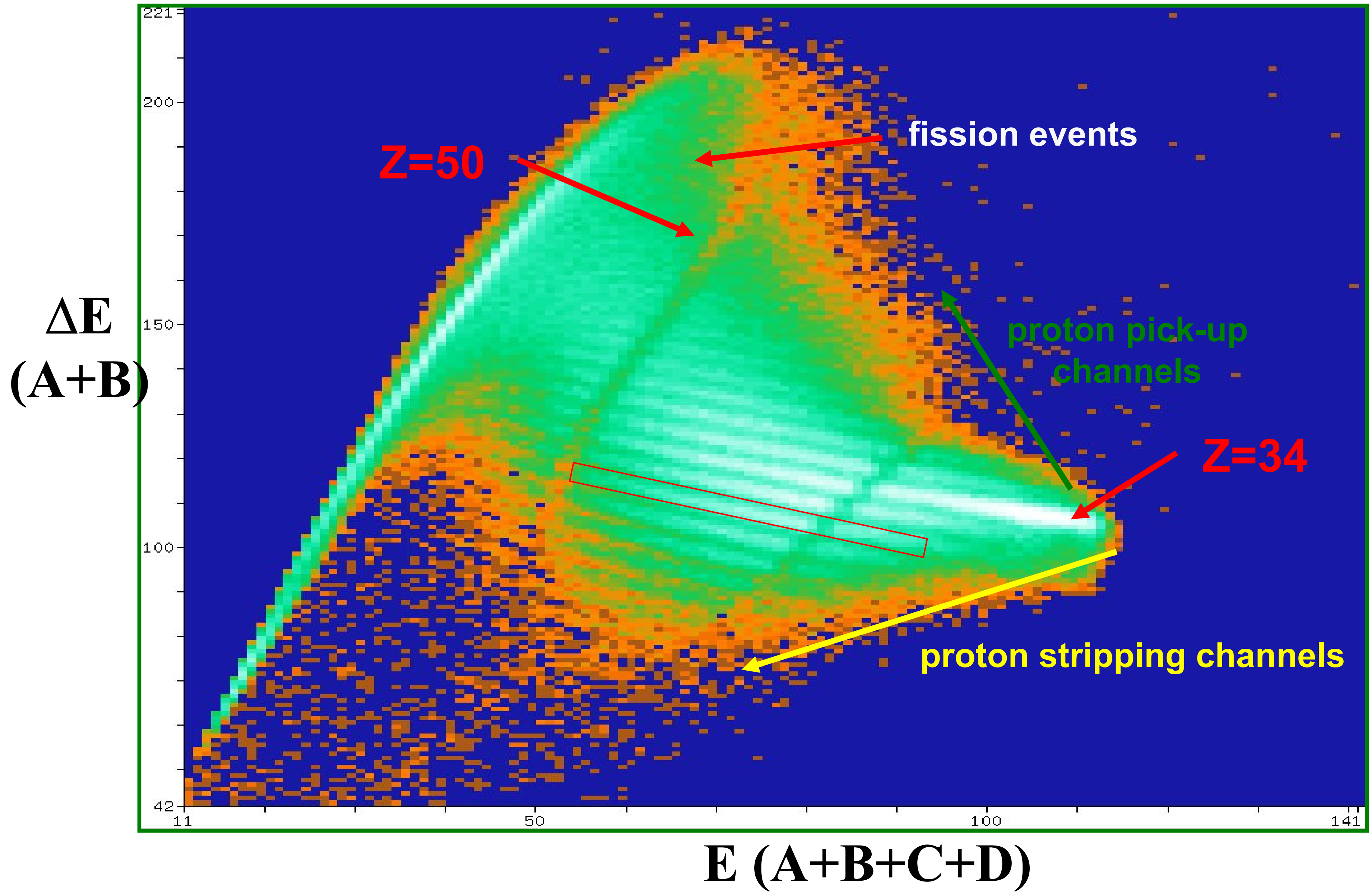


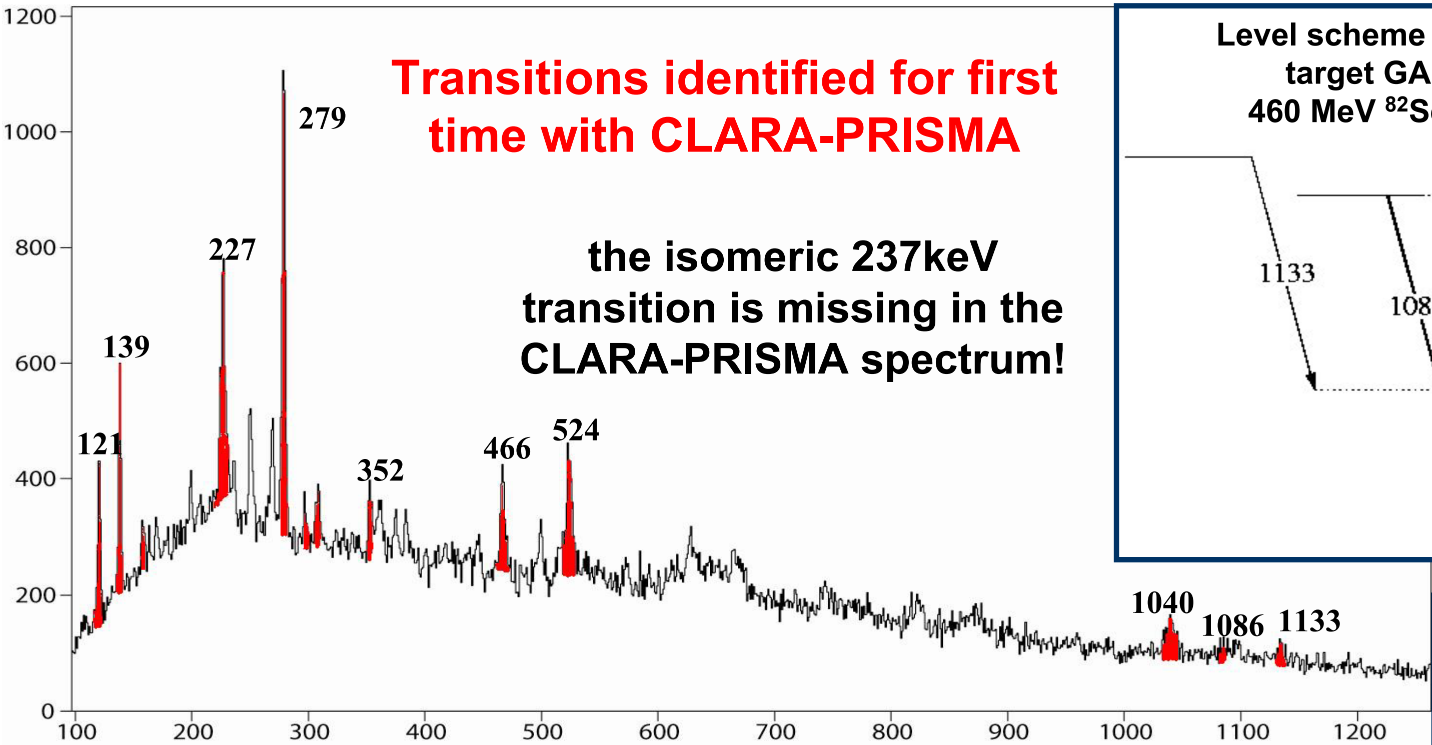


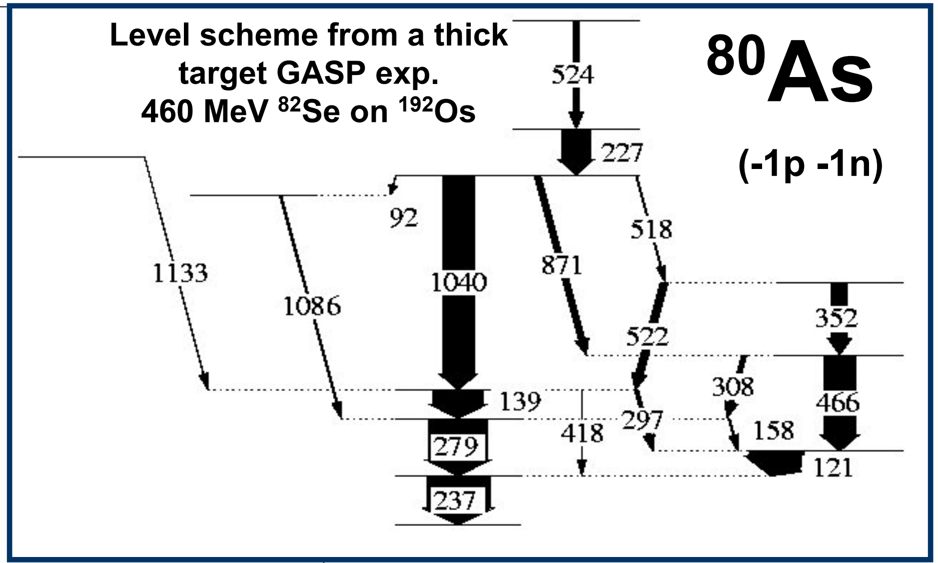
Evolution of the N=50 shell: Searching for the shell gap quenching (onset of deformation as in N=20 Z~12)

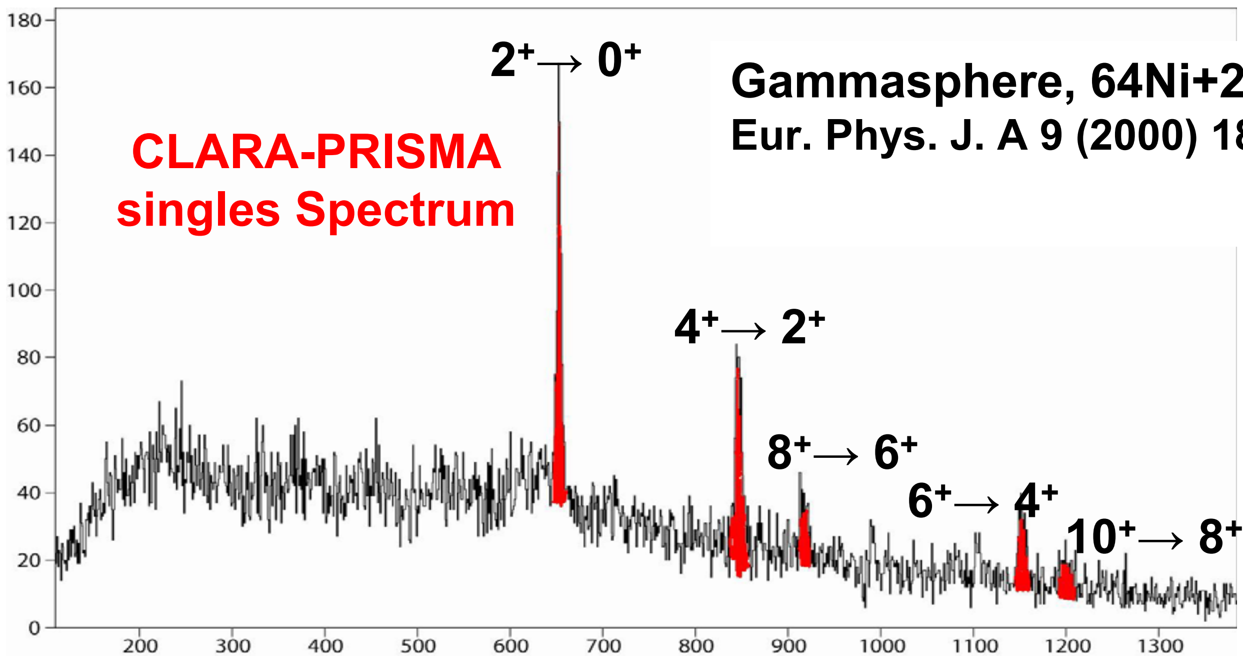
Z=32: INM, R.C.Nayak et al. PRC 60 (1999) 064305
Z=24-26: RMF, L.S.Geng et al. nucl-th/0402083

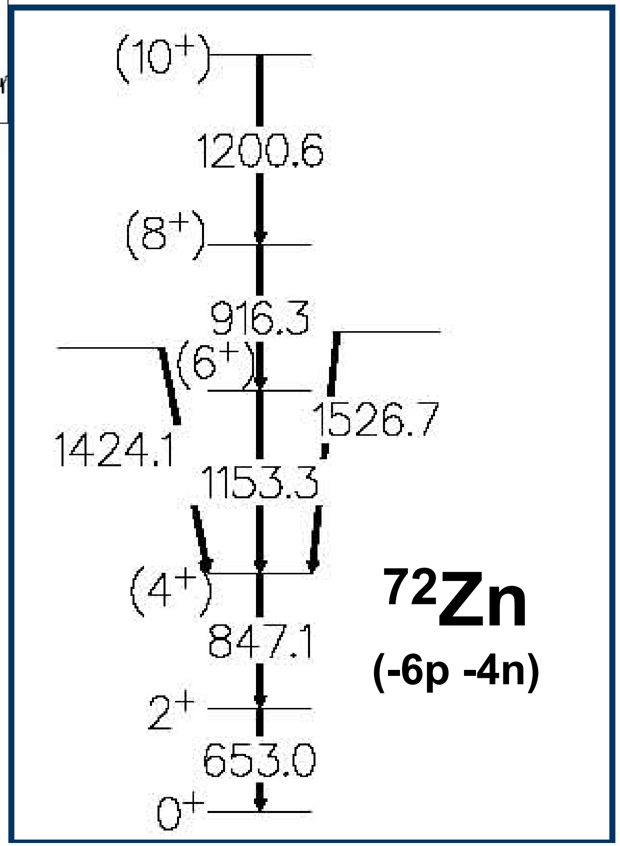
$^{82}Se + ^{238}U$ E=505 MeV $\theta_G=64^o$ IC ΔE-E Matrix



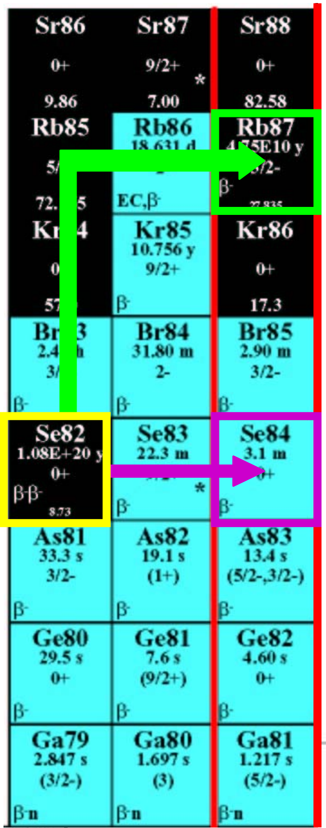

Transitions identified for first time with CLARA-PRISMA
the isomeric 237keV transition is missing in the CLARA-PRISMA spectrum!
121
139
227
279
352
466
524
1040
1086
1133
0
200
400
600
800
1000
1200
100
200
300
400
500
600
700
800
900
1000
1100
1200

