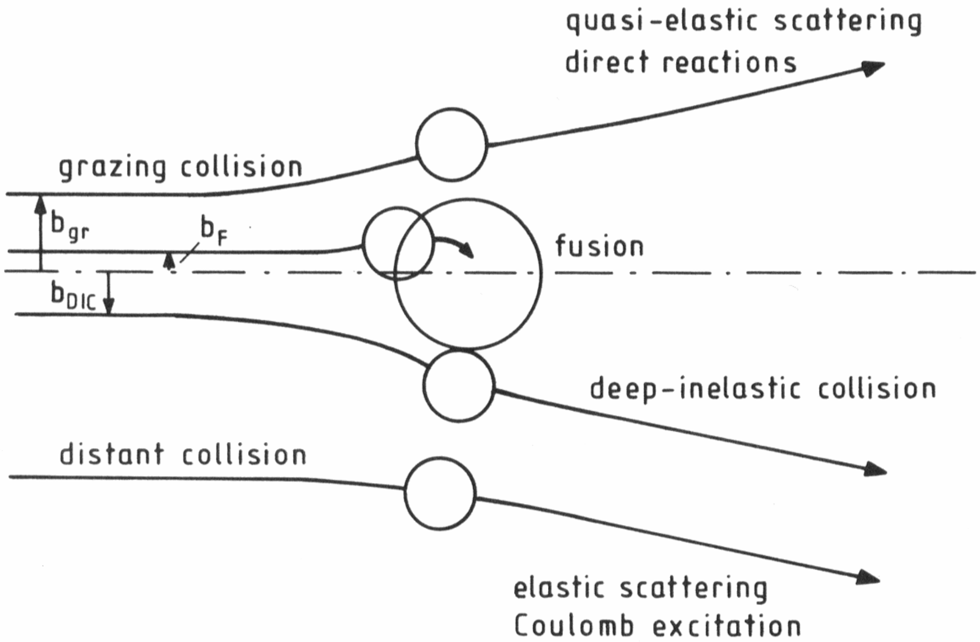
The Spectroscopy of Binary Fragments

Robert Chapman

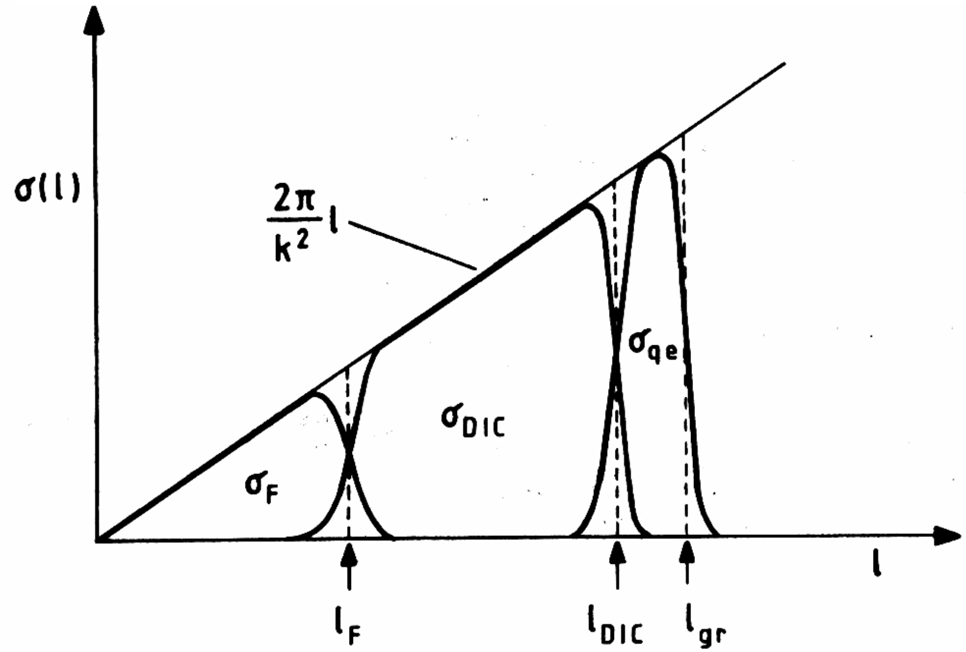
University of Paisley

CLARA and PRISMA collaborators



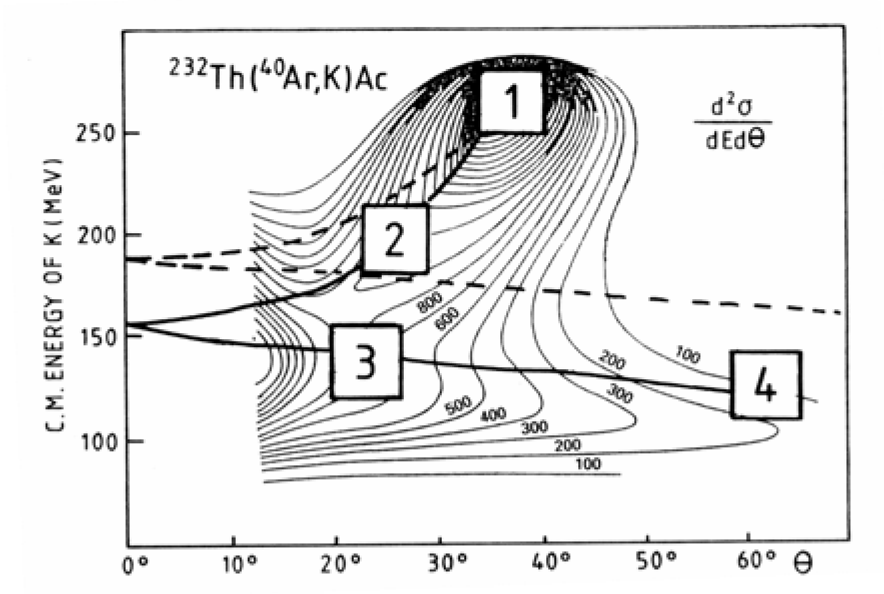
Classification of reactions by impact parameter

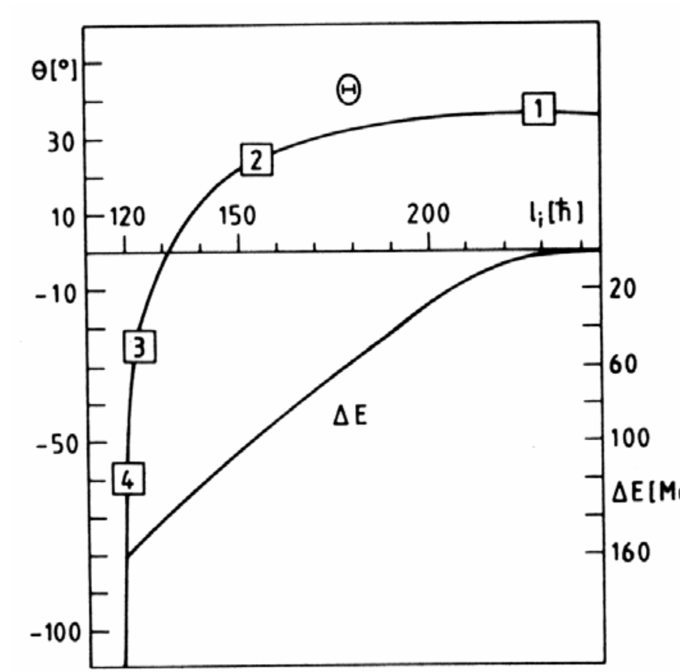
the spin distribution of a heavy-ion reaction

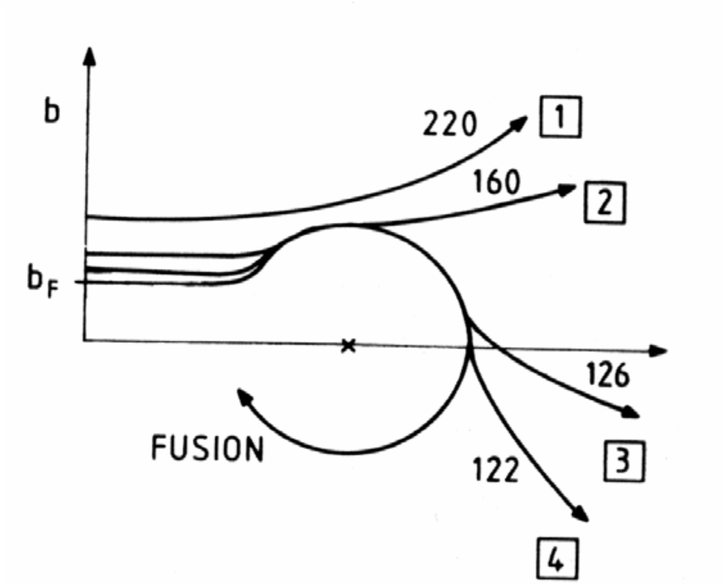


The regions for fusion (σ_F), deep-inelastic (σ_{DIC}) and quasi-elastic collisions (σ_{qe}) are indicated

Experimental Wilczynski plot for the system $^{40}Ar + ^{232}Th$ at $E_{lab}(^{40}Ar)$ =388MeV.   J. Wilczynski, Phys. Lett. **47B**(1973) 484







