

γ spectroscopy with Clara and Prisma at LNL

Daniel R. Napoli

On behalf of the
Prisma – Clara collaboration

Laboratori Nazionali di Legnaro
INFN

γ spectroscopy with Clara and Prisma at LNL

Outline of the presentation

- Laboratori Nazionali di Legnaro dell'INFN
- Nuclear spectroscopy at LNL
- γ - ray spectroscopy of neutron rich nuclei populated in transfer and deep inelastic reactions
- Clara - Prisma setup
- Recent results

Daniel R. Napoli
Laboratori Nazionali di Legnaro
INFN

Laboratori Nazionali di Legnaro

User oriented facility – EURONS (FP6)



Nuclear Physics

Fundamental
Interactions

Interdisciplinary
Physics

Applications
of Nuclear
Techniques

Accelerator
Design

Accelerator
Technology

Superconductivity

Basic research and applications

Laboratori Nazionali di Legnaro

Facilities



+



ALPI - PIAVE



46% INFN,
ENEA, ISS,
Universities

Interdisciplinary
activities and
applications

10.000 hours of beam on target

5500

4500

$p \rightarrow \text{Au}$, from AkeV $\rightarrow$ 20 AMeV, from few pnA $\rightarrow$ few pμA

Tandem – ALPI beams

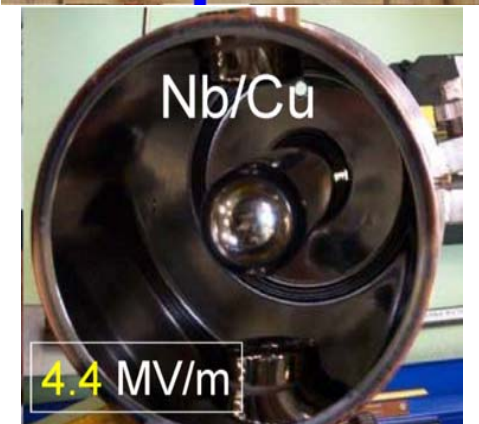
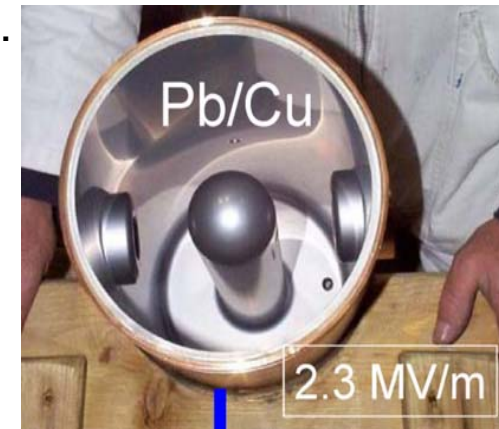
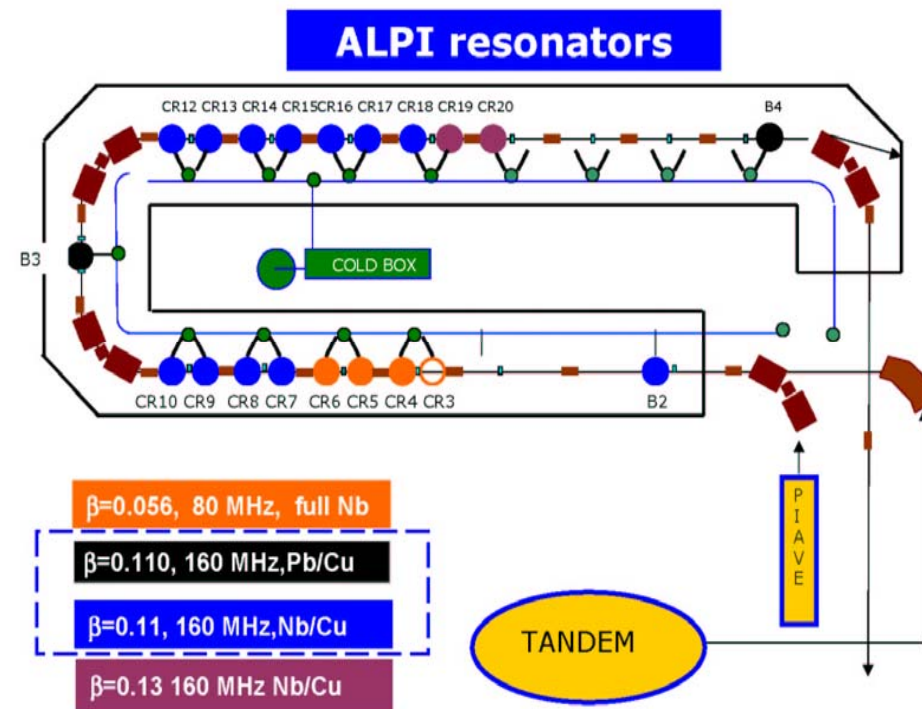
Tandem XTU-Tandem, 15MV. Beams from H (30MeV/amu) up to Au (1.5MeV/amu)

Alpi Superconductive Linac. Beams from Si to Au.

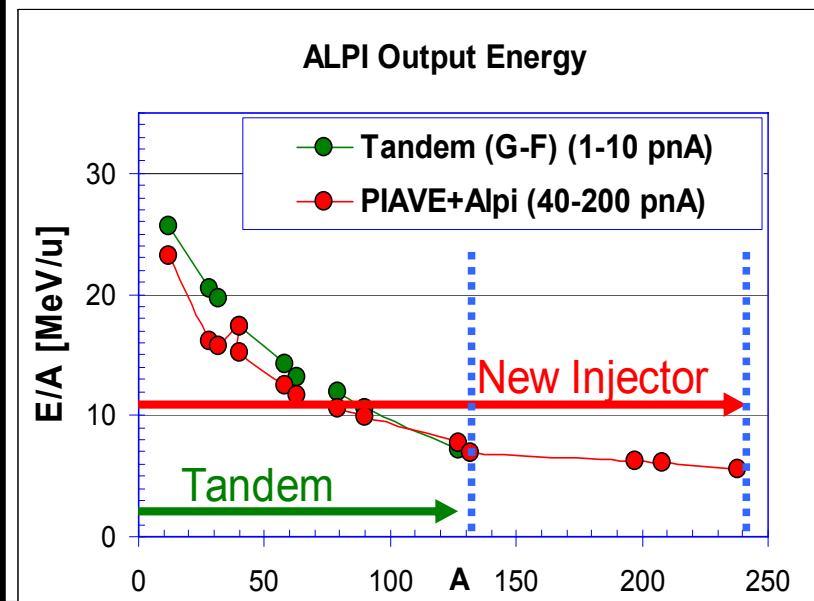
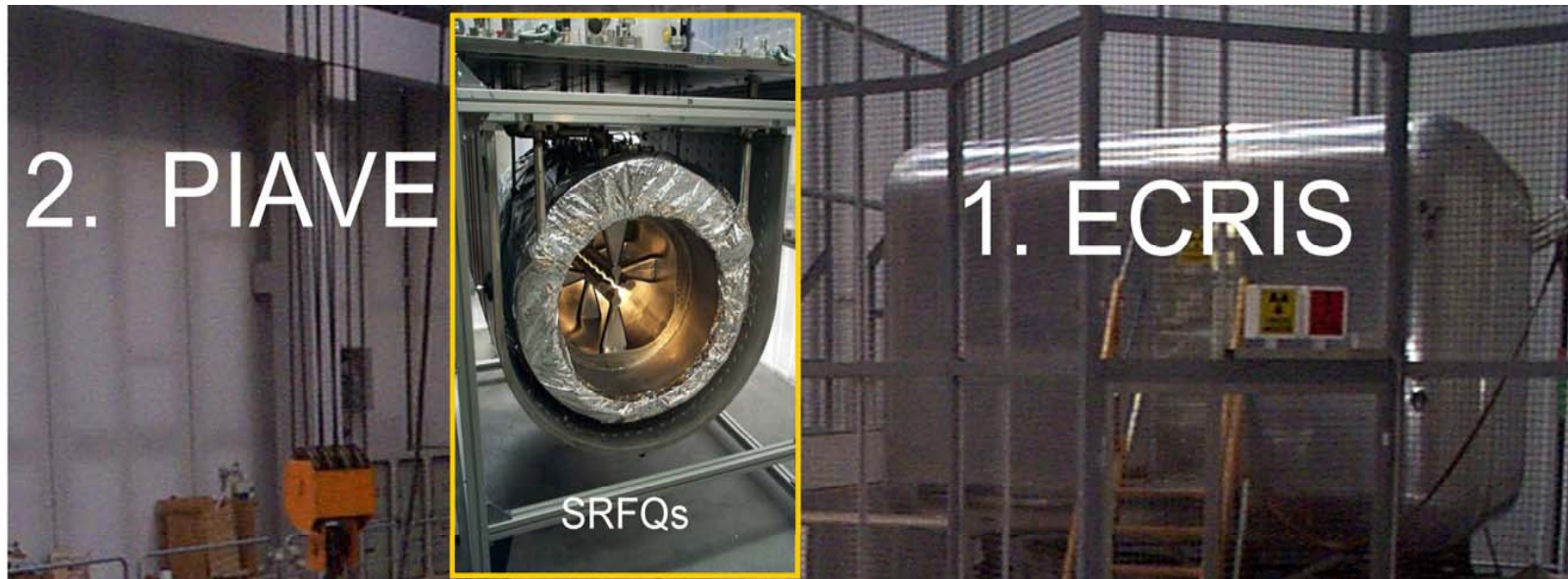
after the upgrade Beam intensities increased up to few pA (6pA for ^{82}Se , 4pA for ^{90}Zr)

Accelerator equivalent potential up to $\sim 32\text{MV}$.

Heavier beams available with the low β cavities.



Piave – Ecris injector



Positive ion injector ECRIS + PIAVE
commissioned with O and Kr beams.
Transmission 40%.

Next step: beam test with heavier beams.
Operational from February 2006 (next
PAC period).

ECR beams: Ar, Kr, Xe, Ag and Cu
Program to develop Sn, Cd, Sm and Pb

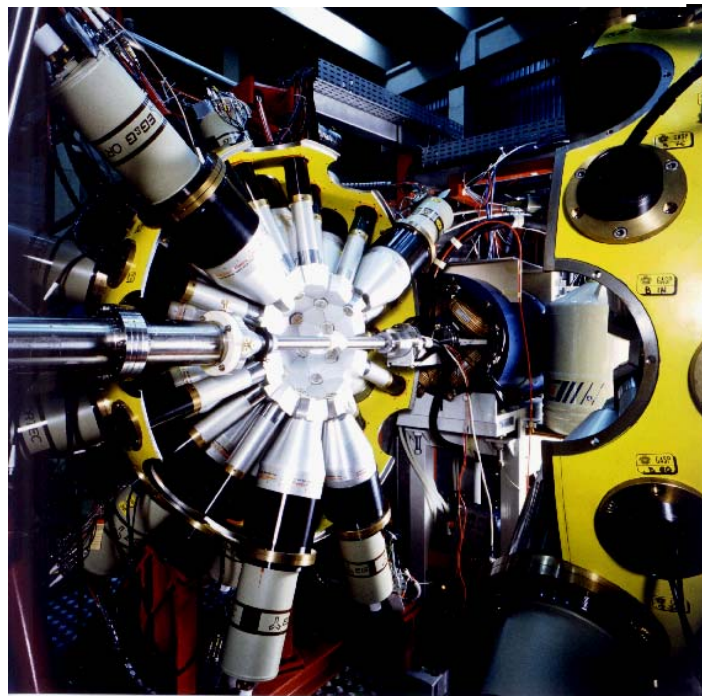
γ spectroscopy with Clara - Prisma at LNL

Nuclear spectroscopy at LNL

- Laboratori Nazionali di Legnaro dell'INFN
- Nuclear spectroscopy at LNL
- γ - ray spectroscopy of neutron rich nuclei populated in transfer and deep inelastic reactions
- Clara - Prisma setup
- Recent results

Daniel R. Napoli
Laboratori Nazionali di Legnaro
INFN

GASP Operational again...