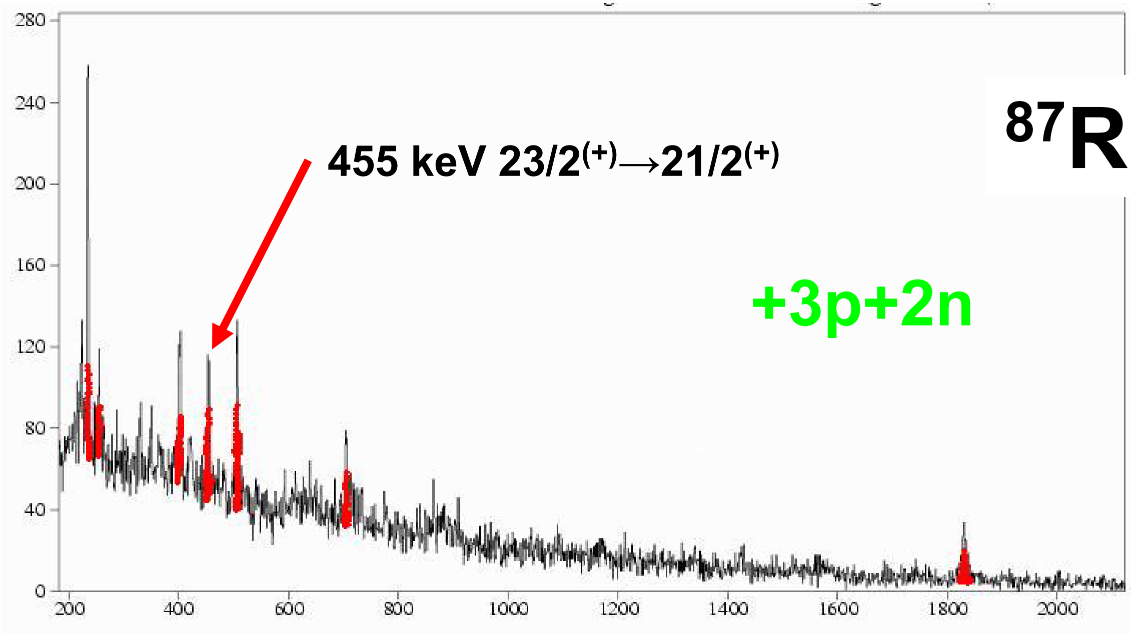

Level scheme from a thick target GASP exp.
460 MeV ^{82}Se on ^{192}Os
^{80}As
(-1p -1n)
524
227
92
518
1133
1086
1040
871
352
522
466
308
139
418
297
158
279
121
237

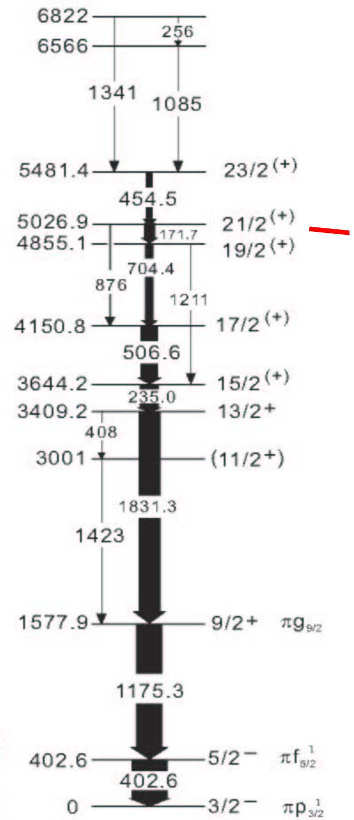

CLARA-PRISMA singles Spectrum
Gammasphere, 64Ni+208Pb
Eur. Phys. J. A 9 (2000) 183
$2^+ \rightarrow 0^+$
$4^+ \rightarrow 2^+$
$8^+ \rightarrow 6^+$
$6^+ \rightarrow 4^+$
$10^+ \rightarrow 8^+$
0
20
40
60
80
100
120
140
160
180
200
300
400
500
600
700
800
900
1000
1100
1200
1300

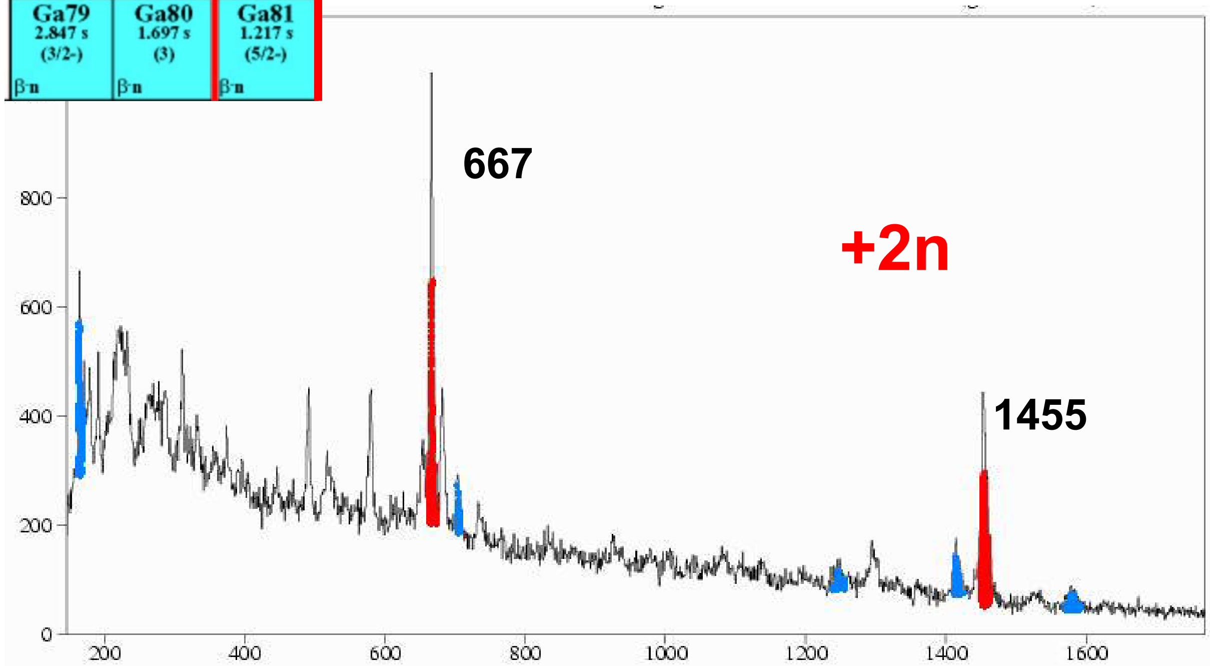

(10^+)
1200.6
(8^+)
916.3
(6^+)
1424.1
1526.7
1153.3
(4^+)
847.1
2^+
653.0
0^+
^{72}Zn
(-6p -4n)

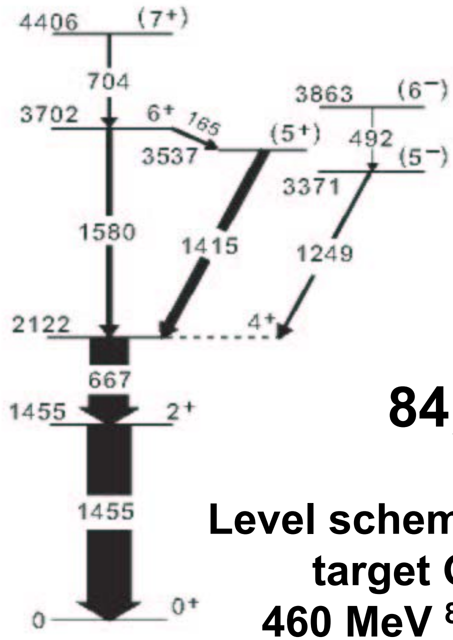
^{82}Se + ^{238}U E=505 MeV





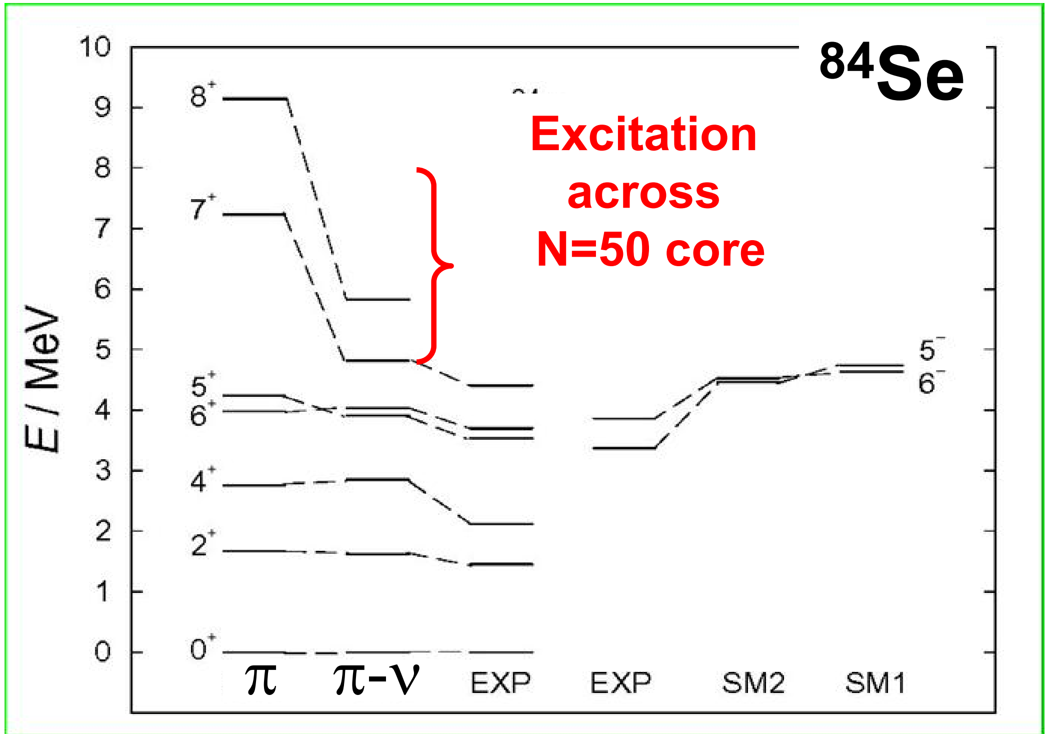






Level schemes from a thick target GASP exp.
460 MeV ^{82}Se on ^{192}Os

Stability of the N=50 Shell down to Z~32



Space: $\pi f_{5/2}\ p_{3/2}\ p_{1/2}\ g_{9/2}\quad \nu p_{1/2}\ g_{9/2}\ d_{5/2}$

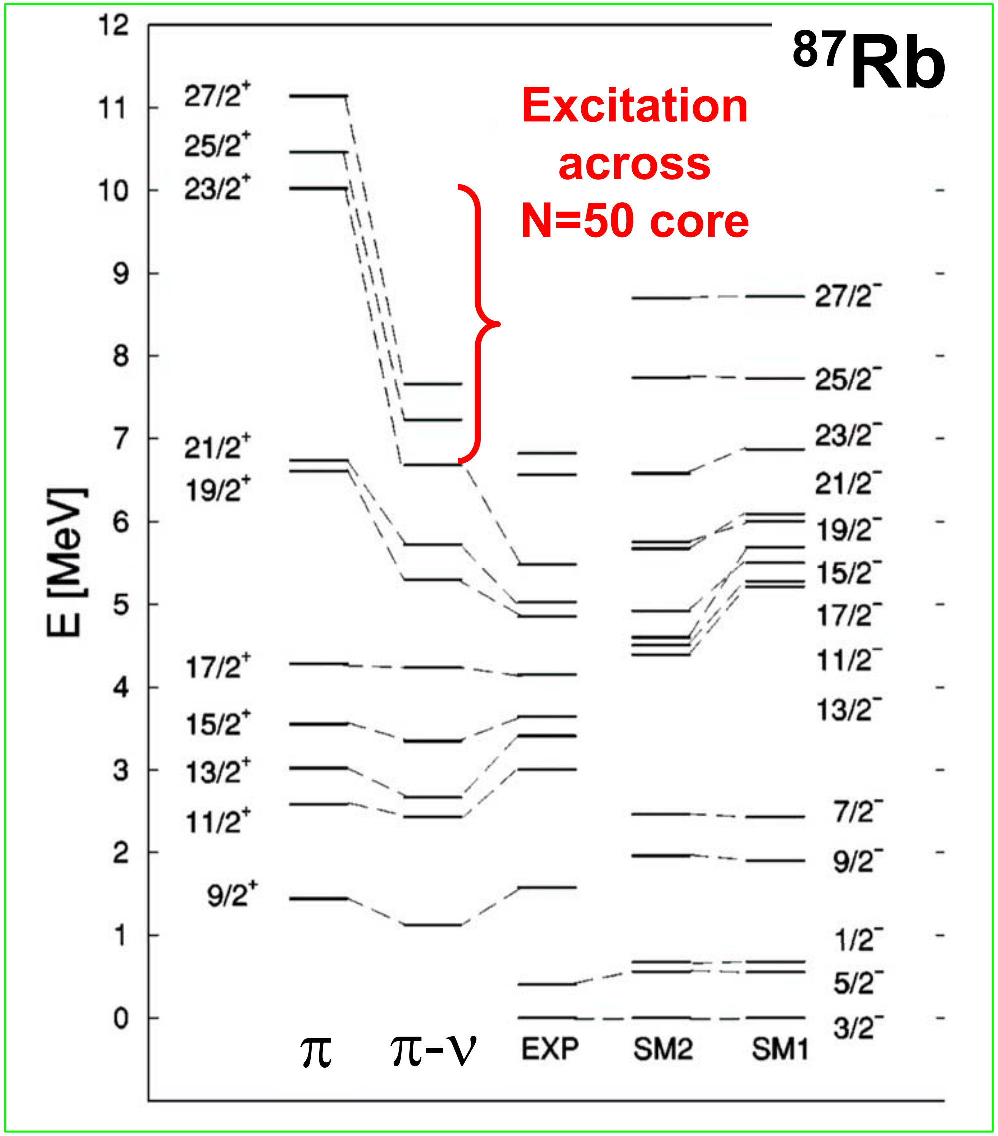
The description of these semi-magic nuclei (within the shell model framework) can be done with a constant N=50 shell gap.

