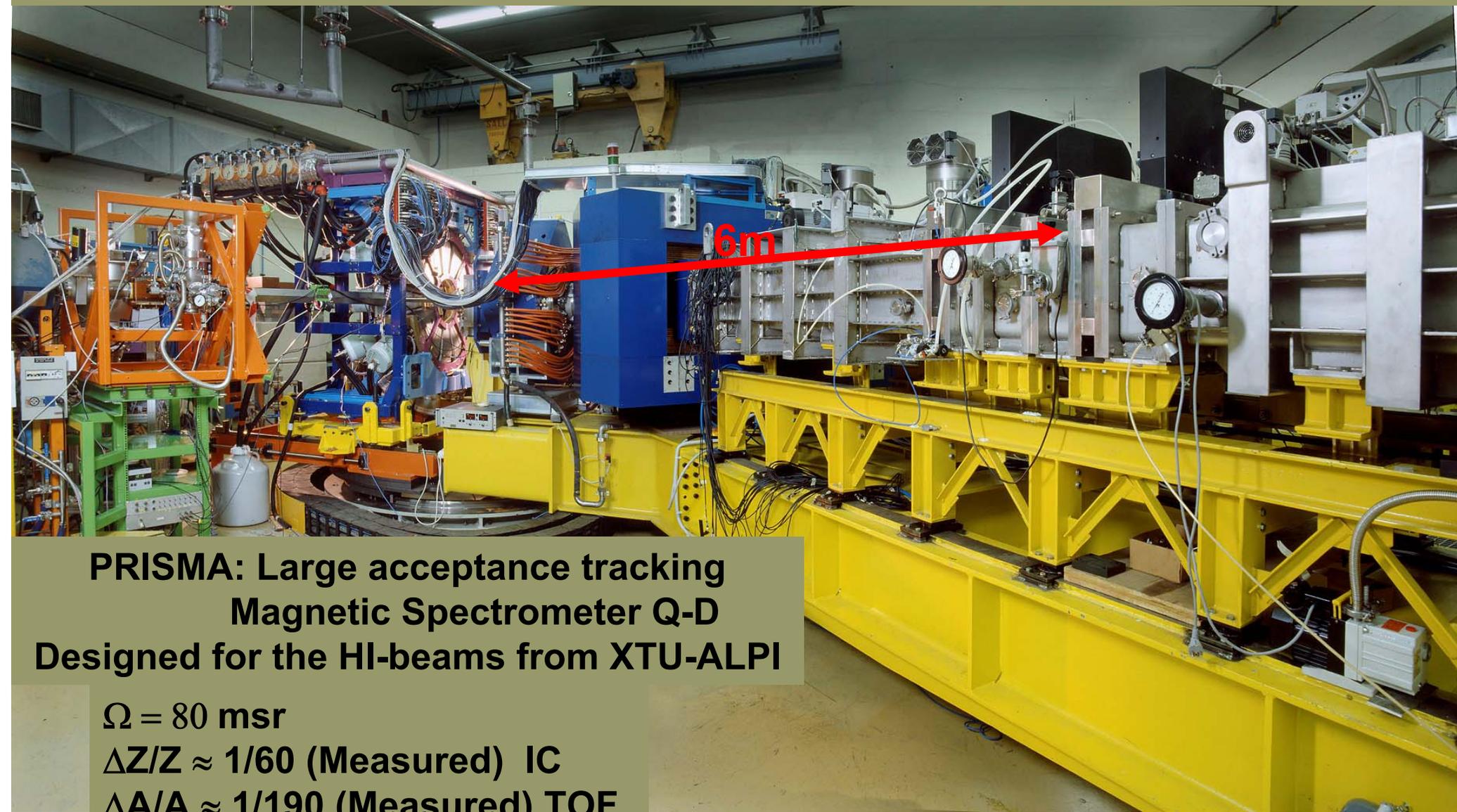


Spectroscopy of n-rich nuclei with CLARA-PRISMA

**A.Gadea INFN-LNL
(for the CLARA - PRISMA collaboration)**

- Description of the setup**
- Grazing reactions as mechanism to study the structure of moderately neutron-rich nuclei**
- Results on n-rich medium mass ($A\sim 80$ and $A\sim 60$) nuclei**
- Perspectives with CLARA-PRISMA and the AGATA Demonstrator-PRISMA setup**





**PRISMA: Large acceptance tracking
Magnetic Spectrometer Q-D
Designed for the HI-beams from XTU-ALPI**

$\Omega = 80 \text{ msr}$

$\Delta Z/Z \approx 1/60$ (Measured) IC

$\Delta A/A \approx 1/190$ (Measured) TOF

Energy acceptance $\pm 20\%$

$B\rho = 1.2 \text{ T.m}$

**Note: Dispersion 4cm / 1%,
focal plane 1m**

THE PRISMA DETECTORS



MWPPAC Detector
10 sect. X,Y & T_F



MCP Start Detector
X,Y & T₁

Mylar foils
1.5 μm thick

Dipole

C foil
20 μg/cm² thick

Ionisation Chamber
10x4 sect. DE - E

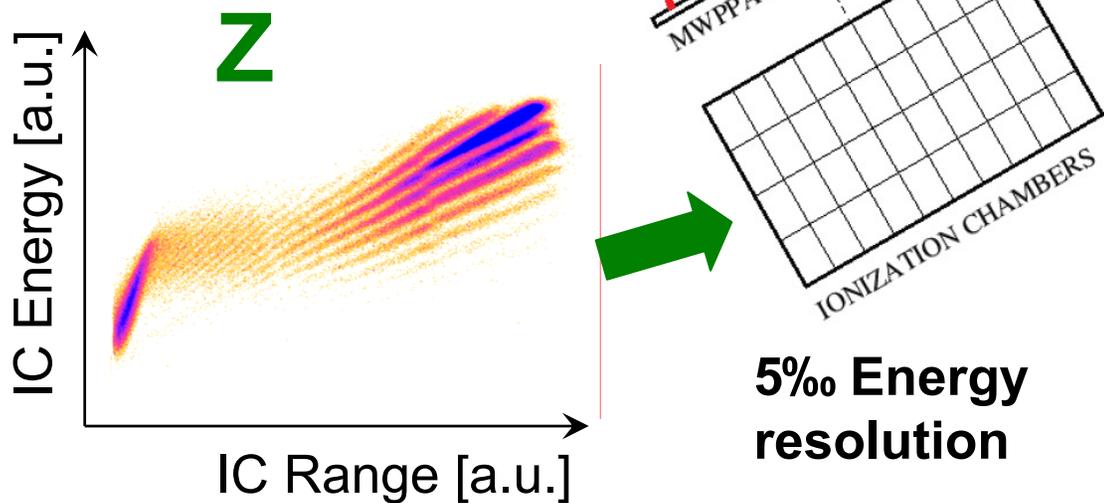
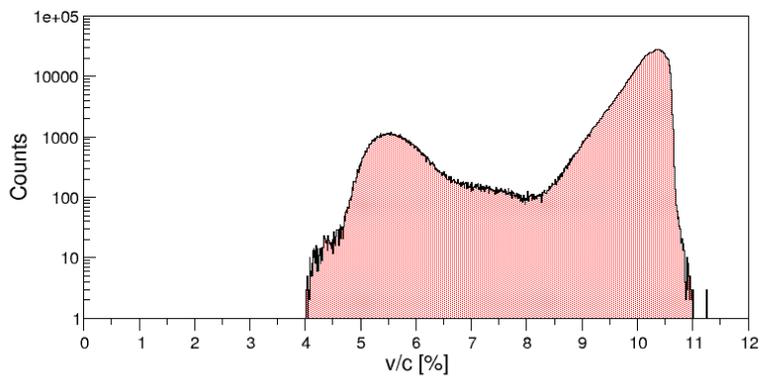
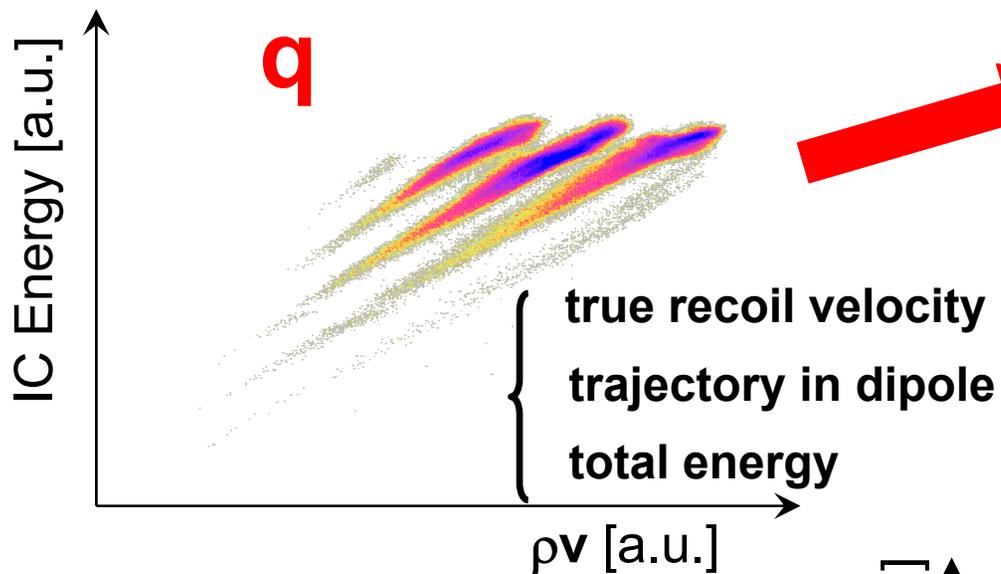
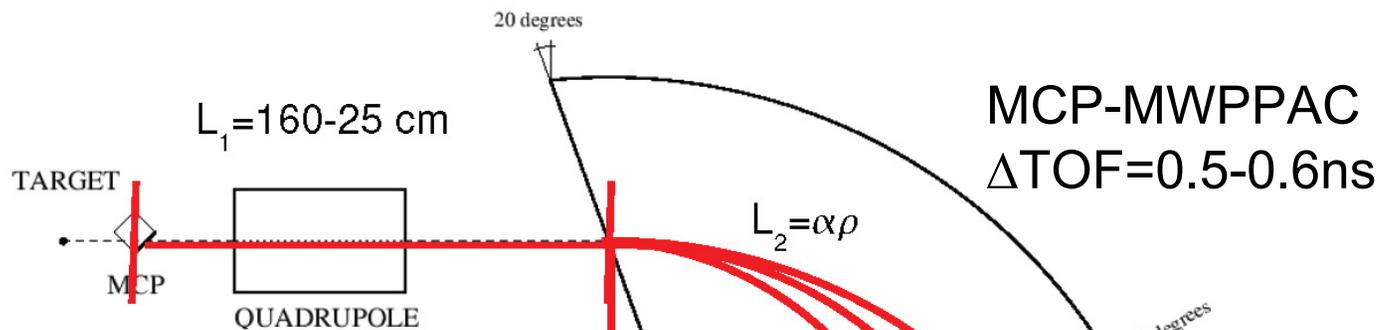
- Entrance detector position (MCP)
- TOF Entrance detector- MWPPAC (~5m)
- Focal Plane position MWPPAC + IC
- Total Energy and Z (DE/E) from IC

S.Beghini et al. Nucl. Instr. Methods Phys. Res. A551, 364 (2005)

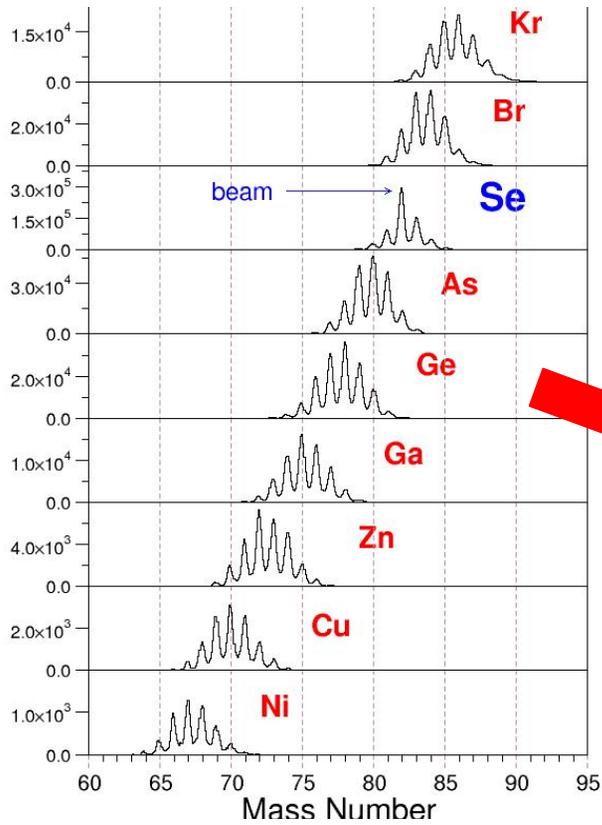
G.Montagnoli et al. Nucl. Instr. Methods Phys. Res. A547, 455 (2005)



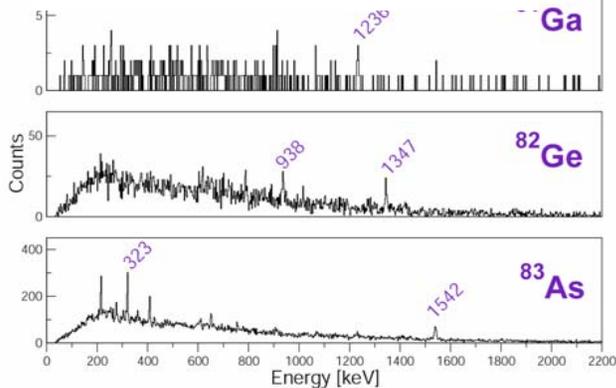
A/q { true recoil velocity
trajectory in dipole



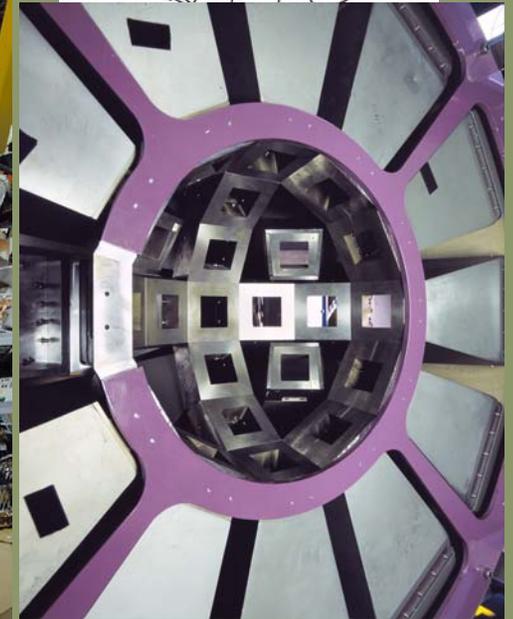
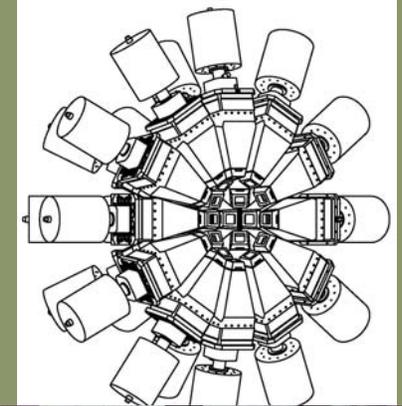
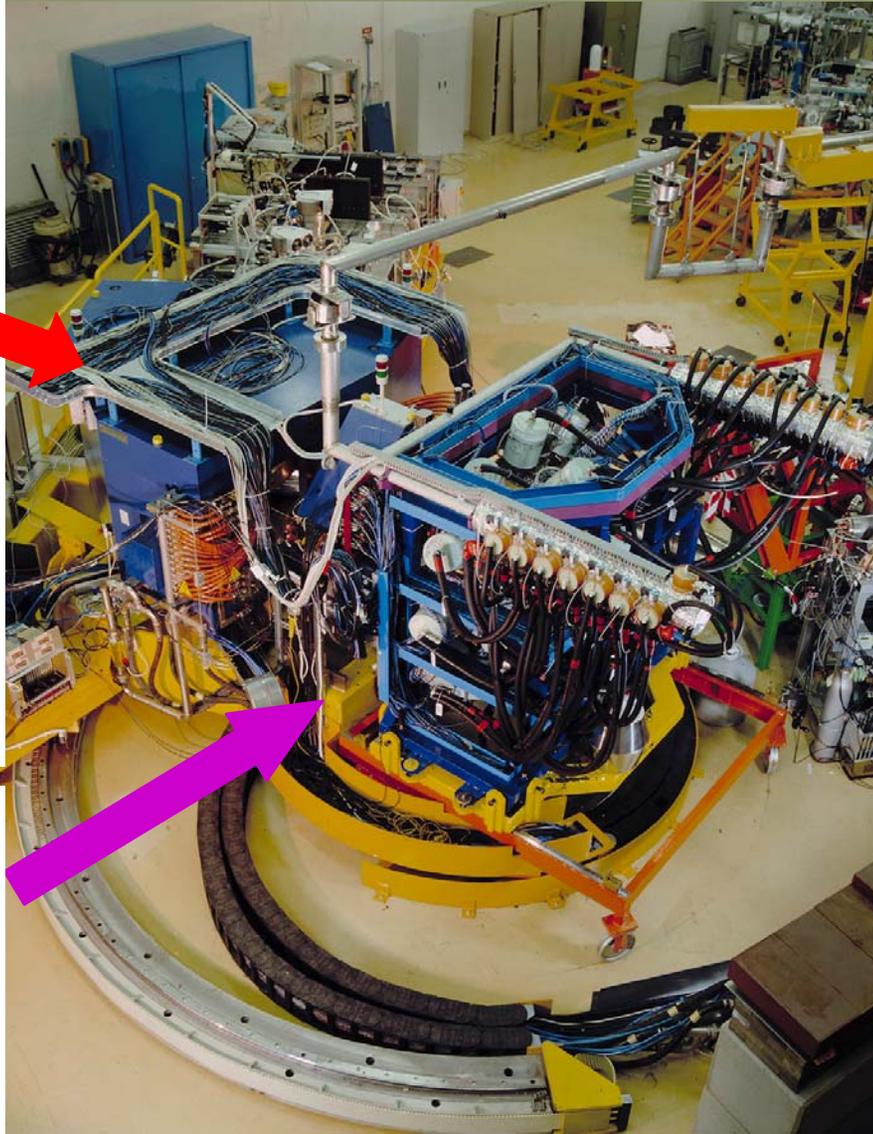
A & Z identification



"in-beam" γ -ray



CLARA: Clover Detector array



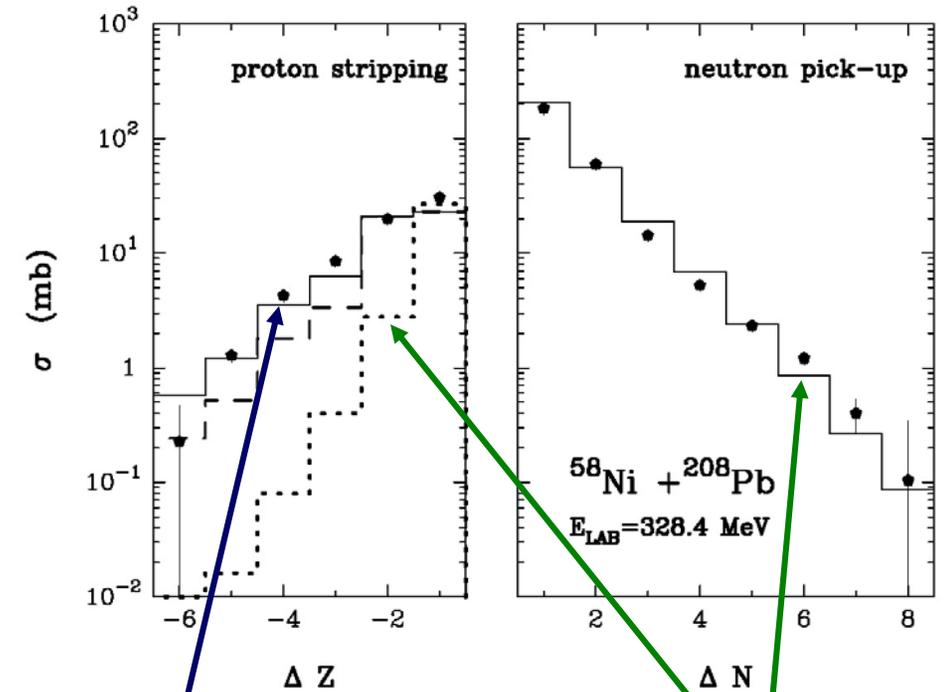
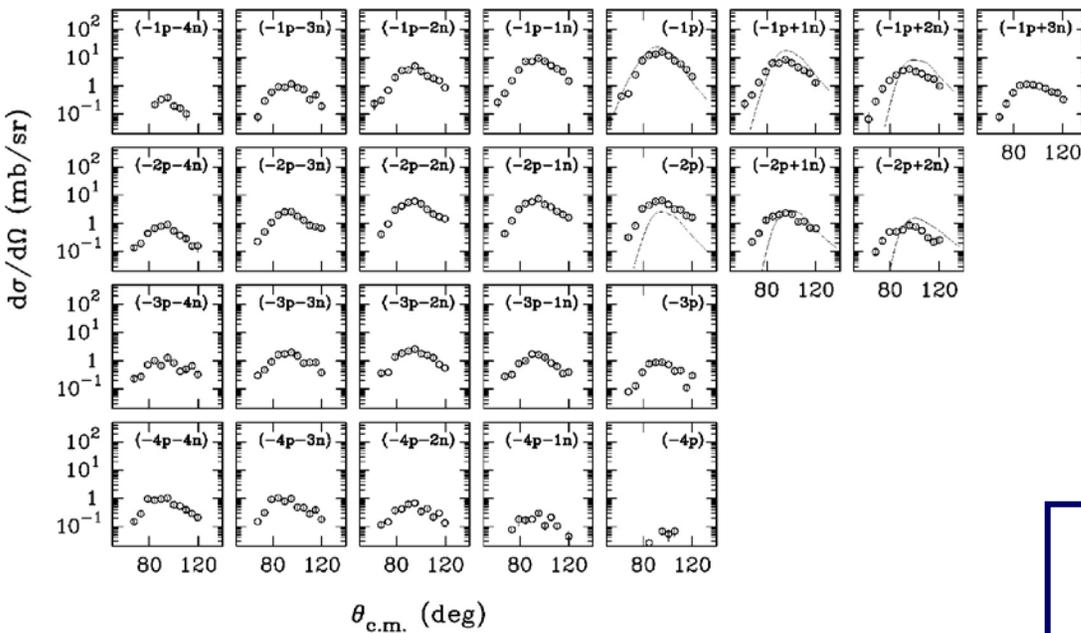
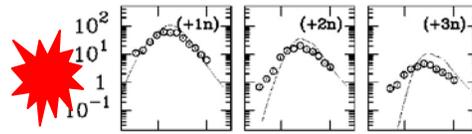
25 Euroball Clover detectors
(EB GammaPool)
Performance at $E_\gamma = 1.3\text{MeV}$
Efficiency $\sim 3\%$
Peak/Total $\sim 45\%$
FWHM $< 10\text{keV}$
(at $v/c = 10\%$)

Grazing reactions transferring several nucleons as a tool to study n-rich nuclei

Deep-inelastic reactions used since thick target pioneering work of R.Broda et al. (Phys. Lett. B 251 (1990) 245)