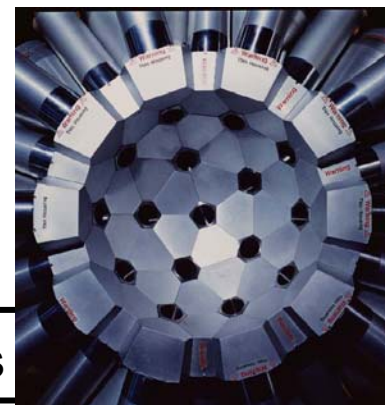


Configuration 1

40 Ge detectors

at 27 cm, $\epsilon_{\text{tot}} = 3\%$

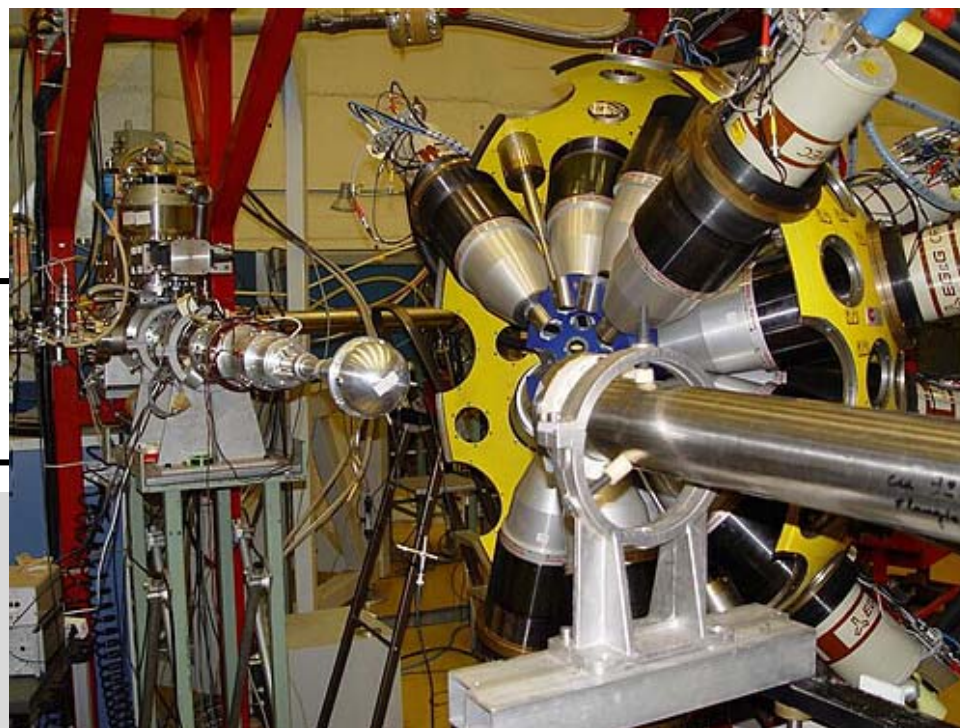
BGO innerball 80 elements



Configuration 2 Ge detectors

at 20 and 24 cm, $\epsilon_{\text{tot}} \sim 5.8\%$

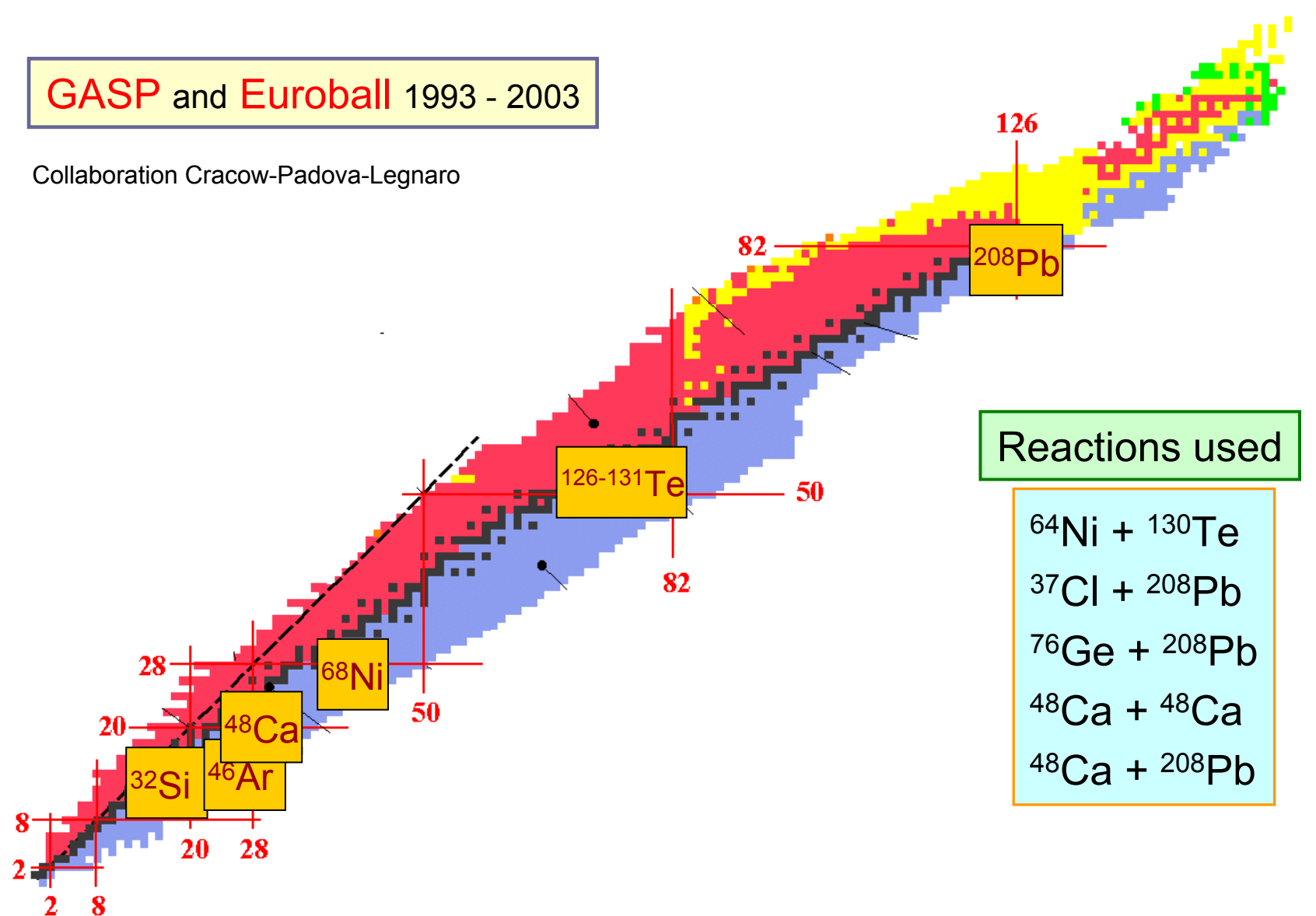
And in combination with:
ISIS, Euclides, neutron detectors,
plunger, RFD, Miniorange, Corset,
etc...



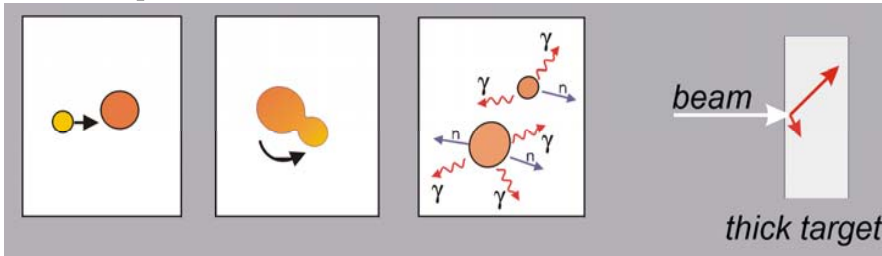
γ -ray studies of Neutron Rich Nuclei Produced in Deep-Inelastic collisions

GASP and **Euroball** 1993 - 2003

Collaboration Cracow-Padova-Legnaro



Deep inelastic reactions



a tool for nuclear spectroscopy

Detecting γ -rays emitted at rest

- no Doppler correction is needed!
- sensitive to the decay of levels which live longer than the stopping time

Identification of new states based on γ -coincidences between the two binary products (cross-coincidences)

Neutron rich heavy projectiles would allow to use transfer reactions as a ΔN - ΔZ filter for driving the multi-nucleon transfer flux to exotic regions

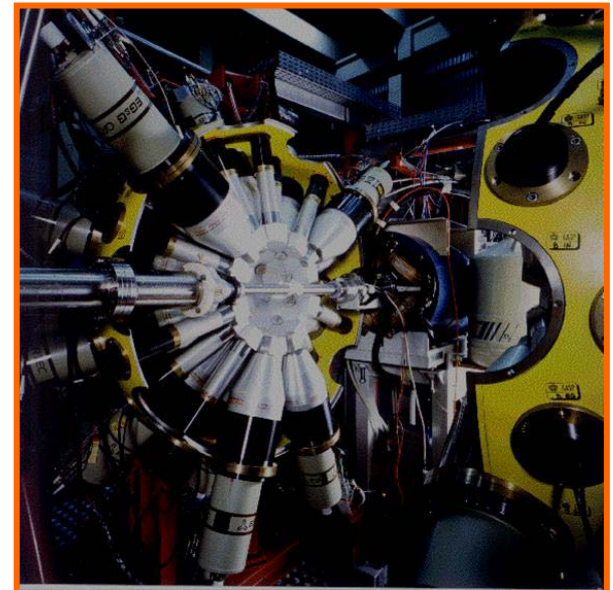
Neutron-rich radioactive beams or beams of heavy ions plus a detection system with good selectivity are needed

Populate high spin states

Rolling limit:

$$L_{TLF} = \frac{2}{7} \left(\frac{1}{1 + (A_B/A_T)^{1/3}} \right) L_{MAX}$$

$$L_{MAX} = \sqrt{\frac{2\mu R^2}{\hbar^2} (E_{CM} - V_C)}$$



γ spectroscopy with Clara - Prisma at LNL

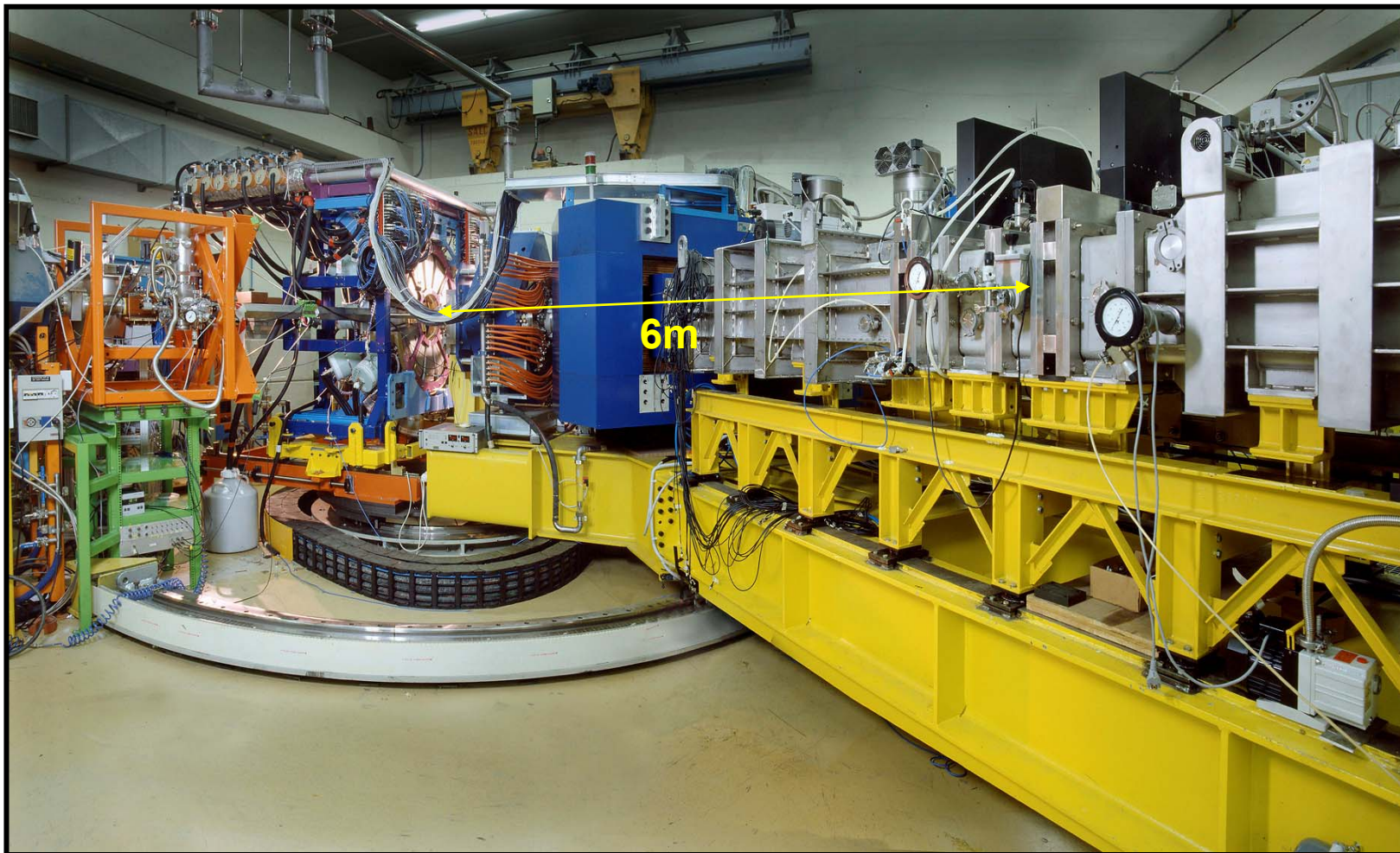
Large acceptance tracking magnetic spectrometer PRISMA

- Laboratori Nazionali di Legnaro dell'INFN
- Nuclear spectroscopy at LNL
- γ - ray spectroscopy of neutron rich nuclei populated in transfer and deep inelastic reactions
- Clara - Prisma setup
- Recent results

Daniel R. Napoli
Laboratori Nazionali di Legnaro
INFN

PRISMA, A.M.Stefanini et al

Large acceptance tracking magnetic spectrometer Q-D



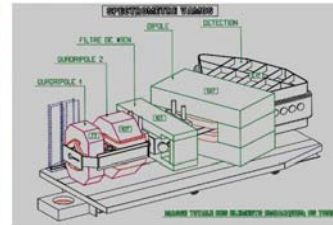
$\Omega = 80 \text{ msr}$, $\Delta Z / Z \approx 1 / 60$, $\Delta A / A \approx 1 / 190$, Energy acceptance $\pm 20\%$ $B_r = 1.2 \text{ Tm}$

Design Characteristics of PRISMA

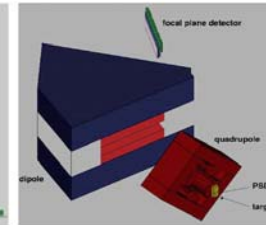
Other magnetic spectrometers



PRISMA



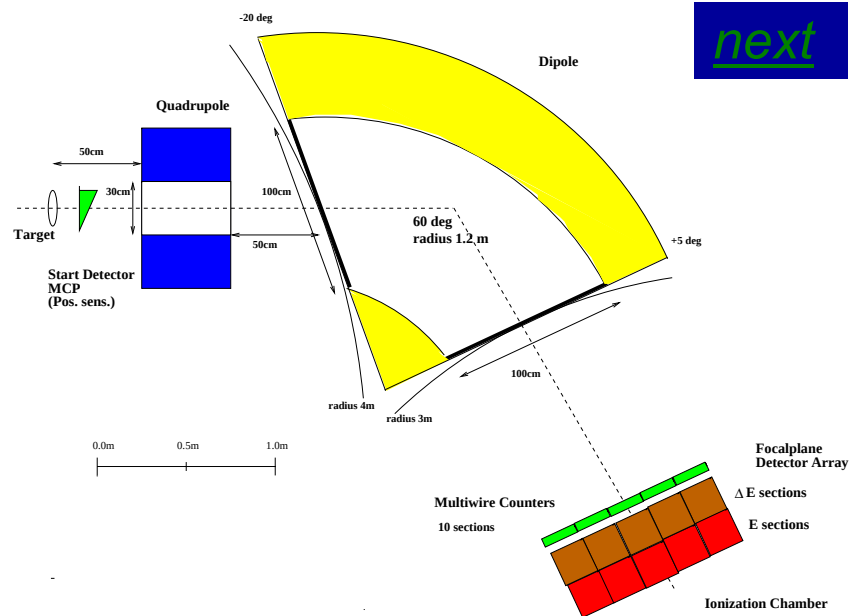
VAMOS



MAGNEX

Solid Angle (msr)	80	100	52
Target-FPD (m)	7	7.3	5.8
Dispersion (cm/%)	4	2.5	3.8
Momentum acceptance	±10%	±5%	±10%
Max Rigidity T·m	1.4	1.6	1.8

particle identification with PRISMA



MCP Start Detector
X, Y & T_I

C foil
20 $\mu\text{g}/\text{cm}^2$ thick

Q

Dipole

Singlet quadrupole focuses vertically the ions towards the dispersion plane.