Y.H.Zhang et al., PRC 70(2004)024301

Shell model with renormalized SPE

X.Ji & B.H. Wildenthal PRC 37(1988)1256

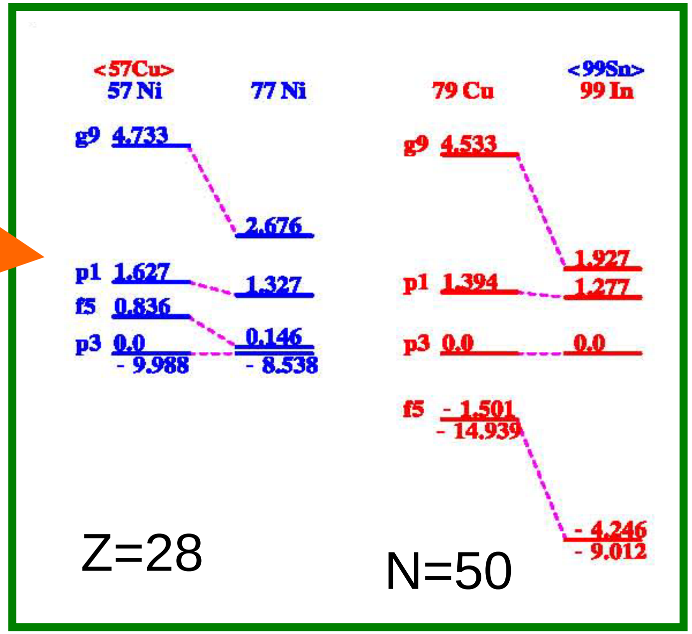
Lisetskiy et al., nucl-th/0402082

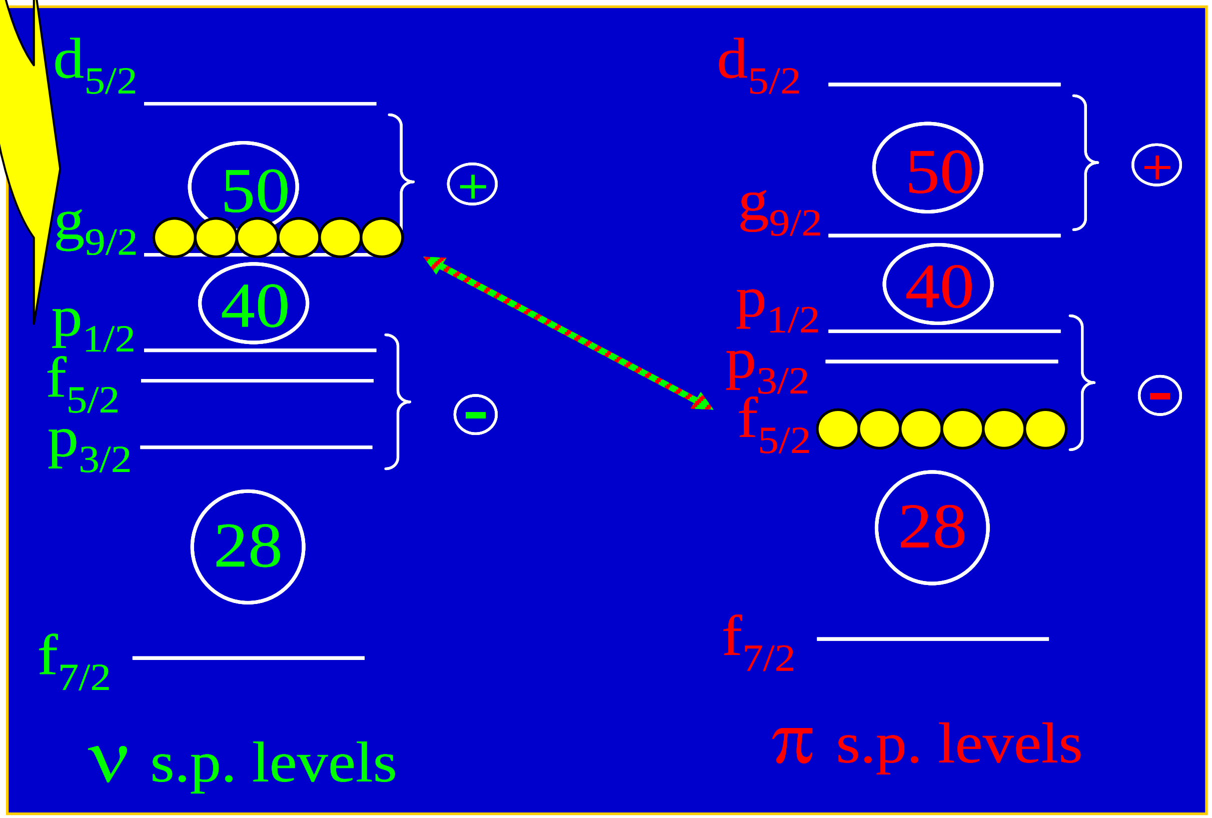


The excited states in the N=50 nuclei have been compared with shell-model calculations allowing neutron particle-hole excitations across the N=50 closed core.

SM with renormalized SPE

X. Ji and B.H. Wildenthal PRC 37 (1988) 1256
A. F. Lisetskiy et al. nucl-th0402082





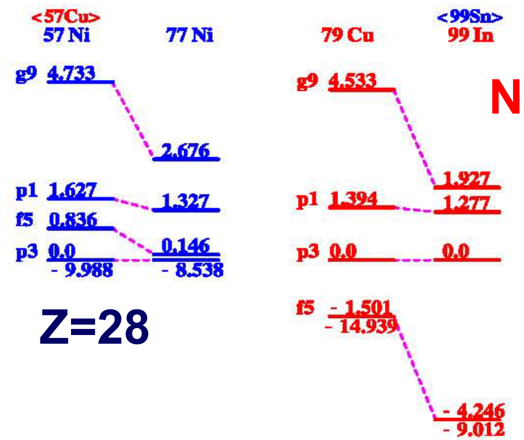
To reproduce reasonably the medium-high spin states it is necessary to introduce ν particle-hole excitation

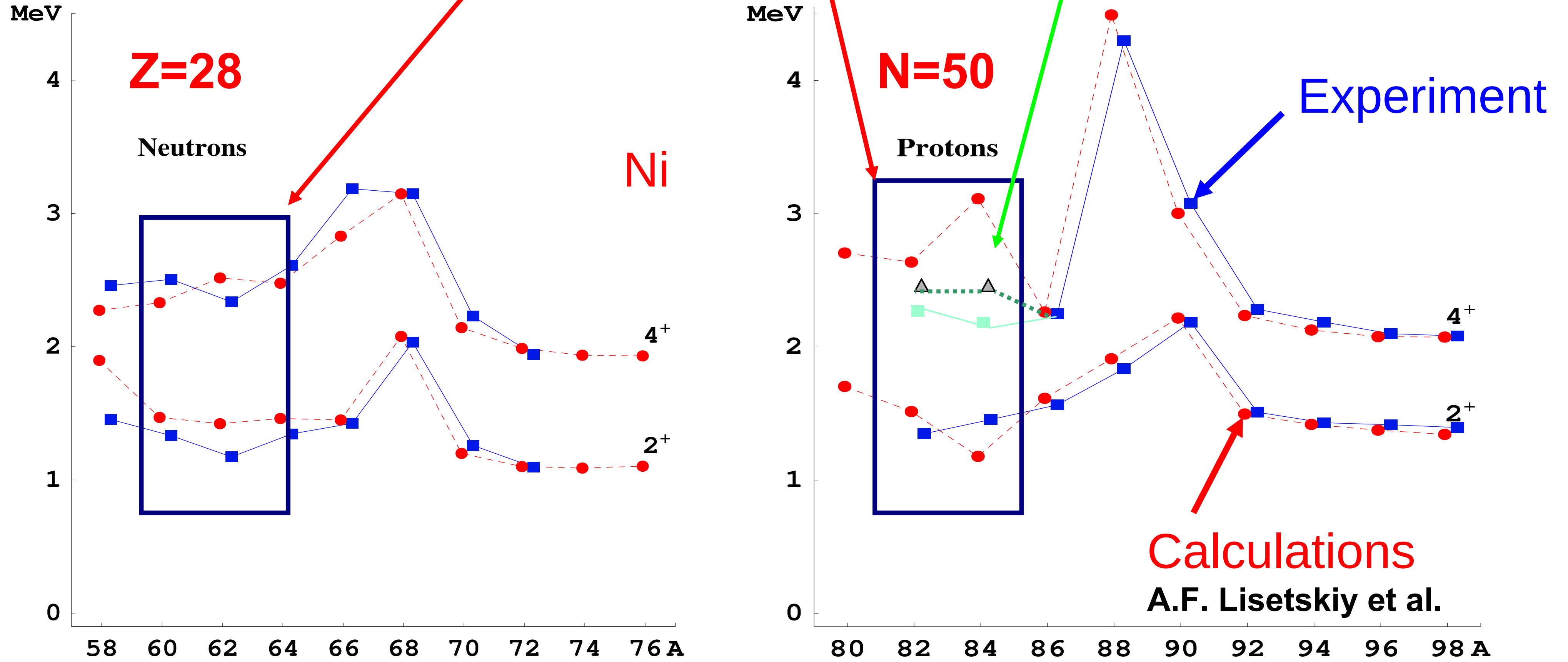
$$\nu g_{9/2} - d_{5/2}$$

across the N=50 gap

Valence Mirror Symmetry restored

Effect on the N=50 shell gap?





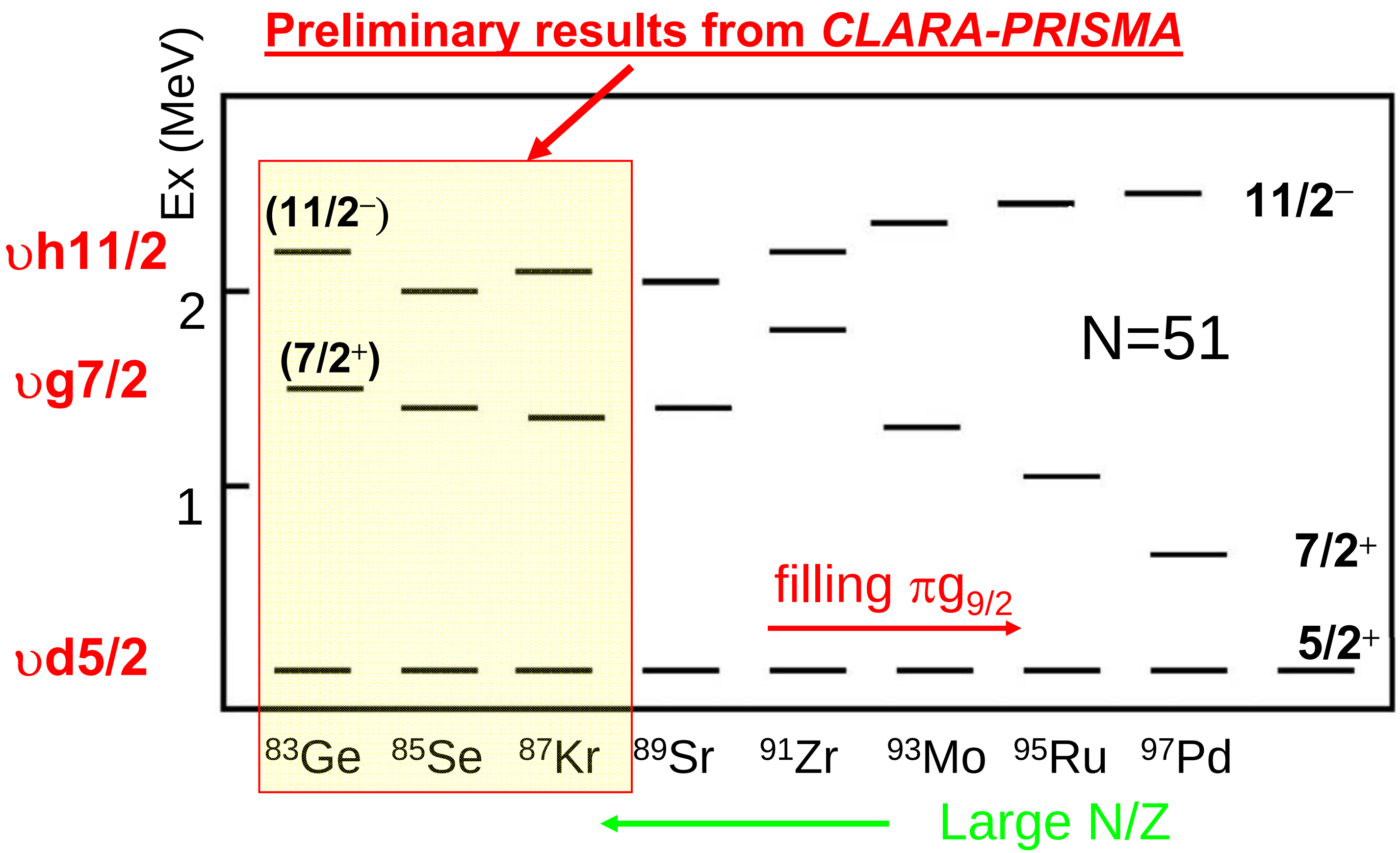
A.F. Lisetskiy, B.A.Brown, M. Horoy, H. Grawe nucl-th0402082 .,

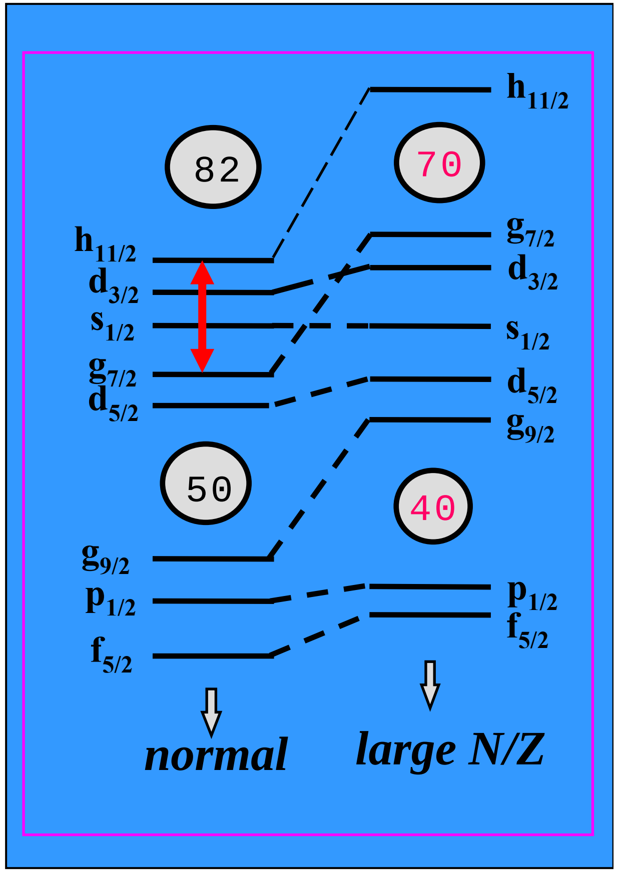
N=51 isotones

Monopole shift of the single particle levels ?