P. Fröbrich and R. Lipperheide (1996)
Theory of Nuclear Reactions,
Clarendon Press, Oxford

Deep-inelastic processes

N/Z equilibration; many projectile-like + target-like nuclei produced

160 MeV $^{26}Mg + ^{150}Nd$

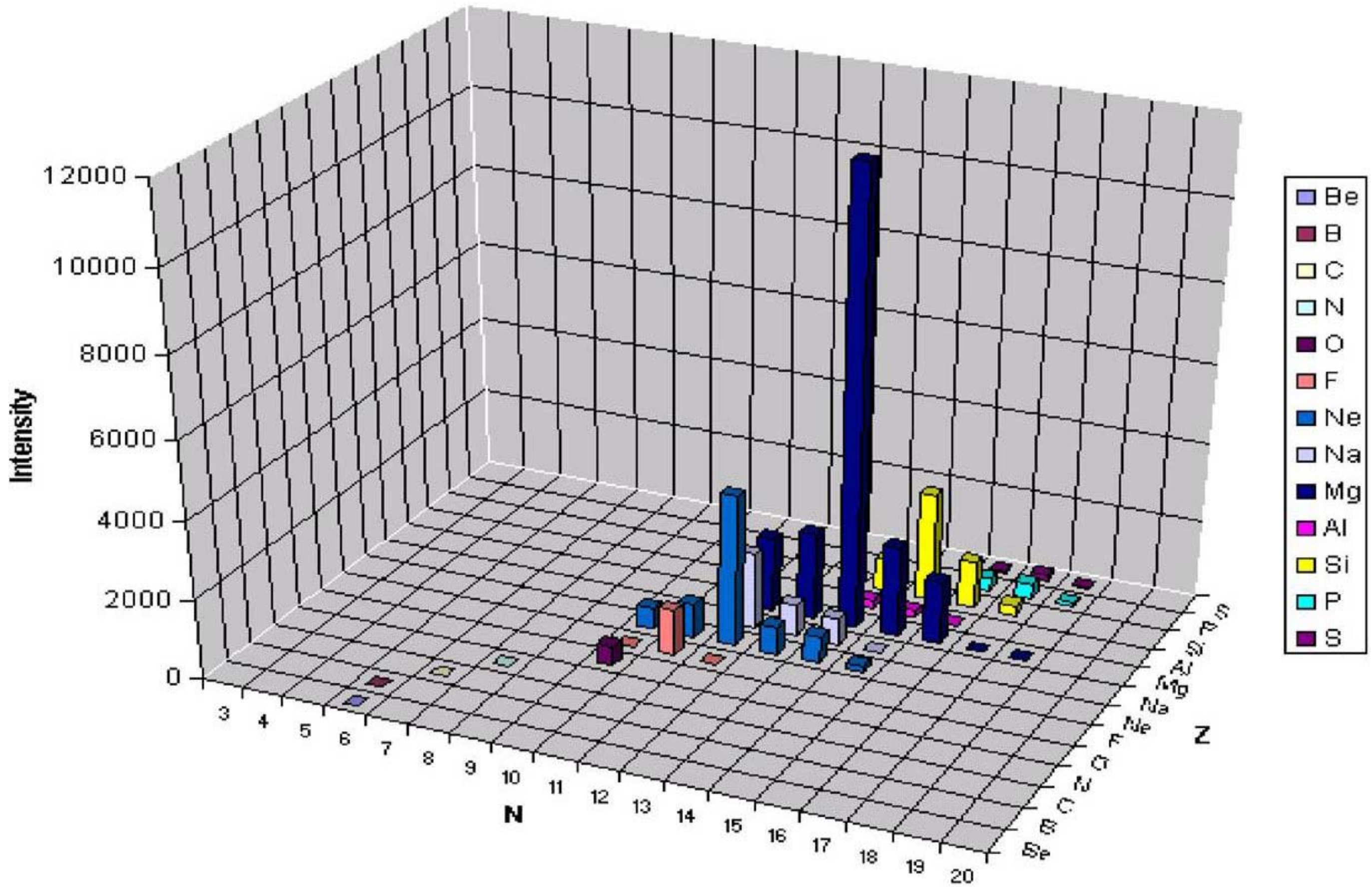
Binary Reaction

Spectrometer +

EUROBALL

K. Keyes,

A Papenberg, et al

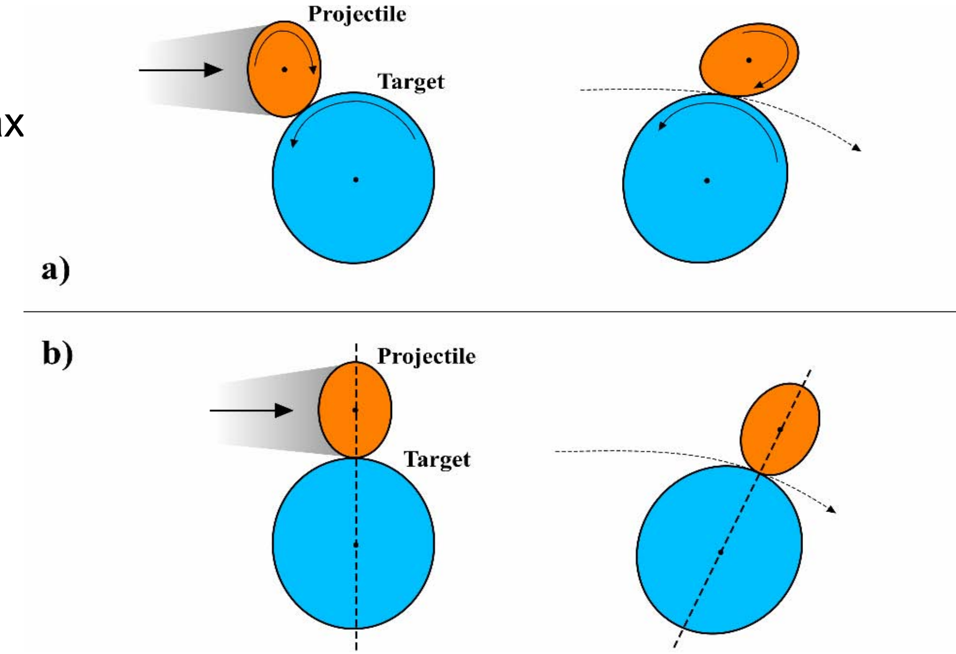


Indication of enhanced yields to ^{22}Ne ($^{26}Mg - \alpha$) and to ^{18}O ($^{26}Mg - 2\alpha$) **Why?**

Angular momentum transfer
Rolling and sticking models

rolling

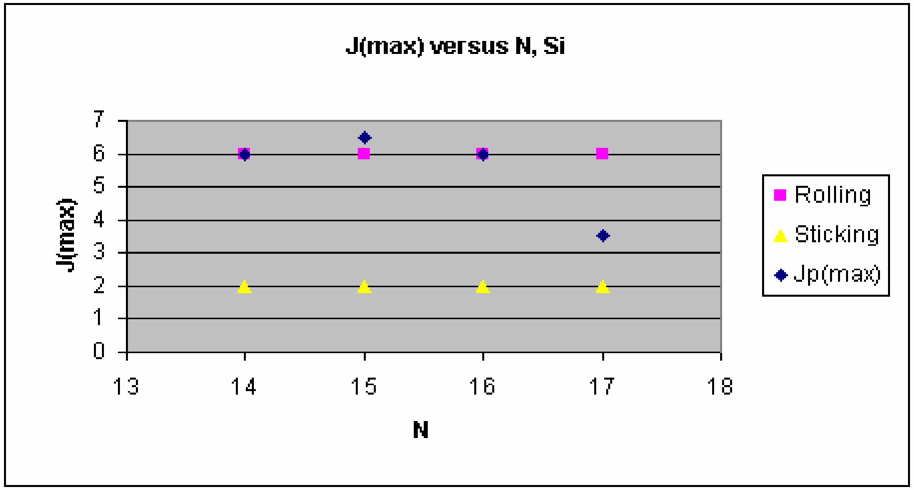
- $J_{p,roll} = 2/7\ [\ A_p^{1/3} / (A_p^{1/3} + A_t^{1/3})]\ L_{max}$
- $J_{t,roll} = 2/7\ [\ A_t^{1/3} / (A_p^{1/3} + A_t^{1/3})]\ L_{max}$

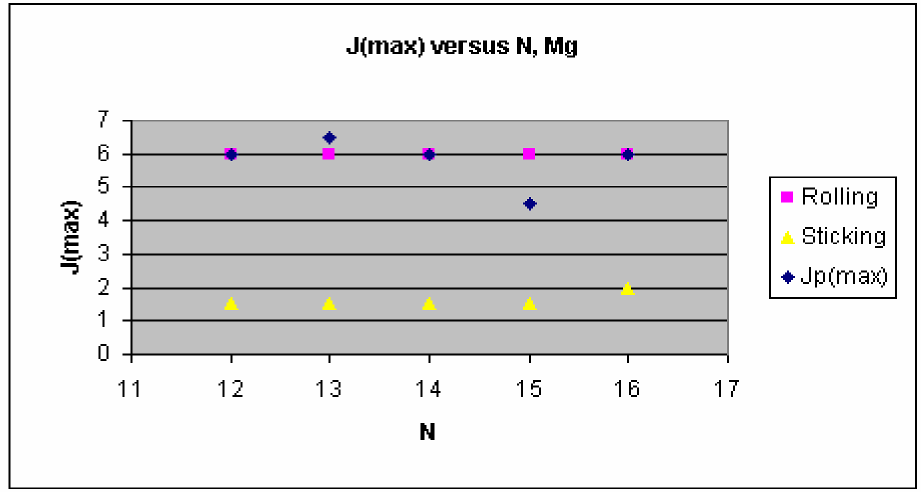


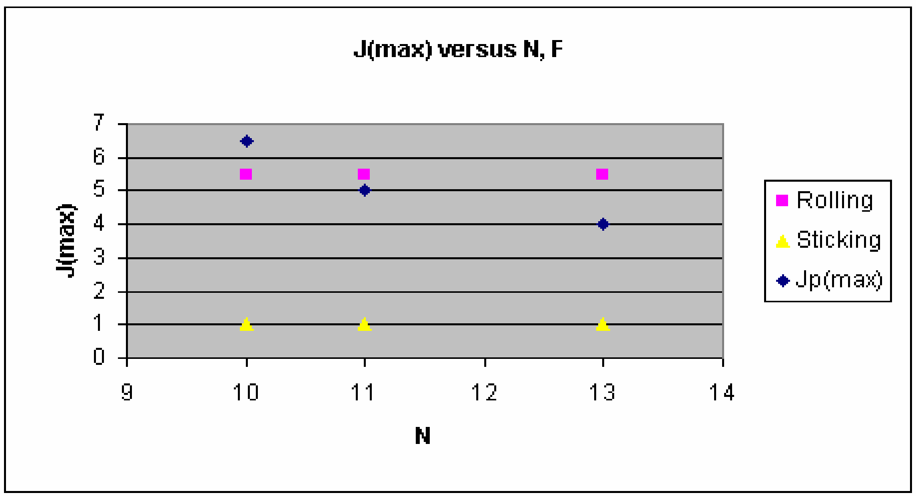
- $J_{p,stick} = [\ I_p / (\mu R^2 + I_p + I_t)]\ L_{max}$
- $J_{t,stick} = [\ I_t / (\mu R^2 + I_p + I_t)]\ L_{max}$