Magnetic dipole bends horizontally the ions with respect of their magnetic rigidity $B\rho$

MWPPAC Detector
10 sect. X, Y & T_E

Mylar foils
1.5 μm thick

Ionisation Chamber
10x4 sect. DE - E

γ spectroscopy with Clara - Prisma at LNL

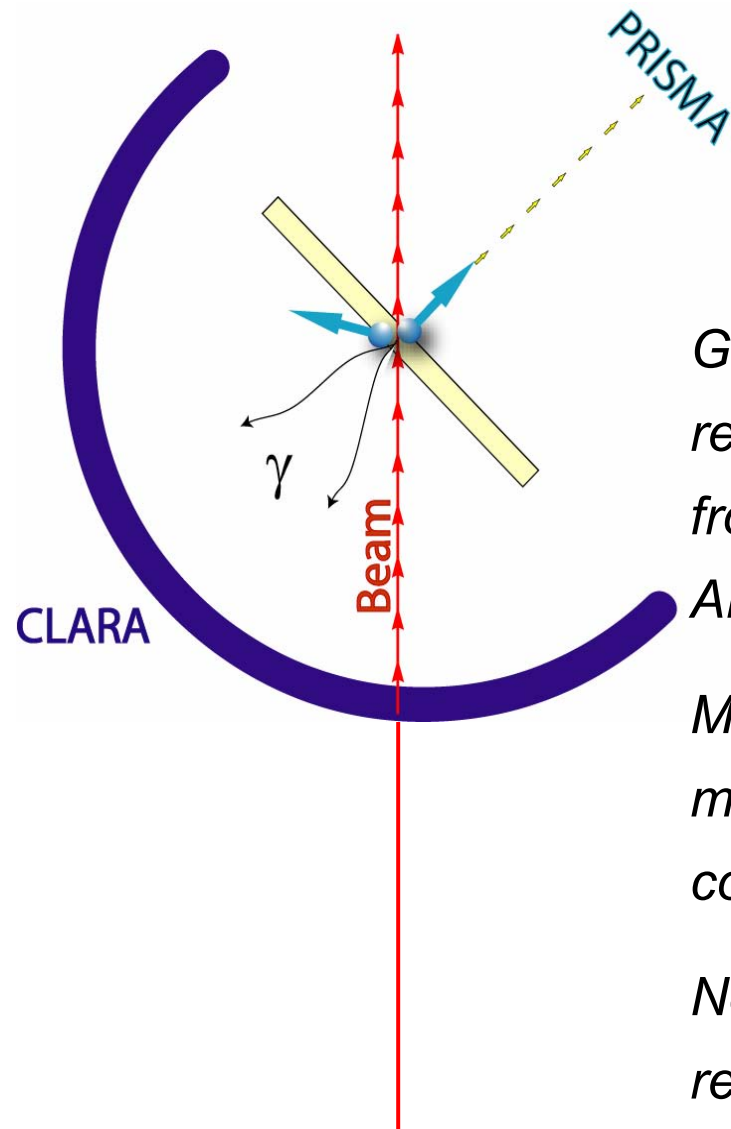
CLARA

- Laboratori Nazionali di Legnaro dell'INFN
- Nuclear spectroscopy at LNL
- γ - ray spectroscopy of neutron rich nuclei populated in transfer and deep inelastic reactions
- Clara - Prisma setup
- Recent results

Daniel R. Napoli
Laboratori Nazionali di Legnaro
INFN

CLARA – PRISMA proposal

A. Gadea (INFN-LNL Legnaro) et al.



Gamma Spectroscopy in products of binary reactions with the “intense” stable beams from the LNL Tandem-ALPI and PIAVE-ALPI

Moderately neutron rich nuclei produced by multi-nucleon transfer or deep inelastic collisions

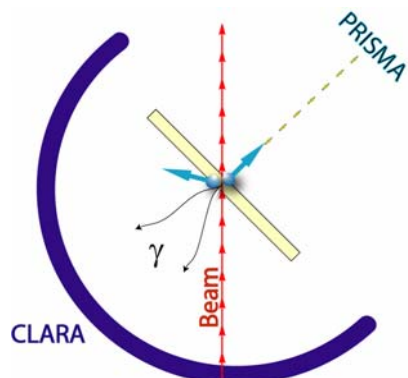
Non-Yrast states populated in quasi-elastic reactions

CLARA

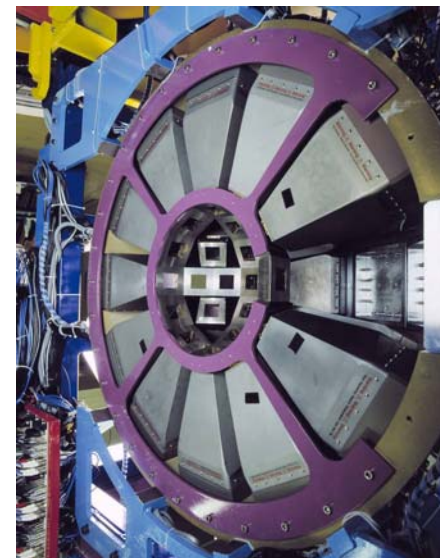
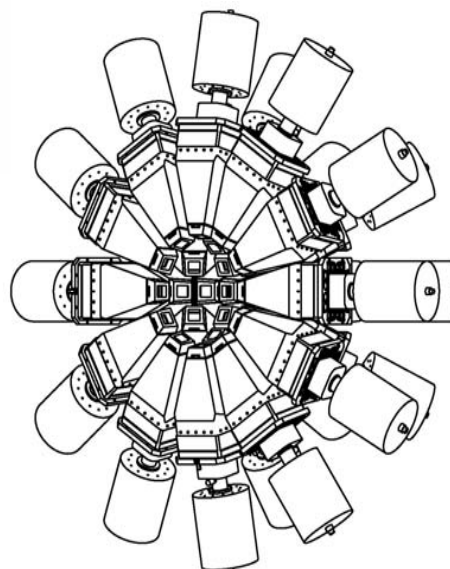
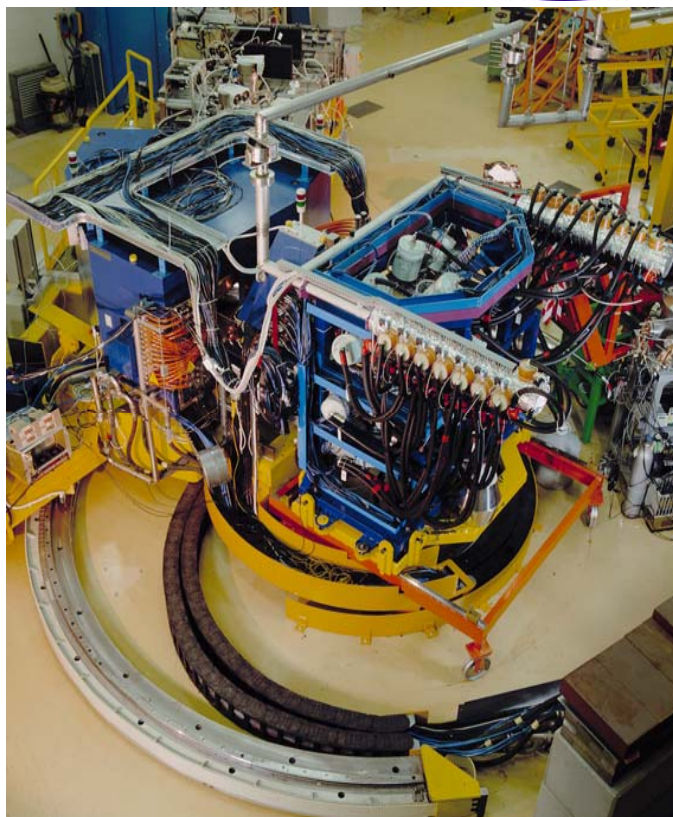
2π coverage

AC BGO shields

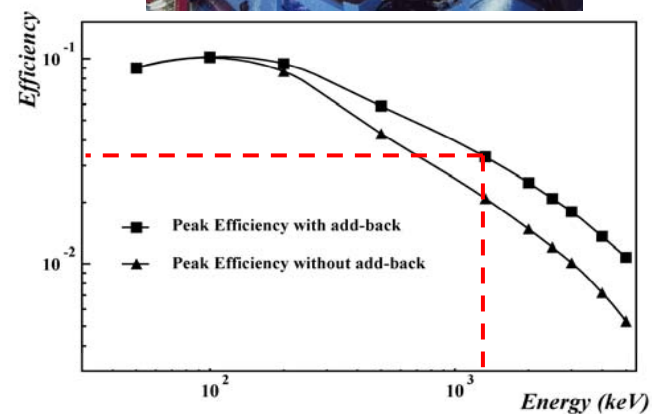
High granularity



25 Euroball Clover detectors placed at backward angles respect to the optical axis of PRISMA



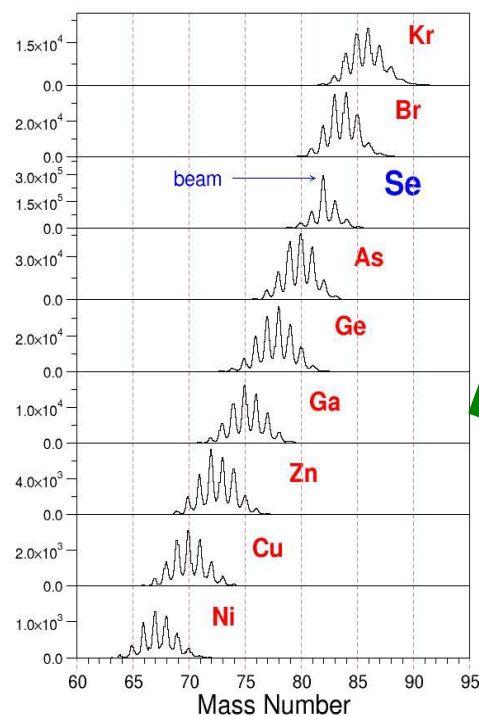
Italy
France
Germany
UK
Romania
Spain



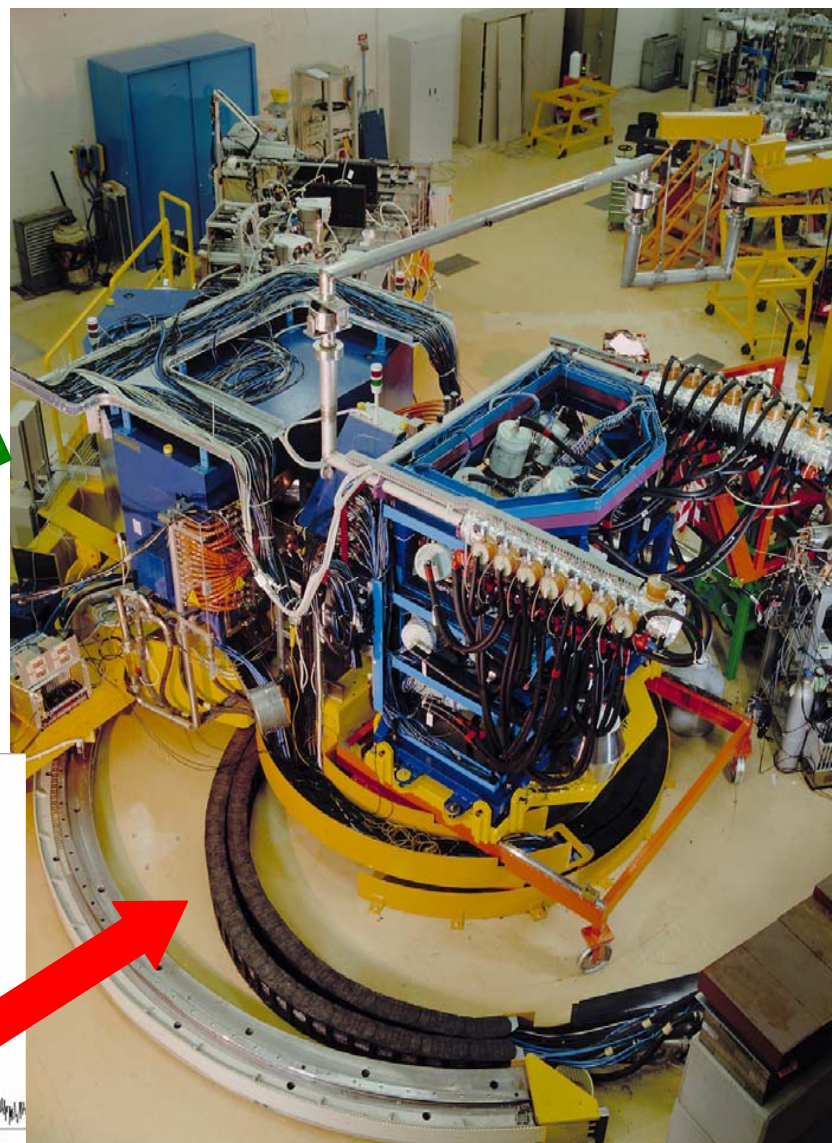
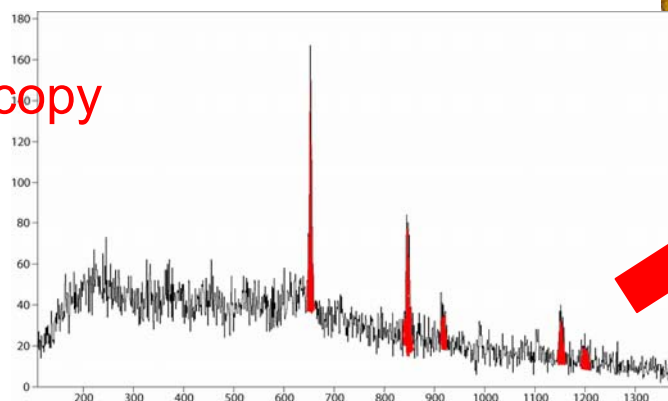
for $E_\gamma = 1.3$ MeV: Efficiency $\sim 3\%$, Peak / Total $\sim 45\%$, FWHM $\sim 0.8\%$ at $v/c = 10\%$

For mass and Z identification in coincidence with γ - ray

Mass and Z
identification



In beam
 γ spectroscopy



Analysis of PRISMA/CLARA data

A complete tracking algorithm for PRISMA was developed

Doppler correction

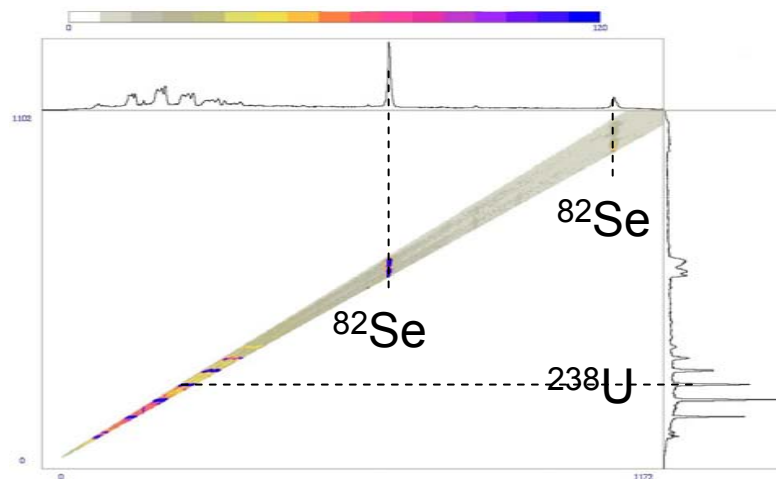
A/q

Charge state

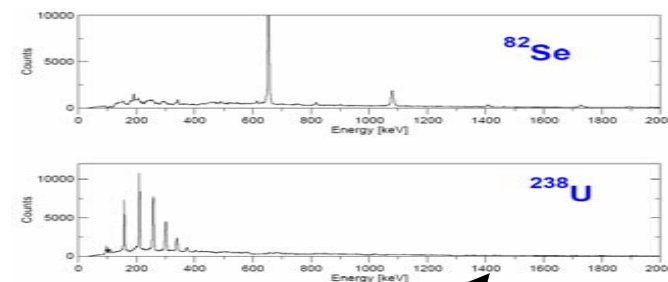
- ◆ precise position on entrance detector
- ◆ true recoil velocity
- ◆ radius of the trajectory in the dipole
- ◆ total energy