Use of Multinucleon-transfer triggered by the work of L. Corradi et al. at LNL

^{64}Ni 390MeV + ^{238}U



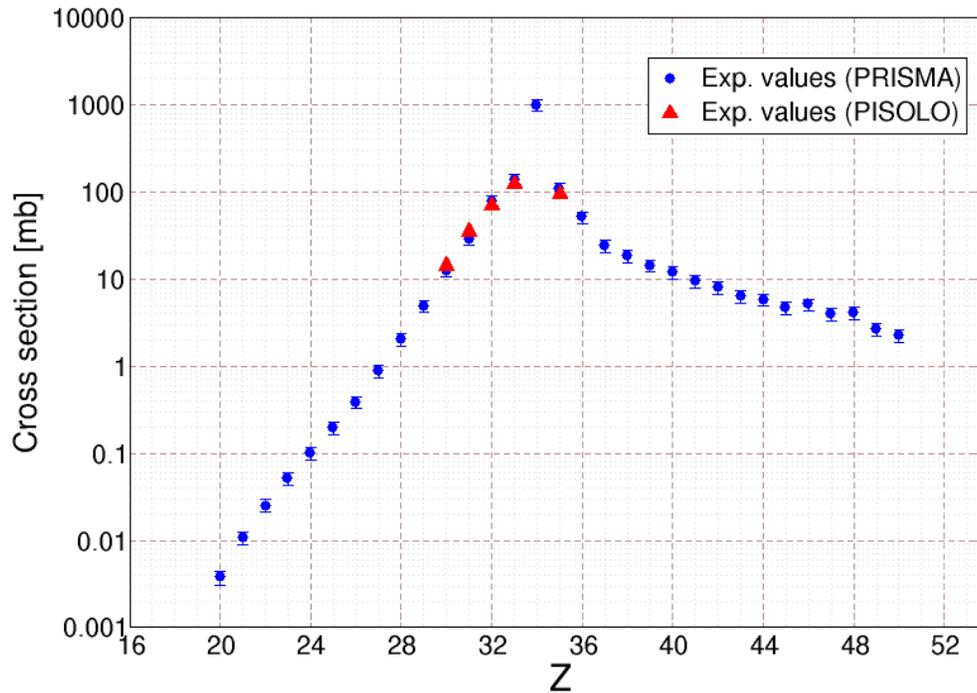
Effective Pairing Term

Grazing calculations

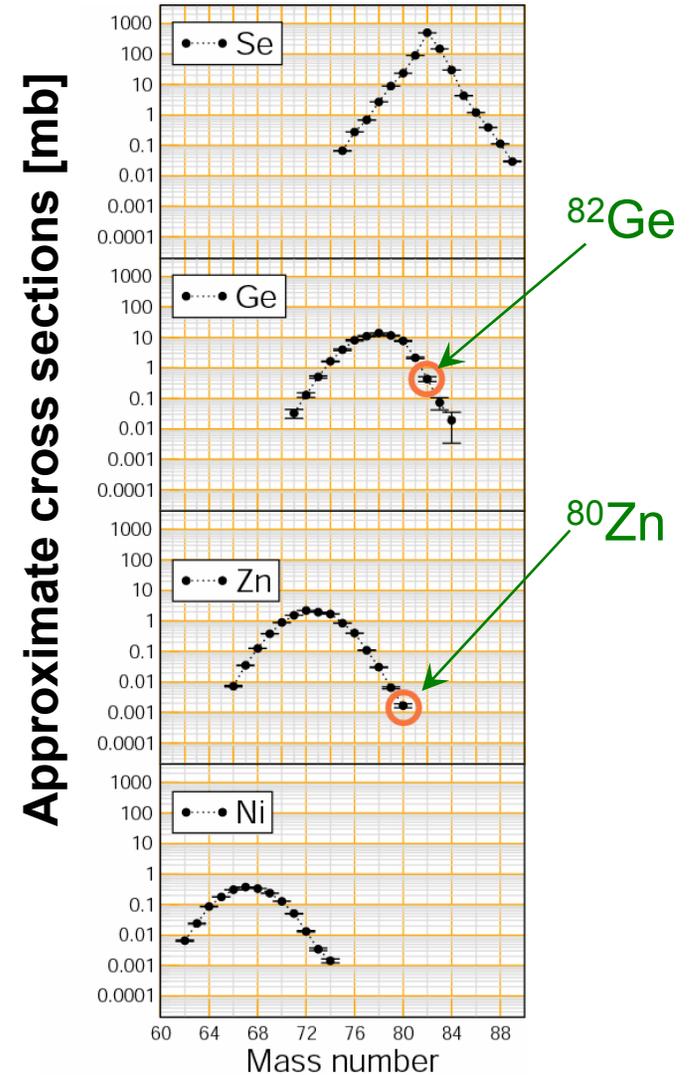
Sequential Transfer

Estimated cross sections for N=50 n-rich nuclei

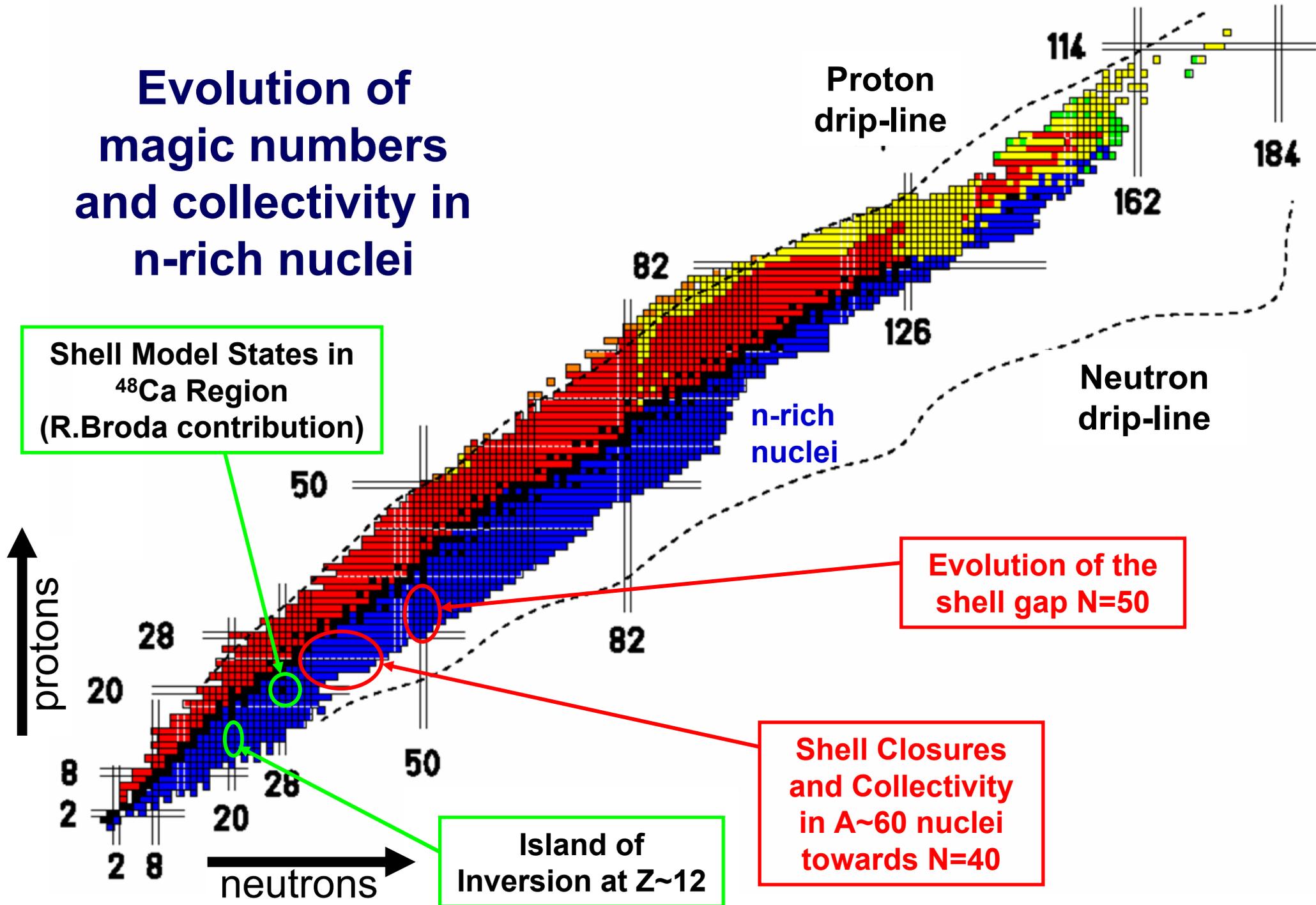
$^{82}\text{Se}(500 \text{ MeV}) + ^{238}\text{U}$



PISOLO: LNL electrostatic spectrometer used for binary reaction cross section measurements



Evolution of magic numbers and collectivity in n-rich nuclei



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

PRISMA at $\theta_G=64^\circ$

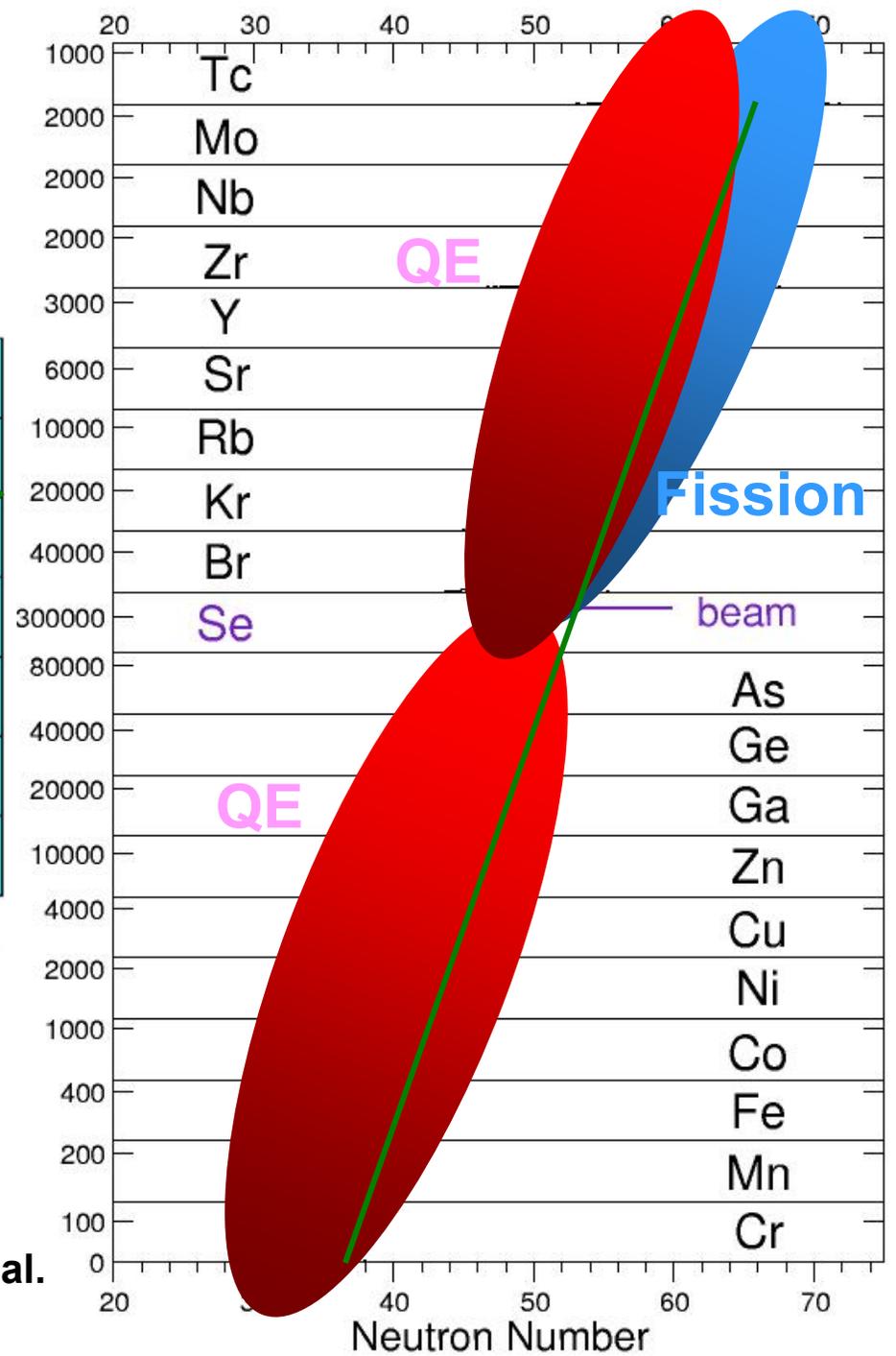
G.deAngelis, G.Duchêne
Analysis: N.Marginean

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 31.80 m 3/2-	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+ ββ	Se83 22.3 m 9/2+	Se84 3.1 m 0+	Se85 31.7 s (5/2+)	Se86 15 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 s 1+	As81 8.50 m 1+	As82 19.1 s (1+)	As83 13.4 s (5/2-,3/2-)	As84 1.92 s 0+	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 8.50 m 0+	Ge79 18.98 s (1/2-)	Ge80 8.50 m 0+	Ge81 4.60 s 0+	Ge82 1.85 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 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+		

40 42 44 46 48 (50)

Evolution of the N=50 shell:
Searching for the shell gap quenching

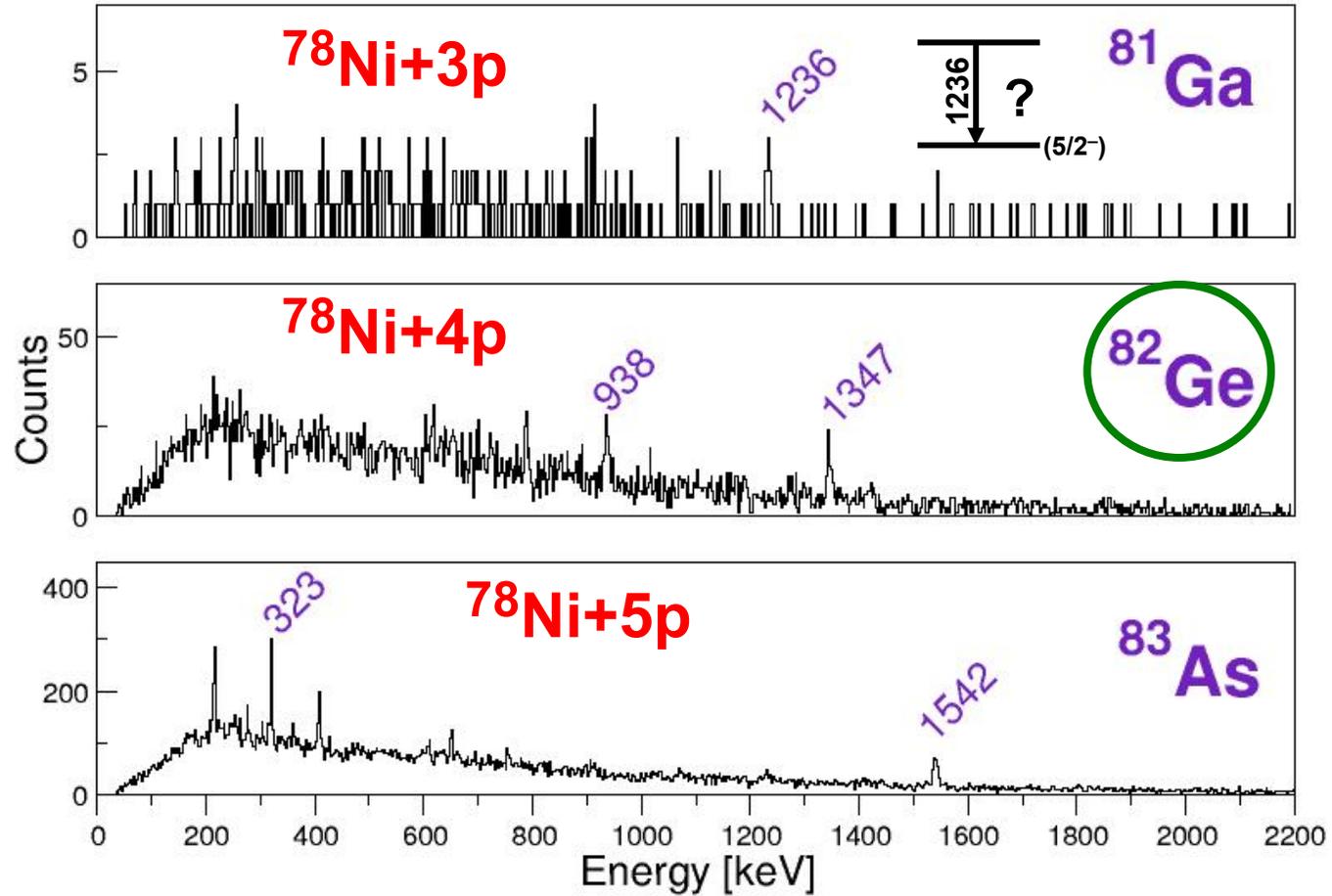
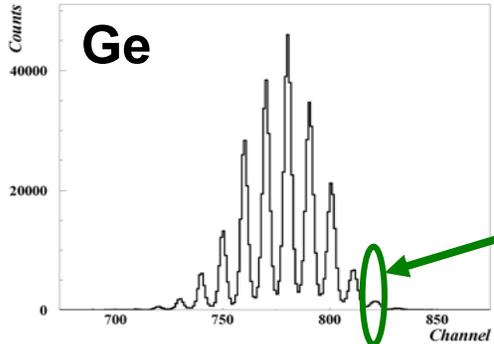
Z=32: INM, R.C.Nayak et al.
PRC 60 (1999) 064305
Z=24-26: RMF, L.S.Geng et al.
J. Phys. G 30 (2004) 1915



Spectroscopy of the N=50 Isotones

Kr82 0+ 11.6	Kr83 9/2+ 11.5	Kr84 0+ 57.0	Kr85 10.756 y 9/2+ 1.3	Kr86 +	Kr87 76.3 m 5/2+
Br81 3/2- 49.31	Br82 35.30 h 5- 1.3	Br83 2.40 h 3/2- 1.3	Br84 31.80 m 2- 1.3	Br85 25.0 m 3/2- 1.3	Br86 55.1 s (2-)
Se80 0+ 49.61	Se81 18.45 m 1/2- 1.3	Se82 1.08E+20 y 0+ ββ 873	Se83 22.3 m 9/2+ 1.3	Se84 3.1 m 0+ 1.3	Se85 31.7 s (5/2+)
As79 9.01 m 3/2-	As80 15.2 s 1+ 1.3	As81 2.8 s 3/2- 1.3	As82 19.1 s (1+) 1.3	As83 13.4 s (5/2-;3/2-) 1.3	As84 4.02 s 1.3
Ge78 88.0 m 0+	Ge79 18.98 s (1/2-) 1.3	Ge80 29.5 s 0+ 1.3	Ge81 7.6 s (9/2+) 1.3	Ge82 4.60 s 0+ 1.3	Ge83 1.85 s (5/2+)
Ga77 13.2 s (3/2-)	Ga78 5.09 s (3+) 1.3	Ga79 2.847 s (3/2-) 1.3	Ga80 1.697 s (3) 1.3	Ga81 1.217 s (5/2-) 1.3	Ga82 0.599 s (1,2,3)
Zn76 5.7 s 0+	Zn77 2.08 s (7/2+) 1.3	Zn78 1.47 s 0+ 1.3	Zn79 995 ms (9/2+) 1.3	Zn80 0.545 s 0+ 1.3	Zn81 0.29 s 1.3
Cu75 1.224 s	Cu76 0.641 s	Cu77 469 ms	Cu78 342 ms	Cu79 188 ms	Cu80
Ni74 1.1 s 0+	Ni75	Ni76 0+ 1.3	Ni77	Ni78 0+ 1.3	

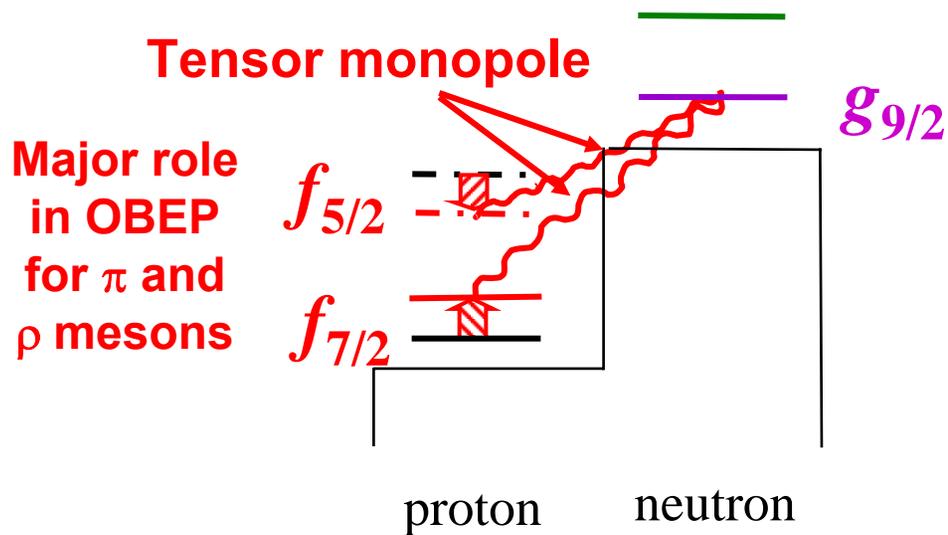
46 48 50



82Ge

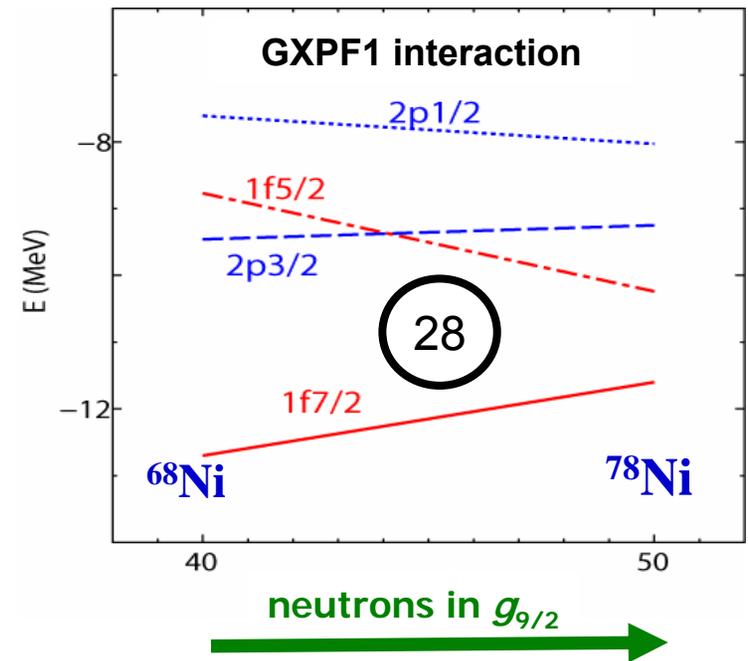
S.M. for the N=50 isotones

Systematic variation of proton effective single-particle energies from N=40 to N=50 due to the evolution of the monopole interaction.