Downward shift of the υ$g_{7/2}$ in proton rich N=51 isotones as π$g_{9/2}$ is filled

The υ$d_{5/2}$-$h_{11/2}$ splitting is "constant" in neutron rich N=51 isotones: it should increase if the *ls* term was getting weaker – No diffused potential?





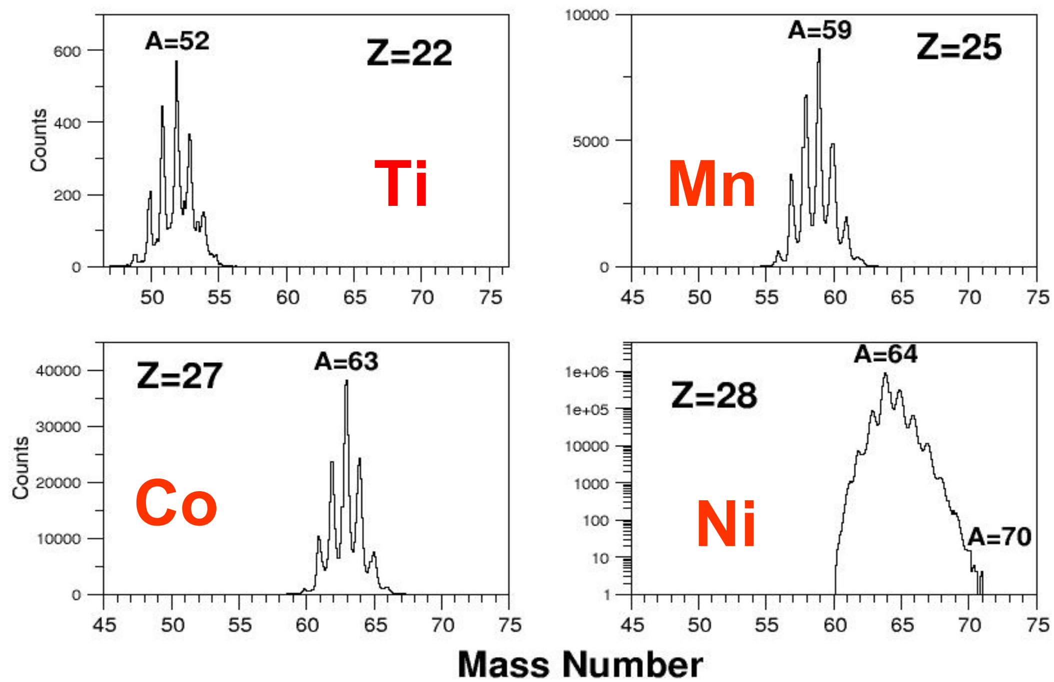
Spectroscopy of deformed neutron rich A ~ 60 nuclei

^{64}Ni 400MeV + ^{238}U

S.M.Lenzi, S.J.Freeman
Analysis: N.Marginean

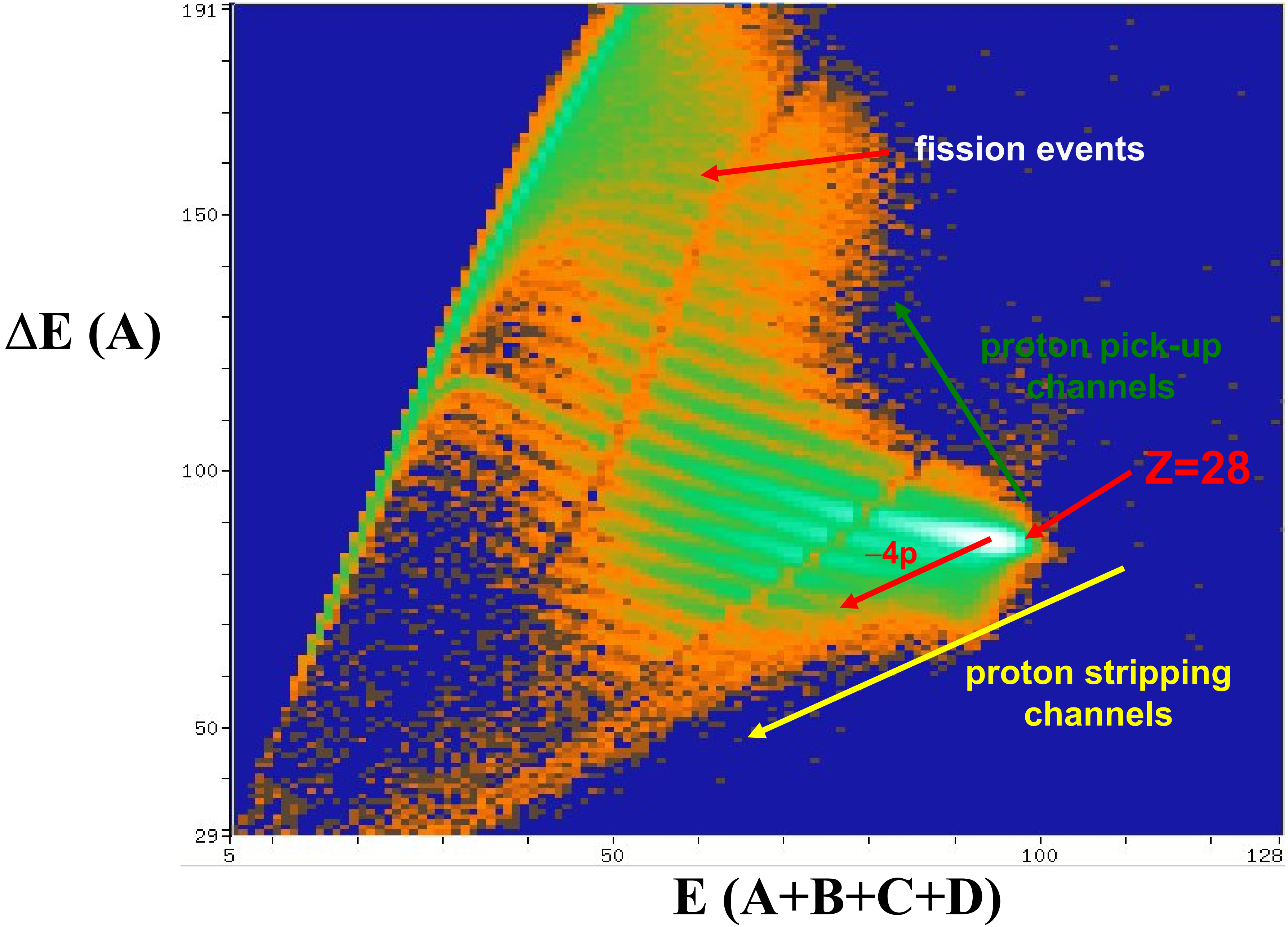
Preliminary (only ½ sorted)

MASS & Z selection

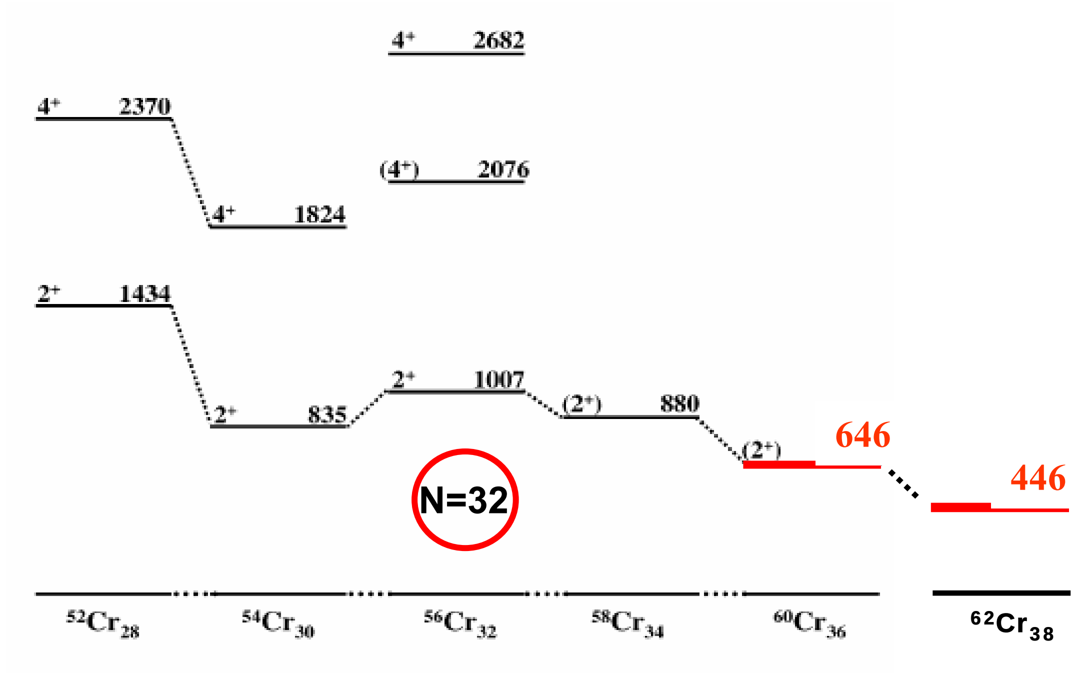


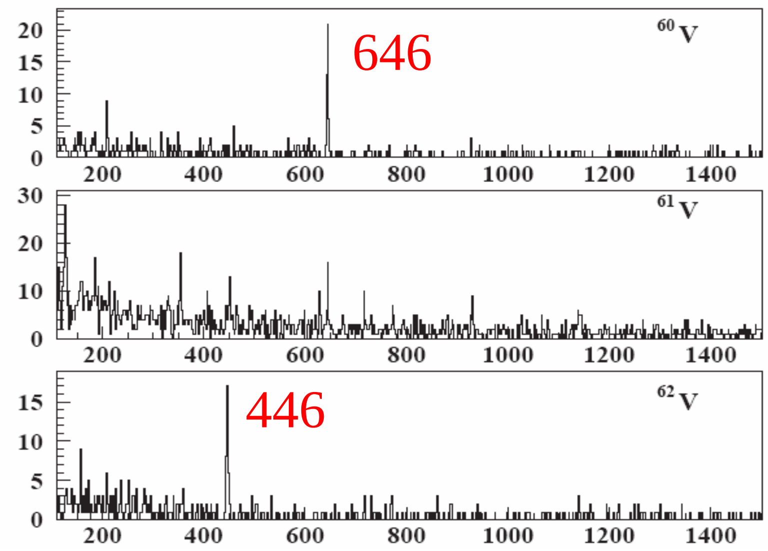
Goal: n-rich <u>A~60 (Cr,Fe &Ti) nuclei</u>, deformation effects in the middle of the $\pi f_{7/2}$ νpf-shell

^{64}Ni 400MeV + ^{238}U IC ΔE-E matrix



Neutron-rich Cr isotopes with N>32: only the 2^+ known from β-decay studies

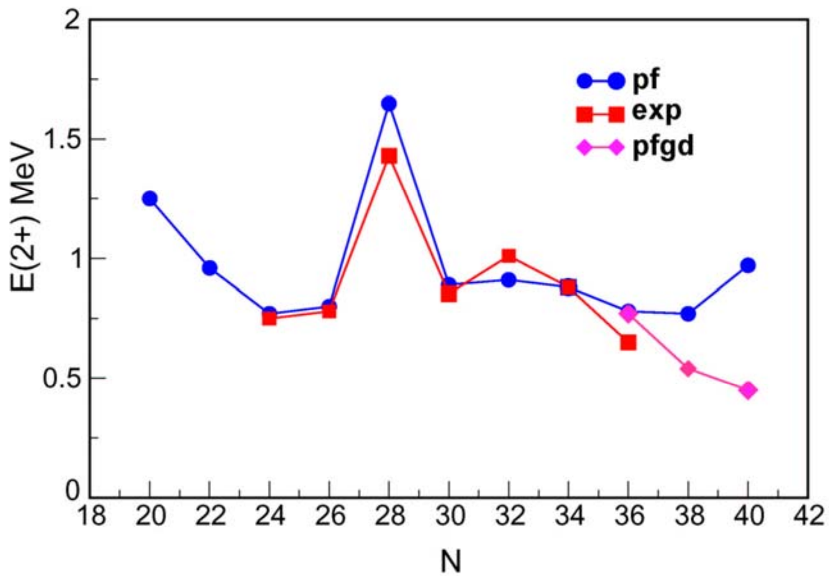




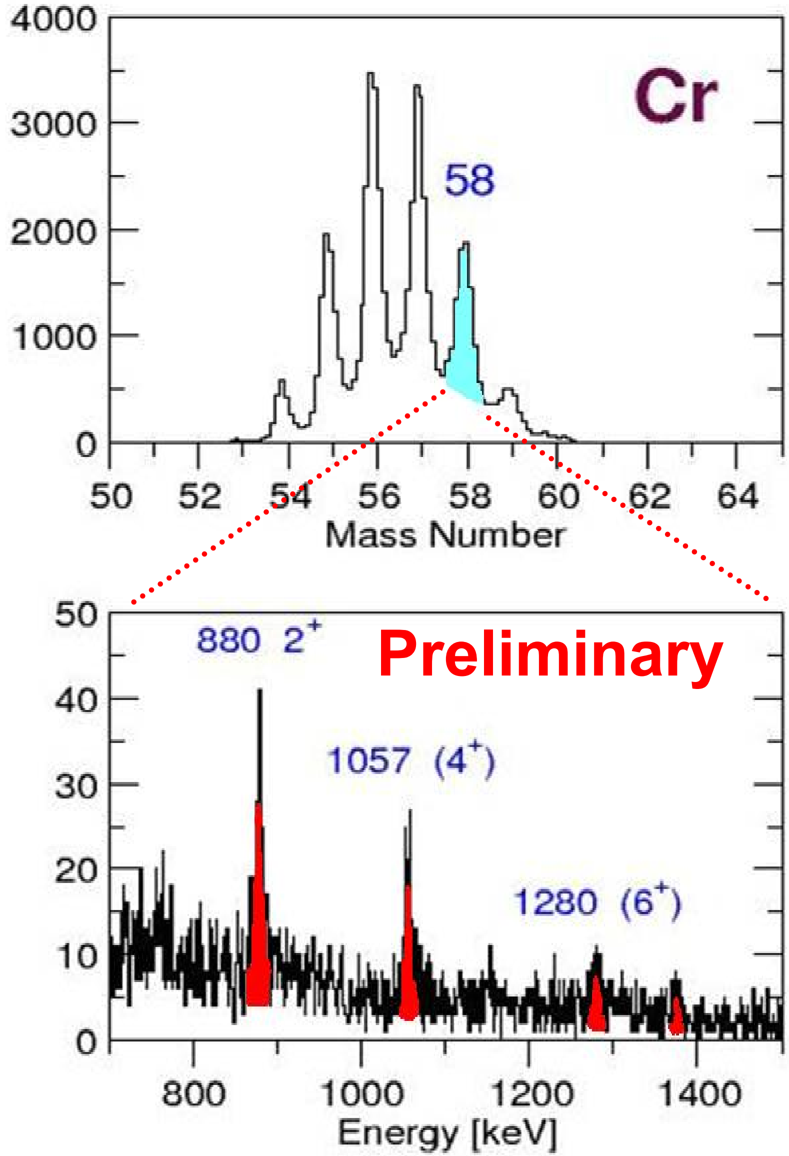
GANIL: O.Sorlin et al.,
Eur. Phys. J. A 16 (2003) 55
MSU: P.F.Mantica et al.,
Phys. Rev. C 67 (2003) 014311