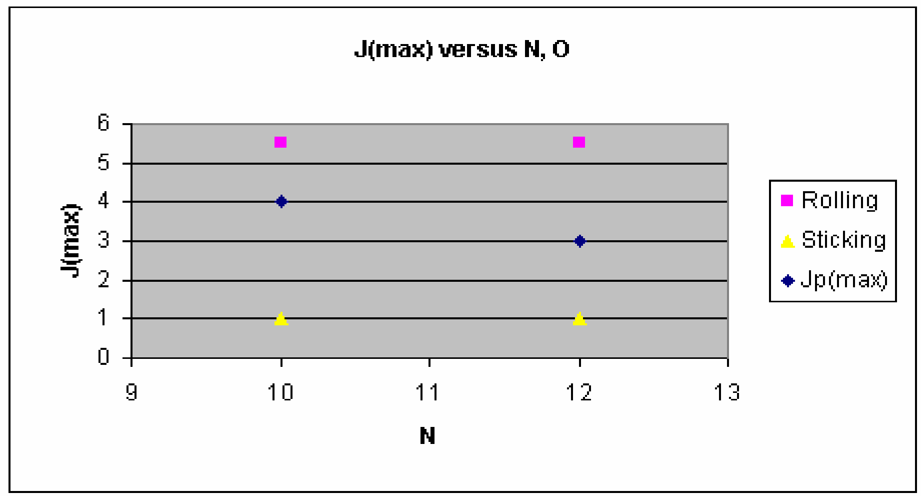
sticking

160 MeV ^{26}Mg + ^{150}Nd J_{max} for projectile-like species

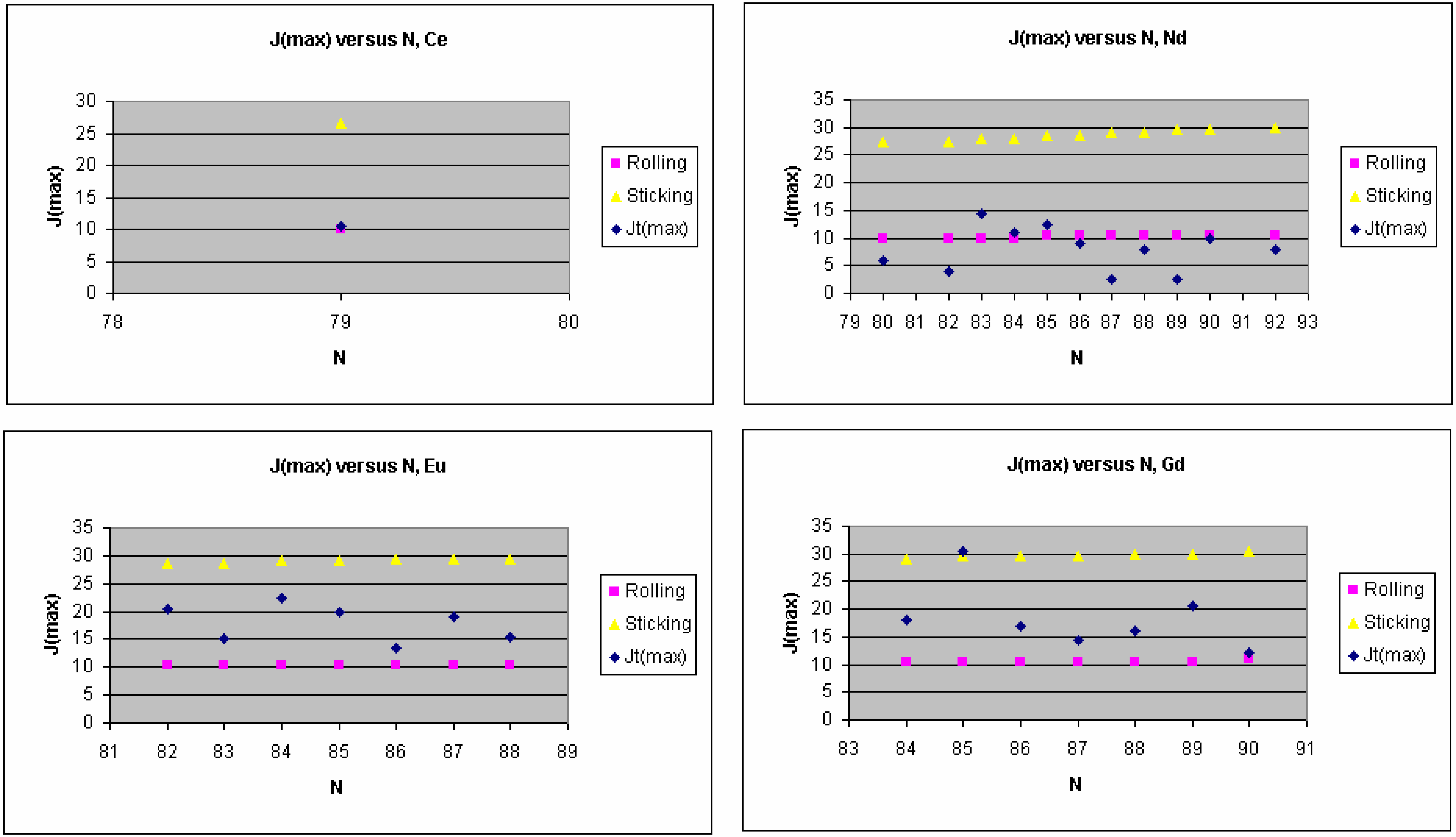






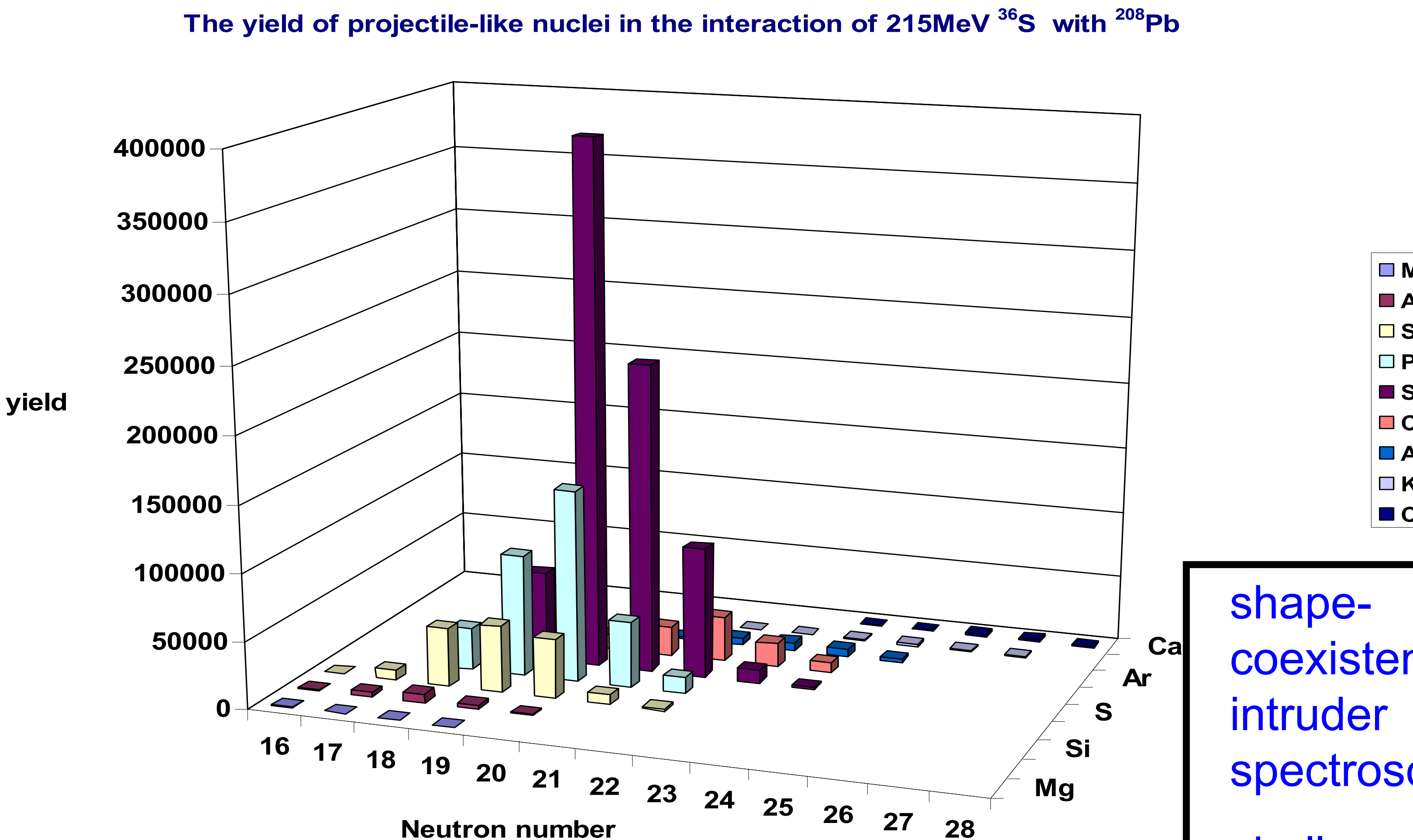


160 MeV $^{26}Mg + ^{150}Nd$ J_{max} for target - like species



Neutron-rich sdfp-shell nuclei 215MeV $^{36}S + ^{208}Pb$

PRISMA + CLARA INFN Legnaro

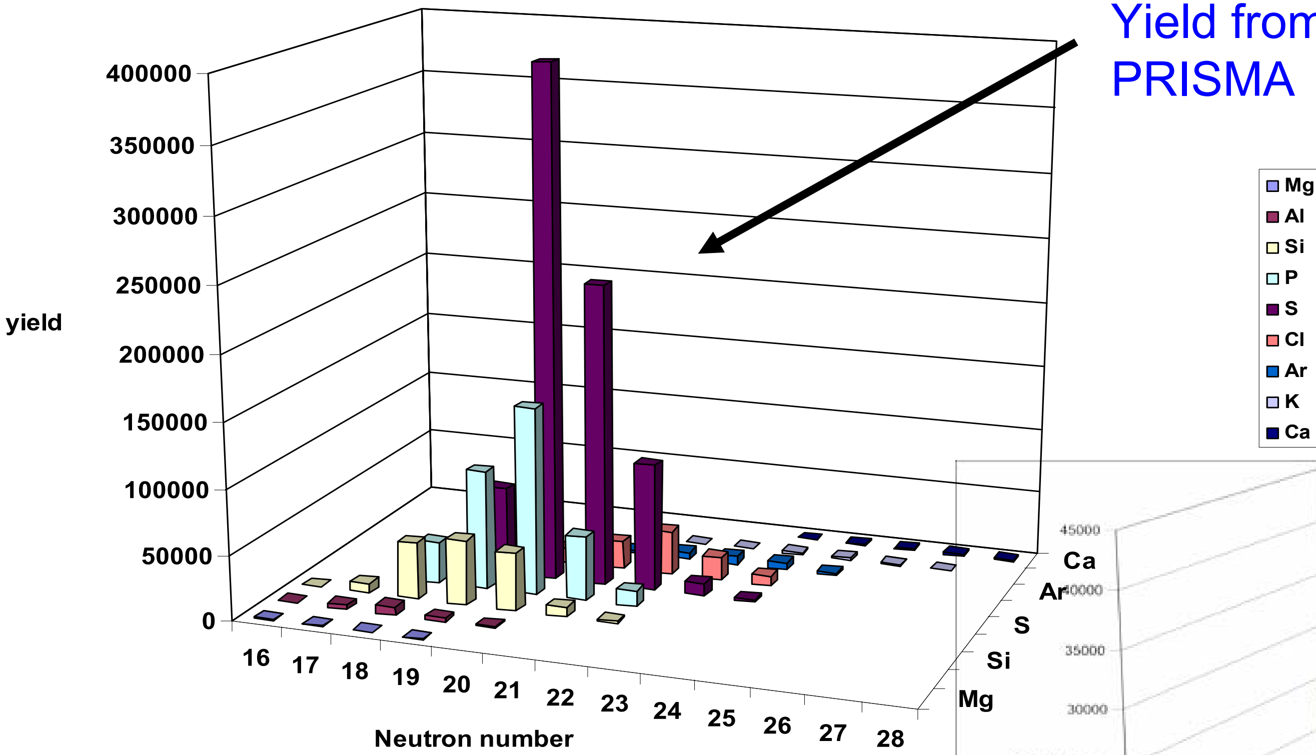


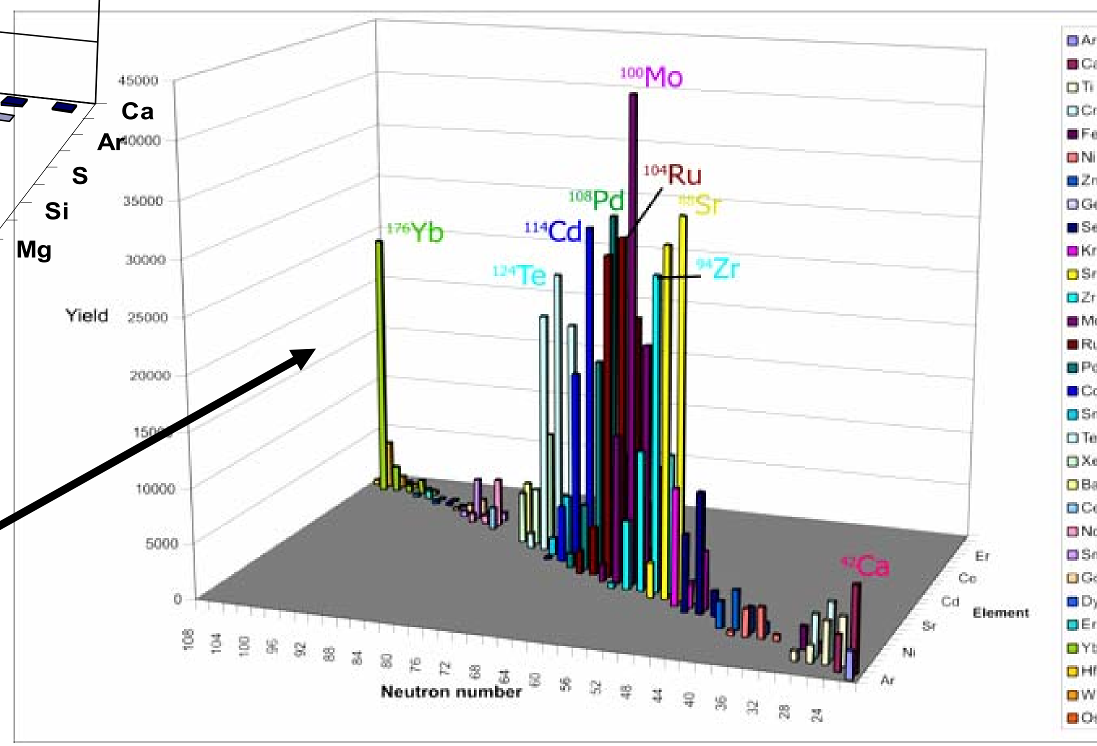
shape-coexistence;
intruder spectroscopy;