Basic trend reproduced using realistic interactions (Shell model with renormalized SPE: monopole migration)

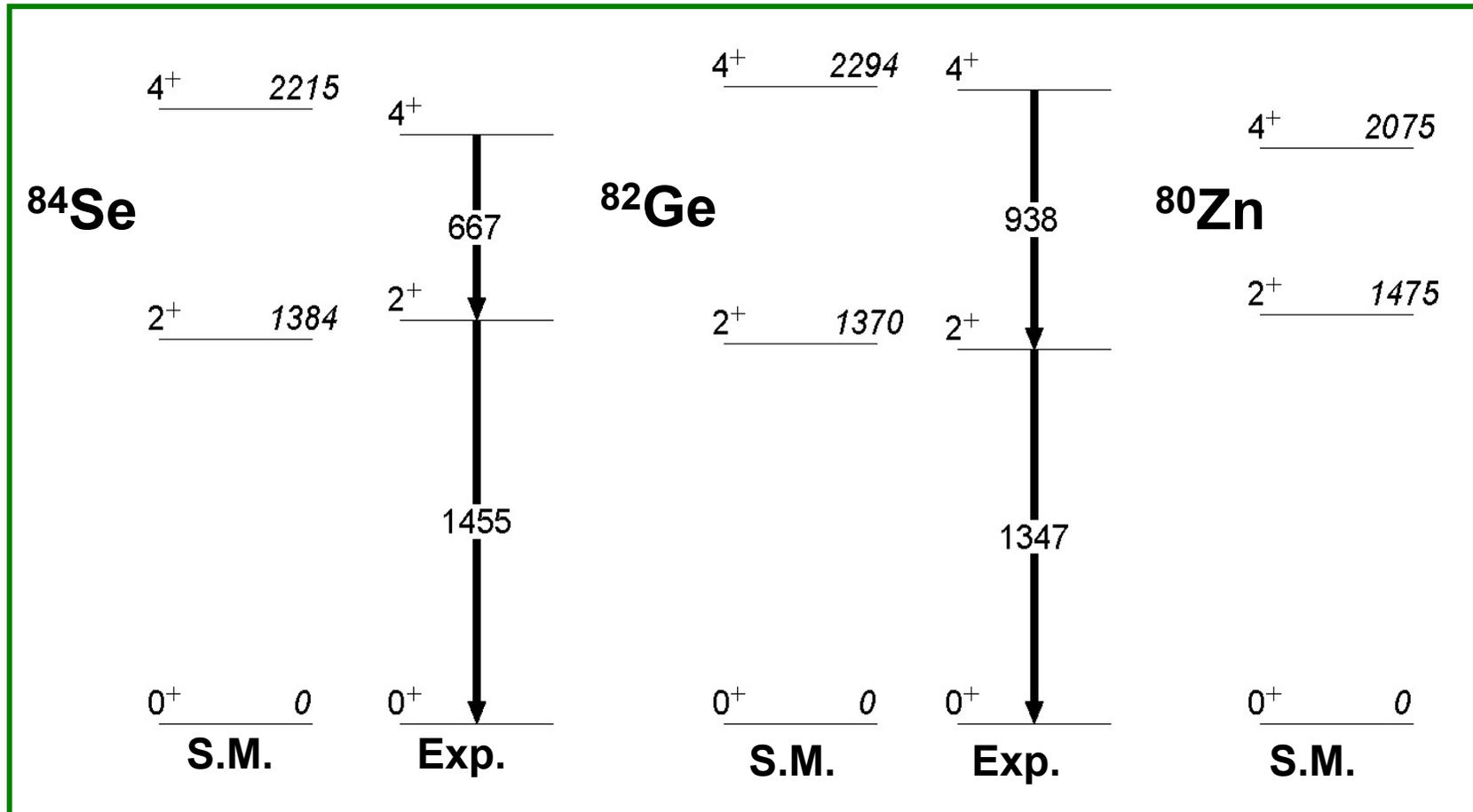
A.F. Lisetskiy et al., PRC 70, (2004) 044314
 X. Ji and B.H. Wildenthal PRC 37 (1988) 1256
 Y.H. Zhang et al., PRC 70 (2004)24301



Inversion of the effective single particle orbitals $f_{5/2}$ and $p_{3/2}$.

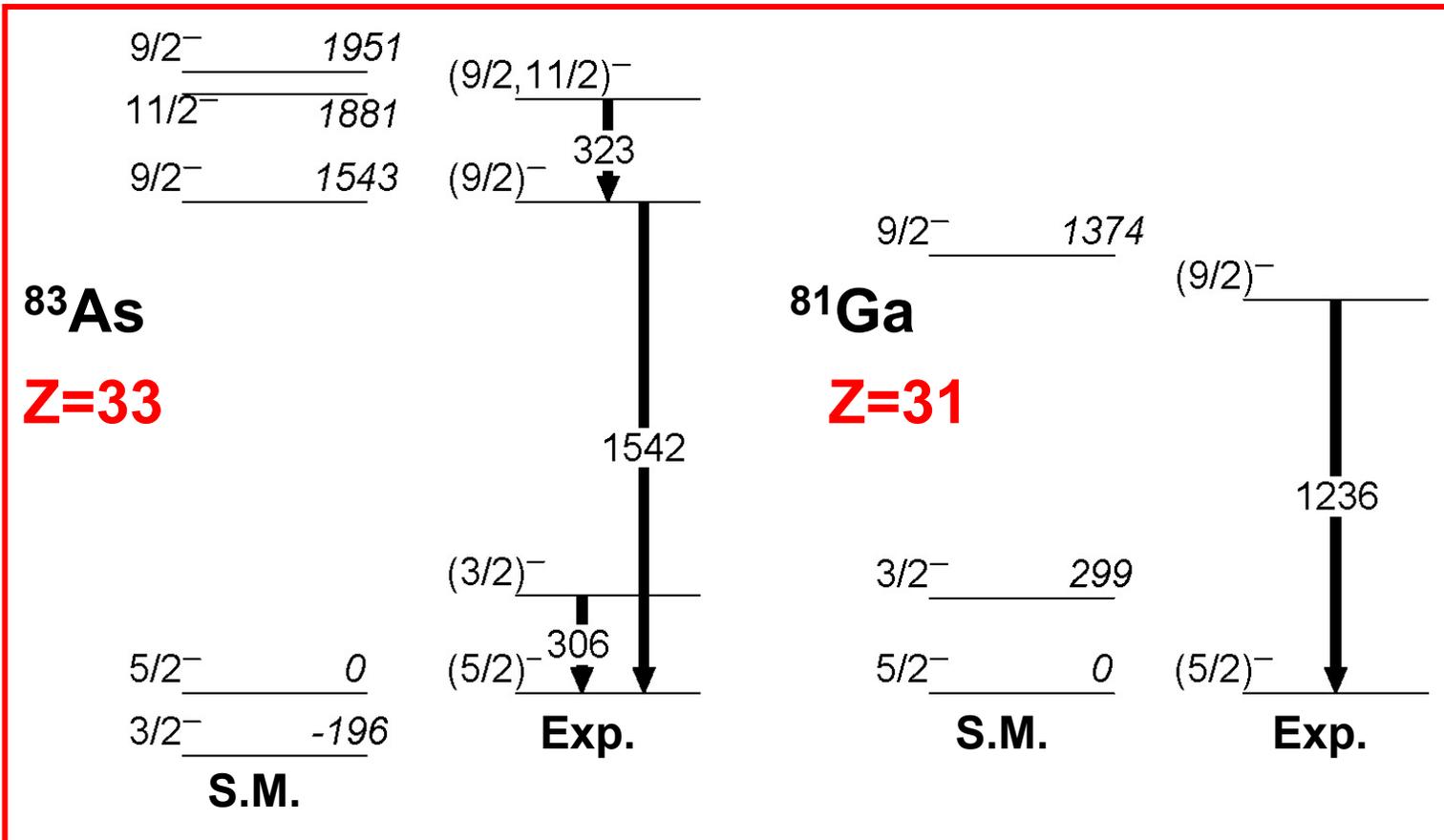
T. Otsuka et al. PRL95, 232502 (2005)

Even-even N=50 isotones



Interaction from A.F. Lisetskiy, B.A. Brown, M. Horoy, H. Grawe
 PRC 70 (2004) 44314, EPJA 25 s01 (2005) 95
 (G-Matrix based on Bonn-C)

Odd-Z N=50 isotones

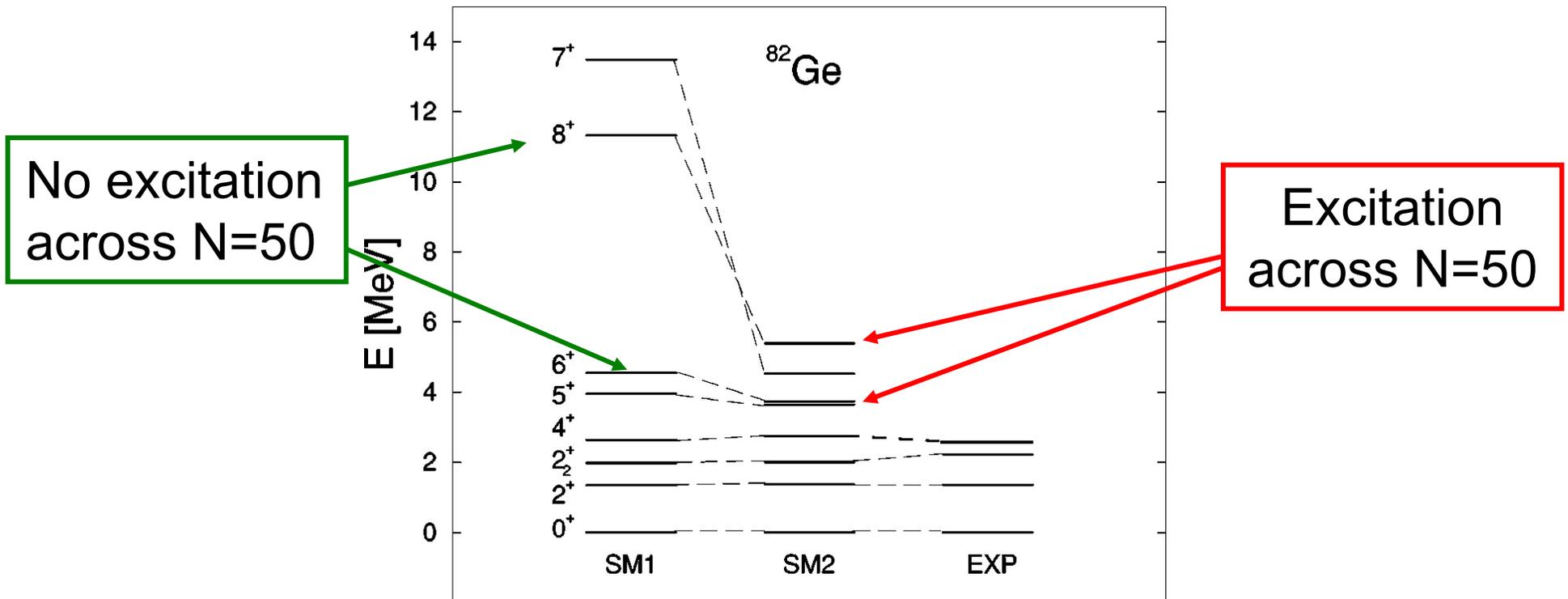


Interaction from A.F. Lisetskiy, B.A.Brown, M. Horoy, H. Grawe
 PRC 70 (2004) 44314, EPJA 25 s01 (2005) 95
 (G-Matrix based on Bonn-C)

Conclusions on N=50

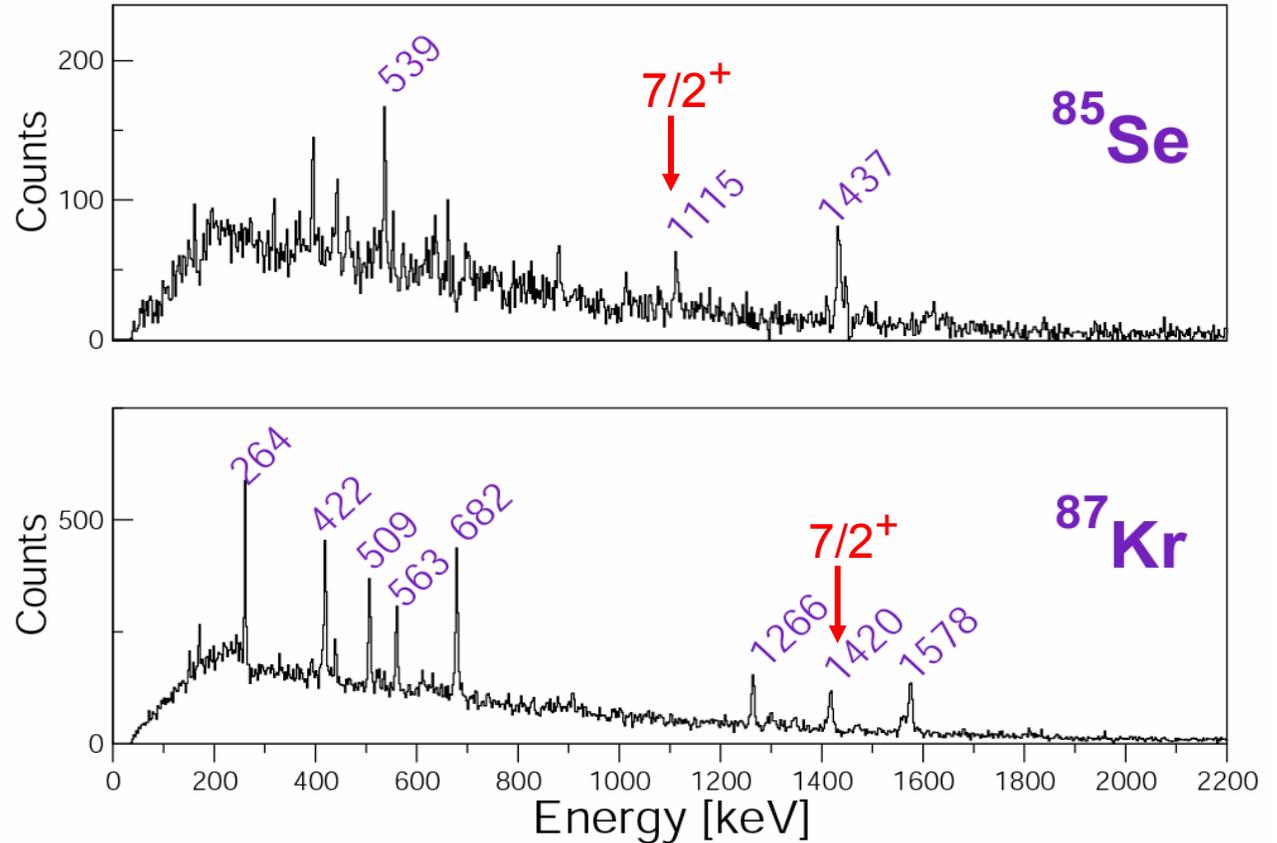
No evidence of shell gap change down to ^{81}Ga ($Z=31$)

Information can be derived from high spin states in ^{82}Ge and ^{81}Ga .



Spectroscopy of the N=51 Isotones

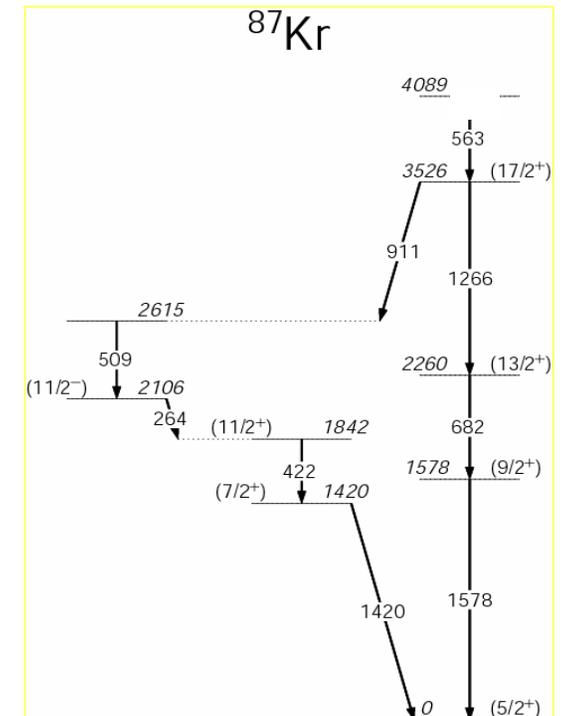
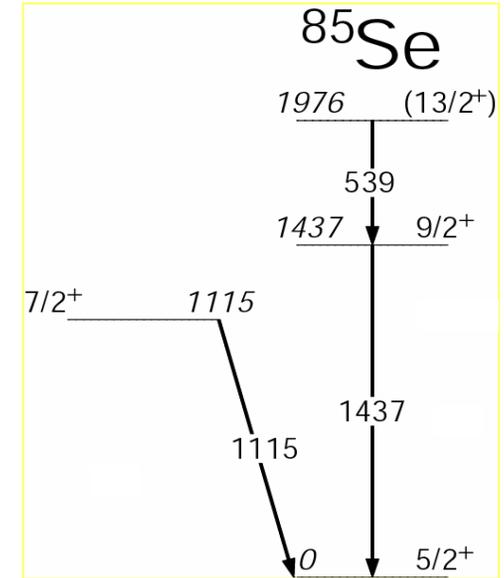
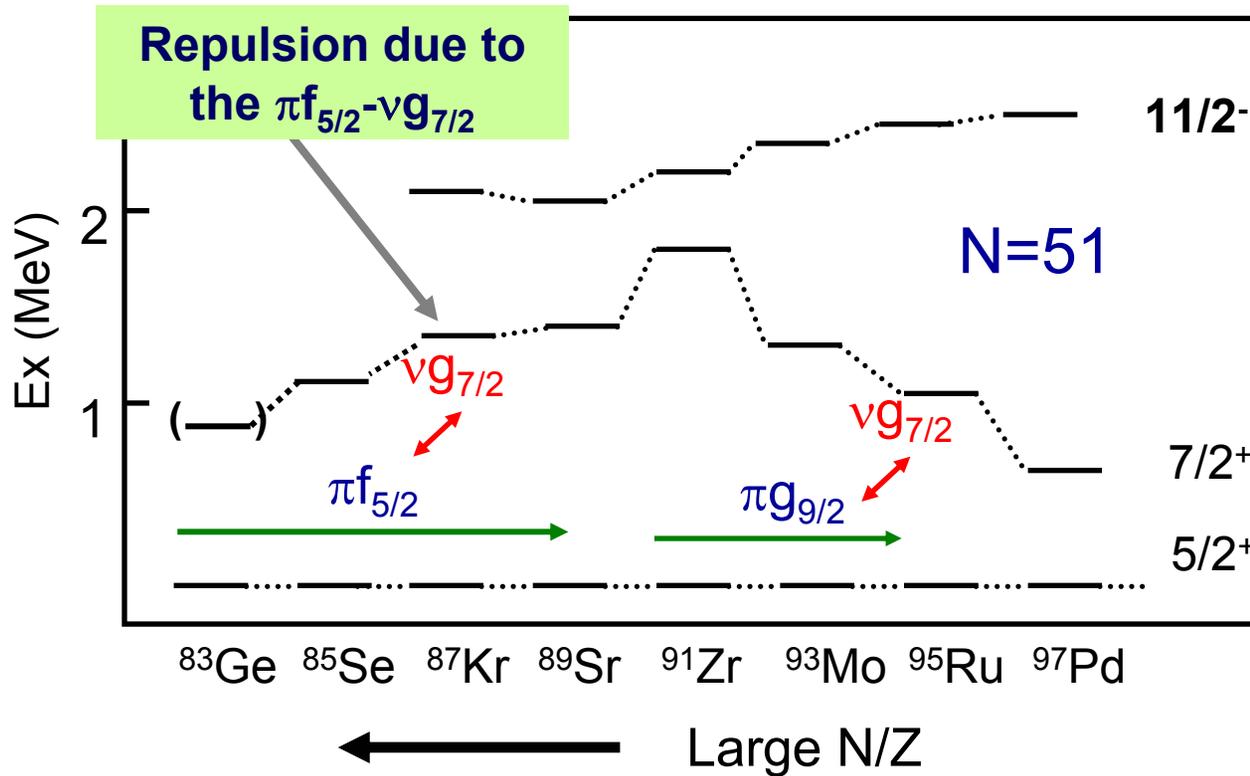
Kr82	Kr83	Kr84	Kr85	Kr86	Kr87
0+	9/2+	0+	10.756 y 9/2+	0+	76.3 m 5/2+
11.6	11.5	57.0		17.3	
Br81	Br82	Br83	Br84	Br85	Br86
3/2-	5-	3/2-	31.80 m 2-	2.90 m 3/2-	55.1 s (2-)
49.31					
Se80	Se81	Se82	Se83	Se84	Se85
0+	18.45 m 1/2-	1.08E+20 y 0+ $\beta\beta$	22.3 m 9/2+	3.1 m 0+	31.7 s (5/2+)
49.61					
As79	As80	As81	As82	As83	As84
9.01 m 3/2-	15.2 s 1+	33.8 s 3/2-	19.1 s (1+)	13.4 s (5/2-,3/2-)	4.02 s
Ge78	Ge79	Ge80	Ge81	Ge82	Ge83
88.0 m 0+	18.98 s (1/2)-	29.5 s 0+	7.6 s (9/2+)	4.60 s 0+	1.85 s (5/2+)
Ga77	Ga78	Ga79	Ga80	Ga81	Ga82
13.2 s (3/2-)	5.09 s (3+)	2.847 s (3/2-)	1.697 s (3)	1.217 s (5/2-)	0.599 s (1,2,3)
Zn76	Zn77	Zn78	Zn79	Zn80	Zn81
5.7 s 0+	2.08 s (7/2+)	1.47 s 0+	995 ms (9/2+)	0.545 s 0+	0.29 s
Cu75	Cu76	Cu77	Cu78	Cu79	Cu80
1.224 s	0.641 s	469 ms	342 ms	188 ms	
Ni74	Ni75	Ni76	Ni77	Ni78	
1.1 s 0+		0+		0+	
46	48	50			



N=51 is the ideal region to study the evolution of the neutron $g_{7/2}$ monopole due to the $\pi f_{5/2} \leftrightarrow \nu g_{7/2}$ tensor interaction

The N=51 isotones

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



Calculations in progress by T.Otsuka.