Energy resolution $< 0.8\%$ at recoil velocity $v/c = 10\%$

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



Projectile-like



Target-like

next

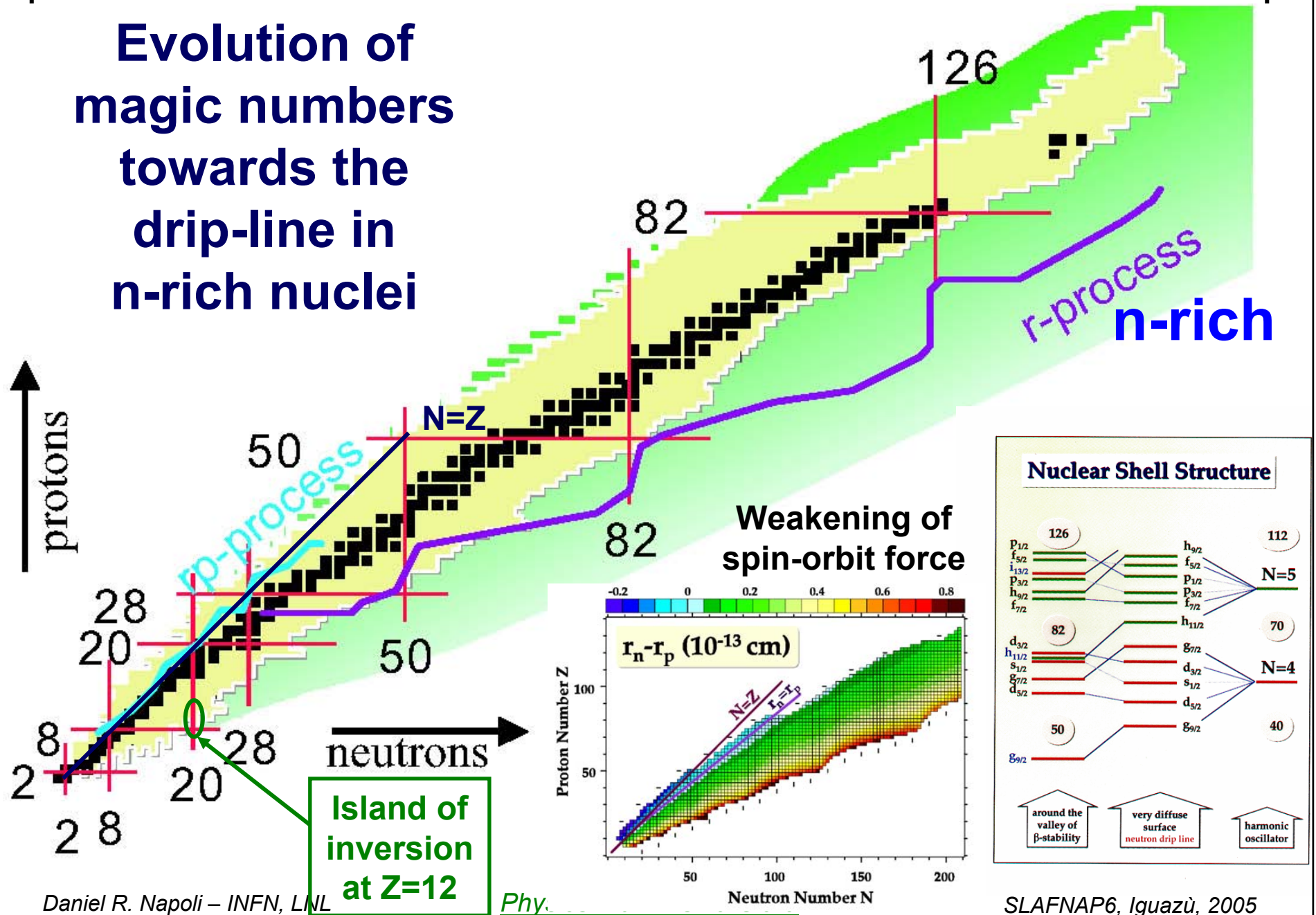
γ spectroscopy with Clara - Prisma at LNL

Recent results

- Laboratori Nazionali di Legnaro dell'INFN
- Nuclear spectroscopy at LNL
- γ - ray spectroscopy of neutron rich nuclei populated in transfer and deep inelastic reactions
- Clara - Prisma setup
- Recent results

Daniel R. Napoli
Laboratori Nazionali di Legnaro
INFN

Evolution of magic numbers towards the drip-line in n-rich nuclei



Research activities of Prisma-Clara

43% of the Tandem-ALPI beam time in 2004

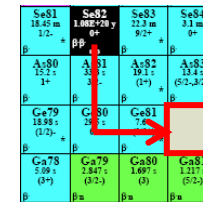
$^{54}\text{Fe}+^{50}\text{Cr}$

Spectroscopy of ^{54}Co
Isospin non conserving
part of the effective
interaction

Multi-nucleon transfer

$^{90}\text{Zr}+^{208}\text{Pb}$

32



$^{82}\text{Se}+^{238}\text{U}$

Shell closure evolution at
the magic number N=50

$^{64}\text{Ni}+^{238}\text{U}$

Shell model A~60

$^{58}\text{Ni}+^{60}\text{Ni}$

Large-angle scattering

$^{40}\text{Ca}+^{208}\text{Pb}$

Pairing-vibration states in ^{42}Ca

$^{36}\text{S}+^{208}\text{Pb}$

Shell model in ^{37}P and ^{39}P
Breaking of a semi-magic shell
closure far from stability

$^{32}\text{S}+^{58}\text{Ni}$

Mirror pair ^{31}S and ^{31}P

Resonances in $^{24}\text{Mg}+^{24}\text{Mg}$
and molecular states in ^{48}Cr

$^{24}\text{Mg}+^{24}\text{Mg}$

Kr76 14.8 h 0+	Kr77 74.4 m 5/2+	Kr78 0+ 0.35	Kr79 35.04 h 1/2-	Kr80 0+ 2.25	Kr81 2.29E+5 y 7/2+	Kr82 0+ 11.6	Kr83 9/2+ 11.5	Kr84 0+ 57.0	Kr85 10.756 y 9/2+	Kr86 0+ 17.3	Kr87 76.3 m 5/2+	Kr88 2.84 h 0+
Br75 96.7 m 3/2-	Br76 16.2 h 1- *	Br77 57.036 h 3/2- *	Br78 6.46 m 1+	Br79 3/2- *	Br80 17.68 m 1+	Br81 3/2- 50.69	Br82 35.30 h 5-	Br83 2.40 h 3/2-	Br84 31.80 m 3/2-	Br85 2.90 m 3/2-	Br86 55.1 s (2-)	Br87 55.60 s 3/2-
Se74 0+ 0.89	Se75 119.779 d 5/2+	Se76 0+ 9.36	Se77 1/2- 7.63	Se78 0+ 23.78	Se79 1.13E6 y 7/2+	Se80 0+ 49.61	Se81 18.45 m 1/2-	Se82 1.08E+20 y 0+ $\beta\beta$ 8.73	Se83 22.3 m 9/2+	Se84 3.1 m 0+	Se85 31.7 s (5/2+)	Se86 15.3 s 0+
As73 80.30 d 3/2-	As74 17.77 d 2-	As75 3/2- 100	As76 1.0778 d 2-	As77 38.83 h 3/2-	As78 90.7 m 2-	As79 9.01 m 3/2-	As80 15.2 s 1-	As81 3.5 s 3/2-	As82 19.1 s (1+)	As83 13.4 s (5/2-, 3/2-)	As84 4.02 s (3/2-)	As85 2.021 s (3/2-)
Ge72 0+ 27.66	Ge73 9/2+ 7.73	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 7.6 s (2+)	Ge81 7.6 s (2+)	Ge82 4.60 s 0+	Ge83 1.85 s (5/2+)	Ge84 966 ms 0+
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 2.6 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)	Ga83 0.31 s
Zn70 5E+14 y 0+ 0.6	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	Zn82 0+
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	Cu74 1.594 s (1+, 3+)	Cu75 1.224 s	Cu76 0.641 s	Cu77 469 ms	Cu78 342 ms	Cu79 188 ms	Cu80	
Ni68 19 s 0+	Ni69 11.4 s	Ni70 0+	Ni71 1.86 s	Ni72 2.1 s 0+	Ni73 0.90 s	Ni74 1.1 s 0+	Ni75	Ni76 0+	Ni77	Ni78 0+		

40

42

44

46

48

50

52

 $^{82}\text{Se} + ^{238}\text{U}$

G.Duchene Strasbourg

G.de Angelis Legnaro

Analysis:

N.Marginean Legnaro

4 days,

PRISMA at

 $\theta_G = 64^\circ$

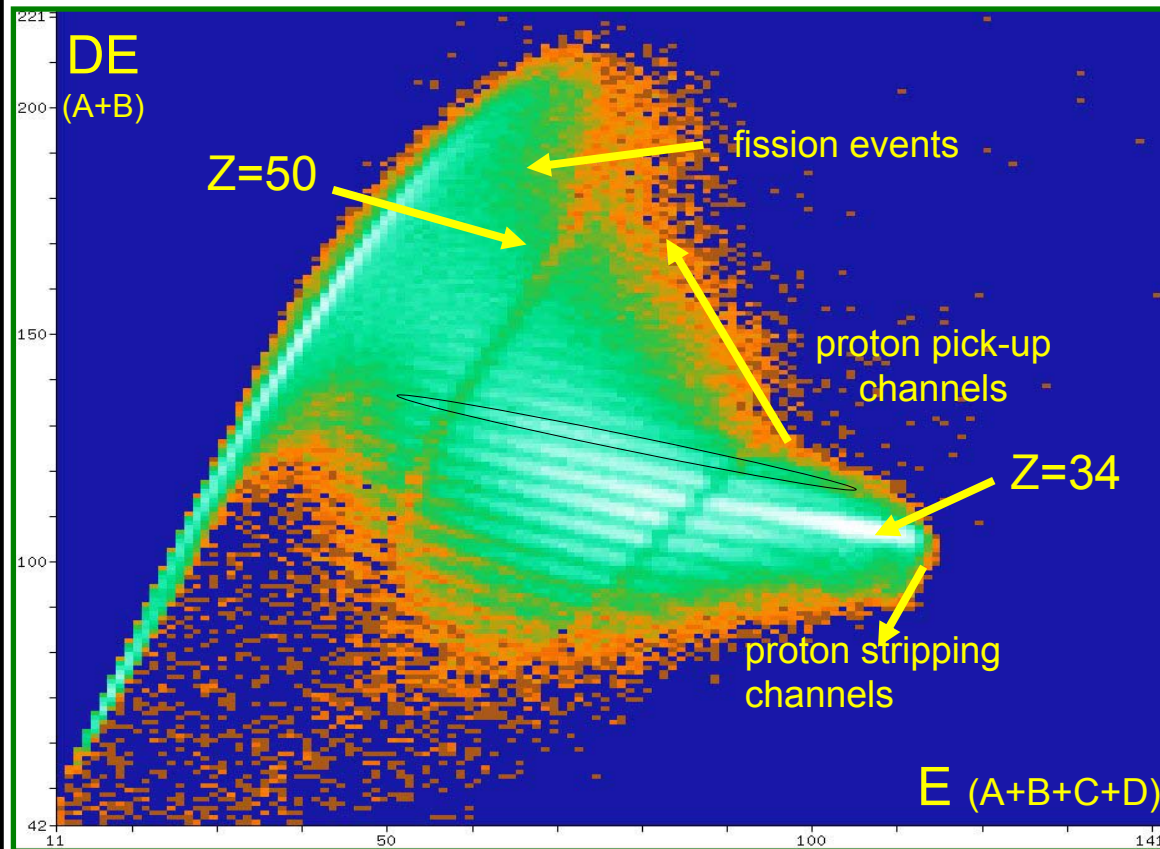
ALPI - Tandem

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

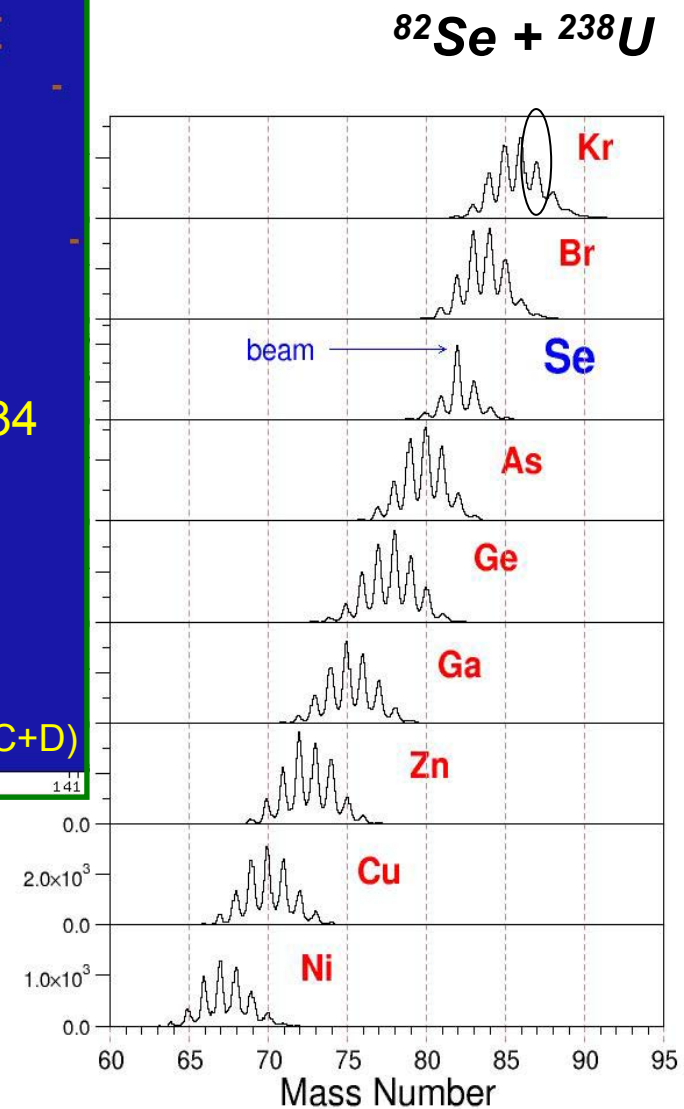
IC ΔE -E Matrix



$^{82}\text{Se} + ^{238}\text{U}$, $E=505$ MeV, $\theta_G=64^\circ$
4 days beam time