shell quenching

ECT* May 2006

Yield from $^{36}S + ^{208}Pb$ at 215MeV
PRISMA + CLARA data

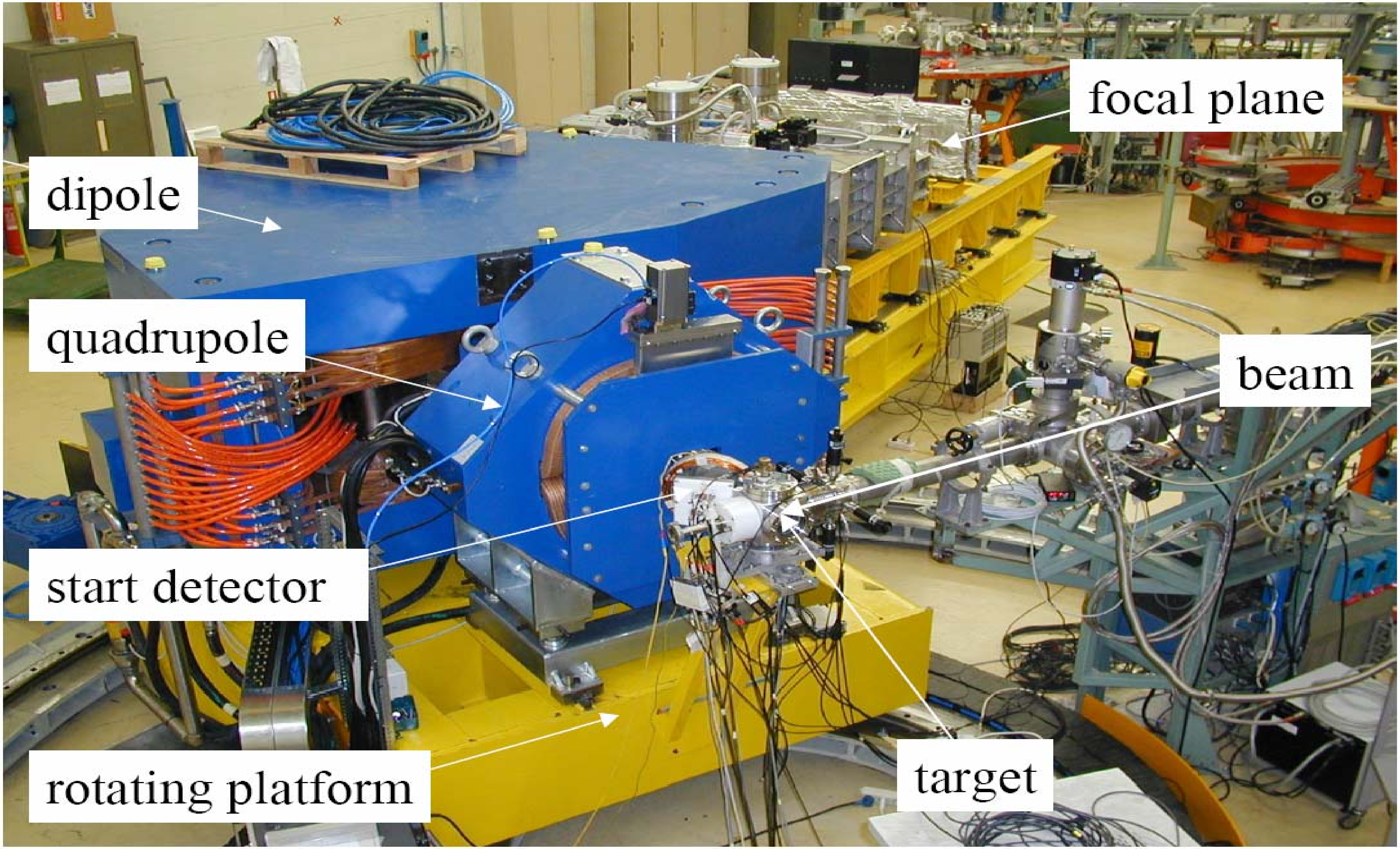




Yield from $^{36}S + ^{176}Yb$ at 230MeV
GASP
thick target data

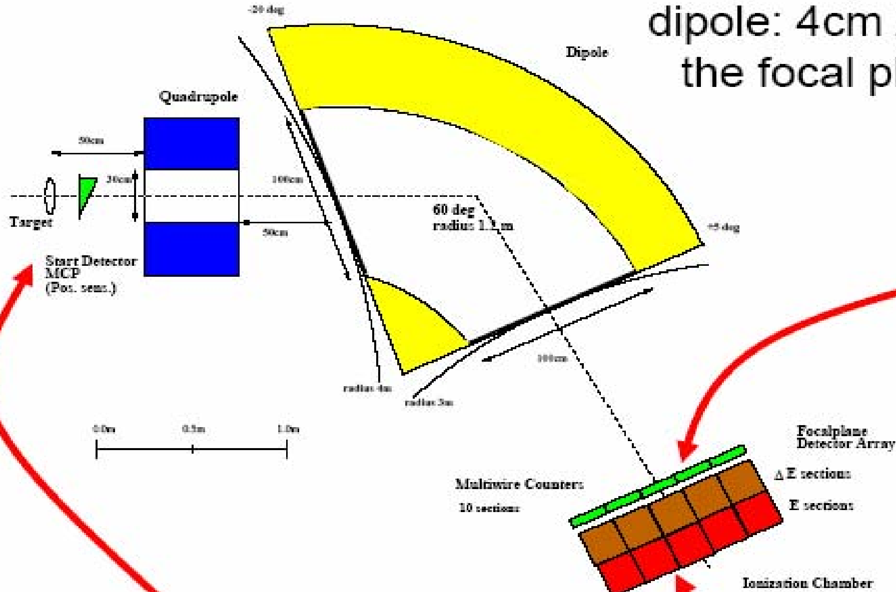
PRISMA is a magnetic spectrometer for heavy ions installed at Legnaro, with very large solid angle (80 msr), wide momentum acceptance (± 10 %) and good mass resolution (1/300)

The magnetic spectrometer PRISMA installed at LNL



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

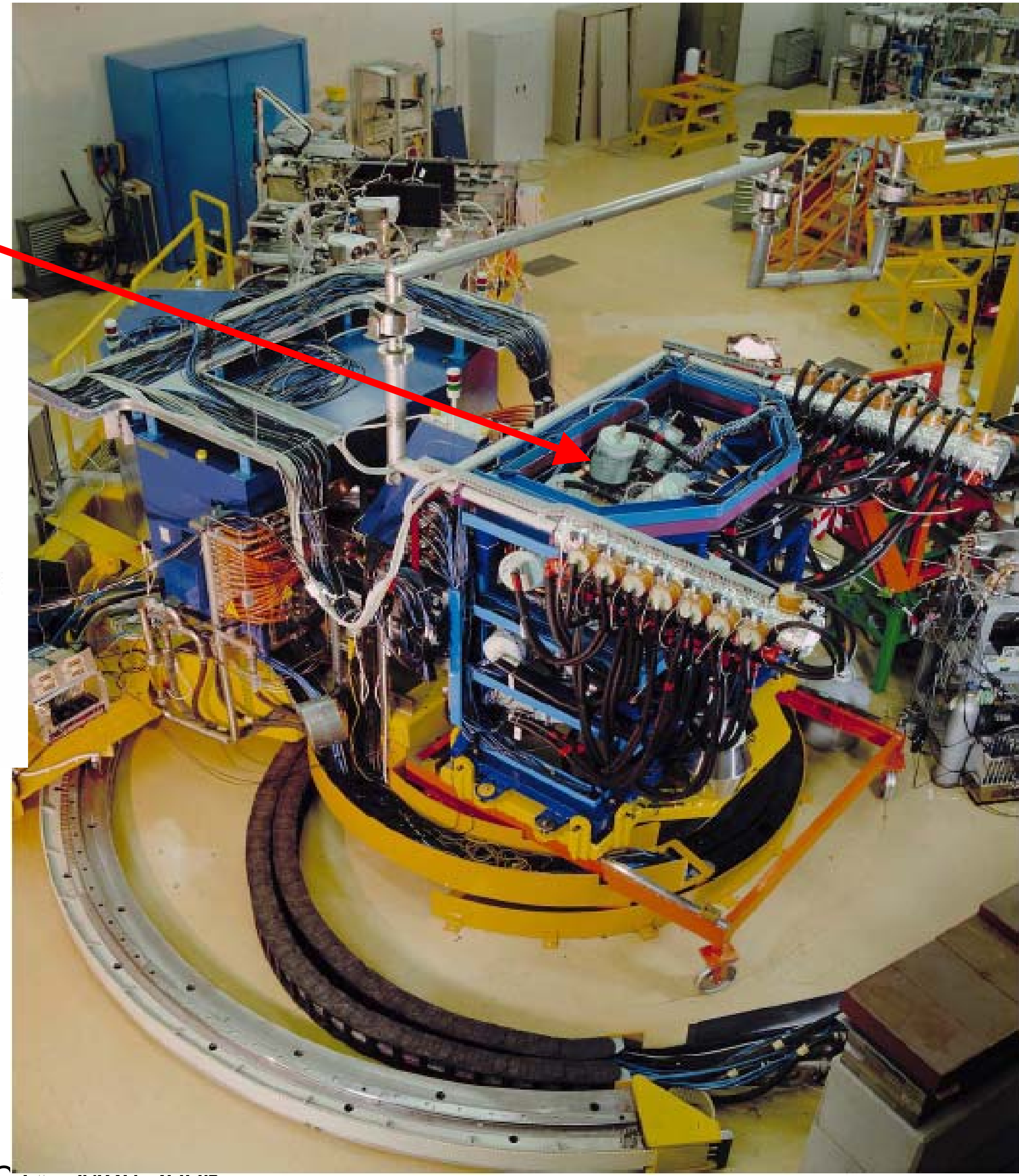
G.Montagnoli et al. LNL annual Report 2000 pg.165

Main Characteristics of the PRISMA Spectrometer

angular acceptances	$\Delta\theta \sim 12^{o}$ $\Delta\phi \sim 22^{o}$
solid angle	$\Delta\Omega \sim 80$ msr
distance target-focal plane	7 m
energy acceptance	± 20%
max rigidity	70 MeV amu
dispersion	3.3 cm/%
mass resolution	~ 1/300 FWHM
event rate	up to 200 kHz

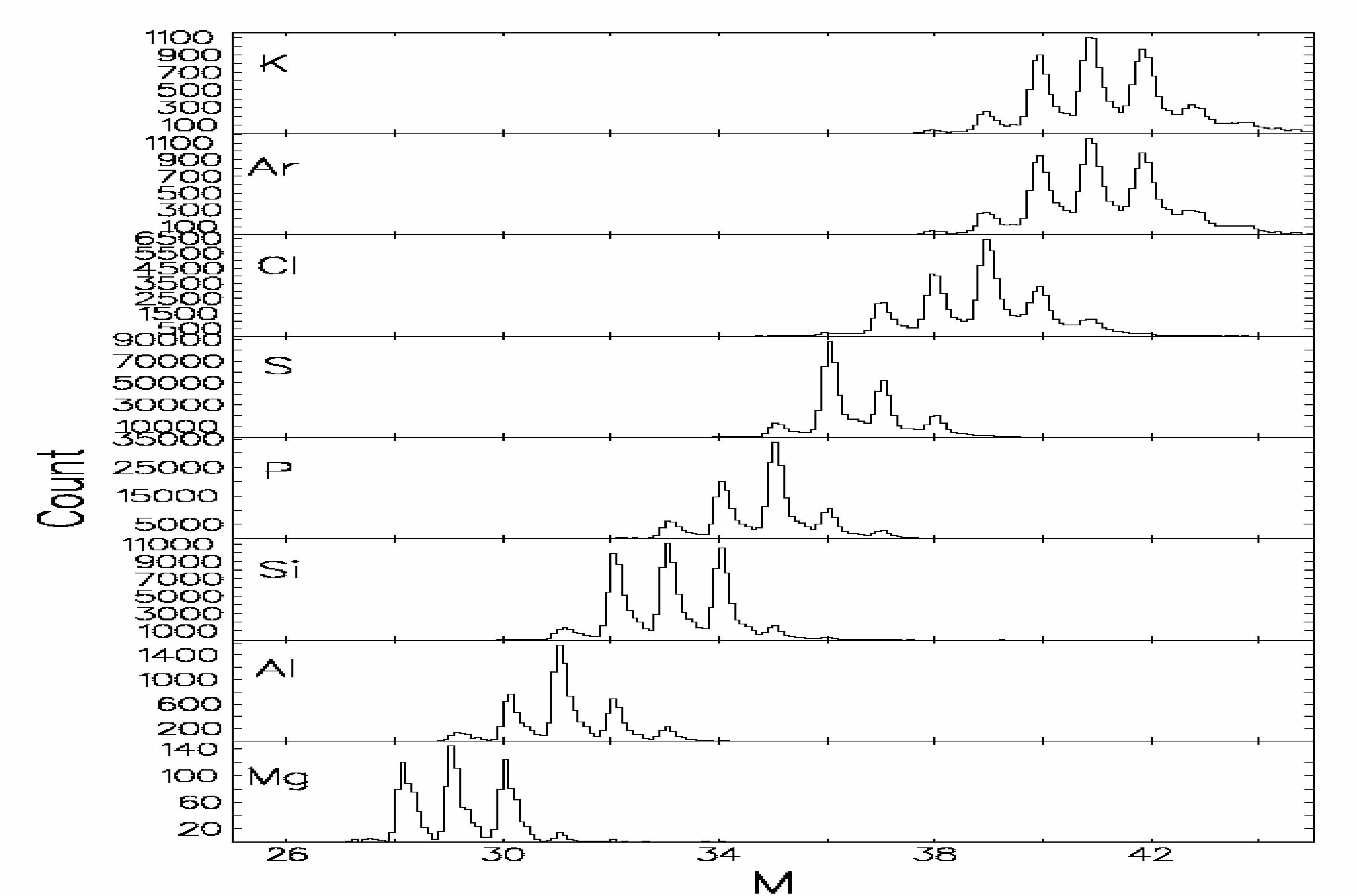
CLARA

- 25 Clovers setup
- Efficiency ~ 3 %
- Peak/Total ~ 45 %
- Position θ = 104°-180°
- FWHM ~ 10 keV for E_γ = 1.3 MeV at v/c = 10 %