A~60: Neutron-rich Fe isotopes

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

CLARA-PRISMA

$$\theta_G = 64^\circ$$

Doubly magic character suggested
R.Broda et al.,
PRL 74 (1995) 868

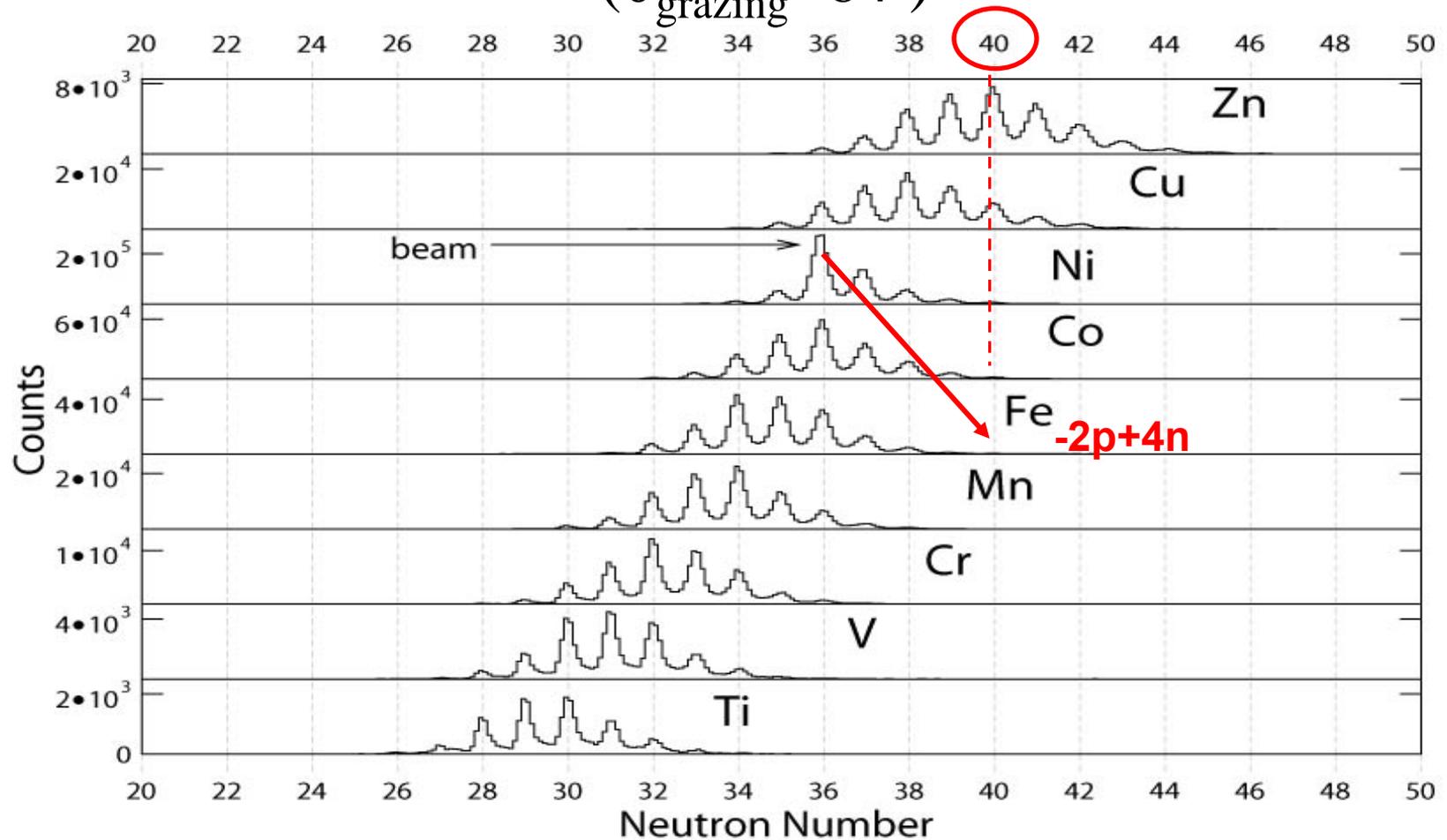
Yrast states:
evolution of the
collectivity towards
N=40 in the Fe
(Z=26) isotopes

28	Ni59 7.6E+4 y 3/2-	Ni60 0+	Ni61 3/2-	Ni62 0+	Ni63 100.1 y 1/2-	Ni64 0+ 0.926	Ni65 2.5172 h 5/2-	Ni66 54.6 h 0+	Ni67 21 s (1/2-)	Ni68 19 s 0+	Ni69 11.4 s
	Co58 70.82 d 2+	Co59 7/2-	Co60 5.2714 y 5+	Co61 1.650 h 7/2-	Co62 1.50 m 2+	Co63 27.4 s (7/2)-	Co64 0.30 s 1+	Co65 1.20 s (7/2)-	Co66 0.23 s (3+)	Co67 0.42 s (7/2-)	Co68 18 s
	Fe57 1/2-	Fe58 0+	Fe59 44.503 d 3/2-	Fe60 1.5E+6 y 0+	Fe61 5.98 m 3/2-,5/2-	Fe62 68 s 0+	Fe63 6.1 s (5/2)-	Fe64 2.0 s 0+	Fe65 0.4 s	Fe66 0+	Fe67
	Mn56 2.5785 h 3+	Mn57 85.4 s 5/2-	Mn58 3.0 s 0+	Mn59 4.6 s 3/2-,5/2-	Mn60 51 s 0+	Mn61 0.71 s (5/2)-	Mn62 0.88 s (3+)	Mn63 0.25 s	Mn64	Mn65	Mn66
	Cr55 3.497 m 3/2-	Cr56 5.94 m 0+	Cr57 21.1 s 3/2-,5/2-,7/2-	Cr58 7.0 s 0+	Cr59 0.74 s	Cr60 0.57 s 0+	Cr61	Cr62 0+	Cr63	Cr64 0+	Cr65
	V54 49.8 s 3+	V55 6.54 s (7/2-)	V56	V57	V58	V59	V60	V61	V62	V63	
	Ti53 32.7 s (3/2)-	Ti54 0+	Ti55	Ti56 0+	Ti57	Ti58 0+	Ti59	Ti60 0+	Ti61		
	Sc52 8.2 s 3+	Sc53	Sc54	Sc55	Sc56	Sc57	Sc58	Sc59			
20	Ca51 10.0 s (3/2-)	Ca52 4.6 s 0+	Ca53 90 ms (3/2-,5/2-)	Ca54 0+	Ca55	Ca56 0+	Ca57				

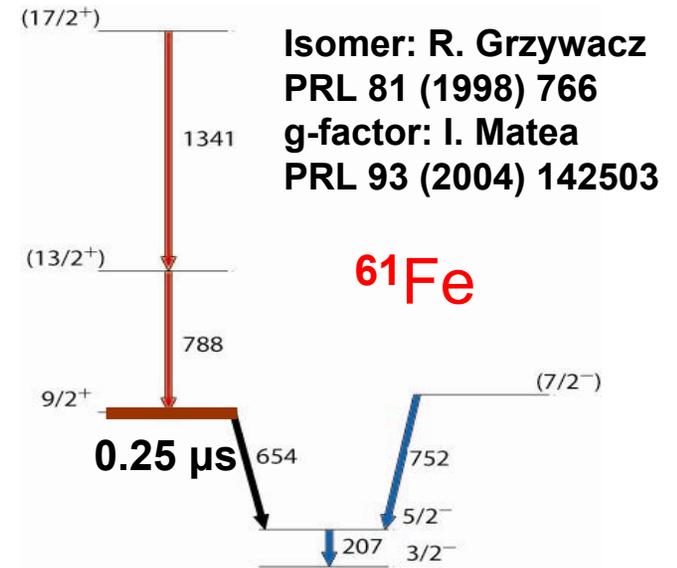
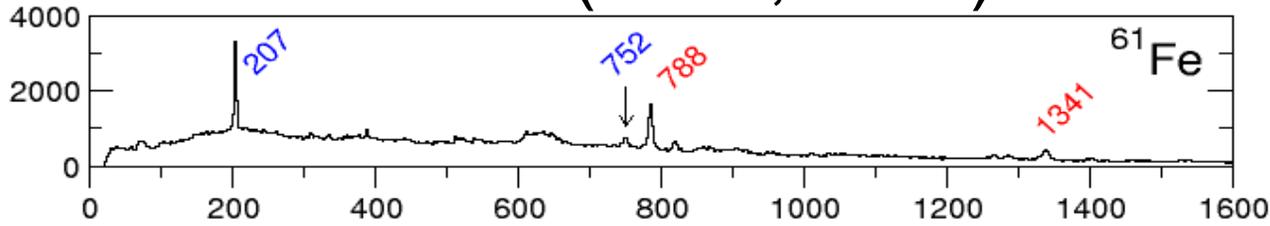
Mass distribution

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

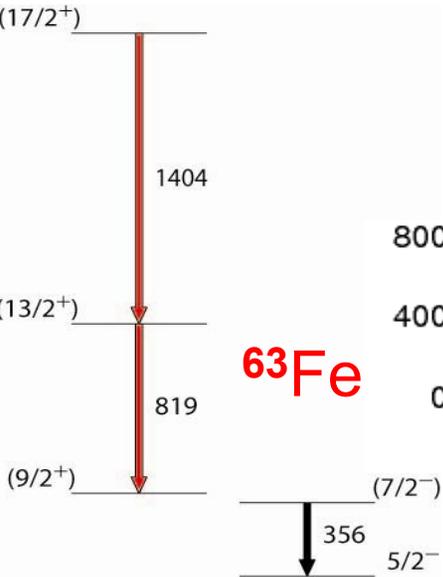
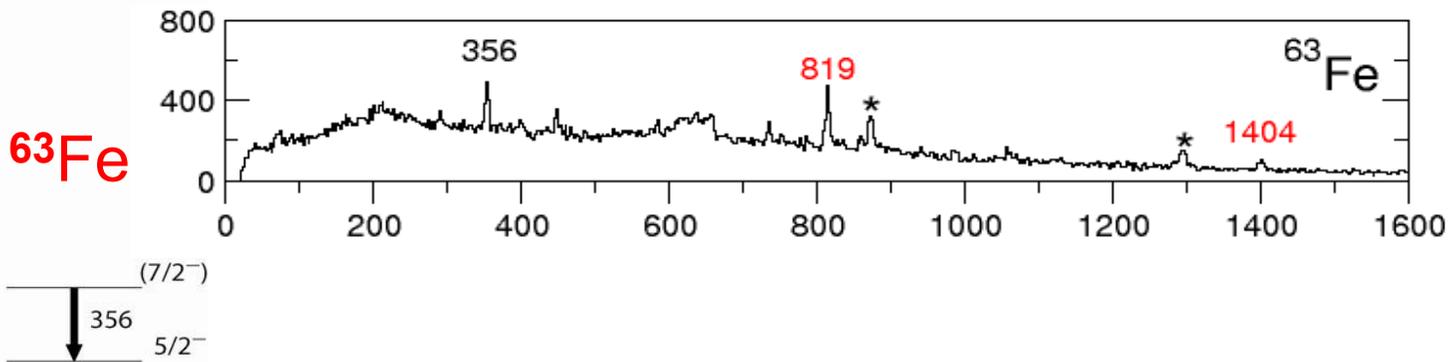
($\theta_{\text{grazing}} = 64^\circ$)



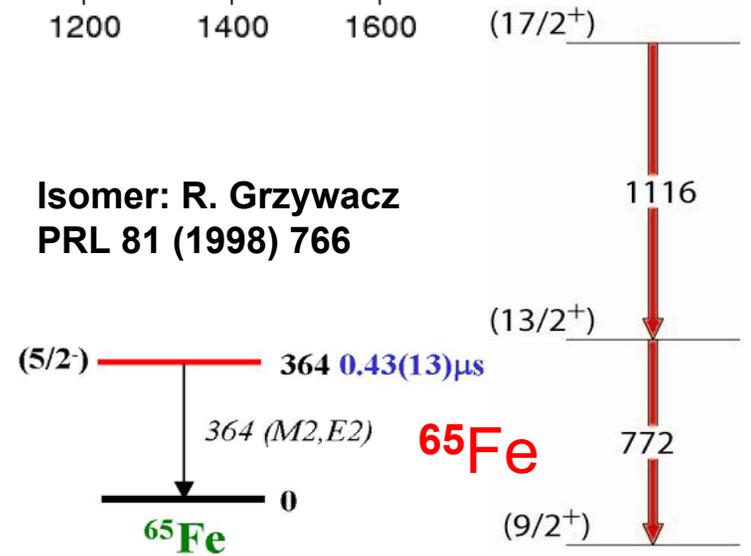
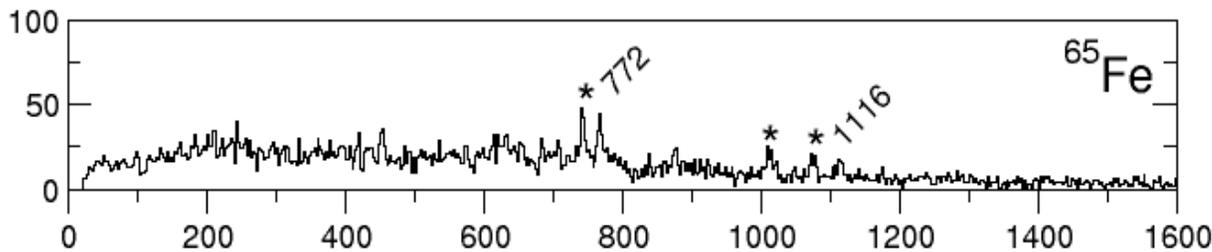
^{61}Fe (Z=26, N=35)



^{63}Fe (Z=26, N=37)



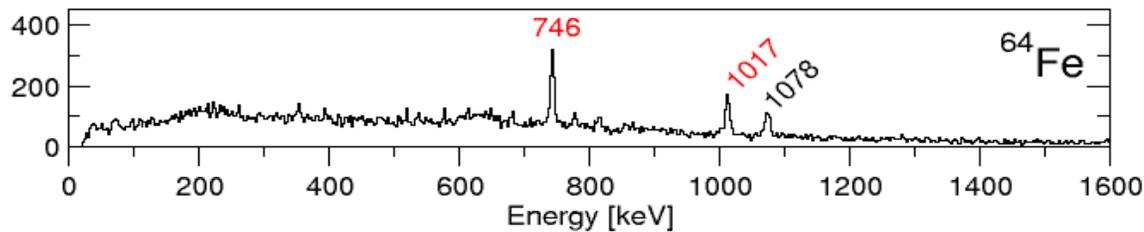
^{65}Fe (Z=26, N=39)



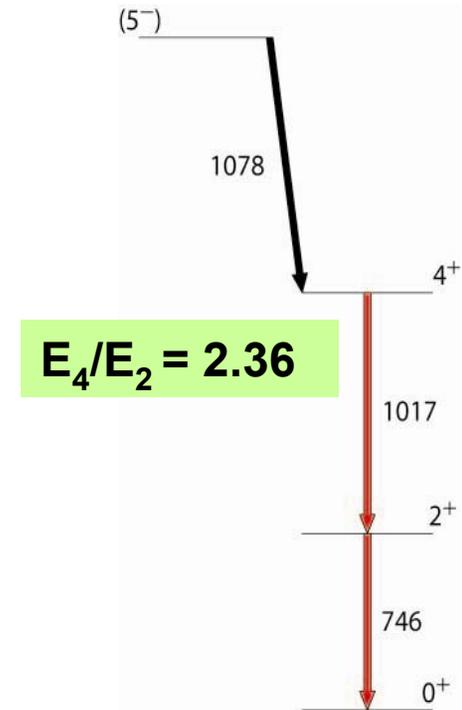
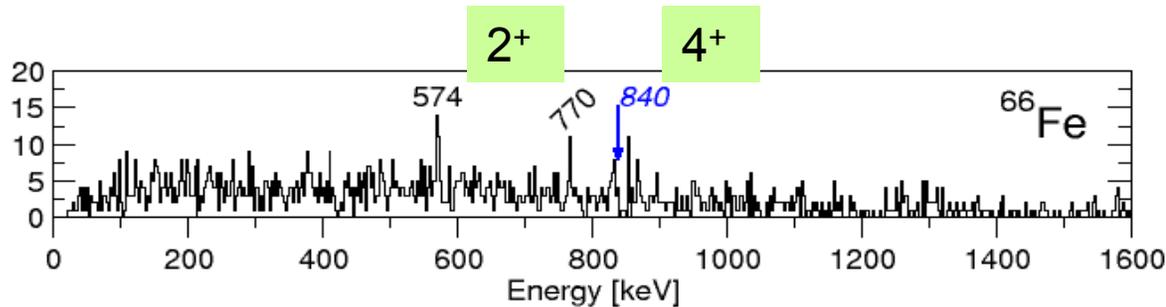
Neutron-rich even Fe nuclei

2^+ in ^{64}Fe and ^{66}Fe known from Mn β -decay measurements at ISOLDE (M.Hannawald et al., PRL 82 (1999) 1391)

^{64}Fe (Z=26,N=38)

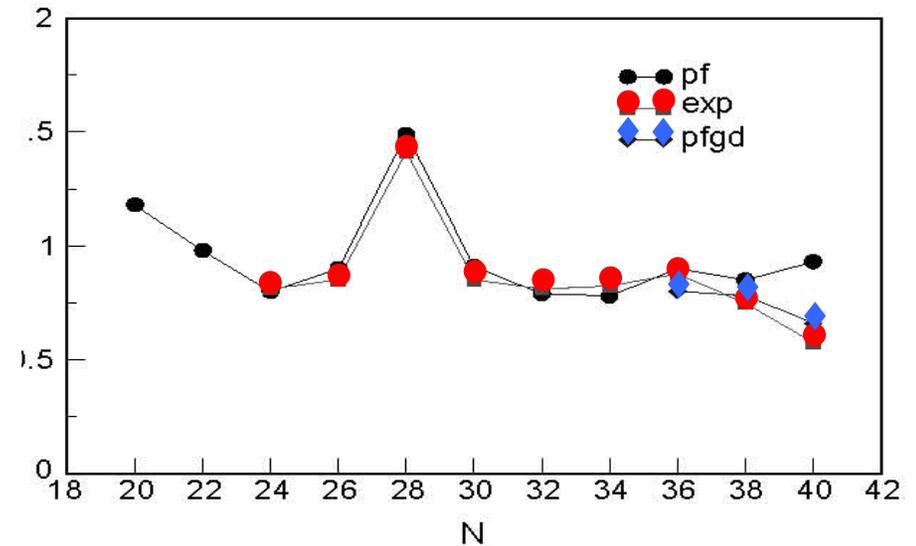
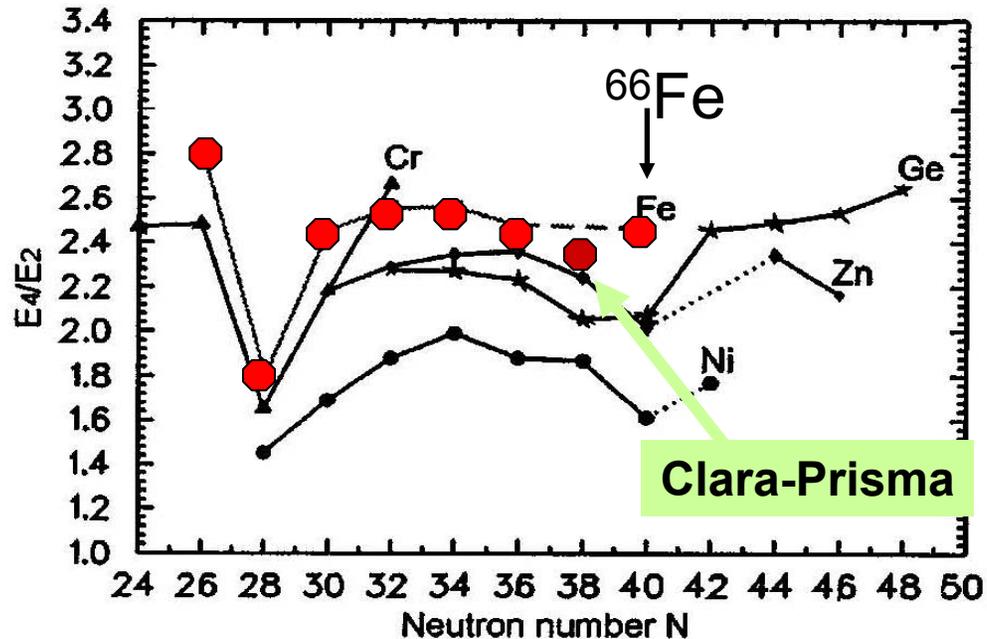


^{66}Fe (Z=26,N=40)



Observed the known 2^+
Two candidates for 4^+

New region of deformation



7. Excitation energy of the 2^+ states in MeV: Fe isotopes.

In nuclei where the $1f_{7/2}$ proton shell is not filled, the neutrons excited to the sdg -shell couple to the pf -proton and deformation appears. The removal of 2 protons from ^{68}Ni drives ^{66}Fe into prolate shapes generating a new region of deformation.

M. Hannawald et al., PRL82, 1391 (1999)

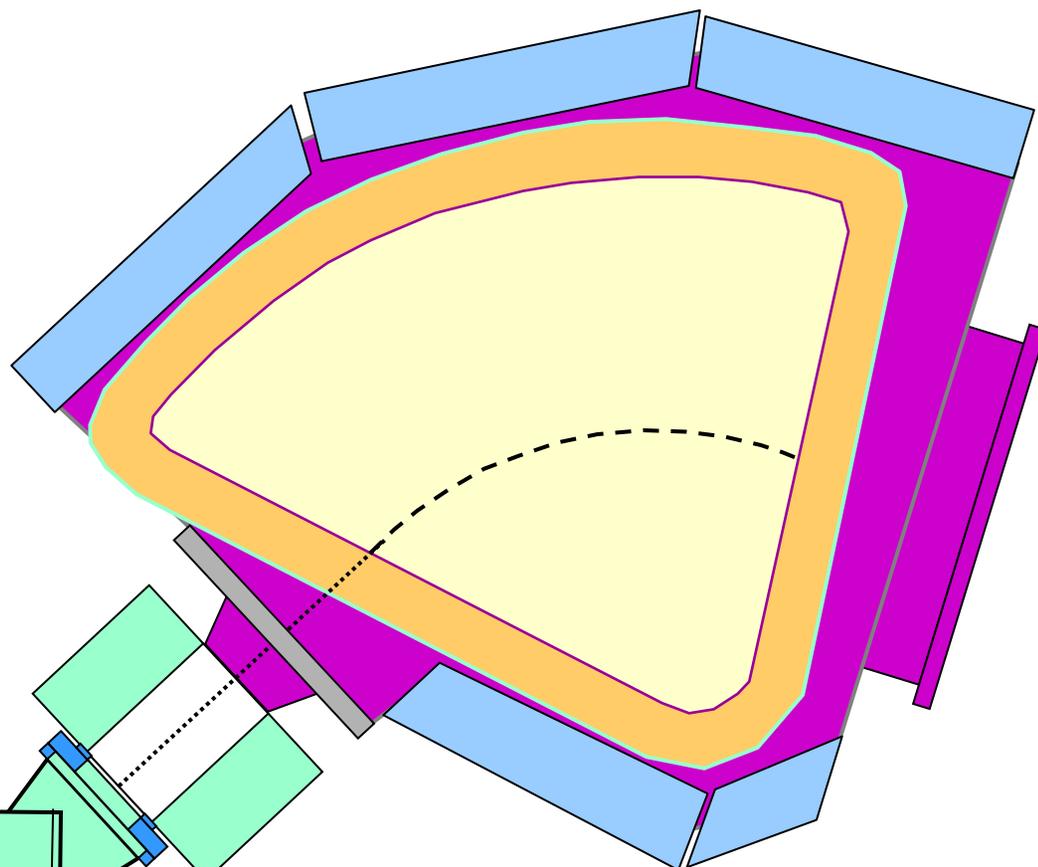
E. Caurier et al., Eur. Phys. J A 15, 145 (2002)

Differential RDDS Measurements with CLARA-PRISMA

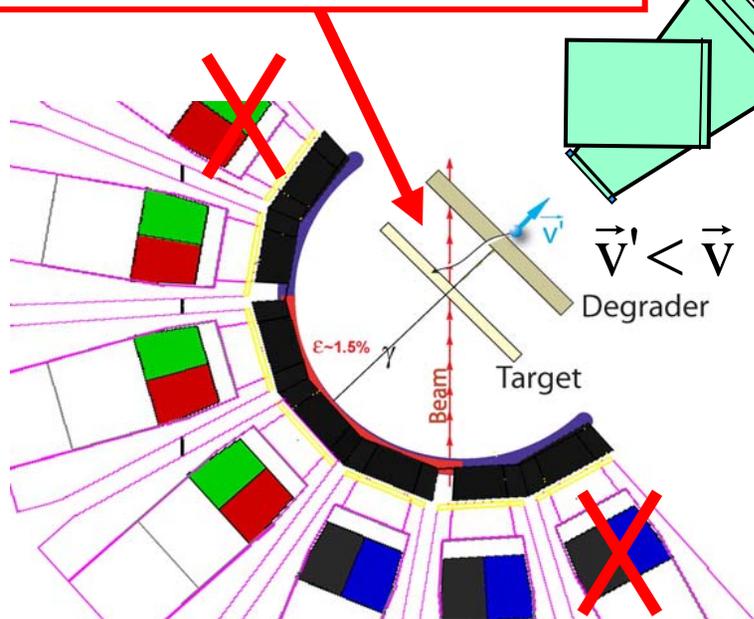
A. Dewald, N. Marginean, A. Gadea



Differential Plunger for angles $\neq 0^\circ$



**PRISMA mass
(A) resolution
after degrader**



102° ring (1/2 efficiency)
not usable for lifetime
measurements

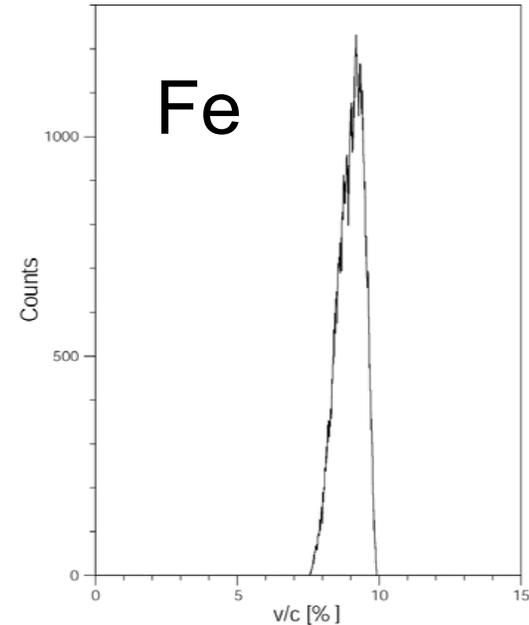
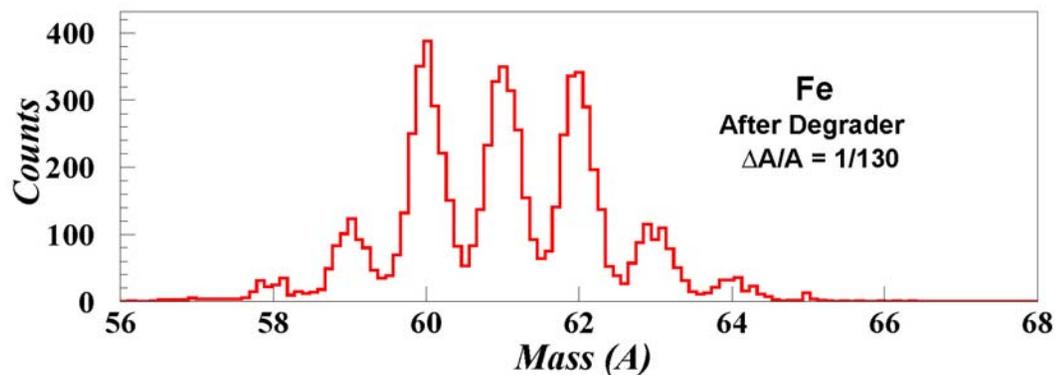
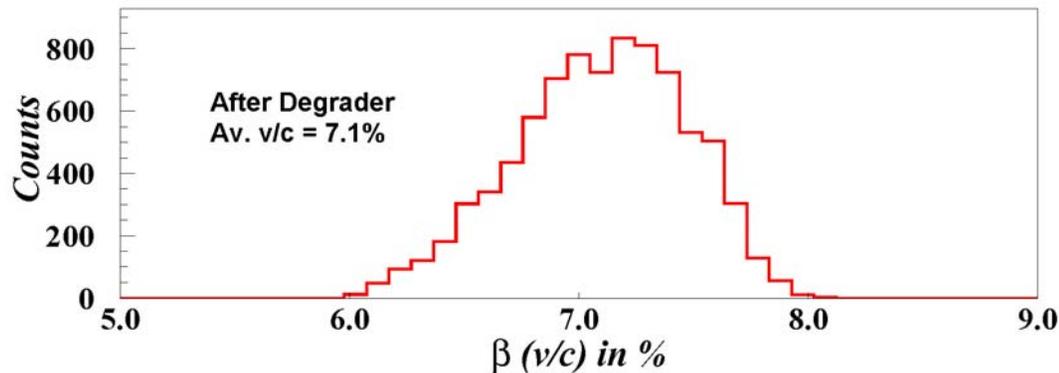
Test Experiment performed in June 2006