E.Caurier et al.,
Eur. Phys. J. A 15 (2002) 145

LSSM Calculations



^{64}Ni 400MeV + ^{238}U



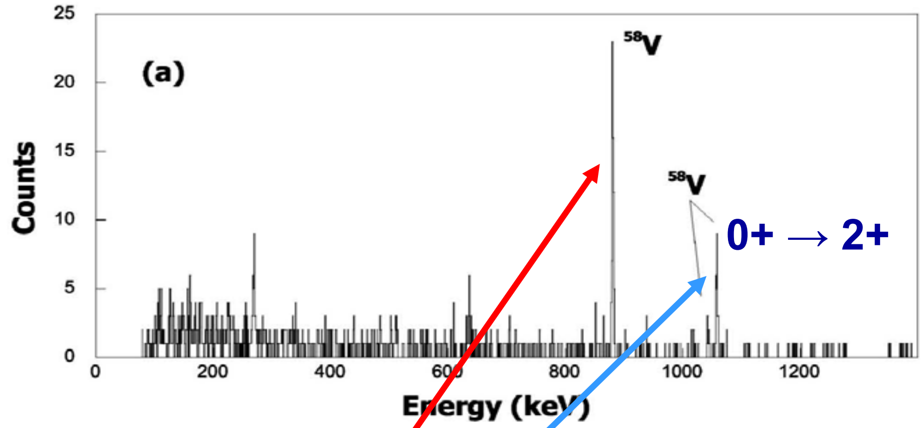


TABLE V. γ rays observed following the decay of ^{58}V.

E_γ (keV)	I_γ^{abs} (%)	Initial state (keV)	Final state (keV)
879.7±0.4	62±7	880	0
1041.2±0.7	8±3		
1056.4±0.5	28±4		
1501.4±0.6	5±2		
1570.6±0.6	5±2		
2216.8±0.7	13±2		

P.F.Mantica et al.,
Phys. Rev. C 67 (2003)014311

From our data the 1056.4 keV transition is the $4^+ \rightarrow 2^+$ member of the yrast cascade. The ^{58}V g.s. is probably 3^+, also predicted at low energies.

Pure fp shell LSSM calculations reproduce the experimental levels in this slightly deformed nucleus

$E_{4+}/E_{2+} = 2.20$

$E_{6+}/E_{2+} = 3.65$

E(5) critical point symmetry

vibrator to
γ-unstable rotor

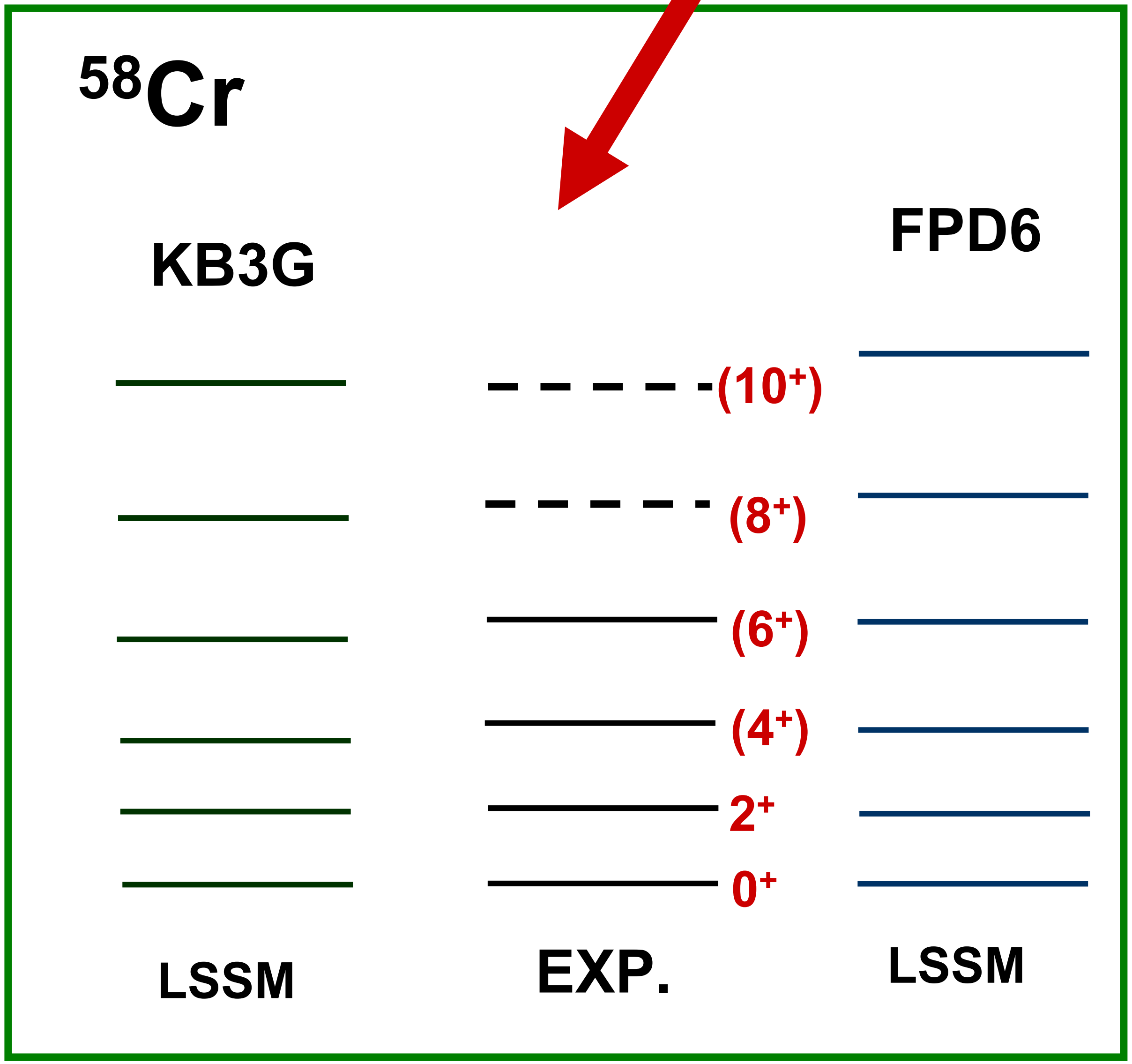
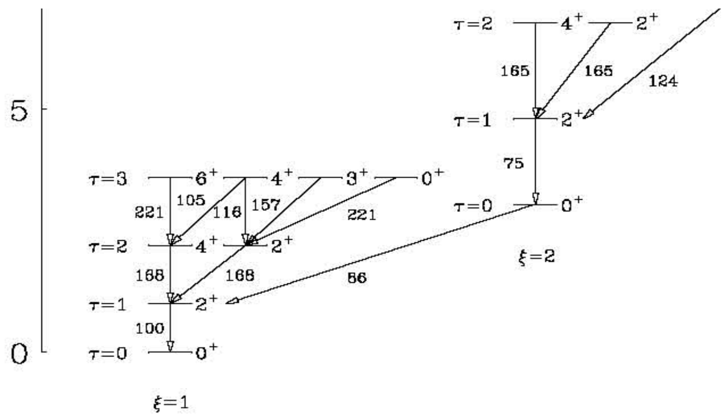


TABLE 1. Excitation energies of the E(5) symmetry.

	$\xi=1$	$\xi=2$	$\xi=3$	$\xi=4$
$\tau=0$	0	3.03	7.58	13.64
$\tau=1$	1	4.80	10.11	16.93
$\tau=2$	2.20	6.78	12.86	20.44
$\tau=3$	3.59	8.97	15.81	24.16

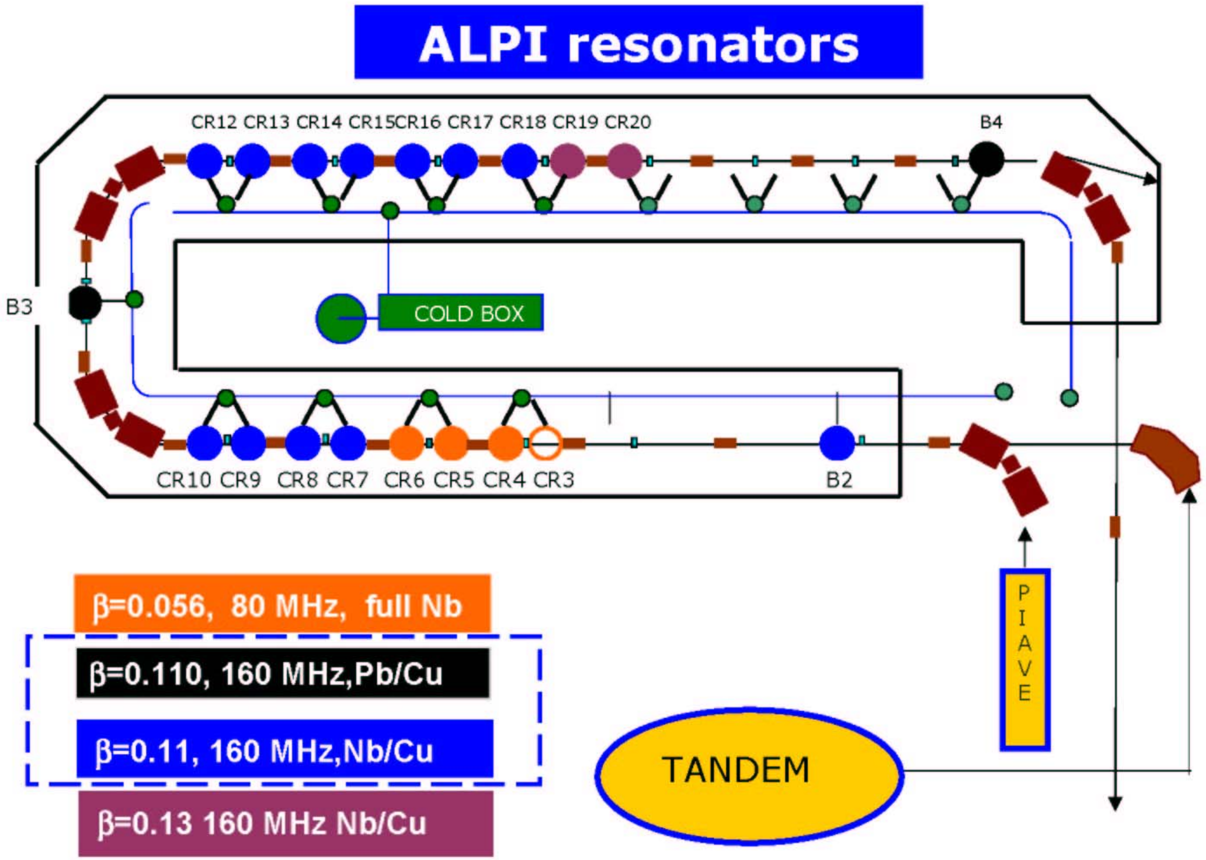


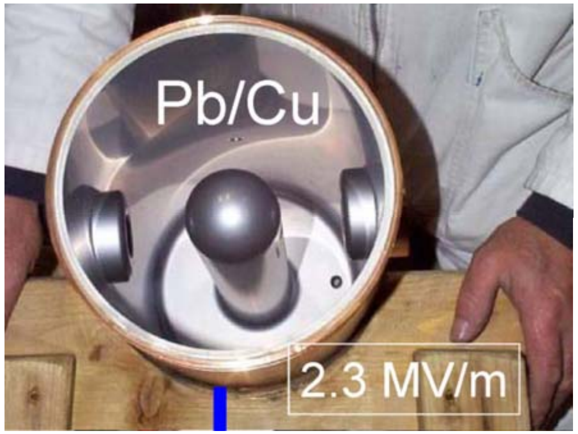
VOLUME 85, NUMBER 17 PHYSICAL REVIEW LETTERS 23 OCTOBER 2000

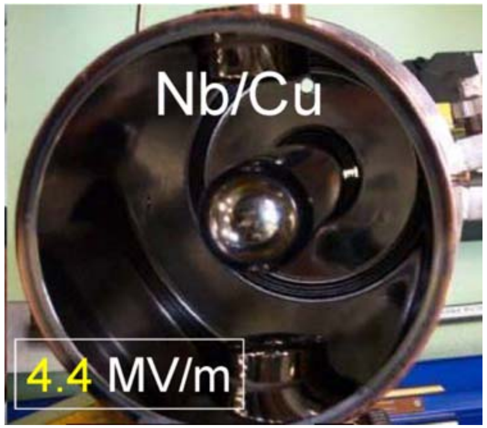
Dynamic Symmetries at the Critical Point

F. Iachello
Center for Theoretical Physics, Sloane Laboratory, Yale University, New Haven, Connecticut 06520-8120
(Received 8 May 2000)