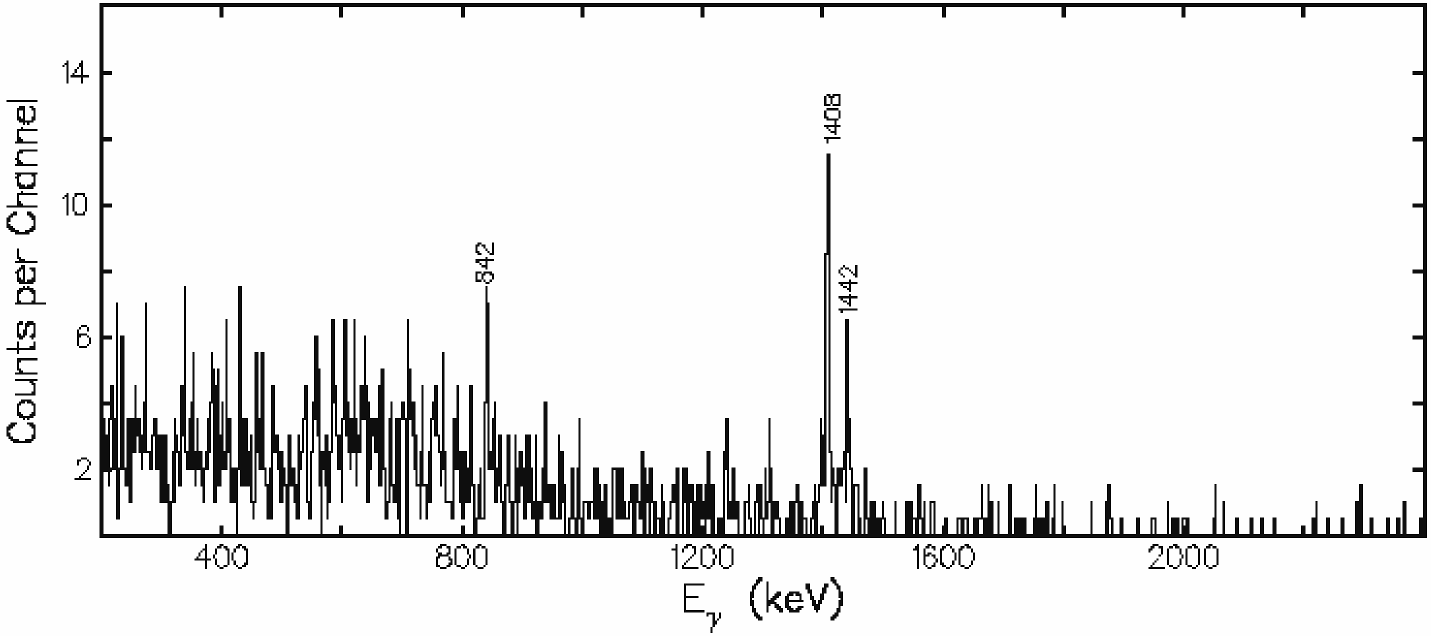


Mass spectra for projectile-like species

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

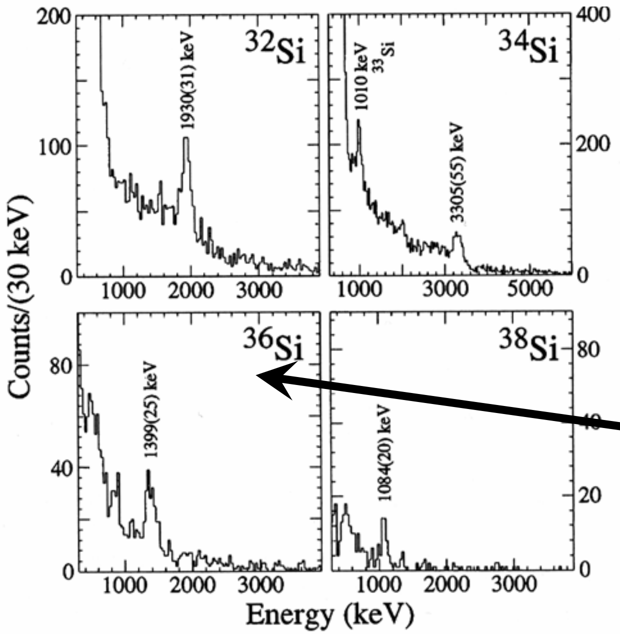


215MeV $^{36}S + ^{208}Pb$ PRISMA + CLARA



^{36}Si

X. Liang et al.,
Phys. Rev. C,
submitted



In-beam Coulomb excitation following projectile fragmentation MSU

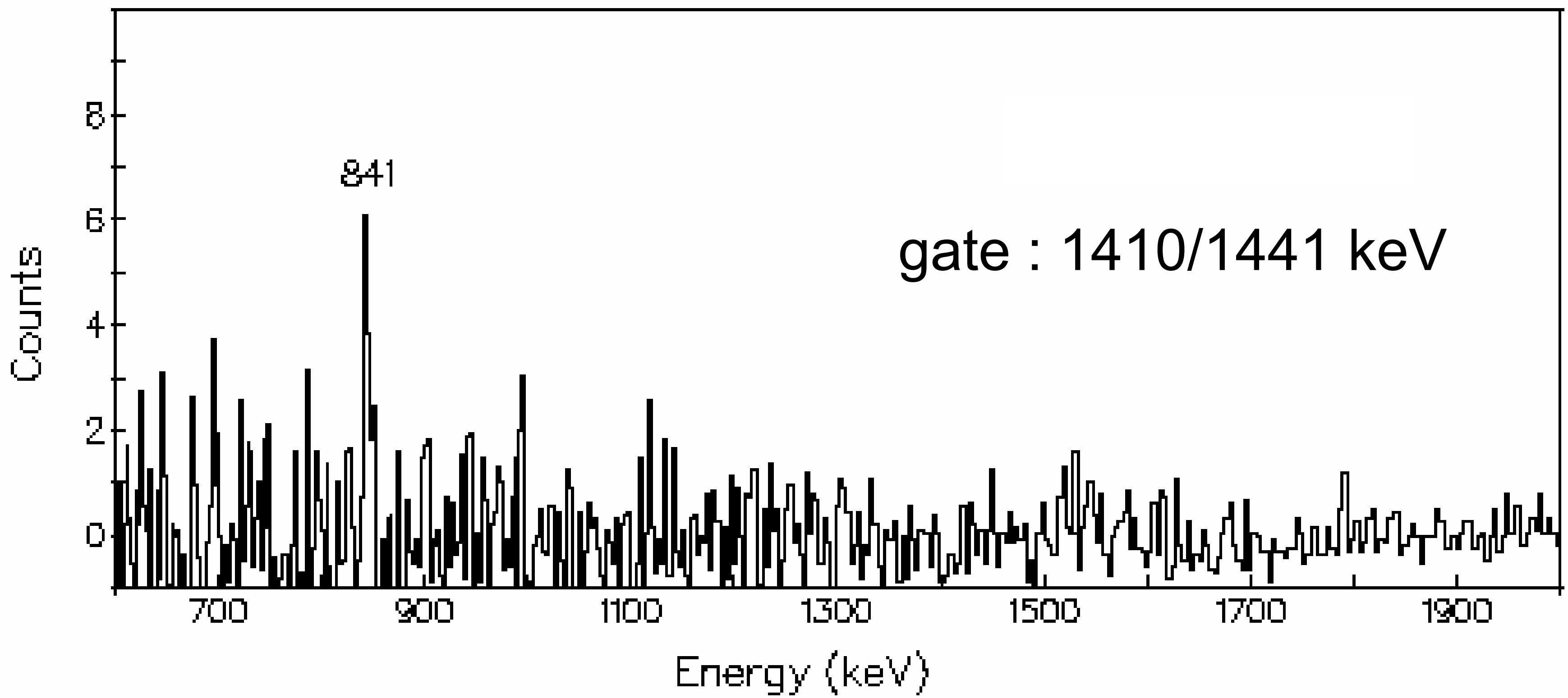
Array of 39 NaI(Tl) detectors

R.W. Ibbotson et al., Phys. Rev. Lett. **80**(1998)2081

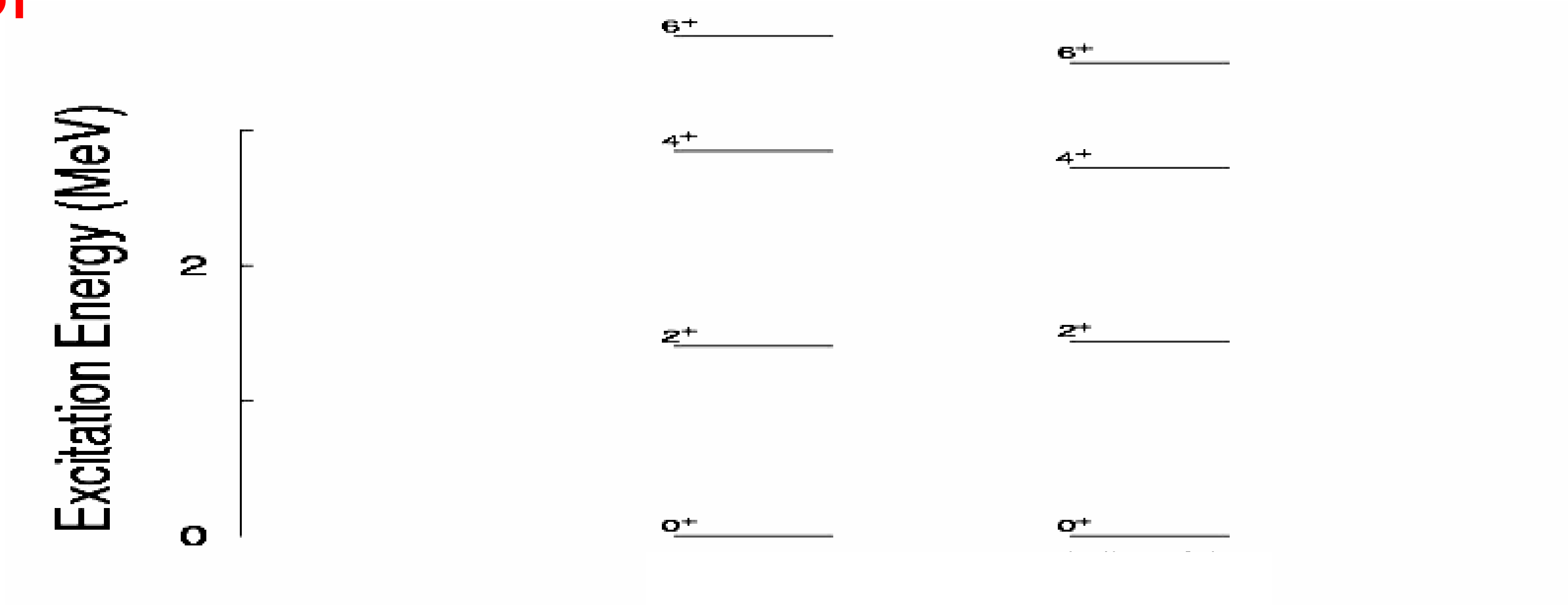
70MeV/A $^{48}Ca + ^{9}Be$

Double gated ^{36}Si spectrum from data obtained in thick target 230MeV ^{36}S + ^{208}Pb experiment

J. Ollier, PhD thesis University of Paisley (2004) unpublished



^{36}Si



Experiment Shell model

Strasbourg shell-model calculation

modified SDPF-NR interaction E. Caurier et al., Rev. Mod. Phys. 77(2005)427

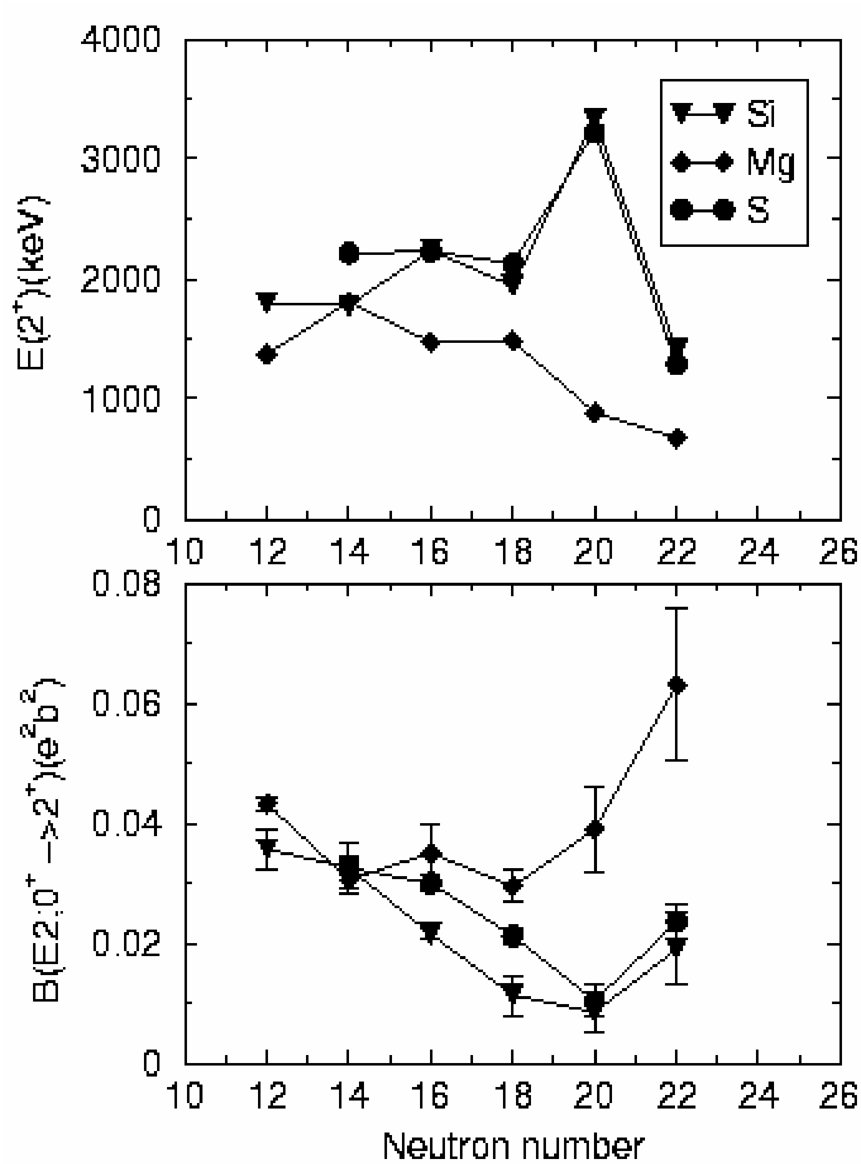
π sd-shell

ν fp-shell

pf shell pairing reduced by 200keV to reproduce E_{2+}

$2p_{3/2}$ orbital energy decreased by 1MeV, otherwise higher spin levels too compressed.