Beam: ^{64}Ni at 400MeV

Target: ^{93}Nb 1mg/cm 2 + ^{208}Pb 1mg/cm 2

Degrader: ^{24}Mg 2mg/cm 2

Debugging of the setup + 2 days of measurement at 150 μm and 50 μm performed with limited beam intensity



Average v/c after reaction 8.8% and after degrader 7.1%

Product Energies $\sim 4\text{MeV.A}$

Mass and Z resolution preserved

Preliminary Results for 150 μ m Target-Degrader Distance

Test case ^{60}Fe

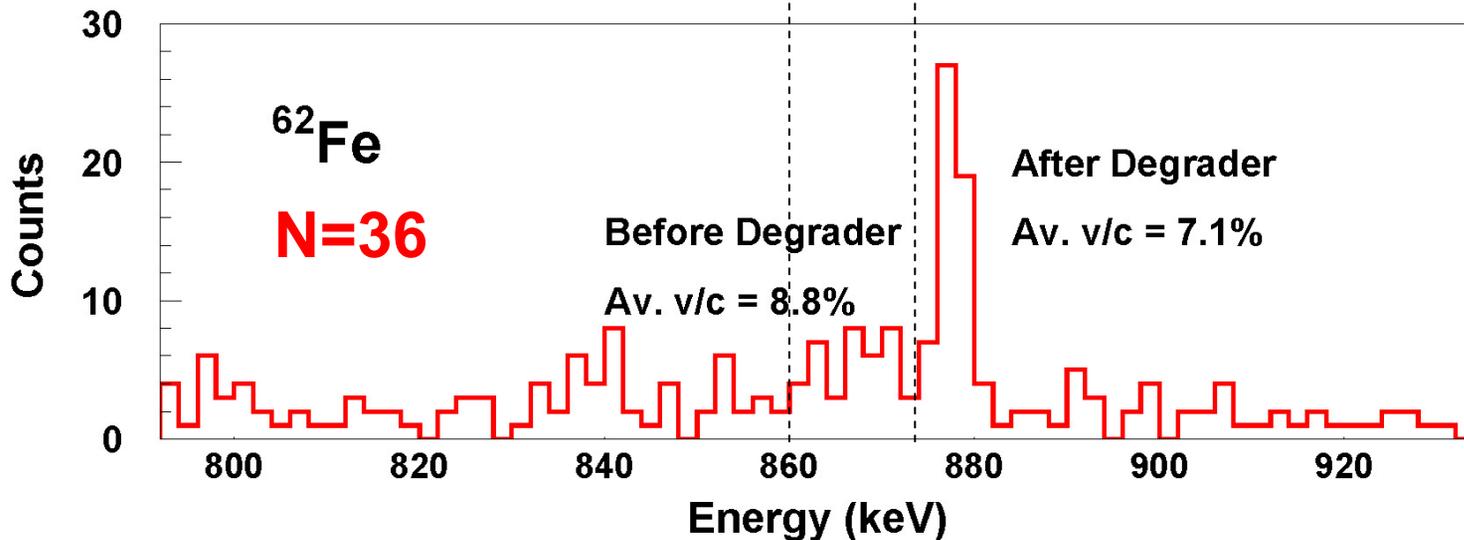
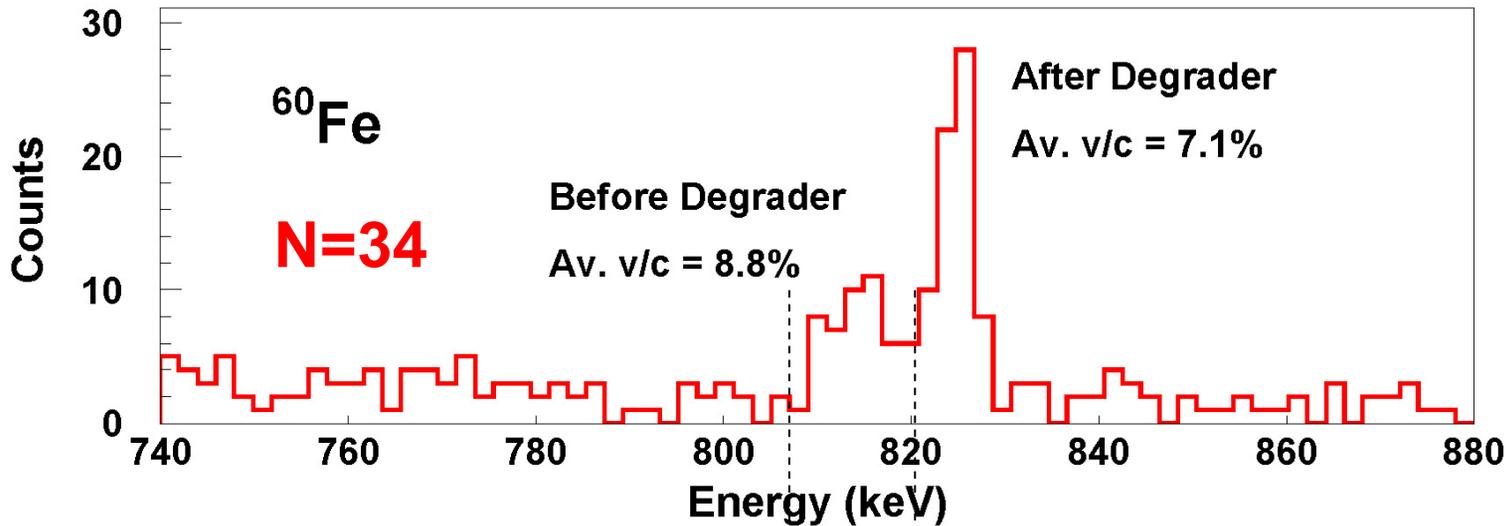
(2^+ at 824 keV)

$T_{1/2} = 8.2(15)$ ps
(agreement with known 8.0(15) ps)
 $B(E2) = 0.018 e^2b^2$
(13 W.u.)

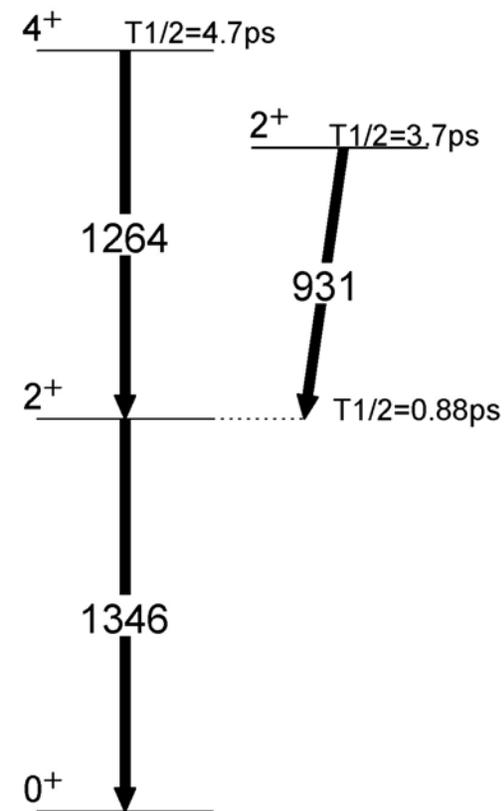
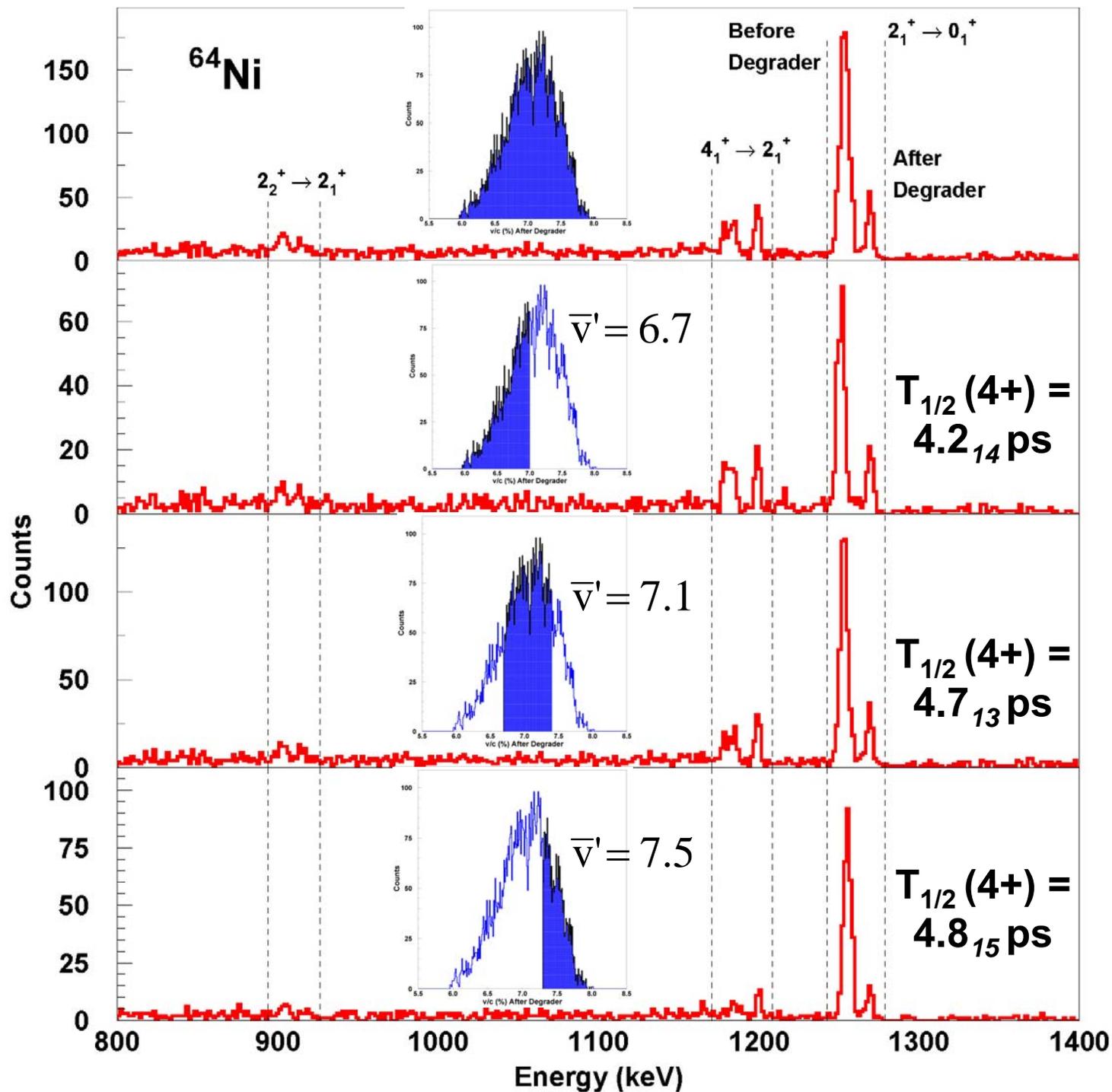
sign of “longer”
lifetime in ^{62}Fe

(2^+ at 877 keV)

$T_{1/2} \sim 9.5(20)$ ps
 $B(E2) \sim 0.012 e^2b^2$
(8 W.u.)



^{64}Ni Inelastic Scattering



CLARA-PRISMA 2006-2007

Drawback of the setup: low efficiency for γ - γ -PRISMA coincidences: Development of complementary ancillary devices for Doppler correction.

Measurement of γ -PRISMA coincidences (Identification) and γ - γ -ancillary coincidences (γ - γ coincidences with Doppler correction).

DANTE: MCP array, developed in collaboration with FLNR Dubna, in phase of data evaluation of firsts runs.

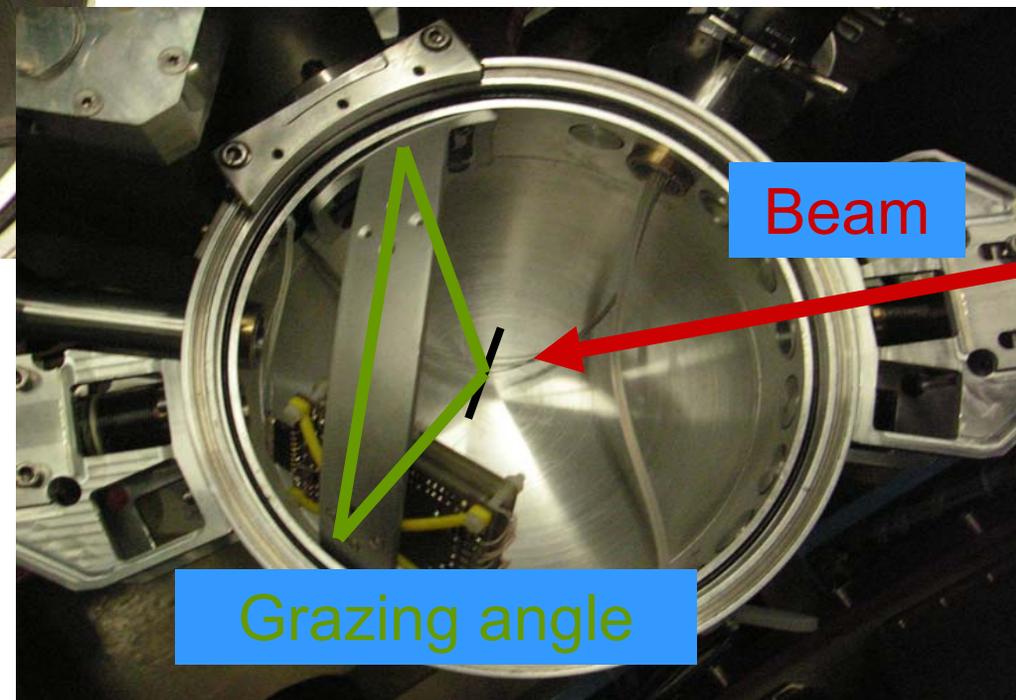
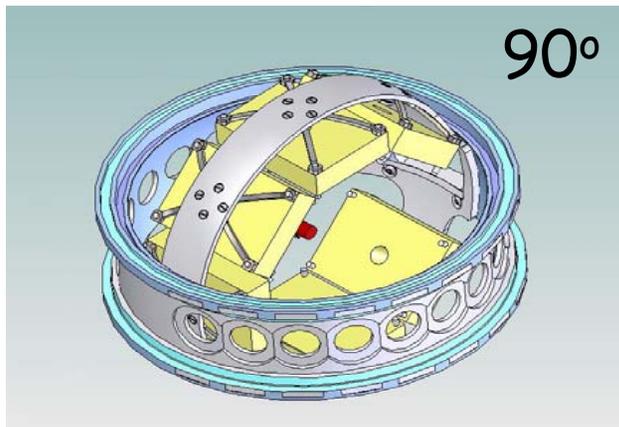
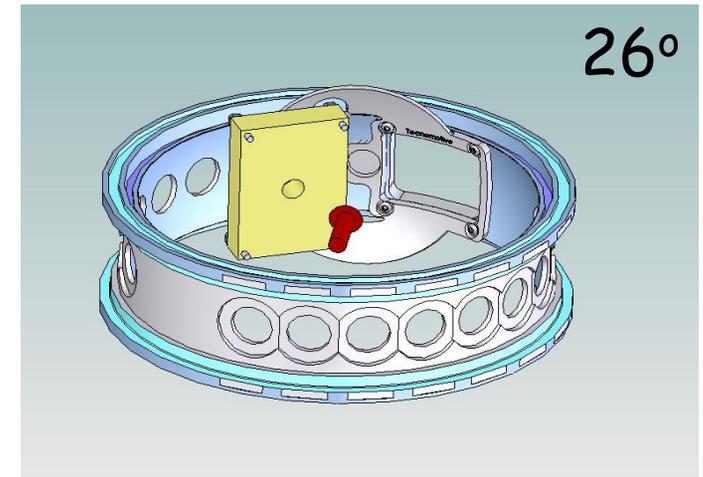
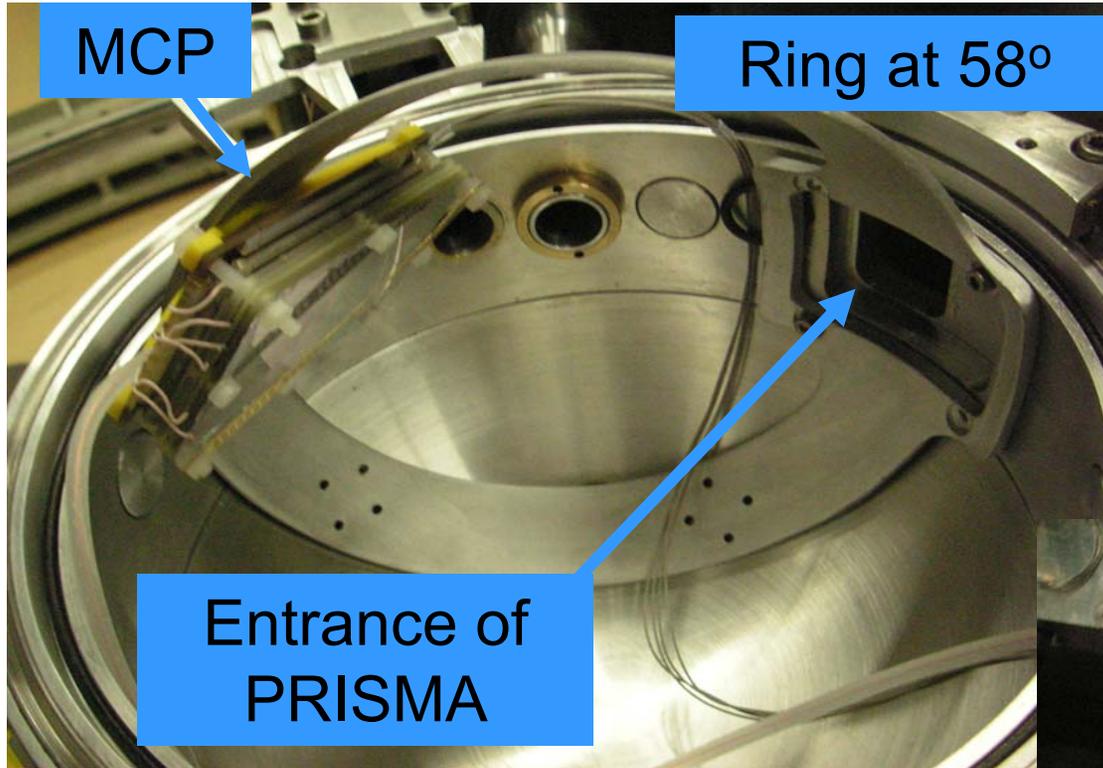
Development of the Differential Plunger RDDS technique for CLARA-PRISMA in collaboration with IKP-Koeln.

Development of a new focal-Plane detector for PRISMA based on SeD (collaboration U.K. - INFN)

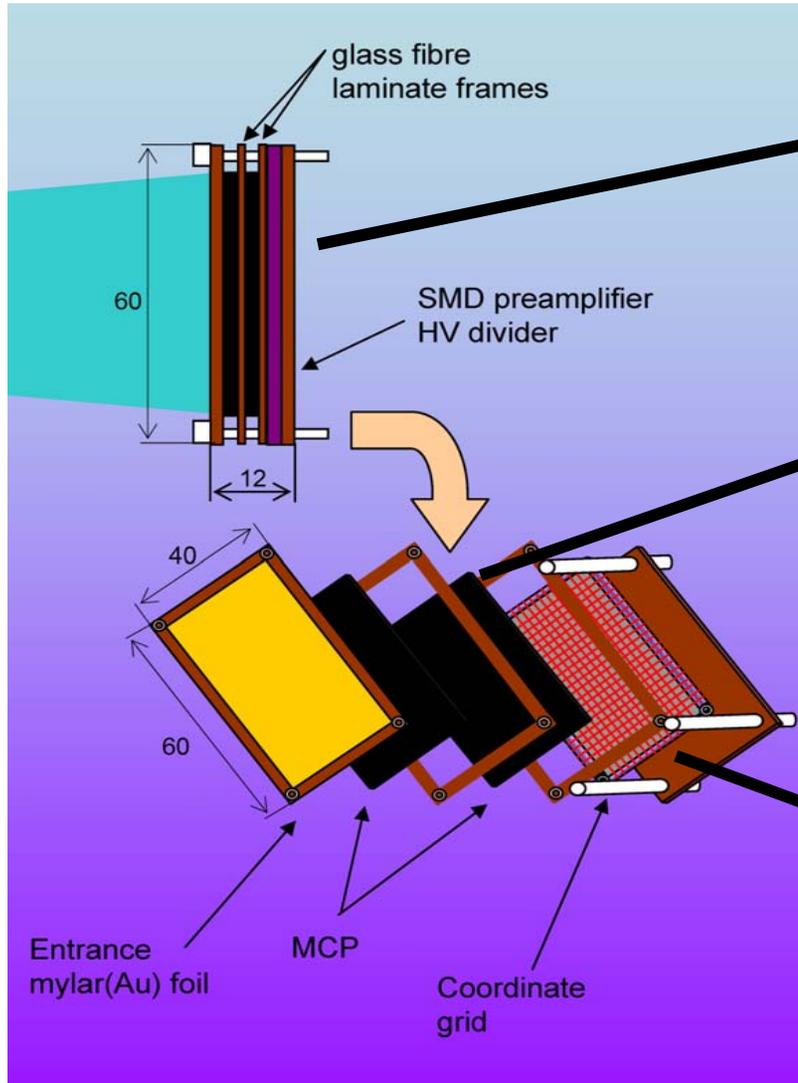
Heavier beams from ALPI linac with the new positive ion injector PIAVE.