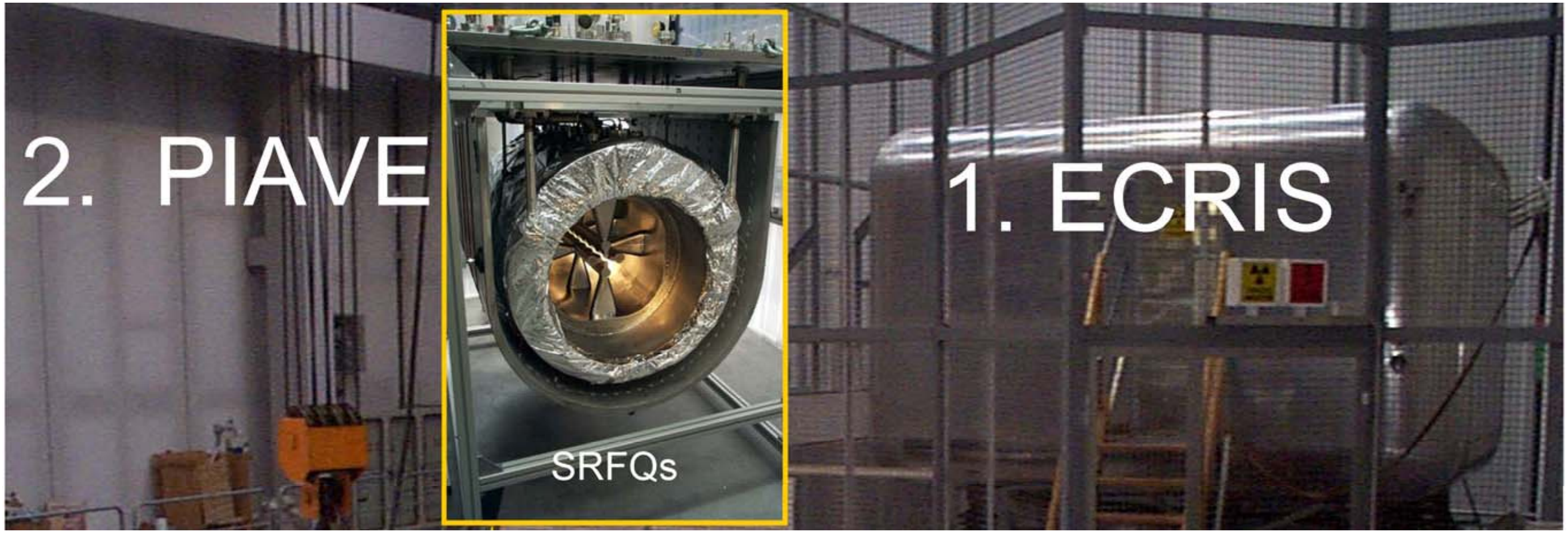
Present at LNL :
Tandem – ALPI beams (therefore Tandem beams) up to A~100. Beam intensities increased up to few pnA (6pnA for 82Se, 4pnA for 90Zr) due to the ALPI energy upgrade (equivalent to ~32MV).

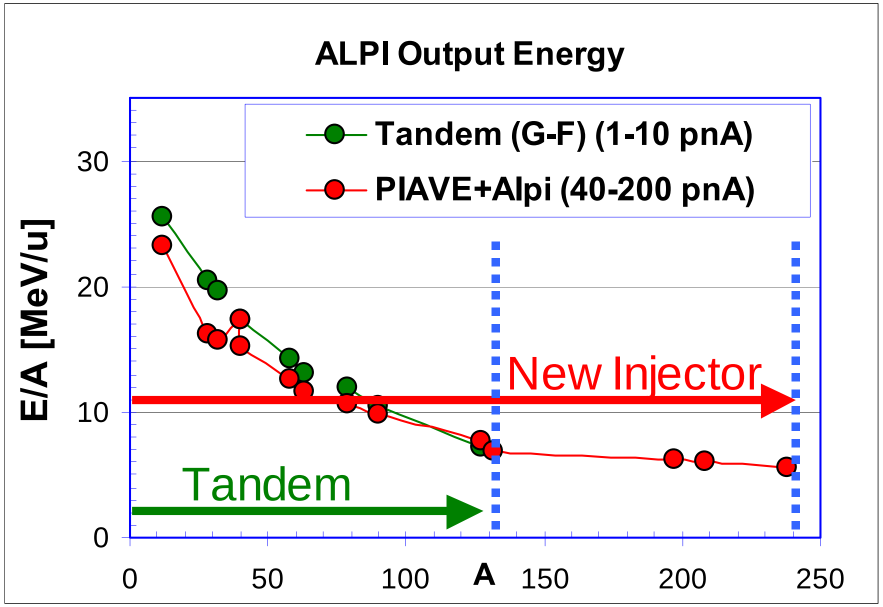






Perspectives:





Positive ion injector ECRIS + PIAVE (commissioning with ALPI expected October 2004). Ar, Kr and Xe (also Ag and Cu) beams during 2005, program to develop Sn, Cd, Sm and Pb beams at the ECR started

Summary

- The CLARA-PRISMA setup consisting on an array of EUROBALL Clover detectors coupled with the large acceptance magnetic spectrometer PRISMA is installed and fully functional al LNL.
- The first preliminary result show the capabilities of such installation in combination with the stable beam delivered by the LNL Tandem-ALPI complex.
- In a single few days experiment ~50 nuclei could be studied.
- At the present stage of the instrument and for most cases, additional experimental information is required to build the level scheme once the transitions are assigned.
- The first results show how experiments with stable beams and instruments as CLARA-PRISMA can contribute to the study of exotic nuclei

The CLARA-PRISMA collaboration

•France

IReS Strasbourg

•U.K.

University of Manchester
Daresbury Laboratory
University of Surrey
University of Paisley

•Germany

HMI Berlin

GSI Darmstadt

•Italy

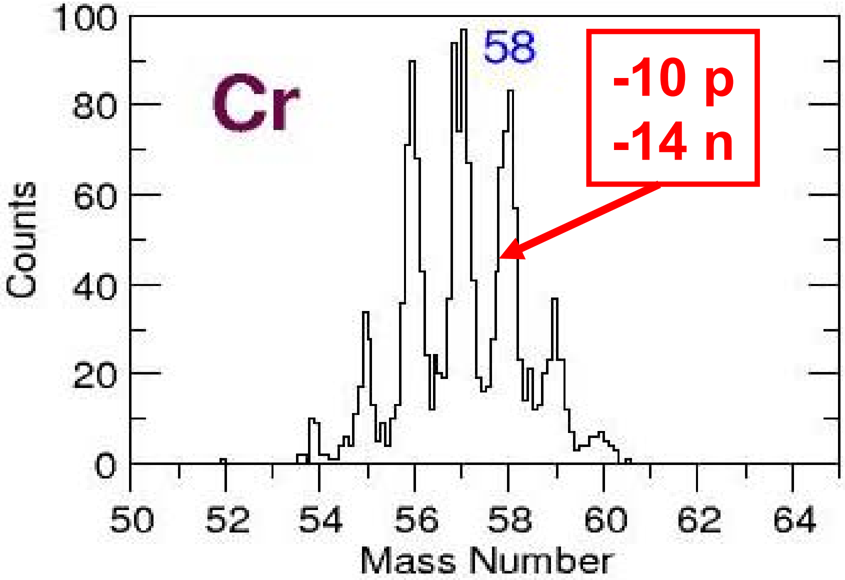
INFN LNL-Legnaro
INFN and University Padova
INFN and University Milano
INFN and University Genova
INFN and University Torino
INFN and University Napoli
INFN and University Firenze
University of Camerino