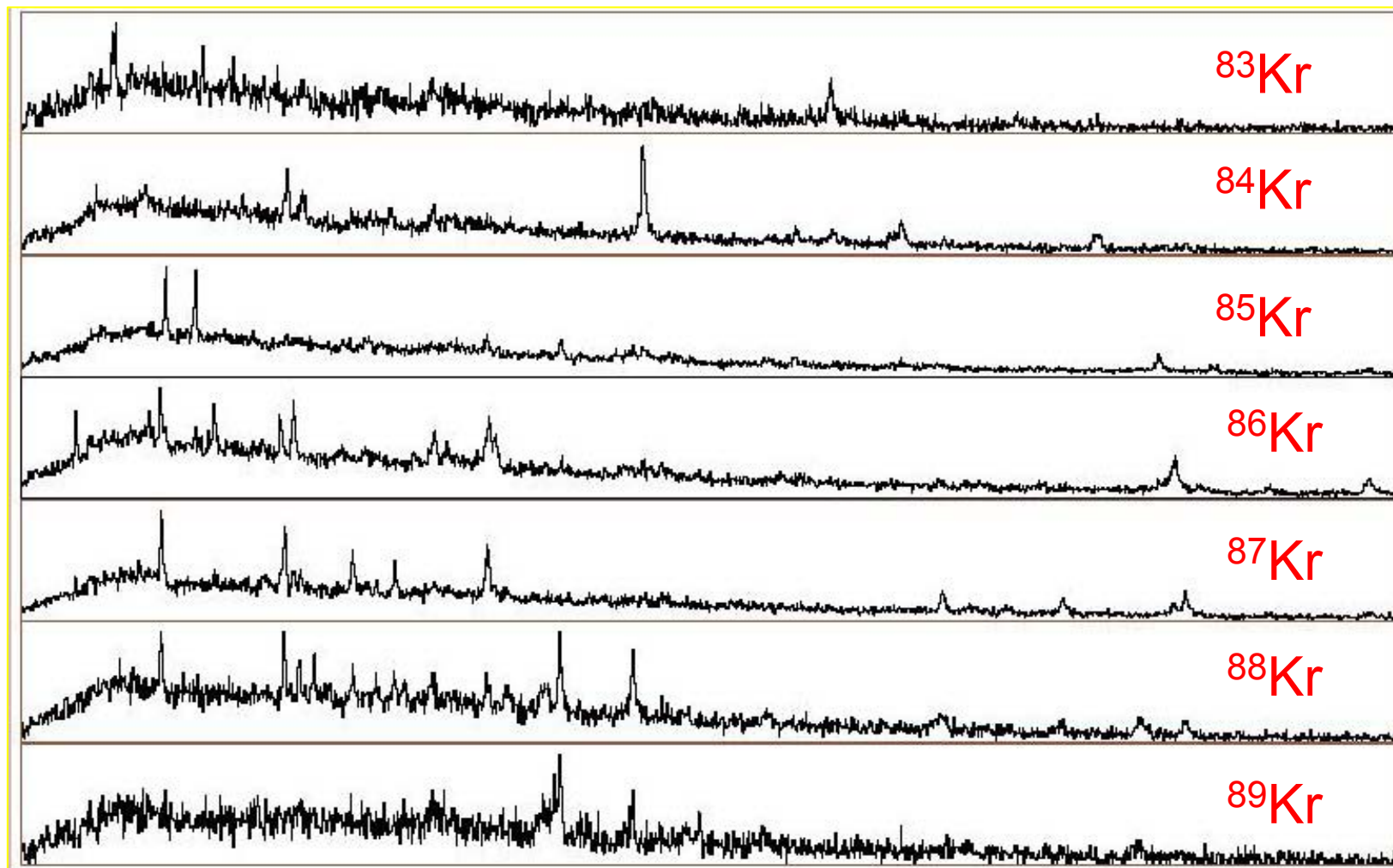
G.Duchene Strasbourg, G.de Angelis Legnaro

Analysis: N.Marginean Legnaro



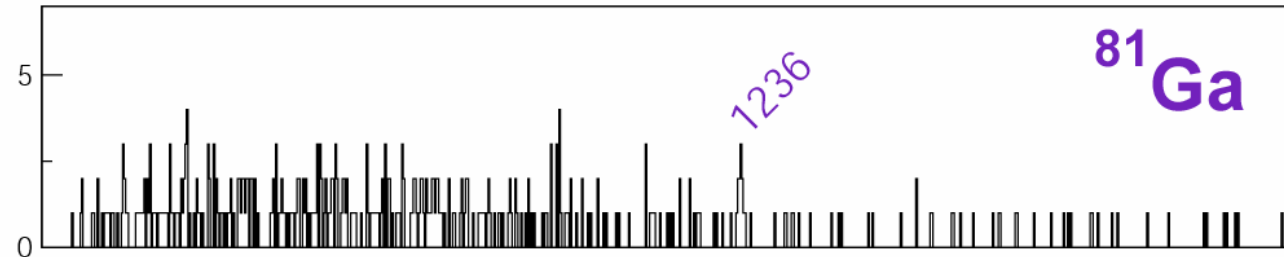
γ -spectroscopy of neutron rich nuclei

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

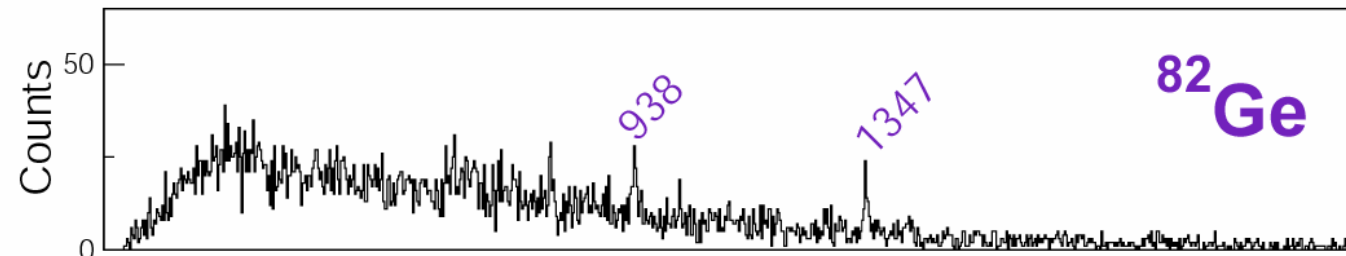


Spectroscopy of the lightest $N=50$ isotones

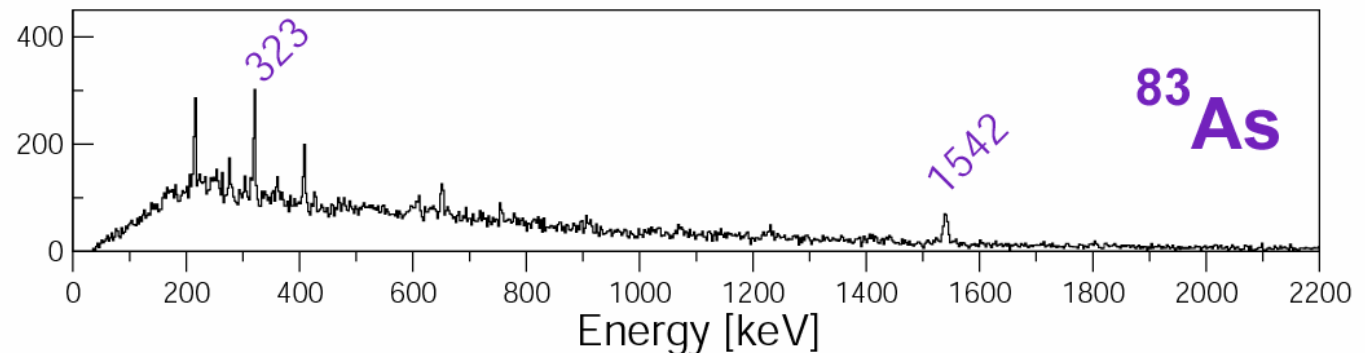
- First observation of γ rays from the decay of ^{81}Ga



- The excitation energy of the 4^+ state in ^{82}Ge firmly established



- First observation of the yrast levels of ^{83}As



Nuclear spectroscopy of neutron rich nuclei in the N=50 region

$^{82}\text{Se} + ^{238}\text{U}$, $E=505\text{ MeV}$, $\theta_G=64^\circ$

4 days beam time

Kr76 14.8 h 0+	Kr77 74.4 m 5/2+	Kr78 0+	Kr79 35.04 h 1/2-	Kr80 0+	Kr81 2.29E+5 y 7/2+	Kr82 0+	Kr83 9/2+	Kr84 0+	Kr85 10.756 y 9/2+	Kr86 0+	Kr87 76.3 m 5/2+	Kr88 2.84 h 0+
Br75 96.7 m 3/2-	Br76 16.2 h 1-	Br77 57.036 h 3/2-	Br78 6.46 m 1+	Br79 3/2-	Br80 17.68 m 1+	Br81 3/2-	Br82 35.30 h 5-	Br83 2.40 h 3/2-	Br84 31.86 m 2+	Br85 2.90 m 3/2-	Br86 55.1 s (2-)	Br87 55.60 s 3/2-
Se74 0+	Se75 119.779 d 5/2+	Se76 0+	Se77 1/2-	Se78 0+	Se79 1.13E6 y 7/2+	Se80 0+	Se81 18.45 m 1/2-	Se82 1.08E+20 y 0+	Se83 22.3 m 9/2+	Se84 3.1 m 0+	Se85 31.7 s (5/2+)	Se86 15.3 s 0+
As73 80.30 d 3/2-	As74 17.77 d 2-	As75 3/2-	As76 1.0778 d 2-	As77 38.83 h 3/2-	As78 90.7 m 2-	As79 9.01 m 3/2-	As80 15.5 s 1+	As81 19.1 s (1+)	As82 13.4 s (5/2-, 3/2-)	As83 4.02 s (3/2-)	As84 2.021 s (3/2-)	As85 2.021 s (3/2-)
Ge72 0+	Ge73 9/2+	Ge74 0+	Ge75 82.78 m 1/2-	Ge76 0+	Ge77 11.30 h 7/2+	Ge78 8.0 m 0+	Ge79 18.98 s (1/2)-	Ge80 5.7 s (3/2)-	Ge81 4.6 s 0+	Ge82 4.60 s (5/2+)	Ge83 1.85 s (5/2+)	Ge84 966 ms 0+
Ga71 3/2-	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)	Ga83 0.31 s 0+
Zn70 5E+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+	Zn82 0+
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+	
Ni68 19 s 0+	Ni69 11.4 s 0+	Ni70 0+	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+		

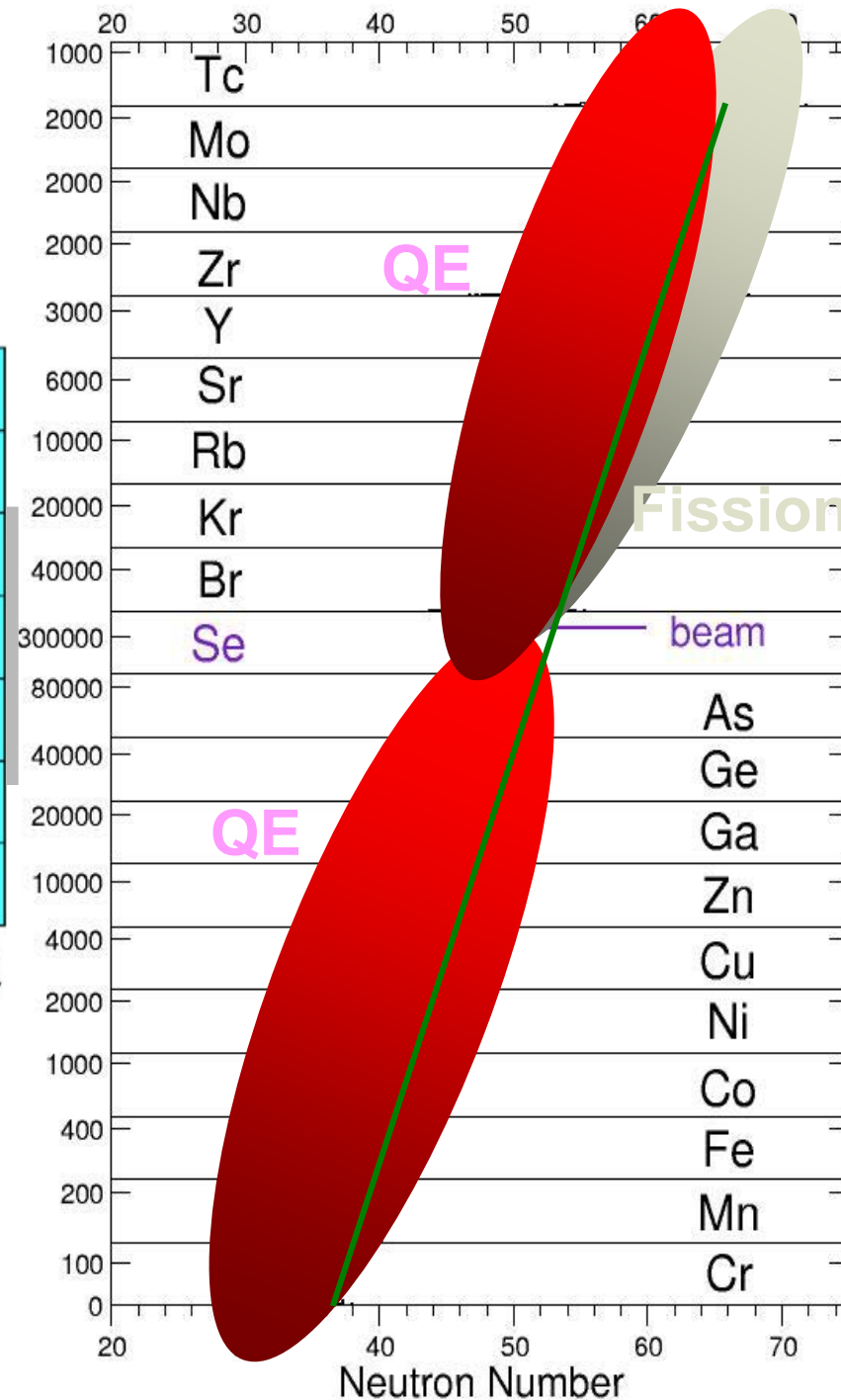
-2p
+2n

52

Analysis: N. Marginean Legnaro

Daniel R. Napoli – INFN, LNL

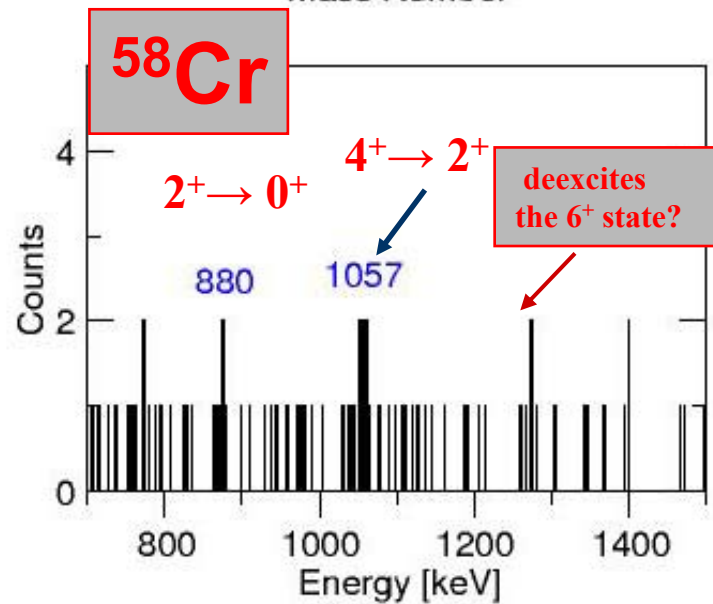
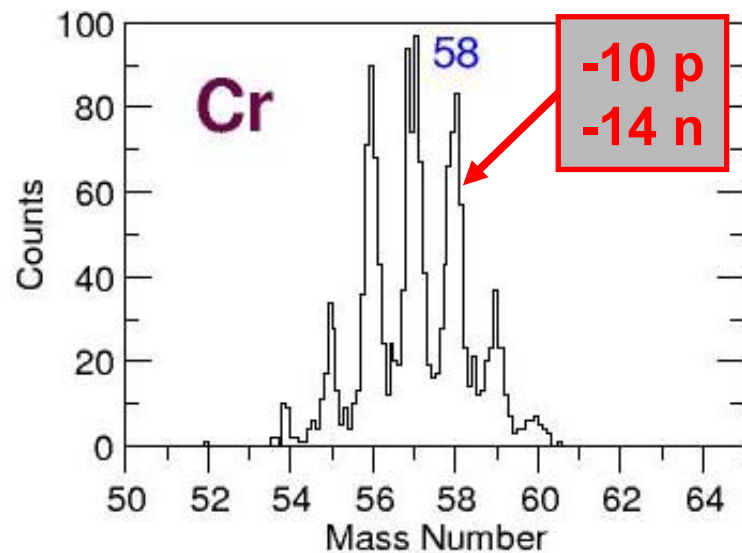
Physics with P.