systematics for Si, S and Mg

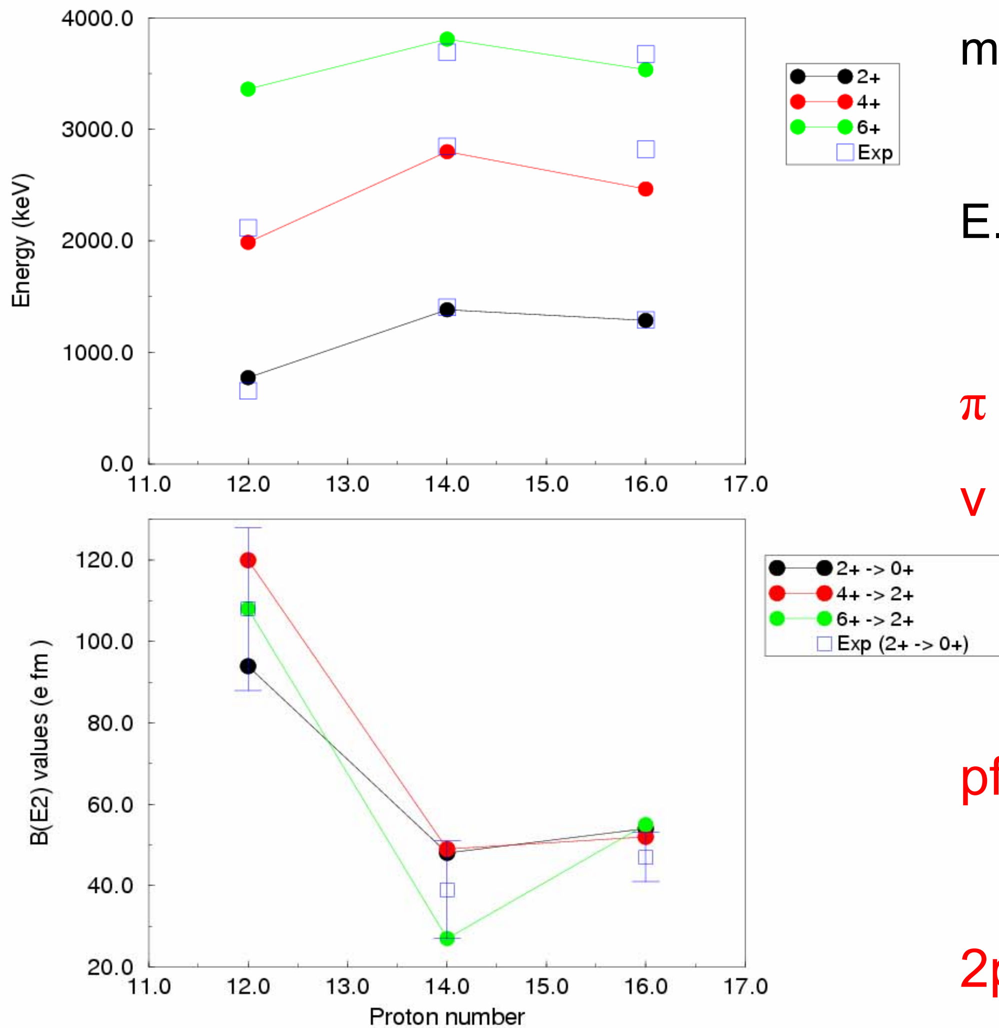


H. Iwasaki et al., Phys. Lett. B 522(2001)227

S, Raman et al., At. Data Nucl. Data Tables **78(**2001)1

N=22 isotones

Strasbourg shell-model calculation



modified SDPF-NR interaction

E. Caurier et al., Rev. Mod. Phys. 77(2005)427

π sd-shell

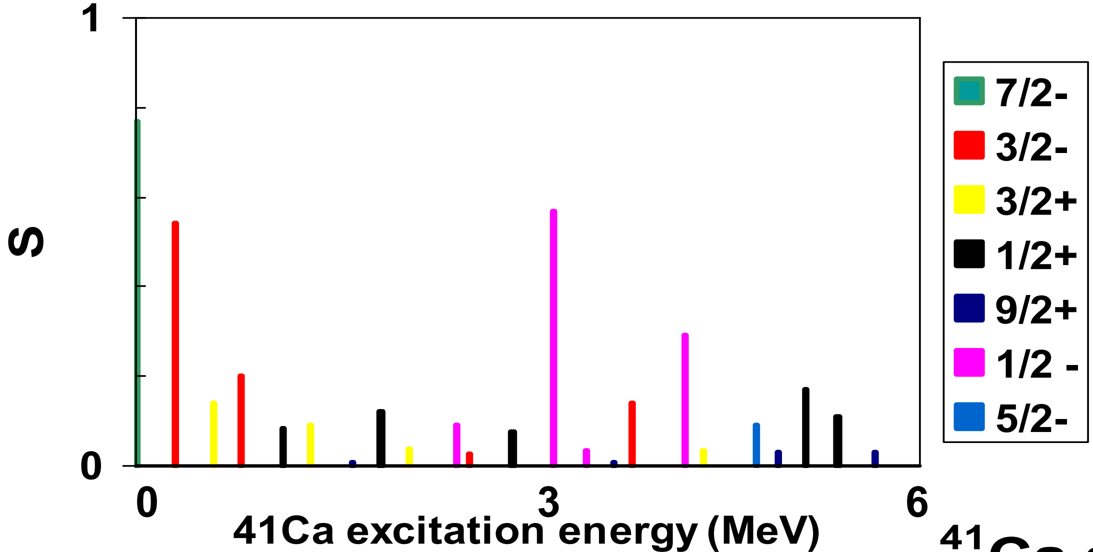
ν fp-shell

X. Liang et al., Phys. Rev. C submitted

pf shell pairing reduced by 200keV

$2p_{3/2}$ orbital energy decreased by 1MeV

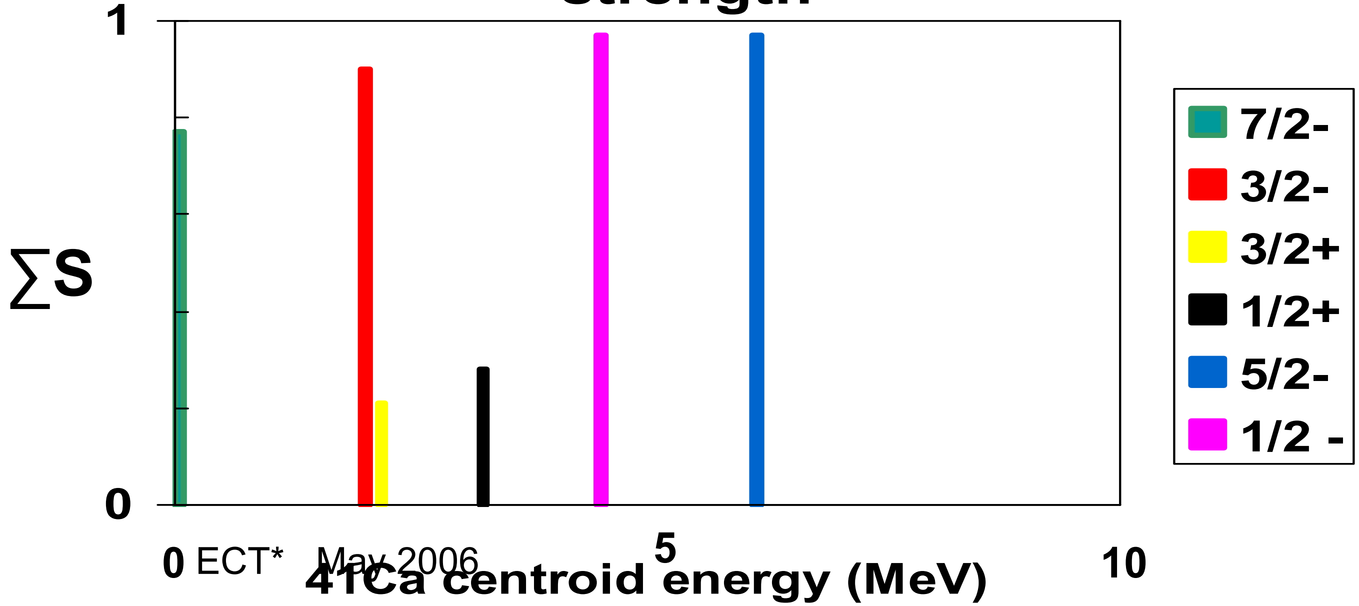
^{41}Ca spectroscopic factors



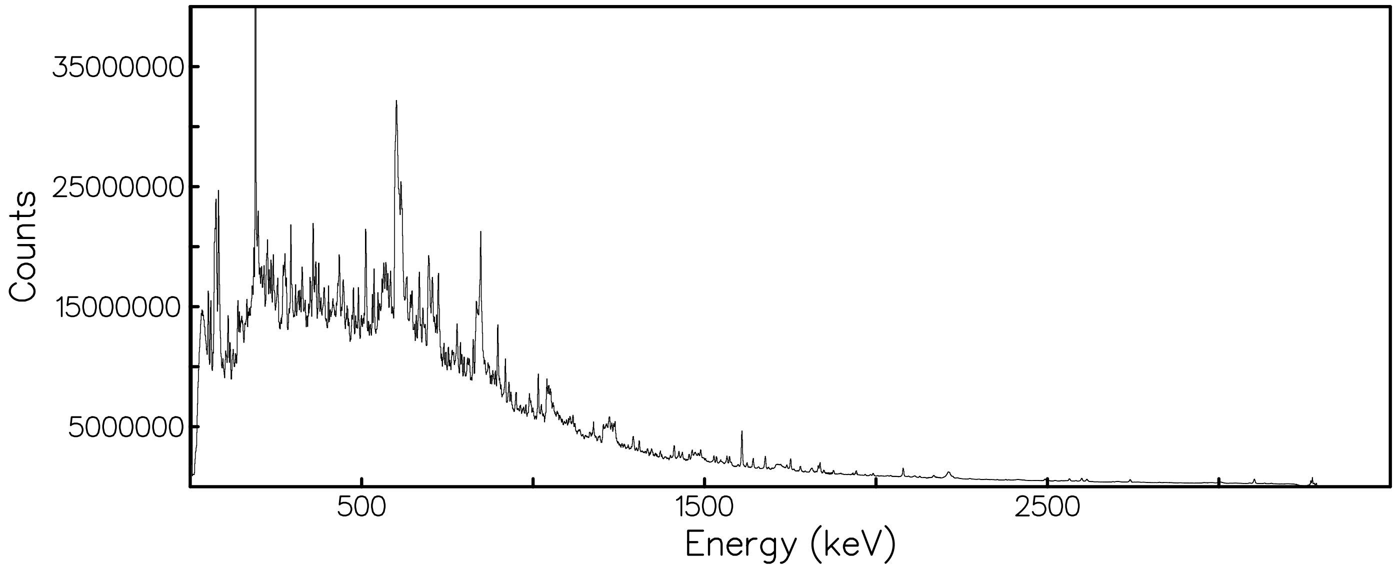
experimental results

Uozumi et al., Phys. Rev. C 50 (1994) 263

^{41}Ca summed spectroscopic strength



230MeV ^{36}S + ^{176}Yb thick target total gamma-ray projection



^{37}P

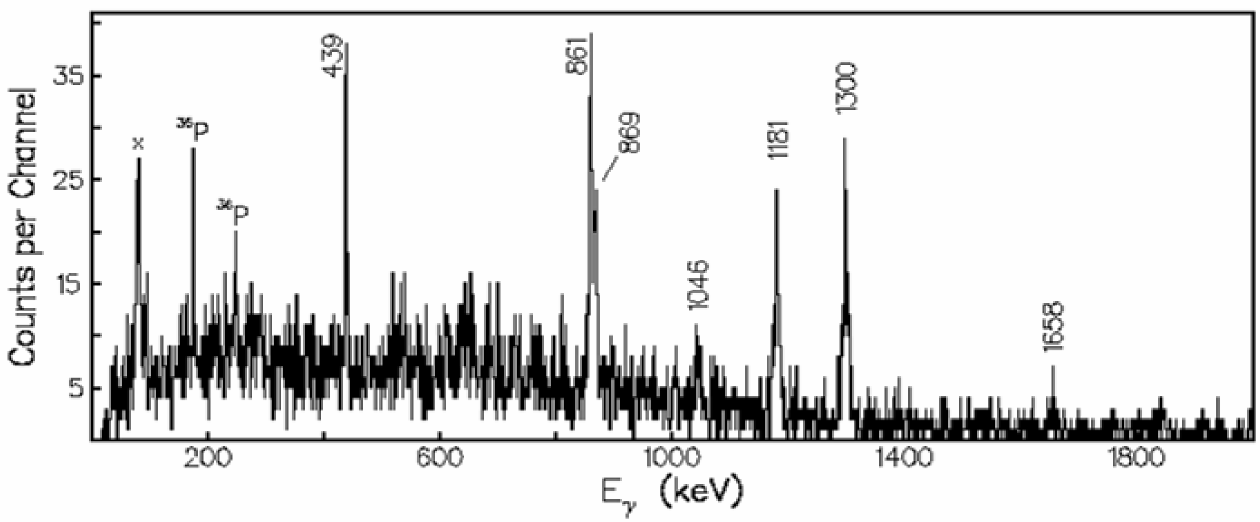
GASP

J. Ollier et al, PhD thesis

University of Paisley (2004)