DANTE

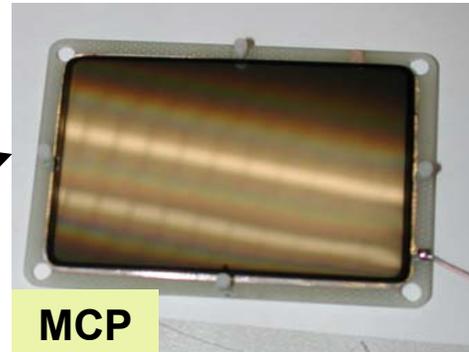
INFN-LNL, INFN-Milano, FLNR-Dubna, INFN-Padova,



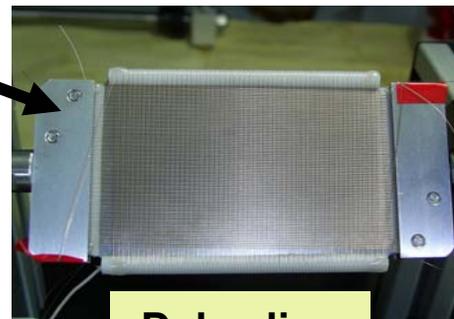
The DANTE detectors



Preamplifier in vacuum



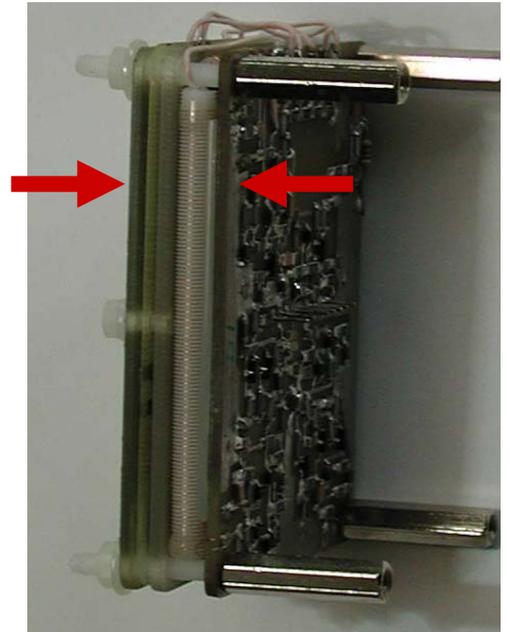
MCP



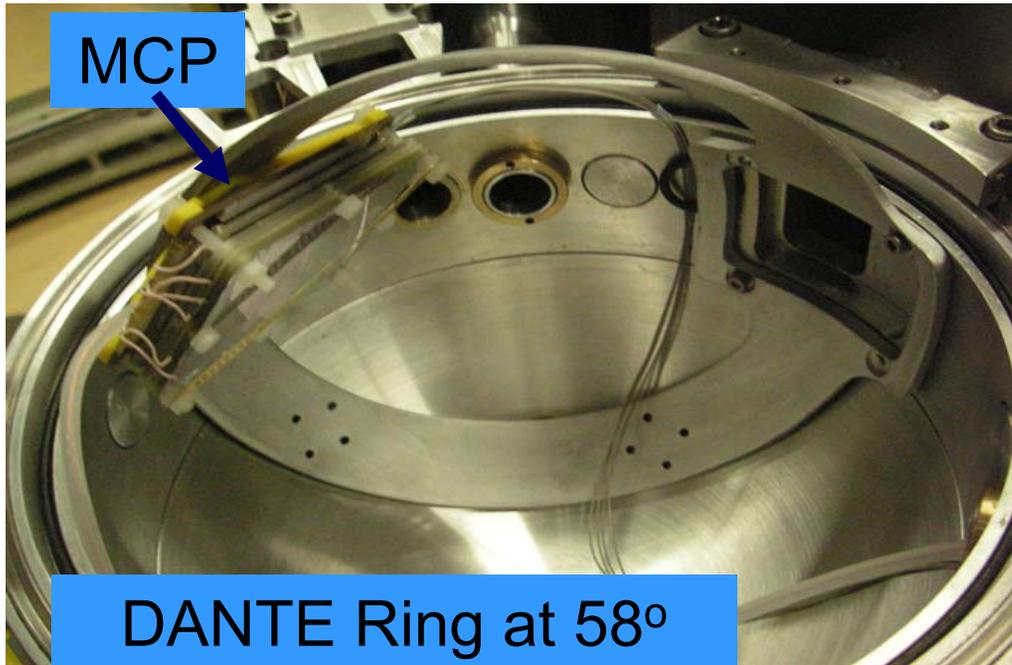
Delay line

Based on FLNR–Dubna
Corset design

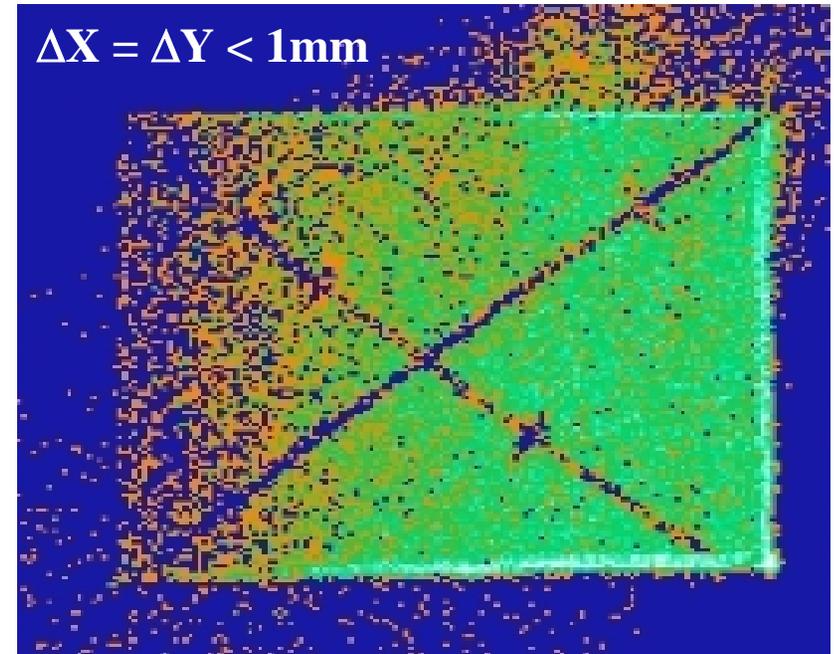
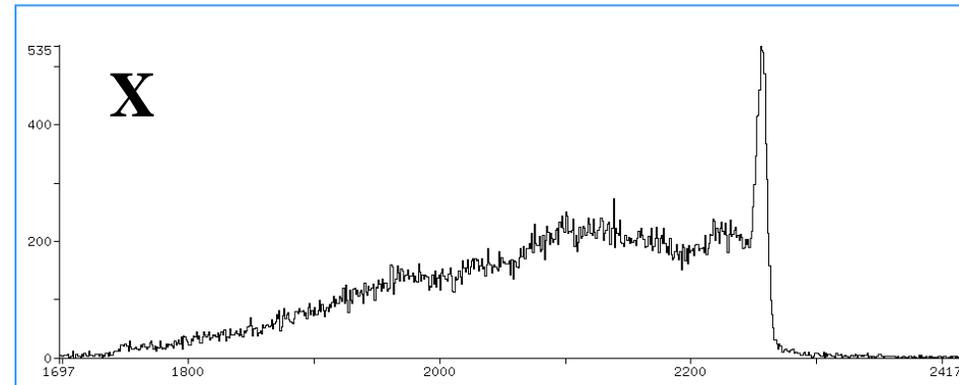
Thickness: 13mm



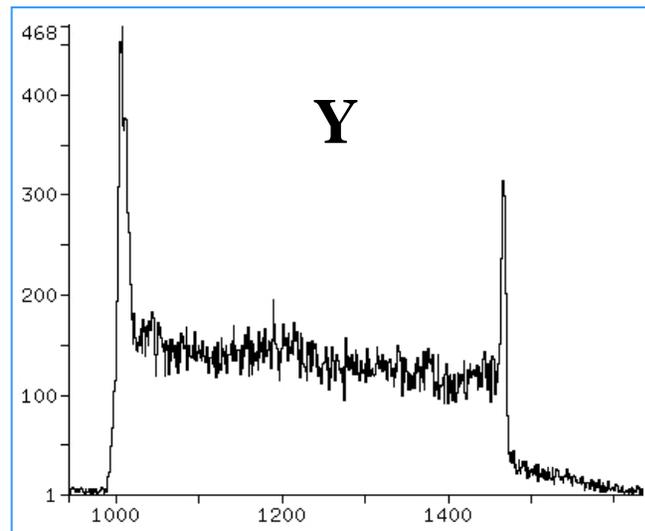
Lateral section of a
DANTE detector



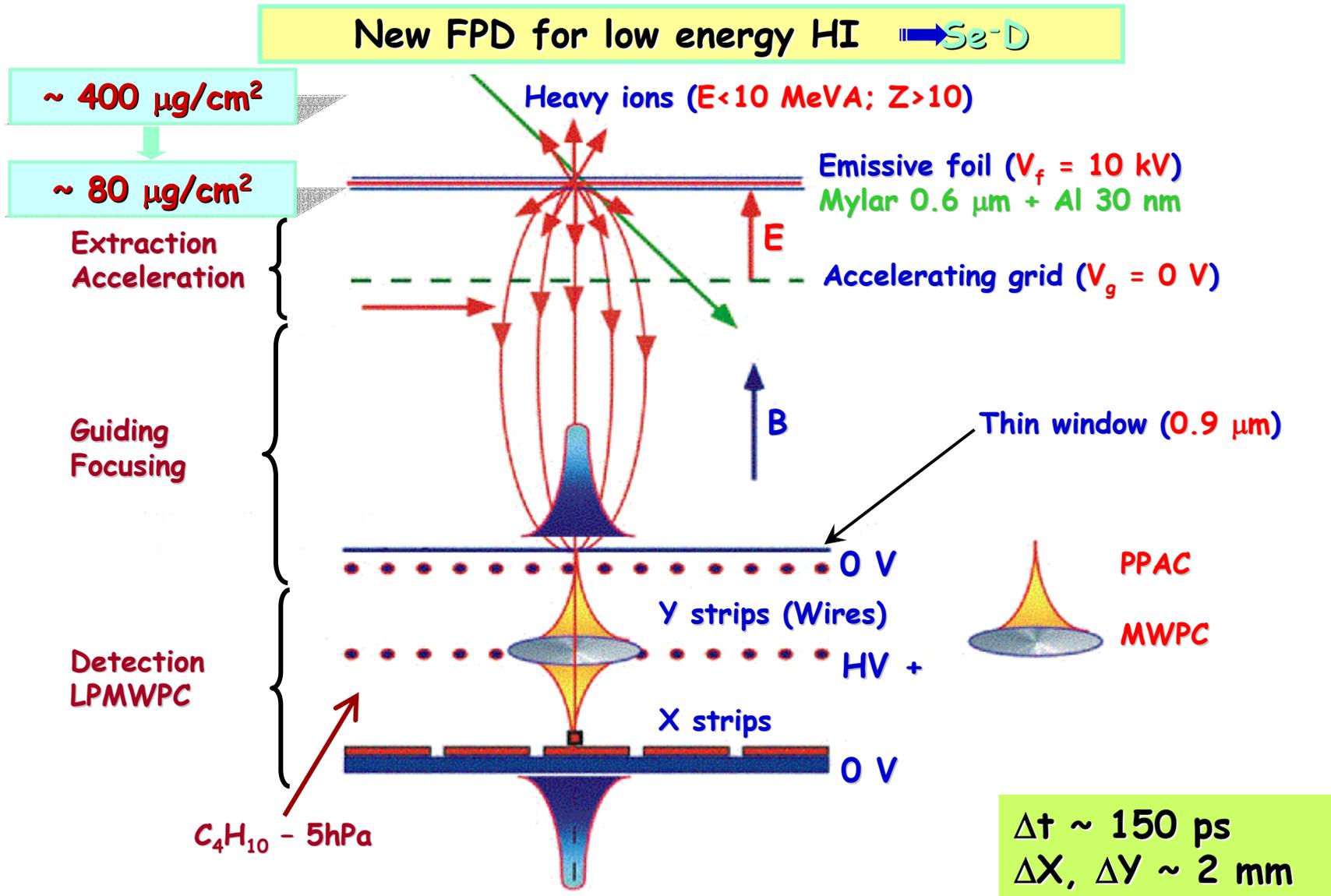
In-Beam Commissioning at LNL Legnaro



Time resolution
130ps
Position resolution
<1mm
High counting rate
High noise rejection

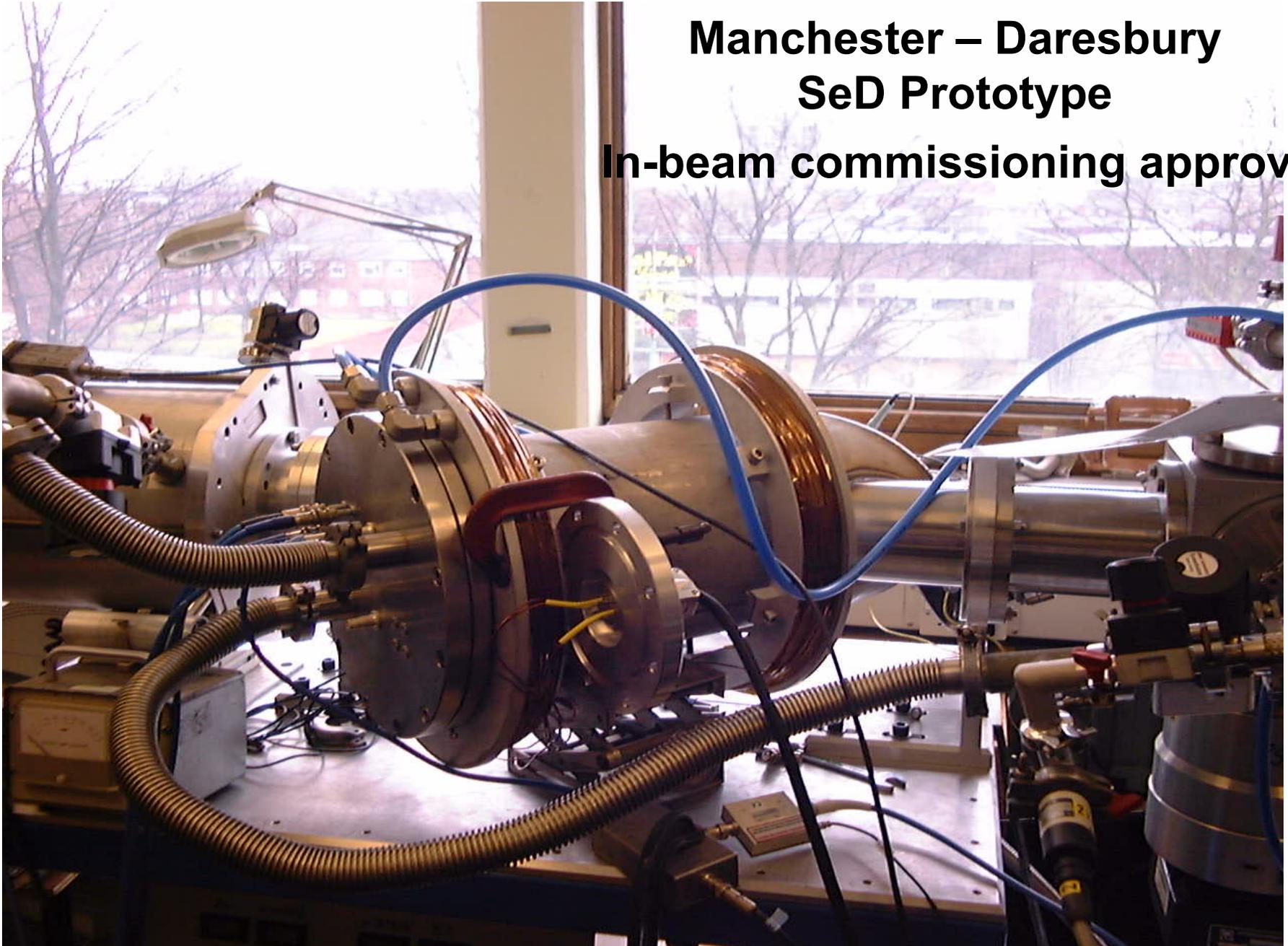


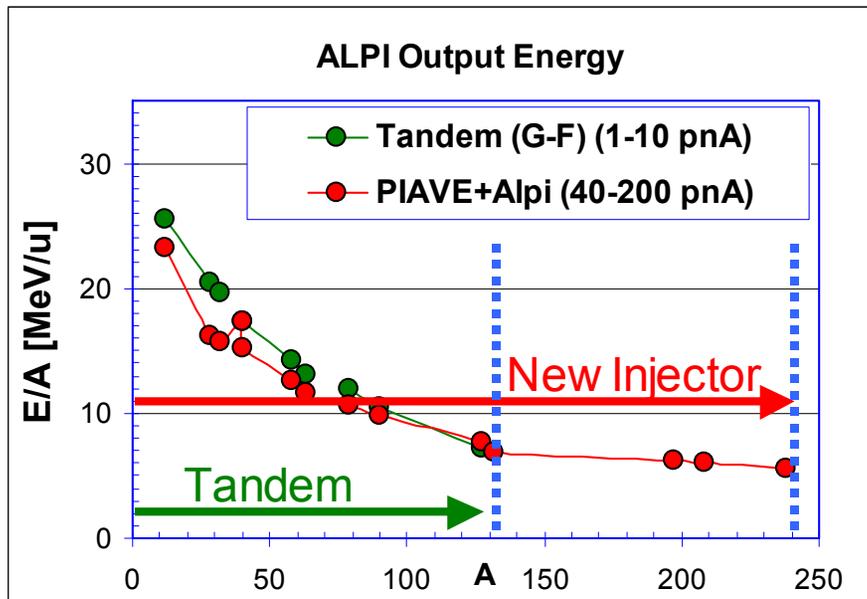
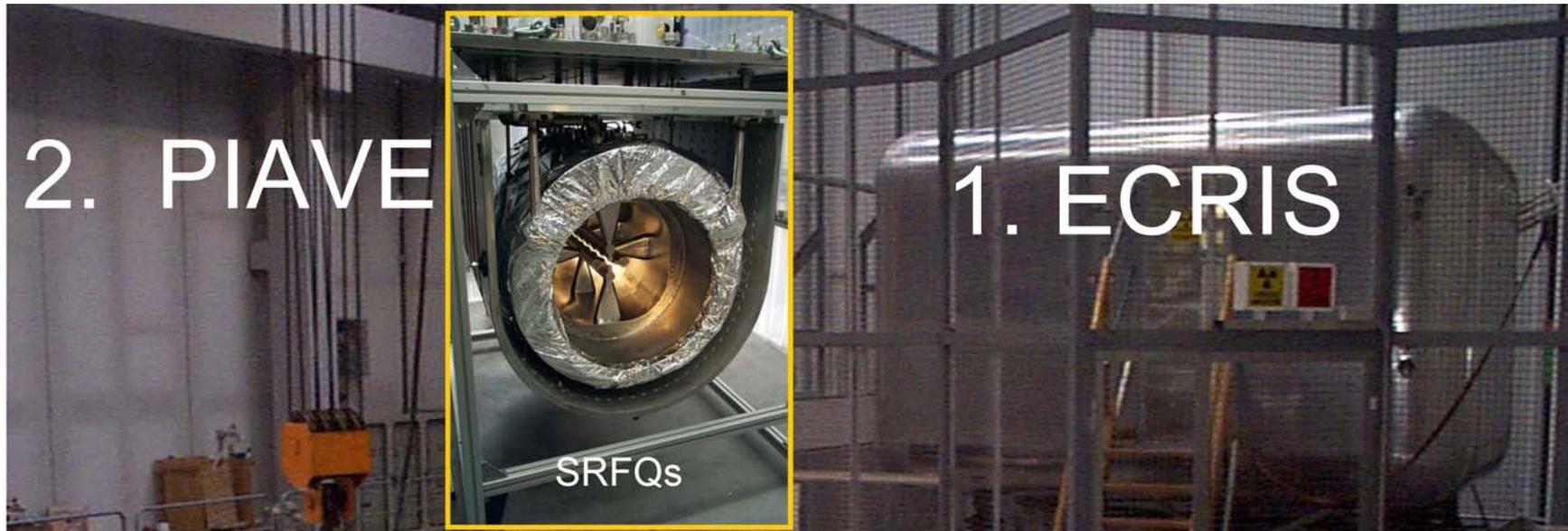
Development of a new FPD for PRISMA



**Collaboration of several U.K. groups
Manchester - Daresbury - Paisley**

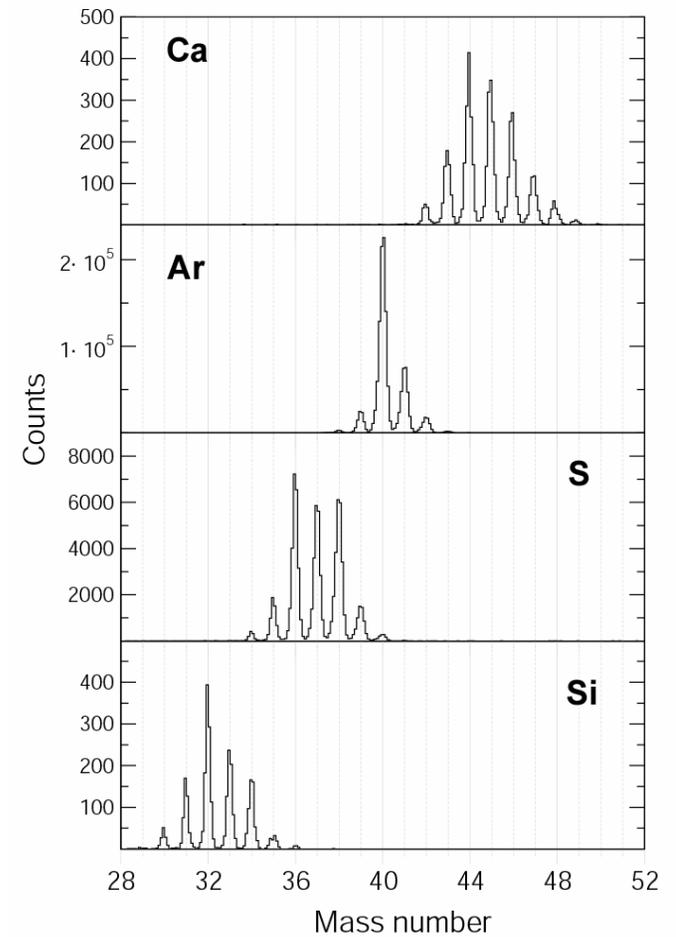
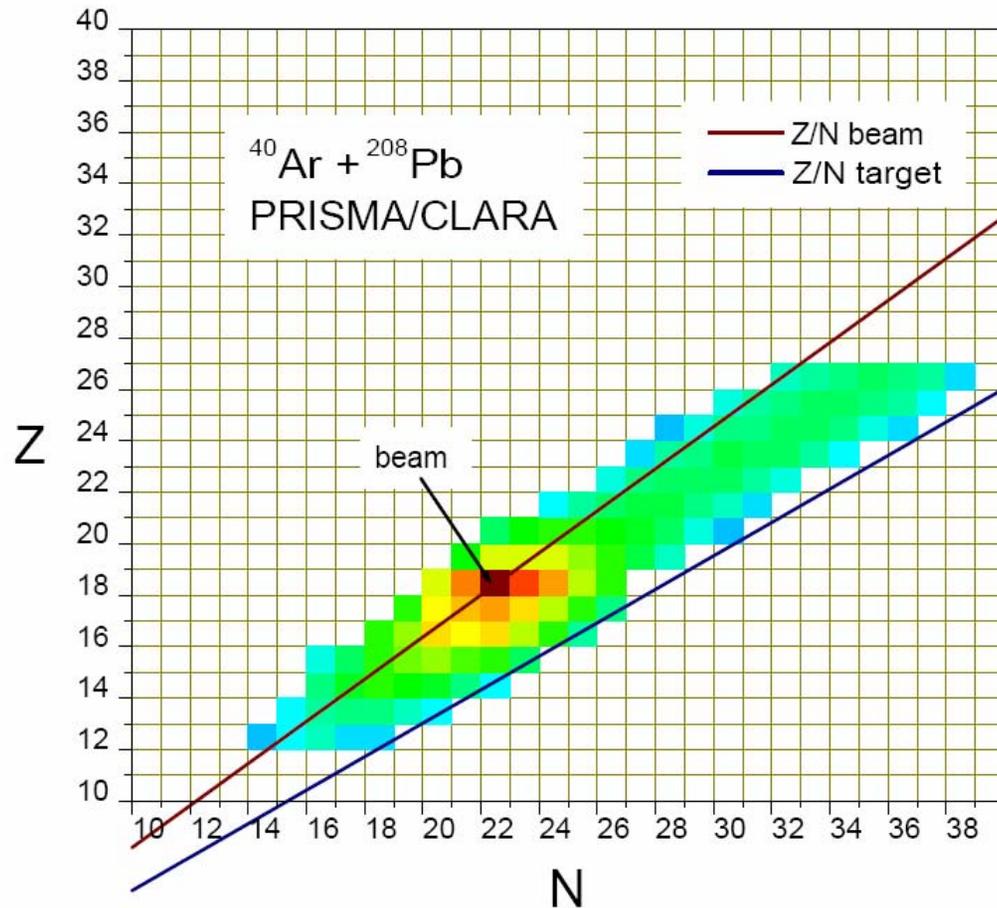
**Manchester – Daresbury
SeD Prototype
In-beam commissioning approved**