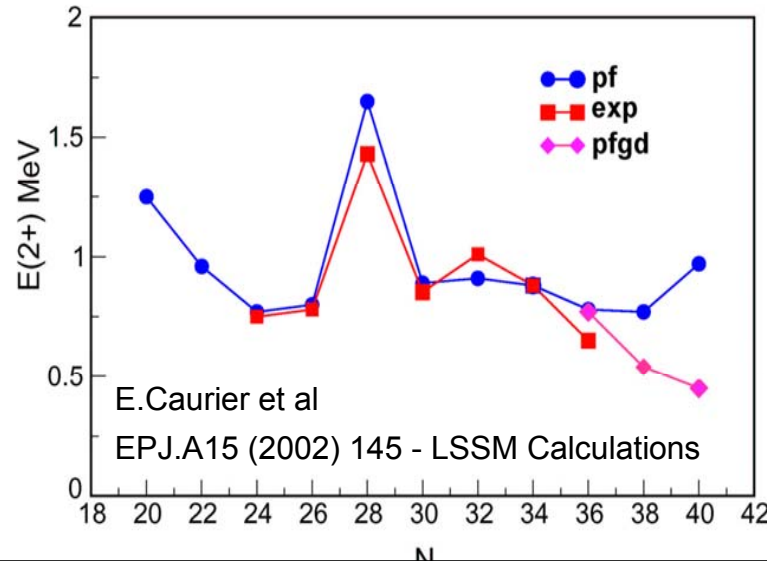
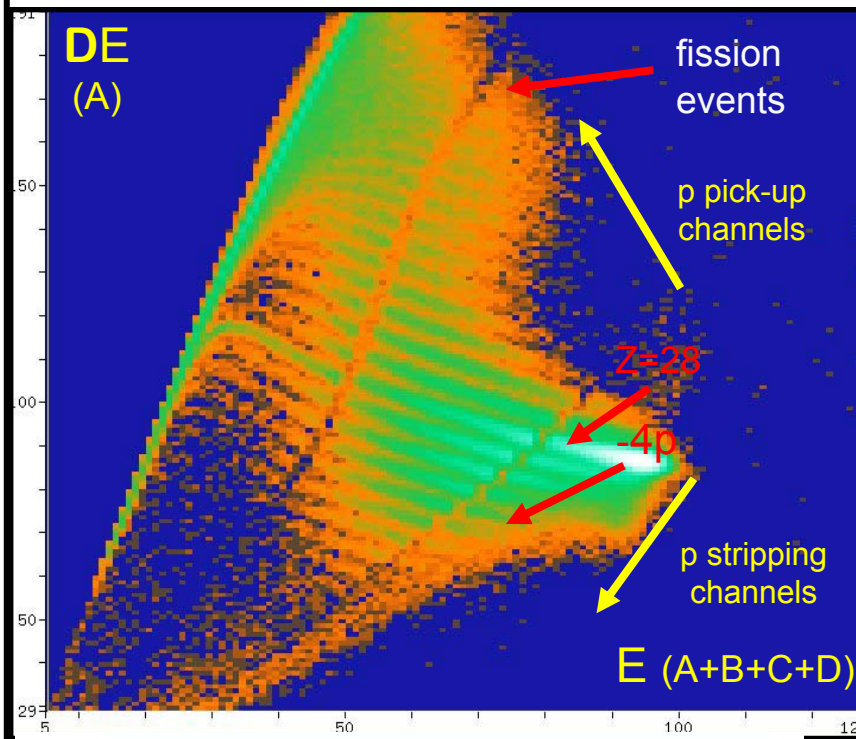
$^{82}\text{Se} + ^{238}\text{U}$ E=505 MeV

$\theta_G = 64^\circ$

**24 nucleons removed
from projectile**



Spectroscopy of deformed neutron rich $A \sim 60$ nuclei



^{64}Ni (404MeV) + ^{238}U

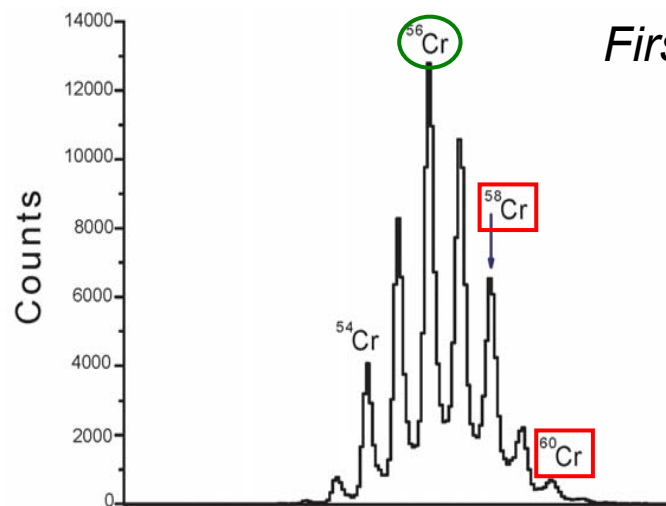
S.M.Lenzi Padova, S.J.Freeman Manchester

To study n-rich $A \sim 60$ (Cr, Fe & Ti) nuclei, to investigate a new deformation region in the middle of the $\pi f_{7/2}$ νpf -shell, and to test recent SM predictions

Ni57 35.60 h 3/2-	Ni58 0+ 68.077	Ni59 7.6E+4 y 3/2- EC	Ni60 0+ 26.223	Ni61 3/2- 1.140	Ni62 0+ 3.634	Ni63 100.1 y 1/2- β^-	Ni64 0+ 0.926	Ni65 2.5172 h 5/2-
Co56 77.27 d 4+ EC	Co57 271.79 d 7/2- EC	Co58 70.82 d 2+ EC *	Co59 7/2- 100	Co60 5.2714 y 5+ *	Co61 1.650 h 7/2- β^-	Co62 1.50 m 2+ *	Co63 2.4 s (0+) β^-	Co64 0.30 s 1+ β^-
Fe55 2.73 y 3/2- EC	Fe56 0+ 91.72	Fe57 1/2- 2.2	Fe58 0+ 0.28	Fe59 44.503 d 3/2- β^-	Fe60 1.5E+6 y 0+ β^-	Fe61 5.98 m 3/2-, 5/2- β^-	Fe62 0+ β^-	Fe63 6.1 s (5/2-) β^-
Mn54 312.3 d 3+ EC, β^-	Mn55 5/2- 100	Mn56 2.5785 h 3+ β^-	Mn57 85.4 s 5/2- β^-	Mn58 3.0 s 0+ *	Mn59 4.6 s 3/2-, 5/2- β^-	Mn60 0+ *	Mn61 0+ β^-	Mn62 0.88 s (3+) β^-
Cr53 3/2- 9.501	Cr54 0+ 2.365	Cr55 3/2- β^-	Cr56 0+ β^-	Cr57 21.1 s 3/2-, 5/2-, 7/2- β^-	Cr58 7.0 s 0+ β^-	Cr59 0+ β^-	Cr60 0.7 s β^-	Cr61 β^-
V52 3.743 m 3+ β^-	V53 1.61 m 7/2- β^-	V54 49.8 s 3+ β^-	V55 6.54 s (7/2-) β^-	V56 β^-	V57 β^-	V58 β^-	V59 β^-	V60 β^-
Ti51 5.76 m 3/2- β^-	Ti52 1.7 m 0+ β^-	Ti53 32.7 s (3/2-) β^-	Ti54 0+ β^-	Ti55 β^-	Ti56 0+ β^-	Ti57 β^-	Ti58 0+ β^-	Ti59 β^-

with Prisma Clara

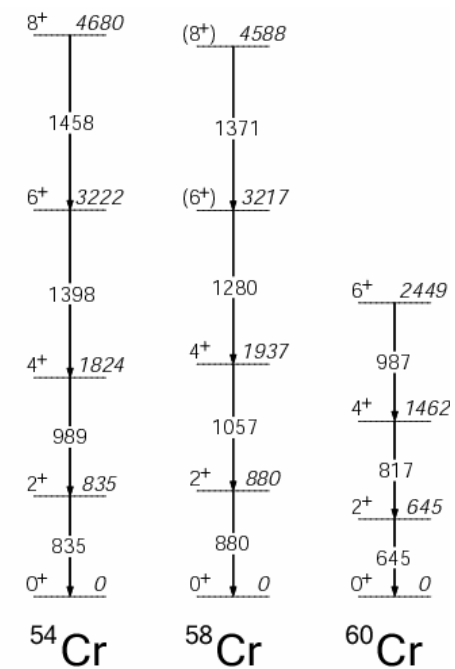
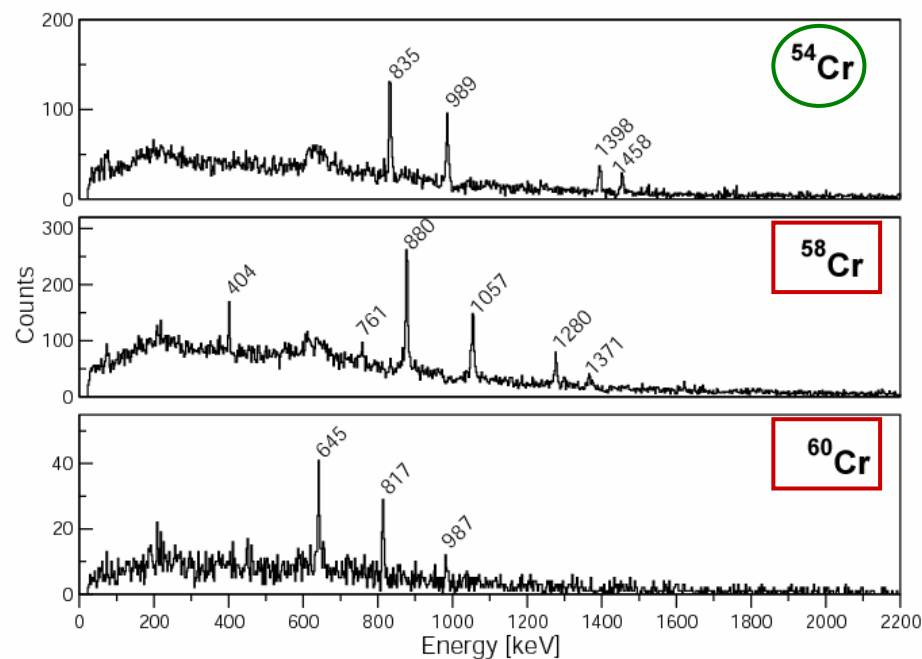
SLAFNAP6, Iguazù, 2005



First observation of γ rays from the yrast levels of ^{58}Cr
 ^{64}Ni (400MeV) + ^{238}U

S.M.Lenzi Padova, S.J.Freeman Manchester

From our data, the 1057 keV transition in ^{58}Cr is the $4^+ \rightarrow 2^+$ member of the yrast cascade.



Analysis N.Marginean, LNL

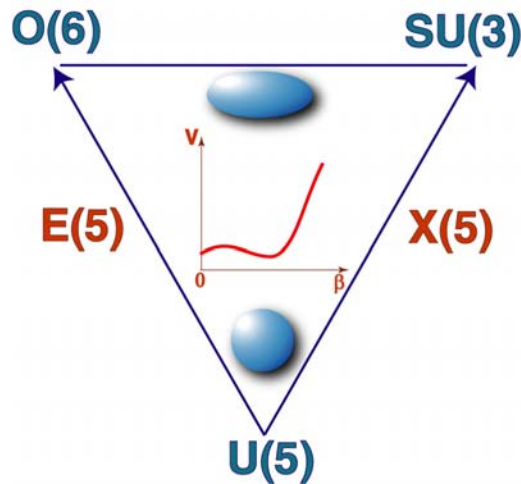
Pure fp shell LSSM calculations reproduce the experimental levels in this slightly deformed nucleus

^{58}Cr

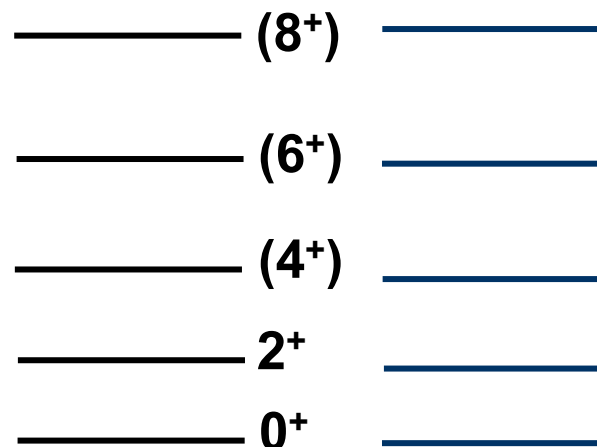
KB3G



LSSM



FPD6



Clara exp.

LSSM

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

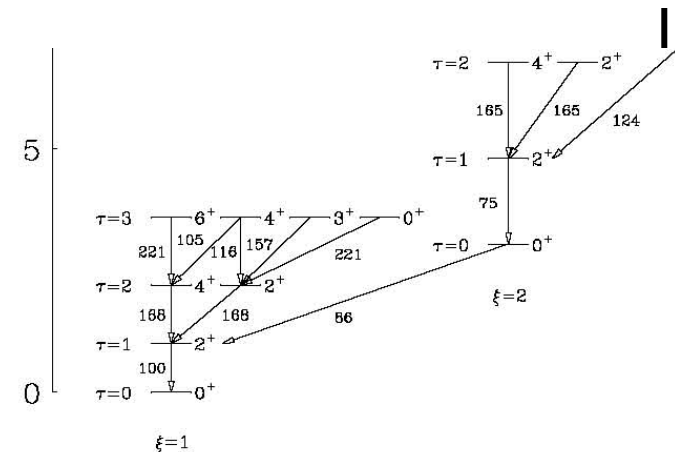
$$E_{6+}/E_{2+} = 3.65$$

E(5) critical point symmetry

**vibrator to
γ-soft 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

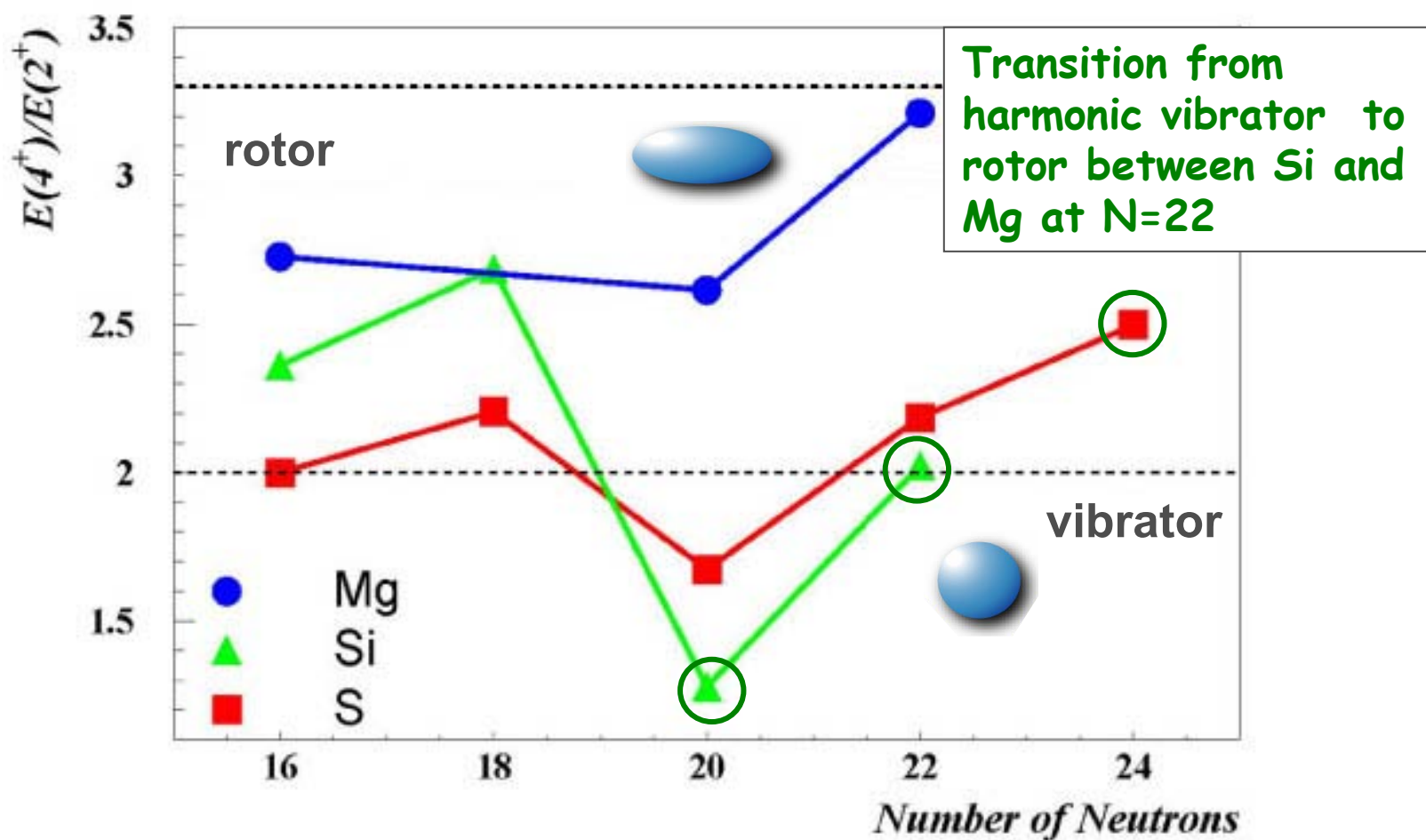
Dynamic Symmetries at the Critical Point