unpublished

215MeV ^{36}S + ^{208}Pb thin target ^{37}P– gated gamma-ray spectrum

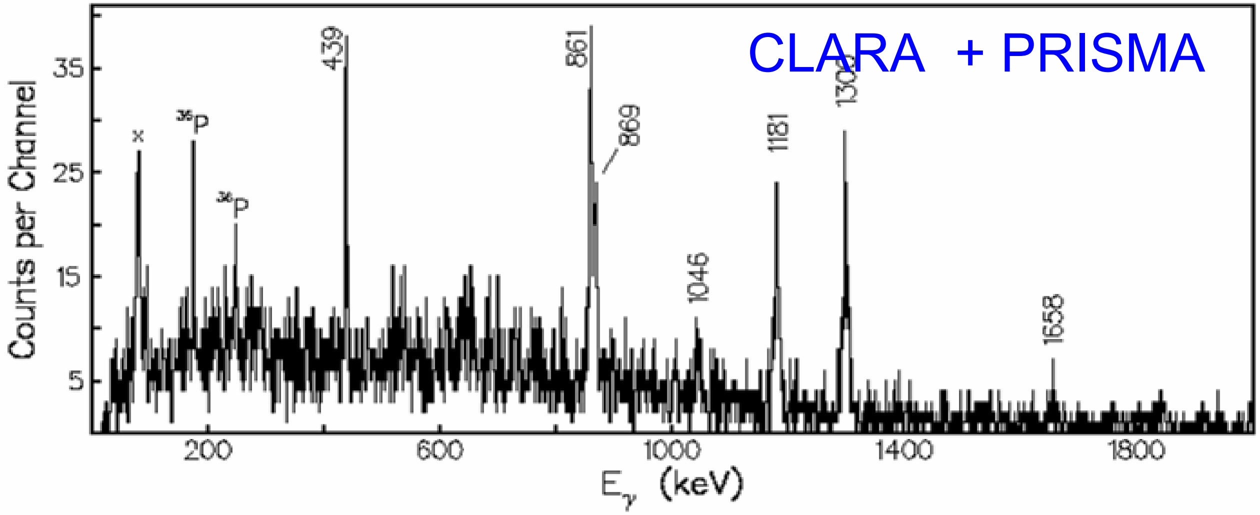


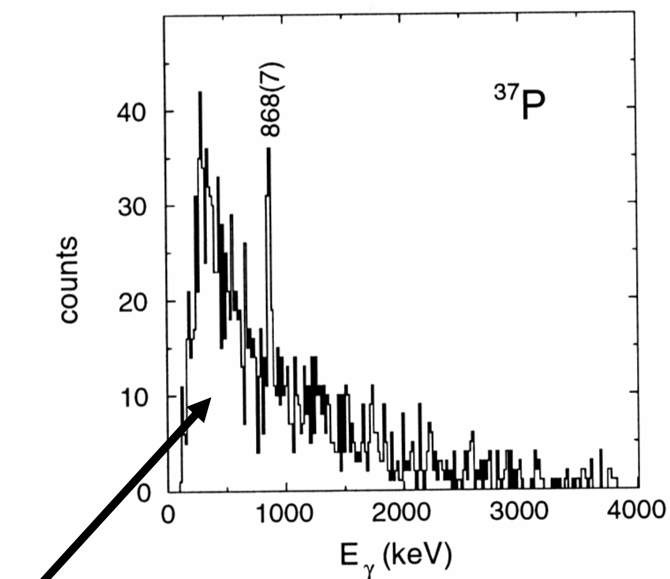
PRISMA + CLARA

A. Hodsdon et al.,

Phys Rev C, submitted

215MeV ^{36}S + ^{208}Pb thin target ^{37}P– gated gamma-ray spectrum

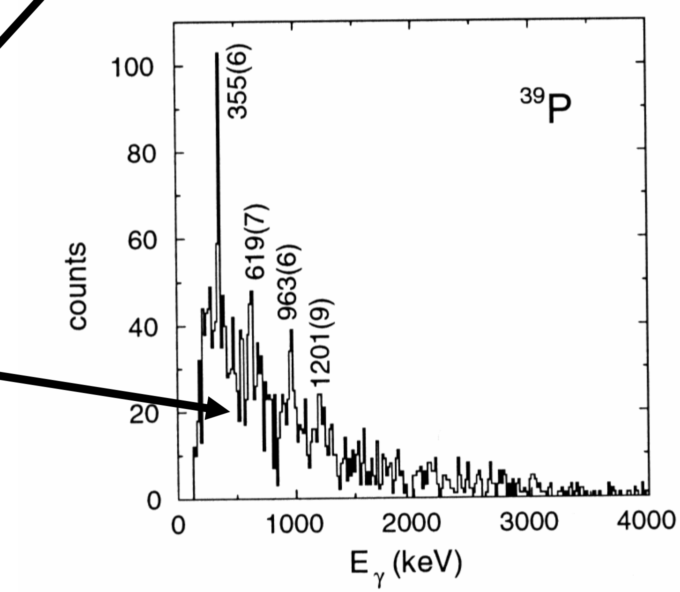




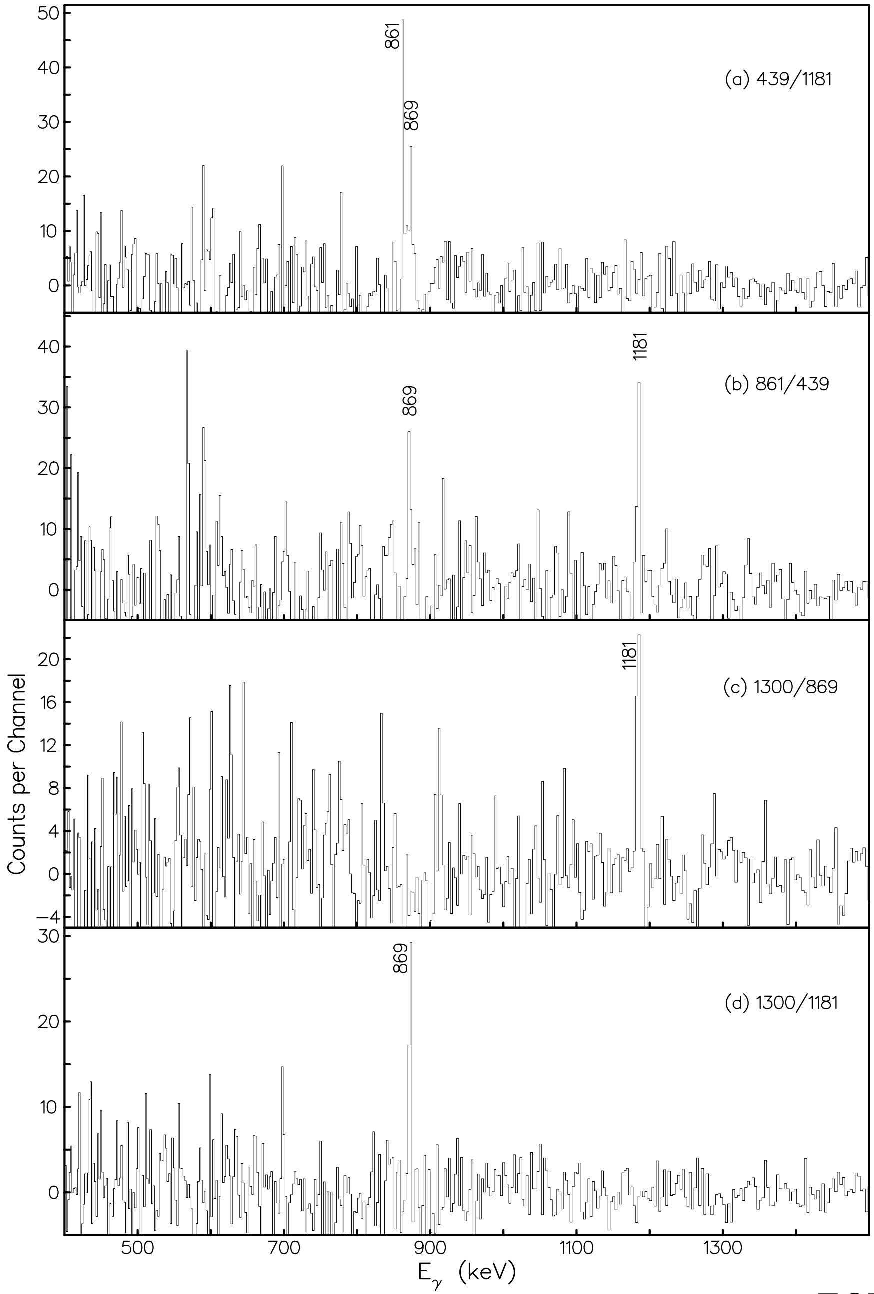
Fragmentation 60•3A MeV ^{48}Ca + Be

SPEG + 74 BaF_2 + 3 segmented Ge

Ge gamma-ray spectra



O. Sorlin et al., Eur. Phys. J. A22 (2004) 173

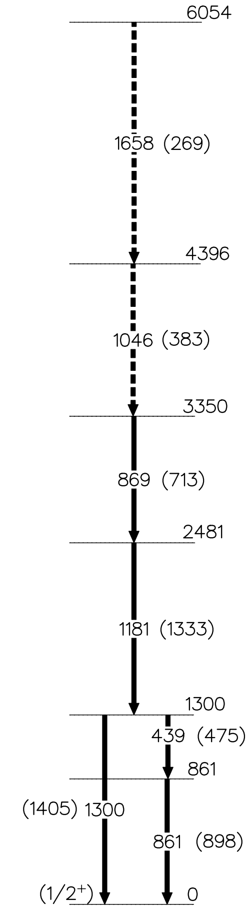


Data from

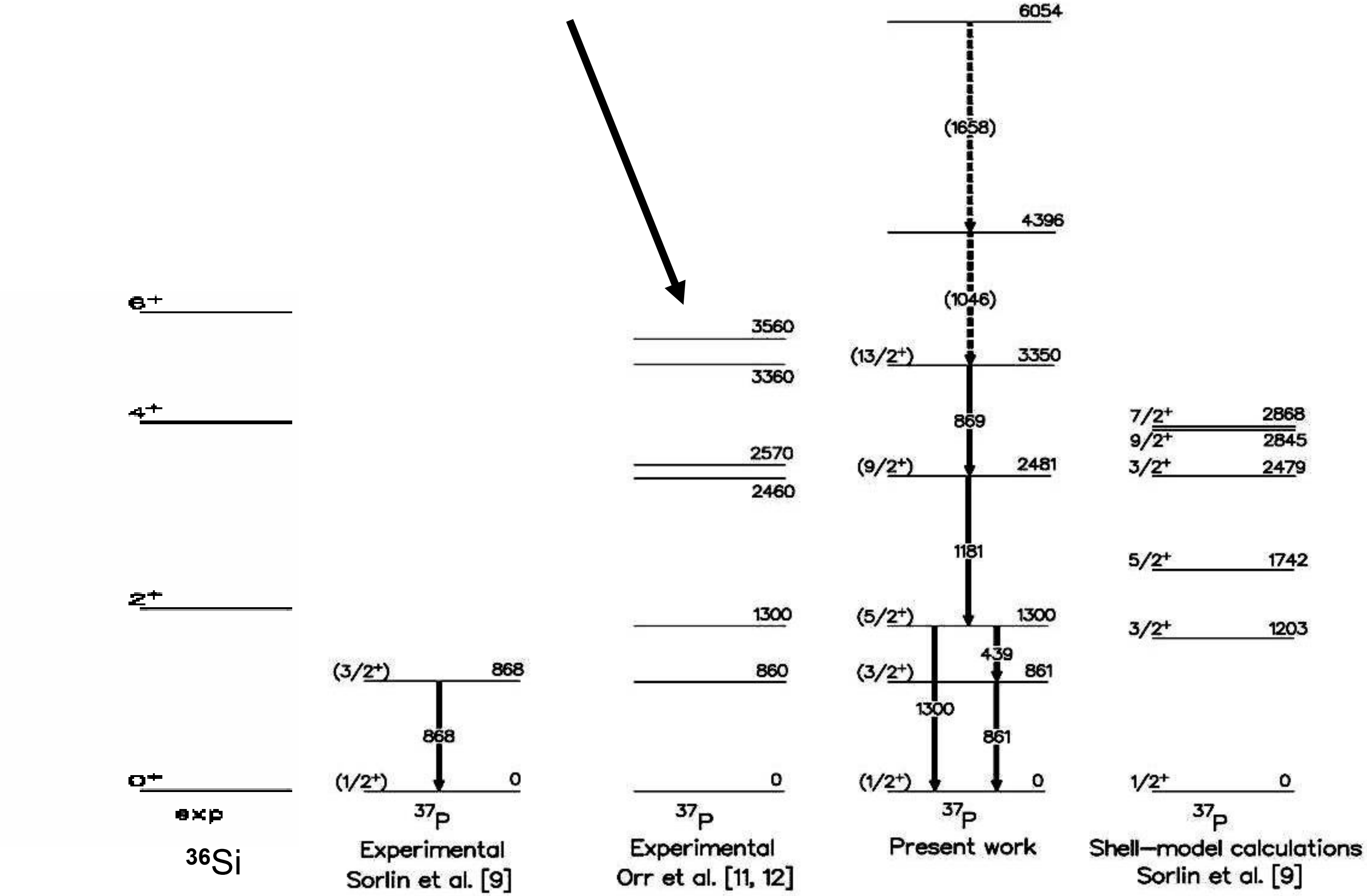
230MeV ^{36}S + ^{176}Yb

J. Ollier et al.

GASP



$^{36}S(^{18}O,^{17}F)^{37}P$



O. Sorlin et al., Eur. Phys. J. A 22(2004) 173

N. A. Orr, PhD thesis, Australian National University (1989)

Next project

Proposal 04.33

New Spectroscopy South-West of ^{132}Sn: quenching of the N=82 shell gap for neutron-rich nuclei?

750MeV ^{124}Sn + ^{208}Pb DIC

Collaboration

Paisley -- IReS Strasbourg -- IPN Orsay -- Madrid -- Surrey
Debrecen -- INFN Legnaro -- INFN Napoli
INFN Padova -- INFN Torino
Manchester

ECT* May 2006

Quenching of N = 82 shell gap

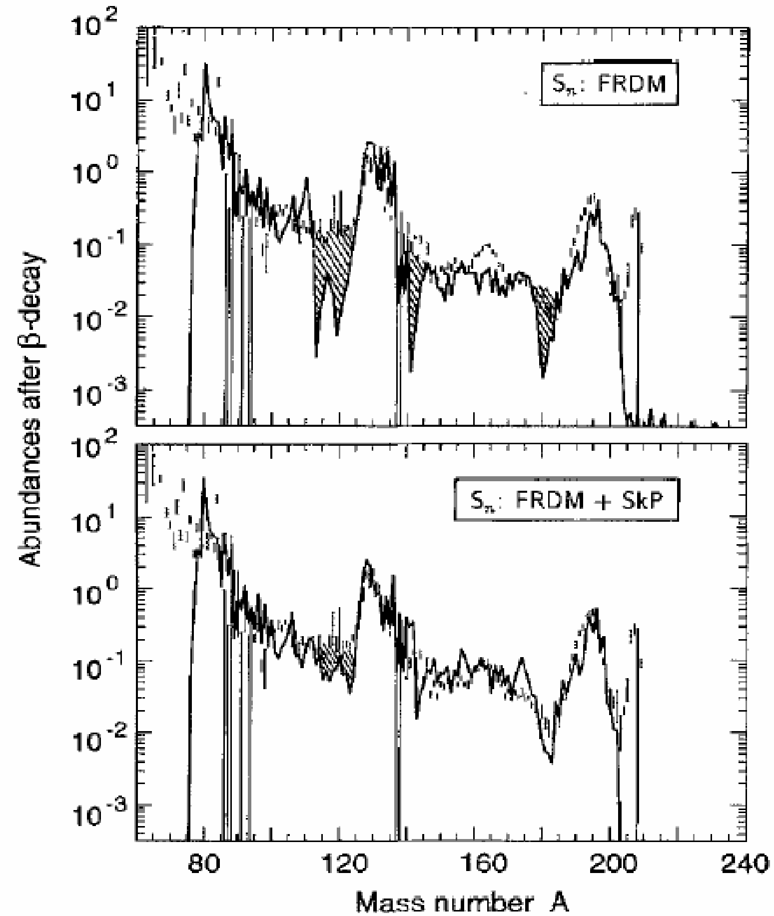
- r-process solar abundances
- discrepancies in A ≈ 120 mass region below the N = 82 shell closure

Kratz et al., Ap. J. **403**(1993)216

- Quenching of N = 82 gap

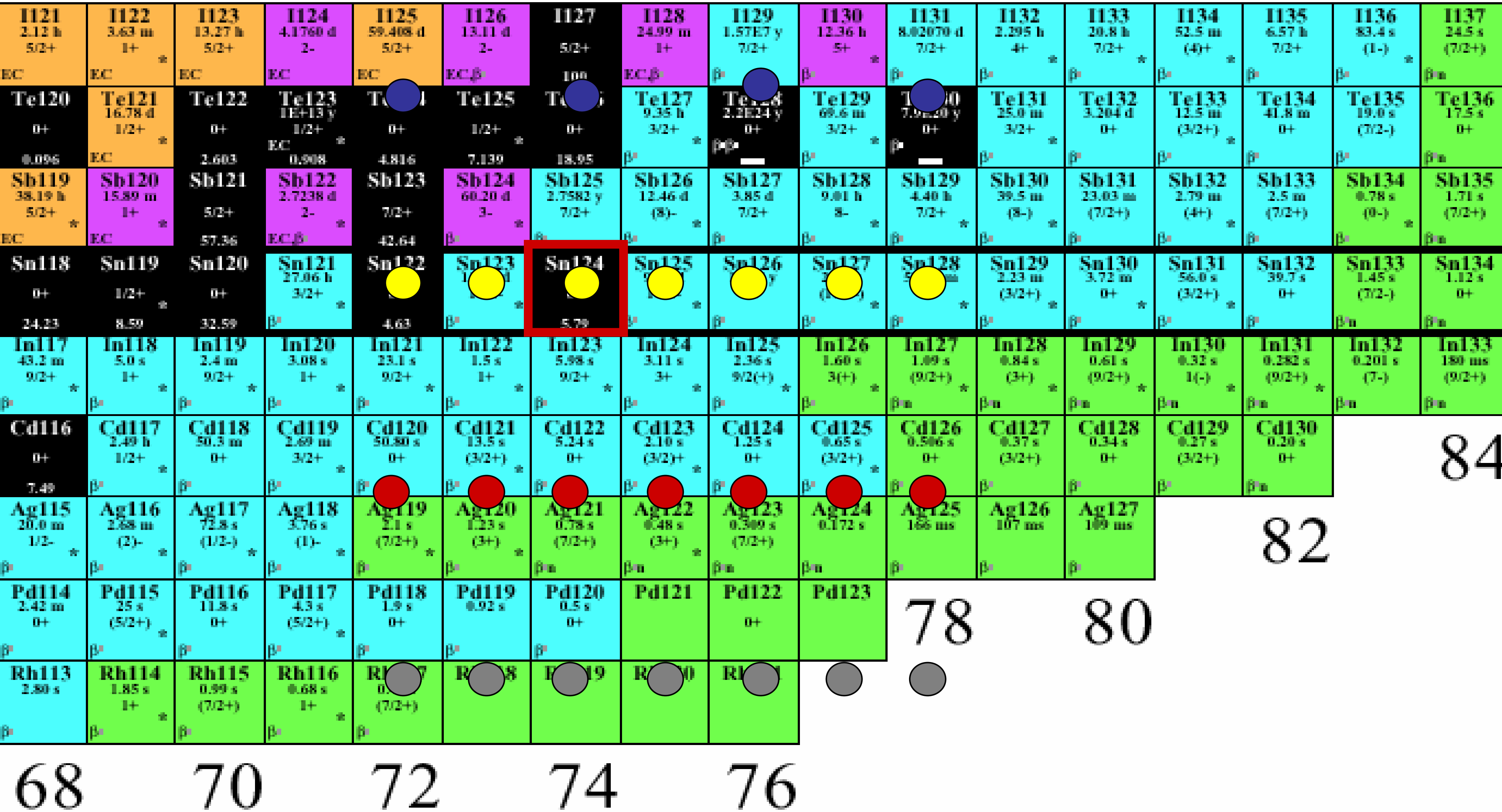
  considerably improves fit