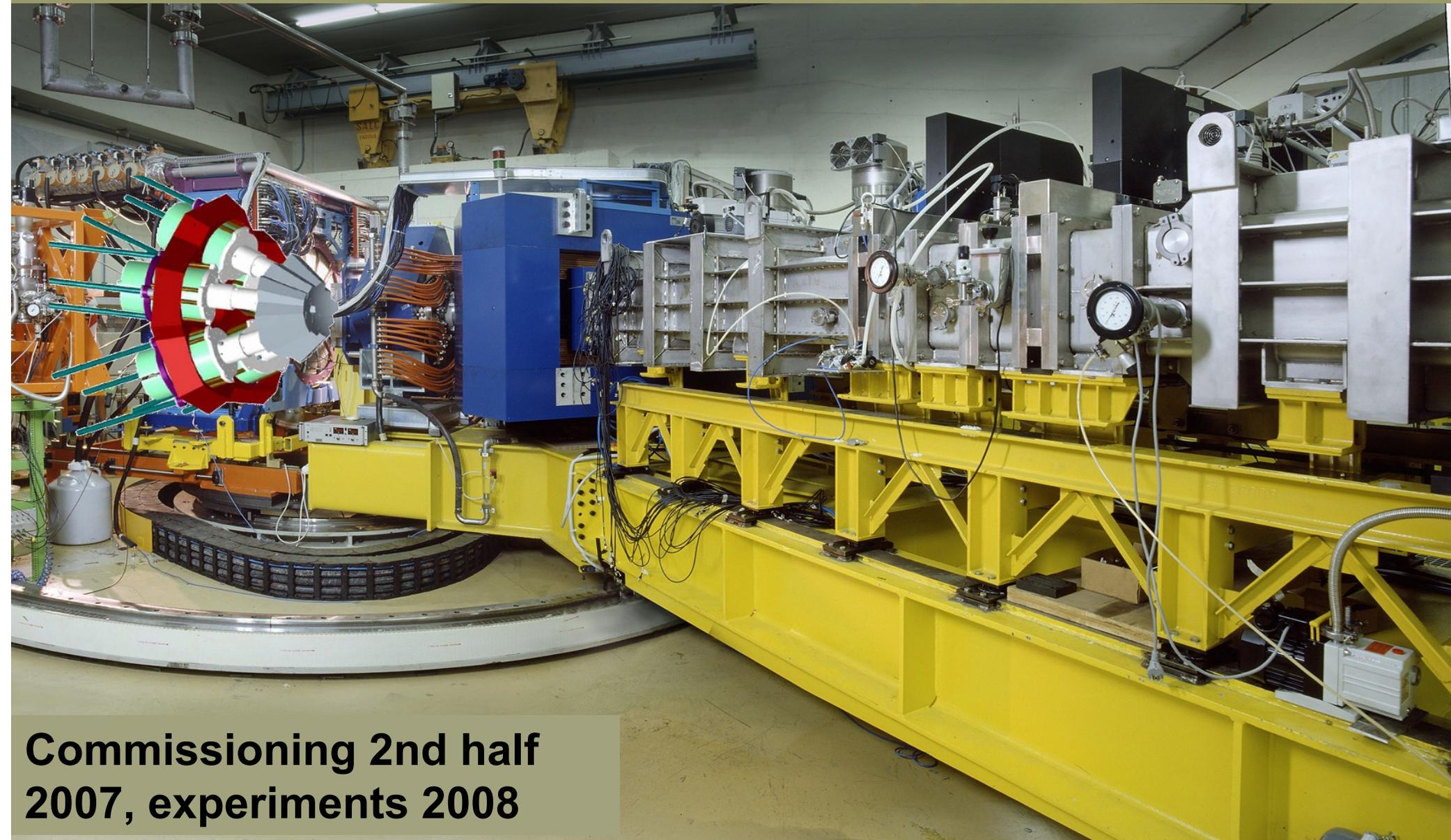


Positive ion injector ECRIS + PIAVE commissioned
Last quarter 2005 - first quarter 2006: Ne, Ar and Kr beam delivered to the experimental areas for test.
PIAVE beams for users during second semester 2006.

^{40}Ar (238 MeV) PIAVE-ALPI beam test CLARA-PRISMA, January 2006



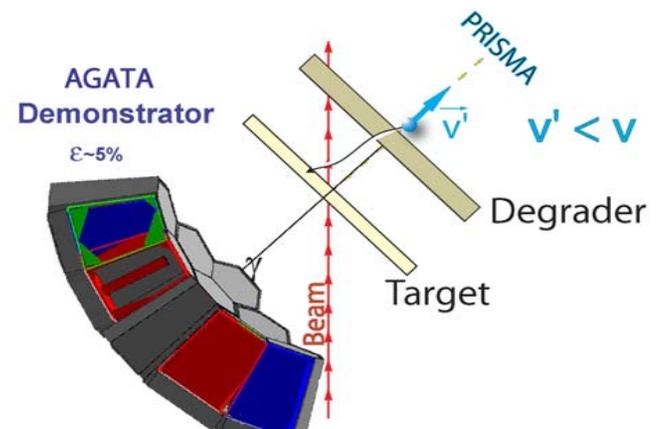
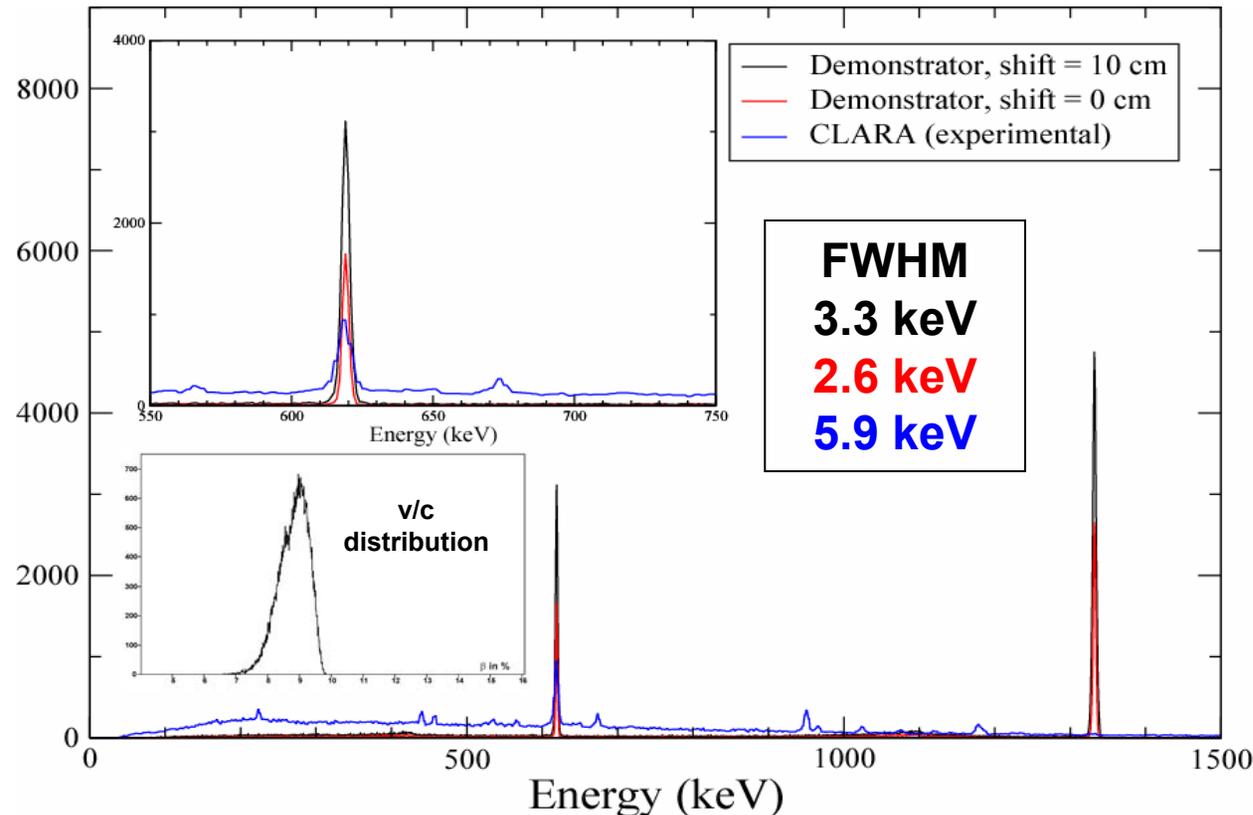
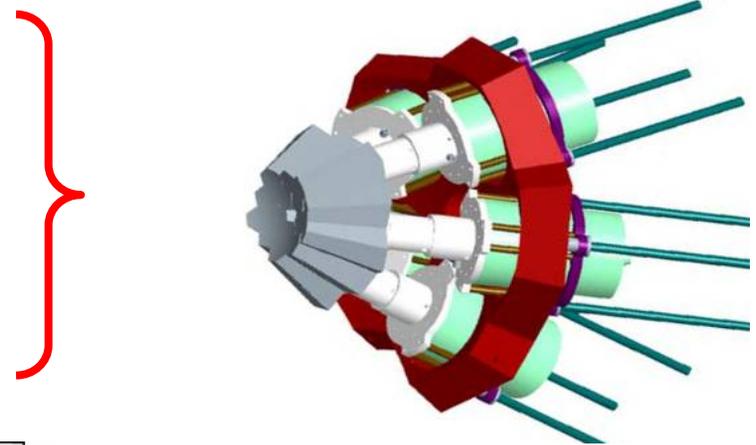
AGATA Demonstrator – PRISMA setup



**Commissioning 2nd half
2007, experiments 2008**

AGATA Demonstrator at PRISMA

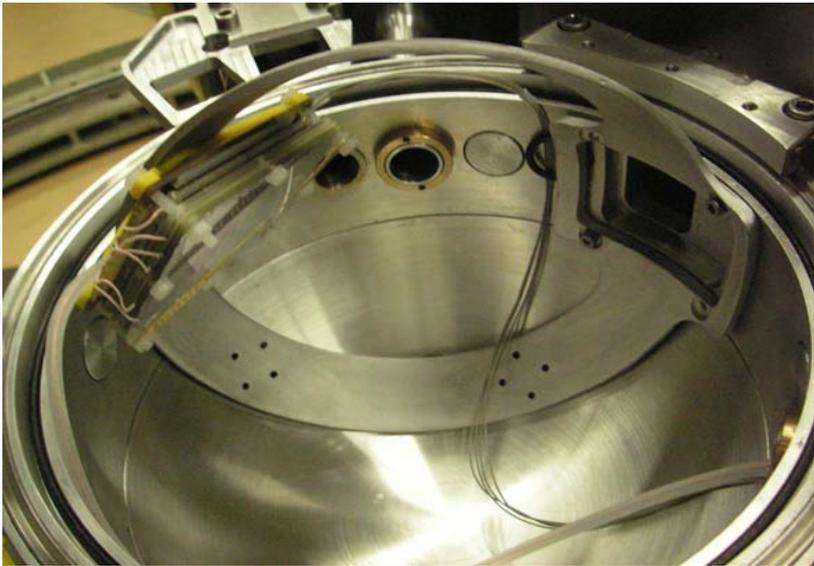
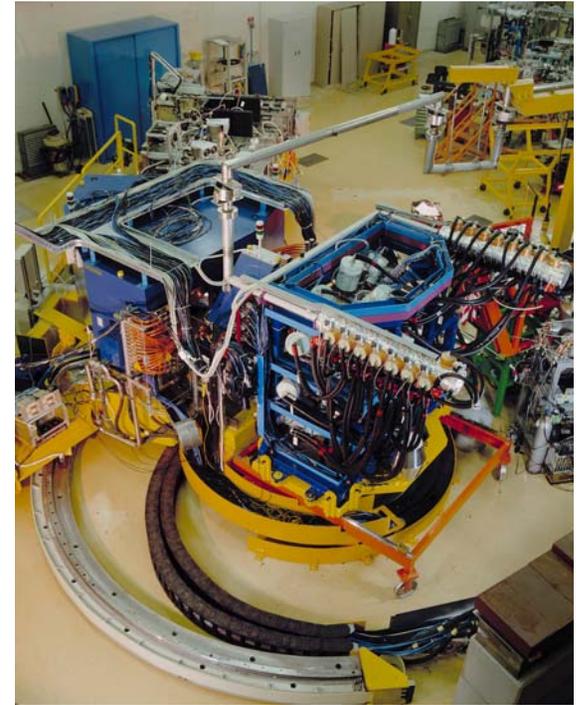
Efficiency at 1MeV: $\sim 6\%$ at 14cm
Peak/Total: $\sim 50\%$
Angles covered: from $\sim 135^\circ$ to 180°
FWHM, $\beta \sim 10\%$, 1MeV: < 4 keV



The full demonstrator at 14cm (6% efficiency) can be used for RDDS lifetime measurements

Conclusions:

- Spectroscopy with grazing reactions, using the combination of a gamma- array and a large acceptance spectrometer (as CLARA-PRISMA), provides valuable structure information on moderately n-rich nuclei.
- Differential RDDS technique been developed in collaboration with IKP-Koeln,



- CLARA has been upgraded with an ancillary array to perform “in beam” γ - γ coincidences with Doppler correction.
- New SeD based FPD for PRISMA are under development (U.K. – INFN)
- Runs using the CLARA-PRISMA setup with the medium-mass and heavy beams from PIAVE-ALPI during the second semester 2006.

The CLARA-PRISMA collaboration

•France

IReS Strasbourg

GANIL Caen

•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

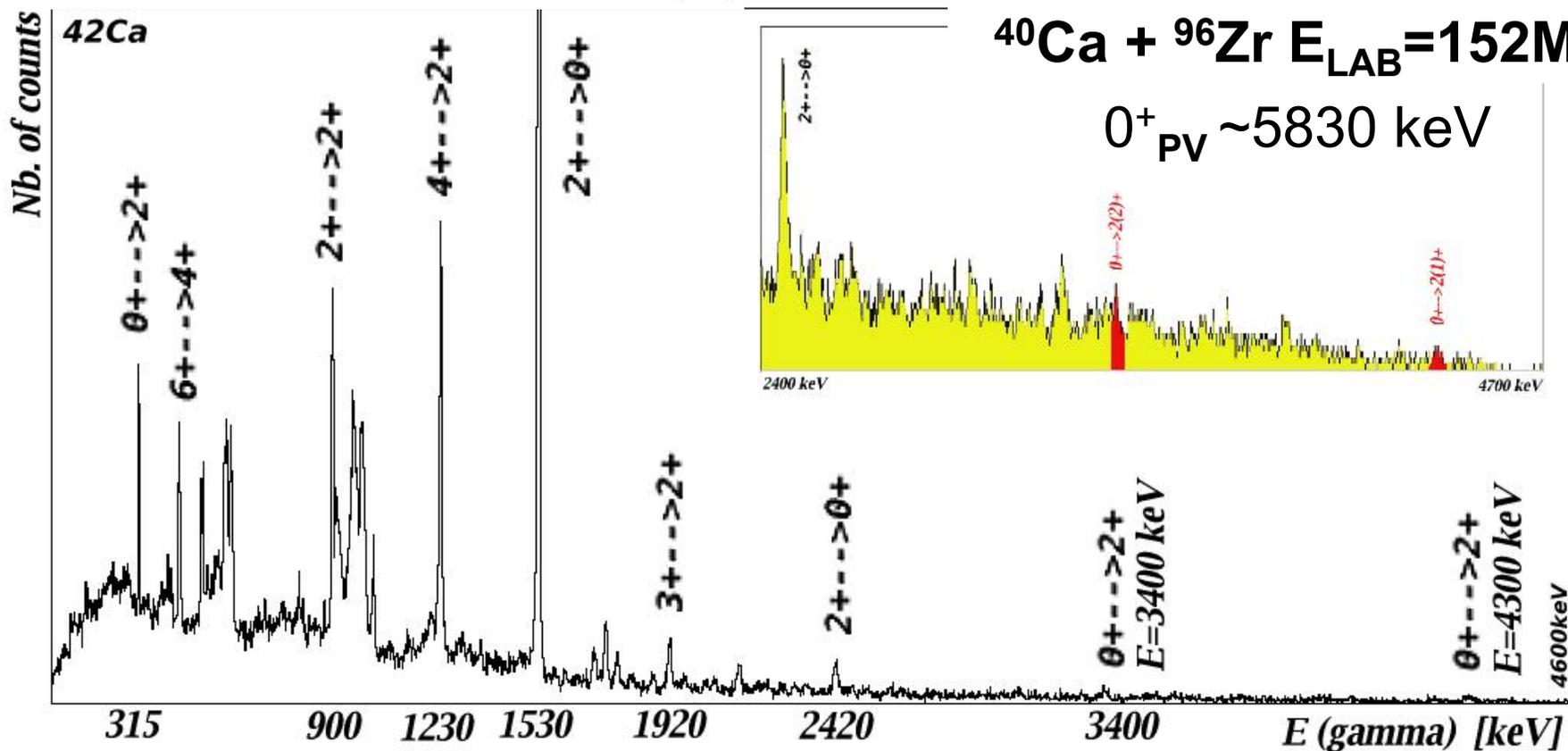
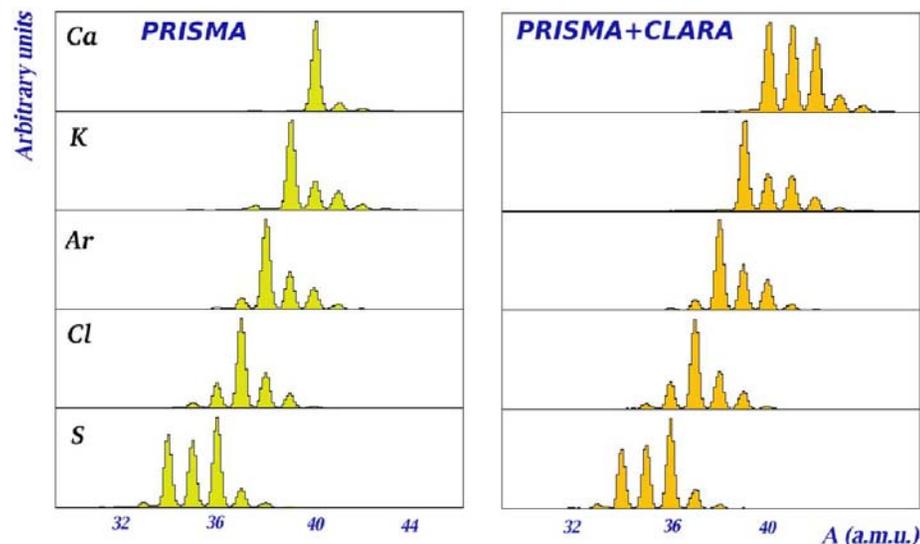
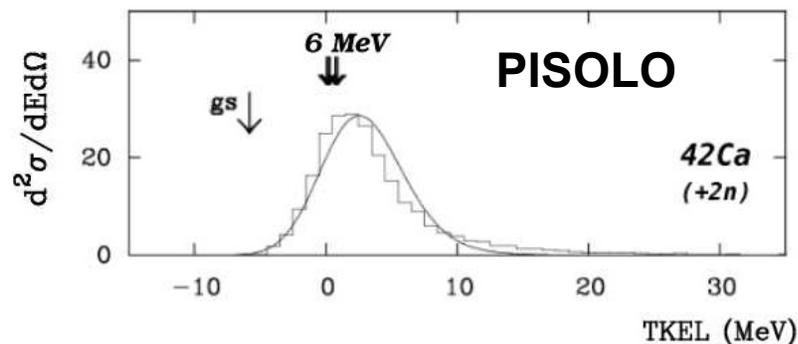
University of Salamanca