F. Iachello

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

Shell evolution @ $N=20$

M. Stanoiu, F. Azaiez (IPN Orsay) X. Liang (Manchester)

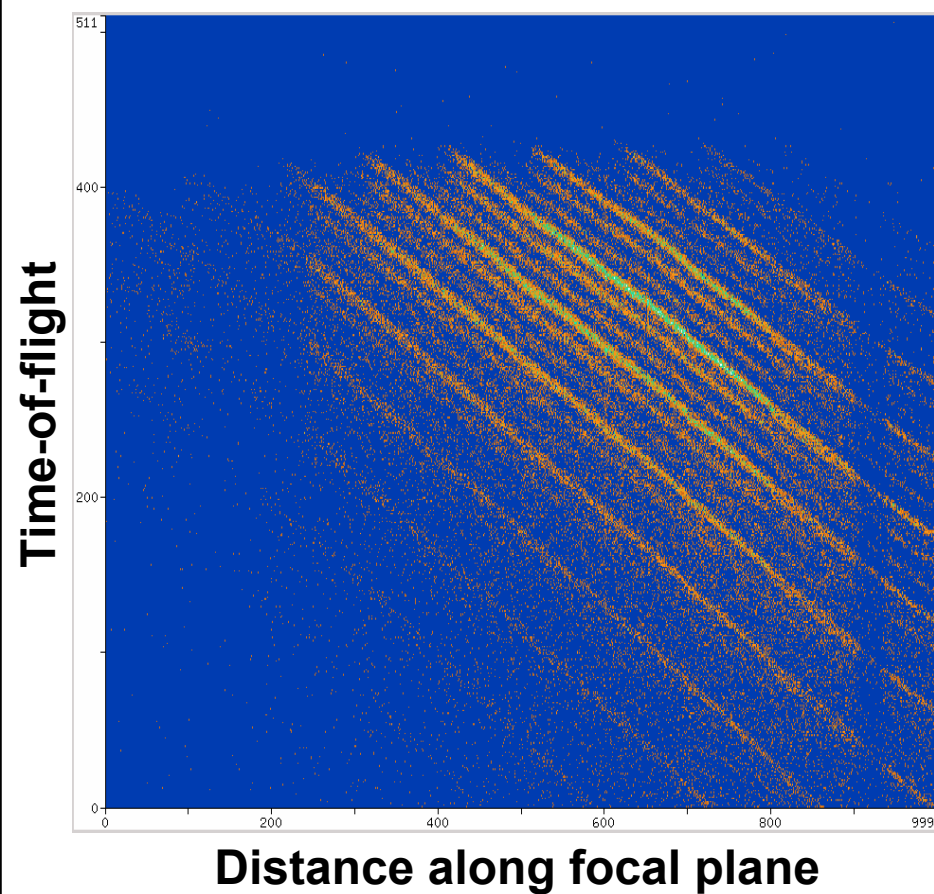


The spacing between the 2^+ and 4^+ can suggest, to good extent the shapes of the $N \sim 20$ nuclei

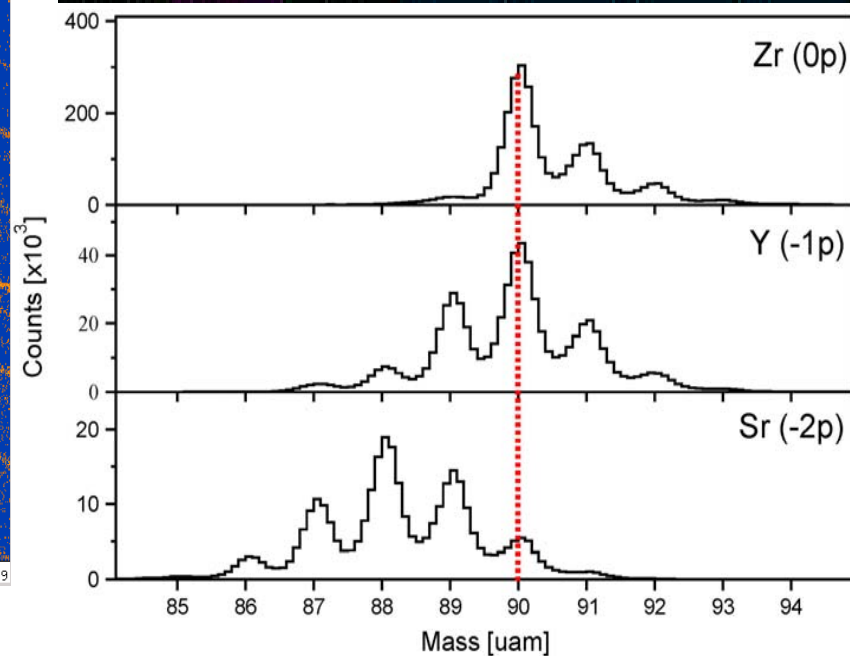
$^{90}\text{Zr } 560\text{MeV} + ^{208}\text{Pb}$

L. Corradi Legnaro, C. Ur Padova

1 day beam run

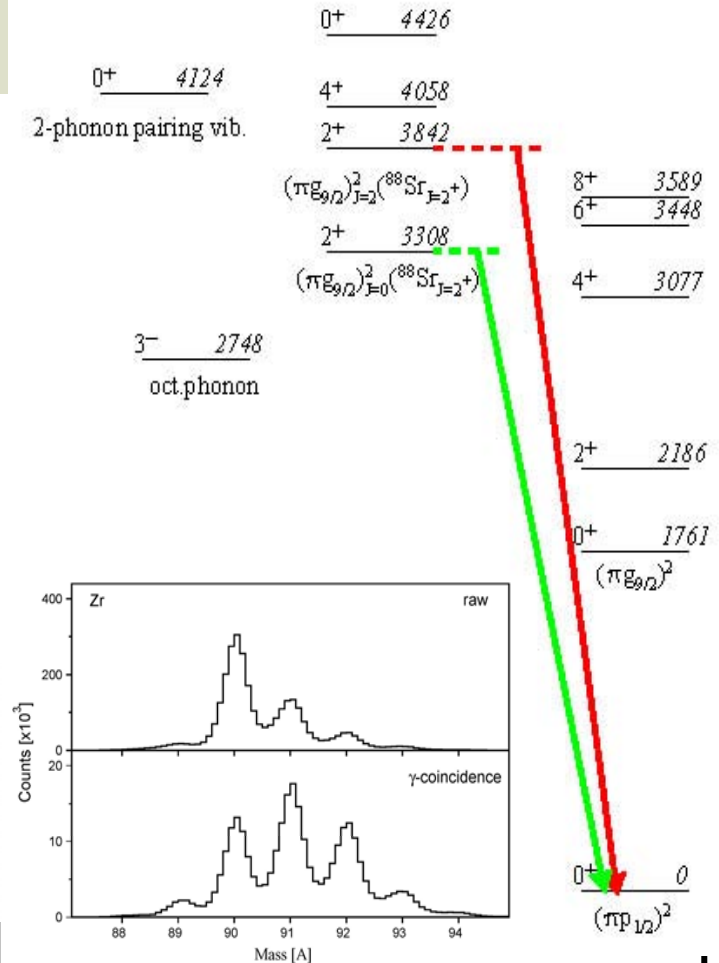
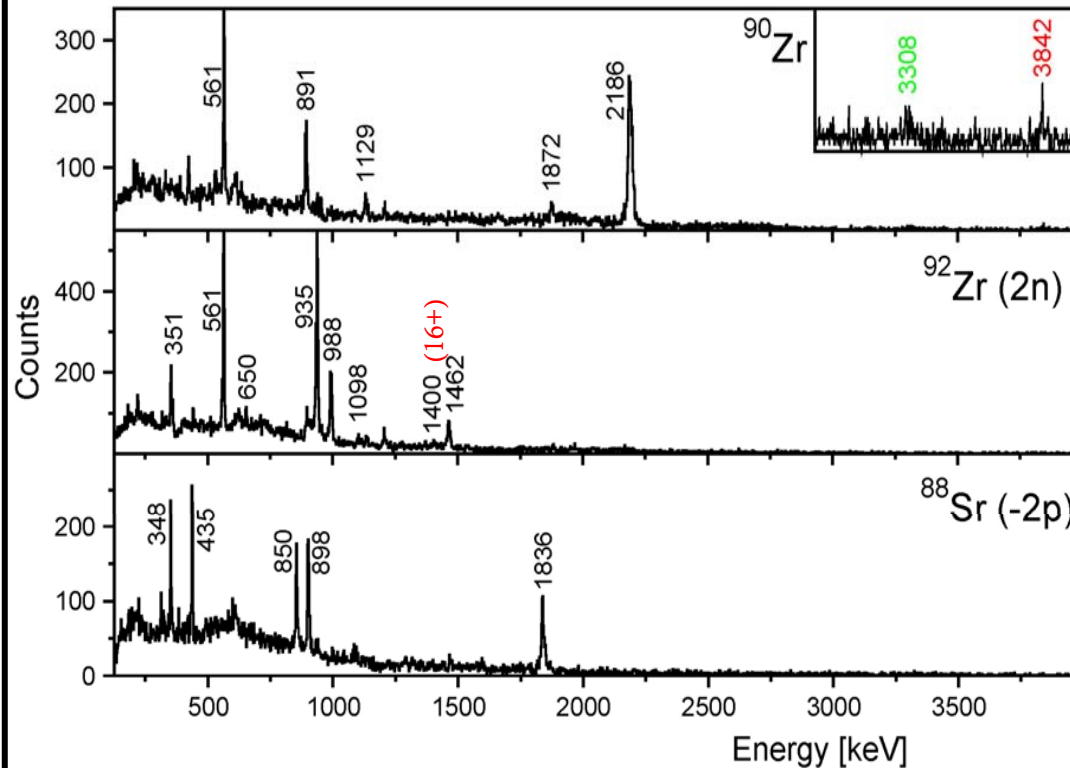


Nb89 1.9h (9/2 ⁺)	Nb90 1.450h 8 ⁺	Nb91 65D ₇ 9/2 ⁺	Nb92 3.40E+7 ₇ (7) ⁺	Nb93 9/2 ⁺	Nb94 200E+4 ₇ (9) ⁺	Nb95 34.975 d 9/2 ⁺
Hf	Hf	Hf	Hf, β	100	β	β
Zr88 23.4d 0 ⁺	Zr89 78.4 h 9/2 ⁺	Zr90 0 ⁺	Zr91 11.22 0 ⁺	Zr92 17.15 0 ⁺	Zr93 1.53E+6 ₇ 5/2 ⁺	Zr94 17.28 0 ⁺
Hf	Hf	9.45	11.22	17.15	β	17.28
Y87 79.8h 1/2 ⁻	Y88 10565 d 4	Y89 12 ⁻	Y90 6410h 2	Y91 585 d 1/2 ⁻	Y92 354h 2	Y93 1018h 1/2 ⁻
Hf	Hf	10	β	β	β	β
Sr86 0 ⁺	Sr87 9/2 ⁺	Sr88 0 ⁺	Sr89 9053 d 5/2 ⁺	Sr90 28.78 ₇ 0 ⁺	Sr91 965h 5/2 ⁺	Sr92 2.7 h 0 ⁺
953	700	2258	β	β	β	β
Rb85 5/2 ⁻	Rb86 18231 d 2	Rb87 478E10 ₇ 3/2 ⁻	Rb88 17.78m 2	Rb89 1515m 3/2 ⁻	Rb90 193. 0	Rb91 98.4s 3/2 ⁻
72135	Hf, β	β	β	β	β	β



$^{90}\text{Zr } 560\text{MeV} + ^{208}\text{Pb}: ^{90}\text{Zr}, ^{92}\text{Zr}(+2n), ^{88}\text{Sr}(-2p)$

L.Corradi, C.A.Ur et al.