- HFB calculations with Skyrme SkP force



Dobaczewski et al., Phys. Rev. Lett. **72**(1994)981

Dobaczewski et al., Phys. Scr. T **56**(1995)15


I121 I122 I123 I124 I125 I126 I127 I128 I129 I130 I131 I132 I133 I134 I135 I136 I137
Te120 Te121 Te122 Te123 Te125 Te127 Te129 Te131 Te132 Te133 Te134 Te135 Te136
Sb119 Sb120 Sb121 Sb122 Sb123 Sb124 Sb125 Sb126 Sb127 Sb128 Sb129 Sb130 Sb131 Sb132 Sb133 Sb134 Sb135
Sn118 Sn119 Sn120 Sn121 Sn122 Sn124 Sn129 Sn130 Sn131 Sn132 Sn133 Sn134
In117 In118 In119 In120 In121 In122 In123 In124 In125 In126 In127 In128 In129 In130 In131 In132 In133
Cd116 Cd117 Cd118 Cd119 Cd120 Cd121 Cd122 Cd123 Cd124 Cd125 Cd126 Cd127 Cd128 Cd129 Cd130
Ag115 Ag116 Ag117 Ag118 Ag126 Ag127
Pd114 Pd115 Pd116 Pd117 Pd118 Pd119 Pd120 Pd121 Pd122 Pd123
Rh113 Rh114 Rh115 Rh116
84
82
78
80
68
70
72
74
76

ECT* May 2006

Future

- Deep-inelastic experiments: heavier systems
  e.g. 750MeV ^{124}Sn + ^{208}Pb DIC

- Mismatched single nucleon transfer reactions:
  location of high-j orbitals e.g. $k_{17/2}$

- Pair transfer in heavy-ion interactions

Collaborators

X.Liang, F.Azaiez, R.Chapman, F.Haas, N.Marginean, S.Beghini, B.R.Behera, M.Burns, E.Caurier, L.Corradi, D.Curien, A.Deacon, Zs.Dombradi, E.Farnea, E. Fioretto, A.Hodsdon, A.Gadea, F.Ibrahim, A.Jungclaus, K.Keyes, A.Latina, G.Montagnoli, D.Napoli, F.Nowacki, J.Ollier, A.Papenberg, G.Pollarolo, F.Scarlassara, J.F.Smith, K.Spohr, M.Stanoiu, A.M.Stefanini, S.Szilner, M.Trotta, D.Verney, Z.Wang