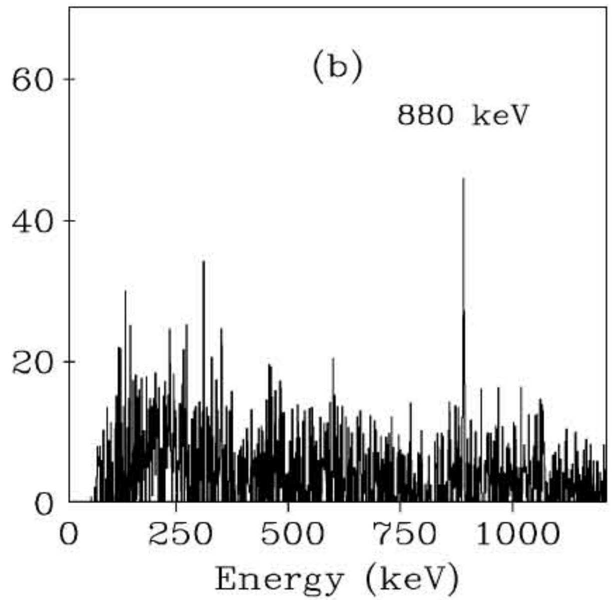
•Spain

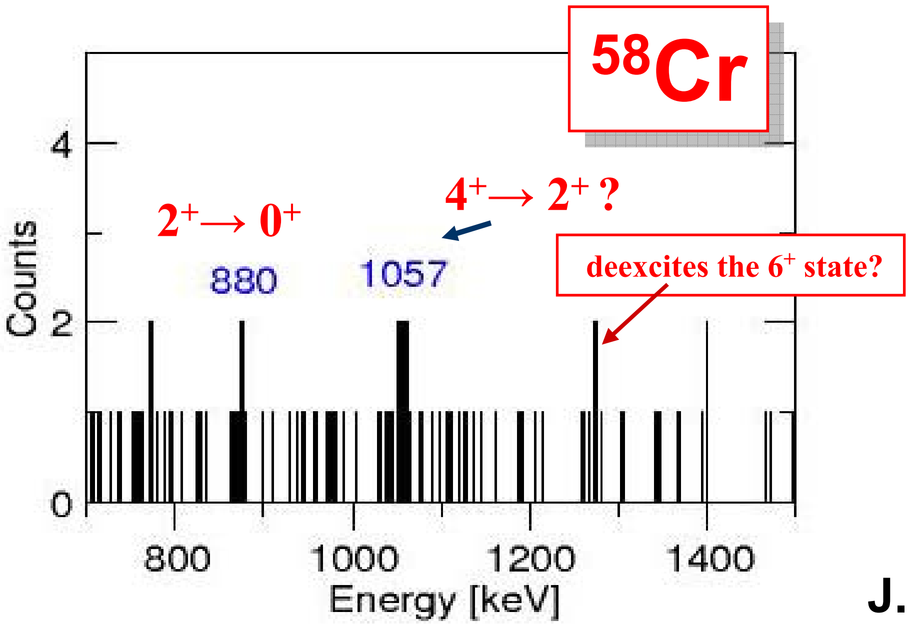
University of Salamanca

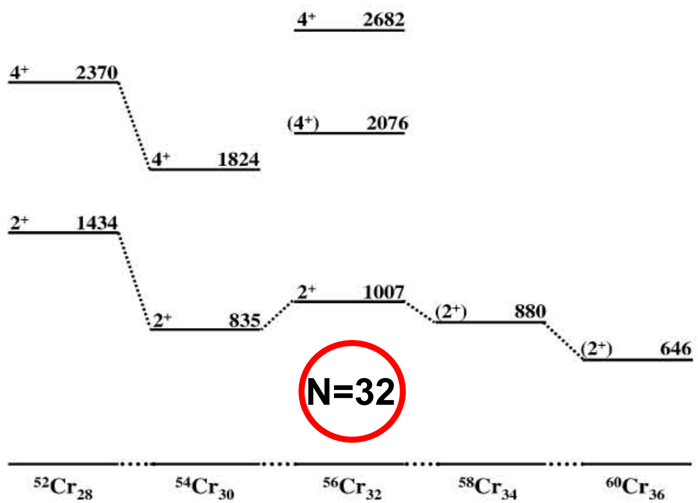
•Romania
Horia Hulubei NIPNE Bucharest

^{82}Se 505 MeV + ^{238}U 24 nucleons removed from projectile





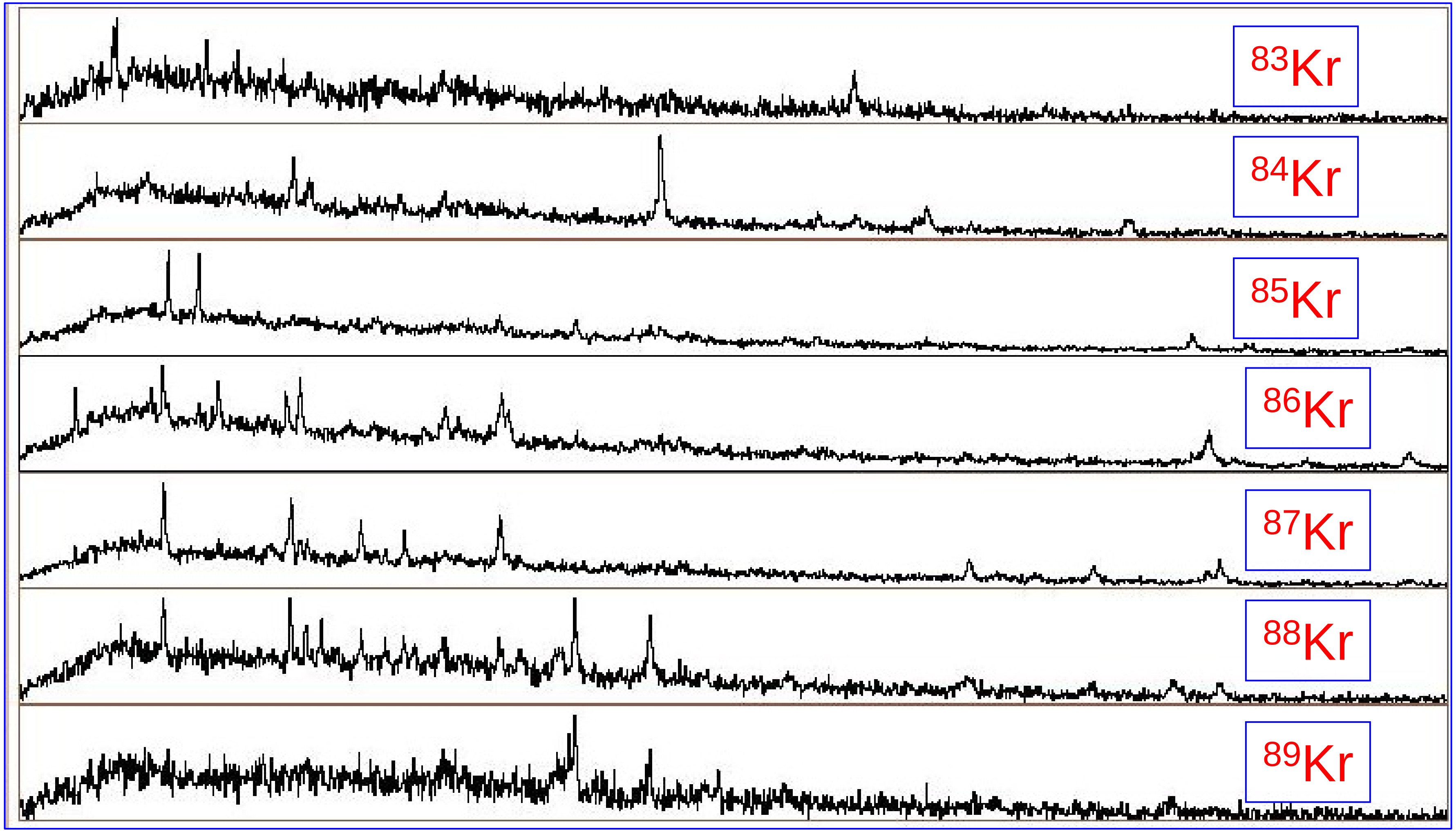




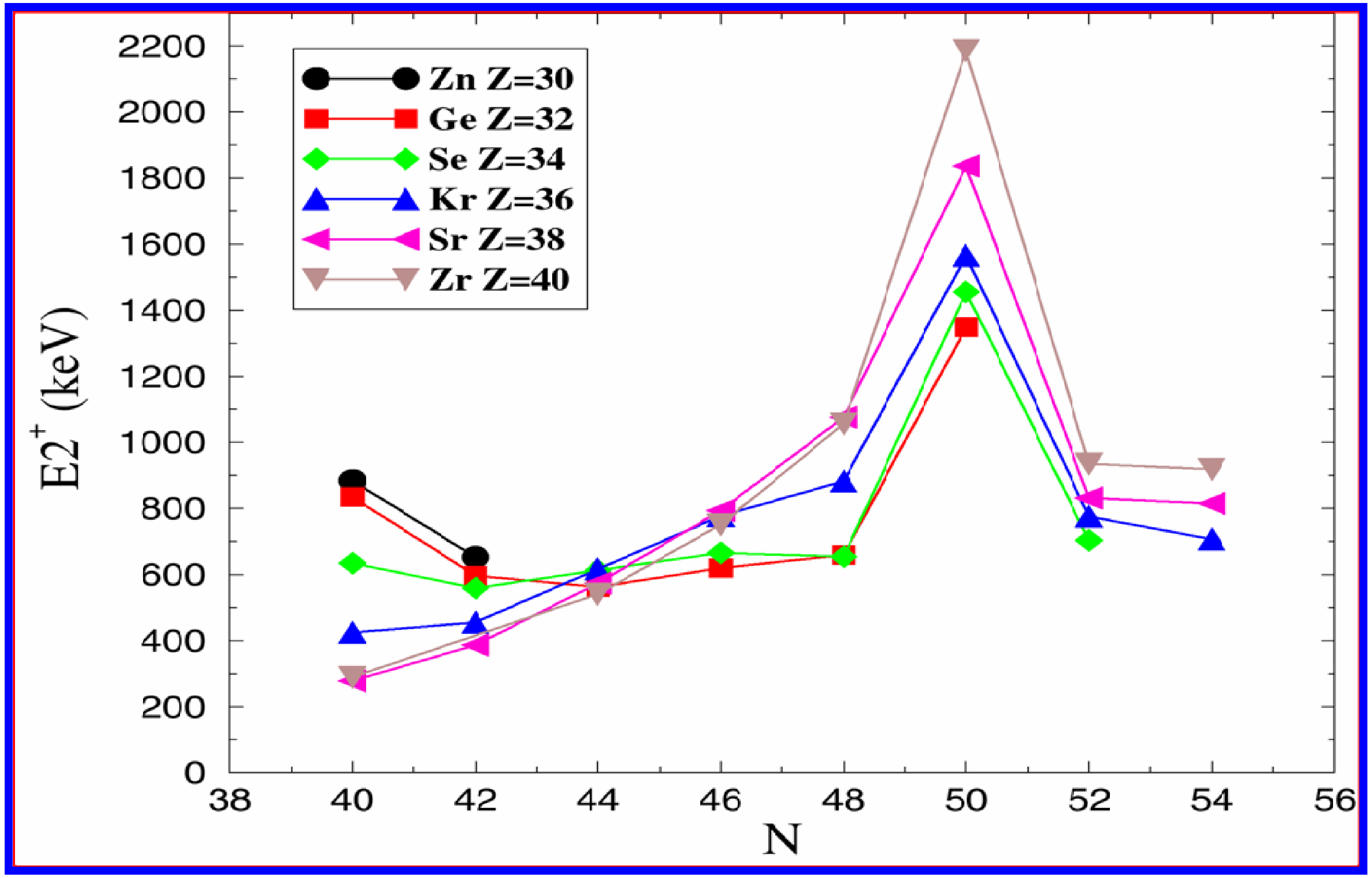
J.I.Prisciandaro et al., Phys.Lett.B 510(2001)17

γ-spectroscopy of neutron rich nuclei

Kr isotopes populated in the 505 MeV ^{82}Se + ^{238}U reaction



The evolution of N=50 shell:



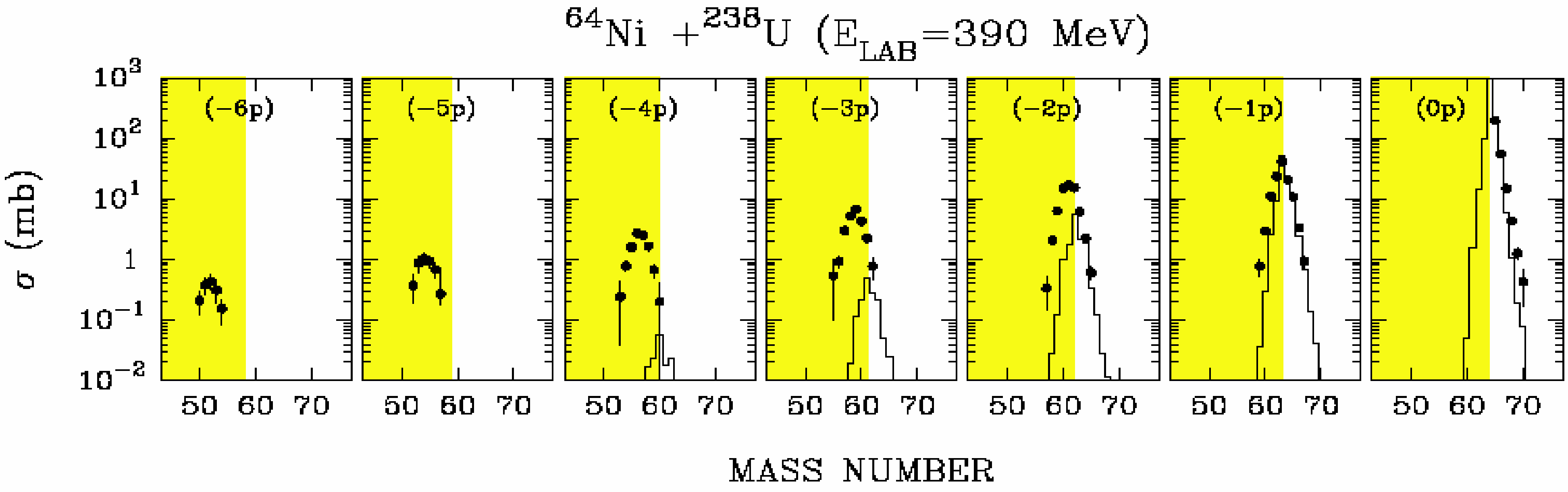
Challenge: extend the systematics of the

2⁺ energies around N=50 to Zn and Ni

PHYSICAL REVIEW C VOLUME 59, NUMBER 1 JANUARY 1999

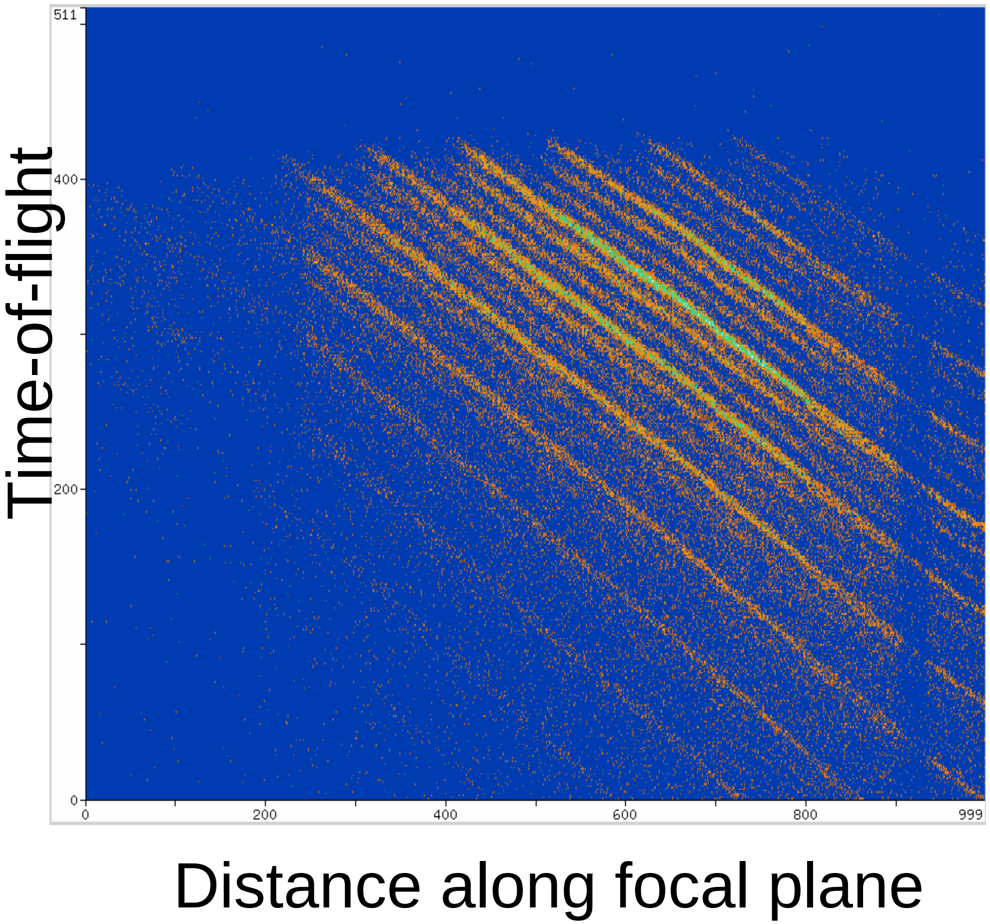
Multinucleon transfer processes in $^{64}Ni + ^{238}U$

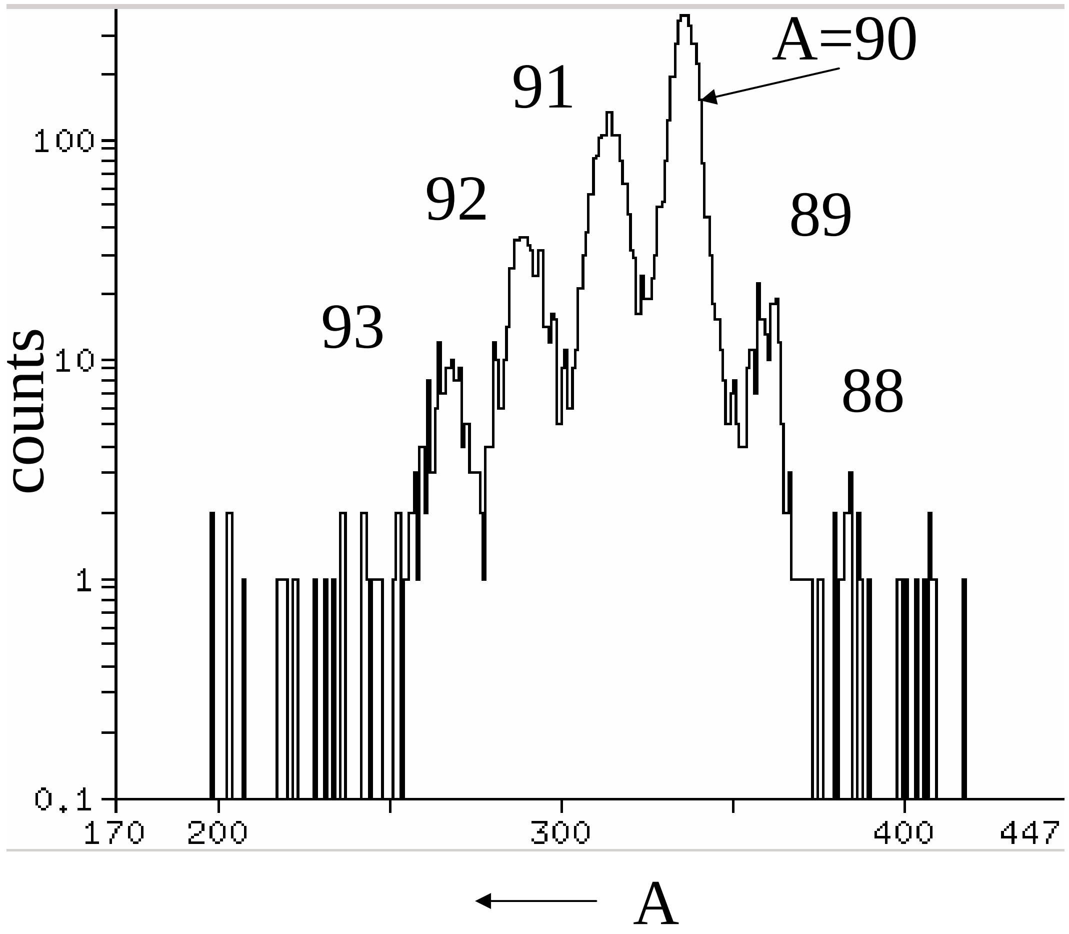
L. Corradi, A. M. Stefanini, and C. J. Lin
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, Via Romea 4, I-35020 Legnaro, Padova, Italy