•Romania

Horia Hulubei NIPNE Bucharest

Pairing-vibration states in ^{42}Ca

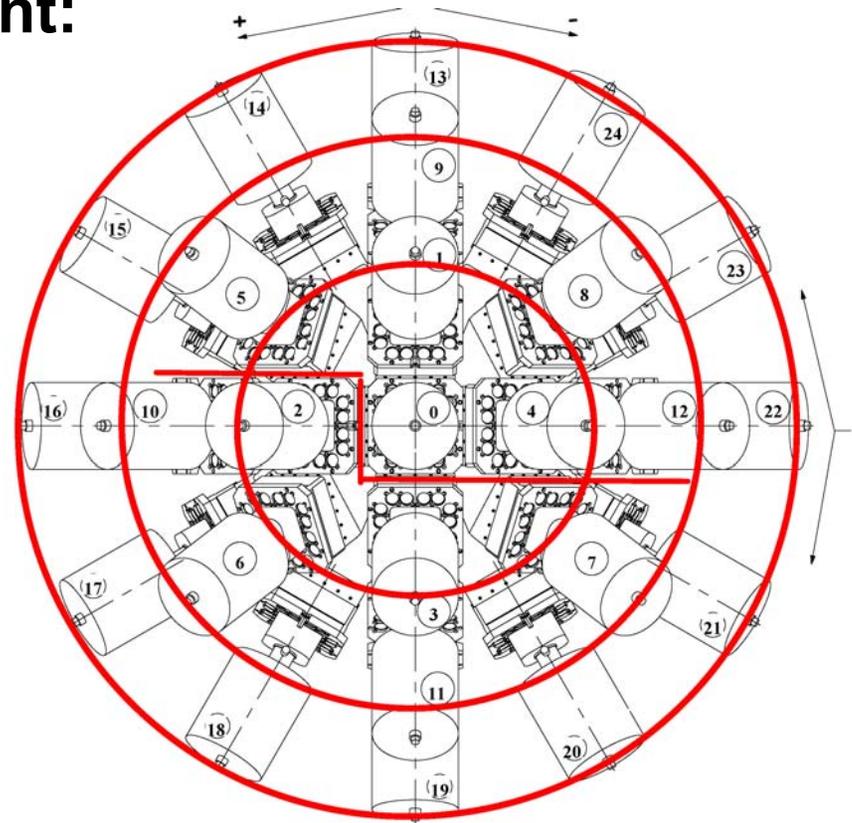
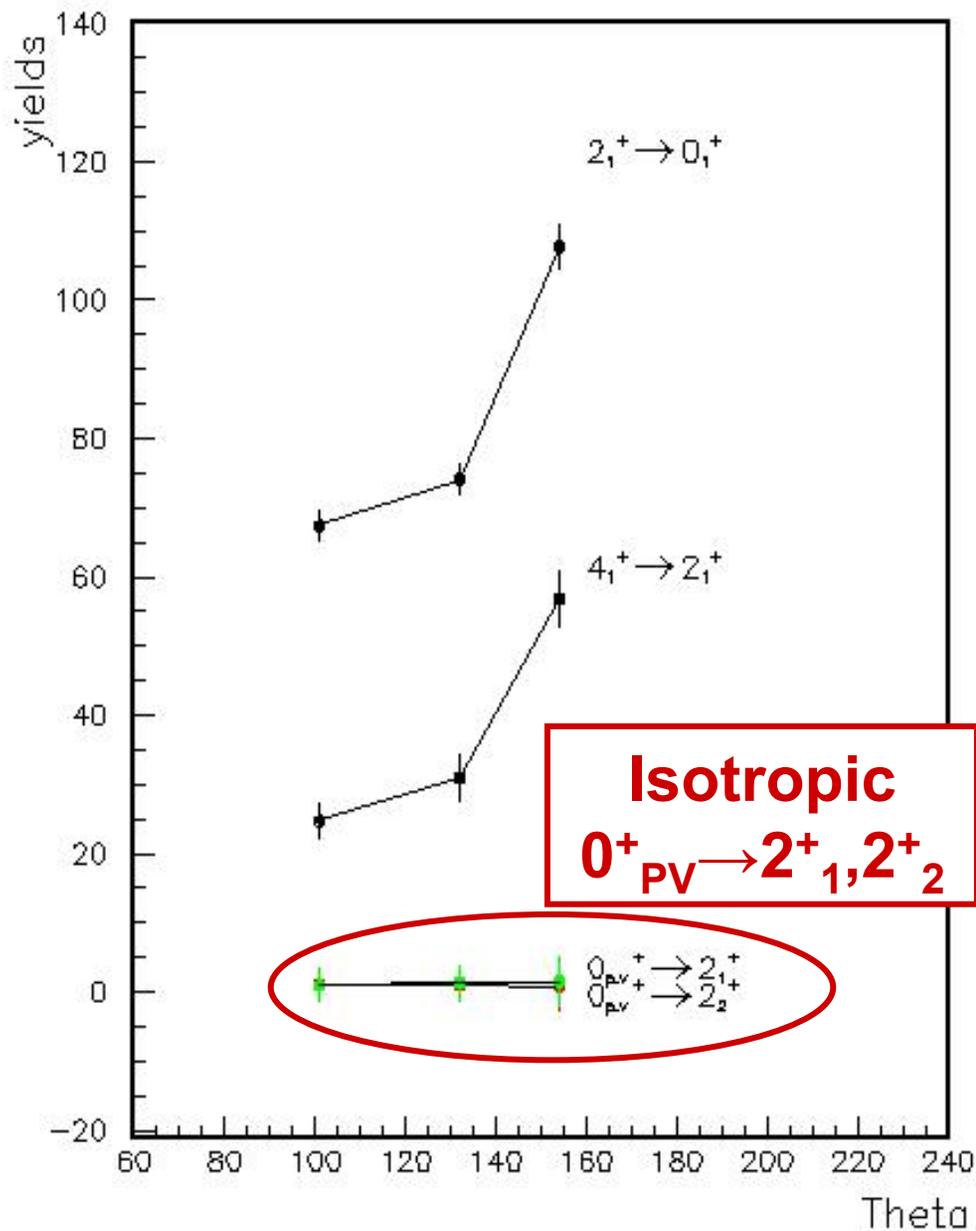
S.Szilner (LNL and Zagreb)



$^{40}\text{Ca} + ^{96}\text{Zr}$ $E_{\text{LAB}} = 152 \text{ MeV}$

$0^+_{\text{PV}} \sim 5830 \text{ keV}$

Angular Distribution measurement:

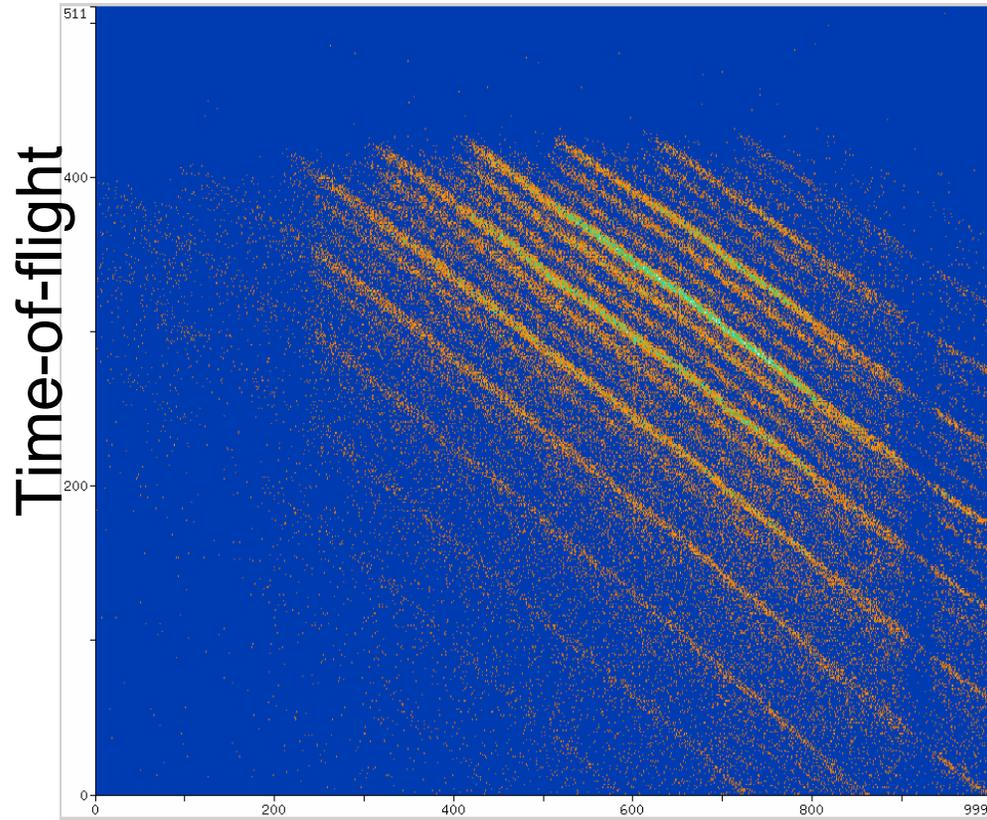


Angular Distribution of
 $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 0^+$
 transitions indicates:
 $\sigma/J \sim 0.3$

S.Szilner, LNL & Zagreb

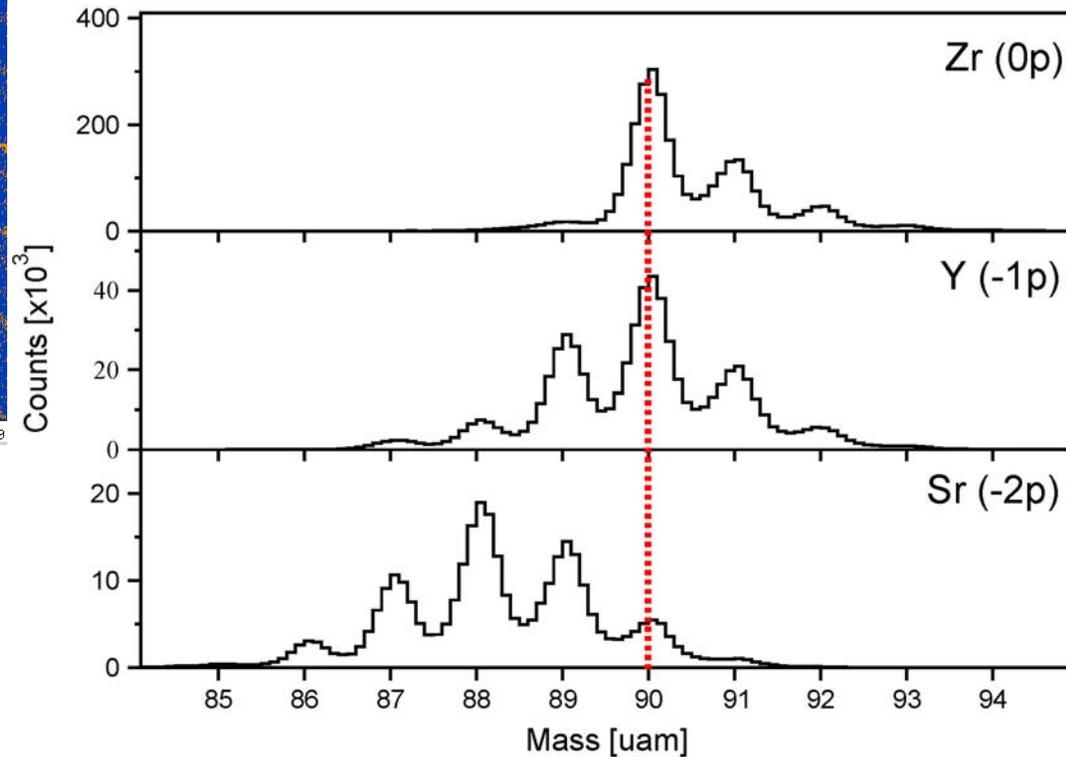
^{90}Zr 560MeV + ^{208}Pb

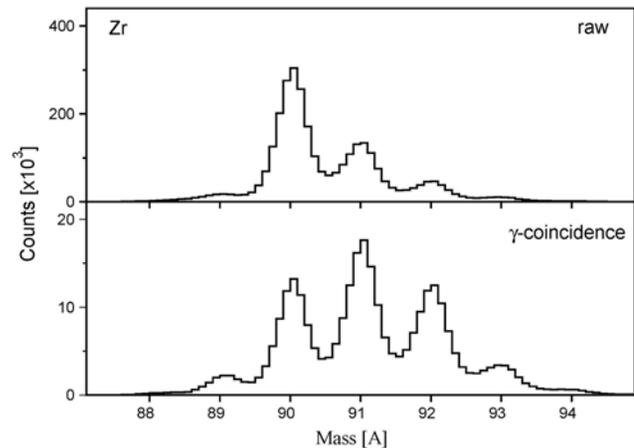
1 day beam time
L.Corradi, C.A.Ur, et al.



Distance along focal plane

Nb89 1.9h (92+)	Nb90 14.50h 8+	Nb91 0.5D ₇ 92+	Nb92 3.48E-7 ₇ (7)+	Nb93 92+	Nb94 20.3E-4 ₇ (9+)	Nb95 34.9E-4 92+
Zr88 83.4d 0+	Zr89 78.4h 92+	Zr90 0+	Zr91 52+	Zr92 0+	Zr93 1.53E-6 ₇ 52+	Zr94 0+
Y87 798h 1/2	Y88 1050E-4 4	Y89 1/2	Y90 6410h 2	Y91 585d 1/2	Y92 354h 3	Y93 1018h 1/2
Sr86 0+	Sr87 92+	Sr88 0+	Sr89 9053d 52+	Sr90 28.7E ₇ 0+	Sr91 9d3h 52+	Sr92 2.3h 0+
Rb85 5/2 721.6E	Rb86 18.6E-4 2	Rb87 479E-10 ₇ 3/2	Rb88 17.7E ₇ 2	Rb89 1515m 3/2	Rb90 19E ₇ 0	Rb91 55.4E 3/2(-)





^{90}Zr 560MeV + ^{208}Pb

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

0^+ 4124
2-phonon pairing vib.

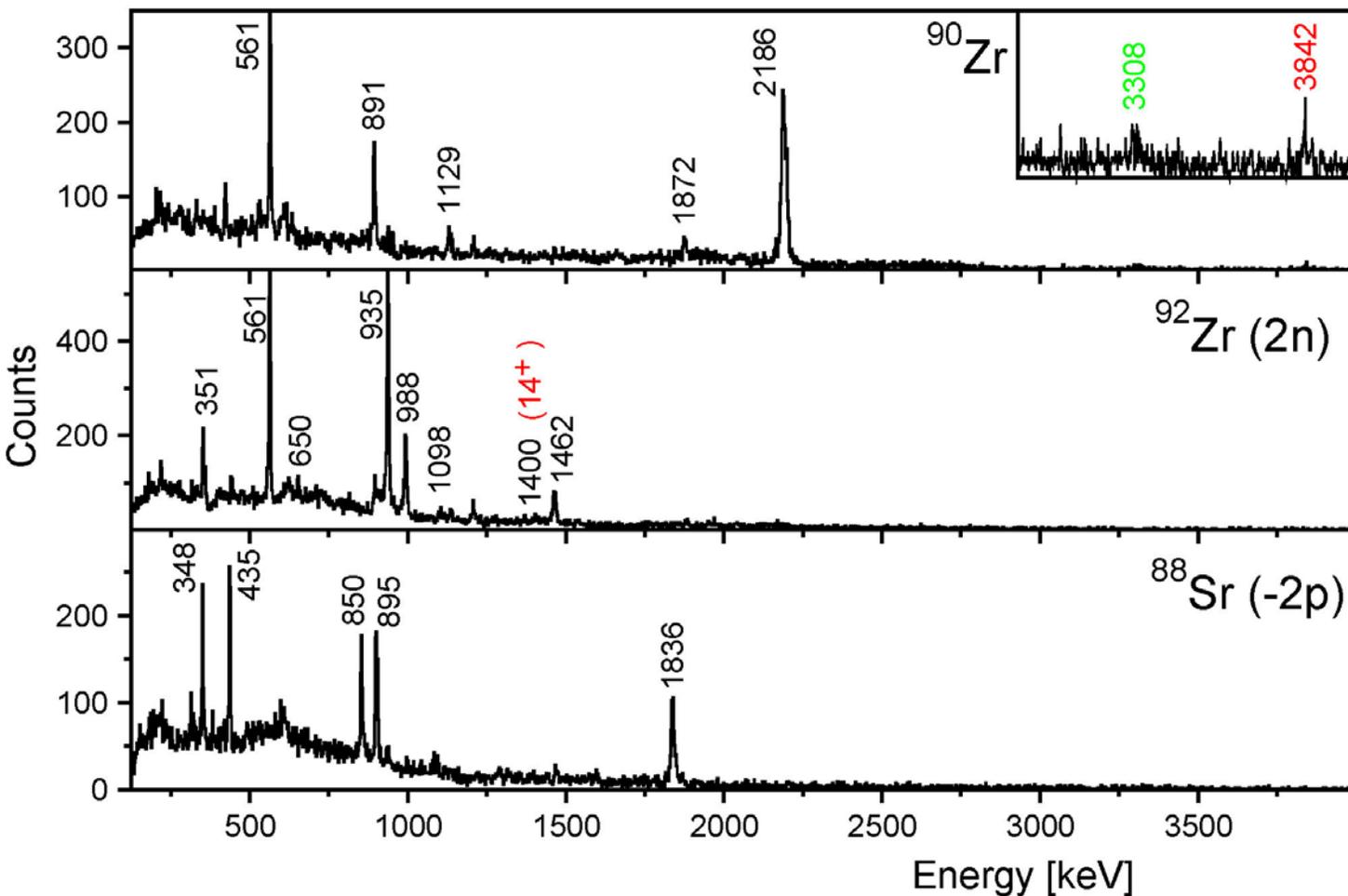
0^+ 4426
 4^+ 4058
 2^+ 3842

$(\pi g_{9/2})^2_{J=2} (^{88}\text{Sr}_{J=2^+})$ 8^+ 3589
 6^+ 3448
 2^+ 3308
 $(\pi g_{9/2})^2_{J=0} (^{88}\text{Sr}_{J=2^+})$ 4^+ 3077

3^- 2748
oct. phonon

2^+ 2186
 0^+ 1761
 $(\pi g_{9/2})^2$
 0^+ 0
 $(\pi p_{1/2})^2$

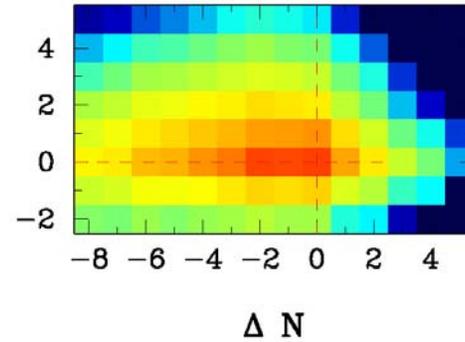
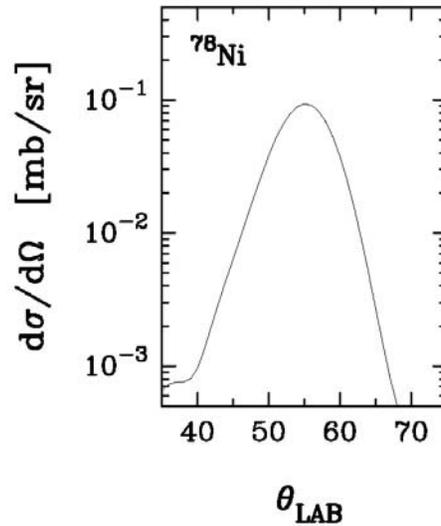
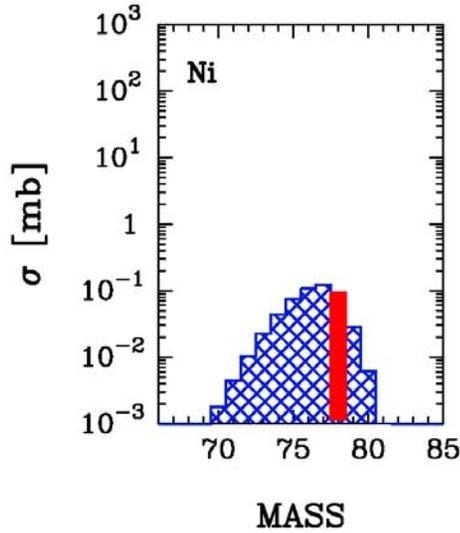
Level Scheme from:
 $^{90}\text{Zr}(n, n'\gamma)$
P.E. Garrett et al.,
Phys. Rev. C68
(2003)024312



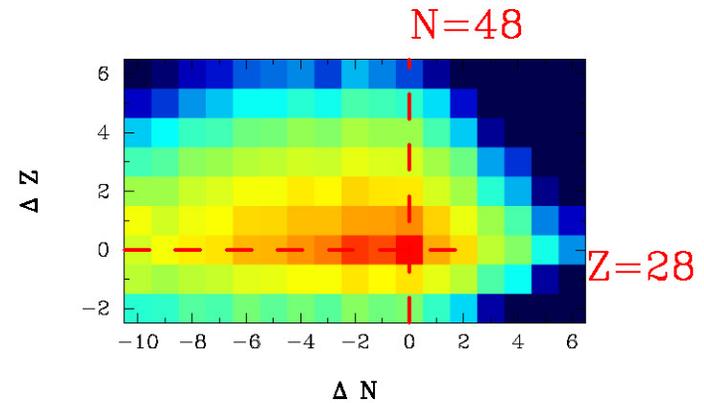
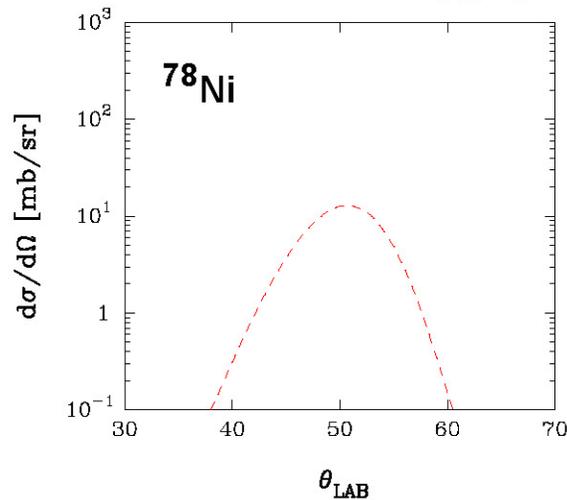
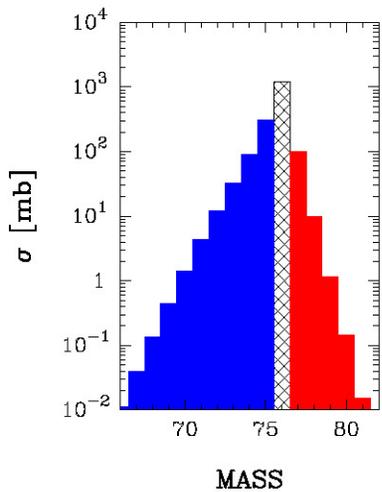
Transfer with Radioactive Beams at Coulomb barrier Energies



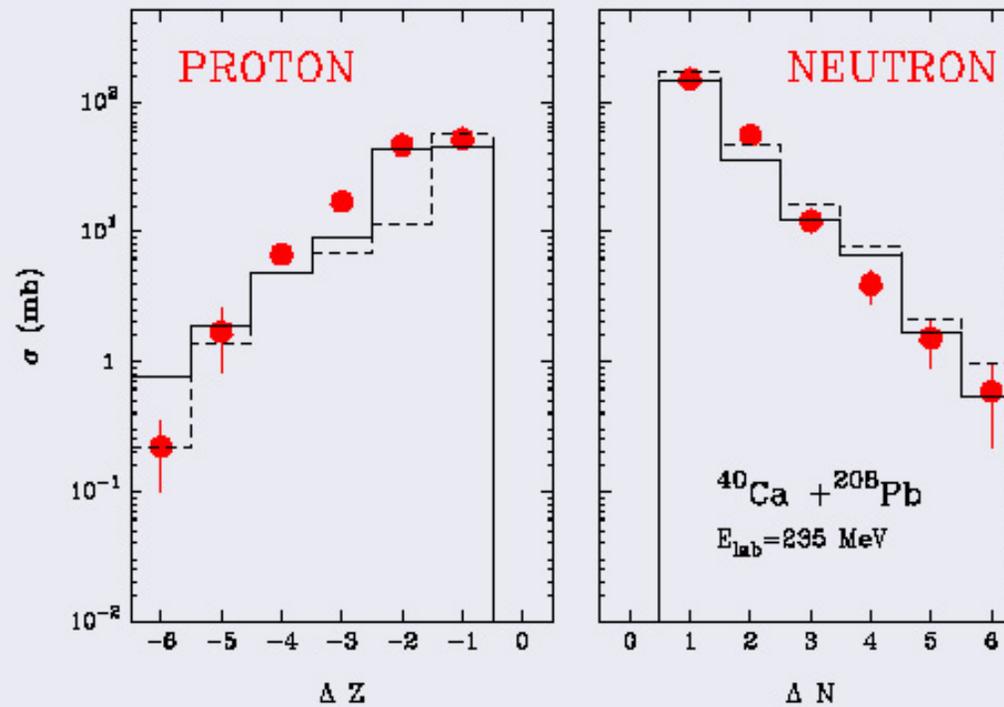
Calculations by
G.Pollarolo



$d\sigma/d\Omega = 10 \text{mb}$



Pure neutron, proton transfer channels



Simultaneous transfer:

Is achieved by adding a PAIR-MODE ($\delta n_{fi} = \pm 2$, $\delta z_{fi} = \pm 2$)

$$F_{fi}^{pair}(r) = \beta_p \frac{\partial V^{opt}(r)}{\partial A}$$

where the strength β_p is adjusted to the experiment.

DANTE

(Detector Array for multi Nucleon Transfer Ejectiles)

INFN-LNL, INFN-Milano, FLNR-Dubna, INFN-Padova,

- Start detector of PRISMA \Rightarrow No possible to place PPACs
- DANTE (heavy ion detector based on MCP) reveals the position interaction of the recoils \Rightarrow Doppler correction.
- DANTE placed at the grazing angle, has a high efficiency \Rightarrow γ - γ coincidences \Rightarrow No need of extra experiments to build up a level scheme.