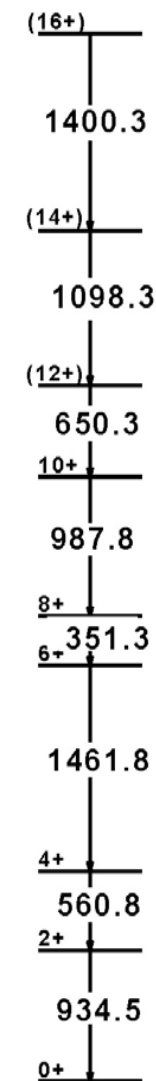
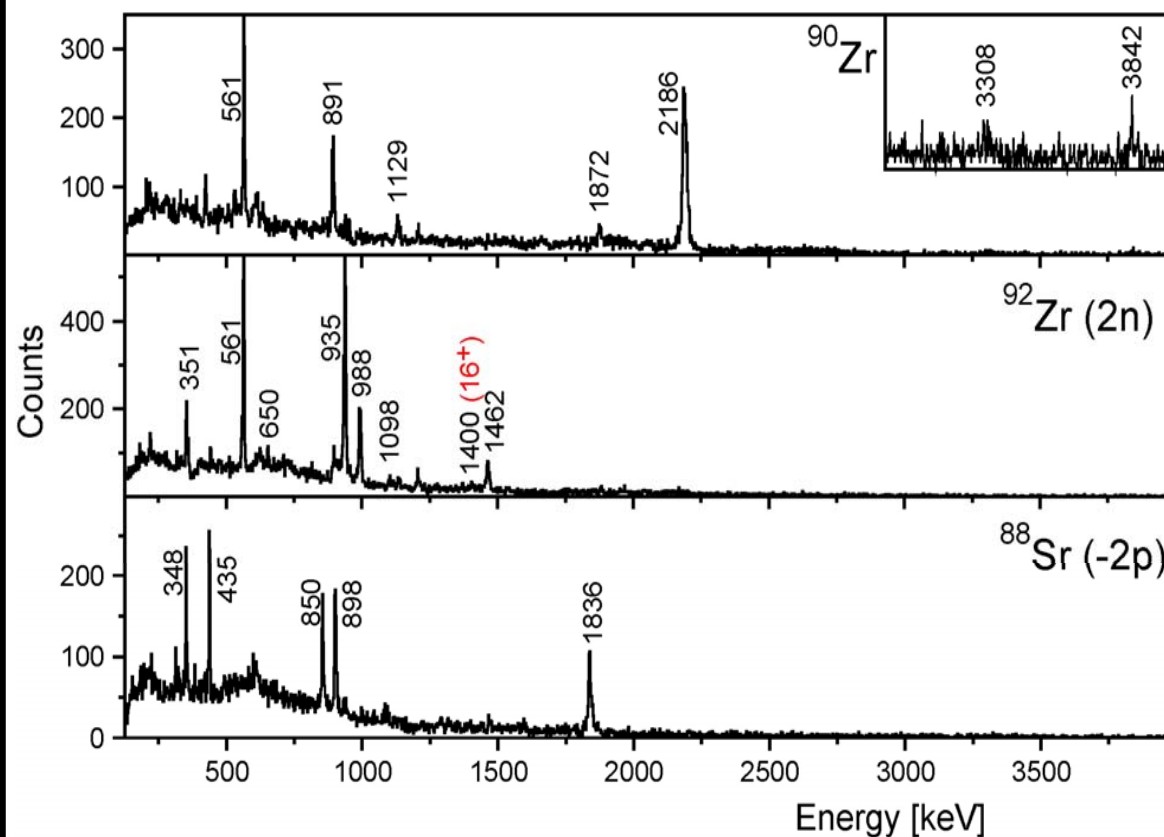
Level Scheme from:
 $^{90}\text{Zr}(n,n'g)$
 P.E.Garrett et al.
 PRC68 (2003)024312

$^{90}\text{Zr } 560\text{MeV} + ^{208}\text{Pb} : ^{92}\text{Zr}$

Adopted NNDC
Level Scheme

^{92}Zr

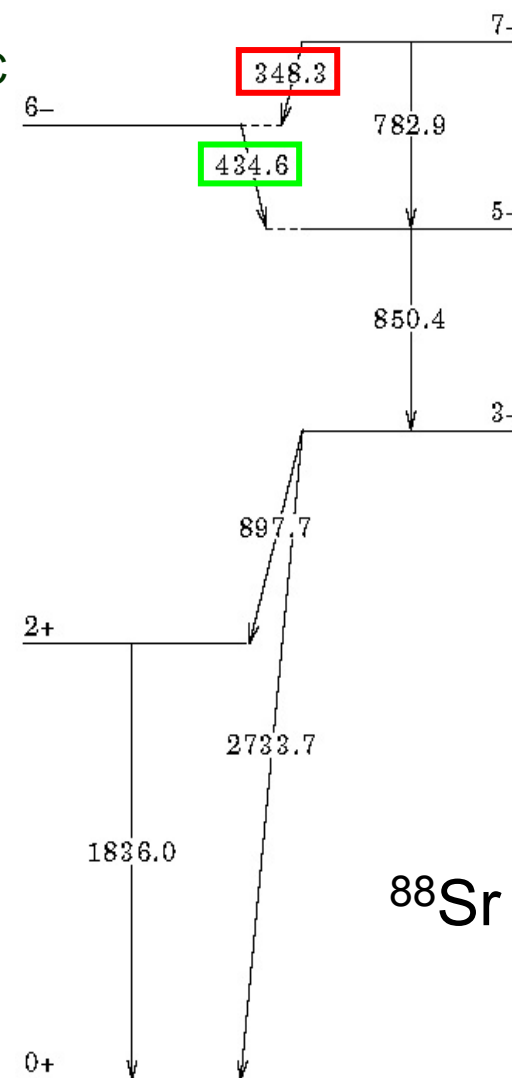
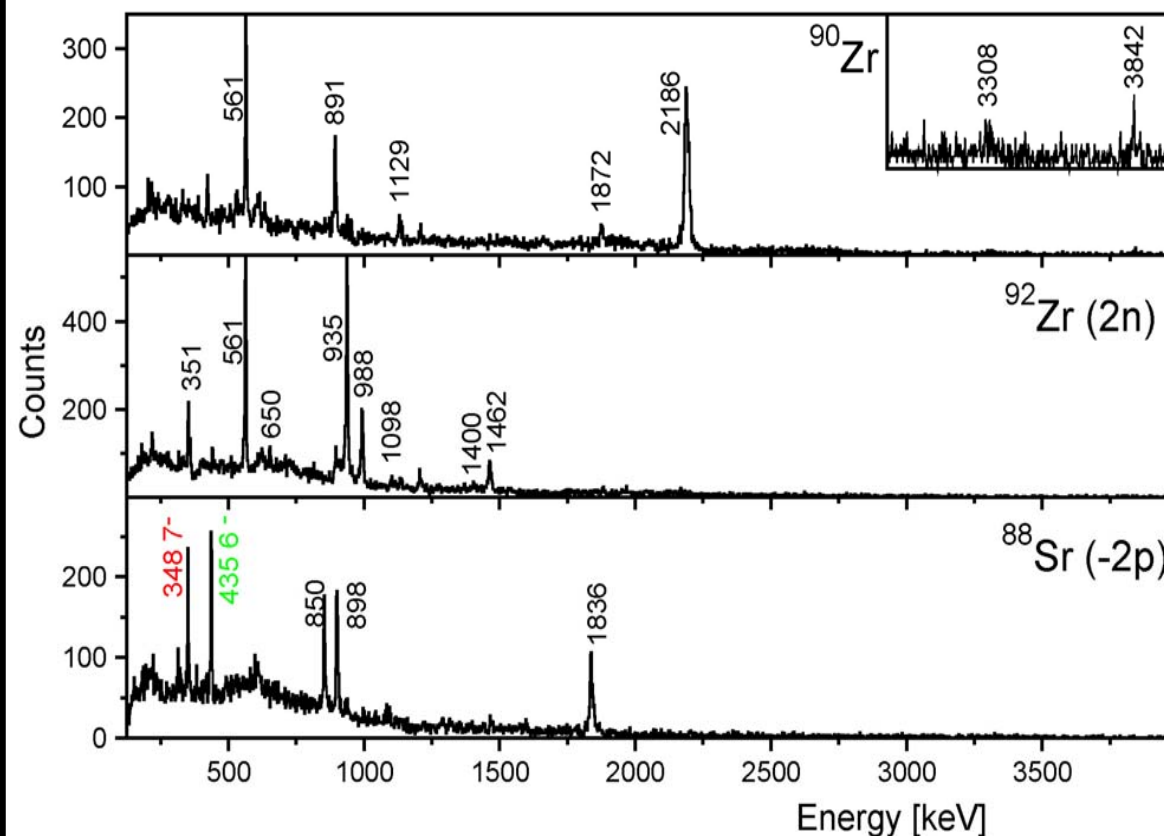
L. Corradi, C.A. Ur et al.



$^{90}\text{Zr } 560\text{MeV} + ^{208}\text{Pb} : ^{88}\text{Sr}$

Adopted NNDC
Level Scheme

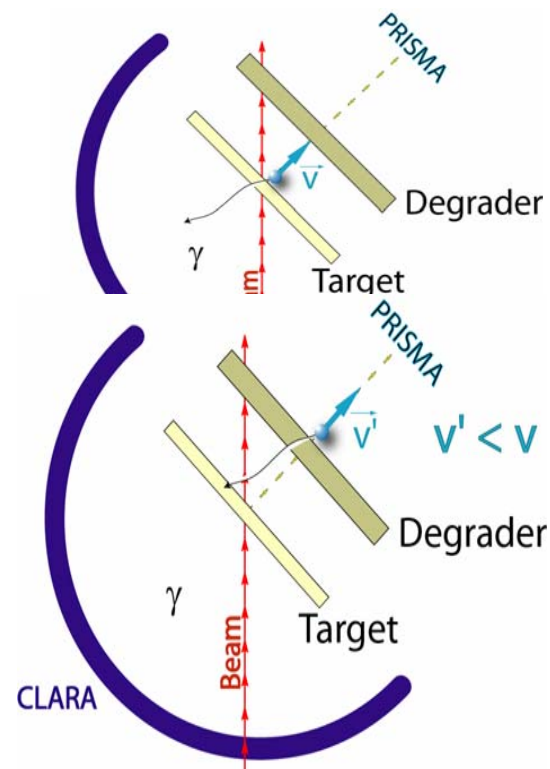
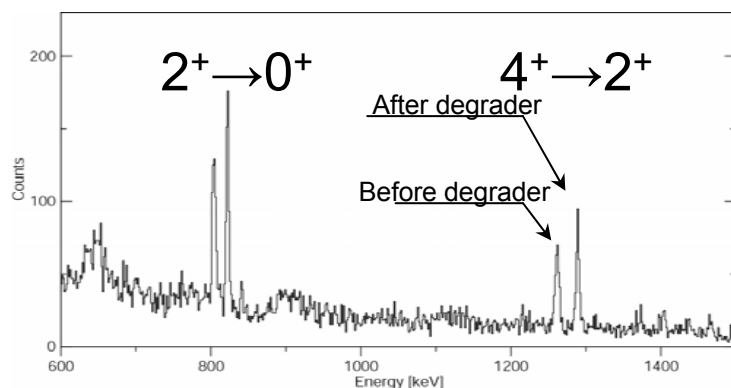
L. Corradi, C.A. Ur et al.



Differential plunger with PRISMA/CLARA

- Consists in having an energy degrader at fixed distance after the target
- The gamma rays emitted before or after the recoil passes the degrader will have different Doppler shifts
- The lifetimes will be obtained from the intensity ratio before/after degrader

^{60}Fe – simulation based on existing experimental data



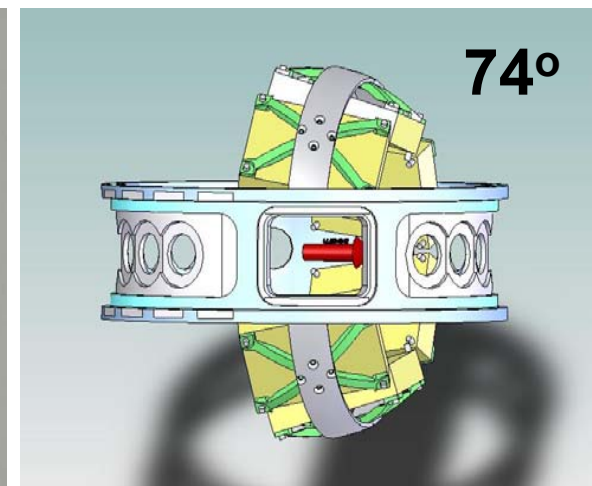
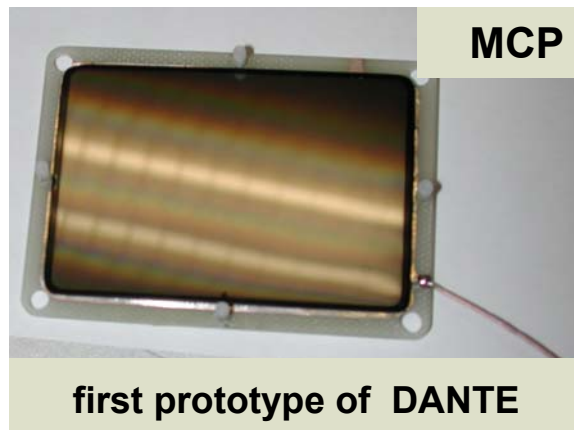
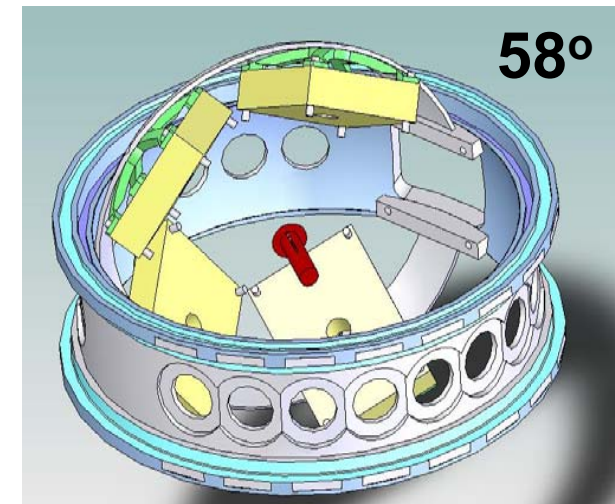
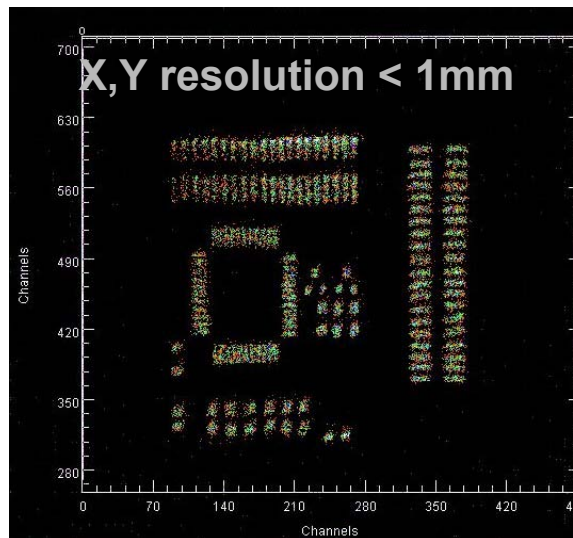
DANTE

MCP Detector array

γ -PRISMA

$\gamma\gamma$ -DANTE

3% $\rightarrow$ 20% of 4π



J.J. Valiente-Dobon, et al. in collaboration with FLNR Dubna

Summary

- *The CLARA-PRISMA setup consisting on an array of 25 EUROBALL Clover detectors coupled with the large acceptance magnetic spectrometer PRISMA is starting its second year of operation at LNL.*
- *The first preliminary results show the capabilities of such installation in combination with the stable beam delivered by the LNL Tandem-ALPI complex and gives good perspectives for the future, with PIAVE-ALPI.*
- *In a single experiment ~ 50 nuclei can be studied.*
- *At the present stage of the instrument and for most cases, additional experimental information is required to build up 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*
- *Near future improvements: ECR-Piave beams, Dante (γ - γ), Lifetimes...*

CLARA-PRISMA collaboration

- *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

- *Romania*

NIPNE Bucharest

- *France*

IReS Strasbourg
GANIL Caen

- *UK*

University of Manchester
Daresbury Laboratory
University of Surrey
University of Paisley

- *Germany*

HMI Berlin
GSI Darmstadt

- *Spain*

University of Salamanca

Thanks to

A. Gadea, N. Marginean, S.Lunardi, G. de
Angelis, S. M. Lenzi, A.Latina, E.Fioretto,
A.M. Stefanini, L. Corradi,
and many others from Legnaro, Padova,
Manchester, Daresbury, Paisley, Orsay,
Strasbourg, Cracow, Surrey,