90Zr 560MeV + 208Pb

Spokesperson: L.Corradi

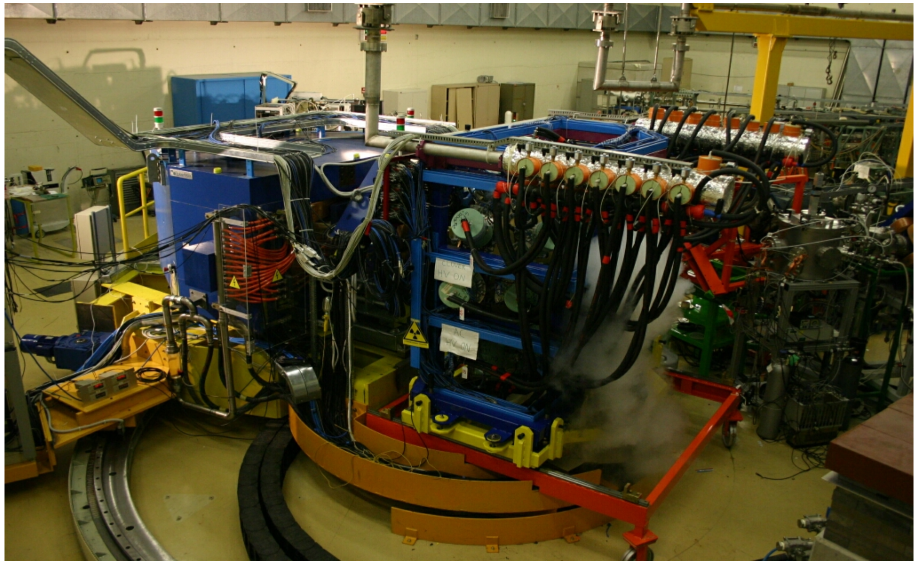


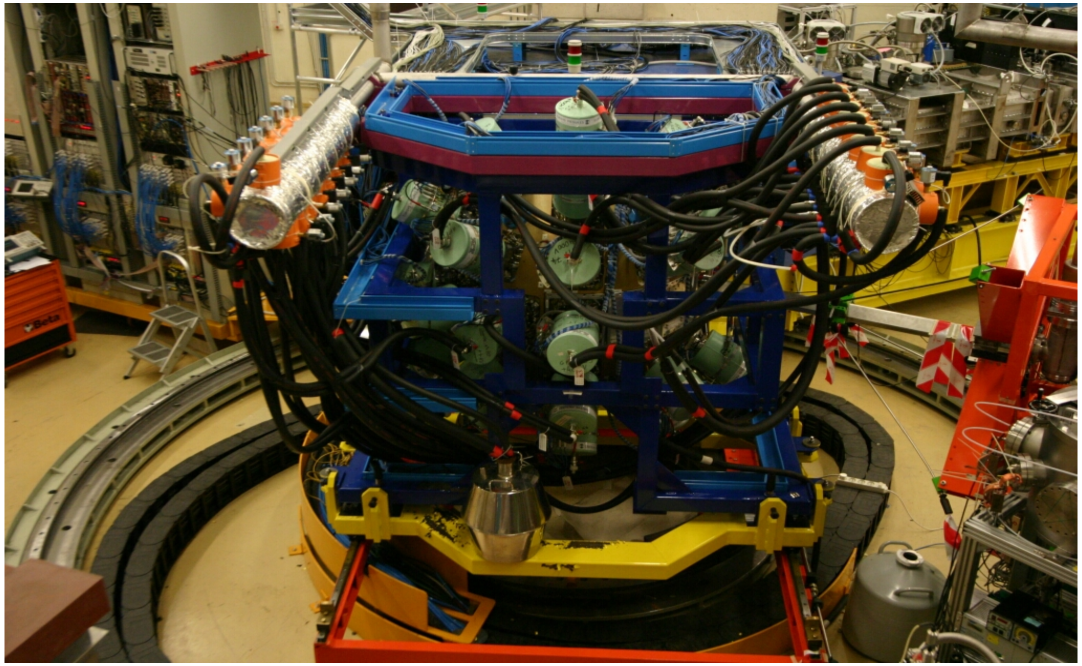


CLARA status

22 CLOVER detectors installed in the frame. Average resolution ~2.3 keV

Experimental P/T ratio ~44%
New beam line mechanics ready.
LN2 Filling system (IReS) stable.





Data acquisition, merging and VXI electronics stable.
DAQ rates ~20KHz at ~50% dead time
GUI (OCP + MIDAS) ready.
HV control system ready
Trigger electronics ready

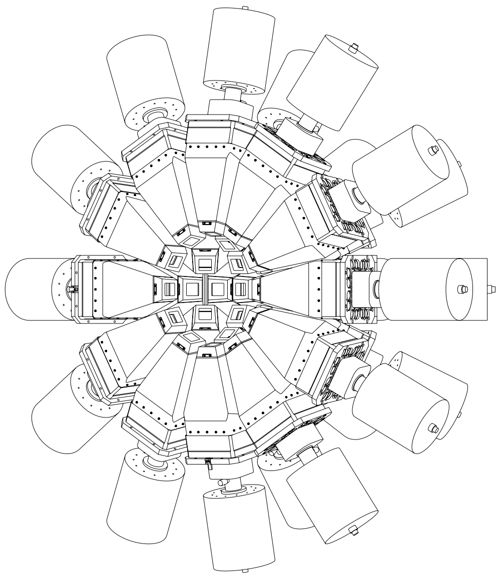
Lifetime measurements with the Clover array at Prisma

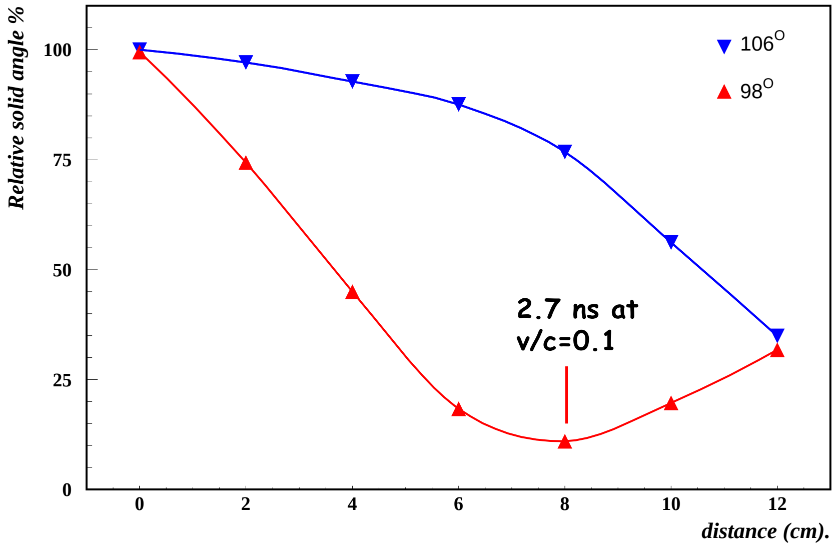
- Recoil Shadow anisotropy method:
  Based on the array-collimator geometry.
  Lifetimes ranging from ~0.5 to ~20 ns.
  E.Gueorguieva et al. NIM A 474 (2001) 132.

- Differential Plunger method (to be developed):
  Needs a degrader foil at different distances form target.
  Lifetimes ranging from ~1 ps to ~1 ns.

- RFD method:
  Developed at the Krakow Recoil Filter Detector.
  Based on the line shape analysis of the Doppler shifted lines and the change of momentum introduced by the straggling of the products in the target.
  Needs an accurate position sensitive detector as the PRISMA start MCP .
  Lifetimes ranging from ~50 fs to ~1 ps.
  P.Bednarczyk, W.Meczynski, J.Styczen et al.

Recoil Shadow Anisotropy Method

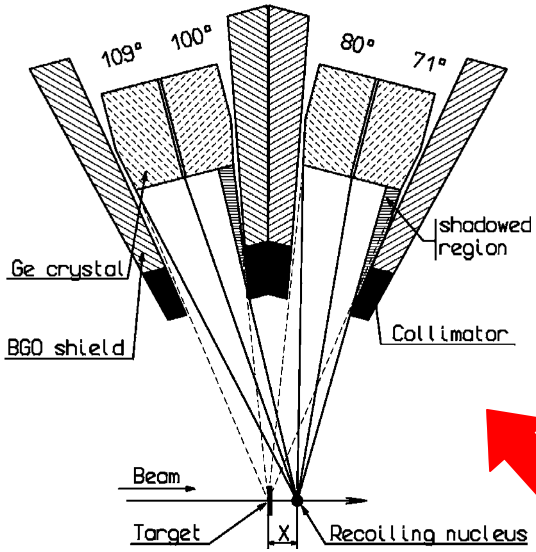


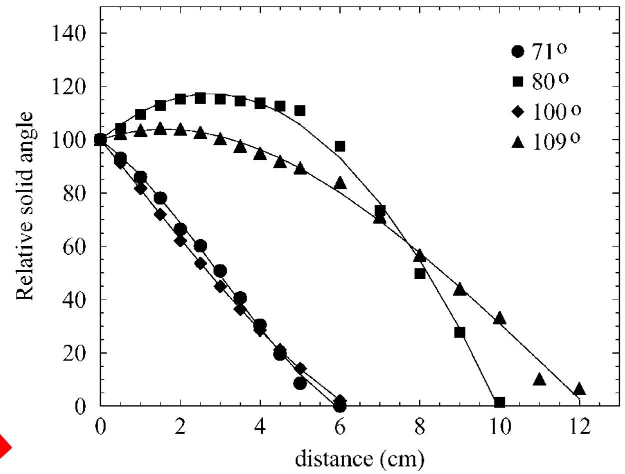


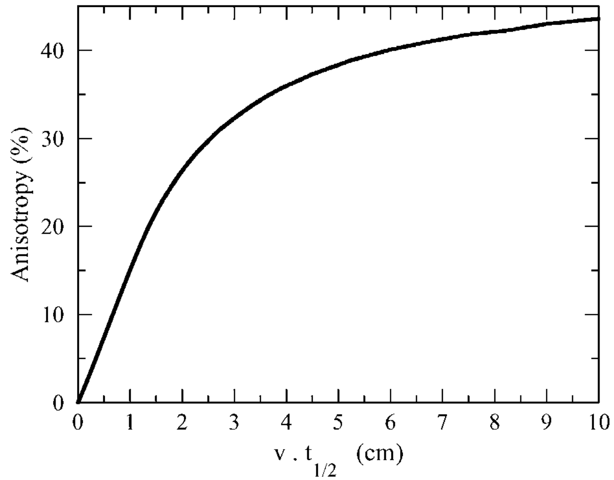
Angles for the Ge crystals of the Clover array ring:

θ = 106 °

θ = 98 °

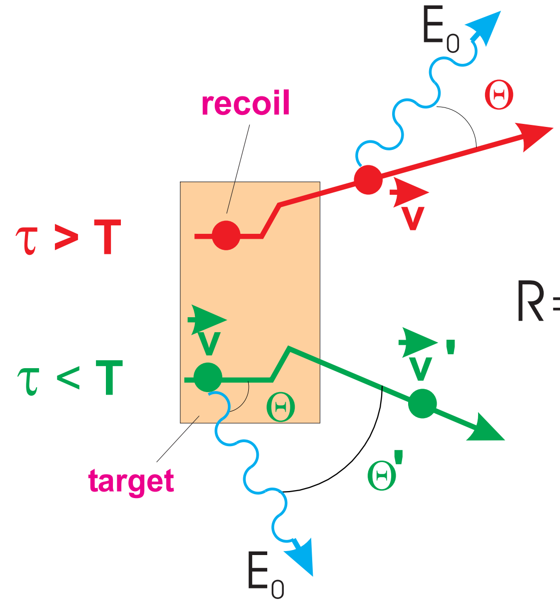




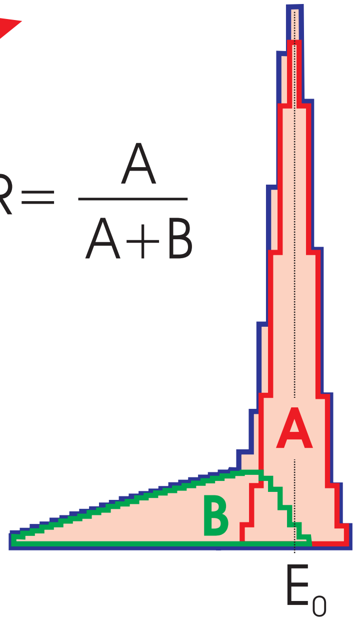


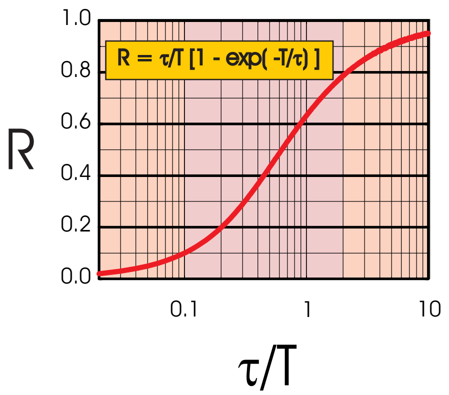
For EUROBALL: **E.Gueorguieva et al. NIM A 474 (2001) 132**

A short lifetime determination with RFD

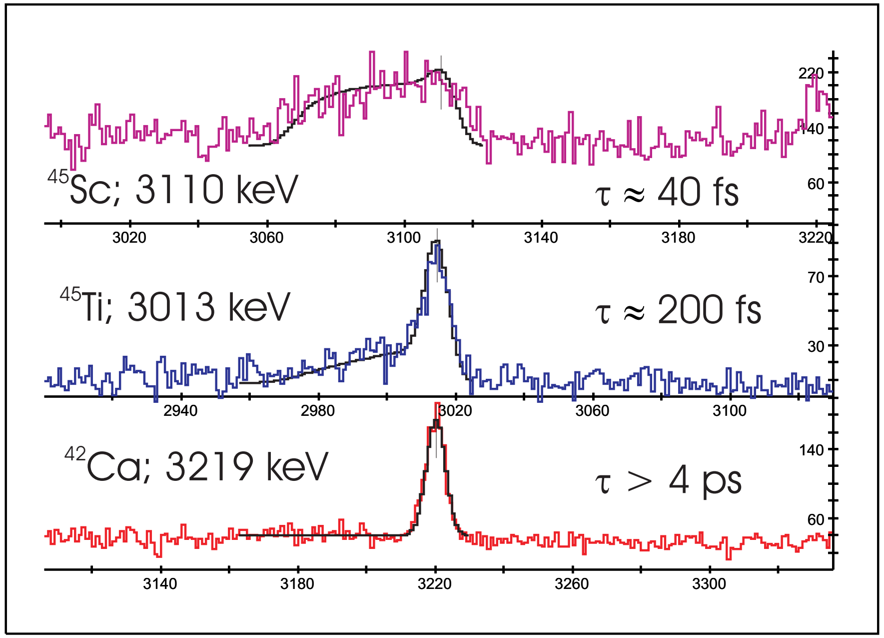


$$R = \frac{A}{A+B}$$





68MeV ^{18}O + 0.8mg/cm^2 ^{30}Si;
Recoil transit time ≈ 0.4 ps



The range of measured lifetimes can be chosen by a selection of the target thickness.

In the measurement τ ranging from 40 to 800 fs could be determined.